→ 7th COASTAL ALTIMETRY WORKSHOP

ABSTRACT BOOK

7–8 October 2013 | Boulder, USA

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Abstract Book

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Day 1, Monday 7 October 2013

Opening Session

Improving the Spatial Resolution of Wet-Path Delay Corrections for Coastal Altimetry and Inland Water Using High-Frequency Microwave and Millimeter-Wave Radiometers

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Current satellite ocean altimeters include nadir-viewing, co-located 18-34 GHz microwave radiometers to measure wet-tropospheric path delay. Due to the area of the surface instantaneous fields of view (IFOV) at these frequencies, the accuracy of wet path retrievals is substantially degraded near coastlines, and retrievals are not provided over land. Retrievals are flagged as not useful within approximately 40 km of the world's coastlines. A viable approach to improve their capability is to add wide-band high-frequency millimeter-wave window channels in the 90-180 GHz band, thereby achieving finer spatial resolution for a fixed antenna size. In this context, the upcoming NASA/CNES/CSA Surface Water and Ocean Topography (SWOT) mission, in formulation and planned for launch in late 2020, is intended to characterize ocean mesoscale and sub-mesoscale processes on 10-km and larger scales in the global oceans and provide measurements of the global water storage in inland surface water bodies and the flow rate of rivers. Therefore, an important new science objective of SWOT is to transition satellite altimetry from the open ocean into the coastal zone and over inland water.

The addition of 90-180 GHz millimeter-wave window-channel radiometers to current Jason-class 18-34 GHz radiometers is expected to improve retrievals of wet-tropospheric delay in coastal areas and to enhance the potential for over-land retrievals. In 2012 the Ocean Surface Topography Science Team Meeting recommended to add high-frequency millimeter-wave radiometers to the Jason Continuity of Service (CS) mission.

To reduce the risks of wet-tropospheric path delay measurement over coastal areas and inland water bodies, we are developing and producing an new airborne radiometer for the coastal altimetry community, combining three high-frequency millimeter-wave window channels at 90, 130 and 168 GHz, along with traditional microwave channels at 18.7, 23.8 and 34.0 GHz, and validation channels sounding temperature and water vapor near 118 GHz and 183 GHz, respectively. This instrument development and subsequent flight demonstration will (1) assess wet-tropospheric path delay variability on 10-km and smaller spatial scales, (2) raise the technology readiness level (TRL) of high-frequency millimeter-wave radiometry with direct detection and internal calibration to improve wet-tropospheric delay estimation over both coastal and inland water areas, and (3) provide an instrument for calibration and validation in support of the SWOT and Jason-CS missions.

Session 1: Ka-band

AltiKa the New Altimetric Mission : Overview of the Data Quality in the Coastal Area

Picot, Nicolas[1]; Steunou, Nathalie[1]; Valladeau, Guillaume[2]
[1]CNES; [2]CLS

The SARAL/AltiKa project, which was developed by CNES, is based on a wideband Ka-band altimeter (35.75 GHz, 500 MHz), and is the first oceanography altimeter to operate at such a high frequency. This unique technical characteristic of the instrument offers higher performance both in terms of spatial and vertical resolution. The instrument's more accurate measurements will lead to improved observation of ice, coastal areas, inland waters and wave height.

We will present the results obtained with SARAL in coastal areas and we will discuss the working plan set up in place by CNES in order to increase the Ka band expertise thanks to the PEACHI prototype.

Coastal Altimetry with the Ka Band

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The Saral/AltiKa mission, launched in February 2013, is the first oceanographic altimeter using a Ka-band frequency. The use of the Ka-band is expected to supply more accurate measurements (better signal/noise ratio, improvement of the spatial and vertical resolution) enabling a better observation of ices, coastal areas, continental water bodies as well as the waves' height. We will revisit the problem of extending satellite altimetric products into the shelf and coastal seas with these new data, and consider three specific points:

- AltiKa/Saral SSH altimeter measurements, as compared with traditional Ku altimeter data;
- The characteristics of altimeter waveforms near the coast;
- Editing criteria for Ka-band altimetry.

This study will present the results of two regional test cases with very different weather and ocean conditions: the northwestern Mediterranean Sea and along the coast of Vietnam. Both the conventional 1-Hz data (i.e a resolution of ~6-7 km along the track) and the original high-rate altimetry data (40 Hz i.e. ~150m for AltiKa, a lower 20 Hz frequency i.e. ~300m in the case of Jason missions) will be analysed.

Early Look at SARAL/AltiKa Data in Coastal Areas

Scharroo, Remko[1]; Lillibridge, John[2]
[1]Altimetrics LLC; [2]NOAA / Laboratory for Satellite Altimetry

The launch of the SARAL satellite last February added a new tyke to the string of altimeters that has been operating continuously since 1991. While its orbit mimics that of ERS-1, ERS-2 and Envisat, its altimeter instrument, AltiKa, does none of that. AltiKa is the first Ka-band altimeter, and is also the first to provide 40-Hz elementary measurements, twice the rate we were used to. With a smaller footprint, higher range precision (even at 40-Hz) and higher range rate, everything appears cued to provide an excellent coastal altimeter. The high spatial resolution of the 35-day repeat orbit is an additional bonus over the 10-day repeat orbit of the Jason series.

The novelty of the altimeter as well as the radiometer causes some setback too: we need to totally relearn how to deal with the impact of the atmosphere. For example, the absorption of the signal by the dry troposphere is about 3 times as large in Ka-band as in Ku-band. The absorbtion by water vapour and cloud liquid water is even 6 to 7 times larger than we have been used to. In addition, the new radiometer design requires the development of new neural network algorithms for the determination of the parameters generally derived from the radiometer brightness temperatures, i.e., wet tropospheric path delay, backscatter attenuation, water vapour content, and liquid cloud water vapour.

The relationship between backscatter and wind speed in Ka-band also departs from that in Ku-band. Likewise, the sea state bias is also expected to differ from what we have traditionally used.

This presentation highlights some of the "novelty" aspects of SARAL, with particular focus on coastal areas. We will show some of the recent developments to improve the SARAL data sets, and give some detailed views of SARAL's performance in coastal areas.

Session 2: Applications of Coastal Altimetry

Comparison and Validation of Multi-Mission Coastal Altimetry Around Venice

Cipollini, Paolo[1]*; Passaro, Marcello*[2]*; Vignudelli, Stefano*[3]
[1]*National Oceanography Centre;* [2]*University of Southampton;* [3]*Consiglio Nazionale delle Ricerche*

Following on the coastal altimetry work for Envisat started in the COASTALT project (2008-2012), the NOC coastal altimetry processor is being extended to process data from multiple altimetric missions within the ESA DUE eSurge project for the provision of Earth Observation data in support of storm surge monitoring, modelling and forecasting.

An important calibration and validation site is the area around Venice, where storm surges (locally called "acqua alta") are particularly frequent. For this validation activity we have processed Envisat and Cryosat data in the area, as well as Jason-2 and Jason-1 (in interleaved orbit) over a wider area in the Northern Adriatic, and compared them with data from the CNR tide gauge at the "Acqua Alta" platform 8 km from the coast of Venice Lido.

Envisat, Jason-2 and Jason-1 have been processed with the new ALES retracker (see the contribution by Passaro et al. in this meeting), which is included in the eSurge processor. Cryosat-2 data have been retracked with the SAMOSA3 model also included in the eSurge processor. All the comparisons are done at high-rate (20Hz).

The comparison of our retracked data against the standard data in the Envisat and Jason GDRs shows that with the dedicated ALES retracker we can retrieve more and better data closer to the coast. Correlations with the tide gauge data improve especially in the coastal strip (~10-20 km from the coast) but also, slightly, in the open ocean region, as many waveforms in this area suffer from the presence of bright-target-like artefact and therefore do not conform well with the Brown model. 20-Hz noise levels for the ALES-retracked Envisat are flat until about 3 Km from the coastline, as apposed to ~5 Km for the SGDR data. RMS values between ALES and tide gauge are at ~10 cm order of magnitude on the absolute water level (i.e. NOT using anomalies) which is a good result indicating a substantial closure of the SSH equation. Cryosat-2 data show an even better performance very close to the coast, with noise levels compared to the offshore ones up to less the 1 km from the coast, even if unresolved bias problems prevent an absolute RMS calculation so far: the RMS difference with the tide gauge, computed with anomalies, is of the order of 8 cm.

Ocean Currents near Heron Island, Great Barrier Reef, as Observed Using Altimetry, In-Situ Current Meters and HF Radar.

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

Heron Island is located on the outer shelf of the Southern Great Barrier Reef.

The location offshore of the East Australia Current is quite variable in this region and its presence appears to have a significant influence on cross-shelf processes.

In-situ observations of velocity and temperature have been made in 50m of water at the shelf edge close to an Envisat track. We compare estimates of current anomaly derived from along-track altimetry with observations of velocity from current meter and HF radar. Altimetric sea level anomaly (SLA) in the shelf and slope region are also used to indicate the presence or absence of a large recirculation eddy and by comparison with observations of temperature whether the eddy is associated with upwelling.

Spatiotemporal Variability in Ocean Circulation Observed by Altimeters on the Northwest Atlantic Shelf and the Gulf of Maine

Feng, Hui[1]; Vandemark, Doug[2]
[1]University of New Hampshire; [2]OPAL/EOS

The Gulf of Maine (GoM) region resides on the Northwestern Atlantic shelf margin. This marginal sea has been studied for decades and from many perspectives due partly to large fisheries production and the energetic ocean circulation dynamics tied to the tied Bay of Fundy, and a persistent along-shelf current driven by upstream Scotian Shelf and Labrador Sea source waters. Satellite altimetry has become a reliable technique for studying the circulation dynamics in deep oceans. In the coastal oceans, additional technical issues arise when making altimeter observations, leading to large data gaps and degraded accuracy. With significant community efforts in recent years (Vignudelli et al., 2011), various solutions targeting to these issues have been proposed to improve quality of sea surface height and derived currents from existing altimetric observations. Feng and Vandemark (2011) recently demonstrated improved regional observational capabilities using a revised satellite altimeter data product that employs latest coastal altimeter reprocessing approaches.

This study presents our effort to utilize the satellite altimeter (TOPEX, Jason1-2) sea surface data time series to derive and examine regional geostrophic current anomalies. The processing will be based on the latest version of altimeter GDR data (e.g. GDR-D for Jason1-2) and geophysical corrections. Analysis is focused to characterize the surface circulation patterns and the seasonal variability in the region.

First, a long-term buoy ADCP current time series from the North East Channel in the GOM is used to assess the accuracy of altimeter-derived surface geostrophic currents (Vg). Preceding work has demonstrated a good quality of performance in Vg at seasonal time scales. As expected, significant discrepancies still exist between altimeter-derived geostrophic currents and in-situ measurements, with likely explanations tied to ageostrophic factors (i.e. baroclinic and Ekman currents) as well as remaining high-frequency aliasing. The tidal aliasing, particularly tied to the ~62 day M2 alias term, is a prominent issue for this region. In this study, the newly released tidal corrections (e.g. GOT 4.8) will be evaluated. Alternatively we are exploring frequency-based filtering approaches to improve the quality using constraint from in situ measurements. Perspectives surrounding these documented discrepancies are discussed. Next, analyses of all regional altimeter tracks near the NEC and the surrounding area, extending from the deeper shelf/slope oceans to the nearby basins in the southeastern GoM, are presented to characterize the spatial pattern and its seasonal evolution of the surface geostrophic anomaly flows. Finally, results will be discussed within the context of present knowledge of regional circulation dynamics and new contributions that altimetry can provide towards improved understanding of the inter-annual and seasonal circulation within the satellite altimeter era.

Evaluation of Altimetry-Derived Surface Current Products Using Lagrangian Drifter Trajectories in the Eastern Gulf of Mexico

Liu, Yonggang[1]; Weisberg, Robert H.[1]; Vignudelli, Stefano[2]
[1]University of South Florida; [2]Consiglio Nazionale delle Ricerche, Area Ricerca CNR

Lagrangian particle trajectory models based on several altimetry-derived surface current products (OSCAR and AVISO + different mean fields) are used to hindcast the drifter trajectories observed in the eastern Gulf of Mexico during May-August 2010 (the Deepwater Horizon oil spill incident). The performances of the trajectory models are gauged in terms of Lagrangian separation distances (d) and a non-dimensional skill score (s), respectively. A series of numerical experiments show that these altimetry-based trajectory models have about the same performance; however, they have slightly better skills than those of the data assimilative numerical model output from the Global HYCOM, the Gulf of Mexico HYCOM, and the IASNFS. After three days' simulation the altimetry-based trajectory models have mean d values of 103-134 km and 34-38 km (s values of 0.34-0.45 and 0.33-0.36) in the Gulf of Mexico deep water area and on the West Florida Continental Shelf, respectively. Adding surface wind Ekman components improves the AVISO-based model skills, especially over the shelf region. These satellite altimetry data products are useful for providing essential information on ocean surface currents of use in water property transport, offshore oil and gas operations, hazardous spill mitigation, search and rescue, etc.

Hurricane Sandy's Storm Surge - A Case Study Using HY-2A Altimetry

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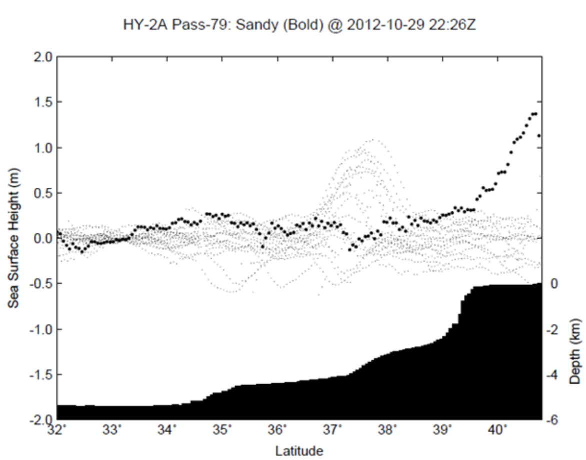
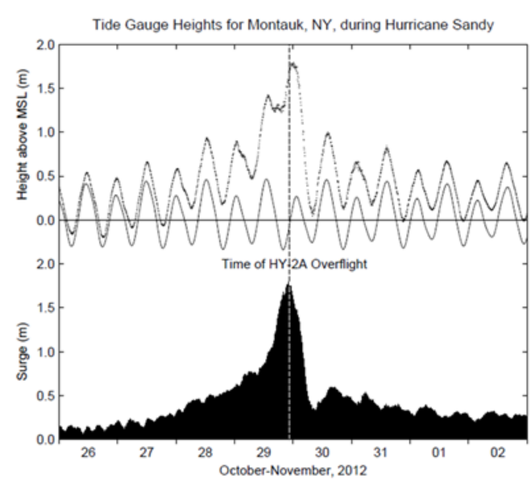
[1]NOAA Lab. for Satellite Altimetry; [2]National Satellite Ocean Application Service; [3]Ohio State University

Hurricane Sandy, which made landfall shortly before midnight October 29th, 2012, was the second costliest hurricane in U.S. history. What made the storm so devastating was the combination of a large storm surge and high surf. Fortuitously, the HY-2A altimetry satellite observed sea surface height and wave conditions on a track across the southern Long Island shore, right at the time of maximum storm surge. A nearly linear 1.5 meter rise in sea level was observed between the continental shelf break and coastline. Tide gauges observations at the nearby Montauk tide gauge, 55 km away, saw even higher surge levels of 1.8 meters on the Long Island Sound. High water benchmark data provided by SURGEDAT show that regional variations in surge amplitude explain much of the altimetry vs. tide gauge discrepancy. NOAA's Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model shows a similar linear rise in sea level across the continental shelf, but underestimates the altimetric observations by nearly one half. Details of the HY-2A processing and analysis of the altimetric and in situ measurements of Hurricane Sandy's storm surge will be discussed.





Session 3: Corrections

Regional Tidal Modelling from 2D to 3D

Cancet, Mathilde[1]*; Lyard, Florent*[2]*; Jeansou, Eric*[1]*; Birol, Florence*[3]*; Delebecque, Caroline*[3]
[1]*NOVELTIS;* [2]*LEGOS;* [3]*LEGOS/CTOH*

With amplitudes ranging from a few centimetres to several meters in some continental shelf regions, the oceanic tide is a large contributor to the ocean topography variability observed by the satellite altimeters, and more particularly in the coastal areas. In most scientific applications using altimetry data, global models are used to correct the altimeter sea surface heights from the tide in order to focus on other ocean dynamics signals. The accuracy of these models is generally at the centimetre level in the open ocean. The main error sources are principally located in the coastal areas and in the polar regions, where the tidal signal is amplified and more difficult to comprehend because of the complex and often not well-documented bathymetry. Another issue is the strongly non-linear dynamics of the tide in the shelf seas.

The recent improvements in the coastal altimeter data processing now enable to retrieve better-quality sea surface heights in shallow waters. It has naturally led to the implementation of regional high resolution tidal models, with the objective to more properly correct the altimeter data by increasing the models accuracy and extending the prediction spectrum, in particular with non-linear constituents.

However, despite quite successful efforts at regional scales, the coastal accuracy of the existing tidal atlases still need to be improved, especially in the perspective of the future SWOT mission. Among others, the limitations of the shallow-water (2D) approach can be questionned, on the barotropic dynamics point of view as well as on the baroclinic dynamics one. In addition, the development of offshore engineering applications such as tidal turbines increases the need for local high resolution, 3D tidal modelling. We present here some preliminary results about the evaluation of 3D tidal modelling compared to 2D modelling, and its impact and potential benefit for coastal altimetry.

Atmospheric Corrections for Altimetry Studies Over Inland Water

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[1]*Univ. Porto, Fac. Ciencias & CIMAR-LA, CIIMAR-UP;* [2]*Altimetrics LLC;* [3]*Inst. Politecnico do Porto/ISEP & CIMAR-LA/CIIMAR-UP*

Although primarily designed for ocean and ice studies, satellite radar altimetry has been successfully used in the monitoring of continental water surfaces. Being freely available and due to its all-weather, day and night capability, it may often be the only source of information in some remote areas.

A correct handling of the range and geophysical corrections is of major importance for hydrological studies, in parallel with the improvement of the range estimates from dedicated retracking. For inland water studies using satellite radar altimetry, the most relevant range and geophysical corrections are those from the troposphere (dry and wet), from the ionosphere, and from tides (solid earth and ocean tide loading).

This study addresses the main issues associated with the atmospheric corrections that shall be applied to the radar altimetry measurements over continental water bodies to achieve the required accuracy for most hydrological studies. Rather than being a review of the relatively well-known issues, the main problems identified in the atmospheric corrections in most of the present altimetric products are discussed, identifying the main sources of error and suggesting suitable approaches.

Since most radar altimeter products have been designed for oceanographic purposes, they often fail to provide valid corrections over continental water regions. Consequently, in various altimetric products the corrections are often not handled properly and in a consistent way. Some of the addressed topics include:

1) Handling of the height dependence of the tropospheric corrections. In contrast to the ocean domain, inland water studies require the handling of height dependent dry and wet tropospheric corrections. While the dry tropospheric correction is one of the most precise range corrections over oceans (better than 1 cm), in some of the present altimeter products it is the correction with the largest errors for inland water studies, up to several decimetres. This is due to the fact that some products provide the correction at sea instead of surface level or, when provided at surface level, it may also contain large errors coming from the interpolation from numerical weather models surface pressure grids. The correct handling of the dry correction from sea level pressure grids further reduced to surface height is presented.

2) Errors in the wet tropospheric correction related to the land contamination in the on-board microwave radiometer and inconsistencies in the handling of the correction derived from numerical weather models. The most suitable models for deriving this correction are discussed.

3) Issues associated with the uncertainty in the dual-frequency ionospheric correction due to the different land effects in the Ku and C (or S) bands and the ability to perform the necessary along-track smoothing of this correction. The most suitable models and climatologies are presented.

Session 4: Retracking

ALES, the Multi-Mission Adaptive Leading Edge Sub-Waveform Retracker, Design and Validation.

Passaro, Marcello[1]; Cipollini, Paolo[2]; Vignudelli, Stefano[3]; Quartly, Graham[4]; Snaith, Helen[2]
[1]NOC Southampton; [2]National Oceanography Centre, Southampton; [3]Consiglio Nazionale delle Ricerche (CNR-ISTI); [4]Plymouth Marine Laboratory

Satellite altimetry has revolutionized our understanding of ocean dynamics thanks to high repetition rate and global coverage. Nevertheless, coastal data has been flagged as unreliable due to land and calm water interference in the altimeter and radiometer footprint and high frequency tidal and atmospheric forcing.

Our study addresses the first issue, i.e. retracking, presenting ALES, the Adaptive Leading Edge Subwaveform Retracker. ALES is potentially applicable to all the pulse-limited altimetry altimetry missions and its aim is to retrack with the same precision both open ocean and coastal data with the same algorithm.

ALES selects part of each returned echo and models it with a classic “open ocean” Brown functional form, by means of least square estimation whose convergence is found through the Nelder-Mead nonlinear optimization technique. By avoiding echoes from bright targets along the trailing edge, it is capable of retrieving the majority of coastal waveform up to 2 to 3 Km from the coasts. By adapting the estimation window to the significant wave height, it aims at preserving the precision of the standard data both in open ocean and in the coastal strip.

ALES is validated against tide gauges in the Adriatic Sea and in the Greater Agulhas System for three different missions: Envisat, Jason-1 and Jason-2. Considerations on noise and biases provide a further verification of the strategy.

LRM (Ku, Ka) and Delay/Doppler Waveform Processing in Coastal Zones

Thibaut, Pierre[1]; *Moreau, Thomas*[1]; *Poisson, Jean Christophe*[1]; *Boy, François*[2]; *Picot, Nicolas*[2]
[1]*CLS*; [2]*CNES*

Over ocean surface, the conventional altimeter 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 has been launched in February 2013 bringing new instrumental and orbital characteristics that has slightly modified the nature of the backscattered signals (typically the footprint of the measurement and the shape of the waveforms) and that has impacted the associated performances. We propose to show some illustrations of the very good performances of AltiKa close to the coasts.

In the same time, Cryosat-2 is providing new altimeter data and methods to estimate the geophysical parameters from the Delay Doppler waveforms have been improved and validated. As for AltiKa, we propose to illustrate the performances of Cryosat-2 in SAR mode when approaching the coasts.

For both altiKa and Cryosat-2 altimeters, we will show how the higher azimuth resolution and measurement precision will offer the potential to greatly improve our ability to measure sea surface characteristics at closer distance to the shore.

Retracking Saral/AltiKa Data Near the Coasts

Blumstein, Denis[1]; *Nino, Fernando*[2]; *Steunou, Nathalie*[3]; *Boy, Francois*[3]; *Birol, Florence*[2]
[1]*CNES/LEGOS*; [2]*CTOH/LEGOS*; [3]*CNES*

The SARAL program is a joint mission conducted by ISRO and CNES dedicated to environment monitoring. The satellite, which was successfully launched on the 25th of February this year, carries the first altimeter using the Ka band: AltiKa. This instrument provides new opportunities for understanding altimetry in the coastal region thanks to its reduced footprint, improved range resolution and excellent measurement noise but it also poses new challenges linked to the new frequency band. The Cal/Val phase of the system is ongoing and the first results are very promising.

In this work, we analyse the waveforms provided by the AltiKa instrument focusing on some typical situations encountered near the coast (calm seas, sigma bloom, perturbations by strong reflectors on the coast) and show how they impact the quality of the retracking provided in the current Level2 products (MLE4 based on the Haines model). Some ways to mitigate the impact of these situations are presented and tested on real data. Their applicability to other missions is also tested.

Retracking SARAL/AltiKa Waveforms Over the Gulf of Mexico Coastal Ocean

Lee, Hyongki[1]; *Tseng, Kuo-Hsin*[2]; *Yi, Yuchan*[2]; *Kuo, Chung-Yen*[3]; *Shum, C. K.*[2]
[1]*University of Houston*; [2]*Ohio State University*; [3]*National Cheng Kung University*

In this study, we validate SARAL/AltiKa satellite altimeter Sensor Interim Geophysical Data Records (SIGDR) by retracking 40-Hz radar waveforms over the Gulf of Mexico (GoM) coastal ocean. We test orignal Threshold retracker [Davis, 1997], Modified Threshold Retracker [Lee et al., 2008], and Threshold Tracker with modified waveforms [Tseng et al., 2013] with various threshold levels, and compare the retracked sea surface heights with nearby in situ tide gauges and EGM08 geoid over shallow (depth<200 m) and deep (depth>200 m) oceans to select an optimal retracking method. In addition, we evaluate the sea surface heights from the OCEAN, ICE-1, ICE-2, and SEA ICE retrackers included in the AltiKa SIGDR data. Finally, the performance of this first Ka-band altimeter over the GoM coastal ocean is compared with that of the contemporary conventional Ku-band OSTM/Jason-2 altimeter.

Day 2, Tuesday 8 October 2013

Session 5: SAR/SARIn Altimetry (joint with OSTST)

A Generalized Semi-Analytical Model for Delay/Doppler Altimetry and its Estimation Algorithms

Halimi, Abderrahim[1]; Mailhes, Corinne[1]; Tourneret, Jean-Yves[1]; Thibaut, Pierre[2] ; Moreau, Thomas[2] ; Boy, François[3] ; Picot, Nicolas[3]
[1]University of Toulouse; [2]CLS; [3]CNES

The concept of delay/Doppler radar altimeter has been under study since the mid 90's, aiming at reducing the measurement noise and increasing the along-track resolution in comparison with the conventional pulse limited altimeters. This paper introduces a generalized semi-analytical model for the delay/Doppler echo that accounts for antenna mispointing, as well as an associated least squares estimation algorithms. The mean power of a delay/Doppler echo can be expressed by a convolution of three terms that are the probability density function (PDF) of the heights of the specular scatterers, the time/frequency point target response (PTR) of the radar and the flat surface impulse response (FSIR). The first contribution of this paper is the derivation of a generalized analytical model for the FSIR that accounts for antenna mispointing. The proposed analytical expression for the FSIR also considers Earth curvature, a circular antenna pattern and a Gaussian approximation for the antenna gain. The two dimensional delay/Doppler map (DDM) is then obtained by a numerical computation of the convolution between the proposed analytical FSIR expression, the PDF of the sea wave height and the time/frequency PTR. The resulting DDM depends on five altimetric parameters that are the epoch, the significant wave height, the amplitude, the along-track and the across-track mispointing angles. Appropriate processing, including range migration and multi-looking, is applied to the resulting DDM yielding the Doppler echo (also known as the multi-look echo). The second contribution of this paper is the derivation of estimators for the five parameters associated with the multi-look echo. A least squares approach is investigated by means of the Levenberg-Marquardt algorithm. Moreover, the study of the effect of antenna mispointing shows high correlation between the along-track mispointing and the echo's amplitude. Thus, a four parameter estimation strategy has been proposed rather than the mere estimation of the five parameters of interest. In order to evaluate these strategies, we compare their estimation performance to that obtained using the three parameter model derived in a previous paper [1]. Validation of the proposed model and the corresponding algorithms is achieved on simulated and real Cryosat-2 data. The obtained results are very promising and confirm the accuracy of the proposed model.

[1] A. Halimi, C. Mailhes, J.-Y. Tourneret, P. Thibaut and F. Boy, "A semi-analytical model for delay/Doppler altimetry and its estimation algorithm," IEEE Trans. Geosci. and Remote Sensing, 2013, to be published.

CryoSat-2 SAR Mode Over Ocean: One Year of Data Quality Assessment

Boy, Francois[1]; Picot, Nicolas[1]; Desjonqueres, Jean-Damien[1]; Labroue, Sylvie[2]; Moreau, Thomas[2]; Thibaut, Pierre[2]
[1]CNES; [2]CLS

In the frame of the Sentinel3 project, CNES is involved in the overall topography payload product quality. Sentinel3 embarks an altimeter including a conventional LRM mode and a SAR mode. The SAR mode propose enhanced performances compared to the conventional mode, thanks to a reduced along track resolution (from 10km to 300m) and a lower measurements noise level. However, 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. To contribute to those analysis, CNES took the opportunity of the availability of CRYOSAT-2 SAR data over ocean and started, three years ago, the development of a Cryosat Processing Prototype to generate Level2 product including Sea Level Anomaly and Significant WaveHeigh information from both LRM L1B and SAR FBR products. In the frame of the OSTST, we propose to present a global data quality assessment of SAR data over ocean using one year of SAR data. We will present the cross comparison between SAR and RDSAR (LRM reference built from SAR measurements) SLA and SWH estimates, we will analyze the data quality continuity when the altimeter switches from one mode to the other and we will also detail SLA spectrum analysis. In addition, the SAR processing techniques and the algorithms developed on CNES side will be recalled and the improvements from 2012 OSTST and AGU meetings will be summarized.

Validation of Open-Sea CRYOSAT-2 Data in SAR Mode in the German Bight Area

Dinardo, Salvatore[1]*; Fenoglio-Marc, Luciana*[2]*; Roland, Aron*[2]*; Lucas, Bruno*[3]*; Scharroo, Remko*[4]*; Becker, Matthias*[5]*; Benveniste, Jérôme*[6]*; Dutour Sikiric, Mathieu*[7]*;*

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Altimetry Data acquired by the CryoSat-2 in SAR Mode in the interval 2011-2012 are processed and validated in the area of the German Bight at distance to coast larger than 10 Kilometers.

Instantaneous sea surface height (SSH), significant wave height (SWH) and wind speed (U10) from altimetry are compared to in-situ measurements at platforms, buoys and tide gauges and to results from an operational circulation model run by the German Federal Maritime and Hydrographic Agency (BSH). The in-situ data are available from a network of stations having a good geographical distribution, which allows considering three relevant zones: (1) open sea, (2) coastal zone and (3) inland water. The network is maintained by the Waterway and Shipping Administration (WSV) and by the German Federal Institute of Hydrology (BFG, http://www.bafg.de). The relevant in-situ data are sea level, GPS coordinates and wave data. Wave and wind model data are compared to the SWH and Wind speed derived from altimetry.

The CryoSat-2 Data have been Delay-Doppler processed from the FBR (Full Bit Rate) Level 1A to Level 1B and subsequently re-tracked using the SAMOSA's SAR Echo Model and a fitting scheme based on Levenberg-Marquard Least Square Minimization Algorithm. Sea surface height, significant wave height and wind speed at 20 Hz and 1 Hz have been derived. The Delay-Doppler processing (L1B) and the re-tracking processing (L2) has been carried out by the EOP-SER Altimetry Team at ESA/ESRIN. Pseudo pulse-limited (PLRM) data derived from CryoSat-2 in SAR mode and provided via the RADS database are compared with parameters derived from the CryoSat-2 SAR Data to estimate possible biases and trends between SAR mode and LRM mode and tune up the SAR re-tracking scheme.

The low sea state conditions in this area are suitable to assess the capacity of the SAR Altimetry to retrieve wave heights also at low sea state part of the sea spectrum.

The wind speed is derived using the same wind model used in Envisat mission and correcting for a little sigma nought bias to align CryoSat absolute backscattering to Envisat absolute backscattering.

Performance metrics to measure the quality of the results, scatter plots, cross-correlations, standard deviations, regression slopes and biases between the in-situ and the CryoSat-derived measurements (SSH, SWH, U10) will be presented.

A very good agreement has been achieved between both PLRM and SAR processed altimeter and in-situ data for the SSH (mean bias 2 cm, standard deviation 20 cm, slope 0.94) and SWH (mean bias 2 cm, standard deviation 30 cm, slope 0.97) set.. In the comparison with two wave models, the best agreement is obtained with the regional LSM model of the Deutsche Wetterdienst (DWD) (9 cm /34 cm 0.98)

Jason-CS Poseidon-4 Ground Prototype Processor (GPP): Processor Results Using Simulated Raw Data and in Orbit CryoSat-2 Data

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Jason-CS is an operational oceanography programme of two satellites that will ensure continuity to the Jason series of operational missions. The main payload of the Jason-CS satellite is the Poseidon-4 radar altimeter that has evolved from the altimeters on-board the Jason satellites (Poseidon-2 of Jason-1, Poseidon-3A of Jason-2 and Poseidon-3B of Jason-3). Poseidon-4 also inherits the Synthetic Aperture Radar (SAR) Altimeter mode of CryoSat-2 SIRAL and Sentinel-3 SRAL now proven to reduce errors in elevation and SWH retrieval over ocean. Furthermore, Poseidon-4 will be the first radar altimeter embarked on a satellite that includes improved digital and radio frequency hardware and, in particular, open burst Ku-band pulse transmission (an operation currently termed the interleaved mode), that performs a near continuous transmission of Ku-band pulses, that will allow SAR and pulse limited data to be gathered simultaneously. As with the Jason series and Sentinel-3, the Poseidon-4 transmits C- band pulses in order to retrieve a correction for ionospheric path delay. The mission is being developed by a multi Agency partnership consisting of ESA, EUMETSAT, NOAA, CNES and NASA-JPL. ESA is responsible for the Jason-CS Space Segment development along with Astrium GmbH as a prime contractor. isardSAT is developing the Ground Prototype Processor for the Poseidon-4 under Astrium. This prototype processes all the chains starting from the Instrument Source Packets, and up to the Level 1b (calibrated pulse- width limited or multi-looked SAR data). The prototype has been verified using simulated data generated by the Jason-CS mission performance simulator and also using in-orbit CryoSat data adapted in format to Jason-CS. These data have been provided by ESA. This paper will present the Ground Processor Prototype developed for Jason-CS, and the results of its verification, focusing on the new features of the processing chain compared to previous altimeters. Typical examples concern: the assessment of performance improvement thanks to the interleaved mode; the un-correction of the Range Migration Correction (RMC) performed on-board in order to reduce the data rate; the weighting applied to the Doppler beams before the multi-looking to correct the different echo shapes as a function of the incidence angle; or the reconstruction of the waveform scaling factor in order to be able to compute the surface backscatter.

Waveform Aliasing in Satellite Radar Altimetry

Smith, Walter[1]; Scharroo, Remko[2]
[1]NOAA, USA; [2]Altimetric LLC/NOAA

Beginning with Seasat and continuing through the design for Jason-CS, all satellite radar altimeters have employed a pulse compression scheme known as full-deramp of a linear FM chirp. The process by which all conventional altimeters create a waveform from digitized radar echoes can lead to aliasing of the waveform. This was first noted by Bob Jensen in a 1999 paper (IEEE TGRS 37(2):651-658, doi:10.1109/36.752182). We have examined the problem both theoretically and experimentally, using raw digitized echo samples from CryoSat's SAR mode.

We derive theoretically the chirp bandwidth necessary to resolve sea surface height (SSH) and significant wave height (SWH) in waveforms of echoes scattered by a Gaussian rough surface approximating the ocean. A chirp bandwidth of 320 MHz, as used in Ku-band altimeters, is not wide enough to fully record the echo when SWH is less than about 1 meter, and aliasing should occur. AltiKa's wider bandwidth, 500 MHz, should be prone to aliasing when SWH is less than about 64 cm.

This theoretical aliasing through a bandwidth limitation applies to the raw digitized receiver output of an altimeter. This output is then converted to a time series of complex echo amplitudes by a discrete Fourier transform (DFT). After the DFT, a conventional altimeter obtains the power by simply squaring the magnitude of the discrete sequence, without resampling. Since squaring a signal doubles its frequency, the sampling rate for power may under-sample the sequence, and it is this under-sampling of a squared sequence that is the potential source of aliasing that Jensen's 1999 paper notes. This problem can be fixed by zero-padding the digital receiver output prior to the DFT, which effectively doubles the sampling rate of the waveform gate samples. This resampling must be done prior to forming the power in individual echoes,

and thus prior to forming the mean power echogram averaged over a radar cycle (nominally 1/20 of one second) known as the waveform.

We processed 29 days of CryoSat SAR mode data over oceans, forming simple pulse-limited (pseudo-LRM) waveforms at a 20-Hz rhythm by the conventional method and by the zero-padded and resampled method. Geophysical retrievals were then made by MLE3 retracking of both the conventional and resampled waveforms. SSH variance is reduced by about 10% and SWH variance is reduced by up to 22% when zero-padding is employed. The significance of the variance reduction is shown by the statistical F-test. The error reduction and its significance are functions of SWH, and show that zero padding is most useful for SSH estimation when SWH is less than 2 m, and for SWH estimation when SWH is less than 4 m. Zero-padding makes a very small but statistically significant change in backscatter estimates as well. The 20-Hz range uncertainty decreases by 5 mm and the 20-Hz SWH uncertainty decreases by 9 cm when zero-padding is employed. The bias in SSH is unchanged, SWH changes by up to 5 cm, and backscatter changes by 0.051 dB when zero-padding is employed.

When CryoSat is in SAR or SARIN mode it still employs the conventional (no zero padding) processing scheme to obtain a waveform known as the tracking echo, which drives the automatic gain control and range tracking feedback loops. These ultimately govern the digital echo samples that it can make available. We suggest that future altimeters should be designed to include zero-padding in the chirp deramp DFT so that the echo power sampling process does not introduce any aliasing.

However, for very low values of SWH, even zero-padding cannot overcome a fundamental limitation: the roughness of the surface can be too small for the bandwidth available to the altimeter. We conjecture that this aliasing may contribute to the phenomenon known as sigma-naught blooms, in which a very specular echo drives the altimeter loops to yield poor results.

Observing Coastal Dynamics with SAR Altimetry

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[1]CLS; [2]ASPlus; [3]CNES

The Cryosat-2 altimeter is operated almost continuously over ocean, either in Low Resolution Mode (like conventional pulse-limited altimetry sensors) or in the so-called Doppler/SAR mode (higher-resolution and lower noise level). This paper shows the results obtained with a new Cryosat-2 demonstration data set derived from the Marine Collaborative Ground Segment project (MCGS). This data set aims at promoting SAR mode over coastal areas and inland waters as a collaborative effort to ESA ground segments (Cryosat-2 and Sentinel-3) and CNES dedicated coastal altimetry products derived from conventional altimetry (PISTACH products).

While pulse limited altimetry provides a resolution between 5 and 10 km due to the size of the radar footprint, the delay Doppler altimetry on board Cryosat-2 provides a true 300 m resolution. This capacity should allow, in most of the coastal configurations, in retrieving good data up to less than 1 km from the coast compared to standard altimetry which is corrupted at 5 to 10 km from the coast. Furthermore, promising results show that this new technique helps to reach smaller spatial scales compared to standard altimetry (30 km wrt 70 km).

This paper illustrates these two major improvements through several examples located in areas with different regimes (sea state and oceanic currents) and different coastal configurations. The SAR derived data will be compared to conventional altimetry provided by Jason-2 data and to the new SARAL altimeter in Ka band which should also improve the accuracy of the measurement in the coastal domain.

Validation of Coastal CRYOSAT-2 Data in SAR Mode in the German Bight Area

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Unlike previous altimetric missions CryoSat-2 has a Synthetic Aperture Radar (SAR) mode that should allow a higher resolution and improved altimeter derived parameters in the coastal zone. The scope of this study is a regional analysis and inter-calibration of the CryoSat-2 SAR altimeter products in the German Bight against in-situ data and model results at distances to coast smaller than 10 Kilometers. The in-situ data are from a network of tide gauges, GNSS stations in coastal zone. The validated geophysical parameters from CryoSat-2 altimeter are the sea surface height above the ellipsoid (SSH), the significant sea wave height (SWH) and wind speed (U10). The time interval spans the two years 2011-2012.

Data in SAR mode are processed as from Full Bit Rate (L1a) level to produce both pseudo pulse-limited (PLRM) and Delay-Doppler processed SAR waveform data. The first are provided via the RADS database, the second by the EOP-SER Altimetry Team at ESRIN, which autonomously Delay-Doppler processes and re-tracks subsequently the SAR waveform data using the SAMOSA model.

The comparison of the SWH derived from SAR and PLRM will be made with two models, namely the Wave Watch III model run within the IOWAGA project and the WAM/LSM model that is run operational at BSH. Beside resolution, the main difference is the physical description of the wind input and dissipation that is used in the wave models and the fact that the BSH model is assimilating altimeter wave height measurements.

The wind speed will not be inter-compared in coastal zone since the altimeter wind speed model is only valid in open sea but the absolute sigma nought parameter (backscattering coefficient) will be derived and inter-compared with respect RADS PLRM.

The CryoSat L2 Data produced by ESRIN EOP-SER Altimetry Team have already undergone a successful validation exercise in the open sea domain (distance to coast > 10 km) as presented in CryoSat Third User Workshop. In the present work, instead, we draw essentially our interest in exploring the sea segment between 0 and 10 km from the coast.
In order to carry out this task and validate the results in coastal zone, special metrics, methods and flagging criteria (explicitly dedicated to coastal zone and different from the ones used in the open ocean domain) will be designed and applied. The metrics will make use of the distance to coast parameter (calculated from MERIS water mask at 300 meter resolution) and of the misfit between the SAMOSA's model waveform and the received power waveform.

The ultimate work objectives are:

- to quantify the level of land contamination in coastal zone in LRM mode (RADS Data) and in SAR mode (ESRIN Data) and assess how much the land contamination is attenuated in SAR mode with respect to conventional LRM mode thanks to the SAR footprint shrinkage in along-track direction.

- to demonstrate the SAR Altimetry capacity to detect coastal short scale signals in SAR mode that are undetectable or invisible in the conventional LRM mode (RADS data). Examples of short scale signals may be also cargo ships and off-shore platforms whose radar signature is clearly distinguishable in SAR Data.

- assess the effect of the ground track orientation with to respect the coastline (consequence of the anisotropic SAR footprint) on the land-contaminated waveforms.

Coastal SAR Altimetry at 80 Hz

Dinardo, Salvatore[1]; *Lucas, Bruno*[2]; *Benveniste, Jérôme*[3]
[1]*Serco*; [2]*Deimos*; [3]*ESA*

Thanks to the CryoSat-2 instrumental capacity to downlink on ground unprocessed Full Bit Rate (FBR) data, different data processing strategies can be attempted and implemented on ground. In particular, when operating in the coastal zone domain, it seems sensible to have SAR-processed echoes posted at highest repetition frequency possible in order to capture all the short scale variability of the coastal scenario.

In the Delay-Doppler processing algorithm, the parameter controlling the echo posting frequency is the grid space step that conventionally has been fixed at frequency of 20 Hz (300 meter) in order to match the instrument along track resolution but virtually the grid space step can be arbitrarily defined to any value.

In the present work, we will attempt to Delay-Doppler process the FBR data with a finer space step -around 80 meter that corresponds to a frequency of 80 Hz (Burst Repetition Frequency)- and we will try to quantify the improvement, in term of precision and in term of observability of short scale signals, that is achieved from usage of that finer space step.

It is worth to notice that, whereas the grid space step shrinks from 300 meters to 80 meter, the theoretical along-track resolution of 300 meter will remain unaltered.

Once that the SAR echoes have been generated at 80 Hz, they will be re-tracked at 80 Hz using the SAMOSA model in order to retrieve the geophysical quantities: Sea Surface Height (SSH), Significant Wave Height (SWH) and Wind Speed at 10 meter (U10).

The experiment will be run in the coastal waters of the German Bight (Wadden Sea) and Northern Caspian Sea and it will consists in processing the same FBR dataset at 20 Hz (standard grid case) and at 80 Hz (overgrid case) and in spotting the differences between the two cases in term of statistics and resolving power.

The current work is a feasibility study, preparatory for the data exploitation of the Sentinel-3 Topography Mission over coastal zone.

Can We Really Achieve 300-Meter Resolution from A SAR Altimeter?

Smith, Walter
NOAA

Conventional altimeters use a pulse repetition frequency (PRF) around 2 kHz because work by Ed Walsh suggested that this PRF would make statistically uncorrelated measurements over ocean surfaces at (nearly) the maximum possible rate. (The optimal PRF depends on orbit height and sea state and pulse limited footprint; 2 kHz is appropriate for a typical Ku altimeter at 800 km altitude over a sea having 2 m SWH.) If an altimeter acquires radar echoes at a much higher PRF then one expects pulse-to-pulse correlation. This correlation can be exploited through coherent processing to achieve an aperture synthesis in what is known as delay-Doppler or SAR altimetry. In theory this may narrow the measurement footprint in the along-track direction. The expected narrowing depends on orbital altitude, PRF, spacecraft velocity, and the number of pulses that can be processed coherently. For CryoSat and Sentinel-3 the along-track footprint width is usually said to be about 300 m.

My investigation of pulse-to-pulse coherency in CryoSat FBR SAR data acquired over ocean surfaces (presented at previous CoastAlt and OSTST meetings) finds that the coherency between one pulse echo and another pulse echo decays with the time separating the two pulse emissions. The shape of the decay is approximately as Walsh's papers suggested it should be. Thus for the 18 kHz PRF of CryoSat, the correlation between pulse echoes separated by N pulse emissions decreases with N and is very low by the time N reaches 9, i.e. the interval between pulses is equivalent to that of a 2 kHz PRF, Walsh's value. However, the 300-meter resolution number is derived assuming that 64 echoes can be processed coherently to achieve aperture synthesis. Thus it seems there is a contradiction between Walsh's theory that ocean echoes decorrelate after approximately 0.5 msec (reciprocal of 2 kHz PRF) and the SAR notion that echoes acquired over 3.2 msec (64 pulses at 18 kHz PRF) can be processed coherently. I remark that this contradiction applies only to scattering from surfaces that are rough and have nearly constant sigma0 throughout the footprint, such as open ocean surfaces; I do not see a problem when the footprint contains a narrow and bright target, such as a lead in sea ice.

If echoes decorrelate as Walsh said (and my analysis shows) then we cannot expect to narrow the footprint to as narrow as 300 m, and the actual achievable narrowing might be something on the order of N times 300 m, that is perhaps on the order of 2 km or more. However this is not a bad thing, as it means that we can optimize a trade-off between coherent processing to narrow the footprint and incoherent averaging to reduce noise. It is possible then that there is additional noise reduction to be achieved in ocean measurements if we are willing to sacrifice the hope of 300 meter resolution to something more practically achievable.

Cryosat-2 SAR-In Altimetry for Coastal Sea Level Recovery - Results from the Fjords of Eastern Greenland.

Andersen, Ole Baltazar; Ablat, Adil; Stenseng, Lars
DTU Space

Cryosat-2 offers the first ever possibility to perform coastal altimetric studies using SAR-Interferometry. As part of the cryospheric mask on Cryosat, this was designed to map the margins of the ice-sheet using SAR interferometry when the slopes are high.

Scoresbysund on the east coast of Greenland is a large fjord system at 70N, that falls in under the SAR-in mask employed on Greenland and this region has been mapped using SAR interferometry with Cryosat-2.

We perform an investigation into the retrieval of sea surface height in the fjord systems using SAR-In from Cryosat-2 L1B data processed with baseline B processing for the period 2011-2013 and investigate the use of the phase signal and possible multi-peak analysis in the recovery of coastal sea surface within the fjord. For the analysis we have tested sea surface recovery using the ESA L2 retracker and several empirical retrackers.

In Scoresbysund, DTU Space has been operating a tide gauge since 2009 and comparison with sea level recovery in the Fjords will be presented. Twenty years of conventional satellite altimetry have so far only resulted in retrieval of very few sea surface height observations from the combined ERS-1 ERS-2 and Envisat missions.

Session 6: New Data and CAL/VAL

Regional Products and Studies Based on CTOH Altimeter Data

Birol, Florence[1]; *Delebecque, Caroline*[1]; *Niño, Fernando*[1]; *Lyard, Florent*[2]; *Morrow, Rosemary*[1]; *Fleury, Sara*[1]; *Blarel, Fabien*[1]; *Rogé, Marine*[1]; *Blumstein, Denis*[1]
[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. Over the last few years, one of its objectives has been to optimise the dynamical information which can be derived from existing coastal altimeter measurements. Therefore, it has investigated the potential of specific re-processing, developed regional altimetry products and provided its support to scientists working in coastal altimetry. 1Hz along-track Sea Level Anomaly (SLA) time series dedicated to the observation of the coastal ocean (computed using the X-TRACK processing system ; Roblou et al., 2011) are regularly updated for all precise altimeter missions (Topex/Poseidon, Jason-1&2, Geosat Follow on and Envisat). Higher sampling rate (10/20 Hz) along-track SLA are also available in some regions. Since 2012, a regional product of along-track tidal harmonic constants (including the amplitude, phase lag and error estimates for a number of tidal constituents) is also routinely computed by harmonic analysis of X-TRACK SLA time series. There are currently 23 regional archives of different altimetry products which are regularly updated (http://ctoh.legos.obs-mip.fr/products/coastal-products). They are used for a large number of studies and applications. Some of them will be illustrated here.

In parallel, the CTOH continue to investigate potential improvements of coastal altimetry data (new AltiKa and Cryosat-2 altimeter missions, waveform analysis, choice of altimetry corrections, editing process, post-processing, new regional altimeter product,…) and how it may impact the observation of coastal dynamics. The most recent results of this study will be shown.

Innovative Approaches for Altimetry Mapping in the Coastal Band: Applications to the NW Mediterranean Sea

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We present new techniques to the generation of remotely sensed high-resolution sea surface topography that improve coastal and mesoscale dynamic characterization. The methods are applied to the northwestern (NW) Mediterranean Sea, an area marked by a small Rossby radius.

The first approach employs the standard altimeter gridded products as a first guess, and subsequently, an optimal interpolation is performed on the along-track raw data with the aim of resolving features at smaller scales. The optimal interpolation can be isotropic or a bathymetric constraint can be included in order to improve the representation of coastal structures. The spectral content of the new mapped data is closer to that of the along-track signal and displays higher levels of energy in the mesoscale bandwidth with the probability distribution of the new velocity fields is 30% closer to drifter estimations. The fields yield levels of eddy kinetic energy 25% higher than standard altimetry products, especially over regions regularly impacted by mesoscale instabilities. Moreover, qualitative and quantitative comparisons with drifters, glider, and satellite sea surface temperature observations further confirm that the new altimetry product provides, in many cases, a better representation of coastal features.

The second approach is based on the Data-Interpolating Variational Analysis (DIVA), a gridding method based on the minimization of a cost function using a finite-element technique. The cost function penalizes the departure from observations, the smoothness or regularity of the gridded data and can also incorporate a pseudo-velocity field derived from regional bathymetry that enhances the correlations along the coastal band. We present the application and adaptation of DIVA to the analysis of SLA in the Mediterranean Sea and the production of weekly maps of SLA in this region. The analysis and error fields are compared with the available gridded products from AVISO and from the first method proposed in this study. In situ measurements from several multi-sensor experiments carried out in the NW Mediterranean (including a recent glider mission along a SARAL/AltiKa track) serve to assess the quality of the gridded fields in the coastal area.

Corsica: A Cal/Val Experiment to Link Offshore and Coastal Altimetry

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In collaboration with the CNES and NASA oceanographic projects (T/P and Jason), the OCA developed a verification site in Corsica since 1996. CALibration/VALidation embraces a wide variety of activities, ranging from the interpretation of information from internal-calibration modes of the sensors to validation of the fully corrected estimates of the reflector heights using in situ data. Corsica is, like the Harvest platform (NASA side), an operating calibration site able to support a continuous monitoring with a high level of accuracy: a “point calibration” which yields instantaneous bias estimates with a 10-day repeatability of around 30 mm (standard deviation) and mean errors of 3-4 mm (standard error). For a 35-day repeatability (ERS, Envisat, SARAL/AltiKa) the standard deviation is at the same level but, due to a smaller time series, the standard error is about the double (~8 mm).

Due to the size of Corsica (not a tiny island), the altimeter measurement system (range and corrections) can be contaminated by land. The aim of this study is to evaluate this land contamination by using GPS measurements from a fixed receiver on land and from another receiver onboard a life buoy (or zodiac). Concerning the altimeter land contamination, we have quantify that this effect can reach 8 mm/km and then affects the Sea Surface Height bias values already published in the framework of the Corsica calibration site by 5-8 mm for TOPEX and Jason missions. On the other hand, the radiometer measurements (wet troposphere correction) are also sensitive to land and we have been able to quantify the level of improvement of a dedicated coastal algorithm that reconciles our results with those coming from other calibration sites. Finally, we have also shown that the standard deviation of the GPS buoy sea level measurements is highly correlated (~87 %) with the Significant Wave Height derived from the altimeters and can be used to validate such parameter.

Preliminary results on SARAL/AltiKa absolute calibration and data quality near the coast will be given.

Annual Cycle in Coastal Sea Level from Gridded Satellite Altimetry and Tide Gauges

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Sea level anomalies as retrieved from satellites are nowadays essential to describe and understand large to mesoscale process in the ocean, to climate-related studies and to operational oceanography. Despite altimeter data have been historically calibrated and validated mostly against coastal tide-gauges, their use in the coastal regions keeps limited. In this work we compare the annual component computed at 478 tide gauges worldwide distributed with the annual component extracted from gridded multi-mission altimeter products. Gridded altimetry products allow for spatio-temporal analyses that are not possible using along-track altimetry data. Root-mean-square differences (RMSD) between the two datasets show values lower than 3 cm for 84.3% of the sites. Regions with larger differences correspond to regions where narrow coastal currents, areas affected by strong river outflows or other local phenomena. The analysis suggests that in the coastal regions where the RMSD are small the analysis of the spatio-temporal variability of the annual component of the gridded altimetry product can be addressed.

Session 7: Future Missions

Current Status of the Japanese Altimetry Mission, COMPIRA

Uematsu, Akihisa; the, JAXA COMPIRA team
Japan Aerospace Exploration Agency

COMPIRA (Coastal and Ocean Measurement mission with Precise and Innovative Radar Altimeter) is a new Japanese altimetry mission by the Japan Aerospace Exploration Agency (JAXA). We will use a wide-swath altimeter, SHIOSAI (SAR Height Imaging Oceanic Sensor with Advanced Interferometry), to maximize the spatial coverage of the altimetry measurements and to reduce errors in the tidal model in coastal area and shallow marginal seas. SHIOSAI is a X-band interferometric SAR with two antennas, and will have a capability to obtain sea surface height data observe 80 km swath in both left and right sides, with resolution of 5 km and accuracy of several cm. Totally 160 km swath width with recurrent period of 10 days quite improves temporal and spatial coverage, which is expected provide information for various oceanic applications including operational oceanography including coastal forecast.

We are now working on a conceptual design of the satellite system and payloads. In parallel, we conducted aircraft experiments of the sea surface height measurement with an airborne interferometric SAR.

We have been discussing specification of the mission through a user team called “COMPIRA team”. Also, we recently constructed two additional user teams, “Science team” and “Coastal forecast core team”. The former team is aimed to maximize scientific outcome of COMPIRA data, and latter team is aim to discuss development of coastal forecast through pre-launch activities toward COMPIRA.

In the paper, we will present current status of COMPIRA-related activities including coastal applications, conceptual design, and experiments.

POSTER SESSION

Applications of Coastal Altimetry Data

One Year of CryoSat SAR Data Analysed in Coastal Data

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

Like CryoSat, Sentinel3 embarks an altimeter which includes a conventional LRM mode and a SAR mode. While there is a long experience of LRM data processing, the nadir SAR data are new and will need an extensive prototype development and an in depth validation.

Thanks to ESA CryoSat project, acquisitions of SAR data are performed routinely over dedicated areas and we have now access to several coastal zones (Algulha current, North Atlantic, Med Sea, ...). 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. This prototype process the FBR data provided by ESA and generates level2 products delivered to PIs.

This paper will focus on the results obtained with CryoSat data acquired from May 2012 to April 2013. Specific attention will be paid in the coastal area where the CryoSat SAR data will improve the resolution of the ocean variability. In particular the analysis over the Med sea and the comparison between PLRM and SAR modes will be performed on all retracking parameters (Sea Surface Height, SWH and Sigma0).

Inter-Comparisons of CryoSat-2, HY-2 and Jason-1/2 Satellite Altimetry Data in the Bohai and Yellow Seas

Cheng, Yongcun.; Andersen, Ole Baltazar.
DTU Space

The CryoSat-2 and HY-2 satellite altimetry observed wind speed, significant wave height (SWH) and sea level anomaly (SLA) are compared with that from Jason-2 satellite altimetry in the Bohai and Yellow Seas (34°N-41°N, 117°E-127°E) over the period between October 2011 and June 2013. The CryoSat-2 and Jason-1/2 data are taken from RADS (Radar Altimeter Database System). The HY-2 altimetric data are downloaded from NSOAS (National Satellite Ocean Application Service, China).

The reasons for selecting the regions lie in that: (1) the regions are covered by CryoSat-2 SAR mode mask. (2) The mean depth of the Bohai and Yellow Seas are about 20 m and 44 m with maximum of 70m and 152 m, respectively. (3) Errors of over 15 cm of tidal correction were recognized in the AVISO along-track data in the western and northern parts of the Yellow Sea (e.g., Morimoto, 2009).

The initial results show mean SWHs of 1.05 m and 0.97 m from CryoSat-2 and Jason-2 data over the given period. The mean wind speeds of 6.16 m/s and 5.91 m/s are obtained from CryoSat-2 and Jason-2 data, respectively. The CryoSat-2 and Jason-2 observed SLAs show the standard deviation of 16.77 cm and 13.79 cm over the regions, respectively. The HY-2 data presents mean SWH of 1.68 m from the cycle1-cycle 4 measurements. Further investigations are required to merge the multi-mission sea level anomaly over the regions.

Comparison and Validation of Multi-Mission Coastal Altimetry Around Venice

Cipollini, Paolo[1]; *Passaro, Marcello*[2]; *Vignudelli, Stefano*[3]
[1]*National Oceanography Centre;* [2]*University of Southampton;* [3]*Consiglio Nazionale delle Ricerche*

Following on the coastal altimetry work for Envisat started in the COASTALT project (2008-2012), the NOC coastal altimetry processor is being extended to process data from multiple altimetric missions within the ESA DUE eSurge project for the provision of Earth Observation data in support of storm surge monitoring, modelling and forecasting.

An important calibration and validation site is the area around Venice, where storm surges (locally called "acqua alta") are particularly frequent. For this validation activity we have processed Envisat and Cryosat data in the area, as well as Jason-2 and Jason-1 (in interleaved orbit) over a wider area in the Northern Adriatic, and compared them with data from the CNR tide gauge at the "Acqua Alta" platform 8 km from the coast of Venice Lido.

Envisat, Jason-2 and Jason-1 have been processed with the new ALES retracker (see the contribution by Passaro et al. in this meeting), which is included in the eSurge processor. Cryosat-2 data have been retracked with the SAMOSA3 model also included in the eSurge processor. All the comparisons are done at high-rate (20Hz).

The comparison of our retracked data against the standard data in the Envisat and Jason GDRs shows that with the dedicated ALES retracker we can retrieve more and better data closer to the coast. Correlations with the tide gauge data improve especially in the coastal strip (~10-20 km from the coast) but also, slightly, in the open ocean region, as many waveforms in this area suffer from the presence of bright-target-like artefact and therefore do not conform well with the Brown model. 20-Hz noise levels for the ALES-retracked Envisat are flat until about 3 Km from the coastline, as apposed to ~5 Km for the SGDR data. RMS values between ALES and tide gauge are at ~10 cm order of magnitude on the absolute water level (i.e. NOT using anomalies) which is a good result indicating a substantial closure of the SSH equation. Cryosat-2 data show an even better performance very close to the coast, with noise levels compared to the offshore ones up to less the 1 km from the coast, even if unresolved bias problems prevent an absolute RMS calculation so far: the RMS difference with the tide gauge, computed with anomalies, is of the order of 8 cm.

Using CTOH Tidal Constants for Coastal Studies

Delebecque, Caroline[1]; *Lyard, Florent*[2]; *Birol, Florence*[1]; *Ayoub, Nadia*[2]; *Testut, Laurent*[3]; *Roblou, Laurent*[2]
[1]*CTOH/LEGOS;* [2]*CNRS/LEGOS;* [3]*LEGOS*

Since 2012, the Centre de Topographie des Océans et de l'Hydrosphère (CTOH) provides the community with large collection of tidal constants estimates over more than 23 coastal regions and continental shelves (http://ctoh.legos.obs-mip.fr/products/coastal-products/coastal-products-1/tidal-constants). This tidal constants database is computed using the CTOH regional Sea Level Anomalies datasets, taking advantage of the TOPEX-Poseidon, Jason-1 and Jason-2 long time series and the X-TRACK coastal processing tool (Roblou et al., 2011).

It provides tidal experts and coastal modelers with amplitude, phase lags and accuracy estimates for a wide spectrum of tidal constituents, every 6-7 km along the satellite ground tracks

This presentation aims to highlight the performance of this regional tidal product through various case studies over coastal and shelf seas around the world.

The performance of an empirical tidal correction derived from the CTOH along-track tidal constants database is compared to classical tidal corrections provided by models. In the Bay of Biscay, such strategy is expected to improve the observation of a seasonal slope current, the so-called Iberian Poleward Current. The coastal dynamics along the West coast of India, including this empirical tidal correction, has also been studied.

Case studies of tidal modeling applications are also presented here. The recently-issued FES2012 global tidal model as well as several regional models have been validated using this independent tidal constants database. It has been used for constraining a regional tidal model using data assimilation techniques. It has also provided a complete set of tidal estimates for prescribing open boundary conditions in local tidal models.

Observing High Resolution Dynamics with Conventional Altimeters

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[1]CLS; [2]CNES

Since a few years, many studies try to extract smaller spatial scales from the altimetry data sets in the coastal zones and more generally over regional oceans. This objective is restricted to the along track data since the resolution achievable with maps is mainly driven by the spatial and temporal sampling offered by the altimetry constellation.

In order to reach smaller spatial scales, one important issue is to work with the native 20 Hz sampling of altimetry data rather than the traditional use o f 1 Hz. Tournadre et al, Birol et al have shown that this kind of approach is meaningful.

The Level 3 PISTACH data sets generated by CNES and CLS teams have also been used to derive along track geostrophic currents. Such altimetric currents were compared with currents derived from SAR over the Agulhas Current and currents measured by a current meter located in the Florida Keys. It came out that such comparisons are difficult, raising questions about the physical content of different types of measurements but also about the error in the altimetry measurements.

This paper highlights the main advantages of working with 20 Hz data regarding the optimal choice of the corrections in the Sea Level Anomaly, the detection of 20 Hz outliers and the optimal trade off to be found between the achievable resolution and the data errors.

This paper shows over several regions (Agulhas Current, Brazilian Current) that dedicated processing of the 20 Hz data allows retrieving more accurately the oceanic structures compared to the standard altimeter processing.

Predicting High Frequency Sea Level During Tropical Cyclones by Integrating Satellite Altimetry and Tide Gauge

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[1]University of Newcastle; [2]Danish National Space Centre, Technical University of Denmark

There are a variety of tropical cyclones in terms of their frequency and intensity in Australian coastal zones. Subsequently, spatial and temporal sea level changes should be anticipated near the coastal area. As a result, sea-level change prediction is critical during tropical cyclones. The aim of this paper is to find a suitable model for high frequency sea-level prediction by integrating Non Tidal Sea Level (NSL) from satellite altimetry and tide gauges. The data used are from Topex, Jason-1 and Jason-2 satellite altimetry missions and nine tide gauges from 1992 to 2010 over the Northern Australian Coastal zone . These two types of datasets have been integrated to take advantages of the longest and precise records from tide gauges and a global spatial coverage of satellite altimeters. The temporal correlation of sea level anomaly from satellite altimeter and individual tide gauge has been studied at nine gauges. The multivariate regression method and nonlinear autoregressive models with exogenous inputs (NARX) model have been applied and compared. The performance of these models is evaluated using the hindcast skill, which is 90 % around tide gauges. The minimum Root Mean Squared (RMS) Error between altimetric observations and model predictions is 3.68 cm in the study area. In addition, measured NSL from satellite altimetry and NSL predicted by models have been investigated during several tropical cyclone periods to recognize whether the models are able to capture tropical cyclones. The results suggest that both predicted and measured NSLs can detect almost all of tropical cyclones during the study period. Finally, we conclude that altimetry-derived sea level when complementing with tide gauge observations has potential for improving of tropical cyclone models.

Activities for Coastal Forecast Using COMPIRA

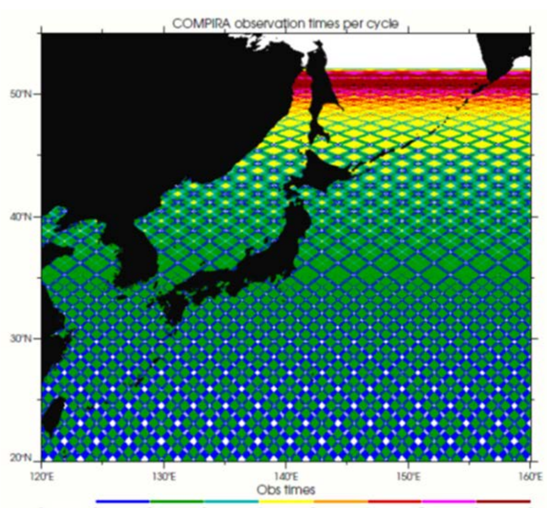
Isoguchi, Osamu[1]; *JAXA, COMPIRA team*[2]
[1]*Remore Sensing Technology Center of Japan;* [2]*Japan Aerospace Exploration Agency (JAXA)*

Japan Aerospace Exploration Agency (JAXA) is working on a conceptual study of altimeter mission named Coastal and Ocean measurement Mission with Precise and Innovative Radar Altimeter (COMPIRA), which will carry a wide-swath altimeter named Synthetic aperture radar (SAR) Height Imaging Oceanic Sensor with Advanced Interferometry (SHIOSAI). A framework called "Coastal forecast core team" has recently started to aim at developing coastal forecast through pre-launch activities toward COMPIRA. It consists of 3 segments, satellite, assimilation, and in situ ones.

COMPIRA orbit specifications were designed to be better for operational oceanography including coastal forecast. That is, a spatial grid sampling is 5km and an observation times per revisit period (about 10 days) is 2 to 3 times(Image 1). Although this sampling frequency is, of course, not enough high to capture time evolution of coastal phenomena, an assimilation process would compensate its time evolution if 2D SSH fields were observed at least once within decay time scale of phenomena.

As a first step, our team plans to investigate the impact of wide-swath SSH observation by COMPIRA on coastal study using COMPIRA simulated data. It includes generation of mapping data products, tide detection, and identical twin experiments. Improving a tide model especially in marginal seas as well as coastal areas is one of the issues to be investigated because the current tide models still have relatively large errors in the marginal seas around Japan, such as East China Sea, and the Sea of Okhotsk, and it prevented ones from deriving current variations from altimeter data. A very simple estimation using simulated data indicates that COMPIRA wide-swath observations would improve tide detection especially in M2 constitute.

We are also interested in synergy with SWOT (Surface Water hydrology and Ocean surface Topography mission) that is a wide-swath altimeter proposed by CNES/NASA. We calculated a sampling frequency map that would be expected by SWOT/COMPIRA simultaneous observations. It shows the increase of sampling frequency and makes us expect that temporal evolution of very fine-scale SSH structure captured by SWOT would be compensated by moderate-spatial scale but relatively higher temporal sampling of COMPIRA. COMPIRA thus plays a role in some kinds of boundary conditions when nesting is done. In the workshop, preliminary results on the impact of SWOT/COMPIRA synergy including twin experiments will be presented.



Coastal-Trapped Wave Forcing of the Loop Current in the Gulf of Mexico

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At irregular intervals ranging from time periods of a few weeks to longer than 18 months the Loop Current (LC) retroflection within the deep eastern Gulf of Mexico sheds large anticyclonic rings, commonly called Loop Current Eddies (LCEs). While it has been recently shown that there is some statistically significant variation in the frequency of LCE separation as a function of season, the LC intrusion and eddy shedding cycle is, nevertheless, highly irregular in time. The source of this irregularity was hypothesized to be due primarily to upstream influences associated with eddy, wind, and vorticity forcing of the Yucatan Current inflow into the Gulf from the Caribbean. More recently, coastal-trapped waves along the Atlantic seaboard and the coastal Gulf have been implicated as a possible source of LC variability. In this paper, we show that coastal-trapped wave forcing of the LC can be observed using coastal altimetry and sea level measurements and that this forcing mechanism is potentially an important source of external forcing of LC variability at weekly, seasonal, annual and interannual frequencies.

Validation and Use of Coastal Envisat and Jason Satellite Altimetry Products for Storm Surges?

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The North Sea – Baltic Sea area is an ideal region for validation of coastal altimetry due to the dense network of tide gauge data, varied coastline and high natural sea level variability. Within the ESA DUE eSurge project, we have prepared for data assimilation of coastal sea level into the DMI hydrodynamic model for the North Sea – Baltic Sea area, focusing on storm surge situations. Standard along-track altimetry products have limited quality closer than approximately 50 km from the coast, and are not available within approximately 10 km of the coast. Envisat and Jason-2 high resolution (18 and 20 Hz) data from the coastal zone has now been processed for a selected tracks in the North Sea/Baltic Sea, and here we investigate how to construct the high resolution sea level anomaly for coastal applications and validate the coastal altimetry products from the CoastAlt and eSurge projects against tide gauge data. The coastal altimetry data will be used to develop a revised and operationalized version of our statistical sea level model (Madsen et. Al. 2007) within eSurge.

Analysis of Sea Level Trends with Altimetry Around the Coastal Zone of Gavdos Permanent Cal/Val Facility

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The aim of this work has been to examine and monitor the sea level trends in the coastal areas around the permanent Cal/Val facility of Gavdos. Results are based on the produced calibration values for the Jason-2 satellite altimeter as monitored over 5 years of calibration and along the pass No. 18 and No. 109. Different reference surfaces and models have been chosen for this evaluation. Details regarding the methodology applied for the determination of calibration values, as well as comparative results against time, correlation, weak signals, and data structure will be provided. Finally, this work describes the relation between these parameter trends and the region's local characteristics.

Relationship Between Position of the Kuroshio Path and Sea Level Anomaly in the Seto Inland Sea in Japan

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The Seto Inland Sea has one of the most complicated coastal geometry in Japan. In the coastal zones in the Seto Inland Sea, unusual sea level anomalies (SLAs) often cause significant damages. One of the reasons why the unusually high SLAs take place is variation of ocean current, e.g., Kuroshio.

We statistically investigated the relationship between SLA in the Seto Inland Sea and the Kuroshio path variation. In order to do this, we used the reanalysis result (for 32 years) of an ocean data assimilation system, MOVE/MRI.COM-WNP, covering the northwest Pacific Ocean.

It was revealed that there are two key areas. One is the area near the Kii Channel (135°E) which connects the Seto Inland Sea and the Pacific Ocean. The other is the area off the Boso Peninsula (141°E). It was found that when the position of the Kuroshio path in either key area is located near the coast of Japan, SLA in the Seto Inland Sea becomes high. It was also found that, the position of the Kuroshio path off the Boso Peninsula has a significant impact on sea level variability not only in the Seto Inland Sea but also in wide coastal area south of Japan. This implies that sea level variation in the wide south coast area due to the location change of the Kuroshio path in this key area is caused by coastal trapped waves.

Coastal Altimetry Derived Velocities for the Agulhas Current

Rizopoulou, Konstantina[1]; Cipollini, Paolo[1]; Quartly, Graham[2]; Snaith, Helen[1]
[1]National Oceanography Centre; [2]Plymouth Marine Laboratory

The Agulhas Current (AC) is the western boundary current of the South Indian Ocean and has a crucial role on ocean circulation and climate. In this study AC is observed and characterized by coastal altimetry. Using reprocessed along-track altimeter data with specific data editing and processing strategies, more data can be retrieved near the coast with better spatial coverage and improved quality, compared to standard altimetry datasets. Jason track #96, which crosses the AC nearly orthogonally and on which ACT (Agulhas Current Time-series) array is located and the Envisat track #343 which is also almost coincident with a slightly different orientation have been used in this study to demonstrate our methodology. Altimeter across-track geostrophic current velocity anomalies are derived from the reprocessed Jason-2 along track sea level anomalies from both PISTACH L2 and eSurge processor (the evolution of the COASTALT processor). These velocities are compared with the ones derived by conventional altimetry RADS (1-Hz) data for both the J-2 and Envisat track as well as the near surface current vector components from the ADCP observations from the ACT cruise. Time-series of geostrophic surface velocity anomalies (GSVA) every 10 days from Jason #96 and a complementary dataset of GSVA's every 35 days from Envisat are examined. The results indicate the potential usefulness of the along-track altimetry data in contributing to descriptions of surface circulation of western boundary currents and the challenges of such applications on the shelf edge.

DAHITI: A New Database of Water Level Time Series for Lakes, Rivers, and Wetlands from Multi-Mission Satellite Altimetry

Schwatke, Christian; Dettmering, Denise; Bosch, Wolfgang
DGFI

Since many years satellite altimetry is becoming increasingly important for hydrology. The fact, that satellite altimetry, originally designed for open ocean applications, can also contribute reliable results over inland waters helps to understand the water cycle of the system earth and makes altimetry to a very useful instrument for hydrology. In this presentation, we introduce the new database DAHITI (Database for Hydrological Time Series of Inland Waters) which provides water level time series for about 180 globally distributed lakes, rivers, and wetlands. The results are derived from multi-mission satellite altimetry using a newly developed approach. The estimation is based on altimeter data from Topex, Jason-1, Jason-2, Geosat, IceSAT, GFO, Envisat, Cryosat, HY-2A, and Saral/Altika. Depending on the extent of the investigated water body we use 1Hz, high-frequent or retracked altimeter measurements. For the estimation of the water levels we use a Kalman filter approach applied to the grid nodes of a hexagonal grid covering the water body of interest. After applying an error limit on the resulting water level heights of each grid node, an average water level per time interval is derived referring to one reference location. The time series have temporal resolutions of 30 days, 10 days or 1 day depending on the data coverage. For validation of the time series, we compare our results with gauges and other altimeter data sets. Hereby we achieve very high correlations between time series from altimetry and gauges.

Interannual Variability of Seasonal Cycles of Coastal Altimeter Fields

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Oregon State University

Along the coast of Oregon, alongtrack altimeter sea surface height anomalies provide estimates of alongshore coastal currents and the average density of the water column, both of which respond to seasonal changes in the alongshore winds. Several methods are used to define the annual cycles of wind forcing and ocean response, alternating between upwelling and downwelling. The goal is to quantify the interannual variability in the timing of seasonal transitions, along with the length and strength of the seasonal peaks. Traditionally, annual cycles are defined by averages of the calendar months or harmonic analysis, which allows for a more quantified characterization of the cycles. These methods determine "stationary" seasonal cycles, whereas the timing of seasonal transitions vary from year to year. Here we explore methods that define seasonal cycles but allow variability in the timing and strength of the seasonal components. Different approaches include bandpass filters and several variations of empirical orthogonal functions.

Interpolation of SLA Using the Data-Interpolating Variational Analysis in the Coastal Area of the NW Mediterranean Sea

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[1]Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB); [2]GHER, University of Liege

The spatial interpolation of along-track Sea-Level Anomalies (SLA) data to produce gridded map has numerous applications in oceanography (model validation, data assimilation, eddy tracking, ...). Optimal Interpolation (OI) is often the preferred method for this task, as it leads to the lowest expected error and provides an error field associated to the analyzed field. However, the method suffers from limitations such as the numerical cost (due to the inversion of covariance matrices) as well as the isotropic covariance function, generally employed in altimetry.

The Data-Interpolating Variational Analysis (DIVA) is a gridding method based on the minimization of a cost function using a finite-element technique. The cost function penalizes the departures from observations, the smoothness of the gridded field and physical constraints (advection, diffusion, ...). It has been shown that DIVA and OI are equivalent (provided some assumptions on the covariances are made), the main difference is that in DIVA, the covariance function is not explicitly formulated. The technique has been previously applied for the creation of regional hydrographic climatologies, which required the processing of a large number of data points.

In this work we present the application and adaptation of Diva to the analysis of SLA in the Mediterranean Sea and the production of weekly maps of SLA in this region. The peculiarities of SLA along-track data are addressed:

• number of observations: the finite-element technique coupled to improvements in the matrix inversion (parallel or iterative solvers) lead to a decrease of the computational time, meaning that sub-sampling of the initial data set is not required.

• quality of the different missions: the weight attributed to each data point can be easily set according to the satellite that provided the observations, so that different measurement noise variances are considered.

• spatial correlation scale: it varies spatially in the domain according to the value of the Rossby radius of deformation.

• long-wavelength errors: each data point is associated a class, and a detrending technique allows the determination of the trend for each class, leading to a reduction of the inconsistencies between missions.

• anisotropy of physical coastal features: a pseudo-velocity field derived from regional bathymetry enhances the correlations along the main currents. Particular attention will be paid to the influence of this constraint in the coastal area.

The analysis and error fields obtained over the Mediterranean Sea are compared with the available gridded products from AVISO. Different ways to compute the error field are compared. The impact of the use of multiple missions to prepare the gridded fields is also examined.

In situ measurements from an intensive multi-sensor experiment carried out north of the Balearic Islands in May 2009 serve to assess the quality of the gridded fields in the coastal area.

Application of Coastal Altimetry to Shelf Dynamics Studies on the East Coast of South Africa

Tyesi, Mbongeni; *Roberts, Mike*
Oceans and Coasts

The east coast of Southern Africa is characterised by a narrow continental shelf bounded on the east by a strong Agulhas Current that retroflects at the far Southern edge of African Continent. The inshore of this major current is defined by the occurrence of mes-soscale features that play a significant role by influencing the dynamics of biological material as well as the distribution of sediments in this region.

In the past, research into the variability and propagation of the natal pulse has been hindered by the absence of altimeter data closer to the coast. The main purpose of this research is to establish the usefulness of coastal altimetry in detecting circulation processes in the Natal and Delagoa Bight and Port Alfred upwelling zones of South Africa. Preparatory work is underway to collect insitu observations using ships and satellite drifters for comparison with available coastal altimetry products for the region. Coastal altimetry data will be used to detect small scale structures within the continental shelf of Southern Africa as part of a local contribution to the global development of new applications for coastal altimetry.

Technical Issues in Coastal Altimetry

Coherent Processing of Envisat Individual Echoes in Narrow Rivers

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Rivers are challenging targets for satellite remote sensing. Most of them are narrow in width and shallow in depth. There is a growing interest in monitoring river water levels. Generally, river levels derived from satellite radar altimetry represent an incoherent average of values calculated for a large number of echo reflected back. However, if the footprint touches the shoreline the reflected echo may be contaminated with some effect on the average. Here in this poster we propose the use of individual echoes (IEs) and the possibility of applying coherent processing for a better exploitation of satellite radar altimetry over rivers. Abileah et al. (2013) showed that there is sufficient pulse-to-pulse coherence for Doppler processing with Envisat IEs in open ocean and that some improvement in determining the water level can be achieved. In addition, it was supposed that coherent processing enables more efficient use of fewer pulses, which is the typical situation of narrow rivers. Case studies are under selection, according to their peculiarities, i.e., shoreline shape, nature of the surrounding land, water level variability, etc. The potential of using IEs will be illustrated, and the implications with the altimetry timeseries will be analysed.

Cryosat-2 SAR Altimetry for Recovering Sea Surface Height Around and Within Denmark - First Results from the LOTUS Project.

Andersen, Ole Baltazar; Villadsen, Heidi; Per, Knudsen; Jain, Maulik; Lars, Stenseng; Nielsen, Karina

DTU Space

The LOTUS project (preparing land and ocean take-up from Sentinal-3) is a recent funded EU project exploring the use of SAR altimetry in the coastal zone and on land. In the project sea level is pioneered using Cryosat-2 SAR altimetry for coastal and in-land studies to gain expertise and experience with SAR altimetry before the launch of Sentinel-3 which will likely work as an operational satellite in SAR mode (mode mask not fully confirm by ESA yet).

SAR altimetry from Cryosat-2 seems to be able to recover sea surface height nearly all the way to the coast with only minor degradation and the first results from sea surface recovery using Cryosat-2 SAR altimetry around and within Denmark has been performed. Focus on near-coastal sea surface height recovery is performed using SAR altimetry. A region in the northern part of Denmark contains both coastal and an in-land fjord system called Limfjorden has been mapped with SAR altimetry from 2012 from Cryosat-2 Baseline B processed and processed using empirical retrackers.

Theoretical Description of a Calibration System for Ocean Altimetry Using the GNSS-R Signal

Bao, Lifeng; Wang, Nazi

Institute of Geodesy and Geophysics, Chinese Academy of Sciences

Currently, the most precision satellite altimeter observations of sea surface height can reach 2 ~ 3cm, which has a close relationship with the satellite altimeter calibration. With the development of science and technology as well as the deepen exploration of unknown marine world, requirements to sea level observations accuracy are increasingly high. Such sea surface height field measurement techniques need to meet the following conditions: observations need to be more reasonably approximate nadir mean sea level;

observation techniques is not influenced by the geographical location; the accuracy of the method itself has nothing to do with the calibration field conditions; reduce as much as possible other ancillary data requirements (e.g. sea surface topography gradient); calibration accuracy is better than requirements of altimeter accuracy index. GNSS-R (GNSS Reflect) ocean altimetry, mainly using different GNSS receiver antenna to receive the direct signal and the sea surface reflected signal, through the analysis of signal time delay and the correlation function waveform and characteristics of the trailing edge, combined with the sea, wave scattering theory of wave to obtain the average height, sea surface wind field, wave height and sea surface salinity information. GNSS-R altimetry has high-precision, high-resolution characteristics, which make the use of GNSS-R for the precise calibration of satellite altimeter possible. Compared with the traditional altimeter calibration technique, shore-based GNSS-R sea surface altimetry can take advantage of the rich marine GNSS-R signal, to achieve multi-point sea level computation of stations near the sea water. Whereby regional average sea surface height has closer nature to satellite altimeter observations, and calibration results are more accurate and reliable. In similar time period of the satellite altimeter transition, GNSS-R spatial distribution of the reflected signal (relating with the receiver position and GNSS orbits)is approximate irregular grid shape, by selecting region of GNSS-R sea surface height calculation, consistent with satellite altimeter ground-based footprint, the two results can be used to compare with each other directly without going through complicated imputed sea surface topography gradient calculation, which avoid the influence of sea surface topography gradient imputation error on the altimeter calibration, and improve satellite altimeter calibration precision significantly. Furthermore, drawing on existing geodetic observation techniques and data processing methods, such as increasing the number of receive reflected signal antennas, making adjustment calculation for irregular net-shaped GNSS-R observations of sea surface height, and using new high-precision GNSS-R receiver, etc, can further improve the mean height accuracy of the sea area to be determined by GNSS-R.

Retracking and Validation of Pulse-Limited and SAR Altimeter in Coastal Zone

Fenoglio-Marc, Luciana[1]*; Buchhaupt, Christopher*[1]*; Weiss, Robert*[2]*; Becker, Matthias*[1]
[1]*Technische Universität Darmstadt;* [2]*German Federal Institute of Hydrology, Koblenz, Germany*

Improved methods of re-tracking and the new SAR technique allow the use of altimeter data in the coastal zone.

We investigate the quality of altimeter data at distances of less than 10 Kilometers from the land.

The altimeter waveform are first classified and based on the classification are processed with different retrackers to derive the improved sea level height and significant wave height.

A validation of the improved data pulse-limited and SAR data is performed in the German Bight against in-situ and model data and Level 2 products.

GPD Wet Tropospheric Correction for the ESA and NASA/CNES Altimetric Missions

Fernandes, M. Joana[1]*; Lazaro, Clara*[1]*; Nunes, Alexandra L.*[2]*; Pires, Nelson*[3]*; Ablain, Michael*[4]*; Benveniste, Jérôme*[5]
[1]*Univ. Porto, Fac. Ciencias & CIMAR-LA, CIIMAR-UP;* [2]*Inst. Politecnico do Porto/ISEP & CIMAR-LA/CIIMAR-UP;*
[3]*Univ. Porto, Fac. Ciencias;* [4]*CLS;* [5]*ESA/ESRIN*

The aim of the ESA Climate Change Initiative (CCI) Sea Level project is to produce and validate the Sea Level Essential Climate Variable (ECV) product. For this purpose, the best algorithms for climate applications are being developed, tested and selected.

As part of this work, the GNSS-derived path delay (GPD) algorithm for computing the wet tropospheric correction (WTC), the path delay in the altimeter measurements due to the presence of water vapour in the atmosphere, developed by the University of Porto (U.Porto) was selected as the best candidate for use in the generation of the final sea level ECV. In the sequel, the algorithm which has initially been designed as a coastal correction for Envisat in the scope of the ESA project COASTALT, has been extended to open ocean and tuned to all NASA/CNES (TOPEX/Poseidon, Jason-1, Jason-2) and ESA (ERS-1, ERS-2 and Envisat) missions.

This paper gives an overview of the GPD implementation for these six altimetric missions. The basis of the algorithm is the data combination, by objective analysis, of three main wet path delay data types: valid measurements from the microwave radiometer (MWR) on board each altimetric mission, wet path delays derived from Global Navigation Satellite Systems (GNSS) coastal stations, and those derived from the European Centre for Medium-range Weather Forecasts (ECMWF) ReAnalysis (ERA) Interim model. According to pre-defined criteria, the algorithm estimates the WTC in all satellite track points for which the MWR WTC has been considered invalid.

For each mission, the state-of-the art correction from the onboard MWR has been used and the algorithm was tuned to allow a proper detection of the points at which the WTC has to be estimated (either due to, for example, land, ice or rain contamination, or to instrument malfunction). The GPD products have been validated by comparison with other wet tropospheric corrections, such as the base MWR WTC and the so-called composite correction, by sea level anomaly (SLA) variance analysis at collinear tracks, function of distance from the coast and function of latitude. The highlights of these results are presented with emphasis on the impacts of the correction on the building of the 20-year long altimeter record for climate applications and on coastal sea level studies.

Envisat RA-2 Still Alive: Validation of Coastalt High Spatial Resolution Products in the Strait of Gibraltar

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High spatial resolution altimetry data (18 Hz) from RA-2 Envisat have been validated, using two tide gauges located in Tarifa and Ceuta, which are in the area surrounding the Strait of Gibraltar.The altimeter data used for this study are the outputs of the processor originally developed under the framework of the COASTALT project and now being upgraded within the ESA DUE eSurge Project. The processor retracks waveforms at 18 Hz rate (i.e., with an approximate spacing of 350 m along-track), with the ALES (Adaptive Leading Edge Subwaveform) retracker, a new retracker which represents an evolution of the sub-waveform retracking approach described by Yang et al. (2012) and Idris & Deng (2012). High along-track resolution altimeter-derived sea level data from May 2003 to May 2010 will be compared against in-situ data along the descending pass#180, which crosses the study area with a land-to-ocean and an ocean-to-land transition that covers a track-segment of about 30 km.

Comparison of Altimetric Datasets in the Southern California Bight

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The Southern California Bight (SCB) provides an interesting testing ground for coastal altimetric datasets. Altimetry is notorious for its problems with coastal areas. This is mostly due to land contamination and correction algorithms that are tuned for deep oceans and not shallow/coastal ones. To address these challenges, several datasets have been created specifically for coastal regions using tailored correction algorithms and retracking techniques. But, how accurate are these datasets? Islands and the curvature of topography in the SCB provide a good test site to see how well the different coastal datasets deal with the challenges in removing land contamination and correcting for known errors in the altimetric signal. This study considers tide gauges as “truth”. Tide gauges are compared against four altimetric datasets: CLS’s along-track coastal altimetry dataset (PISTACH), the NASA MEaSUREs along-track multi-mission integrated altimeter data, Legos’/CNES’ gridded coastal dataset (CTOH), and the OSTM/Jason-2 GDR version D dataset to evaluate differences in the various coastal datasets and to perform an initial assessment of their accuracy. There will also be a brief overview of a similar study done off the US north- and mid-west coast that compared the accuracy of the different datasets in these two regions.

The Importance of Retracking and Detiding In Coastal Regions

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The retrieval of sea level anomalies (SLAs) from altimeter range measurements involves a number of corrections for geophysical signals (e.g., tides and sea state bias) and atmospheric attenuations (e.g., wet and dry tropospheric delay and inverse barometric effect). Near coasts, these corrections need special attention because they are less accurate, thus decreases the accuracy of the coastal sea level observation. This paper therefore, provides two necessary steps to increase the accuracy of altimetric derived coastal sea level. One is the application of optimal waveform retracking technique, and another is the use of a pointwise tide model based on the retracked observations rather than a global ocean tide model (e.g, GOT4.8 or FES2012).

The 20-Hz waveforms from Jason-2/OSTM in the Great Barrier Reef Australia are reprocessed from 2009-2012. Results show that the tidal signals in the experimental region are better resolved with the pointwise ocean tide model than those of the global tidal models of GOT4.7, FES2012 and DTU10. Thus, the ocean tide seems well removed from the SLAs signals. Comparison with tide gauge data indicates that SLAs from this study has in general higher temporal correlation and smaller RMS error than those of MLE4 and Ice retrackers. It retrieves higher correlations (>0.8) and smaller root mean square errors (<16.6 cm) than those of MLE4 (<0.78 and <19 cm) and Ice (<0.78 and <18.7 cm) retrackers.

Validation of Waveform Retrackers: Assessment of Altimeter-Derived Geostrophic Velocity Using High Frequency Radar Observations

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The performance of altimeter-derived geostrophic velocity over a wide continental shelf is assessed using three years of ocean current observations by high frequency (HF) radar on the Great Barrier Reef, Australia. It is derived from the Jason-1 retracked sea level anomalies from 2009-2011. To allow comparison between both datasets, the HF velocity has been corrected from the influences of the tidal signal and wind-driven current. The velocity in u (east) and v (north) components of both datasets are compared. They are found consistent to each other with small (<2.5 cm s-1) root mean square (RMS) error and standard deviation (STD).

Overall, the results have demonstrated the value of HF velocity as a promising tool to validate the altimeter retracked velocities. It provides a systematic validation of the altimetry retrackers along the continental shelf. However, the processing of both datasets still requires improvements to make them more compatible and understand the limitations of this comparison.

Improving the Accuracy of Sea Surface Heights near Coasts Through an Iterative Coastal Waveform Retracking System

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This paper improves the accuracy of altimeter-derived sea level anomalies (SLAs) near the coast through an iterative waveform retracking system. The principle of this system is twofold. First is to reprocess the altimeter waveforms using the optimal retracker that is searched base on the analysis from a fuzzy expert system. Second is to reduce the relative offset in the retrieved SLAs when switching from one retracker to another, using a neural network. Through the system, the optimal retracker is selected by considering the information about the physical features of waveforms and the statistical features of retracking results. This minimises the risk of assigning the waveform to a wrong retracker when classification procedures are unable to precisely classify the corrupted waveforms. By including additional information in the fuzzy expert system to support the selection criteria of the optimal retracker, the uncertainty of altimeter-derived SLAs has been reduced. In order to keep consistency of the retracked SLAs when switching retrackers, a multi-layer feed forward neural network is constructed. This is because the offset between various retrackers is not a constant, but varies depending on the variation of SWH. The neural network with capability of identifying a complex relationship between various retrackers is, therefore, introduced to estimate the offset.

The system has been used to reprocess 20-Hz waveforms from Jason-2/OSTM in the Great Barrier Reef, Australia. Through a comprehensive analysis, it shows that the offset in retracked SLAs can be more effectively removed by the neural network method than by subtracting the mean of difference value between SLAs from various retrackers. Comparisons with tide gauge data have shown that there is a satisfactory agreement between the altimetry-retrieved SLAs and the tide-gauge sea level records. The results show SLAs from this study generally outperforms SLAs from MLE4 and Ice retrackers. It yields higher correlations (>0.8) and smaller root mean square errors (<16.6 cm) than those of MLE4 (<0.78 and <19 cm) and Ice (<0.78 and <18.7 cm) retrackers.

AltiKa Microwave Radiometer Performances on Coastal Areas

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The CNES/ISRO altimetry mission SARAL/AltiKa was successfully launched on February 25, 2013. First performance analyses showed the very good quality of the microwave radiometer on-board in terms of sensitivity and stability.

One specificity of this radiometer (a bi-frequency (23.8 GHz, 37 GHz) total power radiometer) is the quality of its antenna patterns characterized by a very good directivity (0.84°, resp. 0.58°, angular width at -3dB for channel 23.8 GHz, resp. 37 GHz.) for the two channels but also by a low level of the secondary lobes. Combined with an altitude of 800 km, these characteristics raise AltiKa radiometer as the instrument with the best resolution on altimetry missions, 12 km, resp. 8 km, for channel 23.8 GHz, resp. 37 GHz. Then, the performances on coastal areas are expected to be noteworthy.

In order to asses the quality of AltiKa radiometer on coastal areas, we will compare brightness temperatures of both channels to JMR on Jason-1, AMR on Jason-2 and MWR on Envisat/RA2. We will determine the distance from the coast line where the land contamination occurs, at a global scale and considering various precise coastal configurations. We will then assess the impact of the interpolation strategies specific to each instrument.

We will consider the performance in terms of wet tropospheric correction as well, comparing radiometer and ECMWF corrections for each instrument at a global scale and on some specific locations.

Understanding Altimetry Retrievals for US Coastal Currents Using HF Radar and Imagery

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Preliminary studies, off the US West coast, have demonstrated the value of HF Radar (HFR) surface currents as a promising tool to find new strategies to correct coastal altimetric Sea Surface Heights (SSHs) and refine their spatial resolution. The continuous network of coastal HFR along the California coastline, with an offshore range up to 150 km and a resolution up to 2 km, provides an excellent testbed. By referencing the PISTACH retrackers to the HFR derived SSHs, the optimal method for altimetry retracking seems to be a combination of different retrackers for various segments of the altimeter track and depends on the cycle.

However the altimeter and HFR instruments capture different oceanic geophysical phenomena. In this study, the HFR data are better evaluated to specify how effectively they can detect the erroneous altimetric SSH measurements (mainly from Jason-1-2) and improve their quality. This will be done first in the offshore regions (> 25 km) in situations when the standard-retracked altimeter data are reliable. The influence of the seasonal currents or wind patterns will also be examined on the quality of the HFR SSH. In a second step, the cases when the two data sets diverge will be analyzed and checked to determine which one is a better estimate of the true SSH; by looking at the waveforms, or by introducing auxiliary information such as sea surface temperature and ocean color. In this context, the HFR could provide some insight into the altimeter behavior as a function of ocean conditions to account for some oceanic mechanism and various sea sates, particular to the continental shelf, that affect the conventional altimeter measurements.

Surface Circulation in the Northern Bay of Bengal During Winter Using Satellites, Argo Floats and RAMA Buoy Observations

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Information on surface currents derived from Satellite altimetry (AVISO), Temperature and salinity profile data from Argo float and RAMA Buoy (time series observations at daily intervals of temperature and salinity profiles and winds, at 15o N, 90o E) collected between October 2012 and March 2013 were analyzed to study the upper layer circulation in the Northern Bay of Bengal during winter. A characteristic feature of the Northern Bay of Bengal is the formation of a thick barrier layer where temperature inversions to the tune of 4o C occur during winter. The analysis of spatial maps at weekly intervals of temperature (AVHRR version 4), salinity (Aquarius) and currents (AVISO) at the sea surface reveal the presence of an anticyclonic gyre (in early January) in the northern Bay centered around 17o N, 90o E having a diameter of about 200 km. Southward flow of low salinity, low temperature waters from north caused well stratified layer leading to larger subsurface temperature inversions. In the present study, the characteristics of the surface circulation in sustaining the observed inversion are discussed.

Water Level Height Estimation over the Ukai Dam / Reservoir by Retracking Algorithms Using SARAL / AltiKa Dataset

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The reduction of effective footprint and increase in along track resolution offers SARAL/AltiKa a clear advantage over previous altimeters with respect to lake/reservoir monitoring. Observing the water level via altimetry and combining with satellite imagery for surface area estimates, can offer the potential to monitor variation in total volume storage. Although there are several limitations for utilizing radar altimetry over inland bodies, such as due to highly varying elevation and due to land contamination in the foot print. Still by improving the tracking logic by means of more efficient retrackors, altimetry can play a vital role for water resource management.

The study area is Ukai dam that is constructed across the Tapi River and located at 21.14° N and 73.35° E. Area of the dam is 612 km2. This Dam is meant for irrigation, power generation and flood control. SARAL pass no 825 passes over this reservoir, IGDR data of first three cycles is being used for observing the water level. In SARAL cycle 1, pass no 825, loses its track in the middle of the dam, and 1km drift is observed between cycle 2 and cycle 3. So this time temporal changes could not be estimated. Multispectral Liss-4 image with 5 m resolution has been used for defining the extent/boundary of the reservoir.

We performed Brown, ICE2, Beta5 and Off Centre of Gravity (OCOG) retracking algorithms using 40-Hz of SARAL waveform data for determination of range parameter with better accuracy. Range is then corrected for atmospheric corrections which consist of three parts, i.e. wet tropospheric correction (WTC), dry tropospheric correction (DTC) and ionospheric correction (IC). The ECMWF WTC was used instead of WTC measured by onboard radiometer. The corrected range and pole & solid earth tide were then subtracted from the altitude for determination of height. Other open Ocean corrections were not applied because the lake/reservoirs are closed systems.

Based on the Liss-4 image, fifty-three 40-hz points were selected over the dam for further consideration. Due to non-ocean like waveform brown retracker was not able to find the exact range information, even in some of the points it could not fit any data. The OCOG provide range information on all the 53 points, but a large average and standard deviation was found in these results, i.e. 0.59 and 0.73 meter respectively. The results of Beta5 and ICE2 retracker were really encouraging. Both works well, with very small variance and standard deviation, i.e. 0.04 and 0.21 respectively. The coefficient of variation was close to 0.0022 in both the cases. The mean height of the dam was observed to be 96.25 meter which matches with the time series given by the hydro web of LEGOES at (virtual) point located at latitude 21.22 and longitude 73.68 referenced to Envisat track for the year 2002-2010. The water level validation exercise over the reservoir will be performed soon.

SARAL/AltiKa 40-Hz Waveform Classification and Retracking for the Indian Coastal Regions

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Coastal regions of the world ocean are important part of the global oceans because of several crucial aspects pertaining to science, society and economy. Satellite altimetry has potential to provide coastal observations of Sea Surface Height (SSH), surface wave and wind speed that can be of immense value to understand changing coastal dynamics. However, satellite altimeter and radiometer observations are perturbed near the land, which lead to absence of data in this important part of the ocean. Operational datasets distributed by various agencies are mostly meant for open ocean studies. However, altimeter and radiometer also make measurements for coastal oceans, which contain valuable information. Due to the high demand of the above mentioned parameters in the Indian coastal regions, present study is devoted towards exploiting various retracking methods for deriving accurate SSH, wind speed and wave height information.

We have made use of the 40-Hz SARAL/AltiKa waveform data for this purpose. First step towards performing meaningful retracking is to classify the waveforms. Diverse nature of waveforms has been seen in the Indian coastal region due to different types of vegetation, slope and relief. It has been observed that most of the waveforms from AltiKa have exponential trailing edge. We have also studied the shapes of waveforms over the land/ocean transitions with regard to ascending and descending passes. It has been found that large numbers of the waveforms are of peak echo type and/or multiple peak type. Therefore standard open-ocean Brown-model retracker cannot work for such waveforms. Several other reported retrackers like, ß-parameter retracker and sub-waveform retrackers have been used. The study has been carried out separately for east and west coast of Indian land-mass due to their different characteristics. . Along with the AltiKa data, we have also made use of Jason-2 20-Hz waveform data in this study. The detailed results of this study will be discussed in the workshop.

Assimilation of SWH from SARAL/AltiKa and Jason-2 Altimeter Data in Coastal Wave Model

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Sea level rise due to global warming, being a societal threat, is important to monitor in long run. The space-based, nadir looking, microwave, radar altimeters are major players in observing such phenomena over time. Scientific community of this era is augmented with several altimeters that include SKYLAB, GEOS, SEASAT, TOPEX/POSEIDON, ERS-1/2, GFO, JASON-1/2, Envisat etc that have been providing us with several decades of valuable ocean data resources to enhance our understanding about oceans. All of these altimeters operated in Ku, C and S band. SARAL/AltiKa being operated at high frequency Ka-band is a new milestone to the history of altimetry. With high Frequency altimeter, SARAL/AltiKa is able to make observations very near to the coasts. It provides the valuable data of Sea Surface Height (SSH), Significant Wave Height (SWH) and wind speed over ocean.

In the present study, attempts have been made to assimilate the SWH from SARAL/AltiKa in the numerical coastal ocean wave model SWAN (Simulating WAve Near-shore). Prior to the assimilation of SARAL/AltiKa wave heights, to verify the quality of the data, SARAL observations have also been validated with global in-situ observations as well inter-comparison with available altimeter data. Along with the assimilation SARAL SWH, the Jason-2 SWH have also been assimilated in the model. The optimum interpolation technique has been used for assimilating the SWH data in the model. Validation of the predicted wave conditions has been carried out using the in-situ observations of the Indian coastal regions as well from these altimeters. The results show that the wave fields predicted by assimilating SARAL/AltiKa as well as Jason-2 SWH are well matched with the observations. It has also been observed that the assimilation of the SARAL data has significantly improved the prediction skill scores of the SWAN model as compared to Jason-2.