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


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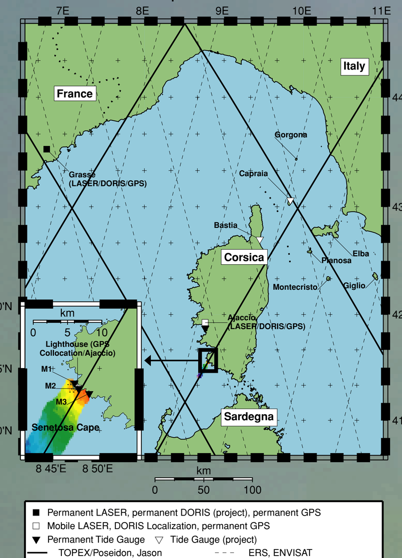
**All the trends given in this analysis have no absolute meaning due to the small set of data. They are only given to understand relative behaviors**

## GENERAL OVERVIEW

### Calibration Process

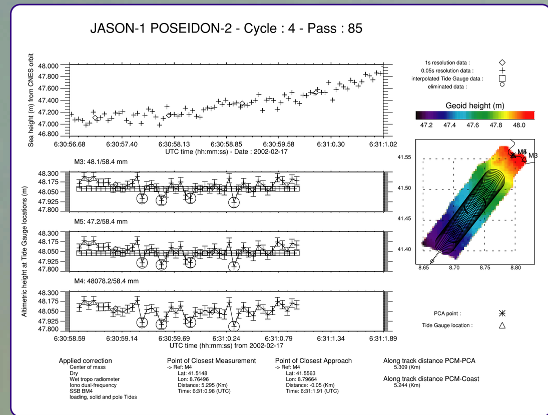
Senetosa/Capraia Calibration Site




The Senetosa calibration site provides in situ sea height estimations and local condition parameters (tide gauges, GPS buoy, meteorology station), that are compared to altimetric data.

In a first step, hi-rate altimetric sea heights (upper panel) are corrected from geoid slope by computing the sea height differences from the altimetric data location to each tide gauge location (3 lower panels). At each altimetric data location, the mean geoid height is computed inside the footprint area (left panel) which size is defined by the formula given in Chelton et al. (1989). At the tide gauges locations the geoid heights are constant and have been determined by the mean of GPS sea heights of the 99 Catamaran campaign.

In a second step, tide gauges data are linearly interpolated for each hi-rate altimetric data time (3 lower panels). The mean values of sea height differences, and the associated standard deviations, are then computed (Haltimeter - Htide gauges) for each tide gauge. This gives the estimated impact of altimeter range bias on the sea height determination. Altimeter bias is thus defined in the following as the difference between altimetric determination and "in-situ sea height".




The corrections used for altimetric sea heights determination are listed at the bottom of the Figure. They follow the recommendations of the AVISO handbook [AVISO, 1996] allowing users to use our bias determination in agreement with their sea level determination.

Same process is used for the GPS buoy but at its off-shore location (~10km).

Products Main Differences for Calibration

| | TOPEX/Poseidon | Jason-1 |
|---|---|---|
| IGDR | Orbit from NASA (SLR+GPS); Pole tide correction is set to zero; Sea state bias from TGS; Wallops correction not included*; Range bias of +15 mm is not applied; Wind Speed | MOE from CNES (DORIS only); 20 Hz data are not corrected from Doppler effect |
| GDR | POE from NASA; Sea state bias from TGS; Wallops correction not included*; Range bias of +15mm is applied; Wind Speed | |
| M-GDR | POE from NASA and CNES | POE from CNES |

MOE: Medium precision Orbit Ephemeris
POE: Precise Orbit Ephemeris
*Range bias changes for the NASA radar altimeter of the TOPEX/POSEIDON mission

### Definitions on products and processes

TOPEX/Poseidon IGDR and GDRT from PO.DAAC are modified using AVISO standards (Aviso User Handbook AVI-NT-02-101-CN) in order to be more coherent with M-GDR products:

- Sea state bias from TGS is replaced by the BM4 model
- Pole tide correction is included
- Wallops correction is included
- Wind Speed from Witter and Chelton (1991) formulation
- Range bias of +15mm is applied (TOPEX range too short)

In order to improve calibration process orbit from IGDR can be replaced by better solution. Results will be shown in a dedicated section.

The resulting products are then consistent with CALVAL standards (pdf format) as defined by B. Haines and results can be directly compared to Harvest ones. The GCP (GDR Correction Products) from JPL are not used.

### Definition of altimeter bias calibration

The sea height bias is defined by the relation (1):

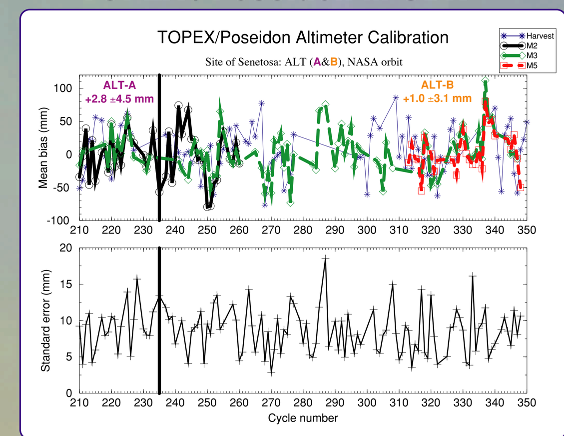
sea height bias = altimeter sea height - in situ sea height (1)

Sea height bias < 0 meaning the altimetric sea height being too low (or the altimeter measuring too long)

Sea height bias > 0 meaning the altimetric sea height being too high (or the altimeter measuring too short)

## ALTIMETER CALIBRATION WITH TIDE GAUGES

### TOPEX / Poseidon M-GDR




TOPEX/Poseidon altimeters (ALT-A and ALT-B) have been calibrated from 1998. Results show a great coherence between both altimeters 2.8 ±4.5 mm and 1.0 ±3.1 mm for ALT-A and ALT-B respectively. Moreover, results are very close to those obtained from the Harvest Platform (difference of 6 and 2 mm respectively for ALT-A and ALT-B).

### TOPEX / Poseidon and Jason-1 altimeter biases

Figure 9 show Jason-1 altimeter bias determination from cycle 2 to cycle 25 and for the three tide gauges settled at Senetosa Cape. Cycle 22 corresponds to the last T/P over flight (365, 14th august 2002) but also to a change in the JMR corrections. Cycles 23 to 25 will then be removed from the statistics in order to work on a consistent set of data. In this Figure a different behavior appears on M5 tide gauge: when comparing common observed cycles the relative trend of M5 is about -2.5mm/cycle. In fact, the data show that it is mainly due to strange behaviors in M5 measurements localized on relatively short time scale. These problems will be submitted to AANDERAA manufacturer because it is not acceptable for such kind of instruments. Data from M5 will not be used to estimate absolute bias in this study. However because of a similar behavior on T/P and Jason-1 bias calculation, they can be used for relative bias estimate and comparison with global estimation.

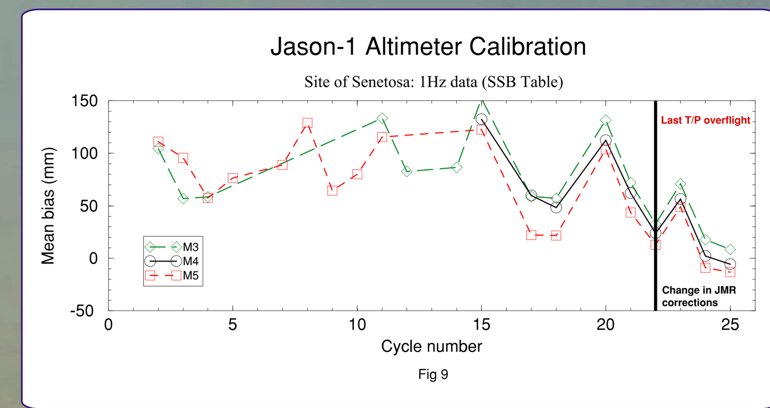



Fig 9

### Altimeter bias using IGDR

Results presented in Figure 12 shows a good agreement between Senetosa and Harvest calibration sites in terms of absolute altimeter biases even for M4 tide gauge that has been settled in June 2002. Results differ by about 32mm from those presented in the previous SWT (Biarritz, June 2002) mainly due to the use of the interim SSB model.
Jason-1 (Poseidon-2): +85.6 ± 10.8 mm
TOPEX/Poseidon (ALT-B): -1.4 ± 10.6 mm
(for comparison, ALT-B bias determination from cycle 208 to 350 using M-GDR is: +1.0 ± 3.1 mm)
The relative bias between T/P and Jason-1 using a combined solution of M3, M4 and M5 determinations is:
Poseidon-2 – ALT-B: +84.1 ± 8.1 mm

### Altimeter bias using "pseudo GDR"

In order to estimate the improvement that will be available with GDR products orbits of T/P and Jason-1 IGDR have been replaced by the Precise Orbits Ephemeris computed respectively by NASA and CNES (Figure 11).
While T/P shows a relatively important improvement (4mm, for M3) of the standard error it is not really the case for Jason-1 where standard error is a little bit increased when using POE (1mm, for M3). These results are not in agreement with our short-arc analysis presented in the poster "Validation Activities for Jason-1 and TOPEX/Poseidon Precise Orbits": indeed, we have shown that radial accuracy is far better for Jason-1 POE than for T/P POE over the Mediterranean area (16mm versus 28mm). This point needs further investigation.

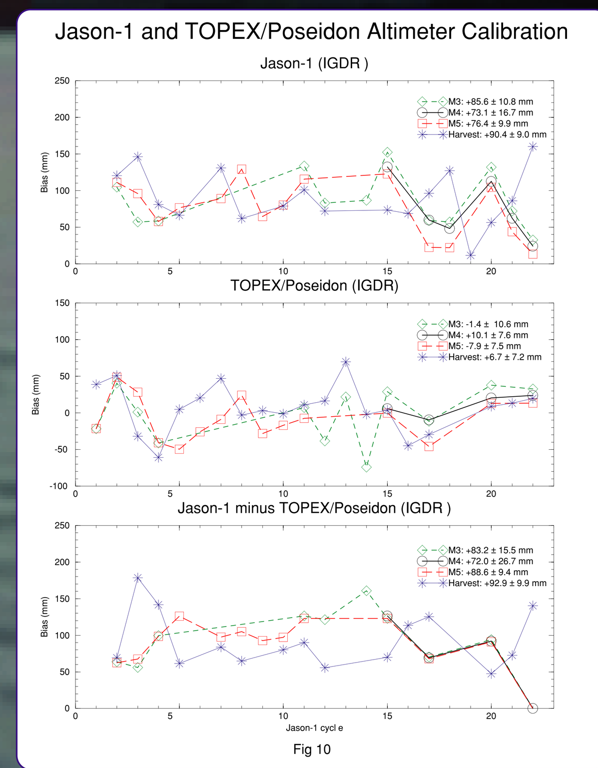



Fig 10

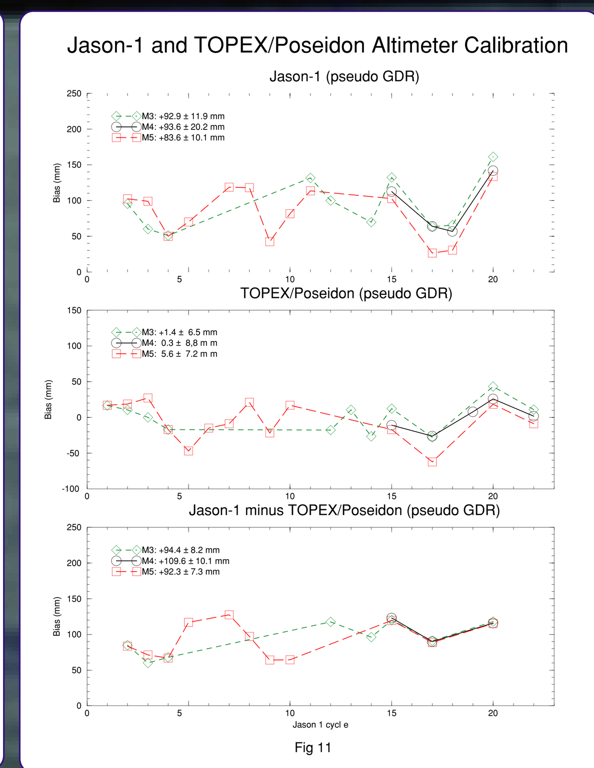



Fig 11


## Abstract

The Corsica site, which includes Ajaccio-Aspretto site, Senetosa Cape site, and Capraia (Italy) in the western Mediterranean area has been chosen to permit the absolute calibration of radar altimeters to be launched in the next futur. Thanks to the French Transportable Laser Ranging System (FTLRS) for accurate orbit determination, and to various geodetic measurements of the local sea level and mean sea level, the objective is to measure the altimeter biases and their drift. The semi-permanent use of these sites over a period of time of several years is expected.
The double geodetic site in Corsica (Aspretto, near Ajaccio and Senetosa Cape 40 km south under the Jason-T/P ground track N° 85) has been used to calibrate the TOPEX/Poseidon (T/P) altimeters from 1998, and the Jason-1 ones since the beginning of the mission. Permanent and semi-permanent geodetic equipments are used to monitor these calibrations.
Concerning the Aspretto site, a permanent GPS station and an automatic tide gauge have been installed since 1999. Since the beginning of 2002, the French Transportable Laser Ranging System is tracking mainly Jason-1 and T/P satellites, but also GFO and EnviSat.
A Senetosa cape, permanent geodetic installations have been installed since 1998 and different campaigns have been conducted in view of Jason-1 mission. Three tide gauges have been installed at the Senetosa Cape and linked to ITRF using GPS and leveling. In parallel, since 2000, a GPS buoy is deployed every 10 days at Senetosa (10 km off-shore). Results are presented in a dedicated poster "Radar Altimeter Calibration using a GPS-buoy in Corsica". as been performed from cycle 344 to 365, and Jason-1calibration has been performed from cycle 1 to 25 using IGDR products and new the new correction for SSB; all parameters (orbit, corrections,...) are listed and discussed in the poster. Results are very close to Harvest ones which make us very confident for whole calibration process.
Our semi-permanent experiment is planned to last over several years in order to detect any drift in the space borne instruments.


## Problem on the 20 Hz Jason-1 altimetric data

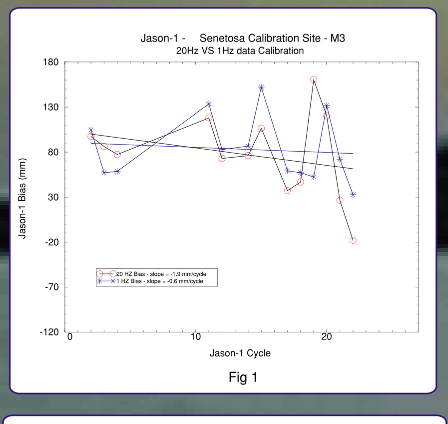



Fig 1

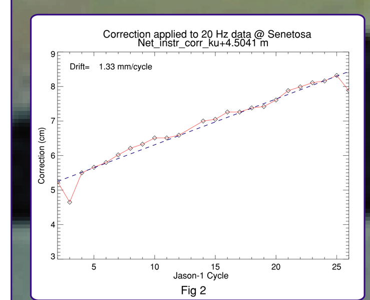



Fig 2

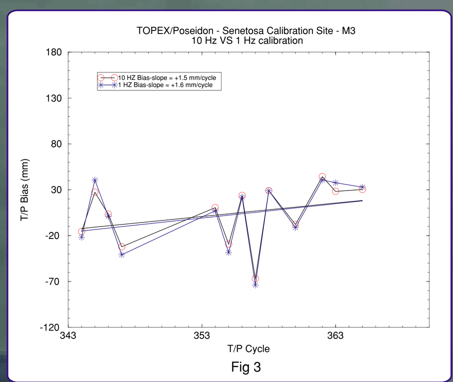



Fig 3

The 20 Hz altimetric data on IGDR are not properly corrected of the Doppler effect. This problem was identified before the previous SWT (June, Biarritz) and P. Vincent and S. Desai have given a formulation for the correction. However, our recent analysis of Jason-1 data has shown that this formulation introduces a drift on the altimeter bias determination. Indeed, a trend of -1.3 mm/cycle appears between bias determination using 1 Hz or 20 Hz data (Figure 1) while such phenomenon does not exist on T/P data (Figure 3). This trend has been identified as an error on the formulation to correct 20 Hz data and is in agreement with trend observed in the correction that is supposed to be almost constant (Figure 2): indeed this correction produces an increase of the altimeter range and then a decrease in the bias determination.
The high rate delta range parameters to be found in the IGDRs were in error because in fact corrected for the USO drift, the CoG and the internal path delay. Then, applying the correction method refered to in "June" message resulted in applying twice the USO correction.

**New formulation will be soon given by the project but for this analysis, only 1 Hz data will be used.**

## Analysis of Jason-1 Altimeter corrections

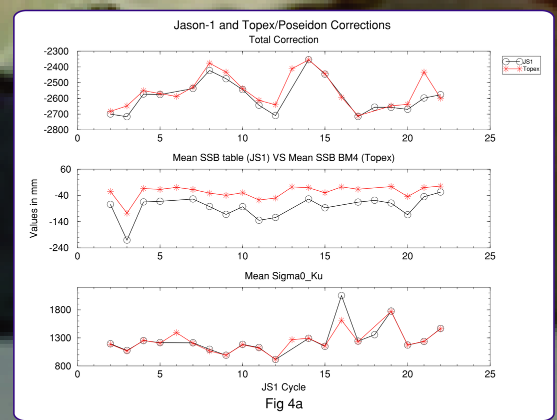



Fig 4a

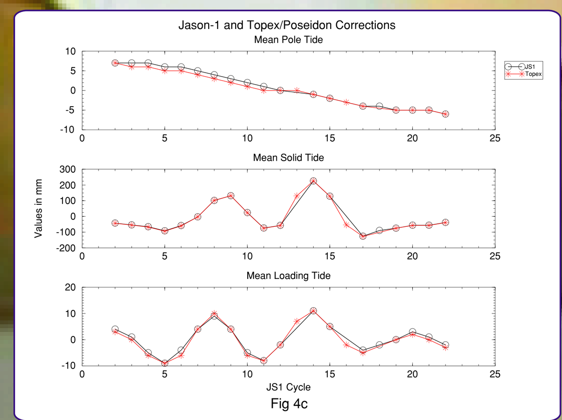



Fig 4c

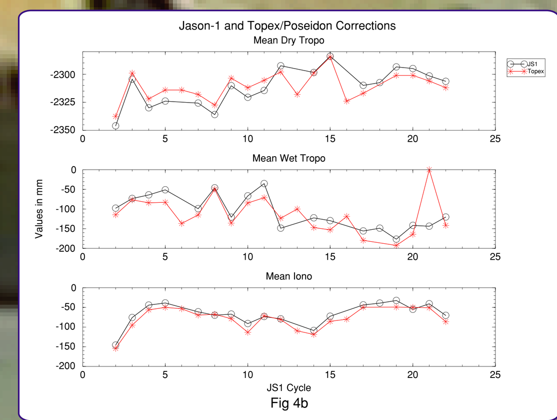



Fig 4b

Figures 4a to 4c show the corrections applied to altimetric data for Jason-1 and T/P, from cycle 2 to 22 (respectively 345 to 365), where Jason-1 IGDR are consistent. Sigma0_Ku has also been plotted to identify cycles for which a sigma bloom has appeared at Senetosa. Cycles 16 and 19 (respectively 359 and 362 for T/P) have been eliminated from this analysis due to such phenomenon.

### Sea State Bias

The interim SSB model developed by Sylvie Labroue (CLS) has been used in place of the BM4 given in the Jason-1 IGDR products. The use of this model increases the Jason-1 altimeter bias by 32mm but this fact is not significant because it probably reveal better the instrumental part of the bias.

However, SSB depends on the SWH and this parameter seems to be more poorly estimated than for T/P. Indeed, Figure 7 shows the bad correlation between Jason-1 and T/P SWH. Our comparisons with local estimations (GPS buoys, see "Radar Altimeter Calibration using a GPS-buoy in Corsica" poster) have proven the quality of T/P SWH determination and we have then used T/P SWH to compute interim SSB correction for Jason-1. Results given in Figure 8 show that the differences between the two estimations can reach 20 mm. It means that the interim SSB model could suffer from the use of Jason-1 SWH to generate it.

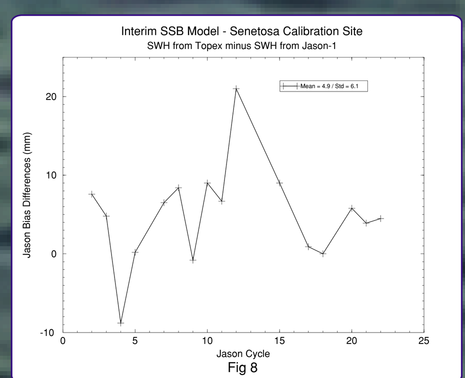



Fig 8

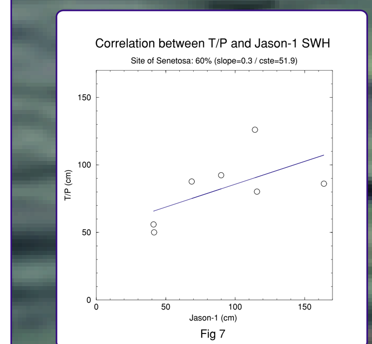



Fig 7

### Geophysical corrections

They are very coherent for both satellites (Figure 4c) with differences at the millimeter level mainly due to the unit used in the two sets (mm for T/P and 0.1mm for Jason-1).

For the other corrections a more detailed analysis has been conducted to estimate the impact on the bias determination (Figures 5a to 5d). It consists on using T/P correction in place of the corresponding Jason-1.

### Ionospheric correction:

No significant differences have been evidenced. Jason-1 ionospheric path delay is shorter by 8mm and there is no significant relative trend induces by this correction.

### Tropospheric correction

**Wet**

This analysis excludes cycles 23 to 25 where new corrections for JMR have been introduced and reduce considerably Jason-1 bias (see Figure 9). For cycle 2 to 22 Jason-1 wet tropospheric path delay is shorter by about 16mm and the behavior of the two sets shows a small trend of about -0.5mm/cycle.

**Dry**

No significant constant biases between T/P and Jason-1 has been identified for this correction. However the relative trend of about -0.8mm/cycle appears to be linked to a different behavior in the model interpolation before and after cycle 12 between Sardegna and Corsica (Figures 6a and 6b). This problem has been submitted to the project because it can affect other "shelves seas areas".

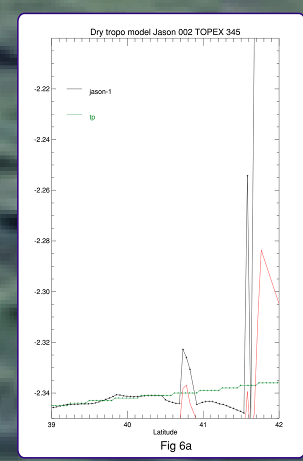



Fig 6a

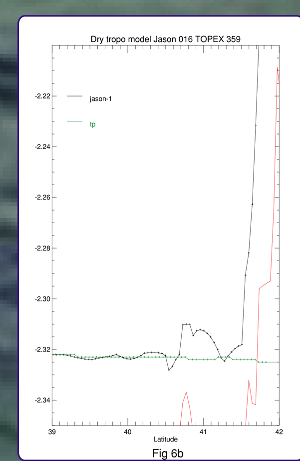



Fig 6b

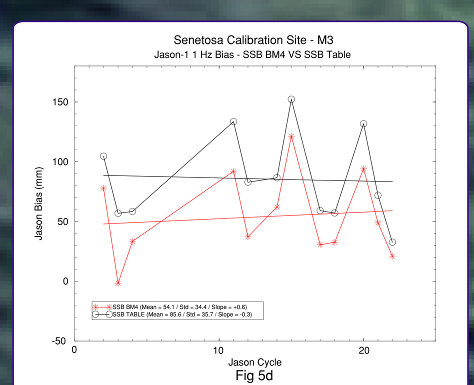



Fig 5d

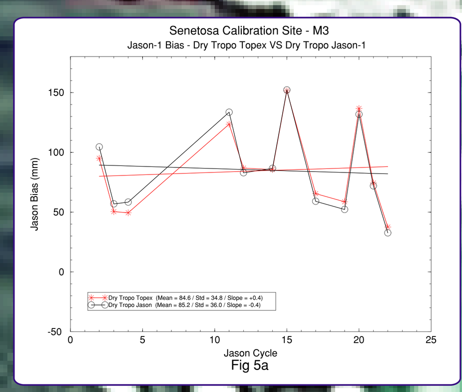



Fig 5a

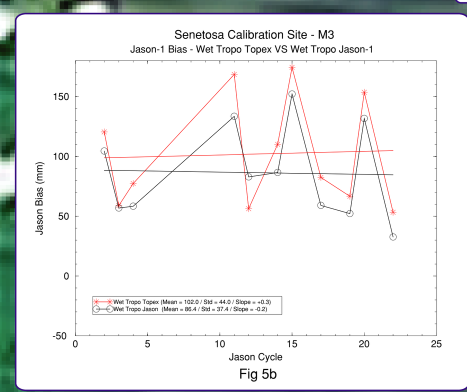



Fig 5b

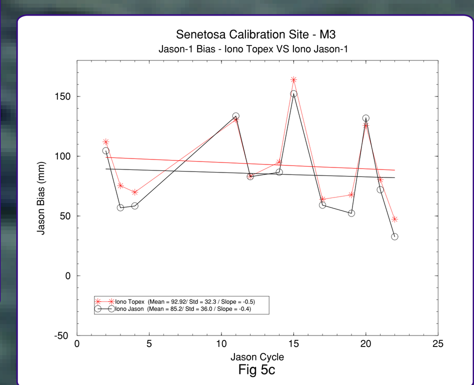



Fig 5c

In conclusion, in comparison with the use of T/P corrections, applied corrections for Jason-1 data can contribute to the altimeter bias at the level of:
Wet troposphere: -16 mm
Dry troposphere: 0 mm
Ionosphere: -8 mm
Interim SSB: +32 mm

### Impact of Orbit

Figure 12 shows Jason-1 altimeter bias computed from various orbit solutions including the short-arc one, developed at CERGA (SAO), which is based on laser measurements and notably the ones obtained by the FTLRS settled at Ajaccio (Corsica), from January to September 2002.
The smallest standard error is obtained when using SAO or GPD orbits (GPS+DORIS reduced dynamic computed at JPL). However, JPL orbits seems to increase Jason-1 bias by about 10 mm which is in agreement with our analysis of these orbits over the Mediterranean area (radial differences of -9mm between SAO and GPD orbits, see "Validation Activities for Jason-1 and TOPEX/Poseidon Precise Orbits" poster).

Calibration passes :

| | FTLRS (Ajaccio) | SLR (Grasse) |
|---|---|---|
| [illegible] | J | J + T |
| [illegible] | no returns | J |
| [illegible] | J | J + T |
| [illegible] | J + T | J + T |
| [illegible] | J | weather |
| [illegible] | weather | J |
| [illegible] | weather | J |
| [illegible] | J | J |
| [illegible] | J | weather |
| [illegible] | J + T | J + T |
| 27/04 | J + T | J + T |
| 07/05 | weather | weather |
| 17/05 | J + T | J |
| 27/05 | weather | weather |
| 06/06 | weather | weather |
| 16/06 | J + T | J+T |
| 26/06 | weather | J+T |
| 06/07 | J + T | J+T |
| 16/07 | J + T | no returns |
| 25/07 | T | J+T |
| 04/08 | J + T | J+T |
| 14/08 | J + T | J+T |
| 24/08 | J | J |
| 03/09 | T | weather |

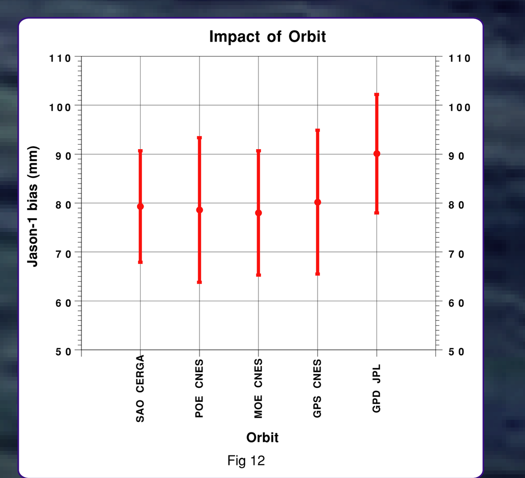
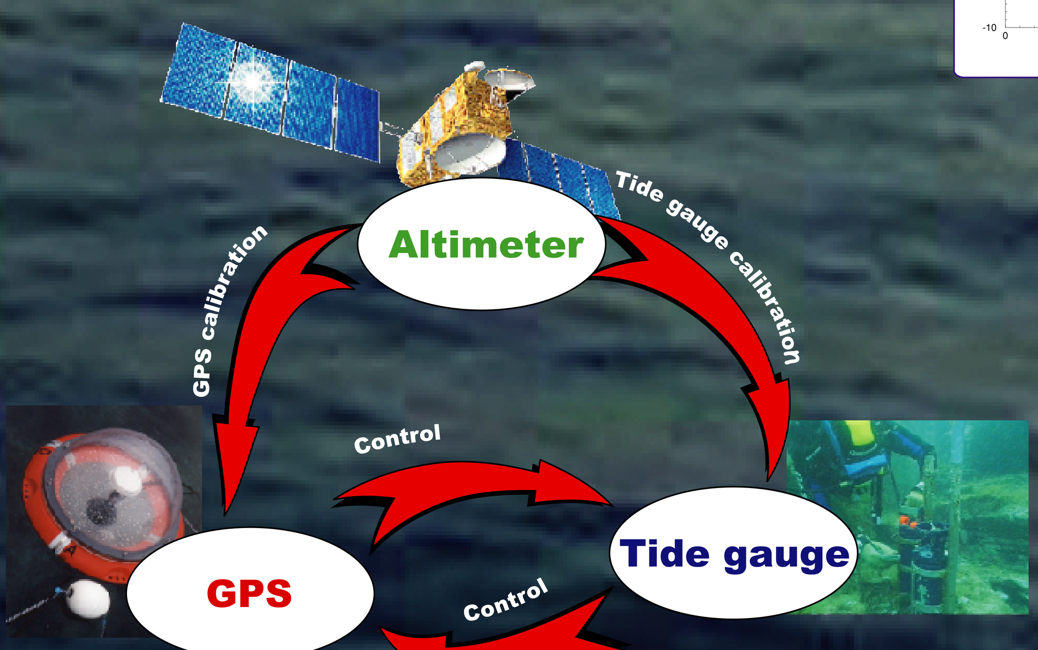



Fig 12

The whole calibration process (Tide gauges and GPS buoy) have been validated with TOPEX/Poseidon over 4 years of data and results are very consistent with Harvest ones:
- TOPEX/Poseidon (ALT-A): 2.8 ±4.5 mm
- TOPEX/Poseidon (ALT-B): 1.0 ±3.1 mm

For the common period between T/P and Jason-1 (before cycle 23) results are:
- TOPEX/Poseidon (ALT-B): -1.4 ±10.6 mm
- Jason-1 (POSEIDON-2): +83.6 ±10.8 mm
- POSEIDON-2 - ALT-B: +84.1 ±8.1 mm

Results will be continuously updated through Jason-1 validation phases and are available on the web site:
http://grasse.obs-azur.fr/cerga/gmc/calval/alt/




For calibration results using GPS buoy see poster:
**Radar Altimeter Calibration using a GPS-buoy in Corsica**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