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# Ocean Surface Topography Science Team Meeting

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Abstracts Book

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# 1 - The effect of geocenter motion on Jason-2 and Jason-1 orbits and the mean sea level

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4406>

## Abstract :

We have investigated the impact of geocenter motion on Jason-2 orbits. This was accomplished by computing a series of Jason-1, Jason-2 GPS-based and SLR/DORIS-based orbits using ITRF2005 and the IGS05 framework based on the most recent GSFC standards. From these orbits, we extract the Jason-2 orbit frame translational parameters per cycle by the means of a Helmert transformation between a set of reference orbits and a set of test orbits. The fitted annual and seasonal terms of these time-series are compared to two different geocenter motion models. Subsequently, we included the geocenter motion corrections in the POD process as a degree-1 loading displacement correction to the tracking network. The analysis suggested that the GSFC's Jason-2 std0905 GPS-based orbits are closely tied to the center of mass (CM) of the Earth whereas the SLR/DORIS std0905 orbits are tied to the center of figure (CF) of the ITRF2005 (Melachroinos et al., 2012 submitted). In this study we extend the investigation to the centering of the GPS constellation and the way those are tied in the Jason-1 and Jason-2 POD process. With a new set of standards, we quantify the GPS and SLR/DORIS-based orbit centering during the Jason-1 and Jason-2 inter-calibration period and how this impacts the orbit radial error over the globe, which is assimilated into mean sea level (MSL) error, from the omission of the full term of the geocenter motion correction.

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## 2 - Altimeter Calibration and Tectonics Inference Oceanographic Network (ACTION): From OSTM to SWOT

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### Abstract :

We will report on recent results and on the extension of the eastern Mediterranean Altimeter Calibration network'eMACnet, to an Aegean-wide network of coastal tide gauges equipped with GNSS receivers and offshore buoys near OSTM groundtracks (ACTION). In collaboration with the Nat. Tech. Univ. of Athens (NTUA), the Hellenic Navy Hydrographic Service (HNHS) and the Hellenic Center for Marine Research (HCMR), the original network is expanding to cover all of the Aegean area, from the northernmost site at THASOS to the southernmost one on GAVDOS. The south Aegean is already adequately covered from four tide gauge sites equipped with CORS GNSS: at MANI-KARAVOSTASI on southern Peloponnese, EMPORIO on the island of Chios, KASTELI on northern Crete and PALEKASTRO on the easternmost edge of Crete. Additional tide gauges and GNSS will now be deployed at KYMI-EVIA and NEA SKIONI, before the end of 2012, to densify the network in the mid- and northern Aegean. The primary purpose of the extended network is the absolute calibration and validation of altimetry missions through the continuous monitoring of sea level and tectonics at locations near the OSTM mean groundtrack. This Aegean-wide network samples at the moment the OSTM/Jason-2 tracks 18, 33, 94, 109, and 185, some of them in more than one location. It will support current and future altimeter missions JASON-2/3, ENVISAT, Cryosat-2, HY-2A, JASON-CS and SWOT, especially the latter, requiring calibration over an area rather than a single track. In discussions with HCMR we have also reached agreement for the future use of their open-sea buoys once we outfit them with CORS GNSS receivers. Furthermore, HNHS has a funded proposal to obtain new, state-of-the-art tide gauges with GNSS receivers to replace their old equipment throughout their Aegean network, and for two additional buoys (NOAA's DART II type) and equipment for open-sea environmental monitoring. The main thrust of the project at the moment is to connect the currently deployed equipment with the global grid so that the data can be collected and made available in near real-time (e.g. on GTS). Our facilities will contribute the collected data to many other projects in the area (CLIVAR, WMO initiatives, IOC, GCOS, GOOS, GGOS, etc.) and the European Tsunami Warning System (ETWS). We will present the latest results from the current network and the latest bias estimates for OSTM/Jason-2.

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### 3 - Calibration of Envisat radar altimeter over the Lake Issykkul

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#### **Abstract :**

This study presents the results of Calibration/Validation (C/V) of Envisat satellite radar altimeter over the Lake Issykkul located in Kyrgyzstan, which was chosen as a dedicated radar altimetry C/V site in 2004 for multi mission's purposes. The objectives are to estimate absolute altimeter bias of Envisat and to present some corrections on the orbit of this satellite based on cross over analysis with Topex Poseidon, Jason-1 and Jason-2 over the ocean. We have used a new method of GPS data processing in kinematic mode, developed at the Groupe de Recherche en Geodesie Spatiale (GRGS) which allow calculating the position of the GPS antenna without necessity of having a GPS fix reference station. The C/V is conducted using various equipments: GPS local network, moving GPS along the satellites tracks over the Lake Issykkul, in situ level gauges and weather stations. The absolute bias obtained for Envisat from field campaigns conducted in 2009 and 2010 is comprised between 62.1 and 63.4 +/- 3.7 cm, with the Ice-1 retracking algorithm, and between 46.9 and 51.2 with the ocean retracking algorithm. These results differ by about 10 cm from previous studies, principally due to improvement of the C/V procedure. Apart from the new algorithm for GPS data processing, and the new correction on orbit of Envisat, some more attention has been paid on the GPS antennas height calculation, and we have avoided the errors induced by seiche over the Lake Issykkul. To respect this requirement we have done the cruise along the Envisat satellite track at the exact date of the pass of the satellite for the two campaigns. The calculation of Envisat radar altimeter bias is essential to allow the continuity of multi-missions on the same orbit, with the expected launch of Altika/Saral mission in 2012. Implication for hydrology in particular, will be to produce long term homogeneous and reliable time series of lakes level worldwide.

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## 4 - Quality assessment of altimeter and tide gauge data for Mean Sea Level and climate studies

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### **Abstract :**

The overall quality assessment of altimeter data can be performed by analyzing their internal consistency and the cross-comparison between all missions. As a complementary approach, tide gauge measurements are used as an external and independent reference to enable further quality assessment of the altimeter sea level and provide a better estimate of the multiple altimeter performances. In this way, both altimeter and tide gauge observations, dedicated to climate applications, require a rigorous quality control. This study thus focuses on results deduced from the comparison method between altimetry and tide gauges and the way both types of data are used as input for controlling the quality of each other. Concerning altimeter data, the long-term drift assessment can be evaluated thanks to a widespread network of tide gauges, on condition that these in-situ measurements are considered of good quality. Indeed, one major part of the error related to the assessment of Sea Surface Height (SSH) at tide gauge location originates in land motion. The combination of multiple techniques (altimeter, in-situ and geodetic data) is a way of providing relevant tide gauge time series for end-users and climate applications and then gives a reliable assessment of the altimeter long-term drift. This study is performed with the first objective of detecting global and regional drifts in the altimeter Sea Surface Height (SSH). The combination of arrays of tide gauge measurements is used to monitor the stability of altimeter missions, especially along coastal areas. Then, as a way of evaluating new standards in altimeter products, tide gauge measurements are used to demonstrate the relevance of new altimeter correction (orbit solution, instrumental correction, retracking algorithm). Finally, since tide gauges are expected to give an accurate estimate of SSH, in-situ time series are compared to both DORIS and GPS data as a reliable way of assessing vertical land motion at tide gauge location. But although such projects as the International Global Navigation Satellite System Service (IGS) Tide Gauge Benchmark Monitoring Pilot Project (TIGA) are willing to install GPS at each tide gauge site, only a few stations supplying data to the current existing database can be corrected from crustal drift movements by means of geodetic time series. Therefore, multiple altimetric systems (Jason1&2, Envisat and T/P) are used to perform a cross-comparison indicator of the tide gauge time series (available on the AVISO website) and thus detect potential drifts or jumps which might remain in the tide gauge measurements.

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## 5 - POSEIDON3 calibration using a transponder

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### **Abstract :**

Absolute and relative calibrations of altimetry missions is a key concern to insure the required long term stability of the sea surface height estimates. For example, on CNES/AVISO data center side, the global MSL for the entire altimetric period is calculated by combining the time series from all three Topex/Poseidon, Jason-1 and Jason-2 missions before filtering out the periodic signals. The three missions are linked together during the formation flying phases of the Jason-1 and Jason-2 missions in order to calculate very precisely the bias in global MSL between these missions. But after the formation flying phases, we do not have direct comparison possibles. We have to rely on long term comparison exercices based on statistical analysis and/or dedicated insitu sites. Among the insitu technics, the transponder is certainly a very powerful mean to calibrate and monitor the onboard instrument range. Range calibrations of POSEIDON3 (JASON2) are currently performed every cycle using a transponderbased on Gavdos Island. The altimeter emits radar impulsions which are received, amplified and re-transmitted by the transponder back to the altimeter. The altimeter is programmed in calibration mode with specific parameters to perform the measurement. Data are then processed on ground with a dedicated algorithm using auxiliaries data. This paper will present the calibration methodology and first results.

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## 6 - Quality assessment of Cryosat-2 data over ocean

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**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4558>

### **Abstract :**

Cryosat-2 is ESA's ice mission which primary objective is to serve Cryosphere science. Nevertheless, Cryosat-2 has, in theory, the potential to be a mission of opportunity for oceanography. Indeed, the satellite embarks an innovative radar altimeter, and high-precision orbit determination (POD), which are expected to be at least as accurate as ENVISAT's. Even if Cryosat-2 is not an optimised payload for mesoscale observation (no radiometer and single frequency altimeter), Labroue et al. (2011) showed, with a few months of data, that the Cryosat-2 system gives very good performance. Indeed, the altimeter shows very good results with 20 Hz noise close to 6.5 cm. This study provides further results that confirm the quality of the system for ocean, based on the analysis of data processed with CNES prototype (CPP). The Cryosat-2 altimeter is operated almost continuously over ocean, either in Low Resolution Mode (like conventional pulse-limited altimetry sensors) or in the so-called Doppler/SAR mode (higher-resolution and lower noise level). While the optimised SAR processing are not yet available, CNES has developed a pseudo LRM processing that allows recovering data in all the SAR acquisition regions. Even if the noise is higher than the traditional LRM mode, this is a major achievement that provides a global continuous coverage, especially for European seas such as North Atlantic Ocean, Mediterranean Sea and Black Sea. One of the objectives is to provide data with a seamless transition between LRM and pseudo LRM processing. The present results show the methodology used for the detection of a possible bias between both processing. The aim is to assess our capacity in detecting correlated differences between LRM and future dedicated SAR processing, for Cryosat-2 and then for the next generation of altimeters (Sentinel-3 and Jason-CS). Insuring a seamless transition is not so easy since LRM and SAR areas are completely distinct without any overlapping and moreover, the SAR acquisitions are limited to small regions which prevent from using classical statistical approaches based on global analysis.

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## **7 - Altimetry biases in the Amazon basin : the concern of retracking algorithms for non-oceanic calval sites (part of the FOAM project)**

**Dr CALMANT stephane** IRD

**Moreira daniel**, CPRM / UFRJ /IRD ; **Santos da Silva Joecila**, UEA ; **Seyler frederique**, IRD ; **Perosanz felix**, CNES ; **Shum CK**, OSU

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4552>

### **Abstract :**

Altimetry is now widely used in the computation of water level time series in the major hydrological basins. Combining the series obtained from different different missions is a major concern when dealing with long term, climatic, records of the water level in these basins, and consequently, long term records of the continent/ocean exchange. Such a combination requires that the bias specific to each mission is known. In the case of continental waters, the biases mostly come from the retracking algorithm selected to compute the water levels. In the frame of the TOSCA/FOAM project, we levelled >30 gages by means of GPS campaigns in the Amazon basin (both in static and cinematic modes) to built up a reference of daily absolute levels throughout the basin. Comparing altimetry-derived time series of water level with the aforementioned reference, we determined the mean biases of the ENVISAT and JASON-2 missions, in the specific cases of ice1 retracking algorithms, and ice-3 (PISTACH) retracking for J2.

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## 8 - Global Jason-2 Data Analysis of reprocessed Gdr-D products

*Ms PHILIPPS Sabine CLS*

**PHILIPPS Sabine**, CLS ; **ROINARD Helene**, CLS ; **ABLAIN Michael**, CLS ; **PICOT Nicolas**, CNES

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4545>

### **Abstract :**

Since the beginning of the Jason-2 mission in July 2008, the GDR (Geophysical Data Record) product version available was GDR-T (T for Test, see:

[http://www.aviso.oceanobs.com/fileadmin/documents/data/products/Jason-2\\_GDR\\_T\\_disclaimer.pdf](http://www.aviso.oceanobs.com/fileadmin/documents/data/products/Jason-2_GDR_T_disclaimer.pdf)). The OSTST community requested (during the OSTST meetings of 2009, 2010, and 2011) several modifications in order to correct for some problems in the GDR-T and to improve several standards. After taking into account these requests, the reprocessing of the Jason-2 mission started in April 2012. The new GDR-D version contains numerous evolutions concerning the orbit, the altimeter and radiometer derived corrections, but also external corrections such as ocean tides and mean sea surface. The main objective of this study is to assess the data quality of the reprocessed Jason-2 GDR-D products. Several methods are used, such as the comparison with the Jason-2 GDR-T version, but also by cross-calibration with other altimetry missions (Jason-1, Envisat) and with in-situ measurements (Tide gauges and Temperature/salinity profiles). We also focus our analyses on the sea-level performances for short time scales (for mesoscale applications) as well as for the long-term stability (for climate applications).

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## 9 - Perspectives of a new marine campaign in the western Mediterranean for altimeter calibration

*Pr Martinez-Benjamin Juan Jose* Technical University of Catalonia

**Martinez-Benjamin Juan Jose**, Technical University of Catalonia ; **Gili Josep**, Technical University of Catalonia ; **Lopez Rogelio**, Technical University of Catalonia ; **Tapia Ana**, Technical University of Catalonia ; **Bosch Ernest**, Cartographic Institute of Catalonia ; **Perez Begonha**, Puertos del Estado

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4456>

### Abstract :

A new marine campaign in the western Mediterranean in the area of Ibiza island for altimeter calibration, mainly dedicated to Jason-2, Jason-1 and SARAL/AltiKa is to be organised for 2013. The most interesting sites located around satellite nodes, observed twice by satellites. The main objective consists in the in-situ absolute calibration and validation establishing a link from coastal to open-ocean altimetry according to the Proposal EUMETSAT/CNES, 'Implementation of Ibiza and l'Estartit Cal/Val Spanish Sites for Jason-2/OSTM and Jason-1' selected in March 2008. A Spanish JASON-1 calibration campaign, IBIZA 2003, was carried out in June 9-17, 2003 in the area of Ibiza Island in the NW Mediterranean Sea. The objective of the campaign was to map the instantaneous sea level/local geoid gradient in three areas around Ibiza: at the crossing point of an ascending and descending JASON-1 tracks located to the north of the island, and along these tracks to the SE and SW of the Island. GPS catamaran and buoys measurements off-shore at dedicated satellite tracks locations along the previous sea surface realized during the 2003 campaign together coastal tide gauges and GPS reference stations were used. The campaign was based on the experience gained from three previous campaigns in the region of Cape Begur near l'Estartit. They were carried out in March 1999 and July 2000 for TOPEX/POSEIDON and August 2002 for JASON-1, as part of the JASON-1 CalVal Team. The presentation is directed to the description of the objectives of the upcoming 2013 marine campaign and the actual situation of the geodetic infrastructure of Ibiza site. This research has received funding from the MICINN Ministerio de Ciencia e Innovacion of Spain under National Project ref: CGL2009-13435

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## 10 - An update on Cryosat-2 POD and LRM CAL/VAL results

*Dr Naeije Marc TUDelft*

**Naeije Marc**, TUDelft ; **Schrama Ernst**, TUDelft ; **Scharroo Remko**, NOAA ; **Yi Yuchan**, OSU ; **Shum C.K.**, OSU

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.avisio.oceanobs.com/index.php?id=1719&uid=4441>

### **Abstract :**

CryoSat-2 was successfully launched in April 2010 to map the cryosphere with an advanced microwave altimeter system, including SAR and SARin capabilities. The mission goal is to observe sea ice freeboard and ice sheet elevation changes for a nominal period of 3 years. Precision orbit determination (POD) of CryoSat-2 relies on DORIS Doppler tracking and ground based satellite laser ranging (SLR). Here we show an update on the results of our CryoSat-2 POD efforts. The Delft orbits compare well with the MOE and POE trajectories computed by CNES and can be considered of Jason-class. We find RMS of SLR residuals around 2cm and RMS of radial differences around 1.5cm when compared to the CNES POE orbits. We address data sources, availability, latency, quality and editing, software, standards and methods and focus the discussion on possibilities to further improve the orbit, e.g. by the use of a dedicated satellite macro model. Then, we also show an update on the results of our CryoSat-2 LRM CAL/VAL efforts. The SIRAL altimeter onboard CryoSat-2 perfectly samples the ocean surface. To be able to exploit these data it is necessary to assess and validate them. Another reason is that we want to complement the Radar Altimeter Database System RADS with this dataset to improve the combined altimeter sampling resolution both in time and space. This has become very pressing, now Envisat stopped providing data and meanwhile its successor Sentinel-3 is not yet in place. So, we validate and calibrate the LRM data, add and improve corrections (including modeling of corrections that are not directly available from the CryoSat-2 platform), and verify the orbit accuracy. The present status of the absolute and relative calibration of LRM Level-2 data is discussed, also by comparison of CryoSat-2 with other satellites (crossover and grid analyses) and with tide gauge data. We provide estimates on range and timing biases and try to explain them. In this update of CAL/VAL results we focus on the latest ESA version of the product and compare with our own efforts to improve the ocean product. Alongside we give thought to the capability of CryoSat-2 to aid in the mesoscale sampling of ocean circulation patterns, combined with Jason-2 and the, this year to be launched, AltiKa mission, now Envisat is lost and Jason-1 has been moved to a shifting geodetic orbit and by that has degraded mesoscale variability measuring capabilities.

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## 11 - Assessing Altimeter Bias Drift: An Australian Contribution using the Global Tide Gauge Network and GPS Estimates of Vertical Land Motion.

*Dr Watson Christopher* University of Tasmania

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4411>

### **Abstract :**

While in-situ validation sites are able to yield estimates of absolute altimeter bias, they are limited in their ability to infer bias drift given the inherent noise in the altimeter system at any given point location. To increase the degrees of freedom and allow the precise estimation of bias drift in the evolving altimeter climate record, the global tide gauge network has long been used. This process involves forming the difference between altimeter and tide gauge derived sea surface heights, at many comparison points. GPS estimates of land motion assist in removing the effect of vertical land motion in the tide gauge records. The ensemble residual time series is then used to investigate any potential drift in the altimeter measurement system, thus providing an independent validation of the climate record. In this poster we present our analysis of bias drift present in TOPEX/Poseidon, Jason-1 and OSTM/Jason-2 missions using the standard GDR products with updated orbits. We place an emphasis on the comparison of alternate methodologies for the selection of valid comparison points, and treatment of tidal differences between tide gauge and altimeter measurement locations. We conclude with an initial sensitivity analysis to highlight the influence of anomalous tide gauge records.

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## 12 - Improving the Sea Level Data Record for Studying Climate Variability

*Dr Masters Dallas* University of Colorado

**Nerem R. Steve**, University of Colorado ; **Choe Chong-Deok**, University of Colorado

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4401>

### **Abstract :**

The University of Colorado has been producing and publishing a time series of global mean sea level (GMSL) since the TOPEX/Poseidon mission, and we continually refine our altimeter data processing and applied corrections. We report on recent improvements to update the processing to the latest, state-of-the-art corrections, including updated microwave radiometer drift parameters, mean sea surface, sea state bias models, orbits, etc., and efforts to test different processing techniques to improve and understand the variability in the long-term global mean sea level record. In past work, we found that choices of processing techniques, such as computing the global mean sea level from along-track versus gridded sea surface height anomaly estimates or editing shallow water areas, significantly changes the sensitivity of the GMSL time series to interannual variability, especially during strong El Nino-Southern Oscillation (ENSO) events. We also found that these different processing techniques are responsible for some of the larger interannual differences among the GMSL time series produced by different research institutions. We continue and extend this previous work by exploring modifications and improvements to our altimeter processing and by comparing the resulting sea level climate data records with other climate data records, such as sea level from tide gauges and the Multivariate ENSO Index (MEI). These efforts should help improve our interpretation of the global mean sea level time series as a climate data record and our understanding of linkages between sea level and climate variability.

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## 13 - Kerguelen Islands CAL/VAL activities

*Dr Testut Laurent* LEGOS

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4376>

### **Abstract :**

Kerguelen Island, due to its permanent instrumentation and already existing infrastructures has been chosen as a dedicated cal/val site in the frame of the OST/ST 'From Ocean To Inland Waters Aaltimetry Monitoring' (FOAM) project. The LEGOS is indeed in charge for many years now of the Observation Service ROSAME tide gauges network composed of four permanent tide gauges located on islands in the southern part of the Indian Ocean in Kerguelen, Crozet, Saint-Paul and in Dumont d'Urville in Antarctica. This network is part of the GLOSS Global Sea Level Observing System. The Kerguelen tide gauge is fully operational since 1993, its benchmark network has been fully leveled in 2004 and tied to the ellipsoid. The tide gauge site is less than about 25 km from the nearest Jason ground track 179. GPS buoy sessions are regularly scheduled near the permanent tide gauge for calibration purposes. In 2008 a mooring was deployed at the entrance of the bay of Kerguelen directly under a Jason-1 track in order to estimate the difference of oceanographic behavior between Port-aux-Français and the entrance of the bay. This mooring was displaced in 2009,2010 and 2011 on the south of the Island under the same track. We will present in this poster the main results of the instrumental network in term of cal/val activities.

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## 14 - Regional CALVAL method in Corsica: validation of the Jason-1, Jason-2 and Envisat missions at non-dedicated sites

*Ms Cancet Mathilde NOVELTIS*

**Cancet Mathilde**, NOVELTIS ; **Jeansou Eric**, NOVELTIS ; **Bonnefond Pascal**, OCA/GEOAZUR ; **Laurain Olivier**, OCA/GEOAZUR ; **Lyard Florent**, LEGOS ; **Féménias Pierre**, ESRIN ; **Bronner, Emilie**, CNES

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4344>

### **Abstract :**

In situ calibration allows insuring regular and long-term control of altimeter sea surface height (SSH) time series with independent records. Usually, in situ calibration of altimeter SSH is done at the vertical of a specific CalVal site by direct comparison of the altimeter data with the in situ data. In the framework of CNES and ESA oceanographic projects, the OCA established the Senetosa and Ajaccio calibration sites in Corsica, respectively in 1998 and 2005. Both sites are equipped with tide gauge instruments. The Senetosa site is dedicated to the absolute calibration of the Topex/Jason nominal orbits, whereas the Ajaccio site was used for the Envisat mission up to its orbit change in October 2010. At the same time, NOVELTIS developed a regional CalVal technique, which aimed at increasing the number and the repeatability of the altimeter bias assessments by determining the altimeter bias both on overflying passes and on satellite passes located far away from the calibration site. The strong interest of this principle is to extend the single site approach to a wider regional scale. It is also a mean to keep on calibrating a mission when good-quality in situ data happen to be missing at its dedicated calibration site. The method was used to compute the biases of the Jason-1 and Jason-2 missions in Senetosa, as well as the Envisat mission bias in Ajaccio, before and after its orbit change. In order to evaluate the stability and generality of the method, an exercise of cross-calibration was also carried out where the biases of both Envisat and Jason-2 missions were quantified at the two Corsican calibration sites. All these experiments show the robustness and the adaptability of the regional calibration method, and consequently its high advantage for monitoring missions on new orbits such as Envisat, CRYOSAT-2, HY-2A, Jason-1 end-of-life or the future Sentinel-3 mission.

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## 15 - Corsica: a multi-mission absolute calibration site

*Dr Bonnefond Pascal* OCA-GEOAZUR

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4173>

### Abstract :

In collaboration with the CNES and NASA oceanographic projects (T/P and Jason), the OCA developed a verification site in Corsica since 1996. CALibration/VALidation embraces a wide variety of activities, ranging from the interpretation of information from internal-calibration modes of the sensors to validation of the fully corrected estimates of the Sea Surface Heights using in situ data. Now, Corsica is, like the Harvest platform (NASA side), an operating calibration site able to support a continuous monitoring with a high level of accuracy: a 'point calibration' which yields instantaneous bias estimates with a 10-day repeatability of around 30 mm (standard deviation) and mean errors of 3-4 mm (standard error). For a 35-day repeatability (ERS, Envisat, SARAL/AltiKa), due to a smaller time series, the standard error is about the double (~7 mm). In-situ calibration of altimetric Sea Surface Heights is usually done at the vertical of a dedicated CAL/VAL site, by direct comparison of the altimetric data with in-situ data. Adding the GPS buoy sea level measurements to the 'traditional' tide gauges ones, it offers the great opportunity to perform a cross control that is of importance to insure the required accuracy and stability. This configuration leads to handle the differences compare to the altimetric measurement system at different scales: the Geographically Correlated Errors at regional scale (orbit, sea state bias, atmospheric corrections...) and local scale (geodetic systematic errors, land contamination for the instruments, e.g. the radiometer and the altimeter). Our CAL/VAL activities are thus focused not only on the very important continuity between past, present and future missions but also on the reliability between offshore and coastal altimetric measurement. With the recent extension of the Corsica site (Capraia in 2004 and Ajaccio in 2005) and the ESA support, we are now able to perform absolute altimeter calibration for ERS 2, Envisat, HY-2A and SARAL/AltiKa in a next future with the same standards and precision than for T/P and Jason missions. This will permit to improve the essential link between all these long time series of sea level observation.

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## 16 - Multi-Mission Crossover Analysis: Merging 20 years of altimeter data into one consistent long-term data record

**Dr Dettmering Denise** *Deutsches Geodätisches Forschungsinstitut (DGFI)*

**Dettmering Denise**, DGFI ; **Bosch Wolfgang**, DGFI

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4428>

### **Abstract :**

The satellite altimeter scenario of the past two decades provides continuous and precise monitoring of the ocean surface with a beneficial spatio-temporal sampling. Since 1992 two or more contemporary missions are continuously available. For climate studies a consistent long-term data record is a fundamental requirement. However, combining missions with different sampling capabilities requires a careful preprocessing and calibration of all altimeter systems. A global multi-mission crossover analysis is able to connect the measurement from individual missions and merge them to one consistent long-term data record even if some of the missions are not operating on a repeat ground track. Upgrading and harmonization to the most up-to-date models and corrections is performed in advance. Then, we realize the cross-calibration by a least squares adjustment minimizing single- and dual-satellite crossover differences in all combinations as well as consecutive differences of the radial component of single satellites. Minimizing consecutive differences ensures a certain degree of smoothness of the radial component without introducing an analytical error function. This method provides time series of radial errors for the complete missions' lifetimes, the associated auto-covariance functions, relative range biases, systematic differences in the center-of-origin realization, as well as geographically correlated error pattern for all missions analyzed. In this contribution we show results of a twenty years data record by cross-calibrating ERS1, Topex, ERS2, GFO, Jason1, Envisat, ICESat, Jason2, and CryoSat2. Special focus will be on the range biases of the different missions including their temporal behavior as well as on geographically correlated error patterns which map, if not corrected, directly to the sea surface.

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## 17 - Using high rate altimeter measurements for coastal studies: example in the NW Mediterranean Sea.

*Dr Birol Florence* CTOH/LEGOS

**Birol Florence**, CTOH/LEGOS ; **Delebecque Caroline**, CTOH/LEGOS ; **Roblou Laurent**, CTOH/LEGOS ;  
**Morrow Rosemary**, CTOH/LEGOS

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4413>

### **Abstract :**

Appropriate data (re)processing and analysis allow the optimisation of the number of informations which can be derived from altimeter measurements. This is particularly true in the coastal zone where data are generally discarded due to problems with the altimeter radar echoes or to inaccurate corrections, but also because the standard processing is not tuned for ocean marginal regions. This results in a relatively large (10-40 km) data gap next to the coast in standard altimetric products. Even if this remains a very challenging exercise, several scientific groups work on extending satellite altimetric products into the shelf and coastal seas (COASTALT, PISTACH, CTOH, ...), by means of appropriate corrections and (re)processing of the data. This enhances data availability and accuracy close to land and then allows a better observation of the coastal oceans. Here, the potential of full rate measurements will be analysed in the context of coastal studies in the Northwestern Mediterranean Sea. We compare Topex/Poseidon, Jason-I, Jason-II and Cryosat-2 performances, for both 1Hz and 20 Hz SLA data, using a dedicated data processing system, the X-TRACK software. This tool, developed and routinely operated at LEGOS by the CTOH group, has been specifically designed to provide greater availability of quality altimetry data in the coastal seas. The objective of this study is to analyse the actual resolution of different satellite altimetry missions for the observation of the coastal circulation. This will be done by investigating the consistency between altimetry and other observations (SST, tide gauge, ADCP currents). The NW Mediterranean Sea is an interesting case study because of the complex nature of its flow (short spatial and temporal wavelengths).

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## 18 - Jason-2 global error budget for time scales lower than 10 days

**Ms PHILIPPS Sabine** CLS

**PHILIPPS Sabine**, CLS ; **ABLAIN Michael**, CLS ; **PICOT Nicolas**, CNES

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4554>

### **Abstract :**

The objective of this study is to provide an estimation of the global error budget of Jason-2 altimeter for level 2 products: Operational Geophysical Data Records (OGDR), Interim Geophysical Data Record (IGDR) and Geophysical Data Record (GDR). The main goal is to provide a synthetic table with all the global errors estimated versus each level-2 products. The global errors have been estimated for several instrumental parameters but also geophysical corrections. Several types of errors can be defined in order to describe the error of altimetry measurements. These errors are depending on time and spatial scales. For time scales, the following errors may occur: white noise, short-time temporal errors, medium temporal errors, and long-term errors. However, in this study we focus only on short-time temporal errors (< 10 days) corresponding to the Jason-2 cycle duration which is about 10 days. The ocean is therefore globally covered within the 10 days period which allows us to estimate accurately the global mean error. In order to assess the errors, several approaches are used: taking advantage of the formation flight phase of Jason-2 with Jason-1, spectral analysis, analysis of the rms of 20 Hz data, comparison with other corrections, as well as looking in the available literature. In a first part, these methods are briefly described. In the second part, the short-time global errors are detailed for several altimeter parameters and corrections used for the sea surface height.

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## 19 - Accounting for spatial error correlations in altimetric data assimilation

*Dr Cosme Emmanuel* Université Joseph Fourier - Grenoble 1

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**Brasseur Pierre**, CNRS/LEGI

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4279>

### **Abstract :**

The Kalman filter is a widely spread data assimilation method in oceanography. The standard Kalman filter observational update requires the inversion of the innovation error covariance matrix, what is prohibitive regarding its size. Most implementations of the Ensemble Kalman filter circumvent this difficulty assuming the diagonality of the observation error covariance matrix, that makes the analysis calculation numerically tractable. However, when observation errors are actually correlated spatially, such hypothesis yields too much weight to the observations, and may lead to an inappropriate use of the observations. Spatial altimetric measurements, because they are performed along tracks, are very likely subject to spatial error correlations. In this presentation, we describe a parameterization of the observation error covariance matrix that preserves its diagonal shape, but represents a simple first order autoregressive correlation structure of the observation errors. This parameterization is based upon an augmentation of the observation vector with gradients of observations. Numerical applications to ocean altimetry show the detrimental effects of specifying the matrix diagonal when observations errors are correlated, and how the new parameterization not only removes the detrimental effects of correlations, but also makes use of these correlations to improve the data assimilation products.

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## 20 - Error Budget Analysis of a Mean Dynamic Topography

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**Pail Roland**, Technical University Munich

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4388>

### **Abstract :**

Knowledge of the overall error budget and accuracy of a Mean Dynamic Topography and subsequently derived Geostrophic Velocities is important information for ocean studies. Following the basic Equation  $MDT = MSS - N$  with the Mean Dynamic Topography (MDT), a Mean Sea Surface (MSS) and the Geoid Height (N), one can clearly see that the MDT is composed of two entities derived from different measurement types and hence different error budgets. They can be considered as uncorrelated as they are in our case derived by different and independent techniques. The Error Budget of the MDT has therefore two contributions, the Geoid error and the MSS error. They both simply sum up to the overall MDT error. The investigations are based on the statistical analysis of the full covariance information provided from a GOCE geoid and the error information from an existing MSS. The core part of the analysis represents the stochastic modeling of the MDT computation and therefore the propagation of the variance-covariance information to an MDT error estimate. Special attention will be drawn to the effects of the filtering applied to the MSS and geoid heights in order to ensure spectral consistency between the two entities. This analysis will allow quantifying the respective contributions of the two MDT ingredients to the overall MDT error and its derivatives like geostrophic velocities.

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## 21 - Error assessment of dynamic ocean topography profiles (iDOT)

*Dr Bosch Wolfgang DGFI*

**Bosch Wolfgang**, DGFI ; **Savcenko Roman**, DGFI

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4559>

### **Abstract :**

The geodetic way to estimate the dynamic ocean topography is to subtract geoid heights of one of the most recent satellite-only gravity fields (e.g. GOCO02S) from sea surface heights observed by satellite altimetry. Both, geoid and sea surface heights, are to be consistently filtered. We follow an approach performing the filtered differences along individual altimeter ground tracks in order to avoid an initial gridding and to maintain as much sea surface height details as possible. The method results in instantaneous dynamic ocean topography (iDOT) profiles which exhibit not only the well-known large scale gyres of the ocean topography but also meso-scale eddies along with their temporal evolution. In order to assess the quality of the iDOT profiles and to assimilate them into numerical models an utmost realistic error estimate should be provided. In this paper we assess the accuracy of our approach and propagate the errors of both, the geoid and the sea surface heights. For the sea surface heights, an auto-covariance function derived from a multi-mission cross-calibration is taken into account. In order to estimate the geoid error we consider various strategies for a propagation of the full variance-covariance matrix of the satellite-only gravity field.

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## 22 - High resolution dynamic ocean topography in the Southern Ocean from GOCE

*Dr Albertella Alberta IAPG Technische Universitaet Munich Germany*

**Albertella Alberta**, IAPG - TU Muenchen ; **Savcenko Roman**, DGFI Munich ; **Janjic Tijana**, AWI Bremerhaven ; **Rummel Reiner**, IAPG TU Muenchen ; **Bosch Wolfgang**, DGFI Munich ; **Schroeter Jens**, AWI Bremerhaven

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4551>

### **Abstract :**

A Mean Dynamic ocean Topography (MDT) has been computed using a high resolution GOCE gravity model and a new mean sea surface obtained from a combination of satellite altimetry covering the period October 1992 till April 2010. The considered gravity model is GO-CONS-GCF-2-TIM-R3, which computes geoid using 12 months of GOCE gravity field data. The GOCE gravity data allow for more detailed and accurate estimates of MDT. This is illustrated in the Southern Ocean where the commission error is reduced from 20 cm to 5 cm compared to the MDT computed using the GRACE gravity field model ITG-Grace2010. As a result of the more detailed and accurate MDT, the calculation of geostrophic velocities from the MDT is now possible with higher accuracy and spatial resolution. In order to assess properties of the derived geostrophic velocity field, velocities are compared with independent data from satellite tracked surface drifters in the area of the Antarctic Circumpolar Current (ACC).

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## 23 - Evaluating an ensemble of global ocean circulation estimates using satellite altimetry, gravity field models and ARGO data

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**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4547>

### **Abstract :**

We compare an ensemble of ocean circulation hindcasts for years 1993 to 2007 to geodetic estimates of dynamic topography and in situ measurements of temperature and salinity (ARGO). Dynamic topography is based on multi-mission altimetry referenced to the GOCE geoid. The hindcasts are simulated by FESOM, a general circulation ocean / sea-ice model on unstructured meshes with spatially variable resolution. It allows to refine areas of particular interest in the global context. The ensemble members differ slightly by atmospheric forcing, by their initial states and/or by the model meshes. Refinement was done in various key regions for the large scale ocean circulation, such as equatorial belt, Denmark Strait, and the mean background resolution. We compare the model trends in sea level and steric height. Results show that the ensemble mean trend pattern at large compares with observations. The estimated mean and spread in sea level as well as steric height are discussed in comparison to observations.

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## 24 - Dynamical ocean topography from satellite measurements and its impact on Southern Ocean circulation estimates

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**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4538>

### **Abstract :**

We use the geodetic method to obtain the dynamical ocean topography (DOT). This method combines the multi-mission altimeter sea surface height and the GRACE/GOCE gravity field. Using the new global filtering approach, the spectral consistency of both fields is achieved by filtering the sea surface height and the geoid. The new global filtering approach reduces the artifacts near the coast lines. Further, results of assimilation of multi-mission altimeter data and the GRACE/GOCE gravity data into the finite element ocean model (FEOM) are investigated. By assimilating only absolute dynamical topography data using the ensemble Kalman filter and time varying observation error covariances, we were able to improve modeled fields. Results are closer to observations which were not used for assimilation and lie outside the area covered by altimetry in the Southern Ocean (e.g. temperature of surface drifters or deep temperatures in the Weddell Sea area.)

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## 25 - Anisotropic filtering to improve the geodetic determination of the Surface Geostrophic Currents: Edge Enhancing Diffusion

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**Vigo Isabel**, University of Alicante

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4374>

### **Abstract :**

The Surface Geostrophic Currents (SGC) can be determined from the gradient of the Mean Dynamic Topography (MDT) which is defined as the mean sea surface height referenced on the Earth's geoid. Due to the noise in the MDT, particularly for short space wave lengths, some filtering is required before the SGC computation. Since the SGC have a strong directional behaviour (emphasized when the current increases) anisotropic filtering would be preferred for the case. Here we deal with the capabilities of the Edge Enhancing Diffusion (EED) filters for filtering the MDT in order to improve the computation of the SGC. It is proved how this method conserves all the advantages that the non-linear isotropic filters have over the standard linear isotropic Gaussian filters. Moreover, the EED is shown to be more stable and almost independent of the local errors. This fact makes this filtering strategy more appropriated when filtering noisy surfaces.

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## 26 - Ocean Geostrophy from Satellite Altimetry and GOCE Data

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**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4372>

### **Abstract :**

The geostrophic currents are the result of the geostrophy balance between the pressure gradient force and the Coriolis force. In lack of direct observations, the surface geostrophic currents (SGC) can be derived from the ocean dynamic height as a function of space and time. The dynamic height is the current-induced deviation of the actual sea level (e. g. observed by satellite altimetry) from the Earth's geoid (e. g. estimated from satellite gravimetry). In this paper, we evaluate the capabilities of a 'full-potential' geoid estimated from the first 61-days cycle of the GOCE mission in estimating the global mean SGC that are derived and analyzed against a combined solution of several altimetric satellites (T/P, Jason 1/2, ERS-1/2, GEOSAT). Results are compared with those obtained from a GRACE-induced mean geoid for the period 2002/08-2009/08, as well as with mean circulation patterns from drifter buoys and from simulations of the ECCO Ocean General Circulation Model. We found GOCE clearly leads to significant improvements in determination and resolution of SGC globally except at the Equator (where special filtering of data is needed), with velocities and spatial patterns much closer to in-situ measurements of currents than those from GRACE data or ECCO model simulations.

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## 27 - A Study on the Conformance of Altimetry and in-situ Sea Surface Data near coast in the German Bight

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**Weiss Robert**, BFG ; **Dinardo Salvatore**, ; **Becker Matthias**,

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4555>

### Abstract :

Altimetry data near coast are validated in the German Bight in the interval 2000-2011 using a network of tide gauge stations and GNSS stations maintained by the German Federal Institute of Hydrology (BfG) and by the Federal Agency of Cartography and Geodesy (BKG). The network consists of two measurement platforms off-shore and of other stations on islands and on the continent. Tide gauge stations are equipped with continuous GNSS and instruments to measure sea waves and currents. The observed sea level is further compared to sea level simulated by regional operational model run by the German Federal Maritime and Hydrographic Agency (BSH). For standard altimetry products the comparison of instantaneous (1-Hz and higher frequency) measurements with tide gauge data shows good agreement. Interference from coast is almost absent for passes at the small isle of Helgoland, with distance of 8 km between altimetry and tide gauge. The correlation of 0.9 and standard deviation of 6-7 cm and absolute differences in observed heights of a few centimeters (6.2/2.7/-0.4cm depending on the mission) confirm a very good agreement at offshore locations. The consistency is lower at coastal stations, due to disturbance of the signal as in Borkum with distance of 24 km between measurements. Reduced correlation and increased standard deviation (10.4 cm) and ellipsoidal height differences (31.1/29.3/25.3cm depending on the mission) are characteristic of coastal stations. PISTACH coastal products give very small improvement in noise reduction. Reduced correlation, increased standard deviation and data lost are also in this case typical of the coastal stations. Cryosat SAR data are validated against sea level and significant wave heights derived from in-situ and model data to estimate eventual biases occurring in SAR mode with respect Pulse-Limited (LRM) Mode and tune up the SAR re-tracking scheme.

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## 28 - IMPROVEMENT OF INLAND WATER AREAS ALTIMETER HEIGHT ESTIMATION USING NEW RETRACKING TECHNIQUES

*Dr Amarouche Laïba* CLS

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**Steunou Nathalie**, CLS

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4481>

### **Abstract :**

Over open ocean retracking algorithms use analytical physical model to estimate geophysical parameters. The physical models have been developed thanks to a statistical description of the ocean surface. Over heterogeneous areas like coastal and inland water, the altimeter waveform contains contributions from different surfaces depending on the content of the altimeter footprint. Moreover, the non water surfaces present very high height and roughness variations that are very difficult to describe. We analysed Jason-2 waveforms acquired over coastal and inland water areas and we developed new retracking techniques for those waveforms. The first one is based on a new waveform analytical model and the second one based on the waveform deconvolution. Both of them used an automatic fitting of some parameters as for example the parameters estimation and the retracking window width. Those two methods showed a improved ability to fit the varying waveforms shapes over inland water. The obtained results have been compared to in-situ data over more than 50 areas and one year of data. Those retrackings showed high improvements on the height estimation errors. We will present the main results of this work and the main perspective studies for conventional altimeters and also for Ka band altimeters and new nadir Doppler altimeters.

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## 29 - Altimeter Mission end-to-end simulators to assess global performance and develop new algorithms for future missions

*Dr Amarouche Laïba CLS*

**Amarouche Laïba, CLS ; Obligis Estelle, CLS ; Mercier Franck, CLS ; Picard Bruno, CLS ; Jourdain Sylvain, CLS ; Dubois Pierre, CLS**

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4478>

### **Abstract :**

In the last two decades, we performed several simulation activities to assess end-to-end mission performances, to develop and analyze new processing algorithms and also to evaluate the impact of physical phenomena or instrumental effects on the performance. The methodology has been successfully used for conventional altimeters (Jason 1/2 and Envisat/RA-2 instruments), Doppler altimeters (CryoSAT and Sentinel-3), Wide Swath interferometric altimeters (WSOA and SWOT configurations) and radiometers (SARAL/AltiKa, Sentinel-3). CLS has also participated in the development of the SWIM simulator (on board CFOSAT mission). For example, those simulators have already been used to analyze the sea state bias on the altimeter geophysical estimates in the case of conventional altimetry and future AltiKa and SWOT missions. In the field of Doppler altimetry, they are helping us to test and develop the SAR processing algorithms and are being used for the development of new retracking techniques over ocean. Those simulators have also been extended to coastal, inland water and ice areas and are used for the analysis of the estimation algorithms. This paper will provide an overview of such end-to-end simulators and their main application studies and the corresponding achievements. Examples will be provided showing the importance of mastering the simulated effects depending on the analysis objectives. Finally, we will give some perspective studies using end-to-end simulators for the development of the future missions.

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## 30 - A multi-peak waveform retracker for coastal altimetry

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**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4457>

### **Abstract :**

In this contribution we present a retracker specially designed to process waveforms where the open-ocean, Brown-like model is modified by the presence of one or more peaks, normally due to bright targets like those often encountered in coastal waters. The retracker has been developed within the ESA-funded eSurge project (whose main aim is the integration of Earth Observation data in storm surge modelling and forecasting) following the experience learnt in the COASTALT Project. The code has been implemented using object-oriented techniques. Being able to cope with multiple peaks, this retracker can be seen as an evolution of COASTALT's mixed retracker and of the BAG (Brown+Gaussian Peak) retracker developed within CNES-PISTACH project. The retracker is capable to process data from multiple altimeter missions; we will present examples of its performance on Envisat, Topex and Jason-1 waveforms, and preliminary validation of the result along some of the pilot COASTALT tracks.

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## 31 - Radar waveform inversion: an application to coastal altimetry

*Dr NIÑO Fernando* LEGOS

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**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4454>

### **Abstract :**

In coastal and continental hydrology applications, the use of altimeter data has always been tricky. Indeed, the pulses emitted by satellite altimeters are usually analyzed by retracking algorithms optimized for the open ocean, unsuitable for handling the complexity of echoes returned by land surfaces. In the latter case, the full inversion of the radar return waveform is clearly impossible - too many parameters are needed to take into account the electromagnetic interactions. The problem becomes tractable if we make some assumptions (e.g. a gaussian surface, in the case of the ocean). Over and close to land, we focus on the inversion of two sets of parameters: the geometrical description of the surface, as well as its backscattering properties. Our methodology tackles the inversion of these parameters, not on the basis of one radar echo only, but analysing simultaneously the whole set of waveforms measured over a given region and during a given time. We thus take advantage of the information redundancy (the signature of a reflecting body being recorded in successive echoes) to reduce the phase space of possible solutions. Here, we present first results of this inversion methodology, applied to a coastal case (where the transition from ocean to land is easily observed in the waveforms) and to Jason-2 SGDR data. The successful application of the methodology yields information on the geometrical configuration of the landscape beneath the satellite (namely a better DEM and the positions of water bodies), as well as the backscattering parameters of the surfaces. Using more than one pass (and sensor) is not only possible but desirable, since the informations provided by additional passes give additional constraints for the inversion process. Examples of the benefit and drawbacks of this additional information will be shown as well.

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## **32 - Influence of Small Scale Ocean Surface Variations in US West Coast Satellite Altimetry by Comparison with Coincident HF Radar Synthetic Sea Surface Heights**

**Dr Emery William** *Univ of Colorado*

**Roesler Carolyn**, Univ. of Colorado ; **Qazi Waqas**, Univ. of Colorado

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4452>

### **Abstract :**

Comparisons between coastal altimetric sea surface height (SSH) and SSH derived from coincident HF radar currents reveal areas of poor agreement and this study seeks out sources of these differences between the two independent estimates of SSH from land to 150 km offshore. We suspect the presence of phenomena with length scales smaller than the altimeter footprint to alter the typical open ocean altimeter response. Small-scale variations in the altimeter radar backscattering cross section  $\sigma_0$  could be explained by wind speeds, but also by secondary effects such as surface currents and surface films. (all of which having shorter time and spatial scale variability over coastal waters). Here we distinguish cases of obvious blooming events with unrealistic high  $\sigma_0$  returns to cases with moderate contamination. Wind speed can be estimated from the altimeter itself and from the coincident measurements made by the boresighted microwave radiometer. It should be noted that this latter instrument measures the wind speed over a relatively large area while the altimeter wind speed estimate applies to a much smaller surface target. This is important since the inhomogeneity of the surface conditions could significantly influence the wind speed estimate. This could explain some of the markedly different estimates of wind speed from these two different sources. Using satellite estimates of ocean color it is possible to see some surface chlorophyll signatures associated with natural surface slicks that may be causing increased variations in the altimeter backscatter. The influence of these surface films to dampen the sea surface depends on the wind strength: inexistent when disturbed by sufficiently high winds, a coincident low wind speed will make these patches highly reflective. It is important to also consider the role of significant wave height in understanding the nature of the surface backscatter signal. We hope to be able to prioritize the various surface effects on the nature of the surface altimeter signal return. We will also take into consideration the influence of the sea state bias correction. Resolving the sources of these differences will make it possible to better retrack coastal altimetry for the correct coastal SSH estimation.

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## **33 - A specific coastal wet tropospheric correction for the Envisat RA2 altimeter**

**Dr OBLIGIS Estelle** CLS

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**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4443>

### **Abstract :**

The exploitation of radar altimetry data requires an accurate knowledge of all error sources that influence the measurements. One of them, the atmospheric humidity (mainly concentrated in the troposphere), strongly affects the range measured by the altimeter. Today, no meteorological model can provide this quantity with enough accuracy, so a Microwave Radiometer is added to altimetry missions (Envisat/MWR, Jason1/JMR, Jason2/AMR; AltiKa, Sentinel3). Methods have been established since the launch of SEASAT/SMMR to relate the integrated content in water vapor to the brightness temperatures measured by on-board radiometers using empirical relationships and are still used today for the processing of radiometer measurements for altimetry missions. But a major limitation has been identified these last years. The growing need for an accurate wet tropospheric correction in coastal areas leads to the development of specific retrieval algorithms. Different approaches have been proposed: use of GPS measurements available on the coast, allowing an improved estimation thanks to a specific processing (Fernandez et al, 2010), combination with meteorological models (Fernandez et al, 2009, Mercier et al, 2007), specific processing of the brightness temperatures, either at level 1 (decontamination of the brightness temperatures, Desportes et al, 2007) or level 2 (land proportion considered in the level 2 inversion, Brown et al, 2009). The objective of this paper is to present an operational algorithm, specifically developed for the processing of Envisat/MWR coastal data. Performances are assessed through different comparisons, including comparisons with other instruments and models.

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## 34 - Development of a 20-year Climate Quality Wet Tropospheric Correction from Altimeter Radiometers

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**Brown Shannon, JPL ; Desai Shailen, JPL ; Keihm Stephen, JPL**

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4404>

### **Abstract :**

This year will mark the 20th anniversary of the start of the modern record of global mean sea level (GMSL) from satellite altimetry. Over the past two decades, the GMSL has risen by approximately 6cm while under the watchful eye of eight altimeter measurement systems. However, precisely monitoring the rise of the GMSL would not be possible without the careful calibration of the instruments that are a part of the altimeter measurement system. In particular, the microwave radiometers on the altimeter satellites have been shown to be one of the largest sources of error in the long term stability of the GMSL measurement. Microwave radiometers have flown on all ocean altimeter missions over the past 20 years to provide a correction for the delay of the radar signal (relative to the speed in a vacuum) due the refractivity of water vapor in the troposphere. Over the years, the radiometer instrumentation has steadily improved as well as the algorithms used to retrieve wet path delay (PD) from the radiometer's brightness temperature (TB) measurements and we have correspondingly seen a reduction in the radiometer derived PD error, particularly the geographically and temporally correlated components of the error. But, the effort that has gone into ensuring a stable long term PD record, free from drift, is among the most important. In the mid-1990s, comparisons of Topex/Poseidon measurements with a global network of tide gauges showed a relative drift that was eventually attributed to a drift in the Topex Microwave Radiometer (TMR). Later, drifts were identified in the radiometers on other altimeter systems. This prompted the need to develop methods to estimate and correct for the drift in the radiometers. Various methods have been developed over the past two decades including comparisons to numerical weather prediction models, stable natural Earth references and other satellite sensors. The evolution of these methods will be discussed along with an assessment of the current understanding of the residual uncertainty in the radiometer drift corrections enabled by these techniques and a perspective for the future, including instrument improvements that show promise to reduce or eliminate the need for these corrections altogether.

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## 35 - Reprocessing TOPEX for the Climate Data Record

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**Callahan Philip**, Jet Propulsion Laboratory ; **Williams Brent**, Jet Propulsion Laboratory

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4369>

### **Abstract :**

TOPEX/POSEIDON as the first mission in the partnership between NASA and CNES in dedicated, high accuracy ocean altimetry missions forms a crucial part of the 20 year ocean climate record. TOPEX/POSEIDON used three altimeters over its lifetime: TOPEX (NASA) Alt-A and Alt-B and the experimental CNES POSEIDON, forerunner of the Jason series. The TOPEX altimeters had certain waveform features ('leakages') that have become increasingly important as altimetry is pushed to the sub-millimeter per year accuracy level. There was also the important transition from TOPEX Alt-A to Alt-B necessitated by changes in the point target response (PTR) of Alt-A, most clearly manifested by an apparent increase in significant wave height (SWH). An important difference between TOPEX and the CNES altimeters is that the TOPEX geophysical data records (GDRs) were produced by correcting onboard linearized estimates with parameterized algorithms on the ground, while CNES altimeters used waveform retracking. In addition to these instrument processing differences many advances in orbits and ancillary data have been made over the years. In order to bring TOPEX data up to the standard of more recent altimeter data and to correct for waveform features and PTR changes the TOPEX data are being retracked with newly derived PTRs from calibration data and waveform adjustments ('weights') to correct for leakages. The basis for and progress on this work will be described. The plan for producing Climate Data Records consistent with the current Jason series data will be discussed.

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## 36 - Retracking Contaminated Alimetry Waveforms over Coastal and Inland Lake Regions

*Mr Tseng Kuo-Hsin The Ohio State University*

**Shum C. K.**, The OHio State University ; **Kuo Chung-Yen**, National Cheng Kung University ; **Doug Alsdorf**, The Ohio State University ; **Lee Hyoungki**, University of Houston

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4512>

### **Abstract :**

Extended usage of satellite altimetry has covered monitoring inland/coastal water variation and other hydrological events. Relying on the advance in altimetry waveform retracking technique, a variety of distorted waveforms is now can be used by identifying their possible leading edge from multi-peaks pattern. Here, we demonstrate two novel techniques developed for either land or ice contaminated waveforms. When the altimetry measurements moving across the shoreline, both entering and leaving, the land signal usually induce a spurious peak migrating in the waveform that lead to an overestimate of telemetered range. The waveform modification developed in this study efficiently mitigate the overlapped peaks and yield a better accuracy compared with gauge data in 1-7 km offshore region. On the other hand, for alpine lakes with transitional surface conditions between water and ice, we introduce a track offset correction for returned waveform over ice, with a sharp leading edge and concentrated power compared to theoretical ocean return. Our case study has been done in Qinghai lake on the Tibetan plateau, and an improvement in accuracy, in terms of rms and correlation compared with in situ data, has been concluded with >50% better than convertional retrackers.

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## 37 - Trend and Variability of the Atmospheric Water Vapor: a Mean Sea Level Issue

*Mr THAO Soulivanh CLS*

**THAO Soulivanh**, CLS ; **OBLIGIS Estelle**, CLS ; **PICARD Bruno**, CLS ; **EYMARD Laurence**, LOCEAN

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4387>

### **Abstract :**

The ocean mean sea level is a key indicator of the global warming. Its long-term survey is an issue not only for climate understanding, but also for economic and social consequences of its elevation. The exploitation of altimetry measurements over Ocean relies on the feasibility to correct the altimeter range for different perturbations. One of them, the wet tropospheric correction is directly proportional to the integrated water vapor and is provided by a dedicated instrument, a microwave radiometer. The uncertainty on this correction is today the main important part of the mean sea level error budget. Most of the past and current radiometers onboard altimetry missions experienced problems or drifts, which are hardly detectable due to the natural variability of water vapor. Methods to detect these drifts are based on the long term survey of the measured brightness temperatures over stable targets, on the comparison with measurements from other radiometers, or on the comparison with meteorological models. These analyses show many inconsistencies and bring out the necessity to understand them. In this context, the objective of this study is to compare water vapor products from different sources. The comparison of different estimations from radiometers is tricky, because of inherent conception disparities in the products (orbit, spatial and time resolution, processing and editing). Therefore methodological considerations to implement these comparisons are needed to avoid artifacts or biases in the results. A preliminary study has been made to compare RSS water vapor products from SSM/I F15, SSMIS F16 and AMSRE radiometers with water vapor products from JMR and MWR radiometers. Comparisons with ERA-Interim analyses have also been performed. Monthly grids of 3x3 degrees of resolution have been used as a unit of comparison for the period 2004 to 2011. First results show good general agreement between the different water vapor estimations but discrepancies remain in terms of trends, global and local biases. The analysis exhibits three distinct groups. The first consists of the wide-swath radiometers (AMSRE and SSMIS F16) which seem well inter-calibrated. The second group gathers the JMR and MWR nadir-viewing radiometers with similar behaviors in terms of trends and means, while the calibration and processing of these two instruments are completely independent. Finally, the ERA-Interim model forms the last group with higher global mean values and trend. Contrary to MWR, the water vapor trend differences of ERA-Interim, JMR and SSMI15 with AMSRE depend on the value of water vapor and by consequence of their geographic positions. A specific study of differences between AMSRE and MWR shows that most of the disagreements come from low values of water vapor ( $wv < 2 \text{ g/cm}_3$ ) and are located in the coastal regions of the northern hemisphere and near Antarctica. Those structures of discrepancies evolve according to the annual water vapor cycle. While, this first study can help us characterizing the temporal and spatial variability of differences in the different estimations of water vapor, further investigations are needed in order to explain the observed discrepancies and correct them if necessary.

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## 38 - Development of an Enhanced Geophysical Data Record for the TOPEX mission

*Dr Misra Sidharth JPL, Caltech*

**Brown Shannon, JPL, Caltech**

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4485>

### **Abstract :**

The current Geophysical Data Record (GDR) for the TOPEX mission applies a standard wet tropospheric path delay retrieval algorithm developed by (Keihm et al. 1995 - TGRS). The algorithm applies unique retrieval coefficients gridded with respect to wind speed and a first order global path delay retrieval value to the TMR microwave brightness temperatures. Wet tropospheric path delay values retrieved using this retrieval algorithm work well over open ocean areas, allowing accurate altimetry path delay corrections. Near coastal areas though, due to land contamination and different antenna beam-widths for different microwave frequencies of TMR path delay values retrieved are erroneous and significantly impact coastal altimetry capabilities. A new mixed-pixel algorithm developed by (Brown 2010 - TGRS) works on a similar coefficient gridding principle. The new algorithm grids path delay retrieval coefficients based on land fraction and first order global path delay value. This algorithm has been successfully applied towards GDR processing for the Jason-1 Microwave Radiometer (JMR) on Jason-1 and Advanced Microwave Radiometer (AMR) on Jason-2. The following paper discusses the implementation of the new mixed-pixel algorithm to TOPEX data and generation of a TMR enhanced GDR data product. This paper discusses the use of TMR land brightness temperatures, a high resolution global land mask and coastal radiosonde database to train the coastal retrieval coefficients. These coefficients are then applied to coastal TMR brightness temperatures and the retrieved PD values are validated using the MERRA climate model (Modern Era Retrospective Analysis for Research and Applications) developed by NASA's GMAO (Global Modeling and Assimilation Office). MERRA is used to generate model PD values and the standard 'open-ocean' algorithm and new mixed-pixel algorithm performances are compared in terms of mean and RMS of the PD value differences. The new mixed-pixel algorithm shows a 0.5 to 2cm error improvement near the coastal regions. The TMR enhanced GDR product will also contain MERRA generated model PD values as well as land TMR Tb values previously missing from TMR GDR products. A few other validation techniques are being tested concurrently with enhanced TMR product generation. A brief description of the original tropospheric wet path delay algorithm will be presented, followed by a discussion on the mixed-pixel algorithm. The parameters involved in implementing and validating the mixed-pixel algorithm for improved coastal altimetry measurements will be presented. A brief discussion of the various validation techniques will also be presented. Finally, other improvements and additions to the enhanced GDR product will be discussed.

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## 39 - X-band interferometric SAR sensor for the Japanese altimetry mission and aircraft experiment

**Dr Uematsu Akihisa** *Japan Aerospace Exploration Agency (JAXA)*

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**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4432>

### Abstract :

In the Japanese new altimetry mission (COMPIRA; Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter), we will use wide-swath altimeter in order to maximize spatial coverage of the altimetry measurement maximize to reduce error of the tidal model in the shallow marginal seas. We have a plan to develop X-band interferometric SAR (interferometric synthetic aperture radar), SHIOSAI (SAR Height Imaging Oceanic Sensor with Advanced Interferometry) with two antennas for COMPIRA mission. Requirement for spatial resolution is 5 km, that for swath width per each side is 70 km (totally 140 km swath). We are now on conceptual study of the SHIOSAI. To minimize rain attenuation and maximize data acquisition around Japanese coast, we use X band (center frequency of 9.6 GHz). To satisfy requirement and reduce risk related to thermal strain and/or deployment structure, baseline size will be designed to be 3-5 m. Now trade-off study of antennas, transmitter and receiver is ongoing. In parallel, to demonstrate sea surface height measurement of X-band interferometric SAR and obtain some parameters for design of SHIOSAI, we have a plan to conduct aircraft experiment of sea surface height measurement with airborne interferometric SAR. The airborne SAR will be composed of X-band FM-CW radar with baseline size ~10 cm to adjust geometric relation compared to SHIOSAI. Aircraft for experiment will be Kingair or Gulfstream-II. In the experiment, we will choose either one or two ocean areas out of typical ocean current region. Candidate areas are as follows; Kuroshio region around offshore of the Boso Peninsula and/or offshore of the Muroto around Shikoku Island, and/or Tsushima current region around the Tsushima Island. The aircraft will be flown over Jason-2 satellite orbit to compare sea surface height, significant wave height, and sea surface wind. To calibrate radar backscatter and ocean backscatter coefficient, we will install corner reflector on the land around the target ocean area. Also we will use available data of HF radar and buoys. We will conduct several flights in the end of 2012 or in the beginning of 2013. In the paper, we will present current status of conceptual study of SHIOSAI sensor and current plan of the airborne experiment.

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## 39B - Cryosat Plus For Oceans ? User Consultation

*Dr Cotton David SatOC*

Gil Elizabeth, Starlab ; Clarizia Maria Paola, Starlab

**Session:** Instrument Processing

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4705>

### **Abstract :**

The ESA Cryosat-2 mission is the first space mission to carry a radar altimeter that can operate in Synthetic Aperture Radar (SAR) mode. Although the prime objective of the Cryosat-2 mission is dedicated to monitoring land and marine ice, the SAR mode capability of the Cryosat-2 SIRAL altimeter also presents the opportunity of demonstrating significant potential benefits of SAR altimetry for ocean applications, based on expected performance enhancements which include improved range precision and finer along track spatial resolution. The 'Cryosat Plus for Oceans' (CP4O) project is supported under the ESA Support To Science Element programme and brings together an expert consortium comprising, CLS, DTU Space, isardSAT, National Oceanography Centre (UK), Noveltis, SatOC, Starlab, TU Delft, and the University of Porto. The objectives of CP4O are:- to build a sound scientific basis for new scientific and operational applications of Cryosat-2 data over the open ocean, polar ocean, coastal seas and for sea-floor mapping.- to generate and evaluate new methods and products that will enable the full exploitation of the capabilities of the Cryosat-2 SIRAL altimeter, and extend their application beyond the initial mission objectives.- to ensure that the scientific return of the Cryosat-2 mission is maximised. One of the first activities is the consolidation of preliminary scientific requirements for the four sub-themes under investigation, which are: open ocean, high-resolution coastal zone, high-resolution polar ocean and high-resolution sea floor. To achieve this goal the CP4O team will carry out a user consultation, undertake an analysis of limitations and drawbacks and finally define the scientific and operational requirements. All the activities envisioned will be done on a sub-theme basis. This poster will present the CP4O project and the first initial results from the ongoing work to define the scientific requirements.

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## 40 - SARAL SCIENCE AND APPLICATIONS PLAN

*Dr KUMAR RAJ ISRO*

**KUMAR RAJ, ISRO ; GAIROLA RAKESH MOHAN, ISRO ; SHARMA RASHMI, ISRO**

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4494>

### **Abstract :**

SARAL-AltiKa is the ISRO-CNES joint collaborative project. The objectives of ALTIKA mission are: To realize precise, repetitive global measurements of sea surface for studying mesoscale variability, developing coastal oceanography applications, inland waters and ice sheets monitoring and understanding of climate change. The advantages of AltiKa is that it is based on a wideband Ka-band altimeter (35.75 GHz, 500 MHz), which will be the first oceanography altimeter to operate at such a high frequency with higher performance both in terms of spatial and vertical resolution. The present discussion contains the plans outlined for thrust areas of science and applications to be taken up using AltiKa data in India. A comprehensive Science and Applications plan has been worked out. The major activities proposed in the resulting national ?AltiKa science and applications plan? primarily includes ocean mesoscale studies and assimilation of sea level anomaly (SLA) and wave height from SARAL AltiKa in ocean models for its operational usage. Application of AltiKa in operational oceanography will also comprise of automatic detection of mesoscale features from track data of AltiKa and for wave climate and extreme wave studies. A study has been carried out to examine the optimum requirement of altimeters in detecting the eddy features in the Arabian Sea and Bay of Bengal. Different techniques for assimilating SLA and sea surface temperature in potential operational ocean models have been tried out. A synergistic application by combining data of scatterometer, altimeter and radiometer sea surface temperature has been demonstrated to compute global ocean surface current. The comparison of the water vapor corrections estimated from radiosonde measurements near the coastal regions with the model estimated corrections applied in the altimeter range measurements have also been studied. Under SARAL/AltiKa mission, we have several projects (a total of 24 in number) from different national academic institutions and research organizations. These application projects cover wide range of subjects, notable among them are studies pertaining inland water and coastal studies. Other potential application subjects of immense interest to operational users are (i) Study on tropical cyclone intensity over Indian Ocean prediction using Ocean Heat Content information from satellite Altimeter and light rainfall climatology from altimeter and radiometer. Some other possible areas planned under Science studies and Applications are, wave period estimation using AltiKa, characterization of Indian Ocean Rossby/Kelvin waves, investigations of the inter-annual polar Ice dynamics using multi-source satellite observations, exploring application of radar altimetry for water resources management, a study of the structure, tectonics and isostasy of the Andaman Subduction Zone using SARAL/AltiKa derived geoid/gravity and bathymetry data. Since one of the objectives of the SARAL/AltiKa mission is to improve the quality of coastal sea level measurements, we have carried out studies to check the quality of correction terms for coastal regions. Some of the salient results from above research areas will be presented in the meet.

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## 41 - Impact of Altimeter sea level on ocean reanalyses at the National Centers for Environmental Prediction

**Dr Carton James** *University of Maryland, Department of Atmos. Ocean. Sci.*

**Penny Steve**, University of Maryland ; **Behringer David**, NOAA National Centers for Environmental Prediction ; **Carton James**, University of Maryland ; **Kalnay Eugenia**, University of Maryland

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4492>

### **Abstract :**

This talk will present a new ensemble-based data assimilation system for the National Centers for Environmental Prediction (NCEP) as well as a new way of handling satellite altimeter observations. The system is used to examine the impact of altimeter observations on the resulting analysis with emphasis on seasonal variability. In the tropics the impact is greatest in the Atlantic. The impact grows in the subtropics because of the more limited in situ observation set, while it declines at high latitude due to increasingly complex dynamics.

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## **42 - Monitoring marine debris from the March 11, 2011 tsunami in Japan with the diagnostic model of surface currents**

**Dr Maximenko Nikolai** *IPRC/SOEST, University of Hawaii*

**Hafner Jan**, IPRC/SOEST, University of Hawaii

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4487>

### **Abstract :**

Near-realtime diagnostic model of near-surface ocean currents (SCUD) is developed using the mean dynamic topography and satellite data of altimetry (sea level anomaly) and scatterometry (wind stress), with the coefficients optimized to reproduce concurrent velocities of drifting buoys, drogued at 15m depth. Model experiments, simulating motion of debris from Tohoku area in Japan, are used to assess real-time location of tsunami debris, describe its fate, build the timeline of debris impact on different coast lines and suggest a plan of action, optimizing the use of resources. Model outcome is compared with reports of sightings of various types of debris. This paper has been also accepted as a poster presentation at the '20 years of progress in radar altimetry' conference.

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## 43 - Observatory and Research on extreme PHENomena over the Oceans (ORPHEO)

*Dr Quilfen Yves ifremer*

**Chapron Bertrand**, IFREMER ; **Reul Nicolas**, IFREMER ; **Queffeuilou Pierre**, IFREMER ; **Ardhuin Fabrice**, IFREMER ; **Tournadre Jean**, IFREMER

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4438>

### **Abstract :**

Thanks to satellite-based observations, extreme weather events such as tropical cyclones or explosive mid-latitude storms and polar lows can be more commonly reported, directly analyzed (e.g. Quilfen et al., 2010, 2011, Reul et al., 2012) or indirectly characterized (Ardhuin et al., 2009, Collard et al., 2009; Delpey et al., 2010). These measurements are critical for short term forecasting, but also offer means to better question the role of extreme conditions for the state of ocean at local and global scales, and effects on ocean circulation and ocean heat transport. Energy inputs in the region of intense storm tracks are indeed thought to represent the main kinetic energy sources necessary to maintain the deep ocean stratified and to strengthens ocean stirring processes. As demonstrated by radiometers onboard the DMSP satellite series, WindSat, TRMM, AMSR-E and now SMOS (i.e. Reul et al., 2012), as well as by scatterometers onboard the ERS, ADEOS, QuikScat and METOP satellites, unprecedented synoptic observations of surface wind and atmospheric water content are now possible and are revealing the storm structures with impressive details. Satellite estimates don't necessarily provide direct measurements of geophysical parameters and can suffer from limitations linked to the sensors characteristics, but the combined use of sensors helps to build methods to retrieve geophysical content. For instance, while certainly limited by its relatively coarse across-track sampling, the altimeter dual frequency radar cross section measurements have been demonstrated to provide very valuable information. Altimeter signals can be processed using specialized algorithms to retrieve the surface wind speed and significant wave height, along with the rain rate in extreme weather events. Quite surprisingly, winds up to 50 m/s have been estimated in hurricanes for the first time using altimetry, to open new perspectives for estimation of extreme event intensity (Quilfen et al., 2011). Furthermore, the SMOS L-band radiometer has a large swath coverage to actually provide measurements the least affected by heavy precipitations. In this project, we then intend to further elaborate on these previous results to explore in depth these capabilities to observe and quantitatively characterize extreme events. From a sensor physics point of view, special attention will be given to more thoroughly understand and model of foam characteristics (coverage and thickness) which strongly impact the passive and active measurements under very high wind conditions. Moreover, between the altimeter and SAR sea state measurements, the methodology already developed (Collard et al., 2009) will then be extended to more precisely provide valuable information to describe the sea state structures in the wake, near the center, and ahead of the storm, to characterize the intensity near the intense generation area. Finally, in combination with other sensors and numerical models, the available time series of wind and wave measurements obtained from different satellite platforms since the beginning of the nineties, will be used to analyze these data to characterize the variability in the surface wind and associated wave fields. The link between changes in the mean fields with changes in storms distribution characteristics will then be more closely investigated and assessed.

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## 44 - The Near-Real Time Global Reservoir and Lake Monitor

*Dr Birkett Charon University of Maryland*

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**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=3884>

### **Abstract :**

A USDA/NASA funded program is performing near-real time altimetric monitoring of the largest lakes and reservoirs around the world. The near-real time stage measurements are currently derived from incoming data from the NASA/CNES Jason-2/OSTM mission. Archived data from the NASA/CNES Topex/Poseidon and Jason-1 missions, and from the NRL GFO mission are also utilized to provide historical time series variations from 1992-2008. The program was recently expanded and enhanced by including part of the ESA ENVISAT archive data set (2002-2010) which will allow the additional monitoring of several hundred lakes. Radar, lidar and ground-based data sets are all used for relative or absolute validation exercises. The USDA/FAS utilize the products for assessing irrigation potential (and thus crop production estimates), and for general observation of high-water status, short-term drought, longer-term climatic trends, and anthropogenic effects. Here, we report on performance evaluations of the Poseidon-3 radar altimeter, in terms of overall product quality and quantity and minimum target size. We also report on recent upgrades to the merged Topex/Jason/OSTM products. Preliminary (ENV.1) ENVISAT products are also given, and we take a look at future requirements and program expansion elements, as additional science objectives and end-user needs are considered.

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## 45 - Near Real-Time Jason-2 Product Operations

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**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4463>

### **Abstract :**

In partnership with CNES and NASA, NOAA and EUMETSAT have joint responsibility to process and disseminate the Near Real-Time (NRT) Jason-2 products. Several activities are entailed in NRT product operations, including processing, dissemination, data quality monitoring and user service notifications. An important input to the processing, under the responsibility of EUMETSAT, is the operational provision of meteorological path delay corrections based on the ECMWF Numerical Weather Prediction model. This poster provides an overview of the activities associated with the day-to-day operations, including coordination of routine activities and end-to-end monitoring. With respect to product quality, the functionality and recent enhancements of the JPL/NOAA Near Real Time Altimeter Validation System (NRTAVS) tool are reviewed, and examples of its use in routine operations are provided. The system that provides operational ECMWF files to the Jason-2 ground segment will be discussed, focusing on recent improvements with a summary and outlook of the main changes. The latter are driven by evolutions in the ECMWF model (with various degrees of impact) such as updates of the model physics, changes in data format, and changes in horizontal or vertical grid resolution.

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## 46 - Contribution of the SARAL/Altika mission for sea-state analysis and prediction at mesoscale and in coastal zones

**Mr LEFEVRE Jean-Michel** METEO-FRANCE

**Aouf Lotfi**, Meteo-France ; **Bouin Marie-Noelle**, Meteo-France ; **Nuret Matthieu**, Meteo-France ;  
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**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4460>

### Abstract :

Saral/Altika mission has been designed to provide information in coastal zones. It is expected that measurements from this mission should better contribute to the prediction of waves at meso-scale and in coastal areas through several aspects. The first one is related to implementation of an atmospheric model at 2/3 km horizontal resolution over the Western Mediterranean Sea. The validation of wind speeds from high resolution (2.5 km horizontal mesh), non hydrostatic Numerical Weather Prediction (NWP) is an important issue, in particular in the coastal zone. Under the developing program HyMeX (HYdrological cycle in the Mediterranean Experiment), the AROME model (Bouttier et al. 2006) deployed over the France domain (AROME-France), will be deployed in the Western Mediterranean Sea (AROME-WM) over a period of several months. The second one is related to the improvement of the Meteo-france wave prediction system MFWAM with a new physics package (Ardhuin et al. 2010). The physics implemented in the new wave model has reduced significantly the model errors for various sea-state conditions. The downscaling of the model at mesoscale and close to the coast at a resolution close to AROME model is on going. The validation of such modeling and the understanding of the errors accumulated when waves are reaching the coast relies on a very few wave buoys and on the ability of an altimeter to measure waves in the coastal zones. It is expected that SARAL-Altika should be able to provide such measurements for validation. The data will be used after being validated and calibrated with procedures that will have been developed in the Laboratoire d'Océanographie Spatiale (LOS/IFREMER). Those data will be merged with an existing data base consisting in homogeneously calibrated measurements from the various altimeter missions (Queffeuou et al., 2004, 2009). Those procedures will be adapted to the specificity. The third one is related to optimal use of remote sensed wind/Wave for data assimilation in wave models at global scale and regional scale. The impact of using additional data from SARAL/Altika for operational forecasting of waves in addition to existing sensors of the same type, in an optimal way, will be made in the continuity of the work undertaken with previous altimeters (Skandrani et al. 2004). This capacity will be developed in the context of assimilation combined with spectral data from previous existing sensors type like ASAR (Aouf et al. 2006, 2009) or future type with the CFOSAT mission (Hauser et al. 2001). The last one is related to the impact of waves on the turbulent fluxes. Turbulent fluxes are currently parametrized in the NWP models using « bulk » formulas. Recent studies (Semedo et al., 2009) showed that these parameterisations are not accurate enough, as fluxes (wind stress) depend on the sea state especially in low wind/swell conditions and/or far from neutral conditions. Within the Hymex campaign, we aim to better understand how waves have an impact on the turbulent fluxes. First validation results based on MWAM/France, data from current altimeters and buoys are presented.

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## 47 - JASON-2 GPS BASED OGDR PRODUCTS

**Mr Andres Yago** EUMETSAT

**Andres Yago**, EUMETSAT ; **Thepaut Olivier**, EUMETSAT ; **Figa Julia**, EUMETSAT ; **Bonekamp Hans**, EUMETSAT

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4365>

### **Abstract :**

EUMETSAT has started generating experimentally 'GPS based' OGDR products which make use of the GRAS GSN support data and the GPSP data from the Jason-2 to compute a GPS based orbit. This product requires a more complex processing on ground but contains a more accurate orbit as compared to the OGDR product. The product is derived by adding two fields to the official OGDR (GPS orbit altitude and GPS based sea surface height anomaly) in a similar way to the JPL produced GPS OGDR products. Two types of product are being produced: without and with one orbit lag. The first one has a latency which is very similar to the official OGDR but usually a more accurate orbit, and the second one has a two hours larger latency and reaches an accuracy comparable to the MOE orbit used for generating the IGDR product. These very accurate products are possible thanks to the high precision GPS support data provided by the GRAS GSN service. This approach for accurate orbit determination in NRT is applicable also to the processing of other future similar altimetry missions at EUMETSAT, such as Jason CS and Sentinel-3, thanks to the availability at EUMETSAT of high quality GPS data provided by the GRAS GSN. The approach has the potential to meet and improve the required orbit accuracy performances for those missions. The common multi-mission aspect of this capability provides additional advantages for operational NRT altimetry services, in terms of operations and maintenance.

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## 48 - Ssalto/Duacs: Towards regional products

*Ms Pujol Marie-Isabelle* CLS

**Dufau Claire**, CLS ; **Renaudie Cecile**, CLS ; **Labroue Sylvie**, CLS ; **Faugere Yannice**, CLS ; **Dibarboure Gerald**, CLS ; **Bronner Emilie**, CNES

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4541>

### **Abstract :**

Ssalto/Duacs system processes data from all altimeter missions (Jason-1&2, T/P, Envisat, GFO, ERS-1&2, Cryosat-2...) to provide a consistent and homogeneous catalogue of products for varied applications, both for near real time applications and offline studies in the framework of the SALP/CNES and MyOcean/SL TAC project. The global duacs products (along track and gridded data) are used by hundreds of teams around the world. Beside these global products, the catalogue also contains several high resolution regional products. During the last years specific efforts have been done to improve this range of products. A product focused on the Mozambic Canal has been disseminated since the beginning of 2011, and 3 others are available to the users since mid/end 2011, around the Kerguelen island to support the KEOPS-2 Oceanographic campaign, one over the European Seas, and finally one over the Arctic ocean, area of great interest for Climate studies. For each product, Level 2/3/4 algorithms have been tuned in order to obtain an optimal sea level in each area: choice of the best geophysical correction, tuning of the editing criteria, lowering of the along track filtering, use of specific correlation scales for the mapping ... The obtained products allow a better restitution of the mesoscale process, and should notably answer to data assimilation needs in terms of resolution and physical content.

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## 49 - A Kerguelen regional Sea Level product to support the KEOPS2 experiment

*Ms Pujol Marie-Isabelle CLS*

**Rio Marie-Helene**, CLS ; **Renaudie Cecile**, CLS ; **D'Ovidio Francesco**, LOCEAN-IPSL ; **Morrow Rosemary**, CNES ; **Faugere Yannice**, CLS ; **Dibarboure Gerald**, CLS ; **Lambin, Juliette**, CNES ; **Bronner Emilie**, CNES

**Session:** Near Real Time Products and Applications

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4540>

### **Abstract :**

The KEOPS2 campaign (PI: S. Blain, Observatoire Océanologique de Banyuls sur mer, UPMC) took place during October-November 2011 around Kerguelen Islands. The aim is to elucidate the response of ecosystem functioning and of the biogeochemical cycles to natural iron fertilization, a key factor controlling ecosystem dynamics (including CO2 export) in the Southern ocean and other basins. It is a multidisciplinary campaign heavily relying on high quality satellite data. A specific support from CNES enables KEOPS2 to benefit from such products, both in real time and delayed time production. CNES contributes via Ssalto/DUACS project and in collaboration with LEGOS/CTOH, to specifically process altimeter products and derivatives for Kerguelen area. They consist in Mean Dynamic topography, Along-track and gridded altimeter products (Sea level anomalies and absolute dynamic topography) and derivatives (anomalies and absolute geostrophic surface currents). Combined product, such as total surface current (including Ekman component) will be also delivered. The products were successfully used before and during the campaign, to have Synoptic monitoring of surface state, predict the drifters and moorings trajectories, and choice the positions of in situ measurements. Results obtained underlined the quality and accuracy of the regional products. In turn, KEOPS2 campaign will contribute to improve the products, via in situ measurements and users feedback.

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## 50 - Recent advances on mesoscale variability in the Western Mediterranean: complementarity between altimetry and other sensors

**Dr Pascual Ananda** [ananda.pascual@imedea.uib-csic.es](mailto:ananda.pascual@imedea.uib-csic.es)

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4532>

### **Abstract :**

Satellite altimetry has provided a unique contribution to the global observation of mesoscale variability, the dominant surface signal in the ocean circulation at mid and high latitudes. In particular, it is now possible to quantify and monitor surface mesoscale eddies. However, the single use satellite altimetry only allows providing surface information with a limited spatio/temporal coverage. Thus, to circumvent these limitations and to fully understand the three-dimensional variability it is necessary to complement altimetry data with alternative remote and in-situ sensors. In this study we review recent advances on mesoscale variability as seen by the synergy of altimetry and independent observations in the Western Mediterranean, where the circulation is rather complex due to the presence of multiple interacting scales, including basin, sub-basin scale and mesoscale structures. The challenges of characterizing these processes imply therefore precise and high-resolution observations in addition to multi-sensor approaches. Accordingly, multi-platform experiments have been designed and carried out in the different sub-basins of the Western Mediterranean Sea highlighting the need of synergetic approaches through the combined use of observing systems at several spatial/temporal scales, with the aim of better understanding mesoscale dynamics.

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## 51 - Reconstruction of global sea level variations from tide gauges and altimetry

**Dr Wenzel Manfred** *Alfred Wegener Institute*

**Wenzel Manfred**, Alfred Wegener Institute ; **Schroeter Jens**, Alfred Wegener Institute

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4530>

### **Abstract :**

Sea level variations prior to the launch of satellite altimeters are estimated by analysing historic tide gauge records. Recently, a number of groups have reconstructed sea level by applying EOF techniques to gappy data. We complement this study with alternative methods. In a first step gaps in 178 records of sea level change are filled using the pattern recognition capabilities of artificial neural networks. Afterwards satellite altimetry is used to extrapolate local sea level change to global fields. Patterns of sea level change are compared to prior studies. Global mean sea level change since 1900 is found to be on average 1.65 mm per year.

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## 52 - Large-scale interannual variability of sea level and water mass properties in the southeast Pacific

**Dr Volkov Denis** *Jet Propulsion Laboratory*

**Volkov Denis**, Jet Propulsion Laboratory ; **Zlotnicki Victor**, Jet Propulsion Laboratory

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4517>

### **Abstract :**

The southeast Pacific sector of the Southern Ocean plays an important role in regulating the climate of Antarctica. This is the region where the Antarctic Circumpolar Current (ACC) reaches its southernmost latitude and brings heat towards the western side of the Antarctic Peninsula, and where the biggest source of the Antarctic Intermediate Water (AAIW) formation is located. Nearly 20 years of high accuracy satellite altimetry measurements have revealed a large-scale pattern of the interannual variability of sea surface height (SSH) in the region. Three phase changes occurred during the observational period: in 1998, 2003, and 2008. The positive (negative) phase is associated with higher (lower) than average sea level west of the South America and lower (higher) than average sea level over the ACC and south of it. We have shown that the observed variability of SSH is related to wind forcing over the region, and to Pacific Decadal Oscillation suggesting the importance of large-scale teleconnections. The wind strengthens/weakens the convergence/divergence zones that is reflected in the SSH variability. The flow of the ACC is known to be concentrated in jets that are associated with frontal regions. We use altimetric measurements of SSH to detect the ACC fronts and to establish their relation, in terms of location and strength, to the observed interannual fluctuations of SSH and wind stress. We also use the Southern Ocean optimized solution from the ECCO2/ECCO3 (Estimating Circulation and Climate of the Ocean, Phases 2 and 3) ocean data synthesis and available hydrography data (mainly based on ARGO measurements) to investigate the associated interannual changes in water mass properties. Particular attention is paid to the variability of the AAIW. Preliminary statistical analysis of the ECCO2 model output shows that the vertical distribution of salinity is strongly coupled to sea level and wind stress; convergence/divergence of Ekman transport west of the Drake Passage corresponds to an decrease/increase of salinity in the surface layer and in the core of the AAIW.

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## 53 - Beta-plumes and origin of striated patterns in the ocean

*Dr Maximenko Nikolai* IPRC/SOEST, University of Hawaii

**Melnichenko Oleg**, IPRC/SOEST, University of Hawaii ; **Di Lorenzo Emanuele**, Georgia Institute of Technology ; **Belmadani Ali**, IPRC/SOEST, University of Hawaii ; **Schneider Niklas**, IPRC/SOEST, University of Hawaii

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4489>

### Abstract :

Dynamics of 'striations', quasi-zonal jet-like features seen on maps of multi-year mean geostrophic velocity (see Figure), is analyzed in the framework of beta-plumes, ocean circulations generated by localized sources of vorticity. Beta-plumes are exemplified in the ocean by the Azores Current induced by the outflow of Mediterranean water from Gibraltar, the Hawaiian Lee Countercurrent generated by the orographic wind stress curl in the lee of Big Island of Hawai'i, and features off of the California coast resulting from nonlinear interaction between baroclinic meander of the California Current and Ekman flow. Experiments with the idealized ROMS model demonstrate formation of the system of jets west from the source area in linear regime and of system of eddy trains in nonlinear regime. In the presence of the background meridional flow, common in the regions populated by striations, beta-plumes change in two ways: orientation and generation of eddies. Axes of beta-plumes are tilted by the large-scale advection in the same manner both in linear and non-linear regimes. In linear case, tilted axes allow trapped Rossby waves to propagate meridionally against the flow. In nonlinear case, the tilt is achieved by a superposition of westward drift of eddies and their meridional advection by the flow. Due to instability of meridional flow, new eddies are generated not only in the beta-plume vorticity source but also along the jets west from the source area. Both the tilt of striations, consistent with the direction of the large-scale flow, and formation of eddies away from eastern boundaries are confirmed using altimetric maps of the sea level anomaly. New eddies are shown to form preferentially on crests and troughs of pre-existing striations. This complex organization of eddies is also confirmed by the structure of space correlation functions of geostrophic velocity and vorticity. The functions combine 'eddy' correlations, suspiciously coinciding with the AVISO mapping functions, and long-range correlations extending up to 2000 km in the zonal direction and including a set of crests in the meridional direction. This study demonstrates how originally simple physics of a beta-plume, when placed into realistic conditions of unstable ocean gyres, develops complex organization of mesoscale eddies, which both results from and visualizes the striated pattern of the plume. This paper was also accepted for oral presentation at the '20 years of progress in radar altimetry' conference.

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## 54 - Decadal Variability of Net Water Flux at the Mediterranean Sea Gibraltar Strait

*Dr Fenoglio-Marc Luciana Darmstadt University of Technology*

**Mariotti Annarita, ; Sannino Gian Maria, ; Meyssignac Benoit, ; Kusche Juergen, ; Rietbroek Roelof,**

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4468>

### **Abstract :**

Long-term variability of the net water flux into the Mediterranean Sea at the Gibraltar Strait over the period 1960-2011 is explored based on an approach combining multiple observational datasets and results from a regional climate model simulation. The approach includes deriving Gibraltar water fluxes from the application of the Mediterranean Sea mass conservation equation using observationally based estimates of mass variation from GRACE, sea level and its steric component from satellite altimetry, sea level reconstruction and in-situ data, evaporation, precipitation and simulated river discharge and Bosphorus Strait water fluxes. This derivation is compared with results from a simulation using the PROTHEUS regional oceanatmosphere coupled model considering both individual water cycle terms and overall Gibraltar water flux. Results from both methodologies point to an increase in net water flux at Gibraltar over the period 1970-2009 (0.8 +/- 0.2mm/mo per year based on the observational approach). Simulated Gibraltar net water flux shows decadal variability during 1960-2009 including a net Gibraltar water flux decrease during 1960-1970 before the 1970-2009 increase. Decadal variations in net evaporation at the sea-surface, such as the increase during 1970-2009, appear to drive the changes in the net inflow at Gibraltar, while river runoff and net inflow at the Bosphorus Strait have a modulating effect. Mediterranean Sea mass changes are seen to be relatively small compared to water mass fluxes at the sea surface and do not show a long-term trend over 1970-2009. The Atlantic Multi-decadal Oscillation (AMO) and the North Atlantic Oscillation (NAO) are seen to influence net water flux at Gibraltar indirectly via the influence they bear on regional evaporation, precipitation and runoff. The extension of the study to the interval 1960-2011 includes mass variation derived from improved GRACE gravity field solutions.

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## 55 - Coastally Trapped Waves Signals and Their Thermal Impacts : Synthesis of Results from Altimetry and Models in the tropical Atlantic

*Dr LAZAR alban LOCEAN-IPSL, UPMC*

**LAZAR alban**, LOCEAN-IPSL, UPMC ; **WADE Malick**, LPAOSF-UCAD ; **POLO Irene**, Departamento de Física de la Tierra, Astronomía y Astrofísica; Universidad Complutense de Madrid ; **PETER Anne-Charlotte**, LOCEAN-IPSL ; **RODRIGUEZ de FONSECA Belen**, Departamento de Física de la Tierra, Astronomía y Astrofísica; Universidad Complutense de Madrid

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4467>

### **Abstract :**

We present a synthesis of a several-year investigation conducted with altimetry datasets on characterization and impacts of equatorial and coastally trapped waves in eastern Atlantic at fine temporal and spatial scales. It was first shown that fine scales of intra-seasonal coastal propagations were captured at first order by radar altimetry, despite the reputed poor quality of sea surface height anomaly reconstruction within the first fifty kilometers offshore. Hence the TOPEX-Poseidon dataset was first able to reveal, when properly filtered, an impressive continuous activity of long range SSHA propagations from the equator up to the two Atlantic extremities of Africa. As expected from several equatorial studies, coastal intra- seasonal propagations appear dominated by the arrival of first modes equatorial Kelvin waves, that follow the coast at speed estimates of 1.5 to 2.1 m/s at low latitudes, and almost infinite poleward of the coastal Angola and Senegal upwelling fronts. Amplitudes range from -5 to + 5cm, with also important along-track variations. These characteristics were however subject to a certain level of suspicion, due to the near-coast breakdown of measurement quality, as well as tide-model uncertainties. NEMO OGCM \_° runs proved to reproduce with good accuracy most of these characteristics, opening therefore the way to thorough analyses of these signals and their impacts on SST. Interannual run and idealized experiments supported the altimetry results, and particularly the observed amplitude and velocity changes. Attribution of possible causes was therefore more robust and will be presented. SST impacts of up to 0.4°C/cm, suggested in observations by regression of SST on SSH along coastlines, are also supported by the model runs. The latest allow for a partition of advection and mixing processes at play, and uncover the competing or constructive mechanisms of upwelling and downwelling waves effects on the thermal stratification and the SST field.

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## 56 - SEA LEVEL CHANGE AND VERTICAL MOTION FROM SATELLITE ALTIMETRY, TIDE GAUGES AND GPS IN THE INDONESIAN REGION

*Dr Fenoglio-Marc Luciana Darmstadt University of Technology*

**Fenoglio-Marc Luciana**, Darmstadt University of Technology ; **Schöne Tilo**, ; **Illigner Julia**, ; **Becker Matthias**, ; **Manurung P.**, ; **Khafid C.**, ; **Subarya, C.**,

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4465>

### **Abstract :**

We investigate the sea level rise in the Indonesian region in the interval 1993-2011 based on satellite altimetry and tide gauges data. Satellite altimetry indicates a positive sea level rise everywhere in the Indonesian region, with a mean of 6 mm/yr, which is higher than the global average mean sea level rise of 3 mm/yr. Values near four selected tide gauge stations are between 2 and 4 mm/yr. The difference between the altimeter and tide gauge sea level trends are larger than 3 mm/yr and are possibly related to seismic activity and vertical land motion. We find land subsidence at the three stations of Jakarta, Surabaya and Benoa and land uplift in Sibolga. GPS derived rate and altimetry-tide gauge trend differences are in agreement at the two GITEWS stations of Enggano and Tanjung Lesung, and indicate land subsidence at the first station.

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## 57 - The Wavenumber Spectrum of SSH in the Caribbean Sea

*Dr Zaron Edward* Portland State University

Ray Richard, NASA/Goddard

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4453>

### **Abstract :**

Output from a high-resolution operational ocean model is compared with along-track altimetric SSH in order to understand processes governing the wavenumber spectrum of SSH, particularly the dual roles of tidal internal waves and mesoscale variability. The Caribbean Sea is the focus of study because it contains several internal wave generation sites and a relatively homogeneous mesoscale eddy field. Tides, while small, influence the SSH spectrum slope at scales smaller than 150km, with contributions from both the coherent (phase-locked) and incoherent internal tides. Causes and consequences of incoherent tides are diagnosed in the model with consideration of their role in the noise budget of future wide-swath altimeter missions.

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## 58 - Accuracy requirements for detecting changing trends in sea level

**Dr Quartly Graham** *National Oceanography Centre, UK*

**Quartly Graham**, National Oceanography Centre, UK

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4450>

### **Abstract :**

According to tide gauges the global mean sea level has been rising at an average rate of  $\sim 1.6$  mm / yr for most of the 20th century, although with some decadal variations. Since the 1990s, the mean rate from both altimetry and tide gauges has been  $\sim 2.8$  mm/yr, with the implied forecast that if this trend continues mean sea level will be  $\sim 30$  cm higher at the end of the 21st century. This foretells major societal crises in low-lying lands such as Bangladesh and the Maldives, as well as increased costs of flood defences, such as the Thames Barrier, for other nations. However, a number of climate models (both as part of IPCC's Assessment Reports and independent of those initiatives) have suggested an increase by the end of the century of 50 cm or even more than a metre, which would precipitate the need for more immediate action by world governments. To make the best plans for possible eventualities requires that the observing systems are able to distinguish between these scenarios in a timely manner. Here I undertake a rudimentary assessment of the ability of the altimetric observing system to detect an acceleration in sea level rise, augmenting it by a further 1 mm / yr. Using the spectrum of variability noted in the pre-altimetry era, one can determine the minimum duration of a time series to allow a robust determination of such a change. I consider the sensitivity of the system to drifts in the bias of the altimeters providing the so-called reference mission. This evaluation also covers breaks in the continuous altimetry record, requiring that partial series are aligned by the use of maintained validation sites and tide gauges. Given the present uncertainty in the funding for Jason-CS and the chance that any mission may expire prematurely, it is crucial to quantify how degradation in the altimetry observing system will affect our ability to detect enhanced sea level rise as promptly as would be desired.

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## 59 - Altimeter's Effect on Global Ocean Heat Content and Mean Surface Dynamic Height Analyzed by the MRI Global Ocean Data Assimilation System

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**Fujii Yosuke**, Meteorological Research Institute ; **Toyoda Takahiro**, Meteorological Research Institute ; **Fukuda Yoshikazu**, Japan Meteorological Agency ; **Ishizaki Shiro**, Japan Meteorological Agency ; **Nakano Toshiya**, Japan Meteorological Agency ; **Ito Wataru**, Japan Meteorological Agency ; **Kamachi, Masafumi**, Meteorological Research Institute

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4429>

### **Abstract :**

Temperature and salinity fields for global ocean are obtained from a data assimilation system of the Meteorological Research Institute (MOVE/MRI.COM). They are also obtained from a statistical objective analysis of in-situ temperature and salinity data by the Japan Meteorological Agency, and sea level (SL) also from an objective analysis of altimeter data. To clarify effects of satellite altimeter data on our assimilation system, thermal expansion (including salinity effect) for global ocean obtained from the assimilation results with the altimeter data are compared to those without altimeter data. The assimilation method of the altimeter data is contrived not to reflect the sea level rise due to the global increase of the water mass on temperature and salinity fields. The objective analyses show that global mean SL rose around 4 cm from 1993 to 2007, and thermal expansion above 700 dbar contributes one third of the SL rise. Thermal expansion below 700 dbar and water mass increase should contribute to the rest of the SL rise. The assimilation results without (with) altimeter data shows that thermal expansion above 700 dbar contributes 2.5-cm (3-cm) rise for the same period, larger than the objectively analyzed thermal expansion, and that below 700 dbar has 0.5-cm (1-cm) positive impact on the SL rise. It shows that the altimeter data has a positive impact for SL rise in our assimilation system, reducing the deviation between thermal expansion and the SL rise from altimeter data, but causing a larger deviation of the thermal expansions between the assimilation and the objective analysis for temperature and salinity. Considering that SL rise observed by altimeter is quite precise, estimation of thermal expansion is critical for estimation of mass increase. Difference of thermal expansions between objective analysis and the assimilation results should be detailed more for monitoring ocean climate change.

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## 60 - Guiding biogeochemical campaigns with high resolution altimetry: waiting for the SWOT mission

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**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4421>

### Abstract :

Biogeochemical processes in the ocean are strongly affected by the horizontal mesoscale (~10-100 km) and submesoscale (1-10 km) circulation. Eddies and filaments can create strong dishomogeneity, either amplifying small-scale diffusion processes (mixing) or creating tracer reservoirs. This variability has a direct effect on the biogeochemical budgets - controlling for instances tracer fluxes across climatological fronts, or part of the vertical exchanges. This variability also provides a challenge to in situ studies, because sites few tens of kms or few weeks apart may be representative of very different situations. Here I will discuss how altimetry observation can be merged with other satellite data in order to track in near-real-time transport barriers and mixing regions and guide a biogeochemical adaptative sampling strategy. In particular, I will focus on the recent KEOPS2 campaign (Kerguelen region, October-November 2012) which employed Lagrangian diagnostics of a specifically designed high resolution, regional altimetric product produced by CLS (with support from CNES). The integration of such product with Lagrangian diagnostics, drifters, CTD casts, and other satellite data allowed to sample the evolution of the bloom over several contrasted sub-regions of the Kerguelen area, providing a detailed picture of its biophysical dynamics for more than one month. Such approach opens to way to the exploitation of incoming high resolution altimetry data for biogeochemical studies.

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## 61 - SSH wavenumber spectra in the North Pacific from a high-resolution realistic simulation

**Dr Sasaki Hideharu** Earth Simulator Center/JAMSTEC

**Klein Patrice**, L.P.O/IFREMER

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4420>

### Abstract :

Following recent studies based on altimetric data (Le Traon et al. 2008; Xu and Fu, 2011), we analyze the spectral characteristics of the Sea Surface Height (SSH) using a new realistic simulation of the North Pacific Ocean with high resolution at  $1/30^\circ$ . This simulation resolves smaller scales (down to  $\sim 10$  km) than altimetric data (limited to 70 km because of the noise level). In high eddy kinetic energy (EKE) regions as in the western part of the North Pacific, SSH wavenumber spectral slope almost follows a  $k^{-4}$  (with  $k$  the wavenumber) or slightly steeper law in agreement with altimeter studies. The new result is that such a  $k^{-4}$  slope is also observed in low EKE regions as in the eastern part of the North Pacific, that mostly concerns a scale range including smaller scales than those resolved by altimetric data. Such  $k^{-4}$  SSH spectral slopes are weaker from what is expected from Quasi Geostrophic turbulence theory but closer to Surface QuasiGeostrophic (SQG) turbulence theory. Consequence is that the small scales concerned by these spectral slopes, in particular in low EKE regions, may affect the larger ones because of the inverse EKE cascade. Based on the kinetic energy equation in spectral space, the spectral energy fluxes are mostly negative within a large spectral range both in the high and low EKE regions, that confirms the inverse EKE cascade. Mesoscale turbulence is significantly affected by the scales not resolved by conventional altimetric data. These results emphasize the need to observe and monitor this small-scale dynamics on a global scale. In this aspect, future space mission such as SWOT (Fu and Ferrari 2008) will allow to better highlight their impact. Further high-resolution in-situ observations such as the high-frequency radar observation (Kim et al. 2011) can complement satellite observations, and modeling studies with a much higher resolution that take into account internal tides should be very useful.

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## 62 - Rossby wave theories: Where do we stand?

*Dr Tailleux Remi* University of Reading

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4393>

### **Abstract :**

Satellite altimetry has over the past 20 years revolutionized our understanding of Rossby waves, by revealing their ubiquitous existence in all ocean basins at nearly all latitudes at unprecedented temporal and spatial resolutions. These new observations have provided the incentive for a renewal of interest in the theoretical study of how topography, the background mean flow, nonlinearities, all affect the propagation of oceanic Rossby waves and eddies, initially motivated by the "too-fast" Rossby wave riddle. Subsequent theoretical developments provided new insights into how barotropic and baroclinic waves interact over topography, how baroclinic instability and/or linear dispersive effects limit the westward propagation of boundary-driven waves, how the topography and mean flow can both contribute to surface-intensify Rossby waves, how nonlinearities and/or a background mean flow may render the waves quasi-nondispersive at high wavenumbers. As Rossby wave theories become increasingly realistic, there is increasing interest in understanding whether it can be used to project meaningfully the surface observations onto the vertical, which is a central issue in data assimilation. Testing such ideas, however, requires using high-resolution numerical ocean models to access the information about the vertical structure. In this talk, I'll review the theoretical progress achieved, and discuss future directions of research.

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## 63 - Advances in Climate Monitoring Using a Consistent Sea Level Record from 1900 to Present

*Dr Hamlington Benjamin* University of Colorado at Boulder

**Hamlington Benjamin**, University of Colorado at Boulder ; **Leben Robert**, University of Colorado at Boulder ;  
**Kim Kwang-Yul**, Seoul National University

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4391>

### **Abstract :**

Studying past climate variations is vital to improving the understanding of current and future climate change. In order to make adequate comparisons between past and present climate variations, a long and consistent data record is necessary. Although sea level measurements provide an excellent indication of the state of the ocean, forming a sea level record that meets the requirements of sufficient duration, continuity and quality is a challenge. An inability to seamlessly and consistently marry the satellite altimetry record of the past two decades with the tide gauge record of the past century has restricted the ability to monitor the changing climate using the best measurements available at each point in time. To overcome the respective shortcomings of tide gauges and satellite altimetry, sea level has generally been reconstructed by combining the shorter but essentially complete global coverage offered by satellite altimetry with the longer but sparsely distributed tide gauge dataset. Such sea level reconstructions suffer from a decreasing number of tide gauges back through time and questions remain as to how well known climate signals are resolved. Previous reconstruction studies have focused on global mean sea level (GMSL) and the regional distribution of sea level trends with little discussion of the large-scale climate variability. Checking the degree to which known climate signals are resolved is one of the best validations of a sea level reconstruction. Here, we present results of a technique for reconstructing sea level using cyclostationary empirical orthogonal functions (CSEOFs) that creates a consistent sea level record from 1900 to present. We show how this reconstruction advances our understanding of the sea level signals associated with the large-scale ocean phenomena such as the seasonal signal, ENSO and longer time-scale signals like the Pacific Decadal Oscillation (PDO). Using our ability to capture large-scale climate signals and with the longer time series resulting from the reconstruction, we further investigate recent studies that have attributed downturns and upswings in global mean sea level to signals like ENSO and the PDO. Traditionally, a stationary annual cycle is removed from (GMSL) prior to computing trends and analyzing inter-annual variability. We show, however, that by not accounting for modulation in the strength of the seasonal signal over time, the apparent effect of ENSO on GMSL is enhanced and can lead to misinterpretations of the influence of ENSO on trends in GMSL. For large events such as the 1998 El Nino, ENSO can contribute short-term trends to GMSL approaching 4 mm/year. By separating the modulated annual cycle, ENSO and the PDO from GMSL and regional sea level, we can obtain better estimates of trends at global and regional scales over both the full time period of the reconstruction and the satellite altimeter era.

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## 64 - Toward the Next Generation of Altimeter Data Assimilation for Physical Ocean and Marine Ecosystem Monitoring and Prediction

*Dr Brasseur Pierre* CNRS

**Brasseur Pierre, CNRS ; and the project team ,**

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4346>

### **Abstract :**

In this poster we plan to present the status of a collaborative research project, gathering contributions from the ongoing FP7 SANGOMA GMES project to be expanded in the near future to new contributions in the framework of the OSTST. The overarching objective of this project is to further develop, implement and assess advanced methods for the assimilation of altimeter data, in combination with other data sources, into the next generation of ocean circulation and ecosystem models. The project will uniquely contribute to the development of operational oceanography, and will enable better understanding of the role of the ocean on climate variability through the production of improved ocean reanalyses based on altimetry and other observational components. The methods that are being explored and further developed to assimilate altimeter data are multiple, taking advantage of the most recent advances in the field of stochastic modelling, statistical estimation and optimal control. On the one hand, well established methodologies such as Kalman-type filters and smoothers and variational methods are expanded and complexified to take into account non-Gaussian error statistics or non-linear model dynamics. On the other hand, more generic methods such as particle filters will be adapted to cope with the huge dimension of realistic ocean models. Altimetry from the JASON suite, and from forthcoming missions (HY-2A, Sentinel-3, SARAL/Altika), are the primary source of data for this project, in conjunction with ENVISAT, Cryosat-2 and other historical altimetry data sets, GRACE and GOCE for gravimetry, and SMOS for salinity. A particular effort is set on the use of multiple data sources including in situ observations and to their optimal complementarity to altimetry. We will illustrate how the application of the assimilation methods enable improved ocean real-time analyses as well as multi-year reanalyses, providing a unique source of ocean information to - improve our understanding of the role of the mesoscale variability on the general circulation, - develop our capability to monitor and forecast the mesoscale/submesoscale variability, - contribute to the scientific understanding, monitoring and forecasting of seasonal to interannual climate anomalies and climate variability, - demonstrate the capability of coupled physico-biological systems with data assimilation to provide a rationale basis for the future management of living resources, especially in coastal regions and for the understanding of the ocean carbon dioxide storage and fluxes.

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## 65 - Mean field and annual variation of surface flow in the East China Sea as revealed by combining satellite altimeter and drifter data

*Dr Morimoto Akihiko* Hydrospheric Atmospheric Research Center, Nagoya University

**Takahashi Daisuke**, Hokkaido National Fisheries Research Institute, Fisheries Research Agency ; **Morimoto Akihiko**, Hydrospheric Atmospheric Research Center, Nagoya University

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4337>

### **Abstract :**

A surface flow field in the East China Sea (ECS) has been studied by many oceanographers using various approaches such as hydrographic observation, geomagnetic electrokinetographs data, current meter, satellite tracked drifters, ocean Radar, and numerical models. Accumulation of findings from those studies has gradually made us understand mean field and seasonal variation in surface flow in the ECS. Although main features of the mean field and seasonal variation in surface flow in the ECS have been roughly clarified, there is still a matter of discussion about its persistency and seasonal variation. Therefore, we made monthly mean absolute sea surface current data in the ECS from 1995 to 2009 combining satellite altimetry data with buoy trajectory data to see surface flow variation. Using the data set, we investigated seasonal variation in sea surface current in the ECS. Especially, we focused on the variation with an annual cycle because the signal is a dominant component in seasonal variation. Contribution of the annual cycle to seasonal variation was estimated as 50 % over the ECS, and the percentage was greater than 70 % in the Kuroshio, Taiwan Warm Current, and northeastward Kuroshio branch west of Kyushu, Japan. The annual variation was characterized by propagation of vorticity anomalies from northeast of the Taiwan Strait and in the Tsushima Strait. The vorticity anomaly from northeast of Taiwan Strait propagates downstream in the northeastward Kuroshio branch along isobaths of about 100 m on the shelf edge. On the contrary, the vorticity anomaly in the Tsushima Strait propagates upstream in the Tsushima Warm Current along isobaths of 100-200 m. The propagations of the vorticity anomaly could be well explained by a dispersion relation of a quasigeostrophic topographic Rossby wave in a mean flow for a first approximation. Generation of the vorticity anomalies from northeast of the Taiwan Strait and in the Tsushima Strait appears to be closely related to annual variation in current speed of the Kuroshio northeast of Taiwan and in volume transports through the Tsushima Strait, respectively.

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## **66 - Causes for the Indian Ocean Decadal Variability of Sea Level, Thermocline, and Vertical Warming Structure during Recent Decades**

**Dr Han Weiqing** *Dept. of atmospheric and oceanic sciences, University of Colorado*

**Trenary Laurie**, Dept of atmospheric and Oceanic sciences, U. of Colorado ; **Han Weiqing**, Dept of atmospheric and Oceanic sciences

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4324>

### **Abstract :**

Analysis is performed on a set of diagnostic OGCM experiments designed to isolate local versus remote oceanic influence from the Pacific on decadal variability of subsurface temperature, sea level and thermocline depth of the south Indian Ocean since the 1970s. It is found that the vertical structure of decadal temperature variability varies from decade-to-decade, with maximum variability peaking in the vicinity of the thermocline. The decadal scale temperature variations in the tropical southwestern Indian Ocean between 5oS-17oS are primarily associated with the vertical displacements of the thermocline. Prior to the early 1990s, decadal variations in sea level and thermocline depth can be described in terms of a baroclinic Sverdrup balance, forced by Ekman pumping velocity associated with windstress curl acting on the Indian Ocean. Beginning in the early 90's, decadal variability of the equatorial Pacific trades forces thermocline variations that modify the sea level and thermocline depth across the entire tropical southern Indian Ocean basin. Farther south, between 20oS-30oS, decadal variability of thermocline appears to be contributed significantly from oceanic instabilities. The anomalies along the western coast of Australia are primarily driven by regional forcing acting on the Indian Ocean prior to 1990s, and signals originating from the Pacific make a greater contribution thereafter.

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## 67 - Using radar altimetry, combined with bottom pressure data, to measure underwater vertical movements

*Dr BALLU Valerie IPGP / CNRS*

**Ballu Valérie**, IPGP / CNRS ; **Bonnefond Pascal**, OCA / GeoAzur ; **Calmant Stéphane**, LEGOS /IRD ; **Bouin Marie-Noelle**, MétéoFrance ; **Pelletier Bernard**, IRD ; **Crawford Wayne**, IPGP / CNRS ; **Christian**, IPGP, FR ; **Olivier OCA-GeoAzur**, FR ; **de Viron Olivier**, IPGP

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4292>

### **Abstract :**

Subduction zones, when locked, have the potential of generating the most devastating events (earthquakes and tsunamis) on Earth. As subduction plate boundaries always lie underwater, measuring the deformation offshore is crucial for understanding the stress accumulation at these zones and thus for mitigating potential seismic risk. However, GNSS methods are not suitable as electro-magnetic waves do not penetrate underwater and alternative methods need to be used. Here, we combine altimetry and tide gauge data to obtain vertical deformation at two offshore sites in the New Hebrides subduction zone. The two sites, Sabine and Wusi Banks, are located on both sides of the tectonic plate boundary, respectively on the subducting Australian plate and the over-riding Vanuatu Arc. The 1999-2010 water depth series derived from seafloor pressure are combined with altimetry data to determine movements in a global reference frame. Sabine Bank pressure data combined with EnviSat data show that the deformation rate on the subducting plate is close to zero ( $-0.1 \pm 1.2$  mm/yr) and Wusi Bank pressure data combined with Jason-1 and EnviSat data show that the over-riding plate is subsiding at this site at a rate of several mm/yr. This subsidence (downward motion) indicates that the subduction is locked and that stress is accumulating in the area. This study demonstrates for the first time that combined altimetry and pressure data can be used to derive absolute vertical motion offshore and thus bring new insights on processes occurring at subduction zones. It also illustrates the usefulness of continuous long-term high accuracy radar altimetry records, even at local scale.

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## 68 - Investigation of the interannual variability of the tropical Atlantic Ocean from satellite data

**Dr Arnault Sabine** LOCEAN UMR CNRS/IRD/UPMC/MNHN

**Melice Jean Luc**, LOCEAN UMR CNRS/IRD/UPMC/MNHN

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4172>

### Abstract :

The interannual variability of the tropical Atlantic Ocean is analyzed from series of altimetric dynamic topography data, sea surface temperatures, and wind stress between October 1992 and January 20. Empirical Orthogonal Functions and Singular Value Decompositions are used to realize this study. Three regions of maximum variability are highlighted: a northern, a southern and an equatorial ones. In the northern region, between 10 and 20°N, altimetry, sea surface temperature and wind stress are strongly connected through thermosteric and Ekman pumping effects in particular in 2010. The same relationship can be found in 1998 and in 2005, but with a smaller intensity. During these periods, altimetric topography and temperatures increase in response to a weakening of the wind. Conversely, for a long period lasting from 2007 until early 2009, a tradewind intensification is associated to a cooling and a decrease in altimetric topography. In the southern region, altimetric topography decreases in particular in 1997 and in 2010 in agreement with surface temperature cooling and southern trade intensification, and increases in 1998, 2003 and 2009 with inverse relationship. However, the altimetric signal in 2005 associated with southerly increase has no counterpart in temperature so that deeper thermal and/or salinity contributions must be suspected. In the equatorial region, the variability appears either as an East-West slope of the topography and temperature all along the equator (2005 and 2010) or as a (cold) tongue in the Gulf of Guinea (1997 and 2002). Both local wind (meridional component) and western remote (zonal component) effects can be involved in this oceanic triggering. First results of the teleconnections between this tropical Atlantic interannual variability and the tropical Pacific El Niño-Southern Oscillation indicate a possible connection of the tropical Atlantic between 10-20°N with a 4 months delay, and in the Gulf of Guinea with a 16 month one.

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## 69 - Unexpected Contributions of Satellite Radar Altimetry to Tsunami Research

*Dr Song YTony Jet Propulsion Laboratory*

**Song YTony**, Jet Propulsion Lab ; **Fukumori Ichiro**, Jet Propulsion Lab ; **Shum CK**, Ohio State University ; **Yi Yuchan**, Ohio State University

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.avisio.oceanobs.com/index.php?id=1719&uid=3906>

### Abstract :

Satellite altimeters were not initially designed for observing tsunamis because tsunamis were not believed to happen often enough, and it is not always feasible to observe a fast propagating wave from space. Surprisingly, satellite altimeters had observed all the recent mega tsunamis, revealed previously unknown features and revised longhypothesized theories. For the first time, satellite altimeters unambiguously observed tsunami waves in the open ocean after the 2004 Indonesian earthquake. The observations were close to the epicenter, leading to new development of the tsunami genesis theory [Song et al, 2005; 2008; Song and Han 2011]. In 2010, satellite altimeters observed the Chilean tsunami in the Southern ocean, providing successful testing of using ground GPS networks for early detection and warnings [Song 2007]. Most recently, three satellites observed the 2011 Tohoku-Oki earthquake-induced tsunami, and for the first time, one of them, at the right time and location, recorded a tsunami height about twice as high as that of the other two, confirming the long-hypothesized tsunami merging theory that can double its destructive potential in certain directions [Song et al 2012]. These altimetry observations have advanced the understanding of tsunami dynamics as well as provided tests of a new approach to tsunami early detection and warnings. This talk will review these unexpected, but significant and unique contributions from satellite altimetry to tsunami research, their potentials for hazard mitigation, and an outlook for the use of the future swath interferometric altimetry, i.e., NASA's/CNES's Surface Water and Ocean Topography, for improved tsunami observations and research.

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## 70 - Generalized Lagrangian Coherent Structures in altimetry data

*Dr Beron-Vera Francisco* RSMAS, University of Miami

**Beron-Vera Francisco**, RSMAS, University of Miami ; **Haller George**, McGill University

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=3658>

### **Abstract :**

We have recently introduced a unified approach to locating key material curves (transport barriers) that shape global mixing patterns in two-dimensional unsteady flows. The theory generalizes Lagrangian Coherent Structures (or LCSs) from hyperbolic material curves (centerpieces of stretching and folding) to elliptic (eddy boundaries) and parabolic (jet-like transport barriers) material curves. The transport barriers follow as solutions of an ordinary differential equation, and hence are available in a smooth, parametrized form. This is in marked contrast with earlier approaches to transport barriers, which visually observed them as ridges of scalar quantities such as the FTLE or FSLE. In this poster the main elements of the newly derived theory are described, and results from applying the theory to altimetry data are discussed.

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## 71 - Extreme events and statistical structure of sea-level variability: AVISO vs multi-resolution DRAKKAR simulations

*Dr Penduff Thierry* CNRS - LEGI

**Penduff Thierry**, CNRS - LEGI ; **Juza Mélanie**, CNRS-LEGI ; **Sura Philip**, EOAS, Florida State University

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=3648>

### **Abstract :**

The DRAKKAR Consortium has performed an ensemble of global, multi-decadal ocean/sea-ice simulations that mostly differ by their horizontal resolution ( $2^\circ$ ,  $1^\circ$ ,  $1/2^\circ$ ,  $1/4^\circ$ ,  $1/12^\circ$ ). These simulations are first collocated at the spatial and temporal resolution of the AVISO altimeter SLA dataset, then quantitatively compared to AVISO and among themselves with respect to the first four statistical moments of SLA (mean, variance, skewness and kurtosis), in three frequency ranges. We precisely quantify in this study how increased model resolution progressively improves the magnitude and geographical patterns of simulated mean flows, mesoscale activities and large-scale interannual variabilities. Based on a statistical mechanics theory, we extend this observation/multi-model global comparison to the distribution and statistical structure of extreme events (skewness and kurtosis of SLA distributions), and to the dynamical relationships between the latter 2 statistical moments. Beyond this multi-moment assessment of our simulations, our results raise open questions about the ocean dynamics, and the contribution of multiplicative noise in numerical simulations.

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## 72 - TIDE CONSTITUENTS EXTRACTION BY HARMONIC ANALYSIS USING ALTIMETRIC SATELLITE DATA IN THE BRAZILIAN NORTHERN COAST

*Mr Daher Victor* Federal University of Rio de Janeiro

**Daher Victor**, Federal University of Rio de Janeiro ; **Paes Rosa**, Federal University of Rio de Janeiro ; **Alvarenga João**, Brazilian Navy ; **França Gutemberg**, Federal University of Rio de Janeiro ; **Poças Jansen**, Brazilian Navy

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4469>

### **Abstract :**

This work has analyzed Sea Surface Height (SSH) dataset from Topex/Poseidon, Jason 1 and Jason 2 satellites for 19-year time series in order to extract the tide harmonic constituents (amplitudes and phases) for the oceanic region nearest Penrod Oil Platform (3°N, 49°17.1'S), located near North mouth of Amazonas river. The harmonic analysis are generally based on Fourier analysis of discrete series, which should attend Nyquist theorem conditions, which state that the sampling frequency should be at least twice higher than the harmonic frequency which the extracting is desired. Presently, the altimetric data available have a frequency of 9.9156 days (or 0.10085/day), which certainly does not fulfill Fourier theory conditions to extract the main tide constituents. On the other hand, Rayleigh Criterion states that two harmonic constituents with close frequencies can be separated depending on the sampling interval and the time series length. Rayleigh's assumptions are attended in this work since a 19-year time series is used and the main diurnal and semidiurnal tide constituents can be properly separated. The problem to obtain the harmonic of a wave given is basically to solve a linear equation system, such as:  $Ax = b$ , in which in this work  $A$  is the coefficient matrix,  $x$  is the variable vector to be calculated and  $b$  is the vector of SSH obtained from satellite data. In here, the above system is solved for the eight tide constituents using the Singular Values Decomposition (SVD) technique to invert the coefficients matrix. The SSH data used are named by AVISO as along-track corrected sea surface heights wrt reference ellipsoid (CorSSH) to which the oceanic tide signal was also added. These data were intercalibrated at each point since different satellites data may not be homogeneous. The preliminary method results were compared with a Penrod Oil Platform tide gauge data of the Brazilian Navy for a 30-day time series. The harmonic constituents of the gauge data are extracted using Fourier method. The in situ (tide gauge) and satellite measurements are 5.1446 km apart. The results have shown that the maximum difference between the amplitudes is 6.06 cm for N2 which represents 24% of this constituent amplitude obtained by the tide gauge. The minimum difference is 0.11 cm for K2 which represents 1.4% of amplitude from the tide gauge. Regarding to the phases, the maximum difference is 12.3892° for N2 which represents 7.94% of this constituent phase obtained by the tide gauge. The minimum difference is 3.3623° for M2 constituent which represents 2.1% of the phase from the tide gauge. The present results suggest that the method could be considered quite efficient to extract tide constituents from altimetric satellite data.

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## **73 - Mixing and water mass characteristics off western Greenland from satellite altimetry, hydrodynamic model data and in-situ observations**

**Mr Blüthgen Jonas** *Center for Ocean and Ice, Danish Meteorological Institute*

**Hoeyer Jacob**, Center for Ocean and Ice, Danish Meteorological Institute ; **Ribergaard Mads Hvid**, Center for Ocean and Ice, Danish Meteorological Institute

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4415>

### **Abstract :**

The Labrador Sea Water (LSW) is an intermediate water mass that can be tracked throughout the North Atlantic. Changes in its formation and spreading have a large effect on the rest of the North Atlantic. A region with high eddy kinetic energy (EKE) southwest of Greenland is known to play a role in LSW formation and spreading. The region is of particular importance, as it is associated with a local recirculation and mixing. Variations in the mixing and circulation can have a large impact on the transport of fish larvae and hence on fisheries resources. Our study compares the representation and variation of EKE between 20 years of (1) 3D hydrodynamic model hindcast data, (2) in-situ measurements from DMI's repeated CTD sections, and (3) satellite altimetry observations. We present spatial and temporal correlations between model data and satellite observations on timescales ranging from monthly to decadal. The modeled and observed variability is linked to the observed changes in the water mass characteristics, as seen in the annual CTD transects.

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## 74 - Current status of the Japanese Altimetry Mission

**Mr NAKAYAMA HIROSHI** *Japan Aerospace Exploration Agency*

**MATSUI KAI**, Japan Aerospace Exploration Agency ; **the JAXA COMPIRA Team** **Japan Aerospace Exploration Agency JAPAN** ,

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4375>

### **Abstract :**

The U.N. Commission on the Limits of the Continental Shelf has recognized another 310,000 square kilometers as part of Japan's continental shelf in April 2012. It is equivalent to over 80 percent of the country's total land area. The information management of a wide ocean area is an issue in that ocean resources management and safe management. Due to restrictions on ship and aircraft observations, the observation of high density and high frequency using satellite has become increasingly important for Japan. Above all, sea surface height is as important as ocean color and surface temperature, because it is a key information on bathymetric feature, sea water temperature and ocean currents. The Japan Aerospace Exploration Agency (JAXA) has started a new altimetry mission, Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter (COMPIRA), since 2009. The mission was inspected by Mission Definition Review(MDR) as the primary review in June 2012. The dominant purpose of MDR is to confirm the significance and the feasibility of missions. The significance of the mission was confirmed through the relation between requirements from relevant ministries and mission specifications. The requirements consist of the following three fields. Ocean currents forecast; the aim is the planar measurement with wide swath altimeter. This will improve the tidal model and the ocean currents forecast especially in coastal regions and marginal seas. Improving ocean currents forecast is expected to help forecasts of the diffusion for radioactive materials, the current drift by ocean accidents and the ocean current for efficiency of marine navigation. Fishery; the aim is to observe the ocean surface topography. This will make it efficient to estimate fishing places related to sea surface height and ocean salinity/temperature under the sea. Science; the aim is to improve TSUNAMI forecast model using inversion method with the observation of TSUNAMI waves by a magnitude 8-9 class earthquakes centered in oceanic regions. The feasibility of this mission was confirmed in terms of satellite system, risk management and cost. For further consideration, we have a plan to conduct an aircraft experiment to measure sea surface height for our main sensor, SAR Height Imaging Oceanic Sensor with Advanced Interferometry (SHIOSAI). The experiment will be implemented on the sea around Japan later this year. This paper will present the latest specifications of COMPIRA and a future schedule.

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## 75 - Feasibility Study of the Satellite System for the Japanese Future Altimetry Mission

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**Nigo Kenichiro**, Japan Aerospace Exploration Agency ; **Kobayashi Takashi**, Japan Aerospace Exploration Agency ; **Miyashita Naoki**, Japan Aerospace Exploration Agency

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4423>

### **Abstract :**

The Japan Aerospace Exploration Agency (JAXA) is conducting a conceptual study of an altimetry mission for marine environment monitoring, fishery, etc. JAXA's internal conceptual study team names the mission COMPIRA (Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter) and its main sensor SHIOSAI (SAR Height Imaging Oceanic Sensor with Advanced Interferometry). The sensor is a Cross-Track Interferometric Synthetic Aperture Radar (CT-InSAR) which enables much wider observable area than an existing nadir-looking radar altimeter. This paper aims at reporting the present state of our feasibility study of the COMPIRA satellite system, especially concerning four issues as the very first phase results. First is orbit selection, considering compensation for the effects of oceanic tidal constituents which requires non-sun-synchronous orbit and temporal/spatial coverage of observation. Second, amount of possible electrical power generation is estimated. CT-InSAR requires much electrical power in spite of the unfavorable and unstable sunlight condition in non-sun-synchronous orbit. Third is data transmission analysis. Data amount obtained from SHIOSAI will be enormous due to the measurement principle of CT-InSAR and its much wider observable area. The sea area to be targeted is discussed with the priority of each sea area. Fourth, our current major issue: on-orbit deformation of SAR baseline structure induced by thermal strain. Although requirement of micron-order mechanical alignment is indispensable for highly precise altimetric measurement by CT-InSARs, it will be quite difficult to hold thermal strain in range of requirements due to its long baseline. Roll-angle deformation analysis is also needed because thermal distribution may cause out-of-plane bending. In addition, thermal design of non-sun-synchronous satellite is typically more complex than sun-synchronous satellite. Then, we roughly analyzed temperature distribution in some special case of orbit, and estimated thermal strain distribution. Moreover, the way to reduce and/or measure those thermal strain are pointed out as a problem to be studied.

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## 76 - Preliminary studies on empirical roll angle error reduction and tidal detection for COMPIRA

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**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4422>

### **Abstract :**

Japan Aerospace Exploration Agency (JAXA) is working on a conceptual study of altimeter mission named Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter (COMPIRA), which will carry a wide-swath altimeter named Synthetic aperture radar (SAR) Height Imaging Oceanic Sensor with Advanced Interferometry (SHIOSAI). As preliminary studies on sea level anomaly (SLA) measurements by COMPIRA, we conducted simulations about 1) the reduction of roll angle errors which is peculiar to the SAR-typed altimeter and 2) the effect of the wide-swath SSH observation on tide detection in the marginal and coastal seas where the tide model derived by traditional nadir-type altimeters is not, under existing conditions, accurate enough to derive SLAs. Empirical correction methods of roll angle errors have been developed as studies toward SWOT by some researchers (i.e., Dibarboure et al., 2011). We performed, by following them, the crossover method to examine the effect of the proposed COMPIRA orbit configuration on the roll angle error reduction. The current orbit configuration of COMPIRA is as follows: the revisit time is 9.8671 days and the inclination is about 51°, which makes acquisition time differences of crossover points relatively short. Simulated sea surface heights (SSH) were obtained from Japan Coastal Ocean Predictability Experiment (JCOPE) 2 produced by JAMSTEC. Error factors such as roll angles, orbit, baseline length, sensor thermal noise, and wet tropospheric delays were added to the SSHs. Their dependence on cross-track distance was defined as linear, constant, quadratic, random, and 50km cycle, respectively. The amplitude and cycle of the roll angles were given as 1arcsec and 800km, respectively, giving rise to a 27cm SSH error at the 80km cross-track distance. Roll angles were locally estimated at each crossover by a least square method from the SSH differences and the cross-track distances. The result showed that the error of the estimated roll angles was 0.07arcsec corresponding to 2.9cm error at 80km. It was thus demonstrated that the proposed roll angle error reduction method could reduce the SST error caused by low frequency roll angle to several centimeters which is equivalent to those caused by the principal error factor. Next, we examined the effect of wide-swath SSH observations on tide detection. We simulated 3-year ocean tide measurements using the proposed COMPIRA orbit configuration. The tide model we applied is NAO.99b tidal prediction system (Matsumoto et al., 2000). Amplitude and phase of the major 8 tidal constituents were calculated by a harmonic analysis from the simulated tide time series at each grid. The derived amplitudes and phases were then interpolated onto 0.25deg. grid for two cases: one used SHIOSAI plus nadir altimeters and the other nadir altimeter only. The interpolated tidal parameters were evaluated by comparing the model tidal parameters. The result showed significant improvement in SHIOSAI plus nadir altimeter case especially in the marginal and coastal seas. In the East China Sea, whereas the total error of the major 8 tidal constituents was 2.6cm for the SHIOSAI plus nadir altimeter case, it was 9.9cm for the only nadir altimeter case.

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## 77 - On the nature of buoyancy-driven interannual tropical sea level changes

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**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4367>

### **Abstract :**

It is commonly held that spatial patterns of interannual tropical sea level variability mainly represent the ocean's direct response to momentum input from winds. This paradigm is based partly on modeling studies of wind-driven sea level changes along the tropical Pacific. However, since the effects of buoyancy forcing on sea level are usually ignored, such a view may overemphasize the importance of the winds. To consider the influence of surface buoyancy exchanges on interannual sea level patterns, we make use of a dynamically consistent, data-constrained ocean general circulation model solution, produced by the ECCO ('Estimating the Circulation and Climate of the Ocean') group. Through a set of numerical experiments, we separate the influences of momentum input by winds and buoyancy input by air-sea fluxes of heat and freshwater. In all tropical oceans, buoyancy-driven sea level anomalies are evident, exhibiting a nonlocal character that is made manifest in westward propagating features, which tend to occur alongside propagating sea level anomalies of opposite sign driven by the winds. Such behavior suggests that the forcing mechanisms could be collocated and potentially coupled locally. In-depth consideration of closed steric height budgets reveals that the buoyancy-driven sea level changes represent the combined action of both local atmospheric forcing as well as dynamic ocean transports' mainly density advection by ocean currents. Thus, our results demonstrate that accurate modeling of interannual changes in regional sea level requires explicit consideration of the dynamical effects of surface buoyancy exchanges.

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## 78 - The Role of Heating, Winds and Topography on Interannual SeaLevel Changes in the North Atlantic Ocean

**Ms Zhang Jinting** *University of Washington*

**Zhang Jinting**, Applied Physics Laboratory, University of Washington, Seattle, WA ; **Kelly Kathryn**, Applied Physics Laboratory, University of Washington, Seattle, WA ; **Thompson LuAnne**, School of Oceanography, University of Washington, Seattle, WA

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4285>

### **Abstract :**

Large-scale sea level in the North Atlantic region is studied using sea surface height (SSH) from the TOPEX/Poseidon/Jason altimeters, wind stress curl from the European Center for Medium-Range Weather Forecasting (ECMWF) and Smith and Sandwell gridded bathymetry. We model SSH changes owing to heating, wind forcing and topography. On interannual time scales surface heating is an important contributor to SSH anomalies, modifying the low-frequency changes of SSH. The baroclinic Sverdrup model with motionless abyss can capture large-scale spatial patterns of nonsteric SSH observations with the correct magnitude but with a spatial pattern that is shifted to the north relative to the observations. It significantly correlates with SSH observations in the subtropical region. Different versions of the topographic Sverdrup balance are modeled and compared with the nonsteric SSH. In the eastern subpolar and subtropical regions the topographic Sverdrup balance works well.

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## 79 - A 34-Year Historical and Altimetric Perspective of Loop Current Intrusion and Eddy Separation in the Gulf of Mexico

**Pr Leben Robert** CCAR/University of Colorado Boulder

**Hall Cody**, CCAR/University of Colorado Boulder ; **LoDolce Gabriel**, CCAR/University of Colorado Boulder

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4390>

### Abstract :

Continuous altimetric monitoring of Loop Current intrusion and eddy separation in the Gulf of Mexico has been possible since ERS-1 was placed in the multidisciplinary 35-day repeat orbit in April 1992. In the 20-year time period since then a total of 30 major anticyclonic eddies have separated from the Loop Current, which gives an average separation period of 8 months over the continuous altimetric record. A recent reanalysis of the available satellite and industry observations back to July 1978 found 19 additional eddies giving a total of 49 separation events over the 34-year record or an average separation period of 8.4 months. The average separation period is thus relatively stable over the more than three decades of observation; nevertheless, the time interval between separation events is quite irregular, exhibiting a range from 2 weeks to over 18 months. Over a dozen dynamical mechanisms have been proposed to explain eddy separation; however, no Loop Current eddy separation precursor had been identified until Loop Current retreat following eddy separation was shown to be a good predictor of the subsequent eddy separation period. A simple Loop Current vorticity model provides a theoretical basis for this empirical relationship. After suitable scaling approximations, the theory predicts that the Loop Current separation period is a linear function of retreat latitude, which agrees well with altimeter-derived empirical results. The regression results show that this relationship is statistically stable over the 34-year record, as would be expected of a physically controlled phenomenon. Other Loop Current statistics show similar stationarity. A histogram of separation times binned by month shows a clear seasonal signal in the monthly distribution with separation occurring more often in late winter/early spring and late summer/early fall, with 'fall' separation events being 50% more likely than 'spring'. The stationarity of the Loop Current separation period and retreat latitude statistics, including the seasonality of the separation times, over the 34-year record is remarkable and is the most significant result found in this analysis of the historical and altimetric records. In honor of the 34-year anniversary of the launch of Seasat and the progress in radar altimetry, we will highlight satellite observations of the initial separation event in our record using Seasat synthetic aperture radar imagery and radar altimetry from July 1978.

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## 80 - The Coherence and Impact of Meridional Heat Transport Anomalies in the Atlantic Ocean Inferred from Observations

*Pr Kelly Kathryn University of Washington*

**Kelly Kathryn**, Kelly ; **Thompson LuAnne**, University of Washington ; **Lyman John**, NOAA/PMEL

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4286>

### **Abstract :**

Changes in the meridional transport of heat and in oceanic heat storage are important for understanding climate variability and prediction. Observations of thermosteric sea level (TSL) from hydrographic data (including Argo), equivalent water thickness (EWT) from GRACE gravity data, as well as altimetric sea surface height (SSH) anomalies, are used to construct budgets of heat and mass for the Atlantic Ocean from 31S to 67N and to infer changes in the meridional transport of heat. Time-varying thermosteric and mass contributions to sea level are predicted using surface heat and freshwater flux anomalies in each of seven regions; discrepancies between the modeled and observed sea level components, as well as the total SSH anomaly are used to infer lateral heat and mass convergences. Given reasonable estimates of the model and observation errors, the 'unknown control' version of a Kalman filter creates both smooth time series of sea level anomalies and a smooth residual that represents heat and mass convergences. Regional convergences are summed to estimate meridional heat transports for 1993-2010 within estimated errors. The analysis reveals that meridional heat transport (MHT) is coherent between 31S and the separated Gulf Stream and that increases in MHT are accompanied by increases of heat loss through surface fluxes in the subtropical gyre. The inferred MHT reproduces both in timing and in magnitude the 2009 drop and subsequent reversal in 2010 seen in the RAPID/MOCHA observations at 26N. The analysis also reveals previous anomalies, with values as large as 0.5PW in the South Atlantic in 1999. An intensification of MHT anomalies toward the south and a correlation of MHT with the Antarctic Oscillation suggest a southern source for the coherent MHT anomalies.

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## 81 - SEASONAL COUPLING IN THE GULF STREAM REGION BETWEEN THE ATMOSPHERE AND THE OCEAN

*Pr Thompson LuAnne* University of Washington

**Thompson LuAnne**, University of Washington ; **Kelly Kathryn**, University of Washington ; **Booth James**, Columbia University ; **Menemenlis Dimitris**, Jet Propulsion Laboratory

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4282>

### **Abstract :**

Seasonal coupling in the Gulf Stream region between the atmosphere and ocean is investigated using models and observations. Heat budget analysis in a regional diagnostic model constrained by SSH (sea surface height) observations shows that on interannual time scales, the heat content in the upper ocean leads the flux of heat from the ocean to the atmosphere by approximately three months, with a warmer ocean leading to oceanic heat loss. These results are consistent with that found in an eddying, data-constrained simulation provided by the ECCO2 (Estimating the Circulation and Climate of the Oceans, Phase II) project. To investigate the seasonal dependence of the coupling, we calculated the lag correlation for multi-year time-series of upper ocean heat content and surface heat flux for each month of the year for the model, and between sea surface height (SSH) from AVISO as a proxy for upper ocean heat content and surface turbulent heat flux from the OAFLUX project. For the period between 1993 and 2011 in a region encompassing the separated Gulf Stream between 33N and 43N and 75W and 57W, significant correlations were found with the ocean leading the atmosphere by a season during two different times of the year. Summer ocean heat content leads late fall surface flux south of the Gulf Stream where the maximum winter mixed-layer depth is deepest. During late fall the flux of heat is out of the ocean as the mixed layer nears its maximum depth; the atmosphere then has access to the heat stored in the deep layer. Later in the winter, the deep heat content loses its memory of the previous year as it is more directly affected by the atmosphere. North of the Gulf Stream spring ocean heat content leads surface flux in early summer. Here, the turbulent heat flux is into the ocean in the early summer and the mixed-layer is shallow with warm atmosphere overlying the cold ocean. During this time of the year the atmospheric boundary layer is shallow and stable and the surface winds are relatively quiet compared to other times of the year. Because of the lack of influence of tropospheric processes in the boundary layer, the atmosphere at the surface is influenced by ocean. These results suggest that during the summer, the influence of the ocean will likely not be felt outside of the boundary layer, while in the late fall, because the boundary layer is unstable and communicates freely with the troposphere, the ocean may have an impact on the atmosphere beyond the Gulf Stream region. Lagged auto-correlations show that heat content anomalies persist for several months, while surface flux anomalies do not. The results show that ocean heat content may have predictive skill for the atmospheric state in late fall and early summer.

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## **82 - Submesoscale turbulence generated by Charney baroclinic instability: Implications for inferring subsurface structure from surface observations**

*Pr Smith Shafer Courant Institute/New York University*

**Keating Shane**, Courant Institute/New York University ; **Vanneste Jacques**, University of Edinburgh

**Session:** Others (Posters only)

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4536>

### **Abstract :**

A number of recent studies have demonstrated that surface observations of the ocean's eddy field reflect the combined influence of surface buoyancy anomalies and interior potential vorticity anomalies. The former have an exponentially-decaying vertical structure with a scale depth that depends on horizontal scale, while the latter are associated with more grave, deep structures that are less dependent on horizontal scale. Numerical simulations show that such flows may be generated by the interaction of mean gradients of surface buoyancy and interior potential vorticity, analogous to the Charney model of baroclinic instability; analysis of hydrography indicates that the ocean is broadly susceptible to this type of instability. The resulting submesoscale flow field is more rich and three-dimensional than expected from the classic geostrophic turbulence viewpoint, implying serious challenges to reconstruction of the flow from satellite altimetry. The flow at depth can be reconstructed from surface observations if one knows how motions at different scales project onto vertical modes. To do so, one first needs an orthogonal basis that separates the influence of the surface and interior components; standard baroclinic modes fail in this regard, because they cannot accurately represent the horizontal-wavenumber-dependent surface-trapped structure associated with surface buoyancy anomalies. It will be shown that an alternative basis, arising from the simultaneous diagonalization of the energy and a surface-aware generalization of potential enstrophy, accomplishes this task efficiently. Such a basis can be used in conjunction with a stochastic filtering model, the parameters of which can be estimated by adaptively learning these parameters 'on-the-fly' from the observations themselves. We show that, by extracting high-wavenumber information that has been aliased into the low wavenumber band, one can derive 'stochastically superresolved' velocity fields with a nominal resolution increase of a factor of two or more. Observations of the surface field can then be projected onto a truncated set of the new modes, providing a real-time prediction for the three-dimensional flow.

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## 83 - LearnEO!: an ESA Learn Earth Observation Project

*Dr Byfield Valborg* NOC

**Banks Chris**, NOC ; **Del Frate Fabio**, GEO-K ; **Mathieu Pierre-Philippe**, ESA/ESRIN ; **Rosmorduc Vinca**, CLS

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4327>

### **Abstract :**

The development of remote sensing technology over the past 20 years has significantly increased our capacity to monitor the environment, understand environmental variability and change, support modelling and forecasting activities, manage natural resources, and providing support for humanitarian aid and the management of natural and man-made emergencies. Societal benefits of Earth Observation (EO) are increasingly familiar to a broad community of scientists and engineers; planners; natural resource managers, policy makers and industry leaders; local, national and international agencies; non-governmental organizations, educators and students. For many remote sensing is no longer a specialist technology, but simply a powerful observational tool. The interpretation of satellite images is a skill of inter-national, strategic and economic importance, which should be developed widely and distributed globally. The need for EO data distribution and training in the application of these data go hand in hand. This was a major consideration behind the start of the UNESCO-Bilko project in 1987. LearnEO! is an ESA-funded project which aims to 'stimulate the understanding and application of ESA EO data sets by implementing and maintaining an educational framework for teachers and students in the 18-25+ age group (upper high school to university level)'. In that frame, we will:- develop a more extensive set of EO training resources, covering a wider variety of application areas that span the breadth of ESA themes and missions, and- stimulate and support the development of an EO educational user community that includes experts from a variety of disciplines who collaborate to develop EO lessons and analysis/learning tools, and will continue to do so beyond the life-span of LearnEO! LearnEO! is intended to be comprehensive rather than specialist, and provide resources for Earth System science education targeted at an age range where students are starting to specialise, but have not yet become specialist. The Bilko software, specifically designed for education, is recommended as a key tool to support the activities of the LearnEO! project. It is well suited for this because of its generalist nature; it can access data from different sensors and apply basic processing and analysis routines that are common to many of these. It is easy to use, so is particularly suitable for the target audience - upper high school students and university students at BSc to MSc level. It is also increasingly seen as a useful tool by PhD students and professional users who are not specialists in remote sensing, but who need to use remote sensing products in their work. Bilko thus bridges a gap between the LeoWorks software provided by Eduspace for use in schools and ESA's specialist toolboxes, aimed mainly at users of data from specific missions.

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## **84 - A new interface to download altimetry data in Toulouse**

***Ms Rosmorduc Vinca*** CLS

**Rosmorduc Vinca**, CLS ; **Bronner Emilie**, CNES ; **Gasperi Jerome**, CNES ; **Nino Fernando**, LEGOS / CTOH

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4548>

### **Abstract :**

CNES, in cooperation with LEGOS and CLS, in the frame of AVISO, is working on a new interface to download altimetry data in an interactive frame.

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## 85 - Reaching Operational Users ? A JPL/CCAR collaboration

**Ms SRINIVASAN Margaret** *Caltech Jet Propulsion Laboratory*

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**Session:** Outreach, Education & Altimetric data services

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4491>

### **Abstract :**

Since 1996 NASA's Jet Propulsion Laboratory and the University of Colorado's Colorado Center for Astrodynamics Research (CCAR) have collaborated on an effort to support both science and operational users via an automated web-based user data interface located at CCAR. This web-based data system, partially funded by NASA/JPL, provides data processing, near real-time (NRT) data, and FTP archived data to operational and research users. The data users include a community that do not generally have the technical expertise or resources to process this valuable data stream and would be otherwise unserved in this capacity. In addition, they provide NRT blended OSTM/Jason-2 and Jason-1 sea surface height (SSH) anomaly maps to the NASA/JPL PO.DAAC for hosting on the PO.DAAC State of the Ocean (SOTO) web page. The collaboration provides an outlet for altimetry data products and exposure of the missions through the CCAR web pages. It also provides the mission team with an opportunity to highlight and applications and user highlights for web features and reporting on applications and data users.

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## 86 - Sea Level Experiments for Climate Science Education of High School Students

**Ms Fitzpatrick Kyra** *University of Colorado at Boulder*

**Fitzpatrick Kyra**, University of Colorado at Boulder ; **Hamlington Benjamin**, University of Colorado at Boulder ; **Leben Robert**, University of Colorado at Boulder

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4397>

### **Abstract :**

The Colorado Association of Black Professional Engineers and Scientists (CABPES) is a non-profit organization dedicated to encouraging African-American and underrepresented youth to pursue careers in the engineering and applied science professions. While CABPES offers several after-school courses focusing on engineering and math, there is considerable interest in educating and informing students about the growing field of climate science. To meet this interest and to fill a gap in their curriculum, we provide resources and materials to the students and instructors at CABPES that will increase their interest in research and scientific activities related to the study of climate. We provide 8-week courses on climate and sea level change twice yearly to CABPES students. As part of these courses, we have worked on developing hands-on experiments that help students understand both how sea level changes and how sea level is measured. Creating such experiments is a challenge given the scale difference between the classroom and the ocean. Here, we discuss a demonstration designed to teach students about the difference between melting sea ice and melting continental ice, while helping students understand the role of satellite altimetry in monitoring sea level. We also show how this experiment could be adapted to study tsunamis and other types of waves.

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## 87 - CTOH: 20 YEARS OF ALTIMETER DATA

*Dr Fleury Sara* CTOH/LEGOS/CNRS

**Morrow Rosemary**, CTOH/LEGOS ; **Fleury Sara**, CTOH/LEGOS ; **Niño Fernando**, CTOH/LEGOS ; **Biol Florence**, CTOH/LEGOS

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4583>

### Abstract :

The Center for Topography of the Oceans and Hydrosphere (CTOH) is a French Observation Service created in 1989 and dedicated to satellite altimetry studies. Its objectives are to 1) maintain and distribute homogeneous altimetric databases for ocean, hydrosphere and cryosphere applications, 2) help scientific users develop new altimetry derived products and 3) contribute to the development and validation of new processing approaches of the altimetric data for emerging research domains. The CTOH maintains homogeneous altimetric GDR data bases for the following missions : Topex/Poseidon (1992 - 2005); GFO (2000 - 2008); ENVISAT (2002 - today); Jason-1 (2002 - today); Jason-2 (2008 - today), covering the 20 years of altimetry data. Both 1Hz and 18-20Hz data are available over all possible oceanic and continental surfaces. In addition we add about 20 recent corrections in a homogeneous way to all of the missions. These include tide models, DAC, MSS, geoids, and tropospheric corrections. Retracking of ERS-1 and ERS-2 waveform with the ICE-2 algorithm is underway. A web-based tool allows users to select, visualize and download data using spatio-temporal criteria (<http://ctoh.legos.obs-mip.fr/>). This tool is complementary to the AVISO website, and BRAT Toolbox, as it allows users to extract GDR data and homogeneous corrections in regions where the standard products and data are not adapted: coastal zones, continental water surfaces and the cryosphere. In addition, the CTOH works on developing and distributing new altimetric products which can be accessed from the web site (<http://ctoh.legos.obs-mip.fr/products>). These include : Coastal products : Alongtrack data are available in a dozen regions, with specific X-TRACK processing in the coastal band. SLA are available on a nominal groundtrack (1hz and 20hz for some regions), as well as a high-resolution MSS ([/?products/coastal-products](http://ctoh.legos.obs-mip.fr/products/coastal-products)). Tidal constants (amplitude and phase lag with error estimations for each tidal constituent) have been newly added to this product. Continental hydrology products : including the [Hydroweb](http://ctoh.legos.obs-mip.fr/products/hydroweb) data base for monitoring river and lake levels ([/?products/hydroweb](http://ctoh.legos.obs-mip.fr/products/hydroweb)). Hydroweb now integrates the CASH project Topex reprocessed data over terrestrial surface waters. Global Surface Current product, combining altimetric geostrophic anomalies, mean currents based on the MDT\_CNES\_CLS09\_v1.1, and QuikScat Ekman currents up till 2009, and under extension using EKMAN ([/?products/global-surface-currents](http://ctoh.legos.obs-mip.fr/products/global-surface-currents)). Global SubMesoscale filaments. Amplitude and position of sub-mesoscale filament barriers calculated from gridded AVISO surface currents using the Finite-Size Lyapunov Elements (d'Ovidio et al., 2009), at 4 km resolution from 1993 to today ([/?products/submesoscale-filaments](http://ctoh.legos.obs-mip.fr/products/submesoscale-filaments)). Regional Maps of Sea Level Anomalies: The maps are derived from 1Hz multi-satellite coastal altimetry (X-TRACK) data. This promising product is under evaluation (Dussurget et al., 2011).

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## 88 - Ssalto/Duacs: Preparation of the next products version

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**Renaudie Cecile**, CLS ; **Dufau Claire**, CLS ; **Briol Frederic**, CLS ; **Faugere Yannice**, CLS ; **Dibarboure Gerald**, CLS ; **Bronner Emilie**, CNES

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4542>

### **Abstract :**

Ssalto/Duacs provides GODAE, climate forecasting centers, the MyOcean EU FP7 project, and oceanographic research centers with directly usable, high quality near real time and delayed time altimeter data. Products are delivered both along the tracks of the different altimeters, and on a regular grid merging the measurements of the altimeters available. Ssalto/Duacs data process is regularly improved in order to deliver the best quality products. In order to reduce as much as possible the measurement noise without impacting physical signal of interest, work is on going to improve the along-track data noise reduction processing. Mapping process is also improved with a more precise parameterization. Physical correlation scales characteristics of the signal reconstructed with Duacs gridded products were re-estimated. The newest version allows us to take into account the geographical variability of the scales in a more efficient way. The first sensitivity tests clearly underline the higher precision of the maps constructed using these newest correlation scales. We will also present how the specificity of non-repetitive mission and non-frequency measurements are taken into account in the mapping process. A specific error budget for these missions allows to reduce the error of the gridded product. According to the users' feedback, other changes could be integrated in the next version of the products. Higher spatial/temporal resolution could be used for the gridded product generation and change of the 7-year [1993, 1999] reference period, until now used for the SLA computation, is envisaged.

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## 89 - Improved Modelling of Time-Variable Gravity for Altimeter Satellite POD

**Mr Zelensky Nikita** SGT Inc.

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**Session:** Precision Orbit Determination

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4473>

### **Abstract :**

The stability and accuracy of the altimeter satellite orbit through time is essential for POD. One component of dynamic orbit modeling that has emerged as a critical issue is the best parameterization of time-variable gravity (TVG) for application to precision orbit determination - in particular how TVG can be applied consistently over the entire span of the altimeter satellite data record. We consider several alternative parameterizations and test their implementation on TOPEX, Jason-1, Jason-2, GFO-1 Envisat and Cryosat-2. Although the GRACE mission supplies weekly, ten-day, or monthly solutions routinely to varying resolutions, these high-resolution snapshots are only available since the start of the GRACE mission. Other time-variable gravity solutions based on SLR+DORIS processing of various satellites can extend the time series backward in time but only provide estimates of the low degree field, for example to 4x4 in spherical harmonics (e.g. Lemoine et al., 2011). Another possibility is to derive a model from the NASA GSFC mascon solutions (e.g. Sabaka et al., 2010; Luthcke et al., 2011). We take care to update the base model of the static field where appropriate, for example a model derived from GRACE and GOCE. We evaluate these different approaches by computing orbit time series for the different altimeter satellites, and evaluate the change in the orbits and POD performance (e.g. RMS of fit, altimeter crossovers). For TOPEX, Jason-1 and Jason-2 we evaluate how these new orbits might affect regional or global estimates of the change in mean sea level on different time scales. As a component of the evaluation, we examine the impact of the new orbit time series on the tide gauge calibration.

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## 90 - Recent results in LEO GPS ambiguity fixing at CNES : HY2A and Jason 2

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**Session:** Precision Orbit Determination

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4448>

### **Abstract :**

The Chinese HY-2A altimetry satellite is on his mission orbit since 1st October 2011. This satellite carries on board a Doris receiver, a GPS receiver and a SLR retro-reflector for the precise orbit determination. The GPS is a dual frequency semi-codeless receiver. Precise GPS/Doris/SLR orbits are computed at CNES on the basis of 7 days arcs with a configuration similar to Jason 2, and delivered for altimetry processing. Recently, GPS ambiguity fixing was performed successfully on the HY2A data, using the GRG (CNES/CLS) IGS products for the constellation orbits and clocks. The fixed ambiguities improve the observability of the orbit determination process, which allows to significantly reduce the dynamic constraint of the solutions. These new orbits are compared with the current POE product. For Jason 2, the ambiguity fixing is not performing well due to half cycles biases present in a significant number of measurements. Preliminary results will also be shown on this subject.

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## 91 - Evaluation of new precise orbits of Envisat, ERS-1 and ERS-2 using altimetry

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**Session:** Precision Orbit Determination

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4434>

### **Abstract :**

Precise orbits of altimetry satellites are a prerequisite for a range of altimetry investigations, such as sea level anomalies computations, global and regional sea level change studies and others. New precise orbits of altimetry satellites Envisat, ERS-1 and ERS-2 have been recently computed at different institutes within ESA funded projects, such as 'Reprocessing of Altimetry Products for ERS (REAPER)' and Sea Level Project of the ESA Climate Change Initiative (SLCCI). Precise orbits of satellites Envisat (from April 2002 till December 2010), ERS-1 (from August 1991 till July 1996) and ERS-2 (from May 1995 till July 2003) computed at GFZ at the time periods given within the SLCCI project in the ITRF2008 reference frame and based on the SLCCI Standards are evaluated in this paper using a dedicated cross-calibration between ERS-1, ERS-2, Envisat, and other altimeter missions operating contemporaneously. The crossover analysis has the potential to investigate differences in the geocentering of orbits and to identify geographically correlated errors. The results of the evaluations will be presented.

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## 92 - Jason-1 and Jason-2 POD using GPS

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**Lemoine Frank G**, NASA/GSFC Code 698, Planetary Geodynamics Laboratory ; **Zelensky Nikita P**, NASA/GSFC Code 698, Planetary Geodynamics Laboratory, SGT-inc ; **Rowlands David D**, NASA/GSFC Code 698, Planetary Geodynamics Laboratory ; **Luthcke Scott B.**, NASA/GSFC Code 698, Planetary Geodynamics Laboratory ; **Beckley Brian D**, NASA/GSFC Code 698, Planetary Geodynamics Laboratory

**Session:** Precision Orbit Determination

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4405>

### Abstract :

The Jason-2 satellite, launched in June 2008, is the latest follow-on to the successful Jason-1 altimetry satellite mission launched in December 7, 2001. Both, Jason-2 and Jason-1 are equipped with a GPS dual-frequency receiver, a laser retroreflector array, and a DORIS receiver for precise orbit determination (POD). A series of dynamic and reduced-dynamic Jason-2 orbits computed at NASA GSFC, based on GPS-only data and the std0905 standards, have been completed through cycle 74 using the IGS05 framework. These orbits, now publicly available, have been shown to agree radially at 1 cm RMS with the GSFC std0905 SLR/DORIS orbits and in comparison with orbits produced by JPL, ESA and CNES (Melachroinos et al. 2011 OSTST 2011). In this paper, we describe the implementation of the IGS08 and repro1 framework for the Jason-2 and Jason-1 GPS POD processing with the NASA GSFC GEODYN software. In our updated GPS POD, ambiguity fixing and updated time variable and static gravity fields, are implemented. We also combine the GPS data with SLR data, which include SLRF2008. We evaluate the implementation of non-tidal and degree-1 loading displacement as forward modeling to the tracking stations. Reduced-dynamic versus dynamic orbit differences are used to characterize the remaining force model errors and TRF instability. In particular, we assess their consistency radially and the stability of the altimeter satellite reference frame in the North/South direction as a proxy to assess the consistency of the reference frame. We evaluate the performance of orbits based on standard tests, such as altimeter crossovers, orbit overlaps, high-elevation SLR fits, and inter-comparison with independently-determined orbits.

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## 93 - Plans and status for UCL non-conservative force models for precise orbit determination in altimetry missions.

*Dr Grey Stuart* University College London

**Ziebart Marek**, University College London ; **Grey Stuart**, University College London ; **Allgeier Shawn**, University College London

**Session:** Precision Orbit Determination

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4377>

### **Abstract :**

Physically based non-conservative force models have been shown to significantly reduce the orbit error in Precise Orbit Determination (POD). University College London is applying its existing techniques for Solar Radiation Pressure (SRP) and Thermal re-radiation forcing (TRR) in addition to forthcoming models of other surface forces to improve the accuracy of POD solutions for a number of science missions. The UCL models are based on the physical interaction between photons and the spacecraft structure. Models for SRP/TRR and Planetary Radiation Pressure (PRP) implement a ray tracing algorithm which allows for the efficient modelling of the interaction between the incident photons and the structure of the spacecraft. The structure of the spacecraft is modeled to a high degree of accuracy using geometrical primitives which, along with the ray tracing algorithm, eliminates tessellation errors for complex geometry. The radiation fluxes are computed using the Frolich model for solar irradiance and the CERES data for upper atmosphere Earth radiation fluxes. The methodology has been validated using the Jason-1 and Envisat missions and analysis of Jason-2, Cryosat-2, SPOT-4 and SPOT-5 are planned. The aim is to calculate the non-conservative forces for a majority of DORIS enabled satellites. In this way the improvements in POD to be gained by using high fidelity physical models for non-conservative forces can be used to help calculate the DORIS reference frame. The UCL group is also carrying out further research into currently under modelled non-conservative forces. Thermal re-radiation by the bus and antenna thrust are already included in the models and more complete models for PRP and atmospheric drag are being developed. It is hoped that an improved PRP model will contribute to understanding the geographically correlated orbit error. An improved drag model based on the interaction between the physical structure of the spacecraft and the latest atmospheric density models is being developed which could have a large impact on LEO missions. The thermal effects of the solar panels are also to be considered and to be combined with the SRP and PRP models. Overall, the aim is to develop a suite of robust and physically defined models that can be applied to a number of missions to help improve the POD process and thus the downstream scientific products.

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## 94 - On the proper use of the EIGEN-6 models for altimetric orbit computation over decades

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**Session:** Precision Orbit Determination

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4703>

### **Abstract :**

The EIGEN-6 Earth gravity models are commonly used for altimetric orbit computation. They are mainly based on GRACE KBR data and provide for that reason a series of time variable coefficients, namely: drift, once per year and twice per year terms up to spherical harmonic degree 50. These terms can be modeled globally over the GRACE period (around 10 years now) or annually. However extrapolating these time variable terms in the past until the beginning of altimetric missions or even in the near future can generate some degradation of the orbital precision which can lead to noticeable radial discrepancies. Dedicated SLR satellites such as Lageos1/2 or Starlette/Stella are a good help for improving the knowledge of the very low degrees in the past. We propose to show the orbital impact of these time variable terms and to give certain rules for their application in orbit computation.

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## 95 - How well can we estimate high frequency non-tidal ocean variability for de-aliasing purposes?

**Dr Quinn Katherine** *Atmospheric and Environmental Research (AER)*

**Ponte Rui**, Atmospheric and Environmental Research (AER)

**Session:** Tides, internal tides and high-frequency processes

**Presentation type:** poster

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4474>

### **Abstract :**

Reducing aliasing in altimetry missions requires accurate estimates of rapid sea level variability (periods <20 days for Jason). We assess how well we know rapid, non-tidal ocean bottom pressure (OBP) signals by analyzing in-situ bottom pressure recorder (BPR) data and available OBP estimates from different ocean models. OBP can be considered equivalent to sea level if we assume barotropic variability at high frequencies. Previous theoretical and model-based studies suggest the existence of a barotropic regime at mid to high latitudes for periods <20 days. We use 7-day GRACE solutions and equivalent satellite altimetry maps to provide direct evidence of barotropic behavior at mid and high latitudes. Various model estimates of OBP variance are generally lower than that measured by the BPRs, suggesting the presence of correlated model errors. Deriving uncertainties from differencing the model estimates can thus severely underestimate the aliasing errors. Removing estimated series from BPR data tends to reduce the variance but residuals are not negligible relative to expected variance in climate OBP signals. The residual OBP variability can be correlated over hundreds of kilometers. Results indicate the need to improve estimates of rapid oceanic variability in order to minimize aliasing noise in the altimeter records.

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## 96 - Twenty Years of Altimeter Calibration from an Offshore Platform: An Update from the Harvest Experiment

**Dr Haines Bruce** *Jet Propulsion Laboratory, California Institute of Technology*

**Haines Bruce**, Jet Propulsion Laboratory, California Institute of Technology ; **Born George**, Colorado Center for Astrodynamic Research ; **Desai Shailen**, Jet Propulsion Laboratory, California Institute of Technology

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4511>

### Abstract :

Located about 10 km off the coast of central California, the Harvest Platform has served as a dedicated altimeter calibration site since the launch of TOPEX/POSEIDON (T/P) in 1992. The calibration experiment has supported the collection of accurate in-situ data for two decades, enabling continuous monitoring of the emerging climate record from T/P, Jason-1 and OSTM/Jason-2. Over the past year, we have focused on the analysis of data from OSTM/Jason-2 overflights of the platform, the first of which occurred on July 13, 2008. At this writing, Jason-2 had passed over the platform 142 times, providing the basis for long-term monitoring of both bias and drift in the sea-surface height (SSH) measurements on the Test Geophysical Data Records (T-GDR). Current analysis indicates these (T-GDR) SSH measurements at Harvest are erroneously high by 184 +/- 3 mm (one standard error). The drift (+1 +/- 3 mm/yr) is statistically indistinguishable from zero. Jason-1 made its 259th and final flyover of Harvest on January 18, 2009, after which it was moved to a new repeat orbit that produces an interleaving ground track with Jason-2. We find that the Jason-1 (GDR-C) SSH measurements are erroneously high by 96 +/- 2 mm (one standard error). The long-term drift in the SSH measurements is  $\approx 2$  +/- 1 mm/yr. We note that systematic error sources, such as uncertainty in the GPS-based measurements of platform subsidence, are not represented in these error figures. Significant progress has been made in understanding the sources of the biases in the Jason-1 and -2 SSH data. Recent investigations by CNES (Desjonquieres et al.) have led to the identification of important inconsistencies between the characterization files for the Jason-1 and Jason-2 altimeters at the primary (Ku-band) frequency. In addition, CNES discovered an error of 180.92 mm (common to both missions) due to competing interpretations of the altimeter antenna reference points (mechanical plane vs. aperture plane). We illustrate the effectiveness of these corrections in explaining long-standing inconsistencies in the climate data record from the combined missions. After applying these corrections, the SSH bias estimates for Jason-1 and OSTM/Jason-2 are reduced to +35 and +28 mm respectively. Additional adjustments to the altimeter SSH measurements were made to reflect upcoming improvements to various corrections: a new sea-state bias model (from Tran et al.) for both Jason-1 and -2, and updated ionosphere and wet troposphere corrections for Jason-2. These corrections further reduce the SSH bias estimates to +6 and +3 mm respectively for Jason-1 and -2. For the first time, the SSH bias estimates for all five altimeter measurements systems monitored at Harvest are indistinguishable from zero. We also discuss recent progress in determining the long-term evolution of the platform vertical height with respect to the geocenter. These measurements are used to transform the tide-gauge record from relative (platform) to absolute (geocenter). New precise GPS orbit and clock products, coupled with advanced new positioning strategies have enabled important improvements in our monitoring of the platform subsidence, and also on our assessment of the associated errors.

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## 97 - GLOBAL CALIBRATION AND VALIDATION OF THE JASON-2 GDR-D PRODUCTS

**Dr Desai Shailen** *Jet Propulsion Laboratory, California Institute of Technology*

**Desai Shailen**, Jet Propulsion Laboratory, California Institute of Technology ; **Haines Bruce**, Jet Propulsion Laboratory, California Institute of Technology

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4488>

### **Abstract :**

We present results from a statistical analysis of the most recent version, version D, of the Jason-2 Geophysical Data Records (GDRs). Our results encompass inter-comparisons between the GDR-D products and their predecessor, the ?Test? GDRs (GDR-T). We also discuss updated results from the differences between the measurements from Jason-1 and Jason-2 missions during their formation flying phase, using the most recent version of the data products, GDR-D for Jason-2 and GDR-C for Jason-1. Our analysis leverages off the fact that identical oceanographic and environmental conditions are effectively being observed by the two missions during this phase, since they are flying approximately 54 seconds apart on the same ground track. We characterize both geographically correlated and systematic differences between the measurements from the two data products (GDR-T and GDR-D) for Jason-2, as well as the two missions (Jason-1 and Jason-2). We consider inter-mission differences segregated by quadrant, namely ascending and descending ground tracks in the northern and southern hemisphere, as one metric for geographically correlated errors. We also consider systematic differences in the altimeter measurements as a function of significant wave height and wind speed. For example, any relative sea state bias difference is quantified by differences of uncorrected sea surface height, namely orbit-range-mean sea surface, as a function of SWH.

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## 98 - Global Jason-2 Data Quality Assessment including first results of GdrD reprocessing

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4544>

### **Abstract :**

Long-term monitoring of the Jason-2 altimetric system is routinely performed at CLS, as part of the CNES SALP (Système d'Altimétrie et Localisation Précise) project since the Jason-2 launch in July 2008. The main objective of this activity is to provide an estimation of the mission performances for oceanic applications such as mesoscale or climate studies. The monitoring of all altimeter and radiometer parameters is routinely performed in order to detect jump or drift. Cross calibration with other altimetry mission or in-situ measurement is also systematically performed in order to estimate altimetry errors at different spatial and temporal scales: high frequency signals (noise), geographical bias, drift... However this activity has been recently impacted by 2 major events in the altimetry community. Recently, Jason-1 has been moved to a geodetic orbit (May, 2012) after more than 2 months without altimeter data. In the meantime, the Envisat mission has been ended as a result of the communication loss in April 2012. These changes have several consequences on the Jason-2 validation activities. First of all, the Jason-2 cross-calibration with Envisat is of course no longer possible. Jason-1 and Jason-2 comparisons are still possible but likely less relevant to estimate long-term errors. As the Jason-2 mission is now the more accurate mission used in operational applications or for delayed time studies, the assessment of Jason-2 data quality is still a main issue. The objective of this study consists in giving an overview of Jason-2 data quality concerning altimeter and radiometer parameters, but also the sea-level performances for delayed and real time products (GDR, IGDR, OGDR). As 4 years of Jason-2 data are now available, we pay special attention to the long-term stability of Jason-2 Global Mean Sea Level (GMSL) thanks to comparison with Jason-1 and Envisat, and in-situ measurements. Furthermore, some first results with reprocessed (GDR-D standard) Jason-2 data are shown.

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## 99 - Global Jason-1 Data Quality Assessment on the new geodetic orbit

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4543>

### **Abstract :**

After 10 years in orbit as a precise altimeter mission on two different repeat ground tracks, Jason-1 had early this year an interruption of its science mission for over 2 months. In the following, it was moved to a geodetic ground track in early May 2012. Though this orbit is less interesting for the tandem mission with Jason-2 to solve mesoscale oceanography, the mission can still provide valuable and useful data for several applications. Therefore, the objective of this study is to provide an overview of the global data quality of Jason-1 data on the new geodetic orbit. Firstly, the stability of the altimeter and radiometer parameters is carefully monitored and the system performances assessed. This consists in long-term monitoring of the parameters, as well as comparison to Jason-2 data, in order to assess the possible impact of the lower altitude on the altimeter data. Furthermore the impact of the geodetic orbit on the sea-level performances is accurately analysed.

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## 100 - Arctic Ocean Sea-Level Rise

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**Kuo Chungyen**, National Chung Kung University ; **Yi Yuchan**, Division of Geodetic Science, Ohio State University ; **Junkun Wan**, Division of Geodetic Science, Ohio State University ; **Tseng Steven Kuo-Hsin**, Division of Geodetic Science, Ohio State University ; **Alexander Braun**, Division of Geodetic Science, Ohio State University

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4496>

### **Abstract :**

Satellite altimetry measurement of the Arctic Ocean sea-level rise are approximately 2 times less accurate than of the mid- to low-latitude measurements of sea-level rise. This is primarily due to the presence of seasonally or permanently covered sea-ice over the Arctic Ocean, and that the high-latitude observing satellite altimetry data from ERS-1/-2, Envisat, or Geosat/GFO, are less accurate than that of the TOPEX-class altimetry data. There have studies indicating that the use of more accurate mean sea surface model enabling gradient corrections have improved the quantity and accuracy of altimetry-observed sea-level data records. Here we conduct studies examining various geophysical and media corrections and waveform retracking techniques towards generating an improved multi-mission radar altimetry sea-level climate data record in the Arctic Ocean.

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## 101 - Evaluation of Jason-2 GDR-D sea level and retracking parameters

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**Leuliette Eric**, NOAA ; **Lillibridge John**, NOAA ; **Mitchum Gary**, University of South Florida ; **Scharroo Remko**, Altimetrics LLC/NOAA ; **Smith Walter**, NOAA

**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4483>

### Abstract :

Because Jason-2 is the sea level reference mission, it requires particularly careful evaluation of its stability to ensure the integrity of the sea level climate data record from altimetry. Using the recently released Jason-2 Geophysical Data Records version D (GDR-D), we present an evaluation of how well the 1-mm/year stability goal has been met with the official data products. We will show cross-calibrations of Jason-2 with Jason-1 and Envisat, and with the independent network of tide gauges. A significant change to the GDR-D products is the inclusion of a full suite of variables from 3-parameter Maximum Likelihood Estimator (MLE-3) retracking as well as the conventional MLE-4 retracking. In addition to the parameters that can be estimated from the altimeter waveforms (range, significant wave height, and backscatter) the GDR-D data include two sets of altimeter instrument corrections and sea state biases consistent with each form of retracking. We will present an analysis of these parameters, and their impact on sea level cal/val. In particular we will evaluate GDR-D performance during the calibration phase with Jason-1. Leuliette and Scharroo [2010] reported that the relative bias between Jason-1 and Jason-2 during the calibration phase was dependent on the mispointing parameter produced by MLE-4. For a significant number of pairs of coincident measurements with large mispointing values of opposite sign, they found a tracker bias of 10 mm. Using the GDR-D we will present an analysis of the dependence of the Jason-1/Jason-2 bias on retracking parameters and the impact of retracking on the error budget.

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## 102 - Reassessment of Jason-2 stability based on revised POD standards

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4466>

### Abstract :

Recent assessments of the stability of Jason-2 during the mission's first three years evaluated from comparisons of the altimeter derived sea surface height variations to a near-global tide gauge network show trends exceeding 1.5 mm/yr (Leuliette, et al., 2011). By comparison, the first three years of Jason-1 (based on GDR\_C) results in a stability estimate of 0.1 mm/yr via the same tide gauge network analysis. One plausible explanation for this discrepancy can be traced to the time variable gravity (TVG) component in the precise orbit determination (POD). For both the Jason-1 GDR\_C and the current Jason-2 GDR\_T (as well as the GSFC std1007 orbit), the TVG is based on a similar model, which includes the secular rates in the low degree zonals (C20, C30, C40) and applied C21 & S21 according to IERS (McCarthy and Pétit, 2004). The gravity variations due to the atmosphere come from ECMWF pressure (Klinker et al., 2000), and the annual geopotential variations from a fit to four years of GRACE-derived spherical harmonic solutions (Luthcke et al., 2006). No pseudo-secular variations in the TVG are applied that might be due to short-term changes, but normally would account for the well known long-term signals (e.g. due to post-glacial rebound). An apparent ?omission error? is incurred by not including more detailed information about TVG leading to progressive degradation of orbit accuracy outside the model's GRACE observation period. At GSFC, we have evaluated a more detailed modeling of the time-varying geopotential in two ways: (1) using the more recent EIGEN6S gravity model, consisting of annual, semi-annual, and secular terms to 50x50, determined with GRACE+Lageos data from 2003 to 2009.5; (2) using an 18 year time series of weekly 4x4 geopotential coefficients obtained from tracking of nine SLR & DORIS satellites (Lemoine et al., 2011). In this presentation we assess the efficacy of revised TVG modeling strategies towards reconciling the Jason-2 trend via comparisons to an expanded global tide gauge network, as well as the impact on the 20-year record of global and regional mean sea level estimates.

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## 103 - HY-2A and DUACS multi-missions products

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.avisooceanobs.com/index.php?id=1719&uid=4431>

### **Abstract :**

Aviso/Duacs system processes data from all available altimeter missions to provide near real time and delayed time products. They cover a large spectrum of operational oceanography needs, from ocean mesoscale observations to climate applications. These products are of great interest thanks to the combination of multiple satellites such as the Jason-1 & 2 tandem with Envisat and more recently CryoSat. But the product's quality has been affected by the recent loss of the Jason's tandem and Envisat mission. Hence the contribution of a new altimeter such as the Chinese HY-2A (Hai Yang stands for 'ocean' in Chinese) has to be examined. The satellite has been launched by the CNSA in August 15th 2011 with a sun-synchronous orbit at an altitude of ~970km. Repeat cycles of 14 days are planned for the first two years with oceanographic purpose and 168 days geodetic cycles will follow for the third year of the mission. The satellite is equipped with a Ku / C bands altimeter and a triple bands radiometer and the orbit is determined thanks to SLR, GPS and DORIS systems. In this study, altimeter parameters are characterized and a calibration and validation of these data is performed. The inter-comparison with Jason-2 and Envisat measurements also contributes to the estimation of the data quality and system performances. The contribution of HY-2A altimeter data to the DUACS multi-missions products is assessed and their interest for the ocean mesoscale observation is analyzed in the context of the loss of Jason's tandem and Envisat mission.

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## 104 - JASON-2 / ENVISAT CROSS-CALIBRATION

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4426>

### **Abstract :**

Cross calibration of Jason-2 measurements with other flying precise altimetric missions is essential to assess data quality and performances. Thorough comparisons with Jason-1 and Envisat have been performed from the beginning of the Jason-2 mission and are still mandatory for validating but also for allowing combination of altimeter datasets as required by scientific applications and operational oceanography. Global cross-calibration analysis between Envisat, Jason-2 carried out as part of the SSALTO/CaIVal activities. They show that Envisat enables to give an interesting external point of comparison to explain discrepancies between Jason-1 and Jason-2. It also enables to better quantify altimetric performances and to potentially point out anomalies in the data. Since April 8th of this year, communication was lost with Envisat with extremely poor hope to get it back. Still, the last 9-year data set remain very usefull for on-going studies, and even more than ever this year. Indeed, the first whole mission reprocessing was achieved in January this year, providing a more homogeneous dataset in terms of data processing. Furthermore, the correction of two main terms of the Sea Level Anomaly (POE and Instrumental drift) on Envisat side but also on the Jason1 and 2 side concerning the POE. These upgrades enabled to improve dramatically the consistency between the 3 missions. The new metrics of comparison after reprocessing between the different missions will be presented with a particular focus on the Mean Sea Level Global and Regional improvements aspects.

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## 105 - Updated Absolute Bias Results from the Australian In-Situ Calibration Sites: Bass Strait and Storm Bay.

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4410>

### **Abstract :**

The Australian absolute calibration site located in Bass Strait (40° 39' S, 145° 36' E) has been involved in the production of altimeter absolute bias estimates over the complete duration of the TOPEX/Poseidon, Jason-1 and ongoing OSTM/Jason-2 missions. As part of a global effort, this contribution continues to underpin the validation of the climate record derived from satellite altimetry over this 20 year period. With support from the Australian Integrated Marine Observing System (IMOS), the Bass Strait site has been augmented with a second comparison point in Storm Bay (43° 18'S, 147° 39'E), located on the same descending pass (pass 088). Storm Bay has on average twice the significant wave height as Bass Strait, allowing the exploration of sea state effects on absolute bias determination using a single-pass, multi-site methodology. In this contribution we present updated results from the Bass Strait site, and initial results from the Storm Bay site. We use a geometric approach that includes data from a series of oceanographic moorings (including high accuracy pressure gauges and associated instrumentation), GPS buoys, a coastal tide gauge site and land based GPS reference stations.

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## 106 - Global Cal/Val of CryoSat-2 LRM and SAR data over oceans

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.avisio.oceanobs.com/index.php?id=1719&uid=4402>

### **Abstract :**

Since its launch, the CryoSat-2 low-bit rate ocean data products from ESA (LRM for off-line and FDM for near realtime) have gone through various evolutions of data processing. In parallel, NOAA has started retracking CryoSat-2 waveforms from the Level 1B products, aiming both near realtime applications as well as the global long-term record of sea level data. The resulting IGDR- and GDR-type products have been provide to a wide community of users IGDR- through FTP and through the Radar Altimeter Database System (RADS).More recently, we have started to merge the 'conventional' low-bitrate mode (LRM) data with SAR mode data in order to fill numerous regional holes in the global ocean coverage. This is done through creating a pseudo LRM waveforms and then retracking those wave forms.This presentation discusses various issues related to the data processing, analysis, and calibration and validation, such as:Retracking of the LRM and SAR mode dataIssues with merging the LRM and SAR mode dataLong-term stability of the retracked dataComparison between Level 1B and Level 2 dataSelecting and updating environmental and geophysical correctionsDeveloping a sea state bias model for LRM and SAR mode dataCross-calibration with other altimeters (Jason-1 and Jason-2)

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## 107 - Precise Jason-2 absolute altimeter calibration by means of a microwave transponder

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4399>

### **Abstract :**

Numerous altimeter calibration sites around the world build up a dedicated scientific infrastructure for accurate calibration and validation of altimeter satellites and related products. Besides the standard equipment for in-situ measuring the instantaneous sea surface height (tide gauges, GPS buoys, etc.) the cal/val site on Gavdos, Crete, is in particular equipped with a dedicated land based altimeter transponder operated by the Austrian Academy of Sciences. This electronic instrument receives and sends back amplified radar pulses which are recorded by the altimeter on-board the spacecraft again. The transponder site on the small island of Gavdos is located directly beneath a Jason cross-over point. Since the ellipsoidal height of the transponder is determined by means of GPS, altimeter ranges referring to that reference have the clear advantage of being unaffected from any local sea level fluctuations in the calibration area. This makes the transponder technique independent from error sources associated with sea surface dynamics (tides, sea state bias, etc.) and we may rather refer to an altimeter bias than to an SSH-bias. In order to ensure the operability in conjunction with Jason-2, its altimeter (Poseidon-3) has to be switched to the DIODE/DEM mode for every single overpass which allows an adjustment of the ranging gate appropriate to the transponder's elevation. Much in contrast to the Brown model of a typical ocean response generated by the radar footprint, the transponder echo shows the characteristics of a point target response appearing as a strong spiky signal in the altimeter waveform. We developed and tested several waveform retracking algorithms following different strategies of modeling the waveform patterns, i.e. Gauss fit, energy centroid, sinc-function and zero padding. For the presented study we carried out a Jason-2 measurement campaign on Gavdos from Oct. 2010 to Jan. 2012 (cycles 083 through 126) comprising 26 passes. In the course of this analysis we retrieve the waveform data, precise orbit information and the range corrections from both, the SGDR and SIGDR data products. The analysis yields a bias value of  $25.7 \pm 0.3$  cm with a very good agreement of mostly  $\pm 1$  cm among all the implemented methods. There is neither a trend in the time series of bias values, nor correlations between the biases of ascending and descending passes. However, the transponder derived absolute bias resulting from this investigation shows an offset of approx.  $8$  cm compared to the results of conventional methods. Possible causes of this behavior are under further investigation. From the results of this analysis, we conclude that the transponder method yields a remarkable precision of only  $3$  mm which is significantly better compared to alternative methods referring to the SSH. If the potential of transponder calibration is fully exploited, it becomes an appropriate and powerful technique, especially to supplement and validate conventional calibration techniques.

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## **108 - Latest results for the determination of absolute bias for Jason-2 and HY-2 satellites using the Gavdos & Crete Cal/Val permanent facilities.**

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4379>

### **Abstract :**

This work presents the latest results for the determination of absolute altimetric bias for the Jason-2 and the HY-2 satellites using the Gavdos and Crete calibration facilities. At first, the absolute altimeter biases of Jason will be presented, by using in-situ observations and precise geoid undulations along the ascending Pass No.109 as well the descending Pass No. 18. Then alternative calibration techniques will be presented using a locally determined mean sea surface (MSS) model and a microwave transponder. This work also examines how changes in steep bathymetry (from 200 m to 3500 m depth over a distance of 10 km) are reflected on the determined sea surface anomalies based on various reference surfaces for altimeter calibration. Finally, it describes the relation between these parameter trends and the region's local characteristics. The determination of the Chinese HY-2 altimetric bias will be also presented using a site on the West Crete, where the satellite is flying close by. Comparative results for the Jason-2 and the Chinese HY-2 bias in the region as well between different calibration techniques will be given.

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## 109 - Comparing altimetry with Argo and GRACE data for quality assessment and Mean Sea Level studies

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4362>

### **Abstract :**

Altimeter missions provide accurate measurements of sea surface height from 1992 onwards with TOPEX/Poseidon, Jason-1, Envisat and Jason-2. The global quality assessment of altimeter data is usually performed by the analysis of their internal consistency and the cross-comparison between all missions. In this study, the steric and mass contributions to the sea level provided by Argo profiling floats and the Gravity Recovery And Climate Experiment (GRACE) mission respectively are used as independent sources of comparison to detect potential anomalies and to better assess the multiple system performances. Argo profiling floats provide Temperature and Salinity vertical profiles with an almost global coverage of the open ocean since 2004, representing a dataset of about 600 000 profiles. The mass contribution to the sea level derived from the GRACE dataset (Chambers and Willis, 2010; CSR UT) is available between 2003 and 2011. These both types of data provide an estimation of the total height of the water column which can thus be compared with the altimeter measurements of various missions. The comparison is performed with the first objective of detecting global and regional drifts in the altimeter Sea Surface Height (SSH). A second goal is to assess the impact of new altimeter standards (orbit, geophysical corrections, ground processing) thanks to the Argo and GRACE reference. Finally, Argo data are quality controlled by cross-comparison with all available altimeters and the use of the corrected in-situ data further improves the SSH comparison with altimeter measurements. Results presented demonstrate the close link between the three steps of the method.

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## 110 - FOAM: From Ocean to inland waters Altimetry Monitoring

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**Session:** Regional and Global CAL/VAL for Assembling a Climate Data Record

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4174>

### **Abstract :**

The FOAM project is focused on the important continuity between past, present and future missions but also on the reliability between offshore, coastal and inland altimetric measurement. Purpose is to aggregate the effort of several groups, in order to notably establish a homogeneous network of calibration site geographically distributed for more robust characterization of the existing and future radar altimeter system instrument biases and their drifts. Due to the increasing need of altimetry to monitor inland waters and in preparation to future missions (e.g., SARAL/AltiKa, Sentinel-3, Jason 3, Jason CS, SWOT) we have integrated the calibration activities on the oceanic domain and those on different water bodies such as rivers and lakes. CAL/VAL activities on the oceanic domain have a long history and protocols are well established. CAL/VAL activities on rivers and lakes are much recent but in turn they enable to avoid the contributions of the Sea Surface Bias (SSB) and liquid tides in the range calibration and to address other problems such as the performance of the various retracking algorithms, altimeter technologies (LRM/SAR), wavelength (Ku/Ka), and more globally assess the quality of the geophysical corrections. In order to increase statistically the sea surface bias estimation but also to cover larger areas, the calibration opportunities have been extended by using, not only over-flying passes, but also satellite passes located far away from the CAL/VAL site (few hundreds kilometers). This Regional CAL/VAL method has been developed since 2003 and validated on the Corsica tide gauges network dedicated to Jason 1&2 and EnviSat. We will present a synthesis of the results of our CAL/VAL activities obtained by the FOAM project during the past four years at various sites (Corsica, Vanuatu, Kerguelen, lakes and rivers...) and the planned activities and development for the coming years.

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## 111 - Error specification on SLA observations in the Mercator assimilation systems

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**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4553>

### **Abstract :**

Data assimilation algorithms give an estimate of the state of a system, here the ocean, from a combination of the model forecast and the difference between the observations and their model counterpart taking into account the prescribed model and observation error. Each week, Mercator Ocean delivers ocean analysis and forecasts where in situ, SST and SLA observations are assimilated. Reanalysis are also produced, using delayed time reprocessed data sets. The successful assimilation of a given data set requires a precise computation of the model equivalent knowing the model physic and the information content of the observations, including the applied posttreatment, as well as an error estimate on the observations. The solution of the assimilation algorithm will reflect the ratio between the model error and the different prescribed data set errors. A fine knowledge of model and observation error is required to get the most from the observations with respect to the model physic. Delayed time and near real time along track sea level anomalies are assimilated in our systems. The model equivalent of the observations is obtained through various calculations, including the removal of the high temporal frequency signals found in the model SSH simulation. The spatially and temporally filtered model SSH is then compared to the sum of the SLA data and the MDT. The error assigned to the SSH is the sum of the processed SLA observation error, the MDT error and representativity error. The latter takes into account what part of the observed physic the model is able to represent. It is then dependent on the model configuration. As the model resolution increases and new physical parametrizations are introduced, like the tides in regional model, the computation of the model equivalent will change as well as the associated representativity error. In our system, spatially dependent error maps are prescribed and will be discussed. We will illustrate the importance of a fine knowledge of the observation information content and the errors to efficiently constrain the model solution.

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## 112 - Altimetry errors in sea surface height at wavelengths less than 100 km

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**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4515>

### **Abstract :**

The instrument noise from conventional pulse-limited altimeters has a magnitude of 1.5-2 cm when averaged/smoothed to 1-sec sampling interval. This noise has basically a white spectrum in wavenumber at a level of  $1 \text{ cm}^2/\text{cycle}/\text{km}$ , which is generally above the signal level at wavelengths shorter than 100 km, preventing the study of small-scale ocean features. The recent study by Xu and Fu (poster presentation in the Symposium) has demonstrated the effects of the noise on the estimation of the spectral slope at longer wavelengths. A goal of the SWOT Mission is to reduce the measurement noise of sea surface height (SSH) by two orders of magnitude for resolving ocean circulation features down to wavelengths of 15-20 km. The approach of SWOT is radar interferometry to make raw measurements at resolution of tens of meters. Because ocean surface current velocity is most sensitive to the noise level, it is more convenient to specify the SWOT performance requirement in terms of SSH slope. Given the finite slope error, which is specified at 1 micro-radian (rms) when smoothed to 15 km wavelength, the ultimate resolution and accuracy of ocean surface current velocity from SWOT is a key issue. Simulation results will be presented to illustrate possible approach to optimal sampling and estimation of small-scale ocean current velocity from SWOT.

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## 113 - Determining errors in the climate data record

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**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4486>

### **Abstract :**

Because of their demonstrated stability and unique coverage, sea level observations from altimetry are essential to building a climate data record (CDR). In order to fulfill NOAA's responsibilities for monitoring the stability of the current and future reference series of satellite radar altimetry missions (Jason-2, Jason-3, and Jason-CS), an observation strategy to determine drifts and offsets in the data record includes 1) rigorous inter-satellite comparisons with the Radar Altimeter Database System, 2) a Jason Radiometer Stability Monitoring System, 3) collaborations to monitor system stability with a global network of tide gauges, and 4) assessments of the sea level budget. First, we will present drift estimates from our extensive program of tide gauge comparisons, examining correction products for 8 phases during 6 altimeter missions (ERS-2, Envisat, GFO, TOPEX/Poseidon, Jason-1, and Jason-2). In this presentation, we will focus on fields with the greatest impact on stability. For example, we will discuss the impact on the climate data record of the application of wet troposphere corrections from models with a consistent reanalysis versus corrections from on-board radiometers. Second, one way to interpret the sea level CDR is to evaluate the relative contributions to sea level rise budget -- the major processes that alter the total volume of the ocean. With sufficient observations of sea level, ocean temperatures and salinity, and either land reservoirs or ocean mass, the total budget of global mean sea level can, in principle, be closed. Here we present seven years of altimetry observations of total sea level, upper ocean steric sea level from the Argo array, and ocean mass variations inferred from GRACE gravity mission observations and assess how closure of the sea level budget can contribute to determining errors in the global ocean observing system.

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## 114 - Error Estimation of Altimeter Wind Speed and Significant Wave Height

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**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4475>

### **Abstract :**

Any measured or modelled data set should be used with a clear idea about the amount of error (or uncertainty) associated with that data source. Error estimates are usually missing or not readily available. Traditionally, statistics regarding the difference between pairs of measurement types are considered enough to provide a statement regarding the accuracy of the data. For wind and wave data, the common practice is to use in-situ measurements as the truth. Being measured data themselves, they are suffered from errors. Therefore, any statement made using this approach may provide an idea about the relative 'quality' of various measurements but, for sure, it would not be a proper statement regarding the 'absolute error'. Triple collocation technique, which was introduced to the field of wind satellite measurements by Stoffelen (1998), has proved to be useful in random error estimates. After more than a decade since its introduction, the technique is gaining momentum and is now used for a wide range of applications. Janssen, et al. (2007) who also used the triple collocation technique, showed that it is possible to use the super-observation concept to estimate the errors associated to the ECMWF data and the individual 1-Hz ERS-2 altimeter data. This technique has two advantages: only two (rather than 3 in the case of triple collocation) collocated sources of data are needed and it is able to estimate the random error associated with the 1-Hz observation irrespective of the scales of the used data sources (while the results from the triple collocation technique are controlled by the selected scales). Both techniques were used to estimate the surface wind speed and significant wave height data from several altimeters and from the ECMWF model. The results will be presented and discussed.

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## 115 - Apparent Sea Level Variability and Trends Arising From the Choice of Orbit

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**Schöne Tilo**, German Research Centre for Geosciences, Helmholtz-Centre Potsdam

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4470>

### **Abstract :**

For every mission of the 20-year altimetric record several state of the art orbit solutions are available. This study aims at quantifying the error of local sea level variability and trends related to the actual choice of the orbit solution. We have started our analysis for the ERS-2 mission where we had an outstanding number of orbit solutions available. The focus has been on 7 different orbit solutions based on the same reference system and originating from three independent software packages and different orbit parametrizations. In order to investigate the temporal and spatial characteristics of the orbit related error, time series of radial orbit differences for each cycle have been calculated on a 1 by 1 degree grid for May 1995 to July 2003. Even though the global mean sea level trends are very close to each other the local trends differ by up to 1mm/year and seem to reflect drifts of the geocenters of one orbit solution relative to the other. Most differences contain annual components with amplitudes of up to 1.5 cm. The corresponding spatial patterns are again large scale and are related to shifts of the geocenter. Empirical orthogonal function (EOF) analysis shows that about 70% of the observed variability can be explained by motions between the geocenters of the analyzed orbits. A similar behaviour has been observed for the radial differences between two recent Topex, ENVISAT, and Jason-1/2 orbit solutions. Possible reasons for the observed orbit differences are discussed.

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## **116 - Spatial and temporal characteristics of the errors in Jason-2 and Jason-1 sea surface height measurements**

**Dr Ponte Rui** *Atmospheric and Environmental Research (AER)*

**Quinn Katherine**, Atmospheric and Environmental Research (AER)

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4461>

### **Abstract :**

For the first 20 cycles of the Jason-2 mission, the satellite was in the same orbit as the Jason-1 satellite, separated by only 55 seconds. Data from this initial tandem phase allows for direct comparison of the Jason-2/Jason-1 sea surface height measurements with the goal of investigating the differences as a function of location and time. These differences can be used to estimate the combined errors of the two altimeters. Spatially dependent rms differences generally increase towards the poles, with values of ~2cm near the equator going up to ~4cm at higher latitudes, similar to previous results based on data from TOPEX/Poseidon and Jason-1 tandem mission. Other regional dependences include higher values of ~3cm coinciding with the inter-tropical convergence zone. Errors in sea state bias and path-delay corrections are likely to contribute to the observed spatial patterns. The temporal autocorrelations of the Jason-2/Jason-1 differences show no significant values at any nonzero time lag, indicating uncorrelated noise in time. We also examine the spatial correlations along track, binned by location. In general, the spatial autocorrelations are sharply peaked at zero lags except for regions near the western boundary currents where the zero-crossing lag values can be up to ~150km and the e-folding length scales are ~20km. Corresponding wavenumber spectra are analyzed in terms of their slope and magnitude and compared to the observed sea surface height spectra to assess the relation between signal and noise in the Jason satellites.

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## **117 - Error estimates for a data assimilation system: what modellers really need**

**Dr Oke Peter** *CSIRO*

**Oke Peter**, CSIRO

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4412>

### **Abstract :**

Several ocean forecast systems have been developed under the Global Ocean Data Assimilation Experiment (GODAE) and its successor, GODAE OceanView. Each system uses data assimilation to combine model fields with a range of observations, including satellite altimetry, Argo, and satellite SST. Error estimates for all observations are important, and control the impact of each observation on the analysis and forecast system. Modellers prefer to over-estimate, rather than under-estimate, observation errors, for fear of over-fitting. Over-fitting an observation, particularly a bad observation, can degrade the quality of an entire forecast and compromise future forecasts for multiple subsequent forecasts. There are typically two components of error considered for each observation - an instrument error, and a 'representation' error. The representation error is typically the dominant component and depends on the application. Representation error of an observation for a coarse-resolution model is much greater than the representation error of the same observation for a high-resolution model. This is because for a coarse-resolution application, the observation 'represents' different processes and dynamics than the observation. If the observation represents eddies, for example, but the model doesn't, then the signal of the unrepresented eddy should be treated as an observation error. Even a perfect observation that faithfully measures reality should be assigned a representation error for a data-assimilating model. A description of how representation error is typically estimated for GODAE systems will be outlined, along with a series of examples demonstrating the impact of different estimates.

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# 118 - Investigating and reducing the differences between the satellite altimetry-based Global Mean Sea Level time series provided by the different processing groups

*Dr Cazenave Anny* LEGOS

**Henry Olivier**, LEGOS ; **Meysignac Benoit**, LEGOS ; **Ablain Michael**, CLS ; **Cazenave Anny**, LEGOS ; **Masters Dallas**, CCAR ; **Nerem Steve**, CCAR

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4360>

## **Abstract :**

Satellite altimetry-based global mean sea level (GMSL) time series provided by the different processing groups agree well in terms of trend over the whole altimetry era (1993-2010) but show significant differences at interannual time scale. In a recent paper, Masters et al (2012) investigated the effect of the different geophysical corrections and computing methodology adopted by the different groups, and found that the method of data averaging and minimum depth criteria seemed to be the main causes of discrepancies. Here we go one step further and attempt to discriminating between the best approach for averaging the satellite data to product the GMSL time series. We also address the effect of considering or not the shelf areas. For that purpose, we use two versions of the high-resolution MERCATOR ocean circulation model, one with data assimilation (temporal and spatial resolutions of 1-day and 0.25°) and the other without data assimilation (temporal and spatial resolutions of 3-day and 0.25°). We produce a set of synthetic sea surface height (SSH) data by interpolating the model data at the time and location of 'true' along-track satellite altimetry measurements. We focus on the Jason-1 and Jason-2 operating periods (i.e., 2001-2010). These synthetic SSH data are then treated as 'true' altimetric measurements. With this synthetic data set, we test the different averaging methods classically used by the processing groups: along-track averaging, simple gridding (on 2°x2° or 3°x1° grids) and more sophisticated gridding procedures. We also test the effect of considering or not shallow depths (<120 m) and of including or not the Caspian and Black seas, Hudson Bay, etc. Finally we also discuss the effect of the bias adjustment between the Jason-1 and Jason-2 missions, as adopted by the different groups

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## 119 - Error characterization of the global and regional Mean Sea Level evolution for climate applications.

*Mr Ablain Michaël* CLS

**Faugere Yannice**, CLS ; **Larnicol Gilles**, CLS ; **Cazenave Anny**, Legos/CNES ; **Meyssignac Benoit**, Legos/CNES ; **Picot Nicolas**, CNES ; **Benveniste Jérôme**, ESA/ESRIN

**Session:** Quantifying Errors and Uncertainties in Altimetry Data

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4446>

### **Abstract :**

With the satellite altimetry missions, the global mean sea level (GMSL) has been calculated on a continual basis since January 1993. 'Verification' phases, during which the satellites follow each other in close succession (TOPEX/Poseidon--Jason-1, then Jason-1--Jason-2), help to link up these different missions by precisely determining any bias between them. Envisat, ERS-1 and ERS-2 are also used, after being adjusted on these reference missions, in order to compute Mean Sea Level at high latitudes (higher than 66°N and S), and also to improve spatial resolution by combining all these missions together. The global mean sea level (MSL) deduced from TOPEX/Poseidon, Jason-1 and Jason-2 provides a global rate of 3.2 mm from 1993 to 2011 applying the post glacial rebound (MSL aviso website <http://www.jason.oceanobs.com/msl>). Besides, the regional sea level trends bring out an inhomogeneous repartition of the ocean elevation with local MSL slopes ranging from +/- 8 mm/yr. Thanks to studies performed in the framework of the SALP project (supported by CNES) since the TOPEX era and more recently in the framework of the Sea-Level Climate Change Initiative (SLCCI) project (supported by ESA), strong improvements have been provided on the estimation of the global and regional MSL over all the altimetry periods for all the altimetry missions. Thanks to these efforts, a better characterization of the errors impacting the evolution of the global and the regional MSL has been performed. These errors concern different time scales as the long-term evolution (mean sea level trend) which is likely the most important scale for climate studies. Studies already performed have shown that the global MSL trend error is 0.6 mm/yr in a confidence interval of 90%. But other time scales are also of great interest for climate studies such as the inter-annual signal and other periodic signals (annual and semi-annual periods). Such errors could reduce the accuracy of the observation of the global MSL variations at these scales and can make it difficult to provide interpretation of geophysical mechanisms at the origin of these inter-annual signals. In this paper, we propose to describe and quantify these errors as far as possible and discuss of their potential origin. The errors are also described in regards of the Climate User Requirements defined in the frame of the SLCCI project.

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## 120 - CryoSat-2 SARIN Mesoscale Observations of the Kuroshio Current

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**Galina Natalia**, Center for Polar Observation and Modelling, UCL ; **Dibarboure Gerald**, C.L.S. Space Oceanography Division

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4513>

### **Abstract :**

The principal mission goal of the European Space Agency's CryoSat-2 satellite, successfully launched 8th April, 2010 is to measure fluctuations in Earth's marine and land ice-fields. To that end, the CryoSat-2 main payload, SIRAL, is a normal incidence Ku-band synthetic-aperture radar altimeter with a second antenna, placed 1.16 m across-track, forming the interferometer baseline and allowing measurement of the across-track slope of the surface. The primary goal of the interferometer mode of SIRAL is to accurately measure the elevation of the sloping margins of the Greenland and Antarctic ice sheets. To meet this goal, the interferometer was designed to measure phase difference with an accuracy of 200 micro rad. However, pre-launch testing of the hardware indicated that a much higher accuracy might be achieved. Post-launch calibration of the CryoSat-2 interferometer over the ocean surface revealed that the interferometer across-track accuracy of 26 micro rad at 10 km in practice. Such accuracy has already allowed the first observations from space of the vector gradient of the ocean surface. In this paper we test the performance of the interferometric mode further, by examining the capacity of the instrument to detect, measure, and track mesoscale eddies and features in the region of the Kuroshio current.

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## 121 - Observing System Evaluation for the Black Sea: Focus on ARGOfloats and altimetry during 2005-2012

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**Grayek Sebastian**, ICBM, University of Oldenburg ; **Stanev Emil**, Institute for Coastal Research, HZG

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4509>

### **Abstract :**

Availability of ARGO float observations for the Black Sea varied strongly over the last years. Ongoing efforts increased and will further increase the number of deployed floats therefore an objective estimate of the enhancement of the quality of observing network may give useful information for further development strategies. An observation system evaluation (OSE) exploiting the combined observations from ARGO floats and altimetry during the period from 2005 up to now has been performed. The analyses are focused on the temperature, salinity and steric sea level elevation. Based on statistical background information derived from numerical simulations the OSE gives a quantitative estimate of the feasibility to reconstruct data of larger areas based on the availability, the accuracy and the spatial configuration of the measurements. Additional state reconstruction experiments were carried out in order to optimise the usage of the data, to check the plausibility of estimates derived from the OSE and for a detailed investigation of the utilised correlation patterns. During the investigated period measurements from altimetry and at least one float were available at all time. The highest density of observations including measurements from four and six floats were found during the time intervals from July-2006 to October-2010 and from March-2011 to January-2012, respectively. Preliminary observation system simulation experiments (OSSE) assuming idealised ARGO measurements with a regular distribution of floats gave support to the optimistic hypothesis that a state reconstruction of the deeper part of the Black Sea would be feasible within a reasonable error range based on observations from five floats. By investigating the mentioned two periods with relatively high density of measurements this hypothesis is reviewed under realistic conditions.

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## 122 - The geodetic mission phase of Jason-1: Benefits for regional marine gravity field modeling

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**Dettmering Denise**, DGFI ; **Bosch Wolfgang**, DGFI ; **Schmidt Michael**, DGFI

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4419>

### **Abstract :**

After more than 10 years mission lifetime, the Jason-1 satellite started its End-Of-Life (EOL) scenario at the end of April this year. The satellite was moved from its repeat orbit to a new geodetic orbit with a cycle duration of 406 days leading to a very dense observation distribution on the ground. This 'new' mission allows improving the resolution and the accuracy of the marine gravity field by using data acquired on the new tracks in combination with data from Cryosat-2 and other missions. In our approach we use sea surface height (SSH) profiles of different altimeter missions to compute high resolution regional gravity models over the ocean. In combination with sea surface topography information, the SSH is used to extract gravity potential information serving as input data for the estimation of the unknown model coefficients. The model approach is based on series expansions in spherical base functions, i.e. spherical scaling and wavelet functions in order to derive corrections to a given background model (e.g. GOCO02S). This contribution gives a short overview on the approach used for regional gravity modeling. Based on first data from the geodetic mission phase of Jason-1 EOL in combination with data of ERS-1 and Cryosat-2 gravity field calculations for selected regions are shown and compared to existing models and ship-borne gravity measurements.

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## 123 - Assessment of the first three generations of GOCE geoid models through their induced surface geostrophic currents

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**Sanchez-Reales Jose M**, University of Alicante ; **Andersen Ole Baltazar**, Danish National Space Center

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4373>

### **Abstract :**

With three generations and a total of eight geoid models provided by GOCE using various data from the first year of observations, it is a good time to evaluate the differences between these models in order to assess the skills of these in predicting surface geostrophic currents. In this investigation we focus on the Central Western Pacific Ocean, where a strong gravity signal together with the confluence of three major currents make it a challenging and representative frame for the purpose. We found, that the use of altimetric data for the background model for the first direct geoid solution from GOCE creates much less noisy results when used to derive a mean dynamic topography. However some signals could be cancelled when combining the altimetric mean sea surface with this geoid model. The newest release of GOCE (release three) is generally found to provide the less noisy models between those with no altimetric a-priori information. Main differences between the models are located at those areas with the strongest gravity signal. When filtering all the eight GOCE derived mean dynamic topographies with an Edge Enhancing Diffusion filter, the derived geostrophic currents are depicted to be quite similar for all the eight models.

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## 124 - Southern Ocean 4-D circulation: combining altimeter and Argo float data

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**Zajaczkovski Uriel**, Scripps Institution of Oceanography ; **Gille Sarah**, Scripps Institution of Oceanography ;  
**Mazloff Matthew**, Scripps Institution of Oceanography

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4484>

### **Abstract :**

Studies of temporal variability and eddy processes in the Southern Ocean depend on knowing the time-mean background circulation, which is not inferred solely by altimetry and was not well-sampled in situ prior to the start of the Argo program. Accurately describing the circulation of the Antarctic Circumpolar Current and detecting large-scale changes in its density structure during the last decade is key to understanding the role of the Southern Ocean in the global climate system. The increasing array of Argo floats, in combination with satellite altimetry measurements, provides a new opportunity to assess this problem. We present a new estimate of the mean and temporal upper ocean circulation, density ( $\rho$ ), temperature (T) and salinity (S) fields of the Southern Ocean by combining in situ Argo float measurements and satellite altimeter data. Eddy variability is estimated using sea surface height (SSH) anomaly maps and linear regression coefficients of SSH anomalies onto anomalies of T, S and  $\rho$  as a function of position and depth. On average, 40% of the anomaly variance can be explained by the altimeter. Higher values can be found at the core of the Antarctic Circumpolar Current (1000db) and lower percentages near the surface (above 300db), where other processes mask the geostrophic signal. The removal of the altimeter signal from T, S and  $\rho$  produces more stable and less noisy estimates of the mean fields of the Southern Ocean and a substantial improvement of the signal to noise ratio is achieved. The 4-D fields of T, S and  $\rho$  show the highly filamented nature of the Antarctic Circumpolar Current in greater detail than in traditional spatially averaged climatologies, which tend to oversmooth fronts. The estimated mean dynamic topography (MDT) will be compared with two recent MDT products along with and MDT diagnosed from a Southern Ocean state estimate.

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## **125 - Mapping of the Absolute Dynamic Topography from multi-satellite along track Sea Surface Height and GOCE geoid height: a direct method.**

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**Mulet Sandrine**, CLS, Space Oceanography Division ; **Rio Marie-Hélène**, CLS, Space Oceanography Division ; **Faugere Yannice**, CLS, Space Oceanography Division ; **Pujol Marie-Isabelle**, CLS, Space Oceanography Division

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4445>

### **Abstract :**

Since 20 years, the altimetry missions have revolutionized the observation of the ocean circulation. Whereas altimetric data only give information about the Sea Surface Height (SSH), the interesting quantity for the study of the dynamic of the ocean is the Absolute Dynamic Topography (ADT), i.e. the difference between the SSH and the geoid height. Because the geoid is not known with enough accuracy at high resolution, the ADT is classically computed by an indirect method: a Mean Sea Surface (MSS) is first removed to the SSH, then a Mean Dynamic Topography (MDT) is added. The computation of these two intermediate quantities (MSS and MDT) makes this method complex and introduces errors, especially when the MSS loses accuracy (eg. in the high latitude regions or for non-repetitive altimetry mission). With the Gravity Field and Steady-State Ocean Circulation (GOCE) mission and its perspective to reach a 100 km resolution geoid with a 1-2 cm accuracy, the ADT computation has been revisited. In this study we propose a direct method to map the ADT using the EGM\_TIM\_R3 geoid model computed in the framework of ESA HPF (High Processing Facility) from one year of GOCE data. The EGM\_TIM\_R3 geoid height model is subtracted to the SSH to compute along track ADT. Errors associated with along track ADT field are evaluated taking into account the omission and the commission geoid errors as well as the errors from altimetry measurement. Then the multi-satellite ADT are combined through an optimal analysis to compute a regular gridded ADT map. Different inputs and parameters of the optimal analysis have been tested. These ADT maps have been compared with the classical indirect method and show promising results.

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## 126 - Dominance of Eastward Currents in Southern Hemisphere Oceans: the Impact of GOCE Data

**Ms Menezes Viviane** *University of Tasmania*

**Menezes Viviane**, University of Tasmania ; **Bingham Rory**, Newcastle University ; **Vianna Marcio**, VM Oceanica ; **Phillips Helen**, University of Tasmania

**Session:** The Geoid, Mean Sea Surfaces and Mean Dynamic Topography

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4408>

### **Abstract :**

One of the main goals of the Gravity and steady-state Ocean Circulation Explorer (GOCE) satellite mission, launched in 2009, is to improve the previous estimates of the global ocean circulation structures determined from Mean Dynamic Topographies (MDTs). Several studies published to date suggest that the GOCE-based MDTs and their respective mean geostrophic circulations (MGCs) are superior to those obtained from GRACE (Gravity Recovery and Climate Experiment)-only data. These studies focus mostly on the circulation of the North Atlantic and North Pacific oceans with emphasis on the strong western boundary current systems. No detailed assessment has yet been made to determine the impact of the GOCE in the southern hemisphere (SH) upper-ocean circulation especially in the subtropical region. It is generally recognized that the SH circulation is still not well established even at large scales, and the new GOCE and GRACE products can contribute to increase our understanding of the dominant currents of these regions, which may have even greater impact on the global climate than the NH counterparts. In the present work, we compute four global GOCE-derived MDTs with a 0.25 x 0.25 degree spatial grid based on two GOCE geoid models (TIM3, GOCO02S) and two mean sea surfaces (CLS01, CLS11) using the standard spectral approach (MSS minus Geoid). The TIM3 model with degree and order (d/o) 250 belongs to the third generation GOCE-only time-wise solution and is based on more than one year of GOCE data, while the GOCO02S with d/o of 240 is from the second generation of GOCE-GRACE blended models and is based on 8 months of GOCE and 6.5 years of GRACE. Since both CLS01 and CLS11 MSS are referenced to same time period 1993-1999, our four GOCE-based MDTs refer to this period. Although these MDTs do not have the large-amplitude striation-type noise that plagued all of the GRACE-only MDTs it is still necessary to apply spatial filters to eliminate commission errors. Since Gaussian-type filters strongly smooth the MDT gradients that we are interested in, we applied the more efficient filtering techniques based on Singular Spectrum Analysis. Additionally, the MGCs were calculated by use of the Anderssen-Hegland averaging scheme for estimation of derivatives, which is able to filter out the well-known high amplitude noise of the standard finite-difference method. Comparison with previous GRACE-only MGCs show that GOCE permits retrieval of currents with much higher intensities, e.g., the Agulhas Current reaches 50-60cm/s in the GOCE-only solution compared with 20cm/s in the GRACE-only MGCs. GOCE-based MGCs show all known SH current systems in a very clear way: the weak Brazil, Falkland, the Zapiola Anticyclone, Tristan da Cunha, Benguela, and South Atlantic Currents, the Agulhas and its retroflexion, the East Madagascar, the South Indian Countercurrent, the East Australian, the South Pacific Tropical Countercurrent, Humboldt and South Equatorial Currents and the Antarctic Circumpolar. What the satellite-geodetic data applied to determination of global geostrophic circulation is showing is the dominance of eastward flows in the SH oceans, resembling the wind systems observed in the SH of major planets (e.g. Jupiter).

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## 127 - Reaching sub-centimetre range noise on Jason-CS with the Poseidon-4 continuous SAR interleaved mode

**Dr Phalippou Laurent** *Thales Alenia Space*

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4560>

### Abstract :

The benefit of the SAR mode for ocean altimetry was identified back in 1998 in an empirical manner [1]. In 2007, the mathematical framework including accurate numerical re-tracking of SAR echoes was given in [2]. The predicted accuracy for range was below the centimetre for a SIRAL/Cryosat configuration. With the launch of Cryosat-2 and thanks to the availability of SIRAL-2 altimeter raw data, it was demonstrated in [3] that the range and significant wave heights noises were in very good agreement with the theoretical expectations of [2]. Similar results were also presented by scientific groups at the OSTST 2011. This rapid breakthrough has triggered a profound interest among worldwide scientists as the range noise improvement compared to conventional altimeters can be reduced by a factor 2 for SIRAL and a factor of 3 for future missions as Jason CS. Jason CS, CS standing for continuity services, is the successor of the Jason 1-3 reference missions. The primary objective of Jason CS is to ensure, as a minimum, the same level of data quality. This operational need has been taken as the driver for the design of Poseidon-4, the altimeter of Jason CS. In particular, the along track sampling of the ocean shall be maintained identical to previous Jason series, i.e. around 2 kHz in Ku band and around one every 7 pulses in C band. A SAR mode is also requested for Jason CS, but primarily this mode was thought to be activated only in coastal areas. With the clear in flight demonstration of the SAR mode capability over open ocean brought by SIRAL-2, it became clear during the early study phases of Poseidon 4, that a continuous SAR mode operation was desirable while care shall be taken not to perturb the operational mission objectives. To respond to that constraint, TAS proposed to ESA to introduce a SAR mode operating in the so-called "interleaved mode" where, at the difference of SIRAL, echoes from the ocean are received in between each transmitted pulses. In addition it is also demonstrated that the Pulse Repetition Frequency can be much lower (about a factor 2) than the Nyquist Doppler bandwidth. This paper will present the rationale for the functioning point of the altimeter and the expected performances in terms of range and SWH accuracies. The results are supported by accurate simulations, and by correlations with the results obtained on in flight SIRAL-2 data. Moreover, sensitivity to antenna pointing and the capability to extract the pointing from the data will also be presented and discussed. [1] Jensen and Raney, Delay/Doppler Radar Altimeter: Better measurement precision. IGARSS 1998. [2] Phalippou and Enjolras, Re-tracking of SAR altimeter ocean power-waveforms and related accuracies of the retrieved sea surface height, significant wave height and wind speed. IGARSS 2007. [3] Phalippou and Demeestere : Optimal re-tracking of SAR altimeter echoes over open ocean: Theory versus results for SIRAL2 data. OSTST 2011, San Diego, USA

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# 128 - An improved objective analysis scheme of scanning radiometer measurements to compute the water vapor path delay for altimetry

*Dr Stum Jacques* CLS

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4550>

## **Abstract :**

Permanent gases in the atmosphere induce propagation delay to pulses emitted by satellite-borne radar altimeters to the ocean surface : the range measurement has to be corrected for this effect. The path delay due to water vapor (PD) varies from 1 cm in dry, cold air, to 40 cm in wet, hot air, and is highly variable in space and time. It has long been recognized that the most accurate way to measure it is to fly a microwave radiometer together with the radar altimeter, sensing the atmosphere at frequencies near the 22.235-GHz water vapor absorption line, along the altimeter path (i.e., nadir viewing). A second possibility is to compute the PD from meteorological models, but with poorer accuracy because such models often cannot map the atmospheric humidity short space and timescales. An alternate approach has recently been proposed by Stum et al. (IEEE Trans. Geosci. Remote Sens., 2011): it combines, through an objective analysis (OA) method, all existing scanning radiometer columnar water vapor observations, to derive the PD for any altimeter mission. This approach is motivated by the need to offer an improved PD correction for altimeter missions that do not embark a microwave radiometer, but also by the potential benefit to sea level rise studies using altimeter missions for which the long term stability of both the aboard radiometer PD and the meteorological model PD are uncertain. Improvements of the method will be presented, taking into account more sensors, refinements of the calculation of the statistical properties of the field of (sensor - ECMWF) PD anomalies to be analyzed, and of the sensor errors. More extensive validation results will also be shown, including statistical crossover analysis and spectral analysis. Its applicability to near real time altimeter processing (including Jason-2 and Cryosat-2) will be assessed.

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## 129 - A Comparison of Altimeter Noise from Double Retracked Geosat, ERS-1, Envisat, CryoSat and Jason-1 Data

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**Sandwell David**, Scripps Institution of Oceanography ; **Garcia Emmanuel**, Scripps Institution of Oceanography ; **Smith Walter**, National Oceanic and Atmospheric Administration

**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4462>

### Abstract :

The largest error source in the construction of marine gravity models from satellite altimetry is due to errors in picking the arrival time of the return radar echo. The shape of this echo depends on 3 main parameters of arrival time, rise time (or SWH), and amplitude. In a previous study [Sandwell and Smith, 2005] we showed that for the standard pulse-limited radar mode, the arrival time and rise time are highly correlated during the non-linear parameter estimation, especially when the waveform data are weighted by the inverse of the power in each gate. This correlation in the 3-parameter retracking results in less than optimal estimates of arrival time. One way to improve the arrival time is to perform a 2-parameter adjustment where the rise time is held to a fixed value based on the along-track smoothed value of the rise time from a 3-parameter retracking. This double retracking approach improved the range precision of Geosat and ERS-1 data by a factor of 1.5 and reduces the adverse effects of increasing noise in range with increasing SWH. Here we have performed the same double retracking approach on 6 types of data including SAR-mode data from CryoSat (the Jason-1 analysis will be completed at the time of the meeting). For Envisat and CryoSat LRM we also achieve the factor of 1.5 in range precision as measured by the standard deviation of the range computed over a 1 second interval. At 2 m SWH, CryoSat LRM has the best range precision of 42.7 mm while ERS-1 has the worst precision of 61.8 mm. We attribute this 1.44 improvement in range precision to the nearly factor of 2 increase in pulse rate of CryoSat LRM with respect to ERS-1. We retracked the waveforms of the CryoSat L1b SAR data using an analytic formulation. The analytic waveform model is derived under the approximations of nadir pointing, single look, and along-track SAR focusing. When the off-nadir pointing angle is less than 0.12°, the model matches the numerical waveform models from the SAMOSA development. We use this approximate model and its analytic derivatives to perform 3-parameter and 2-parameter retracking of the SAR data in the same North Atlantic region. The 3-parameter retracking results in a range precision of 49.5 mm which is a factor of 1.3 times better than the 3-parameter retracked CryoSat LRM data. However, we find no improvement in the 2-parameter retracked SAR data and note that the range precision of the retracked SAR data is slightly worse than the double retracked LRM data (Table). This lower range precision could be due to the approximate shape of the model waveform which does not include the 'toe' seen in the actual L1b SAR data. An alternate explanation is that the number of effective looks in the SAR-mode data is lower than the LRM-mode data so the SAR-mode waveforms have an inherently higher noise level. The overall improvement in range precision of the newer non-repeat altimeters (Envisat, hopefully Jason-1, and CryoSat) with respect to the older non-repeat altimeters (Geosat and ERS-1) will directly translate into improvements in the global marine gravity models.

TABLE - Altimeter Noise (mm)

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Altimeter	3-PAR @ 2 m	2-PAR @ 2 m	2 PAR @ 6 m
Geosat	88.0	57.0	105.4
ERS-1	93.6	61.8	111.8
Envisat	78.9	51.8	88.6
Jason-1	-	-	-
CryoSat LRM	64.7	42.7	71.7

CryoSat SAR 49.5 49.7 110.9

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Standard deviation of retracked 20 Hz height estimates with respect to EGM2008 (mean removed). The analyzed data have a 1 year time span and are from a region of the North Atlantic with relatively high sea state. The values represent the median of millions of estimates over a 0.4 m range of SWH. The 10Hz Geosat estimates were scaled by 1.41 to approximate the errors in at a higher sampling rate.

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## 130 - Precise Estimates of Ocean Surface Parameters from CryoSat

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.avisio.oceanobs.com/index.php?id=1719&uid=4458>

### **Abstract :**

The CryoSat-2 radar altimeter provides the first opportunity to investigate whether using measurements from a SAR-mode (Synthetic Aperture Radar) altimeter over the ocean to estimate the wind-speed and wave height results in an improvement in their precision. Theory suggests that SAR-mode will provide a twofold improvement on conventional pulse limited altimetric measurements, however the theory does not account for the contribution to the echo power from off nadir returns, whose effect is uncertain. In this study we take data collected in CryoSat-2's SAR-mode over a section of the Atlantic. CryoSat-2's SAR data is formed by processing pulse limited echoes. By comparing the data before it has been SAR processed (Calibrated Full Bit Rate data) with the data after it has been processed to form SAR data, we directly compare pulse limited and SAR data. We present methods to re-track the CryoSat-2 SAR and pulse limited data, based on an analytical model combined with numerical integrations. For both cases we account for CryoSat-2's elliptical antenna pattern, antenna mis-pointing, ocean wave height and variations in satellite altitude. The SAR-mode re-tracker also accounts for the multi-looking, which is comprised from returns from off nadir angles. We compare the SAR-mode and pulse limited estimates of oceanographic parameters, derived from the re-trackers, to show the improvement gained from using a SAR-mode altimeter over the ocean.

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## **131 - Development and performances of a numerical method for re-tracking altimeter SAR echoes over open ocean**

*Dr MOREAU Thomas CLS*

**MOREAU Thomas**, CLS ; **AMAROUCHE Laiba**, CLS ; **THIBAUT Pierre**, CLS ; **POISSON Jean-Christophe**, CLS ; **BOY François**, CNES ; **PICOT Nicolas**, CNES

**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4447>

### **Abstract :**

The Delay Doppler/SAR radar altimeter is expected to provide better performances than a conventional radar altimeter: higher azimuth resolution and measurement precision. The current CryoSat-2 flight data shall allow to assess the theoretical performance of the SAR radar altimeter. However, no retracking algorithms have been yet implemented in operational production chain for reprocessing, analyzing and interpreting SAR radar altimeter echoes over ocean. There exist essentially two alternative ways of developing a model for the SAR echo power: the solved-analytical model and the numerical one. We proceed with computing numerically the derivatives of the mean return power with respect to the retrieval parameters (e.g., epoch, significant wave height, ?). The idea of this approach is to approximate the derivative by a finite difference involving a database of pre-simulated echo models in the retracking schemes. This paper explains the new developed technique - the end-to-end SAR radar altimeter simulator and the numerical retracking method - and presents the corresponding performance over ocean.

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## **132 - Pulse-to-pulse correlation in CryoSat SAR echoes from ocean surfaces: implications for optimal pseudo-LRM waveform averaging**

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**Scharroo Remko**, Altimetrics LLC

**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4444>

### **Abstract :**

Temporal correlation among successive pulse echoes backscattered from the ocean surface is an important design consideration in radar altimetry of sea surface heights. The maximum rate at which one may obtain statistically uncorrelated looks at the surface, and hence the maximum speckle noise reduction achievable by averaging over any given time, is limited by the decorrelation time. Prior to CryoSat, altimeter missions have pulsed continuously with pulse repetition frequencies (PRFs) of 1 to 4 kHz, expected to yield an uncorrelated echo sequence, and have employed simple incoherent averaging of the power in successive echoes to obtain mean radar echograms from which range, backscatter, and the standard deviation of ocean surface heights are estimated. This scheme will be called conventional altimetry in this paper. CryoSat, when in its SAR mode, pulses fast enough to receive strongly correlated echoes, providing data sufficient to investigate in detail the temporal correlation between successive echoes. We present our findings on echo correlation and their implications for optimal averaging of echoes to produce a 'pseudo-LRM' product. The operation plan for Sentinel-3 and baseline scenario for Jason-CS is to operate in SAR mode in the coastal zone and LRM mode in the open ocean. These modes, as on CryoSat, would be exclusive. Because absolute height calibration of altimeters is mainly to tide gauges, which are necessarily at coastlines, it will be necessary to turn SAR echoes into 'pseudo-LRM' waveforms in order to compare the coastal calibration to the open ocean data collection mode. The question of how best to do this hinges on the pulse-to-pulse correlation explored in this paper.

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## 133 - Finer, Better, Closer: Advanced capabilities of SAR altimetry in the open ocean and the coastal zone

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4396>

### **Abstract :**

SAR altimetry promises to deliver FINER along-track spatial resolution, BETTER range retrieval performance and valid data CLOSER to the coast than is possible with the conventional pulse-limited altimeters that have flown for more than 20 years. The Cryosat-2 SIRAL altimeter represents the first opportunity to test these notions with observations, thanks to altimeter data collected in SAR mode over a number of ocean and coastal regions. The Cryosat-2 SAR mode is a precursor for the SRAL altimeter on the GMES Sentinel-3 Surface Topography Mission (STM) and of the SAR altimeter on the Jason-3 follow-on mission, Jason-CS. The improved capabilities of SAR altimetry open appealing prospects in particular for coastal oceanography and ocean bottom topography applications. Cryosat-2 has been providing SAR altimeter waveforms to the science community continuously since July 2010. This paper presents analyses of the retrieval performance for sea surface height (SSH) and significant wave height (SWH) of Cryosat-2 SAR mode compared to Jason-2 over the open ocean and in various coastal regions. The paper discusses how Cryosat-2 L1B SAR waveforms are retracked using theoretical models to retrieve ocean geophysical parameters from peaky SAR waveforms. We consider the sensitivity of SAR mode altimetry to antenna mispointing and to ocean wave conditions and quantify the retrieval errors and biases in Cryosat-2 SAR mode data using independent validation datasets from in situ and other independent sources. This comprehensive assessment of Cryosat-2 SAR altimetry in the open ocean and the coastal zone helps to highlight opportunities and challenges introduced by this step change in altimeter technology when it comes to building long-term altimetric records.

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## **134 - Impact of GDR\_D standards on SSB corrections**

***Dr Tran Ngan*** CLS

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4378>

### **Abstract :**

Due to the empirical nature of the SSB models, even with approaches based on SSH differences, one cannot totally eliminate all geographically correlated signals coming from sources other than sea state. For instance, orbit solutions can contain geographically correlated errors that can leak into SSB models through geographic correlation with sea state distribution. The purpose of this analysis is to evaluate the impact of the new GDR\_D standards on the SSB corrections across the different altimetry missions.

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## 135 - Numerical Solution for the Retracking Algorithm: Performances on Conventional Altimeter Waveforms

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4556>

### **Abstract :**

In altimetry, precise estimates of geophysical parameters are obtained by fitting a theoretical model to the measured waveform. This operation called "retracking" is carried out in most of past and present conventional altimeter missions (Topex, Envisat, Jason-1 and Jason-2) by an unweighted Least Square Estimator derived from the Maximum Likelihood Estimator (MLE) (Dumont 1985; Rodriguez 1988). The Brown model is commonly used to represent the return echo acquired by the altimeter over deep ocean surfaces. In all the current operational retracking algorithms, a Gaussian approximation of the Point Target Response (PTR) is considered allowing to derive a compact analytical formulation for the model and for its derivatives that are used in the iterative Newton-Raphson LSE algorithm. However, the improved performance of computers has led us to review this strategy by computing numerically the derivatives (finite difference) of the Brown model which can now account for the real shape of the PTR. This paper explains the new developed technique and presents the corresponding performance over ocean on Jason-2 data. We also show how this method can be very valuable to retrack Topex data and SAR waveforms.

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## **136 - CryoSat Processing Prototype, LRM and SAR Processing on CNES Side and a Comparison to DUACS SLA**

**Mr Boy François** CNES

**Boy François**, CNES ; **Desjonquères Jean-Damien**, CNES ; **Halimi Abderrahim**, INPT ; **Thibaut Pierre**, CLS ; **Moreau Thomas**, CLS ; **Picot Nicolas**, CNES

**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4380>

### **Abstract :**

In the frame of the Sentinel3 project, CNES is involved in the overall topography payload product quality. Like CryoSat, Sentinel3 embarks an altimeter including a conventional LRM mode and a SAR mode. While there is a long experience of LRM data processing, SAR nadir looking data are new and will need extensive prototype development and an in depth validation. Thanks to CryoSat project, acquisitions of SAR data are performed routinely over dedicated areas (Algulha current, North Atlantic, ...). Those SAR data are very valuable to assess the quality of the SAR processing methods currently under development. For example, a Cryosat Processing Prototype (C2P) has been developed on CNES side to prepare the CNES SAR ocean retracking study. In order to validate our prototype, the analysis has been conducted first on the LRM data, then on LRM\_look\_like data reconstructed on ground with the SAR data (results presented in the frame of OSTST 2011). This year, this paper will present the results obtained with SAR CryoSat data during April-June 2012 using a CNES retracking algorithm based on a numerical model. SAR sea surface information will be compared to pseudo LRM information to assess the SAR results accuracy. In addition, the continuity between LRM and SAR sea level measurements will be analysed.

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## 137 - An analytical model for Doppler altimetry and its estimation algorithm

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**Session:** Instrument Processing

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4366>

### Abstract :

The concept of delay/Doppler radar altimeter has been under study since the mid 90's, aiming at reducing the measurement noise and increasing the along-track resolution in comparison with the conventional pulse limited altimeters. This paper introduces an analytical model of the mean backscattered power waveform acquired by a radar altimeter operating in SAR mode, as well as an associated least squares estimation algorithm. As for conventional altimetry, the mean power can be expressed as the convolution of three terms: the flat sea surface response, the sea wave height probability density function and the time/frequency impulse response of the radar. An important contribution of our work has been to derive an analytical formula for the flat sea surface response associated with Doppler altimetry. The double convolution defining the mean power can then be computed numerically. The resulting single-look model depends on three parameters: the epoch, the sea surface wave height and the amplitude. A multi-look model is obtained by summing all the reflected power from the along track beam surface of interest after applying appropriate delay compensation. The second contribution of our work concerns the estimation of the parameters associated with the single and multi-look analytical Doppler models. A least squares approach is investigated by means of the Levenberg-Marquardt algorithm (which does not need computing the exact model derivatives). Simulations conducted on synthetic altimetric waveforms allow the performance of the proposed estimation algorithm to be appreciated. The proposed analytical model (and the associated estimation algorithm) are finally compared with other models developed by the Centre National d'Etudes Spatiales (CNES) and the company Collecte Localisation Satellites (CLS) both located in Toulouse, France. The analysis of a huge number of Cryosat waveforms shows an improvement in parameter estimation when compared to the conventional LRM mode altimeter. These results are very promising.

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## **138 - Assimilation of altimeters and ASAR wave data in the wave model MFWAM : preparation study related to CFOSAT mission**

**Dr Aouf Lotfi** *Météo France*

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**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4549>

### **Abstract :**

Ocean waves play an important role in the exchange processes (heat and momentum fluxes) at the air-sea interface. Therefore, it is important to better understand physical processes at the interface and to have a better knowledge of the sea-state itself. Since March 2011 the new operational wave model MFWAM of Meteo-France is assimilating altimeters significant wave heights (from Jason-1, Jason-2, and Envisat) and the level 2b directional wave spectra from Envisat-ASAR. The goal of this paper is the validation of 1-year of wave parameters from MFWAM in comparison with buoys and altimeter independent data. It is clearly showed that the accuracy of wave parameters (wave height and wave period) is significantly improved in both the period of analysis and forecast. The assimilation scheme is adjusted by using dedicated correlation length related to the wave prediction errors and the wavelength cut-off used for the ASAR directional wave spectra. Further results concerning the impact of using satellite wave observations in case of high waves are also discussed and analyzed. In order to prepare the CFOSAT satellite mission, assimilation tests have been performed by using synthetic wave spectra obtained from the simulator of the SWIM instrument. CFOSAT (Chinese and French Oceanic SATellite) is a mission dedicated to the measurements of ocean surface waves and wind vectors. The satellite will embark a Ku band rotating fan beam scatterometer and a Ku band real aperture radar called SWIM with a 6 beams rotative antenna. The complementary use of SWIM, ASAR and altimeters wave data in the wave forecasting system has been also investigated.

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## **139 - Beyond the sensor, linking the altimeter infrastructure from the antenna to the public**

**Dr Jacobs Gregg** *Naval Research Laboratory*

**Jacobs Gregg**, Naval Research Laboratory ; **John Lillibridge**, National Oceanic and Atmospheric Administration

**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4479>

### **Abstract :**

The operational implementation of altimeter observations has been a long term goal for many years. It is not feasible in and of itself because the satellite data must not only be produced on a regular basis, it must be provided to result in information on which people make regular decisions. By ensuring the data is used for significant application, the end to end application is enabled in which the altimeter data becomes a critical link. Linking the altimeter sensor to consumption has become an endeavor requiring multiple agencies throughout the globe. The present state of data stream implementation and flow of the data between groups is examined that results in a wide range of products being provided. The end results range from global ocean environment forecasts, hurricane prediction to safety of navigation through the ocean wave field. Here we review the present state to which recent developments have brought us. This includes bringing the altimeter observations from the data sets that are constructed daily by many groups to the point at which analyzed products are constructed and following on to forecast information. The present state of development is a very positive demonstration as efforts are turning toward whole Earth system prediction. The work within the altimeter community has provided an essential part of enabling the next grand challenge development to provide regular Earth system forecasts out to seasons and years.

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## 140 - The Use of NRT Altimeter Wind and Wave Products at ECMWF

**Dr Abdalla Saleh** *ECMWF*

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**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4477>

### **Abstract :**

Wind and wave measurements from radar altimeters are invaluable source of information for operational ocean-wave as well as (surface-) atmospheric predictions. Altimeter significant wave height (SWH) is assimilated directly in the ocean wave component of the ECMWF Integrated Forecast System (IFS). SWH from altimeters onboard ERS-1/2, Envisat and Jason-1/2 were/are assimilated. The positive impact of such assimilation is not limited to the ocean wave products but extends to the atmosphere through the two way coupling. Altimeter wind and wave data are also used to assess the performance of the IFS. They are also used for the verification of the model updates. If there is an issue in the model or the update, this is usually reflected in the comparison statistics between the model and the altimeter products. Such uses will be described and discussed with reference to related cases.

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## 141 - Predictability of the Middle Atlantic Bight Shelf Break Front given Satellite Data

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**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4451>

### **Abstract :**

The Middle Atlantic Bight (MAB) continental shelf break region features strong horizontal and vertical gradients in water properties characterized by a permanent and highly variable thermohaline front. In this work we evaluate to what extent assimilation of satellite data can improve prediction of mesoscale and submesoscale variability in the Mid Atlantic Bight Shelf Break Front using variational data assimilation in the Regional Ocean Modeling System (ROMS). The observations considered in the assimilation experiments are along-track Sea Surface Height anomalies and individual passes of infrared satellite Sea Surface Temperatures. A set of hydrographic observations in the shelf break area collected during 2006 and 2007 are used to evaluate to what extent the assimilation of the satellite data can improve nowcast of the observed variability. In addition, ROMS forecast initial conditions are generated every 3 days by assimilating the available satellite data 3 day prior to the forecast initial time. It is shown that assimilation of satellite information only (SST and SSH), if adequately projected to the subsurface, can improve nowcast of the true subsurface ocean state (as depicted by the not assimilated hydrographic data) and therefore improve forecast skill of the full state vector.

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# 142 - Application of Near-Real Time Satellite Altimetry for Initializing the Ocean Component of Coupled Tropical Cyclone-Ocean Forecast Models

*Dr Yablonsky Richard* University of Rhode Island, Graduate School of Oceanography

**Yablonsky Richard**, University of Rhode Island, Graduate School of Oceanography ; **Ginis Isaac**, University of Rhode Island, Graduate School of Oceanography

**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4439>

## **Abstract :**

Satellite altimetry is crucial for properly initializing the ocean component of coupled tropical cyclone-ocean forecast models. The U.S. National Oceanic and Atmospheric Administration's (NOAA's) and the U.S. Navy's operational tropical cyclone forecast models, namely the Hurricane Weather Research and Forecast (HWRF) model, the Geophysical Fluid Dynamics Laboratory (GFDL) model, and the Navy's version of GFDL (GFDN) are currently coupled to a version of the Princeton Ocean Model (POM) that has been modified at the University of Rhode Island (URI) to simulate the coupled interaction between a tropical cyclone and the underlying ocean during a five-day forecast (POM-TC). The POM-TC ocean is initialized at the beginning of the forecast using a diagnostic, feature-based model that modifies a monthly climatological temperature and salinity field by assimilating information from near real-time satellite altimetry maps to adjust the position, shape, and strength of major oceanic fronts and eddies, such as the Loop Current and Loop Current eddies in the Gulf of Mexico. Accurate initialization of these fronts and eddies is crucial for simulating the sea surface temperature cooling response to the tropical cyclone wind forcing and the subsequent intensity response of the tropical cyclone to the modified sea surface temperature via modified enthalpy flux at the air-sea interface. Recent advances have been made in the development of global ocean circulation models that run continuously, such as the HYbrid Coordinate Ocean Model (HYCOM), and the data assimilation products they employ, such as the U.S. Navy Coupled Ocean Data Assimilation (NCODA) system. Hence, efforts are now being undertaken to assess whether HYCOM + NCODA, which continuously assimilates satellite altimetry (in addition to available in situ data) may provide a superior ocean initialization to the feature-based model used operationally in the POM-TC component of HWRF, GFDL, and GFDN. As part of this effort, it is important to understand the details and the limitations of the altimeter observations (and/or derived products) assimilated into NCODA and other ocean data assimilation systems.

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## **143 - Assessment of Cryosat near-real-time sea level anomaly data using HF radar and SST imagery**

**Dr Griffin David** CSIRO

**Griffin David**, CSIRO ; **Cahill Madeleine**, CSIRO

**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4417>

### **Abstract :**

It is widely accepted that four nadir-sampling altimeters are required to adequately map the ocean mesoscale. The last day that four altimeters were used in the Australian near-real-time analysis system was 17 February 2012. At the time of writing (16 May 2012) we are only using two (Jason-2 and Cryosat) and our maps are very clearly suffering. We look forward to using Jason-1 geodetic mission, HY-2 and AltiKa and are doing what we can to preserve the reputation of altimetry in the near-real-time end-user community during this unfortunate (but not unanticipated) data drought. We are especially grateful to the ESA Cryosat mission and NOAA for making near-real-time ocean data available (since Dec 2011) even though it is not a mission requirement. The impact of using Cryosat as a companion to Jason-2 is that the data distribution in a ~10d window has a very uneven density. In places the data density is higher than provided by the Jason-1,2 tandem but elsewhere the data is from Jason-2 alone. In this talk we will use HF radar data (in addition to drifters and SST imagery) to validate the short length-scale features that can be mapped using the closely-spaced Cryosat tracks.

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## 144 - Could Satellite Altimetry Have Improved Early Detection and Warning of the 2011 Tohoku Tsunami?

*Dr Hamlington Benjamin University of Colorado at Boulder*

**Hamlington Benjamin**, University of Colorado at Boulder ; **Leben Robert**, University of Colorado at Boulder ; **Godin Oleg**, NOAA ; **Gica Edison**, NOAA Center for Tsunami Research ; **Titov Vasily**, NOAA Center for Tsunami Research ; **Haines Bruce**, Jet Propulsion Laboratory ; **Desai, Shailen**, JPL

**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.avisioceanobs.com/index.php?id=1719&uid=4392>

### **Abstract :**

Early warning of an impending tsunami threat is heavily dependent on the detection of the tsunami in the open ocean away from shore. The wave amplitude in the open ocean is small (generally much less than one meter), making it difficult to distinguish the tsunami signal from other ocean variability until the tsunami approaches the shore and grows rapidly in amplitude. Recent studies have demonstrated, however, that satellite observations can be used to detect the tsunami in the open ocean while the wave amplitude is still relatively small. Here, we present methods for objective and quantifiable detection of tsunamis in the sea surface height and radar backscattering strength data obtained by satellite altimeters. We focus on the 2011 Tohoku tsunami, which devastated Japan and affected coastal populations all around the Pacific Ocean. While the lead-time was not sufficient for use in warning coastal populations in Japan, satellite altimetry observations of the tsunami in the open ocean could have been used to improve predictions and warnings for other affected areas. By comparing to both the results of the Method of Splitting Tsunami (MOST) model and historical satellite altimeter data, we use near real time satellite altimeter measurements to demonstrate the potential for detecting the 2011 Tohoku tsunami in the open ocean within a few hours of the tsunami being generated. Comparisons between the MOST model and satellite altimeter sea surface height measurements serve two purposes related to the early warning and detection of tsunamis. First, such tests on the lag time between model and satellite ocean observations could lead to better projections from MOST. By using the near real-time satellite altimetry provided by NASA/JPL PO.DAAC for such a comparison to the MOST model data, the tsunami signal can be definitively detected in the open ocean and the observations can potentially be used to improve MOST model estimates for areas affected by the impending tsunami. Secondly, such comparisons could be used to aid in near real-time to determine the presence of the tsunami signal in the satellite altimetry data. In addition, we compare radar backscatter strength data obtained by satellite altimeters during the 2011 Tohoku tsunami to historical satellite altimetry data to demonstrate the ability to detect the tsunami signal in the open ocean due to changes in ocean surface roughness, thus supporting previously published results for the 2004 Sumatra-Andaman tsunami and 2010 Chilean tsunami. The findings presented here challenge the previously held idea that the current constellation of satellite altimeters is not appropriate for use for early tsunami detection and warning.

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## 145 - Ssalto/DUACS : Status on the Real Time system upgrades and impact of the altimetry constellation events

*Mr Faugere Yannice* CLS

**Briol Frederic**, CLS ; **Labroue Sylvie**, CLS ; **Pujol Isabelle**, CLS ; **Dibarboure Gerald**, CLS ; **Picot Nicolas**, CNES ; **Bronner Emilie**, CNES

**Session:** Near Real Time Products and Applications

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4557>

### **Abstract :**

DUACS-NRT provides GODAE, climate forecasting centers, the MyOcean EU FP7 project, and real time oceanographic research (e.g.: in-situ campaigns) with directly usable, high quality near real time altimeter data. Regional products (Mediterranean Sea, Mozambic, Arctic, European Shelves ?) are also delivered to operational projects. Ssalto/Duacs system was significantly modified to integrate Cryosat-2 data since early February 2012. Only a few days after this integration, Jason-1 tandem and then Envisat, the two older satellites of the altimeter constellation used in the Duacs multimission system, have been impacted by severe anomalies. Whereas Envisat was definitively stopped on the 8 April 2012, Jason-1 has been reintegrated into Ssalto/Duacs system in May 2012, on its new geodetic orbit. This abstracts highlights the quality of the multi mission products during these different phases. Thank to Cryosat-2, the impact of the loss of two altimeters on the performances of the multi-satellite system was greatly minimized. During the period when both Envisat and Jason-1 data were missing, Cryosat-2 contribution to the multi-satellite maps is nearly 35%. The Jason-2/Cryosat-2 constellation thus allowed a reduction of the formal mapping error from 10 to up to 60% of the variance of the ocean and insuring an improved restitution of mesoscale structures especially in high energetic areas. Cryosat-2 also makes it possible to maintain the sampling at high latitudes. The altimetry constellation now relies on Jason-2 on the historical repeat orbit completed by the two Cryosat-2 and Jason-1 on geodetic orbit.

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## 146 - Indonesian Throughflow Proxy from Satellite Altimeters

**Dr Susanto R Dwi** Lamont Doherty Earth Observatory of Columbia University

**Susanto R Dwi**, Lamont Doherty Earth Observatory of Columbia University ; **Song Y Tony**, Jet Propulsion Laboratory (JPL)

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4526>

### Abstract :

It is known that Indonesian throughflow (ITF), a transfer of water mass and heat/freshwater fluxes from the Pacific to Indian Ocean, plays role in global ocean circulation and climate. Yet, continuous ITF transport measurement remains difficult and expensive. Despite many previous field studies, it is still logistically challenging to obtain sufficient in-situ data and accurate models for a full understanding of the inter-ocean transports globally and to determine their role in the general circulation of the ocean and climate. Strait and inter-ocean volume transports and their associated heat and freshwater fluxes are of fundamental interest to physical oceanography and are an important component of oceanic heat and freshwater budgets for climate studies. Hence, it is important to have ITF proxy from satellite data as an alternative to the in-situ measurements. We will focus on local altimetry sea surface height data for a proxy of the throughflow in the Makassar and Lombok Strait. It is hypothesized that the imbalanced pressure gradient between two interconnected oceans is the major driving force of strait transports. We believe the combined 20-year altimetry data and 10-year Gravity Recovery and Climate Experiment (GRACE) OBP, and in situ ITF measurement in the Makassar Strait from 2003-2011 as well as a high-resolution global model with a terrain-following coordinate system for better resolving the strait geometry in the right approach to derive ITF proxy. For the last several years, we have successfully established a theoretical method—a combination of the “geostrophic control” formula and the “hydraulic control” theory—using sea-surface height (SSH) and ocean bottom pressure (OBP) to estimate strait and inter-ocean transports. We will report these new results and discuss planned future activities.

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## **147 - Education, Outreach, and Societal Benefits of Ocean Altimetry Missions: 20 Years of Communication & Collaboration**

**Mrs RICHARDSON ANNIE** JPL

**Srinivasan Margaret**, JPL

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4596>

### **Abstract :**

A nearly 20-year record of ocean surface topography (OST) measurements has resulted in benefits not only to altimetry science team members, but also to the broader scientific and education communities, and to society as a whole. The outreach and applications efforts, which came into being with TOPEX/Poseidon and have continued with the Jason missions, has focused throughout, on the importance of making the knowledge gained from the missions available to the general public, using tools and media that are audience appropriate. The goals of our team continue to include: - Increasing awareness of ocean altimetry missions- Featuring operational and research applications (both altimeter and multi-sensor)- Promoting the societal benefits of altimetry data and science results- Providing oceanography content for educational uses- Inspiring the next generation of scientists and engineers. It is increasingly relevant to promote the use of mission data and results for science and societal benefits as well as for education purposes, which support the teaching of science, technology, engineering and math (STEM) subjects in schools. Reaching our target audience members in the education, general public, and current or potential operational/commercial data users, has been primarily achieved through web interfaces, printed products, and media stories addressing scientific results, education, OSTST member activities, and mission milestones. An underlying message for all communities is the direct societal benefits gained from ocean altimetry measurements. As we review our past efforts, focus on current datasets and results, and look toward future missions and new discoveries, we continue to seek support and interactions with OSTST members as partners in our outreach and applications efforts. We recognize this partnership as key to a successful ocean altimetry outreach program, which keeps the public fully informed and involved in our missions and scientific breakthroughs in the upcoming decades.

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## 148 - Climate Science Education for Underrepresented Students through Collaboration with CABPES

*Dr Hamlington Benjamin University of Colorado at Boulder*

**Hamlington Benjamin**, University of Colorado at Boulder ; **Leben Robert**, University of Colorado at Boulder

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** oral

**URL:** <http://www.avisio.oceanobs.com/index.php?id=1719&uid=4389>

### **Abstract :**

The Colorado Association of Black Professional Engineers and Scientists (CABPES) is a non-profit organization dedicated to encouraging African-American and underrepresented youth to pursue careers in the engineering and applied science professions. The goal is to increase the number of minority scientific and technical professionals to a level that better represents the minority population, while assisting in meeting the growing demand for engineers and scientists. CABPES works primarily with underrepresented students from grades 6 through 12 and offers assistance with schoolwork as well as counseling for students preparing for college. Professional engineers and scientists volunteer their time and effort to provide this help to students. While CABPES offers several after-school courses focusing on engineering and math, there is considerable interest in educating and informing students about the growing field of climate science. CABPES, however, lacks the resources and advisors capable of teaching students climate science. To meet this interest and to fill a gap in their curriculum, we are providing resources and materials to the students and instructors at CABPES that will increase their interest in research and scientific activities, develop their knowledge of climate science (specifically sea level change and variability), and provide them with research and hands-on experience that will aid them in future scientific endeavors. The main thrust of this project involves providing 8-week courses on climate change and sea level change twice yearly to CABPES students. With the first of these courses nearing completion, we provide an update on the success of the project to this point and highlight some of the difficulties encountered in relating the science of sea level change to the students at CABPES. We discuss the curriculum of the course that has been created and the activities that are used to help the students better understand climate science. By considering the early success and failures of the project, we provide some recommendations on ways to better communicate the subject of sea level change to high school students. The future of the project is also outlined, including the development of teaching modules that will hopefully be used in the future for dissemination to a wider audience than just the students at CABPES.

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## 149 - The 7th Continent Expedition : International Student Participation in a Voyage to the ?Great Pacific Garbage Patch?

*Mrs Vernières-Chevalier Julie* CNES

**Vernières-Chevalier Julie**, CNES ; **Richardson Annie**, NASA-JPL ; **de Staerke Danielle**, CNES

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4436>

### **Abstract :**

To meet their demands for its use, humans produce more than 300 million tons of plastic each year - approximately 10% of which ends up in the ocean. Due to ocean currents, this plastic waste collects in particular areas of our global ocean. Solely a result of human activities, plastic pollution has environmental consequences for both marine and non-marine ecosystems, but few people are aware of it. One such region of accumulated plastic debris is the North Pacific Subtropical Gyre, where the prevailing ocean currents have created a large mass of very small particles of plastics, which have resulted in a "plastic soup" commonly referred to as the "Great Pacific Garbage Patch". French yachtsman Patrick Deixonne has organized the first French, '7th Continent- Expedition', sailing with his crew from San Diego, California to this 'garbage patch'. The goal of the expedition is to obtain precise scientific data about the marine environment in this area, and to increase international public awareness of the problem - to decrease its impact, or even to stop it if we can. Middle and high school students at schools in France and the United States are participating in this expedition through the CNES-developed Argonautica educational project. Using data collected by drifting buoys via the Argos satellite system, Argonautica students and others interested, can access buoy data, and also sea surface height and current data from altimeter satellites like Jason, and surface wind data from other sensors. Students will use telecommunications to interact with the crew during the voyage, and will use tools on the Argonautica website, to examine the buoy and satellite data to better understand the currents at the heart of the North Pacific Subtropical Gyre where the plastics accumulate. At the same time, the students will learn more about the problem of microplastic and other marine debris, and about the usefulness of satellites for global oceanography.

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## 150 - ARGONAUTICA, an educational project using JASON data

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de Staerke Danielle, CNES

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4435>

### **Abstract :**

The Argonautica educational project makes actual oceanographic data available to primary and secondary students. This satellite data makes it possible to understand the oceans, their relation to environmental change and the effects on the living world. It is a chance for them to undertake a real investigation by taking part in a scientific projects that alerts them to the evolutions in society and make them aware of the major challenges facing humanity and what is needed to protect the planet. The Argonautica project, in relation to various events and/or with help from scientific partners, proposes the following activities:

- monitoring of drifting buoys, some of which are made by the classes, or Argos beacon. This will enable the students to understand oceanic circulation, the links between ocean and environment (climate...) and how they vary, by comparing the data with that supplied by the JASON satellite.
- showing the impact of these variations on marine animals, by monitoring their migrations with Argos transmitters. At the end of the school year, the students come together to report back on their work and two of the best projects have been chosen for a presentation at the OST-ST Meeting.

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# 151 - JASON-1 GEODETIC DATASETS AT PO.DAAC AND THE IMPACT ON ITS USERS AND SERVICES

*Ms Hausman Jessica JPL/Caltech*

**Hausman Jessica**, JPL/Caltech

**Session:** Outreach, Education & Altimetric data services

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4459>

## **Abstract :**

The Physical Oceanography Distributed Active Archive Center (PO.DAAC) is NASA's data center responsible for data management and distribution of satellite physical oceanographic data, as well as for providing support for its scientific user base. By supporting satellite missions that have collected Ocean Surface Topographic (OST) data over the past three decades, PO.DAAC has acquired a vast knowledge base and level of expertise that is provided to and utilized by the user community. PO.DAAC's data holdings relevant to OST include sea surface height and significant wave height from SEASAT, TOPEX/Poseidon, Jason-1, OSTM/Jason-2, and gravity measurements from GRACE. The holdings now include marine geodetic data as Jason-1 has entered into a new geodetic mission as a result of the orbit change to maintain the safety of the altimetry orbit that continues to be used by the newer Jason series satellites. This new Jason-1 mission creates a challenge for the PO.DAAC and its user community as the mission transitions from one that has provided excellent data for ocean mesoscale measurements to one more appropriate for geodetic measurements. Users who have used the Jason-1 data for years, whether for science research or operational applications, now need to either find a new source of data or adapt to using the new orbit data. The presentation will first cover what new Jason-1 geodetic datasets are available at PO.DAAC. Second, we will discuss how PO.DAAC's user community changed and what their new needs are. Some of the sea level users will not be adversely affected as they have an expertise in altimetry and will know how to adjust the data to their needs and/or are geodesists. Other users will need to know what the new errors and accuracies are, which will not be available until after the calibration and validation period and require new documentation.. Other discussions will include usage metric comparisons between the previous Jason-1 data and the new geodetic data.

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## 152 - Assessment of Orbit Quality through the SSH calculation

*Ms PHILIPPS Sabine CLS*

**PHILIPPS Sabine**, CLS ; **OLLIVIER Annabelle**, CLS ; **CERRI Luca**, CNES ; **PICOT Nicolas**, CNES

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4546>

### **Abstract :**

The quality of the orbit ephemerides is crucial for the computation of the sea surface height. The objective of this study is to assess the quality of precise orbit ephemerides analyzing the Sea Surface Height (SSH) performances derived from the main on-going altimeter missions (Jason-1, Jason-2), but as well past altimeter missions (Envisat). Several validation diagnoses are used to estimate the performances of new orbit solutions on the SSH calculation in order to describe their impact at different temporal scales. For instance the analysis of SSH consistency at crossovers allows us to estimate the SSH consistency between ascending and descending passes in terms of mean and variance within a 10-day window. Others analyses are performed along-track to estimate the potential reduction of correlated geographical biases. We also pay a great attention to the long-term stability of SSH analyzing the impact on the global and local Mean Sea Level (MSL) trends using several orbit solutions. Finally, the comparison with in-situ measurements as tide gauges data and temperature/salinity profiles (ARGO data) is a good way to know which solution is the best. In this study, we have mainly used the orbit solutions provided by the CNES (Centre National d'Etudes Spatiales).

Several aspects are analyzed. First, the orbit solutions of the final GdrD standard version are analyzed for Jason-1, Jason-2 and Envisat. Indeed these solutions were recently included in the operational GDR production (since end of January for Envisat, May for Jason-1 and since end of June for Jason-2). It is also part of the standards used for Jason-2 GDR-D whole mission reprocessing. We have analyzed and compared their performances on the SSH calculation applying diagnoses previously defined. In particular, now that the Envisat mission is over (since April 2012), a study was performed to estimate the remaining errors induced by the gravity field modeling at the beginning and end of the time series with the GDR-D orbit standard. Indeed, these standards use the EIGEN-GRGS\_RL02bis\_MEAN-FIELD (2011) gravity field as well as the time varying gravity model (annual, semi-annual and drift), estimated over 8 years. To quantify the errors introduced by this model, it was compared to an orbit solution computed with the 10-day series of Grace-derived gravity fields. Finally, in order to explain the remaining differences between Jason-1 and Jason-2 orbits, a set of (CNES) orbit solutions using the same orbit determination techniques (Doris/Laser) are compared for the formation flight phase of Jason-2 (cycles 1 to 20).

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# 153 - 20-Years of Precision Orbit Determination For Altimetry With GPS

**Dr Bertiger Willy** JPL

**Bertiger Willy**, JPL ; **Desai Shailen**, JPL ; **Haines Bruce**, JPL ; **Selle Christina**, JPL ; **Dorsey Angie**, JPL

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4482>

## **Abstract :**

With the launch of Topex/Poseidon (TP) in 1992, we began the era of precise orbit determination (POD) with data from the Global Positioning System (GPS) using reduced dynamic techniques for the series of climate level altimetry missions. TP carried an experimental 6-channel GPS receiver that could operate in dual-frequency mode when anti-spoofing (AS) was off. The missions following TP, Jason and Jason-2, carried more capable non-mission critical GPS receivers with a codeless dual-frequency mode, tracking 8-10 GPS satellites. Over the last year, JPL has been reprocessing GPS data from the global set of GPS data to better determine the GPS constellation's orbit and clock values from 1993 to the present. This determination includes updated models, ITR2008 reference frame, and information to resolve integer phase ambiguities with a single receiver. We will examine the POD using only GPS data for TP, Jason, and Jason-2 from 1993 through the present when the receivers operate in dual-frequency mode resolving integer phase ambiguities. We do not expect uniform accuracy over the entire time span due to many issues including sparse ground tracking of the GPS constellation in the early years and less capable TP flight receiver. Orbit precision and accuracy will be assessed with residuals to the data, residuals to reserved Satellite Laser Ranging (SLR) data, altimeter cross-overs and differences with the latest orbits available on the Geophysical Data Records (GDR) as well as orbits produced by other POD centers. For Jason and Jason-2, these techniques produced sub-centimeter accuracy.

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## 154 - Improved Orbit Standards for Altimeter Satellite POD at GSFC

*Dr Lemoine Frank* NASA GSFC

**Lemoine Frank**, NASA GSFC ; **Zelensky Nikita**, SGT Inc. ; **Melachroinos Stavros**, SGT Inc. ; **Chinn Douglas**, SGT Inc., ; **Pavlis Despina**, SGT Inc., ; **Rowlands David**, NASA GSFC ; **Beckley, Brian**, SGT Inc ; **Ray Richard**, NASA-GSFC ; **Luthcke Scott**, NASA-GSFC

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4472>

### **Abstract :**

The stability and accuracy of the altimeter satellite orbit through time is essential for POD. The primary limitations in the POD at the present time concern the fidelity of the time-variable gravity modeling, the accuracy of the terrestrial reference frame, and errors in the non-conservative force modeling. Additionally, we are also concerned with improvements to the troposphere modeling which affect both the GPS and the DORIS processing. In this paper, we discuss improvements to the std1007 set of standards and their implementation. The improvements include the adoption of a new static geopotential model based on both GRACE and GOCE (e.g. GOC02S). For the proper modeling of the time-varying geopotential we consider (1) the adoption of monthly or ten-day solutions where these are available; (2) the use of independent weekly solutions of the 4x4 geopotential from SLR & DORIS; (3) the adoption of parameterized mass variations derived from mascon solutions (e.g. Sabaka et al., 2010). For the nonconservative force modeling, we consider changes in solution parameterization (cf Zelensky et al., 2011) and implementation of improved models of planetary radiation pressure. Ocean tides affect the POD both directly through the dynamics, and indirectly through the ocean loading. It is well known (e.g. see Ray et al., 2009) that ocean tide models have deficiencies in the Arctic and Antarctic regions. We consider use of a patched model ? combining a well known global model (e.g. GOT4.8) with regional models such as those of Padman et al. At GSFC, we have recently implemented the VMF1 mapping function, using the gridded hydrostatic and wet zenith delays reduced to station height following the procedure of Kouba (2008). We apply the VMF1 on Jason2 POD and also assess whether time correlation of the station-dependent troposphere refraction corrections can improve the POD results. The goal is the development of a uniform and consistent set of standards that can be applied to all altimeter satellites from 1993 to 2013 (e.g. TOPEX, Jason-1, Jason-2, GFO-1, Cryosat-2 and Envisat).

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## 155 - ESOC Integer Ambiguity Resolved Precise and Homogeneous Orbits for Jason-1 and Jason-2

**Mr Otten Michiel** ESA/ESOC

**Otten Michiel**, ESA/ESOC ; **Flohrer Claudia**, ESA/ESOC ; **Springer Tim**, ESA/ESOC ; **Enderle Werner**, ESA/ESOC

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4433>

### **Abstract :**

Our presentation focuses on the new Jason-1 and Jason-2 orbits generated in 2012 at the European Space Operation Centre ESOC. The main improvement compared to the orbits presented at the 2011 OSTST meeting is that we now resolve for integer ambiguities for both Jason-1 and Jason-2. The orbits are generated in the ITRF2008 reference frame with the NAPEOS software which is fully compliant with the latest IERS2010 conventions. Data of all three tracking instruments on-board the satellites, i.e. GPS, DORIS, and SLR measurements, were used in a combined data analysis. About 10 years of Jason-1 data and about 4 years of Jason-2 data were processed. We present the orbit determination results, focusing on the effect of fixing the integer ambiguities on the solution. Integer ambiguities are resolved by making use of the Undifferential Phase Delays (UPD) obtained from our IGS processing. We evaluate the orbit accuracy by analysing post-fit residuals, orbit overlap errors, and orbit differences between our orbits and external orbits generated by other analysis centres as well as showing altimeter crossover residuals. The consistency between our solutions and external orbits is below the 1 cm level in the radial direction, the most crucial component for altimetry height measurements.

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## **156 - Influence of time varying geopotential models and ITRF realizations on precise orbits of altimetry satellites and derived mean sea level**

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**Ablain Michael**, Collecte Localisation Satellites (C.L.S.) ; **Schöne Tilo**, GFZ German Research Centre for Geosciences

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4430>

### **Abstract :**

Determination of precise orbits of Earth artificial satellites is a complicated and challenging task. The accuracy of precise orbits of altimetry satellites depends on many factors, such as models and algorithms, a reference frame realization, corrections, tracking data, parameterization used and some others. Since the orbits of altimetry satellites are located at the altitude of 700-1400 km, the motion of these satellites is highly affected by irregularities of the Earth gravity field. In this paper we investigate the influence of some recent time varying geopotential models, such as EIGEN-6S and EIGEN-GL04S, taking into account periodic terms and drifts of the geopotential coefficients on the precise orbits of altimetry satellites ERS-1, ERS-2 and Envisat and regional and global mean sea level computed using these orbits. Additionally, the influence of three last realizations of the International Terrestrial Reference Frame, namely, ITRF2000, ITRF2005 and ITRF2008 on the precise orbits of these satellites and mean sea level derived is studied.

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## 157 - Reducing the dependency of precise orbits for altimeter missions from the Time Varying Gravity field

**Mr Cerri Luca** *Centre National d'Etudes Spatiales (CNES)*

**Cerri Luca**, Centre National d'Etudes Spatiales (CNES) ; **Couhert Alexandre**, Centre National d'Etudes Spatiales (CNES) ; **Houry Sabine**, Centre National d'Etudes Spatiales (CNES) ; **Mercier Flavien**, Centre National d'Etudes Spatiales (CNES)

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4394>

### **Abstract :**

In recent years non-tidal time varying gravity has emerged as the most important contributor to the error budget of the altimeter satellites' orbits. The modeling of these effects has evolved over subsequent generation of orbit standards from the launch of TOPEX-POSEIDON, mainly thanks to the GRACE gravimetric mission : originally neglected in early GDR solutions, linear rates in the degree 2,3,4 zonal harmonics derived from SLR-data analysis were included from 2005 (GDR-B standards); seasonal variations (annual and semi-annual) were added in GDR-C orbit standards (operational in 2008), and linear rates were extended up to degree/order 50 with the latest GDR-D standards (operational in 2012). GDR-D orbits behave well over the 2002-2011 time-span, as demonstrated by the clear improvement in consistency between the Envisat- and Jason-derived Sea Surface Heights. However, the linear trends derived from the time-series of GRACE geopotentials only constitute an empirical model which does not account for the underlying geophysical phenomena. We should not expect this model to propagate well into the future. Although to some extent this problem can be solved by reprocessing dynamic orbits with more recent models, this approach will reinforce the need for a gravimetric mission in support of an ocean topography mission in order to maintain the geographically correlated orbit errors at the same level. Alternatively, we can reduce the dependency from errors in the gravity model by improving the configuration of the adjusted empirical parameters. We address the problem of the solution parameterization focusing on DORIS-based orbits, as for these solutions the issue of observability is more critical than for GPS-based orbits, and as several upcoming missions (SARAL-Altika, Jason-3) will still use a DORIS receiver as mission-critical tracking instrument.

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## 158 - Jason-1 and Jason-2 POD Status

*Mr Couhert Alexandre CNES*

**Couhert Alexandre**, CNES ; **Cerri Luca**, CNES ; **Mercier Flavien**, CNES ; **Houry Sabine**, CNES

**Session:** Precision Orbit Determination

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4383>

### **Abstract :**

The reference OSTM/Jason-2 satellite has been in orbit since June 2008 and extends the time series of centimeter-level ocean topography observations begun in 1992 by the Topex/Poseidon mission and continued in 2001 by the Jason-1 mission. The whole set of Jason-1 and Jason-2 cycles has lately been reprocessed with the new GDR (version D) Precision Orbit Determination standards, including the latest release of the Eigen-GRGS mean field (using the GRACE data over the period 2003-2010 and including secular drifts up to degree 50) and the latest realization of the international reference frame (ITRF2008). This talk will address the issues of accuracy and long-term stability of the Jason-1 and Jason-2 GDR-D orbit solutions. The overall accuracy of the orbits is evaluated through intercomparisons with external analysis centers, using different models, combinations of tracking data or parameterization techniques. As dynamic orbits, the GDR-D solutions quality is dependent on the fidelity of force models; in particular long-term variations of the geopotential are still one of the largest remaining sources of orbit error. Thus we will focus on the impact of the time-varying gravity field on the geographically correlated errors that are of interest for the altimeter analyst. We will also give an overview of the performance of all available tracking systems operating on Jason-1 and Jason-2, aiming at monitoring the long-term stability of the measurement systems.

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## 159 - Improving the dynamic atmospheric correction for mean sea level and operational applications of altimetry

*Dr Carrere Loren CLS*

**Carrere Loren**, CLS ; **Faugere Yannice**, CLS ; **Bronner Emilie**, CNES ; **Benveniste Jerome**, ESA, ESRIN

**Session:** Tides, internal tides and high-frequency processes

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4418>

### **Abstract :**

Given its current accuracy and maturity, altimetry is considered a fully operational observing system dedicated to various applications such as climate studies or operational oceanography. Altimeter measurements are corrected for several geophysical effects in order to isolate the oceanic variability, and the dynamic atmospheric correction (DAC) is an important one; this correction allows for the removal of high frequency variability induced by the atmospheric forcing and aliased by the altimetric measurements. The high frequency part of the DAC is based on a barotropic model simulation forced by atmospheric pressure and winds (MOG2D; Carrère and Lyard 2003); the low frequency part is an inverse barometer response. A 20-day cutoff-period was chosen because it corresponds to the Nyquist period of T/P-Jason reference altimeters' sampling and because the variability is mostly barotropic in this high frequency band. The purpose of the study is to improve the performances of the DAC for users of altimetry, for mean sea level applications and also for operational altimetry. Indeed, some errors remain in the DAC on the first years of altimetry, due to the bad quality of the meteorological forcing, and in the Near Real Time/Real Time corrections due to the use of a degraded DAC (decentered filtering window) or even the IB . In order to improve the DAC on the older altimeter missions and to homogenize the correction on the entire altimetric period for MSL applications, we have tested the new ECMWF reanalysis ERA-Interim. Concerning the NRT DAC, the operational filtering has been improved thanks to the use of forecasts of DAC forced by ECMWF operational forecasts. Several analyses have been performed using multi-mission (Topex-Poséidon, Jason-1, Jason-2, ERS, ENVISAT) analysis of crossovers differences (SSH) and sea level anomalies (SLA) and also global and regional mean sea level estimations. Results are very interesting and particularly the use of ERA-interim allows a significant variance reduction of the residual signal on the first years of altimetry (for mesoscale studies) and has a strong impact on regional MSL estimations. Concerning the forecasts of DAC, the impact study has proven their great interest to improve the accuracy of the DAC correction for near real time and real time products. Note that the results presented here have been obtained within the SALP/CNES project and the CCI/ESA project.

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## 160 - FES 2012: A new tidal model taking advantage of nearly 20 years of altimetry measurements

*Dr Carrere Loren CLS*

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**Roblou Laurent**, LEGOS

**Session:** Tides, internal tides and high-frequency processes

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4416>

### **Abstract :**

Thanks to its current accuracy and maturity, altimetry is considered as a fully operational observing system dedicated to scientific and operational applications. In order to access the targeted ocean signal, altimeter measurements are corrected for several geophysical parameters among which the ocean tide correction is one of the most critical. Global ocean and loading tide models GOT and FES are operationally used in present altimeter GDRs. FES is a finite elements hydrodynamic model which assimilates altimeter and in situ data, while GOT model is build as an empirical adjustment based on altimeter data of a prior atlas (such as FES). The accuracy of tidal models has been much improved during the last 20 years. Still, significant errors still remain mainly in shelf seas and in polar regions. A new global tidal FES model is being developed taking advantage of longer altimeter time series, improved modelling and data assimilation techniques, and more accurate ocean bathymetry. Special efforts have been dedicated to the determination of accurate tidal currents and to address the major non-linear tides issue. We detail the most significant advances in the dynamic modelling, data analysis and assimilation. Finally we present the main improvements achieved compared to former releases of the FES model and the available modern global ocean tide models.

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## **161 - Evaluation of CTOH new along-track tidal constants database for dealiasing coastal altimetry over the North-West European continental shelf.**

**Mr ROBLOU Laurent** CNRS/LEGOS

**ROBLOU Laurent**, CNRS/LEGOS ; **LYARD Florent**, CNRS/LEGOS ; **DELEBECQUE Caroline**, CTOH/LEGOS ; **BIROL Florence**, CTOH/LEGOS ; **MORROW Rosemary**, CTOH/LEGOS

**Session:** Tides, internal tides and high-frequency processes

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4449>

### **Abstract :**

A large fraction of the variance in the North-West European continental shelf sea level is due to tides. As a result, for most applications in this area, accurate knowledge of tidal elevations or currents is almost indispensable so that tides can be removed from the data prior to studies of longer period dynamics. The performance of global tidal atlases used to correct tides from altimeter data is limited in terms of accuracy and resolution over the coastal and shelf seas so the satellite altimeter sea level error budget increases in those regions, and undermines the altimeter satellite missions capabilities for observing the coastal ocean dynamics. Initiatives such as regional modeling, improving dataset quality and improving data assimilation techniques are current solutions to overcome this issue. Another option consists in taking advantage of the brand new CTOH altimetry-derived tidal constants database to set up an empirical, local (i.e. along the ground track) tidal correction. This novel database (2012) is providing the community with large collection of tidal constants estimates over more than 20 coastal regions and continental shelves ([http://ctoh.legos.obs-mip.fr/products\\_coastal-products/coastal-products-1/tidal-constants](http://ctoh.legos.obs-mip.fr/products_coastal-products/coastal-products-1/tidal-constants)). It aims to provide tidal experts and coastal modelers with amplitude, phase lags and accuracy estimates for a wide spectrum of tidal constituents, every 6-7km along the satellite ground tracks and taking into account a state-of-the-art reprocessing of coastal altimetry dataset. Thanks to TOPEX-Poseidon, Jason-1 and -2 outstanding duration and design, most of the usual limitations on the altimeter data harmonic analysis are now overpassed and harmonic tidal constants accuracy is believed to be close to tide gauge data standards. In this presentation, CTOH along-track tidal constants provided over the North-West European continental shelf are compared to other available tidal models and in situ data. The performance of an empirical tidal correction inferred from the use of CTOH along-track tidal constants database is assessed in comparisons to classical tidal corrections in terms of variance reduction. Potential use for studies of the coastal and shelf dynamics is discussed.

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## 162 - 59-day Oscillations, Beta-prime, S2, and All That

**Mr RAY Richard** NASA Goddard Space Flight Center

**Ray Richard**, NASA Goddard Space Flight Center

**Session:** Tides, internal tides and high-frequency processes

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4384>

### **Abstract :**

The problematic 59-day oscillations in global mean sea level are clearly related to the satellite's beta-prime angle, i.e. the angle between the orbit plane and the sun. The orbit plane precesses relative to the sun at a full period of 117.304 days, with the plane aligned twice within each period. Thus, the 59-d oscillations are a manifestation of errors somehow related to radiational or thermal forcing, including a part from errors in the S2 tide models. From the Jason-1 Verification campaign data, it is clear that the effects in T/P and Jason-1 differ, and that the two satellites are inconsistent at the period of the S2 tide by 5 to 10 mm, or roughly the amplitude observed in the MSL oscillations. Several problematic corrections add to the effect. For example, the Cg correction for TOPEX plays a role, as does the error in the T/P GDR dry-tropospheric correction which inadequately models the S2 air tide. The latter is easily mitigated (as is already done in Jason GDRs). A series of altimetric tide solutions -- GOT4.7, 4.8, 4.9,? -- differ only in S2 in ways that attempt to shed light on these errors. A new bottom-pressure tidal validation dataset gives a completely independent method to assess whether corrections improve or harm the altimetric tide solutions. These topics will be reviewed in this paper. But we have not yet resolved the inconsistency of TOPEX and Jason at the S2 period.

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## 163 - Evaluation of Contemporary Ocean Tide Models

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**Fok Hoksum**, Division of Geodetic Science, Ohio State University ; **Yi Yuchan**, Division of Geodetic Science, Ohio State University

**Session:** Tides, internal tides and high-frequency processes

**Presentation type:** oral

**URL:** <http://www.aviso.oceanobs.com/index.php?id=1719&uid=4493>

### **Abstract :**

Advances in satellite radar altimetry technology enabled a globally sampled climate data record of accurate sea surface topography and its changes over 2 decades benefiting numerous scientific studies, including improved global ocean tide modeling and advancing tidal sciences. Since the last major effort in the accuracy evaluation of ocean tide models in 1997, numerous contemporary barotropic ocean tide models have been developed or are under development, including assimilation tide models (FES2004, FES2012, NAO.99b and TPXO7.2, etc), and empirical tide models (e.g. EOT11a, GOT4.7, OSU12, etc). Here we provide an evaluation of the available ocean tide models using data from pelagic constants, coastal tide gauges, and data from multiple mission satellite radar altimetry, with a focus on the coastal regions and the polar oceans, where the model fidelity still significantly lags model accuracy over deep ocean.

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