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Absolute Calibration of TOPEX/Poseidon & Jason-1 Altimeters in Corsica: Y2K certified

Abstract

The double geodetic site in Corsica (Aspretto-Senetosa) has been used to calibrate the TOPEX/Poseidon altimeters, in order to control the geodetic installations which have been performed since 1997 in view of the Jason-1 mission.
Senetosa is located under the T/P ground track No 85 and since 1998, three tide gauges have been installed and linked to ITRF 96 using GPS and leveling. Besides, Two GPS campaigns (1998 and 1999) have been performed to measure the marine geoid slope from the coast to 20 km off Senetosa cape - in this area the geoid slope can reach 6 cm/km. This technique is describe in more details in the poster "Leveling the Sea Surface using a GPS Catamaran". The most important result of all these geodetic operations is that all the ground segment (tide gauges and marine geoid) of the closure equation has been linked to ITRF 96 with a precision of the order of 1 cm.
T/P altimeters calibration has been performed from cycle 208 to 246 in the framework which will be used for Jason-1; all parameters (orbit, corrections, ...) are listed and discussed in the poster. Results for ALT-A is 0.0 mm ±7.4 mm and based on 7 overflights, ALT-B bias is estimated to be -13.5 mm ±7.3 mm. SSALT bias has also been determined with 4 overflights (+7.5 mm ±9.1 mm). Results are then very close to Harvest ones which make us very confident for using Corsica site for Jason-1 calibration.

Introduction

The double geodetic Corsica site (Aspretto-Senetosa, Plate 1) is dedicated to the absolute calibration experiment in the framework of the Jason-1 mission. While Aspretto (near Ajaccio) will be used to concentrate satellite tracking techniques (SLR, DORIS, GPS) to locally improve orbit, Senetosa permits the realization of the closure equation (tige gauges / altimeter). The particular contribution of Senetosa is to determine altimeter bias with 10 Hz altimetric data (GDR-Ms) from 20 km off-shore to the coast using only coastal tide gauges. For doing this, a local marine geoid has been determined using kinematic GPS (see "Leveling the Sea Surface using a GPS Catamaran" poster). Three permanent tide gauges (AANDERAA, Plate 1 and Photo 1) have been installed since may 1998 with a 5 min data sampling rate. This redundancy allows the continuous determination of altimeter bias by limiting the impact of tide gauges period of outages or erroneous data.
The slight degradation of Side A and finally the use of Side B of ALT altimeter (since cycle 236) gives us the opportunity to check the Corsica site in the frame of linking altimetric missions. We first present the "1- Calibration Process" (method and corrections) and the "2- Impact of Environment Parameters" such as SWH and geoid slope. "3- Calibration Stability and Robustness" arethen be presented. Finally, "4- Calibration Results" are discussed.

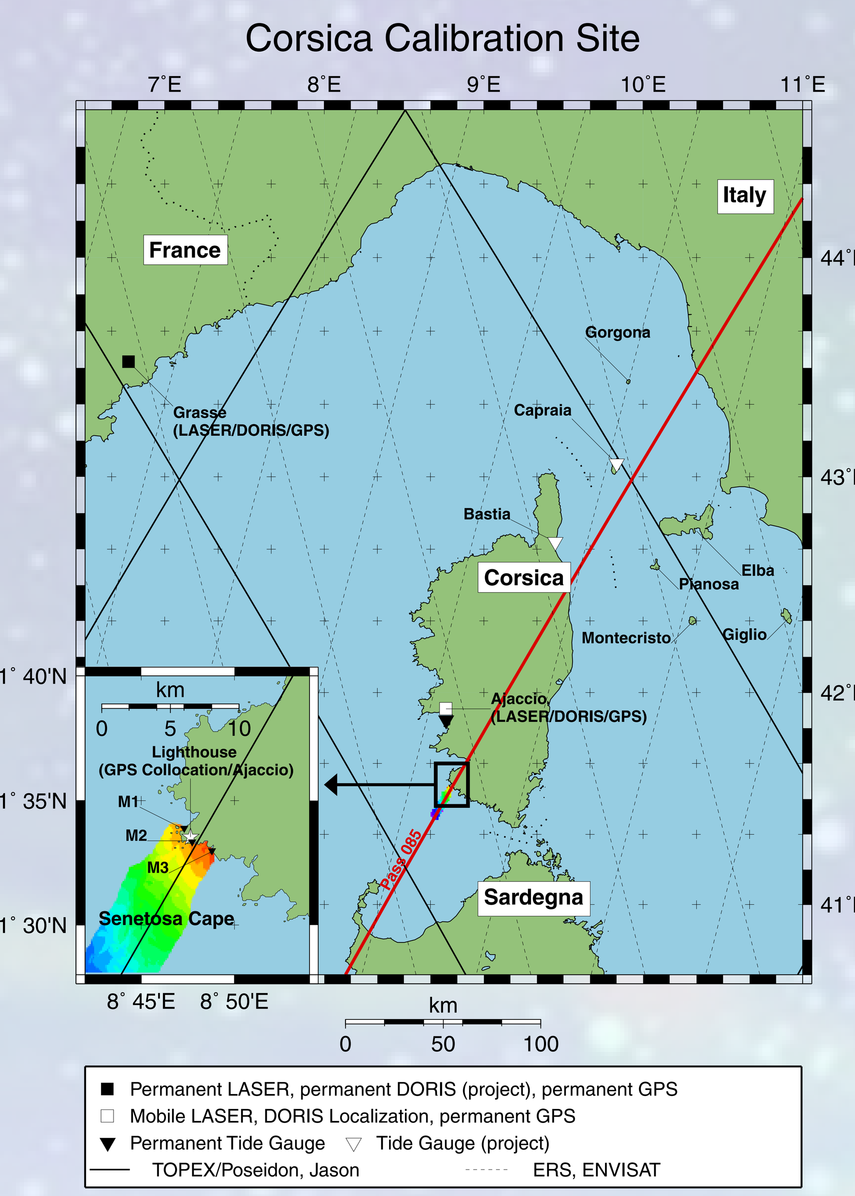

Plate 1. Configuration of the Corsica site.
Contour map represents the geoid heights determined from Catamaran GPS measurements.

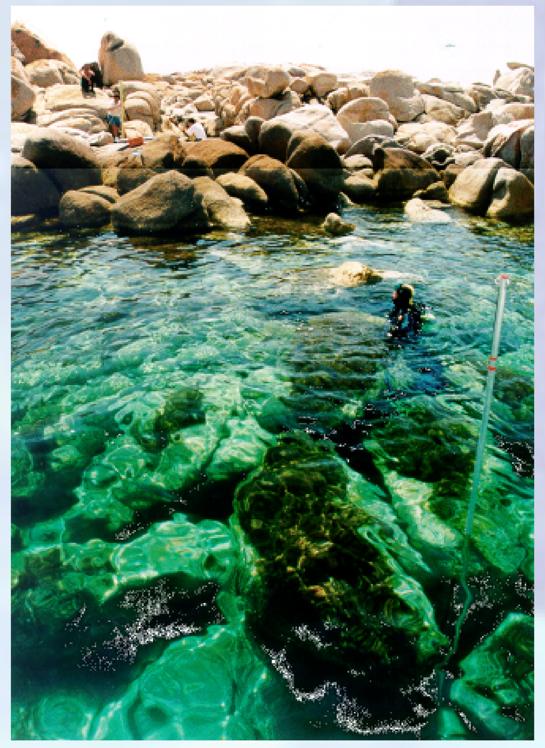

Photo 1. Tide gauge leveling at M3 location.

1- Calibration Process

Figure 1a illustrates the calibration process. In a first step, 10 Hz 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 (Figure 1a, 3 lower panels). At each altimetric data location, the mean geoid height is computed inside the footprint area (Figure 1a, 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 10 Hz altimetric data time (Figure 1a, 3 lower panels). The mean values of sea height differences, and the associated standard deviations, are then computed ($H_{altimeter} - H_{tide\ gauges}$) 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 Figure 1a and an example of their time evolution on the overflight time scale (few seconds) is given in Figure 1b. They follow the recommandations of the AVISO handbook [*AVISO*, 1996] allowing users to use our bias determination in agreement with their sea level determination. Only NASA orbits have been used for this study due to known problems in the CNES orbits during this period (Figure 5). However, biases using each orbit will be provide in the future.

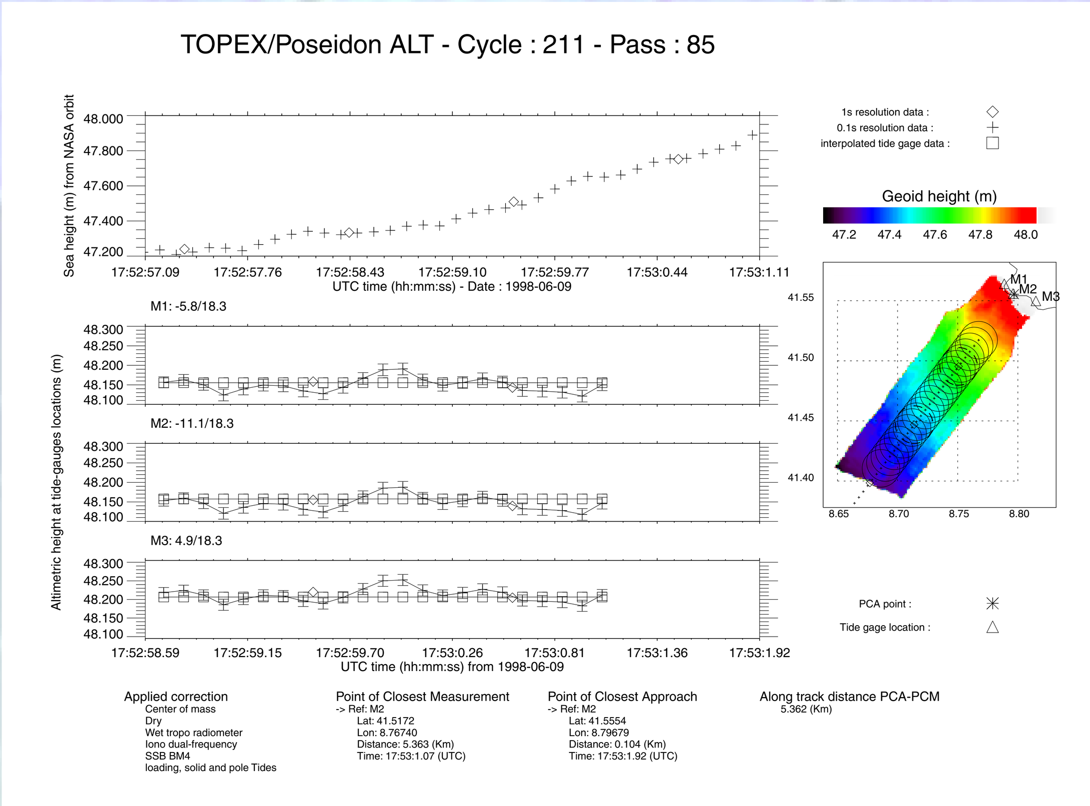

Figure 1a. Calibration process for cycle 211.

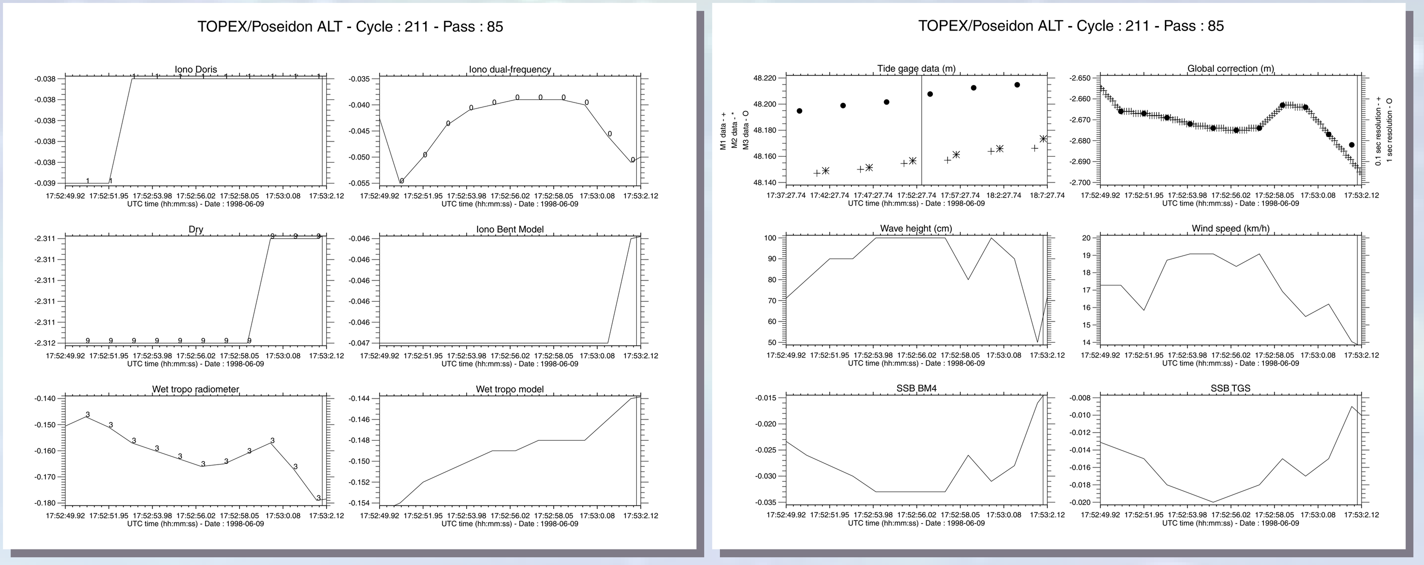

Figure 1b. Altimetric corrections for cycle 211.

2- Impact of Environment Parameters

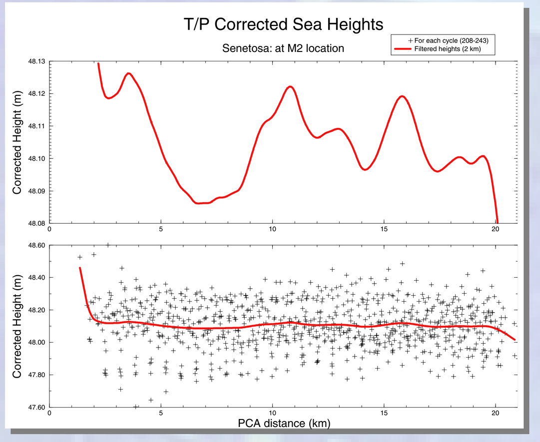

Figure 3. T/P Sea heights (1/10s) corrected from geoid slopes at tide gauge (M2) location.
- Red lines correspond to filtered heights using low-pass filter with 2 km cutoff.
- Upper panel is a zoom for filtered heights.

In this part we want to study the possible correlation with some parameters linked to the calibration process. Figures 2a and 2b give respectively the calibration value (bias) and its standard deviation as a function of (from top to bottom):
- Point of Closest Approach (PCA) distance (across-track, negative for west)
- Point of Closest Measurement (PCM) distance
- Wind Speed
- Significant Wave Height (SWH)
- Standard deviation of tide gauge measurements
- Number of 10 Hz altimetric data used
- Standard deviation of 10 Hz altimetric data.

No clear correlation have been evidenced except for very low wind speed (and then SWH, cycle 241). Tide gauges data dispersion and across track distance seems to have very low impacts. The standard deviation of bias determination seems to be mainly due to 10 Hz altimetric data precision (at least half part).
On the other hand, the geoid gradient determined during the 99 GPS Catamaran campaign seems to well represent what T/P altimeter "see". Figure 3 shows the corrected sea surface heights profiles at M2 location as a function of along-track PCA distance. The observed signal which represents differences between geoid grid and mean T/P sea heights (over 1 year) have a standard deviation of 1 cm. The main part of the signal seems to be linked to coast vicinity, probably due to corrupted altimetric signal. This leads us to limit the altimeter data processing to those with more than 5 km along-track distance from PCA (see Figure 1a).

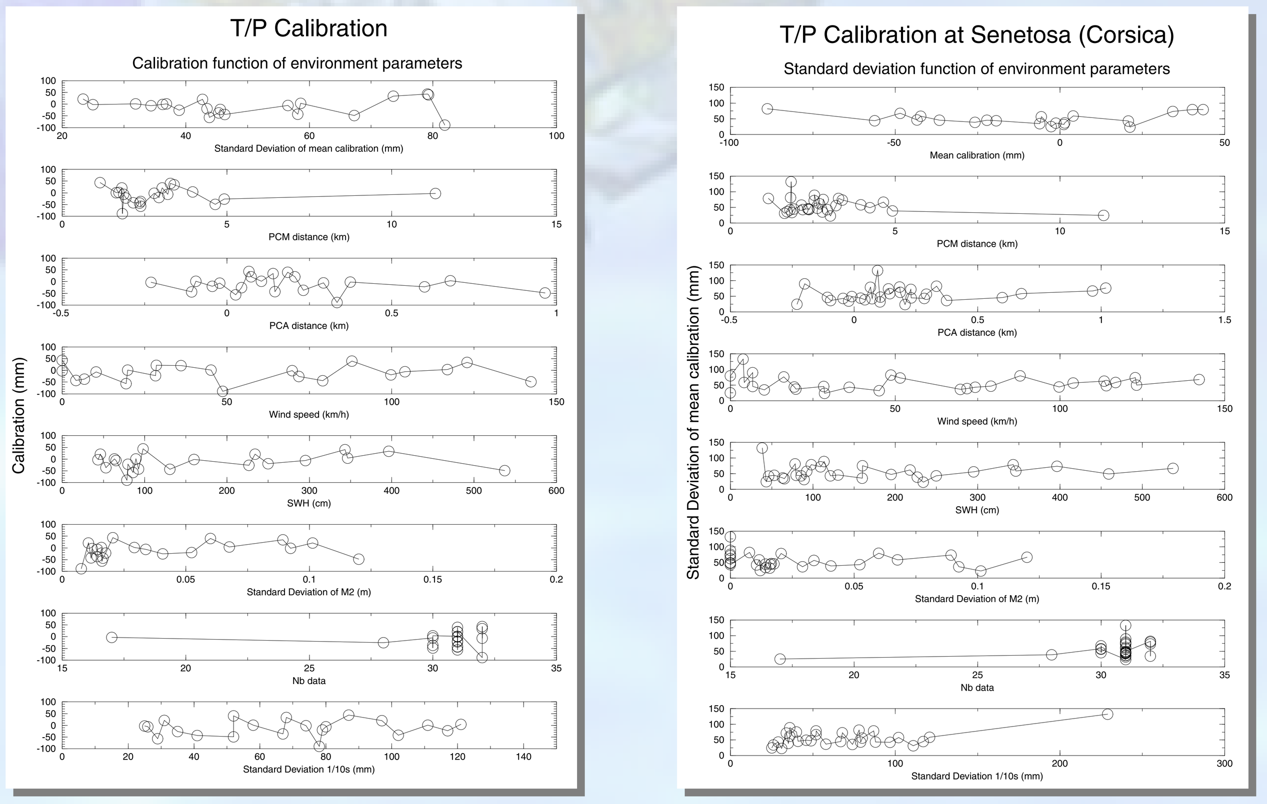

Figure 2. Calibration results as a function of parameters.
- (a, left) for Calibration (bias).
- (b, right) for Standard deviation of bias determination.

3- Calibration Stability and Robustness

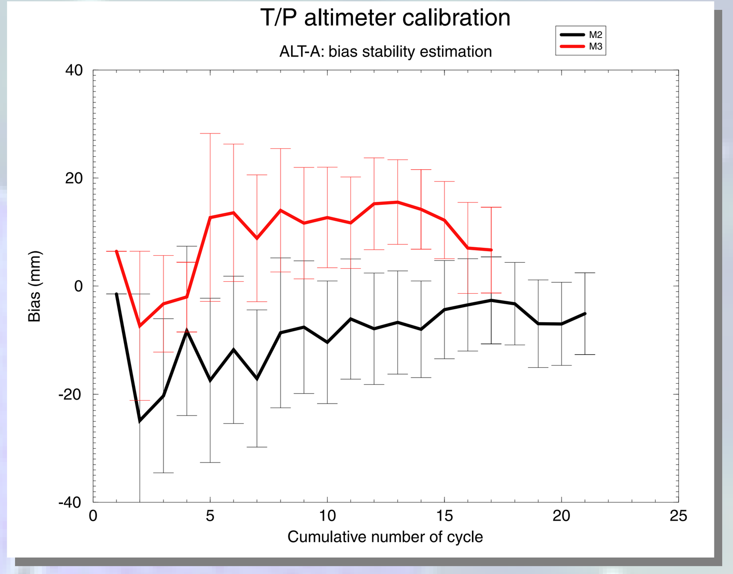

Figure 4. T/P altimeter bias as a function of cumulative number of cycles.

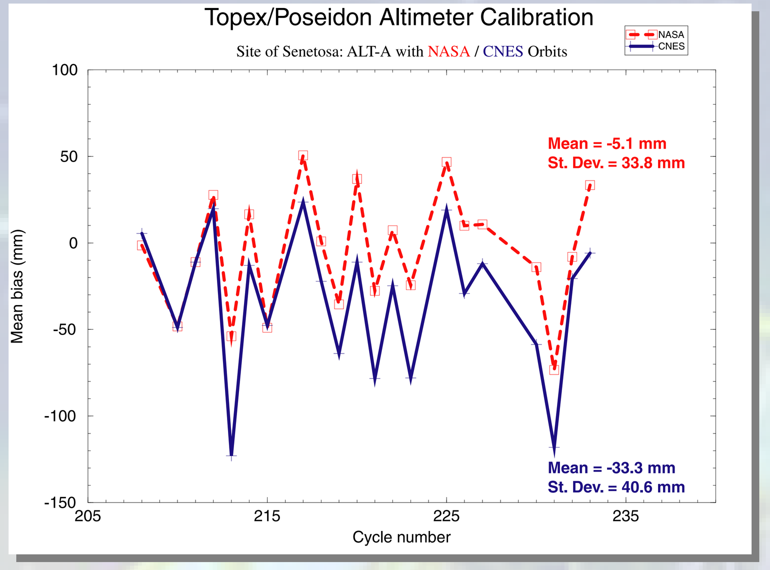

Figure 5. T/P altimeter bias using NASA and CNES orbits.

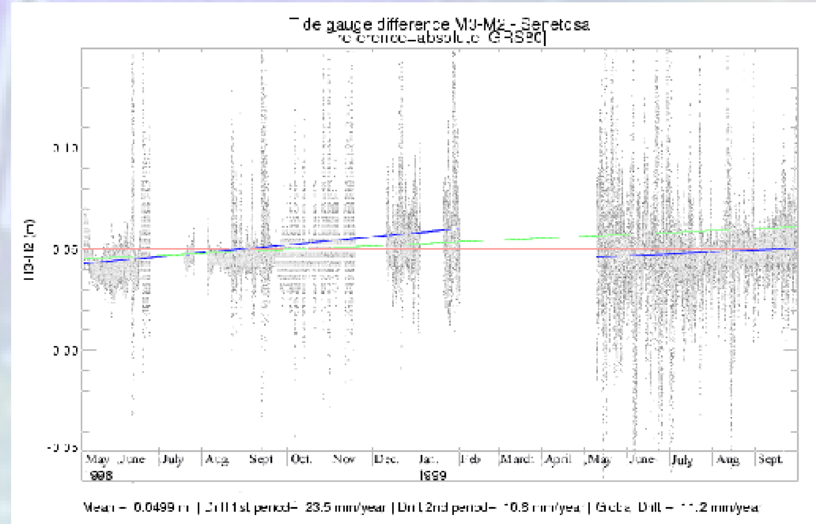

Figure 6. Tide gauge differences between M2 and M3 over 1.5 year.

Figure 4 gives the bias values as a function of cumulative number of cycles. A minimum of 10 cycles (3 months) is required for 1 cm precision but a longer time period (at least 1 year) will be necessary to reach the 1 mm challenge and to monitor possible altimeter drift.
During the calibration period, results obtained by using either NASA or CNES orbits differ by about 28 mm (Figure 5). This is mainly linked to some problems in the orbit process encounter during this period and emphisazes the importance of the tracking side of Corsica site (Aspretto). Indeed, the french SLR system (FTLRS) will allow to reduce the orbit error part which can be geographically correlated [*Bonnefond et al.*, 1999].

Figure 6 shows tide gauge differences between M2 and M3 over ~1.5 yr (gaps correspond to outages for either M2 or M3). Linear trends have been computed over ALT-A (23.5 mm/yr) and ALT-B (10.8 mm/yr) periods. However, these high values are not significant and differences between M2 and M3 seem to be due to steps in measurements. This implies a mean differences on ALT-A bias of about -12 mm (see Table 1), meaning M3 is measuring too short (taking M2 as reference). In view of checking more precisely these differences, tide gauges comparisons and calibrations will be done regularly (~2 months).

4- Calibration Results

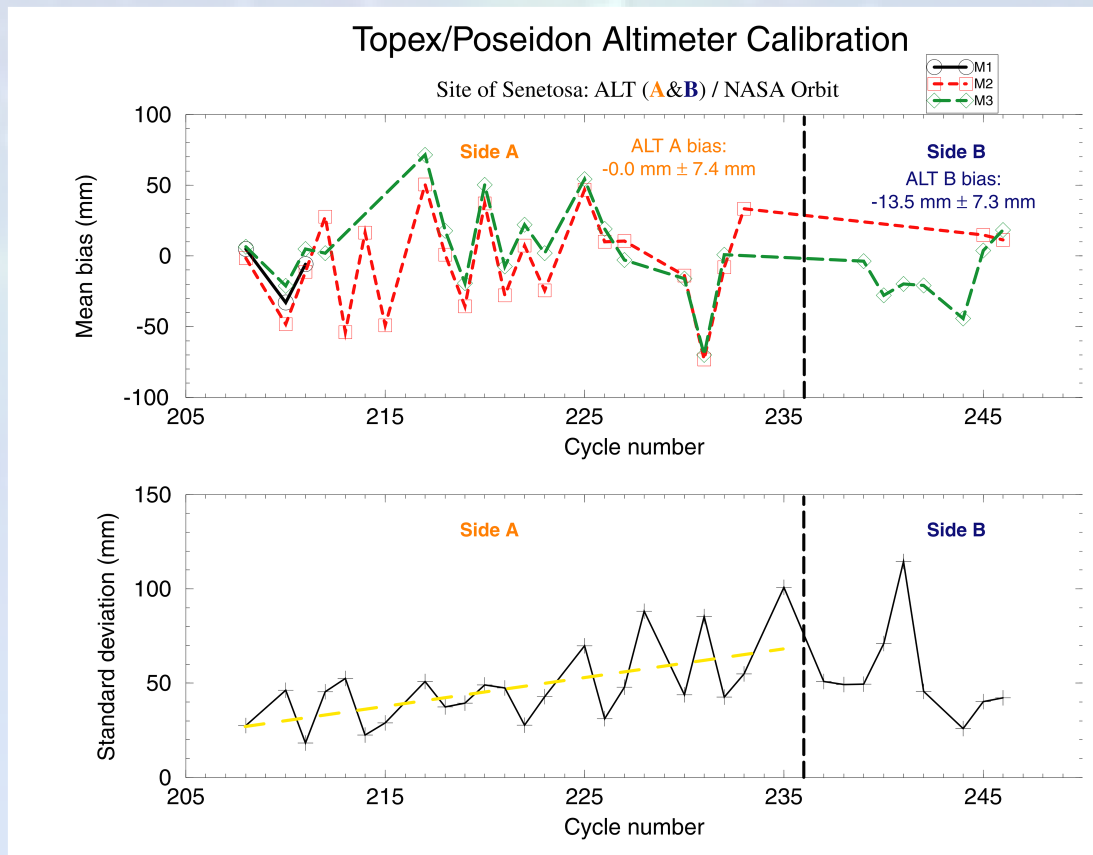

Figure 7. T/P ALT altimeter bias using NASA orbits for cycle 208 to 243.
- Upper panel shows the mean values per cycles for each tide gauge.
- Lower panel shows the standard deviation of corrected altimetric sea heights.

Table 1. Calibration values using Catamaran GPS grid (cycle 208-246), units are in millimeter

Altimeter	Number	Mean	Stddev	Tide Gauges
ALT-A	21	-5.1	33.8	M2
ALT-A	16	+6.7	31.7	M3
ALT-B	7	-13.5	19.4	M3
SSALT	4	-0.2	17.7	M2
SSALT	4	+15.1	18.7	M3

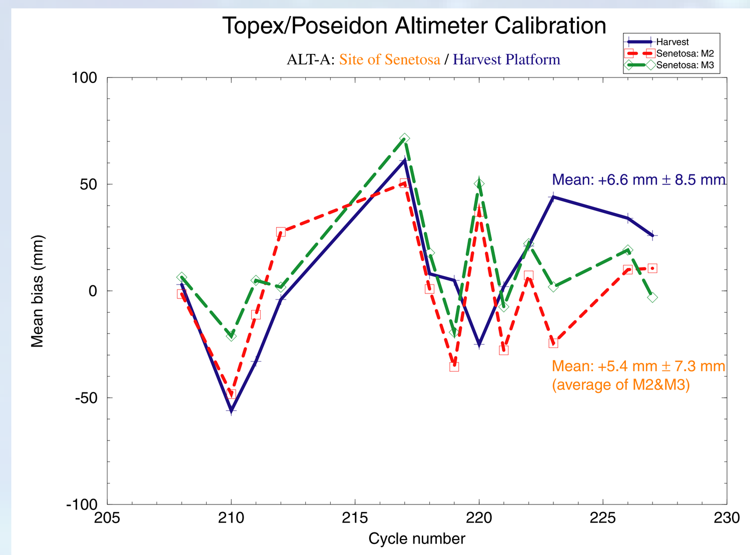

Figure 8. T/P bias at Harvest and Senetosa for 13 common cycles.

Figure 7 shows calibration results for ALT altimeter (Side A&B). In the upper panel, bias determinations per cycle are plotted for each tide gauges location. Results between tide gauges are coherent within 1 cm. Statistics for each altimeter (ALT A&B and SSALT) are listed in Table 1. The difference between ALT-A and ALT-B is about -20.2 mm ($SSH_{ALTB} - SSH_{ALTA}$). For comparison the difference found in *AVISO/CALVAL* (1999) using SLA relative to cycle 235 is -13. mm. However, the very low number of determinations for either ALT-B or SSALT do not permit to be very confident in the results.
The lower panel shows the standard deviation for each bias determination which mainly reflects the standard deviation of 10 Hz altimetric data. The mean value of this standard deviation is 48 mm but clearly shows a trend (yellow dashed line) which is probably linked to side A degradation. The maximum value (cycle 241, side B) is probably due to very flat sea conditions (see Figure 2b).
Figure 8 shows comparison for ALT-A bias between our results and Harvest ones, for common cycles (13). Standard deviation and bias values are in very good agreement. Moreover, the time variation seems to be very coherent for both calibration sites (cycles 208-219 notably).

Future improvements before Jason-1 launch

1- Displacement of M1 tide gauge close to M2 (d<1m) (better check tide gauges precision and stability)
2- Installation of a meteorological station (close to the light-house)

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