2007
Ocean Surface Topography
Science Team Meeting

Wrest Point
Hobart, Tasmania, Australia

March 12-15 2007

cover image (NASA World Wind):
Tasmania from an altitude of 1336km

Contents

2007 Ocean Surface Topography Science Team
Agenda

Sunday, March 11

17:00 -19:00 Registration, upload presentations, and icebreaker
Wrest Point Conference Centre – Exhibition Foyer

Monday, March 12

9:00 Welcome – (D. Griffin and L.-L. Fu) Wrest Point Conference Centre – Plenary Hall
Official opening (His Excellency the Honourable William Cox AC RFD ED, Governor of Tasmania)
9:10 N. Smith (BMRC)
9:20 A. McCrindell (RAN)
9:30 Meeting Overview (L-L. Fu and D. Griffin)
9:40 NASA Program (E. Lindstrom)
9:55 CNES Program (E. Thouvenot)

10:10 Break

10:30 CNES Jason-1 Status (S. Coutin-Faye/CNES)
10:50 NASA Jason-1 Status (G. Shirtliffe/NASA)
11:10 Jason-1 GDR reprocessing and SALP status (N. Picot/CNES)
11:30 OSTM/Jason-2 mission status (J. Perbos/CNES, P. Vaze/NASA, W. Bannoura/NOAA, F. Parisot/EumetSat)
12:00 Splinter session overview
12:30 Lunch

14:00 Science talks I (Chair: K. Kelly) – Plenary Hall
Global observations of westward energy propagation: Rossby waves or nonlinear eddies? - D. Chelton
Eddy-Mean Flow Interaction: Insights from Satellite Altimetry Measurements – B. Qiu

15:00 Poster session and refreshments
Wrest Point Conference Centre – Exhibition Foyer and Tasman Room

17:30 OSTST adjourn.
International Altimetry Service meeting – Tasman room

Tuesday, March 13

8:30 Science talks II (Chair: S. Nerem)
Understanding sea-level rise - J. Church
Observing decadal variability in the oceans – D. Roemmich

9:30 Splinter sessions I
Local and global calibration/validation (P. Bonnefond, S. Nerem, B. Haines) – Plenary Hall
Outreach (V. Rosmorduc, M. Srinivasan) – Tasman A

10:30 Break

11:00 Splinter sessions I continue

12 :30 Lunch

14:00 Science talks III (Chair: S. Arnault)
Seasonal to Interannual Variability of Global Sea Level: Recent Progress in Monitoring and Prediction – T. Busalacchi
Large-scale subseasonal sea level variability over the global ocean **–** R. Ponte

15:00 Break

15:30 Status of other on-going and future altimetry missions
15:30 Altika/SARAL project status (J. Noubel)
15:50 WaTER/Hydrosphere Mapper (L-L Fu)
16:10 ESA Programs (J. Benveniste)
16:30 Jason-3 status (S. Wilson/ F. Parisot)

17:00 Adjourn

17:45 Buses depart for Reception at Government House
19:30 Harbor cruise/dinner

Wednesday, March 14

8:30 Science talks IV (Chair: Y. Chao)
Combining ocean velocity observations and altimeter data for OGCM verification – P. Niiler
Ocean Surface Topography Applications to Circulation Mapping in the Coastal Ocean – W. Emery

9:30 Splinter sessions II

Sea-state bias and re-tracking analysis (P. Callahan, O. Zanife) – Plenary Hall
Precision orbit determination and geoid (J-P. Berthias, J. Ries) – Tasman A

10:30 Break

11:00 Splinter sessions II continue

12:30 Lunch

14:00 Science talks V (Chair: F. Lyard)
Internal Tides, Tides in Shallow Seas, and Altimetry – G. Egbert
Monitoring terrestrial surfaces waters by satellite – A. Cazenave

15:00 Poster session and refreshments
16:30 Splinter sessions III

Local and global calibration/validation, part 2 (P. Bonnefond, S. Nerem, B. Haines) – Plenary Hall
Precision orbit determination and geoid, part 2 (J-P. Berthias, J. Ries) – Tasman A
Multi-satellite/operational applications (G. Jacobs, C. Birkett, P. Oke) – Tasman B

18:00 Adjourn

18:30 Conference dinner (Royal Tasmanian Yacht Club - 800m NW along waterfront)

Thursday, March 15

8:30 Science talks VI (Chair: D. Griffin)
Ocean state estimation for studies of climate variability – T. Lee
Operational applications of altimetry – E. Dombrowski

9:30 Splinter sessions IV
Tides and high-frequency aliases (R. Ray, R. Ponte, F. Lyard) – Plenary Hall
Multi-satellite/operational applications, part 2 (G. Jacobs, C. Birkett, P. Oke) – Tasman A

10:30 Break

11:00 Splinter sessions IV continue

12:30 Lunch

14:00 Summary of splinter sessions

15:00 Break

15:30 Summary of splinter sessions

16:30 Discussion and wrap-up

17:00 Adjourn

Tuesday a.m. splinter agendas

Local and global calibration/validation – Plenary Hall

P. Bonnefond, S. Desai, B. Haines, S. Nerem and N. Picot

0930	P. Bonnefond	**Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica**
0945	B. Haines	**Monitoring Jason-1 and T/P from a California Offshore Platform: Latest Results from Harvest**
1000	C. Watson	**In-situ calibration at the Bass Strait site, Australia**
1015	G. Jan	**Altimeter sea surface height regional calibration with in-situ network**
1030	**BREAK**	
1045	G. Mitchum	**Improved comparisons of altimeter sea surface heights and tide gauge sea levels**
1100	W. Bosch	**Multi-mission cross calibration for contemporary altimeter systems – results with upgraded data**
1115	M. Ablain	**Global Statistical Quality Assessment of Jason-1 data**
1130	M. Ablain	**Jason-1 - TOPEX/Poseidon consistency**
1145	Y. Faugere	**Jason-1 / Envisat Cross-calibration**
1200		**Short introductions to posters**
1230	**LUNCH**	

Outreach – Tasman A

V. Rosmorduc and M. Srinivasan

0930	V. Rosmorduc	**Overview & Past/Future Activities**
0945	V. Rosmorduc	**Basic Radar Altimetry Toolbox & Tutorial**
1005	R. Stewart	**New Material for Teaching Oceanography**
1020	M. Srinivasan	**Ocean Altimetry Data: Operational Users and Applications**
1030	**BREAK**	
1100	A. Richardson	**Supporting Ocean Literacy: JPL Ocean Surface Topography (OST) Education and Public Outreach Activities for 2007-2008**
1115	R. Sullivant	**Ocean Altimetry: Anticipating News and Public Interest**
1130	S. Zicus	**Climate Change, Sea Level Rise and the Polar Regions: Using visuals to promote public understanding**
1200	All	**Showcase of SWT outreach "products”**
1230	**LUNCH**	

Wednesday a.m. splinter agendas

Sea State Bias and Retracking Analysis – Plenary Hall

P. Callahan and O. Zanife

0930	D. Vandemark, H. Feng, N. Tran, B. Chapron, B. Beckley	**Inclusion Of Wave Modeling In Sea State Bias Correction Refinement**
0950	E. Rodriguez, P. Callahan, T. Lungu	**Cross Calibration Of TOPEX And Jason Using MAP And LSE Retracking To Improve Global Sea Level**
1010	P. Thibaut, S. Labroue, N. Granier	**Evaluation Of Ground Retracking Algorithms On Jason Data**
1030	**BREAK**	
1100	Y. Faugere, A. Olivier, P. Thibaut, G. Dibarboure, N. Picot, J. Lambin	**Analysis Of The High Frequency Content Of Jason-1, Topex And Envisat Data**
1120	S. Labroue, M. Ablain, J. Dorandeu, N. Tran, P. Gaspar, O.Z. Zanife	**Comparison Of Topex And Jason-1 Sea State Bias Models**
1140	**Discussion:** Do retracking approaches show reduction in SSB? What is the approach to aligning TOPEX and Jason data? What error model should be used with the corrected data?	
1200	**LUNCH**	

Precision Orbit Determination and geoid – Tasman A

J.P. Berthias and J.Ries

Time	Authors	Title
0930	J.-P. Berthias	**Introduction: Status of Pending Actions and Key Issues**
0945	L. Cerri	**Jason-1 POD Reprocessing at CNES: Current Status and Further Developments**
1000	L. Cerri, J.-P. Berthias	**Toward an Operational Implementation of Atmospheric Gravity For Jason-1**
1015	W. Bertiger, B. Haines	**Precision Orbit Determination, Trade Studies and Improvements for Jason-1 with GPS**
1030	**BREAK**	
1100	F. Lemoine	**Improvement of the Complete TOPEX and Jason Orbit Time Series: Current Status**
1115	P. Bonnefond	**Validation Activities for Jason-1 and Topex/Poseidon Precise Orbit**
1130	J. Ries	**Orbit Error Budget for Jason-1 and Topex/Poseidon Precision Orbits**
1145	Ch. Foerste	**On the use of Temporal Gravity Field Models Derived from GRACE for Altimeter Satellite Orbit Determination**
1200	P. Willis	**Validation and Extension of ITRF2005 for DORIS POD**
1215	J. Ries	**Validation and Extension of ITRF2005 for SLR POD**
1230	**LUNCH**	

Wednesday p.m. splinter agendas

Local and global calibration/validation: part 2 – Plenary Hall

1630	S. Brown	**Calibration and Performance Assessment of the JMR and TMR**
1645	S. Desai	**Validation of the TMR and JMR Wet Path Delay Measurements using GPS, SSM/I, and TMI**
1700	E. Obligis	**The wet tropospheric correction for altimetry in coastal and inland water regions**
1715	J. Tournadre	**Modification of Jason rain flag for MLE4 Processing**
1730		**Discussions/Synthesis**
1800	**ADJOURN**	

Precision orbit determination and geoid, part 2 – Tasman A

Time	Authors	Title
1630	**Discussion**	**Key POD Issues: ITRF2005 implementation, time variable gravity, other model recommendations**
1700	J. Ries	**GRACE Mission Status and Current Results**
1715	R. Biancale	**EIGEN5 activities at GFZ and GRGS**
1730	X. Deng	**Assessment of Geoid Models off Western Australia Using Oceanographic In-Situ Measurements**
1745	M.-H. Rio	**Ocean Mean Dynamic Topography from Altimetry and GRACE: Toward a Realistic Estimation of the Error Field**
1755	**Discussion**	**Remaining Geoid Issues**
1800	**ADJOURN**	

Multi-satellite/operational applications – Tasman B

G. Jacobs, C. Birkett, P. Oke

1630	J. Wilkin	**Predictability of Mesoscale Variability in the EAC given Strong Constraint Data Assimilation**
1645	D. Griffin	**Explaining the extraordinary: operational oceanography in Australia**
1700	P. Oke	**The Bluelink Ocean Data Assimilation System: an ensemble approach to an eddy-resolving application**
1715	G. Brassington	**Bluelink> ocean model analysis and prediction system delivering operational forecasts**
1730	A. Hobday	**Near real-time spatial management for a longline bycatch species based on sea surface topography and temperature observations**
1745	J. Verron	**AltiKa: a Ka-band altimetry system in tandem with JASON-2**
1800	**ADJOURN**	

Thursday a.m. splinter agendas

Tides and High-Frequency Aliases – Plenary Hall

R. Ray, R. Ponte, F. Lyard

0930	R. Ray	**Comments on sun-synch altimetry**
0950	J. Dorandeu	**Comments on sun-synch altimetry**
1010	L. Fu/R. Ray	**General discussion on sun-synch altimetry**
1030	**BREAK**	
1100	F. Lefevre	**Improvements to FES2004**
1115	R. Ray	**New tide validation dataset**
1120	L. Carrere	**Improvements to MOG2D**
1135	R. Ponte	**Baroclinic data-constrained models and HF correction**
1145	R. Ponte	**Update on surface pressure errors**
1150		**General discussion and recommendations**
1210	C. Maraldi	**Tides in South Indian Ocean**
1220	C.K. Shum, X Wang	**Coastal tide modeling**
1230	**LUNCH**	

Multi-satellite/operational applications, Part 2 – Tasman A

0930	Y. Chao	**Development, Implementation and Evaluation of a Real-Time Ocean Forecasting System off the California Coast**
0945	G. Lagerloef	**Combining altimeter-derived currents with Aquarius salinity to study the marine freshwater budget**
1000	P. Queffeulou	**Merging wave height measurements from altimeters. Application to the investigation of large scale and regional features of sea state.**
1015	J. Lefevre	**Wave Model Error Analysis from Altimetry**
1030	**BREAK**	
1100	J. Dorandeu	**Future altimeter systems: is the mesoscale observability good enough for operational oceanography?**
1115	G. Larnicol	**Quality of real time altimeter maps: impact of data delay**
1130	J. Bouffard	**Improved satellite altimetric data dedicated to coastal areas: Validation over the northwestern Mediterranean**
1145	J. Tournadre	**Effect of rain and cloud on Ka band (ALTIKA) altimeter data**
1200	N. Steunou	**Impacts of atmospheric attenuations on AltiKa expected performances**
1215	J. Alpine	**Moveable Feasts: The Eddy and the Marine Protected Area?**
1230	**LUNCH**	

Posters
Outreach

OUT-1 Outreach products showcase

Sea State Bias and Re-Tracking analysis

SSB-1 TOPEX Retracked GDR – Features and Statistics
Philip S. Callahan, Ernesto Rodriguez, Ted Lungu

SSB-2 A New Altimeter Waveform Retracking Algorithm Based On Neural Networks
Arnaud Quesney, Eric Jensou, Juliette Lambin, Nicolas Picot

SSB-3 Unsupervised Classification Of Altimetric Waveform Over All Surface Type
Arnaud Quesney, Eric Jeansou, Christian Ruiz, Nathalie Steunou, Bruno Cugny, Nicolas Picot, Jean-Claude Souyris, Sylvie Thiria, Mustapha Lebbah

SSB-4 Sigma0 Blooms In The Envisat Radar Altimeter Data
Pierre Thibaut, F. Ferreira, Pierre Femenias

SSB-5 Simulator Of Interferometric Radar Altimeters: Concept And First Results
Pierre Thibaut, Olivier Germain, Fabrice Collard, Bruno Picard, Laurent Phalippou, Christopher Buck

Tides and High-Frequency Aliases

TID-1 A Tidal Model in the Northwest Atlantic
Guoqi Han, Shastri Paturi, Brad de Young, Yuchan Yi, C.K. Shum

TID-2 An M3 Tidal Resonance in the Great Australian Bight
Richard Ray

TID-3 The influence of stratification on semidiurnal tides in Monterey Bay, California
Xiaochun Wang, Yi Chao, Changming Dong, James C. McWilliams, Jeffrey D. Paduan, Leslie K. Rosenfeld, C. K. Shum, Yuchan Yi

Local and global calibration/validation

CV-1 Preparing for the additional errors on wide-swath altimetry: precise roll error reduction
Michael Ablain, G.Dibarboure, S.Philipps, J.C.Souyris

CV-2 Global Statistical Quality Assessment of Jason-1 data.
M. Ablain, S. Philipps, J. Dorandeu, N. Picot

CV-3 Jason-1 - TOPEX/Poseidon consistency.
M. Ablain, S. Philipps, J. Dorandeu, N. Picot

CV-4 Assessment of Recent Revisions to the TOPEX/Jason-1 Sea Surface Height Time Series
Brian Beckley, N.P. Zelensky, G. Mitchum, F.G. LeMoine, S.B. Luthcke, R.D. Ray, P.S. Callahan, S. Desai, A. Labroue, N. Tran

CV-5 Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica
Bonnefond, P. Exertier, O. Laurain, Y. Ménard, F. Boldo, E. Jeansou, G. Jan

CV-6 Improving of High quality data of coastal altimetric measurements
Dorothée Coppens, S. Bijac, P. Prunet, E. Jeansou

CV-7 Jason-1 / Envisat Cross-calibration.
Y. Faugere, J. Dorandeu, N. Granier, A. Ollivier, N. Picot

CV-8 Suggestion of a common exercise for in situ CalVal and data consistency
Gwenaele Jan, P. Bonnefond, Y. Ménard, O. Laurain

CV-9 Monitoring of altimeter measurements against a global tide gauge network
Fabien Lefevre, the CLS CalVal team

CV-10 Sea Surface Determination Experiences in the Ibiza Island
Juan Jose Martinez-Benjamin, Jose Martin Davila, Jorge Garate, Pascal Bonnefond, Marina Martinez-Garcia, Miquel Angel Ortiz, Gema Rodriguez-Velasco, Begoña Perez ; the IBIZA2003 Team

CV-11 New CGPS Reference Station at l'Estartit for Sea Level Monitoring
Marina Martinez-Garcia, Miquel Angel ortiz, Roman Leckzinsky, Juan Jose Martinez-Benjamin

CV-12 Absolute calibration of the Jason-1 altimeter by ship-buoy GPS cruise along the Drake passage
Stavros Melachroinos, Biancale R., P. P. Sundaramoorthy, Faillot M., Menard Y.

CV-13 Feasibility of an accurate wet tropospheric correction for the CRYOSAT mission
Franck Mercier, E. Obligis, J. Dorandeu, P. Schaeffer

CV-14 An Assessment of Jason GDR-Bs for Monitoring Long-Term Sea Level Change
R. S. Nerem, G. Mitchum, D. P. Chambers, J. Choe, E. Leuliette

CV-15 The Envisat/MicroWave Radiometer five years after launch: Drift correction, new in-flight calibration and consistent retrieval algorithm
Estelle Obligis, L. Eymard, S. Labroue

CV-16 JASON-1 Absolute Calibration Results from the Eastern Mediterranean GAVDOS Project
Erricos C. Pavlis, Stelios P. Mertikas

CV-17 X-track, a new processing tool for altimetry in coastal oceans.
Laurent Roblou, G. Jan, J. Bouffard

Precision orbit determination and geoid

POD-1 A 4-year Series of Earth Mass Changes Derived from GRACE and LAGEOS data
Richard Biancale, J.-M. Lemoine, S. Loyer, S. Bruinsma, F. Perosanz, G. Balmino

POD-2 Validation Activities for Jason-1 and Topex/Poseidon Precise Orbits
Pascal Bonnefond, P. Exertier, O. Laurain, P. Berio and D. Coulot

POD-3 Evaluation of Orbits for the WATER Hydrosphere Mapper Mission
Don Chambers, Richard D. Ray, John C. Ries

POD-4 Toward EIGEN-05: Global Mean Gravity Field Models from Combination Of Satellite Mission and Altimetry/Gravimetry Surface Data
Christoph Foerste, F. Flechtner, R. Schmidt, R. Koenig, Ul. Meyer, R. Stubenvoll, M. Rothacher, F. Barthelmes, H. Neumayer, R. Biancale, S. Bruinsma, J.-M. Lemoine, S. Loyer

POD-5 New Mean Sea Surface DNSC07
Per Knudsen, Ole Andersen

POD-6 Evaluation of the Geosat and Geosat Follow-On Precise Orbit Ephemeris
Frank Lemoine, Nikita P. Zelensky, Brian D. Beckley, Douglas S. Chinn, David. D. Rowlands, John L. Lillibridge, Remko Scharroo, Walter H.F. Smith

POD-7 Jason 1 GPS Processing at CNES
Flavien Mercier, Luca Cerri, Sabine Houry, Pascal Perrachon, Jean-Paul Berthias

POD-8 Ocean Mean Dynamic Topography from altimetry and GRACE: Toward a realistic estimation of the error field
Marie Helene Rio, Philippe Schaeffer, Jean-Michel Lemoine, Gilles Larnicol

POD-9 Validation and Extension of ITRF2005 for DORIS and SLR POD (DPOD2005 and LDPOD2005)
Pascal Willis, J.C. Ries, F.G. Lemoine, E.C. Pavlis, L. Soudarin, N. Zelensky

Multi-satellite/operational applications

MSO-1 Near Real Time Monitoring of Global Lakes and Reservoirs
Charon Birkett, Brian Beckley, Brad Doorn and Curt Reynolds

MSO-2 Seadatanet, a pan-european infrastructure for ocean & marine data management
Frederique Blanc, Olivier Lauret, Nicolas Picot and Seadatanet partners

MSO-3 A view from multi-mission satellite altimetry over the coastal ocean: application to the Ligurian Sea and the Corsica Channel
Jérôme Bouffard, S. Vignudelli, P. Cipollini, F. Lyard, G. P. Gasparini, F. Birol

MSO-4 SSALTO/DUACS : Daily multi-mission products for global and regional applications
Joel Dorandeu, G. Dibarboure, N. Picot, P.-Y. Le Traon

MSO-5 Future altimeter systems : is the mesoscale observability good enough for operational oceanography?
Joel Dorandeu, P. Escudier , G. Dibarboure

MSO-6 Mediterranean water mass budget variations: revisited
David García, Benjamin F. Chao, Isabel Vigo

MSO-7 Generation of DEMs for the new tracking mode onboard Poseidon-3 and AltiKa
Jerome Helbert, G. Moreaux, Ch. Ruiz, J. Lamouroux, E. Jeansou, J.-D. Desjonquères, G. Carayon, N. Steunou, P. Sengenes, J. Noubel, J.-F. Crétaux, M.-C. Gennero

MSO-8 Validation in operational oceanography at the global scale in the GODAE and MERSEA framework : Overview of the Mercator Global Operational system assessment
Fabrice Hernandez, Ali Belmadani, Laurence Crosnier, Marie Drevillon and Eric Dombrowsky

MSO-9 Power spectral parameterizations of error as function of resolution in gridded altimetry maps
Alexey Kaplan, Mark A. Cane, Dake Chen

MSO-10 Control of a free-surface barotropic model of the Bay of Biscay by assimilation of multi-source sea-level data (altimetry and tide-gauges) in presence of atmospheric forcing errors
Julien Lamouroux, Pierre de Mey, Florent Lyard, Eric Jeansou

MSO-11 Design of the future altimetry missions: a first prototype of an « end-to-end » mission simulator
Julien Lamouroux, Laurent Roblou, Juliette Lambin, Pierre De Mey, Florent Lyard and Eric Jeansou

MSO-12 Quality of real time altimeter maps: impact of data delay
Gilles Larnicol, Ananda Pascual, Christine Boone, Pierre-Yves Le Traon

MSO-13 A method for estimating representation error of oceanic observations
Peter Oke, Pavel Sakov

MSO-14 Ocean Surface Topography Data at the JPL Physical Oceanography DAAC
Kelly L. Perry, Patricia K. Liggett

MSO-15 AltiKa : a new concept of altimeter for the SARAL mission
Nathalie Steunou, P. Sengenes, J. Noubel, B. Durand, F. Robert, J. Verron

MSO-16 Impact of multisatellite altimetric missions on the Tropical Atlantic circulation from some Observing Systems Simulations Experiments
Clément Ubelmann, Jacques Verron, Jean Michel Brankart, Pierre Brasseur

MSO-17 Investigating ocean altimeter data and applications in the Gulf of Maine
Douglas Vandemark, H. Feng, R. Scharroo, B. Chapron

MSO-18 ALTICORE - a consortium serving European Seas with Coastal Altimetry
Stefano Vignudelli, Helen M. Snaith, Paolo Cipollini, Fabio Venuti, Florent Lyard, Jean François Cretaux, Florence Birol, Jérôme Bouffard, Laurent Roblou, Andrey Kostianoy, Anna Ginzburg, Nickolay Sheremet, Elena Kuzmina, Sergey Lebedev, Alexander Sirota, Dmitry Medvedev, Svetlana Khlebnikova, Ramiz Mamedov, Khasiyat Ismatova, Amir Alyev, Tural Nabiyev

Science Results

SA - modeling/data assimilation
SB- mean dynamic topography
SC- tropical ocean
SD- coastal ocean
SE- sea level
SF- ocean circulation/air-sea interaction
SG- ocean eddies
SH - land/ice/hydrology

SC-7 First results from the ARAMIS program
Sabine Arnault, the ARAMIS group

SA-4 Impact of small changes in the atmospheric forcing fields on SST, SSH and mixed-layer heat content in an eddy-permitting model of the North Atlantic
Nadia Ayoub, M. Lucas, G. Valladeau P. De Mey

SA-1 Comparing sea-surface topography modes of variability from altimetry and global models
Bernard Barnier, Thierry Penduff, Mélanie Juza

SB-1 Calculating the Ocean's Mean Dynamic Topography from a Mean Sea Surface and a Geoid
Rory Bingham, Chris Hughes, Keith Haines

SH-5 Exploration of multi-satellite altimetric data over North American lakes
Charon Birkett

SD-3 Observation of coastal ocean dynamics in the Northern Indian Ocean using improved altimetric data.
F. Birol, F. Durand, D. Shankar, S.S.C. Shenoi, L. Roblou, F. Lyard, Y. Ménard .

SC-1 Equatorial waves and warm water volume changes in the equatorial Pacific
Christelle Bosc and Thierry Delcroix

SA-5 Improved altimetry in the Northwestern Mediterranean: Comparison of Ocean Dynamics with a regional circulation model
Jérôme Bouffard, S. Vignudelli, M. Herrmann, F. Lyard, P. Marsaleix, Y. Ménard, F. Birol, P. Cipollini

SD-1 Evaluation of sea level anomalies from coastal tide gauges and satellite altimetry for the shelf zone
Gary Brassington, Jean-Roch Nader, Peter Oke, Tim Pugh

SC-2 El Niño/La Niña Preconditioning During the 2000's
Antonio Busalacchi, Hackert, Ballabrera-Poy, Zhang, Murtugudde

SG-3 Fidelity of high-frequency SSH anomaly signals in the Agulhas Current region
Deirdre A. Byrne, Julie McClean, Sheekela Baker-Yeboah

SA-6 A consistent assimilation of altimetric and temperature data in a model of the tropical Pacific ocean
Frédéric Castruccio, Lionel Gourdeau, Jacques Verron, and Jean-Michel Brankart

SG-9 Planetary waves and biogeochemistry in the North Atlantic Ocean
Guillaume Charria, Paolo Cipollini, Isabelle Dadou, Véronique Garçon

SE-1 Seasonal and Interannual Global Mean Sea Level Variability and Implications for the Hydrological Cycle
Catia M. Domingues, J.A. Church, N.J. White, and J.K. Willis

SE-7 New on line Mean Sea Level database and related products
Joel Dorandeu, A. Cazenave, A. Lombard, K. Do Minh, M. Ablain, S. Guinehut, V. Rosmorduc

SD-4 Computing coastal ocean surface currents from ocean color satellite imagery
William J. Emery, Roger Ian Crocker

SG-4 Spatial propagation of eddy variability in the world's oceans
Lee-Lueng Fu

SE-8 A near-uniform basin-wide sea level variation of the Japan/East Sea
Ichiro Fukumori, Seungbum Kim

SG-5 Geostrophic Transport and Biological Productivity in Southern Drake Passage
Sarah Gille, Marina Frants, Mati Kahru, Greg Mitchell

SF-4 Air-Sea Gas Fluxes using Altimeter-Derived Transfer Velocities in an Ocean General Circulation Model
David M. Glover, Nelson M. Frew, Scott C. Doney, Ivan D. Lima, Michael J. Caruso, Scott J. McCue

SF-1 Evaluation of the ocean observing system for upper ocean heat content and surface dynamics using *in situ* and altimetry observations
Gustavo Jorge Goni, Pedro DiNezio, Claudia Schmid and Rick Lumpkin

SE-2 Global and Regional ocean thermosteric sea level change from in-situ data: Influence of sampling, complementarities with satellite altimetry, role of salinity
Stephanie Guinehut, Gilles Larnicol

SD-2 Coastal surface currents northeast of Taiwan detected by along-track altimetry data
Kaoru Ichikawa, Daisuke Ambe, Ryoko Tokeshi

SG-1 Global pattern of mesoscale variability in sea level and its dynamical causes
Alexey Kaplan, Mark A. Cane, Dake Chen

SF-2 Heat and Mass Transport Anomalies in the Gulf Stream Region
Kathryn Kelly, LuAnne Thompson and Suzanne Dickinson

SC-3 Surface currents and evolution of the 2006-2007 El Nino
Gary Lagerloef, Fabrice Bonjean, John Gunn, Laury Miller, Gary Mitchum

SF-3 Monitoring of the ocean variability thanks to global observed ocean products
Gilles Larnicol, S. Guinehut, M.H. Rio, J. Dorandeu

SH-1 Creation GCRAS06 Mean Sea Surface Model and Investigation of Hydrodynamic Regime of the Caspian Sea based on TOPEX/Poseidon and Jason-1 Satellite Altimetry Data.
Sergey A. Lebedev

SG-2 Characteristics of planetary waves in the North Atlantic from altimetry and the CLIPPER 1/6° model
Albanne Lecointre, Thierry Penduff, Paolo Cipollini

SH-2 Hydrologic Study of Vegetated Wetland Using Retracked Satellite Altimetry
Hyongki Lee, C. K. Shum, Yuchan Yi, Motomu Ibaraki, Frank Schwartz

SH-3 Along track repeat altimetry for land studies : application to ice sheets.
Benoit Legresy, F. Remy, F. Blarel, L. Testut

SE-9 Uncertainties in thermosteric sea level estimates
Eric Leuliette

SD-5 Margin Altimetry Project: a joined effort toward shelf, coastal and continental altimetry processing
F. Lyard, Birol F., Cipollini P., Crétaux J-F., Marsaleix P., Ménard Y., Roblou L., Vignudelli S.

SG-6 An evaluation of the classical and extended Rossby wave theories in explaining spectral estimates of the first few baroclinic modes in the South Pacific Ocean
Angela Maharaj, P. Cipollini, N.J. Holbrook, P.D. Killworth and J.R. Blundell

SD-6 The Upwelling of Downwelling Currents
Ricardo P. Matano, E. D. Palma, P. T. Strub

SG-7 Jets standing in meridional flow as revealed by joint analysis of satellite and in situ data
Nikolai Maximenko, Peter Niiler

SH-4 Improvement of the Topex/Poseidon altimetric data processing for hydrological purposes and investigations on the performances of Jason over

continental waters (CASH Project)
Franck Mercier

SE-3 Global Sea Level Estimates from the GCOS Tide Gauge Network
Mark Merrifield, G. T. Mitchum, B. Giese, S. T. Merrifield, J. Foster, B. Brooks, M. Bevis, and S. Nakahara;

SE-4 Extending the TOPEX/Jason global mean sea level time series with GEOSAT observations
Laury Miller, Remko Scharroo, John Kuhn, and Caroline Harbitz

SE-10 Gyre-scale atmospheric pressure variations and their relation to 19th and 20th century sea level rise
Laury Miller, Bruce C. Douglas

SE-11 Observed subsurface signature of Southern Ocean sea level rise
Rosemary Morrow, Guillaume Valladeau and Jean-Baptiste Sallee

SE-12 Hydrologic Contributions to Global Mean Sea Level Change
R. S. Nerem, D. P. Chambers, J. Famiglietti, E. W. Leuliette

SA-7 The Bluelink Ocean Data Assimilation System: an ensemble approach to an eddy-resolving application
Peter Oke, Gary Brassington, Andreas Schiller and David Griffin

SA-2 Assessment of DRAKKAR global simulations against altimetry and hydrography.
Thierry Penduff, Mélanie Juza, Bernard Barnier

SC-8 The need of TPJ accuracy to make further progress in ENSO
Claire Perigaud, B. Dewitte, J.P Boulanger, C. Cassou

SC-4 Intra-Seasonal Kelvin Waves In The Tropical Atlantic Ocean
Irene Polo, Alban Lazar, Belen Rodriguez-Fonseca and Sabine Arnault

SA-2 A cut across the Madagascan flow recorded by moorings and satellites
Graham Quartly

SF-11 Hurricane Juan: A triple view from Envisat
Graham Quartly, Trevor Guymer

SC-5 Chlorophyll and westerly wind events in the western tropical Pacific: a multi-sensor approach
Marie-Helene Radenac, Messié Monique

SF-8 Altimetry and Seagliders: an observing system for high latitude ocean climate
Peter Rhines, Charles Eriksen, Sirpa Hakkinen

SF-6 Flow around Tasmania - An oceanic intersection
Ken Ridgway

SF-12 Multiple jets of the Antarctic Circumpolar Current
Steve Rintoul, Serguei Sokolov

SC-6 Low-frequency variability in the Indian Ocean and its connection with Indian Ocean Dipole mode in 2006
Irina V. Sakova, Gary Meyers, Richard Coleman

SF-9 Response of the Antarctic Circumpolar Current to atmospheric variability
Jean Baptiste Sallee, Kevin Speer, Rosemary Morrow

SA-8 A Satellite and Model Study of the Circulation in the SE Pacific
P. Ted Strub, Ricardo Matano, Elbio Palma, Corinne James

SG-8 The effects of dispersion on the propagation and amplitude variations of baroclinic Rossby waves
Remi Tailleux

SF-7 Ocean Cooling by Tropical Cyclones
Wenqing Tang, W. Timothy Liu

SA-3 Seasonal Sea Level Variability Estimated From a Data-Constrained General Circulation Model
Sergey V. Vinogradov, Rui M. Ponte, Patrick Heimbach, Carl Wunsch

SF-10 Heat budget of the Southern Ocean Mixed Layer from 1992 to 2002
Frédéric Vivier, F. Busdraghi, Y-H Park, D. Iudicone

SE-13 Thermosteric Sea Level and Ocean Heat Content Changes and the Contribution to the Earth's Energy Balance
Neil White, Catia Domingues, John Church, Susan Wijffels

SE-5 Closing the seasonal to interannual sea level budget on regional scales in the tropical N. Pacific
Josh Willis, Don Chambers

SE-6 Global Coastal Sea Level Change on Decadal and Century Timescales
Philip L. Woodworth, S.J. Holgate, S. Jevrejeva

Abstracts

Science Results - Invited Plenary

Seasonal to Interannual Variability of Global Sea Level: Recent Progress in Monitoring and Prediction

Antonio J. Busalacchi
ESSIC/U. Maryland

Since 2004 continuous progress has been made in monitoring global sea level variability on seasonal to interannual time scales with radar altimetry and related use in support of climate prediction. This presentation highlights some of the most important accomplishments over the past three years of the application of altimeter observations to describe the dominant modes of ocean variability within this spectral window, the use of such observations in coupled ocean-atmosphere prediction systems, and advances in ocean climate state estimation enabled via the assimilation of altimeter data with in situ observations. Anticipated challenges and future prospects for the application of sea level observations will be placed in the context of the recently released NRC Decadal Survey, IPCC Fourth Assessment, and the future directions for the WCRP and CLIVAR.

Monitoring terrestrial surfaces waters by satellite

Anny Cazenave[(1)], Charon Birkett[(2)]
(1) LEGOS-CNES
(2) GFSC/NASA

In the recent years, monitoring water levels of rivers, lakes and floodplains has become a routine application of satellite altimetry. Several online data bases provide water level time series on rivers and lakes worldwide based on Topex/Poseidon, Jason-1, ERS and Envisat satellites observations. These data, together with other remote sensing data (e.g., satellite imagery, INSAR, space gravimetry), in situ data, and/or model results, have been used by a number of investigators for various hydrological applications such as : impact of climate variability (e.g., ENSO, moonsons) and anthropogenic pressure (e.g., dam building, irrigation, etc.) on river basins hydrology, surface water volume change during flooding season, levelling of in situ gauge networks, river profiles and stream flow, etc. Here we review recent advances in these areas. We also briefly recall limitations of nadir-viewing altimetry for land hydrology applications and discuss current status of wide-swath interferometric altimetry, a new instrumental concept strongly supported by the international scientific community (in hydrology and ocean sciences) and seriously considered by NASA and CNES space agencies for future altimetry missions. Finally we briefly present a number of applications in hydrology offered by this new technology (e.g., water resources management, flooding hazards, flow hydraulics, water cycle and climate modelling, etc.).

Global observations of westward energy propagation: Rossby waves or nonlinear eddies?

Dudley Chelton, M. G. Schlax, R. M. Samelson and R. A. de Szoeke
Oregon State University

The 10-year record of TOPEX/Poseidon (T/P) data has been analyzed extensively to investigate large-scale variability of the sea-surface height (SSH) field. These studies have documented nearly ubiquitous westward propagation with speeds close to (somewhat faster than) the phase speed of nondispersive, linear Rossby waves. This has led to widespread interpretation of the observed variability as baroclinic linear Rossby waves. The speedup (by up to a factor of two) relative to the phase speeds predicted from the classical theory for extratropical Rossby waves has been attributed to various effects that are neglected in the classical theory (primarily vertical shear, with additional possible contributions from bottom topography and wind forcing). Other investigators have advocated a different point of view in which the ocean is dominated by nonlinear eddy variability, rather than Rossby waves. This alternative view is difficult to support observationally from T/P data alone because of the coarse resolution of SSH fields that can be constructed from a single altimeter dataset. The higher resolution afforded by the merged T/P and ERS satellite altimeter datasets (about double that of the T/P data alone) allows a quantitative assessment of the two seemingly contradictory points of view.

Recent results obtained from the merged T/P-ERS data will be summarized in this presentation. The higher resolution SSH fields reveal that variability over much of the World Ocean consists largely of long-lived, eddy-like structures that propagate nondispersively westward over a broad range of wavenumber-frequency space. While the direction of the observed propagation is very nearly westward, there are preferences for cyclonic eddies to propagate slightly poleward and for anticyclonic eddies to propagate slightly equatorward, consistent with theories for nonlinear vortices. By three different measures of nonlinearity, the observed eddies are found to be nonlinear in the eddy-rich regions, although not strongly so. A global census of these eddies, combined with analysis of historical hydrographic data, suggests that they may be generated by baroclinic instability. The observed characteristics of the eddy-like structures call into question the linear Rossby wave interpretation and suggest the importance of nonlinear dynamical processes in broad regions of the open ocean, thus favoring the nonlinear eddy interpretation of the observed SSH variability.

Understanding sea-level rise

John Church
Antarctic Climate and Ecosystems Cooperative Research Centre and CSIRO Marine and Atmospheric Research

Sea level has risen by over 120 m since the last glacial maximum, about 20 thousand years ago. The majority of this rise occurred before 6 thousand years ago. From ancient Roman times until the 18th century there has been little rise in global average sea level. The longest tide gauge records, extending over several centuries, indicate an increase in the rate of rise commenced in the 19th century. A combination of tide gauge data and satellite-altimeter data have been used to estimate sea levels from 1870 to the present. These data show sea levels have risen by about 20 cm over this period, a 20th century rate of rise of 1.7 ± 0.3 mm/yr and a significant acceleration in the rate of rise. Satellite-altimeter data from 1993 indicate a rate of rise closer to 3 mm/yr.

The largest contributions to late 20th century sea-level rise are ocean thermal expansion and the melting of glaciers and ice caps. The ice sheets of Greenland and Antarctica have made smaller contributions. The contributions from changes in terrestrial storage have significant uncertainties. Volcanic activity is one of the causes of decadal variability in sea level. Immediately after an eruption, the decrease in short wave radiation reaching the ocean surface results in an ocean cooling that can persist in the oceans for decades to centuries.

Sea level is likely to continue to rise through the 21st century and beyond. Even after stabilization of greenhouse gas concentrations in the atmosphere, sea levels are likely to continue to rise for decades and centuries because of the long time scales associated with ocean circulation and the ice sheets. There is increasing concern that the large ice sheets of Greenland and Antarctica might contribute significantly to sea-level rise through surface melting (for Greenland) and dynamic responses unless there is a significant reduction in the emission of greenhouse gases.

A rise in sea level leads to more frequent flooding events of a given level. There is already evidence that this has occurred during the 20th century. Changes in the intensity of atmospheric weather patterns (for example, an increase in the intensity of tropical cyclones) will also alter the frequency and intensity of extreme events. By 2100, tens of millions of people may be vulnerable each year to coastal flooding events associated with sea-level rise and extreme events. Appropriate planning and adaptation actions can significantly reduce the number of people affected.

Operational applications of altimetry

Eric Dombrowsky
Mercator Ocean

The idea of operational oceanography emerged in the eighties in some research groups and national agencies. However, the spinup of this movement took really place in the nineties, after the successful launch of the modern altimeter missions Topex Poseidon and ERS. Several initiatives started at that time in different countries to settle operational ocean monitoring and forecasting centers, all based on 3 pillars:
1) real-time reliable access to high quality observation, either remotely sensed or in situ,
2) state-of-the-art OGCM realistic configurations, global or regional, and
3) data assimilation schemes, either advanced such as variational or ensemble methods or simple such as optimal interpolation.
This movement was mainly technology pushed: the opportunity of being able to build such systems was there: access to high quality observations from space with a high level scientific community strongly associated to the space missions; large progress made in ocean modeling, both on the academic side and on the coding with the emergence of high quality OGCM codes; algorithmic development implementing advanced data assimilation schemes in a computing efficient way, the deployment of high capacity computing capabilities in the different countries involved in this business. This constructive competition between different emerging groups was then organized within the Global Ocean Data Assimilation Experiment (GODAE) which contributed to build other important components through two pilot projects: the Global High Resolution Sea Surface Temperature (GHRSST), and Argo for the in situ T and S profiles. Another important step towards operational oceanography was made in July 2003, when the GEOSS (Global Earth Observation System of Systems) initiative was decided, whose goal was to study the possible international coordination of existing and future earth observing systems. Two years after in 2005, a new international coordination entity was decided in Brussels: GEO whose goal is to implement the GEOSS. In Europe commission and the European Space Agency initiated the GMES (Global Monitoring for Environment and Security) initiative which aims at building the full chain from observations to services, based on existing or new infrastructures, following the model of operational meteorology. After a brief presentation of this context, we'll present some of the most representative initiatives in the field of operational oceanography, with a special focus on the applications and services provided to users.

Internal Tides, Tides in Shallow Seas, and Altimetry

Gary D. Egbert
Oregon State University

In the early years of TOPEX/Poseidon a number of groups throughout the world worked to develop global tidal elevation maps, driven mainly by the mission's requirement for highly accurate tidal corrections. These efforts have long since converged to a consensus (within 1-2 cm) throughout the sub-polar deep ocean, where the barotopic surface tides are well enough sampled by the altimeter ground track to be mapped more-or-less directly. There remain, however, important problems in both practical and fundamental tidal science which altimetry data can help resolve. We consider two in this review: tides in shallow marginal and coastal seas, and internal tides generated over rough topography in the deep ocean. A common theme is that in both cases the important spatial scales are not well sampled by a single altimeter ground track. Indeed, the generally consistent global elevation models mentioned above often disagree by as much as a meter in shallow and marginal seas. These large errors in tidal elevations must certainly be reduced, both to allow altimetry to be used for studies of lower frequency variability in coastal seas, and for accurate characterization of the tides for other purposes. We will discuss progress on using data from multiple satellites for improved tidal mapping in these areas, considering both empirical mapping, and data assimilation approaches. We will also review progress on using altimetry to map non-linear tides, which can be significant in areas with broad shelves. With regard to internal tides, we note that although altimetry has played an important role in the renaissance in studies on this topic, the spatial scales of internal tides are actually rather poorly sampled by typical ground track spacing. Thus, for example, published estimates of the internal tide energy flux away from the Hawaiian ridge based on models and/or altimetry have varied by a factor of 5. Again, using data from multiple satellites, and applying assimilation methods may provide a solution. We will discuss recent progress on this front.

Ocean Surface Topography Applications to Circulation Mapping in the Coastal Ocean

William J. Emery
Aerospace Eng. Sci. Dept. Univ of Colorado

Rapid changes in bottom topography coupled with the presence of the coastline and smaller space and time scales of circulation changes makes it a challenge to use satellite altimetry data to map changes in coastal ocean currents. Various methods are used to extrapolate offshore altimetry data, correct for bottom topography and coastline influences. One approach is to combine altimetry data with other types of direct measurements of the circulation variability such as trajectories of drifting buoys, acoustic Doppler current measurements, etc., in order to overcome the lack of altimetric spatial resolution and correct for bottom topography. Another is to use numerical models to provide the space-time resolution of circulation changes needed in the coastal ocean. Also important in the coastal ocean is the role of tidal currents, which vary too rapidly in space and time for altimetry measurements alone. Methods to resolve these changes in the coastal circulation will be reviewed and discussed. The accuracies and applicability of these methods will be discussed and recommendations will be made for the use of altimetric measurements in the coastal ocean. The promised improvements of mapping coastal circulation with a future Wide Swath Ocean Altimeter (WSOA) will also be discussed.

Ocean State Estimation for Studies of Climate Variability

Tong Lee
Jet Propulsion Laboratory

Ocean state estimation optimally synthesizes observational data with dynamical models given the knowledge of uncertainties of the data and models. Sea level data obtained from the TOPEX/Poseidon and JASON-1 altimeters have been the backbone of many ocean state estimation systems. This presentation provides a brief overview of recent progress in state estimation using altimeter data, focusing on efforts that are oriented towards the studies of large-scale, low-frequency climate variability (as opposed to the initialization of climate prediction and nowcast/forecast of meso-scale ocean variability). Recent attempts to understand and to account for data and model errors, which dictate the outcome of the estimation, will be described. Various aspects of scientific applications of ocean state estimation will be highlighted. These include sea level changes, property transports, and upper ocean heat budget. On decadal time scales, many regions in the Indo-Pacific Ocean exhibit a decadal tendency of sea level that is different between the 90's and the past several years. An ocean data assimilation product is used to investigate the vertical structure associated with such decadal changes of sea level and the corresponding variations in horizontal and meridional circulation. On interannual time scales, the TOPEX/Poseidon and JASON-1 data have captured several events of El Nino/La Nina and Indian-Ocean dipole/zonal mode. The utility of dynamically consistent estimates of the oceanic state to characterize the similarity and difference of these events and the related heat budget will be presented.

Combining ocean velocity observations and altimeter data for OGCM verification

Peter Niiler[(1)], L. Centurioni[(1)] and N. Maximenko[(2)]
[(1)] Scripps Institution of Oceanography
(2) University of Hawaii

The data set of global ocean current observations at 15m from Lagrangian drifters are combined with altimeter observations to obtain near geostrophic ocean surface circulation maps on weekly intervals. The quasigeostrophic vorticity balance is used to obtain upper layer divergences of mass and thermal energy. These data also identify regions of significant eddy convergences. It is shown how circulation patterns, eddy vorticity and thermal energy convergence distributions can be used to formulate constraints on the validity of global ocean circulation models.

Large-scale subseasonal sea level variability over the global ocean

Rui M Ponte
Atmospheric and Environmental Research, Inc.

Altimetric observations have highlighted the presence in many oceanic regions of substantial sea level variability on subseasonal timescales and spatial scales longer than a few hundred kilometers. We review recent developments in our knowledge and understanding of such variability, as determined from altimeter and other oceanic observations and a variety of modeling efforts. The dynamics and forcing of these subseasonal signals are quite diverse, involving for example oscillations in semi-enclosed seas related to nonequilibrium response to pressure loading or basin-scale quasi-resonant signals associated with propagation of waves and driven by wind stress. The vertical structure is primarily barotropic but may involve baroclinic motions, particularly in the tropics. Effects of basin geometry, bottom topography, and dissipation are all important, and other commonly neglected processes (e.g., self-gravitation and loading) can be relevant as well. Some of the subseasonal energy is aliased in the altimetric datasets and can hamper even more severely other satellite missions like GRACE. We review on-going efforts to estimate the subseasonal variability over the global ocean and to use such estimates to de-alias the observations.

Eddy-Mean Flow Interaction: Insights from Satellite Altimetry Measurements

Bo Qiu
Dept of Oceanography, University of Hawaii at Manoa

Concurrent, high-precision satellite altimetry missions of the past 15 years have produced unprecedented sea surface height (SSH) data of the global oceans. This data set now provides us with not only a means to monitor the time-varying surface ocean circulation, but also a tool to explore the dynamics that govern the changes of the ocean circulation. This study presents a brief review of the insights into the eddy-mean flow interaction obtained from the long-term SSH measurements. The past 15 years are marked by distinct phase changes in several well-known climate indices (e.g., the NAO, the PDO, and the SAM). We explore first how these climate index changes impact the large-scale mean circulations which, in turn, modulate the mesoscale eddy field on the interannual and longer timescales. Effects of oceanic adjustment, bottom bathymetry, and instability processes will be investigated. We next examine the extent to which the mesoscale eddy signals influence the large-scale mean circulation. Quantification of this feedback effect in terms of directional, scale-dependent energy transfers will be explored.

Observing decadal variability in the oceans

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(1) Scripps Institution of Oceanography, UCSD
(2) Jet Propulsion Laboratory,

The era of TOPEX and the World Ocean Circulation Experiment (WOCE) produced the first global views of decadal variability in ocean circulation and property distributions. Decadal signals in upper ocean temperature and steric height, 1994 – 2004, included wind-driven changes in gyre-scale circulations in the subtropical and subpolar oceans in both hemispheres. The largest signal of the past decade in terms of zonally integrated heat content and steric sea surface height was a warming at 40oS in all three oceans, caused by enhanced Ekman pumping leading to downward displacement of isopycnals and spin-up of the subtropical gyre circulations. The largest signal in terms of temperature and salinity change was a warming/salinity increase in the northern North Atlantic. The tropical oceans also warmed under a small increase in the tradewinds, though decadal and interannual variability are difficult to separate there. While a description of global decadal change is possible for temperature in the upper 750 m of the oceans, pre-Argo measurements of deeper temperature levels and of salinity are very sparse for global analysis. However, measurements from WOCE and Argo indicate that the wind-driven isopycnal displacements extend to at least 2000 m and that the freshening of intermediate waters seen in the WOCE era continues in Argo data. There are also estimates of decadal variability in basin-integrated heat and freshwater transports at a few locations, but the ocean observing system is not yet globally capable of measurements of ocean boundary currents and transports.

The Argo array achieved sparse global coverage in 2004 and has now progressed to include more than 2700 active floats providing more than 8000 temperature/salinity profiles per month. Argo is observing the global oceans and is in many respects a subsurface analog to satellite altimetry. We illustrate the complementary nature of Argo and altimetry using a monthly gridded Argo dataset from 2004 – 2006. With a stable mean and annual cycle of temperature, salinity and steric height on large spatial scales, Argo provides a reference dataset for comparison/combination with altimetry and to anchor studies of interannual and decadal variability in the oceans.

Local and Global Calibration/Validation

Global Statistical Quality Assessment of Jason-1 data

Michaël Ablain [(1)], Phillipps Sabine (CLS), Dorandeu Joël (CLS), Picot Nicolas (CNES)
[(1)] CLS

A global statistical evaluation of Jason-1 data has been carried out as part of the SSALTO/CalVal activities. The objectives of this study are to assess the Jason-1 data quality and to estimate the altimeter system performances from the beginning of the mission. The last GDR “b” release is used to perform this study. The main evolutions in the GDR “b” are the implementation of a new retracking algorithm (order 2 MLE4), a new precise orbit based on a GRACE gravity model, new geophysical corrections (tidal models, Dynamic Atmospheric correction, Sea State Bias) and a new wet tropospheric radiometer correction. Particular attention is paid to these improvements and especially for the new wet tropospheric radiometer correction and its impact on the mean sea level estimation.

Jason-1 - TOPEX/Poseidon consistency

Michaël Ablain [(1)], PhillipsS Sabine (CLS), Dorandeu Joël (CLS), Picot Nicolas (CNES)
[(1)] CLS

The sea surface height consistency of the Jason-1 and T/P data is analyzed using the last GDR release for both satellites from Jason-1 cycles 1 to 21 (T/P cycles 344 to 364). During this period, Jason-1 (J1) and TOPEX flew on the same track. The main evolutions in the reprocessed data (GDR “b” for J1 and RGDR for TOPEX) are the implementation of a new retracking algorithm (MLE4 for Jason-1, MLE5 and MAP for TOPEX), a new precise orbit based on a GRACE gravity model and new geophysical corrections (tidal models, Dynamic Atmospheric correction, Sea State Bias). Jason-1 GDR “b” and TOPEX RGDR were reprocessed in the beginning of 2006, but a new TOPEX RGDR should be available in the beginning of 2007 containing improvements for the retracking methods. The objective of this study is to analyze the sea surface height consistency of the Jason-1 and T/P data using the new RGDR data.

Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica

Pascal Bonnefond [(1)], P. Exertier [(1)], O. Laurain [(1)], Y. Ménard (CNES), F. Boldo (IGN-CNES), E. Jeansou (Noveltis), G. Jan (Noveltis)
[(1)] OCA-GEMINI

The Corsica site, which includes Ajaccio-Aspretto site, Senetosa Cape site, and Capraia (Italy) in the western Mediterranean area has been chosen to permit the absolute calibration of radar altimeters. Thanks to the French Transportable Laser Ranging System (FTLRS) for accurate orbit determination, and to various geodetic measurements of the local sea level and mean sea level, the objective is to measure the altimeter biases and their drifts. The expected outputs of this on site verification experiment are dedicated obviously to the determination of the calibration bias of TOPEX/Poseidon and Jason-1. On the other hand, it is also an opportunity to contribute to the orbit tracking of oceanographic and geodetic satellites and to the analysis of the different error sources, which affect altimetry. In the field of positioning, we expect to contribute also to the decorrelation between the possible vertical displacements of our site (Earth crust) and the Mediterranean mean sea level. The double geodetic site in Corsica (Aspretto, near Ajaccio and Senetosa Cape 40 km south under the Jason-T/P ground track N° 85) has been used to calibrate the TOPEX/Poseidon altimeters from 1998, and the Jason-1 ones since the beginning of the mission. Permanent and semi-permanent geodetic equipments are used to monitor these calibrations. Concerning the Aspretto site, a permanent GPS station and an automatic tide gauge have been installed since 1999. Two dedicated tracking campaigns of the French Transportable Laser Ranging System have been realized in 2002 and 2005. Results of the last campaign, in term of calibration, are presented. At Senetosa cape, permanent geodetic installations have been installed since 1998 and different campaigns have been conducted in view of Jason-1 mission. Four tide gauges are installed at the Senetosa Cape and linked to ITRF using GPS and leveling. In parallel, since 2000, a GPS buoy is deployed during overflights at Senetosa (10 km off-shore). Moreover, since 2003, a permanent GPS has been installed to monitor possible vertical displacements of our site. In addition, using a local weather station, we derived the wet tropospheric path delay from GPS measurements which are compared to the Jason Microwave Radiometer ones at the overflight times. T/P altimeter calibration has been performed from cycle 208 to 365. All the produced Jason-1 GDR cycles have been also analyzed in the altimeter calibration process. However, a detailed analysis has been performed for the reprocessed (GDR-B) cycles 1 to 21 which have been compared to T/P improved MGDR (TMR, orbit, …). In addition, new JMR (as included in GDR-B) path delay has been compared for all the available cycles to the ECMWF and GPS derived tropospheric correction.

Multi-mission cross calibration for contemporary altimeter systems – results with upgraded data

Wolfgang Bosch[(1)]
[(1)] DGFI

A discrete form of crossover analysis (DCA) has been proven to be a powerful tool for the common estimation of radial errors of different altimeter systems. For two or more contemporary altimeters the total set of nearly simultaneous single- and dual-satellite crossovers creates a strong network with high redundancy allowing a reliable and dense sampling of the radial errors of all satellites involved. The procedure allows to assess the spectral properties of the radial error components, captures relative range biases and indicates systematic variations due to centre-of-origin shifts. Most challenging is the capability to estimate for all altimeter systems the geographically correlated mean error. The approach is applied to altimeter data of ERS-1, ERS-2, TOPEX, Poseidon, GFO, Jason1, and ENVISAT, with data widely upgraded by re-tracking efforts and/or improved by new GRACE based orbits.

Calibration and Performance Assessment of the JMR and TMR

Shannon Brown [(1)], Shailen Desai, Wenwen Lu, JPL
[(1)] Jet Propulsion Laboratory

Results will be presented from the on-going calibration improvements being made to the JMR and TMR path delay retrieval with regards to systematic mm-level errors that are either geographically or temporally correlated.

The JMR and TMR brightness temperatures are calibrated using stable on-Earth hot and cold brightness temperature references. Systematic errors that are correlated with instrument temperature, time and location are detected and removed. An intensive effort to provide an end-of-mission recalibration for the TMR PD was recently completed and is available in the TMR replacement product. Long-term calibration drifts, instrument temperature dependencies and systematic biases in the calibration near land were addressed. The removal of the long term drifts in the TB calibration is dependent on the stability of the on-Earth calibration references over many years. Small corrections to these references were required to remove seasonal and climatic signals, which would otherwise be spuriously introduced into the calibrated PDs. Details of these corrections to the on-Earth references and results of the recalibration will be presented.

Validation of the TMR and JMR Wet Path Delay Measurements using GPS, SSM/I, and TMI

Shailen Desai [(1)], S. Brown, B. Haines, W. Lu, V. Zlotnicki
[(1)] Jet Propulsion Laboratory, Caltech

Independent measurements of wet path delay are used to validate respective measurements from the Topex and Jason Microwave Radiometers (TMR and JMR). The independent measurements include those from terrestrial Global Positioning System (GPS) sites, the Special Sensor Microwave Imager (SSM/I) onboard the Defense Meteorological Satellite Program satellites, and the Tropical Rainfall Measuring Mission's Microwave Imager (TMI). Through these comparisons we characterize errors in the TMR and JMR wet path delay measurements, including scale errors, geographically correlated errors, and temporal errors. These comparisons are used to validate wet path delay measurements provided on the Geophysical Data Records, and recalibrated measurements such as those on the recently released TMR replacement product.

Jason-1 / Envisat Cross-calibration

Yannice Faugere[(1)], J. Dorandeu[(1)], N. Granier[(1)], A. Ollivier[(1)], N. Picot[(2)]
[(1)] CLS
[(2)] CNES

Cross calibration of Jason-1 measurements with other flying precise altimetric missions is essential to assess data quality and performances. Thorough comparisons with TOPEX/Poseidon and Envisat have been performed from the beginning of the Jason-1 mission and are still mandatory for validating and for ensuring the continuity of the altimeter time series. Since the end of the TOPEX/Poseidon mission, cross calibration with Envisat has become even more relevant for data quality assessment but also for allowing combination of altimeter datasets as required by applications and operational oceanography.

A global cross-calibration analysis between Envisat and Jason-1 data has been carried out as part of the SSALTO/CalVal activities. More than four years of Jason-1 and Envisat altimetric observations over ocean are available on the same period (October 2002 to the end of 2006) in Geophysical Data Record (GDR) products. The two missions have been compared in terms of data quality over this period: data availability and validity, monitoring of the most relevant altimeter and radiometer parameters, altimeter system performance. New versions of Envisat and Jason-1 products have been released (CMA V7) in October 2005. Since then the consistency between the two mission has been improved both in terms of geographically correlated SSH differences and high frequency content of the SSH signal. These two aspects are detailed in this analysis.

Monitoring Jason-1 and T/P from a California Offshore Platform: Latest Results from Harvest

Bruce Haines [(1)], George Born (University of Colorado/CCAR); Shailen Desai (JPL/Caltech); Steve Gill (NOAA/NOS)
[(1)] Jet Propulsion Laboratory; Calif. Inst. of Tech.

We present calibration results from Jason-1 (2002–) and TOPEX/POSEIDON (1992–2006) overflights of the Harvest offshore platform. The Arguello Inc. Harvest Oil Platform is located about 10 km off the coast of central California near Point Conception. Attached to the sea floor, the platform sits in about 200 m of water near the western entrance to the Santa Barbara Channel. Harvest served for a decade (1992–2002) as a calibration site for the TOPEX/POSEIDON (T/P) mission, and is serving in a similar capacity for Jason-1. Harvest is a dedicated verification site, and features carefully designed collocations of space-geodetic and tide-gauge systems to support the absolute calibration of the altimetric sea-surface height (SSH).

Our evaluation of the Jason-1 data focuses on the latest version (B) of the Geophysical Data Records (GDR). Using initial releases of the GDR-B data (cycles 1–21, 128–168), we find that the Jason-1 SSH measurements are erroneously high by 96 ± 5 mm (one standard error). The long-term drift in the SSH measurements is –2 ± 3 mm/yr, and is thus statistically indistinguishable from zero. This represents a significant improvement over the results obtained with the prior (A) version of the Jason-1 GDRs, which yielded a negative (SSH) drift exceeding 10 mm/yr. We present updated estimates of the bias and drift using all available GDR-B data, and examine potential sources of remaining errors. We also re-examine the agreement between T/P and Jason-1 data during the verification phase of Jason-1 (cycles 1-21), when the two satellites passed over the platform in formation.

Altimeter sea surface height regional calibration with in-situ network

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Recent results on the sea surface height bias computation are presented using an extended observations network and the calibration method based on offshore satellites passes. Since 1998, started with the Corsica calibration site, in the Mediterranean Sea, a tide gauges network has been extended. We focus on the regional use of this in situ CalVal computing process, in complement of to the single altimeter pass calibration technique. We realise thus a multiple calibration applied to each altimeter (Jason-1, Topex-Poseidon, GFO and Envisat). One uses the altimeter pass over the dedicated site, one uses several passes far from the site and one uses these selected passes adding the contribution of measurements from a distant CalVal site. It's a way to bolster statistically the absolute sea surface height bias estimation by increasing the number of measurements (from altimetry and tide gauges), respective to one altimeter. Results for Jason-1 are analysed in term of statistical improvement of the absolute sea surface height bias. The calibration method is focused on the necessity to preserve the continuity in the altimeter sea surface height time series, even in case of an unexpected gap in the time series from one satellite.

Improved comparisons of altimeter sea surface heights and tide gauge sea levels

Gary T. Mitchum [(1)], Brian Beckley, GSFC/NASA; Natacha Bernier, CMS/USF; Kara Sedwick, CMS/USF
[(1)] College of Marine Science, University of South Flo

With the support of the U.S. NOAA and NASA agencies we have developed a number of improvements to the altimeter to tide gauge intercomparison methods developed by one of us during the T/P and Jason missions. The methods are now applicable to an arbitrary altimeter regardless of record length or orbit, and the land motion corrections at the tide gauges are substantially improved. The altimeter products created at GSFC/NASA are used as a testbed for these new methods and results will be presented for multiple altimeters and for several different versions of the present Jason dataset.

The wet tropospheric correction for altimetry in coastal and inland water regions

Estelle Obligis [(1)], C. Desportes (CLS), L. Eymard (CNRS/LOCEAN)
[(1)] CLS

The exploitation of altimetric measurements over ocean relies on the possibility to correct the altimeter range from all external perturbations. One of them, the atmospheric humidity, strongly affects the range measured by the altimeter. Today, no meteorological model can provide this quantity with the required accuracy, so a dedicated instrument is added to the mission, a microwave radiometer (ERS2/MWR, Envisat/MWR, Jason/JMR, and TOPEX-Poseidon/TMR). In open ocean, the combination altimeter/radiometer is satisfactory both in terms of accuracy and spatial resolution. This is not the case for transition areas (sea/land): the signal coming from the surrounding land surfaces (with a strong and very time variable emissivity) contaminates the measurement and makes the humidity retrieval method unsuitable. Nevertheless, the exploitation of altimeter measurements in coastal areas becomes necessary for oceanography, and studies are in progress to exploit altimetry for hydrological budgets over large continental basins. Until now, the different tests performed to retrieve the wet tropospheric correction near coasts are empirical and give poor results. Recent studies conducted by Karbou et al (2004) have shown the feasibility of an estimation of land emissivity depending on the soil type, frequency, incidence angle, allowing the exploitation of radiometric measurements over land. We propose here to evaluate the feasibility of an operational retrieval of the wet tropospheric correction over these transition areas, which could fulfill the constraints related to the altimeter measurement processing, both in terms of accuracy and spatial resolution. The first part of the work consists in an evaluation of the current methods. A radiometer simulator is built, using data from the FETCH experiment (high resolution meteorological model, in-situ measurements and collocated TOPEX/TMR measurements), to perform sensitivity tests and to analyze and compare the performances of the different methods. Then in a second part, refinements are proposed. We developed a new method that takes into account the land surface effect in the brightness temperature estimation, through the proportion of land in the pixel. Results obtained on simulated and real brightness temperatures are satisfactory, and show a significative improvement with respect to current performances of altimeter products.

Modification of Jason rain flag for MLE4 Processing

Jean Tournadre [(1)]
[(1)] IFREMER DOPS/LOS

Since October 2005, the Jason Maximum Likelihood Estimator has been changed and now includes a fourth parameter, i.e. the off-nadir angle. MLE4 is certainly more robust for large off-nadir angles, (up to 0.5°, as encountered in August-September 2005) and improves the rms of geophysical parameters.

The joint estimation of the off-nadir angle and power in case of rain which is known to affect the plateau region of the waveforms (and thus the off-nadir angle) artificially modifies the sigma0 and cancel a great part of attenuation of the signal (or transform the measured attenuation in off-nadir angle). The behavior of Ku and C band sigma0 and Ku and C band sigma0 difference as well as the Ku/C band sigma0 relationship and its rms used in the rain flagging process are thus significantly modified. Then, the main problem is that if a new rain flagging process is set up using a Ku/C band relation based on the new sigma0, the rain flagging process will miss most of the rain affected samples and as the noise level between Ku and C band sigma0 is doubled with MLE4 the probability of false alarm will significantly increase . This will also be true if the version A relation is used.

To insure the continuity with Topex and coherence with Envisat it is important to keep a rain flag based on the physics, i.e. the real attenuation of the signal. This can be easily achieved by using a criterion based on AGC and not on sigma0. This can also allow to keep continuity of the rain flagging process if further MLE improvements are performed. The whole Jason archive has been reprocessed using an AGC based rain flagging process. The results are compared with the MLE3 sigma0 based rain flagging.

In-situ calibration at the Bass Strait site, Australia

Christopher Watson [(1)], Neil White [(2,3)], Richard Coleman [(1,2,3)] and John Church [(2,3)].
(1) University of Tasmania
(2) CSIRO Marine and Atmospheric Research
(3) Antarctic Climate and Ecosystems Cooperative Research Centre

The Bass Strait absolute calibration site is the sole in-situ altimeter calibration facility in the Southern Hemisphere, located on the north west coast of Tasmania, Australia (40° 45' S, 145° 40' E). The site is situated under Jason-1 descending pass 088.

Recent absolute bias estimates from the Bass Strait site will be presented. These will include a comparison of bias estimates determined using the standard release and new 'b-series' Jason-1 GDR data.

In 2006, National Collaborative Research Infrastructure Strategy (NCRIS) funds were obtained to trial the FLTRS system at the Bass Strait site in late 2007. Initial plans and aims will be discussed.

Outreach

Supporting Ocean Literacy: JPL Ocean Surface Topography (OST) Education and Public Outreach Activities for 2007-2008

Annie H. Richardson [(1)], Margaret Srinivasan/Jet Propulsion Laboratory
[(1)] JPL/Ocean Surface Topography Outreach

In 2007-2008 the JPL OST Outreach team will focus on products and programs which support the publicÆs understanding of the ocean and our responsibilities as stewards of this essential resource. In June 2006, a national conference on ocean literacy was held in Washington, D.C. and concurrently in other cities across the United States. At the conference, a team of educators and scientists unveiled what they deemed to be the seven essential principles and fundamental concepts that should be understood by a society if the members are to be considered ocean literate.

In December 2006, the JPL team produced a bookmark highlighting these essential principles and at the same time celebrating the fifth anniversary of the Jason-1 launch. During the next year and leading up to the scheduled launch in June 2008 of the Ocean Surface Topography Mission on Jason-2, we will continue to focus on ocean literacy by developing additional products emphasizing the seven essential principles and fundamental concepts. These products will include a web-based quiz, a lithograph, and an educational poster with classroom activities. We will work with our international partners to develop new, joint products and we will continue our participation in programs such as the CNES Argonautica Educational program.

Basic Radar Altimetry Toolbox & Tutorial

Vinca Rosmorduc [(1)], J. Benveniste (ESA), D. Earith, O. Lauret (Silogic), N. Picot (CNES), P. Poilbarbe (CLS)
[(1)] CLS

The Basic Radar Altimetry Toolbox is a collection of tools, tutorials and documents designed to facilitate the use of radar altimetry data. It is able to read most distributed radar altimetry data, from ERS-1 & 2, Topex/Poseidon, Geosat Follow-on, Jason-1, Envisat, and the future Cryosat missions, to perform some processing, data editing and statistic, and to visualise the results.

As part of the Toolbox, a Radar Altimetry Tutorial gives general information about altimetry, the technique involved and its applications, as well as an overview of pas present and future missions, including information on how to access data and additional software and documentation. It also presents a series of data use cases, covering all uses of altimetry over ocean, cryosphere and land, showing the basic methods for some of the most frequent manners of using altimetry data.

The Basic Radar Altimetry Toolbox has been developed under contract with ESA and CNES.

Ocean Altimetry Data: Operational Users and Applications

Margaret Srinivasan [(1)]
[(1)] NASA/Jet Propulsion Laboratory

More than fourteen years of continuous global coverage of ocean surface topography data have allowed researchers and operational users to evaluate important oceanic variations on broad temporal ranges of weeks to months to years.

The very successful ocean altimeter missions continue to provide an important data resource not only for numerous significant scientific studies but also for operational and recreational users and others. The data are used in a broad range of fields including hurricane tracking and intensity forecasting, El Niño/La Niña research, climate research, ship routing, offshore industries, fisheries management, marine mammal research, modernizing global tide models and lake level studies, among others. Multi-satellite applications such as sea surface height combined with ocean color, radiometry, gravity data are emphasized. Specific examples of recent applications highlights include ocean race support, forecasting ocean currents, a new Google Earth interface being developed by JPL partners at the University of Colorado, climate studies (ie, hurricanes, El Niño, ocean warming estimates), and new educational initiatives.

Some of the recent outreach tools used to advertise these efforts include web pages dedicated to societal benefits, the Satellite Altimetry Yellow Pages, and posters featuring recent science results.

New Material for Teaching Oceanography

Robert Stewart [(1)]
[(1)] Texas A&M University

The National Geographic Society, NOAA, COSEEs, and the College of Exploration published "Ocean Literacy: The Essential Principles of Ocean Sciences K-12" in 2005. I have been publishing material on the web that supports the teaching of the Essential Principles within the context of earth-system science and NASA's mission. The material is being used to teach college-level courses in Introduction to Environmental Geoscience and in Oceanography. The environmental geoscience course was identified as one of the top examples of best practices in a national study of environmental science courses conducted by the College Board Advanced Placement Best Practices Course Study.

I will describe the new material now available on the web, and it's relevance to oceanography in the 21st century.

Ocean Altimetry: Anticipating News and Public Interest

Rosemary Sullivant [(1)]
[(1)] Jet Propulsion Laboratory

2007 promises to be a banner year for raising public awareness about Earth sciences and climate change in particular. It kicked off with an announcement that 2007 may be the hottest year on record due to global warming and an El Nino.

While ocean altimetry doesn't always make news on its own, as it will when Jason-2 launches in 2008, it does have an important place in other stories on Earth's climate. By definition, news can't be planned ahead of time, but it is possible to anticipate some topics that will certainly be making headlines in the coming year. Among those will be heightened discussions of climate change, sea level rise, the International Polar Year, and hurricane season.

We hope that by planning in advance for stories that are bound to happen, we can increase our efficiency in communicating what we are learning about the ocean's role in climate and what impact that may have on the public.

Climate Change, Sea Level Rise and the Polar Regions: Using visuals to promote public understanding

Sandy Zicus[(1)], Craig Macaulay [(2)]
(1) Antarctic Climate and Ecosystem Cooperative Research Centre
(2) CSIRO Marine and Atmospheric Research

With the recent publication of the IPCC's Climate Change 2007: The Physical Science Basis Summary for Policy Makers, public attention has been firmly fixed on problems of global warming and sea level rise. The launch of the 4th International Polar Year (IPY) on 1 March is also raising the profile of the role of the oceans and the polar regions in regulating global climate. We now have a great opportunity to promote public understanding of important science and technology through the use of visuals developed through satellite altimetry and related tools.

Here we discuss recent climate change communication efforts with a focus on sea level, evaluate communication opportunities during the IPY and show animations developed for education and outreach by the Australian climate Change Science Program.

Sea-State Bias and Re-tracking Analysis

Analysis of the high frequency content of Jason-1, Topex and Envisat data

Yannice Faugere [(1)], A. Ollivier[(1)], P. Thibaut[(1)], G. Dibarboure[(1)], N. Picot[(2)], J. Lambin[(2)]
(1)CLS, Space Oceanography Division
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Through the past years, several studies on the noise determination of the radar altimeters have been carried out (Zanife et al, 2003, …). The present study is based on user products and aims at analysing the high frequency (HF) part of the Sea Surface Height (SSH) signal of Jason-1, Envisat and Topex. This signal includes instrumental noise, processing noise, correction noise, residual geophysical signals...

Two types of method have been used to analyse such a signal: a spectral analysis, and a filtering technique. The first method allows us to quantify accurately the global SSH HF for 1Hz and 20Hz data. The second method is used here to characterize the geographical distribution of this HF signal at 1Hz.

In this study the HF signal of the SSH of Jason-1, Envisat, and Topex are compared. Several retracking technique are tested. Notably, the improvement of the consistency between Envisat and Jason-1 HF content using a MLE4 retracking for Jason-1 is demonstrated. A sensivity study to various parameters is also carried out.

Comparison of Topex and Jason-1 sea state bias models

Sylvie Labroue [(1)], M. Ablain (CLS), J. Dorandeu (CLS), N. Tran (CLS), P. Gaspar (CLS) and O.Z. Zanife (CLS)
[(1)] CLS

Comparison of Topex and Jason-1 sea state bias corrections is a critical issue in order to get consistent data sets between both missions but also to improve knowledge in the electromagnetic bias field. At the last OSTST meeting held in Venice, major results have been presented on Topex and Jason-1 SSB models. These SSB corrections have been estimated on the last version of data for each mission. For Topex, retracked data have been analysed and the obtained SSB model is different from the one obtained with the GDR data. The SSB correction has been deduced form retracked data using a 5 parameter LSE algorithm. The SSB solution provides a higher magnitude than the GDR solution and moreover the new model exhibits a smoother correction for high waves instead of the saturation detected on GDR SSB models. This new behaviour is physically consistent and is in agreement with waves and wind speed related variations observed on all the other altimeters. For Jason-1 mission, the GDR version B data have been analysed and the new SSB correction is slightly reduced by about 0.3% SWH, which comes from the change of the skewness coefficient in the Hayne waveform model used for the retracking algorithm. A new figure of skewness of 0.1 has been used which is in agreement with Topex processing. The comparison of these new SSB corrections has shown that both models are now in very good agreement. They insure a very good spatial consistency at the centimetre level for the 21 cycles where satellites were flying together.

These results on SSB corrections have been obtained with a data set spanning only the first 21 cycles of Jason-1 mission. Results will be confirmed on a larger data set with at least one year of data for both missions. The analysis of (Topex-Jason) residuals has demonstrated that the quadrant errors present on Topex data, due to the waveforms leakages, are not cancelled by the LSE retracking algorithm. Special attention will be paid to the analysis of these signals in order to assess their spatial and temporal evolution with their potential impact on the estimated SSB solution.

Cross Calibration of TOPEX and Jason Using MAP and LSE Retracking to Improve Global Sea Level

Ernesto Rodriguez [(1)], Philip Callahan, Ted Lungu; Jet Propulsion Laboratory
[(1)] Jet Propulsion Laboratory

In order to continue the 10-plus year global sea level record of TOPEX with Jason data it is necessary to obtain a relative calibration of the individual time histories to much better than 1 cm. To study regional changes, the relative calibration must be independent of sea state and other environmental conditions. Thus, in addition to a global bias, the relative sea state bias of the two altimeter systems must be understood. The currently observed differences may be related to the different processing of the waveform data.

In the past, the use of altimeter waveform retracking has been limited by computer resources. With the advent of faster computers, we are using a truly optimal retracking algorithm – Maximum a Posteriori (MAP) – which significantly improves the covariance of the retrieved parameters relative to the Least Square Estimate (LSE) which we also produce.

We have performed waveform retracking of TOPEX and Jason-1 data during their colinear phase in 2002 using the MAP retracker in order to understand and remove instrumental effects that may affect the cross calibration. Because the satellites were on the same track only about 70 seconds apart, environmental effects are identical, so one can more directly compare the instrumental response. By using the same algorithms on the two altimeters we also eliminate this source of difference in the comparison. We will present findings on variations in the instruments in a variety of conditions, e.g., wave heights, to produce geographically consistent results.

Evaluation of ground retracking algorithms on Jason data

P. Thibaut [(1)], S. Labroue[(1)], N. Granier[(1)]
[(1)] Collecte Localisation Satellites

The JPL has implemented two retracking algorithms to process the Topex waveforms: a Least Square Estimate (LSE) algorithm and a Maximum a Pasteriori (MAP) algorithm. These two algorithms have also been applied on Jason waveforms. We propose here to analyze the results obtained by these two retracking algorithms and to compare them with those obtained by the Jason nominal retracking algorithm, results which are provided to users in the Jason-1 GDR products.

Inclusion of wave modeling in sea state bias correction refinement

Douglas Vandemark [(1)], H. Feng/UNH, N. Tran/CLS, B. Chapron/IFREMER, B. Beckley/Raytheon
[(1)] Univ. of New Hampshire/EOS

A promising approach for improvement of the now long-standing empirical method for the altimeter sea state bias correction lies in blending contemporaneous altimeter and wave model information. Two activities are ongoing in this regard and this talk will discuss their progress. First is an objective clustering analysis that divides the total multi-year data set into distinct gravity wave provinces where one then creates province-specific sea state bias models. These models then serve as a framework to compare, contrast, and inform regarding the veracity of the globally applied nonparametric SSB model for multiple missions. The second complementary activity involves global nonparametric solutions developed using alternate input parameters derived from some combination of altimeter and wave model variables. We also investigate a hybrid of these two approaches where province-specific sea state bias models will be developed using nonparametric solutions. Both studies rely on wave model data from Wave Watch III hindcast runs with wind forcing from the ECMWF reanalysis - this merged to each altimeter sample in the multi year multi mission data set. We will also report on the impact of latest high frequency barotropic (MOG2D) and orbit corrections (based on ITRF2005 and GGM02c gravity field)upon our findings with a particular focus on correction artifact versus physical wave impact information in our global ocean results.

Precision Orbit Determination and Geoid

Precision Orbit Determination, Trade Studies and Improvements for JASON with GPS

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[(1)] JPL
(2) Institut Geographique National/Institut de Physique du Globe de Paris, France

In our talk we will evaluate the impact on positioning of JASON from 2002 through 2006. A number of models will be examined, including time variable gravity fields, antenna calibrations, new albedo models, and implementation of ITRF 2005 coordinate systems. To evaluate these effects, we will examine residuals to reserved SLR data, altimeter cross overs, apparent GPS antenna offsets, orbit overlaps, and orbit differences with other techniques and analysis centers.

Jason-1 POD reprocessing at CNES: current status and further developments

Luca Cerri [(1)], Sabine Houry (CNES), Pascal Perrachon (CNES), Flavien Mercier (CNES), Jean-Paul Berthias (CNES)
[(1)] Centre National d'Etudes Spatiales (CNES)

In order to provide the scientific community with a continuous and homogeneous trajectory for Jason1, CNES has filled the gap of the GDR-B POE series by reprocessing Doris-SLR-GPS orbits from cycle 22 to 127. We summarize here the main results in terms of orbit performance. Also, in view of the next reprocessing standards definition, we assess the impact of the adoption of the newly released ITRF2005 reference frame and of current time-varying-gravity models on the overall orbit quality.

Assessment of Geoid Models off Western Australia Using Oceanographic In-Situ Measurements

Xiaoli Deng [(1)], R. Coleman[(2)] and K.R. Ridgway[(3)]
(1) School of Engineering, The University of Newcastle
(2) Centre for Marine Science, University of Tasmania
(3) CSIRO Marine and Atmospheric Research

The recently released Earth geoid models from the Gravity Recovery and Climate Experiment (GRACE) have reached 20 cm accuracy and spatial scale of 350 km. Data from Gravity field and steady-state Ocean Circulation Explorer (GOCE), scheduled to be launched in 2007, should further improve the geoid at the level of 1 cm accuracy with spatial scales down to 160 km. As such, the ocean mean dynamic topography (MDT) and the corresponding mean geostrophic circulation can be estimated by subtracting an available geoid model from altimetric mean sea surface (MSS). Australia's coastal dynamics are influenced by four major ocean currents characterised by mesoscale features. Of these currents, the Leeuwin Current flows poleward over the continental shelf along the Western Australian coastline. The first baroclinic Rossby radii in the Leeuwin Current area range from 20 km to 60 km (cf. Chelton et al., 1998), from which a precise and full spatial scale of geoid is crucial in the region to better understand the current. In this paper, we estimate ocean MDTs off Western Australia bounded by latitudes 20S to 45S and longitudes 108E to 130E using available geoid models (e.g., GGM02, EGM96 and AUSgeoid98) and the time-averaging MSS estimated by altimetry. Estimates are then compared to independent ocean climatologies, such as the Climatology of the Australasian Regional Seas (CARS) (cf. Ridgway and Dunn, 2002). In quantifying the impact of using a particular geoid model to compute the ocean MDT, we directly assess the accuracy of the geoid model in the Western Australian coastal regions by statistical comparison.

On the use of temporal gravity field models derived from GRACE for altimeter satellite orbit determination

Frank Flechtner [(1)], Ch. Foerste [(1)], R. Schmidt [(1)], R. Biancale [(2)], J.-M. Lemoine [(2)], S. Loyer [(3)], S. Bruinsma[(2)]
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In precise orbit determination of altimeter and other geodetic satellites a wide set of disturbing forces are taken into account via analytic and parametric models. In the domain of the time-variable gravity forces phenomena such as oceanic and atmospheric tides or secular changes of the static field are included as a standard. Further changes in the Earth's gravity field due to climatological processes, e.g. from hydrology, were typically not taken into consideration due to missing relevant models. However, from modern gravity field missions such as GRACE such gravity variations are now detectable and could be included as an additional background model in precise orbit determination in terms of a correction model describing dominant annual and (less dominant) semi-annual gravity variations derived from GRACE data.

This presentation highlights latest gravity field time series from GFZ (EIGEN-GRACE05S, RL04) and GRGS (EIGEN-GL04S) and focuses on the impact of using gravity temporal variations in orbit positioning. The corresponding geoid variations are compared with maps derived from independent hydrology models like the WaterGAP Hydrological Model (WGHM). Additionally, first results on altimeter satellite orbit determination including annual and semi-annual correction models will be presented.

Improvement of the Complete TOPEX and Jason Orbit Time Series: Current Status

Frank G. Lemoine [(1)], Scott B. Luthcke [(1)], Nikita Zelensky [(2)], David D. Rowlands [(1)], Brian Beckley [(2)], Teresa Williams [(2)], Doug Chinn [(2)]
[(1)] NASA GSFC
[(2)] SGT Inc. at NASA GSFC

Orbit error is a major component in the overall error budget of all altimeter satellite missions. Jason-1 is no exception and a 1 cm radial orbit accuracy goal has been set, which represents a significant improvement over what is currently being achieved for TOPEX/Poseidon (TP). Studies have demonstrated this goal is being met and that the orbit accuracies can be improved (Luthcke et al. 2003 and Haines et al. 2004). However, the challenge is to continually achieve this high accuracy, verify the performance, and characterize and quantify the remaining errors over the lifetime of the mission. The computation, verification and error characterization of such high accuracy orbits requires the reduction and analysis of all available tracking data (GPS, SLR, DORIS and altimeter). Current analysis also indicates the history of TP orbits can be further improved employing new solution strategies developed and tested on Jason-1. Our research focuses on the calibration, validation and improvement of the complete TP and Jason-1 orbit time series using all available tracking data including altimetry. Our effort will result in a complete and consistent time series of improved orbits for both TP and Jason, significantly benefiting the long time series of altimeter climate data records. The resultant high accuracy orbits and the characterization of their error will allow further improvements to the accuracy and overall quality of the altimeter measurement time series making possible further strides in radar altimeter remote sensing. Our evolving POD strategy using improved models (Lemoine et al. 2006) promise even further improvement in orbit accuracy and long term consistency for both TP and Jason (Beckley et al. 2005). In this presentation we summarize the current status of our research effort which includes evaluation of the ITRF2005 reference frame and a new time varying gravity model.

Multi-satellite/Operational applications

Moveable Feasts: The Eddy and the Marine Protected Area?

Jane Alpine [(1)], Alistair Hobday[(1)]
[(1)] CSIRO Marine and Atmospheric Research

Spatial management via Marine Protected Areas (MPAs) for oceanic biological resources has garnered recent support and there are now several examples of application in the open sea. A potential obstacle to further implementation of this approach, however, is the large size requirements of static managed areas. In response to this concern, mobile protected areas have been proposed; smaller areas can cover key moving habitats, rather than contain all the locations of the habitat over an entire year. Mobile MPAs may also prove to be a superior management response in addressing additional issues such as climate variability and change; as flexibility in MPA placement is an inherent component. We suggest utilising specific oceanic habitat features known to attract and aggregate pelagic species (e.g. sharks, tuna and billfish) as the foci for MPA design. In terms of MPA efficacy, selected habitats should show both predictability and temporal persistence: from a management perspective it is desirable that habitats can be described and detected via remote sensing. Eddies form one oceanic habitat that meets both these criteria. We describe the steps taken to identify suitable eddies based on altimetry data, determine eddy attractiveness for a range of pelagic species, and explore the feasibility of using remotely-sensed eddies as the basis for developing a network of pelagic MPAs along the eastern seaboard of Australia.

Improved satellite altimetric data dedicated to coastal areas: Validation over the northwestern Mediterranean

Jérôme Bouffard [(1)], Y. Ménard[(2)], L. Roblou[(3)], F. Birol[(1)], F. Lyard[(1)], R. Morrow[(1)]
(1) LEGOS
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Two improved coastal multi-satellite altimetric datasets (HiReA and X-track) with a 10/20 Hz along-track sampling have been derived from routine geophysical data records using new processing softwares dedicated to coastal shelf zone applications. These processings, developed in the framework of the Margin Altimetry Project (MAP), are characterized by: new editing criteria on the altimetric corrections, improved de-aliasing corrections, a high frequency along-track sampling, a new large-scale error reduction algorithm and control quality procedures relevant to coastal areas. The datasets have been validated over the Northwestern Mediterranean Sea with tide gauge records. Cross-comparisons made with a standard regional altimetric product highlight significant qualitative and quantitative improvements: The standard deviations of the differences between altimetric and tide gauge sea level anomalies have been decreased by more than 30 % over the continental shelf of the Gulf of Lions. In addition, the data processed by the new methods are able to detect very small dynamical processes, closer to the coast than the ones observed with a standard altimetric product. Last but not least, the new processings allow to recover about 10 % of the available coastal data.

BLUElink> Ocean Model Analysis and Prediction System delivering operational ocean forecasts

Gary Brassington [1], A. Schiller[2], P.R. Oke[2], T. Pugh[1], G. Warren[1]
(1) Bureau of Meteorology
(2) CSIRO Marine and Atmospheric Research

The Ocean Model Analysis and Prediction System (OceanMAPS) started providing routine global ocean forecasts in January 2007. Establishing routine ocean forecasts is the concluding stage of a three and a half year research and development project, initiated by the Australian government in 2003. The project was conducted through a collaboration between the Australian Commonwealth Bureau of Meteorology, the Commonwealth Scientific and Industrial Research Organisation and the Royal Australian Navy. The system combines an implementation of MOM4, a sophisticated ocean data assimilation system together with operational atmospheric forecasts and communications and data management infrastructure of the Bureau of Meteorology. The current system assimilates near real-time sea surface height anomaly products from Jason1 and Envisat together with in situ observations from the GTS and Argo GDAC's. The operational prediction system is being delivered through the Bureau of Meteorology to service the Royal Australian Navy, CSIRO and the broader Australian marine user community as a public service.

Development, Implementation and Evaluation of a Real-Time Ocean Forecasting System off the California Coast

Yi Chao [(1)], Zhijin Li, John Fararra, KJ Park, Xiaochun Wang (All at JPL)
[(1)] Jet Propulsion Laboratory

The development and implementation of a real-time ocean forecast system based on the Regional Ocean Modeling System (ROMS) off the coast of California are described. Results produced by the real-time ocean forecast system during two field experiments during the summers of 2003 and 2006 are presented. The real-time ocean forecasting system is based on a nested ROMS configuration including the U.S. West coastal ocean at 15-km resolution, the central California coastal ocean at 5-km, and the Monterey Bay region at 1.5-km. All nested models have 32 vertical sigma (or terrain-following) layers. Using the 3-dimensional variational data assimilation (3DVAR) scheme, we assimilate both the satellite altimeter data and other complementary data sets (both in situ and remote sensing) every six hours to produce nowcast (or analysis) field, from which a 48-hour forecast can be performed. The nowcast and forecast fields are first compared with the assimilated data for consiste! ncy check. An evaluation of the ROMS nowcast and forecast against the independent measurements that are not assimilated into models is then conducted. Predictability analysis will also be presented and discussed.

The above described real-time ocean forecast system is currently being implemented for real-time operational demonstrations on the 24/7 basis. The system will provide 3-dimensional ocean nowcast and 48-hour forecast fields every six hours. We will share our early experiences interacting with application users (e.g., coast guard, oil spill response team, coastal resource managers). The potential impact of the next generation altimeter mission at high resolution will also be discussed.

Future altimeter systems : is the mesoscale observability good enough for operational oceanography?

Joel Dorandeu [(1)], P.Escudier (CLS), G.Dibarboure (CLS)
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The exceptional longevity of T/P and GFO added to the performance of Jason and ENVISAT allowed a better understanding the observing capability of altimeter constellations. A two satellite sampling is assumed to be the minimum needed for offline mesoscale applications. However the dense 4 satellite sampling proved to be an invaluable asset for NRT applications. Firstly the amount of usable data is divided by two in NRT as it is not possible to use 'future' data to centre the time window like in offline processing. Secondly having more independent sources of data increases the NRT system robustness against data delay, platform events, ground segment anomalies, network or hardware issues. More altimeters flying mean less critical anomalies and better chances to have a minimum data delivery for real time applications.

The current missions are still performing well but they were not designed to reach the launch of Jason-2. Real time processing are affected by trivial anomalies and significant events on one or two satellites would be problematic as three satellites are needed to achieve the minimum mesoscale observability in near real time. Not only is the altimeter sampling weakened with few satellites, but the risk of critical failure will be maximum in the coming years. Once these risky years are over, new instruments will hopefully strengthen the altimeter observing capability.

In this paper is used a probabilistic model to better assess the chances to have an observing system (combining multiple altimeters) accurate enough to provide the input measurements needed for operational oceanography, as well as to explore alternate scenarios and to identify major risks.

Explaining the extraordinary: operational oceanography in Australia

David Griffin [(1)], Madeleine Cahill[(1)], Jim Mansbridge[(1)]
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The behaviour of the East Australian Current from mid 2006 to the present (Jan 2007) sparked an unprecedented number of enquiries from the public. Coastal water temperatures near Sydney were 4° above normal in August, then 4° below normal in January, reversing the normal seasonal cycle. The question asked in August was "is this global warming?" while in January it was "when will this stop?". We struggle to keep up with the public's growing expectations when it comes to answers, despite the enormous improvements (over the past decade) in our systems for observing and analysing the state of the ocean. At www.cmar.csiro.au/remotesensing/oceancurrents/, we provide daily-updated, publicly-available analyses of the latest data from the altimeters (Jason, Envisat and GFO), radiometers (AVHRR and microwave), profiling (Argo) and surface (GLD) drifters, and coastal tidegauges. The sequence of maps over the period clearly demonstates the impact of mesoscale eddies on the inshore conditions. Feedback indicates that the analyses are used for a host of purposes by a public with a growing interest in ocean dynamics. The altimeters all suffered technical problems in 2006, exacerbating the impact of the loss of Topex/Poseidon in 2005. It is ironic indeed that we face the prospect of even poorer data availability in the coming years while our data-assimilating models become more able to exploit the data, and the demand for explanations of events as they occur, and forecasts of upcoming events, becomes ever greater.

Near real-time spatial management for a longline bycatch species based on sea surface topography and temperature observations

Alistair Hobday [(1)], Klaas Hartmann[(1)]
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Southern bluefin tuna (SBT) is a quota-managed species that makes annual winter migrations to the Tasman Sea off south-eastern Australia. During this period it interacts with a year-round tropical tuna longline fishery (Eastern Tuna and Billfish Fishery, ETBF), with the result that many SBT are accidentally caught by ETBF fishers. To reduce this accidental bycatch of SBT, most of the ETBF fishers are now excluded from fishing in regions where SBT are believed to be. The boundaries of the region where only SBT quota holders may fish is determined by the ETBF managers with reference to an SBT habitat model. Adult SBT temperature preferences were determined using pop-up satellite archival tags. The near real-time predicted location of SBT was determined by matching temperature preferences to three-dimensional estimates of the ocean temperature based on satellite observations of the surface temperature and topography anomaly. The SBT habitat model included: (i) predictions based on the current vertical structure of the ocean; (ii) seasonally-adjusted habitat preference data; and (iii) development of a SBT habitat climatology that allowed visualisation of the expected change in the distribution of the SBT habitat zones throughout the season. Near real-time fishery management continues to be a realistic prospect that new scientific approaches using remotely sensed data can support and advance.

Combining altimeter-derived currents with Aquarius salinity to study the marine freshwater budget

Gary Lagerloef [(1)], Fabrice Bonjean (ESR), John Gunn (ESR), Jonathan Lilly (ESR), Yi Chao (NASA/JPL)
[(1)] Earth & Space Research

The Aquarius/SAC-D mission, due to be launched in mid 2009, will provide global sea surface salinity (SSS) data with temporal and spatial resolution commensurate with satellite surface topography fields. Combining the SSS data with the OSCAR (www.oscar.noaa.gov) surface currents, derived from satellite topography and vector winds, will provide an unprecedented capability to map the salt advection terms in the marine freshwater budget. This presentation will introduce preliminary estimates with the product of OSCAR and objectively analyzed SSS fields from the in situ observing system and use OGCM fields to illustrate the enhancements that will be achieved with the satellite SSS data.

Quality of real time altimeter maps: impact of data delay

Gilles Larnicol [(1)], Ananda Pascual (IMEDEA/CSIC-UIB), Christine Boone (CLS), Pierre-Yves Le Traon (IFREMER)
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The timeliness of satellite altimeter measurements has a significant impact on their value for operational oceanography. In this paper, we use an OSE (observing system experiment) approach to assess the quality of fast delivery altimeter products, a key issue for a correct monitoring and modelling of the ocean state.

In a first step, we generate a delayed time data set used as a reference for comparisons with real time data. A near real time data set is then simulated using a realistic orbit error and consistent asymmetric time windows in all processing used to generate altimeter maps. Then we compare the performance of fast delivery products with respect to delayed time data. The validation with tide gauge and drifter data shows a clear degradation of the performance in the fast delivery configuration. Namely, in a nominal near real time situation, at least 3 altimeters are needed to get the same scores as in delayed time with only 2 altimeters: to compute real time maps, only past data are accessible, as opposed to delayed time processing where altimeter measurements of the map “future” can be used.

The analysis is extended with an assessment of the NRT error degradation when altimeter flows cannot be delivered normally (operational delay, platform anomaly, or ground segment issues). The quality of simulated NRT maps quickly deteriorates when altimeter data are delayed or missing. After a few days of anomaly, is a three altimeter NRT observing system still able to meet the minimum requirement for mesoscale observability?

Wave Model Error Analysis from Altimetry

Jean-Michel Lefevre [(1)], Chafih Skandrani[(1)] Pierre Queffeulou[(2)], Abderrahim Bentamy[(2)]
(1) Meteo-France
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Satellite altimeter data are uniformly distributed over the ocean making them very useful to estimate wave model errors, at global as well as regional scales. They are the only data providing synoptic view of wave model behaviour. Significant wave height measurements derived from altimeters on board TOPEX, GEOSAT Follow-On, Jason and ENVISAT, have been collected, checked and corrected in order to build a consistent and homogeneous altimeter data set suitable for wave model validation. A period of almost two years, for which TOPEX, GFO and ENVISAT data are available, has been selected in order to assess the behaviour of several wave models : WaveWatch III, V and WAM. Results from comparisons between wave height altimeter measurements and model output have been used to give some guidance for wave model improvements. Some interesting features have been found such as the effect of strong ocean currents, possible effect of ice. Regional studies have been also carried out, with particular focus to the Mediterranean Sea in order to investigate the effect of ocean currents on ocean wind waves. Ocean Currents from Mercator have been used as input of the WAM model implemented with a 0.25° resolution for two periods of three months, a winter period and a summer period.

Merging wave height measurements from altimeters. Application to the investigation of large scale and regional features of sea state.

Pierre Queffeulou [(1)], D. Croize-Fillon [(1)] J-M Lefevre [(2)] C. Skandrani [(2)]
(1) IFREMER
(2) Météo France

Significant wave height measurements derived from altimeters on board the six following missions, ERS-1&2, TOPEX, GEOSAT Follow-On, Jason and ENVISAT, have been collected to build a fifteen year period data set, from 1991 to nowadays.

The past validation effort enables to get presently a consistent and homogeneous altimeter significant wave height data set over the global oceans. The altimeter Geophysical Data Records from the six satellites have been checked and corrected using almost the same processing. A merged altimeter wave height data base has been set up and can be used to investigate large scale and regional features of wave height over the oceans.

In a first part, the paper describes briefly the data base: the data filtering and correction processing, and check of updated corrections, particularly for the data from Jason and ENVISAT. Specific future application developments are discussed.

In a second part, spatial and temporal features of the significant wave height fields are investigated as an application of the data set which is analyzed by two different approaches.

The first approach takes advantage of the long fourteen year time series (1992-2006) of TOPEX-Jason measurements over the same ground track network. Long term statistics such as mean value and standard deviation of 0.05° latitude sampling of wave height along the individual ground tracks are estimated. Results are used to describe the spatial variations of the significant wave height for various oceanic regions over the globe and at various spatial scales. Examples are shown for geographical areas of low wave height variability, as in Trade Winds area, or of high variability, as in areas of active low pressure meteorological systems in both hemispheres.

The fine along track altimeter resolution also enables to detect the effect on wave height of oceanic currents such as Gulf Stream and Agulhas current. This last aspect is of interest for the assessment of wave current interaction modeling in numerical wave models.

The second approach of the study aims to demonstrate the usefulness of altimeters for wave climate, particularly for remote areas over which very few in situ measurements are available, and for which numerical wave model outputs are not always reliable, partly because of the inaccuracy of the forcing fields such as the surface wind and air-sea temperatures.

Altimeter time and space samplings are too poor to infer extreme wave height statistics, but the measurements from several altimeters, flying together, enable to estimate seasonal and interannual variability of wave height over regional ocean areas. The demonstration was already done for the Mediterranean Sea. Here, mean wave height climate and time variability are compared over various remote geographical areas.

Impacts of atmospheric attenuations on AltiKa expected performances

N. Steunou [(1)], J.D. Desjonqueres;P. Sengenes/CNES;J. Lambin/CNES;A. Quesney/Noveltis;J. Tournadre/IFREMER
[(1)] CNES

AltiKa payload will be part of the SARAL mission, which is a cooperation between CNES and ISRO (Indian Space Research Organisation) and will be launched at the end of 2009. The main instrument of the AltiKa payload is the Ka-band radar altimeter. This altimeter is derived from the Poseidon altimeter and operates at 35.75 GHz. Selecting the Ka-band allows a larger bandwidth (500 MHz), which provides a vertical resolution of 0.3 m instead of 0.5 m in Ku-band. This, combined with a higher Pulse Repetition Frequency (around 4000 Hz), contributes to improve the measurement precision. Moreover, due to the smaller antenna beamwidth, by comparison with conventional Ku-band altimeters, the Brown echo is sharper and the antenna footprint is reduced. At 800 km of altitude, the 3-dB footprint radius is about 4 km versus 15 km for Poseidon 2 (Jason-1). This contributes to improve spatial resolution and to discriminate types of surface in transition zones (coastal areas, sea ice boundaries, and so on). In addition, in the Ka-band, ionospheric effects are most often negligible. However, propagation of Ka-band electromagnetic waves is known to be sensitive to atmospheric conditions which may lead to significant attenuation. Two kind of effects can be distinguished. First, a constant attenuation in the radar footprint induces a reduction of the instrument signal to noise ratio. A study has been conducted in order to estimate the maximum rain rates compatible with the specified performances and thus the availability of the data. Secondly, an inhomogeneous attenuation in the radar footprint can lead to a distortion of the brown shape echo and in the worst case, to an error in the estimation of the physical parameters. This point is under study. At first, a waveforms simulator has been used in order to estimate errors on parameters depending on the cloud liquid water, the cloud thickness and diameter. Then, in order to evaluate the impact of data availability, a cloud climatology has been performed using MODIS data. It consists roughly in classifying several days of water liquid content scenes with their occurrences, using a neuronal approach, in typical attenuation grids. Afterward, the impacts on parameters estimation can be evaluated by simulation for each class of scene. This allows to estimate percentage of contaminated echoes, and to build some new algorithms if necessary. First results show that most of liquid water content scenes shall have a negligible or very low impact on AltiKa performances.

Effect of rain and cloud on Ka band (ALTIKA) altimeter data

Jean Tournadre[(1)], Juliette Lambin, CNES, Nathalie Steunou, CNES
[(1)] IFREMER DOPS/LOS

In partnership with scientific laboratories and industry, CNES studies the feasibility of a high-resolution ocean topography mission based upon a new class of wide-band Ka-band altimeter in preparation for the post-ENVISAT mission and in order to complement the OSTM/Jason-2 mission. The central objective is the retrieval of the ocean mesoscale circulation in global or regional ocean models by data assimilation.

One major drawback of Ka band is that attenuation due to liquid water in the troposphere is high, one order of magnitude larger than that at Ku band. It is thus important to analyze thoroughly the impact of liquid water (i.e. rain and cloud) on Ka band altimeter measurements to insure that the disponibility of the altimeter data is lager than 90%, to identify the samples possibly affected by rain or clouds and to define an efficient rain/cloud flag.

Preparatory studies (Tournadre, 1999) have already been conducted on the impact of rain alone on the Ka band altimeter waveform. These studies based on the modelisation of the altimeter waveforms in presence of rain cells showed that rain rate greater than 1 mm/hr strongly distort the echo waveform resulting (as expected in the lost of meaningfull geophysical parameters). Rain climatologies estimated from Topex, Jason and Envisat altimeters shows that about 2-4% of the Ka band data will thus been lost. It should be noted that locally (in the Warm Pool for example this proportion can exceeds 15%). They also showed that rain flagging can be perform easily.

At Ka band, cloud liquid water can also significantly attenuated the altimeter signal. In a first step, we developped a model to compute the altimeter waveform in presence of liquid water. The model was applied for a large range of LW, cloud diameter, and cloud thickness. Both 20 Hz and 1s average atenuation, change of the slope of the leading edge and estimate of the off-nadir angle are estimated to determine the extent of the waveform distorsion. A cloud flag based on both attenuation and change of off-nadir angle will be defined and tested. In a second step, availibility maps based of cloud climatolgy will be derived from the modelisation results.

In operation the altimeter geophysical parameters will be estimated using a Maximum Likelihood Estimator based on 3 or 4 parameters (sigmanaugh, epoch, SWH and off_nadir angle). The impact of rain and cloud on the parameter retrieval has also been tested using the modelled waveforms. The first results shows that the impact of clouds on 1s average are quite minimal except for very high LW content.

AltiKa: a Ka-band altimetry system in tandem with JASON-2

Jacques Verron [(1)], The AltiKa mission group (P. Brasseur, S. Calmant, A. Cazenave, B. Chapron, JF. Créteaux, P. De Mey, J. Dorandeu, L. Eymard, J. Lambin, B. Legresy, PY. Le Traon, F. Lyard, N. Mognard, E. Obligis, F. Rémy, N. Steunou, P. Sengenes, E. Thouvenot, J. Tournadre, P. Vincent)
[(1)] LEGI

In partnership with scientific laboratories and industry, CNES has studied the feasibility of a high-resolution ocean topography mission based upon a new class of wide-band Ka-band altimeter in preparation for the post-ENVISAT mission and in order to complement the OSTM/Jason-2 mission. The central objective is the retrieval of the ocean mesoscale circulation in global or regional ocean models by data assimilation. Moreover, other applications of the mission have been identified: continental water studies, ice sheet monitoring, coastal altimetry, low-rain systems characterization and seasonal forecasting/climate studies (in connection with other observations).

The proposed architecture for the Ka-band altimeter takes benefits of Alcatel Space and CNES experience in the development of Poseidon-1, -2 and -3 and SIRAL (Cryosat). In addition to a combined altimeter and bi-frequency radiometer, the AltiKa payload consists of a DORIS plus Laser Retroreflector Array orbitography system. The technical feasibility of this coupled altimeter / radiometer AltiKa payload has been demonstrated. This kind of altimeter affords a number of advantages:
- Light weight and low power consumption
- Better signal-to-noise ratio, reducing noise to under one centimeter
- More transmission bandwidth, offering higher vertical resolution (30 cm against 50 cm).
- The antenna lobe is narrower and the ground footprint smaller. Combined with a higher pulse repetition frequency, these features allow a better description of coastal processes.
- Ka band measurements should also resolve more detailed features over inland water bodies (closed seas, big lakes and major rivers).
- Better description of sea surface roughness than in Ku band. The eight-millimeter wavelength enables more accurate measurement of the backscatter coefficient over calm or moderate seas.
- Lower radar penetration of snow and ice. Combined with better spatial resolution, this will allow closer monitoring of sea and continental ice.

The one major drawback of Ka band is that attenuation due to water or water vapor in the troposphere is high. However, active studies are conducted to try minimizing this constraint, knowing the fact that it will be a limiting factor for less than 8% of the time.

The payload is to be embarked on the SARAL platform within the framework of a cooperation project between India and France. Launch is planned for Fall 2009.

Predictability of Mesoscale Variability in the EAC given Strong Constraint Data Assimilation

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The objectives of data assimilation in oceanography are typically the reanalysis of a suite of observations for the purposes of hindcast state estimation, and determining initial conditions for model forecasting. In this project we focus on the latter objective and evaluate the Incremental, Strong constraint, 4-Dimensional Variational (IS4DVAR) data assimilation method implemented in the Regional Ocean Modeling System (ROMS) for predictions of mesoscale variability in the East Australia Current (EAC) System. The observations assimilated are daily composites of AVHRR SST, 7-day reanalysis of AVISO SSH anomalies, and high resolution expendable bathythermograph (XBT) temperature profiles from Volunteer Observing Ship (VOS) transects of the Tasman Sea. Considering a 2-year data set for 2001 and 2002, ROMS forecast initial conditions are generated every week by assimilating observations from the 7 days preceding the forecast initial time. Forecast ensembles are produced by adding to the forecast initial conditions so-called optimal perturbations computed from singular vectors of the ROMS Tangent Linear model.

Assimilation of satellite data only (SST and SSH) results in relatively poor estimates of the true subsurface ocean state observed by XBTs, and consequently a poor subsurface forecast skill. Furthermore, the modeled circulation shows significant sensitivity to errors in the initial conditions and therefore the uncertainty, or spread, in the forecast ensemble is high. Including the XBTs in the assimilation experiments improves the ocean state estimation in the vicinity of the XBT transects and reduces the sensitivity to errors in the initial conditions resulting in a more skillful ensemble forecast. Motivated by this finding we explore the utility of including subsurface pseudo-observations based on an empirical relationship between subsurface information and satellite observed surface conditions (CSIRO's "Synthetic XBT" analysis). The preliminary results show that better ocean state estimates and more skillful forecasts are obtained in all the domain considered.

Tides and High-Frequency Aliases

Improvements on the global tide model FES2004

Fabien Lefevre [(1)], Yannice Faugère [(1)], Michaël Ablain [(1)], Jean-Paul Dumont [(1)], Olivier Francis [(2)], Florent Lyard [(3)]
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During the last OSTST meeting in Venice, some recommendations were given to improve the last release of FES2004. Validation studies within the SSALTO processing chains also noted some inaccuracies in a few set of tide wave grids distributed in the FES2004 package. During the talk, we will present our recommended improvements on FES2004 (new S1 grid, new K2 grid and new loading effect grids). Numerical results of comparative studies will illustrate our conclusions.

New improvements on the Dynamic Atmospheric Corrections

Fabien Lefevre [(1)], Loren Carrère (CLS), Frédéric Briol (CLS), Joël Dorandeu (CLS), Laurent Roblou (Noveltis), Eric Jeansou (Noveltis), Florent Lyard (LEGOS/CNRS)
[(1)] C.L.S.

The former SWT and OSTST meetings concluded that the ocean response to atmospheric wind and pressure forcing modelised by the Inverse Barometer (IB) corrections is not accurate enough for altimetric purposes. They recommended to use the Dynamic Atmospheric Corrections (DAC) derived from the MOG2D barotropic model for high frequencies (less than 20 days) and from an IB correction for lower frequencies. In order to improve these corrections, a new MOG2D model was set using a new coarser finite element grid, a new bathymetry and new meteorological fields. The new model as well as validation results for the new DAC will be presented during the talk.

Barotropic tides in the South Indian Ocean

Claire Maraldi [(1)], Testut L. (LEGOS), Coleman R. (UTAS)
[(1)] LEGOS

The challenge for modern tidal models lies now in their ability to provide accurate solutions in shelf and coastal areas and at high latitude where strong discrepancies between models remain. The approach used here was to test the ability of a high resolution purely hydrodynamic tidal model to produce accurate tidal solutions in a region where many (if not all) of the above cited limiting factors are present. To do this the 8 main tidal waves have been computed from a hydrodynamic finite element ocean tide model over the South Indian Ocean. The discretisation of the domain, of the order of 100 km over the deep ocean, is refined down to few hundred meters along the coasts, such refinement enables wave propagation and damping over the continental shelves to be correctly solved. We will present the validation of the model outputs with in-situ observations, Topex-Poseïdon measurements and others tidal models. The solutions are in very good agreement with the data and are significantly better than solutions published to date in the literature : the combined standard deviation error (computed with the 8 main tidal constituents) is 1.6 cm for this new regional model compared with 2.3 cm for the FES2004 solution and about 4 cm for the other models.

Coastal Ocean Tide Modeling Using Satellite Altimetry

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(5) Hong Kong Polytech University, China

Advances in coastal ocean tide modeling in the improved accuracy and spatial resolution are limited primarily by the lack of observations (in situ and satellite data) and complicated dynamics due to shallow coastal ocean bottom topography. Here we present our progress on the use of multi-satellite radar altimetry in the modeling of tides in some of the tidal energetic coastal regions including the Yellow Sea, South China Sea, Patagonia Shelf, Californian coast, Alaska, Hudson Bay, and other areas. The results includes ocean tide modeling using retracked satellite altimetry in these regions and example of tide modeling using ocean circulation modeling embedded with tidal hydrodynamics.

Science Results - poster

First results from the ARAMIS program

Sabine Arnault [(1)], the ARAMIS group[(1)] LOCEAN

The ARAMIS program (Altimétrie sur un Rail Atlantique et Mesures In Situ) has been developed by the french CNES (Centre National d'Etudes Spatiales) and IRD (Institut de Recherche pour le Développement) organizations in order to get a long term survey of temperature, salinity structures in the tropical Atlantic along a merchant ship line during at least 5 years, 2002-2007. Combined with satellite data such as TOPEX/Poséïdon and Jason ones, this experiment will offer the opportunity to approach scientific questions such as the characteristics of the surface circulation long term variability in the tropical Atlantic Ocean; the connection to other parameters (temperature, salinity, CO2…), other oceanic basins (Indian, Pacific, Southern ocean…) and climatic indexes (NOA, Antarctic Oscillation AAO, ENSO…); the role of specific oceanic processes (upwellings, equatorial waves, eddies…) in that variability. We will present here the results obtained using the data from the first ARAMIS campaigns.

Impact of small changes in the atmospheric forcing fields on SST, SSH and mixed-layer heat content in an eddy-permitting model of the North Atlantic

Nadia Ayoub [(1)], M. Lucas [(2)], G. Valladeau [(1)] P. De Mey [(1)]
(1) LEGOS/CNRS
(2) CNRM Meteo-France

Our work aims to improve the understanding of the influence of small changes in atmospheric forcing on sea surface temperature and elevation and mixed-layer processes in an eddy-permitting OGCM at monthly time scales. The small changes in the atmospheric forcing fields represent uncertainties in a given atmospheric dataset or those due to the use of two different atmospheric products. The study addresses the case of the North Atlantic during a period of seasonal deepening of the mixed-layer (September 1994 – March 1995). We use the NEMO model with a ¼°x ¼° horizontal resolution and 46 vertical levels, in the 'NATL4' configuration from the DRAKKAR project. The atmospheric fields are stemming from the ERA40 reanalysis and from the CORE product of Large and Yeager (1994). The study consists of two different approaches. The results are analysed in three regions: the Gulf Stream area, the northern tropics and the north-east. The first approach is a classical sensitivity study where the model is forced by ERA40 and CORE fields; the results in terms of SST and SSH representation and heat budget in the mixed-layer are then compared. Significant differences are observed at weekly time scales not only in the heat content and its time variability, but also on the contribution to the mixed-layer heat budget of the main processes at work (vertical diffusion, horizontal advection, vertical advection). The second approach is based on stochastic modelling. The ERA40 wind velocity, air temperature and incoming solar radiation are randomly perturbed and an ensemble of 50 simulations is generated with the perturbed atmospheric fields. The model response in terms of subsurface temperature is then characterized from the analysis of the ensemble spread, of its spatial distribution and time evolution. We have identified three main mechanisms that are responsible for the distribution in subsurface of the ensemble spread in temperature: 1/ vertical diffusion, 2/ effect of mesoscale activity (Gulf Stream and Northern Tropical areas) and 3/ horizontal advection.

Comparing sea-surface topography modes of variability from altimetry and global models

Bernard Barnier [(1)], Thierry Penduff/LEGI-CNRS, Mélanie Juza/LEGI-CNRS
[(1)] LEGI/CNRS

The international DRAKKAR group is building a hierarchy of ocean/sea-ice models to simulate and study the dynamical processes involved in the oceanic variability and scale interactions over the last 50 years. This hierarchy includes Global Ocean models at 2 and 0.25 degree resolution, both forced over the last five decades by the same reanalysed and observed atmospheric fields.

The quasi-global sea-level anomaly AVISO altimetric database (weekly SLA, 1993-present) is compared with its colocated counterparts simulated by the models in various wavenumber-frequency bands. This assessment concerns the structure and intensity of the leading modes of variability at global and basin scale, the part of the observed SLA variance simulated by the model (and their mutual correlation), and local investigations of the simulated and observed variabilities in selected regions.

The realism of the oceanic variability simulated by those models is discussed, and its sensitivity to resolution is commented. More generally, this validation procedure is applied to all DRAKKAR simulations to guide physical investigations, characterize the structure of model biases, and assess the impact of numerical and physical choices.

Calculating the Ocean's Mean Dynamic Topography from a Mean Sea Surface and a Geoid

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In principle the global mean geostrophic surface circulation of the ocean can be diagnosed by subtracting the geoid from the mean sea surface (MSS). However, because the resulting mean dynamic topography (MDT) is approximately 2 orders of magnitude smaller than either of the constituent surfaces, and because the geoid is most naturally expressed as a spectral model while the MSS is a gridded product, in practice complications arise. Here we consider two computational approaches: a pointwise approach, whereby the geoid height anomaly is expressed geographically and then subtracted from the MSS on a common grid; and a spectral approach, whereby the MSS is expressed in the spectral domain and a spectral MDT computed which is then transformed to a gridded product. It is found that this latter, somewhat counterintuitive, approach results in much less noise in the computed MDT compared to its pointwise equivalent. Careful consideration of errors shows that this is because the spectral approach ensures a matching of omission errors in the geoid and MSS. The local and non-local effects of geoid omission errors and their impact on the MDT are discussed. The positive and negative impacts of filtering on the MDT are assessed. It is demonstrated that the spectral MDT requires less filtering to remove noise and therefore it retains more oceanographic information than its pointwise equivalent.

Exploration of multi-satellite altimetric data over North American lakes

Charon Birkett [(1)]
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Satellite radar altimetry is a valuable tool in providing surface height (stage) measurements of inland water targets and the technique has been utilized in many interdisciplinary projects. This Jason-1 SWT project seeks to explore several investigations using data from the TOPEX/POSEIDON, Jason-1, Topex/Jason tandem period, GFO, ERS, and ENVISAT missions. With the unique opportunity to combine datasets to improve both spatial and temporal resolution, the project seeks to enhance one technical and two science-related programs. The technical program is linked to an ongoing, semi-operational, near-real time reservoir-monitoring project that has evaluation of regional drought and irrigation potential as part of its overall goal (see separate abstract). The science programs are
I. Evaluating the response of lakes and reservoirs to variations in climate, and
II. Exploring the dynamics of the Amazon River.

In this presentation, focus is on investigations looking into the response of inland reservoirs to fluctuations in precipitation and temperature via observation of both altimetric stage and radar backscatter. Stage variations are correlated with major precip events, and the identification and variation of freeze/thaw periods across a 15-year time span are discussed. The major lakes and reservoirs of Northern Canada and Alaska are the primary targets with altimetric results validated and compared to both ground-based gauge observations and findings derived from the utilization of scatterometer data such as QuickSCAT and SSM/I.

Observation of coastal ocean dynamics in the Northern Indian Ocean using improved altimetric data.

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The coastal currents in the Northern Indian Ocean are believed to play a prominent role in the heat and salt exchanges between Arabian Sea and Bay of Bengal. Hence it appears timely to carefully monitor their structure and variability at all timescales from intraseasonal to interannual. The objective of this study is to determine to what extent the sea surface height (SSH) variability associated to these coastal processes can be observed with satellite altimetry, in the Northern Indian ocean sector. Indeed, radar altimetry, which allows to measure SSH at centimetric accuracy, has been shown to be a powerful tool to obtain a wealth of information about open-ocean dynamics. Unfortunately, today, the use of standard satellite altimetric products in coastal zones remains challenging. This study explores a newly released coastal altimetric dataset, obtained from a complete reprocessing of the Topex/Poseidon data. We first present an objective method to derive geostrophic current from the raw SSH. Then we present the validation of the altimetric SSH against in situ observations. Finally we briefly analyze the observed variability of the East India Coastal Current at various timescales.

Equatorial Waves and Warm Water Volume Changes in the Equatorial Pacific

Christelle Bosc [(1)] and Thierry Delcroix [(1)]
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Observational and modelling studies showed that variations of Warm Water Volume (WWV) in the tropical Pacific mainly consist of a zonal seesaw pattern in the equatorial band at the ENSO time scale, and a meridional seesaw pattern between the equatorial and off-equatorial regions at the ENSO and decadal (PDO) time scales. The meridional seesaw pattern is reminiscent of the ENSO recharge / discharge oscillator theory, and WWV changes in the equatorial band can be used to improve ENSO prediction.

This presentation aims at analyzing the mechanisms responsible for the WWV changes in the 5°N-5°S equatorial region during the period 1992-2006. This is done relying on sea level data derived from the TOPEX/Poseidon and Jason missions and wind stress measurements from the ERS and Quiksat satellite missions.

The WWV changes in the 5°N-5°S equatorial box are derived from sea level changes, assuming the ocean behaves like a 1.5-layer ocean. Changes in this WWV are analyzed in terms of geostrophic and Ekman transports filling up or draining the 5°N-5°S equatorial box. The geostrophic transports in the upper layer are computed from surface geostrophic currents (derived from sea level gradients) and statistical current profiles obtained from TAO/TRITON moorings and cruise measurements. The satellite-derived geostrophic transports in the upper layer are validated against in situ hydrographic measurements. The Ekman transports are computed from the wind stress data alone.

The relative roles of geostrophic and Ekman transports in changing the equatorial WWV are discussed, focussing in particular on the effects of propagating equatorial Kelvin and Rossby waves as they affect the basin-scale sea level gradients and related geostrophic currents. It will be shown, in particular, that first baroclinic, first and third meridional mode equatorial Rossby waves, play a key role in changing WWV at the ENSO time scale.

Improved altimetry in the Northwestern Mediterranean: Comparison of Ocean Dynamics with a regional circulation model

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The main objective of the Margin Altimetry Project (MAP) is to improve the quality and availability of satellite-derived products in the coastal and shelf seas, with a strategy optimized for coastal targets. In the framework of the CAP, a coastal multi-satellite altimetric dataset (TOPEX/Poseidon, Jason-1, Envisat, GFO) at a 10-20 Hz sampling rate has been derived from routine geophysical data products using a new processing software (HiReA) dedicated to coastal zone applications. The improved along-track sea level variations with finer space scales are available in the Northwestern Mediterranean Sea from 2001 to 2003, and compared to high-resolution numerical model elevations. This preparatory work emphasizes the potential of improved multi-satellite altimetry for validating coastal hydrodynamical models and will contribute in the future to a better tuning of the boundary conditions in the simulations.

Evaluation of sea level anomalies from coastal tide gauges and satellite altimetry for the shelf zone

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The BLUElink ocean forecasting system performs a routine analysis based on satellite altimetry and in-situ observations. Following accepted practice, satellite altimetry sea level anomalies are not applied in regions shallower than 200m. Australia has an extensive coastline with continental shelves that can extend up to 500km offshore leaving a significant region observed only by a limited network of coastal tide gauges. A comparison of the sea level anomalies from Australia's coastal tide gauges with sea level anomalies from satellite altimetry demonstrated that there is a coherent signal within the shelf zone. The relationship was confined to the continental shelf region with significant elongation following the coastline. The relationship was found to be strongest in shelf regions with modest tidal signals typical of narrow shelves but was also found off the Australian bight. The anisotropic scales were found to be consistent with the covariance statistics obtained from an ensemble of sea level anomalies from an eddy-resolving ocean model. We conclude that it is essential that covariance statistics capture this anisotropy to successfully apply satellite altimetry observations over the shelf zone.

El Niño/La Niña Preconditioning During the 2000's

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Long time series of high quality ocean surface topography (SL from Jason 1), sea surface temperature (SST), subsurface temperature (Tz) and salinity (Sz) observations allow a thorough comparison between distinct El Niño/La Niña conditions. In this study, these data are assimilated using the Ensemble Reduced-Order Kalman Filter (EROKF) technique to improve the initial state of the ocean for November of each year. Ocean model experiments are then used to isolate differences between initial states of the system for El Niño/La Niña development for each year, 2001-2006 (the 1997 event is included as a reference). A statistical atmospheric model is utilized to highlight the atmospheric response to anomalous SST fields. Analysis of the model experiments show several key dynamical elements of the 2006 El Niño were evident in the initial state of the system. Between November 2005 and March 2006, the eastern Pacific was cold due to an upwelling Kelvin wave. Similar to the early stages of the 1997 event, the combined impact of downwelling Kelvin and upwelling Rossby waves carried warm SST eastward over the entire equatorial Pacific in March 2006. However, from March until September, cold water was advected westward by a downwelling Rossby wave which temporarily reduced temperatures in the tropical Pacific. The El Niño fully took hold when the second downwelling Kelvin traversed the Pacific in October to December 2006. A statistical atmospheric model forced by the sea surface temperature anomalies from these experiments isolates the atmospheric sensitivity to the ocean's initial condition and can serve to help guide coupled model forecasts. Similar to the 2002 El Niño, easterlies east of the dateline limit the early growth of the 2006 El Niño prior to May 2006 through destructive interference of any downwelling signal. During May 2006, warm SST is associated with westerly wind anomalies which stretch across the entire basin. However, cold advection from an upwelling Rossby wave and corresponding easterlies limits the duration of this anomaly. After July, westerlies prevail over the central Pacific as the 2006 El Niño develops into a fully coupled event. We show that initial states of the system in November 1996, 2001, 2005 and 2004 are predisposed to induce subsequent El Niños and La Niña, respectively, and these events are predictable 14 months in advance. Wind patterns of the large El Niño (i.e. 1997), moderate El Niño (2002, 2006), La Niña (2005), and non-El Niño years are distinct, reproducible and easily recognized well in advance suggesting that this methodology be included as part of a comprehensive ENSO forecast tool.

Fidelity of high-frequency SSH anomaly signals in the Agulhas Current region

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Using three years of output (1999-2001) from the 0.1 degree global POP model, we derive the steric height and mass-loading signals in the sea surface height anomaly. Working with daily averages of model output in the Agulhas Current System between 10S and 50S, we evaluate the realism of these signals in the model (e.g., their frequency spectra and spatial correlation scales) by comparing them with in situ data from a suite of moorings deployed in the southeastern South Atlantic Ocean in 2003-2005. We then derive the high-frequency (f > 1/20 days) components of the SLA signal and examine their correlation, relative amplitudes and spatial patterns. Within the Agulhas Current and its source regions, the Agulhas Return Current and the Agulhas eddy corridor, high-frequency steric height variability is significant (RMS of 1 - 8 cm); outside of this region it is negligible. Also within the region described, the high frequency component of the mass-loading signal is positively correlated with steric height, but at the same time describes on average less than 20% of the variance in the total SSH anomaly, which is dominated by the steric signal. Outside of this region, the high frequency component is not significantly correlated with steric height, and describes most (83%) of the variance in the total high-frequency SSH anomaly signal. Possible causes of the high-frequency steric signal within the Agulhas Current System such as meandering and transport fluctuations are considered. In addition, the physical source of the high frequency mass-load variability in the Agulhas Current System is sought in the curl of the wind stress upstream of it.

A consistent assimilation of altimetric and temperature data in a model of the tropical Pacific ocean

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Altimetry is a major ground of the today oceanographic program, however, the altimetric measured signal, i.e. the Sea Surface Height (SSH) can only be used in oceanography in its residual component, i.e. the Sea Surface Anomaly (SLA) because of geoid uncertainties. The recent advances of our knowledge of the geoid brought by the CHAMP and GRACE satellite gravity missions provide the possibility to exploit the absolute sea surface height measurements in physical oceanography studies and especially on altimetric data assimilation. In this study we investigate the joint assimilation of this absolute altimetric signal and of the TAO temperature data in a numerical model of the topical Pacific. The assimilation scheme is a reduced-order sequential Kalman filter (SEEK filter), and the model is the OPA 8.2 general circulation model, in its global configuration ORCA2. Despite the relative low resolution of the gravimetric field in areas of strong gradients, both data types are coherent enough to provide a realistic 4D simulation of the tropical Pacific Ocean. A 1993-1998 assimilation experiment has been performed which has been validated against in-situ XBT over the entire tropical Pacific. Results are good enough to assess in a physical point of view the zonal mass flux of the different currents, and their variability for this 6 years period marked by the strong 1997-1998 ENSO event.

Planetary waves and biogeochemistry in the North Atlantic Ocean

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Planetary waves play a major role in the dynamics of the oceans, but their role is not limited to the physics. In fact, several studies (e.g. Machu et al., 1999; Cipollini et al., 2001; Uz et al., 2001; Charria et al., 2006) have shown that these waves have a distinct signature on surface chlorophyll concentration. These observations, made possible by the advent of remotely sensed ocean colour data, prompt several important questions:
- How do planetary waves influence surface chlorophyll concentrations?
- Which vertical or horizontal coupled processes are involved?
- Have planetary waves a measurable influence on primary, new and exported productions?
- Is that influence significant within the global ocean carbon cycle?

Two recent and complementary lines of investigation will be presented, with examples over the North Atlantic. The first approach is the use of remotely sensed data combined with theoretical modelling of the various processes, and then the adoption of a statistical decomposition of the observed signal; this allows an initial assessment of the relative importance of the processes that could explain the chlorophyll signature of planetary waves (Killworth et al., 2004; Charria et al., 2006). The second approach, based on 3D coupled physical/biogeochemical modelling, allows investigating in a more quantitative way the processes involved and the impact of these waves on primary, new and exported production. Finally, the temporal variability (in both amplitude and phase) of the wave signature in chlorophyll is compared to major climatic indices like ENSO and NAO, in order to investigate any correlations.

Seasonal and Interannual Global Mean Sea Level Variability and Implications for the Hydrological Cycle

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The global mean sea level (GMSL) observed by altimetry shows significant seasonal and interannual variability superimposed on a long term trend. This variability is generally explained by the thermosteric effect (eg. change in ocean heat content) and water mass exchange between the ocean and other reservoirs (eg., continental water storage and atmospheric water vapour). In this study, we reconstruct global mean thermosteric sea level 0/300m for the 1993-2005 period using a reduced space optimal interpolation technique to overcome difficulties in undersampled ocean regions, particularly the southern hemisphere. We use GMSL from altimetry, water vapour from reanalysis products and our thermosteric estimates to examine changes in global mean sea level due to continental water storage at annual, semi-annual and interannual timescales. We also compare the latter with estimates from land surface models.

New on line Mean Sea Level database and related products

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A new on line altimeter database has been created on the AVISO web site: http://www.aviso.oceanobs.com/msl. The aim of this new service is to provide users with the more recent altimeter series, frequently updated, with state of the art calibrations and corrections applied, as soon as data become available. It allows a large number of operations and selections on all altimeter mission data series in order to compute Mean Sea Level (MSL) estimations from different criteria: geographical area, time period, corrections used to compute Sea Level Anomalies (SLA), filtering of non relevant signals. MSL time series can be downloaded for all past and present altimeter missions (TOPEX/Poseidon, Jason-1, ERS, EnviSat and GFO), together with geographical estimations of local MSL rise and low frequency signals (seasonal) depending on the selected configuration. Besides this large amount of altimeter data and results, other products related to MSL and climate change are also presented: ocean mass variations from gravity missions (Grace), steric and thermosteric variations using in-situ T/S data, and comparisons between each contribution. Through frequent updates and scientific analysis, the goal of this web site will be to gather a large number of results and consequently to become a forum for MSL change studies.

Computing Coastal Ocean Surface Currents from Ocean Color Satellite Imagery

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Numerous studies have shown that coastal ocean surface currents can be effectively computed by applying the maximum cross correlation (MCC) method to sequential thermal IR imagery from the AVHRR. Unfortunately, this application of the MCC method is limited to tracking surface features in the cloud-free regions of imagery where strong surface thermal gradients exist. In this study, the MCC method is applied to year-long collections of AVHRR IR imagery and MODIS ocean color and IR imagery for the coastal regions off California and the Gulf of Mexico. Spatially and temporally coincident thermal and ocean color MCC velocities have a strong agreement (correlation of 0.74, rms difference of 7.4 cm/s, and mean bias less than 2 cm/s), suggesting that surface currents can be successfully computed from ocean color imagery. The increased sampling of the ocean surface achieved by processing both thermal and ocean color imagery reduces the effects of transient cloud cover and significantly increases the velocity coverage provided by the MCC method. Additionally, ocean color data can provide velocity information for isothermal coastal regions, such as those found in the Gulf of Mexico. Analyses between MCC and ADCP velocities indicate that MCC currents likely represent the bulk flow of approximately the upper 30 meters of the coastal ocean surface. Comparisons between MCC and altimetry-derived velocities confirm that both the thermal and ocean color MCC velocity products accurately depict the surface circulation, and indicate that MCC velocities compliment those from altimetry, providing velocity data over the continental shelf where altimetry data is somewhat unreliable.

Spatial propagation of eddy variability in the world's oceans

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The mesoscale ocean eddy variability is among the first oceanic phenomena observed by satellite altimetry. The Seasat data of only 24 days' duration revealed the large-scale patterns of the geographic distribution of global ocean eddy variability. The combined decade-long data records from TOPEX/Poseidon (followed by Jason) and ERS (followed by Envisat) has allowed the study of ocean eddy variability at much improved spatial and temporal resolutions. Using the AVISO merged data from the two series of satellite missions, a study was conducted of the velocity of spatial propagation of the global ocean eddy variability. A technique of space-time lagged correlation was applied to the time series of sea surface height in a space-time window suitable for oceanic mesoscales. The space and time lags of the maximum correlation allow the estimation for the propagation velocity of the dominant eddy variability. The results indicate that the eddy propagation is heavily influenced by the mean flow and bottom topography. Westward mean flows generally enhance the intrinsic westward propagation of eddy variability, whereas eastward flows tends to diminish the westward propagation and occasionally reverse the zonal propagation to eastward within strong eastward mean flows. It is apparent that barotropic flows are most effective in steering eddy propagation. Interesting patterns of meridional convergence and divergence of eddy variability in the equatorial oceans were observed, probably related to the boundary reflection of zonally propagating equatorial variability. Comparisons with simulations by an ocean general circulation model were also conducted. Excellent agreement was found in the zonally-averaged speed of westward propagation. Global maps of both observed and simulated eddy propagation will be presented with close-ups in various regional maps.

A near-uniform basin-wide sea level variation of the Japan/East Sea

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Sea level of the Japan/East Sea (JES), observed by the TOPEX/Poseidon (T/P) satellite altimeter, is analyzed using a 1/4-deg resolution ocean general circulation model. A significant fraction of the JES sea level variability is found to be spatially uniform with periods ranging from 20 days to a year. The simulation agrees with the T/P records in terms of spectral energy and coherence within the frequencies of interest. The non-seasonal basin-wide JES sea level changes are barotropic in nature and are controlled by the mass transports through the straits of the JES driven by winds in the vicinity of the Korea/Tsushima (KT) and Soya (SY) Straits. Analytical analyses and a series of barotropic simulations suggest that the sea level fluctuations are the result of a dynamic balance among near-strait winds, bottom friction, and geostrophic control at the straits. The winds away from the straits are not influential and the balance is linear. In particular, the basin-wide sea level response is a linear superposition of sea level changes due to the winds near the individual straits.

Geostrophic Transport and Biological Productivity in Southern Drake Passage

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The Shackleton Fracture Zone in southern Drake Passage separates low chlorophyll water to the west from high chlorophyll, biologically productive water in the Ona Basin to the east. Measurements collected in two research cruises in the region indicate that the difference in chlorophyll concentrations most likely occurs because iron-rich shelf water is entrained into the water as it flows eastward within the southern Antarctic Circumpolar Current Front at the southern edge of the Shackleton Fracture Zone. Satellite altimeter data provide information needed to place these research cruise findings in a broader context. Using sea surface height measurements in comparison with time varying chlorophyll measurements, we explore two possible mechanisms that might explain how iron mixes into the Ona Basin. First, changes in transport of the SACCF could drive changes in the supply of iron to the Ona Basin. Second, changes in the off-shore meandering of the SACCF on the eastern side of the Shackleton Fracture Zone may determine the extent to which iron can be stirred into the Ona Basin. The first hypotheses is not supported by the satellite data, since geostrophic transport into the southern portion of the Ona Basin is uncorrelated with chlorophyll. However, the second shows some skill in explaining the observed spatial and temporal variability in chlorophyll concentrations in the Ona Basin.

Air-Sea Gas Fluxes using Altimeter-Derived Transfer Velocities in an Ocean General Circulation Model

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A twelve-year record of air-sea gas transfer velocities estimated from altimeter-derived sea surface roughness (mean square slope of small-scale waves) has been assimilated into a variant of the NCAR Community Climate System Model-Parallel Ocean Program (CCSM-POP). This ocean general circulation model includes a fully coupled marine ecosystem/carbon cycling sub-model. Historical hindcast simulations were integrated from 1958 to the beginning of 1993 using gas transfer velocities derived from NCEP reanalysis wind speeds and the Wanninkhof quadratic wind speed algorithm. Twin experiments were then conducted from 1 Jan 1993 to 1 Jan 2005 using gas transfer velocities derived either from NCEP reanalysis winds or from TOPEX Ku-band and C-band normalized backscatter. We will focus our analysis on a comparison of the time/space differences in air-sea CO2 and O2 fluxes and surface water pCO2 and pO2 fields between the two experiments. Our objectives are to explore the sensitivity of ocean biogeochemistry to global and basin scale variations in gas transfer velocity, gain greater understanding of the global accuracy of the altimeter algorithm, and provide insight into the various processes influencing the net CO2 and O2 fluxes across the air-sea interface.

Evaluation of the ocean observing system for upper ocean heat content and surface dynamics using *in situ* and altimetry observations

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The upper ocean heat storage is a key parameter to better understand the climate system and has been shown to have a significant impact on weather over adjacent landmasses and on the strength and frequency of tropical cyclones. We evaluate the accuracy of global estimates of upper ocean heat storage and its time derivative, using observations from profiling floats, XBTs, and CTDs. The error of heat storage from these in situ observations is derived as based on the statistics and data distribution, and quarterly reports were produced from 1992 to present. A correlation analysis between altimetry-derived sea height anomalies and hydrography-derived estimates of the upper ocean heat storage are done to investigate the vertical extent of the sea height signal in different regions of all ocean basins. Altimetry observations allow us to complete our estimates in regions where hydrographic data are not available or severely under-sampled in space and time and the correlation between altimetry- and hydrography-derived heat content is good.

Additionally, the status of the observing system for surface currents obtained from quality-controlled, drogued Lagangrian drifter observations, is derived. Sea height anomaly data are used to match with those from the drifters to evaluate the correlation between along-track sea height anomaly gradients and across-track drifter-derived geostrophic velocity anomalies. Global fields of correlations and eddy kinetic energy are presented and differences between estimates from both observations are evaluated. High correlations indicate where altimetry observations can be calibrated by the in-situ measurements to provide a good proxy for surface currents. On the other hand, low correlations may be indicative of errors in the winds or where the Ekman model is problematic, where ageostrophic ocean dynamics are contributing significantly to the surface momentum budget, where the signal-to-noise ratio is low, or where there are depth-compensating effects in the upper layer causing the sea height to have low variability.

Global and Regional ocean thermosteric sea level change from in-situ data: Influence of sampling, complementarities with satellite altimetry, role of salinity

Stephanie Guinehut [(1)], Gilles Larnicol [(1)]
[(1)] CLS

In situ data sets have been recently used to estimate interannual variability of global ocean heat content and global ocean thermosteric sea level change for the 1993-2006 periods. Unfortunately, in situ measurements are discrete in time and space and are far from sampling the total surface of the ocean. The study pursues three objectives. First, a careful estimation of sampling error is made in terms of global trend and spatial tendency. Particularly, the influence of the large under sampled areas of the Southern Ocean is quantified and the link between the observed tendency and the increase of observations is studied. Second, the complementarities with satellite altimetry are studied in term of global trend and regional tendency for the last 14 years. Finally, the role of salinity is quantified since the year 2003 (it is unfortunately impossible before) and steric sea level change are compared to thermosteric sea level change and to the full sea level change deduced from satellite altimetry.

Coastal surface currents northeast of Taiwan detected by along-track altimetry data

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Combining surface drifter data with along-track altimetry temporal anomaly data, the temporal mean geostrophic velocity component normal to the tracks is determined. The mean geostrophic velocity in the East China Sea along a TOPEX/Poseidon and Jason-1 track northeast of Taiwan clearly reveals existence of coastal currents; northeastward one with approximately 50-km width on the continental shelf between 100m and 200m depth is considered to be the Kuroshio Branch Current (KBC), and another one near the 100-m isobath to be the Taiwan Warm Current (TWC) originating from the Taiwan Strait. From the time series of the absolute velocity, the sum of the mean and anomaly velocities, the KBC is found to vary intensively with periods of a few months, accompanied by the Kuroshio axis movement; the KBC northeast of Taiwan tends to be strengthened when the Kuroshio moves southward to the north of Yonaguni Island to be away from the continental shelf. Meanwhile, the surface TWC is relatively stable, although its volume transport tends to decrease in winter and autumn and to increase in spring. This seasonal signal is relatively evident later than 2000, but uncertain in 1995-1996 and 1999.

Global pattern of mesoscale variability in sea surface height and its dynamical causes

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Using gridded satellite altimetry fields, we separate the mesoscale variability of sea surface heights into its spatial and temporal components. The ratio of these components shows a strong latitudinal dependence and to a large degree is controlled by Rossby radius of deformation for the first baroclinic mode. Further analysis results in the attribution of mesoscale variability in different areas to dynamical causes. Major portion of it can be explained as a local response to the mesoscale variability in the wind. The propagation of ocean eddies modify the pattern in such areas and nearby. Another major mechanism of generating high mesoscale variability is generation of instability waves in the areas of ocean countercurrents. Comparison with ocean models show that they mostly reproduce mesoscale variability due to current instabilities, but not the one caused by the mesoscale variability in winds. Eddy-permitting ocean models reproduce temporal variability much better than the spatial variability, although the simulation of the latter is improved with the refinement of models' resolution. The pattern of mesoscale variability often appears as a pattern of model error and also as a pattern of gridding error on altimetry-based sea surface height maps.

Heat and Mass Transport Anomalies in the Gulf Stream Region

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Strong western boundary currents in the Northern Hemisphere midlatitude oceans transport heat from the warm tropical regions to 35-40N, where much of the heat is fluxed to the atmosphere. Some of this heat continues on into the subpolar gyre to warm the high-latitude regions, as part of what is commonly termed the ocean's heat "conveyor belt". Observations of sea surface height (SSH) anomalies show large interannual-to-decadal variations in the structure of current systems such as the Gulf Stream. Changes in SSH represent changes in the strength of the geostrophic currents: an increase in the SSH difference across the boundary current represents an increase in the surface (mass) transport. On what spatial and temporal scales are current anomalies coherent in the western North Atlantic? In other words, is the conveyor belt continuous through the Gulf Stream region and into the North Atlantic Current?

It is sometimes assumed that changes in the meridional overturning circulation (MOC, of which the Gulf Stream is the upper limb) imply changes in the meridional heat transport. If much of the the heat is transported in the relatively shallow (wind-driven) ocean, as suggested by some recent studies, then the circulation changes observed by the altimeter may give an estimate of changes in the meridional heat transport and those changes may be wind-driven. What is the relationship between changes in mass transport and changes in heat transport?

Using both a simple thermodynamical model (with currents specified by SSH) and an ocean general circulation model (Mercator PSY1, 1/3-degree) that assimilates SSH, we examine the spatial and temporal coherence of current anomalies and the relationship between changes in the strength of the Gulf Stream and changes in heat transport.

Surface currents and evolution of the 2006-2007 El Nino

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The OSCAR surface current data (www.oscar.noaa.gov)were shown to be very useful in diagnosing the evolution of the previous two El Ninos (1997-98 and 2002-03). Equatorial surface current anomalies led SST anomalies by ~2 months. We will apply the most recent data to describe the current 2006-07 El Nino life cycle through February 2007. These data now indicate that the SST anomalies peaked in late November – early December 2006, very similar in phase with the previous two events. As of this writing (8 January 2007), the surface current anomalies have abruptly reversed direction in recent weeks and now are westward at 0.5-0.8 m/s in the Nino 3.4 region. This portends a rapid SST anomaly decrease during the next month or two, and the likely possibility that the 2006-07 El Nino will have ended at the time of this conference in early March 2007.

MONITORING OF THE OCEAN VARIABILITY THANKS TO GLOBAL OBSERVED OCEAN PRODUCTS

Gilles Larnicol [(1)], S. Guinehut[(1)], M.H. Rio[(1)], J. Dorandeu[(1)]
[(1)] CLS

Producing comprehensive information about the ocean has become a top priority for operational oceanography centers. A way to understand and monitor the ocean state is to develop observation-based products at high temporal and spatial resolution. The later generate accurate information for ocean monitoring using satellite (mainly altimetry) and in-situ measurements representing the two most important complementary components of the Global Ocean Observing System (GOOS).

Two products have been developed. First, accurate but sparse in-situ T/S data are merged with high resolution altimeter and SST data in order to reconstruct global instantaneous 3D thermohaline fields (ARMOR-3D products). Second, global instantaneous surface currents are derived from a combination of altimeter geostrophic currents, Ekman currents derived from wind-fields and in-situ surface currents derived from drifting buoys (SURCOUF products).

The Global Observed Ocean Products (GOOP) represent a powerful Earth Observation tool to understand the role of the ocean in modulating climate. On the other hand, they help us to characterize the model accuracy and to quantify the contribution of the model dynamic.

Creation GCRAS06 Mean Sea Surface Model and Investigation of Hydrodynamic Regime of the Caspian Sea based on TOPEX/Poseidon and Jason-1 Satellite Altimetry Data.

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The Caspian Sea level have strong interannual or climatic variability, then since 1992 to 2006 (time of active altimetric measurements) it amplitude amount to a 60 cm. Thus calculated methods of MSS models which are existing on present time a priori are prove useful to investigate variability of synoptic dynamic topography of the Sea. So then new MSS model (GCRAS06) was developing in the Geophysical Center of Russian Academy of Sciences. It is based on TOPEX/Poseidon and Jason-1 satellite altimetry date with exclude from seasonal and synoptic variability. The GCRAS06 MSS Model was constructed as function of a latitude, longitude and time with taking into consideration climatic dynamic topography. The climatic dynamic topography (or hydrodynamic level) was calculated on the base of three-dimensional baroclinic model with a free surface, average monthly fields of temperature and salinity, climatic Volga River run-off, irregular evaporation from sea surface, and atmospheric fields from the regional atmospheric model over the period from 1948 to 2006. This model was developed in Laboratory of Sea Applied Research of Hydrometeorological Research Center (HRC) of Russian Federation. Synoptic dynamic topography was constructed on the basis of the superposition of the sea level anomalies (SLA) distribution over the climatic dynamic topography which was calculated by the HRC model. The SLA were calculated relative to the GCRAS06 MSS Model. Analysis of seasonal dynamic topography shows existence of a gyre in the Middle Caspian, which changes its direction of rotation from a cyclonic one in winter months to an anticyclonic one in summer months. This transformation seems to be conditioned by seasonal variability of the Volga river run-off and wind conditions over the Caspian Sea. Dynamics of the Southern Caspian Sea has a pronounced vortical nature. Wind variability is a cause of this phenomenon. This study was supported by the grant of the Russian Foundation for Basic Research (06-05-64871), and by the INTAS Project “ALTImetry for COastal REgions” (ALTICORE).

Characteristics of planetary waves in the North Atlantic from altimetry and the CLIPPER 1/6° model

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Satellite altimetry has been recording the surface signature of planetary waves in the world's oceans since 1992. These observations have highlighted the limits of standard theories about planetary waves, and stimulated the development of new ones (Killworth et al 1997, Tailleux and McWilliams 2001), both of which emphasize the importance of subsurface features, i.e. the impact of baroclinic shears and bottom topography. However, the subsurface structure of these waves is still poorly known, and realistic numerical simulations have a clear potential for such a 3D investigation. The present study focuses on the North Atlantic subtropics, and makes use of altimeter (Topex/Poseidon + ERS) sea-level anomalies (SLA) and of a 1/6° realistic Atlantic simulation performed during the French Clipper project. Westward-propagating surface structures are tracked over the period 1993-2000 from both observed and simulated SLAs. Our method, based on the Radon Transform (Hill et al., 2000), has been improved to extract the first baroclinic mode of the planetary waves. This surface validation of observed and simulated waves is done in terms of zonal phase speeds and amplitudes, and reveals the realism of modelled waves. The same analysis is thus extended below the surface. Our analysis highlights the complex structure of simulated waves in the vertical, the impact of the Mid-Atlantic Ridge, and might help support theoretical investigations.

Hydrologic Study of Vegetated Wetland Using Retracked Satellite Altimetry

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Conventional satellite radar altimetry is designed to observe ocean topography and significant technological advance has enabled our capability to measure sea level change, ice sheet elevation and sea ice freeboard height changes, hydrologic changes for large inland lake and rivers, and potentially land deformation. Here we demonstrate the use of retracked Ku-band altimetry (TOPEX) to observe water level changes in wetlands with vegetations in Louisiana wetlands and in the pothole regions of North America which are seasonally ice-covered. Backscatter coefficients are used to classify the surface response including calm/ice-covered water surface or vegetated wetlands. We find that most of the radar altimeter waveform response over the study areas are specular or narrow-peaked, and various retrackers have been tested including the conventional OCOG, threshold, and the modified threshold algorithms. These algorithms are used to obtain a decadal (1992-2002) or longer height time series over selected regions of the Louisiana and pothole region wetlands. While the use of JASON data is attempted, it is not successful because of the loss of lock problem. The use of ENVISAT data and ICESat laser altimetry are used primarily to validate the TOPEX measurements. It is found that the use of various corrections including wet troposphere delays computed from models (FMO/ECMWF) and DORIS ionosphere delays reduces variance of the wetland water level measurements. The comparison of available data from in situ and nearby river stages qualitatively confirm the altimeter observations of wetland water level change.

Along track repeat altimetry for land studies : application to ice sheets.

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Satellite altimetry is the unique possibility for continuous and extensive survey of the large polar ice sheets volume change. With ERS1 it became possible to measure the surface topography of 80% of the antarctic and quite all of the greenland ice sheets with an unprecedent accuracy. The accuracy of the classical radar altimeter measurements over continental surfaces is however limited by a number of factors of which the first is the topographic induced error (commonly called slope induced error). In addition volume echo induce penetration effect on the altimeter waveforms. The temporal survey of the surface height is classicaly made using crossover points differences in order to limit the topographic induced errors. However the measurements show difference as to volume echo induced errors between ascending and descending tracks. A method has been developped at LEGOS to survey along track by taking into account the fluctuations across track of both the height measurement and the waveform shape parameters. This method has the advantage to avoid the ascending/descending difference in echoing and also to lead to around 100 times more measurements available to survey the evolution. It also helps to look at the time evolution of the ice sheet surface at small scales of the order of few km in regional or local studies. In this presentation, we'll show the principle and aspects of the methods and the impact in terms of accuracy and local signal. We show applications on Antarctica and Greenland, using ERS and Topex. The development of a systematic correction to be included in ENVISAT products at GDR level is discussed.

Uncertainties in thermosteric sea level estimates

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ARGO hydrographic profiles have vastly improved the sampling of temperature and salinity in the global oceans, in particular by providing relatively frequent observations in regions (e.g. the Southern Ocean) with a sparse climate record. When compared with satellite altimetry and ocean mass estimates from GRACE, these observations, in principle, can provide a nearly complete picture of recent sea level change.

Hydrographic observations demonstrate an apparent cooling of the ocean since 2002, which would imply up to a 2 mm drop in thermosteric sea level. We present the recent Jason altimetry observations of total sea level and GRACE measurement of ocean mass. We have sampled the altimetric observations at the times and locations of the ARGO profiles and have developed an error estimate for the hydrographic observations of heat storage.

In an analysis of the World Ocean Database (WOD), Antonov et al. [2005] reported a linear trend of 0.33 +/- 0.04 mm/year in thermosteric sea level for the global (50S–65N, 0-700 m) oceans during the period 1955-2003 and trend of 1.23 +/- 0.2 mm/year during 1993-2003. Miller and Douglas [2004] have suggested that smoothing errors in high variability regions such as the Gulf Stream can bias thermosteric estimates. Gregory et al. [2004] have demonstrated that gaps in the observational record can have a significant effect on the estimated global trend.

We present the results of thermosteric estimates derived from high-resolution coupled climate models (Parallel Climate Model and MIROC). We have simulated the results of the objective analysis method of Antonov et al. using climate model output sampled at the times and locations of the profiles in the WOD. We compare this analysis to regional and global mean sea level averaged from the full output from each model.

Margin Altimetry Project: a joined effort toward shelf, coastal and continental altimetry processing

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Using altimetric products in the shelf and coastal seas, as well as over the continents for surface hydrology, is still very challenging. Not only the right observation is more difficult to acquire properly, but also the standard processing and delivered products (such as AVISO GDRs) are not tuned for those ocean marginal regions. Consequently the error budgets are often too large to provide a useful observation. The future generation of altimetric missions will certainly better fulfil the requirements for. But in addition, we need a new generation of data processing software and strategies to combine information from altimetry with other in situ observations (tide gauges, coastal radar data, buoys network...). The Margins Altimetry Project (MAP) gathers several groups that have joined efforts to promote and develop altimetry data tools and applications in regions away from the open ocean. A dedicated data processing is being developed by the MAP. Among other improvements, it uses regional modelling for the HF de-aliasing (tides and storm surges), new editing criteria for the environmental corrections and the altimeter range measurement; missing corrections re-construction techniques. It addresses also the orbit error reduction problem and higher sampling rates processing (up to 5Hz). The products have been validated on different experimental regions against in situ observations and the improvement compared to the standard altimetric products has been assessed. First, it substantially increases the number of valid data in the coastal domain and their accuracy. Secondly, shelf and coastal ocean dynamic can be clearly observed through this new set of data. For instance, it allows documenting coastal trapped wave activities and the meso-scale variability of the coastal circulations. So far, existing dedicated data processing has proven to be efficient to provide a quality data set that can be very useful either in scientific or in operational ocean applications. There is still a lot of room for new developments and integration such as enhanced re-tracking, measurement, decontamination techniques and so on. Starting from today's technology and keeping developing and improving the MAP data processing will allow making quality altimetry data rapidly available to a wide community for shelf and coastal seas applications, and for hydrology.

An evaluation of the classical and extended Rossby wave theories in explaining spectral estimates of the first few baroclinic modes in the South Pacific Ocean

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Previous literature has suggested that multiple peaks in sea level anomalies (SLA) detected by two-dimensional Fourier Transform (2D-FT) analysis are spectral components of multiple propagating signals, which may correspond to different baroclinic Rossby wave modes. We test this hypothesis in the South Pacific Ocean by applying a 2D-FT analysis to the long Rossby wave signal determined from filtered TOPEX/Poseidon and European remote sensing-1/2 satellite altimeter derived SLA. The first four baroclinic mode dispersion curves for the classical linear wave theory and the Killworth and Blundell extended theory are used to determine the spectral signature and energy contributions of each mode. South of 17S, the first two extended theory modes explain up to 60% more of the variance in the observed power spectral energy than their classical linear theory counterparts. We find that Rossby wave modes 2 and 3 contribute to the total Rossby wave energy in the SLA data. The second mode contributes significantly over most of the basin. The third mode is also evident in some localized regions of the South Pacific but may be ignored at the large scale. Examination of a selection of case study sites suggests that bathymetric effects may dominate at longer wavelengths or permit higher order mode solutions, but mean flow tends to be the more influential factor in the extended theory. We discuss the regional variations in frequency and wave number characteristics of the extended theory modes across the South Pacific basin.

The Upwelling of Downwelling Currents

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The term “downwelling currents” designates currents with a downslope flux in the bottom boundary layer. Typical examples are the Malvinas and Southland Currents in the southern hemisphere and the Oyashio in the northern. It seems paradoxical but many of these currents foster the development of the same kind of highly productive ecosystems that is usually associated with upwelling regimes. These highly productive areas are symptomatic of the upwelling of nutrient-rich waters to the surface, but the mechanisms that may drive such upwelling are unknown. In this article we postulate that the interaction between downwelling currents, particularly those flowing over the continental slope, and the bottom topography generates shelfbreak upwelling. To prove our hypothesis we present the results of a series of process-oriented numerical experiments using a 3-D primitive equation model. First we discuss the results of experiments focusing on the role of a slope current on the generation of shelfbreak upwelling and their sensitivity to several of the model parameters (magnitude of the inflow, bottom friction, density stratification, etc). Then we discuss the role of shelf currents and the interaction between the shelf- and deep-ocean.

Jets standing in meridional flow as revealed by joint analysis of satellite and in situ data

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Jointly processed within a simplified model of balance of horizontal momentum, data of satellite altimetry, drifters, wind and GRACE mission provided a high quality 12-year mean absolute seasurface dynamic topography with fine mesoscale resolution and nearly global coverage. Its accuracy is good enough in a wide range of scales to outline jet-like structures associated both with known currents (such as Azores Current, Hawaiian Lee Countercurrent, etc.) and newly found systems (such as jets in eastern parts of all oceans). It is puzzling how these fine structures are capable of surviving the effects of advection and stirring by sensible meridional flows associated with gyres of wind-driven large-scale ocean circulation.

The answer found in this study suggests that the jets behave as Rossby waves standing in the background flow. Based on the dispersion equation, phase of a Rossby wave may propagate with a meridional component only if its wavevector also has a westward component, i.e. to stand in the meridional external flow a jet can't be exactly zonal but must be tilted. Our analysis shows that, indeed, regardless of their origin all jets are oriented northeast-southwest, if in the southward flow, and northwest-southeast, if in the northward flow. Results are presented of a quantitative analysis based on the linear theory. Also limitations of this theory in application to essentially non-dispersive standing waves are discussed.

Improvement of the Topex/Poseidon altimetric data processing for hydrological purposes and investigations on the performances of Jason over continental waters (CASH Project)

Franck Mercier CLS

Satellite altimetry technique and products are primarily designed for open ocean studies. The same technique has been progressively applied to inner seas, lakes and large rivers. Early results have highlighted the potential contribution of this technique to the monitoring of continental water bodies levels, and the gains than can be expected in measurement quality (accuracy, frequency) through better definition of ground track location, improved algorithms for waveform retracking, improved methods to quantify tropospheric propagation delays. Actually, over non-ocean surfaces (wet or dry), the accuracy of the T/P altimetric measurements is degraded to several cm or tens of cm (or even worse), mainly because of the heterogeneity of the reflecting surface (a mix of water and emerged lands). For Jason, the situation is much more problematic since the GDR only contain a very few amount of data over continental waters. Another important source of error lies in the propagation of the signal through the atmosphere. This study focuses on these 2 issues.

In the framework of the CASH project (Contribution de l'Altimétrie Satellitaire à l'Hydrologie) founded by the French Ministry of Research, it has been decided to initiate a global re-processing of the Topex/Poseidon data (1992-2005) that is dedicated to the constitution of an hydrology-oriented altimetric data base.

Over the open ocean, only water is present within the radar footprint. Over continental water bodies, emerged lands within the footprint generate complex radar echoes (waveforms) over which the height retrieval process is not as accurate as it is for oceanic echoes. As a first step, we applied to the Topex waveforms the same 4 retracking algorithms that are routinely applied to the ENVISAT measurements. Consequently, Topex/Poseidon products become coherent with ENVISAT Geophysical Data Records. These retracking algorithms are known as "Ocean", "Ice1", "Ice2" and "SeaIce" in the ENVISAT processing. Although not specifically dedicated to the large variety of waveforms that can be found over continental waters and therefore not fully optimized for hydrological purposes, these algorithms nevertheless provide, over water bodies, promising results in terms of accuracy improvement and recovering of data that are missing in the Topex/Poseidon MGDRs. Several examples showing the resu! lting gain are presented.

Early users of Jason data over the continental water bodies spotted out the depletion of the GDR with respect to the corresponding T/P products. We therefore investigated the SGDR products that contain the altimetric waveforms over two sites: lake Chad and TonleSap. It appears that those radar echoes are most of the time either largely missing over area-limited water bodies or present but deeply deformed.

Simultaneously, we investigated the correction of the propagation delay induced by the water vapour within the troposphere. This correction can amount 50 cm, with an annual cycle amplitude of up to 20 cm, and is usually computed over oceans with simultaneous radiometric measurements. Such measurements generally default over non-ocean surfaces and may be superseded by a correction computed from meteorological model outputs (usually the ECMWF model). We first show that the model correction included in the widespread altimetric data sets is not reliable over non-ocean areas because the changes in the altitude of the reflecting surface (and thus the thickness of the atmosphere column) are not taken into account. Then, we demonstrate that a computation based on the use of a gridded Digital Elevation Model is not adequate. We finally propose a new method where the altitude of the reflecting surface is deduced from the altimetric measurement itself. This method is applied (with the NCEP Reanalysis model outputs) and is evaluated via comparisons with radiometric measurements acquired over a selection of large inland water bodies.

Global Sea Level Estimates from the GCOS Tide Gauge Network

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The Global Climate Observing System (GCOS) includes 180 island and coastal tide gauges distributed throughout the major ocean basins. Estimates of globally averaged sea level from the network are subject to errors associated with sparse spatial coverage, varying tide gauge record lengths, and unresolved vertical land motion at each station. An assessment of these errors is made by comparing estimates from the tide gauge network with more complete averages from altimeter observations and SODA-POP model simulations. Even with simple spatial averaging strategies, the GCOS network does reasonably well in reproducing global sea level variability when the majority of the network is in operation. The results degrade as the number of available stations within latitude bands decreases going back in time, particularly in the southern hemisphere. The impact of land motion corrections on the global sea level estimates is assessed using vertical rates derived from continuous GPS measurements. The error analysis is used to assess global sea level rise trends obtained from the GCOS network and comparisons are made with rates derived from altimetry and other recent tide gauge based studies.

Extending the TOPEX/Jason global mean sea level time series with GEOSAT observations

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The rate of global mean sea level rise over the past 15 years determined from TOPEX/Jason satellite altimeter observations is ~3 mm/yr, more than 50% greater than tide gauge-based estimates of sea level rise over the past century. Determining whether the present higher rate is a reflection of decadal variability or long-term change is an important Global Warming issue. Here we extend the length of the altimetric global mean sea level record to 22 years, using tide gauge measurements to connect a new, improved version of GEOSAT observations (1985-1988) with TOPEX observations beginning in 1992. The GEOSAT data set has been enhanced with orbits based on a new GRACE gravity model, resulting in a significant reduction in the rms crossover differences. A statistical analysis showing the day/night effects of the ionosphere on the single frequency GEOSAT observations is presented.

Gyre-scale atmospheric pressure variations and their relation to 19th and 20th century sea level rise

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Most of the long tide gauge records in the North Atlantic and North Pacific universally used in estimates of global sea level rise and acceleration display a very different behavior in the 19th and 20th century. The rates of rise are lower in the 19th compared to the 20th century. We show that this behavior is closely related to gyre-scale atmospheric pressure variations, suggesting that regional re-distribution of water plays a role in this difference.

Observed subsurface signature of Southern Ocean sea level rise

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Satellite altimetry data show a strong increase in sea level in various parts of the Southern Ocean over the 1990s. In this paper we examine the causes of the observed sea level rise in the region south of Australia, using 13 years of repeat hydrographic data from the WOCE-SR3 sections, and the SURVOSTRAL XBT and surface salinity data. The hydrographic data show a poleward shift in the position of the Subtropical and the Subantarctic Fronts over the period. In the Antarctic Zone, the Antarctic Surface Water has become warmer and fresher, and the Winter Water tongue has become warmer, fresher, thinner and shallower. Increased freshening south of the Polar Front is linked to increased precipitation over the 1990s. Temperature changes over the upper 500 m account for only part of the altimetric sea level rise. The CTD sections show that the deeper layers are also warmer and slightly saltier and the observed sea level can be explained by steric expansion over the upper 2000 m. ENSO variability impacts on the northern part of the section, and a simple Sverdrup transport model shows how large-scale changes in the wind-forcing, related to the Southern Annular Mode, may contribute to the deeper warming to the south.

Hydrologic Contributions to Global Mean Sea Level Change

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Time series of variations in global mean sea level from TOPEX/Poseidon and Jason show a large amount of interannual variability, especially during ENSO events. Analysis of thermosteric sea level suggests that not all of the interannual variability is related to changes in the ocean heat storage, which implies that it may be explained by interannual variations in the exchange of freshwater mass with the continents. Unfortunately, observations of the hydrologic contributions to sea level change are sparse at best, and thus assessing the contributions to sea level change is difficult. Nevertheless, we have embarked on an effort to quantify these contributions using the available river gauge, precipitation, and evaporation data, as well as model output that incorporates these measurements. In addition, GRACE time variable gravity measurements provide a way to directly determine the hydrologic contributions to sea level change, but only over the last 4 years. We will review the results of our analysis of these datasets, but on the whole, they suggest that the exchange of freshwater between the continents and the oceans is a significant driver of interannual variability in global mean sea level.

The Bluelink Ocean Data Assimilation System: an ensemble approach to an eddy-resolving application

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The Bluelink Ocean Data Assimilation system (BODAS) is a multivariate ensemble optimal interpolation system that assimilates observations of in situ and satellite-derived sea-level anomaly (SLA), satellite-derived sea-surface temperature (SST), and in situ temperature and salinity. BODAS uses stationary, ensemble-based, anisotropic and inhomogeneous covariances to combine observations with a model background field. To date, BODAS has been tested in combination with the Ocean Forecasting Australia Model (OFAM), a global configuration of MOM4.0 with 1/10deg resolution around Australia. Results from a multi-year ocean reanalysis, referred to as the Bluelink ReANalysis (BRAN), demonstrate that in combination BODAS and OFAM provide a good representation of the three-dimensional time-varying ocean circulation. In the Australian region BRAN is typically within 0.8deg of observed SST, within 8cm of observed SLA and has anomaly correlations of about 0.7 and 0.6 for SST and SLA respectively. Relative to persistence, BRAN typically has positive skill during the 7-day forecast cycle between assimilation steps. We find that this skill is significantly better in austral summer, compared to austral winter.

Assessment of DRAKKAR global simulations against altimetry and hydrography.

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The international DRAKKAR program is building a hierarchy of ocean/sea-ice models to simulate and study the dynamical processes involved in the oceanic variability and scale interactions over the last 50 years. This hierarchy includes 1/2° and 1/4° configurations of the Global Ocean, 1/4° and (soon) 1/12° models of the Atlantic Ocean between 30°S and 80°N, all forced over the last decades by various reanalysed and observed atmospheric fields through bulk formulae. In order to guide physical investigations, characterize the structure of model biases, and assess the impact of numerical and physical choices, DRAKKAR simulations are evaluated against altimetric sea-level anomalies (AVISO: 1993-present), and temperature/salinity profiles (ENACT/ENSEMBLES: 1956-present). Model outputs are first sub-sampled like actual observations to build altimetric and hydrographic "synthetic observations". Real and synthetic observations and more integral quantities (mixed layer depth cycle, heat/salt contents, etc.) are then compared over various regions, periods, and timescales. This study presents the methods and a validation of DRAKKAR simulations.

The need of TPJ accuracy to make further progress in ENSO

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Since 1992, our objective has been to use sea level (SL) data in Intermediate Coupled Models (ICMs) of the tropical Pacific Ocean/Atmosphere system to make progress in understanding ENSO. ICMs are anomaly models in which the mean state of the ocean and atmosphere are prescribed to observed values. Today like in the early 1990s, one approach consists in using the TOPEX-Poseidon-Jason (TPJ) data to improve the initial conditions, possible improvement of the model predictive skill might follow. To study ENSO, one needs a climatological reference. The Jan 1980-to-Dec 1996 is our reference period. For all results including model outputs, anomalies are computed relative to the climatologies derived from the DATA sets over this period. Using SL data to initialize the model has a strong impact on ENSO forecasts, but the predictive skill remains poor. Using SL data to reduce model deficiencies during the forecast (coupled experiments) is much more efficient than during the initialization (forced experiments). By contrast to forced experiments, coupled experiments ARE sensitive to SL changes of a few centimeters only. This is still true today for all the ICMs we improved and tested. Thus, processes such as the Indo-Pacific connection or the off-equatorial ocean/atmosphere recharge, which affect the equatorial SL by less than 2 cm and the Nino3 index by less than 0.2 DegreeC during initialization (Figa), make forecasts differ by more than 3 DegreeC (Figbc). Because errors are known to grow in the coupled experiments, this could be a model artefact only. To find out if the process plays a role in reality, we perform almost-data free experiments (Figc) where a few SL and wind data are used to prescribe the process during the coupled model integration since 1980. The challenge consists in avoiding model error growth while preserving the model sensitivity to the few centimeter changes that we prescribe. When we finally succeed to simulate warm and cold events in decent agreement with observations like in Figc, we can conclude that the so far neglected process does play a role in reality. Otherwise, the design and results of such experiments point out to what needs to be improved in the model (for exple, we had to add physics with vertical mixing to the ICM to obtain the results of Fig c). Presently we are still struggling to get realistic almost-data-free simulations controlled by the North and South recharge while we test recently released SL estimates over the Jason period. The current event is a beautiful example of how TPJ accuracy combined to the sensitivity of the ICM detects processes of North-South-Indian oceanic changes that matter for the evolution of this event which cannot be detected in forced models and which differ from any previous ENSO event observed with TPJ. TPJ accuracy continues to be THE guide without which modelers cannot figure out which process in the coupled system needs attention and improvement.

INTRA-SEASONAL KELVIN WAVES IN THE TROPICAL ATLANTIC OCEAN

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The intra-seasonal variability of the tropical Atlantic dynamic height is investigated over the TOPEX-Poseidon decade in the framework of the Kelvin and Rossby waves activity. Based on satellite measurements and an OGCM simulation, this work focus on the morphology of the equatorial and coastal horizontal propagations observed within the fifteen days to three month period, and examines the sources and sinks of the signals. A two months periodicity characterizes the clearest activity and the winter season presents the most coherent Kelvin wave propagations. We evidence first the robustness of the continuity between the equatorial Kelvin waves and the coastal propagation at the African coasts. Near five degrees of latitude, these trapped waves appear frequently to trigger equatorial Rossby waves that propagate as far as the American coasts in both hemispheres. In the meantime the coastally trapped signals often reach as far as 12 degrees of latitude, near the oceanic fronts of the Mauritanian and Benguela upwelling regions. In these regions, the waves loose their identity under the forcing of the local winds associated to high frequency variations of the southern and northern subtropical highs. A large fraction of the propagations is sufficiently recurrent and in phase with the seasonal cycle to be representatively synthesised by a climatology of the intra-seasonal activity.

A cut across the Madagascan flow recorded by moorings and satellites

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During the first MadEx cruise (February 2005) three moorings were laid along Jason track 196 where it cuts the current flow to the south of Madagascar. These moorings were collected 14 months later during MadEx II. The current meters reveal significant knockdown of the mooring, with currents around 1 m/s for periods of weeks, which correspond to the passage of positive sea surface height anomalies in the altimetry data. The mooring data show that these altimetric features are caused by deep anticyclones, and the temperature and salinity records enable us to determine the associated heat and salt fluxes. Ocean colour data also contribute by delineating the path of the East Madagascar Current (which is chlorophyll poor) and revealing that some of the variations in flow are due to meanders in the position of the current. The 14-year record of TOPEX and Jason overflights help us to put these 14-month records in context, and determine not only the interannual variations in flow in that region, but also the associated heat and salt transport.

Hurricane Juan: A triple view from Envisat

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In September 2003, Hurricane Juan became the severest hurricane to hit Nova Scotia in more than a hundred years. A few days earlier Envisat recorded observations of it whilst it was just north of Bermuda. In this talk we will show the geophysical data recorded by three of the on-board sensors, and especially look at the asymmetric structure that was present. The radar altimeter, RA-2, yielded information on wind speed, wave height and rain rate. The wind speed along this section reached 15 m/s, with wave heights of 6m, and the rain occurred in bands with a peak rate exceeding 10 mm/hr. The microwave radiometer, MWR-2, provided estimates of water vapour and liquid water content (LWC), although the standard retrieval had to be modified because attenuation by rain affected the estimates of sigma0_Ku used in the normal inversion. The wider picture was provided by the 500 km swath of the infra-red radiometer, AATSR, whose data were used to infer the cloud top height and their optical depth (OD). Heavy rain was found only to occur where the OD exceeded 30 and LWC was greater than 1 kg/m^2. However, not all locations matching these conditions had significant rain as that varied on smaller spatial scales than the cloud parameters. We conclude that active radar systems are a prerequisite for fine-scale studies of rain structure.

Chlorophyll and westerly wind events in the western tropical Pacific: a multi-sensor approach

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Westerly wind events in the western tropical Pacific warm pool dominate the intra-seasonal variability. Their impact on biology has been seldom studied. It is generally stated that the associated phyoplankton growth is caused by vertical inputs of nutrients in the euphotic layer resulting from an increased vertical mixing. Nevertheless, examination of the SeaWiFS ocean color images shows that other processes such as horizontal advection can explain the chlorophyll increase in the warm pool. We infer the response of surface chlorophyll to westerly wind events from the SeaWiFS data together with QSCAT winds, T/P-ERS sea level anomaly, and TMI SST. We point out and investigate two types of impacts. In the first type, local physical processes drive nutrient entrainment to the surface layer. In the second type, nutrient- and chlorophyll-rich waters are advected from the west. Interactions between interannual ocean dynamics, monsoon and intra-seasonal wind forcing are h! ighlighted as well as their possible consequences on the warm pool growing greener during El Niño events.

Altimetry and Seagliders: an observing system for high latitude ocean climate

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Altimetry combined with robotic, deep-diving Seagliders observing the oceanic water-column and velocity provide an observational network of global climate. The far northern Atlantic and Arctic are head-waters for much of the global meridional overturning circulation (MOC). We are interested particularly in global-warming induced climate change, which has intricate feed-backs in the atmosphere, ocean and cryosphere in the far North. Seaglider sections from 2 years in the Labrador Sea, funded by NOAA, have shown the key role of surface fresh-water layers in controlling deep wintertime convection and hence regulating the middle-depth branch of the global MOC. Altimetric velocity fields combine with sub-surface Seaglider data to show the origins of these fresh-water layers along the west coast of Greenland. The 1992-2006 altimetry record reveals the continuing, sustained 'spin-down' of the surface circulation of the subpolar Atlantic Ocean, as well as changes in gyre shape that strongly affect the MOC. In the northern Atlantic/Nordic Seas a new NSF-funded program establishes a Seaglider network between Iceland and Scotland, to 'catch' both the northward (upper ocean, warm, saline) and southward (deep, cold, dense) flows which are dominant arms of the MOC (for example 2/3 of the deep overflow source waters pass through the network). Altimetry gives estimates of the upper ocean branch and crucial spatial structure of the adjoining subpolar gyre. We are also using near-real-time altimetery for logistic navigation of the Seagliders on a day-to-day basis. High latitude circulation involves boundary currents, jets and eddies at scales as small as a few km. Circulation near the coasts strongly affects glacial outflows and can cause the break up of floating ice shelves. A WSOA (Wide Swath Ocean Altimeter) would be able to resolve these circulations far more accurately than is presently possible.

Flow around Tasmania - An oceanic intersection

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Tasmania sits on the northern end of a Southern Ocean choke-point. The circulation in the region links the subtropical gyres of the Pacific and Indian Oceans. The three Southern Hemisphere gyres are nested within a ‘supergyre’ with connections south of Tasmania and South Africa. The greater gyre flow is squeezed into a narrow band of latitude between Tasmania and the ACC in the south. The northern arm of the gyre is composed of the Tasman Outflow jet, which arises from the residue of East Australian Current (EAC) derived transport turning westward past Tasmania and entering the Indian Ocean. At the surface, the EAC encounters the eastward flow of the Leeuwin/Zeehan Current system. Distinctive summer and winter patterns are controlled by the EAC and the Leeuwin/Zeehan Current respectively. The eddy variability off the east coast is dominated by the western boundary dynamics of the EAC. In the west it arises from the seasonal rise and fall of coastal sea level due to seasonal reversing wind patterns driving onshore and offshore Ekman flux. Several eddies develop at those boundary regions with meridional orientation which propagate westward across the basin with typical Rossby wave phase speeds. The final expression of an ENSO signal propagates into the region along the southern Australian waveguide. The EAC exhibits both decadal variability and a long-term trend in strength. This trend is associated with the spin-up of the South Pacific gyre and a southward enhancement of the EAC.

Multiple jets of the Antarctic Circumpolar Current

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Maps of the gradient of sea surface height (SSH) and sea surface temperature (SST) reveal the Antarctic Circumpolar Current (ACC) consists of multiple jets or frontal filaments. The braided and patchy nature of the gradient fields is reminiscent of simulations of geostrophic turbulence on a beta-plane, but seems at odds with the traditional view, derived from hydrographic sections, that the ACC is made up of three continuous circumpolar fronts. By applying a nonlinear fitting procedure to 638 weekly maps of SSH gradient, we show that the distribution of maxima in grad(SSH) (ie fronts) is strongly peaked at particular values of absolute SSH (ie streamlines). The association between the jets and particular streamlines persists despite strong topographic and eddy-mean flow interactions, which cause the jets to merge, diverge and fluctuate in intensity along their path. The SSH values corresponding to each frontal branch are nearly constant along the circumpolar path of the ACC. The front positions inferred from SSH agree closely with positions inferred from hydrographic sections using traditional water mass criteria. Recognition of the multiple branches of the Southern Ocean fronts helps to reconcile differences between front locations determined by previous studies. The “meander envelopes” of the fronts are narrow on the northern slope of topographic ridges, where the sloping topography reinforces the beta-effect, and broader over abyssal plains.

Low-frequency variability in the Indian Ocean and its connection with Indian Ocean Dipole mode in 2006

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Spectral analysis of the sea surface height variability in the Indian Ocean (IO) using satellite altimetry shows that in most regions of the ocean the low-frequency part of spectra (corresponding to signals with periods from six months to six years) is concentrated in five frequency bands separated by substantial spectral gaps: semi-annual, annual, 18-20 months 3 years, and 4-6 years. Cooling of the sea surface temperature in 2006 along Sumatra-Java coast in East Indian Ocean indicates the development of a new Indian Ocean Dipole event. This poster will present the analysis of the contributions from each frequency band in the recent anomalous cooling process.

Response of the Antarctic Circumpolar Current to atmospheric variability

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Historical hydrographic profiles, combined with recent ARGO profiles, are used to obtain an estimate of the mean geostrophic circulation in the Southern Ocean. Thirteen years of altimetric sea level anomaly data are then added to reconstruct the time variable sea-level, and this new dataset is analyzed to monitor the position of the two main fronts of the ACC during the period 1993-2005.We relate their movements to the two main atmospheric climate modes of the Southern Hemisphere, the Southern Annular Mode (SAM) and the El-Nino Southern Oscillation (ENSO). We find that although the fronts are steered by the bathymetry, which sets their mean pathway at first order, in flat bottom areas the fronts are subject to large meandering due to mesoscale activity and atmospheric forcing. While the dominant mode of atmospheric variability in the Southern Hemisphere (SAM) is relatively symmetric, the oceanic response of the fronts shows substantial regional differences. Around the circumpolar belt the fronts vary in latitude, exposing them to different Ekman transport anomalies induced by atmospheric forcing. Three typical scenarios occur in response to atmospheric forcing : poleward movement of the ACC structure in the Indian basin during positive SAM event, a northward movement in the Central Pacific, and an intensification without substantial meridional movement in the Indo-Pacific basin. The study also shows the geographical regions which are dominated by a SAM or ENSO response.

A Satellite and Model Study of the Circulation in the SE Pacific

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Aspects of the surface circulation of the SE Pacific are described using two primary types of satellite data: sea surface temperature (SST) fields from the Pathfinder (1985-2003) and Reynolds (1982-2005) data sets; and sea surface height (SSH) fields from the JPL alongtrack SLA and the gridded AVISO SSH and velocity data sets (1993-2003). Results from the satellite analyses are compared to results from numerical simulations of the circulation. These are higher-resolution regional numerical simulations, nested within a lower-resolution global model. Two versions of the regional models are analyzed, one with boundary conditions forced by the global model and another with only regional wind forcing. This allows us to investigate the effect of the equatorial dynamics on the circulation off Peru and Chile. The time scales of interest include both the seasonal cycle and the interannual variability, which is dominated by the ENSO phenomenon. The altimeter data reveal both annual and semiannual periodicity in the seasonal cycle, along with a strong El Niño SSH signal along Peru and Chile. The model data also show both annual and semiannual periodicities in SSH, with a nearshore annual signal contributed primarily by the distant equatorial signal. Subsurface model fields indicate a deep displacement of isotherms in July and a shallow displacement in January, both due to distant equatorial forcing. Further differences in the response to distant and regional forcing will be presented.

The effects of dispersion on the propagation and amplitude variations of baroclinic Rossby waves

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Ten years ago, Chelton and Schlax (1996) questioned the validity of the linear standard theory (LST) for Rossby waves by showing that observed westward propagating signals seemed to propagate about two to three times faster than predicted at mid-and high-latitudes, using 4 years of TOPEX/Poseidon satellite altimeter data. To account for the discrepancy, two main theories were initially proposed: 1) the zonal mean flow theory of Killworth et al. (1997), which emphasized the importance of the background zonal flow in modifying the planetary vorticity gradient; 2) the bottom-pressure compensated theory of Tailleux and McWilliams (2001), which emphasized the decoupling roles of steep/rough topography, friction, and nonlinearities in decoupling the bottom and upper layers, thus surface-intensifiying the modal structure of the waves and thereby speeding them up. Both theories improved upon the LST, but they nevertheless systematically underestimated and overestimated observations respectively. Furthermore, both theories neglected dispersive effects, owing to the the wavelengths initially observed being much larger than the Rossby radius of deformation. Since then, the merging of various satellite altimeter datasets have led to a significant increase in spatial resolution. This in turn led to an improved description of westward propagation, revealing finer details and a higher concentration of energy at smaller scales than previously thought, prompting the need for a theoretical re-examination of the respective roles of nonlinearities and dispersion on the observed features. To that end, I will present a dispersive extension of the bottom-pressure compensated theory of Tailleux and McWilliams (2001), and discuss its links with the dispersive theory of Killworth and Blundell in presence of mean flow and topography. I will also compare the performance of the theory compared to empirically-determined dispersion relations, as well as discuss the important role of dispersion on the westward penetration of Rossby waves excited along eastern boundaries.

Ocean Cooling by Tropical Cyclones

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The Tropical Cyclone Heat Potential, the variability of which is determined from radar altimeter measurement, has been suggested and examined as an indicator of the intensification of approaching tropical cyclones. A few studies also show intense cooling of the surface ocean caused by the passage of tropical cyclones and the cooling is suggested to exert negative feedback to the intensity of the tropical cyclone. The availability of microwave sensors, which measure sea level anomalies, surface wind/stress vector, and sea surface temperature, under both clear and cloudy conditions allows us to examine the ocean-atmosphere interaction related to the intensification of tropical cyclones. All the hurricane-strength tropical cyclones in the Pacific, Atlantic, and Indian Oceans for three years between 2003 and 2005, have been examined using space-based data. Reduction of both the heat potential and sea surface temperature, may start at cyclone passage but the strongest manifestation of ocean cooling occurs after cyclone passage. The air-sea interaction and feedback mechanism under various conditions will be postulated and explored.

Seasonal Sea Level Variability Estimated From a Data-Constrained General Circulation Model

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The ECCO-GODAE v2.177 product combines numerous types of oceanographic observations, including data from all the altimetric missions, 1992-2004, with the MIT general circulation model in an optimization procedure that minimizes model-data misfits in a least-squares sense. The result is an estimate of the global ocean state (temperature, salinity, currents and sea level) and the surface atmospheric forcing fields (wind stress, heat flux and freshwater flux) since 1992 that is consistent within error bars with the observations. This estimate of sea surface variability on seasonal scales is studied in this work. The annual cycle tends to be more important than the semi-annual cycle, except in tropical regions. The seasonal cycle in the wind field is the primary driver for the sea level variations in the tropics, and seasonal surface heat flux variations is the dominant forcing in mid-latitudes. A substantial part of the sea level variability can be assigned to changes in thermosteric height; integrals of thermosteric height to 100 m depth in mid-latitudes and to 200 m in the tropics explain 80% of the annual cycle in sea level. Bottom pressure changes are also important in shallow and near-coastal areas, and in some deep-ocean regions (Southern Ocean, North Pacific) where bottom relief leads to enhanced barotropic motions. The difference between sea level variability in coastal areas and the open ocean is also highlighted in comparisons among the ECCO-GODAE estimate, altimetry observations and tide gauges. Estimates of the seasonal cycle in global mean sea level are ~3.5 mm (maximum in April) for the thermosteric component and ~5.5 mm (maximum in October) for the net freshwater component, which are comparable to previous data estimates.

Heat budget of the Southern Ocean Mixed Layer from 1992 to 2002

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Satellite observations, and particularly altimeter missions, have provided an unprecedented view of the Southern Ocean. The long data records evidence substantial large scale interannual variations in the upper ocean properties. Some of these modes of variability have a peculiar, well organized spatial structure such as the well known Antarctic Circumpolar Wave.

As advection by the ACC plays a central role in the Southern Ocean, we here analyse the mixed layer heat budget from 1992 to 2002 based on a 2D finite element model for temperature anomalies where mean and anomalous geostrophic advection is prescribed from altimeter observations, following Qiu and Kelly (1993). Mixed-layer depth and temperature at the base of the mixed layer are determined from hydrographic observations, including recent Argo data.

We examine the relative contribution of Ekman and geostrophic advection of temperature anomalies, anomalous Ekman and air-sea heat fluxes, boundary conditions in the subtropics and in the ice regions to the south, in the generation and evolution of SST anomalies. The impact of nonseasonal ML depth variations, estimated from a 1D TKE budget, is also considered. The relationship between SST anomalies and different climate indices is discussed.

Thermosteric Sea Level and Ocean Heat Content Changes and the Contribution to the Earth's Energy Balance

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Sea level is an indicator of changes in the Earth's energy balance. The sum of changes in its components (ocean thermal expansion, glaciers, ice-sheets and terrestrial storage) have not adequately explained the observed sea-level rise of the last five decades. One potential reason is that current ocean thermal expansion estimates are deficient because of sparse data coverage, particularly in the southern hemisphere. In attempt to overcome this difficulty, we have constructed global thermosteric sea level and ocean heat content estimates based on reduced space optimal interpolation. Our results focus on changes of global mean thermosteric sea level and ocean heat content in the upper 750 m for a historical period (1961 to 2000) and the recent period (1993 to 2005). For post mid-1970s the sum of the contributions are closer to the observed sea-level rise than earlier estimates. We will also present estimates of the equivalent heat content changes and compare our results with climate model simulations.

Closing the seasonal to interannual sea level budget on regional scales in the tropical N. Pacific

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With the ongoing success of the satellite altimeter missions, the launch of the Gravity Recovery and Climate Experiment (GRACE) satellite in 2002 and the spin up of the Argo array of profiling floats over the past several years, the global ocean observing system has finally reached a point where complete dynamic descriptions of large-scale sea level signals based on observations has become feasible. Using temperature and salinity data from the Argo array and gravity variations from GRACE, the total sea level signals observed by satellite altimetry can be decomposed into steric and mass-related parts. In addition to providing a dynamical description of observed variability, this allows for closure of the sea level budget within the accuracy of each measurement system and serves as an important validation of the observing system as a whole.

We consider the sea level budget in a 20° x 10° box in the tropical N. Pacific centered around 140°W and 10°N. This encompasses a large part of the equatorial current system in the N. Pacific and was shown by Chambers et al. (JGR, 1998) to be a region where total and thermosteric sea level variability showed significant differences. Monthly time series of thermosteric, halosteric, bottom pressure and total sea level for this region will be presented and the sea level budget will be evaluated. In addition, implications for basin-wide and global analyses of a similar nature will also be considered.

Global Coastal Sea Level Change on Decadal and Century Timescales

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[(1)] Proudman Oceanographic Laboratory

Several papers have been published recently which have made use of the global mean sea level data set (of the Permanent Service for Mean Sea Level) to study rates of global sea level change on decadal and longer timescales. Studies have indicated a high rate of rise in the 1990s broadly consistent with the rate observed from TOPEX/Poseidon/Jason altimetry, but similarly large decadal rates have been found in other parts of the historical record. On century timescales the data indicate almost no acceleration, or even a small deceleration, of sea level rise for the 20th century alone in most station records, but a small acceleration between the 19th and 20th centuries. This poster will provide an overview of these recent findings and comment on the uncertainties and their various sources. It will also point to the methods (e.g. tide gauge data archaeology, archaeological surveys, salt marsh data acquisition) by which information on century-timescale change might be better understood.

Local and Global Calibration/Validation - poster

Preparing for the additional errors on wide-swath altimetry: precise roll error reduction

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Wide swath altimetry is based on a technology combining altimeter and interferometer measurements. A wide-field radar altimeter is able to measure the sea-surface height across a swath centered on the satellite ground track. The instantaneous field of view would be wider than with a conventional altimeter, making it possible to cover coastal zones and to improve temporal resolution. However one significant drawback of this system is the additional errors and limitations of the technology used.

The error induced by satellite attitude and notably by the roll angle could induce decimetric to metric errors on altimeter measurements. This error would be one to two orders of magnitude higher than the accuracy needed for most altimetry applications. This error can be minimized with various algorithms, but the question becomes: can we realistically reach the performance needed for demanding ocean applications?

This paper uses an OSSE (Observing System Simulation Experiment) approach to analyse the performance one could obtain with various error reduction processes using swath crossover diamonds and optimal inverse methods. The Los Alamos North Atlantic high-resolution model is used as a reference for oceanic variability and various scenarios are considered: roll angle (optimistic to pessimistic), consistent error budget and correlations... Large swath and nadir altimeter measurement data sets are simulated and corrected.

Multiple error removal reduction processes are assessed and compared to estimate their respective performance as well as the accuracy of the output correction. Local (crossover diamonds, perfect or coastal) and global analyses are used to produce nominal and “worst case” statistics. Sensibility studies are also carried out to assess the performance degradation when the method used is not consistent with the a priori knowledge used (correlation, variance), or when additional errors are neglected, or when some observations are ignored.

Assessment of Recent Revisions to the TOPEX/Jason-1 Sea Surface Height Time Series

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The Jason-1 verification phase has proven to be a unique and successful calibration experiment to quantify the agreement with its predecessor TOPEX/POSEIDON (TP). Although both missions have met prescribed error budgets, comparison of the mean and time varying sea surface height (SSH) profiles from near simultaneous observations derived from the missions' initial versions of Geophysical Data Records (GDR) exhibit significant basin scale differences. The terrestrial reference frame is linked inseparably to the measurement of global mean sea level estimates from satellite altimetry and provides the context for the interpretation of the causes of current mean sea level trends. In an effort to adhere to cross mission consistency, we have generated the full time series of orbits for both TP and Jason-1 through reduced dynamic methods based on the GGM02c GRACE derived gravity field within a consistent well defined ITRF2005 terrestrial reference frame. Recent revisions to the Jason-1 GDR and the TOPEX GDR Compatibility Product (GCP) also require the further re-examination of TP/Jason-1 consistency issues. Here we present an assessment of these recent improvements to the accuracy of the TP/Jason-1 SSH time series via tide gauge validation procedures, global crossover and collinear SSH residual statistical analysis, and evaluate the subsequent impact on global and regional mean sea level estimates.

Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica

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The Corsica site, which includes Ajaccio-Aspretto site, Senetosa Cape site, and Capraia (Italy) in the western Mediterranean area has been chosen to permit the absolute calibration of radar altimeters. Thanks to the French Transportable Laser Ranging System (FTLRS) for accurate orbit determination, and to various geodetic measurements of the local sea level and mean sea level, the objective is to measure the altimeter biases and their drifts. The expected outputs of this on site verification experiment are dedicated obviously to the determination of the calibration bias of TOPEX/Poseidon and Jason-1. On the other hand, it is also an opportunity to contribute to the orbit tracking of oceanographic and geodetic satellites and to the analysis of the different error sources, which affect altimetry. In the field of positioning, we expect to contribute also to the decorrelation between the possible vertical displacements of our site (Earth crust) and the Mediterranean mean sea level. The double geodetic site in Corsica (Aspretto, near Ajaccio and Senetosa Cape 40 km south under the Jason-T/P ground track N° 85) has been used to calibrate the TOPEX/Poseidon altimeters from 1998, and the Jason-1 ones since the beginning of the mission. Permanent and semi-permanent geodetic equipments are used to monitor these calibrations. Concerning the Aspretto site, a permanent GPS station and an automatic tide gauge have been installed since 1999. Two dedicated tracking campaigns of the French Transportable Laser Ranging System have been realized in 2002 and 2005. Results of the last campaign, in term of calibration, are presented. At Senetosa cape, permanent geodetic installations have been installed since 1998 and different campaigns have been conducted in view of Jason-1 mission. Four tide gauges are installed at the Senetosa Cape and linked to ITRF using GPS and leveling. In parallel, since 2000, a GPS buoy is deployed during overflights at Senetosa (10 km off-shore). Moreover, since 2003, a permanent GPS has been installed to monitor possible vertical displacements of our site. In addition, using a local weather station, we derived the wet tropospheric path delay from GPS measurements which are compared to the Jason Microwave Radiometer ones at the overflight times. T/P altimeter calibration has been performed from cycle 208 to 365. All the produced Jason-1 GDR cycles have been also analyzed in the altimeter calibration process. However, a detailed analysis has been performed for the reprocessed (GDR-B) cycles 1 to 21 which have been compared to T/P improved MGDR (TMR, orbit, …). In addition, new JMR (as included in GDR-B) path delay has been compared for all the available cycles to the ECMWF and GPS derived tropospheric correction.

Improving of High quality data of coastal altimetric measurements

Dorothée Coppens [(1)], S. Bijac, P. Prunet, E. Jeansou : Noveltis, France
[(1)] Noveltis

The Jason-1 satellite, which was launched on December 7, 2001, has been designed to ensure continued observation of the oceans for several decades. The radar altimeter Poseidon-2 emits pulses and measures their round trip time reflected by the ocean. The on-board Jason Microwave Radiometer (JMR), which operates at 18, 21 and 37 GHz, monitors and corrects the propagation path delays of the altimeter radar signal due to water vapour and non-precipitating liquid water in the atmosphere. In the case of coastal measurements, the JMR field of view (FOV) is spoiled by the presence of land. Based on the cloud-clearing scheme successfully applied on infrared sounder measurements to remove the cloud contribution, a land-clearing algorithm has been developed for the exploitation of the JMR data in coastal regions. The method uses two or three successive measurements contaminated by consequent proportions of land in order to extract the JMR brightness temperature associated with the sea component of the FOVs, taking into account the antenna gain pattern at each frequency. The preliminary tests on simulated database give encouraging results which would make it possible the correction of the JASON altimeter range errors in coastal areas.

Suggestion of a common exercise for in situ CalVal and data consistency

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CalVal in situ produces absolute sea surface bias referred to a number of parameters (corrections, orbits, in-situ measurements, etc)or a set of altimeter satellites. The existing in situ CalVal methods can compute absolute sea surface height (ssh) bias independently to other satellites. These methods make the in situ approach very useful in order to be able to insure a continuity in the altimeter sea surface height time series, even in case of an unexpected gap in the time series. Since more than 10 years, a set of equipped sites provides results to the CalVal phases. The addition of all these results inquire on the ssh bias precision and its dispersion. In situ methods are based on highly controlled local observations and altimetry data. Local means that bias results depend on geophysical condition (e.g. geographically correlated error, local systematic errors, etc). If these results could be obtained from a processing protocol and defined standards, as homogeneous as possible, it would serve the interpretation and the analysis of the results collected altogether, thanks to a greater consistency on the types of corrections, the number of cycles used, epoch, etc. In this poster, we suggest to the in situ CalVal teams, a sort of common exercise that could be run for the OSTST meetings. The objective is to realize a common shared selection of process parameters to try to find a consensus on ssh bias, respecting the geophysical conditions of each site. This poster is a suggestion to cooperate with the in situ calval teams to establish a list of criteria required to define a common computing basis, in agreement with the in situ CalVal teams. It should also help to define what would be the right criteria to synthesise and analyse the differences in our bias results.

Monitoring of altimeter measurements against a global tide gauge network

Fabien Lefevre [(1)], the CLS CalVal team
[(1)] C.L.S.

The usefulness of tide gauge data networks for calibrating satellite altimetry systems was demonstrated by several authors (Mitchum [1994, 2000], Chambers et al. [1998], Cazenave et al. [1999]…). Their proposition was to use tide gauge data as an independent system to monitor drifts and bias of altimeter system over time. We took over their works and improved them to compare altimeter measurements with a specific tide gauge database processed at CLS: Badomar (based on the GLOSS/CLIVAR "fast" sea level data tide gauge network, formerly known as the WOCE network). The main interest of tide gauges for altimetry is to provide independent measurements of sea surface height variations. The basic idea of the method is that differences between tide gauges and altimetry should not have any drift or bias over long time scales. Selecting tide gauge stations where the differences between altimetry heights and tide gauge sea levels are small, is essential to get good variance estimates. The methodology of the comparisons of altimeter data against tide gauge measurements is now operational.

Sea Surface Determination Experiences in the Ibiza Island

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Three Begur Cape experiences on radar altimeter calibration and marine geoid mapping made on 1999, 2000 and 2002 are overviewed with a description of the l'Estartit facilities. One campaign has also been made in June 2003 at the Ibiza island area (Martinez-Benjamin et al., 2003). The marine geoid has been used to relate the coastal tide gauge data from Ibiza and San Antonio harbours to off-shore altimetric data. A technical Spanish contribution to the calibration experience has been the design of GPS buoys and GPS catamaran taking in account the University of Colorado at Boulder and Senetosa/Capraia designs. The main objective of the marine campaigns is to check the value of Ibiza Island as a permanent calibration site in the western Mediterranean Sea, to complement the Corsica site in the network of altimeter calibration sites.

We present a synthesis of the sea level results results obtained from Topex/Poseidon and Jason-1 altimeter calibration campaigns using the direct measurements from GPS buoys and the derived marine geoid. The Ibiza results, related to Jason-1, agree relatively well with results obtained at Corsica,+120±7 mm (Bonnefond et al., 2003), where the geographically correlated errors should be comparable as the orbit, sea state, etc; Harvest, +138±7 mm (Haines et al., 2003), and Bass Strait, +131±11 mm (Watson et al., 2003) calibration permanent sites, together with Lake Eire (Shum et al., 2003) and Gavdos (Pavlis et al., 2003) sites. It is planned a new Ibiza campaign at the Calibration/Validation period for Jason-2 in 2008.

These campaigns were supported by the Spanish Ministery of Science and Technology under projects of the National Space Program ref: ESP1997-1816-CO4-03 and ESP2001-4534-PE.
IBIZA2003 TEAM: Cristina Garcia, Julia Talaya, Anna Baron, Enrique Alvarez, Sergio Gonzalez, Amparo Nuñez, Felipe Buill, Jaime Lopez-Marco, Manuel Espino, Damia Gomis, Marta Marcos, Yves Menard, Florent Lyard, Olivier Laurain, Gwenaele Jan, Eric Jeansou, Laurent Roblou

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New CGPS Reference Station at l'Estartit for Sea Level Monitoring

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L'Estartit tide gauge is a classical floating tide gauge set up in l'Estartit harbour (NE Spain) in 1990. Data are taken in graphics registers from which each two hours the mean value is recorded in an electronic support and delivered to the Permanent Service for Mean Sea level (PSMSL). Periodic surveying campaigns along the year are carried out for monitoring possible vertical movement of the geodetic benchmark adjacent to the tide gauge. In the framework of a Spanish Space Project, the instrumentation of sea level measurements has been improved by providing this site with a radar tide gauge and with a continuous GPS station nearby. This will have a significant incidence in the satellite altimeter calibration activities. The radar tide gauge is a Datamar 3000C device and a Thales Navigation Internet-Enabled GPS Continuous Geodetic Reference Station (iCGRS) with a choke ring antenna. It is intended that the overall system will constitute a CGPS Station of the ESEAS (European Sea Level) and TIGA (GPS Tide Gauge Benchmark Monitoring) networks. A description of the actual infrastructure at l'Estartit is presented and its applications to sea level monitoring and altimeter calibration in support of the main CGPS at Ibiza harbour.

Absolute calibration of the Jason-1 altimeter by ship-buoy GPS cruise along the Drake passage

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Several satellite altimeter missions are currently operating (ENVISAT, JASON) and others are planned for the future such as JASON-2. With the current evolutions of global warming and mean sea level changes, these instruments are anticipated to contribute to the monitoring of global oceans. Therefore the monitoring and precise calibrations of biases and drifts of these altimeter systems are required. The Drake campaign, which took place in January and February 2006, has been a very successful mission in collecting a wide range of oceanographic data along the JASON-1 altimetric ground track n°104. In order to provide a good validated altimetric data-slot for oceanographers during this mission, a sea-level GPS campaign took place all along JASON's ground track on the Drake passage during the same period of one month. These GPS sessions where performed in the harbour of Puntas Arenas during departure, in the open sea, at O'Higgins in the Antarctic peninsula during arrival, and back. A set of GPS receivers installed onboard the research vessel Polarstern, and a waverider GPS buoy for the calibration of the ship's floating position, were used. This sea level data combined with altimetric data, allow us to cross-compare the sea surface height (SSH) estimates and measure the significant wave height (SWH) during the cruise across the Drake passage. These independent SWH measurements allow us to validate and correct the altimetric data as sea-state bias is one of the major sources of altimetric errors.

Feasibility of an accurate wet tropospheric correction for the CRYOSAT mission

Franck Mercier [(1)], E. Obligis, J. Dorandeu, P. Schaeffer (CLS)
[(1)] CLS

The main objective of the European satellite CRYOSAT is the observation of the polar ice. For this reason, and on the contrary to ocean altimetry missions, it is not equipped with a microwave radiometer to provide the wet tropospheric correction. In order to exploit the CRYOSAT measurements on a global scale, i.e. to use measurements over ocean to retrieve the sea surface height, an accurate wet tropospheric correction is required. For the time being, it is planned to use the model-derived correction provided by the European Center for Medium Range Weather Forecasts (used as a backup on the usual ocean altimetry missions), which is known reliable at large scale, but insufficient to catch small atmospheric humidity structures. The actual resolutions of the model are 0.5 degree in space and 6 hours in time, so they are not always/everywhere adapted for the atmospheric humidity scales that may be shorter than half a degree/ 1 hour. In this context, the objective of this study is to evaluate the feasibility and the potential benefit of using existent water vapor measurements provided by other in-flight microwave radiometers to build an accurate wet tropospheric correction. First results are based on the global combination of different available data sources: SSM/I, TMI, AMSR-E, AMSU. In this first step, we analyzed the spatio-temporal cover of the different satellites, and quantify the benefit with respect to the ECMWF model.

An Assessment of Jason GDR-Bs for Monitoring Long-Term Sea Level Change

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Calibrating records of sea level change from satellite altimeters is a challenging endeavor, as instrument biases, changes in instrument behavior, and changes in the measurement corrections can all masquerade as an apparent change in sea level. We use the global tide gauge network to monitor these effects, but even this technique has limitations because of the sparse geographic distribution of the tide gauges. Jason has proved particularly challenging because of uncertainties in the sea state and wet troposphere corrections, and the lack of availability of a consistent set of GDRs for analysis. In this study, we present an analysis of the available GDR-B data from Jason, including the results of our tide gauge calibration, and an intercalibration with the TOPEX altimeter data.

The Envisat/MicroWave Radiometer five years after launch: Drift correction, new in-flight calibration and consistent retrieval algorithm

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The European satellite Envisat has been launched on 1st of March, 2002. It is equipped with many instruments, and among them with the RA-2 Radar Altimeter. In order to correct the altimeter range for water vapor path delay over ocean, a nadir-looking microwave radiometer has been added to the mission, as for previous altimetry missions (ERS-1, ERS-2, TOPEX, JASON). This radiometer provides at the location of the altimeter footprint brightness temperatures measurements at 23.8 and 36.5 GHz. These two brightness temperatures, as well as the backscattering coefficient in Ku band are used to retrieve the wet tropospheric correction. As any error in this term directly impacts the sea level determination, the constraints on the quality and stability of the in-flight calibration and data processing of the radiometer are particularly stringent.

After 5 years in orbit, we recently proposed to improve the quality of the past (reprocessing) and future radiometer products. This improvement lies on 3 different evolutions in the radiometer data processing. First we corrected the instrumental drift observed at 36.5 GHz since the beginning of the mission. The correction is based on a linear correction of the calibration counts, allowing an accurate correction of the radiometer gain. Then we proposed a new calibration of the radiometer. Our approach consists in adjustment of the measured brightness temperatures on simulated ones. This has been performed using the last version of the ECMWF model and of our radiative transfer model. The in-flight calibration is performed by adjusting the transmission coefficient of the reflector, as well as the sky horn feed transmission coefficient. Finally, to be fully consistent, we developed a new neural retrieval algorithm based on the same version of the meteorological and radiative transfer models as for the calibration. Global performances of this new algorithm are satisfactory, but it appeared that errors due to the retrieval algorithm are geographically correlated, implying systematic over or under-estimations of the sea surface height.

JASON-1 Absolute Calibration Results from the Eastern Mediterranean GAVDOS Project

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The Gavdos permanent absolute calibration facility, initially established with joint EU, NASA, and Swiss Federal Government funding in 2002, while fully operational at the moment, it is also being expanded to a regional absolute sea level monitoring and altimeter calibration facility applicable to many missions, in the Eastern Mediterranean. The main site is still at Karave, located under a crossing point of the Jason-1 ground-tracks (passes 018 and 109), and adjacent to an ENVISAT pass, on the isle of Gavdos, about 50 km to the south of the main island of Crete, Greece. The project is now continuing under the OSTM program with funding from NASA and the Greek government. The current plans include the relocation of the Gavdos "Karave" facility to the final and originally intended location, on a new pier (finally constructed!), a move that will improve vastly the protection of the facility from heavy winter storms and minimize the need for maintenance. The Karave GPS receiver operated continuously throughout the past years, the tide gauges however were placed in storage to avoid damage during the construction period, and they have been redeployed as of last fall. The facility now has "off the wall" electric power at all times, and it will be upgraded to include an ISDN line and a computer, so that we will be able to download all of the data, including GPS observations, on a hourly/daily basis. This is expected to happen in early 2007. We have already selected the location for the establishment of an identical setup at a site on the main island of Crete, at Kastelli, near the TUC site (60 km west of TUC), on a TUC-owned area and situated exactly under the descending Jason-1 pass 018. We have selected a radar gauge as well as a backup system of similar type for the new location. Once tested and calibrated, we plan to replace the Karave system with one of these since they are much less demanding in terms of maintenance, always a concern during the winter months. This gives us access to a second site and use of the altimeter measurements made to the north of Crete, in the Aegean Sea. It will thus allow the collection of additional information on the circulation and currents of the area between the Cape Maleas and Western Crete (e.g. Cretan cyclone). The project is now producing results on the basis of the new GDRs and extending our efforts to include the ENVISAT and GFO missions. We are also planning to repeat the co-location at the TUC facility site with the French Transportable Laser Ranging System (FTLRS) that established an initial link of the entire GAVDOS network of sites with the ITRF2000 frame, in order to update the link to the global TRF. This is contingent on FTLRS' availability, which in turn is tied to its deployment in Australia and the launch of JASON-2.

X-track, a new processing tool for altimetry in coastal oceans.

Laurent Roblou [(1)], G. Jan (Noveltis), J. Bouffard (LEGOS) [(1)] Noveltis

Oceanographic applications using satellite altimeter data become very challenging when leaving the deep ocean for the coastal regions. Close to the coast, altimeter observations are often of lower quality for a number of reasons, including land contamination of the satellite footprints or inaccurate resolution of the corrections of the high frequency ocean response to tidal and atmospheric loading. This poster presents a new processing toolbox, called x-track, to derive improved altimeter products, such as SSH, MSSH or SLA, dedicated for coastal applications. Starting from classical GDR products, particular attention is made to recover a maximum amount of exploitable data (dedicated data editing, interpolation of missing corrective terms). Where possible, local modelling of the high frequency response of the ocean to the tidal and atmospheric loading is applied instead of standard, global corrections given in the GDRs. In addition, orbit errors are reduced by a stability criterion and a high resolution mean sea surface consistent with the altimeter data set is computed along the satellite ground track. Finally, x-track produces altimeter SLA time series collocated onto mean tracks dedicated for coastal applications. This poster presents preliminary results when using x-track to determine the Jason-1 SSH bias at Senetosa calval site.

Outreach - poster

« Courants d'air, courants d'eau », a public exhibition held in Nouméa based on oceanography and satellite remote sensing

Christophe Maes [(1)], Valérie Vattier/director of the Maritime Museum
[(1)] IRD/LEGOS

A collaborative effort between the Maritime Museum of New Caledonia and the IRD centre of Nouméa resulted in an exhibition for the public and the school children of New Caledonia. The exhibition was held at the Maritime Museum in Nouméa between 4 May and 30 July, 2006. The emphasis was on oceanography at large and global scales, focusing, in particular, on currents and on the role of the oceans in present-day climatic variations. Visitors could learn about the present research in physical oceanography and the pioneering work of early scientists who try to measure currents at the surface and at depth. Indeed, the year 2006 coincided with the celebration of the 50th anniversary of the first oceanographic cruise originating in New Caledonia to study the Pacific Ocean. The modern era of oceanographic research was illustrated by the presentation of autonomous floats developed to routinely monitor the oceans and by the different ways to observe the ocean using satellite remote sensing. An important component of this last category was the story of the great success of TOPEX/Poseidon and the ongoing Jason-1 mission that was highlighted by a model of the Jason-1 satellite loaned by the CNES agency. Pedagogic kits developed by the outreach teams of these satellite missions were given to the teachers who visited the exhibition in order to expand the discovery of the oceans in their classrooms. With more than 5000 visitors, including more than 1200 young students from different educational levels, we consider the exhibition to have been a great and a surprising success. "Courant d'air, Courants d'eau" represented the first exhibition by the Maritime Museum that was dedicated exclusively to scientific research. Depending on potential responses from school teachers, an overview of the use of the pedagogic kits will be tentatively presented.

Sea-State Bias and Re-tracking Analysis - poster

TOPEX Retracked GDR – Features and Statistics

Philip S. Callahan [(1)], Ernesto Rodriguez, Ted Lungu; Jet Propulsion Laboratory
[(1)] Jet Propulsion Laboratory

We have released two years of TOPEX Alt-B Retracked GDR (RGDR) data. In addition to retracking with two algorithms – Least Squares Estimation (LSE) and Maximum Posteriori (MAP), the data include new orbits from the GSFC group and corrected TMR data from Desai and Brown.

In retracking we have not been able to remove the well-known waveform leakages, so we seek to determine a post-facto correction that will be added to the final version of the RGDR to remove the range rate and SWH dependent effects. We display the changes between the GDR and the two retracking algorithms. The comparison with Jason data for overall calibration will also be considered.

An initial investigation of the changes in Alt-A during its later cycles will also be presented. The sensitivity of the Alt-A changes to point target response (PTR) changes will be investigated.

Proposals for the final RGDR data product will be presented.

A new altimeter waveform retracking algorithm based on neural networks
Arnaud Quesney [(1)], Eric Jeansou (Noveltis), Juliette Lambin (CNES) and Nicolas Picot (CNES)
[(1)] Noveltis

We have developed a new method for waveform retracking, based on neural network. A set of synthetic Jason-1 waveforms was created according to the Hayne model, taking into account the thermal noise and the data compression used for telemetry, assuming a single Gaussian PTR. An appropriate neural network was determined to retrieve the epoch (range), and the significant wave height from the waveform samples, given a fixed skewness. The obtained neural network can be seen like a non-linear mathematical function giving the two parameters (Epoch, SWH) given the 64 waveforms samples: (Epoch, SWH)=F(s1,...,s64). The neural network was applied to simulated and SGDR (Scientific Geophysical Data Records) Jason-1 waveforms. We show the following results: - The standard deviation of the neural network epoch estimation is equivalent or slightly better than the one obtained with the MLE3 (Maximum Likelihood Estimate) algorithms of the SGDRs. - The standard deviation of the neural network SWH estimates is reduced by a factor two in comparison with the MLE3 estimate. Given the simplified modelling applied in this study, the neural network estimate have non-negligible biases, but we demonstrate that this problem can be solved by optimising the network, using a more sophisticated forward model (Hayne 2nd order) and by creating correction tables.

Unsupervised classification of altimetric waveform over all surface type
Arnaud Quesney [(1)], Eric Jeansou (Noveltis), Christian Ruiz (Noveltis), Nathalie Steunou (CNES), Bruno Cugny (CNES), Nicolas Picot (CNES), Jean-Claude Souyris (CNES), Sylvie Thiria (LOCEAN), Mustapha Lebbah (LOCEAN)
[(1)] Noveltis

We have developed a method for the automatic identification of the surface type from a sample of altimetric waveforms. It is a preliminary stage to the treatment of the waveforms specific to each surface type which provides an adequate algorithm able to extract relevant geophysical information. Noveltis has implemented a waveform unsupervised classification scheme using a neuronal approach founded on the self-organizing topological maps (Kohonen approach). The interest of such a method is that it is fast, powerful and that it makes it possible to process information mixing quantitative and qualitative data. The performances of the classifier are performed through a comparison with expert fields produced by CNES. The results have shown that the classes are labelled with more than 80% success for the Ocean (98%), Land Surface, Sea Ice and Coasts types. We have applied the learned classifier to the Jason-1 cycle 116. The results obtained have underlined the robustness of the neuronal waveform classification. The interpreted classes present good space-time coherence. Sea ice space covers can, for example, be clearly delimited. A first validation of the sea ice extension has been carried out using the products deduced from SSM/I data. Lastly, we have shown that neuronal classification made it possible to very finely identify the continental ice surface type.

Sigma-0 blooms in the Envisat Radar Altimeter data

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Data from satellite altimeters are often degraded by the occurrence of unrealistically high values of the ocean surface radar backscatter cross sections (sigma-0). Various studies on Topex and Jason-1 altimeters data have shown that these events called “sigma-0 blooms” affect almost 6% of the over ocean measurements. It has been shown (Mitchum, Tournadre, …) that blooms occur most of the time, but perhaps not always, in regions of climatologically weak winds. Surface slicks could also be the cause of sigma-0 blooms. In any case, contamination of altimeter data by “sigma-0 blooms” is an important issue if we consider that only 60% of the sigma-0 bloom events seem to be rejected by classical altimeter data flagging. This paper gives a comprehensive description of the blooms occurrence (where, when and how long) which is important because many people of the community that make use of the altimetric data are generally unaware of this phenomenon. Statistical characteristics of sigma bloom events are presented using 1-Hz data as well as 20-Hz data. Analysis is done for many cycles of Envisat data distributed along the year and also on local and limited data sets. Moreover, we show how waveforms are corrupted and we propose criteria to characterize their occurrences. The analysis is performed on Ku-band data but relation with S-band data is also considered. Spatial and temporal correlations with geophysical parameters (wind, waves …) are highlighted. Besides the precise characterisation of the blooms, one of the major interests of the study concerns the estimation of the errors induced by these events on the estimated altimetric parameters.

Simulator of Interferometric Radar Altimeters: concept and first results

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To improve further its understanding of mesoscale ocean variability, the oceanographic community needs to observe the ocean at higher spatial and temporal resolutions than is presently allowed by classical nadir radar altimeters. The interferometric radar altimeter is an attempt to meet this requirement using a single platform. From this point of view, we developed a simulator of interferometric radar altimeter (SIRA) able to be used for the understanding of the measurements and of the processing to be applied to retrieve altimetric information from them. At the pulse repetition frequency (PRF) rate, the radar transmits a modulated pulse from one antenna and receives the ocean backscatter via two passive antennas. For a given “shot”, the waveforms are defined as the pair of time-resolved, complex signals obtained after on-board processing - which includes down-conversion and focusing (i.e. range compression) - of the electric fields received by both antennas. The waveform model requires a description of the on-board processing and above all, of the ocean surface scattering process. The simulator is based on three main boxes. The sea surface state model developed within this simulator is able to produce a virtual but realistic ocean surface in a broad range of wind/wave and current conditions. Then, a core module of the simulator handles the generation of the instrument waveforms, driven by the altimeter configuration and a realization of the ocean’s surface. The selected scattering model is required to faithfully render some phenomena well-known in ocean altimetry -such as the EM bias or the Doppler anomalies caused by surface currents- while remaining numerically tractable in typical scenarios. Since a realization of the ocean’s surface is explicitly provided, we could in principle apply exact (i.e. not statistical) EM methods to determine the scattered field. However, it is obviously expected that even simple methods like the Kirchoff approximation suffer from an intractable numerical burden when it comes to integrating large ocean patches (some km2) at the radar wavelength resolution (some cm2). Our approach has been to adopt a two-scale integration scheme. Since the ocean’s surface is provided in a multi-scale fashion, we have adopted an exact EM model to explicitly integrate the longer scales and have addressed the shorter scales in a statistical manner, relying on various statistical methods. Hence, short-scale ocean surface realizations may be used to estimate the required statistics (e.g. elevation and slope distributions or spectrum) while long-scale ocean surface realizations are readily integrated with an exact method. An interferogram is computed by correlation of the waveforms generated on both antennas. Altimetric estimates are derived thanks to an inversion chain taking into account the geometry of observation, the characteristics of the satellite and the chosen resolution of the image to reconstruct. Integration process used to reduce the noise on the interferogram is clearly addressed in the cross-track and along track directions.

Precision Orbit Determination and Geoid - poster

A 4-year series of Earth mass changes derived from GRACE and LAGEOS data

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The CNES/GRGS Team of Space Geodesy provides global gravity field model since 2005 at a spatial resolution of 400 km and at a temporal resolution of 10 days. Now more than 4 years of data have been processed with some refinements for the latest models. The complete set over 4 years gives a good global image of what is happening on Earth in terms of hydrologic or glaciological mass changes. Contrary to some other modelling, these models can be directly used for mass variation studies, for they are stabilized in the processing phase in order to minimize meridian striping without modifying the signal. These models are available in the form of s.h. coefficients like in grids through the BGI and ICGEM web site.

Validation Activities for Jason-1 and Topex/Poseidon Precise Orbits

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Considering the 1 cm challenge to be reach for the global determination of the orbit of altimeter satellites using DORIS and/or GPS measurements, we plan to evaluate the accuracy of the Jason-1 and TOPEX/Poseidon (T/P) precise orbits using Satellite Laser Ranging (SLR) data. Above the Europe area and, as a consequence, above the Mediterranean sea where several calibration/validation sites have been or will be installed in the next future, the fact that the orbit of both altimeters is largely covered by SLR is a very interesting aspect for altimetry. Obviously, other SLR sites around the world (US, south Pacific, mainly) largely contribute to the tracking of the tandem mission, thanks notably to the role of the International Laser Ranging Service (ILRS) through its recommendations, its data storage and distribution, and its monitoring of the up-to-date activity (qualitative and quantitative monitoring). Thus, this permits to enlarge the possibilities of CAL-VAL activities. We have developed a short-arc orbit technique for the validation of altimeter satellite precise orbits. It is based on SLR data, and on rigorous geometrical adjustment criterions. These developments and capacities have been installed on a dedicated Internet site: http://grasse.obs-azur.fr/cerga/gmc/calval/pod/. The goal is to permit the quasi-immediate validation of Jason-1 and T/P orbits. Since the beginning of the Jason-1 mission, it is possible to use this site to evaluate a given orbit cycle or results of the overall missions; orbit and/or SLR residuals (eventually per station) are presented "permanently". The proper error budget of the method, being at the level of less than 1 cm, this has allowed us to study the radial orbit error, which appears above a given site. Thanks to a selective choice of SLR measurements, taking into account their intrinsic precision/accuracy, and the precision of the station coordinates of the SLR network, the error budget of the orbit validation has been reduced to 1 cm. In the frame of the Jason-1 GDR-B products, orbit validation of the new CNES precise orbit strategy (SLR+DORIS+GPS, GRACE gravity field, …) as well as new GPS-Reduced dynamic orbits (JPL) has been performed and analyzed. Impact of the new standards (IERS 2003 convention, ITRF 2005, …) on the calibration process is also evaluated.

Evaluation of Orbits for the WATER Hydrosphere Mapper Mission

Don Chambers [(1)], Richard D. Ray (Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center), John C. Ries (Center for Space Research, The University of Texas at Austin)

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The WATER Hydrosphere Mapper Mission is a proposed concept utilizing wide swath and nadir altimeters to map the ocean topography and surface water elevation at higher resolution than has been possible with other altimeter missions. In order to map the large number of rivers poleward of 65° inclination, the orbit will have to be different than that of TOPEX/POSEION and Jason. In order to map the majority of the Earth's rivers with a return time of approximately 1 week, the repeat period will have to be around 20 days or longer. Here, we evaluate the tidal aliasing properties of high inclination orbits with exact repeat periods around 20 days, with a goal of finding a single orbit that has very good aliasing properties for further study. We will also examine the residual geographical correlated orbit error predicted by new GRACE gravity models, noting that the T/P and Jason-1 orbits still have large error associated with the degree 2, order 1 gravity coefficients, while other orbits have much smaller errors.

TOWARD EIGEN-05: GLOBAL MEAN GRAVITY FIELD MODELS FROM COMBINATION OF SATELLITE MISSION AND ALTIMETRY/GRAVIMETRY SURFACE DATA

Christoph Foerste [(1)], F. Flechtner [(1)], R. Schmidt [(1)], R. Koenig [(1)], Ul. Meyer [(1)], R. Stubenvoll [(1)], M. Rothacher [(1)], F. Barthelmes [(1)], H. Neumayer [(1)], R. Biancale [(2)], S. Bruinsma [(2)], J.-M. Lemoine [(2)], S. Loyer [(3)]
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Precise high-resolution global mean gravity field models can be derived from the combination of satellite tracking and surface gravity data. At GFZ Potsdam and GRGS Toulouse, such global gravity models are routinely produced in the framework of the EIGEN processing activities (EIGEN = European Improved Gravity model of the Earth by New techniques). Here the latest results of a new generation of gravity model products, labeled EIGEN-05, are presented and compared with outcomes of former analyses. The long-wavelength components of these improved models are obtained from the processing of GRACE, CHAMP and SLR satellite tracking data, based on a new GRACE and CHAMP data reprocessing using improved processing standards and models. This satellite-based data are then combined with partially newly available surface gravity data sets, for instance a mean sea surface data set generated at GFZ Potsdam from global altimetry mission data. The combination with the satellite data was carried out on the basis of full and block-diagonal normal equations to derive a global gravity field model, combining the high precision and homogeneity of the satellite data in the long- to medium-wavelength part with the short-wavelength resolution of the surface data. A special band-limited combination technique was applied to get a smooth transition from the satellite-only to the surface-based wavelength bands. The obtained Earth gravity field parameters are an update of former EIGEN models of a resolution corresponding to a half-wavelength of 55 km and degree/order 360, respectively.

New Mean Sea Surface DNSC07

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Satellite altimetry is one of the key elements in global high resolution models of the mean sea surface and the global gravitational models. In this presentation we will focus on the latest development in the accuracy and processing of satellite altimetry. The latest version (DNSC07) of the formerly KMS global marine gravity fields and mean sea surfaces (MSS) will be presented. The DNSC07 mean sea surface have been derived with a spatial resolution of 1 minute by 1 minute and cover all marine regions of the world including the Arctic Ocean up to the North Pole.

Amongst the improvement in satellite altimetry are retracking of the entire ERS-1 GM mission using a highly advanced expert based system of multiple retrackers to gain data from both the open sea surface and from all ice-covered regions within the coverage of the ERS-1, in order to derive products with higher accuracy that are presently available.

The Mean Dynamic Topography is the quantity that bridges the geoid and the MSS and the impact of these new quantities with respect to an accurate determination of the Mean Dynamic Topography will be investigated.

Evaluation of the Geosat and Geosat Follow-On Precise Orbit Ephemeris

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The U.S. Navy GEOSAT mission provides the first long-term altimetric record for studies of ocean circulation, marine gravity/bathymetry and continental ice, from early 1985 through 1989. The GEOSAT Follow-On spacecraft (GFO), launched in 1998, began continuous radar altimeter coverage of the oceans in 2000 and is still operating By providing high quality altimeter data, GEOSAT delivers the first and only altimetric measurements over the 1980's, and GFO can supplement Jason, TOPEX/POSEIDON(T/P), and Envisat, providing a different synoptic sampling of the oceans with its 17-day ground track repeat cycle. Altimeter crossover analysis suggests GFO and Geosat are capable of POSEIDON class altimetry, both showing crossover residuals averaging below 7.5 cm, with 5-cm orbit error the largest contributor to the altimeter error budget. This study evaluates possible improvements to the recently released Geosat GGM02C GDR orbits and current GFO GDR orbits. POD model improvem! ents include using model standards consistent with the latest generation of GSFC reprocessed TOPEX and Jason orbits as well as re-estimated coordinates of the Geosat Doppler stations. In this presentation we summarize the current status of our research effort.

Jason 1 GPS processing at CNES

Flavien Mercier [(1)], Luca Cerri, Sabine Houry, Pascal Perrachon, Jean-Paul Berthias
[(1)] CNES

Jason GPS measurements are very important to achieve the best orbit precision. The current solution used in the POE processing is presented, whith a description of some Jason measurements specific characteristics (receiver widelane behaviour, preprocessing, cycle slip detection...). The Jason code and phase bi-frequency measurements are used, together with the precise ephemeris and clocks produced by JPL for igs solutions.

The possible improvements for Jason 2 processing are also developed.

Ocean Mean Dynamic Topography from altimetry and GRACE: Toward a realistic estimation of the error field

Marie Helene Rio[(1)], Philippe Schaeffer/CLS, Jean-Michel Lemoine/GRGS, Gilles Larnicol/CLS
[(1)] CLS-DOS

The accurate estimation of the ocean absolute dynamic topography from past, present and future altimetric data is directly related to our knowledge of the geoid, via the Mean Dynamic Topography (MDT). Significant improvements have already been made in the estimation of the ocean MDT at scales larger than 400 km thanks to GRACE data and strong improvements are expected from the GOCE mission, whose objective is the estimation of the geoid at a 100 km resolution with a 1-2 cm accuracy. At the time the first results of the GOCE mission will be available, the French system MERCATOR will be operating routinely the PSY3v2 protoype, providing on a global 1/4° grid forecasts and analysis of the ocean state through the joint assimilation of altimetric data and in-situ measurements. The integration in the system of the information brought by GOCE will be highly valuable provided an accurate knowledge of the error level of all information entering the system (MDT, altimetry data, in-situ measurements) is accurately known and overall consistent. The most direct way to compute the ocean MDT from altimetry and a geoid model is to subtract the latter from an altimetric Mean Sea Surface and to further filter the obtained field. However, the obtained MDT field is usually given without any error estimate. Furthermore, due to the difference in spectral content of the two fields, some problems usually arise in specific areas (along the coast, in strong subduction areas…). In this paper, we use an optimal filtering technique where the error budget of both the geoid model and the altimetric data is taken into account to compute the MDT and its associated error field. Compared to the direct method, we show that such a technique allow to preserve the strong gradients of the ocean circulation while correctly smoothing unrealistic short scales. The resulting field is validated comparing it to independent synthetic estimates of the MDT, where synthetic estimates are obtained from the combined use of altimetric Sea Level Anomalies and in-situ measurements of the ocean absolute dynamic topography (or related geostrophic circulation). A thorough analysis of the differences between the optimal MDT and the synthetic MDT is done to make sure that all signals are consistent in the range of their error bars and that the MDT error estimate obtained through optimal filtering is realistic.

Validation and extension of ITRF2005 for DORIS and SLR POD (DPOD2005 and LDPOD2005)

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Recently, the new ITRF2005 solution was released by the IERS, providing updated station coordinates for many of the GPS, SLR, DORIS and VLBI tracking stations. However, this set of coordinates is not complete; several new tracking stations were not included, some velocity determinations can be improved using more recent tracking data or collocation information with GPS, and some sites had insufficient data to reliably determine both position and velocity. For precision orbit determination applications, particularly for the various altimeter satellites, a complete set of usable station coordinates is required. Following a similar study (DPOD2000) done for DORIS with ITRF2000, we propose here new coordinates data sets for DORIS (DPOD2005) and Laser tracking stations (LPOD2005), both being consistent with ITRF2005. In a first step, we show a limited numbers of cases for which positions or velocities in ITRF2005 should not be used directly for POD applications. We also propose a list of tracking periods for which data should not be used for POD purposes. Finally, we propose additional or updated station positions and velocities consistent with ITRF2005 for all tracking stations that were not included in the original ITRF2005 computation.

Multi-satellite/Operational applications – poster

Near Real Time Monitoring of Global Lakes and Reservoirs

Charon Birkett [(1)], Brian Beckley (SGT), Brad Doorn and Curt Reynolds (USDA)
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Satellite radar altimetry has the ability to monitor variations in surface water height (stage) for large lakes and reservoirs. A clear advantage is the provision of data where traditional gauges are lacking or where there is restricted access to ground-based measurements. A USDA-funded program is performing near-real time altimetric monitoring of the largest lakes and reservoirs in the world. Data ingestion and manipulation follows the path of the NASA Ocean Altimeter Pathfinder although extra provisions have to be made regarding these smaller targets. The near-real time stage measurements are derived from incoming data from the Jason-1 mission (IGDR data, <10cm orbit accuracy, delivery time <4days after satellite overpass). Archived data from the TOPEX/ POSEIDON mission is also utilized to provide historical time series variations from 1992-2002. The database currently holds around 70 lakes with stage product accuracies ranging from a few centimetres to many ten! s of centimetres depending on the target size and mission dataset. The database contains simple graphic and text products, which are available via a clickable map interface on an internet web site (http://pecad.fas.usda.gov/cropexplorer/global_reservoir. This enables free public access as well as the delivery of information to the USDA for irrigation potential estimates and observation of potential drought or high-water conditions. With continued funding from NASA and the USDA data from the NRL GFO satellite is being ingested and analysed to a) increase the number of observation targets and b) to replace some missing results (data processing problem) pertaining to the Jason-1 (2002-current) data set.

Seadatanet, a pan-european infrastructure for ocean & marine data management

Frederique Blanc [(1)], Olivier Lauret (CLS), Nicolas Picot (CNES) and Seadatanet partners

[(1)] CLS

SeaDataNet aims to develop an efficient data management infrastructure for the present and futur ocean observing and forecasting programmes, able to handle the diversity and large volume of data collected via the Pan-European oceanographic fleet and the new observation systems, both in real-time and delayed mode.

SeaDataNet initiative is undertaken by a consortium of 49 partners of major european oceanographic institutes of the 35 participating countries, acting as National Oceanographic Data Centres (in situ data sets), Satellite Data Centres (AVISO/Altimetry & CERSAT), two expert modelling centres and three international bodies (IOC, ICES & JRC).

SeaDataNet is based on a semi-distributed system that incorporates and enhances the existing NODC network and satellite data centres, making use of the new possibilities offered by the communication technology. A virtual data centre will be developed to integrate and link, in a reliable and interoperable manner, marine data streams across disciplines, institutions, time scales, and geographic regions. It will thus focus on implementing of a central up to date catalogue and will provide integrated on-line access to the most comprehensive multidisciplinary available sets of in-situ and remote sensing marine data, meta-data and products.

Satellite altimetry participates to such initiative and will develop interconnection with all AVISO facilities. The presentation will introduce Seadatanet project and other related European projects contributing to the setting up of such integrated and coherent information system architecture within GMES, and, more precisely, comment on AVISO contribution and evolutions. Among them, first thought on future needs for Jason-2, will also be presented. The GMES European strategy & this initiative complement the US-Integrated Ocean Observing System (IOOS) goals, which aim to establish a system that routinely and continuously provides required data and information in forms and at rates specified by the users in order to service specified societal objectives.

A view from multi-mission satellite altimetry over the coastal ocean: application to the Ligurian Sea and the Corsica Channel

Jérôme Bouffard[(1)], S. Vignudelli/CNR, P. Cipollini/NOCS, F. Lyard/LEGOS, G. P. Gasparini/CNR, F. Birol/LEGOS
[(1)] LEGOS

Usually, altimeter data are processed and used over open sea. In the coastal ocean, specific correction models and new quality control procedures are necessary. This is the reason for developing new processing strategies with the aim of increasing the quality and quantity of retrieved measurements, therefore making altimetry more exploitable over these regions. The Ligurian Sea, including the Corsica Channel, is a perfect site for evaluating performance of altimeter data over a marginal sea, thanks to the availability of long-term in-situ observations from current meters, tide gauges and bottom pressure recorders. The ALBICOCCA (ALtimeter-Based Investigations in Corsica, Capraia and Contiguous Area) initiative greatly contributed to improve altimeter data in this area, but the success was limited to single satellite studies with a relatively poor 1 Hz along-track sampling. A step forward was to exploit a higher along track sampling and the synergy of multiple satellite sources to increase coverage in time and space. In the framework of the Margin Altimetry Project (MAP), High Resolution Anomalies (HiReA) from multi-mission satellites have been generated. Here, we evaluate in detail the improvement of the new multi-satellite product when compared to the official altimetric products, and assess its ability to resolve coastal circulation in the study area at various time scales.

SSALTO/DUACS : Daily multi-mission products for global and regional applications

Joel Dorandeu [(1)], G.Dibarboure (CLS), N.Picot (CNES), P.Y Le Traon (IFREMER)
[(1)] CLS, Space Oceanography Division

=== Near Real Time (NRT): Daily Operational Products ===

DUACS-NRT provides GODAE, climate forecasting centers, and real time oceanographic research with directly useable, high quality near real time altimeter data. Regional products are delivered to operational projects such as MERSEA. Commercial applications are also developed for the fishery and offshore industries. NRT altimeter data from SSALTO/DUACS are distributed by AVISO. Since the beginning of summer 2006, all DUACS near real time products are generated and distributed on a daily basis to reduce the NRT delay, and to smooth the operational procedures or NRT users.

DUACS features a quality control of the input data, the system itself, and its products with detailed reports put online twice per week. The DUACS system also provides offline validations and reprocessing as well as a long term monitoring of NRT data it has used, to quickly detect anomalies, drifts and discontinuities in incoming altimeter data.

== Delayed Time (DT): A consistent data set from built upon all altimeters ==

The second generation of DUACS-DT products is composed of global data sets of along track and gridded Sea Level Anomaly, Absolute Dynamic Topography, and geostrophic currents, but also of regional-specific products (higher resolution, optimized parameters). DUACS reprocessed all past altimeter data: Jason-1, T/P, ENVISAT, GFO, ERS1/2 and GEOSAT. These delayed time products are regularly updated when new GDR are released and fully validated.

The system operationally integrates the state-of-the-art corrections, models and references recommended by the altimeter community, as well as the best Cal/Val and intercalibration algorithms.

=== Ongoing Improvements to secure multi-mission products ===

The ongoing effort to improve the quality of DUACS combined data, and the robustness of the NRT system will be maintained in 2007 with studies of impact on NRT processing, or the integration of new ancillary data and models. Significant improvements will be added to the data validation and analysis with online, simpler and more user-friendly quality flags and indicators. Moreover, new demonstration data sets and formats will be released : Google Earth graphical data with high-resolution maps and satellite pass overlays, along-track data coverage expected by DUACS in the coming days…

Most importantly, with the aging of current missions and the altimeter launch schedule, the probability to have two or three altimeters in operations is getting dangerously low. It is therefore important to use as many data flows as possible to maintain an acceptable quality level on the multi-mission altimetry observation. Preliminary studies are carried out to merge the innovative information of lower quality altimeter data (either real time data delivered in a few hours or opportunistic ocean measurements from CryoSat) into the high-accuracy NRT system. Similarly, the system is being upgraded to dynamically toggle processing parameters, algorithms and references based on the altimeter status.

Mediterranean water mass budget variations: revisited

David García [(1)], Benjamin F. Chao/National Central University; Isabel Vigo/University of Alicante
[(1)] University of Alicante

Assuming negligible deformation of the ocean basin, sea level variations (SLV) are the result of two terms: steric and mass-induced. The steric change is the contraction/expansion of the column of water due to density changes which are mainly thermal effect; the mass-induced variation is produced simply by the water mass change by adding/subtracting mass to/from the ocean through exchange of water with the continents and atmosphere. Both terms are indicators of global warming in different senses, so the quantification of each component is of great importance to climate change studies. Altimetry is a best tool to measure the total absolute SLV, or the combination of the two terms. On the other hand, temperature profiles from XBT (or similar) or general ocean circulation models can be used to estimate the steric term, while the mass-induced term could be estimated from time variable gravity (TVG) data. In previous studies we showed, using 2 years of the first releas! e of TVG data from the GRACE mission from mid-2002 to mid-2004, the ability of GRACE to measure the annual signal of the mass-induced component in the Mediterranean Sea. In the present study we revisit the Mediterranean water mass budget variations problem using new releases of GRACE TVG data with improved corrections and longer time series, which provide new insights into the interannual variations. We also adopt new filters that reduce correlated errors in high degree spherical harmonics, which enable higher spatial variations.

Generation of DEMs for the new tracking mode onboard Poseidon-3 and AltiKa

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[(1)] Noveltis

The Poseidon-2 tracker onboard Jason-1 altimeter has proved to be very accurate over open ocean surfaces but less robust over other surfaces like coastal areas, inland waters, and ice sheets. Therefore, an experimental tracking mode, combining the satellite height provided by the DIODE real-time navigator and a Digital Elevation Model loaded with the altimeter package, has been designed by CNES to optimise the observation of these regions of interest by new generation altimeters (Poseidon-3 and AltiKa). The study, supported by CNES and performed by Noveltis in collaboration with CNES and LEGOS, has been focused on the generation of two DEMs (one for each altimeter) aimed at following the ocean and land topography. Several input DEMs have been merged to build an accurate global DEM (in particular the LEGOS water level database), and a sampling algorithm has been implemented to generate the onboard DEMs at a constant sampling step along the orbit path (0.01°). This algorithm takes into account the radar spot extension on the ground and includes an optimisation method to improve off-nadir observation occurring when passing along, entering or exiting regions of interest. This new tracking mode will be assessed during the Jason-2 in-flight commissioning phase (2008) and has also been adopted as an experimental tracking mode onboard AltiKa.

Validation in operational oceanography at the global scale in the GODAE and MERSEA framework : Overview of the Mercator Global Operational system assessment

Fabrice Hernandez[(1)], Ali Belmadani/LEGOS, Laurence Crosnier/Mercator-Ocean, Marie Drevillon/CERFACS and Eric Dombrowsky/Mercator-Ocean
[(1)] Mercator-Ocean/IRD

Both GODAE (Global Ocean Data Assimilation Experiment) and MERSEA (Marine EnviRonment and Security for the European Area) projects are gathering ocean operational forecasting system which goals are to demonstrate capacity in real time estimation and forecast of the ocean dynamics. The assessment of the corresponding operational ocean products is a necessary task, which relies on scientific approach. The validation approach, based on five forecasting systems intercomparison has started with the MERSEA Strand 1 project (2003-2004). Validation diagnostics, based on four classes of metrics were defined in the North Atlantic Ocean and the Mediterranean Sea, and then used to perform the assessment. This approach has been kept for the assessment during the MERSEA Integrated Project (2004-2008), and extended at the global scale, in collaboration with GODAE members. During the first demonstration phase of the MERSEA IP project (October 2005-April 2006), these metrics have been implemented in Mercator, the French global operational forecasting system (the global component of MERSEA). A description of the diagnostics and examples from the Mercator validation are provided. Observations play a significant role in the validation. When assimilated, like satellite altimetry or temperature and salinity in-situ data, they allow to measure the inner performance of the assimilation schemes and model errors. While independent data, like sea level from tide gauges, or velocity from drifting buoys allow to infer both the accuracy and the performance of the systems. Note also that a series of methodology for exchanging data, based on common formats and tools (NetCDF, OpenDAP servers) has been developed and is now agreed and shared among the GODAE community.

Power spectral parameterizations of error as function of resolution in gridded altimetry maps

Alexey Kaplan [(1)], Mark A. Cane, Dake Chen (all - LDEO)
[(1)] LDEO of Columbia University

Gridded altimetry products allow us to estimate wavenumber and frequency power spectra of sea surface heights. These power spectra in turn make it possible to estimate the gridding error in sea surface height maps as a function of their spatial and temporal resolution, and of the location. Calculations are verified by comparison with difference maps of pairs of gridded altimetry products, with their nominal error estimates, and by comparisons with in situ data. This approach also produces estimates of altimetry data error with respect to model grid values, which are useful in data assimilation procedures.

Control of a free-surface barotropic model of the Bay of Biscay by assimilation of multi-source sea-level data (altimetry and tide-gauges) in presence of atmospheric forcing errors

Julien Lamouroux [(1)], Pierre de Mey/LEGOS-POC, Florent Lyard/LEGOS-POC, Eric Jeansou/Noveltis
[(1)] Noveltis / LEGOS-POC

A data assimilation method is set up in the barotropic, free-surface, finite element MOG2D model, implemented in the Bay of Biscay and nested in a North East Atlantic domain. The model is forced by the ARPEGE meteorological model.

In a first step, we explore the model error subspace in presence of coherent atmospheric forcing errors. This is done via an ensemble modelling approach in which the atmospheric fields are perturbed in a multivariate and coherent way: by generating an a priori ensemble of perturbed atmospheric forcing fields, and calculating the corresponding a posteriori ensemble of model simulations, one can approximate the forecast errors of the model by ensemble spread statistics, such as background error Ensemble EOFs.

These approximated model error covariances, in form of 6D-EOFs (Sea Level Anomaly, barotropic velocities, atmospheric pressure and wind-stress), are shown to be neither homogeneous over the domain, nor stationary, since they are very dependent on the meteorological forcing.

Such statistics are then used in a Reduced-Order Optimal Interpolation sequential scheme (SEQUOIA, developed at LEGOS/POC) to constrain the model forecast via sea level data assimilation. Twin experiments are conducted in the last quarter of 1999. Results show that the use of time-independent error statistics allows controlling the model but that time-dependent statistics often lead to better results, advocating for a more advanced scheme in a future step.

Finally, several Observing System Experiments (OSEs) and Observing-System Simulation Experiments (OSSEs) are carried out in order to test the sensitivity of the results to various altimetry satellites configuration, with or without tide gauges. Results highlight that both types of sea level data act in a complementary manner in the control of the model error. The impact of velocity measurements near the coast (HF radars) is also illustrated: the assimilation of velocity data appears to enhance the control of both the sea level and velocity signals.

Design of the future altimetry missions: a first prototype of an « end-to-end » mission simulator

Julien Lamouroux [(1)], Laurent Robou (Noveltis), Juliette Lambin (CNES), Pierre De Mey (LEGOS), Florent Lyard (LEGOS) and Eric Jeansou (Noveltis)
[(1)] Noveltis

Operational oceanography reached a new level with the publication of the first global forecast bulletin by the French group MERCATOR in October 2005. Since then, global ocean fields are available in real time not only for scientific studies but also for commercial or military applications. At a regional scale, the knowledge of the coastal dynamics takes part in key challenges for our society among others the response of the coastal ocean to the global climate changes (extreme events, shore erosion, eutrophication...), marine pollution management or marine security monitoring. However, as for the deep ocean, coastal hydrodynamics models still remain limited in precision due uncertainties in the atmospheric forcing fields, in the bathymetry solutions or in the boundary conditions prescription for instance. In this framework, data assimilation appears to be a solid and efficient technique to improve the quality of model solutions and the range of forecasts. Satellites observing systems provide a dense and repetitive network of observations needed for ocean modelling. However, such remote-sensed systems are costly and it is then essential to examine the merits of the available observing configurations in order to find the best compromises between the needs of the scientific community and of socio-economic partners. This poster presents a first prototype of an “End-to-End” Mission Simulator for altimetry. Based on a simplified version of the recently published Ensemble Twin Experiments methodology (Mourre et al., 2004), the simulator aims at quantifying the potential of an altimetry observing system by estimating its ability to reduce the statistical error of a storm surge model of the Bay of Biscay. Relative performance score helps discriminate the various observing scenarios. In these conditions, it is expected that this “End-to-End” Mission Simulator will constitute a powerful decision-making tool to help CNES in the definition of the future altimetry observing systems.

A method for estimating representation error of oceanic observations

Peter Oke [(1)], Pavel Sakov [(1)]
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A simple method for estimating the representation error (RE) of sea-level (SL), temperature (T) and salinity (S) observations for oceanic data assimilation is described. The method exploits the availability of mapped sea-level anomalies (MSLA) and along-track sea-level anomalies (atSLA). We propose using the MSLA fields for application to intermediate to coarse resolution ocean models and present examples of RE estimates for a 1° and 2° global grid. These examples show that RE is largest in western boundary currents (WBCs) and along the path of the Antarctic Circumpolar Current (ACC); but is also relatively large elsewhere. We show that RE has sub-grid scale features; and is likely to be the dominant source of observation error (from the data assimilation perspective) for intermediate to coarse resolution models. We also propose a method using atSLA observations for application to ocean models with resolution ranging from high to coarse resolution. We compare the atSLA-derived estimates to the MSLA-derived estimates of RE for SL for the 1° and 2° resolution grids and generally find good agreement. We also present examples of atSLA-derived RE estimates for a 1/3° global grid and for the Ocean Forecasting Australia Model (OFAM) grid, with variable resolution ranging from 1/10° around Australia to 2° resolution in the North Atlantic Ocean. These examples demonstrate that even for an eddy resolving grid, the RE is of the same order as instrument error, and is significantly larger than instrument error in WBCs and along the path of the ACC, where mesoscale variability is large. Based on estimates of RE for SL, we use a standard vertical projection technique to obtain consistent estimates of RE for T and S. We demonstrate that these estimates are very inhomogeneous in space, with values that are typically much greater than instrument error, particularly in regions of strong mesoscale variability.

Ocean Surface Topography Data at the JPL Physical Oceanography DAAC

Kelly L. Perry [(1)], Patricia K. Liggett
[(1)] JPL Physical Oceanography DAAC

The JPL Physical Oceanography Distributed Active Archive Center (PO.DAAC) distributes a variety of ocean surface topography data. In addition to the standard, validated science products of the Jason-1 and TOPEX/Poseidon missions, PO.DAAC also distributes near-real time data for operational applications such as seasonal forecasting. PO.DAAC has worked with the oceanographic community to develop value-added data sets including the Jason-1 Along-Track Gridded Sea Surface Height Anomaly (SSHA) product. PO.DAAC has also formed partnerships with other data providers in order to supply users with the most complete altimetry data sets available. This is exemplified by the distribution of the NASA/GSFC Altimeter Ocean Pathfinder data set.

PO.DAAC plans to further its role in the oceanographic community in upcoming years. In April 2007, Jason-1 and TOPEX/Poseidon data will be added to the PO.DAAC Hurricane Subsetting Tool (http://podaac.jpl.nasa.gov/hurricanes/). This tool allows users to request near-real time data for recent, major storms and historical subsets of past weather events from validated scientific products. PO.DAAC also plans to further its commitment to local researchers by continuing support of the regional near-real time Jason-1, QuikSCAT and MODIS data streams for the Southern California Coastal Ocean Observing System (http://sccoos.jpl.nasa.gov).

This poster will present additional information on current and future services involving the PO.DAAC altimetry data products.

AltiKa : a new concept of altimeter for the SARAL mission

Nathalie Steunou [(1)],
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[(1)] CNES

In partnership with scientific laboratories and industry, and for several years, CNES has studied the feasibility of a high-resolution ocean topography mission named AltiKa based upon a new class of wide-band Ka-band altimeter in preparation of the post-ENVISAT mission and in order to complement the OSTM/Jason-2 mission. The central objective is the retrieval of the ocean mesoscale circulation and data assimilation in global or regional ocean models. Moreover, main “secondary” objectives of the mission have been identified : coastal altimetry, continental water studies, ice sheet monitoring, low-rain systems characterization. The proposed architecture for the Ka-band altimeter is based on the classical deramp technique for pulse compression and takes benefits of Alcatel and CNES experience from the realizations of Poseidon1, 2 & 3 and SIRAL (CryoSat mission). A bi-frequency radiometer is part of the compact Ka-band instrument. Both altimeter and radiometer share the same antenna. Apart from the combined altimeter and radiometer, the AltiKa payload also consists of a DORIS plus LRA (Laser Retroreflector Array) orbitography system that will ensure a high level of accuracy in terms of orbitography. Moreover, an experimental processing feature will be implemented AltiKa : the coupling of the altimeter with the DORIS/DIODE navigator which provides with real time position information. The aim of this new mode is to improve the behavior of the instrument in coastal regions and above in-land waters. The poster describes the AltiKa instrument and the expected performances. The phase C/D has started at the beginning of 2006. AltiKa payload will be embarked in the SARAL satellite at the same time as the Argos3 instrument, in the frame of a cooperation between CNES and ISRO (Indian Space Research Organization) with an expected launch at the end of 2009.

Impact of multisatellite altimetric missions on the Tropical Atlantic circulation from some Observing Systems Simulations Experiments

Clément Ubelmann [(1)], Jacques Verron, Jean Michel Brankart, Pierre Brasseur
[(1)] LEGI

Observing System Simulation Experiments (OSSE) are realized over the tropical Atlantic domain in order to assess the performances of multisatellite altimetric missions to control the oceanic circulations in this basin through altimeter data assimilation. A particular interest is given to Tropical Instability Waves (TIW) which are most prominent variability features of the tropical oceans.

Various satellite scenarios are investigated, especially the coupled situation of JASON-2 and AltiKa flying simultaneously. One objective is to estimate how beneficial is the addition of one or two satellites over a JASON-like satellite, and in particular the addition of AltiKa to JASON-2 data.

Tropical ocean models are relatively faithfull to represent the circulation although a key issue is the correct specification of fluxes and wind surface forcings. The role of altimetric data assimilation will be specially focused on this particular difficulty as well as on TIW dynamics. OSSEs are conducted within the 15°S-17°N Atlantic domain with OPA ocean model and radiatives boundaries embedded in a global ¼° global model. Data assimilation is performed with the SEEK filter.

Investigating ocean altimeter data and applications in the Gulf of Maine

Douglas Vandemark [(1)], H. Feng/UNH, R. Scharroo/Altimetrics, B. Chapron/IFREMER
[(1)] Univ. of New Hampshire/EOS

The Gulf of Maine is a marginal sea on the east coast of the United States encompassing a region with famously productive local and offshore fisheries, active ports, and one with extensive recreational usage and population along its shores. It is also home to large tidally driven sea level changes, complex bathymetry, and an ocean circulation and ecosystem that is strongly influenced by waters from the Labrador Sea and Scotian Shelf. We have initiated a study to assess the ability of single and/or multi-mission altimeter data sets to monitor seasonal-to-interannual variability in this circulation and sea level rise within the Gulf. Our efforts focus first on data quality including measurement precision against tide gauge measurements and frequency of dropouts caused by the numerous potential correction failures near the coast - a primary focus is on the tidal and radiometer corrections. Second, we are investigating altimeter-derived geostrophic currents nort! heast of Georges Bank, the location of greatest transport into and out of the Gulf. First results will be shown comparing satellite and buoy-measured currents over a 3 year time span using data from the Gulf of Maine Observing System (GoMOOS) network. This coastal area has a maturing regional observing system in place and we intend to use ongoing modeling and observing platform efforts to document and prioritize where and when coastal altimetry can aid in monitoring key processes across the Gulf.

ALTICORE - a consortium serving European Seas with Coastal Altimetry

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The ALTICORE project (value-added ALTImetry for COastal REgions) began in December 2006 and runs for two years thanks to funding provided by the European INTAS scheme (www.intas.be). The main objective of the project is to bridge the current altimetry gap over coastal areas, by improving the quality and availability of coastal altimetry data in European Seas (Mediterranean, Black, Caspian, White and Barents). ALTICORE is a follow-on from the regional ALBICOCCA (ALtimeter-Based Investigations in COrsica, Capraia and Contiguous Areas) initiative. The ALBICOCCA project partners are further strengthened by leading teams from Russia and Azerbaijan. An important aspect of ALTICORE is that it should provide more effective ways of data exchange, in a reliable way, through the development of data management infrastructures that ensure long-term continuity and interoperability, in view of a rapidly growing usage of coastal altimetry.

We will summarize the anticipated project stages, namely: 1) improvement of the most widely distributed, 1 Hz, data by analyzing the corrective terms and providing the best solutions, including those derived from appropriate local modelling; 2) development of a set of algorithms to automate quality control and gap-filling functions for the coastal regions; 3) development of testing strategies to ensure thorough validation of the data.

We will also outline the design and implementation of a Grid-compliant system for efficient access to distributed archives of improved coastal altimeter data; this consists of regional data centres, each having primary responsibility for regional archives, local corrections and quality control, and operating a set of web-services allowing access to the full functionality of data extraction and integration.

We will conclude by discussing a follow-on phase of the project; this will investigate further improvements to the processing strategy, including the use of higher frequency (10 or 20 Hz) data. The whole project aims to promote the 15 years of largely unexploited global altimetry over the coastal areas to the rank of an operational record.

Tides and High-Frequency Aliases - poster

A Tidal Model in the Northwest Atlantic
Guoqi Han [(1)], Shastri Paturi, Brad de Young, Memorial University of Newfoundland, Yuchan Yi, C.K. Shum, Ohio State University
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We developed a three-dimensional tide model for major semi-diurnal and diurnal constituents in the Northwest Atlantic. Multi-mission altimetric tides were assimilated into the model. The impacts of the data assimilation were investigated. The model tidal heights were compared with coastal tide gauge and bottom pressure gauge data. The model tidal currents were evaluated against current meter data.

An M3 Tidal Resonance in the Great Australian Bight
Richard Ray [(1)]
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The M3 tide is a small, linear, terdiurnal tide, generated by the third-degree term in the moon's tidal potential. It is usually sub-cm in amplitude, but a known resonance occurs along the coast of Brazil, where amplitudes reach almost 10 cm at the coast (Huthnance, DSR, 1980). A global analysis of the long Topex/Poseidon-Jason time series has been performed to search for other possible M3 resonances. Another has been found along the coast of southern Australia, in the Great Australian Bight, approximately where the shelf reaches its greatest width. Amplitude at the coast is about 11 cm. Confirmation has been obtained by analyzing 15 years of hourly tide gauge data from the Australian station at Thevenard. With these data we could also solve for 2 much smaller terdiurnal tides, and we find that the estimated admittances are quite consistent for all three tides, indicating a clear resonance for the entire (linear) terdiurnal band. The resonance is approximately a quarter-wave "organ pipe" resonance between the coast and the shelf edge.

The influence of stratification on semidiurnal tides in Monterey Bay, California

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As part of our on-going effort in developing a tide-permitting coastal forecasting system, the influence of stratification on semidiurnal tides in Monterey Bay, California is investigated by using numerical models and comparing model solutions with observations. Models used are configured from the Regional Ocean Modeling System (ROMS) for the central and northern California coast and have horizontal resolutions ranging from 16 km to 1.6 km. Observations from satellite altimetry and high-frequency coastal radar, which can reveal certain spatial signatures of tides, are used in our study.

Numerical experiments from a high resolution model for Monterey Bay show that the Monterey submarine canyon can generate and also trap baroclinic tides generated in surrounding regions. The barotropic tidal currents are greatly enhanced within Monterey Bay by the presence of stratification. The surface tidal current is sensitive to stratification through the changes in both barotropic and baroclinic tidal currents. For given bathymetry and model configuration, surface tidal currents can be improved with a better representation of stratification. On the other hand, tide solutions in a larger domain covering the central and northern California coast, indicate that the propagation of baroclinic tides, as measured by the depth integrated baroclinic tidal energy, seems not to be very sensitive to stratification. Thus in the generation region of baroclinic tides, the tidal features can be influenced greatly by subtle changes in stratification. The propagation of baroclinic tides, however, is not very sensitive to the changes in stratification. Our findings are consistent with earlier research revealing the surface manifestation of baroclinic tides thousands of kilometers away from their generation sites. The research, however, does underline one of the challenging issues in the development of tide-permitting coastal forecasting systems which generally contain generation regions of baroclinic tides. The issue could only be addressed with innovative observing platforms that can provide high resolution and continuous monitoring of coastal regions.

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