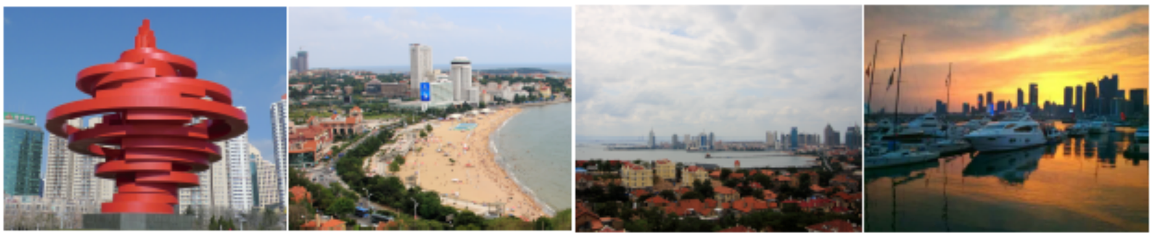
Charting the course for climate & ocean research

CLIVAR
Open Science Conference
Qingdao, 2016



CHARTING THE COURSE FOR CLIMATE AND OCEAN RESEARCH

18-25 SEPTEMBER 2016 QINGDAO, CHINA

18, 24-25 September: **Early Career Scientists Symposium**

19-23 September: **Open Science Conference**

Abstract Book

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CLIVAR Open Science Conference

Day 1 - Monday, 19th September 2016

Keynote talk

Keynote Speaker **Monday, 19th September 2016** **11:00hrs**

Dr. Thomas Stocker

Thomas Stocker was born in Zürich and obtained a PhD in Natural Sciences of ETH Zürich in 1987. He held research positions at University College London, McGill University (Montreal), Columbia University (New York) and University of Hawai'i (Honolulu). Since 1993 he is Professor of Climate and Environmental Physics at the University of Bern. From 2008 to 2015 he co-chaired Working Group I "The Physical Science Basis" of the IPCC, the United Nations Intergovernmental Panel on Climate Change. Thomas Stocker has co-authored more than 200 publications; he holds an Honorary Doctorate from the University of Versailles and has received several awards for his work. He is a Fellow of the American Geophysical Union and a Foreign Member of the Accademia Nazionale dei Lincei, Italy, and the American Academy of Arts and Sciences.

Anthropogenic Climate Change: Time to Focus on the Ocean

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The most recent comprehensive assessment carried out by the Intergovernmental Panel on Climate Change has concluded that "Human influence on the climate system is clear," a headline statement that was approved by all governments in consensus. Impacts in all components of the climate system are already documented. In the past decade, our knowledge about ongoing physical changes in the world ocean has greatly improved owing to an unprecedented density of in situ observations and better modeling. Three fundamental services of the world ocean are already now under threat: (i) the uptake of heat, (ii) the uptake of freshwater from the melting cryosphere, and (iii) the uptake of anthropogenic CO2. However, the vulnerability of the most importance ocean service, food production, is virtually unknown. The multiple short and long-term risks associated with the reduction or destruction of these ocean services must become a research priority. On the short term, sea level rise commitment is substantial with committed sea level rising essentially irreversible change will push the system across other critical thresholds such as those about an order of magnitude faster than observed sea level change. Similarly, acidification commitment has already crossed some thresholds of under saturation. Even if the warming is stabilized, the declared goal of the Paris Agreement, sea level is expected to stay high for many millennia. The key question is whether this associated with the functioning of marine ecosystems, the overturning circulation or the stability of ice streams around ocean-ice sheet boundaries. Such key aspects must be investigated at high priority in order to inform the decision makers about the speed and amplitude of change in, and the vulnerability of, these fundamental ocean services.

Plenary Oral Presentations

Plenary Session 1 **Monday, 19th September 2016** **14:00hrs**

Dr. Monika Rhein

Dr. Monika Rhein is a Professor at MARUM, Bremen University and leads the Physical Oceanography Department. She was a Coordinating Lead Author for Chapter 3 "Ocean Observations" of the 5th IPCC Report, WG1, and Lead Author for the WG1 Technical Summary and for the Summary for Policymakers.

The ocean's role in the energy cycle

Monika Rhein (1), Gregory C. Johnson (2), Don. P. Chambers (3), Stephen R. Rintoul (4), Lynne Talley (5), and Sarah Purkey (6)

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The 5th report to the IPCC highlights the crucial role of the oceans for the increase of the global energy inventory. Owing to sparse historic observations, reliable yearly global estimates of Upper Ocean warming could be made starting around 1970. By the mid-2000s, the argo program allowed reliable yearly global estimates to 2000 m with considerable reduction of uncertainties. WOCE, CLIVAR, and GO-SHIP observations have also revealed net warming below 2000 m since the early 1990s. Ocean warming accounts for more than 90% of the increase in the Earth's energy inventory between 1971 and 2010, while only small fractions heated the atmosphere, the continents, and led to melting of sea ice, glaciers and ice sheets. The upper 2000 m of the ocean has continued to warm since 2010. Much of the warming has occurred in the upper 700m, but deep-ocean warming has increased with time. Ocean warming has repercussions for global sea level rise both through thermal expansion and increased melt of marine terminating ice sheets. Warming also affects the uptake of anthropogenic carbon by enhancing the vertical density stratification. Since the IPCC report, studies have demonstrated that the internal redistribution of ocean temperature causes variability of the global atmospheric temperatures, modulating the rate of mean global temperature increase over decades.

Dr. Laurent Bopp

Dr. Laurent Bopp is a Senior Scientist at the Institute Pierre-Simon Laplace in Paris, France. He received his PhD from the University of Paris in 2001. His research focuses on the links between climate, climate change and marine biogeochemistry. In particular, he has been among the first to use global climate models to explore how anthropogenic climate change might affect marine productivity & ocean air-sea fluxes. He has been involved in the last IPCC report as a lead author for the chapter on Biogeochemical Cycles. He has received the Medaille de la Societe d'Oceanographie de France in 2011.

The ocean carbon sink, today and tomorrow: what we know, what we don't know

Laurent Bopp

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The ocean is currently absorbing one quarter of all anthropogenic carbon emissions due to fossil fuel combustion and deforestation, thus significantly limiting the pace of increasing atmospheric CO2 and anthropogenic climate change. The more recent estimate of the ocean carbon sink amounts to 2.6 (+/- 0.5) GtC/y for the last decade available (2005-2014), and is obtained through a combination of atmospheric and oceanic observations as well as ocean models. For the next decades, ocean models indicate that ocean carbon uptake will continue under all representative concentration pathways through to 2100 (very high confidence, IPCC, 2013). There is also high agreement between models that climate change, through ocean warming and circulation changes will partially offset this increase of the sink caused by rising atmospheric CO2. Yet, there are still some severe inconsistencies between model simulations and carbon cycle observations over the last decades, very large regional differences in future projections performed with ocean carbon cycle models, and important processes that are still missing in the models used for the last IPCC assessment. In this presentation, I review some of these shortcomings and present some on-going work aiming at resolving these issues. I will specifically focus on (1) the potential role of unrepresented processes related to marine ecosystems – global ocean models are limited to the simulation of lower trophic levels with very crude parameterizations for growth and loss processes, on (2) the potential role of coastal ocean processes, poorly represented in global models due mostly to too coarse horizontal resolution, and on (3) the potential large variability in air-sea carbon fluxes, as shown by observations and underestimated by ocean models, and how it affects both future projections and the detection of the impact of climate change on ocean CO2 uptake.

Dr. Raymond W. Schmitt

Dr. Raymond Schmitt is a Senior Scientist in the Department of Physical Oceanography at the Woods Hole Oceanographic Institution (WHOI) and holds the Van Allen Clark Sr. Chair for Excellence in Oceanography. His research has focused on the ocean's role in climate, small-scale mixing processes, double-diffusive convection, the global water cycle, and instrumentation for a global ocean observing system. Schmitt has served on a number of national and international committees concerned with climate and is currently the Salinity Science Team Leader for NASA and serves on the Earth Sciences Subcommittee of the NASA Advisory Council. Schmitt is a Fellow of the American Geophysical Union and was awarded a J.S. Guggenheim Fellowship in 1997. He has authored or co-authored over 100 publications.

The Global Water Cycle

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The ocean has a much larger water cycle than the land, with global ocean evaporation of 13 Sverdrup's being 10 times larger than the sum of all river flows. This disparity and the different dynamics of dry surfaces, have led to a disconnect between terrestrial hydrologists and oceanographers. Here we show that there is in fact a close coupling between the water cycles of ocean and land. In both cases there is much local recycling of moisture, since it does not travel far in the atmosphere. We argue that the most important water cycle variable is the net export (or import) of water to (from) an area. Over the open ocean this is just evaporation minus precipitation (E-P). The "P vs E" plot is a valuable tool for identifying the source and sink regions of the water cycle. The subtropical high pressure systems are the source regions of the water cycle, with a global net export of ~4.5 Sv. The three sinks are the ITCZ in the tropics, the high latitude sub polar lows, and the land which receives about 30% of this exported water. The sub polar lows receive more water than the tropics, where high rainfall is maintained by local recycling. Of course, the signature of E-P in the ocean is the sea surface salinity (SSS), as only net freshwater fluxes can create salinity variations. With the land receiving ~30% of the oceanic export, conservation of water and salt assures that there is close coupling between terrestrial rainfall and the salinity of nearby oceans, and SSS variations have indeed been found to be valuable for seasonal rainfall forecasts on land. The remarkable 3-6 month lead of winter-spring SSS over summer rainfall appears to be mediated by the recycling process on land through soil moisture. When soil moisture is high, terrestrial regions can become more oceanic-like, with solar heating energizing evaporation and leading to down-stream propagation of the moisture signal. The correlation of high SSS with high rainfall promises to be a very sensitive climate prediction tool for a variety of regions around the world and may be especially useful for prediction of extreme flooding events.

Dr. Lijing Cheng

Dr. Lijing Cheng received his PhD from the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS) in 2014 for his research "Estimation on global ocean heat content and the tropical cyclone's impact on ocean energy budget". He then worked in IAP/CAS as a Research Associate. His work includes examination of instrumental bias in ocean temperature observations (XBT) and study of historical ocean heat content change.

Historical ocean heat content estimation and the implication for assessing historical Earth's energy budget

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Ocean heat content (OHC) change contributes substantially to global sea level rise and is a key metric for the Earths energy imbalance, so it is a vital task for the climate research community to estimate historical OHC. In the latest IPCC-AR5 report, the available upper 0-700m ocean heat content estimates from 1970 to 2010 show large differences ranging from 74 TW to 137 TW, implying a large uncertainty. The community has made a great effort to reduce the errors in the observation-based OHC calculations in recent years. Among these efforts are the removal of XBT biases, the selection of an appropriate climatology, the removal of errors due to the insufficient vertical resolution of the data, and a new understanding on the mapping (gaps-filling) methods. We will review recent progress to reduce the errors in OHC estimates. These improvements lead to a better reconstruction of historical OHC change and we show that the updated OHC estimates by different groups significantly reduce the uncertainties in historical OHC changes compared with IPCC-AR5. Moreover, we will show that the CMIP5 models show large spread in OHC changes, but the ensemble median has excellent agreement with the updated observational estimate. These results increase confidence in both the observational and model estimates to quantify and study changes in Earths energy imbalance over the historical period (since 1970).

Parallel Orals – Session 1.1

Parallel Session 1.1 Energy

Monday, 19th September 2016 - 16:00hrs **Exposition Hall - 3rd Floor**

1.1-A

Insights into Earth's energy imbalance from multiple sources

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The current Earths energy imbalance (EEI) represents the most fundamental metric defining the status of global climate change, and can best be estimated from changes in ocean heat content (OHC), complemented by radiation measurements from space. Sustained observations from the Argo array of autonomous profiling floats have been analyzed into near-global analyses but insufficient continuity can result in non-physical changes over time. A model enables past observations to be brought forward in time thereby infilling gaps in space and time via data assimilation, improving OHC analyses, and with the potential to provide superior products more in tune with observations of EEI from space. New estimates of OHC and their changes show considerable cancellation in the upper 300 m and with 44% of the short-term trend of 0.8 W m-2 (globally) occurring below 700 m depth for 2005-14. Many objective analyses of the ocean that do not use a dynamic model have rates of change of monthly OHC 20 times too large to be physical.Rates of change of OHC should be routinely produced and compared with CERES to better ensure that physical constraints are adhered to

1.1-B

A new concept for space-time integration of surface turbulent heat fluxes and analysis of long-term change in basin-scale surface flux

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Space-time integration of surface turbulent heat fluxes is important for obtaining area-averaged budget estimates and for producing climatologies of surface fluxes. Uncertainty of the integration or averaging of fluxes in space and in time are especially high when the data are sparse as in the case of the use of information from Voluntary Observing Ships (VOS) which are characterized by inhomogeneous sampling density in contrast to NWP products and satellite data sets. In order to minimize sampling impact onto local and larger scale surface flux averages we suggest an approach based upon analysis of surface fluxes in the coordinates of steering parameters (vertical surface temperature and humidity gradients on one hand and wind speed on the other). These variables are distributed according to the Modified Fisher-Tippett (MFT) distribution (temperature and humidity gradients) and Weibull distribution (wind speed) which imply a 2-dimentional distribution for the fluxes. Since the fluxes in these coordinates are determined in a unique manner (within a chosen bulk transfer algorithm), they can be easily integrated in the space of 2-dimentional distribution in order to get the averaged values dependent on the parameters of the MFT and Weibull distributions. Conceptually, the approach is similar to that oceanographers apply for analysing volumetric T,S-diagrams of water mass properties. We developed an algorithm for applying this approach and also provided the analysis of integrated surface fluxes for different regions of the North Atlantic for which heat flux estimates can be obtained from oceanographic cross-sections. Analysis was performed for the last 5 decades. 2-dimensitonal diagrams also make it possible to analyse temporal variability of integrated surface fluxes in the dimension of steering parameters and to further compare estimates with changes in the ocean heat content.

1.1-C

Sea level accelerations, the recent surface warming slowdown and the planet's energy balance

<u>Rui Ponte</u> (1), Christopher Piecuch (1), Patrick Heimbach (2,3), Xinfeng Liang (4), Gaël Forget (2)

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The role of ocean heat uptake in the global surface warming slowdown during the 00;s compared to the 90's remains uncertain. Sub-surface ocean temperature data provide a direct measure of heat storage, but coverage prior to Argo float deployment is not optimal, and existing ocean "reanalyses" exhibit large spreads and discrepancies with the data. Our examination of satellite altimeter data, with homogeneous high-quality coverage since 1993, reveals statistically significant large-scale sea level accelerations over the tropical Indian and Atlantic oceans, but decelerations are also seen elsewhere (e.g., subtropical North Pacific, subpolar North Atlantic). A recent data-constrained ocean state estimate is consistent with these findings and allows further quantitative inference about the observed patterns and underlying physical mechanisms. Most sea level patterns reflect thermosteric height changes. Related heat content changes can be significant down to depths of 1000 m. Thermosteric changes do not necessarily reflect local surface heat input (e.g., eastern equatorial Pacific), mainly because advection redistributes heat horizontally and can dominate the heat budgets (e.g., tropical Indian Ocean). In the global mean, there is an acceleration of thermosteric sea level consistent with enhanced ocean heat uptake, which is concentrated at depths of 100–400 m and equivalent to an extra net surface heat input of ~0.2 W/m2 in the 00's compared to the 90's. Global means are, however, small residuals of much larger regional anomalies, and a truly global view is needed for a full understanding of the ocean's role in the surface warming slowdown.

1.1-D

An idealized 50 years decomposition of the impact changing surface conditions have on ocean subsurface temperature trends

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Ongoing anthropogenic climate change is responsible for considerable changes in oceanic and atmospheric properties. Long-term changes to ocean surface salinity reflect a changing global water cycle (evaporation-precipitation; E-P), driven by a coherent and consistent warming of the Earth's atmosphere. During the last decades, the ocean surface warmed at a rate of about 0.5oC in 50 years. Concurrently, the surface salinity pattern was amplified compared to the mean salinity at a rate of about 8% in 50 years. Furthermore, the wind pattern has shifted and amplified, which drives changes of the water-masses and differences in the penetration of surface properties into the ocean interior. While salinity changes along with warming of the global ocean is a well-documented response to ongoing climate change, the processes that drive changes in the ocean interior in response to surface-forced salinity amplification, warming and wind stress changes are not well understood. The Australian Community Climate and Earth System Simulator Ocean Model (ACCESS-OM) is utilized to decompose the drivers of observed subsurface ocean temperature changes. We imposed independently and together surface salinity and surface temperature changes that mimic idealized estimates of observed change along with lesser-constrained estimates of observed wind changes. The nature and structure of changes in the wind field are however not fully known, so we use 4 independent estimates and investigate the model response. These forced idealized simulations allow for a decomposition of the long-term observed changes estimated from sparse observations over a period of 50-years. These simulations suggest that the model closely reproduces most observed estimates of ocean warming in the ventilated gyres in simulations that include surface-forced warming, along with imposed wind changes. Conversely, in the higher latitudes, the observed patterns are most closely replicated in simulations that include surface-forced changes in salinity and wind. Additionally, a subsurface temperature maxima appears in the ventilated gyres through changes in the surface salinity. The perturbations in surface temperature, salinity and momentum are complementary in defining the changes in the subsurface temperature field.

1.1-E

Global ocean vertical heat flux and its bidecadal change

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Using a dynamically consistent state estimate, the vertical redistribution of heat within the ocean is investigated over a 20-year period (1992-2011). The 20-year mean vertical heat flux shows strong variations both horizontally and vertically, consistent with the ocean being a dynamically active and spatially complex heat exchanger. Between mixing and advection, the two processes determining the vertical heat transport in the deep ocean, advection plays a more important role in setting the spatial patterns of vertical heat exchange. The global integral of vertical heat flux shows an upward heat transport in the deep ocean, suggesting an abyssal cooling trend over 1992-2011. These results support the inference that the near-surface thermal properties of the ocean are a consequence, at least in part, of internal redistribution of heat, some of which must reflect water that has undergone long trajectories since last exposure to the atmosphere.Analysis of linear trends in the bidecadal vertical heat flux provides dynamical insights into the global ocean heat content change. Preliminary results show that above 1500 m more heat is transported downward during 2002?2011 than 1992-2001. The spatial pattern of the vertical heat flux change shows consistent features with previous studies. Whereas the spatial pattern of vertical heat flux change is closely related to the advection change, its global integral is largely determined by the change in mixing, indicating a crucial role of ocean mixing in explaining the long-term change of ocean vertical heat exchange.

1.1-F

Attribution of observed Southern Ocean warming and freshening using a new Super Ensemble

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Observations show that the subsurface Southern Ocean is warming rapidly, and faster than global ocean average. This enhanced warming has previously been partly attributed to a wind-driven poleward shift in the fronts of the Antarctic Circumpolar Current (ACC). However recent research shows that the winds have not shifted poleward in the annual mean (only in DJF), and careful altimetrically-derived transport based metrics also show no shift in the positions of the ACC fronts. Therefore the role of horizontal advection in warming the Southern Ocean is likely to be smaller than previously inferred, but the relative contributions of advection and surface fluxes remain poorly known.

Here we use an observed climatology of Southern Ocean temperature and salinity, derived over the well sampled Argo era, and compute historical rates of warming and freshening using differences between this climatology and hydrographic profiles extending back to 1900. We show that there has been a continuous and statistically significant warming and freshening of the Southern Ocean which is concentrated above 1000 m. To understand the drivers of these changes we make use of a 'Super-Ensemble' of the Canadian Earth System Model version 2, comprised of Large Ensembles for the "All forcing", "Natural", "Misc" and "Ozone" experiments, with 50 members each. The ensemble means from each experiment provide us with the fingerprints of forced change associated with all forcing, volcanoes and solar variability, anthropogenic aerosols and stratospheric ozone respectively, while the ensemble spread quantifies the internal variability. The simulations also allow us to examine the relative roles of surface fluxes and horizontal advection in the forced changes.

Volcanic eruptions, aerosols and ozone depletion each drive a clear forced response in the Southern Ocean which is detectable using the Super Ensemble. The "All forcing" experiment shows a strong warming over the upper 1000 m of the Southern Ocean, particularly since 1970, which is largely attributable to increases in surface heating. Large volcanic eruptions such as Agung, El Chichon and Pinatubo led to sudden cooling, followed by a slow warming during recovery, also driven mostly by surface fluxes. Ozone depletion contributed significantly to the total warming over the period, which is likely linked to changes in both surface fluxes and horizontal advection. Finally, we attempt to identify these patterns of change in the observations using a multiple linear regression approach. We conclude that observed Southern Ocean changes are driven by a variety of forcing agents and occur as a result of both surface fluxes and horizontal advection.

Parallel Orals – Session 1.2

Parallel Session 1.2 Carbon

Monday, 19th September 2016 - 16:00hrs **Exposition Hall - 4th Floor**

1.2-A

Investigating the mechanisms behind the reinvigoration of the Southern ocean carbon sink

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The oceans mitigate the rate of climate change by absorbing about 25% of anthropogenic CO2 emissions annually from the atmosphere. The Southern Ocean makes a substantial contribution to this oceanic carbon sink: more than one third of the anthropogenic CO2 in the ocean has entered south of 35°S. Contrasting with this mean-state characteristics of the modern Southern Ocean carbon sink, two recent surface ocean data–based air-sea CO2 flux products have shown that the Southern Ocean carbon sink exhibits large decadal fluctuations between 1992 and 2011. They represent an amplitude of about 0.6 Pg C y-1, corresponding to roughly 60% of the modern Southern Ocean carbon sink. Although current generation Earth system models are able to capture the modern mean-state characteristics of the Southern Ocean carbon sink, they fail at reproducing both the timing and the amplitude of such fluctuations occurring at decadal time scales, questioning their reliability to provide suitable projections of the future ocean carbon sink. Here, by prescribing the observed sea surface temperature or surface wind stress over the tropical Pacific in an Earth system model, we uncover the mechanisms behind the recent Southern Ocean carbon sink fluctuations. We show that the remote processes between the tropical Pacific and the Southern ocean reconcile Earth system model simulations and observations over years 1992 to 2011. We consequently demonstrate that the same chronology of mechanisms which has caused the equatorial Pacific cooling and the global warming hiatus are also responsible for the decadal fluctuations of the Southern Ocean carbon sink and hence its recent reinvigoration.

1.2-B

Temporal and Spatial Scale-Sensitivities of Air-Sea CO2 Fluxes in the Southern Ocean

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Recent work has emphasized not only the important role of the Southern Ocean in the global carbon cycle but also some not fully understood differences in the seasonal cycle characteristics of CO2 fluxes between models and observations. These differences could be related to the parameterizations of complex biogeochemical processes as well as dynamics being excluded through pragmatic choices of model resolution. These differences between models and observations become an important challenge to constraining the non-steady state component of the trends in CO2 ocean - atmosphere fluxes of CO2.

In this presentation we make use of our high resolution observations and model outputs for the SAZ of the South East Atlantic Ocean as examples of scale sensitivities of the mean annual CO2 fluxes. High resolution CO2 data were collected using ocean gliders in the course of two seasonal cycle experiments undertaken between 2014-2015 and 2015-2016. Early analysis of these data suggests that the seasonal mean is sensitive to the temporal sampling scale. These results showed that for regions of the Southern Ocean dominated by intraseasonal modes of CO2 variability that resolving the synoptic scale variability was critical to reducing the uncertainty of the mean seasonal CO2 fluxes.

This result is tested using modal analysis of a hierarchy of peri-Antarctic and regional models as well as two consecutive seasonal observational data sets. These results are then extended to the Southern Ocean system.

1.2-C

Current and Future Ocean Carbon Uptake - Carbon Hot Spot: A new field program to understand the role of eddies in carbon sequestration within the Kuroshio Extension region

Stuart P. Bishop (1), Andrea J. Fassbender (2,3), Meghan F. Cronin (2), Dongxiao Zhang (2), Ryuichiro Inoue (4), Christopher L. Osburn (1), Eitarou Oka (5), Qiu Bo (6), Xiaopei Lin (7)

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Western Boundary Current regions experience the most intense surface heat loss of anywhere in the world's oceans. This heat loss near the Kuroshio Extension (KE) has important feedbacks on the atmospheric circulation; affecting the jet stream path and the regional climate of the western United States, as well as the formation of Subtropical Mode Water (STMW). The formation of mode water is thought to account for a majority of anthropogenic carbon dioxide (CO2) sequestration outside of the polar regions. Yet, there are still many open questions about what processes drive the formation and long-term evolution of STMW in the presence of meso- and submesoscale eddies. Coupled climate models that include biogeochemical (BGC) properties are in their infancy and still rely on parameterizations for mesoscale eddies. In order to adequately make and understand regional and future climate projections on decadal time scales and longer it is pivotal that we characterize the drivers and implications of STMW variability.

A field program using autonomous vehicles to measure physical and BGC properties of the upper kilometer of the ocean is planned for winter/spring of 2018 in the vicinity of the KE Observatory (KEO). The goals of the field program are to observe the atmospheric fluxes of CO2 while resolving the spatial and temporal scales of submesoscale eddies, and to close dynamical budgets of heat and BGC tracers during the winter/spring transition when STMW formation peaks. KEO is in the optimal location for this study and meteorological observations as well as temperature and salinity measurements throughout the surface mixed layer have been made since 2004. Additionally, observations of pCO2 in the surface ocean and atmosphere have been made since 2007, as well as a suite of ocean acidification measurements, which began in 2011.

1.2-D

Updated global trends in surface ocean pCO2: decadal to multidecadal timescales

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Ocean carbon uptake substantially reduces the rate of anthropogenic carbon accumulation in the atmosphere and thus slows global climate change. In the interest of understanding how this ocean carbon sink has responded to climate variability and climate change in recent decades, trends in globally observed surface ocean partial pressure of CO2(pCO2ocean) are evaluated over 17 gyre-scale,biogeochemically defined biomes. Trends from decadal to multidecadal timescales between 1981 and 2014 are considered utilizing the quality-controlled, and consistently updated, SOCAT dataset (Bakker et al. 2015). Select comparisons to thesame analysis using the LDEO database (Takahashi et al. 2014) are also made. On decadal timescales, pCO2ocean trends have been of variable magnitude and sensitive to the chosen start and end years. In many biomes, positiveΔpCO2trends (pCO2ocean – pCO2atm) do occur for trends shorter than 20 years, which is consistent with forcing by climatic variability. On longer time frames, several regions of the tropics and subtropics display ΔpCO2trends indistinguishable from zero, given uncertainty bounds. In the Southern Ocean through the mid-2000s, ΔpCO2 trends are positive, but after this point they are uniformly negative - indicating a strengthening of the Southern Ocean CO2sink in the last decade.Warming has also become a significant contributor to increasing pCO2 oceanin many biomes since the mid-2000s.

1.2-E

Sources of uncertainties in 21st century projections of potential ocean ecosystem stressors

Thomas Frölicher (1), Keith Rodgers (2), Charles Stock (3), William Cheung (4)

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Future projections of potential ocean ecosystem stressors, such as acidification, warming, deoxygenation and changes in ocean productivity, are uncertain due to incomplete understanding of fundamental processes, stochastic climate variability, and divergent carbon emissions scenarios. This complicates climate change impact assessments. We evaluate the relative importance of these uncertainty sources in projections of potential stressors as a function of projection lead-time and spatial scale. Internal climate variability is the dominant source of uncertainty in low latitudes and in most coastal Large Marine Ecosystems over the next few decades, suggesting irreducible uncertainty inherent in these short projections. Uncertainty in projections of century-scale global sea surface temperature (SST), thermocline oxygen, and regional surface pH is dominated by scenario uncertainty, highlighting the critical importance of policy decisions on carbon emissions. In contrast, uncertainty in century-scale projections of net primary productivity (NPP), low oxygen waters, and Southern Ocean SST is dominated by model uncertainty, underscoring the importance of overcoming deficiencies in scientific understanding and improved representation in Earth System Models are critical for making more robust projections of these quantities. We also show that changes in the combined potential stressors emerge from the noise in 36% of the ocean by 2016-2035 and in 54% of the ocean by the end of the century following a high carbon emissions scenario. Projected large changes in surface pH and SST can be reduced substantially and rapidly with aggressive carbon emission mitigation, but only marginally for oxygen and NPP. The regional importance of model uncertainty and internal climate variability underscores the need for expanded and improved projection ensembles for regional marine resource impacts.

1.2-F

Estimation of anthropogenic carbon in global ocean using transit time distribution and evaluation of its uncertainties based on ocean model output

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Quantifying the uptake and distribution of anthropogenic carbon (Cant) in the oceans is crucial for understanding the ocean's role in the climate system. However, the Cant in the ocean is not a directly measurable quantity, and the observational-based estimations of Cant are therefore relied on inference methods. Unlike most other inference methods, the transit time distribution (TTD) method allows for a spectral of water mass ventilation time and avoids the large uncertainties introduced by attempts to discriminate the small Cant perturbation from the large background of natural carbon. The uncertainties of the TTD method arises from common essential assumptions as other inference methods, such as steady state ocean circulation assumption and constant air-sea carbon disequilibrium assumption defined as the difference between the preformed carbon at the ocean surface and the dissolved carbon concentration in equilibrium with the atmospheric carbon dioxide. To evaluate the uncertainties in the TTD method, the Cant is estimated by applying the TTD method with the model simulated passive tracer of chlorofluorocarbon-12 (CFC-12), and the results are compared to the directly simulated Cant in the ocean carbon cycle model. The model simulated global inventory of Cant in year 2002 is 148 Pg-C, while the estimation of Cant by TTD with model simulated CFC-12 is about 9 Pg-C more than the direct model simulation. It is found that an unit mixing ratio (Δ/Γ) of the assumed TTD generally fits most regions of the global ocean, but in the Arctic and Nordic Seas smaller mixing ratio ($\approx$0.8) is preferable, and the in the Southern Ocean, larger mixing ratio ($\approx$1.2) should be used. The steady state circulation assumption causes uncertainty less than 1%, while the constant carbon disequilibrium assumption leads to large uncertainties in the Southern Ocean, the Nordic Seas and Arctic Ocean. An time-dependent air-sea carbon disequilibrium scheme is proposed according to the model output, which reduces the bias of the global Cant inventory to about 1.5 Pg-C, and also improves the spatial distribution of Cant compared with the model output.

Parallel Orals – Session 1.3

Parallel Session 1.3 Water

Monday, 19th September 2016 - 16:00hrs **Multifunctional Hall**

1.3-A

Connections between oceans and continents via the atmospheric water cycle

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The Quasi-Isentropic Back Trajectory (QIBT) scheme traces sources of precipitation back to their regions of origin as evaporation using observational data and/or reanalyses. The proportion of moisture from oceanic versus terrestrial evaporative sources indicates the linkage in the hydrologic cycle between ocean and land via the atmosphere. This varies significantly across the annual cycle for most but not all locations, and also varies interannually for many locations, particularly across the subtropics. Hydrologic linkages between the ocean basins through the atmosphere and land are also described. A key factor for many floods is the anomalous supply of evaporated moisture from oceanic sources, carried onto continents by so-called "atmospheric rivers" and other advective features. The linkages between maritime evaporative moisture sources and floods over various parts of the world will also be characterized.

1.3-B

Dry gets drier, wet gets wetter? Why ocean responses do not translate into land climate behaviour

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Assessments of observed and projected continental dryness trends yield contradicting results since they are substantiated using diverse methodologies and data sources. In this context, the "dry gets drier, wet gets wetter" paradigm is often being used as a simplifying summary of anticipated as well as observed water-related climate changes over land, although it is mostly based on oceanic data. However, recent studies cast doubt on the validity of the paradigm and on applying the widely used P-E (precipitation-evapotranspiration) metric over global land surfaces. Here we provide a comprehensive and robust assessment of historical and future land dryness changes by analyzing more than 300 combinations of various hydrological observations-based datasets and a large ensemble of state-of-the-art climate models. Dryness changes are evaluated through the joint analysis of both water availability (P-E) and aridity (ratio of potential evaporation and precipitation) to fully account for the hydroclimatological characteristics of the land surface. In the first part of this presentation we will discuss results of a recent study investigating robust trends in water balance over land (Greve et al., 2014). The results confirm previously identified hotspots of changing dryness, but also highlight that over large extents of global land area (ca. 75%) robust dryness changes cannot be detected. Within the 25% land area fraction with robust changes, only the minority (11%) confirms the "dry gets drier, wet gets wetter"paradigm. Of the remaining regions 10% display opposite changes (i.e. wettening dry areas and drying wet areas) and another 4% display drying/wetting in transitional climate regions. In the 2nd part we consider how these response are modified in the context of climate change projections (Greve and Seneviratne, 2015). The results show that projected changes in mean annual P-E are generally not significant, except for high-latitude regions showing wetting conditions until the end of the 21st century. Significant increases in aridity do occur in many subtropical, but also adjacent humid regions. However, combining both metrics still shows that ca. 70% of all land area will not experience significant changes. Based on these findings we conclude that the "dry gets drier, wet gets wetter" paradigm is generally not confirmed for historical and projected changes in most land areas.

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1.3-C

Current changes in precipitation and its extremes across wet and dry regions

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Regional energy and moisture transports are expected to alter as the climate warms with serious implications for water resource management. It is therefore important to both monitor and understand current changes in the water cycle. Observationally derived global low level water vapour increases with temperature at the rate expected from Clausius Clapeyron equation (~7%/K), consistent with the rate of increase in 5-day extreme (99th percentile) rainfall projections with warming. However for observed interannual variability, precipitation increases around 15%/K over the ocean and does not change significantly over land in observations and atmosphere-only AMIP simulations. This result is explained by the aliasing of El Nino variability (warmer El Nino years are associated with less rainfall on average over the land) and we demonstrate that interannual variability is not a good proxy for projected changes in extreme rainfall over land (Allan et al. 2014). Changes in precipitation with global temperature are very sensitive to the intensity bin (higher intensities produce more positive responses). We also find contrasting responses in precipitation in the high and low precipitation regimes of the tropical circulation (defined as the upper 30% and lower 70% of the precipitation totals across the tropics (30oS–30oN) each month). Observed decreases in precipitation over the lowest rainfall part of the tropical circulation over land (1950–2010) are captured by coupled atmosphere–ocean climate models (-0.3%/decade) with trends projected to continue into the 21st century. Discrepancies between observations and simulations over the wettest land regions since 1950 are explained by decadal fluctuations in El Niño southern oscillation, the timing of which is not represented by the coupled simulations (Liu and Allan, 2013). When atmosphere-only simulations are instead driven by observed sea surface temperature they are able to adequately represent this variability over land. Global distributions of precipitation trends are dominated by spatial changes in atmospheric circulation. For example, increases in Sahel rainfall since the 1980s may be linked to radiative forcing while increases in rainfall over southern Africa are linked with internal decadal Pacific ocean variability (Maidment et al. 2015); a possible change in phase of this variability may signal an end to this trend. Unforced variability appears to dominate trends for the present over many regions but land-surface feedbacks and secular changes in atmospheric circulation patterns become increasingly important into the future. Although precipitation is larger than evaporation on multi-annual time-scales, on seasonal time scales evaporation can exceed precipitation and this may explain how trends in wet season becoming wetter and dry season becoming drier are likely (Kumar et al. 2015).

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1.3-D

North Atlantic Salinity as a Predictor of Extreme Precipitation Events in the US Midwest

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Moisture evaporating from subtropical oceans fuels extreme precipitation on land. This ocean-to-land moisture transport leaves an imprint on sea surface salinity (SSS). We are motivated to explore whether SSS in certain areas of the subtropical oceans can be utilized as a predictor of extreme terrestrial precipitation. Evidence is presented that springtime SSS in the northwestern portion of the subtropical North Atlantic can be a practical predictor of extreme summer precipitation in the US Midwest. Specifically, five out of six historical extreme precipitation events in the Midwest follow a saltier-than-normal subtropical North Atlantic in the spring. Meanwhile, in all of the six years with the saltiest subtropical ocean, a wet summer ensued in the Midwest. Such a high predictive skill using SSS as a predictor is attributable to the close relationship between SSS and the oceanic water cycle, and the influence of the oceanic water cycle on terrestrial precipitation. With a saltier North Atlantic in the spring, more moisture is transported out of the subtropical ocean. The moisture is then transported to and converges in the Southern US, which increases local soil moisture content. As the season progresses, the gradual intensification of the Great Plains low-level jet mediates the spread of anomalous soil moisture content to the entire Central US. The spatial distribution of soil moisture in the Central US exerts dual effects on atmospheric thermodynamics (humidity) and dynamics (wind), which collectively bring excessive precipitation to the US Midwest. Thermodynamically, the increased soil moisture moistens the atmospheric boundary layer along 36°N, and strengthens a meridional gradient of atmospheric humidity. Thus, more moisture will be converged into the Midwest by the climatological low-level wind. Dynamically, the increases in soil moisture over the central US enhance the west–east soil moisture gradient eastward of the Rocky Mountains, which can help to intensify the Great Plains low-level jet in the summer, converging more moisture into the Midwest. Due to the close physical linkages, North Atlantic SSS outperforms SST-based predictors by a large margin in forecasting Midwest extreme precipitation. Thus, our study urges sustained monitoring of ocean salinity which can immensely benefit the prediction and early-warning of extreme events in the Midwest.

1.3-E

Changes in European extreme precipitation over the last decades

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Ongoing and projected changes in continental water cycle are closely connected with extreme events which provide specific mechanisms of water cycle changes. We are going to address observed variability and change in continental water cycle in the context of precipitation extremes. Although hydroclimate extremes result from many factors that sometimes act together, the major factor underlying hydroclimate extremes is precipitation. Using best available rain gauge daily data over Europe and Eurasia for the period from 1950s onwards we consider decadal and longer scale variability in the absolute and relative extremeness of precipitation arguing for a strong seasonality of linear trends evident in Central Europe. Among the major problems of changes in water cycle associated with extremes we will consider changes in temporal structure of precipitation or precipitation timing. Over last several decades both wet and dry periods have become longer in several large European regions, specifically in Central and Eastern Europe. This effect is not associated with changes in the number of wet days but, rather, with the grouping of wet days into prolonged wet and dry periods, increasing the likelihood of floods and droughts, respectively. Another critical problem for accurate quantification of the changes in extremes is the scaling of precipitation which will be considered for a shorter period of the last 2 deacdes. The impacts of precipitation extremes strongly depend on spatial and temporal scales resolved by observational networks and models. We will particularly demonstrate potential of very dense observational networks for accurate estimation of precipitation extremes and their impact on continental scale water cycle. Finally, we will discuss the requirements for data characteristics and model resolution for accurate estimation of the strongly localized nature of hydroclimate extremes and their impact on continental water cycle.

1.3-F

Arctic Freshwater Export: Status, Mechanisms, and Prospects

Thomas Haine (1), Beth Curry (2), Ruediger Gerdes (3), Edmond Hansen (4), Michael Karcher (3,5), Craig Lee (2), Bert Rudels (6), Gunnar Spreen (9), Laura de Steur (4,7), Kial Stewart (8), Rebecca Woodgate (2)

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Large freshwater anomalies clearly exist in the Arctic Ocean. For example, liquid freshwater has accumulated in the Beaufort Gyre in the decade of the 2000s compared to 1980–2000, with an extra ≈ 5000 km3 (about 25%) being stored. Both the sources of freshwater and the Arctic surface wind are important controls on freshwater anomalies, and both have changed in the last decade. Coupled climate models project continued freshening of the Arctic during the 21st century, with a total gain of about 50000 km3 for the Arctic, CAA, and Baffin Bay (an increase of about 50%) by 2100. Rapid discharges of excess freshwater through Fram or Davis straits appear possible, triggered by the wind, but are hard to predict. This paper describes recent changes in the Arctic Ocean freshwater system, reviews attempts to understand the mechanisms causing these changes, and speculates about future prospects, especially for the oceanic export of Arctic freshwater.

CLIVAR Open Science Conference

Day 2 - Tuesday, 20th September 2016

Keynote talk

Keynote Speaker **Tuesday, 20th September 2016** **17:00hrs**

Dr. Magdalena A. Balmaseda

Dr. Magdalena Balmaseda is currently the Head of Predictability Section at the European Centre for Medium-Range Weather Forecasts (ECMWF). Her main research activities are on improving the skill of initialized predictions of weather and climate with coupled models, by advancing the science, the modeling infrastructure and maximizing the use of earth observations. She is a leading expert on ocean reanalysis and data assimilation, and its applications for detection of climate signals, earth energy budget and coupled model initialization. Some of her latest initiatives are the Ocean Reanalysis Intercomparison Project (ORA-IP), that has led to the multi-analysis real-time ocean monitoring; coupled data assimilation activities at ECMWF, leading the CERA-20C (a coupled ocean-atmosphere-land-ice-wave reanalysis for the XX century); and, Promoting the seamless predictions at ECMWF, which now include the ocean and sea-ice components in the probabilistic forecasts of weather and climate, covering the medium, monthly and seasonal range. She is also a leading expert on ENSO and seasonal forecasts.

Seamless Prediction and the interactions of time scales, earth system components and institutions

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The increasing demand for reliable forecasts of Meteorology at different time scales has motivated the adoption of seamless predictions systems. In those systems, climate forecasts benefit from models well tested and verified in short-term prediction mode. At the same time, weather forecasts improve by including new components of the earth system, such as ocean, sea-ice and atmospheric composition. The inclusion of new earth system components improves the reliability of short term forecasts, expands the predictability horizon and offers new perspectives to the traditional problems of model development, verification and initialization. The increasing complexity inherent to this model of seamless prediction requires more effective collaboration between institutions, which can only be achieved by a new paradigm in software infrastructure.

Plenary Oral Presentations

Plenary Session 2 **Tuesday, 20th September 2016** **09:00hrs**

Dr. Harry H. Hendon

Dr. Harry Hendon is a Senior Principal Research Scientist Bureau of Meteorology, Melbourne and is the leader of Climate Processes Team. His research interests are the dynamics and predictability of intraseasonal to interannual climate variability. His major contributions have been to the diagnosis and understanding of tropical intraseasonal variability, and in particular the Madden-Julian Oscillation, and on understanding variability and predictability of the Australian Monsoon. His recent work has focused on development of coupled model sub seasonal-seasonal climate prediction He has previously been research scientist at Division of Atmospheric Research, CSIRO Australia and the Climate Diagnostic Center, NOAA, Boulder Colorado. He is currently a member of the WWRP-WCRP S2S Steering Group and the TPOS-2020 Steering Committee.

Progress in Sub-Seasonal and Seasonal Prediction

Harry H. Hendon

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Recent progress in coupled model sub seasonal and seasonal climate prediction is reviewed. Seasonal prediction using coupled model is a maturing field but progress is still being made through improved models, initial conditions, ensemble techniques and development of improved forecast products. Some examples of key model errors that are acting to limit predictive capability and the challenge of initializing salinity and its possible role in predictable evolution of ENSO will be discussed. Sub seasonal prediction (weeks 2-6) is an emerging capability, but which has great promise for providing meaningful advice for impending extreme events. Examples of recent progress for sub seasonal prediction of tropical cyclone activity, the Madden Julian oscillation, active and break monsoon episodes, and heat waves will be discussed. Because sub seasonal prediction bridges the weather and climate interface, focused development of sub seasonal prediction capability should benefit both numerical weather prediction and longer term climate prediction.

Dr. Rowan Sutton

Dr. Rowan Sutton is the Director of Climate Research in the UK National Centre for Atmospheric Science (NCAS). Decadal climate variability and predictability has been a major focus of his research for over 20 years. He is a member of the CLIVAR Climate Dynamics Panel and previously served on the CLIVAR Atlantic panel. He was a Lead Author of Chapter 11 ("Near-term Climate Change: Projections and Predictability") of the WG1 contribution to IPCC AR5.

Decadal Climate Variability and Predictability

Rowan Sutton

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The recent "pause" in the global mean surface temperature rise drew unprecedented worldwide attention to the importance of understanding decadal variability in the climate system. Progress in understanding, quantifying, and predicting decadal variability - not only on global scales, but also regionally - is enormously important for policy making on adaptation and mitigation. It is also very challenging science, because it pushes observations, climate models, and theoretical understanding, to their very limits. There is no comprehensive theory for the natural variability of the climate system on decadal timescales, nor do we adequately understand the role of anthropogenicforcings in climate changes on these timescales. Consequently, even though decadal variability is ubiquitous, our ability to attribute specific observed changes to natural or anthropogenic causes is as yet very limited. Notwithstanding these challenges, considerable progress has been made recently, and there are good reasons to anticipate more rapid progress in the near future. This talk will review some of the challenges in understanding and predicting decadal climate variability, the progress that has been made, and new opportunities to accelerate progress. The decadal variability of the North Atlantic region will be discussed as a particularly interesting and important case study: in the map of surface air temperature anomalies for the record warm year of 2015 the North Atlantic stands out as a rare region of cooling amidst the global warming pattern. There are interesting events taking place in this basin that could exert a significant influence on the climate of many regions in the decade ahead.

Dr. Kim Cobb

Dr. Kim Cobb's research uses high-resolution records of tropical Pacific climate to probe the mechanisms of past, present, and future climate change. With an exclusive focus on the equatorial Pacific, she has generated numerous records from corals and cave stalagmites, and operates a basin-wide network water isotope collection sites to aid in proxy calibration.

Paleo-constraints on recent trends in tropical Pacific climate

Kim Cobb

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Recent studies highlight the importance of tropical Pacific climate variability in modulating global temperature trends on decadal timescales. The identification of natural versus anthropogenic trends in the tropical Pacific represents a critical step towards more accurate near-term climate change projections, but instrumental climate data from this region are extremely limited in both space and time, especially prior to the satellite era. High-resolution, well-replicated paleoclimate data extend the instrumental record of tropical Pacific climate back 100yrs, 1000yrs, or even longer, depending on the location and the climate variable of interest. In this talk, I will provide an overview of recent advances in the field of high-resolution tropical Pacific paleoclimate in the context of data-model intercomparisons, with the explicit goal of identifying natural versus anthropogenic climate trends in this key region. Specifically, I will present evidence from corals as well as tree ring studies that support an anthropogenic shift in the hydrological cycle of the tropical Pacific, as well as an intensification of ENSO variability in recent decades. Collectively, these new data can be used to probe the accuracy of numerical climate models in simulating ENSO's response to a variety of past climate forcing. Such data-model comparisons highlight key areas where our process-level understanding of the ENSO phenomenon, and its representation in numerical models, can be improved by further studies. Most notably, the relationship between the seasonal cycle and ENSO emerges as a target where significant investments in research – both data- and model-based – are warranted.

Dr. Iuliia Polkova

Dr. Iuliia Polkova received her MS degree in computer-integrated technological processes and manufacturing from the National Aviation University, Kyiv in 2008. During her undergraduate studies, she attended additional training in environmental protection, and after graduation, further advanced her knowledge in this field by joining the research group of environmental safety problems at the Institute of Environmental Geochemistry, Kyiv, as a Junior Research Assistant. In 2010, Iuliia began her PhD research at the Max-Planck Institute for Meteorology and joined a doctoral program in the School of Integrated Climate System Sciences (SICCS) of the DFG funded excellence initiative CliSAP of the University of Hamburg. Her thesis focused on investigating predictability of the climate system at interannual-to-decadal timescales, sensitivity of predictive skill of a climate model to different initialization strategies, and understanding mechanisms for predictability. After obtaining a PhD at the University of Hamburg in 2014, she joined the Institute of Oceanography, Hamburg, as a Postdoctoral Researcher and is currently involved in a German National Research Project “MiKlip” on decadal climate prediction. Her research focuses on improving initialization and ensemble generation strategies for decadal climate predictions.

Predictive skill for regional interannual steric sea level and mechanisms for predictability

Iuliia Polkova, A. Köhl, D. Stammer

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In the estimate of global-mean sea level rise, natural fluctuations represent a significantly smaller contribution than the anthropogenic forcing of Earths energy budget. On the other hand, regional sea level variability can be very different from the global mean and is strongly influenced by internal climate Earth System Models from the observed climate state improved predictive skill for important climate variables such as sea surface temperature and ocean heat content. In this study, we performed decadal variability. Decadal prediction studies demonstrated that, in addition to prescribing external forcing, initializing hind casts initialized every five years over the period 1960-2000, to study the predictive skill of annual-mean regional steric sea level and associated mechanisms for predictability. The experimental design follows the CMIP5 protocol. The ensembles of hind casts are carried out with the UCLA/MITgcm climate model. The ocean initial state is provided by the German contribution to Estimating the Circulation and Climate of the Ocean project (GECCO) and includes temperature, salinity, zonal and meridional velocities, and sea surface height (SSH). The assessment of skill is based on the correlation coefficient and root-mean-squared-error, for which GECCO ocean synthesis and tide gauges data are used as

verification datasets. The initialized hind casts are also compared to the low-skill persistence hindcasts.Predictive skill for steric sea level is found over large areas of the ocean, notably over the subtropical Atlantic and Pacific Oceans, along the path of the North Atlantic Current, and over the Indian and Southern Oceans (up to lead time yr6-9). These patterns of skill are very similar to those for dynamic topography. After the first lead year, both dynamic topography and steric sea level anomalies show larger skill than the persistence. In terms of predictability from temperature and salinity contributions to sea level changes, similar skill patterns are found over the extra tropical Southern Hemisphere and the Atlantic Ocean. In addition, both thermosteric and halosteric terms showed skill over the tropical North Atlantic and eastern North Pacific, which is not present in the total steric signal and is associated with the density-compensated temperature-salinity anomalies. Mechanisms for the predictability of the thermosteric and halosteric contributions to the steric signal are studied by separating these components into signals originating from processes within and beneath the mixed layer. Contributions originating from below the mixed layer are further decomposed into density-related (isopycnal motion term) and density-compensated (spice term) changes. In regions of the subtropical Pacific and Atlantic Oceans, predictive skill results from the interannual variability associated with the contribution from isopycnal motion to thermosteric sea level. Skill related to thermosteric mixed layer processes is found to be important in the subtropical Atlantic, while the spice contribution shows skill beyond the persistence over the sub polar North Atlantic. In the subtropics, high predictive skill can be rationalized in terms of westward-propagating baroclinic Ross by waves for a lead time of yr2-5, as demonstrated using an initialized Ross by wave model. Because of the low Ross by wave speed in high latitudes, this process is not separable from the persistence there.

Parallel Orals – Session 2.1

Parallel Session 2.1 Intraseasonal to Interannual

Tuesday, 20th September 2016 - 14:00hrs **Ballroom 1**

2.1-A

The Role of Reversed Equatorial Zonal Transport in Terminating an ENSO Event

Han-Ching Chen (1,2), Zeng-Zhen Hu (3), Bohua Huang (2), Chung-Hsiung Sui (1)

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This study shows that the sudden basin-wide reversal of anomalous equatorial zonal transport above the thermocline at the peaking phase of ENSO triggers rapid termination of ENSO events. The anomalous equatorial zonal transport is controlled by the concavity of anomalous thermocline meridional structure across the equator. During developing phase of ENSO, opposite zonal transport anomalies form in the western-central and central-eastern equatorial Pacific, respectively. Both are driven by the equatorial thermocline anomalies in response to zonal wind anomalies over the western-central equatorial ocean. At this stage, the anomalous zonal transport in the east enhances ENSO growth through zonal SST advection. In the mature phase of ENSO, off-equatorial thermocline depth anomalies become more dominant in the eastern Pacific due to the reflection equatorial signals at the eastern boundary. As a result, the meridional concavity of the thermocline anomalies is reversed in the east. This change reverses zonal transport rapidly in the central-to-eastern equatorial Pacific, which is joined with the existing reversed zonal transport anomalies further to the west and forms a basin-wide transport reversal throughout the equatorial Pacific. This basin-wide transport reversal weakens the ENSO SST anomalies by reversed advection. More importantly, the reversed zonal transport reduces the existing zonal tilting of equatorial thermocline and weakens its feedback to wind anomalies effectively. This basin-wide reversal is built-in at the peak phase of ENSO as an oceanic control on the evolution of both El Niño and La Niña events. The reversed zonal transport anomaly after the mature phase weakens El Niño in the eastern Pacific more efficient than that does in the La Niña.

2.1-B

Tropical Rainfall, Rossby Waves and Regional Winter Climate Predictions

Adam Scaife (1), Ruth Comer (1), Nick Dunstone (1), Jeff Knight (1), Doug Smith (1), Craig MacLachlan (1), Nicola Martin (1), Drew Peterson (1), Dan Rowlands (2), Eddy Carrol (1), Stephen Belcher (1), Julia Slingo (1)

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Skilful climate predictions of the winter North Atlantic Oscillation and Arctic Oscillation out to a few months ahead have recently been demonstrated, but the source of this predictability remains largely unknown. Here we investigate the role of the tropics in this predictability. We show high levels of skill in tropical rainfall predictions, particularly over the Pacific but also the Indian and Atlantic Ocean basins. Rainfall fluctuations in these regions drive clear signatures in tropical and extratropical atmospheric circulation that are approximately symmetric about the equator in boreal winter. We show how these patterns can be explained as steady poleward propagating linear Rossby waves emanating from just a few key source regions. These wave source "hotspots" become more or less active as tropical rainfall varies from winter to winter but they do not change position as they are anchored to regions of strong vorticity gradient associated with the climatological jets. Finally, we show that predicted tropical rainfall explains a significant fraction of the predicted year to year variation of the winter North Atlantic Oscillation.

2.1-C

Characterization of soil moisture variability over South America: linkages to remote sources of variability

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Slowly evolving variables, like sea surface temperature (SST) and soil states (e.g. soil moisture), have the potential to increase the atmospheric predictability through the influence on the surface fluxes, affecting thereby the boundary layer development and finally the atmospheric circulation at different time scales. During the last 30 years the influence of local and remote SST conditions over the climate in South America has been extensively studied. However, the influence of the land surface conditions on the predictability of that particular region has not been deeply investigated yet. A better comprehension of land-atmosphere interactions requires an improvement in the understanding of all the components of the hydrological cycle from a regional perspective. A basic aspect of the hydrological cycle, like the main characteristics of the soil moisture (SM) variability is barely documented. A better knowledge of SM variability has highly relevance, because locations with high SM variability are related with regions of potentially strong land-atmosphere interactions. The absence of a detailed analysis of SM climatology over South America could be explained by the lack of observational data. To fill this gap, this work documents the mean fields and main modes of SM variability at different soil depths over South America, using 29 years (1980-2008) of monthly mean 1°x 1° data derived from the Global Land Data Assimilation System (GLDAS) version 2.0. In addition the linkages with sea surface temperature (SST) are analyzed. Over Southern South America, part of the La Plata Basin (LPB), a local maximum of SM anomalies variability is observed. For deeper layers (0-100 cm), this variability is mostly explained by the low frequencies (i.e internannual). Furthermore the interannual variance of the low-pass filtered SM anomalies exhibits a similar spatial distribution to that obtained for the SM anomalies leading pattern based on an EOF analysis. This confirms the relevance of the interannual variability in explaining the SM variance in LPB. Lagged correlation between SST (leading) and SM anomalies averaged over SESA show significant negative correlations over central equatorial Pacific from lags -30 to -12 months, which reaches its maximum negative value on lag -24. Furthermore, this pattern resembles very much that associated with precipitation variability in the same region, as extensively described in previous works. In special the SST anomaly pattern is highly associated with ENSO, which exhibits the largest influence on precipitation variability in SESA from austral spring of the year in which ENSO develops to austral fall of the next year. The results found in this study could have potential implications in forecast improvements of SM conditions over SESA at seasonal time scales. This could be achieved combining coupled models forecasts and statistical methodologies, using for instance the SST as a predictor of

SM conditions. Still, further studies are needed to analyze the potential improvements in prediction of SM and its implications to the socio-economic sectors.

2.1-D

The MISVA project: From a better understanding of the intraseasonal and synoptic variability toward forecast

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The intraseasonal time scale is critical in West Africa where resources are highly rainfall dependent. Nevertheless, the intraseasonal variability (ISV) has been explored only recently. Three main modes of variability have been identified, two with a mean periodicity of 15 days called the 'quasi-biweekly zonal dipole" (QBZD; Mounier et al. 2008) and the "Sahel mode" (Sultan et al. 2003) and one with a mean periodicity around 40 days called "African MJO" mode (Matthews, 2004; Janicot et al. 2009). These modes have a regional scale and can strongly influence precipitation and convective activity. They are mainly controlled by atmospheric dynamics and land-surface interactions. They can also modulate the very specific phase of the African summer monsoon onset.

Chauvin et al. (2010) identified a robust propagative mode of variability of the Saharian Heat Low (SHL) over North Africa and the Mediterranean in the 10-25 days range, forced by midlatitude Rossby waves over Europe. When penetrating into Africa these waves modulate the low-level ventilation from the eastern North Atlantic and Mediterranean, thus modifying the location and intensity of the SHL. Roehrig et al (2011) showed that one third of the dry and wet spells over Sahel are partly explained by the midlatitude ISV, through a major role played by the SHL.

Poan et al. (2013; 2014) assessed the Sahelian ISV from the perspective of the distribution of precipitable water (PW). Whereas eastern Sahel PW variability is dominated by time scales longer than 10 days, synoptic scales dominate in the western Sahel, especially because of the influence of African easterly waves (AEWs). Corresponding dry and wet PW anomalies significantly modulate convective activity and can be tracked back to the eastern Sahel and over a long period. This implies a potential skill for short- to medium-range forecasts of wet and dry events over the Sahel.

To explore the potential forecast skill brought about by the advanced understanding of the ISV, several initiatives have been launched to monitor the tropical ISV in general and more recently with a focus on Africa (CPC, SUNY). Among them, the MISVA[1] collaborative project between Senegal and France aims at monitoring and forecasting the ISV over Africa in real-time. This project has provided a series of diagnostic indices during the WAM season since 2011 and the experience has showed that dry and moist events can be detected up to a week in advance, even as Numerical Weather Prediction models have almost no skill at these scales, at least for precipitation. In general such events are the result of the combination of several synoptic-to-intraseasonal modes. The physical understanding of the WAM discussed above helped to improve forecasting methods over West Africa and led to the current writing of the "Forecaster's Handbook for West Africa" to be published this year, in close collaboration between forecasters and scientific international communities, under the World Meteorological Organization WMO umbrella.

[1] Monitoring and forecast of IntraSeasonal Variability over Africa http://misva.sedoo.fr/

2.1-E

Tropical atmospheric forcing of the wintertime North Atlantic Oscillation

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The relationship between the interannual wintertime variability of the North Atlantic Oscillation (NAO) and tropical heating anomalies is examined using the NCEP-NCAR reanalysis and observation based sea surface temperature (SST) and precipitation data for the period from 1980-2011. The NAO is found to be significantly correlated with the precipitation anomalies over the tropical Indian Ocean and tropical America-Atlantic, but not with the underlying SST anomalies. The anomalous tropical Indian Ocean heating is related to the Madden-Julian Oscillation (MJO) occurrence in that region. The tropical heating impact on the NAO is examined and the evolution process of the influence is explored by numerical experiments using a primitive equation atmospheric model forced by atmospheric heating perturbations. Results from both the reanalysis data and numerical experiments suggest that the tropical Indian Ocean atmospheric heating appears to be a driving forcing for the NAO variability. The atmospheric response to the tropical forcing involves the combined effects of Rossby wave dispersion, normal mode instability and transient eddy feedback. The influence of the forcing on the NAO tends to be organized and achieved by the circumglobal teleconnection pattern. By contrast, the influence of the tropical American-Atlantic heating on the NAO appears to be weak. The linkage between the NAO and the tropical American-Atlantic heating is likely through the anomalously meridional atmospheric circulation over the Atlantic Ocean.

2.1-F

Intraseasonal SST and Precipitation Variability of the Indian Summer Monsoon: Impact of Ocean Mixed Layer Depth

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The Indian summer monsoon (ISM) is characterized by prominent intraseasonal fluctuations in atmospheric convection and winds, known as the monsoon intraseasonal oscillation (MISO). The northward-propagating MISOs induce pronounced sea surface temperature (SST) and precipitation variations in the eastern Arabian Sea (EAS) and Bay of Bengal (BoB). These variations, together with the SST-precipitation relation, are investigated in this study by analyzing satellite observational data and performing ocean general circulation model (OGCM) experiments. Distinct from the BoB, MISOs in the EAS achieve the largest intensity in the developing stage of the ISM (May-June). The MISOs induce intraseasonal SST variability primarily through surface heat flux forcing (contributed by both shortwave radiation and turbulent heat flux) and secondarily through mixed layer entrainment. The shallow MLD (&lt 40 m) in the developing stage and decaying stage (September-October) of the ISM significantly amplifies the heat flux forcing effect on SST and causes large intraseasonal SST variability. Meanwhile, the high SST (29 C) during the developing stage leads to enhanced response of MISO convection to SST anomaly. It means that during the developing stage, the ocean state of the EAS region favors active two-way air-sea interaction and thereby enhances the MISO intensity. These results provide compelling evidence for the vital role played by the ocean in the MISO mechanisms. Comparing to satellite observation, MISOs in CFSR data have weaker SST variability by ~50% and biased SST-precipitation relation. Reducing these biases CFSR which serves as the initial condition of the National Center for Environmental Prediction (NCEP) climate forecast system version 2 (CFSv2) may help improve the ISM rainfall forecast.

2.1-G

Understanding and Predicting Subseasonal Extreme Events: Relationship between Warm Airmass Transport into the Upper Polar Atmosphere and Cold Air Outbreaks in Winter

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This study investigates dominant patterns of daily surface air temperature anomalies in winter (November–February) and their relationship with the meridional mass circulation variability using the daily Interim ECMWF Re-Analysis in 1979–2011. Mass circulation indices are constructed to measure the day-to-day variability of mass transport into the polar region by the warm air branch aloft and out of the polar region by the cold air branch in the lower troposphere. It is shown that weaker warm airmass transport into the upper polar atmosphere is accompanied by weaker equatorward advancement of cold air in the lower troposphere. As a result, the cold air is largely imprisoned within the polar region, responsible for anomalous warmth in midlatitudes and anomalous cold in high latitudes. Conversely, stronger warm airmass transport into the upper polar atmosphere is synchronized with stronger equatorward discharge of cold polar air in the lower troposphere, resulting in massive cold air outbreaks in midlatitudes and anomalous warmth in high latitudes. There are two dominant geographical patterns of cold air outbreaks during the cold air discharge period (or 1–10 days after a stronger mass circulation across 60N). One represents cold air outbreaks in midlatitudes of both North America and Eurasia, and the other is the dominance of cold air outbreaks only over one of the two continents with abnormal warmth over the other continent. The first pattern mainly corresponds to the first and fourth leading empirical orthogonal functions (EOFs) of daily surface air temperature anomalies in winter, whereas the second pattern is related to the second EOF mode.

2.1-H

ENSO Diversity: Past, Present, and Future. Causes and Consequences of the 2015-16 El Niño

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An El Niño of surprising intensity developed in 2015-16, affecting patterns of weather variability worldwide. The event rivaled the 1997-98 El Niño, the strongest on record, in its magnitude and impacts. In its present stage of development, the 2015-16 El Niño is quickly weakening and will likely end in boreal spring, followed by the possible onset of La Niña conditions later in 2016. This presentation will describe the evolution of the event, the oceanic and atmospheric processes that gave rise to it, how well the event was predicted by various forecasting centers, and how it influenced weather around the globe.

Parallel Orals – Session 2.2

Parallel Session 2.2 Decadal

Tuesday, 20th September 2016 - 14:00hrs **Ballroom 2**

2.2-A

The Pacific decadal oscillation, revisited

Matthew Newman (1,2), Michael Alexander (2), Toby Ault (3), Kim Cobb (4), Clara Deser (5), Emanuele Di Lorenzo (4), Nathan Mantua (6), Arthur Miller (7), Shoshiro Minobe (8), Hisashi Nakamura (9), Niklas Schneider (10), Daniel Vimont (11), Adam Phillips

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Since its identification in the late 1990's as the dominant pattern of North Pacific sea surface temperature (SST) variability, the Pacific decadal oscillation (PDO) has been connected both to other parts of the climate system and to impacts on natural resources and marine and terrestrial ecosystems. Variability associated with the PDO has often been confused with externally forced climate change including anthropogenic effects. Subsequent research, however, has found that the PDO is not a single physical mode of climate variability but instead largely represents the combination of three groups of processes: (1) changes in ocean surface heat fluxes and Ekman (wind-driven) transport related to the Aleutian low, due to both local, rapidly decorrelating, unpredictable weather noise and to remote forcing from interannual to decadal tropical variability (largely El Nino) via the "atmospheric bridge"; (2) ocean memory, or processes determining oceanic thermal inertia including "re-emergence" and oceanic Rossby waves, that act to integrate this forcing and thus generate added PDO variability on decadal time scales; and (3) decadal changes in the Kuroshio-Oyashio current system forced by the multi-year history of basin-wide Ekman pumping, manifested as SST anomalies along the subarctic front at about 40N in the western Pacific ocean. Thus, the PDO represents the effects of different processes operating on different timescales, with few of its apparent impacts due to extratropical SST anomalies. This talk presents a synthesis of this current view of the PDO, and discusses corresponding implications for climate diagnosis, including of PDO climate impacts and predictability (both oceanographic and atmospheric); potential decadal regime-like behavior; simulations of the PDO in climate models; the interpretation of paleoclimate multicentennial

reconstructions of the PDO; and its impacts on marine ecosystems. We conclude with some suggested “best practices” for future PDO diagnosis and forecasts including investigating the potential role of the PDO in the global temperature hiatus.

2.2-B

A novel use of climate predictions to identify unprecedented climate extremes

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Near term climate predictions provide multiple simulations of the current climate. These climate simulations can include events more extreme than have yet been observed unprecedented extreme events. Assessing the likelihood and dynamics of these events can improve our understanding of the risks associated with climate extremes. We use the Met Office decadal climate prediction system. This provides twenty realisations initialised each year from 1980 to 2015, 700 individual simulations. It is therefore capable of sampling much more extreme cases than the available observations and can potentially allow sampling down to at least the 1/100 worst case level to allow better risk estimates. We compare the distribution of the model data to the observations to ensure any unprecedented extremes identified are not caused by model errors. Characteristics of the distributions including variance and skewness are assessed to look at both the overall distribution and the behaviour in the tails. In regions where the model does not agree with the current observations either an adjustment is applied to the model or the region is not assessed. This novel use of these near-term prediction simulations has many applications for various regions around the globe. Here we focus on the UK and South East China to explore the current risk of unprecedented extreme precipitation and temperature events.

2.2-C

Impact of observed North Atlantic multidecadal variations to European summer climate: A linear baroclinic response to surface heating

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The observed prominent multidecadal variations in the central to eastern (C-E) European summer temperature are closely related to the Atlantic Multidecadal Variability (AMV). Using the Twentieth Century Reanalysis project version 2 data for the period of 1930 to 2012, we present a mechanism by which the multidecadal variations in the C-E European summer temperature are governed by a linear baroclinic atmospheric response to the AMV-related surface heat flux. Our results suggest that over the north-western Atlantic, the positive heat flux anomaly triggers a surface baroclinic pressure response to diabatic heating with a negative surface pressure anomaly to the east of the heat source. Further downstream, this response induces an east-west wave-like pressure anomaly. The east-west wave like response in the sea level pressure structure, to which we refer as North-Atlantic-European East West (NEW) mode, is independent of the summer North Atlantic Oscillation and is the principal mode of variations during summer over the Euro-Atlantic region at multidecadal time scales. The NEW mode causes warming of the C-E European region by creating an atmospheric blocking-like situation. Our findings also suggest that this NEW mode is responsible for the multidecadal variations in precipitation over the British Isles and north-western Europe.

We further investigate the relation between AMV and European summer climate in the coupled model MPI-ESM and we find that the model is able to simulate a similar NEW mode. However, the spatial location of the mode differs from the reanalysis which could be due to the model bias in simulating observed sea surface temperature (SST) anomalies over the north-west Atlantic region. For further confirming this inference, AMIP type experiments with the atmospheric component of MPI-ESM (ECHAM6.1) are conducted, where the observed composite positive and negative phases of the Atlantic Multidecadal Variability (AMV) are given to the model as boundary conditions. The results suggest that for the negative phase of AMV, ECHAM6.1 simulates the NEW mode in SLP related to the extra-tropical SST similar to that seen in the 20th century reanalysis. However, in the positive phase of AMV SST we did not find any similar response as seen in the reanalysis. Interestingly, also in 20th century reanalysis, the NEW mode is stronger in the negative phase of extra-tropical AMV SST. Therefore, it indicates a non-linear characteristic of the NEW baroclinic response which is mainly arising in the negative phase of AMV.

2.2-D

The role of the Atlantic Multidecadal Variability on extreme climate conditions over North America and Europe

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The Atlantic Multidecadal Variability (AMV) is associated with marked modulations of climate anomalies over many areas of the globe. This includes droughts in Africa and North America, decline in sea ice, changes of tropical cylcone activity in the Atlantic, and changes in the atmospheric large-scale circulation. However, the shortness of the historical observations compared to the AMV period (~60-80yr) makes it difficult to show that the AMV is a direct driver of these variations. To isolate the AMV climate response, we use a suite of global coupled models from GFDL and NCAR, in which the North Atlantic sea surface temperatures are restored to the observed AMV pattern, while the other ocean basins are left fully coupled. In order to explore and robustly isolate the AMV impacts on extreme events, we use large ensemble simulations (between 30 and 100 members depending on the model) that are run for 10 years. We investigate the importance of model resolution by analyzing GFDL models that vary in their atmospheric resolution and we assess the robustness of the results by comparing them to similar experiments performed with the NCAR coupled model. Further, we investigate the influence of model surface temperature biases on the simulated AMV teleconnections using a flux-adjusted experiment based on a model configuration that corrects for momentum, enthalpy and freshwater fluxes. All models show that during boreal summer the AMV alters the Walker Circulation and generates precipitation anomalies over the whole tropical belt. During boreal winter, the AMV warming is associated with large anomalies over the Pacific, with a response that projects onto the Interdecadal Pacific Oscillation pattern, i.e., a Pacific Decadal Oscillation-like anomalies in the Northern hemisphere and a symmetrical pattern in the Southern Hemisphere. This winter response comes from a lagged adjustment of the Pacific Ocean to the AMV forcing in summer, which highlights the importance of using a global coupled framework to investigate the climate impacts of the AMV. We focus in this presentation on the impact of the AMV on extreme events over land. We find that a positive phase of the AMV increases the frequency of occurrence of droughts over the southern part of North America. It also leads to more extremely cold conditions over northern North America during winter, and to an increase in the number of heat waves over the southern part of North America during summer. We further show that a positive AMV leads to an increase in the number of heat waves over the Southern part of Europe. By comparing the results from all the model configurations, we highlight the importance of atmospheric resolution in the representation of weather regimes and hence on the modulation of weather regimes by the AMV. We also

stress the influence of model's mean state biases on the simulated AMV impacts in particular on the representation of extremes events over North America and Europe.

2.2-E

Southern Ocean deep convection in global climate models: a driver for variability of subpolar gyres and Drake Passage transport on decadal timescales

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We investigate decadal variability and co-variability of Southern Ocean state variables such as the strength of Ross and Weddell Gyres, Drake Passage transport, and sea-ice area using the National Institute of Water and Atmospheric Research UK Chemistry and Aerosols (NIWA-UKCA) model and CMIP5 model output. Additional variability in these variables is stimulated by strong deep reaching convective events in the Southern Ocean. The deep convection results in the formation of a dense water mass in the models which is comparable to Antarctic Bottom Water and its variability. Thus, deep convection affects the large-scale meridional density structure in the Southern Ocean. An increase in the (near) surface stratification, due to freshwater perturbations, can be a pre-condition for subsequent strong convection activity. Enhanced gyre driven sea-ice export and sub surface heat accumulation, leads to a phase shift in freshwater and heat content, and weaken the stratification such that the subsurface heat can be released to the atmosphere by sudden strong mixing events. We find that strong convection reduces the sea-ice cover, weakens the subpolar gyres, increases the meridional density gradient, and subsequently results in a positive Drake Passage transport anomaly. Results of CMIP5 models confirm that variability in sea-ice, Drake Passage transport and, the Weddell Gyre is enhanced if models show strong open ocean convective events. Connections between convection, sea-ice and Drake Passage transport variability are independent if models host open-ocean convection. They are dependent for relations between convection and the strength of Ross and Weddell Gyre.

2.2-F

Impacts of Ocean Model Parameterizations on the Atlantic Meridional Overturning Circulation (AMOC) Variability in the Community Earth System Model (CESM)

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AMOC is presumed to play a major role in decadal and longer time scale climate variability and in prediction of the earths future climate on these time scales. The primary support for such a prominent role for AMOC comes from coupled model simulations. They show rich AMOC variability, but time scales of variability and mechanisms differ substantially among models. Our previous studies with CESM showed that the ocean models subgrid scale parameterizations play a role in creation of the Labrador Sea density anomalies that lead to changes in AMOC. Here, we present a systematic assessment of the impacts of several ocean model parameter choices on AMOC characteristics in CESM with the primary goal of identifying both robust and non-robust elements of AMOC variability and mechanisms. Our control is a 2200-year pre-industrial simulation. We branch off from this control and perform several 600-year simulations where some loosely-constrained parameter values in mesoscale, sub-mesoscale, vertical mixing, and lateral viscosity parameterizations in the ocean model are changed. The characteristics of AMOC from these simulations are compared with a three-member ensemble of 600-year perturbation experiments in which the initial atmospheric temperature field is slightly perturbed. A significant finding is that both the amplitude and time scale of AMOC variability differs considerably among all these experiments with dominant time scales of variability ranging from decadal to centennial. There are also substantial differences in the relative contributions of temperature and salinity anomalies to the positive density anomalies created in the models deep-water formation (DWF) region prior to AMOC intensifications. Nevertheless, we identify some robust elements of AMOC variability mechanisms. These include: i) The Labrador Sea is the key region with upper-ocean density and boundary layer anomalies preceding AMOC anomalies ii) Enhanced Nordic Sea overflow transports do not lead to an increase in AMOC maximum transports iii) Persistent positive phase of the North Atlantic Oscillation plays a significant role in setting up the density anomalies that lead to AMOC intensification via surface buoyancy fluxes and iv) After AMOC intensification, subsequent weakening is due to advection of positive temperature anomalies into the models DWF region.

Parallel Orals – Session 2.3

Parallel Session 2.3 Centennial to Millennial

Tuesday, 20th September 2016 - 14:00hrs **Ballroom 3**

2.3-A

Storm Tracks during the Deglaciation

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Mid-latitude storms contribute substantially to the transport of heat and moisture towards the pole. Understanding their behaviour with respect to climate change is therefore essential. We examine changes in storms tracks during the Last Deglaciation using a sequence of 48 simulations (at 500 year intervals) with the Hadley Centre climate models. The results confirm previous studies showing that the Northern hemisphere storm tracks are more zonal during the Last Glacial Maximum, but identifies a "new" storm track over the Eurasian continent. This is the first time that a terrestrial storm track has been seen. This storm track is responding to strong baroclinity in the region. The baroclinic eddies are strong but relatively shallow, resulting in strong surface winds in the region but relatively small contribution to heat and moisture transports. Subsequently, as the climate warms, the storm tracks gradually move to their modern day locations. The movement seems to be strongly controlled by the baroclinicity of the means state, which is heavily influenced by the ice sheets and sea ice. No threshold behaviour is identified. The storm tracks appear to respond relativly linearly to the imposed forcing.

2.3-B

Dependence of the AMOC stability on the background climate

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The Atlantic conveyor belt circulation is an important global scale oceanic circulation which contributes significantly to the global heat balance. Paleo-proxy records and modeling studies suggest that changes in this circulation may be responsible for the past abrupt climate change events. Here, by using two versions of a coupled climate model, we show that the stability of this circulation depends on the background climate. Under glacial conditions with a closed Bering Strait, a sudden collapse of this circulation is possible and induces an abrupt climate change events in the North Atlantic and surrounding regions. However, under present day condition with an open Bering Strait, this circulation could collapse due to either thermal or haline forcings without causing abrupt climate change events. Our result is important to understand the paradox regarding frequent occurrence of the abrupt climate change event during glacial time, but nearly none during the Holocene.

2.3-C

Understanding the bipolar seesaw through ocean energetics

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Ice-core records indicate that temperatures in Greenland and Antarctica were negatively correlated during the millennial timescale Dansgaard-Oeschger oscillations that occurred during the last glacial period. This phenomenon, known as the bipolar seesaw, is probably driven by negatively correlated changes in interhemispheric heat transport by the Atantic meridional overturning circulation (AMOC) and in the supply of heat to the surface within the Antarctic overturning cell. However, interactions between the AMOC and the Antarctic cell are poorly understood.

Here, the bipolar seesaw is explored using numerical experiments with the ocean model NEMO-ORCA2. The ocean is forced with periodic variability in buoyancy forcing over the North Atlantic, driving oscillations in the AMOC. Surface forcing over the rest of the ocean is kept constant, so that any response of the Antarctic cell is due to its interaction with the AMOC. Under periodic variability with centennial or longer timescales, we find that the Antarctic cell is strongly anti-correlated with the AMOC. On centennial timescales this response is damped, but on millennial timescales the amplitude of the (e.g.) weakening of the Antarctic cell closely matches the strengthening of the Atlantic cell.

An analysis of mechanical energy input to the ocean is used to understand these results. Buoyancy forcing supplies available potential energy (APE) to the ocean by increasing the density of dense surface waters. As North Atlantic buoyancy forcing strengthens, the AMOC strengthens, and consumes more APE in proportion with the increase in North Atlantic APE input by buoyancy. This causes a global shoaling of isopycnals, reducing the potential for further APE to be added by buoyancy forcing. As a consequence of this, APE input by buoyancy forcing in the Southern Ocean decreases, even though the buoyancy forcing itself does not change. The Antarctic cell weakens in proportion with the weakening of the local APE input. The same process applies in reverse when North Atlantic buoyancy forcing weakens. These results indicate that the bipolar seesaw may be understood in terms of a competition between the Atlantic and Antarctic overturning cells for a global resource of mechanical energy.

2.3-D

Simulated response of the mid-Holocene Atlantic Meridional Overturning Circulation in ECHAM6-FESOM/MPIOM

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Changes of the Atlantic meridional overturning circulation (AMOC) in the mid-Holocene compared to the pre-industrial state are explored in different coupled climate models. Using time-slice integrations by a newly developed global finite-element model ECHAM6-FESOM with unstructured mesh and high resolution, our simulations show an enhanced mid-Holocene AMOC, accompanied by an increase in the ocean salinity over regions of deep water formation. We identify two different processes affecting the AMOC: 1) a more positive phase of North Atlantic Oscillation (NAO) increased water density over the Labrador Sea through anomalous net evaporation and surface heat loss; 2) a decreased import of sea ice from the Arctic causes a freshwater reduction in the northern North Atlantic Ocean. Using the coupled model ECHAM6-MPIOM in T63GR15 and T31GR30 grids, we find that the simulated AMOC is strongly affected by the model resolution. In detail, stronger-than-present mid-Holocene AMOC is revealed by simulations with the T63GR15 grid, which resembles the result of ECHAM6-FESOM, while a decline of the mid-Holocene AMOC is simulated by the low resulution model with the T31GR30 grid. Such discrepancy can be attributed to different changes in Labrador Sea density which is mainly affected by 1) NAO-induced net precipitation, 2) freshwater transport from the Arctic Ocean, and 3) the strength of AMOC itself. Finally, we analyzed available coupled climate models showing a diversity of responses of AMOC to mid-Holocene forcings, most of which reveal positive AMOC changes related to northern high latitudes salinification.

2.3-E

The global monsoon response to volcanic eruptions in the CMIP5 past1000 simulations

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We examine the global monsoon (GM) precipitation response to volcanic eruptions in the Coupled Model Intercomparison Project Phase 5 (CMIP5) past1000 simulations. The spatial patterns of precipitation exhibit drying in the monsoon regions in their respective warm season for years 1 and 2 combined following volcanic eruptions. The cooling in the western Pacific is much stronger than that in the eastern Pacific. This zonal SST gradient across the Pacific induces lowering SLP in the EP where the two subtropical Highs straddle the equator. This will weaken the trades which transports and converges moisture into the eastern hemisphere monsoon regions, thereby leading to the reduced GM precipitation. The ‘‘cold land-warm ocean’’ and ‘‘cold NH-warm SH’’ mechanisms can also explain why the NH monsoon has a strong reduction, while only the ‘‘cold land-warm ocean’’ lead to a weak SH monsoon. The summer monsoon rainfall shows a general decreasing anomaly across the majority of the regional monsoon regions. In contrast to a weakened global summer monsoon precipitation, most arid and semiarid desert regions, located to the west and poleward of each monsoon region, show wetting anomalies. The water budget analysis indicate that the change of the dynamic and thermodynamic terms equivalently dominate the change of precipitation. The vertical component dominates the dynamic and thermodynamic bars, whereas the magnitudes of the horizontal component are much smaller than the vertical component.

2.3-F

Timescales of AMOC collapse

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The Atlantic Meridional Overturning Circulation (AMOC) has been predicted to weaken over the coming century due to warming from greenhouse gases and increased input of freshwater into the North Atlantic. There have also been some suggestions that there is a possibility of a rapid decrease due to advective feedbacks, however current climate models have not found such a rapid decrease. Observations have shown that the AMOC exports fresh water from the Atlantic, whereas in many climate models the AMOC imports fresh water. It has been suggested that this bias could lead to an overly stable AMOC in climate models which is less prone to a rapid decrease. Since some impacts of climate change have been shown in models to be dependent on the amount of AMOC reduction, it is important to understand the timescales on which the AMOC might decrease in the future, and what controls these timescales.

Here we explore timescales of AMOC weakening in an eddy-permitting global climate model which exports fresh water from the Atlantic, in agreement with observations. We conduct idealised experiments by adding different rates of fresh water input into the North Atlantic and explore how the AMOC weakening depends on the fresh water flux and total fresh water added. We also explore the mechanisms behind the timescales and which feedbacks are important for setting the timescales.

Poster Clusters Abstracts

Tuesday, 20th September 2016

Poster Cluster

Atlantic Meridional Overturning Circulation

Chair: Gokhan Danabasoglu (gokhan@ucar.edu)

Session: 2.2 - Decadal

Description: The Atlantic meridional overturning circulation (AMOC) is thought to play a major role in interannual to decadal and longer time-scale climate variability as well as in prediction of the earth's future climate on these time scales. We invite modeling and observational (proxy and instrumental) studies focusing on the role of AMOC in climate and its variability and prediction, including work on AMOC's climate, ecosystem, and societal impacts.

Tue-001

Atlantic Meridional Overturning Circulation: Coherence of AMOC Variability in the Atlantic Ocean from an Eddy-resolving Global model

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Latitudinal coherence of the Atlantic Meridional overturning circulation (AMOC) variability in the Atlantic Ocean is examined in a global 1/12 simulation from 2003 to 2012, using the Hybrid Coordinate Ocean Model (HYCOM). The simulation has been shown to represent well the observed AMOC structure in the North Atlantic at 26.5N as well as in the south Atlantic near 34S. On seasonal time scale, the variability is high and coherent from 35S in the South Atlantic to about 15N. In the North Atlantic the variability is also coherent from 65N to about 20N. In the area from 15N to 20N, the variability is significantly weaker and there is a change in the phase of the variability. On interannual and longer time scale, the magnitude of the AMOC variability is weaker than on seasonal time scale.

Tue-002

Atlantic Meridional Overturning Circulation: Impacts of Ocean Model Parameterizations on AMOC Variability in the Community Earth System Model (CESM)

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AMOC is presumed to play a major role in decadal and longer time scale climate variability and in prediction of the earths future climate on these time scales. The primary support for such a prominent role for AMOC comes from coupled model simulations. They show rich AMOC variability, but time scales of variability and mechanisms differ substantially among models. Our previous studies with CESM showed that the ocean models subgrid scale parameterizations play a role in creation of the Labrador Sea density anomalies that lead to changes in AMOC. Here, we present a systematic assessment of the impacts of several ocean model parameter choices on AMOC characteristics in CESM with the primary goal of identifying both robust and non-robust elements of AMOC variability and mechanisms. Our control is a 2200-year pre-industrial simulation. We branch off from this control and perform several 600-year simulations where some loosely-constrained parameter values in mesoscale, sub-mesoscale, vertical mixing, and lateral viscosity parameterizations in the ocean model are changed. The characteristics of AMOC from these simulations are compared with a three-member ensemble of 600-year perturbation experiments in which the initial atmospheric temperature field is slightly perturbed. A significant finding is that both the amplitude and time scale of AMOC variability differs considerably among all these experiments with dominant time scales of variability ranging from decadal to centennial. There are also substantial differences in the relative contributions of temperature and salinity anomalies to the positive density anomalies created in the models deep-water formation (DWF) region prior to AMOC intensifications. Nevertheless, we identify some robust elements of AMOC variability mechanisms. These include: i) The Labrador Sea is the key region with upper-ocean density and boundary layer anomalies preceding AMOC anomalies ii) Enhanced Nordic Sea overflow transports do not lead to an increase in AMOC maximum transports iii) Persistent positive phase of the North Atlantic Oscillation plays a significant role in setting up the density anomalies that lead to AMOC intensification via surface buoyancy fluxes and iv) After AMOC intensification, subsequent weakening is due to advection of positive temperature anomalies into the models DWF region.

Tue-003

Atlantic Meridional Overturning Circulation: Variability of the Boundary Current Systems and AMOC at 11°S

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The western boundary current system off Brazil is a key region for variations of the Atlantic meridional overturning circulation (AMOC) and the southern subtropical cell. In July 2013 a mooring array was installed off the Brazilian coast at 11°S similar to an array operated between 2000 and 2004 at the same location. Three research cruises and the moored observations between 2013 and 2015 are analyzed in comparison to the observations a decade ago. Average transports of the North Brazil Undercurrent and the Deep Western Boundary Current (DWBC) have not changed between both observational periods. DWBC eddies, which are predicted to disappear with a weakening AMOC, are still present with similar characteristics. Interannual transport variability as assessed between 2000-2004 from observations is consistently found in the output of a forced ocean model. Upper layer changes in salinity and oxygen within the last decade are consistent with an increased Agulhas leakage, while at depths water mass variability is likely related to changes in the North Atlantic as well as tropical circulation. The Eastern Atlantic Boundary system is also investigated based on ship-board measurements and a moored array, which was also installed in 2013. Additionally, bottom pressure sensors were deployed at 300m and 500m depth on both sides of the Atlantic basin, in order to estimate the interior mid-ocean transport. Together, the boundary transport estimates, the mid-ocean transport and the Ekman contribution will be combined to give a comprehensive AMOC estimate for the tropical Atlantic at 11°S.

Tue-004

Atlantic Meridional Overturning Circulation: A successful AMOC reconstruction from a new high-resolution reanalysis

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Observations have shown a significant weakening of the Atlantic Meridional Overturning Circulation (AMOC) over the last decade. Global climate models predict an AMOC weakening in response to anthropogenic climate change resulting in significant impacts on the surface climate, and recent work has suggested that a weakening has already occurred over the last century. On the other hand, many ocean models forced with historical conditions have found an AMOC increase up to the mid 90s, followed by a decrease, in response to changes in the North Atlantic Oscillation, which is a mode of climate variability. Hence it is currently unclear whether the observed weakening is part of decadal variability or a persistent weakening. We present results from a state-of-the-art reanalysis product (GloSea5) which reproduces the observed AMOC timeseries at 26.5N. This is the first time a model has been shown to capture the interannual variability and decadal trend of the AMOC. We use this reanalysis to put the recent trend into context, showing that the observed decrease is consistent with a recovery following a previous increase. We suggest that this decadal variability is caused by density anomalies propagating southwards from the Labrador Sea. Water parcels propagate to 26.5N with faster pathways (2-6 years) along the western boundary and slower pathways (>10 years) interacting with eddies in the interior.

Tue-005

Atlantic Meridional Overturning Circulation: The Climate Variability and Predictability (CVP) Program at NOAA

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The Climate Variability & Predictability (CVP) Program supports research aimed at providing process-level understanding of the climate system through observation, modeling, analysis, and field studies. This vital knowledge is needed to improve climate models and predictions so that scientists can better anticipate the impacts of future climate variability and change. To achieve its mission, the CVP Program supports research carried out at NOAA and other federal laboratories, NOAA Cooperative Institutes, and academic institutions. The Program also coordinates its sponsored projects with major national and international scientific bodies including the World Climate Research Programme (WCRP), the International and U.S. Climate Variability and Predictability (CLIVAR/US CLIVAR) Program, and the U.S. Global Change Research Program (USGCRP). The CVP program sits within NOAA's Climate Program Office (http://cpo.noaa.gov/CVP). The CVP Program currently supports multiple projects aimed at improving the understanding Atlantic Meridional Overturning Circulation (AMOC), its impact on decadal predictability, and its relationship with the overall climate system. Recent results from CVP-funded projects will be summarized in this poster.

Tue-006

Atlantic Meridional Overturning Circulation: Results from MOVE at 16N

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The Meridional Overturning Variability Experiment (MOVE) has been making observations of the southward flow of North Atlantic Deep Water across 16N continuously since 2000. Here, we will present the time series from these observations, and discuss interannual variability in comparison with results from numerical simulations and satellite measurements. MOVE contributes to the international OceanSITES effort, and is part of the US AMOC (and thereby CLIVAR) program.

Tue-009

Atlantic Meridional Overturning Circulation: Variability of AMOC Components in the subpolar North Atlantic from observations

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Atlantic Meridional Overturning Circulation (AMOC) is thought to weaken considerably under global change scenarios, and we need to observe continuous transport time series to be able to separate natural variability from climate change trends. Here we present more than 20 years of transports from the major AMOC components at 47N together with the transport of warm and subtropical water from the western into the eastern Atlantic. This is a joint effort from the IUP-MARUM in Bremen and the BSH in Hamburg, starting in 2006.The transports have been calculated from direct measurements and extended to 1993 with altimeter data. The transport time series are complemented by composite transports from large-scale shipboard measurements (2003 - 2015) of the velocity field and hydrography.

Tue-010

Atlantic Meridional Overturning Circulation: The South Atlantic MOC international initiative: Status and preliminary results

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The meridional overturning circulation (MOC) is a primary mechanism for the transport and storage of heat, freshwater and carbon by the ocean and therefore has a large impact on climate variability and change. The transport of properties by the MOC depends on the rate of overturning and the difference in property concentration between the upper and lower limbs of the overturning as well as well as modification of water properties along their global journey. Therefore observations of the MOC must extend throughout ocean basins to quantify changes in the MOC and to determine their cause and impact. This expansion requires an increased international commitment to the design and maintenance of the observing network and the implementation of technologies for collecting deep ocean data and transmitting these data to shore in a cost effective manner. In particular, it is critical to monitor flow rates and properties at sites where upper ocean waters are injected into the deep ocean and where these waters are exchanged between sub-basins. Within the MOC, the South Atlantic Ocean plays a key role as a nexus for water masses formed elsewhere and en-route to remote regions of the global ocean. Because of this important interbasin exchanges, the South Atlantic Ocean is the only major ocean basin that transports heat from the pole towards the equator. However, the South Atlantic is not merely a passive conduit for remotely formed water masses. Indeed, within this basin water masses are significantly altered by local air-sea interactions and diapycnal/isopycnal fluxes, particularly in regions of intense mesoscale activity and steep topography. These contributions have been shown to have a crucial role in the strength of the MOC in paleoceanographic and modelling studies. The monitoring of the North Atlantic portion of the MOC has been ongoing for a decade now through the RAPID/MOCHA/WBTS program as well as other national and

international initiatives. They all provide a scope for understanding the MOC variability in that region. Given the complex, multibasin nature of the MOC, achieving a more complete understanding of its behaviour and changes requires a more comprehensive observing system, one that extends across neighbouring ocean basins as the one we are developing for the South Atlantic within the CLIVAR SAMOC initiative. In this presentation, we will discuss the SAMOC Initiative observing and modelling status. Moreover, we will present the various ongoing MOC estimates (from high-resolution XBTs, Argo, satellite altimetry and models) and revisit the estimates of the daily MOC strength at 34.5°S obtained during a ~20 month long pilot array between 2009 and 2010 with recently recovered data covering almost three additional years (2012-2015).. The new results will be also compared to the long-term (10-year) estimates from the 26.5°N RAPID/MOCHA/WBTS array. The resulting variability is partitioned in terms of total, Ekman, geostrophic and boundary volume transport components. We will also discuss the variability of the transport due to eastern-boundary eddies (Agulhas rings, cyclones, etc) from the analysis of 2 year CPIES data in the Cape Basin and multisatellite sea-level data.

Tue-011

Atlantic meridional overturning circulation: temperature-salinity structure of the North Atlantic circulation and associated heat and freshwater transports

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Despite its importance to the Earth's climate system, the structure of the oceanic heat and freshwater transports is not fully understood. This study documents the relative importance of circulation components, which contribute to the time mean North Atlantic heat and freshwater transports, by performing a detailed examination of the circulation and water mass distribution using a high-resolution ocean numerical model. The model results are shown in excellent agreement at key locations with the observed circulation structure as well as the heat and freshwater transports. The results suggest that across 26.5N in the subtropics, the wind-driven gyre's contribution to the heat transport is close to zero, lower than the value traditionally derived from the classical vertical versus horizontal decomposition. The wind-driven gyre contributes about 1/3 of the total freshwater transport northward and reduces the southward freshwater transport by the Atlantic meridional overturning circulation (AMOC). Across 58N in the subpolar, the diapycnal water mass transformation of the AMOC, i.e., from the warm saline upper Atlantic water into colder and fresher deep waters, represents essentially all heat and freshwater transports. The results underscore the need to better understand the spatial structure and the driving processes of the water mass transformation in both observations and numerical models.

Tue-012

Atlantic Meridional Overturning Circulation: The "53°N Array" in the Labrador Sea from 1997 to 2016

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The Deep Western Boundary Current (DWBC) is a key element of the Meridional Overturning Circulation in the Atlantic. The source of the DWBC can be considered in the region south of the Greenland-Scotland-Ridges were overflow water, substantially modified by entrainment of ambient waters, assemble in the DWBC. En-route, the next substantial modification of the DWBC is the Labrador Sea where locally transformed water, the Labrador sea Water (LSW), joins the DWBC. At the exit of the Labrador Sea the DWBC consists of all its primary water masses and the transport has increased to about 30 Sv. Further downstream of the Labrador Sea certain parts of the DWBC flow, in particular the LSW depth classes, follow more complex pattern and flow bifurcation, recirculation and flow/topography interaction have been reported. Here the assumption of a single DWBC seems too be much of an oversimplification.In order to monitor the DWBC flow at the exit of the Labrador sea an array of moorings, the "53°N-Array" has been installed in 1997 and is operational since then. Despite the fact that the array was operated in different degrees of completeness it still provide one of the longest full ocean depth records of boundary circulation worldwide. The transports derived for water mass layers show variability from days to decades with two frequency bands dominating the variability. The first variance maximum is found at 10 to 20 days period and can be explained by topographic Rossby Waves that relocate the DBWC core periodically up and down the Labrador Shelf break and also seen in hydrographic record. The second variance maximum is found at quasi-decadal time scales in the deep overflow components of the DWBC. The signal is imprinted in the deep baroclinic current core hugging the continental slope at depth below 2000 m and also seen in hydrographic records at some of the moorings. First results from the latest deployment period of the array, from August 2014 to June 2016, will be presented. The deployment is embedded in the international "Overturning in the Subpolar North Atlantic Program" (OSNAP) that aims to measure the overturning transport for the first time, combining multiple observing elements across the full width of the basin.

Tue-013

Atlantic Meridional Overturning Circulation: Reanalysis of the AMOC

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Reanalysis of the AMOC (RAMOC) is a research project whose objective is to improve ocean state estimates by assimilating data, including RAPID array measurements, into a high-resolution ocean model. The main aims are i) to understand and develop methods to distinguish between high and low frequency signals in the RAPID-AMOC data using model processes ii) to use that understanding to assimilate RAPID-AMOC observational data focusing on the low-frequency signal, iii) to develop new, more dynamically consistent, ocean state estimates. Using different experiments with an OGCM, low frequency density variability down the western boundary of the Atlantic basin, linked to changes in the buoyancy forcing over the Atlantic Sub-Polar Gyre (SPG) region, is found to explain a large part of the geostrophic AMOC variability at 26N. The timing of the density anomalies appearing at the western and eastern boundaries at 26N has revealed two propagation speeds of these anomalies leading to ~7months and ~3years lags between boundaries. These different propagating modes have different vertical density anomaly profiles, with maxima along 1300m and 3200m respectively. Similar signals impacting both boundaries at 26N are also found in a long high resolution coupled model experiment in HadGEM3. The analysis of the depth structure and the lagged variability between the two boundaries in the model provides useful tools for i) studying the variability within the RAPID array observational dataset itself ii) establishing the lagged covariances between the AMOC at 26N and densities in the Labrador Sea 2-3 years earlier, in order to improve the assimilation of the AMOC. To this end, techniques from 4D ensemble variational assimilation (4DEnVar) are being tested in order to avoid the need for a high resolution adjoint. Promising test simulations have been carried out so far. These techniques, together with covariances determined from a high resolution coupled experiment, will be used to assimilate the RAPID data.

Poster Cluster

Climate of the 20th Century Plus

Chairs: Daithi Stone (dstone@lbl.gov) and Jim Kinter (ikinter@gmu.edu)

Session: 2.1 - Intraseasonal to Interannual

Description: The C20C+ project uses climate models and observational data products to study climate variations and changes over periods of up to 150 years. Current activities include detection and attribution of changes in extreme weather, development of relevant observational products and modelling tools, the contribution of the atmosphere to climate variability, and variations and trends in precipitation.

Tue-017

Climate of the 20th Century Plus: Contrasting Impacts of the Arctic Oscillation on Surface Air Temperature Anomalies in Southern China between Early and Middle-to-Late Winter

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In the boreal winter, the Arctic Oscillation (AO) evidently acts to influence surface air temperature (SAT) anomalies in China. This study reveals a large intra-seasonal variation in the relationship between the winter AO and southern China SAT anomalies. Specifically, a weak in-phase relationship occurs in December, but a significant out-of-phase relationship occurs in January and February. We show that the linkage between the AO and southern China SAT anomalies strongly depends on the AO-associated changes in the Middle-East jet stream (MEJS) and that such an AO-MEJS relationship is characterized by a significant difference between early and mid-late winter. In mid-late winter, the Azores center of high pressure anomalies in the positive AO phase usually extends eastward and yields a significantly anomalous upper-level convergence over the Mediterranean, which can excite a Rossby wave train spanning the Arabian Sea and intensify the MEJS. In early winter, however, the Azores center of the AO is apparently shifted westward and is mainly confined to the Atlantic Ocean; in this case, the associated change in the MEJS is relatively weak. Both observational diagnoses and experiments based on a linearized barotropic model suggest that the MEJS is closely linked to the AO only when the latter generates considerable upper-level convergence anomalies over the Mediterranean. Therefore, the different impacts of the AO on the MEJS and the southern China SAT anomalies between early and mid-late winter are primarily attributed to the large intra-seasonal zonal migrations of the Azores center of the AO.

Tue-018

Climate of the 20th Century Plus: Experimental design

Dáithí Stone (1), Oliver Angélil (2), Shreyas Cholia (1), Nikos Christidis (3), Andrew Ciavarella (3), Andrea Dittus (4), Chris Folland (3), Jonghun Jin (5), Andrew King (4), Jim Kinter (6), Harinarayan Krishnan (1), Seung-Ki Min (5), Don Murray (7), Sarah Perkins (2), Judith Perlwitz (7), Mark Risser (1), Hideo Shiogama (8), Michael Wehner (1), Piotr Wolski (9)

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Over the past decade there has been a remarkable growth in interest concerning the effects of anthropogenic emissions on extreme weather. However, research has been constrained by the lack of a public climate-model-based data product optimised for investigation of extreme weather in the context of climate change, relying instead on products designed for other purposes or on bespoke simulations designed for the particular study and not generally applicable to other extremes. The international Climate of the 20th Century Plus (C20C+) Detection and Attribution Project is filling this gap by producing the first large ensemble, multi-model, multi-year, and multi-scenario historical climate data product, specifically designed for resolving variations in the occurrence and characteristics of extreme weather from year to year and their differences from what might have been in the absence of anthropogenic emissions. Project status information and simulation output are available at http://portal.nersc.gov/c20c.Here we describe the experimental design of the first phase of the project, conducted with half a dozen atmospheric climate models, and discuss its various strengths and weaknesses with respect to various types of extreme weather. We also present select analyses indicating the relative importance of climate model, estimate of anthropogenic ocean warming, spatial and temporal scale, and aspects of experimental design on estimates of how much emissions have affected extreme weather.

Tue-028

Climate of the 20th Century Plus: Quantifying the effect of ocean variability on the attribution of extreme climate events to human influence

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In recent years, the climate change research community has become highly interested in describing the influence of anthropogenic emissions on extreme weather events, commonly termed "event attribution". Limitations in the observational record motivate the use of climate models to estimate anthropogenic influence, while computational limitations motivate the use of uncoupled, atmosphere-only climate models with prescribed ocean conditions. In this approach, large ensembles of high-resolution simulations can be obtained and used to estimate anthropogenic risk; however, fixing the ocean state does not account for the long-term internal variability of the climate system. This source of uncertainty is extremely important, as large internal variability can lead to qualitatively different conclusions about anthropogenic influence. In this work, we develop a hierarchical Bayesian model to estimate the changing risk over time of extreme weather events due to anthropogenic influences. Unlike related approaches in event attribution, the model allows us to quantify the internal variability present in statements of risk, after adjusting for long-term trends. Furthermore, based on the magnitude of this variability, we develop a metric that allows climate change scientists to identify event types and regions of the globe for which single-year atmosphere-only climate simulations are sufficient for assessing the true risk. The methodology is illustrated by exploring extreme temperature and precipitation events for the northwest coast of South America and northern-central Siberia.

Poster Cluster

ENSO Diversity: Past, Present, and Future

Chairs: Antonietta Capotondi (antonietta.capotondi@noaa.gov)

Session: 2.1 - Intraseasonal to Interannual

Description: El Niño Southern Oscillation (ENSO) is the dominant mode of tropical Pacific climate variability at interannual timescales, with large impacts worldwide. ENSO events differ in amplitude, temporal evolution, and spatial patterns, and these inter-event differences appear to deeply affect the nature of associated atmospheric teleconnection patterns and ENSO event impacts. This poster cluster highlights the many aspects of ENSO diversity in past, present, and future climates, examines the predictability of different event types, and explores the differences in their impacts.

Tue-035

ENSO Diversity: Past, Present, and Future. ENSO in a changing climate in the CMIP suite of models

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Since the establishment of the basic physical mechanisms 30 years ago, major progress in ENSO research has been made. New theoretical insights, together with longer and more comprehensive observations, increased computer power, and improved physical parameterizations of subgrid-scale processes, have resulted in better understanding of ENSO dynamics and much improved simulations of ENSO statistics in CGCMs. If the basic properties of ENSO are now better understood and simulated, the community is nevertheless now faced with the much harder problem of addressing its detailed properties (e.g. skewness, diversity of events, physical feedbacks, asymmetries between El Nio and La Nia, etc.) and how these interact with the slowly (decadally to centennially) varying background. Further progress requires coordination of diverse research communities, a process recently undertaken through intercomparison of state-of-the-art CGCMs (CMIP3 and CMIP5). We here report on the progress made in the newly established CLIVAR ENSO Research Focus group that seeks to 1) better understand processes that control ENSO characteristics in nature and in the models, 2) propose a standard ENSO evaluation protocol for CGCMs as a resource for model developers and impacts studies and 3) understand how ENSO characteristics, particularly ENSO extremes, might be modified in the next decades, namely under the influence of anthropogenic climate change.

Tue-036

ENSO Diversity: Past, Present, and Future. Optimal Precursors of ENSO Diversity

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Not all El Niño-Southern Oscillation (ENSO) events are the same. ENSO global impacts can differ substantially depending on whether the associated sea surface temperature (SST) anomalies are larger in the Eastern Pacific (EP) or Central Pacific (CP), making the predictability of such differences of very high societal relevance. In this study, we first examine the ability of SST-based extra-tropical "precursors" to trigger different types of ENSO events. We then objectively identify the optimal two-season precursors of EP and CP-type events in a Linear Inverse Modeling (LIM) framework, using SST and thermocline depth data over 1958-2007. The results highlight the importance of the initial subsurface ocean conditions for the development of different event types. The results are finally examined in the context of the evolution of SST and thermocline depth conditions over recent decades.

Tue-037

ENSO Diversity: Past, Present, and Future. Metrics of ENSO Diversity from a Linear Inverse Modeling Perspective

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One important aspect of ENSO diversity is the longitudinal position of the maximum sea surface temperature (SST) anomalies, as the location of those anomalies can exert a large impact on atmospheric teleconnections patterns, and lead to differences in ENSO impacts. The longitudinal distribution of maximum SST anomalies may result, in turn, from the relative contribution of different oceanic feedbacks, whose amplitude and influence are spatially dependent. The climate models ability to simulate the broad range of ENSO expressions, and for the correct physical reasons, as inferred from the observational record, is critical to the assessment of model performance in the representation of the ENSO phenomenon. However, the observational record only provides us with a sparse picture of ENSO diversity, thus limiting our ability to properly evaluate model performance. In this study we use Linear Inverse Models (LIMs) trained on various observational data sets and climate model outputs, to create multi-millennia time series of quantities that are relevant for characterizing and understanding ENSO diversity (e.g. SST, SST anomalies, SST zonal and meridional gradients, wind stress, thermocline depth). These long time series are then used to examine those relationships among variables that can highlight the underlying physical processes, providing us with a basis for devising physically relevant metrics for ENSO diversity. Finally, the LIM methodology is exploited to diagnose the dynamical and stochastic forcing operators in both observations and models, and use them to compare and contrast the inter-variable relationships in the various products.

Tue-038

ENSO Diversity: Past, Present, and Future - Atmospheric Feedbacks in the ENSO cycle and the Role of the Hydrological Cycle

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El Niño Southern Oscillation (ENSO) is a dominant mode of inter-annual variability in the equatorial Pacific linked to extreme weather events worldwide. We investigate processes that determine the behaviour of ENSO in CMIP5 models, with a particular focus on the role of latent heat fluxes in damping east Pacific Sea Surface Temperature (SST) anomalies. We find that the latent heat damping has a wide range of values in the CMIP5 models and is generally underestimated when compared to the observed damping rate. Boundary-layer atmospheric humidity tends to dominate east Pacific latent heat flux variability. Despite this, a significant fraction of the spread of latent heat damping between CMIP5 models is driven by differences in the sensitivity of surface wind speed to SST anomalies. This sensitivity is also overestimated in a number of models reducing the strength of latent heat damping. Furthermore, variations in latent heat damping are related to spatial variations in the equatorial Pacific climatological mean rainfall and surface wind speed in the CMIP5 models. The results suggest a central role for the coupling between the hydrological cycle and ENSO in models and show how biases in the mean climate can be linked to differences in variability. Future work hopes to extend the analysis to produce a more complete conceptual model for ENSO-hydrological cycle coupling, adding further important feedbacks such as radiative damping from clouds. This work also provides the basis for development of metrics that may be used in model development to improve ENSO simulation in models and to constrain future projections of ENSO characteristics.

Tue-039

ENSO Diversity: Past, Present, and Future - ENSO in the Holocene

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New reconstructions of ENSO variability across the Pacific Ocean offer the opportunity to test the relative impact of long term climate forcing and internal variability on the characteristics of El Niño and La Niña events. They show in particular that, even most models tend to produce a reduced ENSO magnitude in the mid-Holocene, they do not properly represent the relationship between interannual variability and the annual mean cycle (e.g. Emile-Geay et al. 2015). Here we go one step further and discuss the differences in the annual mean cycle and internnual variability across the Pacific basin, using PMIP3/CMIP5 simulations and a suite of multi-complexity simulations with the IPSL model. For these ensembles, we'll highlight ENSO diversity in the simulations, the relationships between ENSO variability and the location of the SPCZ in the southwest Pacific following Saint-lu et al (2015), and the characteristics of the ocean discharge. How the different simulations compare with the proxy records will be highlighted. Limitation in the model simulations in terms of simulation length, model biases will also be considered. They call for particular care in the realization of the future CMIP4/CMIP6 simulations, and the provision of long time series in the database.

Tue-040

ENSO Diversity: Past, Present, and Future. Collapse of the Easterly Wind Along the Equator in Super El Nino Events of 1997-1998 and 2015-2016

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Conventional wisdom dictates that the surface zonal wind component at the equator strongly influences sea surface temperature variations, which would produce the El Nino and La Nina phenomenon. For a super El Nino, a substantial reduction in westward wind speed would be expected, including a reversal in direction to eastward wind speeds; this latter condition is representative of "easterly wind collapse." This paper compares the easterly wind collapse in satellite wind speed and direction measurements recorded in super El Nino events of 1997-1998 and 2015-2016. Satellite scatterometer instruments provided sustained estimates of vector wind components at 10-m height (called surface) for twenty years: ERS-2 (March 1996 – January 2001: KNMI v2.4), QuikSCAT (July 1999 – October 2009: RSS v4), and ASCAT-A (June 2007 – present: RSS v1.2). Comparison tests between ERS-2 and QuikSCAT and between ASCAT-A and QuikSCAT revealed, in a preliminary estimate because computations are not yet completed, that zonal wind speed differences larger than 0.9 m s-1 would be real and not generated by different datasets, recognizing that the accuracy of moored buoy surface wind measurements was about 0.5 m s-1. Analyses associated with super El Nino events will be referenced to the average of four non-super El Nino events, which will be considered to represent the average "usual" El Nino event. For the average usual El Nino event, easterly wind collapsed from 135°E (the Pacific western edge of analyses) to 164°E. For the February 2015 to January 2016 segment of the current super El Nino (more data will be analyzed by the time of the Conference), the region of the easterly wind collapse extended eastward to 178°E and the region of a reduction in westward wind speed greater than 1 m s-1 compared to the average usual El Nino event extended to 140°W. The easterly wind anomaly in the 2015-2016 super El Nino reached to the eastern Pacific, which provided wind-generated conditions for thermocline deepening due to reduced upwelling. Wind analyses for the 1997-1998 super El Nino event are not completed at the time of abstract preparation and will be reported at the Conference. In particular, the eastward penetration of the easterly wind collapse is of interest.

Tue-041

ENSO Diversity: Past, Present, and Future. The extreme El Niño of 2015: the role of westerly and easterly wind bursts, and the preconditioning by the failed 2014 event

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El Niño of 2015 developed into an extreme warm event comparable to that in 1997 or 1982. Given the vast impacts of such events, it is important to understand how they evolve. At the beginning of 2015, as one year earlier in 2014, the scientific community anticipated that El Niño conditions could develop by year-end. Such projections were related to the occurrence of westerly wind bursts during winter-spring of each year that generated strong downwelling Kelvin waves indicative of an emerging El Niño. However, the event's progression quickly stalled in 2014, but actively continued in 2015. In this talk, we will compare climate evolutions during these two years using satellite observations and numerical simulations. We find that a key difference between the events' development is the fate of the positive Bjerknes feedback. During 2014 this feedback was interrupted mid-year by an exceptionally strong easterly wind burst, whereas during the second year this feedback persisted through the summer. Furthermore, we will talk about how the failed 2014 event created favorable conditions for El Niño development next year. Ensemble simulations with coupled GCMs wherein we superimpose a sequence of westerly and easterly wind bursts support these conclusions, stressing the role of the failed event for the development of an extreme El Niño. We will discuss these results in the context of El Niño diversity, and further explore their implications for decadal climate variability and the presumed global warming hiatus.

Tue-043

ENSO Diversity: Past, Present, and Future - A further Study of ENSO Rectification: Results from an OGCM with a Seasonal Cycle

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The potential role that rectification of ENSO plays as a viable mechanism to generate climate anomalies on the decadal and longer time-scales demands a thorough study of this process. In this paper, rectification of ENSO was studied using an Ocean GCM that has a realistic seasonal cycle. In addition to conducting a pair of forced ocean GCM experiments with and without ENSO fluctuations as done in a previous study, we have also conducted a forced experiment with the sign of wind anomalies reversed, with the goal of clarifying the role of the asymmetry in the wind forcing and more generally to better understand the nonlinear dynamics responsible for the rectification. It is found that the rectification effect of ENSO is to cool western Pacific warm-pool, warm the eastern equatorial Pacific. It is found that when the sign of the wind stress anomalies is reversed, the impact of the rectification on the mean state remains almost unchanged. This lack of change is further explained by noting that the upper ocean temperature and velocity anomalies (t',u',v',w') are found to respond to the wind stress anomalies linearly except for the strongest El Niño years. Thus the correlation between t' and (u',v',w') (and thus the nonlinear dynamical heating NDH) remains the same when the sign of the wind stress anomalies is reversed. Indeed, the spatial patterns of nonlinear dynamical heating (NDH) in all four seasons is found to resemble the rectified effect of ENSO in the mean temperature field in the respective seasons, indicating the critical role of NDH in the rectification.

Tue-044

ENSO Diversity: Past, Present, and Future - Relationship between internal climate variability and ENSO amplitude under global warming

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It is a central issue in climate community how the ENSO properties would be changed under global warming. Internal climate variability rises from the Earth's coupled processes including atmosphere, ocean, land, and cryosphere. It is evident that that the climate system in Earth would be changed under the global warming, therefore, it is necessary to understand how the internal climate variability contributes to the ENSO amplitude in a changing climate. By using CESM large ensemble runs, we analyze the relationship of ENSO amplitude and internal climate variability under global warming. The CESM large ensemble contains 30 members using the same model and the same external forcing from the historical run to the RCP8.5 run. It is found that the state of ENSO amplitude simulated in the historical run is closely associated with the changes in the ENSO amplitude under global warming. This indicates there exists a present-future relationship in the ENSO amplitude in a CESM. It is also found that the relationship of ENSO amplitude-tropical Pacific mean state is not the same in the two groups of CESM ensemble where the ENSO amplitude is large or small in the historical run. These results suggest that the reason why the ENSO amplitude changes under global warming is so diverse among climate models might be associated with the amplitude in the internal climate variability in the historical run.

Tue-045

ENSO Diversity: Past, Present, and Future - Ocean processes affecting the 21st century shift in ENSO SST variability

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Sea surface temperature (SST) variability associated with El Niño and the Southern Oscillation (ENSO) slightly increased in the central Pacific Ocean but weakened significantly in the eastern Pacific at the beginning of 21st century relative to 1980–1999. This decadal shift led to the greater prominence central Pacific (CP) El Niño events during the 2000s relative to the previous two decades, which were dominated by eastern Pacific (EP) events. To confirm and expand upon previous studies that have examined the physical processes responsible for this shift in ENSO variability, temperature and temperature variance budgets are examined in the mixed layer of the Niño3 (5°S–5°N, 150°W–90°W) and Niño4 (5°S–5°N, 160°E–150°W) regions. From seven ocean model products spanning the period 1980–2010, we find that thermocline and zonal advective feedbacks are the most important positive feedbacks for generating ENSO SST variance and thermodynamic damping is the largest negative feedback for damping ENSO variance. Consistent with the shift towards more CP El Niños after 2000, thermocline feedbacks experienced a substantial reduction from 1980–1999 to the 2000s in the Niño3 region and a somewhat smaller reduction in the Niño4 region, while zonal advective feedbacks were less affected. Thermocline feedbacks also became less effective in 21st century ENSO phase transitions, in keeping with the idea that compared to EP El Niños, recharge of heat in the equatorial band is less reliable as a predictor of CP events and discharge of heat has less impact on the termination of CP events.

Tue-046

ENSO Diversity: Past, Present, and Future. Causes and Consequences of the 2015-16 El Niño

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An El Niño of surprising intensity developed in 2015-16, affecting patterns of weather variability worldwide. The event rivaled the 1997-98 El Niño, the strongest on record, in its magnitude and impacts. In its present stage of development, the 2015-16 El Niño is quickly weakening and will likely end in boreal spring, followed by the possible onset of La Niña conditions later in 2016. This presentation will describe the evolution of the event, the oceanic and atmospheric processes that gave rise to it, how well the event was predicted by various forecasting centers, and how it influenced weather around the globe.

Tue-047

ENSO Diversity: Past, Present, and Future - The New Generation of System of ENSO Monitoring, Analysis and Prediction (SEMAP2.0) in Beijing Climate Center

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As an effort to improve the operational prediction of ENSO, Beijing Climate Center (BCC) has formally launched the new generation System of ENSO Monitoring, Analysis and Prediction (SEMAP2.0) in the end of 2015. In this new system, the group of Niño indices of sea surface temperature (SST) anomalies for representing ENSO and its two flavors have been utilized to monitor the evolutions of the ENSO events. A diagnosis tool has been developed to quantify evolutions of different major physical feedback processes during the ENSO lifecycle. The three prediction methods are adopted in SEMAP2.0, including the routine forecast and corrected forecast by BCC-CSM1.1(m) as well as a statistical ENSO prediction. The first method for ENSO prediction is made by the seasonal forecast of BCC-CSM1.1(m), the coupled climate system model developed by BCC, including 24 ensemble members initiated from the beginning of every month. In the second method, to reduce the ENSO prediction errors, an analogue-dynamical ENSO prediction system has been established by introducing a method of analogue-based correction of errors (ACE) into the prediction of the BCC operational climate model. The third method is the statistical ENSO prediction model, developed based on the recharge-discharge mechanism that serves for ENSO phase transition and the external forcing indicator, by which the ENSO indices including those for the two types can be directly predicted using the equatorial upper oceanic heat content, western-Pacific zonal wind stress, and Indian Ocean dipole signal as the precursors. The cross and independent validations indicate the good performance of this new ENSO prediction system. The SEMAP2.0 provides the routine prediction in the middle decad of each month out to 12 months using three prediction methods. The SEMAP2.0 has been applied to rolling predictions of the ENSO event during 2014-2016. Results showed a relatively reasonable reflection for the up-and-down situation in 2014 summer, successful predictions for the central-Pacific type of ENSO event occuring in 2014/15 winter and its transition to the eastern-Pacific type during 2015 summer as well as the peak time in 2015/16 winter as a strong event. In the late spring of this year, the current ENSO event will be ended with a large probability.

Tue-048

ENSO Diversity: Past, Present, and Future: The Role of Stochastic Forcing in Generating ENSO Diversity

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El Nino / Southern Oscillation (ENSO) variations with Central Pacific (CP) or East Pacific (EP) characteristics are initiated with subtly different initial structures. In particular, initial SST structures resembling the Pacific Meridional Mode (PMM) tend to lead to ENSO events with CP characteristics, while initial conditions with Kelvin-wave-like structures along the equatorial thermocline tend to lead to ENSO events with EP characteristics. Predictability of ENSO events with CP or EP characteristics is influenced by the growth of these initial conditions toward the CP or EP structures, as well as the evolution of stochastic forcing that can push the system away from those trajectories. For a given lead time, then, stochastic forcing can influence predictability of ENSO events in two ways. First, stochastic forcing can excite the initial structures that optimally grow toward CP or EP events, and in doing so can potentially increase predictability of CP or EP characteristics (provided sufficient growth toward the respective CP or EP condition). On the other hand, once growth toward a CP or EP structure begins, stochastic forcing can alter the system trajectory through either constructive excitation of the temporally evolving optimals (hence enhancing growth), or by destructive interference with these optimals (hence pushing the system away from events with a predetermined structure). This study uses Linear Inverse Modeling to examine the spatial and temporal evolution of stochastic forcing that can lead to ENSO events with CP or EP characteristics. First, spatially coherent structures in the stochastic forcing are examined to determine physical mechanisms that generate optimal initial conditions that lead to CP or EP ENSO characteristics. Second, stochastic forcing will be examined as the state of the system evolves to determine physical mechanisms that either enhance growth along a particular trajectory, or push the system away from that trajectory. Results will help inform on the role of stochastic forcing in the evolution of CP and EP ENSO events.

Tue-049

ENSO Diversity: Past, Present, and Future. A Robust Metric for ENSO Pattern Diversity Applied to Historical Observations and Coupled Models

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A means to objectively quantify the diversity of spatial patterns of El Nino-Southern Oscillation (ENSO) events is developed and applied to a gridded data set of observed sea surface temperature (SST) over the satellite era (1982-2013), four instrumental SST reconstructions spanning the historical period (1870-2013), 24 Coupled Model Intercomparison Project—Phase 3 (CMIP3) models simulating the historical period (1900-1999), and 42 CMIP5 models simulating the historical period through the remainder of the 21st century under projected radiative forcing (1862-2100). The ENSO pattern diversity (EPD) metric describes the extent to which the spatial patterns of SST anomaly (SSTA) for members of a set of events are dissimilar to the sample mean amplitude-normalized pattern. The algorithm benefits from a flexible, unbiased event selection process that minimizes the need to know or assume a priori the spatial pattern(s) or absolute amplitude of ENSO variability residing in the observations or models. Applying the EPD algorithm first to observations over the satellite era indicates that, on average, 35% of the spatial variance of SSTA—or 61% of the zonal variance—for a given El Nino event is not explained by the sample mean pattern, a result that is very closely reproduced over the same time period using the instrumental reconstructions. Although the instrumental reconstructions strongly disagree on the chronology of multidecadal variability of EPD over the first ~100 years of the historical period, all four are in closer agreement since 1959 including an increasing trend followed by a large step-change in 1973. It is suggested that both the reduced observational spread and the seemingly unprecedented EPD in recent decades may be partially explained by an improved ability to resolve differences between individual El Nino events aided by global satellite observations and sustained in situ platforms in the tropical Pacific. Examining EPD in the historical experiments of CMIP3 and CMIP5 models reveals that, overall, both generations of coupled models do simulate the level of EPD present in observations, including the presence of large multidecadal variability. There is a clear tendency for models from the same institution to simulate either higher or lower EPD “as a family,” implying that EPD as formulated is indeed a basic model characteristic. In response to future radiative forcing (8.5 W m-2 by 2100), many models simulate large trends in EPD of one sign or the other, but few of such trends are cleanly separable from internal variability and, as a whole, the CMIP5 model projections offer no consensus on how EPD may change over the 21st century.

Poster Cluster

Understanding and Predicting Subseasonal Extreme Events

Chairs: S.-Y. Simon Wang (simon.wang@usu.edu) and Kathy Pegion (kpegion@gmu.edu)

Session: 2.1 - Intraseasonal to Interannual

Description: The cluster focuses on the increasingly important week 3-4 forecast of extreme events, the research needs and how to communicate with users about utilizing the forecast. Emphasis is also given to predictability and prediction issues that are potentially different for warm vs. cold season predictions

Tue-019

Understanding and Predicting Subseasonal Extreme Events: Explaining the widespread Extreme Events of December 2015

Boniface Fosu (1), Shih-Yu Wang (1), Kathleen Pegion (2), Jin-Ho Yoon (3)

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December 2015 was fraught with deadly extreme weather events in all the five major continents of the world. Some of these events include heavy torrential rains that led to severe flooding in the Southern and Midwestern states of the United States. The United Kingdom bore the brunt of several storm systems, one of which broke all previous rainfall records. All the while, Southern Asia got hit with historic rains that caused a deluge and left a trail of destruction in its wake. Such an extensive cross continental widespread of events could seldom be random, leading some scientists to attribute this breakout of extreme weather to the strong record breaking 2015 El Niño amidst an increasingly warming climate; but is the El Niño the only explanatory factor? In this study, we used a suite of reanalysis data sets to explain the role of the dominant climate patterns in the Dec 2015 events, and estimated the portion of variability attributable to them. Based on the synthesis of computations, both El Niño and a strong Madden Julian Oscillation (MJO) episode in Dec 2015 contributed to the referenced extreme events; with the strongest contribution coming from the MJO.

Tue-020

Understanding and Predicting Subseasonal Extreme Events

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The large-scale circulation condition favorable to the extreme Taiwan Mei-yu rainfall event was identified using 65 years of daily precipitation data at 10 meteorological stations and the 850-hPa winds of the NCEP/NCAR reanalysis data set during the period of 1951-2015. An extreme event is identified when the daily rainfall total is larger than a threshold value determined on the station basis. The result shows that the circulation pattern of a cyclonic flow over southern part of China and Taiwan and an anticyclonic flow over the South China Sea and the Philippine Sea, that induces strong westerly winds at the area with strong vorticity gradient, is favorable to the occurrence of the extreme event. A southwesterly flow index (SWFI) was defined to describe the circulation and strong southwesterly wind condition. The SWFI can capture the above and below normal variations with above 60% hit rate for the prediction period. The conceptual downscaling approach is proved useful for predicting the predictability of the extreme rainfall frequency in Taiwan Mei-yu based on the model data available at the NMME and S2S databases.

Tue-021

Understanding and Predicting Subseasonal Extreme Events - DROUGHT OVER WESTERN ODISHA: A CASE STUDY OF REGIONAL CLIMATE CHANGE

Sanjeeb Kumar Sahoo (1,2), Krushna Chandra Gouda (1), Himesh S (1), Payoshni Samantray (1,2)

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The western part of the Odisha state, lying in the east coast of India is vulnerability to droughts. It is observed that the western part severly affected by the drought situation almost every year in the last two decades.In the present study a regional drought index is developed using long term rainfall observation at different time scales (i.e. annual, seasonal and monthly) over different regions like western, northern, southern, central and coastal Odisha. The analysis shows, over western part drought is increased drastically in present decade. It is also found that there is strong impact of drought on agriculture and socio-economic livelihood of people of western Odisha. Also an integrated modeling approach is presented to study the regional climate change. Using the WRF meso-scale model the extended prediction of the dry zone is being carried out.

Tue-022

Understanding and Predicting Subseasonal Extreme Events: Identifying and Assessing Gaps in Subseasonal to Seasonal Prediction of Extremes

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Estimates of predictability together with calculations of current prediction skill are often used to define the gaps in our prediction capabilities on subseasonal to seasonal timescales and to inform the scientific issues that must be addressed to build the next forecast system. However, different methods for estimating predictability can produce substantially different estimates of the upper limit of skill, leading to different conclusions regarding the gaps in our prediction capabilities. This project systematically quantifies estimates of the upper limits of predictability, assesses similarities and differences between predictability estimates, and compares predictability estimates with current skill. We focus on the predictability of extremes events on subseasonal to seasonal timescales using the North American Multimodel Ensemble (NMME). The results provide information on the regions, variables, and phenomena where predictability estimates agree about whether current skill have or have not reached the limits of predictability and provide information on when and where we do not know the predictability limits.

Tue-024

Understanding and Predicting Subseasonal Extreme Events - Climate Variability over the Himalayan Region: Case of Extreme Rainfall Events due to Cloud Burst

Payoshni Samantray (1,2), K C Gouda (1), Sanjeeb Kumar Sahoo (1,2), Himesh S (1)

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Himalayan mountain range in the north part of India has important role in the tropical climate system over the Indian subcontinent. Over the time its obseved that the mountain range receives low rainfall annually or seasonaly (during monsoon), but the number of extreme rainfall events generated due to the cloud burst are being increased in the Himalayan belt. In the present study using the multi-source observations like IMD gridded, APHRODITE, CRU, TRMM etc. the extreme event analysis are carried out. Then the contribution of the EREs in the climate variability over the mountain system are developed and the vulnearbility index is also defined which can be used as an indicator of the impact of extreme climate system over other disasters like land slide, flash flooding etc. Also a non hydrostatic model (NHM) configuration for the advanced prediction of such events are done and the hind cast simulation of about 15 cloud burst events are simulated and the model shows very less error with respect to observation and it can be used for the prediction of such climate variability.

Tue-025

Understanding and Predicting Subseasonal Extreme Events: Possible mechanism behind organization of Boreal Summer Intraseasonal Oscillation (BSISO) based on TRMM and reanalyses data

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Boreal summer Intraseasonal oscillations (BSISOs) show a meridional propagation from the Indian Ocean (IO) region to the Continental India. The BSISOs are the main source of rainfall variability over the Indian Summer Monsoon (ISM) Region. The recent research has revealed a basic understanding of the scale selection and northward propagation of the BSISOs. But the complete understanding about the initiation and organization mechanisms of BSISOs remains elusive.The question remains unrevealed that what mechanism is responsible behind the scattered cloud cluster getting organized to form an envelope of well organized large scale convection anomaly that propagate northward as BSISOs. One of the important issues from forecaster's point of view would be to know, whether or not a scattered low cloud clusters observed on any day would initiate a deep convection and eventually become large scale organized convection in the subsequent days. Recently Moncrieff et al. 2012 in connection to Year of Tropical Convection (YOTC) has given a framework how the small scale cloud and the large scale organized convection interact with each other. He has proposed that the upscale transformation of energy from cumulus and cumulonimbus cloud to the MJO/MISO through Mesoscale convective systems (MCS) are very much important. He has proposed that the Mesoscle convective organization can bridge the gap between the ISO scale and the cumulus scale in the traditional climate model. Presently no climate model incorporates a satisfactory parameterization of Mesoscale organization. Thus there is a need to understand the mechanism through which the small scale scattered cloud clusters organize into a large scale deep convective cloud and its subsequent propagation. This study uses observation and reanalysis data that covers summers (June-Sep) of 1998 2013 to investigate the mechanism behind the organization of BSISOs. Based on rainfall analyses, two types of BSISOs are defined, one with weaker and the other with stronger intensity. Stronger BSISOs show persisting lower level moisture convergence to the north of the convection centre (CC) and a strong vertical velocity collocated with CC. A new perspective based on the energetics study is applied to understand the mechanism. The analyses reveal that the eddy kinetic energy (KE) and conversion of eddy available potential energy (AE) to eddy kinetic energy (KE) increases as the BSISOs approaches towards organized stage. Thus it appears that eddy kinetic energy (KE) and its conversion from eddy available potential energy play an important role for the movement of BSISOs. Further analyses show that organization and intensification of BSISOs from the initial stage of formation is associated with the reduction in generation of eddy available potential energy. But for the weak events the structure is completely opposite. These suggest the key role played by the energy transformation.

Tue-026

Understanding and Predicting Subseasonal Extreme Events: Relationship between Warm Airmass Transport into the Upper Polar Atmosphere and Cold Air Outbreaks in Winter

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This study investigates dominant patterns of daily surface air temperature anomalies in winter (November–February) and their relationship with the meridional mass circulation variability using the daily Interim ECMWF Re-Analysis in 1979–2011. Mass circulation indices are constructed to measure the day-to-day variability of mass transport into the polar region by the warm air branch aloft and out of the polar region by the cold air branch in the lower troposphere. It is shown that weaker warm airmass transport into the upper polar atmosphere is accompanied by weaker equatorward advancement of cold air in the lower troposphere. As a result, the cold air is largely imprisoned within the polar region, responsible for anomalous warmth in midlatitudes and anomalous cold in high latitudes. Conversely, stronger warm airmass transport into the upper polar atmosphere is synchronized with stronger equatorward discharge of cold polar air in the lower troposphere, resulting in massive cold air outbreaks in midlatitudes and anomalous warmth in high latitudes. There are two dominant geographical patterns of cold air outbreaks during the cold air discharge period (or 1–10 days after a stronger mass circulation across 60N). One represents cold air outbreaks in midlatitudes of both North America and Eurasia, and the other is the dominance of cold air outbreaks only over one of the two continents with abnormal warmth over the other continent. The first pattern mainly corresponds to the first and fourth leading empirical orthogonal functions (EOFs) of daily surface air temperature anomalies in winter, whereas the second pattern is related to the second EOF mode.

Tue-027

Understanding and Predicting Subseasonal Extreme Events: Dynamic Linkage between Cold Air Outbreaks and Intensity Variations of the Meridional Mass Circulation

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This study investigates the dynamical linkage between the meridional mass circulation and cold air outbreaks using the ERA-Interim data covering the period 1979–2011. It is found that the onset date of continental-scale cold air outbreaks coincides well with the peak time of stronger meridional mass circulation events, when the net mass transport across 608N in the warm or cold air branch exceeds ~88*109 kg s-1. During weaker mass circulation events when the net mass transport across 60oN is below ~71.6*109 kg s-1,most areas of the midlatitudes are generally in mild conditions except the northern part of western Europe. Composite patterns of circulation anomalies during stronger mass circulation events greatly resemble that of the winter mean, with the two main routes of anomalous cold air outbreaks being along the climatological routes of polar cold air: namely, via East Asia and North America. The Siberian high shifts westward during stronger mass circulation events, opening up a third route of cold air outbreaks through eastern Europe, where lies the poleward warm air route in the winter-mean condition. The strengthening of the Icelandic low and Azores high during stronger mass circulation events acts to close off the climatological-mean cold air route via western Europe; this is responsible for the comparatively normal temperature there. The composite pattern for weaker mass circulation events is generally reversed, where the weakening of the Icelandic low and Azores high, corresponding to the negative phase of the North Atlantic Oscillation (NAO), leads to the reopening and strengthening of the equatorward cold air route through western Europe, which is responsible for the cold anomalies there.

Poster Abstracts

Tuesday, 20th September 2016

Tue-014

The Relationship between the Dominant Northern Equatorial Precipitation modes and Seasonal Global Climate during Boreal Summer

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The current study investigated the simultaneous relationship between the dominant precipitation modes over northern equatorial Africa (lat 5o -10oN, lon10o – 30oE) and seasonal global sea surface temperature (SST) distribution and associated upper atmospheric flows during the boreal summer. The analysis utilized nearly 60 years of data which consisted of Climate Research Unit(CRU) precipitation data (spatial resolution: 0.5o lat x 0.5o lon), horizontal winds from National Centers for Environmental Prediction-National Center for Atmospheric Research(NCEP-NCAR) reanalysis (spatial resolution: 2.5o lat x 2.5o lon), National Oceanic and Atmospheric Administration(NOAA) Extended Reconstructed Sea Surface Temperature(ERSST; spatial resolution: 2.0o lat x 2.0o lon).The analysis period (1951-2008) was based on the framework of previous studies which have been extended to all the major sub-Saharan regional climate systems. Empirical orthogonal function (EOF) analysis was used as exploratory data analysis tool, to delineate the dominant spatially coherent precipitation patterns and their associated timeseries during July-August-September (JAS) season. Gridpoint correlation was computed between each precipitation timeseries and standardized global SST anomalies, to describe their relationships. Standardized divergent atmospheric structures associated with each mode were computed at 200 hPa level, using the horizontal winds. EOF analysis revealed that the three leading modes accounted for 42.73% of the total explained variance, with EOF 1, 2, and 3 explaining 24.07%, 10.20% and 8.46%, respectively. A dipole mode was observed for EOF 1, in which positive(negative) eigenvector loadings were located over north of Cameroon, southern Chad, Central African Republic and west of South Sudan (southern Cameroon). A reverse pattern of EOF 1 was observed for EOF2, whereas EOF 3 revealed positive (negative) weights at the flanks of the zone and over the center, respectively. All the timeseries of the three modes showed interannual variability. The link to global SST distributions revealed the following distinctive findings: (i) The relationship between EOF 1 and the global SST distribution was regional in essence. The main oceanic features resided in the Pacific and the Atlantic Oceans. The Pacific demonstrated both direct and indirect relationship with the mode, in contrast to the Atlantic which was largely direct, (ii) EOF 2 was linked to quasi regional-scale interhemispheric SST distribution, in which the Northern Hemisphere (Southern Hemisphere) showed indirect (direct) relationships, and (iii) The SST distribution to EOF 3 relationship could be described as near-global. The dominant feature was near-equatorial-to-Southern Hemisphere direct relationship. On a smaller scale, both direct and indirect SST relationships were observed for this mode in mid-latitudes. The associated upper level divergent flows showed that the center of action of the flows were located over Northern Hemisphere Africa, extending to Asia, for both EOF 1 and 2 modes. These indicated strengthened upper-level Tropical Easterly Jet (TEJ). In contrast, weak divergent flows were associated with EOF 3, which were mainly centered

over northern Africa and indicated a weakened TEJ. It was concluded that the precipitation modes had distinct links to global SST distributions and their associated upper level atmospheric flows. Implicit in the atmospheric flows was the role of the TEJ in the African climate systems.

Tue-015

Simulation of the Madden-Julian Oscillation and its influence on South American intra-seasonal variability by the CFSv2 model

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Recent studies have shown the influence of the Madden-Julian Oscillation (MJO) in the climate of South America (SA). This influence is greater during austral spring and summer, that is, during the onset and the mature phase of the South American Monsoon System. The accurate representation of the features associated to the MJO evolution is therefore crucial in order to produce skillful subseasonal forecasts. This works aims to study how a global model that runs subseasonal forecasts operatively represents the MJO and its influence on intraseasonal (IS, 10-90 days) variability in SA. The CFSv2 model of the NCEP was selected for this study, and 123 day-long reforecasts during 1999-2010 for DJF and JJA, the target periods, were used. For each year, 10 runs were selected to study the variability of the model, which were considered as simulations. Spectral and spatial properties of the tropical convective anomalies associated to the MJO were studied in the CFSv2 and compared to those observed. Zonal wave number-frequency spectra were used to detect the representation of the MJO in the model. The signal is present in the simulations during DJF, though it maximizes in longer wave numbers than those observed. During JJA the MJO is weaker than observed. The spatial representation of the MJO by the CFSv2 was studied using Filtered-MJO OLR (FMO) patterns, which showed that convective anomalies associated with the MJO are weaker and located more to the east (west) during DJF (JJA) than observed. The ability of the CFSv2 model in representing the main seasonal features associated with the IS variability in SA was also assessed. They are described by the leading pattern (EOF1) resulting from an EOF analysis of bandpass filtered OLR anomalies (FOLR). When the South Atlantic Convergence Zone (SACZ) is in average active (warm season, October to April), EOF1 structure is a dipole one with centers of action of opposite sign located over the SESA and SACZ regions. Its variability is associated to that of the tropical convection in the Indian and Pacific oceans and to the MJO. During the cold season, when the SACZ is absent, EOF1 pattern is a monopole over SESA. The associated PC1 time series was used to indicate the level of activity of the pattern, and it was previously proved to be related to the occurrence of wet spells in SESA. The leading patterns for both, DJF and JJA, are well represented by the model, though with some differences in the tilting of the centers during summer and a region of higher simulated variability over northern Argentina during austral winter. The PC1 was used to compute lagged correlation maps against simulated OLR and upper-level geopotential height anomalies, and those were compared to the observations. OLR evolution showed indications of MJO-like anomalies propagating along the tropics, which are less intense during JJA for the model and observations. The associated wavetrains are better represented during winter, while in summer the differences in tilting and location might explain the differences observed in the convective centers.

Tue-016

Evaluation of subseasonal forecast models for a strong heat wave over Southern South America

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The prediction skill of subseasonal forecast models is evaluated for a strong and long-lasting heat wave occurred in December 2013 over Southern South America. Reforecasts from two models participating in the WCRP/WWRP Subseasonal to Seasonal project, the Bureau of Meteorology Poama and Beijing Climate Center model (CMA), were considered to evaluate their skill in forecasting temperature and circulation anomalies during that event. The Poama reforecast of 33 member ensemble size, initialized every five days, and CMA reforecast of 4 members ensemble size for each day were considered for the 1994-2013 period. CMA ensemble was constructed using the forecast of the same date of Poama plus the previous 4 days resulting in a 20 ensemble-members forecast. Weekly forecasts were computed with leadtimes from 2 days up to 22 days every five days. For each model, 2 meter temperature, 200-hPa and 850-hPa geopotential height and outgoing longwave radiation were used to describe the regional circulation. Daily ERA Interim reanalysis of 2 meter temperature and 200-hPa and 850-hPa geopotential height from 1994 to 2013 were used as observations while outgoing longwave radiation was taken from NOAA interpolated satellite estimates. Weekly anomalies were calculated for observations from 13th of December to 31st of December 2013. Anomalies for both observations and reforecast were calculated with respect to their own climatology. Results show that both models forecast lower temperature anomalies than those observed during week 1 and week 2 of the heat wave while Poama model overestimate temperature anomalies for week 3. Poama model forecasts the first two weeks of the heat wave at long and short leadtimes better than CMA although week 3 anomalies were better forecasted by CMA, especially for long leadtimes. Strong positive circulation anomalies over Southern South America at high and low levels during week 1 and 2 were well forecasted by Poama more than 15 days in advanced while CMA produced skillful forecast just two days prior to the beginning of the event. Week 3 negative circulation anomalies were of the opposite sing in long lead forecast of both Poama and CMA. In summary, for this case, models skill in forecasting surface temperature resulted moderate at long lead times. However, their performance for regional upper and low level circulation leads to the question whether the used of these forecasted variables in combination to other dynamic and statistic forecast tools could improve skill.

Tue-023

Diagnosing Sea Ice from the North American Multi Model Ensemble and Implications on Mid-latitude Winter Climate

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Arctic sea ice plays an important role in weather and climate. In addition to moderating the exchanges of energy and moisture at the surface, changes in sea ice have been shown to impact surface air temperature (SAT) and sea level pressure (SLP). Specifically, declines in fall sea ice have been linked to winter cold out breaks in the mid-latitudes and surface pressure patterns consistent with the negative phase of the Arctic Oscillation (AO). This study looks at how well models from the North American Multi-Model Ensemble (NMME) project estimate fall sea ice extent between 1982 and 2009. Then, the models with the best skill are used to reanalyze the results of Liu, Curry, Wang, Song, and Horton (2012), which investigates the impacts of fall ice decline on winter climate variables, SAT and SLP. Three of the 14 NMME models showed skill in ice estimation and when an ensemble average of those models is used to investigate the impact on SAT and SLP, it is found that cold outbreaks occur in the mid-latitudes, consistent with previous studies, while SLP shows positive AO like pressure patterns, highlighting the need for accurate model estimates of sea ice.

Tue-029

The new operational ECMWF eddy perimting ocean and sea-ice reanalysis ORAS5

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The new operational ECMWF eddy perimting ocean and sea-ice reanalysis ORAS5. A new ocean reanalysis system called ORAS5 is going to be implemented operationally at ECMWF in 2016. It will be used to iniitalize the operational coupled forecats at different time scales (medium range, monthly and seasonal). ORAS5 consists on an ensemble of 5 members, spanning the period 1979 to real-time. Compared to its predecessor ORAS4, the new reanalysis has higher horizonal and vertical resolution (approximately 0.25 degrees in the horizontal and 1m veritical resolution in the upper ocean). It also has a dynamical sea-ice model. ORAS5 is state of the art in that it uses the most up-to-dates observational data streams and a novel ensemble generation technique. The main features of ORAS5 are described. Its performance regarding climate indices and impact on coupled forecasts is evaluated and compared with ORAS4. It is envisaged that ORAS5 will replace ORAS4 in 2017 (when ORAS4 will be discontinued).

Tue-030

CERA-20C: a 20th century record of consistent ocean-atmosphere states

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Within the ERA-CLIM2 project, ECMWF has developed an ocean-atmosphere coupled data assimilation system (CERA) that aims at producing a self-consistent estimate of the climate system. In CERA, ocean and atmospheric observations are simultaneously ingested, and the coupled model constraints of the variational method imply that the assimilation of an ocean observation can impact the atmospheric state, and vice-versa. An ensemble technique is also used to take into account uncertainties in the observational record. CERA is being used to generate the first coupled climate reanalysis of the 20th century (CERA-20C) at moderate resolution (about 120 km, 91 vertical levels in the atmosphere and 42 in the ocean) using conventional observations only. In CERA-20C, 3-hourly estimates of the coupled ocean-atmosphere state are available from 1901 to 2010. CERA-20C can be used to monitor the climate, identify decadal variability, as well as providing initial conditions (and verification states) for extended-range forecasts. After completion and evaluation, CERA-20C will be made available to the research community to identify its strengths but also its weaknesses and ways forward to address them. In this poster, the CERA system will be described, and preliminary results from CERA-20C will be presented.

Tue-031

Equatorial Wave Expansion of Instantaneous Flows: A New Tool for Diagnosis of Equatorial Wave Fields from Data and Models

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Equatorial waves have been studied extensively due to their importance to the tropical climate and weather systems. Historically, their activity is diagnosed mainly in the wavenumber-frequency domain. Recently, many studies have projected observational data onto parabolic cylinder functions (PCFs), which represent the meridional structure of individual wave modes, to attain time-dependent spatial wave structures. The non-orthogonality of wave modes has yet posed a problem when attempting to separate total wave fields into individual wave modes where the waves project onto the same structure functions. We have formulated a new methodology for equatorial wave expansion of instantaneous flows (EWEIF) using the full equatorial wave spectrum and wavenumber-frequency domain. Because all meridional modes are shared by some subset of the wave classes, we require constraints on the wave class amplitudes to yield a closed system with a unique solution for all waves' spatial structures, including IG waves. By creating a mapping from the meridional structure function amplitudes to the equatorial wave class amplitudes, we are able to diagnose individual wave fields from an instantaneous flow and thereby determine their evolution. A series of synthetic fields are created covering a wide range of scenarios to determine how some properties of the wave fields are represented by the EWEIF. These include effects of multiple vertical modes and the treatment of signals unrelated to equatorial waves. We have validated that the EWEIF is capable of successfully partitioning the wave spectra by decomposing the waves in physical space in each of the scenarios.

Tue-032

The Continuous Mutual Evolution of Equatorial Waves with the QBO diagnosed using the Equatorial Wave Expansion of Instantaneous Flows

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An equatorial wave expansion method is applied to geopotential height data in the equatorial stratosphere to observe the evolution of individual equatorial wave classes with the background quasi-biennial oscillation (QBO) of zonal mean zonal wind. The wave class spectra diagnosed mostly match their expected dispersion curves, showing that this method successfully partitions the wave spectra by calculating wave amplitudes in physical space. This is particularly striking because the time evolution, and therefore the frequency characteristics, is determined simply by time series of independently-diagnosed instantaneous horizontal fields. We use the wave fields diagnosed by this method to study wave evolution in the context of the stratospheric QBO of zonal wind, confirming the continuous evolution of the selection mechanism for equatorial waves in the middle atmosphere. The amplitude cycle synchronized with the background zonal wind as predicted by QBO theory is present in the wave class fields even though the dynamics are not forced by the method itself. We have additionally identified a time-evolution of the zonal wavenumber spectrum responsible for the amplitude variability in physical space. Similar to the temporal characteristics, the vertical structures are also the result of a simple height cross-section through multiple independently-diagnosed levels.

Tue-033

The temporal variations of eastward flows in the southeast Indian Ocean

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A striking feature of the South Indian Ocean circulation is near-surface eastward flows that extend from Madagascar to Australia. The eastward flow concentrates into jets that have recently been described as branches of the South Indian Countercurrent (SICC), the northern branch of which feeds into the Eastern Gyral Current (EGC). The eastward flows are remarkable because they flow against the Sverdrup gyre circulation and against the wind-driven surface Ekman flow. There are near-surface eastward flows in the subtropics of other ocean basins, but none so strong, and none extending all the way to the eastern boundary, as in the South Indian Ocean. Recent work has provided a detailed description of the observed vertical structure of near-surface eastward flows and their seasonal variability from an exploration of gridded climatologies, altimetry and mean dynamic topography (Fig. 1). We complement this broad-scale view with a detailed analysis of the temporal variations of the SICC and in particular the strong 1.5 to 1.8 year quasi-biennial oscillation found in these fronts, and how this oscillation is strongest in the western part of the Southern Indian Ocean. In the weak phase the fronts are closer together, in the strong phase they are more widely separated. The spectral content varies over the duration of the record and shows that the SICC fronts have a complex, time variable energy content, quite distinct from the spectrum of the equatorial region and Southern Ocean.

Tue-034

Reconstructing extreme AMOC events through nudging of the ocean surface: A perfect model approach

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In this work, we follow a perfect model approach with the IPSL-CM5A-LR model to assess the performance of several nudging techniques in reconstructing the variability of the Atlantic Meridional Overturning Circulation (AMOC). Special attention is given to the representation of an extreme positive AMOC peak. Nudging includes standard relaxation techniques towards the sea surface temperature and salinity anomalies of a target control run, and/or the prescription of the wind-stress fields. All these nudging approaches, applying a standard fixed restoring term (γfix), succeed in reproducing most of the target AMOC variability, including the timing of the extreme event, but underestimate systematically its amplitude. Our analysis also highlights the sensitivity to the initial conditions of the nudged experiments, which is only reduced when sea surface temperature and salinity together with wind-stress initialization are applied. A detailed analysis of the AMOC variability precursors reveals that the underestimation of the extreme AMOC maximum comes from a deficit in the formation of the dense water masses in the main convection region, located south of Iceland in the model. This issue is largely corrected after introducing a novel nudging approach, which uses a varying restoring coefficient (γvar) that is proportional to the mixed layer depth. This new technique substantially improves transformation of dense water masses in the regions of convection, and in particular the representation of the AMOC extreme. This is therefore a promising nudging strategy that may help to better constrain in the models the AMOC variability and other ocean features over the last few decades

Tue-050

Future freshwater stress for island populations

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Global climate models project large changes in the terrestrial water balance for many regions this century in response to greenhouse gas emission, but insufficient resolution precludes such knowledge for approximately 18 million people living on small islands scattered across the world ocean. By accounting for evaporative demand a posteriori at 80 island groups distributed among Earth's major ocean basins, we reveal a robust yet spatially variable tendency towards increasing aridity at over 73% of island groups (16 million people) by mid-century. Although about half of the island groups are projected to experience increased rainfall—predominantly in the deep tropics—projected changes in evaporation are more uniform, shifting the global distribution of changes in island freshwater balance towards greater aridity. In many cases, the magnitude of projected drying is comparable to the amplitude of the estimated observed interannual variability, with important consequences for extreme events as well as mean climate. Future freshwater stress, including geographic and seasonal variability, has important implications for climate change adaptation scenarios for vulnerable human populations living on islands across the world ocean.

Tue-051

The opposite relation between extreme precipitation over southwestern Amazonia and southeastern Brazil. Observations and Model Simulation

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The objective of the present study is to identify the atmospheric and oceanic characteristics associated with extreme precipitation over western Amazon region and verify the ability of CPTEC/INPE AGCM in reproducing the observed features. The GPCP precipitation, ERA Interim data sets and the model climate simulation are analyzed for the climatological period of 1981-2010. In addition, atmospheric features that occurred during the extreme precipitation in January 2014 and 2015, which resulted in floods in the Acre state, are discussed. The extreme precipitation in the area is calculated from the Standard Precipitation Index (SPI) and composites and correlation analysis using atmospheric variables and SST indicate the main large scale and regional characteristics. The general results of climate analyses indicate an opposite relation of precipitation between western Amazon and Southeastern Brazil, besides the typical precipitation dipole between the SACZ region and areas to the south. Composites of wet and dry Januaries in ACRE (southwestern Amazon) show similar patterns. In January of 2014 and 2015 the anomalies presented the same patterns of the wet composite. This configuration is related to anomalous humidity flux at low levels and associated anomalous sea level pressure over eastern South America induced by subsidence. An opposite situation occurred in January 1985, when there was opposite precipitation anomalies configuration over South America and higher than normal sea level pressure over southeastern Brazil, cyclonic circulation at low levels and opposite humidity flux compared to the 2014 and 2015 cases. The anomalies in 1985 were similar to the dry composite in ACRE. Correlation of precipitation in the ACRE area with zonal and meridional humidity flux indicate that positive precipitation anomalies in that region occur when there is easterly flux over eastern Brazil and northward flux over western South Atlantic Ocean and Northeastern Brazil. Thus, the source of humidity for the southwest Amazon region is located in the South Atlantic region and eastern Brazil rather than in the North Atlantic, which is the humidity source for northern Amazon. This configuration is consistent with the opposite rainfall anomalies between ACRE area and SE Brazil. The model reproduced some observed atmospheric patterns related to precipitation extremes and the results are discussed in terms of climate variability and prediction.

Tue-052

Multiple climate model evaluation of simulated precipitation in the Congo River Basin: biases and teleconnections

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The hydrological cycle provides vital linkages for maintaining ecosystem services in the Congo River Basin (CRB), where the resources are shared by nine countries. Yet, the understanding of its spatiotemporal variability as modulated by climate, vegetation and topography is limited. Due to the location near the equator, high energy inputs and abundant precipitation act as key drivers of hydrological cycle in the CRB. Precipitation, in particular, shows strong spatial and temporal variations, including wet-dry gradients that stretch from the equator towards both the northern and southern latitudes. The precipitation cycle and its inter-annual variability are modulated by combined departure patterns of atmospheric and oceanic fields in the Atlantic (eastern) and Indian (western) ocean sectors. Global (as well as regional) climate models, due to inadequate and unresolved representation of physical processes, exhibit substantial biases in simulating the magnitude and seasonality of precipitation in the CRB. In this presentation, we will present an assessment of simulated precipitation fields in the CRB by 25 climate models that contributed outputs to the IPCC's Fifth Climate Change Assessment Report. Further, we will also show that the differences in model simulations are partly dependent on how they replicate teleconnections between large-scale circulations, with particular focus on departures in sea surface temperatures (SSTs) in the Atlantic and Indian Ocean sectors. Initial results reveal that strong (weak) coupling with large-scale circulations may be causing substantial biases in simulated precipitation fields. Our study further suggests that evaluating linkages between external forcings, such as SSTs, could provide more insights with which climate model performance in data scarce regions like the CRB can be improved.

Tue-053

Influence of South Atlantic SST anomalies on droughts and extreme precipitation events over South America from observations and models

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The El Niño-Southern Oscillation (ENSO) in the tropical Pacific is the dominant mode of coupled ocean-atmosphere interaction with large repercussions on global weather and climate. However, there are significant ocean-atmosphere interactions in other ocean basins that affect and modulate regional weather and climate variability. In this study, we present analyses of both observations and model runs to show that rainfall over Southeast Brazil is significantly impacted by the leading modes of SST variability in the South Atlantic Ocean. Our analyses of output from the pre-industrial run with the Community Earth System Model version 1 (CESM1) show that this model is able to reproduce the dominant modes of coupled ocean–atmosphere interaction in the tropical and subtropical South Atlantic. The highlight of our findings is that precipitation over Southeast Brazil, which is a region that has suffered severe climate extreme events in recent years, is highly and significantly correlated with the South Atlantic Subtropical SST Dipole (SASD) in both observations and CESM1 pre-industrial run. Our analyses also confirmed an earlier finding that precipitation over Southeast Brazil is not strongly, directly correlated with ENSO variability. In the ongoing investigation, which includes analyses of the upper layer heat content and meridional heat transports, we find that the SASD variability is significantly influenced by extra tropical teleconnections emanating from the tropical Pacific. These preliminary results collectively reinforce the suggestion that the SASD is an important modulator of the ENSO influence on rainfall variability over Southeast Brazil.

Tue-054

The Mean Structure and the Intensification of the Global Subtropical Underwater

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This study examines the global subtropical salinity maximum water, or Subtropical Underwater (STUW) in the subtropical regions of the North and South Atlantic, North and South Pacific and Indian Oceans. These high salinity water masses are important components of the upper-ocean overturning and global water cycle. In this work, we use the global, observation-based, version 4 of the Met Office Hadley Centre ‘‘EN’’ series of data (EN4) from 1950 to 2014 to investigate 1) the basic structure and characteristics of STUW in each ocean basin in the climatological fields 2) the interannual variability and trends of the global STUWs' (water mass) properties. We discuss their individual properties, variabilities and how their surface expressions compare with 3D features. We also investigate similarities and discrepancies among the five STUWs. From a climatological perspective, they each maintain a wind sock shape, with toe(s) tilting equatorward. The North Pacific STUW exhibits the largest outcrop while the South Pacific STUW has the largest volume. The Indian Ocean STUW reaches the deepest depth while the South Atlantic STUW has the least surface outcrop, shallowest depth and therefore the smallest volume. Their latitudinal, longitudinal positions and shapes are associated with the upper ocean subduction and meridional overturning circulation (MOC) as well as Intertropical Convergence Zone (ITCZ) location. During the 64 years examined, the global STUWs' properties shows distinct year to year variations and their surface properties are significantly correlated with their 3D features on interannual time scales which indicate the surface salinity maximums over the outcrop area are the surface manifestation of the 3D STUW. One common feature of all the five STUWs is that the overall trends of all their properties are positive, i.e., their outcrop areas and the 3D volumes become larger with their mean salinity over the outcrop area and over the 3D volume increasing. This suggests that the global STUWs are intensifying in the EN4 data during the time period of study, which is in agreement with the increasing surface salinity trend under the strengthened global water cycle (i.e., salty water becomes saltier and fresh water becomes fresher) and global warming.

Tue-055

The Role of SST Variability on the Recent Rainfall Extremes over Nigeria

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Analysis of extreme climate indices indicates that extreme rain events have persisted over Nigeria in recent years, the rainfall extremes is seen to have significantly increased both in frequency and intensity. This symmetric increments, perhaps explain the recurrent flash flood which have caused unprecedented loss of live as well as economic losses over the country. Results show significant positive correlation between the indices of extreme rainfall and non-stationary inter-hemispheric warming of the Atlantic Sea surface temperature and negative correlation with the cooling of east Pacific Ocean. We demonstrate the physical mechanism with which these ocean regions teleconnection regimes exerts influence on the extreme rainfall variation over Nigeria.

Tue-056

Contribution of Tropical Cyclones to atmospheric moisture transport and rainfall over East Asia

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The coastal region of East Asia (EA) is one of the regions that has the most frequent impacts from Tropical Cyclones (TCs). In this study, rainfall and moisture transport related to TCs are measured over EA, and the contribution of TCs to the regional water budget is compared with other contributors, especially the mean circulation of the EA summer monsoon (EASM). Based on ERA-interim re-analysis (1979-2012), the trajectories of TCs are identified using an objective feature tracking method. Over 60% of TCs occur from July to October (JASO). During JASO, TC rainfall contributes to 10-30% of the overall rainfall; this contribution is highest over the south/southeast coast of China. TC rainfall has a higher contribution to daily extreme rainfall (above the 95th percentile) it is 50-60\% over EA coast, and is as high as 70% over the islands. Compared with the mean EASM, TCs transport less moisture over the EA continent. However, as the seasonal cycle of TCs is out of phase with that of the EASM, moisture transported by TCs is another important source for the water budget over the EA continent when the EASM withdraws. This moisture transport is largely carried out by the westward moving TCs. These results improve our understanding of the water cycle of EA and provided a useful test bed for evaluating and improving seasonal forecast and coupled climate models.

Tue-057

Remotely sensed and modelled soil moisture datasets: an intercomparison and validation study across China

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In this study, two surface soil moisture datasets: (1) a microwave-based multi-satellite product (ESA CCI SM) and (2) soil moisture estimations from the Community Land Model 4.5 (CLM4.5), forced by observation-based atmospheric forcing data, were evaluated using twenty years of in situ observations from 306 stations in China. In general, both soil moisture products showed a good agreement with ground-based observations, with unbiased root mean square differences (ubRMSD) of 0.05 $m^3\ m^{-3}$. The average Spearman rank correlation coefficient (Rsp) between the ESA CCI SM product and all in situ observations was 0.37. Compared to the ESA CCI SM product, the CLM4.5 model produced better temporal variation of surface soil moisture (Rsp = 0.42), but showed larger ubRMSD in southwestern China. The ESA CCI SM product is more likely to be superior to the CLM4.5 model in semi-arid regions, but inferior over areas covered by dense vegetation. Furthermore, the ESA CCI SM product showed a stable to slightly better performance in China over time, except for a decline in performance during 2007–2010, when different data for the satellite product were blended.

Tue-058

Dynamical Ocean Response to Present-day and Future Volume Flux Forcing

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The time-mean impact of a surface volume flux forcing associated with a net surface freshwater flux on the global ocean circulation is investigated over the period 1949-2011. The study is based on an ocean circulation model that, based on the NCEP reanalysis 1, is forced at the surface by either a virtual salt flux or a volume flux, respectively. The resulting difference in the circulation that weakens the mean wind-driven gyre strength of the world oceans by about 1 Sv, can be ascribed to the barotropic Goldsbrough-Stommel circulation (GSC) and is associated with regional changes of the sea level, which are similar in pattern to the barotropic circulations and have a typical amplitude of the order of 1 cm. Another oceanic response is a weakening of the meridional heat and freshwater transports by about 5%. A decomposition of these transport differences reveals that the overturning component prevails over the gyre component, except for the freshwater transport difference in the southern Pacific-Indian oceans. The overturning component of these transport differences can be explained by the volume flux through shallow meridional overturning cells, which can be interpreted as continuation of the freshwater cycle into the interior of the ocean. The volume flux forcing weakens the meridional overturning circulation by about 0.1 Sv in the Atlantic and up to 1 Sv in the Pacific-Indian oceans mainly in the upper 500 m, while slightly enhances the deep meridional overturning by around 0.1 Sv. At the surface this anomaly can be ascribed directly to the transport of the volume flux forcing. On climate time scales, as dynamical response to the reinforcement of the global water cycle in a future warming, the mean GSC pattern of the period 2071-2100 intensifies by approximately 10% for the Representative Concentration Pathway (RCP) 4.5 and 20% for RCP8.5 relative to the period 1986-2005, which implies sea level changes by about +/- 0.15 cm for RCP4.5 and +/- 0.3 cm for RCP8.5.

Tue-059

Feeling the Pulse of the Stratosphere: An Emerging Opportunity for Predicting Continental-Scale Cold Air Outbreaks One Month in Advance.

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Extreme weather events such as cold air outbreaks (CAOs) pose great threats to human life and socioeconomic well-being of the modern society. In the past, our capability to predict their occurrences is constrained by the 2-week predictability limit for weather. We demonstrate here for the first time that a rapid increase of air mass transported into the polar stratosphere, referred to as "the pulse of the stratosphere (PULSE)", can often be predicted with a useful skill 4–6 weeks in advance by operational forecast models. We further show that the probability of the occurrence of continental-scale CAOs in mid-latitudes increases substantially above the normal condition within a short time period from one week before to 1-2 weeks after the peak day of a PULSE event. In particular, we reveal that the three massive CAOs over North America in January and February of 2014 were preceded by three episodes of extreme mass transport into the polar stratosphere with peak intensities reaching a trillion tons per day, twice of that on an average winter day. Therefore, our capability to predict the PULSEs with operational forecast models, in conjunction with its linkage to continental-scale CAOs, opens up a new opportunity for 30-day forecasts of continental-scale CAOs, such as those occurring over North America in the 2013–14 winter. The success of real time forecasts in the winters of 2014–15 and 2015-16 has given support to the idea that it is feasible to forecast CAOs one month in advance.

Tue-060

Summertime extratropical transient wave activity and its influence over southeastern South America

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We explore the variability of transient activity during summertime in the extratropical sector of the south Pacific and Atlantic oceans. Having in mind that subtropical South America is a transition region between a convection dominated regime and one where frontal activity dominates we assessed the degree to which transient activity accounts for rainfall anomalies over southeastern South America. Interannual transient activity is characterized by the group velocity of synoptic waves calculated using daily mean meridional winds at 300 hPa from NOAA DOE Reanalysis during each December-March season for the period 1979 to 2014.We found that extratropical transient activity shows strong interannual variability consisting in patterns that represent a strengthening of wave activity in the subtropical Pacific, and meridional shifts in the position of the Pacific and Atlantic storm tracks. Part of the variability is associated with ENSO. Rainfall in southern Uruguay is well correlated with latitudinal shifts in transient wave activity such that a strengthening in transient energy between 35-45S extending from the southeastern Pacific into the South American continent and south Atlantic favors positive anomalies. Rainfall in the northern region of Uruguay is not associated with significant changes in regional transient activity, but instead shows anomalies very similar (but weaker) to those found during El Nio, that is, enhanced south Pacific activity.Furthermore, we show that for El Nio to induce positive rainfall anomalies over southern Uruguay (together with south Brazil and northern Uruguay) it has to force two stationary waves: a wave that emanates from the central Pacific and describes an arch with low curvature into higher latitudes and then toward the south Atlantic and another shorter wave that emanates from the eastern Pacific and turns northeastward at the latitude of the subtropical jet. If the induced anticyclone off Brazil is strong then surface northerlies will reach southern Uruguay destabilizing the atmosphere due to the enhanced transport of moisture and warm air. At the same time changes in upper level winds strengthen the transient wave activity south of 35S so that the increased associated frontal activity induces positive rainfall anomalies by tapping the increased available moisture. These results suggest that rainfall over southern Uruguay is dominated by transient activity even in southern hemisphere summer, being thus less predictable than the region to the north which is dominated by a deep convective regime.

Tue-061

Influence of the Madden-Julian Oscillation on Extreme Rainfall over the Amazon basin

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The aim of this work is to provide a detailed analysis of the influence of MJO on extreme rainfall in the Amazon basin and its related large-scale circulations. The intraseasonal rainfall variability and extreme precipitation are analyzed using daily rain gauge-based grid data computed from 752 meteorological stations in the whole Amazon basin (AB) for the 1980-2009 period. Non-hierarchical clustering analysis was applied on a data set. The result of this analysis shows seven homogeneous regions that respond to the main atmospheric systems that affect the rainfall in the Amazon basin. The dominant patterns relating to intraseasonal variability were determinate through empirical orthogonal function (EOF) using filtered precipitation anomalies in the intraseasonal time-scale (30-70 days) detected by the wavelet analysis. Composites based on the principal components (PC) time-series showed that the Madden-Julian oscillation (MJO) is the main atmospheric-mechanism modulator of the rainfall variations in the northern and northeast Amazon basin. Furthermore, MJOs signal over AB was associated with MJO index and cross-equatorial regime. For instance, PC1 showed northwest-southeast dipole pattern during December to February (DJF) associated to the passage of the MJO over South America. Thus, during DJF, when the South American monsoon system is active, chances of enhanced rainfall are observed in eastern southeastern AB mainly during MJO phase 8 and northern regime. Impacts and spatial pattern during March to May (MAM) are similar. For all stations, phases 8 (4) and 1(5) are related at enhanced (inhibit) rainfall, principally at southeastern, eastern and northeastern Amazon basin.

Tue-062

Prediction of short-term climate extremes with the North American Multi-Model Ensemble

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This study focuses on the prediction of monthly and seasonal climate extremes at leads of one to several months. The skill of short term climate extremes (STCE) prediction by a state-of-the-art multi-model ensemble, the North American Multi-Model Ensemble (NMME), is assessed, including forecasts for 5th and 95th percentile seasonal events in maximum, minimum, and mean 2 m temperature. Area-aggregate forecast-observation gridpoint anomaly correlations for forecasts of extremes are found to be higher than area-aggregate anomaly correlations for all forecasts; some variation is found depending on season and model. Assessment of the forecast skill for extremes using the Symmetric Extremal Dependence Index reveals several geographic areas where model forecasts are substantially more skillful than a climatological forecast. The potential predictability of STCE is examined using perfect-model studies.

Tue-063

Uncertainty in Tropical Rainfall Projections: Atmospheric Circulation Effect and the Ocean Coupling

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Uncertainty in tropical rainfall projections under increasing radiative forcing is studied by using 26 models from phase 5 of the Coupled Model Intercomparison Project. Intermodel spread in projected rainfall change generally increases with interactive sea surface temperature (SST) warming in coupled models compared to atmospheric models with a common pattern of prescribed SST increase. Moisture budget analyses reveal that much of the model uncertainty in tropical rainfall projections originates from intermodel discrepancies in the dynamical contribution due to atmospheric circulation change. Intermodel singular value decomposition (SVD) analyses further show a tight coupling between the intermodel variations in SST warming pattern and circulation change in the tropics. In the zonal mean, the first SVD mode features an anomalous in- terhemispheric Hadley circulation, while the second mode displays an SST peak near the equator. The asymmetric mode is accompanied by a coupled pattern of wind–evaporation–SST feedback in the tropics and is further tied to interhemispheric asymmetric change in extratropical shortwave radiative flux at the top of the atmosphere. Intermodel variability in the tropical circulation change exerts a strong control on the spread in tropical cloud cover change and cloud radiative effects among models. The results indicate that un- derstanding the coupling between the anthropogenic changes in SST pattern and atmospheric circulation holds the key to reducing uncertainties in projections of future changes in tropical rainfall and clouds.

Tue-064

Impact of Climate Change on Urban Water availability: A Case Study of Million plus Coastal City of India

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India is experiencing rapid urbanisation, and consequently water demand in million plus cities is escalating rapidly. To meet the demand of water supply in cities, there is a lot of pressure on underlying aquifers to fulfill the water demand. Million plus city of India experiences an intensive salt water intrusion in aquifers due to natural and anthropogenic causes. The salinization of these groundwater systems can lead to a severe worsening of the quality of existing fresh groundwater resources. This raises concerns about citys water supply security, and its economic vitality and sustainability. Climate change is already having impacts on temperature and the hydrologic cycle, which complicates planning for water supply and demand and increases water insecurity.The purpose of this research is to understand the complex dynamics of the water sector, to investigate the needs of urban water managers and ultimately to suggest strategies and tools that can help these managers to meet ever growing needs in the face of climate change and increasing water insecurity. It also discusses the concept of an interface between fresh and saline groundwater and problems associated with these groundwater resources, such as salt water intrusion caused by global mean sea level rise. Possible human activities to compensate and control the salinization of coastal aquifers are presented.

Tue-065

Hydrological responses to volcanic eruptions assessed from observations and CMIP5 multi-models

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This study analyzes hydrological responses over the global land to four volcanic eruptions that occurred since 1960s using observations and CMIP5 multi-model datasets. Observations exhibit consistent decreases in humidity and precipitation following eruptions, which are reasonably captured by CMIP5 historical simulations. The observed precipitation decrease is significant but the CMIP5 models considerably underestimate it, as reported by previous studies. In order to explore important physical processes determining hydrological responses to volcanic forcing, a surface energy budget is analyzed together with inter-model relationship between variables. Interestingly, precipitation is found to have the significant correlation with latent heat flux (r = -0.50) and vertical motion (ω) at 500 hPa level (r =- 0.68), which changes are also underestimated by models. Further, by comparing precipitation minus evaporation over land and ocean, which is significantly correlated with vertical motion (r = -0.73), it is demonstrated that monsoon circulation decreases after volcanic eruptions but CMIP5 models substantially underestimate it. Our results suggest that this dynamic response related to monsoon circulation weakening can be critical factors for models' underestimation of precipitation reduction following eruptions.

Tue-066

Historical trends of monthly and annual precipitation in Zimbabwe from 1905 - 2000

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Monitoring, detection and attribution of climate extremes is a priority research area in climate science. Such information is critical for sustainable development particularly for Zimbabwe whose economy is at the mercy of the climate. Extreme weather events especially related to precipitation have led to infrastructure losses, reduced hydro-generation capacity, and the rise of conflict owing to reduced access to natural resources in many African countries. The Expert Team on Climate Change Detection of Extreme Indices has developed precipitation and temperature indices after the publication of the Intergovernmental Panel on Climate Change First Assessment Report. However, not much research in extremes has been done in Zimbabwe. Such indices are critical in identification of climate hot spot areas and climate change detection and attribution. The indices developed for such purposes have to cover long time periods. The following rainfall indices have been used in the classification of the soils of Rhodesia (now Zimbabwe): mean monthly and mean annual rainfall; highest rainfall in any one month and highest total rainfall in any one year and also the lowest rainfall in any one month and lowest total rainfall in any one year for the period 1899 to 1963. Such indices have however not been updated since then. In order to update this data base, we characterise the above indices in addition to annual anomalies for the period 1905 – 2000 using 16 meteorological stations in Zimbabwe. Rainfall data used in this study spanning from 1905 – 2000 was obtained from the National Climate Change Data Centre and was subjected to some quality control checks before processing. To test the rainfall trends, MAKESENS 2.0 Freeware was used. The study reveals a non significant decreasing trend in annual rainfall anomalies; the trends in monthly maximum and minimum are however inconsistent. Stations with either decreasing or increasing trends need to be explored further using other variables of extremes as they might be hot spot areas.

Tue-067

Zooplankton diversity at Chotiari Reservoir, Sindh

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Zooplankton diversity was studied at Chotiari Reservoir during May 2008 to April 2009 seasonally. Of all 6 stations collection, there were 80 zooplankton species identified, including 54 rotifer, 20 cladoceran and six copepod species. Among Rotifera the most dominant genera in terms of diversity were Brachionus and Leacne with 10 species each, genus Alona with 4 species in Cladocera, while three species of Cyclopoida in Copepoda. Eleven Rotifera species were newly recorded from Pkistan for the first time.

Tue-068

Expanding Oceanic Indicators of the Water Cycle Change

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In light of recent and ongoing alteration of the Earth's water cycle, considerable emphasis has been placed on assessing the changes in the terrestrial component of the global water budget, including changes in land precipitation, stream runoff, frequency and intensity of extreme events, atmospheric water vapor, cloudiness, pan evaporation, and soil moisture. Here we advocate for the expansion of indicators of the corresponding changes in the oceanic component of the global hydrological cycle, arguing that creating a comprehensive system of oceanic indicators is the key to successfully monitoring and predicting global changes in the Earth's water budget. In this study we focus on two climate variables — surface fluxes of freshwater over the oceans and surface salinity — to assess whether there have been systematic changes in the ocean water cycle in the last few decades. Previous studies have demonstrated that the long-term patterns in salinity and freshwater flux provide a reliable measure of secular change in the water cycle, whereas pattern detection on shorter timescales remains a challenge. Here we propose an alternative metric to track variability of the ocean water cycle on shorter timescales using salinity and ocean freshwater flux, namely the change in their seasonal cycles. Using a combination of historical observations and data-constrained ocean estimates we demonstrate that there have been persistent changes (defined as significant trends) in the annual cycle of both salinity and freshwater flux in many ocean regions, including amplitude loss in the North Atlantic subpolar gyre (possibly related to a decrease in sea-ice cover), or amplitude gain in the western tropical Pacific (due to the combined effect of decrease in evaporation and increase in precipitation). To gauge the importance of the observed trends in the annual cycle, we compare their magnitudes with those caused by natural and anthropogenic variability as represented by a suite of coupled atmospheric-ocean general circulation models. The goal is to test the hypothesis of a warming-induced intensification of the water cycle using this new metric and to evaluate its consistency with other ocean indicators of climate change. On a broader scale, we aim to use our results as a launching point for discussion on the need for a new line of metrics of recent changes in Earth's water budget and on consistency among different ocean indicators. The latter is essential for our confidence in projections of the potential scarceness of water resources.

Tue-069

Relationship of tropical cloud-rainfall and its association on climate sensitivity in the CMIP5 climate models

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According to previous studies, global precipitation is increasing under global warming resulting from a strengthening of the hydrological cycle. However, this increase largely depends on from region to region. Therefore, it is useful to understand the physical processes on the changes in precipitation in the observations and climate models to improve the accuracy of future changes, in particular, the tropics. Using the CMIP5 climate models, we analyze the relationship of cloud-convective rainfall from the historical run to the climate change run. To examine this, we mainly analyze the cirrus cloud and the convective rainfall ratio in the tropics. There is a large diversity of cirrus amount simulated in the CMIP5 climate models as well as convective rainfall amount. We analyze how such a diversity is associated with the climatological mean sea surface temperature. In addition, it is found that the relationship of cirrus amount-convective rainfall ration is also different among the CMIP5 climate models. We discuss physical meaning of this relationship and its association of climate sensitivity simulated in the CMIP5 climate model.

Tue-070

Interannual Variability in the Summertime Hydrological Cycle over European Regions

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A variety of observations-based hydrological variables from different data sets are used to investigate interannual variability and changes in the summertime hydrological cycle over four European regions – Iberian Peninsula (IP), British Isles (BI), Central Europe (CE) and European Russia (ER). An analysis performed on seasonal means (June, July and August: JJA) suggests that soil moisture variability is impacted almost equally by precipitation and air temperature in BI and ER regions. However, stronger links between soil moisture and precipitation are revealed for CE region and between soil moisture and air temperature for IP region. In all except IP regions summertime interannual variability of column-integrated water vapour is strongly linked to air temperature consistent with the dominating influence of the Clausius-Clapeyron equation. In BI, CE and ER interannual variability of regional precipitation is driven by variations in atmospheric moisture transport into these regions. In IP the link between precipitation and moisture transport is relatively weak. Based on monthly data, analysis of the lag-lead correlations revealed specific regional relationships between different hydrological variables. In particular, it is shown that in some regions (and months) interannual variability of soil moisture is linked more strongly to precipitation and air temperature anomalies in the previous month, rather than in the coinciding month. An analysis of the vertical structure of regional atmospheric moisture transport has revealed that the more continental the climate of the region is, the larger deviation from the mean (i.e., climatological) profile might be observed during anomalously dry/wet summers.

Tue-071

Understanding the Revival of the Indian Summer Monsoon after Breaks

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In this paper, we suggest a dynamical mechanism involved in the revival of summer monsoon after breaks. In this context, we carry out a diagnostic analysis using the datasets from National Centres for Environmental Prediction reanalysis-2 for the period 1979-2007 to identify a robust mechanism that typifies breaks and subsequent revival of monsoon. We find that during the peak of significant breaks, an anomalous southward shift of subtropical westerly jet stream, which is invariably accompanied by anomalous northward shift of a stronger-than-normal easterly jet. These major changes during a break facilitate an instability mechanism, which apparently leads to formation of a synoptic disturbance. Formation of such a disturbance is often critical to the subsequent revival of summer monsoon. Our computations of energetics and correlation analysis suggest an increase in the eddy kinetic energy at the expense of the mean kinetic energy during the breaks, in agreement with the formation of the synoptic disturbance with monsoon trough deepening. This demonstrates that barotropic instability in the presence of a monsoon basic flow is the primary physical mechanism that controls the summer monsoon breaks and subsequent revival of the monsoon.

Tue-072

Impact of Deep Convection Parameterization on Land-Atmosphere Coupling Strength on AGCM-CPTEC

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During the last years, a growing number of numerical experiments suggested that the atmospheric variability is strongly influenced by the land-atmosphere coupling, in particular due to soil moisture anomalies. Previous works in the literature have shown that there are different regions in the globe sensitive to such anomalies where some present a strong coupling whereas other regions seem insensitive to soil moisture anomalies. Moreover, there is not, up to the moment, study that investigates the role of deep convective parameterization on land-atmosphere coupling strength. Through a GLACE type simulation using the global circulation model of the Center for Weather Forecasting and Climate Studies of the National Institute for Space Research (CPTEC/INPE), we analyzed the coupling strength focusing on austral summer considering two different deep convective parameterization schemes, one dependent of the large-scale moisture convergence (kuo scheme) and the other one following the mass flux approach (Grell and Devéniy scheme), coupled with the surface model Integrated Biosphere Simulator (IBIS) that better represents a wide range of ecosystem and land surface processes. It was verified that the CPTEC/INPE global circulation model represents a weak to moderate coupling dependent upon the choice of convective parameterization. Even though low intensity coupling strength, it is comparable to values obtained from other models from international centers. Moreover, all the coupling areas confirm the ones previously found in past studies using other global models. It was observed that coupling strength during austral summer is about 20% higher than during boreal summer. Furthermore, comparing the moisture convergence with the mass flux scheme, we noticed largest values of coupling strength were obtained with the mass flux approach. During the austral summer, when the turbulence fluxes control the triggering of convection, a parameterization scheme that best represents the physical interactions between the convection and the environment, such as those with mass flux approach, implies a more intense coupling strength. This work highlights the importance of the use of a more sophisticated convective parameterization to estimate the regions where precipitation is affected by soil moisture anomalies of surface-atmosphere coupling. Potential benefits of this study may include a better configuration of the model for seasonal prediction applications.

Tue-073

Seasonal forecasts: assessement of ocean initialization in Meteo France System 5

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Many socio-economic sectors have a strong interest in high quality seasonal forecasts, ranging from predicting heat waves or strong floods in some regions. To face this demand, Meteo France participes since many years to the EUROSIP multi-model seasonal forecasting system. Despite the significant progress in recent decades, systematic errors are still present. These errors partly arise from the misrepresentation of some of the physical processes in the upper or deep ocean, and at the atmosphere-ocean interface. Here, we investigate the sensibility of seasonal forecasts from Meteo France System 5 to the initial conditions of the ocean state. The System 5 is based on the Arpege-Climat v6 atmosphere model (T255), coupled to the NEMOv3.2 ocean model (1°x1°). Reforecasts have been carried out during the period 1993-2014, using May and November start dates. Reforecasts are 15-member simulations over 6 months. Two reforecast sets have been produced: one is initialized with ORAS4 (ECMWF) ocean reanalysis, while the other is initialized with an upscaled version of GLORYS2V3 (PSY2G2V3, Mercator Océan) at the 1°x1° resolution. Atmosphere is initialized from ERA-Interim. First, we compare both ocean reanalyses, and highlight the main differences. The upper ocean in Mercator PSY2G2V3 is too fresh and too warm in the Atlantic and eastern Pacific Oceans. In the Southern Ocean, the sea ice cover is underestimated in the Mercator reanalysis compared to observations from NSIDC. Then, we show how these differences affect the prediction skill scores in the two reforecast sets, focusing on specific regions. Forecasts are biased warm in the tropical Atlantic Ocean in both reforecast sets. This warm bias can be explained by atmospheric conditions, for instance lack of cloudiness. In reforecasts initialized with the Mercator reanalysis, a warm biais is found around Antarctica in the summer forecast, which can be related to strong biases in the simulated sea ice cover in the coupled model as well. Results from this study will be used for the setup of the future Meteo France seasonal forecasting systems.

Tue-074

Nonlinear dynamical models of interannual to decadal climate variability from observed time series: data pre-processing, model construction, forecast of climate indices

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Adequate modeling of interannual and decadal processesis necessary condition for correct forecast of climate changes in XXI century, and up to now reproduction of corresponding climate modes by existing global climate models is insufficient. At the same time informativity (number and duration) of climate time series is insomuch increased that empirical approach looks as real alternative to first principal modeling. Such an approach is aimed to construction of prognostic models by way of direct analysis of data without involving any detailed physical equations. We developed a method for empirical modeling basing on reconstruction of prognostic evolution operator in a form of random dynamical system [1,2] – stochastic mapping the current state of the system to the next one. The most complicated problem that should be overcome is contradiction between limited duration of climate time series in time and huge dimension of these time series due to their distribution over the globe. We solve the problem by way of construction of proper model embedding: the optimal set of variables – principal modes – determining the phase space the model works in. We outline two main features these modes should have to capture the main dynamical properties of the system: (i) capturing teleconnections in the atmosphere-ocean system by taking into account time-lagged couplings in data and (ii) reflecting the nonlinear interactions between the time series at different grid points. In accordance to these principles, in this report we present the methodology which includes the combination of a new way for the construction of an embedding by the spatio-temporal data expansion and nonlinear model construction on the basis of artificial neural networks. The methodology is applied to NCEP/NCAR reanalysis data including fields of sea surface temperature, sea level pressure, geopotential height, and wind speed, covering Northern Hemisphere. Its efficiency for the interannual forecast of various climate phenomena including ENSO, PDO, NAO and strong blocking event condition over the mid latitudes, is discussed. Also, we investigate the ability of the models to reproduce and predict the evolution of qualitative features of the dynamics, such as spectral peaks, critical transitions and statistics of extremes.This research is supported by the Government of the Russian Federation (Agreement No. 14.Z50.31.0033 with Institute of Applied Physics of RAS)

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Tue-075

How does Greenland's boundary layer inversion respond to surface warming?

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The Arctic climate is continuously evolving prompting an investigation of the proposed feedback mechanisms within the coupled atmosphere-cryosphere system. The study of ice-sheet dynamics, in particular, is crucial for estimating the risks of sea-level rise. The recently observed surface-wide Greenland ice-sheet melt of July 2012 has been linked to the presence of increased low-level, transparent clouds. One of the major motivations of this study is to investigate Greenland's atmospheric boundary layer (ABL) inversion, and its role as a coupling medium between the ice and the clouds. The ABL influences the turbulent flux-exchange at the surface, which is important for cloud formation as well as melt/freeze processes. Limited ground truth in the hostile polar environment pose a challenge to study and monitor the atmospheric boundary layer. Few, if any, observational evidence exists for the spatial distribution of the ABL inversion height.This study explores the same along with the spatial and interannual variability of surface-based inversion (SBI) frequency over Greenland using eight years of observations (2006-2013) from Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC). Reduced stability is observed over the continent during summer and spring compared to fall and winter. Interannual variability shows a significantly higher ABL inversion over Summit during the summer of 2007 and 2012, years with record melting of the Arctic sea-ice. Station observations indicate that factors other than surface warming are responsible for the same. Three scenarios (viz., the surface-based inversion, the elevated inversion, and the shallow surface-based inversion) are investigated using radiosonde observations over Summit. As expected, elevated inversions occur in a warm regime. On the other hand, shallow SBIs typically occur in a cold regime and are likely caused by an enhanced greenhouse effect due to clouds. The latter is frequently observed during all seasons, and may contribute to surface melting during summer. Thus, while one can expect reduced boundary layer stability with warming, the combined effect of surface and cloud changes must be considered while predicting the ABL height variability and feedbacks over Greenland.

Tue-076

Teleconnections between intraseasonal monsoon variability in South America and Southeast Africa

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The rainy season in most of South America is associated with the summer monsoon. Its main source of intraseasonal variability is the Madden Julian Oscillation (MJO). Summer is also the rainy season in Southeast Africa, where OLR anomalies also suggest significant MJO-related convection. As they may not reflect faithfully the variability of rainfall, an assessment of the MJO influence on precipitation in this region is carried out with daily rain gauge records from South Africa (1970-1999) and Mozambique (1970-2005), between 10°S and 35°S. The daily station data are gridded to 1 degree, and submitted to a bandpass Lanczos filter, which retains intraseasonal oscillations in the 20-90 day band. The MJO cycle is divided into 8 phases, according to the first two variability modes of tropical OLR and zonal winds at 850 and 200 hPa. Composites of precipitation anomalies are made for each phase, and their significance is assessed. The associated anomalous streamfunction and moisture flux show that circulation anomalies associated with MJO-related convection over the tropical Indian Ocean and over South America produce anomalous moisture fluxes from the Indian and AtlanticOceans into Africa, influencing rainfall over the southern part of the continent. Besides the anomalies of moisture flux and its divergence, dynamic aspects associated with the circulation anomalies in each phase of the MJO also explain the precipitation anomalies observed in southeast Africa. To explore teleconnections between the MJO precipitation anomalies in South America and Southeast Africa, the filtered precipitation in 2.5 degree grid boxes over Southeast Africa is correlated with filtered precipitation in 1.0 degree grid boxes over South America during summer. Lags from 0 up to 10 days are applied to the South African data, in order to investigate convection anomalies over South America that could produce atmospheric perturbations associated with precipitation anomalies over Southeast Africa. Significant correlations exist between the intraseasonal variability of Southeast Africa daily rainfall and that over South America, with the latter leading by around five days. For the regions in Southeast Africa displaying highest correlations, anomaly composites are constructed for 200 hPa streamfunction, OLR, 500hPa omega, and vertically integrated moisture flux associated with precipitation anomaly above one standard deviation in the filtered series. The possible origin of the atmospheric circulation anomalies associated with the precipitation anomalies in Southeast Africa is searched with influence functions (IFs) of a vorticity equation model that includes the divergence of the basic state and the vorticity advection by the anomalous divergent wind. The IF for a selected target point indicates the tropical/subtropical regions in which the anomalous upper-level divergence is most efficient in producing streamfunction anomalies around that target point. The results, including simulations with the model, indicate the existence of teleconnections between MJO-related precipitation in South America and in Southeast Africa during austral summer.

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Tue-077

Relationships between extreme precipitation events and interdecadal variability in South America during the monsoon season

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This study aims to clarify the impact of interdecadal climate oscillations (periods of 8 years and longer) on the frequency of extreme precipitation events over South America in the monsoon season (austral spring and summer), and determine the influence of these oscillations on the daily precipitation frequency distribution. Interdecadal variability modes of precipitation during the monsoon season are provided by a continental-scale rotated empirical orthogonal function analysis for the 60 years period 1950-2009. The main disclosed modes are robust, since they are reproduced for different periods. They can produce differences around 50% in monthly precipitation between opposite phases. Oceanic and atmospheric anomalous fields associated with these modes indicate that they have physical basis. The first modes in spring and summer display highest correlation with the Interdecadal Pacific Oscillation (IPO) SST mode, while the second modes have strongest correlation with the Atlantic Multidecadal Oscillation (AMO) SST mode. However, there are also other influences on these modes. As the most dramatic consequences of climate variability stem from its influence on the frequency of extreme precipitation events, it is important to also assess this influence, since variations in monthly or seasonal precipitation do not necessarily imply significant alterations in their extreme events. This study seeks to answer the questions: i) Do opposite phases of the main interdecadal modes of seasonal precipitation produce significant anomalies in the frequency of extreme events? ii) Does the interdecadal variability of the frequency of extreme events show similar spatial and temporal structure as the interdecadal variability of the seasonal precipitation? iii) Does the interdecadal variability change the daily precipitation probability distribution between opposite phases? iv) In this case, which ranges of daily precipitation are most affected? The significant anomalies of the extreme events frequency in opposite phases of the interdecadal oscillations display spatial patterns very similar to those of the corresponding modes. In addition, the modes of extreme events frequency bear similarity to the modes of seasonal precipitation, although a complete assessment of this similarity is not possible with the daily data available. The Kolmogorov-Smirnov test is applied to the daily precipitation series for positive and negative phases of the interdecadal modes, in regions with high factor loadings. It shows, with significance level better than 0.01, that daily precipitation from opposite phases pertains to different frequency distributions. Further analyses disclose clearly that there is much greater relative impact of the interdecadal oscillations on the extreme ranges of daily rainfall than in the ranges of moderate and light rainfall. This impact is more linear is spring than in summer.

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Tue-078

The onset/withdrawal of the South Asian monsoon: from seasonal transitions to interannual variability

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Many differing definitions of the onset/withdrawal of the South Asian monsoon (SAM) exist in the literature. Here, we introduce an objective index for the onset and withdrawal of the large-scale SAM, based on change point detection (Cook and Buckley 2009) in daily moisture flux convergence (MFC) from MERRA reanalysis averaged over the SAM domain (60-100E, 10-30N). More specifically, we compute the daily time series of MFC for each year (1979-2014), starting from Jan 1, and use two-phase linear regression of cumulative MFC vs. day of year to find the change points associated with monsoon onset and withdrawal. The onset day is defined as the change point which minimizes the sum of squares of residuals for the two-phase linear regression between Julian days 1-250, and the withdrawal day is defined as the change point between Julian days 200-365. This index well captures the transitions into and out of the SAM, in terms of its large-scale precipitation and circulation features. This new monsoon onset/withdrawal definition is used to characterize changes in thermodynamic and dynamic fields as the circulation in the SAM region transitions from equinox to monsoon conditions. In the 60 days preceding onset, there is a gradual transition from equinox conditions to northern hemisphere (NH) summer conditions, with the major precipitation zone slowly migrating from the SH to the NH and the meridional overturning circulation in the SH gradually expanding and becoming cross-equatorial. Starting at onset day, the transition accelerates rapidly, with the major precipitation zone abruptly migrating from the southern tip of India well into the subtropics of the Indian subcontinent, the SH meridional overturning cell suddenly intensifying and expanding into the NH subtropics, and the NH cell abruptly disappearing. Within approximately 15 days after onset, the transition to monsoon conditions is complete and mature monsoon conditions are well established in all atmospheric fields. On interannual time scales, we find that a strong negative correlation exists between the onset date and the total length of the monsoon season (withdrawal day - onset day), and a strong positive correlation between the withdrawal date and the season length, that is, earlier onset and later withdrawal are both associated with longer monsoon seasons. Supporting results from previous work, we also find a positive correlation between onset date and Nino 3.4 SSTs in the preceding spring months, i.e. warm (cool) ENSO conditions in the preceding spring are associated with later (earlier) SAM onset. In the summer months (JJA), the withdrawal date and monsoon duration are negatively correlated with the Nino 3.4 SSTs, that is warm (cool) ENSO conditions during the summer monsoon months are associated with earlier (later) withdrawal and shorter (longer) monsoon season length. Future work will explore robust precursors of early/late onset years, and associated mechanisms.

Tue-079

Subseasonal to seasonal predictability and the role of land and ocean

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A large number of forecasts from a suite of models are routinely provided by the Subseasonal to Seasonal (S2S) Prediction Project and the North American Multi-Model Ensemble (NMME) Project. To develop a reliable and timely climate product from these datasets, a new methodology has been proposed to assess individual model's forecast skill, generating statistical weights based on the skill of member model forecasts, and using these weights to produce an optimized single forecast. The results show that the new methodology outperforms individual models and can increase the one-month lead forecast skill of surface air temperature by 50% over the simple multi-model average across much of the area of focus. This study aims to identify regions where there is significant forecast skill of precipitation and air temperature using the best forecast products we produced with the multi-model combination strategy and diagnose the dominant factors influencing such skill. We seek to understand how the variability of precipitation and near-surface air temperature are modulated by SSTs and soil moisture.

Tue-080

On Mid-Holocene ENSO activity appeared in PMIP

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Using the Paleoclimate Modeling Inter-comparison Project (PMIP), we investigated El Niño-Southern Oscillation (ENSO) during the mid-Holocene period (6,000 years before present; 6ka run). For 6ka run compared to the control run (0ka run), the reduced sea surface temperature (SST) and the reduced precipitation due to the basin-wide cooling, and the intensified cross-equatorial surface winds due to the hemispheric discrepancy of the surface cooling over the tropical Pacific were observed. The annual cycle of SST was weaker over the equatorial eastern Pacific, while it was stronger over the equatorial western pacific. The ENSO activity in the 6ka run was suppressed. In general, the weakened air-sea coupling associated with basin-wide cooling, reduced precipitation, and a hemispheric contrast in the climate state led to the suppression of ENSO activity, and on the contrary the weakening of the annual cycle over the tropical eastern Pacific might lead to the intensification of ENSO through the frequency entrainment. Therefore, the two opposite effects may be slightly compensated for by each other, which results in relatively small reduction in the ENSO activity in 6ka run compared to the proxy records. To propose the relative mechanism, BJ index analysis are applied to PMIP. Majority of PMIP participating models show a reduced BJ index along with the reduced Nino index variability. However, some models showed opposite results. Here, we address main cause what causes the difference between two groups.

Tue-081

Developing multi-model ensemble prediction capability for operational subseasonal forecasting

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The U.S. NOAA Climate Prediction Center has been producing experimental subseasonal forecasts with lead times from three to four weeks since September of 2015, in response to increasing demand for forecasts on this timescale, in particular for high impact climate events. Forecast guidance is being derived from multiple ensemble prediction system (EPS) models from operational centers, including the European Centre for Medium-Range Weather Forecasts (ECMWF), the Japan Meteorological Agency (JMA), the U.S. National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS), and the Environment Canada EPS. Multi-decadal retrospective forecast data from each model is used for bias-correction by deriving model-based climatologies, and probabilistic forecasts of above and below normal temperature and precipitation are derived from each ensemble. Methodologies of calibration and consolidation of the multi-model ensemble (MME) probabilistic forecasts are being tested and applied, to maximize skill, by identifying where and when each model system is able to represent signals from large-scale climate drivers, and determining to what extent individual ensemble models and the combined MME correctly represent uncertainty in the forecasts. We will apply methods of calibration and consolidation that retain the maximum signal, while producing reliable probabilistic forecasts, representing the conditional likelihood of climate events. In the future, forecast information will include the likelihood of extreme or high impact climate events.

Tue-082

CLLJ: Mean flow and transients interaction

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The Caribbean Low Level Jet (CLLJ) is a key element of the Mesoamerican Climate. Its intensification during July produces a westward displacement of the Inter-Tropical Convergence Zone (ITCZ) over the eastern Pacific that results in the Mid-Summer Drought (MSD). This acceleration is not produced by a strengthening of the North Atlantic Subtropical High (NASH). Over the Caribbean Sea the mass field adjusts to the wind field. The CLLJ is accelerated and decelerated through a dynamical interaction with high frequency transients. The meridional convergence of zonal momentum at 700 hPa around 15°N provides the required source of momentum for the zonal wind. New daily analysis gives some different variability modes by each year, these modes are associated with phenomenon like MSD and ENSO. Working with ERA-Interim data (1979-2013), we were able to group these modes into a few types using a fourier analysis. This study also links the local zonal acceleration with transients activity by meridional change of meridional flux of zonal momentum. The downward flux of zonal momentum to the 925 hPa occurs from May through July, due to subsidence over Caribbean. Such effect disappears from August through October resulting in deceleration of the CLLJ.The impact of transient mean flow interactions appears to be crucial for climate over Mesoamerica.

Tue-083

Relationship between optimal precursory disturbances and optimally growing initial errors associated with ENSO events: Implications to target observations for ENSO prediction

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By superimposing initial sea temperature disturbances in neutral years, we determine the precursory disturbances that are most likely to evolve into El Niño and La Niña events using an Earth System Model. These precursory disturbances for El Niño and La Niña events are deemed optimal precursory disturbances because they are more likely to trigger strong ENSO events. Specifically, the optimal precursory disturbance for El Niño exhibits negative sea surface temperature anomalies (SSTAs) in the central-eastern equatorial Pacific. Additionally, the subsurface temperature component exhibits negative anomalies in the upper layers of the eastern equatorial Pacific and positive anomalies in the lower layers of the western equatorial Pacific. The optimal precursory disturbance for La Niña is almost opposite to that of El Niño. The optimal precursory disturbances show that both El Niño and La Niña originate from precursory signals in the subsurface layers of the western equatorial Pacific and in the surface layers of the eastern equatorial Pacific. We find that the optimal precursory disturbances for El Niño and La Niña are particularly similar to the optimally growing initial errors associated with El Niño prediction that have been presented in previous studies. The optimally growing initial errors show that the optimal precursor source areas represent the sensitive areas for target observations associated with ENSO prediction. Combining the optimal precursory disturbances and the optimally growing initial errors for ENSO, we infer that additional observations in these sensitive areas can reduce initial errors and be used to detect precursory signals, thereby improving ENSO predictions.

Tue-084

Analysis of trends of mean temperatures and warm extremes in Northern Tropical Africa (1961-2014) and development of seasonal forecast schemes

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While the heat wave impacts on public health have been widely addressed in developed countries especially after the intense event over West Europe during summer 2003, few effort has been made to detect them and evaluate their impacts in least developed countries, and especially Africa, where climate is warmer and adaptation capacities are low. Over West Africa preliminary interviews, climate and epidemiologic analyses show however that this problem is emerging and climate projections indicate that such events should increase in frequency and intensity in the coming decades. Starting from this context, the main objective of ACASIS (Alerte aux Canicules Au Sahel et &agrave leurs Impacts sur la Sant Sahelian heat waves and their health impacts warning) is to set-up a pre-operational heat wave warning system over West Africa tailored to health risks of the population living in this region. Trends in maximum (TX) and minimum (TN) temperatures and indices of warm extremes are studied in tropical North Africa, west of the eastern African highlands, from 1961 to 2014. Averaged over all stations, the linear trends of annual mean TX and TN equal respectively +0.02C/year and +0.028C/year. The frequency of very hot days (TX 35C) and tropical nights (TN 20C), as well as the frequency of daily TX and TN over the 90th percentile (warm days and warm nights), roughly follow the variations of mean TX and TN, respectively. Warm spells are often short (usually &lt 2-3 days) and exhibit noisier variations, even if there is still an increasing tendency, with almost constantly positive anomalies since the mid-1990s. The trend in March-June, the warmest season across the Sahelian and Sudanian belts, shows similar variations as annual means, but usually with larger amplitude. Overall, the local-scale warming in annual temperatures, and in March-June only, may be viewed as a simple shift of the probability distribution function of daily TX and TN. The correlations between the thermal indices and the surface temperatures suggest that the low-frequency (8 years) variations may be viewed at least as a regional-scale fingerprint of the global warming, with largest correlations in the tropical Atlantic and Indian basins, while the high-frequency (&lt 8 years) should be mostly viewed as a delayed remote impact of El Nio Southern Oscillation (ENSO) events over the region, with warm (cold) anomalies tending to follow warm (cold) ENSO events. From these results a multivariate regression based on four December-February SST predictors has been set-up to provide seasonal forecasts of March-June warm spells characteristics over West Africa. This seasonal forecast indicates that spring 2016 will be the warmest since 1960, due to the combination of the global warming trend with the on-going 2015-2016 El Nio event. A dynamical seasonal forecast based on ARPEGE-CLIMAT climate model provides a similar forecast.

Tue-085

Intra-seasonal rainfall variability during Southwest Monsoon in Sri Lanka

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Intra-seasonal prediction is a crucial planning window for agricultural sector, water resource managers, energy sector and other stakeholders.Intra Seasonal Oscillations (ISO)s are near global patterns of anomalous atmospheric circulation that are closely related to variations in precipitation in many regions of the tropics. Pioneer studies discovered that there are two dominant components in the intra-seasonal timescale; one is an eastward propagating component, which is commonly referred to as Madden Julian Oscillations (MJO), the other is a northward propagating component associated with the Asian summer monsoon referred to as Boreal Summer Intra-Seasonal Oscillations (BSISO). The impact of the MJO and BSISO on southwest monsoon (SWM) seasonal rainfall in Sri Lanka is investigated using the Real-time Multivariate MJO (RMM) index (Wheeler and Hendon 2004) and BISISO indices (Lee et al. 2013) respectively and the observational rainfall data from 1981 to 2010. Composite maps of circulation anomalies and rainfall anomalies, each for eight MJO, BSISO 1 and BSISO2 phases are constructed. It is evident that during its life cycle, MJO favoured strengthening of the monsoon during the phase 2 to 4 bringing above normal rainfall, and weakening of monsoon in 7 and 8 phases of the MJO resulting below normal rainfall over southwestern quarter. For BSISO 1 widespread positive anomalies are evident phase 1 to 3 with strengthening of positive anomalies in phase 2 while widespread dry conditions can be seen from phase 5 to 8 with strengthening of negative anomalies are apparent over central hills in phase 7 and 8. In phase 4 slightly above normal rainfall is evident over southwest quarter while slightly below normal rainfall is obvious elsewhere. For BSISO2 widespread positive rainfall anomalies is evident only in phase 1. During Phase 2, the country was nearly divided into two halves with positive anomalies over southern western part and negative anomalies elsewhere. Enhancement of positive rainfall anomalies over western slopes of central hills is also evident in phase 2. Phase 3 and 4 are similar to phase 2 with weakening of wet conditions over southwest quarter and strengthening of dry conditions elsewhere. Enhancement of negative rainfall anomalies over Southwest quarter is also evident in phase 6 and 7. This study implies that the rainfall variability in SWM is largely influenced by the MJO and BSISO modulated circulation over Sri Lanka. The analysis provides a useful reference of when and where the MJO and BSISO have significant impacts on rainfall variability during SWM season in Sri Lanka. This information can be used along with the accurately predicted the MJO and BSISO phase by dynamical or statistical models, to improve intra-seasonal prediction in Sri Lanka. Several empirical and statistical models have been developed to predict the MJO and BSISO and useful predictive skill of the MJO and BSISO from these empirical models can reach a lead time of about 15–20 days at present.

Tue-086

ENSO Frequency Ccascade and Its implication

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The El Niño-Southern Oscillation (ENSO) interacts with the annual cycle and this interaction is not only essential for the frequency and phase locking of ENSO, but also for enriching the spatial-temporal behavior of ENSO through so-called ENSO frequency cascade. This frequency cascade is characterized by the generation of deterministic high-frequency variability on near-annual and subannual timescales. Particularly pronounced variability generated by this cascade is found in the circulations over the tropical Western Pacific. Through climate model experiments and observational analysis, it is documented that a substantial fraction of the anomalous Northwest Pacific anticyclone variability, which is the main atmospheric link between ENSO and the East Asian Monsoon system, can be explained by these interactions and is thus deterministic and potentially predictable.

Tue-087

Space-time evolution of intraseasonal oscillations in Indian monsoon rainfall and their changes in last few decades

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Using rainfall estimates by the Tropical Rainfall Measuring Mission, in this this study, we have extracted the spatiotemporal structures of convection in the intraseasonal timescale and their intensity during boreal summer over south Asia. We found two dominant modes of variability with periodicities of 10--20-days and 20--60-days, with the latter strongly associated with sea surface temperature. The 20--60-days mode exhibits northward propagation from the equatorial Indian Ocean, often linked with eastward propagating modes of convective systems over the tropics. The 10--20-days mode shows a northwestward propagating anomaly pattern emanating from the Indonesian coast. This anomalous pattern is found to be interacting with a structure emerging from higher latitudes propagating southeastwards, which is linked to the vertical shear of the zonal wind. The intensities of these two modes vary heavily in an interannual timescale and their contribution is of comparable amount to the daily rainfall variability in a season. The intensity of the 10--20-days (20--60-days) mode shows a significantly strong direct (inverse) relationship with the all-India June–September rainfall. We also found that the probability of the occurrence of substantial rainfall (very less rainfall) over central India increases significantly if the two intraseasonal modes simultaneously shows positive (negative) anomalies over the region. To examine any trend in the intensities of these intraseasonal modes over Indian region, we have used ground-based observed rainfall data for the period of 1951--2013 and found that the relative strength of the northward propagating 20--60-days mode exhibits a significant decreasing trend during the past six decades. This is possibly because of the weakening of large-scale circulation in the region during monsoon season. This reduction is balanced by a gain in synoptic-scale (3--9 days) variability. The decrease in 20--60-days variability is associated with a significant decreasing trend in the percentage of extreme rainfall events during the active phase of the monsoon. However, this decrease is balanced by significant increasing trends in the percentage of extreme rainfall events in the break and transition phases. The results presented here can be used for understanding the relative contribution of intraseasonal modes to total rainfall and also numerical model evaluation. The second part essentially underline the redistribution of rainfall intensity among periodic (low-frequency) and non-periodic (extreme) modes in a changing climate scenario.

Tue-088

Variation of water properties and its possible reasons near the continental slope off Vincennes Bay, East Antarctica

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Recently, new Antarctic Bottom Water (AABW) signal has been found off the medium-size Vincennes Bay Polynya (VBP), east Antarctica (Kitade et al., 2014), which largely expands the potential of AABW formation sources to so far ignored regions. To fully understand the AABW formation process in such medium bay, it's important to clarify the variation of water properties under the impacts of surface meteorological conditions.High quality CTD data obtained during four ship-based hydrographic observations near the continental slope off Vincennes Bay in January 2011-2014 is primarily analyzed. Results show that vertical range of Winter Water (WW) in the vicinity of the continental slope differ year by year, with the narrowest around 73 dbar in Jan. 2011 and widest ranging from 190 to 365 dbar in Jan. 2014. Correspondingly, Potential temperature (θ)-salinity (S) characteristic of the core of Circumpolar Deep Water , which is beneath the WW layer, has the largest difference observed between 2011 and 2014, θmax2014=θmax2011-0.558oC, Smax2014=Smax2011-0.023. In addition, the θ-S characteristic of AABW (neutral density γn > 28.27 kg m-3) can be generally divided into two branches with the relatively salter and colder one in Jan. 2011 and 2012 (θmin=-0.487 oC, Smin=34.648) and the fresher and warmer one in Jan. 2013 and 2014 (θmin=-0.434 oC, Smin=34.643). These results indicate that variation of water properties occurs throughout the whole water columns from 2011 to 2014, and the trend of freshening and warming is notable in this region. Secondly, Ice concentration rate reveal that ice formation is almost one month earlier in 2013 than that in other three years, which infers a smaller polynya region in austral winter (March-October), 2013. Despite this, if assuming the same square of VBP region in these years, surface heat loss is larger (>4.35×1018 J) in winters of 2010 and 2011, and smaller (<4.30×1018 J) in 2012 and 2013. Similarly, ice formation and salt flux due to brine rejection are also smaller in 2012 and 2013, which is consistent with hydrographic results well. The previous winter surface conditions in the polynya region can affect the deep water properties near the continental slope, which in other words, the variation of surface meteorological conditions in the polynya region can be the important indicators of the variation of deep water properties.

Tue-089

Why was it so wet in winter 2013-14 over North West Europe?

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A central aim for predictions on seasonal and sub-seasonal timescales is to highlight the risk of extreme events and seasons. Such a season occurred in the winter of 2013-2014, which brought exceptionally cold conditions to many parts of North America and record precipitation and storminess to parts of Western Europe including the UK. Although predictability of winter climate is now being realised in seasonal prediction systems, indications in advance of this winter suggested only a modest increase in risk of extreme rainfall. It is a high priority, therefore, to understand the global climate dynamical influences, including climate change, that gave rise to the record precipitation that was actually observed in this case. In this way, it may be possible to identify necessary improvements to prediction systems, or at least better understand their limitations. Here, we attempt to analyse the causes of the very wet winter in Western Europe using observations and model experiments. We investigate the possible influence of forcing of the extratropical atmospheric circulation from different parts of the tropics, and show that, contrary to initial suggestions of a role for unusual conditions in the Tropical West Pacific, the influence of the Tropical Atlantic was likely greater. We further show that conditions in the stratosphere, including the strong westerly phase of the Quasi-Biennial Oscillation, also contributed to the observed circulation patterns. Finally we present observational evidence which indicates that the warming climate likely increased the winter's rainfall totals. Daily England and Wales winter rainfall from 1900 to present is partitioned using an analysis of atmospheric circulation types derived from North Atlantic-European mean sea level pressure data. While the frequency of occurrence of different circulation types can explain much of the year-to-year variability of seasonal rainfall totals, there is also a long-term trend towards wetter winters that is not explained by changes in circulation.

Tue-090

Ensemble-based Experimental Atmospheric Reanalysis Using a Global Coupled Atmosphere-Ocean GCM

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To enhance the capability of the local ensemble transform Kalman filter (LETKF) with the Atmospheric general circulation model (GCM) for the Earth Simulator (AFES), a new system has been developed by replacing AFES with the Coupled atmosphere-ocean GCM for the Earth Simulator (CFES). An initial test of the prototype of the CFES-LETKF system has been completed successfully, assimilating atmospheric observational data (NCEP PREPBUFR archived at UCAR) every 6 hours to update the atmospheric variables, whereas the oceanic variables are kept unchanged throughout the assimilation procedure. An experimental retrospective analysis-forecast cycle with the coupled system (CLERA-A) starts on August 1, 2008, and the atmospheric initial conditions (63 members) are taken from the second generation of AFES-LETKF experimental ensemble reanalysis (ALERA2). The ALERA2 analyses are also used as forcing of stand-alone 63-member ensemble simulations with the Ocean GCM for the Earth Simulator (EnOFES), from which the oceanic initial conditions for the CLERA-A are taken. The ensemble spread of SST is larger in CLERA-A than in EnOFES, suggesting positive feedback between the ocean and the atmosphere. Although SST in CLERA-A suffers from the common biases among many coupled GCMs, the ensemble spreads of air temperature and specific humidity in the lower troposphere are larger in CLERA-A than in ALERA2. Thus replacement of AFES with CFES successfully contributes to mitigate an underestimation of the ensemble spread near the surface resulting from the single boundary condition for all ensemble members and the lack of atmosphere-ocean interaction. In addition, the basin-scale structure of surface atmospheric variables over the tropical Pacific is well reconstructed from the ensemble correlation in CLERA-A but not ALERA2. This suggests that use of a coupled GCM rather than an atmospheric GCM could be important even for atmospheric reanalysis with an ensemble-based data assimilation system.

Tue-091

Disentangling intraseasonal variability from surface drifter trajectories

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The global array of Lagrangian and quasi-Lagrangian instruments (surface drifters, subsurface and profiling floats) supplies a constantly growing data base of position and temperature observations that are irregularly distributed in time and space. The questions remain how to disentangle from these data a valuable information about spatio-temporal variability of the underlying ocean circulation, and whether the derived variability is consistent between the Lagrangian and other data products. In this study we address these questions in the context of intraseasonal variability encoded in surface drifter trajectories and corresponding temperature time series. First, using correlation- spectral analysis, we report on close correspondence of drifter temperatures to the ERA-Interim reanalysis sea surface temperatures and the mixed-layer temperature climatology (MIMOC) over monthly-to-seasonal time scales. The slopes of SST frequency spectra over this scale range exhibit a universal power law. The regional differences in correlation coefficients and spectral amplitudes relate to regional differences in mixed-layer depth. Second, we further investigate the circulation in the Nordic Seas where tailored deployments carried under the POLEWARD project allow drifter pair dispersion statistics. Here, we are able to reproduce intraseasonal variability of drifter positions and temperatures by stochastic Lagrangian simulations and monthly temperature climatologies. Binning and clustering of drifter data reveals a significant (intra-)seasonal signal in underlying circulation, care has to be taken however to draw conlusions about the interannual changes as these may be biased by irregular data distribution.

Tue-092

Monsoon variability over south and east asia: potential role of the southern annular mode

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The roles of the El Nino Southern Oscillation, Indian Ocean Dipole Mode, North Atlantic Oscillation, Eurasian snow etc on the monsoon inter-annual variability have been well documented. However, studies on the possible role of the drivers of the southern Polar regions have been limited. Hence in this study the possible role of the Southern Annular Mode on the monsoon variability over South and East Asia is examined. Southern Annular Mode (SAM) is characterized by a see-saw phenomenon between the sea level high pressure belt normally across ~40S and the low pressure belt across ~70S. The SAM index (SAMI) is defined as the difference of normalized monthly series of zonally averaged MSLP between the latitudes 40S and 70S i.e. SAMI= MSLP40-MSLP70. Data analyzed for the period 1983-2014 reveals that the positive phase of SAM during February-March is favorable for the subsequent summer monsoon (June-September) rainfall over India however the positive phase of SAM during May-June is favorable for the July-August summer monsoon rainfall over South China-South Korea-southern parts of Japan. The most dominant mode of monsoon variability over South and East Asia reveals an out-of-phase relationship over these two regions, while the second mode reveals an in phase relationship. Results further show that a strong positive (negative) phase of SAM during February-March favors the first (second) dominant mode. All these relations from the southern Polar regions through to the monsoon regions of South and East Asia and their dominant modes are relayed through the central Pacific Ocean SSTs. An extreme phase of SAM gives rise to an anomalous meridional circulation in a longitudinally locked air-sea coupled system over the central Pacific that persists up to the subsequent boreal summer and propagates from the sub-polar latitudes to the equatorial latitudes effecting the central equatorial Pacific SSTs, which in turn impact the subsequent monsoons over South and East Asia.

Tue-093

Role of the indian and the pacific oceans in recent trends in the summer monsoon rainfall over south and east asia

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Recent trends, variations and tele-connections between the two large regional sub-systems over the Asian domain, the South Asian and the East Asian monsoons are explored using data for the 1901-2014 period. Based on trend analysis a dipole-type configuration with north-drought and south-flood over South as well as East Asia is observed. Two contiguous large regions, one over South Asia depicting a predominant decreasing trend and one over East Asia depicting an increasing trend in summer monsoon rainfall post 1970s are delineated. Results reveal that the summer monsoon rainfall variations over these two locations were out of phase during the first 3 decades of the 20th century, in-phase during the subsequent 5 decades and again out-of-phase during the recent 4-5 decades. While the South Asian monsoon rainfall still continuous to reel under a decreasing trend, the summer monsoon rainfall over East Asia indicates a sharp increasing trend post 1970s. Possible factors over the recent trends are explored. Analysis of sea surface temperature, mean sea level pressure and winds at lower troposphere indicates that the entire monsoon flow system appears to have shifted westwards, with the monsoon trough over South Asia indicating a westward shift by about 2-3 degrees of longitudes and the North Pacific Subtropical High (NPSH) over East Asia seems to have shifted by about 5-7 degrees of longitudes. These shifts are consistent with the recent rainfall trends. Furthermore, while the West Indian Ocean warming appears to be responsible for the decreasing trends over northern parts of India and North China, the West Pacific Ocean warming appears to be responsible for the increasing trends over southern parts of India and over Southeast China-Korea-Japan sector. To examine the projections over South and East Asia during the middle and end of the 21st century, the CMIP5 data sets are utilized. A few of these models are able to simulate the tele-connections reasonably well. However one model the ACCESS (Australian Community Climate and Earth System Simulator version 1.0) also simulates the decadal variability reasonaby well. Projections with this model indicate decadal regimes when the monsoon rainfall over South Asia (East Asia) depict an increasing (decreasing) trend and vice versa. Furthermore, the behavior of the monsoon trough and the NPSH indicate an east-west oscillatory behavior with some decades indicating an eastward shift followed by some decades with a westward shift. Implications of these on the variability and tele-connections between the South and East Asian monsoons will be discussed.

Tue-094

Skillful seasonal prediction of Yangtze River valley summer rainfall

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China suffers from frequent summer floods and droughts, but seasonal forecast skill of corresponding summer rainfall remains a key challenge. Here we use a new high resolution forecast system to demonstrate useful levels of prediction skills over the Yangtze River valley for summer rainfall and river flows. Analysis of the sources of predictability suggests that the predictability of Yangtze River valley summer rainfall corresponds to skillful prediction of rainfall in the deep tropics and around the Maritime Continent. The associated dynamical signals favor increased poleward water vapor transport from South China and hence Yangtze River valley summer rainfall and river flow. The predictability and useful level of skill demonstrated by this study imply huge potential for flooding and droughts related disaster mitigation and economic benefits for the region based on early warning of extreme climate events.

Tue-095

Formation Mechanism of a Super El Niño in Late 2015

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The extreme El Niño (EN) events in 1997/98 and 1982/83, referred to as super EN, had caused remarkable devastating weather and climate (floods, droughts, heat waves and hurricanes) around the world. A super EN was anticipated on the way in early 2014 but failed to materialize toward the end of 2014. Whilst the scientific community was still puzzling about the cause of the aborted EN event in 2014, the remnants of the decaying warming in late 2014 unexpectedly reignited since February 2015 and grew into a super EN by the end of 2015. Understanding the onset mechanism of the 2015 EN event and its differences from past super EN events is crucial for improving EN prediction in a changing climate. Our observational analyses and modeling studies demonstrate that the principal difference between the 2015 EN and the past super ENs lies in exceptionally strong and consecutive occurrence of westerly wind burst events (WWEs)that turned around unfavorable ocean thermocline conditions in tropical western Pacific in early 2015, reigniting rapidly the surface warming in the eastern Pacific. By August the sea surface temperature anomalies (SSTA) reached critical amplitude similar to that of the past super ENs; positive atmosphere-ocean feedbacks further amplify this warm episode into a super EN by the end of 2015.

Tue-096

Predictability of the Summer East Asian Upper-Tropospheric Westerly Jet in ENSEMBLES Multi-Model Forecasts

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The interannual variation of the East Asian upper-tropospheric westerly jet (EAJ) significantly affects East Asian climate in summer. Identifying its performance in model prediction may provide us another viewpoint, from the perspective of upper-tropospheric circulation, to understand the predictability of summer climate anomalies in East Asia. This study presents a comprehensive assessment of year-to-year variability of the EAJ based on retrospective seasonal forecasts, initiated from 1 May, in the five state-of-the-art coupled models from ENSEMBLES during 1960–2005. It is found that the coupled models show certain capability in describing the interannual meridional displacement of the EAJ, which reflects the models' performance in the first leading empirical orthogonal function (EOF) mode. This capability is mainly shown over the region south of the EAJ axis. Additionally, the models generally capture well the main features of atmospheric circulation and sea surface temperature (SST) anomalies related to the interannual meridional displacement of the EAJ. Further analysis suggests that the predicted warm SST anomalies in the concurrent summer over the tropical eastern Pacific and North Indian Ocean are the two main sources of the potential prediction skill of the southward shift of the EAJ. In contrast, the models are powerless in describing the variation over the region north of the EAJ axis, associated with the meridional displacement and interannual intensity change of the EAJ, the second leading EOF mode, meaning it still remains a challenge to better predict the EAJ and, subsequently, summer climate in East Asia, using current coupled models.

Tue-097

Forcing mechanisms of inter-annual variations of sea level along the coast of Nova Scotia

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The tide gauge and altimeter data during 1993-2012 are analyzed to describe characteristics of sea level variations along the coast of Nova Scotia and adjacent shelf seas. Seasonal cycle of sea level variations at Halifax corresponds with that of steric height at a hydrography survey station (HL2) located nearby. Seasonally-averaged sea level anomalies (SLA) at Halifax are correlated with that in the southern Gulf of St. Lawrence and along the coast of Nova Scotia for all seasons, and in the Gulf of Maine except in summer. In winter and fall, the regression to surface wind stress and the steric change at HL2 together account for 62% and 76% of the Halifax SLA variance respectively. In spring (summer), the steric effect alone can explain 42% (50%) of the Halifax SLA variance. Halo-steric effect dominates interannual variations of the total steric change at HL2 for all seasons. Regarding a significant sea level rise from the fall of 2009 to early 2010 (Goddard et al, 2015), the response to inverse barometer (IB), regression to wind stress and thermo-steric change account for 36%, 37% and 17%, respectively, of the Halifax sea level after removing the linear trend and seasonal cycle. The contributions of the IB-response and surface winds are correlated with the index the North Atlantic Oscillation (NAO). While the NAO index is also correlated with changes in the Atlantic Meridional Overturning Circulation (AMOC), the direct influence of the AMOC on the 2009-2010 sea level rise along the coast of Nova Scotia cannot be established.

Tue-098

On the temporal variability of Meridional Overturning Circulation in the Subtropical North and South Atlantic

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A three dimensional velocity field (Argo & SSH) constructed from Argo observations, AVISO sea surface heights and NCEP reanalysis 2 winds, is used to estimate meridional volume (MOC) and heat transports (MHT) across 20S, 25S, 30S, and 35S for an analysis of the temporal variability and latitude dependence in the years 2000 to 2015. A comparison of the MOC and MHT from Argo & SSH with those estimates from three different ocean models (Hybrid Coordinate Ocean Model, Simple Ocean Data Assimilation and NCEP Global Data Assimilation Experiment) with data assimilation reveals that mean transports from Argo & SSH and models are in good agreement at 35S. At the other three latitudes the estimates from Argo & SSH are slightly higher than the model estimates. An analysis of the relationship between MOC and MHT at the four latitudes confirms the strong linear correlation reported in an earlier study. However, the slopes found herein depend less strongly on the latitude than those derived previously. It is determined from ARGO & SSH that the MHT increases by about 0.046 PW for every 1 Sv increase in MOC at 25S, 30S and 35S. At 20S the corresponding MHT increase is larger with 0.056 PW. With respect of the temporal variability, MOC anomalies from Argo & SSH reveal clear annual cycles at 35S, 30S and 25S, with maxima shifting from February at 35S to November at 25S and a semiannual cycle at 20S with maxima in May and November. MOC anomalies from the models on the other hand have strong annual cycles at all the latitudes with maxima between May and July. A comparison of the contributions of the transport in the boundary currents and the interior at 35S from Argo & SSH and models shows significant differences with respect to the mean and variability. However, the differences between the transports in the three subsections from the various products are largely compensating when adding them up to derive the total transport. In preparation for an expansion into the North Atlantic the method based on Argo & SSH is applied at 26N where a time series of the MOC from the RAPID/MOCHA is available to investigate how well the method works in that region.

Tue-100

Subseasonal to Seasonal Science and Predictions Initiatives of the NOAA MAPP Program

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There is great practical interest in developing predictions beyond the 2-week weather timescale. Scientific communities have historically organized themselves around the weather and climate problems, but the subseasonal to seasonal timescale range is overall recognized as new territory, for which a concerted shared effort is needed. For instance, the climate community, as part of programs like CLIVAR, has historically tackled coupled phenomena and modeling, keys to harnessing predictability on longer timescales. In contrast, the weather community has focused on synoptic dynamics, higher-resolution modeling, and enhanced initial conditions, of importance at the shorter timescales and especially for the prediction of extremes. The processes and phenomena specific to the intermediate range, between weather and climate, require a unified approach to science, modeling, and predictions. Internationally, the WWRP/WCRP Subseasonal to Seasonal (S2S) Prediction Project is a promising catalyzer for these types of activities, including those under the CLIVAR program. Among the various contributing U.S. research programs, the Modeling, Analysis, Predictions and Projections (MAPP) program, as part of the NOAA Climate Program Office, is planning a set of coordinated research activities that help to meet the agency's goals to fill the weather-to-climate prediction gap and will contribute to advance international goals. This presentation will describe ongoing and planned MAPP program S2S science and prediction activities, specifically the MAPP S2S Task Force and the SubX prediction experiment.

Tue-101

The role of forcings in the 20th century North Atlantic multi-decadal variability: the 1940-1975 North Atlantic cooling case study.

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Results from a study inspecting the origins of multi-decadal variability in the North Atlantic sea-surface temperature (NASST), are presented. We target in particular the 1940-1975 "warm-to-cold" transition, an event which is generally framed in the context of the longer-term Atlantic Multi-decadal Variability (AMV) cycle, in turn associated with the Atlantic Meridional Overturning Circulation (AMOC) internal variability. Here a non-paradigmatic approach is followed, considering this mid-20th century transient as a "window of opportunity" to examine the ability of uninitialized, historical integrations from the 5th Coupled Model Inter-comparison Project (CMIP5) archive in retrospectively reproducing a particular and well documented episode of the 20th century climatic history, under a hierarchy of forcing conditions. For this purpose, both standard and so-called "historical Misc" CMIP5 simulations of the historical climate (combining selected natural and anthropogenic forcings) are exploited. Based on this multi-model analysis we find evidence for a significant influence of anthropogenic agents on multi-decadal sea surface temperature (SST) fluctuations across the Atlantic sector, and suggest that anthropogenic aerosols might have played a key role in the 1940-1975 North Atlantic cooling. However, the diagnosed forced response in CMIP5 models appears to be affected by a large uncertainty, with only a limited sub-set of models displaying significant skill in reproducing the mid-20th century NASST cooling. Such uncertainty originates from the existence of well-defined behavioral clusters within the analyzed CMIP5 ensembles, with the bulk of the models splitting into two main clusters. Such a strong polarization calls for some caution when using multi-model ensemble mean in climate model analyses, as averaging across fairly distinct model populations may result, through mutual cancellation, in a rather artificial description of the actual multi-model ensemble behavior. A potentially important role for anthropogenic aerosols on the observed North Atlantic multi-decadal variability has clear implications for decadal predictability and predictions. The uncertainty associated with alternative aerosol emission scenarios should be duly accounted for, in designing a common protocol for coordinated decadal forecast experiments.

Tue-102

Vertical Structure and Energetics of the Western Pacific Teleconnection Pattern

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The Western Pacific (WP) pattern, characterized by north-south dipolar anomalies in pressure over the Far East and western North Pacific, is known as one of the dominant teleconnection patterns in the wintertime Northern Hemisphere. Composite analysis is performed to investigate the three-dimensional structure of the WP pattern and assess the energetics for the maintenance. The composited monthly height anomalies are found to exhibit baroclinic structure with their phase lines tilting southwestward with height in the lower troposphere. Those anomalies can thus yield not only a poleward heat flux across the climatological thermal gradient across the strong Pacific jet but also a westward heat flux across the climatological thermal gradient between the warmer North Pacific and the cooler Asian Continent. The resultant baroclinic conversion of available potential energy from the climatological-mean flow contributes most efficiently to the maintenance of the monthly WP pattern, acting against frictional and thermal damping, including the effects of anomalous heat exchanges with the underlying ocean and anomalous precipitation in the subtropics. The barotropic feedback forcing associated with modulated activity of transient eddies also contributes positively to the maintenance of the WP pattern, but it is largely offset by the effect of anomalous eddy heat flux. The net feedback forcing by transient eddies is therefore not particularly efficient. The present study suggests that the WP pattern has a characteristic of a dynamical mode that can maintain itself by efficient energy conversion from the climatological-mean fields even without external forcing, including remote influence from the Tropics.

Tue-103

Interannual variability of western North Pacific SST anomalies and its impact on North Pacific

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In this study, the interannual variability of the western North Pacific (WNP) sea surface temperature (SST) and its atmospheric teleconnection toward the North Pacific/North America during boreal winter are investigated. Firstly, we defined WNP mode as the first empirical orthogonal function (EOF) mode of SST anomalies over the WNP region, of which the principle component time-series are significantly correlated to the warm pool mode, North Pacific Oscillation (NPO), North Pacific gyre oscillation (NPGO), and central Pacific (CP)-El Nino with 95% confidence level, but not to eastern Pacific (EP)-El Nino. The warm phase of WNP mode starts to evolve when anomalous southerly wind occurs. The anomalous southerly wind reduces the wind speed by offsetting the northerly mean wind over the WNP region during boreal winter season, and the resultant reduced evaporative cooling leads to sea surface warming. Meanwhile, the atmospheric response to the sea surface warming further enhances the southerly wind, which completes the wind-evaporation-SST (WES) feedback. In such a way, WNP mode can be developed and maintained over the whole winter season until the northerly mean wind is disappeared in subsequent spring. Consequently, the WNP mode is somewhat related to various climate phenomena in the Pacific, however, the local air-sea interaction could generate WNP mode.It is important that the southerly wind convergences at surface level near the southern parts of Korean peninsula induce atmospheric convection. At this time, the upper level divergence associated with the deep convection transmits a vorticity flux. The wave activity flux analysis and the linear baroclinic model experiment revealed that the upper level divergence induces the NPO-like structure over the North Pacific and east-west pressure contrast over the North America through vorticity advection.

Tue-104

ROLES OF EL NIÑO MODOKIS ON VARIABILITY AND PREDICTABILITY OF RAINFALL REGIMES OVER SOUTHERN AFRICA

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El Niño Modokis events are recently-discovered phenomena in the well-documented impacts of Pacific sea-surface temperature anomalies on global rainfall variability and predictability. Their impacts on Southern Africa rainfall are still being investigated. Preliminary validation of computed results indicates that correlation trends between canonical El Niño and rainfall in Botswana have changed: negative in the period 1961 to 1980 and positive from 1981 to 2005. This trend is confirmed in the correlation data for rainfall and ENSO at two stations in Botswana: Maun (19°58'S, 23°25'E) and Francistown (21°07'S, 27°33'E). The possible influences of El Niño Modokis on these trends are largely unexplored. While it is established that El Niño Modokis influence the African rainfall mainly through introduction of anomalous rising Walker Circulation resulting in large scale convergence and anomalous enhancement of rainfall over different parts of Africa, their influence on the frequency of generation of inertia gravity waves over the Kalahari Transect of Southern Africa is largely unexplored. These inertia gravity waves are known to initiate the mesoscale systems, which bring much moisture to different parts of Africa. The “travelling” equivalent of these waves in Sahelian Africa is the squall lines. Possibly due to lack of understanding of tropical tropospheric dynamics, numerical and climate models have not adequately captured the fluctuations in the frequencies of mid-tropospheric inertia gravity waves. The dynamics of these fluctuations are examined with a linearised inviscid form of the hydro-dynamical equations, solved in shear with the aid of a two-layer model of the atmosphere. Atmospheric structures that enhance their developments and sustainability are then examined in relation to El Niño Modokis events.

Tue-105

The role of Westerly Wind Events in the contrasted 2014 and 2015 El Niño evolution

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Short-lived wind events in the equatorial Pacific strongly influence the El Nio/Southern Oscillation (ENSO). Contrasting the tropical Pacific evolution in 2014 against that of 2015 (or 1997) provides a compelling illustration of the key role of westerly wind events (WWEs) on ENSO. In late march, the years of 1997, 2014 and 2015 displayed relatively similar oceanic conditions in the tropical Pacific. Those three years were characterized by higher than normal (1 std) equatorial Pacific heat content, and an abnormal extension of the warm pool towards the central Pacific following the occurrence of one or several strong WWEs during winter. Yet, 1997 and 2015 developed into some of the strongest observed El Nio events on record while only a weak warming occurred in 2014. One major difference between 2014 and 1997 / 2015 was however a series of strong WWEs during the summer of the two later years while almost none occurred in 2014. In this study, we investigate the role of summer WWEs in the El Nio development using the CNRM-CM5 coupled model. We find analogs to the state of the Pacific in 1997, 2014 and 2015 in a 200-years control simulation of the model, and perform series of ensemble experiments starting from those initial states with added infinitesimal perturbations. While the recharged equatorial Pacific Ocean heat content excluded the occurrence of a La Nia in any of those years, the intrinsic atmospheric stochasticity leads to a Pacific state that ranges from almost neutral to an extreme El Nio at the end of the year. The amplitude of the El Nio at the end of the year is strongly associated with the number of WWEs that occur during summer. An ensemble sensitivity experiment in which WWEs are artificially removed display a clear reduction in the number of extreme El Nios and a more peaked density probability toward typical El Nio events, confirming the important role of WWEs for the occurrence of extreme El Nios. The observed 2014 evolution is within the distribution of the ensemble without WWEs, implying that the weak El Nio is consistent with a stochastic suppression of WWEs during that summer. The 2014 evolution is however at the edge of the reference ensemble, which suggests that other causes than random effects may be responsible for the supressed occurrence of WWEs in summer 2014 and the resulting weak El Nio at the end of the year.

Tue-106

Southern Annular Mode and its effects on extreme temperature events over Southeastern South America

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Understanding the variability of climate extreme events it is not only important from an economic point of view, it also contribute to develop the weather extreme attribution. In Southeastern-SouthAmerica (SESA) the studies of extreme events are few and most of them analyzed precipitation extremes, but this region it main production is form the agriculture sector, temperature extreme events are also very important. Based on a long-term daily time series, we analyzed frost events. Although frost events not always are considered as extreme event, these kind of events generate big economic looses and energy consumptions. Uruguay is a small country within the SESA region, to filter local signal we analyzed frost events that happened in more than 7 stations. Two different thresholds were studies to determine the frost events because of it impacts, meteorological frost (MF) when daily minimum temperature is below 0ºC and agro meteorological frost (AMF) when daily minimum temperature is below 2ºC. Composite of the anomaly of mean sea level pressure and wind and upper level wind (200 hPa) shows that generalized frost present a Southern Annular Mode (SAM) negative phase structure. Particularly present the asymmetric SAM structure for the period June-July-August. This structure is represented by a strong positive anomaly in MSLP located in the south Pacific with a negative anomaly of MSLP over New Zeland and a negative anomaly in the South Atlantic Ocean. The anomalies in upper levels show an intensified subtropical jet over the region that allows the passage of transient towards the studied region.

Tue-107

Wintertime Meridional Teleconnection associated with Convective Activity over the Maritime Continent

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Anomalous convective activity forced by tropical SST variability associated, for example, with ENSO influences the climate and weather in the extratropics. It has been known that El Niño (La Niña) tends to bring milder (colder) winter to East Asia, providing a statistical basis for wintertime seasonal predictions. However, ENSO variability is found to account only for nearly 50% of the interannual variance of convective activity around the maritime continent, and a significant fraction of the convective variability may therefore be uncorrelated with tropical SST variability. Through analysis of observational data for 1979/80-2011/12, the present study attempts to identify the tropical region where the interannual variability in seasonal-mean activity of SST-uncorrelated convection tend to be strongest and how effectively the variability can force atmospheric teleconnections into the extratropics if compared to ENSO-forced anomalous convection. At each location SST-correlated OLR variability was first identified by regressing seasonal-mean OLR anomalies linearly on the five leading PC time series of tropical SST variability. Defined locally as the residual, seasonal-mean anomalies in SST-uncorrelated OLR variability include no direct contribution from MJO. The leading EOF of the SST-uncorrelated OLR variability in boreal winter over the entire tropics accompanies the largest local variance around the maritime continent, where the variability reaches as much as a third of the ENSO-forced OLR variance. The associated atmospheric anomaly pattern differs considerably from that forced by ENSO, especially in the midlatitude north Pacific. The SST-uncorrelated convective variability around the maritime continent is found to exert remote influence on wintertime East Asian climate, which tends to be even slightly stronger than the ENSO influence. Our analysis thus suggests that the anomalous convective activity around the maritime continent uncorrelated with SST variability significantly limits the wintertime seasonal predictability over East Asia.

Tue-108

Can prediction skill be improved by increasing density of observation?

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A full-field initialized seasonal prediction system was built by using the Norwegian Earth System Model (NorESM1-ME). We use sea surface temperature (SST) and apply the Ensemble Kalman Filter to estimate the observed ocean state (Analysis) based on the covariance between HadISST and model SST, thus to produce the initial condition for the prediction system. Also atmospheric state is nudged to ERA-Interim not only to limit the inconsistency between atmosphere and ocean, but also to reduce the uncertainty in land state. The performance of prediction is evaluated by four different measures: anomaly correlation coefficient (ACC) against observation of both analysis and the predicted season, signal-to-noise ratio (SNR) of the analysis and SNR of the predicted season, in which signal is the predictable variability and noise the unpredictable one. The difference of ACC between Analysis and the predicted season shows the loss of signal, and the difference of SNR of Analysis and the predicted season presents the growth of noise. The prediction skill can be improved by increasing the density of observation if the local noise growth is smaller than signal loss (i.e., by better estimating the signal at the initial time). However, if the noise dominates the signal loss, improving climate model may be the only way to increase prediction skill. However, the system might also be inherently unpredictable in this region. We found most of the extratropical region and Maritime Continent were dominated by the atmosphere noise in the seasonal timescale, thus model improvement focused on these regions are inevitable.

Tue-109

Is the heat transport of the Kuroshio upstream predictable?

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Kuroshio upstream (east of Taiwan) is the main channel conveys heat from tropical to extratropical, and impacts the climate of the northwest Pacific. The predictability of the heat transport of the Kuroshio upstream is remaining unclear because the variabilities of the Kuroshio upstream are associated with the rich eddy activities origin from subtropical front and its interaction with Luzon strait, which cannot be represented by eddy-free ocean models. However, the eddy activities dominate only the intraseasonal variability, suggesting the interannual variability might be predictable by using the eddy-free climate model. This study evaluates the potential predictability of the heat transport conveyed by the Kuroshio upstream using Norwegian Climate Prediction System, in which we applied full-field ocean data assimilation and atmosphere nudging with 30 ensemble members. Signal (predictable interannual variability) to noise (unpredictable interannual variability) ratio is used to determine the prognostic potential predictability (PPP) of all model outputs, including ocean temperature, salinity, mixing layer properties, current velocity and heat flux transport. The potential predictability of mixing layer heat transport and thermocline heat transport as well as the noise source are discussed.

Tue-110

ENSO Precursors or: How I Learned to Stop Worrying and Love Interannual Variability

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An emergent phenomena in modern ENSO science is the establishment of ENSO precursors: a set of oceanic or atmospheric anomalies that precede ENSO events and contribute or in some cases directly create an ENSO event. While many such precursors have been established, little research has been done into the interrelation between precursors, or how these precursors operate on ENSO timescales of variability. To solve this issue, ENSO precursors are analyzed from several perspectives: their form and function, collective usefulness as ENSO predictors, and variability on interannual timescales. In addition, three model runs are conducted using the Community Earth System Model version 1.2 (CESM) to understand how the precursors contribute to ENSO development. In the first part of our analysis, we briefly introduce five ENSO precursors and investigate the mechanisms through which they influence the development of ENSO. Following this, we determine the independence of each precursor as it relates to other precursors and construct regression models for predicting Central Pacific and Eastern Pacific events at twelve- and nine-month lead times. To understand the link between the precursors and the interannual nature of ENSO events, we use Ensemble Empirical Mode Decomposition to isolate the interannual modes of variability for each precursor. The Pacific Meridional Mode (subtropical SST and winds) and Western North Pacific SST and winds are found to operate on interannual timescales, lending credence to their claim of directly stimulating ENSO events. Lastly, we analyze the models ability to both produce with and without extratropical precursors and correctly simulate precursors patterns and magnitudes, and interannual to decadal variability.

Tue-111

New indices of the configuration of blocking high

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The present study proposed a new set of simple indices to detect blocking high and the associated configurations of wave breaking. Only the geopotential height field at 300 hPa was used and, thus, the new indices were easy to calculate. The geopotential height field at 300 hPa was firstly converted into geostrophic wind field. A blocking high could be detected when there were large-scale and persistent easterlies over the region of climatological westerlies. The locations of maximum of geostrophic easterlies were regarded as the breaking centers. Then, the angel of the geostrophic wind at the breaking center relative to its local geostrophic westerlies was defined as the direction of wave breaking (DB) index, while the relative amplitudes of the northern and southern lobes separated by the latitude of breaking center in the breaking area were used to define the relative intensity (RI) index. The detected results of the new method were basically consistent with those of previous studies.

Tue-112

The effects of ENSO on the EAWM and the North Pacific storm track variabilities.

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The variability of north pacific storm track (NPST) is related to the extratropical basic flows, such as East Asian winter monsoon (EAWM) system. In previous study, we investigated that the variability of EAWM had an effect on the location and intensity of the NPST through the change of the distribution of surface air temperature in East Asian continent. Also many studies found that there is a negative correlation between ENSO and EAWM, and ENSO is the predictor of EAWM and the midlatitude baroclinicity. So here, we examine how the variabilities of NPST and EAWM are affected by ENSO and their teleconnection using ERA-Interim reanalysis data and 6 CMIP5 historical simulation results.In observations, negative correlation is obvious between the interannual variabilities of NPST activity and EAWM (-0.70), and also is between EAWM and ENSO (-0.40). But there is no relationship between ENSO and NPST activity (+0.01). So we did EOF analysis for NPST activity, defined as the variance of the 250hPa meridional wind perturbations, then it is found that the 1st principal mode of NPST activity is positively correlated to ENSO variability (+0.53). And we applied linear regression analysis for 850hPa temperature by using EAWM and ENSO time series. It is shown that ENSO and EAWM are oppositely related to lower temperature field. This result is also shown in 700hPa temperature advection field. During El-nino, warm anomaly of surface temperature dominates East Asian continent and the latitudinal distribution of horizontal temperature advection shows a positive maximum near 30-40°N. It relates to the local baroclinicity and significantly strengthens the baroclinic wave activities over the northern latitudes of 40°N. Also we investigated the historical simulation results of 6 CMIP5 models (ACCESS1-3, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-AO, HadGEM2-CC, MPI-ESM-LR). It is obvious that ENSO is well simulated in each model. But the relationships between ENSO and EAWM are very weak in all models, because of the differences in the locations and intensities of Aleutian low and Siberian high during El-nino or La-nina. So the vulnerability of simulating the change of Aleutian low and Siberian high due to ENSO variability is directly connected to the simulation performance of the relationships among ENSO, EAWM and NPST in CMIP5 models.

Tue-113

Numerical simulation study of the runoff forcing on the summer monsoon onset in the Bay of Bengal

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The Bay of Bengal (BOB) represents a typical sunny day in spring characterized by weak surface wind and shallow ocean mixed layer in the upper ocean. The fresh water from rivers discharge in the north of Bay flows into the BOB. All the environmental features affect temperature distribution in the upper ocean, which provide unique conditions for the South Asian summer monsoon onset. The rainy season with annual mean onset date of May 1 is established in the Andaman Sea. However, the state-of-the-art air-sea coupled models still face challenges in simulating monsoon processes. For example, the monsoon onset date in the BOB simulated by CGCMs is generally late. Therefore, improving the understanding of air-sea interaction during monsoon processes is one of the urgent issues and research focus. Before the monsoon breaking in the BOB, the sea surface temperature (SST) in the gulf goes up. At the same time, the changing ocean salinity can influence ocean stratification, thereby affecting the distribution of temperature in the upper ocean. Based on the analysis of the latest Aquarius satellite observations data, when the salinity in the Bengal Bay is low, it will expect the earlier monsoon onset with weaker wind and rainfall. Then the condition is inadequate for the SST rising up, but the increase of water vapor in the atmosphere is favorable for enhanced atmospheric convection instability. It provides good condition to the breaking of summer monsoon. If the SST warming in the Bay, both of atmospheric water vapor and the saturation vapor pressure increase, so that the relative humidity does not change significantly. Several sensitivity numerical experiments are carried out to improve the understanding of how the river discharge with variable salinity affecting the distributional characteristics of SST and monsoon onset in the BOB. In spring, the increased fresh water form river runoff leads to sea surface salinity decreasing, accompanied by SST warming in advance. The enhanced evaporation tents to increasing water vapor and convective instability in the atmosphere, so that the onset of local summer monsoon is earlier. By meliorating the simulation of water cycle in the CGCM, the late onset bias of summer monsoon in climate model has been improved.

Tue-114

Patterns and Drivers of Variability in Seasonal Rainfall over China

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As part of the Climate Science for Service Partnership - China, we identifyregions of spatially coherent rainfall variability in China by applying Empirical Orthogonal Teleconnection (EOT) analysis to observed rainfall data. EOTs, like Empirical Orthogonal Function analysis produce patterns that maximize variance, except that EOTs are orthogonal only in time, not in space. The analysis is performed on seasonal total precipitation data as well as on the combined 3 events of maximum 5-day rainfall in each season, which serves as a metric for seasonal extreme precipitation. Circulation and SST patterns associated with regional inter-annual to inter-decadal rainfall variability are identified by regressing atmospheric reanalysis fields and observed sea-surface temperatures (SSTs) onto the leading EOTs of observed rainfall. To connect regional rainfall variability to large-scale drivers, EOTs are also correlated with indices of modes of variability, e.g., El Niño-Southern Oscillation (ENSO). Finally, lead-lag correlations between EOTs in each season and between seasons are discussed to assess the predictability of regional rainfall. We find that extreme rainfall variability is more closely related to mean rainfall variability during the solstice seasons than during spring and fall. The leading EOT patterns of seasonal total and extreme rainfall in winter and summer are closely connected to ENSO. In spring and fall the primary drivers are related to anomalous convection in the tropical Pacific, which triggers changes in the extratropical atmospheric circulation. The Pacific Decadal Oscillation (PDO) and Atlantic Multidecadal Oscillation (AMO) also have significant relationships with patterns of variability during spring and fall. Convective activity over the Philippines and air-sea coupling mechanisms in the tropical western Pacific are particularly important and affect rainfall variability in various regions of China during all seasons by modulating the strength of moist onshore flow, influencing the position of the subtropical high and affecting the timing of the monsoon onset in southern and central China.

Tue-115

Optimization of CFS Based Grand Ensemble Prediction System for the Sub-Seasonal Prediction of Indian Summer Monsoon

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The goal of this study is to extend the realized predictability limit of a dynamical coupled model over Indian monsoon region. In this study we present an optimal way to design a multi-model ensemble prediction system from a suite of different variants of Climate Forecast System (CFSv2) model popular as CFS based grand ensemble prediction system to increase the spread without compromising the limit of potential predictability of each individual models. The ensembles are generated not only by perturbing the initial condition, but also using different resolutions, parameters, physics formulation and coupling configurations of the same model. Each of these configurations was created to address the role of different physical mechanisms known to have control on the error growth in the 10-20 day time-scale. The skill in predicting large-scale MISO, which is assessed by comparing the predicted and observed MISO indices, is found to be ~18-20 days. It is noted that the prediction skill of actual rainfall is closely related to the prediction of amplitude of large scale MISO as well as the initial conditions related to the different phases of MISO. Categorical prediction skills reveals that break is more skillfully predicted, followed by active and then normal. The categorical probability skill scores suggest that useful probabilistic forecasts could be generated even up to 4th pentad lead. We also present the bias errors arising from incorrect humidity-convection relationship. The prominent biases of the model simulations are a wet bias of rainfall over Western equatorial Indian Ocean and a dry bias over Indian landmass and Bay of Bengal. We hypothesize that most of these biases arise from relative humidity based entrainment formulation in the model and are addressed by performing a few targeted experiments using a possible range of humidity-entrainment relationships. We carry out a model tendency budget analysis to diagnose and evaluate the modifications to the entrainment formulation. The specific changes in the model formulation of convection is being attempted in such a way as to ensure the mean climate of the model does not change much. Finally, we develop a multi-model consensus forecast, including ensemble-based uncertainty estimates.

Tue-116

Two flavors of the Indian Ocean Dipole

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The Indian Ocean Dipole (IOD) is known as an interannual climate mode in the tropical Indian Ocean accompanied by negative (positive) sea surface temperature (SST) anomalies over the eastern (western) pole during its positive phase. However, positive SST anomalies do not always cover the whole area from the east coast of Africa to the central Indian Ocean. For this reason, the IOD is further classified into two types based on SST anomaly patterns for the first time. The first type (hereafter canonical IOD) is associated with negative (positive) SST anomalies in the eastern (central to western) tropical Indian Ocean. On the other hand, the second type (hereafter IOD Modoki) is associated with negative SST anomalies in the eastern and western tropical Indian Ocean and positive SST anomalies in the central tropical Indian Ocean. Based on composite analyses, it is found that easterly wind anomalies cover the whole equatorial Indian Ocean in the canonical IOD, and as a result, positive rainfall anomalies are observed over East Africa. Also, due to the basin-wide easterly wind anomalies, strong downwelling Rossby waves are generated in the off-equatorial region and propagate westward. After their reflection at the western boundary, downwelling Kelvin waves propagate eastward and deepen the thermocline off Sumatra in the following boreal fall, providing a more favorable condition for development of the negative IOD. In contrast, zonal wind anomalies converge in the central tropical Indian Ocean in the IOD Modoki, and no significant precipitation anomalies are found over East Africa. Since off-equatorial downwelling anomalies induced by easterly wind anomalies in the east are counteracted by off-equatorial upwelling anomalies caused by westerly wind anomalies in the west, only weak Rossby waves are generated off-equatorial region. As a result, the thermocline depth off Sumatra does not vary significantly from the climatology in the following boreal fall.

Tue-117

Preliminary Evaluation of High-Resolution GCM Coupled 1-D Ocean Model for MJO Forecast During DYNAMO Period

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Precipitation in Taiwan area is significantly influenced by MJO（Madden-Julian Oscillation） in the boreal winter (Hung et al., 2014). This study is therefore conducted by toggling the MJO forecast with a unique model structure. HiRAM（High-Resolution Atmospheric Model）developed by GFDL （Geophysical Fluid Dynamics Laboratory） has been recognized as one of the best model for seasonal forecasts of hurricane/typhoon activity (Zhao et al., 2009; Chen & Lin, 2011; 2013), but was not as successful in MJO forecast. The one-dimensional TKE (Turbulence Kinetic Energy) type ocean model SIT（Snow, Ice, Thermocline）had demonstrated its skill in improving MJO eastward propagation when coupled with ECHAM5 (Tseng et al., 2015). This study utilizes HiRAM coupled SIT to evaluate its performance in MJO forecast. In the hindcast experiment water temperature at 10-m deep in SIT is nudged to GODAS (Global Ocean Data Assimilation System) data to avoid SST deviation induced by lack of advection in one-dimensional ocean model. The preliminary result of the HiRAM-SIT experiment during DYNAMO period shows improved success in MJO forecast. The improvement is mainly from better-simulated SST diurnal cycle and diurnal amplitude, which is contributed by the refined vertical resolution near ocean surface in SIT.

Tue-118

Prediction of seasonal rainfall's distribution in southern Uruguay Abstract *

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We present the results of a dynamical-statistical methodology for seasonal rainfall prediction in southern Uruguay based on the combination of an Atmospheric General Circulation Model (AGCM) and a statistical downscaling. Southern Uruguay presents a challenge for seasonal prediction because it is a region of high climate variability with an El Niño signal that is not as strong as in northern Uruguay and south of Brazil. We use the ICTP AGCM, a low resolution model with simplified physics which is able to skilfully simulate the large scale flow and circulation anomalies associated with the teleconnections from the tropical oceans. The statistical downscaling is performed searching for relationships between the large scale circulation anomalies at 200 and 850 mb and the accumulated precipitation over the region of interest. We focus on prediction of the mean accumulated precipitation in southern hemisphere's spring (September, October and November) and summer (December, January and February) and its relationship with rainfall distribution during the period. In particular, we investigate the amount of accumulated seasonal precipitation and its composition of strong and small rainfall events. A correlation analysis between observed rainfall and reanalysis data is performed in order to determine the best regions of the wind to construct the indices to be used in the statistical dowscaling model. We choose the ones where the dynamic model has skill and the correlations with rainfall in southern Uruguay are statistically and physically significant. Deterministic and probabilistic forecast models are constructed performing hindcast experiments with the ICTP AGCM forced with sea surface temperature predictions from the NOAA CFS model in the period 1991-2011. The hindcast experiments are started in August and November and run for 3 months. In addition to predict rainfall averaged in southern Uruguay, the particular situation of Carrasco is studied. Different validation criteria are used to evaluate the models' skill. It is found that the meridional wind in 200 hPa averaged in a region containing SESA is the best predictor. This variable impacts rainfall through the surface pressure centers that are affected by the vorticty advection in the 200 hPa level. The results also show that spring is more predictable than summer in southern Uruguay but not in Carrasco, where the forecasts' skill are higher than considering a bigger area.

Tue-119

Subseasonal Predictability of Warm Season Climate Extremes in the Northern Hemisphere: The Role of Stationary Rossby Waves

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Quasi-stationary Rossby waves play an important role in determining subseasonal surface meteorological variations in the Northern Hemisphere (NH) during warm season. These waves in fact have been crucial in the development of many recent short-term warm season climate extremes over North America and northern Eurasia (e.g. 1988 and 2012 North American droughts, 2003 European and 2010 Russian heat waves). This talk presents an overview of the latest understanding of the role of stationary Rossby waves, including the physical mechanisms by which the stationary Rossby waves lead to development of regional climate extremes, the processes that initiate and sustain these waves, and their role as an important source of subseasonal predictability. The emphasis will be on the contribution of stationary Rossby waves to an improved prediction of subseasonal development of regional climate extremes in the NH, taking advantage of the results from various simulations and hindcasts performed using NASA Goddard Earth Observing System (GEOS-5) General Circulation Model (GCM). Case studies will be presented to show the crucial importance of the NH mean jet streams in guiding and constraining the path and speed of wave energy propagation. In order to properly incorporate stationary Rossby waves for improved subseasonal prediction, it is critically important for a GCM to provide a faithful simulation of mean jet streams (location, shape, magnitude).

Tue-121

Intra-seasonal Prediction of Summer Arctic Sea Ice Concentration Using a Vector Autoregressive Model

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A Vector Auto-Regressive (VAR) model is evaluated for predicting the 1979-2014 daily and weekly Arctic sea ice concentration on the intra-seasonal time scale. The cross-validated forecast skill of the VAR model is found to be superior to both the anomaly persistence and damped anomaly persistence on the intermediate to seasonal time scales using only the sea ice concentration. The forecast skill can be further improved in most regions by including sea surface temperature using the Multivariate empirical orthogonal function method. The daily and weekly forecast of ice concentration also lead to predictions of ice-free dates, which have potential societal and economic impacts.

Tue-122

Subseasonal Prediction for Taiwan's Extreme Diurnal Convective Events

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The occurrence of diurnal afternoon convection in Taiwan undergoes substantial modulation from tropical intraseasonal oscillations in the western North Pacific, including the quasi-biweekly (QBW) mode. Analyzing surface station observations and the NCEP CFS version 2 (CFSv2) reforecast data from 1993 to 2010, it was found that the QBW mode plays a significant role in the formation of episodic diurnal convection. When the cyclonic circulation of the QBW mode is located west of Taiwan, followed by an anticyclonic circulation to the east, Taiwan's diurnal convection activity tends to intensify and persists for about 47 days. Synoptically, this situation reflects the enhanced subtropical anticyclone leading to fair weather conditions and increased monsoon southwesterly winds moistening the lower troposphere, all of which are conducive to thermally induced diurnal convection in Taiwan. The opposite situation tends to suppress the diurnal convection activity for a sustained period of time. Based upon this synoptic linkage, an empirical relationship between the precipitation diurnal amplitude and low-level circulation fields of the CFSv2 is derived. It was found that the CFSv2 forecast exhibits an effective lead time ranging from 16 to 24 days for the QBW mode and, subsequently, diurnal convection episodes in Taiwan.

Tue-123

A successful decadal prediction made for the Interior West of USA

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Can regional climate be predicted more than 5 years in advance? The authors demonstrate a successful case in the Interior West of the U.S.A by predicting the lake level change of the Great Salt Lake (GSL) out to 8 years. The GSL and its watershed integrates climate and hydrologic responses including the Colorado River Basin, reflecting the wet/drought cycle. A series of studies identified a pronounced lagged relationship between the GSL level and the Pacific sea surface temperatures (SST) at 10-15 years. As the GSL integrates the hydrological responses to the Pacific teleconnection, this quasi-decadal signal is then transferred to the lake level with a time lag through baseflow. Using this relationship, a statistical model was built to predict the GSL level out to 8 years. The model was able to replicate and forecast turnarounds in the GSL level, that is, where prolonged increasing trends (wet phase) were followed by persistent decreases (drought), and vice versa. The current generation of climate models has shown increased potential in capturing such decadal trends in climate, at least in the western U.S.A.

Tue-124

"Different Responses of Sea Surface Temperature in the South China Sea to Various El Niño Events during Boreal Autumn"

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This study investigates variations of sea surface temperature (SST) anomalies in the South China Sea (SCS) during developing autumn of various El Nio events. The warm SST anomalies are observed in the SCS for canonical El Nio and El Nio Modoki I, whereas the cold SST anomalies are found for El Nio Modoki II. The ocean heat budget analyses show that the latent heat flux change induced by various types of El Nio events is a major contributor to the SCS SST variations. An anomalous anticyclone resides near the Philippine Sea for canonical El Nio and El Nio Modoki I, which induces the southerly wind anomalies over the SCS and thus weakens the climatological northeasterly in boreal autumn. The weakened surface wind speed reduces heat loss from the ocean, leading to a warmer state in the SCS. However, for El Nio Modoki II, the anomalous anticyclone shifts westward to the west of the SCS, and thus the northeasterly wind anomalies appear in the SCS. The northeasterly anomalies enhance the climatological northeasterly monsoon, increase the wind speed, and increase heat loss from the ocean, thus resulting in a cooling in the SCS. The anomalous anticyclone associated with El Nio events also increases shortwave radiation. The increases of the shortwave radiation can also contribute to the SCS warming for canonical El Nio and El Nio Modoki I in addition to the warm effect from the latent heat flux. Because the cooling effect from the latent heat flux is larger than that of the shortwave radiation for El Nio Modoki II, the SCS for El Nio Modoki II tends to be cool.

Tue-125

Analysis of the trend of sea temperature of the coastal China seas

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The average temperature of sea is becoming higher with the global warming since the mid-19th century. China marginal sea ,as the western boundary of the Pacific Ocean and the marginal sea that is closely linked to the continent where people live, the lone-term variability of which is highly focused on. In this paper, we can see the change characteristics of sea surface temperature and subsurface temperature by retrieving and analyze the historical observational data. We can use the Empirical Orthogonal Function expansion to analyze the sea surface temperature anomaly. We alse count the mixed layer depth and analyze the change characteristics , and we can see the correlation between the SST and the MLD by counting the correlation coefficients. We can conclude: 1、The trend of sea temperature of China marginal sea is going upward, and the velocity of increases in SST is higher than that of global warming, and that is more obvious in winter than in summer, and mainly in the way of Kuroshio and warm current on the shelf(the Yellow Sea Warm Current and the Taiwan Current etc.)2、The trend of sea surface temperature is like that of the subsurface temperature of China marginal sea.3、We guess that the Pacific Decadal Oscillation(PDO) and the Atlantic Multi-decadal Oscillation (AMO)play an important role in the variability of sea temperature of China marginal sea.4、The correlation between the sea surface temperature and the mixed layer depth of China marginal sea is not obvious, so we can say that the MLD does little to the temperature change of China marginal sea. We guess it is the marine advection that makes some contribution.

Tue-126

Relationship between Atlantic SST and East Asian Temperature during early summer

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This study investigates how the Atlantic Ocean sea surface temperature (SST) is associated with Korean temperature during early summer (June-July). It is found that the variations of Korean summer temperature during early summer (June-July) are associated with a large-scale circulation in relation to the Atlantic SST. However, the way of how the Atlantic tripolar SST affects to Korean temperature is different from June to July. Korean temperature during June-July is influenced by an Atlantic tripolar SST pattern in the Northern Hemisphere during the previous spring. A tripolar SST pattern persists from spring to summer via a wind-evaporation-SST feedback and a longwave feedback. While a tripolar SST pattern during spring is associated with Korean temperature during June via a Eurasian snow cover, Korean temperature during July is influenced by an EU-like atmospheric circulation forced by a tripolar SST pattern in the Atlantic.

Tue-127

Impacts of different types of El Nino events on the East Asian summer climate

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This article discusses the different types of El Nino event on the East Asian summer climate anomalies relationship. Result shows that: in the three El Niño events occurred in the following year, the East Asian monsoon region 850hPa wind field have shown a clear decreasing trend. In CT-type event, rainfall in southern China is higher than in a normal year, Japan Korea precipitation has decreased, western Pacific subtropical high (WPSH) is weak. WP-type counterparts greatly reduced precipitation in North China; and changes in precipitation in southern China is not, WPSH extended westward than normal year, the monsoon trough southward. CT / WP type corresponding to little change in precipitation across East Asia, a slight decrease in the Huaihe River basin precipitation, a slight increase in precipitation in North and Northeast China, southern groove significantly extends south to 5 ° S, and whether abnormal upward motion or at Shen movement is not particularly strong.

Tue-128

A real-Time Ocean Reanalyses Intercomparison Project for Quantifying The Impacts of Tropical Pacific Observing Systems on Constraining Ocean Reanalyses

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To quantify uncertainties in the current generation of ocean reanalysis products, CLIVAR Global Synthesis and Observations Panel (GSOP) and the GODAE OceanView (GOV) jointly initiated Ocean Reanalysis (ORA) Intercomparison Project (ORA-IP). For those ocean reanalyses produced by operational centers for initialization of climate models or short-range ocean forecast models, there is an opportunity to conduct ORA intercomparison in real-time, and to use the ensemble approach to quantify the signal (ensemble mean) and noise (ensemble spread) in our estimation of ocean climate variability. Motivated by the Tropical Pacific Observing System (TPOS) 2020 Workshop held in January 2014 in La Jolla, CA, with support from NOAA Climate Observation Division, the CPC initiated and led a Real-Time ORA-IP. An ensemble of nine operational ORAs is been routinely collected, and they are used to1) provide estimation where uncertainties among ocean reanalyses are large in real time, 2) to provide the most reliable estimation of climate signal such as ENSO, and 3) to provide the signal to noise ratio for monitoring climate variability in real time. The role of the TAO/TRITON buoy data on constraining the ocean reanalyses is assessed by root-mean-square error (RMSE) and anomaly correlation (AC) with the buoy temperature data directly. The ensemble mean is shown to have a higher accuracy (smaller RMSE and larger AC) than individual product, suggesting the ensemble approach is an effective tool in reducing uncertainties in temperature analysis for ENSO. The spread among the ensemble mean is used to estimate uncertainties among ocean reanalyses, which vary with space and time. The temporal variability of the spread can be partially linked to the temporal variability of in situ observations which reduce ocean reanalysis errors and increase consistency among them. We found that the full deployment of the TAO array significantly reduces the analysis uncertainty in the equatorial Pacific, and the availability of Argo reduces the analysis uncertainty in off-equatorial regions. However, there is still large spread in the northwestern tropical Pacific, the SPCZ region, the central and northeastern tropical Pacific. To support for the framework of TPOS 2020 (http://tpos2020.org), we examined uncertainties in temperature, thermocline depth and upper 300m ocean heat content and discussed if and how the data loss in the TAO/TRITON array in 2012-14 impacted the quality of operational ocean

reanalyses and what are the deficiencies in the ocean reanalyses that require hand in hand efforts in advancing ocean data assimilation systems and enhancing ocean observations.

Tue-129

Distribution and Interannual Variability of Tropical Cyclone Genesis over the Western North Pacific Simulated by a Regional Coupled Model—FROALS: Comparison with an Uncoupled Model

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The tropical cyclone genesis potential index (GPI) can reasonably reproduce the position and region of tropical cyclone genesis. It has been widely used as a metric to evaluate the performance of global climate models in simulating tropical cyclone genesis. In this study, the simulation of GPI over the western North Pacific (WNP) by a regional coupled model, FROALS (Flexible Regional Ocean–Atmosphere–Land System) developed by LASG (State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics)/IAP (Institute of Atmospheric Physics), was assessed and compared with a regional atmosphere model, RegCM3. The simulation bias is discussed by analyzing the five variables associated with GPI. The results show that FROALS can reproduce the spatial pattern and seasonal cycle of GPI in the WNP better than RegCM3. Compared with RegCM3, FROALS performs better in modeling the response to ENSO in the interannual variability of GPI in the WNP; this is due to the improved simulation of the intensity and interannual variability of the South China Sea monsoon trough.

Tue-130

Arctic Sea Ice Seasonal Prediction by a Linear Markov Model

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A linear Markov model has been developed to predict sea ice concentration (SIC) in the pan-Arctic region at the intra-seasonal to seasonal time scales, which represents an original effort to use a reduced-dimension statistical model in forecasting Arctic sea ice year-round. The model was built to capture co-variabilities in the atmosphere-ocean-sea ice system defined by SIC, sea surface temperature and surface air temperature. Multivariate empirical orthogonal functions of these variables served as building blocks of the model. A series of model experiments were carried out to determine the dimension of the model. The predictive skill of the model was evaluated by anomaly correlation and Root-mean-square errors in a cross-validated fashion. On average, the model is superior to the predictions by anomaly persistence, damped anomaly persistence and climatology. The mode shows good skill in predicting the signs of SIC anomalies within the Arctic Basin during summer and fall. Part of the SIC prediction skill comes from the long-term trend. However, the model still beats the anomaly persistence for all targeted seasons after linear trends are removed. Because the Arctic Basin is completely frozen in winter and spring, the predictability can be seen only in the seasonal ice zone during these seasons. The model has higher anomaly correlation in the Atlantic sector of the Arctic than in the Pacific sector. The model predicts well the interannual variability of September sea ice extent (SIE) but underestimates the accelerated long-term decline of SIE, resulting in a systematic model bias. This model bias can be reduced by the constant or linear regression bias corrections, leading to an improved correlation skill of 0.92 by the regression bias correction for the two-month lead SIE prediction. For SIE forecasts in general, the model captures internal variability better than linear trends.

Tue-131

Connecting Equatorial Pacific Surface Currents, Warm Water Volume (WWV) and El Nino Prediction

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For some time it has been known that equatorial Pacific warm water volume (WWV) is an El Nino predictor. Zonally averaged equatorial sea level Etabar is closely related to WWV and has similar prediction properties. Theory is used to link Etabar to the zonal equatorial flow and then show that the zonal flow provides the key WWV lead. The lead is related to long Rossby wave dynamics which previous work has shown applies even at the equator. Since the westward wave speed of these waves decreases rapidly with latitude, away from the eastern boundary sea level poleward of the equator increasingly lags sea level at the equator. Consequently a northward sea level gradient is like a time derivative, and the zonal geostrophic flow is like a time derivative of the sea level. This result is modified by damping of the large scale flow, and then the zonal current leads the sea level, including eastern boundary sea level and El Nino, by the dissipation time scale. The Etabar-zonal current relationship shows that Etabar should lead by more than this. The theoretical results are also consistent with ENSO amplitudes being weaker in the far-eastern equatorial Pacific in La Nina decades and with the Bunge and Clarke (2014) hypothesis for why warm water volume has been a less effective ENSO predictor since 1998.

Tue-132

Influence of the Summer NAO on the Spring-NAO-based Predictability of the East Asian Summer Monsoon

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The dominant mode of atmospheric circulation over the North Atlantic region is the North Atlantic Oscillation (NAO). The boreal spring NAO may imprint its signal on contemporaneous sea surface temperature (SST), leading to a North Atlantic SST tripolar pattern (NAST). This pattern persists into the following summer and modulates the East Asian Summer Monsoon (EASM). Previous studies show that the summer NAST is caused mainly by the preceding spring NAO, while the contemporaneous summer NAO plays a secondary role. The results of this study illustrate that, even if the summer NAO plays a secondary role, it may also perturb summer SST anomalies caused by the spring NAO. There are two types of perturbation caused by the summer NAO. If the spring and summer NAO have the same (opposite) polarities, the summer NAST tends to be enhanced (reduced) by the summer NAO, and the correlation between the spring NAO and EASM is usually stronger (weaker). In this case, the spring-NAO-based prediction of the EASM tends to have better (limited) skill. These results indicate that it is important to consider the evolution of the NAO when forecasting the EASM, particular when there is clear reversal in the polarity of the NAO, as this may impair the spring-NAO-based EASM prediction.

Tue-133

Effect of Initial Uncertainties of Sea Temperature in Indian Ocean on the "Spring Predictability Barrier" for El Niño Predictions

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The initial errors of sea temperature in the Indian Ocean can induce spring predictability barrier (SPB) when predicting El Niño events in the tropical Pacific Ocean across growing phase using the CESM1.0.3 (Community Earth System Model), a fully coupled global climate model. Furthermore, we find that two types of initial errors are most likely to cause SPB for El Niño predictions. Initial error type-1 consists of a positive IOD-like sea temperature pattern, with positive errors in the western Indian Ocean and negative errors in the east, while type-2 has a negative IOD-like structure which is nearly opposite to that of type-1.For initial error type-1, the error evolutions in the tropical Indian Ocean is much like a decaying positive IOD event converting into negative phase; and cold errors in the tropical Pacific propagate from western Pacific to the eastern Pacific, resulting La Niña-like errors at prediction time. While for initial error type-2, initial errors in the Indian Ocean keep developing, and maintain negative IOD-like pattern ultimately; these cold prediction errors usually emerge in the eastern Pacific, experiencing locally evolutions. During the error evolutions for these two types, tropical oceanic channel Indonesian Throughflow (ITF) and atmospheric bridge play dominant role respectively for initial error type-1 and type-2 in the Indian Ocean influencing El Niño predictions. In addition, these initial errors may provide information regarding the "sensitive area" of El Niño predictions, if data assimilation or targeted observations can filter these initial errors, the El Niño forecast skills may be significantly improved.

Tue-134

Precipitation weighted relative sea surface temperature as an index to track tropical rainfall variability

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Spatiotemporal variations in rainfall over the tropics are investigated in relation to sea surface temperature (SST) based on observations and model simulations. Rainfall variations are nonlinearly correlated with two key factors: mean rainfall and relative SST (local SST deviation from the tropical mean). This study combines these two factors to form an index, precipitation weighted relative SST (PWR_SST), to track tropical rainfall variability. This PWR_SST index has several advantages over local SST itself: First, PWR_SST variance in the tropics scales linearly with rainfall variance on the interannual timescale. Specifically, PWR_SST captures El Niño rainfall anomalies more precisely than local SST, especially for moderate events. Second, PWR_SST captures the rainfall biases of coupled atmosphere-ocean general circulation models in the present climate very well, including those due to the excessive westward extension of the equatorial Pacific cold tongue and the double intertropical convergence zone (ITCZ) problem, both in annual mean and seasonal variations. Third, PWR_SST can give an approximate estimates of biases in rainfall projections in the future, which shows a spatially structural bias pattern. With more preferable behavior in tracking tropical rainfall spatiotemporal variations, especially for interannual variance and model biases, PWR_SST shows its strength and is promising to be a competent reference in future rainfall researches.

Tue-135

How does the South Asian High influence the extreme precipitation over the eastern China?

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Extreme precipitation has strong influences on regional ecosystems, agriculture, and human society over the eastern China, which has experienced rapid economic growth in recent decades. This implies the necessity for further investigations on both the variability of extreme precipitation over the eastern China, and the corresponding mechanisms. In this study, through using the observed high-resolution (0.25) daily precipitation data and NCEP reanalysis circulation data, the influences from South Asian High on the summer extreme precipitation over the eastern China are investigated in details. The results show that, the positions and magnitude of South Asian High are significantly correlated with the summer extreme precipitation over the middle-lower reaches of the Yangtze River and the northern part of the eastern China. When the South Asian High locates anomalously north or west, or the South Asian High is anomalously weaker, there are less extreme precipitation over the middle-lower reaches of the Yangtze River but more extreme precipitation over the northern part of the eastern China, vice versa. The mechanisms are that, under the conditions of anomalously north/west displacements or anomalously weaker magnitudes, there are positive 200hPa geopotential heights anomalies over the northern part of the eastern China, with convergence over the high-level and divergence on the low-level. This circulation pattern will induce upward movement over the northern part of the eastern China but downward movement over the middle-lower reaches of the Yangtze River, resulting shifts towards to the high tail or low tail of the daily precipitation cumulative distributions of these two regions, separately, and finally the increases/decreases of the extreme precipitation occurrences. These results will help to improve prediction on future changes of summer extreme precipitation over the eastern China.

Tue-136

An Assessment of the Brazil Current Baroclinic Structure and Variability Near 22°S in Distinct Ocean Forecasting and Analysis Systems

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The Brazil Current (BC) is the Western Boundary Current of the South Atlantic subtropical gyre, the dominant dynamic feature in the South Atlantic. This study assesses the structure and variability of the BC across the nominal latitude of 22S using data from the high density XBT AX97 transect and from three numerical ocean models with data assimilation. The AX97 transect was implemented in 2004, and represents one of the longer-term monitoring systems of the BC in existence. In the present work, 37 XBT realizations using data collected between 2004 and 2012 are used. Daily outputs covering the same time period are evaluated from HYCOM-24 NCODA with a 1/12 horizontal resolution, and GLORYS2V3 and FOAM, both with a 1/4 horizontal resolution. These Ocean Forecasting and Analysis Systems (OFAS) are able to capture the mean observed features in the 22S region, showing a BC core confined to the west of 39W and an Intermediate Western Boundary Current between the depths of 200 and 800 m. However, the OFAS tend to overestimate the mean BC baroclinic volume transport across the AX97 reference transect, and underestimate its variability. The OFAS show that the coastal region between the coastline and the western edge of the AX97 transect plays an important role in the mean BC total transport, contributing to up to 23% of its value, and further that this transport is not sampled by the XBT data. In order to understand the variability of the BC, a statistical classification of the BC is proposed, with the identification of three different events.

Tue-137

Seasonal statistical model for Accumulated Cyclone Energy (ACE) over Southern China

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The western North Pacific region has the highest number of tropical cyclones each year and some of the most intense. There has been extensive research conducted on the interannual variation of tropical cyclones in this basin, with sea surface temperature anomalies due to ENSO shown to be important. Accumulated Cyclone Energy (ACE) is a commonly used metric used to quantify the tropical cyclone activity over a season, and not only takes into account the number of storms, but also their strength. This work explores the relationship between ACE over southern China including Taiwan, and large-scale variables including pressure, winds, sea surface temperature and tropical cyclone heat potential. Using the Best Track dataset to produce an ACE time series over 1970-2014, and reanalysis products for the environmental variables, correlation maps between these were produced. By examining correlations between ACE in the peak JJAS season and the large-scale environment prior to this period, the potential predictability of ACE over the specified region is examined. Regions where the correlation of a predictor and ACE were high, were selected as potential predictors of ACE. Using multivariate stepwise linear regression, a model using a combination of predictors with the highest R2 value is created. From a pool of more than 20 predictors, only 2-3 were selected through this procedure. These predictors include sea surface temperature as well as tropical cyclone heat potential. These selected predictors are located in the Indian Ocean, rather than the West Pacific, where the tropical cyclone activity is being predicted. Results obtained using this approach highlight the importance of the surface and deeper ocean for ACE predictability in southern China. It is not only the local ocean conditions that are important to tropical cyclone activity in the West Pacific, as predictability is provided by large-scale variables in the remote Indian Ocean. It is suggested that such a relationship between the Indian Ocean and West Pacific tropical cyclone activity comes from modulation of the subtropical high. For improved seasonal prediction of West Pacific tropical cyclones, a good representation of the ocean is vital, and a global model that is able to capture such teleconnections is much more valuable than a regional model, where remote variables will not be accounted for.

Tue-138

Reliability of CMIP5 Climate Models in the Interannual Variability of Wintertime Northwestern Pacific Storm Track Activities

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In this study, we try to assess the performance of state-of-the-art climate models in simulating the high correlation between interannual variabilities of EAWM(East Asia Winter Monsoon) and NWPST(Northwestern Pacific Storm Track) by comparing the historical run datasets from 16 CMIP5 climate models with ECWMF-Interim reanalysis(ERA-I) data. During the period of 1979-2005, we found that interannual variabilities of EAWM and NWPST have highly negative correlation(-0.74) in ERA-I and the relationship is relatively well simulated by CMIP5 climate models by showing ensemble mean correlation coefficient of –0.59(range from –0.33 to –0.76). However, a quite large disagreement appears among 18 models in respect to the physical mechanisms(such as baroclinicity and meridional eddy heat flux) that leads the relationship. We select 6 better models by evaluating the performance both in the resultant correlation between two phenomena and in the related mechanisms. Mean EAWM-NWPST correlation coefficient of the 6 models is –0.73 which is almost same as ERA-I. Consequently, it is convinced that CMIP5 climate models(especially selected 6 models) secure some high reliability in the simulation of interannual variabilities of EAWM and NWPST and their relationship over the entire period. In contrast, it appears that no CMIP5 climate models deliver satisfactory reliability in the aspect of the extreme events of EAWM and NWPST. We found that there are a significant disagreement between ERA-I and CMIP5 climate models in the NWPST activities for the abnormally strong or weak EAWMs. Generally, Such biases are more salient for the abnormally weak EAWMs. It is proposed that the poor reliability of CMIP5 climate models can result in the increase of uncertainty in future projections of extreme regional climate.

Tue-139

Three distinct levels of influence from initial conditions on model climates in an ensemble climate system model experiment

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Uncertainty in climate system initial conditions (ICs) is known to limit the predictability of future atmospheric states. On weather time scales, an initially "indistinguishable" separation between two atmospheric model trajectories diverges exponentially-on-average over time, implying that the "memory" of model ICs is eventually lost. However, the influence of perturbations to climate system model ICs---particularly in more slowly evolving climate system components---on the evolution of model "climates" on longer time scales is less well understood. Hence, in order to better understand the role of IC uncertainty in climate predictability, it is necessary to develop approaches to quantifying---at various spatial and temporal scales---the nature of the influence of ICs on the evolution of climate system trajectories. To this end, this presentation explores how differences in ICs influence model climates, as quantified using competing definitions of climate. Motivated by results achieved using simple dynamical system analogues for the climate system (Daron and Stainforth, 2013), we explore the impact of different IC perturbations on the evolution of climate model simulations. The model experiment, conducted with a low-resolution configuration of CCSM4, consists of 11 50-member IC ensemble simulations with constant forcing, and three 50-member ensemble simulations under a climate change scenario with transient forcing. Ensemble members are distinguished by having different atmospheric ICs, whereas different ensembles are initialised from different model system states. We introduce the concept of IC influence, which is defined as the effects of IC differences on climate trajectories and quantifications. IC influence can be quantified by the length of time it takes for the "IC footprint" in climate system trajectories to decay to the extent that the system behaviour can no longer be directly attributed to particular characteristics of the ICs used. IC influence can be seen as reflecting the range of qualitatively different behaviours of the system which are consistent with particular IC uncertainty (Stainforth et al., 2007). We present evidence of three distinct levels of IC influence in the output of a large ensemble climate system model experiment. The levels of IC influence can be characterised as contributing to predictability on weather time scales (microscopic IC influence), decadal time scales (intermediate IC influence) and multi-decadal to centennial time scales (macroscopic IC influence). It is fobund that, over some spatial domains, significant ($p < 0.01$) differences in 60-year atmospheric variable climatological probability distributions occur due to IC differences of a similar order to round-off error. It is concluded that IC ensemble experiments can play a valuable role in better understanding climate variability and change, as well as allowing for superior quantification of model climates.

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Tue-140

Transient Behavior of Climate Feedbacks across Decadal Timescales

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Representation of climate feedbacks in a coupled-model remains the largest source of uncertainty in its projection of future climate change driven by increasing Greenhouse gases (GHGs). The sign and magnitude of a feedback, however, depends critically on the dynamical and thermodynamical properties of a backgroundclimate. Due to internal variability of the climate system and fluctuations in external forcing, climate models inevitably excite low frequency variability and generate a wide range of background climates. The drift of feedbacks with these background climates, hence the transient (time-dependent) behavior of climate feedbacks, presents a major challenge in our assessment of the risk of climate change acceleration and abrupt climate change. Delineating the evolving nature of feedback processes in a model is of particular importance for understanding the source of both the skill and bias in the model's decadal climate prediction. Utilizing the coupled atmosphere-surface climate feedback-response analysis method (CFRAM), here we show for the first time the temporal structure of various radiative and dynamical feedback processes contributing to the global temperature changes since 1979. The spatial structure of these feedbacks will be documented in terms of the partial temperature change contributions made by each feedback process. The implications of these results for understanding climate variability and predictability across decadal timescales will be discussed.

Tue-141

Observed and Simulated Summer Rainfall Variability in Southeastern South America

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The changes in regional climate observed in the last decades have raised concern among policy and decision makers about the importance of the knowledge of how climate would evolve in the next decades. In particular southeastern South America (SESA) has experimented large positive austral summer precipitation trends during the 20th century that impacted many socio-economic sectors. However, regional studies show that natural decadal variability has a large influence in SESA precipitation. As a consequence, a deeper knowledge of the combined influence of both decadal climate variability and global warming is needed in order to project near-term future climate changes with a lower degree of uncertainty. The availability of the different simulations included in the Fifth phase of the World Climate Research Program-Coupled Model Intercomparison Project (WCRP/CMIP5) Experiment provides an excellent opportunity to investigate physical processes involved in SESA precipitation changes and their predictability. The evolution of precipitation during the last 150 years exhibits in SESA considerable multi-decadal variations that have been identified in previous works as forced by the tropical ocean variability. Therefore, in order to better understand the influence of the observed large-scale interannual variability of the sea surface temperatures (SST) on austral summer rainfall in SESA in a global warming context, a singular value decomposition analysis was performed over the 1902-2010 period. The leading mode (SVD1) shows a clear global warming signal, mainly related to warming in the Pacific and Indian Oceans, in association with a rainfall increase in SESA. The temporal series of the mode exhibits significant variability ranging from the interannual scale to long-term trends. In particular, the decadal variability signal is remarkable, with a particular phase shift at around the middle 1970s. After detrending the series, the spatial distribution of both SST anomalies and precipitation anomalies in SESA associated with the first mode resembles that typically related with El Niño-Southern Oscillation. Moreover, the mode temporal evolution has a remarkable variability on decadal scales, which shows that the relationship between SST anomalies, especially in the Tropical Pacific Ocean, and SESA precipitation is non stationary. It is speculated that the latter is related with decadal variations of the Southern Hemisphere circulation conditions that constructively or destructively influence the teleconnection development between the tropical Pacific-Indian oceans and SESA.

Historical and Decadal WCRP/CMIP5 simulations are considered in order to make a preliminary evaluation of the representation of austral summer rainfall variability and trends in SESA and its connection with ocean variability. Models are able to represent a significant positive trend over SESA in agreement with the

observations, although weaker than observed. The model representation of the SVD1 was also assessed. Preliminary results using short-term climate predictions show that some models are able to reproduce the main spatial features associated with the mode, on both SST anomalies and precipitation anomalies in SESA. In particular, these models are able to reproduce the teleconnections linking the tropical Pacific-Indian Ocean sector with SESA. An assessment of the temporal evolution of this mode provided by those simulations will be also presented in the Conference.

Tue-142

Added value in rainfall and temperature simulated by the regional climate model REMO in present and in the climate change signal over Central Africa

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Climate simulations and climate change (CC) projections for Central Africa were made with the regional climate model (RCM) REMO following the COordinated Regional Climate Downscaling EXperiment (CORDEX) experimental protocol. The model was forced by two Global Climate Models (GCMs), one developed by the Europe-wide Consortium Earth System Model (EC-Earth) and the other by the Max Planck Institute-Earth System Model (MPI-ESM), for the period from 1950 to 2100 under the Representative Concentration Pathway 8.5 (RCP8.5) emission scenario included in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The performance of the REMO simulations for current climate is compared first with REMO simulation driven by ERA-Interim reanalysisis, then by the corresponding GCMs in order to investigate whether REMO outputs are effectively able to add value (AV) at regional scale. We found that REMO is generally able to better represent the annual cycle of rainfall, the daily rainfall intensity distribution and the Central Africa monsoon (CAM). It is also found that the geographical distribution seasonal 2-m temperature and rainfall is strongly affected by the boundary conditions. However the regional model is able to add value compared to the simulations of the driving GCMs. From the analysis of the CC signal from the present period 1976-2005 to the future 2066-2095, we found that all models project a warming at the end of the twenty-first century although the details of the CC differ notably between REMO and the driving GCMs, especially for rainfall changes. Fine-scale variability of the CC signal is relatively agreeable for 2-m temperature and robust for rainfall compared to its large-scale component, suggesting that AV in small-scale can be expected

Tue-143

Assessment of simulated rainfall and temperature from the regional climate model REMO and future changes over Central Africa

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This work investigates spatial and temporal changes in rainfall and temperature over Central Africa, using Historical and Representative Concentration Pathways (RCP2.6, RCP4.5 and RCP8.5) of the regional climate model (RCM) REMO forced by two general climate models (GCMs): the Europe-wide Consortium Earth System Model (EC-Earth) and the Max Planck Institute-Earth System Model (MPI-ESM). We found that in the present period (1980 to 2005), the spatial distribution of rainfall is simulated with an annual spatial pattern correlation coefficient (PCC) of 0.76 for REMO driven by EC-Earth and 0.74 for REMO driven by MPI-ESM respectively when compared to CRU data. In terms of temperature, the annual PCC is 0.93 for the two REMO outputs. According to the climatology of Central Africa, we subdivided the study area into five sub-regions, we also noticed that the annual and seasonal PCC depend on the considered sub-region. For the future period (2070 to 2095), temperature is projected to increase following all the three scenarios. The rainfall amount is projected to decrease by up to 5 mm/day towards the end of the twenty first century under RCP8.5 scenario, and by 1 to 2 mm/day under RCP4.5 and RCP2.6 scenarios over Equatorial Guinea, Gabon, Congo, north-western Democratic Republic of Congo (DRC) and the Lake Victoria. Significant decrease is predicted to occur mostly in the northern part of the domain under RCP8.5 scenario. However, future rainfall over High Lands of Cameroon, Adamawa Plateau, north-eastern DRC and Atlantic Ocean is projected to increase.

Tue-144

Decadal Variability of Winds over Tropical Indian Ocean

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Here we explore the decadal variability of teleconnection from tropical pacific to the Indian Summer Monsoon Rainfall (ISMR) over the period 1951 to 2008, using various Observational and Reanalysis datasets for the period 1951 to 2008. In conformation with the earlier findings, Warm Water Volume (WWV) of the equatorial pacific has a lead predictive skill for ISMR over the whole period. However, we find that the interannual correlations between the ENSO and ISMR have continued to weaken since 1950s, irrespective of the choice of an index for tropical pacific variability- be it the NINO4 index or even the Tropical Pacific Warm Water Volume index. To understand the decadal weakening, we carry out a preliminary analysis by exploring the low level circulation over the tropical pacific that influences the Indian summer monsoon variability. Our analysis suggests that, in the post-1977 period, the western boundary of the Walker circulation, which is important for the ISMR variability, is confined to the east of 120E. This may be due to a basinwide broadening of the cross-equatorial flow in the equatorial Indian Ocean in the recent decades. This may imply that with the decrease of influence of Pacific Ocean over the ISMR, Indian ocean seems to play an even bigger role now than it did earlier. The probable cause for this shift of winds over Indian Ocean is being studied now. Our preliminary analysis also shows an eastward shift of the subtropical high in the recent period. The winds over TIO show a north easterly shift post 1970s. Also the winds over North western Pacific show an eastward intensification.

Tue-145

Decadal Prediction in the Indian context

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Indian Summer Monsoon Rainfall (ISMR) has its limitations even in seasonal prediction. Therefore its predictability on a longer time scale comes with its own complications. Decadal Prediction of ISMR is not very unlikely. We analysed the data from Depresys3 (MetOffice Hadley Centre,UK) which shows a much higher skills for ISMR than Depresys2. The correlations are positive all over the sub continent though not always significant. The skill is statistically significant over some regions in India especially over some regions in central India and over Eastern India (above 95% confidence level). The skills are the weakest in South eastern India, the region of North western Monsoon. Since these runs are initialised in November of the previous year, the skills have a lead predictability of eight months which is greater than the seasonal prediction. We are now looking at the predicticibility of various factors that influence ISMR. Our preliminary analysis also shows that decadal prediction of summer temperatures have greater skill than precipitaion. We are now looking at the predictive skills of extreme events.

Tue-146

Decadal variability of Atlantic Meridional Overturning Circulation in the 20th century simulated with an ocean model forced by atmospheric data sets

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Global ocean hindcast simulations for the period 1871–2009 have been run with the ocean-sea ice component of the Norwegian Earth System Model (NorESM-O), forced by an adjusted version of the Twentieth Century Reanalysis version 2 data set (20CRv2 data set), as well as by the commonly used second version of atmospheric forcing data set for the Coordinated Ocean-ice Reference Experiments phase-II (CORE-II) for the period 1948–2007 (hereafter CORE.v2 data set). The simulated Atlantic Meridional Overturning Circulation (AMOC) in the 20CR and the CORE simulations have comparable variability as well as mean strength during the last three decades of the integration. The simulated AMOC undergoes, however, distinctly different evolutions during the period 1948–1970, with a sharply declining strength in CORE but a gradual increase in 20CR. Sensitivity experiments suggest that differences in the wind forcing between CORE and 20CR have major impact on the simulated AMOCs during this period. It is furthermore found that differences in the air temperature between the two data sets do contribute to the differences in AMOC, but to a much lesser degree than the wind. An additional factor for the diverging AMOC in the two decades following 1948 is the inevitable switching of atmospheric forcing fields in 1948 in the CORE.v2-based runs due to the cyclic spin-up procedure of the ocean model. The latter is a fundamental issue for any ocean hindcast simulation. The ocean initial state mainly influence the actual value but to a lesser degree also the temporal evolution (variability) of AMOC. It may take about two decades for the AMOC to adjust to a new atmospheric state during the spin-up, although a dynamically balanced ocean initial state tends to reduce the adjustment time and the magnitude of the deviation. It is implied that a hindcast ocean model run extending back in time, like the 20CR simulation, can provide reliable initial conditions for decadal prediction experiments.

Tue-147

Influence of Internal Climate Variability on Projected Future Regional Sea Level Rise

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Observational evidence shows that as the global mean temperature increases, the global mean sea level is also rising. The rising sea level could impose significant impacts on coastal communities, especially when this rising sea is compounded with storm surges. Here, by analyzing results from two sets of ensemble simulations using the Community Earth System Model version 1, we study impact of internal climate variability on the projected global and regional sea level change over the 21st century based on two future climate pathways. Results show that the global mean sea level rise due thermal expansion of sea water can be reduced by about 25% (~3.7 cm) if a medium RCP scenario was followed vs. the high one. Regionally, this reduction on sea level rise can be marginal in some areas, such Melbourne, Australia (14cm vs. 13cm), and can be very large in others, such as New York (35cm vs. 25cm) due to dynamical forcing induced regional changes. These different sea level rises are related to the changes of the Atlantic meridional overturning circulation (AMOC), Pacific decadal oscillation (PDO), and the Antarctic circumpolar currents (ACC).

Tue-148

Process-based Physical Attributions of the Decadal Climate Difference between 1984-95 and 2002-13

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This study attributes the climate difference between the periods of 2002-13 and 1984-1995 to external forcing and various internal climate processes by a climate feedback-response analysis method using the ERA-Interim reanalysis. The process-based attribution indicates that the direct effect of the increase of CO_2 (0.18 K) is one of the largest contributors to the global warming between the two periods (about 0.32 K), second only to the oceanic heat storage term (1.4 K). The largest warming due to the oceanic heat storage term is found in the tropical Pacific and India Ocean with relatively weaker warming over the tropical Atlantic Ocean. The anomalous amount of heat release from oceans is accompanied with an enhancement of evaporation from oceans that cancels out nearly 60% of the combined warming due to the heat storage term and the direct effect of the increase of CO_2. The changes in clouds (-0.2 K) and atmospheric circulations (-0.1 K) are the main factors that further reduce the surface warming caused by the two leading factors. The ice-albedo and atmospheric dynamical feedbacks are the two leading factors responsible for the Arctic polar warming amplification (PWA). The increase of atmospheric water vapor over the Arctic region also contributes substantially to the Arctic PWA pattern. The increase of atmospheric water vapor and more deep clouds above the western tropical Pacific together with the reduction of water vapor and increase of shallow clouds above the eastern tropical Pacific are the main drivers for the appearance of a La Niña like pattern over the tropical Pacific.

Tue-149

Weakly coupled SST data-assimilation for ocean state estimation and climate prediction

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The Norwegian Climate Prediction Model (NorCPM) uses the ensemble Kalman Filter to assimilate SST anomalies into the ocean component of the fully coupled Norwegian Earth System model. We perform a reanalysis for the period 1950-2010 and corresponding seasonal-to-decadal (s2d) predictions. NorCPM is slightly over-dispersive against assimilated observations and is skilful in constraining independent measurements: SSH, heat and salt content, in particular in the tropical and North Pacific, the North Atlantic and the Nordic Seas. It provides a reliable monitoring of the North Atlantic subpolar gyre (SPG) variability, and constrains the Atlantic meridional overturning circulation (AMOC). NorCPM's good performance is in part linked to the flow dependent assimilation method applied in isopycnal coordinate system. Isopycnal coordinate better capture the vertical structure than standard depth-coordinate discretisation, deepening the influence of the SST observations. The vertical covariance shows a pronounced seasonal and decadal variability, which highlights the benefit of flow dependent data assimilation method. A set of the s2d predictions carried out every second year from 1950 to present with 20 ensemble members has just been completed. A preliminary analysis shows long-term predictability in the AMOC and upper ocean heat content. However, the predictability of the SPG strength appears limited. A careful attribution analysis is being performed to assess sources of skill and error, and identify the climate impacts of oceanic skill. Our results demonstrate the potential of NorCPM to provide a long reanalysis using only SST observation, and the potential to assess decadal predictability over the historical period. Based on our encouraging results an extended analysis covering the period 1850 to present is planned, and preliminary results will be presented.

Tue-150

Impact of the Arctic-Atlantic freshwater exchange variability on the subpolar North Atlantic

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During the recent decades a large volume of liquid freshwater has been accumulated in the Arctic Ocean. We previously showed that the interanual variability of the freshwater content can be explained by the exchange of freshwater with the North Atlantic Ocean. In particular, changes in volume transport through the Canadian Arctic Archipelago are the key factor that determines freshwater transports. Since those transport anomalies can be explained by the wind stress curl changes associated with the Arctic Oscillation (AO), a larger release of freshwater can be expected in the future related to changes in the state of the AO. It has been suspected that the associated freshening of the Atlantic may have a large impact on the circulation in the subpolar North Atlantic. Based on modelling results, we show that the decadal changes of the freshwater content of the Arctic and subpolar North Atlantic are in fact in antiphase. However, upon a detailed investigation of the components of the freshwater balance in the subpolar gyre, it was found that the exchange with the subtropical gyre and the surface freshwater flux over the subpolar North Atlantic are as important as the export from the Arctic. The anti-phase relation is thus a consequence of the compensation between anomalies of freshwater gain though the surface and the anomalous southward export of fresh water from the subpolar gyre into the subtropics. Additional freshwater leaving the Arctic was previously suggested to have a negative impact on deep water formation and the meridional overturning. Our model results suggest that the impact of the freshwater exchange is very small and events of larger freshwater export happened in the past during phases of the atmospheric circulation (positive AO) that promote deep convection. Since the large scale atmospheric forcing drives simultaneously the exchange with the Arctic and the circulation in the subpolar gyre, phases of high subpolar freshwater content coincide with strong subpolar gyre circulation. The impact can be summarized as a damping factor in the variability of water mass formation and overturning. An experiment with constrained freshwater exchange confirmed this damping relation but also suggests that the AO related FW impact on the overturning is only about 10% of the AO driven overturning variability.

Tue-151

Tropical Pacific variability as the key pacemaker of the global warming staircase

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Annual global-mean surface temperature (GMST) has risen since the late 19th century. This temperature increase is not monotonic but with notable decadal variability, resembling a rising staircase. In order to examine the role of tropical Pacific variability on the observed history of global climate, we have performed a long pacemaker experiment with a coupled climate model, where tropical Pacific sea surface temperature anomalies are forced to follow the observed history since the late 19th century. The pacemaker experiment successfully reproduces annual-mean GMST variability with correlation $R = 0.96$ and 15-year running GMST trend with $R = 0.75$ since 1880. Without the tropical Pacific effect, the same model produces a continual warming from the 1900s to the 1960s with gradual slowdown due to increasing aerosols, followed by rapid warming. On the decadal time scale, the tropical Pacific impact on GMST is comparable in magnitude with radiative forcing. We identify four events of decadal warming slowdown due to tropical Pacific cooling over the past 120 years, featuring the Interdecadal Pacific Oscillation (IPO). While changing radiative forcing caused the GMST rise and contributed to the mid-20th century big hiatus, IPO determined the timing of transition into and out of the hiatus, marking the staircase.

Tue-152

Low-frequency Variability of Kuroshio and Oyashio Extensions and Associated Ocean-Atmosphere Coupling

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Interannual to decadal variability in the latitude and strength of the oceanic fronts along the Kuroshio Extension (KE) and Oyashio Extension (OE) is investigated based on observational datasets as well as an eddy-resolving hindcast simulation using the ocean general circulation model for the Earth Simulator (OFES). A particular emphasis is placed on the comparison between the two periods, 1958-1977 and 1988-2012, which exhibit changes in the relationships between the frontal variability of the KE and OE and also in the leading modes of atmospheric variability in the North Pacific. The index time series for the OE latitude and strength are defined based on the meridional gradient of sea surface temperature, while the KE indices are based on the sea surface height. In the recent period, the KE latitude and strength changes are significantly positively correlated to each other, but the correlation is negligible in the early period. Similarly, the OE latitude and strength become significantly positively correlated only in the recent period. These changes are accompanied by the increased influence of the North Pacific Oscillation (NPO)-related atmospheric variability on the KE and OE variability in the later period. Consistent with these changes, the leading mode of the wind stress curl variability over the North Pacific is associated with the Pacific-North American (PNA) teleconnection in the early period, but with the NPO in the later period. The role of atmospheric variability in the KE and OE variability as well as the associated ocean-to-atmosphere feedback in the two periods will be discussed.

Tue-153

Simulation and projection of summer surface air temperature over China: a comparison between a RCM and the driving global model

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The regional climate model (version 3, RegCM3)with the horizontal resolution of 50 km was employed to downscale the historical and projected climate changes over CORDEX East Asia domain, nested within the global climate system model FGOALS-g2(Flexible Global Ocean-Atmosphere-Land System Model: Grid-point Version 2). The simulated (1986-2005) and projected (2046-2065) summer surface air temperature changes under RCP8.5 scenario over China were compared between the RegCM3 and FGOALS-g2. The air temperature indices used in this study included daily maximum temperature (tmx), daily average temperature (t2m) and daily minimum temperature (tmn), and extreme high-temperature events included max of tmx (TXx), warm days (TX90p) and warm spell duration (WSDI). Results indicated that both models reasonably reproduce the climatological distribution of surface air temperature and extreme high-temperature events. Compared to the driving global climate model, the detailed characteristics of summer surface air temperature were better simulated in RegCM3 due to its higher horizontal resolution. Under the RCP8.5 scenario, summer surface air temperature over China will increase significantly during the middle of 21st century. RegCM3 projected larger increase of tmx than tmn over most regions of China, but in the western Tibet Plateau, the increase of tmn was larger. In the projection of FGOALS-g2, the projected changes of the three temperature indices (t2m, tmn, and tmx) were similar with larger increases over northeastern China and Tibet Plateau. Extreme high-temperature events were projected to increase significantly in both models.TX90p will increase more than 60% compared to present day, while WSDI will become twice of present day.

Tue-154

Simulation of climatology and Interannual Variability of Spring Persistent Rains by Meteorological Research Institute Model: Impacts of different horizontal resolutions

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The authors evaluated the performance of Meteorological Research Institute (MRI) AGCM3.2 models in the simulations of climatology and interannual variability of the Spring Persistent Rains (SPR) over southeastern China. The possible impacts of different horizontal resolutions were also investigated based on the experiments with three different horizontal resolutions (i.e., 120, 60, and 20km). The model could reasonably reproduce the main rainfall center over southeastern China in boreal spring under the three different resolutions. In comparison with 120 simulation, the model employing 20km resolution shows the superiority in simulating rainfall centers anchored by the Nanling-Wuyi Mountains, but overestimates rainfall intensity. Water vapor budget diagnosis showed that, both the 60km and 20km versions tended to overestimate the water vapor convergence over southeastern China, which leads to wet biases. With regard to interannual variability of SPR, the model could reasonably reproduce the anomalous lower-tropospheric anticyclone in the western North Pacific (WNPAC) and positive precipitation anomalies over southeastern China in EI Nio decaying spring. Compared with the 120km resolution, the large positive biases are substantially reduced in the 60km and 20km resolution models which evidently improve the simulation of horizontal moisture advection in EI Nio decaying spring. The results highlight the importance of developing high resolution climate model in improving the climatology and interannual variability of SPR.

Tue-155

Atlantic Induced Decadal Climate Variability in the Tropical Ocean and Atmosphere

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During the past three decades, tropical sea surface temperature (SST) exhibited dipole-like trends, with warming over the tropical Atlantic and Indo-Western Pacific but cooling over the Eastern Pacific. The Eastern Pacific cooling has recently been identified as a driver of the global warming hiatus. Previous studies revealed atmospheric bridges between the tropical Pacific, Atlantic, and Indian Ocean, which could potentially contribute to this zonally asymmetric SST pattern. Our study is inspired by these previous studies, and aims at investigating the role of the tropical Atlantic in the entire tropical climate systems on decadal time scales, in particular, the tropical-dipole SST pattern formation. We first performed a pacemaker' simulation using a fully coupled model the Community Earth System Model (CESM1), by restoring the tropical Atlantic SST trend during the satellite era. Results reveal that the Atlantic warming heats the Indo-Western Pacific and cools the Eastern Pacific, enhances the equatorial easterly wind and the Walker circulation, and drives the subsurface Pacific to a La Nia mode. Ensemble simulations show that the Atlantic warming can contribute to more than 50% of the above tropical changes during the last three decades. The same pan-tropical teleconnections have been validated by the statistics of observations and 106 CMIP5 control simulations, showing that the Atlantic-induced tropical-dipole pattern is robust decadal climate variability.We then performed a series of simulations using a hierarchy of atmospheric and oceanic models with different complexities, to reveal the mechanisms of these teleconnections. Through these simulations, we established a two-step pathway for the Atlantic to impact on the entire tropics: 1) Atlantic warming first generates a regional deep convection and induces a Gill-type convective circulation anomaly over the entire tropical atmosphere. This circulation changes force the Indian Ocean and the Pacific with wind-evaporation-SST (WES) effect, and forms a temperature gradient over the Indo-Pacific basins. 2) The Atlantic-induced Indo-Pacific temperature gradient further generates a secondary atmospheric deep convection over the Indo-Western Pacific warm pool region, which reinforces the easterly wind anomalies over the equatorial Pacific and enhances the Walker circulation, triggering the Pacific to a La Nia mode with Bjerknes ocean dynamical feedback. This mechanism indicates that the three tropical ocean basins are linked more closely than previously thought, and on decadal time scales the tropical oceans should be considered as a single entirety. In addition to the well-known ENSO-induced tropical-wide response that is dominant on inter-annual time scales, this study highlights the role of the tropical Atlantic in initiating a different pan-tropical dipole pattern that is important on decadal timescales. This Atlantic-induced pan-tropical variability has broad impacts on the global climate variability. The tropical Atlantic warming is likely due to radiative forcing and Atlantic Multi-decadal Oscillation, the latter tied to the Atlantic meridional overturning circulation (AMOC). Our study suggests that the AMOC may force the pan-tropical decadal

variability, and the slow time scales of the AMOC may contribute to the decadal predictability of the tropical-wide SST pattern, and thus the global climate system.

Tue-156

A decadal time scales biogeochemical simulation in the Baltic Sea using EnOI data assimilation

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The long-term oxygen and nutrient cycles in the Baltic Sea are reconstructed using the Swedish Coastal and Ocean Biogeochemcial model (SCOBI) coupled to the Rossby Centre Ocean model (RCO). Two simulations covered the period 1970-1999 are carried out with and without data assimilation, respectively. Here the “weakly coupled” scheme with the ensemble optimal interpolation (EnOI) method is adopted to assimilate the observed profiles in the reanalysis system. The impact of biogeochemical observations (oxygen and nutrients) assimilation on the ecosystem modelling is accessed. Both not-yet-assimilated and independent in situ observations have been used to evaluate the performance of the two simulations. The simulation results show that the considerable improvements have been yielded in both oxygen and nutrients in the reanalysis relative to the free run. Further, the results suggest that the observation information constraints in assimilation run have significantly effect on the simulation of the oxygen dependent dynamics of biogeochemical cycles. For example, due to variations in net transports and the vertical mixing systematically affect bottom oxygen concentrations on seasonal and decadal scale, the bias of bottom hypoxic area (oxygen concentrations < 2 mL L-1) has been largely reduced in the reanalysis. Moreover, reanalysis increased oxygen concentrations and decreased nutrients concentrations in the upper layers of the water column, which cause the decreased biomass production.

Tue-157

Attribution of the july–august 2013 heat wave in central and eastern China to anthropogenic greenhouse gas emissions

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In the midsummer of 2013, Central and Eastern China (CEC) were hit by an extraordinary heat wave, with the region experiencing the warmest JulyAugust on record. In this study, we compared the JulyAugust mean surface air temperature simulated using the atmospheric general circulation models (AGCMs) CAM5.1 and MIROC5 provided by the International CLIVAR C20C+ Detection and Attribution Project and the coupled general circulation models (CGCMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5) and explored how human-induced greenhouse gas emissions and natural internal variability contributed to this heat wave. The analysis suggested that the atmospheric natural variability and anthropogenic factors contributed to the extreme high temperatures in JulyAugust of 2013 in CEC. The extreme warm midsummer in 2013 in CEC is associated with the positive high-pressure anomaly that is closely related to the stochastic behavior of atmospheric circulation. In addition, human influence has at least doubled the chance of warm mid-summers, such as the 2013 high-temperature event in CEC, based on the CMIP5 model. In the attribution simulations of CAM5.1 and MIROC5 with real climate boundary conditions and hypothetical natural boundary conditions, it was estimated that anthropogenic influence has increased the chance of warm JulyAugust events, such as the 2013 high-temperature event in CEC, by tenfold and threefold, respectively.

Tue-158

Comparisons of Various Sea Level Reconstructions and Sea Level from Data Synthesis Products: 1960-2007

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We investigate sea level trends and variability as reconstructed from tide gauge data and ocean data assimilations (ODA) over the last 60 years. Tide gauge reconstructions (TGR) are mostly based on statistical approaches using selected EOFs, or trained from variability patterns, from altimetric sea level and tide gauge data to extrapolate regional sea level evolution backward in time. Reconstructions also exist from dynamical ocean modeling approaches with and without data assimilation. We intercompare all results and provide ensemble mean and ensemble spreads to describe estimates of past regional sea level changes and their uncertainties. While tide gauge reconstructions match tide gauge data better than ODA, they exhibit less variability in the open ocean. TGRs match the variability better during the satellite-altimetry era than for the entire period from 1960-2007, whereas the ODAs only show some improvement. An average of all products produces the best statistics for comparing to the set of tide gauges. In summary, the results are mixed. The TGRs and ODAs can be useful in some respects, such as calculating a global sea-level signal, and matching altimetric data, and each other, well in the Pacific. But the regional open-ocean sea-level change and variability found from altimetric data are not well reproduced over substantial portions of the ocean. Over periods earlier than the satellite era, these reconstructed regional patterns may not be trustworthy, nor can they be verified.

Tue-159

TWENTY CENTURY ANALYSIS AND FUTURE CLIMATE CHANGE OF THE OCEANS' INFLUENCE ON RAINFALL VARIABILITY OVER SOUTHEASTER SOUTH AMERICA FROM A COMPLEX NETWORK PERSPECTIVE

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Several previous studies have already shown that Southeastern South America (SESA) rainfall is influence by the tropical Pacific, Atlantic and Indian Oceans. At the same time, these tropical oceans can interact among them forcing sea surface temperature (SST) anomalies in remote basins through atmospheric and oceanic teleconnections. However, to our knowledge there are no previous studies that address how the SST anomalies over the three tropical oceans can collectively interact to induce rainfall anomalies over SESA, how the interaction among the tropical oceans and their influence on rainfall variability has evolved with time and how that collective tropical influence on SESA precipitation (SESA PCP) can change in the next century as result of anthropogenic forcing. We employ a tool from the complex network theory to analyze the collective influence of the three tropical oceans on austral spring rainfall variability over SESA. We construct a climate network considering the Niño3.4, the Tropical North Atlantic (TNA), the Indian Ocean Dipole (IOD) and the SESA PCP indices as networks' nodes, and the network distance as a measure of synchronization among all the phenomena. The network was constructed considering the 20th century observations and the 21st century runs of seven different CMIP5 models under the RCP 4,5 and 8,5 scenarios in order to check the possible changes in the network during the next century. For the 20th century observations, this approach allowed to uncover two main synchronization periods characterized by different interactions among the tropical oceans and precipitation nodes. Whereas in the 1930s El Niño and the TNA were the main tropical oceanic phenomena that influenced SESA precipitation variability, during the 1970s they were El Niño and the IOD. After evaluating the skill of the seven CMIP5 models in representing the observed network statistics during the 20th century, we studied changes in the network under RCP 4.5 and 8.5 global warming scenarios in the 21st century. Focusing on the grand CMIP5 ensemble mean, results would suggest that an anthropogenic forcing would increase the number of synchronization periods per century, their time length, and the nodes connectivity (with the exception of TNA and IOD in RCP 8.5). The stronger connectivity of SESA precipitation with the tropical oceans in both scenarios would suggest an increase of the oceanic influence on rainfall over SESA as result of anthropogenic forcing, which would enhance its seasonal predictability. However, these results have to be taken with caution because there is a large disparity in model behavior and thus large uncertainty in conclusions suggested from the grand ensemble mean.

Tue-160

Spatial patterns and frequency of unforced decadal-scale changes in global mean temperature

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The causes of decadal time-scale variations in global mean temperature are currently under debate. Proposed mechanisms include both processes internal to the climate system as well as external forcing. Here, we examine the robustness of spatial and frequency characteristics of unforced (internal) decadal variability among Comparison Model Intercomparison Project Phase 5 (CMIP5) preindustrial control runs. We find that almost all CMIP5 models produce an Interdecadal Pacific Oscillation-like pattern associated with decadal variability, but the timing of decadal-scale change is model- dependent. To assess the roles of atmosphere and ocean dynamics in producing decadal variability, we compare two preindustrial control Community Climate System model (version 4) configurations: one with coupling to a slab ocean and the other fully coupled to a dynamical ocean. Interactive ocean dynamics are not necessary to produce an IPO-like pattern, but do affect the magnitude and timing of the decadal changes primarily by impacting the strength of El Nino Southern Oscillation. However, low frequency El Nino Southern Oscillation variability and skewness explains up to only 54% of the spread in frequency of decadal swings in global mean temperature among CMIP5 models, hence there may be other internal mechanisms that can produce such variability. We conclude that the spatial pattern of decadal changes in surface temperature are robust and can be explained by atmospheric processes interacting with the upper ocean, while the timing of these changes is not well-constrained by models.

Tue-161

Multiyear climate prediction with initialization based on 4D-Var data assimilation

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An initialization relevant to interannual-to-decadal climate prediction has usually used a simple restoring approach for oceanic variables. Here, we demonstrate the potential use of four-dimensional variational (4D-Var) data assimilation on the leading edge of initialization approach particularly in multiyear (5-year-long) climate prediction. We perform full-field initialization rather than anomaly initialization and assimilate the atmosphere states together with the ocean states to an atmosphere-ocean coupled climate model. In particular, it is noteworthy that ensembles of multiyear hindcasts using our assimilation results as initial conditions exhibit an improved skill in hindcasting the multiyear changes of the upper ocean heat content (OHC) over the central North Pacific. The 4D-Var approach enables us to directly assimilate a time trajectory of slow changes of the Aleutian Low that are compatible with the sea surface height and the OHC. Consequently, we can estimate a coupled climate state suitable for hindcasting dynamical changes over the extratropical North Pacific as observed.

Tue-162

Principal nonlinear dynamical modes of multidecadal climate variability

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A new method for reducing the dimension of climate data by reconstructing the principal modes is suggested. The main idea of the method is an improving the traditional linear methods for data expansion by taking into account nonlinear couplings between the time series. Actually, the method is aimed to reveal a few hidden dynamical signals which explain an essential part of data and are interpreted as dominant internal modes driving the observed multivariate dynamics. The main feature of this decomposition distinguishing it from other similar methods is its focusing on the recognition of the spatio-temporal patterns which are clearly separated by the time scale. This is achieved by using the special prior restrictions to the reconstructed time series adjusting its autocorrelation time to the dominant time scales of the dynamics. It is important that the data transformation used for the mode construction is optimized to be relevant to available statistics: its dimension defining the embedding for the manifold, degree of nonlinearity, and prior autocorrelation time, are estimated by Bayesian optimality criterion. First, we applied [1] the proposed expansion to NOAA monthly SST time series covering the Globe and having duration more than 34 years – from 1981 to present. It is shown that the obtained nonlinear modes capture more part of SST variability than principal components (PCs) constructed by either EOF decomposition or its spatio-temporal extension. In particular, a few modes explain a set of key SST-based Pacific and Atlantic indices with correlation coefficient more than 0.7. A relation of the obtained modes to decadal natural climate variability including recent hiatus in the atmosphere warming will be demonstrated and discussed in the report. Further, we will present the analysis of historical data – from mid of nineteenth century to present – by the proposed technique: the multidecadal evolution of extracted principal modes of global climate will be discussed.

This research was supported by the Government of the Russian Federation (Agreement No. 14.Z50.31.0033 with the Institute of Applied Physics RAS)

[1] Mukhin, D., Gavrilov, A., Feigin, A., Loskutov, E. & Kurths, J. Principal nonlinear dynamical modes of climate variability. Sci. Rep. 5, 15510 (2015).

Tue-163

Calendar forecasting for maize crop from global circulation model Ruzizi Plain

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The all world is facing several major challenges like economic crisis and the elaboration of development strategy to attenuate the ominous effects of climate change .That why this study had the objective to foresee an agricultural calendar from the climatic local station data adapted to models of global circulation of the atmosphere. The methodology adopted for this survey lies on the analysis of the evolution of the climate in answer to different dangers incurred by the agriculture of the plain of the Ruzizi while considering the culture of the corn in the evolution of her agricultural calendar. The mathematical equations lasting a period of 30 next years for local station data have been generated. Of this analysis, it has been noticed that the climatic variables (temperature, precipitation) would present some meaningful variations according to the scripts during next thirty years (form 2015 to 2045), notably in the distribution of precipitations into the agricultural calendar. Under the present conditions of the climate produced by the model Echam-5 an agricultural calendar has been produced explaining the shift observed between the old calendar and the new. Contrary to the old calendar that presented the beginning of precipitations to the month of September the new calendar presents a fall of precipitation to the month of October from where the planning of calendar to permit the good growth of the culture. The all world is facing several major challenges like economic crisis and the elaboration of development strategy to attenuate the ominous effects of climate change .That why this survey had the objective to foresee an agricultural calendar from the climatic local station data adapted to models of global circulation of the atmosphere. The methodology adopted for this survey lies on the analysis of the evolution of the climate in answer to different dangers incurred by the agriculture of the plain of the Ruzizi while considering the culture of the corn in the evolution of her agricultural calendar. The mathematical equations lasting a period of 30 next years for local station data have been generated. Of this analysis, it has been noticed that the climatic variables (temperature, precipitation) would present some meaningful variations according to the scripts during next thirty years (form 2015 to 2045), notably in the distribution of precipitations into the agricultural calendar. Under the present conditions of the climate produced by the model Echam-5 an agricultural calendar has been produced explaining the shift observed between the old calendar and the new. Contrary to the old calendar that presented the beginning of precipitations to the month of September the new calendar presents a fall of precipitation to the month of October from where the planning of calendar to permit the good growth of the culture.

Tue-164

Ocean-atmospheric state dependence of the response to sea-ice loss

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The Arctic is warming faster than the global average. This disproportionate warming – known as Arctic amplification – has caused significant local changes to the Arctic system and more uncertain remote changes across the Northern Hemisphere mid-latitudes. But can background ocean-atmospheric states modulate the response to diminished sea-ice cover? Here, we use an atmospheric general circulation model to test the sensitivity of the response to sea-ice loss to the phase of the Atlantic Multidecadal Oscillation (AMO), which varies on (multi-)decadal timescales. Prescribing identical sea-ice losses, a wavetrain response to wintertime sea-ice loss is seen in the Pacific-North America sector in the negative phase, which is missing in the positive phase. The AMO phase influences the circulation over the central North Pacific, with a strengthened Aleutian low in the the negative phase. Anomalous northerly winds in the central and western North Pacific during the negative phase of the AMO reinforce anomalous northerly flow associated with sea-ice loss alone. This cold advection in the negative phase further reduces the lower-tropospheric poleward temperature gradient in the western Pacific in response to sea-ice loss. Amplification of the climatological ridge-trough pattern across the Pacific-North America sector, as seen during the negative AMO phase, is shown to be sensitive to the poleward temperature gradient in the western North Pacific. This robust feature is found in both these model simulations and observations. These contrasting responses could increase skill in decadal prediction of the response to sea-ice decline.

Tue-165

Climate Normals and Variability of Arctic Sea Ice

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Arctic sea ice coverage has been undergoing rapid depletion since satellite-based measurements became available in late 1970s, especially the summer ice coverage. Arctic ice is declining at an accelerating rate for the last 15 years compared to the average measurement of previous 20 years (1980 2000) with the minimum ice coverage record setting in 2007 and again in 2012. Since the late 1970s, about 49% sea ice reduction in extent and 80% in volume were observed. This loss of Arctic ice is also occurring at a rate that is faster than what the climate models have predicted. Temporal and regional variability have also been observed, indicating that not all changes are uniform in both space and time. To help establish baselines for climate state, temporal and spatial variability of Arctic sea ice, climate normals are computed using a long-term, consistent, and mature sea ice concentration climate data record. The method of using the arithmetic average over the latest three-decades as defined by the World Meteorological Organization is adapted. The non-stationarity of decadal trends of global and regional sea ice area and extent will be examined.

Tue-166

A long-term global dataset of temperature and humidity profiles from HIRS

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Temperature and humidity profiles are derived based on NOAA polar orbiting satellites' High-resolution Infrared Sounder (HIRS) measurements from 1979 to present. To achieve homogeneity of the time series, HIRS longwave channel data are inter-calibrated to a base satellite. The retrieval of temperature and humidity are derived using a neural network technique. The algorithm derives profiles at standard pressure levels from the surface to lower stratosphere for temperature and from the surface to upper troposphere for humidity. A two-tiered approach is used to remove cloud-contaminated HIRS observations. Cloudy pixels are first identified and removed by using a neighboring variance method in both spatial and temporal dimensions. The remaining pixels are further screened by co-located Advanced Very High Resolution Radiometer cloud products. Flags are assigned to HIRS pixels to indicate their likelihood of cloud contamination. Radiosonde data and profiles derived from Global Positioning System Radio Occultation are incorporated to reduce retrieval biases. Preliminary results show that for the temperature retrieval scheme, the root mean square errors are 1.96-2.81 K for lower troposphere, 1.48-1.61 K for mid to upper troposphere, and 1.96-2.52 K for stratosphere when compared to global radiosondes. For humidity retrievals, the root mean square error is 2.20 g/kg at 850 hPa and gradually decreases with height. Detailed analyses will be presented.

Tue-167

A comparison of two ensemble generation methods using oceanic singular vectors and atmospheric lagged initialization for decadal climate prediction

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The sensitivity of ensemble spread and forecast skill scores of decadal predictions to details of the ensemble generation is investigated by incorporating uncertainties of ocean initial conditions using ocean singular-vector-based (OSV) perturbations. Results are compared to a traditional atmospheric lagged initialization (ALI) method. Both sets of experiments are performed using the Earth System Model from the Max Planck Institute for Meteorology (MPI-ESM) initialized from the GECCO2 ocean synthesis. The OSVs are calculated from a linear inverse model based on a historical MPI-ESM run. During the first three lead years, the sea surface temperature spread from ALI-hindcasts appears to be strongly underestimated, while OSV-hindcasts show a more realistic spread. However, for later lead times (second pentad of hindcasts), the spread becomes overestimated for large areas of the ocean in both ensembles. Yet, for integrated measures such as the North Atlantic SST and Atlantic meridional overturning circulation, the spread of OSV-hindcasts is overestimated at initial time and reduces over time. The spread reliability measures are shown to be sensitive to the choice of the verification data set. In this context, it is found that HadISST tends to underestimate the variability of SST as compared to Reynolds SST and satellite observations. In terms of forecast skill for surface air temperature, SST and ocean heat content, OSV-hindcasts show improvement over ALI-hindcasts over the North Atlantic Ocean up to lead year five.

Tue-168

High-resolution multi-decadal simulations of tropical cyclone activity using CAM5

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This work examines how characteristics (e.g., intensity, spatial distribution and frequency) of tropical cyclones (TCs) that are explicitly resolved in various versions of the Community Atmosphere Model version 5 (CAM5) are projected to change in a warmer climate. CAM5 is configured with a horizontal grid spacing of approximately 28 km and is forced with prescribed sea-surface temperatures (SSTs). This study includes a comparison of TC activity with two different dynamical cores (i.e., the central fluid flow component of the model) in the CAM5 framework, the hydrostatic finite-volume (FV) and spectral element (SE) configurations. We find a decrease in overall global TC activity as climate warms. By contrast, the frequency of very intense TCs is projected to increase dramatically in a warmer climate, with most of the increase concentrated in the Northwest Pacific basin. Extreme precipitation associated with TCs is also projected to become more common. Basin-scale projections of future TC activity are subject to large uncertainties due to uncertainties in future SSTs.

Tue-169

Sub-decadal North Atlantic Oscillation Variability in Observations and the Kiel Climate Model

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The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic sector. The corresponding NAO index describes the sea level pressure difference between the subtropical high and the subpolar low. This index exhibits variability on a wide range of timescales. The sub-decadal variability of the NAO is pronounced in observations and models, but the underlying mechanism is still under discussion. Other indices of North Atlantic sector climate variability such as indices of sea surface and surface air temperature or Arctic sea ice extent also exhibit pronounced sub-decadal variability. Our analysis is based on the Kiel Climate Model (KCM), a global climate model, which simulates sub-decadal variability in the North Atlantic sector consistent with historical sea surface temperature and sea level pressure observations. The KCM's enhanced sub-decadal NAO variability is suggested to originate from large-scale air-sea interactions. The slow adjustment of the Atlantic Meridional Overturning Circulation to previous surface heat flux variability provides the memory of the coupled mode. The results stress the role of coupled feedbacks in generating sub-decadal North Atlantic sector climate variability, which is important to multiyear climate predictability in that region.

Tue-170

Uncertainty in 21st Century Projections of the Atlantic Meridional Overturning Circulation

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Climate models project a weakening of the Atlantic Meridional Overturning Circulation (AMOC) during the 21st century. However, these projections are subject to uncertainties. Three different sources of uncertainty are quantified in our analysis: internal variability, model uncertainty, and scenario uncertainty. We use the 21st century projections of the Coupled Model Intercomparison Phase 3 (CMIP3) and Phase 5 (CMIP5). At lead times longer than a few decades, model uncertainty dominates uncertainty in future projections of AMOC strength at 30°N in both the CMIP3 and CMIP5 model ensembles. Internal variability is important only during the first few decades and scenario uncertainty is relatively small at all lead times. The model uncertainty in the AMOC projections arises mostly from uncertainty in density, while uncertainty arising from wind stress (Ekman transport) is negligible. Finally, the uncertainty in density projections originates mostly from the simulation of salinity, rather than temperature. High-latitude freshwater flux and the subpolar gyre projections are also analyzed, because these quantities are thought to play an important role for the future AMOC. The freshwater input in high latitudes is projected to increase and the subpolar gyre is projected to weaken. Both the freshening and the gyre weakening likely influence the AMOC by causing anomalous salinity advection into the regions of deep water formation.

Tue-171

A reversal of climatic trends in the North Atlantic since 2005

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In the mid-1990s the North Atlantic subpolar gyre warmed rapidly, which had important climate impacts, such as increased hurricane numbers, and changes to rainfall over Africa, Europe and North America. Evidence suggests that the warming was largely due to a strengthening of the ocean circulation, particularly the Atlantic Meridional Overturning Circulation (AMOC). However, since the mid-1990s direct and indirect measurements have suggested a decline in the strength of the ocean circulation, which is expected to lead to a reduction in northward heat transport.Here we show that since 2005 a large volume of the upper North Atlantic Ocean has cooled significantly by approximately -0.45C or -1.5x10^22 J, reversing the previous warming trend. By analysing observations and a state-of-the-art climate model, we show that this cooling is consistent with a reduction in the strength of the ocean circulation and heat transport, linked to record low densities in the deep Labrador Sea. The low density in the deep Labrador Sea is primarily due to deep ocean warming since 1995, but a long-term freshening also played a role. Finally, the observed upper ocean cooling since 2005 is not consistent with the hypothesis that anthropogenic aerosols directly drive Atlantic temperatures.

Tue-172

Decadal prediction of the North Atlantic subpolar gyre in the HiGEM high-resolution climate model

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Many independent studies have shown that initialising models from observations improves retrospective predictions of North Atlantic surface temperature variability (SST). However, to date, the reasons behind the improved skill have only been studied in a few -- low resolution -- climate prediction systems. Studies have also focused on a single case-study. Therefore, questions still remain regarding the robustness of the improvement and the important mechanisms responsible. Here we present an analysis of initialised retrospective decadal predictions (or hindcasts) made with the HiGEM coupled climate model, which has a nominal resolution of 90km in the Atmosphere, and 1/3 degree in the ocean.HiGEM decadal predictions (HiGEM-DP) exhibit significant skill at capturing 0--500m ocean heat content in the North Atlantic subpolar gyre (SPG), and outperform historically forced transient integrations and persistence for up to a decade ahead. An analysis of case-studies of North Atlantic decadal change, including the 1960s cooling and the mid-1990s warming, shows that changes in ocean heat transport dominates the predictions of the SPG, consistent with previous studies. However, the exact details of the mechanisms are somewhat different, including a less important role of ocean circulation changes at the latitudes of the SPG and a greater role for surface fluxes in the 1960s. The processes that control regional heat content anomalies is also found to be spatially dependent. Ocean advection dominates predicted heat content change in the east SPG, but surface fluxes dominate the west. Finally, in the early 1990s, HiGEM-DP captures a shift in atmospheric circulation to a positive state of the North Atlantic Oscillation, which is consistent with the observed changes. These results support the hypotheses that changes in the North Atlantic ocean circulation played an important role in driving past changes in regional temperatures and the wider climate, and that these changes could have been predicted.

Tue-173

Multi-year prediction of Marine Productivity in the Tropical Pacific

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Phytoplankton is at the base of the marine food web. Their carbon fixation, the net primary productivity (NPP), sustains most living marine resources and global fisheries. In certain regions, e.g. the tropical Pacific, NPP exhibits natural fluctuations at interannual to decadal time scales that have large impacts on marine ecosystems and fisheries. The predictions of NPP fluctuations could be of major relevance to the science-based management of marine resources. Yet, at present, the predictive capacity is hampered by the ability of Earth system models to reproduce the phasing and the amplitude of NPP variations. Here, we use observed sea surface temperature as a simple approach to partly overcome this difficulty. We present the first retrospective prediction of NPP over the last decades (i.e., from 1997 to 2010) with an Earth system model. Our analyses focus on the tropical Pacific, a region hosting the world largest fisheries. Results suggest a predictive skill for NPP of 3 years, which is higher than that of physical ocean fields such as SST (1 year). As opposed to SST, biogeochemical fields are isolated from the stochastic noise of the atmosphere. The increased predictability arises from the poleward advection of surface nutrients and iron anomalies, which sustain fluctuations of ocean productivity over years. These results open novel perspectives to the development of science-based management approaches to marine resources relying on integrated physical-biogeochemical forecasting systems.

Tue-174

Seasonal-to-interannual prediction skills of near-surface air temperature in the CMIP5 decadal hindcast experiments

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This study explores the seasonal-to-interannual near-surface air temperature (TAS) prediction skills of state-of-the-art climate models that were involved in phase 5 of the Coupled Model Intercomparison Project (CMIP5) decadal hindcast/forecast experiments. The experiments are initialized in either November or January of each year and integrated for up to 10 years, providing a good opportunity for filling the gap between seasonal and decadal climate predictions. The long-lead multimodel ensemble (MME) prediction is evaluated for 1981–2007 in terms of the anomaly correlation coefficient (ACC) and mean-squared skill score (MSSS), which combines ACC and conditional bias, with respect to observations and reanalysis data, paying particular attention to the seasonal dependency of the global-mean and equatorial Pacific TAS predictions. The MME shows statistically significant ACCs and MSSSs for the annual global-mean TAS for up to two years, mainly because of long-term global warming trends. When the long-term trends are removed, the prediction skill is reduced. The prediction skills are generally lower in boreal winters than in other seasons regardless of lead times. This lack of winter prediction skill is attributed to the failure of capturing the longterm trend and interannual variability of TAS over high-latitude continents in the Northern Hemisphere. In contrast to global-mean TAS, regional TAS over the equatorial Pacific is predicted well in winter. This is mainly due to a successful prediction of the El Niño–Southern Oscillation (ENSO). In most models, the wintertime ENSO index is reasonably well predicted for at least one year in advance. The sensitivity of the prediction skill to the initialized month and method is also discussed.

Tue-175

Multidecadal Variability in Global Surface Temperatures Related to the Atlantic Meridional Overturning Circulation in a Large CESM Ensemble

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Multidecadal internal climate variability centered in the North Atlantic has been observed in sea surface temperatures and is assumed to be related to variations in the strength of the Atlantic Meridional Overturning Circulation (AMOC). The extent to which variations in the overturning circulation may alter regional and global temperature trends is examined in this work.

We use a large Community Earth System Model (CESM) ensemble, which simulates different, but plausible evolutions of the AMOC during the 20th century. Within this climate model, climate variability associated with AMOC changes superimposes linearly onto the forced response and can therefore be isolated within our large ensemble.

We show that a strengthening (weakening) of the AMOC alters the surface heat flux into the global ocean, mainly the heat flux into the Labrador Sea, and accordingly decreased (increased) amounts of heat are stored in the Atlantic. With a time lag of several decades also ocean heat storage in the Pacific and Indian Oceans is affected. Using ECBilt-Clio, an Earth System Model of Intermediate Complexity, the influence of AMOC on ocean heat storage is confirmed by hosing experiments, in which freshwater is added to the North Atlantic to force the AMOC to weaken.

By influencing ocean heat uptake, AMOC variations modulate global surface air temperature trends on a decadal time scale. Within CESM internal variability associated with AMOC trends can contribute up to about ±0.1 K per decade to 30 year trends and thereby may amplify or suppress the global warming signal significantly on a decadal time scale.

Tue-176

Contribution of Atlantic and Pacific Multidecadal Variability to 20th Century Climate Change

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It has been proposed that parts of the observed warming in the early and the late 20th century were caused by multidecadal internal variability that is centered in the Atlantic and Pacific Oceans. Here, we search for segments of unforced pre-industrial control simulations of CMIP5 climate models that best match the observed Atlantic and Pacific multidecadal variability (termed as "AMV" and "PMV", respectively). The combination of these variability analogues provides an estimate of the influence of AMV and PMV on temperature trends during the 20th century. This method allows to resolve the effects of AMV and PMV on the climate spatially and is internally consistent across climate variables. As the method is based on existing CMIP5 control integrations it does not require specific model setups, but we can utilize the full suite of CMIP5 models. We find the amplitude of internal variability to be up to 0.18°C on a decadal timescale for global surface air temperatures. Around 0.04°C decade-1 or approximately 20% of the observed global warming rate of 0.18°C decade-1 between 1971 and 2000 can be attributed to AMV and PMV. Internal variability also contributed to the warming between 1920 and 1940 and the subsequent period of slight cooling. The contribution of internal variability onto Northern Hemisphere temperatures is with 0.05°C decade-1 to the measured Northern Hemisphere warming of 0.24°C decade-1 (1971-2000) similar to the internal variability influence on global temperatures. The influence of internal variability is particularly large over the Arctic region and part of the observed winter sea ice decline during the last decades may be related to the AMV. The importance of internal variability decreases with increasing length of the period that is considered. Hence, the overall 20th century warming cannot be explained by internal variability and we do not find support for earlier findings, where a substantial part of the overall warming has been attributed to internal variability.

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The sensitivity of ocean heat content from reanalyses to the atmospheric reanalysis forcing: a comparative study

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The global ocean heat content evolution is a key component of the Earth's energy budget and can be accurately determined by ocean reanalyses that assimilate hydrographic profiles. This work investigates the impact of the atmospheric reanalysis forcing through a multi-forcing ensemble ocean reanalysis, where the ensemble members are forced by five state-of-the-art atmospheric reanalyses during the meteorological satellite era (1979-2013). Data assimilation leads the ensemble to converge towards robust ocean heat content estimates and significantly reduces the spread (1.48 +/- 0.18 W/m2, per unit area of the World Ocean); hence the impact of the atmospheric forcing appears only marginal for the global heat content estimates in both upper and deeper oceans. A sensitivity assessment performed through realistic perturbation of the main sources of uncertainty in ocean reanalyses highlights that bias-correction and pre-processing of in-situ observations represent the most crucial component of the reanalysis, whose perturbation accounts for up to 60% of the ocean heat content anomaly variability in the pre-Argo period. These results reveal useful information for the ocean observation community and for the optimal generation of perturbations in ocean ensemble systems. Additional information on the dependence of the quality of ocean reanalyses from atmospheric products are also presented.

Tue-178

The CMCC Global Ocean Reanalysis System

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An eddy-permitting global ocean reanalysis system is under continuous development at CMCC. The system is called C-GLORS (CMCC Global ocean reanalysis system) and implements a 3DVAR data assimilation scheme to assimilate hydrographic profiles and altimetry data, a nudging scheme for assimilating sea-surface temperature and sea-ice concentration data from satellite, and a large-scale bias correction scheme. The ocean model component is NEMO at 1/4 degree resolution coupled with the LIM2 sea-ice thermo-dynamical and dynamical model. Here we present the main results from the production of C-GLORS v4 and v5 in terms of performance of the system. Applications of the reanalysis in comparison studies and process-oriented analyses will be given as well, looking in particular at the effect of data assimilation on polar regions transports and eddy tracking. We also outline motivation and preliminary studies targeted at producing an improved version of the reanalysis.

Tue-179

Climate related multi-decadal variability of tropical oxygen minimum zones

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Subsurface low oxygen layers often called oxygen minimum zones (OMZ) exist in all tropical ocean basins, the most pronounced one in the eastern Pacific Ocean. Both, numerical models and observations show changes in dissolved oxygen (DO), which are likely caused by global warming. Tropical and subtropical DO decreases in most regions of the world ocean, however, isolated regions with increasing DO exist. Typical upper ocean oxygen trends range from -0.5 to +0.4 micromol/kg/yr, with a global mean oxygen trend of -0.066 micromol/kg/yr between 50S and 50N at 300 dbar for the period 1960 to 2010. An estimate for the total world ocean oxygen loss is about 2% over the last 50 years. These DO trends are a combination of long-term trends superimposed with (multi-)decadal and short-term variability. While the exact processes at play remain elusive, causes of the variability involved are climate-change related ocean warming, variations in the supply paths of oxygen-rich water via zonal near-equatorial current bands, changes in the expansion and speed of the subtropical gyres, Pacific Decadal Oscillation (PDO), changes in the subtropical-tropical cell (STC) strength and El Nio events. Historical data were combined with recent measurements from the German research initiative SFB-754 Climate-biogeochemistry interactions in the tropical ocean. An example for the PDO impact on DO in the Pacific region (5N-5S, 105-115W, 300-700 m) is the trend of decreasing oxygen concentration, -0.13 mmol kg-1 yr-1 for the period 1960 to 2012, and at a much higher value of -0.54 mmol kg-1 yr-1 for the period 1979 to 2012. The period since 1960 comprises both, a cold and a warm PDO phase, while the period since 1979 mainly covers the warm PDO phase and a short reversed period thereafter. The oxygen and nutrient trends 1976 2012 in a Pacific area (2S-5S, 84-87W, 50-300 m) show a decrease in oxygen and increase in nutrient concentrations for the warm PDO phase. However, analyzing the data set back to 1960 and computing the trend for the period 1960 to 1995 leads to reverse trends for oxygen and nutrient concentrations related to a slowdown of the Pacific STC by 30% from the 1960s to the 1990s. As another example, in the tropical Atlantic multidecadal variations in oxygen are superimposed on a long-term trend. Mechanisms at play are Atlantic Meridional Overturning Circulation (AMOC) variations as well as changes in the strength of latitudinal stacked zonal jets.The oxygen variations and extend of OMZs interact with natural or eutrophication-induced hypoxic shelf areas and impact pelagic and shelf ecosystem and fishery. Hence, understanding the upper ocean (multi-)decadal oxygen variability is important to predict future shifts in the ecosystem and consequences on coastal state economics.

Tue-180

Enhancement of the summertime 10–25-day oscillations over the northern South China Sea since the mid-1990s

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An interdecadal change is detected in the intensity of summertime intraseasonal oscillations (ISOs, 10–90 days) of convection over the northern part of the South China Sea (NSCS) in the mid-1990s. The abrupt point of the interdecadal change is verified in 1993/1994, according to the moving t-test, and the ISOs over the NSCS are significantly enhanced after the mid-1990s. It is found that the enhancement of the 10–25-day oscillations mainly contributes to the interdecadal intensification of the ISOs over the NSCS. The interdecadal difference of the 10–25-day variance takes up 67% of that of the total intraseasonal variance over the NSCS. The 30–80-day oscillations, by contrast, contribute only slightly to in the interdecadal change of the ISO intensity over the NSCS. The circulation ISOs are in accordance with the convection ISOs, although they tend to extend into the western North Pacific. From the perspective of the energy conversion, the enhancement of the 10–25-day oscillations after the mid-1990s is attributed to the fact that more eddy kinetic energy is transformed from the time-mean kinetic energy. The anomalous eddy kinetic energy conversion is caused by the interdecadal change of the mean state zonal winds, which is characterized by the convergence of the anomalous westerly winds over the northern part of the Philippine Sea in the lower troposphere and the anomalous cyclonic shear over the East China Sea in the upper troposphere.

Tue-181

Interdecadal variability of basin-averaged ocean heat content in the climate model MIROC5.2

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Interdecadal variability of the basin averaged steric sea level was investigated using the climate model MIROC5.2 comparing with recent observations. In the recent decade, the change of global mean SST shows slower rate of warming during the late 20th century. Meanwhile, the change of global averaged ocean heat content continues increasing, that is consistent with the thermosteric sea level change. During this period, we can also see increasing of the ocean surface heat input in the equatorial Pacific related to strengthening of the trade wind. About a half of the heat input plausibly explains the abrupt increase of the Indian Ocean heat content through the Indonesian through flow. Interdecadal fluctuations with a similar heat uptake mechanism were identified in the climate model MIROC5.2 under the fixed external condition of 1850. The result indicates that the inherent interdecadal variability modified the recent anthropogenic global warming trends

Tue-182

The value of Large Ensembles over control runs for estimating internal climate variability

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Large Ensembles (LEs) are a rapidly emerging resource for investigating how internal variability modulates the climate system's response to external forcing. Large ensembles typically consist of multiple (~30-100) runs of the same climate model, driven by the same forcing, wherein the ensemble members differ only in round-off scale changes in their initial conditions. However, despite their value, LEs have until recently been rare, due to their high computational cost and the competing interests of model resolution and complexity. An alternative strategy for estimating internal variability is to examine long unforced control runs. It has been suggested that the internal-variability induced uncertainty in future trends of temperature and precipitation can, under certain assumptions, be estimated as robustly from a pre-industrial control run as it can be from a large ensemble. Since control runs are routinely performed and readily available, this argues against investing resources in Large Ensembles for estimating future trend uncertainty. However, here we show that this is not true for all variables, using Arctic sea-ice as an example. Specifically we show that internal-variability induced uncertainty in Arctic sea-ice trends is significantly underestimated when using control runs relative to the true uncertainty derived from large ensembles of the CESM1 and CanESM2 climate models. We show that the reasons for this are because sea-ice variability is not stationary in time, and because sea-ice trends are not linear, breaking two of the assumptions of the "control run" approach. Furthermore, we show that these factors also mean standard t-like statistical tests often used to test for the (in) consistency of trends between observations and individual model realizations are overly conservative. The underestimation of the true variability of Arctic sea-ice trends leads to a systematic bias in the tests and an inflation of type-I error by a factor of 2 or more. Thus we suggest that previous conclusions that observed and simulated Arctic sea-ice trends differ significantly are far less robust than reported. We posit that other climate variables show similar behavior, and that Large Ensembles are the only mechanism available for robustly quantifying uncertainty in historical and future trends across the full climate system.

Finally we note that control runs cannot constrain the forced response, and this can only be achieved using an ensemble of forced simulations. The clear separation between forced response and internal variability achieved in the large ensembles allows the identification of effects that would otherwise be undetectable given internal variability and inter-model spread, which we demonstrate using the example of the tropical Pacific response to explosive volcanoes. Thus, large ensembles aid in process understanding that would be unachievable using control runs, individual models realizations or mixed-model ensembles. We conclude that single-model large ensembles add significant value to our understanding of the forced response and its modulation by internal variability.

Tue-183

The UK Earth System Model for Climate Prediction

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In this talk we will describe the development and current status of the UK Earth System Model (UKESM). This is a NERC/Met Office collaboration project. We are building numerical models that include all the key components of the global climate system, and contain the important process interactions between global biogeochemistry, atmospheric chemistry and the physical climate system. UKESM will be used to make key CMIP6 simulations as well as long-time (e.g. millennium) simulations, large ensemble experiments and investigating a range of future carbon emission scenarios. I'll describe what are the current UKESM model version and some insights of the key findings from UKESM1 releases.

Tue-184

The CRESCENDO Project: Next generation of European Earth System Models

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CRESCENDO (Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach) is a European Union Horizon 2020 Project funded under the program SC5-01-2014: Advanced Earth-system models. CRESCENDO started in November 2015 and runs for 5 years. The primary aims of CRESCENDO are: (i) to improve the representation of key process-parameterizations in European Earth System Models, (ii) to thoroughly evaluate the scientific performance of these models and (iii) to use the models to generate a new set of Earth system projections for the coming century. CRESCENDO brings together 7 European Earth System Modelling (ESM) teams and 3 European Integrated Assessment Modelling (IAM) groups, with experts in ESM performance evaluation, future projection analysis, climate impacts, regional downscaling and science communication. The project provides a coordinated European contribution to the 6th Coupled Model Intercomparison Project (CMIP6) Model development concentrates on key biogeochemical and aerosol processes, targeting in particular an improved representation of the coupled carbon cycle , through improvements to marine biogeochemistry, inclusion of soil-vegetation nitrogen processes, vegetation dynamics, wildfires and permafrost. Natural aerosol processes and their associated radiative forcing is also a key model development target. All improvements will be evaluated at the process-level and as part of a fully coupled ESM. This will be done through continued development of the community evaluation tool; ESMValTool (Eyring et al 2015). Finally, the project will coordinate an ensemble of ESM projections for the CMIP6 scenarioMIP activity. If you are interested in CRESCENDO, please find more information and sign up for project updates at our website www.crescendoproject.eu, or alternatively contact us at: contact@crescendoproject.eu.

Reference: Eyring et al. (2015) ESMValTool (v1.0) – a community diagnostic and performance metrics tool for routine evaluation of Earth System Models in CMIP, Geosci. Model Dev. Discuss., 8, 7541-7661, doi:10.5194/gmdd-8-7541-2015, 2015

Tue-185

Aerosol optical depth and single scattering albedo variability over Arabian Sea during 2002-2015

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Aerosols are recognized as the major source of uncertainty in earths radiation budget and climate. In this paper an effort has been made to analyze the spatio-temporal distribution of aerosol optical depth (AOD) derived from Aqua-MODIS over Arabian Sea (4o N26o N to 50o E78 E) during the period 2002-2015. We have also analyzed the variability of aerosol single scattering albedo (SSA) from OMI (Ozone Monitoring Instrument) to understand the scattering properties of aerosols. For AOD we have used, for the first time, the latest and more reliable aerosol product MYD08_M3 version 6 at 550 nm data from Aqua-MODIS, while for SSA OMAEROe V003 product at 483.5 nm have been used. The mean annual AOD was found to be 0.36 0.21 with the highest value of 0.8 near the west coast of Pakistan. The AOD was observed to have sharp increase with latitude (4 N26 N) having minimum value of 0.22 at 4 N and maximum value of 0.45 at 26 N. We found an increasing trend (AOD= 13.4 %) in AOD during the study period. The seasonal distribution of AOD has also been discussed in the paper. Two major hotspots (AOD~1.0) were identified during the summer season (JJA) in the study region: one near the west coast of Pakistan and second near the eastern coast of Oman. The AOD remained high (greater than 0.50) during the summer season and below 0.4 during winter (DJF), spring (MAM) and autumn (SON) seasons throughout the study period. The average value of SSA was found to be 0.96 0.02 indicating the dominance of scattering type of aerosols over Arabian Sea. Contrary to AOD, the SSA showed decreasing trend with latitude (4 N26 N) having minimum value of ~0.94 at 26 N and maximum value of ~0.97 at 4 N.

Tue-186

Tropical Atlantic SST decadal variability: the role of tropical Pacific versus subpolar Atlantic

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The Atlantic Multidecadal Variability, or AMV, is one of the most prominent climate modes with a multidecadal time scale. While it is not clear what mechanisms give rise to the multidecadal time scale of AMV, whether it is anthropogenically forced or caused by unforced climate variability, it is clear that the tropical component of the AMV is the one that directly influences the atmospheric circulation and the related climate anomalies. This study explores the inter-relation between tropical Atlantic SST, the tropical Pacific SST, and the subpolar Atlantic SST on decadal time scales to assess the models ability to accurately represent these relationships and the related climate impacts. We found that some CMIP5 models tend to have a stronger link between the tropical Atlantic and the tropical Pacific SST than observations, leading to climate impact that is dominated by the Pacific SST in these models. When the tropical Pacific influence on Atlantic SST is removed, the models and observations tend to agree better in terms of their atmospheric circulation-AMV linkages and the associated climate impacts. We also explore the mechanisms of the decadal tropical Atlantic SST generation using lag-lead multiple regressions.

Tue-187

A new data set of historical coastal climatology: Signal Stations of the German Marine Observatory Hamburg

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A long overseen source of synoptic data collected along the coast of Germany has been detected, and is presently digitized. The data stem from warning posts in harbors along the coast, so called “Signalstationen”, which recorded estimated wind-speed and direction, wave conditions, air pressure and precipitation. The first post began operating in 1877 and the last ceased operation in 1999. Signal Stations were positioned close to the shore to convey severe weather warning of the German Marine Observatory in Hamburg to ships and the coastal population. This was done by raising optical signals such as balloons, triangles, cylinders and flags. Reports were prepared 3 to 9 times per day. These observations did not enter the regular weather analysis process of the weather service, but were later archived: Now, about 800 handwritten journals are archived at the German Meteorological Service in Hamburg, and some are now available for further analysis. A first inspection of these data indicates a wealth of data, which are well suited for high-resolution description of historical coastal events such as the storm surges in the southern Baltic Sea on 31 January 1913 or in the German Bight on 12 March 1906. The temporal homogeneity is sometimes compromised and homogenization is required. Estimated wind conditions, available so far at two stations for more than 100 years, allow for the first time an assessment of changing storm conditions based on wind data (instead of proxies such as annual percentiles of geostrophic wind distributions). The pressure data may be used to generating fine-scale synoptic analysis but also for calculating geostrophic wind statistics on spatial scales much shorter than what was possible so far.

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Assimilation of temperature and salinity profile data in the Norwegian Climate Prediction Model

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Assimilating temperature and salinity profile data is promising to constrain the ocean component of Earth system models for the purpose of seasonal-to-dedacal climate predictions. However, assimilating temperature and salinity profiles that are measured in standard depth coordinate (z-coordinate) into isopycnic coordinate ocean models that are discretised by water density is challenging. Prior studies (Thacker and Esenkov, 2002; Xie and Zhu, 2010) suggested that converting observations to the model coordinate (i.e. innovations in isopycnic coordinate) performs better than interpolating model state to observation coordinate (i.e. innovations in z-coordinate). This problem is revisited here with the Norwegian Climate Prediction Model (NorCPM), which applies the ensemble Kalman filter (EnKF) into the ocean isopycnic model of the Norwegian Earth System Model. We perform first Observing System Simulation Experiments (OSSEs) to compare two schemes (the EnKF-z and EnKF-ρ). In OSSEs, the truth is set to the EN4 objective analyses and observations are perturbations of the truth with white noises. It is found that EnKF-z outperforms EnKF-ρ for different observed vertical resolution, inhomogeneous sampling (e.g. upper 1000 meter observations only), or lack of salinity measurements. It is mostly because converting z-level observations into isopycnic coordinate introduces high uncertainties into the cost function due to high uncertainties in the estimation of layer interface depth of observations. We study also the horizontal localisation radius via the two-point ensemble correlation of temperature and salinity. The moderate localisation radius in the upper ocean is about 1500 km. Finally, we perform EnKF-z in a realistic framework with NorCPM over a 8-year analysis period to demonstrate the reliability of EnKF-z. The analysis is validated by different independent datasets.

Tue-189

A quantitative definition of global warming hiatus and 50-year prediction of global mean surface temperature

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Recent global warming hiatus has received much attention; however, a robust and quantitative definition for the hiatus is still lacking. Recent studies (Scafetta, 2010; Wu et al., 2011; Tung and Zhou, 2013) showed that multi-decadal variability (MDV), is responsible for the multi-decadal accelerated warming and hiatuses in historical global mean surface temperature (GMST) records, though MDV itself has not received sufficient attention thus far. Here, we introduce four key episodes in GMST evolution, according to different phases of the MDV extracted by the ensemble empirical mode decomposition method from the ensemble HadCRUT4 monthly GMST time series. The "warming/cooling hiatus" and "typical warming/cooling" periods are defined as the 95% confidence intervals for the locations of local MDV maxima/minima and of their derivatives, respectively. Since 1850, the warming hiatuses, cooling hiatuses and typical warming have already occurred three times, and the typical cooling, twice. At present, the MDV is in its third warming hiatus period, which started in 2012 and would last until 2017, followed by a 30-year cooling episode, while the trend will sustain the current steady growth in the next 50 years. Their superposition presents ladder-like rising since 1850. It is currently ascending a new height and will stay there until the next warming phase of the MDV carries it higher.

Tue-190

Impacts of the Pacific-Japan and circumglobal teleconnection patterns on interdecadal variability of the East Asian summer monsoon

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Based on the 20th century reanalysis (20CR) dataset, the dominant modes of interdecadal variability of the East Asian summer monsoon (EASM) are investigated through a multivariate empirical orthogonal function analysis (MV-EOF). The first mode (EA1) is characterized by an anomalous cyclone centered over Taiwan and an anomalous anticyclone centered over the Bohai Sea. These phenomena are part of the meridional wave-like teleconnection pattern propagating poleward from the southern tropical western North Pacific (WNP), referred to as the interdecadal Pacific–Japan (PJ) pattern. The interdecadal PJ pattern is driven by negative anomalous convective heating over the southern tropical WNP, which is associated with the Interdecadal Pacific oscillation (IPO) and the interdecadal Indian Ocean basin mode (IOBM). The amplitude of the EA1 and its contribution to the total variance of the EASM decrease remarkably after the 1960s. The second MV-EOF mode (EA2) is characterized by cyclone anomalies extending from northeastern China to Japan, which are part of a circumglobal wave train. Given the spatial scale of the wave train in the zonal direction (wavenumber-5), as well as the fact that it possesses barotropic structures and propagates along the Northern Hemispheric jet stream, we refer to it as the interdecadal circumglobal teleconnection (CGT) pattern. The interdecadal CGT pattern is associated with the forcing from the Atlantic multi-decadal oscillation (AMO). Though the interdecadal PJ and CGT patterns are derived from the 20CR dataset, they are carefully verified through comparisons with various observational and reanalysis datasets from different perspectives.

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Recurrent Replenishment of Labrador Sea Water and Associated Decadal-Scale Variability

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The northern North Atlantic (NA) is a key area to variability in the global climate system because of deep convection contributing to the Atlantic Meridional Overturning Circulation (AMOC) and strong decadal-scale variability contributing to hiatus periods in global warming. With global climate models projecting surface ocean warming and freshening and increasing stratification at high latitudes, as well as weakening of the AMOC, it is important to have ongoing robust observations of various aspects of the AMOC, including water mass properties and export rates in major deep convection areas. Using a combination of hydrographic and tracer surveys, profiling float and mooring data we analyze the depth, strength and extent of winter convection in the Labrador Sea (LS), and its contribution to decadal variability and deep water renewal and ventilation in the NA. Same-year ship surveys conducted on the AR7W repeat hydrography (monitoring) line by the Bedford Institute of Oceanography (Fisheries and Oceans Canada's Atlantic Zone Off-shelf Monitoring Program), the University of Bremen and the GEOMAR Helmholtz Centre for Ocean Research Kiel are used to estimate the properties and volume changes of the Labrador Sea Water (LSW) within first months following its formation. In contrast to a number of recent studies that report an ongoing reduction in deep convection (and hence in the AMOC), we show that the LS convection depths during the winters of 2014-2016 were the largest since the record values of the early 1990s and among the larger ones in the historical record (since 1938). We then examine the associated LS temperature, salinity and density variations in relation to their seasonal and interannual evolution using both mooring and profiling float data, and estimates of their annual means from historical hydrographic profiles. We suggest that intermittent deep convection on pentadal-to-decadal time scales is continuing to generate voluminous "year classes" of LSW with varying properties that can be expected to have broader-scale influences on the NA and AMOC. Temperature and salinity profiles from Argo floats, moored instruments and vessel surveys show that winter convective overturning in the central LS reached an "aggregate" maximum depth of 1700m in both 2015 and 2016 – the deepest since the modern observational record of 2400m in 1994, and the resulting 2012-2016 LSW class is one of the largest ever observed outside of the early 1990s. Annual LSW export rates from the greater LS region since 2002 are estimated to be in the range of 3-11 Sv, with an average difference of ~6 Sv between relatively-strong and relatively-weak convection years. Historical time series indicate that intermittently recurrent deep convection is contributing to predominant decadal-scale variations in intermediate-depth temperature, salinity and density in the central LS, with implications for decadal-scale variability across the subpolar NA and potentially in the Atlantic Meridional Overturning Circulation. Comparison of the interannual variability in LS ocean heat content change and cumulative surface heat loss

during the cooling seasons of the Argo era indicates that anomalously strong winter atmospheric cooling associated with the North Atlantic Oscillation is continuing to drive the recurrent convection.

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Recent hydrographic variability in deep and abyssal waters in the Labrador Sea and along the outer continental margin of Atlantic Canada

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Temperature, salinity and density variability of the major North Atlantic water masses between the Labrador Sea and eXtended Halifax Line (XHL) off Nova Scotia are described using historical datasets, ongoing vessel observations, Argo profiles, and moored measurements. Attention is focussed on particular water masses such as the Labrador Sea Water (LSW), the Northeast Atlantic Deep Water (NEADW) and the Denmark Strait Overflow Water (DSOW), and on the patterns of hydrographic changes and events spreading with these waters both across the Labrador Sea and along the continental margin. The evolution of water mass properties and characteristics of the signals detected at all studied locations is associated with the Labrador Current and the Deep Western Boundary Current (DWBC) steering over complex topography, encountering the Gulf Stream and the Antarctic Bottom Water, recirculating and mixing. For example, there has been a notable warming of the mid-slope near-bottom (~1000m) waters on the Labrador Slope since the early 1990s and on the Scotian Slope since the late 1990s which may include a contribution from anthropogenic climate change. However, examination of earlier data indicates higher temperatures in the preceding decades, and that this change is at least in part a recovery from cooling associated with enhanced LSW production in the late 1980s and early 1990s. There are also indications of decadal-scale variations in the properties of deeper waters in the DWBC and above that can reach the Scotian Rise, resulting from anomalous events in their upstream formation regions. As other examples of the hydrographic and tracer changes spreading in the intermediate, deep and abyssal layers of the northwest Atlantic we discus LSW signals arriving in the Orphan Basin about six months after their initiation by winter convection in the Labrador Sea and at XHL with a longer delay; recent temperature and salinity increases in NEADW and DSOW; 4-6 year cycles in DSOW temperature, salinity, density and dissolved oxygen. We also look at the upstream variability of DSOW and NEADW, and variability in both overflows and entrained cold fresh LSW and warm saline Atlantic Water in our effort to understand and interpret decadal trends and shorter-term variability in the North Atlantic deep and abyssal waters.

Tue-193

The Changing El Niño Dynamics and Impacts since the Early-1990s Climate Shift in the Pacific

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There is substantial evidence that significant changes occurred in broad areas of the Pacific in the early 1990s, including the shift of the location of El Nio events from the eastern Pacific to the central Pacific (CP). Observational analysis and coupled model experiments are conducted to show that the early-1990s climate shift is linked to a phase change of the Atlantic Multi-decadal Oscillation (AMO) that occurred at about the same time. The recent emergence of the CP El Nio can be attributed to this AMO phase change via the following chain of events: a switch in the AMO to its positive phase in the early 1990s led to an intensification of the Pacific Subtropical High. The intensified High resulted in stronger-than-average background trade winds that enhanced the Wind-Evaporation-SST feedback mechanism, strengthening the subtropical Pacific coupling between the atmosphere and ocean, making the subtropical Pacific precursors more capable of penetrating into the deep tropics, and ultimately leading to increased occurrence of the CP El Nio events. Associated with the change of the El Nio type, the El Nio teleconnection is found to become different after the early-1990s. A changing relationship between El Nio and Southern Hemisphere climate will be presented in the talk. Evidence is also found that the typical drought pattern in Eastern China diminished after the early-1990s climate shift and is replaced by a new pattern that is produced by the AMO via a Eurasian wave train emanating from North Atlantic to China. This study indicates that the early 1990s is a time when the Atlantic began to exert a stronger influence on climate over East Asia and a large part of the Pacific.

Tue-194

Detection, Attribution and Projection of Regional Rainfall Changes on (Multi-) Decadal Time Scales: A Focus on Southeastern South America

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Observed austral summertime (November through April) rainfall in the southeastern South America (SESA)&mdash including northern Argentina, Uruguay, southern Brazil and Paraguay&mdash has exhibited substantial low-frequency variations with a multi-decadal moistening trend during the 20th century and a subsequent decadal drying trend during the current century. Understanding the mechanisms responsible for these variations is essential for predicting future long-term rainfall changes. Here with a suite of attribution experiments using a pair of high-resolution global climate models&mdash GFDL CM2.5 and FLOR, we investigate the causes of these regional rainfall variations. Both models reproduce the 20th-century moistening trend, albeit with a weaker amplitude than observed, in response to the radiative forcing associated with the increasing greenhouse gases. The increasing greenhouse gases drive tropical expansion consequently, the subtropical dry branch of Hadley cell moves away from the SESA, leading to the rainfall increase. The amplitude discrepancy between the observed and simulated rainfall changes suggests a possible underestimation by the models of the atmospheric response to the radiative forcing, as well as an important role for low-frequency internal variability in the observed moistening trend. Over the current century, increasing greenhouse gases drive a continuous SESA rainfall increase in the models. However, the observed decadal rainfall decline is largely (~60%) reproduced in response to the observed Pacific trade wind strengthening, which is likely associated with the Pacific decadal variability. These results suggest that the recent summertime rainfall decline in the SESA is temporary and the positive trend will resume in response to both the increasing greenhouse gases and a return of Pacific trade winds to normal conditions. The implication is that, despite the dominance of the radiative forcing for regional rainfall changes on centennial and longer time scales, low-frequency internal variability plays an equal or perhaps larger role on decadal and even multi-decadal time scales, and therefore needs to be fully resolved in the efforts of improving the decadal climate prediction.

Tue-195

NOAA's Global Surface Temperature Dataset and Its Future Development

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Global Surface Temperature (GST) is one of the most widely used indicators for climate trend and extreme analyses. A widely used GST dataset is the NOAA merged land-ocean surface temperature dataset known as NOAAGlobalTemp (formerly MLOST). The NOAAGlobalTemp has recently been updated from version 3.5.4 to version 4. The update includes a significant improvement in the ocean surface component (Extended Reconstructed Sea Surface Temperature or ERSST, from version 3b to version 4). Major advancements include improved SST bias corrections in ship-buoy measured SSTs and corrections to the offsets between ship and buoy measured SSTs. Among the primary findings resulting from the upgrade of the NOAAGlobalTemp is that there has been no hiatus in the rate of warming in global surface temperature in the past 15 years. This is in contrast to previous findings including those of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment. In this presentation we will discuss the details of the NOAAGlobalTemp update and planned further improvements.

Tue-196

Wetting and greening Tibetan Plateau in early summer since the late 1970s due to advanced Asian summer monsoon onset

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Known as the the world water tower, the Tibetan Plateau (TP) is the origin of the ten largest rivers in Asia, breeding more than 1.4 billion people, and exerts substantial influences on water resources, agriculture, and ecosystems in downstream countries. This region is one of the most susceptible areas around the world to changing climate due to the high elevation. Observed evidence have shown significant climate changes over the TP, including surface air warming and moistening, glaciers shrinking, winds stilling, solar dimming, and atmospheric heat source weakening. However, as an essential part of the hydrological cycle, precipitation changes on the TP remain an ambiguous picture. Changes in precipitation vary largely with different seasons, time periods and climate zones considered. This study shows a robust increase in precipitation amount over the TP in May, when the rainy season starts, over the period 1979-2014 (31% relative to the climatology). The wetting trend is spatially consistent over the south-eastern TP, to which both precipitation frequency and intensity contribute. Circulation trends show that the wetting TP in May is resulted from the advanced onset of Asian summer monsoon, which onsets 1~2 pentads earlier since 1979. It intensified water vapor transport from the Bay of Bengal (BOB) to south of the TP in May and local anomalous convection. This relationship is further validated by the significant correlation coefficient (0.47) between the onset dates of Asian summer monsoon (particularly the BOB summer monsoon, 0.68) and precipitation over the south-eastern TP in May. The wetting TP in May has further exerted profound impacts on the hydrological cycle and ecosystem, such as moistening the soil and animating vegetation activities throughout early summer. Both decadal variations of soil moisture (from May to June) and Normalized Difference Vegetation Index (NDVI) (from May to July) coincide well with that of precipitation over the south-eastern TP, significant at 99% confidence level by Mann-Kendall test. This implies that the increasing precipitation in May is favoring a greening TP throughout early summer, benefitting a more favorable ecological environment in the semi-humid region there.

Tue-197

Spatial and temporal characteristics of precipitation in southwest China during flood season

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On the basis of the monthly precipitation data for the period 1960&mdash 2014 collected from 374 observational stations in Southwest China(SWC),this article analyzed the spatial and temporal characteristics of flood season precipitation in summer, research the changes of trend?period?mutation features of precipitation time series.The main results show that :There are five transitions during 1960-2014,and three of them are significant,the most acute mutation was happened on 2000?the flood season rainfall in southwest China has the quasi-periodic of 2a,3-4a and 5-7a?Three mutational sites are found through Mann-Kendall analysis method,55 years is divided into four parts and analysis every parts spatial characteristics.The overall features of precipitation field are steady,while the range and strength of precipitation during flood season are vary from different regions in Southwest China.Combine with the results of REOF,divided Southwest China into 6 zones.Find that the north of Southwest China shows increased tendency of precipitation among the six regions while the south of Southwest China shows decreased tendency. Meanwhile,the more precipitation area in central sichuan showed a significant local change.

Tue-198

Detectable anthropogenic shift toward heavy precipitation over eastern China

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(Climate of the 20th Century Plus) Changing precipitation characteristics directly affect society through their impacts on drought and floods, hydro-dams and urban drainage systems. Global warming increases the water holding capacity of the atmosphere and thus the risk of heavy precipitation. Here, we analyze daily precipitation records from over 700 Chinese stations from 1956-2005. The results show a significant shift from light to heavy precipitation over eastern China. An optimal fingerprinting analysis of simulations from 11 climate models driven by different combinations of historical anthropogenic (greenhouse gases, aerosols, land use, and ozone) and natural (volcanic and solar) forcings indicates that anthropogenic increases in greenhouse gases (GHG) have had a detectable contribution to the observed shift towards heavy precipitation. Anthropogenic aerosols (AA) partially offset the effect of the GHG forcing, resulting in a weaker shift towards heavy precipitation in simulations that include the AA forcing than in simulations with just the GHG forcing. In addition to the thermodynamic mechanism, strengthened water vapor transport from the adjacent oceans and by midlatitude westerlies, resulting mainly from GHG-induced warming, also favors heavy precipitation over eastern China.

Tue-199

Atmospheric Arctic moisture transport from different reanalyses

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The atmospheric water cycle of the Arctic is evaluated via seven global reanalyses and in radiosonde observations covering the 1979-2013 period. In the regional moisture budget, evaporation and precipitation are the least consistent terms among different datasets. Despite the assimilation of radiosoundings, the reanalyses present a tendency to overestimate the moisture transport. Aside from this overestimation, the reanalyses exhibit a remarkable agreement with the radiosoundings in terms of spatial and temporal patterns. The northern North Atlantic, subpolar North Pacific and Labrador Sea stand out as the main gateways for moisture to the Arctic in all reanalyses. Because these regions correspond to the end of the storm tracks, the link between moisture transports and extratropical cyclones is further investigated by decomposing the moisture fluxes in the mean flow and transient eddy parts. In all reanalyses, the former term tends to cancel out when averaged over a latitude circle leaving the latter to provide the bulk of the mid-latitude moisture imports – 89-94% at 70N. Although the Artic warms faster than the remainders of the world, the impact of these changes on its water cycle remains ambiguous. In most datasets, evaporation, precipitation and precipitable water increase in line with what is expected from a warming signal. At the same time, the moisture transports have decreased in all the reanalyses but not in the radiosonde observations, though none of these trends are statistically significant. The fluxes do not scale with the Clausius-Clapeyron relation because the increasing humidity is not correlated with the meridional wind, particularly near the surface.

Tue-200

Impacts Of Climate Change And Variability On Food Security In Kenya

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The economies and livelihoods of countries in Eastern Africa sub-region are dependent on rain-fed agriculture that is highly sensitive to weather and climate variability and to climate extremes such as droughts, floods, and changes in the patterns of cold/hot/wet/dry spell, among others. It is expected that climate change will enhance the variability in climate that is currently being observed. Food security in the sub-region is sensitive to climate and despite progress made in reducing extreme poverty and food insecurity, climate continues to pose significant threats to ensuring food security. The 2010/2011 drought in the region highlight the potential impacts of unprecedented climatic risks. It is therefore critical to address these risks, and focus efforts in building resilience among the most vulnerable populations. There is mounting evidence that climatic extremes such as droughts and floods are increasing in frequency and intensity across the region. Climate change is already, and will increasingly play a pivotal role in food security. In order to identify policies to support the most vulnerable people in the region, it is important to understand what the climate impacts are on livelihoods and food security so that such credible information can inform on the most vulnerable and why in order to prioritize interventions. The Kenyas Vision 2030 advocates for a secure and wealthy Nation anchored by an innovative, commercially oriented and competitive agricultural sector. This cannot be attained if the impacts of extreme climatic events on agriculture and food security are not well understood. This study documents past and current climate trends, identify geographic patterns of variability, understand how previous climate shocks and stressors align with trends in food production outcomes so as to help identify priority areas that are particularly vulnerable to help guide programme design and adaptation planning. This is useful to a wide range of stakeholders in targeting priority areas for intervention. The methodology adopted include an estimation of the annual economical exposition to drought based on Standardized Precipitation Index (SPI), key food security variables for analysis include crop production, area under harvest, yields, and nutrition. The results showed areas vulnerable communities to be highly impacted by climate change and variability.

Tue-201

Disruption of the European climate seasonal clock in a warming world

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Temperatures over Europe are largely driven by the strength and inland penetration of the oceanic westerly flow. The wind influence depends on season: blocked westerlies, linked to high-pressure anomalies over Scandinavia, induce cold episodes in winter but warm conditions in summer. Here we propose to define the onset of the two seasons as the calendar day where the daily circulation/temperature relationship switches sign. We have assessed this meteorologically-based metric using several observational datasets and we provide evidence for an earlier onset of the summer date by ~10 days between the 1960s and 2000s. Results from a climate model show that internal variability alone cannot explain this calendar advance. Rather, the earlier onset can be partly attributed to anthropogenic forcings. The modification of the zonal advection due to winter snow earlier disappearance over Eastern Europe, which reduces the degree to which climate has continental properties, is mainly responsible for the present-day and near-future advance of the summer date in Western Europe. Our findings are in line with phenological-based trends (earlier spring events) reported for many living species over Europe, for which we provide an alternative interpretation to the traditionally evoked local warming effect. Based on the Representative Concentration Pathway 8.5 scenario, which assumes that greenhouse gas emissions continue to rise throughout the twenty-first century, a summer advance of ~20 days compared to preindustrial climate is expected by 2100, while no clear signal arises for winter onset.

Tue-202

Reduced Interdecadal Variability of Atlantic Meridional Overturning Circulation under Global Warming

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Interdecadal variability of the Atlantic Meridional Overturning Circulation (AMOC-IV) plays an important role in climate variation and has significant societal impacts. Past climate reconstruction indicates that AMOC-IV has likely undergone significant changes. In spite of some previous studies, responses of AMOC-IV to global warming remain unclear, in particular regarding its amplitude and time scale. In this study, we analyze the responses of AMOC-IV under various scenarios of future global warming in multiple models and find that AMOC-IV becomes weaker and shorter with enhanced global warming. From the present climate condition to the strongest future warming scenario, on average the major period of AMOC-IV is shortened from ~50 to ~20 years and the amplitude is reduced by ~60%. These reductions in period and amplitude of AMOC-IV are suggested to be associated with increased oceanic stratification under global warming and, in turn, the speed-up of oceanic baroclinic Rossby waves.

Tue-203

Projections of storm surge trend on the coast of Southeast Brazil

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One of the impacts of climate change is the sea level rise due to global warming. The Southeast region of Brazil holds a population that represents about 44% (around 84.4 million of inhabitants) of the entire countrys population, living in an area that corresponds to 10.9% of the Brazilian territory. The region accounts for a large percentage of the Brazilian GDP due to its resources, shipping and trade as well as tourism. However, the area presents low natural stability aggravated by the rapid urban expansion, which may be worsen by climate change. In the city of Santos, one of the most important coastal municipalities of Brazil, long-term observations, have detected the increase of sea level. in this region. Additionally, events of storm surges became more frequent mainly since the end of the nineties, as indicated by long-term observations along the coasts of the States of S o Paulo and Rio de Janeiro. Storm surges have caused coastal erosion along these coastlines and some economic losses related to destruction of urban structures and disruptions in ports and tourism activities. The objective of this work is to assess the trend of storm surges hitting the coast of Southeast Brazil in the future climate. The assessment is based on the detection of storm surges reproduced by the downscaling of global climate model simulations using the Eta Regional Climate Model at 20-km resolution. The downscaling reproduces, at higher resolution, the simulations from the HadGEM2-ES and MIROC5, under RCP4.5 and RCP8.5 scenarios. The number of storm surge detected in the present climate simulations is compared against observations. The extratropical cyclone located off the coast of South Brazil is simulated generally weaker and less frequent than reanalysis data. The projections show more frequent and more intense storm surges. Near the coast, storm surges are assessed using the 5-km resolution simulations from the second nesting of the Eta RCM. The increase of resolution is desirable due to the complex characteristics of the coastline. The high-resolution projections show increased wind speed during storm surge events. The increase of storm surge frequency and intensity on the coastal cities, in particular in Santos, has implications on the adaptation measures for city resilience. This study integrates an international project (Metropole, Belmont Forum, funded by FAPESP, Proc. 2012/51876-0) which aims at evaluating the perception of risks associated with seal level rise due to climate change in three selected coastal sites, in the USA, UK and Brazil.

Tue-204

Rapid variations in deep ocean temperature not unprecedented in the Holocene

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The deep and abyssal oceans are the largest readily exchangeable reservoirs of heat and carbon on the planet. Small perturbations to deep ocean temperatures can therefore have big impacts on the global energy balance and may modulate the current rise in surface air temperatures. Attributing the recently observed deep ocean warming to anthropogenic forcing, however, requires better constraints on the natural variability of the deep ocean. Here, we test a new proxy – the oxygen isotopic signature of individual benthic foraminifera – to detect rapid (i.e. monthly to decadal) variations in deep ocean temperature and salinity in the sedimentary record. We apply this technique at a site in the Eastern Equatorial Pacific at 1000 m water depth during seven 200-year intervals during the Holocene (last 10,000 years). Variability in foraminifer δ18O over the past 200 years is below the detection limit of our method, but there are two intervals when δ18O signatures indicate temperature swings greater than 2°C within 200 years. Rapid communication between the surface and deep ocean that operates on human timescales or natural unforced variability that has not been active during the history of ocean observations are potential explanations. Distinguishing externally forced climate trends in deep ocean properties from unforced variability should be possible with systematic analysis of suitable deep sea cores.

Tue-205

Dynamic controls on the subarctic North Pacific productivity peak during the Bølling-Allerød

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Prominent maxima of biological productivity are recorded in both the Northwest and Northeast Pacific during the deglacial, interstadial Bølling-Allerød. These have been linked to a suite of differing causes and mechanisms, such as preservation effects, iron fertilization, riverine fluxes, upper ocean stratification and coastal upwelling. There is also widespread evidence for shifts in the subarctic Pacific ocean circulation during the deglaciation. However, while the dynamics of nutrient provision and limitation within the photic zone are certainly of high significance, the important role of physical circulation changes in the subsurface to deep ocean in replenishing nutrient supplies to the upper ocean, and of upper ocean temperature changes in fostering productivity peaks, remain largely unconstrained over the course of the last deglaciation. Here, using an Earth System Model COSMOS, we conducted a simulation representing the climate transition from the Last Glacial Maximum to the Bølling-Allerød. In association with marine proxy evidence, we will discuss the deglacial evolution of the surface to deep ocean circulation and mixing in the North Pacific, and examine their respective roles in determining the upwelling of nutrients from deeper layers, along with the formation of the North Pacific Intermediate water.

Tue-206

Cooling trend over the past 4 centuries in northeastern Hong Kong waters as revealed by alkenone-derived SST records

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The climate history over the past few centuries is important to be used to assess how regional climate responds to global forcing. Here we report three high-resolution alkenone-based sea surface temperature (SST) records over the past 4 centuries from three sediment cores collected in the Mirs Bay, northeastern Hong Kong. All three SST records consistently show a general cooling trend toward the present, with most of cooling occurring over the last century. Alkenone-derived SST values stayed around 26.5–27 C at the three sites prior to 1900s and decreased into the range of 25–26 C. The magnitude of cooling approximately from the Little Ice Age (LIA) to present tends to be dampened from 2 C nearshore to 1 C offshore. The cooling trend, as identified in all three SST records, is thus opposite to the global temperature rise over the last century. Assisted with modern observations, we interpret that the alkenone-derived SST reflects increasing upwelling in the Mirs Bay, which likely results from the strengthened East Asian summer monsoon, in the context of global warming over the last century

Tue-207

Seasonal Transitions and the Westerly Jet in the Holocene East Asian Summer Monsoon

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The Holocene East Asian Summer Monsoon (EASM) was previously characterized as a trend towards weaker monsoon intensity paced by orbital insolation. Here, we demonstrate that the Holocene EASM evolution is more accurately characterized as changes in the transition timing and duration of the EASM seasonal stages, namely Spring, pre Mei-Yu, Mei-Yu, and Summer. Following the 'jet transition hypothesis' (Chiang et al., 2015), we examine the role of north-south displacement of the westerlies relative to the Tibet that is hypothesized to determine EASM seasonality downstream. To this end, we employ atmospheric general circulation model (coupled to a slab ocean) time-slice simulations at various times during the Holocene to examine the role of seasonality and the westerlies in modulating the East Asia summer climate. Self-organizing maps (SOMs) applied to rainfall are used to objectively identify the transition timing and duration of the EASM seasonal stages. Compared to the late Holocene, we find an earlier onset of Mei-Yu and an earlier transition from Mei-Yu to Summer in the early-mid Holocene, resulting in a shortened Mei-Yu and prolonged Summer stage. These changes are accompanied by an earlier northward positioning westerlies relative to Tibet, consistent with its hypothesized role in determining the timing of EASM seasonal transitions. We also show that interpreting EASM changes from the viewpoint of seasonal transitions provides a more satisfactory explanation for two key observations of Holocene East Asian climate: the 'asynchronous Holocene optimum' hypothesis (An et al., 2000) and its observed history of dust emissions. A mechanism is proposed to explain the altered EASM seasonality in the early-mid Holocene. The insolation increase over the boreal summer reduces the pole-equator temperature gradient. This leads to northward-shifted and weakened westerlies in the mean, which triggers earlier seasonal rainfall transitions and in particular a shorter Mei-Yu and longer Summer pattern. The earlier northward displacement of the westerlies allows for an earlier poleward penetration of the moisture flux and the northward shift of the occurrence of synoptic-scale eddies, indicating the advance of the frontal systems.

Tue-208

Changes in precipitation over East Asia projected by global atmospheric models with 20-km and 60-km grid sizes

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A set of global warming projections was conducted using global atmospheric models with high-horizontal resolution of 20-km (MRI-AGCM3.2S, the 20-km model) and 60-km (MRI-AGCM3.2H, the 60-km mode) grid sizes. For the present-day climate (1983-2003, 21 years), models were forced with observed historical sea surface temperatures (SST). For the future climate (2079-2099, 21 years, RCP8.5), models were forced with future SST distributions projected by the models of the Fifth phase of Couple Model Intercomparison Project (CMIP5). The uncertainty of projection was evaluated by ensemble simulations for four different SST distributions and three different cumulus convection schemes.In the present-day climate simulations, the reproducibility of the MRI-AGCM3.2 models is higher or comparable to that of the CMIP5 atmospheric models for seasonal average precipitation, the seasonal march of rainy zone and extreme precipitation events. Especially in summer, the advantage of the MRI-AGCM3.2 models over the CMIP5 atmospheric models is striking. This is partly due to the higher horizontal resolution of the MRI-AGCM3.2 models, although the performance of models is sensitive to cumulus convection scheme.In the future climate simulations, the increase of precipitation over China is consistently found in all the simulations by the 20-km and 60-km models for all seasons. Precipitation change by the 20-km model over Japan tends to decrease from June to August especially in June. The projections by the 20-km model indicate the delay in the onset of rainy season over Japan. The increase of precipitation intensity is consistently found over Japan and China for all the simulations regardless of differences in SST distribution and cumulus convection scheme. In some cases changes projected by 60-km models are not consistent with 20-km models. Precipitation changes in May and June can be attributed to the change in water vapor transport associated with the southward shift of the subtropical high. In July and August, precipitation changes can be attributed to the change in water vapor transport associated with the intensification of the subtropical high.

Tue-209

Heterogeneity in Holocene SST trends caused by western boundary currents and atmospheric circulation

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Climate scenarios primarily provides information about forced responses, but that understanding and quantifying internal variability is essential to projecting climate and climate impacts on regional-to-local scales.The long-term Holocene development of these variability modes is not well known. Reconstructed SSTs in the North Pacific Ocean points to heterogenous trends on a regional scale, which are largely unexplained. Using a new climate model simulation, and an updated reconstruction of SST trends, we show that processes in the North Atlantic and Pacific Oceans can explain the Holocene temperature evolution. These trends are associated with orbital forcing in conjunction with a deepening of the winter Aleutian Low, a pronounced weakening of the summer subtropical high-pressure system, and changes in the western boundary currents. We further perform a dynamical downscaling with the ocean model indicating a strong spatial heterogeneity in the North Atlantic and North Pacific Oceans. This result is apparently at odds with the suggestion of larger spatial scales of variability at longer timescales, implying that the climate would not maintain strong gradients over long timescales. However, our model results imply that the persistence of atmospheric circulation pattern and oceanic western boundary currents provides a complex pattern in Northern Hemisphere climate.

Tue-210

Empirical investigation of critical transitions at very long timescales

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At the present time there exist empirical methods to analysis of complex spatially distributed systems, including methods of optimal phase variables retrieval and empirical prognostic models construction by observed time series. Particularly, the Bayesian approach to optimal evolution operator reconstruction by time series is developed by authors. It is based on representation of evolution operator in the form of nonlinear stochastic function represented by artificial neural networks. [1,2]. Also recently we suggested very promising method of the phase space variables construction based on data decomposition into nonlinear dynamical modes which was successfully applied to 34 years long sea surface temperature field and allowed clearly separate time scales and reveal climate shift in the observed data interval [3]. In this work we are focused on the investigation of critical transitions – the abrupt changes in climate dynamics – in match longer time scale process. It is well known that there were number of critical transitions on different time scales in the past. In this work, we demonstrate the first results of applying our empirical methods to analysis of paleoclimate variability. In particular, we discuss the possibility of reveling and indentifying such critical transitions by means of nonlienar empirical modeling the paleoclimate record time series.

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Tue-211

Future Changes in Winter Stationary Waves in East Asia and the North Pacific Induced by Robust Changes in the Tropical Circulation

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In this study, we investigated future changes in winter stationary waves focusing on roles of changes in tropical circulation using Coupled Model Intercomparison Project Phase 5 (CMIP5) models and a linear baroclinic model (LBM). The CMIP5 models projected a weakening of horizontal divergence over the Maritime Continent: the mechanism of the weakening is well understood by many previous studies, and the change is considered to be robust. In addition to the weakening, a wave-like pattern of stationary waves from East Asia to the North Pacific was projected. We found a close relationship between the changes in the divergence and in the waves: coupled models which predicted the former changes stronger projected the bigger amplitudes of the latter waves, and vice versa. This result suggests that the latter change was forced by the former robust change. To clarify dynamical relationships among the two changes, we performed four different LBM experiments using the zonal mean basic state and zonally asymmetric thermal forcing in the tropics. For each experiment, we used the present/ future basic state and the present/future thermal forcing from the CMIP5 models. The acronym of each experiment is as follows: EXP01) present basic state and present thermal forcing, EXP02) present basic state and future thermal forcing, EXP03) future basic state and present thermal forcing, EXP04) future basic state and future thermal forcing. The differences between the future and present experiments (EXP04-EXP01) were similar to the changes projected by the CMIP5 models, although positions and amplitudes differed slightly. In addition, the EXP03 showed that the change in the basic state and the resultant weakening of horizontal divergence over the Maritime Continent explained most of the changes in the stationary wave. On the other hand, EXP02 showed that the change in thermal forcing accounted for the eastward shift of the stationary waves. Additionally, we conducted storm track experiments with the LBM to investigate the role of transient eddy feedback on stationary wave changes. The results suggested that the feedback shifts the thermally forced stationary waves northeastward. This shift may explain the difference between the LBM experiments (EXP04-EXP01) and the CMIP5 future projection. This study implies that the robust weakening of the tropical circulation due to global warming causes change in the mid-latitude circulation by inducing changes in stationary waves which propagate from the tropics to the mid-latitudes

Tue-212

Contributions of soil moisture interactions to future precipitation changes in the GLACE-CMIP5 experiment

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Changes in soil moisture can contribute to future changes in various characteristics of daily precipitation in response to the anthropogenic climate forcing. The possibility of such contributions at the end of the 21st century is investigated on the basis of two sets of transient simulations over the period 1950-2100 with five different global climate models as part of the GLACE-CMIP5 experiment. In both sets of simulations the anthropogenic climate forcing has been prescribed according to observations until 2005 and according to the RCP8.5 scenario between 2006 and 2100. The two set of simulations differ in the way the soil moisture content is prescribed. In one set of simulations the annual cycle of the soil moisture content changes throughout the period 1950-2100 in response to the anthropogenic climate forcing, while in the other the annual cycle of the soil moisture content is kept constant at present-day values, i.e., the mean annual cycle over the period 1971-2000. In addition to mean precipitation, the intensity and frequency of daily precipitation events as well as the frequency and length of extended wet and dry spells are considered as different aspects of daily precipitation.The anthropogenic climate forcing leads to marked future changes in soil moisture content over most of the global land areas, with a general tendency of increases in the tropics and the mid- and high latitudes in the Northern Hemisphere and decreases in the subtropics. Overall, these soil moisture changes contribute to the future changes in mean precipitation and in the different characteristics of precipitation over much of the global land areas. In many areas, the effects of the soil moisture changes are stronger for the frequency of daily precipitation events as well as for the length and duration of extended wet and dry spells than for the intensity of daily precipitation. Despite the overall tendency of contributing to the overall future changes in precipitation, the magnitude of the contributions varies considerably by season and to some extent between different regions, and in some cases weak negative contributions are found. The impact of the soil moisture changes varies also between the five different climate models and might partly account for the strong inter-model variability of the future changes in precipitation simulated by these models in response to the anthropogenic climate forcing.

Tue-213

A multi-decadal lag-response solar model (MLRSM): a novel tool for long-term ocean-climate prediction with focus on the East Asian monsoon climatic region

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Approximately 5 years Based on this lag, the modern solar maximum which occurred from 1880-1986, with its peak being the decade 1934 and 1944, is found to have forced the modern warm period from 1929 to 1998, and especially its decadal peak (1977-1987). Overall, the modern solar maximum (MSM) is found to be driven by the 106.3-year solar cycle, which occurs with a frequency of 0.001cycle/month and a variance of 2.9%. The onset of the 106-year solar cycle in 1880 coincides with the onset of sustained warming in the SCS in 1929, with a lag of 49years, further validating the mathematically computed lag. The current warming hiatus and slight decline of SST in the SCS coincides with the declining limb of the 106-year solar maximum (1944 and 1986), which drove temperatures from 1988 to present, and expected to go on driving SST until 2017. The model has also displayed great skill in hind-casting and long term forecasting of climate variability and can be used to predict the trends of other climatic indices such as rainfall and wind velocity, as well as derive the strength of PDO cycles.

Tue-214

The energetic response of the global meridional overturning circulation to rising atmospheric CO2 in climate models

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The ocean's global meridional overturning circulation (MOC) is one of the principle ocean phenomena that impacts climate. The MOC entails the release of available gravitational potential energy (AGPE) that has been generated by two main pathways: (1) GPE generation due to turbulent diapycnal mixing, which is converted from background GPE to AGPE by surface buoyancy forcing; (2) the conversion of kinetic energy directly to GPE in available as opposed to background form, (A)GPE, by wind driven upwelling of dense water and downwelling of buoyant water. Understanding changes in these energetic pathways is central to understanding the ocean's role in climate change. Here, an analysis is presented of the perturbation to the GPE and AGPE budgets of two coupled climate models, HadCM3 and HiGEM, to CO2 rise on a centennial timescale. The energetic response is dominated by a decrease in AGPE generation by buoyancy forcing, due to the decreased density of high latitude surface waters, and a resulting increase in (A)GPE generation by resolved advection due to the weakening of the MOC, which is a sink. The net result is a decrease in global AGPE but an increase in GPE, which could quickly be made available if buoyancy forcing were to change. Therefore, warming acts to weaken the MOC, but it also preconditions the ocean for a strengthened future MOC if climate change were to be reversed. HiGEM is an eddy-permitting model, whereas eddies in the ocean are parameterised in HadCM3. As a result of this, and the relatively short spin-up of HiGEM, the two models yield qualitatively different (A)GPE budgets for the underlying climate state. However, there is very little difference between the two models regarding the response of the energy budgets to rising CO2. This is because the change in the eddy contribution, whether resolved or parameterised, plays a negligible role in the response of the MOC on the centennial timescale considered here.

Tue-215

Detection and Attribution of the surface air temperature during last millennium

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The optimal fingerprinting method was employed to compare the reconstructed and model-simulated changes of surface air temperature during last millennium. Analyses were conducted from hemispherical to continental scale. Results show that combined effect of all the external forcings on surface air temperature can be detected for both Northern and Southern Hemisphere, and for the continent of Europe, Arctic and Antarctic. The influence of volcanic eruption and solar activity can be detected for all the hemispheres and nearly all the continents of North Hemisphere. Land use forcing can be detected for all the continents of Northern Hemisphere, but only be detected for one continent of Southern Hemisphere, i.e., South America. The orbital forcing is detected for all the continents of Northern Hemisphere, but not detected for the Northern Hemisphere as whole. Influence of greenhouse gases can rarely be detected from hemispherical to continental scale.

Tue-216

Global Trends in the Wind Stress Spectrum

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This study focuses on the variability of the spectrum of the wind stress over the global oceans. Trends in the power spectrum density distribution of the wind stress and its derivatives with periods of months to years potentially affect the ocean dynamics. This include changes in the depth of the mixed layer, in the intensity and meridional position of western boundary and equatorial currents, an din the amplitude of Rossby waves. Estimates of decadal trends in ocean wind patterns are often based on model reanalysis that assimilate observations from a variety of sources to provide continuous and physically consistent data. We used the ECMWF Reanalysis Interim (ERAi) daily global wind data-set that comprises 36years on a ¾° grid; the stress was calculated via bulk formula. The first part of the results addresses basic statistics and trends in the zonal and meridional wind stress components, its magnitude, divergence and curl. This is intended as a basis for comparison. In the second part we estimated trends of the intra--annual standard deviation of these 5 variables. Large scale patterns emerge from maps of these trends with values on the order of 0.1 to 1% per year. The trend ofthe intra--annual standard deviation of the wind stress is on theorder of 10% in 36 years and is consistent over basin scaleregions. Furthermore, we have calculated the trends in spectral powerof the 5 variables for 10 period bands. For each location we estimatedthe decadal trend using the integrated wavelet spectrum within eachperiod band. We obtained trends in the spectral power of the windstress magnitude of the same order as before, in basin--scale regions.Significant changes in the spectrum of oceanic wind stress and derivedvariables were observed in the ERAi data, with potential consequencesfor the ocean stratification and circulation.

Tue-217

Isolating the Temperature Feedback Loop Contribution to Surface Warming

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Climate feedback processes are known to significantly amplify the surface warming response to an increase of greenhouse gases. When the forcing and feedbacks modify the temperature response they trigger temperature feedback loops that amplify the direct temperature changes due to the forcing and non-temperature feedbacks through the thermal-radiative coupling between the atmosphere and surface. This study introduces a new feedback-response analysis method that can isolate and quantify the effects of the temperature feedback loops of individual processes on surface temperature from their corresponding direct surface temperature responses. We analyze a 1% yr increase of CO2 simulation of the NCAR CCSM4 at the time of CO2 doubling to illustrate the new method. The Planck sensitivity parameter, which indicates colder regions experience stronger surface temperature responses given the same change in surface energy flux, is the inherent factor that leads to polar warming amplification (PWA). This effect explains the PWA in the Antarctic, while the direct temperature response to the albedo and cloud feedbacks further explain the greater PWA of the Arctic. Temperature feedback loops, particularly the one associated with the albedo feedback, further amplify the Arctic surface warming relative to the tropics. In the tropics, temperature feedback loops associated with the CO2 forcing and water vapor feedback cause most of the surface warming. Overall, the temperature feedback is responsible for most of the surface warming globally, accounting for nearly 76% of the global mean surface warming. This is three times larger than the next largest warming contribution, indicating that the temperature feedback loop is the preeminent cause of the surface warming.

Tue-218

Individual Feedback Contributions to the Sesonality of Surface Warming

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Using the climate feedback response analysis method, we examine the individual contributions of the CO2 radiative forcing and climate feedbacks to the magnitude, spatial pattern, and seasonality of the transient surface warming response in a 1% per year CO2 increase simulation of the NCAR CCSM4.The CO2 forcing and water vapor feedback warm the surface everywhere throughout the year. The tropical warming is predominantly caused by the CO2 forcing and water vapor feedback while the evaporation feedback reduces the warming. Most feedbacks exhibit noticeable seasonal variations; however their net effect has little seasonal variation due to compensating effects, which keeps the tropical warming relatively invariant all year long. The polar warming has a pronounced seasonal cycle, with maximum warming in fall/winter and minimum warming in summer. In summer, the large cancelations between the shortwave and longwave cloud feedbacks and between the surface albedo feedback warming and the cooling from the ocean heat storage/dynamics feedback lead to a warming minimum. In polar winter, surface albedo and shortwave cloud feedbacks are nearly absent due to a lack of insolation. However, the ocean heat storage feedback relays the polar warming due to the surface albedo feedback from summer to winter, and the longwave cloud feedback warms the polar surface. Therefore, the seasonal variations in the cloud feedback, surface albedo feedback, and ocean heat storage/dynamics feedback, directly caused by the strong annual cycle of insolation, contribute primarily to the large seasonal variation of polar warming. Furthermore, the CO2 forcing, and water vapor and atmospheric dynamics feedbacks add to the maximum polar warming in fall/winter.

Tue-219

Simulated sensitivity of the tropical climate to extratropical thermal forcing: Tropical SSTs and African land surface

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Paleoclimatic data, 20th century observations and climate simulations suggest that the meridional position of the Intertropical Convergence Zone (ITCZ) responds to changes in inter-hemispheric temperature contrast. This study investigates, through numerical simulations, the ITCZ response to an extratropical thermal forcing that represents the asymmetric temperature changes associated with glacial-interglacial and milennial-scale climate variability. The applied forcing pattern consistsof cooling in one hemisphere (Southern Hemisphere) and warming in the other (Northern Hemisphere) poleward of 40°, with zero global average. Two experimental configurations are implemented and in all the cases realistic boundary surface conditions are used. In the first numerical configuration an atmospheric general circulation model (ICTP-AGCM) is coupled to slab ocean and land models. The relative roles of the atmosphere, tropical SSTs and continental surface temperatures in the ITCZ response to the imposed forcing are investigated in a series of experiments designed to separate these influences: in the first series the slab ocean and land models are applied globally; in the second series the tropical SSTs are kept fixed while the slab land model is applied globally; in the third series, in addition, surface temperatures over Africa are kept fixed. We find that the ITCZ shifts toward the warmer hemisphere and that the stronger the forcing, the larger the shift. When the constraint of fixed tropical SST is imposed we find that the ITCZ response is strongly weakened, but it is still not negligible in particular over the Atlantic Ocean and the Sahel region where the precipitation anomalies are of the order of 20% and 60%, respectively, of the magnitude obtained without the SST restriction. Finally, when the constraint of the African surface temperature is incorporated we find that the ITCZ response completely vanishes, indicating that the ITCZ response to the extratropical forcing is not possible just trough purely atmospheric processes, but needs the involvement of either the tropical SST or the continental surface temperatures. The clear-sky longwave radiation feedback is highlighted as the main physical mechanism operating behind the land-based extratropical to tropical communication. In the second numerical configuration an intermediate-complexity model of the tropical oceans (Cane-Zebiak model) is incorporated in order to better understand the role of the dynamical ocean-atmosphere interaction in modifying the forced signal from the extratropics.

Tue-220

Distinct Patterns of Climate Response to Anthropogenic Aerosol Versus Greenhouse Gas Forcing

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Spatial patterns of climate response to changes in anthropogenic aerosols and well-mixed greenhouse gases (GHG) are investigated using eight coupled climate models for the 20th century. The climate response shows both similarities and differences in spatial pattern between aerosol and GHG runs. The GHG forcing gives rise to a vertically amplified warming in the tropical troposphere and an intensified mid-latitude westerly jet in either hemisphere. The troposphere cooling induced by anthropogenic aerosols, by contrast, is locally enhanced in the mid-latitude Northern Hemisphere with a deep vertical structure around 40N. In thermal wind balance, the aerosol-induced cooling anchors a westerly acceleration to the south. Careful comparison indicates that the aerosol forcing dominates the Northern Hemisphere climate response in historical simulations, including the drying trend over the East Asia monsoon region, the southward shift of the East Asia westerly jet and the North Pacific cooling. In the tropics, the aerosol effect induces a southward shift of the Inter-Tropical Convergence Zone and eastward shift of the South Pacific Convergence Zone, while the GHG effect leads to increase rainfall in the equatorial Pacific. The GHG-induced inter-hemisphere symmetric climate response is mediated by the sea surface temperature pattern. Climate response pattern indices are developed to evaluate the relative importance of aerosol and GHG forcings. Specifically, a cross-equatorial Hadley circulation develops to compensate aerosol cooling in the Northern Hemisphere, a response distinct from the GHG induced changes.

Tue-221

Correlation and Anti-Correlation of the East Asian Summer and Winter Monsoons during the Last 21,000 Years

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What are the relations between East Asian summer (EASM) and winter (EAWM) monsoons during the last 21,000 years? The Asian summer and winter monsoons are the most important climate variability over East Asia. Its response to future climate change is of great societal interest but still remain highly uncertain. This work aims to answer one key question associated with the relation between EASM and EAWM, and will improve our scientific understanding of the monsoon dynamics and help improving the climate projection over the East Asia. We would present the results from a comprehensive modeling study of one interesting issue of monsoon dynamics: the co-evolution feature of the East Asia summer and winter monsoons. With a full set of transient climate model simulations of the last 21,000 years, we are able to resolve the seemingly contradictory observations on the monsoon correlation by providing an unified dynamic framework in understanding the monsoon correlation. Our study, for the first time, demonstrated that the correlation between the EASM and EAWM depends on the key physical processes at different time scales. On the orbital timescale, EASM and EAWM are positively correlated with a simultaneous strengthening during the deglaciation and weakening during the Holocene in response to the precession forcing. On the millennial timescale, the EASM and EAWM are negatively correlated, in particular during the deglaciation, because of the forcing by the melt water pulses into the North Atlantic. Furthermore, the greenhouse gases and ice sheet forcing also play interesting roles for the monsoon correlation and tends to cancel out after deglaciation. Our study challenges the traditional views of the monsoon correlation in paleoclimate and modern climate studies and presents a new and unified view of the monsoon behaviors.

Tue-222

A comparison of quasi-millennial extratropical winter cyclone activity between the Northern and Southern Hemisphere

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The winter extratropical cyclone activity on both hemispheres during the last one thousand years within a global climate simulation was analyzed by tracking cyclones, and then clustering them consecutively for each hundred years. There is very strong year-to-year variability for winter extratropical cyclone numbers of both hemispheres. Larger variations on centennial time scale can be seen for Southern Hemisphere (SH), more so than for its Northern Hemispherical (NH) counterparts. However, no obvious trend can be found on both hemispheres. The mean tracks of clusters over the Southern Indian Ocean and near New Zealand shift poleward from the 11th to the 20th century while the clusters in the central Southern Pacific shift equatorward. This is quite different from Northern Hemispheric cyclone positions which change only marginally. Compared to the NH mid-latitude cyclones, the SH cyclones have higher percentage of long lifespan (last over 10 days). Cyclones deepening fast (maximum deepening rates over 10 hPa/12h) over the oceans of the SH are fewer than the oceanic counterparts of the NH. Frequencies of cyclones over the North Pacific and North Atlantic are correlated to the Aleutian Low and the North Atlantic Oscillation (NAO) correspondingly. The winter storm activity in the Southern Hemisphere is closely related to the Antarctic Oscillation (AAO). The cyclone frequency over the Indian Ocean and South Pacific Ocean can be associated with the Indian Ocean Dipole (IOD) and El Nino-Southern Oscillation (ENSO) respectively.

Tue-223

CMCC historical ocean reanalyses (CHOR, 1900-2010) using different data assimilation strategies

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Two historical ocean reanalyses that cover the period from 1900 to 2010 are performed. One ocean reanalysis (CHOR_AS) assimilates both SST and vertical profile data with a 3D-var assimilation scheme, while the other one (CHOR_RL) assimilates vertical profile data, but is nudged to monthly HadISST reconstructed fields. The reanalyses are thus designed to investigate the impact of different strategies for constraining the SST in long-term assimilative experiments and the feasibility of assimilating subsurface observations in the same kind of experiments. The atmospheric forcing comes from the ensemble mean of the 20th Century Reanalysis version 2(20CRv2). Due to biases particularly large at high latitudes, corrections are applied to the atmospheric forcing, based on the comparison with ERA-Interim during the overlapped period. In general these ocean reanlayses capture trends and variability of some key parameters. A warm bias of SST in CHOR_AS in the first half of the century leads to incorrect long-term trends. However, SST anomalies in both CHOR_AS and CHOR_RL are realistically captured. Heat contents at 0-300m, 0-700m and 0-2000m have an increasing trend in both CHOR_RL and CHOR_AS, consistent with available datasets for the second half of the century. In order to have realistic mass transport, mixed layer depth and eddy kinetic energy, it is necessary to assimilate vertical profile data, although this leads to some discontinuities in the reanalysis time series. Based on these findings, we offer ideas for the requirements of future historical ocean reanalyses, e.g. related to the necessity of applying bias correction and minimize the effects of the observing network discontinuities. Meanwhile, the comparison between CHOR_RL and CHOR_AS shows that both direct assimilation and nudging scheme have their advantages and disadvantages. The combination of these two schemes is desirable in future work.

Tue-224

Abrupt glacial climate shifts controlled by ice sheet changes

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During glacial periods of the Late Pleistocene, an abundance of proxy data demonstrates the existence of large and repeated millennial-scale warming episodes, known as Dansgaard–Oeschger (DO) events. This ubiquitous feature of rapid glacial climate change can be extended back as far as 800,000 years before present (BP) in the ice core record, and has drawn broad attention within the science and policy-making communities alike. Many studies have been dedicated to investigat- ing the underlying causes of these changes, but no coherent mechanism has yet been identified. Here we show, by using a comprehensive fully coupled model, that gradual changes in the height of the Northern Hemisphere ice sheets (NHISs) can alter the coupled atmosphere– ocean system and cause rapid glacial climate shifts closely resembling DO events. The simulated global climate responses—including abrupt warming in the North Atlantic, a northward shift of the tropical rain- belts, and Southern Hemisphere cooling related to the bipolar seesaw— are generally consistent with empirical evidence. As a result of the coexistence of two glacial ocean circulation states at intermediate heights of the ice sheets, minor changes in the height of the NHISs and the amount of atmospheric CO2 can trigger the rapid climate transitions via a local positive atmosphere–ocean–sea-ice feedback in the North Atlantic. Our results, although based on a single model, thus provide a coherent concept for understanding the recorded millennial- scale variability and abrupt climate changes in the coupled atmosphere– ocean system, as well as their linkages to the volume of the intermediate ice sheets during glacials.

Tue-225

Projected 21st Century Sea Surface Temperatures: Changes in the Mean, Variability and Extremes

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The burning of fossil fuels and the resulting input of greenhouse gasses into the atmosphere has already warmed the planet and will have a profound impact on the climate system over the 21st century. While basin-wide changes in the ocean are expected, its critical to examine temperature changes in coastal regions, which contain most of the world's marine organisms. Large Marine Ecosystems (LMEs) are defined as ‘‘coherent ocean areas generally along continental margins whose ecological systems are characterized by similarities in bathymetry, hydrography, and biological productivity”. Indeed, more than 80% of the world's marine fish catch comes from the 64 LME regions. In this study we will use global fields from climate models in the CMIP5 archive to investigate how climate change impacts SST trends, variability and extremes, including the percentage of months during periods in the 21st century that exceed temperatures over the base period: 1976-2005. We also use simulations from the Community Earth System Model - Large Ensemble (CESM-LENS) project, which enables the assessment of climate change signal relative internal climate variability. We explore the SST changes in the 18 LME regions adjacent to North America and Europe, and in the Arctic Ocean and adjacent seas. While nearly all of the global oceans warm during the 21st century, there is a large range between the regions and among models simulations. The spread in the trend is much larger in the CMIP5 than in CEMS-LENS, indicating that model physics is a larger source of uncertainty than internal climate variability. There is a large seasonal cycle in the temperature trends, which are substantially greater in summer than in winter. Nearly all months in the last 30 years of the 21st century are warmer than the warmest corresponding calendar month during 1976-2005. After removing the trend, there is a modest change in variance, with some regions experiencing less variability and fewer outliers, i.e. not all extremes are becoming more extreme.

Tue-226

Spatial and Temporal Variability of Rainfall under CMIP5 RCP Scenarios in an Arid Region of Pakistan

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Climate change impact assessment on water resources is much challenging in arid regions, due to extreme behavior of precipitation and uncertainties arising from global climate models (GCMs). Despite the constantly improving horizontal resolution, their level of accuracy still does not lead to direct use in applications. GCM simulations are usually downscaled via statistical and dynamical to finer resolution that replicates station level information. In this study, we used linear i.e. Random Forest (RF) and non-linear i.e. support vector machine (SVM) to downscale the monthly precipitation of arid province Balochistan, Pakistan. Quantile Mapping was applied to remove the biases arises during downscaling models. Seven GCMs from Coupled Model Intercomparison Project Phase 5 (CMIP5) under four Representative Concentration Pathways (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) and combine them with multi-model mean were also used. The performances of models were assessed based on Taylor diagram and other statistical measures including mean bias error (MBE), mean absolute error (MAE), root mean square error (RMSE), index of agreement (Md), Nash–Sutcliffe model efficiency (NSE) and coefficient of determination (R2). Further, we analyzed the changes in precipitation and detected the trends in rainy seasons of future scenario with respect to historical period of 1960–2010. The results of study, indicates that RF and SVM downscaled precipitation successfully and showed very close results with each other. The results obtained from Taylor diagram showed that all models simulate historical precipitation very well. However, GISS-E2-H outperforms other models by giving the lowest errors and highest correlations, on the other hand, MIROC-ESM showed highest errors and lowest correlations. The ensemble of multi-GCMs projected an increase of precipitation ranging from 5.08 to 8.16 %, 2.41 to 11.49%, 3.52 to 16.64%, and 4.53 to 25.59% for RCP2.6, RCP4.5, RCP6.0 and RCP8.5 respectively. The spatial pattern of annual precipitation also showed increased precipitation, especially in period 2070 – 2099 under RCP8.5. Significant increasing trends at 5% level of significance were also detected in annual and other seasons under all scenarios except RCP2.6, where increasing trends were found non-significant. The results of this study can help to formulate the necessary mitigation and adaptation planning under global change scenarios.

Tue-228

What Role for Volcanoes in Future Climate Projections?

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Despite ample evidence for volcanic impacts on climate, volcanic forcing uncertainty has so far been excluded in future climate assessments. To answer how its omission compromises state-of-the-art climate projections, we introduce a probabilistic approach for considering volcanism in climate simulations. A 60-member ensemble covering the 21st century was performed using plausible volcanic activity based on the reconstructed activity from the past two millennia, and compared to a reference ensemble without volcanic forcing. The simulations including volcanic activity show enhanced climate variability on inter-annual to multi-decadal time scales, leading to a widening of the uncertainty range in near-term climate assessments - such as the 2016-2035 global temperature mean and the time when global warming surpasses 1.5C. Volcanic activity further causes a 50% increase in probability for simulating a 10-year global warming pause and a few years delay in the emergence of regional anthropogenic warming signals. The impact on the long-term climate trend is found to be small, with only a 1-5% reduction in the centennial global temperature increase. Accounting for volcanic effects is thus particularly important for applications that require a consideration of inter-annual to decadal-scale variability in future climate.

Tue-231

Multi-model attribution of upper-ocean temperature changes using an isothermal approach

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Both air-sea heat exchanges and changes in ocean advection have contributed to observed upper-ocean warming most evident in the late-twentieth century. However, it is predominantly via changes in air-sea heat fluxes that human-induced climate forcings, such as increasing greenhouse gases, and other natural factors such as volcanic aerosols, have influenced global ocean heat content. The present study builds on previous work using two different indicators of upper-ocean temperature changes for the detection of both anthropogenic and natural external climate forcings. Using CMIP5 simulations, we compare mean temperatures above a fixed isotherm with the more widely adopted approach of using a fixed depth. We present the first multi-model ensemble detection and attribution analysis using the fixed isotherm approach to robustly detect both anthropogenic and natural external influences on upper ocean temperatures. Both the large multi-model ensemble size and properties of the isotherm analysis reduce internal variability of the ocean, resulting in better observation model comparison of temperature changes since the 1950s. We further show that the high temporal resolution afforded by the isotherm analysis is required to detect natural external influences such as volcanic cooling events in the upper-ocean because the radiative effect of volcanic forcings is short-lived.

CLIVAR Open Science Conference

Day 3 - Wednesday, 21st September 2016

Keynote talk

Keynote Speaker **Wednesday,21st September 2016** **17:00hrs**

Dr. Jennifer MacKinnon

Dr. Jennifer MacKinnon is a Professor at Scripps Institution of Oceanography. She studies small-scale processes in the ocean - internal waves, sub-mesoscale instabilities and turbulence, and their relationship to large-scale circulation, primarily through ship-based process studies. She has also been leading a recent Climate Process Team tasked with developing and implementing new parameterizations of diapycnal mixing into global ocean models.

The elephant and the mouse: multiple scales of ocean dynamics

Jennifer MacKinnon

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Though climate models cover vast spatial and temporal scales, they are often quite sensitive to sub-grid-scale parameterizations of the smallest and meekest phenomena. In the ocean abyss, the net effect of turbulent mixing at centimeter to meter scales can sway the ocean into significantly different states of deep circulation and heat transport. In the upper ocean, the complex dance between turbulent mixing and sub-mesoscale exchanges or re-stratification sets the structure of temperature and fresh-water, and thus plays an important role in seasonal to decadal air-sea or sea-ice heat exchanges. Here I'll review results from a decade of small-scale process experiments, attempts to incorporate some resultant insights into large-scale models through a Climate Process Team, and speculate on priorities for the decade to come.

Plenary Oral Presentations

Plenary Session 3 **Wednesday, 21st September 2016** **09:00hrs**

Dr. Rym Msadek

Dr. Rym Msadek is a Research Scientist at CERFACS/CNRS in Toulouse, France. Dr. Rym is interested in the role of the ocean in climate variability particularly in the extra tropics and high-latitudes, with the goal of improving climate predictability on seasonal to decadal time scales. Her research interests span various time scales and include the predictability of sea ice on seasonal time scales and the climate response to decadal oceanic variability. Her work is based mainly on global climate models, which though imperfect, are extraordinary tools to improve our understanding of climate variability. Dr. Rym is a member of the CLIVAR working group on Decadal Climate Variability and Predictability (DCVP). She was also a Contributing Author and an Expert Reviewer of the IPCC Fifth Assessment Report. She is currently contributing to the design of CMIP6 Decadal Predictability Experiments (DCPP component C).

Role of ocean dynamics in climate variability on interannual to multidecadal time scales

Rym Msadek

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We review in this talk the role of ocean dynamics in shaping climate variability on a variety of time scales ranging from few years to several decades. Ocean-atmosphere interactions are very strong over western boundary current regions (e.g. near the Gulf Stream or the Kuroshio/Oyashio) and it has been hypothesized that ocean mesoscale activity can affect the strength and location of the overlying extra tropical atmospheric storm track (e.g. Nakamura et al. 2004). We discuss here whether better resolving such oceanic fronts in global climate models leads to significant changes in the location and intensity of mid latitude storm tracks. Further, we present the role of ocean dynamics in producing decadal climate variability. Indeed, the ocean circulation is thought to be a dominant driver of observed decadal variability, both in the Atlantic basin through the so-called Atlantic Meridional Overturning Circulation (AMOC, e.g. Knight et al. 2005) and in the Pacific through a superposition of several ocean-atmosphere processes (Newman et al. 2016). This decadal variability has been observed in a number of ocean and atmospheric variables (e.g. Goldenberg et al. 2001, Sutton and Hodson 2005,) and the potential to predict it has motivated a number of studies and coordinated experiments. We review recent observational and modeling results on this topic and highlight the strengths and weaknesses of current coupled models in simulating the observed decadal variability. Finally, we discuss the role of the ocean in the climate

response to global warming. Model experiments suggest that ocean dynamics can shape the climate response to greenhouse increase especially in the tropics where ocean feedbacks are large (e.g. Lu and Zhao 2012). The high-latitude climate response to greenhouse-induced sea ice decline was also found to be different in scale and magnitude when ocean dynamics are accounted for (Deser et al. 2015, Tomas et al. 2016). We review the role of ocean feedback in setting the patterns and details of the climate response to greenhouse gas forcing.

Dr. Raffaele Ferrari

Mixing and Stirring

Dr.Weidong Yu

It is about 20 years ago that I joined the FIO/SOA after getting master degree. Firstly I worked on the ocean surface wave modeling and its various applications. My most enjoyable work at that time is to couple one global atmospheric circulation mode with one global surface wave model and that is my first touch on climate topics. Later I turned more to ocean-atmosphere interaction study and got my PhD in 2005. The south Java upwelling and its associated Indian Ocean Dipole (IOD) drew my attention and then I came close with CLIVAR-GOOS Indian Ocean Panel (IOP) and joined such an energetic group to develop the Indian Ocean Observing System (IndOOS), particularly its core component RAMA array. The harsh but amazing cruises to work with buoy and mooring changed my research much. Now I am interested in various monsoon-ocean interactions and try to develop some physical-biological interactions. It's fun to plan the cruises.

Upwelling and Frontal Zones - Example of Complexity in the Monsoonal Indian Ocean

Weidong Yu

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Upwelling and fronts are specific phenomena standing out from the background. Even constrained in the geographic coverage, they are vital to shape the rich and complex ocean movement. The vibrant monsoonal wind and changing Indian Ocean circulation modulate the upwelling and fronts in this poorly sampled basin. Moreover, they are intimately tangled with the biological and biogeochemical processes, which further emphasize their importance. This presentation briefs their peculiar features that are yet to explore, including:

1. The multi-scale nature of the Java coastal upwelling and its biological impacts, in response to the remote central equatorial zonal wind forcing;

2. The seasonal dependant upwelling cross the eastern continental shelf of Andaman Sea in the context of large amplitude internal waves, in response to the equatorial zonal wind forcing during monsoon transitions;

3. Equatorial fronts, their mixing and role in volume/heat/salt/oxygen balance;

The discussion is mainly based on the in situ observation and most of the results are still preliminary with the purpose to call for more attention on such complex meso-scale processes, particularly in the science design of some proposals under the flagship of the Second International Indian Ocean Expedition (IIOE-2).

Prof. Paulo Calil

Dr. Paulo Calil is a Professor of Physical Oceanography at the Laboratório de Dinâmica e Modelagem Oceânica (DinaMO) at the Universidade Federal do Rio Grande (FURG), Brazil. His research focuses on meso- and submesoscale dynamics and physical-biological interactions in the ocean using both high-resolution observations and models. Dr. Calil currently serves as a member of the Global Synthesis and Observations Panel (GSOP).

Frontal Instabilities in the South Atlantic Subtropical Front and their Impact on Phytoplankton Blooms

Paulo Calil

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Subtropical fronts are key regions in the world's oceans as they provide the connection between the dynamically and biogeochemically different sub polar and subtropical oceans. Understanding the mechanisms that modulate the exchange of properties between these regions is not only locally important but may also help explain long-term changes that affect the climate system and may be sensitive to such exchanges. In this study, focus is given to the importance of submesoscale processes in triggering phytoplankton blooms at the subtropical front in the South Atlantic Ocean. A basin-wide model configuration is nested with a higher resolution domain within the frontal region in order to study the exchange of physical properties as well biologically active tracers. On average, a stronger zonal baroclinic jet is observed in the high-resolution domain. Frontal instabilities generated by imbalances in the thermal wind induce rapid changes in the mixed layer depth and generates more episodic blooms with slightly larger biomass during periods when surface stratification is increased. Nonlinearities associated with the Ekman dynamics seem to be responsible for the generation of large vertical velocities and are more important in the high-resolution domain because of larger gradients in relative vortices.

Parallel Orals – Session 3.1

Parallel Session 3.1 Mixing and Stirring

Wednesday, 21st September 2016 - 14:00hrs **Ballroom 1**

3.1-A

Influence of mesoscale and submesoscale dynamics on the seasonal cycle of the ocean mixed layer depth

Xavier Couvelard (1), Julie Deshayes (2), Franck Dumas (3), Valérie Garnier (1), Aurélien Ponte (1), Claude Talandier (1), Anne Marie Treguier (1)

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The intensification of submesoscale activity in fall and winter during episodes of convective deepening of the ocean mixed layer is well documented in realistic ocean models. A global ocean model with a 1/32° zoom in the western part of the North Atlantic subpolar gyre confirms the strong seasonal cycle of submesoscale motions. The mechanisms by which mesoscale and submesoscale turbulence control the mixed layer depth are investigated further, using an idealized periodic channel geometry. A whole cycle of destratification by cooling and restratification is simulated, using an ensemble strategy to assess the robustness of the results. Simulations with grid resolutions varying from 10 km to 2 km show that, at higher resolution, when submesoscale starts to be resolved, the mixed layer formed during the surface cooling is significantly shallower and the total restratification is almost three times faster. Such differences between coarse and fine resolution models are consistent with the submesoscale upward buoyancy flux, which balances the convection during the formation phase and accelerates the restratification once the surface cooling is stopped. The simulations show that mesoscale dynamics also cause restratification, but on longer time scales. Implications for climate models using eddy parameterizations are discussed.

3.1-B

Variability of submesoscale dynamics in the North Atlantic ocean.

Julien Le Sommer (1), Jean-Marc Molines (1), Alexandre Jaymond (2), Sylvie Su (2), Bernard Barnier (1), Thierry Penduff (1), Patrice Klein (3)

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Several processes contribute to energize oceanic flows at scales smaller than the first baroclinic Rossby radius (frontogenesis, mixed-layer instabilities, current-topography interactions...). But the relative strength of these processes and their impact on energy cascades at basin scale is still poorly quantified. Hence, little is known regarding how submesoscale dynamics actually affects larger scale flows at basin and global scales. Here, we use several years of an unprecedented sub-mesoscale-permitting, North Atlantic ocean/sea-ice model simulation performed at 1/60° resolution with 300 vertical levels. We describe the spatio-temporal variability of dynamical regimes at scales <100km at mid and high latitudes in the North Atlantic. Statistical properties of sub-mesoscale dynamics across the basin are described in terms of wavenumber spectra and probability distributions of surface variables and discussed in the light of recent information collected during field experiments at sub-mesoscales. Our results show in particular how the seasonal cycle of surface stratification in the subpolar gyre leads to a strong seasonal modulation of sub-mesoscale activity at high latitudes. We also discuss how the future wide-swath altimetric missions (SWOT) will sample these dynamical regimes.

3.1-C

Geographical distribution and anisotropy of the oceanic inverse kinetic energy cascade

Zhi Liang Liu, **Shi Hong Wang**

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The geographic character of the inverse cascade is analyzed based on the spectral kinetic energy flux calculated in the global ocean, using sea surface height (SSH) data from satellites, reanalysis data, and model outputs. It is shown that the strongest inverse cascade occurs mostly in high-energy eastward-flowing currents, such as the Antarctic Circumpolar Current (ACC), the Kuroshio Extension, and the Gulf Stream, which matches the global distribution pattern of the eddy kinetic energy (EKE). We also want to show that the inverse energy cascade indeed make the scales of energy-containing eddy are much larger than the energy injection scales, based on direct evidence. Furthermore, the depth dependence and the anisotropy of the inverse kinetic energy cascade are diagnosed in the global ocean. We have found that the strength of the inverse cascades decreases with increasing depth, but the global pattern of the strength is nearly invariable. Meanwhile, the variations in depth can hardly affect the energy injection scales. After considering anisotropy in the spectral flux calculation, a possible inertial range for the zonal spectral kinetic energy flux is expected, where the cascade magnitude will keep a nearly constant negative value associated with the oceanic zonal jets.

3.1-D

Wave turbulence interaction induced vertical mixing and its effects in ocean and climate models

Fangli Qiao (1,2,3), Yeli Yuan (1,2,3), Jia Deng (1,2,3), Dejun Dai (1,2,3), Zhenya Song (1,2,3)

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Heated from above, the oceans are stably stratified. Therefore, the performance of the general ocean circulation and climate studies through coupled atmosphere-ocean models depend critically on vertical mixing of energy and momentum in the water column. Many of the traditional general circulation models are based on Total Kinetic Energy (TKE), in which the roles of waves are averaged out. Although theoretical calculations suggest that waves could greatly enhance coexisting turbulence, no field measurements on turbulence have ever validated this mechanism directly. To address this problem, a specially designed field experiment has been conducted. The experimental results indicate that the wave-turbulence interaction induced enhancement of the background turbulence is indeed the predominant mechanism for turbulence generation and enhancement. Based on this understanding, we propose a new parameterization for vertical mixing as an additive part to the traditional TKE approach. This new result reconfirmed the past theoretical model that had been tested and validated in numerical model experiments and field observations. It firmly establishes the critical role of wave-turbulence interaction effects in both the general ocean circulation models and atmosphere-ocean coupled models, which could greatly improve an understanding of the sea surface temperature and water column properties distributions, and hence the model-based climate forecasting capability.

3.1-E

Ocean-atmosphere interactions on the submesoscale field of the Southern Ocean and its associated impacts on the mixed layer variability

Marcel du Plessis (1,2), Sebastiaan Swart (1,2), Isabelle Jane Ansorge (2), Amala Mahadevan (3)

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The ocean-atmosphere exchange of carbon dioxide and heat is a key process in regulating global climate. The oceanic mixed layer forms the window in which these properties are transported from the surface, down the water column and away from the air-sea interface. This study makes use of winter to autumn high-resolution profiling glider data (physics and biogeochemistry observations) collected in the Atlantic Subantarctic, as part of the third Southern Ocean Seasonal Cycle Experiment (SOSCEx III), to assess the role of the submesoscale field in characterising the variability of the upper ocean. In this region, frontal energetics within the Antarctic Circumpolar Current make for a mixed layer environment with large horizontal density fronts present in the spring and summer months. We provide evidence that during this time, wind stress directed along a density front in the direction of the current induces a destabilising flux via an Ekman advection of denser water over more buoyant water. This flux aims to erode the mixed layer stratification and deepen the mixed layer depth. Conversely, wind stress reversals to an up-front direction promote a stabilising of the mixed layer by a flux of lighter water over heavier water. This restratifying flux is driven by the strength of the horizontal density gradients and the extent of the mixed layer. In addition to these findings, potential vorticity estimates indicate a highly unstable mixed layer during a deepening phases, while the restratification of the mixed layer returns the potential vorticity to a stable state. These results promote the importance of horizontal density gradients, which are likely important in determining the stability of the mixed layer, and can have an important influence on the biogeochemistry and carbon fluxes in the Southern Ocean.

3.2-F

Internal wave driven mixing: An energetically consistent replacement for the Osborn relationship in ocean mixing parameterizations

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The well-known Osborn relationship (typically written as K = Γ ε / N2) is commonly used in parameterizations of internal wave driven mixing to convert local energy dissipation rates and stratification into diffusivities. Unfortunately, this expression is not well behaved in unstably stratified regions, nor does it account for the changes that occur when the mixing is applied over a finite timestep. This poster presents a new approach for translating dissipation rates into diffusivities that captures the essential physical content of the Osborn relationship. Specifically, the new approach retains the tight linkage between the local energy dissipation rate and the potential energy changes due to a local diffusivity, but considers the potential energy changes throughout the water column implicitly over a finite timestep. As a result, this approach is more robust in constraining the energy changes due to mixing, works well with a fully nonlinear equation of state, and does not require any assumptions about the relationship between initial and final stratification. Although it is vertically nonlocal, the numerical implementation of this scheme is roughly as costly as an implicit (tridiagonal) vertical discretization of the mixing of tracers, and hence is appropriate for use in ocean-climate models.

Parallel Orals – Session 3.2

Parallel Session 3.2 Ocean and Climate Dynamics

Wednesday, 21st September 2016 - 14:00hrs **Ballroom 2**

3.2-A

Ocean-atmosphere coupling in changing climate: SST pattern dynamics

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Atmospheric circulation change accounts for much of the uncertainty in regional climate projections, and ocean-atmosphere coupling has been further identified as the key to reducing the atmospheric circulation uncertainty in the tropics. This paper highlights the sea surface temperature (SST) pattern effect that emerged in and after the IPCC Fifth Assessment Report. 1) Locally the SST pattern affects atmospheric convection through moist stability, predicting a dynamic convective threshold that increases with the tropical mean SST. This also explains the strong SST pattern effect on projected changes in tropical cyclone basin counts. 2) Remotely the SST pattern affects global climate by changing El Nino-Southern Oscillation (ENSO) and the teleconnections. A robust change under global warming across CMIP5 models is intensified rainfall anomalies associated with El Nino, which imply an enhanced atmospheric feedback.

All this calls for developing coupled dynamics of tropical climate change. We illustrate this with a comparison between climate responses to greenhouse and aerosol forcings. The overall spatial similarity between two types of response suggests a common coupled mode while the distinction in the Hadley circulation response highlights the effect of interhemispheric asymmetry in aerosol forcing. The latter result suggests the possibility to develop dynamical fingerprints to constrain aerosol radiative forcing.

3.2-B

The Meridional Mode in an Idealized Aquaplanet Model: Dependence on the Mean State

Honghai Zhang (1), Amy Clement (2), Brian Medeiros (3)

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The Meridional Mode provides a source of predictability for the tropical climate variability and change on seasonal and longer time scales by transporting extratropical climate signals into the tropics. Previous research shows that the tropical imprint of the Meridional Mode is constrained by the interhemispheric asymmetry of the tropical mean climate state. In this study the constraint of the zonal asymmetry is investigated in an AGCM thermodynamically coupled with an aquaplanet slab ocean model. The strategy is to modify the zonal asymmetry of the mean climate state and examine the response of the Meridional Mode. Presented here are two simulations of different zonal asymmetries in the mean state. In the zonally symmetric case, the Meridional Mode operates throughout the subtropics, but only becomes evident after removing a dominant global scale eastward-propagating mode. In the zonally asymmetric case, the Meridional Mode operates only in regions where trade winds converge onto the equator, and has an enlarged spatial scale due to the modified mean climate including cold sea surface and weak trade winds. In both simulations, the tropical imprint of the Meridional Mode is constrained by the north-south seasonal migration of the intertropical convergence zone. These results suggest that the Meridional Mode does not require the zonal asymmetry of the mean state but is intrinsic to the subtropical ocean-atmosphere coupled system with its characteristics subject to the mean climate state. The implication is that the internal climate variability needs to be assessed in the context of the mean climate state.

3.2-C

Nonlinearities in the evolutional distinctions between El Niño and La Niña flavors

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It has been well documented that the El Niño Modoki events have been occurring with increased frequency since late 1970s, and that the impacts and the canonical and Modoki ENSOs are different in phase or strength from one another. There is an argument that the distinction of the sea surface temperature (SST) patterns of two flavors is just a non-linear manifestation of the ENSO evolution, and that the distinction largely arises because of classification of extreme events of 1982and 1997 as a canonical El Niño. Interestingly, there is another argument that suggests that while the two El Niño flavors are distinct in terms of evolution, the same cannot be said about the La Niña.

Using the HadiSST, SODA reanalysis, and various other observed and reanalyzed datasets for the period 1958-2010, we carry out some linear and nonlinear analysis to shed some more light on these issues. Our composite analysis as well as cluster analysis indicates that seasonal evolutions of Sea Surface Temperature Anomaly (SSTA) during El Niño Modokis (EM) and El Niños (EL) are distinctly different, and not sensitive to the inclusion/exclusion of extreme events.

We also explore nonlinearities in the sub-surface evolutional distinctions between El Niño flavors and La Nina flavors from a few seasons before the onset. Subsurface temperature composites of EL and EM show different onset characteristics in the sense that during EL, warm anomaly in the west spreads eastwards along the thermocline and reaches the surface in the east in March-May of year(0). During an EM, warm anomaly already exists in the central tropical pacific, and then reaches the surface in the east in September-November of year(0). However La Niña (LA) and La Niña Modoki (LM) show nearly similar onset characteristics.

Further, we use a neural network based nonlinear cluster analysis called self-organizing maps (SOM) technique. We carry out a joint SOM analysis for the monthly SSTA and thermocline depth anomalies associated with the Niño3 index and El Nino Modoki Index (EMI) to identify the different evolutionary path of EL and EM. Along with identification of distinct clusters, we also obtain the propagation characteristics, which depict the probability of SSTA and d20 to move to the nearby cluster. We find that the total evolutionary path of EM and EL SSTA is different except for the event 1991-92 and 1967-68. On the other hand, while the SSTA evolution of LA and LM is somewhat similar (difference significant only at 80% confidence level), the subsurface evolutions are distinct at 90% confidence level.

3.2-D

Climate Variability and Predictability Over the Indo-Pacific Ocean: Indonesian Throughflow variations in the eastern Indonesian seas during the onsets of the 2014 and 2015 El Niño

Dongliang Yuan (1), Xiang Li (1), Zheng Wang (1), Yao Li (1), Adhitya Wardana (2), Dewi Surinati (2), Adi Purwandana (2), Dirham Dirhamsyah (2), Zainal Arifin (2)

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The mooring observations deployed in the Maluku Channel of the Indonesian Seas during December 2012 through November 2015 show reversals of the thermocline zonal currents from eastward to westward during relaxations of the westerly wind bursts (WWB) in the springs of 2014 and 2015. The reversals are not in agreement with the changes of the surface currents and local winds, suggesting remote forcing of the variations. Reflections of the equatorial Rossby waves forced by the WWB into upwelling equatorial Kelvin waves inside the Indonesian seas are suggested to be the cause. Observations have shown that the reflected upwelling Kelvin waves in the summer of 2014 are much stronger than those in the summer of 2015, which may explain the disparate onsets of the 2014 and 2015 El Niño events. The meridional transport in the Maluku Strait are also found to reverse from northward to southward at the time of WWB relaxations, which plays the role of enhancing the upwelling Kelvin waves reflected at the western boundary. The meridional transport anomalies between 50 and 315 m in the Maluku Channel, assuming linear interpolation to zero velocity at the coasts, changes from around 4 Sv (1 Sv = 106 m3 s-1) northward during the WWB to more than 2 Sv southward in 2014 and to 5 Sv southward in 2015, respectively, after the WWB relaxation. These are significant interannual variations of the ITF transport, given that the ITF transport is about 11.6 Sv in the Makassar Strait on average.

3.2-E

Ocean and cryosphere interactions: Tropical Pacific Climate Response to Projected Arctic Sea Ice Loss

Kun Wang (1), Clara Deser (2), Markus Jochum (3), Robert A. Tomas (4)

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The transient climate response to an abrupt loss of Arctic sea ice is investigated using an ensemble of transient simulations with Community Climate System Model version 4 (CCSM4) at 1spatial resolution. Here we focus on the role of ocean dynamics in the tropical climate response by comparing simulations with a thermodynamic "slab" ocean and a full-depth dynamical ocean. The slab-ocean coupled model response is characterized by warming in the northern hemisphere and cooling in the southern hemisphere, accompanied by a northward shift of the Inter-tropical Convergence Zone (ITCZ). In contrast, the dynamical-ocean coupled model response exhibits enhanced warming along the equator accompanied by an equatorward intensification of the ITCZ in the Pacific sector. Thus, ocean dynamics plays a key role in the tropical Pacific response to Arctic sea ice loss. The results suggest two pathways for the dynamically-induced warming of the equatorial Pacific. The initial warming (within the first 20-30 years) appears to be triggered by southwesterly wind anomalies in response to warming of the tropical Atlantic, while the subsequent warming (years 30-100) appears to originate via a weakening of the Atlantic meridional overturning circulation (AMOC) and an oceanic Kelvin wave response along the coast of Chile. Thus, both dynamical tropical air-sea interaction and the global-scale adjustment of the oceanic circulation are important for the response of the tropical Pacific to Arctic sea ice loss.

3.2-F

Tropical Atlantic Variability and Predictability - PREFACE project

Noel Keenlyside (1,2,3), Peter Brandt (4), Team Preface (5)

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Our ability to predict tropical Atlantic variability and its major socio-economic impacts remains limited, with current state-of-the-art climate models exhibiting large biases. The PREFACE project – a European Union funded project that brings together scientists in Europe and Africa – is beginning to redress the situation, focusing on the upwelling regions that are important for climate and fisheries. This presentations aims to summarise key results from the project's first two years. PREFACE is contributing to enhance key observations in the equatorial and coastal wave guides. These together with high-resolution regional ocean model experiments have led to a better understanding of mixed layer temperature and salt budgets, and the seasonality of equatorial and coastal currents, including the poorly observed Angola current. Analysis and experiments with climate prediction models shows the importance of wind errors in the development of both the equatorial and Angola-Benguela sea surface temperature (SST) errors. Higher atmospheric model resolution was found to reduce these errors. PREFACE has made progress towards understanding how mean model errors and variability are related, and how errors in different regions are connected. Furthermore, PREFACE research is providing a more complete picture on the roles of dynamics and thermodynamics in the generation of equatorial Atlantic variability, and roles of internal and external factors in driving decadal variability. Importantly, prediction experiments are revealing promising levels of skill for SST and the West African monsoon. A deeper understanding of the role of ocean variability on coastal marine ecosystems indicates a potential for fisheries relevant predictions. Beyond this, new data from surveys of fishing communities is being used to tailor biological-economic models to be applied to future climate change projections.

3.2-G

Coordinated ocean-ice reference experiments (core-ii): an assessment of antarctic circumpolar current and southern ocean meridional overturning circulation during 1958-2007

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The Antarctic Circumpolar Current (ACC) and Southern Ocean Meridional Overturning Circulation (MOC) are analysed in a suite of seventeen global ocean-sea ice models. We focus on the mean, variability and trends of both the ACC and MOC over the 1958-2007 period, and discuss their relationship with the surface forcing. We quantify the degree of eddy saturation and eddy compensation in the models participating in CORE-II, and compare our results with available observations, previous fine-resolution numerical studies and theoretical constraints. Most models show weak ACC transport sensitivity to changes in forcing during the past five decades, and they can be considered to be in an eddy saturated regime. Larger contrasts arise when considering MOC trends, with a majority of models exhibiting significant strengthening of the MOC during the late 20th and early 21st century. Only a few models show a relatively small sensitivity to forcing changes, responding with an intensified eddy-induced circulation that provides some degree of eddy compensation, while still showing considerable decadal trends. Both ACC and MOC interannual variability are largely controlled by the Southern Annular Mode (SAM). Based on these results, models are clustered into two groups. Models with constant or two-dimensional (horizontal) specification of the eddy-induced advection coefficient K show larger ocean interior decadal trends, larger ACC transport decadal trends and no eddy compensation in the MOC. Eddy-permitting models or models with a three-dimensional time varying K show smaller changes in isopycnal slopes and associated ACC trends, and partial eddy compensation. A constant in time or space K is responsible for a poor representation of mesoscale eddy effects and cannot properly simulate the sensitivity of the ACC and MOC to changing surface forcing. Evidence is given for a larger sensitivity of the MOC as compared to the ACC transport, even when approaching eddy saturation.

3.2-H

On Extratropical Frontal- and Meso-scale Air-Sea Interaction

Shoshiro Minobe (1), Ping Chang (2), Stephen Griffies (3)

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Recent studies revealed that oceanic fronts and meso-scale eddies play important roles in air-sea interaction. Here, oceanic fronts include steep gradients of sea-surface temperature, western boundary currents releasing vast heat and moisture, Antarctic Circumpolar current fronts, sea-ice fronts and etc. High-resolution observations and numerical modellings have demonstrated that oceanic fronts and meso-scale eddies can induce substantial atmospheric responses in not only marine atmospheric boundary layer but also free troposphere including basin-scale remote responses in some cases. Therefore, these effects are important in understanding of both the mean climate and climate variability/change, and can provide improved climate forecast at seasonal-to-decadal timescales, as well as regional information of climate change. On the other hand, our understanding on how frontal- and meso- scale air-sea feedback can affect ocean circulations and oceanic response to natural climate variability and climate change needs to be further improved. This talk will introduce the poster cluster that will highlight recent advancements in extratropical frontal- and meso-scale air- sea interaction. Contributions to this cluster vary from modeling (either realistic or idealized) and observational studies of atmospheric responses to the ocean, oceanic responses to the atmosphere and of coupled feedbacks at frontal- and meso-scales.

3.2-I

How is the atmospheric boundary layer responding to the dynamic new Arctic Ocean?

Manisha Ganeshan (1), Dong Wu (2)

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Recently, the shrinking sea ice has generated tremendous speculation regarding the climate of the Arctic Ocean. Mechanisms such as the ice-albedo feedback, cloud radiative forcing, lapse-rate feedback, have been identified to explore the evolving role of surface-atmosphere interactions. The co-variability of clouds w.r.t sea ice concentration in recent observations is testament to the stronger coupling between the ocean and the atmosphere. The atmospheric boundary layer (ABL) is the interfacial layer that facilitates turbulent heat and momentum exchange at the surface. Therefore, monitoring the Arctic ABL is paramount to understanding the changing nature of the ocean-atmosphere coupling. Past field campaigns have mainly recorded ABL observations during the melt season when a strong surface influence is expected due to the peak in shortwave heating. The Arctic ABL was indeed found to be well-mixed during late summer. However, turbulence is primarily generated by clouds and is typically de-coupled from the sea-ice surface. It is therefore unclear how the ABL will respond to enhanced warming of the Arctic Ocean. In our study, we use multi-year in-situ and remote sensing observations to study the spatial and interannual variability of the Arctic ABL. We inspect the cold season (November-April) Arctic ABL height using eight years of Radio Occultation (RO) observations (2006-2013) from the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC). A unique refractivity-based retrieval algorithm is employed that is suitable for dry polar regions. The spatial, seasonal, and interannual variability of the ABL height indicate sensitivity to the underlying surface conditions. In particular, an anomalously high ABL inversion is observed over the central polar ice pack during January 2012 as reflected in the extreme surface warming during that month. We also inspect the interannual variability in the ABL height using ship-based observations. Lately, there have been a number of reports of enhanced cloud cover over the ice-free Arctic Ocean during fall. In our study, we find that the open ocean sensible heat flux can explain ~10% of the ABL height variability, whereas mechanisms such as cloud-driven turbulence appear to be dominant. Nevertheless, there is strong interannual variability in the strength of the ocean-atmosphere coupling. Surface-generated turbulent mixing is favored during episodes of high wind speed, and is also influenced by the prevailing cloud regime. Thus, the changing occurrence of Arctic climate patterns, such as positive surface wind speed anomalies, can easily enhance the ocean's contribution to ABL turbulence during fall. In summary, the ABL over the Arctic Ocean has varied responses to surface warming depending on the season and the surface-type. During the cold season, the stable inversion over the sea ice is sensitive to extreme anomalies in surface air temperature. During

late summer, the ABL is known to be well-mixed by the cloud-generated turbulence yet de-coupled from the sea-ice. Over the ice-free ocean, the surface-generated turbulence is not negligible (~10%). It exhibits significant interannual variability and a strong dependence on the cloud regime. The surface especially exerts a control on the ABL height variability during episodes of high wind speeds.

Parallel Orals – Session 3.3

Parallel Session 3.3 Upwelling and Frontal Zones

Wednesday, 21st September 2016 - 15:22hrs **Ballroom 3**

3.3-A

Frontal structure and transport in southern Drake Passage from ocean gliders

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The southern boundary of Drake Passage hosts strong boundary currents, including the Antarctic Circumpolar Current (ACC) and outflows from the Weddell Sea. Recent work has shown that mesoscale and submesoscale dynamics are important for cross-shelf exchange and water mass modification. However, the local deformation radius and the scale of the fronts are smaller than the sampling resolutions in typical satellite observations or even ship-based CTD transects. For this reason, we carried out a 15-week field program with two Seagliders deployed west and east of the Shackleton Fracture Zone (SFZ) to continuously survey the continental shelf and slope regions. More than 1400 profiles of temperature, salinity, dissolved oxygen, fluorescence and optical backscatter were collected to a maximum depth of 1000 m during the mission. This enables us to examine the frontal structure in this region with unprecedented resolution and precision.Using the hydrographic observations, we calculated baroclinic and full geostrophic velocity fields, the latter using the gliders depth-averaged currents, along 35 individual transects crossing the continental shelf and slope. Strong westward-flowing and eastward-flowing fronts are observed east and west of the SFZ, respectively. Fronts near the continental shelf-break appear in shallow water of depths about 800 m geostrophic velocities peak near the bottom. These boundary currents reach a maximum velocity of 40 cm/s and are confined to horizontal scales of only 10-15 km, which accounts for about 4 Sv of transport. Generation of deep anomalies of potential temperature, salinity and potential density, possibly resulting from the frictional processes in the bottom boundary layer, are observed over the continental slope. The role of these deep anomalies in influencing the vertical structure of the fronts as well as subsurface variability will be discussed.

3.3-B

Interannual Variability of Eastern Indian Ocean Upwelling: Local versus Remote Forcing

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The equatorial Eastern Indian Ocean (EIO) upwelling occurs in the Indian Ocean warm pool, differing from the equatorial Pacific and Atlantic upwelling that occurs in the cold tongue. By analyzing observations and performing ocean model experiments, this paper quantifies the remote versus local forcing in causing interannual variability of the EIO upwelling from 2001 to 2011 and elucidates the associated processes. For all seasons, interannual variability of thermocline depth in the EIO, as an indicator of upwelling, is dominated by remote forcing from equatorial Indian Ocean winds, which drive Kelvin waves that propagate along the equator and subsequently along the Sumatra–Java coasts. Upwelling has prominent signatures in sea surface temperature (SST) and Chlorophyll-a concentration but only in boreal summer-fall (May-October). Local forcing plays a larger role than remote forcing in producing interannual SST anomaly (SSTA). During boreal summer-fall when the mean thermocline is relatively shallow, SSTA is primarily driven by upwelling process, with comparable contributions from remote and local forcing effects. In contrast, during boreal winter-spring (November-April) when the mean thermocline is relatively deep, SSTA is controlled by surface heat flux, and decoupled from thermocline variability. Advection affects interannual SSTA in all cases. The remote and local winds that drive interannual variability of the EIO upwelling are closely associated with the Indian Ocean Dipole events, and to a lesser degree with El Niño and the Southern Oscillation.

3.3-C

Eastern boundary Upwelling systems (EBUS): interannual variability in the eastern south Pacific and biological response

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Field data and modeling have evidenced a gradual increase in wind-driven coastal upwelling in the highly productive coastal zone off Chile over the last 2-3 decades. Physical manifestations are a more intense wind field, colder, more saline, less-oxygenated and less stratified conditions in the water column in recent years over the continental shelf. Our time series observations on biological responses are showing a decreasing trend in zooplankton biomass, changes in size-structure and community composition, and increased diversity. We did not find evidence for decreased primary or secondary production, but potential greater mortality of epipelagic zooplankton due to increased hypoxia, driven by an extremely shallow oxygen minimum zone, and a large fraction of plankton biomass being lost from the upwelling zone due to incremented offshore advection associated with mesoscale activity. Negative trends in zooplankton biomass, size structure and diversity are coherent with long-term trends in small pelagic fish landings of Chile and Peru, reflecting the strong link between fish production and the dynamics of lower trophic levels. Our findings therefore provide insights on the future of coastal upwelling systems impacted by multiple stressors upon a non-uniform changing ocean.

3.3-D

Effects of ocean surface gravity waves: on turbulence, climate, and frontogenesis.

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Surface gravity waves are small (10-100m) and fast (1-10s), so they often are neglected in traditional oceanography where the emphasis is on slower, larger-scale motions. However, it has recently become clear that these waves energize boundary layer turbulence, which in turn

affects the climate system. Additionally, direct interactions between these waves and mesoscale and sub-mesoscale fronts, filaments, and instabilities have been theorized recently. This talk will present our latest quantification and understanding of these interactions and describe their incorporation into climate modeling.

3.3-E

Eastern boundary upwelling systems (EBUS): Intraseasonal to interannual variability of the Angola Current inferred from moored and shipboard measurements

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The eastern boundary circulation off the coast of southwest Africa has been described only sparsely to date, although it is one key component in a very productive marine system that adjacent coastal countries strongly depend upon. These countries now face substantial challenges in terms of societal development, fisheries, and tourism associated with climate variability and global change. From a broader perspective, the region off Angola, connecting the equatorial Atlantic and the Angola-Benguela upwelling regime, is of particular interest to understand the relative importance of transient equatorial versus local forcing of the observed variability in the coastal upwelling region.

For the first time multi-year velocity observations of the Angola Current at 11°S are available. From July 2013 to November 2015 a bottom shield equipped with an ADCP had been deployed at 500m water depth, accompanied by a mooring sitting on the 1200m-isobath with an ADCP being installed at 500m depth. Both upward-looking instruments measured the current speed in the overlying water-column up to about 50m below the sea surface. During the deployment period the Angola Current was characterized by a weak mean southward flow of 5-8 cm/s at 50m depth (slightly stronger at the in-shore mooring position), that decreased with depth and vanished at a depth of 200m. The alongshore velocity component reveals a pronounced seasonal variability, that is dominated by 120-day, semi-annual, and annual oscillations.

An additional dataset of shipboard ADCP and CTD measurements, which is provided by the EAF-Nansen Project, was collected bi-annually with the R.V. Fridjoft Nansen along repeated sections between 2005 and 2014. Data along the fixed monitoring lines at 6°S, 9°S, 12°S, 15°S, and 17°S allow for the description of the mean structure of the Angola current and the calculation of seasonal averages for the summer and winter periods, respectively.

3.3-F

Assessing different hypotheses about the origin of Benguela upwelling warm bias

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Most ocean and climate models exhibit a warm sea surface temperature (SST) bias in tropical upwelling regions. This bias is especially prominent in the Benguela upwelling system, the major eastern boundary upwelling system in the south-east Atlantic Ocean. Despite much research devoted to this problem during the recent years, the origin of the warm bias remains unknown. We aim at understanding the mechanisms leading to the bias by analyzing the effects of different wind forcing products and model resolutions. We are using a global 1/2° ocean general circulation model with a 1/10° two-way nest embedded in the focus area. The model is forced by different wind products ranging from low-resolution CORE forcing based on reanalysis to high-resolution satellite wind products mostly based on QuikSCAT.

The coastal SST bias shows a strong correlation to the coastal upwelling and therefore to the coastal alongshore wind, and is largely reduced with the QuikSCAT winds and at 1/10° model resolution. The offshore SST bias is more persistent, since it is influenced by the coastal upwelling and also by the curl-driven upwelling. The effect of the latter is quite complicated, because its efficiency is depends on both model resolution and wind-forcing resolution.

The impact of horizontal resolution higher than 1/10°, which has been tested with a second nest within the first one, and of enhanced vertical resolution is quite small. Further, the subsurface bias does not correlate with the SST bias and thus does not seem to be the main reason for the remaining SST bias. Overall, when employing "realistic" winds and horizontal model resolution of 1/10°, there is hardly any SST bias near the coast and a bias of less than 1.5°C offshore. The remaining offshore SST warm bias may be due to problems with the curl-driven upwelling, and this issue is the topic of ongoing research.

Poster Clusters Abstracts

Wednesday, 21st September 2016

Poster Cluster

Extratropical Frontal- and Meso-scale Air-Sea Interaction

Chairs: Shoshiro Minobe (minobe@sci.hokudai.ac.jp), Ping Chang (ping@tamu.edu), Steve Griffies (stephen.griffies@noaa.gov)

Session: 3.2 - Ocean and climate dynamics

Description: Recent studies revealed that oceanic fronts and meso-scale eddies play important roles in air-sea interaction. Here, oceanic fronts include steep gradients of sea-surface temperature, western boundary currents releasing vast heat and moisture, Antarctic Circumpolar current fronts, sea-ice fronts and etc. High-resolution observations and numerical modellings have demonstrated that oceanic fronts and meso-scale eddies can induce substantial atmospheric responses in not only marine atmospheric boundary layer but also free troposphere including basin-scale remote responses in some cases. Therefore, these effects are important in understanding of both the mean climate and climate variability/change, and can provide improved climate forecast at seasonal-to-decadal timescales, as well as regional information of climate change. On the other hand, our understanding on how frontal- and meso- scale air-sea feedback can affect ocean circulations and oceanic response to natural climate variability and climate change needs to be further improved. This poster cluster will highlight recent advancements in extratropical frontal- and meso-scale air- sea interaction. Contributions of modeling (either realistic or idealized) and observational studies of atmospheric responses to the ocean, oceanic responses to the atmosphere and of coupled feedbacks at frontal- and meso-scales will be welcomed.

Wed-014

Extratropical Frontal - and Meso-scale Air-Sea Interaction: New insights into quasi-decadal variability in North Pacific Subtropical Mode Water volume and density

Ivana Cerovecki (1), Stuart Bishop (2), Ryan Abernathey (3)

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Satellite altimetry observations starting in 1993 show that the Kuorshio Extension has made multiple transitions between weakly and strongly meandering states in the 23-year long record that correspond with basin-wide changes in the wind stress curl pattern in the Central Pacific, e.g. the Pacific Decadal Oscillation (PDO). Recent observations using Argo floats show a sharp decline in the volume of North Pacific Subtropical Mode Water (NPSTMW) between 2006-2009 that corresponds with changes in the PDO and a transition of the Kuroshio Extension from a weakly meandering to strongly meandering state. However, the Argo record is short and only captures this one event. New results from a fully-coupled eddy-resolving (0.1o) version of the Community Earth System Model show multiple sharp declines in the volume of NPSTMW that occur on decadal time scales and correspond with both phase relationships in basin-wide changes of the PDO and changes in the eddy properties of the Kuroshio Extension. These model results give new insight into the physical mechanisms responsible for the sharp decline in NPSTW seen in observations. When the PDO changes from positive to negative, this triggers negative sea surface height and thermocline depth anomalies that develop in the Central Pacific and propagate westward. When these anomalies reach the Kuroshio Extension region they lead to a shoaling of the permanent thermocline, which defines the bottom of the NPSTMW low potential vorticity (PV) pool. The top of the low PV pool also deepens due to the decrease in surface density that occurs during a negative PDO phase. Both processes act to increase the PV of the NPSTMW low PV pool, so that PV of some water that was initially in the NPSTMW low PV pool increases above the PV limit that is part of the "mode water" definition. A Walin analysis additionally shows that water mass transformation makes water initially in the NPSTMW density range become more buoyant. This near-surface density decrease provides preconditioning for preferential surface formation of a lighter variety of NPSTMW and further decreases the density of water in the pool. Shoaling of the permanent thermocline also acts unfavorably for the development of deep winter mixed layers, further decreasing its volume.

Wed-015

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Net community production at the Kuroshio Extension Observatory (KEO)

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The Kuroshio Extension (KE) region in the western North Pacific Ocean is an extreme ocean environment characterized by large exchanges of heat, momentum, moisture, and carbon dioxide (CO2) between the atmosphere and ocean. In addition, immediately south of the KE is an area of subtropical mode water formation with a dynamic eddy field. The annual carbon (and nutrient) imprint on these waters caused by interacting biological, chemical, and physical processes will be expressed in other ocean regions when the mode waters upwell and are brought back into contact with the euphotic zone and atmosphere. Therefore, alterations to biogeochemical cycling caused by ocean warming, acidification, or natural variability in the KE region could have important downstream influences on air-sea CO2 exchange and biological productivity on decadal timescales, in addition to the immediate local effects. Large ocean CO2 uptake (1.7 ± 0.3 mol C m-2 yr-1) coupled with the energetic meso-and sub-mesoscale eddy field make the KE an interesting and challenging location to study the drivers and sensitivities of biogeochemical cycling.

Seasonal seawater CO2 oscillations in the KE region are primarily driven by temperature, physical mixing, and biological processes. Since 2007, a nearly continuous record of CO2 partial pressure (pCO2) measurements in the surface ocean and surface atmosphere have been made at the KE Observatory (KEO) mooring, located just south of the KE jet. From these data we can determine the influence of seasonal temperature changes on seawater pCO2 content; however, the remaining pCO2 variability is a function of physical and biological processes. In order to differentiate the biophysical drivers of air-sea CO2 exchange in the KE region, we evaluate the mixed layer carbon budget for dissolved inorganic carbon and total alkalinity using ~7 years of observations from the KEO mooring, combined with data from ships, floats, and satellites. The residuals of these two budgets can be interpreted as the biological contribution to regional carbon cycling, as well as errors. Stoichiometric relations then allow us to rewrite these residuals in terms of the annual biological export of organic and inorganic carbon. Using this approach, the export of organic carbon from the ocean surface to the interior, commonly referred to as annual net community production (NCP), was estimated at 4.5 ± 2.2 mol C m-2 yr-1 and the annual export of calcium carbonate was 0.4 mol C m-2 yr-1. The influence of NCP on the mixed layer carbon budget is largely constrained to the spring bloom when seawater pCO2 is already very low due to winter cooling. Summer warming causes the pCO2 to rise dramatically (~100 µatm) after the spring bloom; therefore, the mismatch in timing between these processes means that biology does little to directly combat pCO2 increases resulting from seasonal warming and the KEO region becomes a source of CO2 to the atmosphere in summer – though it remains an annual sink for CO2.

Wed-016

Extratropical frontal- and meso-scale air-sea Interaction: Impact of sea surface temperature anomalies over the western Kuroshio–Oyashio confluence region on explosively developing extratropical cyclones

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We investigated the dynamical response of rapidly developing extratropical cyclones to sea surface temperature (SST) changes over the western Kuroshio–Oyashio confluence (WKOC) region by performing regional cloud-resolving simulations. This study pays special attention to an extratropical cyclone developing along the Kuroshio/Kuroshio Extension in early February 2014 and contains a real SST experiment (CNTL run) and two sensitivity experiments with warm and cool SST anomalies over the WKOC region (warm and cool runs). The results derived from the CNTL run exhibit that surface evaporation from the ocean becomes active as the dry air transported by the cold conveyor belt overlaps with the warm currents. Moreover, the evaporated vapor induces latent heating over the bent-back front with the aid of the CCB, contributing to the cyclone's growth and the strengthening of the asymmetric structure around the cyclone's center. Such successive processes are more active in the warm run than in the cool run, owing to the WKOC SST difference. The dominance of the zonally asymmetric structure corresponds to the difference in sea level pressure around the bent-back front between the two runs. The WKOC SST changes have the potential to influence the distributions of strong wind along the CCB through modification of the cyclone's inner structure. Additional experiments with two other cyclones indicate that the dynamical response of the cyclone to the WKOC SST changes becomes pronounced when the CCB overlaps with that region, confirming that the CCB plays a vital role in latent heat release over the bent-back front through enhanced surface evaporation from the warm currents.

Wed-017

Extratropical frontal- and meso-scale air-sea Interaction: The Atmospheric response to sensible and latent heat fluxes over the Gulf Stream

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Air-sea interaction over mid-latitude oceanic fronts such as the Gulf Stream attracted large attention in the last decade. Observational analyses and modelling studies revealed that atmospheric responses over the Gulf Stream including surface wind convergence, enhanced precipitation and updraft penetrating to middle-to-upper troposphere roughly on the Gulf Stream current axis or on the warmer flank of sea-surface temperature (SST) front of the Gulf Stream. For these atmospheric responses, oceanic information should be transmitted to the atmosphere via turbulent heat fluxes, and thus the mechanisms for atmospheric responses can be understood better by examining latent and sensible air-sea heat fluxes more closely. Thus, the roles of the sensible and latent heat fluxes are examined by conducting a series of numerical experiments using the IPRC Regional Atmospheric Model over the Gulf Stream. The results indicate that the sensible and latent heat fluxes affect the atmosphere differently. Sensible heat flux intensifies surface wind convergence to produce sea-level pressure (SLP) anomaly. Latent heat flux supplies moistures and maintains enhanced precipitation. These heat fluxes causes upward wind velocity at different layers.

Wed-018

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Influence of the Gulf Stream on the hemispheric-scale coupled atmosphere-ocean-sea ice system

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In this study, we artificially changed the path of the Gulf Stream in a global coupled GCM by slightly modifying the bottom topography around the Florida Peninsula and investigated the response of the hemispheric-scale coupled atmosphere-ocean-sea ice system.

When the narrow channel east of the Florida Peninsula is deep enough in the model, the Gulf Stream takes a realistic path around the peninsula (otherwise the Antilles Current is enhanced unrealistically), but it overshoots northward in comparison to the case with the shallower channel. As a result, positive sea surface temperature (SST) anomalies are found around the Gulf Stream "Extension" (after it separates from the east coast of the North America) and in the Barents Sea. This is consistent with the observed fact that northward shift of the Gulf Stream Extension induces positive SST anomaly in the Barents Sea. On the other hand, SST around Japan increases as opposed to the previous studies that warm anomaly in the Barents Sea brings cold anomaly over Eastern Eurasia. In our model, decrease of sea ice in the Arctic Ocean caused by the modification of bottom topography creates negative sea-level pressure anomaly that elongates along the entire Arctic rim, which may induce northward shift of the atmospheric circulation in the lower Troposphere and the subtropical gyre in the North Pacific, and hence, positive SST anomaly around the Kuroshio Extension.

Wed-019

Extratropical frontal- and meso-scale air-sea interaction: Storm track response to SST front in the northwestern Pacific region in an AGCM

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Storm track response to sea surface temperature (SST) front in the northwestern Pacific region is investigated by using Atmospheric general circulation model For the Earth Simulator (AFES) with 50-km horizontal resolution. Two experiments are conducted one uses 0.25 degree daily SST data (CNTL), and the other (SMTHK) uses smoothed SST over an area covering SST fronts associated with the Kuroshio, the Oyashio, the Kuroshio Extension and the Subpolar Front. Storm track estimated by local deepening rate (LDR) based on surface pressure tendency is strong in this region in CNTL in January, whereas the peak of storm track shifts eastward in SMTHK. The storm track difference between CNTL and SMTHK is only found in explosive deepening events corresponding to LDR larger than 1 hPa h-1, but absent in slow deepening events. A diagnostic equation of LDR suggests that latent heat release associated with grid-scale condensation enhanced by surface moisture flux from the Kuroshio and the Kuroshio Extension contributes to the storm track enhancement. The SST front also affects large-scale atmospheric circulation over the northeastern Pacific region. Jet stream at upper troposphere tends to meander northward there associated with positive SLP anomaly in CNTL, whereas the jet stream flows zonally in SMTHK. Composite analysis for the SLP anomaly suggests that frequent explosive cyclone development in the northwestern Pacific in CNTL causes the downstream positive SLP anomaly over the Gulf of Alaska. On the other hands, cyclones in SMTHK developing over the northeastern Pacific cause the horizontal moisture flux flowing into the west coast of North America, increasing precipitation there.

Wed-020

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Spatial Patterns and Intensity of the Winter Surface Storm Tracks in the CESM, GFDL and GISS CMIP5 Models

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The western boundary currents and their extensions (WBCs) coincide with the regions of the atmospheric storm track entrance and strong air-sea interaction, making the surface winds in these regions an important feature for general circulation models to capture. Therefore, the surface storm tracks in WBCs from three CMIP5 models: NCAR CESM1-LE, NOAA GFDL-CM3, and NASA GISS-ModelE2 are examined against the ERA-Interim. GFDL-CM3 and GISS-ModelE2 reproduce storm track location and intensity with moderate skill, while CESM1-LE has too strong surface winds at almost every location. In the reanalysis, the atmospheric wave packets that propagate from upstream drive temporal variability of surface storm tracks in WBCs. This top-down control and the speed of wave propagation are both reproduced realistically by all the models. In terms of spatial patterns, the models capture the westward shift (towards the WBCs) in the maximum surface storm track locations as compared to the free-tropospheric storm tracks. This shift is likely driven by differential momentum mixing within the boundary layer over warm versus cold waters, as shown by estimated storm track location using only the free tropospheric storm track and a bulk measure of low-level vertical stability. In two out of the three models, surface storm track intensity appears to be primarily dictated by the strength of the free tropospheric storm track; in the third model parameterizations appear to affect this relationship. However, spatial biases in the surface storm tracks that occur over the regions of SST biases in the models suggest the ocean partly controls the location of the surface storm tracks.

Wed-021

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Predominant nonlinear atmospheric response to meridional shift of the Gulf Stream path

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A remarkably strong nonlinear behavior of the atmospheric circulation response to North Atlantic SST anomalies (SSTA) is revealed from a set of large-ensemble, high-resolution, and hemispheric-scale Weather Research and Forecasting (WRF) model simulations. The model is forced with the SSTA associated with meridional shifts of the Gulf Stream (GS) path, constructed from a lag regression of the winter SST on a GS Index from observation. Analysis of the systematic set of experiments with SSTAs of varied size and sign representing various GS-shift scenarios provides unique insights into the potential mechanism for emergence and evolution of atmospheric circulation response to GS shift in the North Atlantic. Results show that, independent of sign and amplitude of the SSTA, the time-mean response is characterized by anomalous troughs over the western North Atlantic and the Western Europe concurrent with enhanced storm track, increased rainfall, and reduced blocking days. To the north of the anomalous lows, an anomalous ridge emerges over the Greenland, Iceland, and Norwegian Seas accompanied by weakened storm track, reduced rainfall and increased blocking days. This equilibrium response patterns strongly resemble the negative polarity of the NAO, the leading pattern of the internal variability in the model. The nonlinear component of the total response dominates the weak and oppositely signed linear response that is directly forced by the SSTA, which yields an anomalous ridge (trough) downstream of the warm (cold) SSTA. The amplitude of the linear response is proportional to that of the SSTA, but the nonlinear response shows no particular correspondence to the size and sign of SSTA. The nonlinear response patterns tend to emerge in 3-4 weeks after the initialization in November and reach its first significant peak by week 6-7 in December. Composite evolution of the circulation anomalies in association with the formation of a blocking near the Greenland reveals that both the high-frequency transient eddies, through vorticity flux convergence, and an incoming low-frequency Rossby wave train, through the convergence of wave activity density, appear to contribute equally to the formation of the barotropic ridge near the Greenland. Analysis of NCEP/NCAR reanalysis dataset also supports the existence of nonlinearity in circulation response to the observed GS shift, and points to the importance of southward shift in the North Atlantic eddy-driven jet for the observed nonlinear response.

Wed-022

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Controlling Influence of Ocean Mesoscale Eddy – Atmosphere Feedback on the Kuroshio Extension Jet

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High-resolution satellite observations and numerical modeling have revealed strong mesoscale air-sea coupling in oceanic frontal regions replenished with energetic eddies. Using high-resolution eddy-resolving global and regional coupled climate models, we show that ocean mesoscale eddy-atmosphere (OME-A) feedback has a controlling influence on the Kuroshio Extension Jet (KEJ). Removing OME-A feedback results in a weaker and broader KEJ with a weaker cross-front temperature gradient in the Kuroshio Extension region. The weakening of the KEJ can be explained by the reduced atmospheric thermal damping effect on ocean eddies in the absence of OME-A feedback. Analyses of eddy potential energy (EPE) budget show that the suppression of OME-A feedback significantly reduces eddy potential energy dissipation, which is balanced by a reduction in EPE production from the mean flow through baroclinic conversion. The decrease in baroclinic conversion is accomplished through the weakening of the KEJ. This finding highlights the importance of resolving ocean meso-scale eddy-atmosphere feedback in accurately simulating western boundary current regimes in climate models.

Wed-024

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Connecting boundary currents – the "eddy-highway" in the South Atlantic

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The South Atlantic Ocean is unique in its role as a nexus for water masses formed elsewhere and en-route to remote regions of the global ocean. In particular, the western boundary currents of the Indian and South Atlantic oceans are connected via the Agulhas leakage and the Benguela Current. This connection is particular important for the Meridional Overturning Circulation and the Earth climate as it provides to the North Atlantic the essential fraction of the volume flux of water compensating the outflow of North Atlantic Deep Water. In this way, the South Atlantic Ocean is the only major ocean basin that transports heat from the pole towards the equator. Recent observations show that the Agulhas Current System is changing under a warming climate and recent modelling estimates show how an increase in Agulhas Leakage may have occurred as a result of such changes. Better understanding the nature and variability of the Agulhas leakage is a vital component of climate change science.

Here we present an original study that show how long-lived mesoscale eddies in the South Atlantic materialize the climatically important link between the eastern and western boundary of the basin. The study is based on multisatellite sea-level data, and a high-resolution ship survey that gives access to the subsurface velocity and hydrographic structure of such eddies. We will show that both, anticyclonic and cyclonic eddies, originating in the Cape Basin, follow a rather similar propagation route. They can be spatially separated by as much as the entire basin width. Anticyclones on the "eddy-highway" were characterised by a core of low stratified water. We consider these eddies to be representative for different "life stages" of the same kind of such mesoscale structures. The salinity and oxygen distribution in the core of the anticyclones suggest a re-ventilating of the core that was most likely driven by surface buoyancy fluxes of varying intensity.

When approaching the western boundary, the low stratified core is at a depth that prevents further en-route modifications and a well-developed anomaly will presumably be release at the western boundary with the dispersion of the eddy. The low stratified core in combination with the negative relative vorticity of anticyclonic eddies has implication for the mixing efficiency by internal waves – at least in summer, when a seasonal stratification is well developed. Not only thermocline water but also Antarctic Intermediate Water is transported across the South Atlantic by both, coherent anticyclonic and cyclonic eddies.

Wed-025

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Mesoscale imprints of the Kuroshio Extension and Oyashio fronts on the wintertime atmospheric boundary layer

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Mesoscale structures of the wintertime marine atmospheric boundary layer (MABL) as imprints of the Kuroshio Extension (KE) and Oyashio fronts east of Japan are investigated, by taking advantage of high horizontal resolution data based on satellite measurements and the ERA-Interim global atmospheric reanalysis. The resolution of sea-surface temperature (SST) data prescribed for the ERA-Interim has been substantially improved in 2002. The high-resolution SST data can represent the KE and Oyashio fronts separately. By contrast, the low-resolution SST data prescribed until 2001 cannot separate these oceanic fronts and represent the Kuroshio-Oyashio Extension (KOE) region as a broad single oceanic frontal zone. In this study, wintertime ERA-Interim climatologies constructed for the high-resolution SST period (2002 through 2014) are compared with those for the low-resolution SST period (1979 through 2001), to assess the imprints of the KE and Oyashio fronts on the MABL. Furthermore, variability of the mesoscale MABL structures associated with the decadal-scale variability of KE system, namely, fluctuation between stable and unstable regime of its path and strength, are investigated.Climatologically, satellite observed data capture two local maxima of upward turbulent heat fluxes from the sea-surface, surface wind convergence, cloudiness and precipitation on the warmer flanks of both the KE and the Oyashio fronts. These dual-peak atmospheric features are reasonably reproduced in the ERA-Interim in its high-resolution SST period. Correspondingly, dual-peaks are evident in meridionally high-pass-filtered fields of sea-level pressure (SLP), potential temperature and upward motions. Furthermore, both the satellite data and the ERA-Interim in its high-resolution SST period reveal that these mesoscale atmospheric features are modulated with SST variations associated with the variability of the KE system. The significant imprints of the KE variability on the overlying atmosphere reach 750-hPa level, which is well above the MABL, implying the influence on free atmosphere. However, neither these dual-peak features nor their variability is well represented in the ERA-Interim in its low-resolution SST period.These results indicate that both the KE and Oyashio fronts can leave distinct mesoscale imprints on the climatological-mean MABL including cloudiness and precipitation, which tend to be modulated with the KE variability. Thus, high-resolution SST data is essential for atmospheric reanalysis to improve representation of meso-scale atmospheric structures associated with oceanic fronts.

Wed-026

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Diurnal Precipitation and High Cloud Frequency Variability over the Gulf Stream and over the Kuroshio

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Recent studies show mid-latitude western boundary currents (WBCs) substantially influence the atmosphere aloft, and an important feature is enhanced rain band over the WBCs in climatological mean field. However, how such long-term, climate phenomena are related to shorter, weather timescale phenomena are generally remained to be explored. In this paper, diurnal precipitation and cloud variations are investigated global mid-latitude oceans with emphasis on air-sea interactions over WBCs using satellite-derived precipitation and outgoing longwave radiation (OLR) datasets. Strong 24-h period components of precipitations are found over the Gulf Stream in summer and over the Kuroshio in the East China Sea in early summer (Baiu-Meiyu season), respectively. Similar diurnal precipitations are not observed in WBCs in the Southern Hemisphere year around. The diurnal precipitation cycles over the Gulf Stream and the Kuroshio exhibit peak phases in the early to late morning for the Gulf Stream and late morning to early afternoon for the Kuroshio, with southeastward phase propagations. High cloud frequency derived from OLR data exhibit consistent diurnal cycles. A substantial difference of diurnal cycles between the Gulf Stream and the Kuroshio regions are associated with the large-scale Baiu-Meiyu rain and cloud bands for the latter region. Diurnal precipitation and high cloud variability is found in the vicinity of the Kuroshio itself, embedded in the Baiu-Meiyu rain and cloud bands distributing in a wider area without a strong diurnal component. The spatial and seasonal distributions of the diurnal variability over these WBCs strongly suggests that the diurnal precipitation and cloud cycles are essential aspects of deep heating mode of atmospheric response recently reported for these WBCs. These results indicate that these WBCs in the Northern Hemisphere play an important role in modulating short-term precipitation variations, and on the other hand diurnal variability can be a substantial agent for the mid-latitude air-sea interaction.

Wed-027

Extratropical frontal- and meso-scale air-sea interaction: On the importance of sea surface temperature front for the formation of low-level clouds over the South Indian Ocean

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Over the South Indian Ocean, a strong SST front forms in the confluence of the Agulhas Return Current and Antarctic Circumpolar Current, acting to maintain locally-enhanced storm-track activity. The present study investigates how the SST front and storm-track locally influence low-level clouds, by utilizing up-to-date MODIS satellite observations. Since the MODIS cannot detect those low-level clouds that are overlapped with middle and high-level clouds, our investigation is based only on observations without those clouds.

Through this sub-sampling, we reveal that low-cloud fraction (LCF) increases greatly under enhanced near-surface cold advection across the SST front while no substantial decrease in LCF is observed under enhanced warm advections. In case of cold advection, enhanced upward sensible heat flux at the sea surface acts to destabilize the boundary layer, which is favorable for stratocumulus formation under the enhanced moisture supply from the ocean. In case of warm advection, by contrast, downward sensible heat flux acts to stabilize the boundary layer, and the warm, moist airflow is thus cooled for fog and stratus formation. This increase in fog and stratus can offset the reduced stratocumulus formation under warm advection. No statistically significant difference is found in lower-tropospheric stability (LTS), a parameter widely used for studying seasonal and interannual variabilities of LCF, between the warm and cold advection cases. Obviously, the non-linear LCF relationship with near-surface temperature advection is not well captured by LTS, because the thermal advection tends to be coherent vertically within the lower troposphere.

Unlike in the eastern portion of the South Indian Ocean, where low-level stratocumuli prevail under persistent cold advection associated with the semi-permanent subtropical Mascarene High, thermal advection diminishes climatologically around the midlatitude SST front along the Agulhas Return Current. Nevertheless, LCF is still high through the non-linear LCF relationship with near-surface meridional thermal advection, which is enhanced by the SST front through not only maintaining strong near-surface air temperature gradient but also intensifying storm-track activity.

Wed-028

Extratropical Frontal- and Meso-scale Air-Sea Interaction:Storm track response to resolved oceanic fronts in the NCAR and GFDL global coupled models

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It has been hypothesized that ocean mesoscale can affect the strength and location of the overlying extratropical atmospheric storm track. We examine here whether resolving oceanic fronts in global climate models leads to significant changes in the location and intensity of the storm tracks. Three sets of experiments are used: i) NCAR Community Earth System Model with standard resolution or with ocean eddy-resolving resolution, ii) the same but with GFDL global coupled models, and iii) Community Earth System Model with and without regional ocean refinement of the Gulf Stream. In the NCAR simulations, it is found that higher ocean resolution leads to a reduction of a very warm SST bias at the east coast of the US and Japan coasts seen in standard resolution models. This in turn leads to a reduction of storm track strength at the far western boundary, and a better location of the storm track maxima, over the western boundary currents as observed. In contrast, the change in absolute SST bias is less notable in the GFDL models, and there are modest (10% or less) increases in surface storm track, and smaller changes above. Overall, for the range of ocean model resolutions used here (1º to 0.1º) we find that the differences in SST gradient have a small effect on the storm track strength whilst changes in SST bias can have a larger effect. Differences in SST gradients are shown to have a larger influence on the representation of precipitation. Overall this study shows that the storm track location is better identified with the higher resolution ocean, in line with previous work.

Wed-029

Extratropical frontal- and meso-scale air-sea interaction: Impacts of midlatutide oceanic fronts on the atmosphere as revealed in a new Japanese atmospheric reanalysis as a legacy of the "hot-spot" project

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Impacts of frontal SST gradients associated with midlatitude western boundary currents on the overlying atmosphere are assessed through comparison between two products of a new Japanese reanalysis (JRA-55). One is JRA-55C in which all the observational data except satellite data have been assimilated in a forecast system with horizontal resolution of ~60km and the COBE SST data on 1-degree resolution prescribed over 55 years. The other is JRA-55CHS, which is the same as JRA-55C but with MGDSST data with a quarter-degree resolution but only over 28 recent years. This data set is prepared jointly by the Meteorological Research Institute and University of Tokyo as a legacy of the Japanese "hot-spot" project, which was concluded in March 2015.

The comparison reveals substantial differences in midlatitude atmospheric processes around the SST fronts. For example, enhancement of cloudiness and precipitation in the mixed-water region east of Japan during the unstable regime of Kuroshio Extension (KE) relative to its stable regime is represented well in JRA-55CHS, as in satellite observations, but not in JRA55C. The enhancement arises from augmented heat/moisture release from the warmer ocean with more active warm-core eddies. This oceanic thermal forcing onto the atmosphere is manifested as positive correlation in anomalies between SST and heat/moisture release, which is represented only with the high-resolution MGDSST but not with the COBE SST. Other examples include stormtrack response to meridional displacement of the Oyashio front. Again, the positive correlation between anomalous SST and heat/moisture release is much stronger in JRA-55CHS, and so is the enhancement of convective precipitation over warm SST anomalies. Convective diabatic heating may be essential for the development of synoptic-scale cyclones, which may enhance the sensitivity of a stormtrack to the variability of the SST front. Convective precipitation is also enhanced climatologically along the Gulf Stream in JRA-55CHS. Note that the main JRA-55 product, in which satellite data are also incorporated with the COBE SST, exhibits almost the same characteristics as the JRA-55C.

Wed-030

Extratropical Frontal- and Meso-scale Air-Sea Interaction: How potentially predictable are midlatitude oceanic currents?

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Variability in the atmosphere is well known to include significant uncertainty due to its internal, intrinsic variability that happens independently from external forcing and/or boundary conditions and the observed variability is just one realization of different dynamical states that would possibly take place. In contrast, uncertainty in variability in ocean circulation is still unclear. As atmospheric variability at the sea surface has been considered as a determining forcing for the ocean circulation, ocean is expected to be rather deterministic under varying atmospheric forcing. Here we show that interannual variability in the ocean circulation can be also significantly uncertain based on an eddy-resolving ocean general circulation model simulations driven by observed atmospheric fields under slightly different conditions. Interestingly, the oceanic uncertainty shows remarkable horizontal distribution and the tropical oceans are very deterministic to a given atmospheric variability, while uncertainty is large in the western boundary current (WBC) regions in midlatitude. Although the results can depend on the ocean model, they imply that observed oceanic variability is also just one realization and multi-member ensemble simulations are necessary for understanding mechanisms and predictability in variability in the WBC regions, which are important for midlatitude climate variability and also marine ecosystems.

Wed-031

Extratropical frontal- and meso-scale air-sea Interaction: Dynamical response of the North Pacific Ocean to the tropical variability and its decadal modulation

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While teleconnections from the tropical Pacific to the North Pacific sea surface temperature are well known, the dynamical response of the North Pacific Ocean to the tropical atmosphere-ocean variability is not well investigated. Based on observed and reanalysis data, we investigate this link through a correlation analysis using the indices of Nino3, Nino3.4, and El Nino Modoki Index (EMI). The simultaneous correlation maps of the wind-stress curl indicate that the signal associated with EMI in the eastern North Pacific is stronger than the counterparts with Nino3 and Nino3.4. Responding to these signals in wind-stress curl, sea surface height (SSH) anomalies develop following EMI, but almost no SSH responses are found to Nino3 and Nino3.4. As El Nino Modoki lasts for a longer period than canonical El Nino, the stronger wind-stress curl signal to EMI drives the ocean more persistently, and induces substantial SSH signals. The induced SSH signals propagate westward to the western boundary region around 35N, affecting variability in the Kuroshio Extension. The teleconnection from EMI to the North Pacific, however, was not found before the 1990s, indicating its clear decadal modulation.

Wed-032

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Possibility and mechanism of atmospheric response to wintertime SST anomalies in the North Pacific frontal zone and its relationship to atmospheric internal variability

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Possibility of a large-scale atmospheric response to midlatitude decadal-scale SST anomalies has been investigated. Recent studies have been revealed that a decadal-scale warm SST anomaly observed in the North Pacific subarctic frontal zone (SAFZ) tends to accompany a basin-scale tropospheric anticyclonic anomaly that peaks in January. A set of AGCM experiments was conducted by prescribing the decadal-scale SST anomaly observed in SAFZ, which is found to simulate an anticyclonic ensemble response over the North Pacific in January. As observed, the simulated anticyclonic response is in equivalent barotropic structure and maintained mainly through energy conversion from the ensemble mean circulation realized under the climatological SST, suggesting that the anomaly may have a characteristic of a dynamical mode inherent to its background state. Conversions of both available potential energy (APE) and kinetic energy (KE) from the mean flow are important for the observed anomaly, while only the former is important for the model response. This is because the model response is located to the north of the jet axis whereas the observed anomaly is straddling the jet exit region, which appears to be in correspondence to the northwestward displacement of the center of the dominant atmospheric internal variability in the AGCM relative to its observational counterpart. Net transient eddy feedback forcing also acts to maintain the observed anomaly rather efficiently, but its efficiency is much lower for the simulated response, which seems to be consistent with the poleward displacement of the anticyclonic response from the jet and stormtrack axes. A multi-decadal integration of a CGCM also suggests that atmospheric internal variability may be important for determining atmospheric response to the decadal SST variability over the SAFZ. The weakening of the atmospheric response in February is also simulated in our model, which is consistent with some recent studies.

Wed-033

Extratropical frontal- and meso-scale air-sea interaction: Impact of oceanic front on the ozone-induced stratosphere/troposphere coupling of the Southern Annular Mode

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The Southern Hemisphere Annular Mode (SAM) is the dominant mode of low-frequency atmospheric variability in the extratropical Southern Hemisphere, exerting substantial climatic impacts on extensive regions. A decadal trend of SAM observed in the troposphere during the late 20th century is considered to be related to the intensification of the stratospheric polar vortex induced by the ozone depletion. Known as a manifestation of meridional displacements of the eddy-driven polar-front jet (PFJ) and associated storm-track, the tropospheric SAM and its trend may be sensitive to the near-surface baroclinicity associated with the midlatitude oceanic frontal zone. In the present study, aqua-planet experiments with an atmospheric general circulation model are conducted by prescribing two different latitudinal profiles of zonally symmetric sea-surface temperature (SST) with and without frontal gradient in midlatitudes. A comparison of the tropospheric response to the assigned stratospheric ozone depletion between the two SST profiles reveals critical importance of the frontal SST gradient for translating the direct response of the stratospheric polar vortex to the ozone depletion down to the surface by enhancing the SAM variability and allowing the SAM its deep structure into the stratosphere in late spring through early summer.

Wed-034

Extratropical frontal- and meso-scale air-sea interaction: Impact of oceanic front on the northern hemispheric coupled stratosphere/troposphere-system

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The dynamical and climatic impact of northern hemisphere oceanic fronts and their signature in the stratosphere/troposphere coupled system are still poorly understood. Using a set of semi-idealized experiments with a stratosphere-resolving AGCM, it is shown that the extratropical northern hemisphere oceanic fronts play a fundamental role in shaping the large-scale atmospheric circulation and transferring the stratospheric circulation changes into the troposphere. The impact of Northern hemispheric extratropical oceanic fronts on the stratosphere is shown to be dominated by the Kuroshio-Oyashio front and it is similar to the simultaneous impact of land/sea contrast and orography. It is associated with a strong adiabatic stratospheric warming, vortex weakening and a strengthening of the Brower-Dobson circulation, which are all caused mainly by resolved and partially by unresolved wave forcing. The stratospheric signature of oceanic fronts is shown to be important for understanding the very weak ozone destruction seen in the northern hemisphere. Regarding the stratosphere/troposphere coupling it is shown that the northern hemisphere oceanic fronts play a crucial role in transferring the stationary wave-induced stratospheric perturbations into the troposphere and dictating the latitudinal position of the stratosphere/troposphere coupling. The implications of our results for the mechanisms of the stratosphere/troposphere coupling are discussed.

Wed-035

Extratropical frontal- and meso-scale air-sea interaction: Impact of oceanic front on the tropospheric winter-time signature of the Southern Annular Mode

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A midlatitude oceanic frontal zone is a confluent region of warm and cool ocean currents, characterized by strong meridional gradient in both sea-surface temperature (SST) and surface-air temperature (SAT). While recent observational and modeling studies indicate its potential impacts on the extratropical climatological circulation, including stormtracks and eddy-driven westerlies, the impact on its dominant low-frequency variability (i.e. annular mode) still remains to be understood. This study explores possible impacts of midlatitude oceanic frontal zones on annular mode signatures in the wintertime Southern Hemisphere (SH). To mimic the SH, sets of idealized "aqua-planet" experiments are conducted with zonally symmetric distributions of SST prescribed globally at the lower boundary of a given AGCM. By systematically changing the latitude and intensity of the frontal gradient in the SST profile, the experiments reveal that the characteristics of the wintertime annular mode exhibits strong sensitivity to the position of the SST front, if situated at midlatitude or subpolar latitude. It may be interpreted as a manifestation of wobble of the extratropical tropospheric circulation between two dynamical regimes – one under the strong influence of SST gradient as the lower-boundary condition, and the other under the strong control by atmospheric internal dynamics unrelated to the lower-boundary condition. In fact, this interpretation is found insightful about the observed inter-basin differences in the wintertime SAM signature that are embedded in the zonally symmetric anomalies. The findings suggest possible reinterpretation of the climatological-mean state observed in the wintertime SH as the superposition of those two dynamical regimes.

Wed-036

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Diagnosing Forced Versus Intrinsic Low-Frequency Variability in an Idealized North Atlantic Ocean-Atmosphere Model

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How much do the ocean and atmosphere influence each other at low frequencies? In an effort to help answer this question, we investigate the dynamics of the ocean-atmosphere system in the frequency and wavenumber domains, using the idealized Quasi-Geostrophic Coupled Model optimized to run in the North Atlantic Ocean. The model consists of a box ocean coupled to a channel atmosphere via mixed layers that allow for the vertical exchange of heat and momentum across the ocean-atmosphere boundary. In the frequency and wavenumber domains, we compute spectra and spectral transfers, the latter indicating the relative importance of the forced versus intrinsic contributions to the maintenance of low-frequency variability. We look first at the wind stress contribution to oceanic dynamics, and then at the heat flux contribution to both oceanic and atmospheric dynamics. We run the model in three distinct modes: a dynamic atmosphere only, a dynamic ocean only, and a fully coupled dynamic ocean-atmosphere regime. This analysis on a simplified model provides a better understanding of the source of energy at low frequencies within the climate system, and will help contribute to future studies using more complex models.

Wed-049

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Response of atmosphere-ocean system to latitudinal shifts of the North Pacific Subarctic frontal zone

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While recent observational and modeling studies suggest that sea surface temperature variability associated with latitudinal shifts of the North Pacific Subarctic frontal zone (SAFZ) can have significant impacts on basin-scale atmospheric circulation, few studies have explicitly addressed oceanic feedback of the ocean-front induced atmospheric responses. In this study we examine atmospheric circulation response to the North Pacific SAFZ shifts and its dynamical feedback on the ocean by performing idealized coupled GCM sensitivity experiments. In the experiments, anomalous latitudinal shifts of the simulated North Pacific SAFZ are deliberately induced by imposing idealized wind stress anomaly in the central North Pacific during the first 1.75 years of the coupled integration starting with 25 different initial conditions. The following 2.75 years free coupled integrations without the wind anomaly are then analyzed for the response of atmosphere-ocean system.

The analysis of ensemble mean fields show that the North Pacific SAFZ shifts yield robust local atmospheric response in precipitation and storm track activity but rather vague response in the basin-scale atmospheric circulation. Ensemble composite analysis, however, detects two distinct regimes in the atmospheric circulation response and its feedback on the ocean: warm-SAFZ/weakened Aleutian Low (AL) and cold-SAFZ/enhanced AL responses. These responses lead to two-way positive and negative dynamical feedbacks, each of which contributes to persistence and delayed phase transition of the position and SST anomalies in SAFZ, respectively, a dynamical feedback that may be crucial for Pacific decadal variability. It will be discussed what conditions determine the realization of the two contrasting atmosphere-ocean dynamical feedbacks.

Wed-050

Extratropical frontal- and meso-scale air-sea interaction: Role of mixed layer depth in surface frontogenesis of the Kuroshio Extension region

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The sea surface temperature (SST) front in the Kuroshio Extension region plays an important role in the ocean-atmosphere interaction over the North Pacific. Here, we have examined how meridional variations in the mixed layer depth across the SST front affects the frontogenesis/frontolysis. Based on mixed layer heat budget analyses, we have shown that the surface heat flux term tends to strengthen the SST front despite the stronger net surface heat loss on the equatorward side. Since the mixed layer is much deeper on the equatorward side, the SST there is less sensitive to the surface heat loss. In contrast, the oceanic term contributes to the frontolysis. The cause for shallower mixed layer to the south of the SST front is also discussed.

Wed-051

Extratropical Frontal- and Meso-scale Air-Sea Interaction: Assessing surface heat fluxes in atmospheric reanalyses with a decade of data from the NOAA Kuroshio Extension Observatory

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The ocean and atmosphere interact through air-sea fluxes. These fluxes are the most direct ocean climate indicator of how the ocean influences climate and weather and their extremes; and how the atmosphere forces ocean variability. Momentum fluxes (wind stress) drive general ocean circulation, setting up the ocean gyres and current systems that can redistribute heat and properties within the ocean. Air-sea fluxes of heat are the primary mechanism by which the ocean influences the atmosphere. The intense heat release along the western boundary current and its extension plays a key role in setting and modulating the upper ocean stratification, mode water formation, and large scale ocean circulations, as well as biogeochemical processes.

Previous studies have found large biases and uncertainties in the air-sea fluxes from Numerical Weather Prediction model reanalyses, which must be identified and reduced in order to make progress on weather and climate predictions. Here, air-sea heat fluxes from NOAA Kuroshio Extension Observatory (KEO) measurements are used to assess two new reanalyses, NCEP's Climate Forecast System Reanalysis (CFSR) and ECMWF Reanalysis-Interim (ERA-I), suggesting that these two new generation reanalyses have significantly improved. In both reanalyses, all four flux components (sensible and latent heat flux and longwave and shortwave radiation) are highly correlated with observation, with the correlation of total net surface heat fluxes above 0.96. Although errors of the net surface heat flux have significantly reduced from previous reanalyses, the Root Mean Square Errors (RMSEs) and biases remain high especially for CFSR: the RMSEs of CFSR and ERA-I are reduced to 64 and 61 W/m2 respectively, while biases are reduced to 28 and 21 W/m2. But CFSR overestimates the winter heat release by 90 W/m2. The main cause of biases is the latent heat flux, while RMS errors are primarily due to latent heat flux and shortwave radiation errors. Both reanalyses overestimate the wind speed associated with winter storms and underestimate specific humidity in summer. The ERA-I latent heat flux, and its total net surface heat flux, are however closer to observation. It is the bulk algorithm in CFSR that is found to be mainly responsible for overestimates of winter heat release in CFSR.

Poster Cluster

Coordinated Ocean-ice Reference Experiments (CORE-II)

Chair: Gokhan Danabasoglu (gokhan@ucar.edu)

Session: 3.2 - Ocean and climate dynamics

Description: A major focus of the CLIVAR Ocean Model Development Panel (OMDP) has been the development of the Coordinated Ocean-ice Reference Experiments phase II (CORE-II) framework which now represents the foundation of the CMIP6 Ocean Model Inter-comparison Project (OMIP). The cluster will present OMIP and updates to the forcing data sets and show results from ocean – sea-ice coupled simulations participating in the CORE-II effort.

Wed-052

Coordinated Ocean-ice Reference Experiments (CORE-II): Inter-Annual to Decadal Variability in the North Atlantic

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Simulated inter-annual to decadal variability and trends in the North Atlantic for the 1958-2007 period from twenty global ocean sea-ice coupled models are presented. These simulations are performed as contributions to the second phase of the Coordinated Ocean-ice Reference Experiments (CORE-II). A major focus of the present study is the representation of Atlantic meridional overturning circulation (AMOC) variability in the participating models. Relationships between AMOC variability and those of some other related variables, such as subpolar mixed layer depths, the North Atlantic Oscillation (NAO), and the Labrador Sea upper-ocean hydrographic properties, are also investigated. In general, AMOC variability shows three distinct stages. During the first stage that lasts until the mid- to late-1970s, AMOC is relatively steady, remaining lower than its long-term (1958-2007) mean. Thereafter, AMOC intensifies with maximum transports achieved in the mid- to late-1990s. This enhancement is then followed by a weakening trend until the end of our integration period. This sequence of low frequency AMOC variability is consistent with previous studies. Regarding strengthening of AMOC between about the mid-1970s and the mid-1990s, our results support a previously identified variability mechanism where AMOC intensification is connected to increased deep water formation in the subpolar North Atlantic, driven by NAO-related surface fluxes. The simulations tend to show general agreement in their representations of, for example, AMOC, sea surface temperature (SST), and subpolar mixed layer depth variabilities. In particular, the observed variability of the North Atlantic SSTs is captured well by all models. These findings indicate that simulated variability and trends are primarily dictated by the atmospheric datasets which include the influence of ocean dynamics from nature superimposed onto anthropogenic effects. Despite these general agreements, there are many differences among the model solutions, particularly in the spatial structures of variability patterns. For example, the location of the maximum AMOC variability differs among the models between Northern and Southern Hemispheres.

Wed-053

Coordinated ocean-ice reference experiments (CORE-II) Ocean Heat Content study in the ACCESS-OM: comparison between CORE-II and JRA-55 forcing for the CMIP6 Ocean Model Intercomparison Project (OMIP)

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There is considerable uncertainty in global and regional sea level projections from the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project (CMIP) simulations. Largest model disagreements generally coincide with regions of maximum projected sea level rise in the Southern Ocean and North Atlantic. These high latitude ocean regions are also key for the vertical transport of heat and other tracers (CO2), from the surface to the deep ocean, and therefore play an important role in regulating Earth's climate. Total ocean heat uptake and vertical penetration vary greatly among CMIP models and thus contribute to large uncertainty in sea level projections (as thermal expansion is a non-linear function of ocean temperature and pressure). Here, we investigate the role of two different forcing products on key aspects of the simulation of global ocean climate in the Australian Community Climate and Earth System Simulator (ACCESS; Bi et al., 2013a,b). The simulations (1 degree global ocean-ice model component) were forced by interannual Coordinated Ocean-ice Reference Experiments (CORE-II; Griffies et al., 2012; Danabasoglu et al., 2014) and Japanese 55-year Reanalysis (JRA-55; Kobayashi et al., 2015) atmospheric reanalyses. In future studies, we plan to perform experiments using an eddy permitting resolution and a coupled version of the ACCESS model. These experimental frameworks are being used to develop a fully closed ocean heat budget analysis framework in the ACCESS modelling system. Future experiments will be forced by single (heat, freshwater and wind stress) and/or combined surface forcing perturbation fluxes, as part of a CMIP6 protocol known as the Flux Anomaly Forcing Model Intercomparison (FAFMIP) Project, developed in support of the WCRP Grand Challenge on Regional Sea-Level Change and Coastal Impacts We expect that our outcomes will contribute towards refining the realism of the ACCESS model and therefore to more rigorous constraints on the likelihood of future warming and global/regional sea level rise.

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Wed-054

Coordinated ocean-ice reference experiments (core-ii): north and equatorial pacific ocean circulation

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We evaluate the mean circulation patterns, water mass distributions, and tropical dynamics of the North and Equatorial Pacific Ocean based on a suite of global ocean-sea ice simulations driven by the CORE-II atmospheric forcing from 1963-2007. The first three moments of sea surface height and surface temperature variability are assessed against observations. Large discrepancies are found in the variance and skewness of sea surface height and in the skewness of sea surface temperature. Comparing with the observation, most models underestimate the Kuroshio transport in the Asian Marginal seas due to the missing influence of the unresolved western boundary current and meso-scale eddies. In terms of the Mixed Layer Depths (MLDs) in the North Pacific, the two observed maxima associated with Subtropical Mode Water and Central Mode Water formation coalesce into a large pool of deep MLDs in all participating models, but another local maximum associated with the formation of Eastern Subtropical Mode Water can be found in all models with different magnitudes. The main model bias of deep MLDs results from excessive Subtropical Mode Water formation due to inaccurate representation of the Kuroshio separation and of the associated excessively warm and salty Kuroshio water. Further water mass analysis shows that the North Pacific Intermediate Water can penetrate southward in most models, but its distribution greatly varies among models depending not only on grid resolution and vertical coordinate but also on the model dynamics. All simulations show overall similarly large scale tropical current system, but with differences in the structures of the Equatorial Undercurrent. We also confirm the key role of the meridional gradient of the wind stress curl in driving the equatorial transport, leading to a generally weak North Equatorial Counter Current in all models due to inaccurate CORE-II equatorial wind fields. Most models show a larger interior transport of Pacific subtropical cells than the observation due to the overestimated transport in the Northern Hemisphere likely resulting from the deep pycnocline.

Wed-055

Coordinated ocean-ice reference experiments (core-ii): an assessment of southern ocean water masses and sea ice during 1988-2007

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The Southern Ocean is a key player in global climate change, carbon and heat uptake, and inter-basin exchange of nutrients and gases. However, the scientific community has struggled to comprehensively observe and model this complex, dynamic and remote region. This study focuses particularly on the inter-dependent large-scale water masses, mixed layer depths and sea ice in the Southern Ocean, using the Coordinated Ocean-Ice Reference Experiments (CORE-II) models. The CORE-II models, each with a different ocean-ice mode configuration, are coupled to a common atmospheric state with fluxes computed using the same bulk formulae as a function of the simulated sea surface temperature and surface currents. Here, fifteen of the CORE-II models (most of whose fully-coupled configurations were submitted to the last Coupled Model Intercomparison Project, Phase 5 CMIP5) are being used to assess the representation of the recent mean and changing climate. We find that the common atmospheric state across the fifteen models influences the temperature and salinity biases compared with observations, with a clear cold/fresh and warm/salty bias centered on ~50S. In addition, the CORE-II models underestimate the summer and overestimate the winter mixed layer depths, as well as underestimating the summer sea-ice extent. These biases are primarily a reflection of the oceanic surface heat gain/loss distribution, and errors in the atmospheric state (e.g., katabatic winds and other poorly observed polar processes). Despite their common atmospheric state, the CORE-II models are in disagreement in their spatial pattern of the 20-year trends in the mixed layer depth and sea-ice. Evidently, individual ocean and ice model components (that include, for example, parameterized mesoscale and mixing and overflow dynamics) dictate the response of the model to a changing atmospheric state.

Wed-056

Coordinated ocean-ice reference experiments (core-ii): an assessment of antarctic circumpolar current and southern ocean meridional overturning circulation during 1958-2007

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The Antarctic Circumpolar Current (ACC) and Southern Ocean Meridional Overturning Circulation (MOC) are analysed in a suite of seventeen global ocean-sea ice models. We focus on the mean, variability and trends of both the ACC and MOC over the 1958-2007 period, and discuss their relationship with the surface forcing. We quantify the degree of eddy saturation and eddy compensation in the models participating in CORE-II, and compare our results with available observations, previous fine-resolution numerical studies and theoretical constraints. Most models show weak ACC transport sensitivity to changes in forcing during the past five decades, and they can be considered to be in an eddy saturated regime. Larger contrasts arise when considering MOC trends, with a majority of models exhibiting significant strengthening of the MOC during the late 20th and early 21st century. Only a few models show a relatively small sensitivity to forcing changes, responding with an intensified eddy-induced circulation that provides some degree of eddy compensation, while still showing considerable decadal trends. Both ACC and MOC interannual variability are largely controlled by the Southern Annular Mode (SAM). Based on these results, models are clustered into two groups. Models with constant or two-dimensional (horizontal) specification of the eddy-induced advection coefficient K show larger ocean interior decadal trends, larger ACC transport decadal trends and no eddy compensation in the MOC. Eddy-permitting models or models with a three-dimensional time varying K show smaller changes in isopycnal slopes and associated ACC trends, and partial eddy compensation. A constant in time or space K is responsible for a poor representation of mesoscale eddy effects and cannot properly simulate the sensitivity of the ACC and MOC to changing surface forcing. Evidence is given for a larger sensitivity of the MOC as compared to the ACC transport, even when approaching eddy saturation.

Wed-057

Coordinated Ocean-ice Reference Experiments (CORE-II): A study of impacts of uncertainties in NCEP R2 and CFSR surface fluxes on tropical temperature simulations

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NCEP/DOE reanalysis (R2) and Climate Forecast System Reanalysis (CFSR) surface fluxes are widely used by the research community to understand surface flux climate variability and to drive ocean models as surface forcings. However, large discrepancies exit between these two products and validation of reanalysis flux products are difficult due to lack of observations. The purposes of this study are to understand the impacts of uncertainties in R2 and CFSR surface fluxes on the simulation of ocean temperature. The goals of the study are to inform the user community (1) the salient features of discrepancies in R2 and CFSR surface fluxes, (2) sensitivity of ocean simulations to discrepancies in each flux component, and (2) fidelity of the two products for temperature simulation in the tropical ocean where uncertainties of surface fluxes are largest. To fulfil the goals, daily R2 and CFSR surface fluxes spanning the period 1982-2013 are used to force a series of Oceanic General Circulation Model (OGCM) simulations in which combination of surface flux component (momentum, heat and fresh water fluxes) from R2 and CFSR are used. The model simulations are contrasted to identify sensitivity of model simulations to each component of the fluxes in R2 and CFSR. The accuracy of the model simulations are validated against the TAO/TRITON, PIRATA and RAMA moorings data, and AVISO altimetry SSH data.

The main discrepancies between R2 and CFSR fluxes include (1) a significant reduction of differences in zonal winds in the tropical Pacific and Indian Ocean around 2000 and (2) overall larger net heat fluxes into ocean in CFSR than in R2. Due to the shift around 2000, it is necessary to do analysis for the period before and after 1999 separately. Sensitivity of ocean simulations show that temperature in upper 100m are sensitive to differences in net surface heat flux, while the depth of 20 degree isotherm (D20) is sensitive to discrepancies in winds. Relative to the R2 fluxes, the CFSR fluxes help to reduce the mean bias in the tropical Atlantic, and improve simulation of interannual variability in all three tropical oceans. The improvement in the tropical Atlantic is most significant and is largely attributed to differences in surface winds.

Wed-065

Coordinated ocean-ice reference experiments (core-ii): an assessment of the Arctic sea ice and freshwater

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The Arctic Ocean simulated in fourteen global ocean-sea ice models in the framework of the Coordinated Ocean-ice Reference Experiments, phase II (CORE II) is analyzed. The focus is on the Arctic sea ice and the solid and liquid freshwater (FW). Available observations are used for model evaluation. The variability of sea ice extent and FW budget is more consistently reproduced than their mean state in the models. The descending trend of September sea ice extent is well simulated in terms of the model ensemble mean. Models overestimating sea ice thickness tend to underestimate the descending trend of September sea ice extent. The models underestimate the observed sea ice thinning trend by a factor of two. When averaged on decadal time scales, the variation of Arctic solid FWC is contributed by those of both sea ice production and sea ice transport, which are out of phase in time. The solid FWC decreased in the recent decades, caused mainly by the reduction in sea ice thickness. The models did not simulate the acceleration of sea ice thickness decline, leading to an underestimation of solid FWC trend after 2000. The common modelled sea ice behaviour, including the tendency to underestimate the trend of sea ice thickness and March sea ice extent, remains to be improved.

The models agree on the interannual variability of liquid FW transport at the gateways where the ocean volume transport determines the FW transport variability. The variation of liquid FWC is induced by both the surface FW flux (associated with sea ice production) and lateral liquid FW transport, which are in phase when averaged on decadal time scales. The liquid FWC shows an increase starting from the mid-1990s, caused by the reduction of both sea ice formation and liquid FW export, with the former being more significant in most of the models. The model ensemble means of liquid FW transport through the Arctic gateways compare well with observations. On average, the models have too high mean FWC, weaker upward trends of FWC in the recent decade than the observation, and low consistency in the temporal variation of FWC spatial distribution, which needs to be further explored for the purpose of model development.

Wed-066

Coordinated ocean-ice reference experiments (core-ii): an assessment of the Arctic hydrography and fluxes

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We compare the simulated Arctic Ocean in 15 global ocean–sea ice models in the framework of the Coordinated Ocean-ice Reference Experiments, phase II (CORE-II). Most of these models are the ocean and sea-ice components of the coupled climate models used in the Coupled Model Intercomparison Project Phase 5 (CMIP5) experiments. We mainly focus on the hydrography of the Arctic interior, the state of Atlantic Water layer and heat and volume transports at the gateways of the Davis Strait, the Bering Strait, the Fram Strait and the Barents Sea Opening. We found that there is a large spread in temperature in the Arctic Ocean between the models, and generally large differences compared to the observed temperature at intermediate depths. Warm bias models have a strong temperature anomaly of inflow of the Atlantic Water entering the Arctic Ocean through the Fram Strait. Another process that is not represented accurately in the CORE-II models is the formation of cold and dense water, originating on the eastern shelves. In the cold bias models, excessive cold water forms in the Barents Sea and spreads into the Arctic Ocean through the St. Anna Through. There is a large spread in the simulated mean heat and volume transports through the Fram Strait and the Barents Sea Opening. The models agree more on the decadal variability, to a large degree dictated by the common atmospheric forcing. We conclude that the CORE-II model study helps us to understand the crucial biases in the Arctic Ocean. The current coarse resolution state-of-the-art ocean models need to be improved in accurate representation of the Atlantic Water inflow into the Arctic and density currents coming from the shelves.

Wed-067

Coordinated ocean-ice reference experiments (core-ii): mean states in the north atlantic

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Simulation characteristics from eighteen global ocean sea-ice coupled models are presented with a focus on the mean Atlantic meridional overturning circulation (AMOC) and other related fields in the North Atlantic. These experiments use inter-annually varying atmospheric forcing data sets for the 60-year period from 1948 to 2007 and are performed as contributions to the second phase of the Coordinated Ocean-ice Reference Experiments (CORE-II). Despite using the same atmospheric forcing, the solutions show significant differences. As most models also differ from available observations, biases in the Labrador Sea region in upper-ocean potential temperature and salinity distributions, mixed layer depths, and sea-ice cover are identified as contributors to differences in AMOC. These differences in the solutions do not suggest an obvious grouping of the models based on their ocean model lineage, their vertical coordinate representations, or surface salinity restoring strengths. Thus, the solution differences among the models are attributed primarily to use of different subgrid scale parameterizations and parameter choices as well as to differences in vertical and horizontal grid resolutions in the ocean models. Use of a wide variety of sea-ice models with diverse snow and sea-ice albedo treatments also contributes to these differences. Based on the diagnostics considered, the majority of the models appear suitable for use in studies involving the North Atlantic, but some models require dedicated development effort.

Wed-068

Coordinated ocean-ice reference experiments (core-ii): ocean model intercomparison project (omip)

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The Ocean Model Intercomparison Project (OMIP) aims to provide a framework for evaluating, understanding, and improving the ocean, sea-ice, tracer, and biogeochemical (BGC) components of global climate and earth system models contributing to CMIP6. Thus, OMIP includes the previously separate Ocean Carbon Model Intercomparison Project (OCMIP). OMIP addresses its aims in two complementary manners: (i) by providing a protocol for ocean diagnostics (including ocean physics, inert chemical tracers, and biogeochemistry) to be saved as part of CMIP6, and (ii) by providing an experimental protocol for global ocean sea-ice models run with a prescribed atmospheric forcing. The OMIP diagnostic protocol is relevant for any ocean model component of CMIP6, including the DECK, historical simulation, idealized and realistic anthropogenic greenhouse gas increases, C4MIP, and FAFMIP. The physical portion of the OMIP experimental protocol follows that of the interannual Coordinated Ocean-ice Reference Experiments (CORE-II). Since 2009, CORE has become the standard method to evaluate global ocean sea-ice simulations and to examine mechanisms for forced ocean climate variability. The inert chemical tracer portion of OMIP is based on the OCMIP2 protocol, while the BGC portion uses the OCMIP3 protocol, with each participating group using their own prognostic ocean BGC model.

Wed-069

Coordinated ocean-ice reference experiments (core-ii): development of a new forcing data set based on jra-55

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Framework of CORE and the subsequent Ocean Model Intercomparison Project (OMIP) provides ocean and climate modelers with a common facility to perform hindcast simulations of the past ocean – sea-ice climate variability on interannual to decadal time scales. Given the success of this effort, requests to keep the forcing data set up to date would naturally emerge. This kind of framework should indeed provide opportunities to simulate recent climate extreme events, such as sea-ice reduction in the Arctic, global warming hiatus, and on-going El Nino, and to understand them in the context of long-term variability. Unfortunately, it has been more than ten years since the current data set was first produced and it has not been kept up to date. New atmospheric reanalysis products with state-of-the-art technologies are now available. Some of the new satellite data products have now a duration long enough to be used as a reference data set for adjusting reanalysis products. There are also some concerns that the horizontal resolution (~ 200 km) of the current CORE-II forcing data set based on the NCEP/NCAR reanalysis may not be suitable for simulations that use high (eddy permitting / resolving) horizontal resolution.. International collaborative efforts to replace the existing forcing data sets started in early 2015 to produce a new atmospheric data set for driving ocean – sea-ice models based on JRA-55 (Japanese Meteorological Agency, the Japanese 55-year Reanalysis).

JRA-55 is one of the most recently conducted long-term reanalysis using high resolution (~ 55 km) atmospheric model and updated assimilation techniques. The data set covers the period from 1958 to present and will be continued for forthcoming years. All atmospheric elements necessary for computing surface fluxes are based on the forecast mode of JRA-55. The temporal interval is 3 hours. Data are provided on normal TL319 (~ 55 km) grid. Elements are downward short and long wave fluxes, precipitation (separated into rain and snow), 10-m vector wind, 10-m air temperature, and specific humidity (shifted from their original height at 2 m), and sea level pressure. Our preliminary evaluation indicates that JRA-55 also needs the same kind of adjustments (bias corrections) as was done in CORE for the NCEP/NCAR reanalysis and in DRAKKAR for the ECMWF reanalysis. Necessary adjustments are applied on all elements except for sea level pressure. Time dependent adjustments are considered if spurious features due to a specific transition in the assimilation method are identified. However, to provide data on near-real time basis, adjustment factors for the most recent period will be climatological. River discharge data are also planned to be provided, by operationally running a river model forced by the land surface data of JRA-55.

The poster introduces the new CORE-II forcing data sets based on the JRA-55 reanalysis and presents general features, adjustments methods, and assessments of the latest, yet maybe still preliminary, version of the data set. Any comments and suggestions toward the improvement of the data set are welcomed.

Wed-070

Coordinated Ocean-ice Reference Experiments (CORE-II): An assessment of global and regional sea level for years 1993-2007 in a suite of interannual CORE-II simulations

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We provide an assessment of the sea level as simulated in a suite of global ocean-sea ice models using the interannual CORE atmospheric state to determine surface ocean boundary buoyancy and momentum fluxes. These CORE-II simulations are compared amongst themselves as well as to observation-based estimates. We focus on the final 15 years of the simulations (1993-2007), as this is a period where the CORE-II atmospheric state is well sampled, and it allows us to compare sea level related fields to both satellite and in situ analyses. The ensemble mean of the CORE-II simulations broadly agree with various global and regional observation-based analyses during this period, though with the global mean thermosteric sea level rise biased low relative to observation-based analyses. The simulations reveal a positive trend in dynamic sea level in the west Pacific and negative trend in the east, with this trend arising from wind shifts and regional changes in upper 700~m ocean heat content. The models also exhibit a thermosteric sea level rise in the subpolar North Atlantic associated with a transition around 1995/1996 of the North Atlantic Oscillation to its negative phase, and the advection of warm subtropical waters into the subpolar gyre. Sea level trends are predominantly associated with steric trends, with thermosteric effects generally far larger than halosteric effects, except in the Arctic and North Atlantic. There is a general anti-correlation between thermosteric and halosteric effects for much of the World Ocean, associated with density compensated changes.

Poster Cluster

Eastern boundary upwelling systems (EBUS)

Chairs: Enrique Curchitser (enrique@marine.rutgers.edu)

Session: 3.3 - Upwelling and Frontal Zones

Description: Eastern boundary upwelling systems (EBUS) cover less than 3% of the world ocean surface yet they have a significant role in the climate system, and are home to the largest contribution of ocean biological productivity with up to 40% of the reported global fish catch. Coupled with the vast coastal human populations, these regions play key biological and socio-economical roles. There are common features to eastern boundary upwelling regions: wind-driven flows, alongshore currents, steep shelves and large vertical and offshore nutrient transports. Despite the commonality, each of themain upwelling systems exhibits substantial differences in their circulation, primary productivity, phytoplankton biomass, and community structures. The reasons for these differences are not fully understood.

Wed-075

Eastern boundary upwelling systems (EBUS): THE VERTICAL SRUCTURE OF CROSS-SHELF FLOW DURING WIND-DRIVEN COASTAL UPWELLING IN NORTHERN ARAFURA SEA

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A three dimensional baroclinic nonlinear numerical model - HAMburg Shelf Ocean Model (HAMSOM) developed by Backhaus (1983) has been applied to simulate circulation around Arafura Sea. The observation is focused on learning the vertical structure of offshore-onshore transport during upwelling period in the northern Arafura Sea. The results indicate that the stucture is mainly influenced by Ekman transport in which the southesterly wind moves surface waters away from the coast and then induce subsurface waters to move shoreward and upward. In addition, the nonlinear term is also important factor in affecting the vertical stucture. It is observed that the nonlinear term is responsible in distributing the onshore transport to be more concentrated in the interior and forming two-cell circulation.

Wed-076

Eastern boundary upwelling systems (EBUS): Variability of phytoplankton size structure through the surface bio-optical properties extended to the water column in the upwelling front of central Chile

July Andrea Corredor Acosta (1,2), Marco Correa Ramirez (3,4), Carmen E. Morales (2,5), Samuel Hormazabal (2,4), Angel Rodríguez Santana (6)

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The coupling of satellite observations of ocean color together with in situ water column data is a useful tool to understand changes in the biogeochemical cycles of the ocean according as the phytoplankton community is influenced by sub- and mesoscale structures in the eastern boundary systems. In this study, in situ total and fractionated Chlorophyll-a data (Chl-a; micro-, nano- and picoplankton) were collected in the adjacent frontal zone of the upwelling coastal region of Chile central (FZ , 36.50-36.7°S, 73.10-74.50°W, 3-7 February 2014), and were used to parameterize a model of phytoplankton size structure applied to satellite total Chl-a data (MODIS-a, resol. 4 km). Also, physical in situ properties like temperature, salinity and density were collected in order to perform calculations of geostrophic speed, buoyancy frequency, vertical shear and variations of the Richardson gradient along the frontal section.

The results show high correlations between in situ and satellite total Chl-a data in the surface layer of the water column ($r > 0.60$). The theoretical model allowed us obtain micro-, nano- and picoplankton time series, which were significantly correlated with the original in situ data, as well as with the temperature and density physical properties ($p < 0.05$). The spatial distribution of nano- and picoplankton fractions was wide mainly in the coastal area, while the maximum of the microplankton fraction was observed inside the front (~ 74°W); whereas the vertical distributions of all phytoplankton size class remained in the first ~ 40m of the water column. In terms of the fluorescence, the maximum seems to intensify and deepen in the front itself, possible due to the subduction of particulate matter in response to the vertical shear which favors the mixing, no homogeneous stratification, the lateral gradients of buoyancy in the coastal-ocean section by the upwelling front presence and an adjacent anticyclonic eddy observed during the period of study.

Wed-077

Eastern boundary Upwelling systems (EBUS): interannual variability in the eastern south Pacific and biological response

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Field data and modeling have evidenced a gradual increase in wind-driven coastal upwelling in the highly productive coastal zone off Chile over the last 2-3 decades. Physical manifestations are a more intense wind field, colder, more saline, less-oxygenated and less stratified conditions in the water column in recent years over the continental shelf. Our time series observations on biological responses are showing a decreasing trend in zooplankton biomass, changes in size-structure and community composition, and increased diversity. We did not find evidence for decreased primary or secondary production, but potential greater mortality of epipelagic zooplankton due to increased hypoxia, driven by an extremely shallow oxygen minimum zone, and a large fraction of plankton biomass being lost from the upwelling zone due to incremented offshore advection associated with mesoscale activity. Negative trends in zooplankton biomass, size structure and diversity are coherent with long-term trends in small pelagic fish landings of Chile and Peru, reflecting the strong link between fish production and the dynamics of lower trophic levels. Our findings therefore provide insights on the future of coastal upwelling systems impacted by multiple stressors upon a non-uniform changing ocean.

Wed-078

Eastern boundary upwelling systems (EBUS) First year of an ocean-atmosphere mooring in the Senegalese coastal upwelling

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The Joint International Laboratory ECLAIRS set up an oceanographic and meteorological buoy, dedicated to monitoring and analysis of the short and long-term changes in climate, atmosphere and marine environment within the Senegal coastal upwelling. The buoy "MELAX" was deployed early 2015 in the heart of the Senegalese upwelling by 30m-depth at (14,20’N, 17,14’W). Data collected are, for the atmosphere, surface wind, solar radiation, humidity and rain, and for the ocean, temperatures, salinity, and currents (from the surface to the bottom) and oxygen. We present the first year of observations, in particular the relationship between wind, sea surface temperatures, hydrology and currents. Satellite and model data are used to provide a larger-scale context to the local monitoring.

Wed-079

Eastern boundary upwelling systems (EBUS): Intraseasonal to interannual variability of the Angola Current inferred from moored and shipboard measurements

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The eastern boundary circulation off the coast of southwest Africa has been described only sparsely to date, although it is one key component in a very productive marine system that adjacent coastal countries strongly depend upon. These countries now face substantial challenges in terms of societal development, fisheries, and tourism associated with climate variability and global change. From a broader perspective, the region off Angola, connecting the equatorial Atlantic and the Angola-Benguela upwelling regime, is of particular interest to understand the relative importance of transient equatorial versus local forcing of the observed variability in the coastal upwelling region.

For the first time multi-year velocity observations of the Angola Current at 11°S are available. From July 2013 to November 2015 a bottom shield equipped with an ADCP had been deployed at 500m water depth, accompanied by a mooring sitting on the 1200m-isobath with an ADCP being installed at 500m depth. Both upward-looking instruments measured the current speed in the overlying water-column up to about 50m below the sea surface. During the deployment period the Angola Current was characterized by a weak mean southward flow of 5-8 cm/s at 50m depth (slightly stronger at the in-shore mooring position), that decreased with depth and vanished at a depth of 200m. The alongshore velocity component reveals a pronounced seasonal variability, that is dominated by 120-day, semi-annual, and annual oscillations.

An additional dataset of shipboard ADCP and CTD measurements, which is provided by the EAF-Nansen Project, was collected bi-annually with the R.V. Fridjoft Nansen along repeated sections between 2005 and 2014. Data along the fixed monitoring lines at 6°S, 9°S, 12°S, 15°S, and 17°S allow for the description of the mean structure of the Angola current and the calculation of seasonal averages for the summer and winter periods, respectively.

Wed-081

Eastern Boundary Upwelling Systems (EBUS): Seasonal modes of upwelling variability in the California & Benguela Systems

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Upwelling in the California Current System (CCS) exhibits two independent modes of seasonal variability; the first tracking variability in the primary upwelling season (spring and summer), and a second associated with the winter. The CCS biotic system responds differently to these upwelling modes, with the winter mode having an important synchronizing effect across multiple trophic levels. These modes of variability are driven by different atmospheric forcing: the winter mode is associated with recognized patterns of climate variability in the North and Tropical Pacific Ocean, i.e. El Niño-Southern Oscillation, while the summer mode is hypothesized to relate to global processes such as global warming. In this work, we ask if the patterns and drivers of seasonal modes of upwelling are also found in the Benguela Current System (BCS). Our analyses indicate that upwelling in the BCS displays only one mode of upwelling variability. This result contrasts with the distinct winter and summer modes in the California Current. The impact of the tropical Pacific on upwelling processes in the Benguela appears to be small, which may explain this finding. We continue to investigate the potential that a portion of the variability in upwelling processes are shared between the California and Benguela systems and is related to synchronous variability in the oceanic mid latitude high-pressure fields.

Wed-082

Eastern boundary upwelling systems (EBUS): Poleward displacement of coastal upwelling-favorable winds through the 21st century

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Coastal upwelling is a critical factor influencing the biological production, acidification, and deoxygenation of the ocean's major eastern boundary current ecosystems. A leading conceptual hypothesis projects that the winds that induce coastal upwelling will intensify in response to increased land-sea temperature differences associated with anthropogenic global warming. We examine this hypothesis using an ensemble of coupled, ocean-atmosphere models and find limited evidence for intensification of upwelling-favorable winds or atmospheric pressure gradients in response to increasing land-sea temperature differences. However, our analyses reveal consistent latitudinal and seasonal dependencies of projected changes in wind intensity associated with poleward migration of major atmospheric high-pressure cells. Summertime winds near poleward boundaries of climatological upwelling zones are projected to intensify, while winds near equatorward boundaries are projected to weaken. Developing a better understanding of future changes in upwelling winds is essential to identifying portions of the oceans susceptible to increased hypoxia, ocean acidification, and eutrophication under climate change.

Wed-083

Eastern Boundary Upwelling Systems (EBUS): California-Benguela Joint Investigation (Cal-BenJI)

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Cal-BenJI is a major five-year collaborative research program involving scientists from the United States, South Africa, and Namibia. The program is the first international, interdisciplinary collaboration on climate change and marine ecosystems for South Africa's newly formed Branch Oceans and Coasts of the Department of Environmental Affairs. Through management-oriented science, comparative ecosystem research, and capacity building, marine scientists from four U.S. and three South African institutions are collaborating to investigate how climate change is impacting the environments of the west coasts of each country. The multidisciplinary team includes independent specialists in atmospheric science, physical oceanography, and ecology of marine organisms from plankton to top predators (seabirds and marine mammals).

Over the next five years, researchers of the Cal-BenJI collaborative will assess how warming and other aspects of human-induced or natural climate change affect ecosystem productivity, fisheries, and wildlife populations of North America’s California Current System and Southern Africa's Benguela Current System. While the two systems are driven by similar dynamics (upwelling-favorable coastal winds), there are important distinctions that influence the sensitivity and response of ecosystem components to climate forcing. For example, the California system is strongly affected by the El Niño - Southern Oscillation in the tropical Pacific, while the Benguela system is affected by climate variability of the tropical Atlantic and the warm Agulhas Current at its poleward extent. In addition to more direct climate change impacts on the oceans (e.g., rising temperatures, deoxygenation, increasing stratification), global warming will influence the location and intensity of the large-scale oceanic high-pressure cells that drive alongshore winds in these systems. The combination of these factors are expected to influence the composition, distribution, and productivity of communities in the two regions. In this work, we present the goals and structure of the project, as well as recent findings and results.

Wed-084

Eastern Boundary Upwelling Systems (EBUS): The observed south Java upwelling process and its intraseasonal variations

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The South Java Upwelling (SJU) develops in response to the southeastern monsoon wind forcing. Based on the in situ mooring, tide gauge, satellite and model data, we document its development, mature and decay process. It is interesting to note that SJU exhibits strong intraseasonal variability, in sharp contrast to the conventional picture of smooth seasonal upwelling. In extreme case, SJU even breaks for a while. This reflects its strong nature of remote forcing from the Equatorial Indian Ocean, except for its local wind forcing. High resolution model simulation is assessed on its capacity to capture the key upwelling features.

Poster Cluster

Climate Variability and Predictability Over the Indo-Pacific Ocean

Chair: Dongliang Yuan (dyuan@qdio.ac.cn)

Session: 3.2 - Ocean and climate dynamics

Description: The Pacific and Indian Oceans span over two-thirds of the global tropical domain. The variability of the ocean in this part of the globe is of great importance to the global climate variations and predictability. Among them, ENSO and Indian Ocean Dipole (IOD) are the strongest interannual climate modes that interact over and through the Indonesian seas. Under global warming, the ENSO and IOD are subject to long term variations. In this session, studies about the ocean circulation in the Indo-Pacific Ocean and its climatic effects, the Indo-Pacific warm pool and its role in climate variability and predictability, the interactions of Pacific and Indian Ocean climate variabilities through the atmospheric bridge and the oceanic channel, and the effects of the Indo-Pacific warming on the long term variations of monsoon and typhoon are encouraged to submit abstracts for discussions and information exchange.

Wed-058

Climate Variability and Predictability Over the Indo-Pacific Ocean: On the Response of the Aleutian Low to Greenhouse Warming

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The Aleutian Low, known as a semi-permanent low-pressure system over the North Pacific, influences formation of pack ice in the Bearing Sea and the temperature extremes in the North Pacific Rim. Changes in its intensity and position substantially affect the North Pacific oceanic gyres and upper-ocean temperature field, which can thereby alter marine biological resources and fish stocks in the Northeast Pacific. However, it remains uncertain how robust the climatological-mean Aleutian Low responds to greenhouse warming and what driving mechanisms are involved.

Here we use five different observation-based datasets and CMIP5 multi-models to show that the Aleutian Low has intensified over the 20th century and that it will continue to intensify significantly as the climate warms under the RCP8.5 scenario, manifested in its intensity strengthened by approximately 1.3 hPa (or 0.4 hPa per degree global surface warming) which is 62% larger than the estimated internal variability of NPI, and the central low-pressure region expanded about 7 times as large as that in the past century. A set of idealized experiments with an intermediate climate model further demonstrate that such intensification of the Aleutian Low can be driven by an El-Niño-like warming pattern in the tropical Pacific sea surface temperature (SST), with a reduction in the time-mean zonal SST gradient, which overshadows the effect of the weakened land-ocean thermal contrast that tends to dampen the Aleutian Low response to greenhouse forcing. This warming pattern is also found to influence the winter precipitation responses to greenhouse warming in the North Pacific Rim, likely owning to the Aleutian Low change.

Wed-059

Climate Variability and Predictability Over the Indo-Pacific Ocean: Association of extreme precipitation over the Yangtze River Basin with global air–sea heat fluxes and moisture transport

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Although the effect of sea surface temperature anomalies in the Pacific and Indian Oceans on precipitation over the Yangtze River Basin (YRB) is well known, the impact of air–sea sensible and latent heat fluxes (SHF and LHF) has not been well studied. Based on the statistical and diagnostic analyses of historical precipitation data over the YRB, SHF and LHF over the global ocean, as well as global atmospheric reanalysis data, the impacts of SHF and LHF in the selected ocean regions on YRB extreme precipitation were investigated. The spatial distributions of the correlation coefficients between the YRB extreme precipitation indices (YRB-EPI) and SHF and LHF over the global ocean were analysed to identify critical air–sea interaction regions affecting YRB extreme precipitation. Results show that a significant positive correlation exists between YRB-EPI and air–sea heat fluxes over the Northwest Indian Ocean, Southeast Indian Ocean, Southwest Indian Ocean and South China Sea regions. Negative correlations were found over Central Equatorial Pacific, while positive lagged correlations exist over East Pacific. Composite analyses of global wind, geo-potential height and water vapour transport were also conducted for ten heaviest and ten lightest YRB precipitation years, respectively. In heavy YRB precipitation years, the atmospheric circulation pattern is generally characterized by a strengthened Western Pacific Subtropical High (WPSH) extending northwestward, a strengthened lower tropospheric convergence zone over the YRB, three distinct moisture transport paths from adjacent oceans to the YRB and low-level mid-latitude northerly wind anomalies. Whereas, in light YRB precipitation years, it is dominated by the southwesterly summer monsoon over the YRB, with a convergence zone displaced to the north of the YRB, a weak WPSH, and only two main paths of moisture transport. These distinctions between the heavy and light YRB precipitation years provide a physical basis for establishing a statistical prediction model for YRB extreme precipitation.

Wed-060

Climate Variability and Predictability Over the Indo-Pacific Ocean: Two meridional teleconnection patterns over the summer Northwestern Pacific and their interdecadal modulations

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Structures and dynamics of two dominant meridional teleconnection patterns over the summer Northwestern Pacific (NWP) in intraseasonal to interannual time scales are examined. One of them features a positive correlation between convective activity around the northern Philippines and lower-tropospheric circulation centered near Japan, and called the Pacific-Japan (PJ) teleconnection pattern. Preceding studies argued that this pattern could be regarded as a dynamical mode, which efficiently gain energy from background state. The PJ pattern is significantly correlated with El Niño-Southern Oscillation (ENSO) peaked in preceding winter. Through an empirical orthogonal function (EOF) analysis for over half a century of Japanese 55-year reanalysis (JRA-55), the PJ pattern outstands as the leading mode of lower-tropospheric vorticity. The second EOF mode features a positive correlation between convective activity centered at Guam of the Mariana Islands and lower-tropospheric circulation around the Bonin Islands. We therefore call it the Mariana-Bonin (MB) pattern. This pattern also gains energy from background state through barotropic and baroclinic energy conversion as efficiently as energy generation due to anomalous diabatic heating, and thus bears dynamical mode features. The efficiency, however, is less than in the PJ pattern, consistent with the dominance of the PJ over MB patterns. In addition, the MB pattern is highly correlated with ENSO in developing stage.

The two patterns have undergone significant interdecadal modulations. The PJ pattern amplified from the 1950s to 1980s, and then weakened until the 2000s. It is suggested that interdecadal changes of ENSO forcing of the PJ pattern via Indian Ocean and tropical NWP sea surface temperature anomalies are responsible for these modulations. The MB variance also shows interdecadal modulations but the changes are weaker than in the PJ pattern. As a result, the PJ pattern has degraded to the second EOF mode since the late 1990s, while the MB pattern has been promoted to the leading EOF mode instead.

Wed-061

Climate Variability and Predictability Over the Indo-Pacific Ocean: Influence of South Pacific Subtropical Dipole on South Pacific Convergence precipitation

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This study analyses the influence of the South Pacific Subtropical Dipole (SPSD) on South Pacific Convergence Zone (SPCZ) and explores its dynamic processes by using SST data HadISST of Hadley center and atmospheric reanalysis data of NCEP-NCAR. Analyses show that South Pacific Subtropical Dipole is linearly independent of ENSO, and SPSD with a strong phase locking peaks in summer(12-2). The location of SPCZ precipitation is remarkably affected by SPSD event. Northeast pole (warmer SST) has positive precipitation anomaly because of lower pressure and convergence of moisture in this area during positive dipole event years. However southwest pole (cooler SST) with higher pressure is dominated by divergence of moisture in order to less precipitation, so SPCZ precipitation zone moves north and the location of precipitation is opposite during negative dipole event. The results of this study provide more knowledge of relationship between SPSD and SPCZ, and it's better to understand climate change and air-sea interaction in south Pacific.

Wed-062

Climate variability and predictability over the Indo-pacific ocean:Oceanic channel dynamics of the IOD-ENSO teleconnection in the CMIP5 climate models

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The decadal variability of the teleconnection between oceanic variability in the southeastern tropical Indian Ocean (STIO) in fall and those in the eastern equatorial Pacific cold tongue in the next fall is diagnosed using observed sea surface temperature anomalies (SSTA) and the Coupled Model Intercomparison Project phase 5 (CMIP5) simulations. The running mean lag correlations between the STIO SSTA in fall and the cold tongue SSTA at the one-year time lag are shown to be positive during some decades and negative during the other, with the negative correlations weaker and of short duration than the positive. Similar decadal variability is also identified in the historical runs of the CMIP5, the dynamics of which during the decades of positive correlations are diagnosed using composite lag correlations. The results suggest that the oceanic channel, i.e. the variability of the Indonesian Throughflow, play an important role in the cross-basin teleconnection in most of the CMIP5 models, consistent with observational analysis. In comparison, the atmospheric bridge is highly dispersive among the models and generally inconsistent with the observational analyses, suggesting model deficiencies. Analyses also indicate that the anthropogenic forcing has significant impact on the decadal variability of the IOD-ENSO teleconnection and has enhanced the teleconnection through the oceanic channel during the positive phase of the decadal oscillations.

Wed-063

Climate Variability and Predictability Over the Indo-Pacific Ocean: The analysis of the relationship between the equatorial currents and the western Pacific warm pool in CMIP5

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Based on the historical runs from 26 coupled climate mode of the Fifth Phase of the Coupled Model Intercomparison Project (CMIP5), the relationship between the equatorial currents and climatological mean of the western Pacific warm pool (WPWP) are investigated. The results show that there is high correlation between them. A strong south equatorial current can cause westward stretch of edge of the WPWP over equator, and shrink the south part of the WPWP. A strong north equatorial countercurrent can enlarge the north body of the WPWP. The zonal-advective feedback and Bjerknes feedback play the key role in the mean state of WPWP.

Wed-064

Climate Variability and Predictability Over the Indo-Pacific Ocean: Indonesian Throughflow variations in the eastern Indonesian seas during the onsets of the 2014 and 2015 El Niño

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The mooring observations deployed in the Maluku Channel of the Indonesian Seas during December 2012 through November 2015 show reversals of the thermocline zonal currents from eastward to westward during relaxations of the westerly wind bursts (WWB) in the springs of 2014 and 2015. The reversals are not in agreement with the changes of the surface currents and local winds, suggesting remote forcing of the variations. Reflections of the equatorial Rossby waves forced by the WWB into upwelling equatorial Kelvin waves inside the Indonesian seas are suggested to be the cause. Observations have shown that the reflected upwelling Kelvin waves in the summer of 2014 are much stronger than those in the summer of 2015, which may explain the disparate onsets of the 2014 and 2015 El Niño events. The meridional transport in the Maluku Strait are also found to reverse from northward to southward at the time of WWB relaxations, which plays the role of enhancing the upwelling Kelvin waves reflected at the western boundary. The meridional transport anomalies between 50 and 315 m in the Maluku Channel, assuming linear interpolation to zero velocity at the coasts, changes from around 4 Sv (1 Sv = 106 m3 s-1) northward during the WWB to more than 2 Sv southward in 2014 and to 5 Sv southward in 2015, respectively, after the WWB relaxation. These are significant interannual variations of the ITF transport, given that the ITF transport is about 11.6 Sv in the Makassar Strait on average.

Poster Cluster

Internal Wave Driven Mixing

Chairs: Sonya Legg (sonya.legg@noaa.gov)

Session: 3.1 - Mixing and Stirring

Description: This poster cluster will describe work of the multi-institutional USCLIVAR climate process team, and our international collaborators, on parameterization of mixing by internal waves in ocean climate models. The poster cluster will cover all aspects of the problem, from observations, to numerical process studies, global internal wave modeling, and parameterization frameworks for global models, as well as consider the impacts of parameterized mixing on global ocean circulation and climate.

Wed-071

Internal wave driven mixing: Community Ocean Vertical Mixing (CVMix)

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Community Ocean Vertical Mixing (CVMix) is a software package that aims to provide transparent, robust, flexible, well documented,shared Fortran source code for use in parameterizing vertical mixing processes in numerical ocean models. The project is focused on developing software for a consensus of closures that return a vertical diffusivity, viscosity, and possibly a non-local transport, with each quantity dependent on the tracer or velocity being mixed. CVMix modules are written as kernels designed for use in a variety ofFortran ocean model codes such as MPAS-ocean, MOM, and POP. CVMix modules use MKS units and expect the same for input and output. Code development occurs within a community of scientists and engineers who make use of CVMix modules for a variety of ocean codes. CVMix modules are freely distributed to the open source community under GPLv2 using an open source methodology.

Wed-072

Internal Wave Driven Mixing: Determining the Effect of the Lunar Nodal Cycle on Tidal Mixing and North Pacific Climate Variability

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Oscillations in the Moons orbit around the earth modulate regional tidal dissipation with a periodicity of ~18.6 years. In regions where the diurnal tidal constituents dominate diapycnal mixing, this Lunar Nodal Cycle (LNC) may be significant enough to influence ocean circulation, sea surface temperature, and climate variability. Such periodicity in the LNC as an external forcing may provide a mechanistic source for Pacific decadal variability (i.e., Pacific Decadal Oscillation, PDO) where diurnal tidal constituents are strong. We have introduced three enhancements to the latest version of the Community Earth System Model (CESM) to better simulate tidal-forced mixing. First, we have produced a sub-grid scale bathymetry scheme that better resolves the vertical distribution of the barotropic energy flux in regions where the native CESM grid does not resolve high spatial-scale bathymetric features. Second, we test a number of alternative barotropic tidal constituent energy flux fields that are derived from various satellite altimeter observations and tidal models. Third, we introduce modulations of the individual diurnal and semi-diurnal tidal constituents, ranging from monthly to decadal periods, as derived from the full lunisolar tidal potential. Using both ocean-only and fully-coupled configurations, we test the influence of these enhancements, particularly the LNC modulations, on ocean mixing and bidecadal climate variability in CESM.

Wed-073

Internal wave driven mixing: Numerical process studies of breaking internal tides

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Tidally-generated internal waves lead to diapycnal mixing in the stratified ocean interior when they break. This breaking may occur locally near the abyssal topography where the internal tides are generated, or remotely when propagating low mode tides encounter distant topography. New generation ocean models, which attempt to parameterize internal wave driven mixing in an energetically consistent way, require physically-based representations of these breaking processes. Numerical process studies allow the wave breaking processes to be identified, and their dependence on controlling parameters such as topography, flow speed, stratification and latitude to be quantified. Since climate models have been shown to be highly sensitive to the vertical distribution of internal wave driven mixing, numerical process studies are useful to refine parameterizations of the vertical structure of mixing due to breaking internal tides. Here we will describe numerical process studies of several different internal tide breaking processes, including transient lee waves at tall steep topography, wave-wave interactions above rough abyssal topography, and low-mode wave scattering at continental slopes and canyons. We will also outline parameterizations of these processes and describe progress toward incorporating these physical processes in the global internal wave driven mixing parameterization framework developed through the USCLIVAR climate process team on internal wave driven mixing.

Wed-074

Internal wave driven mixing: parameterizations and climatic impacts in a climate model

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Turbulent diapycnal mixing is a crucial driver of the thermohaline circulation and plays a key role in the transport and storage of heat and carbon dioxide. In the ocean interior, breaking internal waves generated by the interaction of tides and geostrophic flows with the topography, or by wind events at the ocean surface are the main driver of diapycnal mixing. Internal wave driven mixing is patchy in time and space and occurs on scales too small to be explicitly resolved in ocean climate models. Physically based parameterizations of internal-wave driven mixing are therefore needed for realistic simulation of the ocean and for estimating how mixing might change in a changing ocean.

Here, we will present parameterizations of internal-wave driven mixing for ocean models that have been developed as part of the US CLIVAR Climate Process Team on Internal-Wave Driven Mixing (http://www-pord.ucsd.edu/~jen/cpt/) and implemented in NOAA/GFDL's climate model ESM2G. Climate simulations of 1000 years are used to assess the sensitivity of the ocean state to these parameterizations. We will especially focus on the sensitivity of the thermohaline circulation, ocean ventilation, temperature field and of steric sea level to parameterizations of local and remote internal-tide dissipation and of lee-wave driven mixing.

Wed-086

Internal Wave Driven Mixing: Improving the parameterizations from small scale turbulent observations to global climate model implementations

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In the ocean interior, the internal wave field is largely responsible for connecting the forcing scales of the circulation to the dissipative scale of turbulence. In particular, internal-wave-induced mixing drives the diabatic evolution of the ocean's stratification on the very time scales of central interest to the climate prediction problem. The Climate Process Team on internal wave driven mixing has been working over the last 5 years to refine, develop and implement dynamically appropriate parameterizations for diapycnal mixing due to internal-wave breaking for use in global climate models. The problem can be framed in terms of sources and sinks for internal waves. The main sources of internal wave energy in the ocean are internal tides and wind-generated internal waves. Both have a geography that has been well studied, though the latter has more complicated forcing variability. In both cases some of the energy put into the ocean tends to dissipate and produce mixing nearby, producing a global map of mixing that mirrors those of internal wave generation. This so-called "nearfield" part of the problem involves breaking of high-mode internal waves or more nonlinear features. The rest of the energy is able to propagate away, sometimes for thousands of kilometers, in the form of low-mode internal waves. The ultimate graveyard for the propagating part of the energy is less clear, although several possibilities are being actively investigated. Additionally, internal lee waves generated by mesoscale flows over rough topography may also be important energy sources in some locations, particularly the Southern Ocean. As a final conclusion, we attempt to put the sum of these processes in a global context using all available microstructure observations.

Wed-087

Internal Wave Driven Mixing: Basin- and global-scale modeling of internal tides and internal waves

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Over the last 15 or so years, increases in computer power have permitted a growing number of basin- and global-scale modeling studies of the internal tides. Several recent efforts have focused on modeling tides concurrently with the wind-driven oceanic general circulation. Putting internal tides and the wind-driven circulation into the same model allows the study of eddy/tide interactions, and also triggers the development of a partial internal gravity wave continuum. Because the modeled continuum lies closer to the observed continuum as model resolution increases, we suggest that internal tide/wave models will become increasingly useful in mapping the space-time distribution of internal wave waves and associated mixing. Internal tide/wave models will also aid in the interpretation of satellite observations, particularly the upcoming wide-swath satellite altimeter mission, which will provide a global (but temporally aliased) view of the internal wave field, and which will require precise corrections for internal tides and internal gravity waves in order to enable the effective observation of lower-frequency mesoscale and submesoscale motions. Finally, basin- and global-scale internal tide/wave models have proven invaluable in planning and interpreting field campaigns, which in turn feed back onto the models as important physical processes are observed, understood, and parameterized.

Wed-088

Internal wave driven mixing: Representing the propagation and far-field dissipation of internal tides in a global climate model

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Internal tides represent a pathway and redistribution mechanism for roughly half of the energy that ultimately cascades to abyssal mixing in support of global overturning circulation. The low mode components of the internal tide can redistribute the majority of this energy as they propagate thousands of kilometers from their generation sites prior to breaking into turbulence. Despite obvious climatic implications, the propagation and far-field dissipation of internal tides is largely unaccounted for in global climate models in which coarse grid resolution precludes their explicit representation. The current study works to resolve this issue through developing a new parameterization of the propagating internal tides that is based on classic ray tracing techniques. Assuming weak interaction between modes, energy density corresponding to discrete modes and frequencies is horizontally advected using the local mode velocity and re-partitioned in angle orientation (refracted) according to the hydrostatic dispersion relation. The ray-tracing scheme is implemented in Geophysical Fluid Dynamic Laboratory's MOM6 global ocean model using various parameterizations for the generation and dissipation of the internal tide. The impact of far-field dissipation on the ocean state is assessed through a fully-coupled climate simulation using GFDL's ESM2G Earth System Model.

Wed-089

Internal wave driven mixing: An energetically consistent replacement for the Osborn relationship in ocean mixing parameterizations

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The well-known Osborn relationship (typically written as K = Γ ε / N2) is commonly used in parameterizations of internal wave driven mixing to convert local energy dissipation rates and stratification into diffusivities. Unfortunately, this expression is not well behaved in unstably stratified regions, nor does it account for the changes that occur when the mixing is applied over a finite timestep. This poster presents a new approach for translating dissipation rates into diffusivities that captures the essential physical content of the Osborn relationship. Specifically, the new approach retains the tight linkage between the local energy dissipation rate and the potential energy changes due to a local diffusivity, but considers the potential energy changes throughout the water column implicitly over a finite timestep. As a result, this approach is more robust in constraining the energy changes due to mixing, works well with a fully nonlinear equation of state, and does not require any assumptions about the relationship between initial and final stratification. Although it is vertically nonlocal, the numerical implementation of this scheme is roughly as costly as an implicit (tridiagonal) vertical discretization of the mixing of tracers, and hence is appropriate for use in ocean-climate models.

Poster Cluster

PRIMAVERA: High resolution climate processes

Chair: Malcolm Roberts (malcolm.roberts@metoffice.gov.uk)

Session: 3.2 - Ocean and climate dynamics

Description: PRIMAVERA is a European Union-funded Horizon 2020 project which aims to develop a new generation of advanced and well-evaluated high-resolution global climate models capable of simulating regional climate with unprecedented fidelity. We will assess the impact of resolution in atmosphere, land, sea-ice and ocean models (for the latter up to eddy-resolving scales) on the simulation of a wide variety of climate processes particularly relevant for European climate variability and change. https://www.primavera-h2020.eu/

Wed-001

PRIMAVERA: High resolution climate processes. Evaluating the impact of resolution and stochastic physics parameterisations in climate simulations.

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We present here the first results of the Climate SPHINX (Stochastic Physics HIgh resolutioN eXperiments) project, which was conducted in preparation of PRIMAVERA. Climate SPHINX (http://sansone.to.isac.cnr.it/sphinx/) is a comprehensive set of ensemble AGCM simulations aimed at evaluating the sensitivity of present and future climate to both model resolution and stochastic parameterization. The atmospheric component of the EC-Earth Earth-System Model is used to explore the impact of stochastic physics in a large ensemble of 30-year climate integrations at five different horizontal resolutions (from 125km up to 16km for the atmosphere). The project includes more than 110 simulations in both a historical scenario (1979-2008) and a climate change projection (2039-2068), together with coupled transient runs (1850-2100). This paper presents the technical and scientific setup of the experiments and an overview of preliminary results. An improvement in the simulation of Euro-Atlantic atmospheric blocking following resolution increases is observed. It is also shown that including stochastic parameterization in the low resolution runs helps to improve some aspects of the tropical climate - specifically the Madden-Julian Oscillation and the tropical rainfall variability. These findings show the importance of representing the impact of small-scale processes on the large scale climate variability either explicitly (with high resolution simulations) or stochastically (in low resolution simulations). A sub-set of similar experiments with the EC-Earth couple system in which high resolution and stochastic physics will be tested in the ocean component as well are in preparation in the framework of the PRIMAVERA European Union-funded Horizon H2020 project.

Wed-002

PRIMAVERA: High resolution climate processes – Impact of model resolution on the North Atlantic Ocean

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Resolution in climate models is thought to be an important factor for correctly representing certain aspects of climate dynamics, and advancing our current understanding of the climate system. Assessing the impact of resolution in climate models and their ability to faithfully capture the behavior of the real world is the objective of the EU-funded PRIMAVERA project. In the context of this project, we aim to give a general overview of the impact of model resolution on the dynamics of the North Atlantic Ocean. For example, how the North Atlantic Current and the flow in the Nordic Seas are influenced by the increase in the resolution? What is the impact on the AMOC structure and its strength? What are the changes in the associated heat and salt/freshwater transport to the Arctic and the surface fluxes? How does the SST, mixed layer and the deep-water production in the North Atlantic respond to the increase in resolution? The answers to these research questions should provide insight as to what extent the increase in resolution should be an essential part of the future development of the global climate models, and whether increasing resolution alone is a sufficient measure in order to address the current models deficiencies.

Wed-003

PRIMAVERA: High resolution climate processes. Future central Europe Summer Drying in a high-resolution global climate model

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Using the SST forced high-resolution (~25km) Ec-Earth global climate model we have investigated the future central European summer drying. Compared to the standard resolution model (~150 km) a large increase in severe summer droughts for the end of the 21st century is observed. The mechanisms responsible for these differences are analyzed. They are related to changes in large scale atmospheric circulation patterns and moisture transport and changes in local surface moisture budget that involve precipitation, evaporation and runoff. The different contributions of these drivers to the occurrence of future droughts and their representation in climate models are analyzed and discussed.

Wed-004

PRIMAVERA: High resolution climate processes. Resolution dependence of precipitation and convection over the Gulfstream region

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The influence of horizontal resolution of an atmospheric only GCM on precipitation and convection is studied over the Gulf Stream region in the North Atlantic. Both the mean precipitation and the occurrence of extreme events enhance with increasing resolution, which is confirmed by reanalyses and weather forecasts of different resolutions. These changes are not caused by large scale modifications, but mainly by changes in local processes. Due to lack of reliable precipitation data over the ocean, it could not be rigorously confirmed whether the increase in extreme precipitation events resulted in a better agreement with the observations. Alternatively the 10m wind convergence was analyzed, revealing also more extreme events for increasing resolution. For this better agreement with the observations could be confirmed. In addition the number of deep convection events over the Gulfstream region increases for higher resolution in GCMs, reanalyses and operational forecasts. In summary our analyses indicate that higher resolution has a strong impact on the tail of the precipitation distribution and its related convective dynamics. Although we cannot rigorously check it with the available observations, our analyses indicate that the present resolution of (CMIP5) climate models is insufficient for an adequate simulation of the precipitation distribution and its associated convective processes over the Gulfstream region.

Wed-005

PRIMAVERA: High resolution climate processes. Exploring the influence of resolution on Atlantic ocean fresh water transports and implications for the AMOC.

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Observations have shown that the Atlantic Meridional Overturning Circulation (AMOC) exports fresh water from the Atlantic. Hence if the AMOC was to weaken, there would be a reduction in the export of fresh water, freshening the Atlantic and potentially leading to a further weakening of the AMOC. Many models, however, find that the AMOC instead imports salt into the Atlantic, and therefore this destabilising feedback would not occur. A recent study has suggested that increased model resolution can lead to changes in the fresh water transport by eddies, resulting in improvements to the fresh water transport by the AMOC. We explore this hypothesis by comparing Atlantic fresh water transports across a range of ocean resolutions.

Wed-006

PRIMAVERA: High resolution climate processes. Resolution dependence of atmospheric spectral energetics in global general circulation models

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The limited resolution of climate models is a critical source of uncertainty in all applications of climate and Earth System modelling, including predictions, projections and risk assessments. Increasing model resolution allows some of the key climate processes to be directly resolved and more credibly represented (e.g. Sharey et al. 2009; Jung et al. 2012; Demory et al. 2013), while reducing biases (e.g. van Haren et al. 2015) This study is a multi-model assessment on the effect of increasing resolution on the spectral distribution, spectral conversion and spectral transfer of available potential energy (APE) and kinetic energy (KE) in several global climate models using the methodology of Augier et al. (2013) based on spherical harmonics. The spectral distribution of APE and KE and an explicit term for the conversion between these terms, provide a mechanical view of the model atmosphere and the distribution of its drivers over spatial scales. Spectral transfer is determined to provide a view on the nonlinear energy and enstrophy cascades. The analysis also allows for a direct determination of the smallest extent to which energetics are reasonably represented in the model output, serving as a lower limit for the scales to which model output is applicable.

Wed-007

PRIMAVERA: High resolution climate processes at the air-sea interface in the tropical Pacific - the role of coupling frequency for ENSO asymmetry

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Observations show that El Nino-Southern Oscillation (ENSO) is not symmetric: El Nino is stronger than La Nina. However, many CMIP5 models use daily ocean-atmosphere coupling which simulate almost symmetric ENSO. We use the Max Planck Institute Earth System Model (MPI-ESM) to test the sensitivity of ENSO asymmetry to air-sea coupling frequency and model spatial resolution. Increasing coupling frequency from daily to hourly, ENSO asymmetry can be simulated. This can be explained by the ability of the hourly coupling to resolve intra-daily air-sea feedback which affects the distribution and strength of the convection over the tropical Pacific, and consequently, the asymmetry in the strength of El Nino and La Nina. When we compare three different increasing resolutions, i.e.MPI-ESM-LR (T63 atmosphere, 1.5o ocean), MPI-ESM-HR (T127 atmosphere, 0.4o ocean) and MPI-ESM-XR (T225 atmosphere, 0.1o ocean), the strength of ENSO asymmetry is slightly augmented but the dipole structure of ENSO asymmetry is much more well captured.

Wed-008

PRIMAVERA: High resolution climate processes – Evaluating the role of resolution-induced flux changes to AMOC

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One of the main objectives of EU-H2020 project PRIMAVERA is to assess the impact of higher model resolution on simulated European climate. The increase in resolution is expected to lead to better representation of processes, reduce model biases, as well as provide more reliable climate prediction. However, in some models, AMOC starting from an equilibrium state achieved from a lower resolution (LR) breaks down at higher resolution (HR). We perform a comparative study with LR and HR simulations from models with and without a slowdown of AMOC to assess the role of resolution-induced flux changes to AMOC. In this study, we consider models from PRIMAVERA partners such as the Max Planck Institute – Earth System Model (MPI-ESM), EC-Earth model and the Hadley Centre Global Environment Model (HadGEM3).

Preliminary analysis of surface fluxes from MPI-ESM indicates several reasons for an unstable state of the North Atlantic, manifested in a slowdown of the AMOC. Freshening of the subpolar deep water formation region leads to a salinity-driven AMOC decline. This can be caused by local freshwater flux from large-scale precipitation and/or advection of fresher tropical Atlantic water resulting from increased tropical convective precipitation. Another possibility arises from a weakening of the Southern Hemisphere westerlies that tend to flatten the isopycnals, thereby decreasing AMOC. Other mechanisms such as freshwater transport from the Arctic will be further investigated. We will investigate the contribution of various aforementioned flux changes to AMOC and test the robustness of these results across the different models.

Wed-009

PRIMAVERA: High resolution climate processes – Deep water formation in the North Atlantic Ocean

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Higher spatial resolution is expected to improve the representation of ocean boundary currents and frontal areas and the associated heat transport toward high latitudes. Higher resolution may also see increased ocean-atmosphere heat and momentum exchange as the representation of orographically forced features improves (e.g. tip-jets, shore leads and localized Ekman pumping). We will analyze climate simulations in different resolution with the global coupled model EC-Earth and compare the results with CMIP5-simulations with EC-Earth. A diagnostic for the deep water formation has been developed, which takes both horizontal and vertical extension of the mixed water into account and calculates a deep mixed volume below a certain critical depth. In the CMIP5 simulations with EC-Earth, the Labrador Sea accounts for most of the deep convective mixing in the northern hemisphere. Labrador Sea convection is partly driven by air-sea surface fluxes related to the NAO and controls part of the variability of the AMOC at the decadal time scale (correlation of 0.6 when convection leads by 3-4 years). Deep convective activity in the Labrador Sea declines throughout the 20th century, primarily caused by a decrease of sensible heat loss to the atmosphere in winter resulting from increasingly warm atmospheric conditions. Reduced salinity in the Labrador Sea surface layer due a freshening East Greenland Current into the Labrador Sea prevent any possible resumption of deep convection in future simulations. First results from the higher resolution simulations indicate a more realistic position of the deep water formation area in the Labrador Sea together with a reduction of the sea ice extent in the Labrador Sea. While the main formation area in the CMIP5 simulations is situated south of Greenland, it moves further to the north-west into the Labrador Sea. This is related to a more realistic position of the extension of the East Greenland Current into the Labrador Sea. The focus of further analysis will be on the representation of the processes, which govern the convection, as turbulent surface heat fluxes and freshwater transports into the convection regions. Also the affect of higher resolution on the linkage between deep water convection and AMOC will be investigated. As part of PRIMAVERA, sets of already existing high and standard resolution simulations with five global climate models will be analyzed. These will be used to further study the robustness of the impact of high resolution on processes affecting the deep oceanic convection.

Wed-010

PRIMAVERA: High resolution climate processes

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PRIMAVERA is a European Union-funded Horizon 2020 project which aims to develop a new generation of advanced and well-evaluated high-resolution global climate models capable of simulating regional climate with unprecedented fidelity. We will assess the impact of resolution in the physical components of the atmosphere, land, sea-ice and ocean models (for the latter up to eddy-resolving scales) on the simulation of a wide variety of climate processes particularly relevant for European climate variability and change. The concept of model fidelity is central to PRIMAVERA, and its foundations are in process understanding. It is clear that many of the most pressing questions about regional climate change urgently require advances in process simulation. For example, to what extent are recent heat waves, floods and droughts in Europe attributable to natural variability or human influences on the global climate system? How will the risk of such high impact events change over the next few decades and beyond? The extent to which it is possible to provide robust answers to these questions relies fundamentally on the fidelity of the climate models that are used to address them. However, fidelity is insufficient in itself: we must be able to justify why a particular model produces a particular prediction at the process level. The project will develop new strategies and tools for evaluating global high-resolution climate models at a process level. This will include assessment of the representation of North Atlantic ocean processes, such as ocean mixing, air-sea interactions, mid-latitude jets and blocking, eddy fluxes of heat, momentum and vorticity, and their combined effect on moisture and heat transports towards Europe. There will also be a focus on Arctic processes, both sea-ice itself and its interaction with ocean circulation and heat transports, as well as the large-scale drivers of variability both locally (for example the Atlantic Multi-decadal Oscillation) and remotely via the Pacific. A suite of process-based metrics will be developed in order to summarise and understand model performance, as well as help to reduce uncertainty in future projections. The core simulations used in the project will be as defined in the CMIP6 HighResMIP protocol, comprising both standard resolution and high resolution simulations (the latter at around 25km resolution in both atmosphere and ocean), from seven European modelling groups, covering the period 1950-2050. There will also be four groups providing coupled simulations with an eddy-resolving ocean component using the same protocol, as well as several atmosphere-only simulations beyond 10km resolution. There is also extensive model component development and assessment activities, including upper ocean mixing and representation of, for example, Langmuir turbulence, and examination of sea-ice processes and understanding the reasons for the wide range of behaviours in recent Arctic sea-ice trends. In addition there is an examination of the drivers of variability and change in European climate, including the influence of oceanic modes of variability, with assessment of the robustness of European climate responses to the range of considered drivers to atmospheric and oceanic model resolution as well as physics.

Wed-011

PRIMAVERA: High resolution climate processes - air-sea interactions in an eddy-resolving coupled climate model

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Air-sea interactions and the associated fluxes of heat and other quantities are a crucial component in the energetics of global climate system, for example by playing an important role in the rate of heat penetration into the ocean interior. However, for the majority of climate models used currently, in which ocean eddies are not resolved, there must be questions about how well these interactions are represented. This work has used an eddy resolving coupled simulation with a 1/12 degree NEMO ocean model, coupled to 25km atmosphere model, to study air-sea interactions over a 20 year timeframe. It is compared to a similarly configured model with an eddy-permitting &frac14 degree resolution, in order to examine the role of eddies and model resolution in the climate system. We find important improvements in the large-scale circulation due to enhanced ocean resolution, several of which can be traced to air-sea interactions. The eddy resolving coupled simulation has enhanced heat loss adjacent to the North Atlantic Current that acts to reduce a large model bias. This increased heat loss is due primarily to an increased latent heat flux. In an attempt to better understand the air-sea coupling, we followed the work of Chelton and Xie (2010) and Bryan et al (2010), and examined the relationship between SST anomalies and those in surface wind and latent heat flux in order to understand the mechanism of the enhanced heat loss. Using a box-car filter to remove the mean component of the spatial field, there are indications that the more turbulent nature of the eddy resolving ocean allows stronger SST perturbations and hence enhanced wind variability and latent heat flux. Changes to the air-sea fluxes are then implicated in changes to the large-scale circulation. The enhancement of the heat loss over the North Atlantic Current increases the heat transport required by the ocean to balance the atmospheric heat transport implied by the surface fluxes, and indeed the eddy-resolving simulations have a greatly enhanced northward ocean heat transport in much better agreement with observations apart from in the far northern North Atlantic. These results have important implications for climate simulations in terms of heat and energy flows within the system, and also for ocean spin-up and equilibration we find that with an eddy-resolving ocean, the ocean is able to maintain the large-scale structure from the initial conditions much more effectively, and in essence it spins down much less than the eddy-permitting simulation. The European Horizon 2020 project PRIMAVERA, involving 19 European groups, intends to further assess the robustness of processes such as these by producing a multi-model ensemble of eddy-resolving coupled simulations, each of 100 years in length, using the same integration protocol as will be used in CMIP6 HighResMIP. Such simulations will be compared to lower resolution counterparts to better understand climate processes that are either missing or poorly represented in typical climate model configurations.

Wed-012

PRIMAVERA: High resolution climate processes: Benefits of locally refined ocean resolution in climate modeling

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Ocean model biases such as the North West corner cold bias connected to the location of the Gulf Stream path, the warm bias in upwelling zones, the warm bias in the Southern Ocean, and model drift like the deep ocean warm bias which tends to peak in around 800 to 1000 m depth in the Atlantic Ocean are issues common among state-of-the-art ocean models. These issues are often amplified when the ocean model is coupled to an atmosphere model to perform climate simulations. Furthermore, unrealistic freezing of the Labrador Sea is an issue in various climate models. With the unstructured mesh approach in our Finite Element Sea ice Ocean Model (FESOM) we are able to systematically investigate the benefits of local refinement of the ocean model grid both in an uncoupled set-up (sea-ice ocean only) as well as in a fully coupled climate model (atmosphere-land-sea ice-ocean). While the horizontal ocean model resolution is 25 km on average in the finer grids, we refine the grids in some key areas to up to 5 km. Therefore we can explicitly resolve ocean eddies and simulate eddy-mean flow interactions in these key areas. The atmosphere-land component of our AWI-CM (Alfred Wegener Institute Climate Model) is ECHAM6-JSBACH developed at the Max-Planck-Institute for Meteorology in Hamburg, Germany. Here we present results of century-long uncoupled and coupled simulations on ocean model grids with different local refinements while keeping the atmosphere resolution constant in the coupled simulations. Results indicate that high horizontal resolutions in key regions such as the Gulf Stream / North Atlantic Current area or the Agulhas Stream can reduce biases such as the North West corner cold bias and the deep ocean model drift.

Wed-013

PRIMAVERA: High resolution climate processes. Insights from forced multidecadal simulations with eddying ocean/sea-ice models

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A hierarchy of global ocean models has been developed and evaluated since 2003 within "Drakkar", a European network of modelling groups using the NEMO modelling platform. The eddy permitting global configuration at 1/4° will be used in earth system models for CMIP6. The higher resolution 1/12° ORCA12 configuration is a key asset for the Primavera project. We present a synthesis of global multidecadal simulations (50 years and more) at 1/4° and 1/12°, forced by the Drakkar Forcing Set (an atmospheric state based on ECMWF reanalyses). The impact of resolution is demonstrated, and evaluated in the general context of model sensitivity to other factors such as numerical schemes, parameterizations and atmospheric forcing. The presentation is focussed on 1) the meridional transports of heat and salt; 2) the low-frequency stochasticity of climate-relevant oceanic indices as revealed from ensembles of 1/4° oceanic hindcasts with perturbed initial states and identical forcing.

Regarding meridional transports, model results show an important eddy contribution at the boundaries of the subtropical gyres, which is already represented quite well at 1/4°. The main changes brought by increasing the resolution to 1/12° concern the general circulation (especially in boundary currents). In the North Atlantic ocean, higher resolution simulations yield large improvements (e.g., the position of the Gulf Stream and northwest corner) but also new problems (e.g., an excessive warming and salinification of the subpolar gyre).

The interannual-to-multidecadal variability of oceanic heat content, AMOC and sea-surface height (SSH) becomes substantially chaotic in key regions when switching from the laminar (2°) to the eddying regime (1/4°); this low-frequency stochastic character further increases at 1/12° in terms of SSH, but remains comparable to the 1/4° resolution in terms of AMOC.

Comparisons between 1/4° and 1/12° model configurations demonstrate that essential processes such as the turbulent contribution to meridional transports, or the spatial distribution and amplitude of low-frequency chaotic variability are already well represented at 1/4°. More generally, the changes in the mean circulation and the location of major fronts, and the spontaneous emergence of low-frequency chaos in the eddying regime are likely to affect climate variability and projections, through ocean-atmosphere coupling as well as through the coupling with the carbon cycle.

Poster Cluster

Ocean and cryosphere interactions in a warming climate

Chairs: Lynne Talley (ltalley@ucsd.edu), John Fyfe (john.fyfe@canada.ca) and Inga Smith (inga.smith@otago.ac.nz)

Session: 3.2 - Ocean and climate dynamics

Description: This poster cluster (4 word ID: "Ocean and cryosphere interactions") welcomes observational and modeling treatments of climate-relevant interactions between the oceans, ice shelves, and sea ice in both the Northern and Southern Hemispheres, including atmospheric forcing that connects the ocean and cryosphere. Sea ice extent responses to the warming climate differ, decreasing in the Arctic while increasing in the Antarctic. Ice sheet mass loss in both hemispheres is well documented and contributes to global sea level rise. These cryospheric changes can include coupling with adjacent ocean properties.

Wed-038

Ocean and cryosphere interactions: Preconditioning of the Weddell Sea polynya by the ocean mesoscale and topography

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The Weddell Sea polynya is a large opening in the open-ocean sea ice cover that is associated with intense deep convection in the ocean and the release of massive amounts of heat to the atmosphere. A necessary condition to form and maintain a polynya is the presence of a strong subsurface heat reservoir. This study addresses the role of the ocean mesoscale and small-scale topographic features in building up the subsurface heat reservoir in the Weddell Sea. To do so, a modest-eddying (0.25°) and an actively-eddying (0.1°) ocean of a climate model run for 200 years under preindustrial forcing are investigated. While the modest-eddying model does not develop any open-ocean polynya over the course of the simulation, the actively-eddying model develops two polynyas in the Weddell Sea. However, the modest-eddying model does show quasi-continuous deep convection, showing that deep convection is not a sufficient condition for the occurrence of a polynya. The main reason for the absence of a polynya in the modest-eddying model is a weak stratification that enhances the vertical diffusion of heat between the subsurface and the surface, hence preventing the formation of the heat reservoir at subsurface. In contrast, in the actively-eddying model, a more stable stratification of the water column is found, thus allowing the subsurface heat reservoir to build up and to maintain two polynyas, each over a decade. The enhanced stratification in the actively-eddying model arises from the restratifying effect by transient mesoscale eddies. In addition, in the actively-eddying model, a finer representation of topography allows dense saline waters formed on the continent shelf to overflow to intermediate depths. In contrast, in the modest-eddying model, dense saline waters mix at shallower depth thus weakening the stratification.

Wed-039

Ocean and cryosphere interactions: Ocean Heat Transport Mechanisms and CO2–Induced Ocean Climate Change around Antarctica in GFDL CM2.6 and CM2.5

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This study uses two eddy-rich climate models developed at GFDL (CM2.6 and CM2.5) to investigate CO2–induced ocean climate change around Antarctica and its implication for Antarctic ice shelf basal melt. We consider both long-term control runs and the idealized 1% per year CO2 doubling experiments. In particular, CM2.6 and CM2.5 resolve heat transport from the relatively warm offshore Circumpolar Deep Water onto the continental shelf. The strength and depth of the Antarctic Slope Front (ASF) influences the onshore heat transport by controlling cross-frontal eddy transport and shoaling of warm deep waters below the ASF and along the shelf slope. Under CO2 forcing, the models exhibit significant shelf water freshening which strengthen and deepen the density gradient along the ASF. The strong cross-shelf density gradient acts as a barrier to heat transport onto the continental shelf. To quantify the role of the ASF as a barrier to heat transport, we calculate the total heat transport across the ASF and separate this total into the mean and eddy advective heat flux. Our results are not present in previous generation climate models with coarser grid resolution or model experiments that do not include a time-varying freshwater flux.

Wed-040

Ocean and cryosphere interactions: Tropical Pacific Climate Response to Projected Arctic Sea Ice Loss

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The transient climate response to an abrupt loss of Arctic sea ice is investigated using an ensemble of transient simulations with Community Climate System Model version 4 (CCSM4) at 1spatial resolution. Here we focus on the role of ocean dynamics in the tropical climate response by comparing simulations with a thermodynamic “slab” ocean and a full-depth dynamical ocean. The slab-ocean coupled model response is characterized by warming in the northern hemisphere and cooling in the southern hemisphere, accompanied by a northward shift of the Inter-tropical Convergence Zone (ITCZ). In contrast, the dynamical-ocean coupled model response exhibits enhanced warming along the equator accompanied by an equatorward intensification of the ITCZ in the Pacific sector. Thus, ocean dynamics plays a key role in the tropical Pacific response to Arctic sea ice loss. The results suggest two pathways for the dynamically-induced warming of the equatorial Pacific. The initial warming (within the first 20-30 years) appears to be triggered by southwesterly wind anomalies in response to warming of the tropical Atlantic, while the subsequent warming (years 30-100) appears to originate via a weakening of the Atlantic meridional overturning circulation (AMOC) and an oceanic Kelvin wave response along the coast of Chile. Thus, both dynamical tropical air-sea interaction and the global-scale adjustment of the oceanic circulation are important for the response of the tropical Pacific to Arctic sea ice loss.

Wed-041

Ocean and Cryosphere Interactions: Meridional Overturning Circulation under Antarctic Ice

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Around the Antarctica in winter, dense shelf water is produced and sinks to form Antarctic Bottom Water. Using a box inverse model that combines WOCE (World Ocean Circulation Experiment) and GO-SHIP (Global Ocean Ship-based Hydrographic Investigations Program) hydrographic observations around the Antarctica, we estimate that about 8 Sv of surface water subducts across the 1028.2 kg/m3 isopycnal. This volume must be supplied by a poleward near-surface branch of the meridional overturning circulation. In winter, the average position of the seasonal ice edge approximately coincides with the outcrop line of the 1027.5 kg/m3 isopycnal. Thus, the dense shelf water must be supplied by a poleward transport either in summer in open water or in winter under the ice. For summer, eddy transport was estimated by using drift and hydrographic data form Argo floats. For winter, near-surface diapycnal transport was estimated using various estimates of under-ice buoyancy fluxes. Both methods yield consistent near-surface transport estimates but with large uncertainties. Currently available data are not sufficient to constrain the meridional overturning circulation around the Antarctica both in open water and under the winter ice cover.

Wed-043

Ocean and cryosphere interactions: Seasonal and inter-annual changes of deep and bottom waters off the Adélie Coast, Antarctica

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The deep and bottom waters off the Adélie Coast, Antarctica, were observed by deep floats to clarify their seasonal and inter-annual changes. The deep floats were deployed in December 2012 and they had transferred 59 profiles up to the depth of 4000 dbar till August 2014 for 20 months, including deep profiles under sea ice in austral winters. In 2014, the salinity of the Antarctic Bottom Water (AABW) there decreased in austral summer to autumn (March to June) and then increased gradually after the region was covered with sea ice. The volume of AABW, which was deduced from the depth of 28.30γn neutral surface, decreased in summer to autumn and then increased just before the surface freezing. Whereas in 2013, AABW seemed to have salinized and increased its volume slightly during winter to spring, but freshening was hardly found in summer to autumn. The volume increase and the salinization of AABW in winter would be derived from the seasonal changes of the export and the properties of the dense water formed locally (Adélie Land Bottom Water). The inter-annual differences might reflect the circumstance to form the dense water at coast was recovered after the break of the Mertz glacier in 2010. In summer to autumn, water modification due to i.e. vertical mixing would decrease AABW volume. However, its freshening would require another mechanism. The seasonal and inter-annual changes of AABW observed by deep floats suggested that the long-term trends of AABW freshening and decrease might be derived from more complicated mechanisms than the expected.

Wed-044

Ocean and cryosphere interactions in Prydz Bay, Antarctica

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CTD data obtained from research vessels, moorings and seals, as well as remote sensing sea ice and ice shelf data and reanalysis meteorological data are used to analyze the interactions between sea ice, polynya, ice shelf and ocean circulations in Prydz Bay.

In melting season, sea ice in the region of Prydz Bay not only retreats southward from the out edge in deep basin, but also decreases in the near shore area of the bay. Two ice tongues are formed in shallow Fram Bank and Four Ladies Bank, leaving a low ice concentration gap in Prydz Channel. The warm Circumpolar Deep Water upwelling to the shelf break can flow into the bay through this channel, which had been observed by some surveys in summer. A large opening in melt season usually occurs firstly in the southeast part of the bay south to the Four Ladies Bank, starting from the coastal polynyas, the Prydz Bay Polynya and Barrier Polynya. The surface water in this opening area is heated by solar radiation in early summer, and then flows south with the cyclonic gyre in the bay, resulting the extremely warm surface water observed in the region north to the east end of Amery Ice Shelf (AIS) front. These warm waters will influence the lateral melting of AIS front for extensive mixing has been observed by micro-structure profilers in this region. The Mackenzie Polynya near the west end of AIS front is a latent heat polynya, where intense cooling and brine release create deep convection resulting vertical homogenous cold and saline shelf water from surface to 1000 m bottom. This location is also the major outflow area of sea water in the cavity under AIS, where both ice shelf water and super-cooled water were observed. These outflows decrease the salinity of shelf water in middle depth so that high salinity shelf water is left only in deep basin in the bay.

Wed-045

Ocean and cryosphere interactions in a warming climate: Southern Ocean and Antarctic sea ice responses to fresh water from icebergs and ice shelf basal melting in an Earth System Model

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In a warming climate, increased freshwater fluxes from ice sheet and ice shelf mass imbalance would be expected. Freshwater fluxes from ice sheet and ice shelf mass imbalance are largely missing in models that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5). However, on average P-E reaching the Southern Ocean has increased in CMIP5 models to a present value that is about 2600 Gt per year greater than pre-industrial times and 5 to 22 times larger than estimates of the mass imbalance of Antarctic ice sheets and shelves (119 to 544 Gt per year). Two sets of experiments were conducted from 1980 to 2013 in CESM1(CAM5), one of the CMIP5 models, artificially distributing fresh water either at the ocean surface to mimic iceberg melt, or at the ice shelf fronts at depth to mimic basal melting. An anomalous reduction in vertical advection of heat into the surface mixed layer resulted in sea surface cooling at high southern latitudes, and an associated increase in sea ice area. Enhancing the freshwater input by an amount within the range of estimates of the Antarctic mass imbalance did not have any significant effect on either sea ice area magnitude or trend. Freshwater enhancement of 2000 Gt per year raised the total sea ice area by a million square kilometres, yet this and even an enhancement of 3000 Gt per year was insufficient to offset the sea ice decline due to anthropogenic forcing for any period of 20 years or longer. Further, the sea ice response was found to be insensitive to the depth of fresh water injection.

Wed-046

Ocean and cryosphere interactions: ocean circulation and topographic effects on Antarctic sea ice and its decadal trends

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The Antarctic winter sea ice edge is closely associated with the southernmost fronts of the Antarctic Circumpolar Current (ACC). The southwest-northeast orientation of mid-ocean ridges in the western Pacific and eastern Atlantic sectors guides the cold waters of the Ross and Weddell Sea circulations and the winter sea ice edge far to the north, with little interannual variability in the sea ice edge. Kerguelen Plateau has a similar role. In the intervening large zonal sectors of the ACC in the Amundsen/Bellingshausen Seas and along Adelie Land, the southern ACC fronts are free from topographic control, and swing southwards towards Antarctica along with their winter ice edges and warmer waters arising from lower latitudes. This is dynamically consistent with the direction of wind-driven Sverdrup transport due to upwelling. The standing meanders controlled by the topography are associated with net poleward heat flux. Over the past several decades, WOCE and GO-SHIP hydrographic observations indicate much stronger penetration of full-depth, warm ACC water into the Amundsen and Bellingshausen Seas, consistent with diminishing sea ice and increased ice shelf melt. Winter sea ice has increased in the sectors where the southern ACC boundary is locked into a northward pathway, fluxing cold water northwards. Taken together, the standing eddy pattern of ACC heat flux and observed pattern of decadal winter sea ice changes suggest a strengthening of the circulation along the southern side of the ACC over several decades.

Wed-047

Ocean and cryosphere interactions: Pathways and variability of warm Atlantic Water inflow toward the South-East Greenland marine-terminating glaciers

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Mass loss from the Greenland Ice Sheet quadrupled over the past two decades, accounting for a quarter of the observed global sea-level rise, and contributing to freshening of the subpolar North Atlantic with potentially serious consequences for oceanic deep convection and the meridional overturning circulation. This mass loss has been attributed to acceleration of the glaciers on the Greenland South-East and West coasts, with one possible driver being the inflow of warm Atlantic Water (AW) from the adjacent subpolar gyre onto the Greenland shelf and into the fjords with marine-terminating glaciers. The presence of warm AW in these fjords has now conclusively been established. The pathways across the shelf and into the fjord, the accompanying time variability, and the driving mechanisms are poorly constrained by extant observations, however. This hinders understanding of the attendant melting processes and both the actual and potential impact of the warming ocean on the Greenland Ice Sheet.

We use a very high resolution (< 2km) ocean circulation model to study the warm AW flow toward two large glacier-fjord systems in SE Greenland – Helmheim-Sermilik and Kangerdlugssuaq – which have together been responsible for up to 40% of the total increased mass loss of the Greenland Ice Sheet. Using the model fields, we simulate the trajectories of 150,000 Lagrangian particles. They depict two distinct warm AW pathways from the Irminger Basin onto the shelf (one direct, one through the Denmark Strait), and several recirculations on the shelf, emphasizing the role of the Kangerdlugssuaq Trough and the Sermilik Deep Opening. We map the regions where the AW undergoes most intense water mass property transformation through mixing with the Polar Waters, thereby strongly affecting the properties of the water mass that reaches the fjords. We quantify this mixing in both the Lagrangian and Eulerian frames, which is important for both fjord systems, as well as the seasonal variability of the AW inflow, which is more pronounced in the inflow toward the Kangerdlugssuaq fjord. Based on these results, we suggest strategies for future observing systems to monitor the intensity and properties of warm Atlantic inflow toward these glaciers.

Poster Cluster

Tropical Atlantic Variability and Predictability

Chairs: Noel Keenlyside (noel.keenlyside@gfi.uib.no), Ping Chang (ping@tamu.edu) and Peter Brandt (pbrandt@geomar.de)

Session: 3.2 - Ocean and climate dynamics

Description: Prediction of equatorial Atlantic variability and associated climatic impacts remains a challenge. There are changing views on the mechanisms for interannual variability, and how ocean dynamics modifies the large-scale thermodynamic ocean-atmosphere interactions. Further, our understanding of eastern boundary upwelling systems is growing through increased observations and targeted modelling experiments. The impact of mean systematic errors on variability and predictability remains to be understood. This poster cluster aims to bring together research in this topic to identify current research gaps and future research directions.

Wed-090

Tropical Atlantic Variability and Predictability: Seasonal variability of equatorial Atlantic circulation associated with basin mode resonance

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Seasonal variability of the tropical Atlantic circulation is dominated by the annual cycle, but semi-annual variability is also pronounced, despite weak forcing at that period. Here we use multi-year, full depth velocity measurements from the central equatorial Atlantic to analyze the vertical structure of annual and semi-annual variations of zonal velocity. A baroclinic modal decomposition finds that the annual cycle is dominated by the 4th mode and the semi-annual cycle by the 2nd mode. Similar local behavior is found in a high-resolution general circulation model. This simulation reveals that the annual and semi-annual cycles of the respective dominant baroclinic modes are associated with characteristic basin-wide structures. Using an idealized linear reduced-gravity model to simulate the dynamics of individual baroclinic modes, it is shown that the observed circulation variability can be explained by resonant equatorial basin modes. Corollary simulations of the reduced-gravity model with varying basin geometry (i.e. square basin vs. realistic coastlines) or forcing (i.e. spatially uniform vs. spatially variable wind) show a structural robustness of the simulated basin modes. A main focus of this study is the seasonal variability of the Equatorial Undercurrent (EUC) as identified in recent observational studies. Main characteristics of the observed EUC including seasonal variability of transport, core depth, and maximum core velocity can be explained by the linear superposition of the dominant equatorial basin modes as obtained from the reduced-gravity model.

Wed-091

Tropical Atlantic Variability and Predictability: Reducing the Sea Surface Temperature Bias in the Kiel Climate Model to Improve the Representation of Atlantic Niño Variability and Dynamics

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The Atlantic Nio is the leading mode of interannual SST variability in the tropical Atlantic, impacting climate variability both locally and in remote regions. Current-generation coupled global climate models (CGCMs), however, struggle to capture the observed variability, rendering it virtually impossible to issue useful predictions of Atlantic Nio events. Recent research based on CMIP3 simulations suggested that the models' failure can be attributed to the Atlantic Nio being dominated by thermodynamic feedbacks, i.e. by atmospheric noise. NioHere, we hypothesize that strong equatorial Atlantic SST biases common to many CGCMs prevent the models from reproducing the observed dynamical and variability characteristics of the Atlantic Nio. Using the Kiel Climate Model (KCM), we asses the impact of the SST bias on these features. Two assimilation runs are produced in partially coupled mode, one standard run and one run that employs additional surface heat flux correction to alleviate the SST bias.In accordance with previous studies, heat flux correction substantially improves simulated Atlantic Nio variability, especially during the peak season May-June. Building linear models to capture the effect of the thermocline and zonal advection feedbacks on SST, we separate the total SST variability into dynamically driven and stochastically forced components. Bias alleviation allows the KCM to produce an Atlantic Nio that is largely consistent with observations: While stochastic forcing is dominant during boreal spring and early fall, dynamically driven SST variability prevails throughout early summer and winter. The standard run fails to simulate these features, suggesting that bias alleviation exerts a fundamental impact on simulated variability and dynamics. Implications of these findings on the predictability of the Atlantic Nio are discussed.

Wed-092

Tropical Atlantic Variability and Predictability - Relative contributions of dynamical and thermodynamic feedbacks to equatorial Atlantic interannual variability

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Current theories on the equatorial Atlantic Niño are based on the dynamical interaction between atmosphere and ocean. However, dynamical coupled ocean-atmosphere models poorly simulate and predict equatorial Atlantic climate variability. This study therefore quantifies the relative importance of dynamical and thermodynamic feedbacks in equatorial Atlantic interannual variability using observations and numerical model outputs. We found that thermodynamic feedbacks can generate Atlantic Niño variability of 0.28±0.07 K, accounting for 68±23% of the observed interannual variability. In fully coupled models, Atlantic Niño variability strongly depends on the thermodynamic terms of the heat budget. Composite analysis shows that ocean dynamics tends to set in around the mature phase of an event and improves the characteristic Niño-like spatial structure but not necessarily the variance. This poster will also describe the large-scale processes leading to the dominant effects of thermodynamic feedbacks including the roles of St. Helena anticyclone and associated extratropical opposite sea surface temperature anomalies.

Wed-093

Tropical Atlantic Variability and Predictability - Late Quaternary Environment Reconstruction Based on Organic-Walled Dinoflagellate Cysts in Marine Deposits

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The southeastern part of South American has experienced major climate changes since the late Quaternary, which has a significant important not only for the local but also for the global climate change. The marine sediment core GeoB2107-3, located in the southwestern of the Atlantic Ocean off southern Brazil, which has been studied for dinoflagellate cysts, pollen and spores, compared with geochemistry proxies in order to understand how changes in the marine realm influence the climate of South American continent since the late glacial period. From the study, the South Atlantic Ocean sea-surface water parameters such as temperature, nutrient concentrations, salinity variations and the South American continent condition, such as precipitation and temperature could be reconstructed. The results show that the climate change in this area was markedly influenced by changes in the marine currents.

Wed-105

Tropical Atlantic Variability and Predictability: Causes of the large warm bias in the Angola-Benguela Frontal Zone in the Norwegian Earth System Model

Shunya Koseki (1,4), Noel Keenlyside (1,4), Teferi Demissie (2,4), Thomas Toniazzo (2,4), Francois Counillon (3,4), Ingo Bethke (2,4), Mao-Lin Shen (1,4), Mehmet Ilicak (2,4)

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We have investigated the causes of warm sea surface temperature (SST) bias in the southeastern Atlantic Ocean, the Angola-Benguela Frontal Zone (ABFZ) simulated by Norwegian Earth System Model (NorESM). Similar to other models, NorESM exhibits the warm bias in the ABFZ of up to 8K in the annual mean. Our analyses on results of NorESM simulation show that an erroneously strong local clockwise surface wind anomaly around the ABFZ drives the anomalous Angola Current and displaces the ABFZ southward. The demonstration of standalone experiments of atmosphere and ocean with control configuration (AMIP5/COREv2-IAF) shows that both the uncoupled models have basic errors around the ABFZ: the atmospheric model exhibits a similar erroneously strong local clockwise surface circulation anomaly and the ocean model has the warm SST bias that is a half of NorESM full bias in the ABFZ. Another sensitivity experiment shows that the local clockwise surface wind error generates the anomalously strong Angola Current and consequently, the warm SST in the ABFZ is amplified by 2K (equal to a quarter of NorESM full bias). In NorESM, the remote effect via equatorial and coastal Kelvin Waves does not appear to be exposed in the ocean surface, but only ocean subsurface. The thermal atmospheric damping contributes to reduce the ocean surface fluxes and enhances the warm SST bias by about 2K in the coupled system.

Wed-106

Tropical Atlantic Variability and Predictability - PREFACE project

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Our ability to predict tropical Atlantic variability and its major socio-economic impacts remains limited, with current state-of-the-art climate models exhibiting large biases. The PREFACE project – a European Union funded project that brings together scientists in Europe and Africa – is beginning to redress the situation, focusing on the upwelling regions that are important for climate and fisheries. This presentations aims to summarise key results from the project's first two years. PREFACE is contributing to enhance key observations in the equatorial and coastal wave guides. These together with high-resolution regional ocean model experiments have led to a better understanding of mixed layer temperature and salt budgets, and the seasonality of equatorial and coastal currents, including the poorly observed Angola current. Analysis and experiments with climate prediction models shows the importance of wind errors in the development of both the equatorial and Angola-Benguela sea surface temperature (SST) errors. Higher atmospheric model resolution was found to reduce these errors. PREFACE has made progress towards understanding how mean model errors and variability are related, and how errors in different regions are connected. Furthermore, PREFACE research is providing a more complete picture on the roles of dynamics and thermodynamics in the generation of equatorial Atlantic variability, and roles of internal and external factors in driving decadal variability. Importantly, prediction experiments are revealing promising levels of skill for SST and the West African monsoon. A deeper understanding of the role of ocean variability on coastal marine ecosystems indicates a potential for fisheries relevant predictions. Beyond this, new data from surveys of fishing communities is being used to tailor biological-economic models to be applied to future climate change projections.

Wed-107

Tropical Atlantic Variability and Predictability: Annual Cycle and Interannual Variability of Tropical Atlantic Variability in the CESM

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The annual cycle and interannual variability of tropical Atlantic variability are analyzed for the observation (1982-2015) and for the 85-year Community Earth System Model (CESM) simulation. Statistical method of rotated empirical orthogonal function analysis has been used to extract the three major modes of SSTAs in the Atlantic sector, which are northern tropical Atlantic (NTA) mode centered near the northern African coast, the southern subtropical Atlantic (SSA) mode in the open subtropical Atlantic ocean, and the southern tropical Atlantic (STA) mode expanding from the Angolan coast to the central equatorial ocean. The simulations well capture the main features of the observational annual cycle. However, there are some systematic biases such as the double ITCZ and warm bias in the tropical southeastern Atlantic. The three modes are captured in CESM, which is better than the previous version CCSM4. From the SSTA lead-lag regression to the three leading PCs, the influence of remote factors can be seen. For instance, the NTA SST anomalies usually develop serveral months after the peaking phase of ENSO, generated by the ENSO-induced Atlantic tele-connetction through the Pacific/North American pattern (PNA) wave train pattern. Another source of the TNA pattern is the perturbation of the subtropical high through North Atlantic Oscillation (NAO). Both ENSO and dipole low-pressure anomalies in the South Pacific Ocean are associated with the occurence of STA. The ENSO-induced wave train, the Pacific-South American (PSA) pattern in the southern Pacific modulates the SSA in the subtropical Atlantic. The predictability of TAV is being studied by a set of ensemble experiments in CESM simulation based on this relationship between ENSO and TAV.

Wed-108

Tropical Atlantic Variability and Predictability - Sources and Impacts of Tropical Atlantic Ocean Biases

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Generations of global coupled atmosphere-ocean climate models have been plagued by persistent sea-surface temperature (SST) biases in the tropical Atlantic. These biases are shown to hinder model representation of the West African monsoon and tropical cyclones, with seasonal Atlantic tropical cyclone activity reduced by 50%, motivating improvements to advance our capability to make reliable seasonal forecasts and future climate projections. Focus is on the particularly severe (up to 6-10°C) warm SST biases of the southeastern tropical Atlantic Benguela coastal upwelling system, which is characterized by a coastline oriented approximately north-south, and a northward atmospheric low-level coastal jet parallel to the coast, called the Benguela jet. To investigate this problem, observational datasets and output from a suite of regional atmosphere model simulations with horizontal resolutions of 9, 27, 81, and 243 km were used to force a suite of regional ocean model simulations. The coastal SST and upwelling are shown to be sensitive to the surface wind stress and wind stress curl associated with the Benguela jet. Substantial improvements in simulated coastal SST are achieved by forcing the ocean model with a fine-resolution representation of the Benguela jet. In particular, the shape of the near coastal wind profile, with a sudden drop of wind speed towards the coast, is extremely critical for simulating realistic upwelling and SSTs in the ocean model. Satellite wind products show that the Benguela jet has a detailed spatial structure with two near-shore preferred jet core regions, one near the Angola-Benguela Front at 17.5°S where the Kunene upwelling cell is located, and the other near 25-27.5°S where the Lüderitz upwelling cell is situated. The representation of the Benguela jet in atmospheric models depends highly on resolution and the geometry of the coastline, as detailed jet maxima are characterized by a hydraulic expansion fan. Simulations with a high-resolution regional coupled atmosphere/ocean/land climate model developed at Texas A&M identify potential feedbacks that may influence the SST bias in the fully coupled system. This work indicates specific model processes that can lead to improvements in the longstanding tropical Atlantic SST bias problem.

Wed-109

Tropical Atlantic Variability and Predictability: SST bias development in the South-Eastern Tropical Atlantic in a high resolution version of CNRM-CM CGCM

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This study is a part of the EU-FP7 PREFACE project which aims, among other objectives, at better understanding physical mechanisms responsible for the development of the systematic warm SST biases in the Tropical South-Eastern Atlantic (SETA) in Coupled General-Circulation Models (CGCM). Here, based on seasonal hindcast simulations, we evaluate the role of different processes (atmospheric/oceanic, local/remote) in setting the initial SST bias in a High Resolution (HR) version of CNRM CGCM developed at CERFACS. The CGCM includes the atmospheric model ARPEGE-Climat (v5.3) in its T359L31 configuration (horizonal resolution of ~0.5° and 31 vertical levels) and the ocean model NEMO (v3.2) with ORCA025 grid (~25km) containing 75 vertical levels, which are coupled through the OASIS (v3) software. The "control" integrations analyzed cover 10 hindcasts with start dates at 1 February of each year of the period 2000-2009. Each hindcast represents an ensemble of 3 members. A full-field initialization from the atmospheric reanalysis ERA-Interim and oceanic reanalysis GLORYS2V3 is used. First, comparison with control integrations carried out using a Lower Resolution (LR) version of the model (T127L31 and ORCA1 with 42 vertical levels) reveals that increasing the resolution does not allow significantly improving the SST biases in the Equatorial Atlantic and SETA region (the latter defined within 7°E-15°E, 5°S-20°S). However, a strong reduction of the biases in the HR version is observed locally over the near-coastal Southern Benguela region (south of 25°S) and is due to better representation of fine-scale atmospheric and oceanic processes controlling the coastal upwelling. Further analysis suggests that similar processes are responsible for the SETA SST biases in the HR and LR versions. Thus, whereas an initial growth of the SST bias (observed during month 1) is likely associated with an excessive solar radiation, its further development cannot be explained by local atmospheric forcing and is due to remote oceanic processes. Indeed, a mixed layer heat budget analysis indicates an anomalous warm horizontal advection in the SETA from the Equator that appears in the middle of March, peaks in the beginning of May and decays in the middle of June. Analysis of the equatorial region indicates that this advection is related to the errors, typical for the CGCM, that manifest themselves as a reversed thermocline east-west gradient associated with westerly wind biases in MAM season. Second, sensitivity experiments to wind stress over three key regions are conducted and confirm the equatorial origin of the SETA biases. Wind stress correction over an equatorial band (5°S-5°N) leads to a reduction of the SETA bias by 50%. This correction is also associated with a significant improvement of the representation of the relative contributions of the different terms to the total mixed-layer temperature tendency over the Equator, although the June-July SST bias in the cold tongue region are reduced only by 25%.

Poster Abstracts

Wednesday, 21st September 2016

Wed-037

Understanding Ocean Dynamics in a Changing Climate: Insights from a Climate Network Approach

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Network theory is a powerful tool for identification of underlying spatial structures, understanding system stability, and improving predictability in a range of complex systems, from neural networks and power grids to social networks and climate. In this study, we utilize networks to analyze data from the Quasi-Geostrophic Coupled Model - an idealized model with a box ocean coupled to a channel atmosphere. We model climate change by increasing the incoming solar radiation in the model to investigate the alterations in ocean spatial and temporal patterns, through such quantifications as degree, betweenness centrality, and average link length. The main goal of the study is to track how climate network structures reorganize in a changing climate. By applying network analysis to the output from an adjustable and simplified model, we are able to better understand the specific climate mechanisms that elicit various network responses, and investigate the stability of current ocean and climate regimes. We compare our results to real-world climatological data, and look for similar network responses in such climatic phenomena as Rossby waves and midlatitude weather patterns.

Wed-048

Thermobaricity in the transition zones between alpha and beta oceans

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The role of the ocean in Earth's climate is fundamentally influenced by the locally-dominant stratifying property (heat or salt), which in turn can be used to categorise the ocean into three classes: alpha, beta and transition zone oceans. Alpha and beta oceans are regions where the stratification is permanently set by heat and salt, respectively. Transition zone oceans exist between alpha and beta oceans and are regions where the stratification is seasonally or intermittently set by heat or salt. Despite their large ranges of temperature and salinity, transition zone oceans are the most weakly stratified regions of the upper oceans, making them ideal locations for thermobaric effects arising from the nonlinear equation of state of seawater. Here a novel definition and quantification of alpha, beta and transition zone oceans is presented and used to analyse four years (2010–2013) of hydrographic data developed from the Argo profiling float array. Two types of thermobaric instabilities are defined and identified in the hydrographic data. The first type arises from the vertical relocation of individual water parcels. The second type is novel and relates to the effect of pressure on the stratification through the pressure dependence of the thermal expansion coefficient; water that is stably-stratified for one pressure is not necessarily stable for other pressures. The upper 1500 m of the global ocean is comprised of 67% alpha, 15% beta and 17% transition zone oceans, with 5.7% identified as thermobarically-unstable. Over 63% of these thermobarically-unstable waters exist in transition zone oceans, suggesting that these are important locations for efficient vertical transport of water mass properties.

Wed-094

Interaction between the South Atlantic Ocean and Climate Dynamics in South American Inferred from Organic-walled Dinoflagellate Cysts and Pollen in Marine Deposits

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Marine sediment cores GeoB2107-3 and GeoB6211-1 located in the South Atlantic Ocean off southern Brazil, has been studied by dinoflagellate cysts and pollen grains to reconstruct the sea-surface currents circulation of the South Atlantic Ocean and the vegetation evolution during the last glacial and Holocene period. The aim is to understand the interactions between ocean changes and climate dynamics on the continent, and to discover how changes in the marine parameters such as sea-surface currents, sea-surface temperature influence the local and global climate. Living organic-walled dinoflagellates and vegetation are very sensitive and greatly influenced by the environment change, so they are good indicators to reconstruct the physical water conditions and past vegetation changes.

The results show that during glacial times, grassland was dominant vegetation on the south American continent, indicating cold and dry climate, and dinoflagellate cysts data indicate that the Malvinas Current had a markedly stronger influence during the same period, particular during the last glacial maximum period. During Holocene period, the expansion of trees and tree ferns indicate humid and warm climate condition and together shows the increase of the sea-surface temperature in the South Atlantic Ocean. The similar climate background indicate that changes in the South Atlantic Ocean had a strong influence on the vegetation dynamics in South American continent during last glacial and Holocene times.

Wed-095

Submesoscale instabilities and turbulent dissipation at ocean fronts observed during winter in the North Atlantic

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An array of submesoscale-resolving moorings was deployed in the North Atlantic (48.69°N, 16.19°W) during September 2012--September 2013 in order to monitor the ocean surface boundary layer. Measurements made during this time include temperature, salinity and horizontal velocity from moored instruments (50-500 m) and ocean gliders (0-1000 m). In addition, this record is complemented by an estimate of turbulent dissipation rate, ε, from a moored ADCP at 50-m depth. This study focuses on mooring measurements collected during winter and the observed relationship between negative Ertel potential vorticity, q, and mixed layer depth, h.

Measurements suggest that wintertime winds oriented down front reduce an already weak stratification via Ekman transport of dense water over lighter water. This reduction in stratification reduces q and results in mixed gravitational/symmetric instabilities (GI and SI, respectively). Maps corresponding to modified Rossby and Richardson numbers as functions of depth and time depict an interesting relationship between SI, GI and h: SI leads GI, and results in a deepening pycnocline; following decreased down-front wind, GI shuts off, SI lags and the pycnocline shoals. Centrifugal (i.e., inertial) instabilities (CI) are seldom observed. Estimates of ε reveal a uniform distribution of dissipation rate amongst the remaining three instability categories: (1) GI, (2) mixed GI/SI and (3) SI. The results presented here suggest submesoscale mixed layer instabilities are an order-one mechanism for vertical mixing in the upper ocean during winter.

Wed-096

Baroclinic instability within the ocean surface boundary layer: a simple comparison of observation and theory

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A single satellite image of an ocean front coincident with in situ measurements of potential density from a towed, profiling instrument is examined for evidence of submesoscale baroclinic instability (BCI). The image was taken on 19 September 2012 at 03:34 UTC by the Visible and Infrared Imaging Radiometer Suite (VIIRS) on the Suomi/NPP spacecraft over the OSMOSIS site (North Atlantic) and consists of brightness temperatures collected within the infrared band at 390-m pixel resolution. The ocean front (i) is characterized by a 0.5-0.7°C change in temperature over a 10-25-km distance, (ii) results from the convergence of cool/warm water masses by the mesoscale eddy field, and (iii) is populated by several submesoscale vortices, or eddies, along the frontal boundary. While horizontal shear is one mechanism for generating submesoscale eddies (Munk et al., 2000), here we consider an alternative hypothesis: that observed eddies are the result of BCI within the ocean surface boundary layer (SBL, 2002). Vertical and lateral buoyancy gradients, as well as SBL thickness, are estimated from in situ measurements. Theoretical eddy sizes corresponding to the most unstable mode of an Eady model are then computed and compared with observed eddy sizes. Sensitivities to model parameters are discussed. In most cases, we find good agreement between predicted and observed eddy sizes. Growth rates were not estimated due to severe cloud cover before and after the event. Given observed Rossby numbers are small, BCI provides a plausible explanation for the observed submesoscale eddies, with wider application to open-ocean conditions where horizontal shear is small.

Wed-097

Equatorial–extratropical dipole structure of the Atlantic Niño

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Equatorial Atlantic variability is dominated by the Atlantic Niño peaking during the boreal summer. Studies have shown robust links of the Atlantic Niño to fluctuations of the St. Helena subtropical anticyclone and Benguela Niño events. Furthermore, the occurrence of opposite sea surface temperature (SST) anomalies in the eastern equatorial and southwestern extratropical South Atlantic Ocean (SAO), also peaking in boreal summer, has recently been identified and termed the SAO dipole (SAOD). However, the extent to which and how the Atlantic Niño and SAOD are related remain unclear. Here, an analysis of historical observations reveals the Atlantic Niño as a possible intrinsic equatorial arm of the SAOD. Specifically, the observed sporadic equatorial warming characteristic of the Atlantic Niño (~0.4 K) is consistently linked to southwestern cooling (~-0.4 K) of the Atlantic Ocean during the boreal summer. Heat budget calculations show that the SAOD is largely driven by the surface net heat flux anomalies while ocean dynamics may be of secondary importance. Perturbations of the St. Helena anticyclone appear to be the dominant mechanism triggering the surface heat flux anomalies. A weakening of the anticyclone will tend to weaken the prevailing northeasterlies and enhance evaporative cooling over the southwestern Atlantic Ocean. In the equatorial region, the southeast trade winds weaken thereby suppressing evaporation and leading to net surface warming. Thus, it is hypothesized that the wind-evaporation-SST feedback may be responsible for the growth of the SAOD events linking southern extratropics and equatorial Atlantic variability via surface net heat flux anomalies.

Wed-098

The influence of storm fronts on the biogeochemical response in the Southwestern Atlantic Ocean

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The Brazil-Malvinas Confluence region is considered one of the most energetic regions of the global oceans by the formation of many physical processes, as the frontal systems. The storm climatology of the region pointed to a continuous entrance of meteorological events, which might lead to variations on the physical and biological parameters in the upper-ocean of the oligotrophic Southwestern Atlantic around the Subtropical Gyre. From the Southern Ocean Commission, carried out by the Brazilian Navy during the austral autumn of 2015, it was possible to correlate model outputs and satellite products of sea surface temperature, chlorophyll-a concentration, nutrients and wind components with the in situ observations. Vertical profiles demonstrate an upwelling process associated to the mixing occurred to a depth of 100 m, after a strong storm event. Nutrients entrainment (on a rate of around 0.4 mmolNm-3day-1) and the instabilities of the isopycnal drive to an increase post storm condition in surface layer nitrate (~2mmolNm-3). We suggest that wind-enhanced pumping might be the mechanism responsible for the chlorophyll-a and nitrate upwelled into surface waters from the subsurface maximum on the mixed layer, by cumulative effect of followed storms. The innovation within this study lies on the biological response to a physical process on an undersampled remote region with high storm frequency, which might contribute significantly to the region's net productivity.

Wed-099

Modeling physical - biological interactions in the ocean during the passé of the cyclone, Phailin

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The significance of tropical cyclone in increasing the productivity of Bay of Bengal has been well studied by several researchers. Most of the studies are based on remote sensing techniques. Due to lack of data, biogeochemical variability of the ocean along the cyclone passé has often been less studied particularly, subsurface variability of the ocean. During October 9-12, 2013, a category-5 hurrican, Phailin, developed over Andaman & Nicober Islands and made a landfall at the Gopalpur coast of Odisha state in India. An eddy permitting well validated coupled bio-physical model, Regional Ocean Modeling System (ROMS) integrated with an ecosystem model, simulated data has been used to study physical - biological interactions in the ocean along the cyclone passé. It is observed that thermocline is shoaled up after passing the cyclone and causes entrainment of nutrients. It is also observed that, on October 9th, subsurface chlorophyll maximum (SCM) was at the depth of 30-40 meters however, SCM was elevated to the sea surface on October 12th. It is due to the curl of the wind stress which produced a divergence of the Ekman transports leading to a vertical velocity approximately 10 meter/day at the top of the Ekman layer. Additionally, in presence of sufficient light after the passé, near-surface phytoplankton community utilized nutrients entrained from deeper waters which in turn enhanced primary productivity. It is to be concluded that the sea surface chlorophyll concentration (=6 mg/m3) is reaching to its peak approximately with time-lag of 3-4 days with respect to the increase in the nitrate concentration of the surface waters. The shoaling of oxycline and high biological productivity along the cyclone passé increase the oxygen concentration at the surface layer and subsequently, there is a saturation observed in the oxygen concentration in the surface layer. It is further noted that there was a drop of 1°C in sea surface temperature (SST). Recorded cooling has enhanced the holding capacity of CO_2 in the surface water. On top of that entrainment of inorganic carbon from deeper layers increased the partial pressure of CO_2 almost 50 ppm. The subsequent effect of which is that ocean became source to atmospheric CO_2 during the cyclone.

Wed-100

Mesoscale Ocean Large Eddy Simulations

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High resolution is not a panacea. Presently, the majority of high-resolution models use sub-grid schemes which are chosen for simplicity, stability, and tradition. Many of these schemes are inconsistent with physical principles, and so it is often hoped that resolved phenomena will be insensitive to such choices.

It will be demonstrated that choosing among reasonable, extant, and in-development sub-grid closures in simulations with grids significantly finer than the deformation radius differ. These differences may be detected in turbulence statistics on scales near the gridscale, but also at larger separation distances, even beyond the deformation radius. It will be shown that "damping noise," even with scale-selective damping such as biharmonic or higher-order damping, has a significant undesirable impact on resolved turbulence statistics. Some satellite and in situ observations exist which help to constrain this choice, but significantly more work is needed to make these datasets as easy to use as those presently used for coarse-resolution model evaluation.

A sub-grid scheme designed to smoothly terminate potential enstrophy cascade will be presented. This scheme builds on previous work in enstrophy cascade viscosities based on two dimensional turbulence (the Leith and Leith-plus closures used in the ECCO2 model) to provide an extension suitable for quasigeostrophic turbulence. Diffusivity, viscosity, and eddy-induced advection are all predicted in a straightforward manner by the theory. It is demonstrated that the individual and combined effects have desirable behavior, but that only the combined form avoids spurious contamination of larger scales by grid scale errors.

Wed-101

The rapid warming of the North Atlantic Ocean in the mid-1990s in an eddy permitting ocean reanalysis (1982-2013)

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The rapid warming in the mid-1990s in the North Atlantic Ocean is investigated by means of an eddy-permitting ocean reanalysis. Both the mean state and variability, including the mid-1990s warming event, are well captured by the reanalysis. An ocean heat budget applied to the subpolar region (SPG) (50N-66N, 60W-10W) shows that the 1995-1999 rapid warming is primarily dictated by changes in the heat transport convergence term while the surface heat fluxes appear to play a minor role. The mean negative temperature increment suggests a warm bias in the model and data assimilation corrects the mean state of the model, but it is not crucial to reconstruct the time variability of the upper ocean temperature. The decomposition of the heat transport across the southern edge of SPG into time-mean and time-varying components, shows that the SPG warming is mainly associated with both the anomalous advection of mean temperature and the mean advection of temperature anomalies across the 50N zonal section. The relative contributions of the Atlantic Ocean Meridional Circulation (AMOC) and gyre circulation to the heat transport are also analyzed. It is shown that both the overturning and gyre components are relevant to the mid-1990s warming. Additional analysis suggests that the increase of the heat transport due to the strengthening of the circulation can be attributed to the predominantly positive NAO before year 1995.

Wed-102

The role of diabatic heating and baroclinicity in controlling the spatial structure of midlatitude storm tracks

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The northern hemisphere midlatitude storm tracks are regions of enhanced eddy kinetic energy located mostly above the Atlantic and Pacific oceanic basins. Understanding the downstream development of storm tracks, which are characterized by a downstream enhancement and barotropic decay of eddy-kinetic energy accompanied with a downstream northeastward poleward tilt, is key to understanding the storm tracks evolution and possible response to climate change. Using a tracking algorithm coupled to an idealized GCM, and a potential vorticity (PV) tendency analysis, we identify two prime mechanisms which control the trajectory and lifecycle of cyclonic systems: the advection of lower level PV by the upper level flow, and diabatic production of PV due to latent heating causing a low-level poleward PV tendency. We demonstrate these mechanisms, and how they control the spatial structure of storm tracks, through a series of simulations, and analysis of the PV budget along the storm tracks. This also allows better differentiating the tracks of cyclones and anticyclones in the extratropics. We analyze also the interaction of the storm track with stationary waves, and show it contributes positively to the poleward tilt of the storm tracks. Finally, we discuss how these mechanisms will be affected by climate change, and how this will influence the future position and intensity of the storm tracks.

Wed-103

The latitudinal dependence of the oceanic barotropic eddy kinetic energy and macroturbulence energy transport

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Geostrophic turbulence theory predicted already a few decades ago an inverse energy cascade in the barotropic mode, yet there has been limited evidence for it in the ocean. In this study, the latitudinal behavior of the oceanic barotropic energy balance and macroturbulent scales are studied using the high-resolution ECCO2 state estimate, which synthesizes satellite data and in-situ measurements with a high resolution GCM containing realistic bathymatery and wind forcing. It is found that inverse energy cascade occurs at high latitudes, as eddy-eddy interactions spread the conversion of eddy kinetic energy from the baroclinic to the barotropic mode, both upscale and downscale. At these latitudes the conversion scale of baroclinic eddy kinetic energy and the energy-containing scale follows the most unstable and Rhines scales, respectively. Even though inverse energy cascade occurs only at high latitudes, through all latitudes the energy spectrum follows a steeper slope than the -5/3 slope. Different than classic arguments, the Rossby deformation radius does not follow the baroclinic conversion and most unstable scales.

Wed-104

Role of sea ice and SST in the recent Northern Hemisphere climate change

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Under the recent global warming, melting of arctic sea-ice in recent decades could have contributed to recent climate changes including its long-term trend and extreme weather events. While the climatic response to the sea-ice loss have been studied recently, it is still an open question to what extent the sea-ice change has influenced recent climate change. Other factors, such as for example, SST could also have had an influence. A main objective of GREENICE research project is to show what extent of the observed climate trend as well as observed weather extremes could be explained by the change and variability in sea ice and SST, respectively. In this project, we designed two atmospheric general circulation model experiments: In both experiments observed daily sea ice cover variations are prescribed, while for SST, one experiment uses observed daily variations and the other the observed climatology. The experiment is performed by six different state-of-the-art AGCMs. Our preliminary results show that the observed wintertime temperature trend near the surface is poorly reproduced in our hindcast experiments using observed SIC and SST. The impact of SIC variation seems to be confined near the surface, while SST variation seems a key for temperature trend above. It suggests a necessity to consider the atmospheric poleward energy transport associated with SST variation to understand the observed arctic amplification. Other aspects of SIC/SST impact on the observed circulation change such as NAO shall also be discussed.

Wed-110

Evaluating interannual variability of the TOA energy budget in CMIP5 climate models

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Understanding Earths energy budget is fundamental for studying the climate system, since a change in climate is controlled by (1) the budget of energy fluxes entering and leaving at top-of-atmosphere (TOA) and (2) the distribution of the energy remaining in the system. Global climate models serve as our most sophisticated tools for simulating present-day climate and predicting future changes a models ability to accurately recreate Earths energy budget is often used as a benchmark for model quality. Recent high-quality measurements of radiative fluxes using NASAs Clouds and the Earth's Radiant Energy System (CERES) satellite instrument provide an excellent 14-year data record for model evaluation. This study focuses on the evaluation of the widely-used Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble of climate models with performance metrics related to the interannual variance of key radiation budget quantities. Variance within the climate system is generated by physical processes&mdash such as clouds and surface conditions&mdash and is therefore a measure of model response to a forcing variance-related performance metrics are used in this study to evaluate the fundamental physical processes that underpin model projections. It is found that most CMIP5 models reproduce interannual variance and probability distributions of TOA radiation reasonably well compared with CERES observations, and models from the same modeling center tend to behave similarly across the tested performance metrics. However, all models fail at reproducing certain observed conditions, such as the regression between TOA longwave radiation fluxes and surface temperature this metric represents a fundamental measure of atmospheric column energy processes. We explore the various related radiative processes to identify those which models are least able to recapture, highlighting possible avenues for improvement in the next generation of climate models.

Wed-111

Time-dependent eddy-mean energy diagrams and their application to the ocean.

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Insight into the global ocean energy cycle and its relationship to climate variability can be gained by examining the temporal variability of eddy-mean flow interactions. A time-dependent version of the Lorenz energy diagram is formulated and applied to energetic ocean regions from a global eddying state estimate. Total energy in each snapshot is divided into three components: energy in the mean flow, energy in eddies, and energy temporal anomaly residual, whose time mean is zero. These three terms represent, respectively, correlations between mean quantities, correlations between eddy quantities and eddy-mean correlations. Eddy-mean flow interactions involve energy exchange among these three components.

The temporal coherence about energy exchange during eddy-mean flow interactions is assessed. In the Kuroshio and Gulf Stream Extension regions, a suppression relation is manifested by a reduction in the baroclinic energy pathway to the eddy kinetic energy reservoir (EKE) following a strengthening of the barotropic energy pathway to EKE; the baroclinic pathway strengthens when the barotropic pathway weakens. In the subtropical gyre and Southern Ocean, a delay in energy transfer between different reservoirs occurs during baroclinic instability. The delay mechanism is identified using a quasi-geostrophic two-layer model: part of the potential energy in large-scale eddies, gained from the mean flow, cascades to smaller-scales through eddy stirring, before converting to EKE. The delay time is related to this forward cascade and scales linearly with the eddy turnover time. The relation between temporal variations in wind power input and eddy-mean flow interactions is also assessed.

Wed-112

Possible linkage between ocean heat uptake, radiative forcing and surface temperature

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Ocean heat uptake (OHU) is critical to estimating climate sensitivity that is the global mean surface temperature equilibrium response to doubled CO2 concentration relative to the pre-industrial. In conventional energy-balance framework, OHU can be linearized with respect to surface temperature change ΔT multiplied by a factor κ, i.e. OHU efficiency. However, only part of the OHU, represented by the net radiative flux at the top of the atmosphere, can be explained by $\kappa\Delta T$. Using the 1% yr-1 increasing CO2 experiments (1pctCO2) of 24 coupled climate models from the Fifth Phase of Coupled Model Intercomparison Project, we find that the OHU can be regarded as two part: upper ocean heat uptake with a timescale τ and deep ocean heat uptake that can be regarded as a negative feedback. The latter is just $\kappa\Delta T$, while the former seems related to the radiative forcing. Using the κ and τ estimated from the 1pctCO2 can well explain the evolution of OHU in CMIP5 models during the 20th century and in the future projection, though other forcing agents like aerosols are involved. Because the forcing of green-house gas is well constrained, if the timescale of upper OHU can be estimated in a good accuracy, part of the uncertainty in OHU can be constrained as well.

Wed-113

Regional feedback and Bjerknes Compensation

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Shutting down the surface winds over the ocean causes significant reductions in both wind-driven and thermohaline overturning circulation, leading to a remarkable decrease in the poleward ocean heat transport (OHT). The sea surface temperature responds with an increasing meridional gradient, resulting in a stronger Hadley Cell in the low latitudes and enhanced eddy activities in the mid-high latitudes. As a result, atmosphere heat transport (AHT) is increased, compensating the OHT decrease. This is so-called BJC. By investigating the energy balance and climate feedbacks in wind-perturbation experiments, this study confirms that the occurrence of BJC is an intrinsic requirement of local energy conservation, and the local climate feedbacks determine the degree of BJC, consistent with our previous theoretical studies.

Wed-114

Observed strengthening of inter-basin exchange via the Indonesian seas due to rainfall intensification

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The Indonesian Throughflow (ITF) is a unique gateway that connects tropical ocean basins and provides the only low-latitude oceanic transfer of climate signals in the global thermohaline circulation system. The Indonesian region typically possesses heavy rainfall, but has experienced a decadal increase in rainfall due to the interdecadal Pacific Oscillation, as well as a longer-term trend under the warming climate scenarios of the wet-gets-wetter and warmer-gets-wetter. It is not yet clear how the ITF will respond to the increased rainfall and how this will influence the ocean and climate system. Using in situ hydrographic measurements along with assimilations, we show a significant strengthening trend in ITF transport. This trend is primarily induced by a freshening and increase of the halosteric transport related to the enhanced rainfall over the Maritime Continent during the past decade. The strengthening of the ITF transport leads to a significant increase in heat exchange between the Pacific and Indian Oceans and a sharp increase of freshwater input into the Indian Ocean from the Indonesian Seas, and thus plays a key role in the heat and freshwater redistribution in the Indo-Pacific region. Our results show a strong connection between rainfall and ocean circulation variation on a decadal time scale.

Wed-115

Delineation of Thermodynamic and Dynamic Response to SST Forcing Associated with El Niño

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Atmospheric response to an imposed diabatic heating anomaly consists of temperature response and non-temperature response. Non-temperature response includes changes in convective activities, excitation of atmospheric waves, and atmospheric circulation pattern, as well changes in atmospheric water vapor and clouds. Accompanied with changes in water vapor and clouds are radiative heating anomalies resulting in the new diabatic heating anomalies. Changes in atmospheric motions not only redistribute the energy both vertically and horizontally far away from the original diabatic heating anomaly, but also generate additional heating anomalies, such as latent heat anomalies. Temperature response is via thermal radiative cooling anomalies that balance the imposed heating anomaly, the new diabatic heating anomalies, and the energy redistributed due to changes in atmospheric motions.

In this study, we apply this view of framework to understand the atmospheric response in the tropics to SST forcing associated with El Nino. This allows us to delineate how the equatorial SST anomalies drive changes of the atmosphere over tropical Pacific basin from the surface to the upper troposphere. Equatorial SST anomalies associated with El Nino alter thermal radiative fluxes as well as surface turbulent latent and sensible heat fluxes that enter the atmosphere. Most of anomalous radiative fluxes entering the atmosphere are absorbed in the first few layers near the surface and are balanced by the thermal radiative cooling due to temperature changes there. Radiative heating anomalies due to changes in water vapor and clouds explain a large portion of thermal radiative heating anomalies in the lower troposphere above the boundary layer, indicating most temperature anomalies are directly caused by them. Above middle troposphere, thermal radiative cooling anomalies are mainly in balance with the sum of latent heating anomalies, vertical and horizontal energy transport anomalies associate with atmospheric dynamic response and the radiative heating anomalies due to cloud changes. This explains why the Gill-type atmospheric response can be easily identifiable in upper atmosphere but not so in the lower troposphere where diabatic heating anomalies due to SST anomalies and radiative heating anomalies due to clouds and water vapor are dominant.

Wed-116

Wind-driven Ocean Circulation on Exoplanets

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Around 2000 extrasolar planets have been detected. A critical question is which of these exoplanets are potentially habitable. Previous work mostly focused on atmospheric dynamics and its effects on the climates and habitability of exoplanets. Here, we expand the work by examining ocean dynamics. As the first step of the project, using idealized ocean models, we investigate the pattern and strength of wind-driven ocean circulation under various conditions, such as different wind stresses, planetary rotation rate, and ocean basins (closed or open in longitude direction). We find that in closed ocean basins of different planets, planetary rotation is a key factor and western intensification like the Gulf Stream is a common feature on different planets. In open ocean basins (i.e., channel mode having no eastern or western boundaries), there is no western intensification and surface wind stress becomes more important in determining the pattern of ocean circulation. This work will improve our knowledge of exoplanetary oceanography and is one of the keys in studying the climates and habitability of exoplanets those have oceans.

Wed-117

NOAA's Ocean Climate Observation Program

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Over the past 20+ years there has been remarkable progress in developing a global ocean observing system. Global in-situ observations of essential climate variables in the ice-free ocean to 2000m depth are now routinely available to address the long-term observational requirements of forecast and modeling centers, international research programs, major scientific assessments, and decision-makers. The resulting global observations and products contribute to other NOAA Programs, national and international capabilities aimed at understanding, modeling, and forecasting of the earth system, as well as developing targeted information to better inform society about changes of the earth system, including better response options. Access to these global observations and analyses of observational data has provided the international community with invaluable information needed to better minimize climate-related risk and maximize climate-related opportunities. This poster will review NOAA's Ocean Climate Observation program which supports thirteen global ocean observing systems (e.g Argo, deep-ocean hydrography, surface drifters, RAMA, Oceansites, GLOSS); data systems; and a suite of ocean products. The poster will describe the program's scope of current activities and strategic directions.

Wed-118

Ocean velocity wavenumber spectra inferred from space-borne ocean color imagery

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There are currently uncertainties in estimating the slopes of ocean velocity wavenumber spectra partly due to an incomplete or error prone measurement system, especially for scales below 100 km. As shown in previous studies, velocity wavenumber spectra calculated from satellite altimetry differ considerably from those calculated with realistic high-resolution ocean simulations, with measurement errors (instrumental noise and aliasing) flattening the altimetry spectra. On the other hand, ocean processes occurring at scales smaller than the model resolution, notably in the submesoscale (10-1 km or smaller), cannot be represented and therefore the simulations also have limitations. This work presents an alternative method for estimating velocity spectra for scales between 150-10 km in two regions of the North Atlantic: south of Iceland and off the northeastern African coast. To obtain a more realistic estimate of the wavenumber spectra in these two regions, 1-km (nominal) horizontally resolved chlorophyll-a concentration data measured by the MODIS ocean color radiometer are taken to calculate tracer wavenumber spectra. The respective spectral slopes between 150-10 km are then converted to velocity spectral slopes assuming that 1) chlorophyll-a mainly behaves as a passive tracer in the spectral band of interest and 2) a clear relationship between passive tracer and velocity wavenumber spectra exists in that range. The spectral relationship is here retrieved from an idealized open-ocean simulation of mixed-layer instabilities at 500 m horizontal resolution. The converted spectral slopes are consistent in both regions with those from a realistic numerical simulation at 4 km resolution, indicating the realism of the latter, but the inertial range extends down to scales of 10 km for the tracer case. The discrepancy found between altimetry velocity spectra and velocity spectra derived from ocean color data confirms that the current satellite altimeter missions cannot be used to derive reliable slopes of ocean variability. The work further suggests that submesoscale-resolving simulations are of crucial usefulness to understand the processes behind the distribution of energy in the ocean.

Wed-119

Impact of high-frequency variability on the eddy kinetic energy balance of the North Atlantic Ocean

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Despite recent progress in measuring the mesoscale (order of 100km) eddy field with satellite missions, containing the major fraction of ocean kinetic energy, many questions still remain regarding the generation and dissipation mechanisms of Eddy Kinetic Energy (EKE). In this work we use 10 years of daily output from a 4-km resolution numerical simulation of the North Atlantic circulation to study 1) the geographic distribution of EKE (including its depth dependence) and 2) the time variability of the components of the EKE balance: the temporal change and the conversion and generation terms, with emphasis in isolating the oceanographic processes responsible for the variability. We further revisit the problem of estimating the EKE generation by the wind based on current satellite and in situ observations and show, in view of the energetic high-frequency wind fluctuations and their correlated ocean impacts, how inappropriate the current observing system is to address this issue.

Wed-120

High-resolution insights from coupled climate models into the role of the Southern Ocean in a high-carbon future

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The Southern Ocean is responsible for 67-98% of the anthropogenic heat uptake and up to half of the oceanic uptake of anthropogenic carbon. Efforts to determine the future uptake of carbon and heat by the Southern Ocean, however, have been hampered by the enormous computational resources required to simulate ocean biogeochemistry in eddy-resolving coupled climate models. Using the suite of high to low resolution coupled climate model simulations developed and run at NOAA's Geophysical Fluid Dynamics Laboratory, we compare the response of the Southern Ocean with respect to the uptake of heat and carbon to a doubling of atmospheric carbon dioxide. The three different configurations include the eddy-resolving GFDL-CM2.6 with a nominal ocean resolution of 0.1°; the eddy-permitting GFDL-CM2.5, with a nominal resolution of 0.25°; and the standard resolution GFDL-CM2.1 (1°), in simulations in which the atmospheric CO2 increases at 1% per year until doubling is achieved after 70 years. To assess the carbon uptake, CM2.6 is coupled to a computationally-efficient biogeochemical module (Mini-BLING, Galbraith et al. 2010, 2015) with a reduced set of biogeochemical variables that allows an analysis of the uptake of carbon by the Southern Ocean, as well as the effects on nutrient storage and transport and potential acidification impacts. We evaluate these simulations against other CMIP5 Earth System Model simulations, the results of the Southern Ocean State Estimate, and against observationally-based metrics.

Wed-121

Changes in global energy budget at the top of atmosphere and surface 1985-2014

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Combining satellite data, atmospheric reanalyses and climate model simulations, variability in the net downward radiative flux imbalance at the top of Earth's atmosphere (N) are reconstructed and linked to recent climate change. Over the period 1985-2012 we estimate N=0.47±0.54 Wm−2 (uncertainties at 90% confidence level). Variability relates primarily to the eruption of Mt. Pinatubo in 1991 and El Niño Southern Oscillation with good agreement (r~0.6) between the monthly reconstruction and atmospheric simulations using prescribed sea surface temperature and radiative forcings. For the recent period (2000-2015) we estimate N=0.60±0.43 Wm−2. Combining with a simple energy balance climate model we argue that increased ocean heat uptake below the mixed layer is required to reconcile changes in N and surface temperature since 1985 (Allan et al. 2014).

The surface net fluxes are estimated by combining the reconstructed N and the atmospheric energy tendencies and transports from the ERA-Interim reanalysis (Liu et al. 2015). The energy divergences over the oceans are adjusted to remove an unphysical residual global mean atmospheric energy divergence. The estimated net surface energy fluxes are compared with reanalysis and atmospheric model simulations. The spatial correlation coefficients of multi-annual means between the estimations made here and other data sets are all around 0.9. There are good agreements in area mean anomaly variability over the global ocean. The inter-hemispheric heating differences and precipitation biases are also discussed (Loeb et al. 2015). A cross equatorial ocean heat transport of 0.30 PW is inferred from surface energy flux and independent ocean heat storage estimates which is lower than previous estimates.

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Wed-122

AABW's volume and heat content in the last six decades

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The Antarctic Bottom Water (AABW) is one of the densest water masses in the ocean and makes the link between the warm upper limb of the Meridional Overturning Circulation (MOC) and the cold deep one. Oscillations on AABW's export from Antarctic margins may directly affect the global ocean ventilation. Applying the Coordinated Ocean–Ice Reference (CORE) interannual forcing we have run a 60-year simulation (1948–2007) using the Regional Ocean Modeling System (ROMS) with sea ice/ice shelf thermodynamics module to investigate the oscillation on AABW's properties. The experiment employed a circumpolar variable resolution (1/2° to 1/24°) grid reaching less than 5 km at the southern boundary and 40 sigma levels. Results show that AABW temperature has risen during the simulation period from $\theta \sim -0.4$°C in the 1950s to $\theta \sim -0.3$°C in the 2000s, while salinity has lessened from 34.80 to 34.63, which may be related to the freshening and/or reduced production of AABW. In order to quantify the changes in the production of AABW, we have computed AABW's volume and ocean heat content (OHC) along a 1°-thick meridional section crossing the Weddell Sea (40°W) using the neutral density γn= 28.3 kg.m^{-3} for the upper limit of AABW (usually γn= 28.27 kg.m^{-3} on observational data), given the model's relatively coarse vertical resolution at the deep and bottom layers. OHC was normalized by AABW's volume.

Our calculations reveal that the volume of AABW exported from the Weddell Sea dropped during the first three decades of the simulation, from 10.83 x 10-^{5} km^{3} to 6.35 x 10-^{5} km^{3} between the '50s and '70s. This drop was followed by a mild recovery of AABW's volume leaving the Weddell Sea during the 1970s. This is explained considering the Weddell Sea Polynya big events. These started in 1972 and helped to pump AABW back to a steady state of ~ 7.50 x 10-^{5} km^{3} till the end of the simulation. Normalized OHC also declines between the '50s to mid '70s (1,1 J.m^{-3} to 0.95 J.m^{-3}), followed by a significant recovery until 1995 (1.25 J.m^{-3}), which may be related to the production of a fresher AABW. These results are consistent with observations and other numerical experiments who showed that for the entire Weddell Sea, the deep ocean heat content drastically weakened during the '70s due to the Polynya recurrence.

Wed-123

An imperative to monitor Earth's energy imbalance

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The current Earth's energy imbalance (EEI) is mostly caused by human activity, and is driving global warming. The absolute value of EEI represents the most fundamental metric defining the status of global climate change, and will be more useful than using global surface temperature. EEI can best be estimated from changes in ocean heat content, complemented by radiation measurements from space. Sustained observations from the Argo array of autonomous profiling floats and further development of the ocean observing system to sample the deep ocean, marginal seas and sea ice regions are crucial to refining future estimates of EEI. Combining multiple measurements in an optimal way holds considerable promise for estimating EEI and thus assessing the status of global climate change, improving climate syntheses and models, and testing the effectiveness of mitigation actions. Progress can be achieved with a concerted international effort and is the principal objective of the CLIVAR research focus CONCEPT-HEAT, which will be also introduced here.

Wed-124

What have we learned about ocean's energetics using high-resolution OGCMs?

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An OGCM at a horizontal resolution of 0.1 degrees or higher can not only realistically simulate the oceanic general circulation. It will also be able to resolve, in a realistic manner, meso-scale eddies and, when forced appropriately, low-mode near-inertial waves. Thus, the energetics of these oceans could be distinctly different from those simulated by low-resolution models that poorly resolve meso-scale eddies and near-inertial waves. This paper summarizes the results reported in von Storch et al. (2012, JPO) and Rimac et al. (2016, JPO) and discusses the important lessons on ocean energetics learned from high-resolution modelling, especially those concerning the fundamental ways following which a) the ocean circulation and the related eddy field operate in the light of Lorenz's energy cycle and b) surface winds transfer their power into the oceanic interior via near-inertial and sub-inertial variations and time-mean motions.

Wed-125

Evidence and causes of dimming and brightening inferred from sunshine duration observations in China

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There is increasing evidence that the solar fluxes reaching the Earths surface are not stable over time but undergo substantial decadal variations in various parts of the world, popularly known as global dimming and brightening. Consistently in China, a reversal was noted in sunshine duration (SD), a widely used proxy for surface solar radiation (SSR), from dimming by 0.18 h d1 decade1 for the period 19611989 to leveling off by 0.01 h d1 decade1 for 19902013. SD declines covered 86% of 408 observation sites across China in the dimming phase. By contrast, in the brightening phase, SD increased in 50% of the sites while continued to decrease in the remaining parts of China, especially in central and north China. The variability of SD in China was proven to be attributed to anthropogenic air pollution rather than climate change, as the difference between urban and rural sunshine duration records has been increasing during the past half century, whereas total cloud cover remained stable. The air pollution effect on SD and SSR was then quantified under clear-sky conditions as follows: (1) for pristine days, SD is on average 1.1 h d-1 (12.4%) longer than for polluted days and (2) on average, when air pollution increases by one level, i.e. the index for air pollution (API) increases by 50, SSR decreases by 6 W m-2. API was shown to be a useful indicator in studying the effects of aerosols on global dimming and brightening. Besides, air pollution has driven wind speed into a non-negligible regulator of SSR/SD. The regulatory effect of wind speed on SSR starts to be important when API exceeds the level of 125. In addition, in the dimming phase without available API monitoring, urbanization can be used as an applicable proxy for anthropogenic pollution level. Urbanization has significantly affected SD trends in China until the brightening phase when pollution regulations became effective.

Wed-126

The Global Energy Balance From a Surface Perspective

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Despite the central importance of the Global Energy Balance for the climate system, the adequate quantification of its components is still a major issue. While the energy fluxes in and out of the climate system at the top of atmosphere (TOA) are now known with considerable accuracy from new satellite programs such as CERES and SORCE, the accurate determination of the energy exchanges within the climate system and at the land and ocean interfaces remains a challenge. Uncertainties in the energy balance components at the surface have therefore traditionally been larger and less well quantified than at the TOA. This is reflected in greatly diverging global estimates of the surface energy balance components that have been published over the years. Accordingly, also current climate models (CMIP5) still largely differ in their representation of these components. Since the mid-1990s, accurate direct measurements become increasingly available from the networks of surface radiation stations such as BSRN, which allow to better constrain the energy fluxes at the Earths surface. In parallel, recent satellite-derived surface flux products profit from the great advancement in space-born observation systems that became operational since the turn of the millennium. As a consequence, emerging independent global estimates of the surface radiation components based on surface and satellite data converge to within a few Wm-2. We are thus approaching a stage where we are not only confident in the magnitude of the global radiation budget at the TOA, but increasingly also at the surface. Uncertainties remain particularly in the determination of large scale surface albedo, skin temperatures and the partitioning of the surface net radiation into sensible and latent heat, and accordingly in the consistent representation of the energy and water cycles.In addition to the progress achieved in the quantification of the mean state of the global energy balance, from a surface perspective there is increasing evidence that the surface radiative fluxes undergo significant changes on multidecadal timescales. This applies not only for the longwave fluxes as expected from the increasing greenhouse effect, but also for the amount of shortwave radiation reaching the Earth surface. Surface observations suggest an overall increase of downward longwave radiation on the order of 2 Wm-2 per decade, in line with latest projections from the CMIP5 models and an increasing greenhouse effect. On the other hand, strong multidecadal variations in surface shortwave radiation are evident in the observational records (dimming/brightening), which are not fully represented in climate models. It is the combined effect of the shortwave and longwave variations that governs the evolution of radiative energy available at land and ocean surfaces for the non-radiative energy fluxes of sensible and latent heat as well as the net energy fluxes through the atmosphere/land and atmosphere/ocean interfaces.

Some related references:

Wild, M., and co-authors 2015: The energy balance over land and oceans: An assessment based on direct observations and CMIP5 climate models, Climate Dynamics, 44, 33933429Wild, M., 2016: Decadal changes in radiative fluxes at land and ocean surfaces and their relevance for global warming, WIRES Clim Change, 7, 91107

Wed-127

Seesaw of AMOC and PMOC

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Both in site observations and proxy index data confirm a seesaw-like pattern between Atlantic Meridional Overturning Circulation (AMOC) and Pacific Meridional Overturning Circulation (PMOC) from decadal to millennial variability. The seesaw pattern of AMOC and PMOC is especially obvious during the last glacial termination. Previous studies mainly focus on H1 (Heinrich Event 1, 17.5 to 15 ka) when reconstructed Sea Surface Salinity is relatively high and attribute this to buoyancy forcing by salinity change in the North Pacific. For example, ice-melting induced by low salinity in the North Atlantic Ocean would shut down AMOC meanwhile the atmospheric teleconnection would decrease precipitation and increase salinity in the North Pacific Ocean and then enhance PMOC.

However, by compiling all the available paleo record in the Northwest Pacific, this mechanism may be invalid in the YD (Younger Drays, 12.8 to 11.4 ka) event when deep ventilation occurred in the Northwestern Pacific with decreased sea surface salinity. Here we propose an alternative explanation based on the Bjerknes compensation theory. Although the earth may have endured significant heat content change, heat content change induced atmosphere and ocean Meridional Heat Transport (MHT) change is still relative small compared with total MHT change. To maintain a relative steady state of the whole climate system, MHT by Atmosphere and Ocean will compensate each other. The decreasing of northward ocean MHT by shutdown of AMOC will be compensated by increasing heat transport by Atmosphere. Considering that eddy induced Atmosphere MHT dominates total Atmosphere MHT in the mid-high latitudes, increased atmosphere MHT indicates stronger storm activities in mid-latitude in the northern hemisphere. This enhanced storm activities could support the deep convection in the North Pacific Ocean and increase PMOC even with decreased SSS. This speculation has been confirmed by model simulations. Besides, paleo records also indicates a strengthening of east Asian Winter Monsoon.

Wed-128

Production, Service and Future Development of a Global Blended High Resolution Sea Surface Wind Dataset

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In this paper we present the production, service and its future development of the global gridded high resolution sea surface wind dataset. The Blended Sea Winds dataset contains globally gridded, high-resolution ocean surface vector winds and wind stresses on a global 0.25° grid, and multiple time resolutions of six-hourly, daily, monthly, as well as 11-year (1995–2005) climatological monthlies. The period of record is July 9, 1987, to present. Blending observations from multiple satellites (up to six satellites since June 2002) allows for the creation of gridded wind speeds. The wind directions come from two sources depending on the products: for the research delayed mode product, the source is the National Centers for Environmental Prediction (NCEP) Reanalysis 2 (NRA-2) and for the near-real-time products, the source is the numerical weather prediction of the European Centre for Medium-Range Weather Forecasts. Blending multiple-satellite observations fills in the data gaps (in both time and space) of the individual satellite samplings and reduces the subsampling aliases and random errors. These products were developed in response to the demand for increasingly higher resolution global datasets. The global 0.25° gridded data are available in netCDF and IEEE format for the period of record. Users can use the data with support reading programs in FORTRAN, MATLAB, and GrADS. This dataset has been widely used by both research and public communities, including near real time ship routing service and World Coral Reef Watch, among many others to be presented in this talk.

Wed-129

Seasonal and decadal variability of the Arctic Ocean heat content in CMIP5 models

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Observing data in arctic ocean are relatively deficient. Based on these data we can still find that the accuracy of ocean heat content of the three mainly basins are closely related with the ice coverage rate and local water sources. In the regions with large ice extent and coverage, all the datasets differentiate with each other, which brings more difficult to model simulation. In CMIP5 models, the simulations exhibit similar properties as observational datasets. In Eurasian Basin, models have large spread in both original data and seasonal oscillation. In Greenland Sea, simulations resemble observation and also have small spread. It shows that the physical process in ice-cover regions are not well interpreted and more accurate observation data are needed to help improve model simulation abilities.

Wed-130

Influence of mesoscale and submesoscale dynamics on the seasonal cycle of the ocean mixed layer depth

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The intensification of submesoscale activity in fall and winter during episodes of convective deepening of the ocean mixed layer is well documented in realistic ocean models. A global ocean model with a 1/32° zoom in the western part of the North Atlantic subpolar gyre confirms the strong seasonal cycle of submesoscale motions. The mechanisms by which mesoscale and submesoscale turbulence control the mixed layer depth are investigated further, using an idealized periodic channel geometry. A whole cycle of destratification by cooling and restratification is simulated, using an ensemble strategy to assess the robustness of the results. Simulations with grid resolutions varying from 10 km to 2 km show that, at higher resolution, when submesoscale starts to be resolved, the mixed layer formed during the surface cooling is significantly shallower and the total restratification is almost three times faster. Such differences between coarse and fine resolution models are consistent with the submesoscale upward buoyancy flux, which balances the convection during the formation phase and accelerates the restratification once the surface cooling is stopped. The simulations show that mesoscale dynamics also cause restratification, but on longer time scales. Implications for climate models using eddy parameterizations are discussed.

Wed-131

Experimental study on wave turbulence interaction in wave tank

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Surface waves play an important role in the upper ocean mixing. Part of wave energy is transferred to ocean turbulence through wave breaking and wave-turbulence interaction. Lots of work have been done on the interaction of wave-turbulence. In this paper, we do experiment in wave tank to research the interaction effect between wave and turbulence. The homogenous and uniform turbulence was produced with stirring grid and the harmonic wave was generated by wave maker. With ADV, the water velocity was measured. we carry out three kinds of experiments: only mechanical wave, only vibrating grid turbulence, vibrating grid turbulence and mechanical wave. Though analyzing the velocity of water with EMD method, we got that wave will interact with turbulence obviously and transfer energy to turbulence increasing its strength, especially in wave trough.

Wed-132

Mathematical and numerical modeling of the physics of cold water downslope flows

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Downslope flows of negatively buoyant water that forms in the marginal seas around the Antarctic contribute to the formation of bottom water currents. Downslope flows are known to play an important role in the energy transport in the polar seas, thereby affecting the stability and melt rate of ice sheets and as a consequence, also affect the rate of sea level rise. High Salinity Surface Waters (HSSW) forms in polynyas in the western and southern regions of the Weddell sea. This HSSW being negatively buoyant descends and collects in the depression of the marginal sea and eventually overflows over the sill. The overflowing water may diffuse at some intermediate depth if it undergoes sufficient entrainment with ambient waters and becomes neutrally buoyant. However, some of the overflow water may eventually reach greater depths. This paper reviews the observations and conceptual understanding as well as the mathematical and numerical models of the physical processes ie. entrainment, bottom friction, thermobaricity, cabbeling and viscous Ekman drainage. Some numerical models using idealized test cases are compared with existing physical observations of the vertical CTD profiles and microstructure of the Weddell sea. The study is aimed towards an improved understanding of downslope flows by looking at important individual physical processes, as such understanding is required to improve the parameterization of these flows in climate and ocean general circulation models.

Wed-133

The response of the meridional overturning circulation to diapycnal mixing

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The distribution of diapycnal mixing in the ocean is highly heterogeneous. The role of this in the meridional overturning circulation (MOC) has typically been diagnosed in terms of steady state balance, rather than a mechanistic understanding of the effect of diapycnal mixing. Determining the rate of upwelling that balances the downward buoyancy flux associated with mixing, for example, gives no indication of how the MOC responds to mixing, or vice-versa. This presents an obstacle to understanding the role of mixing in the Atlantic (upper) and Antarctic (lower) overturning cells, especially within the context of a changing climate.

A framework is presented here for overcoming this obstacle by determining the tendency in overturning, $\partial\Psi/\partial t$, due to diapycnal mixing. The required steps are (1) diagnosing the gravitational potential energy (GPE) input by diapycnal mixing, using reconstructions of internal wave and lee wave generation and dissipation; (2) linking this to horizontal pressure gradients via the classical equation relating GPE and compressible work; (3) using the semi-empirical relationship between meridional pressure gradients and meridional flow to diagnose a response of the MOC on multi-decadal and longer timescales. Finally, the framework is validated using idealised experiments with a general circulation model.

The response of the Atlantic and Antarctic cells to diapycnal mixing is strongly dependent on the location at which the turbulent kinetic energy is dissipated. Mixing at most locations acts to strengthen both cells, but there are several important exceptions. Mixing at high latitudes can weaken overturning by weakening horizontal pressure gradients (i.e. by increasing GPE but reducing available potential energy), whereas at several locations, mixing supplies negligible net GPE because of conversion of GPE to compressible work by cabelling. Most importantly, diapycnal mixing typically drives upwelling below but downwelling aloft, so that the direct effect of near-bottom dissipation of internal waves and lee waves can be to strengthen the Antartic cell but weaken the Atlantic cell. However, pycnocline dissipation of internal waves strengthens both cells, emphasising the importance of determining the vertical structure of turbulent kinetic energy dissipation.

Wed-134

The influence of seafloor topography on the spatial distribution and dynamics of mesoscale eddies and topographic steering in the Southern Ocean

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The Antarctic Circumpolar Current (ACC) is known as one of the most eddy saturated areas of the World Ocean. It is also well-known that the fronts of this current are steered by the seafloor topography features. In fact, eddy space-time distribution analysis in relation to the seafloor topography seems crucial for an understanding of numerous processes in the Southern Ocean and their reaction to climate changes. The combination of one-minute-resolution GEBCO bathymetry (http://www.gebco.net/) and eddies space-time position and parameters data (http://cioss.coas.oregonstate.edu/eddies/) via GIS software allows to investigate the role of seafloor topography in eddy dynamics and find its space-time patterns. The objective of this study is to investigate eddy space-time distribution and parameters in the relation to the seafloor topography in the Southern Ocean.First of all, the spatial density of eddies field was defined and calculated. It defined as the number of eddies per unit area and was calculated by the &laquo Heatmap&raquo tool (QGIS software). The results shew significantly inhomogeneous distribution of the eddies field spatial density. The minimal concentrations observed over the shelf waters and to the south of the South ACC front. The maximum concentrations embedded in the average concentrations in the form of adjacent spots and stripes and also could be found on the seamounts and gaps between the seafloor ridges. The shapes and sizes of the maximum concentrations areas correspond well with the mean flow and the dynamical activity grade of the investigation area. The large seafloor topography features play guiding and blocking roles, make the clear influence on the eddies concentration areas shapes (and eddies tracks) or block it, in different cases. The most notable example of this can be found in the Scotia sea, where North Scotia ridge blocks eddies concentration areas and tracks, so they pass through this sea only by two deep-water passageways. The same situation occurs also in the Kerguelen plateau area, Campbell plateau etc. As the result, the eddies concentration areas are under the strong influence of the seafloor topography and the fronts position. Their non-uniform distribution shows its deterministic nature and the dependence of large-scale dynamical processes in the ocean. However, there were no any statistical correlations between the parameters of eddies and the depth of the ocean beneath. Thus, using the position and parameters of the mesoscale eddies and the bathymetry data, the eddies spatial distribution and tracks patterns were described due to the seafloor topography features. This results can be used to improve our understanding of mesoscale dynamics of the Southern Ocean (e.g. the estimations of water exchange), as well as to define the regional differences, and enhance the next research efforts.

Wed-135

An assessment of forcing, diffusion and advection processes controlling mean surface salinity over the global ocean

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A data-constrained ocean state estimate that permits closed property budget diagnostics is used to examine the balance between forcing by surface freshwater fluxes and interior advective and diffusive fluxes in maintaining the large-scale time mean surface salinity. Time mean budgets (1993-2010) are considered for the 10 m-thick top layer. In general diffusion tends to counteract surface forcing, but advection is important almost everywhere, and some regions show a main balance between advection and diffusion (Bay of Bengal, Arctic) or advection and forcing (tropical Atlantic and Pacific). Advection tends to freshen the surface in the tropics and high latitudes, with opposite tendencies in mid-latitudes. For various surface salinity tropical extrema, advection adds to the forcing tendencies in precipitation regions and opposes forcing in evaporation regions. Long-term surface salinity conditions thus reflect more than a simple diffusive adjustment to forcing, likely involving the interplay of wind- and buoyancy-driven circulations as well as mixing processes.

Wed-136

Mixing in the equatorial thermocline and its impact on ocean atmosphere interactions

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Ocean mixing in the tropics impacts air-sea interactions as well as basin-scale dynamics through the vertical flux of properties and changes to the thermocline. Measurements in the western equatorial Pacific have shown the importance of flow features with small vertical scale, SVSs, in generating the turbulence responsible for the mixing. These long lived features have a vertical scale of O(10m). We find a strong relationship between the vertical shear and stratification and the turbulent dissipation. Using this relationship we can deduce the vertical mixing length scale and derive a parameterization scheme that is shown to work well when applied to flows with similar characteristics.

The shear-driven turbulence associated with the small vertical scale flow features is found to be enhanced in and above the equatorial thermocline. There are two primary sources for such activity, high vertical mode inertia-gravity waves (IGWs) and flow instabilities. Numerical experiments show that in an idealized tropical ocean forced by a transient wind stress both IGW activity and the energy dissipation have a pronounced maximum in the thermocline close to the equator regardless of the latitudinal distribution of the energy input into the ocean's mixed layer by the wind. We show that this equatorial enhancement is caused by a combination of three factors: a stronger superinertial component of the wind forcing close to the equator, wave action convergence at turning latitudes for various equatorially trapped waves, and nonlinear wave-wave interactions between equatorially trapped waves. Amplification of IGWs also occurs due to refraction at the top of the thermocline.

An additional important source of small scale activity comes from inertial and parametric subharmonic instabilities (or a combination of the two). We find observational evidence for inertial instability leading to enhanced mixing. Numerical experiments show the persistence of the mixing induced by inertial instability. Secondary instabilities of the modified mean flow favor zonally nonsymmetric modes, which leads to a three-dimensionalization of the flow.

The vertical distribution of the enhanced mixing is important in shaping the equatorial thermocline which in turn affects the ocean state and interannual variability of the coupled system, as demonstrated in ocean only and coupled GCMs with a suitable choice for the enhanced mixing based on observations and physical reasoning.

The equatorial ocean provides a playground for a rich assortment of processes leading to turbulence and mixing, but an important lesson from this work is the need to resolve adequately the flow features generating the turbulence in both observations and models.

Wed-137

Exploring the role of ocean mesoscale eddies in the climate of the Southern Ocean

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The US Department of Energy has embarked on a program to develop a new Earth System Model called ACME -- Accelerated Climate Model for Energy. ACME is intended to excel at global, high-resolution simulations of the Earth's climate system with one long-term foci of predicting the likelihood of rapid sea-level rise due to ocean-land ice interaction around Antarctica. For this presentation we will focus on the role of mesoscale eddies in the Southern Ocean and Antarctica Slope Front in mediating the transport of heat to the ocean-land ice interface. In addition, we will attempt to quantify the role of mesoscale eddies on the ocean's climate by employing two novel analysis methods to describe the role of eddies. First, we use the Lagrangian In-situ, Global, High-performance particle Tracking (LIGHT) model to estimate the net mixing produced by mesoscale eddies. Second, we interpret eddy-mean flow interaction through analysis of the Eliassen-Palm flux tensor. In combination, the two analysis methods provide an essentially complete description of how eddies set the climate of the Southern Ocean. The analysis is embedded in simulations using the Model for Prediction Across Scale-Ocean (MPAS-O) which serves as the ocean component of ACME. MPAS-O is a global, unstructured-grid, multi-scale ocean model employing mimetic discretization methods to enforce important constraints, such as conservation of mass, heat, energy and potential vorticity.

Wed-138

Physical processes in the transition zone between North Sea and Baltic Sea.Numerical simulations and observations .

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The dynamics in the transition zone between the North Sea and Baltic Sea are analyzed here using data from a 22-year-long climatic simulation with a focus on the periods 1992–1994 and 2001–2003 when two recent major inflow events occurred. Observations from gauges and in situ measurements are used to validate the model. Parameters, which cannot be easily measured, such as water and salt transports through straits, have been compared against similar previous estimates. The good performance of simulations is attributed to the finer resolution of the model compared to earlier set ups. The outflow in the Kattegat, which is an analogue of the tidal outflows, tends to propagate to the North over the shallows without showing a substantial deflection to the right due to the Earth's rotation. The inflow follows the topography. The different inflow and outflow pathways are explained as a consequence of the specific combination of bathymetry, axial and lateral processes. The circulation in Kattegat is persistently clockwise with an eastern intensification during inflow and a western one during outflow regimes. The tidal wave there propagates as Kelvin wave, keeping the coast on its right. The flows in the two main straits reveal very different responses to tides, which are also highly asymmetric during inflow and outflow conditions. The circulation has a typical two-layer structure, the correlation between salinity and velocity tends to increase the salt transport in the salinity conveyor belt. The transversal circulation in the entrance of the Sound enhances the vertical mixing of the saltier North Sea water. The long-term averaged ratio of the water transports through the Great Belt and the Sound is ~2.6-2.7 but this number changes reaching lower values during the major inflow in 1993. The transports in the straits are asymmetric. During inflow events the repartition of water penetrating the Baltic Sea is strongly in favor of the pathway through the Sound, which provides a shorter connection between the Kattegat and Baltic proper. The wider Great Belt has a relatively larger role in exporting water from the Baltic into the North Sea. A demonstration is given that the ventilation of the Baltic Sea deep water is not only governed by the dynamics in the straits and the strong westerly winds enhancing the eastward propagation of North Sea water (a case in 1993), but also by the clockwise circulation in the Kattegat acting as a preconditioning factor for the flow-partitioning.

Wed-139

Long-range Propagation And Associated Variability Of Internal Tides From Luzon Strait

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Variability of internal tides (ITs) during their long-range propagation from Luzon Strait is investigated using a primitive equation model. ITs from Luzon Strait were found to radiate into Western Pacific with a distance over 2500 km both by satellite altimeter observations and numerical simulations. The propagation process of diurnal and semidiurnal ITs shows different pattern and variation. ITs dissipation processes were also examined based on numerical results.

Wed-140

Impact of Simulated Mixed-Layer Depth Observations on Ocean State Estimation

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The Ocean Surface Boundary Layer (OSBL) modulates the air-sea exchange of heat, momentum, freshwater, carbon dioxide and other trace gases. However, subsurface ocean observations are sparse, such that estimates of OSBL properties and budgets are often dependent on climatological layer depth proxies that fail to capture variability on an appropriate timescale. As part of a larger effort to investigate the science need and potential benefits of a future remote sensing mission to measure OSBL characteristics directly, we conduct an Observing System Simulation Experiment (OSSE) to examine the impact of simulated, remotely sensed OSBL profiles on an ocean state estimate. OSSEs are typically designed to use data assimilation ideas to investigate the potential impacts of prospective observing systems. In this OSSE, the "real ocean" or nature simulation is a one-year (2012) run of a very high resolution (~4km) global eddying version of the Massachusetts Institute of Technology General Circulation Model (MITgcm). The state estimation system is lower resolution (non-eddy permitting), and based on that used by the Estimating the Circulation and Climate of the Ocean (ECCO) project. The simulated OSBL profiles from the nature run are sampled along A-Train satellite constellation tracks and applied to the state estimation system as an additional data constraint. Results from this OSSE are compared to (1) a control assimilation experiment in which no along-track OSBL information is included, but other parameters are still assimilated, and (2) a pure simulation in which no information of any kind is assimilated from the nature run.

Wed-141

Observed 3D Structure, Generation, and Dissipation of Oceanic Mesoscale Eddies

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Oceanic mesoscale eddies with horizontal scales of 50–300 km are the most energetic form of flows in the ocean. They are the oceanic analogues of atmospheric storms and are effective transporters of heat, nutrients, dissolved carbon, and other biochemical materials in the ocean. Although oceanic eddies have been ubiquitously observed in the world oceans since 1960s, our understanding of their three-dimensional (3D) structure, generation, and dissipation remains fragmentary due to lack of systematic full water-depth measurements. To bridge this knowledge gap, we designed and conducted a multi-months field campaign, called the South China Sea Mesoscale Eddy Experiment (S-MEE), in the northern South China Sea in 2013/2014. The S-MEE for the first time captured full-depth 3D structures of an anticyclonic and cyclonic eddy pair, which are characterized by a distinct vertical tilt of their axes. By observing the eddy evolution at an upstream versus downstream location and conducting an eddy energy budget analysis, the authors further proposed that generation of submesoscale motions most likely constitutes the dominant dissipation mechanism for the observed eddies.

Wed-142

Ocean Forcing of the Atmosphere and Feedbacks on the Ocean: the Importance of Small Scale Ocean Features on Ocean/Atmosphere Exchanges of Momentum, Energy and Moisture

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It is well accepted that small spatial scale variability in the ocean surface variables can have relatively strong forcing on the atmosphere. We discuss several roles in which these small-scale upper-ocean features, particularly sea surface temperatures (SSTs) and currents, modify air/sea coupling in the form of ocean/atmosphere exchanges of momentum, energy and moisture and how these modify the ocean.

The influences of Sea Surface Temperature gradients on surface winds are modeled and used to examine changes in surface turbulent fluxes of momentum (stress), sensible heat and latent heat (energy and moisture). The changes in stresses are also used to examine changes in Ekman upwelling. While the changes in wind speed are roughly linear in proportion to the SST gradient and the wind speed at the top of the atmospheric boundary-layer, the corresponding changes in fluxes are non-linear. We find regional and seasonal differences in the above fluxes, with the greatest changes occurring in Winter and by the strongest SST gradients. Maps of seasonal averages show substantial biases in heat fluxes and substantial changes in Ekman upwelling. These analyses are based on observations and simply modeling.

We also apply a two-way coupled ocean-atmosphere modeling system is used to investigate the effects associated with air-sea interaction through the use of wind-current shear in the bulk formula. This study focuses on changes in the mean and the variability of the wind stress magnitude, the heat fluxes, the near surface temperature and the precipitation on meso-scale. The atmospheric and the ocean components of the coupled modeling system are the Weather Research and Forecasting Model (WRF) and the Regional Ocean Modeling System (ROMS) respectively. The ocean and the atmospheric models exchange data fields using the Model Coupling Toolkit (MCT). The ocean surface currents are passed to the atmospheric model for use in surface layer schemes to allow for the current to change the wind shear. The wind stress and heat fluxes computed by the WRF surface scheme are passed to the ocean model, which allows both models to use the same fluxes at the interface. The inclusion of the wind-current shear results in weaker surface stress over most of the Gulf of Mexico compared to the wind alone estimate. Changes are also being found in air-sea heat fluxes. The weekly averaged Latent Heat Flux (LHF) decreases by 1%~2% over most of the Gulf of Mexico by considering the currents effect, but localized LHF increases of ~10% are found in the Loop current. The sensible heat flux changes (> 5%) due to using the wind-current shear are found in the Loop Current as well as over the land. The air-sea heat fluxes associated with surface wind stress feedback onto the upper-ocean thermodynamics. The weekly mean SSTs increase over most of the Gulf of Mexico using the wind-current shear, and significant increases (>0.2 K) are found next to the Loop Current and ocean eddies. However, the SSTs slightly decrease (~0.05 K) in the Loop Current.

Wed-143

Deep-reaching mixing in the thermocline of the Pacific cold tongue inferred from Argo and TAO

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Vertical mixing is an important factor in determining the temperature, sharpness and depth of the equatorial Pacific thermocline, which are critical to the development of ENSO. The adjoint (4D-Var) synthesis GECCO (German Estimating the Circulation and Climate of the Ocean), which is aiming to optimize the mixing parameters (along with other model parameters) of an OGCM in order for the simulation to best match the observations, suggested enhanced mixing in the eastern tropical Pacific thermocline. Yet, the spatial pattern of the vertical mixing, its physical relation to the tropical ocean states, and its effects on the temperature structure at variable time scales are not well understood, relative to that nearer the surface. Based on Argo float and the Tropical-Ocean and Atmosphere (TAO) mooring measurements, we identified a large number of thermocline mixing events occurring down to the lower half of the thermocline and the lower core layer of the Equatorial Undercurrent (EUC), particularly in summer to winter, confirming the finding of GECCO. The deep-reaching mixing events occur more often and much deeper during periods with tropical instability waves (TIWs) than those without. The vertically varying diffusivity substantially impacts the upper ocean temperature structure: it tends to result in local cooling of the upper ocean, shoaling and weakening of the thermocline, and temperature change (either warming or cooling) in both the western and eastern equatorial Pacific via advection and propagation of planetary waves.

Wed-144

Detection of submesoscale disturbances by the Argo floats

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Submesoscale disturbances are ubiquitous in the ocean associated with strain field around fronts and mesoscale eddies according to previous studies mainly using high resolution simulations and numerical experiments. They probably play an important role in the vertical transport of dynamical and biogeochemical properties because of high vertical velocities associated with them (e.g. Perruche et al., 2008; Thomas et al., 2008; Sasaki and Klein, 2012). It is now an essential issue to clarify regional/basin-scale characteristics of submesoscale disturbances based on in-situ observations.

We focused on the high vertical wavenumber structures observed in profiling float data to describe characteristics of submesocale disturbances. This strategy is based on the three dimensional cascade theory by Klein et al. (1998), where not only the horizontal cascade but also vertical one was revealed in submesoscale phenomena. The high vertical wavenumber structure was defined as that having many sharp intrusions in a profile. Submesoslcae disturbances were detected in this way, and their spatial distribution was examined in relation to eddy/strain field in the Kuroshio/Oyashio and their extension region. The second derivative of spiciness with respect to potential density in a profile (diapycnal spiciness curvature), whose extrema were associated with peaks of intrusions (Shchrbina et al., 2009), and the number of sharp intrusions per one profile were calculated to define sharp intrusions and high vertical wavenumber structures, respectively. The dominance of eddy/strain field was evaluated by Okubo-Weiss parameter (Okubo, 1970; Weiss, 1991), which is a measure of the relative importance of deformation and rotation and is computed based on geostrophic flow field from satellite sea surface height data.

The distribution of high vertical wavenumber structures with respect to Okubo-Weiss parameter in three regions (around the Oyashio, north of the Kuroshio Extension and south of the Kuroshio Extension) showed that such structures are distributed asymmetrically and skewed toward strain field, indicating that the high wavebumber structures were observed in the strain-dominated field more frequently than the eddy-dominated field.

Since the thresholds to define sharp intrusion, high wavenumber structures and dominance of eddy/strain field can be arbitrary values, we investigated how the distribution of high vertical wavenumber structures depends on these thresholds with respect to Okubo-Weiss parameter. The distribution maps of Okubo-Weiss parameter mean and skewness in relation to variations in threshold of the diapycnal spiciness curvature and the number of sharp intrusions per one profile made it possible to evaluate responsiveness of the detection method. At large values of two thresholds, large positive mean values were found in all three regions and the mean vales are larger in north/south of the Kuroshio Extension than around the Oyashio. This result suggests that the structures having many especially sharp intrusions tend to be concentrated in the strain field and the tendency is remarkable in the region where the strain activitiy can be high. These results support the conclusion that submesoscale disturbances are found in the active strain field more frequently than the eddy one based on numerical simulations.

Wed-145

Surface wind wave induced entrainment at the base of the ocean surface boundary layer

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The ocean surface wind wave is one important physical process that affects the ocean surface vertical mixing, yet missing in most of the ocean general circulation models. This large eddy simulation (LES) based study focuses on assessing the effects of the surface wind waves, in particular the Langmuir turbulence, on the entrainment at the base of the ocean surface boundary layer (OSBL), which directly controls the deepening of the mixed layer and affects the exchange of heat, momentum and tracer gases between the atmosphere, the surface ocean, and the deep ocean. Preliminary results show that the entrainment rate at the base of the OSBL seems to scale with the surface layer averaged and projected Langmuir number. Modifications to the K-Profile Parameterization will be proposed based on the LES results and evaluated against the observation, which could then be directly implemented and tested in a global atmosphere-ocean-wave coupled model. The effects of the absorbed penetrating solar radiation will also be discussed.

Wed-146

Analysis of the southward wind shift of ENSO in CMIP5 models

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During the mature phase of El Niño-Southern Oscillation (ENSO) events, the anomalous zonal winds shift abruptly from symmetric about the equator to confined to the Southern Hemisphere. Previous studies have suggested that this meridional wind movement, tied to the seasonal cycle, plays a crucial role in the rapid termination of El Niño events, and hence in their seasonal synchronization. Considering that many state-of-the-art coupled climate models underestimate this tendency to peak near the end of the calendar year, while some fail to produce it altogether, we examine here the representation of this southward wind shift (SWS) in phase 5 of the Coupled Model Intercomparison Project (CMIP5). It is found that most models successfully reproduce the observed SWS – although the magnitude of the zonal wind stress is underestimated. Westward biases and weaker magnitudes in both sea surface temperature (SST) and precipitation anomalies during ENSO events are more pronounced in models with poor simulation of the SWS. It is also demonstrated that these models overall exhibit excessive precipitation over the Intertropical Convergence Zone and warmer SST in that region compared to models with better performance in simulating the SWS. By multiple linear regressions, it is suggested that the main mechanism of the SWS is the ENSO-driven convective activity over the northwestern Pacific in DJF. Further, it is revealed that a correctly simulated SWS leads to strong El Niño events and, to a lesser extent, La Niña peaking at around the same time as observed, resulting in a more abrupt termination. This is in sharp contrast to moderate El Niño events, where the simulated SWS has little impact on the timing of event termination.

Wed-147

Wind-Evaporation-SST interactions and the Atlantic Meridional Mode: an observational analysis with CMIP5 comparisons

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The Atlantic Meridional Mode (AMM) is an important mode of tropical SST/wind coupled variability that influences the position of the Intertropical Convergence Zone, the frequency of Atlantic hurricanes, and the distribution of nearby regional precipitation patterns. Numerous modeling studies have implicated wind-evaporation-SST (WES) feedback as the primary driver of the AMM's evolution across the Atlantic basin, but a clear and robust coupling of the SST and winds has not been shown observationally. This study aims to provide an observational basis for AMM growth, propagation, and decay by way of WES interactions. Investigation of an extended maximum covariance analysis shows that boreal wintertime atmospheric forcing generates initial positive SST anomalies off the west coast of Africa through a reduction in evaporation cooling at the surface and a flux of latent heat into the ocean. When the AMM peaks in spring and summer, upward latent heat flux anomalies occur over the warmest SSTs, where anomalous rising air removes heat from the boundary layer and acts to dampen the initial forcing. However, on the southwestward edge of the SST anomalies strong, SST-forced cross-equatorial flow turns southwesterly in the northern hemisphere. This coupled interaction reduces the strength of the climatological trade winds in the region, providing a flux of latent heat into the ocean and propagating the initial atmosphere-forced SST anomalies southwestward through WES dynamics. Additionally, we investigate the lead-lag relationship of the ocean and atmosphere with special attention paid to structural symmetry. Through this, we observe a transition from "atmosphere forcing ocean" in the subtropics to a highly coupled regime consistent with WES feedback in the tropics. A comparison with CMIP5 shows that the models poorly simulate this latitudinal transition from a one-way interaction to a two-way feedback, which may help explain why the models struggle to accurately reproduce coupled interactions between SST and winds in the tropical Atlantic.

Wed-148

The PIRATA South-West Extension: First 10-Year Observations (2005-2015)

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The Prediction and Research Moored Array in the Tropical Atlantic - Southwestern Extension (PIRATA-SWE) scientific rational, array design, implementation arrangements, and samples of the first 10-year (2005-2015) real-time data collected are presented. The high ratio of daily real-time data return (and delayed mode high frequency data time series) allow the robustness and uniqueness of the array regarding long term oceanic monitoring and science quality database over the region. Both the near real-time and free universal access to the observed PIRATA-SWE time series also constitute a breakthrough in ocean observational practices over the region, first introduced by the Tropical Atmosphere Ocean (TAO) array in the tropical Pacific in the 1980's and latter extended by the PIRATA backbone array over the tropical Atlantic in the last years of the previous century. The inspection of the first 10-year available PIRATA-SWE meteo-oceanic data, along with comparisons with outputs of ocean circulation models, indicates local variations in the ocean-atmosphere interaction, as well as an important ocean eddy activity in the region. We provide a set of selected illustrations of the first 10-year of observations, enhanced with numerical comparisons and key examples of environmental and societal impacts of this first phase of PIRATA-SWE.

Wed-149

The Simulated Enso Variability By Applying Supermodelling To The Kiel Climate Model

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Super modelling by combining imperfect model (SUMO) has huge potential for improving the quality of current climate simulation and prediction, and SUMO approach has been applied to improve the simulation of Tropical Pacific in ECHAM-MPIOM coupled model. In order to confirm the SUMO method we apply it in Kiel Climate Model (KCM). The results indicate that the mean states of the Sea Surface Temperature (SST) and precipitation have been dramatically improved. The annual cycle in the eastern equatorial Pacific has more similarity to the observations. Meanwhile, the signal of Nino3.4 index becomes stronger.

Wed-150

Tracing the Sinking of Dense Ocean Waters in the North Atlantic Ocean

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In this study, we investigate the sinking of dense water masses in the North Atlantic. Therefore, we use data from an eddy permitting (0.1 degree) ocean model of the Parallel Ocean Program (POP). Velocity fields of the model are used to advect Lagrangian floats with the Connectivity Modelling System (CMS). Model and float data are used to identify regions where water masses sink into the deep ocean. Theoretical considerations predict that water masses can only sink if the geostrophic balance is broken. We identify mechanisms that are responsible for the ageostrophic dynamics and compare our findings with frequently discussed theories. Especially, we focus on the vertical vorticity balance of the boundary currents.

Since eddies seem to play a dominant role for the deep water sinking, it is questionable to which extent coarser resolved ocean models that do not resolve the eddies are able to capture the deep water sinking. Especially, we aim to clarify if the sinking in a coarser resolved counterpart of the POP ocean model (1 degree) is due to different mechanisms compared to its eddy permitting (0.1 degree) counterpart. By this, we aim at understanding how the deep sinking of water masses as one part of the Meridional Overturning Circulation is represented in typically coarser resolved climate models and how realistic these processes are represented in comparison to higher resolved ocean models.

Wed-151

Teleconnections from land surface anomalies affect SSTs: Two distinct examples

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Two recent coupled modeling studies have shown that variations in the state of the land surface may have systematic impacts on ocean variability. First, a revisit of the classic Amazon deforestation study with a modern coupled Earth system model (CESM) suggests that large-scale land use change in the tropics would affect ENSO variability, with asymmetrical impacts of the El Niño and La Niña phases of the phenomenon. Furthermore, the degree and location (spatial distribution) of the deforestation in South America generates different responses in SST. Second, retrospective seasonal forecasts with an operational climate forecast model (CFS) suggest that soil moisture drift/errors significantly affect SST evolution in certain regions of the globe though their effects on atmospheric circulation. Even the initialization of soil moisture has tangible impacts on SST. These intriguing results suggest this under-investigated linkage from the surface states of the continents back to the oceans via atmospheric dynamics should be further investigated for its impact on climate variability and predictability.

Wed-152

Decadal changes in Indian Ocean sea surface temperature trends during the recent global warming hiatus

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Sea surface temperatures (SSTs) have been rising for decades in the Indian Ocean in response to greenhouse gas forcing. However, in this study we show that during the recent hiatus in global warming, a striking hemispheric gradient in Indian Ocean SST trends developed, with relatively weak or little warming in the northern Indian Ocean north of 10S and accelerated warming in the southern Indian Ocean south of 10S. We present evidence from a wide variety of data sources that this hemispheric gradient in SST trends is forced by a combination of Indonesian Throughflow (ITF) transport from the Pacific and wind stress changes associated with the Indo-Pacific Walker circulation. The enhanced Walker circulation forces increased ITF transport that flows into the Indian Ocean south of 10S, depressing the thermocline to facilitate warming SST through weakening vertical mixing. Furthermore, surface wind changes in the Indian Ocean associated with the enhanced Walker circulation contribute to the observed hemispheric gradient. In particular, downwelling favorable wind stress curl south of 10S deepens the thermocline locally, adding to the thermocline deepening caused by the ITF, while upwelling favorable negative wind stress curl occurs in the thermocline ridge region between the equator and 10S to facilitate SST cooling there. In addition, the anomalous southwesterly wind stresses off the coast of Somalia intensify coastal upwelling and off-shore advection of upwelled water, leading to reduced warming of the northern Indian Ocean. More loss of latent heat from the ocean also favors the relative cooling of SST north of 10S.

Wed-153

The footprint of the inter-decadal Pacific oscillation in Indian Ocean sea surface temperatures

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Superimposed on a pronounced warming trend, the Indian Ocean (IO) sea surface temperatures (SSTs) also show considerable decadal variations that can cause regional climate oscillations around the IO. However, the mechanisms of the IO decadal variability remain unclear. Here we perform numerical experiments using a state-of-the-art, fully coupled climate model in which the external forcings with or without the observed SSTs in the tropical eastern Pacific Ocean (TEP) are applied for 18712012. Both the observed timing and magnitude of the IO decadal variations are well reproduced in those experiments with the TEP SSTs prescribed to observations. Although the external forcings account for most of the warming trend, the decadal variability in IO SSTs is dominated by internal variability that is induced by the TEP SSTs, especially the Inter-decadal Pacific Oscillation (IPO). The IPO weakens (enhances) the warming of the external forcings by about 50% over the IO during IPO's cold (warm) phase, which contributes about 10% to the recent global warming hiatus since 1999. The decadal variability in IO SSTs is modulated by the IPO-induced atmospheric adjustment through changing surface heat fluxes, sea surface height and thermocline depth.

Wed-154

Correcting the North Atlantic cold bias with application to the Kiel Climate Model

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The North Atlantic cold sea surface temperature (SST) bias, associated with a too zonal path of the North Atlantic Current and a missing “northwest corner”, is a common problem in climate models. It affects simulation of North Atlantic sector mean climate, its variability and potentially predictability. The cold SST bias is associated among others with reversed surface heat fluxes and misplaced ocean convection sites which are simulated too far south and east .

We have implemented a flow field correction in the Kiel Climate Model (KCM) to adjust the path of the North Atlantic Current. . The flow field correction consists of three steps. First, climatological potential temperature (T) and salinity (S) fields for use with the model are produced using a three-dimensional restoring technique. Second, these climatological T, S fields are used to modify the momentum equations of the ocean model. In the third stage, the correction terms are diagnosed to construct a flow-independent correction. The flow field correction can be regarded as a way to correct for model error, e.g. associated with deep water pathways and their impact on ocean circulation, and unresolved processes such as eddy momentum flux convergence. Since the correction is applied only to the momentum equation, there is no interference with the budgets of heat and freshwater.

The flow field correction improves the KCM’s mean state and internal variability. It successfully re-establishes a northward flow into the northwest corner, largely eliminating the subsurface temperature bias within the upper several hundred metres of the water column. A remaining surface cold bias can be eliminated by additionally correcting the surface freshwater flux seen by the the ocean model. Sea ice and convection occurs in more realistic positions in the corrected model version, connected to a more northward extension of the Atlantic Meridional Overturning Circulation (AMOC). Also, the SST variability patterns on interannual and multi-decadal time scales (Atlantic Multi-decadal Variability, AMV), are improved. In our model, which lacks interannually varying radiative forcing, the AMV is strongly linked to the AMOC. This relation and the amplitude of the AMV are enhanced in the corrected model version. A model version, in which only the surface fluxes of heat and freshwater are corrected, continues to exhibit the incorrect path of the North Atlantic Current and a strong subsurface temperature bias, stressing the importance of the flow field correction in the northwest corner region.

Wed-155

The Indian Ocean as a Connector

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The Indian Ocean is a conduit for the upper ocean flow of the global thermohaline circulation. It receives water from the Pacific Ocean through the Indonesian throughflow and the Tasman leakage, and exports water into the Atlantic by means of Agulhas leakage. A small contribution from the northern Indian Ocean is also detectable within Agulhas leakage. Changes on different timescales in the various components of the Pacific inflows and the Atlantic outflow have been reported. Little is known on the role of the Indian Ocean circulation in communicating changes from the Pacific into the Atlantic, let alone any eventual alterations in response to climate change. The precise routes and timescales of Indonesian throughflow, Tasman leakage, Red Sea and Persian Gulf Waters towards the Atlantic are examined in a Lagrangian framework within a high-resolution global ocean model. In this presentation, the following questions are addressed: How are Pacific waters modified in the Indian Ocean before reaching the Agulhas system? On what timescale is water that enters the Indian Ocean from the Pacific flushed out? How important are detours in the Bay of Bengal and Arabian Sea?

Wed-159

The Nonlinear Variations of global chlorophyll

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We detected the nonlinear trend of global chlorophyll a observed from MODIS based on EMD method. And we discussed its response mechanisms of dominating factors. The results showed that chlorophyll a displayed a significant nonlinear increase trend, with its rising rate being rise first and then fall in western pacific warm pool. In the pacific equatorial divergence region, the chlorophyll a manifest a pronounced nonlinear decrease trend, with the decline rate being accelerated first and then decelerate. Both not present the reverse phase relationship with SST. All the results indicate that the correlation between both trend component of SST and chlorophyll a still need to be further confirmed. And the effect of global warming resulted in human activity on chlorophyll a also remains a further probe.

Wed-160

The vertical structure of the Eastern Pacific ITCZs and associated circulation using the TRMM Precipitation Radar and in situ data

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The Intertropical Convergence Zone (ITCZ) is key component of the eastern Pacific ocean-atmosphere system and its variability, on seasonal to inter-annual and longer time scales. This feature is generally misrepresented in climate models, which show an excessively strong branch south of the equator, yet basic information on its vertical structure is lacking.

Most methods for estimating the vertical structure of the rate of latent heating rely on profiles from field campaigns in other regions combined with convective/stratiform fractions from the TRMM satellite. In this study we use the radar precipitation profiles from the TRMM precipitation radar (PR) and an to the liquid water and energy budget equations to estimate the vertical profiles of latent heating in the far-eastern Pacific (95°W-85°W) ITCZs in the 800-730 hPa layer for the period 1998-2010. We combined this with EPIC2001 and other in situ data to produce a preliminary characterization of the meridional-vertical circulation.

We found evidence of a double-cell structure in boreal fall between the ITCZ and the equator, with both shallow and upper-level peaks in vertical velocity. In spring, the flow poleward of the two ITCZs has a single-cell structure, although around the equator it shows some hints of the double-cells. Reanalysis and satellite-based data are shown to be unreliable for describing the vertical structure of the circulation.

Wed-161

Effects of random wave on Stokes drift for coupled ocean-wave modeling

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Introduction There are many studies considering effects of Stokes drift on upper ocean current system. Effects of random wave have been discussed recently but few study conducted to consider the random wave effects in depth-limited region. This study develops the coupled ocean-wave model to carry out the calculation of regional ocean environments on a 500m horizontal resolution considering wave-induced transport on random waves incorporating the effect of Stokes drift into the model. Two re-analysis calculations are performed, one considering the Stokes drift on random wave and the other not, for Tanabe Bay in Wakayama as a verification of the model precision to compare with the field observation data. 2 Formulation of Stokes drift on random waves There is large interaction effect between currents and surface gravity waves in finite depth area such as in the coastal ocean. Wave-induced transport, a quantity known as Stokes drift, on random waves is formulated to insert in the model. The Stokes drift can be represented with the two-dimensional energy spectrum. It can be approximated as the two-dimensional Gaussian spectrum whose parameters, frequency variance (&omega) and directional variance (), can be exchanged with Mitsuyasu-type directional spread parameter, S and the Godas spectral bandwidth, Q p respectively in the coupled model. That makes it possible to make the calculation cost reduced because the exchange between ocean-wave model need only two parameters. 3 Results Two runs are carried out for simple topography to confirm the effect of Stokes Drift on random waves. One (referred to as Wave2d) uses the model in which wave-induced transport is provided by random waves and the other (referred to as Wave1d) uses a model in which it is provided by regular wave. The topography has a single slit on middle of itself. In comparison with Wave1d, in Wave2d Stokes Drift velocity on the large directional range is verified around the slit. Three runs are performed by horizontal resolution 500m and 20 vertical layers for Tanabe Bay in Wakayama prefecture. The additional run is carried out using only the Ocean model, i.e. not considering the effect of wave-current interaction. According to the comparison in velocity between these three results and observation data in, a correlation is observed between Wave2d and observation data.

Wed-162

Physical processes on the changes in air-sea interactions in the western tropical Pacific during boreal summer

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It is found that the correlation of sea surface temperature (SST)-precipitation in the western tropical Pacific has been changed from a negative to a positive across the late-1990s during boreal summer. Before the late-1990s, the anomalous warm SST in the central-to-eastern tropical Pacific can induce anomalous precipitation with an enhanced Deep Convective Cloud (DCC) as well as a low-level moisture convergence in the western-to-central tropical Pacific. Subsequently, an enhanced cloudiness as well as an upwelling leads to the anomalous cold SST in the western tropical Pacific, which cause a negative correlation of SST-precipitation. After the late-1990s, in contrast, the intensity of anomalous warm SST in the central-to-eastern tropical Pacific is weak. Consequently, an anomalous precipitation with DCC is also weak in the western-to-central tropical Pacific. It would not act effectively to reduce an incoming solar radiation as well as mean upwelling of subsurface cold temperature, leading to a positive correlation of SST-Precipitation in the western tropical Pacific.

Wed-163

The effect of Ekman transport on the Hadley circulation response to extratropical thermal forcing

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In recent years, there has been significant progress in theories for understanding how extratropical thermal forcing can cause meridional shifts of the Hadley circulation based on the atmospheric energy budget. However, theoretical studies are mostly based on idealized experiments that employ atmospheric models coupled to slab ocean where ocean dynamics are excluded. Recent studies showed that changes in oceanic circulations can oppose the inter-hemispheric difference in energy input in the atmosphere and complicate the tropical response. Thus, in this study, we implement the meridional Ekman transport to the slab ocean model to investigate its role in determining the tropical response to extratropical thermal forcing.The GFDL Atmospheric Model (AM2) is coupled with 50m aquaplanet slab ocean model. To perturb the tropics from the extratropics, heating beneath the slab (Q-flux) is extracted from the Southern extratropics and is injected to the Northern extratropics. The magnitude of the imposed cross-equatorial transport is varied from 1.2 PW to 4.5 PW. All experiments are performed with and without the meridional Ekman transport, but neglecting the upwelling effect. In the case with no ocean dynamics, the prescribed northward ocean transport can only be balanced by atmospheric dynamics and radiative fluxes. With larger degree of compensation by atmospheric dynamics, the Hadley circulation is shifted more to the north. As the Hadley circulation is shifted northward, the heating due to Ekman transport in the southern tropics becomes larger as both the meridional temperature gradient and easterlies get stronger. The Ekman heating increases the convective mass flux, which contributes to enhancing the formation of low level clouds that reflects the top-of-atmosphere radiation. Thus, the inclusion of Ekman transport accompanies two opposing effects: the relative heating (cooling) in the southern (northern) tropics that contributes to compensating the imposed Q-flux, and the induced cloud changes that act to counteract the compensation. The competition between the Ekman heating and cloud radiative forcing will determine whether the Ekman transport opposes or strengthens the inter-hemispheric difference in energy input in atmosphere, in which case the Hadley circulation response will be smaller or larger, compared to the climate with no Ekman transport. Our idealized model result indicates that the relative importance depends on the magnitude of the imposed cross-equatorial flux. In the case with the forcing less than 2PW, the Ekman transport contributes to compensating the imposed Q-flux by 30%, and the reverse applies to the stronger forcing cases. Equivalent simulations are run with an idealized general circulation model with no cloud radiative feedback. In contrast to AM2, an inclusion of Ekman transport decreases the atmospheric compensation and induces a weaker anomalous Hadley circulation, regardless of the amplitude of Q-flux. Our results indicate that the effect of ocean dynamics on the extratropics-to-tropics interaction will depend on the cloud radiative feedback.

Wed-165

A redesigned observing system for the tropical Pacific: the TPOS 2020 project

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The Tropical Pacific Observing System (TPOS) 2020 project is an international, limited-term effort to rethink and rebuild the TPOS. Triggered by the deterioration of the TAO mooring array in 2012-2014, the project now seeks to find opportunity in that crisis. New science issues have come to the fore, and observational technology - both satellite and in situ - has greatly advanced since the TOGA-era arrays were designed, making a redesign timely. While ENSO remains a primary emphasis, the targets have broadened to include a focus on the ocean mixed layer and the surface fluxes that interact with it, which requires resolving the diurnal cycle, as well as biogeochemistry, especially the large carbon signal of the tropical Pacific.

We have released a draft of our Interim Report, laying out the rationale and plans for the first step of the redesign. The plan refocuses the tropical moored arrays (TMA; including the TAO and TRITON arrays) on the targets where moored observations have particular and needed advantages: high-frequency sampling in the near-surface ocean and the ability to make co-located ocean, surface meteorology and flux measurements. Moorings continue to be needed near the equator, and we will expand moored velocity observations to span the equatorial undercurrent at several longitudes. We will extend a few mooring lines farther north and south than the present TAO/TRITON array to cross the ITCZ and SPCZ. However, Argo will increasingly supplant moored subsurface temperature and salinity measurements where the fast sampling capabilities of moorings have been little used. We propose to double coverage by Argo in the 10S-10N region. Satellite measurements: SST, vector wind, sea surface height, surface salinity, and precipitation, will be fully integrated with the in situ sampling, to take advantage of the consistent spatial mapping on small scales possible only from satellites. However, careful account is taken of the need of the various satellite sensors for in situ calibration and referencing between satellite missions. This is especially true for winds under strong rain conditions.

There is risk associated with giving up some mapping capabilities that have been done largely from the present grid-like mooring array, particularly for the near-surface ocean and surface meteorology. We will lose some capability to map quantities like humidity, surface air temperature and pressure from in situ measurements, and there is always risk of failure or disabling of satellite sensors (as occurred with the eruption of El Chichón before the 1982-83 El Niño, contributing to the inability to see that event in real time). We therefore have designed the combination of moorings, Argo and satellites for resilience and redundancy, consistent with reasonable cost.

Finally, our design recognizes that today is a fertile period for autonomous ocean samplers, and will invest in such new technology that may, over the next decade, reduce the need for expensive research vessel time.

Autonomous vehicles also have promise of making possible routine sampling of boundary currents that has been very difficult to accomplish with present technology.

Wed-166

Atmospheric conditions associated with Labrador Sea deep convection

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Deep water formation in the Labrador Sea is thought to result largely from surface heat losses during a positive North Atlantic Oscillation (NAO) phase. As the leading mode of the atmospheric variability in the North Atlantic, the NAO modulates the westerlies in the subpolar North Atlantic and thus carries more cold and dry air from North America into the Labrador Sea in its positive phase. In this presentation, by analyzing reanalysis data and numerical simulations, we show that deep water formation in the Labrador Sea can also be caused by atmospheric conditions centered in the western North Atlantic, which is distinct from the canonical NAO pattern centered in the eastern part of the basin. These atmospheric conditions appear to be associated with a La Niña state in the tropical Pacific through atmospheric teleconnection. A resultant high pressure anomaly is positioned in the western North Atlantic in a way that can efficiently bring an anomalous cold air over the northern North America into the Labrador Sea, which itself is a remote response to La Niña, inducing strong heat release in the Labrador Sea.

Wed-167

Mechanisms underlying annual sss variability in satellite-retrieved salinity fields in the indian ocean

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This study presents the analyses of space-borne salinity data in the Indian Ocean during the period 2010-2014 provided by the European Space Agencys (ESA) "Soil Moisture and Ocean Salinity" (SMOS) and the National Aeronautical Space Agencys (NASA) "Aquarius/SAC-D" missions. The study specifically investigates the annual variability of SSS in the Indian Ocean, which is the dominant mode of variability during the 5-year period and accounts for more than 50% of salinity variance.Through a combined analysis of the satellite data together with ARGO float upper level data various forcing terms of the seasonal salinity cycle are examined, including key processes such as surface external forces (SEF), horizontal Ekman and geostrophic advection (ADV) and subsurface influences (SUB).It is found that surface external forces control salinity tendency of the annual cycle south of the equator between 60E and 75E with a time lag of 2-3 month. Here, SEF accounts to approximately 40% of seasonal variance of salinity tendency. In contrast, advection is the dominant contribution in the northern and equatorial Indian Ocean with a time lag of 1 month. The influence of vertical processes on the salinity tendency is enhanced in coastal upwelling regions. In general, previous results from Lisan Yu (2011) can be reproduced however, different time lags are found. From a combined EOF analysis of the salinity fields after substracting the annual and semiannual cycle as well as precipitation and evaporation for the 60 month period from January 2010 to December 2014 we find that the first EOF mode explaines more than 20% of salinity variance and reveals a coherent pattern of SSS and net freshwater flux variations associated with the IOD. The first principal component of SSS EOF is highly correlated with the Indian Ocean Dipole Mode Index. Nevertheless the EOF pattern shows a meridional tripole structure, while the IOD is characterized by a zonal SST dipole (e.g. Saji et al [1999] Deser et al. [2009]).The study of the salinity budget are supported by the results of a high resolution model.

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Eddy Fluxes and Jet-Scale Overturning Circulations in the Indo-Western Pacific Southern Ocean

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The relationship between the Antarctic Circumpolar Current jets and eddy fluxes in the Indo-western Pacific Southern Ocean (90°E-145°E) is investigated using an eddy-resolving model. In this region, transient eddy momentum flux convergence occurs at the latitude of the primary jet core, whereas eddy buoyancy flux is located over a broader region that encompasses the jet and the poleward inter-jet minimum. In a small sector (125°E-145°E) where jets are especially zonal, a spatial and temporal decomposition of the eddy fluxes further reveals that fast eddies act to accelerate the jet with the maximum eddy momentum flux convergence at the jet center, and slow eddies tend to decelerate the zonal current at the inter-jet minimum. An Eliassen-Palm (EP) cross-section reveals that the momentum contribution to the EP flux accelerates the jets all model depths, whereas the buoyancy contribution mainly affects the jets above a depth of 1-km.

In ocean sectors where the jets are relatively well defined, there exist jet-scale overturning circulations with sinking motion on the equatorward flank, and rising motion on the poleward flank of the jets. These jet-scale overturning circulations, which are also discernible in potential density coordinates, cannot be attributed to Ekman downwelling, because the Ekman vertical velocities are much weaker and their meridional structure shares little resemblance to the rapidly varying jet-scale overturning pattern. Instead, the location and structure of these thermally indirect circulations suggest that they are driven by the eddy momentum flux convergence, much like the Ferrel cell in the atmosphere.

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Geothermal Heat Flux and its Influence on the Oceanic Circulation and Climate

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Geothermal heat flux is rarely regarded as a significant driver of the large-scale oceanic circulation.It adds only a very small contribution (global mean 88mW/m**2) to the oceanic energy budget compared with sea surface heat fluxes(order of 100W/m**2). Numerical experiments with the Community Earth System Model (CESM) suggest, however, that the impact of geothermal heat flux on ocean circulation and climate is not negligible. Oceanic geothermal heating can cause bottom waters several tenths of a degree warmer and help maintain a vigorous abyssal circulation. Futhermore, the oceans and atmosphere are tightly linked, so geothermal heating can indirectly influence the atmosphere by increasing the available potential energy of the ocean and partly fueling the Meridional Overtruing circulation.

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Current Warming Hiatus tied to a Deeper Thermocline beneath the 'Warming Pool'

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Various climate observation datasets show that the rising global-mean surface temperature has stalled during recent decade. However, estimates of radiative imbalance at the top of Atmosphere is positive, which seems to be contradictory to current 'Hiatus'. So, why do we experience GMST hiatus while Earth is absorbing more heat? We suggests that the Pacific surface's cooling leads GMST to get stalled temporarily. According to analysis on Ocean Heat content, heat has moved from upper to the deeper ocean. Our study points out that a deeper thermocline beneath the western tropical Pacific and tropical Indian Ocean, or the 'warming pool', accounts for this ocean heat redistribution. During the 'Hiatus', the wind on the tropical Pacific and Indian Ocean is strengthening, which may have association with a strong La Niña started in 1998. We may expect a cooler SST hereafter, as well as a much deeper thermocline beneath the 'warming pool'. This thermocline variability guarantees the 'warming pool' more capacity to carry heat, which also allows extra heat to come into the deep ocean. And when the wind pattern is broken because of a strong El Niño event, we may have to confront with a world, much warmer than normal.

Wed-175

Intermodel variations in projected precipitation change over the North Atlantic: Sea surface temperature effect

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Intermodel variations in future precipitation projection in the North Atlantic are studied using 23 state-of-art models from Phase 5 of the Coupled Model Intercomparison Project. Model uncertainty in annual mean rainfall change is locally enhanced along the Gulf Stream. The moisture budget analysis reveals that much of the model uncertainty in rainfall change can be traced back to the discrepancies in surface evaporation change and transient eddy effect among models. Results of the intermodel Singular Value Decomposition (SVD) analysis show that intermodel variations in local sea surface temperature (SST) pattern exert a strong control over the spread of rainfall projection among models through the modulation of evaporation change. Indeed, local SST effects of sea-air humidity gradient and surface wind speed reinforce each other on evaporation changes in west boundary current regions. The first three SVD modes explain more than 60% of the intermodel variance of rainfall projection and show distinct SST patterns with mode water-induced banded structures, reduced subpolar warming due to ocean dynamical cooling, and the Gulf Stream shift, respectively. Moreover, much of the annual-mean intermodel spread in precipitation change develops in the boreal winter when the effect of the intermodel variations in SST change is strongest, illustrating the importance of improving simulations of local SST change.

Wed-176

Role of observed Pacific trade wind trends in the recent hiatus and future projections

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Over the last two decades a slowdown (or 'hiatus') in surface warming has occurred that has been the subject of considerable scientific and public debate. Here we investigate the role of the observed trade wind intensification associated with the current negative phase of the Interdecadal Pacific Oscillation (IPO) in driving the recent hiatus. We use a high-resolution global ocean model forced with observed wind and surface flux trends over different regions. In the main experiment all surface fluxes trend as observed in the Pacific region (1992-2011), while the rest of the globe is forced with CORE normal year surface fluxes. Two additional experiments are run, first with only observed wind speed trends superimposed, to isolate changes associated with winds alone. The second imposes observed surface flux trends globally to identify contributions to the hiatus from outside the Pacific.

The intensification of the tropical Pacific trade winds are sufficient to drive part of the observed surface cooling, the majority of the upper 100-500m Pacific Ocean response and all of the 100-500m Indian Ocean response. While we find a decrease in eastern Pacific Ocean heat content (OHC) over these experiments, there is a marked increase in western Pacific, Indian Ocean and importantly total Pacific heat content. Overall there is an increase in surface heat flux into the ocean, which causes an increase in the sub-surface Indo-Pacific heat content, while the surface (top 100m) of the ocean cools. These changes are associated with a strengthening of the Equatorial Undercurrent, which brings cooler water to the surface of the eastern Pacific, an increase in the subtropical overturning cells, which drive heat into the subsurface western Pacific and an increase in the strength and heat transport in the Indonesian throughflow, which moves heat from the western Pacific to the Indian Ocean.

Further experiments impose a symmetric reversal of the surface fluxes over the following 20-year period (2012-2031) to examine how the ocean would behave if the winds revert to their initial state. While the wind forcing decrease is symmetrical to the original increase it does not correspond to an exactly symmetric decrease in the surface fluxes as these are also affected by the sea surface temperature in this region. The wind reversal leads to an increase in both Indian and total Pacific OHC as compared to the beginning of the experiment in 1992, showing that there is a net accumulation of heat even after the winds return to their unperturbed state.

Wed-177

Causes of the regional variability in observed sea level, sea surface temperature and ocean colour

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We analyse the regional variability in observed sea surface height (SSH), sea surface temperature (SST) and ocean colour (OC) from the ESA Climate Change Initiative (CCI) datasets at interannual to decadal time scales. The analysis focuses on the signature of the ocean large-scale climate fluctuations driven by the atmospheric forcing and do not address the mesoscale variability. We use the ECCO version 4 ocean reanalysis to unravel the role of ocean transport and surface buoyancy fluxes in the observed SSH, SST and OC variability. We show that the SSH regional variability is dominated by the steric effect (except at high latitude) and is mainly shaped by ocean heat transport divergences with some contributions from the surface heat fluxes forcing that can be significant regionally (confirming earlier results). This is in contrast with the SST regional variability, which is the result of the compensation of surface heat fluxes by ocean heat transport in the mixed layer and arises from small departures around this background balance. Bringing together the results of SSH and SST analyses, we show that SSH and SST bear some common variability. This is because both SSH and SST variability show significant contributions from the surface heat fluxes forcing. It is evidenced by the high correlation between SST and buoyancy forced SSH almost everywhere in the ocean except at high latitude. OC, which is determined by phytoplankton biomass, is governed by the availability of light and nutrients that essentially depend on climate fluctuations. For this reason OC show significant correlation with SST and SSH. We show that the correlation with SST display the same pattern as the correlation with SSH with a negative correlation in the tropics and subtropics and a positive correlation at high latitude. We discuss the reasons for this pattern.

Wed-178

Inter-basin influence of the Indian Ocean on the Pacific decadal climate change

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We demonstrate significant impacts of the Indian Ocean on the Pacific climate on decadal timescales by comparing two sets of ensembles of data assimilation experiments (so-called pacemaker experiments) over recent decades. Only in the Indian Ocean of an atmosphere–ocean coupled global climate model, we assimilate ocean temperature and salinity anomalies defined as either deviations from climatology or those with subtraction of the area-averaged changes of the Indian Ocean. When the decadal sea surface temperature (SST) trend is observed to be strong over the Indian Ocean, the equatorial thermocline is uniformly deepening and the model simulates the eastward tendency of the surface wind aloft. The surface wind strongly converges around the maritime continent and the associated strengthening of the Walker circulation works to suppress an increasing trend of the equatorial Pacific SST through the ocean thermocline shoaling, similar to the common changes associated with the seasonal Indian Ocean warming.

Wed-179

Sea Ice Retreat and its Impact on the Intensity of Open-Ocean Convection in the Greenland and Iceland Seas

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The air-sea transfer of heat and freshwater plays a critical role in the global climate system. This is particularly true for the Greenland and Iceland Seas, where these fluxes drive ocean convection that contributes to Denmark Strait Overflow Water, the densest component of the lower limb of the Atlantic Meridional Overturning Circulation (AMOC). This buoyancy transfer is most pronounced during the winter downstream of the ice edge, where the cold and dry Arctic air first comes in contact with the relatively warm ocean surface. Here we show that the wintertime retreat of sea ice in the region, combined with different rates of warming for the atmosphere and sea surface of the Greenland and Iceland Seas, has resulted in statistically significant reductions of approximately 20% in the magnitude of the winter air-sea heat fluxes since 1979. Furthermore, it is demonstrated that modes of climate variability other than the North Atlantic Oscillation (NAO) are required to fully characterize the regional air-sea interaction in this region. Mixed-layer model simulations imply that a continued decrease in atmospheric forcing will exceed a threshold for the Greenland Sea whereby convection will become depth limited, reducing the ventilation of mid-depth waters in the Nordic Seas. In the Iceland Sea, further reductions have the potential to decrease the supply of the densest overflow waters to the AMOC.

Wed-180

SST anomalies drive increasing tropospheric ozone over the tropical central Pacific: role of potential vorticity intrusions

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Drawn from multiple reanalysis datasets, an increasing trend and westward shift in the number of Potential Vorticity intrusion events or Rossby wave breaking events over the Pacific are evident. The increased frequency can be linked to a long-term trend in upper tropospheric equatorial westerly wind and subtropical jets during boreal winter to spring. These may be resulting from anomalous warming and cooling over the western Pacific warm pool and the tropical eastern Pacific, respectively. Zonal variation in SST, characterized by gradual warming in the western Pacificwarm pool and cooling in the centraleastern Pacific, is associated with the strengthening of the Pacific Walker circulation. In the Western Pacific enhanced convective activity leads to precipitation, and the latent heat released in the process strengthens the Pacific Walker circulation and hence the equatorial westerly duct. It is linked with the trend in global mean temperature, which is related to the emerging anthropogenic greenhouse signal and negative phase of PDO. On the other hand, the central-eastern Pacific cooling trend is linked to the weakening of the centraleastern Pacific Hadley circulation. It suppresses the convective activity due to sinking air motion and imports less angular momentum to the STJ leading to a weakened STJ. The intrusions brought dry and ozone rich air of stratospheric origin deep into the tropics. In the tropical upper troposphere, interannual ozone variability is mainly related to convection associated with El Nio/Southern Oscillation. Zonal mean stratospheric overturning circulation organizes the transport of ozone rich air poleward and downward to the high and midlatitudes leading there to higher ozone concentration. In addition to these well described mechanisms, we observe a long-term increasing trend in ozone flux over the northern hemispheric outer tropical (1025N) central Pacific that results from equatorward transport and downward mixing from the midlatitude upper troposphere and lower stratosphere during PV intrusions. We observe an increasing decadal trend (2 to 3 DU/decade) over the outer tropical central Pacific and a decreasing trend (-9 to -10 DU/decade) over the midlatitudes (3045N) in TOMS data. This increase in tropospheric ozone flux over the Pacific Ocean may affect the radiative processes and changes the budget of atmospheric hydroxyl radicals.

Wed-181

Interannual variability of the subtropical mode water in the South Atlantic

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Similar to other basins, the western boundary region of the South Atlantic subropical gyre exhibits a subtropical mode water (SASTMW), just northeast of the Brazil-Malvinas confluence. It manifests as a sustained layer of homogeneous volume of water where the net cumulative heat balance through the surface over time is negative. The distinct presence of SASTMW is verified either when it is trapped between the seasonal and the main thermocline during most of the year or even more evidently when it outcrops at surface during the austral winter and early spring months. The outcropping is a result of vigorous exchange of heat between the ocean and the atmosphere when both boundary layers experience convective mixing due to the air-sea interactions. The amount of water formed depends on the strength and duration of this thermodynamical forcing. At subsurface, due to weak lateral mixing and dissipation processes, it tends to last several annual cycles. Mode waters exert their influence in the ocean in many ways: as long term changes in the oceanic heat content leading to variations in the upper limb of the meridional overturning circulation return flow; as modifications in the supply of ventilated water for subduction through thermocline; as variability on coupled processes between the air and sea surface temperature with consequences to climate; as a boost of the sink of atmospheric CO2 in the subtropical gyre, etc. In this study we used a 14-year long time series, from 2002 to 2015, of global monthly climatology of gridded T and S profiles based on in situ measurements to i) detect the SASTMW, ii) map its extent, and iii) estimate the volume that is formed each year and of how much is preserved in the subsurface. This continuous and tridimensional description of the ocean allowed us to determine the SASTMW volume as well to investigate its persistence and interannual variability. The results show that the SASTMW is found near the edge but still within the domain of the subtropical gyre. The detected SASTMW shows a strong seasonal cycle during all stages of its existence, however there is a 2-months phase lag between its outcropped and submerged phases. The time series of the SASTMW volume shows a clear interannual variability mostly due to changes that were introduced during the formation periods. In a more dynamical view, the existence of the SASTMWs is linked to regions of relatively low turbulence. This is concluded from the analysis of the eddy kinetic energy field obtained from altimeters' data, from AVISO.

Wed-182

The NOAA El Niño Rapid Response (ENRR) Field Campaign

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Forecasts by the summer of 2015 indicated a strong El Niño was very likely during winter 2015-16. This lead time was sufficient to identify an exceptional scientific opportunity to accelerate advances in understanding and predictions of an extreme climate event and its impacts while the event was ongoing. Acting on this opportunity, NOAA initiated the El Niño Rapid Response (ENRR) project. The ENRR efforts, led by ESRL Physical Sciences Division (PSD), included an observational field campaign and model experiments performed to optimize observational strategies and support NOAA services in anticipating risks and impacts related to this event. This presentation focuses on the field campaign.

The primary objective of the ENRR field campaign was to determine the initial tropical atmospheric response linking El Niño to its global impacts. The campaign conducted intensive observations in a data-sparse region over the central tropical Pacific Ocean near the heart of El Niño. NOAA's Gulfstream IV (G-IV) was deployed from Hawaii for 22 flights between January 19 to March 9 to obtain wind, temperature, moisture, and precipitation profiles through use of dropsondes, tail Doppler radar, and flight level observations. The majority of those flights were over the central tropical Pacific, sampling organized tropical convection and poleward convective outflow. The G-IV mission concluded with three flights in five days examining the cascade of linked dynamical processes between the Tropics and extratropics that culminated in a landfalling storm with heavy precipitation along the U.S. West Coast March 10-13. The G-IV data were augmented by twice-daily radiosonde launches from Kiritimati (Christmas) Island, up to 8 times/day radiosonde launches from the NOAA Research Vessel Ronald H. Brown in the eastern tropical Pacific during a TAO mooring survey, and scanning X-band radar positioned in Santa Clara CA. During the campaign the ENRR project also coordinated with the NOAA Sensing Hazards with Operational Unmanned Technology (SHOUT) program, which conducted three extratropical North Pacific flights with the unmanned NASA Global Hawk. In addition, NASA Ames conducted a complementary Alpha Jet flight to measure central California coastal jet features, and Scripps Institution of Oceanography organized complementary Air Force C-130 flights targeting atmospheric rivers over the North Pacific.

Data from the ENRR campaign were provided in real-time for assimilation into operational prediction models through the Global Telecommunication System, and are available to the community through the NOAA ESRL/PSD web site http://www.esrl.noaa.gov/psd/enso/rapid_response/data_pub/. Here, we present initial

results to illustrate how this unprecedented set of high-resolution tropical atmospheric observations collected during a strong El Niño are being used to 1) evaluate thermodynamic, wind, precipitation and boundary layer structures around and poleward of deep convection; 2) perform satellite validation and calibration, model sensitivity analyses, and data assimilation studies; and 3) diagnose observed and modeled tropical processes and tropical-extratropical interactions to advance understanding and identify model deficiencies in representing physical processes, with the ultimate goal of improving weather and climate predictions.

Wed-183

The Annual Cycle of Ocean Atmosphere Interaction above the Agulhas Current

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The dynamics of ocean-atmosphere interaction above the Agulhas Current and its impact on the weather and climate of Southern Africa still not well-known. To that effect we are using various parameters from climate observation, reanalysis and satellites remote sensing dataset to study the impact of the Agulhas Current system on the climate of Southern Africa. The first goal is to find out if those products do represent the intense exchange of moisture that occurs above the core of the Agulhas Current and the retroflection region. We are using monthly fields of in situ observations from NOCS; ERA INTERIM, MERRA and CFSR climate reanalysis sea surface temperature (SST), latent heat flux (LHF), surface wind speed and humidity from 1998 to 2005. Corresponding monthly satellites estimates of relevant parameters analysed come from HOAPS3 and SEAFLUX (0.25°*0.25°). We also use the 4x4 km degree resolution MODIS SST as reference for SST and the satellite derived Quicskat SCOW wind climatology as reference for surface wind. We first conducted an inter-comparison of seasonal, annual and monthly mean of all those products in the greater Agulhas Current system and monthly time series at selected locations. We also study the annual cycle of LHF in four locations: three in the Agulhas Current; offshore Durban, offshore Port Elizabeth, in the Retroflection area and one offshore Cape Town in the Benguela upwelling. The LHF is most important during Austral winter in the Agulhas system and in Austral summer in the Benguela Current off Cape Town. The highest value is around 250 W/m2 in the Retroflection area in winter and the lowest is off Cape Town (50 W/m2) in April. The average annual mean of LHF for all locations is 125 W/m2 for NOCS, 163 W/m2 for SEAFLUX, 155 W/m2 for HOAPS3, 168 W/m2 for CFSR, 124 W/m2 for ERA INTERIM and MERRA. Additionally, to understand the driver of variation of LHF, we analysed SST, saturated specific humidity (QSST), specific humidity at 10m (Q10) and surface wind speed at those locations using SEAFLUX. Offshore Port Elizabeth, in the Retroflection area and offshore Cape Town, the LHF strength follows the strength of the wind speed which is not the case for Durban. Correlation between wind speed and LHF for Durban, Port Elizabeth, Retroflection and Cape Town are -0.1, 0.93, 0.98 and 0.98 respectively. Correlation between LHF and the difference between QSST and Q10, which is another driver of LHF, is for Durban, Port Elizabeth, Retroflection and Cape Town respectively 0.94, 0.96, 0.15 and 0.72. This indicates that Qsst-Q10 is the main driver of the amplitude of the annual cycle of LHF off Durban while it is the wind for the Retroflection area and a mix of the two off Port Elizabeth and Cape Town. Finally, using MODIS as SST reference, we find that all products underestimate the core of the Agulhas Current SST off Port Elisabeth but reproduce the SST in the others areas relatively better which will impact on QSST and Q10.

Wed-184

Long-term contribution of Southern Hemisphere atmospheric variability to the meridional transports in the South Atlantic

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Evidences from several atmospheric models and observations have pointed out to a southward migration of the Southern Hemisphere westerlies in the past decades. The upper ocean circulation is mostly driven by the wind dynamic through the Sverdrup theory, therefore it is expected that a long-term variability in the atmospheric forcing lead to an expressive response of the ocean at least in the upper hundreds of meters. A global simulation of an ocean general circulation model forced by NCEP reanalysis data is used to investigate how effectively the ocean response to that atmospheric variability. The present simulation is an eddy--resolving implementation of the Hybrid Coordinate Ocean Model (HYCOM), with a 1/12 degree of horizontal resolution and 32 vertical levels. Because NCEP dataset have captured the poleward shift of the Southern Hemisphere westerlies, we expected our simulation is able to highlight changes in the meridional fluxes in the South Atlantic forced by atmosphere (e.g. the strength of AMOC and their associated heat and freshwater transports). A preliminary investigation at 34.5ºS shows a pronounced positive trend in the AMOC transport for the 1980--2004 period (~ 4 Sv dec--1). Shortly after, AMOC presented a sharp decrease and supposedly achieve a relatively steady behavior until 2009, although this analysis is uncertain because the time series is too short. The contribution of the geostrophic and Ekman transports were investigated and 85% of the total variability of AMOC is associated to its geostrophic component. The Ekman contribution was considerably smaller and no significant trend was detected. However, a clear decadal oscillation was found and its amplitude seems to increase over time since mid--1990s to the end of time series in the Ekman transport. These results suggest that, although the AMOC strength is driven largely by geostrophy, the decadal or longer time-scale signals found in the Ekman component may add a different mode of variability. Further investigation is needed to understand the role of Southern Hemisphere atmospheric variability in modulating the Atlantic inter hemispheric transport.

Wed-185

Frontolysis by surface heat flux in the Agulhas Return current region with a focus on mixed layer processes

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Mechanisms for frontogenesis/frontolysis in the Agulhas Return Current Front, which is defined as the maximum in the meridional of sea surface temperature (SST) gradient at each longitude within the region of (4050E, 5535S), are investigated using observational datasets. Strong SST front causes the meridional gradient of surface specific humidity throughout the year, which leads to that of surface net heat flux (NHF) through the formation of that of latent heat flux. In austral summer, the weaker (stronger) surface warming on the northern (southern) side relaxes the SST front. At the same time, it leads to deeper (shallower) mixed layer on the northern (southern) side, which enhances the frontolysis because deeper (shallower) mixed layer is less (more) sensitive to surface warming. In austral winter, stronger (weaker) surface cooling acts as frontolysis. However, it leads to larger (smaller) entrainment velocity and thus forms deeper (shallower) mixed layer, which suppresses the frontolysis because the deeper (shallower) mixed layer is less (more) sensitive to surface cooling. Therefore, the frontolysis by the NHF is enhanced (weakened) through the mixed layer processes in austral summer (winter). The above mechanisms are confirmed using outputs from a high-resolution coupled general circulation model.

Wed-186

The post-2002 global warming hiatus caused by the Southern Ocean heating acceleration

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In spite of increasing atmospheric CO2 concentration, the warming rate of the global-mean surface temperature has slowed down since 1998. Here we quantify the influence of the ocean heat uptake on the surface temperature anomaly; it is clarified that the Southern Ocean heating acceleration below the sub-surface became an important factor for explaining the post-2002 global warming hiatus. Our numerical simulations, in which the wind stress anomaly in the equatorial Pacific is imposed from reanalysis data, suggest that sub-surface (depth upper than 300m) warming in the Pacific took place during the initial phase of the global warming hiatus (1998–2002), as previously reported. It is newly clarified that meridional heat transport from tropic to extra-tropic is enhanced in the later

phase of the hiatus (after 2002) and the heat strage below depth of 700m in the Southern Ocean is accelarated, leading to the post-2002 global warming hiatus. Historical observational data of ocean temperature also support this scenario. This study provides evidence that deeper parts of the Southern Ocean play a critical role in the past-2002 global warming hiatus.

Wed-188

A coupled decadal prediction of the dynamic state of the Kuroshio Extension system

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Being the extension of a wind-driven western boundary current, the Kuroshio Extension (KE) has long been recognized as a turbulent current system rich in large-amplitude meanders and energetic pinched-off eddies. An important feature emerging from recent satellite altimeter measurements and eddy-resolving ocean model simulations, is that the KE system exhibits well-defined decadal modulations between a stable and an unstable dynamic state. Here we show that the decadally-modulating KE dynamic state can be effectively defined by the sea surface height (SSH) anomalies in the 31-36N and 140-165E region. By utilizing the SSH-based KE index from 1977--2012, we demonstrate that the time--varying KE dynamic state can be predicted at lead times of up to ~6 years. This long-term predictability rests on two dynamic processes: (1) the oceanic adjustment is via baroclinic Rossby waves that carry interior wind-forced anomalies westward into the KE region, and (2) the low-frequency KE variability influences the extratropical storm-tracks and surface wind stress curl field across the North Pacific basin. By shifting poleward (equatorward) the storm-tracks and the large-scale wind stress curl pattern during its stable (unstable) dynamic state, the KE variability induces a delayed negative feedback that can enhance the predictable SSH variance on the decadal timescales.

Wed-189

Inter-annual and Inter-decadal variabilities of the summer Indian Ocean SST associated with the seasonal timing of ENSO decay phase

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ENSO affects the tropical Indian Ocean (TIO) SST in winter-spring of ENSO decay years through an ENSO-induced ‘atmospheric-bridge’ and subsequent air-sea coupling processes. This study reports that, on top of the long-term warming trend of Indian Ocean, the Indian Ocean Basin (IOB) SST also exhibits significant inter-decadal variabilities, particularly for the summer IOB. The physical linkage between the summer SST anomalies over the TIO and the timing of ENSO decay phase is further investigated. Multi-source data are used to distinguish ‘later-decay’ from ‘normal-decay’ El Niño/La Niña events, and then to examine the changes in various thermodynamic and dynamic processes due to later-decay ENSO. The results show that, at both the interannual and interdecadal timescales, variability of the summer IOB SST is intimately related with the seasonal timing of ENSO decay phase. Specifically, significant warmer/colder SST anomalies in the spring TIO can persist into summer only in later-decay El Niño/La Niña years. Most of the ENSO-induced atmospheric-bridge-related processes contribute positively to the TIO SST changes in summer due to later-decay of ENSO, as they do in spring during normal-delay ENSO year. The exceptions are the surface wind-evaporation-mechanism (WEM) and sensible heat-flux anomalies in summer, which always contribute negatively to the summer SST anomalies over most parts of the TIO. The negative contributions from these two processes in summer exist no matter whether there is a weakening or strengthening surface wind due to later-decay of ENSO events. Generally, the presence of five later-decay El Niño events after the 1970s is mainly responsible for the observed interdecadal summer TIO warming in recent decades.

Wed-190

Harnessing Oceans of Data: Supporting Development of Meaningful Ocean Climate Indicators

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The U.S. NOAA's Climate Observation Division sponsors thousands of global ocean observing platforms, and partners with over 70 partners to implement a sustained Global Ocean Observing System to provide high-quality, long-term observations and products to researchers, forecasters, and other users to prepare society for environmental changes. More than 8,000 platforms contribute toward the GOOS systems - including platforms such as Argo, drifting buoys, OceanSites, ship-based and XBT measurements, satellites and drifting buoys arrays. While continually evolving and advancing our knowledge, today the entirety of the system provides an unprecedented volume of observations, products, and analyses of ocean properties and fluxes such as sea surface temperature, salinity and currents, ocean heat content and transport, Air-sea exchanges of heat, momentum and freshwater, sea level change, and ocean carbon uptake and biogeochemistry. Some of these observing systems now provide decades long records.

NOAA's Climate Monitoring program is in the middle of a three-year initiative toward supporting research toward the development of Ocean Climate Indicators that leverage these observing assets and the information and provide added value for research, prediction, and decision makers. These indicators provide information tailored to identified stakeholders and facilitate monitoring and better insight into the status, trends, extremes and variability of important climate features or processes, and are an important evolving aspect of advancing the science of climate diagnostics and prediction.

The program is currently supporting eight distinct projects that focus on primarily regional indices that target specific scientific needs such as informing studies of physical process researchers and creating new diagnostics and indicators to compare with key model quantities or predictive capabilities. Many of the indicators focus on better estimates of derived quantities of fluxes - e.g. ocean heat content and transport, air-sea exchanges, and utitlize some of the longest term ocean records and/or synthesize these with new and multiple data sources.

This presentation will discuss the geographic and scientific diversity of this initial set of projects, provide an overview of the results, and discuss ways in which COD/Climate Monitoring is seeking to expand, sustain and enhance these efforts. These indices can be used as a way to faciliate better two-way information flow between the observational and modeling community. We will discuss efforts to organize the ocean climate and observing community around how to leverage and sustain indicators and products that can demonstrate a strong user community, strategies toward developing robust delivery and update mechanisms, and how these may contribute toward developing a comprehensive ocean monitoring and indicators system for research and prediction.

Wed-191

An Observing System for the Southern Ocean

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The Southern Ocean has a profound influence on the global ocean circulation and the Earth's climate. It provides the principal connections between the Earth's ocean basins, and controls the connection between the deep and upper layers of the global overturning circulation, thereby regulating the capacity of the ocean to store and transport heat, carbon and other properties that influence climate and global biogeochemical cycles.

The upwelling branch of the Southern Ocean overturning circulation returns carbon and nutrients to the surface layer, while the downwelling branches transport heat, carbon and other properties into the ocean interior. The balance between upwelling and release of CO2 versus uptake of carbon into the ocean interior determines the strength of the Southern Ocean sink of CO2. The Southern Ocean contributes more to the ocean storage of anthropogenic heat and carbon than any other latitudinal band. About 40% of the total global ocean inventory of anthropogenic carbon dioxide is found south of 30°S, whilst export of nutrients by the upper limb of the overturning circulation ultimately supports 75% of the global ocean primary production north of 30°S.

Given the central role that the Southern Ocean plays in the global climate system, any changes in the region will have global consequences—and changes in the physical and biogeochemical state of the Southern Ocean are already being observed. The circumpolar Southern Ocean is warming more rapidly, and to greater depth, than the global ocean average. The upper layers have freshened and widespread warming of the Antarctic Bottom Water has been observed. Since 1992, the satellite altimeter record shows an overall increase in sea level, with strong regional trends. Similarly, changes in sea ice extent are showing strong regional trends, with large increases in the Ross Sea sector compared to large decreases west of the Antarctic Peninsula. The uptake of CO2 by the ocean is changing its chemical balance, increasing the acidity and reducing the concentration of carbonate ions. The response of the Southern Ocean food web to changes in ocean chemistry remains largely unknown.

Sustained observations are required to detect, interpret, and respond to the physical, chemical, and biological changes that are, and will continue to be measured. The Southern Ocean Observing System (SOOS) is an international initiative with the mission to integrate the global assets and efforts of the international community to enhance data collection, provide access to datasets, and guide the development of strategic-sustained-multidisciplinary science in the Southern Ocean. This presentation will provide an update on SOOS implementation activities, key products and tools, and data management efforts.

Wed-192

Multidecadal freshening and lightening in the deep waters of the Bransfield Strait, Antarctica

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The deep waters of the Bransfield Strait receive considerable amounts of water from the Weddell Sea continental shelf. The restricted connections to the surrounding ocean and relatively easier access makes the Bransfield Strait an important proxy region for monitoring changes in the dense Weddell Sea shelf water masses, which are an important precursor of Antarctic Bottom Water. In this study, we built a time series of potential temperature, salinity and neutral density using hydrographic data (CTD and bottle) collected within Bransfield Strait between 1963 and 2014. Neutral density higher than 28.27 kg m–3 and depth higher than 800 m were used as a threshold to mark the deep waters of the Strait. In a long-term perspective, the hydrographic data showed statistically significant freshening and lightening of the Bransfield Strait deep water masses, which was likely caused by large freshwater inputs originating from the western shelf of the Weddell Sea. The rates of freshening and lightening were –0.0010±0.0005 yr–1 and –0.0016±0.0014 kg m–3 yr–1 for the central basin, respectively, and –0.0010±0.0006 yr–1 and –0.0029±0.0013 kg m–3 yr–1 for the eastern basin, respectively. The decrease found in salinity and neutral density during the period were responsible for the shrinking trends observed in both basins, which was –5.60±5.27 m yr–1 for the central basin and –24.98±11.09 m yr–1 for the eastern basin. The Bransfield Strait deep waters showed a high degree of interannual thermohaline variability. To analyze the causes of this variability, we applied an Optimum Multiparameter Analysis (OMP) in a repeated hydrographic section conducted by the Brazilian High Latitude Oceanography Group (GOAL) between 2004 and 2014. The OMP results showed that changes in the proportions of source water masses mixing (i.e. High Salinity Shelf Water, Low Salinity Shelf Water and Circumpolar Deep Water) could explain the interannual variability presented in the deep waters of the Strait. Statistically significant negative correlations between salinity/neutral density fields and the Southern Annular Mode (SAM) index were observed (–0.56 and –0.62 for the central basin and –0.58 and –0.68 for the eastern basin, respectively) between 1980 and 2014. During SAM positive phases, communication between the Weddell Sea and the Bransfield Strait is reduced, which leads to less saline and lighter water masses in the Bransfield Strait; however, the opposite pattern is observed during SAM negative phases. We presented results from a long-term period study conducted in the Bransfield Strait, a region that receives waters from Weddell Sea continental shelf. Despite using more than 50 years of data, the time series is not long enough to represent the hydrographic oscillations within the region. Therefore, continued sampling of the Bransfield Strait deep waters must be performed to monitor future changes of the Weddell Sea shelf waters that flow into the Strait.

Wed-193

Pacific Ocean Surface Freshwater Variability underneath the double ITCZ as seen by SMOS

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The salinity budget of the upper tropical Pacific Ocean underneath the double Intertropical Convergence Zone (ITCZ) is studied using the Soil Moisture and Ocean Salinity (SMOS) and Aquarius surface salinity observations. In this shallow mixed layer region of the ocean, precipitation effects on the near-surface salinity budget are large, typically leading to a band of fresh sea surface salinity (SSS) between March and June. The role of precipitation during the freshening period is documented here through a direct correlation between the SMOS SSS fields and the monthly accumulated precipitation. During the same period, the mixed layer salinity budget is impacted by advection, which, based on observations, is found to be another important mechanism for the evolution of the near-surface salinity as documented through a connection between the north equatorial eastern Pacific Fresh water pool and this south equatorial freshwater pattern in boreal spring. However, given the information at hand, the near-surface salinity budget cannot be closed, suggesting that other processes are important too, such as nonlinear effects, mixing and entrainment.

Wed-194

Teleconnected Influence of the Boreal Winter Antarctic Oscillation on the Somali Jet: Bridging Role of Sea Surface Temperature in Southern High and Middle Latitudes

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The teleconnection impact of the boreal winter Antarctic Oscillation (AAO) on the Somali Jet (SMJ) intensity in the following spring and summer is examined in this paper. The variability of the boreal winter AAO is positively related to the SMJ intensity in both spring and summer. The analyses show that the SST in southern high and middle latitudes seems to serve as a bridge linking these two systems. When the AAO is in strong positive phase, SST over the Southern Ocean cools in the high latitudes and warms in the middle latitudes, which persists into summer; however, the variability of SST in southern high and middle latitudes is also closely correlated to SMJ intensity.

A possible mechanism that links SST variability with the AAO–SMJ relationship is also discussed. The AAO in boreal winter produces an SST anomaly pattern in southern high and middle latitudes through the air–sea coupling. This AAO-related SST anomaly pattern modulates the local Ferrel cell anomaly in summer, followed by the regional Hadley cell anomaly in tropics. The anomalous vertical motion in tropics then changes the land–sea thermal contrast between the tropical Indian Ocean and the Asian continent through the variability of low cloud cover and downward surface longwave radiation flux. Finally, the land–sea thermal contrast anomaly between the tropical Indian Ocean and the Asian continent changes the SMJ intensity. The results from Community Atmosphere Model experiments forced by the SST anomaly in southern high and middle latitudes also confirm this diagnostic physical process to some extent.

Wed-195

Coupled sea ice-atmosphere-ocean interactions in the Arctic marginal ice zone

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In recent decades, Arctic climate has changed rapidly. The most apparent physical manifestation of this change is a decline of Arctic sea ice, which is a key indicator of global climate transitions. Consequently, there has been increasing international focus on improved understanding of sea ice variability and forecasting of Arctic sea ice concentrations and thickness. Sea ice also has significant and immediate consequences for evolving societal and economic interests in the region, such as transportation, resource development, safety, and ecosystem responses. Thus, society has an increasing requirement to understand the evolution of sea ice concentrations on scales ranging from days to decades.

Sea-ice evolution in the new Arctic involves the interaction of numerous physical processes in the atmosphere, ice, and ocean, some of which are not yet fully understood. In this presentation we present results from subseasonal forecasts of sea ice and surface energy fluxes for the 2015 freeze-up period from a coupled limited-area climate model designed to improve the understanding of coupled ice-ocean-atmosphere feedbacks that drive Arctic sea ice variability. The underlying hypothesis for this work is that errors on subseasonal time scales limit the skill of seasonal forecasts in the marginal ice zone through the integrated impact on sea ice and ocean fields. The focus of this work is on improving the understanding of coupled cloud-surface-boundary layer-ocean interactions in the Arctic marginal ice zone in order to improve predictions of Arctic sea ice on seasonal and longer time scales.

Wed-196

Application of a flow field correction method to the North Atlantic Ocean in the MPI - Earth System Model

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Current generation climate models still suffer from the lack of ability to represent the oceans sea surface temperature (SST) in the North Atlantic Ocean well compared to observational data. They show a particular cold bias east of Newfoundland where the path of the North Atlantic Current (NAC) should flow north into the so called "Northwest Corner" (NWC). In terms of a prevailing cold biasthe air-sea energy flux in the NWC is reversed so that the atmosphere warms the ocean to compensate the bias. Since the cold bias is located in the North Atlantic Ocean it mainly effects the models representation of the European climate on all timescales. The increase of the SST gradients due to the existing bias reduces the forecast skill of coupled general circulation models by influencing the ocean-atmosphere interaction and hence the atmospheric circulation.

One useful approach to achieve a more reasonable representation of these processes is the so called "semi-prognostic method" [Sheng et al. 2001; Greatbatch et al. 2004] to achieve a flow field correction for the major currents, which is applicable for hydrostatic ocean models. An adjustment of the horizontal baroclinic pressure gradient in the momentum balance equation is used to asses a reduction of the North Atlantic SST cold bias. The introduced forcing leaves the model tracer equations for temperature and salinity free to develop and thus is clearly different to the standard form of "nudging". The simplicity of implementing the procedure to the model code and the fact that it is applied adiabatically manifest as major advantages.

In this study the semi-prognostic method is applied to the ocean component of the Max-Planck-Institute for Meteorology Earth System Model (MPI-ESM) to 1) reduce SST bias in the Northwest Corner, 2) identify sources of errors, 3) investigate the effect of the reversed air-sea energy flux in the coupled earth system, 4) correct for similar errors in a global context. The approach is used as a more physical way to correct for model biases associated with errors due to misleading water mass pathways and their impact on the large-scale circulation, as well as for errors of unresolved small-scale processes by introducing a parameterization of subgrid-scale features implicitly in an eddy permitting model setup. Since even eddy-resolving climate models still evolve a bias as strong as in lower resolution models (depending on small-scale parameterization and details in model setups) this study provides a proper improvement and a useful inside into mechanisms associated with the North Atlantic Current system. The results also contribute to an improvement of the predictability on seasonal to interannual timescale. Additionally the technique appears to have potential to reduce similar model errors in different regions. Regional (in horizontal and vertical extent) application is likely to give evidence of the different sources of wrong representation of ocean water mass pathways and the associated SST distribution.

Wed-197

Long-term variability of the simulated heat content in the Japan/East Sea induced by atmospheric forcing, 1948-2009

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Based on the simulated dataset, we study impact of atmospheric forcing on heat content (HC) variability in the Japan/East Sea (JES), 1948-2009. Using a numerical ocean model (INMOM) and atmospheric forcing extracted from the CORE II dataset, a circulation of the Japan/East Sea (JES) and its variability were simulated given a leading role of atmospheric forcing on the circulation variability. Comparison the simulated JES circulation and that obtained from the SODA2.2.4 reanalysis showed that a simulated velocity field spatial structure reproduced the major features of the basin-scale circulation of the JES expect for some features of the basin-scale circulation driven by the JES straits. Nevertheless, a comparison of the basin-averaged circulation characteristics showed that kinetic energy and total HC obtained from the numerical simulations are a good agreement with those extracted from the SODA reanalysis.

Based on the simulated temperature and salinity, an analysis of spatial-temporal variability of the HC of the upper (from 0 to 300 m) and intermediate (from 300 to 1000 m) layers revealed the regions with intensive heat supply (lost) in the JES associated with atmospheric forcing over the JES. We found that the simulated HC temporal variability was characterized by the interannual oscillations with the period of 3-5 years, intra-decadal variability with the time scale of 5-7 years and decadal variability with the time scale of 12-15 years. In addition, we found that the simulated upper HC variability was dominated by the interannual oscillations in contrast to the simulated intermediate HC variability, which was dominated by intra-decadal and decadal variability. We suggest that heat supply variability in the norther and north-western JES induced by atmospheric forcing variability. An analysis of relationships between the anomalies of the simulated HC in the upper and intermediate layers in the JES and sea level pressure showed that the Arctic Oscillation and the North-Pacific Oscillation are responsible for the revealed long-term variability of the HC in the JES.

Wed-198

Atmospheric drivers of variability and formation of extreme surface turbulent heat fluxes in the North Atlantic

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Surface turbulent heat fluxes are responsible for variability of surface ocean heat budget on synoptic andinterannual time scales and also have strong impact on atmospheric heating. We analyze the origins of the variability of surface fluxes in the context of interaction of the North Atlantic extratropical cyclones withthe ocean in winter. Our focus is on the atmospheric conditions triggering extreme air-sea turbulent fluxes. The main questions addressed in this study are (i) what are the large scale atmospheric conditions associatedwith extreme ocean surface fluxes and are they related to cyclones, (ii) what is the role of extreme surfacefluxes in the variability of surface oceanic heat content, and (iii) which characteristics of atmospheric cyclonesare sensitive to the surface ocean flux signals? To answer these questions, we derive probability distributions of surface fluxes in the North Atlantic from NCEP-CFSR reanalysis 1979-onwards. We show that from 30 to 60%of the oceanic heat loss in winter are due to fluxes exceeding 90th percentile. From composite analysis we foundthat these extreme flux events are associated not with the cyclones per se, but with the cold air outbreaks in cyclone-anticyclone interaction zones. Next, we put the analysis of synoptic air-sea interaction into the context of the cyclone characteristics derived from the numerical storm tracking of reanalysis SLP data. Over the North Atlantic, from 20 to 60% of cyclone occurrences associated with flux extremes exceeding 90th percentile, while 80% of cyclonetracks at least once during lifetime associated with flux extreme. We also show that over the Gulf Stream more than60% of cyclogenesis were associated with extreme surface fluxes.

Wed-199

Ocean heat transports in a coupled system

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Using top-of-atmosphere radiation (CERES) and atmospheric energy divergence (ERA-Interim), net surface energy fluxes are computed and integrated over the ocean to give new estimates of ocean heat transport. By also making estimates of changes in ocean heat storage and utilizing choke points like the Bering Strait, these results give not only the annual mean and annual cycle but also time series. Results will be compared with measured in situ estimates such as from the Rapid array.

Wed-200

Modulating the Pacific Climate Variability and ENSO from the Pacific Asian Marginal Seas

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We investigate the dominant coupled atmospheric and oceanic modes in the North Pacific climate variability and explore the impact of the Pacific Asian Marginal Sea (PAMS) on them using observation and the Community Earth System Model (CESM), both of which clearly indicate the two dominant coupled modes of surface variability. The first mode of the combined empirical orthogonal function (CEOF) analysis represents the Pacific Decadal Oscillation (PDO) / El NioSouthern Oscillation (ENSO) variability, which expresses the zonal variability in the mid-latitudes and tropics. The second mode shows the North Pacific Oscillation (NPO)/Victoria Mode (VM) variability reflecting the footprint of the meridional variability through the tropicalextratropical teleconnection. Wavelet analysis for both the observation and CESM indicates that the first mode is dominated by interannual-scale variability, while the second mode is dominated by decadal-scale variability. These two leading modes can explain most of the North Pacific climate variability and are linked with each other through the ENSO evolution. The development of strong 2015/16 El Nio is a typical example. We also identified the potential origin of these two dominant modes resulting from atmospheric boundary layer variability in the PAMS. The summer zonal wind anomalies in the PAMS link directly to the consequent PDO/ENSO pattern, while the winter meridional wind anomalies in the PAMS acts as a pivotal driver to modulate the NPO/VM pattern through atmospheric teleconnection. Particularly, the upper-level eastward propagation strengthens the south lobe of the NPO from the subtropical pressure low anomaly. The spring VM consequently drives the zonal mode in the subtropical and tropical Pacific (including the zonal wind variability in the PAMS), thus triggering the onset of PDO/ENSO variability. Further analysis shows that the East Asian Winter Monsoon (EAWM) may play an important role in controlling low-level meridional wind variability in the PAMS but does not explain its completed variability. These dynamical processes are also confirmed by the CESM simulation with a difference in the time scale required to modulate the NPO.

Wed-201

Indian Ocean Dipole driven variability along the east and west Indian coasts and its impacts.

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The geometry of the Indian Ocean induces a strong connectivity between the climatically active equatorial region and the densely populated Northern Indian Ocean through the coastal wave-guide. The resulting interannual variability along both coasts of India can have strong societal impacts. For example, the west Indian coast is home to one of the largest coastal hypoxic system in the world during boreal fall, making it susceptible to surface anoxia, which has a devastating impact on ecosystems and local fisheries. In this work, we describe the sea level interannual variability along the rim of the Northern Indian Ocean, discuss its driving mechanisms and investigate its physical and biogeochemical consequences from the joint analysis of oceanic simulations and observations.

Interannual sea level variability is strongest in boreal fall on both Indian coasts, and remotely forced by the Indian Ocean Dipole (IOD). Along the east coast of India, this interannual variability largely results from remote forcing in the equatorial region, with the alongshore and interior forcing signals in the bay of Bengal playing a much lesser role. Positive IOD events force upwelling Kelvin waves that travel around the rim of the Bay and weaken the southward East India Coastal Current in boreal fall. This diminishes the southward advection of fresh water from the vicinity of the Ganges-Brahmaputra river mouth, leading to strong positive sea surface salinity interannual anomalies in a narrow coastal band.

Positive IOD events also induce a positive sea level signal associated with first meridional mode equatorial Rossby waves at the southern tip of Sri Lanka. This positive sea level signal is further reinforced by the IOD-driven eastward wind anomalies near the southern tip of India and Sri Lanka. The resulting signal propagates northward as downwelling coastal Kelvin waves that deepen the thermocline along the entire west Indian coast. While this signal has weaker amplitude than that on the east coast, it has much stronger societal consequences. The thermocline variations indeed largely control the offshore variations of the oxygen content. During positive IOD years, the deepening of the thermocline along the west coast of India increases the upper ocean oxygen content and hence prevents the occurrence of anoxic events. As the influence of a negative IOD on the west coast is weaker than a positive one, a negative or neutral IOD is found to be a necessary but not sufficient condition for the occurrence of surface anoxia along the west coast of India. Since state-of-the-art IOD predictions are skilful one or two seasons in advance, this work raises the interesting possibility of advance warnings for the increased probability of hypoxia along the west coast of India.

Wed-202

Towards downscaling small scale coastal dynamics

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Temporal developments and changes of mall scale coastal dynamics are commonly not well described by observational data sets or climate change simulations. On the other hand, such changes may be of particular interest for planning measures to deal with such changes. We suggest to apply the "empirical downscaling"-concept for consistent specifying of such changes. This needs building links between large-scale states and small-scale statistics. For doing so suitable data sets are needed, which are homogeneous in space and time, and extend across several decades or more.

We have examined the simulation STORM with the 0.1 grid resolution ocean GCM MPI-OM forced with NCEP atmospheric re-analyses; by comparing the variability of sea surface height from the simulation with satellite data and an ocean reanalysis, we found a good similarity between the different data sets. We conclude are that STORM is suitable for developing empirical downscaling models. Using this data set we have derived first such empirical cross-scale links dealing with coastal upwelling in the South China Sea.

Wed-203

Detecting Cross-equatorial Wind Change as a Fingerprint of Climate Response to Anthropogenic Aerosol Forcing

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Anthropogenic changes in greenhouse gases and aerosols are the major drivers of the 20th century climate change. Identifying distinct fingerprints of these forcings is important for attribution. The aerosol forcing, larger in the Northern than Southern Hemisphere, induces an inter-hemispheric Hadley circulation. By analyzing multi-model ensemble of both historical anthropogenic aerosol single forcing and all forcing simulations, we show that the zonal-mean cross-equatorial surface flow is a robust fingerprint for the aerosol effect. This zonal-mean mode follows the evolution of global aerosol forcing that is distinct from regional changes in the Atlantic sector. A conclusive detection of the zonal-mean change in the cross-equatorial flow has been hindered by sparse observations over ocean that occupies 75% of the equatorial belt. From historical ship observations, we detect a robust change in the cross-equatorial wind over the past 60 years, accompanied by physically consistent changes in atmospheric pressure and marine cloud cover changes. This inter-hemispheric mode of 20th century climate change is confirmed by various reanalysis data. Atmospheric simulations forced by observed evolution of sea surface temperature successfully reproduce this inter-hemispheric mode, indicating the importance of sea surface temperature mediation in response to anthropogenic aerosol forcing. As societies awaken to reduce aerosol emissions, a phase reversal of this inter-hemispheric mode is predicted, with a southerly change in cross-equatorial wind and a northward displacement of tropical rain belts in the 21st century.

Wed-204

A global eastward propagation associated with the 4-6-year ENSO cycle

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Longitude-time evolution of sea surface temperature anomalies (SSTA) reveals a slow southeastward propagation from the western North Pacific (WNP) around 20N to the Niño-3.4 region in the equatorial Central Pacific. The propagation is manifested as a narrow, south- west-northeast oriented SSTA band across the subtropical North Pacific, and its journey takes about 23 years. The propagating SSTA appears to engage the initiation of the El NiñoSouthern Oscillation (ENSO). The anomalies of surface winds, sea level pressure, outgoing longwave radiation, and velocity potential all exhibit a concurrent and distinct eastward propagation, one that appears to be circumglobal and is coupled with the predominant 4-6-year frequency of the ENSO cycle. It is suggested that the previously found warming/cooling in the Indian Ocean induced by El Niño/La Niña, the progressive SSTA and wind anomalies across the Indian Ocean towards the WNP, and the predominant 4-6-year frequency of the North Pacific Oscillation collectively contribute to the reported SSTA propagation . The findings implicate that monitoring the SSTA propagation from the WNP towards the tropical central Pacific could be useful in tracking the ENSO development.

Wed-205

Air-sea interaction and frontal variability in the global coastal ocean

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Seven years of satellite observations (2003 - 2009) are used to describe the variability in sea surface temperature (SST) fronts and air-sea interaciont, and to investigate their relations in global coastal ocean. The general patterns of SST frontal activity are remarkably similar in eastern boundary and western boundary, respectively, with high frontal probabilities along the coast decreasing with distance from the coastline. Results from empirical orthogonal function decompositions reveal that the seasonal evolution of SST fronts and wind stress are significantly correlated, with intensified upwelling favorable winds associated with an increase in frontal probabilities. For Eastern Boundary Current Systems, the width of the region of high frontal activity is relatively broader in the California and Benguela Current Systems, and narrower in the Canary and Humboldt Current Systems. The width of the band of high frontal activity may be influenced by multiple factors, including wind forcing, flow topography interactions, and mesoscale dynamics. On the other hand, fronts can in turn influence atmospheric processes, playing an important role in mescoscale air-sea interactions. Enhanced vertical mixing over the warmer side of the front deepens the marine-atmospheric boundary layer, drawing momentum from the upper boundary layer down to the sea surface and increasing winds aloft. Over the cold side of the front, by contrast, surface wind decreases in association with increased stability of the atmospheric boundary layer. When winds blow along a SST front higher winds over the warm side of the front and weaker winds over the cold side of the front generate wind stress curl. If the winds blow across a SST front, wind stress divergence is generated. Since wind stress curl anomalies drive Ekman pumping, they can be associated with significant upwelling or downwelling, leading to modifications in the SST distribution itself. As a result, a linear relation has been found between anomalies of the crosswind component of SST gradients and wind stress curl, and between anomalies of the downwind component of SST gradients and wind stress divergence. The use of a consistent data set and standardized methods allow for direct comparisons between coupling coefficients among global coast ocean. Seasonal variability is dominating over the global coastal ocean. The analysis reveals that strong coupling is observed in Eastern Boundary Current Systems with strong seasonal variability enhanced during local summer, while Western Boundary Current Systems are characterized by strong interaction with less substantial seasonal variability. Stronger intraseaonal variability is found in curl field than divergence field.

Wed-206

Pacific trade winds accelerated by aerosol forcing over the past two decades

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The Pacific trade winds, coupled with the zonal sea surface temperature (SST) gradient in the equatorial Pacific Ocean, control regional sea levels and thereby their trend is a great concern in the Pacific Rim. Over the past two decades, easterly winds have been accelerated in association with eastern tropical Pacific cooling. They may represent natural interdecadal variability in the Pacific and possibly explain the recent global warming hiatus. However, the intensification of the winds has been the strongest ever observed in the past century, the reason for which is still unclear. Here we show using multiple climate simulations for 1921–2014 by a global climate model that approximately one-third of the trade wind intensification for 1991–2010 can be attributed to changes in sulphate aerosols. The multidecadal SST anomaly induced mostly by volcanic aerosols dominates in the western North Pacific (WNP), and its sign rapidly changed from negative to positive in the 1990s coherently with Atlantic multidecadal variability. The WNP warming resulted in intensification of trade winds to the west of the dateline. These trends have not contributed much to the global warming hiatus, but have greatly impacted rainfall over the western Pacific islands.

Wed-207

Sensitivity of AMOC numarical simulation to spatio-temporal resolution of atmospheric forcing field

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Based on a global ocean-ice coupled numarical model, we study the impact of different spatio-temporal resolution of atmospheric forcing field to the numarical simulation of AMOC(Atlantic Meridional Overturning Circulation) and SST(Sea Surface Temperature). Results of sensitivity experiments show that spatio-temporal resolution of atmospheric forcing field can signifacantly impact both SST and AMOC. Compared with control run(6 hourly) coarser spatio-temporal forcing field lead to weaker AMOC and warmer SST. AMOC index in monthly forcing field experiment decreased by 6.7Sv (34% lower) with respect to experiment with 6 hourly forcing field. AMOC index of coarser spatio resolution in 6 hourly forcing field runs decreased by 1.4Sv. Analisis of upper ocean current and sea surface heat flux indicate that coarser spatio-temporal forcing field can result in weakening of wind which is the main cause of weaker AMOC and warmer SST.

Wed-208

Evolution of seasonal pycnocline and its vertical structure in the North Pacific

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For understanding spring-summertime air-sea heat exchange, recent observational study has shown that it is necessary to consider not only ocean's heat received within thin surface mixed layer, as it has been thought previously, but also heat penetration below the mixed layer by vertical eddy mixing in the North Pacific [1]. In order to understand this heat penetration process, we investigated the evolution of stratification below the summertime thin mixed layer (i.e. evolution of seasonal pycnocline) and its vertical structure in the North Pacific only using high vertical resolution Temperature/Salinity profile observed by Argo floats and ships.

We quantified the vertical structure of seasonal pycnocline as deviations from the linear structure where the vertical gradient of density is constant, that is, "shape anomaly". The shape anomaly is variable representing the extent of the bend of density profiles. It becomes larger when the density decreases more rapidly from subsurface toward the base of mixed layer. If the vertical structure of density is linear, the shape anomaly is 0. By mapping shape anomaly after calculating its value from individual high vertical resolution profiles, we gained its spatial distribution without an influence of smoothing. We found that spatial distribution and temporal variations of shape anomalies are different from those of values of density difference between surface and subsurface calculated without considering the vertical structure of seasonal pycnocline. To understand the spatial distribution of shape anomalies, we investigated the relationship between time changes in shape anomalies and net surface buoyancy flux (net heat and fresh water flux) and surface kinetic energy flux (cube of surface frictional velocity). The analysis clearly indicated that, in a large part of North Pacific, there's a tendency for shape anomalies to develop strongly (weakly) under the conditions of large (small) downward net surface buoyancy flux and small (large) downward surface kinetic energy flux. Since week (strong) development of shape anomalies means that buoyancy entered from the surface is well (rarely) carried below the mixed layer, these results suggest that the heat penetration process in the North Pacific is governed primarily by vertical one dimensional process composed of thermodynamical forcing by surface buoyancy flux and dynamical forcing by surface wind.

[1] Hosoda et al. (2015), J. Oceanogr., 71, 541-556.

Wed-209

Analysis of East Asian marginal sea SST variability and its relationship with Pacific Ocean

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Global sea surface temperature (SST) is gradually increasing since the mid-1980 and such a warming tends to be greater at the marginal seas, especially in the East Asia. And it is expected that the role of ocean with warmer SST, which has an interaction with atmosphere, becomes not to be negligible. In this study, we investigate the relationship between the East Asian Marginal sea SST variability and the Pacific Ocean using a very high resolution (0.05 degree) SST dataset on interannual-to-decadal timescales. It is found that the East Asian marginal sea SST variability is associated with that in the Pacific Ocean basin. For example, both the first and second EOF SST in the marginal sea SST are associated with an El Nino-like decadal variability on the low-frequency timescales. However, the detailed connections with Pacific Ocean SST are not the same between EOF1 and EOF2 SST in the East Asian marginal sea on the low-frequency timescales. On the other hand, the EOF1 SST in the marginal sea on interannual timescale is slightly associated with the ENSO, which is in contrast to that in the EOF2 SST in the marginal sea. We further explore how this relationship is associated with weather and climate condition in East Asia.

Wed-210

The seasonality of atmospheric teleconnections between ENSO and the Amundsen sea low

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There have been significant variations in regional climate over West Antarctica in recent decades, including heterogeneous trends in sea ice that are not well understood [Turner 2009]. One possible atmospheric driver of these variations is teleconnections between the tropics and the Amundsen Sea Low (ASL), so it is important to understand the mechanisms for teleconnections and their dependence on season. In particular, the teleconnection to the ASL associated with the El Niño Southern Oscillation (ENSO) is stronger in austral winter (JJA) compared to austral summer (DJF) even though El Niño events tend to peak in DJF.

We use the UK Met Office Unified Model to explore mechanisms for ENSO teleconnections to the ASL. We run nine ~50 year time slice experiments with fixed ENSO sea surface temperature anomalies of varying magnitudes (between -3.0 K and 3.0 K). We apply Rossby wave source (RWS) diagnostics and wave ray tracing techniques to understand the drivers of the seasonality in the ASL teleconnection. The subtropical jet is much stronger in the Pacific sector in JJA compared with DJF. The differences in jet structure mean that a significant RWS due to El Niño only appears in JJA located at around 30°S, 120°W. The dominant term in the RWS anomaly seem to be the absolute vorticity of the wind multiplied by the divergence of the wind. We then apply Rossby wave ray tracing to show that even when a RWS exists Rossby waves can only pass into the Amundsen Sea region in JJA. This is due to the presence of a band of reflection in DJF in the Amundsen Sea region. The ray follows the structure of the PSA as expected.

In the tropics, the response of El Niño is often not symmetrical to La Niña. Furthermore, the linearity of the response between a weak and a strong El Niño is unclear. Therefore, the linearity of the teleconnection to the ASL is also explored.

Wed-211

Water mass transformation in the global oceans

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The global meridional overturning circulation (MOC) makes a significant contribution to the global climate by transporting heat, freshwater, and biogeochemical tracers such as oxygen and carbon dioxide throughout the global oceans. The two overturning cells of MOC are closely related to water mass transformation. Lighter upper water is transformed to denser deep water in polar oceans around the Antarctic and the northern North Atlantic. After completing the overturning loop, it is thought that the denser deep water is transformed back to lighter water and return to the ocean surface. However, the mechanisms that control transformation of these waters are not well understood, and some aspects of the pathways remain controversial.

In a pioneering work, Walin (1982) developed a framework for quantifying water mass transformation rates from one density class to another by air-sea fluxes and mixing. Recent work has pointed out that transformation of abyssal water to surface lighter waters occurs in the ocean interior through mixing. As direct observations of mixing are sparse in the ocean, the impact of mixing on water mass transformations remain largely unexplored. Numerical models are useful tools for exploring complex processes that are not well observed. The underlying dynamical model for the MOM5-TOPAZ simulations used in this study is a one-degree (with equatorial refinement) circulation model with 50 vertical layers. Surface boundary fluxes of buoyancy and momentum have been calculated using the CORE-II product, with normal-year (repeating seasonal cycle) forcing. By employing two water mass transformation diagnosis methods, namely kinematic and process methods (Griffies, 2012), we estimate the contribution of resolved transport, parameterized meso- and submeso-scale transport, surface air-sea fluxes, penetrative shortwave radiation, vertical diffusion, lateral diffusion, and other physical processes to water mass transformation in the global oceans. We also investigate the seasonal and spatial patterns of water mass transformation and its relation to MOC. The analysis will be global but the focus will be on the shallow overturning circulation.

Wed-212

Observations of Interannual Equatorial Fresh Water Jets in the Western Equatorial Pacific

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Surface and subsurface salinity and temperature measurements at 137oE, 147oE, and 156oE since the late 1990s from the western equatorial Pacific TRITON moored array indicate that the large interannual sea surface salinity (SSS) fluctuations there change little with depth over the top 50 m of the water column. Beneath this surface layer the SSS signal decreases and is usually much smaller at about 100 m depth. The isothermal layer depth (ILD) ranges from about 50–70 m and estimates of dynamic height relative to the ILD indicate a near-surface salinity-driven contribution to the monthly sea level anomaly that is uncorrelated with, and smaller than, interannual sea surface height (SSH) estimated from altimeter data. Despite the smaller size of , its meridional gradient dominates the total sea level meridional gradient and thus the corresponding shallow equatorially-trapped interannual fresh water jet dominates the near-surface zonal interannual flow. This jet-like flow has a meridional scale of only about 2–3o of latitude, an amplitude of 23cm/s, and is associated with the zonal back and forth displacement of the western equatorial warm/fresh pool that is fundamental to El Niño. The jet is not forced by the interannual fresh water surface flux but rather by wind stress anomalies that are mostly east of the warm/fresh pool edge during La Niña and mostly west of it during El Niño. Calculations show thatAquarius satellite SSS data match the TRITON in situ data well and that the satellite SSS can be used to estimate hence geostrophically.

Wed-213

On the formation of the South Pacific Subtropical Dipole mode

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In this study, the authors investigate the formation process of the South Pacific Subtropical Dipole (SPSD) mode. The SPSD is the dominant mode of the sea surface temperature (SST)-surface wind covariability in the SP after removing the ENSO-related signals. A positive phase of SPSD is characterized by warm SST anomaly (SSTA) west to coast of South America and cool SSTA in its southwest, overlaid by cyclonic wind anomalies. The northwest wind anomalies weaken the mean southeast trade winds and increase the SSTA in the northeast pole of SPSD through decreasing evaporation and latent heat loss. The southeast wind anomalies advect dry air to the southwest pole, which reduces the SSTA there by increase the latent heat loss. The oceanic horizontal advection also contributes to the SSTAs in the southwest pole during the beginning stage of SPSD. The positive SPSD is accompanied with warm SSTA west to New Zealand and cool SSTA in Tasman Sea. Latent heat flux plays a leading role in forming these SSTAs, too, while oceanic horizontal advection has secondary contributions. SPSD peaks in austral summer (January-March) but its appearance is not dependent on ENSO. SPSD may influence the tropical Pacific climate, which needs further studies.

Wed-214

Response of the tropical Indian Ocean to radiative forcing

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The Indian Ocean dipole (IOD) plays a key role in the climate system of Indian Ocean and its nearby, it can be characterized by opposite sea surface temperature (SST) anomaly between the tropical western Indian Ocean and tropical south-eastern Indian Ocean. Based on the experiments for the past half century with GFDL-CM3, this study investigates the response of the tropical Indian Ocean under greenhouse gas (GHG) and aerosol forcing. Results show that the GHG forcing causes a positive IOD (pIOD)-like pattern in the tropical Indian Ocean, with enhanced warming in the west and reduced warming in the east, accompanying with weaker Walker circulation and easterly anomalies of surface wind along the equatorial, which leads to a shoaling thermocline in the east. In contrast, the aerosol effect causes an negative IOD (nIOD)-like pattern in the tropical Indian Ocean, with enhanced(reduced) coolling in the west(east), associated with enhanced Walker circulation and thermocline deepening in the east, which is opposite to GHG effect.

Wed-215

Rossby and Kelvin Waves Link the Tropical Oceans and Antarctic Climate

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During the past three decades, tropical sea surface temperature (SST) has shown dipole-like trends, with warming over the tropical Atlantic and Indo-western Pacific but cooling over the eastern Pacific. Recent studies link climate changes around Antarctica to the SST of tropical oceans. In this study, observational, reanalysis datasets and a hierarchy of atmospheric and coupled models are used to assess the impacts and the dynamical mechanisms of these teleconnections.

Both the observations and models simulations reveal robust links between the tropical SST anomalies and the Antarctic atmospheric circulation changes, with teleconnections from the Pacific, Atlantic, and Indian Oceans making different contributions. Tropical Atlantic warming, Indian Ocean warming, and Eastern Pacific cooling are all able to deepen the Amundsen Sea Low located adjacent to West Antarctica, while Western Pacific warming increases the pressure to the west of the international date line, encompassing the Ross Sea and regions south to the Tasman Sea. In austral winter, these tropical ocean basins work together linearly to modulate the atmospheric circulation around Antarctica.

By comparing simulation results using a comprehensive atmospheric model, an idealized dynamical core model, and a theoretical Rossby-wave model, we show that these teleconnections critically depend on stationary Rossby-wave dynamics, and are thus sensitive to the background flow, in particular, the sub-tropical/mid-latitude jet. Near the jets, wind shear is amplified, which strengthens the generation of the stationary Rossby waves. On the other hand, strong anticyclonic curvature on the poleward flank of the jet creates a reflecting surface. As a consequence of the Rossby-wave dispersion relationship, the jet edge may reflect stationary Rossby-wave trains, serving as a wave-guide. Our simulation results suggest that a deeper understanding of the tropical-polar teleconnections requires a better estimation of the atmospheric jet structures.

Further analyses and coupled model simulations indicate that the recent observed SST changes in different tropical-ocean basins are linked with each other on decadal time scales. The tropical Atlantic warming may heat the Indian Ocean and drives a La Niña-type response in the tropical Pacific through Rossby and Kelvin waves dynamics and atmosphere-ocean interactions. On the other hand, the La Niña-type SST changes may nagatively feedback by cooling the Indian Ocean and tropical Atlantic. These tropical inter-basin teleconections further complecate the mechanisms of the tropical-polar teleconnections.

These teleconnections establish a physical pathway from the tropical-ocean decadal variability to the Antarctic climate. It helps to explain several recent observed climate changes around Antarctica, including the sea ice

increase and redistribution, the abrupt warming over the West Antarctica and Antarctic Peninsula, and the cyclonic ocean circulation changes over the Ross Sea, etc. Additianaly, these teleconnections may further contribute to the accelarated land ice melting around the West Antarctica, and thus potentially impact on the sea level change.

Wed-216

Changes in temperature and salinity in the Baltic Sea 1986-2015

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The Baltic Sea is a unique basin of the North-Eastern Atlantic. It is shallow, well-stratified and semi-enclosed sea, which is connected to the open ocean (North Sea) via narrow and shallow Danish Straits. The sea has a positive freshwater flux and in combination with limited water exchange with the open ocean, the water in the Baltic is brackish. The water column has a three layer structure in summer: warm and fresh upper mixed layer, cold and saltier intermediate layer, and warmer and saltiest deep layer. Water column is mostly mixed down to the permanent halocline at 60-80 m depth during winters. The ecosystem of the Baltic has been described as very vulnerable to the changes in temperature and salinity. Moreover, consequences of eutrophication, such as toxic algae blooms or hypoxia, are linked to the hydrography.

Due to small volume, the dynamics of the sea is largely controlled by the prevailing air masses and therefore changes in atmospheric conditions impact the Baltic Sea quite rapidly. The rise of air temperature in the Baltic region and corresponding rise of water temperature in recent decades have been detected and reported by numerous studies. Most of the studies are based on the satellite-derived sea surface temperature or (near) coastal time-series. However, estimates based on in-situ data from offshore areas are missing. Thus, long-term trends and variability in the subsurface layers are largely unknown. Decadal changes in salinity in the Baltic Sea depend on the fresh water discharge and on the water exchange intensity between the North Sea and the Baltic Sea.

The aim of the present study was to investigate trends and decadal variability of temperature and salinity in the open Baltic during last 30 years. All available data from eight selected areas at different sub-basins of the Baltic Sea were put together. The data set under investigation includes data from ship-based CTD (including available data from Soviet Union vessels), thermosalinographs (ferryboxes) and moored/fixed instruments.

The warming observed by satellites can be confirmed by statistically significant temperature trend in the upper layer in most of the selected areas by magnitude of 0.04-0.05 °C decade-1. Similar temperature trend can be detected in the sub-halocline water in several basins. Latter might be a result of the upper layer water warming in the North Sea, which is the source water for the deeper layers of the Baltic. Salinity in the deeper layers of the Baltic has been increased while the trends in the upper layer were statistically insignificant or rather slightly negative. Salinity changes in the deep layers have rather pulsating nature though: it is strongly related to the so called Major Inflows that have occurred once a decade since eighties (1993, 2003 and 2014).

Wed-217

Atmospheric response to mesoscale ocean eddies and its feedback onto the ocean

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It has been widely recognized that mesoscale ocean eddies play an important role in the mixing and transport of water properties. However, their direct effects on the overlying atmosphere are not completely understood. Determining the impact of the mesoscale ocean eddies on the atmosphere may have important implication for improving weather and seasonal climate forecast. We examine this impact using both satellite derived observations and high-resolution climate model simulations in the Kuroshio extension region. Our results show that oceanic eddies produce clear imprints in surface wind speed and precipitation, as well as turbulent air-sea heat fluxes and planetary boundary layer height. We further demonstrate that the eddy impact is enhanced during passage of winter storms in the region, suggesting an interaction between atmospheric synoptic storms and ocean mesoscale eddies. We also examine effects of the ocean mesoscale eddy – atmosphere (OME-A) feedback on the ocean by analyzing and comparing ocean eddy statistics in high-resolution climate model simulations with and without OME-A feedback. The results suggest that OME-A feedback can have a significant impact on ocean eddies, which in turn affect the Kurishio front and current.

Wed-218

Simulating the diurnal cycle of precipitation over South America using convective parameterization of ensemble weighted approach for the regional model BRAMS

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The purpose of this work was improve the skill of the Center for Weather Forecasts and Climate Studies of the National Institute for Space Research (CPTEC/INPE) regional model Brazilian developments on the Regional Atmospheric Modeling System (BRAMS) over South America, considering an optimization problem applying the meta-heuristic Firefly algorithm (FY) to weight an ensemble of rainfall forecasts from daily precipitation simulations. The summertime characteristics of January 2006, 2008 and 2010 were performed using an ensemble of simulations using different choices of closures, representing different formulations of dynamic control (the convection modulation by the environment) in a deep convection scheme with 20 km resolution. The purpose of this study was to generate a set of weights to compute a best combination of the convective scheme hypothesis. The application and validation of the methodology was carried out using daily precipitation fields, defined over South America and obtained by merging remote sensing estimations with rain gauge observations and precipitation field estimated by the Tropical Rainfall Measuring Mission satellite. The quadratic difference between the model and observed data was used as the objective function to determine the best combination of the ensemble members to reproduce the observations. Weights were obtained using the FY and the mass fluxes of each closure of the convective scheme were weighted generating a new set of mass fluxes. The validation of the methodology was carried out using classical statistical scores. The model had produced heating and drying rates more realistically and consequently precipitation simulations closest to the observations. The diurnal cycle of precipitation during the analyzed period was better simulated, reducing the lag between the observed precipitation and the simulation. The bad representation of the diurnal cycle by the models is a know problem, with precipitation simulation occurring hours before the observed in the tropical region. Consequently, it impacts strongly the seasonal forecasts of precipitation. In addition to the improvement of the BRAMS diurnal cycle, a better skill of the model to simulate meteorological variables was observed, as temperature near surface and sea level pressure, as closest to the observation as compared with the ensemble mean calculation of the control run.

Wed-219

Pathway of the Kuroshio water traveling to the Bering Sea in a western North Pacific eddy-resolving model analyzed with the tangent linear and adjoint models

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Transport of Kuroshio water to the Bering Sea is a part of the North Pacific meridional overturning circulation and consequently can play an important role in the water cycle. In this study, we analyze the pathway of the Kuroshio water that travels to the Bering Sea simulated by a western North Pacific eddy-resolving Ocean General Circulation Model (OGCM) using the product of a passive tracer by its adjoint variable. We trace the water that is advected eastward across 140ºE by the Kuroshio and travels to the Bering Sea without going out of the model domain, which spans from 117ºE to 160ºW and 15ºN to 65ºN. After being advected eastward by the Kuroshio Extension, the water deviates northward from the Kuroshio Extension mostly before reaching 160ºE, and moves back to the west through eddy activities. It, then, enters the quasi-stationary jet that flows at 43ºN,-155ºE, or the Isoguchi Jet, and is transported eastward along the subarctic front. It, then, moves northward through the gaps between the western subarctic gyre and the Alaskan gyre, and enters the Bering Sea. We also confirm validity of the pathway using the Four-dimensional variational Ocean Reanalysis for the western North Pacific over 30 years (FORA-WNP30), in which the realistic ocean variation is reconstructed through the eddy-resolving 4DVAR ocean data assimilation system used in the operational ocean forecasts in the Japan Meteorological Agency (JMA). The reanalysis indicates that high salinity water migrates northward through gaps of the subarctic gyre, which is consistent with the analyzed pathway.

Wed-220

Enhancement of the southward return flow of the Atlantic Meridional Overturning Circulation by data assimilation and its influence in an assimilative ocean simulation forced by CORE-II atmospheric forcing

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We examined the difference in the Atlantic Meridional Overturning Circulation (AMOC) mean state between free and assimilative simulations of a common ocean model using a common interannual atmospheric forcing. In the assimilative simulation, the reproduction of cold cores in the Nordic Seas, which was absent in the free simulation, enhanced the overflow to the North Atlantic and improves AMOC with enhanced transport of the deeper part of the southward return flow. This improvement also induced an enhanced supply of North Atlantic Deep Water (NADW) and caused better representation of the Atlantic deep layer despite the fact that correction by the data assimilation was applied only to temperature and salinity above a depth of 1750 m. It also affected Circumpolar Deep Water in the Southern Ocean. Although the earliest influence of the improvement propagated by coastal waves reached the Southern Ocean in 10-15 years, substantial influence associated with the arrival of the renewed NADW propagated across the Atlantic Basin in several decades. Although the result demonstrated that data assimilation is able to improve the deep ocean state even if there was no data there, it also indicated that long-term integration was required to reproduce variability in the deep ocean originating from variations in the upper ocean. Our result thus provides insights on the reliability of AMOC and the ocean heat storage in the Atlantic deep layer reproduced by data assimilation systems.

Wed-221

Intraseasonal coastal upwelling signal along the southern coast of Java observed by Indonesian tidal station data

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Sea level variations along the coasts of Sumatra and Java were investigated to understand the coastal upwelling signal that is linked to local sea surface temperature (SST) variability. We used Indonesian tidal station data together with satellite SST data and atmospheric reanalysis data. The sea level variations along the southern coast of Java have a significant coherence with remote wind, local wind, and local SST variations, with an intraseasonal time scale of 20-50 days. Assuming that a coastal upwelling signal would appear as a significant sea level drop (SLD), we focused on intraseasonal-scale SLD events in the data. Significant upwelling signals are frequently observed during both the boreal summer and winter. To evaluate the impact of the coastal upwelling on local SST, we examined statistical relationships between sea level and SST variations off the coast of Java. The results demonstrated that events that occurred in boreal spring and summer were associated with local SST cooling. The horizontal distribution of the SST cooling was analogous with annual-mean SST, suggesting the importance of intraseasonal-scale coastal upwelling in forming the climatic conditions of the southeastern tropical Indian Ocean.

Wed-222

Eastern Indian Ocean Upwelling Processes Modulated by the Equatorial Foring

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Eastern boudary of Indian Ocean witnesses the various upwelling processes, including the local wind driven upwell south of Java island, the intraseasonal upwelling remotely forced by MJOs along equatorial Indian Ocean, the sporadic upwelling associated with large amplitude internal solitions in the Andaman Sea, and the isolated upwelling patch over Sri Lanka dome and etc.. All these upwelling links the physical and biological processes together and help build up the unique habitat in the coastal region, which supports our society and human beijing. Not much is understood yet for the above complex upwelling process, particularly its interaction with the biological/ecological processes. Along with the kicking off of IIOE-2, Eastern Indian Ocean Upwelling Research Initiative (EIOURI) is on its track towards implementation. Based on some pilot cruises study, some exciting preliminary restults are introduced here, including South Java upwelling based on cruise data, the intraseasonal/seasonal South Java upwelling based on mooring data, the seasonal locked internal wave inducing upwelling on the Andaman Sea shelf. Particularly we show the measurements from video plankton recorder which can show the simutaneous measurements of physical and biological parameters. We emphasize here the upwelling along eastern Indian Ocean boundary is strongly modulated by the equatorial Indian Ocean forcing at intraseasonal and semi-annual time scales. Yet a lot more open questions are needed to be addressed in EIOURI.

Wed-223

Impact of riverine nutrients on global marine biogeochemistry in a changing climate

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Riverine transport of nutrients (N, P, Si, Fe) and carbon from land to the costal ocean alters marine primary production and air-sea CO2 exchange, not only regionally but also globally. However, this process is either ignored or poorly represented in state-of-the-art Earth system models. Here we aim at assessing the impact of riverine nutrients and carbon on regional and global marine biogeochemistry and air-sea CO2 exchange in the context of a changing climate. For this purpose, we implemented the Global NEWS 2 (GNEWS 2) river nutrient export data into the marine biogeochemical component of the Norwegian Earth System Model (NorESM) and performed a set of transient historical and 21st century climate simulations using four different riverine nutrient input configurations: deactivated, fixed at contemporary level, transient scaled to prognostic runoff, and transient following future projections of GNEWS 2. Seasonal and decadal consequences on the marine biogeochemical cycles, such as nutrient dynamic, oxygen minimum zone, and ocean acidification will be assessed, especially at continental margins and climate change-sensitive regions. Regional and global changes in biologically-mediated carbon sinks as projected by different riverine schemes will be quantified.

Wed-224

Mechanisms and weather-related variability of ocean cross-frontal exchange south-west of Spitsbergen in winters 2011-2014

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On the south-west of the Svalbard Archipelago located between the Nordic Seas and the Arctic Ocean two poleward flows: the slope-attached West Spitsbergen Current carrying warm and saline Atlantic water and the shelf-located South Cape Current transporting fresh and cold water from the Barents Sea are separated by the shelf break front. To explain water dynamics in the four winters we used several time series from moorings deployed by IMR and IOPAN at depths between 74 m and 1000 m, ECMWF ERA-Interim weather analysis and data from tagged seals collected by the Norwegian Polar Institute and made available through the WOD13 NOAA product. Continuous time weather regimes for the winter seasons were obtained from the Atmospheric Flow Analogues for Climate Change project website.

It is clear these four winters (defined as DJFM period) differ according to dominating weather pattern. Easterlies constitute majority of wind directions every winter, yet they are turned more to the north (north-easterlies) in 2011 and 2013, to the south (south-easterlies) in 2012 and exceeded 20 m/s in 2013 and 2014, when they are almost straight from the east. Furthermore, in some periods of 2011 and 2012 south-westerly winds occurred of speed exceeding 15 m/s, while in 2013 and 2014 there were no strong winds from this direction. This is connected with the switch between the winter NAO index – from more negative phase in 2011 to strict positive phase in 2014, with various fraction of Scandinavian Blocking and Atlantic Rigde regimes in 2012 and 2013.

This implicated the analysis of calculated Ekman transport. Firstly, we used two drag coefficient formulas depending on the wind speed. We also calculated the cross-shelf component of the Ekman transport, orthogonal to the shore and related to the alongshore wind stress.

Water properties and changes in current velocity and directions were tracked in detail in time series collected by instruments located at various depths on the slope in 2010-2011. Warmer and more saline water was also trackable in vertical profiles collected by one seal diving along the shelf break. In that particular winter the upper layer on the shelf was dominated by cold and fresh water of the Arctic provenance and co-existing sea-ice. This situation was unique compared to the following years when there was almost no sea-ice on the shelf and water was significantly warmer and saltier.

The wind-induced events (upwellings) cannot explain all the cases when warm and saline water was found on the shelf, particularly in periods of dominating zonal winds. The eddy overturning - transport caused by cross-shelf eddies, averaged over several days or weeks, may be an explanation as described in the previous studies.

Understanding the cross-frontal exchange mechanisms and their variability in the Arctic where warmer and more saline water is often covered by cold and fresh surface layer is important for bio-chemical structure, marine biotas, glaciers and sea-ice. It also has strong climatic implications.

Wed-225

An investigation on Credible Strategy of Coral Reef Bleaching and their Management using Geospatial Approach for Gulf of Mannar

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Coral reefs are the vital ecosystems sometimes known as rain forests of the sea also as it provides the source of food security and livelihood options for hundreds of millions people and serves for coastal defense and tourist hotspots also. The review study on this topic reveals some facts like Sea temperatures in the tropics has already increased by almost 1°C over the past 100 years and are currently increasing at the rate of approximately 1-2°C per century. Reef-building corals, which are central to healthy coral reefs, are currently living close to their thermal maxima. They become stressed if exposed to small slight increases (1-2°C) in water temperature and experience coral bleaching. Corals dies in a greater amount immediately if coral bleaching event happened, which may cause stretching across thousands of square kilometers of ocean. Bleaching events in 1998, the worst year on record, saw the complete loss of live coral in some parts of the world. In the present study we are reviewing our understanding of coral bleaching in the Gulf of Mannar (GoM) which is one of the four important coral reefs in India lying between the southeastern tip of India and the west coast of Sri Lanka having coordinate 8.47°N 79.02°E (study area) and trying to observe and examine the intensity and extent of parameters such as surface sea temperature, heat content, sea surface height anomaly, photosynthetically active radiation (PAR), hotspots, and North Indian Ocean Dipole events in coral bleaching.

Keywords: Sea temperature, bleaching, Gulf of Mannar

Wed-226

A new mechanism for generating upwelling

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In coastal areas with wide shelf such as China Seas, the wind-driven Ekman transport is not the essential process for upwelling, while the tidal mixing front is identified as the vital factor triggering the formation of the upwelling. According to this understanding, we find the summertime upwelling off the west coast of Hainan Island which is regarded as downwelling areas for decades, which is supported by satellite remote sensing sea surface temperature, and confirmed by both historical field observations and numerical modeling. In the East China Sea, the tidal mixing plays a predominant role in inducing the upwelling. The influence of wind on upwelling is relatively small. In the coastal waters near Zhoushan Islands, the wind forcing exerts negative influences on upwelling by weakening the encroachment of TWC onto the continental shelf, which exceed the positive effects of Ekman pumping. In the Yellow Sea, the upwelling in summer can provide rich nutrients for the algae bloom, which is a serious problem in the Yellow Sea since 2008. The new mechanism for generating upwelling in the China Seas may be applied to other coastal areas of global ocean.

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Contrasting trends of marine phytoplankton in the tropical Indian Ocean

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Marine phytoplankton plays a central role in global biogeochemical cycles, forms the base of the marine food web, and regulates the global climate. The tropical Indian Ocean hosts one of the largest concentrations of marine phytoplankron during boreal summer. Also, this region has been experiencing the largest trends in sea surface temperatures among the tropical oceans, during the past-half century. We analyse long-term trends in marine phytoplankton over the Indian Ocean using multi-sensor blended satellite data, a suite of CMIP5 historical simulations and an Earth System Model. The results suggest contrasting trends in chlorophyll concentrations over the Indian Ocean with a decreasing trend over the western Indian Ocean and increasing trends over the eastern equatorial Indian Ocean. The western and the eastern equatorial Indian Ocean are the sites of important fisheries such as the tuna and are important in terms of biological diversity, and hence trends in marine primary productivity in these regions are crucial to understand.

The significant decline in chlorophyll concentrations over the western Indian Ocean is found to be linked to rising sea surface temperatures which result in enhanced ocean stratification thus, leading to suppressed mixing of nutrients from subsurface to the surface. On the contrary, increasing trends in marine productivity over the eastern tropical Indian Ocean are observed, despite the basin-wide warming and a decrease in the winds over the region. This suggests that the large-scale ocean dynamics must be playing a dominant role in altering the phytoplankton blooms. Hence, we also examine the possible ocean dynamics including the Indonesian throughflow which might drive the phytoplankton variability along this region.

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Modeling coastal biogeochemistry response in the Northern Humboldt Current System (NHCS) during ENSO events

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The impact on primary production and the biogeochemical response to intense ENSO events in the Northern Humboldt Current System is assessed with an eddy-resolving coupled physical-biogeochemical model. El Niño (EN) 1997-1998 and La Niña (LN) 1999-2000 are well reproduced, inducing large spatial and temporal variability of biogeochemical tracers at three important upwelling coastal centers along the Peruvian coast (Chimbote 9.4° S, Callao 12.1 °S, and Pisco 14° S). Primary production appears to be limited by nutrients during EN phase at all locations, whereas during LN phase, Eddy Kinetic Energy (EKE), due to intensification of the Trade Winds, plays a key role in leaking the coastal nutrient inventory by advecting nitrogen from the nearshore region to the oligotrophic ocean at the southernmost location, leading to a reduction of biological production in the coastal zone. Our model results are consistent with the observations and show that the low nitrate concentrations are mainly a consequence of this horizontal advection of warm, nutrient-poor waters and also due to the sinking of the nutricline during the onset of El Niño. Results suggest that denitrification contributes with 60% of the total nitrogen removal during EN phase and an imposition of anammox (70%) during LN phase. However, during the neutral- ENSO phase the contribution of denitrification decreases at the rate of 8% per degree of latitude from North to South with a similar contribution north of Chimbote. First step of nitrification and denitrification are simultaneous and balance each other in terms of coastal nitrite content through ENSO phases. The outgassing of the greenhouse gas nitrous oxide (N2O), an intermediate product of denitrification, is constrained and enhanced during EN and LN phase respectively. It was found that all of these processes are modulated by the spatiotemporal variability of oxygen in the environment. The Oxygen Minimum Zone (OMZ) experiences a sinking and a strong offshore displacement (on average 200m deeper and 80 km offshore than normal conditions) during the El Niño (ventilation phase). In contrast, during La Niña, the OMZ outcrops intercepting the continental shelf.

Wed-229

The interannual variability of the Nha Trang upwelling

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The Nha Trang upwelling located near the central Vietnamese coast is the one of the main dynamical processes of the South China Sea oceanic circulation in boreal summer, and has a strong influence on the marine ecosystems, from planktonic ecosystem to halieutic resources. We performed a group of sensitivity simulations over the South China Sea from 1991 to 2000 with the ROMS numerical ocean model at 1/12° resolution to analyze the interannual variability of this upwelling. For that we constructed a modeled SST-based index to characterize the upwelling variability. Three years 1994, 1999, 2000 are found to have strong upwelling compared to the rest. In agreement with recent studies about the relation between the upwelling location and El Nino, in 1998, our model results show the existence of an abnormal moderate upwelling which appears further north at about 15N compared to around 12N in the other years. We then examine the respective contributions of atmospheric forcing, large scale oceanic forcing, internal variability and river discharge in this variability, as well as the role of ENSO.

Wed-230

Comparison of observed and modelled sub-grid-scale sea-ice thickness distributions in the Weddell Sea, Antarctica

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Sea ice is an important part of Earth's climate system, because it regulates the amount of energy being transferred between the atmosphere and oceans. Analogously, an advanced knowledge of mechanisms redistributing the sea ice is required for an accurate description of the state and evolution of climate. Due to the relatively coarse horizontal resolution of the sea-ice component of a climate model, its sea-ice thickness is typically parameterised as a discrete sub-grid-scale sea-ice thickness distribution. Furthermore, due to the lack of observations, the realism of this sea-ice thickness distribution is not well known. So far, most studies assessing the modelled sea-ice performance have focussed on grid-cell averaged sea-ice thickness by comparing it with observations, which have been either collected during irregular field measurements or processed from satellite data with a significant uncertainty. In particular, Antarctic sea-ice thickness observations are very sparse. To address this shortcoming, we have collected a novel set of ship-borne and satellite-derived sea-ice thickness observations, and compare them with a modelled multi-category sub-grid-scale sea-ice thickness distribution. Comparison of these data helps to identify model weaknesses and provides possibilities to improve the model skill. The ocean model used in this study is the latest version of NEMO-3.6, which is the ocean component of several climate models contributing to CMIP6. The sea-ice model coupled with NEMO is LIM3 with a sub-grid-scale sea-ice distribution and prognostic sea-ice salinity among other physical and numerical improvements compared to the previous version LIM2. For this study, we have completed a simulation from 1979-2015 in a stretched global tripolar grid (ORCA025), with a typical resolution of 10-20 km in the polar regions. In terms of observations, we have collected sea-ice thickness measurements since 2012, using an automatic electromagnetic (EM) device installed on the icebreaker S.A. Agulhas II during her voyages from Cape Town to the Weddell Sea. Furthermore, we have estimated the sea-ice thickness based on waveforms from the SIRAL-2 SAR Altimeter flying onboard the Cryosat-2 satellite. We present results from meridional ship transits between the ice margin and the continental ice shelf, and zonal transits along the shelf in December-February 2013/14. During these transits the sea-ice thickness grew from 0.5 m at the ice margin to 1 m at about 200 km from the shelf. This was followed by an extremely deformed and 1.5-2 m thick ice near the shelf. For the first time, we link the SAR altimeter data to sea-ice induced forces in the ship scale. The areas of high ship loads are distinguishable in maps derived from the waveforms, which shows a promise for SAR altimeter based Antarctic sea-ice charts.

The NEMO-LIM3 grid-cell averaged sea-ice thickness has been compared to the EM measurements. In large spatial scales, the two data sets agree qualitatively well. Next, we will sample the EM based sea-ice thickness into the NEMO-LIM3 grid and calculate observation-based thickness distributions to be statistically tested against NEMO-LIM3 thickness distributions. This will provide much better insights into the small-scale processes, such as atmosphere-ocean momentum and heat exchange, than by analysing the grid-cell averages.

Wed-231

UNDERSTANDING THE MECHANISM OF SEASONAL UPWELLING AT THE SOUTHERN COAST OFF MAKASSAR STARIT

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The mechanism of temporary upwelling in the southern coast off Makassar Strait, Indonesia is determined not only by the wind-driven coastal upwelling during southeast monsoon (SEM) butalso previous research suggested the influence due to the meeting of two current systems. During SEM, water mass of the Flores Sea in eastern area meets the throughflow water coming from northern off Makassar Strait and flow together to Java Sea. The first mechanism is well proven but the second one need more investigation.Twenty years of data result obtained from numerical simulation over the Makassar Strait and adjacent waters are used to describe the seasonal characteristic and mechanism of upwelling in this region. The 3D baroclinic ROMS (Regional Ocean Model System) from Rutgers version was simulated from 1995 to 2014.

The climatological results show the existing of upwelling clearly identified by the decreasing of sea surface temperature ± 2 °C and increasing of surface salinity ± 0.5 Psu than in surrounding waters. The evidence of upwelling starts on June, maximum intensity in August and disappears on September following the easterly wind during southeast monsoon. The mixed layer depth becomes shallow and there is an uplift water from the thermocline to the surface. The instability of water coloum was detected from the Brunt-Väisäläfrequency (N2) and Richarson number (Ri). By calculating the vorticity and investigate the current circulation we detect the eddy formation in southern part of the Celebes Island at Java Sea and Flores Sea and suggested due to the meeting of current system. We found the Ekman transport is moving to the southern direction offshore of Celebes Island and produces the upwelling, while the effect of eddy formation enhanced the upwelling in the same direction.

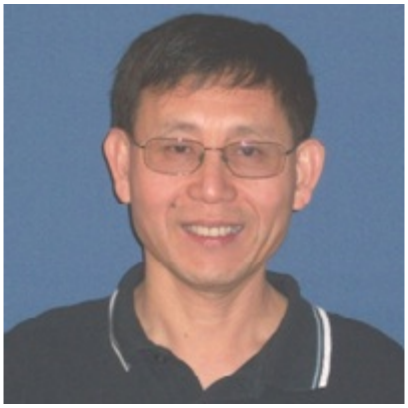
Keyword: eddy formation, Ekman transport, Makassar Strait, wind-driven coastal upwelling, southeast monsoon.

CLIVAR Open Science Conference

Day 4 - Thursday, 22nd September 2016

Keynote talk

Keynote Speaker **Thursday, 22nd September 2016** **17:00hrs**



Dr. Wenju Cai

Dr. Wenju Cai specializes in global climate variability and change research. With 25 years of research and science leadership and experience, his interest spans from identification of modes of climate variability (such as El Nino-Southern Oscillation, the Indian Ocean Dipole), their mechanisms, and their response to greenhouse warming, to climate detection and attribution.

ENSO and greenhouse warming

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The El Niño-Southern Oscillation (ENSO) is the dominant climate phenomenon affecting extreme weather conditions worldwide. Its response to greenhouse warming has challenged scientists for decades, despite model agreement on projected mean state changes. Recent studies have provided new insights into the elusive links between ENSO and Pacific climate mean-state changes. The projected Walker circulation slow-down is expected to weaken equatorial Pacific Ocean currents, boosting the occurrences of eastward propagating warm surface anomalies that characterize observed extreme El Niño events. Accelerated equatorial Pacific warming, particularly in the east, is expected to induce eastern equatorial Pacific extreme rainfall and extreme equator ward swings of the convergence zones, both of which are features of extreme El Niño. The frequency of extreme La Niña is also expected to increase in response to more extreme El Niños, an accelerated Maritime continent warming and surface-intensified ocean warming. ENSO-related catastrophic weather events are thus likely to occur more frequently with unabated greenhouse gas emissions. However, model biases and recent observed strengthening of the Walker circulation highlight the need for further testing as new models, observations and insights become available.

Plenary Oral Presentations

Plenary Session 4 **Thursday, 22nd September 2016** **09:00hrs**

Dr. Michael Alexander

Dr. Michael Alexander is a Research Meteorologist at the Physical Sciences Division of the NOAA Earth System Research Lab in Boulder, Colorado, USA. Currently his three main research foci: air-sea-ice interactions, processes that influence moisture transport and heavy precipitation in the western United States, and climate change including its impact on marine ecosystems. His studies of air-sea interaction include the influence of El Niño on global climate, precursors to El Niño events, and the affects of midlatitude sea surface temperatures and sea ice conditions on the atmospheric circulation.

Modes of sea surface temperature variability in a warmer world

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Climate variability on interannual-to-multidecadal time scales tends to be organized into large-scale spatial patterns that span entire ocean basins and often show global connectivity. Patterns of sea surface temperature (SST) variability on these timescales result from a combination of atmospheric and oceanic processes. These SST anomaly patterns may be due to: i) intrinsic modes of atmospheric variability that imprint themselves upon the SST field via surface energy fluxes and Ekman transport, such as the SST tripole in the North Atlantic; ii) coupled ocean-atmosphere interactions, such as the El Niño-Southern Oscillation (ENSO) phenomenon in the tropical Indo-Pacific with extensions to higher latitudes; and iii) intrinsic oceanic modes, notably the Atlantic Multidecadal Oscillation (AMO). These three broad types of climate patterns may respond very differently in a warming climate. In addition, new patterns may emerge due to climate change. In this talk, we summarize recent findings from the literature and present new results based on model simulations from the Climate Model Intercomparison Project (CMIP) archive and a large initial-condition ensemble of climate change projections conducted with the National Center for Atmospheric Research - Community Earth System Model (NCAR-CSEM). Prospects for continued progress in understanding how climate modes will respond to global warming conclude the presentation.

Dr. Fan Wang

Dr. Fan Wang is a Professor and the Deputy Director of Institute of Oceanology, Chinese Academy of Sciences. Dr. Wang is mainly working on ocean circulation dynamics, including the Pacific low-latitude western boundary currents, tropical ocean circulation, and shelf circulation in China Seas. As one of Principal Investigators, he initiated and constructed the subsurface mooring array in the western tropical Pacific. Dr. Wang was a lead author for the IPCC AR5: latitude western boundary currents, tropical ocean circulation, and shelf circulation in China.

Multi-scale and long-term variability of the western boundary currents in the warming up oceans

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The western boundary currents (WBCs) are strong and narrow oceanic flows locating at the western edge of the world's ocean basins. They balance the Sverdrup transport caused by the wind stress curl in the interior ocean, and are the collector and amplifier of oceanic signals over the whole basin, playing an important role in the global climate system. Changes of these WBCs under global warming scenario have triggered increasingly interests of oceanographers. Recent studies have shown a synchronous surface ocean warming along the path of all subtropical WBCs over the past century that is greater than the global mean, which is associated with the pole ward shift and/or intensification of the WBCs over both hemispheres. A synchronous long-term southward shift of the NEC and the SEC bifurcations in the tropical Pacific is also detected over the past decades. However, climate models appear to project different changes between the northern and southern hemispheres over the 2050-2100 period, which also varies in different basins, indicating the complexity of the ocean circulation change under the global warming scenario. To some extent, the uncertainties in projected changes of climate models are related to the multi-scale variability of the WBCs that has been studied extensively in the past years under the framework of CLIVAR. Mooring observations in the western Pacific by IOCAS revealed significant variability of the WBCs from intraseasonal to interannual time scales, which are also modulated by decadal changes. However, how the WBCs' multi-scale variability responds to the global warming still remains unexplored. On the other hand, the effect of the multi-scale oceanic variability on the climate model projections also needs to be examined.

Dr. Seung-Ki Min

Dr. Seung-Ki Min is an Associate Professor in the School of Environmental Science and Engineering, Pohang University of Science and Technology (POSTECH), Korea. After studying Meteorology for his PhD at University of Bonn in 2006, he worked as a Research Scientist at Environment Canada and the Commonwealth Scientific and Industrial Research Organization (CSIRO) before joining the POSTECH in 2013. His expertise is in understanding and attributing the causes of observed climate changes during the past several decades. His current research interests include changes in weather and climate extremes, global and regional changes in hydrological cycle, and atmospheric and oceanic circulation responses related to climate zone shift under global warming.

Human-caused Indo-Pacific warm pool expansion

Seung-Ki Min (1), Evan Weller (1), Wenju Cai (2), (3), Francis W Zwiers (4), Yeon-Hee Kim (1), Donghyun Lee (1)

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The Indo-Pacific warm pool (IPWP) has warmed and grown substantially during the past century. The IPWP is Earth's largest region of warm sea surface temperatures (SSTs), has the highest rainfall, and is fundamental to global atmospheric circulation and hydrological cycle. The region has also experienced the world's highest rates of sea-level rise in recent decades, indicating large increases in ocean heat content and leading to substantial impacts on small island states in the region. Previous studies have considered mechanisms for the basin-scale ocean warming, but not the causes of the observed IPWP expansion. This study identifies human and natural contributions to the observed IPWP changes since the 1950s by comparing observations with climate model simulations using an optimal fingerprinting technique. Greenhouse-gas forcing is found to be the dominant cause of the observed increases in IPWP intensity and size, while natural fluctuations associated with the Pacific Decadal Oscillation have played a smaller yet significant role. Human-induced changes in the IPWP have important implications for understanding and projecting related changes in monsoonal rainfall, and frequency or intensity of tropical storms, which have profound socio-economic consequences.

Dr. Anny Cazenave

Dr. Anny Cazenave is a Senior Scientist at LEGOS (Toulouse) and Director for Earth Sciences at ISSI (Bern). Research interests: Space Research applied to Earth Sciences and Climate, in particular sea level changes (observations and causes). Lead author of IPCC 4th and 5th Assessment Reports.

Present-day sea level changes at global and regional scales

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The Earth is currently in a state of thermal imbalance because of anthropogenic greenhouse gas emissions. 93% of the associated heat excess is accumulating inside the ocean, the remaining 7% being used to warm the atmosphere and the continents, and to melt sea and land ice. Global mean sea level rise is a direct consequence of ocean warming and land ice melt. In the recent years, availability of different observing systems (e.g., satellite altimetry, Argo, GRACE space gravimetry) have led to significant progress in precisely measuring sea level rise and its components. Today, the global mean sea level budget is often considered as closed, within measurement uncertainties. Besides, physical understanding of processes causing regional sea level variability has significantly improved recently, in particular in the tropical oceans. However, significant challenges remain. For example, are we able to answer key questions such as: what is the deep ocean contribution (below 2000 m; not measured by Argo) to the global mean sea level rise? Can we deduce the deep ocean heat uptake from sea level data and constrain its role in the current Earth's thermal imbalance? Using global sea level or mass budget approaches, can we deduce poorly known contributions such as land water storage? Are sea level trend patterns observed in different oceans mostly due to internal climate variability? Or is the anthropogenic fingerprint already detectable in some regions? In this presentation, we summarize the most up-to-date knowledge about ocean warming, land ice melt and sea level rise. We discuss how different global observing systems, available since 1-2 decades, allow us to close the sea level budget at interannual to decadal time scales. We also discuss the regional variability in sea level and underlying processes. Special highlight will be given to the Arctic region. Next steps in sea level studies and associated requirements will be finally briefly addressed in conclusion

Parallel Orals – Session 4.1

Parallel Session 4.1 Climate Modes

Thursday, 22nd September 2016 - 14:00hrs **Ballroom 1**

4.1-A

Reduced ENSO Variability at the LGM Revealed by an Isotope-enabled Earth System Model

Jiang Zhu (1), Zhengyu Liu (1,2), Bette Otto-Bliesner (3), Esther Brady (3), David Noone (4), Robert Tomas (3), Jiaxu Zhang (1), Alexandra Jahn (5), Jesse Nusbaumer (5), Tony Wong (5)

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El Nino–Southern Oscillation (ENSO) is the most important climate variability at interannual timescale in the climate system. So far, its response to anthropogenic global warming is still inconclusive in the recent Coupled Model Intercomparison Project Phase 5 models. Reconstruction of past climate can serve as a testbed for these climate models used for future projections. It can also provide us the opportunity to study the relationship between ENSO variability and different background climate states. However, model-data comparison in paleoclimate studies is usually not a direct one (e.g., people compare d18O in ocean sediments with ocean temperature and salinity in models), which makes it extremely complicated to interpret the proxy records and to address the possible model-data inconsistencies, as both climate models and proxy data are subject to their own complication and uncertainties.

Disagreement of ENSO variability at the Last Glacial Maximum (LGM, 21,000 years ago) between climate models and paleo-records, and even among themselves, is an excellent example of this complicated indirect model-data comparison. From modeling perspective, half of the Paleoclimate Modelling Intercomparison Project models produce a stronger ENSO at the LGM, with the other half showing opposite results. Moreover, information from multiple proxy reconstructions is also divided. In order to reconcile these contradictions, a better approach is needed, e.g., isotope-enabled climate simulations and a direct model-data comparison.

By utilizing the recently developed water isotope-enabled Community Earth System Model (iCESM), this study makes the first effort to directly compare modeling results with available proxy records with a focus on the ENSO variability at the LGM. Our iCESM simulation suggests a 30% weaker ENSO at the LGM than the preindustrial. The weakened glacial ENSO is consistent with many reconstructions, including d18O record from thermocline-dwelling planktonic foraminifera (Leduc et al., 2009, Paleoceanography). However, our modeling results disagree with d18O records reported by Koutavas and Joanides (2012, Paleoceanography) and Sadekov et al. (2013, Nature Communications): further analysis indicates that the increased variance of d18O in the former study is more likely caused by intensified seasonal cycle, instead of changes at interannual timescale; record from the latter study could be subject to significant uncertainties from the individual foraminifera approach and habitat depth of thermocline-dwelling foraminifera at the core location.

Our isotope-enabled simulation can provide implications for the interpretation of proxy data that is used to infer ENSO changes. Firstly, we find that changes in variance of d18O in ocean sediments are generally a good representation of changes in variance of ocean temperature, with contributions from variance of water d18O and the covariance term negligible. Secondly, changes in total variance of d18O in sediments cannot be simply interpreted as changes at interannual timescale in the eastern equatorial Pacific, because there may be a significant variation in annual cycle. Last but not least, the uncertainties from the individual foraminifera approach and habitat depth of thermocline-dwelling foraminifera can make the interpretation of proxy very complicated in the eastern equatorial Pacific.

4.1-B

Understanding extreme El Niño: the curious case of the 2015/16 event

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An extreme El Niño event is of great societal relevance given its pronounced global impact. Moreover, recent studies have projected an increase in the frequency of extreme El Niño events under greenhouse warming. Yet our knowledge of such an event is incomplete due to the very limited observational sample. Within the short modern observational record, there had only been two exceptionally strong El Niños, the 1997/98 and 1982/83 events, which were not only large in magnitude but also exhibited characteristics that were markedly distinct from other El Niño events. However, in boreal winter of 2015, the world experienced another major El Niño. Based on the intensity of the sea surface temperature (SST) anomalies alone, the 2015 El Niño certainly rivals the 1982 and 1997 events. This immediately poses a question: does the 2015 event fall in the same class as the past two extreme El Niños? Using observational products, we assess the evolution and the various characteristics (e.g., SST indices, zonal phase propagation, westerly wind bursts, rainfall) of the 2015 event, toward a better understanding of what defines an extreme El Niño. The potential role of greenhouse forcing will also be discussed.

4.1-C

Tropical Atlantic decadal variability and how it is affected by external forcing

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Variability in the tropical Atlantic arises from coupled internal variability in the ocean and atmosphere and external forcing. Two major modes of variability have been identified: a zonal mode related to sea surface temperature (SST) anomalies in the southeastern tropical Atlantic and a meridional mode related to an anomalous inter-hemispheric SST gradient associated with latitudinal shifts in the ITCZ location. However, from the limited length of the observational record it is difficult to identify variability on decadal to multi-decadal timescales and analyse how external forcing affects the variability.

In our study, we use a 100-member ensemble of historical (1850-2005) model simulations with the Max Planck Institute for Meteorology Earth System Model (MPI-ESM) to identify patterns of coupled variability between precipitation, atmospheric circulation, and SST. The focus of our study is on anomalous shifts of the ITCZ that are separated into different patterns using an EOF analysis. We differentiate these patterns not only by their spatial distribution, but also by the time-scales associated with them. We analyse how these patterns are triggered, which mechanisms are involved in their development and how they interact with local and remote regions. Therefore we analyse selected patterns of variability under different background conditions.

The large ensemble allows us to do a statistically robust differentiation between internal and externally forced variability. We describe how external forcing modifies the internally generated variability. To investigate these effects, we employ an additional ensemble of model simulations with stronger external forcing (1% CO_2-increase per year for the same period 1850-2005) with 68 ensemble members.

This study provides an insight into the mechanisms of tropical Atlantic variability beyond what can be deduced from observations and thus contributes to a more profound understanding of the variability in the tropical Atlantic in the period since 1850.

4.1-D

An Ensemble Approach to Understanding ENSO Diversity and Climate Change

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ENSO diversity is known to be sensitive to changes in background climate conditions, as well as atmosphere/ocean feedbacks. However, the degree to which shifts in ENSO characteristics can be attributed to external climate forcings remains unknown. Efforts to assess these changes in a multi-model framework are subject to uncertainties due to both differing model physics and internal ENSO variability. New community ensembles created at the National Center for Atmospheric Research and the NOAA Geophysical Fluid Dynamics Laboratory are ideally suited to addressing this problem, providing many realizations of the climate of the 850-2100 period with a combination of both natural and anthropogenic climate forcing factors. Here we analyze the impacts of external forcing on ENSO diversity using four sets of simulations: the CESM Last Millennium Ensemble (CESM-LME), which covers the 850-2005 period and provides long-term context for forced responses; the Large Ensemble (CESM-LE), which includes 20th century and 21st century (RCP8.5) projections; the Medium Ensemble (CESM-ME), which is composed of 21st century RCP4.5 projections; and the GFDL Large Ensemble (GFDL-LE), which includes 20th century and RCP8.5 projections. In the CESM, ENSO variance increases slightly over the 20th century in all ensembles, with the effects becoming much larger during the 21st. Analysis of the CESM-LME reveals that 20th century greenhouse gas (GHG) and anthropogenic aerosol influences on ENSO tend to counteract one another: GHGs tend to strengthen both Eastern and Central Pacific El Nino events, terminate Eastern Pacific El Nino events more efficiently, and enhance Central Pacific El Nino persistence, while the opposite is true for simulations with aerosol forcing only. Under 21st century climate change the effects of greenhouse gases naturally dominate, and with a sufficiently large model ensemble the differences between projections with differing magnitudes of greenhouse forcing become detectable. However, comparison of CESM and GFDL Large Ensemble results shows that the mechanisms for climate change responses differ drastically. Implications for assessing future ENSO responses to external forcing are discussed, as is the detectability of effects from climate mitigation strategies.

4.1-E

Two dominant boreal summer tropical-extratropical teleconnection modes in the Northern Hemisphere in a Warmer World

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Evidence has been emerging that the two dominant tropical-extratropical teleconnection modes in the Northern Hemisphere (NH) during boreal summer are significant sources of climate variability and predictability other the NH extratropics on intraseasonal and seasonal time scales. The Western North Pacific-North America (WPNA) consists of the Hemispheric uniform pattern largely driven by the decaying phase of El Nino and Southern Oscillation (ENSO) and the wave pattern in association with the western North Pacific (WNP) summer monsoon (WNPSM) rainfall anomaly. The circumglobal teleconnection (CGT) is characterized by zonally symmetric seesaw pattern that appears preferentially in summers preceding the peak phase of ENSO and the wave pattern in connection with the Indian summer monsoon (ISM) rainfall anomaly. It is of critical importance to note that the two teleconnections have a global impact by linking convective heating anomalies over the Asian monsoon region with the NH circulation anomalies.

It is noted that the wave pattern of the WPNA has become more important for the extratropical climate variability due to its strengthened relationship with the WNP summer monsoon rainfall since the mid-1970s. On the other hand, the CGT wave pattern has been considerably weakened owing to its weakened connection with ISM rainfall variability.

Analysis of the CMIP5 models' Representative Concentration Pathway 4.5 experiment (RCP 4.5) indicates that the two dominant teleconnection modes will be significantly changed in a warming world. The WPNA is expected to be further enhanced in the latter half of 21st century due to intensification of the WNP anticyclone response to the decaying phase of El Nino but the CGT will be weakened mainly attributable to atmospheric stabilization and weakened relationship with ENSO and ISM.

4.1-F

What controls the divergent projection of ENSO amplitude change under global warming?

Tim Li

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The El Niño-Southern Oscillation (ENSO) is one of the strongest natural variabilities in the earth climate system, yet it is unclear what fundamental factors control ENSO amplitude changes under global warming. Here we show that the fundamental factor that controls the divergent projections of ENSO amplitude change within 20 models that participated in the phase 5 of Coupled Model Intercomparison Project (CMIP5) is the change of climatologic mean Pacific subtropical cell (STC), whose strength determines the meridional width of ENSO perturbations and thus the strength of the thermocline response to wind forcing. The change in thermocline response is the key factor that alters the strength of Bjerknes thermocline feedback and zonal advective feedback, which ultimately cause the divergent ENSO amplitude change. Furthermore, oceanic general circulation model (OGCM) experiments and the CMIP5 multi-model ensemble result show a weakened STC in future projection. Such a change implies enhanced ENSO variability under global warming, which may have a profound socio-economic consequence.

Parallel Orals – Session 4.2

Parallel Session 4.2 Sea Level

Thursday, 22nd September 2016 - 14:00hrs **Ballroom 2**

4.2-A

Dominant modes of natural decadal sea-level variability in the Indian ocean

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The Indian Ocean displays regionally contrasted sea-level trends over the altimeter period, which can have large socio-economical consequences for the fourth of the world population living around the rim of this basin. This trend results from the superposition of anthropogenically driven signals and natural climate variability. The Interdecadal Pacific Oscillation has been identified as the main driver of natural decadal sea-level variations in the Pacific and as a major contributor to the intensified sea-level rise over the western Pacific during the recent decades. In contrast, the Indian Ocean natural decadal sea-level variability, which may obscure the long-term sea-level changes in this basin, remains a largely uncharted territory. Identifying the main patterns of natural decadal sea level variability in the Indian Ocean is hence necessary for climate change attribution purposes but is very challenging from the relatively short satellite record. In this study, we analyse Indian Ocean natural decadal sea-level variations from a large set of observationally derived products (ocean reanalyses and sea-level reconstructions), CMIP3 and CMIP5 pre-industrial simulations. All observational products display very consistent patterns of decadal sea-level variability in the Pacific, but not in the Indian Ocean, most likely because of sparse observational coverage there. In contrast, almost all CMIP simulations exhibit two very consistent mode of natural decadal sea-level variability in the Indian Ocean, which explain a large part the total decadal sea-level variance in this basin. The first mode consists of a dipolar sea-level pattern, with negative signals in the eastern Indian Ocean extending from the northwest coast of Australia to the northern Bay of Bengal and positive signals northeast of Madagascar. This mode is largely driven by the wind variability related to the decadal variations of the Indian Ocean Dipole, which is partly independent from the decadal climate variability in the tropical Pacific. The second mode is completely independent from decadal Pacific variability, and consists of a broad sea-level signature east of Madagascar. This mode is excited by decadal wind variations in the subtropical Indian Ocean, most likely associated with decadal fluctuations of the Mascarene high. The two decadal modes of Indian Ocean sea-level identified in CMIP models are broadly consistent with those deduced from the relatively short altimeter data or from the longer Ocean Reanalysis System 4 (ORAS4) dataset. Sea-level reconstructions generally reproduce the dipolar mode but do not capture the decadal sea-level variability east of Madagascar, presumably due to the lack of long tide-gauge records in this region. This study hence suggests that CMIP outputs analysis can provide some guidance for identifying robust modes of decadal sea-level variability in regions that are not well sampled by observations.

4.2-B

Upper-ocean thermal expansion and contribution to sea level change since 1970: from global mean rise to regional patterns

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Sea level is one of the most difficult aspects of climate change to understand. Its variability and change is an integrated response of various physical components of the climate system and human activities, operating on a broad range of spatial and temporal scales, with significant socio-economic and environmental implications worldwide. Upper-ocean thermal expansion due to ocean heat uptake is a major contribution to the global mean sea level rise observed since 1970s. However, for impact, adaptation and vulnerability assessments, the most relevant information comes from understanding spatio-temporal changes at more regional/coastal scales. Here, we provide an update of our upper-ocean global mean estimates (up to 2015) and expand our work to analyse its spatio-temporal changes since 1970, including comparison to changes in total sea level (from reconstructions and altimetry).

4.2-C

Pacific Sea Level Rise Patterns and Global Surface Temperature Variability

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Since the late 1990s, climate change and sea level rise exhibit two notable features: a slowdown of global surface warming (hiatus) and a rapid sea level rise in the tropical western Pacific. To quantify their relationship, we analyse the long-term control simulations of 38 climate models. We find a significant and robust correlation between the east-west contrast of dynamic sea level in the Pacific and global mean surface temperature variability. The multi-model ensemble mean reveals a 1.91C m-1 and 2.31C m-1 linear regression on interannual and decadal time scales, respectively. Based on this regression, the anomalously fast sea level rise in the western tropical Pacific observed during 1998-2012 indicates suppression of a potential global surface warming of 0.16 0.06C. In contrast, the Pacific contributed 0.29 0.10C to the significant interannual global surface temperature increase in 1997/98. We predict, based on the Pacific dynamic sea level anomalies observed in 2015 relative to 2014, that the strong El Nio in 2015/16 could lead to a 0.21 0.07C jump of global surface temperature.

4.2-D

Sea level variability around Japan during the 20th century simulated by a regional ocean model

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Sea level variability around Japan from 1906 to 2010 is examined by using the Regional Ocean Modeling System (ROMS). The model successfully reproduces observed interdecadal sea level variability along the Japan coast, e.g., high sea level around 1950, low sea level in the 1970s, and sea level rise during the recent three decades. The high sea level around 1950 along the Japan coast is associated with the sea level rise in the western North Pacific. Sensitivity experiments reveal that the high sea level around 1950 is induced by basin-wide negative wind stress curl anomalies over the North Pacific. This atmospheric change is characterized by weakening of the wintertime Aleutian Low. In contrast, the sea level rise during the recent three decades is mainly caused by heat and freshwater flux forcings. Hence, the coastal sea level variability along Japan induced by wind variability is as large as the sea level rise during the recent three decades by heat and freshwater fluxes. It is worth noting that the coastal sea level variability caused by wind stress forcing is relatively small after 1960 compared to the high sea level around 1950. This implies that the high sea level around 1950 is induced by natural variability not by anthropogenic variability. Therefore our results highlight importance of natural variability for understanding regional sea level change even on timescales longer than interdecadal.

4.2-E

Annual sea level changes on the north american northeast coast: influence of local winds and barotropic motions

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Understanding the relation between coastal sea level and the variable ocean circulation is crucial for interpreting tide gauge records and projecting sea level rise. In this study, annual sea level records (adjusted for the inverted barometer effect) from tide gauges along the North American northeast coast over 1980-2010 are compared to a set of data-assimilating "ocean reanalysis" products as well as a global barotropic model solution forced with wind stress and barometric pressure. Correspondence between models and data depends strongly on model and location. At sites north of Cape Hatteras, the barotropic model shows as much (if not more) skill than ocean reanalyses, explaining ~50% of the variance in the adjusted annual tide gauge sea level records. Additional numerical experiments show that annual sea level changes along this coast from the barotropic model are driven by local wind stress over the continental shelf and slope. This result is interpreted in the light of a simple dynamic framework, wherein bottom friction balances surface wind stress in the alongshore direction and geostrophy holds in the across-shore direction. Results highlight the importance of barotropic dynamics on coastal sea level changes on interannual and decadal time scales they also have implications for diagnosing the uncertainties in current ocean reanalysis, using tide gauge records to infer past changes in ocean circulation, as well as identifying the physical mechanisms responsible for projected future regional sea level rise.

4.2-F

Future projection of ocean wave climate change: a community approach to global and regional wave downscaling

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Introduction

Beach erosion and flooding of coastal areas are critical issues for much of the world's densely populated coastline that will likely become increasingly problematic with the changing climate. A warming climate has the potential to not only raise sea level but also to exacerbate coastal hazards of extreme sea level due to changes in storm frequency and intensity. Along open coasts, where wave energy is often the dominant process dictating shoreline positions, changes in mean and extreme wave conditions (height, period, and direction) are likely to alter long-term geomorphic evolution patterns.

A growing number of studies have considered how the global wave climate may respond to climate change based on Global Climate models (GCMs) for different forcing scenarios (or greenhouse emissions). These studies have been carried out independently, using different methods to estimate future wave conditions (Wang and others 2006 and 2014; Mori et al. 2010; Hemer et al 2013a,b; Fan et al. 2013). Within each individual study, only a limited number of climate model simulations were investigated due to limited study scope, resources, and/or availability of suitable climate model data. Individual studies are therefore unable to fully quantify the uncertainty of projected changes in the wave climate. Partly in response to these shortcomings, the Coordinated Ocean Wave Climate Project (Hemer et al. 2013b) was created and supported by the JCOMM/WMO/IOC. A primary objective of COWCLIP is to provide infrastructure to support a systematic, community-based framework that allows for validation and inter-comparison of wave projections, and to make these freely accessible to the scientific community. Here, the primary aim is to 1) present quantitative evaluations of projected global scale wave climates, and 2) to present the framework and preliminary results of regional wave modeling that will provide projections of nearshore wave conditions for use in long-term geomorphic change analyses.

COWCLIP Approach

Phase 1 of COWCLIP was conducted in 2011-2012 using a multi-model and multi-scenario ensemble based on the CMIP3 products and reported by IPCC-AR5. Phase 2 commenced in late 2013 and will summarize a designed ensemble of CMIP5 wave projections for different emission scenarios, including regional projections. Mean and extreme wave statistics along most of the world coasts are being summarized along coasts at a spatial scale of 100 kms; these data sets will be free and openly available to the scientific community.

Results of Global Scale Changes in Wave Climate

Changes in the multi-model annual mean significant wave heights, HS, show consistent projected decrease among models over a larger area and consistent increases over a smaller area. Projected increases are generally limited to the Southern Ocean. Shoreline change is sensitive to directional changes as well. Wave directions are projected to rotate anticlockwise on the northern side of the extra-tropical storm belts. These correspond with projected poleward shifts of storm tracks and are equally relevant to changes in wave heights in consideration of morphodynamic change.

Parallel Orals – Session 4.3

Parallel Session 4.3 Boundary Current Systems

Thursday, 22nd September 2016 - 14:00hrs **Ballroom 3**

4.3-A

The 2014 warm anomalies observed in the eastern boundary current system off southern California

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Time series observations off the southern California coast reveal the anomalous warming in summer 2014. The 2014 warm anomalies in the California Current System are examined from moored observations off Pt. Conception and Del Mar of physical and biogeochemical quantities combined with wind and sea level observations. Enhanced poleward anomalies in alongshore flow, observed already in the preceding year, can provide a precondition of the water column prior to the anomalous warming played in an important role. Concurrent and consistent changes among surface heat fluxes, wind, upwelling intensity, vertical profile of cross-shore

currents, and biogeochemical data will be presented.

4.3-B

Seasonal to interannual variability of the meridional heat fluxes in the South Atlantic

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The South Atlantic ocean is an important conduit for the global meridional overturning circulation (MOC). In a simplified stratified ocean model, one can describe its vertical distribution as composed by an upper layer that carries warmer waters to the north, on top of the North Atlantic Deep Water that flows southward which in turn is above a northward flowing Antarctic Bottom Water. In the South Atlantic, the net balance of such configuration generates a transport of heat and mass to the North Atlantic. Direct measurements of physical parameters such as temperature, salinity, and velocity fields along transatlantic sections would provide us precise estimations of mass and heat transported across the basin. However, such products are costly and therefore not available at a high enough number to resolve at least the low frequency variability at interannual scale. As an alternative, we rely on model output products to determine the mean and evaluate the fluctuations in the oceanic fluxes which are undoubtedly marked by turbulence. In this study, we use a high resolution run of the ocean model HYCOM to estimate the meridional heat fluxes (MHF) across several latitudes along its basin, including the South Atlantic MOC (SAMOC) project line at 34.5oS. This version of the HYCOM model was forced with monthly means of the NCAR/NCEP reanalysis. From those estimates, we are able to evaluate the mean MHF, its errors, the dominant modes of variability from seasonal to interannual, and the heat flux partition between the boundary current and ocean interior. This method of estimating MHF is an adaptation of the direct method based on the zonal and vertical integration of the temperature and velocity fields along a chosen latitude, obtained from in situ measurements. Alternatively, MHF is also a balance between the meridionally integrated surface heat fluxes obtained from air-sea fluxes and the time rate of change of the oceanic heat storage. This method is known as the surface heat budget method. The global net heat and the heat flux components (radiative and turbulent) data will be provided by the OAFLUX project and the heat storage is estimated from the sea surface height based on altimeter data, distributed by AVISO. Our objective is to compare the MHF obtained from the model to the estimates obtained by the surface heat budget. We aim to examine how each method resolves the seasonal to interannual variability in the South Atlantic and what are the limitations of each one.

4.3-C

Response of biological production to the strengthening of the upwelling-favorable Trade Winds in the Northern Humboldt Current System: A Modeling Study

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In response to global climate change, upwelling-favorable winds have increased in mostEastern Boundary Upwelling Systems, such as one of the most productive regions of theworld oceans, the Humboldt EBUS which is very sensitive to physical changes in theenvironment. This is particulary true during upwelling changes related with climatictrends such as the future coastal intensification of the Trade Winds, ocean acidificationand deoxygenation. The biological response and the impact on primary production, dueto the global warming-induced strengthening of the wind forcing, is assessed with aneddy-resolving coupled physical (ROMS UCLA) and NPZD-type ecosystem model with acarbon module. We forced the model with 3 different products for the monthly-averagedwind-stress fields, from SCOW (QuickSCAT), CCMP and COADS. The latter with a coarserresolution (0.5 degree) than the two others (high-resolution 0.25 degree) in order to do asensitivity analysis of the forcings. We simulate this upwelling intensification doubling thewind stress fields. We found that increased winds lead to a proportionally large productionenhancement in the Northern Humboldt Current System (NHCS), while the same windperturbation results in a more limited increase in production at Pisco 14 °S and PuntaFalsa 6 °S upwelling centers. This differential response results from high levels of nutrientlimitation in these two centers due to enhancement of the eddy mesoscale activity thatacts advecting nutrients offshoreward from the nearshore and highly productive coastalzone. Results suggest, on the basis on our model simulations, that the biological response toupwelling intensification depends to the amplitude and resolution of the wind perturbation.

4.3-D

Can the OFES and CESM models reproduce long Rossby waves?

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General circulation models solve primitive equations that have both the physics and the space-time resolution necessary to provide a realistic reproduction of long, first mode baroclinic Rossby waves. In the present context these waves are a key ingredient in the set-up of the subtropical gyre, where they carry energy westward without an efficient eastward counterpart. This asymmetry reinforces western boundary currents and is a relevant part of the wind-driven circulation. In a stratified ocean, internal Rossby waves move the isopycnals O[10-100 m] in the vertical, which in turn is reflected at the surface as O[1-10 cm] vertical anomalies detected by satellite altimetry. Sea surface height anomaly estimates from two ocean general circulation models (OFES and CESM) were used to determine whether climate numerical models reproduce the surface signature of first mode baroclinic Rossby waves in a manner similar to the observations from satellite altimetry in the South Atlantic basin. Because these waves depend on the vertical density structure and wind forcing, we can make inferences about the suitability of these two factors in the models in comparison with the altimetric records used as a reference. A series of filters was applied to isolate the westward propagating signals corresponding to Rossby waves in the altimetric record and the same set of filters was applied to the model's output. Both model results show Rossby waves in the whole domain and clearer results are observed at low latitudes. However, the OFES model reproduced the annual wave parameters found in altimeter with differences of up to 19% for amplitude, 34% for the wavelength, and 38% for phase velocity. By contrast, the greatest differences between the wave parameters computed from the altimeter data and the CESM model were 9% for amplitude, 20% for the wavelength, and 20% for phase velocity. Similar results were obtained from the semi-annual waves. The zero-lag correlation between models output and altimeter for the seasonal signal was calculated and averaged over the South Atlantic basin. The CESM model correlation was approximately 0.7, while the OFES' was approximately 0.4. For annual Rossby waves at latitudes north of 20°S the maximum lag-correlation averages approximately 0.7 for both CESM and OFES models. South of 20°S the OFES model correlations for the same waves average approximately 0.2, and the CESM 0.4. These results are indicative that in low latitudes the physical processes are well captured by both models. However, as latitude increases, the added complexity of the CESM model with a coupled ocean--atmosphere that includes freshwater input and surface heat fluxes makes significant difference in the Rossby waves forecast.

4.3-E

Downscale the future changes of the Indonesian Throughflow

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Climate models consistently project a substantial decrease in the Indonesian Throughflow (ITF) in response to enhanced greenhouse warming, which warrant further examination using high resolution model simulations. In this study, we use a near-global eddy-resolving Ocean General Circulation Model – OFAM3, which was originally developed for upper ocean forecasting, to downscale the future changes of global ocean circulation. The historical simulation of OFAM3 was driven by the JRA-55 atmospheric reanalysis over the period 1979-2014, and flux corrections were used to minimise model drifts. The future downscaling simulation of OFAM3 was driven by a combination of JRA-55 atmospheric reanalysis and RCP8.5 climate model projections during 2006-2101. The Indonesian Throughflow transport in the historical simulation responded to the tropical Pacific wind variations on interannual and decadal time scales. The Indonesian Throughflow transport decreased by about 25% in the projection simulation, and the long term trend of the Indonesian Throughflow transport, however, is not associated with the wind variability in the Pacific. The decrease was associated with a reduction in the net basin-wide upwelling in the Pacific, consistent with climate model simulations. The roles of the Indonesian Throughflow variability in buffering the tropical Pacific decadal variations during climate change hiatus periods in the future climate are assessed

4.3-F

Semi-annually alternating exchange of intermediate waters east of the Philippines

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Intermediate water exchange is explored through our analysis of a ~4 years of synchronous temperature, salinity and velocity records in the upper 800 m, obtained since late 2010 by a mooring system at 8N, 127.05E. For the first time, we report prominent semi-annual (~ 187 days) variability of intermediate-layer current and a significant correlation with salinity, providing direct evidence for the alternating transports of South and North sourced intermediate waters by northward and southward undercurrents, respectively. Using an ocean general circulation model, we demonstrate that the semi-annual co-variations emerge near the Mindanao coast, between 7-11N, and are associated with reversing circulation east of the Mindanao. This study reveals a semi-annually reversing western boundary conveyer that plays an efficient role in the intermediate water exchange in northwest tropical Pacific.

Poster Clusters Abstracts

Thursday, 22nd September 2016

Poster Cluster

Current and Future Ocean Carbon Uptake

Chair: Curtis Deutsch, Annalisa Bracco, Taka Ito

Session: 1.2 - Carbon

Description: This cluster welcome posters on the ocean role in absorbing, storing, and redistributing anthropogenic carbon, and on how such role may change in the future. The responsible processes and feedbacks onto the climate system are complex and remain poorly understood. For example regional changes in the oceanic state can feedback positively onto atmospheric CO_2 concentrations and further enhance warming trends which in turn will slowdown ocean carbon uptake. The strength of these feedbacks depends on the complex interplay between physical and biogeochemical processes regulating the sensitivity of the oceanic biogeochemical cycling to climate perturbations. Uncertainties in the ocean carbon uptake include the degree to which ocean circulation will change with climate warming and changes to the "biological pump" of carbon to the deep ocean. They are currently evaluated with models that do not account for potentially-important ecosystem shifts or for changes in carbon cycling in the near-surface ocean in coastal systems, including estuaries and marshes and the continental shelves is poorly quantified.

Thu-062

Current and Future Ocean Carbon Uptake: Partitioning uncertainty in ocean carbon uptake predictions

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The oceans have absorbed a large fraction of anthropogenic carbon dioxide emissions, having consequences for ocean biogeochemistry and ecosystems. Simulations with Earth System Models can be used to predict the future evolution of ocean carbon uptake in the coming decades and beyond, but there is substantial uncertainty in these model predictions, particularly on regional scales. Uncertainty can be separated into three component parts: (1) uncertainty due to internal variability, (2) uncertainty due to model structure, and (3) uncertainty due to emission scenario. These uncertainties are not constant, but instead vary with prediction lead time and the scale of spatial averaging. Here, we isolate and quantify the evolution of these three sources of prediction uncertainty in ocean carbon uptake over the next century using output from two sets of ensembles from the Community Earth System Model (CESM) along with output from models participating in the Fifth Coupled Model Intercomparison Project (CMIP5). We find that globally-integrated carbon uptake prediction uncertainty grows with lead time and is primarily attributed to uncertainty in emission scenario. At the regional scale of the California Current System and the ocean biomes, we observe relatively high prediction uncertainty that is nearly constant for all prediction lead times, and is dominated by internal climate variability and model structure. Our findings suggest that improvements to model structure on regional scales will drastically reduce the prediction uncertainty in ocean carbon uptake.

Thu-063

Current and Future Ocean Carbon Uptake - Carbon Hot Spot: A new field program to understand the role of eddies in carbon sequestration within the Kuroshio Extension region

Stuart P. Bishop (1), Andrea J. Fassbender (2,3), Meghan F. Cronin (2), Dongxiao Zhang (2), Ryuichiro Inoue (4), Christopher L. Osburn (1), Eitarou Oka (5), Qiu Bo (6), Xiaopei Lin (7)

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Western Boundary Current regions experience the most intense surface heat loss of anywhere in the world's oceans. This heat loss near the Kuroshio Extension (KE) has important feedbacks on the atmospheric circulation; affecting the jet stream path and the regional climate of the western United States, as well as the formation of Subtropical Mode Water (STMW). The formation of mode water is thought to account for a majority of anthropogenic carbon dioxide (CO2) sequestration outside of the polar regions. Yet, there are still many open questions about what processes drive the formation and long-term evolution of STMW in the presence of meso- and submesoscale eddies. Coupled climate models that include biogeochemical (BGC) properties are in their infancy and still rely on parameterizations for mesoscale eddies. In order to adequately make and understand regional and future climate projections on decadal time scales and longer it is pivotal that we characterize the drivers and implications of STMW variability.

A field program using autonomous vehicles to measure physical and BGC properties of the upper kilometer of the ocean is planned for winter/spring of 2018 in the vicinity of the KE Observatory (KEO). The goals of the field program are to observe the atmospheric fluxes of CO2 while resolving the spatial and temporal scales of submesoscale eddies, and to close dynamical budgets of heat and BGC tracers during the winter/spring transition when STMW formation peaks. KEO is in the optimal location for this study and meteorological observations as well as temperature and salinity measurements throughout the surface mixed layer have been made since 2004. Additionally, observations of pCO2 in the surface ocean and atmosphere have been made since 2007, as well as a suite of ocean acidification measurements, which began in 2011.

Poster Cluster

Comparability of oceanic nutrient data

Chairs: Michio Aoyama (r706@ipc.fukushima-u.ac.jp) and Malcolm Woodward (EMSW@pml.ac.uk)

Session: 6 - Future of Climate and Ocean Science

Description: To allow the global community in the future to be able to more accurately detect changes in oceanic nutrient levels, caused by human impact and shifting physical processes, it is important to establish mechanisms for improving the quality of reported oceanic nutrient data. SCOR WG147 "Towards comparability of global oceanic nutrient data", has been established to encourage the use of certified nutrient reference materials, and to advise on improvements in the analysis of nutrients around the world, members and collaborators of the group will present a poster cluster discussing different aspects of this issue.

Thu-033

Comparability of oceanic nutrient data: Results of the IOCCP-JAMSTEC 2015 Global intercalibration exercise

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1, IntroductionThe objective of this inter-comparison exercise was to evaluate and improve comparability of global nutrients data in the world ocean. In 2003, 2006, 2008 and 2012, inter calibration studies of Reference Material of Nutrients in Seawater, RMNS, were conducted (Aoyama, 2006 Aoyama et al., 2007, 2008, and 2010). Firstly, nutrient concentrations of the distributed samples were set to cover the concentration range of nutrients in the Pacific Ocean, which has the highest nutrient concentrations among the open oceans of the world. Second, the distributed samples were prepared in a natural seawater matrix in a single bottle so that 4 determinands (nitrate, nitrite, phosphate, and silicate) could be simultaneously analyzed. 2, 2014/2015 I/C study: SamplesIn 2014, IOCCP and JAMSTEC co-organized an inter calibration exercise of nutrients in seawater using four lots of CRM by KANSO which already shows excellent homogeneity of 0.2 % and long shelf-life of 6 years (Aoyama et al., 2012), and three CRMs by National Metrology Institute of Japan which are certified in March 2014 and four lots of reference material by Korean Institute of Ocean Science and Technology, KIOST. The NIOZ Royal Netherlands Institute for Sea Research also offers to provide silicate stock solution to contribute to the overall assessment of results with this I/C exercise. Therefore a set of four samples of CRMs was distributed to all 71 participating laboratories around the globe (28 countries) in charge of free, and NMIJ CRMs were sent to the laboratories who agree to pay for them. Korean RMs were also distributed to voluntary laboratories who agreed to analyses them. NIOZ stock solutions were sent to selected deep water laboratories who agree to analyses this silicate stock solution. 3, Preliminary resultsResults from 57 of 71 laboratories were reported and included into a database. In this report, tentative summary of 4 CRMs by KANSO and 3 CRMs by NMIJ are presented. It is clear that present comparability among the participants in 2014/2015 I/C exercise is quite similar with previously obtained comparability in 2012. Consensus standard deviations of determinands are one order of magnitude large rather than homogeneity of the samples distributed. Therefore these I/C results show that use of RM will be able to greatly improve comparability of nutrient data among the laboratories in the world. There are good signal in the results that although consensus standard deviations are relatively large, consensus median/mean of each samples showed good agreement with certified values of the CRMs within consensus SDs. This implies that majority of the participating laboratories have good capability to measure nutrients concentration in seawater and using CRM will increase more on the comparability and could be their results to be SI traceable quickly.Acknowledgement: Michio Aoyama as the organizer of this I/C exercise appreciate to all participating laboratories, KIOST and NIOZ for their contribution to this 2014/2015 I/C study. The author also thanks a support team of Marine Works Japan for this I/C study.

Thu-034

Comparability of oceanic nutrients data: GO-SHIP Repeat Hydrography Nutrient Manual - Obtaining Globally comparable data sets.

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El Niño/Southern Oscillation (ENSO) is a mode of natural variability that has considerable impacts on global climate and ecosystems, through rainfall variability in the tropical Pacific and atmospheric teleconnections. In response to global warming, ENSO-driven rainfall variability is projected to intensify over the central-eastern Pacific but weaken over the western Pacific, whereas ENSO-related sea surface temperature variability is projected to decrease. Here, we explore the mechanisms that lead to changes in ENSO-driven rainfall variability in the tropical Pacific in response to global warming, with the help of a moisture budget decomposition for simulations from eighteen state-of-the-art climate models. We identify two opposing mechanisms that approximately offset each other: the increase in mean-state moisture content associated with surface warming strengthens ENSO-related rainfall anomalies, whereas the projected reduction in ENSO-related variability of sea surface temperatures suppresses rainfall. Two additional effects—spatially non-uniform changes in background sea surface temperatures and structural changes in sea surface temperature related to ENSO—both enhance central-eastern Pacific rainfall variability while dampening variability in the western Pacific, in nearly equal amounts. Our decomposition method may be generalized to investigate how rainfall variability would change owing to nonlinear interactions between background sea surface temperatures and their variability.

Thu-035

Comparability of oceanic nutrient data: Report from an International Nutrient Workshop focusing on Phosphate analysis.

Karel Bakker (1), Prof. Michio Aoyama (2), Mr. Malcolm Woodward (3), Sharyn Ossebaar (4), Jan van Ooijen (4)

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From our pre SCOR #147 working group called SGONS (Study Group on Nutrient Standards 2008-2012) a practical analytical nutrient workshop was organised in 2012 at the NIOZ (Royal Netherlands Institute for Sea Research), The Netherlands, to help improve the world wide comparability of nutrient data. Information was gained through feedback from a questionnaire from the global nutrient analytical community about general difficulties which arise when analysing macro-nutrients. The outcome of the questionnaire made it possible to identify specified problem areas that would form the focus of the studies at the workshop and then to attempt to investigate these problems in the laboratory. The workshop focused on the analysis of dissolved Phosphate (PO4) as it was highlighted by the survey that this analyte exhibits most of the common problems encountered when running gas segmented CFA. A small select representative group of International nutrient analysts worked simultaneously on four different gas segmented Continuous Flow Analysers (CFA) ranging from micro- to macro-bore systems. Different methodologies, flow rates, matrices, temperatures and calibration distributions were just some of the topics investigated during the workshop. Comparable interpretations of the experiments were able to be made as a reference material was measured in every test run. The workshop findings resulted in a report that describes recommendations based on group consensus for solving various identified problems for nutrient analysis measured on continuous flow analysers and will be presented in the poster which can hopefully assist the larger community of laboratories worldwide.

Thu-036

Comparability of oceanic nutrient data: Using defined Silicate standards and good lab practice doesn't automatically imply good inter-comparison results.

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The 2008 Inter Comparison Study of Reference Material for Nutrient Standards (IC RMNS) showed a large variance (9%) in the silicate data reported by the different participating laboratories. From our pre SCOR #147 working group called SGONS (Study Group on Nutrient Standards 2008-2012) a study was organised in 2009 to investigate the different types of silicate standards used in the global nutrient analytical community. To investigate if this variance was due to the difference in the silicate material used for making standards, all participants were asked to send their stock silicate solution to one lab in The Netherlands whereby all solutions were analysed and compared. An accompanying questionnaire was sent out with the request to gain further information about the silicate material used, its purity and standard preparation procedure of the stock solution. Results showed recoveries of the stock standards were more or less 100% with only a small variance of 2%.The out-lying values reported in the IC RMNS 2008 study originated from people working with either deionised water (DIW) as a diluent or diluting high concentration samples with DIW in a lower applied calibration range. In both these cases, the difference in salinity causes deviations in the calculated calibration slopes compared to those analysed under the correct saline conditions. Another aspect was the use of un-neutralised alkaline silicate solutions which give pH problems resulting in precipitations if diluted with Low Nutrient Sea Water (LNSW).

Following on from this research, another study was conducted in 2015 to further investigate the comparability of silicate standards and the methods of sample dilution. A single homogeneous silicate stock solution made from sodium silicate fluoride was sent around to the participating labs of the IC RMNS 2015. The reported concentration after diluting the sample under their standard operating procedure gave a variance of 2.5% in silicate data suggesting that there are still inconsistencies in the global analytical procedures. Further interpretation of the data showed trends depending on the silicate material used for the calibration for analysis and therefore it may be necessary to consider the worldwide use of only one type of silicate material for calibration. It is important that the suggested silicate material doesn't have any effect on any of the diluents used for the calibration and doesn't interfere if used simultaneously with other nutrient standards. Good comparability of data is not only dependant on good laboratory practice but also on its chemistry.

Thu-037

Comparability of oceanic nutrient data: SIO'S Oceanographic Data Facility Support for the GO-SHIP and Argo communities.

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The Oceanographic Data Facility (ODF) at the Scripps Institution of Oceanography (SIO) provides high-quality hydrographic technical services. ODF has participated in numerous large-scale, worldwide oceanographic expeditions including Geochemical Ocean Sections Study (GEOSECS), World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), Climate Variability and Predictability (CLIVAR), Ship-based Hydrographic Investigations Program (GO-SHIP), and Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) programs. The advice and support ODF provides these programs enables them to obtain the high quality reference data that is required for the science objectives of the programs to be met.

The ODF chemistry laboratory has been producing world-class reference data for over 40 years. Analyses include dissolved inorganic nutrients, dissolved oxygen, and salinity; both at sea in near real-time and ashore. The ODF chemistry laboratory is involved in the development of reference materials for nutrients in seawater along with their implementation in global time series expeditions. ODF is a full member of the international Scientific Committee on Oceanic Research (SCOR) working group 147- Towardscomparability of global oceanic nutrient data (COMPONUT).

SOCCOM Argo-equivalent floats are being deployed from numerous cruises in the Southern Ocean. ODF has participated on a number of these cruises. ODF provides shipboard nutrient and/or oxygen analysis data to calibrate nitrate and oxygen sensors aboard the floats. ODF is also in charge of collecting, preserving, and shipping or the coordination of the collection and shipping of a large suite of samples back to the USA for calibration of the associated biogeochemical sensors aboard the floats.

Thu-038

Comparability of Oceanic Nutrient Data – Hawaii Ocean Time-series Station ALOHA

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The response of the tropical ocean to global warming is studied using historical and future simulations with the NCAR's CESM1.1. The main features are presented as follows.

(1) In the tropical Pacific Ocean, global warming induces an El Niño-like SST warming pattern associated with the weakening of equatorial easterly wind. In addition, the surface currents weaken and the equatorial thermocline shoals in response to global warming.

(2) The pIOD-like pattern emerges in the Indian Ocean, featured with enhanced warming in the western tropics but less warming in the eastern tropics. It is mainly caused by equatorial easterly wind anomalies.

(3) In the tropical Atlantic, the SST warming pattern appears to be Atlantic Niño-like with an enhanced warming in the eastern equatorial region.

Thu-039

Comparability of oceanic nutrient data : Use of CRMs in the French intercalibration program

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The Atlantic Warm Pool (AWP) is known to impact hurricane trajectories by shifting the origin of the storms eastward, steerting the storms northeastward, and thus reducing the probability of landfall in the United States. However, it is still unclear how the AWP affect hurricane intensifications. Therefore, in this research, the potential role of the AWP on hurricane intensification is investigated. This study adopts the recently improved Maximum Potential Intensity Index (MPI) which applies the depth averaged temperature to involve the subsurface temperature information. By using the Simple Ocean Data Assimilation reanalysis, and the HURDAT data set, a minimum MPI threshold is established for the intensification of TCs into category five hurricanes in the AWP region. The projected changes in accordance with the established minimum threshold under the IPCC RCP 4.5 and 8.5 scenarios are further analyzed using the ensemble MPI mean from CMIP5 models. Results suggest that depth averaged temperature of the AWP will continue to rise attributed to greenhouse gas emissions (GHG). However, the AWP area that supports category five hurricanes does not increase in the 21st century. The result is mainly because the projected atmosphere condition in the future largely compensates for the ocean temperature increases.

Thu-040

Comparability of oceanic nutrient data: Changes in salinity and nutrients along 47N in the North Pacific

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Since reaching global coverage in 2006, the Argo array of profiling floats has been delivering high-quality temperature and salinity profiles from depths of around 2000m to the surface every 10 days (www.argo.net). Argo now supplies the dominant subsurface ocean temperature and salinity data stream underpinning ocean, seasonal climate and weather forecasting. Papers reliant on Argo data are now being published faster than one per day, reporting breakthroughs in tracking ocean inventories of heat and freshwater, ocean change, deep ocean circulation, climate dynamics and air-sea interactions. We will touch on a few key applications and research results enabled by Argo. We will also describe the current status of Argo and its near term challenges and risks. We will also outline progress towards evolving the data system and the design of the Argo array, including progress on piloting extensions to cover existing gaps (marginal seas, deep and ice-covered oceans) and new parameters such as bio-chemical and optical measurements. As only one element of the Global Climate Observing System, Argo's evolution requires strong integration with satellite and other in situ networks.

Thu-045

Comparability of oceanic nutrient data: An overview of SCOR Working Group #147: Towards comparability of global oceanic nutrient data (COMPONUT)

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"The Global Ocean Ship-based Hydrographic Investigation Program (GO-SHIP) brings together scientists with interests in physical oceanography, the carbon cycle, marine biogeochemistry and ecosystems, and other users and collectors of ocean interior data to develope a sustained global network of hydrographic sections as part of the Global Ocean Climate Observing System."

This manual is an updated version of the original nutrien manual provided for the GO-SHIP endeavor. It reviews basic aspects of CFA using an AutoAnalyzer (AA); provided as brief history of past inter-calibration exercises; outlines specific nutrients methods in use by many laboratories doing repeat hydriography for nitrate, nitrite, phosphate, silicate and ammonia; provides laboratory practices including QC/QA procedures to obtain the best results; and gives examples of documentation protocols. It also covers the details of the collection and storage of samples, considerations in the preparation of reagents and the calibrations of the system and determination of low level nutrients concentrations.

Protocols for use of CRM/RMNS solutions to "track" the performance of a system during a cruise and between cruises will also be discsussd.

Thu-046

Comparability of Oceanic Nutrient Data: Results from the Secondary QC of GLODAPv2 Nutrient Data.

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CLIVAR cruises using the R/V Mirai, Japan Agency for Marine-Earth Science and Technology (JAMSTEC) were carried out to study the decadal change of ocean circulation, biogeochemical processes and carbon budget in the ocean. To study the change, it is important to keep the comparability of each parameter of hydrographic measurements among cruises conducted in deferment time and different locations. To get more accurate and high quality nutrients data, the reference material of nutrients in seawater (RMNS) were produced and used in the 8 previous cruises during the period from 2003 to 2014 (Aoyama et al., 2006, 2007, 2008, 2009, 2012, 2014; Sato et al., 2010). Since 2005, we have assigned RMNSs by ourself and have been keeping internal comparability among the cruises. Since we used RMNS at several concentration levels at all stations in all cruises, we could also estimated uncertainty of measurement of nutrients as a function of nutrients concentration based on the result of repeated measurement of RMNSs. In 2014, there are three providers of Certified Reference Material (CRM) of nutrients in seawater. National Meteorology Institute, Japan (NMIJ) certified three levels of CRMs in June 2014. The General Environmental Technos co., Ltd (KANSO TECHNOS) also started to certify RMNS produced by them self and the certification was jointly done by both JAMSTEC and KANSO since 2015. National Research Council, Canada (NRC) is providing MOOS-3, but nutrients concentration of MOOS-3 was found to be unstable and significantly lower rather than certified values for nitrate and phosphate during certification process of KANSO CRMs at JASMTEC in 2015. The MR15-05 cruise by the R/V Mirai, which occupied WHP-I10 linerepeat cruise in the eastern part of the Indian Ocean, in 2015-2016, was conducted from 23rd Dec., 2015 to 11th Jan., 2016arried out in the Eastern Indian Ocean. In this cruise, we used 6 lots of CRM (Lot BY, BU, CA, BW, BV, BZ) produced by KANSO to ensure comparability and traceability to the Système International d'unités (SI). Among 6 lots, 5 lots of CRMs except lot BV were used as calibration standards together with C-6 for every measurement. The CRM lot BV was measured through the measurement run to monitor the comparability among them. Certified value of concentration and uncertainty (k=2) of lot BV are 35.36± 0.35 µmol kg-1 of nitrate, 2.498 ± 0.023 µmol kg-1 of phosphate, 102.2 ± 1.1 µmol kg-1 of silicate, respectively. The results of mean and standard deviation (k=2) of lot BV (n=50) were 35.36 ± 0.07 µmol kg-1 of nitrate, 2.494 ± 0.010 µmol kg-1 of phosphate, 102.29 ± 0.25 µmol kg-1 of silicate, respectively. It means that nutrients measurements during this cruise were ensured excellent comparability and traceability to the SI. We will show a specific example used of CRMs during cruises in the poster.

Thu-047

Comparability of oceanic nutrient data: Use of CRM/RMNS in CLIVAR cruises to ensure comparability

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To better manage and understand the global impacts of human activities on the world's oceans, it is necessary to have accurate observations of changes in carbon and dissolved nutrients in both the upper as well as the deep ocean waters. Currently, too many data sets are reported and published with no reference or calibrations against certified reference materials. SCOR Working Group #147, (Towards comparability of global oceanic nutrient data) was established in 2015, with the aim of addressing this important issue and to bring greater awareness to the global marine science community. By establishing better mechanisms for comparability of nutrient analyses, we will be able to detect changes in nutrient levels due to human impact and shifting physical processes. Such changes could, either alter the supply of nutrients to the upper ocean directly or be from changes to ocean circulation. A recent Framework of Ocean Observing statement introduced the concept of Essential Ocean Variables (EOVs), and the assessment and development of readiness for sustained observations. The aim is to promote collaboration in developing the future requirements, observing networks, and data information streams. Nutrients are identified as one of these EOVs.

The SCOR working group, #147, is working towards improving comparability of global nutrient analysis through international intercomparability exercises (in conjunction with IOCCP), is involved with education and advice to the global community through workshops and targeted research, plus it will be leading an update of the GO-SHIP nutrient analysis manual during the next couple years. The primary goal is that for nutrient data collected anywhere by one individual laboratory, and for data collected over long time periods by one or more laboratories, will be consistent and traceable with certified comparability. For future generations it is unacceptable to produce historical data sets without the absolute consistency necessary to assess spatial and temporal trends.

Thu-048

Comparability of oceanic nutrient data: Revaluation of Redfield ratios using the global nutrient data

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Nutrients have been measured since the very earliest days of scientific ocean observations, back in the late 19th century. Accordingly, nutrients have a long history of measurement, which thus implies that plenty of data exists worldwide, and if so then it would be a great advantage for studies of ocean climate changes. However, studies on ocean climate changes based on nutrient data have hardly been made. This is because historical nutrients data sets have poor internal and external comparability, i.e., it is difficult to compare data collected by one laboratory with data from a similar oceanic area collected by others. In order to improve this comparability, it is important to analyze nutrients and obtain results that are based on certified nutrient reference material (CRM's). Although a few CRMs for nutrients have been developed and been proved in the past, unfortunately they are not in widespread use. Therefore as an activity of the SCOR Working Group 147 we will aim to distribute a range of different concentrations of CRM's worldwide. These CRM's will be sold and distributed by JAMSTEC and produced on a commission basis by the General Environmental Technos (KANSO) company in Japan. Previous commercial batches of KANSO CRM's have already been shown to be stable and have been analyzed by many laboratories as part of repeated global inter-comparison studies, and they have been shown to work well in improving analytical comparability. We intend to produce 5 nutrient concentration variations of CRM's to meet requests received from the world ocean community through a questionnaire conducted in 2015. The 5 levels of seawater are as follows: #1: Low Atlantic; #2: Middle Atlantic; #3: Middle Pacific; #4: High Pacific; #5: High Atlantic. JAMSTEC have already collected 1000 litres of deep Pacific water early in 2016, which will be the source seawater for #3 and #4 CRM production (High and Middle Pacific). The source water was UV sterilized onboard the research ship, and sent back to Japan for autoclaving, checking and bottling on land. The Royal Netherlands Institute of Sea Research, NIOZ, have provided Atlantic surface seawater for #1 CRM (Low Atlantic) production. This has been shipped to Japan and is now also autoclaved and being prepared. For the specific method, see our relevant poster in this cluster: Comparability of oceanic nutrient data: Methods of certified reference material (CRM) production and certification for reference materials for nutrients in seawater (RMNS) by Kitao et al. There is a newly developed sterilization unit which will be sent to Plymouth Marine Laboratory (PML) UK, and the Atlantic High and Middle concentration waters will be collected during summer 2016, and again will be shipped to Japan for autoclaving and processing. The website for distribution of CRM's will be opened on JAMSTEC's homepage, making the CRM' available for sale and distribution on demand from customers.

Thu-049

Comparability of oceanic nutrient data by KIOST Reference Material Series for nutrients (K-RMS)

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Dissolved nutrients in seawater are recognized as an essential biogeochemical factor for detecting global environmental changes. The importance of nutrient reference material for seawater has been increased greatly for the comparison of nutrient data, measured in different time and space in global ocean by various researchers with different levels in nutrient analysis skill. In this study, we described the homogeneity and stability of nutrient reference material for seawater using natural seawater, collected at a station of Shihwa Lake, at a coastal station near Uljin (surface water), and at a station over the Ulleung Basin (surface water and 1500 m depth water) and sterilized. Based on the homogeneity data, the nutrient reference materials have similar homogeneity compared to other nutrient reference materials. During 3-13 month period, there was no unidirectional trend of increase or decrease in nutrient concentration of newly developed nutrient reference material for seawater. However, a sustained measurement is required to check stability for longer period.

Thu-050

Comparability of oceanic nutrient data: Improving global nutrient comparability through distribution of nutrient CRM's

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We present a global ocean-ice system (NEMO-LIM) at high resolution (1/16°), GLOB16, developed at CMCC. The configuration employs a tripolar grid with a horizontal spacing of 6.9 km at the equator decreasing to ~2 km at high latitudes, and uses 98 vertical levels. One of the objectives for the implementation of this system is the development of a pre-operational eddy-permitting global ocean analysis and forecast system, to be further run in operational mode. The second objective is the production of a multi-year reanalysis at the same resolution.

Firstly a 11-year integration, run with ERA-Interim reanalysis as surface forcing, was produced and performance of the model is evaluated against observations and a corresponding coarse-resolution configuration. Analysis of some of the key ocean parameters lead us to conclude that the model average state is realistic, and that the model realistically represents the variability in the upper ocean and at intermediate depths. GLOB16 model configuration showed good skill in simulating exchanges of mass between ocean basins and through key passages. The contributions from the individual straits in the exports from the Arctic Ocean are within the uncertainties of the observational estimates. The seasonal cycles of total ice area and volume are close to satellite observations and the sea ice extent distribution is very well reproduced in both hemispheres. The model is able to hindcast the position and strength of the surface circulation. Extension and separation of western boundary currents are better resolved compared to the eddy-permitting run.

Secondly, the ocean-ice system has been combined with a state-of-the-art 3D-Var data assimilation system capable of assimilating all high resolution space-borne and conventional observing networks, including hydrographic profiles and several satellite data. Preliminary results on the impact of data assimilation on the eddy-permitting system will be presented.

Thu-051

Comparability of Oceanic Nutrient Data: Methods of Certified Reference Material (CRM) Production and Certification for Reference Materials for Nutrients in Seawater (RMNS)

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The General Environmental Technos Co., Ltd. (aka KANSO) started the production of reference materials for nutrients in seawater (RMNS) in 2003. RMNSs were used in the 2003, 2006, 2008, and 2012 global inter-laboratory comparison studies conducted by Meteorological Research Institute (MRI), Japan, and a global inter-comparison study conducted by the International Ocean Carbon Coordination Project (IOCCP) and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in 2015. The GO-SHIP nutrients measurement manual published in 2010 suggested KANSO's RMNS as one of the candidates to be used as common reference materials for all laboratories to improve the comparability of oceanic nutrients data set (Hydes et al, 2010). RMNS is produced by only natural seawater. The production method involves filtration of collected seawater and autoclave in a stainless-steel reaction chamber of which inside is electro-polished. After the seawater has been autoclaved, 90-mL aliquots are transferred into UV-sterilized polypropylene bottles in a clean room. The bottles are hermetically sealed in aluminum-film bag which has excellent barrier properties for suppressing long-term water evaporation. Nutrient concentration levels of RMNS range from low nutrient seawater in subtropical surface water to highest deep Pacific seawater. A range of nutrient levels is achieved by mixing collected natural seawaters of different nutrient concentrations at various mixing ratio (Japan Patent 3477468, 4459752, 5705574; Korea Patent 10-1507432; US Patent Publication No. US-2013-0305660-A1). A 320-L stainless-steel reaction chamber is used to autoclave natural seawater which produces 2500 bottles (ca. 90-mL aliquot) per one lot. The initial homogeneities of high-nutrient RMNS lots are less than 0.2 % (RSD). The stability of 4 determinands (nitrate, nitrite, phosphate, and silicate) is guaranteed up to 7 years (Aoyama et al., 2012). In 2011, KANSO was accredited as a certified reference material (CRM) producer under the Accreditation System of National Institute of Technology and Evaluation (ASNITE) program (accreditation number: ASNITE 0052 R). KANSO also meets the requirements of ISO Guide 34: 2009 (JIS Q 0034: 2012) and ISO/IEC 17025: 2005 (JIS Q 17025: 2005) in tests and measurements involved in the assignment of property values to certified reference materials. The assigned property values were the measured results of 120 randomly selected bottles by KANSO initially. Since 2015, the certified values have become the average of two independently obtained concentrations by JAMSTEC and KANSO. In this poster will show the production method of KANSO CRM and the results of independently measured nutrient concentrations by JAMSTEC and KANSO for certification of existing lots. The results show that two values agreed within measured expanded uncertainty ($k = 2$) for 9 lots produced. With more reliability

in the measured values, the global use of KANSO CRMs is expected to improve comparability of seawater nutrient measurements.

Poster Abstracts

Thursday, 22nd September 2016

Thu-001

Understanding the recent trend in the Atlantic ocean circulation using global ocean reanalysis GLORYS2V3

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Surface temperature trends over the twentieth century show a global warming mostly everywhere except a cooling is found in the north Atlantic region. Few studies suggested that possible changes in the Atlantic Meridional overturning circulation (AMOC) is responsible for this cooling by experiencing unprecedented weakening. The AMOC plays a key role in the climate the north Atlantic by bringing warm water from the tropics to high latitude where they cool. Thus, deep connection occurs and the surface water sinks into the deep ocean before traveling back southward afterwards. This circulation transport advects heat poleward, this heat is transfer from the ocean to the atmosphere at midlatitudes, contributing to the temperate climate of northwest Europe.

Here, using the global ocean reanalysis GLORYS2V3 done at Mercator-Ocean (France) covering the period from 1993 to date, we investigate changes in the North Atlantic ocean. The variability of the AMOC is looked at over that period with a focus on the recent trend. This recent slowdown is evaluated in regards to the relative contribution of the freshwater changes from the Arctic and ice sheet melting from Greenland. Those contributions reduce the density of cold surface waters in the North Atlantic, preventing sinking of dense water, slowing down northward heat transport. If this connections continue in the futur, further weakening of the AMOC is expected with a decrease of the convection as a results of global warming, which has been predicted by some climate models

Thu-002

Shifts in NAO-Linked Sea Level Variability Along the Atlantic Coast of the United States from Bayesian Dynamic Linear Regression Models

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Tide gauge records of relative sea level along the mid-Atlantic coast of the United States exhibit an upward trend over the past century. Accelerated sea level rise has been documented beginning around 1990, potentially linked to weakening of the Atlantic Meridional Overturning Circulation (AMOC), of which the Gulf Stream is a component. Recent studies have demonstrated the impacts of the North Atlantic Oscillation (NAO) on sea level, gyre circulations, and AMOC variability. The NAO is a dominant pattern of interannual variability in north Atlantic sea level pressure and influences basin-scale wind stress patterns, which affect spinup/spindown of the subpolar and subtropical gyres. Therefore, NAO may influence north Atlantic coastal sea level through remote wind and/or surface heat flux forcing near deep water formation sites in the North Atlantic, which can weaken AMOC; by controlling wind stress curl variability which excites westward-propagating Rossby waves in the basin interior; and through local along-shore wind stress and wind stress curl, which affect coastal upwelling. In addition, NAO may influence the latitude of the Gulf Stream separation point as measured by the Gulf Stream North Wall Index (GSNWI), which is associated with sea level variability north of Cape Hatteras. A strong negative correlation (R=-0.62) between wintertime NAO and coastal sea level anomaly has been detected north of Cape Hatteras since 1987; prior to this period, correlation has been found to be negligible.

To document this nonstationarity of NAO impact, isolate its causes, as well as expand these findings spatially, a novel method, Bayesian dynamic linear regression modeling (DLM), is employed. Linear least-squares regression can be used to diagnose relationships between climate variables and sea level anomalies, yet regression coefficients are necessarily constant with time. Bayesian dynamic linear regression admits time-variable regression coefficients which represent the changing influence of the predictor variable(s) on the predictand, as well as a time-variable mean state representing unmodeled features. Smoothing parameters obtained from a specified signal-to-noise ratio control the timescale of variation. In this study, four time series of averaged sea level in and around the South Atlantic Bight, Chesapeake Bay, mid-Atlantic Bight, and Gulf of Maine are obtained from tide gauge records spanning 1950-2013. DLM models of sea level as a function of wintertime NAO are constructed, and the regression coefficients are used to identify two distinct decadal regimes of NAO influence: mid-1960s to mid-1980s and mid-1980s to present. During the former period, the relationship between NAO and sea level anomalies north of Cape Hatteras is weak, and generally positive, on interannual timescales. However, during the latter period, there is a strongly negative association between the NAO index and sea level anomalies. This nonstationarity is found to be attributable to pattern changes of surface winds associated with NAO, which affect coastal sea level via multiple processes, including decadal variability in basin-scale wind stress curl patterns, local alongshore wind and GSNWI.

Thu-003

The role of the Meridional Mode in ENSO under greenhouse forcing

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The Pacific Meridional Mode (MM) is a coupled ocean-atmosphere mode of variability that is recognized as an important precursor of El Niño Southern Oscillation (ENSO) and its different flavors, the Eastern and Central Pacific. Recent study suggests that the coupling between the MM and ENSO is increasing under greenhouse forcing. Using 30 simulations with the Community Earth System Model at 1° spatial resolution over the period 1920-2100 (CESM1 Large Ensemble) we explore the dynamics controlling the MM activity and its coupling to ENSO diversity under a greenhouse forcing scenario. The CESM1 Large Ensemble shows that the equatorial variance increases significantly under greenhouse forcing, with a tendency for frequent large-amplitude (>2°C anomalies) El Niño events in the central tropical Pacific. We show that these changes in ENSO statistics are linked to the changing character of the MM under greenhouse forcing.

Thu-004

Response of the equatorial Pacific Ocean to a uniform heating in a fully coupled GCM

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The response of the equatorial Pacific Ocean to a uniform heating is investigated using the fully coupled Community Earth System Model (CESM). Results show that the initial response to the uniform heating is weak La Niña-like (fast pattern) when the ocean dynamical thermostat (ODT) mechanism is dominant, and then the warming pattern becomes more El Niño-like (slow pattern). The switch in pattern is likely caused by a slowdown of the subtropical cells (STC). In addition, the response of the winds, cloud and solar radiation also acts to promote more SST warming in the east and plays an important role for maintaining the El Niño-like warming pattern.

Thu-005

Increasing climate extremes under global warming – What is the driving force?

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More climate extreme events have occurred in recent years, including the continual development of extreme drought in California, the severe cold winters in the eastern U.S. since 2014, 2015 Washington drought, and excessive wildfire events over Alaska in 2015. These have been casually attributed to global warming. However, a need for further understanding of mechanisms responsible for climate extremes is growing. In this presentation, well use sets of climate model simulation that designed to identify the role of the oceanic feedback in increasing climate extremes under global warming. One is with a fully coupled climate model forced by 1% ramping CO 2, and the other is with an atmosphere only model forced by the same CO 2 forcing. By contrasting these two, an importance of the oceanic feedback in increasing climate extremes under global warming can be diagnosed.

Thu-010

The Indian Summer Monsoon Climate During Last Millennium, As Simulated by the PMIP3

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In this study, using the available model simulations of PMIP3 vintage, we make an effort to understand the mean summer (June-September; JJAS) climate and its variability in India during the Last Millenium (LM), with emphasis on on the Medieval Warm Period (MWP; AD1000-AD1199) and Little Ice Age (LIA; AD1550-AD1749). Out of the eight available models, we identify six 'good models' by validating the corresponding simulated global and Indian mean summer temperatures and their trends, and the mean simulated Idian summer monsoon rainfall (ISMR) from historical simulations (CMIP5) against the observed datasets such as the ERSST, NCEP/NCAR reanalysis, and IMD grided rainfall datasets, for the 1901-1999 period. The identified 'good' models are: BCC-CSM1-1, IPSL-CM5A-LR, FGOALS-s2, MIROC-ESM, MPIESM- P, GISS-E2-R, and CCSM4. We use the composite analysis of the anomalies to obain the multi-model mean results. The models simulate higher (lower) mean summer temperatures in India as well as globally during the MWP (LIA) as compared to the corresponding LM satistics. Our Analysis shows a strong negative correlation between the NINO3.4 index and the ISMR, and a positive Correlation between NINO3.4 and summer temperature over India during the LM, as is observed in the last one-and-half centuries. The magnitude of the simulated ISMR-NINO3.4 index correlations, as seen from the multi-model mean, is found to be higher for the MWP (-0.36; significant at 95% confidencelevel) as compared to that for the LIA (-0.25; significant at 95% confidencelevel) Our preliminary analysis shows that the above (below) LM-mean summer temperatures during the MWP (LIA) are associated with relatively more (less) number of concurrent El Niños as compared to the La Niñas.

Thu-011

Dynamically combining climate models to "supermodel" the tropical Pacific

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We construct an interactive ensemble of two different climate models to improve simulation of key aspects of tropical Pacific climate. Our so-called supermodel is based on two atmospheric general circulation models (AGCMs) coupled to a single ocean GCM, which is driven by a weighted average of the air-sea fluxes. Optimal weights are determined using a machine learning algorithm to minimize sea surface temperature errors over the tropical Pacific. This coupling strategy synchronizes atmospheric variability in the two AGCMs over the equatorial Pacific, where it improves the representation of ocean-atmosphere interaction and the climate state. In particular, the common double Intertropical Convergence Zone error is suppressed, and the positive Bjerknes feedback improves substantially to match observations well, and the negative heat flux feedback is also much improved. This study supports the concept of supermodeling as a promising multimodel ensemble strategy to improve weather and climate predictions.

Thu-012

Rapid warming in the Indian Ocean, and its impact on the tropical climate and the marine ecosystem

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The Indian Ocean has been warming for more than a century, at a rate and magnitude larger than what was thought before. The surface warming is largest in the west-central Indian Ocean, with up to 1.2°C in summer sea surface temperatures (SST) during the past century. Consequences of this rapid warming of Indian Ocean are large, especially on the physical and biological dynamics over the South Asian domain, and eventually on the socio-economic livelihood of the countries bordering it. Our analysis with observed data and model simulations show that the Indian Ocean warming has resulted in weakening the land-sea thermal contrast, an essential driver of the monsoon. This has weakened the monsoon circulation, and in turn reduced the rainfall over a large area extending from Pakistan through central India to Bangladesh.

Further, we find that a warmer Indian Ocean dampens the magnitude of ENSO and also shortens its lifecycle. This involve modulations of the surface winds in the western equatorial Pacific, which trigger eastward-propagating oceanic Kelvin waves responsible for the turnabout of ENSO, through changes in the thermocline.

The rapid ocean warming has also resulted in the surface stratification over the Indian Ocean. The Indian Ocean is one of the most biologically productive regions among the tropical oceans, supporting the second largest share of the most economically valuable tuna catch. We find that the increasingly stratified ocean waters have suppressed the upwelling of nutrients from the subsurface waters, and have resulted in a reduction of up to 30% in the marine primary production. Future climate projections suggest that the Indian Ocean will continue to warm, leading to further reduction in marine productivity, which combined with the fishing pressure, can drive this productive region into an ecological desert. Altogether, the Indian Ocean warming is a factor to be vigilant of, while assessing long-term changes in the monsoon, the marine productivity, and the global climate.

Thu-013

Variational estimation of process parameters in CEN Earth System Assimilation Model

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Parameterizations are used to simulate effects of unresolved sub-grid-scale processes in current state-of-the-art climate models. The values of the process parameters, which determine the model's climatology, are usually manually adjusted to reduce the difference of model mean state to the observed climatology. By contrast, the automatic estimation of the parameters by minimizing a costfunction that measures model – data differences via inverse methods is hindered by the nonlinearity of the atmospheric component. Due to the nonlinearity, secondary minima of the costfunction emerge and sensitivities tend to grow exponentially, which prevent an efficient minimization.

In this work, a recent extension to the variational method was used to estimate process parameters in CEN Earth System Assimilation Model (CESAM). By means of synchronization of attractors, this extension regularizes the adjoint equations. The method requires sufficiently dense observations to describe the real world attractor and the coupling for synchonization is realized by a simple nudging term in the forward model. In identical twin experiments, we show for the dry atmosphere model that the feasible assimilation window can be extended to over 1-year. Besides nonlinearity, discontinuities of the cost function related to moist parameterizations such as convective precipitation, large scale precipitation and dry convective adjustment hinder the inclusion of cloud related parameters, which are needed to realistically simulate the climate and which traditionally are adjusted to tune the sea surface temperature. In order to resolve the problem, two methods have been tested: (1) using the full forward model to calculate the cost function and provide the reference trajectory while using only the adjoint to the dry model, (2) changing the implementation of the moist parameterization to avoid discontinuous processes.

Thu-014

Statistical projection of ocean wave climate based on principal component analysis

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INTRODUCTION

Climate change has serious impacts on human activity. The expected major influences of climate change on coastal region are sea level rise, storm surge and wave change. Above all, there are few studies about future wave projection and its impact assessment before IPCC Fifth Assessment Report (AR5). The characteristics of future wave climate are not well understood in current research on impact assessment of global climate change. We expect that dynamic atmospheric climate changes such as wind speed and atmospheric circulation give significant impacts on wave height and so on. In this study, we have developed simple statistical wave model and validated the model with historical data. The future changes of wave height were estimated using the statistical model forced by different greenhouse emission (GHE) scenarios and compared with previous studies.

OUTLINE OF RESEARCH

A statistical projection model of global wave height was developed using multivariate analysis between atmosphere data and wave height. The data for developing the statistical model was the historical wave hindcast dataset which was computed by WaveWatchIII v4.18 (Tolman, 2014; denotes WW3) forced by JRA-55 reanalysis (Mori et al., 2015). The spatial resolution was 60 km. The explanatory variables of statistical model are square of wind velocity (), mean-sea level pressure () and its gradient (). Seven different types of multi-regression models were tuned for each grid point. Then, the developed statistical models were applied to future projection of wave climate change under several GHE scenarios. The atmosphere data are results of the climate change projection experiment by the 60 km resolution atmosphere global climate model (MRI-AGCM-3.2H) which is basically consistent to JRA-55 both the model and configuration. The future changes of mean and extreme wave heights were estimated globally using the statistical wave model.

RESULTS AND DISCUSSION

Annual mean and maximum wave heights are estimated by the statistical model in comparison with the wave hindcasts. The correlation coefficients of mean wave heights between the statistical model and wave hindcasts are greater than 0.8 over a wide area of globe and are the greatest when we used all three explanatory variables. The estimation errors are small in magnitude where mean wave heights are low such as in tropics. Even if wind speed is high, long fetch makes the influence of swell large. Thus the effects of swell are considered by principal components (PC) of sea level pressure (SLP). The estimation error of wave height has been significantly improved around tropics by PCs.

The estimated mean wave heights in future climates show increase in the northern North Pacific and decrease in the North Atlantic, the central North Pacific, middle latitude and around the equator. In the Antarctic, the projected future changes of wave heights show decrease under the RCP2.6 scenario and increase under the RCP4.5, 6.0 and 8.5 scenarios, respectively. The extreme wave heights change in the future climates show different spatial trends from mean one depending on the latitude and the future greenhouse gas emission scenarios, especially active regions of tropical cyclones.

Thu-015

Simulating storm surge of TC Haiyan in a future climate condition using adaptive mesh refinement

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Accurate modeling of storm surge from tropical cyclones is a major concern for the world's coastal population centers, especially highlighted by recent major disasters such as Typhoon Haiyan (2013) and Hurricane Sandy (2013). Additionally, the impacts of climate change on storm frequency, intensity, and trajectory makes storm surge an important uncertainty in hazard planning. However, numerical simulation of storm surge can be highly demanding due to large computational domains and the need for fine resolution along coastlines, in addition to the high spatial sensitivity to storm tracks, making future inundation projections difficult to estimate. One method to reduce computation cost is to incorporate adaptive mesh refinement, allowing for dynamic localized refinement to track features of interest while less active regions can be coarsely resolved to minimize computation costs. This allows for faster ensemble calculations of storm surge especially when inundation regions are yet to be determined.

We model the storm surge in the Typhoon Haiyan scenario using GeoClaw, a finite volume solver for the nonlinear shallow water equations with adaptive mesh refinement and robust Riemann solvers for wet/dry cells, combined with elevation data and atmospheric forcing using a parametric storm model and best-track data. The results of this hindcast simulation are compared with field survey measurements following the storm. We further consider climate changes for the North Pacific Ocean based on ensemble of CMIP5 projections and downscaling experiments to estimate future changes in storm track and intensity. We compute the storm surge based on these projections and compare changes in surge severity for Haiyan-like super storms in present and future climate scenarios.

Thu-016

Dominant modes of natural decadal sea-level variability in the indian ocean

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The Indian Ocean displays regionally contrasted sea-level trends over the altimeter period, which can have large socio-economical consequences for the fourth of the world population living around the rim of this basin. This trend results from the superposition of anthropogenically driven signals and natural climate variability. The Interdecadal Pacific Oscillation has been identified as the main driver of natural decadal sea-level variations in the Pacific and as a major contributor to the intensified sea-level rise over the western Pacific during the recent decades. In contrast, the Indian Ocean natural decadal sea-level variability, which may obscure the long-term sea-level changes in this basin, remains a largely uncharted territory. Identifying the main patterns of natural decadal sea level variability in the Indian Ocean is hence necessary for climate change attribution purposes but is very challenging from the relatively short satellite record. In this study, we analyse Indian Ocean natural decadal sea-level variations from a large set of observationally derived products (ocean reanalyses and sea-level reconstructions), CMIP3 and CMIP5 pre-industrial simulations.

All observational products display very consistent patterns of decadal sea-level variability in the Pacific, but not in the Indian Ocean, most likely because of sparse observational coverage there. In contrast, almost all CMIP simulations exhibit two very consistent mode of natural decadal sea-level variability in the Indian Ocean, which explain a large part the total decadal sea-level variance in this basin. The first mode consists of a dipolar sea-level pattern, with negative signals in the eastern Indian Ocean extending from the northwest coast of Australia to the northern Bay of Bengal and positive signals northeast of Madagascar. This mode is largely driven by the wind variability related to the decadal variations of the Indian Ocean Dipole, which is partly independent from the decadal climate variability in the tropical Pacific. The second mode is completely independent from decadal Pacific variability, and consists of a broad sea-level signature east of Madagascar. This mode is excited by decadal wind variations in the subtropical Indian Ocean, most likely associated with decadal fluctuations of the Mascarene high.

The two decadal modes of Indian Ocean sea-level identified in CMIP models are broadly consistent with those deduced from the relatively short altimeter data or from the longer Ocean Reanalysis System 4 (ORAS4) dataset. Sea-level reconstructions generally reproduce the dipolar mode but do not capture the decadal sea-level variability east of Madagascar, presumably due to the lack of long tide-gauge records in this region. This study hence suggests that CMIP outputs analysis can provide some guidance for identifying robust modes of decadal sea-level variability in regions that are not well sampled by observations.

Thu-017

Assessment of the 20th century regional sea level rise in historical runs of climate models by comparison with tide gauge observations

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Tide gauge records and satellite altimetry observations indicate that sea level has been rising since 1900 in response to anthropogenic GreenHouse Gases (GHG) emissions (IPCC, 2013) and the associated global warming. State-of-art global climate models (GCMs) show that this rise will accelerate if GHG emissions keep increasing with time. Projections of future global mean sea level rise over 2081-2100 from GCMs have a likely range range of +26 cm to +81 cm compared to 1986-2005, depending on the warming scenario for the 21st century and the GCM considered (IPCC, 2013). These significant rises of the sea level compared to the past 3000 years will have severe impacts on low lying islands and coastal zones (Nicholls and Cazenave 2010). To assess the impacts of future sea level rise, it is essential to develop accurate and reliable projections of sea level at regional scales. However, current projections of regional sea level rise are highly uncertain. For a given climate change scenario, GCMs indicate regional sea level rise over the 21st Century can differ by a factor of 2 or more (IPCC, 2013). This large uncertainty arises from inadequate (or sometimes missing) representations of physical and dynamical processes in the different components of the sea level projections. Sea level rise estimates inferred from climate models are revisited and validated against tide gauge observations in an attempt to understand and reduce the uncertainty of sea level rise estimates from climate models.

In the first part of our study, we estimate the 20th century regional sea level rise and its components from the outputs of the GCMs involved in the Climate Model Intercomparison Project Phase 5 (CMIP5). The contributions to sea level rise included in this study are: ocean warming; glacier ice melt; land water storage changes; and ice sheet mass loss. The ocean warming contribution is estimated directly from the CMIP5 ocean temperature outputs whereas contributions from glaciers and ice sheets are estimated through off-line models driven by CMIP5 simulations of temperature and precipitation. The resolution of the climate models is indeed too coarse to properly simulate the processes responsible for glacier and ice sheet mass loss.

In the second part of this study, we compare the 20th century modelled regional sea level estimates with observations from 31 long-term tide gauge records (covering several decades) in different places around the world. In total, we assess 12 GCMs from CMIP5 and we discuss their discrepancies with sea level in situ observations.

Thu-018

Dynamical downscaling of future sea-level change in the western North Pacific using ROMS

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Future regional sea-level (RSL) over the western North Pacific is investigated by conducting dynamical downscaling with the Regional Ocean Modeling System (ROMS) based on three CMIP5 climate models for the RCP8.5 scenario. The horizontal grid resolution of ROMS is 0.25-degree, and the model domain almost spans the whole North Pacific. Three climate models, which exhibit large regional sea-level rise in future, are selected for base models in order to know worst cases. The selected climate models are MIROC-ESM, CSIRO-Mk3.6.0, and GFDL-CM3. The historical run of the ROMS is forced by the air-sea fluxes calculated from Coordinated Ocean Reference Experiment version 2 data, while future downscaling runs are forced with an atmospheric field constructed by adding the difference between the climate model parameters for the 21st and 20th century to fields in the historical run.

The downscaled future RSLs commonly exhibit strong, bullseye-like RSL rise maxima centered on 41°N, 142°E, a few degrees from Japan coast, but the RSL rise along the eastern coast of Japan is generally one-third or less of the RSL rise maxima off the eastern coast. The projected regional (total) sea level rises along the Honshu coast during 2081–2100 relative to 1981–2000 are 22–29 (101–108), 8–15 (73–80), and 8–18 (80–90) cm in the downscaling of the MIROS-ESM, CSIRO-Mk3.6.0, and GFDL-CM3, respectively. The primary cause of the RSL change is suggested to be wind-stress change, while heat and freshwater fluxes play a secondary role.

Thu-019

Estimation of storm surge risk changes under global warming based on mega-ensemble global climate simulations

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INTRODUCTION

Climate change is getting apparent these days. The latest report of Inter-governmental Panel on Climate Change (IPCC) states that global mean sea level rose by 0.19 m over the period 1901 to 2010. The future climate projection of mean and extreme sea level change, storm surge is important for adaptation strategy to coastal development and protection. However, the occurrence probability of storm surge is too rare to discuss with probabilistic hazard intensity.

In this study, future changes in storm surge risk under global warming are estimated over the globe, quantitatively. The probabilistic (climatological) description of extreme weather events such as storm surge is greatly difficult due to the limitation of the number of samples compared with relatively-static variables such as sea level. In order to overcome the difficulty, storm surge risk is estimated on the basis of mega size ensemble global climate simulations. The total lengths of timeframe is 6,000 years for the historical climate, and 5400 years for the warmer future climate condition.

OUTLINE OF RESEARCH

The large ensemble simulations of global atmospheric climate was performed by Japanese Meteorological Research Institute's Atmospheric General Circulation Model (MRI-AGCM: spatial resolution is 60 km). 100-member ensemble historical (1951 - 2010) climate simulations were forced by observed Sea Surface Temperature (SST) and sea ice conditions. Furthermore, 90-member ensemble future (60-yrs) climate simulations were based on the assumed future SST and sea ice conditions. The future climate is assumed that global surface temperature is warmer by 4°C than the pre-industrial era, which is plausible at the end of 21th century.

First, long-term changes of wind speed at 10-m height (U10) and Sea Level Pressure (SLP) were analyzed. The extreme values such as 50-yr wind speed is generally estimated by fitting the extreme distribution function. In this study, the extreme values were estimated in the non-parametric way using order statistics of annual maxima because the number of samples is long enough (>5000 yrs).

The simple statistical storm surge model was developed on the basis of a series of numerical simulations of nonlinear shallow water model because the length of climate run is too long to simulate storm surge by the dynamic model. As an example, the historical and future storm surge at Osaka Bay in Japan was estimated by applying the model to U10 and SLP data of the large ensemble simulations.

RESULTS AND DISCUSSION

The probability distribution of storm surge of the historical and future climate over the global and Japan. In the case of shorter return level (~5 years), the historical values are larger than the future one due to less tropical cyclone in the future climate. However, future values are larger for longer return level due to stronger tropical cyclone in the future. The change of 500 year value is 0.5 m. The long-term storm surge risk can be easily estimated to other regions. It is found that the large ensemble is greatly useful for estimation of storm surge risk both present and future climate.

Thu-020

Shoreline integrated SLR change prediction in Mombasa and Lamu islands in Kenya.

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The research examined the use of both GIS and interactive models of climate change especially sea level changes research in Kenya using the integrated scientific assessments {ISAs}. The analysis focussed on the climate assessment of Mombasa and Lamu {CLIMAS}. The integrated assessment included three components of vulnerability climate assessments: interdisciplinary, stakeholder participation in vulnerability assessments and the role of perception and awareness in the production of usable knowledge. The challenges faced in an integrated vulnerability assessment to sea level rise (SLR) and the appropriate level of understanding of state and the application of the science. In general, community disciplinary and personal flexibility, are affected by the availability of resources that in turn influence the co-production of science and policy in the context of integrated assessments. Coastal vulnerable communities face daily challenges and knowledge sharing is a way of integrating adaptive results. Further, there may be no single model to fulfil the goals of such assessments, the process is interactive and includes the possibilities of higher levels of adaptation and mitigation to related social impacts.

The scientific modelling of sea level rise was done based on the global climate prediction models. The other objective was to assess physical and spatially risks of expected SLR, in particular, inundation, and its implications for Mombasa and Lamu Island up to the year 2100, using {GIS} techniques. The modelling was done under IPCC different sea level rise scenarios of RCP2.6 (B1) and RCP8.5 (A1FI) (most optimistic and pessimistic scenarios) for the years 2030, 2060 and 2090. The analysis included the present centuries 1.8m SLR scenario was adjusted, based on the predicted high water tide for the coastline of Mombasa including land uplift/subsidence, based on formulae developed by Nichols. The identified areas were superimposed on the land use maps of the two islands to ascertain the extent of the coastline vulnerable to inundation. The GIS analysis gives a good indication of the potential and magnitude of impacts that the two island cities might experience. Results show that the current exposure of the 1:100 storm surge levels for Mombasa is between 150,000-432,000 people and over US$ 900 million in assets by 2090 and almost 14.9\% of its land mass under threat. Lamu Island, the exposure is estimated to be between 50,000 and 124,000 for the three scenarios and over US $ 2.1 Billion especially due to the LAPPSET port development. Under the pessimistic scenario with rapid urbanisation, Mombasa and Lamu islands vulnerability increases to more than 826,000 people and infrastructure costing approximately US$ 4.2billion. Currently, 58% to 62% of these is located on the Islands highlighting its vulnerability to extreme water levels.

Thu-021

Upper ocean heat content (thermosteric sea level) at global and regional scales for 1970-2015: on the impact of XBT bias corrections in the CSIRO-ACECRC-IMAS estimates

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Investigation of ocean heat storage and redistribution is essential for the understanding of our climate system, from natural modes variability (eg, interannual, decadal changes) to the current energy imbalance caused by long-term anthropogenic warming. Thermal expansion induced by changes in ocean heat is also a major contribution to the observed global mean sea level rise since late 20th century and largely explains its regional patterns. A variety of factors, however, can introduce uncertainty into estimates of ocean heat content/thermal expansion. Mapping method was recently shown to be the largest source of uncertainty for global estimates in the upper 700 m of the ocean. The impact of instrumental bias corrections for eXpendable BathyThermographs (XBTs) was only larger than mapping method for estimates from the CSIRO-ACECRC-IMAS group. Here, we further study the sensitivity of the CSIRO-ACECRC-IMAS estimates to existing XBT bias corrections (about 10-12 proposed corrections) for 1970-2015 and discuss the implications of this source of uncertainty for variability and change in ocean heat content and thermosteric sea level at global, basin and regional scales.

Thu-022

The regional sea surface height response to volcanic eruptions in CMIP5 models

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We investigate the impact of volcanic eruptions on regional dynamic sea level in an ensemble of CMIP5 (Coupled Model Intercomparison Project Phase 5) models as well as on the contribution of the worlds glaciers to sea level using a glacier model forced with output from the same models. Large volcanic eruptions eject aerosols into the atmosphere that reflect incoming solar radiation and lead to a widespread tropospheric and surface cooling. In climate models, the response of sea level is a prominent decrease in global mean thermosteric sea level followed by a slow recovery over several decades. However, the spatial pattern of the response is unclear. The response of glaciers to volcanic eruptions has, to our knowledge, not yet been studied but will be impacted by the surface cooling as well as changes in regional precipitation after a volcanic eruption.

We analyse historical simulations (1850-2006) with natural forcing only, with volcanic forcing only and simulations of the past millennium. The dynamic sea level shows the largest response in the tropical Pacific Ocean whereas glacial mass changes affect sea level most strongly close to the glaciated areas in the northern polar regions. The regional response of the dynamic contribution is rather abrupt and short-lived with the largest amplitude 1-2 yrs after the eruption followed by a large reduction. The glaciers response, in contrast, is characterized by a gradual mass gain, resulting in a small sea level decrease away from and a strong increase close to glaciated regions due to the stronger gravitational pull of the growing glaciers. Regional detection is complicated by the enhanced magnitude of internal variability on regional scales. We quantify the magnitude of trends related to internal variability using control simulations with constant forcing only and assess whether, on regional scales, volcanic eruptions induce trends that are larger than those that can be expected from internal variability only. This is of particular importance when attempting to attribute observed regional sea level rise to anthropogenic forcing and for projecting the range of future regional sea level changes. Additionally, we attempt to scale the dynamic sea level response as well as the glaciers response with the magnitude of the volcanic eruption (defined by the aerosol optical depth) such that the impact of large volcanic eruptions can be included in future sea level scenarios.

Thu-025

Anthropogenic forcing dominates global mean sea-level rise since 1970

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Sea-level change is an important consequence of anthropogenic climate change, as higher sea levels increase the frequency of sea-level extremes and the impact of coastal flooding and erosion on the coastal environment, infrastructure and coastal communities. Although individual attribution studies have been done for ocean thermal expansion (TE) and glacier mass loss, two of the largest contributors to 20th century sea-level rise, this has not been done for the other contributors or total global mean sea-level change (GMSLC). Here, we evaluate the influence of greenhouse gases (GHG), anthropogenic aerosols, natural radiative forcings and internal climate variability on sea-level contributions of TE, glaciers, ice sheet surface mass balance (SMB) and total GMSLC. For each contribution, dedicated models are forced with results from the Coupled Model Intercomparison Project Phase 5 (CMIP5) climate model archive. The sum of all included contributions explains 74 ± 22% (± 2σ) of the observed GMSLC over 1900-2005. The natural radiative forcing makes essentially zero contribution over the 20th century (2 ± 15% over 1900-2005), but combined with the response to past climatic variations explains 67 ± 23% of the observed rise prior to 1950 and only 9 ± 18% after 1970 (38 ± 12% over 1900-2005). In contrast, the anthropogenic forcing (primarily a balance between a positive sea-level contribution from GHG and a partially offsetting component from anthropogenic aerosols) explains only 15 ± 55% of the observations before 1950, but increases to become the dominant contribution to sea-level rise after 1970 (69 ± 31%), reaching 72 ± 39% in 2000 (37 ± 38% over 1900-2005).

Thu-026

Assessment of 20th century global mean sea-level rise in climate models compared to observations

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Sea-level change is one of the major consequences of climate change and is projected to affect coastal communities around the world. The reliability of estimates of future sea-level rise depends on the quality of the climate models used. To evaluate the quality of these models, we compare global mean sea-level change (GMSLC) as estimated by climate models to observational estimates over the twentieth century. We discuss each of the contributions that affect GMSLC separately (thermal expansion, glacier mass change, ice sheet mass change, groundwater depletion and reservoir storage). To obtain model estimates for thermal expansion, glaciers and ice sheet surface mass balance we use output from climate models from the 5th phase of the Climate Model Intercomparison Project (CMIP5), of which 12 models provide the required variables for this study. CMIP5 historical simulations are used for 1900-2005 and extended up to 2015 using the corresponding RCP8.5 simulations. The model estimates will be compared to observations. In addition, observation-based estimates of groundwater depletion, reservoir storage and dynamic ice sheet mass change are discussed. We compare the total simulated GMSLC to reconstructions of total observed GMSLC over the period 1900-2015, using tide gauge records, and over the period 1993-2015, using satellite altimetry estimates. We find that models generally underestimate the total sea-level change over the 20th century (models explaining 74% +/- 22% (2σ) of the observed changes) and we discuss the reasons for this. However, models compare more favourably for the more recent period of 1970-2015, which may partly reflect more reliable observations during these years.

Thu-027

The Sea-Level Response to External Forcings in Historical Simulations of CMIP5 Climate Models

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Changes in Earth's climate are influenced by internal climate variability and external forcings, such as changes in solar radiation, volcanic eruptions, anthropogenic greenhouse gases (GHG), and aerosols. Although the response of surface temperature to external forcings has been studied extensively, this has not been done for sea level. Here, a range of climate model experiments for the twentieth century is used to study the response of global and regional sea level change to external climate forcings. Both the global mean thermosteric sea level and the regional dynamic sea level patterns show clear responses to anthropogenic forcings that are significantly different from internal climate variability and larger than the difference between models driven by the same external forcing. The regional sea level patterns are directly related to changes in surface winds in response to the external forcings. The spread between different realizations of the same model experiment is consistent with internal climate variability derived from preindustrial control simulations. The spread between the different models is larger than the internal variability, mainly in regions with large sea level responses. Although the sea level responses toGHGand anthropogenic aerosol forcing oppose each other in the global mean, there are differences on a regional scale, offering opportunities for distinguishing between these two forcings in observed sea level change.

Thu-028

NOAA's contribution to the GLOSS network

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Tide gauges in the United States have been collecting data in some regions for over 150 years. NOAA has the responsibility for maintaining and operating these stations which is critical for the long record of data for understanding sea level rise and climate variability, both on a global and local scale. A subsection of the network of NOAA tide gauge stations is part of the larger global effort for understanding sea level trends. The Global Sea Level Observing System (GLOSS) is an international effort to maintain a core network of 300 gauges in nearly 90 countries to determine global sea level for more than 20 years. The purpose of the GLOSS core network is to provide high quality sea level data for application to climate, oceanographic and coastal research. NOAA's Climate Observation Division supports the GLOSS network by installing, upgrading, and maintaining tide gauge stations in the U.S. and other countries, as well as, data analysis and quality control of the data. The poster will focus on NOAA's activities in support of GLOSS such as upgrading to have GPS co-located at all tide stations. We have upgraded many stations and are in the planning process for several more, mainly in the Arctic.

Thu-029

Dynamic Sea Level Changes in the Western North Pacific in Response to Global Warming Using CMIP5 Models

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Spatial dependency of sea level (dynamic sea level DSL) change attracts much attention, because it directly impacts on the human society. Relatively large sea-level rise is expected to occur in the western North Pacific. It is suggested that wind stress change and heat flux change contribute to DSL change there. However, there is no comprehensive study of DSL dealing with both surface forcings and subsurface ocean using multi-models. In this study, DSL changes over the North Pacific and the associated changes of the subsurface ocean and surface forcings are investigated until 2300 under two greenhouse-gas emission scenarios (RCP4.5, RCP8.5) by analyzing the output from CMIP5 models. DSL rises (falls) in the western subtropical (subpolar) gyre in both the scenarios by 2100. From 2100 to 2300, DSL rises most of the North Pacific with the large positive DSL change located on the Kuroshio Extension (KE) front only in RCP8.5. DSL changes little from 2100 to 2300 in RCP4.5 related to the faster stabilization of the radiative forcing than that of RCP8.5. A density decrease in the Subtropical Mode Water (STMW) and around the KE front explains these DSL rises in the western North Pacific. A large regional density decrease in the STMW is due to a large heat uptake of the STMW related to an excess downward heat flux in the south of the KE. A regional density decreases around the KE front by 2300 induced by the northward migration of the KE. The KE moves northward about 60% (80%) of northward migration of the zonal wind stress by 2100 (2300). A northward migration of the zonal wind stress is suggested to be closely related to the positive trend of the Arctic Oscillation by 2300.

Thu-030

Bayesian Inference on Present-Day Sea-Level Change for the East Coast of North America

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We have better instrumentation today than ever before for observing sea level change, its sources, and its impacts; yet determining variability at anything shorter than decade-scale and spatial variability at scales smaller than ocean basin has proven to be difficult. Combination of multiple data types that constrain the sources of variability and the deformation of the solid Earth with models that predict stero-dynamic sea-level variations and glacial isostatic adjustment (GIA) provides hope for separating with sufficient accuracy the various contributions to sea level. We have extended our method for Bayesian inference of sea-level change [Hill et al., 2010] to include stochastic variation of sea-level while simultaneously inferring the contributions of GIA and stero-dynamic variations in sea level. We have developed a "front-end" processor for gravity fields produced by the Gravity and Climate Experiment (GRACE) missions that preserves statistical information associated with removing systematic errors ("stripes") due to background model errors. We introduce a technique whereby we include Stokes coefficients higher than degree 60 (the GRACE cutoff) as parameters in the Bayesian solution, thereby enabling higher resolution constraints on the gravitational response of sea-level change to self-attraction and loading. We focus on the U.S. east coast, where GIA plays a large role in sea-level change and the melting of the (relative nearby) Greenland ice sheet introduces a significant spatial variability.

Thu-031

Coastal variability and resilience in the coast of Georgia, U.S.A with the influence of climate changing

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A high resolution coastal ocean model is used to investigate salinity variability and water exchange in a complex coastal system off the southern U.S. characterized by three adjacent sounds that are interconnected by a network of channels, creeks and intertidal areas. With a few exceptions, model results are highly correlated with observations from the Georgia Coastal Ecosystem Long Term Ecological Research (GCE-LTER) program, revealing a high degree of salinity variability at the Altamaha River and Doboy Sound, decreasing sharply toward Sapelo Sound. A Lagrangian particle tracking method is used to investigate residence time and connectivity in the system. Residence time is highly variable, increasing with distance from the Altamaha River and decreasing with river flow, demonstrating that discharge plays a dominant role in transport processes and estuary-shelf exchange. Connectivity between the Altamaha River and Doboy Sound is high in all seasons, with exchange occurring both via the oceanic and the marsh pathways. While particles released in the Altamaha and Doboy rarely reach Sapelo Sound, particles released at Sapelo Sound and the creeks surrounding the main channel can influence the entire estuarine system. The influence of sea level change is investigated in the coast to identify regions where sea level rise could alter the coastal inundation, thus vulnerability. Spatial and temporal variability in residence time, inundation and connectivity between the sounds are investigated to improve coastal resilience and vulnerability. River discharge, seasonal-varying winds and tidal forcing are all found identified as influential factors in this region.

Thu-032

Changes and variability of sea level and its components in the Indo-Pacific during the altimeter era

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Regional sea level experiences interannual and decadal variations which are closely related to large-scale climate modes, such as El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), in the Indo-Pacific Basin. These low-frequency sea level variability can be misinterpreted as linear trends during the short altimeter era, which makes it challenging to detect and attribute anthropogenic sea level changes. Although many studies have previously investigated climate mode related sea level variability from various perspectives, the underlying contributions of sea level components on different time scales are not yet clear. In an attempt to address this gap, we applied the multivariate regression to two ocean reanalysis products based on 4D-VAR methodology (ECCOv4 and ESTOC), in the Indo-Pacific. The total sea level is decomposed into the steric (thermosteric and halosteric) and mass components. Then the regional patterns (aka fingerprint) associated with the filtered ENSO and PDO indices, and corresponding residual trends are quantified for each component. For the first time, our study provides a comprehensive decomposition of sea level in terms of components and temporal scales under a consistent framework. We conclude that the steric component dominates regional patterns of sea level trends and the fingerprints in most areas, except in the high-latitude and coastal regions where a significant mass contribution to sea level interannual variability is identified. For the steric sea level, the thermosteric component is the main contributor, and the halosteric component is non-negligible in the north Pacific for trends and decadal fingerprints. In the tropics, the upper steric component (i.e., integral over 0-400 m) can reproduce regional patterns of the trends and fingerprints of total sea level well. However, to achieve the same reproducibility in high-latitude regions, the steric component deeper than 800 m and the mass component also need to be included. For the mass component, its interannual fingerprints, which are dominated by the barotropical vorticity balance, are consistent among two ocean reanalysis products and GRACE satellite observations, but less agreement is found for its trends. The current work emphasizes the need to improve observations and simulation of the halosteric and mass components, in order to achieve better sea level budget closure on regional scales.

Thu-041

Aligning the German Global Marine Data Base with the Modernized MCDS Data Flow

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Using the global nutrient dataset (GND10 provided by M. Aoyama), we re-evaluated basin-wide Redfield ratios. For the same latitudinal ranges for the Atlantic, Indian and Pacific basins as in Anderson and Sarmiento (1994), we constructed one or two end-member mixing models on 14 neutral surfaces in which the data of potential temperature, nitrate, phosphate, dissolved oxygen, dissolved inorganic carbon and alkalinity were used. Then, we estimated Redfield ratios by solving the model equations with a micro-genetic algorithm. Within the depth range of about 400 to 1000 m, the P/N/C/-O2 ratios were estimated to be 1/15±2/85±15/154±21, which are almost consistent with previous reports. One caveat is that we must be careful about the influence of anthropogenic carbon penetration into the ocean interior on our estimates which might lead to underestimation of the estimated C/P ratio. Compared with the previous studies, we found that both N/P and –O2/P ratios decrease with depth. On the other hand, the C/P ratio is relatively constant with depth, which is comparable to the previous studies. These results mean that both the respiratory quotient, i.e., -O2/C, and N/C ratio decrease with depth, suggesting that relative proportion of lipid and protein in organic material settling into the depths decreases with depth and conversely relative proportion of carbohydrate increases. The putative alteration of settling organic matter from our results was actually seen in previous sediment trap experiments. We suggest that alteration of composition of settling organic matter with depth affects Redfield ratios during degradation of organic matter, which leads us to consider variable Redfield ratios when running large-scale biogeochemical models or estimating the uptake of anthropogenic carbon by the ocean based on Redfied ratios.

Thu-042

Mechanisms of change in ENSO-induced tropical Pacific rainfall variability in a warming climate

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Recently, the major synthesis effort Global Ocean Data Analysis Product version 2 were pulished. GLODAPv2 assembles data from some 800 hydrographic cruises mostly from WOCE, CLIVAR and GO-SHIP, where measurements of inorganic carbon and/or other carbon relevant parameters, such as inorganic nutrients, have been made. It has been constructed by merging the three existing carbon data synthesis products GLODAP, CARINA, PACIFICA, and adding data from around 200 new cruises from all oceans. The data included in GLODAPv2 has been subjected to primary QC and been bias corrected following comparison of all the deep ocean data collected at the various cruises using a crossover and inversion routine, a so called secondary QC routine. This effort constitutes is the largest intercomparison effort ever for ocean inorganic nutrients, and the adjusted data product provide a benchmark dataset for evaluating trends in the ocean nutrient pool. During the efforts significant biases in inorganic nutrient measurement from ship-based observations became evident. Biases of that magnitude tend to impede detection of trends in ocean nutrient distribution for the deep layers of the ocean and emphasis that the ocean nutrient community generally needs to do a better job at the accuracy of nutrient measurements. Based on the data in GLODAP we can detect countries/labs that are particularly prone to produce biased data, pointing to the efforts in the SCOR working group COMPONUT to remedy the situation. We also note how for many cruises the precision of the data is only borderline acceptable, sometimes we rejected the nutrient data on these grounds. We also detected systematic biases in silicate values between US and Japanese investigators the reasons behind this have since been largely resolved. This analysis highlights precision and accuracy issues in the global ocean nutrient data base and provides information for the SCOR working group COMPNUT to remedy the situation.

Thu-043

Argo: past achievements, future risks and opportunities

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Marine in-situ observations of meteorological and oceanographic parameters are of great importance for weather prediction as well as climate research. The collection and exploitation of marine data for climate related applications is a challenging task for which JCOMM provides a modernized data flow in its Marine Climate Data System (MCDS) in order to respond to the needs of future research projects. Irregular distribution of observations, data void regions and changing observation systems are some of the factors that complicate the analysis and stewardship of long time series. A thorough data management and quality control in a traceable data flow are essential components to avoid the occurrence of data related artefacts and to facilitate the use of the data in interdisciplinary studies.

The Marine Data Centre of Deutscher Wetterdienst (DWD) maintains an extensive climatological archive of marine meteorological observations. Apart from recent data, the archive consists of a large amount of historic data ranging back to the mid-19th century. Several data streams are combined into a consolidated archive with a constantly increasing data amount. Real-time GTS data from ship, buoys and other marine measurement platforms are added to the archive in near real-time. Additionally, Voluntary Observing Ship (VOS) data, which is collected by the Global Collecting Centres (GCC), is injected into the archive in delayed mode. In a third stream, newly digitized data from the historic ship journal archive of DWD increase data coverage in time and space. All incoming data sets are routinely quality controlled using a sophisticated high quality control (HQC) procedure that performs several formal and meteorological checks on the data. Observations from the German VOS fleet undergo an additional manual quality control.

The presentation will give an overview of the marine data management at DWD and its alignment with the new MCDS. Current developments such as new routines for automatic and manual HQC and the migration of the data archive to a high performance data base system to facilitate user access will be introduced. Operational and planned analysis products in support of climate services and scientific challenges such as process understanding and the verification of satellite climate data records will be highlighted.

Thu-044

An eddy-permitting global sea ice-ocean system for reanalysis and forecasting applications

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The forth occupation of WHP-P1 line along 47N in the North Pacific was conducted in 2014. Since both the third (carried out in 2007) and forth occupations were carried out by JAMSTEC, nutrient measurement biases between the cruises are expected to be enough small to detect the subsurface decadal nutrient changes.

By comparison between two nutrient observations on isopycnal surfaces, we found relatively large nutrient increases below 26.5 neutral density surface in the eastern part of the sections. The nutrient increases were associated with salinity decreases. By using Argo profiling float data, the salinity decreases could be caused by transferring a low salinity anomaly from west to the east after 2003. This suggested that the nutrient changes after 2007 along P1 line can be strongly influenced by the circulation or environmental changes in the western part of the North Pacific, where the decadal and bi-decacal water property changes associated with changes in the Oyashio and/or the Kuroshio variabilities were frequently reported.

Thu-052

Earth system science frontiers - an early career scientists perspective

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The exigencies of the global community towards Earth system science will increase in the future as population and economies continue to grow. This growth, combined with intensifying urbanisation, will inevitably exert increasing pressure on ecosystems and its usage by humanity. It is time to lay the foundation for a unified interdisciplinary approach to Earth system science that accepts this challenge, integrates technical demands and long- term visions, and reconciles user demands with scientific feasibility. Together with the research arms of the World Meteorological Organisation, the Young Earth System Scientists community has gathered early career researchers from around the world to initiate a discussion about Earth System Science Frontiers. Society expects Earth system science to provide a comprehensive overview of anthropogenic influences on the Earth system and the creation of a global seamless environmental prediction framework that is both robust and instructive to local users. Such a prediction framework requires improved physical process understanding, more high-resolution global observations, advanced modelling capability as well as high performance computing on unprecedented scales. Its robustness and usability depends on expanding our understanding of the entire Earth system and improved communication between users and researchers. Earth system science is the fundamental baseline for understanding the Earths capacity to accommodate humanity, providing a means to have a rational discussion about the consequences and limits of anthropogenic influence on and control of the planet we live on. Its progress is essential for future sustainable development.

Thu-053

How the Atlantic Warm Pool Influences Hurricanes Intensity in the 21st Century？

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Since its inception in 1988, the Hawaii Ocean Time-series (HOT) program has sustained active research in the oligotrophic subtropical North Pacific Ocean. During these past decades HOT has conducted near-monthly research expeditions to Station ALOHA (A Longterm Oligotrophic Habitat Assessment), the program's deep ocean (~4800 m) field site, and, to date, more than 280 HOT cruises have been completed. The primary objectives of the HOT program are: 1) to quantify the linkages between seasonal, inter-annual, and long-term (multi-decadal) variability and trends in ocean physics, chemistry, and biology, 2) to identify the processes that control the flux and transformation of carbon from the upper ocean into its deep interior, and 3) to sustain high-quality measurements to elucidate time-varying interactions among ocean-climate, biogeochemistry, and plankton ecology. Providing the scientific community with high-quality data of full ocean depth inorganic nutrients is a key component of the HOT program and essential for quantifying temporal and long-term variability in nutrient inventories and climate driven trends. At Station ALOHA, nutrient concentrations range from (sub)nanomolar in the upper (<100 m) water column to micromolar in the nutrient enriched deep ocean. Such large gradients in inorganic nutrient concentrations challenge routine analyses, as does the requirement to maintain precision and accuracy in these measurements over time. Consequently, the use of certified reference materials (CRMs) and standards is of utmost importance. To assure reproducibility among analysis runs and comparability among nutrient data sets, particularly when sampling spans over many decades, rigorous standardization is required. Although HOT employs natural seawater CRMs for dissolved inorganic carbon and alkalinity measurements (DIC/Alk CRMs, provided by A. Dickson, SIO), equivalent materials have not been readily available for seawater nutrient analysis. However, certified standard materials from two independent vendors (WAKO - CSK standard solutions in sodium chloride, OSIL - nutrient standard solutions) are routinely used. To validate the analytical performance for each run, both vendors' certified materials are used for each of the nutrients analyzed (nitrate+nitrite, phosphate, and silicic acid). Typically, a deviation of no more than ±2% from the certified value is deemed acceptable. HOT has also participated in two recent international, nutrient analysis laboratory inter-comparison studies (2012, 2015) that have further validated the performance of the HOT nutrient analyses. These studies have underscored the importance of inter-comparability to other global nutrient data sets. In addition, the value of repeat observations over long time-periods, i.e., time-series data, is crucial to separate natural climate variability from anthropogenic impact on the global oceans. Here we present a few highlights from the HOT program, demonstrating the dynamic nature, and changing environment of the North Pacific Subtropical Gyre.

Thu-054

The Contribution of Polar Terrestrial Ecosystems in Global Carbon Cycle

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Recent studies emphasize the significant contribution of soil CO2 emissions to the atmospheric CO2 pool. Therefore, understanding the variability in CO2 exchange in terrestrial ecosystems, atmosphere and ocean is a significant step towards understanding the global carbon cycle. The research area is located in the polar north of Western Siberia (Yamalo-Nenets Autonomous District, Russia) within the northern boundary of north taiga. The climatic record (weather station Nadym) indicates a progressive warming of annual air temperatures of ~2C over the past 17 years (an average of -6C to -4C).The research was carried out at three sites: the forest site, the frozen peatland and the relic frozen peatland. Regime monitoring of the carbon dioxide emission and concentration in soil horizons (CO2 flux), regime monitoring of the temperature were determined in field conditions. The values of carbon dioxide emission are low in this region (115 77 mg??2/m2hr), which indicates the low biological activity of research soils. Maximum values of emissions are characterized by soil of forest ecosystems, minimal permafrost-affected peatland soils. Mean values of emissions are virtually identical for the three years of measurement and placed in the confidence intervals for ecosystems. The soils of the study area function in different temperature regimes: under the influence of permafrost (Turbic Histic Cryosol and Cryic Eutric Histosol) and long-term seasonal freezing (Albic Podsol). Sporadic permafrost defines the differences in temperature regimes. Research ecosystems are characterized with small variation of the total carbon content (37-53%) and high variation of labile organic carbon (0,35-1,65% of C total) in organic profile of the soils. The maximum carbon content was found in organic profile of Podsols. Also research ecosystems are characterized with high variation of the microbial carbon content (from 1,3 mg C/g soil in Histosols to 11 mg C/g soil in Podsols).The lack of easily accessible carbon for microorganisms was detected in all investigated soils by the Cmic:Corg ratio despite the high stocks of organic matter. The value of CO2 emission and the Cmic:Corg ratio were site-specific for the region of investigation and may be used as indicators of environmental changes. Peat cryogenic soils represent a unique natural object and provide functional diversity and integrity of northern taiga ecosystems of West Siberia. Soil CO2 emission is one of the major pathways by which CO2 fixed be terrestrial plants is released back into the atmosphere. Understanding of the contribution of polar terrestrial ecosystems in global carbon cycle is very important for the assessment of interaction between ocean, atmosphere and land.

Thu-055

The Seasonal Cycle of CO2 in the Southern Ocean: Diagnosing Anomalies in CMIP5 Earth Systems Models

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The Southern Ocean (SO) forms a key component of global carbon budget: taking up about 50% (1.0 0.5 PgCyr-1) of the total global oceanic annual uptake of anthropogenic CO2 and accounting for most of the uncertainty in the global ocean CO 2 fluxes. A recent synthesis study (Lenton et al., 2013), showed that although Ocean Biogeochemical Models (OBGMs) agree on the mean annual flux of CO 2 in the SO, they disagree on both amplitude and phasing of the seasonal cycle and compare poorly to observations. In this study, we used a diagnostic analysis based on the representation of the seasonal cycle of CO 2 air-sea (FCO 2) fluxes (Mongwe et al., 2016) on seven CMIP5 models. The diagnostic shows how an understanding of the seasonal variability of drivers of CO 2 at a seasonal scale helps explain the anomalies between observations and model output. In this study, we show that the model output observations FCO 2 seasonal cycle anomalies are due to differences in the magnitude of the seasonal cycle of dominant drivers of pCO 2 i.e. thermal and physical-biogeochemical drivers between the models and the observations. We found that 5 out of 7 CMIP5 models underestimate the influence of physical biogeochemical driver during the winter, spring-summer seasons. Weak winter convective CO 2 entrainment, as well as the impact of summer biological CO 2 uptake, have a compound effect on the amplitude of the seasonal cycle of DIC. As a result, the thermal driver SST dominates the seasonal cycle of FCO 2. While 2 of the 7 overestimate the physical biogeochemical driver on pCO 2 due to overestimation of the net CO2 biological uptake.

Thu-056

Greenhouse Gases Stabilizing Winter Atmosphere in the Indo-Gangetic Plains May Increase Aerosol Loading

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The rapid growth of aerosols along the Indo-Gangetic Plains (IGP) and their adverse effects on human health and the environment are well documented. In winter, the IGP is prone to high anthropogenic aerosol loading, resulting from seasonality and topography. In this study, three reanalysis datasets including the MERRA Aerosol Reanalysis are analyzed to characterize the relationship between winter atmospheric stability and aerosols. Due to the lack of long-term aerosol observation, an empirical relationship between particulate matter (PM) and the atmospheric temperature lapse rate is derived. The results reveal a strong relationship between PM and stability at the lower troposphere. Further analyses of the CMIP5 single-forcing experiments indicate that the recent stabilization of the atmosphere in the IGP has been a consequence of both greenhouse gas- (GHG) aerosol forcing. Since a more stable atmosphere traps more PM, stabilization alone can increase aerosols even in the absence of changes in emission sources. Thus, enhanced stabilization caused by both aerosols and GHG in the atmosphere can further increase winter aerosol loading in the IGP.

Thu-057

FIO-ESM global carbon cycle model and its application

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The earth system model FIO-ESM includes the ocean surface model besides tha atmosphere, ocean,land and ice components, and is coupled with the global carbon cycle process which interact with the global climate system. The pre-industrial control run, historical run and future prediction are all conducted following the CMIP5 long-term experiment design. The model results are validated with the observation data. Then, sensitive experiments under different emission scenarios are designed to compare with the CMIP5 global carbon cycle historical run. A more realistic approach name accumulative contribution is pointed out to quantify the contribution of CO2 emission from different nations to the historical climate change.

Thu-058

Watermass Formation, Circulation, and Anthropogenic Carbon Storage from transient tracers

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In the last decades, transient tracers (chlorofluorocarbons, sulphurhexafluoride and others) provided invaluable informations on the changes in water mass formation rates, changes in the storage of anthropogenic carbon and on time scales and main pathways of newly ventilated water. Here we wil summarize the latest results on these topics for the Atlantic ocean.

Thu-059

Quantifying sub-surface carbon fluxes with in-situ isotope labeling and compartmental analysis

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Arctic wetlands potentially impact on atmospheric greenhouse gas concentrations when subject to climate change. A precise prediction of the role of Arctic wetlands in a plus 2°C- world depends on our understanding of sub-surface biogeochemical processes that govern soil-atmosphere greenhouse gas fluxes. Undoubtedly, it is of great importance, whether Arctic wetlands emit methane or carbon dioxide to the atmospheric carbon pool in future scenarios. Our current understanding of these processes is well-developed on a conceptual level, but detecting and quantifying these processes in-situ in the microscale environment of soil-porewater processes is a technologically challenging enterprise. However, a method that allows the quantification of sub-surface carbon allocation processes in Arctic wetlands is required as a validation tool for models predicting Arctic wetland greenhouse gas emissions. Being able to quantify carbon allocation processes in such ecosystems would enhance our understanding of their role in the global carbon cycle. Processes, which cannot be measured directly, as it is the case for microscale sub-surface carbon processes, can be quantified with the help of labeling techniques and the subsequent analysis of tracer dynamics in different system pools by applying a compartmental analysis approach. Compartmental analyses are well-established in medical and biological research, but have scarcely been in use for the interpretation of in-situ stable isotope labeling of carbon cycle processes. Basically, the system compartment´s response function h(t) is deduced by solving a set of ordinary differential equations, which can be formulated based on the compartment size (soil parameter data set from the field site) and the tracer dynamics observed in these compartments (in-situ pore water samples and subsequent isotope ratio mass spectrometry detection of tracer concentration in each pool after the labeling). The equation

$$dMi^*/dt = \sum kij\ Mj - \sum kij\ Mj + Rai,$$

where dMi*/dt is the tracer concentration in the compartment i, kij ,kji are the rate constants and Mj ,Mi* are quantity of tracee and tracer, respectively, and Raiis the rate of appearance of tracer into the ith compartment of the system (from K.H. Norwich, 1977, Molecular dynamics in Biosystems), shows the basic theory underlying the compartmental model analysis. The in-situ 13C labeling experiment has been conducted in August 2013 on Samoylov island, Lena river delta, eastern Siberia, sample analysis has been conducted at the Institute of Soil Science, Hamburg University. The results of a late-summer in-situ 13CO2 labeling experiment in a Siberian polygonal tundra system are presented and sub-surface carbon processes as quantified with the compartmental analysis approach are displayed and the perspective of combining this method with eddy covariance and chamber measurements is discussed.

Thu-060

Indian Ocean Biophysical variability in the CMIP5-ESM models

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The interannual variability of the Indian Ocean (IO) is linked to principally two climate modes: the El Nino Southern Oscillation (ENSO) and the Indian Ocean Zonal Mode (IOZM). In addition, the IO is characterized by a strong warming trend. From a carbon prospective, the IO represents a source of CO2 to the atmosphere, with the largest contribution from the Arabian Sea area. The IO variability is therefore important not only in shaping its surrounding climate but also at a global scale. In this work, we investigate the impact of the Indian Ocean interannual variability on its biophysical interannual variability by analyzing fully coupled carbon/climate models from the CMIP5-ESM (Coupled Model Intercomparison Project 5 – Earth System Models) datasets. Data from five models within the esmHistorical experiments are investigated. Overall, the models depict the two modes well. However, changes in thermocline depth and winds are overestimated. During positive phase of IOZM and ENSO events the eastern IO and the northern Arabian Sea are characterized by an increase in surface chlorophyll, whereas deficit in surface chlorophyll is found along the east coast of Africa. A basin wide increase in sea surface pCO2 is also depicted during the positive phase of the two modes. Changes in surface pCO2 are however relatively small. Analyses of output from the future climate projection esmrcp8.5 models show an increase in surface pCO2 mostly in the western IO and concurrent to IOZM and ENSO positive events.

Thu-064

Re-emergence of Anthropogenic Carbon Through Shallow Overturning Pathways

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What are the large-scale controls on the uptake of anthropogenic carbon (Cant) by the ocean? It has long been known that the principal impedance to the uptake is exchange across the base of the mixed layer (MLbase) associated with subduction/obduction process. However, it is only recently that efforts have emerged that seek to understand and quantify this exchange of Cant across the MLbase. Our special focus here is on the "re-emergence" of Cant (upwelling of Cant via obduction), that will have potential impacts on carbon-climate feedbacks and ocean acidification. Here, the Lagrangian diagnostics for subduction/obduction presented by Blanke et al. (2002) are applied to Cant to estimate Cant transport across the MLbase under WOCE-era climatological conditions in an ocean biogeochemical model. The scientific value of the Lagrangian diagnostics is that they can quantify not only Cant transports, but also the pathways and timescales connecting subduction and obduction regions. Globally integrated Cant transports across the mixed layer base are estimated to be 4.96 PgC/yr downward via subduction and 4.50 PgC/yr upward via obduction, with net transport of 0.46 PgC/yr downward. The spatial distribution of the Cant transport is quite similar to that of physical subduction/obduction, underscoring the importance of ocean dynamics in transferring Cant between surface and interior oceans. The net downward transport only approximately one-quarter of the net air-sea carbon flux of 2.06 PgC/yr during the WOCE-era, implying an important role of diffusion transporting Cant downward given the net accumulation of Cant in the surface mixed layer is only 0.16 PgC/yr. The western boundary regions and the Equatorial upwelling regions are identified as large Cant re-emergence regions. Cant re-emergence is significantly larger than the local uptake through gas exchange over the same regions, pointing to a potentially dominating role for re-emergence in driving surface carbonate perturbations and thereby sustaining ocean acidification in these strong upwelling regions. Using Lagrangian diagnostics to evaluate pertinent timescales suggests most particles (~80%) re-emerge within 10 years in the western boundary regions of the North Pacific and North Atlantic. The timescale is consistent with previous estimates of the renewal timescales of subtropical mode waters. The proportion of particles obducting in the equatorial Pacific within 10 years is a bit less (~50%) but still about 70% of the particles have timescales less than 20 years. These results indicate the existence of relatively rapid cycling pathway for Cant over the vast expanse of waters contributing to the shallow overturning of the Subtropical Cells.

Thu-065

Role of sulfate aerosol forcing in East Asia leading to a surface warming in the western-to-central US

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It is well known that atmospheric radiative forcing can be influenced by the change in the aerosol concentration. In spite of a wealth of studies, however, it is still debatable how the regional anthropogenic aerosol forcing in East Asia affects the climate variability in the North Pacific. In this study, we examine the effect of anthropogenic aerosol forcing in East Asia on the climate variability in the North Pacific based on three idealized experiments using a CAM5. Regarding three experiments, the first run is forced by the historical SST for 1985-2010 with a time-varying SO_2 emission in East Asia. The second run is forced by the historical SST without the emissions and the third run includes the climatological SST with a time-varying emission in East Asia. By comparing three runs with the reanalysis dataset, we examine the role of regional aerosol forcing in East Asia leading to a surface warming in the western-to-central US.

Thu-066

Estimation of anthropogenic carbon in global ocean using transit time distribution and evaluation of its uncertainties based on ocean model output

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Quantifying the uptake and distribution of anthropogenic carbon (Cant) in the oceans is crucial for understanding the ocean's role in the climate system. However, the Cant in the ocean is not a directly measurable quantity, and the observational-based estimations of Cant are therefore relied on inference methods. Unlike most other inference methods, the transit time distribution (TTD) method allows for a spectral of water mass ventilation time and avoids the large uncertainties introduced by attempts to discriminate the small Cant perturbation from the large background of natural carbon. The uncertainties of the TTD method arises from common essential assumptions as other inference methods, such as steady state ocean circulation assumption and constant air-sea carbon disequilibrium assumption defined as the difference between the preformed carbon at the ocean surface and the dissolved carbon concentration in equilibrium with the atmospheric carbon dioxide. To evaluate the uncertainties in the TTD method, the Cant is estimated by applying the TTD method with the model simulated passive tracer of chlorofluorocarbon-12 (CFC-12), and the results are compared to the directly simulated Cant in the ocean carbon cycle model. The model simulated global inventory of Cant in year 2002 is 148 Pg-C, while the estimation of Cant by TTD with model simulated CFC-12 is about 9 Pg-C more than the direct model simulation. It is found that an unit mixing ratio (Δ/Γ) of the assumed TTD generally fits most regions of the global ocean, but in the Arctic and Nordic Seas smaller mixing ratio ($\approx$0.8) is preferable, and the in the Southern Ocean, larger mixing ratio ($\approx$1.2) should be used. The steady state circulation assumption causes uncertainty less than 1%, while the constant carbon disequilibrium assumption leads to large uncertainties in the Southern Ocean, the Nordic Seas and Arctic Ocean. An time-dependent air-sea carbon disequilibrium scheme is proposed according to the model output, which reduces the bias of the global Cant inventory to about 1.5 Pg-C, and also improves the spatial distribution of Cant compared with the model output.

Thu-067

Arctic Inflow Drives Reduction of the North Atlantic Carbon Sink (1990-2100)

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Despite its small area, the high-latitude North Atlantic is the most intense carbon sink per unit area, allowing for it to account for 12% of the 1.7 Pg C yr-1 of global ocean carbon uptake (Takahashi et al 2002, Gruber et al. 2009; Schuster et al 2012). With the use of the physical and biogeochemistry output from the Community Earth System Model - Large Ensemble (CESM-LE) experiment, we find that from 1990-2100, amplification of the Arctic hydrological cycle and resulting changes in freshwater fluxes between the Atlantic and Arctic drive a reduction in the carbon sink in the subpolar North Atlantic. The increasing, low alkalinity, freshwater outflow from the Davis Strait results in a positive trend in ΔpCO_2 of 0.11 ppmv yr-1 in the study region, 44˚N - 76˚N and thus a reduction of the carbon sink. The increasing Arctic outflow into the subpolar gyre is also coincident with a slowdown of the Atlantic Meridional Overturning Circulation (AMOC). This strongly affects the circulation and mixing depths in the region and results in a large scale decline in biological productivity. Using modeled fields of salinity and ΔpCO_2, we compare the results from the CESM-LE to other global climate models included in the Coupled Model Intercomparison Project Phase 5 (CMIP5). We find that the best agreement between the GCMs studied is on the magnitude and trend in the salinity in the subpolar gyre, and we find larger uncertainty in the salinity trends in the Greenland, Iceland, and Norwegian seas.

Thu-068

Strengthening Trade Winds and The Enhanced Equatorial Pacific Carbon Source

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We find that data-based products for ocean carbon fluxes over the observationally-rich period 1990-2010 show a pronounced trend towards stronger outgassing of carbon over the Tropical Pacific. This is consistent with the dynamics of a persistent La Nina-like state over the second half of this period, over which enhanced upwelling in the East and Equatorial Pacific brings carbon rich waters to the surface, increasing pCO2 and thus Sea-to-Air carbon fluxes. Results from CMIP5 multi-model and initial-condition ensemble simulations with an individual CMIP5 model (GFDL's ESM2M) do not capture the observed trends in the Equatorial Pacific outgassing of carbon. We interpret this model-observation disagreement to reflect missing processes in the current generation of Earth System Models, namely, an underestimate of natural decadal variability for CMIP5 models in Equatorial Pacific zonal wind stresses as has been previously identified in the climate dynamics literature.

To address this shortcoming inherent in CMIP5 Earth system models, and the impact on simulated air-sea carbon fluxes over the Pacific basin, we have conducted a suite of wind-over-ride experiments with GFDL's ESM2M model over the period 1979-2015. For the over-ride experiments, wind stress anomalies from the ERA-Interim data product have been imposed over the model's Equatorial Pacific domain. Results over the Equatorial Pacific are evaluated not only for the air-sea fluxes, but the underlying perturbations to the Subtropical Cell overturning circulation, to test the hypothesis that it is variability in the shallow overturning that sustained the large variability in equatorial Pacific air-sea fluxes over the data-rich period1990-2010. A set of ensemble runs with wind over-ride in the coupled Earth system model will also provide a means to evaluate the influence of decadal variability in the equatorial Pacific on extra-tropical air-sea fluxes of CO2 through atmospheric teleconnections.

Thu-069

Integrated In Situ and Satellite Sea Surface Temperature (SST) Observations and Analyses: Current Status and Future Development

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Modern day Global Ocean Observing System (GOOS) consists of multiple platforms and instruments, including in-situ and satellite observing systems. Each system contributes to the understanding and assessment of climate change signals, mostly in complementary to each other. Individual instrument observations have limitations in coverage (in both time and space) and accuracy. To maximize benefits and integrally use all the available observations, it is necessary to combine multiple platform observations. One such case is for climate scale sea surface temperature (SST) over the global ocean for climate change monitoring and assessment. For SST, the global coverage of satellite data is better than in situ data, but satellite data tends to contain systematic biases against in-situ based SSTs. Moreover, because of the denser spatial coverage of satellite data, in situ data tends to be overwhelmed by satellite data in objectively analyzed SST fields when the two systems are combined. Thus, the most important role of the in situ data in the analysis is to correct the large-scale satellite offsets or biases against in-situ based SSTs. One such in-situ SST observing system has been designed for the Advanced Very High Resolution (AVHRR) satellite SST. In this presentation, we will review the design, implementation and operational monitoring of the climate SST in-situ + satellite observing system and its potential future improvements. These include incorporating data from microwave satellites and more recent infrared satellite missions, and studying the long-term stability and accuracy on in-situ based SSTs.

Thu-070

Response of the Tropical Oceans to Global Warming

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Coastal nutrient concentrations are key parameters for the management of eutrophication, since they can be directly linked to nutrient inputs, which can be addressed by abatement measures. In relation with the EU Water Framework Directive (WFD) implementation, Ifremer has organized interlaboratory exercises for the French oceanographic community in the framework of its quality assurance program. In the context of using nutrient concentration in the assessment of ecological status, it is indeed important that all French laboratories set consistent and comparable analytical performances. Eleven exercises, each with two lots of samples for the five main nutrients (ammonium, nitrite, nitrate, phosphate and silicate), were proposed between 2006 and 2015, each exercise involving about 25 independent laboratories.

Interlaboratory comparison exercises require reference material: homogeneous, stable over relatively long periods, with simple storage and mailing conditions and with a preservation treatment inducing no interfering substances and minor changes of the original concentrations. Samples were prepared from low nutrient seawater spiked, or not, with nutrient salts to obtain low level and high level samples, corresponding to spring and winter surface coastal water concentrations. Samples were then pasteurized at 80 +/- 3°C for two hours and stored at ambient temperature. The nutrient concentrations were checked on several occasions: before pasteurization, just after pasteurization (homogeneity test), 3-4 months later (stability test after the period allocated for the exercise). Homogeneity, not altered by sample aging, remains within a few nanomoles per litre for nitrite and phosphate and within a few tens of nanomoles per litre for ammonium, nitrate and silicate. Stability data are close to homogeneity data at the low level and within 0.3 – 0.5 % at the high level, except for ammonium. Ammonium shows a slight drift due to the atmospheric contamination through the plastic cap (0.1 μmol/L per year) but it is nevertheless an acceptable performance over 1-2 month analytical delay. The effect of pasteurization on the nutrient concentrations was not significantly different from zero at the analytical precision, except for ammonium.

Instead of calculating the consensus value as an application of statistical tests based on the results of the participating laboratories, the use of a “certified” consensus value was preferred. These certified consensus values were determined from twenty replicates of each sample calibrated with CRMs by the proficiency testing provider and then calculated according to the algorithm A of ISO 13528:2005. The use of CRMs to certify the consensus values allows us to produce z-scores not biased by the performances of laboratories which use different analytical methods. These pasteurized samples, certified by CRMs, can also be considered as stable secondary standards for internal laboratory use.

Thu-071

User Interface Experiences toward the provision of Climate Services in Argentina

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In the last decades we are witnessing the advancement of science and technology regarding the production of forecasts on different timescales, for example medium and large scale, but in spite of these there is still a gap between climate information and the wide range of climate sensitive users. Communication, translation and interpretation are key words aiming at delivering good products and services toward an informed decision making process. Climate Services is a global framework launched by WMO in 2009 that aims at being a guide at global, regional and national levels at filling this gap. In this sense the framework proposes the development of a User Interface Platform as a tool to link the climate and hydrological communities with climate sectors such as agriculture, energy, health, among others. The implementation of interface spaces is a process that needs a transformative approach that could unify different kind of endeavors of social and natural science, the inclusion of stakeholders, governmental and non-governmental, as well as reconfigurations of how knowledge is been produced and communicated.

This paper presents results of an ongoing regional Project: “Towards usable climate science - Informing sustainable decisions and provision of climate services to the agriculture and water sectors of southeastern South America” funded by the Inter-American Institute for Global Change Research (IAI) - CRN3035. In this case a collaborative interdisciplinary process toward the creation of users interface spaces starts with the agricultural sectors of Argentina. A co-design process that social and natural scientists are carrying out, and includes roundtables with different practitioners, stakeholders and several institutions plus interviews and ethnography. All these, allowed us to notice that an interinstitucional collaborative and reflection space has emerged and focus on new ways to perceive their practices and identities. Furthermore, the heart of matter is how to enhance institutional and social legitimation of the products, predictions and forecast that National Weather and Hydrological Services (NWHS) and other institutions with operative responsibility delivered to users. Not only do these experiences point out the importance of the inclusion of users insights and perspectives to improve the provision of climate services but they also create a network to foster a real engagement in the coproduction of climate knowledge.

Thu-072

Seasonal-to-decadal climate prediction for the improvement of European climate services

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The European project SPECS undertakes research activities to deliver a new generation of European climate forecast systems, with improved forecast quality and efficient regionalisation tools to produce reliable, local climate information over land at seasonal-to-decadal time scales, and provide an enhanced communication protocol and services to satisfy the climate information needs of a wide range of public and private stakeholders. These new systems exploit the most recent knowledge on the processes responsible of climate predictability, always considering the interactions between the different components of the climate system (ocean, atmosphere, sea ice, land surface) and paying special attention to the initialisation of those components. The improved understanding allowed better estimates of the future frequency of high-impact, extreme climatic events and of their prediction uncertainty. A special effort has been made to explain the bases of climate prediction to a wide audience and to illustrate the benefits of investing in improving current climate forecast systems in a close interaction with a wide range of users, including policy making, industry and society, to better adapt to near-future climate variations. Examples that illustrate these points will be provided and discussed in a context where climate predictability research needs to develop closer ties to the development of climate services.

Thu-073

Impact of Solar Panels on global climate

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Regardless of the harmful effects of burning fossil fuels on global climate, other energy sources will become more important in the future because fossil fuels could run out by the early 22nd century given the present rate of consumption. This implies that sooner or later humanity will rely heavily on renewable energy sources. Here we model the effects of an idealized large-scale application of renewable energy on global and regional climate relative to a background climate of the representative concentration pathway 2.6 scenario (RCP2.6) . We find that solar panels alone induce regional cooling by converting incoming solar energy to electricity in comparison to the climate without solar panels. The conversion of this electricity to heat, primarily in urban areas, increases regional and global temperatures which compensate the cooling effect. However there are consequences involved with these processes that modulate the global atmospheric circulation, resulting in changes in regional precipitation.

Thu-074

Drought Risk and management in Mexico

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Drought is one of the most important risks that face regions with a semiarid climate, such as northern Mexico. In terms of risk, an adequate characterization of drought should consider not only the meteorological processes that it involves (precipitation deficit, large positive temperature anomalies, etc.) but also, the socioeconomic and envirnomental context in which drought occurs, which determine the regional vulnerability. A risk analysis of drought has been conducted for Mexico considering various elements that modulate vulnerability to drought, and a vulnerability model is constructed with information for the 2002 - 2013 period, to show the dynamical aspects of drought risk. When the vulnerability indices are combined with hazard (drought) information, an annual drought risk estimate is obtained for various regions of Mexico and such risk models are evaluated when compared with information on impacts, i.e., on agricultural or hydrological droughts. The risk models adequately describe drought impacts. The interannual variation in climate correspond to the high frequency component of risk and impacts, while the low frequency component is determined by the vulnerability evolution.

The drought risk approach has been considered by the Mexican Water Agency to define an estrategy to reduce vulnerability to drought. The National Program against Drought (known as PRONACOSE) considers various stages of action, depending on the severity of the meteorological drought. In the eraly stages of drought, it includes voluntary measures to save water, but when drought becomes extreme, it involves the compulsory implementation of actions and budgets to reduce the costs of drought. The Program is based on diagnosis of drought rather than drought long term forecasts, consequently, it is still more a response to diagnosed high levels of drought risk rather than a program to prevent of drought impacts bsed on long term seasonal climate forescasts.

The present work analyzes both, the dynamics of regional prolonged meteorological droughts in Meixco, and the use of vulnerability to drought estimates used to construct public policies aimed at reducing the costs of drought. The Program against drought may also include the implementation of structural measures against drought as a form of adaptation to a drier climate in case of such condition under climate change.

Thu-075

Sea Level Rise and Coastal Urban Communities: Lessons from India

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Vulnerability of coastal areas to climate change is a key issue, which has gained attention recently. Coastal areas face multiple risks and stresses related to climate change and variability (IPCC 2007a). Thirteen of the world's 20 largest cities are located on the coast, and more than a third of the world's people live within 100 miles of a shoreline (World Bank 2010). Altered frequencies and intensities of extreme weather, combined with sea level rise, are expected to have mostly adverse effects on natural and human systems. Coastal communities are highly vulnerable to global change impacts, mainly because of three reasons, high resource dependency, high exposure and limited adaptive capacity. India has a 7,517 km long coastline with many low-lying and densely populated areas with nearly 260 million people living within 50 km of the seacoast. The report on coastal mega cities (World Bank 2010) states that about 2 per cent of the worlds land area is represented by low-lying coastal areas. This 2 per cent coastal land area contains 13 per cent of the urban population (McGranahan et al., 2007). These highly vulnerable areas house a network of infrastructures. It is highly pertinent to start climate proofing infrastructure and services, given the climate sensitive nature of the existing infrastructure systems in the urban area. It could be maintained and managed in such a way that it is prepared to withstand climate impacts that it may be subjected to during its operational lifetime.This paper discusses on approaches that can increase resilience of infrastructure and the services in coastal urban areas of developing nations. It also highlights the Identification of vulnerable hot spots in the coastal urban area, recommendations for climate proofing infrastructure and services and methodology for vulnerability assessment of coastal cities to climate variability and sea-level rise.

Thu-076

Citizen engagement for adaptation to sea level rise: the case of Santos, Brazil

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Part of an international consortium (Metropole, Belmont Forum) the study aims to improve the understanding of the interactions between scientific knowledge and adaptive capacity in coastal areas, identifying factors that facilitate attitudes, values and decision making about local sea level rise risks and adaptation strategies. The analyses are developed in Santos, Brazil; Selsey, UK and Broward County, US. The project framework includes: (1) evaluation of disaster risk and risk perception by means of SLR scenarios generated by the COAST platform, and Adaptive Capacity Analyses; (2) downscaling of climate change derived by the Eta model; (3) impacts of climate change in human health. Here, we focus on results of framework (1) for two zones of Santos, presenting the consequences of SLR in 2050 and 2100 in two scenarios: no-action and with adaptation measures. The areas evaluated were chosen considering the coastal hazards they are prone to: coastal erosion and inundation caused by storms and tide surges in Southeast Zone (SEZ) and coastal inundation due to heavy rains and high tides in Northwest Zone (NWZ).

In two stakeholder engagement workshops apart two months the economic impacts of SLR and storm surge were introduced by interactive computer-based scenario simulations. In the first meeting it was presented by means of visualization tools the areas to be inundated and the economic damages expected if any adaptation measure is taken (no action scenario): for 2050 a SLR of 0.18 to 0.23m and associated losses up to R$354 million and for 2100 a SLR of 0.36 to 0.45m and losses up to R$1,28 billion. Attendees discussed possible adaptation measures and voted to model two of them for each zone. Results were presented at workshop 2 and showed that for SEZ the chosen measures (fortification, including beach nourishment and dune restoration; structural enforcement/improvement of existent walls; water pumping in existent drainage canals and tide control gates) would represent a cost-benefit rate of 28.58%, while in NWZ the measures modelled (fortification: dredging works and implantation of tide control gates in rivers and drainage canals; implementation of tide control gates in rivers and drainage canals, and accommodation: Mangrove restoration) would produce a cost-benefit rate of 0.32%.

The evaluation also involves a risk assessment through the Adaptive Capacity Index, which provides a mechanism through which existing management priorities, organizational structures and governance can be reviewed for identifying efficient pathways for adaptation. Stakeholders that actively play a role in the economy and viability of Santos from the public, private and civil sectors were gathered in a comprehensive assessment of resilience, evaluating their capacity to reflect on action so as to engage in the process continuously. Respondents identified changes of different aspects for 2005, 2010 and 2015 and in all of them they considered there has been a progressive improvement. Organizational responsibility and ability to plan reached the highest scores, while the lowest were found for command over available resources. Limited financial resources, heavy administrative system and lack of integration were identified as key points for reducing the adaptive capacity in Santos.

Thu-077

Emergence of multiple ocean ecosystem drivers in a large ensemble suite with an Earth system model

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Marine ecosystems are increasingly stressed by human-induced changes. Marine ecosystem drivers that contribute to stressing ecosystems – including warming, acidification, deoxygenation and perturbations to biological productivity – can co-occur in space and time, but detecting their trends is complicated by the presence of noise associated with natural variability in the climate system. Here we use large initial-condition ensemble simulations with an Earth system model under a historical/RCP8.5 (representative concentration pathway 8.5) scenario over 1950-2100 to consider emergence characteristics for the four individual and combined drivers. Using a 1-standard-deviation (67% confidence) threshold of signal to noise to define emergence with a 30-year trend window, we show that ocean acidification emerges much earlier than other driers, namely during the 20th century over most of the global ocean. For biological productivity, the anthropogenic signal does not emerge from the noise over most of the global ocean before the end of the 21st century. The early emergence pattern for sea surface temperature in low latitudes is reversed from that of subsurface oxygen inventories, where emergence occurs earlier in the Southern Ocean. For the combined multiple-driver field, 41% of the global ocean exhibits emergence for the 2005-2014 period, and 63% for the 2075-2084 period. The combined multiple-driver field reveals emergence patterns by the end of this century that are relatively high over much of the Southern Ocean, North Pacific, and Atlantic, but relatively low over the tropics and the South Pacific. For the case of two drivers, the tropics including habitats of coral reefs emerges earliest, with this driven by the joint effects of acidification and warming. It is precisely in the regions with pronounced emergence characteristics whre marine ecosystems may be expected to be pushed outside of their comfort zone determined by the degree of natural background variability to which they are adapted. The results underscore the importance of sustained multi-decadal observing systems for monitoring multiple ecosystem drivers.

Thu-078

Absolute Brazil Current volume transport: Five-year observations at 34.5°S

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The Brazil Current (BC) is a key component of the South Atlantic circulation, closing the subtropical gyre at the western boundary. As the BC flows southward, it advects warm and salty water from subtropical to subpolar regions contributing to the Atlantic Meridional Overturning Circulation (AMOC) variability and influencing the South Atlantic meridional heat transport. Here, the BC transport variability is analyzed from data collected along a line in the western South Atlantic at 34.5°S with four pressure-equipped inverted echo sounders (PIES) from May 2009 to present. In 2012, two current-and-pressure-equipped inverted echo sounders (CPIES) were deployed midway between three of the existing sites to augment the horizontal resolution of the array. The combination of the data from the PIES/CPIES and regional hydrographic surveys yields daily estimates of full-depth vertical profiles of temperature, salinity, density, and the meridional component of the absolute geostrophic velocity. Daily time series of absolute BC transport are estimated by vertically integrating the geostrophic velocities (baroclinic referenced to the bottom plus barotropic) from the sea surface to the neutral density surface at the interface between South Atlantic Central Water and Antarctic Intermediate Water. Continental shelf flows are estimated using high-resolution hydrographic transects, direct velocity measurements from an ADCP mooring, and numerical models. The time-mean absolute southward BC transport at 34.5°S is -13.5 ± 0.8 Sv with a standard deviation of 5.0 Sv. Peak-to-peak transport variations of about 30 Sv occur over periods as short as 3 weeks. Fluctuations with periods shorter than 100 days account for 60% of the variance. The variability of the baroclinic component accounts for the largest fraction of the absolute transport variability (80%). The baroclinic and barotropic transports are uncorrelated ($r = 0.15$), highlighting the need of measuring both transport components independently. No significant seasonal cycle is found. The mean annual absolute transport is remarkably steady during the observed period. Local and basin-wide drivers of BC variability as well as the linkage between BC and AMOC variability observed at 34.5°S will be discussed.

Thu-079

Surface, Subsurface and Intermediate Equatorial Currents in the Western Pacific Ocean Observed by Moored ADCPs

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Time-depth variations of the equatorial currents at surface, subsurface and intermediate depths in the western Pacific Ocean were directly measured by two acoustic Doppler current profiler moorings at 2°N, 140°E and 4.7°N, 140°E during January-August 2014. Intra-seasonal variations of the equatorial currents, with periods of 37-73 days, were observed over the upper 1100 m depth encompassing the North Equatorial Countercurrent (NECC), northern branch of the South Equatorial Current (SEC), Equatorial Undercurrent (EUC), Equatorial Intermediate Current (EIC), North Intermediate Countercurrent (NICC), and North Equatorial Subsurface Current (NESC). Compared with previous studies based mainly on shipboard synoptic surveys, the 8-month time series of velocity profiles obtained direct evidence for the existence of NESC; captured the reversals of the EIC in May and the NESC in June from the westward to eastward direction; revealed larger vertical extensions of the SEC and NESC, and greater depths of the EIC and NICC than previously thought. According to a global analysis product of ocean surface current, during January-April 2014 the NECC was located around its southernmost position and with the weakest intensity over the past twenty years. This is related to the fickle El Niño of 2014, despite of the occurrence of westerly wind events.

Thu-081

mesoscale eddies impact on atmosphere in the Pacific

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By collocating 12years (1998–2010) of remotely sensed surface turbulent heat fluxes with satellite altimetry data, we investigate the impact of oceanic mesoscale eddies on the latent and sensible heat fluxes in the Pacific, especially in the Kuroshio and Kuroshio Extension region.

Thu-082

Interannual Variations of Low Latitude Western Boundary Currents in the Tropical Western Pacific Ocean

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The observations of four research cruises in the northwestern Pacific Ocean in the winters of 2010 and 2012 and in the summers of 2011 and 2015 are analyzed to estimate the interannual variations of the low latitude western boundary currents (LLWBCs) during the 2010 La Niña and the 2015 El Niño. Geostrophic currents and transports are calculated at sections along 18ºN, 8ºN, and 130ºE (129ºE north of 8ºN in 2011) using CTD data, XCTD data (section 8ºN in 2015), and Argo data. Data from two moorings in the 18ºN and 8ºN sections covering the period of 2010 and 2012 are also used for comparison. Both the geostrophic currents and the moored current meter data in the 18ºN and 8ºN sections east of the Philippines have shown that the Kuroshio transport decreases significantly whereas the Mindanao Current transport increases significantly during the 2010 La Niña winter than in the 2012 normal winter. During the 2015 El Niño, the Kuroshio transport immediately offshore of Luzon island of the Philippines is found to be larger than in the summer of 2011. The Mindanao Current transport in the 8ºN section in September 2015 is smaller than that in July 2011. The transport of the North Equatorial Current in the 130ºE section is found nearly unchanged in the 2010 La Niña but reduced significantly during the 2015 El Niño. The comparisons suggest that the transport anomalies of the LLWBCs are southward during La Niña and northward during El Niño, which counter the existing paradigm based on numerical modeling and ship-board ADCP observations. Since the oceanic meridional transport anomalies are important for interannual climate variations like ENSO, the results underline the need for a focus observational study of the LLWBCs and its potential role in ENSO dynamics.

Thu-083

Seasonal Climate Information for rice farming in Suriname

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The Meteorological Service Suriname started with the seasonal forecasting since 2012. Being part of the Caribbean Climate Outlook Forum, since 2012, gives Suriname an opportunity to contribute monthly to the seasonal forecasting for the Caribbean Region. In addition, on national scale the Meteorological Service Suriname produces a monthly climate bulletin regarding the seasonal forecasting, with a three monthly and six monthly rainfall forecast. The forecast has been recently expanded with a temperature forecast and a drought warning.

The selected stations for Suriname are located at the coastal area, and the time period of the data is 30 years. The aim is to expand the number of stations to be included in the seasonal forecast and it should have coverage for the whole country. The purpose of the seasonal forecasting is therefore to improve the service of the Meteorological Service to the sectors such as: the water resources, agriculture and food security, disaster risk reduction and the health sectors. These sectors are very vulnerable to weather and climate events. These four priority areas are the main focus of the Global Framework for Climate Services of the World Meteorological Organization, which Suriname is a member of.

Moreover, the seasonal forecast is useful for planning purposes within the rice farming in Suriname. In addition, it can be included in the decision making processes for the policy makers.

Key words: Seasonal forecast, rice farming

Thu-084

Sustainability assessment tools to support aquaculture development

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Aquaculture production has doubled every decade for the past fifty years, representing the fastest growing food sector. This increase reflects the expansion of production areas, increased know-how in husbandry and advances in production technologies, but most importantly it entails increased use of production-inputs that lead to exploitation of natural resources and hence raising concern on environmental distress. In addition, it suggests a similar range of production-outputs apart from the actual target products that are hardly quantified but often are recognized for causing impacts on the environment as well as potential risks for human health. Although several quantitative multi-impact assessment tools have been explored to evaluate environmental impacts of industrial activities, applications in aquaculture have only recently been carried out. However, impact assessment tools applied so far do not reflect the full range of aquaculture activities, and hence incorporate limitations that impair their use in aquaculture environmental assessment. Therefore, the development of tailored environmental assessment tool incorporating impacts distinctive to aquaculture is necessary. Although large strides have been made in reaching standardized methods for environmental assessment tools such as life cycle assessment (LCA), their use in policy formulation and decision making requires relentless effort to develop the tools using fundamental problems known to aquaculture. As a prerequisite, the most significant impacts of aquaculture are identified but need to be characterised and integrated in aquacultural assessment tool.

Thu-085

El Niño-Southern Oscillation (ENSO) impacts on Eastern Little Tuna (Euthynnus sp) hotspots in the Java Sea

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The ocean climate variability of El Niño-Southern Oscillation (ENSO) in the Java sea was examined using remotely sensed of sea surface height anomaly (SSHA), sea surface temperature (SST), and Chlorophyll-a (Chl-a) data. This study investigates how ENSO affects on oceanographic conditions and further addresses their relations with the Eastern Little Tuna (Euthynnus sp) hotspots. The Eastern Little tuna catch and remotely sensed data were analyzed for the 5 years datasets from January 2010-December 2014 and emphasized the differences of climate conditions during ENSO events. The relationships of oceanographic factors and catch distribution was explored with a generalized additive model (GAM). Eastern Little Tuna catches had significant increment during El Niño (January 2010-April 2010 and October 2014-December 2014) compared to during La Niña events (July 2010-April 2011 and September 2011-March 2012). Changes in oceanographic conditions during ENSO events resulted in perceivable variations in catches, with an average catches of 839.6 t during El Niño. During La Niña event with an average catches of 602.6 t was less favorable for Eastern Little Tuna catches. GAM results showed that the 3-oceanographic parameter combination models explained the highest deviance (41.4%) with Chl-a explained the highest deviance (23.3%). High probabilities of Eastern Little Tuna catches were correspond with marine productivity of Chl-a concentration ranging from 0.3-0.5 mg/m3, for SSHA ranging from 0-8 cm and SST ranging from 28-29°C. The spatial variation showed that during El Niño event, Eastern Little Tuna hotspots having more conducted location as sparse in 3.22 ºS to 6.59 ºS and 108.20 ºE to 109.67 ºE than during La Niña event between 5.39 ºS to 6.60 ºS and 108.64 ºE to 109.22 ºE. Major hotspots located around 3.22-6.59ºS and 108.20-109.67ºE could have been suggested as the most favorable oceanographic condition to Eastern Little Tuna catches in the Java Sea.

Thu-086

Climate Data Management for Climate Change Analysis

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Climatological data has been recorded for many centuries. Early records were written as manuscripts and then collected and retained in specific almanacs or yearbooks for climate data. With the development of instrumentation, much more data was being collected and needed to be kept. This need paved the way for the development of organized management of climate data. Each National meteorological service (NMS) around the world has the expertise to deal with the huge number of climate data. Some of them have been developing and maintaining their own climatological database together with many applications to process and to present the information about the country climate.NMS in developing countries typically use climatological applications provided by large centres. The Czech Hydrometeorological Institute (CHMI) developed the special climatological application CLIDATA for climate data management. In collaboration with World Meteorological Organisation (WMO) the CHMI provides CLIDATA application to NMSs. The CLIDATA is a main tool for climatological data management in several meteorological services around the world (actually 30 countries). It is primary intended for archiving of climatological data, for the data quality process and for metadata administration. Nowadays we see rapidly growing importance of sophisticated applications built above the climatological database storage using analytical GIS tools to prepare graphic and cartographic presentations. The GIS as integral part of CLIDATA provides users with tools not only for quality control and data presentation, as well as tools for analysing changes in regional climate.The basis of any analysis of climate change is built on good quality of climatological data. The 30 countries (Barbados, Benin, Bosnia and Herzegovina, Burkina Faso, Cape Verde, Chad, Czechia, Cuba, Dominican Republic, Estonia, Ethiopia, Gambia, Georgia, Ghana, Guinea Bissau, Guyana, Jamaica, Latvia, Lithuania, Macedonia, Mali, Mauritania, Montenegro, Namibia, Niger, Nigeria, Senegal, Serbia, Tanzania and Trinidad and Tobago) have the opportunity to prepare efficient inputs to the analysis of climate change now. The international organisations (AGRHYMET and ASECNA) working closely with CHMI to train climatologists in Central Africa.Bannerman, B., Stuber, D., Tolasz, R. et al., 2014. Climate Data Management System Specifications. WMO-No. 1131, World Meteorological Organization, Geneva, ISBN 978-92-63-11131-9.Guide to Climatological Practices, WMO-No. 100, Ženeva, ISBN 978-92-63-10100-6.Tolasz, R., 2009. Database Processing of Climatological Data. Praha, Czech Hydrometerological Institute, 66 pp., ISBN 978-80-86690-68-1.

Thu-087

Copernicus Marine Environment Monitoring Service

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COPERNICUS is the European Earth observation and monitoring programme, which aims to give the European Union autonomous and operational capability in space-based observation facilities (see the Sentinel missions) and in situ (measurements in the atmosphere, in the ocean and on the ground), and to operate six interlinked environmental monitoring services for the oceans, the atmosphere, territorial development, emergency situations, security and climate change. In this context, the Copernicus Marine Environment Monitoring Service (CMEMS) provides an open and free access to regular and systematic information about the physical state and dynamics of the ocean and marine ecosystems for the global ocean and six European regional seas. Mercator Ocean, the French center of global ocean analysis and forecast has been entrusted by the EU to implement and operate the Copernicus Marine Service.

We intend here to give an overview on this unique service worldwide accessible via a single point of entry, a web portal. In particular, we will present the Copernicus Marine Service catalogue, which encompasses products derived from satellite and in situ observation, forecasts and analysis in real time, and time series stretching several tens of years into the past (reanalysis). The Copernicus Marine Service has been designed to serve to many public, commercial and scientific purposes in four areas of benefits: Marine Resources, Maritime Safety, Coastal and Marine Environment and Seasonal Forecasting/Climate. We will also introduce Copernicus Marine Service's use cases.

Thu-088

The Ocean State Report of the Copernicus Marine Environment Monitoring Service

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COPERNICUS is the European Earth observation and monitoring programme, which aims to give the European Union autonomous and operational capability in space-based observation facilities (see the Sentinel missions) and in situ (measurements in the atmosphere, in the ocean and on the ground), and to operate six interlinked environmental monitoring services for the oceans, the atmosphere, territorial development, emergency situations, security and climate change. In this context, the Copernicus Marine Environment Monitoring Service provides an open and free access to regular and systematic information about the physical state and dynamics of the ocean and marine ecosystems for the global ocean and six European regional seas. Mercator Ocean, the French center of global ocean analysis and forecast has been entrusted by the EU to implement and operate the Copernicus Marine Service.

In September 2016, the first Ocean State of the Report Copernicus Marine Environment Monitoring Service will be published, and is planned to appear at an annual basis as a unique reference for ocean state reporting. This report contains a state-of-the-art value-added synthesis of the ocean state for the global ocean and the European regional seas from the Copernicus Marine Environment Monitoring Service data products and expert analysis. This activity is aiming to reach a wide audience -from the scientific community, over climate and environmental service and agencies, environmental reporting and bodies to the general public. We will give here an overview on the report, highlight main outcomes, and introduce future plans and developments.

Thu-089

Building a sustainable fishery for future generations: utilizing fishery observers to monitor catch and bycatch

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National Marine Fisheries Service (NMFS) utilizes observers to collect catch, bycatch, fishing effort, biological characteristics, interactions with protected species and socioeconomic information from U.S. commercial fishing and processing vessels. Fishery observers are independent specialists who serve on board commercial fishing vessels and other platforms, and are employed by government agency or by a third party contractor. They had been collecting fisheries data from 1971 as a voluntary basis and mandated by law since 1974 to maximize sustainable fishing while achieving the greatest economic benefits to the nation. In 2012, NMFS deployed observers in 47 fisheries to monitor over 83, 000 days at-sea and reported 0.7 billion bycatch associated 6.0 billion landing. NMFS use observer data to perform stock assessments, construct fishery management regulations, develop bycatch reduction devices, and list protected species. Regional fishery management councils use observer data to set annual catch and bycatch limits, which meets the purpose of conserving marine resources, protecting sustainable fishing and reestablishing the stocks that have been overexploited. At-sea monitoring is a crucial and practical procedure to build a sustainable fishery and prevent illegal, unreported and unregulated fishing, and is required for joining international fishing agreement and non-governmental organizations.

Thu-090

SST anomalies over the central Indian Ocean and heavy precipitation during Indian summer monsoon

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The Indian summer monsoon (ISM) is the wet season of the Indian Peninsula and the pronounced intraseasonal precipitation is a distinct feature during the ISM. However, the monsoonal precipitation does not have a good relation with common climate indices, such as the ENSO index and the Indian Ocean Dipole index. In the study, we propose that the third EOF mode in the Indian Ocean and the associated sea surface temperature (SST) anomalies over the central Indian Ocean play a critical role for the intraseasonal precipitation during the ISM. The downdraft over the central Indian Ocean, which is associated with the deep convection over the western Pacific warm pool, leads to warm SST anomalies. The easterly winds get enhanced over the warm SST anomalies and the westerly winds get enhanced around the monsoon trough due to the zonal temperature difference between the Bay of Bangel (BoB) and the Arabian Sea. Meanwhile, wind anomalies in the upper and the lower troposphere induce an easterly vertical wind shear, which is favorable for the northward propagation of ISV via the convective momentum transport. As a result, the warm SST anomalies shift the ISVs originating in the western Indian Ocean to the north, which supplies a lot of momentum and moisture to the onset and heavy precipitation during ISM.

Thu-091

Tropical ocean initialisation strategies for seasonal forecasting

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Seasonal forecasts of SST show substantial skill in tropical regions, but are crucially dependent on the initialisation procedure used in the ocean. The sensitivity of the equatorial thermocline to errors in wind stress forcing means that an equatorial bias correction method is often used during ocean data assimilation. While this improves the accuracy of the ocean initial state, it leads to an inconsistency at the beginning of the forecast, since the bias correction term is not retained during the forecast itself. This trade-off between providing accurate initial conditions and avoiding rapid model adjustments has the potential to affect seasonal forecast skill in the tropics and elsewhere.

We present results from a number of simulations carried out with the European Centre for Medium range Weather Forecasts (ECMWF) coupled forecast system, comparing different initialisation strategies for the equatorial ocean. Instantaneous changes in the ocean at the beginning of the forecast are found to induce spurious temporal variability in the thermocline, which appears to reduce sea surface temperature forecast skill in key regions at lead times of several months. Superior forecasts are obtained by slowly removing the bias correction term during the first month, which avoids initialisation shocks while retaining information from the bias-corrected reanalysis that provides the initial conditions.

Thu-092

Low-frequency oscillations of East Asia/Pacific teleconnection and simultaneous weather anomalies/extremes over eastern Asia

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The East Asia/Pacific (EAP) teleconnection can substantially modulate weather anomalies over eastern Asia during summer. Wavelet analyses, including ensemble mean power spectrum and accumulated frequency of significant components, highlight 10-30-day oscillations in the EAP index. The influences of these low-frequency oscillations on weather anomalies are further investigated via both phase-dependent and lead-lag composites. On 10-30-day scales, a tripole structure of precipitation anomalies and a temperature seesaw form concurrently over adjacent regions along eastern Asia. These anomalies last for about one week, constituting anomalous weather spells with possible extreme values around the peak/valley phases. For cold spells over Northeast Asia during positive phases, the low-frequency easterly is the determinant factor. On one hand, it advects cold air from the sea east of the land. On the other hand, it conveys moisture to form low-based clouds, which are effective in inhibiting incoming solar radiation. While, for cold spells over central-eastern Siberia during negative phases, regional-scale precipitation and cold advections conveyed by anomalous northerlies combine to make contributions. Both hot spells over central-eastern Siberia/Northeast Asia during positive/negative phases mainly result from the adiabatic heating and increasing solar radiation, both of which are attributed to strong descent in response to upper-level convergences.

In addition to great intensity, the high-impact property of these simultaneous weather anomalies also arises from their long duration and large spatial extent. By taking advantages of the quasi-periodicity of the 10-30-day oscillations, better predictions of these simultaneous weather anomalies/extremes would be anticipated.

Thu-093

The Influence of Sea Surface Temperature Anomaly on the East Asian Summer Monsoon Strength and Its Precursor

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The strength of the East Asian Summer Monsoon (EASM) is closely connected to the summer main rainfall belt in China. The precursor index defined by the difference of zonal wind anomaly at the 200 hPa level between the middle latitude in Asia and eastern Pacific in February is well indicative to the strength of EASM, which is an important predicting factor in flood season. The potential mechanism of precursor signal influencing the EASM is proposed by changing the surface characteristics in South Asia continent, but it is unclear whether the atmospheric circulation anomaly in February persists in the following seasons over middle latitude region. In addition, a further investigation is needed about the surface anomaly variation over South Asia in winter-spring seasons. ERA-interim reanalysis data, NOAA sea surface data, gridded CMAP precipitation data an precipitation observations over China are used. By composite, correlation and regression analysis approaches, the difference of wind in middle latitude over Eurasia, sea surface temperature (SST) in tropics and thermal condition in South Asia continent in previous winter-spring seasons in various strength EASM years are analyzed. Results indicated that tropical SST is the physical connection of accordant variations between the strength of EASM and its precursor.

Results show that the precursor signal of the EASM captures the primary feature for the first mode of empirical orthogonal function (EOF1) of zonal wind anomaly at the 200 hPa level over the Asia and Pacific in February. The EOF1 mode is related to SST in central and eastern Pacific. In previous winter, The SST is below (above) normal in central and eastern Pacific, which is conducive to a northward (southward) shift of westerly jet over the Asia in February. The zonal wind anomaly at the 200 hPa level exhibits meridional positive-negative-positive (negative-positive-negative) pattern, and the precursor index is stronger (weaker) than normal. In summer, the negative (positive) SST anomaly occurs in the vicinity of Indian Ocean and South China Sea, which results in an increasing (decreasing) difference between ocean and land and stronger (weaker) Indian Summer Monsoon. Meanwhile, the western Pacific subtropical high (WPSH) is weaker (stronger) than normal, the EASM is stronger (weaker) than normal. The anomalous feature of zonal wind in the middle latitude of the Asia in February is hardly to persist in spring. The physical connection between the EASM and its precursor mainly derives from the tropical ocean.

Thu-094

THE SOUTH AMERICAN WATER BALANCE: THE INFLUENCE OF LOW-LEVEL JETS

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To study the climatology of the water balance over South America and analyze the influence of low-level jets (LLJs), we performed a climate study of the water balance and its main components, specifically in the Amazon and La Plata Basin (LPB) region, from 1979 to 2008. The results showed that on average for the analysis period, the Amazon Basin and LPB performed as a sink of moisture (ET<P) and as a moisture convergence for the regions, which accounted for approximately 62% and 43% of the precipitation, respectively. During the study period, we observed 884 days with an occurrence of LLJs, which occurred most frequently during the winter and 00 UTC and 06 UTC. When considering the water balance for the days with LLJs, we observed that the Amazon acts as a source of moisture, especially in the dry season, and that the LPB behaves as a sink during all months. The influence of the LLJ as a modulator for precipitation on the LPB is clear, as the precipitation is 32% higher during the LLJ events compared with days without LLJs. This main pattern shows that the moisture convergence trough of the LLJs is crucial for the water balance on the LPB, whereas evapotranspiration is a more important variable of the water balance on the Amazon Basin with or without the LLJs.

Thu-095

Evolution of the Baltic Sea hypoxia during the last 10,000 years

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Spatial extent and intensity of hypoxia (O2<2mg/L) in coastal waters have increased globally over the last decades due to anthropogenic eutrophication. During the last century, hypoxic area in the Baltic Sea increased 10-fold and presently hypoxia covers larger than 60,000 km2 of the Baltic Sea1, making it the largest human-induced "dead zone" in the world. Over the last 10,000 years, there are three intervals with intense hypoxia in the Baltic Sea2, including 8000-4000 cal. yr BP, 1400-700 cal. yr BP and post-1950 AD, linked with stratified water column, relatively warm climate and pronounced human impacts.

In addition to previous studies on the Baltic Sea hypoxia history, we present a reconstruction of hypoxia evolution from a coastal site in the Baltic Sea, named Gåsfjärden, SE Sweden3. Analysis of dinoflagellate cysts, benthic foraminifera, organic carbon (Corg), biogenic silicon (BSi), C/N, C/P, Ti/Al, K/Al and grain size distribution were carried out. The chronology of the sediment sequence is well constrained, covering the last 5500 years.

High C/P ratios (>200) were recorded between 5400 and 2700 cal. yr BP, implying frequent hypoxic bottom water condition in Gåsfjärden. Dark bands observed in the core lithology, which were most likely stained with sulfide, support this interpretation. The most intense hypoxic period from the Gåsfjärden record was between 4400 and 4100 cal. yr BP, overlapping with the intense hypoxia interval of deep basin from Baltic Sea open water. Thus, this hypoxia interval is possibly a basin-wide event, linked with a highly productive and stratified water column due to a warm climate. In the Baltic Sea deep basin, hypoxia was re-established during the Medieval Climate Anomaly (MCA) period between 1000 and 700 cal. yr BP2, whereas in Gåsfjärden, persistent hypoxia was not established during the period, possibly due to the lack of a halocline and a shallower water depth. Presently, hypoxia is recorded during summer-autumn in Gåsfjärden based on hydrographic measurements.

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Thu-096

CHARACTERISTICS OF MOISTURE SOURCES FOR ARCTIC REGION: AN ANALYSIS FOR PRESENT AND FUTURE CLIMATE USING GFDL/CM3.1 MODEL

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The Intergovernmental Panel on Climate Change on his last report suggests that different regions of the world will present different impact caused by the increase of temperature in the future. In particular, the Arctic Region is one with the biggest projected impacts and the changes are already being registered, showing scenarios never seen in recent decades. The temperature in this region warms twice faster than the global average (Arctic amplification), and was also observed a decrease on Arctic sea ice extent and on snow cover extent. At the same time that these changes where observed on Arctic Region, other regions of the world, especially in the Northern Hemisphere mid-latitudes, showed the occurrence of extreme heat and rainfall events, suggesting a link between Arctic change and mid-latitude weather.

Some studies suggest that the most significant changes in the Arctic region can be due to changes in the atmospheric moisture (increased transport from middle latitudes). Recent works show that the main regions that contribute as moisture sources to the Arctic Region are located over Mediterranean Sea, North Atlantic Ocean and North Pacific Ocean. So, the objective of this work is to understand how important is the behavior of these moisture sources regions on present climate and identify their contribution on future climate scenarios.

The analysis were performed for the present period (1980-2005) based on the output of a Lagrangian model (FLEXPART) with the vertical integrated moisture flux from ERA Interim Data and compared with data from GFDL/CM3.1 Model. These analysis enable a better understanding of how each region contribute as moisture source to the Arctic Region, and allow to analyze if the model is able to reproduce the main characteristics of these features.

For the future analysis, the model where analyzed for periods 2046-2075 and 2070-2099 for RCP4.5 scenario, and compared to the present climate. This analysis allows understanding how and where occurs the main changes on moisture sources for the Arctic Region.

This work only shows the analysis for one moisture source region for the Arctic: the North Atlantic Ocean. The results indicate four regions as significant correlated with the moisture transport in the Arctic. The model used could reproduce the main characteristics of this transport in the present climate. For both future periods analyzed, it was found that there is a bigger contribution from sources regions (located on North Atlantic Ocean, North Africa and Middle East) for the Arctic moisture. This may indicate an increase in moisture transport that could lead to a decrease of the ice extent.

Thu-097

Observation of turbulence kinetic energy dissipation in the Yellow Sea

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Vertical distribution of turbulence kinetic energy (TKE) dissipation was measured by MSS-60 at a station in the Yellow Sea from July 12 to July 14, 2010. Three casts of MSS-60 were continuously launched from the sea surface down to the bottom at every hour. Among the three casts, two similar profiles of TKE dissipation were selected and averaged to denote the vertical distribution of TKE dissipation at the observation time. Finally, TKE dissipation were obtained from 7:00 of July 12 to 9:00 of July 14. A strong TKE dissipation layer was found just below the thermocline. The strong dissipation layer exists during the whole observing period, which may be caused by the shear induced by internal waves. The dissipation rate in the bottom layer changes with the tidal current. The dissipation rate becomes larger during stronger tidal current while the dissipation rate is close to the background value for the weak current velocity, which may correspond to the velocity shear in the bottom boundary.

Thu-098

A Linkage Between Movements of Solar System and Decadal Change of Upper Ocean State

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The movements of solar system lead to periodic variations of the astronomic tidal forcing with time scales ranging from semidiurnal to millennia. The variations of the astronomic tidal forcing could have imprint on the tide-induced diapynal mixing and thus the upper ocean state, but little evident has been reported so far. Using long-term oceanic observations/reanalysis data, here we show that the tide-induced diapynal mixing, stratification and sea surface temperature (SST) have a decadal variability following movements of solar system with the same periods. Our findings link the decadal change of the upper ocean state to the movements of solar system, and help to understand the underlying physics of the climate variability as well as to constrain climate models for projecting the climate variability in the future.

Thu-099

Stationary mesoscale eddies, upgradient eddy fluxes, and the anisotropy of eddy diffusivity

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The mesoscale eddies of which parameterization is needed in coarse-resolution ocean models include not only the transient eddies akin to baroclinic instability but also the stationary eddies associated with topography. By applying a modified Lorenz-type decomposition to the eddy-permitting Southern Ocean State Estimate, we show that the stationary mesoscale eddies contribute a significant part to the total eddy kinetic energy, eddy enstrophy, and the total eddy-induced isopycnal thickness and potential vorticity fluxes. We find that beneath middepth (about 1000 m) the upgradient eddy fluxes, or so-called "negative" eddy diffusivities, are mainly attributed to the stationary mesoscale eddies, whereas the remaining transient eddy diffusivity is positive, for which the Gent and McWilliams (1990) parameterization scheme applies well. A quantitative method of measuring the anisotropy of eddy diffusivity is presented. The effect of stationary mesoscale eddies is one of major sources responsible for the anisotropy of eddy diffusivity. We suggest that an independent parameterization scheme for stationary mesoscale eddies may be needed for coarse-resolution ocean models, although the transient eddies remain the predominant part of mesoscale eddies in the oceans.

Thu-100

The eddy-mean flow interaction and the intrusion of western boundary current into the South China Sea type basin in an idealized model

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In this paper, an ideal model on the role of mesoscale eddies in the Kuroshio intruding into the South China Sea (SCS) is developed, which represents the northwestern Pacific and the SCS by two rectangle basins connected by a gap. In the case of only considering intrinsic ocean variability, a time-dependent western boundary current (WBC) driven by steady wind is modeled under both eddy-resolving and non- ddyresolving resolutions. Almost all simulated WBC intrudes into the adjacent sea in the form of loop current with multiple-state transitions and eddy-shedding process, which has aperiodic variations on intraseasonal or interannual scales, determined by the eddy-induced WBC variation. For the parameters considered in this paper, the WBC intrusion exhibits a 30~90-day cycle in the presence of the subgrid-scale eddy forcing (SSEF), but a 300~500-day cycle in the absence of SSEF.

Moreover, the roles of the resolved (grid-scale) and unresolved (subgrid-scale) eddies in the WBC intrusion are studied. It is found that the unresolved eddy-flow interaction strongly regulates the WBC intrusion through the PV forcing induced by shear flows and baroclinic processes. But the resolved eddy forcing, which is dominated by the eddy-eddy interaction solely through baroclinic processes, shows weak correlation to the WBC intrusion. The associated eddy-induced PV exchange between the two basins is mainly accomplished by isopycnal-thickness eddy fluxes, particularly by the cross-front PV fluxes due to the unresolved eddy. And the unresolved eddy-flow interaction, as well as resolved and unresolved eddy-eddy interactions, mainly governs the PV transport for the WBC intrusion.

Thu-101

Tropical cyclones in the Mozambique Channel: January-March 2012

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Tropical cyclone (TC) activity in the Mozambique Channel from January to March 2012 resulted in five landfalls that affected Madagascar and southeastern Africa. The rainfall, circulation, and temperature fields surrounding the TCs were studied for anomalous characteristics. Case studies were considered for two TCs, which brought flooding to southern Mozambique and adjacent areas: Dando 17 January and Irina 3 March. Weather forecasts underestimated rainfall from Dando and poorly resolved the looping track of Irina. An anomalous easterly circulation associated with Pacific La Nin&tilde a and warm SST in the SW Indian Ocean are indicated as mechanisms supporting repeated tropical cyclogenesis in the Mozambique Channel. The downstream shedding of a vortex from Madagascar contributed to the variable nature of TC tracks and forecast errors in January March 2012.

Thu-102

The influence of increasing Arctic river runoff on the Atlantic meridional overturning circulation: a model study

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Observations reveal that the six largest Eurasian rivers' freshwater entering the Arctic Ocean has an increasing trend in the past several decades, and the growth has been accelerating. This freshwater increasing trend will continue in the twenty-first century projected by CMIP5 (Coupled Model Intercomparison Project Phase 5) coupled models. At the end of this century, the water flux from rivers to the Arctic Ocean will be 1.4 times of that in 1950 based on CMIP5 projection results. The influence of increasing Arctic river runoff on the Atlantic meridional overturning circulation (AMOC) is investigated here by using an ocean-ice coupled model. Twin numerical experiments are designed, and the results show that AMOC strengths will decrease by 0.6 (3%), 1.2 (7%) and 1.8 (11%) Sv, at the year of 100, 150 and 200 after the start of Arctic river runoff increase with the rate of 0.22 percent per year. AMOC weakening is mainly caused by freshwater transported from increasing Arctic river runoff inhibit the formation of North Atlantic Deep Water (NADW). The salinity and age of NADW will also be influenced in the whole basin by increasing Arctic runoff. NADW salinity will decrease and age will become older, which also indicate that AMOC will slow down because of increasing Arctic river runoff.

Thu-103

Subsurface Salinity Anomalies and Its Pathways from the Northwestern Subtropical Pacific to the Eastern Luzon Strait

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The subsurface ocean signal propagation from subtropics to tropics has been shown to play a vital role in low-frequency climate variability. In this study, monthly gridded temperature, salinity, and velocity datasets based on Argo profiles, long-term repeat hydrographic observations along 137°E section, and the ocean modeling outputs for 2003-2012 are used to investigate the subduction and propagation of subsurface salinity anomalies along 24.5-25.4kg.m-3 isopycnals in the northwestern Pacific. Both observational and modeling results suggest that the surface salinity anomalies in the northwestern subtropical Pacific (28-35°N, 140-160°E) could be subducted and advected to the eastern Luzon Strait via southwestward thermocline flows. In contrast to salinity anomalies generated in the northeastern subtropical Pacific that propagate slowly and dissipate strongly, these northwestern subtropical Pacific anomalies have a noticeable signature along their propagation pathway and arrive more quickly at the eastern Luzon Strait on time scales of 1-3 years

Thu-104

High and Low salinity water in the northern South China Sea and their relationship with the North Equatorial Current system

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The North Pacific Tropical Water (NPTW), characterized by subsurface high salinity, is observed in the South China Sea (SCS) and is often used as an indicator of the water intrusion from the northwestern Pacific into the SCS. Based on the assimilation product from a global high-resolution Hybrid Coordinate Ocean Model (HYCOM) from 2008 through 2013, this study investigates the seasonal variability of subsurface high-salinity water (SHSW) in the northern SCS and its relationship with the North Equatorial Current–Kuroshio circulation system. Results show that the obvious seasonal variability of the SHSW appears at about 100–200m in depth. It extends as far west as southeast of Hainan, reaching its volume maximum (minimum) in January (May). The seasonal variance contribution (seasonal variance accounting for the entire variance) is 0.38 in the period we considered, albeit with significant annual variance in other years. Further analysis shows that the changes in high-salinity water volume are highly correlated with the shift in the North Equatorial Current bifurcation latitude (NECBL), which reaches its northernmost point in December and its southernmost point in May. Due to the large-scale wind changes in the Pacific, the Luzon Strait transport (LST) weakens (strengthens) when the NECBL shifts to the south (north) during summer (winter), which results in the reduced (enhanced) SHSW intrusion from the northwestern Pacific into the northern SCS. It is also found that, on a seasonal timescale, the Kuroshio transport (KT) does not vary in phase with NECBL, LST and SHSW, indicating that the KT changes are probably not the governing factor for the seasonal variability of SHSW in the northern SCS.

Thu-105

Cause of Severe Droughts in Southwest China during 1951-2010

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The cause of severe droughts over the Southwest China (SWC) during the local dry season is investigated based on the station rainfall data and the NCEP/NCAR reanalysis during 1951-2010. The droughts are in general consistent with local anomalous descent in the middle troposphere. The diagnosis of the vertical motion (omega) equation indicates that the local descent is primarily maintained by the anomalous cold temperature advection processes. Both the advection of anomalous temperature by mean wind and the advection of mean temperature by anomalous wind contribute to maintaining the anomalous descent over the SWC region.

A composite analysis shows that the circulation anomaly over SWC is induced by remote forcing from the tropical Pacific and North Atlantic. During La Niña years, enhanced heating over the Maritime Continent induces anomalous downward motion over SWC through the connection of local Hadley circulation. Adiabatic warming associated with the downward motion helps to set up and maintain the local anomalous anticyclone. Another possible route is through the North Atlantic-Asia (NAA) teleconnection, in which downstream Rossby wave energy propagation plays a crucial role. A negative-phase North Atlantic Oscillation (NAO) may trigger a large-scale wave train pattern that induces an anomalous anticyclone over the subtropical Asia and promotes the dry condition over SWC.

Thu-106

Seasonal variations in the barrier layer in the South China Sea: characteristics, mechanisms and impact of warming

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A new observational dataset, the South China Sea Physical Oceanographic Dataset 2014 (SCSPOD14), is examined to investigate the seasonal characteristics, formation mechanisms, and warming effects of the barrier layer (BL) in the South China Sea (SCS). Statistical analysis reveals that the BL is thicker and occurs more frequently during summer and early autumn, while in winter it often coexists with temperature inversions. The formation mechanisms are discussed from the perspective of the controlling regime and the net turbulent energy required for BL evolution. In the initial stage (March–March), the BL is absent due to weak mixing, scarce rainfall and surface warming. In the formation and maintenance stage (June–September), the BL grows in summer and persists into the transition season. The BLs can be classified into three regimes: the flux regime (in the Luzon Strait), the combined regime (in the eastern basin) and the wind regime (southeast of Vietnam). In the attenuation stage, associated with the winter monsoon, the BL mainly occurs in the combined regime (along the path of western boundary current) and the flux regime (in the southeast corner). The characteristics and generation mechanisms of the temperature inversions near the south Chinese coast, east of Vietnam, and in the Gulf of Thailand are also discussed. Our analysis further demonstrates that the BL has a significant warming effect on upper ocean temperature and heat content in the SCS.

Thu-107

Seasonal thermal fronts on the northern South China Sea Shelf

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Seasonal thermal fronts associated with wind-driven coastal downwelling/upwelling in the northern South China Sea are investigated using satellite measurements and repeated mapping surveys. The results show that vigorous thermal fronts develop over the broad shelf with variable widths and intensities in different seasons, which tend to be approximately aligned with the 20-100 m isobaths. Driven by the prevailing winter/summer monsoon, the band-shaped fronts were observed with a magnitude exceeding 0.1°C/km in the subsurface, and accompanied by energetic coastal downwelling/upwelling due to shoreward/offshore Ekman transport. The downward/upward tilting of seasonal thermoclines significantly contributes to the development of thermal fronts over the shelf. In addition, the diagnostic analysis of Potential Vorticity (PV) suggests that the summer frontal activities induced by the coastal upwelling are more stable to convection and symmetric instabilities in comparison to the winter fronts associated with downwelling-favorable monsoon forcing. This is primarily due to their essential differences in the upper ocean stratification and horizontal buoyancy gradients arising from wind forcing.

CLIVAR Open Science Conference

Day 5 - Friday, 23rd September 2016

Plenary Oral Presentations

Plenary Session 5 **Friday, 23rd September 2016** **09:00hrs**

Dr. Fei Chai

Fei CHAI (柴扉) is a professor of oceanography at the University of Maine. Dr. Chai studies physical and biological processes contributing to global carbon cycle and how climate variability affecting marine ecosystems and fisheries. Dr. Chai is an expert in developing and testing physical-biological models, and using models along with in situ and remote sensing observational data to address key regional and global questions and issues. Dr. Chai teaches oceanography and climate change related courses at the University of Maine during the spring semester each year. Starting in 2016, Dr. Chai has been appointed as the Director of State Key Laboratory of Satellite Ocean Environment Dynamics (SOED) at Second Institute of Oceanography, State Oceanic Administration (SOA) in China. He spends six months a year at SOED in Hangzhou and six months at the University of Maine. Dr. Chai serves as committee member for several international scientific organizations and programs, prompting interdisciplinary and collaborative research projects.

Coastal and Marine Ecosystems in a Changing World

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The ocean plays an important role in regulating global climate, but it also provides natural resources for societal and economic development. Coastal and marine systems are important sources of food, energy and water, and they are also essential for international trade and recreational activities. Most of coastal regions and marine ecosystems have been stressed and altered significantly due to human population growth, rapid industrialization across the world, and global climate change. Environmental stressors induced by global climate change include increasing temperature, alternation of precipitation and runoff, sea-level rise, frequency and intensity of storms and extreme weather events, and ocean acidification. Stressors due to direct human activities (non-climate induced) include over-fishing, coastal eutrophication, land-use change, and loss of habitats. In this talk, I will present a few examples to highlight how changing climate and direct human activities affect the structure and function of coastal and marine ecosystems. The consequences of global change for coastal and marine ecosystems are complex, and predictions of the different factors and their associated impact have varying degrees of confidence. In order to improve our understanding and forecasts about impact of global climate change on coastal and marine ecosystems, we need to establish and maintain ocean observing networks to

monitor variability from environmental conditions to ecosystem levels, design and conduct targeted experiments to address human-natural interactions, and search for meaningful and scalable solutions. Also, we will need to develop and examine different adaptation strategies for resorting and keeping the resilience of coastal and marine ecosystems. Development of ocean economy needs to have science-based and well-informed policies and decision-making processes in order to sustain economic prosperity and maintain ecosystem health from local to global levels.

Dr. Arame Tall

With over 10 years of work experience on climate services in Africa, Dr. Tall is one of the world experts on climate services for society, operating at the nexus of climate knowledge and societal benefits. She started her career with the Red Cross Federation where she served as regional technical adviser for West and Central Africa for several years, before joining CCAFS where she spearheaded among many more achievements, several programs to scale up climate services for smallholder farmers in Africa and South Asia, and published a best practice synthesis report entitled: Scaling up Climate Services for Farmers > Mission Possible" leveraging the research capability of the CGIAR to achieve better targeted climate services for farmers across the globe. A passionate researcher, practitioner and user of climate services herself, Dr. tall now resides in her home of Dakar Senegal where she leads the GFCS' regional coordination work for Africa, serving all of the countries of Africa to achieve coordinated national frameworks to govern and sustain the delivery of climate services.

Dr. Matt Collins

Dr. Mat Collins is the Joint Met Office Chair in Climate Science at the University of Exeter, UK and is a co-chair of the CLIVAR Climate Dynamics Panel. He has broad research interests in modeling climate variability and change.

The Role of Climate Dynamics in Future Climate Change

<u>Matt Collins</u>

University of Exeter, UK and CLIVAR Climate Dynamics Panel

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Dynamical processes in the atmosphere and ocean are major drivers of future regional climate change, yet the role of dynamics is often poorly understood and is the reason for differences in projections between models.This talk will provide an overview of three key dynamical processes and their role in determining spatial patterns of climate change. (i) Storms, blocks and jet streams are features of midlatitude climate but changes are uncertain due to a 'tug-of-war' between surface and upper tropospheric changes in temperature gradients. (ii) Tropical and extra tropical atmosphere-ocean coupling and associated changes in atmospheric circulation are key drivers in changes in precipitation patterns, yet coupling on long climate change time scales is poorly understood. (iii) Tropical-extratropical interactions play a key role in the north-south hemispheric assymetry seen in climate change projections. We highlight opportunities and techniques for progress including the use of partial coupling or pacemaker experiments, the use of hierarchies of models and the potential for exploiting knowledge about present day variability in understanding the forced climate signal.

Dr. Nicolas Gruber

Dr. Nicolas Gruber (1968) holds a Masters degree in Environmental Sciences from the Swiss Federal Institute of Technology (ETH) Zurich and received a Ph.D. from the University of Bern in 1997. Subsequently he worked as Visiting Research Scientist with the AOS program at the University of Princeton for three years. In 2000 he was appointed as an Assistant Professor at the Department of Atmospheric and Oceanic Sciences at the University of California, Los Angeles, where he received tenure in 2005. In 2006 he returned to Switzerland to become Professor for Environmental Physics at ETH Zurich. His main scientific research interests are the global biogeochemical cycles of carbon and other biologically essential elements and their interaction with the climate system. He combines the analysis of observations with modeling studies to better quantify, for example, the fate of the anthropogenic CO2 emissions in the Earth System, particularly the uptake by the ocean and land biosphere. He authored together with Jorge Sarmiento the textbook “Ocean Biogeochemical Dynamics” that has become a standard text in the field. In recognition of his outstanding contribution to Marine Sciences, Dr. Gruber received the Rosenstiel Award from the University of Miami in 2004. In 2012 he was elected fellow of the American Geophysical Union. He currently serves as Chair of the Center for Climate Systems Modeling at ETH Zürich and is member of several national and international research boards.

Climate, carbon and ocean biogeochemistry at a time of change: Recent insights, emerging trends, and future outlook

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Thanks to major advances in our ability to observe and model the ocean's major biogeochemical cycles, we have made great progress in our understanding of these cycles and their interaction with the physical climate system. But we also have come to realize how much we have underestimated the inherent spatiotemporal variability of these cycles, and also how important these interactions are in order to assess the impact of future changes. While ocean warming, ocean acidification and the loss of oceanic oxygen have been identified as major threats to ocean organisms and ecosystems for nearly twenty years, the enormous challenges posed by these interacting stressors and their likely non-linear nature have come to the forefront only in the last few years. And if we consider that extreme events in these conditions likely will have a much larger and also faster emerging impact than changes in the mean state, our current inability to predict the future with confidence becomes even more evident. Further,

we are currently ill positioned to quantitatively assess how large climate-driven trends will be relative to "natural" variability, and to attribute any particular trend or phenomenon to a human influence on climate. Recent developments in coupled modeling and observing technologies have the potential to alleviate these challenges substantially. Especially the emerging ability to push global models into the full-mesoscale-resolving realm will permit to finally address the coupling of physical processes and ocean biology at their natural scales, i.e., those actually experienced by the individual organism or at least the local population. But the development of our conceptual and numerical models of ocean biology and their biogeochemical counterparts is not progressing at a commensurable pace. A key reason is the lack of observations, which are expanding in a rather limiting way in the biological/biogeochemical realm. But the emerging and continuously improving ability to measure biological and biogeochemical properties from floats in a reliable manner now makes it possible to develop a global observing program based on Argo floats. Such a biogeochemical Argo program is bound to revolutionize ocean carbon and biogeochemical sciences in the same way as it did physical oceanography in the past decade.

Dr. Guy Brasseur

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