Jason-1 SWT, Arles, Novembre 2003
Report on "Local to global CalVal experiments" splinter
(P. Bonnefond, B. Haines and S. Nerem)

INTRODUCTION

The main objective of CalVal activities is to arrive at unified assessments of the product accuracy, and especially the bias, drift and stability of the sea-surface height and component measurements. An additional goal is to arrive at a better reconciliation of the results from the in-situ experiments with those from global Jason-1 vs. T/P comparisons.

The splinter session was divided into two parts: a first one dedicated to local experiments such as dedicated calibration sites and a second one focused the global studies.

I- LOCAL EXPERIMENTS PRESENTATIONS:

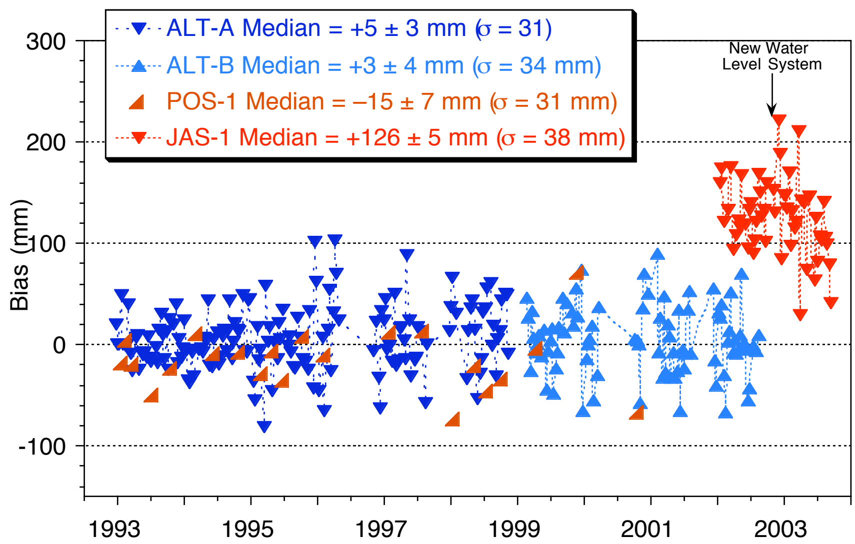
- **Choice of "standards" corrections when processing the T/P-Jason time series for altimeter calibration and then for monitoring the mean sea level**
  P. Bonnefond, B. Haines and S. Nerem

Summary

The aim of this introduction was to setup a list of possible origins of discrepancies of results between local level studies themselves but also between local and global studies. Moreover, it was recalled that we have to clearly identify the standards users should take for T/P MGDR and Jason-1 GDR

- **Recent Results from the Harvest Experiment**
  B. Haines, D. Danan, G. Born and S. Gill

Summary



Based on 52 overflights of the Harvest calibration site, the present estimate of the Jason-1 sea-surface height (SSH) bias is +126 mm (σ = 38 mm). The T/P bias estimates for both sides (A and B) of the NASA radar altimeter are statistically indistinguishable from zero. Further insight on the relative bias between Jason-1 and T/P (side B) was gained by examining data from the dual overflights that occurred when the satellites were flying 70 s apart during the

Jason-1 calibration phase. These data lead to an estimate of +127 mm (σ = 23 mm) for the relative SSH bias (Jason-1 higher than T/P). In contrast, a global comparison (–45˚ to 45˚) yields an estimate of +154 mm. Several sources of geographically correlated errors were discussed as potential explanations for this discrepancy. Noteworthy among them is the atmospheric-delays correction. At Harvest, there is a 15 mm difference between cumulative Jason-1 and T/P atmospheric delay correction, to which the wet troposphere (JMR–TMR) is the largest contributor. Residual sea-state bias errors are possible contributors as well.

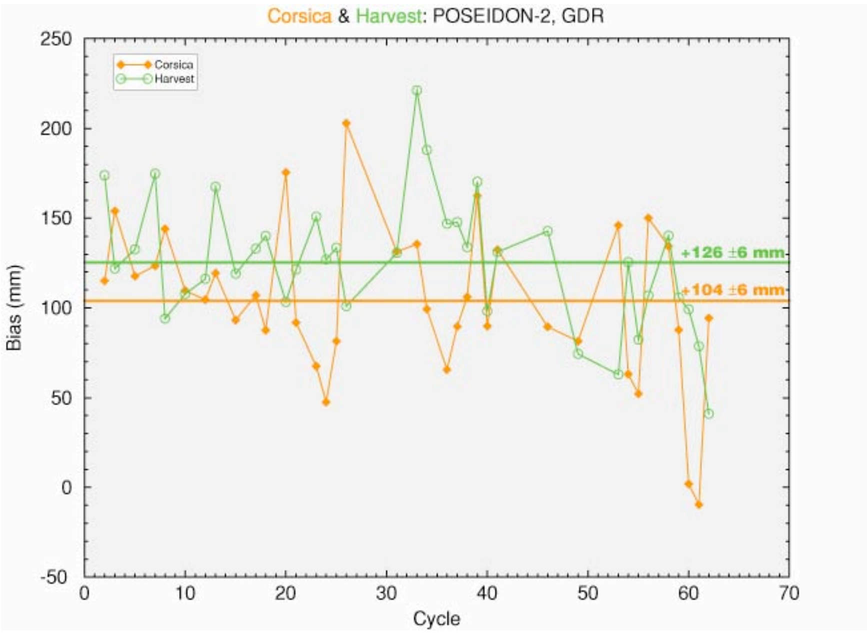
- **Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica**
  P. Bonnefond, P. Exertier, O. Laurain, Y. Ménard, A. Orsoni, E. Jeansou and G. Jan

Summary

From the formation flying phase analysis, we have found that JMR seems to measure to short by 13 mm. Same result is derived from Harvest (10 mm). Global analysis suggests a coastal effect. This JMR effect should increase our altimeter bias by about 13 mm to be comparable to T/P.

For Jason-1 altimeter bias the difference between Harvest and Corsica is +22mm while results were comparable at the mm level for T/P. Reasons for this difference are under investigation.

Both Harvest and Corsica and time series show a drop since the Marine Geodesy publication (study ending at cycle 42) of about 10 mm.



- **In-Situ Calibration in Bass Strait, Australia**
  C. Watson, N. White, R. Coleman, J. Church and R. Govind

Summary

The impact of Geographycally Correlated Orbit Errors is at the level of 15 mm for Bass Strait site. Impact of SSB is less significant.

Absolute Bias Estimates - Bass Strait				
Jason-1 Mission:				
Jason-1 Cycles 001-060 (using corrected Tide Gauge SSH)				
	Mean	Median	Std Dev	Std Error
Jason-1 (POE Orbit)	+138.9 mm	+136.5 mm	42.4 mm	6.2 mm
Jason-1 (GPS RD Orbit)	+122.2 mm	+116.4 mm	40.4 mm	5.9 mm
TOPEX/Poseidon Mission:				
T/P Side A, Cycles 001:235 (using corrected Tide Gauge SSH)				
	Mean	Median	Std Dev	Std Error
T/P MGDR SSB	-3.0 mm	-5.2 mm	30.1 mm	2.3 mm
T/P Chambers SSB	-2.4 mm	-5.5 mm	30.2 mm	2.3 mm
TOPEX/Poseidon Mission:				
T/P Side B, Cycles 236:365 (using corrected Tide Gauge SSH)				
	Mean	Median	Std Dev	Std Error
T/P MGDR SSB	-6.1 mm	-3.0 mm	28.2 mm	2.8 mm
T/P Chambers SSB	-2.3 mm	+1.7 mm	28.1 mm	2.7 mm

- **JCET @ GAVDOS.2003**

  E. C. Pavlis, K. Evans and the GAVDOS TEAM

Summary

FTLRS tracking support from April to October 2003

Tracking of altimetric satellites with a high priority for the Jason-1 calibration passes.
Tracking of geodetic satellites for positionning.

First results with cycles 52 and 53:

Preliminary Bias Calculation from two JASON Cycles (4 passes)

Cycle #	Arc #	DOY 2003	JASON SSH [mm]	TG SSH [mm]	Bias [mm]
52	9	156.1	124 ± 86	41.3 ± 1	83
	55	159.7	52 ± 172	37.7 ± 1	14
53	9	166.0	202 ± 69	31.5 ± 1	171
	55	169.6	63 ± 274	27.9 ± 1	35
Average					75.8
Std. Dev.					±200

Ascending pass 55: 49 ±229 mm
Descending pass 9: 127 ±78 mm
Weighted mean: 119 ±74 mm

Objectives for the coming year:

- Automate the TG data delivery on a daily basis
- Improve (GPS) data links with GAVDOS
- Continue GPS and MSL data analysis
- Continue regular release of altimeter-TG comparisons
- Incorporate in our calibration/validation:
  - Local geoid from airborne gravity survey,
  - GPS buoy observations
  - Altimeter transponder observations,
  - Laser profiler SSH observations

- **Absolute Calibration of the Jason-1 Altimeter using UK Tide Gauges**

  P. Woodworth, P. Moore, X. Dong and R. Bingley

Summary

- bias values: Topex 0.4cm, Poseidon 1.8cm, Jason-1 –14.8cm
- T, P and J-1 (GDR) biases for particular gauges highly correlated e.g. larger negative values for Lowestoft.

T and P bias correlation 0.94; T and J-1 0.80; P and J-1 0.69 ie geographical correlation _ datum bias

- uncertainty in individual bias estimate due to tide gauge and GPS datum uncertainties, and to errors in geoid-difference in the EGG97 model, could be around 2 cm, which is consistent with the spread of individual bias values for each altimeter.
- Systematic sea-surface topography differences including surge differences 1-5cm
    - accuracy of method limited by systematic datum and geoid uncertainties, rather than by accuracy of the tide-difference correction or by the role of the various quasi-random error terms within the short P and J-1 data sets.

Station	Pass	Distance Gauge-Alt (km)	T Bias (cm)	rms (cm)	P Bias (cm)	rms (cm)
Aberdeen	87	45	2.2	4.6	2.0	6.6
	196	54	0.7	4.6	0.3	5.3
N.Shields	163	73	3.6	6.0	6.3	6.8
	120	36	-3.5	3.2	-5.3	6.6
Lowestoft	137	71	-5.3	9.3	-6.7	12.2
	120	76	-4.1	8.9	-6.4	10.4
Newhaven	137	35	-0.2	4.8	1.8	3.5
	222	50	1.5	6.5	5.3	7.6
Newlyn	239	41	0.4	4.6	0.1	5.4
	70	54	-0.5	5.1	2.0	3.6
Average			-0.5		-0.1	
Median			0.4		1.8	

Note: the sign of the bias is the reverse than for all the other presentations

- **Calibration results of Jason-1 altimeter in Lake Erie and S. Pacific**
  Y. Yi, K. Cheng, C. Shum, A. Braun, S. Calmant, D. Chambers

Summary

- Preliminary results from 2 multiple RA calibration sites (Lake Erie, Ohio; Vanuatu, S. Pacific) for T/P (TOPEX Side B), JASON-1 and ENVISAT are presented, as part of the ongoing efforts.
- Marblehead Site Lake Erie JASON-1 cycle 2–48 calibration results [Shum et al., 2003] indicates strong dependence on the choice of sea state bias (SSB) models. Furthermore, lake calibration result does not agree with ocean calibration results
- Preliminary calibration result at Vanuatu Site is in preparation by Calmant et al., (2003) Marine Geodesy.
- The ultimate goal is to establish these absolute calibration sites to complement existing or planned sites, and to contribute to the characterization of altimeter system instrumental biases and their potential drifts

JASON-1 CAL/VAL RESULTS

	JASON-TSB Relative Bias (mm)	Contribution of Bias from CLS SSB Model (mm)	*Instrument Bias* (mm)
Global Collinear Analysis	146 ± 59	76 ± 18	70
Global Crossover Analysis	147 ± 66	76 ± 38	71
Great Lakes Collinear Analysis	77± 49	58± 16	19

Differences of 45 mm depending on sea state bias models used
Lake bias results different from ocean calibration (up to 70 mm)

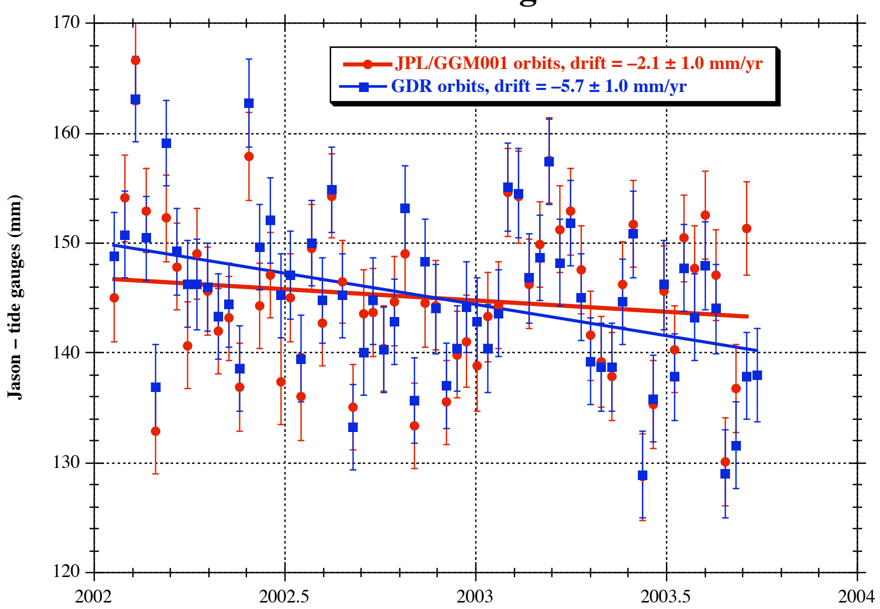
	JASON-TSB Relative Bias (mm)	Contribution of Bias from CSR SSB Model (mm)	*Instrument Bias* (mm)
Global Collinear Analysis	98 ± 60	28 ± 14	70
Global Crossover Analysis	99 ± 66	28 ± 38	71
Great Lakes Collinear Analysis	32 ± 49	13 ± 12	19

II- GLOBAL EXPERIMENTS PRESENTATIONS:

- **Tide Gauge Calibration Results for Jason-1 and the Implications for Measuring Global Mean Sea Level**
  R. S. Nerem, G. T. Mitchum and E. Leuliette

Summary

Jason-1 Tide Gauge Calibration



- Apparent drift in Jason-1 bias is due to orbit errors in POE for cycles 2 to 8
- strong Geographycally Correlated Errors in the SSH differences between T/P and Jason-1 Formation Flying Phase (±30 mm)

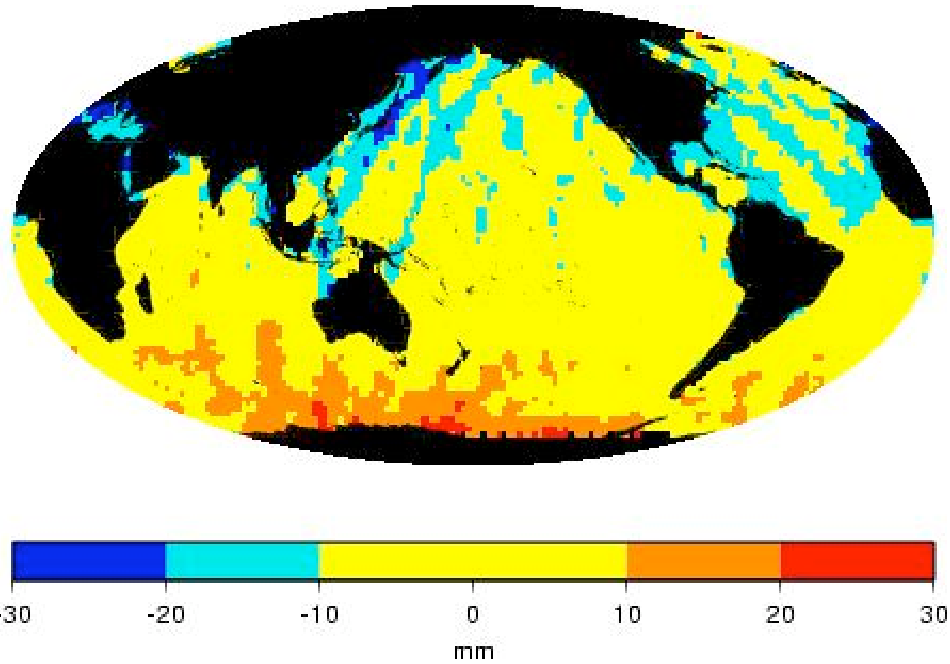
- Comparable results of the tide gauge calibration for T/P on the new ground track (tandem phase since cycle 369)

- **Calibration/Validation of Jason-1 GDR SSH using global residuals with TOPEX and tide gauges**
  D. Chambers, J. Ries and T. Urban

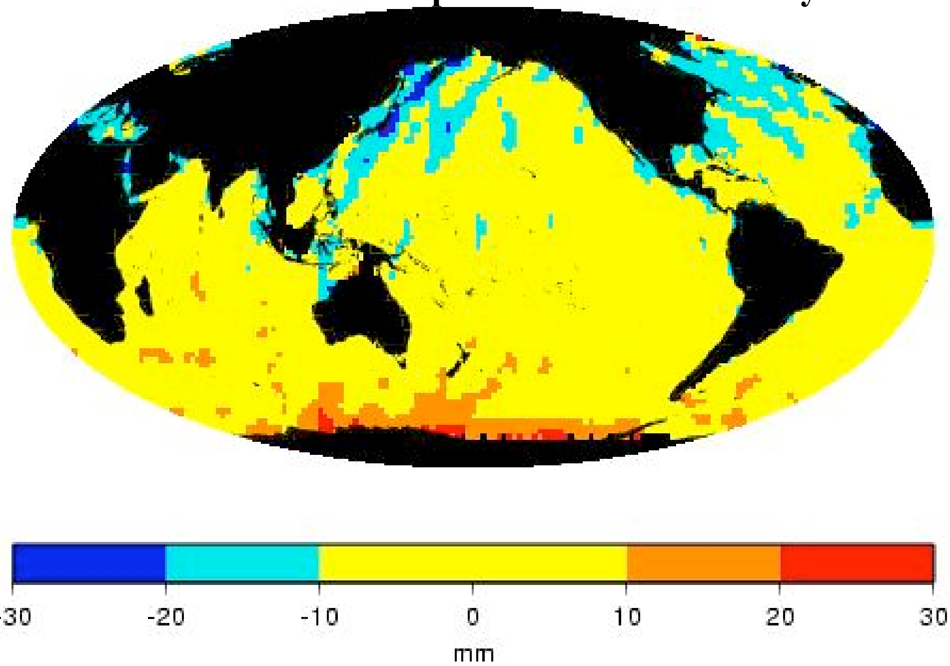
Summary
- GDR orbits have a change in mean radial bias after Cycle 8
  Explains apparent "drift" in SSH residuals during Cal/Val
  Mean radial orbit drift relative to CSR orbits for Cycle 9+ is not significant

- First 8 Cycles with GDR orbits should not be used for GMSL studies because of change in bias
  Orbits after this are consistent
- Global relative bias using GDR sea state bias model is 150 mm
  Local biases generally within ± 10 mm of this
  A SSB model based on more data reduces bias to 144 mm and produces slightly more uniform bias
- Average residuals with tide gauges indicates no significant drift
  However, not significant because of short time-span; if trend continues, may soon be significant.

Global Variation in Bias : GDR SSB



Global Variation in Bias : Updated SSB based on Cycles 2-61



- **Determining Altimeter SSH Absolute Bias From Different Satellites Using Distant Calval Sites**

  G. Jan, M. Faillot, Y. Menard, F. Lyard, and E. Jeansou

Summary

- Idea : To be able to use satellite passes far from the CalVal site, for the altimeter calibration : Increase the calibration opportunities from the in-situ approach.
- It was not possible with a classical in-situ calibration. The limitation came from the SSH bias formulation which does not integrate two main effects at regional scale : the sea level due to the marine geoid gradient, the ocean dynamics variability between a distant satellite pass and the tide gauge. Method enclosed nearby the tide gauge.
- A new formulation of the altimeter bias removes the previous "over-fly" constrain and refines it with two additional corrections terms.
- It is now possible to realise absolute calibration exercises using distant altimeter data.
- Method validated with Jason-1 both (I)GDR, applied to Topex-Poseidon (T/P) on its new orbit and to Geosat Follow on (GFO)
- Method can be apply to any altimeter, assuming that there is calibration site with levelled tide gauges and an accurate mean altimeter profile available.

Perspectives:

- Extend the calibration opportunities: SSH bias at ocean regional scale.
- Estimate the geographically correlated errors related to orbit .

Tab 1 Experimental conditions for each satellite parameters

Satellite	(I)GDR	cycles	Geophysical Correction	Extra correction
Jason-1	GDR 20Hz	1-61	Ionosphere, dry & wet (JMR) troposphere, polar & solid tides, loading effect, SSB model from (S.Labroue, CLS, 2003/01))	Tide & ocean dynamics correc. with MOG2D model (Lyard)
T/P	GDR 10Hz	43	Ionosphere, dry & wet (TMR) troposphere, polar & solid tides, loading effect, SSB EBM4	MOG2D
GFO	NGDR 1Hz	63-115	Ionosphere, dry & wet troposphere, Inverse Barometer, Ocean Water tide, Ocean Load Tide, Solid & Pole Tide + Sea State Bias	MOG2D

Tab 2: SSH bias synthesis from different absolute in-situ calibration methods and with a set of tide gauges installed on sites at Harvest and

SITE	N cycles	σ (cm)	Mean (cm)	Sources
USING JASON-1 GDR ORBIT (POE)				
Harvest (California)	37	43	12.6+/-0.6	JPL (B. Haines)
Senetosa (Corsica)	37	36	10.4+/-0.6	CERGA (P. Bonnefond)
USING EXTENDED VERSION OF IN-SITU CALIBRATION				
Senetosa (Corsica)	38	22	10.8+/-0.4	CNES, Noveltis (G.Jan)

- **Cross Calibration of JASON, TOPEX-Poseidon, ENVISAT, ERS-2 and Geosat Follow-On wind wave data, based on comparisons with in situ data and wave model analysis fields.**
  D. Cotton, P. Challenor and J.-M. Lefevre

Summary

- Need to consider buoy type as well as (instead of?) buoy network
- - TOPEX Ku is the 'best' wave measurement (lowest residual SD) and is close to NDBC
- - JASON SWH is biased (14cm) and reads 13% high (change from last year)
- - More work is needed on the measurement/modelling of high (>8m) waves
- - GFO agrees with NDBC but not CMEDS or WAM!

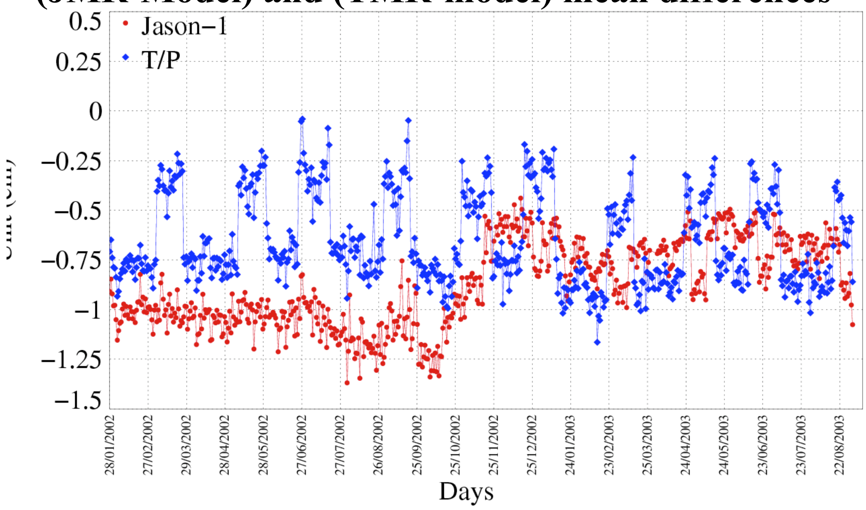
Note: the SWH calibration by Cotton et al. was done with IGDR data, and the GDR SWHs have been corrected to try to remove this bias and trend.

- **Jason-1 GDR SSALTO/CALVAL results**
  M. Ablain, J. Dorandeu, F. Mertz, B. Soussi, N. Picot, and P. Vincent

Summary

- Good general performances of Jason-1 data:
  Altimeter parameters coherent with T/P
  Similar performances with T/P
  SSH bias is quite stable
- Radiometer troposphere wet correction:
  Drift of 5 mm around cycle 26-32
  Signals linked to yaw steering modes
  Direct impact on the mean sea level

(JMR-Model) and (TMR-model) mean differences

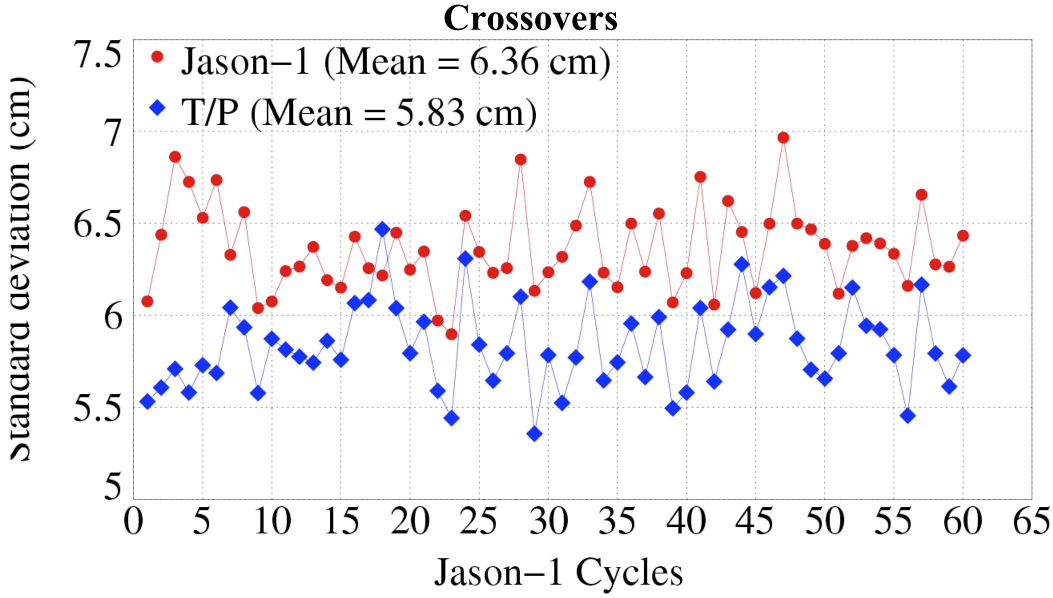


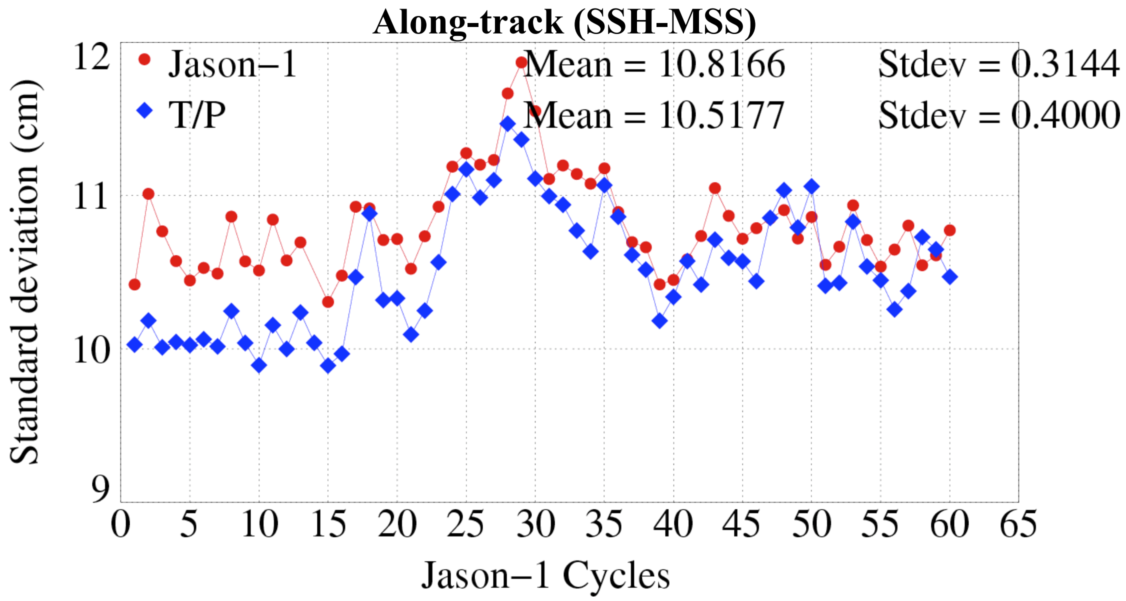
- **Jason-1 performance assessment**
  J. Dorandeu, M. Ablain, F. Mertz, B. Soussi, N. Picot, and P. Vincent

Summary

Good general performances of Jason-1 compared to TOPEX/Poseidon:

- Difference in altimeter ground processing (retracking). Impact on short wavelength content, and interpretation of SSH variability.
- Improvements made to the Jason-1 orbit (maneuvers)
- Differences in orbit calculation depending on laser/DORIS weighting
- Geographically correlated signal (or hemispheric) between T/P and Jason-1 needs monitoring (impact on interpretation of MSL signals).





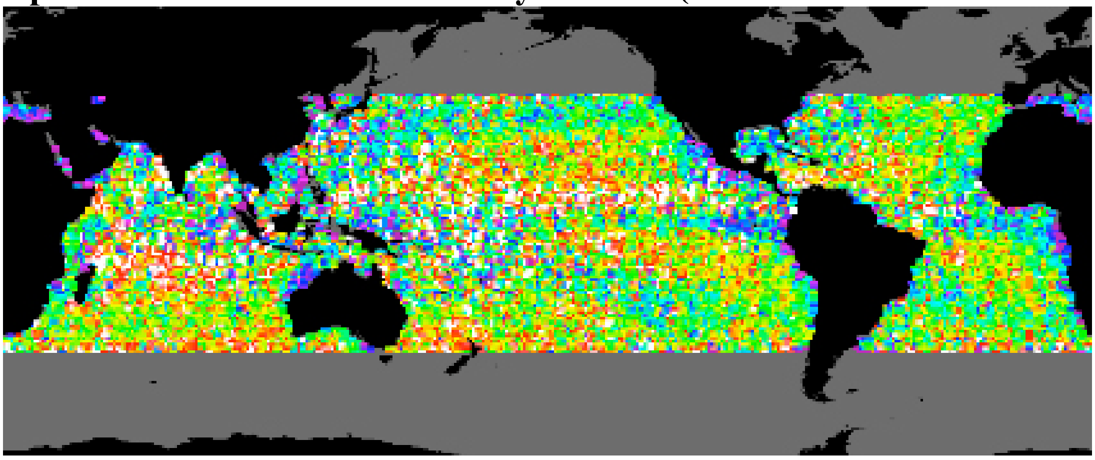
- **JMR instrument performance**
  S. Desai, B. Haines, V. Zlotnicki

Summary

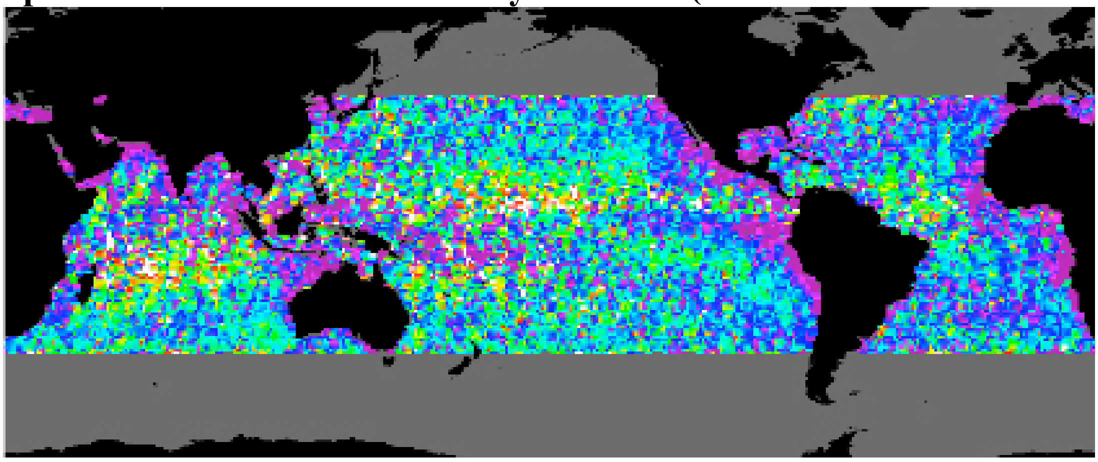
- +3-4 mm step between cycles 29-32 (see Figure in Ablain et al. Presentation)
- -5 mm step at cycle 2 caused by change to ECMWF model

- Similar +4-5 mm step in JMR path delays found in comparisons to GPS.
- ECMWF model relatively stable in comparison.
  - Smaller scatter after cycle 36 when ECMWF model modified.
  - Smaller scatter in (JMR-ECMWF) differences (from 1.5 to 1.25 cm).
- Comparisons to SSM/I and TMI suggest possible geographically correlated errors in JMR wet PD.

Comparisons to SSM/I and TMI: Cycles 2-27 (Color scale is from -9 to +9 mm).



Comparisons to SSM/I and TMI: Cycles 29-59 (Color scale is from -9 to +9 mm).



- **Assessment of the TMR and JMR brightness temperatures and products**
  E. Obligis, N. Tran and L. Eymard

Summary

<u>TMR:</u>

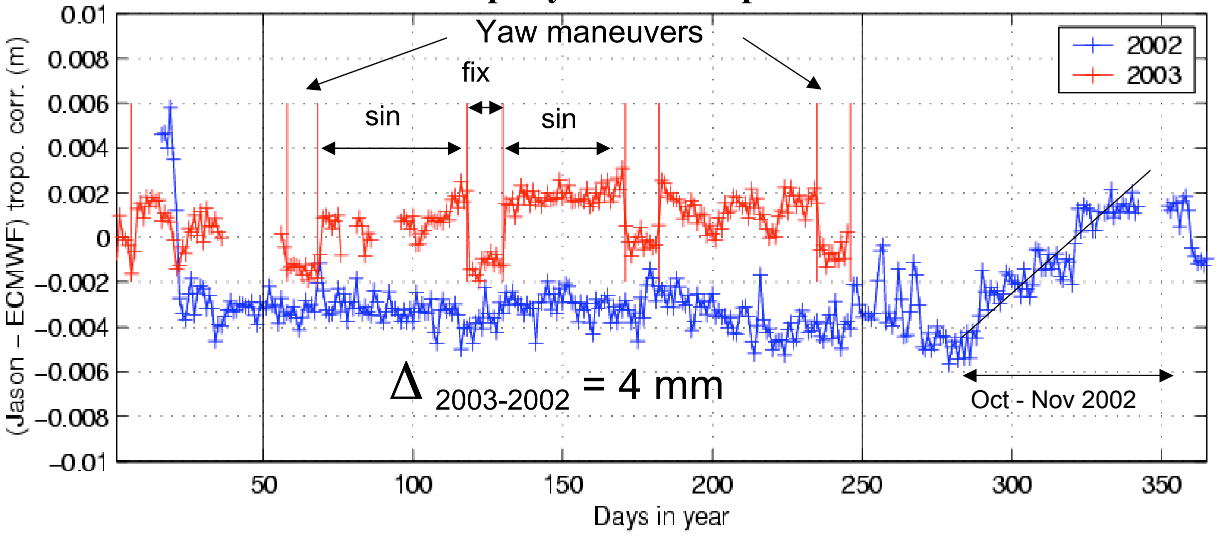
- the 18 GHz drift correction degrades the recomputed product versus radiosonding measurements
- strong yaw state dependence
- TMR brightness temperatures appear very stable in time since Jason launch

<u>JMR:</u>

- products comparison with radiosonde measurements shows a quite good agreement
- descending ramp on dh during October and November 2002 (cycles 27 to 32)
- since this ramp, the yaw state dependence reappears
- at least TBs of channels 2 and 3 are decreasing

=> Instrumental parameters survey is needed to explain these different features

JMR ramp + yaw state dependence

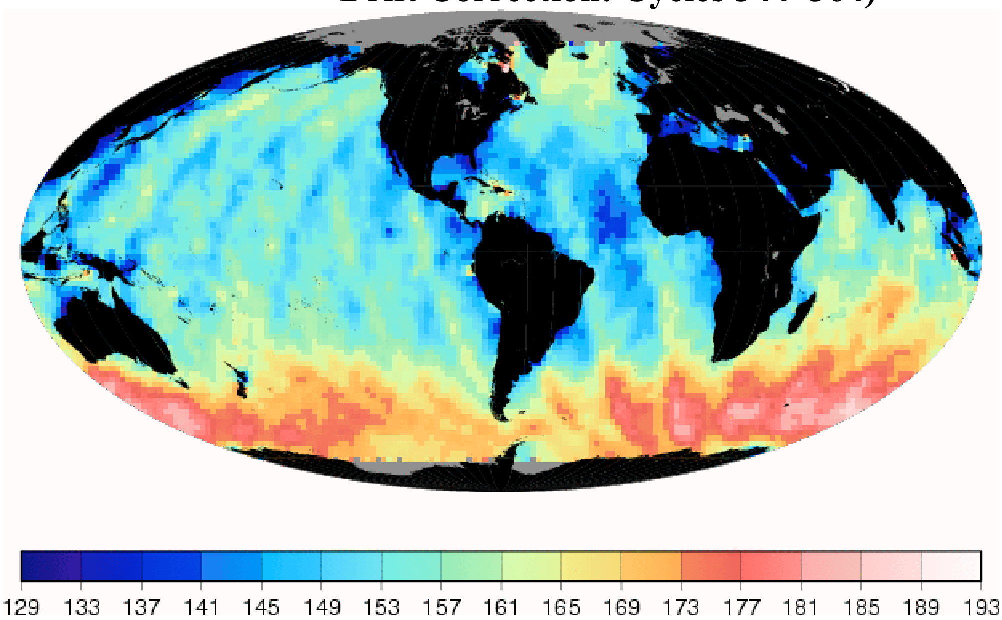


Recommendations

Some leads for reconciling the relative bias derived from local estimates with the global numbers

Total contribution of GCE on the SSH

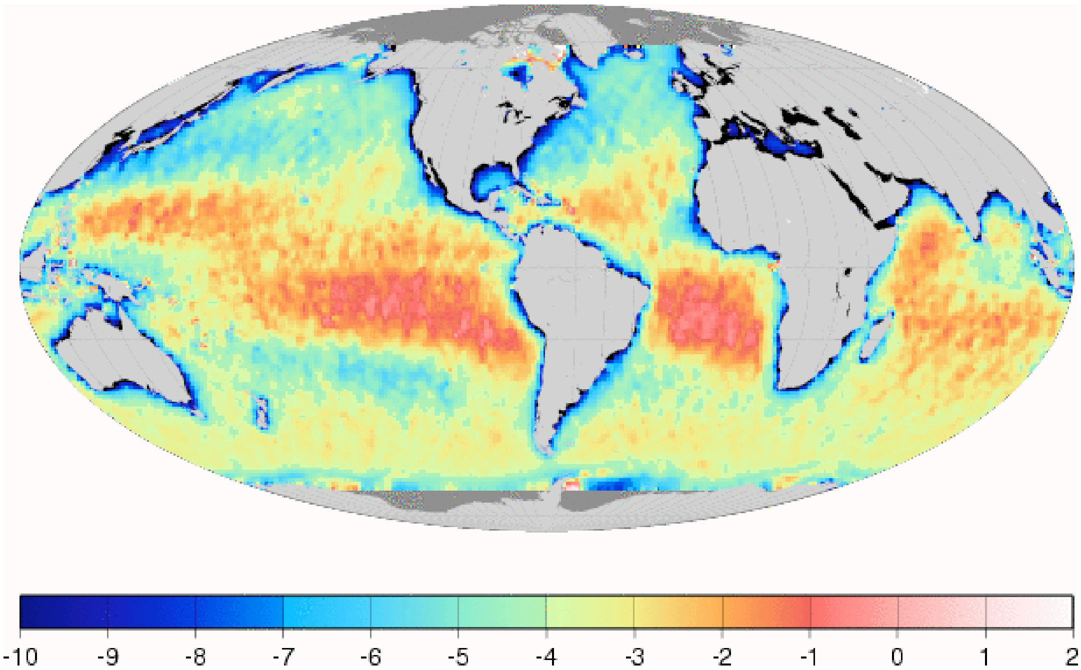
Jason-1 – T/P Sea Surface Height: Ascending & Descending Tracks. Formation Flying Phase (Jason-1 GDR: Cycles 1–21 - T/P MDGR + TMR Drift Correction: Cycles 344–364)



Indentified Possible Contributions to some GCE:

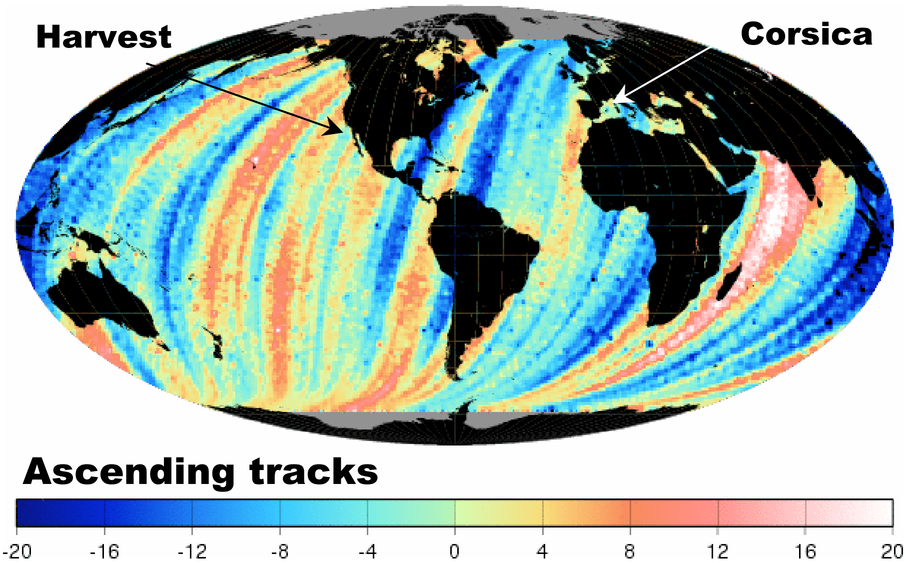
1- JMR

JMR yields drier readings near coasts : Mean = –4 mm, s = 3 mm. It then affects most of the calibration sites in the same way

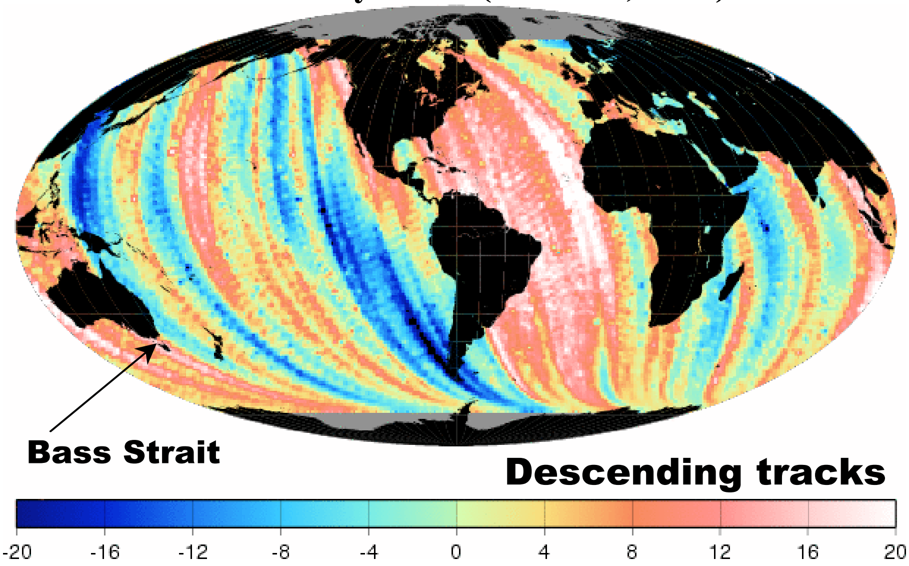


2- Orbit

Radial orbit differences (mm): CNES POE (JGM3, SLR+DORIS) - JPL Reduced Dynamic (GRACE, GPS)



Radial orbit differences (mm): CNES POE (JGM3, SLR+DORIS) - JPL Reduced Dynamic (GRACE, GPS)



3- SSB

The contribution seems to come from both T/P and Jason-1 SSB (see chambers et al. presentation)

List of recommendations:

- The use of GRACE gravity field which removes most of the GCE link to the orbit
- Check if the coastal dependance of JMR can be removed or corrected
- Improve the SSB for both T/P and Jason-1