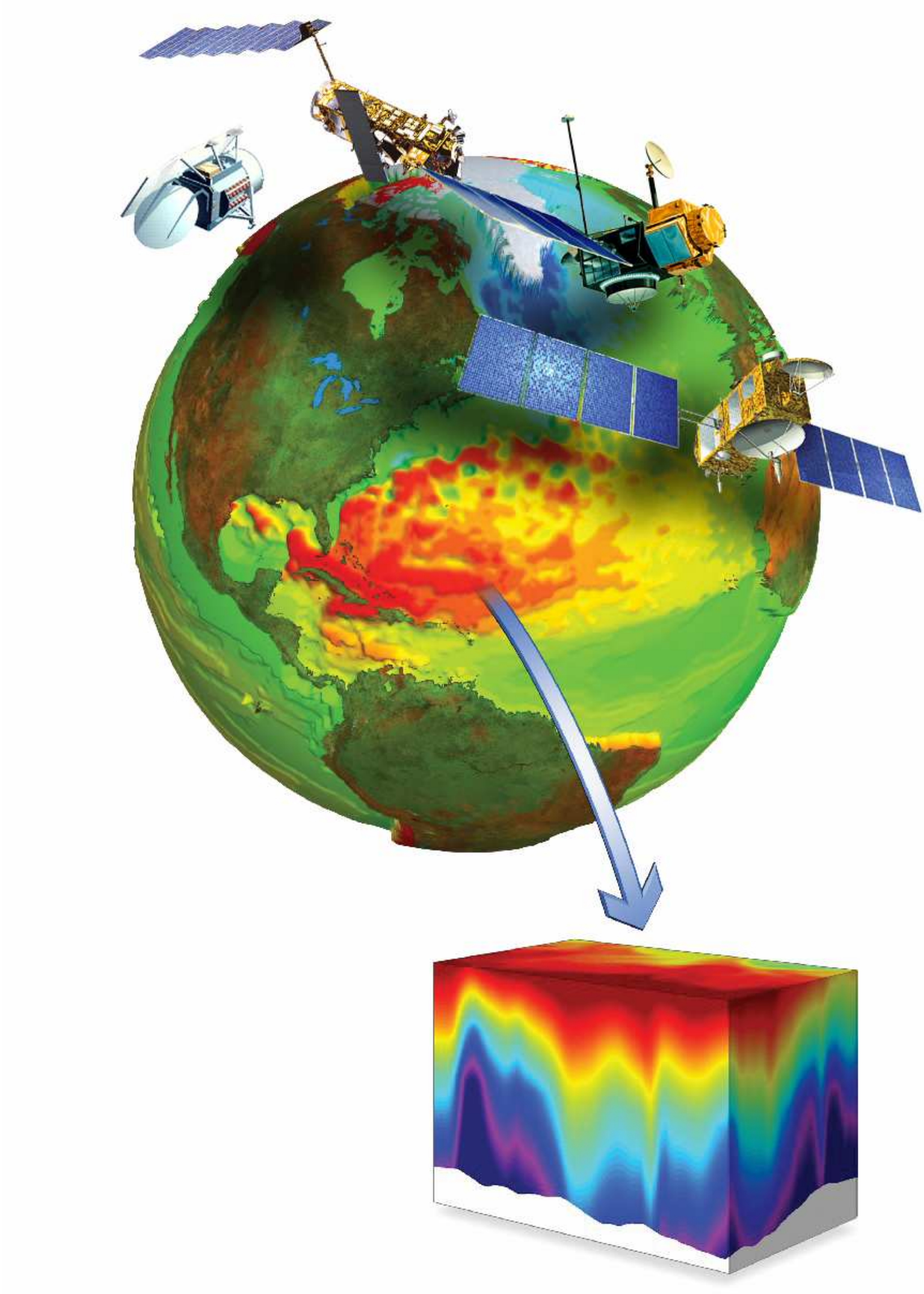
Ocean Surface Topography Science Team Meeting

Venice (Italy), 16-18 March 2006



CENTRE NATIONAL D'ÉTUDES SPATIALES

MINUTES

Ref: SALP-CR-MA-EA-15640-CNES

Minutes of the Ocean Surface Topography Science Team Meeting

16-18 March, 2006
Venice – Italy

Edited by Yves Ménard

Reference: SALP-CR-MA-EA-15640-CNES

The OSTST team will sorely miss two talented and gracious persons who contributed a lot to the progress of altimetry during their careers:

***Roman Glazman**, a Principal Investigator of the SWT and OSTST for many years, passed away on April 24, 2006.His contributions to the science of sea surface processes and microwave remote sensing are a tremendous legacy of his passionate pursuit of science.*

***Tony Elfouhaily**, an expert in fluid turbulence, electromagnetic scattering and nonlinear wave theory, is suddenly gone on July 26, 2006. Among many other remarkable achievements, he contributed in the development of the Sea State Bias theory and its estimation.*

Table of Contents

Introduction

This Ocean Surface Topography Science Team (OSTST) meeting was following the symposium "15 years of progress in altimetry" co-organized by ESA and CNES and sponsored by NASA and many others partners involved in the development and promotion of altimetry. This symposium attracted more than 500 participants in Venice (italy) coming from many countries to present, discuss and exchange past and recent results derived from altimetric data in different Earth observation disciplines (oceanography, ice study, hydrology, geophysics, geodesy). Having the OSTST meeting nearby this major event as well as the Argo and IDS workshops was very helpful to give a global and deep overview of the unique progress which has been done in altimetry over the last years and to foster the dialogue with a wider community, beyond the current OSTST team (see the http://earth.esa.int/venice06 site for loading the abstracts, presentations and minutes of the symposium). Most of the OSTST PIs and CoIs investigations were presented during the symposium contributing to the various discussions. One of the major output of the symposium is the statement on the future of altimetry, its continuity and extension, which was reviewed and approved by all the participants. This statement is attached at the end of this report.

- As an introduction of the OSTST meeting, it was first reminded that the TOPEX/POSEIDON mission ended on October 2005 after 13 years of a unique continuous collection of highly accurate altimetric data. This was an opportunity to thank all the actors who contributed in the development, the exploitation and the outstanding success of this mission. Hopefully, since December 2001, Jason-1 is continuing the T/P mission, completed in terms of coverage and sampling by ENVISAT and GFO. Moreover the Jason-2 project development is on time scheduled now for a launch in 2008 with T2L2 on-board as a passenger (see below Jason-1,Jason-2, ENVISAT, GFO project status summaries for more details)

- The main issues which were addressed during this OSTST meeting were related to the on-going evaluation of the reprocessing of the Jason-1 data, the expression of recommendations to the project regarding this reprocessing scheduled in 2006 (see reports of the splinters for the details) and the expected future T/P/Jason-1 homogeneous global reprocessing.

- Other issues which were discussed during this OSTST meeting included:

- The algorithm evolutions for Jason-2
- The development/validation of higher resolution correction models (tides…)
- The Jason-1/2 cross-calibration in case of an unexpected gap in the time series
- The continuity after Jason-2, i.e. the reference Jason-3 mission definition and recoms (orbit, payload…), the AltiKa mission definition as a complement
- The OSTST Science Plan to be released end of 2006

As usually this OSTST meeting included project and programmatic presentations, T/P, Jason-1 and Jason2 project status, Pis/CoIs oral and poster presentations and splinter working meetings devoted to specific project and science related topics. Reports of the splinters, as well as recommendations, are attached to these minutes. Abstracts as well as some of the poster presentations can be viewed and loaded on the AVISO web site (http://www.jason.oceanobs.com/html/swt/ostst2006/)

The next OSTST meeting will be held in Hobart, Australia, March 12-15 2007. All details on this meeting are provided on the http://sealevel.jpl.nasa.gov/OSTST/2007/ web site.

PLENARY SESSIONS

1. NASA Program Status (E. Lindstrom)

NASA Physical Oceanography Program Priorities

1) **Support missions on orbit:** Jason (Altimetry), QuikSCAT (Winds)

2) **Support missions in development:** **Ocean Surface Topography Mission (Altimetry), Aquarius (Sea Surface Salinity)**

3) **Support next generation mission concepts:** Ocean Vector Winds, High Resolution Ocean Altimetry, Next Generation SST

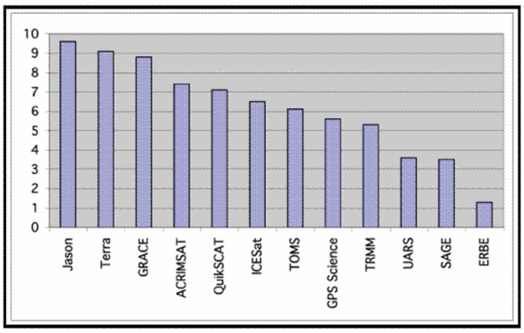
4) **Support Climate Focus Area:** Decadal Climate Variability, US CLIVAR, CCSP, GCOS, JCOMM

5) **Support the National Oceanographic Partnership Program:** GODAE, CODAE, GHRSST-PP

Practical Matters for OSTST

- **USA Team in place until March 2008**
- **Calls for re-competition in ROSES 07 (Issues @ end January 2007).**
- **Proposals due summer 2007?**

Figure 2. Rank based on absolute scientific value (10-8 compelling; 7-4 excellent, but less compelling, and 3-0 modest).



NASA 2005 Senior Review

- **NASA conducted a "senior review" of existing earth missions in spring 2005, evaluating and ranking the scientific value of each mission for deciding the continuation of the mission and operating budget.**
- **A proposal was submitted by each mission to report its scientific findings and articulate the value to continue the mission.**
- **The Jason proposal was ranked number one by the review panel, thanks to the cooperative efforts of the OSTST**
- **Such reviews are to be conducted every two years.**
- **The next is scheduled for spring 2007.**

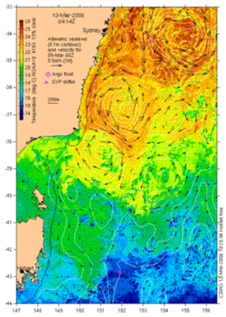
Outside Forces

- **Budget constraints (-20% this year!)**
- **Global Earth Observing System of Systems**
- **U.S. Integrated Ocean Observing System**
- **Research-to-Operations Transition NASA→NOAA**
- **National Academy of Sciences - Earth Science Satellite Missions Decadal Survey**
- **U.S. Ocean Action Plan (Administration response to the U.S. Ocean Commission Report)**
- **NASA Senior Review Process for mission extensions**

Next OSTST Meeting

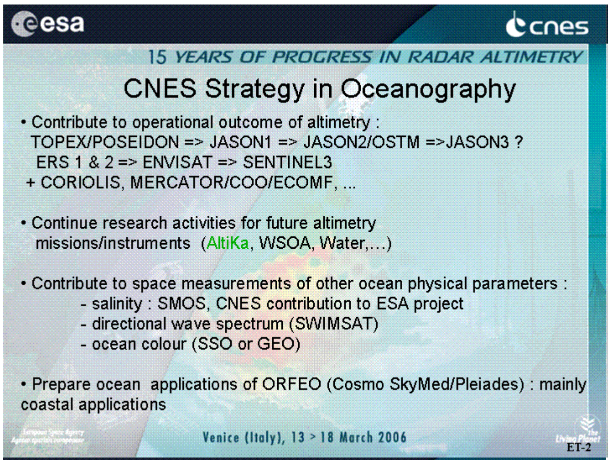
VENUE: Wrest Point, Hobart, Tasmania, AUSTRALIA

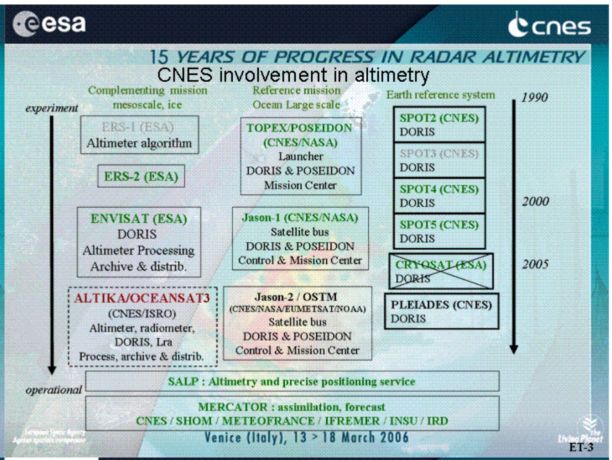
TIME: 12-15 March 2007

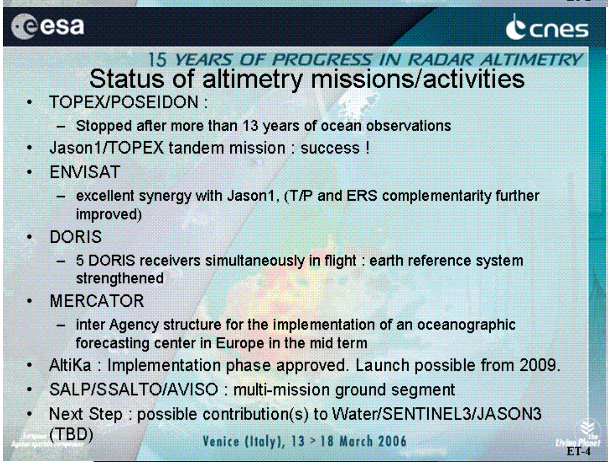


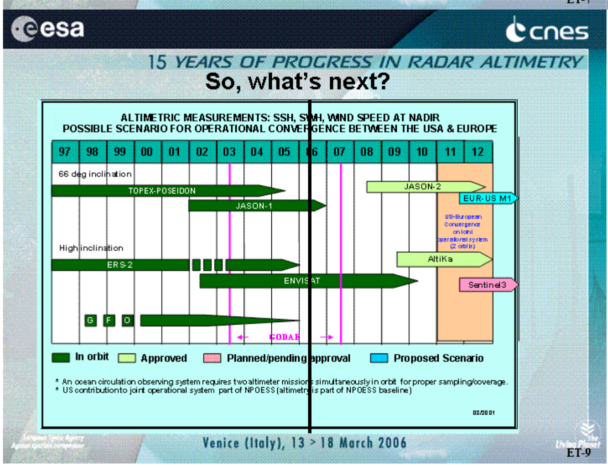
http://www.wrestpoint.com.au

2. CNES Program Status (E. Thouvenot)

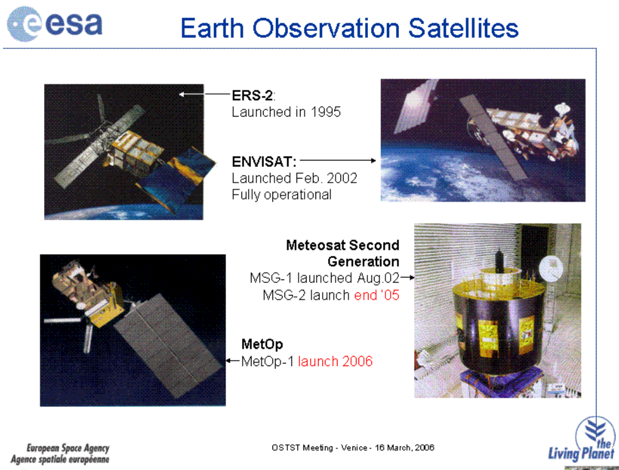


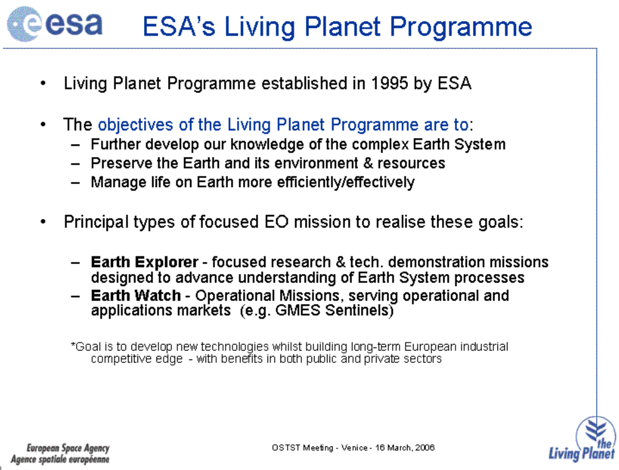


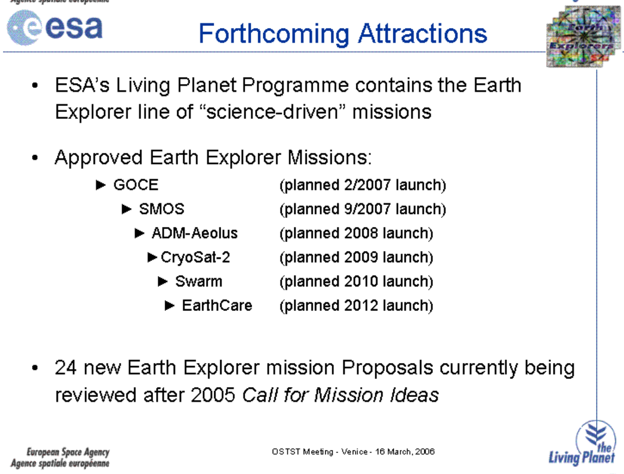


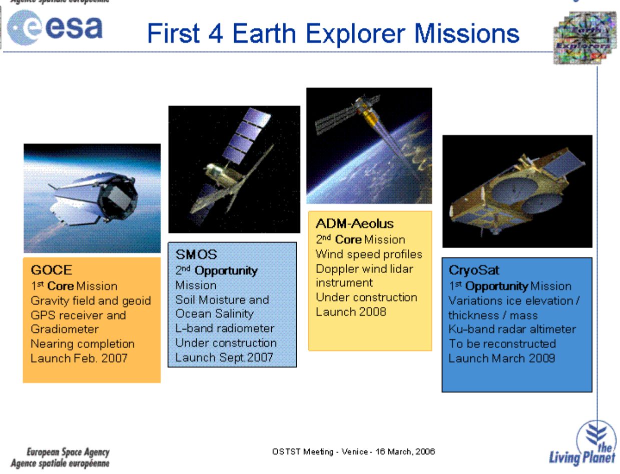


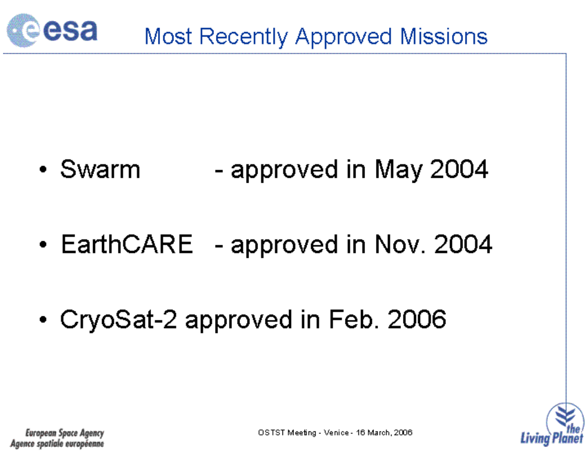
3. ESA Earth Observation Missions Status (J. Benveniste)

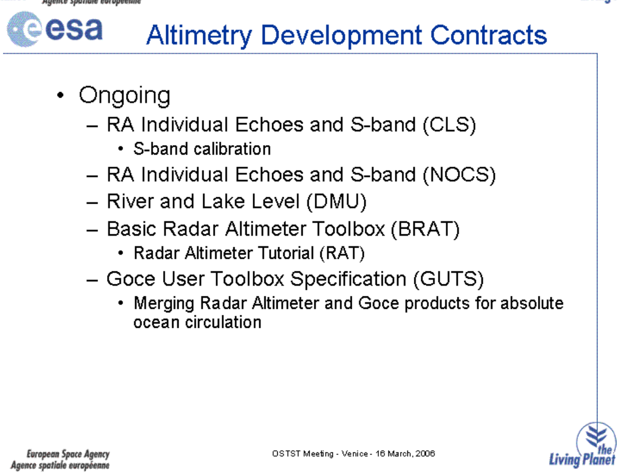












esa

Altimetry Development Contracts

- Foreseen in 2006/2007
  - RAIES Follow-on
    - Creating a RAIES Users Group
  - Altimetry Corrected Elevations 2nd Generation
    - Correcting STRM with RA
  - River and Lake Follow-on
    - Ra performance over inland water
    - Assimilation in hydrological models
    - In-situ data
  - CryoSat SAR mode retracking over ocean, inland water and coastal zone
  - GUT (GOCE Toolbox implementation)
  - SUIT (SMOS Interactive user Toolbox)

esa

Data Exploitation

- Four on-going AOs and the Category-1 continuous submission mechanism.
- On-going AOs involve more than 1100 projects.
- The Category-1 continuous mechanism witnesses a growing success, with currently 25 proposals submitted monthly and more than 800 projects in total.
- 200 Projects using ERS or Envisat Altimeter
- Cat-1 mechanism is supported by the EO PI portal: http://eopi.esa.int

esa

Data Exploitation

- The EO PI portal is increasingly popular. Practical information includes stories about "PIs of the month", round tables on scientific topic, public and scientific news.
- Projects correspondents (ESA Staff) are assigned to stimulate one-on-one dialogue with all PIs.
- Intense scientific promotion efforts:
  - provision of open-code software toolboxes,

http://eopi.esa.int

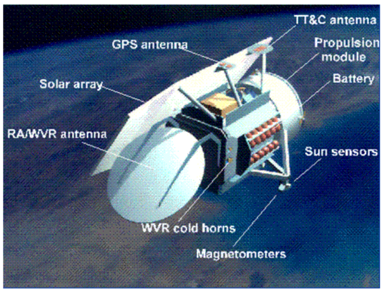
esa

Summary

- ESA's Living Planet Programme has a series of approved missions.
  See: www.esa.int/livingplanet
- Earth Explorers have focused scientific objectives - and each will address key questions about the Earth System
- CryoSat is the first of six approved Earth Explorer Missions
  - It will be reconstructed and relaunched in march 2009
- The next Earth Explorer launch is GOCE in Feb. 2009
- SMOS Launch dated is17 September 2007

4. GFO Mission Status (J. Lillibridge, G. Jacobs)

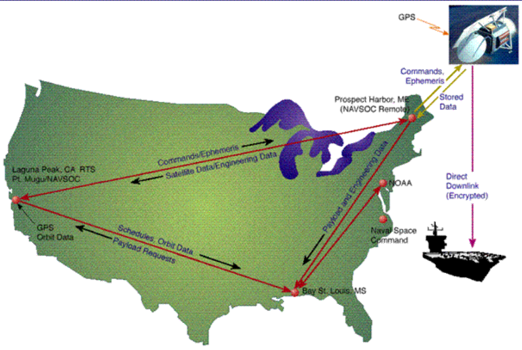
GFO Spacecraft & Sensors



- Ku-band Altimeter
- Dual-*f* Radiometer
-
- Doppler Beacon
- Laser Retro-reflector
- Fixed Solar Array
- Solid State Memory

Venice 2006 OSTST 16-Mar-2006 — GFO Mission & Status #2

Navy GFO Ground Segment



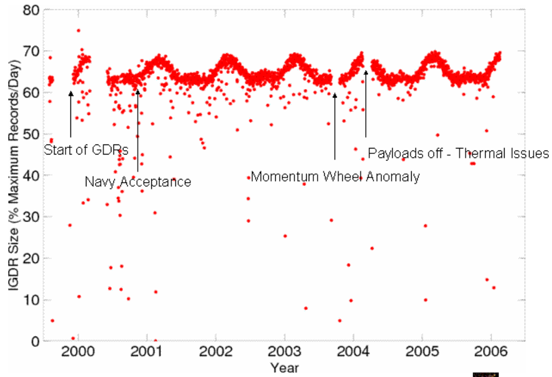
Venice 2006 OSTST 16-Mar-2006 — GFO Mission & Status #3

A Brief History

- Launch: 10-Feb-1998 from Vandenberg AFB
  - 8-year nominal lifetime, celebrated 8th anniversary in 2006
- Initial hardware difficulties
  - Onboard CPU resets during first two years
  - GPS receivers failed in spite of 4-unit redundancy
    - Loss of primary orbit determination system
    - Loss of precision time-tagging
- Ground-based time-tag unit at NAVSOC: June, 1999
- Precision orbit determination based on SLR tracking
- CPU reset problems solved: November, 1999
- Navy acceptance: November 29, 2000
- Momentum wheel anomalies - temperature sensitivity

Venice 2006 OSTST 16-Mar-2006 — GFO Mission & Status #4

Altimetry Data Return



Venice 2006 OSTST 16-Mar-2006 — GFO Mission & Status #5

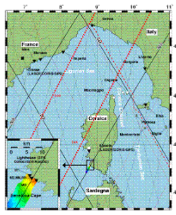
Interagency Participation

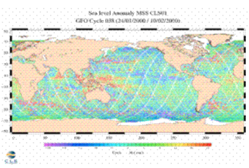
- **U.S. Navy**
  - SPAWAR
    - Program management
    - Navy Cal/Val team
  - NAVSOC
    - Satellite Command/Control
    - Data Telemetry
    - Operational Doppler orbits
  - NAVO/NRL - Stennis
    - Payload Operations Center - ADFC
    - Near real-time altimetry -> GODAE
    - Military data requests
- **NASA**
  - Wallops Flight Facility
    - Instrument performance monitoring & Cal/Val
  - Goddard Space Flight Center
    - Precise Orbit Determination from laser ranging
    - Ice-sheet monitoring via altimeter waveforms
- **NOAA**
  - Final Science-quality GDRs
  - Near real-time IGDRs
  - Civilian Data Requests (Foreign & National)
  - Funding OSU Cal/Val team & GSFC Orbits
  - Funded CLS for sea-state bias model

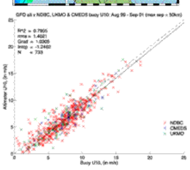
Venice 2006 OSTST 16-Mar-2006 — GFO Mission & Status #6

European Partners

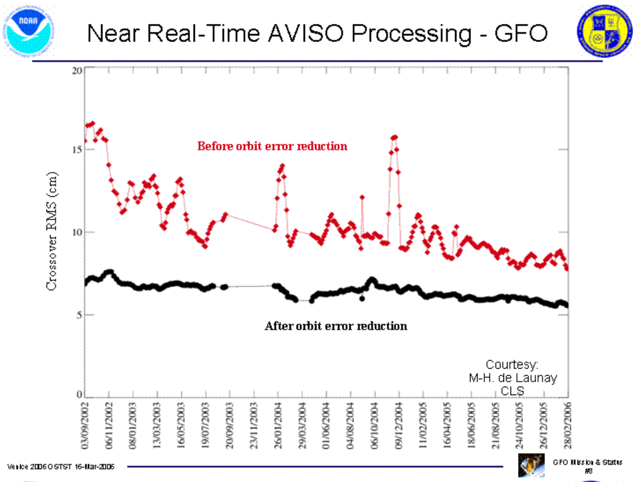
- CNES - Corsica absolute calibration
- CLS - Real-time "DUACS" system
  - Validation of all corrections
  - Editing thresholds and engineering flags
  - Sea surface height, SWH, Wind & Attitude
- S.O.S. (U.K.) - SWH/Wind Buoy validation

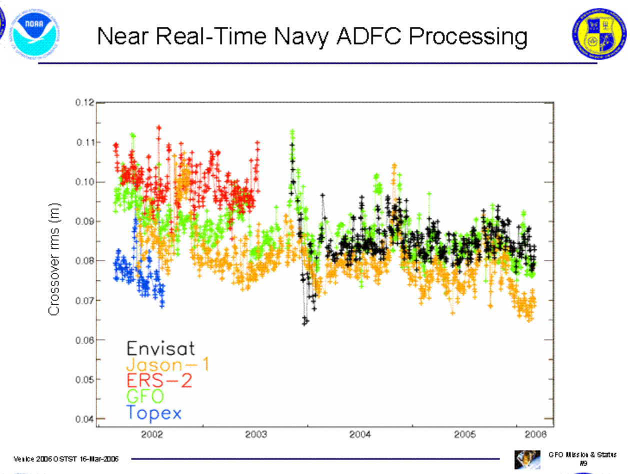


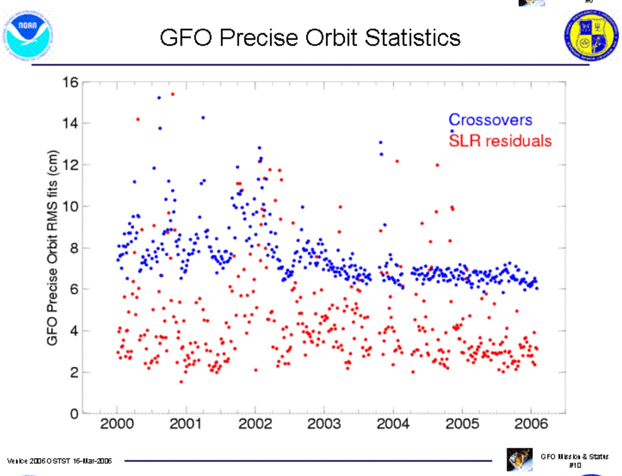


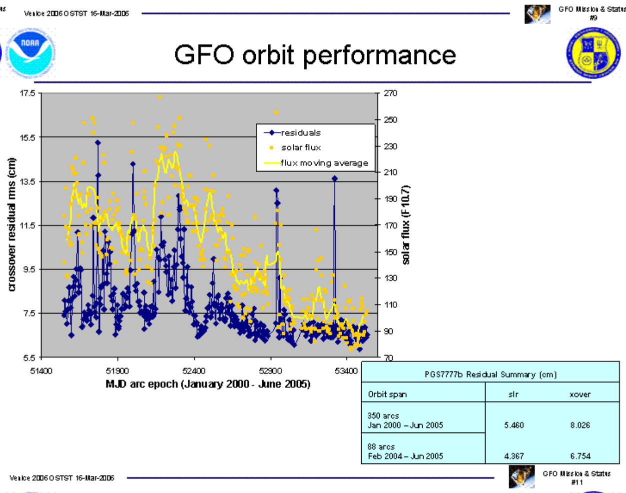


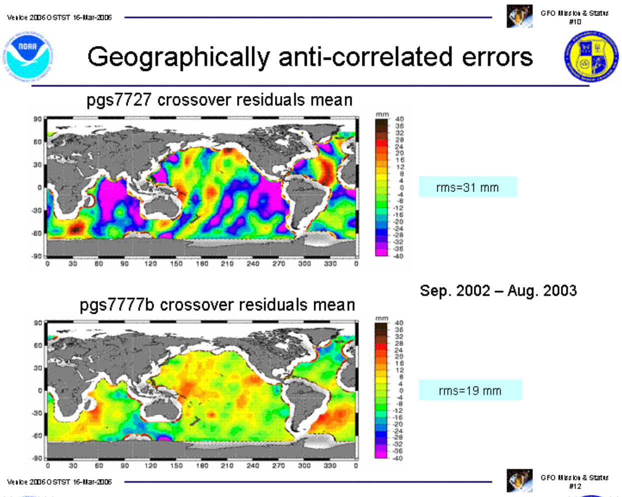
Venice 2006 OSTST 16-Mar-2006 — GFO Mission & Status #7

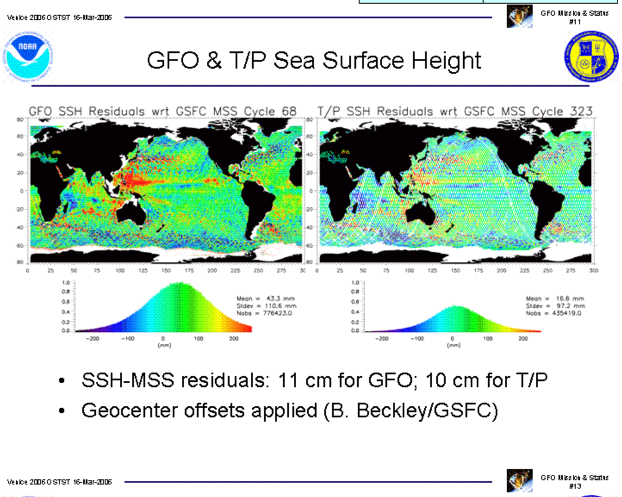

Near Real-Time AVISO Processing - GFO
Crossover RMS (cm)
Before orbit error reduction
After orbit error reduction
Courtesy:
M-H. de Launay
CLS
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status

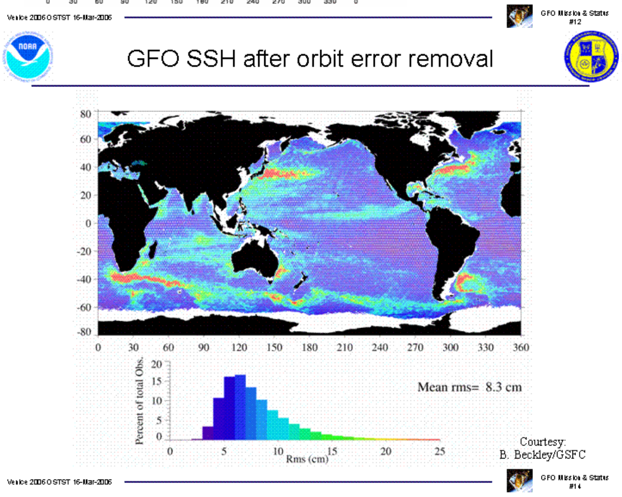

Near Real-Time Navy ADFC Processing
Crossover rms (m)
Envisat
Jason−1
ERS−2
GFO
Topex
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status

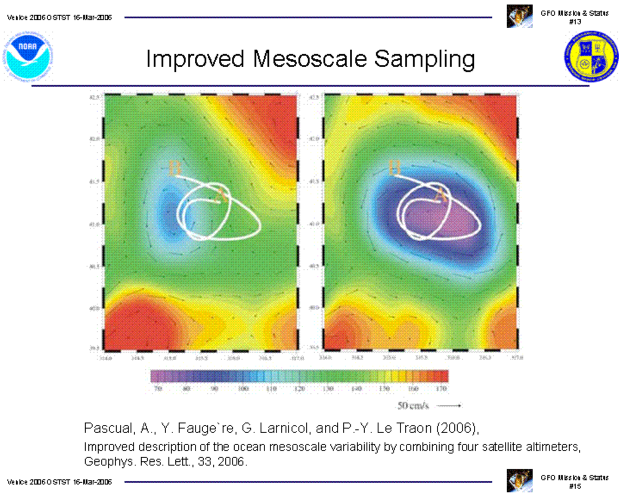

GFO Precise Orbit Statistics
GFO Precise Orbit RMS fits (cm)
Crossovers
SLR residuals
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status
#10


GFO orbit performance
crossover residual rms (cm)
solar flux (F10.7)
residuals
solar flux
flux moving average
MJD arc epoch (January 2000 - June 2005)
PGS7777b Residual Summary (cm)
Orbit span | slr | xover
350 arcs Jan 2000 – Jun 2005 | 5.460 | 8.026
88 arcs Feb 2004 – Jun 2005 | 4.367 | 6.754
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status
#11

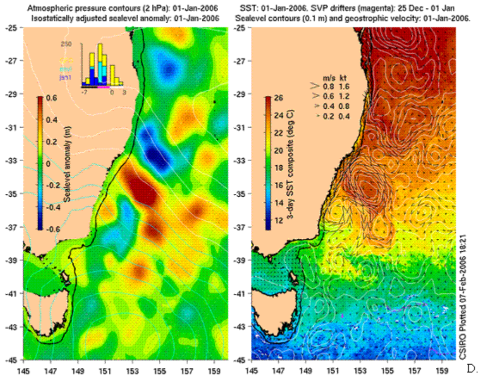

Geographically anti-correlated errors
pgs7727 crossover residuals mean
rms=31 mm
Sep. 2002 – Aug. 2003
pgs7777b crossover residuals mean
rms=19 mm
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status
#12


GFO & T/P Sea Surface Height
GFO SSH Residuals wrt GSFC MSS Cycle 68
T/P SSH Residuals wrt GSFC MSS Cycle 323
• SSH-MSS residuals: 11 cm for GFO; 10 cm for T/P
• Geocenter offsets applied (B. Beckley/GSFC)
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status
#13


GFO SSH after orbit error removal
Percent of total Obs.
Mean rms= 8.3 cm
Rms (cm)
Courtesy:
B. Beckley/GSFC
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status
#14

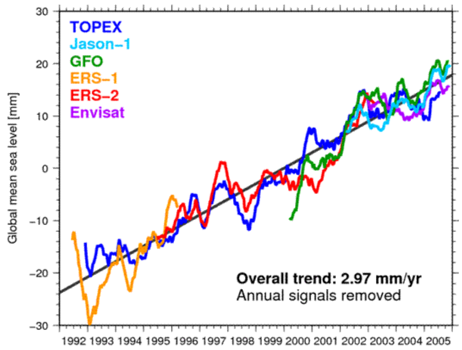

Improved Mesoscale Sampling
50 cm/s
Pascual, A., Y. Faugère, G. Larnicol, and P.-Y. Le Traon (2006),
Improved description of the ocean mesoscale variability by combining four satellite altimeters,
Geophys. Res. Lett., 33, 2006.
Venice 2006 OSTST 16-Mar-2006
GFO Mission & Status
#15

East Australia Current Analysis - CSIRO

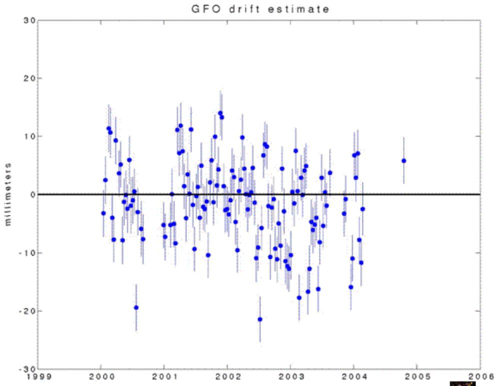


Courtesy:
D. Griffin -CSIRO

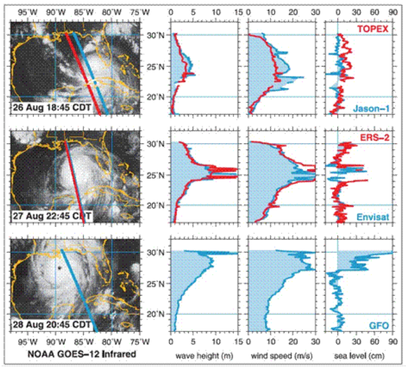
GFO contributes to GSLR records



GFO Tide Gauge Analysis - Mitchum & Beckley

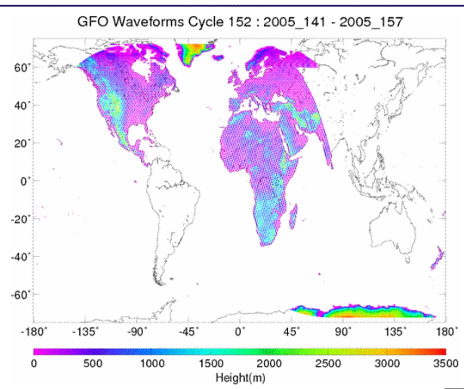


Hurricane Katrina & Altimetry

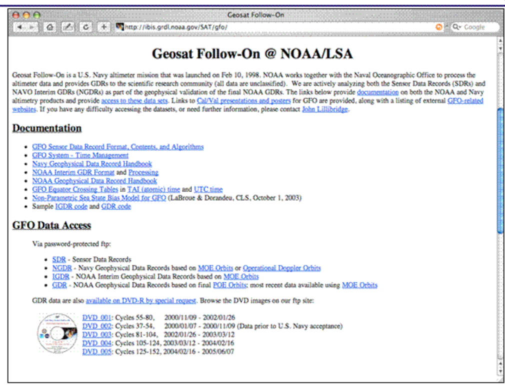


Scharroo, Smith and Lillibridge, EOS, 86(40), 2005

GFO Waveform Data Collection

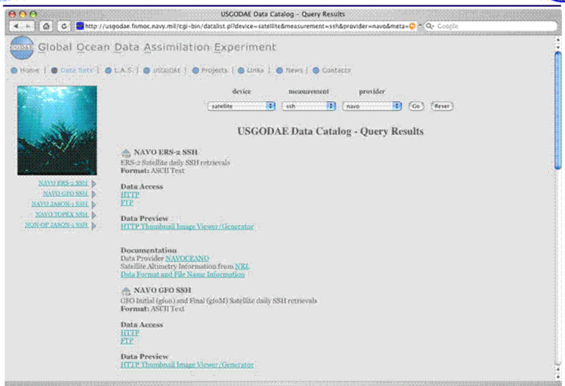


NOAA Lab. for Satellite Altimetry GFO Site

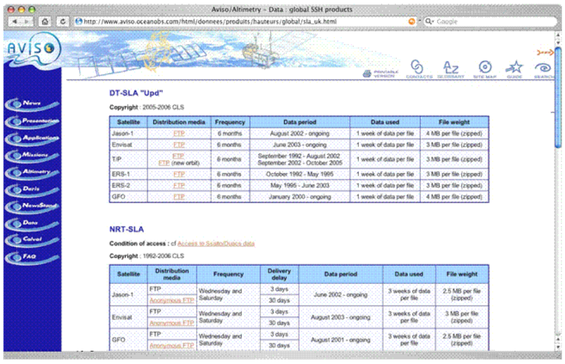


Navy/NRL Data Access

U.S. GODAE Server - NAVO Products



AVISO/DUACS GFO Products



Satellite	Distribution media	Frequency	Data period	Data used	File weight
Jason-1	FTP	6 months	August 2002 - ongoing	1 week of data per file	4 MB per file (zipped)
Envisat	FTP	6 months	June 2003 - ongoing	1 week of data per file	3 MB per file (zipped)
T/P	FTP FTP (new orbit)	6 months	September 1992 - August 2002 September 2002 - October 2005	1 week of data per file	3 MB per file (zipped)
ERS-1	FTP	6 months	October 1992 - May 1995	1 week of data per file	3 MB per file (zipped)
ERS-2	FTP	6 months	May 1995 - June 2003	1 week of data per file	3 MB per file (zipped)
GFO	FTP	6 months	January 2000 - ongoing	1 week of data per file	4 MB per file (zipped)

NRT-SLA

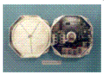
Condition of access : cf Access to Ssalto/Duacs data

Copyright : 1992-2006 CLS

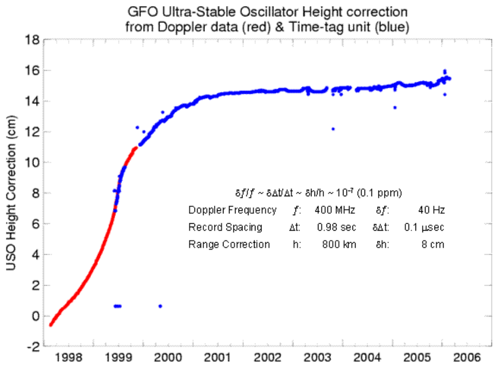
Satellite	Distribution media	Frequency	Delivery delay	Data period	Data used	File weight
Jason-1	FTP Anonymous FTP	Wednesday and Saturday	3 days 30 days	June 2002 - ongoing	3 weeks of data per file	2.5 MB per file (zipped)
Envisat	FTP Anonymous FTP	Wednesday and Saturday	3 days 30 days	August 2003 - ongoing	3 weeks of data per file	3 MB per file (zipped)
GFO	FTP Anonymous FTP	Wednesday and Saturday	3 days 30 days	August 2001 - ongoing	3 weeks of data per file	2.5 MB per file (zipped)

Continuing GFO Operations

- GFO has reached its nominal 8-year lifetime
- Navy, NOAA, & NASA will continue operations as long as possible
- Two significant hardware issues to face:
  - Thermal sensitivity of reaction wheels
    - Wheel #1 taken offline: may still be viable, but requires further study
    - Wheel #3 sensitive to overheating
      - Reduced operations when orbit in "full-sun" orientation
  - Battery aging effects
    - Will reach manufacturer's spec. on charge/discharge cycles this year
    - During orbital eclipse voltages approach undervoltage limit
      - Direct Downlink mode has been terminated (transmitter off)
      - Implement 'one-failed-cell' battery mode to lower UV limits
      - Place altimeter in standby for portion of eclipse (each rev…)
      - Power off Water Vapor Radiometer for extended periods of time



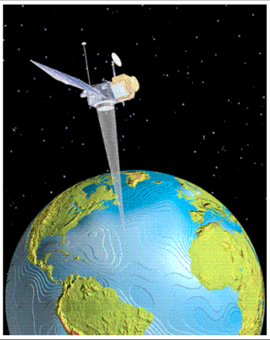
Ultra-Stable Oscillator Clock Drift



NOAA GFO GDR Datasets

- Based on final POE laser orbits
- State of the Art Corrections
- Cycles 37 - 152 on five DVDs
  - January, 2000 - June, 2005
- Cycles 153 to present via ftp
- < 10 cm SSH Variability
- Current 1-2 cycles with MOE orbits
- Daily IGDR files in 3 days NRT

5. TOPEX/POSEIDON Mission completion (M. Fujishin, S. Coutin)



TOPEX/Poseidon
Mission Accomplished!

Mark Fujishin

JPL Earth Science Missions
Program Manager

TOPEX/Poseidon End-of-Mission Chronology

- Pitch reaction wheel ceased normal function on October 9, 2005
  - Problem attributed to radiation induced degradation of optocouplers in wheel circuit
    - roll wheel failed in late May 2004, same cause
  - Anomaly had been tracked since 1994; was well-documented, and occurred as expected
  - Numerous attempts at recovery were unsuccessful
  - JPL conducted "Steering Committee" briefing w/NASA HQ management on 12/1/05
  - Subsequent HQ decision to go forward with satellite decommissioning process
  - HQ direction to decommission NLT 1/31/06 transmitted to JPL on 12/29/05
  - Letter of intent to decommission satellite transmitted from HQ to CNES on 1/4/06
  - **Operations team successfully implemented power-down sequence on 1/18/06**

OSTST Meeting
Venice, Italy
MF - 3
March 16, 2006

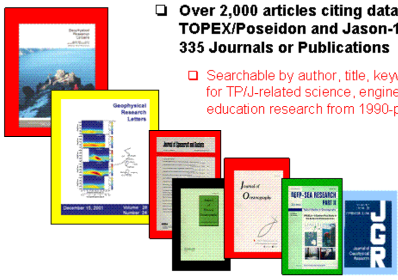
TOPEX/Poseidon Primary => Extended Mission Success

- **Launched on August 10, 1992**
  - original 3-year primary, 5-year extended mission
- **Topex/Poseidon still fully operational when Jason-1 launched on Dec. 7, 2001**
- **Completed Orbit Transfer Maneuver sequence to new Tandem mission orbit on September 16, 2002 following 9+ month formation flying cal/val period**
- **Continued to operate well in Tandem Mission mode**
  - three data recorders failed, utilized real-time TDRSS link to meet mission requirement
  - utilized laser tracking and GPSDR for POD
  - operations extended through FY'06 via competitive NASA "Senior Review" process
    - Jason-1 and T/P considered #1 priority (of 12 missions) for extended mission funding through FY'09

OSTST Meeting
Venice, Italy
MF - 2
March 16, 2006

TOPEX/Poseidon Science/Outreach Legacy

- TOPEX/Poseidon science open literature database available on-line

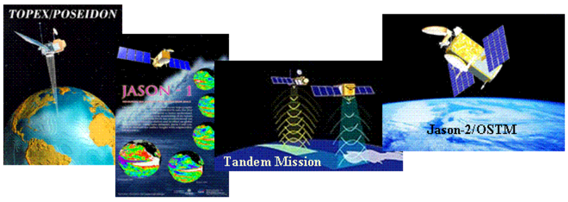


- **Over 2,000 articles citing data utilization from TOPEX/Poseidon and Jason-1 have appeared in over 335 Journals or Publications**
  - Searchable by author, title, keyword, abstract, & category for TP/J-related science, engineering, applications, and education research from 1990-present

OSTST Meeting
Venice, Italy
MF - 4
March 16, 2006

TOPEX/Poseidon's Legacy - Onward and Upward!

- T/P data reprocessing effort ongoing, funded primarily through science team and PO.DACC
  - OSTST input will be critical to ensure a continuous validated data record is available for studies
- Scientists and NASA/CNES must continue joint efforts to demonstrate applications and value of ocean science to the public
  - societal benefits will define NASA/CNES strategy for long-term ocean observing systems



OSTST Meeting
Venice, Italy
MF - 5
March 16, 2006

- **TOPEX/POSEIDON: An enormous success**
  - "Topex/Poseidon will remain the 1st reference data set of a continuous altimetric multi-mission time series allowing to monitor the long term changes of the ocean dynamics".
  - "That data has been the subject of more than 2,100 research publications to date"
  - Today, more than 600 scientific teams use the data
- **A French/American examplary cooperation going on with Jason-1 and Jason-2**
- **A lot of work still to be done by NASA, CNES and the scientific teams**

MAJOR EVENTS SINCE LAST OSTST (St Petersburg, 4-6 Dec. 2004, Florida) 1/2

- **DORIS/TOPEX END OF LIFE**
  - Incident detected by TGS on 2004/11/01 at 09:08:25
  - Last BM block received at 03:21:10 TAI, latitude : -64.126, longitude : 134.565.
  - Last HK bock HK received at 09:09:31 TAI, latitude : -56.421, longitude : 118.335.
  - CNES Precise orbit calculated from Laser data only from 2004/11/01.
  - After 12 years of good performances (DORIS First Turn-On 16 August 1992) providing a continuous precise orbit of 2-3 centimeters radial RMS, DORIS end-of-life declared
- **The DORIS Loss induced to abort the SWITCH ON SSALT operations during T/P cycle 450 (from 02-Dec to 12-Dec 2004) to perform additional cross comparisons between SSALT and Poseidon2/Jason during the tandem phase.**

MAJOR EVENTS SINCE LAST OSTST (St Petersburg, 4-6 Dec. 2004, Florida) 2/2

- **TOPEX/POSEIDON sensors performances annual Workshop in Pasadena, September- 28, 2006:**
  - Status of CNES instruments: DORIS end of life, and by the way POSEIDON
  - Decision to reprocess 21 cycles from TOPEX and Jason-1 Tandem phase using Jason-1 standards, in OSTST perspective
- **Major incident on TOPEX platform: 9-October 2005**
- **A lot of work done by NASA teams and industry support to recover the mission but unsuccessful**
- **Joint NASA/CNES press release to annouce the end of the mission**
- **Start of T/P end-of-life operations on 18- January, 2006**

- **Reprocessing of the data from the whole T/P mission (13 yrs):**
  - Considering improvements of near-instrument algorithms (e.g., ground retracking of TOPEX waveforms, TMR wet correction), of geophysical models and algorithms, and orbitography,
  - To make T/P and Jason-1 series homogeneous in order to support multi-year science analysis to achieve climatic objectives
- **However, differences between Jason-1 and T/P data set remains even with those improved fields included :**
  - Ongoing activity on retracking and SSB might be a key issue to solve for those remaining bias (either on Jason-1 or on T/P)
- **Another major issue for the following years: set up a coherent long-term archive of each elementary data to be able to reprocess data in the future if needed, to take into account future improvment of our knowledge in the ocean processes.**

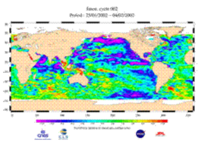
CONCLUSION

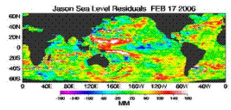
Need for an OSTST recommendation: to confirm the need for whole T/P data reprocessing and archiving as a joint NASA/CNES effort

6. Jason-1 and SALP status (S. Coutin, M. Fujishin)

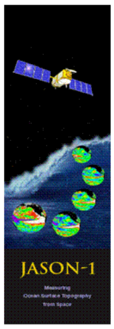
Jason-1 JPL Mission Operations: Current Status

- ❑ Joint operations continuing to proceed extremely well
  - ❑ *Weekly CNES-JPL joint telecon for normal satellite uploads, and as required*
  - ❑ *Regular proficiency and training tests ongoing*
- ❑ Instruments and ground operations systems at JPL are meeting, and routinely exceeding, all mission objectives
- ❑ Entering extended operations phase in December 2006
  - ❑ *Mission funded through October 2009, pending 2nd "Senior Review" process in 2007*





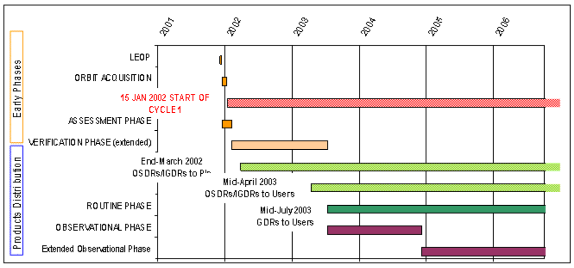
Jason-1 JPL Mission Operations Summary



- ❑ *Mission operations needs to continue through (at least) launch of OSTM/Jason-2 to satisfy long-term goal of contiguous ocean topography data*
- ❑ *Data reprocessing will continue to be a high priority in the near-term*
  - ➜ *planning for major effort to occur in first half of FY'07 (Sept. '06 - Mar. '07)*
- ❑ *OSTST continue efforts to identify both necessity and requirements for future missions to support and maintain robust research programs on ocean circulation, climate variability, and sea-level monitoring*

SALP/JASON-1 MISSION STATUS

JASON-1 SCHEDULE



SALP/JASON-1 MISSION STATUS

MAJOR EVENTS SINCE LAST OSTST
(St Petersburg, 4-6 Dec. 2004, Florida)

- **Project Milestones:**
  - Exploitation Review 22- March 2005 in Toulouse Space Center: successful
  - Joint Steering Group CNES/NASA, 29-September 2005, in JPL in conjunction with T/P Annual Workshop
- **Satellite major events :**
  - Loss of transmitter on PMB: 20-September 2005, NO mission for 182h: no more redundancy
- **Instruments :**
  - No major event

SALP/JASON-1 MISSION STATUS

JASON-1 SYSTEM PERFORMANCES (1/2)

- **Data availability is 97,78% from the beginning of the mission (Cycle 1, 15 Jan 2002)**
- **OSDR, IGDR and IGDR latency: within the requirements except during Safe Hold Mode periods**
- **Data time-tagging: 1-2 µs better than requirements**
- **Altimeter Antenna pointing: typically around 0.05° but sometimes few attitude drifts due to STR out of the AOCS loop**
- **Ground track keeping: good performance since the beginning except 3 excursions outside the +/- 1 km window since St Petersburg (Jan. 2005 due to difference of 255m on equator drift computed by JCCC, Nov. 2005 due to solar activity without significant impact on the data processing, Feb. 2006 due to bad efficiency of braking maneuver)**

SALP/JASON-1 MISSION STATUS

JASON-1 SYSTEM PERFORMANCES (2/2)

- **During the 2005 REVEX, the review board asked the project team to evaluate a change in the +/-1 km specification:**
  - *«To publish as part of next OSTST meeting the results of the study about the new geoid solution delivered to the users and to conclude if it is possible to relax the operational constraints concerning the +/- 1 km around track band with allocation. »*
  - **Status: Change request not approved by the Project scientists. This action has to be cancelled**
- **Project team proposition**
  - Expertise in progress to take into account efficiency uncertainties of maneuvers
  - Guidance and maneuver ground software modifications too heavy, too long, too risky
  - **Different operational workarounds are under study for immediate resolution**
- **For Jason-2:**
  - **+/- 1 km ground track requirement kept: See Jason-2 presentations (G. Zaouche, Saturday):**
  - on-going studies to perform Jason-2 maneuvers not at cycle boundaries

SALP/JASON-1 MISSION STATUS

620 Aviso data user teams around the world in 58 countries on January 2006

SALP/JASON-1 MISSION STATUS

CONCLUSION

- **Jason-1 mission: current status is very good**
- **Within the CNES Altimetry Service (SALP): Jason-1 considered to be highest priority for continued operations**
  - Mission extended through 2009: funding is OK
  - Jason-1 reprocessing activities to be performed in close cooperation with JPL/JSDS: funding is OK
- **Need for an OSTST recommendation: to confirm the need and the schedule of whole Jason-1 data reprocessing**

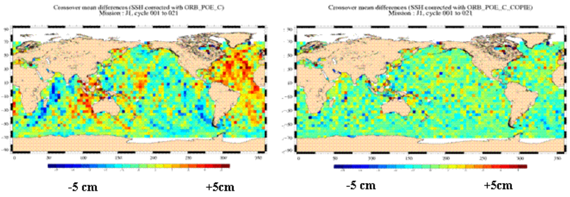
7. Jason-1 Data Reprocessing (N. Picot, S. Desai)

Towards a 2nd generation of GDR products

- **Following past OSTST meetings recommendations :**
  - a large set of evolutions were prepared and validated on mock-ups
- **Evolutions concern :**
  - Improvement of orbit performances
  - Altimeter Waveform processing and instrumental tables
  - Radiometer Brightness Temperature processing
  - Geophysical corrections (recalling that all GDR_a standards were decided five years before), among other :
    - New SSB solution
    - New Tides models
    - New MSS model
    - Handling S1/S2 atmospheric tides
    - Mog2D new interface

Orbit chain evolutions

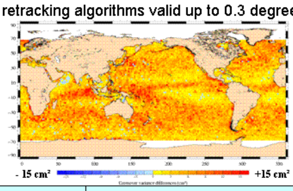
- **Orbit geographically correlated errors were largely illustrated**



Product Version"a"	Product Version"b"
JGM3 Gravity Field DORIS tracking data for IGDRs. DORIS+SLR tracking data for GDRs.	EIGEN-CG03C Gravity Field DORIS tracking data for IGDRs. DORIS+SLR+GPS tracking data for GDRs.

Altimeter retracking evolutions

- **Main driver : star tracker availability**
  - Large decrease in 2002/2003 → risks of large off nadir angles. (0.5 degrees encountered in August 2005)
  - GDR_a ground retracking algorithms valid up to 0.3 degrees



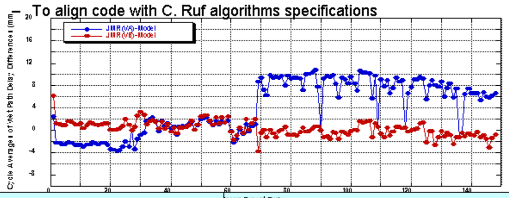
Product Version"a"	Product Version"b"
MLE3 + 1st order Brown model	MLE4 + 2nd order Brown model. : MLE4 simultaneously retrieves the 4 parameters that can be inverted from the altimeter waveforms: epoch, SWH, Sigma0 and mispointing angle. This algorithm is more robust for large off-nadir angles, (up to 0.5°, as encountered in August-September 2005)

Other altimeter related evolutions

Model	Product Version"a"	Product Version"b"
Altimeter Instrument Corrections	Consistent with MLE3 retracking algorithm.	**Consistent with MLE4 retracking algorithm.**
Dry Troposphere Range Correction	From ECMWF atmospheric pressures.	From ECMWF atmospheric pressures **and model for S1 and S2 atmospheric tides.**
Wet Troposphere Range Correction from Model	From ECMWF model	From ECMWF model.
Back up model for Ku-band ionospheric range correction.	Derived from DORIS measurements.	Derived from DORIS measurements.
Sea State Bias Model	Empirical model derived from cycles 19-30 of version "a" data.	**Empirical model derived from cycles 11-100 of MLE3 altimeter data with version "b" geophysical models"**
Altimeter Wind Speed Model	Derived from TOPEX/POSEIDON data.	**Derived from version "a" Jason-1 GDR data.**
Rain Flag	Derived from TOPEX/POSEIDON data.	**Derived from version "a" Jason-1 GDRs.**
Ice Flag	Climatology table	Climatology table

Radiometer algorithms evolutions

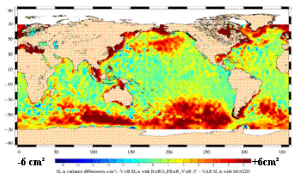
- **Several evolutions were analysed and implemented :**
  - To correct for jumps observed in radiometer wet tropo correction
  - To correct for side lobe effects
  - To align code with C. Ruf algorithms specifications



Product Version"a"	Product Version"b"
Using calibration parameters derived from cycles 1-30.	Using calibration parameters derived from cycles 1-115. New side lobe correction Aloritims inline with C. Ruf specifications

Geophysical corrections : Mog2D

- **MOG2D (LEGOS) ocean model interface added to ground processing chain :**
  - to correct for the high frequency variability of the ocean and bring a correction to the altimeter range



Product Version"a"	Product Version"b"
None (set to default)	Mog2D ocean model on GDRs, none (set to default) on IGDRs. Ocean model forced by ECMWF atmospheric pressures after removing S1 and S2 atmospheric tides.

Other geophysical corrections evolutions

Model	Product Version"a"	Product Version"b"
Mean Sea Surface	GSFC00.1	**CLS01**
Along Track Mean Sea Surface	None (set to default)	None (set to default)
Geoid	EGM96	EGM96
Bathymetry	DTM2000.1	DTM2000.1
Inverse Barometer Correction	Computed from ECMWF atmospheric pressures	Computed from ECMWF atmospheric pressures **after removing S1 and S2 atmospheric tides.**
Tide Solution 1	GOT99	**GOT00.2 + S1 ocean tide . S1 load tide ignored.**
Tide Solution 2	FES99	**FES2004 + S1 and M4 ocean tides. S1 and M4 load tides ignored.**
Equilibrium long-period ocean tide.	From Cartwright and Taylor tidal potential.	From Cartwright and Taylor tidal potential.
Non-equilibrium long-period ocean tide.	None (set to default)	**Mm, Mf, Mtm, and Msqm from FES2004.**
Solid Earth Tide	From Cartwright and Taylor tidal potential.	From Cartwright and Taylor tidal potential.
Pole Tide	Equilibrium model	Equilibrium model.
Wind Speed from Model	ECMWF model	ECMWF model

Jason-1 GDR_B validation and transfer in operations

- **To validate those evolutions :**
  - Orbit of cycles 120 to 129 were generated by CNES POD team and analysed in term of SSH performances
  - Cycles 128 and 132 were processed on dedicated configuration and widely validated
  - Few anomalies were encountered and implemented.
- **Following iterations with Project Scientists, it was decided :**
  - To set up this new chain in operation late October
  - And to reprocess some cycles to support Venice Meeting

Jason-1 altimeter version "B" products

- Start of the routine production and distribution phase to the user community in October, 2005 (CMA v7.1 and OM v3.2 were set in operations):
  - **IGDR production start on data dated October 24th 2005 (ie first day of cycle 140)**
  - **And GDR processing performed on cycle 136 but an anomaly on JMR processing was discovered and a patch was installed** on December, 02
  - GDR Production resumed on December, 03rd
- Shared processing effort **(including validation by both CNES and NASA/JPL groups)** :
  - Reprocessing of GDR cycles 1 to 21 at NASA/JSDS
  - Reprocessing of GDR cycles 128 to 135 at CNES/SSALTO
  - Routine GDR at CNES/SSALTO
- Early February 2006 :
  - **Cycles 1-21 and Cycles 128-146 available to users**

Jason-1 GDR_B early feedbacks

- **Validation performed on CNES and NASA/JPL seems to indicate that all evolutions implemented have a great (and good !!) impact on product quality. But :**
  - Some minor anomalies encountered :
    - Remaining datation bias impacts on hemispheric signals and SSB
    - JMR to be recalibrated to correct for possible drifts and to correct for anomalies after cycle 136 safe hold
    - Dry Tropospheric and Inverse Barometer corrections derived from Meteorological files in coastal areas still impacted by oscillation effects (wrong management of the bathymetry/topography altitude).
  - as part of Topex reprocessing exercise, a tool was developed to generate all geophysical corrections. An in depth comparison with operational Jason-1 products demonstrated that we have some differences (mm level) that needs to be investigated
- **Still to be implemented :**
  - Cross-track gradient correction
  - SGDR products evolutions
  - GIM ionospheric correction inside level2 products
  - Product naming convention (remove ".NASA" or ".CNES")

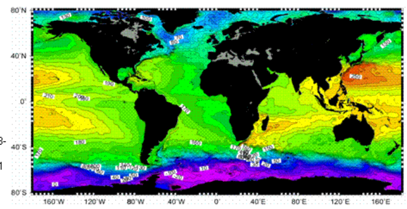
T/P reprocessing
What we do have to look at

- **Topex and Poseidon needs to be reprocessed - a large set of actions have to be conducted :**
  - Updates have to be analyzed and validated in close cooperation
  - All geophysical corrections shall be inline with Jason-1 standards (recalling that the same standards are used on ENVISAT)
  - Retracking algorithms differences need to be understood and solved
  - Sigma0 value has to be calibrated and wind tables updated (offset between Jason and T/P - J=2.5 dB higher than T/P)
  - TMR instrument has to be recalibrated and some algorithms have to be updated (see next slides + latest evolutions on JMR : side lobes effects, drift and yaw corrections, …)
  - POE reprocessing based on latest geoids standards is also a key point :
    - Since Doris switch off early November 2004, POE is computed using laser and Xover points → there might be other solutions to look at (GPS orbit, orbit error reduction on Jason-1 and/or ENVISAT data, …)
  - SSB has to be updated, 2 solutions (one for each Topex altimeters) have to be fitted based on the latest geophysical corrections.
  - Product definition needs to be reviewed :
    - Products shall include High rates data (10 Hz), waveforms, … on both Ku and C band to fulfill specific user needs (coastal/inland waters, etc)

Conclusion

- Jason-1 GDR_B is "state of the art"
- Current algorithms are a good baseline for Jason-2 development (dedicated meeting planned on Friday)
- Need to analyse again user expectations in term of product content : we may add new interfaces for Jason-1, for example the Mean Dynamic Topography computed by M.H RIO could be a good candidate → please provide feedbacks on potential products evolutions

¼ ° resolution - Drifting buoy velocities 1993-2002 - Dynamic heights 1993-2002
Altimetric data : T/P, ERS1,2 - MSS: CLS01 (Hernandez et al, 2002)
Geoid: EIGEN_GRACE03S (GFZ,376)



CNES OSTM/Jason-2 Mission status (J. Perbos)

Main past events (3/3)

- **System Preliminary Design Review :** Held mid of December 2005
- **Main Review Objectives**
  - Verify the system definition consistency with mission objectives and required performances
  - Assess the preliminary system budgets
  - Analyze consistency of system schedule
  - Identify and rank project risks
- **Main Results : Review has been closed successfully**
  - 10 recommendations addressing 5 areas of concern:
    - Organization between 4 partners (exchange of personnel between NOAA and CNES, formally document support between NASA and NOAA, CNES responsible for coordinating the integrated 4-party schedule, ...)
    - NRT product (confirm need for percentage of data available at 3 and 5 hours mark)
    - Propulsion safety and launcher interface issues (give high priority to processing waiver related to propulsion system and confirm technical feasible solution for reducing environmental loads)
    - Schedule (detail and consolidate NOAA ground system schedule)
    - Miscellaneous (objectives of next system review, system documentation, access to spacecraft simulator for NOAA)
- **System is now in Detailed Design Phase**

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-7

Main past events (2/3)

- **Following WSOA cancellation, CNES proposed to embark 3 experiments to enhance DORIS performance (CARMEN and LPT for radiation effects, T2L2 for DORIS clock bias characterization)**
  - No impact on Core Mission accommodation (spacecraft architecture, command control, power, …)
  - No risk on satellite
  - No operational constraint
  - Experiments can be switched off at any time.
  - Experiments shall not impact the development schedule
- **Satellite definition studies have started again with ALCATEL**
  - New satellite Phase B Kick-off held on May 12th 2005 based on the payload definition with the 3 new experiments.
- **Satellite Preliminary Design Review held on November 15**

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-6

Main past events (1/3)

- **Satellite definition until beginning of 2005:**
  - Core mission instruments similar to Jason-1
  - WSOA experiment provided by NASA; demanding in terms of satellite resources
  - no formal decision about WSOA program
  - launcher not yet selected
- **Satellite Definition Studies (Phase B) Kick Off in January 05**
- **NASA WSOA official cancellation and launcher decision (Delta II) announced on Feb. 28th 2005**

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-5

General Program constraints

The following constraints are applied to the OSTM/Jason-2 project:

- The use of the CNES/Alcatel generic PROTEUS platform as the satellite platform with minimized adaptations.
- The procurement of a set of instruments, inherited from previous missions (Jason-1, CRYOSAT,...).
- The use of a US launch vehicle compatible of the PROTEUS platform.
- The use of the PROTEUS generic ground segment (Control Center and one Earth Terminal) adapted to OSTM/Jason2.
- The use of the CNES multi mission center (SSALTO) already operating for Jason-1, T/P, Doris/SPOT, Doris/Envisat and Envisat altimeter data processing and distribution, as CNES mission center with a minimum set of adaptations.
- The re-use of the NASA/JPL Jason-1 ground system (JTCCS) as a baseline for developing the OSTM/Jason-2 Satellite Operation Control Center (SOCC) at NOAA
- Launch date as early as possible in order to ensure data continuity and altimeter data cross-calibration with Jason1

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-4

Partnership Responsibilities

- **NASA responsibilities:**
  - Project Management
  - Launch vehicle
  - Payload
    - Advanced Microwave Radiometer (AMR)
    - GPS Receiver (GPSP)
    - Laser Retroreflector Array (LRA)
  - JPL Payload integration and test
  - Mission Operation support for JPL instruments
- **NOAA responsibilities:**
  - Project Management
  - Ground System & Operations
    - Satellite Operations Control Center (SOCC)
    - CDA Stations (2)
    - NRT product processing
    - All product distribution
    - All archiving
    - Ground network
    - Satellite operations after handover
  - User interface
- **CNES responsibilities:**
  - Project Management
  - Satellite, Proteus bus
  - Payload
    - Nadir Altimeter POS3
    - DORIS tracking receiver package with CARMEN2 - T2L2 - LPT
  - Ground System & Operations
    - Satellite Control Command Center (CCC)
    - OFL product processing and distribution
    - All archiving
    - Ground network
    - Satellite Operations before handover
    - Navigation, Guidance, Expertise for all mission
  - System integration & test
  - Mission Operation support for CNES instruments
  - System Coordination for all mission phases
  - User interface
- **EUMETSAT responsibilities:**
  - Project Management
  - Ground System & Operations
    - Earth Terminal (1)
    - NRT product processing, archiving and distribution
    - Ground network
  - User interface

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-3

Program Background

- **Continuity measurement of ocean surface topography beyond TOPEX/Poseidon and Jason-1 for determining ocean circulation, climate change and sea level rise**
- **Provides a bridge to an operational mission to enable the continuation of multi decadal ocean topography measurements**
- **Decision in July 2002 to conduct a 4 partner program OSTM/Jason2 with 2 new partners in addition to NASA/JPL and CNES : operational agencies EUMETSAT and NOAA**
- **Discussions about the Memorandum Of Understanding started in July 2002 and final agreement reached in June 2005 including responsibility sharing, legal statements, partner contribution (launcher, instruments, satellite, ground system, ...)**
- **OSTM/Jason2 MOU negotiated and ready to be signed**

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-2

Next milestones

- **Satellite Critical Design Review :** **October 2006**
- **Payload instruments integration :** **December 2006**
- **Satellite Assembly, Integration and Test:** **From April 2007**
- **Ground System Interface Review :** **December 2006**
- **Ground System Integration and tests:** **From January 2007**
- **Launch:** **June 2008**

OSTM/Jason2 - OSTST Venice - March 18, 2006 JP-8

8. Jason-2 Performances and Products (G. Zaouche)

System driving requirements and performances (1)

- **Mission success and data availability**
  - reliability: requirement = 0.8
    - Jason-1 performance = 0.858
  - 95% of all possible over-ocean data during any 12 months period
    - Jason-1 performance = 97.75% over 3.5 years
  - **same requirements as for Jason-1**
- **Pointing**
  - Nadir pointing of the radar beam
  - 0.20° (3 σ), end-to-end specification for the altimeter:
    - current performance estimation : 0.14° (3σ) with the star tracker in the Attitude Control loop
  - Calibration maneuvers (pitch and roll mispointing of the satellite) to allow calibration by the altimeter of off-pointing bias
  - **same requirements as for Jason-1**
- **Ground track**
  - The operational orbit and ground track shall be established and maintained (via satellite propulsive maneuvers) such that equatorial nodal crossings are contained with a +/- 1 km longitude band with respect to the reference ground track at each node.
  - **same requirements as for Jason-1**

OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 1

System Driving Requirements and performances (2)

- **Data products latency**
  - **new performances requirements**
    - see "OSTM/Jason-2 Products" section in the current presentation
- **POD and altimeter processing constraints**
  - Pointing knowledge
    - requirement : 0.05° (1σ) on each axis
    - current performance estimation : 0.037° roll – 0.045° pitch – 0.05° yaw
  - Attitude stability (correspond to stability of DORIS phase center)
    - requirement : 0.02° over 10 seconds (1σ) ; performance estimation : < 0.003°
    - 0.05° over 450 seconds (1σ) ; performance estimation : < 0.016°
  - In-orbit mass variation
    - goal : 0.2% ; performance estimation (0.07%) meets the goal
  - Knowledge of optical properties of the satellite surfaces
    - requirement : 10% (to a limit of 0.01) - to be evaluated based on available data sheets
  - Center of mass location variation
    - requirement : ±5 mm on each axis, goal : ± 1 mm on z axis
    - 1.8 mm on X ; 0mmm on Y ; 1.8 mm max on Z (met for SA angle < 33.4°)
  - **same requirements as for Jason-1**

OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 2

Instruments Requirements and Performances

- **Nadir Altimeter - Poseidon-3**
  - altimeter noise : 1.7 cm (1 σ) after ground retracking, with a goal at 1.5 cm
    2.5 cm for the OGDR
    ⇒ compliant (goal achieved on Jason-1)
  - bias corrected by the ground processing
  - electronics stability : 1 mm drift / year (goal) : taken into account in the design
  - Significant Wave Height : 10% of SWH (or 0.4 m) with a goal at 5%
    ⇒ compliant (goal achieved on Jason-1)
  - **same requirements as for Jason-1**
    - See Poseidon-3 presentation
- **Advanced Microwave Radiometer - AMR**
  - Provide measurements from which the wet troposphere path-length delay can be determined to an accuracy of 1.2 cm (1 σ) (goal = 1.0 cm)
  - Path delay drift monitored to 1 mm/year (goal) : taken into account in the design
  - **same requirements as for Jason-1**
    - See AMR presentation

OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 3

Tracking systems requirements and performances

- **DORIS**
  - Derived orbit (radial component) :
    - 2.5 cm (1 σ) for the IGDR and 1.5 cm for the GDR
    - 10 cm for the on-board real time orbit determination (Diode)
  - **new performances requirements for real time orbit**
    - See DORIS presentation
- **Global Positioning System Payload - GPSP**
  - goal for the derived orbit (radial component) : 2.5 cm
  - **same requirements as for Jason-1**
    - See GPSP presentation

⇒ Precise Orbit Determination :
- Goal = 1 cm, using a combined set of the tracking data

OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 4

Algorithms accuracy

- **The level 2 algorithms used (GDR_b) are heritage from Jason-1. Their accuracy has been assessed on T/P and Jason-1 data.**
- **The error budget requirements correspond to the actual accuracy obtained with the Jason-1 algorithms**
- **The goals correspond to improvements obtained through new algorithms definition and verification**

  - See "Jason-2 algorithms" presentation

OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 5

OSTM/Jason-2 Products

- **OSTM/Jason-2 marks a new step in terms of operational commitments**
  - Near Real Time Product :
    - Operational Geophysical Data Record (OGDR)
  - Offline Products :
    - Interim Geophysical Data Record (IGDR) and Sensor/Interim Geophysical Data Record (S-IGDR)
    - Geophysical Data Record (GDR) and Sensor/Geophysical Data Record (S-GDR)
- **Documentation :**
  - Jason-2/OSTM Operational Service Specifications (OSS) document describes :
    - Core altimeter products which are OGDR, IGDR/SIGDR and GDR/SGDR
    - Commitments of the Operational Agencies are described in terms of data latency and services
    - Those core products are the key inputs for higher level products implementation.
  - Other documents are planned:
    - To provide detailed specifications of all OSS products:
      - SALP Products specification – Volume 1: Jason-2 products
      - Series of Handbooks for all OSS products
    - To describe other Jason2 products:
      - Example, CNES Jason-2 Products description for the non-core mission
        - SSALTO/DUACS products, possible coastal zone products, …

OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 7

Jason-2 evolutions in Near Real Time product

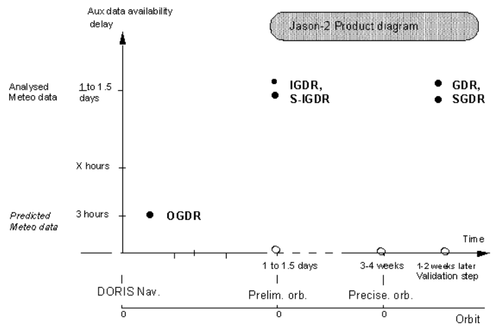
- **OSDR description :**
  - NRT wind/wave oriented product, dedicated to meteorological users.
  - No ground retracking performed and no environmental or geophysical parameters computed.
  - Non fully validated product which contains 1 Hz data for both bands (Ku and C).
- **Keys inputs :**
  - Satellite telemetry
- **Production requirement :**
  - For the OSDR, 75% of the data taken shall be made available to the users within 3 hours from acquisition and 95% of the data within 5 hours.
- **OGDR description :**
  - NRT geophysical product, data latency of 3 hours.
  - DORIS/DIODE onboard orbit : 10 cm rms for the radial component
  - Ground retracking is performed and all environmental and geophysical corrections computed.
  - Non fully validated product which contains data for both bands (Ku and C) at a rate of 1 Hz and 20 Hz.
- **Keys inputs :**
  - Satellite telemetry
  - Auxiliary data
- **Production requirement :**
  - For the OSDR, 75% of the data taken shall be made available to the users within 3 hours from acquisition and 95% of the data within 5 hours.
  - No dynamical auxiliary data shall be considered as a mandatory input for OGDR processing. If possible, the corresponding OGDR field will be computed with the most recent data available otherwise it will be set to default.

The Jason-2/OSTM product generation service

- **OSS Nominal products** (**inherited from Jason-1 and other altimetric missions**) **:**

Major characteristics of the product	*OGDR (NRT)*	*IGDR (OFL)*	*S-IGDR (OFL)*	*GDR (OFL)*	*S-GDR (OFL)*
Content	Not fully validated geophysical level 2 product	Not fully validated geophysical level 2 product	IGDR + waveforms and tracker data	fully validated geophysical level 2 product	GDR + waveforms and tracker data
Alt. ground retracking	Applied	Applied	Applied	Applied	Applied
Orbit information source	Better than 10 cm DORIS Navigator	2.5 cm preliminary orbit	2.5 cm preliminary orbit	1.5 cm Precise orbit	1.5 cm Precise orbit
Structure	segment	pass	pass	pass	pass
Packaging	segment	day	day	cycle	cycle
Ground Processing mode	systematic	systematic	systematic	systematic	systematic
Data latency /availability	3 hours / 75% 5 hours / 95%	1 to 1.5 calendar days / 95%	1 to 1.5 calendar days / 95%	40 days / 95%	40 days / 95%
Format / Ground Processing centers	Native and BUFR / NOAA and EUMETSAT	Native / CNES	Native / CNES	Native / CNES	Native / CNES
Ground Archiving centers	NOAA and CNES and EUMETSAT	NOAA and CNES	NOAA and CNES	NOAA and CNES	NOAA and CNES
Dissemination centers	NOAA and EUMETSAT	NOAA and CNES	NOAA and CNES	NOAA and CNES	NOAA and CNES
Dissemination mode	Systematic Electronic & Satellite	Systematic Electronic	Systematic Electronic	Systematic Electronic - Media	Systematic Electronic - Media

Jason-2 products timeline



Jason-2 data products error budgets

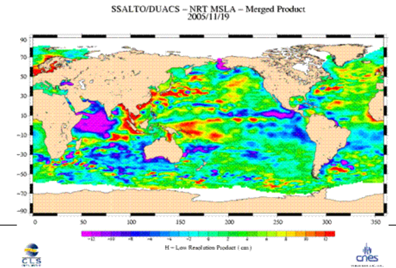
(for : 1 s average, 2 m SWH, 11 dB sigma naught)	OGDR 3 hours	IGDR 1 to 1.5 days	GDR 40 days	GOALS
Altimeter noise	2.5 cm	1.7 cm	1.7 cm	1.5 cm
Ionosphere	1 cm	0.5 cm	0.5 cm	0.5 cm
Sea State bias	3.5 cm	2 cm	2 cm	1 cm
Dry troposphere	1 cm	0.7 cm	0.7 cm	0.7 cm
Wet troposphere	1.2 cm	1.2 cm	1.2 cm	1 cm
Altimeter range RSS	< 5 cm	3 cm	3 cm	2.25 cm
RMS Orbit (radial component)	10 cm	2.5 cm	1.5 cm	1 cm
Total RSS sea surface height	11.2 cm	3.9 cm	3.4 cm	2.5 cm
Significant wave height	10% or 0.5 m	10% or 0.4 m	10% or 0.4 m	5% or 0.25 m
Wind speed	1.6 m/s	1.5 m/s	1.5 m/s	1.5 m/s

Algorithms evolutions and planned services

- **OSTM/Jason-2 algorithms evolutions**
  - see "Jason-2 algorithms" presentation
- **Offline Reprocessing service:**
  - No reprocessing requirement for the OGDR and IGDRs products
  - Data from the verification phase of the Jason-2/OSTM mission shall be reprocessed into GDRs after completion of the verification phase
  - CNES Ground Segment shall be able to reprocess GDR and SGDR products at least once after the first three years of the mission
- **User support service : « CLASSICAL » HELPDESK FUNCTION**
  - provided by NOAA and EUMETSAT for the NRT products
  - provided by NOAA and CNES for the OFL products

Non core mission : CNES DUACS and level3 products

- **SSALTO/Duacs system (SSALTO near real time multi-mission altimeter data processing system)**
  - routine production, only 2 production delays in 2005, merging of all data set from 4 altimeter missions
  - 2005 main evolution : Regional products capabilities
  - 2006 foreseen main evolution : Daily products capabilities

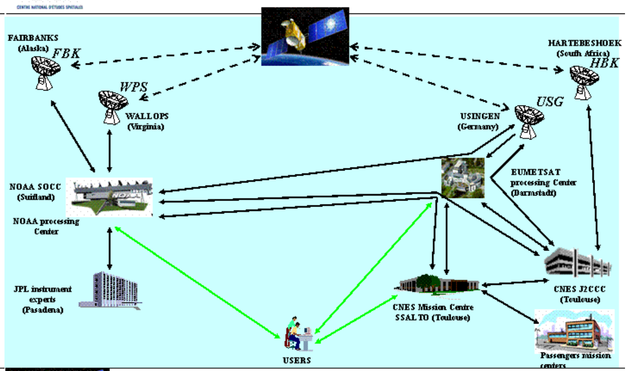


OSTM/Jason-2 Ground System (J2GS) changes

- **Global approach : the same as JASON-1**
- **News partners in the project : NOAA, EUMETSAT**
  - Usingen, Wallops and Fairbanks Stations
  - NOAA control center SOCC
- **New operations sharing (Operational and Science products)**
  - NOAA (instead of JPL) to assume the operational satellite phase
  - NRT products generated and distributed by EUMETSAT and NOAA
- **JASON-1 experience**
  - NRT products processor duplicated at EUMETSAT and NOAA

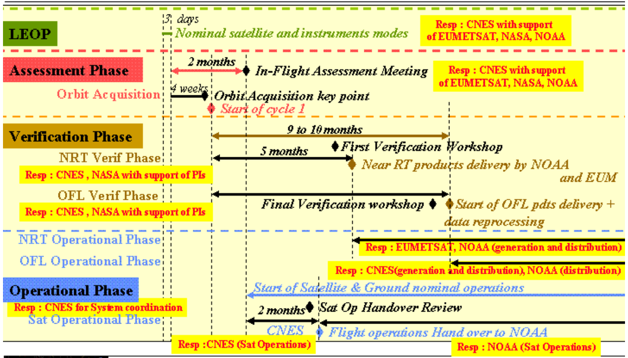
OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 14

Jason-2 Ground System



OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 15

OSTM/Jason-2 Mission Phases



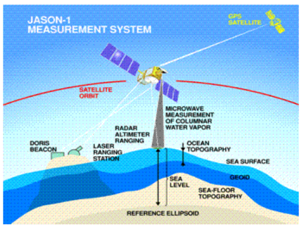
OSTM/Jason-2 - OSTST meeting - Venice - March 16-18, 2006 GZ- 16

NASA OSTM/Jason-2 Mission status (P. Vaze)

Mission Summary

Science Measurements

Global sea surface height to an accuracy of ≤ 4 cm every 10 days, for determining ocean circulation, climate change and sea level rise



Mission Objectives

- Provide continuity of ocean topography measurements beyond TOPEX/Poseidon and Jason-1
- Continue partnership with CNES, as on Jason-1, with the addition of NOAA and EUMETSAT as operational partners
- Provide a bridge to an operational mission to enable the continuation of multi-decadal ocean topography measurements

Mission Overview

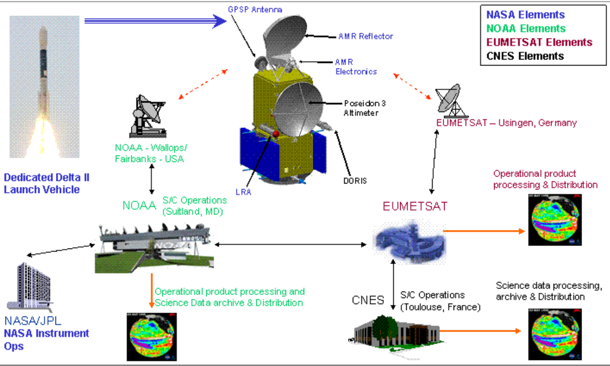
- Launch Date: 15 June 2008
- Launch Vehicle: Delta II 7320
- Proteus Spacecraft Bus provided by CNES
- Mission life of 3 years (goal of 5 years)
- 1335 km Orbit, 66° Inclination

Instruments

- Advanced Microwave Radiometer (AMR)
- GPS Payload (GPSP)
- Laser Retroreflector Array (LRA)
- Poseidon-3 Altimeter
- Precise Orbit Determination Sys (DORIS)

OSTM OSTST Meeting 16 – 18 March 2006 pv -2 March, 2006

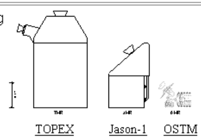
Mission and Partnership Overview



OSTM OSTST Meeting 16 – 18 March 2006 pv -3 March, 2006

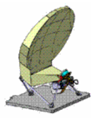
Advanced Microwave Radiometer (AMR)

- The AMR provides path delay correction for the altimeter using three passive bands at 23.8, 18.7, and 34.0 GHz
- AMR electronics was developed under IIP program
- AMR Electronics:
  - Flight Model (FM) Build Completed
  - Full unit level performance testing completed
  - Full unit level environmental testing completed
  - Radiometric performance has been validated and meets requirements.
  - Delivered to payload I&T for further instrument level testing.
- AMR Reflector:
  - Design and build is complete
  - Test program will start in April 2006
  - Full instrument I&T expected to complete in Sep 2006.

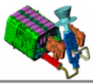


Significant improvement in mass, power, volume of electronics by improving IIP design

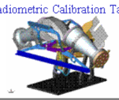
Integrated Electronics and Reflector



Electronics Assembly



Radiometric Calibration Target



OSTM OSTST Meeting 16 – 18 March 2006 pv -4 March, 2006

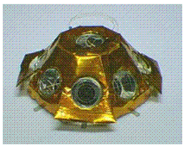
Project Summary

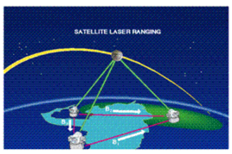
- **Successfully completed all mission and instrument level reviews**
  - **NASA-HQ (MCR) confirmed the mission for full implementation – Feb '05**
  - **NASA provided Authority to proceed with the Delta II LV procurement on 15 March '06**
- **Build and test of all NASA instruments is nearly complete**
- **Current measured NASA payload performance meets/exceeds all requirements**
- **No significant technical implementation issues or risks.**
- **NASA Payload development is nearing completion and meets delivery schedule**
- **The OSTM project is ready to proceed with full project implementation**

OSTM OSTST Meeting 16 – 18 March 2006 pv -8 March, 2006

Laser Retroreflector Assembly (LRA)

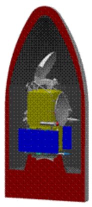
- The LRA is a totally passive reflector designed to reflect laser pulses back to their point of origin on Earth. It is used for the calibration of the POD system on the spacecraft
- Consists of several quartz corner cubes arrayed as a truncated cone with one in the center and the others distributed azimuthally around the cone.
- The LRA is an exact copy of the Jason LRA and has already been fabricated and delivered to JPL. The spare unit is the Jason spare.





OSTM OSTST Meeting 16 – 18 March 2006 pv -6 March, 2006

Launch Vehicle



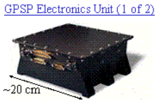
- Boeing Delta II manifested as the baseline launch vehicle
  - Single payload launch confirmed in Feb 05
  - 7320 Vehicle specified
    - 3 Strap-on boosters
    - Single payload
    - 2 Stage
  - Single payload configuration will require a system that reduces vibration loads to the spacecraft
    - Softride isolation system selected for implementation
  - Payload integration at and launch from VAFB (Vandenberg Air Force Base), CA
    - Launch service awarded on NLS (NASA Launch Services) contract
    - Payload Processing Facility (PPF) will be a commercial procurement
  - Implementation timetable based upon ATP (Authority To Proceed) at L-27 months (Mar 06)
  - NASA Flight Planning Board has identified a launch date of 15 Jun 08

OSTM OSTST Meeting 16 – 18 March 2006 pv -7 March, 2006

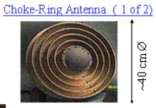
Global Positioning System Payload (GPSP)

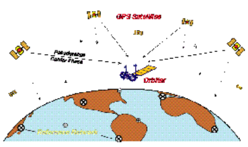
- High performance GPS receiver designed to provide precise orbit determination as a validation to the primary DORIS system and to enhance the accuracy during nominal operations.
- Two fully redundant receivers will be carried on OSTM
- HW design is exact copy of the Jason-1 GPS receiver
  - Build of the flight units is complete
  - Currently undergoing environmental testing
  - Expect delivery of first unit to JPL in April '06
- Utilize best available Flight Software from Jason-1
  - Fully tested instrument expected in Aug '06

GPSP Electronics Unit (1 of 2)



Choke-Ring Antenna (1 of 2)





GPS on Jason-1 S/C

OSTM OSTST Meeting 16 – 18 March 2006 pv -5 March, 2006

9. EUMETSAT OSTM/Jason-2 Mission status (F. Parisot)

Main elements of Eumetsat programme for Jason-2

As detailed in the CNES-EUMETSAT Cooperation agreement

- **A financial contribution by Eumetsat to CNES.**
  - This, along with the CNES, NASA and NOAA funds will ensure the supply of the satellite, launcher and all ground segment and operations not specifically provided by Eumetsat.
  - The absolute maximum contribution of Eumetsat to the program including internal cost is 30M€
- **Acquisition, installation, operations and maintenance of a Eumetsat Earth Terminal to receive data from the satellite and uplink the commands to the satellite. The selected site is Usingen.**
- **Retrieval, processing and dissemination of Near Real Time products**
- **Communication hub for the ground system**
- **Contribution to the management of the Cooperation with CNES, and the US partners**

OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-2

Operational role of Eumetsat

- Receive via the Eumetsat Earth Terminal all data scheduled for reception in Europe
- Transmit all received raw data to control center and mission center for analysis, archiving and offline processing
- Process raw data to produce Near Real Time products
- Receive NRT products generated by NOAA from their reception sites and send to NOAA NRT products generated by Eumetsat
- Distribute NRT products to users and archive them
- Maintain a rolling archive of all data received at Usingen to ensure data are safely archived at the long term archives at CNES and NOAA
- Provide a user interface for enquiries on data formats, quality, availability etc
- Contribute to activities related to scientific Announcements of Opportunity
- Engage in other activities as agreed, to optimise the data service provided to Eumetsat Member states and other users.

OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-3

Project Management

- **EUM management plan and PA, CM applicable documentation tailored to Project plan and PA, CM system rules.**
- **Use of in house practices in place in the OPS Department for MTP, MSG and soon EPS, check of consistency/coherency with system requirements**
- **EUM Ground System element documentation.**
  - Project management plan
  - EUMETSAT OSTM/Jason-2 Ground System Design Document
  - Risk register
  - Earth Terminal Infrastructure documentation

  Available

  - Internal ICD
  - EUMETSAT OSTM/Jason-2 GSE integration and test plan
  - Operational procedure and interfaces agreements…

OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-4

Ground System Overview

- **Design drivers**
  - Satisfy OSTM/Jason2 System Requirements
  - Capitalise on EUM existent infrastructure
    - Dissemination (EUMETCast, GTS and Internet)
    - Archive (UMARF)
    - Communications and security infrastructure
    - Storage infrastructure
    - User Services (helpdesk, internet services)
  - Reuse of EUM operational software components
    - System monitoring and control
    - Service monitoring and reporting
    - Generic file transfer software

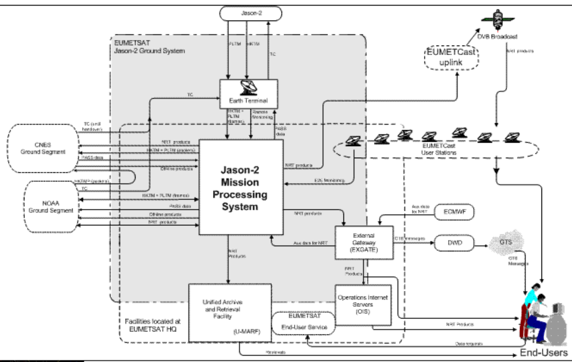
OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-5

Ground System Architecture

- **EUMETSAT Jason2 Earth Terminal**
  - Fully dedicated to the Jason-2 mission
  - Infrastructure provided by EUMETSAT
  - Elements provided by CNES
  - Direct TCP/IP connectivity to NOAA/CNES control centres
  - FTP connectivity to the EUM Central System
  - Maintenance and support via contract to T-Systems/Elta
    - Support contract integration with existent EUM contract to be investigated
    - EUM responsible for 1st line maintenance (failures, software uploads)
  - Acceptance test of the earth terminal performed beginning of March including tracking of Jason-1

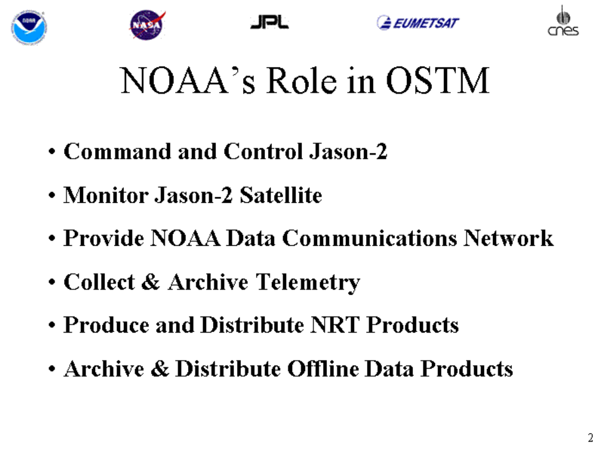
OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-6

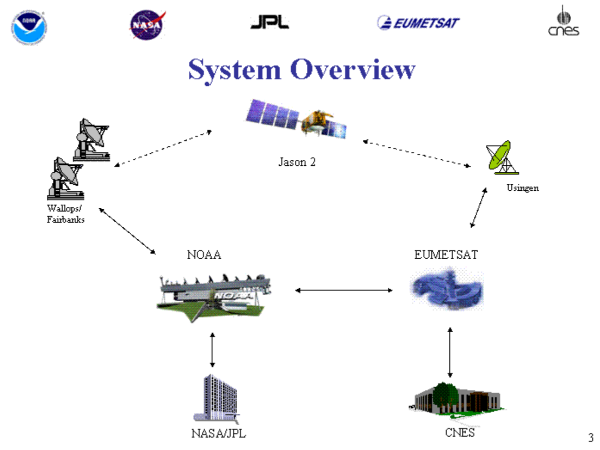
Context and Data Flows

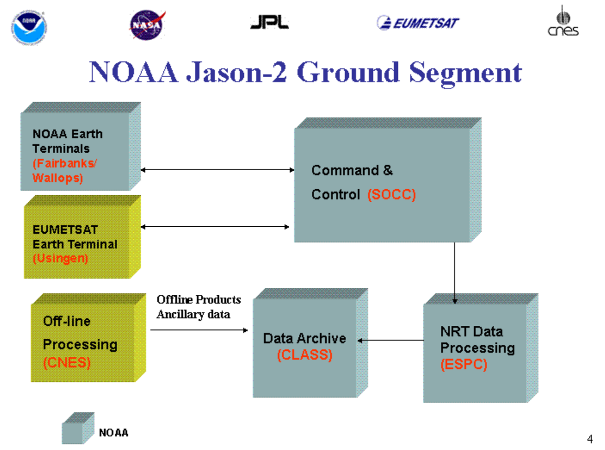


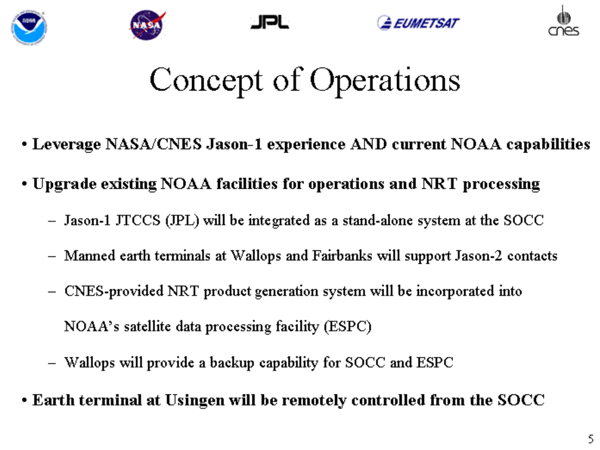
OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-7

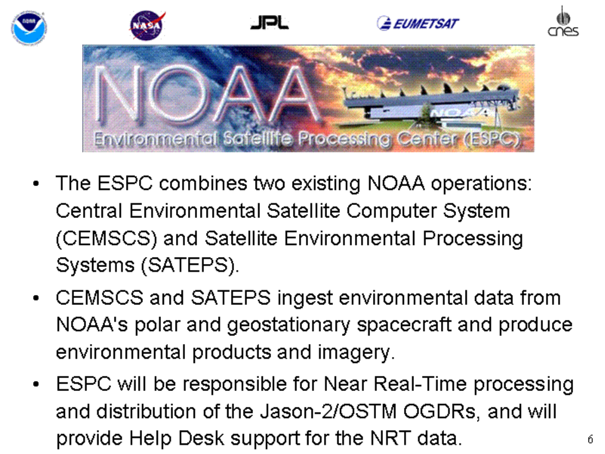
10. NOAA OSTM/Jason-2 Mission status (J. Lillibridge)

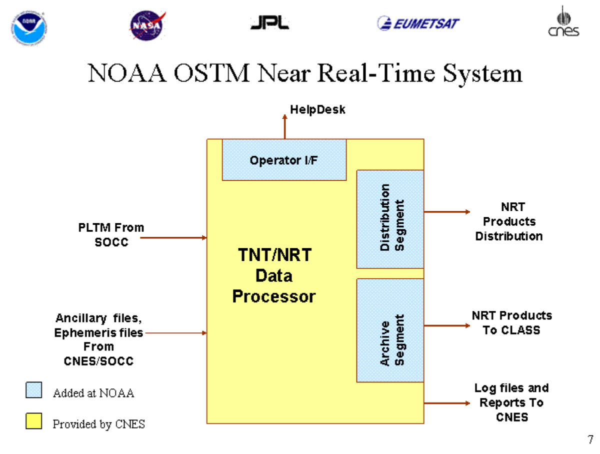


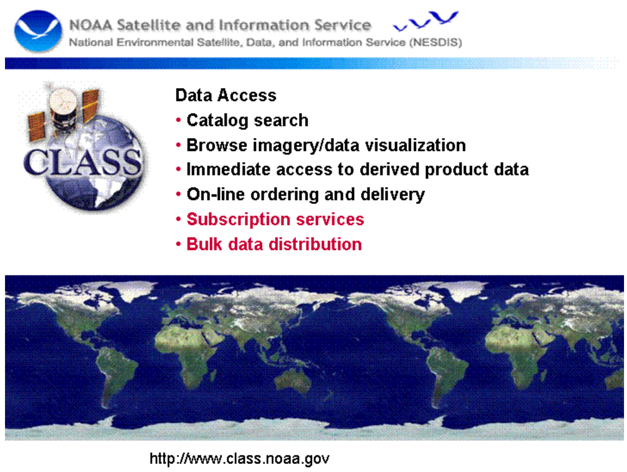


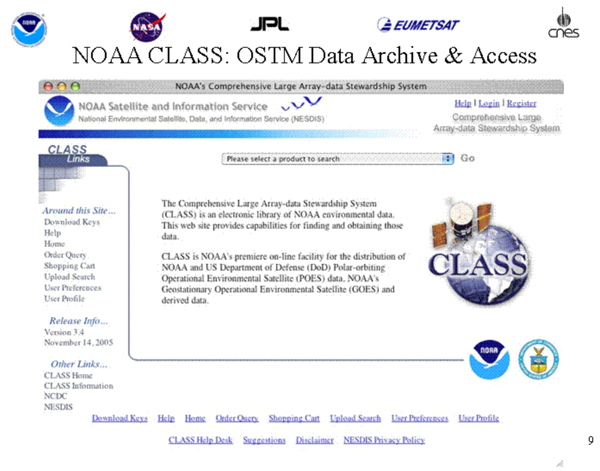






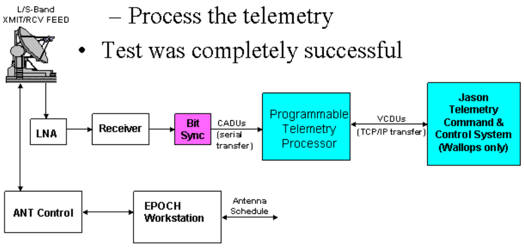




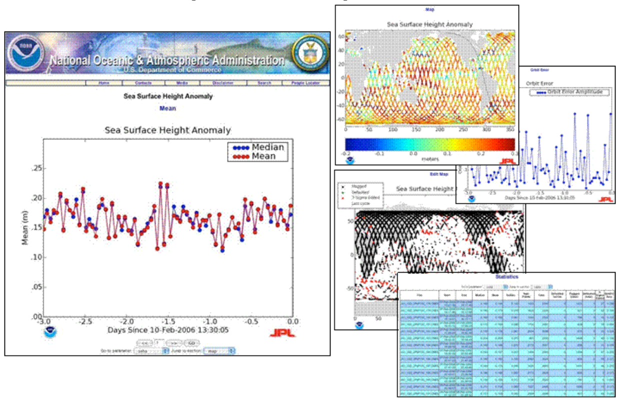


Jason-1 testing

- NOAA conducted a ground segment test June, 2004 using Wallops Earth terminal
- Tracked Jason-1 satellite
  - Receive its housekeeping telemetry
  - Process the telemetry
- Test was completely successful



NRT Quality Assessment System - Desai & Haines

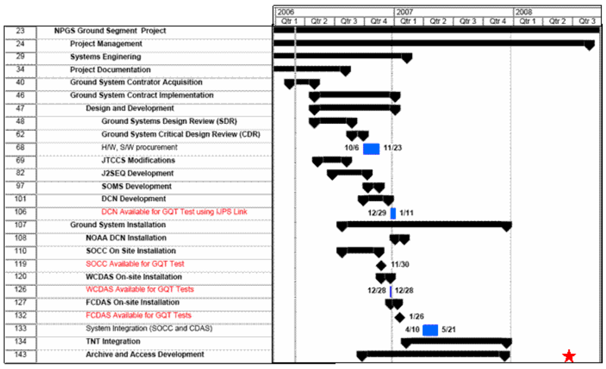


NOAA Jason-2/OSTM Contract

NOAA announced Request for Information for Polar Ground Segment upgrade

- Industry workshop held April, 2005
- 13 vendors responded with presentations
- Solicitation announced September, 2005
- Request for proposal package released February, 2006
- Expect contract award late April / May, 2006

NOAA Ground Segment Project Schedule

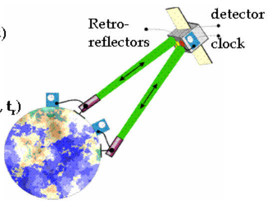


11. T2L2 Jason-2Passenger (E. Samain)

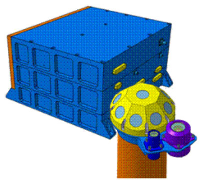
Principle

- Time Tagging of laser pulses emitted from a laser station in the satellite direction
  - Start Time at ground Station t_d (ground clock)
  - Arrival time at satellite t_b (space clock)
  - Return Time at ground station t_r (ground clock)
- Time Transfer between Ground clock and space clock
  - Triplet Construction for each laser pulse(t_d, t_b, t_r)
  - Computation of the time offset :

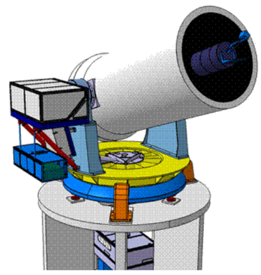
$$\chi = \frac{t_d + t_r}{2} - t_b + \tau_{Relativity} + \tau_{Atmosphere}$$



Space Segment Ground Segment



Space Segment



Ground Segment: Laser Station

Scientific Objectives Time transfer Inter comparison

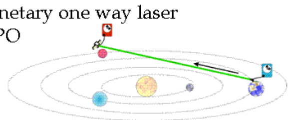
- TwoWay and GPS calibration
  - Common view: amelioration : 2 order of magnitude
  - Possibility to work on very wide bases: synchronization via intermediate ground stations
  - Possibility to perform a direct GPS time transfer from the GPS satellites to ground via T2L2: direct time tagging of the GPS PPS by the T2L2 space event timer-> GPS time transfer without atmosphere perturbation
- Validation & inter comparison of the ACES MicroWaveLink

Scientific Objectives Time and Frequency metrology

- Optical Laser Link validation
  - $\sigma_x^2(\tau) = \left(28.10^{-12} \times \tau^{-1/2}\right)^2 + \left(17.10^{-15} \times \tau^{+1/2}\right)^2 \quad \tau_0 = 0.1$ s
  - $\sigma_y(\tau) = 0.4\ 10^{-13}\tau^{-1/2}$ for $\tau > 10000$ s
  - Uncertainty < 100 ps
- Ground clock Synchronization
  - Compatible with the best clocks available in world
- Time scale participation
  - BIPM/CCD recommandation

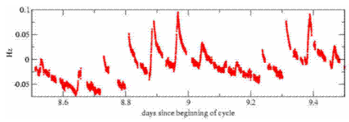
Scientific Objectives Fundamental Physics

- Speed of light Anisotropy
  - Equivalent to the actual measurement: $2{,}7.10^{-9}$ (Oscillator limitation)
- Drift of the fine structure constant α
  - Frequency comparison at the $5\ 10^{-17}$ level over 10 days
  - Measurement limited by the actual ground clocks performances
- Demonstrator of an interplanetary one way laser ranging based on clocks: TIPO



Scientific Objectives DORIS

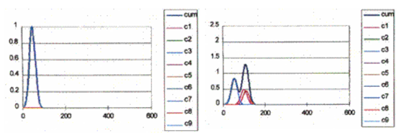
- DORIS Oscillator characterization
  - Radiation and frequency drift correlation with CARMEN-2 & LPT



- Improvement of the DORIS localization in the South Atlantic Anomaly

Scientific Objectives DORIS

- Laser ranging improvement
  - One way laser ranging: Arrival time onboard Jason-2 can be used to reconstruct echoes
  - Direct evaluation of the LRA signature by comparison between one way laser ranging and classical laser ranging



Development plan

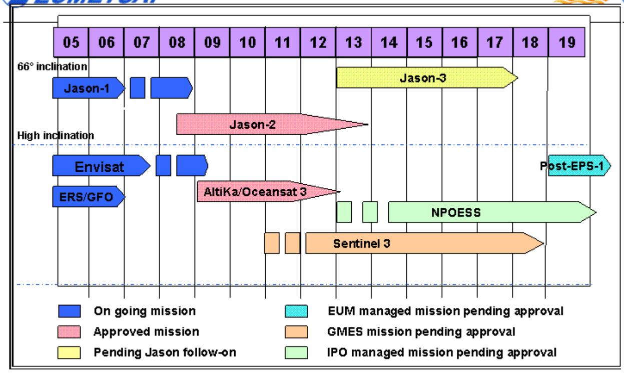
- B Phase: 09/2005 ➔ 02/2006
- CD phases : 03/2006 ➔ end 12/06
- Jason-2 integration : 01/2007
- Exploitation: 06/2008 ➔ 06/2010

- T2L2 working group constitution: 2006
- T2L2 Ground instrumentation: 01/2007

12. Jason-3 Perspectives (F. Parisot)

EUMETSAT

Altimetric measurements : OCEAN TOPOGRAPHY, SEA LEVEL, OCEAN CIRCULATION : <5 cm accuracy class



OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-2

EUMETSAT

Open points : Mission

- **Orbit choice**
- **So called reference orbit (T/P, Jason-1 ..)**
  - Added cost impact due to life time limitation (radiation) and launch cost (single launch)
  - Optimised for altimetry regarding POD, Tides, data continuity
- **Sun synchronous polar orbit (ERS, Envisat…)**
  - 800 Km, polar, sun synchronous, 30 days cycle (among others)
  - Not optimised for altimetry but less costly
- **Alternative orbit(s), never used until now**
  - "Type 800 Km", Inclination open, Non sun synchrounous, cycle TBD
  - Attractive for cost and altimetry except that it was never used before so a full new data set will be initiated
- **From today discussions with users, it seems that the reference orbit is still needed for Jason-3, at least up until a good cross calibration with another ground track could be made but we would need a very strong justification of any orbit choice and clearly show that we have explored the various options**
- **Payload, Satellite bus, Launcher**
- **Dual frequency altimeter, Three frequency radiometer, Doris, GPS, Laser**
- **WSOA ?**
  - Non sun synchronous orbits not optimised for WSOA if yaw steering has to be maintained
- **Satellite bus**
  - PROTEUS or next family, other European bus, possibly able to accommodate WSOA without yaw ?
  - Open for cooperation
- **Launcher , one of the cost driver**

OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-3

EUMETSAT

Open points : Mission

- **Ground segment**
- **Control Ground segment**
  - EUM, NOAA
- **Earth terminal network**
  - open, very much dependant upon the NRT data latency
- **Mission ground segment**
  - Near real time product and services: EUM, NOAA
  - Off line : Open, but based on today existing processing and dissemination facility for sea surface topography (e.g. CNES/CLS SSALTO DUACS)
- **Products**
- **Near Real Time products**
  - Operational Geophysical Data Record (OGDR)
    - Wind, Wave and Sea Surface Height
    - Today "pass" product, trend to release gridded product that are permanently updated by new pass data
  - Interim Geophysical Data Record (IGDR), 24 to 48 hours data latency
    - Today not part of the NRT set, full altimetry product
- **Offline product**
  - Geophysical Data Record

OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-4

EUMETSAT

Open points : Programmatic

- **US/Europe partnership continuation absolutely needed**
  - Built on T/P, Jason and EPS all recognised as very effective cooperation
  - EUM and NOAA can be leading agencies but mission, system, instrument expertise from the other agencies (CNES, NASA) is needed.
    - E.g. EUM will not directly manage instrument development contracts
  - Maximum use shall be made of the existing assets
- **In Europe, articulation of Jason-3 with respect to GMES program shall be defined**
  - EC-GMES funds would be needed for Jason-3
  - Maximum synergy between Sentinel 3 and Jason-3 should be looked at.
    - Ground system, data processing
    - Coordination of equipment procurement
- **Open programmatic questions :**
  - US/EUROPE sharing of responsibilities
  - CNES/NASA involvement in Jason-3, possible contribution
  - Articulation/complementarity wrt Sentinel 3 and NPOESS

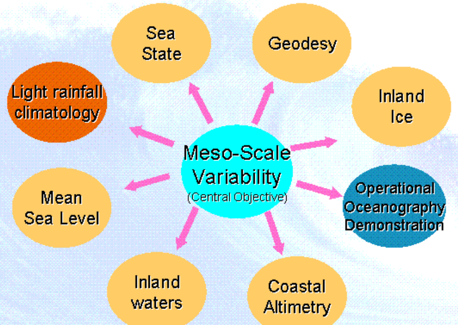
OSTM/Jason2 - OSTST-Meeting - Venice, March 16-18, 2006 FP-5

AltiKa Mission (P. Sengenes)

AltiKa program genesis

- Need expressed by altimetry community and organizations (IGOS, GODAE,...) :
  - *« Continuity of high accuracy, high resolution near-real time observations of the ocean surface topography is required. At least, 2 simultaneous altimetry missions are required (including one of the Jason reference class) »*
  - Consequence : need to prepare a post-ENVISAT mission that would fly at the same time as JASON2
  - Additional mission demonstration goals:
    - performance improvement : higher vertical resolution altimetry, higher spatial resolution for coastal & inland waters altimetry
    - preparation to operational altimetry : feasibility of low cost altimetry system demonstration
    - continental ice sheets monitoring, mean sea level monitoring, low rain characterization
- Pre-development studies have been engaged by CNES since 1998
  - breadboarding to prepare Ka-band altimeter development: *chirp generator, Ka-band SSPA*
  - Phase B definition study (Nov 2001-June 2003) of a Ka-band altimeter embedding a bi-frequency radiometer
  - Accommodation studies of Ka-band altimetry payload (including POD equipment) on European microsat platforms

AltiKa mission applications

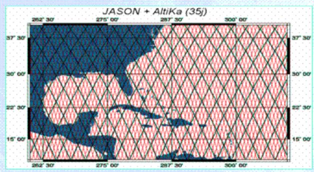


AltiKa payload

- Single frequency Ka-band altimeter with enhanced bandwidth
  - reduced ionosphere effects
  - Ka-band (35.75 GHz) authorizes a compact, lightweight instrument easier to accommodate on a wide range of satellite buses
  - 500 Mhz bandwidth : better vertical resolution => error budget improvement
  - Ka-band limitation : altimeter not operational for rain rate > ~ 2mm/h
    - rain rate > 2 mm/h ⇔ between 5% to 10% of time according to geographic area
- Dual-frequency radiometer (23.8 GHz +/- 200 MHz & 37 GHz +/- 500 MHz)
  - required for wet troposphere correction
  - Embedded in altimeter, three-frequencies common antenna
- Laser Retro-reflector Array
  - POD system calibration and guarantees minimum orbitography
- DORIS
  - required for achieving high accuracy orbitography performances on low earth orbit in a precisely monitored reference frame (mean sea level analysis)
  - required for coastal/inland applications due to real-time coupling with altimeter
  - contribution to DORIS system performance and monitoring (for the benefit of all altimetry missions using DORIS)

AltiKa mission orbit

- AltiKa « ideal » orbit
  - polar orbit : oceans & Antarctica
  - « 6h-18h » sun-synchronous : power management, radiometer calibration
  - ground-track repetitivity : > 15 days , < 35 days

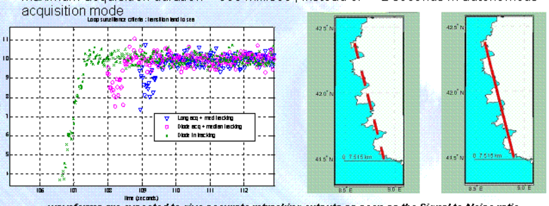


JASON & AltiKa combined sampling with AltiKa on a ERS/ ENVISAT orbit type

  - altitude range : 700 km / 900 km
    - *Altimeter altitude range design : 500 km / 1000 km*
- AltiKa « effective » orbit in 2009 will depend on satellite selection :
  - passenger with an associated mission or on a dedicated platform

Expected performance on "not oceanic" surface

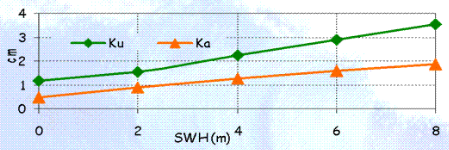
- By coupling the altimeter with DORIS/DIODE navigator information
  - Maximum acquisition duration < 500 millisec , instead of > 2 seconds in autonomous acquisition mode



  - *waveforms are expected to give accurate retracking outputs as soon as the Signal to Noise ratio exceeds 9 dB*
  - Improving data acquisition duration of 1 second allows to get closer to the coast of about 7 km.
  - optimised on-board DEM greatly improves the tracking behaviour in transitions especially from land to water and over continental waters

Expected results on sea surface

- Expected accuracy of the altimeter range measurement over sea surface



  - Improvement of about 40 % on the range noise versus Ku-Band performance
    - About 1 cm for a SWH of 2 meters
  - Better estimate of the velocity fields (topography gradients) and better analysis of the eddies structure along-track
    - Thanks to reduced altimeter footprint and to reduced duration for echoes averaging

AltiKa program status

- AltiKa program has been approved by CNES Governing Board in December 2005
  - Funding for AltiKa development phase and for a 3-years exploitation phase
  - Authorization to engage Altimeter & Radiometer phase C/D
  - High level priority , "gap-filler" requirement : AltiKa has to be launched in 2009
- AltiKa program baseline
  - Development and exploitation of AltiKa mission in the frame of a CNES/ISRO cooperation program
    - Current CNES and ISRO agreement , MOU in preparation
  - AltiKa & Argos payloads embarked on an Indian satellite, launch in 2009

SPLINTER REPORTS

Sea-State Bias and Retracking Analysis

(Co-chaired by P. Callahan and O. Zanife)

March 17, 2006

INTRODUCTION (P. Callahan)

The Sea-state bias & Retracking Splinter meeting was held on March 18, 2006. It was co-chaired by P. Callahan and O.-Z. Zanifé.

Based on past OSTST meetings, the goals of this splinter were essentially to discuss:

- How to remove geographically correlated biases (e.g., SSB) between TOPEX and Jason to better than 1 cm
- How to understand the source and value of TOPEX-Jason range bias to better than 1 cm

In addition to the various talks presented, JPL and CNES held discussions before the OSTST on the comparison of their retracking efforts. A plan was developed for additional tests to be conducted in the next few months (see section ***CNES / JPL Plan & Schedule AT END***). Indeed, there is a strong need to complete main work during 2006 because of budget considerations and length of time for reprocessing (Jason ~ 200 cycles, TOPEX ~ 475 cycles).

Previous Discussion, Decisions

This was the situation after the OSTST meeting in Oct 2004 (St. Petersburg, FL).

- TOPEX and Jason have different SSB
- CNES committed to develop MLE4 retracking because of concern about degradation of star tracker on board Jason-1 (with a skewness to be set to 0.1) (see presentation of P Thibaut)
- Different retrackings used/under study for different missions (MLE3, ML4, LSE, MAP, …). Plan for comparison on simulated data set and on TOPEX Jason tandem phase
  - ⇨ Note: Different convergence criteria (*JPL and CNES retracking use different convergence criteria: CNES – MQE change, JPL – parameter change*.)
- TOPEX and Jason data retracked by JPL, but comparisons to CNES on going
- Concern about correlations among parameters in retracking – bias Vs noise (This was one of the main issues, particularly for geophysical use of data.)
- JPL plan to begin TOPEX retracking by fall 2005

Where We Are

- CNES has updated processing, in particular using "MLE4" to account for attitude (also include new orbits and updates for many geophysical fields. Next version will have fully recalibrated JMR)
  - o Used in processing since cycle 128 , Reprocessed cycles 1-21 for comparison with TOPEX
- JPL has retracked 1 yr of TOPEX data (329-364), including 344-364 (361 is POSEIDON) for comparison with Jason with 2 methods – Least Squares Estimator (LSE), Maximum a Posteriori (MAP), and Jason cycles 1-21 (for internal comparison)

  (*Retracked GDRs (RGDRs) also include new GSFC orbits and CNES values for many geophysical fields. Next version will have fully recalibrated TMR*)
- Objective is to have TOPEX and JASON as coherent as possible (orbit – range) (That is, the desire is to eliminate "(re)tracker bias" from the data so that Sea State Bias (SSB) is only

the actual physical Electromagnetic Bias (EMB, which almost certainly depends on frequency).)

- Analyses have been performed on both data sets and results will be shown in the splinter *(e.g., the CNES and JPL presentations)*
  - ⇨ more TOPEX/JASON comparisons are needed
  - ⇨ more simulation comparisons are needed

SSB Splinter Talks

SSB Modelling

8:45 – 9:10 *Doug VANDEMARK, Hui FENG, Bertrand CHAPRON, Ngan TRAN, Brian BECKLEY, Use of fuzzy logic clustering analysis to address wave impacts on altimeter sea level measurements: Part I data classification; Part II results*

9:10 – 9:30 *Ngan TRAN, Douglas VANDEMARK, Bertrand CHAPRON , Sylvie LABROUE, Hui FENG, Brian BECKLEY, New models for satellite altimeter sea state bias correction developed using global wave model data*

9:30 – 9:50 *Christine GOMMENGINGER, Overview of EM Bias and Frequency Dependence*

Retracking and related SSB

9:50 – 10:10 *Juliette LAMBIN, Nicolas PICOT, Jean-Paul DUMONT, Pierre THIBAUT, Ouan-Zan ZANIFÉ, Evolutions in the ground processing chain: motivation, status and impact*

10:40 – 11:00 *Ernesto RODRIGUEZ, Philip CALLAHAN, Kelley CASE, Theodore LUNGU, Comparison of TOPEX and Jason Retracking using Least Squares and MAP Estimation*

11:00 – 11:20 *Pierre THIBAUT, Sylvie LABROUE, Michael ABLAIN, Ouan Zan ZANIFE, Evaluation of the Jason-1 ground retracking algorithm*

11:20 – 11:40 *Ouan-Zan ZANIFE, Pierre THIBAUT, Laiba AMAROUCHE, Bruno PICARD, Patrick VINCENT, Assessment of the Jason-1 Look Up Tables Using Multiple Gaussian Retracking*

11:40 – 12:00 *Sylvie LABROUE, Philippe GASPAR, Joel DORANDEU, Ouan Zan ZANIFE, Latest Results on Jason-1 Sea State Bias with the Non-Parametric Technique*

12:00 – 12:30 *Phil Callahan / Ouan-Zan Zanife:* ***Summary, Discussion, Recommendations***

Highlights from the talks

VANDEMARK et AL.

Vandermark et al. presented a classification technique for sea-state conditions (e. g. swell-dominated vs. sea-dominated), allowing to adapt different SSB modelling to the various cases. The sea-state classes are defined based on parameters from Alt and Wave model.

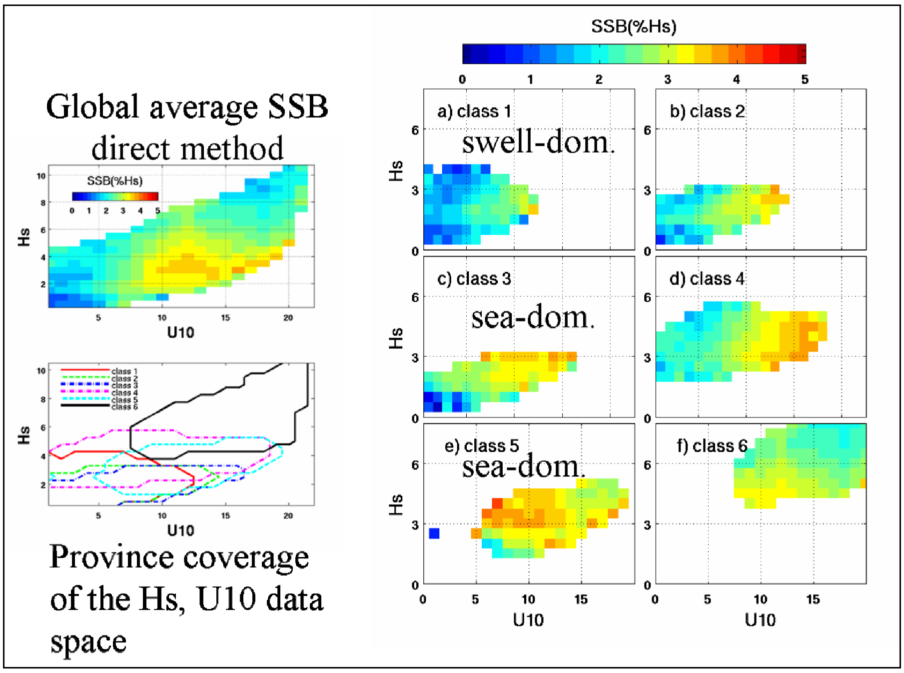


Figure 1 (From Vandermark et al.)

Figure 1 presents the SSB models corresponding to each of 6 classes (right panel) . Left panels show: top – the global average used as reference; bottom – the areas of the different classes in Wind/SWH space

Figure 2 shows the difference (in % Hs) of class-specific SSB models relative to the global average. Classes 2, 4, 6 do not have easily applied names. Note that differences can be ~1% while total effect is ~ 3% .

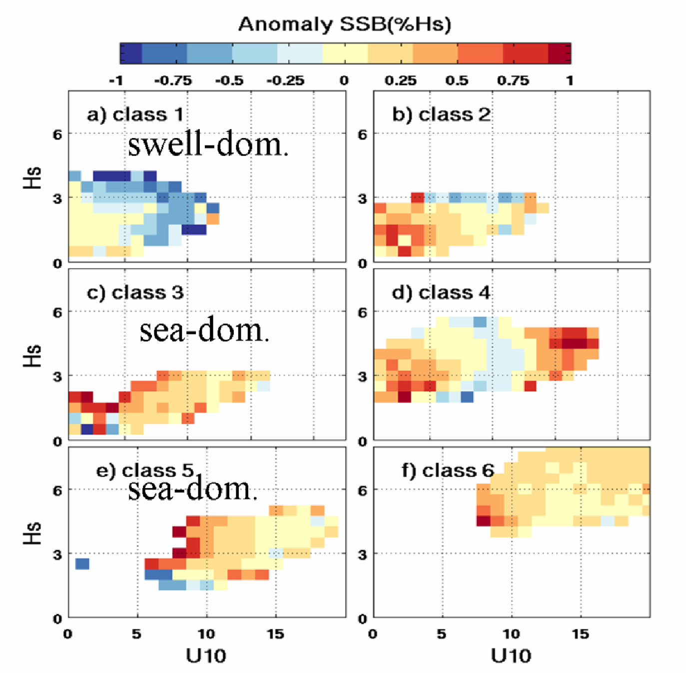


Figure 2

From Vandermark et al.

Tran et AL.

Tran et al. presented a complementary approach to that of Vandemark, in which 12 potential parameters derived from Altimeter measurements or wave models are used as the second parameter of an (SWH;parameter) SSB model.

The table below show the different parameters tested. The combination (SWH;U_alt) performs the best globally, however there exist some regions in which particular models do significantly better than others (Figure 3).

Parameter	**Symbol**	**Source**	**Definition**
ECMWF wind speed	U_ECMWF	Jason-1	
Altimeter wind speed from adapted MCW algorithm (Witter and Chelton, 1991)	U_alt	Jason-1	U_alt =MCW (Ku s0)
Altimeter wind speed from adapted Gourrion et al (2002) algorithm	U_alt_Gal	Jason-1	U_alt_Gal=U (Ku s0, SWH)
Ku-band NRCS	Ku □0	Jason-1	
C-band NRCS	C □0	Jason-1	
Pseudo wave age	ξ	Jason-1	$3.24\left(\frac{SWH}{U\_alt^2}\right)^{0.62}$
Swell height	H_swell	Wave model	
Mean wave period	Tm	Wave model	Tm= m0/m1
Wave steepness	*S*	Wave model	$\frac{8\pi}{g}\frac{m2}{\sqrt{m0}}$
RMS slope	RMS slope	Wave model	$\left(\frac{2\pi}{g}\right)^2\sqrt{m4}$
Inverse wave age	Ω	Jason-1, wave model	$\frac{2\pi}{g}U\sqrt{\frac{m2}{m0}}$

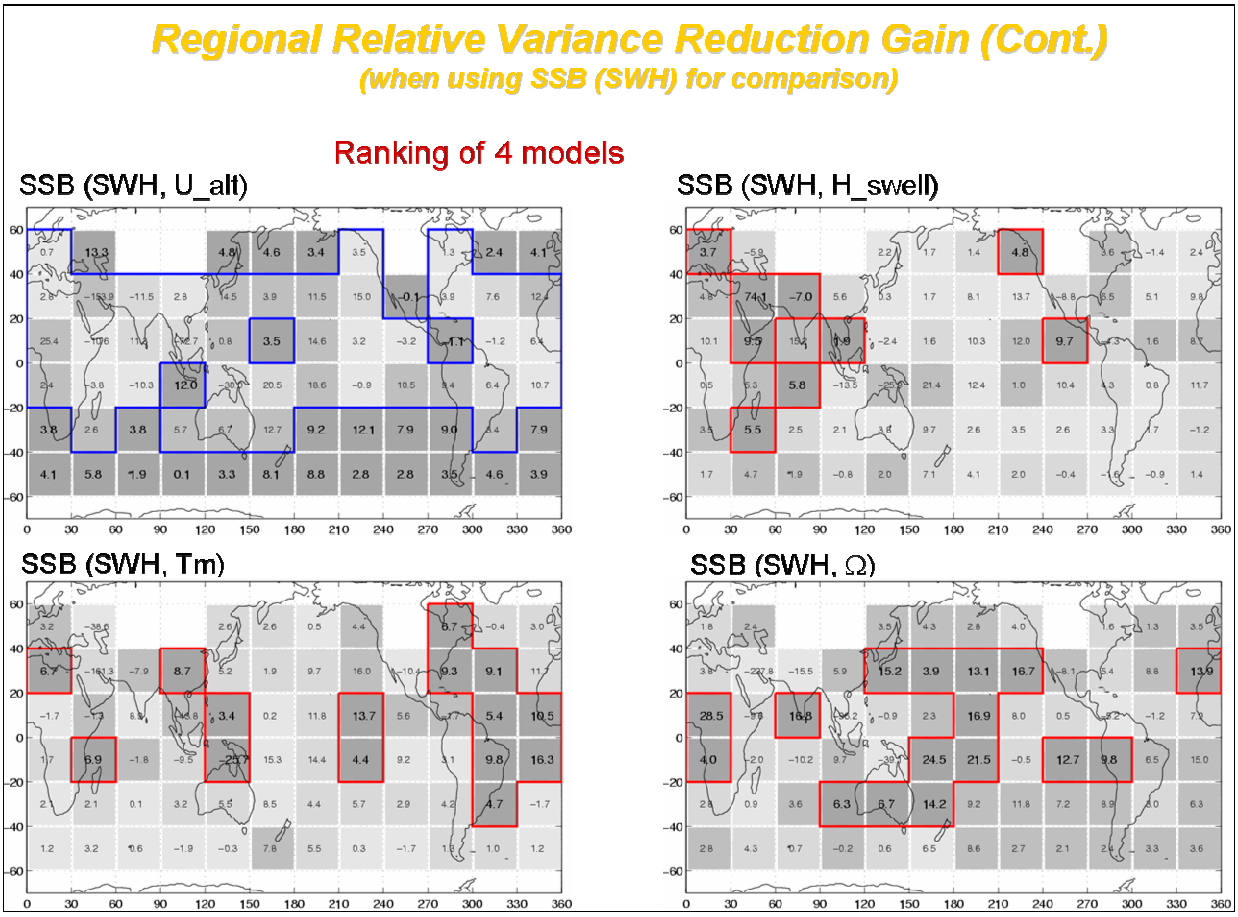


Figure 3

From Tran et al.

THIBAUT et AL.

Thibaut et al. presented some results from the CNES implementation of MLE4 retracking on Jason data. As measured by the variance reduction in SLA, the MLE-4 retracking algorithm performs better than MLE-3 everywhere the waveforms differ from the theoretical Hayne model (especially in the trailing edge of the WF). Figure 4 shows a map of the mean pseudo mispointing angle retrieved by the MLE4 algorithm.

It is important to recall this parameter is different from real mispointing angle, as changes in the trailing-edge slope may be due to other causes. In particular, note the similarity with distribution of rain, which is a major factor of waveform distortion. SLA variance reduction is indeed mostly found in those areas (Figure 5).

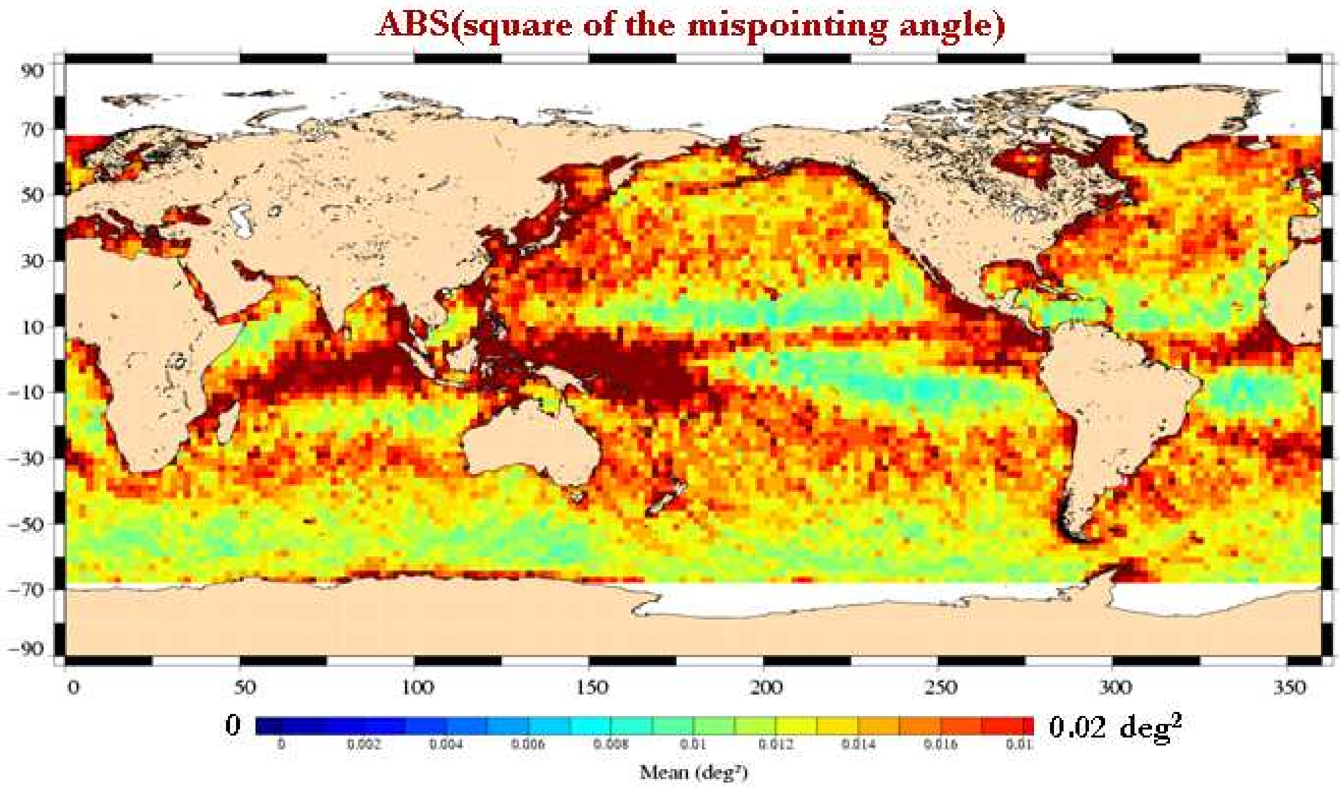


Figure 4

From Thibaut et al.

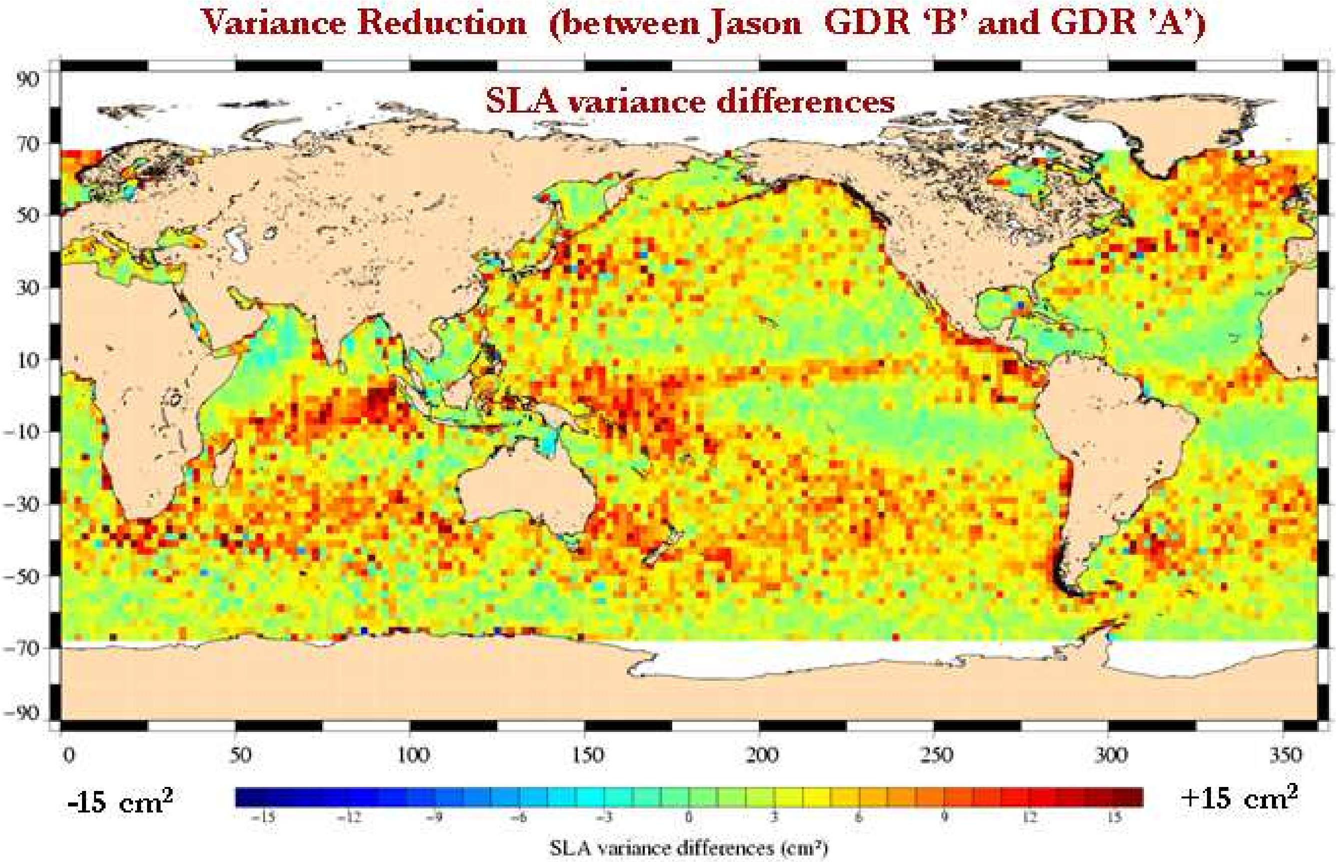


Figure 5

From Thibaut et al

RodrigUez et al.

Rodriguez et al. presented results from the implementation on Jason-1 data of the 2 JPL retracking algorithm, Least Squares(LSE) and Max a Posteriori (MAP). Those where compared to the MLE4 retracking provided in GDRb data. Figure 6 shows ∆h distributions with respect to SWH and wind speed (top 3 panels), and SWH and attitude squared (bottom 3 panel). It appears from this study that MAP has much smaller differences from CNES MLE4 – this is unexpected**.**

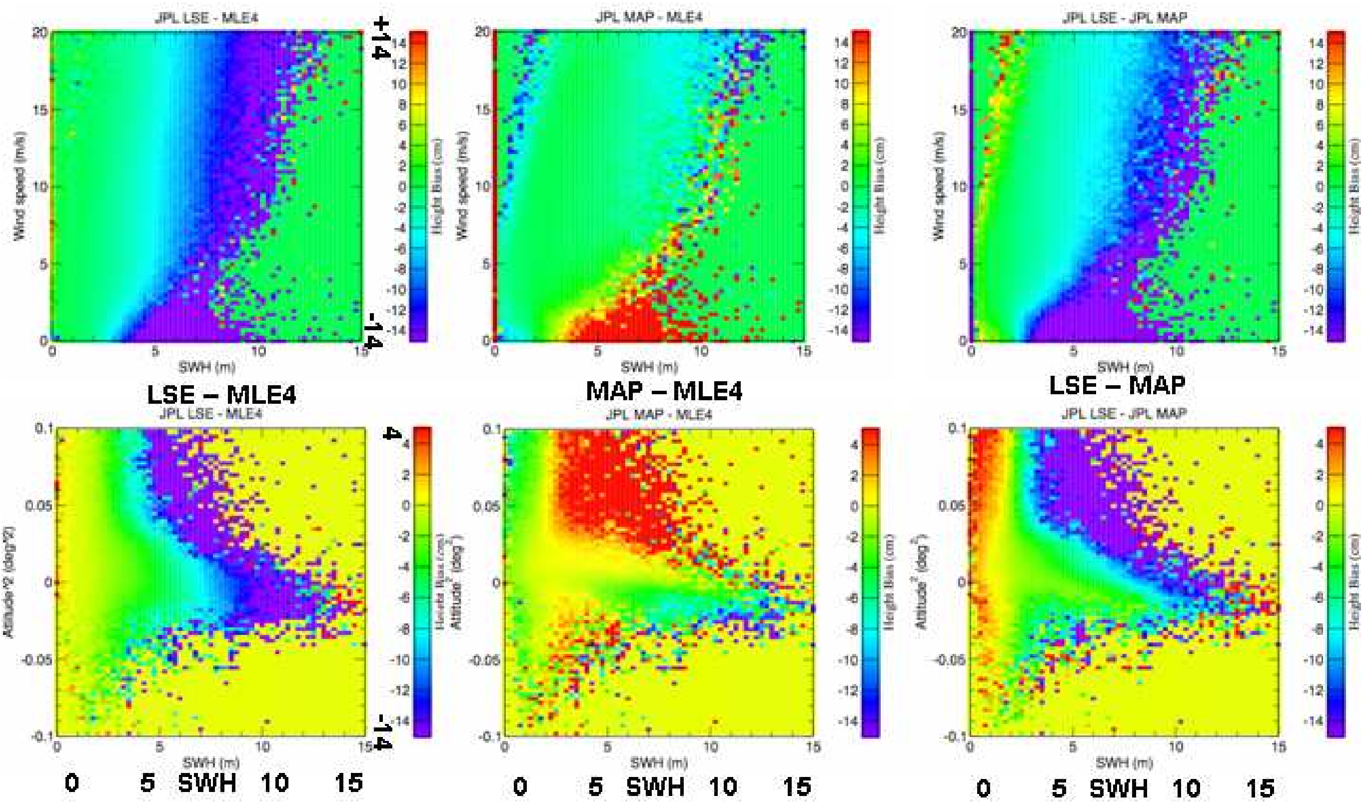


Figure 6

From Rodriguez et al.

Labroue et al.

Labroue et al. presented an assessment of the consistency between Jason and TOPEX during the formation-flying phase, with respect to the new processings. Figure 7 shows the differences in (orbit-range) between Jason (GDRb) and TOPEX (MGDR: left panel, retracked RGDR –using LSE: righ panel). Retracking (LSE) reduces differences globally by 0.4 cm and decreases the SWH related error. Note that based on Rodriguez et al. results, MAP would have reduced more.

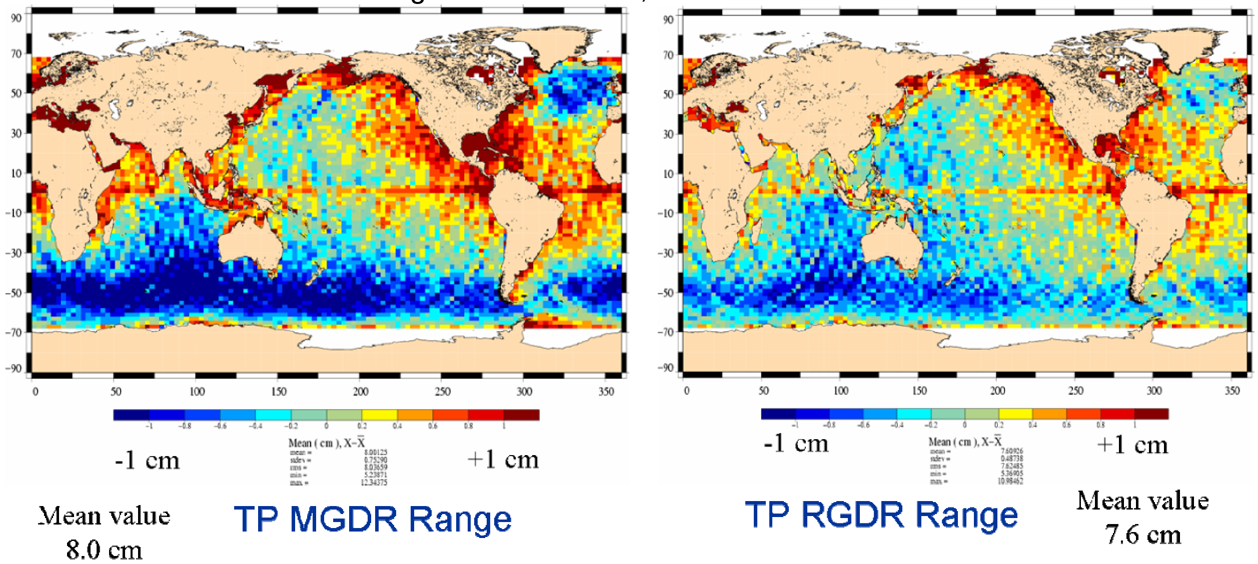


Figure 7 (From Labroue et al.)

However, when separating ascending and descending orbits (Figure 8), very strong North/South features appear, in “Orbit-Range” as well as in SWH differences. This implies that retracking does not eliminate problems from TOPEX waveform features: this ascending/descending and latitude dependency is due to the fact that TOPEX “leakages” or “features” position in waveform depend on range rate.

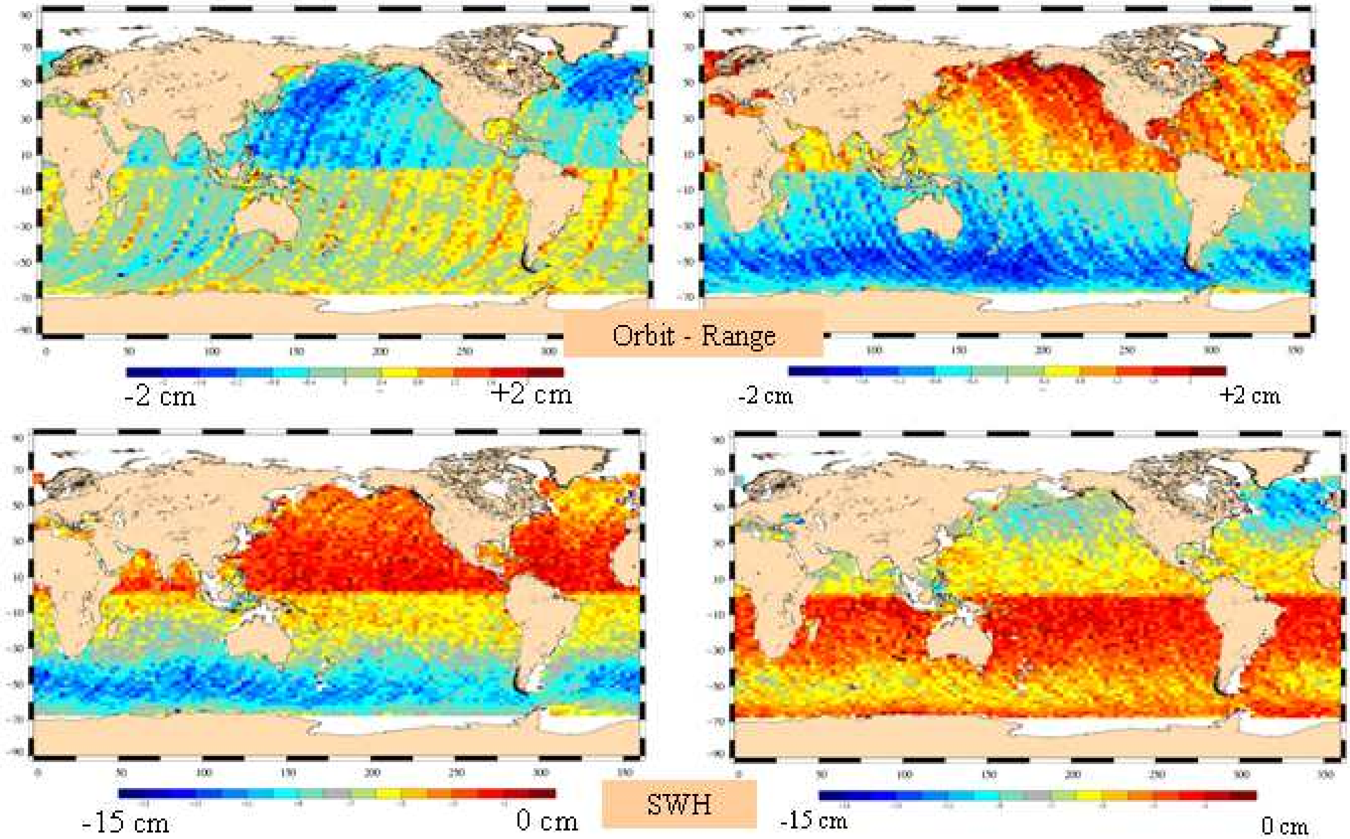


Figure 8   (From Labroue et al.   )

A Sea State Bias model was reestimated for each of the retracked data sets (Jason MLE4, TOPEX LSE). The difference in SSB between the two missions is greatly reduced, as shown on Figure 9. The improvement is due to the retracking algorithms on both missions in equal parts. For Jason, this is the effect of the skewness coefficient set to 0.1 which reduces the SSB magnitude for all SWH. For TOPEX, the improvement is mainly observed for strong waves (greater than 4m).

Once corrected from the new SSB models, the differences JASON-TOPEX (orbit-range-ssb) is shown on Figure 10. An E-W difference appears in this map, but this as been identifyed as the result of small orbit errors that will be corrected (Beckley).

We are approaching the 1 cm goal, BUT we know that there are significant features “hiding” in these maps.

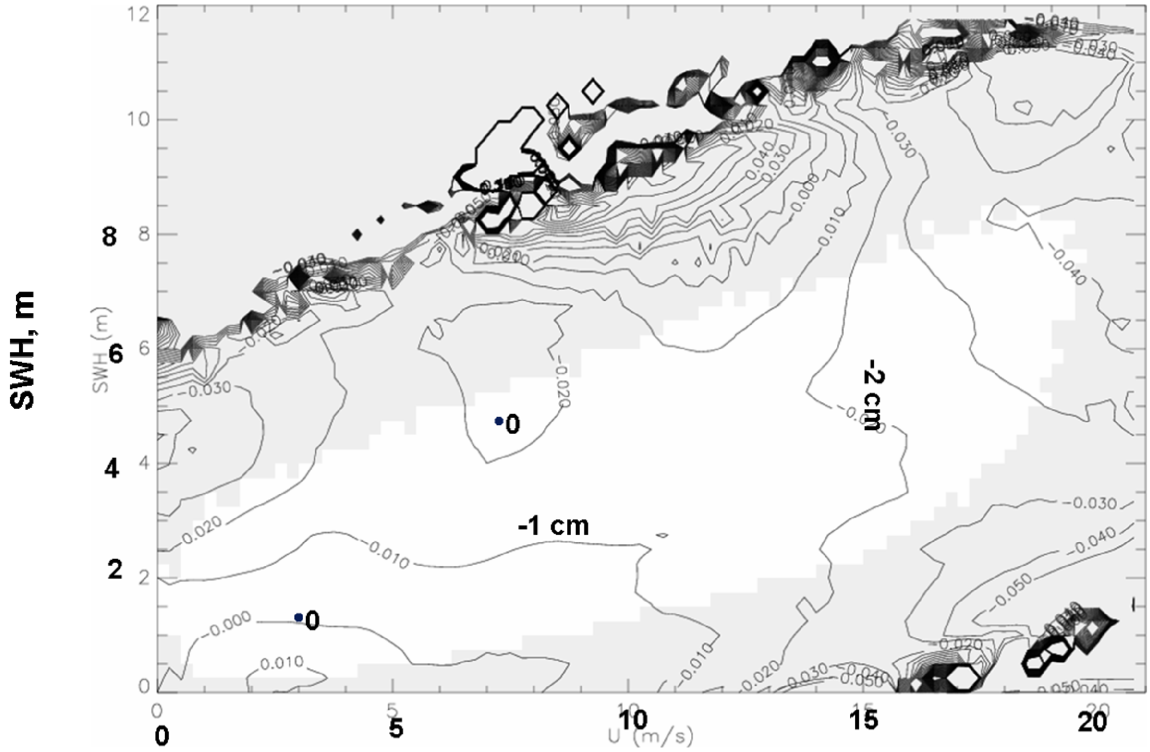


Figure 9 (From Labroue et al.)

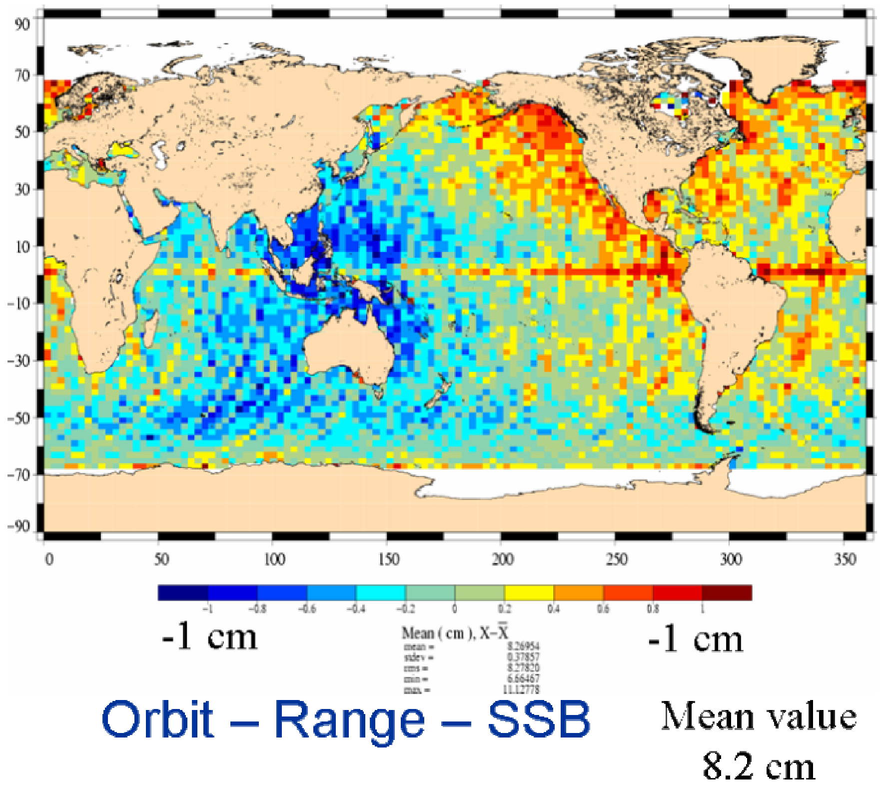


Figure 10 (From Labroue et al.)

SPLINTER CONCLUSIONS and RECOMMENDATIONS

CNES / JPL Plan & Schedule

These are the key points from the JPL-CNES meeting on further understanding the properties of the two retracking schemes.

The first issue was pointed out by Rodriguez et al., showing the two JPL algorithms applied to Jason data (Figure 6). The simulation comparisons are to clear up some remaining points from previous simulation comparisons.

Issues

- MAP and LSE agree on simulated data; a bias appears when using real data – suggesting waveform mismodelling
- Retracking does not cure TOPEX waveform features:
  - "Toward/Away" differences of ~1 cm remain – need to explicitly clean or solve for waveform artifacts

Simulations / Waveform Modeling

- Determine how many Gaussians are needed to get 1mm Range, 1cm SWH agreement with full PTR
- CNES to provide model waveform code, simulated waveforms (N=10,000) for several cases
- CNES to supply PTR and Filter weights (PTR needs to be corrected by filter weights)
  - Test effect of filter weight (daily Vs long term average)
  - Jason processing is using daily – concern that this adds noise as filter is very stable over time. Impact less than 1 mm : CNES to provide technical note.
- JPL to test solving for all parameters at 20Hz as is done in Jason (Current averages to 10Hz, solves for 10 ranges, 1 SWH, 1 Att^2, 1 Skewness)
- Investigate waveform residuals from fit
  - TOPEX: determine variations in features. Develop scheme for removing.
  - JASON : determine if there are unmodeled features
  - *As previously noted, it is necessary to remove the TOPEX features in order to reach the sub-centimeter goal.*
  - *The fact that LSE/MAP do not behave in the expected way on Jason data suggest that there may be mis/un-modeled features in the Jason waveforms also.*

Schedule

- Need to complete main work during 2006 because of budget considerations and length of time for reprocessing (Jason ~ 200 cycles, TOPEX ~ 475 cycles)
  - April-May 2006: CNES and JPL to agree on a simulated data set and perform comparisons
  - June-July 2006: CNES and JPL to perform comparisons on real data
  - August: re-estimate SSB based on the updated retracking
  - September 2006: report to Project Scientist and implementation of the reprocessing
- Reminder of Goal: Cross calibration of TOPEX-Jason with NO geographically correlated errors (<< 1 cm)
  - Lee's Test: Coherence(TPX(Orbit-Range) – J(Orbit-Range), SWH) ~0

Open Questions: (1) evolution of the products, (2) multi-mission context

These are additional issues that the OSTST should consider as the final TOPEX and Jason products are developed for this reprocessing

- Data format and content

- Currently: GDRs for Jason, RGDR for TOPEX
- Products including the altimeter waveforms?
  - Already the case fo Jason (S-GDR or S-IGDR)
  - Allows easier reprocessing (exploratory or systematic)
- Multiple retracking outputs within one product?
  - Already the case for ENVISAT
  - « Expert » product: the user has to choose one
- Interest of adding MQE and/or peakiness to GDR
  - Editing criteria: MQE reflects a posteriori the quality of the fit, peakiness reflects a priori how close is the waveform to Brown echo, 20Hz off-nadir angle (from MLE4)

o Multi-mission context:

- T/P mission ended
- New missions planned (OSTSM/Jason2, AltiKa)
- Importance of multi-mission products
- As much as possible, we should keep coherent processing strategies between missions
  - TOPEX was the reference mission up to now: this is great for the homogeneity of data, BUT future missions will not overlap with Topex
  - Future missions ground processing will inherit from Jason rather than TOPEX (e.g. ground retracking)

Cal/Val and Data Consistency

(Co-chaired by P. Bonnefond, S. Desai, B. Haines, S. Nerem, N. Picot)
March 17, 2006

INTRODUCTION

The Cal/Val and data consistency splinter focused on the new products available either for Jason-1 (GDR-B) or TOPEX/Poseidon (RGDR-1&2). Through 18 talks, all the new parameters (orbit, range, corrections) have been reviewed to quantify the level of improvement and to identify the remaining items that have to be improved before complete reprocessing.

PRODUCTS ANALYSES

Jason-1 (GDR-A / GDR-B)

Sea-Surface Height Biases

Table 1. Jason-1 SSH biases from calibration studies

Site	GDR-A (mm)	GDR-B (mm)	Number of cycles	Reference
Harvest*	+141.8 ±6.3	+97.4 ±7.4	108 / 29	*Haines et al.*
Corsica*	+107.9 ±6.7	+86.3 ±8.6	84 / 21	*Bonnefond et al.*
Bass Strait	+152.3 ±7.7	+105.0 ±8.3	18 / 18	*Watson et al.*
Gavdos	+131.0 ±12	NA	20 / NA	*Pavlis et al.*
Ibiza	+120.5 ±4.4	NA	33 / NA	*Martínez-Benjamín et al.*
Regional	+100.0 ±1.0	91.0 ±8.0	21 / 21	*Jan et al.*

*Biases given at the 2002.0 reference epoch

Table 1 provides a synthetic view of the results presented during the « In-situ and regional » part of the splinter. On average, the Jason-1 SSH bias decreased by 31 mm (from 126 to 95 mm). More important, the sample standard deviation of the bias (from different calibration experiments) has decreased from 26 to 8 mm (GDR-A and GDR-B respectively). This demonstrates that the GDR-B dramatically reduces the geographically correlated errors for Jason-1, leading to more coherent results from local and regional studies. The two main origins of this improvement come respectively from the new POE orbit and the JMR calibration. The main patterns (see 2004 report) of either constant or drifting geographically correlated orbit errors have been removed and this has been clearly identified in *Haines et al.* (Figure 1) and *Watson et al.* (Figure 3) studies. Concerning the JMR, the apparent drift (~ –4 to –5 mm/yr effect on the drift) has been removed thanks to the new calibration coefficients and other improvements and this is confirmed by *Haines et al.* (Figure 4) and *Bonnefond et al.* (Figure 5) studies when comparing the JMR wet path delays to the GPS derived ones.

The remaining observed drift is now not statistically different from zero but the complete time series has to be revisited to increase confidence in this result. Concerning the absolute bias value itself, the number presented here also needs to be updated with the full data set and with any new sea state bias model that may be selected for the final GDR-B reprocessing.

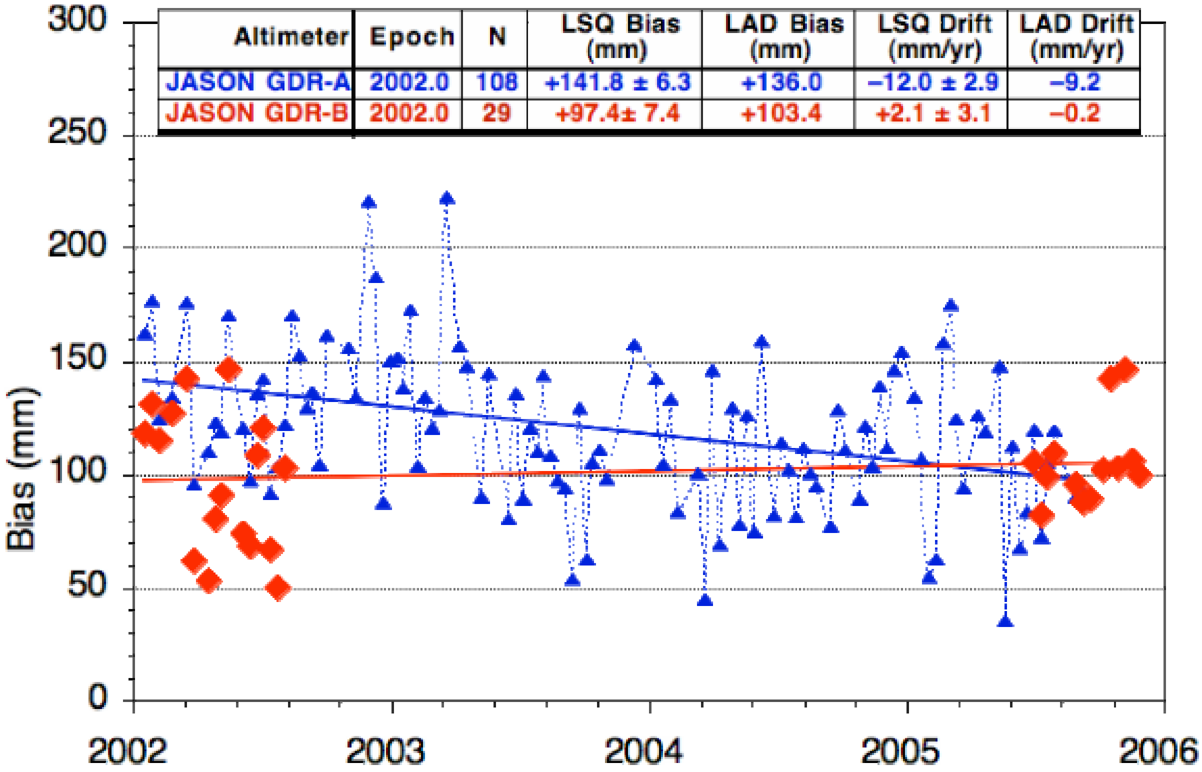


Figure 1. GDR-A and GDR-B altimeter bias time series from Harvest calibration site (*Haines et al.*).

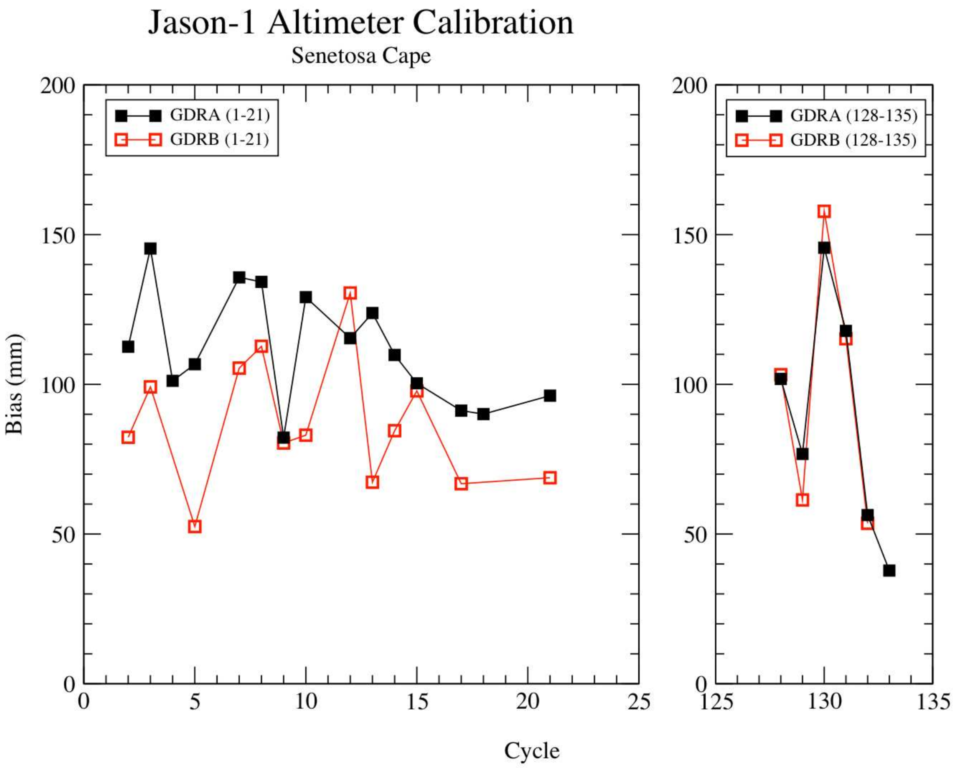


Figure 2. GDR-A and GDR-B altimeter bias time series from Corsica calibration site (*Bonnefond et al.*).

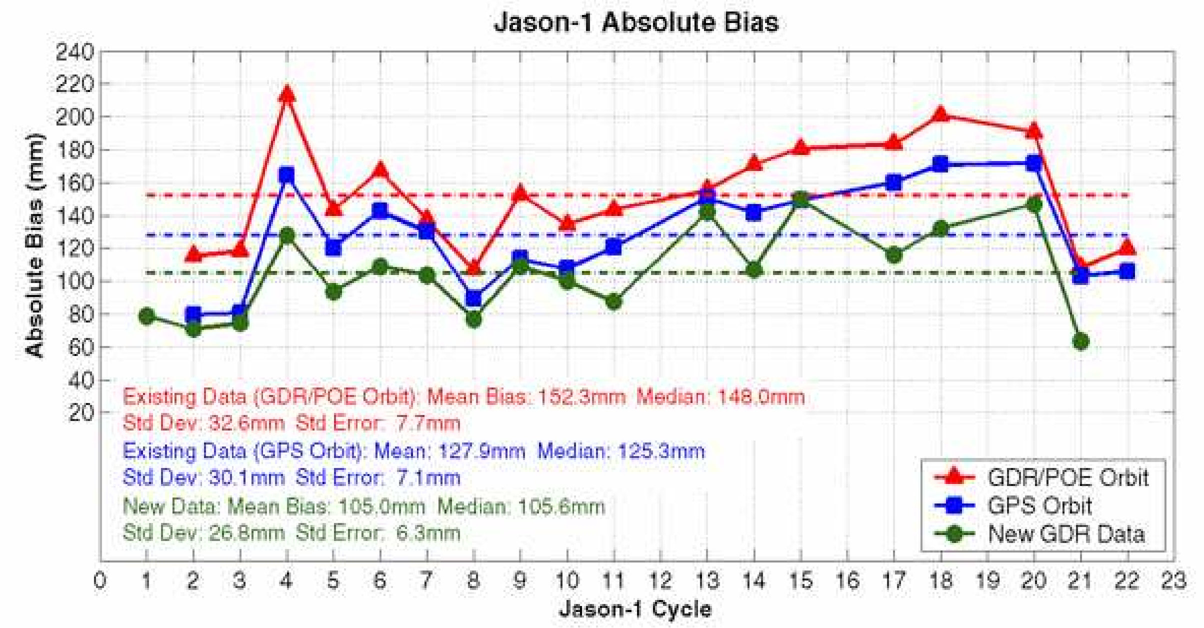


Figure 3. GDR-A and GDR-B altimeter bias time series from Bass Strait calibration site (*Watson et al.*).

JMR

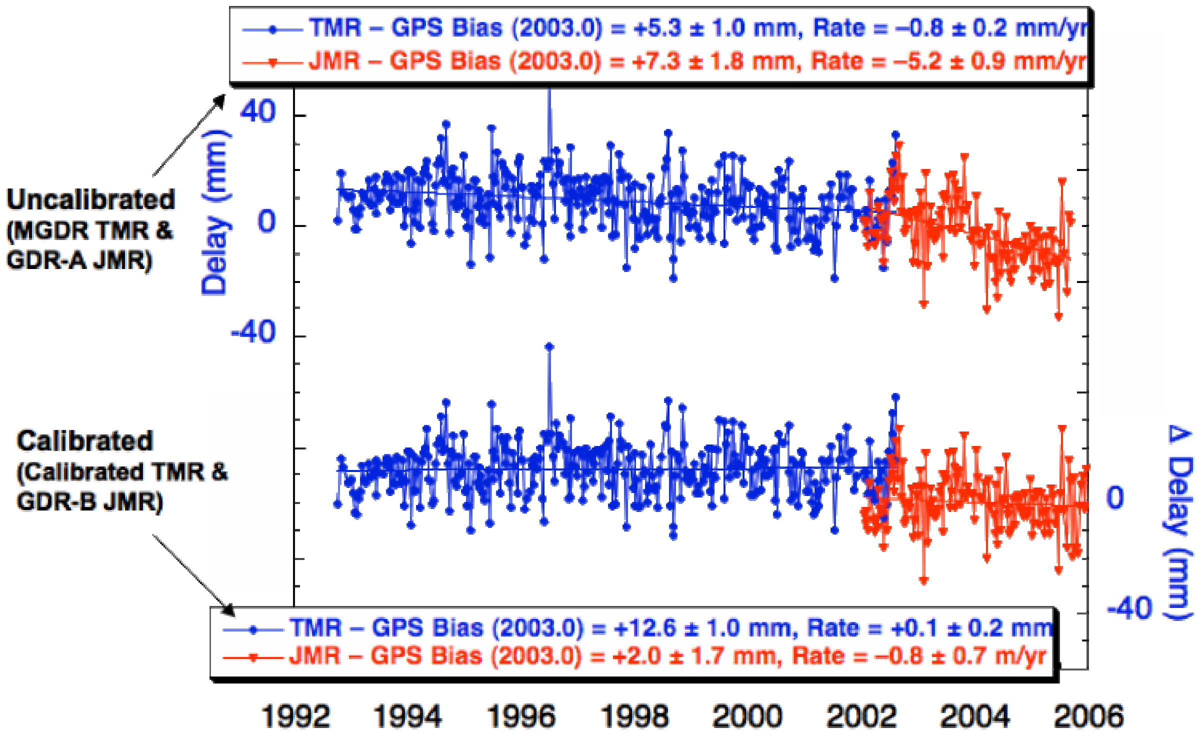


Figure 4. GDR-A and GDR-B JMR wet path delays (positive) minus GPS derived ones from Harvest calibration site (*Haines et al.*). Same for TMR (blue).

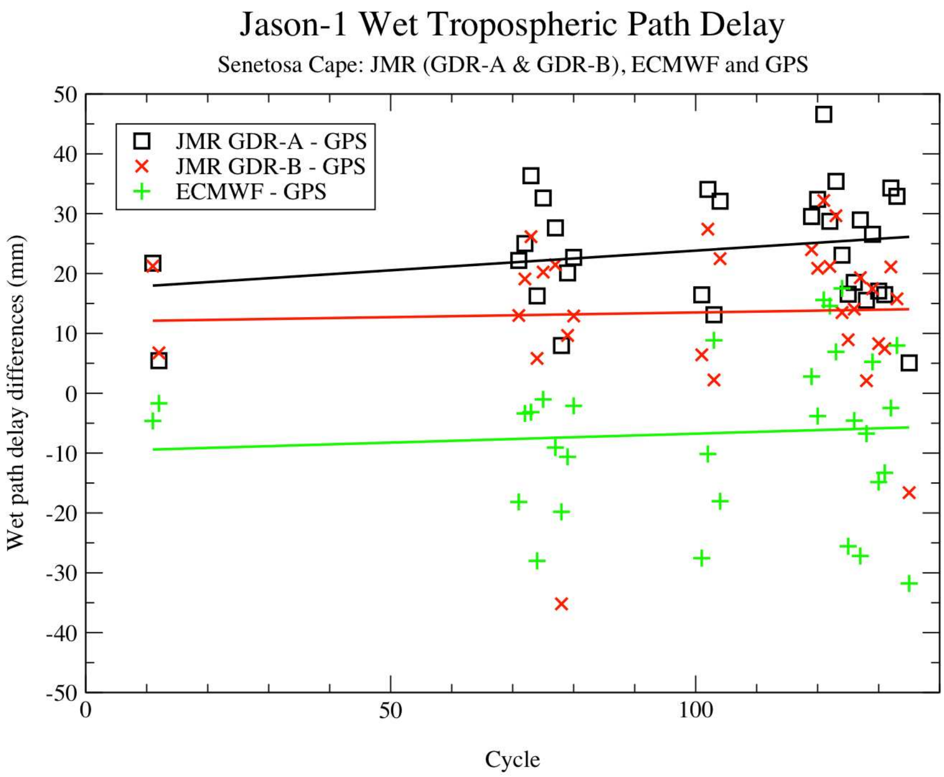


Figure 5. GDR-A and GDR-B JMR wet path delay corrections (negative) minus GPS derived ones from Corsica calibration site (*Bonnefond et al.*).

Desai et al. and *Brown et al.* reported on the status of the JMR recalibration and its validation; their conclusions are:

- Systematic offsets of the JMR WPD in Version A of the GDRs have been removed in Version B, at least through cycle 136 (Figure 6).
- Offsets in some brightness temperatures (Version B) have been detected after the cycle 136 safehold event.
    - Effect on WPD < 2mm.
- Drift of < 1 mm/year may remain.
- Scale error in JMR may exist.
    - Will use radiosondes as one more test for existence of scale error.
- Efforts are underway to further calibrate the JMR data to remove all these effects.
    - Schedule permitting, the calibrated data will be included on the "final" version B GDRs.

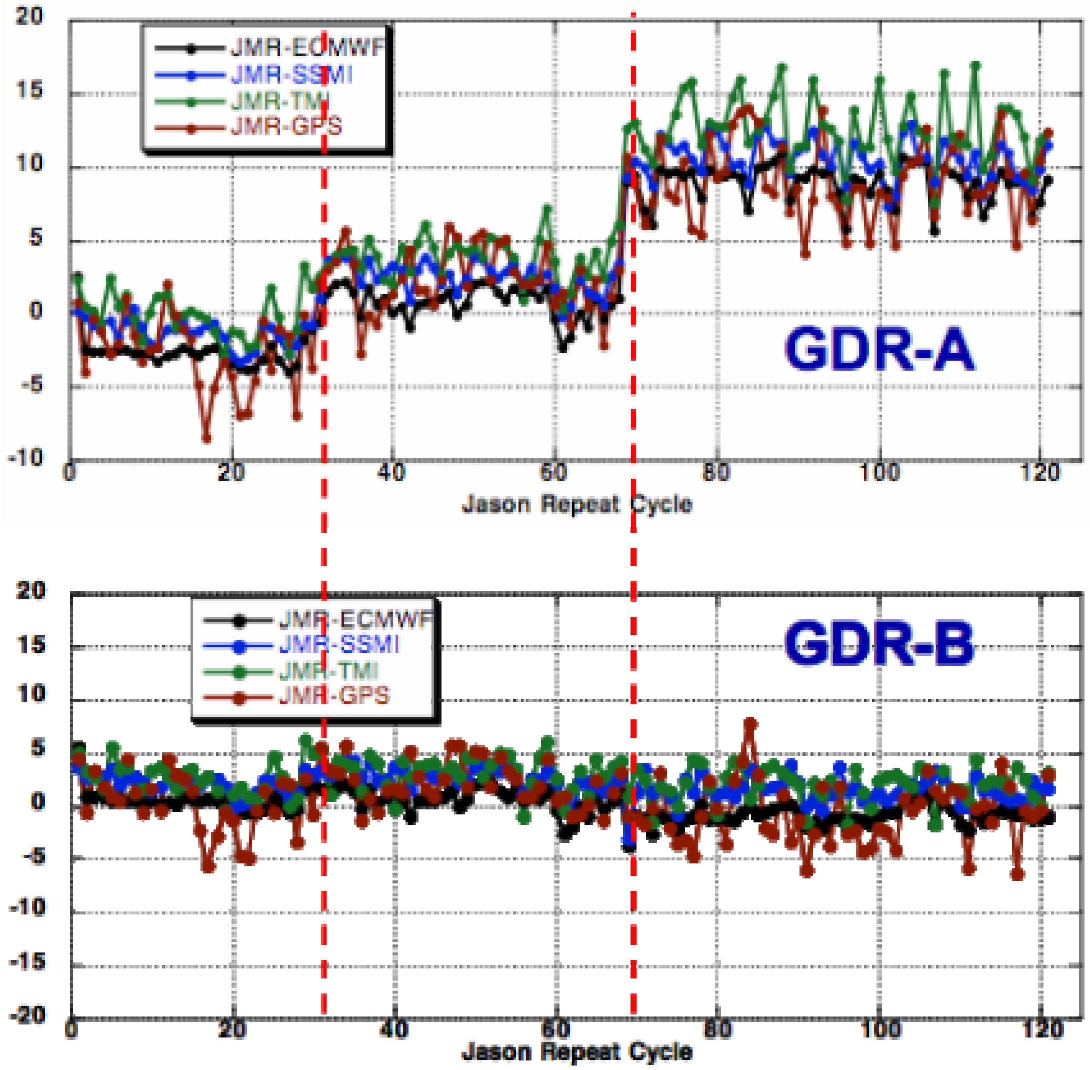


Figure 6. JMR wet path delays minus GPS, SSMI, TMI and model derived ones (*Desai et al.* and *Brown et al.*).

Global GDR-B validation

Ablain et al. presented a complete review of the improvements attributable to GDR-B, but also noted a few anomalies. They observed, for example, that the 0.173 ms time shift added in the GDR-B Level-1B processing creates a hemispheric bias (see "*Conclusions and Recommendations*"). Their overall conclusions are:

- New geophysical corrections, new orbit, and new retracking enable better characterization of the oceanic signal:
  - Differences between ascending and descending passes are reduced
  - SSH variance is significantly reduced: Variance gain = 21 cm² ⇔ 35 % (Figure 7)
- Consistency with T/P is better thanks to these improvements (see *Dorandeu et al.*)

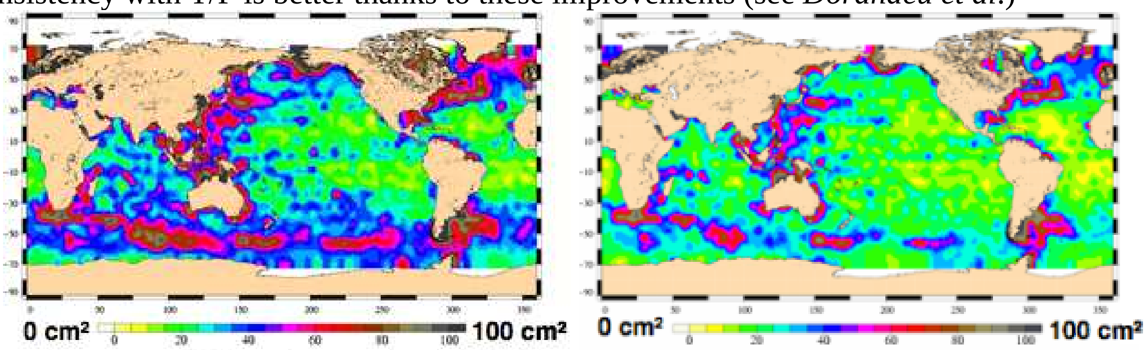


Figure 7. Crossovers SSH variance using GDR-A (left) and GDR-B (right).

TOPEX/Poseidon (MGDR / RGDR-1&2)

Sea-Surface Height Biases

Table 1. Jason-1 SSH biases from calibration studies

Site	MGDR (mm)	RGDR (1 / 2) (mm)	Number of cycles	Reference
Harvest	+3.6 ±8.2	+2.5 ±9,7 / -38+6±11.5	16	*Haines et al.*
Corsica	-4.6 ±8.1	-23.5 ±7.5 / -37.2 ±11.3	13	*Bonnefond et al.*
Bass Strait*	-0.5 ±3.5	-11.1 ±5.9	17	*Watson et al.*

*Using only new orbits from RGDR

For the new T/P products (retrackings and orbits) complete results are available from only the *Haines et al.* and *Bonnefond et al.* studies (*Watson et al.* have analyzed the new orbit solutions, but not the retracked data.). The impact of new POE orbits (GSFC) has been studied separately and decreases the bias by about -10 mm on the average for the 3 calibration sites. Concerning the retracking, while the LSE algorithm (RGDR-1) does not significantly change the bias (+4.9 and -5.9 mm respectively for Harvest and Corsica), the MAP algorithm (RGDR-2) introduces a significant bias (-36.2 and -19.6 mm respectively for Harvest and Corsica). Moreover, the scatter is increased when using the MAP retracking. These are only preliminary results and they need to be further investigated with more complete products (e.g., updated retracked ranges, as well as attendant ionospheric and SSB corrections) and longer time series.

TMR

Desai et al. and *Brown et al.* reported on the status of the TMR recalibration and its validation (Figure 8); their conclusions are:

- ECMWF model on T/P GDRs is biased 6.6 mm drier than on J1 GDRs.
- TMR has geographically correlated errors where WPD gradually becomes too wet by > 4–6 mm as land is approached (Figure 9). This effect can be seen as far as 600 km from land, and is likely due to the algorithmic treatment of land contamination of the TMR side lobes.
    - Should be correctable by applying JMR's APC algorithm (e.g. E. Obligis) to TMR.
- TMR drift appear to span cycle 30-280 with cumulative effect of 5-6 mm (0.7-0.9 mm/year).
    - Caused by drifts in all 3 channels, but primarily 18 GHz channel.
- TMR has 4 mm peak to peak dependence on satellite attitude regime.
- Recalibration of TMR is ongoing by S. Brown and expected to remove drift and satellite attitude regime effects.
    - Are already using new APC algorithm.
    - Will be used on P. Callahan's end-of-mission GDR.

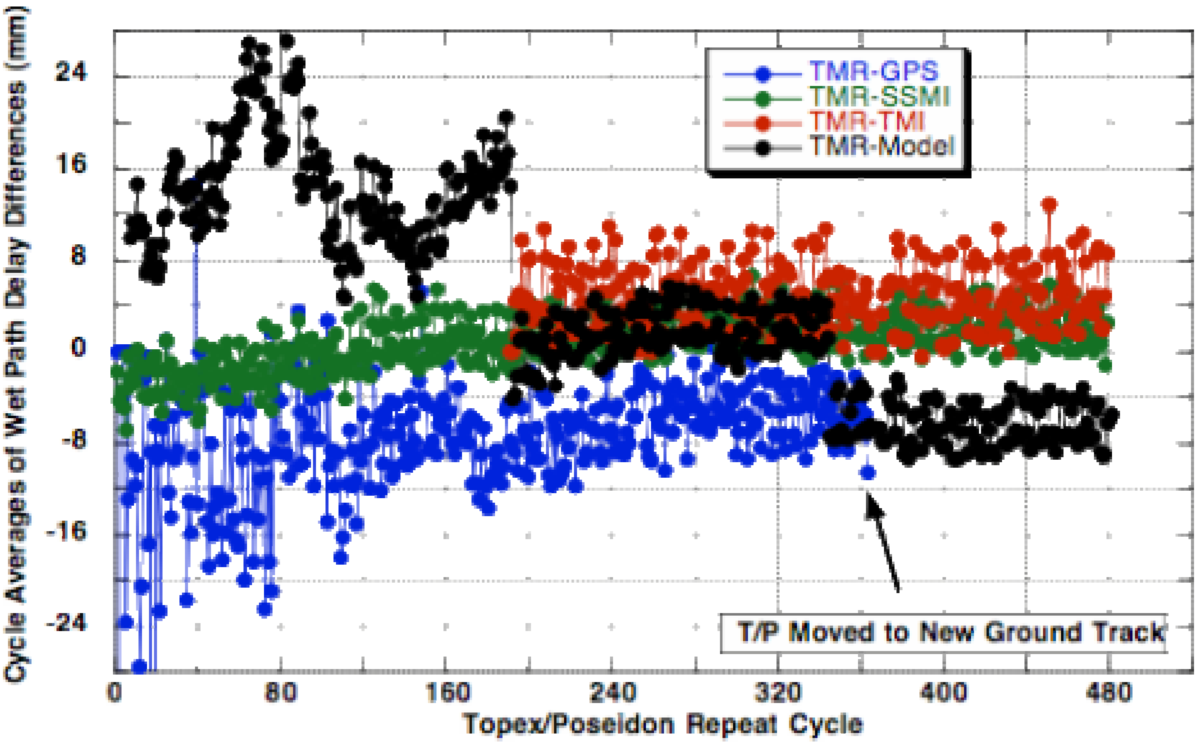


Figure 8. TMR wet path delays (positive) minus GPS, SSMI, TMI and model derived ones (*Desai et al.*).

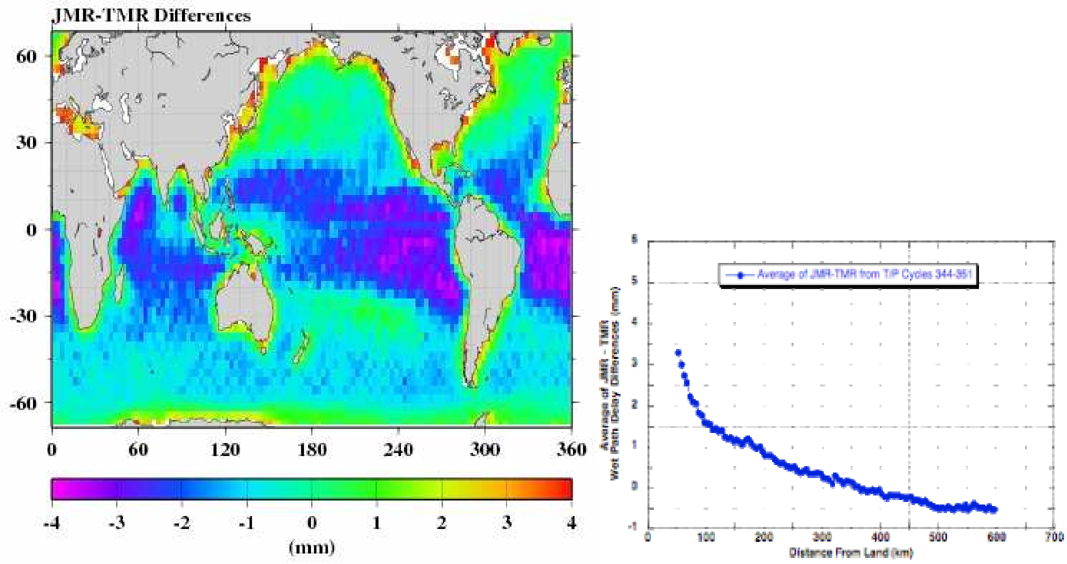


Figure 9. JMR-TMR distance from land correlation (*Desai et al.*).

Obligis et al. showed that important errors on the wet tropospheric correction due to Topex/TMR and Envisat/MWR retrieval algorithms still exist. Their conclusions are:

- Local biases correlated with high wind speed situations
  - The 18GHz channel of the TMR does not correct for all the roughness effects
  - =>Necessity to add the altimeter wind speed or backscattering coeff (better)
  - NN particularly adapted
- Constant bias in the Eastern part of the subtropical basins (Figure 10)
  - Radiometer dh overestimated by more than 1 cm
  - Highly correlated with the lapse rate
  - =>Necessity to use a priori information on the atmospheric profile (ECMWF) in the retrieval algorithm (Figure 11)
  - NN formulation

- 13 years of TOPEX sea level maps are biased by more than 1 cm in these particular areas. JMR should also be affected and this has to be studied.

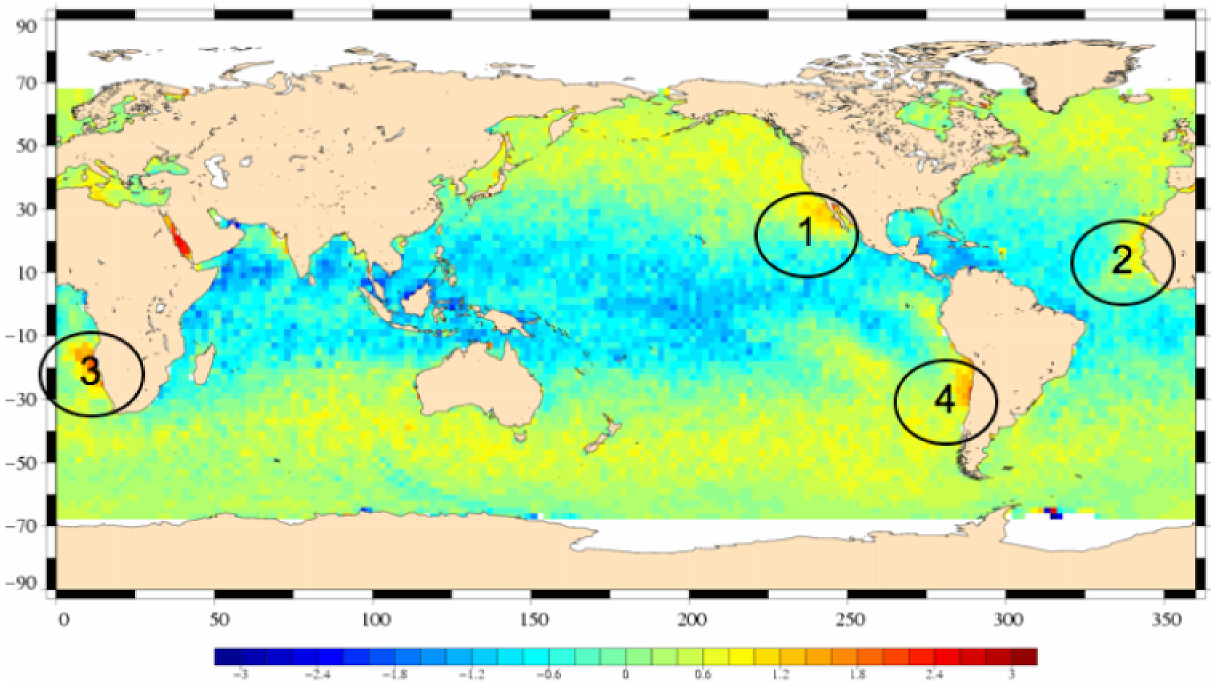


Figure 10. TMR wet path delays (positive) minus ECMWF model derived ones (*Obligis et al.*).

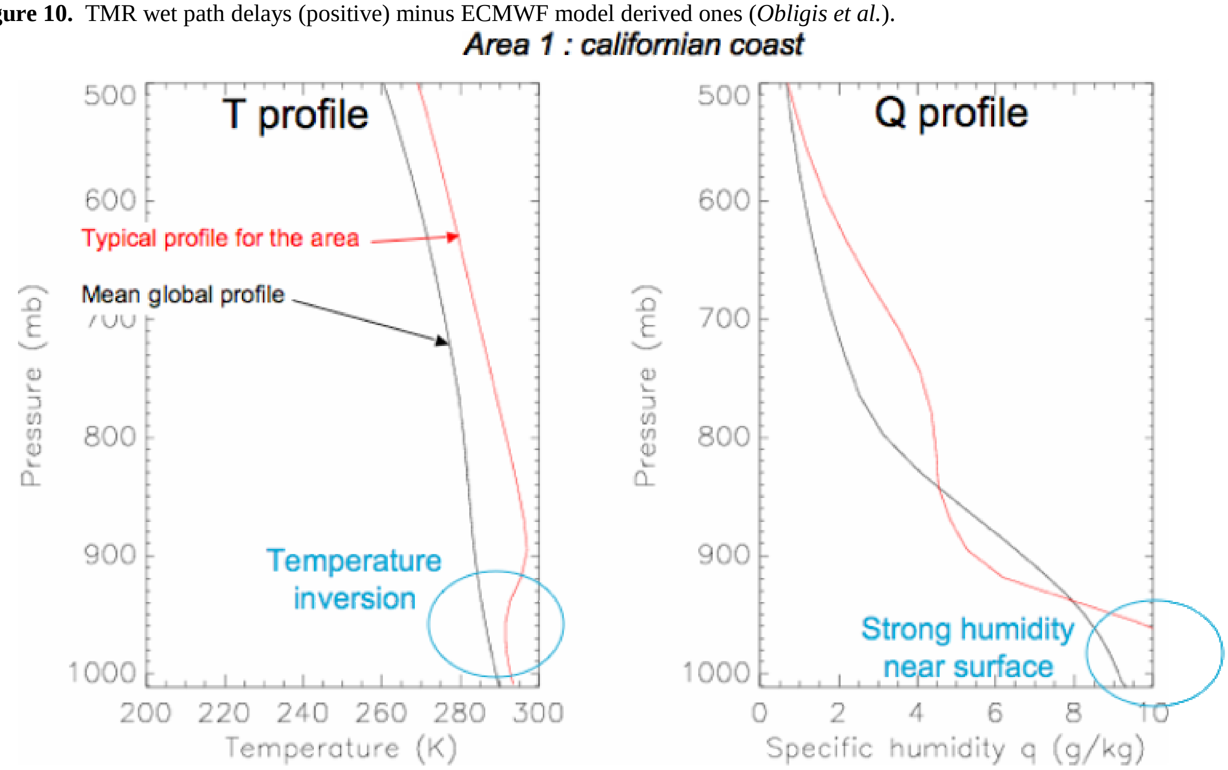


Figure 11. Example of special signature in the temperature and humidity profiles near the Californian coast (*Obligis et al.*).

Another study which is being conducted by a PhD student was presented by *Obligis et al.*. Radiometer contamination by the signal coming from the surrounding land surfaces (with a strong and very time variable emissivity) leads to inaccurate humidity retrieval, because retrieval algorithms implicitly rely on sea surface emissivity models. New algorithms are under development but will not be available for the T/P or Jason-1 reprocessing schedule.

T/P & Jason-1 formation flight phase consistency

Sea-Surface Height Biases

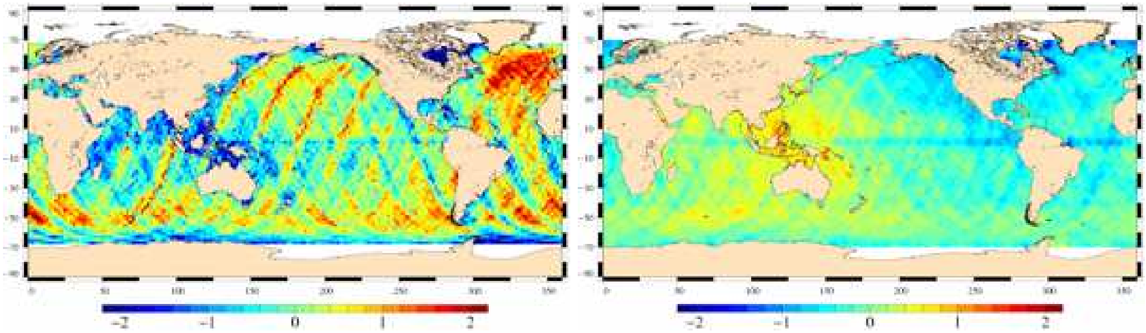


Figure 12. SSH differences between Jason-1 and TOPEX/Poseidon using MGDR/GDR-A (left) and RGDR/GDR-B (right) (*Dorandeu et al.*).

Dorandeu et al. presented a review of the SSH differences between Jason-1 and T/P during the formation flight phase, and their origins and improvements thanks to new products, (Figure 12). They observed:

- Large improvements from new orbits for both TOPEX and Jason-1
  - Reduction of apparent trackiness
  - New signals can now be detected (SSB differences, North/South – ascending/descending signals on TOPEX)
- Improvements from Jason-1 MLE-4 retracking algorithm (P. Thibaut): reduction of (TOPEX-Jason-1) variance
- MLE-5 TOPEX retracking:
  - Strongly reduces the differences between TOPEX and Jason: SSB estimations are now much more consistent
  - But large ascending/descending hemispheric signals still exist in TOPEX data
  - MLE-5 TOPEX retracking:
- New SWH for T/P and Jason-1:
  - homogenization of SWH
  - Slight improvement near coasts
  - Reduction of mean bias (from 8.2 to 5.2 cm)
  - But hemispheric bias when separating asc/desc passes

Beckley et al. presented a detailed analysis of the impacts of orbits, SSB and retracking. First of all, the GSFC JGM3 replacement orbits for Jason-1 GDR_A and for T/P MGDR_B decrease the standard deviation of the relative SSH bias from 7.8 to 5.0 mm. Most of the trackiness and South large patterns are removed but some geographically correlated errors still remain (Figure 13). Further reduction of the geographically correlated error was shown with GSFC replacement orbits based on GGM02c.

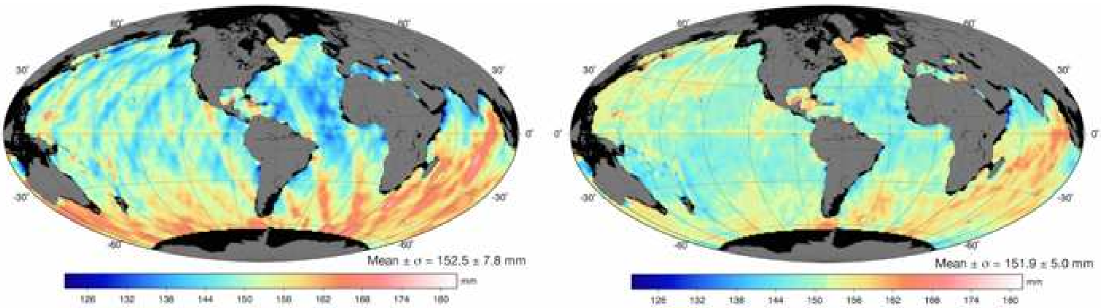


Figure 13. Left Figure presents SSH differences between Jason-1 (GDR-A) and TOPEX (MGDR with revised SSB). Right Figure presents the same SSH differences but with reduced dynamic JGM3 orbits based on a consistent ITRF2000 reference frame from GSFC for both Jason-1 and TOPEX (*Beckley et al*.).

SSH comparison of Jason-1 GDR_B with TOPEX MGDR_B with GSFC GGM02c dynamic TVG replacement orbits for both further reduces the standard deviation to 4.1mm. Note that the mean relative bias (106.5 mm, Figure 14) is very close to the one derived from in-situ studies (95 mm, see "*Jason-1 Sea-Surface Height Biases*" section assuming T/P is not statistically different from 0). *Beckley et al.* stated that this is probably the best current solution that does not employ TOPEX GCP retracking, and that further improvement is foreseen with a consistent non-parametric SSB correction for both TOPEX and Jason-1 based on the GSFC GGM02c dynamic_tvg orbits. Note the absence of the east/west hemispherical offset as seen in Figure 12, due to the consistent orbit strategy.

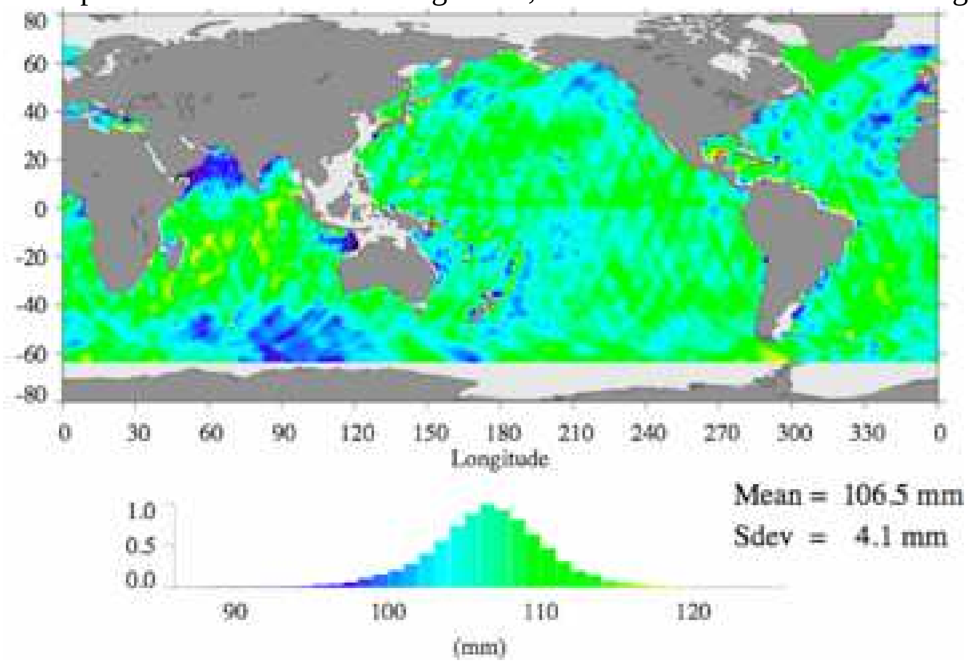


Figure 14. SSH differences between Jason-1 (GDR-B, dynamic TVG orbits from GSFC) and TOPEX (MGDR with revised SSB and dynamic TVG orbits from GSFC) (*Beckley et al*.).

Finally, the new retracking for T/P (LSE and MAP) is analyzed (Figure 15). Results show strong hemispheric patterns between ascending and descending passes probably due to Waveform leakages.

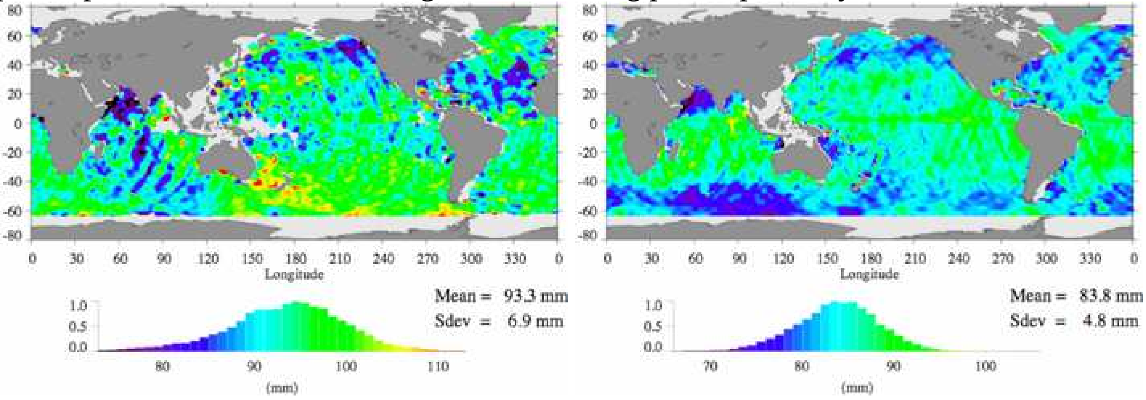


Figure 15. SSH differences between Jason-1 (GDR-B, dynamic TVG orbits from GSFC) and TOPEX/Poseidon (RGDR with SSB LSE retracking and dynamic TVG orbits from GSFC): respectively from LSE (left) and MAP (right) algorithms (*Beckley et al*.).

Beckley et al. in their conclusions listed the improvements to be done before reprocessing:

- Revised GSFC Replacement Orbits
  - TOPEX reduced dynamic_tvg (GGM02c)
  - Jason-1 GPS reduced dynamic_tvg (GGM02c)
  - Improved reference frame, center of mass, time variable gravity
- Sea State Bias
  - "Tune" NP SSB with additional regional correlatives beyond just U and SWH from WAM model (Tran, et al.)
- Model/remove TOPEX Waveform leakages; challenging task but worthwhile investment in order to generate credible Climate Data Records.

OTHER STUDIES

Faugère et al. presented results from the cross-calibration of EnviSat and Jason-1, and listed the improvements and remaining problems in the new products (Figure 16):

- Better consistency of Envisat and Jason-1 is achieved in the new GDR configuration thanks to improvements in:
  - Orbit
  - Geophysical corrections
  - MLE4 retracking
- Still under investigation are the following issues:
  - Envisat/Jason-1 global mean differences during early cycles
  - Geographical differences between Envisat and Jason-1 (Figure 16)

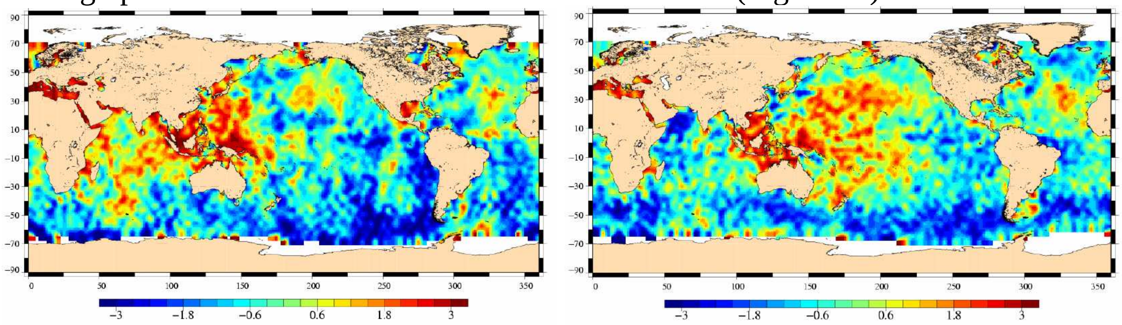


Figure 16. SSH differences between EnviSat and Jason-1 (GDR-A at left; GDR-B at right) (*Faugère et al.*).

They also presented a detailed analysis of the Mean Sea Level trends from various missions (Figure 17). Except for the early EnviSat cycles, results are very coherent.

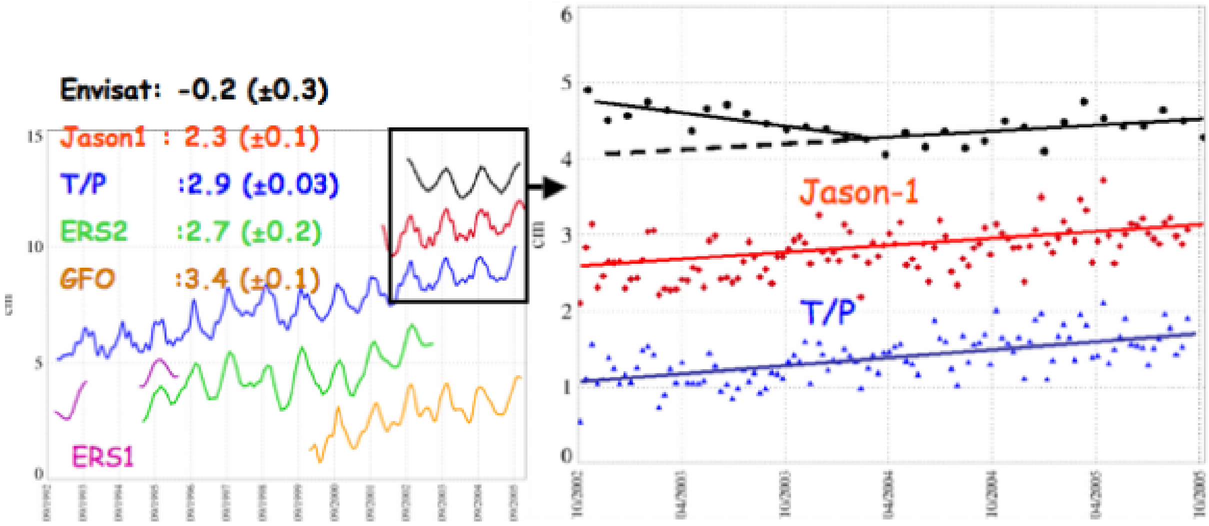


Figure 17. MSL trends for EnviSat, Jason-1, T/P, GFO and ERS-1 (*Faugère et al.*).

Scharroo et al. presented a comparative study of the radiometers on-board Jason-1, TOPEX/Poseidon and EnviSat (Figure 18). They offered the following conclusions concerning the EnviSat MWR:

- Is there a drift? *Yes*
    - Instrumental parameters and wet tropospheric corrections indicate a drift
- Which channel is responsible for the drift? *Uncertain*
    - Depends on how the earlier cycles are dealt with
    - Effect of TB23 drift twice as large (and opposite sign) of TB36 drift
    - TB36 drift may be more complex than previously thought; non-linear dependence on TB23
- For time being?
    - Correct TB23 up by 0.257 K/year
    - Correct SLA up by 1.4 mm/year

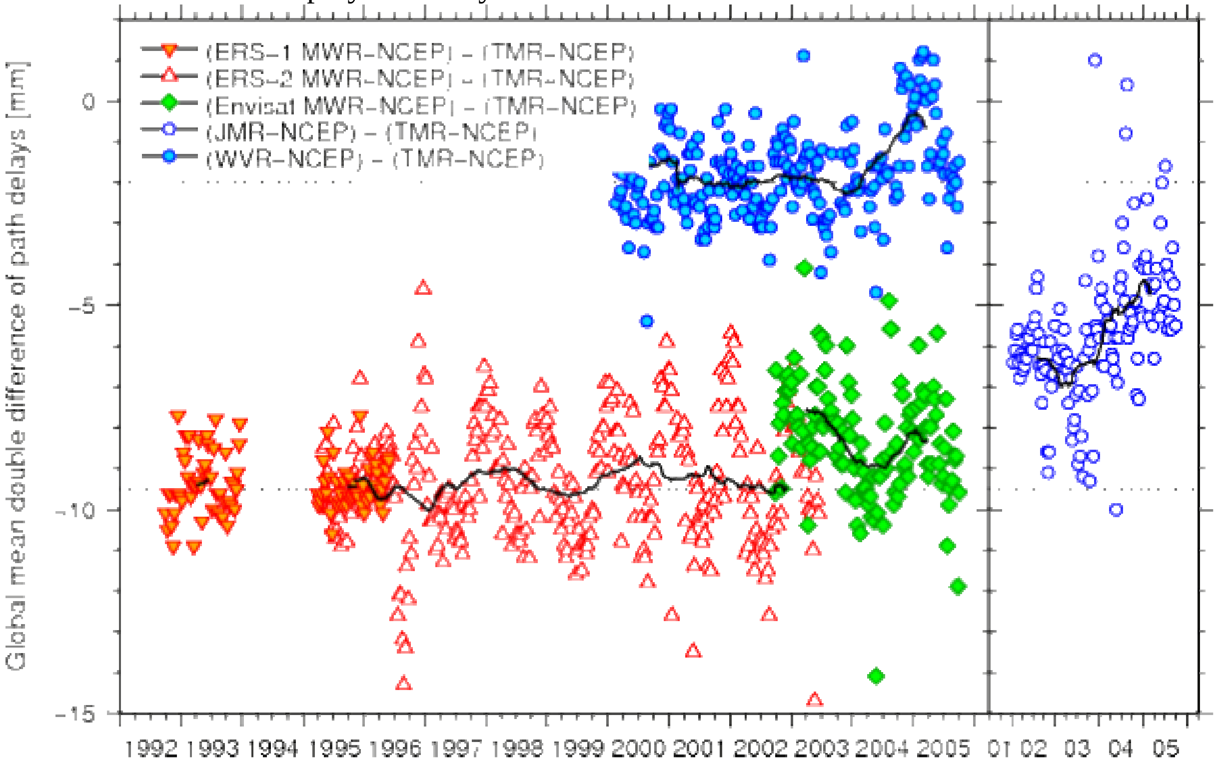


Figure 18. Radiometer behaviors compared to TMR (*Scharroo et al.*).

Leuliette et al. presented a detailed analysis of the impact of the new T/P and Jason-1 products on studies of global mean sea level (Figure 19). They arrived at the following conclusions:

- The standard deviation of the relative TOPEX/Jason bias during the formation flying phase has increased from 1.6 mm to 2.6 mm.
    - This contributes an uncertainty of 0.23 mm/yr to the overall trend (versus 0.13 mm/yr from prior data).
    - It is expected this will drop when TOPEX corrections are updated to the Jason GDR-B standards and JMR wet path delay updated.
- TOPEX retracking appears to have not completely removed spatial variations of the bias.
    - The MAP reduces the spatial bias more than LSE
- The drift in Jason sea level compared to tide gauges (GDR-A+JMR and GDR-B) is not statistically significant.
    - Near the edge of the significance
    - Below the mission goal of 1 mm/yr

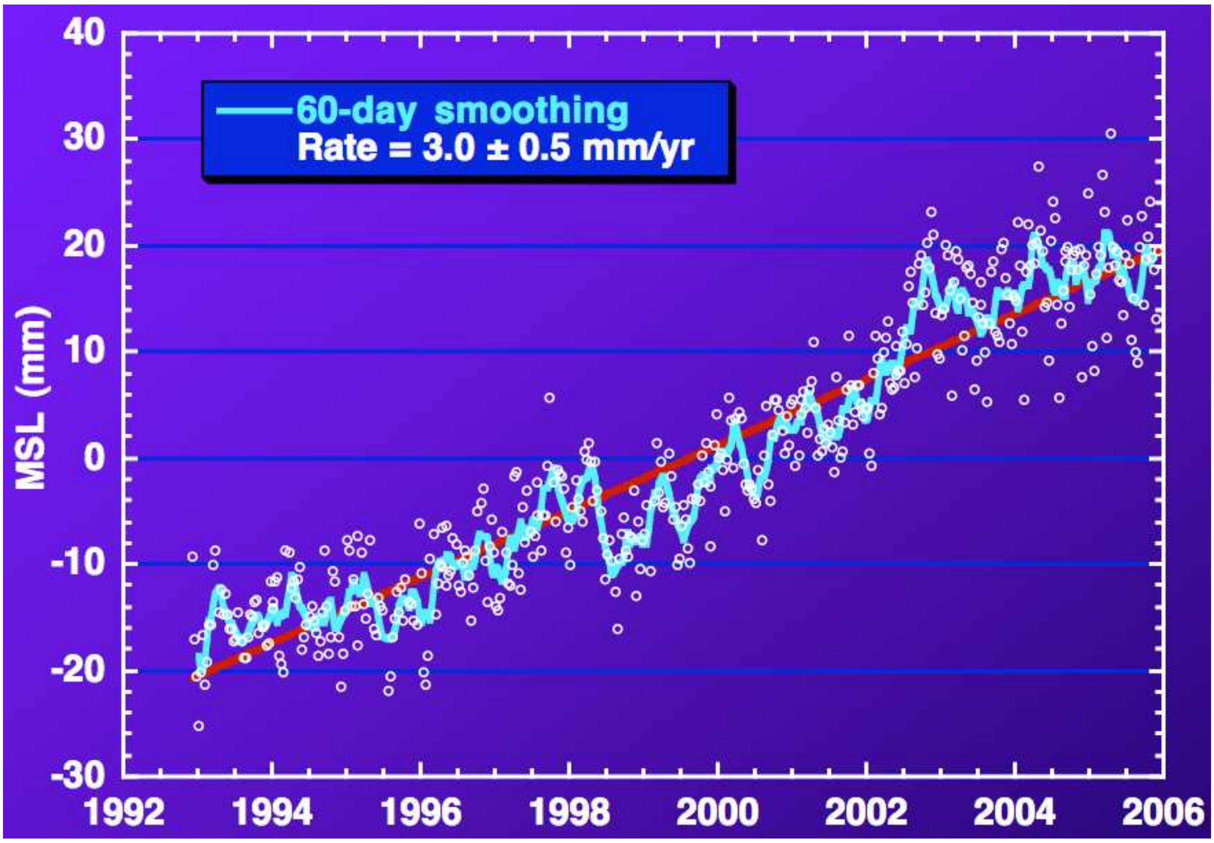


Figure 19. Mean Sea Level trend from T/P and Jason-1 new products (*Leuliette et al.*).

Shum et al. gave an update of the Jason-1 and T/P calibration over Lake Erie, which is summarized below:

- Lake Erie calibration site is established for calibration for JASON-1 providing the similar results (Cycles 1-134) to that of the dedicated sites.
- No valid lake surface height measurements are found at three bins near Marblehead from the Version B of JASON-1 GDR (Cycles 135-145, 2005/09 – 2005/12) .
- The surface gradient estimates from Marblehead gauge to three altimeter bins are consistent with GEOID03 model of NGS.
- Dependence of RA biases on EMB models needs to be further studied.

Watson et al., in their presentation on the updated Jason-1 calibration results at Bass Strait, also presented an interesting study which used the EOF reconstruction technique, together with fast-delivery tide-gauge data from the University of Hawaii Sea Level Centre (UHSLC), to estimate GMSL forward from February 1999 (end of TOPEX A-side) through to the end of 2004. The offset between Jason-1 GMSL for 2002-2004 and the tide-gauge derived GMSL for the same period was within a couple of mm of the known offset (Figure 20). This is preliminary work, but indications are that we may be able to match up altimeter GMSL time series across a gap of a few years to around 1 cm or so.

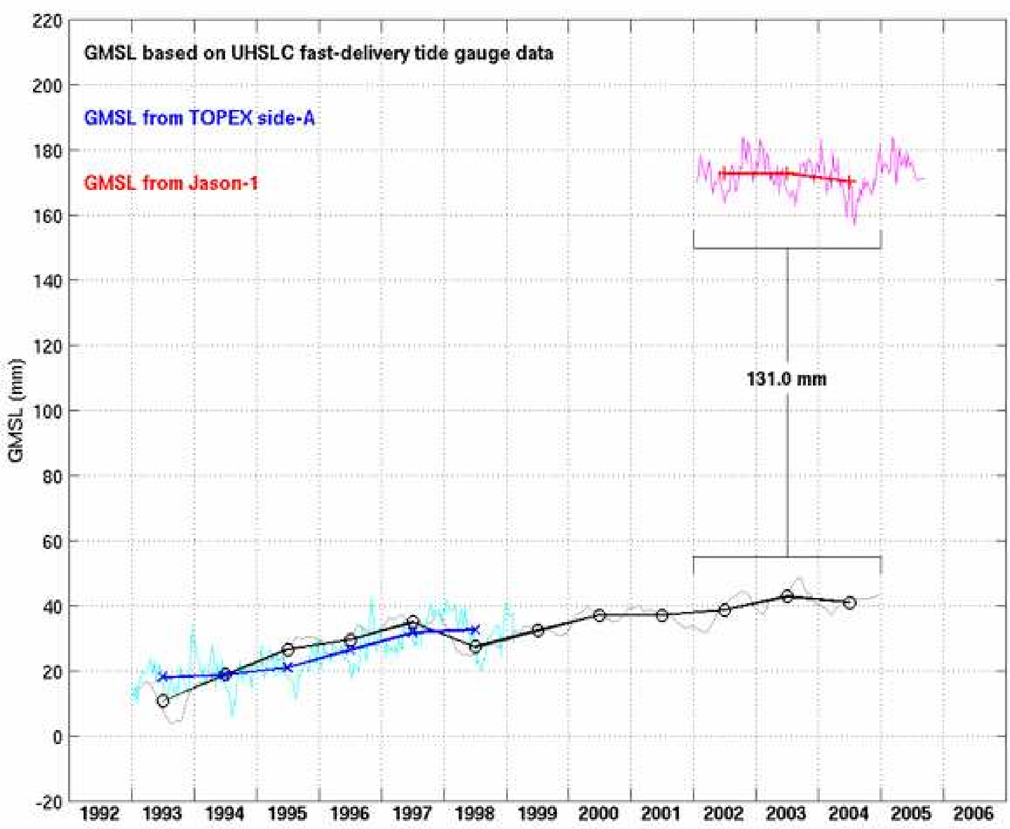


Figure 20. Jason-1 altimeter bias from a simulated data gap between T/P Side-A and Jason-1 phases (*Watson et al.*).

Foster et al. presented a study of the regional trends as observed from tide gauges with GPS monitoring and compared to altimeter data. They gave the following conclusions:

- CGPS@TG data sets are now long enough to get some meaningful regional vertical trend estimates
- Homogeneous reprocessing of entire global GPS network needed before meaningful global estimates can be made
- Some regional estimates show encouraging correspondence with altimeter/tide-gauge differences
- Persistent scatterers technique show promise as a tool for investigating local variations in vertical land motion

CONCLUSIONS AND RECOMMENDATIONS

Data consistency and accuracy

- There is a signifcant improvement in terms of data accuracy for Jason-1 and in the consistency between Jason-1 and T/P. For the MSL trend, there is nearly a seamless transition between the two missions.
- There remain important geographically correlated errors in the T/P data (ALT-B), which principally manifest as hemispherical biases on ascending vs. descending tracks. For more details on these effects, which are thought to be attributable to waveform leakages in the ALT-B data, see the conclusions of the splinter "Sea-State Bias and Retracking Analysis".
- Some minor anomalies and behaviors are still encountered:
    - Dry Tropospheric and Inverse Barometer corrections derived from Meteorological files in coastal areas are still impacted by oscillation effects (related to incorrect management of the bathymetry/topography altitude).
    - A residual bias in the Jason-1 time tag induces a small hemispheric signal to both SSH and SSB.

- The JMR will be recalibrated to correct for a slight drift (~1 mm/yr) and to correct for anomalies after cycle 136 safe hold
- TMR recalibration, including an updated APC algorithm, is expected to remove remaining drift, yaw state dependence and geographically correlated errors.
- To achieve better consistency between the T/P and Jason-1 orbits, the use of identical gravity fields may be required (see conclusions of splinter on POD splinter).
- Geographically correlated errors in the ENVISAT – Jason-1 differences will be investigated in close cooperation with ESA.

• The following enhancements will soon be implemented for Jason-1:
  - Cross-track gradient correction
  - SGDR product evolutions
  - GIM ionospheric correction inside level2 products
  - Product naming convention (remove ".NASA" or ".CNES")

• Timeline
  - We are waiting for final recommendation from retracking comparison team before proceeding with GDR version C (?)

Questions and answers

Is there any improvement to be done before complete reprocessing ?

	TOPEX/Poseidon	**Jason-1**
Orbit	see POD splinter summary	see POD splinter summary
Range (retracking)	See retracking plan MAP or LSE? (fix the waveforms problems to "remove" the hemispheric patterns)	MLE4 is adopted for reprocessing See retracking plan (cf T/P)
Ionospheric	Need to wait for retracking	Need to wait for retracking
Dry tropo.	Same as Jason	Some minor coastal pb have to be solved
Wet model	See dry tropo One request is to have a Consistent meteo model for the whole missions (ECMWF now quality for early years)	See dry tropo
Wet tropo. Rad	Errors in the atm. Profiles (See *Obligis et al.* studies)	Should exist in JMR too (this have to be checked)
SSB	Wait for MAP or LSE (one year of data)	Ready from MLE4 retracking
	Further investigation is needed for in-land water studies (see *Shum et al*. study)	
Geophysical corrections	Current GDR-B Jason standards Geoid=> see POD splinter recommendations	Current GDR-B Jason standards Geoid=> see POD splinter recommendations

Are we now able to link T/P and Jason-1 time series with the formation flight phase?

Be aware of the differences between global, regional and local applications. Global bias?

"Geographical" bias?

Is this period sufficient or do we need to increase it for Jason-1 / Jason-2?

Close to a year would be better. Need to balance CALVAL and high-resolution interests.

Are we able to deal with mission gaps?

Cross calibration if any satellite survives

Using the tide gauges network: about 1.5cm error bar for a 4-year gap. Can be improved by combining results from absolute calibration sites (they strengthen the solution in terms of bias but also drift).

EOF analysis derived from tide gauges (see *Watson et al.* study)

Absolute calibration sites can really contribute, but we must contend with GCE (e,g, see POE drift).

What is the impact of the possible change of orbit for Jason-3?

At least try to fit the orbit to one or more calibration sites.

Better than any gap between Jason-2 and Jason-3

Not a sun synchronous orbit

Find a compromise for the repeat period.

Try to change the period to avoid the 60-day aliasing.

Better define before what we really want (high resolution, long consistent time series, ...)

From tide gauges calibration studies, geoid slopes will not be cancelled but it's a short-term issue (beginning of the mission) and should be solved.

TALKS

All the presentations can be found at:
http://grasse.obs-azur.fr/cerga/gmc/calval/alt/SWT_Venice_2006/

First part: in-situ and regional (Chairmen: P. Bonnefond, B. Haines & S. Nerem)

Algorithms and models evolutions from Jason-1 GDRs Va to Vb

Dr Nicolas PICOT, Dr Shailen DESAI

Monitoring Jason-1 and TOPEX/POSEIDON from an Offshore Platform: Latest Results From the Harvest Experiment

Dr Bruce HAINES, Dr George BORN, Dr Shailen DESAI, Mr Stephen GILL

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

Dr Pascal BONNEFOND, Dr Pierre EXERTIER, Mr Olivier LAURAIN, Dr Yves MÉNARD, Dr François BOLDO, Dr Gwenaele JAN

Jason-1 absolute calibration: Update from Bass Strait, Australia

Dr Christopher WATSON, Dr Neil WHITE, Dr Richard COLEMAN, Dr John CHURCH

Eastern Mediterranean Dynamics and JASON-1 Altimeter Calibration Results from the GAVDOS Project

Prof Erricos C. PAVLIS, Prof Stelios P. MERTIKAS, The GAVDOS TEAM

Calibration of JASON-1 and T/P Over Lake Erie: An Update

C.K. SHUM, K. CHENG, Y. YI, C. KUO, S. CALMANT, A. BRAUN

Experiences on Altimeter Calibration at Ibiza Island and Cape of Begur (Spain)

Juan Jose MARTINEZ BENJAMIN, Marina MARTINEZ GARCIA, Miquel Angel ORTIZ CASTELLON, Julia TALAYA, Anna BARON, Gema RODRIGUEZ VELASCO, Jose MARTÍN DAVILA, Jorge GARATE, Pascal BONNEFOND, Cristina GARCIA and the IBIZA2003 Team

Jason-1 sea surface height bias with Corsica tide gauges network

Dr Gwenaële JAN, Dr Yves MENARD, Dr Pascal BONNEFOND, Mr Olivier LAURAIN, Mr Laurent ROBLOU

Regional Trend Estimates at CGPS@TG Stations
Dr James FOSTER, Dr Mark MERRIFIELD, Dr Michael BEVIS, Dr Benjamin BROOKS

Second part: global (Chairmen: S. Desai & N. Picot)

Analysis of version B Jason-1 GDRs / TP retracked GDRs consistency
Mr Joël DORANDEU, Mr Michaël ABLAIN, Dr Nicolas PICOT, Dr Juliette LAMBIN

Global Statistical Quality Assessment of Jason-1 data and Jason-1 / TOPEX/Poseidon Cross-calibration
Mr Michaël ABLAIN, Mr Joël DORANDEU, Mr Yannice FAUGERE, Dr Nicolas PICOT, Dr Juliette LAMBIN

Evaluation of TOPEX/Jason-1 Consistency Issues
B.D. Beckley, N.P. Zelensky, S.B. Luthcke, R.D. Ray, F.G. Lemoine, P.S. Callahan, S. Labroue, N. Tran

Jason-1 / Envisat Cross-calibration
Mr Yannice FAUGERE, Mr Joël DORANDEU, Mr Michaël ABLAIN, Dr Nicolas PICOT

Status of the JMR/TMR Recalibration Effort: Algorithm Improvements and the Optimal Calibration System
Dr Shannon BROWN, Mr Shailen DESAI, Mr Steve KEIHM, Dr Christopher RUF

Validation of Jason and Topex Microwave Radiometer Wet Path Delay Measurements using GPS, SSM/I, and TMI
Dr Shailen DESAI, Dr Bruce HAINES, Dr Wenwen LU, Dr Victor ZLOTNICKI

Geographical analysis of systematic errors in the wet tropospheric correction
Dr Estelle OBLIGIS, Dr Laurence EYMARD, Dr Ngan TRAN, Ms Sylvie LABROUE

Comparison of the Radiometers of TOPEX, Jason-1 and Envisat
Dr Remko SCHARROO and Dr John LILLIBRIDGE

Impact of Version-B GDRs on Mean Sea Level
Dr Eric LEULIETTE, Prof Steve NEREM, Prof Gary MITCHUM

Precise Orbit Determination and Geoid

(co-chaired by J.P. Berthias and J. Ries)

March 17, 2006

Introduction

The primary goal of the POD/geoid splinter meeting was to finalize the selection of standards that will be used to produce the Jason-1 GDRs (new GDRs as well as reprocessed GDRs). The search for the best POD standards and geoid models has been on the agenda of the POD/geoid working group for the last 4 to 5 years. Over the years models keep improving, however we can now see that the GRACE contribution to the Jason orbit error improvement has reached a plateau. Simultaneously, we now have enough confidence in the fact that the 1 cm goal has been reached, so as to be able to settle on a choice of standards.

A partial upgrade of the POD standards was thus implemented in September 2005 based on the results of the previous OSTST meeting. These intermediate standards were put in place in order to provide altimetry users with improved products (GDR-b) in preparation for this meeting. As an indirect consequence of this upgrade, the old “TOPEX standards” have disappeared. The POD working group has therefore been able to focus its attention to the more subtle differences that appear between all the GRACE-era orbits.

From centimeter to millimeter

Traditionally many set of orbits are produced by POD working group members in preparation of OSTST meetings. Over the years, differences between these orbits have been slowly decreasing, as models and orbit quality improves. For this meeting, ten sets of orbits were available, some of them spanning the whole life of Jason-1.

Thanks to the change in standards in the official production orbits (GDR orbits), there were no more old orbits included in the comparisons (that is, orbits using the pre-GRACE “TOPEX standards”). Consequently, all of these orbits compare at 7 to 14 mm radially. This is an excellent level of agreement given the fact that data, models and software used to produce the orbits are significantly different between groups.

Table 1. Orbits submitted for comparison

Group	Data	Gravity	Tides	Parametrization	Time span (cycles)
UT/CSR	SLR, DORIS	GGM02C	FES2004	dynamic; daily 1/revs, 8-hour drag	1 - 90
NASA/GSFC	SLR, DORIS	GGM02C	FES2004	dynamic; daily 1/revs, 8-hour drag	1 - 135
NASA/GSFC	SLR, GPS	GGM02C	GOT00.3	reduced-dynamics	8 - 21
NASA/JPL	GPS	GGM02C	GOT00.3	reduced-dynamics	1 - 146
CNES (GDR-b)	SLR, DORIS, GPS	EIGEN - CG03C	FES2004	dynamic; 12 hour 1/revs, 2-hour drag	1 - 21 110 - 145
CNES	GPS	EIGEN - CG03C	FES2004	dynamic; 12 hour 1/revs, 2-hour drag	1 - 135

The good agreement between all of the orbits is a clear indication that models have fully converged at this level of precision. In particular, differences between recent releases of gravity fields are so small that they hardly show up in the orbits. Even though the CNES GDR-b orbits use the EIGEN-CG03C gravity model while the latest JPL ‘reduced dynamics’ orbits are based on GGM02C, the level of geographically correlated differences is very low. Figure 1 shows the mean orbit difference between the JPL GPS reduced-dynamics and the GDR-b orbits over two sets of cycles. The maximum mean difference is at the 5 millimeter level; in most places the differences are 2 millimeter or smaller. This is consistent with the sub-millimeter error level predicted from the gravity field covariance. At this point, differences in the other background gravity models (solid earth and ocean tides, pole tide, non-tidal gravity variations) are likely to start to become apparent.

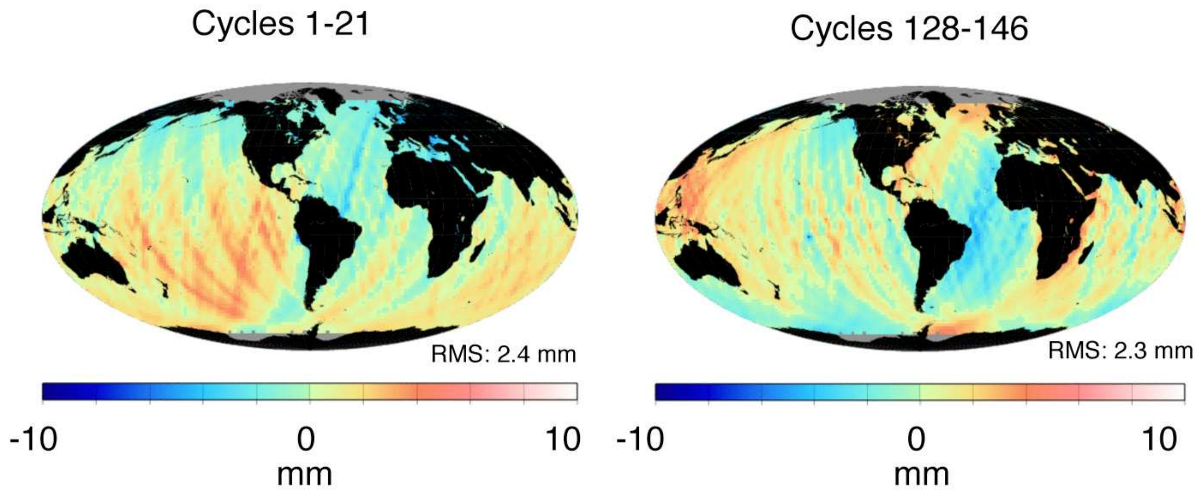


Figure 1. **Geographic Radial Comparison to GDR-B in 2°x2° Bin Averages (courtesy W. Bertiger)**

Even though all of the orbits are very close, GPS 'reduced-dynamics' orbits still consistently outperform the other solutions in altimeter crossovers tests. In addition, this technique leads to strikingly similar orbits whether they are computed using double-differences at NASA/GSFC or undifferenced data at NASA/JPL. The high elevation SLR residual test on these orbits confirm 10 mm or better absolute accuracy (Figure 2). Note that the SLR data were not used in the orbit determination and thus provide a completely independent test.

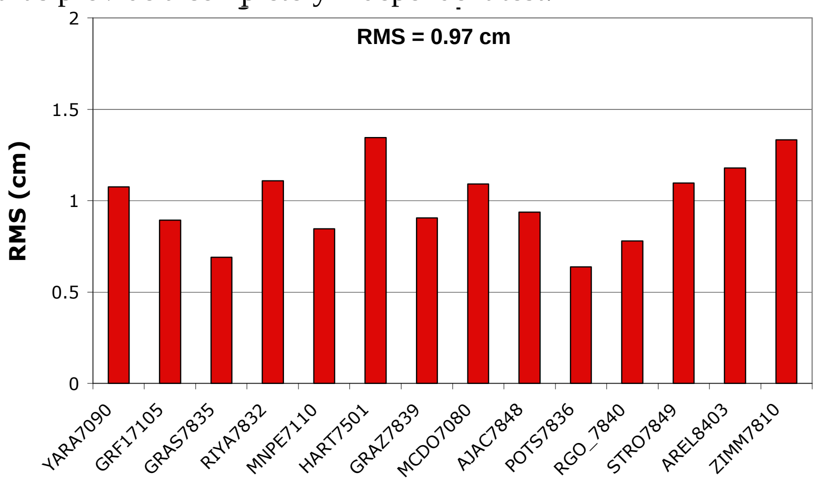


Figure 2. **High elevation SLR residuals for the NASA/GSFC GPS reduced-dynamics orbits (courtesy S. Luthcke)**

At that level of accuracy, and with long time series available for analysis, small systematic differences appear more clearly than ever before. In particular, the Z shift between the various orbits, which looked like noise in the past, now reveals clear structures. Most significantly, GPS-only orbits from CNES and JPL exhibit a centimeter level periodic Z shift when compared with DORIS/SLR orbits. Annual and 120-day signals are the main contributions to this signal.

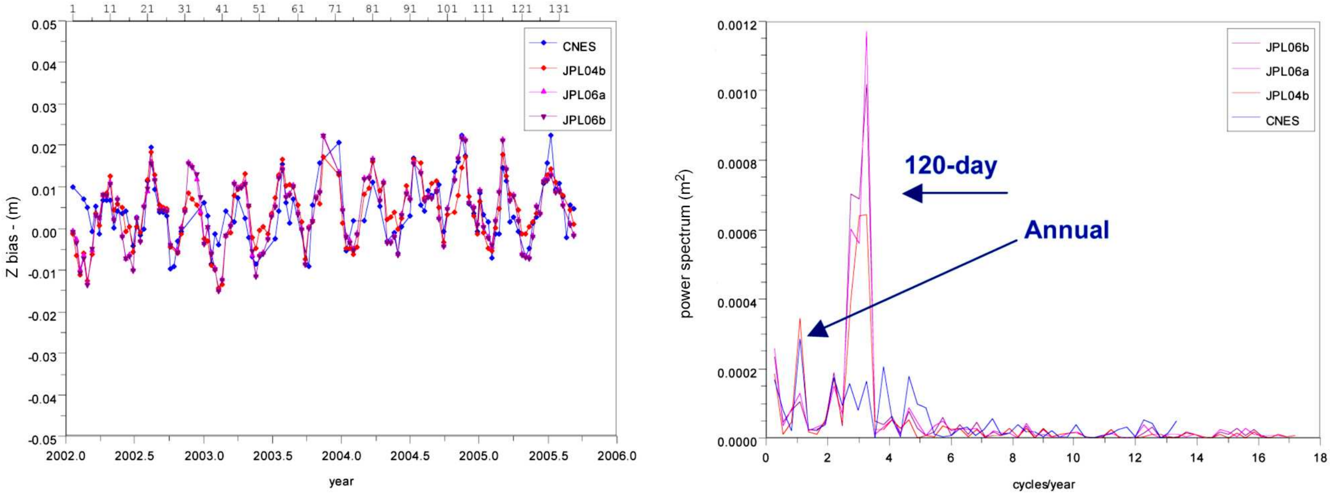


Figure 3. Z shift between CNES and JPL GPS-only orbits and GSFC SLR+DORIS orbits and associated spectral analysis (courtesy L. Cerri)

There is no consensus on the origin of the 120-day signal, although recent tests have made it clear that differences in solar radiation modeling can introduce a geocenter variation in Z that correlates with the orbit beta-prime angle. Tests are underway to identify which modeling performs best. The apparent drift in the Z offset may indicate a drift between the centers of the SLR and GPS reference systems. This may be resolved with the new ITRF2005 reference system. The annual signal bears some similarity with geocenter motion. Some tests indicate that taking into account geocenter motion could reduce the effect. However, in the absence of a consensus on which model to use for geocenter motion, it is difficult to reach any conclusion. This remains a research topic.

POD standards

All the issues left open at the last OSTST meeting have been addressed during the splinter. This provided a consistent set of standards to use for orbit production. Key elements are

- The models are principally based on the IERS2003 Conventions
- The gravity model is EIGEN-GL04C truncated to degree and order 120 for orbit determination (see http://www.gfz-potsdam.de/pb1/op/grace/results/grav/g005_eigen-gl04c.html). The model includes linear time variations for C20, C30 and C40. The IERS standards also specify a linear time variation for C21 and S21, as well as a corresponding model for the pole tide.
- The tide model is FES2004, with the K2 wave of the FES2002 tide model instead of the original K2 wave from FES2004
- The reference system is ITRF 2005, extended with new or “repaired” coordinates for the stations not included in ITRF 2005 (should be available in June 2006)
- The orbits for the GPS constellation are ITRF 2005 orbits computed by JPL clocks are those provided by JPL
- The antenna maps provided by JPL both for Jason-1 and the GPS constellation will be applied (for pseudo-range and phase)
- The DORIS, SLR and GPS tracking data are combined with weights that remain to be tuned.
- The phenomenological model designed to mitigate the effect of the South Atlantic Anomaly on DORIS data is to be used.

A few others standards are still the object of debate and have to be consolidated over the coming months:

- The offset between center of mass of the Earth and center of figure (geocenter motion) should be taken into account at least to clearly identify the origin of all products. To date, however, no consensus exists on a model, and the subject remains open.

- There are indications that time variable gravity (atmosphere, hydrology, etc.) is starting to play a significant role at the current accuracy level. No consensus model currently exists. Groups involved in GRACE data analysis have developed multiple solutions and an inter-comparison of these models will be conducted over the coming months to derive a model that will be part of the standards.

- The role played by solar radiation pressure modeling in the centering of the orbit is not yet fully understood. The UCL ray-tracing model is a likely candidate for the standards. However, its impact still has to be evaluated.

- Laser residuals exhibit a small dependency with respect to the elevation angle of the incoming photons over the reflector array. An array correction map will be included in the standards, however, array engineering data to produce this map is currently lacking. If no additional data can be obtained from the array manufacturer, an empirical map will be produced

The current goal is to be ready at NASA and CNES to start producing orbits with the new standards in the fall of 2006. The availability of ITRF2005 and of the time variable gravity model set the schedule, but all other pending issues also have to be closed before then. A detailed work-plan will be established to achieve this goal.

Best orbits versus TOPEX/Jason-1 intercalibration

Even though the standards listed above have been selected to guarantee the best precision for the Jason-1 orbit, they will not reach their full potential on TOPEX because of significant differences in tracking, solar radiation pressure modeling, laser retroreflector geometry, etc.

Results show that the relative calibration between the TOPEX and Jason altimeters is sensitive to minor orbit differences. The best Jason orbits are not necessarily the ones that will minimize those differences as there are systematic errors left in both orbits. In addition, between TOPEX orbits produced by NASA/GSFC and Jason orbits produced by CNES there are additional differences due to software and data selection.

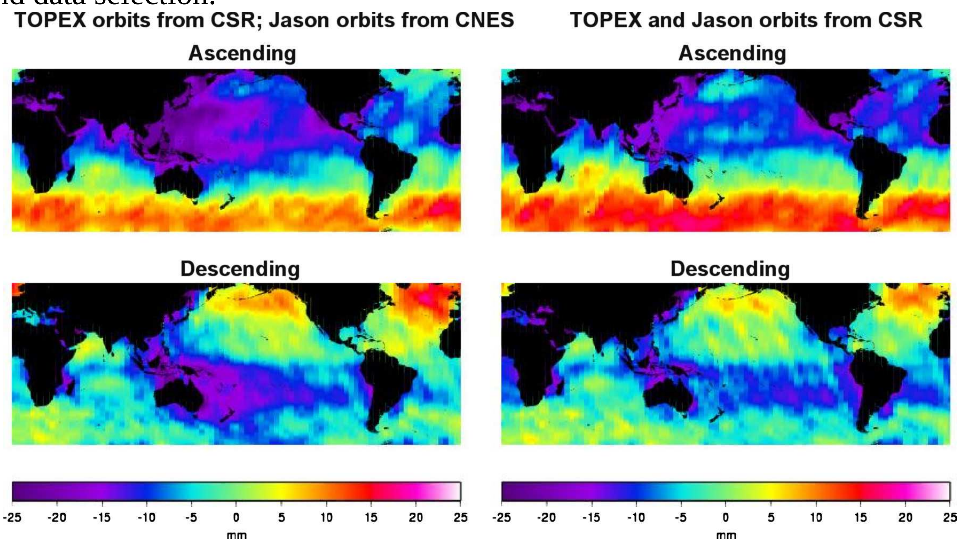


Figure 4. **Difference in sea surface height between TOPEX and Jason-1 computed using orbits from different analysis centers (left) or orbits from the same center (right) (courtesy J. Ries)**

Figure 4 compares the difference in sea surface height between TOPEX and Jason-1 computed with orbits from different groups (on the left, TOPEX orbit from CSR, Jason-1 GDR-b orbit) and with orbits from one center (on the right, both orbits from CSR). Even though the GDR-b orbits for Jason-

1 are intrinsically more precise than the CSR orbits, the difference in sea surface obtained using consistent orbits for TOPEX and Jason-1 offers a much clearer view of the ascending and descending patterns. In order to minimize orbit-induced errors in the altimeter intercalibration work, it might therefore be helpful to produce Jason-1 orbits different from those of the GDRs. These orbits could be fine tuned by NASA and CNES to be as consistent as possible with the existing orbits on the TOPEX GDRs. Inputs from users are needed at this point to know whether this would be helpful.

Evaluation of geoid models for marine applications

This evaluation was limited to global gravity models that could be used to degree and order 360. This included EGM96, GGM02C, EIGEN-CG01C, EIGEN-CG03C, a pre-release version of the EIGEN-GL04C model and a preliminary combination field not released to the public, TEST05. GGM02C used a previously available covariance (TEG4 to 200x200) to constrain the higher degrees to EGM96, allowing a smooth extension to 360 using the EGM96 coefficients above degree and order 200. The other four GRACE models directly ingested surface information. The EIGEN solutions used a special band-limited combination method to combine the CHAMP/GRACE or GRACE/LAGEOS gravity information with the surface information. TEST05 is a rigorous combination of the GRACE information (from GGM02S to 160x160) with full 360x360 surface information equations. All GRACE geoid models show enormous improvement over previous models at the longer wavelengths, up to approximately degree 110; at that point, surface information is required. A comparison of two of the best available geoid models is shown in Figure 5, where the statistics as a function of spherical harmonic degree are shown.

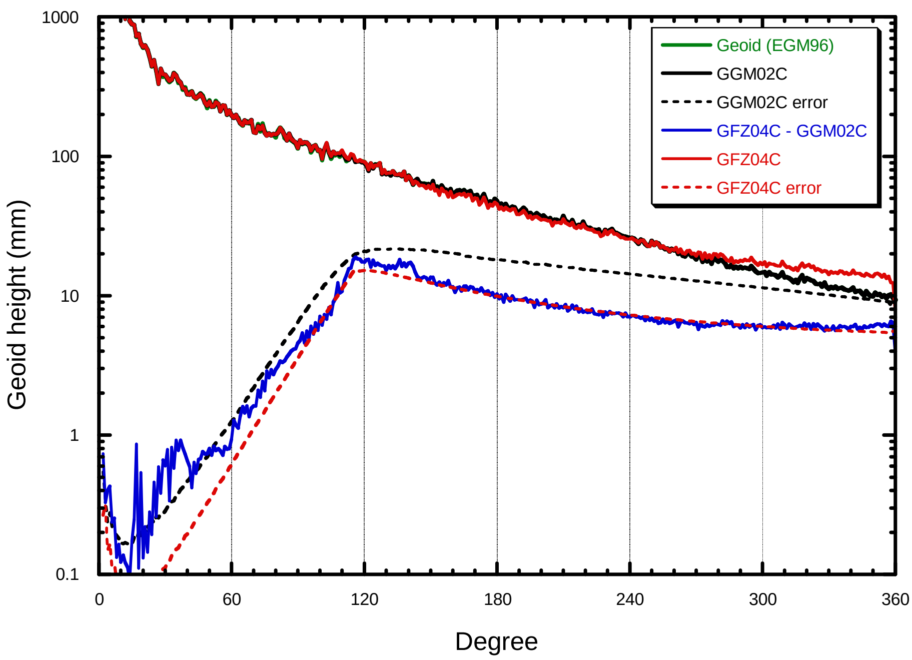


Figure 5. Comparison of selected GRACE models with EGM96. (GFZ04C refers to EIGEN-GL04C).

In Table 2, we compare the implied geostrophic currents (400 km smoothing applied) computed from various geoid models with the World Ocean Atlas 2001 (WOA01) data (relative to 4000 m, courtesy of V. Zlotnicki). EIGEN-GL04C and TEST05 perform the best in this test. To test the quality of these gravity models over the ocean at even shorter wavelengths, we can calculate the global RMS of the residual geoid after removing a model for the mean dynamic ocean topography, i.e. (MSS – WOA01 DOT – geoid model), for different wavelength filtering (shorter and longer than 300 km). We calculate this RMS only along the new T/P groundtrack, so that no solution has an advantage. We see in Table 3 that EGM96 actually performs quite well at the shorter wavelengths, and only TEST05 matches it. Not surprising, since GGM02C was extended to 360x360 using EGM96, it performs nearly the same. EIGEN-GL04C is a significant improvement over the earlier EIGEN models.

Table 2. Geostrophic currents comparison; a higher correlation indicates greater accuracy.

Model (400 km smoothing)	Standard Deviation (cm/s) Zonal	Meridional	Correlation Zonal	Meridional
EGM96	8.2	7.0	0.352	0.288
EIGEN-CG01C	3.2	3.8	0.905	0.398
EIGEN-CG03C	2.9	3.2	0.921	0.494
EIGEN-GL04C	3.0	3.0	0.915	0.542
GGM02S	2.9	3.4	0.919	0.464
GGM02C	3.0	3.2	0.914	0.481
TEST05	2.9	3.1	0.919	0.522

Table 3. Global RMS of residual geoid (MSS – WOA01 DOT – geoid model) along the new T/P groundtrack for different wavelength filtering. Means have been removed along each altimeter pass before computing the RMS. GGM02C extended to 360x360 with EGM96. Units in cm.

Model	> 300 km	< 300 km
EGM96	10.2	13.5
EIGEN-CG01C	10.6	14.4
EIGEN-CG03C	10.8	14.5
EIGEN-GL04C	9.0	13.9
GGM02C	8.5	13.6
TEST05	8.4	13.5

The problem with GRACE combination models has been the appearance of north-south ‘streaks’ or ‘striations’, a consequence of the sectorials and ‘near-sectorials’ of the gravity field model being more susceptible to long-wavelength dynamical orbit errors. Consequently, for a given degree, the near-sectorials tend to have a larger uncertainty and contain more error than the ‘near-zonals’. The challenge is in the transition from the GRACE information to the surface information. As TEST05 demonstrates, a rigorous combination of GRACE and surface information (using a complete set of partial derivatives from both information sets) allows the surface information to have more influence on the less-well-determined near-sectorials. The result is a significantly better marine geoid at wavelengths longer than 300 km. At wavelengths shorter than 300 km, the GRACE information in TEST05 is not negatively affecting the marine geoid accuracy.

The effect of the errors in the near-sectorials on the marine geoid is evident in Figure 6, where the short-wavelength marine geoid residuals are plotted. The residuals are the difference between a ‘high-frequency DOT’ defined as (GSFCMSS00 – geoid) and the smoothed version of the same DOT (smoothed to ~900 km). The residuals represent the signals in the MSS not modeled by the long-wavelength geoid. Note that all GRACE-based marine geoid models show evidence of the striations, although they are significantly reduced with GGM02C and further reduced in TEST05 and EIGEN-GL04C. This is consistent with the results shown in Table 2. Note also that the EGM96 geoid has essentially no residual signal in the areas of the Gulf Stream, the Kuroshio current, or the equatorial currents. This is because the signal has been aliased into the long-wavelength portion of EGM96 geoid.

We note that while TEST05 and EIGEN-GL04C have significantly reduced striations, other artifacts have appeared. Both have an undesirable artifact over the Tonga-Kermadec trench. TEST05 also has an artifact over the Mariana trench, while the pre-release version of EIGEN-GL04C has a 'ringing' feature off the northwestern coast of Africa (corrected in the final release).

Because all the currently available GRACE models suffer from striations or other artifacts, a solution is to smooth the topography to a level where these features disappear. Chambers and Zlotnicki showed that a 440 km smoothing (spatial Gaussian with a half-width of 220 km) was sufficient to remove the striations from GGM02C but retain the important oceanographic signals (see additional details at http://gracetellus.jpl.nasa.gov/dot.html). Figure 7 demonstrates this smoothing applied to the residual sea surface signals from GGM02C and EIGEN-GL04C. The results are nearly indistinguishable after smoothing and demonstrate that these geoids are good to approximately 400 km resolution for marine applications.

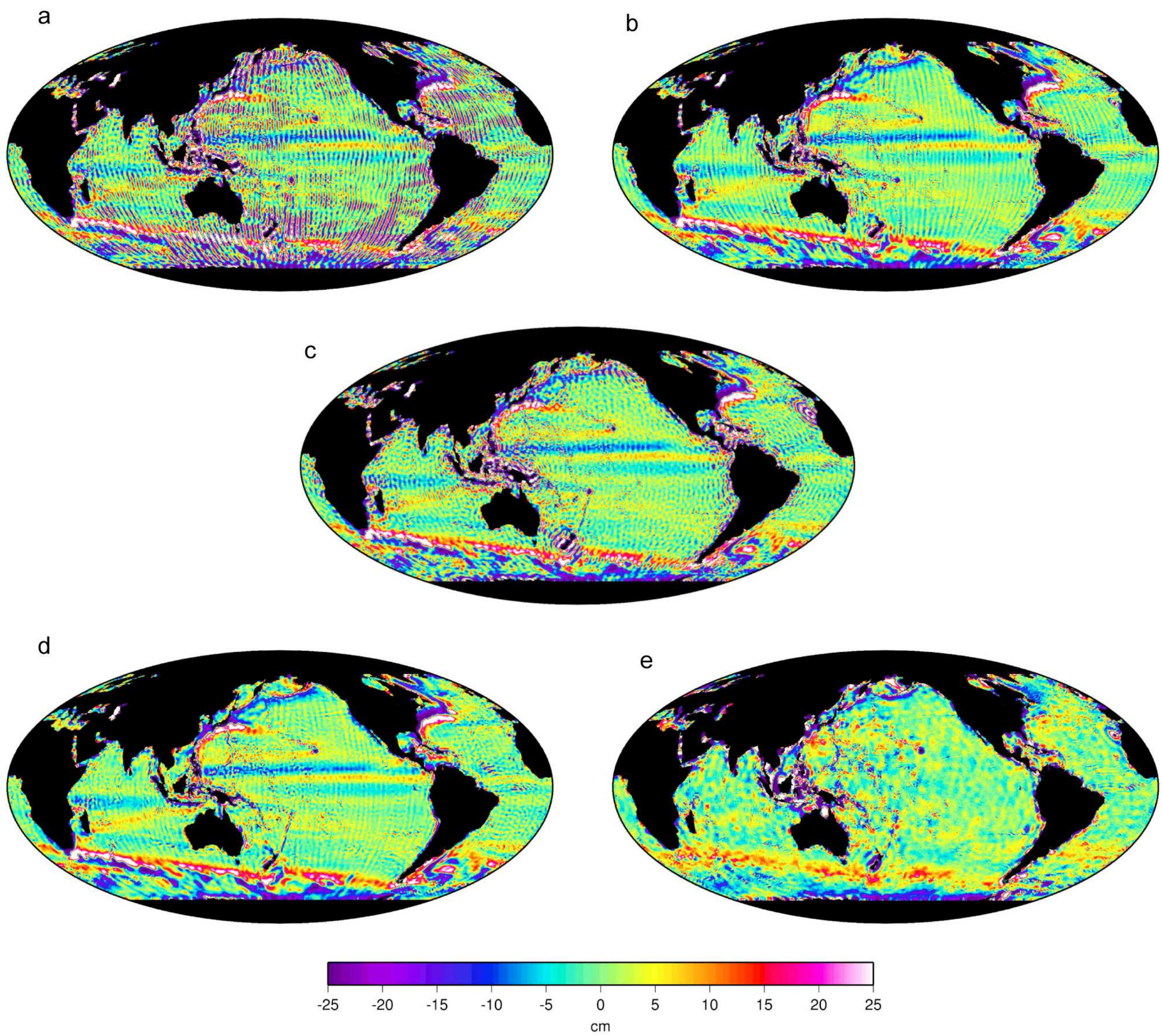


Figure 6. Short-wavelength sea surface residuals for (a) EIGEN-CG03C, (b) GGM02C, (c) EIGEN-GL04C, (d) TEST05 and (e) EGM96.

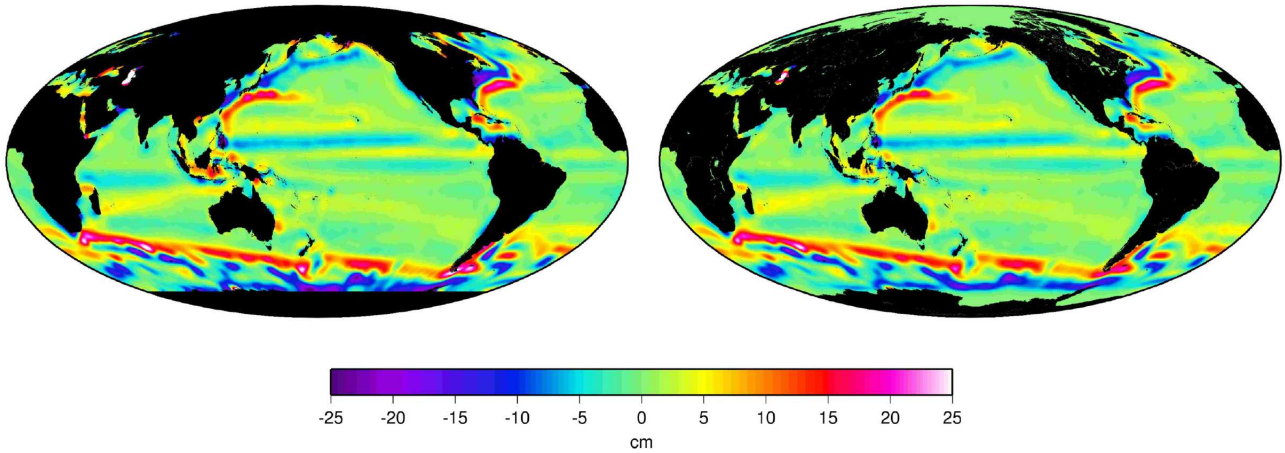


Figure 7. Smooth residual signal using a spherical harmonic expansion of (left) GGM02C/EGM96 and (right) EIGEN-GL04C to degree/order 360.

Marine geoid summary

All GRACE-based models evaluated show some problems with striations or artifacts over the ocean areas. The challenge remains in the proper combination of GRACE and surface information in such a way as to suppress the tendency of the higher degree terms in the GRACE solutions to produce significant 'meridional striping' and other artifacts in the geoid. For now, some level of smoothing is required. The amount of smoothing will depend on which GRACE geoid model is used, but the better GRACE models are good to approximately 400 km resolution. Of the available geoid models, GGM02C and EIGEN-GL04C appear to perform best overall. EIGEN-GL04C should be a good choice for POD and marine geoid applications.

Splinter Talks:

14:00	Introduction J.-P. Berthias / J. Ries
14:10	Jason-1 POD status and performance F. Mercier
14:25	TP and Jason-1 POD evaluation J. Ries
14:45	Improvement of the complete TP and Jason-1 orbit time series: current status S. Luthcke
15:00	GPS based orbit determination : Jason-1 status W. Bertiger
15:15	Analysis of Jason-1 orbit centering with SLR L. Cerri
15:30	Validation activities for Jason-1 and TP precise orbits P. Bonnefond
15:45	Impact of SAA corrections on Jason-1 orbit quality and station positioning J.-M. Lemoine
16:00	Break (20 minutes)

16:20	EIGEN-CGL04C: a global gravity field model for Jason-1 orbit computation and geoid R. Biancale
16:35	Assessing the impact of the time-variable part of the global gravity field model EIGEN-CGL04C on Jason-1 orbit quality R. Biancale
16:45	GRACE mission status and latest results J. Ries
17:00	Precise Orbit Determination for GFO-1 in the GRACE era F. Lemoine
17:15	Using altimetry and oceanographic in situ measurements for geoid models assessment P. Schaeffer
17:30	Discussion of standards, other POD/Geoid issues, plans All

Tides and High frequency aliasing

(co-chaired by R. Ponte, R. Ray and F. Lyard)

March, 17, 2006

1. Tidal corrections (splinter report)

- Tidal model errors

Present global tidal atlases depart significantly in the shelf and coastal oceans, and consequently their accuracy can be questioned in those regions, where there is strong expectation for altimetric products use, either for scientific or for operational and commercial applications. Several groups are presently addressing the issue of the improvement of the tidal corrections in shelf/coastal regions by developing high resolution regional models. Besides better representation of the smaller tidal wavelength in the shallow waters, regional models should allow for the inclusion of non-linear tides, which amplitudes can reach decimetric values, eventually larger than the main astronomical tides (such as the M_4 and K_1 tides in the English Channel). Dedicated regional multi-mission altimetry tidal database are being processed. Because of the shelf/coastal regions characteristics, improved data treatment and analysis are being developed to insure adequate accuracy of the harmonic constants.

- Tidal prediction algorithm improvements

The tidal corrections need to be processed with the best possible algorithms. Continuing efforts are made to improve and validate those algorithms, such as astronomical terms tabulations. The long period tide's corrections are still problematic. In theory, the long period tide solutions computed from hydrodynamic simulations will perform better than the equilibrium tide approximation (especially in the equatorial and very high latitude regions). Nevertheless, the investigations conducted so far are not conclusive, and additional work is needed.

- Inclusion of internal tides in tidal corrections

In some regions, the surface signature of the internal tides reaches several centimeters with O(100) km wavelengths and therefore is a significant contributor to the global de-aliasing error budget. Part of this signal is already spatially aliased into the tidal models, but most of it is left uncorrected. Some encouraging results from 3D models are available in regions of phase locked internal tides (such as Hawaii), but there are no short term perspectives for global ocean corrections.

2. Non-tidal HF corrections (splinter report)

- Barotropic high frequency correction (J. Dorandeu, CLS)

The HF correction recommended by the SWT based on the MOG2D barotropic model has been implemented and validated. The use of the MOG2D simulations instead of the inverted barometer approximation improves the high latitude and shelf/coastal corrections, reduces long wavelength errors, and produces closer agreement between altimetry and tidal gauge observations. The new HF correction is available in new Jason-1 and ENVISAT GDRs and re-processing for the whole T/P period has been completed and will be included in geophysical SSALTO component developed for new TOPEX data (RGDR, P. Callahan).

- Baroclinic high frequency effects (R. Ponte, AER)

The contribution of barotropic signals to the high frequency sea surface variations diminishes in the tropical and equatorial ocean where baroclinic dynamics become more important. Improvements can be expected in low latitude corrections by taking baroclinic contributions into account. Further developments and evaluation are needed to assess the efficiency and real impact of such a correction in future data processing.

- Combined model-data products (J. Lamoroux, LEGOS)

The barotropic simulations used to correct the pressure and wind related high frequency dynamic are presently assimilation-free, and their accuracy depends on the accuracy of the meteorological forcing (presently ECMWF) and the hydrodynamic model characteristics (numerical schemes, spatial resolution, etc.). Similarly to the tides, the error budget tends to increase in the shelf and coastal oceans, with a significant impact on de-aliasing corrections in those regions. A similar picture can be drawn for the high latitudes regions, where the atmospheric forcing get stronger, with smaller horizontal scales. As demonstrated in a Northeast Atlantic experiment, the sea level and current data assimilation improves the accuracy of the barotropic simulations. The coastal regions require an adequate assimilation approach because of their more complex dynamics (anisotropic, non-stationary, etc.).

- Coastal altimetry (J. Bouffard, LEGOS)

Preliminary experiments show that the satellite altimetry products are valuable for coastal circulation studies, provided that accurate HF corrections are applied to the observations. The good coherence between altimetry and tidal gauges allows a combined use of these observations. In fact, the combination of altimetry and tide gauge observations is a very promising product to control and validate the coastal circulation models.

3. Recommendations

- Address the issue of tidal/HF model errors estimates

A special effort is needed to provide the users of altimetry products with synoptic error bars on the tidal corrections. One suggestion is to take advantage of the multiple satellite altimetry missions to estimate tidal model accuracy by computing the harmonic misfits for the major tidal constituents. The accuracy of the satellite time series analysis can be assessed by computing the multi-mission crossover misfits. The authors of tidal models based on assimilation techniques are encouraged to publish the formal posterior errors derived from their assimilation procedure. The various model error estimates should be synthesized to provide users of altimetry products with a global tidal correction error map. A similar effort is needed for the HF correction. Unlike for the tidal issue, the accuracy of the HF correction is difficult to derive directly from the satellite observations. Tidal gauge data should provide local accuracy estimates, but with a very limited correlation to the actual accuracy in the deep ocean. It is suggested to develop and implement data assimilation techniques for the hydrodynamic models and to examine the formal posterior errors.

- Promote coastal region investigations

The improvement of the tidal/HF corrections in shelf and coastal regions is one of the major challenges for the next years. This is possible through the development of precise regional models. Because of the large number of regions that need such a particular treatment, and to promote cross-validation efforts,non OST tidal groups should be encouraged to join into a cooperation/competition working group. A large community is needed to gather accurate data (bathymetry, TG, altimetry), and develop tools and expertise. All feasible approaches should be encouraged, including a variety of hydrodynamic models (2D/3D) and assimilation techniques. It is also necessary to investigate patching methods in order to include regional improvements into the global tide and HF corrections.

- Estimate internal tides effect in GDR's SSH

Provide users with internal tide surface signature gridded information (amplitude, coherence, wavelength, direction), together with an estimate of uncertainty. In some ocean regions, this may not be feasible because of large non-tidal noise, including effects of eddy noise in boundary current and other regions.

- Aliasing/future missions

The tides/HF group has been solicited to provide advice on future mission orbits (ground track and repitition pattern) and technology. The main issues that need to be examined are the tidal aliasing periods, constituents' separation, mission duration (the longer, the better) and the spatial resolution. From the discussions at the splinter, some preliminary recommendations were made, such as:

- Avoid sun-synchronous orbits
- Favour the wide swath altimetry for internal tide issues and coastal regions
- Favour new ground track in case of nadir altimeter (Jason-3), or at least the T/P interlaced ground track to take profit of the already existing observations

Nevertheless, it is necessary to investigate more systematically the possible scenarios before issuing more definite recommendations.

Splinter Talks

08:30	Introduction (R. PONTE, R. RAY, F. LYARD)
08:45	Consistency of along-track tide estimates R. RAY
09:00	Tidal Solution TPXO.7 G. EGBERT
09:15	Long Period Tides F. LEFEVRE
09:30	Regional Tidal Models and Altimetry Analysis F. LYARD
09:45	Discussion on tides All
10:00	Coffee break
10:30	Improvements in Multi-mission Altimeter Products by using MOG2D High Frequency Corrections

	J. DORANDEU
10:45	Baroclinic Effects and High Frequency Correction R. PONTE
11:00	Data Assimilation in a Storm Surge Model J. LAMOUROUX
11:15	Intercomparison of Altimetry, Tide Gauge and Circulation Model in the North-Western Mediterranean Sea J. BOUFFARD
11:30	General discussion and recommendations All
12:30	Adjourn

Outreach

(co-chaired by V. Rosmorduc, CLS and M. Srinivasan, JPL)

March, 17, 2006

The outreach splinter session included a project outreach update, four talks (one by each agency), an "altimetry product showcase" and a discussion period.

Part 1 Outreach activities

Outreach activities since the OSTST meeting in St. Petersburg included:

- Presentations of the basics of altimetry: Ready-made presentations with ideas on communicating altimetry, adaptable to different audiences, available to science team members
- "Depuis l'espace un autre regard" poster series
- 2006 and 2005 Aviso wall calendar
- Update of the 'Jason-1, an Ocean Odyssey' video
- Radar altimetry tutorial and toolbox
- JPL Science Results posters (Jason and Tandem Mission)
- Educational activities: LILA (Lycée International de Los Angeles), Argonautica
- Media activities
- Aviso website
    - New posters online
    - Updated list of products
    - Continued activities include: the Image of the Month, El Niño bulletin, maps, News, "Lively data"…
- Joint web site
    - OST/ST 2006 meeting abstracts and posters.
- JPL 'Sea Level' website
    - Monthly Features
    - Societal Benefits page
    - Literature Database (updated quarterly)
    - Jason Latest Data (biweekly)
    - El Niño Watch
- Ocean literacy framework for National US Earth Science educational standards (R. Stewart)

Talks by NASA, EUMETSAT, CNES, and NOAA revealed that outreach plans for Jason-2/OSTM are not yet mature. Standard launch activities and material will be developed (e.g. launch kit, media relations and press events, etc.). The details of these are still to be defined. Outreach dedicated to Jason-2/OSTM will be in the continuity of current altimetry outreach (e.g. educational launch-related activities could be spread at the European level), and cooperative efforts are already being discussed between the outreach contingents at each agency.

Partnerships should be developed between the participating Jason-2/OSTM agencies part, as well as with other organizations. ESA, already having an established outreach collaboration with CNES, is one of the most evident candidates,. The CNES/ESA altimetry tutorial and toolbox (RAT & BRAT) will be a powerful tool to reach new users, students and professors. Closer collaboration can facilitate more focus on the Envisat altimeter, can strengthen the multi-mission rationale, and profit from the wide European media impact of ESA. Partnerships with non-altimetry ocean missions and experiments can provide a global ocean view. Partnerships with outside educational organizations (e.g. COSEE) will expose our missions and outreach materials to a broader audience. We will need to initiate and nurture such partnerships.

The "outreach product showcase" was the occasion for OSTST members to present their outreach activities in a short, easy, format (one slide, two minutes to present it and/or a place on the poster session to put the printed slide). It gave outreach session participants a quick-view of ongoing and new outreach activities including activities that may not have been developed enough for a full-scale talk. A broad range and scope of ideas and activities were presented, reaching many varied public audiences:

- Geonauts educational CD ROM (P. Bonnefond)
- CSIRO Ocean Surface Currents and Temperature maps and animations (D. Griffin)
- Oregon Museum of Science and Industry T/P-El Niño exhibition (D. Chelton)
- OSCAR Currents maps for a rowing race (G. Lagerloef)
- 3D globes and animations (D. Sandwell)
- Oceanography online textbook (R. Stewart)
- Global Reservoir and Lake Monitor (C. Birkett)
- Ocean mirror the Earth poster (P. Schaeffer / F. Hernandez)

We plan to continue such a showcase during next OST/ST outreach splinter sessions, and hope to be thus able to constitute a sort of PI outreach activities list, to give a better view on existing outreach efforts

Part 2 Discussion.

Outreach Focus. OSTST members expressed a desire to see highlights on the importance of the continued time series, and the need for multi-satellite observations. Some potential examples include the connection between physical and biological oceanography, the heating/cooling of the ocean, ocean circulation with respect to improved geoid measurements from GRACE, and the enhancement of coastal tide models. The important media impact of publications in *Nature* or *Science* was stressed: scientific results published in these two journals provide an important and significant resource for the press. In light of this fact, please contact the outreach team if you submit an article to *Science* or *Nature*.

Emphasis was made on the goal of providing and promoting stories to media outlets on good science rather than on budget cuts or other topics not directly relevant to altimetry outreach.

Media. Understandable pictures, particularly those that are visually appealing, are needed to attract young people and general public audiences. The opportunities to produce more attractive, easy-to-interpret images should be pursued.

Questions.
What's the most efficient way to reach the public?

- Topics close to their experience (e.g. climate, MSL, pollution, hydrology)
- Things linked with the news (e.g. sail race, natural catastrophes)
- Beautiful (and understandable) pictures
- Things that make them dream (the ocean should be as good in that respect as stars)

What is the most useful to reach decision-makers?

- Practical applications, either public good or commercial ones (true also for end-users)
- Things that reach the general public through the media

What can go through the Media?

- Events (e.g. this meeting, international MSL symposium, Paris June 2006, articles in Nature or Science, natural catastrophes)

- Quite a lot of articles are published on topics related to altimetry applications. However, altimetry isn't cited most of the time (e.g. mean sea level rise)
- We have to prepare background material for foreseeable media events (e.g. hurricane season)

Outreach & education feedback is also a continuing concern. Suggestions in that respect are:

- Invite 'outreach users' to present during OSTST meetings, so as to better show the impact of outreach, e.g.:
    - Children and/or teachers participating in Argonautica
    - Journalists
    - Others?

  But this requires funding… Would the Project, on either or both sides, be willing to fund?

Future.
Outreach operations planned for 2006 are:

- Jason-2/OSTM outreach development
- More presentations:
    - Target children ages 5-12
    - "SALP" presentation in English
- Argonautica 2006-2007
- Updates of the "A bird's eye view of the ocean" educational CD Rom
- Aviso web site
    - Image of the Month, El Niño bulletin, News, "Lively data" cont'd
    - Refurbishing of the website?
    - 3D interactive interface
    - More interactive data retrieval and use tools
- JPL 'Sea Level' web site
    - Quarterly updates of Literature Database
    - Monthly features
    - More Societal Benefits
- More Yellow Pages
- Aviso Newsletter special Issue – OST/ST science plan
- Completion of Radar altimetry tutorial and toolbox
- An exhibition in Noumea (New Caledonia) ; maybe one in Barcelona
- Altimetry applications lithograph
- 13 year globe lithograph

Splinter Talks

14:00	Introduction M. Srinivasan, V. Rosmorduc
14:05	Outreach progress since last OSTST M. Srinivasan, V. Rosmorduc, A. Richardson
14:15	NASA/JPL plans for Jason-2/OSTM
14:30	CNES plans for Jason-2/OSTM
14:45	EUMETSAT plans for Jason-2/OSTM
15:00	NOAA plans for Jason-2/OSTM

15:15	Questions
15:30	Showcase of the best outreach "products" Presentation of the products by their authors (1 slide and/or 2 minutes max)
16:00	Break
16:30	**Roundtable discussion:** 1- Jason-2/OSTM outreach; what should be done? what are plans of science team members? 2- Joint products; possible new or updated materials, building on past outreach/applications efforts, what new products should be planned? 3- Focus; What should be highlighted: science, practical applications, extended time series, ocean literacy, formal and informal education (including Argonautica) 4- Resources/partnerships or additional collaborations to support outreach efforts 5- Other topics
18:00	Adjourn

LIST OF POSTERS

Local and Global Calibration/Validation

- Michaël ABLAIN, Joël DORANDEU, Yannice FAUGERE, Nicolas PICOT, Juliette LAMBIN,
  Global Statistical Quality Assessment of Jason-1 data and Jason-1 / TOPEX/Poseidon Cross-calibration

- Pascal BONNEFOND, Pierre EXERTIER, Olivier LAURAIN, Yves MÉNARD, François BOLDO, Gwenaele JAN,
  Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica

- Shannon BROWN, Shailen DESAI, Steve KEIHM, Christopher RUF,
  Status of the JMR/TMR Recalibration Effort: Algorithm Improvements and the Optimal Calibration System

- Shailen DESAI, Bruce HAINES, Wenwen LU, Victor ZLOTNICKI,
  Validation of Jason and Topex Microwave Radiometer Wet Path Delay Measurements using GPS, SSM/I, and TMI

- Yannice FAUGERE, Joël DORANDEU, Michaël ABLAIN, Nicolas PICOT,
  Jason-1 / Envisat Cross-calibration

- James FOSTER, Mark MERRIFIELD, Michael BEVIS, Benjamin BROOKS,
  Regional Trend Estimates at CGPS@TG Stations

- Bruce HAINES, George BORN, Shailen DESAI, Stephen GILL,
  Monitoring Jason-1 and TOPEX/POSEIDON from an Offshore Platform: Latest Results From the Harvest Experiment

- Gwenaële JAN, Yves MENARD, Pascal BONNEFOND, Valérie BALLU, Olivier LAURAIN,
  Altimeter satellite sea surface height calibration with in-situ network

- John LILLIBRIDGE, Shailen DESAI, Bruce HAINES, Melissa SORIANO,
  An Automated Near Real-Time Quality Assessment System for Jason-2/OSTM

- Philippe LIMPACH, Alain GEIGER, Hans-Gert KAHLE,
  Offshore GPS buoy measurements and comparison with JASON-1 radar altimeter data

- Florent LYARD, Laurent ROBLOU,
  Albicocca: an improved altimetry data treatment for coastal and regional oceanography

- Marta MARCOS, Guy WOPPELMANN, Luciana FENOGLIO, Matthias BECKER, Roman SAVCENKO, Wolfgang BOSCH,
  Comparing tide gauges and altimetry: a case study in the Bay of Biscay

- Marina MARTINEZ-GARCIA, Miguel Angel ORTIZ-CASTELLON, Juan Jose MARTINEZ-BENJAMIN,
  Contribution to the Jason-1 altimeter calibration of mapping the marine geoid at Begur Cape with the support of the continuous GPS monitored tide gauge at l'Estartit

- Estelle OBLIGIS, Ngan TRAN,
  Assessment of recalibrated Jason-1 microwave radiometer measurements and products

- Erricos C. PAVLIS, Stelios P. MERTIKAS, The GAVDOS TEAM,
  Eastern Mediterranean Dynamics and JASON-1 Altimeter Calibration Results from the GAVDOS Project

- Pierre QUEFFEULOU,
  Altimeter wave height validation: an update.

- Remko SCHARROO, John LILLIBRIDGE,
  Comparison of the Radiometers of TOPEX, Jason-1 and Envisat

- Alexander SOMIESKI, Beat BÜRKI, Alain GEIGER, H.-G. KAHLE, E. C. PAVLIS,
  Local Validation of Jason-1 Microwave Radiometer (JMR) by ground-based Solar Spectrometry and Water Vapor Radiometry in the North Aegean Sea

Sea-State Bias and Re-tracking Analysis

- Hui FENG, Doug VANDEMARK, Bertrand CHAPRON, Ngan TRAN, Brian BECKLEY,
  Use of fuzzy logic clustering analysis to address wave impacts on altimeter sea level measurements: Part I data classification

- Sylvie LABROUE, Philippe GASPAR, Joel DORANDEU, Ouan Zan ZANIFE,
  LATEST RESULTS ON JASON 1 SEA STATE BIAS WITH THE NON PARAMETRIC TECHNIQUE

- Juliette LAMBIN, Nicolas PICOT, Jean-Paul DUMONT, Pierre THIBAUT, Ouan-Zan ZANIFÉ, Evolutions in the ground processing chain: motivation, status and impact

- Ernesto RODRIGUEZ, Philip CALLAHAN, Kelley CASE, Theodore LUNGU, Comparison of TOPEX and Jason Retracking using Least Squares and MAP Estimation

- Pierre THIBAUT, Sylvie LABROUE, Michael ABLAIN, Ouan Zan ZANIFE, Evaluation of the Jason-1 ground retracking algorithm

- Ngan TRAN, Douglas VANDEMARK, Bertrand CHAPRON , Sylvie LABROUE, Hui FENG, Brian BECKLEY, New models for satellite altimeter sea state bias correction developed using global wave model data

- Doug VANDEMARK, Hui FENG, Bertrand CHAPRON, Ngan TRAN, Brian BECKLEY, Use of fuzzy logic clustering analysis to address wave impacts on altimeter sea level measurements: Part II results

- Ouan-Zan ZANIFE, Pierre THIBAUT, Laiba AMAROUCHE, Bruno PICARD, Patrick VINCENT, Assesment of the Jason-1 Look Up Tables Using Multiple Gaussian Retracking

Precise Orbit Determination and Geoid

- Willy BERTIGER, Bruce HAINES, Shailen DESAI, Pascal WILLIS, GPS-Based Precise Orbit Determination: Jason-1 Status

- Richard BIANCALE, Jean-Michel LEMOINE, Stavros MELACHROINOS, Sylvain LOYER, Assessing the impact of the time-variable part of the global gravity field model EIGEN-CGL04C on Jason-1 orbit quality

- Pascal BONNEFOND, Pierre EXERTIER, Olivier LAURAIN, Philippe BERIO, David COULOT, Validation Activities for Jason-1 and Topex/Poseidon Precise Orbits

- Luca CERRI, Flavien MERCIER, Sabine HOURY, Adele GUITART, Analysis of precise orbits centering using SLR measurements

- Christoph FOERSTE, Richard BIANCALE, Frank FLECHTNER, Sylvain LOYER, Markus ROTHACHER, Jean-Michel LEMOINE, EIGEN-CGL04C: a global gravity field model for Jason-1 orbit computation and geoid

- Jean-Michel LEMOINE, Hugues CAPDEVILLE, Laurent SOUDARIN,
  Impact of DORIS SAA corrections on Jason-1 orbit quality

- Frank LEMOINE, Nikita ZELENSKY, Brian BECKLEY, Douglas CHINN, David ROWLANDS, John LILLIBRIDGE,
  Precise Orbit Determination for GFO-1 in the GRACE era

- Scott LUTHCKE, Nikita ZELENSKY, Frank LEMOINE, David ROWLANDS, Brian BECKLEY, Teresa WILLIAMS,
  Improvement of the Complete TP and Jason Orbit Time Series: Current Status

- John RIES, Don CHAMBERS,
  GRACE mission status and latest results

- Philippe SCHAEFFER, Marie-Hélène RIO, Jean-Michel LEMOINE,
  Using altimetry and oceanographic in situ measurements for geoid's models assessment.

Tides and High-Frequency Aliases

- Florent LYARD, Thierry LETELLIER, Laurent ROBLOU,
  Toulouse Global and Regional Tidal Atlas : a review on progress and recent result in tidal science and products

- Roman SAVCENKO, Wolfgang BOSCH,
  Shallow-water tides on the Patagonian shelf from multi-mission altimetry

- Ed ZARON, Gary EGBERT, Richard RAY,
  Modeling studies of internal tide generation at the Hawaiian Ridge: Comparison to inferences from altimetry

Multi-Satellite/Operational Applications

- Nicolas BARRE, Christine PROVOST,
  Low frequency variability of the eddy field in the Ona Basin, southern Drake Passage

- Wolfgang BOSCH,
  Global multi-mission crossover analysis

- Yi CHAO, John FARRARA, Zhijin LI, Xiaochun WANG, Hongchun ZHANG,
  Operational Applications of Satellite Altimetry in Real-Time Forecasting of the U.S. West Coastal Ocean

- Gerald DIBARBOURE, Nicolas PICOT,
  SSALTO/DUACS: A consistent data set from built upon all altimeters

- Gustavo GONI, Joaquin TRINANES, Pedro DI NEZIO,
  Altimetric products made available by NOAA/AOML

- Jean TOURNADRE,
  Improved level-3 product from dual frequency altimeter systems

Outreach

- Vinca ROSMORDUC, Annie RICHARDSON, Margaret SRINIVASAN,
  Election of the best OST outreach product -2

- Vinca ROSMORDUC, Margaret SRINIVASAN, Annie RICHARDSON,
  Election of the best OST outreach product -1

Consistency in Jason and Topex/Poseidon performance

- Brian BECKLEY, Nikita ZELENSKY, Scott LUTHCKE, Philip CALLAHAN, Sylvie LABROUE, Ngan TRAN,
  Evaluation of TOPEX/Jason-1 Consistency Issues

- Joël DORANDEU, Michaël ABLAIN, Nicolas PICOT, Juliette LAMBIN,
  Analysis of version B Jason-1 GDRs / TP retracked GDRs consistency

- Eric LEULIETTE, Steve NEREM, Gary MITCHUM,
  Impact of Version-B GDRs on Mean Sea Level

Miscellaneous

- Luca CENTURIONI, Carter OHLMANN, Peter NIILER,
Near Surface Structure of the California Current System: Observations and Comparison with OGCM solutions

- Emmanuel COSME, Jacques VERRON, Frederic CASTRUCCIO, Yann OURMIERES, Celine ROBERT, Eric BLAYO,
Some recent advances in ocean data assimilation with the SEEK filter

- Jérôme HELBERT, Eric JEANSOU, Guy CARAYON, Nathalie STEUNOU, Jean-Damien DESJONCQUÈRES,
A Digital Elevation Model onboard POSEIDON-3 for a new tracking mode using the Diode real-time navigator

- Per KNUDSEN, Ole ANDERSEN, Toke ANDERSSON,
Optimal filtering of mean dynamic topography models obtained using GRACE geoid models.

- Per KNUDSEN,
The GOCINA Mean Dynamic Topography Models and Impact on Ocean Circulation Modellin

- Christophe MAES, David BEHRINGER,
The contribution of the salinity field in sea level variability of the equatorial Pacific Ocean: an overview of results

- Frederic MARIN, Charly REGNIER, Gabriela ATHIE DE VELASCO,
Temporal and spatial variability of the Tropical Instability Waves: an interbasin comparison from satellite altimeter and SST data

- Estelle OBLIGIS, Laurence EYMARD, Ngan TRAN, Sylvie LABROUE,
Geographical analysis of systematic errors in the wet tropospheric correction

- Estelle OBLIGIS, Charles DESPORTES, Laurence EYMARD,
The wet tropospheric correction for altimetry in coastal and inland water regions

- Thierry PENDUFF, Bernard BARNIER, Laurent BRODEAU, Mélanie JUZA,
Hybridizing satellite products and reanalyzed atmospheric fields for the forcing of long-term ocean/sea-ice DRAKKAR simulations

- Rui PONTE, Carl WUNSCH, Detlef STAMMER,
Spatial mapping of time-variable errors in Jason-1 and TOPEX/POSEIDON surface topography measurements

- Marie-Helene RADENAC, Veronique GARÇON, Jérome LLIDO, Monique MESSIÉ, Joel SUDRE, Christine PROVOST, MUSICAL (MUlti-Sensors Information: ocean Color and ALtimetry)

- Isabel VIGO, David GARCÍA, Ben CHAO, Jorge DEL RIO, Jesús GARCÍA-LAFUENTE, Understanding Mediterranean and Black Sea Level Variations, 1992-2004.

- Frédéric VIVIER, Fabiano BUSDRAGHI, Young-Hyang PARK, Interannual changes in upper-ocean heat content in the Southern Ocean from satellite observations and simple models

- Manfred WENZEL, Jens SCHROETER, Global ocean heat content variations derived from satellite altimetry and hydrographic data

Statement From
THE SYMPOSIUM ON 15 YEARS OF PROGRESS IN ALTIMETRY
Venice, 16 March 2006

The past 15 years of satellite altimetry has enabled remarkable advances in a variety of disciplines. With these advances in mind, the 510 attendees from 30 countries at this Symposium offer the following consensus recommendations to sustain and advance our capabilities in satellite altimetry.

Recommendations:

1. Recognizing the importance of monitoring climate change – as reflected in the GCOS requirements that have been endorsed by the UNFCCC and GEOSS, as well as new products and services enabled with the advent of operational oceanography – which underpin European GMES Core Services,

   (a) **Maintain continuity of the high-accuracy Jason altimetry time series** established by TOPEX/Poseidon and Jason-1, and being continued with OSTM/Jason-2, through implementation of a Jason-3; and at the same time,

   (b) **Maintain continuity with altimeters on at least two complementary, high-inclination satellites** – such as the present GFO and ENVISAT and the future Sentinel-3, AltiKa, and NPOESS, with the option to reactivate ERS-2 when needed.

2. Recognizing the significant potential of emerging technologies required to facilitate new discoveries in geophysics, mesoscale and coastal oceanography, and terrestrial hydrology, **extend the capability of altimetry to denser observational coverage through the development of swath altimetry.**

3. Recognizing the importance of data policy to the dramatic impact that TOPEX/Poseidon and Jason-1 continue to have in a variety of fields, **maintain an open data policy – with timely access, including near-real time data distribution for operational purposes –** to calibrated and quality controlled data for the benefit of all users.

4. Recognizing the critical role that it plays, especially in satellite altimetry, **any operational system – must be well grounded in, and maintain a continuing partnership with, the scientific community.**

5. Recognizing the benefits of joint efforts as exemplified by ERS-1 & -2, TOPEX/Poseidon, GFO, Jason-1, ENVISAT, and OSTM/Jason-2, **broad collaboration between engineering and science, research and operations, and international partners must be maintained** in future endeavors.

OSTST MEETING AGENDA

Thursday, March 16 (Plenary session)		
14:00	Welcome and meeting overview	L-L Fu, Y. Menard
14:15	NASA program status	E. Lindstrom
14:30	CNES program status	E. Thouvenot
14:45	ESA mission status	J. Benveniste
15:00	GFO mission status	J. Lillibridge, G.. Jacobs
15:15	TOPEX/Poseidon mission completion	M. Fujishin, S.Coutin
15:30	Break	
15:45	Jason-1 and SALP status	S. Coutin, M. Fujishin
16:00	Jason-1 operations and performance	N. Malechaux, G. Shirtliffe
16:15	Jason-1data reprocessing status	N. Picot, S. Desai
16:30	Algorithm evolutions for Jason-2	N. Picot, S. Desai
16:45	Splinter meeting introductions	Splinter chairs
17:00	Poster session	
18:00	Cocktail	
21:00	Adjourn	
Friday, March 17 (splinter sessions)		
08:30	Sea-state bias and re-tracking analysis (P. Callahan, O. Zanife)	
08:30	Tides/high-frequency aliasing (R. Ray, R. Ponte, F. Lyard)	
08:30	Cal/Val and data consistency, Part 1: in-situ and regional (P. Bonnefond, B. Haines, S. Nerem)	
12:30	Lunch	
14:00	Outreach (V. Rosmorduc, M. Srinivasan)	
14:00	Precise Orbit Determination and Geoid (J.P. Berthias, J. Ries)	
14:00	Cal/Val and data consistency, Part 2: global (N. Picot, S. Desai)	
18:00	Adjourn	
Saturday, March 18 (plenary session)		

08:30	**OSTM/JASON-2 Status**	
08:30	CNES Project Status	J. Perbos
08:40	Jason2 System evolutions wrt Jason-1	G. Zaouche
08:55	Altimeter status and improvements	G. Carayon
09:05	DORIS status and improvements	P. Sengenes
09:15	Satellite evolutions	T. Lafon
09:25	NASA/JPL Project status (AMR, GPSP, LRA, launcher)	P. Vaze
09:40	EUMETSAT Project Status	F. Parisot
09:50	NOAA Project Status	J. Lillibridge
10:00	T2L2 on-board Jason-2	E. Samain, P. Exertier
10:15	Break	
10:30	**Post-Jason 2 missions**	
10:30	AltiKA mission status	P. Sengenes
10:45	Jason-3 perspectives (EUMETSAT and NOAA)	
11:00	**Splinter group reports**	
11:00	CalVal and data consistency	
11:30	Outreach	
11:45	Retracking/SSB	
12:00	POD/Geoid	
12:15	Tides/HF aliasing	
12:30	Conclusions	
12:45	Adjourn	
13:00	Lunch	