2017 Ocean Surface Topography Science Team Meeting

Monday, October 23 2017 - Friday, October 27 2017

In celebration of the 25th anniversary of the launch of TOPEX/Poseidon, this ocean surface topography science team meeting will include special splinter sessions on analysis of current SAR data with a focus on benefits in coastal areas and other water surfaces and lasts for the entire week.

Abstracts Book

Abstract list

Keynote/invited

Science Keynotes Session
Mon, Oct 23 2017, 14:00 - 15:45 - Symphony Ballroom IV

14:00 - 14:25: Further understanding the global mean sea level record over the satellite era: Christopher Watson et al.
14:25 - 14:50: Temporal and Spatial Changes in the Dominance of the Wind-driven and Density-driven processes in the South Atlantic MOC: Shenfu Dong et al.
14:50 - 15:15: Satellite-derived ocean heat content variability: implications for weather and climate studies: Lynn Shay et al.
15:15 - 15:40: Analysis of small icebergs (<10km²) size and freeboard around Greeland and Antarctica using Cryosat SARin data: Jean Tournadre et al.

Oral

Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Wed, Oct 25 2017, 11:00 - 12:30 - Symphony II

11:00 - 11:20: Technical aspects of coastal altimetry data processing: Remko Scharroo et al.
11:20 - 11:40: Coastal Altimetry: a review of scientific applications and synergies with complementary measurements: Jerome Bouffard
11:40 - 12:00: Altimetry for Coastal Ocean Modeling and Analysis: John Wilkin et al.

Application development for Operations
Wed, Oct 25 2017, 09:00 - 10:30 - Symphony II

09:00 - 09:15: Combined assimilation of Sentinel-1 and Sentinel-3A wave data in operational wave model : investigation on bias for SAR mode altimetry: Lotfi Aouf et al.
09:15 - 09:30: High-Resolution 3DVAR for Constraining Submesoscale Dynamics: Joseph D'Addezio et al.
09:30 - 09:45: The role of altimetry observations in constraining the Mercator Global Ocean analysis and forecasts: Yann Drillet et al.
10:00 - 10:15: Predictability of Submesoscale Flows Using Multiscale Data Assimilation of Satellite Altimetry: Zhijin Li
09:45 - 10:00: Combining altimetry with in situ data: quantitative impact assessment of operational ocean observation strategy in hurricane applications using Observing System Experiments and OSSEs: Matthieu Le Henaff et al.

Instrument Processing: Measurement and Retracking
Tue, Oct 24 2017, 09:00 - 12:30 - Symphony Ballroom IV

09:00 - 09:15: Progress on Retracked TOPEX Data for the Climate Data Record: Philip Callahan et al.
09:15 - 09:30: Evaluating methods to improve the performance of Sentinel-3 SRAL SAR Altimetry in the Coastal and Open Ocean– The SCOOP Project: David Cotton et al.
09:30 - 09:45: Investigation of SWH bias in SAR Altimetry mode: Thomas Moreau et al.
09:45 - 10:00: New stacking method for removing the SAR sensitivity to swell: François Boy et al.
10:00 - 10:15: Pulse-to-Pulse Correlation Effects on high PRF Low Resolution Mode Altimeters: Alejandro Egido et al.
11:00 - 11:15: Convergent solutions for retracking conventional and Delay Doppler altimeter echoes: Pierre Thibaut et al.
11:15 - 11:30: Along-Track Zero Padding for the Processing of Unfocused SAR Altimetry Waveforms: Christopher Buchhaupt et al.
11:30 - 11:45: Covariant errors in ocean retrackers evaluated using along-track cross-spectra : Walter Smith et al.
11:45 - 12:00: Delay-Doppler Processing of altimetric SAR data over open ocean: precision evaluation of different algorithms: Eduard Makhoul et al.
12:00 - 12:15: ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters.: Marcello Passaro et al.

Instrument Processing: Propagation, Wind Speed and Sea State Bias
Tue, Oct 24 2017, 14:00 - 15:45 - Symphony Ballroom IV

14:00 - 14:18: Jason-3 GDR Calibration Stability Enabled by the Cold Sky Maneuvers: Shannon Brown et al.
14:18 - 14:36: Independent assessment of Sentinel-3A wet path delay: M. Joana Fernandes et al.
14:36 - 14:54: A multi-surface performance assessment of the Sentinel-3A Surface Topography Mission Microwave Radiometer: Marie-Laure Frery et al.
14:54 - 15:12: Exploiting the high spatial resolution of AIRWAVE TCWV data to retrieve the WTC for coastal altimetry in view to its application to Sentinel-3: Clara Lázaro et al.
15:12 - 15:30: 2-channels versus 3-channels configuration for MWR on altimetry missions: latest developments on the role of the 18.7 GHz channel on Wet Tropospheric Correction retrieval performances: Bruno Picard et al.

Outreach, Education and Altimetric Data Services
Tue, Oct 24 2017, 14:00 - 15:45 - Symphony II

14:00 - 14:15: The altimeter product suite for the Sentinel-6/Jason-CS mission: Remko Scharroo et al.
14:15 - 14:30: New Data and Updates at PO.DAAC: Jessica Hausman
14:30 - 14:45: The Antarctic Circumpolar Current as seen in Argonautica: Vinca Rosmorduc et al.
14:45 - 15:10: Science communication through art, design, and hands-on activities: Laura Bracken
15:10 - 15:15: OSTST-Related Outreach Activities: Edward Zaron
15:15 - 15:30: Outreach and data services Showcases: All All

Precision Orbit Determination
Tue, Oct 24 2017, 09:00 - 12:30 - Symphony II

09:00 - 09:15: OSTM/Jason-2, Jason-3 and Sentinel-3A POD Status: John Moyard et al.
09:15 - 09:30: Improvement of the Complete TOPEX and Jason Orbit Time Series (1992-2017): GSFC Status: Frank Lemoine et al.
09:30 - 09:45: GPS-Based Precision Orbit Determination for the Jason-2 and Jason-3 Missions: Shailen Desai et al.
09:45 - 10:00: Jason 3 GPS derived orbits with ambiguity fixing: Flavien Mercier et al.
10:00 - 10:15: Strategy to minimize the impact of the South Atlantic Anomaly effect on the Jason-3 and Sentinel-3A Precise Orbit Determination and on the station position estimation: Hugues Capdeville et al.
10:15 - 10:30: Update of the EIGEN time variable gravity model for precise orbit determination: Jean-Michel Lemoine et al.
11:00 - 11:15: Construction of GPS-based LEO orbits referenced to the “instantaneous” Earth’s center of mass, through the adjustment of a parametric correction in the IGS GPS satellite clock solutions: Alexandre Couhert et al.
11:15 - 11:30: SLR-based geocenter estimates with atmospheric pressure station loading for improving orbit centering: Nikita Zelensky et al.
11:30 - 11:45: The T2L2 contribution to precise orbit determination and positioning: Alexandre Belli et al.
11:45 - 12:00: Assessment of the International Terrestrial Reference System 2014 realizations by Precise Orbit Determination of SLR Satellites: Sergei Rudenko et al.
12:00 - 12:15: Consistent estimation of station coordinates, Earth orientation parameters and selected low degree Earth's gravity field coefficients from SLR measurements: Mathis Bloßfeld et al.

Quantifying Errors and Uncertainties in Altimetry data
Wed, Oct 25 2017, 14:00 - 15:45 - Symphony II

14:00 - 14:20: Assessment of the orbit related sea level errors for TOPEX altimetry at seasonal to decadal time scales: Saskia Esselborn et al.
14:20 - 14:40: How reliable are regional sea level trends ?: Pierre Prandi et al.
14:40 - 15:00: A promising parametric spectral analysis method applied to sea level anomaly signals: Corinne Mailhes et al.
15:00 - 15:20: Altimetric wavenumber spectra: noise floors and resolution capability: Oscar Vergara et al.

Regional and Global CAL/VAL for Assembling a Climate Data Record
Wed, Oct 25 2017, 09:00 - 12:30 - Symphony Ballroom IV

09:00 - 09:15: Connecting Jason-3 to the Long-term Sea Level Record: Results from Harvest and Regional Campaigns: Bruce Haines et al.
09:15 - 09:30: Updated altimeter absolute bias results from Bass Strait, Australia: Christopher Watson et al.
09:30 - 09:45: Corsica: a multi-mission absolute calibration site: Pascal Bonnefond et al.
09:45 - 10:00: Absolute calibration of Jason-3 and Sentinel-3A on Lake Issykkul from GPS field campaigns: Jean-Francois Cretaux et al.
10:00 - 10:15: Comparisons of Jason-3 and Sentinel-3A and tide gauges : Eric Leuliette et al.
10:15 - 10:30: Validation of a global dataset based on subwaveform retracking: improving the precision of pulse-limited satellite altimetry: Marcello Passaro et al.

11:00 - 11:15: Validation of the extended CryoSat-2 ocean data products: Paolo Cipollini et al.
11:15 - 11:30: Sentinel-3A STM Mission Performance after 1 year in orbit: Sylvie Labroue et al.
11:30 - 11:45: Sentinel-3A Marine Center data calibration and validation in a multi-mission setting: Cristina Martin-Puig et al.
11:45 - 12:00: Jason-3 mission performance for operational oceanography applications and long term Climate Data Record continuity: Hélène Roinard et al.

Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Mon, Oct 23 2017, 16:15 - 18:00 - Symphony Ballroom IV

16:15 - 16:30: Understanding the Acceleration of Sea Level Rise During the Altimeter Era: Robert Steven Nerem et al.
16:30 - 16:45: Impact of Pacific Ocean Variability on Global Mean Sea Level: Se-Hyeon Cheon et al.
16:45 - 17:00: Sea Level Monitoring in the coastal zone: impact of retracking and correction choices: Paolo Cipollini et al.
17:00 - 17:15: Evidence of coastal sea level changes along the east coast of United States associated with the Florida Current transport and heat content using satellite altimetry and hydrographic observations: Ricardo Domingues et al.
17:15 - 17:30: Wave climate observed from satellites: trends and inter-annual variability: Justin Stopa et al.
17:30 - 17:45: Comparison of coastal and open ocean sea level trends: Yingli Zhu et al.

Science II: Large Scale Ocean Circulation Variability and Change
Tue, Oct 24 2017, 16:15 - 18:00 - Symphony Ballroom IV

16:15 - 16:30: Malvinas Current volume transport at 41°S: a 24-year long time series consistent with mooring data from 3 decades and satellite altimetry: Camila Artana et al.
16:30 - 16:45: Southern Ocean Circulation and Climate Variability: Subrahmanyam Bulusu et al.
16:45 - 17:00: Observed Decadal Sea-Level Variations Over the Tropical Indo-Pacific Basin: Association with and Indicators for Varying Walker Cells and Climate Modes : Weiqing Han
17:00 - 17:15: Dynamical Links between the Decadal Variability of the Oyashio and Kuroshio Extensions: Bo Qiu et al.
17:15 - 17:30: Using Sea Surface Height to examine Air-Sea Interaction in the North Atlantic Ocean in Winter: LuAnne Thompson

Science III: Mesoscale and sub-mesoscale oceanography
Wed, Oct 25 2017, 16:15 - 18:00 - Symphony Ballroom IV

16:15 - 16:30: Long-distance radiation of barotropic Rossby waves from tropical instability waves: Tom Farrar et al.
16:30 - 16:45: Global Observations of Eddy-Induced Mixed Layer Depth Variabilit: Peter Gaube et al.
16:45 - 17:00: Modulation of the Ganges-Brahmaputra river plume by the Indian Ocean Dipole and eddies inferred from satellite observations: Severine Fournier et al.
17:00 - 17:15: Eddy generation and propagation in the Southern Ocean diagnosed from Satellite Altimetry and an Ocean State Estimate: Uriel Zajaczkovski et al.
17:15 - 17:30: Up to which extent can we characterize ocean eddies using present-day altimetric products?: Angel Amores et al.
17:30 - 17:45: Mapping the Ocean surface current from future current mission concepts and synergy with high-resolution altimetry: Clement Ubelmann et al.

Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Wed, Oct 25 2017, 14:00 - 15:45 - Symphony Ballroom IV

14:00 - 14:15: Quality Assessment of Sentinel-3a PDGS land products for the Monitoring of Lakes and Rivers Water Level: Lionel Zawadzki et al.
14:15 - 14:30: Update and validation of the onboard Jason-3 DEM for enhanced acquisitions over inland water targets: Sophie Le Gac et al.
14:30 - 14:45: The ICESat-2 Inland Water Height Data Product: Overview and Evaluation Using High Altitude Lidar Observations: Michael Jasinski et al.
14:45 - 15:00: AltiCryo: a CNES altimetry concept study for cryosphere monitoring: Amandine Guillot et al.
15:00 - 15:15: Swath Processing improvements of CryoSat-2 for the Study of Ice Caps and Mountain Glaciers: Albert Garcia-Mondejar et al.
15:15 - 15:30: A review of the current altimetry mission performances over the polar ice sheets: Cryosat-2, AltiKa and Sentinel-3A: Jérémie Aublanc et al.

The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Thu, Oct 26 2017, 09:00 - 10:30 - Symphony II

09:00 - 09:15: The Jason-2 Mission Geodetic Phase: Alejandro Egido et al.
09:15 - 09:30: Improvements and limitations of recent mean sea surface models: importance for Sentinel-3 and SWOT.: Marie Isabelle Pujol et al.
09:30 - 09:45: GEOMED2: Geoid estimation of the Mediterranean Sea: Sean Bruinsma et al.
09:45 - 10:00: Comparison and synthesis of geodetic and oceanographic data to improve mean dynamic topography products: Nikolai Maximenko et al.
10:00 - 10:15: A combined mean dynamic topography model – DTU17cMDT.: Per Knudsen et al.

Tides, internal tides and high-frequency processes
Thu, Oct 26 2017, 09:00 - 10:30 - Symphony Ballroom IV

09:00 - 09:15: Coastal improvements for tidal models: the benefit of ALES retracker: Gaia Piccioni et al.
09:15 - 09:30: Comparison and validation of internal tides models for global ocean: Loren Carrere et al.
09:30 - 09:45: Comparison of internal gravity wave spectra in high-resolution global simulations with observations: Brian Arbic et al.
09:45 - 10:00: Global internal tides from satellite altimetry: Next-generation internal tide model and internal tide oceanic tomography: Zhongxiang Zhao
10:00 - 10:15: Solving the mesoscale and internal tide sea surface height signatures in a single massive inversion using a variational approach: Clement Ubelmann et al.

Poster

Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

COAST_001: Coastal Altimetry Using Ku/Ka-Bands Signals of Opportunity: Results From A Recent Experiment at Platform Harvest : Rashmi Shah et al.
COAST_002: Wet Tropospheric Correction dedicated to hydrological and coastal applications : Bruno Picard et al.
COAST_003: Independent assessment of Microwave Radiometer measurements in coastal zones using tropospheric delays from GNSS: Telmo Vieira et al.
COAST_004: Coastal altimetry with SARAL/AltiKa: Emphasis to Indian mainland coastal region: Aditya Chaudhary et al.
COAST_005: Sea Level anomalies and mesoscale activity using altimetry along the African coats in the eastern tropical Atlantic ocean (OSTST Alti-ETAO project): Habib Boubacar Dieng et al.
COAST_006: Coastal Sea Level along the North Eastern Atlantic Shelf from SAR altimetry: Luciana Fenoglio et al.
COAST_007: Linking Sea Surface Height Variations with Hydrographic Variability around the Greenland Ice Sheet to Improve Understanding of Sea Level Rise: Ian Fenty et al.
COAST_008: COSTA v.1.0: DGFI-TUM Along Track Sea Level Product for ERS-2 and Envisat (1996-2010) in the Mediterranean Sea and in the North Sea: Marcello Passaro et al.
COAST_009: Monitoring sea level and topography of coastal lagoons using satellite radar altimetry: the example of the Arcachon's Bay in the Bay of Biscay: Edward Salameh et al.
COAST_010: A study of the fine-scale dynamics in the North-Western Mediterranean Sea using altimetry, in-situ data and a high resolution regional model.: Alice Carret et al.
COAST_011: Multi-Scale Analysis of Coastal Altimetry Data, Multi-Sensor Observations and Numerical Modelling Over the North Western Mediterranean Sea: Marco Meloni et al.
COAST_012: Evaluation and application of operational altimeter-derived ocean surface current datasets on the NW Atlantic shelf : Hui Feng et al.
COAST_013: Satellite altimetry in the continental shelf of the Southwestern Atlantic, Argentina: Loreley Lago et al.
COAST_014: Campeche Ocean Observing System: Jorge Alejandro Kurczyn Robledo et al.
COAST_015: Coastal Circulation off SW Africa: Ted Strub et al.

Application development for Operations
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

APOP_001: One case study on how satellite and in situ ocean observations help to improve hurricane forecasts: Gustavo Jorge Goni et al.
APOP_002: Value added Sentinel-3A sea level products by the Marine Altimetry L2P-L3 Service operational since end of June 2017: Sabine Philipps et al.
APOP_003: Impacts of oil spill on satellite altimetry measurements: Cheng Yongcun et al.

APOP_004: G-REALM: Investigating the Sentinel-3A data set for the next phase of Operational Lake and Wetland monitoring. : Charon Birkett et al.
APOP_005: NOAA's Jason Products: David Donahue et al.
APOP_006: The quasi-operational 4D-Var ocean data assimilation/prediction system for the western North Pacific at JMA: Toshiyuki Sakurai et al.
APOP_007: Jason-2 and Jason-3 Near-Real Time Products Latency over the Past Year: Donald Richardson et al.
APOP_008: CMEMS SEA LEVEL THEMATIC ASSEMBLY CENTER, ACHIEVEMENTS AND PERSPECTIVES: Yannice Faugere et al.
APOP_009: Reconstruction of the surface ocean topography and associated dynamics using image data assimilation in the prospect of the SWOT mission: Pierre Brasseur
APOP_010: Ocean Surface Altimetry with CyGNSS: Mashburn Jake et al.
APOP_011: On the improvement of high resolution AROME winds for operational wave forecast under cyclonic conditions : validation with altimeters wave data: Lotfi Aouf et al.

Instrument Processing: Measurement and Retracking
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

IPM_001: CryoSat/SIRAL Cal1 Calibration Orbits: Marco Fornari et al.
IPM_002: CryoSat SAR/SARin L1B products: BaselineC assessment and improvements towards BaselineD: Michele Scagliola et al.
IPM_003: S6 P4 GPP: The Sentinel-6 Poseidon-4 Ground Processor Prototype. New simulation results.: Eduard Makhoul et al.
IPM_004: Sentinel-6/Poseidon-4 altimeter end-to-end simulator to assess the global mission performances: Jeremie Aublanc et al.

Instrument Processing: Propagation, Wind Speed and Sea State Bias
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

IPC_001: Updated Jason-3 wind speed and SSB solutions (2D and 3D): Ngan Tran et al.

Others (poster only)
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

OTH_001: THE OCEAN SURFACE TOPOGRAPHY SENTINEL-6/JASON-CS SATELLITES: Luisella Giulicchi et al.
OTH_002: Sentinel-6 Poseidon-4 L1B simulator: end-to-end performance evaluation from model-based waveforms: Lisa Recchia et al.
OTH_003: Study of Ocean-Tropical Cyclone interactions with multisensor observations: Clément Combot et al.
OTH_004: Storm waves sharpening in the Agulhas current: satellite observations and modeling: Yves Quilfen
OTH_005: A new look at the Ku-C backscatter relationship to analyze sigmabloom: Jean Tournadre et al.
OTH_006: A revisit of global ocean smooth surface conditions and temporal changes using the Topex-to- Jason altimeter time series data: Doug Vandemark et al.

Outreach, Education and Altimetric Data Services
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

OUT_001: Broadview radar altimetry toolbox: Albert Garcia-Mondejar et al.
OUT_002: SAR ALTIMETRY PROCESSING ON DEMAND SERVICE FOR CRYOSAT-2 AND SENTINEL-3 AT ESA G-POD: Jérôme Benveniste et al.
OUT_003: Aviso+ products & services: what's new?: Vinca Rosmorduc et al.
OUT_004: Outreaching hydrology from space & SWOT: Vinca Rosmorduc et al.
OUT_005: ArgoHydro, Hydrology in the classroom: Danielle De Staerke et al.
OUT_006: SAR-RDSAR: A new Service on G-POD for SAR and RDSAR Products: Christopher Buchhaupt et al.
OUT_007: NOAA Scientific Data Stewardship for Ocean Surface Topography Mission (OSTM)/Jason-2 and Jason-3 Products: Yongsheng Zhang et al.
OUT_008: Access to Sentinel-3 Marine Center data: Bruno Lucas et al.
OUT_009: NOAA Coastwatch/Oceanwatch Altimetry Products: Jessica Burns et al.
OUT_010: X-TRACK regional altimeter products for coastal applications: Fabien Léger et al.

Precision Orbit Determination
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

POD_001: Impact of the next foreseen IERS mean pole model (linear) on altimeter satellite precise orbits, validation of updated measurement models (DORIS antenna phase maps and satellite geometry): Hanane Aït-Lakbir et al.
POD_002: Sentinel-3 orbit determination at the Copernicus POD Service: Jaime Fernández et al.
POD_003: Comparison of SLR station biases: Franck Reinquin et al.

Quantifying Errors and Uncertainties in Altimetry data
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

ERR_001: Continuing the Global Mean Sea Level reference record with Jason-CS / Sentinel-6: Lionel Zawadzki et al.
ERR_002: Characterization of the Errors of Sentinel-3A Small Scale Content in SAR mode: Sylvie Labroue et al.
ERR_003: Eddy detection, spectral, and tide gage evaluation of JPL Gridded Altimetry.: Victor Zlotnicki et al.
ERR_004: Improving Altimetry's Ocean De-aliasing Correction Using Daily GRACE Updates : Jennifer Bonin et al.

Regional and Global CAL/VAL for Assembling a Climate Data Record
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

CVL_001: Fiducial Reference Measurements for Satellite Altimetry Calibration: Stelios Mertikas et al.
CVL_002: Multi-mission Calibrations results at the Permanent Facility for Altimetry Calibration in west Crete, Greece attaining Fiducial Reference Measurement Standards: Stelios Mertikas et al.
CVL_003: Sentinel-3 Transponder Calibration Results: Albert Garcia-Mondejar et al.
CVL_004: The Sentinel-3A SRAL Instrument Calibration Monitoring: Pablo Garcia et al.
CVL_005: Sentinel-3 calibration and validation in Bass Strait as an extension of the Jason site.: Benoit LEGRESY et al.
CVL_006: Mapping the sealevel for altimetry calibration purpose using the future PAMELI marine ASV around the Aix Island sea-level observatory: Valérie Ballu et al.
CVL_007: Regional in situ CalVal of satellite altimeter range at non-dedicated sites: Mathilde Cancet et al.
CVL_008: Analysis of Measurements from a Lidar Instrument for Sea Level and Sea State Studies: Dallas Masters et al.
CVL_009: CONTRIBUTION OF IBIZA, ESTARTIT AND BARCELONA HARBOURS SITES FOR ALTIMETER CALIBRATIONS: Juan Jose Martinez-Benjamin et al.
CVL_010: Calibration and Validation of altimeter observations and models by means of global multi-mission crossover analysis : Denise Dettmering et al.
CVL_011: Results from Inter-Satellite and Independent Calibration and Validation for Jason-2 and Jason-3: Jean-Damien DESJONQUERES et al.
CVL_012: Global Jason-2 Data Quality Assessment on the new Long Repeat Orbit : Hélène Roinard et al.
CVL_013: Global Ocean Data Quality Assessment of SARAL/AltiKa: Annabelle Ollivier et al.
CVL_014: Envisat ocean altimetry second reprocessing on going: Annabelle Ollivier et al.
CVL_015: Global Hy-2a Data Quality Assessment Over Ocean: Ghita Jettou et al.
CVL_016: Performances and assessment of Cryosat-2 and Sentinel-3A SARM over ocean inferred from existing ground processing chains.: Matthias Raynal et al.
CVL_017: CryoSat-2 Ocean Altimetry Assessment: Ernst Schrama et al.
CVL_018: Assessment of TOPEX reprocessed data on the Mean Sea level using several independant approaches: Michael Ablain et al.
CVL_019: Assessment of Revised TOPEX/Jason Global and Regional Mean Sea Level Estimates Referenced to ITRF2014: Brian Beckley et al.

Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

SC1_001: Assessment of the AVISO Mean Seal Level (MSL) indicator with an integrative approach: Michael Ablain et al.
SC1_002: Updates to and Reanalysis of the CU Global Mean Sea Level Climate Data Record: Dallas Masters et al.
SC1_003: Sea level budget closure: status and prospects from an integrative study within ESA's Climate Change Initiative: Martin Horwath et al.
SC1_004: Revisited Earth Energy imbalance from the sea level budget over 2005-2015: Alejandro Blazquez et al.
SC1_005: Teleconnection between the Atlantic Meridional Overturning Circulation and the Mediterranean Sea level: Denis Volkov et al.

SC1_006: Assessment of ocean models in the Mediterranean Sea and Black Sea against altimetry and gravity measurements: Luciana Fenoglio et al.
SC1_007: Reconstructed long-term sea level variability in the North Atlantic Ocean: Yongcun Cheng et al.
SC1_008: Seasonality Change in North Atlantic Sea Level and Forcing Parameters: Martina Ricko et al.
SC1_009: Dueling Climate Cycles Intensified Sea Level Swings in the Pacific: Y. Tony Song
SC1_010: Has the deep ocean warmed in the subtropical South Pacific?: Denis Volkov et al.

Science II: Large Scale Ocean Circulation Variability and Change
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

SC2_001: Estimation of vertical velocities associated with large scale dynamics in the Atlantic ocean.: alban lazar et al.
SC2_002: Quantifying uncertainties on regional sea level change induced by multidecadal intrinsic oceanic variability: Thierry Penduff et al.
SC2_003: A Western Tropical Atlantic Circulation Analysis Using Statistics and Satellites: Frédéric Haykal et al.
SC2_004: Investigation of the intra-annual variability of the North Equatorial Counter Current/ North Brazil Current eddies and of the instability waves of the North tropical Atlantic Ocean using satellite altimetry and Empirical Mode Decomposition: Jean-Luc Mélice et al.
SC2_005: The Brazil Current Variability from XBT data and satellite altimetry: Marlos Goes
SC2_006: Performance of MERCATOR operational model at the Brazil Malvinas confluence: Camila Artana et al.
SC2_007: Malvinas current dynamics from in situ and satellite altimetry data: Martin Saraceno et al.
SC2_008: Satellite altimetry and current-meter velocities in the Malvinas Current at 41°S: comparisons and modes of variations: Ramiro Ferrari et al.
SC2_009: A reconstructed South Atlantic Meridional Overturning Circulation time series since 1870.: Hosmay Lopez et al.
SC2_010: Arctic Freshwater fluxes with EO data and first results: Ole Baltazar Andersen et al.
SC2_011: Learning from large-ensemble ocean simulations to better interpret satellite and in-situ ocean data. - The Occiput large-ensemble dataset and some applications -: Stéphanie Leroux et al.

Science III: Mesoscale and sub-mesoscale oceanography
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

SC3_001: On the permeability of the Malvinas Current: Nicolás Bodnariuk et al.
SC3_002: Using kinetic energy measurements from altimetry to detect shifts in the positions of fronts in the Southern Ocean: Don Chambers
SC3_003: Influence of Mesoscale Eddies on the Deep Ocean Dynamics over the East Pacific Rise: Xinfeng Liang
SC3_004: Effects of westward mountain-gap wind jets on the Red Sea Eastern Boundary Current and the mesoscale eddy field: Menezes Viviane et al.
SC3_005: Salinity advection and Rossby waves in northern Indian Ocean: Xiaosu Xie et al.
SC3_006: Forcing of mesoscale eddy kinetic energy variability in the southern subtropical Indian Ocean, from satellite altimeter and scatterometer data: Andrew Delman et al.
SC3_007: Diagnosing ocean eddy heat and salt fluxes from satellite altimetry and Argo profile data: Oleg Melnichenko et al.
SC3_008: Using ADCP data and altimetry to evaluate high-wavenumber variability in the California Current and the tropics: Sarah Gille et al.
SC3_009: Global wavenumber spectra from SARAL/Altika observations: Oscar Vergara et al.
SC3_010: Spectral signatures of the tropical Pacific dynamics from model and altimetry: A focus on the meso/submesoscale range: Lionel Gourdeau et al.
SC3_011: Synergetic use of surface drifters and altimetry to increase resolution and accuracy of maps of sea level anomaly in the Gulf of Mexico: Sandrine Mulet et al.
SC3_012: Analog data-driven strategies for the reconstruction of altimeter-derived SSH fields: ronan fablet
SC3_013: A new method to detect mesoscale eddies in satellite records: Fabricio Oliveira et al.
SC3_014: Mesoscale Geostrophic Currents and Optimal SSH Mapping: Kathleen Dohan
SC3_015: Upcoming high-resolution regional products of Sea Level Anomaly from Dynamic Interpolation: Clement Ubelmann et al.
SC3_016: Rafting behavior of Scopoli's shearwaters: a proxy to describe surface currents in the western Mediterranean Sea?: Antonio Sánchez-Román et al.
SC3_017: Evaluating CMEMS forecast model products in the western Mediterranean using altimetry, an eddy tracker, and multiplatform in situ data: Evan Mason et al.
SC3_018: The DUACS-DT2018 reprocessed sea level time series soon available in CMEMS: Maxime BALLAROTTA et al.
SC3_019: Impact of the assimilation of high-frequency data in a regional model with high resolution: Mounir Benkiran et al.
SC3_020: Validation of the GlobCurrent surface current products in Australia: Mathilde Cancet et al.
SC3_021: 24 year mesoscale eddy trajectory atlas on AVISO: Antoine Delepoulle et al.

SC3_022: Long-range correlations in altimetric sea level anomaly associated with long-living mesoscale eddies: Christopher Roach et al.
SC3_023: Offshore transport of POC in the California Current System due to mesoscale eddies: Caitlin Amos et al.
SC3_024: Physical and Biological Implications of Agulhas Eddy Signatures: Sheekela Baker-Yeboah et al.
SC3_025: Measuring currents, ice drift, and waves from space: \\ the Sea Surface KInematics Multiscale monitoring (SKIM) concept: Fabrice Ardhuin et al.
SC3_026: Characterizing mesoscale eddies in the Bay of Bengal: Relative performance of Nadir versus Swath Altimeter: Neeraj Agarwal et al.
SC3_027: On the spatial scale resolved by the future SWOT KaRIN measurement over the ocean: Jinbo Wang et al.
SC3_028: Impact of Swot altimetry missions to Ocean analysis and forecast system: Mounir Benkiran et al.
SC3_029: Realistic SSH scenes for preparing SWOT: the NATL60 1/60° North Atlantic Ocean simulations: Julien Le Sommer et al.

Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

SC4_001: HyDrones, an innovative UAV embedded light altimeter to monitor continental water bodies: toward a new Cal/Val in-situ solution for future altimetry missions: Jean-Christophe Poisson et al.
SC4_002: Evaluation of the Sentinel-3 Hydrologic Altimetry Processor prototypE (SHAPE) methods: Albert Garcia-Mondejar et al.
SC4_003: On using water surface slope for estimating discharge in critical backwater conditions: case study of the Poyang lake, China.: Adrien Paris et al.
SC4_004: Water level estimation in the Mekong River Basin based on a classification of CryoSat-2 SAR data: Eva Boergens et al.
SC4_005: Reassessment of the ICESAT-1 data over the Amazon waters: Daniel MOREIRA et al.
SC4_006: Climate Indexes and altimetry-based water levels in Amazon basin rivers: Mylena VIEIRA SILVA et al.
SC4_007: CAUSES AND CONSEQUENCES of the 2014 FLOOD on the MADEIRA RIVER: Jossandra ALVES DAMASCENO et al.
SC4_008: Validation of a large data set of SARAL water levels in the Amazon basin: Taina CONCHY et al.
SC4_009: Evaluation of the SENTINEL-3A water levels over large hydrological basins: Stéphane Calmant et al.
SC4_010: A database of hydrology targets for the new DEM onboard Jason3: Denis BLUMSTEIN et al.
SC4_011: Long term series of discharges distributed in the Congo River basin from hydrological modelling and satellite altimetry: Adrien Paris et al.
SC4_012: Recent evolutions and quality assessment of CryoSat products: Jerome Bouffard et al.
SC4_013: Sentinel-3A for sea-ice and land ice: Salvatore Dinardo et al.
SC4_014: The CryoSat SciEnce-oriented data ANalysis over sea-ICE areas project: Pierre Fabry et al.
SC4_015: SPICE: Sentinel-3 Performance Improvement for Ice Sheets: Malcolm McMillan et al.

The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

GEO_001: Results from GOCE++ Dynamical Coastal Topography and tide gauge unification using altimetry and GOCE: Ole Baltazar Andersen et al.
GEO_002: Geomed2: gravimetric versus combined geoid model : Sean Bruinsma et al.
GEO_003: A new OGMOC mean dynamic topography model – DTU17MDT.: Per Knudsen et al.
GEO_004: GOCE User Toolbox and Tutorial.: Per Knudsen et al.
GEO_005: State-of-the-Art Mean Sea Surface and Geoid Model assessment in the Arctic and implications for Sea Ice Freeboard Retrieval: Henriette Skourup et al.
GEO_006: Global and regional evaluation of recent Mean Sea Surfaces using the first year of Sentinel-3 data and impact for updating the DTU15MSS: Heidi Villadsen et al.

Tides, internal tides and high-frequency processes
Thu, Oct 26 2017, 14:00 - 18:00 - Concerto Ballroom

TID_001: Experiments with tidal analysis and assimilation of CryoSat-2 altimetry in the Weddell Sea and on adjoining ice shelves: Edward Zaron
TID_002: Towards further improving DTU global ocean tide model in shallow waters and Polar Seas: Yongcun Cheng et al.
TID_003: Improvement of the Arctic Ocean Bathymetry and Regional Tide Atlas – first results from the CP4O initiative: Ole Baltazar Andersen et al.
TID_004: Improving the Dynamic Atmospheric Correction for delayed-time and real-time applications of altimetry: Loren Carrere et al.
TID_005: Bathymetry improvement and tidal modeling at regional scales: Mathilde Cancet et al.
TID_006: Estimating tidal constants in the near-shore domain from Jason1-2-3 archive: a case study for the northern Bay of Bengal: Marufa Ishaque et al.
TID_007: Geodetic survey of the freshwater front of the Ganges-Brahmaputra freshwater plume in the northern Bay of Bengal from CalNaGeo GNSS device: Fabien Durand et al.
TID_008: SWOT in the Tropics: High-frequency and small-scale dynamics of sea surface height around New-Caledonia from in situ observations: Guillaume SERAZIN et al.

Abstract details

Further understanding the global mean sea level record over the satellite era

Christopher Watson (University of Tasmania, Australia); Xianyao Chen (Ocean University of China and Qingdao National Laboratory of Marine Science and Technology, China); Xuebin Zhang (CSIRO, Australia); John Church (University of New South Wales, Australia); Matt King (University of Tasmania, Australia); Didier Monselesan (CSIRO, Australia); Benoit Legresy (CSIRO, Australia); Christopher Harig (University of Arizona, USA); Sam Royston (University of Tasmania, Australia)

Session: Science Keynotes Session
Presentation type: Keynote/invited

Abstract:
The satellite era time series of Global Mean Sea Level (GMSL) is a seminal climate data record that describes one of the most robust manifestations of climate change. Accurate estimates of the rate of change and possible acceleration of sea level are of major importance for evaluating model projections and for adaptation planning. Watson et al. (2015) investigated the magnitude of inter- and intra-mission biases in sea level, and in particular, the stability of those biases over time. That work suggested that time variable biases, in particular over the early part of the TOPEX record were significantly different to zero, implying a small over estimation in the rate of sea level change. Subsequently, Chen et al. (2017) further investigated the updated Watson et al. (2015) results and reported an improved instantaneous closure of the sea level budget over the altimeter era. Here we summarise these findings and detail recent insights in order to further understand and assess the evolution of the global mean sea level record.

Corresponding author:
Christopher Watson (**University of Tasmania**, **Australia**), cwatson@utas.edu.au

Temporal and Spatial Changes in the Dominance of the Wind-driven and Density-driven processes in the South Atlantic MOC

Shenfu Dong (CIMAS, Univ. of Miami and NOAA/AOML, United States); Gustavo Goni (NOAA/AOML, USA)

Session: Science Keynotes Session
Presentation type: Keynote/invited

Abstract:
Satellite altimetry and in situ data are used to estimate the meridional overturning circulation (MOC) and meridional heat transport (MHT) in the South Atlantic since 1993 in the region between 20°S and 35°S. Analysis of the 24-year time series of MOC and MHT indicates that the interannual variations in the MOC at different latitudes are statistically correlated, with MOC at 35°S leading that at 20°S by about 20 months. Results also show that the dominance of the geostrophic (density-driven) and Ekman (wind-driven) transports on the interannual variations in the MOC and MHT varies with time and latitude. The time series indicate that at 20°S the Ekman component plays a larger role than the density-driven component. On the other hand, at 35°S the geostrophic component dominates over most of study period, except during 2007-2012 when the Ekman component dominates. Further analysis shows that, consistent with results in other regions, the oceanic heat convergence drives the heat content changes in the study region on interannual time scale, which in turn forces heat fluxes into the atmosphere. The MHT at both 20°S and 35°S appear to contribute equally to the heat convergence in the region. An important key result obtained is that the MOC exhibits positive anomalies since 2013.
Time series of the MOC and MHT in the South Atlantic can be found at:
http://www.aoml.noaa.gov/phod/samoc_altimetry/data_all.php.
Corresponding author:
Shenfu Dong (**CIMAS, Univ. of Miami and NOAA/AOML**, **United States**), shenfu.dong@noaa.gov

Satellite-derived ocean heat content variability: implications for weather and climate studies

Lynn Shay (University of Miami/RSMAS, United States); Jodi Brewster (University Of Miami/RSMAS, United States); Eileen Maturi (NOAA/NESDIS, United States); David Donahue (NOAA/NESDIS, United States); Eric Leuliette (NOAA/NESDIS, United States); Benjamin Jaimes (University of Miami/RSMAS, United States); Jun Zhang (NOAA/HRD, United States)

Session: Science Keynotes Session
Presentation type: Keynote/invited

Abstract:
A 20-year time series of satellite-derived oceanic heat content (OHC) estimates relative to 26C has been generated from quality controlled sea surface height anomaly (SSHA) fields from various missions (e.g., TOPEX, Jason 1-3, Envisat, SARAL, Cryosat-2, Sentinel-3A) cast into a reduced-gravity ocean model and a daily ocean climatology of mean isotherm depths and reduced gravities. Over this time/space series, two or more satellites have been operational at any given time to resolve mesoscale ocean variability. Sea surface temperatures (SST) from the NESDIS Geopolar Blended product and Remote Sensing System's Optimally Interpolated product represent the surface boundary condition to produce isotherm depths of the 20 and 26C (D20, D26), mixed layer depth, and OHC for use in weather (tropical cyclone) and climate (ENSO) studies. For the operational product suite, SSHA data from 10 days before the date in question are used. By contrast, the reprocessed data uses SSHA data from 5 days before and 5 days after the date of interest for more detailed research product including those with longer repeat tracks so mesoscale oceanic features were not unnaturally stretched out. The resulting data products date back to 1998 for three basins. As part of the product generation and updating the climatologies, satellite-derived estimates have been compared to over a million in-situ thermal measurements from multiple platforms (e.g., Argo and APEX Floats, ship transects, moorings) to assess biases and uncertainties in spaced-based estimates and to adjust climatologies. Central to this assessment is the need for sustained moorings in the tropics that provide the evolving isotherm depths and OHC variations for weather and climate studies.

Implications of OHC variations on hurricane passage will be discussed using historical cases such as Earl over the western Atlantic Ocean basin in 2010 (during NASA GRIP), Patricia over the eastern Pacific Ocean basin (2015) and more recently Harvey (2017) over the Gulf of Mexico. Prior to Patricia, the strong El Nino conditions increased the SSHA by more than 12 cm as satellite-derived OHC values were nearly twice those under non El Nino conditions consistent with Argo float data. More recently, Harvey (2017) rapidly intensified over a warm eddy that was separated from the Loop Current in the eastern Gulf of Mexico. Space-based OHC estimates were consistent with those determined from airborne expendable bathythermographs deployed from NOAA research aircraft and APEX-EM profiling floats.

Corresponding author:
Lynn Shay (**University of Miami/RSMAS**, **United States**), nshay@rsmas.miami.edu

Analysis of small icebergs (<10km²) size and freeboard around Greeland and Antarctica using Cryosat SARin data

Jean Tournadre (IFREMER, France); Nicolad Bouhier (IFREMER, France)

Session: Science Keynotes Session
Presentation type: Keynote/invited

Abstract:
Conventional pulse limited (LRM) altimetry is a powerful tool to detect and characterize small (<10km²) icebergs and to measure the profile of large ones (>16km in length). The Cryosat-2 SIRAL is the first altimeter that can operate in two new modes over the ocean besides the classical LRM: the Delay Doppler or SAR and the SAR Interferometric (SARin) modes. Over most of the sea-ice free ocean, SIRAL operates in LRM mode and the classical iceberg detection algorithm, based on the detection of parabolas in the waveform space, can be applied without modification. It can also be applied to the Reduced SAR or pseudo-LRM data computed from SAR and SARin data. In SAR mode, iceberg signatures are bright spots in the thermal noise part of the waveform. They can be easily detected using classical image processing tools.
The SIRAL SARin mode is the most advanced mode, primary used around the ice sheet margins. SIRAL performs synthetic aperture processing and uses a second antenna as an interferometer to determine the across–track angle to the earliest radar returns. The SARin mode provides thus the exact surface location being measured. In SARin mode, the coherence between the two antennas signals can be used to insure the presence of scatterers above the sea surface and to improve the SAR waveform detection algorithm by reducing the probability of false alarm. It also allows to better delineate the icebergs within the waveform. Furthermore, in SARin mode the range analysis window (240m) is four times larger than that in LRM and SAR mode, which double the altimeter's detection swath. However, the main interest of SARin mode is the possibility, for the first time for a satellite sensor, to precisely locate the surface scatterer and to allow the estimation of the iceberg free-board from the phase difference. The high across-track accuracy also allows to map the iceberg topography at an unprecedented resolution. It is thus possible to compute the iceberg volume.
The whole archive of SARin data has been processed to produce a database of small icebergs characteristics, location (lat,lon), time, area, free-board, backscatter around Greenland and Antarctica. The figure which presents the area and freeboard of the icebergs detected near Antarctica from 2010 to 2016 clearly shows the regional variations of the freeboard and area that could reflect the thickness of the ice sheet from which the icebergs calved . The distribution free-board has been regionally analyzed and compared to sea ice thickness data from the BEDMAP2 and NASA Operation IceBridge (OIB) datasets to better understand the origin of the small icebergs. The size distribution has also been regionally computed and analyzed. The distributions follows quite well power law with -1.5 slope. This kind of distribution was already found for the LRM detected icebergs and from visible images analysis and is characteristic of fragile fragmentation.
Figure caption: Freeboard (left) and area (right) of the SARin detected icebergsfor the 2010-2016 period.

Corresponding author:
Jean Tournadre (**IFREMER**, **France**), jean.tournadre@ifremer.fr

Understanding the Acceleration of Sea Level Rise During the Altimeter Era

Robert Steven Nerem (University of Colorado, United States); Brian Beckley (NASA Goddard Space Flight Center, USA); John Fasullo (NCAR, USA); Ben Hamlington (Old Dominion University, USA); Dallas Masters (University of Colorado, USA); Gary Mitchum (University of South Florida, USA)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Oral

Abstract:
Over the last 25 years, data from TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3 have been used to observe changes in global mean sea level (GMSL). A rate of rise of ~3 mm/year has been observed. However, observing a possible acceleration in the rate of sea level rise is more challenging and pushes the limits of the observing system accuracy. This presentation will examine our first attempts at detecting an acceleration in the altimeter sea level record. First, the errors in the altimetry will be discussed in the context of tide gauge validation of the altimeter sea level record, including new improvements to the TOPEX record. We will discuss the influence of interannual variability in GMSL on acceleration estimates and how this influence can be mitigated. We will also discuss the role of decadal variability and how it might influence the determination of acceleration, including the role that the 1991 eruption of Mount Pinatubo had on the altimeter sea level record. Finally, we will present an estimate of the climate-driven acceleration of GMSL over the 25-year record, including the importance of using the tide gauge validation to place an error bar on the acceleration estimate.

Corresponding author:
Robert Steven Nerem (**University of Colorado**, **United States**), nerem@colorado.edu

Impact of Pacific Ocean Variability on Global Mean Sea Level

Se-Hyeon Cheon (Old Dominion University, United States); Benjamin Hamlington (Old Dominion University, United States); Robert Leben (University of Colorado at Boulder, United States); J.T. Reager (NASA JPL, United States)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Oral

Abstract:
The impact of interannual to decadal variability on sea level has been heavily investigated in recent years. Particular focus has been put on the relationship between the El Nino-Southern Oscillation (ENSO) and interannual variability in global mean sea level (GMSL). The positive correlation between well-known ENSO indices and detrended GMSL has led to the attribution of many of the rises and falls in global sea levels to ENSO, with an over-generalization of the relationship often following. Several studies have linked the effect of ENSO on GMSL primarily to the movement of water between ocean and land, while others have highlighted a significant steric contribution that adds to the mass-related signal. Here, we adopt a more general approach, avoiding an index-based approach to find coupled modes of variability in modern observations of the different components of sea level change. Using such an approach, the impact of Pacific Ocean climate variability on GMSL can be quantified and separated into steric and mass contributions. Furthermore, interannual variability associated with ENSO can be preliminarily separated from lower frequency variability often attributed to the Pacific Decadal Oscillation (PDO). Finally, closure is obtained in the global sea level budget on interannual to decadal timescales and used to explain the sharp recent increase in global sea level.

Corresponding author:
Se-Hyeon Cheon (**Old Dominion University**, **United States**), shcheon95@gmail.com

Sea Level Monitoring in the coastal zone: impact of retracking and correction choices

Paolo Cipollini (National Oceanography Centre, United Kingdom); Andrew Shaw (SKYMAT Ltd, United Kingdom); Francisco Calafat (National Oceanography Centre, United Kingdom); Nadim Dayoub (National Oceanography Centre, United Kingdom); Américo Ambrózio (DEIMOS/ESRIN, Italy); Marco Restano (SERCO/ESRIN, Italy); Jérôme Benveniste (ESA/ESRIN, Italy)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Oral

Abstract:
During the second phase (2014-2017) of the ESA Sea Level CCI Project (SL_cci) particular efforts have been put on improving the retrieval of sea level from altimeters in the coastal zone. These efforts aim at filling the observational gap between the rates of sea level rise (SLR) from tide gauges (at the coast) and the rates over the open ocean (from altimetry). Progress in coastal altimetry since the early 2000s has been steady, providing scope for filling this gap, and showing some encouraging results.

Within a dedicate workpackage of the SL_cci, NOC and SkyMAT Ltd have been looking at the impact of specialized retracking (ALES) and correction choices for the Wet Tropospheric correction (WTC) and Dry tropospheric correction (DTC) on rates of SLR retrieved in the coastal zone from along-track Jason-1 and Jason-2 measurements over 2002-2015. The study has focused on two wide coastal regions (A: Western European coast; and B: SE Australian coast) with different oceanographic conditions and tidal regimes. As terms of comparison we have taken: SLR rates from TGs; the gridded SL_cci v2.0 SLR rates, re-interpolated over the altimetric tracks; and the SLR rates from along-track altimetric datasets processed with conventional retracking (SGDR and RADS).

Our results show that a local comparison of altimeter-derived SLR rates with those from tide gauges remains problematic, due to the significant variability of SLR at short (tens of km) spatial scales. Over Region A the SLR rates from along-track altimetry do not match well the mean rates from the TGs, but they are closer to the median SLR rate from the TGs; the likely explanation for this is the extreme variability of the SLR rates over this very wide region, especially over the North Sea. Vertical land motion at the tide gauges is also likely to be a contributing factor to this discrepancy. The agreement improves substantially once the North Sea is excluded from the analysis. Over Region B, where SLR is more homogeneous and TG-derived mean and median trends coincide, the SLR rates computed from along-track altimetry for different datasets and combination of corrections are all very close to those from the TGs.

The choice of a particular retracker does not seem to strongly affect the results: the SLR rate curves as a function of distance from coast for the various data sets are all within 0.5 mm/yr from each other, which is the expected level of accuracy in the estimated trends. However the curves with the ALES dataset are the closest to the SL_cci curve in both regions, and approach the TG-derived rates in the last few km from the coastline in both regions, which is encouraging for the use of this specialized coastal retracker. Another important point is that ALES recovers a significantly higher percentage of valid range measurements in the last few km from the coast than the other datasets, as we illustrate in detail.

The choice of WTC has some noticeable impact on the SLR rates, but the differences are still at the level of the expected noise (~0.5 mm/yr). The GPD+ WTC by University of Porto, which is now recommended by the SL_cci project, yields the highest rates amongst all the considered WTC. The combination of GPD+ and ALES gives the best match to the TG-derived rates (and the closest to the reference SL_cci interpolated rates) over Region B.

The sensitivity of the SLR rates to the choice of DTC is very small, at the level of 0.1 mm/yr, so that no firm recommendation can be made on the choice of DTC in the coastal zone.

Interestingly, in region B we find a mild spatial trend of the rate of SLR, increasing towards the coast at approximately 0.01 mm/yr/km in the last 50 km. While not very large this is important as it would augment the impact of sea level rise on society, which happens predominantly at the coast. This coastal trend increase is clearest for the combination ALES and GPD+ in Region B.

In summary we have found over two separate regions that the combination of coastal retracking and ad hoc correction choices (in particular the GPD+) yields rates of SRL that compare to those from tide gauges almost as well (and in some cases better) than the rates from conventionally retracked datasets and standard correction models.
Corresponding author:

Paolo Cipollini (**National Oceanography Centre**, **United Kingdom**), cipo@noc.ac.uk

Evidence of coastal sea level changes along the east coast of United States associated with the Florida Current transport and heat content using satellite altimetry and hydrographic observations

Ricardo Domingues (UM / CIMAS | NOAA / AOML, United States); Gustavo Goni (NOAA / AOML, USA); Molly Baringer (NOAA / AOML, USA); Denis Volkov (UM / CIMAS | NOAA / AOML, USA)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Oral

Abstract:
Extensive low-lying areas along the east coast of United States are currently affected by recurrent tidal flooding events that have been increasing in frequency and magnitude. These events pose threat for coastal communities and infrastructure and requires efforts to mitigate potential damage and improve resilience. The dynamics associated with the intense Florida Current flow across the Florida Straits sustains a sea-level difference of over 1m between the eastern United States coast, and the Bahamas. Changes in the Florida Current dynamics can, therefore, drive relevant sea-level variability at both sides of the Florida Straits at various time-scales, with a decrease (increase) in transport being associated with an increase (decrease) in coastal sea level along the U.S. coast. In this presentation, data from satellite altimetry, tide gauges, hydrographic surveys and cable-derived transports reveals that changes in the Florida Current transport and temperature provide important sources of coastal sea level variability along the east coast of the United States. On seasonal time-scales, analysis reveals that westward propagating sea-height anomaly signals originated in the east North Atlantic Ocean can affect the Florida Current transport, leading to sea-level changes that can be as large as 20 cm on both sides of the Florida Straits. On interannual time-scales, analysis of the satellite altimetry record and sea level data derived from tide gauges along the east coast of the United States shows that during 2010-2015 sea level increased south of Cape Hatteras at rates exceeding 25 mm per year (approximately 5 times the global average of ~5 mm per year for the same period). Analysis of a comprehensive set of ocean observations including XBT transects, and hydrographic surveys across the Florida Straits has revealed substantial warming of waters carried by the Florida Current during this period. The entire water column in the Florida Straits shifted from a regime of negative temperature anomalies during 2010-2013 to one of positive temperature anomalies during 2014-2017. It is found that during 2010-2015 warming of the Florida Current accounts for a thermosteric sea level increase of 19 mm per year, which explains most of the sea level trend observed by satellite altimetry and tide gauges south of Cape Hatteras, where the Gulf Stream detaches from the coast.

Corresponding author:
Ricardo Domingues (**UM / CIMAS | NOAA / AOML**, **United States**), ricardo.domingues@noaa.gov

Wave climate observed from satellites: trends and inter-annual variability

Justin Stopa (LOPS, France); Pierre Queffeulou (Ifremer, France); Alexis Mouche (Ifremer, Frace); Fabrice Ardhuin (Ifremer/UBO/IUEM/CNRS, France); Yves Quilfen (Ifremer, France); Bertrand Chapron (Ifremer, France)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Oral

Abstract:
Ocean waves have important implications to society through wave driven inundation. With the expected rise of sea level, dangerous high sea levels driven by waves are important events to understand for mitigation of hazards in the coastal zone. Understanding the wave climate and in particular the wave directionality is of key importance to relate high sea-levels with large-scale wave patterns. In this study we focus on describing the wave climate over the past several decades from satellite data.

While the use of altimeters is driven by the sea level community, these data are sufficiently long for climate studies and have high coverage in space and time making them an attractive source of information for wave studies. Altimeters are limited to describing the significant wave height and wind speed. However, important sea state information regarding wavelengths and directions are not possible from altimeters. This is where data from synthetic aperture radars (SAR) is highly valuable since they effectively estimate wavelengths. While GlobWAVE has made significant strides in producing the quality datasets for both altimeters and SARs, these data were not specifically produced for climate studies. This is the main reason, the European Space Agency (ESA) will conduct a climate change initiative on the sea state (CCI-SeaState). The project will focus on producing the better quality data datasets from satellites including altimeters and SARs. There will be emphasis on estimating sea states in the nearshore and in extreme events and most importantly suitable for climate applications.

In this study we explore the GlobWAVE altimeter and SAR datasets to describe the wave climate. The altimeter dataset starts in 1985 with GEOSAT and we have continuous coverage since 1992. The SAR dataset starts in 1995 with ERS2 (1995-1999) and continues with ENVISAT (2002-2012) and the Sentinel-1 missions (2014-present). Using these datasets we describe the inter-annual variability and trends. This 31-year altimeter and 18-year SAR time series have many important applications to better understand the wave climate. We discuss our results within the context of the ESA Sea State CCI and note areas of research that need further efforts to make them suitable for climate studies.
Corresponding author:
Justin Stopa (**LOPS**, **France**), justin.stopa@ifremer.fr

Comparison of coastal and open ocean sea level trends

Yingli Zhu (College of Marine Science, University of South Florida, United States); Gary Mitchum (College of Marine Science, University of South Florida, United States)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Oral

Abstract:
Global mean seal level over the past century is reconstructed from global measurements from tide gauges on coastlines and islands. These measurements reflect not only sea level variations but also vertical movement of the land on which tide gauges sit. In addition, the sea level variations measured by tide gauges can differ from these over the open ocean due to the coastal ocean dynamics. These features of tide gauge measurements raise the question whether mean sea level derived from tide gauges is able to represent global mean sea level. Several studies compared mean sea level derived from tide gauges with that obtained from altimetry observation that has nearly global coverage, and showed that the linear trends of mean sea level obtained from the two datasets differ over short period (10 years), but agree well with each other over longer periods (longer than 15 years). On one hand, the vertical land motions (VLMs) of tide gauges in some of these studies are estimated with a Glacial Isostatic Adjustment (GIA) model, which would be invalid when other processes like tectonic activities occur; on the other hand, the altimetry data is less accurate when approaching the land. Global Positioning System (GPS) data analysis provides useful information for estimating VLMs and an algorithm for assigning a GPS-derived vertical land motion rate to a tide gauge has been developed. The linear trends of the corrected coastal sea level from tide gauges are calculated and compared with those derived from altimetry over the adjacent deep ocean. Preliminary results show that coastal sea level trends from tide gauges agree well with offshore sea level trends from altimetry in large-scale pattern, but have large differences in some regions, possibly owing to coastal ocean dynamics. Analysis of these differences will be presented at the meeting.
Corresponding author:
Yingli Zhu (**College of Marine Science, University of South Florida**, **United States**), yingli@mail.usf.edu

Progress on Retracked TOPEX Data for the Climate Data Record

Philip Callahan (Jet Propulsion Laboratory, United States); Shailen Desai (Jet Propulsion Laboratory, United States); Nicolas Picot (CNES, France); Jean-Damien Desjonqueres (Jet Propulsion Laboratory, United States); Joshua Willis (Jet Propulsion Laboratory, United States); Thierry Guinle (CNES, France)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
We will report progress on delivering the TOPEX Climate Data Record product. The main efforts for this product are retracking the data to account for waveform leakages and point target response (PTR) changes and updating other components of the record and format to be compatible with Jason GDRs.

Previous reports on this work included:
(1) Determining that leakages limited the use of the Cal-1 data for generating PTRs to the first seven lobes.
(2) Developing methods to extend the PTR to the necessary 30 lobes to reach full accuracy.
(3) Determining that it was not feasible to improve upon the original WFF waveform weights.
(4) Determining that WFF range calibration correction derived from specialized processing of internal calibration data is largely accounted for when the Cal-1 PTRs and earlier noise gates are used in retracking.

The final climate product will include a format as closely aligned with Jason Ver E as possible. CNES is supplying auxiliary geophysical corrections, fields, and orbits updated to the Jason Ver E standards. With these enhancements, a final sea state bias correction will be determined.

To validate the version of retracking incorporating the features listed above, the newest data have been compared to Jason-1 during the TOPEX/Jason-1 colinear phase. Other validation will include: comparison to global geophysical data; comparison with the global set of tide gauges analyzed by the Ray-Beckley group; and waveform simulations with varying PTRs. Details of the retracking and validation work to date will be presented.

(Much of the work reported here is based on work by Joseph McMichael (1) when he was at JPL.)

The work reported here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Corresponding author:
Philip Callahan (**Jet Propulsion Laboratory**, **United States**), philip.s.callahan@jpl.nasa.gov

Evaluating methods to improve the performance of Sentinel-3 SRAL SAR Altimetry in the Coastal and Open Ocean– The SCOOP Project

David Cotton (Satellite Oceanographic Consultants Ltd, United Kingdom); Thomas Moreau (CLS, France); Eduard Makhoul (isardSAT, Catalonia); Mònica Roca (isardSAT, Catalonia); Paolo Cipollini (National Oceanography Centre, United Kingdom); Mathilde Cancet (Noveltis, France); Francisco Martin (Starlab, United Kingdom); Luciana Fenoglio-Marc (University of Bonn, Germany); Marc Naeije (Technical University of Delft, The Netherlands); M Joana Fernandes (University of Porto, Portugal); Marco Restano (SERCO/ESRIN, Italy); Américo Ambrózio (DEIMOS/ESRIN, Italy); Jérôme Benveniste (ESA-ESRIN, Italy)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
The Sentinel-3 satellite, launched by ESA in February 2016 as a part of the Copernicus programme, is the second satellite to operate a SAR mode altimeter.

SCOOP (SAR Altimetry Coastal & Open Ocean Performance) is a project funded under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme Element, started in September 2015, to characterise the expected performance of Sentinel-3 SRAL SAR mode altimeter products, in the coastal zone and open-ocean, and then to develop and evaluate enhancements to the baseline processing scheme in terms of improvements to ocean measurements. There is also a work package 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.
At the end of the project recommendations for further developments and implementations will be provided through a scientific roadmap.

The presentation includes:

- Results of an evaluation of the initial SCOOP Test Data Set (SAR mode and RDSAR) in the Open Ocean and Coastal Zone. This test data set is Cryosat-2 Baseline C data processed to be equivalent to Sentinel-3 baseline SAR and RDSAR product.

- Overview of planned modifications to the processing (in both Doppler Processing to L1B, and in re-tracking to L2), intended to improve on the performance of the baseline product, that will be implemented and evaluated in SCOOP. The modifications are expected to include:

  - Doppler Processing: the independent evaluation of individual processing options such as:
    - ♣ the activation of zero-padding in range (suitable for peaky like waveforms with low SWH)
    - ♣ Inclusion of the intra-burst Hamming window to reduce the impact of the Doppler side-lobes (obtaining a cleaner stack with lower impact of these side-lobes in the noise region after geometry corrections, and leading to a better reproduction of the SAR ocean retracker point target response –PTR)
    - ♣ Azimuth processing using the exact method, useful for surfaces with high topographic variability
    - ♣ Antenna pattern compensation in the Doppler dimension and at stack level (using in a first approach the theoretical antenna model)
  - L2 processing:
    - ♣ L2 processing to be aligned with the L1B processing so that the suitability of each individual Doppler processing baseline can be better understood in terms of geophysical parameters retrieval.

- Some early results from initial test implementations of these modifications.

Corresponding author:
David Cotton (**Satellite Oceanographic Consultants Ltd**, **United Kingdom**), d.cotton@satoc.eu

Investigation of SWH bias in SAR Altimetry mode

Thomas Moreau (CLS, France); Jérémie Aublanc (CLS, France); Pierre Thibaut (CLS, France); Pierre Rieu (CLS, France); François Boy (CNES, France); Nicolas Picot (CNES, France); Constantin Mavrocordatos (ESA/ESTEC, The Netherlands); Franck Bordes (ESA/ESTEC, The Netherlands)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
The satellites, Cryosat-2 and Sentinel-3A, equipped with a synthetic aperture radar altimeter are currently in service on a near-polar orbit, performing range measurements over different types of surfaces (ocean, sea ice, ice sheet and in-land waters). Advantages brought by this radar mode to retrieve geophysical ocean parameters with much higher resolution and precision than conventional pulse-limited altimeters are now well acknowledged. However, even though it offers improved ocean measuring capability, there are still remaining issues around the interpretation of some SAR-mode ocean data along with some questions about the model used to fit the waveforms.
While assessing Cryosat-2 and Sentinel-3A SAR-mode data quality over ocean, it is found that some discrepancies between Pseudo-LRM and SAR-mode in range (few cms), but mostly in SWH (10 to 20 cm), occur above 2 m wave height (and in low sea-state conditions too), and that their difference depends on the significant wave height. As long as the P-LRM and SAR mode data are co-localized, one might have expected that the two radar modes retrieve same significant wave heights. Yet, the differences observed between the two radar modes are not understood, and need to be analysed and worked out.
Recent analysis of SAR-mode altimeter data processed with the application of a Hamming window in azimuth direction (which reduces effectively the side lobe effects), has revealed a better match between SWH retrievals. This suggests a possible inconsistency between the model and data, and particularly raises some concerns about the reliability of the square cardinal sine function which is used to describe the along-track point target response (resulting from the synthetic aperture processing) in the SAR altimeter backscattered waveform model. To tackle this issue, we conducted different analyses: characterization of the azimuthal PTR using transponder, evaluation of the effects of the secondary lobes based on simulations, and a long period data analysis with and without the Hamming weighting function (using the CNES Sentinel-3 prototype processing) whose results are compared with findings from the simulation study.
This activity conducted by CLS in a ESTEC contract and with the CNES support, aims at improving the current SAR-mode data ground processing to further stimulate the generation of higher level quality data for the upcoming Sentinel-3 C/D missions.

Corresponding author:
Thomas Moreau (**CLS**, **France**), tmoreau@cls.fr

New stacking method for removing the SAR sensitivity to swell

François Boy (CNES, France); Thomas Moreau (CLS, FRANCE); Pierre Thibaut (CLS, FRANCE); Pierre Rieu (CLS, FRANCE); Aublanc Jérémie (CLS, FRANCE); Nicolas Picot (CNES, FRANCE); Pierre Femenias (ESA, Italy); Constantin Mavrocordatos (ESA, Netherlands)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
First evidence of swell impact on SAR-mode altimetry has been shown with real data by [Aouf and Phalippou, 2015]. In this study, a comparison of Cryosat-2 SAR-mode derived wave heights with model (MFWAM) has revealed that altimeter measurements are likely biased by ocean swell, and most noticeably for the longest waves and swell fields that are propagating in a direction parallel to the satellite track. During last OSTST held in La Rochelle, France in 2016, several expert groups also emphasized that Sentinel-3 SAR observations are sensitive to swell conditions (in terms of large increase of 20-Hz range noise).

As explained by Moreau et al. [RD 2], the higher along-track resolution provided by SAR altimetry (typically of ~300m for Cryosat-2 and Sentinel-3A SAR mode data) makes it close to the wavelength scales of ocean swell with the consequence that the Gaussian statistics of heights and slopes in the range/Doppler resolution cells are no longer satisfied. This may cause distorted echoes shape and subsequent impacts on parameter retrievals. In addition, the multi-looking process stacks the data within 2,5 seconds which may also disturb the homogeneity of looks within the stack in such swell waves conditions where the ocean surface moves quickly.

ESA and CNES jointly run studies with the support of CLS to test different approaches with the objective to reduce the swell impact on SAR mode performances. In this presentation, we focus on a new stacking method, originally developed and used by Thales Alenia Space [Phalippou and Demeester, 2011] to assess the Cryosat-2 SAR mode performances. After the beam sharpening, using an along track FFT as it is currently performed), all the beams contained in a radar cycle (4 bursts of 64 beams) are, first, range migrated with respect to the nadir beam, and then averaged. This approach brings the benefit to stack the data within a much shorter time laps (~50ms) than in the current multi-looking process.

This new stacking method has been evaluated on one cycle of Sentinel-3 SAR mode and performances have been assessed and compared to operational products. We demonstrate that the swell sensitivity is totally removed and that the range/SWH range noises are even improved by 15 to 40% depending on wave heights. Spectral analyses on SLA and SWH also confirm that the SAR mode finer spatial resolution is maintained in Open Ocean. Given these very promising results, the relevance of using such method for Sentinel-3 operational processing is discussed too. Moreover, this stacking approach is already part of the incoming Sentinel-6 science processors (LR-RMC).

RD 1 L. Aouf (Meteo France), L. Phalippou (TAS-F), “On the signature of swell for the Cryosat-2 SAR-mode wave data”, Oral presentation, Ocean Surface Topography Science Team 2015, October 19-23
RD 2 T. Moreau et al., “Effect of swell and wind-waves on the altimeter-derived estimates: Analyzing real and simulated data”, Oral presentation, Ocean Surface Topography Science Team 2016, November 1-4

Corresponding author:
François Boy (**CNES**, **France**), francois.boy@cnes.fr

Pulse-to-Pulse Correlation Effects on high PRF Low Resolution Mode Altimeters

Alejandro Egido (NOAA, United States); Walter Smith (NOAA, USA); Eric Leuliettte (NOAA, USA)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
The correlation of consecutive pulses on nadir looking pulse limited altimeters, what is now commonly referred to as low resolution mode (LRM) altimeters, was a significant topic of study during earlier stages of radar satellite altimetry to determine the maximum pulse repetition rate at which statistically independent samples could be obtained from this type of measurements. Seminal works by Walsh, and Rodríguez and Martin, had significant influence in the design and development of radar altimeters, from the Topex/Poseidon Mission to the Jason altimeter series. In order to make the satellite operation efficient at the same time as retrieving the most information out of the altimeter pulses, these altimeters were designed so that their echoes were mostly decorrelated between each other.

In 1998 the introduction of the delay/Doppler altimetry (DDA) concept posed a new paradigm in the field of radar altimetry. This processing technique, based on the coherent processing of radar echoes transmitted in bursts, reduces the altimeter footprint along the flight direction by an order of magnitude with respect to LRM altimeters, and achieves a significant increase in the effective number of looks (ENL) of the final multilooked waveforms, leading to a noise reduction in the estimation of geophysical parameters.

Unlike in conventional altimetry, DDA requires correlation of the echoes within the bursts to apply the coherent along-track processing, which imposes the need of much higher pulse repetition frequencies (PRF). The first satellite mission of this kind is the European Space Agency's (ESA) Cryosat-2 mission launched in 2010. Initially devoted for cryosphere sciences, the SAR mode capability of the Synthetic Aperture Interferometric Radar Altimeter (SIRAL) altimeter has also provided the opportunity of demonstrating and studying the performance of the DDA technique over the ocean.

The SRAL instrument, onboard the recently launched ESA Sentinel-3 mission, is a similar radar altimeter to SIRAL. In SAR mode both instruments operate in closed bursts at a PRF of 18.1818 kHz, which makes them a perfect tool for studying the correlation properties between adjacent pulses of nadir-looking radar altimeters. In this study, we make use of five full years of Cryosat-2 SAR mode data acquired over the ocean. The reason for such an extended dataset is to obtain a statistically representative sample over a wide range of sea state conditions. From the SAR mode pulse echoes at 18 kHz we made pseudo- low-resolution mode (PLRM) waveforms at 18, 9 and 2 kHz, that we later retrack by means of an MLE-4 ocean retracker, to help us understand what are the effects of the partial correlation of radar pulses in the determination of geophysical parameters.

We observe that, as noticed in previous works, the correlation properties of pulse limited radar altimeter echoes depend on the range gate within the tracking window, and we have verified that the correlation properties depend also on sea state, as predicted by previous simulation studies. Most significantly, we have determined that the noise in the estimation of ocean parameters can be reduced by transmitting pulses at a much higher PRF than the decorrelation limit predicted by Walsh and Rodríguez, particularly in rough sea state conditions. In addition, the partial correlation of radar altimeter pulses transmitted at high PRFs has important implications on the estimation of geophysical parameters from LRM waveforms, such as the introduction of significant biases in the determination of sea surface height and significant wave height, which will need to be accounted for and corrected.

These results are particularly relevant for the upcoming Jason-CS/Sentinel-6 mission, a joint endeavor of NASA, ESA, EUMETSAT, NOAA, and CNES. This mission, meant to be the follow-on mission in the Jason series, will be operated in an interleaved mode that will produce simultaneously both SAR and LRM data by transmitting pulses at a PRF of 9 kHz.

Corresponding author:
Alejandro Egido (**NOAA**, **United States**), alejandro.egido@noaa.gov

Convergent solutions for retracking conventional and Delay Doppler altimeter echoes

Pierre Thibaut (CLS, France); Fanny Piras (CLS, France); Jean Christophe Poisson (CLS, France); Thomas Moreau (CLS, France); Jérémie Aublanc (CLS, France); Laiba Amarouche (CLS, France); Abderrahim Halimi (Heriot-Watt University, United Kingdom); François Boy (CNES, France); Amandine Guillot (CNES, France); Sophie Le Gac (CNES, France); Nicolas Picot (CNES, France)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
During the last years, different teams have devoted huge efforts to improve retracking algorithms for both conventional and Delay Doppler echoes. Recently, for LRM measurements, CLS has developed and successfully validated a new solution called "Adaptive Retracker", implementing a new waveform model and a Nelder Mead optimization method with exact likelihood criterion. Dramatic improvements in the estimation performances over ocean have been shown (respectively 10% and 60% of noise reduction on range and significant wave height, in addition to the reduction of biases in range and SWH estimations). This solution has been presented at the last Eumetsat Conference in 2016 and at the OSTST in La Rochelle, 2016. For non oceanic areas (sea ice and inland water areas), a new model accounting for the roughness of the ocean surface has been introduced to ensure the continuity of estimations from typical Brownian ocean waveforms to peaky waveforms acquired over the leads in the Arctic ocean for example.

Similar developments have been conducted at CLS for retracking the Delay Doppler measurements (Cryosat-2 and Sentinel-3). The roughness parameter has been introduced in both our numerical solution and in the analytical model developed by A. Halimi during his PhD thesis. Consistency between these two solutions is quite perfect allowing us to include such models in our estimation process. As for the conventional LRM retracker, a numerical solution accounting for the real point target response of the instrument, has been privileged with the benefits already seen for conventional altimetry.

The aim of this paper is to present the consistency of this approach and the main figures of performances obtained with such methods (model and estimation algorithm) in both SAR and LRM modes. It will be shown how current (Cryosat-2 and Sentinel-3A) and future missions (Sentinel-3B and Sentinel-6) could benefit from such powerful method that has already proved its worth for conventional missions (Jason-3). Illustrations over different surfaces will be discussed.

Corresponding author:
Pierre Thibaut (**CLS**, **France**), pthibaut@cls.fr

Along-Track Zero Padding for the Processing of Unfocused SAR Altimetry Waveforms

Christopher Buchhaupt (TU Darmstadt, Germany); Luciana Fenoglio (University of Bonn, Germany); Matthias Becker (TU Darmstadt, Germany)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
SAR altimeter processing is possible since the Synthetic Aperture Radar (SAR) Interferometric Radar Altimeter (SIRAL) was launched on board of CryoSat-2 on April 2010.

SAR altimetry, also known as Delay-Doppler altimetry (DDA), is pulse-limited, as conventional altimetry (CA), cross-track and beam-limited along-track. It has therefore the potential to provide a better along-track resolution and a higher Signal-to-Noise ratio (SNR). The SAR processing mode expands the calculations into the along track or pulse to pulse direction, involving additional corrections and processing, e.g. another Fourier transform in addition to the range FFT.

Whereas it is known that adding zeros to the end of the echoes prior the range FFT improves the estimation of geophysical parameters at low wave-heights, the effect of zero padding has not been investigated in the along-track direction yet. This study examines the effect of along-track zero padding prior the beam forming process with respect to its influence on the stochastic properties of the estimated geophysical parameters and the choice of the waveform's surface locations.

Processed unfocused SAR data are compared to a reduced SAR (RDSAR) product having the same surface locations as SAR. The area of interest is the region from 2.5°S to 25.5°S and from 160°W to 85°W (Pacific Box) over the one year interval from October 2012 to October 2013.

The presentation includes the cross comparison of the processed SAR data with a reduced SAR product as well as the spectral analysis of the geophysical parameters sea surface anomaly, significant wave height and backscatter coefficient. The aim is to determine the improvement obtained by oversampling the products from 20 Hz to 40 Hz.

Corresponding author:
Christopher Buchhaupt (**TU Darmstadt**, **Germany**), buchhaupt@psg.tu-darmstadt.de

Covariant errors in ocean retrackers evaluated using along-track cross-spectra

Walter Smith (NOAA Lab for Satellite Altimetry, United States); Eric Leuliette (NOAA Lab for Satellite Altimetry, USA); Marcello Passaro (Technical University Munich, Germany); Graham Quartly (Plymouth Marine Laboratory, United Kingdom); Paolo Cipollini (National Oceanography Centre, United Kingdom)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
An altimeter's waveform displays backscattered power as a function of range. Retrackers fit parametric models to waveforms in order to estimate sea surface height, SWH, and sigma0; some retrackers also fit xisq (off-nadir angle squared). Radar backscatter from the ocean is a random process and the waveform is a random variable, hence the estimated parameters also contain random noise. Previous studies (Sandwell and Smith, GJI, 2005; Quartly, GRSL, 2009; Smith and Scharroo, OSTST, 2011; Zaron and de Carvalho, JTECH, 2016) have found some co-variance among the random errors in the retrieved parameters, and have suggested that parameter estimates could be improved if correlated errors could be reduced.

We evaluate the error characteristics of 5 retrackers (ALES, MLE3, MLE4, PEACHI Nelder-Mead, and PEACHI Newton-Raphson) applied to 3 altimeters (Jason-2, Jason-3, and SARAL), examining a region of the South Pacific (the SAR box) characterized by low sea surface height spectral variability where unwanted noise (the spectral bump) has previously been identified. The SARAL waveform differs from the others in being beam-limited as well as pulse-limited. The PEACHI Nelder-Mead retracker differs from the others in using a weighted fitting scheme. ALES and MLE3 differ from the others in excluding xisq; ALES also excludes the waveform tail. These different waveforms and approaches to parameter fitting allow us to show how the estimated geophysical parameters are affected by random variability in the pulse-limited and beam-limited footprint areas, factors that need to be understood to best use the various retrackers in specific applications.

We analyze the raw sea surface height anomaly (RSSHA, orbit height minus retracked range minus mean sea surface), SWH, sigma0, xisq, and PPP (pulse peakiness parameter). For each retracker, each possible pairing of analyzed parameters was put through an along-track cross-spectral analysis at the maximum possible sampling rate (20 Hz for the Jason data and 40 Hz for the SARAL data). Auto- and cross-power spectral densities were averaged for several cycles and passes in order to estimate auto-spectral density, magnitude-squared coherence, and cross-spectral admittance.

Auto-spectral densities of all parameters are white at wavelengths equal to and shorter than the pulse-limited footprint diameter. Auto-spectra of PPP and xisq are also white, but at higher power level, at wavelengths longer than 50 km, with transition in between. Auto-spectra of RSSHA, SWH, and sigma0 are red, decaying as wavenumber squared, for long wavelengths, with transition bands often having a spectral bump at intermediate wavelengths. The onset of the non-red and bump-like transition band is at 100 km wavelength for RSSHA, 50 km wavelength for sigma0, and 500–2000 km for SWH. Auto-spectral density levels are different from one retracker to another in the transition (spectral bump) region, differing by a factor of 4 in RSSHA, a factor of 10 in SWH, and a factor of 100 in sigma0.

The cross-spectral analysis exhibits correlations among the parameters as a function of along-track wavelength, and shows that the covariance is a function of along-track wavelength, antenna gain pattern and footprint, and (most importantly): (1) whether or not the waveform tail is fitted (ALES does not); (2) whether or not the xisq is fitted (MLE3 and ALES do not); and (3) whether or not a weighted fit is done (Peachi Nelder-Mead does). Examining the along-track wavelengths where parameter covariance is large exhibits how each retracker contributes to its own sea state bias and its own spectral bump.

Random variance in PPP (speckle noise) couples into xisq if it is estimated, and into sigma0 if it is not (MLE3). Variations in sigma0 are dominated by variations in xisq at wavelengths shorter than 50 km for those retrackers that estimate xisq, with the notable exception of SARAL MLE4 (xisq estimation error is lower at Ka band). Errors in xisq and errors due to PPP co-vary with errors in SWH, sigma0, and RSSHA over various bands.

The sea state bias is quite obviously not a constant percentage of SWH or sigma0, as admittance between these shows a complex behavior with generally increasing covariance as wavenumber increases. SWH:RSSHA ratio grows from about –4% at 1000 km wavelength to about –10% at 10 km wavelength. However, and as expected, weighting the retracker (PEACHI Nelder-Mead) strongly increases this correlation, from less than –1% at 500 km to almost –20% at 10 km.

If the overall goal is simply to find the best RSSHA performance, then ALES is best for wavelengths longer than 10 km, where it has the lowest noise and most un-bump-like spectrum; it and MLE3 also have the lowest correlation with PPP and sigma0. ALES, MLE4, and Nelder-Mead also show the lowest coherence between SWH and RSSHA at wavelengths longer than 10 km.

Corresponding author:
Walter Smith (**NOAA Lab for Satellite Altimetry**, **United States**), Walter.HF.Smith@noaa.gov

Delay-Doppler Processing of altimetric SAR data over open ocean: precision evaluation of different algorithms

Eduard Makhoul (isardSAT, Spain); Mònica Roca (isardSAT, United Kingdom); Chris Ray (isardSAT, United States); Albert Garcia (isardSAT, United Kingdom); Roger Escolà (isardSAT, United Kingdom); Gorka Moyano (isardSAT, United Kingdom); David Cotton (SatOC, United Kingdom); Marco Restano (SERCO/ESRIN, Italy); Marco Fornari (RHEA/ESTEC, Netherlands)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
During the last decade the radar altimetry has entered in its golden age as demonstrated by the different number of missions (Jason-3, CryoSat-2, SARAL/Altika, Sentinel-3a) currently operating and continuity missions planned for the near future (Sentinel-3b, Sentinel-6). The relatively new operational SAR mode in CryoSat-2 and Sentinel-3 missions, opens a new paradigm in the capabilities offered by satellite radar altimeter missions. The delay-Doppler processor (DDP), also known as SAR processor, coherently integrates a series of pulses to provide a series of Doppler beams with an improved along-track resolution (around 300 m) and focused to a specific location, which after being correctly aligned (compensating for the slant-range variation, among others) provide several looks that can be incoherently averaged. In this way, an improvement on the performance of the geophysical retrievals compared to a conventional altimetry operation is expected, whenever an optimised processing baseline is set up.

The core of this presentation explores comparatively different processing options in an isardSAT in-house Delay-Doppler chain, exploiting the high-resolution data acquired by CryoSat-2 in the SAR mode over two ocean regions (Central Pacific and Agulhas). The data set considered in the analysis has been provided under the framework of SCOOP (SAR Altimetry Coastal and Open Ocean Performance) project funded under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme Element.

Different state-of-the-art processing baselines have been considered: the nominal CryoSat-2 and Sentinel-3 baselines are comparatively evaluated. Two additional settings are assessed as well: a modified version of the nominal CryoSat-2 baseline, where the artificially forced zeros at stack level are not included in the final incoherent averaging; and finally the promising ACDC (amplitude compensation and dilation compensation) algorithm is integrated and implemented at stack level.

ACDC was originally proposed by Chris Ray and isardSAT team within the Sentinel-6 Ground Prototype Processor (GPP) project. The basic idea is to perform a two-step compensation once the stacking has been performed and right after geometry corrections application: 1) along-track amplitude compensation to equalise the Doppler-dependent weighting induced by the acquisition geometry in combination with both antenna and surface radiation patterns; and 2) across-track dilation compensation to correct for the waveform widening when moving away from the central beam. In this way, a better alignment of the waveforms within the stack is obtained by focusing the spread along-track energy into a single range bin, such that an improved speckle reduction and signal-to-noise ratio (SNR) are expected. This results in a simpler and more computationally efficient analytical retracker over ACDC L1B waveforms when compared to the conventional SAR analytical retracker on L1B waveforms.

The performance of the different processing baselines is analysed in terms of the precision of retrieved geophysical parameters. A dedicated in-house L2 processor, integrating the first fully analytical SAR ocean model (Ray et al 2015), has been exploited. This analytical retracker was adapted side by side with the L1B processing in order to create an L1B waveform modelling which was as accurate as possible. The objective is to gain insights into the most suitable processing options in the L1B+L2 chains, so an improvement in terms of noise estimation of different geophysical parameters can be achieved.

The flexible Delay-Doppler processor that has been implemented is based on the experience gained by isardSAT team in the development of the GPP for the future Sentinel-6 mission. In this sense, it is intended to present some very preliminary results on geophysical parameters retrieval for simulated Sentinel-6 data in the high-resolution (or SAR) mode. The specificities of the Poseidon-4 instrument on-board the Sentinel-6 satellite which has a digital architecture (exploiting the matched filter processing on-board rather than the analog de-ramping counterpart), combined with the interleaved operation mode requires a processing scheme adapted to cope with these particularities in the conventional Delay-Doppler processing.

Corresponding author:

Eduard Makhoul (**isardSAT**, **Spain**), eduard.makhoul@isardsat.cat

ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters.

Marcello Passaro (DGFI-TUM, Germany); Stine Kildegaard Rose (DTU-Space, National Space Institute, Denmark); Ole B. Andersen (DTU-Space, National Space Institute, Denmark); Eva Boergens (DGFI-TUM, Germany); Francisco M. Calafat (National Oceanography Centre Liverpool, United Kingdom); Denise Dettmering (DGFI-TUM, Germany); Jerome Benveniste (European Space Research Institute (ESRIN), European Space Agency, Italy)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Oral

Abstract:
Water level from sea ice-covered oceans is particularly challenging to retrieve with satellite radar altimeters due to the different shapes assumed by the returned signal compared with the standard open ocean waveforms. Valid measurements are scarce in large areas of the Arctic and Antarctic Oceans, because sea level can only be estimated in the openings in the sea ice (leads and polynyas). Similar signal-related problems affect also measurements in coastal and inland waters.

This study presents a fitting (also called retracking) strategy (ALES+) based on a subwaveform retracker that is able to adapt the fitting of the signal depending on the sea state and on the slope of its trailing edge. The algorithm modifies the existing Adaptive Leading Edge Subwaveform retracker originally designed for coastal waters, and is applied to Envisat and ERS-2 missions.

The validation in a test area of the Arctic Ocean demonstrates that, compared to an existing open ocean altimetry dataset, the presented strategy increases the number of sea level retrievals and decreases the covariance error by 0.4 cm in the sea ice-covered area; moreover, it decreases the retracking open ocean noise by over 1.1 cm with respect to the standard ocean retracker. Further tests against in-situ data show that also the quality of coastal retrievals increases compared to the standard ocean product in the last 6 km within the coast and that along the Mekong River the new retracker scores as well as the Improved Threshold Retracker.

This suggests that a single retracking algorithm can be used to improve the sea level records at high latitudes, but also for any other reflecting water surface. Moreover for the first time:
1) a homogeneous retracking strategy is not only verified, but also validated against in-situ sensors
2) the benefit of a subwaveform strategy in the open ocean compared to a full waveform algorithm is demonstrated in terms of a higher precision of the measurement

The algorithm has been used to reprocess Envisat and ERS-2 data for the new DTU/TUM Arctic and Antarctic sea level product available via the European Space Agency's Sea Level Climate Change Initiative (http://www.esa-sealevel-cci.org).
Corresponding author:
Marcello Passaro (**DGFI-TUM**, **Germany**), marcello.passaro@tum.de

OSTM/Jason-2, Jason-3 and Sentinel-3A POD Status

John Moyard (CNES, France); Eva Jalabert (CNES, France); Alexandre Couhert (CNES, France); Hanane Ait Lakbir (CS-SI, France); Flavien Mercier (CNES, France); Sabine Houry (CNES, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Following an extended safe hold mode encountered since May 2017, the NASA/CNES Jason-2 spacecraft (approaching its first decade of duty) was placed into a long-repeat orbit (LRO) beginning of July 2017. In October 2016, Jason-3 had already taken over from its predecessor, as the altimeter reference mission, and is now completing its second year in orbit. Along with Jason-3, the EU Copernicus Sentinel-3A satellite complements the sea level data legacy for more than a year. With the benefit of hindsight, it is now time to consider reprocessing these three missions (Jason2, Jason3, Sentinel-3A), especially as many things (dynamic and measurement models) have improved since the last GDR-E orbit standards (2014).
Preliminary GDR-F precise orbits for Jason-2, Jason-3 and Sentinel-3A will thus be presented in this paper. The main evolutions concern the use of station coordinates from ITRF/DPOD/SLRF2014, the modeling of the non-tidal geocenter variations (DORIS-only estimation based on Jason-2) , an update to the conventional model for rotational deformation as well as time-variable gravity modelling, the improvement of instrument phase center locations, the fixing of ambiguities for the Jason-3 GPS receiver. Comparisons to the current GDR-E and available external solutions will be shown, as a complement to independent SLR validations.

Corresponding author:
John Moyard (**CNES**, **France**), john.moyard@cnes.fr

Improvement of the Complete TOPEX and Jason Orbit Time Series (1992-2017): GSFC Status

Frank Lemoine (NASA GSFC, United States); Nikita Zelensky (SGT Inc., U.S.A.); Brian Beckley (SGT Inc., USA); Pierre Exertier (Observatoire de la Côte d'Azur, FRANCE); Douglas Chinn (SGT Inc., U.S.A.); Despina Pavlis (SGT Inc., U.S.A.); Jean-Paul Boy (EOST/IPGS, Université de Strasbourg, FRANCE)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Orbit error remains a major component in the overall error budget of all altimeter satellite missions. Error sources include terrestrial reference frame and station positions, systematic and unaccounted-for errors in the satellite tracking measurements, mismodeling of nonconservative forces, and incomplete modeling of time-variable gravity. This paper presents our choice of ITRF2014-based complements from among the other 2014 ITRS realizations, resulting in a complete and consistent time series of improved orbits from TOPEX/Poseidon to Jason-3. The altimeter measurement calibration with tide gauges is shown, and the GSFC orbits are compared with orbits from other analysis centers, including the CNES, JPL, ESA and the GFZ. We also characterize the errors due to epoch time corrections in SLR data derived from Jason-2/T2L2, orbit mis-centering and atmospheric pressure loading, the current IERS pole tide model, and incomplete application of time-varying gravity. Plans for updating our POD standards are discussed.

Corresponding author:
Frank Lemoine (**NASA GSFC**, **United States**), Frank.G.Lemoine@nasa.gov

GPS-Based Precision Orbit Determination for the Jason-2 and Jason-3 Missions

Shailen Desai (Jet Propulsion Laboratory, United States); Willy Bertiger (JPL, USA); Bruce Haines (Jet Propulsion Laboratory, United States); Aurore Sibois (Jet Propulsion Laboratory, United States)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
We present results from the precise orbit determination (POD) of the Jason-2 and Jason-3 satellites using tracking data from their respective on-board GPS receivers. Our results begin with an assessment and relative comparison of the radiometric performance of each of the GPS receivers, including tracking metrics as well as data noise. We discuss our approach to calibrating the GPS antennas, compare them to their pre-flight calibrations, and evaluate their impact on our POD solutions.

Our presentation also shows results from the evaluation of our GPS-based POD solutions, primarily through independent metrics such as withheld satellite laser ranging data residuals and sea surface height residuals at locations where ascending and descending passes cross (i.e., crossover residuals). We include results from the assessment of our near-real-time (< 5 hours), next-day, and 2-week latency operational orbit solutions. We also assess the relative performance of our GPS-based POD solutions to the medium-accuracy orbit ephemeris (MOE) and precise orbit ephemeris (POE) that are provided on the science data products, as well as POD solutions from other analysis centers. This performance assessment includes both temporal and geographically correlated differences.

Corresponding author:
Shailen Desai (**Jet Propulsion Laboratory**, **United States**), shailen.desai@jpl.nasa.gov

Jason 3 GPS derived orbits with ambiguity fixing

Flavien Mercier (cnes, France); Hanane Ait lakbir (CS-SI, France); Alexandre Couhert (CNES, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
The blackjack GPS receiver from Jason 3 measures the same observables as the ground geodetic receivers used at IGS for the GPS constellation orbits and clocks. So it is possible to perform ambiguity fixing in the Jason 3 GPS solutions as for ground stations.
CNES has developed since 2008 a method for fixing ambiguities using ‘phase clocks’. This is currently implemented in the CNES/CLS contribution to IGS (solution grg). The advantage of this approach is that using the grg orbits/clocks products available at IGS, it is possible to fix the ambiguities of the LEO satellite phase measurements, without processing simultaneously the ground stations, as for double difference approaches. Thanks to the quality of the Jason 3 current GPS orbits (computed with floating ambiguities), it is possible to directly observe and fix the phase ambiguities using orbit determination residuals. Some specificities of the receiver measurements are detailed (pseudo-range biases, receiver widelane bias).
An orbit determination can be performed using directly this new ambiguity solution, with the same measurements, models and parameters as in the current products. This method has been implemented for Jason 3, and the orbits are compared to the current precise orbits.

Corresponding author:
Flavien Mercier (**cnes**, **France**), flavien.mercier@cnes.fr

Strategy to minimize the impact of the South Atlantic Anomaly effect on the Jason-3 and Sentinel-3A Precise Orbit Determination and on the station position estimation

Hugues Capdeville (CLS, France); Jean-Michel Lemoine (CNES, FRANCE)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
All the Ultra Stable Oscillators (USO) of DORIS satellites are more or less sensitive to the South Atlantic Anomaly (SAA) effect. The last DORIS satellites are also impacted in particular Jason-3. While awaiting a DORIS data corrective model for the satellites Jason-3 and Sentinel-3A, we propose here a strategy to minimize the SAA effect on the Precise Orbit Determination (POD) and on the station position estimation. First, we will show the impact on the Jason-3 and Sentinel-3A POD by showing statistical results such as one per revolution empirical acceleration amplitudes, orbit overlaps and orbit residuals. Secondly, we will give some comparisons to the precise orbits of the CNES used for altimetry (GDR-E) and of the ESA/ESOC Analysis Center. We will also show the impact on the DORIS positions of the SAA stations.
Corresponding author:
Hugues Capdeville (**CLS**, **France**), hcapdeville@cls.fr

Update of the EIGEN time variable gravity model for precise orbit determination

Jean-Michel Lemoine (CNES, France); Stéphane Bourgogne (G&C, France); Richard Biancale (CNES, France); Franck Reinquin (CNES, France); Pascal Gégout (CNRS / UMR5563, France); Sean Bruinsma (CNES, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Precise orbit determination is a key element in the overall accuracy of the altimetric measurements. Since 2002, thanks to the GRACE mission, we have now an amazing - as some would say - knowledge of the Earth gravity field and its time evolution. Based on 28 years of LAGEOS data, 12 years of GRACE data and 3 years of GOCE data, the EIGEN-GRGS.RL03-v2.MEAN-FIELD is the gravity model that is used for the GDR-E standards. It contains a time-variable gravity (TVG) part until degree and order 80, and a static part coming from the model GOCE-DIR5 up to degree and order 300. The TVG part is modeled for each year between August 2002 and June 2014 as an annual bias + slope + annual and semi-annual periodic components. For degree 2, the TVG part extends from January 1985 to June 2014 thanks to the contribution of the SLR satellites.
In order to closely follow the actual evolution of the Earth gravity field and to maintain the accuracy of the POD over medium and long time scales, this model has been updated by adding two more years of GRACE measurements until July 2016 and by increasing the TVG maximal degree to 90.
We will discuss the inclusion of the new data and the necessary coherence between the gravity field model and the other models in the standards, in particular between the mean pole model and the C21/S21 coefficients of the TVG model; and between the gravity field model and the dealiasing models.

Corresponding author:
Jean-Michel Lemoine (**CNES**, **France**), jean-michel.lemoine@cnes.fr

Construction of GPS-based LEO orbits referenced to the “instantaneous” Earth’s center of mass, through the adjustment of a parametric correction in the IGS GPS satellite clock solutions

Alexandre Couhert (CNES, France); Flavien Mercier (CNES, France); Nicolas Delong (CNES, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
The International GNSS Service (IGS) solutions for the GPS constellation are aligned to the ITRF origin. This strategy is not sufficient to model correctly the LEO GPS measurements, because the geocenter motion is not taken into account for the ground station positions in these solutions. As a consequence, the clock products are slightly biased in order to represent directly a convenient ITRF positioning for the users. All Analysis Centers (AC) follow this recommendation to align their solution to conform to the ITRF origin.
In order to be consistent with the dynamic motion of a LEO satellite, and also to be consistent with the other measurement systems where the geocenter motion is modelled (SLR and DORIS, annual part in the current GDR-E standards), it is necessary to take into account or to mitigate the miscentering effect of the constellation solution.
In this paper, we use a parametric model representing the reference network translations, and this model is adjusted in the Jason-2 LEO satellite orbit determination.

Corresponding author:
Alexandre Couhert (**CNES**, **France**), alexandre.couhert@cnes.fr

SLR-based geocenter estimates with atmospheric pressure station loading for improving orbit centering

Nikita Zelensky (SGT / GSFC, United States); Frank Lemoine (NASA / GSFC, USA); Brian Beckley (SGT / GSFC, USA); Doug Chinn (SGT / GSFC, USA); Despina Pavlis (SGT / GSFC, USA); Jean-Paul Boy (EOST/IPGS (UMR 7516 CNRS – Université de Strasbourg), France); Pierre Exertier (UMR Geoazur, Universit´e de Nice, Observatoire de la Cˆote d'Azur, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:

The mass redistribution of continental water, oceans, and atmosphere at the Earth's surface cause seasonal geocenter variations with amplitudes of a few mm. Continental water is believed to be the largest contributor to geocenter motion as compared to the atmosphere and the oceans (Wu et al. 2012). However it is possible the phases and amplitudes of the seasonal geocenter contributions from these different sources will differ over time. Furthermore, the true geocenter is better represented with improved modeling of the center of figure which includes non-tidal surface deformation (Wu et al., 2012). The more accurate representation of the geocenter motion in altimeter satellite POD will ensure that orbit centering more truly reflects the Earth's center of mass, and consequently better references the altimeter sea surface to the Earth's center of mass (CM). Using 24-years (1993-2016) of LAGEOS 1-2 Satellite Laser Ranging (SLR) data we evaluate new ITRF2014-based models of geocenter motion for application to altimeter satellite orbit determination, where we test forward modeling of the station displacement corrections due to atmospheric loading. The derived geocenter annual models are compared to other estimates. Orbit centering is evaluated with TOPEX/Jason SLR/DORIS ITRF2014-based and JTRF2014-based POD.

Corresponding author:
Nikita Zelensky (**SGT / GSFC**, **United States**), nzelensky@sgt-inc.com

The T2L2 contribution to precise orbit determination and positioning

Alexandre Belli (CNRS Géoazur, France); Pierre Exertier (CNRS Géoazur, France); Frank G. Lemoine (NASA GSFC, USA); Nikita P. Zelensky (Stinger Ghaffarian Technologies, USA); Douglas S. Chinn (NASA GSFC, USA); Hugues Capdeville (CLS, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
The Time Transfer by Laser Link (T2L2) experiment on-board the Jason-2 satellite aims to synchronize remote ground clocks which provide Time & Frequency references in Satellite Laser Ranging (SLR) stations. We recently developed a dedicated time transfer method in order to measure the time differences between SLR stations relative to the Grasse Geodetic observatory. It reveals at the measurement level systematic errors in the laser ranging data leading to a desynchronization of the network relative to UTC at the level of several hundreds of nanoseconds to a few microseconds. We show some examples of the time series of time biases for a set of SLR stations and we describe how the time series have been summarized into a unique correction file.

In addition, the T2L2 experiment gave us the opportunity to describe the frequency behavior of the Jason-2 oscillator, by using data from the ground-to-space time transfer passes above some SLR stations. The resulting deterministic model enables to describe the main non linear effects (frequency responses of the oscillator during successive exposures of the satellite above the SAA area, and additionally temperature variations) that affect the on-board oscillator of the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) system. These are at the level of a few 10^(-12) over tens of minutes, which corresponds to around 0.3-0.4 mm/s and thus have the potentiality to improve both the Precise Orbit Determination process and the computation of station-coordinate solutions.
We present the method that has been established to extract these a priori quantities, and we show how these Doppler corrections affect the Doppler measurements over a set of beacons, namely Toulouse, Kourou, Hartebeesthoek and Terre Adelie.
Corresponding author:
Alexandre Belli (**CNRS Géoazur**, **France**), belli@geoazur.unice.fr

Assessment of the International Terrestrial Reference System 2014 realizations by Precise Orbit Determination of SLR Satellites

Sergei Rudenko (DGFI-TUM, Germany); Mathis Bloßfeld (DGFI-TUM, Germany); Horst Müller (DGFI-TUM, Germany); Denise Dettmering (DGFI-TUM, Germany); Detlef Angermann (DGFI-TUM, Germany); Manuela Seitz (DGFI-TUM, Germany)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
A high accuracy, consistent and long-term stable realization of the International Terrestrial Reference System (ITRS) is a basis for the investigations of the global and regional mean sea level changes, dynamics of the points on the Earth's surface, solid Earth deformations, tectonic motion, Earth's rotation, post-glacial rebound, precise orbit determination of the Earth's artificial satellites, precise positioning and navigation on and near the Earth's surface. Three new ITRS realizations were published in 2016. They are DTRF2014 developed at DGFI-TUM (Germany), ITRF2014 developed at IGN LAREG (France) and JTRF2014 developed at JPL (USA). In this presentation, we provide a short description of these new realizations and present the results of the assessment of these realizations by precise orbit determination of ten high and low Earth orbiting geodetic satellites equipped with satellite laser ranging (SLR) retro-reflectors using SLR observations over, in total, a 24-year time interval from 1993.0 to 2017.0. We perform this analysis for LAGEOS-1/2, Etalon-1/2 used for the terrestrial reference frame (TRF) and Earth orientation parameters (EOP) determination for the International Laser Ranging Service (ILRS) contribution to the ITRS 2014 realizations, for altimetry satellite Jason-2, as well as for canon-ball geodetic satellites LARES, Larets, Ajisai, Starlette, Stella used for the improvement of thermosphere models and, together with LAGEOS and Etalon satellites, for the improvement of the low degree Stokes terms of the Earth's gravity field expansion. We show the impact of the ITRS 2014 realizations, as compared to the previous ITRS realization for SLR stations - SLRF2008, on the root-mean-square and mean fits of SLR observations, satellite orbits, weekly estimated mean station-specific range biases, 10-day single satellite sea surface height (SSH) crossover differences and geographically correlated mean SSH errors for Jason-2. We illustrate the importance of modelling non-linear station motions and non-tidal loading corrections to station positions.
Corresponding author:
Sergei Rudenko (**DGFI-TUM**, **Germany**), sergei.rudenko@tum.de

Consistent estimation of station coordinates, Earth orientation parameters and selected low degree Earth's gravity field coefficients from SLR measurements

Mathis Bloßfeld (DGFI-TUM, Germany); Sergei Rudenko (DGFI-TUM, Germany); Alexander Kehm (DGFI-TUM, Germany); Natalia Panafidina (TUM, Germany); Horst Müller (DGFI-TUM, Germany); Franziska Göttl (DGFI-TUM, Germany); Detlef Angermann (DGFI-TUM, Germany); Urs Hugentobler (TUM, Germany); Manuela Seitz (DGFI-TUM, Germany)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Precise knowledge on the fundamental geodetic parameters, such as positions of tracking stations, Earth Orientation Parameters (EOP) and coefficients of the Earth's gravity field is, among others, necessary for precise orbit determination of Earth's artificial satellites, including altimetry satellites. Satellite Laser Ranging (SLR) to geodetic cannon-ball satellites allows determining station coordinates and their velocities, EOP and low degree coefficients of the Earth gravity field. In an actual realization of a global Terrestrial Reference Frame (TRF), only EOP values are consistently estimated with station coordinates and velocities, while the coefficients of the Earth gravity field are determined separately using fixed TRF and EOP.

In this presentation, we show the results of a consistent estimation of weekly 3-D station coordinates, EOP including daily x- and y-pole coordinates and the excess length-of-day (LOD), and selected weekly Earth's gravitational field (Stokes) coefficients up to degree and order 6. We use for this purpose SLR measurements to up to 11 geodetic satellites LAGEOS-1/2, Etalon-1/2, Stella, Starlette, Ajisai, Larets, LARES, BLITS and WESTPAC covering totally a 38-year time span from February 16, 1979 to April 30, 2017. We show that the correlations between the estimated parameters are significantly reduced when multiple satellites with various altitudes and orbit inclinations are combined. This allows us to estimate reliable parameters with better precision compared to the standard four-satellite constellation (LAGEOS-1/2, Etalon-1/2) which is currently used by the International Laser Ranging Service (ILRS) for the determination of the TRF and EOP products. In particular, the Stokes coefficients, EOP and TRF datum parameters (3 translations, 3 rotations, 1 scale factor), which are highly correlated with satellite specific orbit parameters, are improved. A special attention is given in to the improved determination of low degree gravitational field coefficients, in particular, degree 1 coefficients representing the geocentre motion, a proper modelling of which is important for precise orbit determination of altimetry satellites.
Corresponding author:
Mathis Bloßfeld (**DGFI-TUM**, **Germany**), mathis.blossfeld@tum.de

Jason-3 GDR Calibration Stability Enabled by the Cold Sky Maneuvers

Shannon Brown (JPL, United States); Tanvir Islam (JPL, USA)

Session: Instrument Processing: Propagation, Wind Speed and Sea State Bias
Presentation type: Oral

Abstract:
The Jason-3 mission was the first altimeter mission to implement special spacecraft calibration maneuvers for improving the long term climate calibration of the radiometer. The spacecraft is pitched to point the normally nadir viewing Advanced Microwave Radiometer (AMR) to cold space. In the microwave, the sky background is a stable cold calibration source that is used to provide a single point calibration baseline. A drift is observed in the Jason-3 radiometer calibration and has been attributed to drifts in the internal noise diode calibration sources. Similar drifts have been observed in past altimeter radiometers. But in the case of Jason-3, a single point cold sky calibration is able to stabilize the drift with minimal uncertainty since the cold sky brightness is absolutely known. Previously, on-Earth calibration references were required which have much larger uncertainties and are also coupled to the climate system. We will discuss the role the cold sky calibration maneuvers have in the Jason-3 radiometer calibration and estimate the resulting uncertainty in the long term climate calibration of the wet tropospheric path delay. We will compare this to the uncertainty that would result had the cold sky maneuvers not been implemented. Finally, we will discuss the further improvements expected for the Sentinel-6 mission which includes a climate-quality radiometer featuring on-board stable external blackbody calibration sources.

Corresponding author:
Shannon Brown (**JPL**, **United States**), shannon.t.brown@jpl.nasa.gov

Independent assessment of Sentinel-3A wet path delay

M. Joana Fernandes (Universidade do Porto, Faculdade de Ciências; CIIMAR, Portugal); Clara Lázaro (Universidade do Porto, Faculdade de Ciências; CIIMAR, Portugal)

Session: Instrument Processing: Propagation, Wind Speed and Sea State Bias
Presentation type: Oral

Abstract:
Launched on 16 February 2016, Sentinel-3A (S3A) possesses a two-band microwave radiometer (MWR) similar to that of Envisat, aimed at the precise retrieval of the wet tropospheric correction (WTC) through collocated measurements with the SRAL instrument.
Due to their instrumental characteristics and retrieval algorithms, the two-band MWR on board the European Space Agency (ESA) altimeter missions are known for their good performance in the open-ocean. However, when they approach the coast, the retrieval algorithm, designed for surfaces with ocean emissivity, generates very noisy values as the footprint encounters surfaces with different characteristics. The same happens at high latitudes in ice-covered regions.
This study aims at presenting an independent validation of the S3A wet path delay derived from the on-board MWR, present on S3A products, released for validation purposes, for the open and coastal ocean.
The validation is performed by means of comparisons with independent data sets namely: scanning imaging microwave radiometers (SI-MWR) such as the GPM Microwave Imager (GMI); Global Navigation Satellite Systems (GNSS) derived path delays determined at coastal stations; wet path delays from the MWR on board various contemporary altimeter missions - Jason-2 (J2), Jason-3 (J3) and SARAL/AltiKa.
In addition, the overall along-track performance is compared against WTC obtained from the GNSS-derived Path Delay Plus (GPD+) algorithm, developed at the University of Porto, and from atmospheric models. For this purpose, GPD+ wet path delays have been derived by combining, through space-time objective analysis, all available observations but not including those from S3A MWR, i.e. using only third-party observations.
In addition to the statistical comparisons between the S3A MWR-derived WTC and the various WTC sources, the correction is also evaluated by means of sea level anomaly variance, both along-track, at crossovers and function of distance from coast.
Considering the relative short period of the analysis, overall performance of S3A MWR seems good and stable. Small scale factors and offsets relative to GMI, J2 and J3 and a larger bias relative to SARAL have been found. RMS differences (cm) of S3A with respect to the various radiometers of 1.0 (GMI), and in the range 1.3 to 1.6 cm (other altimetric missions) indicate good agreement between these sensors.
In spite of the short analysed period, a stable temporal evolution of the S3A WTC has been observed. Periodic patterns of the differences with respect to GMI are explained by the different orbits and corresponding samplings of these sensors.
In agreement with the similar two-band instruments carried by previous ESA altimetric missions, strong ice and land effects can be observed, the latter one being mainly up to 20 km from the coast. GPD+ corrections tuned to S3A are under development, aiming at generating continuous WTC, also valid in the coastal zones and at high latitudes.

Corresponding author:
M. Joana Fernandes (**Universidade do Porto, Faculdade de Ciências; CIIMAR**, **Portugal**), mjfernan@fc.up.pt

A multi-surface performance assessment of the Sentinel-3A Surface Topography Mission Microwave Radiometer

Marie-Laure Frery (CLS, France); Mathilde Siméon (CLS, France); Pierre Féménias (ESA ESRIN, Italy); Remko Scharoo (Eumetsat, France)

Session: Instrument Processing: Propagation, Wind Speed and Sea State Bias
Presentation type: Oral

Abstract:
The Sentinel-3A Surface Topography Mission has been launched on February 2016 and is now in its second year of operation. Its objectives are to serve primarily the marine operational users but also allow the monitoring of sea ice and land ice, as well as inland water surfaces.
A two-channels microwave radiometer (23.8 and 36.5 GHz) similar to the Envisat and ERS MWR sensors is combined to the altimeter in order to correct the altimeter range for the excess path delay (WTC for wet tropospheric correction) resulting from the presence of water vapor in the troposphere.
First, the performance of the brightness temperatures is assessed at global scale and with a focus on over non-oceanic surfaces, as land and ice.
Then, we will present the latest results of the S3A MWR assessment over ocean, demonstrating the very good performances of the 5-inputs WTC retrieval algorithm proposed in S3A products, based on the two brightness temperatures, the altimeter backscattering coefficient and additional inputs such as the sea surface temperature and atmospheric temperature lapse. S3A WTC quality is compared to other missions such as Jason-3 (NASA/CNES) and AltiKa (CNES/ISRO) using global metrics (differences of SSH variance at cross-overs) and to in-situ measurements (GPS and radiosondes).

Corresponding author:
Marie-Laure Frery (**CLS**, **France**), mfrery@cls.fr

Exploiting the high spatial resolution of AIRWAVE TCWV data to retrieve the WTC for coastal altimetry in view to its application to Sentinel-3

Clara Lázaro (Universidade do Porto, Faculdade de Ciências; Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR), Portugal); M. Joana Fernandes (Universidade do Porto, Faculdade de Ciências; Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR), Portugal); Stefano Casadio (SERCO, ESA/ESRIN, Italy); Elisa Castelli (CNR, Istituto di Scienze dell'Atmosfera e del Clima, Italy); Enzo Papandrea (SERCO, ESA/ESRIN; CNR, Istituto di Scienze dell'Atmosfera e del Clima, Italy); Bianca Maria Dinelli (CNR, Istituto di Scienze dell'Atmosfera e del Clima, Italy); Alessandro Burini (EUMETSAT, Germany); Bojan Bojkov (EUMETSAT, Germany); Jérôme Bouffard (RHEA System SA, ESA, Italy)

Session: Instrument Processing: Propagation, Wind Speed and Sea State Bias
Presentation type: Oral

Abstract:
The AIRWAVE dataset contains Total Column Water Vapour (TCWV) values derived from the measurements of the (Advanced) Along-Track Scanning Radiometers ((A)ATSR) on board ERS and ENVISAT missions. The algorithm for the AIRWAVE data retrieval uses day and night dual-view thermal infrared observations from the (A)ATSR above cloud-free ocean. The (A)ATSR instrument series has been fully exploited and the dataset spans the period 1991-2012. One of the main advantages of using the AIRWAVE dataset to compute the wet tropospheric correction (WTC) over coastal regions is its high spatial resolution, allowing the retrieval of cloud-free TCWV very close to the coastline, which is of utmost importance for Coastal Altimetry.
The focus of this study is twofold. On the one hand, it exploits the AIRWAVE dataset to retrieve an improved WTC in coastal regions by using the GNSS-derived Path Delay Plus (GPD+) algorithm. On the other, it attempts to evaluate whether and to what extent AIRWAVE observations actually improve the WTC in the NW Mediterranean Sea.
To conduct the research, a new GPD+ WTC using AIRWAVE Version 2 (V2) data has been calculated for the entire ENVISAT period and for the NW Mediterranean Sea. Taking advantage of the AATSR and microwave radiometer (MWR) data simultaneity, the inclusion of AIRWAVE data is expected to contribute to a more accurate sea level anomaly (SLA) signal and thus to a better oceanographic characterization of the region.
The GPD+ WTC with AIRWAVE for ENVISAT has been evaluated through statistical analysis of SLA variance (along-track, at crossovers and function of distance from coast) and by direct comparison with other available WTC, namely those from ERA Interim and the GPD+ WTC computed with all data (GNSS, third party scanning imaging MWR and on-board MWR) but excluding AIRWAVE, which has been fully validated in the scope of several ESA projects (e.g., Sea Level Climate Change Initiative). The results from this assessment and the main findings will be provided in detail.
It has been concluded that AIRWAVE data still could be improved by refining the capability of the cloud screening algorithm used in the AIRWAVE generation to detect thin clouds, which in the current version leads to dry biased TCWV values. While a new version of AIRWAVE is not released, strategies to filter out cloud-contamination from data prior to their input in the GPD+ algorithm are being developed. Since the AIRWAVE algorithm can be adapted to Copernicus Sentinel-3 (S3) SLSTR (Sea and Land Surface Temperature Radiometer) data, this study is expected to contribute to the generation of a coastal-improved WTC for S3.
Aiming to evaluate if the high spatial resolution signals present in AIRWAVE actually improve the WTC, the GPD+ WTC with AIRWAVE for ENVISAT has also been computed for high-rate 20 Hz altimetry data. This high rate WTC has been evaluated using sea level anomalies derived from improved ranges from e.g. the Adaptive Leading Edge Subwaveform (ALES) rectracker, available up to 50 km distance from the coast. Results from the validation of this high-rate WTC are also shown for comparison.

Corresponding author:
Clara Lázaro (**Universidade do Porto, Faculdade de Ciências; Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR)**, **Portugal**), clazaro@fc.up.pt

2-channels versus 3-channels configuration for MWR on altimetry missions: latest developments on the role of the 18.7 GHz channel on Wet Tropospheric Correction retrieval performances

Bruno Picard (CLS, France); Marie-Laure Frery (CLS, France); Christophe Goldstein (CNES, France); Pierre Féménias (ESA ESRIN, Italy); Rolv Midthassel (ESA ESTEC, Netherlands)

Session: Instrument Processing: Propagation, Wind Speed and Sea State Bias
Presentation type: Oral

Abstract:
Microwave radiometers on altimetry missions are dedicated to the correction the altimeter range for the excess path delay (WTC for wet tropospheric correction) resulting from the presence of water vapor in the troposphere.

Current and past instruments are divided in two families. NASA/CNES missions (from TMR on Topex/Poseidon up to the latest generation of AMR on Jason-3) rely on 3-channels (18.7 GHz, 23.8 GHz, 34 GHz) configurations. ESA missions (from ERS-1 to Sentinel-3) rely on 2-channels (23.8 GHz, 36.5 GHz) configurations; and so does the CNES/ISRO mission (23.8 GHz, 37 GHz).

The 18.7 GHz channels brings useful information on surface characterization (temperature, roughness).
On a 2-channels configuration, historical approach (Obligis et al. 2006) used the altimeter backscattering coefficient (sig0), well-sensitive to the roughness, to compensate from the lack of this low-frequency channel. Based on a simulation approach, Thao et al (2015) demonstrates that the benefit of using a 18.7 GHz channel is larger than using the sig0 since the brightness temperature (TB) is more sensitive to the water vapour.

Now, Obligis et al. (2009) recommended to use climatological maps of sea surface temperature and the atmospheric temperature lapse rate as additional parameters to the classical three inputs (TBs and sig0) to improve the performance of the WTC retrieval.

We will present the latest performance comparisons between a 2-channels and a 3-channels configuration. Using the metric of SSH variance differences at cross-overs at a global scale, we will discuss the impact on the quality of the WTC retrieval of 1) the Ka-band sig0 wrt to a Ku-band sig0 2) using climatological maps for the SST wrt to L4 optimal interpolation products. Then, we will show that 2-channels configurations MWR performances are similar to 3-channels configurations, based on Jason-2, AltiKa and Sentinel-3 measurements. Finally, we will discuss the role of the 18.7 GHz channels on some particular regions: strong oceanic currents and coastal areas.

Corresponding author:
Bruno Picard (**CLS**, **France**), bpicard@cls.fr

The altimeter product suite for the Sentinel-6/Jason-CS mission

Remko Scharroo (EUMETSAT, Germany); Carolina Nogueira Loddo (EUMETSAT, Germany); Cristina Martin-Puig (EUMETSAT, Germany)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Oral

Abstract:
The Sentinel-6 (Jason-CS) mission will follow TOPEX and the Jason-series of “reference altimeter missions”. But it is in many ways a totally new type of mission, a different platform (similar to CryoSat) and a different altimeter (dissimilar from any of the previous altimeters). Not only will it be the first Synthetic Aperture Radar (SAR) altimeter used on one of the reference missions, it will also be the first altimeter that operates in a continuous high-rate pulse mode, 100% of the time. This particular operating mode allows simultaneous production of Low Resolution (LR) mode measurements on-board as well as the processing of SAR echoes (High Resolution, HR, processing) on-ground. Both types of measurements will be provided in (separate) Sentinel-6 altimeter data products.

Sentinel-6 will bring some unique opportunities for cross-calibrating and cross-validating LR and HR altimetry, housed on the same platform, working from the same altimeter echoes, just using different processing techniques. Also, it will be the first time that we will be able to fully process on-ground 100% of the echoes that would otherwise be averaged on-board. This presentation will show how this is reflected in the Sentinel-6 products, how these compare with the products of the Jason-series and of Sentinel-3 and how continuity is ensured. Particular emphasis will be on highlighting the Level 1A (L1A) and Level 1B (L1B) product content.

Level 1 products will be made available containing all the individual echoes in the time domain (L1A) or the measurement data and waveforms without geophysical corrections (L1B). A L1B-S product (with the individual waveforms stacked and geo-located such as is available for Sentinel-3) can be derived from the L1A after performing Delay Doppler processing. Although L1B-S is not part of the product line, a tool will be provided to the users so that they can process L1A to L1B-S.

Level 2 (L2) products will contain the geophysical measurements of sea level, wind speed, and significant wave height, at 20-Hz and 1-Hz, from both LRM and SAR altimetry. They will also contain an appropriate set of geophysical corrections, outlined in this presentation, aimed at providing sea level measurements at the cutting edge of what is feasible. In numerous cases alternatives are provided to support various applications and error assessment. The L2 products can be easily aligned with the L1B products (and vice versa) in order to combine waveforms and geophysical corrections and retrievals. Sentinel-6 will be the first altimeter mission to provide Level 2 radiometer products at its original posting rate alongside the altimeter products.

Around the time of the OSTST meeting, test datasets will be made available to users, who will be invited to provide feedback on the content, applicability, and format. The presentation will show highlight some of these.
Corresponding author:
Remko Scharroo (**EUMETSAT**, **Germany**), remko.scharroo@eumetsat.int

New Data and Updates at PO.DAAC

Jessica Hausman (JPL, United States)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Oral

Abstract:
The Physical Oceanography Distributed Active Archive Center (PO.DAAC) is NASA's data center responsible for data management and distribution of satellite oceanographic data, as well as providing support for its scientific user base. PO.DAAC's data holdings relevant to Ocean Surface Topography include sea surface height and significant wave height from TOPEX/Poseidon, Jason-1, OSTM/Jason-2, SARAL/AltiKa and gravity measurements from GRACE. Our data holdings are constantly being updated to accommodate improved algorithms that evolve through time. New datasets include Integrated Multi-Mission Ocean Altimeter Data for Climate Research Version 4, a gridded Sea Surface Height Anomaly dataset and altimetric assimilated hydrology output.

To assist in serving out the numerous datasets at PO.DAAC, various tools and services are available with improvements from last year. The State of the Ocean (SOTO) visualizer has been undated with an extended time series and face lift. PO.DAAC 101 tutorial YouTube videos are available on how to use the web portal and OPeNDAP.

Corresponding author:
Jessica Hausman (**JPL**, **United States**), jessica.k.hausman@jpl.nasa.gov

The Antarctic Circumpolar Current as seen in Argonautica

Vinca Rosmorduc (CLS, France); Danielle De Staerke (CNES, France)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Oral

Abstract:
Last year, as every four years, Argonautica was even more centered on the Antarctic Circumpolar Current than usual, since the CNES educational project had a strong focus on the Vendee Globe around the Earth alone sail race.
We will show the data provided to the students, the oceanographic interpretation which was presented to them, but more interesting, what they did with the data.
Corresponding author:
Vinca Rosmorduc (**CLS**, **France**), vrosmorduc@cls.fr

Science communication through art, design, and hands-on activities

Laura Bracken (University of Miami Rosenstiel School, France)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Oral

Abstract:
Communicating complex scientific concepts to students, the general public, or policy makers is challenging and requires some creativity. The Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE) is a research group dedicated to studying ocean currents and oil spill transport through laboratory experiments, observational field campaigns, and modeling. Physical oceanographic processes and associated technology that CARTHE has developed to study those processes can sometimes be difficult for the target audience to understand so CARTHE has developed engaging outreach and educational programs. Through hands-on drifter design lessons and incorporating art into community-based citizen science, CARTHE has actively engaged new environmental stewards and the next generation of scientists and inventors. Join the discuss on developing creative ways to share complex ocean science.
Corresponding author:
Laura Bracken (**University of Miami Rosenstiel School**, **France**), lbracken@rsmas.miami.edu

OSTST-Related Outreach Activities

Edward Zaron (Portland State University, United States)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Oral

Abstract:
Two slides are provided which illustrate my OSTST-related outreach activities:

(1) Participation as a "Science Communication Fellow" at the Oregon Museum of Science and Industry -- The museum provides short workshops and training in public engagement, in exchange for the opportunities to volunteer at Meet a Scientist and other events at the museum.

(2) Short-term projects with undergraduate students -- Projects with undergraduates at my university engage students and provide them with entry points for research or future study in oceanography. My position as Research Assistant Professor does not normally involve teaching or formal interaction with students, so I typically spend $1000 to $1500 of discretionary funds provided by the university to hire undergraduates to work on short projects throughout the year. One of these students has gone on to participate in the Woods Hole REU program and she is currently considering graduate school in oceanography.
Corresponding author:
Edward Zaron (**Portland State University**, **United States**), ezaron@pdx.edu

Outreach and data services Showcases

All All (OSTST, France)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Oral

Abstract:
Once again, we would like to showcase & share examples of your products, activities, new data services, or results that support ocean altimetry educational or public outreach goals. Outreach showcases are short (1-2 min) presentation, showing an outreach activity you've led, a book published, a web site opened/updated, an exhibition you participated to, etc.
Corresponding author:
All All (**OSTST**, **France**), vrosmorduc@cls.fr

Malvinas Current volume transport at 41°S: a 24-year long time series consistent with mooring data from 3 decades and satellite altimetry

Camila Artana (Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN, France); Ferrari Ramiro (CIMA/CONICET-UBA and UMI IFAECI -3351, Argentina); Zoe Koenig (Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN, France); Nathalie Sennéchael (Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN, France); Martin Saraceno (CIMA/CONICET-UBA and UMI IFAECI -3351, Argentina); Piola Alberto (Departamento de Oceanografia, Servicio de Hidrografia Naval, DCAO/FCEN/UBA and UMI IFAECI-3351, CONICET, Argentina); Christine Provost (Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Oral

Abstract:
We combined altimetric data and the in situ data sets from three 10-years apart mooring deployments to compute a coherent and accurate 24 year-long volume transport time series of the Malvinas Current (MC) at 41°S. We used a look-up table method developed in Koenig et al. (2014) for the Antarctic Circumpolar Current in Drake Passage. We explored three types of shear to estimate the uncertainty derived from the lack of velocity data in the upper 300 m.
The mean MC transport over 24 years is 37.1□ 2.5 Sv and the standard deviation 6.6 □ 1 Sv. Since 1993, annual mean transports have varied from 32 to 41 Sv and the three in situ records corresponded to low annual mean transports. The MC transport time series is not stationary, its spectral content evolves with time showing significant energy at the 30-110 days, semi-annual and annual period. The distribution of the MC volume transport anomalies is asymmetric, negatively skewed with larger negative anomalies than positive anomalies. Transport maxima appear to result from cyclonic eddies shed by the Polar Front that propagate northwestward following the 4000-5000 m isobaths and locally reinforce the circulation on the slope when they reached 41°S. During transport maxima, the northernmost extension of the Subantarctic Front (SAF) remain at its mean location (39.5°S). During minima, the SAF migrates southward, over the mooring line as positive anomalies shed by the Brazil Current overshoot move westward onto the slope. Apart from continental trapped waves, changes in the MC volume transport at 41°S show no correlation with upstream conditions on the continental slope.

Corresponding author:
Camila Artana (**Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN**, **France**), camila.artana@locean-ipsl.upmc.fr

Southern Ocean Circulation and Climate Variability

Subrahmanyam Bulusu (University of South Carolina, USA, United States); Brady Ferster (University of South Carolina, USA)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Oral

Abstract:
The SO plays a major role in global ocean circulation, a system of surface and deep currents, linking all oceans and one of the fundamental determinants of the Earth's climate. The Southern Ocean (SO) has been subject to many climatic discussions, capable of transporting vast amounts of salt, heat, and nutrients to help regulate to global climate. Recent climatic studies aim to better understand the SO influence towards a shifting climate. This work discusses the importance of the Antarctic Circumpolar Current (ACC), as well as the role of the strong Westerlies on the ACC. Using nearly 25 years' worth of satellite-derived altimetry data, the interannual and spatio-temporal trends of sea surface height (SSH) and geostrophic currents were explored. Our work focuses on the relationship of surface winds (cross-calibrated Multi-Platform Ocean Surface Wind Vector Analyses) to further convey the role of the Westerlies on the SSH and surface currents. To understand the interannual to decadal variability in SO ocean circulation and transports we used eddy-resolving model simulations from Southern Ocean State Estimate (SOSE) and German-contribution to the Estimating the Circulation and Climate of the Ocean systems (GECCO2) simulations. Our preliminary results are supporting the intensification and southward shifting ACC currents. Additionally, waters at mid-depth (upper 1000m) in the SO have increased in temperature at a faster rate than the average rate for the entire global ocean. Due to the rapid warming of the SO, the thermohaline circulation will be affected as the ocean becomes warmer and atmospheric patterns shift, as well as a weakening overturning circulation.

Corresponding author:
Subrahmanyam Bulusu (**University of South Carolina, USA**, **United States**), sbulusu@geol.sc.edu

Observed Decadal Sea-Level Variations Over the Tropical Indo-Pacific Basin: Association with and Indicators for Varying Walker Cells and Climate Modes

Weiqing Han (The University of Colorado, United States)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Oral

Abstract:
Satellite observed sea surface height (SSH) over the tropical Indo-Pacific basin exhibits distinct spatial patterns of decadal variations since the 1990s: During some periods (e.g., 1998-2002), SSH rises in the maritime continent region that resides in the warm pool and hosts multitude coasts and Islands, and falls in the central-eastern Pacific and west Indian Ocean; during some other periods (e.g., 1993-1997), the SSH pattern reverses. In-situ based upper 700m thermosteric sea level shows evident decadal sea level variations since the 1960s, and can represent the overall pattern detected by satellite observations during their overlapping period. The distinct sea level patterns over both the tropical Pacific and Indian Oceans are largely driven by zonal surface winds associated with the Pacific and Indian Walker Cell (WCs), which vary on decadal timescales (periods of one to few decades) but the two do not always co-vary. Using a Bayesian Dynamic Linear Model (DLM), we explore the causes for the WCs' variability since the 1960s. During northern winter (Nov-Apr), decadal variability of ENSO plays a vital role in determining both the Pacific and Indian WCs, with El Nino–like conditions reducing warm pool convection and weakening the WCs, and the two WCs co-vary. During summer (May-Oct), while the Pacific WC is still determined by decadal variability of ENSO, the Indian WC is associated with decadal variations of ENSO, Indian Ocean Dipole (IOD), Indian summer monsoon convection and tropical Indian Ocean SST, with monsoon convection having the largest effect since the 1990s. The complex causes for the Indian WC during summer result in its poor co-variability with the Pacific WC for the summer season. These results indicate that decadal sea level patterns over the tropical Indo-Pacific basin are direct consequences of, and thus may serve as indicators for, decadal climate variability.

Corresponding author:
Weiqing Han (**The University of Colorado**, **United States**), whan@colorado.edu

Dynamical Links between the Decadal Variability of the Oyashio and Kuroshio Extensions

Bo Qiu (University of Hawaii, United States); Shuiming Chen Chen (University of Hawaii, USA); Niklas Schneider (University of Hawaii, USA)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Oral

Abstract:
Rather than a single and continuous boundary current outflow, long-term satellite observations reveal that the Oyashio Extension (OE) in the North Pacific subarctic gyre is comprised of two independent, northeast-southwest slanted, front systems. With a mean latitude along 40N, the western OE front exists primarily west of 153E and is a continuation of the subarctic gyre western boundary current. The eastern OE front, also appearing along 40N, is located between 153E and 170E, whose entity is disconnected from its western counterpart. During 1982-2016, both of the OE fronts exhibit prominent decadal fluctuations, although their signals show little contemporaneous correlation. An upper ocean temperature budget analysis based on satellite altimetry data and the ECCO2 state estimate reveals that the advective temperature flux convergence plays a critical role in determining the low-frequency temperature changes relating to the OE fronts. Specifically, the western OE front variability is controlled by the decadal mesoscale eddy modulations in the upstream Kuroshio Extension (KE). An enhanced eddy activity increases the poleward heat transport and works to strengthen the western OE front. The eastern OE front variability, on the other hand, is dictated by both the meridional shift of the KE position and the circulation intensity change immediately north of the eastern OE. Different baroclinic adjustment speeds for the KE and OE are found to cause the in-phase changes between these latter two processes.

Corresponding author:
Bo Qiu (**University of Hawaii**, **United States**), bo@soest.hawaii.edu

Using Sea Surface Height to examine Air-Sea Interaction in the North Atlantic Ocean in Winter

LuAnne Thompson (University of Washington, United States)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Oral

Abstract:
As a proxy for upper ocean heat content, the over 20-year record of sea surface height (SSH) allows an examination of whether the atmosphere or the ocean drives air-sea interaction on seasonal time scales. Here we examine seasonal lagged correlations between sea surface temperature (SST) and SSH with turbulent flux of heat (Q) to identify where and what time of year Q is predictable from SST(SSH). The canonical view of air-sea interaction in the mid-latitudes in winter is that the atmosphere forces SST anomalies that are then damped locally by the atmosphere. However, in regions of strong currents such as the Gulf Stream, ocean heat transport convergence controls SST and upper ocean heat content anomalies, and as such we expect that surface fluxes will be correlated with SST (SSH) at zero lag such that a warm ocean (high SSH) results in heat fluxed to the atmosphere. Identifying the regions with this structure in the lagged correlations localizes those regions where heat content anomalies that result from ocean heat transport convergence drive air-sea heat exchange.
We find that near the Gulf Stream but away from the core both early summer SST and SSH predict Q the following winter in the western part of the Northern Recirculation gyre. Both fields also show predictive skill for Q in the North Atlantic current although the predictability from SSH is longer. In addition, SSH, but not SST, shows predictive skill in the Eastern end of the Southern Recirculation Gyre where Subtropical Mode Water resides after subduction.
In addition to evidence for seasonal predictability of Q, observations also suggest that there is predictability for winter mid-level (tropospheric) cloud fraction. Turbulent flux Q is positively correlated with mid-level cloud fraction in the western part of the Northern Recirculation gyre and in the North Atlantic Current in winter at zero lag. We also find that early summer SSH predicts winter mid-level cloud cover in these two regions, consistent with the relationship found between SSH and Q. The relationship between Q and mid-level cloud cover in winter is consistent with the climatological analysis of atmospheric conditions over the Gulf Stream in winter by Minobe and co-workers.

Corresponding author:
LuAnne Thompson (**University of Washington**, **United States**), luanne@uw.edu

Combined assimilation of Sentinel-1 and Sentinel-3A wave data in operational wave model : investigation on bias for SAR mode altimetry

Lotfi Aouf (Division Marine et Océanographie Météo-France, France); Alice Dalphinet (Meteo-France, France)

Session: Application development for Operations
Presentation type: Oral

Abstract:
The increasing number of significant wave heights from satellite altimeters and SAR directional wave spectra will improve significantly the operational wave forecast and the reliability of the wave submersion warning system. During the calibration-validation phase of Sentinel-3A it has been indicated a strong bias of significant wave height retrieved by the SAR mode altimetry. The goal of this study is to investigate this bias by using the combined assimilation of SAR wave spectra provided by Sentinel-1A and 1B and the significant wave heights retrieved by Sentinel-3A. First waves climatology based on wave products from operational data base is implemented for all ocean basins to identify the areas of swell dominant sea state. In particular we will focus on the primary swells with wavelength ranged between 300 and 400 m.
The combined assimilation is performed for the southern winter of 2017 (June to September) because of many events generating swell systems. The results shows that the combined assimilation improves significanty the mean wave parameters. The validation with independent altimeters wave heights reveals the reduction of the bias (30 to 40%) after the assimilation mostly in the high and intermediate latitudes. An index is set depending on the bias reduction and the primary swell wave length and height. The index mapping indicates a strong correlation affecting the ocean areas of swell dominant sea state defined by the waves climatology. A comparison with combined assimilation using significant wave height of S-3A retrieved by PLRM processing, is also performed.
Further conclusions and discussions will be commented in the final paper.
Corresponding author:
Lotfi Aouf (**Division Marine et Océanographie Météo-France**, **France**), lotfi.aouf@meteo.fr

High-Resolution 3DVAR for Constraining Submesoscale Dynamics

Joseph D'Addezio (University of Southern Mississippi, United States); Gregg Jacobs (Naval Research Laboratory, USA); Scott Smith (Naval Research Laboratory, USA); Robert Helber (Naval Research Laboratory, USA); Clark Rowley (Naval Research Laboratory, USA)

Session: Application development for Operations
Presentation type: Oral

Abstract:
The launch of the Surface Water Ocean Topography (SWOT) satellite in 2021 will bring about new high-resolution surface observations that will resolve submesoscale variability like never before. Current high performance computing platforms allow the generation of submesoscale phenomena within regional ocean numerical models. However, due to non-deterministic processes the submesoscale features rapidly diverge from reality. The SWOT global observations are the first that will be capable of constraining the submesoscale for skillful ocean forecasts. Developed in anticipation of real-time SWOT data, an Observation System Simulation Experiment (OSSE) evaluates potential forecast improvements enabled by future SWOT data. A non-assimilative numerical simulation using a primitive equation 1 km resolution model for the entirety of 2016 provides a 'truth' for our OSSE case members. To generate a divergent simulation over the same time period, the initial condition was perturbed while using the same boundary conditions and surface forcing as was used in the simulated truth. As expected, mesoscale and submesoscale features between the two solutions diverge. The simulated truth was then sampled at real observation locations throughout 2016, and the observations were provided to the Navy Coupled Ocean Data Assimilation (NCODA) 3DVAR. The first simulation (the Control run) used only current observation systems to establish a baseline estimate of convergence by mainly constraining the mesoscale ocean features. Test SWOT data, created from the simulated truth using the Jet Propulsion Laboratory's (JPL) SWOT simulator, is used for two additional experiments (one containing all estimated errors and the other with none). The addition of simulated SWOT data both increases the rate and magnitude of convergence when compared with the Control run. The difference between the experiments using SWOT data with full errors and no errors provides a range of expected performance the satellite data will provide when operating.

Corresponding author:
Joseph D'Addezio (**University of Southern Mississippi**, **United States**), joseph.daddezio@usm.edu

The role of altimetry observations in constraining the Mercator Global Ocean analysis and forecasts

Yann Drillet (Mercator Ocean, France); Jean-Michel Lellouche (Mercator Ocean, France); Mounir Benkiran (Mercator Ocean, France); Antonio Bonaduce (Mercator Ocean, France); Mathieu Hamon (Mercator Ocean, France); Olivier Legalloudec (Mercator Ocean, France)

Session: Application development for Operations
Presentation type: Oral

Abstract:
Altimetry data is one of the key observing network to constrain ocean analysis and forecasts from meso scale to large scale. Since October 19, 2016, and in the framework of Copernicus Marine Environment Monitoring Service (CMEMS), Mercator Ocean delivers in real-time daily services (weekly analyses and daily 10-day forecasts) with a new global 1/12° high resolution system. The ocean modelling component is the NEMO platform driven at the surface by the IFS ECMWF atmospheric analyses and forecasts. Observations are assimilated by means of a reduced-order Kalman filter with a 3D multivariate modal decomposition of the forecast error. Along track altimeter data, satellite Sea Surface Temperature and in situ temperature and salinity vertical profiles are jointly assimilated to estimate the initial conditions for short term numerical ocean forecasting. A 3D-VAR scheme provides a correction for the slowly-evolving large-scale biases in temperature and salinity.
The current system benefit from significant improvements compared to its previous version thanks to updates such as: i) new freshwater runoff from ice sheets melting, ii) global steric effect added to the model sea level, iii) new Mean Dynamic Topography taking into account the last version of GOCE geoid, iv) adaptive tuning of altimetry and SST observational errors. The estimated observation errors for the different altimeters are greatly reduced compared to the previous system version. Those improvements lead to a better representation of the Global Mean Sea Level and regional sea level variability with reduced model forecast – observation differences and a better coherency between the in situ and satellite observation data sets assimilated in the system.

Dedicated studies are also conducted to better understand and improve the impact of altimetry data on the real time forecast and analysis. Not only an increasing number of altimeter data is improving the analysis and forecast quality but also their accuracy and their spatial coverage. The coherence between the Mean Dynamical Topography and the assimilated T and S in situ profiles is important: the new MDT (CNES-CLS 2013) allows reducing the T and S bias at depth.

Future challenges include the assimilation of large swath altimeter data. Preliminary assimilation of simulated observations show a clear benefit of 2D swath data compared to 1D track. It does not only improve the Sea Surface Height analysis and forecast but also allow a better velocity field estimation which should represent a significant benefit for Mercator Ocean and Copernicus users. The sensitivity to the complex error of those data will be assessed in the near future but the first results that will be presented are very promising.
Corresponding author:
Yann Drillet (**Mercator Ocean**, **France**), ydrillet@mercator-ocean.fr

Predictability of Submesoscale Flows Using Multiscale Data Assimilation of Satellite Altimetry

Zhijin Li (JPL, United States)

Session: Application development for Operations
Presentation type: Oral

Abstract:
We assess the impact of multi-satellite altimetry data on the representation of circulations down to submesoscales of the order of 1 km. Sub-km horizontal grid spacing is increasingly used in regional forecasting models to resolve submesoscale flows. To ensure a positive impact of satellite altimetry data in a model of sub-km grid spacing, we need to deal with a set of particular difficulties. Among those difficulties are the limited footprint size of altimetry measurement, dynamical imbalance, spatial localization and temporal intermittency, and others. Leveraging a real-time multiscale three-dimensional variational data assimilation (MS-3DVAR) and forecasting system, which supports the Salinity Processes in the Upper Ocean Regional Study (SPURS) field campaign in the North Atlantic Ocean in 2012-2013 (SPURS-1) and the eastern Tropical Pacific ocean in 2016-2017 (SPURS-2), and the SPURS multi-scale observing network, we illustrate those difficulties, address methodologies and formulations to deal with those difficulties, and demonstrate positive impacts of multi-satellite altimetry on the prediction of submesoscale flows.
Corresponding author:
Zhijin Li (**JPL**, **United States**), zhijin.li@jpl.nasa.gov

Combining altimetry with in situ data: quantitative impact assessment of operational ocean observation strategy in hurricane applications using Observing System Experiments and OSSEs

Matthieu Le Henaff (University of Miami/CIMAS and NOAA/AOML, United States); George Halliwell (NOAA/AOML, USA); Michael Mehari (UM/CIMAS and NOAA/AOML, USA); Jili Dong (NOAA/NCEP/EMC, USA); Villy Kourafalou (UM/RSMAS, USA); Robert Atlas (NOAA/AOML, USA); HeeSook Kang (UM/RSMAS, USA); Ioannis Androulidakis (UM/RSMAS, USA)

Session: Application development for Operations
Presentation type: Oral

Abstract:
Altimetry is the backbone of the present global ocean observing system, and its components (namely, altimeter satellites) are constantly evolving. Altimetry data are routinely combined with data from other satellites and in situ platforms by operational monitoring and prediction centers. However, a quantitative assessment of the benefit of the current and future components of the observing network is necessary to assess and improve its performance. The ocean Observing System Simulation Experiments (OSSE) system developed by the Joint Ocean Modelling and OSSE Center (OMOC) of NOAA/AOML, CIMAS, and RSMAS, University of Miami is designed and rigorously validated to ensure that credible observing system impact assessments are obtained. This modeling system covers the North Atlantic hurricane region, and has been used to perform Observing System Experiments, where actual data are assimilated into the ocean model, to assess the performance of the existing observation network. It has also been used to perform OSSEs, in which the data that are assimilated are extracted from an independent simulation that represents the true ocean. These OSEs and OSSEs were aimed at quantifying the ability of the observation network to constrain the upper ocean structure and heat content, which is essential for correct hurricane prediction. These experiments illustrate the key role played by altimetry data for that purpose, in particular for its ability to constrain a large portion of the ocean mesoscale spectrum. OSSEs were also performed during Hurricane Gonzalo (2014) to investigate how the deployment of ocean gliders and/or airborne ocean profilers, in addition to altimetry and other components of the observation network, can improve the overall performance of the network. Ocean profiles that sample both temperature and salinity down to 1000m are more effective for correcting ocean mesoscale features than shallower profiles of temperature alone obtained from typical XBTs and thermistor chains. The error reduction provided by the assimilation of observations from any individual instrument is primarily confined to a diameter smaller than 2° surrounding the measurement location. Large spatial coverage with multiple instruments is, therefore, necessary to reduce ocean initialization errors over a region broad enough to potentially have a significant impact on storm intensity forecasts. A coupled ocean-atmosphere prediction system initialized by ocean analyses from our OSE-OSSE system during the same hurricane allowed investigating the impact of these observations on the hurricane forecast. Assimilation of observations corrected the upper-ocean heat content ahead of the storm, enabling the coupled model to more accurately predict the heat flux from ocean to atmosphere that fuels the storm. The OSE-OSSE results demonstrate that in situ ocean observations combined with altimetry will play an important future role toward improving intensity forecasts of tropical cyclones.

Corresponding author:
Matthieu Le Henaff (**University of Miami/CIMAS and NOAA/AOML**, **United States**), m.lehenaff@miami.edu

Connecting Jason-3 to the Long-term Sea Level Record: Results from Harvest and Regional Campaigns

Bruce Haines (Jet Propulsion Laboratory, California Institute of Technology, United States); Shailen Desai (Jet Propulsion Laboratory, California Institute of Technology, United States); Adam Dodge (Colorado Center for Astrodynamics Research, University of Colorado, Boulder, United States); Bob Leben (Colorado Center for Astrodynamics Research, University of Colorado, Boulder, United States); Dallas Masters (Colorado Center for Astrodynamics Research, University of Colorado, Boulder, United States); Chirstian Meinig (NOAA Pacific Marine Environmental Laboratory, Seattle, United States); Steve Nerem (Colorado Center for Astrodynamics Research, University of Colorado, Boulder, United States); Rashmi Shah (Jet Propulsion Laboratory, California Institute of Technology, United States); Scott Stalin (NOAA Pacific Marine Environmental Laboratory, Seattle, United States)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
We describe the latest satellite radar altimeter calibration/validation (CALVAL) results from data collected at the Harvest offshore platform. Located 10 km off the coast of central California near Point Conception, Harvest has hosted a dedicated CALVAL facility for 25 years, dating to the launch of TOPEX/POSEIDON in August 1992. Harvest is directly in the path of the 10-d repeat ground track for the primary reference (Jason-class) altimeter missions, enabling the development of a continuous 25-year calibration record based on direct (overhead) passes of the platform.

Based on data collected during overflights of the latest (Jason-3) mission, we estimate the sea-surface height (SSH) bias is 0 ± 12 mm (one standard error with N= 29). In contrast, results for Jason-2 continue to yield a slight positive bias: +20 ± 2 mm (N=249; accounting for systematic errors, however, the bias is only slightly significant). Jason-2 has since been shifted to an interleaved repeat orbit which no longer passes over the platform. In terms of characterizing SSH stability using the Harvest data, only the Jason-1 and -2 missions have long enough time series at this time to support monitoring of drift at the 1 mm/yr level or better. Neither the Jason-1 nor Jason-2 SSH drift estimates are statistically distinguishable from zero. We update these results using information from new overflights.

We also report new campaign results from neighboring Jason ground tracks. These campaigns include: 1) a three-month deployment (May–Sept. 2016) of a precise GPS buoy at a Jason-2/3 crossover location (Daisy Bank) off the coast of Oregon; 2) a provisional tide gauge occupation (beginning June 2017) on Catalina Island along the ascending track (No. 119) adjacent to and south of Harvest; 3) a two-month deployment (July–Sept. 2017) of a precise GPS buoy in Monterey Bay along the ascending track (No. 221) adjacent to and north of Harvest. Early results from these campaigns testify to the potential of similar techniques for expanding the calibration footprint of Harvest in order to support other altimeter missions such as SWOT.

Corresponding author:
Bruce Haines (**Jet Propulsion Laboratory, California Institute of Technology**, **United States**), Bruce.J.Haines@jpl.nasa.gov

Updated altimeter absolute bias results from Bass Strait, Australia

Christopher Watson (University of Tasmania, Australia); Benoit Legresy (CSIRO, Australia); Matt King (University of Tasmania, Australia); Will Hextall (University of Tasmania, Australia)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
Through the use of moored oceanographic sensors, episodically deployed GNSS equipped buoys, a coastal tide gauge and continuously operating GNSS reference stations, the Bass Strait altimeter validation facility (40° 39'S, 145° 36' E) continues to provide cycle-by-cycle estimates of absolute altimeter bias. The historical comparison point has served the Jason-series reference missions since the launch of TOPEX/Poseidon. More recently, the site has been enhanced with infrastructure in support of the ESA Sentinel-3A mission.

Here we present our updated results detailing the evolution of absolute bias from the Jason-3 mission. We review the stability of the validation infrastructure prior to investigating sea surface height (SSH) bias and its constituent corrections. We briefly detail results for Sentinel-3A which is the focus of a separate presentation. We conclude with details of GNSS equipped buoy developments planned for the coming 12 months.
Corresponding author:
Christopher Watson (**University of Tasmania**, **Australia**), cwatson@utas.edu.au

Corsica: a multi-mission absolute calibration site

Pascal Bonnefond (Observatoire de Paris - SYRTE, France); Pierre Exertier (OCA-GEOAZUR, France); Olivier Laurain (OCA-GEOAZUR, France); Thierry Guinle (CNES, France); Pierre Féménias (ESA/ESRIN, Italy)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
In collaboration with the CNES and NASA oceanographic projects (T/P and Jason), the OCA developed a verification site in Corsica since 1996. CALibration/VALidation embraces a wide variety of activities, ranging from the interpretation of information from internal-calibration modes of the sensors to validation of the fully corrected estimates of Sea Surface Heights using in situ data. Now, Corsica is, like the Harvest platform (NASA side), an operating calibration site able to support a continuous monitoring with a high level of accuracy: a 'point calibration' which yields instantaneous bias estimates with a 10-day repeatability of around 30 mm (standard deviation) and mean errors of 3-4 mm (standard error). For a 35-day repeatability (ERS, EnviSat, SARAL/AltiKa), due to a smaller time series, the standard error is about the double (~7 mm).
In-situ calibration of altimetric height (SSH for ocean surfaces) is usually done at the vertical of a dedicated CAL/VAL site, by direct comparison of the altimetric data with in-situ data. Adding the GPS-based sea level measurements to the "traditional" tide gauges ones, it offers the great opportunity to perform a cross control that is of importance to insure the required accuracy and stability. This configuration leads to handle the differences compare to the altimetric measurement system at the global scale: the Geographically Correlated Errors at regional (orbit, sea state bias, atmospheric corrections...) and local scales (geodetic systematic errors, land contamination for the instruments, e.g. the radiometer).
Our CAL/VAL activities are thus focused not only on the very important continuity between past, present and future missions but also on the reliability between offshore and coastal altimetric measurement. With the extension of the Corsica site (Capraia in 2004 and Ajaccio in 2005), we are now able to perform absolute altimeter calibration for ERS -2, EnviSat, HY-2A, CryoSat-2 and SARAL/AltiKa with the same standards and precision than for T/P and Jason missions. The Sentinel-3 mission is also naturally included in our CAL/VAL activities. This will permit to improve the essential link between all these long time series of sea level observation.
The presented results will include the full set of TOPEX/Poseidon, Jason-1, Jason-2 and Jason-3 GDR products as well as the latest available set of Sentinel-3A products. First results of the CryoSat-2 SSH bias will be also presented. Concerning SARAL/AltiKa, we will provide updated results of the SSH bias including the drifting phase.

Corresponding author:
Pascal Bonnefond (**Observatoire de Paris - SYRTE**, **France**), Pascal.Bonnefond@obspm.fr

Absolute calibration of Jason-3 and Sentinel-3A on Lake Issykkul from GPS field campaigns

Jean-Francois Cretaux (CNES/LEgos, France); Muriel Berge-Nguyen (CNES/Legos, France); Stephane Calmant (IRD/Legos, France); Pascal Bonnefond (Obs de Paris / SYRTE, France); Nurzat Jamangulova (IWPB, Kyrgyzstan); Rysbek Satylkanov (IWPB, Kyrgyzstan); Florent Lyard (CNRS/Legos, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
Within the framework of Jason-2 mission, a Cal-Val project including continental waters (Rivers and lakes) had been setup in 2007. It includes installation of permanent site (meteo station, limnigraphs, GPS reference point) and regular field campaign for the whole lifetime of the satellite. The lake Issykkul in Kyrgyzstan has been chosen as site dedicated to lakes following a preliminary project in 2004 on this lake. It is funded by CNES.
Over the last decade more and more scientific studies were using satellite altimetry to monitor inland waters. However, same as for ocean studies, linking time series from different missions require to accurately monitoring the biases and drifts for each parameter contributing to the final estimate of the reflector height. Moreover the calibration of satellite altimetry over ocean does not apply to inland seas (e.g., corrections, retracking, geographical effects).
Regional Cal/Val sites supply invaluable data to formally establish the error budget of altimetry over continental water bodies, in addition to the global mission biases and drift monitoring. It allows checking
if specific conditions lead to different estimation of absolute bias of the instruments. Calibration over lakes surfaces for example has interesting characteristics with respect to ocean surface: wave and ocean tides are generally low, and to summarize, dynamic variability is much smaller than in the oceanic domain.
CAL/VAL activities on the oceanic domain have a long history and protocols are well established. CAL/VAL activities on lakes are more recent but in turn they address other problems such as the performance of the various tracking/retracking algorithms and more globally assess the quality of the geophysical corrections. This is achievable when measurements of specific and numerous field campaigns and ground permanent network of level gauges and meteo stations are processed to detect biases, errors in the geophysical corrections, etc. 14 campaigns with GPS receivers have been conducted on Issykkul lake (2004, 2005, and every year from 2008 to 2017), with receivers installed on a boat, and receivers on the shore. Cruise with GPS data along the ground track of each satellite were conducted. They allow estimating absolute bias of each altimeter, and relative bias between them. Cruise also allowed mapping the profile of the mean lake surface which is very steep in the case of the Lake Issykkul. We present here the results obtained from the last 4 campaigns dedicated to the cal/val of the altimeters onboard Jason-3 and Sentinel-3A.

Corresponding author:
Jean-Francois Cretaux (**CNES/LEgos**, **France**), jean-francois.cretaux@legos.obs-mip.fr

Comparisons of Jason-3 and Sentinel-3A and tide gauges

Eric Leuliette (NOAA, United States); Amanda Plagge (NOAA/GST, USA)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
As Jason-3 and Sentinel-3 missions approach nearly two years on orbit, system drifts in global mean sea level can be determined via the global tide gauge network with uncertainties approaching 1 mm/year. Here we extend previously presented work comparing the effect of vertical land motion (VLM) at tide gauges on derived drift for the combined TOPEX/Jason-1/Jason-2/Jason-3 dataset. We also examine the drift in Sentinel-3A using comparisons with the gauges by making comparisons for each half cycle (13.5 days). Since the SRAL altimeter on Sentinel-3A is the first to operate in high-rate/delay-Doppler mode globally, comparisons with tide gauges provide an opportunity to better understand the source of errors in altimeter minus tide gauge residuals. We discuss our expectations for the monitoring the system drift in Jason-CS/Sentinel-CS missions, which have a goal of monitoring the change of global mean sea level to within a 1 mm over a year.

Corresponding author:
Eric Leuliette (**NOAA**, **United States**), Eric.Leuliette@noaa.gov

Validation of a global dataset based on subwaveform retracking: improving the precision of pulse-limited satellite altimetry

Marcello Passaro (DGFI-TUM, Germany); Walter Smith (NOAA, USA); Christian Schwatke (DGFI-TUM, Germany); Gaia Piccioni (DGFI-TUM, Germany); Denise Dettmering (DGFI-TUM, Germany)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
The advantages of reprocessing the data from pulse-limited altimetry with the Adaptive Leading Edge Subwaveform Retracking (ALES) algorithm have been already demonstrated at the coast. We demonstrate in this talk that the same strategy improves the precision of satellite altimetry in the global ocean, presenting the new global ALES dataset, which is available through the Open Altimetry Database (OpenADB, webpage: openadb.dgfi.tum.de).

The validation work consists in a global crossover analysis, a high-rate noise assessment and a spectral analysis. The sea level differences at crossovers are computed using the same procedure for the ALES and the available Sensor Geophysical Data Records (SGDR) at 1Hz. Preliminary results on the Jason-2 missions shows that the standard deviation of the sea level differences at the crossover points is lower in ALES in over the 65 percent of the locations (see Figure). The spectral analysis shows that the use of ALES improves the description of the spectral content at wavelengths shorter than 100 km, i.e. reduces the spectral hump. The high rate noise assessment is based on consecutive differences of uncorrected sea level height (except that the range is corrected for the sea state bias), computed by subtracting the estimated range to the orbital altitude. It shows that, after the sea state bias correction recomputed using ALES Significant Wave Height and Backscatter Coefficient, the ALES ranges are 0.5 cm less noisy than the corresponding SGDR data at a typical significant wave height of 2.5 m in the open ocean (6 percent improvement).

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

Corresponding author:
Marcello Passaro (**DGFI-TUM**, **Germany**), marcello.passaro@tum.de

Validation of the extended CryoSat-2 ocean data products

Paolo Cipollini (National Oceanography Centre, United Kingdom); Christopher Banks (National Oceanography Centre, United Kingdom); Francisco Calafat (National Oceanography Centre, United Kingdom); Helen Snaith (British Oceanographic Data Centre, United Kingdom); Jérôme Bouffard (RHEA/ESRIN, Italy); Pierre Féménias (ESA/ESRIN, Italy)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
Operational marine products from CryoSat-2, generated by a dedicated processor, have been available since April 2014. Here we present some results of a verification and scientific validation of the Geophysical Ocean Products (GOP), which have consolidated orbits and are available 30 days after acquisition. This assessment, carried out within the ESA-funded CryOcean-QCV project, is performed for sea surface height anomaly (SSHA), significant wave height (SWH) and wind speed. ESA have recently made available GOP for the period covering November 2010 through March 2014 (therefore completing the time series) and the CryOcean-QCV project is currently producing the monthly quality/validation reports for this additional period in addition to continuing to provide the operational daily and monthly reports.
In this presentation, we first assess the quality of the global ocean products by showing how various indicators (e.g. histograms of SSHA, SWH, sigma0 and mispointing, and noise statistics for SSHA and SWH) vary over mission time. The results show the low level of noise and excellent stability of the SIRAL instrument, which allow its exploitation for oceanographic applications.
The 7+ year time series of CryoSat-2 data now allow a look at interannual-scale signals of relevance to climate. One particularly intriguing result is the global mean sea level (GMSL) observed by CryoSat-2. While this shows a trend in line with other altimeter-based estimates of GMSL, it also displays a larger amplitude of the seasonal signal (see figure). We illustrate and discuss ongoing work to investigate these differences, including looking at the role played by sampling and the role of hydrology and/or thermosteric effects.

Corresponding author:
Paolo Cipollini (**National Oceanography Centre**, **United Kingdom**), cipo@noc.ac.uk

Sentinel-3A STM Mission Performance after 1 year in orbit

Sylvie Labroue (CLS, France); Matthias Raynal (CLS, France); Pierre Féménias (ESA, Italy); Remko Scharroo (EUMETSAT, Germany); Denis Blumstein (LEGOS, France); Alan Muir (UCL, UK); Graham Quartly (PML, UK)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
Sentinel-3A mission was successfully launched in February 2016. It is a multi-instrument mission to measure surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. We focus here on the observations acquired over ocean by the Surface Topography Mission (STM) payload that encompasses a dual frequency altimeter, a dual frequency radiometer as well as Doris, LRR and GNSS sensors.

ESA and EUMETSAT have defined the Mission Performance Framework for qualifying the performance of the Sentinel-3 mission, sensors and products. One important piece of this component is the Mission Performance Centre (MPC), which is in charge of the performance of the Optical Mission and of the Surface Topography Mission (STM).

The Sentinel-3 Mission Performance Centre (S3-MPC) has been charged with different main activities for the STM:
- Quality Control activities of the Land products
- The calibration, characterisation and performance of the altimeter (SRAL) and the microwave radiometer (MWR) sensors
- Validation of the products and ground processing
- Assessment of the mission performance
- Support for the continuous improvement of the S-3 STM performance

The present paper will detail the results on the STM Sentinel-3A Level 2 mission performance. Based on more than 1 year of Sentinel-3A data, this assessment will address the performance obtained over ocean and coastal areas for different parameters (topography, wind and wave). The mission performance will be measured through the comparison to other altimeters and models.
While the mission performance is estimated with observations over ocean surfaces, we will also present an overview of the quality over other surfaces such as Land Ice, Sea ice and inland waters.

Corresponding author:
Sylvie Labroue (**CLS**, **France**), sylvie.labroue@cls.fr

Sentinel-3A Marine Center data calibration and validation in a multi-mission setting

Cristina Martin-Puig (EUMETSAT, Germany); Remko Scharroo (EUMETSAT, Germany); Carolina Nogueira-Loddo (EUMETSAT, Germany); Bruno Lucas (HE Space Operations, Germany); Salvatore Dinardo (HE Space Operations, Germany)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
Sentinel-3A has been successfully contributing to the continuity of the sea level climate data record for a year and a half. During the lifetime of the mission its processing baseline has considerably evolved, thereby stepwise improving data quality. This presentation is intended to provide an up-to-date Sentinel-3A data quality assessment for the latest reprocessed data in a multi-mission setting, and thus also allows to revisit the status of the Jason-3 and Jason-2 GDRs, compared to Sentinel-3A. In addition, the latest upgrades in the processing baseline and future evolutions will be introduced.

This presentation aims at: providing multi-mission time series of the main climate records (sea level, significant wave height, wind speed, and wet tropospheric path delay); detailing major improvements in processing, corrections and calibrations for the benefit of the data quality; quantifying data quality by mono- and multi-missions cross-overs; as well as providing more than a year worth of global assessment of SAR mode versus Pseudo-LRM measurements. On top of the previous, the next improvements in the processing baseline will be introduced and discussed.

Corresponding author:
Cristina Martin-Puig (**EUMETSAT**, **Germany**), cristina.martin@eumetsat.int

Jason-3 mission performance for operational oceanography applications and long term Climate Data Record continuity

Hélène Roinard (CLS, France); Olivier LAURET (CLS, France); Michael ABLAIN (CLS, France); Nicolas PICOT (CNES, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

Abstract:
Worthy successor to TOPEX/Poseidon Jason-1 and Jason-2, Jason-3 extends the high-precision ocean altimetry data record. Since mid-2016, Jason-3 has been the reference altimetry mission to estimate the Global Mean Sea Level (GMSL), instead of Jason-2. Regional and global biases between missions have to be precisely estimated in order to insure the quality of the reference GMSL serie. For its first 23 cycles, Jason-3 and Jason-2 flew together in tandem configuration, with only 80 seconds delay, which is a unique opportunity to precisely assess parameter discrepancies between both missions and detect geographically correlated biases, jumps or drifts. Jason-2 was moved on October 2nd 2016 to the same interleaved orbit that was used by TOPEX from 2002-2005 and Jason-1 from 2009-2012: since May 17th 2017, Jason-3 is the only satellite on the historical ground-track.

A precise knowledge of Jason-3 data quality and errors is a key activity to ensure a reliable service to scientists involved in climate change studies as well as operational oceanography.
This presentation aims at presenting the overall performance of Jason-3 mission through different metrics highlighting the high-level accuracy of this mission.

Corresponding author:
Hélène Roinard (**CLS**, **France**), hroinard@cls.fr

Technical aspects of coastal altimetry data processing

Remko Scharroo (EUMETSAT, Germany); Joana Fernandes (Universidade do Porto, Faculdade de Ciências; CIIMAR, Portugal)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Oral

Abstract:
The main limitations of conventional (Low Resolution Mode – LRM) ocean altimetry products in the coastal regions are related to the large footprint size of both the radar altimeter and the microwave radiometer, i.e., the difficulty of ocean algorithms to retrieve accurate surface parameters (surface height, significant wave height and backscatter) from coastal waveforms as well as errors in geophysical and range corrections associated to these regions.

In the last ten years, largely fostered by the set of coastal altimetry and OSTST workshops, great progress has been achieved in these topics, namely due to the advent of new instruments—Ka band and Synthetic Aperture Radar (SAR) altimetry—, new retracking algorithms, handling of the coastal contamination of radiometers, and improved corrections.

This paper presents a review of these advances and how they contributed to the development of altimetry products tuned to coastal applications.
Various methods have been proposed and tested to limit the effect of land in the retrievals of geophysical parameters from altimetry. For conventional altimetry (for which the waveforms are a given, sub-waveform retrackers have been shown to work well to retrieve results closer to the coast, even within the dimension of the footprint. To make these measurements unbiased with respect to the usual Brown waveform retrackers is an additional challenge.

In the case of SAR altimetry, one has two approaches: (1) devise a way to exclude echoes that show contamination and build a waveform only from the remaining, and (2) focus the waveform to such a narrow beam, that contamination can be excluded. Both techniques are still in their infancy but show some promising results.

Regarding the range geophysical and range corrections, great progress has been achieved in the wet tropospheric correction (WTC), by means of various approaches to improve the retrieval of the WTC near the coast (e.g. mixed pixel, land decontamination and GNSS-derived path delay algorithms) and in the development of better ocean tide models such as FES2014. Other corrections such as sea state bias still require further research to better understand sea state effects in the coastal zone, while various studies are taking place in modelling these effects in open-ocean and for the various altimeter modes (LRM, SAR). Advances in the modelling of other corrections such as the dynamic atmospheric correction and other atmospheric corrections driven by improved models will be presented. In addition, due to the height dependence on the tropospheric (dry and wet) corrections, the importance of providing them at high rate (20 Hz) in coastal products will be stressed.
Corresponding author:
Remko Scharroo (**EUMETSAT**, **Germany**), remko.scharroo@eumetsat.int

Coastal Altimetry: a review of scientific applications and synergies with complementary measurements

Jerome Bouffard (ESA - RHEA, Italy)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Oral

Abstract:
The coastal area is marked by energetic and complex dynamics covering a wide spectrum of space/time variability, often dominated by slope currents, rapidly evolving mesoscale structures as well as high-frequency extreme events and low-frequency sea level changes. The combination of these multi-scale hydrodynamic processes plays a key role on the across-shore transport and mixing of natural/anthropogenic elements, significantly affecting the biological and optical properties of water masses at the interface between the continental shelf and the open-ocean. It therefore appears fundamental to characterize and forecast the coastal dynamics in a synoptic way in order to better assess their impacts on human activities related to the protection of the marine environment and the sustainable management of coastal resources. These objectives require the support of high resolution modeling as well as long-term and regular observations. In this respect, the satellite altimeters represent an invaluable source of data that provides repetitive views of phenomena unachievable by other means. However, altimetry alone is not sufficient and new challenges still have to be faced concerning the altimetric noise reduction and the full scientific exploitation of both conventional (Ku-band pulse-limited altimetry) and new technologies (SAR/SARin, Ka-band altimetry) to characterise smaller scales of variability typical of coastal currents, winds / waves, sea level and extreme events. Over the past 10 years, continuous efforts have been made by the Coastal Altimetry Community to improve high resolution processing algorithms and develop new applications based on the synergy between coastal altimetry and complementary measurements. This paper proposes to make a review of the main advances in this field.
Corresponding author:
Jerome Bouffard (**ESA - RHEA**, **Italy**), jerome.bouffard@esa.int

Altimetry for Coastal Ocean Modeling and Analysis

John Wilkin (Rutgers University, United States); Claire Dufau (CLS, France); Paolo Cipollini (NOC, United Kingdom); Villy Kourafalou (U. Miami/RSMAS, USA); Pierre De Mey (LEGOS, France)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Oral

Abstract:
In coastal oceans and marginal seas, ocean circulation processes and sea level variability influence numerous human activities and impact environmental health and biological productivity. Altimeter data re-tracked and/or re-processed with range and geophysical corrections appropriate to coastal regions are a valuable complement to observations traditionally employed in shelf sea applications (moorings, drifters, tide gauges, ship-borne CTD, HF-radar, and satellite SST and color). Furthermore, the synthesis of coastal altimetry with hydrodynamic models is enhancing the skill of forecasts that assist decision-making for societal applications, especially with respect to inundation and sub-inertial timescale circulation. Recognizing this synergy of coastal altimetry and coastal modeling, the ARCOM (Altimetry for Regional and Coastal Ocean Modeling) joint initiative of the Coastal Altimetry Workshops (CAW) and GODAE Coastal Ocean and Shelf Seas Task Team (COSS-TT) is exploring how to accelerate the use of altimetry in applied coastal modeling, and how to use models to complement knowledge of MDT and MSS in coastal seas. Presentations at CAW/COSS-TT/ARCOM meetings have demonstrated successes in the complementary uses of altimetry, in situ observations, and models, and highlights of these will be given. These workshops have also noted that coastal oceanographers who lack expert knowledge in altimetry need guidance in using the various specialized coastal altimetry data sets that exist, and indeed seek simplified, unified multi-satellite “L4” altimeter products customized and optimized for coastal oceans.

Corresponding author:
John Wilkin (**Rutgers University**, **United States**), jwilkin@rutgers.edu

Assessment of the orbit related sea level errors for TOPEX altimetry at seasonal to decadal time scales

Saskia Esselborn (GFZ, Germany); Sergei Rudenko (DGFI-TUM, Germany); Tilo Schöne (GFZ, Germany)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Oral

Abstract:
Interannual to decadal sea level trends are indicators of climate variability and change. A major source of global and regional sea level data is satellite radar altimetry, which relies on precise knowledge of the satellite's orbit. Here, we assess the error budget of the radial orbit component for the TOPEX/Poseidon mission for the period 1993 to 2004 from a set of different orbit solutions. Upper bound errors for seasonal, interannual (5 years), and decadal periods are estimated on global and regional scales based on radial orbit differences from three state-of-the-art orbit solutions provided by different research teams (GFZ, GSFC, and GRGS). We have found that the global mean sea level error related to the orbit is of the order of 7 mm (more than 10% of the sea level variability) with negligible contributions on the annual and decadal time scales. In contrast, the orbit related error of the interannual trend is 0.1 mm/year (18% of the corresponding sea level variability) and might hamper the estimation of an acceleration of the global mean sea level rise. We show that for regional scales, the gridded orbit related error is up to 11 mm and for about half the ocean the orbit error accounts for at least 10% of the observed sea level variability. The seasonal orbit error amounts to 10% of the observed seasonal sea level signal in the Southern Ocean. We show that at interannual and decadal time scales, the orbit related trend uncertainties reach regionally more than 1 mm/year. The interannual trend errors account for 10% of the observed sea level signal in the Tropical Atlantic and the south-eastern Pacific. For decadal scales, the orbit related trend errors are prominent in a couple of regions including: South Atlantic, western North Atlantic, central Pacific, South Australian Basin, and Mediterranean Sea. Based on a set of test orbits calculated at GFZ, the sources of the observed orbit related errors are further investigated. We study, in particular, contributions from the errors in Earth's time variable gravity field models, International Terrestrial Reference System realizations (ITRF2008 versus ITRF2014), tracking station sub-networks, i.e., SLR and DORIS. We conclude that the main contributors on all time scales are uncertainties in Earth's time variable gravity field models and on annual to interannual time scales discrepancies of the tracking station sub-networks.

Corresponding author:
Saskia Esselborn (**GFZ**, **Germany**), Saskia.Esselborn@gfz-potsdam.de

How reliable are regional sea level trends ?

Pierre Prandi (CLS, France); Benoit Meyssignac (CNES/LEGOS, France); Michael Ablain (CLS, France)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Oral

Abstract:
In this study we try to quantify realistic uncertainties on regional sea level trends derived from 20+ years of satellite altimetry data.

Different error sources affecting altimeter measurements are modeled to construct a complete error covariance matrix, which is then used as the input of an inverse method for local trend estimation. This results as a map of systematic uncertainties.

We also investigate our ability to detect climate change signals in regional sea level records from satellite altimetry. Outputs of climate models are used to provide a description of natural sea level variability, which is added to the system error covariance matrix. Results show that in the majority of the oceanic domain, observed sea level trends are related to climate change.

Corresponding author:
Pierre Prandi (**CLS**, **France**), pprandi@cls.fr

A promising parametric spectral analysis method applied to sea level anomaly signals

Corinne Mailhes (TeSA, France); David Bonacci (TeSA, France); Amandine Guillot (CNES, France); Sophie Le Gac (CNES, France); Nathalie Steunou (CNES, France); Cécile Cheymol (CNES, France); Nicolas Picot (CNES, France); Gérald Dibarboure (CNES, France)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Oral

Abstract:
Spectral analysis of sea level anomalies (SLA) is widely used in the altimetry community to understand the geophysical content of the measured signal, to assess and compare the outputs of different missions. Spectral content of SLA is used to characterize ocean at different scales and to estimate the instrumental noise. Based on the SLA spectrum, one can estimate the spectral slope at medium to large scales (relied to the Surface Quasi-Geostrophic (SQG) ocean dynamics theory) and the measurement noise (observed as a noise plateau at smallest scales).
A previous contribution [1] has pointed out the weaknesses of spectral analysis based on Fourier transform, mainly due to: (1) the convolutive bias which results in a biased estimation of the slope, the bias being related to the kind of observation weighting temporal window used and (2) the high variance of estimation leading to averaging several spectral estimations and raising the question of stationarity.
To overcome these two drawbacks, a parametric spectral analysis method is proposed. This method is based on Auto-Regressive (AR) modeling [2,3] which is known to provide a spectral estimation with a lower variance than the as outperforming Fourier-based methods in terms of variance, in the case of short observation windows, without any need for choosing a weighting temporal window. Moreover, in order to better match the SLA frequency contents on a log scale to match the log scale interest of the SLA frequency contents , warping is introduced as a preprocessing prior to spectral analysis as it is done in speech coding [4].
Comparisons between the proposed parametric method (called ARWARP) and classical Fourier Fourier-based methods have been performed on both simulated SLA signals obtained from theoretical spectra and real signals from a high-resolution altimeter SARAL/AltiKa at 40 Hz rate (Orbit – Range – Mean Sea Surface). Results on simulated SLA signals highlight the performance of the ARWARP method, in terms of bias and variance on spectral estimation. ARWARP can be applied on short segments of SLA signals, providing a local information of the ocean characteristics, which can be of promising use by the wider Cal/Val and altimetry science community.

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Corresponding author:
Corinne Mailhes (**TeSA**, **France**), corinne.mailhes@tesa.prd.fr

Altimetric wavenumber spectra: noise floors and resolution capability

Oscar Vergara (LEGOS/OMP, France); Rosemary Morrow (LEGOS/OMP, France); Isabelle Pujol (CLS Space Oceanography, France); Gerlad Dibarboure (CNES, France)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Oral

Abstract:
Recent progress in satellite altimetry has greatly improved the observability of mesoscale structures in the ocean. Here we analyze the noise levels and observable spatial scales for the global ocean using the wavenumber spectra of the three-year SARAL/Altika 1Hz Sea Surface Height (SSH) along-track measurements. We observe that noise estimations (for the wavelength range 15-30 km) tend to deviate from a purely white noise spectrum in regions of low eddy energy, and in particular inside the tropical band (15°S-15°N). Noise levels also vary seasonally, with an overall higher noise level during winter months in comparison to summer. The capability for resolving fine spatial scales also varies as a consequence of the noise level seasonality. During winter months, the observable wavelength reduces by about 5 to 20 km with respect to summer season. In general, these variations are less important in western boundary current systems in comparison to less energetic current systems, given the relatively favorable signal to noise ratio that is found in western boundary current systems.
Corresponding author:
Oscar Vergara (**LEGOS/OMP**, **France**), oscar.vergara@legos.obs-mip.fr

Quality Assessment of Sentinel-3a PDGS land products for the Monitoring of Lakes and Rivers Water Level

Lionel Zawadzki (CLS, France); Nicolas Taburet (CLS, France); Rémi Jugier (CLS, France); Maxime Vayre (CLS, France); Matthias Raynal (CLS, France); Sylvie Labroue (CLS, France); Michaël Ablain (CLS, France); Pierre Femenias (ESA/ESRIN, Italy); Stéphane Calmant (IRD/LEGOS, France); Jean-François Cretaux (CNES/LEGOS, France); Denis Blumstein (CNES/LEGOS, France)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Oral

Abstract:
By their essential role in the world's ecology system, rivers and lakes have always been of major importance for the world's population. With the increasing demography, fresh water is a more and more pressured resource for the population needs as well as a societal risk for local populations. It is also a fundamental element for industry and agriculture, therefore becoming an economic and political stake. Rivers and lakes monitoring is thus indispensable but still remains a challenge because of the limited accessibility to upstream regions, the scarce repartition of in situ gauges and the limited dissemination of their measurements.
Though the quality of their measurements over inland waters is lower than over oceans, the existing altimetry data allows a massive live and historical access to a wide network of information: on the THEIA/Hydroweb and Copernicus Global Land service, over 150 lakes and 1200 virtuals stations (intersection between altimeter ground track and river) have been computed with an accuracy of 10-40 cm. The operational products –63 lakes and 58 virtual stations – are currently based on Jason-3. The offline products are based on the whole past and present altimetry constellation. A large part of the lake product covers from 1993 to today.
Sentinel-3a, launched early 2016, will make a major contribution to the monitoring of rivers and lakes and is currently integrated in the products. Thanks to this new operational mission, the lake water level accuracy will be increased and the network will be expanded by 800 new virtual stations by the end of 2017.
The quality assessement of the Sentinel-3a PDGS land products from level 2 to level 3 is essential before the release of the products. In this study, we propose a set of diagnoses to assess routinely the quality of altimetry measurements at global and basin scale. These diagnoses are then applied to the reprocessed Sentinel-3a PDGS land products from the beginning of the missions onwards.

Corresponding author:
Lionel Zawadzki (**CLS**, **France**), lzawadzki@cls.fr

Update and validation of the onboard Jason-3 DEM for enhanced acquisitions over inland water targets

Sophie Le Gac (CNES, France); François Boy (CNES, France); Denis Blumstein (CNES, LEGOS, France); Augé Emmanuel (NOVELTIS, France); Sylvain Biancamaria (LEGOS, Université de Toulouse, CNRS, IRD, UPS , France); Jean-François Crétaux (CNES, LEGOS , France); Stéphane Calmant (LEGOS, Université de Toulouse, CNRS, IRD, UPS , France); Fabien Blarel (LEGOS, Université de Toulouse, CNRS, IRD, UPS , France); Frédéric Frappart (LEGOS, Université de Toulouse, CNRS, IRD, UPS , France); Charon Birkett (Earth System Science Interdisciplinary Center, University of Maryland-College Park (ESSIC/UMD), USA); Nicolas Picot (CNES, France)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Oral

Abstract:
On Jason-3, data acquisition over inland water bodies is performed in either Diode/DEM mode or Autonomous Mode. For the first time, the altimeter tracking command is driven by the “mode bit” allowing switching automatically between these two modes [1].

From previous experience acquired on Jason-2 and SARAL/AltiKa, the DEM version generated for the launch of Jason-3 [2] included about 250 lakes from the Hydroweb database and a network of about 1500 virtual stations over rivers.
A global validation has been performed over the past year and has provided a very satisfying ratio of 95% successful acquisitions over lakes and 80% over rivers in DIODE/DEM mode.

In June 2016 (cycle 11 onwards), the onboard Jason-3 DEM was updated for taking into account a new additional network of 100 stations over France rivers. A subsequent validation work has been carried out [3] and has demonstrated that the altimeter is acquiring high quality measurements over all those virtual stations. Some river reaches have even been observed for the first time with an altimetry system thanks to the DIODE/DEM acquisition mode, including reaches that are only a few tens of meters wide. This study further validates the instrument behavior and demonstrates its capability to observe hydrological targets in this specific acquisition mode.

Building on this success, an update of the onboard DEM has been carried out in order to resolve the few remaining failures and expanding its coverage by including numerous new targets. This constitutes a great leap forward for Jason-3 DEM with a current total number of about 4350 river targets and 350 lakes.
We present details on this version of the DEM and illustrate its global validation, highlighting specific data cases over rivers and lakes.
We believe that the DEM quality and subsequent tracker performance is and will be of growing added-value to the hydrology community in preparation for SWOT.

[1] Desjonqueres et al., Jason-3/POS-3B First results, OSTST 2016.
[2] Augé et al., Performance analysis between autonomous tracker median and new version of OLTC mode, OSTST 2015.
[3] Biancamaria et al., Validation of Jason-3 tracking modes over French rivers, Rem. Sens. Env., submitted, 2017

Corresponding author:
Sophie Le Gac (**CNES**, **France**), sophie.legac@cnes.fr

The ICESat-2 Inland Water Height Data Product: Overview and Evaluation Using High Altitude Lidar Observations

Michael Jasinski (NASA Goddard Space Flight Center, United States); J. Stoll (SSAI, USA); C. Arp (University of Alaska, USA); C. Birkett (University of Maryland, USA); K. Brunt (University of Maryland, USA); W. Cook (NASA GSFC, USA); C. Hiemstra (CRREL, USA); B. Jones (USGS, USA); M. Ondrusek (NOAA, USA); T. Pavelsky (University of North Carolina, USA); E. Stengel (NOAA, USA)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Oral

Abstract:
The Advanced Topographic Laser Altimeter System (ATLAS) on the Ice, Cloud, and Land Elevation Satellite (ICESat-2), is a polar orbiting, high repetition rate, six-beam 532 nm Lidar scheduled to launch in 2018. Although primarily designed for icecap and sea ice monitoring, ATLAS also will conduct dense observations of all inland water body surfaces that it transects during its designed three-year life span. An ICESat-2 Inland Water Body Height Data Product has been developed to estimate along-track water surface height statistics in approximately 100 m length segments, for water bodies greater than about 3 km wide. While the domain of the ATL13 data product is global, the focus is on high-latitude terrestrial regions where the convergence of the ICESat-2 orbits will provide spatially dense observations.
In advance of the mission, the ICESat-2 Inland Water Height algorithm was tested using high altitude airborne Multiple Beam Altimeter Lidar Experimental Lidar (MABEL) observations over wide range of water targets. The current analysis examines several MABEL inland and near coast targets during 2012 to 2015, focusing on the retrieval of surface water height statistics under a range of atmospheric and water conditions. Sites include lakes within the continental U.S. and Alaska, the Chesapeake Bay, and the near shore Atlantic coast.
Overall, the analyses of the MABEL observations have demonstrated an excellent feasibility for the ICESat-2 Inland Water Height algorithm to meet its objective of providing quantifiable surface water height statistics, depending on atmospheric conditions and water states. Future ICESat-2 observations are expected to offer higher elevation precision than is possible from current radar altimeters, thereby offering improved understanding of lake, river and near shore dynamics. Nonetheless, there is continuing need to coordinate ICESat-2 and future radar altimeter observations for improved CAL/VAL.

Corresponding author:
Michael Jasinski (**NASA Goddard Space Flight Center**, **United States**), Michael.F.Jasinski@nasa.gov

AltiCryo: a CNES altimetry concept study for cryosphere monitoring

Amandine Guillot (CNES, France); Frédérique Rémy (LEGOS, FRANCE); Alexandre Guérin (CNES, France); Jean-Luc Courrière (CNES, France); Anne Lifermann (CNES, France); Yves Le Roy (TAS, France)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Oral

Abstract:
The cryosphere monitoring is crucial for environment and climate studies. Alongside Cryosat-2, SARAL/AltiKa, another altimetry mission, developed by CNES and ISRO, has greatly contributed in advancing cryosphere studies . From its launch in 2013 until July 2016, SARAL/AltiKa flew on the same orbit as Envisat, providing continuity of topography measurement on the historic ground track of ERS1,2 since 1992. Also, the AltiKa instrument provides active (altimeter) and passive (radiometer) measurements in Ka-band, which is valuable to understand the ice and snow properties (F. Rémy et al [1]).
The French space agency (CNES) has initiated a study to propose an altimetry concept optimized for cryosphere (sea ice and ice sheets) and based on the SARAL/AltiKa heritage including Ka-Band operation and a single antenna shared by the altimeter and the radiometer. This study has been named AltiCryo. It is highlighted that no interferometric capability is considered for the AltiCryo altimeter since a compact design is foreseen.
The first step of the study was to document users' needs for cryosphere, based on the actual knowledge acquired with current missions (both SARAL and Cryosat) and physical measurement capabilities. The outputs are a User Requirement Document and the notes from the user meeting held in Paris in February 2017 (and co-organized with ESA). The users have pointed out several critical points for the mission: covering very high latitudes (≥88°) in order to monitor Arctic multi-year ice and West-Antarctica, the need of high spatial resolution and precision, and a bi-frequency Ka/Ku altimeter so as to improve our knowledge of the snow penetration effect and enable the snow thickness measurement over sea ice.
The second step consisted in the definition of an instrumental configuration which satisfies the scientific needs. The instrument definition includes a 2 or 3 channels radiometer (to help characterizing surface properties over ice, as well as providing wet tropospheric correction over ocean) and a Ku/Ka band altimeter, thus leading to an antenna carrying up to 5 frequencies. SAR Closed Burst and interleaved modes are proposed in Ka-Band (main band) and Ku-Band, with simultaneous transmission in the two bands. Tracking flexibility is offered since tracking can be performed either in Ku-Band (target: land ice) or in Ka-Band (target: sea surfaces). The architecture, associated performances and the mass/consumption budgets are presented.
Lastly, it is intended to compare the SAR and SARin measurement configurations regarding the impact on slope correction over land ice and off-nadir detection of leads over sea ice.
[1] Frédérique Rémy, Thomas Flament, Aurélie Michel & Denis Blumstein (2015) Envisat and SARAL/AltiKa Observations of the Antarctic Ice Sheet: A Comparison Between the Ku-band and Ka-band, Marine Geodesy, 38:sup1

Corresponding author:
Amandine Guillot (**CNES**, **France**), amandine.guillot@cnes.fr

Swath Processing improvements of CryoSat-2 for the Study of Ice Caps and Mountain Glaciers

Albert Garcia-Mondejar (isardSAT Ltd., United Kingdom); Maria Jose Escorihuela (isardSAT Ltd., United Kingdom); Monica Roca (isardSAT Ltd., United Kingdom); Flora Weissgerber (University of Edinburgh, United Kingdom); Noel Gourmelen (University of Edinburgh, United Kingdom)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Oral

Abstract:
Satellite altimetry has been used extensively in the past few decades to observe changes affecting large and remote regions covered by land ice such as the Greenland and Antarctic ice sheets. Glaciers and ice caps have been studied less extensively due to the limitation of altimetry over complex topography. However, their role in current sea-level budgets is significant and is expected to continue over the next century and beyond (Gardner et al., 2011), particularly in the Arctic where mean annual surface temperatures have recently been increasing twice as fast as the global average (Screen and Simmonds, 2010).
Radar altimetry is well suited to monitor elevation changes over land ice due to its all-weather year-round capability of observing ice surfaces. Since 2010, the Synthetic Interferometric Radar Altimeter (SIRAL) on board the European Space Agency (ESA) radar altimetry CryoSat (CS) mission has been collecting ice elevation measurements over glaciers and ice caps. Its Synthetic Aperture Radar Interferometric (SARIn) processing feature reduces the size of the footprint along-track and locates the across-track origin of a surface reflector in the presence of a slope. This offers new perspectives for the measurement of regions marked by complex topography.

More recently, data from the CS-SARIn mode have been used to infer elevation beyond the point of closest approach (POCA) with a novel approach known as “swath processing” (Hawley et al., 2009; Gray et al., 2013; Foresta et al., 2016). Together with a denser ground track interspacing of the CS mission, the swath processing technique provides unprecedented spatial coverage and resolution for space borne altimetry, enabling the study of key processes that underlie current changes of ice caps and glaciers.
In the frame of the CryoSat+ Mountain Glacier project, we use CS swath observations to generate global maps of ice elevation change over ice caps and glaciers.

Here we present the retracking improvements that have been included in the swath processing chain to better assess glaciers and ice caps changes and their contribution to changes in sea level.
Corresponding author:
Albert Garcia-Mondejar (**isardSAT Ltd.**, **United Kingdom**), albert.garcia@isardsat.co.uk

A review of the current altimetry mission performances over the polar ice sheets: Cryosat-2, AltiKa and Sentinel-3A

Jérémie Aublanc (CLS, France); Pierre Thibaut (CLS, France); Thomas Moreau (CLS, France); Clément Lacrouts (CLS, France); Francois Boy (CNES, France); Amandine Guillot (CNES, France); Nicolas Picot (CNES, France)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Oral

Abstract:
Earth's polar regions have been monitored near continuously by altimeter satellites for 30 years now. Thanks to their wide coverage and high temporal sampling, radar altimeters have greatly improved our knowledge of the ice-sheet topography and our understanding of the ice sheet dynamics. Until the 2010s, radar altimeters have been exclusively operating in the Ku-band, in Low Resolution Mode (LRM). This technique has been successfully exploited for oceanic surveys but suffers from several limitations over the polar ice sheets. The combined effects of surface roughness, surface slope and signal penetration into the snowpack affect the LRM measure in various ways.

A new promising generation of altimeter satellites has been launched in the last few years: Cryosat-2 (2010), Saral/Altika (2013) and Sentinel-3A (2016). Thanks to its Ka frequency, the penetration depth of the AltiKa signal in the snowpack is much smaller than usual Ku frequency radars. This property is supposed to facilitate the estimation of the ice sheet elevation at snow/air interface. In the same time, Cryosat-2 and Sentinel-3A carry a new generation of radar altimeter, operating in the innovative "Delay Doppler" mode (or SAR mode). This specific mode improves the along-track resolution to 300 meters, bringing valuable perspectives for the monitoring of ice-sheet surfaces.

The main objective of this presentation is to show a cross-comparison of the current altimetry missions over the polar ice sheets' interior: Cryosat-2 (LRM, Ku-band), AltiKa (LRM, Ka-band) and Sentinel-3A (SARM, Ku-band). This work has been performed over one year of data in 2016/2017, corresponding to a common acquisition period for the three missions. Firstly, we will illustrate the measure sensitivity to the snowpack volume scattering by analyzing the waveform shapes. Secondly, we will assess the precision and accuracy of the surface elevation retrieved from the waveforms in comparison with laser altimetry data (ICESat), GNSS acquisitions and existing DEMs. Finally, we will present several key results showing the benefits brought by the SAR mode and the Ka-band for monitoring the polar ice sheets. The comparison is of interest in the context of the definition of a future cryosphere observation mission.
Corresponding author:
Jérémie Aublanc (**CLS**, **France**), jaublanc@cls.fr

Long-distance radiation of barotropic Rossby waves from tropical instability waves

Tom Farrar (Woods Hole Oceanographic Institution, United States); Ted Durland (Oregon State University, USA); Steven Jayne (Woods Hole Oceanographic Institution, USA)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral

Abstract:
Analysis of sea-surface height (SSH) anomalies from satellite altimetry shows variability throughout much of the North Pacific that is coherent with tropical instability waves. This variability has regular phase patterns that are consistent with barotropic Rossby waves having northward energy propagation, and the waves can be clearly seen to propagate from the equatorial region to at least 30N. Comparisons with numerical simulations support the conclusion that this remote variability can indeed be attributed to barotropic Rossby waves generated near the equator. Near 40N, the SSH field remains coherent with the near-equatorial SSH variability, but it is not as clear whether the variability at the higher latitudes is a simple result of barotropic wave radiation from the tropical instability waves; for example, there is some wind variability at the higher latitudes that is coherent with both the local SSH and the TIWs near the equator.

These barotropic Rossby waves contribute to the mesoscale variability in SSH in the midlatitudes. This variability is not well represented in the widely used AVISO gridded SSH products, and this appears to be a result of the assumed form of the autocovariance function used for the objective mapping scheme.

Corresponding author:
Tom Farrar (**Woods Hole Oceanographic Institution**, **United States**), jfarrar@whoi.edu

Global Observations of Eddy-Induced Mixed Layer Depth Variabilit

Peter Gaube (Applied Physics Laboratory - Univ. of Washington, United States); Dennis McGillicuddy (Woods Hole Oceanographic Institution, USA)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral

Abstract:
The near-surface mixed layer acts as a conduit between the oceans interior and the atmosphere. Mesoscale eddies, energetic vortices covering nearly a third of the ocean surface, modulate the spatial and temporal evolution of the mixed layer. We present a global analysis of concurrent satellite observations of mesoscale eddies with hydrographic profiles by autonomous Argo floats, revealing rich geographic and seasonal variability in the influence of eddies on mixed layer depth. Anticyclones are shown to deepen mixed layer depth while cyclones thin this layer, with the magnitude of these eddy-induced mixed layer depth anomalies being largest in the winter. Eddy-centric composite averages reveal that the largest anomalies occur at the eddy center and decrease with distance from the center. Furthermore, the extent to which eddies modulate mixed layer depth is linearly related to the sea surface height amplitude of the eddies. Finally, large eddy-mediated mixed layer depth anomalies are more common in anticyclones. We present candidate mechanisms for this observed asymmetry.
Corresponding author:
Peter Gaube (**Applied Physics Laboratory - Univ. of Washington**, **United States**),
pgaube@apl.washington.edu

Modulation of the Ganges-Brahmaputra river plume by the Indian Ocean Dipole and eddies inferred from satellite observations

Severine Fournier (JPL, United States); Jerome vialard (IRD-LOCEAN, France); Matthieu Lengaigne (IRD-LOCEAN/NIO, France/India); Tong Lee (JPL, USA); Michelle Gierach (JPL, USA); A.V.S Chaitanya (NIO, India)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral

Abstract:
The Bay of Bengal (BoB) receives large amounts of freshwater from the Ganga-Brahmaputra river during the summer monsoon. The resulting upper-ocean freshening influences seasonal rainfall, cyclones, and biological productivity. Ocean currents play a prominent role in the BoB sea surface salinity (SSS) space-time variations, in particular the western boundary current known as the East Indian Coastal Current (EICC). Sparse in-situ observations suggest that the EICC transports these freshwaters southward after the monsoon as a ~200-km wide, 2000-km long “river in the sea” along the East Indian coast. Circulation changes associated with the Indian Ocean Dipole (IOD) and offshore meandering of freshwater due to mesoscale eddies can strongly influence the transport of freshwater within the BoB. SSS from the Soil Moisture Active Passive (SMAP) satellite along with altimetry data, including sea surface height (SSH) and currents, provide unprecedented views of this peculiar “river in the sea” feature from intraseasonal to interannual timescales. The good correspondence in the synergistic use of SSS and altimetry, two independent datasets, shows that SMAP SSS well captures mesoscale features such as eddies. In addition, SMAP SSS agree well with in-situ measurements, capturing the strong cross-shore SSS contrasts (~10-pss) measured along ship transects. Our results further show that remote forcing associated with the negative IOD in the fall of 2016 caused a stronger EICC and “river in the sea” that extended approximately 800 km further south than that in 2015. Moreover, mesoscale eddies induced meandering of this plume, exporting freshwater away from the coast.

Corresponding author:
Severine Fournier (**JPL**, **United States**), severine.fournier@jpl.nasa.gov

Eddy generation and propagation in the Southern Ocean diagnosed from Satellite Altimetry and an Ocean State Estimate

Uriel Zajaczkovski (Woods Hole Oceanographic Institution, United States); Sarah T. Gille (Scripps Institution of Oceanography, United States); Matthew R. Mazloff (Scripps Institution of Oceanography, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral

Abstract:
The Southern Ocean features high eddy kinetic energy, identifiable in satellite altimetry along the entire length of the Antarctic Circumpolar Current (ACC). However, analysis of altimeter data and an ocean state estimate show that the generation of relatively large amplitude eddies is not a ubiquitous feature of the Southern Ocean but rather a phenomenon that is constrained to five isolated, well-defined "hotspots". These hotspots, identified using altimeter data, are located downstream of major topographic features, with their boundaries closely following f/H contours. Eddies generated in these locations tend to disperse along f/H contours rather than following lines of constant latitude (or f). Furthermore, eddies generated in these locations show no evidence of a bias in polarity and decay within the boundaries of the generation area rather than propagating long distances. An ocean state estimate shows enhanced values of both buoyancy and shear production inside the hotspots, with buoyancy production one order of magnitude larger than shear production. This is consistent with baroclinic instability being the main mechanism of eddy generation. The mean potential density field estimated from Argo floats shows that inside the hotspots, isopycnal slopes are steep, indicating availability of potential energy and providing further evidence of the main generation mechanism. The hotspots identified in this study overlap with previously identified regions of standing meanders. We provide evidence that hotspot locations can be explained by the combined effect of topographic features, standing meanders that enhance baroclinic instability, and availability of potential energy to generate eddies via baroclinic instabilities. The tracking of eddy trajectories using the altimeter shows that the Southern Ocean has two distinct eddy motion regimes. North and south of the ACC, eddies propagate westward with a mean meridional drift directed poleward for cyclonic eddies (CEs) and equatorward for anticyclonic eddies (AEs). Eddies spawned within the boundaries of the ACC have an effective eastward propagation with respect to the mean deep ACC flow, and the mean meridional drift is reversed, with warm-core AEs propagating poleward and cold-core CEs propagating equatorward. This reversed meridional circulation pattern of semi-coherent eddies in the ACC, drives down-gradient eddy heat transport, which could potentially transport a significant fraction of the net poleward ACC eddy heat flux (30 to 70 x 10^13 W, as inferred in previous studies).

Corresponding author:
Uriel Zajaczkovski (**Woods Hole Oceanographic Institution**, **United States**), uriel@whoi.edu

Up to which extent can we characterize ocean eddies using present-day altimetric products?

Angel Amores (IMEDEA, Spain); Gabriel Jordà (IMEDEA, Spain)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral

Abstract:
The most common methodology used to detect and characterize mesoscale eddies in the global ocean is to analyze altimetry based sea level gridded products with an automatic eddy detection and tracking algorithm. Although the different algorithms differ in the details of the methodology most of them rely on the identification of sea level anomalies as the signature of the eddies. However, a careful look at the altimetry track location shows that their separation is often larger than the Rossby radius of deformation. This implies that gridded products based on the information obtained along-track would potentially be unable to characterize the mesoscale variability and, in particular, the eddy field.

In this study, we analyze up to which extent sea level gridded products are able to characterize mesoscale eddies with a special focus on the North Atlantic and the Mediterranean Sea. In order to perform this task, our approach has been to generate synthetic absolute dynamic topography (ADT) maps using along-track data extracted from realistic high resolution ocean model simulations. Then we apply an eddy detection and tracking algorithm to the gridded synthetic product and to the original model fields and compare the characteristics of the eddy fields.

As the "ground truth" we use two high-resolution numerical simulations, one for the Mediterranean Sea (NEMOMED36 , 10 years with an horizontal resolution of 1/36º and 75 vertical levels) and another for the North Atlantic Ocean (NATL60, one year with an horizontal resolution of 1/60º and 300 vertical levels). The mapping algorithm we developed to interpolate along-track data is formally the same used by AVISO (Pujol et al., 2016). A careful comparison between the results obtained applying the algorithm to real along track data and the AVISO maps shows very little differences giving confidence to the methodology. For the eddy detection and tracking we use the algorithm developed by Faghmous et al. (2015).

Our results suggest that gridded products largely underestimate the density of eddies capturing only between 15-30% of the total number of eddies. Also, the eddies obtained from the gridded products are 3-4 times bigger and with an amplitude 2-3 times larger. Moreover, the results show that it is not simply a matter of not capturing the smaller eddies but that the gridded product misinterprets the actual eddy field. We have estimated that in the Mediterranean Sea (North Atlantic Ocean) around 75% (78%) of eddies of eddies present in the real ocean fields are not detected in the reconstructed fields. From the eddies detected (25% (22%) of the total amount), around a 15% (25%) are false detections (these eddies are created by the optimal interpolation scheme), 45% (55%) correspond to one eddy in real fields and the remaining 40% (20%) has more than one real eddy inside (the interpolation scheme is merging several eddies into one). Moreover, in those cases where an eddy can be identified in the right location in the altimetry based maps its characteristics can significantly differ from the real characteristics.

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Corresponding author:
Angel Amores (**IMEDEA**, **Spain**), angel.amores@uib.es

Mapping the Ocean surface current from future current mission concepts and synergy with high-resolution altimetry

Clement Ubelmann (CLS, Afghanistan); Fabrice Ardhuin (IFREMER, France); Gérald Dibarboure (CNES, France); Lucile Gaultier (Ocean Data Lab, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral

Abstract:
New concepts of Ocean surface current missions are emerging (e.g. SKIM, WACM). A common characteristic of these concepts is the measurement of radial velocities unevenly distributed on a swath. We propose here a multivariate Optimal Interpolation method to reconstruct the full surface current involving a rotational and divergent Helmotz decomposition. An Observing System Simulation Experiment of the SKIM concept (proposed for EE9, Ardhuin et al) has been tested, suggesting interesting resolving capabilities for the full surface current under 100km wavelength. In the context of high resolution altimetry, the addition of surface current at similar resolution may bring very useful information and help solving the challenge of balanced dynamics and internal waves separation. We propose here a general description of the mapping method (to be applied to any radial observation of the mesoscale current) and to go over the anticipated performances for high level SKIM products. The possibility of combining altimetry and radial velocity observations in the same multi-variate OI inversion will be also shown.
Corresponding author:
Clement Ubelmann (**CLS**, **Afghanistan**), cubelmann@cls.fr

The Jason-2 Mission Geodetic Phase

Alejandro Egido (NOAA - Laboratory for Satellite Altiemtry, United States); Nicolas Picot (CNES, France); Cristina Martin-Puig (EUMETSAT, Germany); Shailen Desai (NASA/JPL, USA); Eric Leuliette (NOAA - LSA, USA); Remko Scharoo (EUMETSAT, Germany)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Oral

Abstract:
On June 20th, 2017 the four partners Jason-2 Joint Steering Group decided to move the Jason-2 satellite to its geodetic phase. On July 8th, 2017 Jason-2 reached its final long repeat orbit (LRO), approximately 27 km below the historical T/P reference orbit, and on July 11th the onboard instruments resumed nominal operations. The operational geodetic data records (O-GDRs) were analyzed by the four partners before releasing again the products to users.

The Jason-2 LRO is approximately 27 km below the historical T/P orbit still used by Jason-3. It has the following sub-cycles (near repeat) and cycle (exact repeat):

- Sub-cycle: 4 nodal days - 3.97 days - 51 revolutions
- Sub-cycle: 17 nodal days - 16.86 days - 217 revolutions (434 passes)
- Sub-cycle: 81 nodal days - 80.31 days - 1034 revolutions
- Sub-cycle: 145 nodal days - 143.77 days - 1851 revolutions
- Cycle: 371 nodal days - 367.84 days - 4736 revolutions

The first two sub-cycles are beneficial for sea-state and mesoscale operational applications respectively: they guarantee a nearly geographically homogeneous sampling for the temporal scales of interest (e.g. for operational model assimilation). The very long repeat cycle yields a fine grid of approximately 8-km: it is beneficial for marine geodesy (e.g. improvement of bathymetry and mean sea surface models). The 145-day sub-cycle is also a "fallback geodetic sub-cycle". This sub-cycle was selected as a "coarse geodetic grid", i.e. as a safety net if full geodetic cycles cannot be completed. The strategy is inherited from Jason-1 EoL where we tried to optimize all sub-cycles (shorter ones for sea-state and mesoscale, and longer ones for geodesy). The LRO orbit maximizes the geodetic sampling both at a yearly scale (nominal grid) and for shorter periods of approximately 5 months (fallback grid). To illustrate, assuming Jason-2 dies after 5-6 months of long repeat orbit, at least one “fallback sub-cycle” will be collected. If Jason-2 lives longer than this, multiple coarse resolution grids will be collected. If Jason-2 LRO outlives its first geodetic cycle, it could be possible to let the ground track drift in longitude and to acquire a geodetic dataset with an unprecedented resolution of 4 km or less.

To improve the sea surface height anomaly (SSHA) data quality in the Jason-2 LRO data products an updated mean sea surface (MSS) model has been adopted. The new MSS model is the latest CNES/CLS MSS 2015 solution (https://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mss.html), which is referenced to the 20-year period spanning 1993-2012. The MSS model provided on the prior data products (version “d” products during the 10-day exact repeat phase) was the 2011 solution, referenced to the 7-year period spanning 1993-1999 and has a lower quality on LRO ground track. The global bias between these two MSS models is approximately 2.5 cm, due to their different reference periods.

In this presentation, we provide specific technical details on the Jason-2 mission geodetic phase, concentrating on the long repeat orbit characteristics and on the quality of the Jason-2 data products after the LRO was attained.

Corresponding author:
Alejandro Egido (**NOAA - Laboratory for Satellite Altiemtry**, **United States**), alejandro.egido@noaa.gov

Improvements and limitations of recent mean sea surface models: importance for Sentinel-3 and SWOT.

Marie Isabelle Pujol (CLS, France); Philippe Schaeffer (CLS, France); Yannice Faugère (CLS, France); François-Xavier Davanne (CLS, France); Gérald Dibarboure (CNES, France); Nicolas Picot (CNES, France)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Oral

Abstract:
Previous studies underlined the improved accuracy of the up-to-date Mean Sea Surface (MSS) models. They are greatly induced by the use of geodetic altimeter measurements that contributes to reduce the omission errors. Nevertheless, they also underscored residual errors (omission and commission) for wavelengths shorter than ~100km. These errors represent nearly 30% of the SLA variance along the Sentinel-3A tracks and are on the same order of magnitude as the instrumental noise floor of this altimeter (Pujol et al, OSTST 2016). Reducing the MSS models errors at short wavelengths remains thus necessary to fully exploit the altimetry measurement, especially with new and upcoming altimeter technology as Jason-CS/Sentinel-6 or SWOT.
We focus in this study on the interest to use Sentinel-3A measurements for a new MSS model estimation. Collection of nearly 17 months of high resolution measurements now available allows us to compute a first estimation of high resolution MSS along the track of the altimeter (i.e. mean profile). Contrarily to what was observed for LRM altimeters, the low SAR instrumental noise level allows us to obtain a quite smooth mean profile even with few months of measurements.
This mean profile will at first benefit to the Sentinel-3 sea level error budget: its spectral signature comes closer to the theoretical spectrum with a reduction of the MSS error specific signature. This mean profile could contribute to the estimation of a future MSS model, improving missing or erroneously estimated small geophysical structures.

Corresponding author:
Marie Isabelle Pujol (**CLS**, **France**), mpujol@cls.fr

GEOMED2: Geoid estimation of the Mediterranean Sea

Sean Bruinsma (CNES, France); Riccardo Barzaghi (Politecnico di Milano, Italy); George Vergos (Aristotle University of Thessaloniki, Greece); Marie-Françoise Lequentrec-Lalancette (SHOM, France); Ole Andersen (DTU Space, Denmark)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Oral

Abstract:
The objective of the GEOMED2 project is to compute an updated estimate of the geoid of the Mediterranean. The gravimetric geoid computation is based on ship and land gravity data collected in the area (29°;48°) latitude and (-10°;41°) longitude covering the entire Mediterranean basin. Outlier rejection and bias correction (with respect to the EIGEN-6C4 model) have been carefully performed on the entire database. Wavelengths of the gravity field down to 40 km have been modelled using the EIGEN-6C4 model in the gravity data reduction; gravity data reduced with satellite-only derived models led to significantly less accurate geoids. Reduction for the terrain effect also has been accounted for using the SRTM Digital Terrain Model that has been complemented with bathymetric data. A problem we encountered in this project is the at best negligible bathymetry reduction of the gravity data over sea (as opposed to reduction of topographic masses over land, which is essential), and tests without terrain effect over sea will equally be done.
Different methods will be considered to compute the geoid. Collocation, Fast Collocation, and Stokes/FFT will be used and differences among the different geoid solutions will be analyzed. Based on a set of quality tests, one of the geoid solutions will be selected for the next stage of the project: the estimation of a new, more detailed SST model, both over open-sea and in coastal zones, which will be enhanced with drifter data to develop a new current model for the Mediterranean Sea.

Corresponding author:
Sean Bruinsma (**CNES**, **France**), sean.bruinsma@cnes.fr

Comparison and synthesis of geodetic and oceanographic data to improve mean dynamic topography products

Nikolai Maximenko (IPRC/SOEST, University of Hawaii, United States); Per Knudsen (Technical University of Denmark, Denmark); Jan Hafner (IPRC/SOEST, University of Hawaii, United States)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Oral

Abstract:
GOCE mission and OGMOC analysis resulted into a major improvement of the geoid model and geodetic mean dynamic topography (MDT) products. In this study we validate these products using a combination of most recent in-situ and satellite oceanographic data, including trajectories of drifters, sea level anomaly, and wind. Geographical distribution of the discrepancies is derived in a broad range of space scales.

Particular attention is paid to ageostrophic processes and uncertainties in oceanographic data and their influence on the accuracy of dynamic topography estimates. This includes effects of wind-driven currents and inertial oscillations as well as effects of methods used to filter out these motions. The latter filters are shown to have significant impact on representation of strong meandering jets in the dynamic topography.

The local statistics of the mean dynamic topography estimates, derived from repeat oceanographic observations, are analyzed under various sea state conditions and at different stages of the evolving observing system.

Finally, geodetic and oceanographic data are synthesized into a new high-resolution mean dynamic topography product. We also discuss limitations of thus-far accumulated historical observations with respect to the future improvement of the MDT accuracy and resolution.

Corresponding author:
Nikolai Maximenko (**IPRC/SOEST, University of Hawaii**, **United States**), maximenk@hawaii.edu

A combined mean dynamic topography model – DTU17cMDT.

Per Knudsen (DTU Space, Denmark); Ole Andersen (DTU Space, Denmark); Nikolai Maximenko (IPRC, U Hawaii, USA)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Oral

Abstract:
Within the ESA supported Optimal Geoid for Modelling Ocean Circulation (OGMOC) project a new geoid model have been derived. It is based on the GOCO05C setup though the newer DTU15GRA altimetric surface gravity has been used in the combination. Subsequently the model has been augmented using the EIGEN-6C4 coefficients to d/o 2160. Compared to the DTU13MSS, the DTU15MSS has been derived by including re-tracked CRYOSAT-2 altimetry also, hence, increasing its resolution. Also, some issues in the Polar regions have been solved. The new DTU17MDT has been derived using this new geoid model and the DTU15MSS mean sea surface. Compared to other geoid models the new OGMOC geoid model has been optimized to avoid striations and orange skin like features. The filtering was re-evaluated by adjusting the quasi-gaussian filter width to optimize the fit to drifter velocities. The results show that the new MDT improves the resolution of the details of the ocean circulation. Subsequently, the drifter velocities were integrated to enhance the resolution of the MDT. As a contribution to the ESA supported GOCE++ project DYCOT a special concern was devoted to the coastal areas to optimize the extrapolation towards the coast and to integrate mean sea levels at tide gauges into that process. The presentation will focus on the coastal zone when assessing the methodology, the data and the final model DTU17cMDT.

Corresponding author:
Per Knudsen (**DTU Space**, **Denmark**), pk@space.dtu.dk

Coastal improvements for tidal models: the benefit of ALES retracker

Gaia Piccioni (DGFI-TUM, Germany); Denise Dettmering (DGFI-TUM, Germany); Wolfgang Bosch (DGFI-TUM, Germany); Marcello Passaro (DGFI-TUM, Germany); Florian Seitz (DGFI-TUM, Germany)

Session: Tides, internal tides and high-frequency processes
Presentation type: Oral

Abstract:
The performance of altimetry at coastal areas has always been challenging. During the last years a major focus on this subject brought to a significant progress in sea level determination and geophysical corrections. However, the scientific community still highlights the need of improvements in wet tropospheric and tidal corrections.
A new version of the Empirical Ocean Tide (EOT) model is currently under development at DGFI-TUM, and takes advantage of the most recent altimetric products. The model scheme follows the former EOT11a: residual tidal constituents are derived on a least-squares-based harmonic analysis applied to Sea Level Anomalies (SLA) corrected for the newly-released FES2014 model. In order to improve the solutions at the coast, the range used for SLAs is computed exploiting the Adaptive Leading Edge Slope (ALES) retracker. The whole process is implemented on a grid with spacing of 1/8 by 1/8 degree, and a variable data weighting is applied at each node in proximity of the shore. This flexible weighting is bathymetry-dependent, so that shorter tidal wavelengths at shallow waters are accounted.
This work presents the features of the EOT model at its early stage and provides a first overview on its performance at coastal areas. For this purpose, the effects of ALES on the tidal model will be shown and compared with an ordinary retracker at regional scales. This evaluation represents a crucial point for further improvements in EOT as well as possible benefits in altimetry for coastal monitoring.
Corresponding author:
Gaia Piccioni (**DGFI-TUM**, **Germany**), gaia.piccioni@tum.de

Comparison and validation of internal tides models for global ocean

Loren Carrere (CLS, France); Florent Lyard (LEGOS/CNRS, FRANCE); Romain Baghi (CLS, FRANCE); Nicolas Picot (CNES, FRANCE)

Session: Tides, internal tides and high-frequency processes
Presentation type: Oral

Abstract:
Thanks to its current accuracy and maturity, altimetry is considered as a fully operational observing system dedicated to scientific and operational applications. In order to access the targeted ocean signal, altimeter measurements are corrected for several geophysical parameters among which the ocean tide correction is one of the most critical. Global ocean and loading tide models GOT and FES are operationally used in present altimeter GDRs to remove the barotropic tide component, but the internal tides signature at the surface are not yet corrected.

Internal tides can have a signature of several cm at the surface with wavelength about 50-250 km for the first mode. The perspective of SWOT mission and high resolution ocean measurements make the correction of these small scale signals a challenge, as we need to be able to separate tides from other oceanic signals.

In 2016, a detailed comparison and validation of several internal tide models developed by different scientific teams (Egbert and Erofeeva 2015, Ray and Zaron 2016, Zaron 2016, Zhao et al. 2012, Dushaw 2015) has been presented focusing on the coherent internal tide signal for M2 and K1 frequencies; the analysis showed a significant altimeter variance reduction when using these internal tide corrections.
The purpose of the present study is to evaluate the new versions of these internal tide solutions and also to test the impact of some new models provided by B. Arbic and C. Ubelmann. The validation process is based on a statistical analysis, on a comparison to multi-missions altimetry including Jason-2, AltiKa and Cryosat-2 data, on a spectral analysis approach and we also use some in situ databases.

Corresponding author:
Loren Carrere (**CLS**, **France**), lcarrere@cls.fr

Comparison of internal gravity wave spectra in high-resolution global simulations with observations

Brian Arbic (University of Michigan, United States); Maarten Buijsman (University of Southern Mississippi, USA); Dimitris Menemenlis (NASA Jet Propulsion Laboratory, USA); James Richman (Florida State University, USA); Jay Shriver (Naval Research Laboratory Stennis Space Center, USA); Anna Savage (University of Michigan, USA); Conrad Luecke (University of Michigan, USA); Joseph Ansong (University of Ghana, Ghana); Matthew Alford (UC San Diego, USA)

Session: Tides, internal tides and high-frequency processes
Presentation type: Oral

Abstract:
We present comparisons of the internal gravity wave spectrum in high-resolution global simulations with observations. We use 1/12th and 1/25th degree global simulations of the HYbrid Coordinate Ocean Model (HYCOM), which is used as an operational ocean model by the US Navy, and 1/12th, 1/24th, and 1/48th degree simulations of the Massachusetts Institute of Technology general circulation model (MITgcm) performed on NASA supercomputers. Both the HYCOM and MITgcm simulations have simultaneous atmospheric and tidal forcing, implying that near-inertial waves and internal tides are produced. The high vertical and horizontal resolution of these simulations allows for nonlinear interactions, which fill out an internal gravity wave spectrum. We compare the frequency spectra of kinetic energy and temperature variance in the models with spectra compared from historical moored observations, at more than a thousand instrument locations. We compare the dynamic height variance, the vertical wavenumber-frequency spectrum of kinetic energy, and the vertical wavenumber spectrum of density variance, in models versus moored McLane Profiler observations. We find that the models compare more closely with observations, and with predictions of the Garrett-Munk spectrum, as model resolution increases. Regional simulations conducted with global model forcing along the boundaries indicate that both horizontal and vertical resolution need to be increased to further improve model-data comparisons.

Corresponding author:
Brian Arbic (**University of Michigan**, **United States**), arbic@umich.edu

Global internal tides from satellite altimetry: Next-generation internal tide model and internal tide oceanic tomography

Zhongxiang Zhao (Applied Physics Laboratory, University of Washington, United States)

Session: Tides, internal tides and high-frequency processes
Presentation type: Oral

Abstract:
Empirical internal tide models from past multisatellite altimeters are the only observational and currently the most reliable models. However, all current altimeter-based internal tide models represent the ~20-year-long coherent component and miss the incoherent component. Thus, extracting the time-variable internal tide from satellite altimetry is a challenging and rewarding question. We take up this challenge by developing and improving a plane wave fit method. In this method, internal tides are extracted in two-dimensional fitting windows, rather than at individual sites. This approach is superior to point-wise harmonic analysis because it enables us to resolve multiwave interference and extract internal tides in short time windows. Our analyses in several regions reveal significant seasonal and interannual variations, which in turn confirm the necessity and feasibility of exploring the incoherent internal tide. Using this method, we are constructing global internal tide models for all principal tidal constituents, and for each tidal constituent we are constructing climatological monthly and annual fields using subsetted altimeter data.

Our work inspires two new concepts: next-generation internal tide model and internal tide oceanic tomography (ITOT). First, next-generation internal tide models that resolve seasonal and interannual variations are being developed. Our new models have time-varying amplitude and phase, in contrast to time-invariant harmonic constants in barotropic tide models and current internal tide models. Our new models will be evaluated using in situ moorings and independent altimeter data. Second, we are using our models to develop a new tomographic technique, ITOT, for monitoring global ocean change by tracking long-range internal tides. ITOT is similar to acoustic tomography, but the working waves are internal tides instead of sound. Ocean warming/cooling thus can be monitored using satellite altimetry by precisely measuring changes in the propagation speed of internal tides. This technique will be evaluated using Argo data and the ECCO2 estimates. ITOT may offer a long-term, cost-effective, environmentally-friendly technique for monitoring global ocean change and variability.

Corresponding author:
Zhongxiang Zhao (**Applied Physics Laboratory, University of Washington**, **United States**),
zzhao@apl.washington.edu

Solving the mesoscale and internal tide sea surface height signatures in a single massive inversion using a variational approach

Clement Ubelmann (CLS, France); lauren carrere (CLS, france); gérald dibarboure (CNES, france); yannice faugere (CLS, france)

Session: Tides, internal tides and high-frequency processes
Presentation type: Oral

Abstract:
Presently, the gridded solutions of Sea Surface Height (SSH) mesoscales (e.g. CMEMS) and stationary Internal Tidal Wav (ITW) signatures (e.g. Ray or Zhao solutions) are estimated separately from the same along-track observation datasets. However, it is known that they both leak in each other's estimation. In particular, the mesoscale solution subtracted before computing the ITW may remove a non-negligible part of the original ITW signal leading to underestimated ITW solutions.
To mitigate this problem, we are currently investigating the feasibility of solving the mesoscale and ITW in a single massive inversion covering a multi-decadal period. If the standard OI approach presently used for mesoscale mapping could not invert such a volume of observations, it is possible to perform an inversion using a variational approach. Following a wavelet basis in time and space for the mesoscale and a plane wave basis for ITW, we can solve for more than O(108) parameters iteratively by computing cost function gradients. The standard covariance models used in mesoscale mapping are converted in equivalent wavelet parameter prescribed variance.
After presenting the method, we will show the results of first implementations in the Hawaii and Azores regions covering the 1995-2013 period. The ITW solutions will be compared with existing solutions, by looking at a variance reduction diagnostic of an independent (2014-2017) set of altimetry observations. The results may suggest a significant gain of performing the global mesoscale-ITW inversion, providing more energetic and variance-reductive ITW solutions. Running the analysis globally would be very costly, but not impossible in the future. The possibility of considering non-stationary ITW in the same inversion will be also discussed.

Corresponding author:
Clement Ubelmann (**CLS**, **France**), cubelmann@cls.fr

Assessment of the AVISO Mean Seal Level (MSL) indicator with an integrative approach

Michael Ablain (CLS, France); Lionel Zawadzki (CLS, France); Nicolas Taburet (CLS, France); Rémy Jugier (CLS, France); Maxime Vayre (CLS, France); Anny Cazenave (LEGOS, France); Nicolas Picot (CNES, France)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_001

Abstract:
The global mean level of the oceans is one of the most important indicators of climate change. It incorporates the reactions from several different components of the climate system. Precise monitoring of changes in the mean level of the oceans, particularly through the use of altimetry satellites, is vitally important, for understanding not just the climate but also the socioeconomic consequences of any rise in sea level.
With the satellite altimetry missions, the AVISO Mean Sea Level (MSL) indicator has been calculated on a continual basis since January 1993: https://www.aviso.altimetry.fr/msl. 'Verification' phases, during which the satellites follow each other in close succession (TOPEX/Poseidon--Jason-1, then Jason-1--Jason-2 and Jason-2-Jason-3), help link up these different missions by precisely determining any bias between them. Other missions (SARAL/Altika, Envisat, ERS-1 and ERS-2, Cryosat-2, Sentinel-3a) are also used, after being adjusted on these reference missions, in order to compute Mean Sea Level at high latitudes (higher than 66°N and S), and also to improve spatial resolution by combining all these missions together. In addition, permanent monitoring of quality during the missions (Calval) and studies of the necessary corrections of altimetry data regularly add to our understanding and knowledge. Recently, the AVISO MSL indicator has been reprocessed in order to take into account new altimeter standards (e.g new ocean tide, new orbit solutions, etc …) and also to integrate the new Jason-3 altimeter mission launched in February 2016.
The objective of this study is to assess the evolution of the MSL indicator focusing on the impact of the new altimeter standards over all the period and on the impact of linking the MSL indicator with Jason-3 in April 2016. With an integrated approach, we will also compare the MSL indicator with in-situ measurements as tide gauges and temperature salinity profiles, estimating the uncertainties of such approaches. We will pay a particular attention to provide these analyses within confidence intervals explicitly defined.

Corresponding author:
Michael Ablain (**CLS**, **France**), mablain@cls.fr

Updates to and Reanalysis of the CU Global Mean Sea Level Climate Data Record

Dallas Masters (University of Colorado, United States); R. Steven Nerem (University of Colorado, United States); Gary Mitchum (USF College of Marine Science, United States)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_002

Abstract:
The 24-year global mean sea level (GMSL) climate record made possible by the TOPEX and Jason-series of altimeter missions is an important indicator of climate change. It is being increasingly relied upon for determining evidence of changing rates in the climate system. Therefore, understanding the variability within the GMSL time series is important. Decomposing the record into a long-term and seasonal components leaves a signal with variability on different time scales, from seemingly random short fluctuations to interannual and possible decadal periods. The degradation of the point target response (PTR) on the TOPEX A altimeter and the subsequent switch to the redundant TOPEX B altimeter can be viewed as a new “mission,” albeit on the same spacecraft platform. But unlike the inter-mission phases between TOPEX/Poseidon and Jason-1 or Jason-1 and Jason-2 that allowed intercomparison and bias estimation to link the GMSL climate data record, the change in altimeters at the TOPEX A to B transition did not allow the two altimeters to be intercompared. This represents a potential discontinuity in the GMSL time series that have implications for estimating trends and accelerations and interpreting the climate record. Following renewed efforts to retrack and improve the TOPEX A and B altimeter records by Callahan [2016] and an investigation by Beckley et al. [2016] into the effect of “Cal-1” correction applied to TOPEX MGDR-B, we have reanalyzed our CU GMSL time series taking into account the results of Beckley et al. In this work, we give an update on the CU GMSL time series with the addition of Jason-3 and updated corrections, a recent comparison between all of the altimeters and the tide gauge network, and also summarize our initial efforts to improve the overall TOPEX record and better reconcile the transition from the TOPEX A to TOPEX B altimeter.

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Corresponding author:
Dallas Masters (**University of Colorado**, **United States**), dallas.masters@colorado.edu

Sea level budget closure: status and prospects from an integrative study within ESA's Climate Change Initiative

Martin Horwath (Technische Universität Dresden, Germany); Anny Cazenave (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Toulouse, France); Hindumathi K. Palanisamy (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Toulouse, France); Ben Marzeion (University of Bremen, Germany); Frank Paul (University of Zurich, Switzerland); Raymond Le Bris (University of Zurich, Switzerland); Anna Hogg (University of Leeds, UK); Andrew Shepherd (University of Leeds, UK); Petra Döll (Goethe University Frankfurt, Germany); Hannes Müller Schmied (Goethe University Frankfurt, Germany); Denise Caceres (Goethe University Frankfurt, Germany); Johnny A. Johannessen (Nansen Environmental and Remote Sensing Center (NERSC), Bergen, Norway); Jan E. Nilsen (Nansen Environmental and Remote Sensing Center (NERSC), Bergen, Norway); Roshin P. Raj (Nansen Environmental and Remote Sensing Center (NERSC), Bergen, Norway); Rene Forsberg (DTU Space, Denmark); Per Knudsen (DTU Space, Denmark); Louise Sorensen (DTU Space, Denmark); Valentina Barletta (DTU Space, Denmark); Ole B. Andersen (DTU Space, Denmark); Christopher J. Merchant (University of Reading, UK); Claire Rachel Macintosh (University of Reading, UK); Kristin Novotny (TU Dresden, Germany); Andreas Groh (TU Dresden, Germany); Benjamin Gutknecht (TU Dresden, Germany); Jérôme Benveniste (European Space Agency (ESA-ESRIN), Frascati (Roma), Italy)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_003

Abstract:
For many years, studies of the sea level budget have been a means of assessing and understanding how sea level is changing and what are the causes. Closure of the total sea level budget implies that the observed changes of global mean sea level equal the sum of observed (or otherwise assessed) contributions, namely changes in ocean mass and ocean thermal expansion. Closure of the ocean mass budget implies that the observed ocean mass change equals assessed changes in mass from glaciers, ice sheets, land water storage, snow pack and atmospheric water content. Misclosure of these balances indicates errors in some of the components or contributions from missing or unassessed elements in the budget.
ESA's Climate Change Initiative (CCI) has conducted a number of projects related to sea level, namely the Sea Level CCI project, the Greenland and Antarctic Ice Sheet CCI projects, the Glaciers CCI project and the Sea Surface Temperature CCI project. Using the improved, consistent, and well-documented data products from these CCI projects, it is time to re-assess the sea level budget closure. This is the aim of the CCI Sea Level Budget Closure (SLBC_cci) project.
The project analyzes results based on CCI products in conjunction with data products from ocean profilers (e.g., Argo), GRACE-based ocean mass change assessments, and model-based data for glaciers and land hydrology. Closure of the global mean sea level budget and global ocean mass budget are being investigated in a coherent way and the quality of CCI products is being assessed. In addition, the regional variability of sea level and its steric and mass components are investigated in a case study for the Arctic Ocean. These activities are intended to prepare the way to more comprehensive and more operational assessments of the global and regional sea level budget.
The poster outlines the envisaged developments and prospects from the project. It gives an overview on the status of datasets available and the degree of sea level budget closure at the first iteration of collected datasets.
Corresponding author:
Martin Horwath (**Technische Universität Dresden**, **Germany**), martin.horwath@tu-dresden.de

Revisited Earth Energy imbalance from the sea level budget over 2005-2015

Alejandro Blazquez (LEGOS-CNES, France); Meyssignac Benoit (LEGOS-CNES, France); Couhert Alexandre (CNES, France); Mercier Flavien (CNES, France); Zawadszki Lionel (CLS, France); Michael Ablain (CLS, France); Annabelle Ollivier (CLS, France)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_004

Abstract:
As the dominant reservoir of heat uptake in the climate system (93% of the total Earth heat uptake is located in the ocean [Levitus et al. 2012]), the ocean provides a critical measure of the Earth energy imbalance at the top of the Atmosphere. The ocean heat uptake can be inferred through the thermal expansion of the ocean estimated either directly from in situ Temperature profiles or indeirectly with the sea level budget appraoch by combining satellite altimetry and GRACE observations. In this study we revisit the sea level budget approach and propose new estimates of the deep ocean warmimg and the Earth energy imbalance with reduced error bars (compared to previous studies such as Llovel et al. 2014) .
In past studies GRACE and satellite altimetry observations have been estimated and combined in the international reference frame (ITRF). The ITRF is centered on the center of figure of the Earth (CF) which implies that both GRACE and satellite observations have been considered with respect to the CF. But GRACE and satellite altimeters move around the center of mass of the Earth (CM) and the projection of their observations in reference frames centered on the CF generate significant level of uncertainty in the data. In this study we combine Grace and satellite altimetry in a reference frame centered on the CM to remove this source of uncertainty. We use new satellite altimetry products and new GRACE observations reprocessed with orbits centered on the CM. It enables to close the sea level budget over the period 2005-2015 with unprecedented accuracy and to improve estimates of the deep ocean warming and the Earth energy imbalance.
Corresponding author:
Alejandro Blazquez (**LEGOS-CNES**, **France**), alejandro.blazquez@cnes.fr

Teleconnection between the Atlantic Meridional Overturning Circulation and the Mediterranean Sea level

Denis Volkov (University of Miami/NOAA-AOML, United States); Felix Landerer (Jet Propulsion Laboratory, USA)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_005

Abstract:
The Mediterranean Sea can be viewed as a “barometer” of the North Atlantic Ocean, because its basin-averaged sea level responds to oceanic gyre-scale changes in atmospheric pressure and wind forcing, intrinsic to the North Atlantic Oscillation (NAO). The climate of the North Atlantic and the entire Northern Hemisphere is largely controlled by the Atlantic Meridional Overturning Circulation (AMOC) that transports heat from the South Atlantic towards the Arctic Ocean. In this study, we report for the first time (to the best of our knowledge) on the teleconnection between the AMOC and the Mediterranean Sea level observed in 2004-2015: a reduction/increase in the AMOC transport is associated with a higher/lower than average sea level in the Mediterranean. By using available observations and an ocean model output we perform a comprehensive analysis of dynamical mechanisms responsible for this teleconnection. On one hand, we show that on monthly to interannual time scales the AMOC and the Mediterranean Sea level are both driven by similar NAO-like atmospheric circulation patterns: a stronger/weaker anticyclonic gyre present during a positive/negative NAO state (i) drives northward/southward anomalies of Ekman transport around 26°N that directly affect the AMOC and (ii) are associated with westward/eastward winds over the Strait of Gibraltar that force water to flow out/in the Mediterranean Sea and thus change its sea level. On the other hand, we reveal a connection between the surface and lateral heat and freshwater fluxes near the North Atlantic eastern boundary that drive the interannual variability of the local steric sea level that can propagate in the form of coastally trapped waves towards Gibraltar and also contribute to changes of the Mediterranean Sea level. The lateral advection is directly related to the AMOC, mainly through the upper mid-ocean transport. The two mechanisms (direct wind forcing and indirect effect of remote buoyancy forcing) are found to be contemporaneous and related to NAO and, therefore, they can amplify the effect of each other on the Mediterranean Sea level change.
Corresponding author:
Denis Volkov (**University of Miami/NOAA-AOML**, **United States**), denis.volkov@noaa.gov

Assessment of ocean models in the Mediterranean Sea and Black Sea against altimetry and gravity measurements

Luciana Fenoglio (University of Bonn, Germany); Roelof Rietbroek (University of Bonn, Germany); Joanna Staneva (Helmholtz-Zentrum Geesthacht, Germany); Nadia Pinardi (University of Bologna, Italy, Italy); Andrea Storto (University of Urbino, Italy); Jürgen Kusche (University of Bonn, Germany); Bernd Uebbing (University of Bonn, Germany)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_006

Abstract:
Today, the interval 2002-2017 is the longest time span where space-based measurements from altimetry, GRACE and ARGO are simultaneously available for sea level, mass and steric observations. Although the combination of the first provides valuable constraints on volumetric versus mass driven sea surface height changes, these data are rarely assimilated in ocean simulations and reanalysis runs. The evaluation of ocean model simulations and reanalysis using geodetic data remains challenging, particularly in semi-closed ocean basins, due to model assumptions and limitation of satellite-based data in coastal zone.

We compare in the Mediterranean and Black Sea the sea level change over the basin with its mass and steric components estimated separately. Contamination of land signal in geodetic data is accounted for. The biggest challenge is for the ocean models, due to unrealistic boundary conditions at the Gibraltar and Dardanelli and Bosphorus straits and uncertainties in the air-sea freshwater fluxes and river-runoff. The small sea level trend of the models is implicitly related to the Boussinesq assumption, which implies conservation of volume rather than mass.

The geodetic data are from the gridded multi-mission altimeter dataset of the ESA Sea Level Climate Change Initiative and from GRACE monthly solutions. We account for Glacial Isostatic Adjustment (GIA) and correct the leakage of land signals using hydrological models.

In the Mediterranean Sea we consider two ocean simulations (RMCS, ENEA) and one reanalysis (CMEMS) assimilating satellite altimetry. The models differ mostly in annual amplitude and halosteric trend. Best agreement in trend, with 2.2 +/- 0.5 mm/yr in 1993-2016, is between altimetry and sum of modelled sea level and thermo-steric component.
In the Black Sea we consider the BS-CMEMS multi-year reanalysis based on the Nucleus for European Modelling of the Ocean v.3.6 (NEMO) hydrodynamic model. The data assimilation system ingests hydrographic profiles, altimeter sea level anomaly and space-based sea surface temperature. The trend of thermo-steric component is small over 1993-2016 (0.45 ± 0.01 mm/yr) and the halosteric component highly inaccurate, due to model freshwater forcing and scarcity of salinity data.

The synergy between altimeter data and model simulations could be used to overcome the errors of mass balances. Using tide gauge data, we discuss approaches for separating natural variability and long-term signal in models and data sets.
Corresponding author:
Luciana Fenoglio (**University of Bonn**, **Germany**), fenoglio@geod.uni-bonn.de

Reconstructed long-term sea level variability in the North Atlantic Ocean

Yongcun Cheng (Center for Coastal Physical Oceanography, Old Dominion University, United States);
Benjamin D. Hamlington (Center for Coastal Physical Oceanography, Old Dominion University, United States);
Se-Hyeon Cheon (Center for Coastal Physical Oceanography, Old Dominion University, United States)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_007

Abstract:
The sea level variability at multi-time scales in the North Atlantic Ocean has been well documented from observations and model experiments. In this work, we analyzed long-term sea level variability based on reconstructed sea level product (1900-2012), which combined SST with tide gauge and altimetry data using CSEOF (Cyclostationary Empirical Orthogonal Function) method. Compared with previous sea level reconstructions, (1) the trend at each grid of altimetry data was removed to reconstruct long-term variability and background trend, (2) Atlantic regions were reconstructed separately with Indo-Pacific and then recombined into a global reconstruction to avoid the dominance of Indo-Pacific in global basis functions. The results demonstrate that the reconstructed signal linked to Atlantic multidecadal oscillation (AMO). Moreover, compared with altimetry data, the reconstructed sea level in 20th century exhibits similar correlation spatial patterns with AMOC/NAO.

Corresponding author:
Yongcun Cheng (**Center for Coastal Physical Oceanography, Old Dominion University**, **United States**), yccheng.en@gmail.com

Seasonality Change in North Atlantic Sea Level and Forcing Parameters

Martina Ricko (SGT Inc, United States); Richard Ray (NASA-GSFC, USA); Brian Beckley (SGT Inc, USA)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_008

Abstract:
Changes of the North Atlantic coastal mean sea level and its increased seasonal cycle over different regions using satellite radar altimetry and tide gauge data have been previously confirmed and validated. This study confirms the seasonal cycle variability and addresses the changes in the annual amplitude of the seasonal cycle of both coastal and open sea level regions in the North Atlantic, such as the Gulf of Mexico and the Gulf Stream region. The physical climate forcings responsible for observed increased annual amplitude of sea level during the most recent years are explored by analyzing the connection between the variability in the annual amplitude of sea level and a set of oceanic and synoptic parameters (i.e., sea surface temperature, air temperature, mean sea level pressure, wind curl, evaporation, precipitation, fresh water flux, mesoscale eddies, etc.), including the ARGO parameters of temperature and salinity. The changes observed in the North Atlantic seasonal sea level cycle have very strong correlation to changes in the investigated forcing parameters, especially with temperature parameters during early cold season, and with mean sea level pressure and freshwater flux parameters in later warm season for most regions in the Western Atlantic. Better understanding of these forcing parameters in connection to the seasonal sea level cycle change could offer improved seasonal to inter-annual prediction of sea level variations.

Corresponding author:
Martina Ricko (**SGT Inc**, **United States**), mricko@sgt-inc.com

Dueling Climate Cycles Intensified Sea Level Swings in the Pacific

Y. Tony Song (JPL/NASA, United States)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_009

Abstract:
Over the past decades, the sea level in the western Pacific rose up to three times faster than the global mean, while its counterpart in the eastern Pacific including U.S. west coast was nearly stationary or decreasing [Moon and Song, 2013]. In fact, the regional seal-level trends have undergone two shifts, during the mid-1970s and in the early 1990s, with an east-west dipole pattern in the tropical Pacific. In each of these phases, the regional sea levels accelerated on one side of the Pacific, but decelerated on the other side [Moon et al., 2013]. It is puzzling how long this pattern of regional sea level changes has been gone, what is the dynamic cause, and how these can affect deep ocean. These regional sea level changes, when superimposed on the global trend of sea level rise, could have profound implications for coastal communities and the health of marine and estuarial habitats. Combining recently reconstructed long-term sea level data products, upper-ocean measurements, recent satellite data, and a non-Boussinesq ocean circulation model [Song and Colberg, 2011], we will show that (1) the multi-decadal sea-level swings are the consequence of upper-ocean heat changes, closely related to the Pacific Decadal Oscillation (PDO)-induced ocean circulations; (2) the dueling climate cycles, PDO and ENSO, may have intensified the sea level swings in the tropical Pacific since 1980s [Moon et al., 2015]; and (3) differently, the deep ocean has shown a cooling trend in the tropics while a warming trend in the northern Pacific. Their underling dynamic mechanisms will be discussed.

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Corresponding author:
Y. Tony Song (**JPL/NASA**, **United States**), Tony.Song@jpl.nasa.gov

Has the deep ocean warmed in the subtropical South Pacific?

Denis Volkov (University of Miami/NOAA-AOML, United States); Sang-Ki Lee (NOAA-AOML, USA); Felix Landerer (Jet Propulsion Laboratory, USA); Rick Lumpkin (NOAA-AOML, USA)

Session: Science I: Climate data records for understanding the causes of global and regional sea level variability and change
Presentation type: Poster
Poster number: SC1_010

Abstract:
The persistent energy imbalance at the top of the atmosphere, inferred from satellite measurements, indicates that the Earth climate system continues to accumulate excess heat. As only sparse and irregular measurements of ocean heat below 2000-m depth exist, one of the most challenging questions in global climate change studies is whether the excess heat has already penetrated into the deep-ocean. Here, we perform a comprehensive analysis of satellite and in situ measurements to report that a significant deep-ocean warming occurred in the subtropical South Pacific Ocean over the past decade (2005-2014). The local accumulation of heat accounted for up to a quarter of the global ocean heat increase, with directly and indirectly inferred deep ocean (below 2000-m) contribution of 2.4±1.4 and 6.1-10.1±4.4%, respectively. We further demonstrate that the deep-ocean warming was consistent with the upper-ocean warming, and likely driven (or at least favored) by persistent wind-driven convergence intrinsic to La Niña-like conditions. This suggests that the observed warming at least partially reflects an interannual to interdecadal variation.

Corresponding author:
Denis Volkov (**University of Miami/NOAA-AOML**, **United States**), denis.volkov@noaa.gov

CryoSat/SIRAL Cal1 Calibration Orbits

Marco Fornari (ESA/ESTEC, Netherlands); Michele Scagliola (ARESYS, Italy); Tommaso Parrinello (ESA/ESRIN, Italy); Jerome Bouffard (ESA/ESRIN, Italy)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Poster
Poster number: IPM_001

Abstract:
The main payload of CryoSat is a Ku band pulse-limited radar altimeter, called SIRAL, that transmits phase coherent pulses at a high Pulse Repetition Frequency allowing SAR processing to improve along-track resolution. Being a phase coherent altimeter, SIRAL calibration includes not only corrections for transfer function, gain and instrument path delay (as in previous altimeters), but also corrections for phase (SAR/SARIn) and phase difference between the two receiving chains (SARIN only).
Due to CryoSat non-sun-synchronous orbit, SIRAL temperature slightly changes along the orbit with a period of about 480 days. By analysis of the CAL1 data, it has been verified that SIRAL calibration is affected by the instrument thermal status, leading to calibration measurements (i.e. the instrument behavior) slightly varying along the orbit.
In order to quantify such variation along the orbit, a continuous sequence of CAL1 has been performed over a few orbits. Moreover, the analysis of the CAL1 calibration corrections produced along the Calibration orbits allowed us verifying whether the current calibration plan provides sufficiently accurate corrections at any latitude.
The CryoSat/SIRAL Cal1 Calibration Orbits have been performed twice in 2016, on the 20th of July and on the 24th of November, requiring coordination among many operation teams (Mission Planning, FOS, PDS and Quality).
In this abstract, the Calibration Orbits will be presented together with the calibration corrections generated during this activity. By analysis of such calibrations data, it was possible to derive a model for the calibration corrections as function of the instrument temperature. Comparing the modeled corrections with the actual ones (used in CryoSat operations) it was possible to estimate the accuracy of the current calibration plan. Preliminary results will be shown that confirm that the effectiveness of the CryoSat calibration strategy.

Corresponding author:
Marco Fornari (**ESA/ESTEC**, **Netherlands**), marco.fornari@esa.int

CryoSat SAR/SARin L1B products: BaselineC assessment and improvements towards BaselineD

Michele Scagliola (ARESYS, Italy); Marco Fornari (ESA/ESTEC, Netherlands); Tommaso Parrinello (ESA/ESRIN, Italy); Bouffard Jerome (ESA/ESRIN, Italy)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Poster
Poster number: IPM_002

Abstract:
CryoSat was launched on the 8th of April 2010 and is the first European ice mission dedicated to the monitoring of precise changes in the thickness of polar ice sheets and floating sea ice.
CryoSat is the first altimetry mission operating in SAR mode and continuous improvements in the L1 Instrument Processing Facility (IPF1) are being identified, tested and validated in order to improve the quality of the L1B products. Current IPF, Baseline C, was released in operation in April 2015 and the second CryoSat reprocessing campaign was jointly initiated, proving the users, within a few months, with a coherent data set from July 2010 until present time.
Right after baseline C release, ESA have been collecting inputs for the next processor version, baseline D, planned to be operational in mid 2018. This poster will detail the evolutions that are currently planned for the BaselineD SAR/SARin L1B products together with the expected quality improvements. The major change in Baseline D will be the migration into netCDF format, which is now the standard for altimetry missions. Another change involves the accuracy of the Attitude information, which will be increased by correcting for the aberration of light, thus improving the interferometer performance. Then, the stack characterization parameters will be extended including for example the Stack-Peakiness, which, computed before the multilooking, gives an indication of the peakiness of the stack. The full list of planned changes will be provided in this poster.

Corresponding author:
Michele Scagliola (**ARESYS**, **Italy**), michele.scagliola@aresys.it

S6 P4 GPP: The Sentinel-6 Poseidon-4 Ground Processor Prototype. New simulation results.

Eduard Makhoul (isardSAT, Spain); Roger Escolà (isardSAT, United Kingdom); Albert Garcia (isardSAT, United Kingdom); Gorka Moyano (isardSAT, United Kingdom); Pablo Garcia (isardSAT, Spain); Mònica Roca (isardSAT, United Kingdom); Marco Fornari (RHEA/ESTEC, Netherlands); Robert Cullen (ESA/ESTEC, Netherlands)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Poster
Poster number: IPM_003

Abstract:
During the last decade the radar altimetry has entered its golden age as demonstrated by the different number of missions (Jason-3, CryoSat-2, SARAL/Altika, Sentinel-3) currently operating and the forthcoming Sentinel-6. The latter is an operational oceanography programme of two satellites that will ensure continuity to the Jason series of operational missions. The mission is being developed by a multi-Agency partnership consisting of ESA, EUMETSAT, NOAA, CNES and NASA-JPL. ESA is responsible for the Sentinel-6 Space Segment development along with Astrium GmbH as a prime contractor.

The main payload of the Sentinel-6 satellite is the Poseidon-4 radar altimeter, an evolution from the altimeters on-board the Jason satellites. Poseidon-4 also inherits the Synthetic Aperture Radar (SAR) High Resolution Altimeter mode from CryoSat-2 SIRAL and Sentinel-3 SRAL, with a technological evolution characterized by:
- Improved radio frequency hardware and an on-board digital architecture (matched filter digital operation instead of analog-based de-ramping)
- Interleaved Ku-band mode operation: near continuous transmission of Ku-band pulses. It allows the simultaneous operation of the low resolution mode (LR or LRM) and high resolution (HR or SAR).
- On-board processing, range migration correction (RMC), is performed to reduce the amount of data to download.
- A calibration pulse is included in the tracking cycle to monitor instrumental variations around the orbit.

This new configuration of the Poseidon-4 instrument opens a new paradigm in the capabilities offered by the Sentinel-6 radar altimeter. In order to do so, the specificities of this new instrument have to be carefully considered in order to re-adapt the Delay-Doppler Processing algorithms. isardSAT is responsible for the development of the L1 Ground Processor Prototype (GPP) for the Poseidon-4 under ESTEC/ESA contract. This prototype processes all the chains starting from the Instrument Source Packets, and producing L1A, L1B-S (only for HR processing) and Level 1B (both calibrated LR and HR data processing). This processor includes a lot of new features thanks to the experience gained with CryoSat-2 data as well as to the many studies performed during the course of the Sentinel-6 GPP project. The development of the GPP has been carried out exploiting simulated data produced by ESTEC Sentinel-6 mission performance simulator.

This poster will provide a review of the architectural and algorithmical implementation of the GPP, stressing how this processing chain has been adapted to the new characteristics of the Poseidon-4 instrument and the related implications. The operation of the GPP will be demonstrated with new simulated data (considering different scenario conditions), up to date with the last instrumental configuration. A preliminary validation of the GPP data will be included, based on the geophysical retrievals processor implemented by isardSAT in the frame of the Sentinel-6 GPP project. This processor integrates a fully analytical HR ocean retracker based on Ray et al. 2015 model and adapted to the new Sentinel-6 Poseidon-4 characteristics.

Corresponding author:
Eduard Makhoul (**isardSAT**, **Spain**), eduard.makhoul@isardsat.cat

Sentinel-6/Poseidon-4 altimeter end-to-end simulator to assess the global mission performances

Jeremie Aublanc (CLS, France); Thomas Moreau (CLS, France); Pierre Dubois (CLS, France); Yolanda Maya-Soriano (CLS, France); Pierre Thibaut (CLS, France); Francois Boy (CNES, France); Gilles Tavernier (CNES, France); Gérard Zaouche (CNES, France); Marco Fornari (ESA, Netherlands); Mieke Kuschnerus (ESA, Netherlands); Robert Cullen (ESA, Netherlands)

Session: Instrument Processing: Measurement and Retracking
Presentation type: Poster
Poster number: IPM_004

Abstract:
Sentinel-6 mission is part of the Copernicus program, with the aim to continue the Jason series of operational oceanography missions for the period 2020-2030. Two Sentinel-6 satellites will carry a dual-frequency Ku/C-band radar altimeter (Poseidon-4) with significant evolutions with respect to their predecessors. Among other evolutions, Poseidon-4 will operate in Delay Doppler Mode (DDM), as Cryosat-2 and Sentinel-3A and B, but using an innovative interleaved mode, where pulses will be emitted and received at a regular high-repetition rate (9kHz) (unlike Cryosat-2 and Sentinel-3 operating in "burst mode"). That way, conventional Low Resolution Mode (LRM) and Synthetic Aperture Radar (SAR) mode data will be generated simultaneously. The consequence is that the noise of SAR altimeter ranges should be significantly reduced (by a factor of 1.7 when compared to Sentinel-3 SAR mode). For the sake of continuity with historical missions (Jason series), low- and high-resolution products will be generated with usual data processing, called baseline processors in LR and HR modes. Besides that, the altimeter mission will experiment new products and process developments (called experimental processors).

In the frame of the Sentinel-6 ground prototype processors (GPP) development, and under ESA contract, CLS is in charge of the definition of the level-2 prototype processor, its development and testing. The Level-2 GPP consists of four processors (two baseline and two experimental processors), each of them enabling to generate geo-located geophysical retrievals from high- or low-resolution waveforms. Furthermore, the Level-2 GPP contains new innovative retrackers (in LR and HR modes), ensuring high-performances and notable benefits in comparison with conventional ones.

In parallel to this development, CNES has funded CLS for designing and developing a Sentinel-6 altimeter simulator (including a Level-1 processor), which, combined with the L2 GPP, will form an end-to-end simulator of the Sentinel-6 Poseidon-4 measurement and processing. The Sentinel-6 altimeter simulator consists of a scene generator, and on-board and -ground processors to simulate and generate the level-1B products as defined for the mission. One of its major asset is its ability to simulate realistic oceanic scenes with a large list of possible scenarios. Alternative configurations with coastal or hydrological surfaces are also possible. Consequently, this newly-designed end-to-end simulator will permit to conduct performance evaluations of the instrument system over different types of surface (open ocean, coastal zones, river and lakes and other land areas) and to design and to assess any innovative L1/L2 processing.

This poster describes the different units of the Sentinel-6 altimeter end-to-end simulator and its major characteristics. First validation results demonstrating the potential of this simulator will also be provided.
Corresponding author:
Jeremie Aublanc (**CLS**, **France**), jaublanc@cls.fr

Impact of the next foreseen IERS mean pole model (linear) on altimeter satellite precise orbits, validation of updated measurement models (DORIS antenna phase maps and satellite geometry)

Hanane Aït-Lakbir (CS SI (POD CNES), France); Alexandre Couhert (CNES, France); Flavien Mercier (CNES, France); Sabine Houry (CNES, France); Eva Jalabert (CNES, France); John Moyard (CNES, France)

Session: Precision Orbit Determination
Presentation type: Poster
Poster number: POD_001

Abstract:
To improve the orbits, it is necessary to use the best available models, for the station coordinates (e.g., SLR validation), and measurements modelling. We propose an analysis of three recent models whose effects are seen on the orbit or station coordinates of the DORIS network. This analysis is based on past and current altimeter missions from 1992 to 2017.
The accuracy of the location of the ground stations depends on the mean polar motion model (effect of the pole tide). A linear model for the mean pole was suggested at UAW 2017 (Paris) to better compute the rotational deformation due to the pole tide. Orbit solutions were computed using this model and compared to the cubic-linear model of the IERS Conventions (2010) on the contemporary missions, with the same ITRF realization coordinates. We validate the improvement looking at SLR residuals and geographically correlated orbit differences.
A new phase correction map was provided by CNES for the Alcatel DORIS ground antennas. These antennas were predominant over the TOPEX/Poseidon lifespan. The model is tested and compared to the previous one, focusing on the estimates of DORIS satellite phase center radial offset and vertical station positioning.
Finally, for Sentinel-3A, we re-estimate the phase center offsets of the three POD instruments using the measured attitude and measured orientation of the solar panels, showing that these offset corrections could be represented by an error in the knowledge of the satellite's center of mass location.
Corresponding author:
Hanane Aït-Lakbir (**CS SI (POD CNES)**, **France**), hanane.ait-lakbir@c-s.fr

Sentinel-3 orbit determination at the Copernicus POD Service

Jaime Fernández (GMV, Spain); Heike Peter (PosiTim UG, Germany); Carlos Fernández (GMV, Spain); Pierre Féménias (ESA/ESRIN, Italy)

Session: Precision Orbit Determination
Presentation type: Poster
Poster number: POD_002

Abstract:
The Copernicus POD (Precise Orbit Determination) Service is part of the Copernicus PDGS Ground Segment of the Sentinel missions. A GMV-led consortium is operating the Copernicus POD (CPOD) Service being in charge of generating precise orbital products and auxiliary data files for their use as part of the processing chains of the respective Sentinel PDGS.
Sentinel-3 is the third mission of the Copernicus program. The orbit accuracy requirement is very stringent with 2-3 cm in radial direction mainly because of the radar altimetry observations. In addition to the SAR altimeter, the Sentinel-3 satellites carry as main payloads an Ocean and Land Colour Instrument (OLCI), a Microwave Radiometer, and a Sea and Land Surface Temperature Radiometer (SLSTR). The Sentinel-3 mission thus assures continuity of ERS, ENVISAT and SPOT vegetation data.
The POD instruments are a couple of dual-frequency GPS receivers, a DORIS receiver and a Laser Retro Reflector for Satellite Laser Ranging (SLR) to the satellite. On the one hand, the three different techniques GPS, SLR and DORIS make POD more complex but, on the other hand, it is very helpful to have independent techniques available for validation of the orbit results. The three techniques are, therefore, equally important to fulfil the orbit accuracy requirements. The CPOD Service processes GPS and SLR data routinely and is building up the capacity to process DORIS in Non-time Critical (NTC) and reprocessing campaigns.
Three different orbit products are provided for Sentinel-3, a Near Real Time (NRT) product, a Short Time Critical (STC) product and an NTC product. The NRT processing has been developed by the Copernicus POD Service but it is running externally at the PDGS Marine Centre (EUMETSAT) and at the Core Ground Station in Svalbard. The STC and NTC processing is running at GMV. The orbit predictions needed for successful SLR tracking are provided by the CPOD Service as well.
The first satellite of the mission Sentinel-3A was launched on 16 February 2016. The operational phase started mid of July 2016 and the POD processing is now running successfully for more than one year.
The CPOD Service is supported by the Copernicus POD Quality Working Group (QWG), which consists of several experts for POD of low Earth Orbiting satellites. Independent orbit solutions delivered by this group are used to validate the CPOD results and the recommendations from this body guarantee that the CPOD Service is updated following state-of-the-art algorithms, models and conventions.
The status and evolution of the POD processes for Sentinel-3A at the CPOD Service will be presented. Cross-comparisons among different Sentinel-3A orbit solutions provided by the Copernicus POD QWG showing radial RMS values below 1.5 cm are presented. External orbit validation results based on SLR measurements will show the excellent performance of less than 2 cm RMS of the Sentinel-3A orbit solutions from the CPOD Service.

Corresponding author:
Jaime Fernández (**GMV**, **Spain**), jfernandez@gmv.com

Comparison of SLR station biases

Franck Reinquin (CNES, France); Alexandre Couhert (CNES, France); Sean Bruinsma (CNES, France); Frank Lemoine (NASA GSFC, USA)

Session: Precision Orbit Determination
Presentation type: Poster
Poster number: POD_003

Abstract:
Satellite Laser Ranging (SLR) data, made available by the International Laser Ranging Service (ILRS), is essential to validate and quantify the orbit precision of the altimeter satellites. It is the only independent and unambiguous validation method that can provide the absolute radial orbit accuracy by means of high elevation passes. However, now that we are looking for sub-centimeter accuracy, SLR performance is stretched close to the present limit even for the core stations. In particular, biases and drifts have been detected in the ranging data, the amplitudes of which appear to be altitude (i.e. range) dependent. That complicates the determination of accurate station bias corrections because highest precision and accuracy is achieved on the LAGEOS satellites, which are in orbits several thousand km above the altimeter satellites. A relatively recent geodetic satellite, LARES, is at an altitude of about 1500 km, i.e. only a few hundred km above Jason, and it currently is the optimal LEO target.
In this analysis, SLR station biases from 2001 to 2016 were estimated in precise orbit determinations on the geodetic satellites LAGEOS-1/2 (at 5900 km altitude), Starlette/Stella (at about 850 km) as well as LARES (at about 1500 km), using the ITRF2014 station coordinates in this. Jason-2 GPS+DORIS precision orbits are also used to compute SLR ranging biases.

Corresponding author:
Franck Reinquin (**CNES**, **France**), franck.reinquin@cnes.fr

Updated Jason-3 wind speed and SSB solutions (2D and 3D)

Ngan Tran (CLS, France); Doug Vandemark (UNH, USA); Hui Feng (UNH, USA); Fabrice Ardhuin (LOPS, France); Lotfi Aouf (Meteo-France, France); Sophie LeGac (CNES, France); Nicolas Picot (CNES, France)

Session: Instrument Processing: Propagation, Wind Speed and Sea State Bias
Presentation type: Poster
Poster number: IPC_001

Abstract:
It is proposed to update the Jason-3 wind speed (WS) estimates by both applying a bias on MLE4 sigma0 (-0.16 dB) and using the Jason-2 based wind speed model [Tran, 2015] instead of the Jason-1 version [Collard, 2005]. In this case, the histogram characteristics (shape and mean value) are closer to those observed from ECMWF data.

The Sea State Bias (SSB) correction to sea surface height measurement is an empirical correction that is computed specifically for each altimeter. With the successful launch of the Jason-3 mission on January 2016, 1-year based solutions (2D and 3D) have been developed from collinear dataset. As reported, the differences between Jason-3 (MLE4, 2D, updated WS) with respectively 2015 Jason-1 and 2012 Jason-2 solutions display narrow distributions with standard deviation of about 3 mm and averaged differences of ~1 cm. Updated 3D SSB solution is also available and displays larger improvement (~0.8 cm²) in variance reduction at crossovers when one compares with the Jason-2 based version currently used to generate the GDR products.

These activities have been done within the SALP and Jason-3 PEACHI prototype projects.

Corresponding author:
Ngan Tran (**CLS**, **France**), ntran@cls.fr

Broadview radar altimetry toolbox

Albert Garcia-Mondejar (isardSAT Ltd., United Kingdom); Roger Escolà (isardSAT Ltd., United Kingdom); Gorka Moyano (isardSAT Ltd., United Kingdom); Mònica Roca (isardSAT Ltd., United Kingdom); Miguel Terra-Homem (DEIMOS Engenharia, Portugal); Ana Friaças (DEIMOS Engenharia, Portugal); Fernando Martinho (DEIMOS Engenharia, Portugal); Ernst Schrama (TU Delft, Faculty of Aerospace Engineering, Netherlands); Marc Naeije (TU Delft, Faculty of Aerospace Engineering, Netherlands); Marco Restano (Serco / ESRIN, Italy); Americo Ambrozio (DEIMOS / ESRIN, Italy); Jérôme Benveniste (ESA / ESRIN, Italy)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_001

Abstract:
The universal altimetry toolbox BRAT (Broadview Radar Altimetry Toolbox) is a collection of tools and tutorial documents designed to facilitate the processing of radar altimetry data. It can read all previous and current altimetry missions' data. It now incorporates the capability to read the upcoming Sentinel-3 L1 and L2 products. ESA endeavoured to develop and supply this new capability to support the users of the Sentinel-3 mission.
The toolbox is freely available at http://earth.esa.int/brat. The BRAT suite is mostly made of command line tools, of which the BratGUI is the front-end. BRAT can be used in conjunction with MATLAB/IDL (via reading routines) or C/C++/Python/Fortran via a programming API, allowing users to obtain the desired data, bypassing the data-formatting hassle. BRAT can also be used to simply visualise data quickly or to translate the data into other formats such as NetCDF, ASCII text files, KML (Google Earth) and raster images from the data (JPEG, PNG, etc.).
Several kinds of computations can be done within BRAT, involving both user defined combinations of data fields that can be saved for posterior use and the BRAT's predefined formulas from oceanographic altimetry. BRAT also includes the Radar Altimeter Tutorial, which contains an extensive introduction to altimetry, showing its applications in different fields. Use cases are also available, with step-by-step examples, covering the toolbox usage in the different contexts.

Corresponding author:
Albert Garcia-Mondejar (**isardSAT Ltd.**, **United Kingdom**), albert.garcia@isardsat.co.uk

SAR ALTIMETRY PROCESSING ON DEMAND SERVICE FOR CRYOSAT-2 AND SENTINEL-3 AT ESA G-POD

Jérôme Benveniste (ESA-ESRIN, Italy); Salvatore Dinardo (He Space/EUMETSAT, Germany); Giovanni Sabatino (Progressive Systems Rhea/ESRIN, Italy); Marco Restano (SERCO/ESRIN, Italy); Américo Ambrózio (DEIMOS/ESRIN, Italy)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_002

Abstract:
The scope of this presentation is to feature the ESA-ESRIN G-POD SARvatore service to users for the exploitation of the CryoSat-2 and Sentinel-3 data, which was designed and developed by the Altimetry Team at ESA-ESRIN, Earth Observation Science Data Application Division.

SARvatore (SAR Versatile Altimetric Toolkits for Ocean Research & Exploitation) is a SAR and SARin altimeter data processing on demand service available on the ESA-RSS processing platform (G-POD), recently extended beyond the “Ocean” in its original acronym to Coastal Zone, Sea-Ice, Ice Sheets and Inland Water. It allows users to process, on line and on demand, low-level CryoSat-2 and Sentinel-3 Altimetry data products (FBR, Level 1A) in SAR mode up to Level-2 geophysical products with self-customized options (not available in the default processing chains of CryoSat-2 and Sentinel-3 Ground Segments), exploiting all the capabilities of modern grid computing.

The SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation (SARvatore) takes advantage of the G-POD (Grid Processing On Demand) distributed computing platform to timely deliver custom-processed data products and to interface with ESA-ESRIN FBR data archive, which currently houses around 200 TB of CryoSat-2 (SAR and SARin) and Sentinel-3 (SAR) data. The output data products are generated in standard NetCDF format (using CF Convention), therefore being compatible with the Broadview Radar Altimetry Toolbox (BRAT) and other similar data visualisation and manipulation tools. By using the G-POD graphical interface, data products included in the catalogue can be selected for specific geographical areas and time periods. The processor prototype is versatile, allowing users to customise and adapt the processing according to their specific needs by setting a list of configurable options. These also include the generation of experimental SAR data products, such as L1B Stack data and Range Integrated Power (RIP) waveforms, and can be augmented upon user request. After the task submission, users can also follow, in real time, the status of the processing.

The processing service, which started as an internal tool to support ESA R&D contracts, is now open to the worldwide SAR Altimetry Community for R&D experiments, on-site demonstrations in training courses and workshops, cross-comparison to third party products (e.g. CLS/CNES CPP or ESA SAR COP data products), and for the exploitation of the Sentinel-3 Surface Topography Mission data. Tutorial documents are linked to within the SARvatore.

Initially, the processing was designed and uniquely optimised for open ocean studies. It adopted the SAMOSA2 and SAMOSA3 retrackers developed during ESA's SAMOSA and CP4O projects exploiting CryoSat-2 data. However, since June 2015, a new retracker (SAMOSA+) has been included in the service as a dedicated retracker for coastal zone, inland water and sea-ice/ice-sheet scenarios. In view of the Sentinel-3 data exploitation, a new flavour of the service has been initiated, exclusively dedicated to the processing of Sentinel-3 mission data products. The scope of this new service is to maximize the exploitation of the Sentinel-3 Surface Topography Mission data over all surfaces, allowing users to benefit from advanced processing strategies not yet adopted in the production of official Sentinel-3 products. In June 2017, a trial with a select group of users was started. Once completed, the G-POD SARvatore for Sentinel-3 service will be open to the worldwide community.

The service, supported by the ESA EO R&D Programme, is open, free of charge for worldwide scientific applications and available at:
https://gpod.eo.esa.int/services/CRYOSAT_SAR/
http://gpod.eo.esa.int/services/CRYOSAT_SARIN/
https://gpod.eo.esa.int/services/SENTINEL3_SAR/

For further information:
http://wiki.services.eoportal.org/tiki-index.php?page=GPOD+CryoSat-2+SARvatore+Software+Prototype+User+Manual
Corresponding author:

Jérôme Benveniste (**ESA-ESRIN**, **Italy**), jerome.benveniste@esa.int

Aviso+ products & services: what's new?

Vinca Rosmorduc (CLS, France); Florence Birol (Legos, France); Françoise Mertz (CLS, France); Laurent Soudarin (CLS, France); Thierry Guinle (CNES, France)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_003

Abstract:
Since the launch of Topex/Poseidon, 25 years ago, satellite altimetry has evolved in parallel with the user community. As a result of this evolution, we now have:
- A bigger choice of products, more and more easy-to-use, spanning complete GDRs to high-level products such as eddy trackings and filaments, and indicators such as MSL index or ENSO index.
- a mature approach, combining altimetric data from various satellites and merging data acquired using different observation techniques, including altimetry, to give us a global view of the ocean;

Different services are available either to choose between the various datasets, or to download, extract or even visualize the data. 2016 - 2017 saw several changes which will be detailed in the poster. In the future, we will develop even more the ice, coastal and hydrology thematics on the web.

Corresponding author:
Vinca Rosmorduc (**CLS**, **France**), vrosmorduc@cls.fr

Outreaching hydrology from space & SWOT

Vinca Rosmorduc (CLS, France); Nicolas Picot (CNES, France)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_004

Abstract:
Hydrology from space is one of the rising remote sensing field of application, with huge issues - environmental, human, economic... - to take into account. Among the issues, there's also the question of explaining how to use those data (from current as well as future satellites) to people not so used to remote sensing, why, how they are made, etc. -- in one word, outreaching hydrology from space. Some portals exist, such as the THEIA portal for land applications through which a number of space data dedicated to land applications (including hydrology) are available (https://www.theia-land.fr/en).
SWOT will be a cornerstone of hydrology from space, and will also be a completely new concept. Some pieces of explanations exists through the CNES space technology training courses (animations available on demand with a license), but more can be done -- and will be, with a major focus on hydrology, but not forgetting the ocean, and the complementarity with currents techniques, including nadir altimetry.

Corresponding author:
Vinca Rosmorduc (**CLS**, **France**), vrosmorduc@cls.fr

ArgoHydro, Hydrology in the classroom

Danielle De Staerke (CNES, France); Léa Lasson (CNES, FRANCE); Margaret Srinivasan (NASA/JPL, USA); Annette de Charon (ODYSEA LLC, USA)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_005

Abstract:
For the past 15 years, the ARGONAUTICA educational project has made actual oceanographic data available to primary and secondary students.

In the context of climate change impact, and the increasing research interest in acceleration of the water cycle – such as heavy precipitation, storm surges, severe floods, and droughts – we have added a hydrological component to the ARGONAUTICA project.
This activity is aided by the development of the NASA-Centre National d'Études Spatiales collaborative mission, Surface Water and Ocean Topography (SWOT). After its 2021 launch, SWOT will provide essential information on large rivers, lakes and reservoirs – along with high-resolution measurements of our global ocean – at least twice every 21 days.
The new educational endeavor, called ArgoHydro will consist of in situ measurements by schools (precipitation, soil moisture, lake and river levels) and correlation with satellite data (Global Precipitation Measurement, Soil Moisture and Ocean Salinity, Soil Moisture Active Passive, SWOT).
ArgoHydro is designed to complement the international Global Learning and Observation to Benefit the Environment (GLOBE) Program. GLOBE already offers precipitation and soil moisture measuring protocols for in situ measurements. A similar protocol for measuring the surface water level of lakes and rivers is under development. SWOT will benefit from students taking part in water level studies while supporting GLOBE's mission "to promote the teaching and learning of science, enhance environmental literacy and stewardship, and promote scientific discovery."

Corresponding author:
Danielle De Staerke (**CNES**, **France**), danielle.destaerke@cnes.fr

SAR-RDSAR: A new Service on G-POD for SAR and RDSAR Products

Christopher Buchhaupt (TU Darmstadt, Germany); Luciana Fenoglio (University of Bonn, Germany); Matthias Becker (TU Darmstadt, Germany)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_006

Abstract:
The service SAR-RDSAR has been primarily developed as an offline processor prototype under the working title “PLRM FBR processor for CryoSat-2 at TU Darmstadt”. The PLRM products were intended to serve as a reference solution to validate the SARvatore G-POD service in SAR mode and to support teaching at TU Darmstadt. Recently this processor prototype has been enhanced to produce RDSAR data in coastal zone and SAR L1B and L2 data co-located to RDSAR. Various processing options have been implemented.

To allow open access of the processor results the processor is run through the ESA’s G-POD service. Currently only the RDSAR processor for open ocean CryoSat-2 data is available to registered users. SAR processing will be available after final testing as well. Further options for the extension of the processing to coastal zone and to Sentinel-3 data are foreseen.

This contribution gives a brief introduction of both the applied SAR-RDSAR algorithms and of their particular features. Further on examples and results are given to show their quality and performance in comparison to publicly available SAR and RDSAR data from other processors.

Corresponding author:
Christopher Buchhaupt (**TU Darmstadt**, **Germany**), buchhaupt@psg.tu-darmstadt.de

NOAA Scientific Data Stewardship for Ocean Surface Topography Mission (OSTM)/Jason-2 and Jason-3 Products

Yongsheng Zhang (NOAA/NESDIS National Centers for Environmental Information (NCEI)-UMD/ESSIC/CICS, Silver Spring, MD 20910, United States); Xuepeng Zhao (NOAA/NESDIS/NCEI, Silver Spring, MD 20910, USA); Huai-min Zhang (NOAA/NESDIS/NCEI, Asheville, NC 28801, USA)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_007

Abstract:
In its role as the US archive for oceanographic, geophysical and meteorological data, the NOAA National Centers for Environmental Information (NCEI) provides scientific data stewardship including near real-time and delayed-mode product distribution, rigorous archive services, custom products, and long-term data stewardship for the Ocean Surface Topography Mission (OSTM)/Jason-2 and Jason-3 products. NCEI's basic services for OSTM/Jason-2 and Jason-3 could be outlined as the followings:
1) Primary Datasets: Within the past few years, NCEI has instituted a mirror service, replicating all level-2 Geophysical Data Records (GDRs) directly from NOAA's Data Distribution Service (DDS). This has reduced the latency of providing the operational GDRs to the public to under an hour. All operation, interim and final GDRs from Jason-2/OSTM and Jason-3 have been provided to public through ftp, http, OPeNDAP, and THREDDS servers.
2) Enhanced Data Rich Inventory (RI): Data quality monitoring for the OSTM/Jason-2 and Jason-3 final and interim GDRs is provided on a per-pass basis. The data quality assurance (QA) descriptive statistics are computed at the time of the data file being ingested into the archive. Visualizations of the QA statistics are publicly accessible through the NCEI Jason data quality monitoring website
3) Derived products: Our data quality monitoring system also automatically generates quick-look cycle-mean (~10 days) on 3.0°x1.0° and 0.25°x0.25° (longitude/latitude) grids for the monitored level-2 final and interim GDRs variables including sea surface height anomaly and significant wave height. The NetCDF formatted datasets and real-time visualization are accessible through the NCEI Jason archive homepage.
4) Data Archive Reconcile between NOAA/CLASS and AVISO/SIPAD: This monthly comparison of the data files archived in CLASS and SIPAD, and the re-ingest of the missing files if any, ensures all the OSTM/Jason-2 and Jason-3 products have been successfully archived identically in the two official products archive centers.
The progress and update of NCEI OSTM/Jason-2 and Jason-3 data archive and distribution services and users' access statistics information in the last year will also be reported in the presentation.

Corresponding author:
Yongsheng Zhang (**NOAA/NESDIS National Centers for Environmental Information (NCEI)-UMD/ESSIC/CICS, Silver Spring, MD 20910**, **United States**), yongsheng.zhang@noaa.gov

Access to Sentinel-3 Marine Center data

Bruno Lucas (HE Space, Germany); Remko Scharroo (EUMETSAT, Germany); Carolina Nogueira-Loddo (EUMETSAT, Germany); Cristina Martin-Puig (EUMETSAT, Germany); Salvatore Dinardo (HE Space, Germany)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_008

Abstract:
The Marine data of the Surface Topography Mission of Sentinel3 is produced and distributed by EUMETSAT. The products made available to the users are SRAL/MWR Level 2 (SR_2_WAT___) and SRAL Level 1 (SR_1_SRA_A, SR_1_SRA_BS, SR_1_SRA___).
User can access the data via EUMETcast, EUMETSAT Data Centre, ODA (Online Data Access) and the pilot service CODA (Copernicus Online Data Access).

This poster will show the different manners to access the available datasets (either operational or the reprocessed). The focus will be on access via Data Centre and CODA, especially on the automatization of data download.

Corresponding author:
Bruno Lucas (**HE Space**, **Germany**), bruno.lucas@eumetsat.int

NOAA Coastwatch/Oceanwatch Altimetry Products

Jessica Burns (Global Science and Technology, Inc. (NOAA contractor), United States); Eric Leuliette (NOAA, United States)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_009

Abstract:
The NOAA Laboratory for Satellite Altimetry provides a gridded Level 3 sea level anomaly product publicly available for download through ftp and NOAA's Coastwatch/Oceanwatch Environmental Research Division's Data Access Program data server (coastwatch.noaa.gov). This is a near real time product available daily, having a global spatial coverage with a ¼ degree spatial resolution, and a temporal coverage of February 2017 through the present. It is a multiple altimeter optimal interpolation sea level anomaly product currently using Jason-2, Jason-3, AltiKa, and Cryosat-2 data. Recently we have been working on evaluating the processing of this product. This has included tuning our error-weighting for the optimal interpolation, which has reduced differences between our grids and AVISO grids.

Corresponding author:
Jessica Burns (**Global Science and Technology, Inc. (NOAA contractor)**, **United States**), jessica.burns@noaa.gov

X-TRACK regional altimeter products for coastal applications

Fabien Léger (LEGOS / CTOH, France); Florence Birol (LEGOS / CTOH, France); Fernando Niño (LEGOS / CTOH, France); Sara Fleury (LEGOS / CTOH, France)

Session: Outreach, Education and Altimetric Data Services
Presentation type: Poster
Poster number: OUT_010

Abstract:
Climate change is likely to worsen many problems that coastal environments already face: shoreline erosion, coastal flooding, stress and damage of the coastal biodiversity. Sea level variation is one of the major threat for coastal zones. Improving its observation is essential to better understand and predict the behavior of the coastal ocean. Altimetry provides unique long term observational dataset to characterize how sea level variability evolves from the open ocean to the coastal ocean.

In order to optimize the completeness and the accuracy of the sea surface height information derived from satellite altimetry in coastal ocean areas, X-TRACK has been developed by CTOH (Center of Topography of the Ocean and Hydrosphere) and LEGOS (Laboratoire d'Etudes en Géophysique et Hydrologie Spatiale), and is distributed by the CTOH/LEGOS and by the operational AVISO+ service. X-TRACK is tailored for extending the use of altimetry data to coastal ocean applications and provides freely available along-track Sea Level Anomaly time series as well as along-track empirical tidal constants that cover today all the coastal oceans. We present here the last developments made in X-TRACK products as well as the perspectives for future evolution.

Corresponding author:
Fabien Léger (**LEGOS / CTOH**, **France**), fabien.leger@legos.obs-mip.fr

Estimation of vertical velocities associated with large scale dynamics in the Atlantic ocean.

alban lazar (LOCEAN-IPSL-UPMC, France); Soren François (LOCEAN-IPSL-UPMC, France); Siny Ndoye (LPAOSF-ESP-UCAD & LOCEAN-IPSL-UPMC, Senegal)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_001

Abstract:
Vertical velocities in the ocean are generally too weak to be measured at monthly to interanual time-scales. In particular, that is the case of the vertical movements associated to the large scale basin wide relatively slow dynamics. This prevents any accurate assessment of the thermohaline circulation return flow and the thermocline vertical ventilation (mass, heat, oxygen and carbon fluxes).
In this work, we compute the three-dimensional time-mean vertical velocities of an Atlantic basin simulation, using the density field and the linear vorticity balance (LVB). The validity of the LVB and the errors of the estimated velocities are quantified using the simulation as the reference.
It appears that large regions of the basin are dominated by the LVB dynamics, within the tropical, subtropical, and subpolar gyre, at various depth range, depending on spatial scale considered. The vertical velocity estimated field is accordingly accurate in many regions to first order, especially away from boundaries. The validity of the method also offers a way to interpret vertical movements at various depths in function of the better known horizontal flow.

Corresponding author:
alban lazar (**LOCEAN-IPSL-UPMC**, **France**), alban.lazar@upmc.fr

Quantifying uncertainties on regional sea level change induced by multidecadal intrinsic oceanic variability

Thierry Penduff (CNRS - IGE, France); Guillaume Sérazin (LEGOS, France); Benoit Meyssignac (CNES - LEGOS, France); Laurent Terray (CERFACS, France); Bernard Barnier (CNRS - IGE, France); Jean-Marc Molines (CNRS - IGE, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_002

Abstract:
A global eddy-permitting (1/4° resolution) ocean general circulation model, driven during 327 years by a repeated climatological atmospheric forcing, is shown to spontaneously generate a strong chaotic Intrinsic Oceanic Variability (IOV) which reaches multi-decadal timescales.
In eddy-active regions, the sea-level imprint of this multi-decadal nonlinearly-driven “noise” is substantial, weakly autocorrelated, and is comparable to (and may clearly exceed) the corresponding imprint of Internal Climate Variability (ICV) produced by CMIP5 coupled climate models, whose laminar ocean components strongly underestimate the IOV.
Deriving sea-level trends from finite-length time series in eddy-active regions yields uncertainties induced by this ocean-driven multi-decadal IOV, which are of the same order of magnitude as those due to the coupled ICV.
These results, obtained in the framework of the past CHAOCEAN and current PIRATE OST-ST projects, raise issues about the detection and attribution of sea-level changes in certain regions from the relatively short existing altimeter archive, and from certain tide gauge records.

Corresponding author:
Thierry Penduff (**CNRS - IGE**, **France**), Thierry.Penduff@cnrs.fr

A Western Tropical Atlantic Circulation Analysis Using Statistics and Satellites

Frédéric Haykal (LOCEAN UMR CNRS/IRD/UPMC/MNHN, France); Sabine Arnault (LOCEAN UMR CNRS/IRD/UPMC/MNHN, France); Sylvie Thiria (LOCEAN UMR CNRS/IRD/UPMC/MNHN, France); Khalil Yala (LOCEAN UMR CNRS/IRD/UPMC/MNHN, France); Mounir Bendali Braham (LOCEAN UMR CNRS/IRD/UPMC/MNHN, France); Beyrem Jebri (LOCEAN UMR CNRS/IRD/UPMC/MNHN, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_003

Abstract:
The western tropical Atlantic ocean is a very energetic and highly variable region. It is one of the main contributors to the inter-hemispheric mass and heat transports. This study gives a new picture of the space and time variability of this region using statistical tools applied to satellite measurements such as radar altimeters (TOPEX/Poséïdon/Jason series...), Soil Moisture and Ocean Salinity (SMOS) radiometer, and the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) products. The investigated variables are thus the Sea Surface Temperature (SST), the Sea Level Anomalies (SLA) and the Sea Surface Salinity (SSS) between 70°W-20°E, 0°N-15°N, from 2010 to 2015. Using analytical methods from the statistical and machine learning field, like the Self-Organizing Map (SOM), it is possible to classify the different phenomena located in that area and to identify their characteristics. We will focus on the dynamics of the North Brazil Current, and the North Equatorial CounterCurrent, respectively, and their links with the InterTropical Convergence Zone and the Amazon river run off.

Corresponding author:
Frédéric Haykal (**LOCEAN UMR CNRS/IRD/UPMC/MNHN**, **France**), fhaykal@locean-ipsl.upmc.fr

Investigation of the intra-annual variability of the North Equatorial Counter Current/ North Brazil Current eddies and of the instability waves of the North tropical Atlantic Ocean using satellite altimetry and Empirical Mode Decomposition

Jean-Luc Mélice (IRD, LOCEAN, Paris, France); Sabine Arnault (IRD, LOCEAN, Paris, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_004

Abstract:
The intra-annual variability of the tropical Atlantic Ocean north of the Equator is investigated with satellite altimetry mean sea level anomalies data, and with an algorithm based on Empirical Mode Decomposition (EMD) methods. Two regions of high variability are identified. The first region, between 3°N-12°N, is characterized by the presence of westward propagating eddies linked to the North Brazil Current (NBC) retroflection in the vicinity of the Brazilian coast. They show a strong annual cycle. Our EMD algorithm points out that this signal is frequency modulated shifting from large lengthscale structures in October to smaller ones in March. Consequently, the number of 'eddies' per year can be aliased, according to the time and location of sampling, and can impact the percentage they explain of the inter-hemispheric exchange of mass and heat associated with the meridional overturning circulation's upper limb. A scenario concerning this dynamics is proposed. The second region reveals the presence of westward propagating instability waves centered north of the Equator (3°N-7°N) between 50°W-10°W. These instability waves are also frequency modulated and show a strong seasonal cycle with maximum amplitude around August.

Corresponding author:
Jean-Luc Mélice (**IRD, LOCEAN, Paris**, **France**), jlmelice@locean-ipsl.upmc.fr

The Brazil Current Variability from XBT data and satellite altimetry

Marlos Goes (UM/CIMAS and NOAA/AOML, United States)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_005

Abstract:
The variability of the Brazil Current is examined using data from two XBT transects and altimetry at 22S and 34S. To estimate the transport of the current, two methods are used, one purely from sea surface height and another synthetic using a regression of sea surface height to the estimated dynamic height and density from hydrography. Altimetry is also used to extrapolate the velocities to the continental shelf. The BC transport is in agreement with previous studies (~5Sv at 22S and 12 Sv at 34S). The altimetry based methods can represent well the BC transport seasonal cycle, whereas the XBT only still lacks the time representativeness due to strong mesoscale variability of the current.The interannual variability of the BC is estimated and associated to large scale Sverdrup dynamics and the variability of the recirculation gyre. One event of 2009-2010 is studied, and the BC dynamics is associated with the strong SST and thermosteric anomalies in the region.

Corresponding author:
Marlos Goes (**UM/CIMAS and NOAA/AOML**, **United States**), marlos.goes@noaa.gov

Performance of MERCATOR operational model at the Brazil Malvinas confluence

Camila Artana (Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN, France); Ramiro Ferrari (CIMA/CONICET-UBA and UMI IFAECI -3351, Argentina); Jean Michel Lellouche (Mercator-Océan, France); Martin Saraceno (CIMA/CONICET-UBA and UMI IFAECI -3351, Argentina); Christine Provost (Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_006

Abstract:
Daily outputs from the operational Mercator global-ocean model (1/12□) (PSY4) are analyzed in the complex region of the Brazil-Malvinas Confluence which is a stringent test for model outputs. The performance of the model is assessed by comparing velocity, temperature and salinity model outputs to in situ mooring time series gathered during the CASSIS-MALVINAS project. The data set includes 3 moorings (comprising an upward looking long-range ADCP deployed over the 1000 m isobaths) deployed at 41°S over the Patagonian Shelf break from December 2014 to December 2015.
In general, model means outputs and standard deviations are in good agreement with in situ data. For the along-slope velocity component, the agreement is particularly satisfying in the upper slope instruments where the correlation between along-slope velocity components of the model and 20-day low pass filter in situ velocities are larger than 0.7. During June 2015 the root mean square difference between the along-slope model velocities and the along-slope in situ velocities increases considerably (more than 20 cm/s) at the three mooring sites. The comparison of the sea level anomaly from altimetry data and from model outputs shows that the sea level anomaly is not correctly assimilated in the model during this period. The causes of this failure are discussed here.
The performance of the model is then assessed using the agreement with altimetry. We then use the model outputs to put the in-situ data in a larger spatial and temporal context (10 years), to derive quantities such as along-slope and across-slope transports, when accurate, and to investigate processes on the continental slope such as upwelling and downwelling events.

Corresponding author:
Camila Artana (**Laboratoire LOCEAN-IPSL, Sorbonne Universités (UPMC, Univ. Paris 6)-CNRS-IRD-MNHN**, **France**), camila.artana@locean-ipsl.upmc.fr

Malvinas current dynamics from in situ and satellite altimetry data

Martin Saraceno (Universidad de Buenos Aires- CONICET, Argentina); Guillermina Paniagua (CONICET-UBA, ARGENTINA); Loreley Lago (INIDEP-UBA, ARGENTINA); Ramiro Ferrari (CONICET-UBA, ARGENTINA); Alberto Piola (SHN-UBA, Argentina); Raul Guerrero (INIDEP, Argentina); Christine Provost (CNRS, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_007

Abstract:
In situ data obtained in the framework of the French-Argentine CASSIS project are used with satellite altimetry data to study the circulation in the Southwestern Atlantic. Seven moorings and a fully equipped oceanographic buoy were deployed to measure currents, temperature, conductivity and pressure between December 2014 and May 2017. During the first year (December 2014-November 2015) the moorings were deployed below Jason-2 satellite altimeter track #26, covering the northern portion of the Malvinas Current (MC) and Patagonian continental shelf (PCS). In December 2015 the instruments were recovered and redeployed along a zonal section at 44.7ºS. Final recovery of the instruments was performed on May 2017. The deployment scheme allows to simultaneously monitor the PCS and MC flows. A summary of the results obtained so far at the shelf break in the northern section are presented here and in Ferrari et al. Results on the continental shelf are presented in Lago et al. In the northern section two different regimes are recognized at the shelf-break, that we refer to as strong and weak MC. During the weak MC regime currents measured at the moorings are lower than during strong MC regime. Temperature and salinity data shows that the whole dynamics of the MC is different during the two regimes: water masses in the upper 1600m sink and move to the East. Satellite geostrophic velocities and sea surface temperature clearly show that the weak regime is due to an earlier retroflection of the MC, induced by the southward migration of the Brazil-Malvinas Confluence front. Comparison of in situ and altimetry currents shows that the latter represent adequately (rmsd 12cm/s) in situ currents between 200m and the sea bottom during weak MC while during strong MC only between 200m and 500m. Ekman dynamics dominates the surface layer and the largest variations observed in the vertical structure down to 1000m depth in both regimes.

Corresponding author:
Martin Saraceno (**Universidad de Buenos Aires- CONICET**, **Argentina**), saraceno@cima.fcen.uba.ar

Satellite altimetry and current-meter velocities in the Malvinas Current at 41°S: comparisons and modes of variations

Ramiro Ferrari (Centro de Investigaciones del Mar y la Atmósfera., Argentina); Camila Artana (LOCEAN-IPSL, France); Martin Saraceno (Centro de Investigaciones del Mar y la Atmósfera., Argentina); Alberto Piola (Departamento de Oceanografia, Servicio de Hidrografia Naval, Argentina); Christine Provost (LOCEAN-IPSL, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_008

Abstract:
Three year-long current-meter arrays were deployed in the Malvinas Current at 41°S below a satellite altimeter track at about 10 years intervals. Surface geostrophic velocities (SGV) derived from satellite altimetric data are compared with the in situ velocities at the upper current-meter (300 m). Multi-satellite gridded SGV compare better with in situ observations than along-track SGV. In spite of the proximity of the moorings to the complex Brazil-Malvinas Confluence (BMC) region, satellite SGV are significantly correlated with the 20-day low-passed in situ velocities (0.85 for along-isobaths velocities, 0.8 for cross-isobaths velocities). The recent in situ measurement period (2014-2015) stands out in the altimetry record with a long-lasting (4 months) high level of eddy kinetic energy at the mooring site and a southernmost location of the Subantarctic Front (SAF). The first two modes of variations of sea level anomaly (SLA) over the BMC remarkably match the first two modes of the low-passed in situ velocities. The first mode is associated with a latitudinal migration of the SAF, and the second with a longitudinal displacement of the Brazil Current overshoot. The two modes dominate the 24-year long record of SLA in the BMC, with energy peaks at the annual and semi-annual periods for the first mode and at 3 to 5 months for the second mode. The SLA over the Southwest Atlantic were regressed onto the two confluence modes of SLA variations and showed remarkable standing wave-train like structures in the Argentine Basin.

Corresponding author:
Ramiro Ferrari (**Centro de Investigaciones del Mar y la Atmósfera.**, **Argentina**),
ramiro.ferrari@cima.fcen.uba.ar

A reconstructed South Atlantic Meridional Overturning Circulation time series since 1870.

Hosmay Lopez (University of Miami, United States); Gustavo Goni (NOAA/AOML, United States); Shenfu Dong (NOAA/AOML, United States)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_009

Abstract:
With the aid of altimetry derived sea surface height (SSH) and sea surface temperature (SST), we reconstruct a century-long South Atlantic Meridional Overturning Circulation (SAMOC) index and explores potential factors influencing its variability. The SAMOC reconstruction is possible due to its covariability with SSH and SST. A singular value decomposition (SVD) method is applied on the joint correlation matrix of SSH or SST and SAMOC. The SVD is performed on the trained period of 1993-2017 for which satellite altimetry observations are available. The joint modes obtained are used in the reconstruction of a monthly mean SAMOC timeseries from 1870 to 2017. The reconstructed index is highly correlated to the observed SAMOC timeseries during the trained period and provides a long historical estimate. It is shown that the Pacific Decadal Oscillation and the Atlantic Niño are the leading modes of SAMOC-SST-SSH covariability, explaining 75% and 15%, respectively. The reconstruction shows that SAMOC is currently in an anomalous positive (i.e., stronger than normal) phase.

Corresponding author:
Hosmay Lopez (**University of Miami**, **United States**), Hosmay.Lopez@noaa.gov

Arctic Freshwater fluxes with EO data and first results

Ole Baltazar Andersen (DTU Space, Elektrovej 328, DK-2800 Kongens Lyngby, Denmark); Karina Nilsen (DTU Space, Elektrovej 328, DK-2800 Kongens Lyngby, Denmark); Louise Sandberg Sørensen (DTU Space, Elektrovej 328, DK-2800 Kongens Lyngby, Denmark); Henriette Skourup (DTU Space, Elektrovej 328, DK-2800 Kongens Lyngby, Denmark); Natalia Havelund Andersen (DTU Space, Elektrovej 328, DK-2800 Kongens Lyngby, Denmark); Thomas Nagler (ENVEO, Austria); Elena Zakharova (Legos, Observatoire Medi Pyrenee, Toulouse, France); Alexei Kouraev (Legos, Observatoire Medi Pyrenee, Toulouse, France); Cristina Surdu (ESA, ESRIN, Frascati, Italy); Diego Fernandez (ESA, ESRIN, Frascati, Italy)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_010

Abstract:
Within the Support to Science Elements framework ESA has initiated a new CLIC initiative for the Arctic Ocean (Arctic +) on determining the Arctic Freshwater fluxes using Earth Observation data.
One of the projects supported by this initiative is the ArcFlux works which started in September 2016 will be introduced in this presentation. This project aims to determining the largest component to the Arctic Freshwater budget, namely the contribution from large rivers, glaciers as well as in-out flow of freshwater through the ocean pathways.
The main objectives of the project is to: Identify the major challenges associated with estimation of the Arctic Freshwater budget and Explore, develop and validate different approaches to address the identified challenges and enhance current approaches to compute the freshwater budget in the Arctic and compute a multi-year assessment of the Arctic freshwater budget based on the developed methodology. Finally the obtained results will be evaluated and the project will develop a scientific roadmap for future research activities in this domain of estimating the FWB of the Arctic Ocean.

Corresponding author:
Ole Baltazar Andersen (**DTU Space, Elektrovej 328, DK-2800 Kongens Lyngby**, **Denmark**), oa@space.dtu.dk

Learning from large-ensemble ocean simulations to better interpret satellite and in-situ ocean data. - The Occiput large-ensemble dataset and some applications -

Stéphanie Leroux (Ocean next, France); Thierry Penduff (IGE, Grenoble, France); jean-Marc Molines (IGE, Grenoble, France); Laurent Brodeau (Ocean Next, Grenoble, France); Jacques Verron (Ocean Next, Grenoble, France); Julien Le Sommer (IGE, Grenoble, France)

Session: Science II: Large Scale Ocean Circulation Variability and Change
Presentation type: Poster
Poster number: SC2_011

Abstract:
Over the last decades, altimeter and other satellite and in-situ ocean observations have provided crucial information to increase our knowledge of the global oceanic state, its variability, and long-term changes. Comparing observations to ocean numerical simulations is a routinely-used approach to either validate models, calibrate new observation systems, or inverstigate physical processes and mechanisms. But such comparison requires some knowledge of the different types of uncertainties attached to the compared datasets.
Given the chaotic, non-linear nature of the ocean system, ocean models in the turbulent regime are highly sensitive to initial conditions and spontaneously generate a chaotic intrinsic variability that has recently been shown to be significant even on low-frequency (interannual and longer periods) and on basin scale (e.g. Penduff et al, 2011, Serazin et al, 2015, Leroux et al 2017).
Performing ensemble simulations is a way to take into account this intrinsic uncertainty, inherent to the ocean circulation, by sampling a range of possible trajectories of equal likelihood.
In other words, it means that the most accurate collection of satellite/in-situ observations can only fit a model simulation up to a certain point, as the observations describe the one time-evolution that the ocean state has followed in reality, randomly picked among an ensemble of possible evolutions seen as equally-likely by an ocean model.

At Ocean Next, in partnership with the MEOM group within several projects (e.g. ANR OCCIPUT and PIRATE-OSTST), we develop such probabilistic approaches, based on large-ensemble eddy-permitting ocean simulations. Our goal is to better quantify and characterize the model uncertainty related to the intrinsic variabity of the ocean, and to provide useful information to better interpret satellite and in-situ ocean data. It includes a quantification of the chaotic variability and a better characterization of the locations, depth, temporal and spatial scales that are the most affected by a chaotic behaviour in models, and wich are thus affected by the largest uncertainty in any comparison with satellite or in-situ observations.

This poster will present the ensemble version of the ocean model NEMO adapted in the group to perform large ensemble simulations in one single executable for N ensemble members run in parallel, hence allowing for communication between the members during the integration. The OCCIPUT global 1/4° large-ensemble (N=50) simulation will be introduced, along with the associated sythetic observation dataset which was produced online. This synthetic observation dataset provides 50 synthetic versions of along-track Jason-2 altimeter data and ENACT–ENSEMBLES temperature and salinity profile data, generated online using the NEMO observation operator, used within each of the ensemble member. We will then present some examples of results and discuss applications to valorize from this novel dataset.
Corresponding author:
Stéphanie Leroux (**Ocean next**, **France**), stephanie.leroux@ocean-next.fr

One case study on how satellite and in situ ocean observations help to improve hurricane forecasts

Gustavo Jorge Goni (NOAA/AOML, United States); Jili Dong (NOAA/EMC, USA); George Halliwell (NOAA/AOML, USA); Hyun-Sook Kim (NOAA/EMC, USA); Ricardo Domingues (University of Miami/CIMAS, USA); Francis Bringas (NOAA/AOML, USA); Julio Morell (University of Puerto Rico Mayaguez, USA); Luis Pomales (University of Puerto Rico Mayaguez, USA)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_001

Abstract:
The tropical Atlantic basin is one of seven global regions where tropical cyclones (TCs) are commonly observed to originate and intensify. TCs translate through the region every year, frequently affecting coastal, highly populated areas. In an average year, 2 to 3 of them are categorized as intense hurricanes. Given the appropriate atmospheric conditions, TC intensification has been linked to the upper ocean heat conditions. While errors in hurricane track forecasts have been reduced during the last years, errors in intensity forecasts remain unchanged. Several studies have shown that upper ocean measurements, particularly of temperature and salinity, ahead of the passage of a TC, help identify areas where TCs may potentially intensify. More recently, studies have shown that the combined use of in situ and satellite observations has the potential to improve the representation of the ocean to correctly initialize hurricane intensity numerical forecast models. However, a sustained in situ ocean observing system in the tropical North Atlantic Ocean and Caribbean Sea dedicated to measuring subsurface density (thermal and salinity) fields in support of TC intensity studies and forecasts has yet to be designed and implemented. We highlight here current efforts to implement and maintain a suite of observational efforts that utilize data from satellite and autonomous platforms to better understand air-sea processes during high wind events. The example presented here corresponds to the joint use of underwater gliders and satellite altimetry, which have shown to improve the correct representation of ocean conditions and improved forecast for the Hurricane Gonzalo (2014). The impact study carried out for Hurricane Gonzalo (2014) showed that ocean observations helped reduced the error in intensity forecast by almost 50%. Observing System Experiments will be critical to assess the impact of different observing systems, including satellite altimetry and autonomous platforms, in hurricane intensity forecasts.

Corresponding author:
Gustavo Jorge Goni (**NOAA/AOML**, **United States**), Gustavo.Goni@noaa.gov

Value added Sentinel-3A sea level products by the Marine Altimetry L2P-L3 Service operational since end of June 2017

Sabine Philipps (CLS, France); Emilie Bronner (CNES, France); Marie-Isabelle Pujol (CLS, France); Michael Ablain (CLS, France); Marine Lievin (CLS, France); Isabelino Denis (CNES, France); Carolina Nogueira Loddo (EUMETSAT, Germany)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_002

Abstract:
The Sentinel-3A satellite, which carries among other instruments a dual-frequency SAR altimeter (SRAL) was successfully launched on 2016, February 16th. The Marine Payload Data Ground Segment (PDGS) in EUMETSAT provides Marine Level 2 SRAL products (along-track mono-mission product containing sea surface height anomaly as well as its components (orbit, altimeter range, geophysical corrections and models, etc.)).

In the frame of the Copernicus Programme funded by the European Union, under an EUMETSAT Contract, CNES with its subcontractor CLS has developed and is operating the Sentinel-3 Marine Altimetry L2P-L3 Service. The value added sea level anomaly L2P products are along-track mono-mission products, providing as much as possible the same updated corrections and models for several altimeter missions, in order to facilitate inter-mission comparisons. The sea level anomaly is provided with a validity flag, enabling users to discard data with spurious measurements. The L3 products contain the valid and low-pass filtered sea level anomaly and absolute dynamic topography after inter-calibration with a reference mission. This is a major contribution to the Copernicus Marine Environment and Monitoring Service which distributes the data from all the altimetry satellites.

The Service was pre-operational since mid December 2016 and is fully operational since the 27th of June 2017. The following Sentinel-3A value added products are distributed to the users:
- Marine L2P products in near-real-time (NRT), short-time-critical (STC) and non-time-critical (NTC) timelinesses on AVISO+ ftp; NRT and STC products are also distributed via EUMETCast, EUMETSAT'S multi-service dissemination system.
- Global L3 products in near-real-time (NRT, based on short-time-critical L2P data completed with near-real-time L2P data) and delayed time (DT) timeliness via CMEMS

This new L2P-L3 Service for Sentinel-3 is based on the existing operational system in place for Jason-2, CryoSat-2, SARAL, etc. It takes benefits of the well-proven organization and experience on past and existing activities. This service and its products will be presented in detail. This service will also be provided for Sentinel-3B (the launch of Sentinel-3B is foreseen in early 2018).

Corresponding author:
Sabine Philipps (**CLS**, **France**), sphilipps@cls.fr

Impacts of oil spill on satellite altimetry measurements

Cheng Yongcun (Center for Coastal Physical Oceanography, Old Dominion University, United States); Jean Tournadre (Laboratoire d'Océanographie Physique et Spatiale, IFREMER, CNRS, Université de Bretagne Occidentale, Plouzané, France, France); Xiaofeng Li (GST, NOAA/NESDIS/STAR, College Park, Maryland, USA, United States); Qing Xu (College of Oceanography, Hohai University, Nanjing, China, China); Bertrand Chapron (Laboratoire d'Océanographie Physique et Spatiale, IFREMER, CNRS, Université de Bretagne Occidentale, Plouzané, France, France)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_003

Abstract:
An altimeter is a nadir-looking radar that emits short electromagnetic pulses. It measures the backscattered power by the sea surface as a function of time to construct the echo waveform from which the geophysical parameters are estimated. Ocean surface films can damp short capillary-gravity waves, reduce the surface mean square slope, and induce ''sigma0 blooms'' in satellite altimeter data. No study has ascertained the effect of such film on altimeter measurements due to lack of film data.

The Deepwater Horizon (DWH) oil spill event occurred on 20 April 2010. It was the largest accidental marine oil spill in the U.S. petroleum industry history. The leak was finally stopped on 15 July 2010. An extensive set of in-situ and satellite (Synthetic Aperture Radar (SAR) and radiometers) data have been collected, archived, and distributed.

The availability of Environmental Response Management Application (ERMA) oil cover, daily oil spill extent, and thickness data acquired during the DWH oil spill accident provides a unique opportunity to evaluate the impact of surface film on altimeter data. In this study, the Jason-1/2 passes nearest to the DWH platform are analyzed to understand the waveform distortion caused by the spill as well as the variation of σ0 as a function of oil thickness, wind speed, and radar band. Jason-1/2 Ku-band σ0 increased by 10 dB at low wind speed (<3m/s) in the oil-covered area. The mean σ0 in Ku and C bands increased by 1.0-3.5 dB for thick oil and 0.9-2.9 dB for thin oil while the waveforms are strongly distorted. As the wind increases up to 6 m/s, the mean σ0 bloom and waveform distortion in both Ku and C bands weakened for both thick and thin oil. When the wind exceeds 6 m/s, only does the σ0 in Ku band slightly increase by 0.2-0.5 dB for thick oil.

The study shows that high-resolution altimeter data can certainly help better evaluate the thickness of oil spill, particularly at low wind speeds.

Corresponding author:
Cheng Yongcun (**Center for Coastal Physical Oceanography, Old Dominion University**, **United States**), yccheng.en@gmail.com

G-REALM: Investigating the Sentinel-3A data set for the next phase of Operational Lake and Wetland monitoring.

Charon Birkett (University of Maryland, United States); Martina Ricko (SGT, USA); Xu Yang (SGT, USA); Brian Beckley (SGT, USA)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_004

Abstract:
G-REALM is a NASA/USDA funded operational program offering water-level products for lakes and reservoirs that are currently derived from the NASA/CNES Topex/Jason series of radar altimeters. The main stakeholder is the USDA/Foreign Agricultural Service though many other end-users utilize the products for a variety of interdisciplinary science and operational programs. There is increasing demand for a more global monitoring service that in particular, captures the variations in the smallest (1 to 100km2) reservoirs and water holdings in arid and semi-arid regions. Here, water resources are critical to both agriculture and regional security. There is also demand for surface water level products across wetland zones in respect of inland fisheries and assessments of catch potential. In the next phase of the G-REALM program, focus is on the creation of near real time Sentinel-3A water level products, which will ultimately be merged with those derived from SARAL and ENVISAT. Operational Sentinel-3A products will assist observation of short-term agricultural drought, while the archival SARAL/ENVISAT products will help assess the longer-term hydrological drought.
Corresponding author:
Charon Birkett (**University of Maryland**, **United States**), cmb@essic.umd.edu

NOAA’s Jason Products

David Donahue (NOAA/NESDIS/OSPO, United States); Donald Richardson (Columbus Technologies, Inc., United States); Alejandro Egido (NOAA/NESDIS/STAR, United States); Yongsheng Zhang (NOAA/NESDIS/NCEI, United States); Eric Leuliette (NOAA/NESDIS/STAR, United States)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_005

Abstract:
The interagency Jason-2 and Jason-3 missions measure sea surface height, wind speed, and significant wave height to help track global sea level rise, ocean currents, and upper ocean heat content. Four partner agencies share mission responsibilities: the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), the Centre National d’Etudes Spatiales (CNES), and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). NOAA’s roles include satellite command and control, operational data processing, operational data distribution, and archive of data and processing software. NOAA’s Environmental Satellite Processing Center (ESPC) generates Jason-2 and Jason-3 Operational Geophysical Data Record (OGDR) products. ESPC distributes OGDRs in near real time (within 3-5 hours of observation) in NetCDF format via their Data Distribution Server, and in BUFR format via the World Meteorological Organization (WMO) gateway. All Jason-2 and Jason-3 mission data are archived by NOAA’s National Centers for Environmental Information (NCEI, formerly known as National Oceanographic Data Center) and the Comprehensive Large Array-data Stewardship System (CLASS). The OGDRs, CNES-derived interim Geophysical Data Records (IGDRs), and the final science-quality Geophysical Data Records (GDRs), all in NetCDF, are made available by traditional FTP as well as through modern interoperable data services (see https://www.nodc.noaa.gov/SatelliteData/jason/ and https://www.class.ncdc.noaa.gov/saa/products/welcome for more information). Jason-2 and Jason-3 geophysical data record products are used for ocean nowcasting and forecasting, assimilation into global and region models, hazard monitoring, and hurricane intensification forecasts. Additional product details and data access information are available at http://www.ospo.noaa.gov/Products/ocean/ssheight.html.

Corresponding author:
David Donahue (**NOAA/NESDIS/OSPO**, **United States**), david.r.donahue@noaa.gov

The quasi-operational 4D-Var ocean data assimilation/prediction system for the western North Pacific at JMA

Toshiyuki Sakurai (Japan Meteorological Agency, Japan); Mikitoshi Hirabara (Japan Meteorological Agency, Japan); Masakazu Higaki (Japan Meteorological Agency, Japan); Hiromu Kobayashi (Japan Meteorological Agency, Japan); Norihisa Usui (Meteorological Research Institute, Japan); Yosuke Fujii (Meteorological Research Institute, Japan); Hiroyuki Tsujino (Meteorological Research Institute, Japan)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_006

Abstract:
Japan Meteorological Agency (JMA) has a plan to introduce a new coastal ocean assimilation/prediction system (MOVE/MRI.COM-JPN (referred here after as MOVE-JPN)) in 2020 after an update of super-computer systems of JMA. In MOVE-JPN, developed by Meteorological Research Institute (MRI/JMA), a high-resolution (2 km) prediction model covers whole Japan coast and a 4D-Var assimilation system (MOVE-4DVAR) covers the North Pacific with an eddy-resolving (10 km) model. As a prototype of MOVE-JPN, MRI/JMA also developed a coastal prediction system for a limited area (MOVE-Seto) to be able to calculate with fewer computer resources. It consists of a MOVE-4DVAR covering the western North Pacific and a 2 km model covering western part of Japan around the Seto Inland Sea. This system, MOVE-Seto, has been quasi-operational since June 2016 at JMA. Its output is used as reference for the development of the next operational system, MOVE-JPN.

Our presentation focuses on MOVE-4DVAR that consists in both MOVE-JPN and MOVE-Seto. Usui et al. (2017) has already detailed MOVE-4DVAR and Kuragano et al. (2016) presented the western North Pacific reanalysis for 30 years (FORA-WNP30), a dataset generated by MOVE-4DVAR, in OSTST 2016. We present some modifications made to suit operational requirements. In the quasi-operational mode, 10-days assimilation and subsequent 11-days prediction are executed in a daily basis. This leads to usage of the latest observation data in the analysis. The near-real time observational data such as satellite sea level anomalies (SLA), in-situ temperature and salinity profiles, and analyzed SST data (prompt analysis of MGDSST (Merged satellite and in situ Global Daily Sea Surface Temperature)) are assimilated. The satellite SLA observations are the along-track data of Jason-3, SARAL/AltiKa, Cryosat-2, which are produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS). In-situ observation of temperature and salinity are obtained via GTS, e-mail and facsimile. Another main difference is an external forcing. The quasi-operation system adopts the latest NWP model (GSM: 20km, 3 hourly data), otherwise reanalysis (FOR A-WNP30) adopts the Japanese 55-year Reanalysis (JRA-55: 55km, 6 hourly data).

The validation results against in-situ data show that Root Mean Square Error of 100m depth temperatures for MOVE-4DVAR is significantly reduced in the region with large temperature variability such as the Japan Sea, Oyashio, Kuroshio, and Kuroshio Extension region compared to MOVE-3DVAR (the current operational 3D-var ocean assimilation system). However, positive bias is generally seen in the both systems (MOVE-4DVAR and MOVE-3DVAR) and the bias of MOVE-4DVAR is somewhat larger south of 25°N.
We speculate that the positive biases of both systems are attributed to the method for SLA assimilation. The low frequency variations of observed SLA are mainly caused by 1) steric sea level change (caused by the temperature and salinity change of water column), 2) ocean water mass variation by net surface water flux and 3) ocean water mass variation by wind stress. The cost function includes a term of difference between steric height anomalies estimated from temperatures and salinity in the model and SLA observation, therefore 2) and 3) components of observed SLA possibly contribute to analysis errors or biases of subsurface temperatures and salinity. We will show a simple method for treating 2) and 3) components and preliminary result of the corrected assimilation.

Corresponding author:
Toshiyuki Sakurai (**Japan Meteorological Agency**, **Japan**), tsakurai@met.kishou.go.jp

Jason-2 and Jason-3 Near-Real Time Products Latency over the Past Year

Donald Richardson (Columbus Technologies and Services, United States); David Donahue (NOAA, United States of America)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_007

Abstract:
The latency of Jason-2 and Jason-3 near-real time Operational Geophysical Data Records (OGDR) over the past year is examined using timeliness statistics against the requirement that product distribution be less than 3 hours from data collection. Major gaps in the ODGR production will be addressed, as well as periods of large latencies.

Latency calculations have been automated using the ProPro-005 algorithm as outlined in “ALGORITHMS ABOUT JASON-3 TM DATA AVAILABILITY AND OGDR DATA LATENCY, TP4-J0- NT-86- CNES”, 30-Mar-2011 by C. Juan (CNES) and J. Lillibridge (NOAA).

Corresponding author:
Donald Richardson (**Columbus Technologies and Services**, **United States**), donald.richardson@noaa.gov

CMEMS SEA LEVEL THEMATIC ASSEMBLY CENTER, ACHIEVEMENTS AND PERSPECTIVES

Yannice Faugere (CLS Space Oceanography Division, France); Isabelle Pujol (CLS, France); Antoine Delepoulle (CLS, France); Guillaume Taburet (CLS, France); Maxime Ballarotta (CLS, France); Gerald Dibarboure (CLS, France); Ananda Pascual (IMEDEA, Spain); Florence Birol (Legos, France); Francesco D'Ovidio (CLS, France)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_008

Abstract:
The DUACS system produces high quality multimission altimetry Sea Level products for oceanographic applications, climate forecasting centers, geophysic and biology communities... These products consist in directly usable and easy to manipulate Level 3 (along-track cross-calibrated SLA) and Level 4 products (multiple sensors merged as maps or time series) and are available in global and regional version (Mediterranean Sea, Arctic, European Shelves …).

Since mid 2015, the operational production of the along track and Sea Level maps is now generated as part as the Copernicus Marine Environment and Monitoring Service (CMEMS). The system today merges data from 6 satellites (Jason-3, Sentinel-3, Jason-2, Altika, Cryosat-2 and HY2A). This paper presents the main achievements of the SLTAC during the 3 years of CMEMS, as well as the perspectives.

Corresponding author:
Yannice Faugere (**CLS Space Oceanography Division**, **France**), yfaugere@cls.fr

Reconstruction of the surface ocean topography and associated dynamics using image data assimilation in the prospect of the SWOT mission

Pierre Brasseur (CNRS/IGE, France)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_009

Abstract:
Reconstruction of ocean surface topography is a continuing challenge that requires enrichment of the methods according to the new capacities allowed by present (along-track) and future (wide-swath) altimetry missions, especially in the range of large wavenumber of the power spectrum. For a variety of applications, it is also key to reconstruct sub-surface information (i.e. vertical velocities) consistently with surface topography and horizontal currents, with quantified error estimates.
In the prospect of the SWOT mission, we present a new approach to reconstruct the dynamics of the upper ocean as accurately as possible, using image data assimilation to extract meso- and submesoscale information from the high-resolution scenes that will be captured by future altimetric constellations. It is based on a two-step analysis scheme that combines a reduced-order Gaussian observational update, and a non-Gaussian observational updates to adjust the fine-scale using Lyapunov exponents associated to the structure of the flow (Duran et al., 2016).
A probability distribution of the first guess is defined and updated at each step of the analysis: (i) the first step applies the analysis scheme of a SEEK-type filter to update the first guess probability distribution using SSH observation; (ii) the second step minimizes a cost function using observations of HR image structure and a new probability distribution is estimated. The analysis is extended to the vertical dimension using 3D multivariate empirical orthogonal functions (EOFs) and the probabilistic approach allows the update of the probability distribution through the two-step analysis.
Using simulated data from high-resolution (1/36°) simulations of the circulation in the Solomon Sea, the performance of the method is analysed comparing several observation scenarios that combine orbital characteristics of the Jason, Envisat, AltiKA and SWOT missions. Using the SWOT simulator to generate the noisy data sets to be tested, it is shown that specific algorithms (Ruggiero et al., 2016) are needed to take into account the correlated errors inherent to SWOT measurements.
Further applications explored in the frame of the MOMOMS OSTST proposal based on very-high resolution simulations (NATL60) of the circulation in the midlatitudes, will be illustrated and discussed.

Reference:
M.Duran-Moro, Brankart J.-M., Brasseur P. and Verron J., 2017: Exploring image data assimilation in the prospect of high-resolution satellite ocean observations, Ocean Dyn., 67(7), 875-895, 10.1007/s10236-017-1062-3.
Ruggiero, G. A., Cosme, E., Brankart, J. M., Le Sommer, J., & Ubelmann, C. (2016). An Efficient Way to Account for Observation Error Correlations in the Assimilation of Data from the Future SWOT High-Resolution Altimeter Mission. Journal Of Atmospheric And Oceanic Technology, 33(12), 2755–2768.

Corresponding author:
Pierre Brasseur (**CNRS/IGE**, **France**), Pierre.Brasseur@univ-grenoble-alpes.fr

Ocean Surface Altimetry with CyGNSS

Mashburn Jake (University of Colorado, United States); Penina Axelrad (University of Colorado Boulder, United States); Stephen Lowe (NASA Jet Propulsion Laboratory, United States); Cinzia Zuffada (NASA Jet Propulsion Laboratory, United States); Dallas Masters (University of Colorado Boulder, United States)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_010

Abstract:
CyGNSS is a constellation of 8 small satellites launched in December 2016 that carries the Surrey Satellite Technologies (SSTL) SGR-ReSI GNSS Reflections (GNSS-R) receiver. Developed as the primary science instrument for CyGNSS, the SGR-ReSI receiver performs real time onboard navigation and generates delay-Doppler correlation maps for Earth reflected GPS L1 C/A ranging signals. While these functions were designed primarily to facilitate the retrieval of ocean surface wind speeds, this research explores ocean surface altimetry retrievals using the CyGNSS data sets. The data sets analyzed here span March 18 – June 3, 2017 at +/- 38 deg latitude.

This early analysis includes consideration of the transmitter and receiver orbits, models for ionospheric and tropospheric delays, mean sea surface topography and ocean tides in the propagation model. A statistical analysis of the 1 second integrated surface height residuals is presented. We focus on comparing retrieved sea surface heights from high SNR measurements in the Indian Ocean to regional topographic models. The leading error residuals are estimated to determine the current level of performance of GNSS-R altimetry with the CyGNSS configuration.

Corresponding author:
Mashburn Jake (**University of Colorado**, **United States**), jake.mashburn@colorado.edu

On the improvement of high resolution AROME winds for operational wave forecast under cyclonic conditions : validation with altimeters wave data

Lotfi Aouf (Division Marine et Océanographie Météo-France, France); Alice Dalphinet (Meteo-France, France); Ghislain Faure (CNRM/GMAP/Meteo-France, France); Hervé Giordani (CNRM/GMGEC/Meteo-France, France)

Session: Application development for Operations
Presentation type: Poster
Poster number: APOP_011

Abstract:
Wind forcing at the ocean surface plays a key role for catching accurate initial conditions of wind waves and swell propagation in cyclonic conditions. It is clearly a challenge for weather prediction centres for improving the wind forcing to waves and storm surge operational models. To this end the high resolution atmospheric system AROME-OM of Meteo-France dedicated for regional domains (west-indies, La Reunion and French Polynesia) will be upgraded in September 2017. In this version the AROME-OM system is forced by 1-D ocean mixed layer with initial conditions of sea surface temperature (SST) provided by the Mercator operational ocean model. The goal of this study is to investigate the impact of two wind forcing provided by the upgraded AROME-OM atmospheric system on the wave forecast during cyclones and hurricane events. The first wind forcing is using only the sea surface temperature from operational Mercator ocean system, while the second wind forcing is issued from AROME-OM model forced by 1-d ocean mixed layer with SST from mercator system as initial conditions.
Two events have been investigated for this study : cyclone Fantala in the indian ocean (March 2016) and hurricane Matthew (October 2016) in the Carribean sea. Regional wave models MFWAM with 10 km of resolution are forced by AROME-OM hourly winds and runs have been performed for analysis and forecast periods. A base line run of the wave model MFWAM with wind field from old version of AROME-OM system is also performed for these two events.
The validation with altimeters wave heights shows a significant improvement in the first 0-5 hours of analysis from the run using upgraded winds from AROME-OM with SST of Mercator ocean system. The scatter index of significant wave height is well reduced by 17 % for the cyclone Fantala. The use of 1-D ocean mixed layer improves the significant wave heights during the forecast period. altimeters tracks passing over the domain of cyclone Fantala indicates a good correction of the peak position of significant wave height when using the upgraded AROME-OM winds. Further results will be discussed and commented for hurricane Matthew hurricane.

Corresponding author:
Lotfi Aouf (**Division Marine et Océanographie Météo-France**, **France**), lotfi.aouf@meteo.fr

Fiducial Reference Measurements for Satellite Altimetry Calibration

Stelios Mertikas (Technical University of Crete, Greece); Craig Donlon (ESTEC/European Space Agency, The Netherlands); Constantine Mavrocordatos (ESTEC/European Space Agency, The Netherlands); Demitris Galanakis (Space Geomatica P.C., Greece); Pierre Féménias (ESRIN/European Space Agency, Italy); Achilles Tripolitsiotis (Space Geomatica P.C., Greece); Xenofon Fratzis (Technical University of Crete, Greece)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_001

Abstract:
The concept of Fiducial Reference Measurements for Altimetry has been recommended and defined by the European Space Agency as: "The suite of independent ground measurements that provide the maximum Return-On-Investment for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission."
This work presents a set of recommendations that an entity interested in establishing a satellite altimetry Cal/Val site shall follow (1) To critically review the current methodology applied for calibration and validation using ground-based measurements; (2) To define requirements and establish standards and provide recommendations and best practices for altimerty calibration such that all measurements and results made are well-characterized and linked to other areas of science and technology through a world's measurement system established and maintained under the International System of Units and Metrology Standards; (3) To document procedures so that results are reliable in the long term, comparable world-wide to support an objective and unquestionable monitoring of the Sea Level and Climate Change; and (4) to establish procedures and protocols for characterizing the uncertainty budget of all FRM instruments and derived results over the entire duration of a satellite mission. The criteria to be used for the evaluation of candidate Cal/Val sites are presented.
Working examples from the Permanent Facility for Altimeter Calibration in west Crete, Greece are also given for absolute bias determination of satellite altimeters.

Corresponding author:
Stelios Mertikas (**Technical University of Crete**, **Greece**), mertikas@mred.tuc.gr

Multi-mission Calibrations results at the Permanent Facility for Altimetry Calibration in west Crete, Greece attaining Fiducial Reference Measurement Standards

Stelios Mertikas (Technical University of Crete, Greece); Craig Donlon (ESTEC/European Space Agency, The Netherlands); Constantine Mavrocordatos (ESTEC/European Space Agency, The Netherlands); Pierre Féménias (ESRIN/European Space Agency, Italy); Demitris Galanakis (Space Geomatica P.C., Greece); Ilias Tziavos (Aristotle University of Thessaloniki, Greece); Francois Boy (Centre National d'études Spatiales (CNES), France); George Vergos (Aristotle University of Thessaloniki, Greece); Ole Andersen (Danish Space Center, Denmark); Xenofon Frantzis (Tecnical University of Crete, Greece); Mingsen Lin (National Satellite Ocean Application Service, China); Achilles Tripolitsiotis (Space Geomatica P.C., Greece)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_002

Abstract:
This work presents the updated results for the calibration & validation of several altimeter satellites (Jason-2, Jason-3, Sentinel-3, CryoSat-2, HY-2, SARAL/AltiKa) determined at the permanent facility for altimetry calibration, west Crete, Greece. These absolute Cal/Val results are obtained using sea-surface and transponder techniques followed by uncertainty budgets at metrology standards. This new concept of Fiducial Reference Measurement (FRM) for Altimetry is recommended by ESA to start producing Earth observation results for the future in terms of well-characterized SI units, so they are reliable, comparable world-wide and also linked to other areas of science and technology.
The latest Cal/Val absolute bias results are given at first for the Jason-2 & Jason-3 based upon the descending Pass No.18 but also on the ascending No.109, with GDR-D data at sea and on land with the transponder at the CDN1 Cal/Val site. Biases are also provided for the Sentinel-3A (baseline-2) with the ascending orbit No.14 setting out with the transponder in the mountains of Crete and continuing on the same orbit with the sea-surface infrastructure in the south of Gavdos island. Altimeter results are also produced for Sentinel-3A based on descending pass No. 335 passing over Gavdos. Using the CRS1 Cal/Val site in west Crete, results for the bias of the Chinese HY-2 satellite altimeter bias is also presented using S-GDR data (T) for its descending Pass No.280 (Cycles 1-101). Relative biases are also presented at crossover locations for several altimeters in the vicinity of the permanent facility for altimeter calibration. Future plans for the upscaling of this infrastructure and for improving the derived results will also be presented.

Corresponding author:
Stelios Mertikas (**Technical University of Crete**, **Greece**), mertikas@mred.tuc.gr

Sentinel-3 Transponder Calibration Results

Albert Garcia-Mondejar (isardSAT, Spain); Stelios Mertikas (Space Geomatica PC , Greece); Demitris Galanakis (Space Geomatica PC, Greece); Sylvie Labroue (CLS, France); Jerome Bruniquel (ACRI-ST, France); Graham Quartly (Plymouth Marine Laboratory, United Kingdom); Pierre Féménias (ESRIN/ESA, Italy); Constantin Mavrocordatos (ESTEC/ESA, The Netherlands); Pablo Garcia (isardSAT, Spain); Mònica Roca (isardSAT, Spain)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_003

Abstract:
Sentinel-3 is the Earth observation satellite mission designed to ensure the long-term collection and operational delivery of high-quality measurements of, among others, the sea surface topography. Post-launch calibration and validation of the satellite measurements is a prerequisite to achieve the desired level of accuracy and ensure the return of the investment. These Calibration/Validation (Cal/Val) services are provided by independent, external Cal/Val facilities that determine the error in satellite measurements, using known and controlled signal inputs on the ground. Sentinel-3 altimeter calibration site was established in West Crete, Greece. This site has been named CDN1 Cal/Val site and is located at an elevation of 1050m on the western mountains of Crete.

Transponders are commonly used to calibrate absolute range from conventional altimeter waveforms because of their characteristic point target radar reflection (not in the case of regenerative transponders). The waveforms corresponding to the transponder distinguish themselves from the other waveforms resulting from natural targets, in power and shape.

The transponder is used to calibrate SRAL's range and datation to meet the mission requirements. For this calibration, the S3 L1A data is processed with a specialised transponder processor. Atmospheric delays are acquired directly from the calibration site providing better accuracy to the final range measurement. Ideally, the comparison between the theoretical values provided by the well-known target, and the measurement by the instrument to be calibrated provides us with the error that the instrument is introducing when performing its measurement. When this error can be assumed to be constant regardless the conditions, it will provide the bias of the instrument. If the measurements can be repeated after a certain period of time, it can also provide an indication of the instrument drift.

This poster presents the range and datation results using the Crete transponder for the first 22 cycles. This work is been carried out within the Sentinel-3 Mission Performance Center activity S3MPC.
Corresponding author:
Albert Garcia-Mondejar (**isardSAT**, **Spain**), albert.garcia@isardsat.cat

The Sentinel-3A SRAL Instrument Calibration Monitoring

Pablo Garcia (isardSAT, Spain); Mònica Roca (isardSAT, Spain); Graham Quartly (Plymouth Marine Laboratory, United Kingdom)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_004

Abstract:
The Sentinel-3A is the most recent altimetric mission of a long historical series, and the first altimeter of the Copernicus constellation.

It is well known the crucial importance of the instrumental calibration when processing the altimeter data, in order to produce reliable and accurate L2 geophysical retrievals, such as sea surface height, significant wave height, or wind speed over the oceans.

isardSAT, as ESA Expert Support Laboratory within the Sentinel-3A Mission Performance Centre team, is responsible of monitoring the calibration parameters during the Sentinel-3A SRAL mission. This poster presents the monitoring results of up to date SRAL calibration data, acquired during the Commissioning and Routine Phases of the Sentinel-3A altimeter mission.

The SRAL altimeter permits to operate in two modes, LRM (low resolution) and SAR (high resolution) in two frequency bands, Ku and C. For the 4 combinations, CAL-1, CAL-2 and Autocal calibration modes are monitored and analysed from L1b data. Also the on-board thermal variations are monitored from L0 data. The on-board tracker performance is studied from L2 data.
Corresponding author:
Pablo Garcia (**isardSAT**, **Spain**), pablo.garcia@isardsat.cat

Sentinel-3 calibration and validation in Bass Strait as an extension of the Jason site.

Benoit LEGRESY (CSIRO Oceans and Atmosphere, Climate Science Centre, Australia); Christopher WATSON (University of Tasmania, Australia); Madeleine CAHILL (CSIRO Oceans and Atmosphere, Climate Science Centre, Australia); John ANDREWARTHA (CSIRO Oceans and Atmosphere, Australia)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_005

Abstract:
The Bass Strait satellite altimetry calibration site has provided a valuable and sustained contribution to absolute bias determination since TOPEX/Poseidon was launched. Sentinel-3A happens to have a cross-over point just 8km off the historical Jason mooring calibration site. We have therefore extended our calibration facility to Sentinel-3A. We have also instrumented a third site in preparation for Sentinel-3B. Here, we show the strategy we adopted to develop this facility extension to the Copernicus missions. We present the calibration results of the first year in operation. Using an operational regional ocean model (SHOC) we qualified the expectable differences in SSH measured at the 2 sites. We then install a simple bottom pressure mooring at the Sentinel-3A cross-over site.
Here we show the comparison between moorings and model and the absolute calibration over the first year of satellite operations for the available geophysical products. We also show the validation and analysis of the Jason-3 and Sentinel-3A in the Bass Strait area with altimetry/model comparisons.
The Mooring data are recovered in September which will allow us to present the Jason-3 and Sentinel-3 biases statistics computed over 1+ year of data at the OSTST 2017.

Corresponding author:
Benoit LEGRESY (**CSIRO Oceans and Atmosphere, Climate Science Centre**, **Australia**), benoit.legresy@csiro.au

Mapping the sealevel for altimetry calibration purpose using the future PAMELI marine ASV around the Aix Island sea-level observatory

Valérie Ballu (LIENSs/Université de La Rochelle, France); Laurent Testut (LEGOS, France); Etienne Poirier (LIENSs/Université de La Rochelle, France); Antoine Guillot (DT INSU, Brest, France); Michel Calzas (DT INSU, Brest, France); Christine Drezen (DT INSU, Brest, France); Lionel Fichen (DT INSU, Brest, France); Thibault Coulombier (LIENSs/Université de La Rochelle, France); Philippe Pineau (LIENSs/Université de La Rochelle, France); Nicolas Lachaussée (LIENSs/Université de La Rochelle, France); Christine Plumejeaud (LIENSs/Université de La Rochelle, France); Pascal Bonnefond (Observatoire de Paris, France); Xavier Bertin (LIENSs/Université de La Rochelle, France); Guy Wöppelmann (LIENSs/Université de La Rochelle, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_006

Abstract:
Nadir altimetry in the open ocean has become key in modern oceanography and is commonly used for research and operational purposes. Current and future challenges of altimetry are, among others, to provide data in the coastal zones where are located numerous society assets and scientific questions and to densify the measurements coverage, which will be done in the future thanks to the emergence of a new generation of satellites such as Sentinel3 or SWOT.
New in-situ observing systems are then needed to conduct local CALVAL studies and help quantify errors induced for instance by site-specific land contamination.
In our contribution, we will present our current developments around the PAMELI marine ASV (Autonomous Surface Vehicule) which will be equipped to map the sealevel height in the Pertuis area, in the vicinity of the Aix Island observatory.
Aix Island observatory (close to La Rochelle, France) is located close to several past, current and future radar altimetry ground-tracks and it already benefits from existing in-situ instrumentation (tide gauges, GNSS, meteo station, etc…) and a high-resolution hydro-dynamical model, which makes this area a suitable zone for coastal altimetry calval experiments.

Corresponding author:
Valérie Ballu (**LIENSs/Université de La Rochelle**, **France**), valerie.ballu@univ-lr.fr

Regional in situ CalVal of satellite altimeter range at non-dedicated sites

Mathilde Cancet (NOVELTIS, France); Pascal Bonnefond (OBSPM, France); Bruce Haines (JPL/NASA, USA); Christopher Watson (University of Tasmania, Australia); Florent Lyard (LEGOS/CNRS, France); Olivier Laurain (OCA, France); Pierre Féménias (ESA/ESRIN, Italy)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_007

Abstract:
In situ calibration ensures regular and long-term control of the altimeter sea surface height (SSH) time series through comparisons with independent records. Usually, in situ calibration of altimeter SSH is undertaken at specific CalVal sites through the direct comparison of the altimeter data with in situ data.

However, Noveltis has developed a regional CalVal technique, which aims at increasing the number and the repeatability of the altimeter bias assessments by determining the altimeter bias both on overflying passes and on satellite passes located far away from the calibration site. In principle this extends the single site approach to a wider regional scale, thus reinforcing the link between the local and the global CalVal analyses. It also provides a means to maintain a calibration time series through periods of data-outage at a specific dedicated calibration site.

The regional method was initially developed at the Corsican calibration sites of Senetosa and Ajaccio. It was then successfully implemented at the Californian site of Harvest and at the Australian site of Bass Strait, in close collaboration with JPL and the University of Tasmania, respectively. The method was used to compute the altimeter biases of Jason-1, Jason-2, Envisat and SARAL/AltiKa at all these sites.

These studies gave the first Envisat and SARAL/AltiKa absolute bias estimates at non-dedicated sites using the same method, and showed high consistency with the analyses of the global CalVal teams and the work of the in situ CalVal teams. The method is now used to monitor the CryoSat-2 and Sentinel-3 missions.
Corresponding author:
Mathilde Cancet (**NOVELTIS**, **France**), mathilde.cancet@noveltis.fr

Analysis of Measurements from a Lidar Instrument for Sea Level and Sea State Studies

Dallas Masters (University of Colorado, United States); Adam Dodge (University of Colorado, United States); Bruce Haines (NASA/JPL, United States); Robert Leben (University of Colorado, United States); R. Steven Nerem (University of Colorado, United States)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_008

Abstract:
Since the TOPEX-Poseidon mission, the University of Colorado and JPL have operated a lidar laser ranging instrument on the Harvest Platform in support of altimeter calibration and validation. The instrument is a small, COTS device that continuously estimates the vertical range to the sea surface from a lower deck of the oil platform. The lidar collects measurements coincident with the reference altimeter and in concert with a suite of other tide gauge instruments mounted on the Harvest Platform: two nitrogen bubblers and two radar ranging units operated by NOAA. Although the nitrogen bubbler systems are used as the main reference for altimetry cal/val studies at the Harvest Platform [Haines et al, 2016], the lidar has provided redundancy and insight into effects of sea state on the in situ sea level measurements [Washburn et al., 2011]. Past work has shown that the in situ measurements are sensitive to the sea state conditions and experience effects similar to the satellite radar altimeter sea state bias (SSB) correction. Therefore, the lidar measurements or other future measurements of sea state at Harvest Platform may yield insight into improving the SSB correction. Here we report on recent lidar data collected at the Harvest Platform and an analysis of these data for sea level estimates and their sensitivity to sea state conditions. We also report on a new deployment of the lidar instrument at the USC Wrigley Marine Science Center near Two Harbors, CA on the island of Catalina. This new lidar deployment at Two Harbors is on a Jason-3 ascending track and is an experiment to determine the feasibility of future altimeter cal/val studies in the San Pedro Channel between Catalina and Los Angeles, CA.

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Corresponding author:
Dallas Masters (**University of Colorado**, **United States**), dallas.masters@colorado.edu

CONTRIBUTION OF IBIZA, ESTARTIT AND BARCELONA HARBOURS SITES FOR ALTIMETER CALIBRATIONS

Juan Jose Martinez-Benjamin (Technical University of Catalonia, Spain); Assumpcio Termens (Geoinquiets, Spain); Rogelio Lopez (Technical University of Catalonia, Spain); Ana Tapia (Technical University of Catalonia, Spain)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_009

Abstract:
An overview of the operational infrastructure and instrumentation at Ibiza (one radar TG of Puertos del Estado, PE), Estartit (one float TG) and Barcelona (one radar TG PE, and two of APB Autoridad Portuaria Barcelona) harbours ant their application to altimeter calibration is discussed.
The first campaign was dedicated to the Alt-B TOPEX altimeter bias determination in March 1999 at Cape of Begur, NW Mediterranean. A Baleares in situ bias estimation calibration campaign with Spanish-French cooperation was made on September 2013 for the altimeters of Jason-2 and Saral/AltiKa in the Ibiza island area. A similar Spanish/French experience with Jason-1 was made in June 2003 in this geographical area under IBIZA 2003 campaign.
It is presented Sonmicat, the integrated sea level system aims at providing continuous high-quality continuous measurementof sea (and land) levels at the coast from tide gauges and modern geodetic techniques for geodetic techniques for studies on long-term sea level trends and calibration of radar altimeters.
Finally, an airborne Lidar campaign was carried out in July 2014, with two strips along two laser ICESat target tracks, one along Barcelona harbour. A direct comparison between ICESat and LIDAR DTM results is outlined.
The main objective is the integrationof spaceborne, airborne and in-situ data for the establishement of calibration of radar and laser space missions in this local area of the western Mediterranean in the framework of Global Change.

Corresponding author:
Juan Jose Martinez-Benjamin (**Technical University of Catalonia**, **Spain**), jj.benjamin@upc.edu

Calibration and Validation of altimeter observations and models by means of global multi-mission crossover analysis

Denise Dettmering (Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), Germany); Christian Schwatke (DGFI-TUM, Germany)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_010

Abstract:
The satellite altimeter scenario of the past two decades provides continuous and precise monitoring of the ocean surface with a beneficial spatio-temporal sampling. Since 1992 two or more contemporaneous missions are continuously available. For climate studies a consistent long-term data record is a fundamental requirement. However, combining missions with different sampling capabilities requires a careful pre-processing and calibration of all altimeter systems. The latter can be done by a global cross-calibration of all missions. In addition, a cross-calibration is able to provide information on the quality of single missions and to reveal e.g. instrument drifts or differences in the center-of-origin realization of satellite's orbits.

DGFI-TUM uses an extended multi-mission crossover analysis approach in order to assess the performance of each mission. The cross-calibration is realized globally by adjusting an extremely large set of single- and dual-satellite sea surface height (SSH) crossover differences performed between all contemporaneous altimeter systems. The total set of crossover differences creates a highly redundant network and enables a robust estimate of radial errors with a dense and rather complete sampling for all altimeter systems analysed. Iterative variance component estimation is applied to obtain an objective relative weighting between altimeter systems with different performance. The analysis yields time series of radial errors of each mission and can be used to derive inter-mission biases, to identify potential altimeter drifts, as well as to extract information on the quality of precise orbit determination (POD) and geophysical corrections (e.g., wet tropospheric errors).

This contribution will focus on the missions that are currently active (mainly Jason-2, Jason-3, Sentinel-3). It will present most recent results for long-term drift behaviour and geographically correlated errors.
Corresponding author:
Denise Dettmering (**Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)**, **Germany**), denise.dettmering@tum.de

Results from Inter-Satellite and Independent Calibration and Validation for Jason-2 and Jason-3

Jean-Damien DESJONQUERES (NASA Jet Propulsion Laboratory, United States); Shailen Desai (NASA Jet Propulsion Laboratory, United States); Bruce Haines (NASA Jet Propulsion Laboratory, United States); Rashmi Shah (NASA Jet Propulsion Laboratory, United States); Matthieu Talpe (NASA Jet Propulsion Laboratory, United States)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_011

Abstract:
In this poster, we present calibration and validation results for the Jason-2 and Jason-3 measurement systems. Our results focus on the Jason-3 mission, with more than 1-year of data now available since launch, and the Jason-2 mission after its transition to the long-repeat orbit. Our results show that the transition of Jason-2 to its new orbit was seamless and that the products are consistent before and after the altitude was lowered by 27 km.

Because Jason-2 and Jason-3 are no longer in a tandem configuration and do not share the same ground tracks, cross calibration and validation can be performed using inter-mission differences at crossover locations, namely where their respective ground tracks cross. We use these inter-satellite crossover differences to compare the performance in terms of bias and noise for the typical altimetry measurements (e.g., sea surface height, significant wave height, backscatter, radiometer wet troposphere correction, etc). We also independently evaluate these measurements from each mission.

The validation results are based on the standard Geophysical Data Record products. We also consider alternative GPS-based orbit solutions from JPL. On one hand, this JPL orbit solution demonstrates the global quality of the Jason-2 and Jason-3 products in an independent manner. On the other hand, it reveals geographically-correlated orbit errors.

Corresponding author:
Jean-Damien DESJONQUERES (**NASA Jet Propulsion Laboratory**, **United States**), jean-damien.m.desjonqueres@jpl.nasa.gov

Global Jason-2 Data Quality Assessment on the new Long Repeat Orbit

Hélène Roinard (CLS, France); Michael Ablain (CLS, France); Nicolas Picot (CNES, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_012

Abstract:
After almost 9 years in orbit as a precise altimeter mission on two different repeat ground tracks, Jason-2 had early this year an interuption of its science mission from 17th May to early July 2017. In the following, it was moved to a long-repeat ground track. Though this orbit is less interesting for the tandem mission with Jason-3 to solve mesoscale oceanography, the mission can still provide valuable and usefull data for several applications.

Therefore, the objective of this study is to provide an overview of the global data quality of Jason-2 data on the new orbit. Firstly, the stability of the altimeter and radiometer parameters is carefully monitored and the system performances assessed. This consists in long-term monitoring of the parameters, as well as comparison to Jason-3 data, in order to assess the possible impact of the lower altitude (~-27km) on the altimeter data. Furthermore the impact of the new orbit on the sea-level perfomances is accurately analysed.

Corresponding author:
Hélène Roinard (**CLS**, **France**), hroinard@cls.fr

Global Ocean Data Quality Assessment of SARAL/AltiKa

Annabelle Ollivier (CLS, France); Vincent Debout (CLS, France); Pierre Prandi (CLS, France); Nicolas Picot (CNES, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_013

Abstract:
Since 2013, the SARAL is delivering high quality sea surface topography measurements including during its drifting phase, started in July 2016,.
We present the current Cal/Val status of the SARAL/AltiKa mission over ocean, mainly from GDR data using Patch 2 version, and IGDR data over the drifting phase. The main data quality metrics are presented (data availability, SSH differences at cross-overs) and demonstrate that the mission is still in excellent shape.
The results of efforts to improve SARAL/AltiKa data are also presented. We estimated a preview of SARAL's future Patch 3 performance. This Patch-3 like data will feed the next generation of multi-mission products (CMEMS/AVISO). Investigations were also performed on the Ka ability to map differently the oceanic content, notably influencing the relations between significant wave height and topography measurements.

Corresponding author:
Annabelle Ollivier (**CLS**, **France**), aollivier@cls.fr

Envisat ocean altimetry second reprocessing on going

Annabelle Ollivier (CLS, France); Ghita Jettou (CLS, France); Stephanie Urien (CLS, France); Françoise Bailly-Poirot (CNES, France); Pierre Féménias (ESA, Italy)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_014

Abstract:
In 2012, ENVISAT mission was interrupted, after 10 years of altimetric measurements over ocean.
Five years later, the mission's historical database is still maintained, studied and used as a reference. After a first reprocessing (V2.1 in 2012), data are reprocessed once more to remain in line with the current altimetric missions such as AltiKa, Jason-2 and 3 or Sentinel 3.
Improved at several levels, the new data set include a tenth of algorithm improvements: instrumental corrections, SWH look up tables, improved wet tropospheric correction, GDR-E orbits, new tide models…
Level 2 production started in July 2017 and the whole dataset will be delivered to users after complete validation, in early 2018. At almost mid way of the complete series validation, this poster gives an overview of the future dataset and anticipates the expected impacts on data for several scales : climate, mesoscales, coastal areas, high latitudes,...

Corresponding author:
Annabelle Ollivier (**CLS**, **France**), aollivier@cls.fr

Global Hy-2a Data Quality Assessment Over Ocean

Ghita Jettou (CLS, France); Matthias Raynal (CLS, FRANCE); Isabelino Denis (CNES, FRANCE); Nicolas Picot (CNES, FRANCE); Jean-Michel Lachiver (CNES, FRANCE)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_015

Abstract:
HY-2A is the first altimetry and radiometry satellite of the China National Space Administration (CNSA), successfully launched on 15th of August 2011. The National Satellite Ocean Application Service (NSOAS) is responsible for the ground segment processing system as well as distributing collected data and HY-2A Level 2 products. The French contribution performed by the Centre National d'Etudes Spatiales (CNES) on this project mainly consists in supplying the orbit, computed from DORIS, GPS and laser measurements.

Thanks to the development and the validation of the HY-2A Processing Prototype based on the S-IGDR waveforms analysis, the HY-2A data integration has been completed in the SSALTO/Duacs system in April 2014. Data quality monitoring is routinely performed at CLS, as part of the SALP (Système d'Altimétrie et Localisation Précise) project supported by CNES.

At the end of March 2016, HY-2A was moved towards a geodetic orbit (168 days repetitive). About 15 months of geodetic data have already been processed. The objective of this presentation is to give an overview of data quality before and after its orbital change and to explore the opportunities brought by the new HY-2A ground track.

Corresponding author:
Ghita Jettou (**CLS**, **France**), gjettou@cls.fr

Performances and assessment of Cryosat-2 and Sentinel-3A SARM over ocean inferred from existing ground processing chains.

Matthias Raynal (CLS, France); Sylvie Labroue (CLS, France); Stéphanie Urien (CLS, FRANCE); Laiba Amarouche (CLS, FRANCE); Thomas Moreau (CLS, FRANCE); François Boy (CNES, FRANCE); Pierre Féménias (ESA, ITALY); Jérôme Bouffard (ESA, ITALY)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_016

Abstract:
The ESA (European Space Agency) mission Cryosat-2, launched in 2010, differs from previous altimetry missions as it has been designed to monitor the fluctuations of the thickness of land and marine ice fields (Wingham et al., 2006). To enhance the measurement resolution and precision over these surfaces, the on board altimeter SIRAL is based on a different principle proposed by Raney (1998): the Synthetic Aperture Radar mode (SARM) also referred to as Delay Doppler Mode. Although Cryosat-2 mission is dedicated to the cryosphere observation and was initially designed for this purpose, the altimeter also provides measurements over ocean. The altimetry community exploited this opportunity to process and analyse these new measurements. SARM datasets analyses presented in 2012 and 2013 during the OSTST meetings, demonstrated the potential of this technique to retrieve finest ocean scale signals. These results turned out as a recommendation from the user community to have a full SARM coverage as baseline for Sentinel-3A altimeter.

Sentinel-3A mission was successfully launched in February 2016. It is a multi-instrument mission to measure surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The SRAL (Sentinel Radar Altimeter) altimeter on board Sentinel-3A and inherited from Cryosat-2 altimeter, operates in SARM full coverage since the 12th of April 2016.

Today with these two SARM altimeters flying, the years of experience acquired in SARM processing and the increasing number of SARM datasets derived from different processing, how confident the user community can be in the use of Delay Doppler altimetry products? Based on the assessment of several SARM datasets derived from different processing chains (ESA Cryosat-2 Ocean Baseline C and Sentinel-3a ground segment, CNES Cryosat-2 and Sentinel-3a processing prototypes) this paper aims at giving an overview of the similarities and the main discrepancies that remain between all these datasets. It will demonstrate that the SARM expected benefits are effectively observed through different SARM processing. It will describe how close the estimated geophysical parameters are even if derived from different processing on both missions.

Corresponding author:
Matthias Raynal (**CLS**, **France**), mraynal@cls.fr

CryoSat-2 Ocean Altimetry Assessment

Ernst Schrama (TU Delft, Netherlands); Marc Naeije (TU Delft, Netherlands); Jerome Bouffard (ESA, Italy); Pierre Femenias (ESA , Italy)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_017

Abstract:
CryoSat-2 was launched on the 8th of April 2010, the primary purpose of the mission is to measure sea ice thickness, however the mission is also able to monitor land ice volume variations and ocean height changes. The primary instrument is the Siral altimeter, it comes with an unprecedented accuracy and precision capable of measuring in a low resolution mode LRM, a synthetic aperture mode SAR and an interferometric SAR mode known as SARin. Over ocean areas there are SAR calibration zones, within these zones there is an algorithm to reduce the SAR data to pseudo-LRM data (RDSAR data). In this paper we validate CryoSat-2 LRM and RDSAR measurements and the new ESA ocean dataset developed for CryoSat-2, these are IOP and GOP ocean datasets made available by ESA. In addition we assess the IOP and GOP products with other altimeters; we focus on long term monitoring and cross-calibration with other ocean altimeter data in the Radar Altimeter Database System RADS. We also perform long term monitoring by comparing the CryoSat-2 ocean sea level data with a selected set of tide gauges. In this way we are able to evaluate the stability of the measurement system and the identification of possible biases and bias drifts.

Corresponding author:
Ernst Schrama (**TU Delft**, **Netherlands**), e.j.o.schrama@tudelft.nl

Assessment of TOPEX reprocessed data on the Mean Sea level using several independant approaches

Michael Ablain (CLS, France); Lionel Zawadzki (CLS, France); Hélène Roinard (CLS, France); Anny Cazenave (CLS, France); Nicolas Picot (CLS, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_018

Abstract:
The reference Mean Sea Level (MSL) record strongly relies on four missions: TOPEX/Poseidon and its successors Jason-1, Jason-2 and Jason-3 on the same historical orbit. The global trend uncertainty has been estimated close to 0.5 mm/yr (Ablain et al., 2017) over the whole altimetry period (1993-2015). However, this uncertainty rises (0.8 mm/yr) only considering the TOPEX period (1993-2002) (Ablain et al., 2013). Furthermore, considering only TOPEX-A period (Jan. 1993- Feb. 1999), a significant drift between 1.5 and 2 mm/yr has been highlighted comparing altimetry data with a global tide gauges network. (Watson, et al., 2015; Prandi et al., 2015). Furthermore, a recent MSL closure budget study (Dieng et al., 2017) has highlighted a strong discrepancy between the TOPEX-A global MSL and the steric+mass components. This strong drift might be explained by instrumental anomalies on TOPEX-A data as shown by (Beycley, et al, 2016) during the last OSTST in La Rochelle. It is also worth noting that the correction of this drift would allow to observe an acceleration of the global MSL over all the altimeter period for the first time (Nerem et al, 2016; Dieng et al., 2017).

In order to better understand TOPEX errors, JPL and CNES have been working together for several years in order to provide a reprocessed TOPEX altimeter dataset for users (update of level 2 M-GDR products). In 2017, a new version of this reprocessed dataset will be available with retracked TOPEX data (already provided by JPL in 2016) and including the best geophysical corrections available during this period (provided by CNES in 2017). In this study, supported by CNES, we propose to analyze the impact of this new TOPEX dataset on the global MSL thanks to different approaches which are all independent. After analyzing directly the impact on the global MSL, we will compare the TOPEX MSL time series: (1) with tide gauges with similar method developed by (Valladeau et al, 2012, Prandi et al., 2016); (2) with steric and mass components as in the recent study performed by (Dieng et al., 2017) ; (3) and by comparisons with Poseidon-1 data (Zawadzki et al., 2016). The main interests of all this independent approaches are on the one hand to cross-check the impact of reprocessed TOPEX data on the global MSL, and on the other hand to evaluate the uncertainties of such approaches to know the confidence in the results obtained.

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Corresponding author:
Michael Ablain (**CLS**, **France**), mablain@cls.fr

Assessment of Revised TOPEX/Jason Global and Regional Mean Sea Level Estimates Referenced to ITRF2014

Brian Beckley (SGT Inc./NASA GSFC, United States); Frank Lemoine (NASA/GSFC, USA); Nikita Zelensky (SGT Inc., USA); Bryant Loomis (NASA GSFC, USA); Richard Ray (NASA GSFS, USA); Gary Mitchum (University of South Florida, USA); Xu Yang (SGT Inc., USA)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_019

Abstract:
The terrestrial reference frame is the foundation for analysis and interpretation of Earth science observations, especially for data from ocean radar altimeter satellites. The accuracy of the coordinates as well as the consistency of the technique solutions within an ITRF affect the accuracy with which orbits are computed, and map into the accuracy of the altimeter derived estimates of global mean sea level (GMSL). The recent launch of Jason-3 offers the possibility of continuing GMSL monitoring well into the next decade. In an effort to provide a consistent TOPEX/Jason altimeter sea surface height (SSH) time series and seamless transition to Jason-3, we have generated orbits for the entire time span based on the revised ITRF2014 terrestrial reference frame. We report the efficacy of the revised terrestrial reference frame towards improving precise orbit determinations leading to the development of the NASA MEaSURE's V4.0 revised sea surface height Climate Data Record (http://podaac.jpl.nasa.gov/dataset/MERGED_TP_J1_OSTM_OST_ALL). We provide an assessment of recent improvements to the accuracy of the 25-year SSH time series via mass budget closure and tide gauge comparisons, describe continuing calibration/validation activities, and evaluate the subsequent impact on current global and regional mean sea level estimates.

Corresponding author:
Brian Beckley (**SGT Inc./NASA GSFC**, **United States**), brian.d.beckley@nasa.gov

Coastal Altimetry Using Ku/Ka-Bands Signals of Opportunity: Results From A Recent Experiment at Platform Harvest

Rashmi Shah (Jet Propulsion Laboratory, United States); Soon Chye Ho (Purdue University, USA); James Garrison (Purdue University, USA); Priscilla Mohammed (NASA Goddard Space Flight Center, USA); Jeffrey Piepmeier (NASA Goddard Space Flight Center, USA); Adam Schoenwald (NASA Goddard Space Flight Center, USA); Randeep Pannu (Morgan State University, USA); Bruce Haines (Jet Propulsion Laboratory, USA)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_001

Abstract:
Coastal altimetry can provide important measurements supporting storm surge prediction, development of realistic wave models, and improved forecasts of wave setup and overtopping processes. Current satellite altimeter data has limitations near the coasts, due to land contamination, rapid tidal variation and atmospheric effects.

Over the last two decades, ocean altimetry using signals of opportunity (SoOp) has been demonstrated using transmission from the Global Navigation Satellite System (GNSS). Recently, techniques first developed for GNSS have been expanded to digital communication signals with the promise that the wider bandwidth and higher power would enable sea surface height (SSH) retrievals at a scientifically useful precision.

A reflectometry experiment was conducted at Platform Harvest (Jason-2 calibration and validation site) in July, 2017. Direct broadcast satellite (DBS) transmissions in Ka- and Ku-bands, from a commercial geostationary satellite, were recorded from a height of about 27 meters above sea surface. Sea Surface Height (SSH) was determined from the differences in electromagnetic path delay between the reflected and direct signal, found by cross-correlating the two signals and computing the lag of the peak. These retrievals were compared with the mean sea level reported from a tide gauge located at Platform Harvest.

A preliminary analysis showed a SSH precision of 5.6 cm, when using 0.5 seconds of data with a 4 ms coherent integration. An error analysis, based on the integration time of the cross-correlation, signal-to-noise ratio of the received signal, and the signal bandwidth predicted a theoretical error of 6.1 cm, RMSE , very close to that observed in the data.
Findings from this experiment demonstrate the feasibility of processing the full broadcast spectrum, composed of multiple independent data channels, as a single wide-band (400 MHz) signal and validate an error model that could be used in satellite mission studies.

Corresponding author:
Rashmi Shah (**Jet Propulsion Laboratory**, **United States**), rashmi.shah@jpl.nasa.gov

Wet Tropospheric Correction dedicated to hydrological and coastal applications

Bruno Picard (CLS, France); Marie-Laure Frery (CLS, France); Mickaël Pardé (CLS, France)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_002

Abstract:
The Sentinel-3A Surface Topography Mission has been launched on February 2016 and is now in its second year of operation. Its objectives are to serve primarily the marine operational users but also allow the monitoring of sea ice and land ice, as well as inland water surfaces.
A two-channels microwave radiometer (23.8 and 36.5 GHz) similar to the Envisat and ERS MWR sensors is combined to the altimeter in order to correct the altimeter range for the excess path delay (WTC for wet tropospheric correction) resulting from the presence of water vapor in the troposphere.

Over ocean, the most up-to-date algorithm for WTC retrieval in the Sentinel-3A products is based on simulated parameters (brightness temperatures (TB) and altimeter backscattering coefficient) and neural networks.
For coastal areas, due to the land contamination on TB pixels, the wet tropospheric correction is impacted from 25 km up to the shoreline. A new empirical approach based on measurements instead of simulations and using additional information on land proportion in the Field Of View has been developed.

We will present here an assessment of the S3A MWR performances using this innovative technique over the Issy-Kul lake and over coastal areas.

Corresponding author:
Bruno Picard (**CLS**, **France**), bpicard@cls.fr

Independent assessment of Microwave Radiometer measurements in coastal zones using tropospheric delays from GNSS

Telmo Vieira (Universidade do Porto, Faculdade de Ciências; CIIMAR, Portugal); M. Joana Fernandes (Universidade do Porto, Faculdade de Ciências; CIIMAR, Portugal); Clara Lázaro (Universidade do Porto, Faculdade de Ciências; CIIMAR, Portugal)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_003

Abstract:
Precise water surface height measurements require accurate modelling of several effects, namely the wet tropospheric correction (WTC), which can be derived from Microwave Radiometer (MWR) measurements. Since any error or drift in the MWR observations will directly impact sea level estimations, the independent monitoring of the MWR measurements is especially important for retrieving accurate global sea level from several altimetry missions.
Zenith tropospheric delays (ZTD) from Global Navigation Satellite Systems (GNSS) stations are used in order to assess the MWR measurements in coastal zones, where some of these observations become invalid due to land contamination. This coastal assessment is performed for eight altimetry missions: the so-called reference missions (TOPEX/Poseidon, Jason-1 and Jason-2), the three ESA missions (ERS-1, ERS-2 and ENVISAT), Geosat Follow-On and SARAL/AltiKa.
Firstly, ZTD are computed for a set of 60 GNSS stations with a good spatial and temporal distribution (ZTD UPorto) using the GAMIT software and state-of-the-art methodologies. These ZTD are further converted into zenith wet delays (WTC equivalent) by subtracting the zenith hydrostatic delay estimated from sea level pressure from the ERA Interim model. ZTD provided by international networks, such as the International GNSS Service (IGS) and EUREF Permanent Network (EPN) are compared with ZTD UPorto, showing that ZTD can be determined with an accuracy of a few millimeters, at the station location. However, jumps are detected in ZTD from a few IGS stations. The influence of network geometry on tropospheric parameters estimation is demonstrated.
Secondly, the analysis of the root mean square of the differences between MWR measurements and ZWD UPorto, function of distance from coast, shows the effect of land contamination and the distance from coast where this contamination is minimum. This distance from coast is different for the several altimetric missions, due to their different footprint size and algorithms used to retrieve the WTC from MWR measurements.
The coastal assessment shows also the ability of the GNSS-derived Path Delay Plus (GPD+) algorithm from University of Porto to remove this contamination and to improve the WTC retrieval all over and in particular in the coastal zones.
Aiming at inspecting the stability of the MWR measurements, the time evolution of the same WTC differences is analyzed. In spite of the fact that GNSS-derived and MWR-derived WTC are not collocated measurements, these results show that the former are a useful independent source to inspect the land effects on MWR observations and to monitor the stability of these instruments, thus contributing to the retrieval of precise water surface heights from satellite altimetry.

Corresponding author:
Telmo Vieira (**Universidade do Porto, Faculdade de Ciências; CIIMAR**, **Portugal**), telmo.vieira@fc.up.pt

Coastal altimetry with SARAL/AltiKa: Emphasis to Indian mainland coastal region

Aditya Chaudhary (ISRO, India); Rashmi Sharma (ISRO, India); Neeraj Agarwal (ISRO, India); Raj Kumar (ISRO, India)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_004

Abstract:
SARAL, a joint ISRO-CNES satellite mission, was successfully launched in 2013. It carries a Ka band single frequency satellite altimeter (AltiKa). Satellite altimeters are primarily used to study sea level changes. In the open ocean, the altimetric echo follows a standard shape, with steeply rising leading edge followed by a trailing edge with gradually diminishing power. This standard shape is in agreement with the theoretical Brown model and hence can be easily modeled. However, in the coastal areas, due to the presence of land and other coastal features in the footprint of the altimeter, contamination occurs and the return is different from open ocean. Up to some extent these contaminations can be modeled. Footprint size of SARAL/AltiKa is small which is ideal for coastal studies. The available ocean retracker (MLE4) itself shows good performance near the coast. However, further improvements can be achieved by using algorithms which can simulate contaminations impact in the coastal areas. In this study we have used various models for the return waveforms at 40 Hz to extract maximum information from the altimeter. Our results show that algorithms which are useful in the coastal areas are BETA5, BETA9 and Brown with Asymmetric Gaussian Peak (BAGP). In this study we demonstrate the usefulness of this dataset in depicting seasonal variability of geostrophic currents along the east coast of India. The results are validated with the available HF radar observations at few locations. Details of the analysis will be presented in the meeting.

Corresponding author:
Aditya Chaudhary (**ISRO**, **India**), aditya.osd@sac.isro.gov.in

Sea Level anomalies and mesoscale activity using altimetry along the African coats in the eastern tropical Atlantic ocean (OSTST Alti-ETAO project)

Habib Boubacar Dieng (LEGOS, France); Isabelle Dadou (LEGOS, France); Fabien Léger (LEGOS, France); Florence Birol (LEGOS, France); Yves Morel (LEGOS, France); Alexis Chaigneau (LEGOS/IRHOB/CIPMA, Cotonou, Benin)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_005

Abstract:
The equatorial region, near the coast, represents a major contributor to the ocean/atmosphere/land heat and water fluxes, controlled by SST and the oceanic dynamics. The eastern tropical Atlantic ocean (ETAO, 35°S-20°N ; 25°W - African coast) region remains little studied. This region also encompasses a large-range of peculiar dynamics: large-scale zonal equatorial currents, strong coastal currents, equatorial and coastal trapped waves, the presence of both equatorial and near-coastal upwelling cells, gyre-like structures with the presence of the Guinea and Angola domes (Schott et al, 2004).
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 the 25th anniversary of the TOPEX/Poseidon launch, this year. While spatial altimetry has enabled us to highlight the regional variability of mesoscale dynamics, it still provides incomplete information in coastal areas in the first 10 km from the coasts, especially due to the perturbation of radar echoes by the continents (land, island, etc.). In the OSTST Alti-ETAO project, we studied the meso-scale dynamics using different altimetry sea level anomaly (SLA) products: AVISO gridded product (1/4°) and the coastal X-TRACK product from CTOH (LEGOS) based on Jason1-2 altimeters (Birol et al, 2016). We used also the tide gauge data available in the ETAO region for the validation of the altimetry SLA along the coast.
The comparison between the coastal altimetry along-track data (X-TRACK last reprocessing) and tide gauge data using different statistical criteria depends on the geographical position along the ETAO coasts. Near the coasts of Senegal and the Gulf of Guinea, we note a good agreement, in terms of correlation and quadratic errors (RMS), between the X-TRACK coastal altimetry data (closed to the tide gauge position and not in the first 10 km from the coast) and tide gauge data. On the other hand, near the Namibian and South African coasts, where tide gauge data appear to be better in terms of time cover, low correlations and more significant quadratic errors are found between the X-TRACK coastal data and tide gauge data. This weak agreement could be related to the higher oceanic and atmospheric variability in the Benguela upwelling system and the geographic location of the altimetry data relative to the tide gauges. Studies are also underway at LEGOS to estimate the influence of the tide correction in this region.

Corresponding author:
Habib Boubacar Dieng (**LEGOS**, **France**), habib.dieng@legos.obs-mip.fr

Coastal Sea Level along the North Eastern Atlantic Shelf from SAR altimetry

Luciana Fenoglio (University of Bonn, Germany); Christopher Buchhaupt (Technical University Darmstadt, Germany); Salvatore Dinardo (EUMETSAT, Germany); Bernd Uebbing (University of Bonn, Germany); Ole Andersen (DTU , Denmark); Mederic Gravelle (University of La Rochelle, France); Remko Scharroo (EUMETSAT, Germany); Jürgen Kusche (University of Bonn, Germany); Matthias Becker (Technical University Darmstadt, Germany); Jerome Benveniste (ESA/ESRIN, Italy); Michael Kern (ESA/ESTEC, Germany)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_006

Abstract:
As quality of Synthetic Aperture Radar (SAR) altimetry data is at least as good as conventional altimetry over open ocean and higher in coastal zone up to 2-4 km from coast, SAR data allow meaningful application to oceanography and sea level monitoring. This study investigates the impacts of CryoSat-2 and Sentinel-3 data processed in SAR mode in the 10 Kilometre stripe along the North-Eastern Atlantic shelf.

We use CryoSat-2 SAR altimeter products from the ESA G-POD processor and the in-house reduced SAR altimetry RDSAR/TALES and RDSAR/STAR products. All are derived by processing using coastal dedicated retracking. Additionally an enhanced methodology generates the SAR waveforms applying Hamming weighting window on burst data prior to the along-track FFT, zero-padding prior to the range FFT and doubling of the extension for the radar range swath. The Sentinel-3 SAR and RDSAR data used are the official products distributed by Copernicus. CryoSat-2 data cover the 6-year interval from January 2011 to December 2016 and Sentinel-3 data cover one year from June 2016 to Mai 2017. Conventional altimetry data are from the sea level CCI database.

First we analyse the impact of these SAR altimeter data on the estimation of sea level near coast and its rise. Data quality is analysed as function of distance to coast and orientation of the tracks. We consider various methodologies for building, selecting and absolute comparing CryoSat-2 time-series of ellipsoidal heights to tide gauge records at GPS stations. The methodology is replicated in the various coastal sub-regions. The VLM along the North-Eastern Atlantic shelf is small (+/- 2 cm/yr) compared to the North-Western Atlantic Coast VLM (+/- 6 mmm/yr), which makes the analysis more challenging. We find that VLM rates derived from the altimeter minus tide gauge differences slightly depend on the selection of the altimeter data and are in good agreement with the rates derived from Global Positional System (GPS) analysis. Rates are comparable to the VLM derived from the SLCCI datasets over the longer time span 1993-2015 using a similar methodology.

Second we investigate the impact of the new data in the estimation of an improved mean dynamic topography. A mean surface is derived from the SAR altimeter data and combined to state of the art global geoid EIGEN-6C4 and local geoids as the german local geoid CGC2016 to derive the mean dynamic topography. We compare the results to existing oceanographic and geodetic mean dynamic topography solutions, both on grid and pointwise at the tide gauge stations.

Finally, the SAR data are used for the analysis of extreme sea levels. Individual measurements collected into boxes along the coast are compared to the tide gauge extremes. We investigate the contribution of the present SAR missions to extreme sea level analysis, accounting that the registered extreme levels depend on the repeat period and therefore on the mission characteristics.

Corresponding author:
Luciana Fenoglio (**University of Bonn**, **Germany**), fenoglio@geod.uni-bonn.de

Linking Sea Surface Height Variations with Hydrographic Variability around the Greenland Ice Sheet to Improve Understanding of Sea Level Rise

Ian Fenty (JPL, United States); Stephen Nerem (University of Colorado at Boulder, USA); Dallas Masters (University of Colorado at Boulder, USA); Dimitris Menemenlis (NASA JPL, USA)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_007

Abstract:
Increased melting of the Greenland Ice Sheet has contributed to the recent acceleration of global mean sea level rise. Beginning in the late 1990s, a warming of the marginal seas and boundary currents circulating in the Northwest North Atlantic basins preceded a dynamic retreat, acceleration, and thinning of many of Greenland's marine-terminating glaciers. The simplest inference is that some ocean basin warming is communicated to the ice sheet via advection across the continental shelf and fjords, increasing submarine melt rates and initiating a dynamic ice-sheet response. Historically, very few in situ measurements of ocean temperature have been made on Greenland's continental shelf. Even today, monitoring ocean heat content variability in the region remains challenging and expensive. In this poster we introduce a new project to improve understanding of sea surface height and ocean heat variability on the Greenland shelf, its relationship to hydrographic and atmospheric variability, and the implications for past and future ocean-ice sheet interaction and sea level rise through the development of new techniques to analyze satellite ocean surface topography data. During this project we will investigate the past 25 years of sea surface height variability and ocean heat content on Greenland's shelf using remote sensing data including coastal altimetry, atmospheric reanalyses, in situ hydrographic data, and numerical modelling. By combining our ocean heat content reconstructions with existing and anticipated ice sheet measurements from NASA's Oceans Melting Greenland (OMG) and other missions, including ICESat-1, Operation Ice Bridge, and the forthcoming ICESat-2, we will link observed changes of Greenland's marine-terminating glaciers to ocean temperature changes on their neighboring shelves. It is hoped that this study will pave the way for future monitoring of ocean thermal forcing of the Greenland Ice Sheet using altimetric data from the upcoming SWOT, Sentinel-3, and Jason-CS missions.

Corresponding author:
Ian Fenty (**JPL**, **United States**), Ian.Fenty@jpl.nasa.gov

COSTA v.1.0: DGFI-TUM Along Track Sea Level Product for ERS-2 and Envisat (1996-2010) in the Mediterranean Sea and in the North Sea

Marcello Passaro (DGFI-TUM, Germany); Denise Dettmering (DGFI-TUM, Germany)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_008

Abstract:
The COastal Sea level Tailored ALES (COSTA) dataset contains dedicated coastal altimetry sea level measurements based on the Adaptive Leading Edge Subwaveform (ALES) reprocessing. In this version, the missions involved are ERS-2 (1996-2002) and Envisat (2002-2010), and the data are available in the Mediterranean Sea and in the North Sea.

The dataset is generated by the application of the ALES fitting algorithm to the radar signal provided by the official products of the missions. The ALES algorithm selects only a portion of the altimetric signal (waveform), in order to estimate the distance between the satellite and the sea surface (range) while avoiding the noise in the tail of the signal. The algorithm is based on the relation between estimated sea state, achievable precision and width of the subwaveform. The sea state bias correction, which accounts for the effects of waves and the tracking errors, is recomputed for the ALES output.

Following this pre-processing, the data are post-processed with updated geophysical corrections, tidal and mean sea surface models. Finally, the sea level measurements are averaged at 1 Hz (one measurement every ~7 km along each track) after removing the outliers. To facilitate the temporal analysis, the sea level anomalies for each track are stored in matrices in which each row corresponds to the time series at one latitude-longitude location.

The validation work, presented at the 10th Coastal Altimetry Workshop (2017-02-21 - 24, Florence, Italy), has shown a 15% decrease in the high-rate noise of the measurements if compared to the standard product, with larger improvements in the last 20 km from the coastline and a better precision also in the open ocean.

The COSTA dataset is made available to the scientific community in order to foster the application of coastal altimetry data by users, who are not necessarily trained in radar altimetry processing. Its objective is the provision of easy-to-use along-track sea level data that can be directly used for sea level and circulation studies not only in the open ocean, but also in the coastal regions.
Corresponding author:
Marcello Passaro (**DGFI-TUM**, **Germany**), marcello.passaro@tum.de

Monitoring sea level and topography of coastal lagoons using satellite radar altimetry: the example of the Arcachon's Bay in the Bay of Biscay

Edward Salameh (Laboratory for Studies in Geophysics and Spatial Oceanography - (LEGOS) , France); Frédéric Frappart (Laboratory for Studies in Geophysics and Spatial Oceanography - (LEGOS) , France); Vincent Marieu (Environnements et Paléoenvironnements Océaniques et Continentaux (EPOC), France); Alexandra Spodar (Laboratoire d'Océanologie et de Géosciences, France); Jean-Paul Parisot (Environnements et Paléoenvironnements Océaniques et Continentaux (EPOC), France); Benoit Laignel (Morphodynamique continentale et côtière (M2C), France); Imen Turki (Morphodynamique continentale et côtière (M2C), France)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_009

Abstract:
Satellite radar altimetry was developed to measure ocean surface topography along the nadir track of the satellite. Near the coasts, data acquisition and processing suffers from several flaws. Major efforts are currently undertaken to extend the capabilities of satellite altimetry as close as possible to the coast. We present an investigation on the potential of radar altimetry to monitor sea level and along-track topography (at low-tide) of coastal lagoons. The case study site is the Bay of Arcachon located on the southwest coast of France which was flown over by the RA-2 radar altimetry mission onboard ENVISAT over the 2003-2012 period, and has been under the Altika radar altimetry mission onboard SARAL track since February 2013. The results obtained using ENVISAT and SARAL are validated against ancillary data (i.e. tide gauges records, LIDAR Topography) to estimate the accuracy of the measurements and to show its evolution between the Ku (frequency of 13.5 GHz used by ENVISAT RA-2) and the Ka (frequency of 35.5 GHz used by SARAL Altika) bands. An evaluation was undertaken as well for observations made by the Ku-band satellite mission CryoSat-2 (launched in April 2010) dedicated mainly to polar observations.

Corresponding author:
Edward Salameh (**Laboratory for Studies in Geophysics and Spatial Oceanography - (LEGOS)** , **France**), edward.salameh@legos.obs-mip.fr

A study of the fine-scale dynamics in the North-Western Mediterranean Sea using altimetry, in-situ data and a high resolution regional model.

Alice Carret (LEGOS/OMP, France); Florence Birol (LEGOS/OMP, France); Claude Estournel (LA/OMP, France)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_010

Abstract:
One of the objectives of this study is to analyse the contribution of altimetry, in parallel with other ocean observing systems and high resolution numerical modelling, to observe and understand the ocean dynamics in the North-Western Mediterranean Sea (NWMed). This region offers a particularly interesting area in terms of coastal ocean dynamics (large range of small-scale processes) and available data (in-situ observations and numerical model outputs). It has become a pilot area for coastal altimetry studies.

In the NWMed the ocean dynamics is complex and associated with a large number of fine scale structures which are difficult to capture with altimetry. The new altimeter missions offer new perspectives for mesoscale and sub-mesoscale observation (1-100 km) but it is not always easy to separate the signal from the noise and to validate the data at short wavelength. Here, we use high-resolution numerical simulations from the Symphonie model and in-situ observations to analyse if the major regional ocean processes can or not be captured by altimetric SSH observations (because of their signature in sea level or their wavelength).

Intercomparisons between altimetry data and in situ observations and the model have first been made to study the ability of the model to reproduce the regional dynamics at different scales. In a first time we focused on the Northern Current which flows cyclonally along the Italian, French and Spanish coasts but also analysed the relative importance of the geostrophic and non geostrophic components in the surface circulation at regional scale.

The insitu data - model comparison shows a very good agreement in the variability of both the location and amplitude of the Northern Current, except in some particular cases. The comparison between insitu data, the model and Jason 2 observations shows larger differences which are still under analysis but are partly due to the resolution of altimetry data and to noise/errors in altimetry data. We have started to perform the same kind of analysis with the new generation of altimetry data (SARAL/AltiKa, Sentinel-3) in order to compare the relative performances of the different technologies. Note that this study also helps to identify altimetry errors due to uncorrect processing which might be corrected/reduced in the future.
Corresponding author:
Alice Carret (**LEGOS/OMP**, **France**), alice.carret@legos.obs-mip.fr

Multi-Scale Analysis of Coastal Altimetry Data, Multi-Sensor Observations and Numerical Modelling Over the North Western Mediterranean Sea

Marco Meloni (Serco spa, Italy); Jerome Bouffard (Rhea, Belgium c/o ESA/ESRIN, Italy); Andrea Doglioli (MIO (Mediterranean Institute of Oceanography), France); Anne Petrenko (MIO (Mediterranean Institute of Oceanography), France)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_011

Abstract:
The proposed paper addresses the issue of exploiting and cross-comparing coastal altimetry, in situ data and model-based approaches to monitor the positioning and intensity of the Mediterranean Northern Current (NC). The approach is based on the combination of several tracks from different altimetric missions (lasting more than 12 years), in order to reduce the residual noise and detect the NC position. To achieve this goal, several multi sensor platforms (MVP (Moving Vessel Profiler), ADCP (Acoustic Doppler Current Profiler) and CTD) from marine observatories and cruise campaign (OSCAHR: Observing Submesoscale Coupling At High Resolution) as well as a numerical simulation (SYMPHONIE model), have been conjointly used in order to validate and optimize the altimetry processing methods . Across-track geostrophic currents derived from several altimetric datasets (PEACHI (Experimental Products), X-Track, AVISO) have been cross-compared to the SYMPHONIE model in order to statistically characterize the NC position and intensity over the Ligurian Sea and the Gulf of Lion. MVP , CTD and ADCP measurements from the OSCAHR cruise campaign as well as the JULIO (Judicious Location for Intrusion Observation) current meter have also been processed and compared with geo-located altimetric tracks. The obtained results show a good agreement and pave the way for the definition of new science oriented diagnostics particularly relevant for next altimetric satellite missions (Sentinel-3, Sentinel-6).
Corresponding author:
Marco Meloni (**Serco spa**, **Italy**), marco.meloni@serco.com

Evaluation and application of operational altimeter-derived ocean surface current datasets on the NW Atlantic shelf

Hui Feng (University of New Hampshire, United States); Doug Vandemark (University of New Hampshire, United States); Julia Levin (Rutgers University, United States); John Wilkin (Rutgers University, United States)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_012

Abstract:
The study investigates the accuracy of gridded altimeter-derived upper ocean current datasets along the NW Atlantic shelf oceans using long-term in situ surface and near-surface current measurements. The assessment focuses upon two operational multi-mission altimeter-based ocean surface current products, GlobCurrent and OSCAR. A central focus is on the applicability of such open ocean products for some aspects of regional coastal process studies. The in situ data utilized come from platforms within the US Integrated Ocean Observing System (US-IOOS), including the Gulf of Maine (GoM) moored network of buoy ADCP upper ocean current time series as well as HF radar data from Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS) and a Mid-Atlantic Bight (MAB) HF Radar (CODAR) network from the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS). The latter provides daily spatial surface current coverage across the shelf from Cape Cod, MA to Cape Hatteras, NC. For the application aspects, several questions central to regional shelf dynamics at monthly to seasonal time scales are being assessed. These concern the relative rate of remote water mass inflows to the GoM and modulation of upstream shelf flows that appear to control seasonal and inter-annual hydrographic variability in the GoM and perhaps down to the Mid-Atlantic Bight. We intend to comprehensively document the quality of gridded altimeter-based ocean surface current products in comparison to ground truth and process study results obtained using coastally-processed along track altimeter data used in recent regional investigations.
Corresponding author:
Hui Feng (**University of New Hampshire**, **United States**), hui.feng@unh.edu

Satellite altimetry in the continental shelf of the Southwestern Atlantic, Argentina

Loreley Lago (INIDEP, Argentina); Martin Saraceno (Centro de Investigación del Mar y de la Atmósfera, Argentina); Patricia Martos (Universidad Nacional de Mar del Plata, Argentina); Raul Guerrero (INIDEP, Argentina); Guillermina Paniagua (Centro de Investigaciones del Mar y la Atmósfera, Argentina); Alberto Piola (Servicio de Hidrografía Naval Argentina, Argentina)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_013

Abstract:
The performance of gridded and along-track satellite altimetry data in the Argentinean continental shelf is evaluated with the help of year-long in situ time series of pressure, temperature and salinity data obtained at the sea bottom, and direction and speed of currents in the whole water column obtained in two different sites under Jason track #26.
In situ SLA is reconstructed from bottom pressure measurements. The largest correlation coefficient and lowest RMSD between in situ SLA and 1Hz along-track SLA (0.58, 95% confidence level and 8.6cm) are obtained when a 15-day low-pass filter is applied to in situ data. Similar results are obtained with gridded altimetry data.
When comparing currents, the highest correlation (0.5, 95% confidence level) and lowest RMSD (8cm) is obtained between 15-day low-pass filtered in situ data obtained at 8m depth and gridded altimetry data that included the Ekman component. The same results are obtained when considering the across-track velocities obtained from along-track data produced by CTOH that does not includes Ekman velocities.
To understand the relative poor performance of the satellite altimetry data in the region we analyzed the correlation with sea level pressure (SLP) as estimated from different sources. NCEP SLP variability showed high coherence with the in situ surface currents at all depths, suggesting that the dynamics of the region is dominated by atmospheric forcing. Results also show that currents are better represented by satellite data (that includes he Ekman component) when the wind speed is lower than 0.8m.s-1 (RMSD 10cm.s-1). These results suggest that ageostrophic components might play a significant role in the Patagonian continental shelf, and therefore should be considered to compare with geostrophic currents obtained by satellite altimetry data.

Corresponding author:
Loreley Lago (**INIDEP**, **Argentina**), lslago@inidep.edu.ar

Campeche Ocean Observing System

Jorge Alejandro Kurczyn Robledo (Catedras Conacyt-Instituto Epomex, Mexico); Heber Joctan Uc Gonzalez (Instituto Epomex, Mexico); Eder Andrei Hernandez Martinez (Instituto Epomex, Mexico); Gregorio Posada Vanegas (Instituto Epomex, Mexico)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_014

Abstract:
Since spring 2017, the coastal zone off Campeche coast has been equipped with different measuring technologies aiming to study a coastal ocean. Tide gauges, weather stations, CTD and ADCP moorings, as well as HF radars, together they form what it has been called Campeche Ocean Observing System (Observatorio Marino Campechano). The main purpose of the project is to acquire quality data to analyze the dynamics of the shallow ocean waters of Campeche coasts. The region is characterized by a huge continental plataform, also known as Campeche Bank, with an average slope of -0.5/1000 offshore (-15m/30 km) where strong weather events occur, like hurricanes and northern wind cold surges, known as “Nortes”, making it a very particular region. In general there is very few in situ data of this region, sparse in time and space without any continuity, whereas the idea of the observatory is to start generating long-time series of the places were the equipments has been established, and make these date available to the scientific community. In order to ameliorate the lack of information of the region, satellite data has been proposed as a source of evidence, unfortunately, in the particular case of Sea level comparisons between mooring observations v.s. satellite altimetry data has shown poor correlations (< 30 %), which complicates the use of ocean currents, derived from the altimetric data, in the region. We hope that in the near future, the in situ data gathered by the observatory would be of help to the altimetric community, in order to improve coastal altimetric measurements of this region.
Corresponding author:
Jorge Alejandro Kurczyn Robledo (**Catedras Conacyt-Instituto Epomex**, **Mexico**), jalexkur@uacam.mx

Coastal Circulation off SW Africa

Ted Strub (Oregon State University, United States); Ricardo Matano (Oregon State University, U.S.A.); Corinne James (Oregon State University, U.S.A.); Craig Risien (Oregon State University, United States); Vincent Combes (Oregon State University, United States)

Session: Advances in coastal altimetry: measurement techniques, science applications and synergy with in situ and models
Presentation type: Poster
Poster number: COAST_015

Abstract:
In this new OST-ST project, we are investigating coastal circulation and cross-shelf exchanges along the coast of South Africa. This first study has a focus on the southwest corner of Africa, between 31.5°-36.0°S, 17.0°-20.0°E. The seasonal geostrophic surface circulation anomaly, derived from standard, gridded AVISO SLA products, shows poleward flow in winter and equatorward flow in spring, with a poleward inshore countercurrent that develops during summer in the northern part of the region (north of Cape Town), opposing the local winds. The QUESTION we address here is: IS THIS COUNTERCURRENT REAL? Three approaches are used to answer this question: (1) Coastal tide gauge data are blended with the AVISO gridded data to give more realistic SLA fields in the 50-70km band next to the coast, deriving geostrophic currents from the blended data set; (2) Alongtrack SLA data from the ALES project are examined and compared to standard RADS alongtrack data, to determine whether the improved coverage of ALES provides evidence of the countercurrent; and (3) A realistic numerical circulation model's surface heights and geostrophic currents are analyzed for the same region, using realistic bottom topography and surface winds to drive the model circulation.
Corresponding author:
Ted Strub (**Oregon State University**, **United States**), tstrub@coas.oregonstate.edu

Continuing the Global Mean Sea Level reference record with Jason-CS / Sentinel-6

Lionel Zawadzki (CLS, France); Michaël Ablain (CLS, France); Gérald Dibarboure (CNES, France)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_001

Abstract:
The current Mean Sea Level (MSL) continuous record, essential to understanding the climate evolution, is computed with the altimetric measurements of the TOPEX/Poseidon mission, succeeded by Jason-1, Jason-2 and since 2016, Jason-3. In order to extend the current MSL record, Jason-CS (Sentinel-6) will be the natural successor of Jason-3 in 2020: on the same orbit with a calibration phase.
(Zawadzki & Ablain 2016) demonstrated that the accurate continuity of the record is ensured by the conservation of the “historical” TOPEX orbit as well as by calibration phases between the successive missions. Indeed, these phases enable a rigorous estimation of the inter-mission relative biases with a 1mm uncertainty. It corresponds to a 0.15mm/yr uncertainty on a 10-year MSL record. In the absence of calibration phase, the relative bias uncertainty rises up to 2.5mm, corresponding to a 0.4mm/yr uncertainty. Compared to the 0.3mm/yr GCOS requirement, these uncertainties are very significant.
However, these uncertainties are obviously correlated with the method used to estimate the inter-mission relative bias.
The objective here is to develop a work plan in preparation to Jason-CS (Sentinel-6) launch. How can we improve the accuracy of the methods to estimate the relative biases? Would a multi-mission approach –using Jason-3 and Sentinel-3 (a/b) be accurate? What would be the MSL trend uncertainty induced by the premature loss of Jason-3?

Corresponding author:
Lionel Zawadzki (**CLS**, **France**), lzawadzki@cls.fr

Characterization of the Errors of Sentinel-3A Small Scale Content in SAR mode

Sylvie Labroue (CLS, France); Matthias Raynal (CLS, FRance); Isabelle Pujol (CLS, France); Thomas Moreau (CLS, France); Pierre Féménias (ESA, Italy); François Boy (CNES, France)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_002

Abstract:
The ESA (European Space Agency) mission Sentinel-3A was successfully launched in February 2016. Sentinel-3A is a multi-instrument mission to measure sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability.
The SRAL (Sentinel Radar Altimeter) sensor on board Sentinel-3A differs from previous conventional pulse limited altimeters by providing observations with the Synthetic Aperture Radar mode (SARM). The SARM (or Delay Doppler mode) full coverage was activated over the global ocean since the 12th April 2016 and it is available at global scale for the very first time in the altimetry history. Important benefits from the SARM are expected by the scientific community thanks to the improved precision and resolution offered by this technique. It was already evidenced with Cryosat-2 analysis over SAR regions that the SARM provides a different content of seal level for scales below 60 km, compared to conventional altimetry. While LRM spectrum exhibits a bump signature, SARM spectrum of sea level does not have this artefact. Labroue et al showed in 2015 that a spectral slope different from the continuous decay from large scales to shorter ones was present on SARM data processed for Cryosat-2, but this analysis was restricted to the Agulhas region. More recently, Raynal et al confirmed that the spectral content of Sentinel-3A mission in SARM also contains an error for scales below 60 km. Thanks to the global coverage of Sentinel-3A mission, part of the error was assumed to come from the inaccuracy of the Mean Sea Surface under Sentinel-3A ground track. This assumption is quantified more precisely in the present study. The question still pending on the source of the red noise present on highest frequencies of the SARM spectrum is also revisited.
We further detail the assessment of the signal detected on Sentinel-3A at these scales and discuss the potential of this technique for improving the observation of the small scale ocean content.

Corresponding author:
Sylvie Labroue (**CLS**, **France**), sylvie.labroue@cls.fr

Eddy detection, spectral, and tide gage evaluation of JPL Gridded Altimetry.

Victor Zlotnicki (Jet Propulsion Lab, United States); Zheng Qu (Raytheon, USA); Richard Ray (NASA-GSFC, USA); Joshua Willis (JPL, USA); Brian Beckley (SGT-NASA-GSFC, USA)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_003

Abstract:
A new version of the JPL grids generated under NASA's "Making Earth System Data Records for Use in Research Environments" (MEaSUREs) program has been released; it is dubbed v1709. We use the Goddard Space Flight Center version 4 of the alongtrack data from the TOPEX/Jason series of altimeters, RADS versions of the ERS/Envisat/AltiKa series using ESA's CCI orbital altitudes when available. Grids are constructed from only 2 concurrent satellites. We have conducted a series of quality tests on the grids, and compared them to the corresponding AVISO grids. We present results in terms of eddy identification, root mean squared difference from a select set of tide gage records, and spectral difference from Jason-2 data not used in the gridding.

Corresponding author:
Victor Zlotnicki (**Jet Propulsion Lab**, **United States**), victor.zlotnicki@jpl.nasa.gov

Improving Altimetry's Ocean De-aliasing Correction Using Daily GRACE Updates

Jennifer Bonin (University of South Florida, United States); Himanshu Save (UT - Center for Space Research, United States)

Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_004

Abstract:
To correct for aliasing problems caused by the ~10 day repeat pattern of T/P and Jason 1-3, a non-tidal de-aliasing model constructed of the inverted barometer (IB) response and the Mog2D ocean model is currently applied. However, Mog2D, like many global ocean models, is expected to have relatively high errors in some parts of the ocean. Previous research suggests that a GRACE-based daily series may be more accurate for periods in the 2-20 day range than an ocean model, especially at higher latitudes. A new "swath" update solution is being created to resolve GRACE data into a near-daily, high-spatial-resolution gravity time series with relatively low expected errors. We compare this to the current de-aliasing model, over the GRACE time period. The ultimate goal is to create a better de-aliasing product out of the combination of the two, with the current model dominating at the highest frequencies, but GRACE dominating at periods greater than two days.
Corresponding author:
Jennifer Bonin (**University of South Florida**, **United States**), jbonin@mail.usf.edu

HyDrones, an innovative UAV embedded light altimeter to monitor continental water bodies: toward a new Cal/Val in-situ solution for future altimetry missions

Jean-Christophe Poisson (CLS, France); Guillaume Valladeau (CLS, France); Pierre Prandi (CLS, France); Olivier Lauret (CLS, France)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_001

Abstract:
HyDrones (https://hydrones.cls.fr) is a new service which relies on the complementarity between flying UAVs and autonomous payloads, aiming to monitor continental water bodies, estuaries and coastal zones. Taking the advantage of UAV versatility and fast deployment capabilities, the solution is based on innovative instruments capable of performing high resolution and real-time measurements of hydrological areas through the monitoring of its main parameters such as water surface height (WSH), bathymetry, extent and surface velocity. Moreover, HyDrones instruments are designed to provide a cost-effective solutions that can be easily and rapidly deployed on the end-users' areas of interest. Thus, on-demand fast data acquisition is possible, as well as offline long term monitoring.

In this study, the performances of the HyDrones #MK1.1 light altimeter instrument dedicated to WSH are presented and compared to other measurement systems such as the CalNaGeo GNSS carpet during a 260 km length experiment over the Seine river. In addition, in the frame of Cal/Val in-situ activities dedicated to hydrology, HyDrones WSH time series are also compared to Jason-3 data on the Garonne river close to Marmande (South of France). Finally, the first results of the HyDrones #MK2 light bathymeter solution are presented for different hydrological contexts, aiming to provide an end-to-end/all-in-one Cal/Val in-situ solution for the future altimeter missions over continental water bodies.
Corresponding author:
Jean-Christophe Poisson (**CLS**, **France**), jpoisson@cls.fr

Evaluation of the Sentinel-3 Hydrologic Altimetry Processor prototypE (SHAPE) methods

Albert Garcia-Mondejar (isardSAT Ltd., United Kingdom); Nicolas Bercher (Along-Track S.A.S., France); Pierre Fabry (Along-Track S.A.S., France); Mònica Roca (isardSAT Ltd., United Kingdom); Eduard Makhoul (isardSAT Ltd., United Kingdom); Joana Fernandes (Fac. Ciencias Univ. Porto, Portugal); Clara Lazaro (Fac. Ciencias Univ. Porto, Portugal); Telmo Vieira (Fac. Ciencias Univ. Porto, Portugal); David Gustafsson (Swedish Meteorological and Hydrological Institute, Sweden); Marco Restano (SERCO/ESRIN , Italy); Américo Ambrózio (DEIMOS/ESRIN, Italy); Jérôme Benveniste (European Space Agency/ESA-ESRIN, Italy)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_002

Abstract:
Inland water scenes are highly variable, both in space and time, which leads to a much broader range of radar signatures than ocean surfaces. This applies to both LRM and “SAR” mode (SARM) altimetry.

Nevertheless, the enhanced along-track resolution of SARM altimeters should help improve the accuracy and precision of inland water height measurements from the satellite. The SHAPE project – Sentinel-3 Hydrologic Altimetry Processor prototypE – which is funded by ESA through the Scientific Exploitation of Operational Missions Programme Element (contract number 4000115205/15/I-BG) aims at preparing for the exploitation of Sentinel-3 data over the inland water domain.

The SHAPE Processor implements all of the steps necessary to derive rivers and lakes water levels and discharge from Delay-Doppler Altimetry and perform their validation against in situ data. The processor uses FBR CryoSat-2 and L1A Sentinel-3A data as input and also various ancillary data (proc. param., water masks, L2 corrections, etc.), to produce surface water levels. At a later stage, water level data are assimilated into hydrological models to derive river discharge.

This work presents the improvements obtained with the new methods and algorithms over the regions of interest (Amazon and Danube rivers, Vanern and Titicaca lakes).
Corresponding author:
Albert Garcia-Mondejar (**isardSAT Ltd.**, **United Kingdom**), albert.garcia@isardsat.co.uk

On using water surface slope for estimating discharge in critical backwater conditions: case study of the Poyang lake, China.

Adrien Paris (GET UMR5563 CNES/IRD/CNRS/UPS, France); Laurance Fruteau (LEGOS UMR5566 CNES/IRD/CNRS/OMP, France); Stéphane Calmant (IRD/LEGOS UMR5566 IRD/CNES/UPS/CNRS, France); Jean-François Crétaux (CNES/Legos, 14 Av Edouard Belin, 31400 Toulouse, France); Hervé Yesou (SERTIT, Univ. de Strasbourg, France)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_003

Abstract:
The Poyang Lake has an important influence on the Yangsé River basin hydrology. However, estimating the discharge input in the river is not straightforward. Indeed, as the cycles of both water bodies are not synchronous, the stage/discharge relationship is ambiguous. At a given period of the hydrological year, the conditions may even inverse and part the volume of the Yangsé River flows into Lake Poyang.
In this study, we estimated the discharge at the Poyang Lake mouth using Manning-based formulations of the stage-discharge-slope relationship and both in-situ and satellite datasets. The results show that a classical two-variable (H-Q) power equation is not able to reproduce properly the temporal variations of the discharge. Conversely, use of the daily WSS (Water Surface Slope) estimated from gauge stages as a third parameter in the formulation improved dramatically the fit between observed and estimated discharges. We used 3 Virtual Stations (VSs) from past Nadir altimetry missions (ENVISAT and SARAL) to estimate the WSS at the mouth of the Poyang Lake on a monthly time step. The WSS taken from satellite altimetry also improved the discharges estimates at the Poyang Lake's mouth.
This result illustrates the importance of using the surface slope together with stages and discharges to build a reliable rating curve –hence predict discharge- in such a critical backwater situation. The future SWOT mission will provide an improved (both in frequency and precision) estimate of the WSS. Our capability to estimate discharge in such complex contexts should benefit largely of these new observations.

Corresponding author:
Adrien Paris (**GET UMR5563 CNES/IRD/CNRS/UPS**, **France**), paris@legos.obs-mip.fr

Water level estimation in the Mekong River Basin based on a classification of CryoSat-2 SAR data

Eva Boergens (DGFI-TUM, Germany); Karina Nielsen (DTU Space, Denmark); Denise Dettmering (DGFI-TUM, Germany); Ole B. Andersen (DTU Space, Denmark); Florin Seitz (DGFI-TUM, Germany)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_004

Abstract:
Compared to conventional LRM altimetry CryoSat-2 SAR data is especially useful for measuring small inland waters such as rivers due to the improved along track resolution. Though, a reliable extraction of water levels is still challenging for river with only very few consecutive water measurements. Land-water-masks are often too unreliable for a precise identification of small rivers. We propose a classification approach which overcomes this problem by detecting the water measurements from the altimetry measurements themselves.
The CryoSat-2 SAR data are available with the full stack data which contains all single-looks for one point on the Earth's surface. Each of the single-looks is a returning waveform from a different looking angle. The SAR (multi-look) waveform is the averaged waveform of the stack. The assemblage of the mean power of each single-look is named RIP waveform. In this study, we use both quantities, i.e., the full stack data available for CryoSat-2 SAR, to classify the measurements and to identify the water returns. The classification is performed with a k-means clustering algorithm on features extracted from the waveform and the RIP waveform as well as the waveform and RIP waveform itself.
The classification approach is applied and tested over the Mekong River Basin. We found better results in the classification after dividing the data in two regions, one for small upstream rivers surrounded by hills and mountains, and one for the wider rivers with flatter surrounding terrain.
Out of 20 clusters provided by the k-means algorithm, those forming the water classes are identified in a region with known river locations and based on the mean waveform and RIP for each class. These classes are used in a next step for classifying all measurements in the whole river basin in water and non-water measurements. The classified water measurements are used in a last step to generate water levels for each CryoSat-2 crossing with a river branch in the Mekong River basin.
The long repeat orbit of CryoSat-2 hinders the setup of water level time series at fixed virtual stations, which can be used for validation against in situ gauge data. Under the assumption of a stable seasonal signal, which holds true for the Mekong River, an internal validation of the data is possible. To this end, we compare, first, the water levels of consecutive passes (time difference 369 days) with each other and, second, water levels that are both close in location and close in season. The validation proves the success of the approach for the main river as well as for smaller tributaries.

Corresponding author:
Eva Boergens (**DGFI-TUM**, **Germany**), eva.boergens@tum.de

Reassessment of the ICESAT-1 data over the Amazon waters

Daniel MOREIRA (CPRM, Brazil); stephane CALMANT (IRD / LEGOS, France); Otto CORREA ROTUNO FILHO (UFRJ / COPE, Brazil); Felix PEROSANZ (CNES / GET, FRANCE)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_005

Abstract:
Since the study by Hall et al. (2011), no other study focused on the validation of the ICESAT data over rivers such as the Amazon river. In the latter study, authors compared the ICESAT data with the water levels of in-situ gauges. Yet, the results were quite disappointing, showing large errors of several tens of cm.
In the present study, we also compare the ICESAT data to gauge series but in addition, we made a prelinminary quality check of the series, GPS levelled the gauges and most important, accounted for the slope of the water surface using longitudinal GPS profiles of the water surface collected on the rivers.
Our results, based on the processing of 445 ICESAT passes, show that the RMS difference between the ICESAT measurements and the in-situ weter levels range between 2 to 17 cm, depending on the gauge considered.
Consequently, the ICESAT data can be used with confidence for many applications in the management of large bassins, such as gauge levelling, check of gauge series, gap filling in altimetry series; and we present examples of such uses.

Hall et al., 2011; Geodetic corrections to Amazon River water level gauges using Icesat altimetry, WRR, doi:10.1029/2011WR010895

Corresponding author:
Daniel MOREIRA (**CPRM**, **Brazil**), daniel.moreira@cprm.gov.fr

Climate Indexes and altimetry-based water levels in Amazon basin rivers

Mylena VIEIRA SILVA (CESTU / UEA, Brazil); Joecila SANTOS da SILVA (CESTU / UEA, Brazil)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_006

Abstract:
More than a thousand of series of water level have been computed in the Amazon basin from satellite altimetry in the 2003-2015 time window. These series sample rivers of very different size, from the Amazon main stem which carries 2000 m3/s to small second order rivers which carry only a few 100's m3/s. We worked with monthly and annual averages and divided the Amazon basin in large units. For each unit, we present the correlation with climate indices such as NAO, SAO, OST and El Nino.
The main results, globally at the basin scale, are that the water levels in the Amazon basin are correlated negatively with the Altantic indices (NAO and SAO) while they are positively correlated with the Pacific indices. Yet, regional differences exist, as listed below :
- East (Upper) Amazon, Jutai and Solimoes are negatively correlated with the NAO during the flood seasons and is positively correlated with the PAC during the recession season;
- The Negro river is negaltively correlected with the NAO during the flood season and with the PAC index during the dry season;
- The Madeira river is negatively correlated with NAO all along the year;
- The Xingu river is negatively correlated with SAO during the flood season and positively correlated with the PAC index during the low flow season.
Corresponding author:
Mylena VIEIRA SILVA (**CESTU / UEA**, **Brazil**), mylenavieirasilva@gmail.com

CAUSES AND CONSEQUENCES of the 2014 FLOOD on the MADEIRA RIVER

Jossandra ALVES DAMASCENO (CESTU / UEA, Brazil); Joecila SANTOS da SILVA (CESTU / UEA, BRAZIL); Adrien PARIS (LEGOS, FRANCE); Daniel MOREIRA (CPRM, BRAZIL); Stéphane CALMANT (IRD / LEGOS, FRANCE)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_007

Abstract:
In this study, we present an application of altimetry for the evaluation of the upstream impact of a dam reservoir. In 2014, the Brazilian Madeira river and some of its tributary flowing in Bolivia experienced a major flood, from the city of Porto Velho (Brazil), upstream. Because this flood occured both in Brazil and in Bolivia right after the start of operation of the Jau dam (located at Porto velho in Brazil), a dispute started between Brazil and Bolivia upon the role played by the dam reservoir in the flooding. By the analysis of the altimetry data in the Madeira bassin upstream Porto Velho, a poorly monitored watershed in particular in its Bolivian part, we mapped the extend of the dam reservoir prior the flood. Then, we show that during the flood, tributary reaches were affected by higher-than-normal water levels upstream the bent in surface water line delineating the dam reservoir. Consequently, the dam reservoir does not seem to be responsible of the inundations in Bolivia.

Corresponding author:
Jossandra ALVES DAMASCENO (**CESTU / UEA**, **Brazil**), joba.alves@gmail.com

Validation of a large data set of SARAL water levels in the Amazon basin

Taina CONCHY (CESTU / UEA, Brazil); Joecila SANTOS da SILVA (CESTU / UEA, BRAZIL); stephane CALMANT (IRD / LEGOS, FRANCE); Daniel MOREIRA (CPRM, BRAZIL)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_008

Abstract:
In 2010, SIlva et al. presented the largest validation of ERS-2 and ENVISAT water levels ever published, in the Amazon basin.
Since SARAL has been orbiting for 3 years the same 35 day repeat orbit than ERS-2 and ENVISAT, we performed the same analysis of SARAL series as Silva et al. did for ERS-2 and ENVISAT. The analysis was performed for the ICE-1 retracking, available in the SARAL GDRs and similar to the one used by Silva et al. (2010)
Then, we estimated :
- the RMS difference with in-situ gauges;
- the absolute bias since the gauges are levelled with GPS
- a revision of the ENVISAT absolute bias based on this new -and larger- dataset of levelled gauges.
- the relative bias between ENVISAT and SARAL. Such a bais is required to append SARAL series after the ENVISAT series.

Silva et al. (2010); RSE, doi:10.1016/j.rse.2010.04.020
Corresponding author:
Taina CONCHY (**CESTU / UEA**, **Brazil**), tainaconchy@gmail.com

Evaluation of the SENTINEL-3A water levels over large hydrological basins

Stéphane Calmant (IRD, France); Denis BLUMSTEIN (CNES / LEGOS, FRANCE); Joecila SANTOS da SILVA (CESTU / UEA, BRAZIL); Adrien PARIS (CLS, FRANCE)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_009

Abstract:
SENTINEL-3A, was launched in early 2016 by ESA. Its altimeter is expected to collect water levels in SAR mode in the Ku EM band over the great majority of hydrological basins. In the present study, we evaluate the performance of this new mission in providing valuable water levels over the two major basins on Earth, namely the Amazon and Congo Basins.
Since the launch, the SENTINEL-3A altimetry data have been distributed in a variety of versions. We processed the LAN data in version 1.2 for cycles >= 17 and version 1.5 for cycles up to 16, reprocessed consistently with version 1.2.
For this analysis, we identified 465 sites in the Congo basin and 1140 sites in the AMAZON basin where SENTINEL-3A groundtracks cross the river network and can potentially collect water levels. Note that some of these sites are included in the onboard DEM mask when others are not.
Since almost no gauge is maintained by the national agencies in the Congo basin, we installed two automatic gauges for the validation of the SENTINEL-3A measurements, right under orbit groundtracks. Similarly, we installed gauges in the Amazon basin in order to complement the national network of gauges maintained by Brazil.
We present preliminary assessments of the amount of data collected, or missing, the RMS difference with gauge readings and the absolute bias, for both the OCEAN and OCOG range retracking algorithms.
Corresponding author:
Stéphane Calmant (**IRD**, **France**), stephane.calmant@ird.fr

A database of hydrology targets for the new DEM onboard Jason3

Denis BLUMSTEIN (CNES/LEGOS, France); Sylvain BIANCAMARIA (LEGOS, France); Jean-François CRETAUX (CNES/LEGOS, FRANCE); Stéphane CALMANT (LEGOS, FRANCE); Fabien BLAREL (LEGOS, FRANCE); Elena ZAKHAROVA (LEGOS, FRANCE); Sophie Le Gac (CNES, FRANCE); François BOY (CNES, FRANCE); Nicolas PICOT (CNES, FRANCE)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_010

Abstract:
On Jason-3, data acquisition over inland water bodies is performed in either Diode/DEM mode or Autonomous Mode [1]. The Diode/DEM tracking mode can be very useful in order to have the altimeter providing valid measurements over the water body even in difficult environments like rivers lying in the bottom of narrow valleys (see [2] for example). However, this tracking mode requires that the height of the targets of interest is known with a rather good exactitude (typically a dozen of meters). Otherwise, the remedy would be worse than the evil and the river would be missed by the altimeter for all the overpasses. It is then not a completely trivial task to build a global onboard DEM that meets this constraint.

Therefore, given the interest for the whole users community, LEGOS and CNES teams joined technical and scientific expertise to establish the right strategy for making such onboard DEMs. We first defined a small scale project over France (around 100 targets) where precise topography, water masks and in-situ measurements of water heights are publicly available. This allowed us to validate the methods during the commissioning of Jason3 taking benefit of the tandem phase with Jason2. The results of this validation are presented in [3]. In a second step, we recently expanded the database on a global scale with more than 4500 targets worldwide to build the new Jason3 onboard DEM. In the process, we paid a particular attention not to disturb acquisitions over hydrology targets already monitored in the databases providing measurement from spatial altimetry (GREALM, HYDROWEB and DAHITI). The implementation of the DEM in Jason-3 is presented in [4].

The poster will present the new global database, the expected improvements for spatial hydrology, the methods we have used to build it and some difficulties we had to overcome. We will also present the first results of validation if the new DEM has been put in operation soon enough before the meeting.

[1] Desjonqueres et al., Jason-3/POS-3B First results, OSTST 2016.
[2] Biancamaria et al., Satellite radar altimetry water elevations performance over a 200 m wide river: Evaluation over the Garonne River, Advances in Space Research, Volume 59, Issue 1, 2017
[3] Biancamaria et al., Validation of Jason-3 tracking modes over French rivers, Rem. Sens. Env., submitted, 2017
[4] Le Gac et al., Update and validation of the onboard Jason-3 DEM for enhanced acquisitions over inland water targets, OSTST 2017

Corresponding author:
Denis BLUMSTEIN (**CNES/LEGOS**, **France**), denis.blumstein@cnes.fr

Long term series of discharges distributed in the Congo River basin from hydrological modelling and satellite altimetry

Adrien Paris (GET UMR5563 CNES/IRD/CNRS/UPS, France); Ayan Fleischmann (IPH/UFRGS, Brazil); Taina Conchy (UEA, Brazil); Stéphane Calmant (LEGOS UMR5566 IRD/CNES/UPS/CNRS, France); Vinicius Siqueira (IPH/UFRGS, Brazil); Marielle Gosset (GET UMR5563 CNES/IRD/CNRS/UPS, France); Rodrigo Cauduro Dias de Paiva (IPH/UFRGS, Brazil); Walter Collischonn (IPH/UFRGS, Brazil); Joecila Santos da Silva (UEA, Brazil)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_011

Abstract:
Real-time monitoring of discharges in the Congo River basin is not straightforward given the strong geomorphological diversity, the relatively low level of knowledge of hydrological processes and the size of the basin, spreading on several countries. In this study, we built stage/discharge rating curves based on: 1) the discharges given by the distributed MGB-IPH hydrodynamic model forced by GPM TAPEER precipitation product, and 2) satellite altimetry SWE (Surface Water Elevation) time series from SARAL and Jason-2 missions at each crossing between a river reach and a satellite ground track (the so-called virtual stations – VSs). Within the MGB-IPH, we included a simple representation of lakes, improving the discharge estimates in the upper Congo. Simulated discharges were validated against both in-situ discharge data (coarse) and SWE from altimetry for the overlapping period (namely 2011-2016).
At the locations with available discharge data, the model was found to perform very well (Ens higher than 0.7 and volume error lower than 10%). The high quality of the RCs all over the basin showed that the TAPEER rainfall estimate used as input to the MGB-IPH model permitted to represent well the hydrological and hydrodynamic processes, even for the most upstream ungauged locations. Some discrepancies, observed in simulated discharges with other rainfall inputs, were discarded thanks to this dataset.
The Jason-2 RCs can now be used routinely to derive discharges in near real time (NRT) from forthcoming Jason-3 SWE observations, with a temporal sampling of one every 10 days and at almost a hundred of potential VSs. In addition, the combination with observations coming from former missions flying on the same orbits (T/P for Jason-2, ENVISAT and ERS-2 for SARAL) permitted to produce long term discharge time series, prerequisite for climate-change studies.

Corresponding author:
Adrien Paris (**GET UMR5563 CNES/IRD/CNRS/UPS**, **France**), adrien.paris@legos.obs-mip.fr

Recent evolutions and quality assessment of CryoSat products

Jerome Bouffard (ESA - RHEA, Italy); Tommaso Parrinello (ESA, Italy); Pierre Féménias (ESA, Italy)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_012

Abstract:
The main objective of this paper is to give an overview of recent evolutions and quality assessment of the ESA CryoSat products; as well as to present the next processing algorithm upgrades. CryoSat is the first SAR/SARin altimeter concept to be flown on Earth with the main challenge to quantify how the thickness of the land ice and the floating sea-ice are changing. Beside its ice monitoring and climate objectives, CryoSat is also a highly valuable source of observations for the hydrological and oceanographic community as well as for operational polar services. The CryoSat data are operationally processed and analyzed by ESA both over ocean and ice surfaces with two independent processing chains following two different processing baselines. These data are routinely Quality-Controlled and thoroughly Validated (QCV). Based on the QCV results and feedback from the user community, the data products continuously evolve in order to accommodate a growing range of scientific users and operational services both over the Sea ice, the Land Ice, the Ocean and Inland domains.

Corresponding author:
Jerome Bouffard (**ESA - RHEA**, **Italy**), jerome.bouffard@esa.int

Sentinel-3A for sea-ice and land ice

Salvatore Dinardo (He Space, Germany); Cristina Martin-Puig (EUMETSAT, Spain); Remko Scharroo (EUMETSAT, Holand)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_013

Abstract:
The secondary objective of the Sentinel-3 Surface Topography Mission is to provide surface elevation measurements over sea ice and land ice regions in conjunction with CryoSat-2. In order to assess the present data quality of the Sentinel-3 SRAL PDGS products over sea ice and land ice, a processing of the S3 SRAL L1A products up to L2 has been carried out. The enhancement of this processing with respect the current PDGS processing baseline is to double the length in the range window and to double the resolution by means of zero-padding.
The enhanced products will be cross-compared against the PDGS products in order to highlight the role and effect of the zero-padding for freeboard computation and of the radar window extension for the tracking of the land ice margins.
A cross-comparison against collocated CryoSat-2 products will be presented. The final objective is to assess the add value brought by these two new processing options for potential implementation in the Sentinel-3 SRAL PDGS.
Corresponding author:
Salvatore Dinardo (**He Space**, **Germany**), salvatore.dinardo@eumetsat.int

The CryoSat SciEnce-oriented data ANalysis over sea-ICE areas project

Pierre Fabry (Along-Track, France); Nicolas Bercher (Along-Track, France); Stefan Hendricks (AWI, Germany); Robert Ricker (AWI, Germany); Sara Fleury (LEGOS-CNRS, France); Frédérique Rémy (LEGOS-CNRS, France); Jean-Christophe Poisson Poisson (CLS, France); Pierre Thibaut (CLS, France); Jérôme Bouffard (ESA-ESRIN, Italy)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_014

Abstract:
This communication presents the many aspects and some preliminary results of the ESA funded Cryo-seaNice project that just started (November 2016). The acronym stands for CryoSat SciEnce-oriented data ANalysis over sea-ICE areas. The high level objectives of the project are
- to provide an independent evaluation of Baseline-C operational IPF2 freeboard products,
- to support ESA in the definition of future CryoSat IPF evolutions based on the outcomes of targeted R&D activities focusing on CryoSat data analysis over sea-ice areas,
- to study, prototype, test new or optimized algorithms that may impact IPF-1 and/or IPF-2,
- to study, prototype, test new freeboard products.
A team with very complementary expertises has been set to address the complex subject of sea-ice remote sensing from both the high spatial diversity and the strong temporal variability aspects due to the sea-ice physics, meteorological events as well as local surface currents.
Dedicated science oriented tools therefore need to be put in place to make best profit of both in situ data and imagery to thoroughly understand the signatures within the altimeter signals.
It is expected that some of the CryoSat Ice Processor limitations be detected/analysed through a refined analysis of the physics behind the Ku band SAR/SARin altimeter products and Ka band products over the Sea-Ice domain.
The team will also implement and assess the outputs of new/recent geophysical retrackers.
The various aspects and steps of the projects will be presented : Refine the surface type detection; Improve retracking using physical based retrackers instead of threshold based retrackers ; Tackle continuity issues (proper retracking of specular and brownian WF in sequence, off-nadir hookings, side lobe contamination effects, freeboard continuity especially at the pack ice - fast ice transitions and between SAR and SARIN modes), assess snow cover impact onto freeboard and ice-thickness measurements, Analyse and Improve the existing freeboard SNR, Study, Prototype and Assess new freeboard measurement techniques, Exploit SARIN mode for freeboard measurement, test SARIN swath-altimetry over sea-ice.
Corresponding author:
Pierre Fabry (**Along-Track**, **France**), pfabry@along-track.com

SPICE: Sentinel-3 Performance Improvement for Ice Sheets

Malcolm McMillan (University of Leeds, United Kingdom); Roger Escola (isardSAT Ltd, United Kingdom); Monica Roca (isardSAT Ltd, United Kingdom); Pierre Thibaut (CLS, France); Andrew Shepherd (University of Leeds, United Kingdom); Frederique Remy (LEGOS, France); Jeremie Aublanc (CLS, France); Clemente Lacrouts (CLS, France); Jerome Benveniste (ESA, Italy); Americo Ambrozio (ESA, Italy); Marco Restano (ESA, Italy)

Session: Science IV: 25 years of satellite altimetry for Cryosphere and Hydrology: from experimental to emerging operational applications
Presentation type: Poster
Poster number: SC4_015

Abstract:
For the past 25 years, polar-orbiting satellite radar altimeters have provided a valuable record of ice sheet elevation change and mass balance. One of the principle challenges associated with radar altimetry comes from the relatively large ground footprint of conventional pulse-limited radars, which reduces their capacity to make measurements in areas of complex topographic terrain. In recent years, progress has been made towards improving ground resolution, through the implementation of Synthetic Aperture Radar (SAR), or Delay-Doppler, techniques. In 2010, the launch of CryoSat-2 heralded the start of a new era of SAR Interferometric (SARIn) altimetry. However, because the satellite operated in SARIn and LRM mode over the ice sheets, many of the non-interferometric SAR altimeter processing techniques have been optimized for water and sea ice surfaces only. The launch of Sentinel-3, which provides full non-interferometric SAR coverage of the ice sheets, therefore presents the opportunity to further develop these SAR processing methodologies over ice sheets.

Here we present results from SPICE (Sentinel-3 Performance Improvement for Ice Sheets), a 2 year study that focuses on (1) developing and evaluating Sentinel-3 SAR altimetry processing methodologies over the Polar ice sheets, and (2) investigating radar wave penetration through comparisons of Ku- and Ka-band satellite measurements. The project, which is funded by ESA's SEOM (Scientific Exploitation of Operational Missions) programme, has worked in advance of the operational phase of Sentinel-3, to emulate Sentinel-3 SAR and pseudo-LRM data from dedicated CryoSat-2 SAR acquisitions made at the Lake Vostok, Dome C and Spirit sites in East Antarctica, and from reprocessed SARIn data in Greenland. In Phase 1 of the project we have evaluated existing processing methodologies, and in Phase 2 we are investigating new evolutions to the Delay-Doppler Processing (DDP) and retracking chains. In this presentation we (1) evaluate the existing Sentinel-3 processing chain by comparing our emulated Sentinel-3 elevations to reference airborne datasets, (2) describe new developments to the DDP and retracking algorithms that are aimed at improving the certainty of retrievals over ice sheets, and (3) investigate radar wave penetration by comparing our SAR data to waveforms and elevations acquired by AltiKa at Ka-band.

Corresponding author:
Malcolm McMillan (**University of Leeds**, **United Kingdom**), m.mcmillan@leeds.ac.uk

On the permeability of the Malvinas Current

Nicolás Bodnariuk (Centro de Investigaciones del Mar y la Atmósfera (CONICET-UBA); Instituto Franco-Argentino para el Estudio del Clima y sus Impactos (UMI IFAECI/CNRS-CONICET-UBA); Departamento de Ciencias de la Atmósfera y lo Océanos, Facultad de Ciencias Exactas y Natura, Argentina); Francisco Javier Beron-Vera (Department of Atmospheric Science, Ronsentiel School of Marine and Atmospheric Science, University of Miami, USA); Martín Saraceno (Centro de Investigaciones del Mar y la Atmósfera (CONICET-UBA); Instituto Franco-Argentino para el Estudio del Clima y sus Impactos (UMI IFAECI/CNRS-CONICET-UBA); Departamento de Ciencias de la Atmósfera y lo Océanos, Facultad de Ciencias Exactas y Natura, Argentina); Claudia Gloria Simionato (Centro de Investigaciones del Mar y la Atmósfera (CONICET-UBA); Instituto Franco-Argentino para el Estudio del Clima y sus Impactos (UMI IFAECI/CNRS-CONICET-UBA); Departamento de Ciencias de la Atmósfera y lo Océanos, Facultad de Ciencias Exactas y Natura, Argentina)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_001

Abstract:
We investigate the permeability of the Malvinas Current over a period well sampled by satellite altimetry using geometric and probabilistic nonlinear dynamic techniques for Lagrangian coherence detection. The geometric technique builds on notions of strain and shear expressible through the invariants of an appropriate time average of the right Cauchy-Green strain tensor. The probabilistic technique uses a transfer operator based on short-run trajectories which renders the dynamics autonomous and provides a globale evolution perspective. In agreement with in-situ and remote observations, both seemingly different approaches to Lagrangian coherence detection consistently reveal recurrent water instrusions over the continental shelf, which are verified by direct trajectory integrations. Some implications of these intrusions are discussed.

Corresponding author:
Nicolás Bodnariuk (**Centro de Investigaciones del Mar y la Atmósfera (CONICET-UBA); Instituto Franco-Argentino para el Estudio del Clima y sus Impactos (UMI IFAECI/CNRS-CONICET-UBA); Departamento de Ciencias de la Atmósfera y lo Océanos, Facultad de Ciencias Exactas y Natura**, **Argentina**), nicolas.bodnariuk@cima.fcen.uba.ar

Using kinetic energy measurements from altimetry to detect shifts in the positions of fronts in the Southern Ocean

Don Chambers (University of South Florida, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_002

Abstract:
A novel analysis is performed utilizing cross-track kinetic energy (CKE) computed from sea surface height anomalies derived from along-track satellite altimetry. The mid-point of enhanced kinetic energy averaged over three-year periods from 1993 to 2015 is determined across the Southern Ocean and examined to detect shifts in frontal positions, based on previous observations that kinetic energy is largest along fronts and jets in the Antarctic Circumpolar Current system. It is demonstrated that although the CKE does not represent the full eddy kinetic energy (computed from crossovers), the shape of the enhanced regions along groundtracks is the same, and CKE has a much finer spatial sampling of 6.9 km. Results indicate no significant shift in the front positions across the Southern Ocean, on average, although there are some localized, large movements. This is consistent with other studies utilizing sea surface temperature gradients and the latitude of mean transport, but inconsistent with studies utilizing the movement of contours of dynamic topography.
Corresponding author:
Don Chambers (**University of South Florida**, **United States**), donc@usf.edu

Influence of Mesoscale Eddies on the Deep Ocean Dynamics over the East Pacific Rise

Xinfeng Liang (University of South Florida, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_003

Abstract:
Mesoscale eddies are ubiquitous in the World Ocean. A considerable amount of knowledge about mesoscale eddies has been gained, especially since the advent of satellite altimetry. However, most previous work has focused on signals near the sea-surface and, more recently, down to about 2000 m (thanks to Argo). The signals of mesoscale eddies in the deep ocean and their influence on the deep-ocean dynamics have not yet been intensively studied.

In this study, the connections between mesoscale eddies and deep ocean dynamical processes, including low-frequency flows, internal waves, and ocean mixing, are examined by combing the sea surface height anomaly data and a collection of deep ocean measurement near the crest of the East Pacific Rise (EPR) between 9 and 10 N. First, the relationship between mesoscale eddies and subinertial flows in the deep ocean over the EPR were examined. The subinertial velocities at depth are significantly correlated with geostrophic near-surface currents, which are dominated by westward-propagating mesoscale eddies. It is concluded that the subinertial velocity near the EPR crest is a super-position of velocities associated with eddies propagating westward across the ridge and "topographic flows." Second, the relationship between subinertial flows and internal waves were investigated. The observations reveal subinertial modulations of internal waves, particularly near-inertial oscillations and internal tides. These subinertial modulations are highly correlated with the subinertial flows in the deep ocean. Third, based on a finescale parameterization model, the deep ocean diapycnal diffusivity over the ridge crest was estimated. The estimated diapycnal diffusivity shows a variation on the subinertial time scale. In particular, the measurements imply a significant increase in diapycnal diffusivity near the seafloor during episodes of increased subinertial flow. Fourth, combined with previous numerical and theoretical studies, the observations imply energy transfer near the crest of the EPR from low-frequency flows, including mesoscale eddies, to near-inertial oscillations, turbulence, and mixing.

Considering the ubiquitousness of mesoscale eddies in the ocean, it is expected that the circulation near other portions of the global mid-ocean ridge system is similarly dominated by mesoscale variability and topographic effects. This is particularly important for dispersal of larvae and geochemical tracers associated with hydrothermal sources that are found primarily along the crest of mid-ocean ridges. Also, the observed eddy-modulated mixing is expected to be useful for validating and improving numerical-model parameterizations of turbulence and mixing in the ocean. Furthermore, since the frequency and intensity of mesoscale eddies depend on the state of the climate, the observed eddy modulation of deep ocean mixing connects climate change and climate variability to physical and biogeochemical dynamics in the deep ocean and implies an unexplored feedback mechanism potentially affecting the global climate system.

Corresponding author:
Xinfeng Liang (**University of South Florida**, **United States**), liang@usf.edu

Effects of westward mountain-gap wind jets on the Red Sea Eastern Boundary Current and the mesoscale eddy field

Menezes Viviane (WHOI, United States); Tom Farrar (WHOI, United States); Amy Bower (WHOI, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_004

Abstract:
Winds blowing over the Northern Rea Sea (NRS) are predominantly southward, along the main axis, all year round. This pattern contrasts with the winds in the southern Red Sea, where the along-axis winds reverse seasonally due to the monsoonal regime. Although the winds are mostly along-axis, several works have shown that occasionally the winds blow in a cross-axis direction from Saudi Arabia to Africa during the boreal winter. These westward wind-jet events are intermittent and occasionally hold for several days. They bring relatively cold dry air and dust from the Saudi Arabia desert, increasing heat loss and evaporation off the NRS . Previous works suggest these events contribute to increase eddy activity in the NRS and may impact the northward-flowing Eastern Boundary Current (EBC). In the present work, we investigate how the wind-jet events impact the EBC and the NRS eddy fields, through analysis of altimetric sea surface height anomalies, satellite sea surface temperature (SST), scatterometer winds, and two years of data from a mooring deployed by WHOI. We show that the westward wind jet events increase the NRS eddy activity and destroy the EBC signature in SST images.
Corresponding author:
Menezes Viviane (**WHOI**, **United States**), vmenezes@whoi.edu

Salinity advection and Rossby waves in northern Indian Ocean

Xiaosu Xie (Jet Propulsion Laboratory, United States); W. Timothy Liu (Jet Propulsion Laboratory, USA)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_005

Abstract:
The hydrodynamics of the northern Indian ocean is dominated by the annual reversal of salinity advection between the more saline Arabian Sea and the Bay of Bengal freshened by river discharge. The advection is supposedly driven by the seasonal change of monsoon, but there is slight phase difference between change of surface current and local wind. There are hypotheses that the current is remotely forced through Kevin and Rossby Waves. The westward propagation of sea level anomalies and geostrophic current as manifestation of Rossby Waves in the north Indian Ocean has been well observed by the radar altimeters. We have also developed statistical models, with which we have mapped ocean surface carbon parameters using satellite observations. We found ocean surface salinity, partial pressure of carbon dioxide, and total alkalinity, exhibit westward propagation, with sea level, albeit at different speeds in different seasons. The underlying reasons of these differences in term of monsoon influence, local and remote, are being explored.
Corresponding author:
Xiaosu Xie (**Jet Propulsion Laboratory**, **United States**), xiaosu.xie@jpl.nasa.gov

Forcing of mesoscale eddy kinetic energy variability in the southern subtropical Indian Ocean, from satellite altimeter and scatterometer data

Andrew Delman (Jet Propulsion Laboratory, United States); Tong Lee (Jet Propulsion Laboratory, United States); Bo Qiu (University of Hawai'i, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_006

Abstract:
A region of elevated mesoscale eddy activity spans the southern subtropical Indian Ocean (SSIO) between Madagascar and Australia. The interannual and decadal changes in eddy activity, as represented by the variability of eddy kinetic energy (EKE), have implications for the meridional overturning circulation and heat transport. An analysis of AVISO merged satellite altimeter data decomposes the sea level anomaly (SLA) field into a spatially low-passed SLA field, and a residual SLA field that contains mesoscale activity. Near the Australian coast, where eddies are generated in the Leeuwin Current, EKE derived from the mesoscale SLA field is found to be positively correlated with the total SLA. This correlation is attributed to the remote forcing from the Pacific: a higher sea level in the western tropical Pacific (e.g., during La Niña or negative PDO conditions) propagates through the Indonesian Seas via coastal Kelvin waves to the SSIO eastern boundary. The higher eastern boundary sea level is associated with a strengthening of the Leeuwin Current, increasing the eddy activity generated from horizontal and vertical shear and radiating eddies towards the west.
In the central SSIO, mesoscale EKE correlations with tropical Pacific anomalies are not robust. Eddies in the interior SSIO are generated from barotropic and baroclinic instability between two opposing currents: the westward flowing, surface-intensified South Indian Counter Current and the eastward flowing, deeper South Equatorial Current. Analyses of surface winds from the CCMP merged scatterometer product, and of surface vorticity gradients from AVISO, indicate that changes in SSIO wind energy input and vorticity gradients may control the interannual variability of mesoscale EKE in the SSIO interior. The identification of these boundary and interior mechanisms for EKE variability may permit short-term (6-12 month) predictions of eddy activity levels in the SSIO, and assessment of model simulations of eddy activity in the region.

Corresponding author:
Andrew Delman (**Jet Propulsion Laboratory**, **United States**), Andrew.S.Delman@jpl.nasa.gov

Diagnosing ocean eddy heat and salt fluxes from satellite altimetry and Argo profile data

Oleg Melnichenko (University of Hawaii, United States); Angel Amores (Mediterranean Institute for Advanced Studies, Balearic Islands, Spain)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_007

Abstract:
Mesoscale eddies are believed to play an important role in the ocean transport of heat and salt. Yet, eddy transports are difficult to observe, mainly because of the difficulties in gathering observations with sufficient time and space resolution to resolve the eddy field. In this study, transport properties of mesoscale eddies in various parts of the world ocean are diagnosed from a synergistic use of satellite altimetry data and in-situ temperature and salinity profiles collected by Argo floats. The eddy transports related to coherent mesoscale eddies are expectedly strong in the western boundary currents and in the Southern Ocean along the Antarctic Circumpolar Current (ACC). The transports are generally weak, but not negligible in gyre interiors. In the vertical, the eddy heat and salt transports are surface-intensified and confined mainly to the upper ~500 m layer, but their distribution with depth is not homogeneous throughout the ocean. In the Kuroshio extension (KE) region, for example, the eddy heat transport is poleward everywhere in the surface layer above the thermocline, but oppositely signed relative to the jet's axis in a deeper layer between approximately 300-800 m, where the transport is poleward on the northern side of the jet and equatorward on its southern side. Relatively strong eddy transports at depth are also observed in the ACC, particularly in the Indian sector, and in the subtropical North Atlantic at the level of the Mediterranean Water (MW) at around 1000 m depth. The latter exemplifies the role of eddies in MW spreading. These and other features of the longitude-latitude-depth distributions of the eddy heat and salt transports, constructed exclusively from observational data, are presented and discussed.
Corresponding author:
Oleg Melnichenko (**University of Hawaii**, **United States**), oleg@hawaii.edu

Using ADCP data and altimetry to evaluate high-wavenumber variability in the California Current and the tropics

Sarah Gille (Scripps Institution of Oceanography, UC San Diego, United States); Teresa Chereskin (Scripps Institution of Oceanography, UC San Diego, United States); Saulo Soares (University of Hawaii, United States); Cesar Rocha (Scripps Institution of Oceanography, UC San Diego, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_008

Abstract:
At scales smaller than 50-100 km, observations from altimetry, Acoustic Doppler Current Profiler (ADCP) data, and numerical model output all suggest that oceanic variability is dominated by processes associated with internal waves and not in geostrophic balance. These unbalanced small-scale motions typically have relatively shallow spectral slopes (k⁻² for velocities), but they can be hard to evaluate in many parts of the world, because of the challenges associated with obtaining observations at high spatial resolution. Previous studies have focused on regions with strong baroclinic jets. Here we examine 2 contrasting regions: the California Current, where ADCP data have been collected for many years as part of regular surveys of the region, and the tropics, where regular research ship operations have produced a broad range of long transits that were previously unprocessed and unavailable for research. We carry out our updated assessment of ADCP observations in combination with an examination of new altimetry from the same regions to evaluate the properties of high-wavenumber variability and in particular the length-scales at which balanced geostrophic motions transition into unbalanced motions dominated by internal waves. This analysis is facilitated by three new altimeters: AltiKa, Sentinel-3, and Cryosat. Together these offer the possibility of evaluating sea surface height variability at smaller scales than can be resolved from the Ku-band Jason altimeters. Each of these altimeters, however, offers its own challenges: AltiKa's Ka-band altimeter shows a spectral bump at small scales that is not easily eliminated, although retracking may provide a means to minimize the bump. Cryosat's SAR mode altimetry is only available over geographically limited regions, and because the satellite orbit does not repeat, the signal associated with the time-invariant geoid is not easily removed. Sentinel-3, although on a new ground track with a geoid that is not well mapped, appears to have a smaller spectral bump than AltiKa but higher noise at high wavenumber. By jointly examining altimetry and ADCP data (along with model data when available), we can assess the commonalities in the physics that each resolves, as well as the potential sources of error.

Corresponding author:
Sarah Gille (**Scripps Institution of Oceanography, UC San Diego**, **United States**), sgille@ucsd.edu

Global wavenumber spectra from SARAL/Altika observations

Oscar Vergara (LEGOS/OMP, France); Rosemary Morrow (LEGOS/OMP, France); Isabelle Pujol (CLS Space Oceanography, France); Gerlad Dibarboure (CNES, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_009

Abstract:
The wavenumber spectra of along-track Sea Surface Height from the radar mission SARAL/Altika (1 Hz) are analyzed over the period 2013-2015. Saral is chosen for its low noise levels and improved signal-to-noise. The use of the spectral shape to interpret the surface eddy regime at global scale is revisited. Wavelength range for the spectral slope estimations is determined as a function of local first-baroclinic Rossby radius of deformation (Lr) and the Rhines scale (LR). The wavelength range varies spatially, rather than the fixed wavelength range of previous studies. Results show that spectral slope is generally steeper than k^-3 (where k is the wavenumber) in the extra-tropics (reaching slope values steeper than k^-4 in high energy eddy regions), and flattens towards the equator (values around k^-2). Processing steps of careful editing and corrections, noise removal, and spectral segment lengths can impact on the spectral slope estimates. Results also evidence an important seasonality of the spectral slope values, with an overall flatter spectrum during the winter months in comparison to summer (slope variations are in the order of 0.5 to 1.5 from one season to the other). Analysis of the error levels also exhibit seasonal variations, which suggests a non-negligible contribution of the local sea-state and dynamical regime to the noise levels.

Corresponding author:
Oscar Vergara (**LEGOS/OMP**, **France**), oscar.vergara@legos.obs-mip.fr

Spectral signatures of the tropical Pacific dynamics from model and altimetry: A focus on the meso/submesoscale range

Lionel Gourdeau (LEGOS/IRD, France); Michel Tchilibou (LEGOS, France); Rosemary Morrow (LEGOS, France); Guillaume Serazin (LEGOS, France); Bughsin Djath (Helmholtz-Zentrum Geesthacht, Germany)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_010

Abstract:
The tropics are distinguishable from mid latitudes by their small Coriolis parameter vanishing at the equator, large Rossby radius, and strong anisotropic circulation. These peculiarities are at the origin of dynamics that strongly respond to the wind forcing through zonally propagating tropical waves, and of a large range of wavenumbers covering meso and submesoscale interactions. The main tropical meso and submesoscales features are associated with Tropical Instability Waves, but coherent vorticity structures span the tropical band. This study aims to infer the dynamics of the tropical Pacific through spectral EKE and SSH analyses. We point out the sensitivity of the spectra in the equatorial belt to the choice of spectral window and the data length. From the 1/12° resolution DRAKKAR global, model frequency-wavenumber EKE spectra, and their corresponding 1D wavenumber are analyzed to illustrate the latitudinal dependence and the degree of anisotropy of the tropical dynamics with a focus on intraseasonal motions and the large meso submesoscale wavenumber range. SSH spectra are analyzed to raise the observability of such dynamics by altimetry. Estimation of altimetric mesoscale slope is revisited to take account of the variable mesoscale range in the tropics but internal waves flatten the altimetric spectra. A regional 1/36° resolution model with and without explicit tides is used to illustrate the shape of the altimetric spectra

Corresponding author:
Lionel Gourdeau (**LEGOS/IRD**, **France**), lionel.gourdeau@legos.obs-mip.fr

Synergetic use of surface drifters and altimetry to increase resolution and accuracy of maps of sea level anomaly in the Gulf of Mexico

Sandrine Mulet (CLS, France); Hélène Etienne (CLS, France); Marie-Hélène Rio (CLS, France); Yannice Faugere (CLS, France); Gérald Dibarboure (CNES, France); Nicolas Picot (CNES, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_011

Abstract:
Strong improvements have been made in our knowledge of the surface ocean geostrophic circulation thanks to satellite observations. However, the synergy of different sources of observation (satellite and in-situ) is mandatory in order to go toward higher resolution. In this study, we combined altimetric along track Sea Level Anomalies (SLA) with velocity estimates from surface drifters to map SLA and associated geostrophic current anomalies in the Gulf of Mexico.
First, an important work is done to pre-process drifter data to extract the geostrophic component of the signal in order to be consistent with physical content of altimetry. This step include estimate and remove of Ekman current, Stokes drift and wind slippage. Two kind of drifters are used:
- Drifters from the HMI Company are processed from 2014 to 2016 (this company, part of CLS group, launches their own drifter in the Gulf of Mexico for their downstream services).
- The drifters launched in the framework of the Lagrangian Submesoscale ExpeRiment (LASER) campaign (January-April 2015) are also processed.
Second, drifters and along track SLA from Jason2, HY2 and Saral are combined through multivariate objective analysis to map a time series of SLA and associated geostrophic current anomalies. Finally, comparisons with independent data (along track SLA from Cryosat2 and drifters) show the better agreement of maps merging both altimetry and drifters than maps using altimetry only.
Corresponding author:
Sandrine Mulet (**CLS**, **France**), sandrine.mulet@cls.fr

Analog data-driven strategies for the reconstruction of altimeter-derived SSH fields

ronan fablet (IMT Atlantique, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_012

Abstract:
Ronan Fablet (1), Redouane Lguensat (1), Phi Huynh Viet (1), Ge Chen (2), Bertrand Chapron (3)

1IMT Atlantique; UMR 6285 LabSTICC, Brest, France
2Ocean University of China, Qingdao, China
3Ifremer: UMR LOPS, Brest, France

Event: 2017 Ocean Surface Topography Science Team Meeting
Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Oral or Poster

Multi-satellite measurements of altimeter-derived Sea Surface Height (SSH) have provided a wealth of information about ocean circulation and atmosphere-ocean interactions. Numerous improvements have been brought to the optimal interpolation of daily SSH fields from along-track data. Yet, horizontal scales below 100km remain mainly unresolved.

In this work, we explore analog data-driven strategies for the reconstruction of SSH fields from along-track altimeter data including possible synergies with other sea surface tracers such as Sea Surface Temperature. Broadly speaking, within a state-space setting, analog strategies rely on matching current observations or states to previously observed or simulated ones to infer the state of interest (here the SSH). Using optimal interpolation as a low-resolution condition, we investigate such analog strategies [e.g., Lguensat et al., 2017] for the reconstruction of the high-resolution component of the SSH fields. This framework may be regarded as a two-scale assimilation model, combining a classical optimal interpolation for the low-resolution component and an analog assimilation for the high-resolution component.

We evaluate and demonstrate the relevance of such analog strategies using an OSSE (Observation System Simulation Experiment) case-study in the China Sea. We report gain in the reconstruction error up to 20%-30% compared with an optimal interpolation. Spectrally, this improvement mainly refers to horizontal scales between 50km and 100km. We further discuss the relevance of the proposed analog strategies for the synergy between high-resolution ocean models and satellite-derived measurements compared with classical data assimilation strategies.

Corresponding author:
ronan fablet (**IMT Atlantique**, **France**), ronan.fablet@imt-atlantique.fr

A new method to detect mesoscale eddies in satellite records

Fabricio Oliveira (Federal University of Rio Grande, Brazil); Paulo Polito (University of Sao Paulo, Brazil)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_013

Abstract:
A significant part of the ocean variability in mesoscale is associated with rings, planetary waves, meanders, and others are known by the generic name eddies. Although this term represents a wide number of different features, here we are focused on mesoscale eddies as fluxes in rotation with spatial scales of hundreds of kilometers and temporal scales from weeks to months. Ocean eddies are particularly important for the transport of momentum, heat, salt and nutrients away from their source because they are patches with properties distinct from that of their surroundings. To clarify which features will be considered eddies in our future analyzes, we defined them as closed instantaneous streamlines roughly circular and relatively persistent. Our proposal is to implement a new methodology to separate the signal of nearly-circular mesoscale eddies that are ubiquitous in a variety of radiometer and altimeter records. The proposed method uses an algorithm based on the Radon transform and its inverse function to detect areas occupied by these eddies. The basic premise of this study is that the inverse Radon transform of a circularly symmetric feature is angle-independent. Therefore, the more constant the Radon transform of an image is, the more circularly symmetric the image is. We are able to quantify how circular a feature observed in a satellite image is and suggest whether it is an eddy or not, based on a geometric criteria. A series of tests with synthetic data were performed to assess the sensibility to spectral content, and aspect ratio detectable by the method. Another sequence of tests was carried with realistic sea surface height data. In this last one five areas of 100 by 50 pixels were selected and filtered with exactly the same algorithm and parameters. The tests were expanded to include data sets of sea surface and chlorophyll-a concentration. All the set of tests indicate that the proposed method was able to identify and track eddies in a single time series of satellite data and in multiple series of different variables. The main advantage of this method in comparison with other automatic ones based on dynamics and geometry or manual methods is its versatility to detect eddies in multiple data sets of different variables. Another point is that, eddies tend to preserve their circular symmetry for dynamical reasons and this is the heart of the proposed method.

Corresponding author:
Fabricio Oliveira (**Federal University of Rio Grande**, **Brazil**), fsoliveira@furg.br

Mesoscale Geostrophic Currents and Optimal SSH Mapping

Kathleen Dohan (Earth and Space Research, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_014

Abstract:
Ocean Surface Current Analyses-Realtime currents (OSCAR, podaac.jpl.nasa.gov) are global ocean surface velocities calculated from sea surface height (SSH) gradients, ocean vector winds, and sea surface temperature fields using geostrophy, Ekman, and thermal wind dynamics. OSCAR uses the SSALTO/Duacs gridded MADT SSH fields (www.aviso.altimetry.fr). OSCAR's geostrophic currents have a strong correlation with drifting buoy velocities in highly geostrophic regions like the Gulf Stream, but even in these regions the amplitude is consistently lower than buoys. We have been using local polynomial fitting mapping methods to investigate the mesoscale and sub-mesoscale signal in altimetry and the effect that using gridded SSH fields has on the calculation of currents. An important feature of local polynomial fitting is the order of fit: a first-order (linear) fit provides the SSH gradients as part of the mapping.

The gridding method allows for a variable choice for the radius of points used for the fit. As the radius of points used in the gridding process is increased there is increased coverage for an individual map but the resulting velocities lose amplitude. Gapless coverage comes at the expense of accuracy and detail. What is interesting is that this gridding effect can explain the discrepancy in amplitude between OSCAR and drifter velocities only in some areas, and the structure of this dependence is regional.

We also have been investigating these mapping methods on SSH fields. Optimal parameters for mapping T/P/J alongtrack data onto a regular grid are determined by sampling a high-resolution numerical model along the satellite tracks, then comparing the mapped fields with the original fields. This is done for a large number of different parameter settings, and shows that first-order fits perform systematically better than a zeroth-order fit, and variable bandwidth performs better than fixed bandwidth. These optimal parameters are then used to generate a prototype open-source mapped altimeter product using only the T/P/J data.

Finally, we explore the impact that the missing mesoscale geostrophic signals in OSCAR have on the circulation.

Corresponding author:
Kathleen Dohan (**Earth and Space Research**, **United States**), kdohan@esr.org

Upcoming high-resolution regional products of Sea Level Anomaly from Dynamic Interpolation

Clement Ubelmann (CLS, France); maxime ballarotta (CLS, France); yannice Faugere (CLS, france); Marine Rogé (LEGOS, france); Rosemary Morrow (LEGOS, france); gérald Dibarboure (CNES, france)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_015

Abstract:
The dynamic interpolation method (Ubelmann et al., 2015) has recently been applied to real along-track data to produce high-resolution gridded maps in regional configurations (Gulf-Stream, Mediterranean, ACC,…). A serie of validations and comparisons against independent data have been conducted to assess the performances with respect to the reference CMEMS gridded maps. If it is sometimes a challenge to outperform in low-energy areas, we found that the mesoscale of instense jets can be significantly improved, revealing new eddies and smoother trajectories. We propose here to present these configurations and validations. Beyond the Gulf-Stream configuration, a serie of regional products will be developed soon to be available on Aviso.

Corresponding author:
Clement Ubelmann (**CLS**, **France**), cubelmann@cls.fr

Rafting behavior of Scopoli's shearwaters: a proxy to describe surface currents in the western Mediterranean Sea?

Antonio Sánchez-Román (IMEDEA (CSIC-UIB), Spain); Evan Mason (IMEDEA (CSIC-UIB), Spain); Laura Gómez-Navarro (Univ. Grenoble Alpes, CNRS, IRD, IGE, France); Ananda Pascual (IMEDEA (CSIC-UIB), Spain); Ronan Fablet (labSTICC, Telecom Bretagne, France); José Manuel Arcos (Sociedad Española de Ornitología, Spain); Daniel Oro (IMEDEA(CSIC-UIB), Spain); Simón Ruiz (IMEDEA (CSIC-UIB), Spain)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_016

Abstract:
The relatively recent development of miniaturized bio-logging devices has allowed the study of fine-scale distribution and behavior of seabirds while they are traveling, feeding or searching for food at sea. However, most of the studies presently available in literature are based on the analysis of long range flights, where birds are travelling at high velocities during long time periods. Conversely, rafting behavior of seabirds has been poorly investigated.

In this work we assess feasibility of rafting behavior of Scopoli's shearwaters to estimate surface currents in the western Mediterranean Sea. These birds habitually rest on the sea surface during their foraging trips along the eastern Spanish mainland coasts, the Balearic Islands coasts and the Balearic Sea in between tending to be passive drifters. The final goal of this work is to contribute to the understanding of marine system's dynamics and their spatio-temporal evolution.

We compare the satellite-derived velocity pattern in the western Mediterranean Sea with the paths followed by Scopoli's shearwaters when they are resting on the sea surface in an attempt to determine whether animal-borne GPS data can be used as a proxy to estimate sea surface currents in the area. Moreover, the outputs of the Cross-Calibrated Multi Platform version 2 (CCMPv2) gridded surface L3 ocean vector wind analysis product are used to investigate both the slippage and Ekman drift of the tracked seabirds. The method uses a speed filter to identify rafting behavior outside of 5 km of the breeding colonies and distinguishes between four different rafting patterns according to the prevailing driving force of the tracks: the local wind, the surface currents, a mixture of both driving forces, or none of the above mentioned.

We found that 76 % of the trajectories (306 drifts) were visually associated with the combined effects of slippage & Ekman drift and/or surface drag; almost 59% of them (180 drifts) were directly driven by the sea surface currents. Therefore, shearwaters were likely to be passively transported by these driving forces while resting. These tracks consistently reconstructed some parts of the mesoscale features observed from satellite data and identified through an eddy-tracker tool.

Corresponding author:
Antonio Sánchez-Román (**IMEDEA (CSIC-UIB)**, **Spain**), asanchez@imedea.uib-csic.es

Evaluating CMEMS forecast model products in the western Mediterranean using altimetry, an eddy tracker, and multiplatform in situ data

Evan Mason (IMEDEA, Spain); Ananda Pascual (IMEDEA, Spain); Simón Ruiz (IMEDEA, Spain); Antonio Sanchez-Roman (IMEDEA, Spain)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_017

Abstract:
Improvements in forecast modelling products require ongoing feedback from users to providers. Here, using gridded altimetric sea surface height as a reference, we assess three such products from CMEMS that cover the western Mediterranean for the period 2013-2016. We report on the mesoscale content of these operational models using standard statistical analysis and a robust eddy tracking tool that uses sea surface height as input. Properties including eddy position, polarity, radius and amplitude are produced for each product; these enable construction of 2D and 3D eddy composites of model prognostic variables such as temperature and salinity. 3D eddy composites in the anticyclonic gyres of the Alboran Sea illustrate the strong fronts that are characteristic of this region. The models that include data assimilation approximate most closely the eddy distributions observed with altimetry. In addition, the CMEMS products are evaluated for specific dates, using along-track altimetry and in situ high-resolution multiplatform observations from different observational experiments carried out recently in the western Mediterranean (e.g., ALBOREX). This study is a contribution to the MedSUB project, funded by Copernicus Marine Service within the Service Evolution 21-SE-CALL1.

Corresponding author:
Evan Mason (**IMEDEA**, **Spain**), evanmason@gmail.com

The DUACS-DT2018 reprocessed sea level time series soon available in CMEMS

Maxime BALLAROTTA (Collecte Localisation Satellites (CLS), France); Guillaume TABURET (Collecte Localisation Satellites (CLS), France); Marine LIEVIN (Collecte Localisation Satellites (CLS), France); Marie-Isabelle PUJOL (Collecte Localisation Satellites (CLS), France); Jean-François LEGEAIS (Collecte Localisation Satellites (CLS), France); Yannice FAUGERE (Collecte Localisation Satellites (CLS), France); Gérald DIBARBOURE (Centre National d'Etudes Spatiales (CNES), France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_018

Abstract:

The DUACS system produces, as part of the Copernicus Marine Environment and Monitoring Service (CMEMS), high quality multimission altimetry Sea Level products for oceanographic applications, climate forecasting centers, geophysic and biology communities... These products consist in directly usable and easy to manipulate Level 3 (along-track cross-calibrated Sea Level Anomaly SLA) and Level 4 (multiple sensors merged as maps or time series) products and are available in global and regional version (Mediterranean Sea, Arctic, European Shelves …).

A full reprocessing is carried out almost every 3 years based on the state-of-the-art Level 2 to Level 4 algorithms. Early next year, a new version will be available through the CMEMS catalogue. It will cover the entire 1993 – 2016 period and would benefit from major improvements associated with new altimeter and mapping standards.

Here, we report the first results of this upcoming multi-mission reprocessing. We present the DUACS-DT2018 reprocessing and evaluate the changes associated with the new standards. Several comparisons with independent dataset (along-track, drifters, tide gauges) show that the new altimeter standards participate in up to 5% improvements of the SLA mapping mainly near coastal areas and at high latitude compared with the DUACS-DT2014 dataset. The new mapping standards contribute to ~2% improvement mainly in the inter-tropical band and in high variability regions. Additionally, we found that the mesoscale scale structures are particularly improved in the regional Mediterranean Sea product.

Corresponding author:
Maxime BALLAROTTA (**Collecte Localisation Satellites (CLS)**, **France**), mballarotta@cls.fr

Impact of the assimilation of high-frequency data in a regional model with high resolution

Mounir Benkiran (mercator-ocean, France); Elisabeth Remy (Mercator-ocean, France); Guillaume Reffray (Mercator-Ocean, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_019

Abstract:
Impact of the assimilation of high-frequency data in a regional model with high resolution

Mounir Benkiran, Elisabeth Rémy and Guillaume Reffray

MERCATOR Ocean 8-10 Rue Hermes 31526 Ramonville St Agne Cedex

Abstract

Mercator-Ocean has developed a regional forecasting system at 1/36° (~3km) resolution over the North East Atlantic (IBI: Iberia, Biscay and Irish), taking advantage of the recent developments in NEMO. The model was forced by ERA-interim products (every 3 hours) including the atmospheric pressure. In addition to atmospheric forcing, the model includes astronomical tidal forcing. This regional forecasting system uses boundary conditions from the Mercator-Ocean regional system (with data assimilation, 1/12° resolution, PSY4). The assimilation component of the Mercator Ocean system, is based on a reduced-order Kalman filter (the SEEK or Singular Extended Evolutive Kalman filter). An IAU method (Incremental Analysis Updates) is used to apply the increments in the system. A 3D-Var scheme corrects for the slowly evolving large-scale biases in temperature and salinity. The data assimilation system allows to constrain the model in a multivariate way with Sea Surface Temperature (AVHRR + Multi-satellite High resolution), together with all available satellite Sea Level Anomalies, and with in situ observations from the CORA-04 data base, including ARGO floats temperature and salinity measurements. The background SLA field accounts for the high frequency signal determined by the model and the forcing by atmospheric pressure.
In this study we show the impact of the assimilation of altimetry data unfiltered and uncorrected from fast atmospheric frequencies. Altimetry data assimilated contain the effect of atmospheric pressure and wind unlike conventional data used in operational systems.

Corresponding author:
Mounir Benkiran (**mercator-ocean**, **France**), mbenkiran@mercator-ocean.fr

Validation of the GlobCurrent surface current products in Australia

Mathilde Cancet (NOVELTIS, France); David Griffin (CSIRO, Australia); Madeleine Cahill (CSIRO, Australia); Bertrand Chapron (IFREMER, France); Johnny Johannessen (NERSC, Norway); Craig Donlon (ESA/ESTEC, The Netherlands)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_020

Abstract:
The surface ocean current products (GlobCurrent, OSCAR, AVISO, CTOH…) are generally mainly based on the geostrophic and the Ekman contributions derived from altimetry and wind observations, respectively. However, the ocean tides are often one of the main contributors to the ocean currents on the shelves. Ignoring this contribution in the total surface currents can lead to errors of several cm/s in the surface current estimates, in some regions.
The East Australian Current (EAC), a strong geostrophic structure that flows southward along the Australian eastern coast, and the wide range of tidal regimes ranging from macro-tidal to micro-tidal that characterizes the Australian continental shelf both provide ideal conditions to thoroughly test the GlobCurrent surface current products. In addition, for more than 10 years Australia has been maintaining a network of about 50 ADCP instruments all around the country, principally through its government-supported Integrated Marine Observing System (IMOS). Finally, a large number of drifting buoys have been launched in the EAC region for more than 15 years and the observations are made available by NOAA/AOML.
This paper presents an assessment of the GlobCurrent products against IMOS current meter data and drifting buoys observations in Australia. First, the consistency between the GlobCurrent products and the in situ observations was evaluated on the EAC geostrophic structure, close to the coast and offshore. Second, an evaluation of the ocean current signal that is missed in the GlobCurrent products because of the tides was done in the wide Joseph Bonaparte Gulf, where the tidal currents can reach more than 1 m/s and represent more than 50% of the ocean surface currents in the region.
Corresponding author:
Mathilde Cancet (**NOVELTIS**, **France**), mathilde.cancet@noveltis.fr

24 year mesoscale eddy trajectory atlas on AVISO

Antoine Delepoulle (CLS , France); Michael Schlax (OSU, USA); Dudley Chelton (OSU, USA); Yannice Faugere (CLS, France); Gerald Dibarboure (CNES, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_021

Abstract:
A new “Mesoscale Eddy Trajectory Atlas" was released in July 2017 on the Aviso altimetry portal. This dataset was produced and validated by CLS in collaboration with D. Chelton and M. Schlax from Oregon State University. It replaces the dataset formerly produced and distributed at OSU, and is now run and regularly updated by the SSALTO/DUACS team.

The current version of the eddy atlas was produced from 24 years of daily altimetry maps of SSH based on sampling by two satellites. In addition to the locations of the detected eddies along their trajectories, the atlas includes additional information about the amplitude, rotational speed, radius, and eddy type (cyclonic/anticyclonic). The file format is derived from the NetCDF format formerly used by OSU.

This poster will summarize the methodology and the improvements added in this new version of the eddy dataset, and will describe the associated assessment results, including the impacts with respect to previous releases.

Corresponding author:
Antoine Delepoulle (**CLS** , **France**), adelepoulle@cls.fr

Long-range correlations in altimetric sea level anomaly associated with long-living mesoscale eddies

Christopher Roach (CSIRO, Australia); Nikolai Maximenko (IPRC/SOEST, University of Hawaii, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_022

Abstract:
In this study we analyze the effects of mesoscale eddies on the statistics of sea level anomaly (SLA), measured by satellite altimeters. The recent discovery of long-living eddies suggests significant correlations on larger spatiotemporal scales than was assumed in the production of gridded SLA products.

We verify this effect by demonstrating that the energy of SLA signal in the gridded AVISO product is systematically higher in proximity to satellite tracks both in space and time.
Chelton's eddy dataset was used to calibrate filters, which were then used to extract eddy-scale signals from along-track SLA data. These series were used to calculate spatiotemporal correlations and to characterize propagation speed as well as temporal and spatial decorrelation scales in the Eulerian framework.

The resulting eddy statistics are discussed in different parts of the North Pacific and compared with other available eddy products.

Corresponding author:
Christopher Roach (**CSIRO**, **Australia**), dr.c.j.roach@gmail.com

Offshore transport of POC in the California Current System due to mesoscale eddies

Caitlin Amos (University of Georgia, United States); Renato Castelao (University of Georgia, United States)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_023

Abstract:
Nonlinear mesoscale eddies can have a significant impact on the distribution of organic materials throughout the world's ocean. In the California Current System (CCS), high particulate organic carbon (POC) concentrations found in near shore waters can be horizontally and vertically advected by eddies. Using satellite measurements of ocean color to estimate surface POC, this study quantifies the influence of eddies in the CCS on the offshore transport of POC. In the CCS, cyclonic eddies generally move westward and are characterized by positive POC anomalies. Offshore of 300 km from the coast, cyclonic eddies generated inshore of 300 km have higher POC concentrations on average than eddies generated offshore, indicating that eddies play an important role in redistributing POC into offshore regions.
Corresponding author:
Caitlin Amos (**University of Georgia**, **United States**), cma08462@uga.edu

Physical and Biological Implications of Agulhas Eddy Signatures

Sheekela Baker-Yeboah (University of Maryland and NOAA/NESDIS/STAR/Satellite Oceanography and Climatology Division, United States); Deirdre Byrne (Department of Environmental Affairs, Cape Town, South Africa, South Africa); Eric Leuliette (NOAA/NESDIS/STAR/Satellite Oceanography and Climatology Division, College Park, MD, USA); Paul DiGiacomo (NOAA/NESDIS/STAR/Satellite Oceanography and Climatology Division, College Park, MD, USA); Jessica Burns (Global Science and Technology, Inc. and NOAA/NESDIS/STAR/Satellite Oceanography and Climatology Division, USA)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_024

Abstract:
A strong agreement exists between sea-level variability from alongtrack-gridded altimeter sea surface height (SSH) data and in situ pressure sensor–equipped inverted echo sounder (PIES) data. Variability in sea surface height (SSH) can be decomposed into a barotropic and baroclinic contributions: one from changes in mass in the water column (barotropic) and the other from purely steric changes (baroclinic) (Baker-Yeboah, Watts, and Byrne, 2010). These signals are combined when viewed in altimeter data. Using the strong correlation between altimeter and PIES data---based on previous PIES signals---along the eddy corridor where Agulhas rings pass, carrying cores of Indian Ocean water into the South Atlantic, an analysis is done using current altimeter data and VIIRS Ocean Color data to gain further insight into the physical and biological implications of mesoscale eddies associated with Agulhas rings off of South Africa. The sea surface variability along with the coastal signatures will be presented. Useful applications from the Surface and Water Ocean Topography mission will also be discussed.

Corresponding author:
Sheekela Baker-Yeboah (**University of Maryland and NOAA/NESDIS/STAR/Satellite Oceanography and Climatology Division**, **United States**), sheekela.baker-yeboah@noaa.gov

Measuring currents, ice drift, and waves from space: \\ the Sea Surface KInematics Multiscale monitoring (SKIM) concept

Fabrice Ardhuin (LOPS, France); Yevgueny Aksenov (NOC, UK); Alvise Benetazzo (ISMAR, Italy); Laurent Bertino (NERSC, Norway); Peter Brandt (GEOMAR, Germany); Eric Caubet (TAS, France); Bertrand Chapron (LOPS, France); Fabrice Collard (ODL, France); Sophie Cravatte (LEGOS, France); Team SKIM (many affiliations, world); Justin Stopa (LOPS, France); Clement Ubelmann (CLS, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_025

Abstract:
The Sea surface KInematics Multiscale monitoring mission (SKIM) has been proposed for ESA Earth Exporer 9, and its evaluation is under way. SKIM will open the era of satellite Doppler oceanography, combining nadir and near-nadir radar measurements. It will measure total ocean surface velocity vector (primary goal), using a Doppler technique that is more direct than altimetry for accessing surface currents, and ocean wave spectra (secondary goal). Planned as a five-year explorer experiment, this mission will address central questions for the understanding of our evolving climate, from the tropical current systems, to the rapidly evolving Arctic marginal ice zone. SKIM will demonstrate the maturity of Doppler oceanography, and pave the way for future Doppler missions. The proposed mission uses a high-resolution Ka-band Doppler altimeter, measuring at nadir and rotating off-nadir beams (0, 6 and 12° incidence angles). The expected accuracy on horizontal current velocity is 0.1 m/s, at a resolution of about 40 km. Flying on the 12 day-cycle Sentinel 1 (S1) orbit with a shift in longitude, SKIM will have a swath of 270 km that will allow overlap with S1 data and an ideal synergy for currents and wave sampling. SKIM will cover the world ocean up to 82° N, with daily coverage at latitudes beyond 70°, and an average of three passes per cycle at the Equator. This includes the Southern Ocean and both Arctic and Antarctic marginal seas. SKIM will image ocean current features, including eddies of diameter 80 km and more, a considerable extension of planned satellite altimeter missions capabilities. SKIM will also provide directional wave spectrum down to wavelengths of 20 m, and full azimuth coverage without direction ambiguity: these two aspects are clear improvement on existing and planned missions, giving a global coverage of oceans and regional seas.

In the context of satellite altimetry such a mission would be a unique opportunity to measure details of the sea state bias thanks to the measurement of the full ocean wave spectrum. SKIM will demonstrate that future altimetric missions can be modified to measure both sea level at nadir and currents over a swath, giving access to much smaller scales of the ocean dynamics. Efforts are under way to refine the error budget for SKIM ahead of a possible phase A in 2018. More details can be found in Ardhuin et al. (2007, doi:10.5194/os-2017-65). A particular concern is the wave-induced bias on the measured Doppler velocity. A preliminary analysis of simulated data and Ka-band measurements from a research platform support the 0.1 m/s accuracy for a 40 km pixel.

Corresponding author:
Fabrice Ardhuin (**LOPS**, **France**), ardhuin@ifremer.fr

Characterizing mesoscale eddies in the Bay of Bengal: Relative performance of Nadir versus Swath Altimeter

Neeraj Agarwal (ISRO, India); Aditya Chaudhary (ISRO, India); Jishad M (ISRO, India); Rashmi Sharma (ISRO, India)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_026

Abstract:
Bay of Bengal is dominated by mesoscale and sub-mesoscale eddies. These eddies transport heat and freshwater flux from one region to another. Identification and tracking of these eddies is important in near real time for several useful applications such as marking the potential fishing zones, cyclone track and intensity prediction, oil spill etc. Conventional nadir looking altimeters make along track measurements on a line and mapped sea surface height (SSH) information obtained using a combination of several such altimeters (Jason, SARAL, Cryosat etc.) have lot of uncertainty and missing sub-mesoscale variability because of this limited swath. NASA's surface water and ocean topography (SWOT) mission which is based on radar interferometery is scheduled to be launched in 2020. This will measure SSH along wide swath thus providing detailed ocean information. This study aims to evaluate the performance of SWOT and nadir looking altimeters in characterization of the mesoscale eddies in the Bay of Bengal. For this purpose, SSH fields simulated from a very high resolution numerical model for the Bay of Bengal have been used and the swot-simulator tool is used to simulate these fields on the SWOT as well as different nadir looking altimeter tracks. The study involves three steps, first, the track data from swot-simulator is used to generate gridded fields using optimum interpolation method for both SWOT and nadir altimeters (in a combination of one, two and three altimeters). In the second step, comparison of gridded product from SWOT with the product from constellation of nadir altimeters is carried out. Spectral analysis of both the products show that SWOT has definite advantage over conventional altimeters in representing realistic SSH variability, although, a combination of three nadir looking altimeters performs slightly better in representing mesoscale eddies. In the third step, mesoscale eddies are tracked and analysed in both nadir looking and SWOT altimeter gridded product. An analysis on life cycle, size and amplitude of the eddies is carried out and the results are compared with reference which is the analysis on the direct model output. The study will highlight the relative performance of swath and nadir looking altimeters in characterization of mesoscale eddies in the Bay of Bengal. Detailed results will be presented in the meeting.

Corresponding author:
Neeraj Agarwal (**ISRO**, **India**), neeraj@sac.isro.gov.in

On the spatial scale resolved by the future SWOT KaRIN measurement over the ocean

Jinbo Wang (Caltech/JPL, United States); Lee-Lueng Fu (Caltech/JPL, USA)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_027

Abstract:
The Surface Water and Ocean Topography (SWOT) mission aims to measure the sea surface height (SSH) at a high spatial resolution using Ka-band Radar Interferometer (KaRIN). The primary oceanographic objective is to characterize the ocean eddies at a spatial resolution of 15 km for 68% of the ocean. This resolution is derived from the signal to noise ratio between the wavenumber spectrum of the conventional altimeter (projected to submesoscale) and the SWOT SSH errors. While the 15km threshold is useful as a global approximation of the spatial scales resolved by SWOT (SWOT-scale), it can be misleading for regional studies. Here we revisit the problem using a high-resolution (~2km) tide-resolving global ocean simulation and map the SWOT-scale as a function of latitude-longitude and season. The results show that the SWOT-scale has a strong geographic and seasonal dependence. In general, it is smaller (<15km) in low latitudes, increases to ~30km in mid-latitudes; and is larger in local winter than in summer. Internal gravity waves and internal tides have a significant contribution to the scale variation. These characteristics provide a guideline for interpreting the satellite fidelity with ocean physics in consideration, which in turn sheds light on developing the future SWOT data assimilation system.

Corresponding author:
Jinbo Wang (**Caltech/JPL**, **United States**), Jinbo.Wang@jpl.nasa.gov

Impact of Swot altimetry missions to Ocean analysis and forecast system

Mounir Benkiran (mercator-ocean, France); Elisabeth Remy (Mercator-ocean, France); Yann Drillet (Mercator-Ocean, France); Pierre-Yves Le Traon (Mercator-Ocean / IFRMER, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_028

Abstract:
Impact of Swot altimetry missions to Ocean analysis and forecast system

M. Benkiran(1), E. Remy(1), Y. Drillet and P.Y. Le Traon(1,2)
(1) Mercator-ocean Toulouse (2) IFREMER, Brest

In Mercator-Ocean analysis and forecasting systems we assimilate along track sea level anomalies from conventional altimetry missions (Jason2, Envisat, SARAL / Alti-ka, Cryosat-2 ...). Here we will test the assimilation of a new data such as the one that will be provided by the future SWOT mission. The SWOT mission will allow us to obtain for the first time altimetry measurements at high resolution on a swath. It is a mission with great technological and scientific issues.
In this study, an OSSE baseline was used to underline the observing capability of an altimeter constellation including SWOT to better sample mesoscale and submesoscale ocean signal in an assimilation context. A regional assimilation system developed within the team Mercator-Ocean is used for this study. This system is based on a regional model covering the Iberia-Biscay-Ireland region (IBI) at high-resolution (~ 7km) and the assimilation system SAM2 used in Mercator-ocean. The simulated data sets used for these experiments were extracted from the outputs of a higher resolution model NEMO-NATL60 with 1/60° (North Atlantic simulation from LGGE team, Grenoble; Le Sommer & al.). We highlight the improvement of the analysis and prediction scores thanks to the assimilation of the large swath SWOT observations compared to a constellation of conventional nadir altimeters only.
Corresponding author:
Mounir Benkiran (**mercator-ocean**, **France**), mbenkiran@mercator-ocean.fr

Realistic SSH scenes for preparing SWOT: the NATL60 1/60° North Atlantic Ocean simulations

Julien Le Sommer (IGE, CNRS, France); Laurent Brodeau (Ocean Next, France); Jean-Marc Molines (IGE, CNRS, France); Nicole Audiffren (CINES, France); Aurélie Albert (IGE, CNRS, France); Adekunle Ajayi (IGE, Univ. Grenoble Alpes, France); Emmanuel Cosme (IGE, Univ. Grenoble Alpes, France); Stéphanie Leroux (Ocean Next, France); Thierry Penduff (IGE, CNRS, France); Bernard Barnier (IGE, CNRS, France); Jacques Verron (Ocean Next, France); Pierre Brasseur (IGE, CNRS, France)

Session: Science III: Mesoscale and sub-mesoscale oceanography
Presentation type: Poster
Poster number: SC3_029

Abstract:
The upcoming Surface Water and Ocean Topography (SWOT) satellite mission will provide an opportunity for better understanding ocean surface processes at scales <100km, and their impact on larger scale oceanic flow features. To achieve the above scientific objectives of the mission, specific inversion techniques will be designed to estimate two-dimensional maps of SSH and 3D ocean surface fields from SWOT data. The preparation of such inversion techniques not only requires knowledge of the sampling and errors, but also requires information about typical SSH scenes that will be measured during the mission. This is why several efforts have been undertaken in the SWOT Science Team to produce realistic submesoscale-permitting ocean circulation model-based datasets that provide virtual observational scenes to SWOT science projects. In this poster, we will report on one such dataset, which covers the North Atlantic Ocean from mid to high latitudes. The dataset is based on a NEMO ocean model configuration, NATL60, which is run at 1/60° horizontal resolution (~1km) with 300 vertical levels. This poster will describe the design rationale and the setting of the NATL60 model configuration. The latest distributed dataset will be described and evaluated in terms of large scale circulation patterns and large scale hydrography. The evaluation of the resolved fine scale variability, and fine scale velocity gradients, will also be presented, showing in particular that the gradients of surface flows are statistically consistent with mooring observations down to the model effective resolution at 10km scale. The poster will also provide information about data availability and future evolutions of NATL60 configuration.

Corresponding author:
Julien Le Sommer (**IGE, CNRS**, **France**), Julien.Lesommer@univ-grenoble-alpes.fr

Results from GOCE++ Dynamical Coastal Topography and tide gauge unification using altimetry and GOCE

Ole Baltazar Andersen (DTU Space, Elektrovej 328, DK-2800 lyngby Denmark, Denmark); Per Knudsen (DTU Space, Elektrovej 328, DK-2800 lyngby Denmark, Denmark); Karina Nielsen (DTU Space, Elektrovej 328, DK-2800 lyngby Denmark, Denmark); Christopher Hughes (University of Liverpool (NOC), , UK); Phil Woodworth (University of Liverpool (NOC), , UK); Michael Kern (ESA ESTEC, Noordwejk, The Netherlands); Luciana Fenoglio-Marc (TU Bonn, Germany); Rory Bingham (University of Bristol, UK); Mederic Gravelle (University La Rochelle, LIENS, France); Guy Woppelman (University La Rochelle, LIENS, France)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_001

Abstract:
ESA is currently supporting a study on the investigation and using ocean levelling as a novel approach to the study of height system unification across the oceans taking the recent development in geoid accuracy through GOCE data into account.
The suggested investigation involves the use of measurements and modelling to estimate Mean Dynamic Topography (MDT) of the ocean along a coastline, which contributes/requires reconciling altimetry, tide gauge and vertical land motion. Close to the coast the determination of the MDT is problematic due to i.e., the altimeter footprint, land motion or parameterization/modelling of coastal currents.
The objective of this activity is to perform a consolidated and improved understanding and modelling of coastal processes and physics responsible for sea level changes on various temporal/spatial scales. The study runs from October 2015 to march 2017 and involves the following elements
Develop an approach to estimate a consistent DT at tide gauges, coastal areas, and open ocean; Validate the approach in well-surveyed areas where DT can be determined at tide gauges; Determine a consistent MDT using GOCE with consistent error covariance fields; improving altimetry (SAR) along the coast for MSS/MDT improvement and finally connecting the global set of tide gauges and investigate trends

Corresponding author:
Ole Baltazar Andersen (**DTU Space, Elektrovej 328, DK-2800 lyngby Denmark**, **Denmark**), oa@space.dtu.dk

Geomed2: gravimetric versus combined geoid model

Sean Bruinsma (CNES, France); Marie-Helene Rio (CLS, France); Franck Reinquin (CNES, France)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_002

Abstract:
The GEOMED 2 project aims at the determination of a high-accuracy and resolution marine geoid model based on the availability of improved models for gravity, thanks to GRACE and GOCE in particular, for land topography and bathymetry, and the compilation of a cleaned-up gravity database of the Mediterranean area based on BGI and SHOM data. GEOMED 2 uses land and marine gravity data, the latest satellite-only and combined GOCE/GRACE based Global Geopotential Models and a combination of MISTRALS, EMODnet and SRTM/bathymetry terrain models in the geoid computation. Computation of a gravimetric geoid of the Mediterranean Sea is challenging due to:

- marine gravity data coverage is poor over several parts of the Med;
- quality of the marine gravity data is not homogeneous (bias, precision);
- data reduction is not at the level achieved over land.

Marine gravity data is not available for large parts of the Mediterranean and consequently a gravimetric geoid solution will be significantly less accurate there. Gravity inferred from altimetry data, or a mean sea surface corrected for mean dynamic topography (i.e., an 'oceanographic' geoid model), can be used to fill the gaps. However, ocean dynamic signal always contaminates the derived gravity or geoid, which is why a pure gravimetric solution is preferred.
The effect on the geoid solution of using several altimeter-based datasets, such as DTU10, DTU15 and UCSD V24 gravity, in weighted combinations with the gravimetric data will be evaluated and quantified. To that purpose, test models will be constructed and compared to a gravimetric geoid solution. The (local) uncertainty due to the data gaps, and the subsequent uncertainty in the ocean mean dynamic topography and geostrophic currents, can be estimated via the results of all comparisons. All models are equally compared to drifter-inferred current velocities, which constitutes an independent quality evaluation. This type of evaluation leads to a very detailed quality assessment of the models, notably as a function of spatial scale.

Corresponding author:
Sean Bruinsma (**CNES**, **France**), sean.bruinsma@cnes.fr

A new OGMOC mean dynamic topography model – DTU17MDT.

Per Knudsen (DTU Space, Denmark); Ole Andersen (DTU Space, Denmark); Nikolai Maximenko (IPRC U Hawaii, USA); Thomas Fecher (TU Munich, Germany); Thomas Gruber (TU Munich, DenGermanymark)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_003

Abstract:
Within the ESA supported Optimal Geoid for Modelling Ocean Circulation (OGMOC) project a new geoid model have been derived. It is based on the GOCO05C setup though the newer DTU15GRA altimetric surface gravity has been used in the combination. Subsequently the model has been augmented using the EIGEN-6C4 coefficients to d/o 2160.
The new DTU17MDT has been derived using this new geoid model and the DTU15MSS mean sea surface. Compared to other geoid models the new OGMOC geoid model has been optimized to avoid striations and orange skin like features. Finally, the filtering was re-evaluated by adjusting the quasi-gaussian filter width to optimize the fit to drifter velocities. The results show that the new geodetic MDT improves the resolution of the details of the ocean circulation.

Corresponding author:
Per Knudsen (**DTU Space**, **Denmark**), pk@space.dtu.dk

GOCE User Toolbox and Tutorial.

Per Knudsen (DTU Space, Denmark); Jerome Benveniste (ESA-ESRIN, Italy)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_004

Abstract:
The GOCE User Toolbox GUT is a compilation of tools for the utilisation and analysis of GOCE Level 2 products.GUT support applications in Geodesy, Oceanography and Solid Earth Physics. The GUT Tutorial provides informationand guidance in how to use the toolbox for a variety of applications. GUT consists of a series of advancedcomputer routines that carry out the required computations. It may be used on Windows PCs, UNIX/Linux Workstations,and Mac. The toolbox is supported by The GUT Algorithm Description and User Guide and The GUTInstall Guide. A set of a-priori data and models are made available as well. Without any doubt the developmentof the GOCE user toolbox have played a major role in paving the way to successful use of the GOCE data foroceanography.

The GUT version 2.2 was released in April 2014 and beside some bug-fixes it adds the capability for the computation of Simple Bouguer Anomaly (Solid-Earth). During this fall a new GUT version 3 has been released. GUTv3 was further developed through a collaborative effort where the scientific communities participate aimingon an implementation of remaining functionalities facilitating a wider span of research in the fields of Geodesy,Oceanography and Solid earth studies.Accordingly, the GUT version 3 has:
- An attractive and easy to use Graphic User Interface (GUI) for the toolbox,
- Enhance the toolbox with some further software functionalities such as to facilitate the use of gradients,anisotropic diffusive filtering and computation of Bouguer and isostatic gravity anomalies.
- An associated GUT VCM tool for analyzing the GOCE variance covariance matrices.

Corresponding author:
Per Knudsen (**DTU Space**, **Denmark**), pk@space.dtu.dk

State-of-the-Art Mean Sea Surface and Geoid Model assessment in the Arctic and implications for Sea Ice Freeboard Retrieval

Henriette Skourup (DTU Space, Elektrovej 328 , Denmark); Ole Baltazar Andersen (DTU Space, Elektrovej, 328 DK-2800 , Denmark); Sinead L. Farrell (NOAA Center for Weather and Climate Prediction, College Park, MD, USA, USA); Stefan Hendricks (DTU Space, Elektrovej 328 , Germany); Thomas W. K. Armitage (CPOM University College London, UK, UK); Ridout Andy (CPOM University College London, UK, UK); Haas Christian (York University, Toronto, Ontario, Canada, Canada); Baker Steven (Mullard Space Science Laboratory, University College London, UK, UK)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_005

Abstract:
State-of-the-art Arctic Ocean mean sea surface (MSS) models and global geoid models (GGMs) are used to support sea ice freeboard estimation from satellite altimeters, as well as in oceanographic studies such as mapping sea level anomalies and mean dynamic ocean topography. However, errors in a given model in the high frequency domain, primarily due to7 unresolved gravity features, can result in errors in the estimated along-track freeboard. These8 errors are exacerbated in areas with a sparse lead distribution in consolidated ice pack conditions. Additionally model errors can impact ocean geostrophic currents, derived from satellite altimeter data, while remaining biases in these models may impact longer-term, multi-sensor oceanographic time-series of sea level change in the Arctic. This study focuses on an assessment of five state-of-the-art Arctic MSS models (UCL04/13, DTU15/13/10) and a commonly used GGM (EGM2008). We describe errors due to unresolved gravity features, inter- satellite biases, and remaining satellite orbit errors, and their impact on the derivation of sea ice freeboard. The latest MSS models, incorporating CryoSat-2 sea surface height measurements, show improved definition of gravity features, such as the Gakkel Ridge. The standard deviation between models ranges 0.03-0.25 m. The impact of remaining MSS/GGM errors on freeboard retrieval can reach several decimetres in parts of the Arctic.

Corresponding author:
Henriette Skourup (**DTU Space, Elektrovej 328** , **Denmark**), hsk@space.dtu.dk

Global and regional evaluation of recent Mean Sea Surfaces using the first year of Sentinel-3 data and impact for updating the DTU15MSS

Heidi Villadsen (DTU Space, Elektrovej bldg 328, 2800 Kongens Lyngby, Denmark); Ole Andersen (DTU Space, Elektrovej bldg 328, 2800 Kongens Lyngby, Denmark); Lars Stenseng (DTU Space, Elektrovej bldg 328, 2800 Kongens Lyngby, Denmark); Per Knudsen (DTU Space, Elektrovej bldg 328, 2800 Kongens Lyngby, Denmark)

Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_006

Abstract:
Sentinel-3 offers independent SAR altimetry along new groundtracks and can hence provide independent evaluation of existing mean sea surfaces. We perform an evaluation of the recent available mean sea surfaces using one year of 1 Hz Sentinel-3A data taking into account the shift in temporal average and coverage. Seninel-3A will cover 2016/2017 with a temporal average around January 2017, whereas e.g., the DTU15MSS is an average of altimetry from 1993-2012 with an averaging median year in 2003. Hence, recent models for sea level changes must be introduced in order to account for 14 years of sea level changes which can regionally contribute with a signal on the decimeter scale. The low SAR instrumental noise allows for a relatively smooth mean profile computation with only one year of data.

Subsequently a more detailed coastal evaluation of the Mean sea surface models in the North Sea and Danish waters are performed by using the 20 Hz Sentinel 3 data to study the impact of SAR altimetry on short wavelength Mean sea surface determination. Due to the difference between LRM and SAR wavelength shorter than 100 km important for coastal signal mapping is better determined using SAR altimetry than with conventional altimetry which is the base for most current mean sea surfaces.
The evaluation of the possible residual SLA signal along Sentinel tracks can be used for updating the DTU15 MSS and be introduced into the DTU18MSS based on 25 years altimetry to be released in 2018.

Corresponding author:
Heidi Villadsen (**DTU Space, Elektrovej bldg 328, 2800 Kongens Lyngby**, **Denmark**), hvil@space.dtu.dk

Experiments with tidal analysis and assimilation of CryoSat-2 altimetry in the Weddell Sea and on adjoining ice shelves

Edward Zaron (Portland State University, United States)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_001

Abstract:
Altimeter data from the CryoSat-2 mission have been used to map ocean tides in the Weddell Sea and on the Larsen and Filchner-Ronne Ice Shelves. The orbit of CryoSat-2 was not designed to observe tides, but usefully accurate estimates of the M2, S2, K1, and O1 tides have been obtained by spatially-coupled harmonic analysis which locally represents the tidal elevation as the product of temporal tidal harmonics with spatial basis functions. Analysis of the CryoSat-2 orbit from the point of view of space- and time- aliasing and resolution will be presented, as will issues related to the mean surface and treatment of off-nadir returns from SARin mode data. Comparison of published GPS-based estimates with the empirical CryoSat-2 tide maps finds agreement comparable to that of previous data assimilative tide models. The amplitudes of the annual and semiannual cycles on the ice shelf, but not open-ocean, are much larger than observed by GPS. It is hypothesized that the apparent cycle at these periods is related to snow depth or radar penetration of snow and ice, rather than ice sheet elevation level per se. The purpose of obtaining new tide estimates from CryoSat-2 is to assimilate them into an inverse model for the shape and depth of the under-ice cavities adjoining the Weddell Sea, and the status of this effort will also be reported.

Corresponding author:
Edward Zaron (**Portland State University**, **United States**), ezaron@pdx.edu

Towards further improving DTU global ocean tide model in shallow waters and Polar Seas

Yongcun Cheng (Center for Coastal Physical Oceanography, Old Dominion University, United States);
Ole B. Andersen (DTU Space, Danish National Space Center, Technical University of Denmark, Denmark)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_002

Abstract:
Motivated by the widely applications of the empirical global ocean tide model DTU10 (1/8°×1/8°) to real world, particularly in shallow waters and Arctic Ocean, an updated model DTU16 representing all major diurnal and semidiurnal tidal constituents was developed based on FES2012 model with residual tides calculated using response analysis method. The spatial resolution of the DTU tide model was promoted to 1/16°×1/16°. All available TOPEX, Jason-1, OSTM/Jason-2 (Ocean Surface Topography Mission) primary (data up to June 2016) and tandem missions were used to develop the new model. To decrease the discrepancies between model and in-situ measurements estimated S2 tide constituent, the ERA-Interim model was selected for altimetry data dry tropospheric correction. The updated global ocean tide model was assessed and inter-compared with existing state-of-the-art global ocean tide modes against 10 tide gauge data sets in deep water, coastal regions, shelf water and marginal seas. The new model presented the lowest Root Mean Square in shallow waters (e.g., European Shelf, particularly for S2 tide) and coast regions (e.g., East Asian Marginal Seas). In the Arctic Ocean, Compared with DTU10, further improvements were achieved by adding ERS-1 and introducing new altimetric data from Saral/Altika.

Corresponding author:
Yongcun Cheng (**Center for Coastal Physical Oceanography, Old Dominion University**, **United States**), yccheng.en@gmail.com

Improvement of the Arctic Ocean Bathymetry and Regional Tide Atlas – first results from the CP4O initiative

Ole Baltazar Andersen (Dr, Denmark); Mathilde Cancet (NOVELTIS, France , France); David Cotton (SatOC,, United Kingdom); Jerome Benveniste (ESA ESRIN, Frascati, Italy)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_003

Abstract:
CryoSat Plus for Oceans (CP4O) is a project under the ESA STSE program which aims to develop and evaluate new ocean products from CryoSat data and so maximize the scientific return of CryoSat over oceans. The main focus of CP4O has been on the additional measurement capabilities that are offered by the SAR mode of the SIRAL altimeter, with further work in developing improved geophysical corrections.
The Arctic Ocean is a challenging region, because of its complex and not well-documented bathymetry, together combined with the intermittent presence of sea ice and the fact that the in situ tidal observations are scarce at such high latitudes. The current 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 88N. Subsequently the project progresses to use Cryosat-2 in TWO ways for improved ocean tide modelling in the Arctic Ocean. One is to use Cryosat-2 improved bathymetry, the second is to use Cryosat-2 derived harmonic tidal constituents for assimilation into a regional tide model.
The first evaluation of existing bathymetry in the Arctic (R-TOPO2, IBCAO etc) will be described in this presentation along with the methodology to derive bathymetry from high resolution gravity. With improved gravity being the basis for improved bathymetry we present the first gravity results from DTU17 in the Arctic ocean and evaluate this against existing marine data sources.

The first evaluate of existing bathymetry in the Arctic (R-TOPO2, IBCAO etc) will be performed in this presentation along with the methodology to derive bathymetry from high resolution gravity. With improved gravity being the fundament for improved bathymetry we present the first gravity results from DTU17 in the Arctic ocean and evaluate this against existing marine data sources.

Corresponding author:
Ole Baltazar Andersen (**Dr**, **Denmark**), oa@space.dtu.dk

Improving the Dynamic Atmospheric Correction for delayed-time and real-time applications of altimetry

Loren Carrere (CLS, France); Florent Lyard (LEGOS/CNRS, FRANCE); Yannice Faugere (CLS, FRANCE); Romain Baghi (CLS, FRANCE); Jean-Michel Lachiver (CNES, FRANCE); Nicolas Picot (CNES, FRANCE)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_004

Abstract:

Improving the Dynamic Atmospheric Correction for delayed-time and real-time applications of altimetry

L. Carrère1, F. Lyard2, Y. Faugère1, R. Baghi1, J.M. Lachiver3, N. Picot3
1 CLS, Space Oceanography Division, Toulouse, France. lcarrere@cls.fr
2 LEGOS, OMP Toulouse, France
3 CNES, Toulouse, France

Given its current accuracy and maturity, altimetry is considered a fully operational observing system dedicated to various applications such as operational oceanography and climate studies. Altimeter measurements are corrected for several geophysical effects in order to isolate the oceanic variability, and the Dynamic Atmospheric Correction (DAC) is the second most important one after the tide correction. This correction allows for the removal of high frequency ocean variability induced by the atmospheric forcing and aliased by the altimetric measurements.

The high frequency part of the DAC is based on a barotropic ocean model simulation forced by atmospheric pressure and winds (MOG2D; Carrere and Lyard 2003); the low frequency part is an inverse barometer response, with a 20-days cutoff-period corresponding to the Nyquist period of T/P-Jason reference altimeters' sampling.

The purpose of the study is to improve the performances of the DAC for the three delivery mode corresponding to Near Real Time (NRT-OGDR) products, Short Time Critical (STC-IGDR) and Non Time Critical (NTC-GDR) and these improvements will directly benefit to all altimetry products, including current missions as well as the past time series.

Extending the meteorological forecast window until 10 days in the future (D+10) allows improving significantly the quality of the STC DAC correction: the improvement has been estimated on level-2 altimeter products (along-track and crossovers) and reaches 5-10 cm² in some deep ocean regions and also in shallow waters, which correspond to the areas where the high frequency response of the ocean to atmospheric forcing is maximum. The implementation of this new product is planned in 2017.

A specific work on the width of the filtering window shows a non-negligible impact on the amplitude of the DAC particularly in regions of high variability. The new high-resolution mesh and bathymetry provided by FES2014 study have been tested to improve the global DAC performances and results will be presented. Moreover a review of the correction of the S1 and S2 frequencies in altimeter processing has been performed and some ways of improvements are proposed.

Corresponding author:
Loren Carrere (**CLS**, **France**), lcarrere@cls.fr

Bathymetry improvement and tidal modeling at regional scales

Mathilde Cancet (NOVELTIS, France); Florence Toublanc (NOVELTIS, France); Gérald Dibarboure (CNES, France); Thierry Guinle (CNES, France)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_005

Abstract:
Coastal processes (tidal currents, storm surges, waves) are highly dependent on bathymetry and directly impact offshore and coastal activities and studies. Many studies and applications lie on a growing modelling effort of the ocean and the limited accuracy of bathymetry, especially on the continental shelves, contributes to degrade numerical model performances despite significant use of in-situ and satellite measurements assimilation. In particular, the tidal models are very sensitive to the bathymetry accuracy on the shelves, where the ocean tides show the largest amplitudes and are strongly non-linear. This has a direct impact on the quality of the altimetry sea surface heights as the tide correction is one of the largest corrections on the shelves, ranging from several centimetres to several metres.
Various sources of bathymetry data exist but many regions remain not well known because of too sparse measurements, data access limitation or large temporal variability of the seabed dynamics. This paper presents a project very recently launched by CNES with the aim to improve the bathymetry on a number of continental shelves. The work is divided in several steps: 1/ an inventory of existing datasets and methods to derive the bathymetry on the shelves ; 2/ the integration of the collected datasets into a reference global bathymetry dataset ; 3/ the evaluation of this new bathymetry dataset through hydrodynamic modelling and the production of regional tidal models.
This poster will highlight the methodology that will be followed in the project and the first investigations that have been made.

Corresponding author:
Mathilde Cancet (**NOVELTIS**, **France**), mathilde.cancet@noveltis.fr

Estimating tidal constants in the near-shore domain from Jason1-2-3 archive: a case study for the northern Bay of Bengal

Marufa Ishaque (Maritime University, Dhaka, Bangladesh); Laurent Testut (LEGOS, Toulouse, France); Fabien Durand (LEGOS, Toulouse, France); Stéphane Calmant (LEGOS, Toulouse, France); Yann Krien (LARGE, Université Antilles-Guyane, Pointe-à-Pitre, France); Jamal Khan (IWFM/BUET, Dhaka, Bangladesh); Damien Allain (LEGOS, Toulouse, France); Florent Lyard (LEGOS, Toulouse, France); Valérie Ballu (LIENSs, Université de La Rochelle, France); Sara Fleury (LEGOS, Toulouse, France)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_006

Abstract:
The shoreline of the Bengal delta (Bangladesh and India) is a macrotidal area (over 4 m), with a broad (200 km) and shallow shelf. It is also home to marked variability of the water cycle, over a broad range of timescales, from a few hours (cyclonic surges, flash floods) to a few weeks or months (monsoonal floods in the rivers, mesoscale turbulence in the near-shore ocean). Despite profound implications of the water level variability on the society and economy of the 150 M people populating the near-shore region, the characteristics of the ocean tide is poorly observed and understood in this region. Numerical tidal models also do not perform well in this region, compared to the rest of the tropical oceans. This stems, among others, from the lack of knowledge of the bathymetry of the shelf region.
This poster presents an attempt to curb this lack of knowledge, by making use of along-track spaceborne altimetry. We consider standard products (GDRs) for the whole Jason1-2-3 archive, as well as re-processed PISTACH Jason-2 products. We apply harmonic analysis to these datasets, without any editing criterion prior to analysis. We compare our estimates to standard publicly available altimetric tidal constants (from CTOH) and from state-of-the-art numerical models (FES2014 and BAND-AID/SCHISM).
It is found that our analyses allow to extend shoreward the coverage of standard altimetric tidal constants by 5 km to 15 km (depending on the region considered, within the Bay of Bengal). This implies that the editing strategy applied routinely in the standard altimetric products, though probably suited for the offshore domain, is too stringent/conservative for the coastal ocean. It is also found that the choice of the set of altimetric corrections, is as much instrumental in the estimation of tidal constants in the coastal domain as the retracking algorithm can be.
The observational coverage of our altimetric tidal constants estimates, extended towards the shore, opens promising prospects for the tidal modeling community, as it corresponds to the coastal strip where the various tidal models solutions diverge from one another.

Corresponding author:
Marufa Ishaque (**Maritime University, Dhaka**, **Bangladesh**), marufa_ishaque@yahoo.com

Geodetic survey of the freshwater front of the Ganges-Brahmaputra freshwater plume in the northern Bay of Bengal from CalNaGeo GNSS device

Fabien Durand (LEGOS, France); Stéphane Calmant (LEGOS, Toulouse, France); Michel Calzas (DT-INSU, CNRS, Plouzané, France); Valérie Ballu (LIENSs, Université de La Rochelle, France); Laurent Testut (LEGOS, Toulouse, France); Pierre Valty (DITTT, Nouméa, New Caledonia); Yann Krien (LARGE, Université Antilles-Guyane, France); Pascal Bonnefond (Observatoire de Paris - SYRTE, France); Fabrice Papa (LEGOS, IRD, France)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_007

Abstract:
The Bay of Bengal is home to massive continental freshwater supply during the summer monsoon season. During this season only, about 800 km3 of freshwater flow through the Bengal delta into the northern Bay, provided by the Ganges-Brahmaputra river system. Although the ocean tide is expected to play a strong role in the spreading of this freshwater, the spatio-temporal evolution of this seasonal plume as well as the exact processes governing its dispersal in the open ocean remain largely unknown, due to the lack of in situ observations.
To try to shed light on this issue, we conducted a pilot experiment in the near-shore region of the northern Bay of Bengal in the post-monsoon season of 2014, along SARAL track#810. Our observational strategy is based on an original ship-borne towed GNSS device: CalNaGeo. This device is designed to measure the absolute sea surface height within a few centimeters accuracy. Unfortunately, it was not possible to conduct the cruise during a SARAL overpass for validation of the SARAL measurements. However, our data are shown to capture multi-scale variability of sea surface height, from horizontal scales of a few meters to dozens of km. Our dataset evidences the signature of an hydrological front in the de-tided GNSS record, taking the form of a steric stair separating coastal (warm and fresh) waters from off-shore (cooler and salty) waters. We also assess the capability of along-track altimetry to capture the steric height gradient associated to this hydrological front.

Corresponding author:
Fabien Durand (**LEGOS**, **France**), fabien.durand@ird.fr

SWOT in the Tropics: High-frequency and small-scale dynamics of sea surface height around New-Caledonia from in situ observations

Guillaume SERAZIN (LEGOS/IRD, France); Frédéric MARIN (IRD, FRANCE); Sophie CRAVATTE (IRD, France); Lionel GOURDEAU (IRD, France); Rosemary MORROW (CNRS, France)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_008

Abstract:
The oceanic circulation around New Caledonia involves a substantial mesoscale eddy field, associated with submesoscale features, as well as substantial internal tides generated by the steep bathymetry of the region. The future SWOT satellite will fly next to New Caledonia during the Cal/Val cycle and will provide an unprecedented opportunity to characterize the small-scale dynamics down to 20 km in this region. In order to understand the complex content of the observed small-scale sea surface height as well as the impact of the errors linked to the subsampling of scales shorter than 20 km, in situ observing systems could be deployed from the oceanographic centre of Noumea during the Cal/Val cycle. Before such a deployment, analyzing former observing dataset is worthwhile to characterize high-frequency small-scale dynamics in the region and would provide valuable feedbacks on the capacity of different observing systems to probe those dynamics during the SWOT Cal/Val Cycle.

Former glider observations are used to characterize the M2 internal tides around New Caledonia by performing a harmonic fitting on the isopycnal displacements. Such observations are also used to try to estimate high-frequency vertical velocities and detect subsmesocale fronts. Structure functions of surface velocities are computed from several ship ADCP measurements in this region to characterize the kinetic energy spectrum at small scales. A Helmotz decomposition is performed to separate divergent and rotational motions and to analyze a change in the spectrum slope. Those preliminary results will eventually be used to assess the capacity of the high-resolution MITGCM model, forced with barotropic tides, to be representative of the high-frequency and small-scale dynamics around New Caledonia.
Corresponding author:
Guillaume SERAZIN (**LEGOS/IRD**, **France**), guillaume.serazin@legos.obs-mip.fr

THE OCEAN SURFACE TOPOGRAPHY SENTINEL-6/JASON-CS SATELLITES

Luisella Giulicchi (ESA, Netherlands); Robert Cullen (ESA, Netherlands); Craig Donlon (ESA, Netherlands); Pierrik Vuilleumier (ESA, Netherlands)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_001

Abstract:
The Sentinel-6/Jason-CS mission consists of two identical satellites flown consecutively. The mission is designed to provide operational measurements of sea surface height, significant wave high and surface wind speed, to support operational oceanography and climate monitoring. The mission will continue the ocean surface topography started nearly three decades ago with Topex/Poseidon and the Jason satellite series (Jason-3 was launched in January 2016).
The interleaved low resolution (LRM) and Synthetic Aperture Radar (SAR) acquisition modes featured by the numerical architecture of the Poseidon-4 altimeter provide the operational and scientific oceanographic community with continuity of the reference data series and enhanced state-of-the-art operational data.
As a secondary objective the mission also includes a Radio Occultation user services. Each satellite will be launched sequentially into the 1340km, 66 deg inclined reference orbit (~10-day repeat) and after a six-month commissioning phase, have a planned nominal operational lifetime of five years.
The principle payload instrument is a high precision Ku/C band radar altimeter featuring an interleaved mode of operation designed to provide contemporaneous synthetic aperture (SAR) and conventional pulse limited acquisitions. The altimeter is supported by a DORIS and a GNSS (GPS+Galileo) receivers, used for Precise Orbit Determination (POD), and the Climate Quality Advanced Microwave Radiometer (AMR-C) for high stability path delay correction. Orbit tracking data are also provided by a Laser Retro-Reflector Array (LRA) used with ground based satellite laser ranging system (ILRS). An additional GNSS receiver will be dedicated to Radio Occultation measurements.

The Sentinel-6/Jason-CS is a cooperative mission with contributions from NASA, NOAA, EUMETSAT, ESA, CNES in addition to the European Union. It forms part of the European Community Copernicus initiative, whose objective is to support sustainable development and global governance of the environment by providing timely and quality data, with a free and open policy, information, services and knowledge. Sentinel-6/Jason-CS introduces a major enhancement in reference-mission altimetry capability serving the operational and science oceanographic community with the state of the art in terms of spacecraft and payload instrumentation that will secure optimal operational and science data return until at least 2030.

Corresponding author:
Luisella Giulicchi (**ESA**, **Netherlands**), luisella.giulicchi@esa.int

Sentinel-6 Poseidon-4 L1B simulator: end-to-end performance evaluation from model-based waveforms

Lisa Recchia (Aresys srl, Italy); Mieke Kuschnerus (ESA - ESTEC, The Netherlands); Michele Scagliola (Aresys srl, Italy); Davide Giudici (Aresys srl, Italy); Roberta Bertoni (ESA - ESTEC, The Netherlands)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_002

Abstract:
Lisa Recchia, Aresys
Michele Scagliola, Aresys
Davide Giudici, Aresys
Mieke Kuschnerus, ESA
Roberta Bertoni, ESA

The Sentinel-6/Jason-CS mission is the latest successor of the Jason altimetry series and part of the ESA Copernicus Programme. Its main objective is to continue the long-term climate data record of sea level measurements that started in 1992 with the Topex/Poseidon mission, followed by the Jason series. Sentinel-6 will operate in the same reference orbit as the current Jason-2 system and its altimeter POSEIDON-4 will retrieve sea level, wind speed and wave height measurements in near real time. POSEIDON-4 is a new generation of altimeter based on the SRAL instrument of the Sentinel 3 mission and it will be able to operate in the so-called interleaved mode. The interleaved mode allows not only to produce high resolution (HR) and low resolution (LR) measurements at the same time, but also increases the number of single look waveforms for each measurement and therefore reduces the noise effects.
In the framework of the development studies for the Sentinel-6 Poseidon-4 and to support the on going performance analysis of the mission, a level 1B (L1B) simulator has been developed with the main objective to provide L1B data sets over periods longer than an orbit. The flexible design of the simulator also allows assisting with studies into concepts for other possible future radar altimeter missions.
This poster is presenting the architecture of the simulator as well as the first simulated data sets and a preliminary performance assessment. The design of the simulator was driven mainly by the goal to efficiently generate long scale data sets. To this aim, a novel semi-analytical model for HR waveforms has been developed to manage the trade-off between runtime performance, accuracy and flexibility of the models. The echo impairments in the form of speckle contribution and thermal noise are based on theoretical models as well. The fully configurability of impairments and errors injections allows for the evaluation of each single contribution to the end-to-end performance on geophysical parameters retrieval from both LR and HR waveforms. In fact, by comparison of the geophysical parameters provided as input to the simulation and the corresponding parameters retrieved by analysis of the L1B products generated by the simulator, the expected end-to-end performance of the Sentinel-6 mission can be assessed.

Corresponding author:
Lisa Recchia (**Aresys srl**, **Italy**), lisa.recchia@aresys.it

Study of Ocean-Tropical Cyclone interactions with multisensor observations

Clément Combot (IFREMER, France); Bertrand Chapron (IFREMER, France); Yves Quilfen (IFREMER, FRANCE); Alexis Mouche (IFREMER, FRANCE)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_003

Abstract:
Moving tropical cyclones (TCs) are extreme atmospheric phenomena that powerfully impact the ocean. Indeed, TCs are intense sources of surface stress and stress curl generating a variety of responses : surface waves, internal currents and turbulence in the upper layer that causes vertical mixing and enhances thermocline erosion often leading to large sea surface temperature (SST) changes. There is also a measurable barotropic response with an associated trough in sea surface height (SSH). Taking advantages of multi-sensor observations, this study aims to help infer the TC intensity and life-cycle evolution. The method is based on simplified analytical models describing asymmetrical sea states, SST and SSH anomalies. As suggested, a new parametric wind stress model can then be derived. In particular, our approach underlines the better capacity of an outer radius forced model to reproduce the global wind forcing profile, compared to previous Rmax-based parametric models.

Corresponding author:
Clément Combot (**IFREMER**, **France**), clement.combot@ifremer.fr

Storm waves sharpening in the Agulhas current: satellite observations and modeling

Yves Quilfen (IFREMER, France)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_004

Abstract:
Interactions between surface waves and currents strongly modify the waves characteristics, height and shape, and in favourable conditions cause extreme sea states. In particular current systems, the risk of extreme waves is a known hazard because it is also the place of main shipping routes. It is the case for the Agulhas current where many ships recorded severe damages. Modelling of these interactions in standard wave numerical models is an active area of research, that would benefit from the increased availability and accuracy of satellite observations. Lack of observations of these phenomena has long been a main limitation to their understanding and prediction. We analyse a particular case of a swell system propagating in the Agulhas current by the mean of wind and sea state measurements from several satellites, jointly with state of art analytical and numerical modelling of wave/current interactions. Synthetic Aperture Radar and altimeter measurements are used to show the evolution of the swell train and associated extreme waves. A ray tracing analysis shows that the significant wave height variability at scale under 100 km is associated with the current vorticity patterns. Predictions of the WaveWatch-III numerical model in a version that accounts for wave / current interactions are coherent with observations although their effects are clearly under-predicted in the current configuration. It is shown from altimeter measurements that very large significant wave height gradients are systematically associated with the current patterns, that reflect increased steepness of waves interacting with surface currents.

Corresponding author:
Yves Quilfen (**IFREMER**, **France**), yquilfen@ifremer.fr

A new look at the Ku-C backscatter relationship to analyze sigmabloom

Jean Tournadre (IFREMER, France); Vandemark Doug (U. New-Hampshire, USA); Hui Feng (U. New-Hampshire, USA); Chapron Bertrand (IFREMER, France)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_005

Abstract:
Most altimeters operates at dual frequencies, in general Ku (13.5GHz) and C (5.3GHz) band. The relationship between the two band backscatter has been used to detect the altimeter samples affected by rain samples using the differential attenuation of the signals by liquid water. However, the KU-C band relationship contains much more informations than the rain attenuation. In particular it could provide a new way to analyze and interpret the altimeter sigmabloom events. The analysis of Jason1 and 2 and Envisat data during the Deepwater Horizon oil spill and the comparison with oil spill thickness and extent data showed that the presence of oil spills on the sea surface can distort the altimeter waveforms and cause 'blooms' in the radar backscatter cross-section signal, but compresses the surface capillary wave and reduce the sigma0 in synthetic aperture radar (SAR) imagery.
The comparison of high resolution surface sigma0 obtained by waveform inversion method and ERMA oil cover fields showed that locally the Jason-1/2 Ku band sigma0 increased up to 10 dB in low wind speed. At low wind speed (<3 m.s^{-1}), the mean sigma0 in Ku and C bands increased by 1.0 to 3.5 dB for thick oil and 0.9 to 2.9 dB for thin oil while the waveforms are strongly distorted. At medium winds (up to 6 m.s^{-1}) the mean sigma0 bloom and waveform distortion in both Ku and C bands weakened for both thick and thin oil. For larger winds (> 6 m.s^{-1}) only does the Ku band sigma0 slightly increase by 0.2-0.5 dB for thick oil. (See Y. Cheng et al Poster)
A further analysis reveals that surface films have a differential impact at Ku and C band depending on the existing surface roughness (due to wind) and film thickness. This differential impact reflects in the Ku-C band relationship by modifying the departure from the "normal" Ku-C band relation. Examples of the modification of the Ku-C band backscatter difference by surface film of different thickness will be analyzed and compared to low winds cases to show that the departure from a "normal" Ku-C band relation can be used to detect the presence of surface film.
The Jason2 archive has thus been processed to analyze the sigmabloom events. In a first step, all the bloom events (whatever their length) of sigma0 larger than 16dB are detected and their characteristics (occurrence, geographical distribution, length, strength, wind speed) analyzed. In a second step, the departure from the Ku-C band relationship within the bloom is analyzed to give a tentative estimate of the presence of surface films.

Corresponding author:
Jean Tournadre (**IFREMER**, **France**), jean.tournadre@ifremer.fr

A revisit of global ocean smooth surface conditions and temporal changes using the Topex-to- Jason altimeter time series data

Doug Vandemark (Univ. of New Hampshire, United States); Hui Feng (Univ. of New Hampshire, United States); Jean Tournadre (IFREMER, FRA); Bertrand Chapron (IFREMER, FRA)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_006

Abstract:
An unanticipated complication for precision ocean altimetry has been the loss of valid ranging data under light wind or smooth water conditions that occur at length scales of 0.1-300 km. Such conditions have been shown to occur over 4-6% of the global ocean, and to persist 20-30% of the time in certain tropical and sub-tropical oceans. Originally termed the AGC or sigma0 blooms in the altimetry context, these quasi-specular conditions lead to greatly increased levels in the radar altimeter return signal and they also frequently lead to erratic estimates of range and platform pointing angle. Altimeter measurements under these conditions have been documented, particularly using TOPEX and Envisat observations. In several respects, the ocean altimeter is better-suited to assess such surface conditions than other available ocean wind observing radar or radiometer systems. This new investigation revisits the phenomena and its altimeter detection from several new directions. Here we first seek to ascertain if long term ocean altimeter datasets can reveal additional information on spatial and temporal variation of smooth water regions from 1992-present. Sigma0 bloom data from the 10 day repeat altimeter missions, TOPEX to Jason-3, are harmonized to develop seasonal time series across ocean warm pools and then to evaluate interannual change. New approaches to delineate between calm wind and biogenic slick control of these smooth surface conditions and their length scales will also be presented.

Corresponding author:
Doug Vandemark (**Univ. of New Hampshire**, **United States**), doug.vandemark@unh.edu