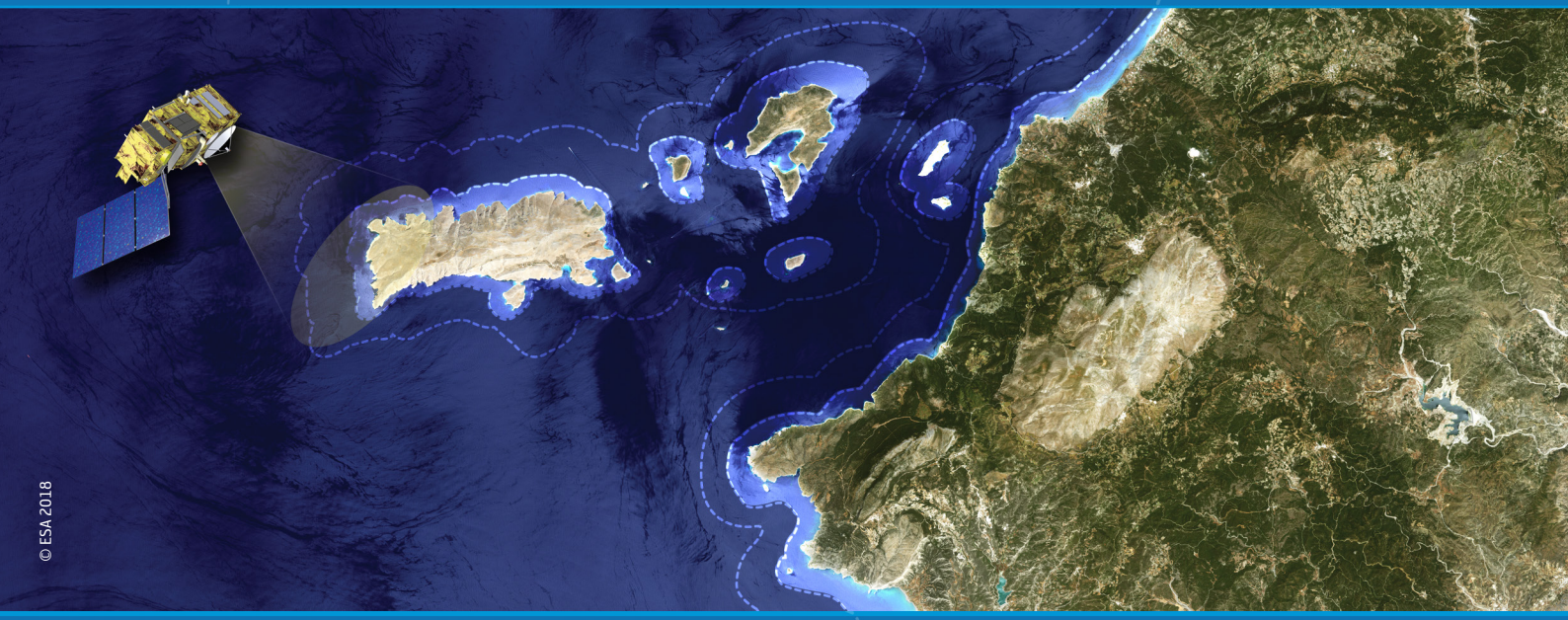
→ 11th COASTAL ALTIMETRY WORKSHOP



FINAL REPORT

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

11th COASTAL ALTIMETRY WORKSHOP (CAW11)

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CAW11 Final Report

written by

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Introduction

The 11th edition of the Coastal Altimetry Workshop was organized by the European Space Agency (ESA) with the support from seven institutions. The workshop brought together 88 scientists from 28 countries and included a Coastal Altimetry Training course for students and young researchers.

Key topics discussed at the workshop covered 5 themes:

1. Retracking
2. Corrections, Calibration & Products
3. Application of Coastal Altimetry Data
4. Sea Level, Currents & Data Assimilation
5. Synergistic and Climate Studies

This final report includes the highlights from each session, the main recommendations and the summaries of all the presented contributions.

All presentations given during the Workshop and the Coastal Altimetry Training course can be downloaded at www.coastalaltimetry.org

Highlights from Sessions

Session 1 - Thematic areas: Retracking & Corrections, Calibration and Products

- The evaluation of performance of altimetry missions over the coastal zone continues to be of cardinal importance.
- Beneficial effects from adaptive retracking on SWH and from the open-loop tracking mode (OLTC) in SAR mode.
- First results on FF-SAR (resolution pushed to 65 cm) have been reported, further research is required.
- Optimized coastal processing including Hamming window, Zero Padding, extended receiving window size and advanced retrackers (e.g. SAMOSA+) improves results for Sentinel-3.
- For LRM, the ALES retracker can be used with confidence as a global retracker: more data available in the coastal zone, better description of the 10-100-km scale of variability and better sea state bias correction applied at high-rate (-> decrease in crossover variance). A global 1-Hz ALES multi-mission dataset is now available at http://openadb.dgfi.tum.de/.
- A new version for the proximity to coast parameter was suggested to replace the one available in Sentinel-3 products.
- Coastal tide models including ALES data perform better. Improvements have no clear dependence on sea state.
- Bathymetry plays a key role on tidal dynamics especially in coastal waters and estuaries. Bathymetric improvements and tidal modelling at regional scales in the NE Atlantic Ocean and between the Philippines and Indonesia have been reported.
- Evaluating the accuracy of the different altimetry corrections when approaching the coast is of cardinal importance. Areas presenting different coastal dynamics shall be considered.
- Tropospheric Corrections (DTC & WTC) in current altimetry products (including Sentinel-3A) are inadequate. They shall be computed at 20-Hz (not just interpolated).
- The High Resolution Microwave Radiometer on Sentinel-6 is expected to provide valid wet tropospheric path delay correction closer to the coast.
- The Calibration of Sentinel-3A SAR SSH at Ajaccio and Senetosa has been presented. In the coastal zone, the SAMOSA+ retracker clearly performs better than the SAMOSA2 retracker adopted to produce official Sentinel-3 products.
- Sea State Bias model (based on Jason-2) is probably not well fitted for the SAR mode on Sentinel-3.
- A new generation of DUACS products is provided by CNES and CLS (L3: 5-Hz , L2: 20 Hz). They allow the full exploitation of the fine scale content in SAR mode and to better observe the small scales of ocean dynamics.

Session 2 - Thematic areas: Application of Coastal Altimetry Data & Sea Level, Currents and Data Assimilation

- Investigating altimeter and tide gauge sea level differences with CryoSat-2 and Sentinel-3A underlined once again the importance of using a processing tailored for coastal zone.
- The comparison of altimetry data and high-resolution (HR) wave model runs allowed to investigate the minimum distance to the coast to obtain acceptable SRAL measurements. By using bathymetry information, the minimum water depth of acceptable measurements can also be inferred.
- The benefit of using satellite-derived sea surface height to understand intra-seasonal oscillations (ISOs) has been demonstrated.
- New instruments (Ka band), processing techniques (SAR) and data editing approaches are needed to better resolve sub-mesoscale/mesoscale dynamics and to characterize small-scale processes (e.g. ocean geostrophic currents).
- Problem related to datum unification have been addressed in the production of the Philippine Geoid Model (PGM).
- The monitoring of the altimetric sea level signal in the Strait of Gibraltar allowed to study the flows through the Strait. A local MSS has been adopted to improve the analysis of the oceanographic processes in the area. The analysis of the along-track absolute dynamic topography showed a positive correlation with the zonal component of the wind.
- The monitoring of the dynamics can be improved by combining coastal altimetry data with in-situ and land-based remote sensing data.
- Coastal Altimetry activities on the ESA Coastal Thematic Exploitation Platform have been presented. It allows users to process data online using predefined processing options. To try out the platform contact coastal-tep@esa.int. Users' own algorithms can be uploaded and run near data...
- Sea level variability in North Australia has been evaluated through EOF-decomposition along with trends calculated through harmonic analysis. The need for advanced retracking strategies in the coastal zone has been underlined.
- Tide gauges located in regions where signals have relatively long length scales generally have a better agreement with altimetry observations and provide a more accurate assessment of the altimeter's performance. Therefore, dominant sea level signals at different tide gauge locations may have very different length scales. To improve the closure of the link between open ocean and coastal waters, ocean models data trends (e. g. NEMO outputs) can be used to investigate long length scales and correctly group the tide gauge locations for a more consistent analysis.
- In view of the future SWOT mission, the possibility to reconstruct sub-mesoscale surface currents from high-resolution sea surface heights (from observations or numerical model outputs) in the coastal zone and to generate SSH maps from High Frequency Radar-derived surface current maps has been investigated.
- Currents derived from satellite altimetry have been used to investigate the regional circulation in the Patagonian Continental Shelf. The choice of geophysical

corrections plays a cardinal role. In-situ Total Water Level appears to be well represented by altimetry and the circulation is highly dominated by the winds.

- The Coastal Water Research Synergy Framework (Co-ReSyF, accessible at http://co-resyf.eu/) is an online user-friendly platform, allowing users to exploit a set of tools and default applications to process Earth Observation (EO) data for monitoring coastal waters (several altimetry missions are available).
- The assimilation of HR altimeter data at 5-Hz in both the Low-Resolution IBI forecasting and in NEMO3.6 models confirmed that forecasts contain more mesoscale structures and that models are able to correctly propagate these structures. DA diagnostics improve when the correction of the DAC is omitted.
- The sea surface current in the Kuroshio path in Japan has been successfully investigated assimilating various altimetry datasets in the Northwest Pacific Model (part of the Regional Ocean Operational Forecasting System in NMEFC). Coastal altimetry data will be assimilated in the future.
- A comparison between GNSS sea/river surface heights and satellite altimetry in the coastal environment has been presented for the Bay of Bengal.
- The coastal sea level change near Hong Kong from ALES-retracked Jason-2 data has been presented evaluating the impact of geophysical corrections. Coastal sea level trend has been found about twice larger than in the open ocean: the short-term sea level trend significantly increases when approaching the coast.
- Last Developments and Perspectives of the X-TRACK Regional Altimeter Products were presented.
- A past study using CryoSat-2 data to detect ships has been enhanced including Sentinel-3 data. GPOD SARvatore 20-Hz & 80-Hz data were used to infer the possibility of estimating some geometric features and to resolve ambiguities among multiple targets.
- The inter-comparison of different altimetric datasets through spectral analysis in the coastal zone allowed studying the dynamics from sub-monthly to inter-annual timescales at the Bay of Biscay and in the New-Caledonia region. The issue of separating mesoscale and internal tides signals has also been addressed, in complement to in situ data, as a contribution to the preparation of the SWOT mission.
- The dependence of the radar cross section on the incidence angle can be used for the classification of different types of sea ice. Differences in monitoring the formation and destruction of ice cover for inland waters and the sea have been also investigated.
- Satellite altimetry and land-based High-Frequency (HF) radars can be combined to study the ocean circulation patterns in coastal areas & continental shelf and deep ocean interactions. The Gulf of Farallones off Central California has been considered for a pilot study.
- The Jason-Series Missions Applications Program has been presented. The objectives are to: 1) Identify current applications and develop new potential applications, 2) Demonstrate the benefit of ocean surface topography data to society and increase the use and utility of data products and 3) Engage broad user communities through the altimetry missions' life cycles.
- To address issues in U.S. coastal areas and ecosystems that are facing multiple sea level rise threats and effects, the NOAA National Ocean Service (NOS) evaluated new metrics from satellite altimetry (AVISO/Copernicus) and MODIS IR flood extents

to isolate nodes of atmospheric variability indicative of elevated sea level and nuisance flood events. This is expected to support both the integration of satellite products and models development.

- The passage of westward subtropical counter-current eddies into the Luzon Strait, and their transformations upon contact with the Kuroshio Current have been investigated. 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.

Session 3 - Thematic areas: Synergistic and Climate Studies

- An investigation of coastal currents along the Yucatan Peninsula with HF radar and satellite (OSTIA) sea surface temperature (SST) data revealed coastal currents that run alongshore and are constantly reversing at both short and seasonal time scales.
- The use of altimeter data for an assessment of century-based wind and wave climate data records in the coastal zone around Turkey was reported. A cross validation of the hindcast model wind speed against altimeter data was presented.
- Climate variability and trends of coastal currents off Atlantic Canada were reported within a study supported by the Canadian Space Agency's SWOT-C Project. The objective now is to explore the potential of coastal altimetry for assessing inter-annual and decadal-scale variability of the coastal currents.
- Results of a study on SW Atlantic currents from in situ and satellite altimetry were presented. In this site altimetry represents on average the subsurface currents very well. The agreement is lower when the Turbulence Kinetic Energy and eddy scales are weaker (i.e. the vertical temperature/salinity structure changes).
- Trends and variability in Coastal Sea State and Sea Level from the CCI+ Sea State Project were reported. The CCI+ Sea State Project has a strong heritage from the ESA GlobWave project. The priority is to develop long-term consistent climate-quality products. As ocean processing schemes so far have been optimized for retrieving sea surface height (from range), this project will support development of approaches optimized for SWH and sigma0 retrieval.
- The C-RISe (Coastal Risk Information Service) project aims to develop, deliver and evaluate a coastal risk information service around South Africa, Mozambique and Madagascar, an area with very sparse long-term in situ measurements. A series of 25 use cases, grouped in 5 themes, provide the basis for practical implementation and the monitoring and evaluation of the C-RISe service. The regional capacity development of the project has been underlined.
- Measurements of Normalized Radar Cross Section (NRCS) and slope variance over inland water bodies from the Dual Frequency (Ku and Ka) Precipitation Radar on the JAXA/NASA GPM mission were presented. The study derived the slope variance, correlated with mean square slope, from the decrease of RCS with increasing incidence angle. Classification of wave age is also possible.
- Results from a study into sea level variations due to ice sheet melting In Greenland were presented. An inversion 'fingerprint' technique which resolves simultaneously and consistently for mass changes over land and steric changes in the ocean has

been used. Greenland ice sheet melting has been shown to be the second largest contribution to global mean relative sea level rise.

- ESA SL_cci (Sea Level Climate Change Initiative) and SLBC_cci (Sea Level Budget Closure Climate Change Initiative) projects were described. In the SL_cci project, the key aspect is the homogenization of the various missions, reducing the systematic biases, and a better characterization of errors at global and regional scales. The SLBC_cci project aims to lead to a comprehensive assessment of the ocean budget, including a better understanding of the processes, identifying changes and accelerations of the individual components and identifying data gaps investigating the impact of missing data.
- Lag correlation and empirical orthogonal function (EOF) analyses were performed in different parts of the Philippine archipelago investigating on the responses of sea level anomalies to variabilities with intra-seasonal (MJO), seasonal (monsoons) and inter-annual (ENSO) timescales.
- The possibility to support coastal planning by studying the vulnerability related to long-term changes of sea level has been investigated. A study assessed to what extent Tuscany has to be considered vulnerable to sea level rise and which areas would be more impacted.
- Investigations of a slope water intrusion event in the gulf of Maine have been reported. While surface SSS and SST data provided one compelling view of shelf/slope interactions, the study integrated DOPPIO model outputs, which did not assimilate SMAP SSS data, to further investigate associated slope sea and coastal dynamics and freshwater transports associated with the event.
- An analysis of the sea level change in the Black Sea using sea level time series from January 1993 to May 2017 shows that level has risen with a mean rate of 2.5 ± 0.5 mm/year (in very good agreement with the 2.3 ± 1.0 mm/year estimated from GRACE mascons solutions in the period of 2002–2017).
- The surface velocity fields of the Brazil Current (BC) in deeper areas up to the 200 m isobath have been positively compared to the BC transport volume along the NOAA high-density AX97 XBT transect between Cabo Frio and Trindade Island considering altimetry (AVISO/ATOBA) and temperature data from the MOVAR project.
- Coastline changes and water level of Burdur lake and Kızılırmak Delta (Turkey) have been investigated using Landsat TM data. For the Burdur lake, 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. For the Kızılırmak Delta, a Standardized Precipitation Index (SPI) method was used to determine the relation between meteorological drought and lake surface area changes.

Recommendations from the Workshop

From the plenary discussion the main recommendations from the workshop are:

- The need to have an SSB correction at 20Hz and a specific SSB for each retracker has been pointed out. The SSB could be split into a retracker correction (surely to be applied at 20Hz) and geophysical one that is smoother.
- We need internal wave corrections. High-resolution data must be distributed with all corrections (like in RADS).
- A specific processing for Sentinel-3 and Cryosat-2 data in the coastal zone has been recommended by many contributions.
- Additional investigations on FF-SAR capabilities in coastal zone and inland water are recommended.
- On climate scales we need to look at Sea Level and Sea State at the coast: a cross-ECV activity has been recommended.
- In regional or local studies, the adoption of a global MSS to investigate the SLA might hide some of the sea level variability compromising the oceanographic interpretation. The exploitation of dedicated HR coastal altimetry reprocessed data to generate a local MSS has been recommended as it gives a more realistic indication of the oceanographic processes in the area.
- There are significant challenges to improve ocean current estimations. Some contributions reported promising progress but there are still issues of interpretation. A discussion took place on whether currents should be estimated from altimetry data or rather just assimilate the heights in models that will then provide the currents. Studies to answer this question are recommended.
- A few contributions exploited current altimetry missions to perform analyses in view of the SWOT mission. More studies in this sense are recommended as well as initiatives to allow the coastal altimetry community to support SWOT.
- More investigations on the real spatial and temporal resolution that satellites can achieve are recommended.
- Considering conclusions from some of the contributions, future studies should continue investigating how closely the variability at the coast reflects the one offshore. This will impact the requirements of ESA CCI projects. The coastal challenge for sea state and winds is potentially greater, due to variability on very short time and space scales, and to the impact of local topography/bathymetry. However, altimetry is more likely to provide more reliable consistent long-term time series than in situ measurements, as buoys drift/change.

- A global value of the sea level trend at the coast is probably not scientifically meaningful. Regional sea level trends could have greater scientific and practical value.

- The development of a global sea level product recognized by the community that will enable all regional studies has been recommended.

- It is recommended to benchmark the Tide Gauges with GPS for comparisons.

- Coastal Altimetry should be part of the recipe to provide a local sea level/sea state assessment for coastal planners.

- It is recommended that sea state includes the mean square slope (mss) in the future. This is the roughness parameter that governs exchanges and is particularly relevant in the coastal zone as CO_2 uptake is still a big unknown there.

- More in-situ data in the zone 0-3 km from the coast are needed for validation.

- For investigations on long-term changes in coastal currents, it is recommended to integrate altimetry data along with other observing techniques as the assumption of geostrophy will not hold for most coastal currents.

Recommendations to ESA for changing the CryoSat-2 geographical mode mask are welcome: how can we exploit CryoSat-2 SARin data to support Sentinel-3 investigations in the Coastal Zone?

The CAW Community recommends to all Space Agencies, the European Commission and the National Funding Agencies:

1. to investigate how to fund non-French and non-US-based research teams in the next SWOT (2019) and OSTST (2020) Science calls.

2. to support contributions to the joint exploitation of the CEOS Ocean Surface Topography Constellation, in order to induce and facilitate the preparation of the SWOT data uptake, in conjunction with the already flying altimeters.

Summaries from the Individual Sessions

Opening Session

Overview of Coastal Altimetry Workshop achievements

P. Cipollini

The Coastal Altimetry Community has achieved a lot and the CAWs have been (and continue to be) an effective way to grow and exchange ideas. However, a significant number of challenges remain. To overcome them, future investigations should focus on:

- The contribution to coastal observing systems (for dynamics/level/sea state/extreme events) via a step-up of data assimilation in models.
- The exploitation of long time series of coastal altimetry data for coastal sea level and sea state climate.

Session 1A – Technical issues – Retracking

CHAIRS: Marcello Passaro & Marco Restano

Compared performances of current altimetry missions over coastal areas

P. Thibaut, M. Raynal, M. Ablain, F. Boy, N. Picot, T. Guinle, P. Femenias

The evaluation of performance of altimetry missions over the coastal zone continues to be of cardinal importance. The contribution started by defining the coastal zone: 5-10 km range, of particular interest when L1 & L2 processing baselines are considered. The aim is to maintain as close as possible the deep ocean performances. Beyond 5/10 km, coastal altimetry users can benefit from recent deep ocean processing improvements (SAMOSA,LR-RMC…) and better radiometry and geophysical corrections.

LRM/PLRM suffer from coastal artefacts. SAR can be much better depending on the angle of approach. The percentage of valid points and the SLA, SWH & sigma0 noise levels were presented for Jason-3, AltiKa and Sentinel-3A as a function of both the distance to the coast and the angle of approach. The analyses confirmed: 1) better performances in LRM Ka than LRM Ku (larger Bandwidth, higher PRF, …), 2) better performances in SAR Ku than in LRM Ku and 3) better performances in LRM Ka than in SAR Ku. Higher SAR Ku noise very close to the coast (<2km) due to high dispersion between consecutive measurements. However, S3 SSHA oscillates less in approaching the coast than Jason-3 and AltiKa. The beneficial effects of adaptive retracking on SWH were also reported, as those coming from the open-loop tracking mode (OLTC) in SAR mode.

AltiKa will be reprocessed (GDR-E). Other expected improvement will come from higher frequency radiometers. Results of FF-SAR in coastal zone, pushing resolution to 65 cm (which still require further research) have been reported.

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

S. Dinardo, L. Fenoglio, C. Buchhaupt, R. Scharroo, M.J. Fernandes, M. Becker, J. Benveniste

Two years of coastal SAR and PLRM in NE Atlantic from Sentinel--3A and CryoSat-2 data processed in GPOD with an optimized coastal processing profile (Hamming window, zero padding and extended receiving window size) have been presented. Same corrections applied to the two datasets (TPX08 tides, GIM, SSB 4.7% of SWH, GPD+…). SAM+ retracker has been presented. Due to the position of nominal tracking point (leading edge), CryoSat-2 has more Doppler beams than the Sentinel-3A, but the open loop tracking (OLTC) in Sentinel-3 has a beneficial impact and is to prefer. SAR GPOD does a better job, closer to coast, than official S3 SAR Marine products.

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

M . Passaro, W.H.F. Smith, C. Schwatke, G. Piccioni, D. Dettmering

A comparison between publicly available multi-mission global datasets was presented. ALES can be used with confidence as a global ocean retracker. A new ALES SSB with sea state and wind, which is applied at 20 Hz, has been developed. Crossover analyses over the open ocean (not just coastal) show that ALES does better than the SGDR in 74% (for Jason-1) and 85% (for Jason-2) of locations with a 30% reduction in variance. The statistics are favourable showing: 1) a reduction in standard deviation both in the 3-20km interval and in the global ocean and 2) less outliers.

The improvement is a mix of better retracking (-> much more data available in the coastal zone, better description of the 10-100-km scale of variability) and better sea state bias correction applied at high-rate (-> decrease in crossover variance: will be detailed at the next OSTST by analyses underway). Compared to the current GDR products, the ALES dataset has: 1) A better representation of the spatial scales up to 10 km, 2) an improved precision, 3) a 30% Variance reduction,4) more data availability in the coastal zone.

A global 1-Hz ALES multi-mission dataset is now available at http://openadb.dgfi.tum.de/ via direct download. 20-Hz data on request.

In the future: 1) ALES will be extended to SAR altimetry, 2) a New ALES Sea State Bias MODEL for ALES will be presented and 3) ALES will be regionally combined with X-Track Post-Processing from CTOH in the context of ESA‘s Sea Level Climate Change Initiative.

Assessing Sentinel-3 Wave Height Records in the Coastal Zone

F. Nencioli, G. Quartly, D. Conley

The selected area of study is SW England: complex coastal morphology allowing the study for different angles of approach. Authors aimed at assessing: 1) the Improved accuracy near the coast offered by SAR mode, 2) the ability to resolve small scale dynamics (below large mesoscale ~O(100 km)). 12 Sentinel-3A tracks considered (baseline including the SAMOSA2 retracker).

Authors redefined a new version for the *proximity to coast* parameter, based on the ETOPO1 bathymetry (the same field in Sentinel-3A data is based on a not reliable coarse coastal outline). Data from two monitoring programmes – the Coastal Channel Observatory (Time-series of SWH, direction and period) and the Western Channel Observatory (Time-series of SWH and direction) have been used. With 17 buoys available, the presentation focused on the 4 representing different morphological conditions: open sea, coastal and enclosed, coastal and sheltered, coastal and enclosed. The in situ observations were found to be consistent with the WAVEWATCH III model. Authors developed a completely automated analysis (track selection, etc.). The results in terms of correlation are good for the open location, both for SAR mode and PLRM, but the matchup is much worse for the coastal-sheltered location.

Authors divided results into 'good buoys" and "bad buoys" based on correlation. The discussion highlighted that it would be beneficial to categorize the buoys for the Sea State CCI. In conclusion Sentinel-3A SAR observations of SWH show: 1) accurate values close to shore, 2) accurate trends towards the coast and better performances than PLRM, but not everywhere and every time. Future work will include HF radar data (waves & current).

Coastal Improvements for Tide Models: the Impact of ALES Retracker

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

Coastal tide models including ALES data to investigate issues in tide models at coastal level were presented. Tides are a large source of errors in coastal altimetry.

The Empirical Ocean Tide Model (EOT) has been updated with ALES data over 14 years of Jason-1 and Jason-2 missions. Solution for 8 constituents were compared to SGDR. The TG datasets for comparison is the Global Extreme Sea Level Analysis (GESLA) dataset: TGs assimilated in FES2014 and those near estuaries were discarded.

Results show an improvement both in terms of a greater number of observation and uncertainty, especially close to the coast, and RMS differences with TGs. Results highlight a dependence of track verse (ocean to land vs land to ocean). The average improvement is of 0.4 cm with a maximum of 1.9 cm (highest values when close to the coast) The improvements of the ALES tidal solution have no clear dependence on Sea State. A long-term goal of this work is the development of a new global EOT model.
It was suggested that this approach should also be used to look at the 18.61-year nodal cycle.

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

M. Cancet, F. Toublanc, F. Lyard, G. Dibarboure, T. Guinle

Authors presented bathymetric improvements and tidal modelling at regional scales in two areas, the NE Atlantic ocean and between the Philippines and Indonesia. The presentation highlighted that bathymetry plays a key role on tidal dynamics especially in coastal waters and estuaries. Unrealistic structures in the bathymetry cause wrong tides. Noveltis is integrating bathymetry with new high-resolution DEMs and bathymetric survey data before modelling via T-UGOm in a regional configuration (increased resolution compatible with a global model). The following results have been obtained: 1) Regional tidal modelling allows

to reach higher resolutions than global modelling 2) Comparison to Tidal gauges tidal harmonics: significant reduction of the mean complex error, 3) Comparison to Satellite altimetry tidal harmonics: error reduced on the diurnal tides, increased on the semi-diurnal tides. The comparison with Altimetry harmonics is affected by very bad points in a few location – so there is the need to look at specific areas in future investigations.

Session 1B: Technical Issues in Coastal Altimetry - Corrections, Calibration & Products

CHAIRS: Kaoru Ichikawa & Graham Quartly

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

F. Birol, F. Niño, F. Léger, F. Blarel

The objective of this talk is to evaluate the accuracy of the different altimetry corrections when approaching the coast and the impact of their errors. Some corrections are more difficult to compute in the coastal areas and may lead to stronger SSH errors. Authors analysed ~300 cycles (8 years) of Jason-2 data acquired in a low tide region in the NW Mediterranean Sea. Corrections analysed: 1) wet tropospheric correction: radiometer, model and GPD+, 2) SSB (only the correction provided in GDR-D) and 3) Ionospheric correction: dual frequency, GIM. The standard deviation of corrections has been used as a proxy for the evaluation of the error. The study reached the following conclusions: 1) GPD+ seems to be a good solution for coastal applications, 2) The SSB induces significant errors but locally (local errors may lead to larger coastal sea level variations: significant impact on coastal current computation), 3) GIM seems to be a good solution for coastal applications in the absence of a good data editing strategy. The tidal correction has not been assessed in this microtidal area but could be very important in other regions, for this reason the study will be extended to other sites with different costal dynamics. The error contribution of the dry tropospheric correction is usually low, but in certain regions can have surprising behaviour (if it is derived from land surface pressure instead of sea level atmospheric pressure).

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

J. Fernandes, N. Pires, T. Vieira, E. Vieira, C. Lázaro

The presented study aims at assessing the impact of having corrections at high frequency (20-Hz) in satellite altimetry L2 products and focuses on tropospheric (dry, wet) corrections analysed in both coastal region and inland water domain. ENVISAT, CryoSat-2 and Sentinel-3A products have been considered.

The best available DTC models are: ECMWF Operational (6h intervals, 0.125°x0.125° (16kmx16km) – best after 2004), ERA Interim (6h intervals, 0.75°x0.75° (80kmx80km) – best for missions with data before 2004), ERA5 (1h intervals, 0.3°x0.3° (30kmx30km)). In most past and current products (including Sentinel-3A) the DTC is provided at 1-Hz. In Envisat v3.0 products, soon to be released, there are two DTCs at 1-Hz (ECMWF Op. & ERA Interim) and one DTC at 20-Hz (ERA Interim).The DTC analysis evidenced in the coastal zone that: 1) due to the strong height dependence of the DTC, over the open and coastal ocean, it should be given at sea level, 2) Considering the small space-time variability of the correction, 1Hz DTC provide enough detail/accuracy. The inland water

analysis concluded that: 1) Due to its strong height dependence, the DTC needs to be computed (not just interpolated) at 20Hz and computation should be from sea level pressure (SLP), further reduced to surface height, 2) For global products, best reference seems to be an accurate DEM such as ACE2; for local studies, best reference surface is mean river profile or mean lake level.

Regarding WTCs: in the open ocean they are better determined by using the co-located MWR. In coastal areas various approaches have been developed (LDA, MPA & GPD+). Over inland waters, model-derived corrections may be the best approach, particularly over rivers. The WTC analysis evidenced in the coastal zone that: 1) Considering footprints of present MWR, 1Hz rate is adequate (MWR-derived WTC always refer to sea level). For future high-frequency MWRs, high-rate WTC are advisable. 2) Over the open and coastal ocean, WTC from models should be given at sea level. Considering the spatial resolution of current models, 1Hz is adequate. The inland water analysis concluded that: 1) Due to the WTC height dependence (though smaller than for the DTC), it should be computed (not just interpolated) at 20Hz, 2) When computed from model single layer fields, it should be further reduced to surface height, 3) For global products, the best reference surface seems to be an accurate DEM such as ACE2; for local studies, best reference surface is mean river profile or mean lake level.

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

S. Brown, A. Tanner, S. Padmanabhan, I. Ramos, P.Kangaslahti

Low-frequency radiometer systems are not able to provide valid wet tropospheric path delay correction close to the coast or over land. High-frequency radiometers offer the potential to fill this measurement gap and improve altimetric observations in the coastal and inland regions. Airborne data indicate higher variability near land (60% increase in variance) and certain areas (e.g. presenting off-shore winds) are expected to introduce systematic errors (diurnal, seasonal). Sentinel-6 AMR-C will include two new design features based on OSTST recommendations: 1) An external calibration system for long term stability, 2) A High Resolution Microwave Radiometer for coastal path delay (PD). It will operate in 3-frequencies at 90, 130 and 166 GHz (Co-located footprints with a spatial resolution of 2-5km). At 90 GHz, the brightness temperature (TB) is roughly 8 time more sensitive to Cloud Liquid Water (CLW) than the 23.8 GHz brightness temperature.

Channels between 90-160 GHz are sensitive to water vapour continuum and are also more sensitive to cloud liquid water and the water vapour scale height. A hybrid concept has been developed to use high-frequency channels near land with a dynamically trained retrieval algorithm (referenced to AMR low frequency channels). Standard low-frequency channels (18-34 GHz) are used for PD retrieval in open ocean (> 30 km from land). High-frequency window channels (90, 130 and 166 GHz) are used to continue PD measurements to ~3km from land.

Authors simulated coastal crossing for the AMR-HF concept to assess performance. They generated random profiles of path delay and cloud liquid water content as a function of the distance to coast. Simulations show PD retrieval error < 7mm to within 3 km from coast in a global average sense.

Moreover, the considered real data to test the algorithm. The Global Precipitation Measurement Microwave Imager (GMI) has 18.7-37 GHz channels and also a high resolution 90 GHz channel. GMI data that have bene used to evaluate the algorithm performance in real atmospheres. The path delay has been computed from GMI low-frequency (18-37 GHz) channels whereas the High-frequency (HF) coastal extrapolation algorithm has been applied to the 90 GHz channel. They computed statistics for a large number of realizations, encompassing various atmospheric conditions. In conclusion, assuming a low-frequency radiometer that is contaminated at 50km from the coast, the HF algorithm reduces the excess extrapolation error from 10mm to 4mm. In another investigation, data from the HAMMR Airborne Radiometer have been used confirming the reduction of the error (PD error <0.8 cm).

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

P. Bonnefond, O. Laurain, T. Guinle, N. Picot, P. Féménias

The Calibration of Sentinel-3A SAR SSH at Ajaccio and Senetosa has been presented. From Processing baseline (PB) 2.15 to PB 2.27: SARM SSH bias decreased by 37 mm, PLRM SSH bias decreased by 23 mm and the standard deviation improved by 6 mm for SARM and12 mm for PLRM. Investigation of the SSH bias dependency suggests that SSB model (based on Jason-2) is probably not well fitted for Sentinel-3.

CryoSat-2 data processed by the ESA GPOD SARvatore for CryoSat-2 service by using two retrackers (SAMOSA2 and SAMOSA+) have been also considered. SAMOSA2 is the retracker adopted in the Sentinel-3 PB 2.27 whereas SAMOSA+ is only available in GPOD. Applied on CryoSat-2 data, SAMOSA+ improves that retrieval in approaching the coast (at less than 500 m in across-track). The standard deviation of the SSH bias time series, for SAMOSA+, is clearly improved at Ajaccio (26 mm vs. 33 mm). For SAMOSA+, CryoSat-2 averaged SSH bias is -746 ± 5 mm (range is measuring too long). This looks coherent with updated Svalbard transponder result: 722 ± 6 mm.

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

Y. Faugere, M-I. Pujol, M. Ablain, C. Ubelmann, C. Dufau, N. Picot, G. Dibarboure

A new generation of DUACS products is provided by CNES and CLS. They allow: 1) the full exploitation of both global S3A and S3B data and the fine-scale content of SAR mode, 2) to optimize the use of the current LRM altimetric missions, 3) to prepare the synergistical use of current missions with the future SWOT mission and 4) to better observe the small-scales of ocean dynamics, particularly located over continental shelves and coastal areas. Altimetric missions considered are Jason-2/3, Sentinel-3A, SARAL/AltiKA and CryoSat-2. Applied to all the LRM missions is a correction for noise measurement reduction (Zaron et al., 2016). This strongly reduces the white noise (-40%). A new processing chain has been developed providing products at 20Hz (L2) and 5Hz (L3). Data are edited and selected following both a threshold criteria on SLA and SWH and an iterative analysis of signal variability. Improvements are the following: 1) Globally more edited measurements vs. 1Hz CMEMS products, especially in coastal areas (less points), 2) Reduction of the number of invalid points in high SWH areas (thanks to the noise reduction), 3) SLA variance reduction at mesoscales (30-200km) in the wet troposphere areas. For Sentinel-3: more measurement available in the 5Hz products over high latitudes areas and in coastal areas.

For AltiKA and Jason-3: Less measurements available in the 5Hz products in coastal areas. In terms of L3 product physical content, the SLA is provided with additional geophysical fields (inherited from TAPAS): DAC, tides, LWE, internal waves corrections, low frequency (>20 days) of inverse barometer, mean dynamic topography (MDT), geostrophic velocities derived from SLA and MDT. Products can be accessed on demand onto ftp-access.aviso.altimetry.fr after the creation of a free Aviso+ account here: https://www.aviso.altimetry.fr/en/data/data-access/registration-form.html. Next steps in 2018: improve editing, get users feedback. Product currently available in NRT. They are targeting operational NRT production in 2020 over Europe in CMEMS.

Session 1– Discussion

- How do we use the high resolution? It should be used statistically. The need to have an SSB correction at 20Hz and a specific SSB for each retracker has been pointed out. The SSB could be split into a retracker correction (surely to be applied at 20Hz) and geophysical one that is smoother.
- We need internal wave corrections. High-resolution data must be distributed with all corrections (like in RADS)
- A coastal solution for S-3 is recommended.

On climate scales we need to look at Sea Level and Sea State at the coast – perhaps a cross-ECV activity for the future.

Session 1 - Posters

Contribution of Waveform Decontamination for Improving Coastal Altimetric Sea Surface Heights

H. Wang, Y. Chu, C.K. Shum

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 demonstrated that removing or modifying anomalous peaks in waveforms is helpful for further improving the coastal SSH data. In this study, authors proposed several strategies for detecting and remedying anomalous samples in waveforms. These strategies are applied to process coastal altimeter data from multiple satellite missions. Contributions of each waveform decontaminating method have been assessed by comparing retracked SSHs from decontaminated and original waveforms using various retrackers. Finally, obtained results are compared to updated datasets for coastal altimetry, such as, PISTACH, PEACHI, ALES.

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

J. Lumban-Gaol, S. Vignudelli, R. Leben, D. Adrian, O. Takahiro, I. Nurjaya, B.P. Pasaribu

In this study, authors 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 Records (SGDR). They analysed the percentage of valid coastal altimetry XTRACK 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. In general, the percentage of valid data in steeper waters is higher than in sloping waters. The waveform types formed in coastal waters are peaky and respect the Brown model. 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

M. Cancet, O. Andersen, D. Cotton, J. Benveniste

The CryoSat Plus for Oceans (CP4O) project, under the ESA STSE programme, aims to develop and evaluate new ocean products from CryoSat-2 data. The Arctic Ocean is a challenging region, because of its complex and not well-documented bathymetry. 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.

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

D. Cotton, T. Moreau, M. Raynal, E. Makhoul, M. Cancet, L. Fenoglio-Marc, M. Naeije, M.J. Fernandes, C. Lazaro, A. Shaw, M. Restano, A. Ambrosio, J. Benveniste

SCOOP (SAR Altimetry Coastal & Open Ocean Performance) is a project funded under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme Element. It 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 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.

Results from the SCOOP project demonstrate the excellent performance of SRAL in terms of measurement precision. Authors illustrated the development and testing of new processing approaches designed specifically to improve performance close to the coast. 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

J. Hausman, I. Fenty, J. Nilsson, K. Madsen, P. Knudsen

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. 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 have been compared against tide gauge data. 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 have been 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 has also been quantified reporting clear issues.

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

K. Ichikawa, X. Wang

A coastal retracking method using along-track waveform echograms has been tested in seas of Indonesia where a complicated topography with several islands prevents the full use of satellite altimeter data. In other seas, the method has successfully eliminated unexpected strong reflections from calm water surfaces in semi-closed bays within the footprint of the altimeter.

In the seas of Indonesia the method does not appear to be applicable: large areas of high microwave reflectors, or slicks, are intermittently but frequently present in the sea even away from the coasts. These are not accounted in the method. To solve, authors modified the method to include an additional process to detect presence of slicks as extraordinary strong reflections in the echograms. This allowed to estimate the sea surface height in the seas of Indonesia.

Session 2A: Application of Coastal Altimetry Data

CHAIRS: Jesús Gómez-Enri & Salvatore Dinardo

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

L. Fenoglio, S. Dinardo, C. Buchhaupt, B. Uebbing, R. Scharroo, M.J. Fernandes, J. Kusche, M. Becker, J. Benveniste

Authors considered altimeter (LRM & SAR) and TG data studying time series of differences. This allowed to infer: 1) the different change in sea level at the two locations, 2) the Vertical Land Motion (VLM) and 3) the instrumental drifts (in-situ or/and in space). Both SLCCI ECV gridded data and CryoSat-2 and Sentinel-3 data processed in different operative modes (SAR/RDSAR) and through different retrackers (SAMOSA2 & SAMOSA+ for SAR and TALES & STAR for RDSAR) have been considered in the analysis. Both ESA SAR GPOD data and official S3 Marine data have been considered. GPD+ WTC corrections have been applied. The methodologies included a monthly analysis of RDSAR data (correlation, stdd, investigation of monthly trends). For the analysis of along-track SAR data, in addition to correlation and stdd, trends of instantaneous differences have been calculated. RDSAR and SAR Data were corrected for the ocean tide but not corrected for DAC. The regions under investigations are the German Bight and Baltic Sea. The VLM has been evaluated < 3 mm/yr for LRM data (SLCCI monthly data) from the difference between altimetry and TG data. The difference between VLM and GPS rate has also been evaluated. For a few locations, the VLM rates are different from GPS rates by less than 1 mm/yr, in all other locations the VLM rate error is larger if compared to GPS. Also the noise of altimetry data in approaching the coast has been investigated and SAR and RDSAR data compared. Sentinel-3 GPOD data (processed ad-hoc for coastal applications including Hamming, Zero Padding and the SAMOSA+ retracker) present a larger number of valid data points in approaching the coast and a better stability of the SSH bias (std<2cm) when compared to Official S3 Marine data (no Hamming, no Zero Padding and SAMOSA2 retracker). Authors found comparable the quality of coastal GPOD Sentinel-3 and CryoSat-2 data. The SAR mode performs better than PLRM and the new limit for the usability of SAR altimetry data has been found to be 2-3 km from the coast. The absolute bias and relative bias between Sentinel-3 and CryoSat-2 (in all data flavours) are around 3cm. In the future, longer time series (TG and Altimetry) should be used to provide reliable estimations of the VLM.

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

S. Abdalla, J-R. Bidlot

Authors answered the question: How valid Sentinel-3A SAR significant wave height data are close to the coast near Mekong Delta? Sentinel-3 SRAL Ku-band 20 Hz significant wave height data measured along relative orbit number 360 during Cycles 016, 017 and 018 were examined (April-June 2017, all acquired around 3:00 UTC). A high resolution wave model (WAM) run was conducted for each pass over the area. The model grid was selected as irregular 0.05° in both directions (corresponds to about 5.5 km). The model was forced using ECMWF operational wind data. No reliable ground data were available.

SRAL 20-Hz SWH measurements show relatively large variability (which reduces considerably for the 1-Hz measurements). As the variability is higher than normal during Cycle 16, data from this cycle have been excluded. However, there is a considerable correlation between the model (not perfect near the coast) and the measurements and the running standard deviation seems to be a good indicator of the validity of SRAL measurements. The difference between SRAL and model SWH can be used as a criterion for the validity of SRAL measurements. Also the standard deviation (SD) of SRAL Ku-band 20 Hz SWH measurements can be used as a criterion to reflect the accuracy of the product and therefore its validity. Considering both criteria, the minimum distance to the coast of acceptable SRAL 20 Hz measurements is about 8-9 km. In any case, the measurements should be fine when the distance to the coast is at least 10-13 km. The standard deviation of 20-Hz SWH measurements as a function of the water depth (according to the wave model bathymetry) has been also investigated. With a small tolerance towards few imperfections in measurements, the minimum water depth of acceptable SRAL 20 Hz measurements is about 14 m. In any case the measurements should be fine when the water depth is at least 23 m. There is a need to cover other areas and more cycles to get general conclusions.

Detection of Intraseasonal Oscillations in the Indian Ocean from Satellite Altimetry

S. Bulusu, C. Trott, V.S.N. Murty

Authors demonstrated the benefit of using satellite-derived sea surface height (SSH, coastal altimetry data) to understand intra-seasonal oscillations (ISOs) in the Indian Ocean. It is a big challenge for coupled Atmospheric-Ocean models to generate these ISOs. This work evaluated band-pass filtered analysis of altimetric observations for the study of ISOs ranging over a variety of periods.

The Indian Ocean is observed to respond to 3 types of monsoonal intraseasonal oscillations: those with periods of 30-90 days (due to Madden Julian Oscillations), 10-20 days (quasi-biweekly signal), and 3-7 days (synoptic-scale events as a reaction to changes in the monsoon trough). Oscillations: 1) are critical driver of the upper-ocean response to active and break rainfall phases, 2) impacts all mixed layer parameters, 3) contribute to the ocean-atmosphere feedback loop: downwelling phase of MJO-related
equatorial Rossby waves correspond to strengthened outgoing longwave radiation (OLR) anomalies.

The SSH can quantify and track: Kelvin & Rossby waves, Eddying Upwelling & Downwelling. Moreover, it allows a clear spatial and temporal understanding of how surface waters are redistributed as a response to atmospheric events. A Wavelet Analysis of SSH evidenced: the Highest SSHA in the SW monsoon (lowest in the NE monsoon), a strong 180-day period due to semi-annual Rossby waves and very small amplitudes in 10-20 day and 3-7 day signals. Interesting meridional distribution of ISOs were found: 1) primarily strongest in the southern Bay of Bengala (BoB) for all periods, corresponding with Rossby waves, 2) 30-90 day signal also found in northern BoB, 3) 10-20 day ISOs generally constrained to southern BoB 4) 3-7 day ISOs were very low-amplitude and showed the noisiest spatial and temporal distribution.

Session 2A: Application of Coastal Altimetry Data (cont'd)

CHAIRS: Luciana Fenoglio & Stefano Vignudelli

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

M. Meloni, A. Doglioli, A. Petrenko, J. Bouffard, G. Valladeau

Satellite altimetry enabled the global characterization of open-ocean large scale and mesoscale processes. The main challenge now is the characterization of fine scale processes in the coastal domain: characterizing mesoscale/sub-mesoscale processes is particularly critical over the coastal domain where the local Rossby Radius is smaller than in the open-ocean. Authors pointed out the need of innovating altimetric instruments (Ka Band) and processing techniques (SAR) introducing ad-hoc validation approaches (multi-disciplinary in situ data acquired by marine observatories and oceanographic campaigns).

They propose to exploit these in-situ data resources to quantify the potential benefit of innovative coastal altimetry processing techniques for the characterization of small-scale ocean geostrophic currents. The area under investigation is the NW Mediterranean Sea.

PEACHI SARAL AltiKa (40Hz) and Jason-2 (20Hz) data retracked in several ways (MLE, Adaptive and Red3) have been edited and filtered to be compared with AVISO 1Hz SLA data. As the absolute dynamic topography (ADT) is given by ADT = SLA + MDT, the accurate knowledge of the mean dynamic topography (MDT) is crucial for a number of oceanographic applications. Authors adopted the last two MTDs prepared by M.-H. Rio. The 2015 OSCAHR campaign, exploring the link between fine-scale physics and phytoplankton diversity in the NW Mediterranean Sea, provided in-situ data. Geostrophic currents derived from altimetry were therefore compared to those from the Moving Vessel Profiler (MVP, sampling along AltiKa and Jason-2 altimetry tracks) and Acoustic Doppler Current Profiler (ADCP) used in the OSCAHR campaign. The agreement between altimetry and MVP is generally satisfying when considering the deepest reference level (i.e. 360 m). However, MVP should be considered in synergy with ADCP. The new MDT shows better results and the adaptive Retracking and editing show better performances in coastal areas (with AltiKa better than Jason-2). Altimetric data from AVISO are not always reliable close to the coast. In conclusion, new experimental post processing and editing approaches of the altimetric signal are needed to better resolve the sub-mesoscale/mesoscale dynamics. Authors also presented an assessment of altimetry derived currents w.r.t. JULIO (Judicious Location for Intrusion Observation) currents, for the full period of observations from JULIO.

Satellite Altimetry and Tide Gauge Data in Local Vertical Datum Unification

R. Reyes, R. Forsberg

The National Mapping and Resource Information Authority (NAMRIA) is now initiating the migration from local datum to a geocentric datum. The Philippine Geoid Model (PGM) (Forsberg et al., 2014) has been developed in line with this initiative. The main problem is that present topographic heights are referred from disparate mean sea levels (MSL) from

Tide Gauges (TGs) all over the country. As the country is located in a tectonically active area the stability of these TGs are also in question. Moreover, land subsidence also occurs in some areas (e.g. Manila).

The Philippine Geoid Model is computed in a global vertical reference system then fitted to the ITRF GNSS/Levelling and validated with RMS value of 0.50m. It is shifted to +.80 cm to Manila MSL to fit to the local vertical datum defined by MSL. Validation with GNSS-leveling derived geoid heights gave a STD of 30 cm. Some Tide Stations are located near faults and may possibly affect the measured sea level. These were analyzed and filtered. Considering the Seismic history, a single TG was found in a more stable place.

Further validation by using one year of Jason-2 satellite altimetry (SA) products collected over the Philippines evidenced a difference of 0.127 m (Mean SSH from SA - Mean Sea Level from TG) which is close to allowed difference of 12 cm (CLS, 2014). In a final investigation in Manila Bay, CryoSat-2 and Jason-1 data (retracked with ALES) were validated against TGs, showing differences of 21 cm and 15 cm from CryoSat-2 (6 years of data) and Jason-1 (4 years of data), respectively. If the allowable 12 cm difference is considered, then around 9 cm (CryoSat-2) and 3 cm (Jason-1) may be attributed to the contribution of VLM to sea level rise in Manila Bay.

Coastal Altimetry for Ocean Applications in the Strait of Gibraltar

J. Gómez-Enri, S. Vignudelli, A. Izquierdo, M. Passaro, C.J. Gonzalez, P. Cipollini, M. Bruno, O. Alvarez, R. Mañanes

As stated by (Hughes et al., 2015), monitoring the sea level signal will provide us information about the exchange flows through the Strait of Gibraltar. Moreover, "*because of geostrophy, the sea-level on the south side of the strait is higher than on the north side.*" (Ross et al., 2000). ESA ENVISAT RA-2 (SGDR: Phase E2) data were used to analyse altimetry data in the Strait of Gibraltar. Data were retracked with ALES. Tidal model, MSS and MDTs were considered both at global as well as at local level along with TG, bottom pressure, bathymetry and wind velocity data. All models adopted have been assessed by authors. In conclusion: 1) the global tidal model DTU10 shows a good performance in the Strait of Gibraltar to de-tide altimetric records, 2) the use of a global MSS in the Strait of Gibraltar to obtain the anomalies might hide some of the sea level variability, and hence complicate their oceanographic interpretation, 3) an ad-hoc local along-track MSS (based on ERS2/ENVISAT) gives a more realistic cross-strait variability in the Strait (this improves the analysis of the oceanographic processes in the area), 4) the analysis of the along-track absolute dynamic topography showed a positive correlation with the zonal component of the wind. Severe easterlies can infer a negative sea level difference between south and north, due to Ekman transport, modulating the water exchange through the Strait of Gibraltar. In the future, the analysis will be extended considering Sentinel-3A/B data.

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

A. Caballero, A. Rubio, M.-H. Rio, N. Ayoub, J. Mader, G. Larnicol, I. Manso-Narvarte, C. Dufau

For this study authors considered SLA and EKE interpolated maps of the Bay of Biscay (from AVISO) for describing interannual and seasonal variability. Such maps describe mesoscale eddies (distribution, generation place/time and migration of mesoscale eddies). They characterized a seasonal 4W Quasi-stationary eddy with satellite images, a drifter and model simulations. Ocean dynamics have been studied combining altimetry, glider data and other remote sensing images (SST and Chla) leading to the possibility to monitor cyclones and anticyclones from the surface to 1000 m in 2013.

Although altimetry interpolated maps are able to observe mesoscale eddies in the abyssal plain, their limitations near the coast makes necessary to work with along track data. Also land-based HFR data have been considered. They used Jason-2 1-Hz X-Track and CMEMS reprocessed global ocean along-track L3 products. From the comparison of these data at cross-overs and along the track authors concluded that: 1) the altimetry data shows higher variability near the coast which decreases at deeper waters, 2) the best altimetry-HFR agreement is observed where the geostrophic component is stronger due to a seasonal slope current.

The BB-TRANS glider mission has been presented. A deep glider acquired data in the area covered by the HFR. The aim of the mission is to study the 3D circulation and transport in the area covered by the coastal HFR system to: 1) validate the accuracy of coastal altimetry along-track data within the footprint area, 2) evaluate different methodologies for deriving transport in the water column, by means of HFR and glider data.

Moreover, in an additional joint analysis with coastal altimetry along track data, HF radar data and satellite data, a mesoscale process (eddy) has been observed for almost one month. The quantitative analysis of the HFR currents permitted to estimate the induced onshore/offshore transport. To conclude, the COMBAT Project (CMEMS) which aims at using HFR data to calculate an improved MDT solution for the Bay of Biscay has been presented.

Coastal Altimetry activities on the Coastal Thematic Exploitation Platform

S. Clerc, S. Vignudelli, C. Bevy, E. Tuhoy

The project started in 2015 as part of the ESA network of Thematic Exploitation Platforms (TEPs). In operation since July 2017, with 5 different pilot projects. An on-line exploitation platform: 1) brings the user to the data providing pre-defined & user-defined processing, 2) includes optimized, scalable processing resources and 3) offers private data storage and sharing capabilities. Several use-cases were presented, for EO data processing experts, EO data users, Service developers, stakeholders & decision-makers. Among the main features: 1) a “geobrowser”: to search for data, launch processing tasks and visualize results, 2) a processor integration service (a user-friendly interface to: register a new processor, describe its input parameters and upload the processor as tar.gz file). 3) an interactive application server web-based interface to run Linux applications such as: SNAP,

QGIS, Jupyter & Jupyterlab notebooks, Ubuntu desktop. Objectives are to support the coastal community, developing contents on the basis of user projects, and to exploit the synergy among different projects. A project investigating the match-up between satellite altimetry data and tide gauge in-situ data has been discussed to demonstrate the capability of TEPs. Project steps included the collection of satellite (X-Track coastal altimetry products from CTOH/LEGOS) and in-situ data (available on the platform or uploaded by the user), the selection of the processor & parameters and the implementation of new visualization functions. Output data can be downloaded as .zip files and contain a temporal match-up plot and a correlation map that can also be viewed directly in the TEP browser. The presented project is a first step to develop altimetry applications in TEPs: ideas and proposals for new projects are welcome. Main advantages are: 1) multi-disciplinary platform dedicated to coastal areas, 2) easy processor integration thanks to a dedicated GUI, 3) possibility of sharing knowledge within the community while respecting traceability and IPRs. Ideas for development, proposals and requests to try the platform can be sent to **coastal-tep@esa.int**

Session 2B: Application of Coastal Altimetry Data - Sea Level, Currents & Data Assimilation

CHAIRS: Martín Saraceno, Remko Scharroo

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

Z. Gharineiat, X. Deng

This study is motivated by the exceptionally high sea levels events that have claimed many victims throughout the history of northern Australia. The data used consist of 20 years of sea surface heights (SSHs) (1993- 2013) from satellite altimeters T/P, Jason-1 and Jason-2 along with sea levels observed at 14 tide stations over the northern Australian coastal region. Selected corrections included ECMWF models (DTC & WTC), BM4 model (SSB), MOG2D-1B (Dynamic Atmosphere), DTU13 (MSS), smoothed dual-frequency altimetry corrections for the ionosphere and the response method for tides.
Sea Level Empirical orthogonal function EOF-Decomposition (EOF1, EOF2, EOF3) has been presented with a significant 44.6% for EOF1. By calculating the empirical orthogonal function (EOF) decomposition, authors separated the sea level variability into three leading modes of variability (EOF1: 44.6 %, EOF2: 13.3%, EOF3: 6.8%). Sea level trends were calculated using Harmonic analysis method and annual and semi-annual signals discussed. The rate sea level rise around Northern Australian coastlines has been 3- 4 times more than the recent rate of global mean sea level +2.9 ± 0.4 mm yr−1 (Watson et.al, 2015). Sea level trend of altimetry and tide gauges were compared at the nearest along-track altimeter point, results underlined some agreements but also some challenging discrepancies. Further research is required to improve the altimetry sea-level measurement close to the coastline (using advanced retracking techniques) and additional altimetry missions (e.g., Jason-CS, Jason-3, CryoSat-2 and SARAL/AltiKa) should be included in future research.

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

A. Shaw, F. Mir Calafat, N. Dayoub

Tide gauges located in regions where signals have relatively long length scales generally have a better agreement with altimetry observations and provide a more accurate assessment of the altimeter's performance. Therefore, dominant sea level signals at different tide gauge locations may have very different length scales. Starting from this consideration, the objectives of the study are: 1) to improve the closure of the link between open ocean and coastal measurements in sea level trends, 2) to provide evidence, for or against, that the coastal sea level may be rising at different rates compared with the open ocean and 3) to identify groups of tide gauge locations that have relatively long sea level trend length scales for the purpose of improving the validation technique of coastal altimetry sea level rates against in-situ tide gauge measurements. The region of Interest for this study is the North Sea.

Ocean model NEMO data trends calculated from sea surface height (1965-2012 runs, spatial resolution is 1/12 degree with a monthly temporal resolution) are used to investigate long length scales. Moreover, PSMSL tide gauge data and Jason-1/2 altimetry data, retracked with ALES, have been used. The Methodology to investigate NEMO sea level data included: 1) the creation of coherence maps, related to the TG location, OR variograms to evaluate and compare length scales, 2) the grouping of tide gauges according to their trend decorrelation range value (length scale) and coherence, 3) the application of the tide gauge grouping to real tide gauge and altimetry data.

The two approaches in 1) evidenced different results. The grouping of TGs in 2) has been achieved by applying three criteria constraining each combination of two tide gauges to the trend length scales calculated by the two approaches in 1). Afterwards, TGs have been grouped based on their relationships to each other.

The combination of the two approaches in 1) to estimate the trend length scales and subsequently, the grouping of the tide gauge locations based on three criteria appears to be working well. Up to now, only NEMO sea level trends have been considered. To implement 3) one tide gauge group has been considered to extract the altimetry data based on the trend length scales and tide gauge trend observations for a comparison. In conclusion: the methodology using NEMO trend observations for determining the length scales and subsequently grouping of the tide gauge locations for consistency works well. However, NEMO accounts only for coherence in the steric contribution, and so in reality the identified regions may not be as coherent. To improve the validation, a localized sampling of altimetry observations (based on length scales) will help to close the link between coastal waters and the open ocean.

Feasibility Evaluation of Extracting Submesoscale Surface Currents from High-Resolution Sea Surface Heights in a Coastal Region

E. A. Lee and S. Y. Kim

Authors investigated the possibility to reconstruct sub-mesoscale surface currents from high-resolution sea surface heights (SSHs; from observations or numerical model outputs) in the coastal zone and to generate SSH maps from HFR-derived surface current maps. The area of study is the US West Coast. To do this, the authors: 1) assumed the high-resolution regional ocean modeling system (ROMS)-simulated SSHs (hourly, 2km) and HFR-derived currents (hourly, 6 km) as true values, 2) estimated the geostrophic and ageostrophic currents from the ROMS simulations, 3) found the relationship between SSHs and currents and evaluate the reconstruction feasibility. Energy spectra of ROMS and HFR surface currents have been compared: ROMS currents show consistent variance distribution to observation in space and time. The degree of ageostrophic and geostrophic unbalance has been investigated and regions of dominance reported. 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. This work can be closely related to the coastal altimetry and SWOT mission.

The Performance of Satellite Altimetry Currents in a Wide Continental Shelf

L.S. Lago, M. Saraceno, P. Martos, R. Guerrero, A. Piola, C. Provost

The Patagonian continental shelf is one of the most productive biological areas of the world oceans. Currents derived from satellite altimetry can help to further understand regional circulation. The continental shelf is challenging for coastal altimetry (shallow region, very large coastline, large tides) and there is scarcity of in-situ data. Plots of correlation (satellite vs in-situ) were shown confirming that 20Hz Jason-2 ALES-retracked SLA data adequately match 22 months of in-situ data at 3km from the coast. Objectives of the study are to: 1) evaluate satellite altimetry currents, by comparing to in-situ currents time series, in a wide continental shelf at time-scales lower than the seasonal and 2) improve the description of currents in the Patagonian shelf. Data used: 1) L4 multi-mission altimeter gridded sea surface heights data and derived variables computed with respect to a twenty-year mean (daily data with ¼° resolution), 2) CLS regional currents data (CLS0, daily data with 1/8° resolution) and 3) along-track sea surface height data (Jason-2 20Hz data & Jason-2 and Jason-3 1Hz SLA data). Authors also analysed the variability of in-situ data in the various locations. Wind dominates the variability of the currents at all depths. In the first analysis, they compared in-situ and satellite velocity data reporting a low correlation coefficient and high RMSD. As satellite velocity is inferred from sea level, they decided to analyse this variable, using Jason-2 20Hz AVISO SDGR data, and compare to in-situ data. Also in this case, no good agreement in SLA was found between the two datasets (correlation coefficient =0.2). Better results (correlation coefficient >0.9) have been obtained by comparing the total water level (TWL, Altitude-Range). Then, authors started including geophysical corrections, one by one, to understand the impact on the comparison: the high frequency fluctuations (HFF) correction increases the RMSD between in-situ and satellite SSH while the ocean tide correction decreases the most the correlation coefficient (this correction is the main source of error). Moreover, by analysing in-situ currents, authors reached the following conclusions for the Patagonian continental shelf: 1) circulation is highly dominated by winds, 2) velocities present a bathymetry restraint, 3) currents are barotropic, and 4) in-situ TWL is very well represented by altimetry. The weak correlation between in-situ and satellite currents might be due to the tide model used to correct the SSH (not accurate enough) and to the wind-related currents not well represented in MOG2D.

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

N. Dayoub, P. Cipollini, H. Snaith, V. Byfield

Funded by the European Union's Horizon 2020 research and innovation programme, the **Coastal Water Research Synergy Framework (**Co-ReSyF) is an online user-friendly platform, accessible at http://**co-resyf.eu/**, allowing registered users to exploit a set of tools and default applications to process Earth Observation (EO) data for monitoring coastal waters. It offers a simple user interface to select and process data with the platform's applications or user's uploaded applications. A built-in catalogue provides access to a wide range of EO data. Platform's applications: 1) Bathymetry determination from SAR images, 2) Bathymetry, benthic habitat classification and water quality determination from optical sensors, 3) Vessel & oil spill detection with SAR & Optical, 4) Time series processing for hyper-temporal optical data analysis, 5) Ocean and Coastal Altimetry**.**

This talk is about the Ocean and Coastal Altimetry application. NOC's altimetry algorithm is based on the ALES re-tracker (Passaro et al, 2014) **t**hat is applied on waveforms available on the Sensor Geophysical Data Record (SGDR). It uses updated corrections from the Radar Altimeter Database System (RADS) providing output files in netCDF format. The flowchart of the algorithm has been presented. Regarding the output data, along-track netCDF data files (20Hz, 40Hz) include the following fields: Time, Lon, Lat, Range, Alt, SSHA, TWLE, SWH, Sigma0 (from ALES & SGDR) & all used corrections. In the future, collocated netCDF data files (20Hz, 40Hz) will be disseminated. Jason-1/2/3 data are fully available, SARAL/AltiKa and Sentinel-3A PLRM mode data will be included shortly and ENVISAT ERS-1/2 in the future. The service is offered at different level of complexity for basic and expert users. Expert users can select the altimeter pass, the cycle and have different choices of range and geophysical corrections to apply. Customised output files are also available. The online interface and the selection & processing of the data have been presented. Searching the Co-ReSyF Catalogue is an open access service but running the research applications will be available for registered users. Co-ReSyF will provide an easy and efficient access and processing of coastal altimetry data for several altimetry missions.

Session 2B: Application of Coastal Altimetry Data - Sea Level, Currents & Data Assimilation (cont'd)

CHAIRS: Nadim Dayoub & Guoqi Han

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

M. Benkiran, E. Rémy, J-M. Iellouche, C. Dufau

The motivation for this presentation is to prepare the assimilation of altimeter data to investigate high frequency processes. A new assimilation in the regional model which includes Iberia, Biscay and Ireland (IBI36) is under testing.

The Low-Resolution IBI forecasting model (SLA, SST, S&T) covers Iberia, Biscay and Ireland (Horizontal resolution:1/36°, available from April 2018).The data assimilation adopts a reduced order Kalman Filter approach (SEEK formulation) and the quality control of in-situ observation. The assimilated observations are along track sea level anomaly (SLA) observations from AVISO (1Hz, usual corrections applied).

In case of assimilation of High-Resolution products, the following points shall be investigated: 1) the capability of the assimilation scheme to take into account mesoscale structures and 2) the Model's ability to propagate these mesoscale structures. Authors run several Observing System Evaluations (OSE) using different 1-Hz (OSE) and 5-Hz (OSE1) data (Jason-3, AltiKa, Sentinel-3A & CryoSat-2) and applying different corrections. They confirmed model forecasts contain more mesoscale structures. In particular, by assimilating HF (SLA data): the model is able to better explain the observed signal (everywhere in the basin) and is able to assimilate mesoscale structures. The is also an improvement of DA diagnostics without the correction of the DAC (OSE2) in the model and data (5-Hz): defining the as Innovation = Data – Model Forecast, the average Std(Innovation)/Std(Data) =0.51 for OSE2 and 0.8 for OSE1. More energy is also available at small scales.

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

Z. Wang, G. Lyu, H. Wang, G. Liu

Regional Ocean operational Forecasting System in NMEFC include the follow five regional ocean models (Northwest Pacific model, Indian ocean model, South China Sea model, East China Sea model, Bohai Sea model) having horizontal resolution from 1/12 deg to 1/60 degree. Wind Forcing is the NMEFC-WRF whereas the tidal forcing is included only in the Northwest Pacific & Indian ocean models. Authors adopted the EnOI (Ensemble Optimal Interpolation) Scheme. Boundary conditions are on water level, temperature, salinity and velocity at the open boundaries. The sea surface current in the Kuroshio path in Japan has been investigated assimilating the following data in the Northwest Pacific Model (1/20 deg h-resolution): 1) SST: MGDSST, 2) SSH: Jason/2/3, CryoSat-2, AltiKa and Sentinel-3A, 3) Temperature & Salinity: Argo profiles and buoys. Results indicate a very good simulation of the sea surface current. In the future, the plan to: 1) Improve the horizontal resolution from 1/20 deg to 1/36 deg, 2) Consider the 3DVAR/4DVAR method to compare with EnOI

results, 3) perform a reanalysis of the Northwest Pacific. 4) Assimilate coastal altimetry data.

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

M. Benkiran, C. Dufau, G. Smith, Y. Liu, F. Davidson

The system NWA12 has been presented, it includes the: 1) NEMO3.6 (1/12°) model including the FES2014 tidal model, 2) open boundaries from GLORYS2V4 ¼° reanalysis (daily), 3) atmospheric forcing: CGRF (Canadian Global ReForecast, 33Km) and 4) optional atmospheric pressure forcing. The data assimilation follows the reduced order Kalman filter SEEK formulation and data assimilated are: 1) along track SLA observations from AVISO (typical corrections applied) acquired by Jason-2, AltiKa, CryoSat-2, 2) MSSH and T&S Profiles from CMEMS, 3) CMC Sea Surface Temperature (1/3°). Observing System Experiments (OSEs) have been made also in this study along with a run including no DA. The atmospheric forcing has been considered in all cases, 1-Hz SLA altimetry data have been assimilated only in the OSE0, 5-Hz SLA data in OSE1 & OSE2 whereas the dynamic atmospheric correction has been applied only in OSE2. Performance and quality of the system have been evaluated. Authors also reported on a specific HR multi-mission L3 product that was developed in 2016 over the Eastern Canadian Shelf. It includes: 1) 40 Hz & 20 Hz input Level 2 data with specific retracking, 2) valid data selection based on altimeter-derived multi-parameter (mean quadratic error, waveform classification,…), 3) spatial filtering tuning to cut-off the small scales affected by observation errors, 4) 5Hz along-track sampling (~1 km). Dufau et al. showed that this regional HR product improves: 1) the spatial coverage near the coasts and sea ice, 2) the capability to monitor mesoscale and coastal ocean dynamics. In a comparison with HR satellite images it has been demonstrated the benefit of using 5-Hz data. The Assimilation of High-Resolution Altimetry in a 2-km Canadian East Coast has been presented. HF data contain more mesoscale structures and allow using more valid data close to the coast. The defined the Innovation: Data – model Forecast to infer the improvement. The assimilation of 5-Hz data clearly improves the results and the impact is clear also in small basins. In the future, the plan to: 1) Use the NWA12 (1/12°) model in the OSE2 configuration without the DAC Correction, 2) Estimate the new LWE with model DAC, 3) Examine the model physics output, 4) Extend the 5-Hz altimetry over all the domain and 5) Verify the results with tide gauges, drifters, HF Radar data.

Session 2 – Discussion

The discussion started on the vertical datum, and how coastal altimetry may help. Unfortunately many parts of the world are missing the land-based gravity data. The MSS that we use are averaged over >20 years and every time we add data the mean time goes up. And with climate change the mean is going up to. The challenges to improve ocean current estimations are great; some studies show promising progress but there are still issues of interpretation. There was a detailed discussion on whether we really want to estimate currents from altimetry (i.e. do we trust them? are they of value?) or rather just assimilate the heights in models that will then provide the currents. Finally a discussion on what are the limits in the spatial and temporal resolution that satellite can achieve. Is there a way to get prepared to the SWOT resolution by exploiting the current missions.

Session 2 - Posters

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

M. Ishaque, S. Calmant, D. Moreira, F. Durand, L. Testut, Y. Krien, V. Ballu, F. Papa

The shoreline of the Bengal delta (Bangladesh and India) is a macrotidal area (over 4 m), with a broad (200 km) and shallow shelf. Despite profound implications of the water level variability on the society, 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, (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), authors performed a survey associating GNSS measurements of the water surface and levelled bathymetry (by associating the soundings with the GNSS station). They presented the comparison of the GNSS heights of the water surface with various tidal solutions, including a harmonic analysis of a T/P (CASH reprocessing), Jason-1/2/3 (GDRs) series gained close to the shore. Moreover, at the river mouth, water levels have been compared to SENTINEL-3A data (corrected for tides to account for the difference in time between our survey and the overpasses). A cross checking analysis between the GLOSS tide gauge series in Chittagong and obtained GNSS profiles has been also presented.

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

X. Xu, F. Birol, A. Cazenave

Authors presented 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 analysed, 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 inter-annual time scale. Different retrackers from the ALES and PISTACH products were considered. For each retracker, authors evaluated the quality of the derived coastal sea level by comparing with data from the Hong Kong tide gauge (located 10 km away). They also analysed 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), they 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

F. Léger, F. Birol, F. Niño, S. Fleury, M. Passaro

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 many altimetry data as possible in the coastal zone. 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.

Authors presented the latest developments of the product. In particular, it has been decided to inject the L2 ALES (Adaptive Leading Edge Subwaveform Retracker) products 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. A first version of this new product as well as its potential for coastal applications have been presented.

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

J. Gómez-Enri, R. Mulero, S. Vignudelli, A. Scozzari

Following a previous analysis made with CryoSat-2 data, in this work authors exploit the capabilities of Sentinel-3A SRAL delay-Doppler instrument for the detection and characterisation of ships. In particular, they 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.

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

H.B. Dieng, I. Dadou, F. Léger, F. Birol, F. Lyard, Y. Morel, A.Chaigneau

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. In the OSTST Alti-ETAO project, authors 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. They used also the tide gauge (TG) data available in the ETAO region for the validation of the altimetry and modelled SLA along the coast. Comparisons among the coastal altimetry along-track data (X-TRACK last reprocessing), AVISO gridded product, the NEMO model and TG data using different statistical criteria have been presented. 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

M-L. Dabat, N. Ayoub, F. Marin, L. Gourdeau, G. Sérazin, F. Léger, F. Birol

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. Preliminary results from Sentinel-3 are also presented. In Bay of Biscay, the shelf is an important constraint on the dynamics, that lead the authors to consider separately the shelf and the plain. Sensitivity of the spectra to the two dynamical regimes is assessed. The issue of separating mesoscale and internal tides signals has also been addressed, 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

M. Riabkova, V. Karaev, A. Maksimov

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 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. 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.

Synergy Between Coastal Altimetry Data and Land-based High-Frequency (HF) Radars

F. Oliveira, P.L. Mazzini

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. In the past years, efforts have been made to improve the application of altimeters in coastal regions turning 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 authors chose the Gulf of Farallones off Central California, where HF radar observations began as early as January-2006 and are still ongoing. 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, authors intend to expand this analysis to other coastal regions especially in Southern Brazil.

Coastal Region Applications from Satellite Altimetry Missions

M. Srinivasan, A. De Charon

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.

Authors are collaborating to implement 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 are to: 1) Identify current applications, users and uses of OST information, 2) Establish the scope of existing applied research and develop new potential applications, 3) Demonstrate the benefit of OST to society, 4) Increase the use and utility of data products and 5) 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

V. Ransi, D. Pirhalla, S. Sheridan

U.S. coastal areas and ecosystems are facing multiple sea level rise threats and effects. 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, the NOAA National Ocean Service (NOS) evaluated new metrics from satellite altimetry (AVISO/Copernicus) and MODIS IR flood extents to isolate nodes of atmospheric variability indicative of elevated sea level and nuisance flood events. 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 the NOAAs Climate Program Office and NOS office of Center for Operational Oceanographic Products and Services (CO-OPS).

Tracking of Eddy Propagation in the Southern Luzon Strait

A.L. Del Rosario, C.L. Amedo-Repollo, C. Villanoy

The dynamics affecting intrusion of Kuroshio Current into the Luzon Strait (LST) have been an active area of study for years. 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.

Session 3: Synergistic and Climate Studies

CHAIRS: David Cotton & Doug Vandemark

Coastal Currents Along the Yucatan Peninsula

J.A. Kurczyn Robledo, C.M. Appendini, X. Flores, G. Posada

This a study of the coastal currents along the shallow continental shelf to the east of the Yucatan peninsula, which is largely unstudied compared to the deeper water of the Gulf of Mexico. Analyses of hydrographic measurements (CTDs, and moored ADCPs), HF radar and satellite (OSTIA) SST data reveal coastal currents that run alongshore and are constantly reversing at both short and seasonal time scales. An initial look at AVISO SLA derived currents shows low correlation, perhaps not surprising in these very shallow seas. At present the objective is to gather the current, wind and wave data and then begin to look at coastal altimeter data to support improved understanding. The area is also interesting for episodic cold wind bursts that make a distinctive signature in SST and SWH, and which are important for fisheries.

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

S. Abdalla, B. Ozbahceci, A.R. Turgut, A. Bozoklu

The use of altimeter data for an assessment of century-based wind and wave climate data records in the coastal zone around Turkey was reported. The application is from an engineering perspective, with the aim to derive long term wind and wave return values for locations on the Turkish Coast, in the Mediterranean Sea, Aegean Sea and Black Sea. The initial baseline for the study is the NATO-TU wind wave project atlas (2002), with the CERA-20C reanalysis done by ECMWF (covering the period 1900-2010). The presentation reported on a cross validation of the hindcast model wind speed against altimeter data, calibrated vs ERA5 over 13 points. The correlation is good in some points, but not so good in others (especially in the Aegean Sea). Return values for wind speed calculated from the altimeter data gave lower values than from the hindcast model. The study will next look at significant wave height data. In the discussion it was flagged that ERA5 already assimilates altimetric data – but S. Abdalla confirmed that CERA-20 does not.

Climate Variability and Trends of Coastal Currents off Atlantic Canada from Satellite Altimetry

G. Han, N. Chen

Climate variability and trends of coastal currents off Atlantic Canada were reported within a study supported by Canadian Space Agency's SWOT-C Project. Since 1990 his group has been studying the equatorward Labrador current and its transport along shelf, and has developed a climate index for transport at the shelf edge. Now their objective is to explore the potential of coastal altimetry for assessing inter-annual and decadal-scale variability of the coastal currents. Barotropic geostrophic transport anomalies were computed from CTOH X-TRACK TP/Jason data for the period 1993-2016 and compared to the output from a coupled ocean-ice model. Authors found reasonable agreement with modelled transports

at 3-5 year time scales from 1992-2015. In the Strait of Belle Isle they found excellent agreement of Model Transport and Sea Level difference.

Southwestern Atlantic Currents from InSitu and Satellite Altimetry

M. Saraceno, G. Paniagua, L. Lago, C. Artana, R. Ferrari, A. Piola, C. Provost, R. Guerrero

Results of a study of South-western Atlantic Currents from in situ and satellite altimetry were presented. In the study area the interaction of the Malvinas Current (MC) with the shelf is responsible for a large upwelling area that sustains Patagonian fisheries. There were significant instrument deployments in 2015-17 including ADCPs, CTD/current moorings and buoys, and these data have been analysed together with long term altimetry data (focussing particularly on along-shelf currents. The array location was chosen to be aligned with a TP/Jason satellite track.

An EOF analysis demonstrated that the MC goes through ‘strong’ and ‘weak’ phases. In strong MC conditions the MC passes through the instrumented array while in weak conditions the MC makes an eastward turn at the latitude of the array. Both satellite SST and SSHA help to verify and confirm the spatial extent and timing. In this site altimetry on average represents subsurface currents very well, especially using gridded data and comparing to 20-day filtered in situ data. The agreement is rather good above 600m depth in strong MC conditions, and for the whole column in weak MC conditions. However, when the Turbulence Kinetic Energy and eddy scales are weaker, then the agreement with the satellite Sea Level Anomaly derived currents is lower. This is connected to the changing vertical temperature/salinity structure. Analysis of the full altimetry record has provided new knowledge on the inter-annual variability in the MC.

Session 3: Synergistic and Climate Studies (cont'd)

CHAIRS: David Cotton & Paolo Cipollini

Invited talk

Coastal Altimetry for Sea_Level_cci & Sea_Level_Budget_Closure_cci

SL_cci and SLBC_cci Projects

S. Vignudelli (CNR, Italy) reported on the ESA SL_cci (Sea Level Climate Change Initiative) and SLBC_cci (Sea Level Budget Closure Climate Change Initiative) projects.
He first presented the framework of the Climate Change Initiative and the reprocessed v. 2.0 SL_cci dataset, covering 1993-2015 with data from 9 satellite missions. This dataset includes two new sea level products in the Arctic. The key aspect of the project is the homogenization of the various missions, reducing the systematic biases, and a better characterization of errors at global and regional scales. In the SL_cci data we see an acceleration of 0.1 mm/yr^2. While the errors on the global mean sea level trends are now very close to the GCOS requirements, there is still work to be done at regional level. The CCI Sea Level Budget Closure is focusing on the Arctic ocean and aims to lead to a comprehensive assessment of the ocean budget, including a better understanding of the processes, identifying changes and accelerations of the individual components, identifying data gaps and investigating the impact of missing data (for instance data below 2000m, where ARGO floats do not normally go).

There remains much work to be done in coastal regions, where the "last 50 km" sea level is the sum of global, regional and local components, including land elevation changes and morphological changes, and wave and storm climate. Satellite altimetry is capable to provide a unique long-term observational dataset, coastal altimetry has already demonstrated that coastal sea level can be recovered and this is addressed in the CCI+ new phase.

Work to be done includes studying the sea level budget at regional scale, developing a global multi-mission Coastal Altimetry dataset, further improvements to sea level in the Arctic and continued Research and Development to feed into Copernicus Climate Change Services (C3S) operations.

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

C. Gommenginger, N. Dayoub, F. Wimmer, A. Shaw, C. Banks, F.Calafat, H. Snaith, M. Srokosz, E. Ash

This presentation was about a study of trends and variability in Coastal Sea State and Sea Level in the Sea State CCI+ project. The GCOS requirements were noted: these are for a resolution of 25 km, though this may not be the most appropriate for all applications. The parameters identified as crucial for this Essential Climate Variable (ECV) are Significant Wave Height (SWH), surface backscatter at nadir (sigma0) and the mean square slope (mss). Altimetry is the core dataset for sea state due to cross-mission consistency, so there is a strong heritage of this project from the ESA GlobWave project. The priority is to develop long-term consistent climate-quality products, not to validate the most recent missions which is done in other projects. It was noted that most ocean processing schemes so far have been optimized for retrieving sea surface height (from range), this project will support development of approaches optimized for SWH and sigma0 retrieval.

A number of validation diagnostics have been proposed for the comparison with in situ data and models, and for inter-mission comparisons. Some current validation results on CryoSat-2 from a validation suite at NOC, which will be adapted and extended for the CCI purposes, have also been shown. There will be a strong focus on coastal regions, high sea states and swell dominated seas.

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

D. Cotton, A. Becker, V. Byfield, F. Calafat, N. Dayoub

The C-RISe (Coastal Risk Information Service) project aims to develop, deliver and evaluate a coastal risk information service around South Africa, Mozambique and Madagascar, an area with very sparse long-term in situ measurements. C-RISe is providing reprocessed altimetry from the NOC ALES processor (2002-2016), wind and wave climatologies from GlobWave, and a demonstration Near Real Time wind and wave service to support coastal vulnerability assessment and hazard management.

A series of 25 use cases provide the basis for practical implementation and the monitoring and evaluation of the C-RISe service. They are grouped under 5 themes: Marine Protected Areas Management, NRT Sea State information, Sea Level analysis, Wave and Wind (and current) climatologies, climate change impact on Marine Ecosystems. An important aspect of the project is regional capacity development, and to support this there is a strong training element with a series of workshops on accessing and applying satellite data. A suite of python software has been developed to support this. An initial analysis has validated the coastal altimeter sea level data against available Tide Gauge data, and looked at inter-annual variability through an EOF analysis. There are also plans to apply the data to Storm Surges and a number of storm events in the area have been identified.

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

M. Panfilova, V. Karaev

Measurements of Normalized Radar Cross Section (NRCS) and slope variance over inland water bodies from the Dual Frequency (Ku and Ka) Precipitation Radar on the JAXA / NASA GPM mission were presented. This instrument operated at low incidence angle, has a swath of 245 in Ku and 125 Km in Ka, and a footprint of 5 km. The orbit is not sun-synchronous between 65S and 65N. Comparisons were made with data from the NDBC buoys in the USA Great Lakes. Slope variance is derived from the decrease of RCS with increasing incidence angle. Classification of wave age is also possible and was confirmed. The mean square slope turns out to be in good correlation with the slope variance – something to be explored further. They explored also the dependence on wind speed.

Estimating Sea Level Variations Due to Greenland Ice Sheet Melting

S. Stolzenberger, R. Rietbroek, J. Kusche

Results from a study into sea level variations due to ice sheet melting were presented. The study area is the 79N Glacier and the Zachariae Isstrøm that together drain about 16% of Greenland ice. The aim is to improve the understanding of the changing dynamics of the Greenland ice sheet, studying the interactions between the warming ocean, glaciers and the glacier outlet, using GRACE data and sea level budgets from altimetry. An inversion 'fingerprint' technique is used which resolves simultaneously and consistently for mass changes over land and steric changes in the

ocean. Trends in ice sheet heights were calculated for different regions of the Greenland ice cap, and the loss in some areas exceeded –60 cm/year over the period 2002-2016, with a total ice mass loss of 262 ±10 Gt/yr.

Greenland ice sheet melting has been shown to be the second largest contribution to global mean relative sea level rise. Further investigations will look at the influence of melting on the Sea Level budgets and coastal circulation around Greenland, and also at the steric variations in the North Atlantic based on the FESOM model of AWI.

Session 3 – Discussion

The discussion focused on the requirements of the ESA CCI projects, and started with a consideration of the different characteristics / trends and challenges in sea level and sea state measurements close to the coast. How closely will the variability at the coast reflect that offshore in the same region?

The coastal challenge for sea state and winds is potentially greater, due to variability on very short time and space scales, and to the impact of local topography / bathymetry. However, it could be argued that altimetry is more likely to provide a more reliable consistent long-term time series than in situ measurements, as buoys drift/change. One issue noted for coastal wind speed and wave measurements is that altimeters in a sun-synchronous orbit will have a diurnal bias, only sampling at set local times of day.
There was a lively discussion on the merit of a global value of the sea level trend at the coast, in that such a value may not be scientifically meaningful, though it could have the benefit of an easier message to pass to the media. It was argued that regional sea level trends have greater scientific and practical value.

The following recommendations were suggested:

- The development of a global sea level product recognized by the community that will enable all the regional studies.

- Coastal Altimetry should be part of the recipe to provide a local sea level/sea state assessment for coastal planners.

  Sea state must include mean square slope (mss) – this is the roughness parameters that governs exchanges, and is particularly relevant in the Coastal Zone as CO2 uptake is still a big unknown there.

- More in situ data in the zone 0-3 km from the coast are needed for validation.

- Long-term changes in coastal current are also a useful application, but need integration of altimetry with other observing techniques as the assumption of geostrophy will not hold for most coastal currents.

Session 3 – Posters

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

A. Gallentes, A. Punongbayan, C. Repollo

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

S. Gorelli, J. Gómez-Enri, M. Rotonda, S. Vignudelli

Authors focused on the vulnerability related to long-term changes of sea level and proposed a scenarios analysis that exploits the current SL-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 consisted of two phases: 1) identifying 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. 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

S. Vignudelli, F. De Biasio, A. Scozzari, S. Zecchetto

This work reported 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 Venice and Trieste provided an accurate independent source of sea level information to be used as reference of long-term sea level variability at the coast. Altimetry products processed with consistent coastal processing for all missions have been used.

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

D. Vandemark, S. Grodsky, J. Levin, J. Wilkin, H. Feng

Ocean altimeter data from the Gulf Stream region and onto the coast of the NW Atlantic impact heavily on the performance of an operational ocean circulation prediction forecast system. A 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. Satellite ocean current, SSS, and SST data suggested that the feature interacted with Gulf Stream meanders and eddies several times, helping to sustain the water mass. While surface SSS and SST data provided one compelling view of shelf/slope interactions during this period, this study integrated 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 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

N.B. Avsar, S.H. Kutoglu

Authors presented 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. 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. A 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

I. Pita, M. Cirano, M. Mata, M. Lima

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 is 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 main objective 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 (42^0 W, 23^0 S) and Trindade Island (30^0 W , 2 0^0 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: AVISO and Altimetry Tailored and Optimized for Brazilian Applications (ATOBA). AVISO (ATOBA) data are daily (weekly) and present a spatial resolution of $1/4^0$ ($1/12^0$).This study analysed data from Jan/2004 to Dec/2013. The values obtained by coupling altimetry and MOVAR datasets are supported by a series of previous researches. 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)

Ş. Şener, E. Şener, A. Davraz

This study aimed to investigate coastline and water level changes of the Burdur lake (Turkey) 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 analyse 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, the lake water body was extracted using a supervised classification method. Finally, coastline changes of the lake were detected for analysing 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 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

E. Şener, Ş. Şener, M. Güler

The Kızılırmak Delta is one of the most important wetlands of our country in terms of biodiversity. 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.

Conclusions

The continuous improvement in data processing and the recent progress in technology have allowed the development of high-resolution products suitable for coastal zone studies. The main goal of coastal altimetry today is to characterize the sea level variability from the open ocean to the coastal zone, in synergy with other complementary measurements (e.g., tide gauge records) and modelling tools. The prospect that coastal altimetry is capable of providing more and better wind and wave data closer to the coast is also promising to investigate the coastal ocean dynamics.

Coastal altimetry has achieved important milestones in recent years, including new radar waveform processing strategies and improved corrections. High-resolution products made available by the synthetic aperture radar (SAR) altimetry technology, adopted in both CryoSat-2 and Sentinel-3 missions, have demonstrated that it is possible to enhance the quality and quantity of the altimetric record close to the coast. SAR altimetry missions are boosting new development in fields that exploit the quality of Hi-Res products for sea level, wave height and wind speed estimation.

During the previous edition of the workshop (CAW10 in Florence), a novel SAR technology named Fully Focused SAR was presented. This year, some promising results from this technology, obtained in preliminary coastal zone investigations, were discussed. Theoretically, the Fully Focused SAR technology allows reducing the spatial resolution from 300m (unfocused SAR) to half the antenna size, 0.5m.

The potential of new available platforms, like the ESA Thematic Exploitation Platforms, the European Union Coastal Water Research Synergy Framework and the ESA Grid Processing on Demand (GPOD) processing suite, was underlined at the Workshop, along with the added value brought by the ALES, X-TRACK and DUACS multi-mission altimetry datasets. It was shown that the coastal-dedicated reprocessing of the 25+ years altimetric time series can shed new light and change our knowledge of the dynamics and mean circulation of the coastal ocean. The workshop recommended coastal-dedicated processing also for CryoSat-2 and Sentinel-3 to produce coastal altimetry data sets of better quality for assimilation in ocean models.

The synergy among coastal altimetry data, in-situ observations and models has been the central topic. Many contributions also focused on analyses preparing for the Surface Water Ocean Topography (SWOT) mission due to launch in 2021. Initiatives to allow the coastal altimetry community to support SWOT have been recommended.

For the first time, it was evident that users are getting more familiar with coastal-dedicated datasets, which are now being used for scientific analysis. The trade-off between an expert and critical use of different coastal-dedicated processing options and the availability of user-friendly coastal datasets remains an issue, but clear progresses have been made. The community encouraged efforts of documentation, comparison and synergy between different datasets.

Final recommendations from the workshop include the development of a global multi-mission sea level product, recognized by the community, which will enable regional studies. In particular, future studies should continue investigating how closely the variability at the coast reflects the one observed offshore. To support such investigations, more tide gauges

for validation purposes in the zone 0-3 km from the coast are needed. In the future, coastal altimetry should be part of the recipe to provide local sea state assessment for coastal planners.

The workshop report and all presentations and posters from the Coastal Altimetry series are available online at https://www.coastalaltimetry.org.