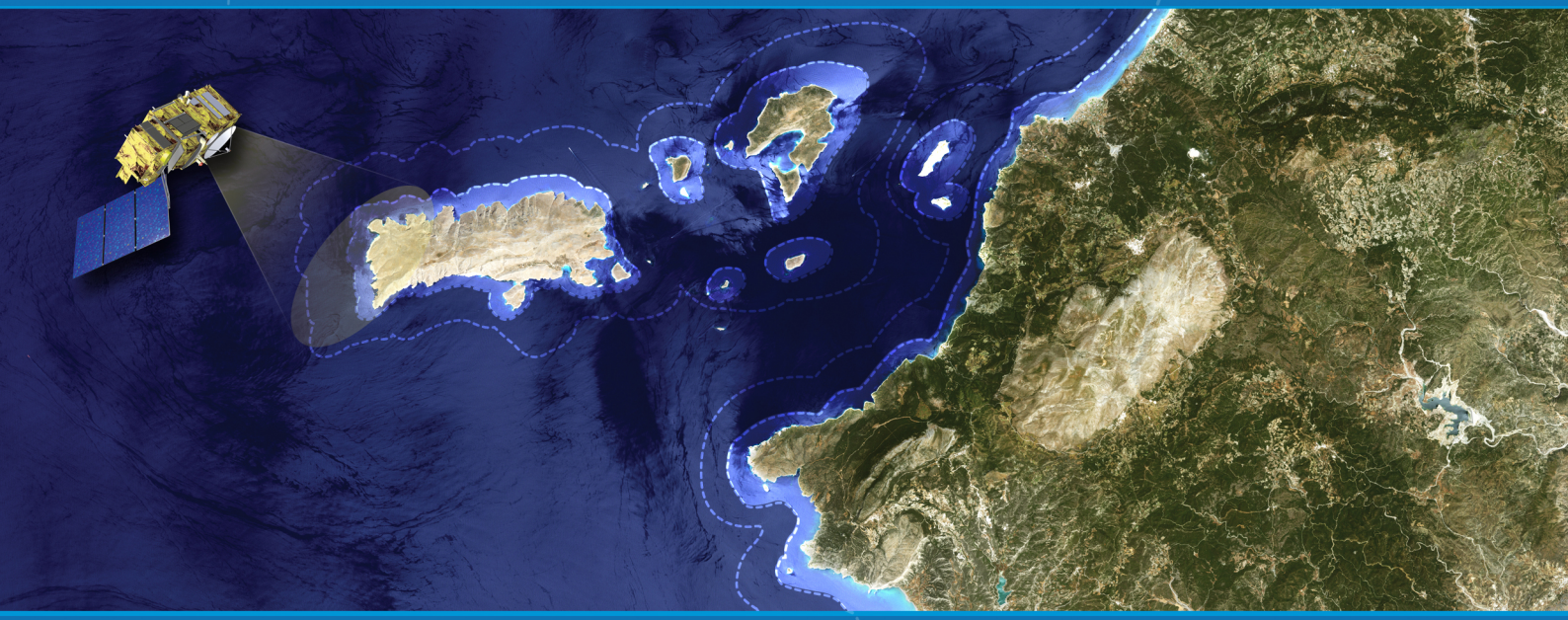
→ 11th COASTAL ALTIMETRY WORKSHOP



ABSTRACTS

12–15 June 2018 | ESA–ESRIN | Frascati (Rome), Italy

ABSTRACT BOOK

11th Coastal Altimetry Workshop

SAR Altrimetry Training Course

12 - 15 June 2018

Frascati

Italy

Last update: 07 June 2018

1 Table of Contents

2 Committees

ORGANISING COMMITTEE

Jérôme Benveniste	*European Space Agency – ESRIN*, Italy
Paolo Cipollini	*National Oceanography Centre*, U.K.
Marcello Passaro	*DGFI Technical University of Munich,* Germany
Nicolas Picot	*Centre National d'Etudes Spatiales*, France
Marco Restano	*SERCO,* Italy
Remko Scharoo	*EUMETSAT,* Germany
Doug Vandemark	*University of New Hampshire*, USA
Stefano Vignudelli	*Consiglio Nazionale delle Ricerche*, Italy

SCIENTIFIC COMMITTEE

Lifeng Bao	*Chinese Academy of Science*, China
Florence Birol	*LEGOS*, France
Pascal Bonnefond	*Observatoire de Paris – SYRTE,* France
Jérôme Bouffard	*RHEA/ESA–ESRIN,* Italy
Madeleine Cahill	*CSIRO,* Australia
Mathilde Cancet	*Noveltis*, France
Emanuel F. Coelho	*NATO CMRE,* Italy
Xiaoli Deng	*University of Newcastle*, Australia
Fabien Durand	*IRD-LEGOS,* France
Alejandro Egido	*NOAA/CICS-MD,* United States
Luciana Fenoglio-Marc	*Technical University Darmstadt*, Germany
Joana Fernandes	*University of Porto*, Portugal
Christine Gommenginger	*NOC,* UK
Jesús Gómez Enri	*University of Cadiz*, Spain
Guoqi Han	*Fisheries and Oceans Canada*, NAFC, Canada
Jessica Hausman	*NASA Jet Propulsion Laboratory*, USA
Kaoru Ichikawa	*Kyushu University*, Japan
Andrey Kostianoy	*P.P. Shirshov of Oceanology*, Moscow, Russia
Villy Kourafalou	*University of Miami*, USA
Raj Kumar	*Space Applications Centre, ISRO*, India
Cristina Martin-Puig	*EUMETSAT*, Germany
Ananda Pascual	*IMEDEA,* Spain
Samantha Royston	*UTAS,* Australia
Martín Saraceno	*University of Buenos Aires*, Argentina
C. K. Shum	*Ohio State University*, USA
Pierre Thibaut	*Collecte Localisation Satellites (CLS),* France

3 Abstracts

S1A: Technical Issues in Coastal Altimetry - Retracking

Compared Performances of Current Altimetry Missions Over Coastal Areas

Thibaut P.[1], Raynal M. [1], Ablain M.[1], Boy F.[2], Picot F.[2], Picot N.[2], Guinle T.[2], Femenias P.[3]

[1]CLS, Ramonville Saint Agne, France; [2]CNES, Toulouse, France; [3]ESA-ESRIN, Frascati, Italy

In the recent years, two new altimetry missions have provided measurements over coastal areas with improved performances with respect to conventional Jason or Envisat missions. Saral/AltiKa mission, operating in a conventional mode but in Ka band, and Sentinel-3A operating in Ku band but in SAR mode, have proved their ability to obtain more accurate and precise measurements of sea surface height and significant wave-height. Because of their reduced footprint, because of the measurement geometry and thanks to dedicated algorithms (level 1 or level 2), data can be acquired closer and closer to the coastline with performances similar to those obtained over open ocean.

We propose in this paper to make a comparative analysis of the performances of these different systems illustrating with comprehensive metrics/diagnoses the benefits that can be exploited by oceanographers focused on coastal regions.

****

Two Years of Coastal SAR and PLRM Altimetry in the North East Atlantic With Sentinel-3A and CryoSat-2

Dinardo S.[1], Fenoglio-M. L.[2], Buchhaupt C.[6], Scharroo R.[3], Fernandes M.[4], Becker M.[6], Benveniste J.[1]

[1]He Space, Darmstadt, Germany; [2]University of Bonn, Bonn, Germany; [3]EUMETSAT, Darmstadt, Germany; [4]University of Porto, Porto, Portugal; [5]ESA-ESRIN, Frascaty, Italy; [6]University of Darmstadt, Darmstadt, Germany UK

The scope of this study is a regional analysis and inter-comparison between CryoSat-2 and Sentinel-3A SAR altimeter data against in-situ data and regional model results at distances to coast smaller than 10 km. The in-situ data are from a network of tide gauges and GNSS stations around German Bight and West Baltic Sea managed by BfG & WSV institutions. The regional ocean circulation models are the BSH and the GCOAST model.

We have carried out, from CryoSat-2 FBR products, a Delay-Doppler processing and waveform retracking tailored specifically for coastal zone by applying Hamming Window and Zero-Padding, using an extended vertical swath window in order to minimize tracker errors and a dedicated SAMOSA-based coastal retracker, named SAMOSA+. SAMOSA+ accepts the mean square slope as free parameter and the epoch's first-guess fitting value is decided according to the peak in correlation between 20 consecutive waveforms, in order to mitigate land off-ranging effect [1].

Exactly the same processing baseline has been considered to process Sentinel-3A L1A data and the same geo-corrections will be used between the two missions in the inter-comparison.

Since the highest remaining uncertainties in the altimeter parameters derived in coastal shallow waters arise from residual errors in the range and geophysical corrections, we use a regional high-resolution ocean tide model and high resolution mean sea surface model (TPXO8-ATLAS for tide and DTU15 for the mean sea surface). We also apply improved wet tropospheric corrections computed from the GPD+ algorithm at University of Porto, both for Sentinel-3A and CryoSat-2.

In parallel with SAR measurements, in order to quantify the improvement with respect to pulse-limited altimetry, we build PLRM (pseudo-LRM) data from CryoSat-2 FBR and Sentinel-3 L1A and retrack them with a numerical coastal retracker based on a revised ALES approach [2 and 3]. PLRM is used as proxy for conventional pulse-limited products (LRM).

Further, we will use these PLRM and SAR data from the enhanced coastal retrackers to assess the performance of EUMETSAT marine products in coastal water. We remind that the altimetric parameters in EUMESAT products are not yet built by dedicated coastal retrackers and limitations may be identified.

The region of interest is the North-East Atlantic Ocean [60N-35N, 12W-16E], which is covered by CryoSat-2 in SAR mode. The period of interest is the common time period between CryoSat-2 and Sentinel-3A missions spanning since April 2016 to May 2018.

With a dataset as long as two years, the final objectives are:

- to verify that, with a dedicated coastal processing and retracker (SAMOSA+) applied by GPOD, the Sentinel-3 SAR data are able to measureto verify that, with a dedicated coastal processing and retracker (SAMOSA+) applied by GPOD, the Sentinel-3 SAR data are able to measure the annual cycle of sea level in the coastal zone as well as CryoSat-2 [1];

- to identify any detrimental effect of using the open-loop tracking mode (OLTC) in the region of interest; to identify any detrimental effect of using the open-loop tracking mode (OLTC) in the region of interest;

- to assess the performance of the SAR Sentinel-3 Marine products in coastal zone and highlight potential limitations; to assess the performance of the SAR Sentinel-3 Marine products in coastal zone and highlight potential limitations;

- to assess the importance of having a dedicated coastal retracker in the Sentinel-3 Marine products.to assess the importance of having a dedicated coastal retracker in the Sentinel-3 Marine products.

References:

[1] https://doi.org/10.1016/j.asr.2017.12.018

[2] https://doi.org/10.1016/j.asr.2017.11.039

[3] https://doi.org/10.1016/j.rse.2014.02.008

****

Validation of a Global Dataset Based on Subwaveform Retracking: Improving the Precision of Pulse-Limited Satellite Altimetry

Passaro M.[1], Smith W.[2], Schwatke C.[1], Piccioni G.[1], Dettmering D.[1]

[1]Deutsches Geodätisches Forschungsinstitut Der Technischen Universität München, München, Germany; [2]National Oceanic and Atmospheric Administration, Silver Spring, USA

The advantages of reprocessing the data from pulse-limited altimetry with the Adaptive Leading Edge Subwaveform Retracking (ALES) algorithm have been demonstrated at the coast in various studies, but only limited to few regions and without continuity with open ocean data. We demonstrate in this talk that the same strategy improves the precision of satellite altimetry in the global ocean, presenting the new global ALES dataset, which is available at 1 Hz through the Open Altimetry Database (OpenADB, webpage: openadb.dgfi.tum.de) and at 20 Hz under request. This is the first published global dataset processed with a coastal altimetry retracker to be applied on more than one mission.

The validation work consists in a global crossover analysis, a high-rate noise assessment and a spectral analysis. The sea level differences at crossovers are computed using the same procedure for the ALES and the available Sensor Geophysical Data Records (SGDR) at 1Hz. Preliminary results on the Jason-2 missions shows that the standard deviation of the sea level differences at the crossover points is lower in ALES in the vast majority of the locations at the coast and in the open ocean. The spectral analysis shows that the use of ALES improves the description of the spectral content at wavelengths shorter than 100 km, i.e. reduces the spectral hump. The high rate noise assessment is based on consecutive differences of uncorrected sea level height (except that the range is corrected for the sea state bias), computed by subtracting the estimated range to the orbital altitude. It shows that, after the sea state bias correction recomputed using ALES Significant Wave Height and Backscatter Coefficient, the standard deviation of the ALES crossover differences over the global ocean up to 3 km from the coast is 0.35 m against 1.84 m for SGDR, despite the availability of over 2400 crossover differences that are flagged in the SGDR.

A more detailed analysis will be provided in the talk, considering deep and shallow waters and applying the same analysis to other pulse-limited missions. Our conclusion is that the use of the ALES global dataset can improve the description of the global ocean circulation and the understanding of the scales of oceanic variability below 100 km for over 20 years of data, which is now of particular importance given the availability of more precise Delay-Doppler altimeters and in preparation to the SWOT mission. Further improvements to the dataset will be brought in the near future by a dedicated sea state bias model for ALES.

****

Assessing Sentinel-3 Wave Height Records in the Coastal Zone

Nencioli F.[1], Quartly G.[1], Conley D.[2]

[1]Plymouth Marine Laboratory, Plymouth, United Kingdom; [2]University of Plymouth, Plymouth, United Kingdom

Delay-Doppler altimetry offers a narrower footprint and multi-looking processing options that not only offer improvements in sea surface height retrieval in the coastal zone, but also better recovery of significant wave height (SWH). The SWH records from conventional LRM instruments are usually only assessed via the limited set of wave buoys that exist far from the coast, whereas the promised resilience of SAR altimeters to minimise the effects of land reflections should enable a vastly larger array of wave buoys to be used for validation purposes.

We analyse the recent reprocessing of Sentinel-3A data that provides PLRM data as well as SAR retrievals according to the SAMOSA 2.5 retracker, and compare these data with an initial network of 15 buoys located around the southwest coast of the UK. As swell propagates in to the region from the North Atlantic, the wave height diminishes due to diffraction effects; this reduction is borne out by the SAMOSA-derived data, with the scatter plot of altimeter and wave buoy measurements approaching the 1:1 line as the altimeter records get closer. Problems were noted with the land masking in the S-3A data and in associated data quality issues. The quality of the retrievals will vary with the height of the coast, and the direction of the altimetric approach. As expected, Sentinel-3A's performance in SAR mode exceeds that in PLRM, especially given the challenging coastal morphology in this region.

****

Coastal Improvements for Tide Models: the Impact of ALES Retracker

Piccioni G.[1], Dettmering D.[1], Passaro M.[1], Schwatke C.[1], Bosch W.[1], Seitz F.[1]

[1]DGFI-TUM, Munich, Germany

Since the launch of the first altimetry satellites, ocean tide models improved dramatically for deep and shallow waters. However, issues are still found for coastal regions, which are areas of great interest for climate change. The purpose of this study is to analyze the influence of the ALES coastal retracker on tidal modeling with respect to a standard open ocean retracker (SGDR). The approach used to compute the tidal constituents is an along-track, updated version of the Empirical Ocean Tide model developed at DGFI-TUM. The harmonic constants of EOT are derived from a residual least-square harmonic analysis based on the FES2014 tidal model. The study compares an EOT version based on ALES sea-level estimations with respect to the original EOT version based on SGDR.

Better performances are found with respect to the fitting error of the least-squares for the EOT-ALES solution, especially at distances closer than 20 km from the coast.

The harmonic constants estimated in the two experiments are compared in terms of root mean square and root sum squared values against in-situ data. Preliminary results show that in the global average, the solutions based on ALES are superior to solutions based on SGDR for every constituent. Among the major tidal constituents, the use of ALES produces an improvement of over 10% for K2, O1 and P1. For Q1, the improvement is over 25%. It was observed that these improvements are larger for distances closer than 10 km from the coast, and are independent on the sea state. Lastly, it was found that the performance of the solutions changes according to the satellite's flight direction: for tracks approaching land from open ocean, root mean square differences larger than 1 cm are found in comparison to tracks going from land to ocean.

The improvements shown in this study were found despite the ALES retracking strategy was only applied in the residual analysis of the EOT procedure, while the original FES2014 model, which corrects for most of the tidal variability, is still based on SGDR data. We expect therefore that the use of ALES data could bring a decisive improvement in coastal tide modeling if used as a data source to estimate the full tidal component of the sea level variability.

****

Bathymetry Improvement and Tidal Modelling at Regional Scales in the NEA and in Indonesia

Cancet M.[1], Toublanc F.[1], Lyard F.[2], Dibarboure G.[3], Guinle T.[3]

[1]Noveltis, Labège, France, [2]LEGOS/OMP/CNRS, Toulouse, France, [3]CNES, Toulouse, France

Coastal processes (tidal currents, storm surges, waves) are highly dependent on bathymetry and directly impact offshore and coastal activities and studies. Many studies and applications lie on a growing modelling effort of the ocean and the limited accuracy of bathymetry, especially on the continental shelves, contributes to degrade numerical model performance despite significant use of in-situ and satellite measurements assimilation. In particular, the tidal models are very sensitive to the bathymetry accuracy on the shelves, where the ocean tides show the largest amplitudes and are strongly non-linear. This has a direct impact on the quality of the altimetry sea surface heights as the tide correction is one of the largest corrections on the shelves, ranging from several centimetres to several metres.

Various sources of bathymetry data exist but many regions remain not well known because of too sparse measurements, data access limitation or large temporal variability of the seabed dynamics. In this context, a project was launched by CNES with the aim to improve the bathymetry in the North-East Atlantic Ocean and on the Indonesian continental shelves. The work was divided in several steps: 1/ an inventory of existing datasets and methods to derive the bathymetry on the shelves ; 2/ the integration of the collected datasets into a reference global bathymetry dataset ; 3/ the evaluation of this new bathymetry dataset through hydrodynamic modelling and the production of regional tidal models.

This paper presents the methodology and the most recent results obtained in this project.

****

S1B: Technical Issues in Coastal Altimetry - Corrections, Calibration & Products

Impact of Geophysical Corrections on Altimetry Sea Level Estimations Near the Coast

Birol F.[1], Niño F.[1], Léger F.[1], Blarel F.[1]

[1]LEGOS, Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France

During the last 15 years, substantial progress has been achieved in altimetry data processing; nowadays, coastal altimetric data has enough accuracy to illustrate the potential of these observations for coastal applications. In parallel, new altimetry techniques (the Ka-band of SARAL/AltiKa, the SAR mode of Cryosat-2 and Sentinel 3) improve data quality by reducing land contamination and an enhancing the signal-to-noise ratio. Satellite altimetry provides ever more robust and accurate measurements ever closer to the coast and resolves ever shorter ocean features. The SWOT mission planned in 2021, with its SAR interferometer in Ka-band measuring SSH over 120-km wide swaths will still be a step forward. We can easily predict that altimetry will become rapidly an important component of coastal observing systems.

The progress of altimetry in coastal zones places the data processing issues in a new context, and we need to revisit a number of technical and scientific questions. It also requires the knowledge of the error budget associated with coastal altimetry observations, which is fundamentally different than over the deep ocean. Here we will focus on the geophysical correction component and analyze the errors associated with each correction and quantify how they impact the coastal sea level variations estimated from altimetry data. As we may expect a significant regional tendency in the results we use a regional approach. In parallel of error quantification, the objectives are to define the best possible set of altimetry corrections, as well as where more research efforts are needed.

****

On the Need for High-Rate Range Corrections for Satellite Altimetry Studies Over Coastal and Inland Water Regions

Fernandes J.[1,2], Pires N.[1,2], Vieira T.[1,2], Vieira E.[1], Lázaro C.[1,2]

[1]Universidade Do Porto, Faculdade De Ciências, Porto, Portugal; [2]Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR/CIMAR), Matosinhos, Portugal

Together with accurate orbits and satellite-to-surface altimeter range retrievals, the range corrections are a crucial component in the derivation of geophysical parameters from satellite altimetry. These corrections account for the radar signal delay as it propagates through the atmosphere (atmospheric path delay) and by the sea surface (sea state bias, SSB). The first includes the effect of the ionosphere and of the troposphere, the latter including the effect due to the dry gases (dry tropospheric correction, DTC) and due to the water vapour and liquid water (wet tropospheric correction, WTC).

Traditionally, most altimeter users and applications make use of 1 Hz altimeter measurements and, consequently, the range corrections are provided in the altimeter products, in particular in the Level 2 (L2) products, also at 1 Hz. This approach is in the interest of reducing product size and because it is believed that the spatio-temporal variability of the corrections and the available information used to generate them are associated to scales of variability larger than those associated to the 1 Hz data (6-7 km and 1 second, respectively).

The recent developments in coastal and inland water altimetry, namely the advent of new instrument modes and new retracking algorithms, leading to increasing accuracy and spatial resolution (e.g. SAR delay Doppler measurements with 300 m resolution in the along-track direction), as well as a better knowledge of the modelling of the corrections, lead to the discussion about the possible need of having range corrections at higher rate associated to these measurements.

This study aims at assessing the impact of having corrections at high frequency (20 Hz) in Sentinel-3A L2 Non Time Critical Synthetic Aperture Radar Altimeter (SRAL) products. For this purpose, sea level anomalies (SLA) at 20 Hz are generated using various range corrections: i) computed at 1 Hz and interpolated to 20 Hz (classical approach); ii) computed at 20 Hz (new approach).

The study focuses on the tropospheric corrections (DTC and WTC) and on the sea state bias. The main factor inducing high spatial variability of the tropospheric path delays is due to their height dependence (namely on the DTC), this factor being of major importance over continental water surfaces and steep coastal regions. Model tropospheric corrections from the European Centre for Medium range Weather Forecasts models (DTC and WTC) and WTC from the GNSS-derived path Delay algorithm will be considered. Concerning the SSB, the computation of the correction at high rate may allow the modelling of oceanic signatures of the same order of

magnitude of the sampling rate. In this context, non-parametric SSB UPT models based on three inputs will be adopted.

Assessment of the impact on SLA derived both from Sentinel-3A SAR and Pseudo Low Resolution Mode (PLRM) observations is performed by means of SLA variance analysis, both along track, at crossovers and function of distance from coast. Moreover, validation against independent data sources such as in situ surface pressure, zenith total delays from GNSS and water vapour products from ground-based water vapour radiometers are also performed.

****

The High-Resolution Microwave Radiometer (HRMR) on Sentinel-6: Measuring Path Delay in the Coastal Zone

Brown S.[1], Tanner A.[1], Padmanabhan S.[1], Ramos I.[1], Kangaslahti P.[1]

[1]Jet Propulsion Laboratory, Pasadena , United States

The next generation of altimeter measurement systems feature high resolution altimetric observations from SAR and InSAR systems. This enables new science applications in the coastal region, including estuaries. But, the heritage 18-37 GHz microwave radiometer systems which provide the important wet tropospheric path delay correction do not provide valid retrievals close to the coast or over land. Higher frequency radiometers have been proposed to fill this gap. Operating at higher frequencies gives improved spatial resolution for the same antenna size which will aid in retrievals near the coast.

Sentinel-6 will carry an experimental microwave radiometer called the High-Resolution Microwave Radiometer (HRMR) specifically for improving the wet tropospheric path delay measurement in the coastal zone. This radiometer operates at 90, 130 and 166 GHz and has a spatial resolution of 2-5km. The HRMR shares the same 1m antenna as the low-frequency Advanced Microwave Radiometer (AMR). The radiometer is currently being developed at the Jet Propulsion Laboratory.

The concept of the radiometer is to use the high-frequency, high-resolution measurements to extend the well-calibrated open ocean path delay to within 5km of the coast. This is done using a dynamically trained retrieval algorithm constrained by the low-frequency radiometer path delay measurements from 300km to 75km from the coast. We will provide an overview of the HRMR instrument and discuss the expected performance using actual pre-launch data and simulations.

****

Calibrating SAR SSH of Sentinel-3A and CryoSat-2 Over the Corsica Facilities

Bonnefond P.[1], Laurain O.[2], Guinle T.[3], Picot N.[3], Féménias P.[4]

[1]Observatoire de Paris - SYRTE, Paris, France, [2]Observatoire de la Côte d'Azur - Géoazur, Sophia-Antipolis, France, [3]CNES, Toulouse, France, [4]ESA-ESRIN, Frascati, Italy

Initially developed for monitoring the performance of TOPEX/Poseidon and follow-on Jason legacy satellite altimeters at Senetosa Cape, Corsica, this calibration/validation site, has been extended to include a new location at Ajaccio. This addition enables the site to monitor Envisat and ERS missions, CryoSat 2 and, more recently, the SARAL/AltiKa mission and Sentinel 3A satellites. Sentinel-3A and CryoSat-2 carry altimeters that use a SAR (Synthetic Aperture Radar) mode that is different to the conventional pulse-bandwidth limited altimeters often termed "Low Resolution Mode" (LRM). The aim of this study is to characterize the Sea Surface Height (SSH) bias of the new SAR altimeter instruments and to demonstrate the improvement of data quality close to the coast. Moreover, some passes of Sentinel 3A and CryoSat 2 overfly both Senetosa and Ajaccio with only a few seconds time difference allowing us to evaluate the reliability and homogeneity of both ground sites in term of geodetic datum. The results show that the stability of the SAR SSH bias time series is better than standard LRM altimetry. Moreover, compared to standard LRM data, for which the measurements closer than ~10 km from the coast were generally unusable, SAR mode altimeters provide measurements that are reliable at less than few hundred meters from the coast.

****

From Level-2 Algorithms to High-Resolution Altimeter Products to Better Observe Ocean Dynamics in Coastal Areas

Faugere Y.[1], Pujol M.[1], Ablain M.[1], Ubelmann C.[1], Dufau C.[1], Picot N.[2], Dibarboure G.[2]

1CLS, Ramonville-Saint-Agne, France, 2CNES, Toulouse, France

CNES and CLS have started the development of the new generation of DUACS products to allow the full exploitation of the fine-scale content of the current altimetric missions and prepare their synergistical use with the future SWOT mission.

Using the global Synthetic Aperture Radar mode (SARM) coverage of Sentinel-3A, soon completed by Sentinel-3B, and optimizing the LRM altimeter processing, this development proposes Level-3 5Hz products and improved Level-4 products combining the new Level-3 products and a new mapping methodology.

This paper will explain and illustrate how level-2, level-3 and level-4 altimeter processing have to be performed to get efficient observations of the ocean dynamics over continental shelves and coastal areas.

****

S2A: Application of Coastal Altimetry Data

Investigating Altimeter and Tide-Gauge Sea Level Differences With CryoSat-2 and Sentinel-3A

Fenoglio L.[1], Salvatore D.[2], Buchhaupt C.[3], Uebbing B.[1], Scharroo R.[4], Fernandes M.[5], Kusche J.[1], Becker M.[3], Benveniste J.[6]

1University of Bonn, Bonn, Germany, 2HeSpace, EUMETSAT, Darmstadt, Germany, 3Technical University Darmstadt, Darmstadt, Germany, 4EUMETSAT, Darmstadt, Germany, 5University of Porto, Portugal, 6ESA-ESRIN, Frascati, ItalyGermany

Satellite altimeter observations form an important component of ocean observing systems in the coastal ocean, and along with other satellite and in situ measurements, can be used to constrain ocean models using data assimilation methods. We present here a quantitative assessment of the impact that various recent altimeter missions have on estimates of cross-shelf fluxes of mass, heat and salt in the Mid-Atlantic Bight when these data are assimilated into the Regional Ocean Modeling System (ROMS). The data assimilation method used is a 4-dimensional variational (4D-Var) approach, and using techniques employed routinely in numerical weather prediction, we can partition the 4D-Var transport increments into contributions from each observing platform. Particular attention will be paid here to the impact of the coastal satellite altimeter measurements on the cross-shelf transport.

****

Validity of Sentinel-3 SAR Wind and Wave Data Near the Coast

Abdalla S.[1], Bidlot J.[1]

[1]ECMWF, Reading, United Kingdom

The knowledge of surface wind speed and significant wave height in the coastal areas is of crucial importance for a wide range of coastal and marine applications. This type of information comes from various sources like in-situ measurements (buoys, platforms, … etc.), remotely-sensed data (e.g. radar altimeters, synthetic aperture radars, … etc.) and models. Each source of data has its own limitations in the coastal zones.

Radar altimeters provides ample of wind and wave measurements. However, due to the size of the ground footprint of the radar signal in conventional altimetry the validity of those measurements was limited to areas relatively far from the coast. The new technology of Delayed-Doppler (also known as Synthetic Aperture Radar, SAR) altimetry implemented by Sentinel-3A for the first time on global scale, promises the ability to provide more useful measurements in the coastal zone up to short distances from the coast.

This work will assess the validity of Sentinel-3 SAR surface wind speed and significant wave height in the coastal zone. The validation will be carried out using self-consistency tests as well as comparisons to a high-resolution wave model run forced by wind fields from the high-resolution ECMWF Integrated Forecasting System (IFS). This assessment study is geographically limited but we hope to draw conclusions which will guide the SAR altimetry data users in coastal areas.

****

Detection of Intraseasonal Oscillations in the Indian Ocean From Satellite Altimetry

Bulusu S.[1], Trott C.[1], Murty V.[2]

[1]University of South Carolina, COLUMBIA, United States, [2]CSIR/National Institute of Oceanography Regional Centre, Visakhapatnam, India

The role of air-sea interaction on Intraseasonal Oscillation (ISO) propagations across the tropical Indian Ocean is analyzed using integrated multi-mission satellite measurements of Sea Surface Height (SSH). SSH variability is a good indicator of changes in upper ocean circulation and atmospheric convection associated with the intraseasonal Madden-Julian Oscillations (MJOs), and is highly responsive to ISOs, and is observable via eddies and Kelvin and Rossby waves that are not seen as clearly in other oceanic parameters. The SSH 30-90 day ISOs driven by (MJO) of period between 30 and 50 day in surface wind stress are observed in the eastern equatorial Indian Ocean indicating a unique interaction in this region. In the eastern equatorial Indian Ocean the atmospheric conditions and the propagation of equatorially trapped Kelvin waves aid in the creation of equatorial Rossby waves, while in the central and western Indian Ocean, different phases of oceanic Rossby wave propagations seem to have a strong influence on the MJOs. This manifests in the oscillations of higher SSH for downwelling Rossby waves and lower SSH for upwelling Rossby waves, most strongly seen in the southern Bay of Bengal (BoB) at 5°N. Also, the equatorial Kelvin waves propagate along the coast of BoB and radiate westward moving Rossby Waves an influence the circulation in the BoB and the coastal currents. The downwelling phase of equatorial Rossby waves corresponds to a strengthening of OLR anomalies in extent and magnitude across the equatorial Indian Ocean, while the upwelling phase appears to weaken atmospheric MJO activity. These OLR anomalies correspond with SSH anomalies, further motivate us for this research. Submonthly ISOs including the MJOs are present along the coastal basin, hence the need for the application of coastal altimetry data for accurate observation of ISOs. This study improves climate research by identifying the ISOs and MJO signals in the coastal altimetry data.

****

Multi-Scale Analysis and Applications of Coastal Altimetry Observations Over the Ligurian Sea

Meloni M.[1], Doglioli A.[2], Petrenko A.[2], Bouffard J.[3], Valladeau G.[4]

[1]Serco Spa, Frascati, Italy, [2]MIO (Mediterranean Institute of Oceanography), Marseille, France, [3]Rhea c/o ESA-ESRIN, Frascati, Italy, [4]CLS, Ramonville Saint-Agne, France [1]

This paper addresses to cross-compare and exploit conjointly innovative high–resolution altimetry data and in situ measurements acquired by the Mediterranean institute of oceanography (MIO) through cruise campaign (OSCAHR) and fixed observing system (JULIO) located in the Ligurian sea, a coastal region characterised by complex fine-scale oceanographic features. We take advantage of using several kinds of multi-platform in situ observations (CTD, ADCP, MVP) which are perfectly almost collocated with multi-mission altimetry tracks from Jason-2 and AltiKa. The main objectives are to assess new altimetry processing technics and Ka/Ku-band sensors while better understanding differences with respect to in situ measurements respectively due to physical content inconsistencies and due to instrumental or altimetric data processing limitations. The obtained results show a remarkable agreement between satellite altimetry and in situ observations over spatial scales of few tens of kilometres, paving the way for the definition of innovative science-oriented diagnostics relevant for present and future high resolution ocean topography missions. Beside this, the combined use of coastal altimetry technics and multi-platform in situ observations have allowed to better depict the space/ time variations of the Mediterranean north current and its interactions with surrounding mesoscale features.

****

Satellite Altimetry and Tide Gauge Data in Local Vertical Datum Unification

Reyes R.[1], Forsberg R.[2]

[1]University of The Philippines Department Of Geodetic Engineering, Quezon City, Philippines, [2]Denmark Technical University, Denmark

The adoption of a geoid as a vertical reference surface level still requires validation as to its suitability to replace the conventional heights i.e. mean sea level (MSL) heights. The inhomogeneity of heights due to the variability of MSLs from different sites caused confusion as to which reference MSL should these be referred from. Thus, to effectively validate the geoid, these disparate MSLs that constitute the local vertical datums (LVDs) should be unified. At present, the geoid was shifted to the Manila Bay MSL and adjustment of the leveling network was constrained to the existing LVDs. However, due to the on-going accelerated sea level rise in Manila Bay and land subsidence issues in the locality, its integrity is put in question. This study explores alternative means to identify a suitable vertical reference level to unify the LVDs in the country. Observed data from tide gauges not only includes sea level variations but also vertical land motions as the country is on a tectonically active area. The use of satellite altimetry data was used to assess the consistency of the tide gauge data as this is deemed unaffected by any crustal movement. However, near the coast its accuracy is also compromised due to the contamination of the signal from nearby land mass. New re-procesing techniques, produced coastal products that are still experimental but showed potential for validating tide gauge data. The DTU15 MSS was used in conjunction with the Philippine Geoid Model (PGM) to determine the offset or mean dynamic topography (MDT) of the sea surface from the geoid. Similarly, the local MDT was also computed using MSL from tide gauge measurements. These MDTs provide the necessary information to fit the PGM to the LVDs.

The local MSLs from tide gauge sites is on average 1.051 m higher than the PGM while sea level from DTU15 MSS is on average 0.681 m higher than the same geoid. The results of the analyses identified four (4) TGBMs representing the LVDs as best candidates as reference levels but with seismicity in the country considered, only the TGBM in Palawan (TGBMXPLW3) is suitable. To check further the stability of TGBMXPLW3, satellite altimetry coastal product from OSTM/Jason-2 was used. The difference of the tide gauge data from the latter is around 12.7 cm with only 1 year of data considered. The assessment also showed MSL data from several TGBMs including BM66 in Manila Bay as questionable. Given the large offsets, the MDTs should not be ignored during the nationwide leveling network adjustment. Several unification approaches can be used based on its practical applicability in the Philippines. The PGM can be shifted by 1.109 m based on the MDT at TGBMPLW3 where the adjustment of the leveling network can be constrained. The standard deviation after shifting is around 20 cm with no fitting done yet. The fitting of the geometric geoid (GNSS-leveling derived geoid) to the gravimetric geoid (PGM) can be carried out with correction factors provided based on LVD offsets from the reference level.

****

Coastal Altimetry for Ocean Applications in the Strait of Gibraltar

Gómez-Enri J.[1], Vignudelli S.[2], Izquierdo A.[1], Passaro M.[3], Gonzalez C.[1], Cipollini P.[4], Bruno M.[1], Alvarez O.[1], Mañanes R.[1]

[1]University Of Cadiz, Puerto Real, Spain, [2]Istituto di Biofisica (CNR), Pisa, Italy, [3]Deutsches Geodätisches Forschungsinstitut (TUM), Munich, Germany, [4]Telespazio VEGA UK for ESA Climate Office, Harwell, U.K

Accurate coastal altimeter data are important for coastal observing systems (monitoring) and to re-analyse previous datasets. In this work, we analysed the cross-strait variability in the eastern side of the Strait of Gibraltar using one descending track from the European Space Agency (ESA) Envisat RA-2 descending track #0360. We developed an accurate coastal altimeter product at high spatial resolution along track (~350 m

between two consecutive 18-Hz measurements). We focused on the analysis of the spatio-temporal variability of along-track Absolute Dynamic Topography (ADT) profiles. We first estimated the Sea Level Anomalies (SLA) using the Adaptive Leading Edge Subwaveform (ALES) retracker. In order to get the anomalies, an along-track Mean Sea Surface based on ALES data was computed (and subtracted to the SSH profiles) by interpolating the along-track SSH track segments onto nominal tracks. Then, along-track ADTs were obtained using a local Mean Dynamic Topography from a two-dimensional (depth-averaged), two-layer, finite-difference, hydrodynamic model UCA2.5D. The cross-strait variability observed with the ADT profiles and its dependence with the wind regime was analysed and discussed. Our preliminary results from the improved altimeter data sets shows an inversion of the sea level between the southern / northern sector of the Strait during strong easterlies. This was confirmed by the analysis of two tide gauge data located at both sides of the Strait. The joint processing and exploitation approach can be applied to Sentinel 3A and future altimeter missions, and might be extended to other challenging coastal zones.

****

Combining Coastal Altimetry Data With In-Situ and Land-Based Remote Data for Improving the Monitoring of the Dynamics in the Southeastern Bay of Biscay

Caballero A.[1], Rubio A.[1], Rio M.[2], Ayoub N.[3], Mader J.[1], Larnicol G.[2], Manso-Narvarte I.[1], Dufau C.[2]

[1]Azti, Pasaia, Spain, [2]CLS, Toulouse, France, [3]LEGOS, Toulouse, France

The aim of this contribution is to showcase the last results of the applications of coastal altimetry data in the southeastern Bay of Biscay, an area deeply affected by the topography and orientation of the coast. Although, coastal altimetry data have allowed us to describe certain coastal mesoscale processes, one of the main limitation of using these data in this area is the accuracy of the global Mean Dynamic Topography (MDT). This is due to the larger errors and the lack of in situ observations at mesoscale and sub mesoscale of the global MDT solutions available to date. The HF radar system operating in the study area since 2009, can afford high spatial and temporal resolution of surface velocities for improving the local MDT performance. This is the objective of the COMBAT project (CMEMS-Service Evolution-2), an incipient project that besides these main datasets (altimetry and HF radar) will include in situ data and outputs from regional numerical models; the former as input to the new MDT and the latter for a better understanding of the processes contained in both databases. All these efforts will enable an improved monitoring of the coastal ocean dynamics in the southeastern Bay of Biscay.

****

Coastal Altimetry Activities on the Coastal Thematic Exploitation Platform

Clerc S.[1], Vignudelli S.[2], Bevy C.[1], Tuhoy E.[3]

[1]Acri-st, Sophia Antipolis, France, [2]CNR, Rome, Italy , [3]University of Cork, Cork, Ireland

The Coastal Thematic Exploitation Platform is an on-line service providing access to data and exploitation tools relevant for the observation of Coastal areas. The platform allow users to analyse, process and visualize data remotely from a web interface, without caring about data download and storage. The site provides a single interface to access a collection of Earth Observation datasets (e.g. Sentinel-2 medium resolution imagery), as well as in-situ and model data (e.g. European bathymetry from EMODNET). Processors cover a large range of applications (bathymetry retrieval, water quality, land use monitoring).

In a recent project, a tool has been developed to compare satellite coastal altimetry to tide gauge data. The tool uses the Level 3 coastal altimetry products from CTOH/LEGOS available on the platform and user-provided tide gauge measurements. For demonstration purposes, the publicly available data from the Acqua Alta platform in the Venice Laguna can be used. Simultaneous observations are extracted, then along-track correlation coefficients are computed and plotted.

This first step should lead to future developments: new data sets (including raw unfiltered satellite data, and other in-situ measurements) and new processors e.g. to perform customized filtering. The availability of other datasets (such as sea state, wind data) will also help developing multi-disciplinary approaches for storm surge monotiring.

****

S2B: Application of Coastal Altimetry Data-Sea Level, Currents & Data Assimilation

Regional Sea-Level Trends and Variability From Altimetry and Tide Gauges at the Northern Australian Coast

Gharineiat Z.[1], Deng X.[2]

[1]University Of Southern Queensland, Brisbane, Australia, [2]University of Newcastle, Newcastle, Australia

This paper investigates a consistent view of the low frequency sea level variability along the northern Australian coastline using data from both satellite altimetry and tide gauges. The 20 years of sea level observations from multi-satellite altimetry missions and tide gauges are analysed. Firstly, the impact of the

geophysical corrections applied to the altimetry sea level measurements and the consistency of the altimetric and the tide gauge sea level observations are examined. Both observations are then used to characterize sea level trends and inter-annual variability over the study region. The results show that the basin average of 14 tide-gauge time series is in good agreement with the basin average of the altimeter data, with correlation coefficient 0.95 and root mean square difference 18 mm. The rate of the sea-level trend over the altimetry period (6.3 ± 1.4 mm/yr) estimated from tide gauges is slightly higher than that (6.1 ± 1.3 mm/yr) from altimetry in the time interval 1993-2013, which can vary with the length of the time interval. The different trends are likely related to the higher interannual variability of coastal sea level, caused by the regional sea level. Here we provide new insights into examining the significance of sea-level trends by applying the non-parametric Mann-Kendall test. This test is applied to assess if the trends are significant (upward or downward). Apart from a positive rate of sea-level trends are not statistically significant in this region due to the effects of natural variability. The findings suggest that altimetric trends are not significant along the coasts and some parts of the Gulf Carpentaria (14°S-8°S), where geophysical corrections (e.g., ocean tides) cannot be estimated accurately and altimeter measurements are contaminated by reflections from the land.

****

Progress in the Validation of Coastal Sea Level Rates Using Coastal Altimetry Products

Shaw A.[1], Mir Calafat F.[2], Dayoub N.[2]

[1]SKYMAT, Southampton, United Kingdom, [2]National Oceanography Centre, Southampton, United Kingdom

In recent years, improvements of the altimeter retrackers such as the Adaptive Leading-Edge SubWaveform (ALES) have led to exciting new and improved coastal altimetry products. Validation of coastal altimetry sea level products against in-situ tide gauge measurements is an essential part of verifying the altimetric sea level observations. However, it is well known that tide gauge observations are influenced by coastal processes with small cross-shelf length scales that may not be captured by altimetry measurements taken a certain distance from the coast. Therefore, improved validation techniques are needed for assessing the performance of coastal altimetry products. One way to address this limitation is to find tide gauge locations where processes relevant to sea level have longer length scales. As part of a study conducted within the framework of the ESA Sea Level Climate Change Initiative (SL_cci) program, we identify tide gauge locations of long length scales based on the high-resolution NEMO (1/12 degree) global ocean model and use only these tide gauges for the validation of the altimetry products. The technique and the results of our work will be presented).

****

Relevance of Submesoscale Surface Currents and High-Resolution Sea Surface Heights in a Coastal Region

Kim S.[1]

[1]Korea Advanced Institute of Science And Technology, Daejeon, South Korea

This paper presents the relevance of submesoscale surface currents and high-resolution sea surface heights (SSHs) in a coastal region in a view of geostrophy and ageostrophy and the feasibility of retrieval of coastal surface currents from SSHs, based on statistical and spectral analyses of (1) observations of high-frequency radar (HFR)-derived surface currents and altimeter-derived geostrophic currents off the Oregon coast and (2) forward regional circulation model simulations forced with realistic wind stress and tides and boundary conditions. As anomalies from the geostrophic currents, which are the balanced currents between the Coriolis force and pressure gradients caused by the slope of SSHs, ageostrophic currents account for up to 50$\%$ of the total variance. The stream functions and SSHs and the stream function-derived currents and geostrophic currents show the high coherence in the low-frequency band ($|\sigma|$ $\leq$ 0.2 cycles per day). The submesoscale ageostrophic currents are primarily associated with near-inertial currents and internal tides, which can be missing components in the currents retrieved from solely submesoscale SSHs. A discussion on limitations to retrieve coastal submesoscale currents using in-situ observations is presented.

****

The Performance of Satellite Altimetry Currents in a Wide Continental Shelf

Lago L.[1,2,3], Saraceno M.[2,3,7], Martos P.[1,4], Guerrero R.[1], Piola A.[2,5], Provost C.[6]

[1]INIDEP, Mar Del Plata, Argentina, [2]Departamento de Ciencias de la Atmósfera y los Océanos, Buenos Aires, Argentina, [3]Unidad Mixta Internacional Instituto Franco-Argentino para el estudio del clima y sus impactos, Argentina, [4]FCEyN National University of Mar del Plata, Mar del Plata, Argentina, [5]Departamento de Oceanografía, SHN, Buenos Aires, Argentina, [6]Laboratoire d'Océanographie et du Climat: Experimentation et Approches Numériques, Paris, France, [7]CIMA-CONICET/UBA, Buenos Aires, Argentina

With the aim of analyzing the performance of satellite altimetry surface currents we compared four ocean currents time series collected by upward-looking ADCPs deployed within the French-Argentine CASSIS project (http://www.cima.fcen.uba.ar/malvinascurrent/es/) over the Patagonian Continental Shelf (PCS) to different satellite products. Results show low correlation coefficients (vector correlations lower than 0.3) and a root mean square differences (RMSD) of ~6 cm/s. We associate the low correlation to the fact that in situ currents are mostly ageostrophic. Indeed, this region is highly affected by winds. The best representation of surface currents was accomplished by a regional product developed by CLS that includes an estimation of

the Ekman component. We also found that the difference between satellite and in situ currents was larger during specific events associated to the passage of synoptic storms near the PCS. Nevertheless, we did find excellent agreement between in situ sea surface height (SSH) and satellite total water level (TWL, = altitude – range) computed from 20Hz Jason 2 data (correlation coefficients exceed 0.9 and RMSD is ~10 cm). By adding each satellite correction one by one to the TWL, we found that high-frequency atmospheric fluctuations and ocean tides need to be improved to accomplish a better representation of SSH and, consequently, of surface geostrophic currents.

The wide Patagonian Continental Shelf (PCS) is one of the most biologically productive areas of the world ocean. It harbors the spawning and nurturing area of several fish species of economic relevance.In order to better understand biological processes, it is important to characterize the spatio-temporal variability of the main physical variables.In this sense, satellite altimetry data will be very useful once validated.

****

ALES on Co-ReSyF: a Platform for Easy and Efficient Access to Coastal Altimetry Data

Dayoub N.[1], Cipollini P.[2], Snaith H.[1], Byfield V.[1]
[1]National Oceanography Centre, Southampton, United Kingdom, [2]Telespazio VEGA UK for ESA-ECSAT, Harwell Campus, United Kingdom

The Adaptive Leading-Edge Subwaveform (ALES) retracker, originally developed at the National Oceanography Centre (NOC) Southampton (Passaro et al. 2014), is capable of retrieving previously unreliable data in coastal areas by avoiding echoes from bright targets in the trailing edge portion of the waveform. ALES aims at retaining in the coastal areas the processing accuracy typical of open ocean altimetry, by adapting the width of the estimation window based on significant wave height (SWH).

NOC's coastal data from ALES reprocessing are available globally from PODAAC for the Jason-2 and Envisat missions, while Jason-1 data have only been available on request for certain projects. However, data from the NOC's ALES processor are now becoming available from a new EU-funded initiative, the Coastal water Research Synergy Framework (Co-ReSyF).

Co-ReSyF aims at developing a platform for combined data access, processing, visualisation and output in one place. The project is currently structured around six coastal research applications one of which is the ALES-based Coastal and Ocean Altimetry Application which we will present in detail.

The altimetry application targets both novice and more experienced users. Users choose their region of interest, time span, distance from the coast limits, range and geophysical corrections available from the Radar Altimeter Database System (RADS) to be applied in the processing, and the richness of the output from the processor. The processor then produces along-track and reference track outputs in a NetCDF format, containing geo-located oceanographic quantities such as Sea Surface Height Anomaly, Total Water Level Envelope, Significant Wave Height and backscatter intensity (Sigma0) in addition to all corrections selected by the user. The application currently runs on Jason-1, Jason-2 and Jason-3 missions, but it will be extended to include SARAL/ Altika, Sentinel-3A PLRM mode, Envisat, ERS1 and ERS2 missions.

****

Impact of the Assimilation of High-Resolution and High-Frequency Data in a Regional Model

Benkiran M.[1], Rémy E.[1], lellouche J.[1], Dufau C.[2]
[1]Mercator-ocean, Ramonville St-agne, France, [2]CLS, Ramonville St-agne, France

Mercator-Ocean has developed a regional forecasting system at 1/36° (~3km) resolution over the North East Atlantic (IBI: Iberia, Biscay and Irish), taking advantage of the recent developments in NEMO. The model was forced by ECMWF (European Centre for Medium-Range Weather Forecats) products (every 3 hours) including the atmospheric pressure. In addition to atmospheric forcing, the model includes astronomical tidal forcing. This regional forecasting system uses boundary conditions from the Mercator-Ocean global system (with data assimilation, 1/12° resolution). The assimilation component of the Mercator Ocean system, is based on a reduced-order Kalman filter (the SEEK or Singular Extended Evolutive Kalman filter). An IAU method (Incremental Analysis Updates) is used to apply the increments in the system. The error statistics are represented in a sub-space spanned by a small number of dominant 3D error directions. A 3D-Var scheme corrects for the slowly evolving large-scale biases in temperature and salinity. The data assimilation system allows to constrain the model in a multivariate way with Sea Surface Temperature, together with all available satellite Sea Level Anomalies, and with in situ observations, including ARGO floats temperature and salinity measurements. The background SLA field accounts for the high frequency signal determined by the model and the forcing by atmospheric pressure.

In this study we show the impact of the assimilation of altimetry high-resolution (5Hz) data unfiltered from high atmospheric frequencies. Altimetry data assimilated then contain the effect of atmospheric pressure and wind on the SLA unlike conventional data used in operational systems. We compare ocean analysis and forecasts obtained with those two different SLA data sets OR we analyse the impact of using those high resolution and high frequency observations.

****

Data Assimilation of Along-Track Sea Level Anomaly on Regional Ocean Modeling System.

Wang Z[1], Lyu G[1], Wang H[1], Liu G[1]

[1]National Marine Enviromental Forecasting Center Of China, Beijing, China

Abstract: In this work, the Satellite Sensing Data of along-track Sea Level Anomaly (TSLA) is assimilated into the Regional Ocean Modeling system (ROMS) using Ensemble Optimal Interpolation (EnOI) data assimilation method, which is a computationally very efficient data assimilation method. This system is tested with an eddy-resolving system of the South China Sea (SCS). Background errors are derived from a running seasonal ensemble to account for the seasonal variability within the SCS. A fifth-order localization function with a 250 km localization radius is chosen to reduce the negative effects of sampling errors. Also observation error (AGE-ERR) caused by discrepancy between observation time and assimilation is achieved by enlarging the observation error for the older observations to reduce their influence on the analysis. The error is calculated from the model daily output from 2000-2008. The data assimilation system is tested from January 2004 to December 2006. A lot of dependent Altimeter data, profiles and surface drifter data are collected for validation.

The results showed that the Root Mean Square Deviation (RMSD) of the Sea Level Anomaly for 7 days forecast is decreased from 10.57 cm to 7.01 cm, which represents a 33.68% reduction of the error and the reduction is relatively stable for the whole assimilation time. Data assimilation reduced the error for temperature within the upper 800 m and for salinity within the upper 200 m, although the error degraded slightly at deeper depths. Surface currents were in better agreement with trajectories of surface drifters after data assimilation than before. Furthermore, the variance of sea level is improved significantly in terms of both the amplitude and position of the strong and weak variance regions after assimilating TSLA.

Furthermore, based on the assimilation system, the forecast ability of SLA in the SCS is investigated. The results show that the RMSD of SLA is within ~10cm for 7days forecast for the whole SCS, while the forecast error increase rapidly for 15 days forecast, especially in regions with strong eddy activity like west of the Philippine Island ,east of Vietnam. Considering the time evolution of RMSD, it is shown that for January and October, the forecast error is relative small compared with model free run, and the forecast while the forecast error increase rapidly for April and July.

Lastly, the SLA has been assimilated into the Northwest Pacific operational forecasting system and the Indian Ocean operational forecasting system. The RMSDs of SLA have a ~30% reduction of the error, which can effectively improve the sea surface height prediction effect.

Keywords: Ensemble Optimal Interpolation, Data assimilation, along-track Sea Level Anomaly, ROMS.

****

Assimilation of High-Resolution Altimetry in a Canadian East Coast Forecasting System

Benkiran M.[1], Dufau C.[2], Smith G.[3], Liu Y.[1], Davidson F.[4]

[1]Environment And Climate Change Canda, Dorval, Canada, [2]Mercator Ocean International, Toulouse, France, [3]Collecte Localisation Satellites, Toulouse, France, [4]Fisheries and Oceans Canada, St. John's, Canada

A new Government of Canada initiative called the Ocean Protection Plan seeks to provide a world-class capacity in emergency environmental prediction. A significant component of this project is the development of high-resolution coastal and near-shore ocean analysis and forecasting systems. Coastal ice-ocean prediction systems are being developed for the Canadian east and west coasts on 2-km resolution grids. A critical aspect of these systems is their capacity to accurately capture mesoscale and sub-mesoscale features for drift prediction applications. The assimilation of a high-resolution coastal altimetry dataset is essential to be able to adequately constrain these features.

For this purpose, a multi-mission high-resolution altimetry chain has been set up over the Canadian Eastern Seas, from the US border to the Baffin Bay [95°W-43°W; 42°N-82°N]. A regional tuning has been done in terms of corrections and reference surface. Issued from the most recent research activity in altimetry field, a new estimation of the satellite-sea distance based on the waveform classification has been proposed for the satellite mission Jason-2 and SARAL/Altika missions. For the satellite mission Cryosat-2, data measured by its Synthetic Aperture Radar (SAR) mode have locally been used when available. A dedicated data selection strategy has been developed for this regional production in order to take more precisely into account the seasonal ice coverage. It provides a good compromise between the quantity of observations and their variance reduction. A dedicated spatial filtering has been applied on native 20Hz/40Hz observations to remove their noise level. The choice of the cut-off length has been done on the basis of a regional spectral analysis. Each mission has been considered separately.

This paper will present a quality assessment of the high-resolution altimetry data set optimized for the observation of small scale oceanic structures near the Eastern Canadian coasts and in sea ice areas, with a particular attention on to the Gulf of St Lawrence and Grand Banks areas. This paper will also present the impact of assimilating this dataset in both the Canadian Regional Ice-Ocean Prediction System (RIOPS) (at ~6km resolution) as well as in a higher-resolution (2km) coastal prediction system. The ocean analysis component of the system is the System d'Assimilation Mercator version 2 (SAM2), which uses a multivariate reduced-order Kalman filter that assimilates sea level anomaly, sea surface temperature and in situ profiles of temperature and salinity. A particular focus is on the use of Dynamic Atmospheric Correction and Long Wave Error terms and the downstream impact on drift prediction.

****

S3: Synergistic and Climate Studies

Coastal Currents Along the Yucatan Peninsula

Kurczyn J.[1], Appendini C.[2], Flores X.[3], Posada G.[1]
[1]Instituto Epomex, Universidad Autónoma de Campeche, San Francisco De Campeche, Mexico, [2]Laboratorio de Ingeniería y Procesos Costeros, Instituto de Ingeniería, Universidad Nacional Autónoma de México, Sisal, Mexico, [3]Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California, Ensenada, Mexico

The Yucatan Peninsula, situated in south-eastern Mexico, has one of the worlds widest continental shelves, spanning more than 700 km of coastline and with a continental slope located 50 to 200 km offshore. This is a highly dynamic oceanographic region, where strong, energetic currents and mesoscale eddies occur. However, due to the shallowness of its waters, much of the energy of this system is dissipated far from the coast. Thus, leaving the control of these coastal waters to the force of winds, tides and buoyancy effects derived from the interaction between seawater against estuarine and freshwater discharges (from rivers or submarine groundwater discharges). Also, strong atmospheric events affect this coastal region; cold wind bursts (locally known as “nortes”) happen every year during fall, winter and spring, and frequently hurricanes are present during summer and fall. Numerical efforts have been employed to understand the mean and seasonal characteristics of the coastal currents flowing in this region. However, in-situ observations obtained from a set of ADCPs along the Yucatan Peninsula, differ from model results. Also, comparisons between satellite altimeter-derived geostrophic velocities and local observations have shown low correlations. Upon recently, a set of HF radars have been installed along the eastern coast of Yucatan Peninsula, with more scheduled for the end of the year. All these in-situ observations can aid to enhance regional coastal altimetry observations, to better understand the local oceanographic process governing in this shallow environment, and help improve regional analysis of waves, currents, storm surges, and sea level variations.

****

Assessment and Calibration of Century Based Wind and Wave Climate Data Record in Coastal Zone Using Radar Altimeter Data

Ozbahceci B.[1], Turgut A.[1], Bozoklu A.[1], Abdalla S.[2]
[1]Izmir Institute of Technology, Izmir, Turkey, [2]ECMWF, Reading, UK

Reliable wind and wave data affecting a coastal region is very essential for almost all coastal and marine activities. Especially for the design of the coastal structures, not only reliable but also long-term data is necessary. Satellites that are equipped with instruments capable of observing marine surface wind and ocean waves like Radar Altimeter (RA), Synthetic Aperture Radar (SAR) and Scatterometer provide remotely sensed observations data. Such data source has good global coverage and is usually very reliable. Satellites are usually designed to serve for a few years (around 3-7 years) although they last twice as long on average. This time period is however not enough to construct a record suitable for climate computations. Therefore numerical model estimates are commonly used because of their wide temporal and spatial coverage as well as lower cost. For example, European Centre for Medium-Range Weather Forecasts (ECMWF) has been producing wind and wave parameters for the last few decades. ECMWF has also carried out several reanalyses to extend the climate record by several decades in the past using an unchanged model version throughout the whole period. All the reanalysis cover the period from 1979 to the present. ECMWF with the help of several international organizations conducted a reanalysis Project known as ERA-CLIM and its follow-up ERA-CLIM2 covering more than 100 years (from January 1900 to December 2010). The uncoupled atmospheric reanalysis ERA-20C assimilates only conventional observations of surface pressure and marine wind, obtained from well-established climate data collections. Another global 20th-century reanalysis known as CERA-20C was also conducted using a coupled Earth system including the atmosphere, ocean, land, waves and sea ice.

The main purpose of this study is to derive the wind and wave climate along the Turkish coasts based on the two century-long data sets of ERA-20C and CERA-20C. A pilot study was carried out to compare surface wind speed and significant wave height data from ERA-20C and CERA-20C against ENVISAT data over the whole Black Sea for two years (2007-2008). Comparison results show that both data give similar results but CERA-20C seems to be better from the significant wave height point of view. Then CERA-20C data are calibrated and validated by using various satellite radar RA datasets including ERS-1 (1991-1996), ERS-2 (1995-2011) and ENVISAT (2002-2012).

****

Climate Variability and Trends of Coastal Currents Off Atlantic Canada From Satellite Altimetry

Han G.[1], Chen N.[1]

[1]Fisheries And Oceans Canada, St. John's, Canada

The inshore Labrador Current and the Nova Scotian Current are important coastal current features off Atlantic Canada and can significantly affect physical and biological environments off eastern Canada and northeastern United States on seasonal and interannual time scales. So far, there is no long-term in situ monitoring of the two coastal currents. In this study coastal altimetry product from CTOH over 1993-2015 is used to investigate seasonal and interannual variations of the inshore Labrador Current and the Nova Scotian Current. The geostrophic currents derived from along-track altimetry data are compared with available in situ measurements and coastal circulation model output. Both currents are stronger in fall and winter and weaker in spring and summer, and show substantial interannual variations. The inshore Labrador Current has a positive linear trend over the study period, while the Nova Scotia Current has little linear trend.

****

Southwestern Atlantic Currents From In-Situ and Satellite Altimetry

Saraceno M.[1,2,3], Paniagua G.[1,2,3], Lago L.[2,3,4], Artana C.[6], Ferrari R.[1,2,3], Piola A.[2,3,5], Provost C.[6], Guerrero R.[4]

[1]University of Buenos Aires, Buenos Aires, Argentina, [2]CIMA/CONICET-UBA, Buenos Aires, Argentina, [3]UMI-IFAECI/CNRS-CONICET-UBA, Buenos Aires, Argentina, [4]INIDEP, Mar del Plata, Argentina, [5]Servicio de Hidrografía Naval, Buenos Aires, Argentina, [6]LOCEAN/UMR 7159, Paris, France

The CASSIS project is a French-Argentine cooperation to study the circulation in the Southwestern Atlantic from in situ and satellite altimetry data. Seven moorings that measure currents, temperature, conductivity and pressure and a fully equipped oceanographic buoy collected in situ data between December 2014 and May 2017. During the first year (December 2014-November 2015) the moorings were deployed below Jason-2 satellite altimeter track #26, covering the northern portion of the Malvinas Current (MC) and Patagonian continental shelf (PCS). In December 2015 the instruments were recovered and redeployed for a year and a half along a zonal section at 44.7ºS. A summary of the results obtained are reviewed here and in a complementary presentation in this meeting (Lago et al). In-situ surface currents and geostrophic velocities obtained from satellite altimetry are significantly correlated at the shelf-break (0.7). In the continental shelf correlation is low and significant (0.3) only when the Ekman component is added to the satellite data. During specific events associated with the presence of mesoscale eddies at the shelf-break and to the passage of synoptic storms at the continental shelf, differences between remote and in-situ currents are larger.

During the period of measurement, the MC at 41ºS can be characterized by two distinct regimes where along-slope velocities are either (i) large, surface-intensified or (ii) weak with almost zero vertical shear. The weak regime is due to a deflection of the Malvinas Current to the East, upstream of the moorings. A large shift of the structure of the water masses accompany the along-slope velocity change: all water masses sink and shift eastward during the weak regime. The change in the structure of the currents at the mooring location directly affects the comparison between in situ and altimetry-derived currents: during the weak regime altimetry adequately represents (rmsd 12cm/s) in situ currents in the whole water column, while during strong regime rmsd are larger than 15cm/s below 600m depth. Thus, measurements show that the vertical structure of the water column is a critical information that is needed in the attempt to use satellite altimetry as a proxy of subsurface currents.

****

Trends and Variability in Coastal Sea State and Sea Level From the CCI+ Sea State Project

Gommenginger C.[1], Dayoub N.[1], Wimmer F.[1], Shaw A.[2], Banks C.[1], Calafat F.[1], Snaith H.[3], Srokosz M.[1], Ash E.[4]

[1]National Oceanography Centre, Southampton, United Kingdom, [2]Skymat Ltd, Southampton, United Kingdom, [3]British Oceanographic Data Centre, Southampton, United Kingdom, [4]SatOC Ltd, United Kingdom

Knowledge of long-term changes in wave climate and extremes is currently relatively limited. The Climate Change Initiative Sea State project initiated in 2018 plans to develop new satellite-derived climate-quality records of sea state parameters obtained from satellite altimeter and SAR missions over the past two decades. Understanding wave climate and extremes at the coast is an issue of critical societal relevance - not just for the direct impact of ocean waves on coastal infrastructures and populations - but also for the contribution made by sea state to sea level rise and coastal flooding. There is consequently a natural synergy between the work in CCI+ Sea State and activities linked to storm surges and to coastal sea level in CCI Sea Level. This paper will outline the current plans to evaluate and exploit CCI Sea State products in the coastal zone in order to better understand long-term sea state variability and its relations with sea level change in the coastal zone.

****

Application of Satellite Altimetry as a Tool for Managing Coastal Risk in Mozambique, Madagascar and South Africa

Cotton D.[1], Becker A.[2], Byfield V.[3], Calafat F.[3], Dayoub N.[3]

[1]Satoc Ltd, Stockport, United Kingdom, [2]National Oceanography Centre-University of Liverpool, Liverpool, United Kingdom, [3]National Oceanography Centre, United Kingdom

It is well established that global sea-level is increasing and that large-scale weather patterns are changing, however, across large parts of the world, there is a lack of observational data from in-situ instrumentation available on which to implement evidence-based approaches to coastal adaptation. Mozambique, Madagascar and South Africa have large coastal populations whose lives and economic security are vulnerable to the consequences of climate variability and change.

In the past it has been difficult to retrieve satellite altimeter data close to the coast, due to land contamination of the return waveform. Using an innovative coastal processor, developed by the NOC, UK, a new satellite altimeter sea-level dataset for the South West African coastline has been generated. These data are now being validated against available tide gauge data and analysed for regional characteristics in sea-level variability, including long-term sea-level trends.

These data are being provided through C-RISe, a Coastal Risk Information Service, to partner organisations in South Africa, Mozambique and Madagascar to inform decision-making and reduce the impact of coastal inundation and increasingly variable weather patterns.

A key objective of C-RISe is to support the development of local capacity to access, process and apply satellite sea-level data. This is achieved through case studies which will evaluate the C-RISe service in different application areas. Local users are also being trained in the use of marine satellite data to quantify coastal hazards and incorporate this information into ongoing programmes.

This presentation will introduce the project, present some early results on the characteristics of sea level variability in the SW Indian Ocean region, and provide an overview of the use cases.

C-RISe is funded by the UK Space Agency under the International Partnership Programme

****

Normalized Radar Cross Section and Slope Variance Measured Over Inland Water Bodies

Panfilova M.[1], Karaev V.[1]

[1]IAP RAS, Nizhny Novgorod, Россия

The Precipitation radars (Ku- and Ka-bands) onboard the Glopal Precipitation Measurement (GPM) satellite which was loanched in 2014 operate in scanning mode at low incidence angles. It allows to obtain within the frameworks of Kirchhoff approximation the normalized radar cross section (NRCS) at nadir and the slope variance of sea waves along the scanning direction [1, 2]. Here we mean the slope variance of waves being large-scale compared to the probing wave length in the frameworks of the two-scale model of the sea surface. In the present work the data of DPR in the area of inland water bodies (Great Lakes) was used. The data of the precipitation radar was processed together with the data of buoys on wind speed and waves parameters. The dependencies of NRCS at nadir and slope variance retrieved from the DPR data on wind speed and wave parameters were obtained. In Great Lakes pure wind waves dominate. The results for Great Lakes were compared with the same dependencies for the open ocean, where swell is present.

1. Panfilova M.A., Karaev V.Yu., Guo Jie, Oil Slick Observation at Low Incidence Angles in Ku-Band, Journal of Geophysical Research, Oceans, March 2018, pp. 1-13, http://onlinelibrary.wiley.com/doi/10.1002/2017JC013377/abstract.

2. Panfilova M.A., Karaev V.Yu., The precipitation radar as an instrument for measurement of sea waves slopes, IGARSS, Fort Worth, TX, USA, 23-28 July 2017, proceedings, pp. 739-742.

****

Estimating Sea Level Variations Due to Greenland Ice Sheet Melting

Stolzenberger S.[1], Rietbroek R.[1], Kusche J.[1]

[1]Institute of Geodesy, University of Bonn, Bonn, Germany

Within the collaborative research program GROCE (Greenland Ice Sheet Ocean Interaction) funded by the German Federal Ministry of Education and Research, the role of the warming ocean in affecting processes and dynamics of the Greenland ice sheet, and of modifying interactions with the surrounding ocean are studied. The focus of the program is on the region around the 79°N glacier and the North East Greenland Ice Stream (NEGIS).

In our sub-project, we investigate the mass balance of Greenland and the sea level budget of the North Atlantic by jointly analyzing GRACE (Gravity Recovery And Climate Experiment) gravimetric data and sea surface heights via radar altimeter measurements (available products from e.g. ENVISAT, CRYOSAT-2, etc.). Including different datasets is beneficial as potential weak points in one dataset can be compensated by the other. As altimetry measures the total contribution and gravimetry measures the mass-driven contribution to

sea level change, this joint inversion method enables to resolve for steric sea level variations due to temperature and salinity changes in the ocean. Steric effects will be compared and reconciled with model simulations performed with the global ocean model FESOM (Finite Element Sea Ice Ocean Model), which will be locally refined in the surroundings of Greenland in order to capture coastal currents more accurately and realistically. The combination of gravity and altimetry in the inversion method allows the decomposition of global and regional sea level rise budget in a consistent way, which will be studied from 2002 until today.

****

Poster Session

Contribution of Waveform Decontamination for Improving Coastal Altimetric Sea Surface Heights

Wang H.[1,2], Chu Y.[1,2], Shum C.[3,4]

[1]School of Geodesy and Geomatics, Wuhan University, Wuhan, China; [2]Key Laboratory of Geospace Environment and Geodesy, Ministry of Education, Wuhan, China; [3]Division of Geodetic Science, School of Earth Sciences, Ohio State University, Columbus, USA; [4]State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan, China

Although great progresses have been made in coastal altimetry in the last decade, it is still a challenge to obtain accurate coastal sea surface height (SSH) observations, especially over the 0-8 km strip along the coast. Some recent studies (Tseng et al., 2014; Huang et al., 2017; Wang and Ichikawa, 2017) show that removing or modifying anomalous peaks in waveforms is helpful for further improving the coastal SSH data. In this study, we propose several strategies for detecting and remedying anomalous samples in waveforms. These strategies are applied to process coastal altimeter data from multiply satellite missions. Contributions of each waveform decontaminating method will be assessed by comparing retracked SSHs from decontaminated and original waveforms using various retrackers. Finally, we will compare our results with updated datasets for coastal altimetry, such as, PISTACH, PEACHI, ALES.

****

An Assessment of a Coastal Altimetry Data Product in the Indonesian Waters

Lumban-Gaol J.[1], Vignudelli S.[2], Leben R.[3], Adrian D.[1], Takahiro O.[4], Nurjaya I.[1], Pasaribu B.[1]

[1]Department of Marine Science And Technology, Bogor Agricultural University, Bogor, Indonesia; [2]Consiglio Nazionale delle Ricerche (CNR-IBF) Istituto di Biofisica, Area Ricerca CNR San Cataldo, Pisa, Italy; [3]Colorado Center for Astrodynamics Research (CCAR), Colorado University, Colorado, USA; [4]Center for Remote Sensing and Ocean Sciences (CreSOS), Udayana University, Bali, Indonesia

In this study, we used the along-track (X-TRACK) Jason-2 satellite altimeter data product developed by the Center for Topographic Studies in Sea and Hydrosphere (CTOH), and Sensor Geophysical Data Record (SGDR) are distributed by NOAA National Ocean Data Center. We analyzed the percentage of valid coastal altimetry X-TRACK data and Sea Level Anomaly (SLA) in two different coastal types, the sloping beaches in the north of Java Island and the steep coast of southern Java Island. The percentage of valid data on the closest point of the coastline in sloping waters is 34% lower than on the steep coast (86%). The percentage of valid data after the first point of the shoreline is greater than 90%. In general, the percentage of valid data in steeper waters is higher than sloping waters. The waveform types formed in coastal waters are peaky and Brown. However, spatially there is a difference where at a steep coast at a distances greater than 5 km from the coastline the type of waveform is identified Brown, while on the sloping beach the new Brown type is found at a distance greater than 10 km. The SLA time series data indicate the presence of variations in which the SLA is negative during the southeast monsoon (May-October) and positive during west monsoon (November-April).

****

Improvement of the Arctic Ocean Bathymetry and Regional Tide Atlas – a CP4O Initiative

Cancet M.[1], Andersen O.[2], Cotton D.[3], Benveniste J.[4]

[1]Noveltis, Labège, France; [2]DTU Space, Kongens Lyngby, Denmark; [3]SatOC, Bramhall, United Kingdom; [4]ESA-ESRIN, Frascati, Italy

The CryoSat Plus for Oceans (CP4O) project, under the ESA STSE program, aims to develop and evaluate new ocean products from CryoSat-2 data. The main focus of CP4O has been on the additional measurement capabilities that are offered by the SAR mode of the SIRAL altimeter, with further work in developing improved geophysical corrections, such as a regional tidal model in the Arctic Ocean.

The Arctic Ocean is a challenging region, because of its complex and not well-documented bathymetry, together combined with the intermittent presence of sea ice and the fact that the in situ tidal observations are scarce at such high latitudes. This initiative initially addresses the bathymetry in the Arctic in attempting to improve altimetric bathymetry using the near 7 years of Cryosat-2 high quality and high resolution "geodetic"

SAR altimetry all the way up to 88°N. Subsequently the project progresses to use Cryosat-2 in two ways for improved ocean tide modelling in the Arctic Ocean. One is to use the Cryosat-2 improved bathymetry implemented in the frame of the project, and the second is to use Cryosat-2 derived harmonic tidal constituents for assimilation into a regional tide model.

First, the project bathymetry in the Arctic will be presented and evaluated in this presentation. It will also present the methodology to derive bathymetry from the high resolution DTU17 marine gravity field derived from Cryosat-2. Second, this presentation will highlight the methodology followed to develop the tidal model and the performances of this new regional tidal model in the Arctic Ocean.

****

Sentinel-3 SAR Altimetry Over Coastal and Open Ocean: Performance Assessment and Improved Retrieval Methods in the ESA SCOOP Project

Cotton D.[1], Moreau T.[2], Raynal M.[2], Makhoul E.[3], Cancet M.[4], Fenoglio-Marc L.[5], Naeije M.[6], Fernandes M.[7], Lazaro C.[7], Shaw A.[8], Restano M.[9], Ambrosio A.[10], Benveniste J.[11]

[1]Satoc Ltd, Stockport, United Kingdom; [2]CLS, Toulouse, France; [3]IsardSAT, United Kingdom; [4]Noveltis, France; [5]University of Bonn, Germany; [6]Delft University of Technology, The Netherlands; [7]University of Porto, Portugal; [8]SKYMAT, United Kingdom; [9]SERCO-ESRIN, Frascati, Italy; [10]DEIMOS-ESRIN, Frascati, Italy; [11]ESA-ESRIN, Frascati, Italy

The European Sentinel-3 satellite, launched by ESA in February 2016 as a part of the Copernicus programme, is the second satellite to operate a SAR mode altimeter. The Sentinel 3 Synthetic Aperture Radar Altimeter (SRAL) is based on the heritage from CryoSat-2, but this time complemented by a Microwave Radiometer (MWR) to provide a wet troposphere correction, and operating at Ku and C-Bands to provide an accurate along-track ionospheric correction.

SRAL is operated in SAR mode over the whole ocean and promises increased performance w.r.t. conventional altimetry. SCOOP (SAR Altimetry Coastal & Open Ocean Performance) is a project funded under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme Element, started in September 2015, to characterise the expected performance of Sentinel-3 SRAL SAR mode altimeter products, in the coastal zone and open ocean, and then to develop and evaluate enhancements to the baseline processing scheme in terms of improvements to ocean measurements. Another objective is to develop and evaluate an improved Wet Troposphere correction for Sentinel-3, based on the measurements from the on-board MWR, further enhanced mostly in the coastal and polar regions using third party data, and provide recommendations for use.

In this presentation we present results from the SCOOP project that demonstrate the excellent performance of SRAL in terms of measurement precision, and we illustrate the development and testing of new processing approaches designed specifically to improve performance close to the coast.

The SCOOP test data sets and relevant documentation are available to external researchers on application to the project team. At the end of the project recommendations for further developments and implementations will be provided through a scientific roadmap.

****

Comparison of Altimetric Datasets Along the Greenland Coast

Hausman J.[1], Fenty I.[1], Nilsson J.[1], Madsen K.[2], Knudsen P.[3]

[1]JPL PO. DAAC, Pasadena, United States ; [2]Danish Meteorological Institute, Copenhagen, Denmark; [3]Danish Technological University, Lyngby, Denmark

NASA's Oceans Melting Greenland (OMG) mission is investigating how Greenland's glaciers are melting and contributing to global sea level rise in response to changing ocean temperatures. Satellite altimetry has the potential to provide information about ocean temperature changes through thermosteric expansion, but altimetry is notorious for having large errors in coastal areas. These coastal altimetry errors are mainly from land contaminated altimeter signal, uncorrected wet troposphere effects due to land contamination of the radiometer and uncorrected tide effects due to inadequately-constrained tidal solutions. Around the Greenland coast, sea ice and icebergs can also contaminate the signal. Various approaches have been used to address these coastal issues, such as retracking algorithms and correcting for atmospheric and oceanographic signals to reduce land contamination. To see how well these datasets measure sea surface height around Greenland, they will be compared against tide gauge data.

Tide gauges, considered "truth", from University of Hawaii's Sea Level Center are compared against altimetric datasets to evaluate differences in the various coastal datasets and to perform an assessment of their accuracy. The datasets include CLS/CNES's along-track coastal altimetry dataset (1) PEACHI, (2) CryoSat-2, and (3) Sentinel-3. The accuracy of these altimetric datasets are evaluated by comparing against tide gauges found on the west, east and south coasts of Greenland. The extent to which they mutually agree or disagree in these sectors is also quantified.

****

Coastal Retracking Using Along-Track Waveform Echograms in Seas of Indonesia

Ichikawa K.[1], Wang X.[2]

[1]Riam, Kyushu University, Kasuga, Japan; [2]Dalian Ocean University, Dalian, China

A coastal retracking method using along-track waveform echograms is examined in Seas of Indonesia where complicated topography with numbers of islands prevents full use of satellite altimeters in spite of high depends. In other seas, the method has successfully eliminated bright parabolic shapes in along-track echograms, namely unexpected strong microwave reflection from calm water surface in semi-closed bays within a footprint of an altimeter. But the method is found not properly applicable in Seas of Indonesia. Large areas of high microwave reflectors, or slicks, are intermittently but frequently present in the sea even away from the coasts. They are not accounted in the method that eliminates bright parabolas from single-point reflectors in the echograms. The method is modified to include an additional process to detect presence of slicks as extraordinary strong reflections in the echograms, which enables to estimate the sea surface height in Seas of Indonesia.

****

Absolute Water Levels at the Estuary of the Karnaphuli River (Bay of Bengal, Bangladesh): Comparison Between Sea/River Surface Heights Gained by GNSS Survey and Satellite Altimetry in Coastal Environment

Ishaque M.[1], Calmant S.[2,4], Moreira D.[2], Durand F.[2], Testut L.[2,3], Krien Y.[5], Ballu V.[3], Papa F.[2]

[1]BSMR Maritime University, Dhaka, Bangladesh, [2]LEGOS, Toulouse, France, [3]LIENSs, La Rochelle, France, [4]IFCWS, Bangalore, India, [5]LARGE, Univ. des Antilles, Guadeloupe, France

The shoreline of the Bengal delta (Bangladesh and India) is a macrotidal area (over 4 m), with a broad (200 km) and shallow shelf. It is also home to marked variability of the water cycle, over a broad range of timescales, from a few hours (cyclonic surges, flash floods) to a few weeks or months (monsoonal floods in the rivers, mesoscale turbulence in the near-shore ocean). Despite profound implications of the water level variability on the society and economy of the 150 M people populating the near-shore region, the characteristics of the ocean tide is poorly observed and understood in this region. Numerical tidal models also do not perform well in this region, compared to the rest of the tropical oceans. This stems, among others, from the lack of knowledge of the bathymetry of the shelf region.

In order to curb this lack of knowledge in the area of the Bay of Bengal along Chittagong, (Karnaphuli River), we performed a survey associating GNSS measurements of the water surface (either it is river water line or sea surface) and leveled bathymetry (by associating the soundings with the GNSS station). In this poster, we present the comparison of the GNSS heights of the water surface with various tidal solutions, including a harmonic analysis of a T/P (CASH reprocessing), Jason1-2-3 (GDRs) series gained close to the shore. In the river mouth, we compare our water levels with measurements collected by SENTINEL-3A (corrected for tides to account for the difference in time between our survey and the overpasses) which track # 193 crosscuts the river in three places of our survey. We also present the cross checking analysis that we performed between the GLOSS tide gauge series in Chittagong and our GNSS profiles.

****

Evaluation of Coastal Sea Level Change Near Hong Kong From Jason-2 Altimetry

Xu X.[1], Birol F.[2], Cazenave A.[2]

[1]The CAS Key Laboratory of Microwave Remote Sensing, National Space Science Center, Chinese Academy of Sciences, BEIJING, China, [2]LEGOS, Toulouse, France

In the recent years, methodologies have been developed by different groups worldwide to recover sea level data within 10–20 km to the coast from standard altimetry missions. These include computation of geophysical corrections adapted to the coastal zone and retracking of raw radar echoes. Here we present an analysis that combines coastal geophysical corrections and retracking along a Jason-2 satellite pass that crosses the coast near the Hong-Kong tide gauge. Six years and a half of data were analyzed, from July 2008 to December 2014. The purpose of this study was to assess and evaluate how sea level changes from the open ocean to the coast at interannual time scale. Different retrackers from the ALES and PISTACH products were considered. For each retracker, we evaluated the quality of the derived coastal sea level by comparing with data from the Hong Kong tide gauge (located 10 km away). We also analyzed the impact of the different geophysical corrections in the coastal zone. The study showed that, in the Hong Kong area, after outlier removal, the ALES retracker performs better, both in terms of noise level and trend uncertainty. By comparing short-term trends computed over the study period, both in the coastal zone and in the open ocean (using the Climate Change Initiative sea level data), we found a coastal sea level trend about twice larger than in the open ocean. This result suggests that in the Hong Kong region, the short-term sea level trend significantly increases when approaching the coast.

****

Last Developments and Perspectives of the X-TRACK Regional Altimeter Products

Léger F.[1], Birol F.[1], Niño F.[1], Fleury S.[1], Passaro M.[2]

[1]LEGOS/CTOH, Toulouse, France, [2]DGFI-TUM, Munich, Germany

Climate change is likely to worsen many problems that coastal environments already face: shoreline erosion, coastal flooding, stress and damage of the coastal biodiversity. Sea level variation is one of the major threat for coastal zones. Improving its observation is

essential to better understand and predict the behavior of the coastal ocean. Altimetry provides unique long term observational dataset to characterize how sea level variability evolves from the open ocean to the coastal ocean.

More than 10 years ago, the CTOH (Center of Topography of the Ocean and Hydrosphere) and LEGOS (Laboratoire d'Etudes en Géophysique et Hydrologie Spatiale) started to develop the X-TRACK processing chain in order to recover as more as possible altimetry data in the coastal zones. Now, X-TRACK is a multi-mission product covering all the coastal ocean, freely distributed by the CTOH/LEGOS and by the operational AVISO+ service. Both along-track Sea Level Anomaly time series and along-track empirical tidal constants are available. We present here the latest developments of the product. In particular, it has been decided to inject the L2 ALES (Adaptive Leading Edge Subwaveform Retracker) product in the X-TRACK post-processing algorithm, using the best possible set of altimetry corrections, in order to combine the different efforts that have been done to advance the capabilities of satellite altimetry near coastlines, in a product which will be available for the research community. Here, we will show a first version of this new product as well as its potential for coastal applications.

****

On the Use of Sentinel-3A SRAL Altimeter Waveforms at the Finest Posting Rate (80 Hz) for the Detection of Ships

Gómez-Enri J.[1], Mulero R.[1], Vignudelli S.[2], Scozzari A.[3]
[1]University Of Cadiz, Puerto Real, Spain, [2]Istituto di Biofisica (CNR), Pisa, Italy, [3]Istituto di Scienza e Tecnologie dell'Informazione (CNR), Pisa, Italy

The detection of non-ocean scatterers over the sea surface by using pulse-limited satellite altimeters involves a series of challenging targets, such as icebergs, lighthouses and ships, which have been investigated in the literature. In particular, past works focused on the hyperbolic features observed in the thermal noise area of the received waveforms, in order to detect the presence of such non-ocean targets. Following previous analysis made with CryoSat-2 data, in this work we exploit the capabilities of Sentinel-3A SRAL delay-Doppler instrument for the detection and characterisation of ships. In particular, we analyse the shape of the waveforms at two along-track sampling rates: 20 Hz – 80 Hz, in order to investigate the effect of the two resolutions in the discrimination of ships. This analysis might help to investigate the possibility to estimate some geometric features of the detected vessels from the echoes returned by the altimeter. The presented approach offers the opportunity to: i) study the compatibility between the detected target(s) and the known ship traffic, by using the Automatic Identification System (AIS) data; ii) resolve ambiguities among multiple targets, by using two different along-track spatial resolutions, due to the different sampling rates. Ship traffic statistics, as introduced by the literature, may take benefit from the method described in this work, providing a contribution to improve the overall precision of such statistics. The Sentinel-3 mission used in this work will provide a constellation with global SAR coverage (S3A and the new S3B) and free accessibility to the data, with a potential enhancement to the estimation of the number and characteristics of the ships with respect to past literature approaches.

****

Sea Level Anomalies and Mesoscale Activity Using Altimetry Along the African Coasts in the Eastern Tropical Atlantic Ocean (OSTST Alti-ETAO Project)

Diengh H.[1], Dadou I.[1], Léger F.[1], Birol F.[1], Lyard F.[1], Morel Y.[1], Chaigneau A.[1,2]
[1]LEGOS/CNRS, Toulouse, France, [2]IRHOB/CIPMA, Cotonou, Benin

The equatorial region, near the coast, represents a major contributor to the ocean/atmosphere/land heat and water fluxes, controlled by SST and the oceanic dynamics. The eastern tropical Atlantic ocean (ETAO, 35°S-20°N; 25°W-African coast) region remains little studied. This region also encompasses a large-range of peculiar dynamics: large-scale zonal equatorial currents, strong coastal currents, equatorial and coastal trapped waves, the presence of both equatorial and near-coastal upwelling cells, gyre-like structures with the presence of the Guinea and Angola domes.

In this area, there are few in-situ measurements and the time coverage of these data is not better. Since 1993 Sea Level Anomaly (SLA) are routinely measured using high-precision satellite altimetry (Topex/Poseidon, Jason-1/2) with this year, the 25-year anniversary of progress in Radar Altimetry. While spatial altimetry has enabled us to highlight the regional variability of mesoscale dynamics, it still provides incomplete information in coastal areas in the first 25km from the coasts, especially due to the perturbation of radar echoes by the continents (land, island, etc). In the OSTST Alti-ETAO project, we studied the mesoscale dynamics using different altimetry SLA products: AVISO gridded product (1/4°) and the coastal X-TRACK product from CTOH based on Jason1-2 altimeters; but also, validated modelled SLA using a NEMO model configuration (from LEGOS) in this region at high spatial resolution. We used also the tide gauge (TG) data available in the ETAO region for the validation of the altimetry and modelled SLA along the coast.

The comparison between the coastal altimetry along-track data (X-TRACK last reprocessing), AVISO gridded product, the NEMO model and TG data using different statistical criteria depends on the geographical position along the ETAO coasts. Near the coasts of Senegal and the Gulf of Guinea, we note a good agreement, in terms of correlation and quadratic errors (RMS), between the X-TRACK coastal altimetry data (closed to the tide gauge position and not in the first 10 km from the coast), the NEMO model data and tide gauge data. On the other hand, near the Namibian and South African coasts,

where tide gauge data appear to be better in terms of time cover, low correlations and more significant quadratic errors are found between the X-TRACK coastal data, NEMO model and tide gauge data. This weak agreement could be related to the higher oceanic and atmospheric variability in the Benguela upwelling system not detected by altimetry (also due unadapted altimetry corrections)and the geographic location of the TG relative to the altimetry data. We also show that, for locations (both altimetry and model) distant to the coast (several hundred km), the correlation is good with low rms, between the Pointe Noire TG, the altimetry products and the modelouputs, due to the equatorial waves propagating from the equator to the coasts, in this region. This is not the case in the Senegal and Benguela upwelling regions.

Studies are also underway at LEGOS to estimate the influence of the tide correction in this region, using the regional ocean dynamics numerical model T-UGOm based on unstructured meshes.

****

Inter-Comparison of Different Altimetric Datasets Through Spectral Analysis: Application to the Dynamics of Bay of Biscay and New Caledonia.

Dabat M.[1], Ayoub N.[1], Marin F.[1], Gourdeau L.[1], Sérazin G.[1], Léger F.[1], Birol F.[1]

[1]LEGOS, University of Toulouse, IRD, CNES, CNRS, UPS, Toulouse, France

We are interested in characterizing mesoscale circulation and internal tides through statistical and spectral analysis of sea level anomalies from different altimetric datasets. The main objective is to assess the spectral content of each dataset in near-coastal regions and to interpret it in terms of dynamics from submonthly to interannual timescales.

Two regions are considered : at midlatitudes, Bay of Biscay which is characterized by a wide shelf and a slope current, and in the tropics, the New-Caledonia region with no shelf but a well-defined regional circulation and mesoscale dynamics. Both regions are the location of strong internal tides.

X-Track datasets from several altimetric missions (Topex/Poseidon, Jason-1 and Jason-2 multimission, and Saral/Altika) are compared. The coverage and statistical properties of the available data in the two regions are first summarized. We compute the along-track spectra estimated from the different datasets over a common time period (2013-2015) and evaluate the sensitivity of these spectra to the choice of the filter and to the sampling frequency (1 Hz, 20 Hz or 40 Hz). Preliminary results from Sentinel-3 are also presented.

In Bay of Biscay, the shelf is an important constraint on the dynamics, leading us to consider separately the shelf and the plain. Sensitivity of the spectra to the two dynamical regimes is assessed.

In New Caledonia, we focus on the meso-scale signature on the spectra. A strong signal associated with internal tides is found. The issue of separating mesoscale and internal tides signals is adressed here, in complement to in situ data, as a contribution to the preparation of the SWOT mission.

****

The First Results of Monitoring the Ice Cover of the Sea of Okhotsk in 2015-2016 According to the Measurements of the Radar Cross Section at Small Incidence Angles

Ryabkova M.[1], Karaev V.[1], Maksimov A.[2]

[1]Institute of Applied Physics of the Russian Academy of Sciencies, Nizhny Novgorod, Russian Federation, [2]State Research Center "Planeta", Moscow, Russian Federation

The Dual-frequency Precipitation Radar (DPR) has a swath of ±65° covering regions with cold climate where waters are covered with ice for prolonged periods of time. It is operating at small incidence angles (less than 19°) and at two frequencies (13.6 and 35.5 GHz). The high spatial resolution (4–5 km) of DPR allowed our group to conduct in 2017 a study of ice cover of the internal waters such as Ilmen lake, Gorky reservoir, Volga river, Moksha river basin and Baikal lake. In those studies the original algorithm for separation of the open water and ice cover was suggested. It was shown that the dependence of the radar backscatter cross section on the incidence angle for autumn ice is different from that of spring ice, and can be used for classification. The sea of Okhotsk is the object of this study. The ice maps and meteorological data are provided by State Research Center "Planeta", the ice maps are based on the data from TERRA/MODIS, NOAA-18/AVHRR. The information on the sea ice thickness is provided by the European space agency (SIRAL/Cryosat). It is shown that the dependence of radar cross section on the incidence angle can be used for classification of different types of sea ice. The differences in monitoring the formation and destruction of ice cover for inland waters and the sea are investigated. Information on the sea ice thickness derived from altimeter data is used as additional parameter in classification of the sea ice along with ice cohesion and sea ice temperature.

This research is supported by the Russian Foundation for Basic Research (project No. 17-05-00939-a). The DPR data are presented by the Japan Aerospace Exploration Agency (the 8th GPM/TRMM RA of the Japan Aerospace Exploration Agency (PI 306))

****

Synergy between Coastal Altimetry Data and Land-Based High-Frequency (HF) Radars

Oliveira F.[1], Mazzini P.[2]

[1]Federal University Of Rio Grande, Rio Grande, Brazil, [2]San Francisco State University, San Francisco, United States

The ocean circulation patterns in coastal areas have been traditionally studied using regional numerical models and observations, however little is known about their interactions with large-scale oceanic remote forcings. Associated to these methods, radar altimeters are also commonly used to study the surface ocean circulation and its dynamical features, but they are usually restricted to the open sea. Among the dynamical features are the propagating signals and mesoscale eddies that can reach the coastal zones and are a potential remote forcing mechanisms that may influence the continental shelf circulation. Unfortunately, altimeter records fail in shallow waters due to inaccuracy to resolve the tidal variability and they provide low spatial resolution, hence they are inadequate to resolve these dynamical features over the shelf. In the past years, efforts have been made to improve the application of altimeters in coastal regions resulting in which we know as coastal altimetry. Integration of tide gauges measurements, refined tide models, improvements in the propagation corrections, retracking methods and others, turned the coastal altimetry into a powerful tool to investigate the ocean circulation closer to the coast. The goal of this study is to combine coastal altimetry with another promising tool to monitor and study continental shelf and deep ocean interactions: the land-based High-Frequency (HF) radars. HF radars are a relatively new technology in physical oceanography, which allows the real-time and continuous measurements of ocean surface currents in high spatial and temporal resolution. As a pilot study we chose the Gulf of Farallones off Central California, where HF radar observations began as early as January-2006 and are still ongoing. In this region lies the Greater Farallones National Marine Sanctuary, an important marine protected area which supports a rich and diverse ecosystem including many threatened and endangered species. Therefore the detailed knowledge about the coastal circulation and dynamics are crucial for the proper management of this sanctuary. In the near future, when the synergy between the data set is sufficiently robust, we the intend to expand this analysis to other coastal regions especially in Southern Brazil.

****

Coastal Region Applications From Satellite Altimetry Missions

Srinivasan M.[1], De Charon A.[2]

[1]Caltech Jet Propulsion Laboratory, Pasadena, United States, [2]ODYSEA, LLC, Edgecomb, USA

Data and information products from the NASA-CNES and partners' satellite altimeter missions—Jason-2, Jason-3, and the future Sentinel-6 missions—have clear and demonstrated societal benefits. A wide range of existing and potential land-based surface water, coastal and oceanography applications utilizing current altimetry data products will be further enhanced with the launch of the Jason-CS/Sentinel-6 mission, as well as the introduction of high spatial resolution data anticipated from the future Surface Water and Ocean Topography (SWOT) mission. The collective time series of ocean surface topography (OST), as well as SWOT's capability of measuring conditions close to coasts will support a broad range of ocean applications that can inform coastal managers and marine operators of offshore conditions and currents in their region.

The applied science community is a key component of measuring mission success and demonstrating the high value of these international endeavors, as well as the utility of science and data products in addressing societal issues and needs. In particular, as reference missions for continuous measurements of sea level rise, the Jason-series satellites are a crucial component to understanding the effects that global climate change will have on our coastal regions.

Our team is implementing a strategy to engage new users and promote applications research by highlighting operational and societally beneficial uses of OST data. The goal of this Jason-Series Missions Applications Program is to enhance and highlight the applications value of the missions. The objectives of this project include:

- Identify current applications, users and uses of OST information to better understand its impacts and societal benefit;
- Establish scope of existing applied research and develop new potential applications in support of the Jason-series missions concept;
- Demonstrate the benefit of OST to society and contribution to the achievement of societal outcomes;
- Increase the use and utility of data products and facilitate access via PODAAC and AVISO+; and
- Engage broad user communities through the altimetry missions' life cycles.

****

Use of Satellite Altimetry and Moderate Resolution Imaging Technology of Flood Extent to Support Seasonal Outlooks of Nuisance Flood Risk Along United States Coastlines and Managed Areas

Ransi V.[1], Pirhalla D.[1], Sheridan S.[2]
[1]NOAA, Silver Spring, United States, [2]Kent State University, Kent, United States

U.S. coastal areas and ecosystems are facing multiple sea level rise threats and effects: heavy rain events, cyclones, and changing wind and weather patterns all influence coastal flooding, sedimentation and erosion along critical barrier islands and can strongly impact habitat resiliency and water quality in protected habitats. These impacts are increasing over time and have accelerated the need for new tracking techniques, models and tools of flood risk to support enhanced preparedness for coastal management and mitigation. To address this issue, NOAA National Ocean Service (NOS) evaluated new metrics from satellite altimetry AVISO/Copernicus and MODIS IR flood extents to isolate nodes atmospheric variability indicative of elevated sea level and nuisance flood events. Using de-trended time series of cross- shelf sea surface heights (SSH), we identified specific Self Organizing Maps (SOM) nodes and transitions having strongest regional association with oceanic spatial patterns (e.g., heightened down welling favorable wind-stress and enhanced southward coastal transport) indicative of elevated coastal sea levels. Results show the impacts of the inverted barometer effect as well as the effects of surface wind forcing; Ekman-induced transport along broad expanses of the U.S. east coastline. Higher sea levels and corresponding localized flooding are associated with either patterns indicative of enhanced on-shore flow, deepening cyclones, or local- scale winds, generally coupled with increased local to regional precipitation. These findings will support an integration of satellite products and will inform seasonal outlook model development supported through NOAAs Climate Program Office and NOS office of Center for Operational Oceanographic Products and Services (CO-OPS). Overall results will prioritize ecological areas and coastal lab facilities at risk based on numbers of nuisance floods projected, and informs coastal management of flood risk around low lying areas subjected to bank erosion.

****

Tracking of Eddy Propagation in the Southern Luzon Strait

Del Rosario A.[1], Amedo-Repollo C.[1], Villanoy C.[1]
[1]Marine Science Institute, Quezon City, Philippines

The dynamics affecting intrusion of Kuroshio Current into the Luzon Strait (LST) have been an active area of study for years. Kuroshio Current path changes, notably during fall and winter when it loops around LST into South China Sea. Westward eddies have been identified to interact with Kuroshio Current at LST, however, the effect of speed and direction of eddies coming from North Pacific Subtropical Countercurrent (STCC) has not been discussed. This study investigates the passage of westward STCC eddies into the LST, and their transformations upon contact with Kuroshio Current. Using satellite-derived sea level anomaly (SLA) data from 1993 to 2017, eddies were tracked and their corresponding speeds, vorticity, eddy kinetic energy and eddy radius were determined to measure their effect on the mean current of Kuroshio. Shifts in the North Equatorial Current (NEC) bifurcation latitude were also observed to related to the spatio-temporal changes of eddies in the LST. Correlation analysis of tide gauge data with SLA in the northeastern tip of Luzon is done to validate the derived eddy tracking calculations.

****

Philippine Sea Level Responses to Intraseasonal, Seasonal and Interannual Variabilities in the Tropical Western Pacific Region.

Gallentes A.[1], Punongbayan A.[1], Repollo C.[1]
[1]University of the Philippines Marine Science Institute, Quezon City, Philippines

Sea level data from satellite observations and tide gauges in different parts of the Philippine archipelago exhibit spatial variability depending on a site's exposure to the Pacific Ocean and other water basins (e.g., West Philippine Sea, Sulu Sea). Lag correlation and empirical orthogonal function (EOF) analyses were performed, investigating on the responses of sea level anomalies to variabilities with intraseasonal (MJO), seasonal (monsoons) and interannual (ENSO) timescales.

****

Long Term Sea Level Changes From Satellite Altimetry Used in Geographical Multicriteria Analysis to Support Coastal Planning

Gorelli S.[2], Gómez-Enri J.[3], Rotonda M.[2], Vignudelli S.[1]
[1]Consiglio Nazionale delle Ricerche (CNR-IBF), Pisa, Italy, [2]Environmental Management Agency srl, Pisa, Italy, [3]Applied Physics Department - University of Cadiz, Cadiz, Spain

Understanding sea level and sea state variability at the coast is important for an effective coastal management and planning. As the rate of sea level accelerates and changes in climate bring increase in the frequency and intensity of storms, the coastal zone will be more and more impacted. In this work, we focus on the vulnerability related to long-term changes of sea level. The European Space Agency (ESA) Climate Change Initiative (CCI) project on "Sea Level" has produced an improved set of satellite-based sea level products by reprocessing altimeter data over 1993-2015. These products are based on open ocean altimetry data, and provide high quality monthly sea level variability and trends for the open ocean. During the CCI+ phase (2018-2019) particular efforts will be dedicated to the retrieval of sea level from altimeters in the coastal zone in order to extend the sea level climate record to the coastal zone with quality comparable to the open ocean. Here, we propose a scenarios analysis model that exploits the current CCI dataset of climate-quality sea level and an

accurate Digital Elevation Model (DEM) to create a vulnerability map around Tuscany coasts (Italy). The analysis consists of two phases: 1) an extreme sea level scenarios necessary to classify the territory under investigation in relation to its flooded areas due to the sea level rise and other relevant environmental characteristics; 2) a coast anthropic activity analysis to evaluate and map the coast anthropic activity adaptation propensity to the changes induced by flooded areas and the planning effects. Both extreme sea level scenario and coast anthropic activity analysis are implemented using Geographic Multicriteria Decision Aiding Techniques that permit to rank the spatial decisional alternatives under study in relation to different and often conflicting evaluation criteria represented by standardized map layers. This study aims at preliminarily assessing to what extent Tuscany has to be considered vulnerable to sea level rise and which areas would be more impacted.

****

An Assessment of the Quality of the ESA Sea Level CCI Products in the Coastal Zone of the Northern Adriatic Sea Using Tide Gauge Measurements and Coastal Altimetry Products

Vignudelli S.[1], De Biasio F.[2], Scozzari A.[3], Zecchetto S.[2]
[1]Consiglio Nazionale delle Ricerche (CNR-IBF), Pisa, Italy, [2]Consiglio Nazionale delle Ricerche (CNR-ISAC), Padova, Italy, [3]Consiglio Nazionale delle Ricerche (CNR-ISTI), Pisa, Italy

Since 1990's, a series of radar altimetry missions accumulated a satellite-based record of sea level that is now long enough to estimate trends. The European Space Agency (ESA) Climate Change Initiative (CCI) project on "Sea Level" has reprocessed these altimeter data over 1993-2015 to provide homogenous sea level for all altimetry missions. The ESA Sea Level CCI products are generated using open ocean altimetry data, and include along track sea level anomalies (SLA) at 1 Hz (around 7 km) and monthly gridded time series of multi-mission merged SLA at a spatial resolution of 0.25° (around 25km) from which some oceanic indicators (e.g., trends) are derived. During the CCI+ phase (2018-2019) the objective is to extend the satellite-based sea level climate record to the coastal zone with quality comparable to the open ocean. This work will report on the initial assessment of the quality of the ESA Sea Level CCI products in the coastal zone of the Adriatic Sea and in particular around the city of Venice. Tide gauges available around Venìce and Trieste will provide an accurate independent source of sea level information to be used as reference of long-term sea level variability at the coast. Coastal altimetry has demonstrated that if standard products are reprocessed with dedicated algorithms reliable data can be obtained up to few kms from the coasts. Therefore, additional along-track data sets (e.g., CTOH, COSTA, etc.) with consistent coastal processing for all missions and derived products dedicated to coastal regimes will be used to evaluate their current capabilities and perspectives for usage in long term sea level research studies.

****

Investigating a Slope Water Intrusion Event into the Gulf of Maine – Parallel Assessment Using a Data Assimilative Regional Ocean Model and New Satellite Salinity Observations

Vandemark D.[1], Grodsky S.[2], Levin J.[3], Wilkin J.[3], Feng H[1]
[1]University Of New Hampshire, Durham NH, United States, [2]University of Maryland, College Park, United States, [3]Rutgers University, New Brunswick, United States

Ocean altimeter data from the Gulf Stream region and onto the coast of the NW Atlantic factor heavily into the performance of an operational ocean circulation prediction forecast system produced using a data-assimilating version of the Regional Ocean Modeling System (ROMS). This model, DOPPIO, was in full operation during winter 2017-2018 when new surface salinity data from NASA's Soil Moisture Active Passive (SMAP) satellite observed a significant increase in warm and salty surface water entering the Gulf of Maine (GoM) across the shelf break front. SMAP salinity anomaly data indicate that a feature moved along the Northwestern Atlantic shelf break from near the Grand Banks SW to the GoM over a 10 month period in 2017-2018. Satellite ocean current, SSS, and SST data suggest the feature interacted with Gulf Stream meanders and eddies several times, helping to sustain the water mass. While surface SSS and SST data provide one compelling view of shelf/slope interactions during this period, this study will integrate DOPPIO output which did not assimilate SMAP SSS data to further investigate associated Slope sea and coastal dynamics and freshwater transports associated with the event. Model results will also provide a larger context that includes assessment of key observational contributions including that from the satellite altimeter network in the study timeframe.

****

An Evaluation of Present-Day Sea Level Change in the Black Sea by Considering of Steric and Mass Components

Avsar N.[1], Kutoglu S.[1]
[1]Bulent Ecevit University, Zonguldak, Turkey

The Black Sea, located in southeastern of the Europe, is almost completely land-locked sea. Its only connection to the world's oceans is the narrow and shallow Bosphorus Strait. In this study, we present an analysis of present-day sea level change in the Black Sea using sea level time series from January 1993 to May 2017 by also considering the contribution of steric and mass components, separately. The result shows that during this period the Black Sea level has risen with a mean rate of 2.5 ± 0.5 mm/year. Besides, as steric data, global steric sea level (thermosteric, halosteric, and total) anomaly fields over 2005–2017 are used from the

National Oceanic and Atmospheric Administration (NOAA)'s National Centers for Environmental Information (NCEI). This data set contains 3-month sea level anomalies which are providing steric component of sea level change of the 0–700 m layer. For this study, mass contribution to the sea level change in the period of 2002–2017 has been also estimated from the Gravity Recovery And Climate Experiment (GRACE) mascon solutions within an observed increase by 2.3 ± 1.0 mm/year. In order to reveal of total steric and mass-induced contribution to the Black Sea level change, 3-month GRACE time series have been obtained from monthly solutions. Although different uncertainties and systematic errors of the sea level observations from altimetry, GRACE and in-situ; 3-month time evolution of sea level in the Black Sea shows that the observed sea level change and total of observed contributions almost exhibit similar fluctuations.

****

The Importance of Altimetry Data on Deciphering Brazil Current Core Velocities and Corresponding Volume Transport

Pita I.[1], Cirano M.[1], Mata M.[2], Lima M.[3]

[1]Federal University of Rio de Janeiro, Rio de Janeiro, Brazil, [2]Federal University of Rio Grande, Rio Grande, Brazil, [3]Preamar Gestão Costeira, Salvador, Brazil

Brazil Current (BC) is the Western Boundary Current (WBC) linked to the circulation of the South Atlantic subtropical gyre. The BC is considered the main dynamic feature of the South Atlantic Ocean. The analysis of WBC dynamics could be challenging for altimetry because the main flux could deviate from isobath-parallel flow toward coastal, and shallower, areas. Coastal areas provide a great source of error for altimetry products. The proximity with land generates problems related with correction of tides, high-frequency atmospheric signal and wet tropospheric components. Considering these aspects, the main objectives of this research was to compare the surface velocity fields of BC from deeper areas up to the 200 m isobath and the BC transport volume along the NOAA high-density AX97 XBT transect between Cabo Frio - RJ (42º W, 23º S) and Trindade Island (30º W, 20º S), based on altimetry and temperature data. In situ temperature data were collected by MOVAR (MOnitoring the upper ocean transport VARiability in the western South Atlantic) project during 43 oceanographic cruises between 2004 and 2013. Altimetry data consists of two different databases: Archiving, Validation, and Interpretation of Satellite Oceanographic (AVISO) provided by "Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise" / Developing Use of Altimetry for Climate Studies (SSALTO/DUACS); and Altimetry Tailored and Optimized for Brazilian Applications. AVISO (ATOBA) data are daily (weekly) and present a spatial resolution of 1/4º (1/12º).This study analyzed data from Jan/2004 to Dec/2013. MOVAR geostrophic velocity values were calculated based on temperature data using the σθ = 26.8 as the isopycnal reference level. The altimetry surface geostrophic velocities were obtained based on maps of absolute dynamic topography. A coupling between altimetry and in situ data was carried out by using the surface geostrophic velocities provided by AVISO and ATOBA, and using the thermal wind equation to obtain the subsurface velocity fields. The volume transport was inferred by the vertical integration of the velocity fields, from the surface to the σθ = 26.8 isopycnal depth, for the AX97 transect. The BC mean surface velocity is -0.18 ± 0.26, -0.21 ± 0.12 and -0.15 ± 0.17 m/s for the MOVAR, ATOBA and AVISO data, respectively. At 51% of the 43 cruises, BC surface core was observed at coastal areas (onshore of the AX97 domain) for at least one of altimetry products. The analysis of the BC flow indicates that along the AX97 transect, the mean volume transport is -2.66 ± 3.52 Sv for the MOVAR data, -6.28 ± 9.54 Sv for the AVISO data, and -5.16 ± 7.64 Sv for the ATOBA data. The values obtained by coupling altimetry and MOVAR datasets are supported by a series of previous researches. The use of altimetry data near the coast was crucial for a better understanding of BC core horizontal variability, and the extension of AX97 transect is an aspect that must be considered in order to achieve a better in situ temperature sampling. Coupling between altimetry and MOVAR data obtained a positive outcome.

****

Investigation of Relationship Between Lake Coastline Change and Climatic Factors Using Satellite Images: a Case Study Burdur Lake (Turkey)

Şener Ş.[1], Şener E.[1], Davraz A.[1]

[1]Isparta, Turkey

Burdur Lake, a tectonic lake NE-SW trending, is one of the deepest lakes of Turkey. The lake is closed basin and is recharged by rainfall, surface flows and underground flow. Discharging of the lake is only supplied with evaporation from the lake. It is also an important wetland site for many bird species and have experienced a severe decline in water levels in recent decades. This study aimed to investigate coastline and water level changes of the Burdur lake and identify the causes for decline in the lake levels. Nine satellite images from different times, precipitation, evaporation, discharge and lake level records were used to analyze the coastline changes of the lake. Each image was acquired in different dates: Landsat TM in 1975, 1987, 1996, 2000, 2002, 2009, 2014 and 2016 years and SPOT XS acquired in 1996. After the required geometric and atmospheric corrections of images were made, lake water body was extracted using supervised classification method. Finally, coastline changes of the lake were detected for analyzing changes in 1975–2016. From the results of the image analysis, the levels of the Burdur Lake dramatically and shrunk in area from 1975 to 2016. The lake area decreased from 210 km2 to 131 km2 between 1975 and 2016 years, the area shrinking was 37%. The results of hydrologic, climatic and human activities data analyses suggest that the change of lake levels might depend more on human effects than on climatic factors.

****

Coastline Change Assessment on the Shallow Lakes in Kızılırmak Delta (Turkey) Using Worldview-2 and Landsat Satellite Images Time Series

Şener E.[1], ŞENER Ş.[1], Güler M.[1]

[1]Isparta, Turkey

Kızılırmak Delta is located in the Black Sea Cost in Samsun Province of Turkey. The Delta was formed by alluviums carried by Kızılırmak River which is one of the largest rivers of the Turkey. The Kızılırmak Delta is one of the most important wetlands of our country in terms of biodiversity. A large part of the delta was designated with 1st, 2nd and 3rd degrees natural sites in 1994. Also, the property was designated as the Ramsar site because of variety of habitat, rich flora and fauna. A large part of the Kızılırmak Delta is a wetland area and there are many lakes in the delta. Balık, Uzun, Tatlı, Gıcı, Cernek and Liman lakes are located in the eastern part of the delta while the Karaboğaz and Mülk lakes are located in the western part. Changes have occurred in the surface areas of the lakes due to changes in rainfall regime and land use especially in recent years. This study aims to determine coastline change of the Kızılırmak Delta using Landsat TM in 1975, 1984, 1999 and Worldview-2 satellite image which is provided by European Space Imaging in 2017. For this aim, the relationship between spatiotemporal lake coastline change and precipitation - temperature have been determined. In addition, Standardized Precipitation Index (SPI) method was used to determine relation between meteorological drought and lake surface area changes.