2015 Ocean Surface Topography Science Team Meeting

Tuesday, October 20 2015 - Friday, October 23 2015

The objectives of the 2015 OSTST Meeting will be: (1) provide updates on the status of Jason-2 (2) conduct splinter meetings on system performance (orbit, measurements, corrections), altimetry data products, science outcomes, and outreach

In addition to the traditional in-depth analyses of TOPEX/Poseidon-Jason missions, analyses from other missions bringing reciprocal benefits are welcome.

Abstracts Book

Abstract list

Keynote/invited

OSTST Opening Plenary Session
Tue, Oct 20 2015, 09:00 - 12:30 - Grand Ballroom 1

11:00 - 11:20: What Do We Really Know About 20th Century Global Mean Sea Level?: Benjamin Hamlington et al.
11:20 - 11:40: AlborEx: a multi-platform interdisciplinary view of Meso and Submesoscale processes: Ananda Pascual et al.
11:40 - 12:00: Explaining the spread in global mean thermosteric sea level rise in CMIP5 climate models: Angelique Melet et al.

Oral

Application development for Operations (previously NRT splinter)
Wed, Oct 21 2015, 09:00 - 10:30 - Grand Ballroom 2

09:00 - 09:15: Are SAR wave spectra from Sentinel-1A ready for operational use in the wave model MFWAM: Lotfi Aouf et al.
09:15 - 09:30: Improved Representation of Eddies in Fine Resolution Forecasting Systems Using Multi-Scale Data Assimilation of Satellite Altimetry: Zhijin Li
09:30 - 09:45: NOAA Operational Satellite Derived Oceanic Heat Content Products : Eileen Maturi et al.
09:45 - 10:00: On the use of recent altimeter products in NCEP ocean forecast system for the Atlantic (RTOFS Atlantic): Liyan Liu et al.
10:00 - 10:15: Operational Oceanography in support of the search for MH370: David Griffin
10:15 - 10:30: Predictability of marine debris motion, simulated with numerical models and diagnosed using oceanographic satellite data: Nikolai Maximenko et al.

Instrument Processing: Corrections
Tue, Oct 20 2015, 14:00 - 15:45 - Grand Ballroom 1

14:00 - 14:15: SAR mode altimetry and sea state bias: Clare Bellingham et al.
14:15 - 14:30: A new proposal for SSB modelling with three parameters exclusively derived from altimetric data : Nelson Pires et al.
14:30 - 14:45: Inter-calibrated wet path delays for eight altimetric missions: M. Joana Fernandes et al.
14:45 - 15:00: A one-dimensional variational approach for wet tropospheric correction retrieval in the perspective of high resolution altimetry mission: defining the the background error covariance matrix: Laura Hermozo et al.
15:00 - 15:15: Spectral analysis of microwave radiometers brightness temperatures and atmosphere water vapour content.: Bruno Picard et al.
15:15 - 15:30: Analysis of the Wet Path Delay Spectrum from High-Resolution Airborne Observations: Shannon Brown et al.
15:30 - 15:45: Issues and solutions involved in global wave model application to routine sea state bias range correction across the satellite altimeter constellation : Doug Vandemark et al.

Instrument Processing: Measurement and retracking (SAR and LRM)
Tue, Oct 20 2015, 16:15 - 18:00 - Grand Ballroom 1

16:15 - 16:27: Retracked TOPEX Climate Data Record: Philip Callahan et al.
16:28 - 16:40: On the signature of long swell for the SAR-mode wave height of Cryosat-2: Lotfi Aouf et al.
16:41 - 16:53: Separation of Coherent and Incoherent Scattering Components from Delay/Doppler Altimeter Waveforms: Alejandro Egido et al.
16:54 - 17:06: Impact of the antenna diagram approximation in conventional altimetry waveform processing: application to SARAL/AltiKa data: Sophie Le Gac et al.
17:07 - 17:19: Level-2 assessment of along-track antenna pattern compensation for SAR altimetry: Salvatore Dinardo et al.
17:20 - 17:32: Improved SAR-mode ocean retrievals from new Cryosat-2 processing schemes: Thomas Moreau et al.
17:33 - 17:45: Ensuring the sea level continuity between open ocean and sea iced regions in the Arctic Ocean: some LRM processing solutions: Jean-Christophe Poisson et al.

Outreach, Education and Altimetric Data Services
Tue, Oct 20 2015, 16:15 - 18:00 - Grand Ballroom 2

16:15 - 16:30: Updated Altimetric Datasets and Services at PO.DAAC: Jessica Hausman
16:30 - 16:45: SAR altimetry processing on demand service for Cryosat-2 and Sentinel-3 at ESA G-POD: Salvatore Dinardo et al.
16:45 - 17:00: Radar Altimetry Toolbox: Albert Garcia-Mondejar et al.
17:00 - 17:15: Multivariate Reconstruction of Sea Level from 1900 to Present: Benjamin Hamlington et al.
17:15 - 17:30: Outreaching a space technique through its climate applications: Jason-3: Vinca Rosmorduc et al.
17:30 - 17:45: Observations of El Niño impacts using in situ GLOBE protocols and satellite data: Danielle De Staerke et al.
17:45 - 18:00: Outreach Showcases: All et al.

Precision Orbit Determination
Wed, Oct 21 2015, 09:00 - 12:30 - Grand Ballroom 1

09:05 - 09:20: Jason-2, Saral/AltiKa and CryoSat-2 POD status: Eva Jalabert et al.
09:25 - 09:40: A new time series of orbits (std1504) for TOPEX/Poseidon, Jason-1, Jason-2 (OSTM): Frank Lemoine et al.
09:45 - 10:00: Jason-2 Orbit Determination With GPS, Instrument Status And Reference Frame Sensitivity: Willy Bertiger et al.
10:05 - 10:20: Improvements in precise orbit determination of altimetry satellites: Sergei Rudenko et al.
11:00 - 11:15: GDR-E gravity field model EIGEN-GRGS.RL03-v2.MEAN-FIELD : Jean-Michel Lemoine et al.
11:20 - 11:35: Improved orbit-centering parameterization for mean sea level applications: Alexandre Couhert et al.
11:40 - 11:55: Status DORIS RINEX Processing at GSFC: nikita zelensky et al.
12:00 - 12:15: Update of the South-Atlantic Anomaly corrective model for JASON-1 DORIS data using the maps of energetic particles from the CARMEN dosimeter onboard JASON-2: Hugues Capdeville et al.
12:20 - 12:35: Analysis of SLR station biases: Sean Bruinsma et al.

Quantifying Errors and Uncertainties in Altimetry data
Thu, Oct 22 2015, 09:00 - 10:30 - Grand Ballroom 1

09:00 - 09:15: Seasonal effects on the pitch measurements for Cryosat: Salvatore Dinardo et al.
09:15 - 09:30: Identification and Reduction of Retracker-Related Noise in Altimeter-Derived Sea-Surface Height Measurements: Edward Zaron
09:30 - 09:45: Error Characterization of Altimeter Missions over Ocean : Comparison and Interpretation : Pierre Thibaut et al.
09:45 - 10:00: Accuracy of the mean sea level continuous record with future altimetric missions: Jason-3 versus Sentinel-3a: Lionel Zawadzki et al.
10:00 - 10:15: Uncertainty estimates of altimetric Global Mean Sea Level timeseries: Martin Scharffenberg et al.
10:15 - 10:30: Uncertainties Affecting Regional Sea Level Trends: Pierre Prandi et al.

Regional and Global CAL/VAL for Assembling a Climate Data Record
Wed, Oct 21 2015, 14:00 - 18:00 - Grand Ballroom 1

14:00 - 14:15: Corsica: a multi-mission absolute calibration site: Pascal Bonnefond et al.
14:15 - 14:30: An Update from Harvest: New Results from the TOPEX/Poseidon, Jason-1 and Jason-2 Missions: Bruce Haines et al.
14:30 - 14:45: Absolute altimeter bias from the Australian in situ calibration sites in Bass Strait and Storm Bay: Christopher Watson et al.
14:45 - 15:00: Regional CalVal of Jason-2 and SARAL/Altika at three calibration sites: Corsica, Harvest and Bass Strait: Mathilde Cancet et al.
15:00 - 15:15: Jason-1, Jason-2, SARAL/AltiKa and HY-2 altimeter calibrations over a decade at the Gavdos/Crete Cal/Val sites: Stelios Mertikas et al.
15:15 - 15:30: Validation of altimeter-derived sea level seasonal cycle with tide gauges over the Gulf of Mexico: Martina Ricko et al.
16:15 - 16:30: Jason-2 data performances over ocean: global assessment and improvement for multi-mission sea-level products: Sabine Philipps et al.
16:30 - 16:45: Global calibration and validation of the Jason-1 version E GDRs: Shailen Desai et al.
16:45 - 17:00: Global Ocean Data Quality Assessment of SARAL/AltiKa: Pierre Prandi et al.
17:00 - 17:15: Global Hy-2a Data Quality Assessment Over Ocean: Matthias Raynal et al.
17:15 - 17:30: Latest results of DGFI's multi-mission crossover analysis: Denise Dettmering et al.
17:30 - 17:45: Assessment of recent revisions to the TOPEX/Poseidon/Jason Sea Surface Height Climate Data Record: Impact on global and regional sea level estimates: Brian Beckley et al.

Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Tue, Oct 20 2015, 14:00 - 15:45 - Grand Ballroom 2

14:00 - 14:15: Is the Altimeter-Era Acceleration of Global Mean Sea Level Rise Being Masked by the 1991 Eruption of Mt. Pinatubo?: John Fasullo et al.
14:15 - 14:30: On the decadal trend of global mean sea level and its implication on ocean heat content change: Lee-Lueng Fu
14:30 - 14:45: Accuracy of Global Comparisons Between Altimetry and Tide Gauges: Pierre Prandi et al.
14:45 - 15:00: Assessing satellite era global mean sea level change using tide gauges and estimates of land motion: Christopher Watson et al.
15:00 - 15:15: Balancing regional sea level budgets: Eric Leuliette et al.
15:15 - 15:30: Advances in correcting vertical land motion at tide gauges using GPS estimates: Alvaro Santamaría-Gómez
15:30 - 15:45: Examining the role of land motion in estimating altimeter system drifts: Amanda Plagge et al.

Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Wed, Oct 21 2015, 14:00 - 15:45 - Grand Ballroom 2

14:00 - 14:15: Sea surface height observational capabilities: from mesoscale to submesoscale: Gregg Jacobs et al.
14:15 - 14:30: Exploring 3D velocity field reconstructions using the SWOT simulator and a submesoscale-resolving OGCM: Bo Qiu et al.
14:30 - 14:45: The Resolution Capabilities of Geostrophic Velocity, Relative Vorticity and Ekman Pumping Fields Estimated from Noisy SWOT Observations of Sea Surface Height: Dudley Chelton et al.
14:45 - 15:00: Mesoscale physical-biological interactions as revealed in satellite observations and eddy resolving models: from regional to global scales: Dennis McGillicuddy et al.
15:00 - 15:15: Mesoscale and submesoscale variability in the Luzon Strait: A data-assimilative two-way nested modeling approach: Javier Zavala-Garay et al.
15:15 - 15:30: Application of SWOT to the dynamics of Amazon plume and adjacent regions: James carton et al.
15:30 - 15:45: A frontal eddy intensively sampled at sea and overflown by SARAL: David Griffin et al.

Science III: Large scale and global change ocean processes: the ocean's role in climate
Thu, Oct 22 2015, 09:00 - 10:30 - Grand Ballroom 2

09:00 - 09:15: Heat and Freshwater Convergence Anomalies in the Atlantic Ocean Inferred from Observations: Kathryn Kelly et al.
09:15 - 09:30: Mean structure, long-term change and eddy motions in the Southern Ocean: A perspective from altimetry, Argo and state estimation: Sarah Gille et al.
09:30 - 09:45: Low-frequency transport variability in the Southern Ocean: the importance of regional variations: Don Chambers et al.
09:45 - 10:00: A new approach to detection and attribution of ocean thermal expansion: Elodie Charles et al.
10:00 - 10:15: Is anthropogenic sea level fingerprint already detectable in the Pacific Ocean over the satellite altimetry era?: Hindumathi Palanisamy et al.
10:15 - 10:30: The impacts of ENSO/PDO on regional sea level change: After 20 years, are we finally seeing a change in the pattern of Pacific sea level change?: Robert Steven Nerem et al.

The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Wed, Oct 21 2015, 16:15 - 18:00 - Grand Ballroom 2

16:15 - 16:30: The POD gravity field model for GDR-E: EIGEN-GRGS.RL03-v2.MEAN-FIELD : Sean Bruinsma et al.
16:30 - 16:45: Stacking repeat cycles of 40-Hz AltiKa data resolves the geoid anomalies of very small seamounts: Walter Smith et al.
16:45 - 17:00: The DTU15 MSS (Mean Sea Surface) and associated MDT (Mean Dynamic Topography) focusing on Arctic issues and development. : Ole Baltazar Andersen et al.
17:00 - 17:15: The recent drift of SARAL: an unexpected MSS experiment: Marie Isabelle Pujol et al.
17:15 - 17:30: Assessing the contribution of GOCE and altimetry to improvements in geodetic MDT determination: Rory Bingham
17:30 - 17:45: Variations of observed correlations between satellite altimetry and tide gauge data along the U.S. east coast: Yongcun Cheng et al.

Tides, internal tides and high-frequency processes
Wed, Oct 21 2015, 11:00 - 12:30 - Grand Ballroom 2

11:00 - 11:13: FES 2014, a new tidal model on the global ocean with enhanced accuracy in shallow seas and in the Arctic region: Loren Carrere et al.
11:13 - 11:26: Reduction of the 58.77-day Signal in the Mean Sea Level derived from TOPEX/Poseidon, Jason-1 and Jason-2 data with the latest FES and GOT ocean tide models: Lionel Zawadzki et al.
11:26 - 11:39: High resolution tidal modeling in the Arctic Ocean: Mathilde Cancet et al.
11:40 - 11:53: Internal tides for, from, and in satellite altimeter data: Richard Ray et al.
11:53 - 12:06: Global M2, S2, O1 and K1 internal tides from multisatellite altimetry: Zhongxiang Zhao et al.
12:06 - 12:19: Progress in internal tides modelling using T-UGOm model: Florent Lyard et al.
12:19 - 12:32: SSH signature of the internal wave spectrum inferred from profiling moorings: Matthew Alford et al.

Poster

Application development for Operations (previously NRT splinter)
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

APOP_001: DUACS sea level products, a step beyond with Jason-3 and Sentinel-3: Yannice Faugere et al.
APOP_002: 20 years of reprocessed Lyapunov exponents from altimetry available on Aviso: Marie Isabelle Pujol et al.
APOP_003: DT2014 version of Ssalto/DUACS products: 21 years Sea Level products reprocessed: Marie Isabelle Pujol et al.
APOP_004: Validation of Cryosat-2 SAR Wind and Wave Products: Saleh Abdalla et al.
APOP_005: Satellite Altimetry Sea Surface Height Anomaly Processing At The Naval Oceanographic Office's Altimetry Data Fusion Center: Carolyn Cooper
APOP_006: Operational ocean data assimilation/prediction system for the western North Pacific at JMA : Toshiyuki Sakurai et al.

Instrument Processing: Corrections
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

IPC_001: Revised sea state bias models for retracked TOPEX altimeter data: Hui Feng et al.
IPC_002: ACCRA : A Study on Future Microwave Radiometers for Atmospheric Correction of Radar Altimeters on Coastal Regions: Bruno Picard et al.

Instrument Processing: Measurement and retracking (SAR and LRM)
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

IPM_001: Simultaneous multi-waveform retracking in coastal regions : application to the NW Mediterranean Sea: Fernando Niño et al.
IPM_002: SENTINEL-3 STM Products & Processing Algorithms Definition: Femenias Pierre et al.
IPM_003: "PEACHI Jason-3": a processing laboratory for innovative altimetry products: Sophie Le Gac et al.
IPM_004: Using SARAL/AltiKa to improve Ka-band altimeter measurements for coastal zones, hydrology and ice: status of the PEACHI project: Guillaume Valladeau et al.
IPM_005: A new method to determine the antenna pointing directly from Altimeter SAR mode data: Chris Ray et al.
IPM_006: ERS-2 mission reprocessing for long-term continental surfaces studies: Benoît Legrésy et al.
IPM_007: A Fast Convolution based Model for SAR Altimetry Waveforms and their Retracking: Christopher Buchhaupt et al.
IPM_008: SAR Altimetry at 80 Hz : Salvatore Dinardo et al.
IPM_009: Performance analysis between autonomous tracker median and new version of OLTC mode: Emmanuel Auge et al.
IPM_010: Open-Sea CryoSat-2 data in SAR and PLRM mode in South East Pacific and North East Atlantic : Luciana Fenoglio-Marc et al.
IPM_011: A global coastal altimetry dataset for coastal dynamics and sea level research: Marcello Passaro et al.
IPM_012: MAPS: the Multi-mission Altimetry Processing Software: Frédéric Frappart et al.

Others (poster only)
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

OTH_001: Multi-altimeter observations of the Yukon River Alaska: Assessment of the determination of river discharge within this complex river system.: Charon Birkett et al.
OTH_002: G-REALM: Investigating datum translations for integration of altimeter-derived operational water level products with in situ lake and reservoir gauge data. : Charon Birkett et al.

OTH_003: Sea-ice and snow facies classifications from Altika data over the Polar Regions: Ngan Tran et al.
OTH_004: Retrieval of coastal sea surface height from along-track continuous AltiKa data: Xi-Feng Wang et al.
OTH_005: Leveling tide gauges with GNSS reflectometry: Alvaro Santamaría-Gómez et al.
OTH_006: Study of altimetry precision error using GNSS-R: Rashmi Shah et al.
OTH_007: Small scale sea level budgets in the North-Atlantic.: Marcel Kleinherenbrink et al.
OTH_008: The response of the Black Sea to fluctuations of the Mediterranean sea level: Denis Volkov
OTH_009: Eddies and SST frontal variability in Eastern Boundary Currents: Renato Castelao
OTH_010: Evaluating the performance of JASON and ENVISAT satellite altimeter missions at detecting prior errors in eddy-resolving ocean models. : Pierre Brasseur et al.
OTH_011: Simple OSE of Argo using space-time scales statistically derived from altimeter data: Tsurane Kuragano et al.
OTH_012: JPL Gridded Altimetry Products: Victor Zlotnicki
OTH_013: Detection of ocean white-capping by combined use of Jason radiometer and radar datasets alongside global wave model predictions: Doug Vandemark et al.
OTH_014: The Geosat 30th Anniversary Data Set: John Lillibridge et al.

Outreach, Education and Altimetric Data Services
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

OUT_001: Regional X-TRACK altimeter products for coastal applications: updates and evolutions : Nicolas Fuller et al.
OUT_002: Swot on Aviso+: promoting the mission, explaining the technique: Vinca Rosmorduc et al.
OUT_003: Aviso+ products & services: what's new?: Vinca Rosmorduc et al.
OUT_004: New datasets for ODES (Online Data Extraction Service): Vinca Rosmorduc et al.
OUT_005: Database for Hydrological Time Series of Inland Water (DAHITI): Christian Schwatke et al.
OUT_006: Sentinel-6/Jason-CS Altimeter Products and Performance Budget: Remko Scharroo et al.
OUT_007: CTOH altimetry products (L1 to L4) for ocean and continental surfaces applications: Florence Birol et al.
OUT_008: NOAA archive and access services for Jason-2/3 products: Baker-Yeboah Sheekela et al.
OUT_009: Sea Level Experiments for Climate Science Outreach: Andrei Iskra et al.
OUT_010: The Colorado Center for Astrodynamics Research Ocean Data System: Robert Leben et al.

Precision Orbit Determination
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

POD_001: New orbits of ERS-1, ERS-2, TOPEX/Poseidon, Envisat, Jason-1 and Jason-2 for altimetry applications and their validation: Sergei Rudenko et al.
POD_002: Assessment of Orbit Quality through the SSH calculation Towards GDR-E orbit standards: Annabelle Ollivier et al.
POD_003: New phase correction maps for Jason 2 GPS processing: flavien mercier et al.
POD_004: A new time series of orbits (std1504) for TOPEX/Poseidon, Jason-1, Jason-2 (OSTM) (poster): Frank Lemoine et al.

Quantifying Errors and Uncertainties in Altimetry data
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

ERR_001: Sentinel-3 Delay Doppler Altimeter: a New Insight on High Resolution Ocean Dynamics: Sylvie Labroue et al.
ERR_002: Sea level ECV quality assessment via global ocean model assimilation: Martin Scharffenberg et al.
ERR_003: Sea level budget over 2005-2013: Missing contributions and data errors: Habib Dieng et al.
ERR_004: Satellite altimetry data validation in San Matias Gulf, Argentina: Loreley Selene Lago et al.
ERR_005: Use of satellite data in the Rio de la Plata estuary: Laura Ruiz Etcheverry et al.

Regional and Global CAL/VAL for Assembling a Climate Data Record
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

CVL_001: An ESA absolute and permanent site with a transponder for the altimeter calibration of Sentinel-3, Cryosat-2, and Jason-3 in West Crete, Greece: Stelios Mertikas et al.
CVL_002: Towed and static GPS buoys for CAL/VAL and SSH: Cédric Brachet et al.
CVL_003: Jason-1 GDR-E Reprocessing: Hélène Roinard et al.
CVL_004: Global Assessment of TOPEX reprocessed products (Release 5): Hélène Roinard et al.
CVL_005: Evaluation of Topex Retracked Data: Rashmi Shah et al.
CVL_006: SIRAL and SARAL Ocean Data Validation: Marc Naeije et al.
CVL_007: Evaluation of new CryoSat-2 measurements over the ocean: Francisco Mir Calafat et al.
CVL_008: A Seamless Transition Between LRM and SAR Altimetry: 3 Years Dataset Assessment of Cryosat-2 SARM: Matthias Raynal et al.
CVL_009: The Role of the Sentinel-3 Mission Performance Centre in Maintaining High Standards within Operational Altimetry: Graham Quartly et al.

CVL_010: Sea Surface Height from Spaceborne GNSS-R: a Demonstration with TechDemoSat-1 Data: Maria Paola Clarizia et al.

Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?

Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

SC1_001: Dynamical Coastal Topography and tide gauge unification using altimetry and GOCE: Ole Baltazar Andersen et al.
SC1_002: Revisiting the sea level closure budget over 2004-2014 from a GRACE perspective: Alejandro Blazquez et al.
SC1_003: Combination of satellite altimetry, tide gauges and shipborne GNSS measurements in the German Bight: Ole Roggenbuck et al.
SC1_004: Regional and coastal long-term sea level change assessment from geodetic data: Luciana Fenoglio-Marc
SC1_005: Analyses of altimetry errors using Argo and GRACE data: Jean-François Legeais et al.
SC1_006: Priorities for installation of continuous Global Navigation Satellite System (GNSS) near to tide gauges: Matt King et al.
SC1_007: Impact of loss of the 35-day repeat tracks on estimates of the mean sea level evolution: Andrew Shaw et al.

Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT

Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

SC2_001: Capturing Mesoscale Features In Surface Currents: Kathleen Dohan et al.
SC2_002: Long-range Radiation of Barotropic Rossby Waves from the Equatorial Pacific Ocean: Tom Farrar et al.
SC2_003: Surface Lagrangian transport in a submesoscale permitting simulation: Beron-Vera Francisco
SC2_004: Particle diffusion against mean flow as a new framework for local estimate of mixing coefficient: Nikolai Maximenko et al.
SC2_005: Transient zonal jets and “storm tracks”: A case study in the eastern North Pacific: Oleg Melnichenko et al.
SC2_006: Variability of sub-mesoscale dynamics in the North Atlantic ocean from a 1/60° ocean model simulation.: Julien Le Sommer et al.
SC2_007: Coastal Circulation in the Southern Benguela Current: P Ted Strub et al.
SC2_008: Combining altimetry, numerical modeling and in-situ observations for the observation and the understanding of fine scale coastal processes in the Bay of Biscay: Florence Toublanc et al.
SC2_009: Observing fine-scale ocean structures in the NW Mediterranean Sea from altimetry, gliders and HF radar: Rosemary Morrow et al.
SC2_010: Small-scale and high-frequency SSH variability inferred from in-situ measurements in support of AirSWOT: James Girton et al.
SC2_011: Net primary production in the Gulf Stream sustained by quasi-geostrophic vertical exchanges: Ananda Pascual et al.
SC2_012: Preparing for the next interdisciplinary challenges unlocked by SWOT fine-scale observations: Francesco d'Ovidio et al.
SC2_013: Observation and modeling of tropical cyclones wakes and their evolution: Yves Quilfen et al.
SC2_014: Dynamic mapping of ocean altimetry: method and performances from Observing System Simulation Experiments: Clement Ubelmann et al.
SC2_015: Value of the Jason-1 geodetic phase to study rapid oceanic changes: Gerald Dibarboure

Science III: Large scale and global change ocean processes: the ocean's role in climate

Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

SC3_001: Sensitivity study on the use of Argo data for the validation of altimeter products in the Mediterranean Sea: Antonio Sánchez-Román et al.
SC3_002: Global Ocean Surface and 15m depth currents from the synergetic use of altimetry, GOCE and in-situ data.: Marie-Hélène Rio et al.
SC3_003: Estimating the velocity and transport of the East Australian Current using Argo, XBT, and Altimetry: Nathalie Zilberman et al.
SC3_004: Multi-decadal change of the South Pacific Gyre circulation: Dean Roemmich et al.
SC3_005: Seasonal and interannual variability of the Brazil - Malvinas front: an altimetry perspective: Martin Saraceno et al.
SC3_006: Iceberg detection using the three modes of SIRAL on Cryosat: Jean Tournadre et al.
SC3_007: Meridional Heat Transport in the South Atlantic Ocean: Gustavo Jorge Goni et al.
SC3_008: An altimetric based metric for Gulf Stream position in climate models : Andrew Davis et al.

SC3_009: A wave investigation in the tropical Atlantic Ocean using satellite altimetry.: Jean-Luc Mélice et al.
SC3_010: Using Sea Surface Height to examine Air-Sea Interaction in the North Atlantic Ocean in Winter: LuAnne Thompson et al.
SC3_011: Altimetry-derived changes in the Gulf Stream properties and its impact on air-sea interaction: Shenfu Dong et al.
SC3_012: Atlantic Water transport and temperature anomalies through the Nordic Seas towards the Arctic Ocean: Leon Chafik
SC3_013: Extending and Improving Sea Level Measurements in the Ice Covered Arctic Ocean: Pierre Prandi et al.
SC3_014: Accurately measuring sea level change from space: an ESA Climate Change Initiative for MSL closure budget studies: Jean-Francois Legeais et al.
SC3_015: Warming of the global ocean : consistency of thermal and altimetric fields and dominance of descending density surfaces: Sirpa Hakkinen et al.
SC3_016: Assessing regional deep-ocean warming from satellite and in situ data: Denis Volkov et al.
SC3_017: A probabilistic description of the forced and intrinsic oceanic variability: SSH, SST, MOC, water masses.: Thierry Penduff et al.
SC3_018: Which part of the low-frequency sea-level variability is purely due to intrinsic ocean processes ?: Guillaume Serazin et al.
SC3_019: A Probabilistic Description of the Mesoscale Eddy Field in the Ocean: Martin Scharffenberg et al.
SC3_020: Mesoscale eddies in the North Atlantic subtropical gyre: 3D composite structure from satellite altimetry and Argo profile data: Angel Amores et al.

The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

GEO_001: Pointwise comparison of geostrophic currents of altimetry-derived instantaneous Ocean Dynamic Topography with in-situ measurements: Felix Müller et al.
GEO_002: The updated geodetic mean dynamic topography model – DTU15MDT.: Per Knudsen et al.

Tides, internal tides and high-frequency processes
Thu, Oct 22 2015, 11:00 - 18:00 - Grand Ballroom Foyer

TID_001: Improving the dynamic atmospheric correction for delayed-time and operational applications of altimetry: Loren Carrere et al.
TID_002: Tidal estimation in China Seas based on satellite altimetric data: Yongcun Cheng et al.
TID_003: Non-Stationary Internal Tides Observed Using Dual-Satellite Altimetry: Edward Zaron
TID_004: Updating the pole tide model for satellite altimetry: Shailen Desai et al.
TID_005: Global mapping of low-mode semi-diurnal and diurnal internal tides with a data-assimilative reduced gravity model: Gary Egbert et al.

Abstract details

What Do We Really Know About 20th Century Global Mean Sea Level?

Benjamin Hamlington (Old Dominion University, United States) ; Philip Thompson (University of Hawaii, USA) ; Felix Landerer (JPL, USA)

Session: OSTST Opening Plenary Session
Presentation type: Keynote/invited

Abstract:
Recent studies have resulted in a range of published estimates for the 20th century trend in global mean sea level (GMSL). Discrepancies can be attributed to two factors: 1) differences in analysis and/or reconstruction techniques; and 2) differences in tide gauge selection and quality control of the data. While it is difficult to conclusively determine the best method for estimating GMSL over the past century, it is possible to critically assess the impact of tide gauge selection and editing. Questions remain regarding to what extent the tide gauge network can inform us about GMSL over the past century. Here, we provide an in-depth examination of the tide gauge record and its utility in estimating GMSL both during the altimeter era and further into the past. As a starting point, we show how tide gauge selection choices can affect estimates of the long-term trend in GMSL. Extending beyond this simple test, we also provide a new approach to tide gauge selection and editing, relying on quantitative selection criteria wherever possible and accounting for the potential impact of spatial and temporal sparseness of the tide gauge record on the computation of GMSL and associated error estimates. We further attempt to address challenges posed by vertical land motion in our quality control process, either correcting or removing gauges significantly impacted by the movement of land. In doing so, we arrive at a quality-controlled set of tide gauges that yields an improved estimate of GMSL during the 20th century, and that can be broadly used in studies of regional and global sea level. Finally, using a simple data experiment, we constrain the 20th century rate of GMSL change, providing a lower bound on the trend estimate. Through this work, we will obtain an improved understanding of GMSL during the 20th century and provide context for the increased trend observed during the satellite altimeter era.
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AlborEx: a multi-platform interdisciplinary view of Meso and Submesoscale processes

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Session: OSTST Opening Plenary Session
Presentation type: Keynote/invited

Abstract:
Vertical motion associated with mesoscale and sub-mesoscale features plays a major role in the exchanges of properties between the surface and the ocean interior. Modelling studies of frontal regions suggest that vertical exchange is enhanced at density fronts. Significant uncertainty still exists, however, in our understanding of the net effect of fine-scale variability on biochemical tracer redistribution and the consequent marine ecosystem response.

One of the key challenges in estimating vertical fluxes from observations is related to the availability of high-resolution data. To anticipate the 2D SSH fields that will be provided by SWOT, allowing first-time measurements in the 15-100 km band, multi-sensor synoptic observations need to be collected to contribute to the understanding of the vertical exchanges associated with (sub)-mesoscale structures. The observational approach must be integrated with numerical simulations, both realistic and process-oriented.

In this study, we present the results of ALBOREX, a multi-platform and multi-disciplinary experiment completed in May 2014 as a part of PERSEUS EU funded project. This unique process-oriented experiment in the Eastern Alboran Sea, aimed at studying submesoscale dynamics and interactions at the mesoscale. The field campaign, conducted during 8 days, included 25 drifters, 2 gliders, 3 Argo floats and one ship (66 CTDs and 500 biochemical samples). The drifters followed coherently an anticyclonic gyre. Near real time data from ADCP showed consistent patterns with currents up to 1m/s (2 knots) in the southern part of the sampled domain. This is almost a factor of 2 larger than the magnitude of derived surface currents from standard altimetry gridded fields. The Rossby number derived from ADCP data reaches a value of 1.5 suggesting significant ageostrophic motion. QG Omega equation is used to investigate the mesoscale contribution (structures larger than 20 km) to the upward/downward motion associated with the anticyclonic gyre in the frontal zone. Vertical velocities of about ±20 m/day have been diagnosed.

Quasi-synoptic glider observations revealed submesoscale structures associated with a frontal zone and a deep chlorophyll maximum (DCM), at a resolution that enabled us to investigate its relationship with mesoscale and submesoscale dynamics. The front was formed where Atlantic Waters (AW), entering from Gibraltar, encounter local Mediterranean waters, with a density difference of about 1.5 kg/m^3 in less than 5 km. Simultaneous Argo profiler samplings, equipped with Photosynthetic Active Radiation (PAR) sensor, allowed to calibrate and empirical function to model instantaneous PAR profiles in the Glider temporal and spatial frame as a function of depth and Chlorophyll. Then, a standard bio-optical model was applied to assess the instantaneous primary production rates along the glider trip. Negative exponential relationships between Apparent Oxygen Utilization (AOU) and instantaneous primary production, within the high biomass patches, draw different slopes as function of the water masses. Integrated primary production maxima are detected in correspondence of the AW veins intercepted by the glider.

Observations are complemented by numerical simulations. A retrospective simulation has been carried out over the sea-trial period using data assimilation, with the aim to simulate the small scale oceanic fields as realistically as possible so to support the analysis and interpretation of the collected dataset. The outputs of this simulation in synergy with glider observations are used to initialize a Process Study Ocean Model that resolves vertical transport at (sub-) mesoscale fronts in the Eastern Alboran Sea. The aim is to explain subduction features (namely tongues of temperature, chlorophyll and oxygen observed from glider data and in good agreement with nutrient vertical distributions, CTD and Argo data), sampled during the ALBOREX experiment. From a physical point of view, frontal baroclinic instabilities at mesoscales and submesoscales are linked, since submesoscale instabilities at the upper layer seem to trigger deeper frontal mesoscale instabilities. From a biological viewpoint, remineralization and production are combined, but might be spatially separated. Large production occurs on the Western Alboran due to entrainment of nutrients through Gibraltar Strait . This production then is laterally advected by the Atlantic jet towards the Eastern Alboran Sea. On this side, Mediterranean and Atlantic origin waters form mesoscale fronts with large density gradients that trigger submesoscale instabilities. Vertical transport associated with these instabilities is typically of the order of tens of meters a day, which might explain the subducted features observed.
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Explaining the spread in global mean thermosteric sea level rise in CMIP5 climate models

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Session: OSTST Opening Plenary Session
Presentation type: Keynote/invited

Abstract:
The ocean stores more than 90% of the energy excess associated with anthropogenic climate change. The resulting ocean warming and thermal expansion is a leading contributor to global mean sea level (GMSL) rise. Confidence in projections of GMSL rise therefore depends on the ability of climate models to reproduce global mean thermosteric sea level (GMTSL) rise over the 20th century.
In this study, we first compare the GMTSL of climate models of the Coupled Models Intercomparison Project Phase 5 (CMIP5) to observations over 1961-2005.
Although the model-ensemble mean is within the uncertainty of observations, the model ensemble exhibits a large spread. We then aim at explaining the spread in CMIP5 climate models GMTSL over the 20th and 21st centuries. We show that climate models' GMTSL rise linearly depends on the time-integrated radiative forcing F (under continuously increasing radiative forcing).
The constant of proportionality (nu) expresses the transient thermosteric sea level response of the climate system. nu depends on the fraction of excess heat stored in the ocean, the expansion efficiency of heat, the climate feedback parameter and the ocean heat uptake efficiency.
The across-model spread in nu explains most (>70%) of the across-model spread in GMTSL rise over the 20th and 21st centuries, while the across-model spread in time-integrated F explains the rest. The time-integrated F explains less variance in the across-model GMTSL rise in 21st than in 20th century simulations, as the spread in F is reduced over the 21st century because the anthropogenic aerosol forcing, which is a large source of uncertainty in F, becomes relatively smaller.
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SAR mode altimetry and sea state bias

Clare Bellingham (National Oceanography Centre, United Kingdom) ; Christine Gommenginger (National Oceanography Centre, UK) ; Meric Srokosz (National Oceanography Centre, UK)

Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
SAR mode altimetry over the ocean was demonstrated for the first time in orbit with the ESA Cryosat-2 mission. Scientific studies since then have convincingly established the improved performance of SAR altimetry in terms of reduced altimetric noise, finer along-track spatial resolution and improved performance near land. Currently, no solution is available for sea state bias in SAR mode, and there remain uncertainties about the sensitivity of SAR mode altimetry to long ocean surface waves (swell) and their direction of propagation. Here some initial investigations of these issues are presented.
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A new proposal for SSB modelling with three parameters exclusively derived from altimetric data

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Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
The sea state bias (SSB) is a geophysical altimetric correction caused by the influence of local sea-state in the altimetric radar pulse and is still one of the largest terms in satellite altimetry error budget. Research on the understanding the SSB and on the improvement of SSB retrieval methods is an up-to-date topic, crucial to the full exploitation of altimeter measurements made both in the conventional Low Resolution Mode (LRM) and the new Synthetic Aperture Radar (SAR) mode.
This study presents the recent developments at the University of Porto in SSB modelling.
Traditionally, SSB operational models have been developed using empirical relationships between altimeter range bias, significant wave height (SWH), wind speed (U10) or radar backscatter cross-section measurements (σ0). Past studies suggested that two-parameter SSB models may be insufficient for this range bias parametrization leading to new developments of SSB models with additional information from wave field statistics captured from numerical ocean wave models. Additionally, in another field of study, some models have been proposed to retrieve wave period information (Tm, Tz) exclusively from the radar altimeter signal, combining both SWH and sigma0 fitted with buoys measurements.
A new global SSB model has been developed at University of Porto, based on 3 parameters, solely derived from altimetric data (SWH, U10 and Tz). This SSB model was designed using penalized regression splines embedded in a general framework provided by Generalized Additive Models (GAMs), allowing to model not only the relationship between SSB and each of the three parameters, but also their interdependencies, taking into account the fact that they are not independent. The adopted methodology has been applied to Jason-1 and TOPEX using wave period information retrieved from altimetric data and wave field statistics generated from WW3.
The chosen criteria for this new SSB model design and obtained results when implemented for Jason-1 and TOPEX altimetric missions, using wave field information derived from both altimetric data and numerical ocean wave models, will be presented.
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Inter-calibrated wet path delays for eight altimetric missions

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Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
The delay induced by the water vapour content of the atmosphere in the altimeter signal or wet tropospheric correction (WTC) is still one of the largest sources of uncertainty for studies such as sea level variation or ocean circulation. One of the aims of the ESA Climate Change Initiative Sea Level (SL-cci) project is to derive the sea level essential climate variable (ECV) and to estimate the long term sea level variation with an uncertainty less than 0.3 mm/yr. In view to meet these requirement, in the phase 2 of the project, wet path delay corrections for all missions used to generate the SL ECV were envisaged.
This paper presents the work developed at University of Porto (UPorto) to generate a new and inter-calibrated set of wet path delays, using the GNSS-derived Path Delay Plus (GPD+) algorithm, for eight altimetric missions: TOPEX/Poseidon (TP), Jason-1 (J1), Jason-2 (J2), ERS-1 (E1), ERS-2 (E2), Envisat (EN), CryoSat-2 (C2) and SARAL/AltiKa (SA).
The GPD+ are improved wet path delays based on: i) WTC from the on-board microwave radiometer (MWR) measurements whenever they exist and are valid; ii) new WTC values estimated by data combination, through objective analysis of all available data sources, whenever the first one is considered invalid; iii) model-derived WTC in the absence of measurements. In the estimation of the new WTC values, the following data sets are used: valid measurements from the on-board MWR, from water vapour products derived from scanning imaging radiometers (SI-MWR) on-board various remote sensing satellites and wet path delays derived from Global Navigation Satellite Systems (GNSS) coastal and island stations. In the estimation process, WTC derived from an atmospheric model such as the European Centre for Medium-range Weather Forecasts (ECMWF) ReAnalysis (ERA) Interim or the operational model are used as first guess.
To ensure the long term stability of the corrections, the large set of radiometers used in the GPD+ estimations require proper inter-calibration. For this purpose, all radiometers have been inter-calibrated, using the set of Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSM/IS) on-board the Defense Meteorological Satellite Program (DMSP) satellite series (F10, F11, F13,F14, F16 and F17) as reference, due to their well known stability and independent calibration. Due to the different orbits and sampling of the various satellites this was performed in three steps: 1) TP, J1 and J2 were adjusted to the FXX set by minimizing the WTC differences at match points; all other SI-MWR were adjusted to TP, J1 and J2 again minimizing the differences at match points; 3) E1, E2, EN and SA were adjusted to TP, J1 and J2 minimizing the differences at crossover points. In each step, a three parameter (offset, scale factor and linear trend) adjustment was performed.
Results show that the calibration parameters are generally small but not negligible, with offsets, scale factors and trends in the range [-12.7, 8.8] mm, [0.85, 1.03] and [-0.25, 0.25] mm/yr, respectively. The new products are shown to reduce sea level anomaly variance with respect to previous non-calibrated versions and to other WTC data sets. The original and calibrated WTC products are also compared with the presently most stable, though not perfect reference, the ERA Interim model, evidencing the improved alignment and consistency of the new products.

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A one-dimensional variational approach for wet tropospheric correction retrieval in the perspective of high resolution altimetry mission: defining the the background error covariance matrix

Laura Hermozo (CLS, France) ; Bruno Picard (CLS, France) ; Estelle Obligis (CLS, France) ; Laurence Eymard (LOCEAN/IPSL, FRANCE) ; Fatima Karbou (CNRM/GAME, FRANCE) ; Jean-François Mahfouf (CNRM, FRANCE)

Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
The future altimetry missions planned for the coming months (Jason-3, Sentinel-3) or for the coming years (SWOT) aim to deliver a measurement of the topography at a finer spatial resolution, a higher temporal rate and over heterogeneous surfaces, open ocean but also coastal regions, hydrological targets and over ice and sea-ice.
In this perspective, the role played by the wet tropospheric correction (WTC) is critical, due to its large temporal and spatial variability and its crucial weight in the final budget error.
Current algorithms are based on empirical approaches parameterized using measured (radiosonde) or modeled (numerical weather prediction analysis) atmospheric profiles; in both cases, a radiative transfer model relates the integrated content of WTC to the top of the atmosphere brightness temperatures (TB) and a relation is fitted between the two datasets.
This method is valid over open ocean only, where a model of the emissivity is available. The performances are then degraded wherever the instrumental measurements are contaminated by other surfaces (land, ice, sea-ice); solutions exist to correct for this contamination but will not be able to satisfy the future constraints on the retrieval errors over coastal regions or hydrological surfaces.
In this context, a one-dimensional variational approach (1D-VAR) for wet tropospheric correction retrieval is a good candidate to provide a unique method well adapted to all surfaces. Where current algorithms directly provide an integrated value of WTC, this latter aims to estimate the atmospheric profiles that best explain the TOA TB measurements. The WTC is then computed from integration of the retrieved profiles. Depending on the surface, the emissivity is provided by a model (open ocean) or emissivity atlas (other surfaces) estimated from TOA measured brightness temperatures. Previous work (Desportes et al. 2010) has already shown the potential of 1D-VAR over coastal regions.
In this presentation, we will focus on the background error covariance matrix. The method applied for its computation is presented and a set of matrices is defined according to specific atmospheric conditions. A sensitivity analysis of the impact of this set of matrices on the retrieval performances is performed using AMR Jason-2 TB and AMR WTC as a reference.

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Spectral analysis of microwave radiometers brightness temperatures and atmosphere water vapour content.

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Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
The wet tropospheric correction (WTC) plays a critical role on the altimetry mission budget error due to its large spatial and temporal variability.
Ubelmann et al 2013 has shown the effect of the WTC on the performance of the future SWOT mission using simulated 2D fields obtained from spectral analysis of existing WTC measurement provided by radiometers.
We propose here to compare the power density spectra (PSD) of the water vapour estimated from different microwave radiometers MWR (2-channels radiometers (23.8 GHz, 37GHz) as AltiKa MWR, 3-channels radiometers (18.7GHz, 23.8 GHz, 34 GHz) as Jason-2 AMR, multi-channels radiometers (such as AMSRE) and Numerical Weather Prediction analysis (ECMWF).
The differences in terms of linearity, slopes and the level white noise plateau are discussed and are related to the power density spectra of the observed brightness temperatures at various observation frequencies and different temporal rates. The impacts of the instrument spatial resolution, the interpolation scheme and the retrieval algorithm spectra are discussed as well.
Conclusions are drawn on the architecture and the processing of radiometer measurements on future altimetry missions with larger constraint on spatial resolution and budget errors.

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Analysis of the Wet Path Delay Spectrum from High-Resolution Airborne Observations

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Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
This talk presents an analysis of the wet path delay spectrum from high-resolution airborne measurements with the HAMMR microwave radiometer. Knowledge of the path delay spectrum is important for SWOT, particularly at high spatial frequencies, below the SWOT radiometer spatial resolution. Currently, the spectrum at high frequencies is extrapolated from ~25km resolution satellite measurements. With the HAMMR system, the spectra are measured to 150m. This system includes a scanning version of the Advanced Microwave Radiometer flying on Jason-2 and -3 as well as high frequency channels from 90-183 GHz. Flights were conducted in November 2014 along the west coast of the United States and over some inland rivers and lakes. This talk will describe the instrument and the calibration applied to the radiometer. It will also discuss the path delay retrieval algorithm that was developed for the sensor. During the campaign, observations were made in both clear and cloudy conditions and spectrum will be shown for both cases. Finally, a comparison will be made to the extrpolated spectrum currently used in the SWOT error budget.
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Issues and solutions involved in global wave model application to routine sea state bias range correction across the satellite altimeter constellation

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Session: Instrument Processing: Corrections
Presentation type: Oral

Abstract:
More accurate sea state bias (SSB) models that include global ocean surface wave model data have been shown to reduce error in the overall sea level variance signal and potentially alter the mean dynamic topography across ocean basins. However, there is a range of ocean wave models to choose from and their output is: i) highly dependent on the surface wind forcing product used to run them and ii) somewhat dependent on variations of the physics, optimization, data assimilation, and application that defines each specific wave model configuration. In order to consistently apply ocean wave model data to altimeter range correction, a strategy is needed to do this in a fashion that preserves the integrity and accuracy of each satellite's measurements, and do this over the long term, i.e. from ~1992 to present. Ideally, this strategy can also provide pseudo-operational SSB corrections suitable for interim and science quality (IGDR and GDR) data records that are made available for use within weeks or less of real time. This study proposes and evaluates an approach that involves use of an existing hindcast WAVEWATCH III wave model database at IFREMER (using NCEP-CFSR wind data) that runs from 1990-2012 and then transitioning to the use of the operational Meteo-France WAM model (using ECMWF winds) starting in Dec. 2014. Potential problems with switching between models comes both in long term drift and spatial/temporal biases in the wind and wave field estimates that may in turn impact the SSB. In the present SSB model the focus is on the mean wave period parameter. Our results will address wave model differences observed in recent assessments, the proposed approaches to remedy differences and transitions in the context of the SSB correction, and assessment of the level of SSB error that results from transitioning between products. One encouraging preliminary result is the finding of improved SSB model performance when using wave period information from the data assimilating Meteo-France WAM output.
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Is the Altimeter-Era Acceleration of Global Mean Sea Level Rise Being Masked by the 1991 Eruption of Mt. Pinatubo?

John Fasullo (NCAR, United States) ; Robert Nerem (University of Colorado, USA)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
Recent variability in global mean sea level rise is examined using the NCAR CESM1-CAM5 Large Ensemble, with an emphasis on identifying and distinguishing between its forced and internal components. The residual influence of the 1991 eruption of Mt Pinatubo is identified as a major source of inter-decadal variability during the altimeter era, an influence manifested by anomalous increases in ocean heat content following the forced minimum in 1993. On its own, OHC recovery explains an additional 5 mm of sea level rise during the era's first decade and is sufficient to fully explain reported inter-decadal variations. The magnitude of terrestrial water storage variability, both associated with the eruption and with also with internal modes of variability (e.g. PDO), is also quantified and its influence on GMSL is found to be small relative to OHC contributions.
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On the decadal trend of global mean sea level and its implication on ocean heat content change

Lee-Lueng Fu (Jet Propulsion Laboratory, United States)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
The variability of the trend of global mean sea level on decadal scales is of great importance to determining its long-term evolution. Trend determination is affected by the temporally correlated processes in the record. The problem is treated as one of optimal estimation weighted by the auto-covariance of the time series, which takes into account the various time scales affecting trend estimation. On decadal scales, the estimated standard error of the trend determined from the global mean sea level record from radar altimetry is about 0.3 mm/yr. The uncertainty does not include the systematic errors (~0.4 mm/yr) in the altimeter bias calibration. The time scale of the systematic errors is assumed to be much longer than decadal. The approach is also applied to determining steric sea level from the difference between altimeter-measured sea level and ocean mass estimated from the GRACE observations of the change of Earth's gravity. The uncertainty of the estimated trend of steric sea level, 0.12 mm/yr, suggests that the change of the global ocean heat content over decadal scales can be estimated from space observations to an accuracy on the order of 0.1 W/m2. The difference between of the steric sea level estimated from Argo and that from altimeter and GRACE, 0.08 +/- 0.23 mm/yr, provides an estimate of the upper bound of the systematic errors of altimetry and GRACE.
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Accuracy of Global Comparisons Between Altimetry and Tide Gauges

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
Quality assessment of altimeter data on the long-term is critical when one is looking for climate signals. Tide gauges measurements provide external and independent Sea Surface Height measurements which are used to check the quality and stability of altimeter sea levels. Comparisons to tide gauges are either performed at dedicated and carefully monitored calibration sites or through global analyses where a much larger set of in-situ stations is used. The main interest of both techniques is the detection of any altimeter drift or sudden bias.

The latter class of methods is based on existing tide gauges networks (GLOSS/CLIVAR, PSMSL, REFMAR), quality controlled and corrected to provide a physical measurement comparable with altimetry measurements. Results are highly dependent on processing choices like station selection, altimetry collocation, geophysical corrections for both in-situ and altimetry data. In the present study, we look for the source of observed discrepancies between tide gauges and satellite altimetry: do they reflect errors in satellite altimetry or tide gauges networks.

Results from comparisons between TOPEX/Poseidon, Jason-1 and Jason-2, which define the climate sea level record, and in-situ stations are considered here. We try to separate true altimetry problems from artifacts linked to in-situ events. This represents a new step in establishing the accuracy of our methodology for performing global comparisons between altimetry and in-situ.

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Assessing satellite era global mean sea level change using tide gauges and estimates of land motion

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
The satellite era sea level record is comprised of data from the TOPEX/Poseidon, Jason-1 and OSTM/Jason-2 missions, and is now approaching 23 years in duration. The accuracy of the record is dependent on the determination of any inter- and intra-mission biases, as well as the stability of these biases over time. Recent work published by our group suggests that these biases were significantly different to zero over the early part of the TOPEX record, having the effect of lowering the estimated rate of sea level rise over the full record from +3.2 mm/yr to between +2.6 to +2.9 ± 0.4 mm/yr, depending on the choice of land motion applied at the tide gauge.

In this contribution, we provide updated results from our method and present further sensitivity tests to assess the performance of the technique. We extend our analysis in time for Jason-2 mission, and provide results for the candidate RGDR data for the TOPEX mission. We investigate strategies for minimising residual noise between the offshore altimeter comparison point and the coastal tide gauge sites, as well as assess the influence of applying the new ULR6 GPS based estimates of vertical land motion. We conclude with an assessment of the influence of the estimated bias drift corrections on the inferred rate of GMSL rise and its variation over the ~23 year record.
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Balancing regional sea level budgets

Eric Leuliette (NOAA, United States) ; Laury Miller (NOAA, USA)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
Balancing the sea-level budget is critical to understanding recent and future climate change as well as balancing Earth's energy budget and water budget. During the last decade, advancements in the ocean observing system — satellite altimeters, hydrographic profiling floats, and space-based gravity missions — have allowed the global mean sea level budget to be assessed with unprecedented accuracy from direct, rather than inferred, estimates. In particular, several recent studies have used the sea-level budget to bound the rate of deep ocean warming [e.g. Llovel et al. 2014].

On a monthly basis, the sum of the steric component estimated from Argo and the ocean mass (barostatic) component from GRACE agree total sea level from Jason within the estimated uncertainties with the residual difference having an r.m.s. of less than 2 mm [Leuliette 2014]. Direct measurements of ocean warming above 2000 m depth during January 2005 and July 2015 explain about one-third of the observed annual rate of global mean sea-level rise.

Extending the understanding of the sea-level budget from global mean sea level to regional patterns of sea level change is crucial for identifying regional differences in recent sea level change. The local sea-level budget can be used to identify any systematic errors in the global ocean observing system. Using the residuals from closing the sea level budget, we demonstrate that systematic regional errors remain, in part due to Argo sampling. We also show the effect of applying revised geocentric pole-tide corrections for GRACE [Wahr et al. 2015] and altimetry [Desai et al., 2015].

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Advances in correcting vertical land motion at tide gauges using GPS estimates

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
The University of La Rochelle's group (ULR) has recently reprocessed data from a global GPS network of 750 globally distributed stations spanning 20 years from 1995 to 2015. This effort was part of the second International GNSS Service reanalysis campaign for the next International Terrestrial Reference Frame. We estimated velocities for 500 stations, 325 of which are located less than 15 km from a tide gauge station.

Here, I present the estimated ULR vertical velocities and show comparisons with different GPS estimates to highlight the progress that has been made in this field. Comparison to modeled GIA land motion is also provided. Particular focus is given to the discussion of limitations that arise when using GPS velocities to correct the vertical land motion from tide gauge observations of sea level.

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Examining the role of land motion in estimating altimeter system drifts

Amanda Plagge (NOAA, United States) ; Eric Leuliette (NOAA, USA) ; Laury Miller (NOAA, USA)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Oral

Abstract:
As Jason-3 and Sentinel-3 extend the sea level climate record from altimetry into a third decade, it becomes even more important to establish the differences in bias estimates produced using these options.

In the ongoing attempt to determine mission-specific satellite altimeter bias drift via comparison with the tide gauge network, accurate estimates of vertical land motion (VLM) at tide gauges are essential. Previous drift studies have used a variety of VLM estimates or methodologies [e.g. Watson et al., 2015; King et al., 2012; Mitchum 2008], but none have evaluated the full range of VLM estimates. We consider VLM estimates from a variety of methods, including King et al. (2012, updated), JPL's GPS time series (http://sideshow.jpl.nasa.gov/post/series.html), the Université de La Rochelle ULR5 (Santamaria-Gomez 2012), and Doran (2010), and produce individual drift bias estimates for each mission with each VLM solution.

We find that the drift estimates from both the combined TOPEX/Jason-1/Jason-2 dataset and the combined Envisat/AltiKa record vary by ~0.5 mm/year depending on the VLM estimate. We will discuss the implications of VLM choice and station selection criteria on the drift estimates.
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Retracked TOPEX Climate Data Record

Philip Callahan (Jet Propulsion Laboratory, United States) ; Joseph McMichael (Jet Propulsion Laboratory, United States) ; Brent Williams (Jet Propulsion Laboratory, United States) ; Doug Vandemark (University of New Hampshire, Institute for the Study of Earth, Oceans, Space, United States) ; Hui Feng (University of New Hampshire, Institute for the Study of Earth, Oceans, Space, United States)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

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

It was previously determined that leakages limited the use of the Cal-1 data for determining PTRs to the first seven lobes. Methods to extend the PTR to the necessary 30 lobes to reach full accuracy were implemented. It was also determined that it was not feasible to improve upon the original WFF waveform weights. The resulting PTRs and the original waveform weights were used to retrack all of the TOPEX data in three modes: fixed skewness of 0 and 0.1 and solving for skewness. Previously only the solve-skewness mode has been extensively evaluated. The fixed skewness of 0.1 is of particular interest as that is what is done for Jason.

The retracked data with GSFC orbits std1410, updated tides from GOT4.10c, and fully corrected sigma0s were used to solve for new sea state bias models for Alt-A and Alt-B.

During the process of updating the data, we became aware of a difference between the original GDRs and the MGDR-B from PODAAC that is widely used. The latter includes the WFF range calibration correction. The properties of this correction were investigated.

Results from the final TOPEX Climate Data Record product delivered to NOAA will be presented.

The work reported here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration with funding from the NOAA Climate Data Records program.

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On the signature of long swell for the SAR-mode wave height of Cryosat-2

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

Abstract:
The SAR Radar ALtimeter (SRAL) of the Sentinel-3 mission will operate continuously in the SAR mode over the oceans. The wave heights that will be retrieved in that mode needs to be validated before operational assimilation in wave models. This paper reports on the results of a comparison over a long period between the SAR mode wave heights obtained with CryoSat-2 and wave model significant wave heights. The impact of assimilating SAR mode wave data in the wave model MFWAM is also shown.

Two sets of wave data from SAR mode of Cryosat-2 have been provided by the French space agency CNES. The first set of data starts from May until september 2012, and it is retrieved by the processing called V13.The second set of data starts from November 2013 until March 2014, and it is retrieved by an upgraded processing called V14.

Several assimilation tests with the wave model MFWAM are performed for these periods. The results are validated with independent altimeter wave data and available buoys data. A comparison with the assimilation of LRM-mode wave data from Cryosat-2 is also examined. The results show slightly better scatter index of significant wave height when using the SAR mode wave heights.

The comparison between the wave model MFWAM and SAR mode wave heights reveals significant biases when long swell travels parallel to the satellite ground tracks. This feature is slightly reduced for V14 processed data. Further discussions will be presented in this paper.

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Separation of Coherent and Incoherent Scattering Components from Delay/Doppler Altimeter Waveforms

Alejandro Egido (NOAA, United States) ; Walter Smith (NOAA, United States)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

Abstract:
One of the main benefits of the delay/Doppler altimeter (DDA) is the improved resolution of the system along the satellite track. By means of an unfocussed Synthetic Aperture Radar (SAR) processing technique, the altimeter footprint along the flight direction can be reduced by an order of magnitude with respect to conventional altimeters. This has allowed to resolve small-scale features on the ocean, and to provide altimetry data up to several hundreds of meters off the coast.

However, with the delay-Doppler processing the resolution improvement occurs only on the along-track direction, while the across-track direction remains pulse-limited. The result is an elongated footprint perpendicular to the satellite flight path. This is particularly significant in the case of coastal altimetry, as the DDA's response in coastal regions depends on the relative orientation between the coastline and the spacecraft orbital plane.

The combination of the effects of several scatterers with different backscattering intensities on the surface can lead to random variations of the DDA waveforms, preventing conventional retracking techniques from retrieving geophysical parameters from altimeter data. In the case of coastal areas, the scattering is essentially composed of a coherent component, from static targets on the land, which are able to maintain their phase history, and an incoherent component from reflections of the radar echoes off the ocean surface, which acts as wide distributed target. If the land surface scattering is much higher than the one of the ocean, a strong coherent component is expected to arise from these areas, which will highly distort the ocean-like waveform shape.

We have developed a processing technique that allows the separation of the coherent and incoherent scattering components from SAR altimetry waveforms. The technique is similar to the one used in imaging SAR systems, and is based in the exploitation of the phase history of coherent targets during their illumination period with the antenna beam.

For the development of the technique we have used the CryoSat-2 SAR Mode data. The starting point of our processing is the full bit rate (FBR) I/Q complex echo samples. By accounting for the phase evolution of the static targets in the scene, it is possible to counter-rotate the phase of the FBR complex echoes along the aperture, which allows to perform an inter-burst coherent averaging, potentially, as long as the target illumination time. This reduces the incoherent components of the radar signal, which results in a radar waveform that contains only the coherent scattering component. The coherent component can later be removed from the original delay/Doppler waveform.

For the coastal areas, this can be used to remove the contribution of static coherent targets on the land from the SAR mode L1b waveform. This is expected to remove most of the land contamination from the DDA waveforms, thus enabling the application of ocean-like retrackers at much closer distances to the coast, regardless of the coastline/satellite track relative orientation. This technique has also promising applications for the cryosphere, as it can be used for the separation of the contribution of sea-ice freeboard and leads, as well as for in-land waters, where small water bodies act as perfect coherent scatterers.

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Impact of the antenna diagram approximation in conventional altimetry waveform processing: application to SARAL/AltiKa data

Sophie Le Gac (CNES, France) ; Jean-Christophe Poisson (CLS, France) ; Fanny Piras (CLS, France) ; Pierre Thibaut (CLS, France) ; François Boy (CNES, France) ; Guillaume Valladeau (CLS, France) ; Amandine Guillot (CNES, France) ; Jean-Damien Desjonqueres (CNES, France) ; Nicolas Picot (CNES, France)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

Abstract:
In all ocean retrackers, the Brown model includes a Gaussian approximation of the antenna diagram. This approximation does not take into account possible distorsions from the theoretical antenna diagram. This effect appears non negligible for SARAL/AltiKa altimeter, whose antenna beam illuminates an 8.4 km-wide footprint only. Previous studies have shown a possible impact of AltiKa antenna Gaussian approximation on geophysical parameters, especially on the mispointing angle estimated using MLE4 retracking algorithm: a high dependency is observed in function of the wave height.
In the frame of the PEACHI project, this study aims at comparing the Gaussian approximation and the consideration of AltiKa's real antenna patterns in the Brown model. For this purpose, actual ground measurement of AltiKa antenna diagram has been used. Differences between the Gaussian approximation and the real antenna diagram of up to 10% (0.3 dB) appear at the edge of the antenna footprint.
Brown models accounting for either the Gaussian approximation, or the real antenna diagram interpolated onto the waveform samples, have been simulated using analytical and convolved formulations. We show that the impact of the Gaussian approximation is not negligible on the retrieved parameters and is strongly dependent on wave height. These results suggest that for AltiKa, considering the antenna gain either in the retracker or via updated correction look-up tables is mandatory. In the latter case, we show that we correct for most of the dependency previously observed on the mispointing slope with respect to the wave height.
Further steps of this study include a comparison to Ku-band Jason-3 antenna gain patterns, whose impact is expected to be lower than AltiKa and an application to the numerical retracker, for a complete consideration of the altimeter instrumental features.

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Level-2 assessment of along-track antenna pattern compensation for SAR altimetry

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

Abstract:
One of the main benefits of the along-track processing in SAR altimetry [1] is the speckle reduction that is achieved by multi-looking the single look echoes that are gathered for a given position on the Earth surface. Further advantages in terms of speckle reduction can be achieved on sea waveforms by compensating the along-track antenna pattern on the stacks of single look echoes before multi-looking.

This abstract is mainly aimed at investigating the precision of the geophysical parameters that are retrieved from the multilooked waveforms after the compensation of the Along-track antenna Pattern Compensation (APC). Experiments have been conducted on CryoSat-2 acquisitions processed using the ESA GPOD service (SARvatore) to produce a wide dataset of multilooked waveforms with APC.

It is worth recalling here the standard processing chain for a SAR altimeter [1]: firstly an approximately equally spaced set of ground locations on the Earth surface, i.e. surface sample, is identified. A surface sample gathers a stack of single look echoes coming from the processed bursts during the time of visibility.

However, in a surface sample stack, each single look echo has been acquired from a different position of the instrument along the orbit and, as a consequence, it results to be scaled in power by the antenna pattern as function of the look angle. According to [2], on a uniformly rough spherical surface, e.g. the ocean, the power of the single look echoes in the stack is modulated by the along-track antenna pattern.

But the speckle being a multiplicative noise, the speckle noise power will also be shaped by the antenna pattern so that the speckle has not the same power in different single look echoes in the stack. Thus, by simply averaging the single look echoes, the speckle will not reduce as much as possible.

An increased speckle reduction can be obtained by compensating the power modulation due to the along-track antenna pattern on the stack before averaging. This way, the power of the speckle from the off-nadir beams is increased at the same power of the speckle in the central beams, so that the speckle in all the single look echoes in the stack is raised approximately to the same level. It is worth underlining here that, to correctly compensate the along-track antenna pattern, an accurate knowledge of the pitch is needed and the approach described in [2] has been here used, since it is well suited for ocean acquisitions. Moreover, together with APC the most off-nadir single looks echoes in the stack are ruled out from the multi-looking because they are expected to carry less information due to the limited receiving window of the CryoSat instrument and because their leading edge is expected to be much less steep than ones closer to the nadir.

Experiments have been conducted on CryoSat-2 acquisitions over ocean, aimed at verifying the improvements in speckle reduction and in precision of the retrieved physical parameters using APC in Level1 processing. The test dataset is planned to be composed by CryoSat acquisitions in SAR mode over both the Wadden Sea and open ocean, in order to test APC performance under a wide range of sea states.

As a metric to evaluate the speckle reduction, the Equivalent Number of Looks (ENL) has been used, which is defined as the estimate of the effective number of statistically independent looks and it is expected to be bounded by the number of averaged single look echoes. At first the experimental ENL has been evaluated on the two CryoSat Level1 datasets (without APC and with APC) as function of the SWH. Preliminary results show that an increase of about the 10% of average ENL along the waveforms is obtained using APC, independently of the SWH.

Moreover, we aim at verifying the possible improvements on the retrieved physical parameters. The SAMOSA retracker has been applied on the two CryoSat Level1 datasets (in case of APC an isotropical along-track antenna pattern was used in the retracker). Preliminary results show that that the misfit (here defined as the percentage root mean square error between the SAMOSA power waveform model and the 20Hz power waveforms) for the APC dataset is about 4% lower for SWH higher than 1 m that than for the dataset without APC applied. Further analysis have to be performed to assess the precision and the accuracy of the APC dataset in the sense of SSH, SWH and Sigma0.

[1] R. Raney, “The delay/doppler radar altimeter,” Geoscience and Remote Sensing, IEEE Transactions on, vol. 36, no. 5, pp. 1578–1588, Sep 1998.
[2] M. Scagliola, M. Fornari, and N. Tagliani, “Pitch estimation for cryosat by analysis of stacks of single-look echoes,” IEEE Geosci. Remote Sens. Letters, vol. PP, no. 99, pp. 1–5, 2015.
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Improved SAR-mode ocean retrievals from new Cryosat-2 processing schemes

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

Abstract:
New SAR-mode processing schemes enabling a more efficient exploitation of the capabilities of the SIRAL altimeter compared to those obtained with the actual Cryosat-2 ground processing, have been investigated and analyzed thanks to easy-to-use and versatile tools developed in CNES/CLS premises.
It has been clearly demonstrated that the actual SAR-mode performances are not optimized since the current method does not take maximum advantage from the Doppler processing. This observed limited improvement is due to the fact that in a stack, the contributing beams to the final averaged waveform have different mean shapes related to the looking angle of measurement, leading to an effective number of looks that is lower than the number of beams. This number has been computed theoretically and is consistent with the actual SAR retracking estimation noise.
It is thus essential to develop alternative methods allowing a better processing to improve the range noise reduction and ensure maximized scientific returns from Cryosat-2 data, but also from the upcoming Sentinel-3 and Sentinel-6 missions.
Different processing approaches have been then recently studied with Cryosat-2 data showing potential improvement of the SAR altimetric measurements' precision over ocean, at the expense of a slightly lower spatial resolution for some of the proposed solutions. For each SAR/Doppler processing scheme, a data set of at least one-month duration has been produced over open ocean and their performances assessed through the use of common validation tools and protocols via comparison with operational-like data products (generated with CNES processor CPP). The aim is to determine whether the new processing schemes have a potential impact in operational use or not.
We will present the principle of these methods, and their benefits will be displayed.
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Ensuring the sea level continuity between open ocean and sea iced regions in the Arctic Ocean: some LRM processing solutions

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Oral

Abstract:
The Arctic Ocean is an important component of the climate system whose exact influence on ocean circulation is still poorly understood today. Due to the presence of sea ice and its temporal variability, sea level data coverage is seasonal and this hampers the use of altimetry for climate studies. It is thus crucial to increase the coverage of altimetry measurements in these areas. Considering that the sea ice is not homogeneous but fractured by small openings or water channels called leads or polynyas, it is essential to distinguish ice-free regions from regions covered by sea ice, to identify lead returns and to improve the estimation process for those particular measurements.
Thanks to the CNES PEACHI project and the ESA Sea Level CCI project, Ka-band AltiKa waveforms and Ku-Band RA-2 waveforms have been respectively processed in order to retrieve sea level height estimates in the Arctic Ocean regardless of the sea ice presence. Peaky waveforms coming from leads or polynyas have been identified and a new retracking algorithm developed based on an ocean model including the mean square slope of the surface in its formulation. This new analytical adaptive 4-parameter solution allows us to fit very well both ocean waveforms as well as peaky waveforms from leads, accounting for the major instrumental characteristics (point target response, antenna gain pattern …) and ensuring the continuity between open ocean and ice covered sea level estimations. Finally, the use of such a physical model allows to mitigate the poor sampling of the returned waveform that is particularly limiting in such highly contrasted and reflective areas.
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Updated Altimetric Datasets and Services at PO.DAAC

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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. Jason-1 will be reprocessed into version E and be available to the user community this year. Other updates are version 3 of the Integrated Multi-Mission Ocean Altimeter Data for Climate Research and US West Coast coastal altimetry. Coastal altimetry for Jason-2 from ALES is also available at PO.DAAC.

There will be a new user registration to access data at PO.DAAC, along with the rest of NASA's DAACs. PO.DAAC plans on having a transition period early next year to give users a chance to get use to the new system before switching over. Other new services include datasets having Digital Object Identifiers (DOI) so that users can now reference datasets as a citation rather than in the acknowledgments. The forum has been updated to distribute a digest keep users who are signed up on the latest announcements and topics being discussed.

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SAR altimetry processing on demand service for Cryosat-2 and Sentinel-3 at ESA G-POD

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

Abstract:
The scope of this work is to feature the new ESA service (SARvatore) for the exploitation of the CryoSat-2 data, designed and developed by the Altimetry Team at ESA-ESRIN EOP-SER (Earth Observation – Exploitation, Research and Development). The G-POD Service, SARvatore (SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation) for CryoSat-2, is a web platform that provides the capability to process on-line, on-demand and with user-selectable algorithm configuration CryoSat-2 SAR/SARin data, from L1a (FBR) data products until SAR/SARin Level-2 geophysical data products. The Processor makes use of the G-POD (Grid-Processing On Demand) distributed computing platform to deliver timely the output data products and interfaces with ESA-ESRIN FBR data archive (155'000 SAR passes and 41'000 SARin passes). The output data products are generated in standard NetCDF format (using CF Convention), and they are compatible with the ESA Multi-Mission Radar Altimetry Toolbox and other NetCDF tools. Using the G-POD graphic interface, it is easy to select the geographical area of interest along with the time-frame of interest, based on the Cryosat-2 SAR/SARin FBR data products availability in the service's catalogue. The processor prototype is versatile in the sense that the users can customize and adapt the processing, according their specific requirements, setting a list of configurable options. After the task submission, the users can follow, in real time, the status of the processing task. From the web interface, the user can select to generate experimental SAR data products as stack data and RIP (Range Integrated Power) waveforms.
The processing service, initially developed to support the development of awarded contracts confronting the deliverables to ESA, is now available to be used by the SAR Altimetry Community worldwide for research & development experiments, on site demonstrations/training in training courses and workshops, cross-comparison against third party products (CLS/CNES CPP Products or ESA SAR COP data products for instance), preparation for the Sentinel-3 Surface Topography Mission, producing data and graphics for publications, etc. Initially, the processing was designed and optimized for open ocean studies solely, based on the SAMOSA model developed for Sentinel-3 Ground Segment using CryoSat data, but since June 2015, a new retracker (SAMOSA+) is offered in the service as dedicated retracker for coastal zone, inland water and sea-ice/ice-sheet. In the view of the Sentinel-3 launch, a new flavor of the service will be initiated specifically dedicated to process the Sentinel-3 mission data products. The scope of this new service will be to maximize the exploitation of the upcoming Sentinel-3 Surface Topography Mission over all surfaces. The service is open and free of charge and available at: https://gpod.eo.esa.int/services/CRYOSAT_SAR/
More info can be read at:
http://wiki.services.eoportal.org/tiki-index.php?page=GPOD+CryoSat-2+SARvatore+Software+Prototype+User+Manual

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Radar Altimetry Toolbox

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

Abstract:
The prime objective of the SEOM (Scientific Exploitation of Operational Missions) element is to federate, support and expand the large international research community that the ERS, ENVISAT and the Envelope programmes have build up over the last 20 years for the future European operational Earth Observation missions, the Sentinels. Sentinel-3 builds directly on a proven heritage of ERS-2 and Envisat, and CryoSat-2, with a dual-frequency (Ku and C band) advanced Synthetic Aperture Radar Altimeter (SRAL) that provides measurements at a resolution of ~300m in SAR mode along track. Sentinel-3 will provide exact measurements of sea-surface height along with accurate topography measurements over sea ice, ice sheets, rivers and lakes. The first of the two Sentinels is expected to be launched in early 2015.

The current universal altimetry toolbox is BRAT (Basic Radar Altimetry Toolbox) which can read all previous and current altimetry mission's data, but it does not have the capabilities to read the upcoming Sentinel-3 L1 and L2 products.

ESA will endeavour to develop and supply this capability to support the users of the future Sentinel-3 SAR Altimetry Mission. BRAT is a collection of tools and tutorial documents designed to facilitate the processing of radar altimetry data. This project started in 2005 from the joint efforts of ESA (European Space Agency) and CNES (Centre National d'Etudes Spatiales), and it is freely available at http://earth.esa.int/brat. The tools enable users to interact with the most common altimetry data formats, the BratGUI is the front-end for the powerful command line tools that are part of the BRAT suite. BRAT can also be used in conjunction with Matlab/IDL (via reading routines) or in C/C++/Fortran via a programming API, allowing the user to obtain desired data, bypassing the data-formatting hassle. BRAT can be used simply to visualise data quickly, or to translate the data into other formats such as netCDF, ASCII text files, KML (Google Earth) and raster images (JPEG, PNG, etc.). Several kinds of computations can be done within BRAT involving combinations of data fields that the user can save for posterior reuse or using the already embedded formulas that include the standard oceanographic altimetry formulas.

The Radar Altimeter Tutorial, that contains a strong introduction to altimetry, showing its applications in different fields such as Oceanography, Cryosphere, Geodesy, Hydrology among others. Included are also "use cases", with step-by-step examples, on how to use the toolbox in the different contexts.

The new Altimetry Toolbox shall benefit from the current BRAT version. While developing the toolbox we will revamp of the Graphical User Interface and provide, among other enhancements, support for reading the upcoming S3 datasets and specific "use-cases" for SAR altimetry in order to train the users and make them aware of the great potential of SAR altimetry for coastal and inland applications. As for any open source framework, contributions from users having developed their own functions are welcome.

The first Release of the new Radar Altimetry Toolbox is expected fot mid September. It will incorporate the capability to read S3 products, the new CryoSat-2 Baseline C as well as the Jason-3.
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Multivariate Reconstruction of Sea Level from 1900 to Present

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

Abstract:
We present a recently created sea level reconstruction dataset using a new technique relying on cyclostationary empirical orthogonal functions (CSEOFs). Our focus in creating this dataset is on how other ocean observations such as sea surface temperature can be leveraged to create an improved reconstructed sea level data set spanning the time period from 1900 to present. Here, we demonstrate the use of this reconstructed data set for climate monitoring, creating indices computed solely from sea level measurements for monitoring signals such as the eastern Pacific (EP) El Niño–Southern Oscillation (ENSO), central Pacific (CP) ENSO, and Pacific Decadal Oscillation (PDO). The primary goal of this presentation is to advertise the upcoming release and public availability of the global multivariate sea level reconstruction from 1900 to present that will be hosted by NASA JPL/PO.DAAC.

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Outreaching a space technique through its climate applications: Jason-3

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

Abstract:
Climate, and Climate change, are among the main general public interests. Altimetry is one of the most important tools for monitoring ocean dynamics, and as such is a source of vital data for including in forecasting models of ocean-atmosphere coupled events such as El Niño, monsoons, the North Atlantic Oscillation or decadal oscillations. Seasonal climate forecasting is also showing interesting results. The oceans are in turn affected by climate variations, as the sea level rises and falls in response to their fluctuations.
Jason-3 (CNES/EUMETSAT/NASA/NOAA) will be launched soon, with one of its main goals continuing on the now 23-year continuous time series into a 30-year climate-relevant length.

On another plan, the United Nations Climate Change Conference 21st yearly session of the Conference of the Parties (COP 21) meeting will take place in Paris end of 2015 (30 November to 11 December 2015). Outreaching radar altimetry through its climate-related applications using both the conference and the launches (Jason-3 but also Sentinel-3) is thus an evidence. However, how, what and when?

We will detail the points we consider as focus for this outreach (e.g. sea level rise measurement, but also El Niño, monsoons, etc.), how to broach them in order to reach the general public interest, via web, journalists, teachers etc. In particular, the Argonautica educational project (https://enseignants-mediateurs.cnes.fr/fr/web/CNES-fr/7161-argonautica.php) will focus in 2015-2016 on climate issue, in relation also with formal school curricula, other satellite data and animal tracking. Past experience will be detailed, from the Aviso+ altimetry data distribution center, current activities at Cnes but also future plans.
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Observations of El Niño impacts using in situ GLOBE protocols and satellite data

Danielle De Staerke (CNES, France) ; Margaret Srinivasan (Caltech Jet Propulsion Laboratory, USA) ; Vinca Rosmorduc (CLS, France) ; Annie Richardson (Caltech Jet Propulsion Laboratory, USA)

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

Abstract:
The El Niño phenomenon is a periodic ocean condition that occurs every two to ten years in the central and east-central equatorial Pacific Ocean. It alters the normal patterns of ocean circulation, surface temperature, and evaporation, causing noticeable and often severe changes in weather conditions in many areas of the world. El Niño is the warm phase of the El Niño Southern Oscillation (ENSO), and usually reaches its peak between December and February time period.

El Niño and its worldwide consequences are studied by the school network of the GLOBE Program (www.globe.gov) which brings together students, teachers, and scientists in support of student research and validation of international Earth science research projects.

Since the start of the GLOBE Program over 20 years ago, GLOBE classrooms utilize carefully developed daily, weekly, or seasonally protocols such as maximum, minimum and current temperatures, rainfall, soil moisture, and others, to measure changes in the environment. The data collected by the students is entered in an online GLOBE database. In addition to the student-contributed data, automated stations also collect and send measurements to the GLOBE database.

Students compare their data with global data acquired by satellites to help validate the satellite data. With a potentially historic-level El Niño event thought to be on the horizon--possibly one of the strongest in 50 years—we will propose an emphasis on measurements from GLOBE schools that will support studies and satellite observations of El Niño. We plan to provide the schools with additional satellite data sets such as ocean temperature measurements from Advanced Very High Resolution Radiometer (AVHRR), sea surface elevation measurements from Jason-2 and 3 (after it launches), and others to be identified.

We wish to address and support the following educational objectives:
- Demonstrate how El Niño affects local precipitation and temperature across the globe,
- Link teachers, scientists and students to improve understanding of the local effects of El Niño on weather, ecosystems, and society, and compare these effects in different countries,
- Provide insights to the essential elements of satellite images and their use in identifying physical changes on Earth’s surface,
- Strengthen scientific reasoning abilities in GLOBE students.

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Outreach Showcases

All ; Margaret Srinivasan (Caltech Jet Propulsion Laboratory, USA) ; Vinca Rosmorduc (CLS, France) ; Jessica Hausman (JPL, USA)

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.
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Are SAR wave spectra from Sentinel-1A ready for operational use in the wave model MFWAM

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

Session: Application development for Operations (previously NRT splinter)
Presentation type: Oral

Abstract:
The assimilation of satellite wave observations plays a key role in the operational wave forecasting system of Meteo-France. Since July 3 the European space agency has released the level 2 wave products of sentinel-1A for the global coverage. The goal of this paper is to check the quality of the C band SAR wave spectra provided by Sentinel-1A. The assimiation tests in the wave model MFWAM are also performed to examine the impact on the analysis and forecast periods. This work is necessary in order to prepare the SAR wave spectra for operational use.
In this work we investigated separately the assimilation of SAR wave spectra from the two different look angles off nadir. The preliminary results show that the SAR swell wave height from the second look angle is underestimated regarding to the wave model MFWAM. The sensitivity of the assimilation with the wavelength cut-off is also examined. The results have been validated with altimeters wave data.
Further, combined assimilation of SAR wave spectra and altimeters wave data have been also performed. We expect using Jason-3 wave data in the combined assimilation. The results are discussed in the analysis and forecast periods. The impact of the combined assimilation in storm events generating high waves are analysed in this paper.

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Improved Representation of Eddies in Fine Resolution Forecasting Systems Using Multi-Scale Data Assimilation of Satellite Altimetry

Zhijin Li (JPL, United States)

Session: Application development for Operations (previously NRT splinter)
Presentation type: Oral

Abstract:
The impacts of multi-satellite altimetry on the representation of eddies across the spectrum of meso-scales from 500 km to the order of 10 km are assessed. Horizontal grid spacing down to the order of 1km is now often used for regional forecasting models. To assimilate satellite altimetry data into such fine resolution models, we need to deal with a set of particular difficulties. Among those difficulties are scale differences among sea surface height, salinity and temperature fields, density compensation, spatial localization and temporal intermittency of small mesoscale and sub-mesoscale systems, and others. Leveraging a real-time multi-scale three-dimensional variational data assimilation (MS-3DVAR) and forecasting system, which has successfully supported the Salinity Processes in the Upper Ocean Regional Study (SPURS) field campaign in the North Atlantic Ocean, 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 representation of mesoscale and sub-mesoscale eddies whose scales can be down to a few ten km.
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NOAA Operational Satellite Derived Oceanic Heat Content Products

Eileen Maturi (NOAA/NESDIS/STAR, United States) ; David Donahue (NOAA/NESDIS/OSPO, United States) ; Nick Shay (RSMAS - University of Miami, United States) ; Jodi Brewster (RSMAS - University of Miami, United States) ; Jerry Guo (: MAXIMUS, United States)

Session: Application development for Operations (previously NRT splinter)
Presentation type: Oral

Abstract:
In September 2012, the National Oceanic and Atmospheric Administration (NOAA) and the National Environmental Satellite, Data, and Information Service (NESDIS) began providing a suite of operational satellite derived ocean heat content (OHC) products. The satellite derived OHC is a measure of the integrated vertical temperature from the sea surface to the depth of the 26°C isotherm including the surface mixed layer. The product is computed from altimeter-derived isotherm depths in the upper ocean relative to 20°C based on a daily climatology from the World Ocean Atlas(WOA) and Global Digital Elevation Model (GDEM) cast within a 2.5 layer ocean model. Product generation requires data from at least two satellite altimeters and the daily Sea Surface Height Anomaly updates from the U.S. Navy Altimeter Processing System.
In the present model, the OHC estimates are calculated from 5 km resolution sea surface temperatures (SST) obtained from NESDIS GEO-POLAR Blended SST Analyses (Harris and Maturi, 2012) combined with Jason-2, SARAL and Cyrosat-2 altimeter estimates of the 20°C and 26°C isotherm depths; the altimeter estimates are derived from a scheme using a daily ocean climatology of mean isotherm depths and reduced gravities. Based on a mean ratio between the 20°C and 26°C isotherm depths, the depth of the 26°C isotherm and the ocean mixed layer depth are inferred. By integrating the 26°C isotherm depth to the surface (where SST is the surface boundary condition) an OHC is calculated. The product fields are evaluated monthly when thermal structure data from various ocean data collection platforms become available (e.g. Argo floats, XBT transects, mooring measurements, and airborne profiling from NOAA research aircraft).
Satellite derived OHC is currently produced operationally for the North Atlantic, North Pacific, and South Pacific. A suite of Ocean Heat Content Products are planned for the North and South Indian Oceans.
As new altimeters are available, they will be incorporated into the Oceanic Heat Content algorithm for product generation.

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On the use of recent altimeter products in NCEP ocean forecast system for the Atlantic (RTOFS Atlantic)

Liyan Liu (NOAA, United States) ; Carlos Lozano (noaa, us) ; Avichal Mehra (noaa, us) ; Dan Iredell (noaa, us)

Session: Application development for Operations (previously NRT splinter)
Presentation type: Oral

Abstract:
Satellite altimeter sea surface height anomalies (SSHA) from Jason-2, AltiKa, and CryoSat-2; and recent estimates of mean dynamic topography (MDT) are explored for use in real time RTOFS-Atlantic for SSH data assimilation, and in delayed mode for daily SSH analysis.. Sensitivity of assimilation parameters in the performance of these products and revised SSH assimilation algorithms will be illustrated. An overall improvement in the forecast can be traced to the quality of the new products; and there remain some open questions including the extension of useful altimeter data in the continental shelves of the Atlantic.
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Operational Oceanography in support of the search for MH370

David Griffin (CSIRO, Australia)

Session: Application development for Operations (previously NRT splinter)
Presentation type: Oral

Abstract:
On 30 July 2015 the world's media focused again on one of the most mysterious tragedies of our time: the disappearance of Malaysia Airlines flight MH370 16 months earlier. The focus of attention was the flaperon that washed up on Reunion, east of Madagascar. Operational ocean modelling had been used in the initial 6-week search of the ocean surface for debris but none was found. One reason for that was the huge uncertainty of the splashpoint, which ranged during the search to much lower latitudes than are now thought to be likely. The finding of the flaperon immediately ignited questions of whether its location on Reunion was consistent with current estimates (based on the Inmarsat handshakes, etc) of where the plane entered the water. At the time of writing (3 days after the finding), we have advised the authorities that the Reunion finding 'does not cast doubt' on the present understanding of the splashpoint area, which is still being searched with side-scan sonar. Indeed, landfall in the Madagascar region was foreshadowed a year ago. But nor can the finding be used to refine the bounds of that area, since splashpoints in many parts of the east Indian Ocean are also consistent with the finding, because of ocean eddies and various uncertainties. The trajectory modelling (both forwards and backwards in time) performed to produce this advice used the operational wind, wave and ocean current analyses that society now assumes to be a mature service.
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Predictability of marine debris motion, simulated with numerical models and diagnosed using oceanographic satellite data

Nikolai Maximenko (IPRC/SOEST, University of Hawaii, United States) ; Jan Hafner (IPRC/SOEST, University of Hawaii, United States) ; Amy MacFadyen (NOAA Emergency Response Division, United States) ; Masafumi Kamachi (Meteorological Research Institute, Japan Meteorological Agency, Japan)

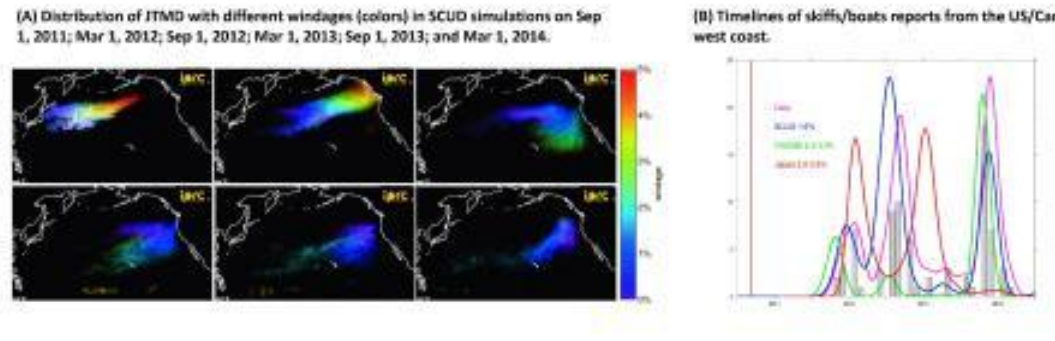
Session: Application development for Operations (previously NRT splinter)
Presentation type: Oral

Abstract:
Ocean mixing, induced by various ocean processes and ranging from unresolved (turbulence, breaking waves, tides, inertial oscillations, submesoscale eddies and fronts etc.) to under-resolved (mesoscale eddies) presents a challenge for general circulation models and other techniques utilizing oceanographic and meteorological observations to estimate motion of objects floating on or near the sea surface. At the same time, existing Global Ocean Observing System (GOOS) including a constellation of oceanographic satellites provides high-quality information that allows accurate description of surface currents and ocean drift on larger scales and longer periods.

Complex dynamics of the air-sea interface make it difficult to directly measure or even to define “surface currents” and to separate drift due to these currents from the combined effect of wind waves and direct wind force (so-called windage or leeway). Generally, complexity of marine debris composition and rudimentary state of the marine debris observing system do not allow direct calibration of numerical models. Exceptions are data from “scientific” marine debris such as Lagrangian drifters and also from the accidents and catastrophes when particular items or large volumes are released nearly instantaneously from known locations. In this study we use three different models (SCUD, GNOME, and SEA-GEARN/MOVE-K7) to simulate motion and fate of marine debris (JTMD), generated by the tragic 2011 tsunami on the east coast of Honshu, Japan (A in Figure). Model assessments are compared with timelines of reports collected in the NOAA Disaster Debris, Japan Office of Ocean Policy, and IPRC/UH datasets (B in Figure). Models successfully simulate main peaks of JTMD arrival on the US/Canada west coast and after calibration provide an estimate of the total amount and location of the JTMD still floating in the ocean.

Other applications of the utility of oceanographic models, highlighted in this presentation, include identification of pathways and accumulation areas of general marine debris, routes of lost and rescued fishing boats and probable trajectories and fate of debris from the MH370 flight.

Figure caption. (A) Distribution of JTMD with different windages (colors) in SCUD simulations on Sep 1, 2011; Mar1, 2012; Sep 1, 2012; Mar 1, 2013; Sep 1, 2013; and Mar 1, 2014. (B) Timelines of skiffs/boats reports from the US/Canada west coast and three model solutions.



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Jason-2, Saral/AltiKa and CryoSat-2 POD status

Eva Jalabert (CNES, France) ; John Moyard (CNES, France) ; Alexandre Couhert (CNES, France) ; Flavien Mercier (CNES, France) ; Sabine Houry (CNES, France) ; Silvia Rios-Bergantinos (C-S, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
This talk focuses on the main altimetry missions currently on orbit. The reference OSTM/Jason-2 satellite (launched in 2008) extends the time series of centimeter-level ocean topography observations begun in 1992 by Topex/Poseidon mission and continued in 2001 by the Jason-1 mission. Saral/AltiKa (launched in 2013) is the first mission to use Ka-band altimeter, and Cryosat2 (launched in 2010) is an ESA mission studying the thickness of the vast ice sheets that overlie Greenland and Antarctica.

These missions have been reprocessed with the new GDR (version E) Precision Orbit Determination standards.

This talk will address the issues of accuracy and long-term stability of Jason-2, Saral/AltiKa and Cryosat2 GDR-E orbit solutions. The overall accuracy of the orbits is evaluated through data and parameterization techniques; in particular long-term variations of the impact of the time-varying gravity field. We will also give an overview of the performance of SLR tracking systems. We will try to understand and investigate the origin of the apparent bias of the core-network stations.

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A new time series of orbits (std1504) for TOPEX/Poseidon, Jason-1, Jason-2 (OSTM)

Frank Lemoine (NASA GSFC, United States) ; Nikita Zelensky (SGT Inc., USA) ; Douglas Chinn (SGT Inc, USA) ; Brian Beckley (SGT Inc, USA) ; David Rowlands (NASA GSFC, USA) ; Despina Pavlis (SGT Inc, USA)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
The Jason-2 (OSTM) spacecraft has now been in orbit for seven years (since June 2008), and the full set of altimeter data from TOPEX/Poseidon, Jason-1, and Jason-2 now span more than twenty-three years. In order to properly use the altimeter data, especially for the most demanding applications such as the determination of mean sea level, we must develop a time series of precise orbits that are as accurate as possible over the entire time span, using a consistent set of modeling and geophysical standards. In this paper, we give an overview on the improvements we have incorporated into our latest release of orbits, std1504, which include application of the Vienna Mapping Function (VMF) to better correct the DORIS data for tropospheric refraction, improvement to the background geopotential modeling to account for the recent changes in the time-variable gravity field of the Earth, and improved measurement modeling for the DORIS measurement. We discuss the impact of improved non-conservative force modeling we have applied to the Jason-1 and Jason-2 satellites and the improvements we see in comparison to reduced-dynamic orbits. Our evaluations include analysis of the sea-surface-height differences during the Jason-1/Jason-2 and the TOPEX/Jason-1 calibration periods. We also present an update on our preparations for Jason-3, including our readiness to process the DORIS/RINEX data expected to be routinely delivered Jason-3, and all future DORIS-equipped missions

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Jason-2 Orbit Determination With GPS, Instrument Status And Reference Frame Sensitivity

Willy Bertiger (JPL, United States) ; Shailen Desai (JPL, United States) ; Angie Dorsey (JPL, United States) ; Bruce Haines (JPL, United States) ; Felix Landerer (JPL, United States) ; Mike Heflin (JPL, United States) ; Aurore Sibois (JPL, United States) ; David Wiese (JPL, United States) ; Dah-Ning Yuan (JPL, United States)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
In August 2014, the GPS receiver, GPSP-A, stopped outputting data and Jason-2 switched to the redundant instrument, GPSP-B. The GPSP-B had some differences in software and configuration. Over the past year, the software and configuration have been modified. We will discuss its current status and performance. Internal metrics show a slight degradation relative to the GPSP-A instrument.

With the pending release of ITRF2014, we will asses the impact of the newer reference frame on the long-term stability of the Jason-2 orbit with respect to altimetry measurements. To do this, we will test one or two reference frames constructed using modernized GIPSY software coupled with annual terms for geocenter motion. Test frames will be built using sinex files submitted as input for ITRF2014 from DORIS, GPS, SLR, and VLBI as well as ties between the techniques. We will apply appropriate frame and geocenter constraints to GPS orbit and clock solutions as they would be delivered to the IGS for the IGS final products, producing a Jason-2 precision orbit determination time series for each test frame. Long-term statistics from altimeter cross-overs and satellite laser ranging to Jason-2 will be used to assess the impact of reference frame choice.

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Improvements in precise orbit determination of altimetry satellites

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Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Precise orbits of altimetry satellites are a prerequisite for investigations of global and regional mean sea level changes. Using the recent versions of the orbit solutions of altimetry satellites Jason-1, Jason-2, TOPEX/Poseidon, Envisat, ERS-1 and ERS-2 derived at GFZ in the frame of the ESA Sea Level Climate Change Initiative and DFG UHR-GravDat projects we show improvements in the orbit quality, as provided by the orbital analysis, altimetry single-satellite crossover analysis and the multi-mission crossover analysis. These improvements are due to using new time variable Earth gravity field models, improved satellite attitude and macromodels, new tropospheric correction models for DORIS observations, improvements in the solar radiation pressure modeling. Thus, the internal consistency in the radial direction of the latest (VER11) orbit solutions derived at GFZ is 1.8 cm for ERS-1 and ERS-2, 1.0 cm for TOPEX/Poseidon, 0.4 cm for Envisat, 0.8 cm for Jason-1 and Jason-2. However, there are still some deficiencies in the quality of the latest orbit solutions, providing a room for further improvements by using new realizations of the Terrestrial Reference Frame, new models of the Earth gravity field models, improved modeling of non-gravitational forces acting on altimetry satellites and other improvements.

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GDR-E gravity field model EIGEN-GRGS.RL03-v2.MEAN-FIELD

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

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
The gravity field model EIGEN-GRGS.RL03-v2.MEAN-FIELD has been chosen to be part of the new GDR-E standards. EIGEN-GRGS.RL03-v2.MEAN-FIELD is complete to degree and order 260. It is based on GOCE-DIR5 for the part between degree 81 and 260. The time-variable gravity (TVG) coefficients between degrees 1 and 80 are obtained from a regression on the GRGS-RL03-v2 monthly time series (2002.5-2014.5). For degree 2 this TVG part is extended to 1985-2014.5 through the use of a GRGS SLR-only (Lageos+Lageos-2) solution between 1985 and 2003. Outside of the measurements period (1985-2014.5 for degree 2, 2003-2014.5 for degrees 3 to 80), the gravity field is extrapolated with a zero-slope assumption. The modeling of the TVG part includes for the first time two annual and two semi-annual coefficients for each year, in addition to one bias and one drift for each year.
We propose to explain here the way this model has been computed, to describe the TVG coefficients that are included in the model and to discuss the zero-slope assumption that is used for extrapolation. Since this assumption is not satisfactory on the long term, we will propose a method for a regular update of the extrapolated part.
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Improved orbit-centering parameterization for mean sea level applications

Alexandre Couhert (CNES, France) ; Flavien Mercier (CNES, France) ; John Moyard (CNES, France) ; Eva Jalabert (CNES, France) ; Sabine Houry (CNES, France) ; Silvia Rios-Bergantinos (CS-SI, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
As recommended by the 2014 OSTST meeting at Lake Constance, Germany, the orbit-centering discrepancies between the different POD analysis centers remain to be elucidated. Since the satellite orbit defines the reference frame for the altimetric measurements, care must be taken to better understand the nature and origin of the miscentering of the orbit.

While geocenter motion estimates from the DORIS stations network or the GPS constellation agree reasonably well for their X and Y components with those from SLR, they differ significantly in the Z direction. Also, the transfer function to DORIS/GPS-based orbits of the current state-of-the-art seasonal SLR CoM correction model is rather complex, especially as the actual variations of the non-tidal geocenter motion may not only be limited to annual terms.

Thus, we will examine strategies to mitigate sensitivity to miscentering effects on the orbit coming from the DORIS tracking measurements. Test orbits will be calculated on different altimeter satellites to illustrate and validate this approach.
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Status DORIS RINEX Processing at GSFC

nikita zelensky (SGT / GSFC, United States) ; Frank Lemoine (NASA/GSFC, USA) ; David Rowlands (NASA / GSFC, USA) ; Douglas Chinn (SGT / GSFC, USA) ; Oleg Bordyugov (SGT / GSFC, USA)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Status DORIS RINEX Processing at GSFC

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DORIS satellite tracking data based on the DGXX receiver have established their accuracy and utility in the computation of precise orbits, achieving near 1-cm radial accuracy for recent missions such as Jason-2, SARAL and Cryosat-2, and is regarded as one of the three satellite tracking technologies for realization of the terrestrial reference frame. Currently the DORIS satellite tracking data is provided by the CNES in both the traditional Version 2.2 range rate data format (V2.2) and in the new RINEX phase data format. However for all new missions having DORIS, starting with Jason-3, only the DORIS RINEX phase data will be provided. In preparation for this transition we have implemented the use of DORIS RINEX phase data in the GSFC GEODYN data processing system by constructing range-rate measurements which are very similar to the V2.2 data. GEODYN can directly process phase data as well, but an initial evaluation of DORIS RINEX is greatly aided by comparison with available V2.2 range-rate data. The method and implementation of the DORIS RINEX data in GEODYN are discussed. Both DORIS RINEX and V2.2 range-rate Jason-2 tracking data are processed. Orbits are evaluated by direct comparison and through analysis of DORIS, SLR, and crossover residuals. We compare the impact of the Jason-2 DORIS contribution to the GSC solutions on the terrestrial reference frame for DORIS RINEX and V2.2 range-rate data.

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Update of the South-Atlantic Anomaly corrective model for JASON-1 DORIS data using the maps of energetic particles from the CARMEN dosimeter onboard JASON-2

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

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
The sensitivity of the ultra stable oscillator (USO) of DORIS/Jason-1 to the high energy protons trapped in the Van Allen belts is now well known. This sensitivity causes a fluctuation of the frequency when the satellite crosses the area of the South-Atlantic Anomaly (SAA). The principal consequence is the impossibility of using the measurements of the DORIS beacons located in the SAA area for cm-precision positioning since the real frequency of the on-board oscillator is varying rapidly in that area. Moreover, these DORIS measurements do not contribute (or little) to the determination of the orbit of Jason-1 because they are eliminated during the pre-processing on residuals criteria.
To correct for this sensitivity to the effects of solar radiation, a model of the frequency evolution of the USO was designed and validated by Lemoine and Capdeville in 2006. This model allows a significant improvement in the orbit adjustment. It takes into account the geographical characteristics of the SAA region (1x1 degree SAA grid) as well as the parameters of the USO's response to this external stimulation: an amplitude, a relaxation time-constant and a memory effect of the SAA disturbance.
The Jason-1 data corrective model is currently used by several Precise Orbit Determination (POD) groups, in particular CNES POD, for altimetry in order to improve the orbit quality. In the framework of the IDS contribution to the new realization of ITRF, the Jason-1 DORIS data from the end of TOPEX' life (November 2004) to the launch of Jason-2 (July 2008) have been used, corrected by this model. The corrected DORIS data have been provided to the data center for the use of the IDS Analysis Centers.
The Jason-2 satellite carries a dosimeter instrument (CARMEN). The purpose here is to take the advantage of this instrument to improve our SAA corrective model by using the maps of energetic particles provided by CARMEN. First, a correlation study between the SAA DORIS grid and the CARMEN maps has been done to determine the dosimeter map which has the best agreement. Then, this map is used to calculate the others parameters of the model. The new model will be used to correct the DORIS data and we will examine its impact on the orbit and on the stations positioning.
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Analysis of SLR station biases

Sean Bruinsma (CNES, France) ; Reinquin Franck (CNES, France) ; Couhert Alexandre (CNES, France)

Session: Precision Orbit Determination
Presentation type: Oral

Abstract:
Satellite Laser Ranging (SLR) data, made available by the International Laser Ranging Service (ILRS), is used to validate and quantify precise orbits of the altimeter satellites. It is essentially the only independent and unambiguous validation method that can provide the absolute radial orbit accuracy. However, the accuracy of the data, even of the core stations, is fluctuating. Unknown errors in the ranging data (the ILRS provides incomplete station error information), which are used in the validation process without bias estimation, directly affect validation results.
The geodetic satellites LAGEOS-1/2 (at 5900 km altitude) and Starlette/Stella (at about 850 km) are used to estimate SLR station biases from 2001 to 2014. All advertized station corrections by the ILRS are applied in this computation. The estimated biases are compared with validation results of the same stations on Jason-1/2 and Cryosat-2 orbits. Finally, a more realistic external validation of the Jason-1/2 and Cryosat-2 orbits is obtained by taking the station biases into account.

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FES 2014, a new tidal model on the global ocean with enhanced accuracy in shallow seas and in the Arctic region

Loren Carrere (CLS, France) ; F. Lyard (LEGOS, France) ; M. Cancet (NOVELTIS, France) ; A. Guillot (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. The accuracy of tidal models has been much improved during the last 20 years. Still, significant errors remain mainly in shelf seas and in polar regions. A new global tidal model, FES 2012, was developed in 2012, taking advantage of longer altimeter time series, improved modelling and data assimilation techniques. Compared to other global tidal models, FES 2012 showed very good performances in all shallow water regions, but the validation diagnostics also pointed out a few regions were the model tended to raise the residual variance; these problems have been partly explained by some local bathymetric issues, such as the Hudson Bay for example.

An improved FES 2014 version was developed in 2014 and finalized in 2015. FES 2014 benefits from recent developments in the physical and numerical modelling (T-UGO model) that result in the decrease by a factor of two of the error of the pure hydrodynamic model.
Several issues detected in the FES2012 bathymetry have been corrected in the FES2014 version. Moreover the grid resolution has been increased in areas of interest like shallow waters and on the slope of the continental shelves.
Additional upgrades have been carried out, such as the use of longer altimeter time series (TP-J1-J2), new altimeter standards (instrumental and geophysical corrections, orbits), and better tide estimations for high latitudes. Finally a larger assimilation dataset has been considered, including tidal gauges.
FES2014 performances have been estimated thanks to comparisons to tidal gauges and altimeter measurements. They show significant improvement particularly in shallow waters and in some part of the Arctic region. Final validation results of FES2014 are presented here.
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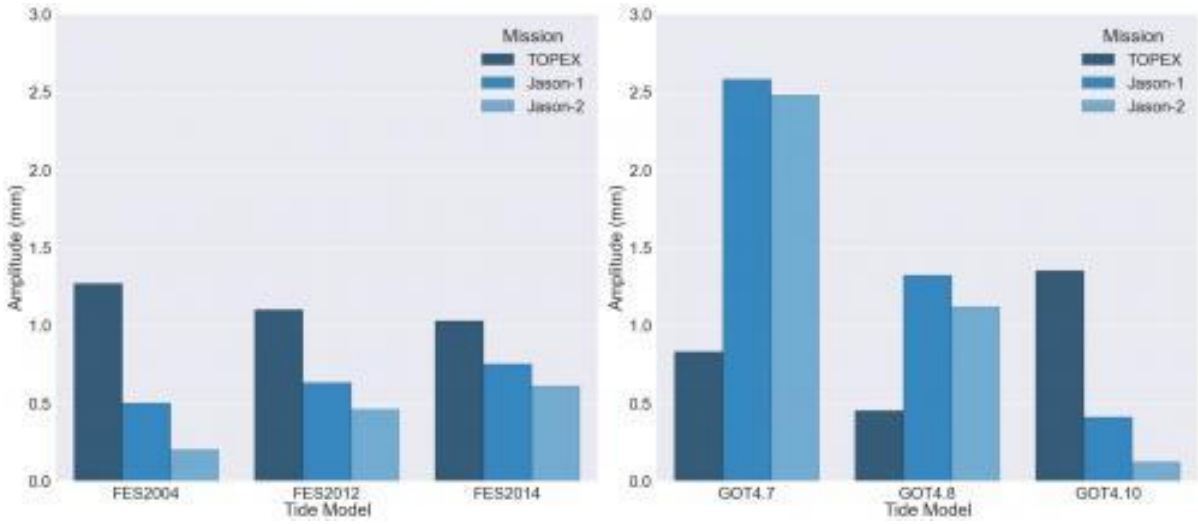
Reduction of the 58.77-day Signal in the Mean Sea Level derived from TOPEX/Poseidon, Jason-1 and Jason-2 data with the latest FES and GOT ocean tide models

Lionel Zawadzki (CLS, France) ; Michaël Ablain (CLS, France) ; Loren Carrere (CLS, France) ; Amandine Guillot (CNES, France) ; Nicolas Picot (CNES, France) ; Florent Lyard (LEGOS, France) ; Nikita Zelensky (NASA, US) ; Richard Ray (NASA, US)

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

Abstract:
Mean Sea Level (MSL) is one of the main signals of interest for physical oceanographers. Since the beginning of the altimeter mission TOPEX/Poseidon, followed by Jason-1 and Jason-2 on similar orbits, MSL products became essential to the comprehension of Global ocean circulation.
At the 2010 OSTST in Lisbon, a dedicated session highlighted a strong 58.77-day signal on Jason-1 and Jason-2 MSL records whereas it was smaller on TOPEX/Poseidon. The conclusions were this signal is the aliasing of a higher frequency error inherited from the tide model correction: the semi-diurnal wave S2. The source of this error is attributed to TOPEX measurements which are assimilated in ocean tide models. When these models are used in the computation of TOPEX/Poseidon MSL, most of the error cancels. However, this error is communicated to Jason-1 and Jason-2 MSLs, which explains why it is stronger for these missions than for TOPEX/Poseidon.
Since 2010, considerable efforts have been undertaken within the ocean tide community in order to correct ocean tide S2-waves from this error, particularly in the Goddard Ocean Tide (GOT) and Finite Element Solution (FES) latest versions: GOT4.8 and GOT4.10, FES2012 and FES2014. This study aims at assessing, quantifying and characterizing the reduction of the 58.77-day error. It is the continuation of the dedicated session at OSTST 2010 completed with (i) analyses of the 58.77-day error in the latest GOT and FES releases, (ii) regional analyses in addition to the global ones, (iii) analyses on Jason-2 MSL record in addition to TOPEX and Jason-1, and (iv) the comparison of three versions of FES2014 which assimilate different sets of altimetry data to characterize the error reduction



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High resolution tidal modeling in the Arctic Ocean

Mathilde Cancet (NOVELTIS, France) ; Ole Andersen (DTU Space, Denmark) ; Florent Lyard (LEGOS/OMP/CNRS, France) ; Ann-Theres Schulz (DUT, Netherlands) ; David Cotton (SatOC, UK) ; Jérôme Benveniste (ESA/ESRIN, Italy)

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

Abstract:
The Arctic Ocean is a challenging region for tidal modeling, 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 rather scarce at such high latitudes. As a consequence, the accuracy of the global tidal models decreases by several centimeters in the Polar Regions. In particular, it has a large impact on the quality of the satellite altimeter sea surface heights in these regions (ERS1/2, Envisat, CryoSat-2, SARAL/AltiKa and the future Sentinel-3 mission).

Better knowledge of the tides would improve the quality of the high latitudes altimeter sea surface heights and of all derived products, such as the altimetry-derived geostrophic currents, the mean sea surface and the mean dynamic topography. In addition, accurate tidal models are highly strategic information for ever-growing maritime and industrial activities in this region.

NOVELTIS and DTU Space are currently working on the development of a regional, high-resolution tidal atlas in the Arctic Ocean. In particular, this atlas will benefit from the assimilation of the most complete satellite altimetry dataset ever used in this region, including Envisat and SARAL/AltiKa data up to 82°N and the CryoSat-2 reprocessed data between 82°N and 88°N. The combination of all these satellites will give the best possible coverage of altimetry-derived tidal constituents. The available tide gauge data will also be used either for assimilation or validation.

This paper presents the performances of the global tidal models in the Arctic Ocean and the on-going work to develop an improved regional tidal atlas in this region.
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Internal tides for, from, and in satellite altimeter data

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

Abstract:
Using multi-mission satellite altimeter data, we have developed an empirical model of the surface elevations associated with the stationary M2 internal tide. Predominantly north-south satellite track orientations and contamination from non-tidal oceanographic variability can lead to some deficiencies in the mapped tides. However, independent data from Cryosat-2 and other altimeters are used to test the solutions and show positive reduction in variance except in regions of large mesoscale variability. Thus, our new model can be used as a first-cut "correction" to altimetry to remove internal-tide signals from the data.

The tidal fields are subjected to two-dimensional wavenumber spectral analysis, which allows construction of an empirical map of modal wavelengths. Mode-1 wavelengths show good agreement with theoretical wavelengths calculated from the ocean's mean stratification, with a few localized exceptions (e.g., Tasman Sea). Mode-2 waves are detectable in much of the ocean, with wavelengths in reasonable agreement with theoretical expectations, but their spectral signatures grow too weak to map in some regions.

In the construction of the tidal solution we employ AVISO gridded sea-surface height data as a prior correction to remove non-tidal variability from the data. We examine the pros and cons of this approach, and note especially that the DUACS-2010 data are superior to the DUAC-2014 data for this task, because the newer data, while aiming for higher spatial resolution, show slightly greater evidence of leakage from tidal signals.

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Global M2, S2, O1 and K1 internal tides from multisatellite altimetry

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

Abstract:
We aim to construct a global internal tide model consisting of 4 principal tidal constituents M2, S2, O1 and K1. Sea-surface height (SSH) measurements from multiple satellite altimeters during 1992–2012 are used (50 satellite-years in total). The results represent a 20-year coherent internal tide field. Two-dimensional plane wave fits in 160-km (M2) or 250-km (S2, O1 and K1) windows are employed to (1) suppress mesoscale contamination by extracting internal tides with both spatial and temporal coherence, and (2) separately resolve internal tides in multiple propagation directions. M2 usually has the strongest SSH signals; however, the contribution of S2, O1 and K1 may be greater in a few regions (e.g., the western Pacific). M2 and S2 have similar, but different, spatial patterns. We will present global maps of the amplitude and phase of each tidal constituent and their superposition.

The generation and propagation of M2 internal tides are discussed in detail. M2 internal tides are mainly generated over topographic features including continental slopes and mid-ocean ridges. Internal tidal beams of 100–300 km width are observed to propagate hundreds to thousands of km. Multi-wave interference is widespread, due to the existence of multiple internal tides at any one site. M2 internal tides propagate across critical latitudes for PSI (28.8 S/N) with little energy loss, consistent with field measurements by MacKinnon et al. (2013). In the eastern Pacific Ocean, M2 internal tides lose significant energy in propagating across the Equator, likely due to the loss of coherence in the varying equatorial jets. In contrast, little energy loss is observed in the equatorial zones in the Atlantic, Indian, and western Pacific oceans. Global integration of the altimetric M2 internal tides yields a lower bound energy of 36 PJ (1 PJ = 10^15 J). The satellite altimetric and field moored M2 internal tides are in fairly good agreement. The M2 internal tides from satellite altimetry and a global eddy-resolving numerical model agree favorably in the central North Pacific.

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Progress in internal tides modelling using T-UGOm model

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

Abstract:
The approach developed in LEGOS to address the internal tides issue for future altimetry correction is based upon frequency-domain, hydrodynamical modeling (T-UGOm unstructured grid model). It is based on a 3D wave equation, where level displacements and periodic density anomaly (due to advection) are the primary unknowns. Frequenccy- domain solver coupled to unstructured grids allows for dramatically reducing the numerical cost of internal tides modelling, in terms of computational time and state vector archive volume. Recently, it has been validated in an academic study (COMODO project, funded by ANR) that includes 3 different types of stratification (and internal tide regime). The first realistic simulations are now being tested, and will be presented. The most challenging issue in realistic modelling remains the size of the linear system to be solved (sparse matrices containing over 1 billion non-zero coeffcicients) and performances of various sparse system solvers will be discussed in the perspective of practical use in regional and/or global altimetry product processing.
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SSH signature of the internal wave spectrum inferred from profiling moorings

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

Abstract:
Wavenumber-frequency spectra of velocity and isopycnal displacement from vertically profiling moorings are used to explore the high-frequency sea-surface height (SSH) variability caused by internal waves. Horizontal structure can be inferred from the linear internal wave dispersion relation and baroclinic mode equations, and directional information can be obtained from the velocity-displacement phase relationship.

While the broadband structure of internal waves in the ocean is well-described by a varying-level Garrett-Munk spectrum, the narrowband peaks from internal tides and near-inertial internal waves are largely absent from the GM model. The datasets considered here include a range of coastal and open ocean regimes with different levels of tidal and near-inertial energy, and so provide a reasonable description of the flavors of SSH spectra expected.

Synthetic fields from these SSH spectra run through the SWOT simulator illustrate what sorts of apparent patterns internal waves might produce and suggest ways in which the SWOT mission may be able to identify and/or remove them.

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Corsica: a multi-mission absolute calibration site

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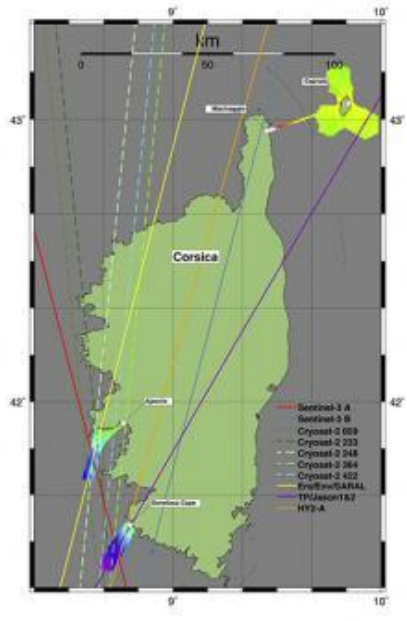
Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Oral

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 the reflector 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 recent 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 and SARAL/AltiKa with the same standards and precision than for T/P and Jason missions. The upcoming Sentinel-3 mission will naturally be 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 be focused on the full set of TOPEX/Poseidon, Jason-1 and Jason-2 GDR products. Updated values of the altimeter biases for Jason-2 (GDR-D) will be presented as well as a detailed study on the impact of orbit and outliers on the SSH bias and drift. If available the Jason-1 reprocessed cycles (GDR-E) will be also analyzed. Recent results of SARAL/AltiKa based on the latest process cycles will be also presented.



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An Update from Harvest: New Results from the TOPEX/Poseidon, Jason-1 and Jason-2 Missions

Bruce Haines (Jet Propulsion Laboratory, United States) ; Born George (University of Colorado, USA) ; Shailen Desai (Jet Propulsion Laboratory, USA) ; Rashmi Shah (Jet Propulsion Laboratory, USA)

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 about 10 km off the coast of central California near Point Conception, Harvest has hosted a dedicated altimeter CALVAL facility since the launch of TOPEX/POSEIDON (T/P) 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 calibration record based on direct (overhead) passes of the platform. The experiment has produced a CALVAL time series spanning 23 years, enabling connection of the sea-level records from the T/P, Jason-1 and OSTM/Jason-2 missions.

For the current Jason-2 mission, we estimate the sea-surface height bias and drift are +10 ± 4 mm and +2 ± 1 mm/yr respectively (one standard error with N = 173). When we account for systematic error sources—such as uncertainty in the platform vertical position and velocity—these estimates are not statistically distinguishable from zero. We provide updates to these estimates that reflect the latest overflights, and also provide comparable estimates for T/P (based on new releases of retracked data) and Jason-1 (based on newly reprocessed geophysical data records).

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Absolute altimeter bias from the Australian in situ calibration sites in Bass Strait and Storm Bay

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

Abstract:
The altimeter validation facilities in Bass Strait (40° 39'S, 145° 36' E) have provided cycle-by-cycle estimates of altimeter absolute bias for the TOPEX/Poseidon, Jason-1 and OSTM/Jason-2 missions. A secondary in situ facility in Storm Bay is located ~330 km south-east on the same descending pass (pass 088) has assisted in understanding the evolution of absolute bias for the OSTM/Jason-2 mission.

Here we present updated results from both sites using our single-pass / multi-site approach. We discuss our preparations for the launch of Jason-3 as well as the ESA missions Sentinel-3A and Sentinel-3B missions – these include investigations using high resolution ocean modelling of Bass Strait in order to assess instrumentation needs and deployment sites.

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Regional CalVal of Jason-2 and SARAL/Altika at three calibration sites: Corsica, Harvest and Bass Strait

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

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 done at the vertical of a specific CalVal site by direct comparison of the altimeter data with the in situ data.

However, for more than ten years, Noveltis has been developing 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. The strong interest of this principle is to extend the single site approach to a wider regional scale, thus reinforcing the link between the local and the global CalVal analyses. It is also a mean to keep on calibrating a mission when good-quality in situ data happen to be missing at its dedicated calibration site.

The regional method was initially developed at the Corsican calibration sites of Senetosa and Ajaccio. The method was used to compute the biases of Jason-1, Jason-2 and Envisat (before and after the orbit change in 2010) at both sites, and proved its stability and generality through this cross-calibration exercise.

In 2013 and 2014, the regional method was successfully implemented for Jason-2 and Envisat at the Californian site of Harvest, in close collaboration with JPL, and at the Australian site in Bass Strait, in close collaboration with the University of Tasmania.

In 2015, it was implemented for the SARAL/Altika mission at the three calibration sites. The Jason-2 mission was also monitored at the three sites and the results are in very good agreement with the other calval groups.

The results presented in this paper highlight the numerous advantages of this technique for monitoring missions on any orbits such as CryoSat-2, HY-2A or the future Sentinel-3, Jason-3 and Jason-CS missions.
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Jason-1, Jason-2, SARAL/AltiKa and HY-2 altimeter calibrations over a decade at the Gavdos/Crete Cal/Val sites

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

Abstract:
This work presents and compares the latest altimeter calibration results for the Jason-1 and Jason-2, as well as the SARAL/AltiKa and the Chinese HY-2 missions, conducted at the Gavdos/Crete calibration/validation facilities. At first, the Jason altimeter calibration values will be given for the ascending Pass No.109 and the descending Pass No.18, based on the the GDR-C (Jason-1) and GDR-D (Jason-2) products. Secondly, these values will be cross-examined against the altimeter bias for the SARAL/AltiKa satellite at Gavdos Cal/Val using its reference ascending orbit No. 571. Finally the Chinese HY-2 satellite altimeter bias will be presented using the CRS1 permanent site in south west Crete for the descending HY-2 Pass No. 280, at 20 Hz based on SGDR data products. Additionally, altimeter biases as determined by locally developed Mean Sea Surface model will be presented and compared with the conventional sea-surface calibration methodology.

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Validation of altimeter-derived sea level seasonal cycle with tide gauges over the Gulf of Mexico

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

Abstract:
Global gridded AVISO satellite altimetry data of mean sea level is compared and validated against the monthly tide gauge data from the Permanent Service for Mean Sea Level (PSMSL), UK, over the Gulf of Mexico. Here, we discuss the AVISO altimetry data, assessing the accuracy via comparison with in situ tide gauge data. Anomalies of mean sea level at a number of stations along the coastline of the Gulf of Mexico are investigated. Analysis shows close agreement between the tide gauge and altimeter annual cycle components of the sea level anomalies most of the time and confirms a steady increase in annual amplitude for chosen stations in most recent years (similar to recent work by Wahl and colleagues). In order to address differences between the coast and open sea level variations observed in the altimeter data, annual amplitude for a full time period of 1993-2013 is computed over the Gulf of Mexico region. In particular, temporal variability of regional annual amplitude shows a significant increase in the latest period (2007-2013) over most of the Gulf of Mexico region, especially over the north-eastern coastline waters in the Gulf of Mexico from 10 cm to 14 cm, and even larger in the central part (up to 5-6 cm). Part of this increase appears to be due to changes in atmospheric pressure, acting through the inverted barometer response of the sea level. Similarly as for the Gulf of Mexico, global annual amplitude of the mean sea level anomalies for the same time period confirms a noticeable increase in the recent years for most of the regions, especially over those areas with the annual amplitude that initially experiences higher values (i.e., between 12-20 cm).
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Jason-2 data performances over ocean: global assessment and improvement for multi-mission sea-level products

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

Abstract:
Since Jason-2 has being launched (in 2008), it is currently used as the reference mission in the altimetry satellite constellation to generate multi-mission sea level products (e.g.: CMEMS/AVISO products). This is possible thanks to the very good performances of the sea level estimated by Jason-2. This concerns the long-term stability of Global Mean Sea Level (GMSL) evolution, as well as the smaller spatial and temporal scales for mesoscale applications. This highlights the importance to evaluate and monitor the altimeter mission performances.

The global assessment of Jason-2 measurements over ocean has been performed from the beginning of the mission in the framework of the CNES SALP (Système d'Altimétrie et Localisation Précise) project. The main objective of this activity is to provide an estimation of the mission performances over ocean. This consists in analyzing the Jason-2 data coverage as well as for missing measurements as for valid sea level measurements, in monitoring all altimeter and radiometer parameters, in estimating the sea level performances of delayed and real time products (GDR, IGDR, and OGDR/OSDR), and monitoring accurately the GMSL evolution.

In this paper, we have two separate objectives. The first one consists in giving a synthesis of the Jason-2 data performances over ocean. As the satellite is still working very well, a summary of the main diagnoses highlighting the very good performances of sea level is presented. They are mainly based on crossover analyses, comparisons with other missions and also in-situ measurements. The second objective is to describe improvements in the Jason-2 sea level processing in order to improve multi-mission sea-level products (e.g.: CMEMS/AVISO products). We will focus on the improvement of valid measurements selection in some specific areas (costal, high wave, rain cells), on the improvement of data quality on coastal areas, and on the improvement of the restitution of small scale oceanic feature. It is worth noting that these studies are of crucial importance for future altimetry mission (Jason-3 and Sentinel-3a to better validate these missions) and also past missions (T/P, Jason-1, Envisat, etc…) .
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Global calibration and validation of the Jason-1 version E GDRs

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

Abstract:
We present results from the global calibration and validation of the Jason-1 Version E Geophysical Data Records (GDR-E). The goal of our presentation is to provide an understanding of the impact of changes between the recently reprocessed version E and the preceding version C data products for Jason-1. To this end, we evaluate temporal and geographically correlated differences between data from these two versions of the products. Given that Jason-1 provides the important link between the Topex/Poseidon and Jason-2/OSTM data records, we also consider the impact of the new data products on the overall climate data records from the three mission by evaluating the impact on inter-mission differences during their tandem and inter-leaving phases. We consider sea surface height and its measurement system components, as well as wind speed and significant wave height.
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Global Ocean Data Quality Assessment of SARAL/AltiKa

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

Abstract:
The SARAL mission was successfully launched on February, 25th 2013 and is delivering high quality sea surface topography measurements since. For more than two and a half years, data quality assessment of OGDR, IGDR and GDR data is performed at CLS, as part of the CNES SALP project.

We present the current Cal/Val status of the SARAL/AltiKa mission over ocean, mainly from GDR data using Patch 2 version. The main data quality metrics are presented (data availability, SSH differences at cross-overs) and demonstrate the excellent mission performance. We also introduce an error budget for the mission.

Since last OST/ST, the spacecraft has experienced several special events: safe-hold mode, failure of a reaction wheel, 10+ km shift from the nominal ground track… These events are reviewed and we show that they have had a limited impact on the overall mission performance.

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Global Hy-2a Data Quality Assessment Over Ocean

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

Abstract:
HY-2A is the first altimetry and radiometry satellite of the China National Space Administration (CNSA), it was successfully launched on 15th of August 2011. The National Satellite Ocean Application Service (NSOAS) is responsible for the ground segment and for distributing collected data and HY-2A L2 products. The French contribution performed by the Centre National d'Etudes Spatiales (CNES) on this project consists mainly in supplying the orbit computed from DORIS, GPS and laser measurements.
Thanks to the development and the validation of the HY2 Processing Prototype based on the S-IGDR waveforms analysis, the HY2 data integration has been completed in the SSALTO/Duacs system in April 2014.
The data quality monitoring is routinely performed at CLS, as part of the CNES SALP (Système d'Altimétrie et Localisation Précise) project. The objective of this presentation consists in giving an overview of HY2 data coverage and data quality concerning altimeter parameters, but also the performances of delayed and real time products (GDR, IGDR) at mono-mission crossovers and along-track.

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Latest results of DGFI’s multi-mission crossover analysis

Denise Dettmering (Deutsches Geodätisches Forschungsinstitut der TU München (DGFI-TUM), Deutschland) ; Christian Schwatke (DGFI-TUM, Germany) ; Wolfgang Bosch (DGFI-TUM, Germany)

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

Abstract:
A global multi-mission crossover analysis is a powerful tool to check the consistency between different altimeter missions, to extract information on the noise level of different instruments, and to detect systematic errors in the data sets. The latter allows analyzing the temporal and geographically correlated characteristics of the errors which essentially influences the accuracy of estimation regional sea level trends and ocean circulation. For this reason, the inter-mission calibration is one of the basic methods of CAL/VAL activities and an inevitable prerequisite for all applications based on multi-mission altimetry.

This contribution will present recent results of DGFI’s global multi-mission crossover analysis (MMXO). The main emphasis will be on long-term instrument bias drifts of different missions as well as on influences of new orbit computation standards (GDR-E) to sea surface height estimation. Moreover, results of reprocessed data sets (ESA Reaper products) and new missions (Jason-3, Sentinel-3) will be shown in case the necessary data sets are available in time.

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Assessment of recent revisions to the TOPEX/Poseidon/Jason Sea Surface Height Climate Data Record: Impact on global and regional sea level estimates

Brian Beckley (SGT Inc./NASA GSFC, United States) ; Richard Ray (NASA GSFC, USA) ; Frank Lemoine (NASA GSFC, USA) ; Nikita Zelensky (SGT Inc., USA) ; Xu Yang (SGT Inc., United States) ; Shailen Desai (JPL, USA) ; Shannon Brown (JPL, USA) ; Gary Mitchum (University of South Florida, USA) ; Martina Ricko (SGT Inc., USA) ; Doug Vandemark (University of New Hampshire, USA) ; Hui Feng (University of New Hampshire, USA)

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

Abstract:
The determination of the rate of change of mean sea level (MSL) has undeniable societal significance. The measurement of geocentric sea level change from satellite altimetry requires vigilant monitoring of the altimeter measurement system stability since the signal being measured is at the level of a few mm/yr. Foremost, advances in Precise Orbit Determination (POD) provided by, in particular, revisions to the time variable gravity (TVG) realizations, continue to improve the accuracy and stability of the POD, directly affecting mean sea level estimates. Recent GSFC modeling improvements to the gravity field, Jason-1/2 surface forces, station positions, and SLR/DORIS tracking measurements have been applied to generate a new version of the MEaSURES orbits across the TOPEX/Jason-1/Jason-2 missions: std1504. Additional revisions to the Climate Data Record under review include re-calibrated/enhanced TOPEX and Jason-1 radiometer measurements, revised geocentric pole-tide correction (Desai et al., 2015), GOT4.10 ocean tide, 3D sea state bias models, and the verification and implementation of the TOPEX retracked GDR data.

In this presentation we report the efficacy of correction algorithm revisions leading to the development of the MEaSURE's TPJAOS V3.0 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 23-year sea surface height time series, describe continuing calibration/validation activities, and evaluate the subsequent impact on current global and regional mean sea level estimates.

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Sea surface height observational capabilities: from mesoscale to submesoscale

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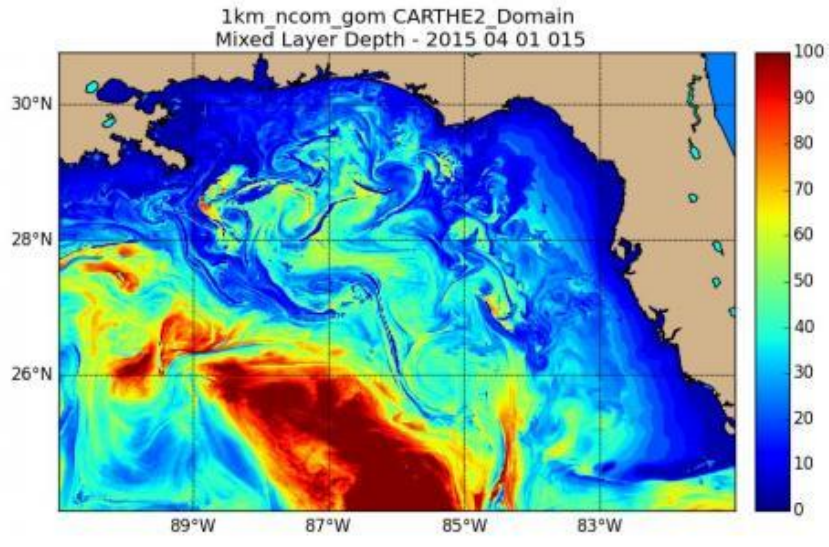
Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
The Surface Water / Ocean Topography (SWOT) mission will change our perceptions of the ocean, and this can be shown by examining how sea surface height (SSH) has been used in the past, the processes expected to be observed by SWOT and the fundamentally different dynamical relations. This motivates research at the present to understand the implication of the SWOT data in the domain of previously unresolved ocean features. Historically, because of the relatively sparse spatial sampling, SSH observations have been related to mesoscale eddy circulations in the ocean. To first order, mesoscale eddies are in geostrophic and hydrostatic balance. The eddy signature in SSH is due to the thermocline depth variations changing heat content in the water column and reflected in steric expansion. This understanding has been exploited and enabled mesoscale ocean predictions from global scales such as the Global Ocean Forecast System (GOFS) to the reloctable forecast system (RELO) to the coupled ocean / atmosphere mesoscale prediction system (COAMPS). SWOT will reveal submesoscale eddies that are not in geostrophic balance, and their vertical extent is mainly in the mixed layer rather than to the deep thermocline. High resolution model experiments are used to estimate relationships between the surface height signatures and subsurface structures due to mesoscale and submesoscale eddies. Understanding these relationships and their role in accurate monitoring of submesoscale dynamics is critical to enabling SWOT observations to be used in ocean forecast systems in the future. The results from a 1 km resolution ocean model covering the Gulf of Mexico provide the 3D structure representing both mesoscale and submesoscale to begin to understand the correlations throughout the water column. Both scales have effects on mixed layer depth as shown in the figure below. The initial examinations provide insight to the relation between SSH and its spatial gradients to the underlying temperature, salinity and velocity structure within the mixed layer and at the deeper thermocline depths. One key problem for using SWOT involves separating mesoscale and submesoscale signal from the SSH observations alone. The answer to this problem is critical to relate the surface observations to the subsurface structure. The model-derived SSH correlations at the thermocline depth and within the mixed layer can lend insight to horizontal length scales to classify mesoscale and submesocale features.



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Exploring 3D velocity field reconstructions using the SWOT simulator and a submesoscale-resolving OGCM

Bo Qiu (University of Hawaii, United States) ; Shuiming Chen (University of Hawaii, USA) ; Patrice Klein (IFREMER, France) ; Clement Ubelmann (NASA/JPL, USA)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
Utilizing the theoretical framework of effective surface quasi-geostrophic (eSQG) dynamics, we explored the potential of reconstruting the 3D upper ocean circulation features, including vertical velocity (w), from high-resolution sea surface height data expected from the planned SWOT mission. Specifically, we used the 1/30-deg, submesoscale-resolving, OFES simulation as the SSH input and subjected it through the SWOT simulator that has irregular SWOT sampling swaths and expected measurement errors. By focusing on the Kuroshio Extension region, we found the eSQG dynamics is an effective formulation to retrieve the 3D velocity field. For the simulation output itself, the eSQG-reconstructed relative vorticity and w are able to reach an overall correlation of 0.8 and 0.7, respectively in the 1000m upper ocean when compared to the original model output. With the irregular sampling and measurements errors, these correlation values drop to 0.7 and 0.5 that show, nevertheless, promising reconstructability.
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The Resolution Capabilities of Geostrophic Velocity, Relative Vorticity and Ekman Pumping Fields Estimated from Noisy SWOT Observations of Sea Surface Height

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
A goal of the Surface Water and Ocean Topography (SWOT) altimetry mission is to measure sea surface height (SSH) with sufficient accuracy to achieve a signal-to-noise variance ratio greater than 1 for wavelengths of 15–1000 km over 68% of the world ocean. To achieve this goal, the SWOT Science Requirements Document specifies that the wavenumber power spectral density of the white-noise component of the total SSH measurement errors must be no larger than 2 cm2/cpkm (cycles per km) for wavenumbers between 1/1000 cpkm and 1/15 cpkm. It can be shown that this corresponds to uncorrelated measurement errors with an RMS value of 2.74 cm after filtering with a half-power filter cutoff wavelength of 2 km.

The objective of this presentation is to quantify the effects of this SSH measurement noise on the resolutions of geostrophic velocity, relative vorticity and wind-driven Ekman pumping fields estimated from SWOT measurements of SSH. Derivation of these higher-order quantities from SSH requires single differentiation for geostrophic velocity, double differentiation for relative vorticity and triple differentiation for the dominant contribution to Ekman pumping. These differentiations amplify the noise in the SSH measurements, thus reducing the effective resolutions compared with that achieved for SSH itself.

The resolution capabilities will be assessed based on the SSH fields from a high-resolution model of the California Current System, with and without the addition of uncorrelated noise with the aforementioned RMS of 2.74 cm. The resolutions will be quantified from alongshore wavenumber spectral analysis and from the ratio of the variances of the signal and noise fields computed over the model domain as a function of the half-power filter cutoff of 2-dimensional smoothing with wavelengths ranging from 10 km to 100 km.

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Mesoscale physical-biological interactions as revealed in satellite observations and eddy resolving models: from regional to global scales

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
Mesoscale eddies influence upper ocean ecosystems by a variety of mechanisms, including some that stimulate productivity through nutrient supply (eddy pumping, eddy-wind interaction) and/or influencing light availability (eddy impacts on mixed layer depth), as well as those that simply redistribute biogenic material (stirring and trapping). It has been known for some time that these mechanisms can be differentially expressed in space and time. However, it is only recently that regional variations in the influence of mesoscale eddies on near-surface chlorophyll have been quantified on a global basis (Gaube et al., 2014). Coherent patterns of both positive and negative correlation between anomalies of sea level (SLA) and chlorophyll (CHL) reflect variations in the relative balance between these various eddy-driven processes. Areas of positive correlation are indicative of positive CHL anomalies associated with anticyclonic eddies (positive SLA) and negative CHL anomalies with cyclonic eddies (negative SLA). Conversely, regions of negative correlation are indicative of positive CHL anomalies associated with cyclonic eddies, and negative CHL anomalies associated with anticyclones. Attribution of these correlations to specific mechanisms is not possible on the basis of observations alone, as each of these correlation patterns can be produced by multiple mechanisms. A global eddy-resolving coupled physical-biological model is able to simulate many of the observed patterns in SLA-CHL correlation, providing a framework in which to diagnose the contributions of the various processes of mesoscale physical-biological interaction. We have looked in detail at the Gulf Stream region in a basin-scale version of the model, where the SLA-correlation is negative. Both eddy pumping and eddy trapping are candidate mechanisms to produce the observed correlation, and the model suggests eddy trapping is the dominant mechanism in this region. Moreover, we find that the time-evolution of CHL in anticyclonic eddies reflects nutrient supply via eddy-wind interaction, which would tend to produce positive correlation between SLA and CHL. However, this tendency is overshadowed by the influence of trapping in the overall correlation. Analysis of the global solution continues, and we intend to focus next on an area of positive correlation in the South Indian Ocean.

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Mesoscale and submesoscale variability in the Luzon Strait: A data-assimilative two-way nested modeling approach

Javier Zavala-Garay (IMCS, Rutgers, United States) ; John Wilkin (IMCS, Rutgers, USA)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
The Luzon Strait is the strait separating Luzon island of the Philippines and Taiwan. The most prominent dynamical feature of the area is the Kuroshio, the most important current in the North Pacific. This western boundary current flows northward along the northern tip of Luzon Island, where it veers westward and meanders while crossing the Luzon Strait to continue its path along the east coast of Taiwan. It therefore serves as a "semi-permeable barrier" mediating the interchange of surface waters between the western Pacific and the regional South China Sea. The combination of the Kuroshio Current, westward propagating eddies from the Pacific ocean, the monsoon, strong tides, and the dramatic topography of the Luzon Straits lead to a rich physical forcing environment that is not fully understood, specially at the meso- and submeso-scales. We present a data-assimilative two-way nested model application based on the Regional Ocean Modeling System (ROMS), designed to study mesoscale and submesoscale variability. The parent model of the nested application is constrained by satellite (SSH and SST) and in-situ hydrographic observations using variational data assimilation, effectively propagating the remotely-sensed surface information to the subsurface. The information content of the assimilated observations is then propagated to the scales not resolved by the parent model using a two-way nested approach, where the child grid benefits from the improved analysis in the parent model via the boundary interface between both grids. A preliminary evaluation of the performance of the system is presented, with special emphasis to the value added by the altimeter data.

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Application of SWOT to the dynamics of Amazon plume and adjacent regions

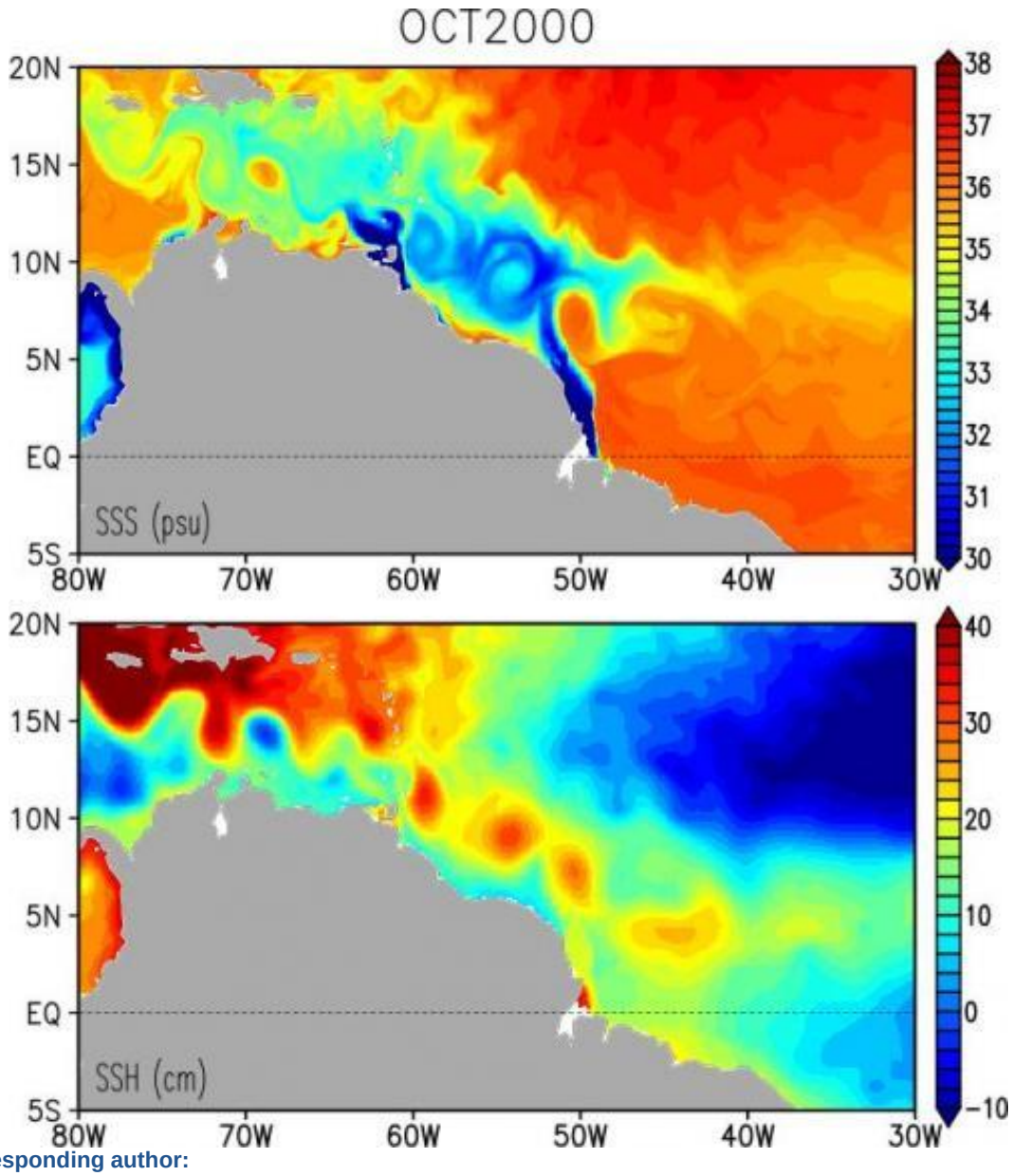
James carton (University of Maryland, United States) ; Semyon Grodsky (University of Maryland, United States) ; Frank Bryan (NCAR, country United States) ; Eric Leuliette (NOAA, country United States)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
The Amazon/Orinoco plume is a shallow, seasonally varying, turbid low salinity layer that spans an area in excess of 10^6 km^2 by late summer - early fall. It has striking features that make it an appealing target for a SWOT mission. It is the World's largest river-forced freshwater plume, forced by massive discharge from the Amazon and Orinoco River systems, and thus links an active continental hydrologic system to oceanic dynamics. It lies in a region of some of the highest seasonal rainfall rates anywhere in the World Ocean. Its high values of SST and evaporation, and low rates of vertical heat exchange with the cooler water below promote interaction with, and intensification of, fall season hurricanes. And most importantly, the plume lies on top of the vigorous eddy-shedding North Brazil Current system.

This study explores the potential application of mesoscale resolution remote sensing together with numerical modeling to examine plume dynamics; including the roles of surface processes, entrainment, and continental transport; and interactions with the mesoscale/sub-mesoscale ocean dynamics of the western tropical Atlantic. The talk will show preliminary results using remotely sensed winds and rainfall, TERRA/MODIS ocean true color and diffusive attenuation coefficient, surface salinity, and AltiKa sea level as well as analyses of a 0.1x0.1 degree resolution simulation (Fig. 1 shows a snapshot of surface salinity and sea level from the simulation). As an indication of the potential of swath altimetry Altika is interesting because of its 6 km alongtrack sampling, which is clearly able to detect the plume boundaries. Our presentation also highlights features associated with sub-mesoscale mixing and exchange, which are poorly represented in the current model.

Figure 1: 5-day average properties from October, 2000 of the western tropical Atlantic as simulated in a 0.1-deg spatial resolution global general circulation ocean model. The simulation began in 1979 and is forced by daily wind forcing and climatological monthly river discharge. (top) SSS [psu] and (bottom) SSH [cm]. During this season the plume is displaced to the north, while significant amounts of amazon water are carried eastward by the North Equatorial Countercurrent.



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A frontal eddy intensively sampled at sea and overflown by SARAL

David Griffin (CSIRO, Australia) ; Roughan Moninya (University of NSW, Australia)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Oral

Abstract:
Frontal eddies are sub-mesoscale cyclonic features that are especially prone to form on the landward side of western boundary currents. In June 2015, a team of scientists lead by Iain Suthers of UNSW used Australia's new research vessel RV Investigator to intensively sample a 30km-diameter frontal eddy that formed near Sydney, inshore of the East Australian current. The formation of the eddy (first detected in SST imagery) during the voyage was very fortuitous. Even more fortuitous was the perfect coincidence of the in-situ sampling and the overflight of Altika, which determined the central anomaly of sea level to be -15cm, in close agreement with the central anomaly of dynamic height. Geostrophic estimates of cross-track velocity of ~1m/s agree well with the vessel's ADCP and the velocity of buoys released into the eddy.
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The POD gravity field model for GDR-E: EIGEN-GRGS.RL03-v2.MEAN-FIELD

Sean Bruinsma (CNES, France) ; Jean-Michel Lemoine (CNES, France)

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

Abstract:
The gravity field model EIGEN-GRGS.RL03-v2.MEAN-FIELD has been selected for the new GDR-E standards. The model is complete to degree and order 260. It is based on GOCE data (i.e. EGM-DIR5 model) for the part between degrees 81-260. The time-variable gravity (TVG) coefficients for degrees 1 to 80 were obtained from a regression on the GRGS-RL03-v2 monthly time series (2002.5-2014.5). For degree 2 this TVG part was extended to 1985-2014.5 through the use of a GRGS SLR-only (Lageos+Lageos-2) solution between 1985 and 2003. Outside the measurements period (1985-2014.5 for degree 2, 2003-2014.5 for degrees 3 to 80), the gravity field is extrapolated with a zero-slope assumption. The modeling of the TVG part includes for the first time two annual and two semi-annual coefficients for each year, in addition to one bias and one drift for each year.
In this presentation we will explain how the model was constructed, describe the TVG coefficients that are included in the model, and discuss the zero-slope assumption that is used for extrapolation. Since this assumption is not satisfactory on the long term, we will propose a method for a regular update of the extrapolated part.

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Stacking repeat cycles of 40-Hz AltiKa data resolves the geoid anomalies of very small seamounts

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

Abstract:
Seamounts are volcanoes on the world's ocean floor that may number in the hundreds of thousands. It is important to know how many there are, and where they are, in order to correctly model ocean circulation and mixing, tsunami propagation, fishing grounds and habitats, hazards to submarines, etc. Because the oceans are mostly unmapped by ships, most of the world's seamounts have been found when their geoid anomalies were revealed by satellite altimetry.

Small seamounts are much more common than large ones. One fractal model for their size-frequency distribution suggests that, as seamount height goes down two-fold, the number of seamounts goes up seventeen-fold. If a two-fold reduction in height implies an eight-fold reduction in mass, then one may expect that the amplitude of a seamount's geoid anomaly will decrease very rapidly as its size decreases, making small seamounts much harder to find with an altimeter. Searching marine gravity maps derived from satellite altimetry for seamount anomalies finds many thousands, and their size-frequency distribution fits expected models when seamount heights are greater than 2 km tall. This is interpreted as evidence that altimeters have already found the seamounts 2 km tall and taller, but are failing to find the smaller ones.

Smith [Marine Geodesy, 2015, doi 10.1080/01490419.2015.1014950] compared seamount resolution by AltiKa to resolution by Envisat. He found that sea surface height profiles over seamounts less than 2 km tall showed seamount geoid anomalies much more clearly in AltiKa than in Envisat data. He attributed this to AltiKa's lower noise level and denser sampling (5 cm at 40 Hz versus 8 cm at 18 Hz). His study characterized the ability of these altimeters to detect a seamount in only one pass over a feature, as would be necessary if an altimeter were put into a "geodetic mission" orbit.

Our present study characterizes the improvement in seamount resolution that can be achieved by "stacking" the repeated sea surface height profiles that AltiKa obtains every 35 days. We take all data at 40 Hz along-track sampling rate, group data across repeat cycles by aligning points nearest to a common latitude, and then take the mean or median of all such aligned points. The mean or median profile (the "stack") has reduced noise and clarifies seamount anomalies. The noise variance decreases in inverse proportion to the number of cycles stacked. Because the median is a less efficient estimator than the mean, a median stack should be noisier than a mean stack; however, we find little penalty for using medians and we prefer them because they are robust with respect to outliers, which occur occasionally. We find that the root-mean-square noise level in the median stack is around (5.8 cm)/sqrt[(2N+1)/3] at 40 Hz, where N is the number stacked, and is below 2 cm at 40 Hz when 12 or more repeat cycles are stacked (about 1 year of data).

Stacking always reduces the noise in the mean sea surface height profile. Translating a reduction in noise into an improvement in seamount resolution requires also a specification of the seamount geoid anomaly being sought. In areas where AltiKa repeat tracks cross previously mapped small (< 1.5 km tall) seamounts, we can evaluate the coherency between sea surface height profiles and verified in situ bathymetry. The previous study [loc. cit.] found coherence at wavelengths greater than 17 km if only a single altimeter profile was used. In our present study, if we stack 9 profiles, the stacked geoid anomaly is coherent with seamount bathymetry at wavelengths as short as 10 km. This suggests that a seamount detection process using a matched filter approach will reliably detect seamounts smaller than 2 km, with reliability increasing as the number of repeat cycles stacked increases.

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The DTU15 MSS (Mean Sea Surface) and associated MDT (Mean Dynamic Topography) focusing on Arctic issues and development.

Ole Baltazar Andersen (Dr, Danmark) ; Gaia Piccioni (DTU Space, Denmark) ; Per Knudsen (DTU space, Denmark)

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

Abstract:
The DTU15MSS is the latest release of the global high resolution mean sea surface from DTU Space. The major new advance leading up to the release of this DTU15MSS the use of an improved 4 years Cryosat-2 LRM, SAR and SAR-In data record and the downweighting of ICESat data used previously in the Arctic Ocean for DTU10MSS and DTU13MSS.
The presentation will focus on the difficult issues as consolidating Cryosat-2 onto a 20 year mean sea surface derived using multiple satellites (but only at low to medium latitude) as well as the importance of merging Cryosat-2 data from different operating modes like LRM, SAR and SAR-In as these requires different retrackers. Also the importance of downweighting the ICESat data is highlighted.
The first evaluation of the new MSS is performed and comparison with existing MSS models is performed and presented as well.

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The recent drift of SARAL: an unexpected MSS experiment

Marie Isabelle Pujol (CLS, France) ; Gerald Dibarboure (CLS, France) ; Amandine Guillot (CNES, France) ; Nicolas Picot (CNES, France)

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

Abstract:
In this paper, we take advantage of the recent AltiKa ground track drift from is nominal position to quantify the accuracy of recent MSS models. We also measure how the error increases as AltiKa departs from the charted ERS/ENVISAT track (i.e. where the MSS errors are expected to be very small). The performances of MSS models using or not geodetic measurements from CryoSat-2 and Jason-1 GM are analysed. We focus our analysis in a favourable area with low ocean variability and large MSS gradients. The comparison of the SLA variability observed from Jason-2 and AltiKa for the wavelengths lower than 200 km clearly underlines an MSS error increase along AltiKa track when the satellite ground track is drifting away from it nominal track. This error is substantially smaller on recent models exploiting the dense geodetic coverage acquired since 2011.
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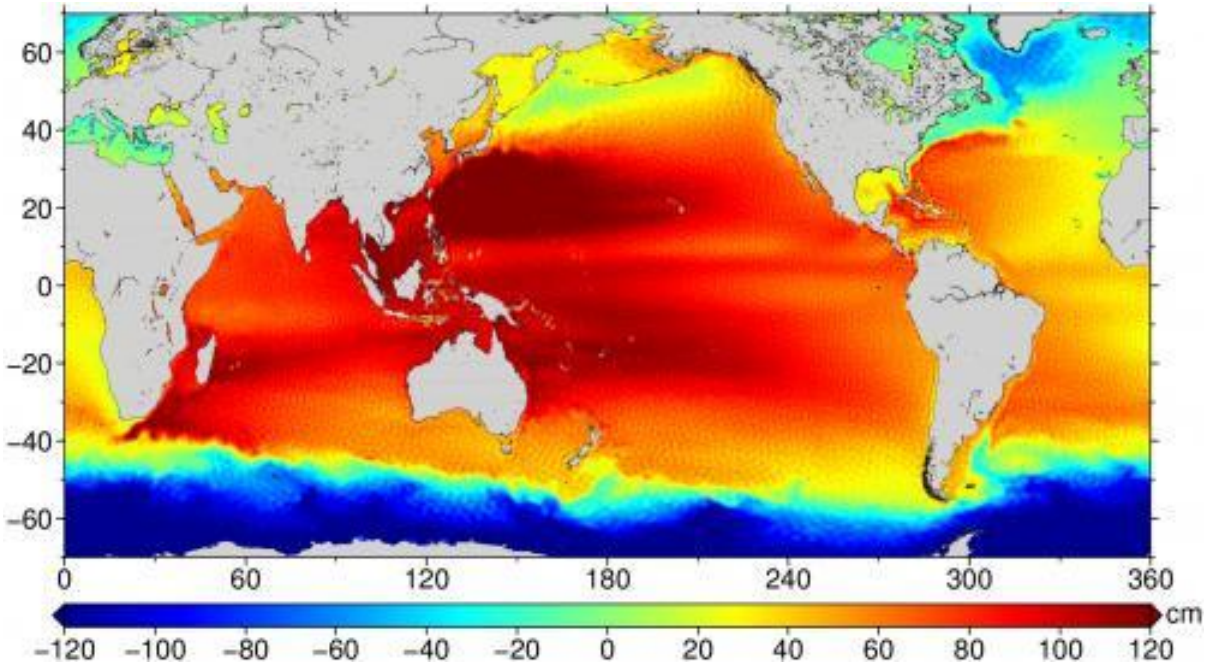
Assessing the contribution of GOCE and altimetry to improvements in geodetic MDT determination

Rory Bingham (University of Bristol, United Kingdom)

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

Abstract:
From the first gravity release of the mission, based on just two months of observations, it was clear that GOCE had improved our ability to measure the global ocean's time-mean dynamic topography (MDT). Over the life of the mission four subsequent generations, based on an expanding set of observations, were produced, each computed by two independent methods. Here we track the improvement, in terms of decreasing MDT error, across releases and approaches, showing an ultimate convergence of the two approaches, with MDTs based on the final releases having an accumulated error of 5 cm at 100 km spatial resolution. This error also includes contributions from the MSS used in the calculation and numerical errors and we estimate the contribution from each of these sources. We also examine in a similar fashion how MDT error depends on the choice of MSS surface used, showing that while geoid errors swamp MSS errors at short wavelengths, the choice of MSS does have a noticeable impact at the 1 cm level on MDT error for spatial scales greater than about 130 km. A number of informal approaches are used to estimate MDT error and we compare the estimated geoid component of this informal error with the formal geoid errors derived from the full error variance/covariance matrices. Finally we assess the geodetic MDT approach using GOCE data in the context of alternative approaches to calculating the ocean's MDT.



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Variations of observed correlations between satellite altimetry and tide gauge data along the U.S. east coast

Yongcun Cheng (Center for Coastal Physical Oceanography, Old Dominion University, United States) ; Plag Hans-Peter (Mitigation and Adaptation Research Institute, Old Dominion University, United States) ; Ezer Tal (Center for Coastal Physical Oceanography, Old Dominion University, United States) ; Hamlington Benjamin D. (Center for Coastal Physical Oceanography, Old Dominion University, United States)

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

Abstract:
Understanding the regional sea level variability is significant for coastal planning and implementing local sea level change adaptation and mitigation. The accelerated sea level rise has been detected between Cape Hatteras and Cape Cod at the U.S. east coast based on tide gauge data. Satellite altimeter provides accurate near global sea surface height data. Are there high correlations between low frequency tide gauge data and altimetry data over deep water regions in the North Atlantic? Do the correlations vary on decadal time scale? In the present study, the CSEOF (cyclostationary empirical orthogonal function) method is used to remove the annual signal in tide gauge and satellite altimetry data (e.g., Absolute Dynamic topography from DUACS). Then the low frequency sea level variations are calculated from the EMD (empirical mode decomposition) analysis. Significant correlations and correlation variations between tide gauge data at the north of Cape Hatteras and altimeter data in the Northern and subtropical Atlantic Ocean are observed in the last two decades. The slowing down of Atlantic Meridional Overturning Circulation (AMOC) might be related with the phase reversal of correlations between composite tide gauge in the north of Cape Hatteras and satellite altimeter data in the subpolar Atlantic Ocean as well as strengthening of positive correlations in the subtropical regions of the mid-Atlantic Ocean. The sea level variations in the Labrador Sea are highly correlated to local sea level variations at the north of Cape Hatteras with phase leading of about 3 years. The spatial distribution characteristics of the correlation variations are linked to the variations of winter NAO, atmospheric forcing and Ocean Heat Content in the North Atlantic Ocean.

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Seasonal effects on the pitch measurements for Cryosat

Salvatore Dinardo (SERCO/ESRIN, Italia) ; Michele Scagliola (aresys, italy) ; Marco Fornari (ESA, italy) ; Jerome Benveniste (ESA, France)

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

Abstract:
This abstract is aimed at describing an analysis of the pitch bias in CryoSat products acquired over the German Bight spanned from 2010 till 2015. The pitch information, as extracted from CryoSat-2 FBR Baseline B products and computed from on board star trackers, has been cross-compared against the pitch as estimated by analysis of the stacks of the SAR single look echoes according to [1].
It is worth recalling here the standard processing chain for a SAR altimeter [1]: firstly an approximately equally spaced set of ground locations on the Earth surface, i.e. surface sample, is identified. A surface sample gathers a stack of single look echoes coming from the processed bursts during the time of visibility. However, in a surface sample stack, each single look echo has been acquired from a different position of the instrument along the orbit and, as a consequence, it results to be scaled in power by the antenna pattern as function of the look angle. According to [2], on a uniformly rough spherical surface, e.g. the ocean, the power of the single look echoes in the stack is modulated by the along-track antenna pattern.
Thus, by fitting the along-track antenna pattern on the power distribution of each stack, it is possible to measure with sufficient accuracy the actual pitch of the satellite directly from the acquired and processed data. It is worth underlining that the pitch retrieved exploiting this method is totally independent of the attitude information annotated in the FBR products.
In the present work, the pitch bias was estimated similarly to [1] building from each SAR stack data a sub-stack of 64 looks and multi-looking 100 consecutive sub-stacks together in order to knock-down the speckle noise. The outcome was that the pitch bias resulted in the combination of a constant term equal to 0.055 deg and a sinusoidal function of the time, that has been addressed to the seasonal solar illumination on the Star Trackers, as shown in the attached figure. By compensating the pitch bias on the pitch from Star Tracker (that is annotated in the FBR products), the residual difference between the two pitch measurements results to have a standard deviation equal to about 2.5 millideg.
Possibly, the analysis will be repeated also on a wider region, as the South-East Pacific Box, in order to investigate any spatial correlation between the two pitch estimations.

[1] M. Scagliola, M. Fornari, and N. Tagliani, “Pitch estimation for cryosat by analysis of stacks of single-look echoes,” IEEE Geosci. Remote Sens. Letters, vol. PP, no. 99, pp. 1–5, 2015.

[2] Wingham D. J., Phalippou L., Mavrocordatos C. and Wallis D., The Mean Echo and Echo Cross Product From a Beamforming Interferomet-ric Altimeter and Their Application to Elevation Measurement, IEEE Transactions on Geoscience and Remote Sensing, 42 (10), 2305-2323,doi:10.1109/TGRS.2004.834352, 2004.

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Identification and Reduction of Retracker-Related Noise in Altimeter-Derived Sea-Surface Height Measurements

Edward Zaron (Portland State University, United States)

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

Abstract:
Data from the Jason-2 calibration/validation mission phase are analyzed to identify the correlation between the measurement errors of sea-surface height (SSH) and significant wave height (SWH). A cross-spectral analysis indicates that the SSH and SWH errors are nearly white and coherent at scales from 12 km to 100 km, consistent with the hypothesized error source, the waveform retracker. Because of the scale separation between the SWH signal and noise, it is possible to correct the SSH data by removing the noise correlated with the SWH noise. Such a correction has been developed using data from the calibration orbit phase and applied to independent data from other phases of the Jason-1 mission. The efficacy of the correction varies geographically, but variance reductions between 1.6 cm^2 and 2.2 cm^2 have been obtained, corresponding to reductions of 20% to 27% in the noise floor of along-track spectra. The corrections are obtained from, and applied to, conventional, 1 Hz, altimetry data, and lead to improvements in the signal-to-noise for identification of short-wavelength features, such as the internal tides.

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Error Characterization of Altimeter Missions over Ocean : Comparison and Interpretation

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

Abstract:
For more than 20 years, altimeter missions have been providing measurements of the ocean. Depending on their characteristics, orbit (altitude, pointing, ...), on-board hardware (frequency, bandwith, antenna gain pattern, pulse repetition frequency, ...), on-ground processing (retracking algorithm, corrections, ...), their performances can be computed, compared and explained. The objective of this presentation is twofold. The first aim is to provide to the users, large performance intercomparison references based on different metrics such as Sea Surface Height spectra or standard deviation. The knowledge of these metrics should allow them to improve/optimize their use of the altimeter data set. The second one is to give keys to agencies to anticipate the future altimeter mission peformances depending on their main characteristics.
Based on the analysis of many altimeter mission data set (Envisat/RA-2, ERS, Jason (1/2/3), Saral, HY-2, Cryosat-2), we propose to give an overview of the main results illustrating their relative performances.

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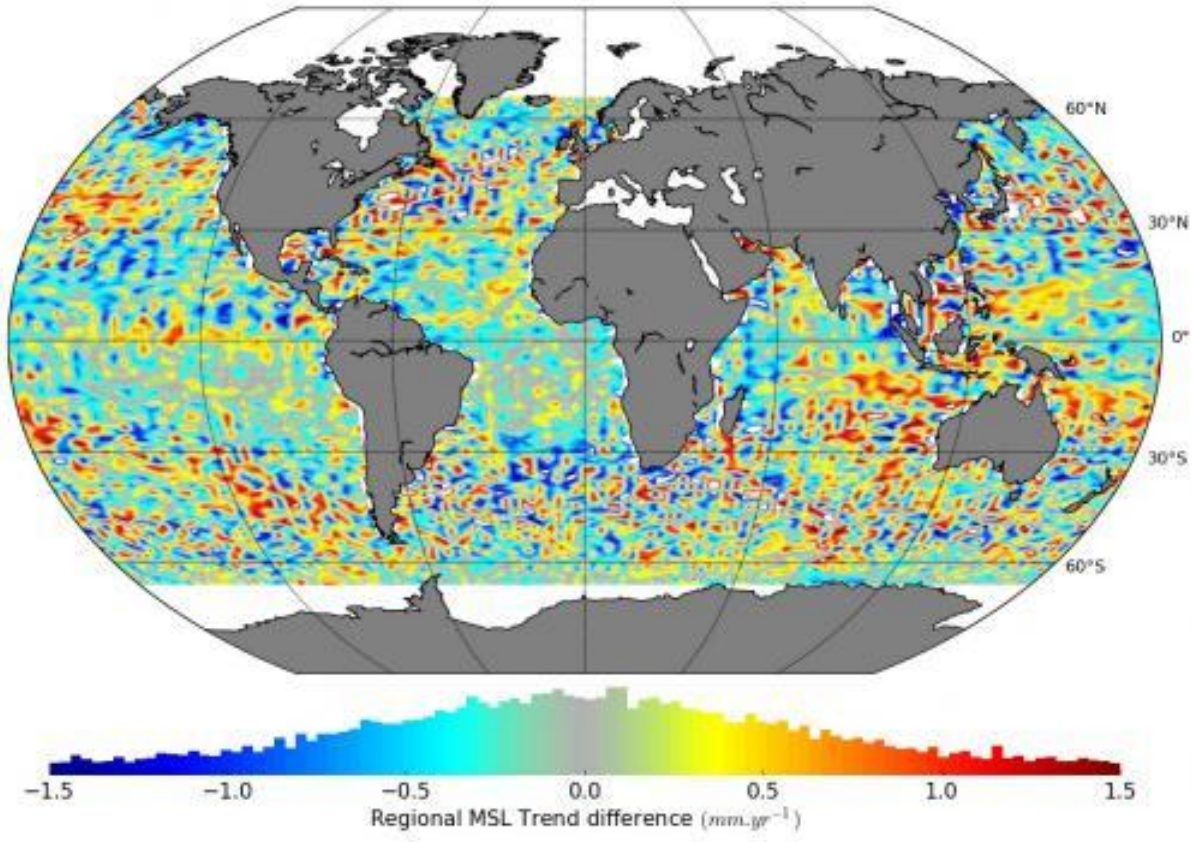
Accuracy of the mean sea level continuous record with future altimetric missions: Jason-3 versus Sentinel-3a

Lionel Zawadzki (CLS, France) ; Michaël Ablain (CLS, France)

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

Abstract:
The current Mean Sea Level (MSL) continuous record, essential for the understanding of climate evolution, is computed with the altimetric measurements of the TOPEX/Poseidon mission, succeeded by Jason-1 and later Jason-2. The accurate continuity of the record is ensured by the conservation of the “historical” TOPEX orbit, but also by calibration phases between the successive missions which enable a rigorous computation of their relative biases. In order to extend the current MSL record, Jason-3 will be the natural successor of Jason-2: on the same orbit with a calibration phase. Shortly after Jason-3, another altimetric climate-oriented mission, Sentinel-3a, will be launched on a different orbit. In this paper, simulated altimetric sea level data is used to study the sensitivity of the MSL continuous record to the change of the “historical” orbit for the new Sentinel-3a orbit. By estimating the impact of the absence of calibration phase on the MSL continuous record trend accuracy at global and regional scale and the impact of the orbit change on the long-term continuity of this MSL record, this study shows that linking Sentinel-3a data instead of Jason-3 to the MSL continuous record would prevent from meeting climate users requirements regarding the MSL trend accuracy.



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Uncertainty estimates of altimetric Global Mean Sea Level timeseries

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

Abstract:
An attempt is being presented concerned with providing uncertainty measures for global mean sea level time series. For this purpose sea surface height (SSH) fields, simulated by the high resolution STORM/NCEP model for the period 1993 - 2010, were subsampled along altimeter tracks and processed similar to techniques used by five working groups to estimate GMSL. Results suggest that the spatial and temporal resolution have a substantial impact on GMSL estimates. Major impacts can especially result from the interpolation technique or the treatment of SSH outliers and easily lead to artificial temporal variability in the resulting time series.
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Uncertainties Affecting Regional Sea Level Trends

Pierre Prandi (CLS, France) ; Michaël Ablain (CLS, France) ; Benoit Meyssignac (CNES/LEGOS, France) ; Nicolas Picot (CNES, France)

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

Abstract:
Satellite altimetry missions now provide a more than 20 years record of continuous measurements of sea level along the reference ground track of TOPEX/Poseidon. These measurements are used by different groups to build the mean sea level rise record, which is an essential climate change indicator. Estimating a realistic uncertainty on the sea level rise rate deduced from satellite is of crucial importance for climate studies such as sea level budget closure.

Ablain et al., 2015 estimated the GMSL trend uncertainty 0.5 mm/yr (90% confidence interval) by a careful study of the differences between altimeter standards. In this study we derive confidence intervals for regional sea level trends in order to build a map of sea level trends uncertainties than can be associated with the map of the sea level trends.

We use a generalized least squares approach, based on the a priori knowledge of the error variance-covariance matrix. Three types of errors that can affect altimetry are modeled (drifts, biases, noise) and combined to derive realistic confidence intervals on local sea level trend estimates. The approach is extended to account for the impact of natural ocean variability on the reliability of trend estimates.

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Heat and Freshwater Convergence Anomalies in the Atlantic Ocean Inferred from Observations

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Oral

Abstract:
Observations of thermosteric and halosteric sea level from hydrographic data, ocean mass from GRACE and altimetric sea surface height are used to infer meridional heat transport (MHT) and freshwater convergence (FWC) anomalies for the Atlantic Ocean. An "unknown control" version of a Kalman filter in each of eight regions extracts smooth estimates of heat transport convergence (HTC) and FWC from discrepancies between the sea level response to monthly surface heat and freshwater fluxes and observed heat and freshwater content. The model is run for 1993-2014. Estimates of MHT anomalies are derived by summing the HTC from north to south and adding a spatially uniform, time-varying MHT derived from updated MHT estimates at 41N (Willis 2010). Estimated anomalies in MHT are comparable to those recently observed at the RAPID/MOCHA line at 26.5N. MHT estimates are relatively insensitive to the choice of heat flux products and are highly coherent spatially. MHT anomalies at 35S resemble estimates of Agulhas Leakage derived from altimeter (LeBars et al 2014) suggesting that the Indian Ocean is the source of the anomalous heat inflow. FWC estimates in the Atlantic Ocean (67N to 35S) resemble estimates of Atlantic river inflow (de Couet and Maurer, GRDC 2009). Increasing values of FWC after 2002 at a time when MHT was decreasing may indicate a feedback between the Atlantic Meridional Overturning Circulation and FWC that would accelerate the AMOC slowdown.

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Mean structure, long-term change and eddy motions in the Southern Ocean: A perspective from altimetry, Argo and state estimation

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Oral

Abstract:
The low stratification of the Southern Ocean means that eddies detected by altimetry at the ocean surface extend through the top 2 km of the ocean. Sea surface height anomalies are more strongly correlated with sub-surface variability at depths between about 600 and 1400 dbars than they are with variability in the upper 200 dbars. Altimetric variability can thus be used to remove eddy-related anomalies from individual Argo profiles, resulting in a smoother estimate of mean temperature and salinity. This “eddy-free” mean field serves as a benchmark against which to assess decadal-scale changes in the Southern Ocean, and we use historic hydrographic data to evaluate temperature and salinity changes through the second half of the 20th century. We also evaluate the behavior of Southern Ocean eddies themselves: Although in most parts of the ocean closed oceanic eddies appear to result in thermally indirect heat transport, eddies that are carried eastward by the ACC tend to propagate in the opposite direction, resulting in thermally direct, cross-ACC heat transport. This thermally direct cell seems to be unique to the ACC. Evidence suggests that this cell is maintained by the effective eastward propagation of eddies relative to the mean flow at deep levels.

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Low-frequency transport variability in the Southern Ocean: the importance of regional variations

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Oral

Abstract:
We use satellite altimetry, temperature/salinity from Argo, ocean bottom pressure from GRACE and the ECCO2 state estimate, and satellite vector winds to quantify and understand zonal geostrophic transport variability in the Southern Ocean. Altimetry and Argo data are used to estimate the transport variability above 2000 dbar, while GRACE and ECCO2 are used to measure the full-depth transport associated with the bottom current (i.e., the barotropic component). We find that for interannual periods, the transport variations are dominated by the Southern Annular Mode (SAM) variability, but that there are significant differences in the two estimates. The barotropic component is more highly correlated with SAM, suggesting either issues in the altimetry/Argo estimate or significant baroclinic differences. More importantly, we observe a significant difference in decadal trends between the Southern Indian Ocean and South Pacific, with different signs. This is found in both the GRACE and ECCO2 estimates, and is shown to be related to regional wind differences – the winds in the Atlantic/Indian Ocean sectors have been decreasing over the last decade while they have been increasing west of the Drake Passage, although zonally averaged winds show little change. These results have important implications for studies trying to estimate changes of the Antarctic Circumpolar Current transport at the Drake Passage.
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A new approach to detection and attribution of ocean thermal expansion

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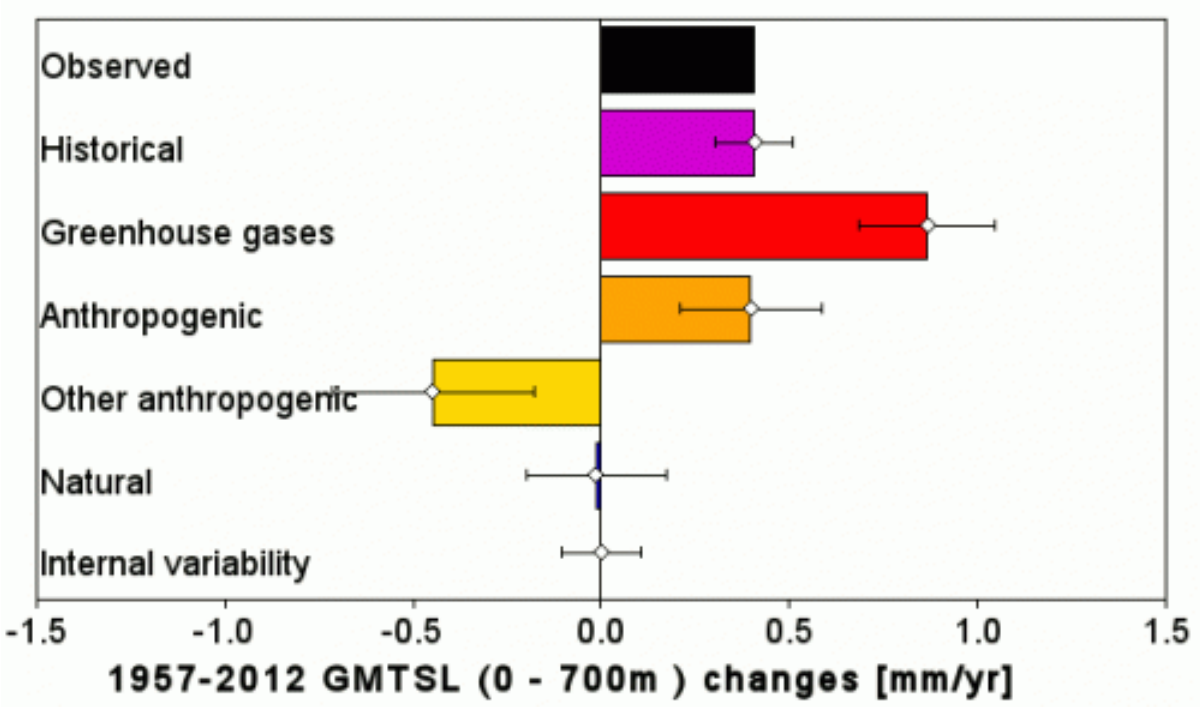
Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Oral

Abstract:
Tide gauges and satellite-based radar altimeter measurements provide evidence that the global mean sea level (GMSL) has been rising during the last two centuries and that this rate has been accelerating since the early 1900's, reaching 2.0±0.3 mm/year over 1971-2010 and 3.2±0.4 mm/year over 1993-2012 (Church et al. 2013). Ocean thermal expansion was identified as one of the main contributors, accounting for about 40% of the GMSL rise over 1971-2010 and 30% over 1993-2012 (Church et al. 2013).

However, the influence of natural and anthropogenic external forcings and of internal variability on the climate system and more specifically on the global mean thermosteric sea level (GMTSL) remains unclear while its understanding is essential to project sea level rise. This study aims at assessing the contributions of each forcing to the GMTSL changes, using a new detection and attribution method, based on additive decomposition. Developed by Ribes et al. (2015), this new approach dismisses the usual linear regression and proposes a symmetric treatment of the magnitude and pattern of the climate response to each forcing.

Idealized simulations of the climate system, with none or a chosen combination of forcings, provide some information on the pattern and amplitude of the GMTSL response to each forcing. We use a large ensemble of forced and unforced simulations issued from CMIP5 to calculate a first estimate of the GMTSL response to natural, anthropogenic, greenhouse gas and other forcings. Observational datasets are then used to constrain this first estimate to a more accurate result. Uncertainties may be further reduced by applying this statistical analysis to a bivariate case, i.e. to the responses over two different periods and/or regions.

First results on the layer 0 to 700 m deep from 1957 to 2012 (see figure) show that the observed GMTSL trend cannot be explained by climate internal variability and natural forcing only, nor by greenhouse gas emissions or other anthropic activity (including anthropic aerosols and ozone emissions, changes in land use). The response to the combination of all anthropogenic forcings gives a trend closer to observations, and, as expected, the response to all forcings (historical simulations) explains most of the observed trend. Investigation of more periods, regions and layers of the ocean, using bivariate analysis, will allow a more accurate quantification of each forcing contribution to observed GMTSL changes.



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Is anthropogenic sea level fingerprint already detectable in the Pacific Ocean over the satellite altimetry era?

Hindumathi Palanisamy (CNES-LEGOS, France) ; Benoit Meyssignac (CNES-LEGOS, France) ; Anny Cazenave (CNES-LEGOS (France), ISSI (Switzerland),) ; Thierry Delcroix (IRD-LEGOS, France)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Oral

Abstract:
Sea level rates up to three times the global mean rate are being observed in the western tropical Pacific since 1993 by satellite altimetry. From recently published studies, it is not yet clear whether the sea level spatial trend patterns of the Pacific Ocean observed by satellite altimetry are mostly due to internal climate variability or if some anthropogenic fingerprint is already detectable. A number of recent studies have shown that the removal of the signal corresponding to the Pacific Decadal Oscillation (PDO)/ Interdecadal Pacific Oscillation (IPO) from the observed altimetry sea level data over 1993-2010/2012 results in some significant residual trend pattern in the western tropical Pacific. It has thus been suggested that the PDO/IPO-related internal climate variability alone cannot account for all of the observed trend patterns in the western tropical Pacific and that the residual signal could be the fingerprint of the anthropogenic forcing. In this study, we investigate if there is any other internal climate variability signal still present in the residual trend pattern after the removal of IPO contribution from the altimetry-based sea level over 1993-2013. We show that subtraction of the IPO contribution to sea level trends through the method of linear regression does not totally remove the internal variability, leaving significant signal related to the non-linear response of sea level to El Niño Southern Oscillation (ENSO). In addition, by making use of 21 CMIP5 coupled climate models, we study the contribution of external forcing to the Pacific Ocean regional sea level variability over 1993-2013. We show that CMIP5 based externally forced (that includes anthropogenic fingerprint) sea level spatial trend pattern in the tropical Pacific over the altimetry period do not display any positive sea level trend values that are comparable to the altimetry based sea level signal after having removed the contribution of the decadal natural climate mode. Moreover, the CMIP5 based externally forced sea level trend amplitude in the tropical Pacific is significantly lower than the expected error in trend patterns from satellite altimetry. This suggests that satellite altimetry measurement is still not accurate enough to detect the anthropogenic signal in the 20 year tropical Pacific sea level trends.

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The impacts of ENSO/PDO on regional sea level change: After 20 years, are we finally seeing a change in the pattern of Pacific sea level change?

Robert Steven Nerem (University of Colorado, United States) ; Ben Hamlington (Old Dominion University, USA) ; Mark Merrifield (University of Hawaii, USA) ; Phillip Thompson (University of Hawaii, USA)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Oral

Abstract:
Over the first 20 years of the TOPEX/Jason-1/Jason-2 missions, sea level in the western Pacific has been steadily going up at a rate of ~10 mm/year while sea level in the eastern Pacific has been modestly declining. Merrifield (2010) used long time series of tide gauge data in the western Pacific to show that the altimeter record occurs at a rather unique period in the history of sea level, likely related to the phase of the Pacifiic Decadal Oscillation (PDO). However, since roughly late 2013, this pattern may be beginning to reverse, as regional sea level has been falling in the western Pacific and rising in the eastern Pacific. If this is truly a change from the "cool phase" to the "warm phase" of PDO, then we can expect sea level rise along the coast of California to dramatically increase over the next decade with rates well above the 3 mm/year global average as it recovers from its PDO-induced sea level "deficit". Coupled with the shorter-term ENSO response, this could lead to record high sea level along the western coast of the U.S. Global mean sea level is also likely to hit a new record in the next year in response to ENSO variability. We will review the observational sea level record from altimetry and tide gauges in these contexts and offer some insight into how Pacific regional sea level change might be expected to unfold over the coming years.
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Revised sea state bias models for retracked TOPEX altimeter data

Hui Feng (Univ. of New Hampshire, United States) ; Doug Vandemark (Univ. of New Hampshire, United States) ; Joseph McMichael (JPL, United States) ; Phillip Callahan (JPL, United States)

Session: Instrument Processing: Corrections
Presentation type: Poster
Poster number: IPC_001

Abstract:
New empirical models for the radar altimeter range bias associated with ocean waves have been produced in 2015 as part of ongoing NOAA and NASA projects directed at finalizing the long term data record for the TOPEX ocean altimeter. These sea state bias (SSB) models were developed using the latest timeframe geophysical data record corrections (e.g. orbits, tides, wet path delay) and the SSB models were built for both the MGDR and the new retracked datasets (RGDR) provided by JPL that contain revised range and wave height data derived from an intensive ground system retracking of the altimeter return waveform measurements. The SSB model creation methods applied involve using a multi-year ensemble of yearly SSB correction models produced using direct sea level anomaly data coincident with wind speed and wave height (2D models) or wind speed, wave height, and wave period (3D models). In the latter case the wave period data come from global wave model hindcast data of an NCEP wind forced WAVEWATCH III model produced at IFREMER. SSB models are derived for both Side A and Side B of TOPEX and the model results assessed against currently available SSB models using a series of metrics, the tandem Jason/TOPEX orbit datasets, and ascending vs. descending passes. Recommendations for optimal and sufficient 2D and 3D SSB models for TOPEX application in support of climate record objectives will be provided, both with respect to MGDR and RGDR datasets.

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ACCRA : A Study on Future Microwave Radiometers for Atmospheric Correction of Radar Altimeters on Coastal Regions

Bruno Picard (CLS, France) ; Marie-Laure Frery (CLS, FRANCE) ; Laurence Eymard (LOCEAN/IPSL, FRANCE) ; Fatima Karbou (CNRM/GAME, France) ; Janet Charlton (JCR, UK) ; Adrian R.L. Tatnall (RAL, UK) ; Brian Monya (STFC, UK) ; Soe Min Tun (SMT, UK) ; Manuel Martin-Neira (ESA/ESTEC, Netherland)

Session: Instrument Processing: Corrections
Presentation type: Poster
Poster number: IPC_002

Abstract:
The wet tropospheric correction (WTC) is a major source of uncertainty in altimetry budget error, due to its large spatial and temporal variability: this is why the main altimetry missions include a microwave radiometer (MR) The commonly agreed requirement on WTC for current missions is to retrieve WTC with an error better than 1cm rms.
With the introduction of the along-track synthetic aperture processing, first implemented in CryoSat-2, and now in the upcoming operational altimetry missions such as Sentinel-3 and Jason-CS, more accurate altimetry data are anticipated for coastal and inland waters. Nevertheless, the quality of data in those areas are expected to be degraded with respect to those of the open oceans due to the rather wide field of view of the MR (-3 dB beam-width of ~20 km). As a matter of fact, the MR observations over those waters are subject to contamination by land brightness temperatures which fall within the MR footprint.
The present team has been selected by ESA/ESTEC to work on a MR instrument design for future operational radar altimetry missions. Such a design shall include the classical MR channels for ensuring observation continuity, augmented by a set of high frequency channels for enabling accurate altimetry over coastal and inland waters.
In this study team, the extensive systems and radiometric engineering experience of JCR Systems is complemented by a significant expertise of LOCEAN , CLS and CNRM in water vapour retrievals, a considerable experience in design and development of microwave and millimetre wave radiometer front ends from RAL and a substantial knowledge of SMT Consultancies in microwave and millimetre-wave antenna design.
We will present the first results of the on-going study on the selection of an optimal set of observation frequencies based on an analysis of both potential horizontal resolution and the value of the physical information provided. In order to properly select this optimal set for the wet tropospheric correction (WTC) retrieval over ocean and in coastal regions, the combination between all frequency candidates (including high frequencies such as 89 GHz, 157 GHz, 183 GHz) will lead to the definition of a set of retrieval algorithms based on ECMWF analysis, RTTOV radiative transfer model associated with an emissivity data base and a neural network inversion. The statistics on the algorithmic error defined as the difference between the retrieved WTC applied on simulated brightness temperatures (BT) and the ECMWF WTC will allow to quantify the performances and discriminate these algorithms over open ocean, land surface and polar ice. Eventually, design considerations are taken into account in order to select between different potential combinations.

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Dynamical Coastal Topography and tide gauge unification using altimetry and GOCE

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_001

Abstract:
ESA has recently released a study on the potential of ocean levelling as a novel approach to the study of height system unification taking the recent development in geoid accuracy trough 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. The fundamental use of the MDT computed using altimetry, ocean models or through the use of tide gauges has values of between -2 and +1 meters at different points in the ocean. However, 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 elements like: 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; Connect measurements of a global set of tide gauges and investigate trends
The project and roadmap will be outlined in this presentation.

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Revisiting the sea level closure budget over 2004-2014 from a GRACE perspective

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_002

Abstract:
Based on the sea level budget closure approach, this study investigates the consistency of observed Global Mean Sea Level (GMSL) estimates from satellite altimetry, observed Ocean Thermal Expansion (OTE) estimates from in-situ hydrographic data (based on Argo for depth above 2000m and oceanic cruises below) and GRACE observations of land water storage and land ice melt for the period January 2004 to December 2014. The consistency between these datasets is a key issue if we want to constrain missing contributions to sea level rise such as the deep ocean contribution. Numerous previous studies have addressed this question by summing up the different contributions to sea level rise and comparing it to satellite altimetry observations (see for example Llovel et al. 2015, Dieng et al. 2015). Here we propose a novel approach which consists in correcting GRACE solutions over the ocean (essentially corrections of stripes and leakage from ice caps) with mass observations deduced from the difference between satellite altimetry sea level observations and in-situ hydrographic data OTE estimates. We check that the resulting GRACE corrected solutions are consistent with original GRACE estimates of the geoid spherical harmonic coefficients within error bars and we compare the resulting GRACE estimates of land water storage and land ice melt with independent results from the literature. We test the sensitivity of the method to different deep ocean contribution to GMSL and propose a best estimate.
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Combination of satellite altimetry, tide gauges and shipborne GNSS measurements in the German Bight

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_003

Abstract:
High precision and reliable information about the sea surface height (SSH) are of vital interest for the global scientific community. Such data can be collected with remote sensing techniques like satellite altimetry and GNSS reflectometry. These techniques deliver spatially distributed data over the oceans but suffer from interfering signals near coastlines. In this areas tide gauges collect information about the SSH at specific stations. Ship-based GNSS measurements of the SSH can be used to beneficially expand these set of techniques. All three techniques have their own characteristics and show different spatial coverage and temporal resolution of the deduced SSH.

In a newly founded project at the Jade University of Applied Science in Oldenburg an approach for the combination of all three techniques will be developed. The region of interest is the German Bight and data from all available altimetry satellites will be merged with tide gauge readings and ship-derived SSH data. As ship-based SSH measurements are influenced by systematic geophysical, hydrostatic and hydrodynamic effects a processing procedure for these data will be developed and tested in a first step. In addition to the project outline the results from former projects will be shown which indicate the great potential of ships used as GNSS sensor platforms.

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Regional and coastal long-term sea level change assessment from geodetic data

Luciana Fenoglio-Marc (Technische Universität Darmstadt, Deutschland)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_004

Abstract:
A long-term satellite-based monitoring of the sea level Essential Climate Variable (ECV) as required for climate studies is provided by the ESA Climate Change Initiative Sea Level Project (SLCCI).

We assess here in a regional study the quality of the Fundamental Climate Data Record (FCDR) and ECV over the German Bight and the Mediterranean Sea. Reliable and long time-series of in-situ stations exist in the two regions. The results from the various observing systems (altimetry, tide gauges, GNSS stations) are compared and their uncertainties are quantified.

The first objective is to extract the long-term climate signal and its error in open sea and coastal zone. Altimeter data are validated against geodetic-referenced in-situ data, referred to the Earth's reference ellipsoid GRS80 via the Global Navigation Satellite System (GNSS).

In the second part we combine satellite gravity measurements from GRACE, models and climatic data and assess the basin averaged altimeter-derived sea level change and its error in the Mediterranean Sea.

The study highlight the importance of multidisciplinary studies to understand and discriminate causes of current sea level changes integrating the various factors that interfere at local scale (as climatic component, atmospheric and oceanographic processes, ground subsidence, etc.).

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Analyses of altimetry errors using Argo and GRACE data

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Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_005

Abstract:
Since the first altimeter missions and the improvements performed in the accuracy of sea surface height measurements from 1992 onwards, the importance of global quality assessment of altimeter data has been increasing. Global Cal/Val studies are usually performed by the analysis of internal consistency and cross-comparison between all missions. In this study, the steric and mass contributions to the sea level provided by Argo profiling floats and the Gravity Recovery And Climate Experiment (GRACE) mission respectively are used as independent sources of comparison to analyze the altimetry errors.

Argo profiling floats are spread out over almost the global open ocean since 2004. However, they measure temperature and salinity vertical profiles, providing only the steric contribution to the total sea level content measured by altimeters. The missing mass contribution is derived from the GRACE data set from 2003 onwards.

The comparison is performed with the first objective of detecting global and regional altimeter mean sea level drifts. A second goal is to assess the impact of new altimeter standards (orbit, geophysical corrections, ground processing) and of new version of altimeter merged products such as the 2014 AVISO reprocessing or the Sea Level CCI data set. We also focus our work on sensitivity analyses of the method of comparison to various parameters. In particular, we determine to which extent the altimeter quality assessment is affected by a different pre processing of altimeter data, a sub sampling of the Argo network and a change of the reference depth used to compute Argo dynamic heights.

Keywords: Altimetry errors, Argo, GRACE, Mean Sea Level
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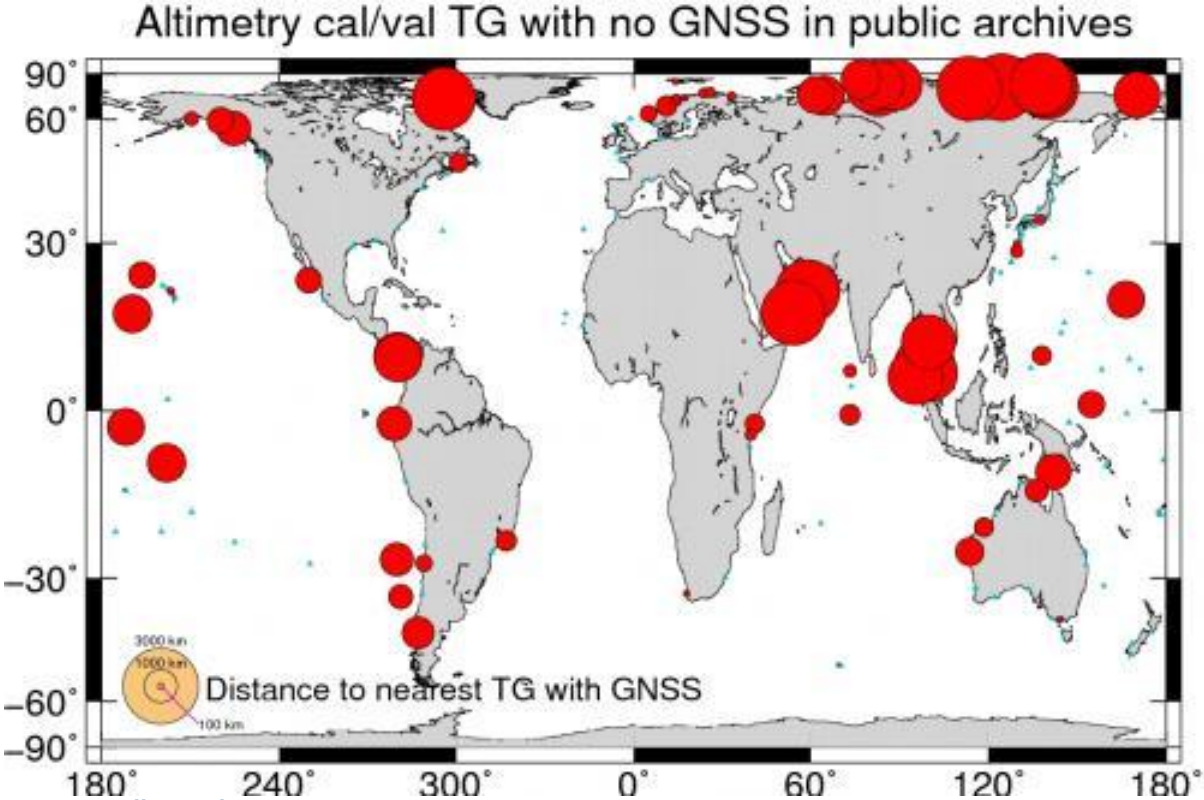
Priorities for installation of continuous Global Navigation Satellite System (GNSS) near to tide gauges

Matt King (University of Tasmania, Australia) ; Christopher Watson (University of Tasmania, Australia)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_006

Abstract:
It has now been more than 20 years since geodetic measurement of vertical land movement at, or near to, tide gauges (TGs) was proposed. A large number of mainly Global Positioning System (GPS) receivers have been deployed since these recommendations were made, either to explicitly monitor TG motion or, more often, as part of larger-scale scientific and/or government-funded networks. As a result, vertical land movement is now being measured at several hundred sites “near” to tide gauges, although “near” could be tens or hundreds of kilometres. Even allowing for this, there are still a large number of TGs that are routinely used for climate studies that are not presently adequately monitored by geodetic techniques. Here, we report on a priority list of TGs where GNSS data are not available for analysis by the international community. We provide this analysis from the perspectives of two applications: (i) Long-running tide gauges contributing data for studies of long-term sea-level change; and (ii) Tide gauges used in calibration/validation of satellite altimeters.



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Impact of loss of the 35-day repeat tracks on estimates of the mean sea level evolution

Andrew Shaw (SkyMAT Ltd., UK, United Kingdom) ; Cipollini Paolo (National Oceanography Centre, United Kingdom) ; Mir Calafat Francisco (National Oceanography Centre, United Kingdom) ; Benveniste Jérôme (ESA/ESRIN, Italy)

Session: Science I: Mean sea level monitoring: how to reconcile altimetry, tide gauges, land motion and other in situ observations?
Presentation type: Poster
Poster number: SC1_007

Abstract:
The 18-year time series of altimetry on the ERS-1/2 and Envisat 35-day orbit repeat tracks were discontinued in October 2010 when Envisat orbit changed into a 30-day repeat cycle. 18 months later, on 8th April 2012, Envisat ceased operations. This investigation, carried out within the ESA Sea Level Climate Change Initative (SL_cci), addresses the impact of the loss of sea surface height (SSH) measurements on the 35-day tracks with respect to the mean sea level (MSL) Essential Climate Variables (ECV) indicators. The ECV indicators that we explored are the trend and the annual and semiannual signals for MSL on both global and regional scales. SL_cci ECV indicators have been compared with different resampling satellite tracks scenarios using the TOPEX-Jason-1/2 (10-day) and 35-day orbits. To reproduce the real scenario, after the missing data period between November 2010 to February 2013 (28 months) the 35-day orbits have been reinstated to coincide with the start of the sampling by the AltiKa mission in March 2013.

In detail, we assessed the impact of the temporal gap in the 35-day orbit by flying a satellite along the 10-day reference mission and 35-day tracks, over real altimetric gridded SSH anomaly field for the period between 1993 and 2013, to obtain the SSH observations. The input fields were the daily gridded 'two-satellite' SSH anomalies (SSHA) from Aviso. Four monthly-gridded SSHA datasets with a spatial resolution of 1° were created corresponding to the following scenarios:

1) Resampled along 10-day orbital track only.
2) Resampled along 35-day orbital track only.
3) Resampled along 10-day + 35-day orbital tracks
4) Resampled along 10-day and 35-day orbital tracks, with the 35-day orbits missing for the period between November 2010 and February 2013.

The first three scenarios were designed to provide a validation check and to assess the sensitivity of the ECV indicators with respect to the SL_cci ECVs indicators. The results show no statistically significant impact of the missing 35-day data (i.e. Nov 2010 to Feb 2013) on the global and regional ECV indicators and therefore the impact of the loss of data are minimal. However the 35-day mission remain most useful as it's the only one that allows to study the regional trends in the polar regions.

Finally we report the results of a sensitivity study to estimate to what extent does the sea level trend need to increase within the polar region (where only the 35-day orbit observations are available) in order for the global trend to be statistically different at the 95 % confident interval.
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Simultaneous multi-waveform retracking in coastal regions : application to the NW Mediterranean Sea

Fernando Niño (IRD/Legos, France) ; Florence Birol (UPS/Legos, France) ; Denis Blumstein (CNES/Legos, France) ; Nicolas Fuller (CNRS/Legos, France)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_001

Abstract:
Altimetric waveforms near the coast are difficult to analyze because of the complexity of echoes returned from land and coastal waters. Most tracking algorithms are optimized for the open ocean; others try to fit the observed signal to one or more signal templates suitable for a particular setting and then estimate the altimetric range from the deduced parameters. We present new developments in which the goal is to use the reflective ground properties as the main parameters for a radar signal inversion problem over. Instead of trying to fit the waveform data to an a priori reference set of waveforms, from which one can deduce the “real” satellite-earth surface range, we try to model the observed waveform in terms of the configuration of the topography and water and their backscattering properties beneath the satellite. For this, we simultaneously fit a set of waveforms over the study region, instead of using the usual approach of optimizing each waveform individually.

The current version of the inversion algorithm uses a set of parametric generators from which several parameters can be chosen to be inverted (topography, sigma-naught, radar penetration). An iterative optimization algorithm based on evolutionary computation is applied on a realistic altimetry waveform model, obtaining suitable parameters of the generators to describe the waveforms acquired by the satellite(s) over the study area.

An application is shown for the NW Mediterranean region, and the range results compared to those of standard retracking and the PISTACH coastal data processing chain.
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SENTINEL-3 STM Products & Processing Algorithms Definition

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_002

Abstract:
The Sentinel-3 Surface Topography Mission (STM) is a key component of the Copernicus Sentinel-3 mission, set to revolutionise operational oceanography with a suite of advanced surface topography data products over ocean and sea-ice. In addition the STM will collect data over all earth surfaces providing improved monitoring of River and Lake stage heights and inputs to the development of Digital Elevation Models.

Sentinel-3 will be the first Earth Observation mission to provide 100% SAR altimetry coverage and LRM mode will be maintained as a backup-operating mode. In order to fully exploit the SAR capability, and validating the algorithms evolution, lower level data products (L1A, L1B and L1B-S) will be made available to the users, in addition to the level 2 products.

The processing algorithms developed for the Sentinel-3 Topography mission have been selected to meet the operational objectives of the Copernicus program and do benefit from 20 years of Altimetry experience gained with the ERS, Envisat, T/P, Jason & Cryosat missions. On top of the heritage processing algorithms, the S-3 Topography processing baseline includes more recent processing algorithm such as the SAMOSA SAR Ocean Retracker.

This paper provides an overview of the S-3 STM data products that will be generated operationally within the Sentinel-3 Payload Data Ground Segment (PDGS) by the Instrument Processing Facilities (IPFs), as well as an overview of the Sentinel-3 STM processing algorithms baseline.

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"PEACHI Jason-3": a processing laboratory for innovative altimetry products

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_003

Abstract:
With proven experience from the PEACHI project, whose goal is to provide expertise products including the latest algorithms and corrections in Ka band using SARAL/AltiKa data, CNES is leading a similar initiative for Jason-3.
Jason-3 has been long-awaited by the users' community to ensure continuity with current altimeters and will contribute as reference mission to provide a global mean sea level data record.
Complementary to the official O/I/GDR products, expert users will be granted access to enhanced products through the "PEACHI Jason-3" prototype. Results from current studies and latest improvements of the data processing will be included.
For the first time, numerical retracking outputs will be available over the global ocean: performance of this algorithm has been demonstrated using Jason-2 data. By taking into account the natural long-term instrumental drift through the use of the real PTR measurement, we demonstrate it stands out as a significant improvement to conventional altimeters instrument processing and to Jason-3 even more so.
Complimentary benefits brought by numerical retracking include a significant reduction of the wave height and range estimation noise.
"PEACHI Jason-3" products will also include other solutions such as a new wet tropospheric correction based on neural network simulations, a three-dimensional sea state bias correction, and all up-to-date geophysical corrections needed to compute the sea level anomaly at 20 Hz and 1 Hz resolution.
We foresee that "PEACHI Jason-3" prototype will successfully demonstrate the need for numerical retracking processing of Jason-3 data and, more generally, the feasibility of taking into account any instrumental constraints such as PTR response evolution or altimeter antenna diagram.
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Using SARAL/AltiKa to improve Ka-band altimeter measurements for coastal zones, hydrology and ice: status of the PEACHI project

Guillaume Valladeau (CLS, France) ; Pierre Thibaut (CLS, France) ; Nicolas Picot (CNES, France) ; Amandine Guillot (CNES, France) ; Sophie Le Gac (CNES, France)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_004

Abstract:
With the objective to ensure the complementarity but also the continuity with the SARAL/AltiKa Level-2 products provided in the open ocean, the PEACHI (Prototype for Expertise on AltiKa for Coastal, Hydrology and Ice) project has been set up as an initiative of the French space agency, CNES. The PEACHI prototype is designed to process and fine tune enhanced algorithms dedicated to the assessment of Ka-band parameters, from the instrument processing to geophysical corrections. As a result, end users are routinely provided with the latest available altimeter corrections for scientific applications.

Complementary to the last update of SARAL/AltiKa processing software and the dissemination of the operational Level-2 products, some new or improved algorithms have been developed in the framework of the PEACHI project to better observe the open ocean and achieve SARAL secondary objectives on the study of coastal dynamics, inland waters, polar oceans, or continental and sea ice. The purpose of this work is to provide a global status of the PEACHI project and the reprocessing performed in 2015. We focus on a handful of key algorithm improvements with regard to the operational GDR (Geophysical Data Record) products: new waveform retrackers improving performances over ocean, continental and sea ice, improved 2D and new 3D sea state biases, new tide models, better altimeter wind correction, new editing process over rain and bloom areas or sea ice regions.

We would like to foster all current and prospective users to provide us with independent assessment and feedback in order to determine which parameters should be transferred into the classical GDR, or applied to other missions. Feedback would also be appreciated to define possible innovative algorithms and studies that should be added to future PEACHI versions, keeping in mind the project goal: deliver a long, rich and consistent time series of demonstrative algorithms.
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A new method to determine the antenna pointing directly from Altimeter SAR mode data

Chris Ray (isardSAT, United Kingdom) ; Roca Mònica (isardSAT, UK)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_005

Abstract:
Recently we showed that it is possible to compensate the amplitude variations of the delay-Doppler map that are not related to the sea state and likewise also compensate for a dilation of range that causes a variation along track in the power. With both amplitude compensation (AC) and dilation compensation (DC) the resultant AC/DC delay-Doppler map is much simpler.

Here is presented an application of that simplified delay-Doppler map (or stack).
It is shown that because of the simple shape of the AC/DC delay-Doppler map the antenna pointing can be computed algebraically from the AC/DC delay-Doppler map.
This technique has been validated using simulated data, and then it is used to estimate the bias of the CryoSat star-tracker and compared to other previously presented methods.

This work has been carried out under the ESTEC/ESA contract to develop the Sentinel-6 Poseidon-4 Level 1 Ground Processor Prototype.
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ERS-2 mission reprocessing for long-term continental surfaces studies

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_006

Abstract:
Satellite altimetry has been a very powerful tool in oceanography and continental surface studies over the last 25 years. While instrument processing and retracking techniques have been improved over the years for all satellite missions towards ocean applications, less effort has been made for continental studies. ESA's ENVISAT mission has been updated regularly, improving the quality of processing of continental data, unlike the ERS missions.

The CTOH processed the ERS-2 waveforms (WAP data) with a new implementation of the Ice-2 retracker algorithm, adding improvements and corrections to make it compatible and homogenous with the ENVISAT mission, hence providing suitable grounds for continuity and long-term altimetry data analysis. The other differences with the REAPER ERS-2 product are: we used the newer Rudenko et al. (2014) orbit product, a dry troposphere correction using ERA fields valid over all surfaces (Blarel and Legresy, 2013), and a new Doppler correction valid over all surfaces using range rates (Blarel and Legresy, 2012). They have significant impact over continental surfaces.

Envisat/ERS-2 mission continuity is tested by cross-validating data obtained during the tandem phase when they flew with 30 minutes time separation. We show here the main validation and cross validation of the two missions. We find a good general agreement, but some differences in the ice-2 retracker behavior over continental surfaces which we discuss. We show a global validation, as well as of the actual height and radar measurements over the continents, over inland water bodies and over ice sheets. The high level (geophysical data record and beyond) product is available and distributed by the LEGOS/CTOH altimetry service.

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A Fast Convolution based Model for SAR Altimetry Waveforms and their Retracking

Christopher Buchhaupt (TU Darmstadt, Deutschland) ; Luciana Fenoglio-Marc (TU Darmstadt, Germany) ; Salvatore Dinardo (SERCO, ESA/ESRIN, Italy) ; Scharroo Remko (EUMETSAT, Germany) ; Matthias Becker (TU Darmstadt, Germany)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_007

Abstract:
Since the start of the Cryosat-2 mission SAR Altimetry contributes through a higher signal to noise ratio and a better along track spatial resolution to a better understanding of the oceanic processes. Unfortunately, to achieve an analytical solution for the retrieval of geophysical parameters from the radar echo, the Point Target Response (PTR) in the time/frequency domain has to be approximated by Gaussian bell-curves. This approach leads to errors in the estimated parameters, particularly in Significant Wave Height (SWH).
In an alternative method, which allows to use the correct PTR in the convolution of Delay/Doppler Altimetry waveforms, the Flat Sea Surface Response (FSSR) is calculated analytically and the convolution with the PTR and the Probability Density Function (PDF) of the sea surface is computed numerically.

In this work a close form solution without special functions and infinite sums of SAR Altimetry waveforms is developed in the frequency/time domain by calculating analytically the two-dimensional Fourier Transform of the Convolution term. The corresponding signal in the time/frequency domain can then be computed fast and easily with a two-dimensional fast inverse Fourier transform. Furthermore a Retracking algorithm is developed from this functional model.
Estimable parameters are the amplitude, epoch, SWH, sea surface mean square slope, mispointing angles, and wave skewness.
Finally the algorithm is validated in the German Bight by comparison with in-situ data and the results from ESRIN/SAR and RADS/PLRM solutions.
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SAR Altimetry at 80 Hz

Salvatore Dinardo (SERCO/ESRIN, Italia) ; Jerome Benvensite (ESA, France)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_008

Abstract:
Thanks to the CryoSat-2 unique capacity to downlink unprocessed Full Bit Rate (FBR) data, different data-processing strategies and/or approaches can be attempted and implemented on ground.
This is particularly helpful, when operating in the coastal zone, inland water or land. On these particular domains, It seems sensible to have SAR-processed echoes treated at highest repetition frequency possible in order to capture all the short scale variability of the coastal scenario.
In the Delay-Doppler processing algorithm, the parameter controlling the echo posting frequency is the grid space step that conventionally has been fixed at frequency of 20 Hz (300 meter) in order to match the instrument along track resolution, but the grid space step can be arbitrarily defined to any desired value.
In the present work, we will attempt to Delay-Doppler process the FBR data with a finer space step, around 80 meter, that corresponds to a frequency of 80 Hz (Burst Repetition Frequency) and we will try to quantify the improvement, in term of precision and in term of observability of short scale signals, that is achieved from usage of that finer space step. It is worth to notice that, whereas the grid space step shrinks from 300 meters to 80 meter, the theoretical along-track resolution of 300 meter will remain unaltered.
Once that the L1B SAR echoes have been generated at 80 Hz, they will be re-tracked at 80 Hz using the SAMOSA model in order to retrieve the geophysical quantities: Sea Surface Height (SSH), Significant Wave Height (SWH) and Wind Speed at 10 meter (U10).
The experiment will be run in the waters of the North East Atlantic and it will consist in processing the same FBR dataset at 20 Hz (standard grid case) and at 80 Hz (overgrid case) and in spotting the differences between the two cases in term of statistics and resolving power.
Averaged wavenumber spectra will be produced at 80 Hz and 20 Hz and it will be proved the higher short-scale resolving power of the 80 Hz mode.
The current work is a feasibility study, preparatory for the data exploitation of the Sentinel-3 Topography Mission over open ocean, coastal zone and inland water.

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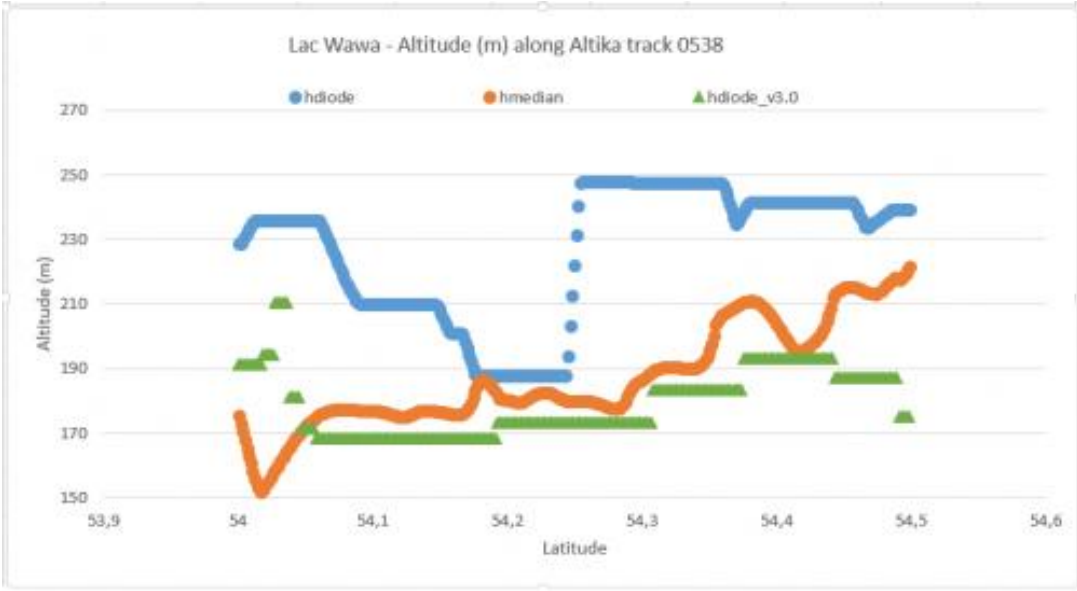
Performance analysis between autonomous tracker median and new version of OLTC mode

Emmanuel Auge (NOVELTIS, France) ; François Boy (CNES, France) ; Mathilde Cancet (NOVELTIS, France)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_009

Abstract:
The autonomous median trackers on-board the satellite altimetry missions have lower performances in the coastal zones and over the continental ice caps and waters (rivers, lakes, reservoirs), mainly because of the land contamination in the radar waveforms. As the number of satellite altimetry applications in these regions has significantly grown for a decade, some techniques have been developed in order to answer these new user requirements. In particular, the DIODE/DEM or OLTC (Open Loop Tracking Command) mode has been implemented with the objective to obtain a larger number of exploitable radar waveforms over these areas of interest.
The principle of the OLTC (Open Loop Tracking Command) mode consists in driving the altimeter with a priori information available on-board: real-time estimates of the satellite orbit with the DIODE navigator and theoretical height of the point located under the satellite, provided by a Digital Elevation Model (DEM) stored in the on-board memory and previously sampled along the satellite track. The sampled DEM is prepared pre-launch by assembling various elevations data: a Mean Sea Surface for ocean and coastal zones, a global DEM for continental areas, inland water elevations from specific databases and specific DEM over ice caps where available.
The Jason-2 and SARAL/AltiKa missions are currently flying with an on-board DEM. The analysis of the altimeter cycles operated in OLTC mode have shown the great interest of this technique in the areas of interest and some limitations. This study allowed us to identify improvement of new algorithms resulting in a more accurate on board DEM.
These algorithms show better agreement between the classic mode (autonomous median tracker) and the OLTC. We compared AltiKa on board DEM with the autonomous median tracker and the resulting new DEM produced with these new algorithms. Results over inland water and ice caps are very encouraging. On flight validation tools are developped to estimate in real time OLTC performance versus autonomous mode. The CNES and NOVELTIS will operate these tools during the first flight phases of JASON-3 and SENTINEL-3 missions.



OLTC difference between V2.0(blue) / V3.0 (green) and tracker median (orange)

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Open-Sea CryoSat-2 data in SAR and PLRM mode in South East Pacific and North East Atlantic

Luciana Fenoglio-Marc (Technische Universität Darmstadt, Deutschland) ; Christopher Buchhaupt (Technische Universität Darmstadt, Germany) ; Salvatore Dinardo (SECO, ESA/ESRIN, Italy) ; Remko Scharroo (EUMETSAT, Germany) ; Jerome Benveniste (ESA/ESRIN, Italy) ; Matthias Becker (Technische Universität Darmstadt, Germany)

Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_010

Abstract:
This work aims to generate, validate and analyse the altimetric geophysical parameters measured by the CryoSat-2 in SAR and PLRM Mode during one full year in the interval 10/2012-10/2013 in the South East Pacific box and North East Atlantic box at distance to coast larger than 10 km (open-sea).
The selection of two aforementionned regions provides us with a very calm region (the Pacific Ocean, with wave height between 1 and 4 meters) and a dynamic region with high seasonal variability (the Atlantic Ocean, with wave height between 0 and 10 meters).

The CryoSat-2 Data have been Delay-Doppler processed as from the FBR (i.e. L1a) to Level 1B and subsequently re-tracked using the SAMOSA's SAR Echo Model (full solution) and a curve-fitting scheme based on Levenberg-Marquard Least Square Minimization Algorithm. The Delay-Doppler processing (L1B) and the re-tracking processing (L2) has been carried out by the EOP-SER Altimetry Team at ESA/ESRIN.
In the open ocean analysis, Hamming function is not applied to the collected burst data. The zero-padding prior range-FFT is applied and an extended vertical swath window is used to mitigate the on board tracker shift errors. Along with multilooked return waveform, also the RIP (Range Integrated Power) is built from the stack and fitted in order to retrieve significant geo-parameters (slope, mean square slope, skewness).

The altimeter wind speed is derived using the wind model used for the Envisat mission and correcting for a sigma nought bias to align CryoSat absolute backscattering to Envisat absolute backscattering. Finally, a sea state bias solution is built for the two areas of interest gridding the residuals elevation from mean sea level in the space SWH-Sigma Nought.

Instantaneous sea surface height (SSH), sea level anomalies (SLA), significant wave height (SWH) and wind speed at 10 meter from sea surface (U10) at 20 Hz and 1 Hz are derived and cross-compared against PLRM L2 data, as generated by TU Darmstadt (TUDa). TUDa L1b PLRM data are retracked using both a conventional Brown model with a Look Up Table (LUT) and a convolutional numerical model, without the approximation of the radar Point Target Response (PTR) as Gaussian function. Numerical retracking in PLRM allows to estimate biases and systematic trends between SAR and PLRM mode and to highlight imprecisions in the SAR re-tracking scheme. Wind speed and sea state bias are derived like in the SAR processing.

SAR and PLRM derived geophysical parameters are cross-validated and validated against numerical models outputs. Performance metrics and plots are produced to assess the quality of the results (as scatter plots, cross-correlations, standard deviations, temporal monthly differences, regression slopes, performance curves, histograms and color-coded density plot).

Given the one year long analysis and the long ground-tracks, averaged wavenumber spectra of each retrieved geophysical parameters are estimated in the Pacific Box. In the North East Atlantic we assess the SAR capability in retrieving wave heights at the low end of the sea state spectrum and the impact of seasonal phenomena (as swell fields) in the SAR data.

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A global coastal altimetry dataset for coastal dynamics and sea level research

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_011

Abstract:
Improvements in coastal altimetry are now bringing new possibilities to studies of coastal dynamics and coastal sea level and allow the exploitation of synergies with the other components of the coastal observing systems (gauges, buoys, mooring, HF radars, floats) and with regional models. Those improvements come from technological advances in altimeters (i.e. the SAR mode altimeter on board CryoSat-2 and soon Sentinel-3) as well as improved processing techniques (better waveform retracking and data screening) and corrections.
Our research has focused on the retracking, i.e. the on-ground processing that fits a model to the signal received by the satellite in order to increase the precision of the estimated geophysical parameters. This study will present its outcome, i.e. a new global multi-mission coastal-retracked altimetry dataset based on the ALES (Adaptive Leading-Edge Sub-waveform retracker) algorithm. ALES aims at retracking both open ocean and coastal data with the same precision, and is therefore tailored to the needs of the coastal and shelf oceanographers and modellers.
As an introduction we present the details of the algorithm and summarize its validation against in-situ measurements of tide gauges (TGs) located in the Adriatic Sea and on the Agulhas Bank. We also briefly recall the validation of the Significant Wave Height (SWH) against buoy data in the German Bight. We show a couple of example applications of the reprocessed data to sea level variability studies and coastal oceanography in the Danish Straits and in the Indonesian Sea.
We finally describe the coastal altimetry datasets deriving from the application of ALES to the entire Jason-1, Jason-2 and Envisat missions in the global coastal strip. This dataset is being made available free of charge from the Physical Oceanography Distributed Active Archive Center (PO.DAAC) at the NASA Jet Propulsion Laboratory, Pasadena, CA. http://podaac.jpl.nasa.gov. The file structure is the same as standard SGDR products, with the addition of the fields concerning the ALES retracking, i.e. range and SWH. Users are invited to integrate the new retracked fields with state-of-the-art geophysical corrections in order to maximise the impact of the improvements.

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MAPS: the Multi-mission Altimetry Processing Software

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Session: Instrument Processing: Measurement and retracking (SAR and LRM)
Presentation type: Poster
Poster number: IPM_012

Abstract:
Definition of altimetry vitual stations over inland water bodies requires a very specific processing composed of a refined selection of valid data for estimating water levels and eventually the correction of hooking effect. The Multi-mission Altimetry Processing Software (MAPS) offers the opportunity to end-user to define their own virtual stations using the altimetry data contained in the Geophysical Data Records (GDRs) for the most recent nadir-looking (i.e., ERS-2, Envisat, Topex-Poseidon, Jason-1, Jason-2, and Saral) and SAR (Cryosat-2) altimetry missions. Once achieved a coarse selection of the altimetry measurements present in the sudy zone using a kml file defined with Google Earth, altimetry heights are computed using the geophysical and environmental corrections for different type of surface (rivers and small lakes, great lakes, ocean, and coastal areas). A graphical user interface allows to visualize not only the altimetry heights derived from the different retracked ranges available for each mission (e.g., Ocean, Ice-1, Ice-2, Sea Ice, MLE-3) inside the study area, but also any corrections used and other parameters (e.g., backscattering coefficients) that can be useful for selecting the valid altimeter heights. Correction of the hooking effects can be performed on the selected or a part of the selected data at any cycle. The selection of the valid data can be saved at any time and reloaded. Time-series of altimeter heights are then computed based on the user's selection of the valid data and can be exported. This software, developed as a collaboration between LEGOS-OMP, GET-OMP, and EPOC-OASU will be soon available on the CTOH website: http://ctoh.legos.obs-mip.fr. It can be used for estimating levels of wáter inland bodies, SSH and SLA over oceans.

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Regional X-TRACK altimeter products for coastal applications: updates and evolutions

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

Abstract:
The CTOH (Centre of Topography of the Oceans and the Hydrosphere) is an independant research service dedicated to satellite altimetry studies. One of its objectives is to optimize the completness and the accuracy of the sea surface height information derived from satellite altimetry in coastal areas. A dedicated tool, called X-TRACK, has been used since 2008 in order to process up-to-date altimeter products from Topex/Poseidon, Jason-1&2, Geosat Follow On and Envisat satellites. X-TRACK produces 1Hz along-track Sea Level Anomaly (SLA) time series over 23 coastal regions, which are available on our website (http://ctoh.legos.obs-mip.fr/products/coastal-products) and on the new AVISO+ web portal. Along-track tidal constants (including the amplitude, phase lag and error estimates for a number of tidal constituents) are also computed from the harmonic analysis of the SLA long time series.

Recently, X-TRACK code was rewritten to gain consistency and efficiency in the data processing workflow. We also revisited several aspects of the processing, as the altimetry corrections or the data editing strategy which has been significantly improved in order to obtain a better data quality for the points closest to the coast. Finally, the new finite element global tides atlas FES2014 (F. Lyard et al.) is used in place of FES2012 to remove the tidal signal. We present here our first results by comparing the new X-TRACK along track SLA with co-located tide gauges in various regions and discuss the future improvements of our products.

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Swot on Aviso+: promoting the mission, explaining the technique

Vinca Rosmorduc (CLS, France) ; Emilie Bronner (CNES, France) ; Selma Cherchali (CNES, France) ; Jean-François Crétaux (LEGOS, France) ; Rosemary Morrow (LEGOS, France) ; Nicolas Picot (CNES, France) ; Claire Pottier (CNES, France)

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

Abstract:
Swot is the next challenge in the altimetry world. A number of innovations will be brought by this mission, with many changes to be taken into account by current and would-be users.
Aviso+ continues on its mission to promote altimetry and help users by creating a series of pages explaining the missions, its technical aspects, the expected applications, what was done (during the SRD meetings especially), and providing schemes and images to illustrate presentations of the mission.

Hoping to see you soon on www.aviso.altimetry.fr/swot/!
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Aviso+ products & services: what's new?

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

Abstract:
Since the launch of Topex/Poseidon, more than 23 years ago, satellite altimetry has evolved in parallel with the user community and oceanography. As a result of this evolution, we now have:
- A bigger choice of products, more and more easy-to-use, spanning complete GDRs to pre-computed sea level anomalies and gridded datasets 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. 2014 - 2015 saw several changes:
- opening of the Odes service
- mobile/light version of the web site
- Filament datasets in cooperation with LOcean
Moreover, the web site was restyled in Feb. 2014, with a strengthened partnership with Legos/CTOH; the Online data extraction service with X-Track, CorSSH with a format change, Peachi and "enhanced" GDR products (see dedicated poster).
In the future, we will develop even more the ice, coastal and hydrology thematics on the web.
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New datasets for ODES (Online Data Extraction Service)

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

Abstract:
Altimetry users have a wide variety of needs ranging from research to operational applications. Standards datasets provide a robust base to meet most of them but research-grade algorithms and corrections are not easily accessible to the general audience. Similarly, classical distribution channels make it difficult to provide ad-hoc datasets in a convenient way especially when product size and bandwidth are a concern.
To address such evolving user needs, AVISO+ is proposing the Online Data Extraction Service (ODES), in order to provide users and applications with a wider range of altimetry-derived data (including high-resolution and experimental data).

The interface is designed to distribute both operational products from CNES and partner Agencies (Eumetsat, ESA, NOAA, NASA) but also research-grade data from LEGOS/CTOH and CLS and other contributions from the OSTST research community. Accessible products include GDR-class level 2 data and an "enhanced" version of those with up-to-date corrections and processings, CorSSH, PEACHI and PISTACH demonstrators and X-TRACK level 3 data. Various research-grade parameters (e.g. alternative geophysical corrections...) from the OSTST PI community are also available. New datasets will be regularly proposed to users.

Most importantly, the ODES system provides flexible interfaces and an ad-hoc response. To illustrate, ODES users can use a user-friendly web interface to download along-track altimetry data only over their area of interest, choose their period of interest, limit the parameters and variables they wish to download (e.g. select only significant wave height-related variables) and apply threshold criteria. Most features aim at streamlining the data acquisition in an intuitive way.
The extraction service is also "on-the-fly", with no delay nor cache necessary, so that users can immediately begin their downloading. Lastly the ordering and downloading process can be automated and scripted for operational users with a custom and ad-hoc environment containing only the products they want. Thanks to this framework, AVISO+ is able to include up-to-date corrections and information (e.g. updated tide model, results from a new or alternative algorithm to compute significant wave height, etc.) to streamline the reprocessing strategy and provide intermediate releases phased with the research advancement of OSTST members and other users.

New functionalities (drifting orbit capabilities, easier-to-use parameter extraction...) and new datasets (Cryosat LRM and pseudo-LRM mode, Jason-1 and Envisat drifting orbit, "enhanced" GDR for the Saral mission, reprocessing of X-Track coastal SLAs...) should be added to the tool and available from the OSTST meeting time in 2015.

ODES is available at the following address: http://odes.altimetry.cnes.fr
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Database for Hydrological Time Series of Inland Water (DAHITI)

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

Abstract:
Satellite altimetry was designed for ocean applications. However, since some years, satellite altimetry is also used over inland water to estimate water level time series of lakes, rivers and wetlands. The resulting water level time series can help to understand the water cycle of system earth and makes altimetry to a very useful instrument for hydrological applications.

In this poster, we introduce the "Database for Hydrological Time Series of Inland Waters" (DAHITI). Currently, the database contains about 250 water level time series of lakes, reservoirs, rivers, and wetlands which are freely available after a short registration process via http://dahiti.dgfi.tum.de. In this poster, we introduce the product of DAHITI and the functionality of the DAHITI web service. Furthermore, selected examples of inland water targets are presented in detail.

DAHITI provides time series of water level heights of inland water bodies and their formal errors . These time series are available within the period of 1992-2015 and have varying temporal resolutions depending on the data coverage of the investigated water body. The accuracies of the water level time series depend mainly on the extent of the investigated water body and the quality of the altimeter measurements. Hereby, an external validation with in-situ data reveals RMS differences between 5 cm and 40 cm for lakes and 10 cm and 140 cm for rivers, respectively.
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Sentinel-6/Jason-CS Altimeter Products and Performance Budget

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

Abstract:
The Sentinel-6 (Jason-CS) mission will follow TOPEX and the Jason-series of altimeters as one of the "reference missions". But it is in many ways a totally new type of mission, a new platform (similar to CryoSat) and a new altimeter. 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, such that there is no longer the need to wait 2/3 of the time for pulses to be received, while transmitting only 1/3 of the time, like the altimeters of CryoSat-2 and Sentinel-3. On top of that, Sentinel-6 will be operating in this mode 100% of the time. This particular operating mode allows simultaneous production of low-resolution mode (LRM) measurements on-board as well as the processing of SAR echoes 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 LRM and SAR altimetry, housed on the same platform, working from the same altimeter echoes, just different processing. 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 how continuity is ensured. Of course, at the same time EUMETSAT is striving to allow a good synergy with altimeter products from the Sentinel-3 mission.

The baseline for Sentinel-6 is to provide near-realtime (NRT) products compatible with those of the previous missions within 3 hours. Additionally, slow-time-critical (STC, latency 36 hours latency) and non-time-critical (NTC, 60 days latency) products will be made available with all of the variables needed to fully exploit and analyse the SAR and LRM mode data.

In addition, 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, is not part of the planning, as these data products can be derived from the L1A directly.

During the process of writing up the Mission and System Requirement Documents, the performance budget for the Jason-CS satellites was painstakingly scrutinized, ensuring that Sentinel-6 would provide the end user with measurements of sea level, wind speed, and wave height with at least the precision and accuracy of the Jason-2 mission in LRM, and pushing the boundaries on the expected SAR mode performances. The final performance budget for both operating modes and for the various product latencies is reported in this presentation as well.
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CTOH altimetry products (L1 to L4) for ocean and continental surfaces applications

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

Abstract:
The Center for Topography of the Oceans and Hydrosphere (CTOH) is a French Observation Service created in 1989 and dedicated to satellite altimetry studies. Its objectives are to 1) maintain and distribute homogeneous altimetric databases for ocean, hydrosphere and cryosphere applications, 2) help scientific users to develop new altimetry derived products and 3) contribute to the development and validation of new processing approaches of the altimetric data for emerging research domains (coastal ocean, continental surface water monitoring, cryosphere, ...).

The CTOH maintains homogeneous altimetric GDR data bases for the following missions : Topex/Poseidon, GFO, ENVISAT, Jason-1, Jason-2, Saral/Altika and Cryosat2 (ESA, CNES). Except for GFO, all these products are provided in netcdf format. A very new version of ERS-2 data, reprocessed by the CTOH, including both ICE-1 and ICE-2 retrackers and all the usual corrections is also now available (see posters by Legresy et al.). Jason-3 and Sentinel-3 will be added soon after the data areavailable.

Both 1Hz and 10/20/40Hz data are available globally (for oceans and continental surfaces). The CTOH database contains L1 products (waveforms) as well, for some altimeter missions. We also add about 20 recent altimetry corrections and auxiliary parameters in a homogeneous way to all GDRs. It includes tide models, DAC, MSS, geoids, and tropospheric corrections. New geophysical corrections are being developed for continental surfaces applications and distributed.

In addition, the CTOH works on developing new altimetric products :

• Coastal products : Along-track SLA time series are available in 23 different regions, computed with the X-TRACK software designed for coastal altimetry processing (…/products/coastal-products). A regional product of along-track tidal harmonic constants (including the amplitude, phase lag and error estimates for a number of tidal constituents), computed by harmonic analysis of X-TRACK 1-Hz SLA, is also available. In 2015, X-TRACK code was rewritten and the editing strategy revisited (see poster by Fuller et al.).

• High resolution products: Over the open ocean, multi-satellite data approaches are being developed to improve the mapping and representation of finer-scale structures in gridded regional maps. Lagrangian techniques are also used to recreate finer-scale structures in ocean tracer fields (e.g. temperature and salinity) using the lateral stirring from gridded altimetric currents. These have been developed in a number of test regions.

• Continental hydrology products : including the “Hydroweb” data base for monitoring river and lake levels (…/products/hydroweb). Hydroweb integrates the CASH project: Topex reprocessed data over terrestrial surface waters. Water level maps are also developed for 5 rivers: the Amazon, Orenoque, Gange-Bramhapoutre, Congo and Mekong.

All these products are now progressively re-distributed via AVISO+, our new common platform with AVISO: http://www.aviso.altimetry.fr/en/home.html.

More information can be found on the CTOH website http://ctoh.legos.obs-mip.fr/.
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NOAA archive and access services for Jason-2/3 products

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

Abstract:
In its role as the US archive for oceanographic data, the NOAA National Centers for Environmental Information (NCEI) provides scientific stewardship of the data including near real-time and delayed-mode product distribution, rigorous archive services, custom products, and long-term data stewardship for the OSTM/Jason-2 and Jason-3 products. NCEI's basic services for Jason2/3 could be outlined as the followings:

• Primary Datasets: O/I/GDR. Within the past few years, NCEI has instituted a mirror service, replicating all GDRs directly from NOAA's Data Distribution Service. This has reduced the latency of providing the OGDR to the public to under an hour. The OGDR is currently distributed through NCEI. Service of all level-2 X-GDR products continues to be provided through ftp, http, OPeNDAP, and THREDDS Data Sever (TDS).

• Enhanced Data Rich Inventory (RI): Data Quality Monitoring (DQM) for the Jason-2 GDR/IGDR is provided on a per-pass basis. The data assuarance decriptive statistics are computed at the time of ingest of each data file into the archive and stored in CF-compliant NetCDF format. Visualization of these statistics is provided via a Live Access Server (http://data.nodc.noaa.gov/las/) and Jason-2 DQM homepage (http://www.nodc.noaa.gov/SatelliteData/Jason2/qa.html), and they are publicly accessible via ftp, http, OPeNDAP and TDS at data.nodc.noaa.gov. DQM was instituted for the OGDR this year and is currently experimental.

• Derived products: Our Data Quality Monitoring system also automatically generates cycle-mean 3.0°x1.0° and 0.25ox0.25o grids for the monitored I/O/GDR variables (including SLA and SWH). The 3.0°x1.0° gridded I/GDR data (in NetCDF format) are accessible via ftp, http, OPeNDAP and TDS (http://www.nodc.noaa.gov/SatelliteData/Jason2/).

• Data discovery: While Jason-2/OSTM products news and RSS-feed webpages have been developed for improved data access, data discovery has been enhanced by implementation of a Geoportal server (http://data.nodc.noaa.gov/geoportal).

• Preparation for future Jason missions: Archive, access and quality monitoring tools developed for Jason-2 are being generalized into NOAA the Jason Ground System (NJGS) to support Jason-2 and Jason-3 simultaneously in the future. This will allow for a consistent, integrated access to data from the two satellites.

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Sea Level Experiments for Climate Science Outreach

Andrei Iskra (University of Colorado Boulder, United States) ; Justus Leben (University of Colorado Boulder, United States) ; Gabrielian Taylor (Fairview High School Boulder Colorado, United States) ; Benjamin Hamlington (Old Dominion University, United States) ; Robert Leben (University of Colorado Boulder, United States)

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

Abstract:
The motivation for this outreach effort is to establish a learning curriculum in Climate Science for high school students. Several experiments are performed in a sequence, designed to spark interest in scientific method and testing of theories, leading students to some predictable and non-trivial results in Climate Science. Two aspects of scientific theory are tested experimentally: salinity distribution in the ocean and the impact of fresh water influx on local sea levels. The learned concepts are used to understand basics of altimetry, determination of mean sea level and computation of mean dynamic topography. The students are also taught the basics of scientific experimentation, data collection, analysis and reporting. A logical chain of experiments builds knowledge about state of the ocean and use of radar for ocean remote sensing. The learning process emphasizes the role of altimetry in monitoring the state of the Earth's climate system. This work was supported the NASA Supplemental Education Award for ROSES Investigators Program Grant 10-EDUC210-0003.

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The Colorado Center for Astrodynamics Research Ocean Data System

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

Abstract:
Colorado Center for Astrodynamics Research (CCAR) altimeter ocean data viewers have been online since 1996. Major updates of the processing and visualization system were performed in 2002 and 2010. The most recent update consolidated the data processing codebase into MATLAB with the goal of improving the processing and gridding methods used to produce sea surface height (SSH) data products. Since the last major upgrade it has become clear that the stability of the system is at risk because of software rigidity and deprecation of functionality over time. We are in the process of rewriting the architecture (but not the algorithms) in an effort to modularize the system and add programmatic access to the data by using a three tiered networked architecture where components do not have to reside at the same location. The first tier would encompass the raw data access consisting of FTP, OpenDAP, Web Map Service, and SQL. The last three would be available through HTTPS remote procedure calls. The second tier would include the MATLAB processing refactored into distinct yet cohesive portable modules and ported to Python and a Flask (Python) based web API for interfacing with the processing and viewers. The last tier would consist of an AngularJS based web application interfacing with the Flask API to deliver a responsive mapping and plotting site to users on all platforms. The modularization mentioned above allows three major benefits to both the producers and consumers of CCAR ocean data: integration of CCAR data and services into users programs and/or services, increased ease of incorporating new data products, and the possibility of mirroring CCAR processing and viewers in whole or in part at other locations. Both SSH and reconstructed sea level data sets produced at CCAR and Old Dominion University will be hosted on the new system.

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DUACS sea level products, a step beyond with Jason-3 and Sentinel-3

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Session: Application development for Operations (previously NRT splinter)
Presentation type: Poster
Poster number: APOP_001

Abstract:
The DUACS system has produced, up to now, as part of the CNES/SALP and the MyOcean projects, 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 …).

With the integration of HY-2A data in 2014, the Near Real Time system now merges data from 4 satellites. In parallel of the constellation management, on April 2014, the entire catalogue was significantly upgraded with impacts on scientific content and format, improving the quality and accessibility of the products. Besides, a full reprocessing of the whole altimetry time series has been performed allowing us to make available a set of 21 years of homogeneous along–track and map products.

In 2015, we are now starting a new step. 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), a European project launched in May. Besides, new satellites, Jason-3 and Sentinel-3, will be launched in the coming month, and will contribute to the robustness of this service. Moreover, the processing of the sea level can be improved to fully exploit this increase of real time altimetry observations, combined with the advanced technology of the new sensors. This paper will present the latest development and the main perspectives for the DUACS Sea level products in the coming years.
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20 years of reprocessed Lyapunov exponents from altimetry available on Aviso

Marie Isabelle Pujol (CLS, France) ; Yannice Faugere (CLS, France) ; Francesco d'Ovidio (LOCEAN - IPSL, France) ; Rosemary Morrow (LEGOS, France) ; Jean-Damien Desjonquères (CNES, France) ; Nicolas Picot (CNES, France)

Session: Application development for Operations (previously NRT splinter)
Presentation type: Poster
Poster number: APOP_002

Abstract:
Altimetry-derived maps of Lyapunov exponents (LEs) provide proxies of (sub-)mesoscale transport fronts. They are being increasingly used in physical, biogeochemical, and ecological applications, ranging from real-time support to field studies to co-localisation of animal tracking with Lagrangian Coherent Structures. Their calculation however is more complex than standard Eulerian diagnostics, because it requires a Lagrangian algorithm which integrates the velocity field. During the past 20 years, in parallel with the altimeter measurement Level2 (a.k.a [O/I]GDR) to Level3 and Level4 (along-track cross-calibrated SLA, and multiple sensor merged maps) processing, different applications and derivated Level4+ products were developed by AVISO+. In order to better serve the users need, and in collaboration with different laboratories (LOCEAN and CTOH), the LEs and vectors are computed over the 21-year altimeter period and over the global ocean within the SSALTO/DUACS project. This product provides the position, and intensity, and orientation of fronts induced by the mesoscale eddies and underlining part of sub-mesoscale activity. We present here the Lyapunov products that are available on AVISO+ since early 2015.
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DT2014 version of Ssalto/DUACS products: 21 years Sea Level products reprocessed

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Session: Application development for Operations (previously NRT splinter)
Presentation type: Poster
Poster number: APOP_003

Abstract:
During the last 20 years, altimeter high quality near real time and delayed time Level3 (along-track cross-calibrated SLA) and Level4 products (merging multiple sensors) were developed in parallel with Level2 (a.k.a [O/I]GDR) processing improvements. Directly usable and easier to manipulate, L3/4 products are vastly used and contribute to various studies in different fields, from climate and meteorological phenomena, to geophysics and biology.
In early 2014, many changes have been implemented in the products and processing, impacting both along-track and gridded products. A full reprocessed dataset of the 20 years of altimeter measurements, including all of these changes, has been delivered in April 2014.
The quality of these datasets was estimated in different part of the ocean by comparison with independent measurements. We present here the reprocessed dataset and its consistancy with independant measurements.
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Validation of Cryosat-2 SAR Wind and Wave Products

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Session: Application development for Operations (previously NRT splinter)
Presentation type: Poster
Poster number: APOP_004

Abstract:
Significant wave height (SWH) and surface wind speed (WS) products from the CryoSat-2 Synthetic Aperture Radar (SAR) Mode are validated against operational ECMWF atmospheric and wave model results in addition to available observations from buoys, platforms and other altimeters. The data used here is output from the SAMOSA ocean model processed in the ESRIN G-POD service open to the Community called SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation (SARvatore). The data cover two geographic boxes: one in the northeast Atlantic Ocean extending from 32°N to 70°N and from 20°W to the prime meridian (NE Atlantic Box) and the other in eastern Pacific extending from 2.5°S to 25.5°S and from 160°W to 85°W (Pacific Box). The period extends from 6 September 2010 to 30 June 2014 for the NE Atlantic box and from 7 May 2012 to 30 June 2014 for the Pacific Box. The amount of data is limited by the CryoSat SAR mode acquisition capability over ocean but high enough to ensure robustness and significativeness of the results (Sentinel-3 will operate in SAR mode over the whole ocean). The results show that the quality of both SWH and WS products is very high. Detailed statistics will be reported.

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Satellite Altimetry Sea Surface Height Anomaly Processing At The Naval Oceanographic Office's Altimetry Data Fusion Center

Carolyn Cooper (Naval Oceanographic Office, United States)

Session: Application development for Operations (previously NRT splinter)
Presentation type: Poster
Poster number: APOP_005

Abstract:
The Altimetry Data Fusion Center (ADFC) at the Naval Oceanographic Office processes, evaluates, produces, and disseminates near real-time altimetry-derived Sea Surface Height Anomaly (SSHa) products for assimilation into operational oceanographic models. The ADFC produces and distributes timely, accurate, and quality-controlled altimetry SSHa observations to agencies in the Department of Defense, the National Centers for Environmental Prediction, the National Aeronautics and Space Administration, and other civilian agencies. Current SSHa products provided by the ADFC utilize altimetry satellite data from the Jason-2, SARAL/AltiKa, and Cryosat-2 missions.
The ADFC produces ~ 50,000 SSHa observations per satellite per day. SSHa data latency is 24 to 48 hours from the satellite observation time. SSHa data are calculated by differencing along-track SSH observations (time and position) to a long term along-track reference mean. SSHa data are assimilated into ocean models that provide ocean circulation and acoustic predictions. SSHa observations measure the thickness of the ocean column, which varies with ocean mesoscale features, and are also the primary input into the upper ocean heat content analysis for the hurricane intensity models. These models are used to predict ocean energy potential for tropical storms.
Satellite data outputs are verified and compared with the other operational satellite outputs for the fraction/percent data used, orbit correction applied, and crossover RMS difference comparisons. Also, the ADFC is currently conducting a study, to be operationalized in the future, for satellite SSHa comparisons with in situ temperature-salinity profiles. This study compares satellite altimeter SSHa to steric height anomaly calculated from quality controlled temperature-salinity profiles. The two data sets are matched using a range of time and distance constraints, and the differences are examined. These comparisons can be used to identify future discrepancies or anomalies found in either data source. Ultimately these results can assist to identify sensor measurement constraints and improve satellite inputs to ocean forecast models.
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Operational ocean data assimilation/prediction system for the western North Pacific at JMA

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Session: Application development for Operations (previously NRT splinter)
Presentation type: Poster
Poster number: APOP_006

Abstract:
Japan Meteorological Agency (JMA) has been routinely operating an ocean data assimilation and prediction system for the western North Pacific (MOVE/MRI.COM-WNP*) developed by the Meteorological Research Institute (JMA/MRI) since March 2008. The operational system assimilates the Jason-2 along-track sea level anomaly (SLA) data produced by Ssalto/Duacs and distributed by AVISO+, in addition to in situ temperature and salinity observations, and daily SST analysis (MGDSST**).
This poster will show the outline of MOVE/MRI.COM-WNP system and the impact of using additional SLA data (SARAL/AltiKa, CryoSat-2 and HY-2A).

* Multivariate Ocean Variational Estimation system / Meteorological Research Institute Community Ocean Model for the Western North Pacific, Usui et al. 2006
** Merged satellite and in-situ data Global Daily SST

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New orbits of ERS-1, ERS-2, TOPEX/Poseidon, Envisat, Jason-1 and Jason-2 for altimetry applications and their validation

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

Abstract:
New VER11 precise orbits of altimetry satellites ERS-1 (1991-1996), ERS-2 (1995-2003), TOPEX/Poseidon (1992-2005), Envisat (2002-2012), Jason-1 (2002-2013) and Jason-2 (2008-2015) have been derived at GFZ using EPOS-OC software at the time intervals given covering totally about 24 years. The orbits are processed using SLR and single satellite altimeter crossover differences for ERS-1, by using additionally PRARE data for ERS-2. SLR and DORIS measurements were used to compute orbits of four other satellites. The orbits are computed in the same for all six satellites terrestrial reference frame realization (ITRF2008), using consistent background models for precise orbit determination, like, e.g. EIGEN-GRGS.RL03-v2.MEAN-FIELD geopotential model, EOT11a ocean tide model etc. These orbits have been processed in the frame of the ESA Sea Level Climate Change Initiative and DFG UHR-GravDat projects. The paper provides some details on precise orbit determination, presents some results of the validation of the quality of these orbits using orbital, single-satellite altimetry crossover analysis and the multi-mission crossover analysis, shows improvements in the orbit quality of these orbit solutions, as compared to the previous versions of the GFZ orbits of altimetry satellites and provides an outlook for the further possible improvements.

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Assessment of Orbit Quality through the SSH calculation Towards GDR-E orbit standards

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

Abstract:
The quality of the orbit ephemerides is crucial for the computation of the Sea Surface Height (SSH). Conversely, analyzing the impact of precise orbit ephemerides on SSH performances enables to describe their impact at different temporal scales and to detect remaining weakness in the orbit solution with a very fine precision.
In 2014, a large panel of evolutions was developed in order to be integrated in the GDR-E orbit standards. They had been qualified and compared to the previous GDR-D orbit standards for Jason-2 mission.
During 2015, the final version of the POE-E orbit standards is made available for Jason1, Jason-2 and Cryosat-2.

This poster synthesizes the final quality of these orbits, with respect to the previous standards, using mono-mission and multi-missions diagnosis. In particular, the effect of the different orbit solutions concerning long term trends and inter-annual signatures observed on the Sea Surface Height are addressed. Climatic scales stability is analyzed as well as regional and higher frequency signals.
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New phase correction maps for Jason 2 GPS processing

flavien mercier (cnes, France) ; alexandre couhert (cnes, france)

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

Abstract:
Since the beginning of Jason 2 mission, the phase correction map computed by the JPL was used for the CNES GPS orbits determination. This map was for the first Jason GPS antenna. A specific extension of the IGS GPS phase maps has been constructed for each GPS satellite model to achieve a correct phase processing.

For the Jason 2 reprocessing, we build a new map for the first antenna, and also for the second antenna, which is now in use since september 2014. These maps are estimated using the igs08 antex data file available at IGS, wich contains now the extension estimated at IGS for LEO processing.

The map definition is 2*2 degrees. They can be delivered to the users in antex format.

These two maps remove efficiently the dependencies of the residual errors in azimuth and elevation, the phase residuals are now around or below 5 mm rms.

The parametrization of the orbits used for the maps construction, and the processing method are detailed.

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A new time series of orbits (std1504) for TOPEX/Poseidon, Jason-1, Jason-2 (OSTM) (poster)

Frank Lemoine (NASA GSFC, United States) ; Nikita Zelensky (SGT Inc, USA) ; Douglas Chinn (SGT Inc, USA) ; Brian Beckley (SGT Inc, USA) ; David Rowlands (NASA GSFC, USA) ; Despina Pavlis (SGT Inc, USA)

Session: Precision Orbit Determination
Presentation type: Poster
Poster number: POD_004

Abstract:
The Jason-2 (OSTM) spacecraft has now been in orbit for seven years (since June 2008), and the full set of altimeter data from TOPEX/Poseidon, Jason-1, and Jason-2 now span more than twenty-three years. In order to properly use the altimeter data, especially for the most demanding applications such as the determination of mean sea level, we must develop a time series of precise orbits that are as accurate as possible over the entire time span, using a consistent set of modeling and geophysical standards. In this paper, we give an overview on the improvements we have incorporated into our latest release of orbits, std1504, which include application of the Vienna Mapping Function (VMF) to better correct the DORIS data for tropospheric refraction, improvement to the background geopotential modeling to account for the recent changes in the time-variable gravity field of the Earth, and improved measurement modeling for the DORIS measurement. We discuss the impact of improved non-conservative force modeling we have applied to the Jason-1 and Jason-2 satellites and the improvements we see in comparison to reduced-dynamic orbits. Our evaluations include analysis of the sea-surface-height differences during the Jason-1/Jason-2 and the TOPEX/Jason-1 calibration periods. We also present an update on our preparations for Jason-3, including our readiness to process the DORIS/RINEX data expected to be routinely delivered Jason-3, and all future DORIS-equipped missions.

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Improving the dynamic atmospheric correction for delayed-time and operational applications of altimetry

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Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_001

Abstract:
Given its current accuracy and maturity, altimetry is considered a fully operational observing system dedicated to various applications such as climate studies or operational oceanography. 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 variability induced by the atmospheric forcing and aliased by the altimetric measurements.

The high frequency part of the DAC is based on a barotropic model simulation forced by atmospheric pressure and winds (MOG2D; Carrere and Lyard 2003); the low frequency part is an inverse barometer response. A 20-day cutoff-period was chosen because it corresponds to the Nyquist period of T/P-Jason reference altimeters' sampling and because the variability is mostly barotropic in this high frequency band.

The purpose of the study is to improve the performances of the DAC for all users of altimetry for Delayed-Time (DT) and Near Real Time (NRT) delivery modes.
A recent study (2013) has shown that using a few MOG2D forecasts (forecasts only available until D+2days, 12h) allowed improving the quality of the NRT correction. In this study, operational meteorological forecasts until D+10days have been used, showing a significantly greater improvement on altimeter level-2 products.
The optimal combination of MOG2D and IB at the cutoff-period of 20 days is also checked compared to in situ and altimeter data.
Then in order to improve the DAC correction (DT and NRT) in the high latitudes, the ice cover effect has been implemented in MOG2D model and preliminary results will be presented.
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Tidal estimation in China Seas based on satellite altimetric data

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Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_002

Abstract:
In this study, response analysis of TOPEX-Jason-1-Jason-2 (T/P-Jason) primary mission and TOPEX-Jason-1 (TOPEX-Jason) interleaved mission along-track data is performed to derive 4 principal tidal constituents (M2, S2, K1 and O1) in the Bohai, Yellow and East China Seas (BYE).

The inter-comparison at crossover points and comparison with the ground truth show that the combination of TOPEX-Jason primary with TOPEX-Jason interleaved mission data are suitable for estimating the 4 principal tidal constituents in the regions. Three datasets of harmonic constants determined from tide gauge records are used to investigate the impacts of TOPEX-Jason interleaved mission data on tidal constituent estimation over the BYE regions. The accuracy of estimated tidal constituents using 18 years Topex-Jason data is slightly better than that using 10 years of Topex data (1993-2002) in comparison with tide gauge data over the coastal regions. However, comparisons with 116 tide gauge data show that the root mean square differences in amplitude are reduced by 31.26%, 38.31%, 6.62% and 7.19% (M2, S2, K1 and O1) when using primary mission and interleaved mission data to replace the Topex-Jason primary mission data for tide estimation in the study area.

Moreover, the co-tidal charts of the major tide constituents are well produced because the satellite altimetry recovers the tidal signal twice with dense ground tracks and more available measurements available in the regions.

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Non-Stationary Internal Tides Observed Using Dual-Satellite Altimetry

Edward Zaron (Portland State University, United States)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_003

Abstract:
Dual-satellite crossover data from the Jason-2 and Cryosat-2 altimeter missions are used in a novel approach to quantify stationary and non-stationary tides from time-lagged mean square sea-surface height (SSH) differences, computed for lags from 1 hour to 1440 hours (60 days). The approach is made feasible by removing independent estimates of the stationary tide and mesoscale SSH variance, which greatly reduces the sampling error of the SSH statistics. For the semi-diurnal tidal band the stationary tidal variance is approximately 0.73 cm^2, and the non-stationary variance is about 0.33 cm^2, or 30% of the total. The temporal correlation of the non-stationary tide is examined by complex demodulation and found to be oscillatory with first zero-crossing at 400 hours (17 days). Because a significant fraction of the time-variable mesoscale signal is resolved at time scales of roughly 150 h by the present constellation of satellite altimeters, the results suggest that it may be feasible to predict the non-stationary tide from modulations of the resolved mesoscale, thus enhancing the efficacy of tidal corrections for planned wide-swath altimeters such as the SWOT mission.
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Updating the pole tide model for satellite altimetry

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Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_004

Abstract:
We evaluate errors in the pole tide model that is currently adopted by most users of satellite altimeter sea surface height measurements and identify possible improvements to that model. Of the various geophysical models that are typically applied as corrections to these measurements, those for the pole tide and luni-solar body tide have not been revised since the launch of TOPEX/Poseidon more than two decades ago. We describe two improvements to the pole tide model for satellite altimeter measurements. Firstly, we recommend an approach that improves the model for the response of the oceans by including the effects of self-gravitation, loading, and mass conservation. Our recommended approach also specifically includes the previously ignored displacement of the solid Earth due to the load of the ocean response, and includes the effects of geocenter motion. Altogether, this improvement amplifies the modeled geocentric pole tide by 15%, or up to 2 mm of sea surface height displacement. We validate this improvement using two decades of satellite altimeter measurements. Secondly, we recommend that the altimetry pole tide model exclude geocentric sea surface displacements resulting from the long-term drift in polar motion. The response to this particular component of polar motion requires a more rigorous approach than is used by conventional models. We show that erroneously including the response to this component of polar motion in the pole tide model impacts interpretation of regional sea level rise by +/- 0.25 mm/year.

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Global mapping of low-mode semi-diurnal and diurnal internal tides with a data-assimilative reduced gravity model

Gary Egbert (Oregon State University, United States) ; Lana Erofeeva (Oregon State University, USA)

Session: Tides, internal tides and high-frequency processes
Presentation type: Poster
Poster number: TID_005

Abstract:
We have developed data assimilation methods for mapping low-mode phase-locked internal tides from altimetry data, using a reduced gravity (RG) approach.
Dynamical equations are derived following the approach of Griffiths and Grimshaw (2007), with the vertical dependence of pressure and velocities in the linear Boussinesq 3D equations expanded in basis functions derived from local 1D modes for a stratified ocean. This results in a system of coupled 2D PDEs for the coefficients of the modal expansion. Excluding coupling terms between modes (which arise in the presence of variable bottom topography) the resulting equations for each mode are analogous to the usual shallow water equations for the barotropic tide. With modest changes to the OSU tidal inversion software (OTIS) an assimilation scheme for this linear model is readily implemented. The coupling terms can be used to derive the forcing (by the barotropic tide), and also can be used to quantifythe component of model error associated with unmodeled topographic scattering. Because the inversion yields currents as well as elevations, mode energy fluxes can obtained with minimal further calculation. Relatively high spatial resolution (at least 1/30 degree) is required for the RG dynamical model, so the inversion must be done in modest sized overlapping patches, which can then be merged to obtain global maps of phase-locked low-mode internal tides. To obtain reliable results some care with preliminary data processing has proven necessary, including correction for lower frequency SSH variations in areas of strong mesoscale activity, and filtering to reduce Long wavelength error, especially in ERS/Envisat data. We will present global maps of M2 and K1 constituents, and discuss he possibility of using this model to better quantify slow temporal variations in internal tides, using the dynamically consistent spatio-temporal basis functions derived from the RG assimilation scheme.

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An ESA absolute and permanent site with a transponder for the altimeter calibration of Sentinel-3, Cryosat-2, and Jason-3 in West Crete, Greece

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Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_001

Abstract:
A new calibration site at a cross-over point of the tracks of multiple missions (Sentinel-3A, Sentinel-3B, Jason series, SARAL/AltiKa, etc.) has been established in West Crete, Greece. This research infrastructure has been already established and is operational with a microwave transponder. It aims at monitoring and controlling, in an absolute sense, satellite altimetry measurements and results by (1) continuously keeping track of their quality, biases, errors and drifts and (2) by establishing an absolute reference of altimetry on a common and reliable standard for settling relations among different, as well as on ascending and descending orbits, at the same location and settings. This external calibration site, called CDN1, will act as a monitoring service, mainly, for the Sentinel-3 satellite missions. In this work, successful responses of the transponder as well as calibration results for the Cryosat-2 will be presented

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Towed and static GPS buoys for CAL/VAL and SSH

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Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_002

Abstract:
The observation of the sea level variations and the ocean sea surface topography calibration is achieved thanks to a set of specific instruments developed for these missions by Technical Division of INSU (National Institute of Universe Science) in Brest (France).

We present a static and a towed GPS buoys dedicated to altimetric
satellites calibration (CAL/VAL) and absolute sea level determination (SSH).

These developments have been supported by FOAM (From Ocean to inland waters Altimetry Monitoring), a project funded by CNES that aims to perform calibration and validation of the altimetric measurement systems over both ocean and inland water. Continuous monitoring over ocean is performed in operational sites like Corsica that is equipped with tide recorders and permanent GPS stations for in situ measurements.

These systems consist of a geodetic GPS on dedicated structures for static and towed use.

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Jason-1 GDR-E Reprocessing

Hélène Roinard (CLS, France) ; Sabine Philipps (CLS, France) ; Michael Ablain (CLS, France) ; Emilie Bronner (CNES, France) ; Nicolas Picot (CNES, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_003

Abstract:
Jason-1 was launched in December 2001 and routinely monitored the ocean until June 2013, date of its final measurement. It first flew on the historical ground track, as a successor of TOPEX/Poseïdon mission. In February 2009, Jason-1 assumed a new orbit midway between its original ground track but with a time lag of approximately 5 days with Jason-2 to provide an optimal coverage for Near Real Time (NRT) applications. In May 2012, it left its repeat track orbit for a geodetic phase until it was finally decommissioned.
Jason-1 time series continued the extraordinary sea level record first initiated by TOPEX/Poseïdon mission. Even if this mission is finished, the quality of such a record can still be improved, as science progresses are continuously made.
In 2014, CNES and NASA have started work on the reprocessing of the new Jason-1 GDR-E release. The main improvements concern the geophysical content of the products. Here is presented an overview of the first GDR-E products, and particularly:
- The assessment of the standard E orbits which use a new gravity field model that should enhance the regional mean sea level by reducing the basin scale discrepancies.
- The impact of the new ocean tides and mean sea surface.

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Global Assessment of TOPEX reprocessed products (Release 5)

Hélène Roinard (CLS, France) ; Sabine Philipps (CLS, France) ; Sylvie Labroue (CLS, France) ; Michael Ablain (CLS, France) ; Pierre Thibaut (CLS, France) ; Jean-Damien Desjonqueres (CNES, France) ; Nicolas Picot (CNES, France)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_004

Abstract:
The TOPEX/Poseidon mission was the first precise altimeter mission specially designed for studying the circulation of the world's oceans. The TOPEX/Poseidon mission furnished altimetry data for 13 years (1992 – 2005). Equipped with a redundant main altimeter (TOPEX) and an experimental altimeter (Poseidon-1, which was operated roughly one cycle in ten), altimeter data were first furnished by the TOPEX side-A instrument. Nevertheless changes in the side-A PointTarget Reponse (PTR) degraded (from mid-1996 onwards) progressively the altimeter measurements [Hayne and Hancock, 1998]. The main impacts were an increase of Significant Wave Height (SWH), an increase of range rms, and an error on range estimate. Sea State Bias (SSB) was also impacted (as it is based on SWH). In February 1999, TOPEX side-A was turned off and TOPEX side-B was turned on. In order to correct for this PTR drift of TOPEX-A a retracking of the data is necessary. Several retracking releases have been computed over the last years, those analysis have been presented in previous OSTST sessions.

The latest retracking release "Retracked GDR Release 5.0" computed by P. Callahan is an evaluation release of the TOPEX Retracked GDR (RGDR) covering cycles 21 to 364. Retracking has been completed for fixed skewness values of 0 and 0.1, as well solving for skewness. The results presented here are only covering data with skewness equal to 0.1. Retracking provide corrected SWH and range measurements.

Hereafter, the impact of the retracking is evaluated. Therefore only parameters from the retracking (range, SWH) or based on retracked parameters (SSB) are compared with previous data version. The reference parameters are non retracked data used in AVISO2014 products (which are based on MGDR products concerning altimeter parameters) and updated geophysical and orbit standards. The new solutions are also compared with Jason-1 data. Furthermore mesoscale performances (SSH differences at crossovers) and global mean sea level are also computed and compared to AVISO 2014 standards.
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Evaluation of Topex Retracked Data

Rashmi Shah (Jet Propulsion Laboratory, United States) ; Shailen Desai (Jet Propulsion Laboratory, United States) ; Bruce Haines (Jet Propulsion Laboratory, United States)

Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_005

Abstract:
We present results from the global calibration and validation of the sea surface height and component measurements from the Topex retracked product. Our study is based on cross calibration between Topex and Jason-1 data during the tandem flying phase. Also, included in the study is the effect of significant wave height and wind speed measurements on the sea state bias contribution to the sea surface height measurements. A comparision between the differences in sea surface height of non retracked and retracked data is also done.
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SIRAL and SARAL Ocean Data Validation

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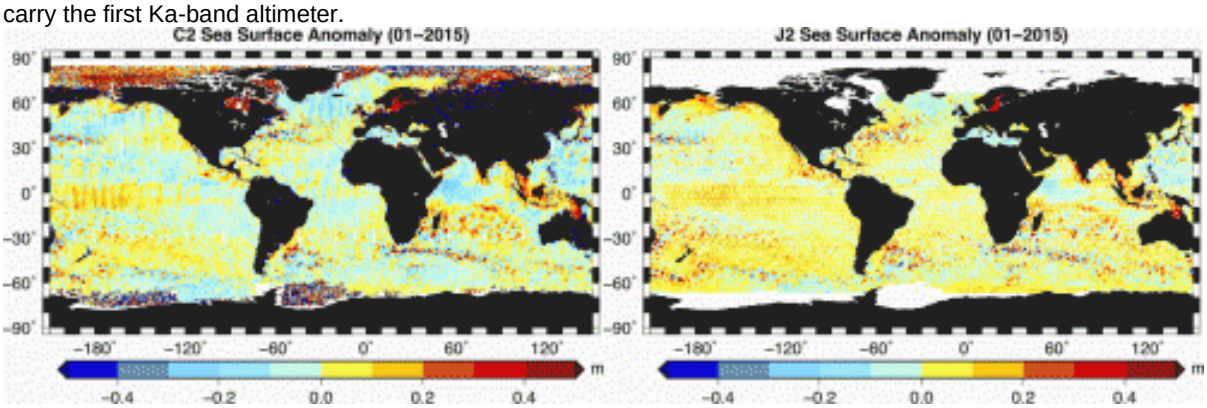
Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_006

Abstract:
CryoSat-2, in orbit since April 2010, observes the cryosphere with an innovative altimeter system capable of conventional (LRM) and delayed-Doppler (SAR) altimetry. In addition to sea ice freeboard and ice sheet elevation change, the SIRAL altimeter onboard CryoSat-2 perfectly samples the global ocean surface and all its dynamics. We present results of the CryoSat-2 LRM and pseudo-LRM (reduced SAR) calibration and validation efforts in frame of the ESA GOP/IOP/FDM project. To be able to exploit the data to the fullest it is necessary to assess, validate and improve them where possible. Up to now we have been complementing the Radar Altimeter Database System RADS with an improved dataset (based on NOAA retracker) not just for the sake of altimeter database completeness but also for using CrySat-2 data as climate data record (CDR) and for improving sampling resolution in combined altimetry solutions from different missions. We have validated the LRM data, added and improved corrections, added pseudo-LRM (compressed/reduced SAR) to complement the global coverage, and verified the orbit accuracy. The present status of the absolute and relative calibration of LRM data is discussed, also by comparison and evaluation with ESA's CryoSat-2 GOP/IOP/FDM, with other concurrent altimeter satellites by crossover analyses and with in-situ data from selected tide gauges. Partly based on these results ESA intends to upgrade its processing chain in 2016. The enclosed figure shows the SSA from CryoSat-2 (left) and from JASON-2 (right) data. The (mesoscale) variations compare very well, only an apparent relative bias between the two of around 4 cm remains.

In addition we reviewed the combined capacity of Cryosat-2 and SARAL altimeter data data to reestablish the altimetric mesoscale variability measuring capability from before the demise of Envisat and Jason-1. For this we also validate and monitor the data from the Altika instrument onboard SARAL, which was launched in 2013 to carry the first Ka-band altimeter.



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Evaluation of new CryoSat-2 measurements over the ocean

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Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_007

Abstract:
CryoSat-2 is a tremendous asset to the oceanographic community, and the exploitation of its data over the ocean represents a welcome additional return for ESA's investment in a mission whose primary objective is to monitor the cryosphere. The CryoSat Project has approved, in the frame of the CryoSat routine phase, the generation of additional ocean products, which are available since April 2014. Here we present the results of a scientific validation of the Geophysical Ocean Products (GOP), which have consolidated orbits and are available 30 days after acquisition. The validation is performed for the sea surface height (SSH), the significant wave height (SWH), and the wind speed. The performance of the altimeter generally degrades as it gets closer to the coast due to contamination of the altimetric waveforms and/or inadequacy of some of the corrections, therefore it is important that validation be conducted both in the coastal zone and the open ocean. The SSH is validated at the coast against the sea level measured by a set of carefully selected and quality controlled tide gauges. Correlations between SSH and tide gauge records are statistically significant at nearly all stations, though they are spread across a broad range of values from 0.3 to 0.9. Comparisons between Jason-2 and the tide gauges show that CryoSat-2 outperforms Jason-2 at many stations. In the open ocean the SSH is compared globally with the steric heights derived from ARGO temperature and salinity profiles. Correlations between the two quantities are larger than 0.6 at most Argo floats and the mean normalized RMS difference is 40%. As an additional validation test, geostrophic velocities derived from the SSH are compared with the surface velocities from HF radars located along the Australian coast. Regarding the SWH and wind speed, they are both validated against buoy observations. The SWH shows an RMS of 12 cm with virtually zero bias, however the performance of the CryoSat-2 for wind speed is worse with a bias of almost 2 m/s. In addition, the SWH is also compared with Jason-2 observations as well as with the SWH provided by the Wavewatch III model.

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A Seamless Transition Between LRM and SAR Altimetry: 3 Years Dataset Assessment of Cryosat-2 SARM

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Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_008

Abstract:
The ESA (European Space Agency) mission Cryosat-2 was successfully launched on April 2010. The Cryosat-2 altimeter radar differs from previous conventional pulse limited altimeter in that it is capable of operating in several modes. The low resolution mode (LRM) is used over Antarctic and Greenland interiors and over the ocean. To better detect transitions between the open Ocean and land ice sheets, the Synthetic Aperture Radar mode (SARM) is used, since it provides a better along-track resolution (around 300 m). Finally, over land ice sheet margins, the Synthetic Aperture Interferometric mode (SARInM) provides more information with an interferometric across-track operation to estimate the arrival angles of the echoes.

As part of the Sentinel-3 project, the “Centre National d’Etudes Spatiales” (CNES) has developed a Cryosat-2 Processing Prototype (CPP) (Boy et al 2012, 2013). This processor starts from Cryosat-2 level-0 telemetry files and generate Sea Level Anomaly (SLA) measures for each record in LRM or SAR mode.

The present study shows some results obtained on a longer time series with a three year CPP SAR data record. This data set represents a major achievement in the understanding of the SAR mode altimetry (Raynal et al in prep). Data quality has been assessed through different metrics that are presented here. We analyse more deeply the main features to check the reliability and the improvements of the SAR processing (noise reduction, increased along track spatial resolution, check of the dependencies that may induce geographically correlated errors, continuity with LRM processing...).

All these efforts will result in achieving a seamless transition between LRM and SAR altimetry techniques and fulfilling the operational needs for assimilating sea level in operational forecast models. On the other hand, the Sentinel-3 SAR mode observations of sea level shall provide for the first time at global scale a data record with an improved accuracy, paving the way for high resolution altimetry and for a better observation of small scale ocean dynamics.

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The Role of the Sentinel-3 Mission Performance Centre in Maintaining High Standards within Operational Altimetry

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Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_009

Abstract:
The series of Sentinel satellites mark a major step forward in the collection of Earth Observation data with the commitment to a series of spacecraft and sensors to construct long time series of data suitable for both climate applications and widespread operational use. Amongst its many sensors, Sentinel-3 will carry a delay Doppler altimeter, providing global high-resolution data for the first time. The Sentinel-3 Mission Performance Centre (S3-MPC) has been charged with ensuring the usefulness of such data by performing quality control checks on the data (near real-time and offline products), assessing the long-term performance through a series of ongoing validation experiments. Although different processing centres will produce the "marine" and the "terrestrial" data, the S3-MPC will be responsible for the quality control (QC) and validation across all surfaces (ocean, cryosphere and inland waters). The other tasks of the MPC deal with the calibration of the altimeter (SRAL) and the microwave radiometer (MWR) sensors but also with the validation of the algorithms in the ground processing from Level 0 up to Level 2.
The MPC calibration component will include monitoring of SRAL instrument performance, such as the Ultra Stable Oscillator (USO) and any changes in the Point Target Response (PTR). Absolute calibration of SRAL range bias and datation bias will be achieved by use of a purpose-built transponder in Crete.
The on-board microwave radiometer MWR will also be monitored during the lifetime of the satellite to detect any possible anomaly or drift of the instrument. The first months of the mission will be dedicated to the calibration of the MWR and of the retrieval algorithms that provide all the geophysical parameters relevant for the mission (wet tropospheric correction, atmospheric attenuations etc…).
The validation component will address the needs and concerns of the different altimetric communities. The performance over ocean will be assessed at global scale, using cross calibration with other flying altimeters. The sea surface height data will be also compared to local measurements at dedicated sites such as Lake Issyk-kul and to the southwest of Corsica, as has been done previously for Jason-1, Jason-2 and Envisat, whereas the information on currents derived from the SSH gradient will be assessed relative to coastal HF radar data in the southwest of England.. The oceanic records of wind speed and wave height will be compared to buoy data and output from the ECMWF model. The delay Doppler altimeter should enable better performances in coastal waters or over inland waters (lakes and rivers) as it uses a much smaller instrument footprint than conventional low-rate mode altimeters. The S3-MPC will make a particular effort to evaluate the operation of the on-board algorithms and ground processing for dealing with such relatively small expanses of water. There will also be dedicated effort to validate the quality of the altimeter information over ice sheets, by comparing data over the Arctic sea-ice with measurements made within the IceBridge programme.

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Sea Surface Height from Spaceborne GNSS-R: a Demonstration with TechDemoSat-1 Data

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Session: Regional and Global CAL/VAL for Assembling a Climate Data Record
Presentation type: Poster
Poster number: CVL_010

Abstract:
The altimetric application of GNSS-Reflectometry (GNSS-R) was proposed for the first time back in 1993 (PARIS concept), and has undergone numerous improvements since then, becoming recently the main focus of the GEROS-ISS experiment, scheduled to be deployed in 2018 on the International Space Station. The current predicted precision for Sea Surface Height (SSH) estimation using GNSS-R still remains on the order of tens of centimeters, but the multistatic nature of GNSS-R makes this technique very attractive in virtue of the high space-time sampling, free transmitters and low-cost receivers. Airborne and tower-based experiments have proven the feasibility of the technique, but a full error budget assessment for SSH from satellite GNSS-R data has so far only been based on simulations. With the launch of TechDemoSat-1 (TDS-1) satellite by Surrey Satellite Technology in July 2014, a fairly large dataset of oceanic GPS-Reflections (GPS-R) has recently become available. The global dataset of GPS-R data is expected to increase dramatically with the launch of the CYGNSS microsatellite constellation in October 2016.
This study presents an analysis of TDS-1 data for SSH estimation. Two test areas are selected, one in South Atlantic and one in North Pacific, and SSH is extracted from delay waveforms, using the simple Leading Edge Derivative (LED) algorithm. Results are compared with the mean SSH over the two areas, from the DTU10 model. A reasonable and encouraging agreement is observed between SSH derived from TDS-1 and the DTU10 model, despite the numerous limitations of the data used, being the GPS-R instrument onboard TDS-1 designed primarily for scatterometric purposes.

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Capturing Mesoscale Features In Surface Currents

Kathleen Dohan (Earth and Space Research, United States) ; Jonathan Lilly (NorthWest Research Associates, United States)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_001

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 AVISO gridded MADT SSH fields (http://www.aviso.altimetry.fr/).

OSCAR successfully captures the surface currents in highly geostrophic regions with larger-scale and relatively slowly evolving eddies, such as in the Gulf Stream. When compared with global surface drifters, though, velocity standard deviations are underestimated by 20-50% in OSCAR over much of the oceans. This is in part due to missing dynamics in the simple model for OSCAR -- such as Stokes drift. However, much of the loss of signal is also due to the use of level 4 gridded fields rather than using level 2 fields directly, which is particularly important when taking gradients.

We have been using local polynomial fitting mapping methods to investigate the mesoscale and sub-mesoscale signal in both altimetry and ocean vector wind fields. A main question to address is the degree to which the use of smoothed level 4 fields affects the calculation of surface currents. An important feature of local polynomial fitting over optimal interpolation methods is the order of fit: a first-order (linear) fit calculates gradients as part of the mapping. Geostrophic velocities will therefore be directly calculated from the data, which is expected to result in stronger, more accurate, albeit noisier, velocities.

Here we will contrast AVISO-based geostrophic currents against those obtained directly from along-track SSH anomalies. In addition, wind-driven currents based on ERA Interim winds will be compared with local currents calculated directly from ASCAT winds. These will all be compared with drifting buoy velocities. The main goals are to retain the most information on surface currents possible from high-resolution satellite fields as well as to gain a better understanding of the limits to which simple physical models can accurately reproduce higher-resolution surface currents from satellite sensed fields. Ultimately, how much additional information on the mesoscale surface circulation can SWOT provide?

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Long-range Radiation of Barotropic Rossby Waves from the Equatorial Pacific Ocean

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_002

Abstract:
Analysis of sea-surface height (SSH) anomalies from satellite altimetry shows variability throughout the North Pacific that is coherent with Tropical Instability Waves. In the tropics (10N-20N) this variability has regular phase patterns that are consistent with barotropic Rossby waves having northward energy propagation (Farrar, J. Phys. Oceanogr., 2011). Further north, the phase patterns become confused and the variance decreases, but hot spots of coherent variability reemerge in the Gulf of Alaska and south of the Aleutian Islands. Ray-tracing calculations and comparisons with numerical simulations support the conclusion that this remote (and seemingly isolated) variability can indeed be attributed to barotropic Rossby waves generated near the equator and undergoing bathymetric refraction as they propagate northward. This sort of barotropic wave variability, coupled to mesoscale instabilities and occurring at similar space and time scales, contributes to the mesoscale variability observed in SSH.
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Surface Lagrangian transport in a submesoscale permitting simulation

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_003

Abstract:
We investigate Lagrangian transport on the surface of the ocean using a submesoscale permitting simulation of the Gulf of Mexico based on the Navy Coastal Ocean Model (NCOM). We find that simulated surface velocities and velocities inferred geostrophically from simulated sea surface height sustain Lagrangian transport with very similar characteristics. Our findings follow from the analysis of Lagrangian coherent structures and the statistics of separations produced by synthetic trajectory pairs, which show consitency with those produced by drifter trajectory pairs from the Grand LAgrangian Deployment (GLAD). Implications for high-resolution altimetry are discussed. Work supported by the BP/Gulf of Mexico Research Initiative.

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Particle diffusion against mean flow as a new framework for local estimate of mixing coefficient

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_004

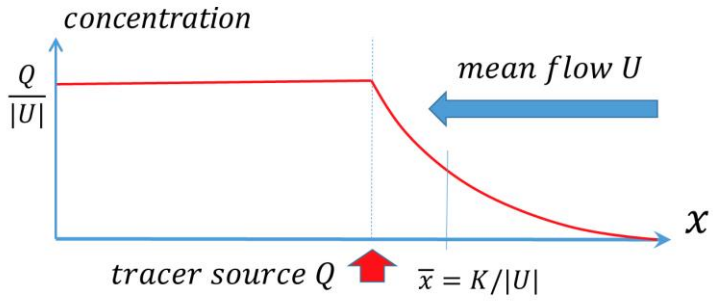
Abstract:
One of classical methods, used to estimate mixing coefficient, utilizes the rate of dispersion of particles from a source or from initial locations. This method is based on the assumption that on times significantly larger than Lagrangian time scales steady asymptotic statistic exists. The “cloud” of particles expands in time that limits the ability of the method to resolve complex structures. In addition, calculations are performed in a coordinate system, moving with the mean flow, so that, when the flow is strong, it may be difficult to translate Lagrangian information in to Eulerian grid needed for practical applications.

Such method implies the existence of sufficient spectral gap between scales of resolved (large-scale, time-averaged or slowly changing) currents and anomalies (traditionally referred as “eddies”). At the same time, recent studies reveal a tremendously complex structure of the mean ocean circulation, in which fronts remain sharp and narrow even on long-time averages and long-living, coherent mesoscale eddies are often organized along preferred paths, producing a weak but persistent “texture” of the mean ocean circulation.

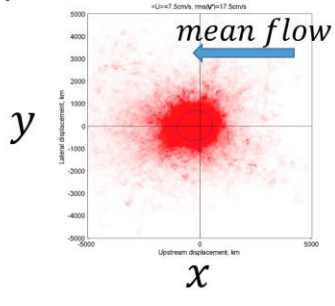
Our study proposes a new technique, allowing to increase spatial resolution of the mixing coefficient estimates, by converting Lagrangian trajectories into Eulerian probability density function near the source. The method is based on the analytical solution of the diffusion equation for a tracer released from a singular source in the presence of a mean flow (A in Figure) and generalized for two-dimensional case and for particles with a finite life span (B in Figure). The method characterizes excursions of the particles against the mean flow and uses them to estimate mixing. For the same mixing coefficient, the stronger the flow the weaker are the excursions. We show that in most areas of the real ocean excursions of satellite-tracked drifting buoys against the mean flow are relatively small that justifies our method. Results of the analysis of simulated particle trajectories, derived from satellite data of altimetry and scatterometry and consistent with the actual drifter “spaghettis”, are used to study the factors controlling the intensity of the multi-scale horizontal mixing near the ocean surface.

Figure caption. (A) Analytical solution of one-dimensional mixing equation with a singular tracer source in a steady flow. (B) Example of drifter density distribution relative to start points.

A. One-dimensional solution of tracer mixing from a singular source in a steady flow



B. Example of drifter density distribution relative to start points



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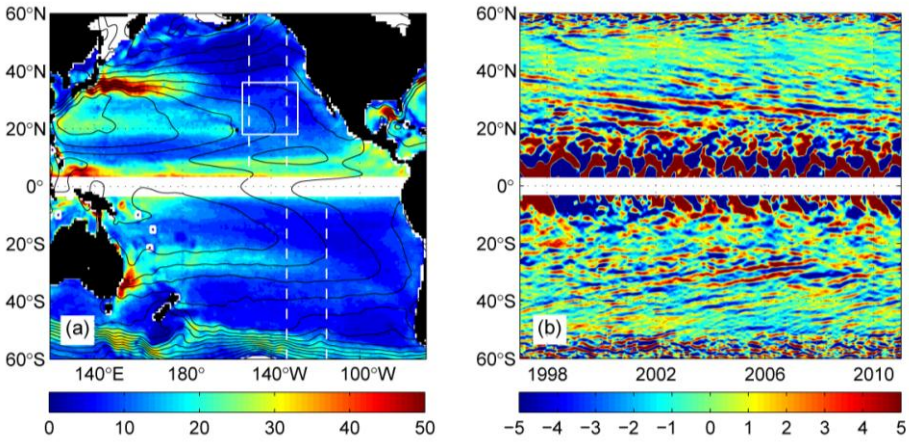
Transient zonal jets and “storm tracks”: A case study in the eastern North Pacific

Oleg Melnichenko (University of Hawaii, United States) ; Nikolai Maximenko (University of Hawaii, United States) ; Hideharu Sasaki (The Earth Simulator Center, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_005

Abstract:
Satellite sea level anomaly observations show that low-frequency motions in the subtropics are characterized by long-lived jet-like features (striations) that slowly, at a speed of about 0.3-0.5 km/day, propagate toward the equator. In their presence, the space-time distribution of mesoscale eddies is not random but rather anchored to the striations. Specifically, the distribution of eddies alternates between “troughs” of enhanced concentration of cyclonic eddies and “ridges” of enhanced concentration of anticyclonic eddies, termed “storm tracks”, which follow the striations in their meridional propagation. The factors controlling such a behavior are investigated using output of the Ocean general circulation model For the Earth Simulator (OFES), which is shown to reproduce these features remarkably well. The diagnostics suggest that the striations’ life-cycle can be characterized by two dynamically distinct components. The first one is attributable to baroclinic instability of a large-scale, weakly sheared meridional flow in the subtropical gyre, which serves as the main energy source for the zonal striations. The second component arises from the nonlinear interactions between the zonal striations and eddies. Transient striations locally alter the mean potential vorticity distribution associated with the large-scale background flow in which they reside. This alteration is in turn responsible for the formation of eddies preferentially along the striations, consistently with the meridionally localized regions of enhanced or reduced baroclinicity and stabilizing or destabilizing effect of the planetary vorticity gradient and horizontal shear. When the striations move, the dynamics that generate eddies move with them, producing migrating “storm tracks”. Aligned eddies feed back onto the zonal flow, reinforcing the pattern of the striations.

Figure: (a) Root-mean-square surface geostrophic velocity variability (cm/s) based on satellite altimetry data from November 1992 to October 2012. Shown on top are contours of the mean dynamic topography (Maximenko et al., 2009). (b) Time-latitude diagram of the zonally averaged zonal geostrophic velocity anomaly (cm/s). Boundaries of the zonal bands, over which the zonal averaging is applied, are shown in (a) by the white dashed lines. The white rectangle in (a) delineates the study area.



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Variability of sub-mesoscale dynamics in the North Atlantic ocean from a 1/60° ocean model simulation.

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_006

Abstract:
Several physical processes contribute to energize oceanic flows at scales smaller than the first baroclinic Rossby radius (frontogenesis, mixed-layer instabilities, current-topography interactions...). But the relative strength of these processes and their impact on energy cascades at basin scale is still poorly unknown. Recent studies also suggest that sub-mesoscale dynamics may exhibit a distinctive seasonal cycle at mid-latitudes.
In this poster, we use several years of a sub-mesoscale-permitting, North Atlantic ocean/sea-ice model simulation performed at an unprecedented 1/60° resolution with 300 vertical levels. We describe the spatio-temporal variability of dynamical regimes at scales <100km at mid and high latitudes within the basin in terms of velocity wavenumber spectra and in terms of small scale variance of relative vorticity. Our results show in particular how the seasonal cycle of surface stratification in the subpolar gyre leads to a strong seasonal modulation of submesoscale activity at high latitudes. We will finally discuss how future wide-swath altimetric missions (SWOT) will sample these dynamical regimes.
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Coastal Circulation in the Southern Benguela Current

P Ted Strub (Oregon State University, United States) ; Matano Ricardo (Oregon State University, USA) ; James Corinne (Oregon State University, United States) ; Vincent Combes (Oregon State University, United States) ; Hermes Juliet (University of Cape Town, South Africa) ; Collins Charine (University of Cape Town, South Africa)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_007

Abstract:
Altimeter data are used to describe the surface circulation in the southern Benguela Current (30°-35°S) and its connection to the circulation over the Agulhas Bank east of Cape Agulhas (20°E). Seasonal changes in wind forcing drives summer upwelling in the coastal branch of the southern Benguela Current, enriching an ecosystem that supports an important fishery. The life history of small pelagic fish in this region includes a period of spawning in a nursery region on the Agulhas Bank east of Cape Agulhas, followed by migration around the Cape and into the southern Benguela and St. Helena Bay. The surface circulation is hypothesized to connect these regions and aides in the seasonal movement of larval fish. Alongtrack and gridded altimeter data are used to look at this hypothesis and other suggested features of the seasonal and interannual variability of the circulation in this region. Details of the circulation as it connects St. Helena Bay to the outer cape region will be especially interesting for SWOT, which will provide high resolution fields of SSH with 1-day repeat coverage connecting the bay, Cape Columbine and the outer cape region during the initial phase of the mission.
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Combining altimetry, numerical modeling and in-situ observations for the observation and the understanding of fine scale coastal processes in the Bay of Biscay

Florence Toublanc (LEGOS/CNRS, France) ; Nadia Ayoub (LEGOS/CNRS, France) ; Florence Birol (CTOH/LEGOS, France) ; Patrick Marsaleix (LA/CNRS, France) ; Nicolas Fuller (CTOH/LEGOS, France)

Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_008

Abstract:
The aim of this work is to study mesoscale processes occurring in the Bay of Biscay, using coastal altimetry products (X-TRACK, CTOH) from the Jason missions, 3D numerical modeling (SYMPHONIE code) and a wide range of in-situ datasets (tide gauges, buoys, salinity and temperature databases, …).

The SYMPHONIE configuration is characterized by a variable horizontal resolution, from 3 km in the open sea to less than 800 m on the shelf, and less than 300 m in the Gironde estuary and the Pertuis Charentais. This approach allows the representation of different scales, without using nested grids.

The sea surface elevation signature and the geostrophic currents derived from along-track altimetry are compared and analyzed in complement to other data (SST satellite products, surface buoys, moorings) and numerical simulations. Preliminary model results show a good agreement between estimated and observed SST and SSS. Surface geostrophic currents associated with the slope currents and mesoscale eddies are also obtained numerically in the southern Bay of Biscay.

First, we analyze the SLA data close to the coast and the main corrections (tides, wet tropo, SSB). The seasonal and interannual variability of the slope currents and the shelf circulation is then more particularly investigated. Both modeling results and altimetric data are processed to produce monthly means of along-track geostrophic currents (by year and also for the longest period available). Ultimately, these products could be used by the community as diagnostic tools for their models. We investigate as well the impact of the MDT on the sea surface elevation and on the geostrophic currents.
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Observing fine-scale ocean structures in the NW Mediterranean Sea from altimetry, gliders and HF radar

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_009

Abstract:
The NW Mediterranean Sea has distinct ocean dynamics, with relatively strong boundary currents and moderate eddy energy, but with variations at small Rossby radius which are difficult to detect with conventional satellite altimetry. In this study, we analyse alongtrack altimetry from 3 different missions and measurement systems : Jason-2 Ku-band data, SARAL Ka-band data, and Cryosat-2 SAR data. We apply spectra analysis over short, 300-500 km sections in the NW Mediterranean Sea and estimate the mesoscale capabilities of the ocean dynamics here. The « white noise » background error levels differ between the 3 missions and for different seasons. This limits our ability to detect alongtrack mesoscale structures, and we quantify the typical length scales we can detect with each mission, depending on their seasonal signal to noise levels.

In the second part of the study, we also look at the observational capabilities of gliders and HFradar to study the geostrophic variability in the NW Mediterranean Sea. The high-frequency noise of the gliders limits us to observing signals greater than the Rossby radius (10-15 km). Only a few colocated glider and alongtrack altimetry data are available and these provide good results for the larger mesoscale structures. Validation of smaller-scale ocean variations is more difficult : with weaker amplitudes they are close to the noise levels for both observation types, and their rapid evolution means only a few days of short glider tracks are usefully colocated. The final data set we use is HFradar, which provides good synoptic 2D data coverage which can be easily colocated with the altimeter passes. In calm weather, the geostrophic currents associated with boundary currents and eddies are well detected and we can estimate their spatial and temporal characteristics. However, in periods of strong wind forcing (Mistral, Tremontagne), the surface currents become ageostrophic and fail to monitor the depth-integrated geostrophic flow.

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Small-scale and high-frequency SSH variability inferred from in-situ measurements in support of AirSWOT

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_010

Abstract:
In April 2015 a small army of investigators was mobilized to aid in site selection and in-situ data collection for an AirSWOT validation campaign in the coastal ocean off Monterey Bay, California. We report here on measurements of dynamic height and velocity collected by profiling floats (EM-APEX), under-way CTD (UCTD), surface drifters, and shore-based HF Radar, and their relationship to satellite sea-surface height (SSH) from AltiKa, sea-surface temperature (SST) imagery, and coastal ROMS forecasts.
While the height comparisons among the various platforms are encouraging, the spatial resolution of the ROMS model limits its ability to capture submesoscale eddy and frontal features. In addition, temporal sampling by the EM-APEX floats reveals substantial SSH variability from the internal tide in certain locations. Velocity comparisons are more problematic, with HF Radar and ROMS (assimilating HF Radar data) showing substantially reduced speeds relative to the surface drifters and profiling floats.
Subsurface structures sampled in space and time by the UCTD and EM-APEX, along with high-resolution SST imagery, illustrate the complexity and rapidly-evolving state of the submesoscale field off Monterey and clarify the challenges of observing these types of features from AirSWOT and SWOT.

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Net primary production in the Gulf Stream sustained by quasi-geostrophic vertical exchanges

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_011

Abstract:
We analyze 12 years of mesoscale vertical motion derived from an observation-based product in the top 1000 m of the North West Atlantic Ocean. Vertical velocities [O(10 m day-1)] associated with Gulf Stream instabilities consist of alternating cells of upwelling and downwelling. Here we show that the magnitude of the vertical motions decays exponentially southwards with an e-folding length scale is informative on the dynamics of the system. We further investigate the impact of the vertical supply of nutrients on phytoplankton growth with a conceptual model incorporating the mean effect of nutrient distribution, quasi-geostrophic dynamics and Ekman suction/pumping. Results confirm that the mean effect of mesoscale vertical velocity variability alone can sustain observed levels of net primary production in the immediate vicinity of the Gulf Stream, while other mechanisms, including horizontal advection and submesoscale dynamics, need to be considered when moving towards the subtropical gyre.

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Preparing for the next interdisciplinary challenges unlocked by SWOT fine-scale observations

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_012

Abstract:
SWOT will substantially improve our understanding of the fine scales of the ocean circulation. These novel observations will be primarily a leap forward for physical oceanography. At the same time, they will bridge an observational gap on a spatiotemporal domain critical for interdisciplinary problems. Here we aim at identifying some of the new challenges in biogeochemistry and marine ecology that SWOT may contribute to address. In biogeochemistry, a key open question is the effect of filaments on the export of anthropogenic carbon inside the ocean. This question is important for better quantifying the role of the ocean in the climate system and relies on the possibilities of estimating at the ocean upper layer submesoscale vertical velocities, which in turn may be accessible by high resolution measurements of sea surface heights provided by SWOT and re-analysed in theoretical framework like surface quasi-geostrophy. In marine ecology, lot of interest is now concentrated on the connection between submesoscale fronts and patchiness of marine organisms, in particular fish. The possibility of detecting from space ecological hotspots - regions which aggregate biomass, trophic interactions, or biodiversity – would be a major step forward in the design of conservation policies and in the management of marine resources. For both these biogeochemical and ecological applications, we describe here model studies and proposed multiplatform in situ strategies which we are designing in preparation of the SWOT mission, in particular for its fast sampling phase, during which both the spatial and the temporal variability of synoptic maps of sea surface height will be observed for the first time.

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Observation and modeling of tropical cyclones wakes and their evolution

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_013

Abstract:
Satellite-based observations offer means to better question the role of extreme conditions for the state of ocean at local and global scales, and effects on ocean circulation and ocean heat transport. Energy inputs in the region of intense storm tracks are indeed thought to represent the main kinetic energy sources necessary to maintain the deep ocean stratified and to strengthen ocean stirring processes (Emanuel, 2001; Sriver and Huber, 2007). Strong winds associated with tropical cyclones (TCs) generate vigorous vertical mixing in the upper ocean (about 10 times the usual mixing), stirring warm surface waters with colder waters below. Cyclonic rotating winds also induce an Ekman pumping that is particularly strong for slow or static storms. It is characterized by a very strong upwelling of cold deep water under the cyclone track with weaker and more widespread downwelling on the sides. The upwelling strongly participates in the surface and subsurface thermal response by uplifting the thermocline (Price, 1981; Shay et al., 2000; Jullien et al., 2012). After the TC passage, the sea surface cold anomaly quickly dissipates by the mean of positive net air–sea heat fluxes, whereas the subsurface warm anomaly is believed to persist over a much longer period. It then corresponds to a net ocean heat uptake whose fate is the subject of active debate. Such a flux of heat into the low-latitude ocean has been proposed to be an important modulator of local and remote climate.

Techniques using satellite altimetry can help to quantify changes in sea surface height in storm-affected regions during the months following tropical cyclones (Jansen et al., 2010; Haney et al., 2012; Mei et al., 2013; Sriver, 2013). Changes in sea surface height are closely linked to changes in ocean heat content, which enable direct estimates of the vertically integrated changes in ocean temperatures caused by tropical cyclones. However, limitations in the observational systems and in methodological approaches are likely to hamper severely significance of the results, because TC-induced SSH steric anomalies are small (~1cm) with respect to large scale SSH variations (~1m) and background variability. While SSH measurements from the current altimeter constellation shall be used for this study, it can be anticipated that the much larger coverage by the 2D SSH imaging capability of the SWOT satellite will enable more accurate estimate of these anomalies, and more direct and better tracking of the cold wake mesoscale processes. Indeed, as the surface fluxes quickly restore the pre-cyclonic SSTs (10-day timescale) and then erase the SST gradients, a 2D SSH imaging will enable to track at the monthly/seasonal timescale, for a given event, the sub-surface fronts associated with the sub-surface bolus of warm water anomaly, to better evaluate the spatial scales of the processes. Improved knowledge of the wakes restratification spatial and temporal scales is crucial to define the best methodology for heat content uptake estimation. First results will be presented to discuss the feasibility and representativeness of an approach combining all the observations available (Argo floats, satellite SSH, SSS, SST) conjointly with the understanding of processes that modeling experiments can offer.

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Dynamic mapping of ocean altimetry: method and performances from Observing System Simulation Experiments

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_014

Abstract:
From simulated ocean altimetry data, we implement the use of a non-linear dynamic propagator to perform three-dimensional (time and 2-d space) interpolation of mesoscale Sea Surface Height (SSH). Based on the same dynamic framework as presented in in Ubelmann et al., 2015, we develop here an inverse approach allowing to process any altimetry data unevenly sampled in time and space into high-level gridded altimetry maps. The inverse approach, similar to the standard objective mapping, contains some correction terms to the innovation vectors to account for non-linearities and the covariances through a Green's function approach. From the Observing System Simulation Experiments carried out, simulating a typical 3-satellite constellation over the Gulf-Stream region, we show that this dynamic interpolation method can significantly reduce mapping errors compared to the standard linear objective analysis such as used by AVISO gridding. Beyond the prospects of improving the present and past mesoscale altimetry reconstructions, we will also discuss the potential benefits of the method for the future high-resolution measurements from SWOT.
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Value of the Jason-1 geodetic phase to study rapid oceanic changes

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Session: Science II: Mesoscale and sub-mesoscale ocean processes: current understanding and preparation for SWOT
Presentation type: Poster
Poster number: SC2_015

Abstract:
Thanks to the drifting nature of the ground track of Jason-1 during its geodetic mission (Jason-1 GM), there are 1200 overlap events where both altimeters are measuring the ocean topography on the same track (less than 10 km from one another, i.e. the altimeter footprint radius) over an entire pass, i.e. tens of thousands of kilometres.

This paper reports the first statistical analysis of this dataset with variance maps, spectra, auto-correlation and space / time scales that are consistent with past observations. Our results highlights the value of this Jason-1 GM overlap dataset for more sophisticated studies of the rapid ocean variability, but also two major limitations: 1/ the noise level of Jason-class altimeters prevents from analyzing scales smaller than 80 km, and 2/ short time differences also absorb a fraction of the derivative of slower signals.

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Pointwise comparison of geostrophic currents of altimetry-derived instantaneous Ocean Dynamic Topography with in-situ measurements

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Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_001

Abstract:
In order to validate dynamic ocean topography (DOT) data, derived from current satellite altimetry measurements and high-accurate Earth gravity field models, we perform a comparison with in-situ velocity measurements. Our instantaneous DOT (iDOT) is based on the “profile-approach” (Bosch & Savcenko, 2010 and Bosch et al., 2013) estimating so-called iDOT profiles along individual altimeter ground tracks which allows the monitoring of temporal variations of the DOT on spatial scales, close to meso-scale structures.
For the intended pointwise comparison we correct the in-situ surface velocity data provided by surface drifters and ARGO floats for wind and Ekman drift. Furthermore, we convert the iDOT profiles to geostrophic velocity vectors by using the geostrophic equations and interpolate them to the individual in-situ positions. Both velocity fields agree quite well with the majority of the differences being smaller than 0.15 m/s. However, the interpolation method causes a smoothing of the iDOT data and yields about two-times smaller geostrophic velocities than the in-situ measurements. It can be underlined that the interpolation and the related undesired smoothing constitute a limiting factor for the consistency of both velocity fields.
In the present investigation we conduct a sensitivity analysis quantifying the impact of the smoothing to the occurring scaling factor by modifying the temporal and spatial resolution parameters within the interpolation. Results are presented for a chosen study area containing strong western boundary currents and different periods.

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The updated geodetic mean dynamic topography model – DTU15MDT.

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Session: The Geoid, Mean Sea Surfaces and Mean Dynamic Topography
Presentation type: Poster
Poster number: GEO_002

Abstract:
An update to the global mean dynamic topography model DTU13MDT is presented. For DTU15MDT the newer gravity model EIGEN-6C4 has been combined with the DTU15MSS mean sea surface model to construct this global mean dynamic topography model. The EIGEN-6C4 is derived using the full series of GOCE data and provides a better resolution. The better resolution fixes a few problems related to geoid signals in the former model DTU13MDT. Slicing in the GOCO05S gravity model up to harmonic degree 150 has solved some issues related to striations. 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. Finally, the filtering was re-evaluated by adjusting the quasi-gaussian filter width to optimize the fit to drifter velocities. Subsequently, geostrophic surface currents were derived from the DTU15MDT. The results show that geostrophic surface currents associated with the mean circulation have been further improved and that currents having speeds down to below 4 cm/s have been recovered.
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Sentinel-3 Delay Doppler Altimeter: a New Insight on High Resolution Ocean Dynamics

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Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_001

Abstract:
Although conventional radar altimetry products (Jason1, Jason2, LRM Cryosat-2, etc) have a spatial resolution between 5 and 10 km (due to the size of the radar footprint), the observation of ocean scales in the along track direction smaller than 100 km is limited by the existence of a “spectral bump”, i.e. a geographically coherent error between 10 and 20 km, observed on all conventional altimeters.
Dibarboure et al (2014) have largely discussed the bump artefact which appears to be a mixed effect between the Brown model used for retracking the data (which has been designed for a homogeneous scene and is not fully relevant during backscattering events) and the criteria for selecting the 20 Hz valid data. They showed that dedicated processing could better discard outliers and reduce the energy in the mean PSD of the sea level. More recently, dedicated editing procedure based on the mispointing angle on AltiKa (Poisson et al OSTST 2014) has also enhanced the description of the corrupted data. In parallel, other groups are also working on retracking as Amarouche and Sandwell, also showing some significant improvement.
Another important issue for understanding the oceanic turbulence at short scales is the use of the new delay Doppler technique that should yield measurement less altered by the heterogeneities issue since the thin stripe-shaped synthetic footprint of SARM is reduced to 300 m in the along track direction. Preliminary results have shown that the SARM data derived from Cryosat-2 do not show the spectral bump.
As the delay Doppler processing have become more mature in the last couple of years, the content of the shortest spatial scales is further investigated here by analyzing several oceanic regime acquired in SAR mode with Cryosat-2 mission and comparing the results with other LRM processing (AltiKa, Jason-2 and Cryosat-2). This work allows understanding the outcomes of the SARM processing that we could expect from Sentinel-3 mission. Furthermore, in the frame of the future altimetry missions (SAR for Cryosat -2 and Sentinel-3 missions and interferometry for the SWOT mission), it becomes crucial to investigate again and to better understand the signals obtained at small scales by conventional altimeter missions.

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Sea level ECV quality assessment via global ocean model assimilation

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Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_002

Abstract:
We aim to quantify improvements in Sea Level (SL) data obtained through the ESA - Climate Change Initiative (cci) effort and to test the consistency of the Essential Climate Variable (ECV) of Sea Level (SL_ECV) with other ECVs through the assimilation process. For this purpose we assimilate SSH data jointly with in situ ocean data into the GECCO2 assimilation framework. Because the dynamically consistent ocean state estimation adjusts only uncertain model parameters to bring the model into consistency with ocean observations, improvements in data products can be investigated by studying the residuals between the different data products and the constrained model. With this approach and the assimilation of SL_ECV_V0 we are able to demonstrate that in many regions the SL_ECV has been improved from version V0 (AVISO product) to version V1 (SL_cci product). However, there are regions where SL_ECV_V1 is further away from the model "truth". In contrast we find clear improvements due to the updated improved data set SL_ECV_V1.1 for these comparisons. The improvement gets even more evident when using the changed model "truth" due to the assimilation of the improved data set SL_ECV_V1.1.

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Sea level budget over 2005-2013: Missing contributions and data errors

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Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_003

Abstract:
Based on the sea level budget closure approach, this study investigates the residuals between observed global mean sea level (GMSL) and the sum of components (steric sea level and ocean mass) for the period January 2005 to December 2013. The objective is to identify the impact of errors in one or several components of the sea level budget on the residual time series. This is a key issue if we want to constrain missing contributions such as the contribution to sea level rise from the deep ocean (depths not covered by observations). For that purpose, we use several data sets as processed by different groups: six altimetry products for the GMSL, four Argo products plus the ORAS4 ocean reanalysis for the steric sea level and three GRACE-based ocean mass products. We find that over the study time span, the observed differences in trend of the residuals of the sea level budget equation can be as large as ~0.55 mm/yr (i.e., ~17% of the observed GMSL rate of rise). These trend differences essentially result from differences in trends of the GMSL time series. Using the ORAS4 reanalysis (providing complete geographical coverage of the steric sea level component), we also show that lack of Argo data in the Indonesian region leads to an overestimate of the absolute value of the residual trend by about 0.25 mm/yr. Accounting for this regional contribution leads to closure of the sea level budget, at least for some GMSL products. At short time scale (from sub-seasonal to interannual), residual anomalies are significantly correlated with ocean mass and steric sea level anomalies (depending on the time span), suggesting that the residual anomalies are related to errors in both GRACE-based ocean mass and Argo-based steric data. Efforts are needed to reduce these various sources of errors before using the sea level budget approach to estimate missing contributions such as the deep ocean heat content.

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Satellite altimetry data validation in San Matias Gulf, Argentina

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Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_004

Abstract:
The objective of this work is to evaluate satellite altimetry data and its corrections terms in a complex coastal environment. Satellite altimetry data are compared with data obtained from a bottom pressure recorder deployed during 22 months. The instrument is moored at 1 km from the coast in San Matias Gulf, Argentina, at only 38m from the nominal intersection of satellite tracks 52 (descending) and 189 (ascending) of Jason 2. Data obtained from the bottom pressure recorder are therefore ideal to test coastal satellite altimetry products. Correlation between the two datasets is 0.9 (95% CL) when no corrections are applied to the altimeter data, until a distance of 3 km to the coast for track 189, and 10 km for track 52. Results show that both sea bias and ionosphere corrections reduce the correlation between altimetry and in-situ data near the coast: a correlation value of 0.9 is found at a distance from the coast of 7 km (track 189) and 13 km (track 52). Tide correction also reduces the correlation between the two datasets along the tracks. Eight global models were considered, and the one with lower root sum square of the difference considering the first 11 amplitude and phase constants is FES2012 (0.84 cm). Finally two retracking algorithms were considered: a classic Brown model (MLE4) and a more recent developed method: ALES (Adaptive Leading Edge Subwaveform Retracker). Both ALES and MLE4 show similar correlation with in-situ data when applied to satellite altimetry data for distances larger than 10km from the coast, obtaining a correlation factor of 0.9 (95% CL). ALES has the ability to recover more data close to the coast, especially for the ascending track 189 (the one that has a transition from ocean to land), up to 3km from the coast. We conclude that satellite data from Jason 2 can adequately represent the sea level variability as close as 3 km from the coast depending on the relative motion of the satellite to the coast and the corrections used.
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Use of satellite data in the Rio de la Plata estuary

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Session: Quantifying Errors and Uncertainties in Altimetry data
Presentation type: Poster
Poster number: ERR_005

Abstract:
The La Plata River Estuary is located in the eastern coast of South America at approximately 35ºS. This extensive and shallow region is one of the largest estuaries of the world. The estuary is formed by the confluence of the Paraná and Uruguay rivers that generate a mean discharge of about 23000 m3/sec. Previous studies have shown that the estuarine circulation is vulnerable to the river run-off and wind variability. In particular, changes in wind seem to be the main forcing of the river circulation, especially at sub-annual scales. The objective of this work is to analyze the descending pass #0964 and ascending pass # 0493 of ENVISAT RA2 (18 Hz) in this region. We evaluate the performance of each correction applied to the altimetry data. Results show that both passes are sensible to the different retrackings. ICE1 recover more data in the proximity of the coast in pass #0493 and pass #0964. We applied a criterion to remove outliers (-/+2 standard deviation) keeping the nominal position along the track with less that 20% of missing values in both passes. As a result, correlation coefficients between altimetry data and a tide gauge deployed in the study area are 0.61 (95%CL) and 0.87 (95%CL) for pass #0493 and #0964, respectively when no tide and atmospheric corrections are considered. We also analyze the dynamic atmospheric correction obtained with a global barotropic model (MOG2D: Modèle aux Ondes de Gravitè 2-Dimensions) and two regional barotropic models (HamSOM: Hamburg Shelf Ocean Model, SMARA). Results show that the global model underestimates the variability of the sea level response to pressure and wind forcing in comparison with the regional models. The ENVISAT RA2 data will be corrected by the atmospheric effect with the best model. Then we will examine the capabilities of the altimetry data to measure the sea level variability due to freshwater discharges from the main tributaries of Río de la Plata.
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Sensitivity study on the use of Argo data for the validation of altimeter products in the Mediterranean Sea

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_001

Abstract:
The existing Argo network strongly complements the observations of the ocean surface from space, especially the observation of the surface topography with satellite altimeters. The comparison of Sea Level Anomalies (SLA) provided by satellite altimeters with in-situ Dynamic Heights Anomalies (DHA) derived from the temperature and salinity profiles of Argo network contributes to better characterize the error budget associated to the altimeter observations. However, the uncertainty associated with some of these results remains relatively high and some impact studies assessing to which extent the validation of altimeter measurements by comparison with in-situ steric heights derived from the Argo network is sensitive to these in-situ data and their processing are still needed.

In this work, performed in the frame of the E-AIMS FP7 European project, we review the method of comparison between SLA and DHA in the Mediterranean Sea (regional scale) in order to validate altimeter sea level measurements with an increased confidence. Namely, we focus on the sensitivity of specific SLA gridded products provided by AVISO in the Mediterranean Sea to the reference depth (400 or 900 dbars) selected in the computation of the Argo dynamic height as an integration of the Argo T/S profiles (Coriolis-GDAC dataset) through the water column. As a previous step to the comparison, the dynamic height anomalies were referenced to a synthetic climatology (400 or 900 m). Finally, to perform the comparison of both datasets, altimeter grids and synthetic climatologies were spatially and temporally interpolated at the position and time of each in-situ Argo profile by a mapping method based on an optimal interpolation scheme. Then, statistics and coherence analyses were carried out between altimetry and the in-situ Argo reference. The analysis was conducted in both the entire Mediterranean Sea and different sub-regions of the basin in order to (1) check biases in the altimetry validation to different reference depths of Argo DHA and (2) investigate the impacts of a given reference depth of integration on the regional and sub-regional Argo sampling and on the comparison with altimeter data. Preliminary results show that correlations between altimeter product and Argo data using 400 m as reference level are slightly higher than those obtained using a 900 m reference level. On the other hand, the standard deviation of the difference between both datasets exhibits the opposite behaviour with higher mean values in the later.

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Global Ocean Surface and 15m depth currents from the synergetic use of altimetry, GOCE and in-situ data.

Marie-Hélène Rio (CLS, France) ; Claire Dufau (CLS, France) ; Hélène Etienne (CLS , France) ; Sandrine Mulet (CLS, France)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_002

Abstract:
Accurate estimate of ocean surface currents is both a challenging issue and a growing end-users requirement. Advancing the quantitative estimation of ocean surface currents from satellite sensor synergy and demonstrating the impact in user-led scientific, operational and commercial applications is the main objective of the GlobCurrent project, a Data User Element (DUE) from the European Space Agency (ESA). In the framework of this study, a global reanalysis of 12 years (2002-2014) of global ocean currents at two depths (surface and 15m) has been calculated as the sum of the geostrophic and Ekman components. The geostrophic component is based on the SSALTO-DUACS multimission altimeter maps of velocity and the CNES-CLS13 Mean Dyanmic Topography. Ekman currents at two levels (surface and 15m) are calculated from an empirical model. The model parameters (amplitude and angle) have been derived as to minimize the misfit between wind stress data and the ageostrophic component extracted from in-situ drifter velocities (SVP drifters at 15m depth, Argo floats at the surface). Parameters have been fitted by month, longitude and latitude and a number of tests have been performed to investigate the impact of taking into account other information as the Mixed Layer Depth (from an Argo floats based climatology), effective wind stress, and Stokes drift from the WaveWatchIII model. The best model accounts for up to 50% of the observations variability. Currents have been calculated over a 12 years period (2002-2014) and validated through comparison to independent in-situ observations and other existing observed products.

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Estimating the velocity and transport of the East Australian Current using Argo, XBT, and Altimetry

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_003

Abstract:
Western Boundary Currents (WBCs) are the strongest ocean currents in the subtropics, and constitute the main pathway through which warm water-masses transit from low to mid-latitudes in the subtropical gyres of the Atlantic, Pacific, and Indian Oceans. Heat advection by WBCs has a significant impact on heat storage in subtropical mode waters formation regions and at high latitudes. The possibility that the magnitude of WBCs might change under greenhouse gas forcing has raised significant concerns. Improving our knowledge of WBC circulation is essential to accurately monitor the oceanic heat budget. Because of the narrowness and strong mesoscale variability of WBCs, estimation of WBC velocity and transport places heavy demands on any potential sampling scheme. One strategy for studying WBCs is to combine complementary data sources. High-resolution bathythermograph (HRX) profiles to 800-m have been collected along transects crossing the East Australian Current (EAC) system at 3-month nominal sampling intervals since 1991. EAC transects, with spatial sampling as fine as 10-15 km, are obtained off Brisbane (27°S) and Sydney (34°S), and crossing the related East Auckland Current north of Auckland. Here, HRX profiles collected since 2004 off Brisbane are merged with Argo float profiles and 1000 m trajectory-based velocities to expand HRX shear estimates to 2000-m and to estimate absolute geostrophic velocity and transport. A method for combining altimetric data with HRX and Argo profiles to mitigate temporal aliasing by the HRX transects and to reduce sampling errors in the HRX/Argo datasets is described. The HRX/Argo/altimetry-based estimate of the time-mean poleward alongshore transport of the EAC off Brisbane is 18.3 Sv, with a width of about 180 km, and of which 3.7 Sv recirculates equatorward on a similar spatial scale farther offshore. Geostrophic transport anomalies in the EAC at 27°S show variability of ± 1.3 Sv at interannual time scale related to ENSO. The present calculation is a case study that will be extended to other subtropical WBCs.

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Multi-decadal change of the South Pacific Gyre circulation

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_004

Abstract:
Multi-decadal trends in ocean heat and freshwater content are well-documented. Much less evidence exists for long-term changes in ocean circulation, although these could be equally informative of a changing climate. In previous work, a 12-year increase in the circulation of the South Pacific subtropical gyre interior (from 1993 to 2004) was described (Roemmich et al., J. Phys. Oceanogr., 2007). That analysis was based on comparing early Argo results with 1990's hydrographic data, and on changes in satellite sea surface height. Here we show that the increasing circulation trend continues, and is seen distinctly within the Argo decade, 2005 to 2014. Patterns that indicate an increase in the equatorward circulation of the eastern portion of the interior South Pacific Gyre are seen in Argo temperature and steric height, Argo trajectory data, sea surface height, sea surface temperature and salinity, sea level pressure, and wind stress. Between 2005 and 2014 the circulation was enhanced by about 5 Sv of anomalous equatorward flow extending from 160°W to the South American coast along 35°S. The northward anomaly was balanced by an equal southward transport anomaly between the dateline and 160°W. Thus a 5 Sv anticlockwise circulation anomaly is seen centered on 35°S, 160°W. Corresponding temperature anomalies during the Argo decade span the 2000 m depth range of Argo observations, with warming maxima seen in thermocline and in intermediate water layers. The 22-year trend in sea surface height is 8 cm/decade, centered at 35°S, 160°W. Trends in sea surface temperature over 35 years show a very similar spatial pattern to that of the 22-year sea surface height record, with an increase of 0.5 °C/decade at 35°S, 160°W since 1980. While there are aspects of South Pacific trends in circulation and ocean properties that are not understood, it is demonstrated that the Argo dataset has sufficient coverage and duration to accurately describe the signatures of climate variability and change.
Figure: The linear trend in SSH (cm/decade) in the South Pacific, 1993 - 2014

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Seasonal and interannual variability of the Brazil - Malvinas front: an altimetry perspective

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_005

Abstract:
The Brazil and Malvinas Confluence in the Southwestern Atlantic is one of the most energetic regions of the world ocean. Using recent measurements of sub-surface velocity currents, collected along 2348 nautical miles with a vessel mounted acoustic Doppler profiler onboard R/V BIO Hespérides, we validate geostrophic velocities derived from gridded fields of sea surface height (SSH). A remarkable correspondence between in-situ surface hydrographic data collected from the vessel and satellite sea surface temperature (SST), color and altimetry data allows selecting a specific SSH contour to track the position of the Brazil-Malvinas front. We then use 21 years of SSH data distributed by AVISO to show that the Brazil-Malvinas front shows a NS orientation in winter and a NE-SW orientation in summer, in good agreement with results based on the analysis of nine years of SST gradients. Furthermore, a clear southward migration of the front during the 21 year period is observed. The migration is associated with the southward shift of the South Atlantic high-pressure system that is in turn related to large climate changes in the southern portion of the South American continent.
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Iceberg detection using the three modes of SIRAL on Cryosat

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_006

Abstract:
Cryosat is the first ESA satellite mission dedicated to the study of the Cryosphere.
Its primary goal is to monitor the thickness of land ice and sea ice and help explain the connection between the melting of the polar ice and the rise in sea levels and how this is contributing to climate change. The main instrument is the SAR/Interferometric Radar Altimeter SIRAL-2.It operates in threee modes:
-Low-resolution mode (LRM) like a conventional altimeter, on land ice or sea which are composed of few rough surfaces,
-SAR mode (Delay Doppler Altimetry) operating a high resolution measurement on sea ice,
-SAR interferometer (SARIn) mode operating on rough surfaces like on the sea ice/land limit.
This three modes capabilities allows to investigate in details the advantages of each mode for the detection of icebergs and ships. The method of detection of icebergs using conventional altimeters data was developed byDelay Doppler Altimetry (DDA), proposed by R.K. Raney (1998), offers improved altimetric precision and better along-track resolution than conventional pulse limited altimeters. DDA altimeters have a high pulse repetition frequency to ensure pulse-to-pulse coherence, leading to an along-track resolution about 300 meters, improved signal-to-noise ratio and enhanced altimeter ranging performance. The delay doppler maps, the beam stacking capabilities and the improved along-track resolution offers new possibilities for the detection and the determination of the characteristics of both icebergs and ships. Using Cryosat SAR L1b and L2 date, a method of detection of target emerging the sea has been developed. This method is based firstly on the analysis of the pseudo LRM waveforms obtained without stacking. Within these waveforms, the signature of a target emerging from the sea is a parabola that can be easily detected using the method developed by Tournadre et al (2008) for classical pulse limited altimeters. It should be noted that within the stacked waveforms the signature is bright spot that can also be easily detected by classical image processing methods. Using the estimate of the iceberg's position the Delay Doppler Maps (DDM) at 85 Hz are then used to estimate the area of the icebergs by averaging the DDM taking into account the iceberg displacement in both range and doppler. This allows to compute an image of the iceberg backscatter at high resolution. The results are then compared to the SAR (refocused) waveforms to estimate the precision of the area estimate using the waveforms alone.
The new ESA SARVATORE project nows allows to obtain full resolution stack data. These data include more than 300 range bins before the mean sea level that can be exploited to improve the iceberg and ship detection by increase more than twofold the detection swath of the altimeter. Several examples of such detection of icebergs and ships are analyzed and presented.
DDA altimetry offer improved capabilities of both iceberg and ship compared to classical altimetry as it is demonstrated using a limited Cryosat SAR dataset. In the perspective of Sentinel 3 it can be of importance for the scientific community whose interest for icebergs and its impact on both the southern ocean circulation and ecosystems has increased during the recent year to develop an operational processing chain design to detect icebergs.
The SAR interferometer mode uses the phase difference between returning radar waves: in order to measure the arrival angle, a second receive antenna is activated so that the radar echo is received by two antennas simultaneously. When the echo comes from a point not directly beneath the satellite there is a difference in the path length of the radar wave, which is measured by the phase difference. Simple geometry provides the angle between the baseline joining the antennas and the echo direction. An iceberg being a target emerging from the sea surface its echo lies within the noise part of the waveforms where the power received by the two antennas is incoherent. The phase difference has thus a zero mean as well as the coherence. An iceberg can be simply detected using either the parabola detection in pseudo LRM or the bright spot detection within the stacked waveforms. The signature are also characterized by a high (>0.6) coherence between the two antennas and a non zero phase difference. The phase difference is then converted to incidence angle using the interferometric equation. Knowing the satellite altitude the incidence is converted in distance from nadir. As the range of the iceberg's signature (i.e. the range bin where it is detected) depends on the distance from nadir and the freeboard elevation, it is possible to compute the icebergs freeboard. As the DDM maps are also available he surface of the icebergs can also be estimated using the DDM. SARin allows to estimate all the iceberg's characteristics: surface, freeboard, surface backscatter with a better precision than any other sensor.

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Meridional Heat Transport in the South Atlantic Ocean

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_007

Abstract:
This work present results that use blended satellite altimetry observations together with XBT, Argo profiling float, and climatological data to investigate the year-to-year variability of the meridional overturning circulation (MOC) and meridional heat transport (MHT) along 35°S since 1993. The barotropic and baroclinic components are extracted from the altimetric and hydrographic records. The baroclinic component is validated using the XBT derived MHT and MOC estimates. Results from the altimetry-based methodology during 1993-2011 indicate that the MHT ranges between a slightly negative value of -0.07PW and a large positive value of 1.11PW. Large interannual variability is observed with amplitudes of up to 1PW, which is comparable to similar values derived from XBT measurements. Changes in MOC and MHT are analyzed in terms of variations of the wind field and in the subtropical gyre, which has exhibited a warming trend during the last 20 years. Results obtained from this study demonstrate the importance of satellite altimetry observations for MOC studies in the South Atlantic Ocean and in particular to extend the time series of the in situ observational record and to obtain estimates where observations are not available.

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An altimetric based metric for Gulf Stream position in climate models

Andrew Davis (University of Washington, United States) ; Thompson LuAnne (University of Washington, USA)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_008

Abstract:
The long spin-up time of the ocean requires multiple centuries, precluding coupled equilibrium simulations at eddy resolving scales. As such, the Coupled Modeling Intercomparison Project (CMIP) guidelines suggest a nominal 1° ocean resolution with higher meridional resolution in the tropics. Additional CMIP6 simulations will be run at 0.25°, however, while baroclinic instability generates eddies in mid-latitudes at this resolution, they are not well resolved. Detailed comparisons of SST biases in ocean-only simulations show that even at 0.25° degree, there is a greater than 5°C warm bias North of Cape Hatteras along the Eastern Seaboard and a greater than 5°C cold bias in the North Atlantic Current at 40°W. At 1/12° these biases are much diminished and of smaller spatial scale owing to the increased strength and higher Reynold's number of the Gulf Stream and North Atlantic Current.

Here we present model metrics for Gulf Stream position and strength, providing both their climatological mean and variance. For high-resolution models we fit the sea level across the Gulf Stream to an error function. In a comparison between and North Atlantic ocean-only and coupled simulations at high resolution (0.1°) we find qualitative agreement with observations in both mean and variance of position. We also develop a metric for low-resolution models based on the location of maximum zonal velocity and apply it to historical simulations of models in the CMIP5 archive. While the mean position of the Gulf Stream is qualitatively similar among the models, there are large differences in the spatial and temporal variance of its position.

Quantifying biases in Gulf Stream position and strength (both mean and variability) is vital to evaluating and improving the performance of climate models in the North Atlantic as Gulf Stream strength and position are closely related to sea surface temperature in the subpolar North Atlantic. In addition, understanding and predicting decadal-scale changes in the Gulf Stream can provide insight into the decadal variability of the North Atlantic processes to which it is closely linked.

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A wave investigation in the tropical Atlantic Ocean using satellite altimetry.

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_009

Abstract:
The intra-annual variability of the tropical Atlantic Ocean is investigated with satellite altimetry Absolute Dynamic Topography data. Three regions of high variability are found. The first region, between 3°N and 11°N, is characterized by the presence of westward propagating eddies linked to the North Equatorial Counter Current (NECC) retroflection in the vicinity of the Brazilian coast. In the second region, we observed the presence of westward propagating instability waves centered at 5°N between 30°W and 10°W. The third region, around the Equator, is characterized by the presence of eastward propagating Kelvin waves at the Equator, and westward propagating Rossby waves centered at 5°S and 5°N.

The eddies linked to the NECC show a strong annual cycle: their number varies from ~4 per year in October to ~9 per year in March. The more powerful eddies occur in October around 40°W. Their diameter varies from 5° of longitude at 40°W to 2.5° at 60°W, and their speed is 18 cm/s. The instability waves also shows a strong seasonal cycle with maximum amplitude around August. They are generated by meridional winds at the African coast and by zonal winds at the Equator.

The Kelvin waves at the Equator are generated by zonal wind anomalies at the Equator at 30°W with a 2.6 weeks delay, and their speed is 175 cm/s (2nd order baroclinic). The speed of the Rossby waves is 50 cm/s at 5°N, and 49 cm/s at 5°S.

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

LuAnne Thompson (University of Washington, United States) ; Kathryn Kelly (University of Washington, United States)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_010

Abstract:
As a proxy for upper ocean heat content, the 22 year record of sea surface height (SSH) allows an examination of the interaction of heat stored below the seasonal thermocline with the atmosphere. We use monthly averaged sea level from AVISO, turbulent fluxes of heat (latent plus sensible heat flux, Q) and sea surface temperature (SST) from OAflux, ISCCP (International Satellite Cloud Climatology Project) Cloud Fraction, and ERA-20C precipitation to investigate seasonal variability in air-sea interaction. Lagged correlation analysis shows that SSH has longer persistence than SST throughout the North Atlantic. In both the Northern and Southern Recirculation gyres of the Gulf Stream, early summer SSH is correlated with surface flux in winter while SST is correlated with surface flux one month in advance. In the recirculation gyres, the SSH anomalies are not forced locally by surface flux; instead they result from oceanic heat transport convergence.

There is also evidence for stored heat forcing changes in the atmosphere. Turbulent flux of heat Q out of the ocean is linked to an increase in mid-level (tropospheric) cloud fraction in winter over the Gulf Stream, as well as changes in precipitation. These relationships are consistent with the climatological analysis of atmospheric conditions over the Gulf Stream in winter by Minobe and co-workers. In addition, early summer SSH is correlated with winter cloud cover, giving predictive skill for winter cloud cover over portions of the Eastern seaboard; at the same time, SST does not have this predictive skill. This suggests that the persistence of SSH may be useful seasonal forecasts of along the Eastern Seaboard.

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Altimetry-derived changes in the Gulf Stream properties and its impact on air-sea interaction

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_011

Abstract:
The location and strength of the Gulf Stream determined from altimeter measurements from 80W to 50W since late 1992 are analyzed, and compared with these from XBT and current meter measurements along a high-density XBT transect and Oleander section. During the altimeter period, the Gulf Stream experiences a strong southward shift, which is dominated by the region east of 65W after the Gulf Stream passes the New England Seamount. This southward shift is accompanied by a weakening of the Gulf Stream, also dominated by the region east of 65W. This explains why the measurements from the oleander section, crossing the Gulf Stream around 70.5W, did not capture the weakening of the Gulf Stream. On interannual time scales, the Gulf Stream experiences strong intensification during two periods, 1995-1996 and 2003-2004. Interestingly, the 1995-1996 peak in the Gulf Stream strength mainly comes from the eastern region, east of 65W. Whereas, the 2003-2004 peak is dominated by the region to the west of 65W. Gulf Stream changes in different regions may have different impact on air-sea interaction processes. In this study, the corresponding changes in the vertical thermal structure in the upper ocean, changes in the air-sea heat fluxes and in the subtropical mode water processes are investigated.

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Atlantic Water transport and temperature anomalies through the Nordic Seas towards the Arctic Ocean

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_012

Abstract:
The climatic conditions over the Arctic Ocean are strongly influenced by the inflow of warm Atlantic water conveyed by the Norwegian Atlantic Current (NwAC). Based on sea surface height data from altimetry, we develop a dynamical measure of the NwAC transport to diagnose its spatiotemporal variability. We find that the Fram Strait Branch west of Spitsbergen is regulated by regional atmospheric conditions. In combination with hydrography, we find that warm anomalies propagate polewards after anomalously strong flow events in the southern Norwegian Sea and reach the Fram Strait after approximately 12 months. Our results are valuable for the predictability of the oceanic heat and salt transport that eventually enters into the Arctic.

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Extending and Improving Sea Level Measurements in the Ice Covered Arctic Ocean

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_013

Abstract:
The Arctic Ocean sea level remains largely unobserved by satellite altimetry missions, either due to orbit constraints (e. g. for Jason missions) or because ice coverage hinders the ability of conventional radar altimeters to retrieve sea surface height. Over the last few years, several efforts have been made to improve the observability of the Arctic Ocean and generate tailored sea level products (Prandi et al, 2012 & Andersen et al., 2015). These products remain based on the processing of 1Hz measurements, with dedicated editing and choice of geophysical corrections.
In this study, we take advantage of the waveform classification developed for the Envisat (CCI project) and SARAL/AltiKa missions (PEACHI project) that allows discriminating echo returns from leads in the ice pack, ice floes and open ocean. All echoes are retracked using the same adaptive algorithm. After editing and correction the measurements are used to build cycle-wise grids of sea level anomaly in the Arctic Ocean with unprecedented data availability in ice covered areas.
We present the methodology used to build this new dataset, its validation and the new insights on Arctic Ocean sea level variability that can be derived from it.

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Accurately measuring sea level change from space: an ESA Climate Change Initiative for MSL closure budget studies

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_014

Abstract:
Sea level is a very sensitive index of climate change and variability. Sea level integrates the ocean warming, mountain glaciers and ice sheet melting. Understanding the sea level variability and changes implies an accurate monitoring of the sea level variable at climate scales, in addition to understanding the ocean variability and the exchanges between ocean, land, cryosphere, and atmosphere. That is why Sea Level is one of the Essential Climate Variables (ECV) selected in the frame of the ESA Climate Change Initiative (CCI) program. It aims at providing long-term monitoring of the sea level ECV with regular updates, as required for climate studies.

After a first phase (2011-2013), the program has started in 2014 a second phase of 3 years. The objectives of this second phase are to involve the climate research community, to refine their needs and collect their feedbacks on product quality, to develop, test and select the best algorithms and standards to generate an updated climate time series and to produce and validate the Sea Level ECV product. This will better answer the climate user needs by improving the quality of the Sea Level products and maintain a sustain service for an up-to-date production. To this extent, the ECV time series has been extended and it now covers the period 1993-2013 with the 2014 additional year provided by the end of the year.

We will firstly present the main achievements of the ESA CCI Sea Level Project. On the one hand, the major steps required to produce the 21 years climate time series are briefly described: collect and refine the user requirements, development of adapted algorithms for climate applications and specification of the production system. On the other hand, the product characteristics are described as well as the results from product validation, performed by several groups of the ocean and climate modeling community. At last, the work plan and key challenges of the second phase of the project are described: this includes yearly extensions of the ECV time series as well as the production of a full reprocessing of the dataset. Efforts are also focused on the improvement of the sea level estimation in the Arctic Ocean and in coastal areas for which preliminary results suggest that significant improvements can be achieved.

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Warming of the global ocean : consistency of thermal and altimetric fields and dominance of descending density surfaces

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Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_015

Abstract:
We have investigated the multidecadal warming and interannual and decadal heat content changes in the upper ocean from observational data sets and from a modeled state estimate. Multidecadal warming is dominated by a contribution from deepening of the mid-thermocline isopycnals, resulting in an expansion of the subtropical mode water volume, rather than shifts of the temperature/salinity relationship. In fact temperatures of the same mode waters have cooled slightly. The contribution from this volume increase outweighs the surface warming contribution in the upper ocean heat content. The multidecadal isopycnal sinking has been the strongest over the southern basins. On interannual to decadal scales, sinking and shoaling of density surfaces dominates ocean heat content changes, while the contribution from temperature changes along density surfaces decreases as time scales shorten. Decomposition of ocean heat content changes into heaving and isopycnal temperature changes is shown to provide insight to the satellite sea surface height measurements of the last two decades.
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Assessing regional deep-ocean warming from satellite and in situ data

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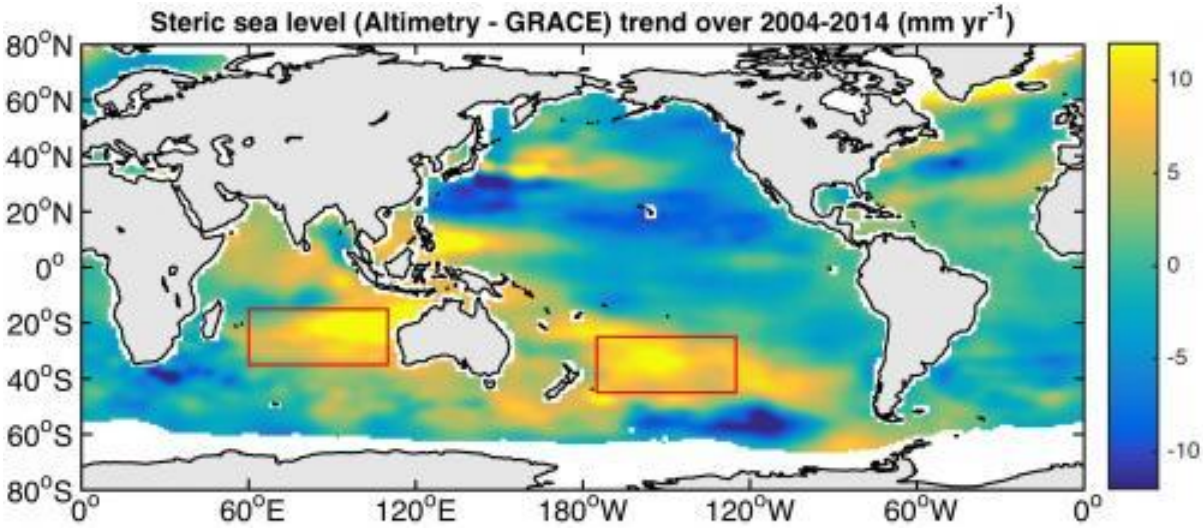
Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_016

Abstract:
The observed Earth's net energy imbalance requires that all extra heat is stored in the climate system, mostly in the World Ocean, which is the dominant reservoir of heat uptake. Sea level, as a natural indicator of the full-depth ocean heat content, has been accurately measured by satellite altimetry since 1992. Measurements of ocean mass variations provided by the GRACE twin satellites since 2002 can be subtracted from altimetric Sea Surface Height (SSH) to derive steric changes (due to temperature and salinity) of sea level. The advent of Argo profiling floats has made available global observations of temperature for depths above 2000 m since 2003. Recent analysis of globally averaged quantities over the 2005-2013 time interval has shown no significant deep-ocean warming below 2000 m depth. In the present work, we combine satellite and in-situ data to address the regional redistribution of heat content and investigate whether and how local processes lead to accumulation of heat at deeper layers. Our analysis shows that the largest trends of the steric sea level over the 2004-2014 time interval are in the South Indian and South Pacific Oceans (see figure). In the South Indian Ocean, warming is limited to the upper 1000 m, while in the South Pacific Ocean a significant warming is observed between 1000 and 2000 m depth. Indirect estimates (difference between the satellite and in situ estimates of the steric sea level change) show a significant warming below 2000 m depth in the South Pacific Ocean; the linear trend of the steric SSH linked to this warming is approximately equal to the linear trend of the steric SSH over the upper 2000 m. We further show that the deep-ocean (below 2000 m) warming in the South Pacific Ocean was caused by an increased Ekman convergence associated with the strengthening of westerly winds over the Southern Ocean and trade winds in the South Pacific.



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A probabilistic description of the forced and intrinsic oceanic variability: SSH, SST, MOC, water masses.

Thierry Penduff (CNRS - LGGE, France) ; Stéphanie Leroux (CNRS - LGGE, France) ; Guillaume Sérazin (CNRS - LGGE, CERFACS, France) ; Jean-Marc Molines (CNRS - LGGE, France) ; Laurent Bessières (CERFACS, France) ; Bernard Barnier (CNRS - LGGE, France) ; Laurent Terray (CERFACS, France)

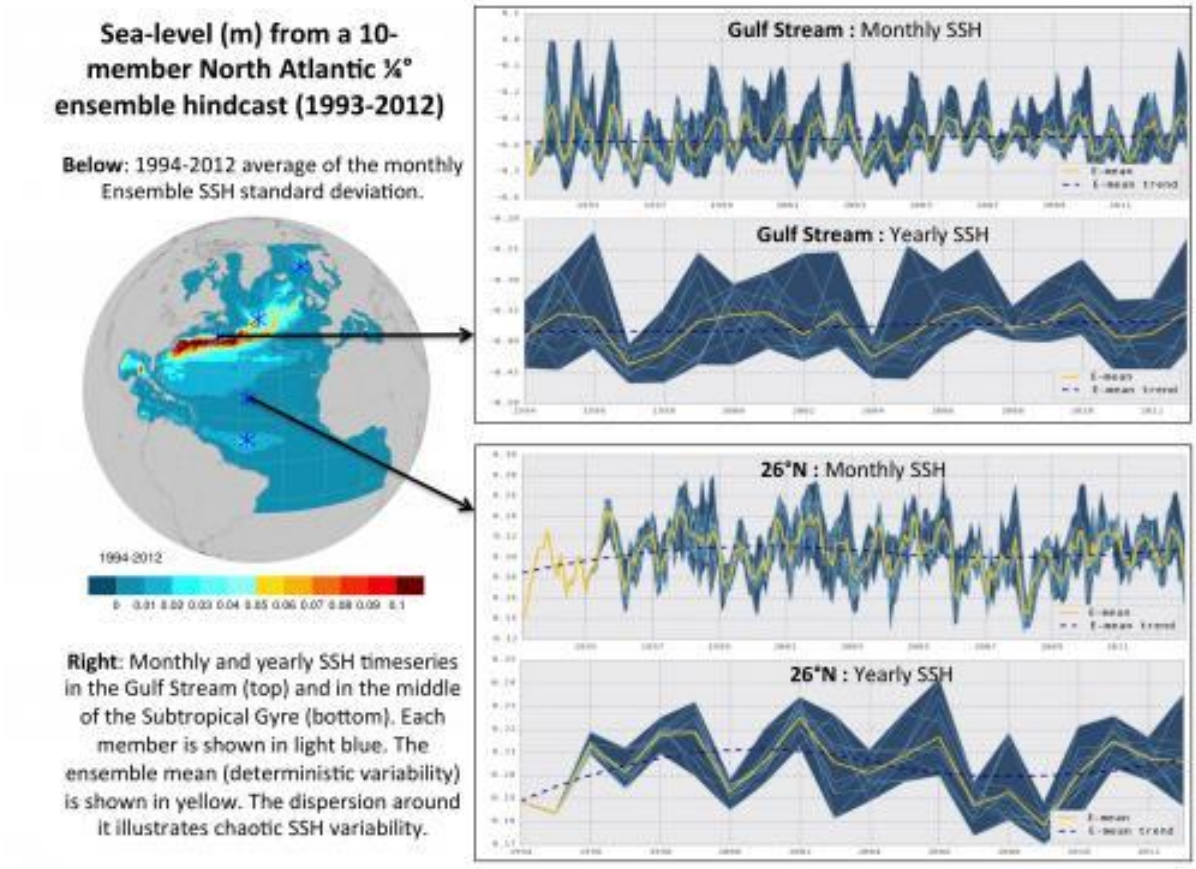
Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_017

Abstract:
Laminar Ocean General Circulation Models (2° to 1° resolution) used in recent climate projections are being progressively replaced by turbulent ocean models (about 1/4° resolution) in the perspective of the next CMIP exercise. Atmospherically-forced ocean simulations show that this resolution increase improves the physical consistency of simulations, but also allows the ocean to spontaneously generate a large variability up to multi-decadal timescales. Consistently with idealized studies, this low-frequency intrinsic variability (LFIV) is negligible in the laminar regime.

This oceanic LFIV has a stochastic character, a marked signature on sea-level variability and on the upper ocean temperatures in mid-latitude regions where air-sea heat fluxes are maximum in Nature. Global eddying ocean simulations analyzed in the framework of the current CHAOCEAN OST/ST project exhibit the strong, small- and large-scale imprints of this stochastic LFIV on several climate-relevant oceanic indices: sea-surface height (SSH) and temperature (SST) in western boundary current systems and the Antarctic Circumpolar Current, water masses at various depths, Meridional Overturning Circulation (MOC), etc.

How these low-frequency intrinsic variability modes are impacted, and may be paced, by the interannually-varying atmosphere is an important question for attributing and interpreting the observed low-frequency variability and long-term trends. The ongoing OCCIPUT ANR/PRACE project aims at investigating these questions probabilistically through a 50-member ensemble of 1/4° global ocean/sea-ice 57-year hindcasts, driven by the same 1958-present atmospheric forcing. Present results demonstrate that initial state perturbations spontaneously grow, cascade toward long space and time scales, and non-linearly saturate. The resulting ensemble spread is then modulated by the atmospheric forcing and oceanic nonlinearities ; it describes the atmospherically-paced stochastic LFIV (uncertainty), with marked imprints on oceanic variables at large space and time scales both at the surface (SST, SSH) and below (AMOC, mode/intermediate/deep water mass properties and depths, etc).

This ensemble experiment provides the first probabilistic description of the ocean state and evolution over the last decades, and a measure of the actual constraint exerted by the atmosphere on low-frequency ocean variability. Besides SSH, the imprint of this stochastic LFIV on upper-ocean thermal fields and AMOC will then provide insights into how this eddy-driven low-frequency oceanic “noise” might ultimately impact the atmosphere and climate predictability in future coupled climate projections.



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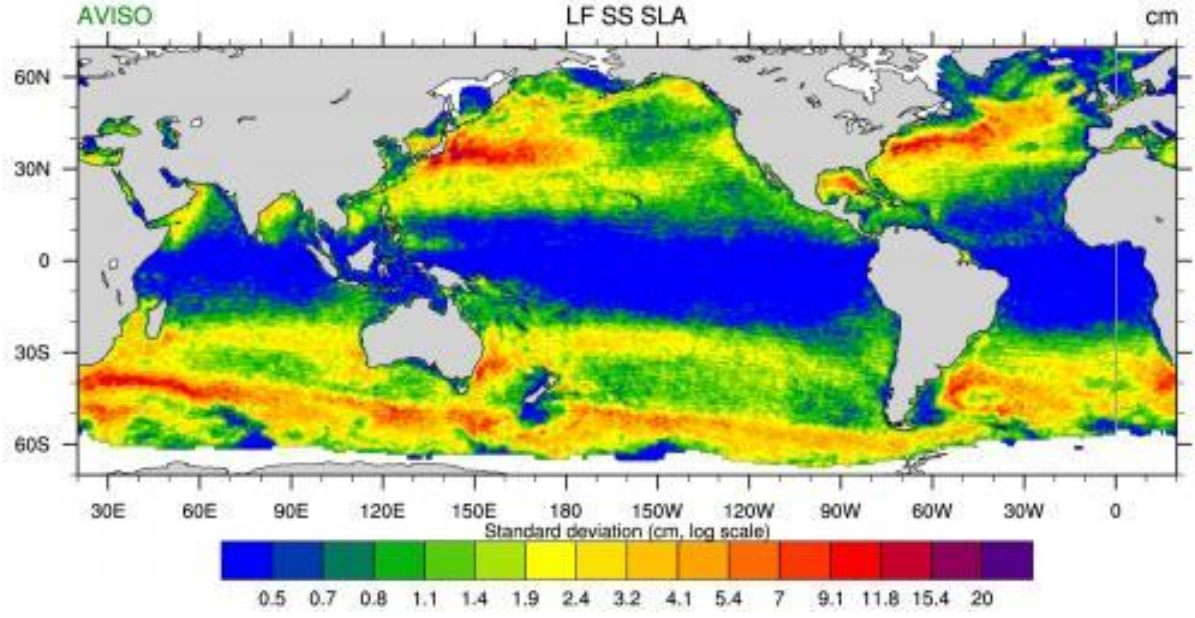
Which part of the low-frequency sea-level variability is purely due to intrinsic ocean processes ?

Guillaume Serazin (CNRS-LGGE/CERFACS, France) ; Thierry Penduff (CNRS-LGGE, France) ; Laurent Terray (CNRS-CERFACS, France) ; Bernard Barnier (CNRS-LGGE, France) ; Jean-Marc Molines (CNRS-LGGE, France)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_018

Abstract:
Altimetric observations are often interpreted by comparing them with Ocean General Circulation Model (OGCM) simulations in the turbulent regime, or with Coupled General Circulation Model (CGCM) simulations in which the ocean is generally laminar. Recent OGCM studies have highlighted that when the mesoscale is resolved, the ocean spontaneously generates erratic fluctuations causing strong low-frequency intrinsic sea-level variability over a wide range of spatial and temporal scales (Penduff et al. 2011, Sérazin et al. 2015) ; this nonlinear phenomenon is almost absent in the laminar regime, hence in most CGCM simulations. Using two eddying (1/4° and 1/12°) global OGCMs, we describe the imprint of this low-frequency intrinsic variability on three features of the oceanic circulation obversed by altimetry: interannual sea-level variance, regional sea-level trends, and Western Boundary Currents (WBCs) variability modes.
The interannual (i.e. from 1.5 to 20 years) small-scale (< 6°) intrinsic sea-level variance that spontaneously emerges under purely seasonal forcing is very comparable to that obtained in fully-forced hindcasts (i.e. with interannual forcing). These scales, which are the main contributor to low-frequency intrinsic variability, may be isolated in the 22-year record of altimetric data using a spatio-temporal filtering as done in Fig. 1. This low-frequency intrinsic variability also has a substantial imprint at larger scales (> 12°) and on the Atlantic Meridional Overturning Circulation (Gregorio et al., 2015).
The ocean spontaneously generates erratic sea-level fluctuations in eddy-active regions up to decadal-to-multidecadal timescales. This ocean-only variability has an imprint on observed regional sea-level trends, especially in the ACC and in the WBC areas. The truncation of this very low-frequency intrinsic variability in the current 22-year altimeter dataset yields an uncertainty in observed sea-level trends ; this eddy-induced uncertainty is actually comparable (and should be added) to that estimated from the Coupled Model Intercomparison Project 5 (CMIP5) simulations with laminar ocean models.
Finally, the spatial structure of the observed sea-level variability modes in WBCs, which is well simulated by our model with or without low-frequency forcing, is shown to be shaped by oceanic intrinsic processes. The temporal evolution of these spatial modes may be triggered by the low-frequency atmospheric forcing when present, leading to a longer memory than in the purely seasonally-forced case.



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A Probabilistic Description of the Mesoscale Eddy Field in the Ocean

Martin Scharffenberg (CEN - University of Hamburg, Deutschland) ; Stavroula Biri (CEN - University of Hamburg, Germany) ; Detlef Stammer (CEN - University of Hamburg, Germany)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_019

Abstract:
Global and regional probability density functions and higher statistical moments are analyzed for anomalies of the surface geostrophic velocity components inferred from the 3 year Jason-1 TOPEX/POSEIDON Tandem mission and for sea level anomalies (SLA) observed through the TOPEX/POSEIDON, Jason-1 and Jason-2 altimetric missions, together covering a 19 year period. Results are compared with those obtained from the AVISO 19 year, 1/3° gridded SLA space-time objective analysis, and associated geostrophic velocity anomalies. The study reveals that eddy variability appears to be Gaussian over most parts of the ocean, outside the influence of energetic current systems, and that specific flow regimes in the ocean can be identified through higher statistical moments of the flow field and SLA observations. However, the moment-ratio diagrams of skewness and kurtosis reveal that in energetic boundary currents the ocean does not follow Gaussian statistics, but rather behaves like an exponential distribution. Higher statitical moments of SLA and velocity anomalies do vary seasonally and thereby provide valuable information about the seasonal changes of the oceans' flow field.

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Mesoscale eddies in the North Atlantic subtropical gyre: 3D composite structure from satellite altimetry and Argo profile data

Angel Amores (International Pacific Research Center, University of Hawaii. Honolulu, Hawaii., United States) ; Oleg Melnichenko (International Pacific Research Center, University of Hawaii. Honolulu, Hawaii., United States) ; Nikolai Maximenko (International Pacific Research Center, University of Hawaii. Honolulu, Hawaii., United States)

Session: Science III: Large scale and global change ocean processes: the ocean's role in climate
Presentation type: Poster
Poster number: SC3_020

Abstract:
The mean vertical structure and transport properties of mesoscale eddies in the subtropical North Atlantic are investigated by combining historical records of Argo temperature/salinity profiles and satellite sea level anomaly data in the framework of the eddy tracking technique. The area of interest, defined as (55-19° W, 18-32° N), delineates the interior of the subtropical gyre and is generally characterized by low level of eddy kinetic energy. The mean sea level anomaly amplitude of eddies, used in the composite, is about 3 cm. Despite being relatively weak at the sea surface, the eddy signal is found to penetrate to at least 1200 m depth, which is clearly seen in the eddy-induced salinity anomalies at the depth of the Mediterranean outflow water. The analysis also reveals that the eddy vertical structure is strongly affected by the background stratification, leading to the variability in the eddy structure across the gyre. A common feature of all the eddy composites, reconstructed in different parts of the gyre, is the phase shift between the eddy temperature/salinity and velocity anomalies in the upper ~300 m layer, resulting in the transient eddy transports of heat and salt. The main effect of the eddies is shown to be transport of the excess of heat and salt out of the gyre. As an illustration, a box model of the near-surface layer is used to evaluate the role of mesoscale eddies in maintaining a quasi-steady-state distribution of salinity at the North Atlantic subtropical salinity maximum. The model shows that mesoscale eddies are able to provide between 20 and 40% of the freshwater flux into the area required to compensate for the local excess of evaporation over precipitation, the rest being delivered by the mean advection, vertical mixing, and other processes.

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Multi-altimeter observations of the Yukon River Alaska: Assessment of the determination of river discharge within this complex river system.

Charon Birkett (University of Maryland, United States) ; Bjerklie Dave (USGS, USA) ; Carabajal Claudia (Sigma Space Corp, USA)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_001

Abstract:
Both radar and laser altimetry can be utilized to monitor both water level variations and channel surface gradients for the largest river systems around the world. Here, we focus on the Yukon River, Alaska. Despite it's extent and complexity, and the issues of flooding, few US and Canadian gauges exist across the basin. Both standard (Jason-2, ENVISAT) and enhanced (SARAL, CRYOSAT-2) radar altimetry, and laser altimetry (ICESat-1), offers spatially and temporally varying measurements and multiple data sets allow for cross-validations. Here, we re-examine the performance of the various instruments with focus on tracking, acquisition, and elevation accuracy. We also discuss the merits of combining the data sets and look to their application with respect to the determination of river discharge. Applications are nationally based with basin hydrology, conservation, and hazards, as the main objectives.

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G-REALM: Investigating datum translations for integration of altimeter-derived operational water level products with in situ lake and reservoir gauge data.

Charon Birkett (University of Maryland, United States) ; OBrien Kate (UMD, USA) ; Beckley Brian (SGT, USA) ; Ricko Martina (SGT, USA) ; Holmes Simon (SGT, USA) ; Yang Hunter (SGT, USA)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_002

Abstract:
G-REALM is a NASA/USDA funded operational program offering water-level products for lakes and reservoirs as derived from the NASA/CNES and ESA/ISRO/CNES radar altimeter missions. The main stakeholder is the USDA/FAS though many other end-users utilize the products for a variety of interdisciplinary science and operational programs. While USDA analysts require relative lake level variations, there is a demand for products based on orthometric datums to more easily integrate the altimeter results into time series of archival (and often sporadic) gauge-based measurements. A recent G-REALM 10-day resolution product upgrade and expansion has allowed for more accurate lake level products and for a greater number of water bodies. The upgrade also introduces datum translation factors that enable the satellite measurements to be converted to WGS84 and various Geoid reference frames. Here, we discuss both the upgrade and the translation factors, assessing their accuracy via comparison with in situ data from around the world.
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Sea-ice and snow facies classifications from Altika data over the Polar Regions

Ngan Tran (CLS, France) ; Frédérique Rémy (LEGOS, France) ; Amandine Guillot (CNES, France) ; Nicolas Picot (CNES, France)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_003

Abstract:
Two sets of classification algorithms have been computed for Altika mission following developments performed previously for the Envisat altimetry mission. There is one specific algorithm for each polar region within each set. They take advantage of having both passive and active microwave sensors on the same platform with co-registered measurements.
The first set of algorithms concerns sea-ice. They detect sea-ice corrupted sea surface height data for oceanography applications, but also provide sea-ice type (i.e. first-year ice, multi-year ice, ambiguous ice observed during summer and mixture of types) for cryosphere studies. Their performances have been evaluated based on collocations between the along-track Altika data with daily grids of sea ice type from the Ocean and Sea Ice Satellite Application Facility (OSI SAF). Results show better performances for the present approach for recognition of sea-ice corrupted data vs. ice-free ocean data when one compares with those observed with the operational algorithm. Concerning the sea-ice extent monitoring, we obtain a good continuity with the Envisat time-series and a good agreement with other mission estimations.
The second algorithm aims to separate different snow regions within the polar ice sheets based on measured microwave signatures. Our approach broadens the description of the snow pack by taking into account characteristics such as surface roughness, grain size, stratification, and snow melt effects, whereas this latter has often been solely considered in most previous works. This difference in snow morphology is due to variable conditions in local climate which is governed by local topography. Such partition of the ice sheet might help to better understand relationships between microwave signatures and snow morphology and might represent a useful and simple tool for tracking the effects of climate change. Comparison with past Envisat results has been performed.
All these results come from the CNES PEACHI project.
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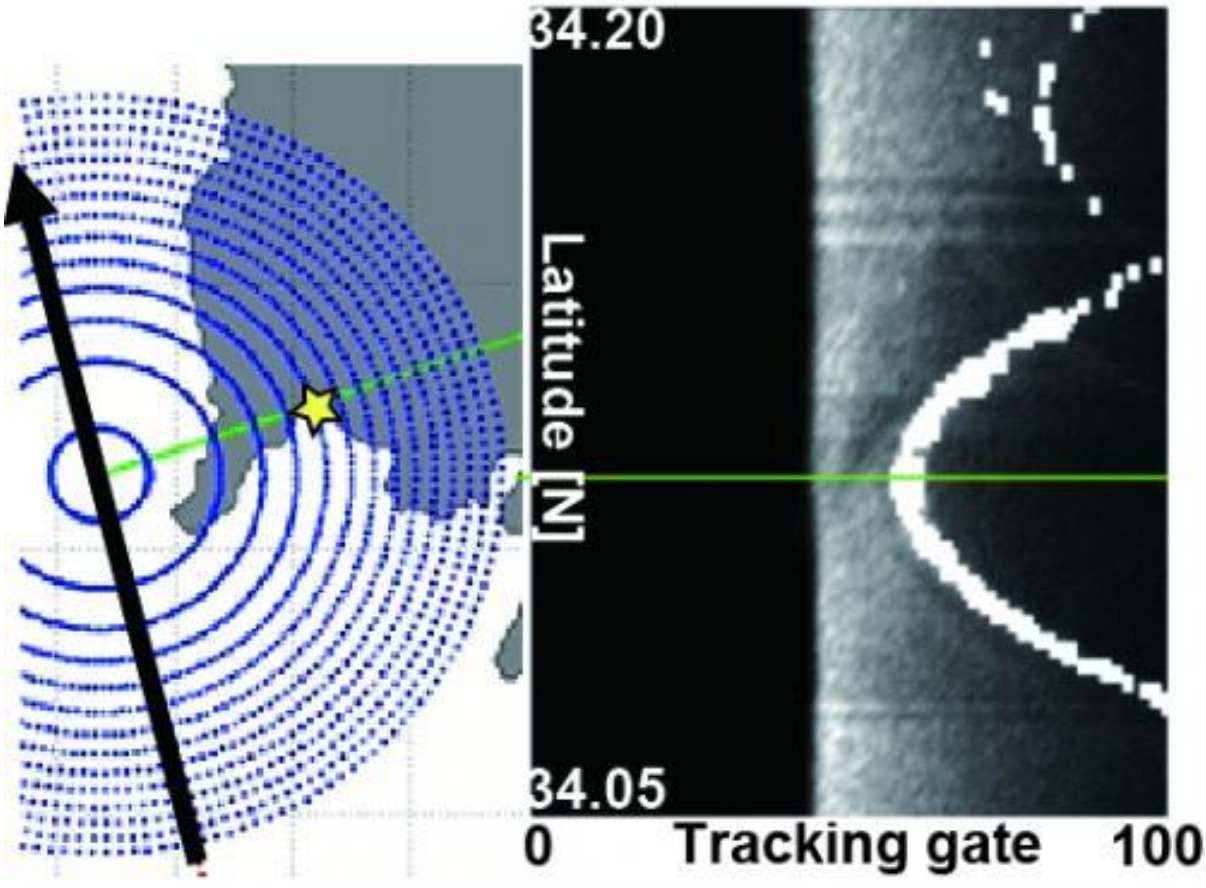
Retrieval of coastal sea surface height from along-track continuous AltiKa data

Xi-Feng Wang (ESST, Kyushu University, 日本) ; Kaoru Ichikawa (RIAM, Kyushu University, JAPAN)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_004

Abstract:
Waveforms of satellite altimeters are often contaminated in coastal areas by strong radar reflection from calm water in semi-closed bays or weak reflection from lands. Several algorithms have been proposed to retrieve the sea surface height (SSH) avoiding these contamination in a waveform, but such retrievals are independent for each single waveform and waveforms of the adjacent points have never been referred. In this study, along-track AltiKa 40 Hz data near Tsushima Island, Japan, are processed at once for each cycle to retrieve the coastal SSH accounting contamination in waveforms of the adjacent points. Since the reflection from a point source results in a parabolic shape in an echogram with latitude versus altimeter tracking gate, extremely strong echo values with parabolic shapes are first masked. For each tracking gate at each point, lost echo by land is roughly compensated based on the ratio of the land area in the altimeter's footprint ring, then the Brown model is fitted to each modified waveform. The retrieved SSH shows reasonable values with no abrupt changes along tracks.



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Leveling tide gauges with GNSS reflectometry

Alvaro Santamaría-Gómez (Université de La Rochelle / University of Tasmania, France) ; Christopher Watson (University of Tasmania, Australia)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_005

Abstract:
Traditional leveling serves as the primary technique used to assess the stability of tide gauges relative to the crust as well as to provide their ellipsoidal height by means of the vertical connection between the tide gauge zero and a nearby GNSS site.

The GNSS reflectometry (GNSS-R) technique provides valuable information related to the geometry and physical properties of the reflecting surfaces surrounding a GNSS antenna, including the vertical distance to them. Here, we use sea-surface reflections of GNSS signals, recorded as oscillations in the observed signal-to-noise ratio (SNR), to estimate the GNSS to tide gauge (TG) leveling connection. This can be done remotely, continuously and at no additional cost, yielding a possible alternative to traditional leveling surveys.

We present results of a leveling campaign conducted in Spring Bay, Australia, where comparison with traditional in situ leveling reveals promising differences at the millimeter level. These differences include errors from this technique, mainly due to the tropospheric refraction, but also errors related to the traditional in situ leveling (e.g., errors in the GNSS antenna calibration) and to the calibration of the TG zero. The latter opens the possibility of using this technique to monitor the stability of the TG zero.

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Study of altimetry precision error using GNSS-R

Rashmi Shah (Jet Propulsion Laboratory, United States) ; Cinzia Zuffada (Jet Propulsion Laboratory, USA) ; Maria-Paola Clarizia (University of Michigan, USA) ; Estel Cardellah (Institut de Ciències de l\'Espai, Spain)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_006

Abstract:
This study presents an analysis and comparison of the performance of different algorithms to estimate sea surface height from Global Navigation Satellite System Reflectometry (GNSS-R) data. It provides results from inter comparision of different GNSS-R simulators to generate synthetic realistic GNSS-R waveforms. These simulators are JPL's GNSS-R simulator which generates waveforms using semicodeless approach, CYclone Global Navigation Satellite System (CYGNSS) End-to-End Simulator (E2ES) which uses Global Positioning System (GPS) Coarse Aquisition (C/A) code to generate waveforms, and Spanish simulator which generated waveforms using interferometric approach. HALF algorithm is implemented and applied to synthetic data, and the achieved precision in the SSH for the different algorithms is assessed and compared. An analysis of data from TechDemoSat-1 (TDS-1) will also be conducted to retrieve sea surface height.

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Small scale sea level budgets in the North-Atlantic.

Marcel Kleinherenbrink (Delft University of Technology, Nederland) ; Riccardo Riva (Delft University of Technology, Netherlands)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_007

Abstract:
Time series of regional sea level budgets provide a better understanding of the causes for sea level variations as well as a better understanding of the errors of the measurement systems involved. This study therefore aims at closing the budgets in the North-Atlantic of 10x10 degree boxes using the Jason satellites, GRACE and the ARGO float network. Time series for altimetry are created using along-track data from the RADS database. A new averaging method is applied to altimetry data to overcome problems with conventional gridding (a large ground-track seperation at the Equator) and the latitude weighting (underweighting at high latitudes). Additionally, geographical dependencies of the intermission biases are considered. Using the full covariance matrices provided by CSR, GRACE solutions are statistically filtered to minimize hydrological leakage and reduce striping. The ARGO data are statistically interpolated to a grid with full variance-covariance matrices. For all three systems, the errors are propagated to provide time series of monthly averages over the considered region including formal error bars. We are able to close the budgets for most of the 10x10 degree boxes in the North-Atlantic.

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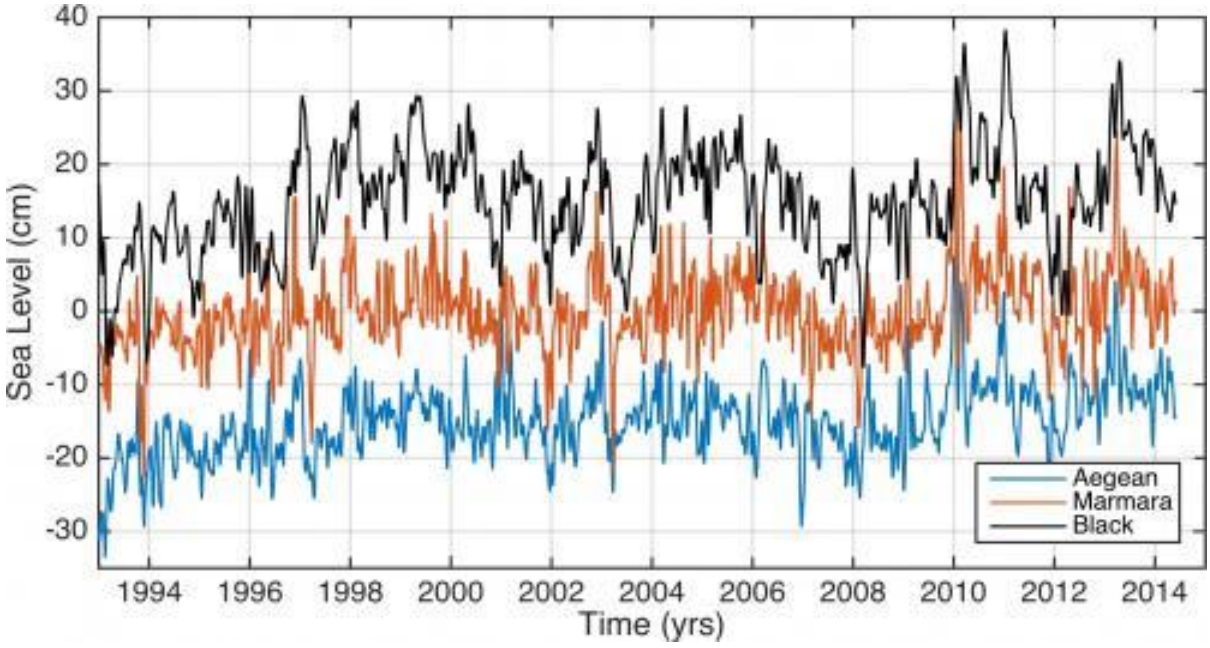
The response of the Black Sea to fluctuations of the Mediterranean sea level

Denis Volkov (CIMAS/University of Miami/NOAA-AOML, United States)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_008

Abstract:
The response of the Black Sea elevation to sea level changes in the eastern Mediterranean (Aegean Sea and Sea of Marmara) is studied using satellite altimetry data and a linear analytical model. We show that winds near the Strait of Gibraltar and over the Aegean Sea are able to dynamically change sea level in the Mediterranean and Black seas, respectively. The nonseasonal sea level in the Black Sea is coherent with that in the Aegean Sea and Sea of Marmara, but lags them by 10-38 days at sub-annual periods. The observed time lag is mainly due to friction that constrains the exchange through Bosphorus, and it represents the time required for the Black Sea level to adjust to locally and remotely forced changes of sea level in the Aegean Sea. On the other hand, no significant time lag is found between the Aegean Sea and the Sea of Marmara. The analytical model, employed in this study, is able to explain the amplitude and, to a large degree, phase of the response of the observed Black Sea elevation to sea level changes in the Sea of Marmara and Aegean Sea. The response is due to the barotropic flow through the Bosphorus Strait constrained mainly by friction. The geostrophic control is found to be important only at low and unrealistic friction. Using a realistic friction coefficient, we find that the magnitude of the response increases from 50 to 100% of the disturbance magnitude (10 cm) and the time lag increases from 17 to 25 days at period between 100 and 500 days. The inclusion of fresh water fluxes into the Black Sea in the model increases the magnitude of the response by about 5±1.5 cm, and the inclusion of the along-strait wind in the direction of the Black/Marmara Sea increases/decreases the magnitude of the response by about 1 cm at periods greater than 150 days. The phase of the response appears to be insensitive to both the wind stress and freshwater flux.



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Eddies and SST frontal variability in Eastern Boundary Currents

Renato Castelao (University of Georgia, United States)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_009

Abstract:
The majority of mesoscale eddies in the ocean have been shown to be highly nonlinear. This is important, because as such they are capable of trapping water in their interior as they propagate. By transporting momentum, heat, mass and the chemical constituents of seawater, they can contribute to water mass distributions and ocean biology. Here, we use satellite observations of sea surface height and sea surface temperature to specifically focus on the influence of eddies on the distribution of fronts in Eastern Boundary Currents. Previous studies have shown that the area near the coast with high frontal activity broadens during the upwelling season, and several mechanisms have been suggested to explain that phenomena. Satellite observations and idealized numerical model simulations are used to demonstrate that nonlinear eddies play an important role in that process. Model simulations are further used to investigate the influence of the coupling between eddies and winds on upwelling and SST frontal variability in Eastern Boundary Currents.
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Evaluating the performance of JASON and ENVISAT satellite altimeter missions at detecting prior errors in eddy-resolving ocean models.

Pierre Brasseur (CNRS/LGGE, France) ; Adeline Bichet (CNRS/LGGE, France) ; Jean-Michel Brankart (CNRS/LGGE, France) ; Pierre-Antoine Bouttier (CNRS/LGGE, France)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_010

Abstract:
In this poster we compare the capacity of different satellite missions at detecting prior simulation errors in ocean circulation models. The methodology used to quantify the gain in information brought by the satellite data flow is inspired from the Representer Matrix Spectrum (RMSpectrum) method (Le Hénaff et al. 2009). Given an assimilation system based on the Ensemble Kalman filter, the assessment is performed with the North Atlantic DRAKKAR configuration of NEMO version 3.4 from January 1, 2005 to June 30, 2006. The horizontal resolution is 1/4°, which is considered as eddy-permitting in the mid-latitudes (Candille et al., 2015). The impact of four observational networks (two JASON and ENVISAT satellites and two in situ ARGO measurements) is evaluated individually and together, on the free run ensemble as well as on the assimilated ensembles. Our results show that the gain of information brought by the satellite data is generally stronger and spatially more homogeneous than with ARGO, but that as compared to the satellites, ARGO brings additional information in the tropical Atlantic. We also show that assimilating two satellites at the same time brings quantitatively twice as much information as assimilating only one satellite, and that assimilating ARGO data in addition to the two altimetric data does not add a lot more information, as assimilating altimetric data already decreases considerably the ensemble spread.
Such evaluation methodologies enable a better understanding of the impact of different observational networks on assimilation systems, and thereby a better and objective design of future multi-mission satellite altimetry constellations.

Candille G., J.-M. Brankart, and P. Brasseur (2015). Assessment of an ensemble system that assimilates Jason-1/Envisat altimeter data in a probabilistic model of the North Atlantic ocean circulation. Ocean Science 11: 425-438.

Le Hénaff M., P. De May, and P. Marsaleix (2009). Assessment of observational networks with the Representer Matrix Spectra method – application to a 3D coastal model of teh Bay of Biscay. Ocean Dynamics 59: 3-20.

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Simple OSE of Argo using space-time scales statistically derived from altimeter data

Tsurane Kuragano (Meteorological Research Institute, 日本) ; Yosuke Fujii (Meteorological Research Institute, Japan) ; Masafumi Kamachi (Meteorological Research Institute, Japan)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_011

Abstract:
This study shows an application of altimeter data for observing system evaluation (OSE) of the Argo observation network especially for monitoring eddy-scale variation. At first, correlation scale of eddy-scale variations in space-time domain are statistically estimated from along-track sea level anomaly (SLA) data of the 20-year altimetry. Averaged seasonal variations, which sometimes overwhelm eddy signals, and global mean SLA trend are removed a priori from SLA data. Sea surface dynamic height anomalies (DHAs) from mean seasonal variation are derived from Argo temperature and salinity profile data.
DHA fields are obtained by an optimum interpolation (OI) based on the space-time correlation scales estimated from altimeter data. The DHA fields are compared with the SLA fields derived from the same OI applied to the along-track SLA data. The results show that the equatorial Kelvin waves and tropical instability waves are well captured by Argo floats (Figure 1). Eddies are also monitored effectively in the subtropical western North Pacific. The OI results of DHA do not agree well with those of SLA in the high latitudes.
A simple test of the space-time OI analysis shows that more than six data in the e-folding correlation scale, in which the correlation coefficient of ocean variation is above e-1, are required for the reliable analysis with 99% confidence level. Argo floats provide sufficient number of observations for the reliable analysis in the low latitudes and some areas in the North Pacific. Two to three times more Argo data would be required in most of mid-latitudes and much more in high latitudes for capturing eddy-scale variation.
The number of 3,000 Argo floats were considered insufficient to monitor small-scale eddies and rapidly propagating equatorial waves. However, the results show that the Argo floats provide significant information for analysis in the tropical region and for eddy-scale analysis in some other regions. The reason is that the space-time correlation adopted for the OI in this study represent realistic anisotropic feature, e.g. propagation feature of eddy signal, in space-time domain.

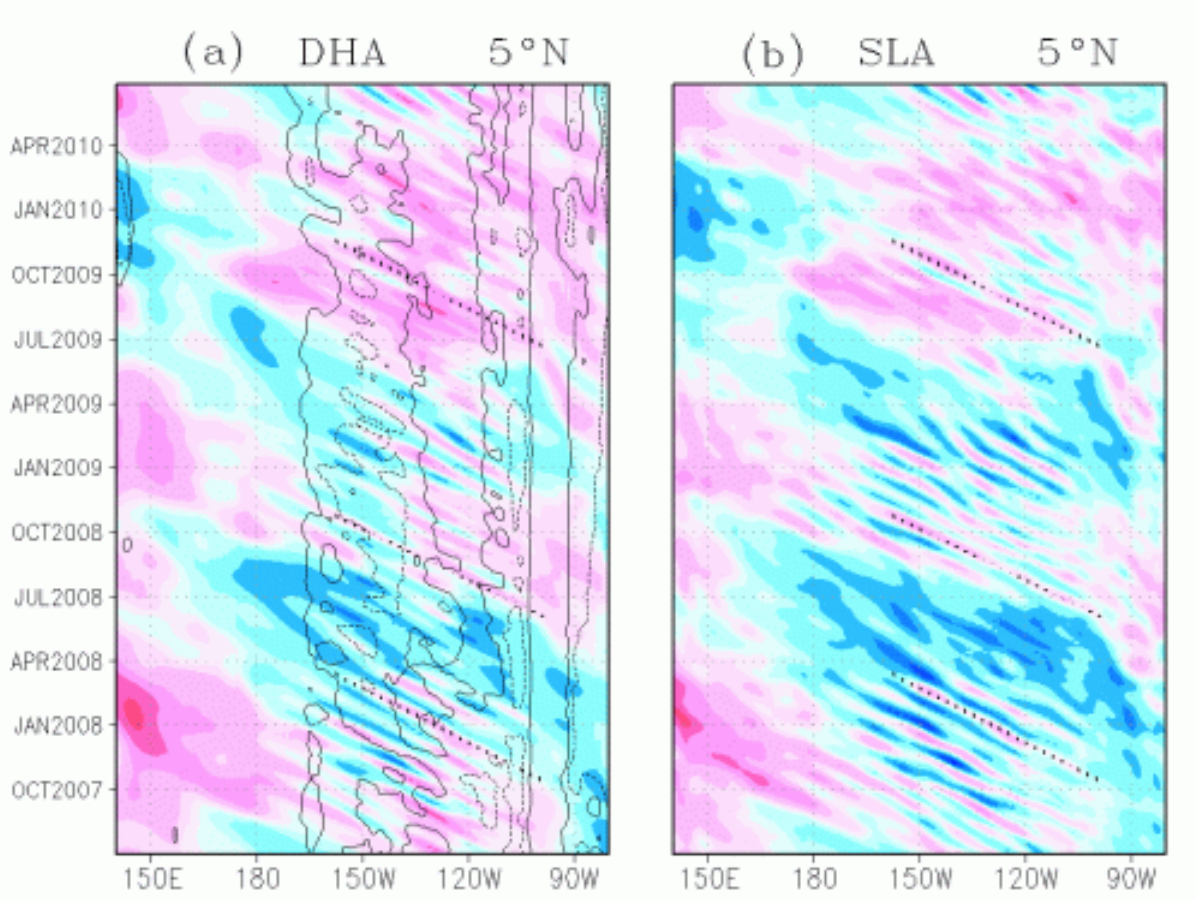

Figure 1. Time series of analyzed DHA (a) and SLA (b) along 5°N in the tropical Pacific. Bold dotted lines in the SLA panels indicate some of propagating signals detected by the SLA analysis, and the same lines are drawn in the DHA panels. Solid and thin broken contours in the DHA panels show the numbers of DHA data are six and two in the e-folding correlation scale, respectively.

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JPL Gridded Altimetry Products

Victor Zlotnicki (Jet Propulsion Lab, United States)

Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_012

Abstract:
JPL Gridded Altimetry Products

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Under NASA's "Making Earth System Data Records for Use in Research Environments" (MEaSUREs) program we are carrying out improvements to altimetry data, such as orbits, sea state bias, etc, in a collaboration between the Jet Propulsion Laboratory, Goddard Space Flight Center, U. South Florida, U. Colorado and U. New Hampshire. As part of this activity, we are generating a new set of altimetric grids. The alongtrack data for the T/P, J1, J2 series use the GSFC std1504 orbits computed at the Goddard Space Flight Center (with improvements to the gravity field, J!/J2 surface forces, station positions, and SLR/DORIS tracking. The std1504 gravity model includes 5x5 degree/order using stacked solutions of linear, annual, semi-annual terms estimated over two spans: 1993-2002, 2003-2014). GOT4.10 (GSFC Ocean+load) tide model, cross-track gradient correction based on slopes from DTU10 MSS, as well as GDR-D versions of the remaining corrections. For the 'other' satellite (ERS-1,2, Envisat, SARAL/AltiKa) we use R. Scharroo's RADS products, indicating the least squares gridding process that these have long wavelength errors and increased noise level; for near-real time AltiKa we use S. Desai's data product, crossover-adjusted to Jason-2. We currently use the same covariance functional form used in the Dibarboure/LeTraon series of papers and currently used by CLS/CNES, but with a newly-derived map of spatial zero-crossings of the covariance function (and its RMS), as well as a new, time-varying- set of propagation velocities computed directly from consecutive grids estimates without propagation. The maps are weekly, on a 1/6 degree grid. We evaluate the maps by withholding J1/J2 data for one day every so often and comparing the interpolated results with the withheld altimetric data; the final maps include all the data. We present results in terms of spectral content, RMS discrepancy and other quality measures. Contact: victor.zlotnicki[at]jpl.nasa.gov

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Detection of ocean white-capping by combined use of Jason radiometer and radar datasets alongside global wave model predictions

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Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_013

Abstract:
It is common knowledge that ocean microwave radiometer measurements of brightness temperature are sensitive to sea foam produced as waves break with increasing wind speed. But this phenomenon coexists with thermal emission variations due to a changing surface geometry and overlying atmosphere, the former also closely linked to changes in wind waves. Thus empirical or simple additive models remain the primary approaches to estimate some measure of whitecap surface coverage (percentage) as well as foam thickness or active vs. passive breaker information from ocean radiometer surface emissivity measurements. A recent example is the use of WindSat off-nadir radiometer data at 10 and 37 GHz to produce an empirical measure of these parameters. This project has similar objectives but will make use of coincident multi-frequency radar and radiometer data onboard the Jason platforms. The clearest potential advantage for this near nadir combination comes in the very different impact of geometry and foam on these passive and active sensors for the same surface during wave breaking onset and development; this for moderate to high wind speeds of 7-20 m/s. Analyses will make use of metoc buoy measurements and global wave model (WAVEWATCH 3) data to provide underlying measures wind as well as the degree of expected wave steepness and breaking.

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The Geosat 30th Anniversary Data Set

John Lillibridge (NOAA Lab. for Satellite Altimetry, United States) ; Eric Leuliette (NOAA Lab. for Satellite Altimetry, USA) ; Frank Lemoine (NASA/GSFC, USA) ; Nikita Zelensky (SGT, USA) ; Brian Beckley (SGT, USA) ; Remko Scharroo (EUMETSAT, Germany) ; Walter Smith (NOAA Lab. for Satellite Altimetry, USA)

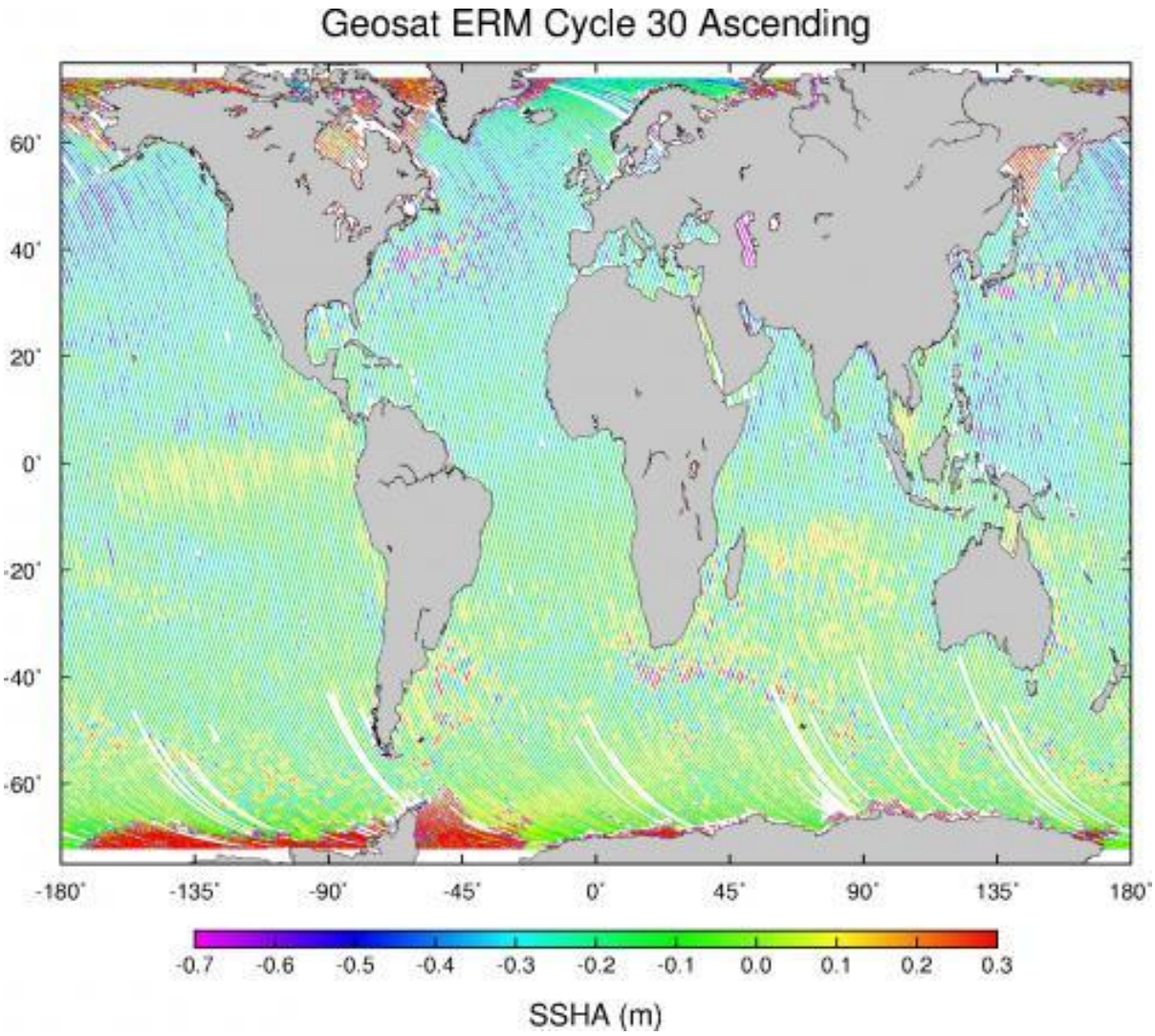
Session: Others (poster only)
Presentation type: Poster
Poster number: OTH_014

Abstract:
The U.S. Navy's Geosat mission yielded the first multi-year high-precision radar altimetry data set, and provides the only global sea surface height measurements from the late 1980s. NOAA has produced several versions of the Geophysical Data Records (GDRs) for the mission, with the most recent data release in 1997. This was the first set of GDRs that spanned both the Geodetic Mission (GM: March, 1985 to September, 1986) and Exact Repeat Mission (ERM: November, 1986 to December, 1989).

In April, 2009 we concluded a major data archaeology effort to recover the original Sensor Data Records (SDRs) for the ERM from 9-track tapes. After the SDRs are combined with their companion Waveform Data Records (WDRs) it is possible to retrack the original radar echoes, yielding an improved level-2 data set. This had previously been done for the GM in 2004, and has now been completed for the ERM as well.

This poster describes the steps involved in assembling the full GM+ERM retracked altimetry data set. A major enhancement involves the calculation of precise orbits based on the latest gravity models, terrestrial reference frames, and Doppler station coordinates, with improved Vienna Mapping Function atmospheric refractions. The best possible geophysical corrections are provided, along with the retracked sea surface heights, including GOT4.8 tide models, ECMWF tropospheric corrections, NIC09 climatological ionospheric corrections, and a new sea state bias model.

Ultimately our hope is to extend the altimetric sea level climate data record back to 1985, with the inclusion of these retracked Geosat measurements. Validation via the global tide gauge network from the late 1980s will allow us to assess the accuracy of the sea level trends observed by Geosat.



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