→ 6th COASTAL ALTIMETRY WORKSHOP

ABSTRACT BOOK

20-21 September 2012 | Riva del Garda, Italy

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Abstract Book

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Day 1, Thursday 20 September 2012

Opening Session

An Overview of the Cosmo-SkyMed Mission and its Main Applications

Coletta, Alessandro; Battagliere, Maria Libera
Italian Space Agency

COSMO-SkyMed, the largest Italian investment in EO Space Systems, is a Dual-Use end-to-end Earth Observation System aimed at establishing a global service supplying provision of data, products and services relevant to a wide range of applications and providing near-real time, all-weather accurate information. COSMO-SkyMed consists of a constellation of four LEO mid-sized satellites equipped with a multi-mode high-resolution SAR operating at X-band. The COSMO-SkyMed constellation is fully operational from the beginning of 2011. In the general framework of its wide application scenario the COSMO-SkyMed constellation is able to provide continuous and accurate information on some interesting parameters related to conditions of seacoasts, seas and inland waters, so as to evaluate phenomena of coast erosion and pollution and to guarantee activity of sea traffic control. Particularly, COSMO-SkyMed constellation significantly improves the role of SAR in this kind of application due to its high revisit frequency. The COSMO-SkyMed system is also able to monitor large areas for oil spills detection using its SCANSAR acquisition mode. As a matter of fact, despite the protection of the marine environment is a primary international concern, illegal oil spills into the sea continues to pose a serious threat to the marine ecosystem, especially in coastal environments. The release of oil is usually caused by human activity, however, in some cases may be caused by natural events, such as fractures of the seabed. The SAR instrument can easily detect oil slicks as areas of lower back-scattered signal, moreover the short revisit time of the COSMO-SkyMed constellation supports an operational use of a SAR-based oil spill monitoring service making it easier to link an oil spill with a specific ship. In the framework of a collaboration with the Japanese Space Agency (JAXA) it is planned to deeply investigate oil spill detection methods in coastal areas using COSMO-SkyMed and ALOS data. Furthermore, thanks to the location of the baseline X-band ground station in Matera, COSMO-SkyMed is able to cover the Mediterranean basin with Near Real time (NRT) services (30 minutes from satellite pass). The satellite system offers a well-grounded support to maritime surveillance: in this context, COSMO-SkyMed is not only important for prevention and monitoring, but also to build an archive data to analyze. In order to provide operational continuity to COSMO-SkyMed mission, the Italian Space Agency (ASI) and Italian Ministry of Defense (It-MoD) are conceiving the next generation of the system.(COSMO-SkyMed Seconda Generazione). This work summarizes the potentialities and services that a space system based on a constellation as COSMO-SkyMed can provide for maritime applications and coastal monitoring, including support data and information near the coasts where the accuracy of altimeter data dramatically decreases.

Session 1: The New Coastal Altimetry Data

CTOH Studies on Regional Altimetry in 2011/2012

Birol, Florence[1]; Delebecque, Caroline[1]; Roblou, Laurent[1]; Morrow, Rosemary[1]; Fleury, Sara[1]; Nino, Fernando[1]; Lyard, Florent[2]
[1]CTOH/LEGOS; [2]LEGOS

The CTOH (Centre of Topography of the Oceans and the Hydrosphere) is an independant research service dedicated to satellite altimetry studies (http://ctoh.legos.obs-mip.fr). Its main objective is to maintain homogeneous altimetric data bases (including a large number of missions and up-to-date corrections) for the long-term monitoring of sea level, lake and river levels, the cryosphere, and the planet's climate. In parallel, the CTOH also develops new altimetric products and applications in coastal altimetry and provides its support to scientists working in this emerging field.

Using the X-TRACK processing software (Durand et al., 2008; Bouffard et al., 2010; Birol et al., 2010; Roblou et al., 2011), the CTOH routinely produces regional along-track Sea Level Anomalies (SLA) research products which have already been distributed to many users over the last few years. There are currently ~20 regional archives which are regularly updated (http://ctoh.legos.obs-mip.fr/products/coastal-products). In parallel, the CTOH continues to develop new regional products, including 10/20 Hz along-track SLA for T/P and Jason-1/2; high resolution regional multi-mission gridded products; and along-track tidal harmonic constants products. We also work on optimising the dynamical information which can be derived from existing coastal altimeter measurements.

Here we will review the most recent CTOH regional products, illustrate some examples of applications, and show some results of recent investigations. As an example, the potential of full rate altimeter measurements (10/20Hz) will be analysed in the context of a coastal study in the Northwestern Mediterranean Sea. The impact of different altimeter corrections on the observation of the coastal circulation will also be investigated. The general objective of all these studies is to enhance data availability and accuracy close to land and then allows a better observation of the coastal oceans. Indeed, data processing (data sampling rate, choice of corrections, editing, filtering, …) becomes really critical in those areas.

Level-3 Coastal Sea Level Anomalies from PISTACH Products

Dufau, Claire[1]; Labroue, Sylvie[1]; Peyridieu, Sophie[1]; Collard, Fabrice[1]; Cancet, Mathilde[2]; Guillot, Amandine[3]; Picot, Nicolas[3]; Guinle, Thierry[3]
[1]CLS; [2]NOVELTIS; [3]CNES

In order to recover altimeter data close to the coast that may contain useful information for coastal studies, the French Spatial Agency (CNES) funded the development of the PISTACH prototype dedicated to Jason-2 altimeter processing in coastal ocean. Since November 2008, the PISTACH products have been providing new retracking solutions, several state-of-the-arts, or with higher resolution, corrections in addition to standard fields at a high-level sampling rate (~300m). Newly, in order to ease the use of these products, the PISTACH team has developed an adapted data post-processing (editing, filtering) and produced level-3 PISTACH Sea Level Anomaly (SLA) datasets along several tracks in the Agulhas Current system, near the Florida Keys, in the Mid Atlantic Bight and along Oregon coasts. This presentation will summarize the main achievements of this level-3 coastal PISTACH SLA development and highlight how these new coastal datasets contribute to a finer observation of coastal oceans.

CryoSat Processing Prototype, LRM and SAR Processing on CNES Side and a Comparison to DUACS SLA

Boy.François; Desjonquères, Jean-Damien; Picot, Nicolas
CNES

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.

Session 2: Applications of Coastal Altimetry

Sub-Mesoscale Circulation Features off Perth, WA, as Seen by HF Radar, Altimetry and Imagery.

Griffin, David; Cahill, Madeleine; Oke, Peter
CSIRO

Two Jason-2 tracks cross each other just offshore of Perth, Western Australia, within the footprint of a WERA long-range HF radar system that has been making very good measurements of the surface current velocity since March 2010. This location also has very clear skies, so SST and ocean colour imagery give excellent views of the dynamic meso- and sub-mesoscale ocean features associated with the Leeuwin Current and its eddies. In this talk I will discuss comparisons of altimetric current velocities with other estimates, drawing on Pistache data products as well as Cryosat-2.

Comparing In Situ Current Data with Current Anomalies Derived from the PISTACH Products: the Agulhas Current

Cancet, Mathilde[1]; Labroue, Sylvie[2]; Birol, Florence[3]; Beal, Lisa[4]; Dufau, Claire[2]; Jeansou, Eric[1]; Morrow, Rosemary[3]; Guillot, Amandine[5]; Picot, Nicolas[5]
[1]NOVELTIS; [2]CLS; [3]LEGOS/CTOH; [4]RSMAS/University of Miami; [5]CNES

Using geostrophic current anomalies derived from the altimeter data to observe the coastal currents or meso-scale structures is a real challenge considering the difficulties to retrieve good-quality altimetry data near the coasts. In the frame of the PISTACH project, funded by CNES, new processing methods and corrections dedicated to coastal applications were developed for the Jason-2 mission products. In order to demonstrate the gain owed to the PISTACH algorithms, the CNES supported the processing of level 3 products based on this dataset. The aim of this study is to estimate the added value of these products, compared to classical SLA level-3 products. Several zones were chosen for the demonstration, among which the Agulhas Current, which flows along the South-African coast. In this area, the current follows the continental shelf, being particularly well oriented to be monitored using along-track satellite altimetry data. Moreover, in situ velocity data have been collected along a Jason-2 track across the Agulhas Current since April 2010, as part of the ACT (Agulhas Current Time series) experiment, a US NSF-funded project led by

Lisa Beal at RSMAS. These datasets are a unique opportunity to evaluate and quantify the improvements owed to the PISTACH processing in this region.

Satellite Altimetry of Inland Water Bodies in Turkmenistan

Kostianoy, Andrey[1]; Lebedev, Sergey[2]; Solovyov, Dmytro[3]
[1]P.P. Shirshov Institute of Oceanology; [2]Geophysical Center; [3]Marine Hydrophysical Institute

Satellite monitoring of water resources is of great importance for countries located in arid zones especially now when significant changes in global and regional climate are observed. In Central Asia, Turkmenistan is a country where 80% of territory is occupied by Karakum desert. Nevertheless, the southeastern part of the Caspian Sea, Kara-Bogaz-Gol Bay of the Caspian Sea, and the southern part of Sarykamysh Lake belong to Turkmenistan. From 2000 P.P. Shirshov Institute of Oceanology and Geophysical Center of Russian Academy of Sciences in cooperation with Marine Hydrophysical Institute (Ukraine) perform satellite monitoring of these water bodies, which includes satellite altimetry. In the report we will focus on the interannual and seasonal variability of the sea, bay and lake levels, which are traced from 1993 to the end of 2011. We investigated also wind speed and wave height (derived from the altimetry data) in the Caspian Sea waters of Turkmenistan. The Altyn Asyr Lake will be an artificial lake 103 km long, 18.6 km wide and 69 m deep, which is under construction in Turkmenistan since 15 July 2009. The lake will appear in 10-15 years at the place of a natural Karashor Depression, which will be filled by drainage waters gathered from the irrigated lands of the country. Fortunately, altimetry tracks of TOPEX/Poseidon, Jason-1 and Jason-2 cross the Karashor Depression. Karashor Depression (still empty in summer 2012) and then the Altyn Asyr Lake (slowly filled by drainage waters in the nearest future) can be used as a test ground for the present and future satellite altimetry missions. As a first step, a digital elevation model of the depression was prepared basing on the data base of NASA Shuttle Radar Topography Mission (SRTM version 4.1) with 90 m spatial resolution.

Coastal and Arctic Marine Gravity from Cryosat and Jason-1 Geodetic Mission Altimetry

Andersen, Ole Baltazar; Stenseng, Lars; Jain, Maulik
DTU Space

A number of geophysical phenomena in particularly the coastal marine regions are still unresolved by conventional 1 Hz altimetry. Firstly as altimetry generally do not map scales below the 15-20 km scale and secondly as waveforms are contaminated and data are missing in the coastal regions typically up to 50 km from the coast, as well as in the Arctic regions where the waveforms are not Brown-like. Consequently, particularly, the coastal and Arctic regions are degraded compared with the open ocean in global marine gravity fields. The recently launched ESA Cryosat-2 offers up to a factor of 20 better spatial resolution compared with conventional altimetry used to derive i.e., DTU10. This offered by SAR, or Delay-Doppler (DD) altimeter. With the launch of Cryosat covering all oceans up to 88N and with its 369 day repeat and 7 km ground track spacing at the equator a very exciting new source of gravity has become available. Recently, the Jason-1 satellite was put into a geodetic mission for its end of life scenario. This means that we do not know how dense this geodetic mission will become. The altimeter onboard Jason-1 are generally more accuracte that the older geodetic mission from ERS-1 and GEOSAT. The first exciting results from employing the Croysat-2 and Jason-1 geodetic data to gravity field modeling in coastal and Arctic regions focusing on the Baffin Bay are presented in this work. The Baffin Bay has a lot of ground truth from marine observations and is currently under massive investigation and operating in this area is becoming more and more possible due to recent climate change.

Observations of Storm Surges by Satellite Altimetry: Hurricane Igor off Newfoundland

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We have investigated the ocean response to Hurricane Igor over the Grand Banks of Newfoundland. Coastal tide gauge can be used to monitor variations of a storm surge along the coast, but not in the cross-shelf direction. As a result, the cross-shelf structure of a storm surge has rarely been observed. In this study we combine the Jason-2 (it concurrently passed over the Grand Banks during the Igor¡¯s passage) altimetry with tide-gauge data to study the storm surge. Altimetric observations reveal prominent cross-shelf variation of sea surface height during the storm passage, including a large nearshore slope and mid-shelf depression. A significant surge of 60 cm (25 km from the coast) observed by satellite altimetry is found to be consistent with tide-gauge measurements (about 90 cm) at nearby St. John¡¯s tide-gauge station at 2:40, September 22, 2010 UTC. The tide gauge at St. John¡¯s observed a maximum surge of 96 cm after (at 2:30, September 22, 2010) the storm passage. The maximum surge at St. John¡¯s was thought to be associated with a free equatorward-propagating continental shelf wave, generated along the northeast Newfoundland coast hours after the storm moved away from St. John¡¯s. The e-folding scale of the wave was estimated to be ~100 km. The study for the first time shows the utility of satellite altimetry to observe the cross-shelf features of a storm surge, complementing tide-gauge observations for the analysis of storm surge characteristics and for the validation and improvement of storm surge models.

Estimation of Extreme Sea Levels from Altimetry and Tide Gauges at the Coast

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[1]The University of Newcastle; [2]NSW Office of Environment and Heritage; [3]Technical University of Denmark

Sea level rise will continue over the 21st century and beyond. This will lead, along with possible changes in frequency and intensity of severe storms, to more extreme sea level events and hence an increased likelihood of coastal flooding and erosion. This paper is to investigate the estimation of extreme sea levels at the coast using data from multi-satellite altimetry missions (e.g., Topex, Jason-1 and Jason-2) and tide gauges. Sea level observations are merged using a multivariate regression approach. The performance of the model is analysed through the investigation of the temporal correlation coefficient, hindcast skill and root mean square error between tide-gauge and altimeter observations. The estimated sea level is used to predict high frequency sea level variations during extreme sea level events, and is compared to in-situ observations. The Peaks-Over-Threshold (POT) is applied to obtain statistically independent extreme sea level estimates (both offshore and inshore). The results from this study suggest that altimetry data may be applicable to estimation of extreme sea levels in coastal areas.

Session 3: Synergy with Models

Contributions of Coastal Altimetry to the GODAE/OceanView Coastal and Shelf Seas activities

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Development and improvement of Ocean Forecasting Systems demands an international approach. The Coastal and Shelf Seas Task Team (COSS-TT; https://www.godae-oceanview.org/science/task-teams/coastal-ocean-and-shelf-seas-tt/) coordinates international coastal forecasting efforts, under the GODAE OceanView initiative (GOV; www.godae-oceanview.org), a continuation of the Global Data Assimilation Experiment (GODAE). The main goal of the COSS-TT is to work in coordination with GODAE

OceanView and other international initiatives related to ocean observing systems, data assimilation and prediction, towards the provision of a sound scientific basis for sustainable multidisciplinary downscaling and forecasting activities in the world coastal oceans. The strategic goal of the TT is to help achieve a truly seamless framework from the global to the coastal/littoral scale. Under this framework, a close synergy with the Coastal Altimetry community is essential. Examples of coastal altimetry contributions to coastal ocean forecasting activities will be presented. A discussion will follow on the future outlook for the utility of coastal altimetry products in enhancing the forcing, data assimilation and evaluation of coastal ocean forecast systems.

SSH Variability Along the US West Coast in Winter

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CEOAS, Oregon State University

Analyses of satellite altimetry and high-resolution regional ocean model simulations show seasonal increase in the SSH along the coasts of the US Northwest in winters, associated with the wind-driven coastal downwelling. The strength of downwelling varies from year to year. For instance, winter 2008-9 conditions were close to average, while in winter 2009-10 downwelling was much stronger and extended much farther to the south than in the previous year. In February 2010, a chain of energetic anticyclonic eddies was generated and detached from the downwelling front, clearly seen in the satellite altimetry and well reproduced by the 2-km resolution model. Generation of these eddies is associated with flows around topographic irregularities on the continental slope, such that the location of the emerging eddies is not random. At the surface, the radius of those eddies is close to 100 km, and the current along the eddy rim can be 40 cm/s. These eddies are also detected in surface current measurements made by land-based high-frequency (HF) radars. The influence of these surface intensified eddies extends to a 1000-m depth. Analysis of subsurface flows (e.g., tracer fields on isopycnal surfaces) suggests that these long-lived eddies modify the transport of subsurface source waters, which will be upwelled off the Oregon coast in summer. Analysis of the 2-year model simulation (2009-2010) additionally suggests that energetic jets separating from the coast into the adjacent interior ocean (mostly in summer) are deep enough to entrain offshore the warmer and saltier Californian waters associated with the poleward along-slope undercurrent. Eddy variability detected by the satellite altimetry is well-correlated with the along- and cross-shore undercurrent water transports.

Coastal Mean Dynamic Topography Computed Using ROMS Variational Assimilation of Long-Term Mean Observed Currents and Hydrography

Wilkin, John; Levin, Julia; Zavala-Garay, Javier
Rutgers, The State University of New Jersey

Like many broad continental shelves, the across-shelf momentum balance of the Mid Atlantic Bight (MAB) coastal ocean is predominantly geostrophic and the associated sea level gradient is evident in coastal corrected altimetry. However, the mean along-shelf balance involves a significant contribution from an along-shelf sea surface tilt (sea level increasing northward). This sea level slope ($\sim 10^{-7}$) is not captured well in mean dynamic topography (MDT) fields derived from direct observations or hydrography, and is poorly represented in global or basin scale dynamical models. We have produced an MAB region MDT for use in conjunction with coastal corrected along-track altimetry in a real-time data assimilative ocean prediction system. The MDT was computed using the ROMS (Regional Ocean Modeling System) 4-Dimensional Variational (4DVar) data assimilation (DA) scheme in its strong constraint formulation with open boundary sea level and velocity among the control variables. The long-term average current observations assimilated were: (i) ~4 years of surface current observations from HF-Radar covering the region from the coast to approximately 150 km offshore, (ii) 10 years of monthly shipboard ADCP currents (to 400 m below the sea surface) on an across-shelf transect (the Oleander Line), and (iii) approximately 40 moored current-meter deployments on the shelf. Also assimilated was (iv) a regional hydrographic climatology of temperature and salinity computed by locally weighted least squares to preserve anisotropic length scales in the thermal wind. The model was forced by climatological mean river inflows and air-sea fluxes, but with the DA system adjusting the latter â€“ in addition to the 3-dimensional ocean state itself â€“ to further minimize the model-

data misfit. The analysis was conducted for annual mean, and seasonal mean conditions. In the latter case, the seasonal cycle in Jason-2 along-track altimetry was included as a further data constraint. The 4DVar solution adds the anticipated mean slope that was absent from the prior solution for sea level boundary conditions that were adopted from a global data assimilative model. Model performance improves in DA simulations that augment along-track altimetry with the new MDT, and in freely running simulations that employ the MDT in open boundary conditions.

State Estimates and Forecasts in the Gulf of Mexico

Gopalakrishnan, Ganesh[1]; Cornuelle, Bruce[1]; Hoteit, Ibrahim[2]; Rudnick, Dan[1]; Owens, Brechner[3]
[1]Scripps Institution of Oceanography, UCSD; [2]King Abdullah University of Science and Technology; [3]Woods Hole Oceanographic Institution

An ocean state estimate has been developed for the Gulf of Mexico (GoM) using the MIT general circulation model (MITgcm) and its adjoint. The estimate has been tested by forecasting Loop Current (LC) evolution and eddy shedding in the GoM. The adjoint (or four-dimensional variational (4D-VAR)) method was used to match the model evolution to satellite-derived along-track sea surface height (SSH) and gridded sea surface temperature (SST) observations by adjusting model temperature and salinity initial conditions, open boundary conditions, and surface forcing fields. The model fit along-track SSH observations, separated into temporal mean and anomalies, and gridded SST observations for two months and used the optimized state to forecast two months from the end of the fitting period. Forecasts explore LC predictability and provide a cross-validation test of the state estimate by comparing it to independent observations. The model forecast was tested for several Loop Current Eddy (LCE) separation events, including Eddy Franklin (Eddy-F) in May 2010 during the Deepwater Horizon (DwH) oil spill in the GoM. The forecast used monthly climatological open boundary conditions, surface forcing, and runoff fluxes. The model performance was evaluated by computing model-observation root-mean-square-difference (rmsd) during both the hindcast and forecast periods. The rmsd metrics for the forecast generally outperformed persistence (keeping the initial state fixed) and reference (forecast initialized using assimilated HYCOM 1/12 degree global analysis) model simulations during LCE separation events for a period of 1 ~ 2 months. The forecast product has potential application in advising operational decisions and also to facilitate the tracking of LC waters during an emergency response similar to the DwH incident in the GoM.

Session 4: Corrections

An Inter-Comparison Between Algorithms for Wet Path Delay Retrieval in the Coastal Regions

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In the last years, major advances have been made in the field of Coastal Altimetry, with the development of various methodologies for the computation of the wet tropospheric correction in the coastal zone. Three main approaches have been proposed for the retrieval of the wet path delay in the altimeter measurements in the coastal regions, where the Microwave Radiometer (MWR) measurements become invalid due to land contamination in the radiometer footprint:

(1) Land Contamination Algorithm (LCA)
(2) Mixed-Pixel Algorithm (MPA)
(3) GNSS-derived Path Delay (GPD) approach

The first method, based on the correction of the MWR measured Brightness Temperatures (TBs) from the contamination by the percentage of land in the radiometer footprint, followed by a retrieval of the path delay (PD) by reapplying the same algorithm developed for open ocean, has been implemented to Jason-2 data in the scope of project PISTACH. The second approach, based on the parameterization of the algorithm

coefficients as a function of the 18.7 GHz land fraction using a database of modeled coastal TBs has been developed at the Jet Propulsion Laboratory (JPL) and applied to Jason-1 and Jason-2 data. The third technique (GPD) is based on the combination of PDs derived from GNSS (Global Navigation Satellite System) with valid MWR measurements in the vicinity of the point and PDs derived from a Numerical Weather Model (NWM) such as the European Centre for Medium-range Weather Forecasts (ECMWF). GPD has been developed in the scope of ESA project COASTALT, further refined and implemented to Envisat in the scope of ESA project Sea Level CCI.

This study presents an inter-comparison of the three techniques with respect to various issues. A summary of each technique is first presented with focus on the methodology, data requirements, accuracy and specificities of the application to each altimeter mission.

For the Jason-2 mission these methods are inter-compared and validated by performing a set of analyses such as: 1) Sea level anomalies (SLA) variance function of the distance from the coast and SLA variance at crossovers; 2) comparison with independent measurements of wet PDs such as GNSS-derived PDs (at stations not used in GPD), global and local NWM and observations from radiosondes; 3) SLA comparisons at tide gauges.

Finally, the strengths and weaknesses of each methodology are discussed, as well as the possibilities for improvement of each individual technique or through the merge of techniques.

A Specific Coastal Wet Tropospheric Correction for the Envisat RA2 Altimeter

Obligis, Estelle[1]; Picard, Bruno[1]; Femenias, Pierre[2]; De Boer, Jean-Remi[1]
[1]CLS; [2]ESA/ESRIN

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.

Comparison of Recent Ocean Tide Models in the China Seas

Li, Dawei; Chu, Yonghai; Jin, Taoyong; Li, Jiancheng
Wuhan University

Ocean tides has been observed and studied for a long time. Due to its role in the complex interactions between ocean and atmosphere, tides have been identified as the main contribution to the global sea level change; this is the key factor why the accurate ocean tide models are needed in oceanographic and geophysical research. With the advent of high precision satellite altimetry and advances in numerical method, the global ocean tide models are able to give predictions with the accuracy of the order of 2 cm rms in the deep ocean and with a spatial resolution of 50 km. In contrast, the accuracy is significantly degraded over the continental shelves and coastal sea areas, because the tidal range is usually large and the tidal waves are much more complicated, as well as the nonlinear hydrodynamics caused by resonance or near

resonance response in shallow water. The China Seas is one of the most complicated areas with poor performance of ocean tide models, it is part of the western Pacific Ocean bordering the Asian mainland on the east-southeast, the region consists of four main parts. The tides in these areas have been studied by numerous oceanographers, and the global ocean tides show the great diversity in theses areas, different models seem to perform better in certain regions. we are intended to evaluate which current model works best in the China Sea Areas.The accuracy assessment is carried out through comparison of the tidal harmonic constants provided by 6 ocean tide models and 200 tide gauges (TGs) along the coastline of China.

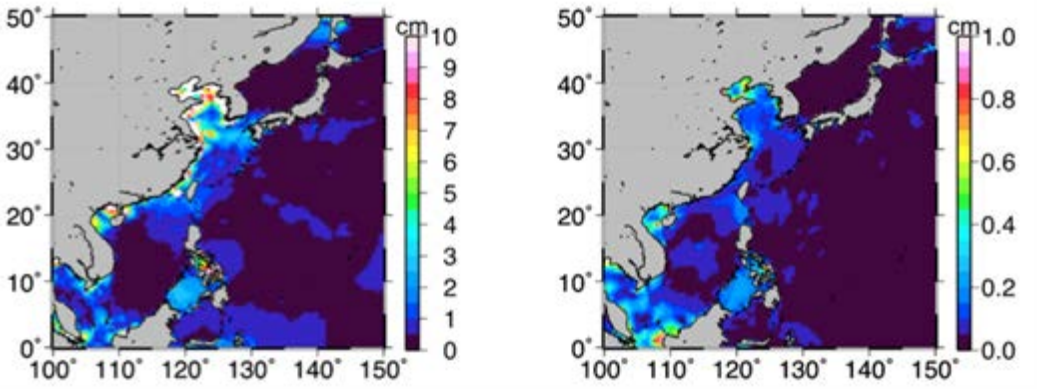

Fig. 1 Standard deviation of 5 global ocean tide models for M2 and K1 constituent.

We selected 5 global ocean tide models (EOT10a, FES2004, GOT4.7, NAO99b and TPXO7.2) and a regional tide model (CS2010) to estimate the regional accuracy of the recent global ocean tide models in China Seas. In order to identify the performance of different sea areas, the TGs are divided into two datasets: TG-A comprises all TGs located in the SCS, TG-B located in the BS, the YS and the ECS. The comparison reveals that the global ocean tide model NAO99b shows the best results over the West Pacific continental shelf between the global tide models. The Root Sum Square of the misfit of the 4 tidal constituents provided by the models(M2, S2, K1, O1) with the tide gauge data is higher than 27.6 cm for global ocean tide models and higher than 14.8 cm for regional model. It also proves that the performance of SCS is better than the other areas, and the tide model with high spatial resolution that assimilates tide gauge data and satellite altimeter data can improve the accuracy of tide model close to the coast and over the continental shelf.

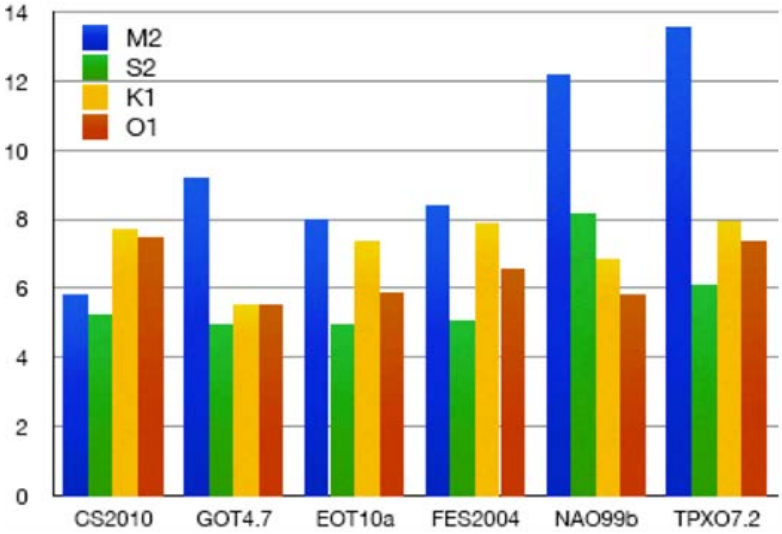

Fig. 2. The RMS misfits for the four major constituents between tide models and TG-A. (unit: cm)

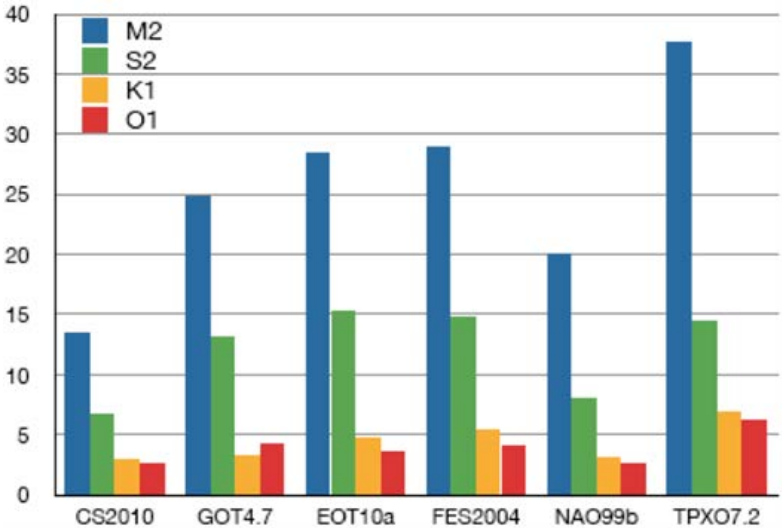

Fig. 3. The RMS misfits for the four major constituents between tide models and TG-B.(unit: cm)

Day 2, Friday 21 September 2012

Session 5: LRM Retracking

Assessing the Transition from Open-Ocean to Coastal Retracking Algorithms

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Considerable research has been carried out in recent years on modifications of the retracking algorithms to achieve a more accurate estimation of range and significant wave height (SWH) in the coastal zone. A number of coastal retracking schemes have been proposed as a result, including some that attempt to exploit the information in a number of adjacent waveforms (sequential retrackers); the validation of these new algorithms is continuing.

One particular aspect of the performance of these new retrackers is their behaviour at the interface between the open-ocean condition and the coastal zone i.e. the transition zone that lies normally at 5-10 km from the coast where the effects of land or bright targets in close proximity to the coast start modifying the Brown-like shape of the returns. Some applications may favour a seamless – as far as possible – transition rather than a marginally more accurate estimation of the parameters in close proximity of the coastline. Continuity in height might be traded for continuity in SWH, and vice versa.

Here we discuss some criteria to evaluate the goodness of transition when switching from the open ocean (Brown model) retracker to the coastal retrackers; these include bias evaluation over various zones of overlap, and continuity of the first derivative. We illustrate these concepts with examples taken from some of the most popular coastal retrackers, like Brown plus Gaussian Peak (BGP) and Brown plus Asymmetric Gaussian Peak (BAGP), in their implementations in the PISTACH and eSurge processors. We also discuss the adoption, as switching criterion, of a modified independent parameter that quantifies the effect of coastal morphology (coastal proximity), rather than crude distance from coast.

The Coastal Waveform Retracking Using Fuzzy Expert System Approach

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Due to the demand for precise altimetry sea level measurements in coastal regions, a number of new/improved waveform retrackers have been developed in the last few years. Some retrackers have been identified as performing better at the coast. However, the issue remains, which is difficult to determine which ones have performed the best and which ones should be used under various conditions in the extraction of meaningful information of sea level. This study selects the most appropriate retracker at the coast using a fuzzy expert system. Several retracking algorithms were used to retrack waveforms, and the results were analysed using the fuzzy expert system. The system is developed based on specific rules used to evaluate the performance of each waveform retracker. The rules are defined based on physical features of waveforms and statistical features of retracking results. During the processing, the input retracked sea levels were transformed into fuzzy membership functions; and the complex nonlinear input-output relationships were defined. The fuzzy inference processed these fuzzy inputs to evaluate the performance of retrackers based on ranking values determined by the rules. This system, therefore, conveniently handles the uncertainty in the coastal retracking results. The retracked sea level produced by the selected 'best-performing' retracker will be used as the output of the sea level profile. The expert system processed 20-Hz waveforms data from Jason-1 and Jason-2/OSTM in the Great Barrier Reef, Australia. The results from this study show that the fuzzy expert system can be used to determine an optimal retracker for deriving precise sea level near the coast. By using the system, additional data near the coastline have been recovered up to ~4.5 km for Jason-1 and ~7 km for Jason-2 in the study area. Comparison with independent data has shown that the derived sea levels agree with those from tide gauges and high frequency radar with correlation coefficients of >0.7. The derived sea level profiles are also consistent to those from high frequency radar data.

Adaptive Retracking of Jason-1 Altimetry Data for Inland Waters on the Example of the Volga Reservoirs

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One of the recent applications of satellite altimetry originally designed for measurements of the sea level is associated with remote investigation of the water level of inland waters: lakes, rivers, reservoirs. In the open ocean conditions geophysical parameters are retrieved with very high accuracy, because solution of the re-tracking inverse problem is based on the strong a-priory information about the wave form of the averaged telemetric impulse given by Brown's formula. Since for the case of inland waters, the telemetric impulse is strongly contaminated by reflections from the land, this a-priory information is not applicable. Then, errors in the water level retrieved from the altimetric measurements are enormous, as we demonstrate on the basis of comparison of ground measurements of the water level of Gorky Reservoir of the Volga River and all available along track 10Hz TOPEX/Poseidon and 20Hz Jason altimetry data over the reservoir area. These conditions are typical for the majority of reservoirs of the Volga river cascade (with one exception, Rybinskoe Reservoir). Under these conditions a few telemetric impulses fit the validity criteria, which cause a severe loss of data. To provide new a-priory information for the re-tracking algorithm, a theoretical model of a telemetric impulse scattered by a statistically inhomogeneous surface was constructed. For the model of the terrain in the vicinity of Gorky Reservoir, the model represents the main typical features of the waveform examples, and the modeled waveforms are in good agreement with the Jason-1,2 waveforms for the same area. It was shown that for the Gorky Reservoir the retracking algorithm based on the detection of the beginning of the leading edge of telemetric impulses is preferable for correct assessment of variations of water level in Gorky Reservoir. Comparing of the data with in situ measurements of the water level of Gorky and Rybinsk Reservoirs shows that re-tracking dramatically increases the number of data involved in monitoring and significantly improves measurements of the water level. Correlation of in-situ and altimetry water level measurement after re-tracking increased from 0.3 to 0.9 for Gorky reservoir and from 0.9 to 0.99 for Rybinsk reservoir. In August-September 2011 the first series of ground experiments were carried out at the Gorky reservoir directed to calibration of significant wave height in the algorithm of altimetry data re-tracking adapted to the conditions of an inland water body. Data on surface wave spectra and probability distribution function of waver elevation in water waves were obtained. Peculiarities of wind surface waves in inland water bodies and possibilities of significant wave height retrieval from the satellite altimetry data are discussed. General principals of retracking algorithms for complex areas based on taking into account statistical inhomogeneity of the reflecting surface adjusted to a certain geographic region , are discussed.

Improved Retrieval of Altimetry Heights in Coastal And Sea Ice-Covered Region via Waveform Modification and Retracking

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[1]The Ohio State University; [2]National Chiao Tung University; [3]National Cheng-Kung University; [4]University of Houston

Accurate retrieval of the ocean surface topographic heights near coastal and shallow inland water region is a challenge using satellite radar altimetry, as the radar waveforms are distorted by land contamination in the topographically inhomogeneous area. Similar contaminations are found in the polar oceans where ice floes dominate returned signals when the large radar footprint (~7km) covers the interface of ocean and sea ice. In this study, we develop a novel technique to modify spurious waveforms at ocean surface where the mixed surface properties induce additional peaks in the theoretical Brown's ocean model. These peaks shift the leading edge backward when the land/ice is at the edge of footprints, or move it frontward at zenith of the interface. We statistically filter out the unnecessary peaks and facilitate the retrieval of ocean surface information from the remaining waveform gates. Our preliminary result shows that a 61% improvement in accuracy (RMS) is averagely estimated at four places around North America coastal region, by validating with in situ gauge data and comparing with onboard ocean retracker. Also, a 77% improvement in RMS is obtained at eastern Greenland offshore under the presence of sea ice during winter. We demonstrate that the waveform modification technique is applicable to both Envisat and Jason-2 altimeters, which broaden the usage of traditional deep-ocean altimetry measurements to within a few kilometers near the shoreline. The technique is also effective in retrieval of more altimetric heights in seasonally sea-ice covered regions of the Arctic Ocean.

Using HF Radar Coastal Currents to Correct Satellite Altimetry

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A challenge of coastal ocean satellite altimetry is correcting for altimetric waveform distortions due to the presence of land within the instrument footprint. Many retracking procedures have been developed for this correction but there is great difficulty in knowing what is the proper method and where it is best applied. A possible fiducial data set is the Coastal HF radar (CODAR) network which continuously monitors surface currents hourly off the west coast of the U.S from 50 km to 150 km offshore depending on the horizontal resolution (2 km and 6 km respectively). First the time and space scales of the coastal ocean are computed using the CODAR velocities. Second, we remove shorter time scale effects of tides and wind forcing over the California Coast by averaging the CODAR over three day to get an approximation of the geostrophic currents. Third, we assume that the local current fields are isotropic and homogeneous and fit them to a stream function to retrieve their matching synthetic height fields mapped with a varying spatial scale optimal interpolation. Testing on regions more than 30 km offshore demonstrates a similarity between the CODAR derived synthetic height fields and those computed directly from satellite altimetry. Data from satellite altimetry are degraded by the occurrence of unusually high radar return backscatter cross-section sigma0. Called sigma0 blooms they occur in regions of weak winds, and in the presence of surface slicks. These higher sigma0 values cause a breakdown in the typical Brown open-ocean waveform model. The waveforms may also be corrupted when the backscattering cross section is not uniform in the footprint of the altimeter with reflecting and localized patches. Such events occur frequently on the California coast and we are now searching for strategies to reduce the errors due to blooming events using CODAR synthetic surface heights as a reference. We use the evolution of the waveforms before and after the point of retrieval to depict the changes in sigma0 over the footprint and incorporate them in the retracking method to adjust for an inhomogeneous ocean. We intend to improve the altimeter surface heights estimate closer to shore due to land contamination using the CODAR synthetic heights as a guideline. First we will use the 20 Hz Jason-2 PISTACH coastal product. This product gives the altimeter's range from several retrackers such as MLE4, Red3 and Ice3. Over the open ocean the 1-Hz range rate measurement is sufficient to describe mesoscale variability, but not in the coastal regions where the spatial scales decrease. The 20 Hz data, although noisy, enables us to examine the possibilities of new sampling strategies for higher altimeter resolution such as 5 Hz closer to shore. We wish to also determine which retracker better fits the CODAR synthetic heights depending on sea state. Other retrackers such as the Gaussian Peak retracker need to be implemented and validated near the coast.

Session 6: Waveform Analysis and SAR Retracking

Pulse-Pair (Doppler) Processing of Envisat Individual Echoes

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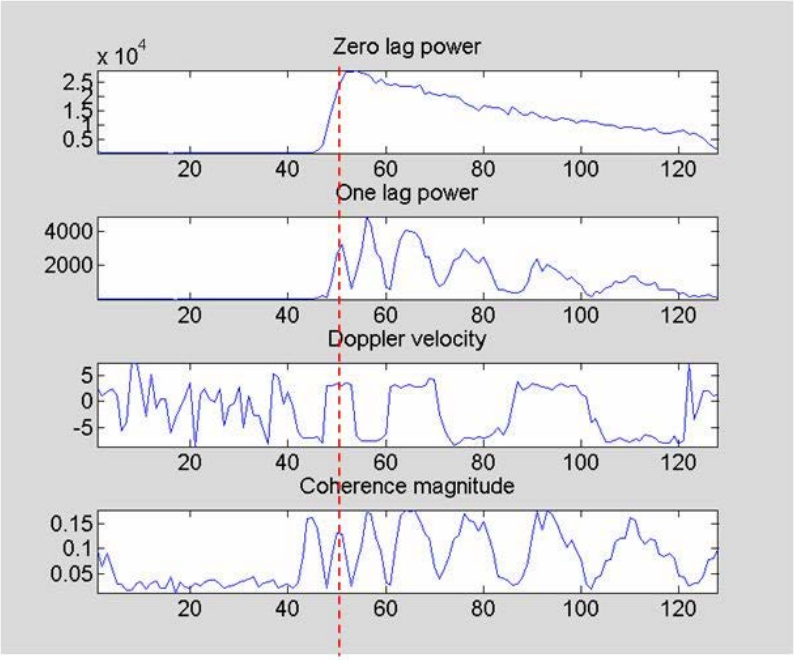
The Envisat 'Individual Echoes' (IE) recording mode provides a 1-second burst of 1984 individual complex echo returns every 1 minute (the rest of the time the data stream is processed into 20 Hz bursts). One record of IE data is 1984 pulses x 128 range bins. This collection mode was designed for experimentation beyond the conventional burst processing. This paper follows on several other research publications discussing various possibilities for exploiting complex IE data. We investigate Doppler processing and the potential for increasing in-range resolution through "Doppler focusing". We processed IE data with Fourier transforms. Envisat PRF of 1800 is intended for a maximum number of independent (uncorrelated) echoes. If the echoes where indeed uncorrelated, the spectra would be featureless. But instead there was immediate evidence of significant spectral lines, indicating coherence in Envisat pulse train. This is not a contradiction of the Envisat goal for independent samples. The coherence levels are small and the samples are almost uncorrelated. However with 1984 samples a coherence as small as 0.05 is statistically significant and sufficient to obtain some of the benefits of Doppler processing. Borrowing an idea from the meteorological radar community, we also use Pulse Pair Processing (PPP), which under certain conditions provides more accurate estimates of the spectral moments than the Fourier Transforms. PPP uses lagged products of echoes, conj(z(n))z(n+k). The magnitude of the sum with k=0 is the usual incoherent power. A new and

possibly more useful 1-lag power can be produced. Doppler velocity and coherence are also obtained from such lagged products. Doppler and PPP are demonstrated on IE data time series over open ocean. A companion poster titled “Examples of Pulse-Pair (Doppler) Processing of Envisat Individual Echoes In Coastal and Inland Waters” will provide additional case-studies. Coherence levels are 0.05 to 0.3 and are in inverse proportion to sea state (calm seas has the highest coherence). The measured Doppler velocities correspond to the satellite vertical velocity, with an rms of 0.26 m/s. The peaks in 1-lag power and 1-lag coherence appear to sharply focus on the water surface. The accompanying figure illustrate PPP for one IE data set. A dashed red line at range bin 50 indicates the alignment of the Brown waveform (top), a peak in one-lag power, Doppler velocity, and a peak in coherence (bottom). In summary benefits of Doppler processing, similar to those being reported with the newer CryoSat-2, are possible with Envisat. CryoSat-2 has a PRF of 17,800 which is 10 time greater than Envisat, and specifically designed for Doppler processing. But our results suggest that there is a possibility for Doppler processing on Envisat's longer operational time span, beginning with IE collections in September 2004 up to the present. Figure 1. PPP spectral moments vs. range bin



Echo to Echo Correlation and Time Alignment in CryoSat FBR SAR Data: Implication for Range and SWH from Coastal SAR Data

Smith, Walter
NOAA

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 and echo time alignment explored in this paper.

At the time of this writing we have problems to recover SWH from Cryosat SAR multi-looked waveforms, at least when SWH is small. One known problem is that multi-looking includes slant-range views for which the impulse response is broader than the echo spread due to SWH, obscuring the SWH signal. A less appreciated problem is that the tracking echo in SAR mode is noisier than in LRM mode, contributing a large error to the

range time alignment in the echoes. This makes it difficult to align the echoes to produce a clean Pseudo-LRM waveform, unless a priori knowledge of the mean sea surface is supplied.

If successive SAR mode echoes can be properly aligned in time, then these data may be used to investigate the pulse-to-pulse correlation structure in the echoes. Knowing this correlation one could then design an optimal strategy to yield the best Pseudo-LRM echoes for use in inter-calibrating between SAR and LRM modes. This could also be used to select an optimal pulse repetition frequency for LRM operation. Our preliminary work suggests that the pulse-to-pulse correlation in Cryosat SAR mode echoes is far more interesting than the simple rules of thumb that have driven the choice of 2 kHz PRF for conventional altimeters. Ideally we may be able to use this correlation structure to investigate the scattering process at the sea surface, and the sensitivity of the SAR mode to wave height and wave direction.

Land Contamination in SAR Mode in Coastal Zone and in Calm Waters

Dinardo, Salvatore[1]; Benveniste, Jerome[2]
[1]Serco/ESRIN; [2]ESA/ESRin

To date, Cryosat-2 is the only radar altimeter in Earth orbit able to operate in the novel and promising Synthetic Aperture Radar (SAR) Mode. The increasing interest in SAR mode is due firstly to its higher resolving measurement capability that shall enable scientists to aspire to measure even short-scale weak coastal phenomena, (thanks to the 20-fold smaller along track radar resolution and 10 dB higher Signal to Noise ratio) and, secondarily, but very significant in coastal zone, to the shrinking of the radar footprint that is expected to reduce the impact of land contamination on the radar waveforms in the proximity of the shore. As a consequence of this effect, the advent of SAR focusing promises to bring the satellite altimetry remote sensing closer to the shore up to around 500 meters. This lower bound of 500 meter on coastal proximity is not always reachable, as the footprint shrinking occurs only in along-track direction while the across-track resolution remains basically unaltered. Hence, the orientation of the satellite ground-track with respect the coastline plays a role crucial for an effective filtering out of the off-nadir land-originated signals. In order to investigate fully the impact of the land contamination on the Delay-Doppler Maps for different ground-track orientation and coastlines conditions, the CryoSat-2 Altimeter raw data shall be focused and stacked using a CryoSat SAR processor prototype developed internally at ESRin. The input dataset shall be the Cryosat-2 Full Bit Rate (FBR) products, now archived systematically at ESRin. These data shall be focused, stacked, multi-looked and subsequently re-tracked using a theoretical SAR waveform model to derive sea surface height and significant wave-height (SWH) measurements. The possibility to retrieve the ocean surface rms slope in along track direction exploiting the range-integrated stack power distribution, calculated from the Delay-Doppler Map, will be outlined for different sea state conditions. In the analysis of the results, emphasis will be placed to show how land contamination, approaching the coastal zone, affects and disrupts the shape of the Delay-Doppler Map and how the SAR waveforms behave in relatively coastal calm waters (low sea state conditions). From previous works, it has been shown that at low sea state conditions (SWH<1 m) it may be challenging to retrieve reliable SWH measurements. This effect may be due to the far off-nadir Doppler beams, being accumulated in the multi-looking stage, that are not perfectly aligned with the near-nadir Doppler beams. This aspect will be addressed in depth in the present work exploiting the in-house SAR processor and adopting different stacking and multi-looking algorithms in order to minimize the waveform leading edge distortion and peak width broadening.

CryoSat-2 SAR Waveform Retracking Over the Ocean: Does Multilooking Distort the Leading Edge?

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Development of sea surface slope profiles from CryoSat altimetry requires retracking the multi-looked SAR waveform over the ocean. We have developed an analytic model for the CryoSat SAR waveform under the assumptions of a single-looked, nadir-pointing radar. The result is analogous to the Brown model where the shape of the echo depends on 3 main parameters of arrival time, rise time (or SWH), and amplitude. In our

marine gravity analysis we are mainly interested in the along-track slope of the ocean surface and are not interested in estimating SWH. We show that under certain conditions of moderate SWH and small off-nadir pointing angle, the fully analytic model is adequate for estimating along-track slope to better than 1 µrad. Moreover because the formulation is fully analytic, we can retrack 12 months of CryoSat SAR waveforms in about a day on a desktop computer. This rapid analysis enables us to explore and refine least squares approaches and waveform weighting functions as well as parameter reduction approaches. To assess the accuracy of the simple analytical model for estimating waveforms, we used our approach to retrack waveforms generated from the full-multilooked theoretical model including variations in SWH, and off-nadir roll angle [SAMOSA Project]. The simulated waveform data was provided at a sampling of ½ gate to simulate the new L1b SAR format being provided by ESA. The first test involved retracking single-looked SAMOSA waveforms over a range of SWH and off-nadir roll. When the off-nadir roll is 0°, the analytic model and SAMOSA model waveforms agree in shape to better than 1 part in 1000 at all gates for the full range of SWH. The arrival time estimated from the fit of the analytical model to the nadir-pointing SAMOSA data agreed to better than 1 mm in absolute range. The least-squares fit of the analytic model to the multilooked (253 looks) SAMOSA waveform data show good visual fits for larger SWH but a poor fit at the toe of the waveform (gates -5 to -2) for an SWH of 0.5 m. Multilook averaging causes an overall smoothing of the waveform and creates a "toe" at the leading edge that is not available in the analytic model. Although the multilook averaging has a significant effect on the entire shape of the waveform, it is nevertheless, possible to adjust the parameters of the analytic model to provide a good match. The question is how does this adjustment of the wrong-shaped analytic model affect the recovered parameters of arrival time and rise time? Remarkably, in the case of zero roll angle, the recovered arrival time agrees to better than 1 mm with the actual arrival time over the full range of SWH. However, the estimated rise time is over-estimated with respect to the true SWH, especially when the SWH is low. The more important issue is the arrival time error caused by a non-zero off-nadir roll angle. Again we use the modeled SAMOSA data to estimate the magnitude of this effect.

Coastal Altimetry : Evolution of Measurement and Retracking Problems when Switching from Conventional (Ku, Ka) to SAR Altimetry

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[1]*CLS;* [2]*CNES*

Over ocean surface, the conventional altimetric echo has a well-defined shape, with a steeply rising leading edge followed by a gradual decline in power over the rest of the waveform. When the altimeter approaches the coast, this shape can be corrupted by land returns or by the summation of backscattered signals coming from inhomogeneous reflective surfaces. In recent years, several studies have been devoted to improve retracking algorithms efficient for those particular waveforms in order to move the altimetric measurements ever closer to shore. The SARAL mission will be launched by the end of 2012 bringing new instrumental and orbital characteristics that will slightly modify the nature of the backscattered signals (typically the footprint of the measurement and the shape of the waveforms) and that should impact the associated estimation performances. Nowadays the new Delay Doppler/SAR radar altimeter concept promises to provide better performances than a conventional radar altimeter over open-ocean, in particular higher azimuth resolution and measurement precision. These features offer the potential to greatly improve our ability to measure sea surface characteristics at closer distance to the shore. The SAR mode is already implemented on-board Cryosat-2 mission (on specific coastal areas) and will be the nominal coastal operating mode for the future Sentinel-3 mission. A performances study of the different technologies in coastal zones will be addressed in this paper using Jason-2, Envisat/RA-2 and CryoSat-2 flight data.

Session 7: CAL/VAL

Altimetry and Bathymetry Trends Around the Coastal Zone of Gavdos Permanent Cal/Val Facility

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[1]Technical University of Crete; [2]Aristotle University of Thessaloniki; [3]Danish Space Center; [4]University of Aegean

The aim of this work has been to examine the relationship of steep bathymetry in the coastal areas around the permanent Cal/Val facility of Gavdos, and their influence on the produced calibration values for the Jason-2 satellite altimeter. Three reference surfaces have been chosen for this evaluation. Details regarding the methodology applied for the determination of calibration values, as well as comparative results against all available reference models and surfaces will be provided. This work outlines how the changes of steep bathymetry (from 200 m to 3500 m 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.

A Study on the Conformance of Altimetry and In-Situ Sea Surface Data Near Coast in the German Bight

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Altimetry data near to the coast have been validated in the German Bight during the period 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 off-shore measurement platforms and of other stations both on the islands and 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 a regional operational model run by the German Federal Maritime and Hydrographic Agency (BSH). For standard altimetry products, the comparison of instantaneous (1-Hz ad higher frequency) measurements with tide gauge data provides similar results. Interference from the coast is almost absent for passes at the small isle of Helgoland, with a distance of 8 km between the altimetry and tide gauge. The correlation of 0.9, standard deviation of the differences of 6-7 cm and absolute differences in observed heights of a few centimeters (6.2/2.7/-0.4cm depending on the mission) provide a positive comparison at offshore locations. The consistency is lower at coastal stations. This is mainly due to the decreased number of available altimeter data and to their increased noise, as in Borkum, with a distance of 24 km between tide gauge and co-located altimeter measurements. Reduced correlation and increase of both standard deviation of the differences (10.4 cm) and of the ellipsoidal height differences (31.1/29.3/25.3cm depending on the mission) are characteristic of coastal stations. With the PISTACH coastal products, a small improvement (reduction of noise) is observed. Reduced correlation and increase in both standard deviation of the differences and ellipsoidal height differences are also in this case, characteristic of the coastal stations. Sea level and significant wave heights derived from in-situ data, are compared to the parameters derived from Cryosat SAR data to estimate eventual biases occurring in SAR mode with respect to Pulse-Limited (LRM) Mode and tune up the SAR re-tracking scheme. The new GRACE- and GOCE-based geoid models are further considered to validate the sea level near to the coast.

Calibration and Validation of Combined Conventional and Reduced SAR Mode Data Over Oceans and in the Coastal Regime

Scharroo, Remko[1]; Smith, Walter[2]; Lillibridge, John[2]; Leuliette, Eric[2]
[1]Altimetrics LLC; [2]NOAA Lab. for Satellite Altimetry

Two year after the launch of CryoSat, oceanographic uses of the CryoSat data have well taken off, after several institutes, NOAA included, have spend a dedicated effort to upgrade the official CryoSat data products to a level that is suitable for monitoring of mesoscale phenomena, as well as wind speed and wave height. But in the coastal areas, this is much less the case. This is mostly the result of the fact that CryoSat is running in SAR or InSAR mode in many of the focus areas, like the Mediterranean Sea.

We have shown, however, that the CryoSat data is intrinsically of high quality and for nearly a year now have been producing "IGDR" type data through FTP and through RADS. These steps include:

- Combine final (LRM) and fast-delivery (FDM) products and split the segmented files into pass files.
- Divide the 369-day repeat cycle into subcycles of 29 or 27 days.
- Retrack the conventional low-rate data to determine range, significant wave height, backscatter and off-nadir angle
- Add or replace the usual corrections for ionospheric and atmospheric delays, tides, dynamic atmospheric correction, sea state bias, mean sea surface.
- Update orbits and corrections whenever they become available.

This way NOAA produces an "IGDR" product from the fast-delivery FDM and the CNES MOE orbit in about 2 days after real time, and a "GDR" product from the final LRM data and the CNES POE orbit with a delay of about 1 month.

In order to extend the data products to the coastal regime, we have developed a process in which the SAR data are first combined to "Pseudo-LRM" or "reduced SAR" wave forms, that are similar to the conventional low-rate wave forms. After this the reduced SAR data are retracked and combined with the conventional data to form a harmonised product. Although this sounds relatively straightforward, many steps were needed to get this done.

- Combine the SAR wave forms to conventional wave forms, without loss of information. This is the topic of another presentation by Walter Smith.
- Reconstruct backscatter and significant wave height in a meaningful way, consistent with low-rate data.
- Cross-calibrate the conventional and SAR mode data.
- Validate the data quality of conventional and SAR mode data through crossovers and collinear track analyses.

In this presentation we will demonstrate that the CryoSat data quality compares to other altimeters (Envisat, Jason-1 and Jason-2) by means of data distribution maps, histograms and crossover comparisons. In this we will particularly focus on coastal regions and discuss the possibilities of further improvements.

Following this meeting we intend to publicly release out combined CryoSat LRM/SAR mode data through a NOAA FTP site and the RADS server at the Delft University of Technology.

Session 8: Future Data and Missions

The Future of PISTACH for 2013-2015

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CNES

The PISTACH prototype routinely provides coastal and hydrological products at a global scale based on Jason-2 S-IGDR products. Operated since 2009, the prototype has already shown its potential. The coastal/hydro community has specific needs in terms of multi-mission aspects, new algorithms, reprocessing, etc. CNES proposes an overview of what is planned for the future of PISTACH in terms of upgrades, integration of new missions and reprocessing campaigns.

The Surface Water / Ocean Topography Mission (1): Capabilities for Coastal Oceanography

Callahan, Philip; Fu, Lee-Lueng; Rodriguez, Ernesto; Pollard, Brian; Esteban-Fernandez, Daniel; Vaze, Parag
Jet Propulsion Laboratory

The Surface Water / Ocean Topography (SWOT) mission, a proposed partnership between NASA, CNES (Centre National d'Etudes Spaciales), and the Canadian Space Agency, promises to provide first-of-their kind measurements of rivers to 100 m, lakes to 250 m, and sea surface topography to 1 km or better resolution globally and repeatedly. The fine scale of the measurements would result in large data volumes starting at the instrument and flowing through the spacecraft and ground system. Mission data acquisition is limited by the space-to-ground link, but in initial planning there is the possibility to accommodate some coastal data at high (~50 m) resolution in addition to the standard ocean ("low resolution") product. The SWOT error budget would provide height accuracy of a few centimeters in both high and low resolution data.

We will provide an overview of the proposed mission capabilities with a focus on features of interest for coastal oceanography. We will also provide an overview of the science processing system and data products.

SWOT would be put into an exact repeat orbit with a cycle of about 22 days and a sub-cycle optimized for mesoscale oceanography. The Ka-band interferometer would have two 50 km swaths on either side of nadir with a gap of about 20 km around nadir. Open ocean data would be partially processed onboard to reduce the data rate. The resulting interferograms will be converted to height and resampled on the ground to provide 1 km gridded sea surface height (SSH). The planned Geophysical Data Record (GDR) for the ocean would be a relatively straightforward extension to the swath geometry of the traditional ocean altimeter (TOPEX, Jason) GDR.

High resolution data would have a collection rate of about 270 Mbps after onboard presuming. The data will be sent to the ground for SAR and interferometric processing to surface heights. The high resolution hydrology data product poses unique challenges including distinguishing land from water and a requirement for 50 m posting of water heights. It is not feasible to make this product as a raster, so it would be made as a triangularly interpolated network (TIN) with location, elevation, classification, and errors, as well as metadata, for areas within and near water detected in the SWOT swath. The form of a coastal ocean product will be determined in consultation with the science team.

(1) Some of the work reported here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. (1)The SWOT mission has not been formally approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process. Material in this paper related to SWOT is for information purposes only.

Current Status of the Japanese Altimetry Mission

Uematsu, Akihisa; the, JAXA COMPIRA Team
Japan Aerospace Exploration Agency (JAXA)

The Japan Aerospace Exploration Agency (JAXA) has started a conceptual design of a new altimetry mission, COMPIRA (Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter). The main sensor of the COMPIRA mission is a wide-swath altimeter (SHIOSAI; SAR Height Imaging Oceanic Sensor with Advanced Interferometry). SHIOSAI is a X-band interferometric synthetic aperture radar with two antennas. Swath width per each side is 80 km (totally 160 km swath), spatial resolution is 5 km, and recurrent period is 10 days. Coverage (observable area) is 98 %, which will dramatically improve the coverage compared to nadir-looking altimeters. This means that observable areas including coastal regions are expanding, and tidal model especially in the coastal regions is expected to be improved. The COMPIRA will provide a great amount of data for operational and scientific use, and data will be used to help to estimate fishing places and to forecast ocean currents. The COMPIRA mission has been assessed by Mission Definition Review (MDR) as a initial review in June 2012. In the presentation, we will present the current status.

POSTER SESSION

FES 2012: A New Tidal Model Taking Advantage of Nearly 20 Years of Altimetry Measurements

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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 crtitical. 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 adjustement 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 ocean tide models.

Continental Shelf Dynamics from Coastal Altimetry in the Bay of Biscay

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In the Bay of Biscay, located at midlatitudes of the Eastern North Atlantic Ocean, circulation over the continental shelf is mainly driven by tides, winds, and river runoffs. These forcings drive a wide spatio-temporal range of ocean processes. Previous studies from hydrodynamical model or observations highlighted major circulation patterns modulated by a strong interannual variability. For example, Lazure et al. (2008) showed the development of a poleward current in autumn along the French coast. This current does not occur every year for reasons that remain not fully explained. However, we build these conclusions on a limited number of observations (collected during cruises at sea since 2005). In this context, coastal altimetry appears as a potential significant contributor to observe and to analyse these intermittent processes over long time periods. Based on Jason 2 satellite altimetry data, we compare Pistach and SlaExtended standard AVISO products from 2009 to 2011. These data are validated using tide gauge data in the Bay of Biscay. Along track spectra allow describing spatial scales observed in the different datasets. Finally, the interannual variability is analysed to describe processes visible in altimetry data. A special care is given to the occurrence of the autumn poleward current by comparing 3D operational model results (PREVIMER project) with altimetry.
This study aims to determine if some major ocean processes over the continental shelf in the Bay of Biscay can be inferred from coastal altimetry products.

The Use of Coastal Altimetry to Support Storm Surge Studies in Project eSurge

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One of the most promising applications of the new field of coastal altimetry, i.e. the discipline aiming to recover meaningful estimates of geophysical parameters (sea level, significant wave height and wind speed) from satellite altimeter data in the coastal zone, is the study of storm surges. The understanding and realistic modelling of surges supports both preparation and mitigation activities and should eventually bring enormous societal benefits, especially to some of the world's poorest countries (like Bangladesh). Earth Observation data have an important role to play in storm surge monitoring and forecasting, but the full uptake of these data by users (such as environmental agencies and tidal prediction centres) must first be encouraged by showcasing their usefulness, and then supported by providing easy access.

Having recognized the above needs, The European Space Agency has recently launched a Data User Element (DUE) project called eSurge. The main purposes of eSurge are a) to contribute to an integrated approach to storm surge, wave, sea-level and flood forecasting through Earth Observation, as part of a wider optimal strategy for building an improved forecast and early warning capability for coastal inundation; and b) to increase the use of the advanced capabilities of ESA and other satellite data for storm surge applications. The project is led by Logica UK, with NOC (UK), DMI (Denmark), CMRC (Ireland) and KNMI (Netherlands) as scientific partners.

A very important component of eSurge is the development, validation and provision of dedicated coastal altimetry products, which is the focus of the present contribution. Coastal altimetry has a prominent role to play as it measures the total water level envelope directly, and this is one of the key quantities required by storm surge applications and services. But it can also provide important information on the wave field in the coastal strip, which helps the development of more realistic wave models that in turn can be used to improve the forecast of wave setup and overtopping processes. In this poster we present examples of how altimetry has captured a few significant surge events, and we will describe how a multi-mission coastal altimetry processor is going to be integrated in the eSurge system. The delayed-time reprocessed coastal altimetry data will be blended with tide gauge data to extract the main modes of variability in the coastal regions. Then data from the tide gauges can be used to estimate water level in real time, based on the modes of variability found. In a later phase of the project, the eSurge coastal altimetry processor will be extended to be able to ingest Near-Real-time (NRT) raw altimetric waveforms and generate the relevant NRT products, a definite first for coastal altimetry. The pilot regions for this application will be the European Seas (where an area of specific interest is the Northern Adriatic, which is being investigated by esurge-Venice

Cryosat Plus For Oceans - User Consultation

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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.

Retracking of Altimeter Waveforms over the Prince William Sound

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The Prince William Sound (PWS) is a semi-enclosed sea located at the northern part of the Gulf of Alaska. It is a region of complex topography consisting of islands, narrow channels and fjords. The region is also controlled by the Aleutian low during the winter. The PWS region, thus, produces highly complicated waveforms when it is covered by the altimeter footprint. In this study, altimeter waveforms from Jason-1 (interlaced), Jason-2 and Envisat missions are retracked using existing and newly developed algorithms. The preliminarily retracked results from Jason-1 and Jason-2 suggest that a detailed retracking procedure is essential in the PWS region, as the MLE4 retracked data currently available in GDRs are inaccurate near the coast. The retracked sea surface heights are compared with available in-situ data, as well as validated using sea surface heights generated by the PWS regional ocean modelling system (ROMS). The retracked results from this study will, in turn, be able to provide new data sets for the ROMS in the future.

The GMES Sentinel-3 Mission

Donlon, Craig
ESA, NETHERLANDS

Global Monitoring for Environment and Security (GMES) is a joint initiative of the European Commission (EC) and European Space Agency (ESA), which aims at achieving an autonomous and operational Earth observation capacity. GMES marks the transition from R&D oriented efforts in earth observation towards operational services. The development of the space infrastructure i.e. the GMES “space segment” for the provision of Earth remote sensing data is led by ESA partly in cooperation with EUMETSAT. Two Sentinel-3 satellites are in development with the second satellite expected approximately 18 months after the first. The overall service duration is planned to be 20 years with several satellites. Currently, the launch of the first Sentienl-3 satellite is planned in late 2013. This poster paper describes the Sentinel-3 Mission.

The GMES Sentinel-3 Topography Mission

Donlon, Craig
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Sentinel-3 is an operational mission in high-inclination, low earth orbit for the provision of observational data to marine and land monitoring services [4]. These services include the generation of sea, ice and land surface altimetry products, the generation of land and ocean colour products, the generation of sea and land surface temperature products, and the generation of vegetation products. Full performance will be achieved with a constellation of two identical satellites, separated by 180 degrees in the same orbital plane. This configuration is driven by (i) trade-off between ocean and land coverage requirements and (ii) operational constraints. The operational character of the mission implies a high level of availability of the data products and fast delivery time, which have been important design drivers for the mission. Sentinel-3 Payload Includes a topography payload consisting of a SAR Radar Altimeter (SRAL) and a Microwave Radiometer (MWR) plus a suite of instruments for precise orbit determination (POD). These instruments will ensure the continuation of important data streams established with ESA’s ERS and ENVISAT satellites. This poster paper provides an overview of the Sentinel-3 altimetry payload.

Regional Assessment of Altimetry Products in the NW Mediterranean : Comparisons to In-Situ Data and Model Outputs.

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The accuracy of satellite altimetry products has been significantly improved during the past decade and a number of new regional and coastal products have been developed. Some of these improvements open new perspectives for regional and coastal oceanographic studies, such as the better geophysical and instrumental corrections, allowing the observation of fine mesoscale structures offshore and a better sampling of energetic coastal dynamics.

In the context of emerging application of satellite altimetry data for coastal oceanography studies and operational oceanography, we make a preliminary investigation of the observed variability in two different families of products : regional *SLAextend* products (Jason-2, Envisat and Cryosat-2) which have now been made commonly available in regional seas, and experimental Level-3 coastal sea level products from *PISTACH* developed at CLS from Jason-2 data in the Northwestern Mediterranean Sea. Comparisons are done with data from the IMEDIA March 2012 cruise off the coasts of Southern France and Corsica, as well as simulations from the regional NORMED configuration of the MARS3D model developed at IFREMER.

Two approaches are chosen for the analysis of small scale variability : 1) by colocating in-situ observations with geostrophic currents deduced from satellite altimetry to assess the realism of sampled structures, and 2) by performing spectral analysis of the sea level from satellite altimetry data to better understand the effects of data processing on the representation of the different scales of variability, and comparing to the spectral representation of the oceanic variability simulated by the model. In fine, this study tries to focus on possible feedbacks for operational oceanography such as the use of dedicated altimetry products while at sea on scientific cruises, and to help improving the regional model (MARS3D), which now runs operational forecasts in the frame of the PREVIMER project.

Characterizing Spatiotemporal Variability in Altimeter-Derived Ocean Currents on the Coastal NW Atlantic Shelf

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This study focuses on use of the long-term satellite altimeter data record to assess both spatial and temporal variability of ocean current within and surrounding the Gulf of Maine (GoM) region that resides on the NW Atlantic coastal margin. This marginal sea has been studied for many decades and from many perspectives due in part to large fisheries production as well as the energetic ocean circulation dynamics tied to the tied Bay of Fundy, and a persistent along-shelf current from upstream Scotian Shelf and Labrador Sea sources. Feng and Vandemark (2011) recently developed a new regional observational capability by producing satellite altimeter data product using latest coastal data reprocessing approaches. From these new sea surface height anomaly data, the cross-track surface geostrophic velocity anomalies for the suite of regional altimeter satellite tracks have been estimated from the along-track slope. In this study, we assess the ability of altimeter-derived surface geostrophic currents to characterize the surface circulation patterns and the seasonal variability in the region. For satellite data validation and interpretation, in situ ADCP current measurements taken by the Univ. of Maine in the North East Channel (NEC) from 2004 thru 2011 are used to assess the accuracy of altimeter-derived surface geostrophic velocity anomalies. The NEC region is critical for GoM transport as it is the only location for deepwater exchange and the location dominates the total water mass exchange for the GoM. Time series comparison at this mooring node shows close agreement with altimeter-derived surface geostrophic currents at seasonal time scales. This suggests that altimetry is reliable for synoptic variation characterization. As expected, significant discrepancies still exist between altimeter-derived geostrophic currents and in-situ measurements, with likely explanation tied to baroclinic forcing. Analyses of the altimeter track data surrounding the NEC and its nearby region, including deeper shelf/slope waters are presented to characterize both the spatial pattern and the seasonal evolution of the surface geostrophic anomaly flows. Discussions follow with respect to present knowledge of regional circulation dynamics and contributions that altimetry can provide towards improved understanding of interannual and seasonal circulation within the satellite altimeter era of 1993-present.

Coastal Radar Altimetry: What Can we Learn from the Costa Concordia Accident?

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The retracking of radar waveforms is crucial in order to extend satellite altimetry information to the coastal zone, where particular targets (i.e. land, flat waters, ships) may act as signal contamination sources. On 13th of January 2012 the Costa Concordia cruise ship, with about 4200 passengers onboard, smashed its hull against the coast of Giglio Island, a tiny piece of land in the Tuscan Archipelago (Northwestern Mediterranean). Since then, the ship lies partly submerged in the water off the coast of the island. The dual-frequency radar altimeter (RA-2) on-board the ENVISAT satellite makes one descending pass (orbit 274) near Giglio Island, very close to the accident area (about 2Km), with a revisit time of 30 days. This particular condition represents a unique investigation opportunity, given by a steady and relatively large artificial target represented by the Concordia ship, being the orbit in the vicinity of a well-defined reflector, in addition to the pre-existing structure represented by the island. We propose here to analyze the physical and electromagnetic effects associated with this particular feature on the RA-2 waveforms, using a recently experimented tomographic technique (Scozzari et al., 2012). This activity can provide additional information for the interpretation of “bright targets” phenomena in the framework of a wider research activity aimed at the extraction of the geophysical information from radar altimetry signals in contaminated contexts.

Comparison of Altimetric Datasets Near the US West Coast

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Correction algorithms and orbits for satellite altimeter missions have been successfully improved over time; however, such improvements have primarily focused on the deep ocean since coastal measurements suffer from land contamination and measurement errors associated with the different oceanic physics in shallow and coastal waters versus deep water. To address these challenges, several datasets have been created specifically for coastal regions by using tailored correction algorithms or integrating tide gauge data with the altimetric data. But, how accurate are these datasets? In this study we used the tide gauge augmented coastal altimetry dataset developed by Oregon State University/Cooperative Institute for Oceanographic Satellite Studies (OSU/CIOSS) as "truth" to evaluate several along track altimetry datasets within 0.75 degrees of the US West coast during June 2008 to October 2009. Four altimeter datasets: CLS's along-track coastal altimetry dataset (PISTACH), the NASA MEaSUREs along-track multi-mission integrated altimeter data, Legos' gridded coastal dataset (CTOH), and OSTM/Jason-2 GDRs with enhanced radiometer correction are compared to the OSU dataset in this region to evaluate differences in the various coastal datasets and to perform an initial assessment of their accuracy.

Performance Evaluation of Traditional and Improved Waveform Retrackers for Processing Cryosat2 Data.

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Sea surface height determination is done using waveform retracking of Cryosat2 Level 1B data. Traditional retrackers like OCOG and Threshold are used in order to compute the precise bin location where the reflection of the radar signal occurred. In coastal areas and in the Arctic where there is a strong presence of sea ice, the received echo waveform contains contaminations from land, sea ice etc. in the same footprint. As a result, sea surface height computation either becomes very difficult or gives inaccurate results. Two improved retrackers have been developed and tested in order to rectify this problem. In traditional retrackers, OCOG/Threshold methods are applied on the complete waveform. In contrast the new retrackers developed are applied on the first leading edge of the power waveform, rather than the complete waveform. Hence in order to apply the OCOG/Threshold method this leading edge is extracted and sea surface height computed. The logic behind this identification and extraction of the leading edge is that it is the only part where the reflection with the sea surface occurs, and hence it makes sense to focus just on this part. The

leading edge is extracted using the statistics of the SAR power waveform based on the power difference in the consecutive/alternate bins to compute the start/stop locations of the leading edge. In order to compare the performance of the four retrackers, first the sea surface heights for the Baffin Bay for the year 2011 were computed. Next, the gravity fields for these locations were computed using the sea surface heights. The standard deviation of the difference between these gravity fields and marine gravity field is computed. The smaller the value of this standard deviation, the better the retracker is. The computed standard deviations reveal that processing just the leading edge as compared to the complete SAR waveform indeed leads to better results.

Flood Wave Propagation Model of the Caspian Sea Based on Satellite Altimetry Data

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In this research simple flood wave propagation model was based the Saint-Venant equations represented a good way to describe problems concerning with flood waves propagations in open channels. For solution of this task the Caspian Sea was approximated as channel with a rectangular section. Channel axis coincided with the sea longitudinal axis or location of descending pass 092 of satellites TOPEX/Poseidon and Jason-1/2. Altimetric measurements of this satellites permit to define more exactly empiric parameters of the flood wave (propagation speed amplitude et al.) which are solution of the model. Also it allows estimating of effective evaporation. In this approach it is possible to consider as an integrated difference between sea surface heights between previous and the subsequent cycles altimetric measurements. Results of calculations have confirmed well conformity given calculated by other researchers and the model. As is shown than interannual variability of flood wave speed in the North Caspian was well correlated with interannual the Caspian Sea level variability. However for the Middle and Southern Caspian Sea interannual variability of flood wave speed become in an antiphase to interannual sea level change. This study was supported by the grants of the Government of Nizhny Novgorod District and the Russian Foundation for Basic Research (No 08-05-97016-r_povolzhye_a, 10-01-00806-a, 11-01-12046-ofi-m-2011 and 11-07-12025-ofi-m -2011)

Interannual Variability of the Black Sea Level basing on the Radar Altimetry

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The Black Sea level varies in response to global and regional climate changes. In accordance with in situ measurements, it increased by 20 cm in the last 100 years. Satellite altimetry enables tracing of seasonal and interannual variability of sea level both of the sea as a whole and of individual regions from September 1992 to the present time. Information and software of the Integrated Satellite Altimetry Data Base (ISADB) developed in the Geophysical Center of Russian Academy of Sciences were used for the Black Sea altimetry data processing and analysis. The analysis was based on altimeter data of the TOPEX/Poseidon, Jason-1 and Jason-2 satellites for 1993-2009 time period. For all satellite altimetry data all necessary corrections were used without tidal and inverse barometer corrections. An increase of the Black Sea level in 1993-1999, 2003-2004 and 2008-2009 was established, with its noticeable decrease after the high of 2004. Calculations have shown that during the period from January 1993 to September 2008 sea level in the sea as a whole increased with velocity of 1.34±0.11 cm/year; in the western and eastern regions it increased with velocity of 1.42±0.16 and 1.28±0.12 cm/year, respectively. For comparison, from the middle 1920s to about 1985 sea level increased with 1.83±0.7 mm/year. Thus, velocity of sea level rise in the last 16 years was about seven times greater than in the preceding half a century. The general sea level rise, interannual and seasonal variability in 1993-2002 correlated well with a variability of the Danube River discharge.
Since 2003, surprisingly, there is no more correlation between the Black Sea level and the Danube River discharge. The interannual variability of the total Danube runoff at 54 mile transit during the period 1982-2009 was analyzed and its continuing growth at the present time was set. Estimated runoff trends appeared

to be +1.1 km3/year and +0.8 km3/year in 1982-2009 and 1993-2009, respectively. The trends obtained for these relatively short time intervals (27 and 16 years) are several times higher than the known average for more than a hundred period 1860-1987 (+0.126 km3/year). In addition, weekly Pathfinder data (1982-2009) with spatial resolution of 4 km were used to investigate interannual and seasonal variability of sea surface temperature (SST) in the Black Sea (the sea as a whole and its three regions: near-Bosporus, northeastern, and near-Kerch regions).
Further warming of the Black Sea was found, with trend of mean annual temperature of about 0.06 °ñ/year, 2007-2009 being the years with the highest mean annual temperature in the period under consideration. The correlation analysis for the Black Sea level variability was completed by the analysis of atmosphere pressure and precipitation variability over the Black Sea. This study was supported by the grants of the Government of Nizhny Novgorod District and the Russian Foundation for Basic Research

Trajectory of Giant Jellyfish by Satellite Altimetry Data

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Giant jellyfish blooming has occurred several times since 2000 in the East China and Japan Seas and damaged to fishery industry in the Japan Sea. The giant jellyfishes appear in the East China Sea and are transported to the Japan Sea by the current such as the Tsushima Warm Current. In the present study, we examined the possibility of trajectory of the giant jellyfish using satellite altimetry data. The particles regarded as giant jellyfish were tracked by Euler-Lagrange method. Initial condition of the calculation is applied from the distribution of visual observation using ferry boat. Sea surface currents were derived every 7 days from sea surface current anomaly evaluated from satellite altimetry, climatological sea surface current calculated from a numerical model, and wind driven current estimated from sea surface wind data. The trajectory experiment is carried out the case in 2009, giant jellyfish blooming occurred and visual observations were conducted many times.
□@40 passive traces were set around Changjiang River mouth where giant jellyfish were observed on 10 June 2009 and were added every 72 minutes for 12 hours, and then 400 traces were tracked. The tracers deployed on 10 June were transported to the northeastward, and almost tracers distributed east of Cheju Island on 23 June. Since enormous giant jellyfishes were observed by visual observation, the result of tracer experiment was consistent with observation. Many of the tracers went through the Cheju Strait and then arrived in the western channel of the Tsushima Strait on 4 July. Giant jellyfishes were observed in the western channel of the Tsushima Strait on the same day by visual observation. It is suggested that giant jellyfishes observed in the Tsushima Strait on 4 July come from Changjiang River mouth taking about 1 month.
According to visual observation on 20 June, enormous giant jellyfishes distributed in the central part of the Yellow Sea. In order to investigate where the giant jellyfish were transported, tracer experiment was conducted. Almost tracers were transported to the northeastward and reach the west coast of Korea. This result suggests that giant jellyfish in the central part of the Yellow Sea were not transported into the Japan Sea.

Validation of the Sea Level Simulated by MRI.COM-JPN, a Japan Coastal Ocean Model

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Oceanographic phenomena around coastal areas, for example, unusual sea level events, Kyucho (a sudden rapid coastal boundary current), and Seiche, have harmful effects to human lives around coastal area, fishery activity, and marine transport. We develop a Japan coastal ocean model, MRI.COM-JPN, with a horizontal resolution of 2 km and eight tidal components, in order to forecast such phenomena. The sea level simulated by the model is compared to the observation by the tide gauges around Japan. Although the sea level is well reproduced at the coasts facing the open ocean, it is rather degraded at the inland coastal areas. The degradation is probably caused by nonlinear interaction between tidal components and coastal topography, local wind effects, etc. In order to improve sea level distribution, an assimilation method for sea level observation such as coastal altimeter and tide gauge data will be adopted in the model.

Small Scale Storm Variability and Satellite Altimeter Data

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Altimeter data have been routinely assimilated and used to assess the reliability of wave forecasts for many years . A more recent application of such is to provide an indication of Small Scale Storm Variability due to the irregular wind structure at the sea level ("gustiness").
Such SSSV can be examined by making use of Jason-1 and ESA Envisat altimeter SWH data along passes in enclosed seas and by interpolating a trend in space for each passage. Statistical parameters such as standard deviation and autocorrelation of the oscillations around the trend are extracted and compared with similar statistics from state-of-the-art Meteo/Wave models. (Pugliese Carratelli et al., 2008 and 2012, Al Ragum et al., 2009). A variability has shown to exist on a scale as low as the resolution of altimeter data,. i.e. down to a few kilometres, while even the highest resolution models show a much smoother behaviour - probably due the inherent limitation of numerical techniques. Not all the signal behaviour is necessarily related to real variations of the wave height since the altimeter response is affected by many errors, especially in the vicinity of a coast: a discussion of such effects is reported in Goìmez-Enri et al. (2010); most of it, however, is certainly a measure of the oscillations of wave agitation, related to atmospheric instability (Abdalla and Cavaleri, 2002) The evaluation of wave climate for coastal and offshore works when no long records of wavemeter data are available, is generally based on the analysis of global and local weather and wave models , so the importance of SSSV cannot be overlooked; especially when dealing with archive data, which are normally computed on coarse grids and stored at a few hours intervals, research is needed to correlate statistical extremes to sampled data. The long history of altimeter wind and SWH data, acquired at intervals of a few kilometers, can be useful to this purpose.
The poster will present the latest development of this research activities: if available, tests will be carried out and shown for 20 Hz data, to evaluate the effects of higher spatial resolution, and for both Ku and C frequency to take into account the effects of rain and the influence of land or floating objects which may confuse the issue.

Evaluation Of CTOH New Along-Track Tidal Constants Database For Dealiasing Coastal Altimetry Over The North-West European Continental Shelf.

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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 have to 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). 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.

Seasonal Sea Level Anomaly Patterns over Argentine Continental Shelf

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Argentine Continental shelf circulation has been studied principally with numerical models. Results of these models have shown a marked seasonal behavior of the currents. The seasonal pattern has been described also with in-situ data but only for a limited number of dates corresponding to oceanographic campaigns. Satellite data provide an opportunity to solve the spatial and temporal issue. In particular, the 20-year database of sea surface height collected by radar altimeters is a unique dataset to study the circulation in regions with low density of in-situ data. Altimetry over continental shelf and coastal regions has improved considerably in the last few years, allowing researchers to study these complex areas. The aim of this work is to study the shelf circulation with gridded altimetry data produced by AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic data) over the Argentine Continental Shelf (36ºS-55ºS). Our first objective was to estimate the accuracy of the data sets with in-situ data. Results show that the error is minor than 5.6 cm for periods larger than 20 days. We then analyse the seasonal component of 18 years of SLA (sea level anomaly). The seasonal signal of the SLA could be explained by the cooling and heating of the column water due to the solar radiation. This steric-effect depends on the Net Heat Flux and the thermal expansion coefficient. The results show that this effect explains almost the 100% of the seasonal SLA, south of 44ºS. However, in the northern part of the shelf, the seasonal SLA is not well represented by the steric-effect. Our hypothesis is that the climatology of Word Ocean Atlas 98 is not representing properly the thermocline in the north part of the shelf. Therefore, thermal expansion coefficient is subestimated.

Towards Assimilation of Satellite Altimetry Products Into a Storm-Surge Model Ensemble Along the Argentine Coast

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The southeastern coast of South America is located in one of the most cyclogenetic areas in the Southern Hemisphere. Occasionally, those systems may lead to large floods in highly populated areas as the Buenos Aires Province with important economical and social impacts. A numerical model (SMARA) has already been implemented in the region to forecast storm surges. The large extension and limited depth of the Argentinean Shelf permits a smooth transition of the storm surge to the Rio de la Plata and a relatively long forecast horizon for its innermost zone. Within a collaborative effort of the Argentine Naval Hydrographic Service and the University of Buenos Aires, we aim to investigate the impact and potential benefit of storm surge level data assimilation into the models with the objective of improving the forecast. In these experiments, the surface wind stress from an ensemble prediction system drives a storm surge model ensemble, based on the operational 2-D depth-averaged SMARA model. A Local Ensemble Transform Kalman Filter initializes the ensemble in a 6-hour cycle, assimilating the very few tide gauge observations available along the northern coast and altimeter data. In this initial stage, we assess the effects of the localization scale and the observational errors of coastal altimetry on the assimilation. These results preliminary confirm our expectations of enabling an effective use of the sparse altimeter observations to be merged with tidal gauges in a data assimilation scheme.

On the Accuracy of Satellite Altimetry Data Over Continental Shelves: a Case Study in Southeastern South America

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We analyze the trend and seasonal scale variability and inter-annual Sea Level Anomaly (SLA) in the South American continental shelf influenced by freshwater plumes of the Rio de la Plata and the Laguna Los Patos. Almost 20 years of satellite altimetry observations of TOPEX and Jason missions are used. Results show that at these scales data compare very well with in situ observations. In addition, spatiotemporal coverage of gridded SLA data identifies diverse patterns of variability and associated physical processes. Interestingly, seasonal SLA in the subtropical regions of the Uruguayan and Brazilian coasts are negative in summer and positive in winter. This stems from the fact that seasonal SLA in the region depends not only on solar radiation, but is greatly affected by wind variability. The orientation of the coast and of the prevailing winds favors upwelling (downwelling) during spring and summer (autumn and winter). In areas in which the orientation of the coast is not favorable to upwelling or downwelling the solar radiative cycle dominates seasonal SLA. As a result, wind variability is responsible for differences of up to 20 cm between the south coast of the Rio de la Plata and the Uruguayan and Brazilian coasts. At inter-annual time scales, SLA is correlated with El Niño Southern Oscillation phenomena. SLA also shows a significant positive trend up to 5 mm yr-1 across the platform, except in the area near the Laguna de los Patos and in a smaller region of the Rio de la Plata. Beyond the regional significance of the results, this study suggests that satellite altimetry data are accurate enough to reveal spatiotemporal patterns near the coast and on the continental shelves for timescales ranging from seasons to interannual.

Classifying Radar-Echos of Envisat Altimeter Data for an Optimized Retracking

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Satellite altimetry originally designed for ocean application has been proven to be also a valuable technology for monitoring costal zones and inland water. However, close to the shore or over inland water the altimeter waveforms do not have the typical ocean-like shape. The contamination of the radar signal by land areas leads to waveforms which are peaky and noisy and require dedicated retracking algorithms.

Knowing the shape of the waveform allows to decide which is best suited retracker algorithm. In this poster, we investigate an approach for classifying the waveforms in categories which can be subsequently used to assigned an optimal retracking algorithm. While ocean-like waveform are reliably retracked using the Beta-5 retracker, ranges over coastal zones and inland waters can be improved by first classifying the shape of the waveform and second applying one of the alternative retracking algorithms such as the Offset Center of Gravity Retracker (OCOG) or different Beta-parameter retrackers.

A 20-Year Satellite Climatology of Ocean Circulation in the Northern Indian Ocean

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Over the past twenty years, progress has been made in defining and understanding the seasonal circulation along the east and west coasts of India, where the major features are: (i) the East India Coastal Current (EICC), (ii) the larger-scale Bay of Bengal gyral circulation; and (iii) the West India Coastal Current (WICC). This has been accomplished through traditional oceanographic hydrographic cruises (Babu et al., 1991; Murty et al., 1992; Shetye et al., 1993; 1996), analytic and numerical modeling studies (Shankar et al., 1996; McCreary et al., 1996) and (more recently) analysis of satellite altimeter data (Somayajulu et al., (2003); Durand et al., 2009; Vialard et al., 2009; Shenoi, 2010; Nienhaus and Subramanhyam, 2012). Most of this work has focused on the EICC and the Bay of Bengal, where the coastal currents sometimes flow against the strong monsoon wind forcing. This apparent anomaly has been explained as the consequence of coastal Kelvin waves that originate along the eastern margin of the Bay of Bengal or of even more distant Equatorial Kelvin waves. The role of Rossby waves in bringing signals from the east to the southern tip of India has also been examined using satellite data. In our presentation, we will build on these previous

studies to examine the annual and interannual variability in the circulation of both the EICC and WICC, as well as their connections to the larger-scale Northern Indian Ocean. To do this, we will primarily use altimeter data.

Examples of Pulse-Pair (Doppler) Processing of Envisat Individual Echoes in Coastal and Inland Waters

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A provision was made for Envisat satellite to collect 1-second bursts of 1984 Individual Echoes (IEs) returns every 1 minute. At present, there is a global archive of IE data since September 2004 that can be exploited, especially for experimenting beyond the conventional methods. A subset of this large archive has been catalogued and stored on disk. Matlab routines were developed for extracting, visualizing and processing IE data. A GUI interface locates one or multiple packets for analysis. The first analysis shows the satellite nadir track during the 1-second data interval superimposed on a Google Earth map which can be very useful for analysis of tracks at land/sea interface in relation to surface morphology. The visualization of the typical radargram aids in interpreting the behaviour of the radar return amplitudes vs. latitude. The processing also includes Doppler analysis with conventional Fourier transforms and with Pulse Pair based spectral moments. In this poster some case-studies of coastal ocean and inland waters are presented and discussed. The examples complement the content of a presentation titled "Pulse-Pair (Doppler) Processing of Envisat Individual Echoes".

A Multi-Peak Waveform Retracker for Coastal Altimetry

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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 of 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 waveforms, and preliminary validation of the result along some of the pilot COASTALT tracks.