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

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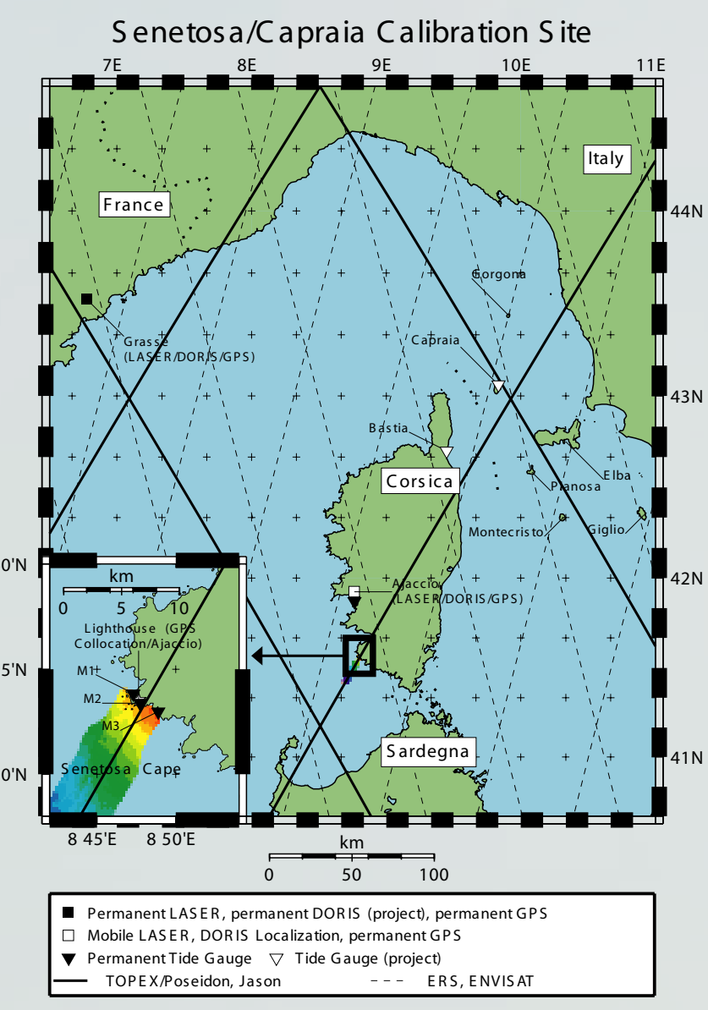
GENERAL OVERVIEW

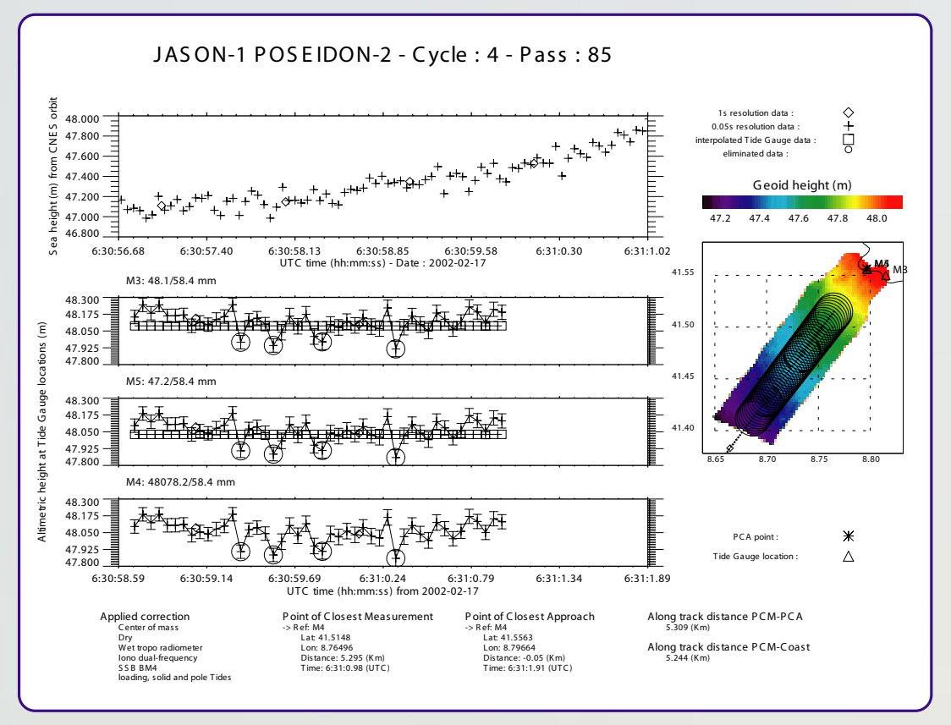


The Senetosa calibration site provides in situ sea height estimations and local condition parameters (tide gauges, GPS buoy, meteorology station), that are compared to altimetric data.

Calibration Process

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
GDRT	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 measuring 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.

IGDR Jason-1: 20Hz Doppler correction has been applied

If not corrected Jason-1 altimeter bias is increased by 62.7 mm

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):

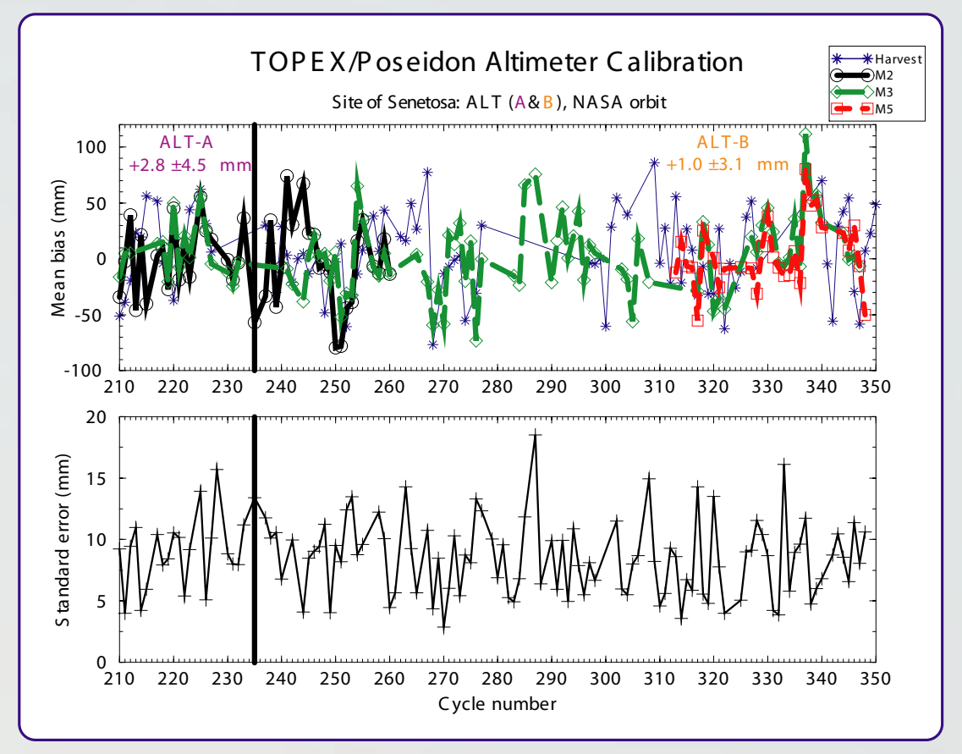
sea height bias = altimeter sea height - in situ sea height (1)

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)

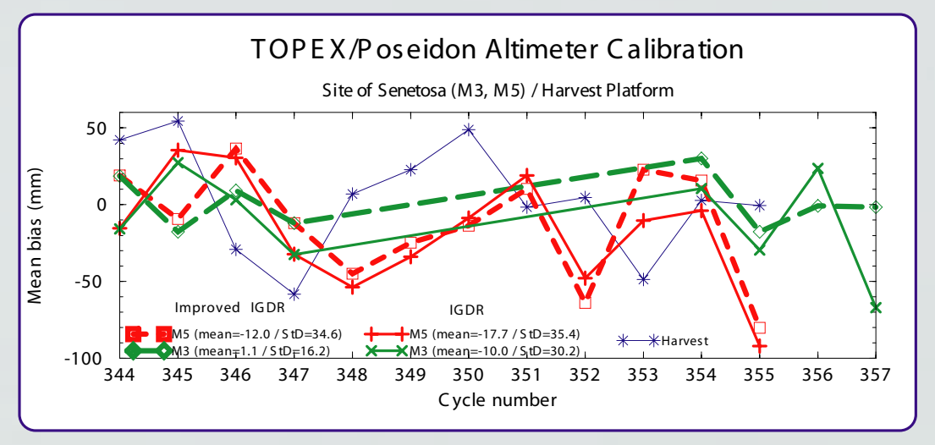
ALTIMETER CALIBRATION WITH TIDE GAUGES

TOPEX / Poseidon M-GDR



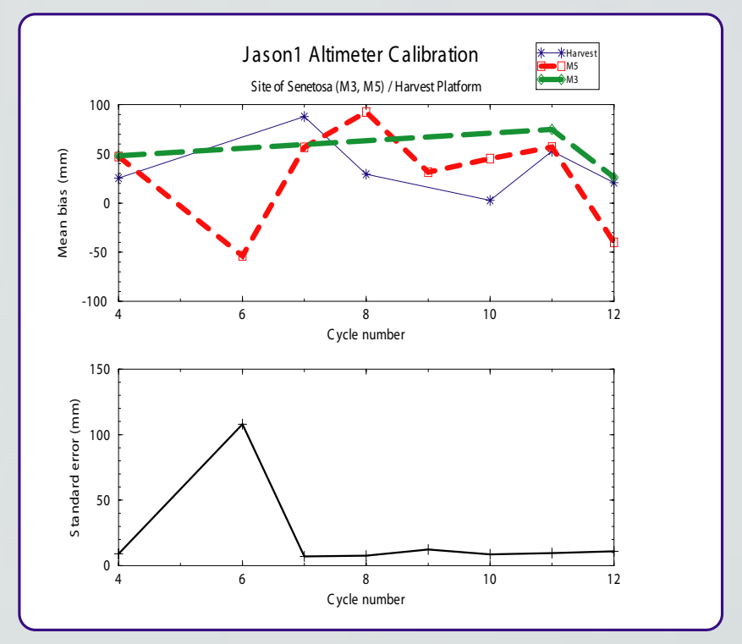
TOPEX/Poseidon altimeters (ALT-A and ALT-B) have been calibrated from 1998. Results show a great coherence between both altimeters 2.8 ±4.5 mm and 1.0 ±3.1 mm for ALT-A and ALT-B respectively. Moreover, results are very consistent with those obtained from the Harvest Platform (difference of 6 and 2 mm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

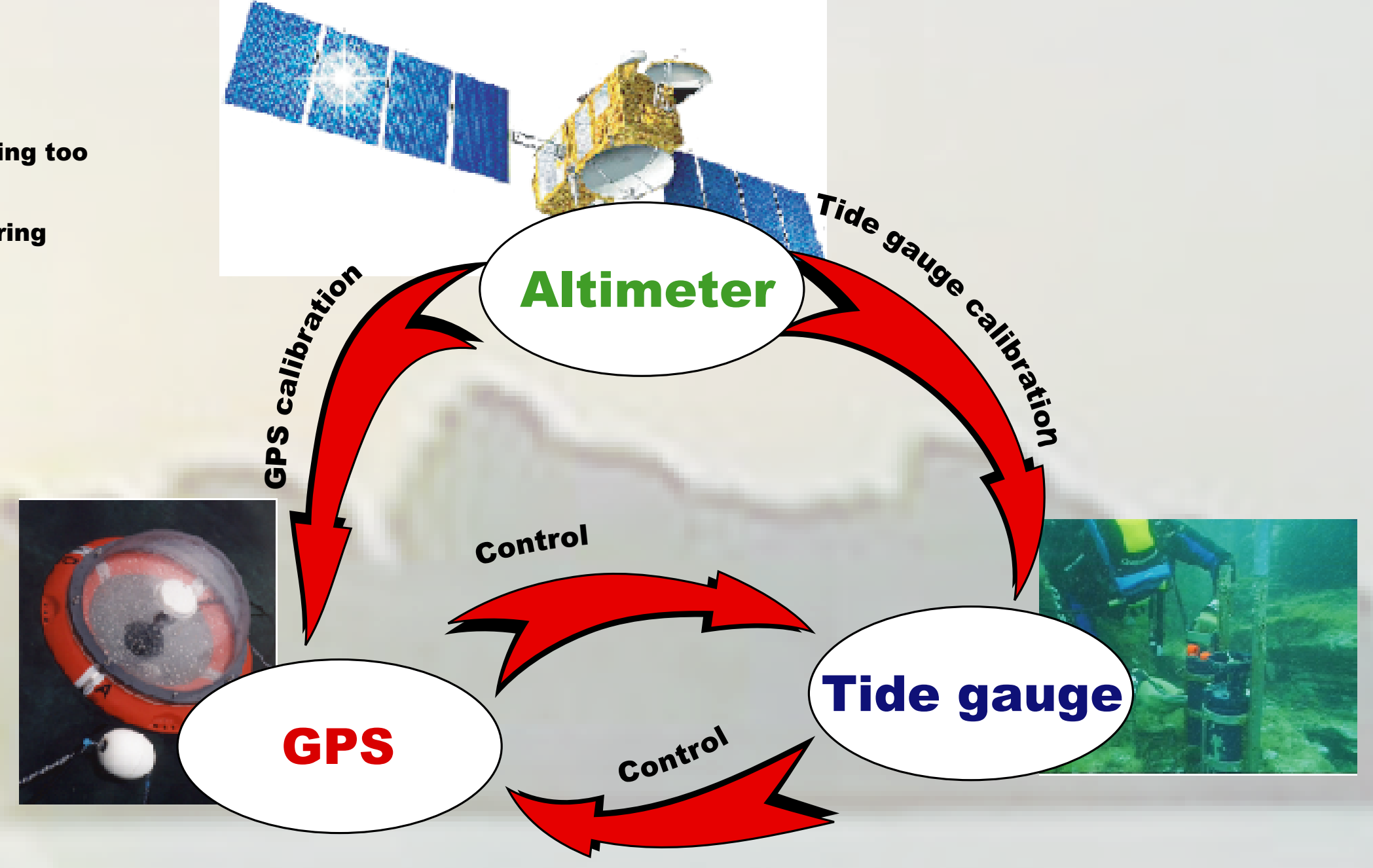
Improved TOPEX / Poseidon IGDR



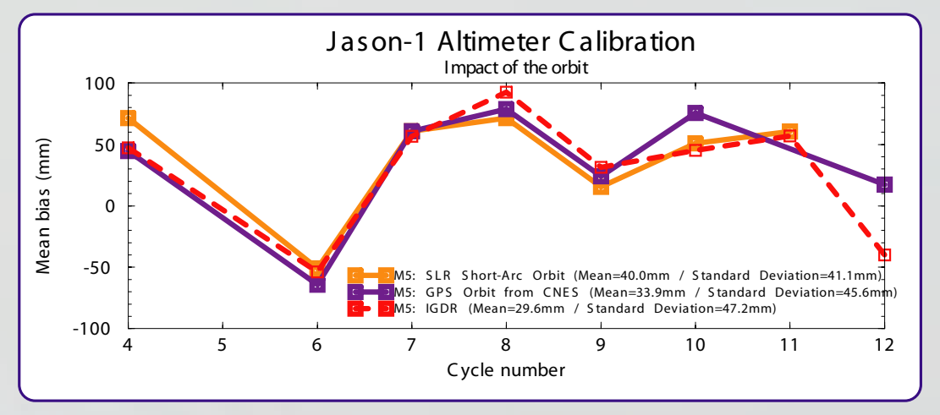
The orbit quality in T/P IGDR is not at the level of Jason-1 ones. So we have replaced orbits of T/P IGDR with the daily MOE computed by CNES using DORIS (same technique as the one used for Jason-1).

Jason-1 IGDR





Impact of the orbits for Jason-1



Tests have also been realized for Jason-1 by replacing the orbit with those computed from GPS data by CNES and our laser-based Short-Arc orbits. Results show that altimeter bias is changed up to 10 mm and that

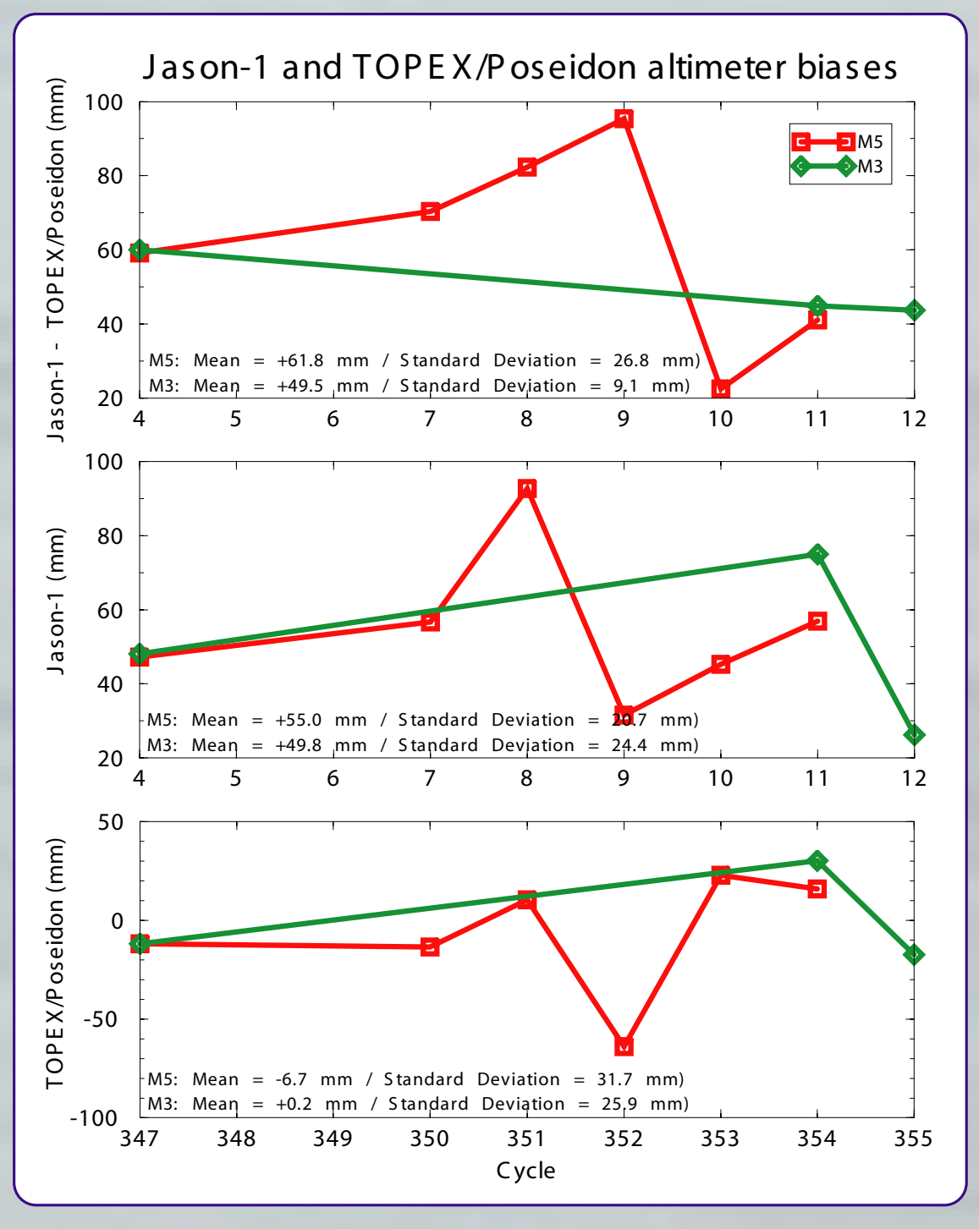
Altimeters biases on IGDR data at Senetosa and Harvest for common period (cycle 4 to 12),in mm	T/P			Jason-1			Jason-1 - T/P		
Tide gauge	Nb values used	Standard Deviation	Mean†	Nb values used	Standard Deviation	Mean†	Nb values used	Standard Deviation	Mean†
M3	3	23.9	-17.1 ±13.8	3	24.4	+49.8 ±14.1	3	12.6	+66.8 ±7.3
M5	6	23.3	-14.0 ±9.5	6	20.7	+55.0 ±8.5	6	10.0	+69.0 ±4.1
All (weighted by number of values)			-15.0 ±10.9			+53.3 ±10.4			+68.3 ±5.2
Harvest	6	39.0	-9.5 ±15.9	6	29.9	+36.4 ±12.2	6	21.7	+46.0 ±8.9

†± is defined as (Standard Deviation)/sqrt(Nb values used)

Altimeters biases on IGDR data at Senetosa (cycle 4 to 12): common values for TOPEX/Poseidon and Jason-1, in mm	T/P (Improved IGDR)			Jason-1 (IGDR)			Jason-1 - T/P		
Tide gauge	Nb values used	Standard Deviation	Mean†	Nb values used	Standard Deviation	Mean†	Nb values used	Standard Deviation	Mean†
M3	3	25.9	+0.2 ±15.0	3	24.4	+49.8 ±14.1	3	9.1	+49.5 ±5.2
M4									
M5	6	31.7	-6.7 ±12.9	6	20.7	+55.0 ±8.5	6	26.8	+61.8 ±10.9
All (weighted by number of values)			-4.4 ±11.9			+53.3 ±10.4			+57.7 ±9.0

†± is defined as (Standard Deviation)/sqrt(Nb values used)

TOPEX / Poseidon and Jason-1 altimeter biases

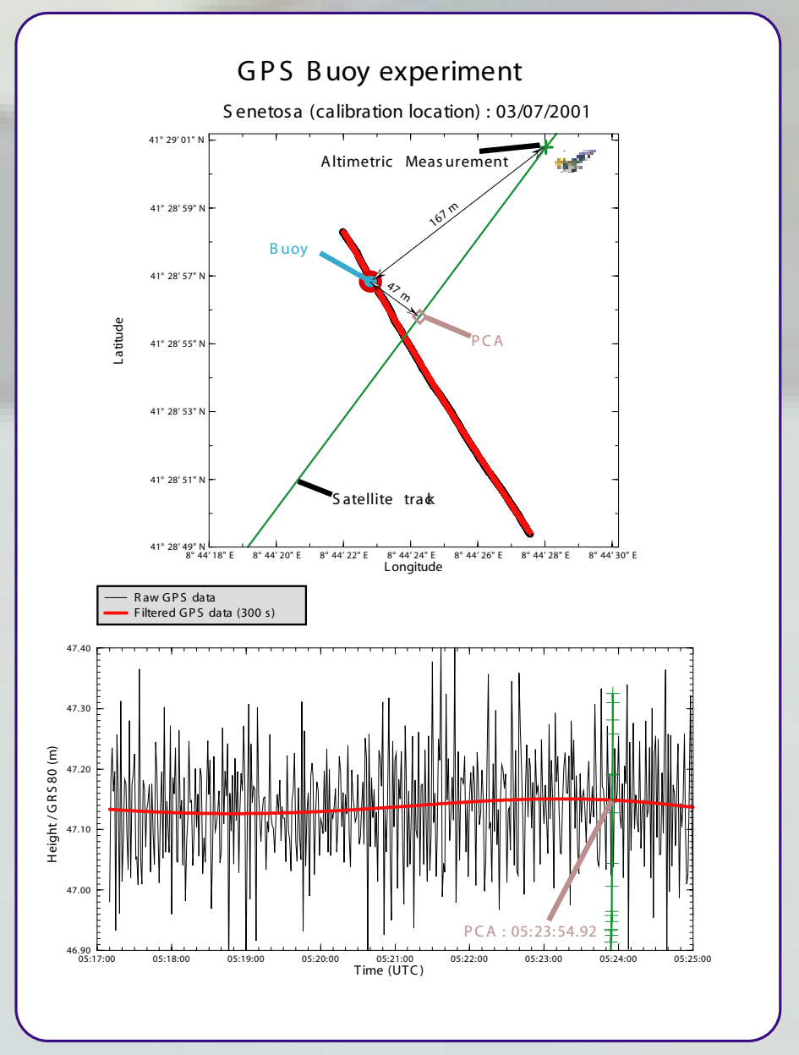


The resulting "homogeneous" biases can then be compared to Jason-1 ("normal IGDR"):

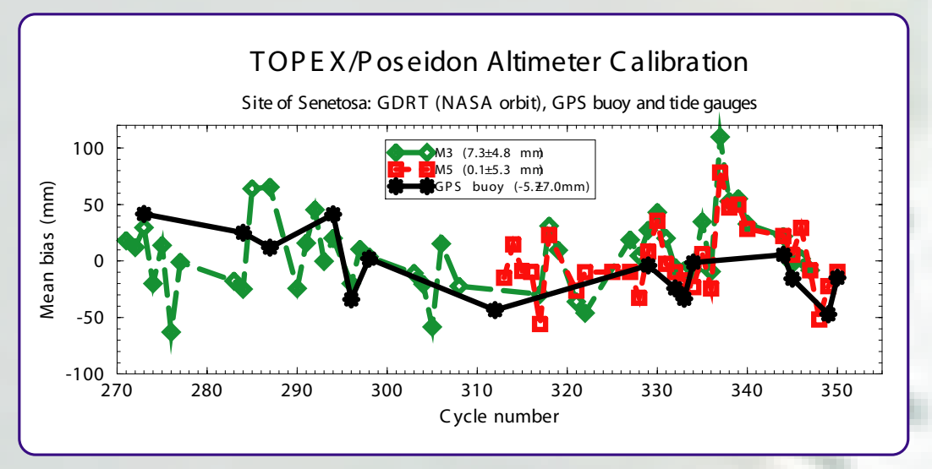
- TOPEX/Poseidon (ALT-B): -4.4 ±11.9 mm
- Jason-1 (POSEIDON-2): +53.3 ±10.4 mm
- Jason-1 - TOPEX/Poseidon: +57.7 ±9.0 mm

On this sample (common values for T/P and Jason-1), biases on T/P have a higher standard deviation than for the whole set (cycle 344 to 357). However mean bias for ALT-B is more coherent with the global analysis performed on M-GDR (cycle 235 to 348) where we have found a value of 1.0 ±3.1 mm.

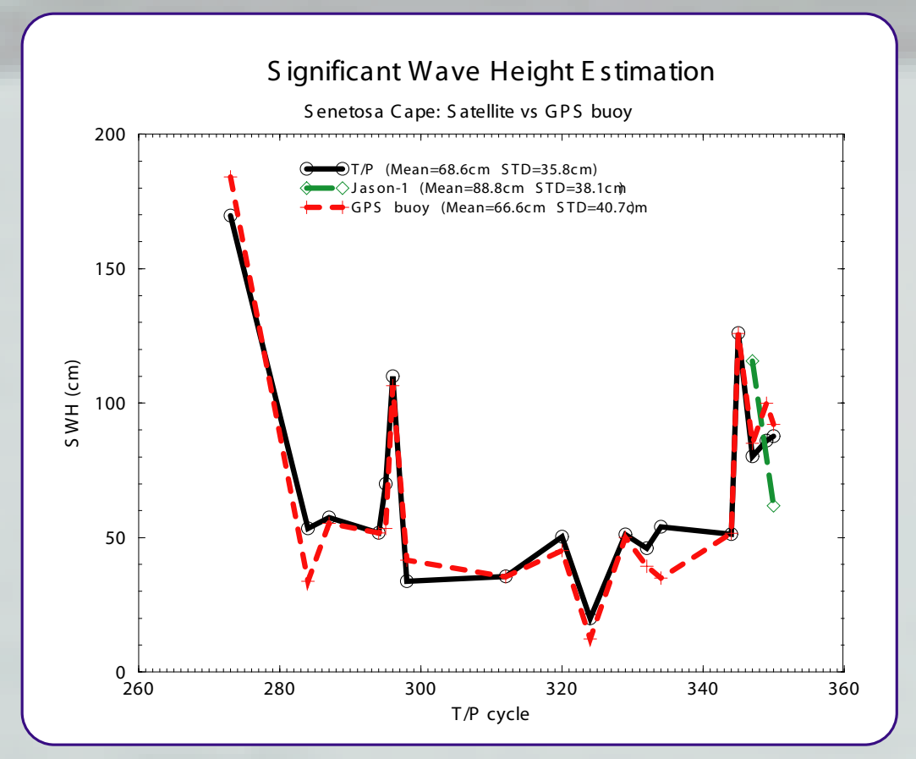
ALTIMETER CALIBRATION WITH GPS BUOY

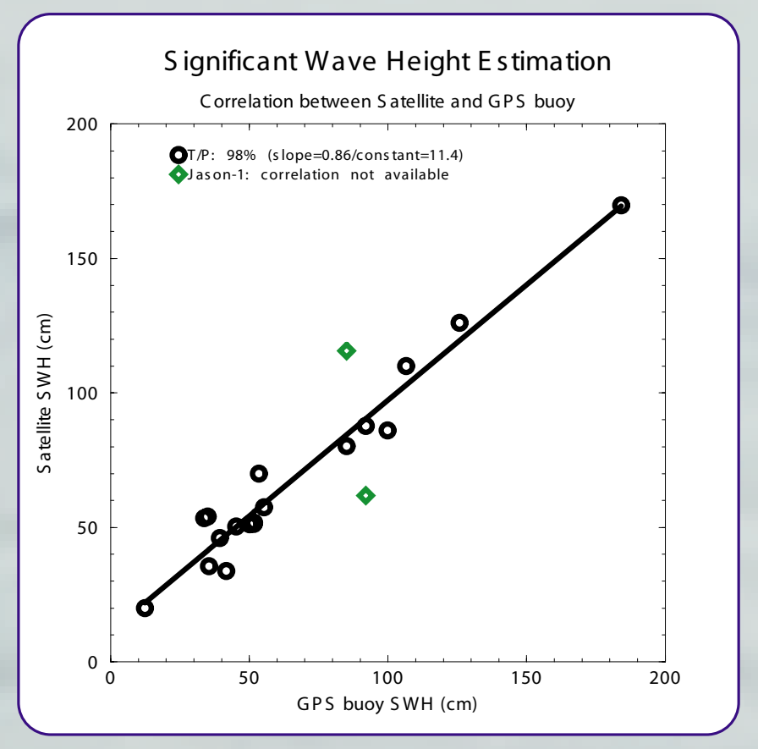


Since 2000, a GPS buoy is also used in the calibration process (GPS buoy are deployed at sea whenever sea state conditions are not too harsh to ensure safe navigation). Results show a good consistency between tide gauges and GPS buoy altimeter calibration even if GPS results have not the same statistical significance due to the lower number of determination.



GPS BUOY "BY-PRODUCTS"
Significant Wave Height





GPS buoy measurements also provide the sea height variations due to waves. Because GPS buoy is drifting during the calibration pass (about 1 hour of measurement centered on Time of Closest Approach) filtered sea height is removed to avoid sea height variations due to geoid slope. Standard deviation on the GPS buoy sea height residuals is then computed (σ_{shr}). GPS buoy measurements have also their internal error which have been estimated during quasi-static session to be at the level of 2.6cm (σ_{gps}). The Standard deviation on the GPS buoy sea height residuals is then the root square sum of σ_{gps} and s_{wave} (where σ_{wave} is the standard deviation of GPS buoy measurements due to waves):

$(\sigma_{shr})^2 = (\sigma_{gps})^2 + (\sigma_{wave})^2$ where $\sigma_{gps} = 2.6$cm

So, $\sigma_{wave} = \mathrm{SQRT}((\sigma_{shr})^2 - (\sigma_{gps})^2)$

SWH (or $H_{1/3}$) is then deduced from the formula below (Stewart R., [2001], Introduction to physical oceanography)

$SWH_{buoy} = 4.\sigma_{wave}$ where SWH_{buoy} is the resulting significant wave height deduced from GPS buoy measurements

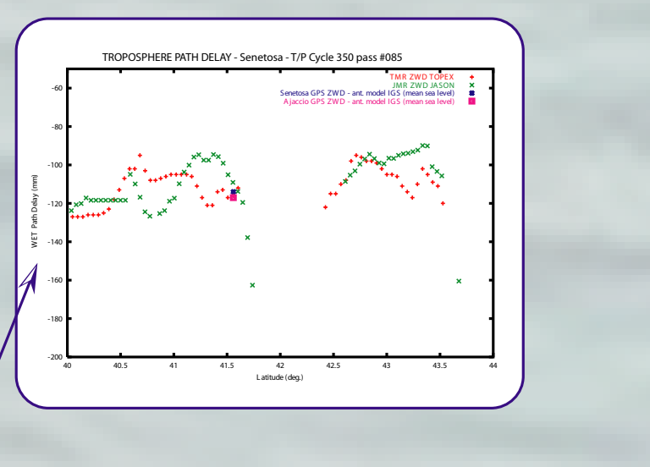
Results shows a very good agreement with T/P SWH of the GDR products. Correlation between both estimations is 98% when using a simple linear regression (slope=0.86 and constant=11.4cm).

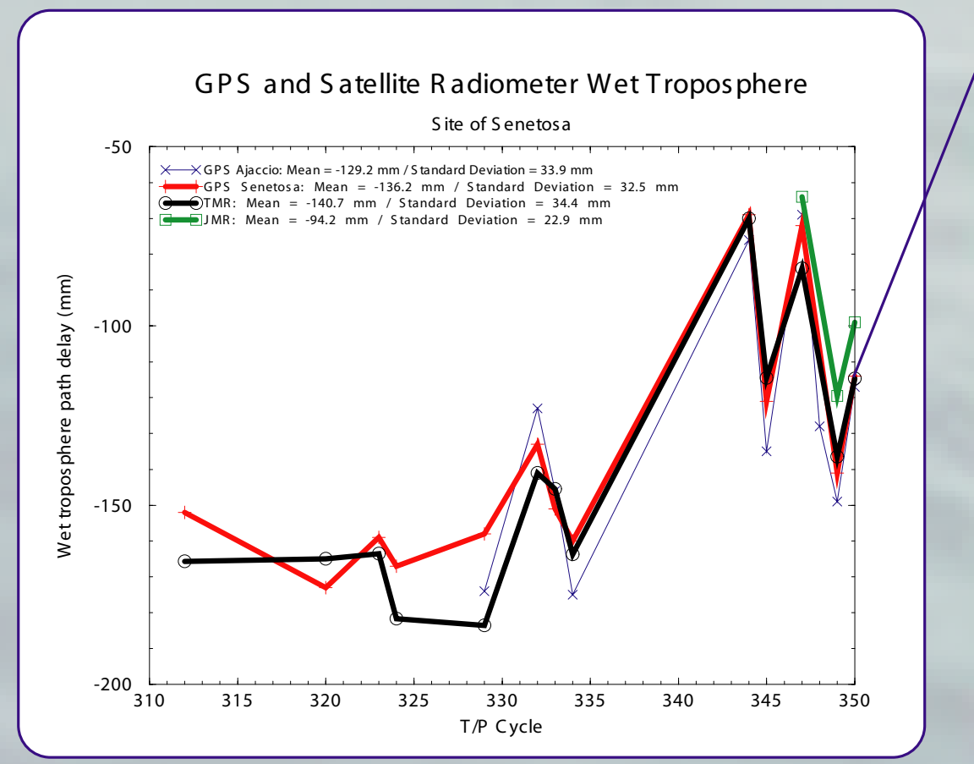
Results for Jason-1 are not significant due to the small number of cycle processed.

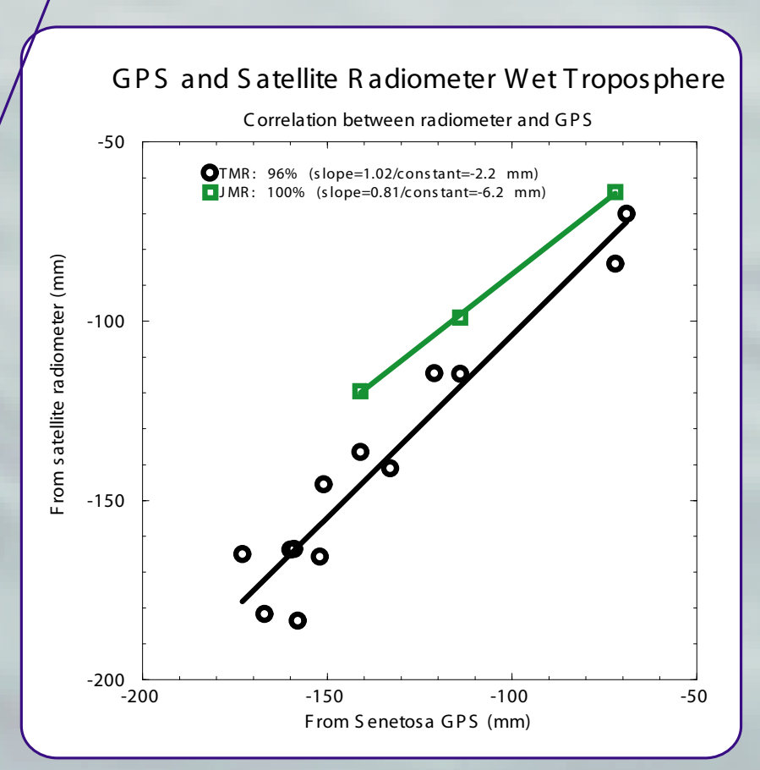
GPS BUOY "BY-PRODUCTS"
Wet Troposphere

Using GPS data from the geodetic reference point (Lighthouse) the wet troposphere path delay is computed with GAMIT software using the following methodology:

- Computation of a one per hour troposphere path delay constraint by a piecewise linear model (0.02m/sqrt(hour)). The Senetosa station is determined relatively to the European network using the stations of Grasse, Ajaccio, Cagliari, Zimmerwald, Wettzell, Matera, Roquetes-Torto. Low constraints are applied to the coordinates and the precise ephemeris (GAMIT relax mode). An elevation cutoff of 10 is used and the fixed ambiguities solution is considered.
- The dry contribution is computed from Saastamoinen model using local meteorological data (lighthouse meteorology station) and is removed from GPS determination
- The resulting wet troposphere path delay is then computed by a linear interpolation at the time of closest approach.





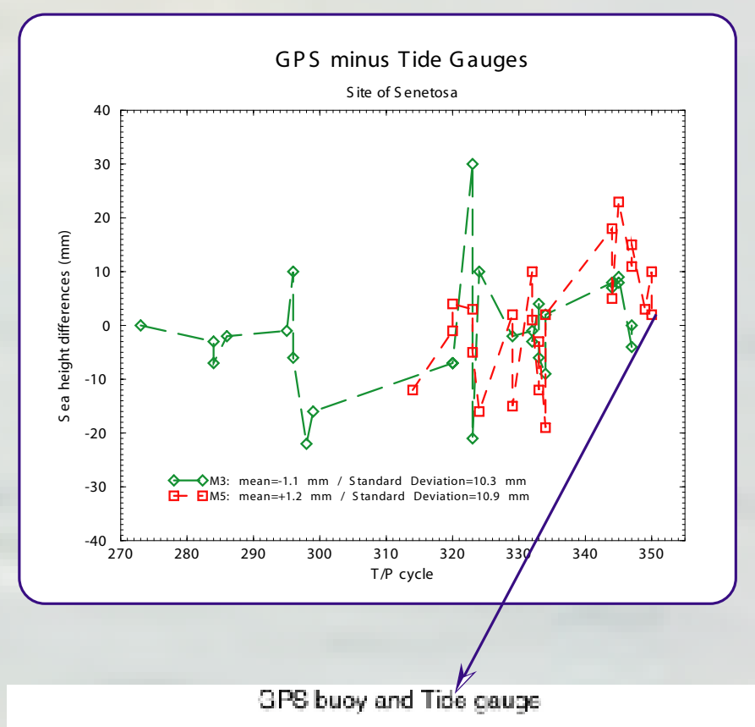


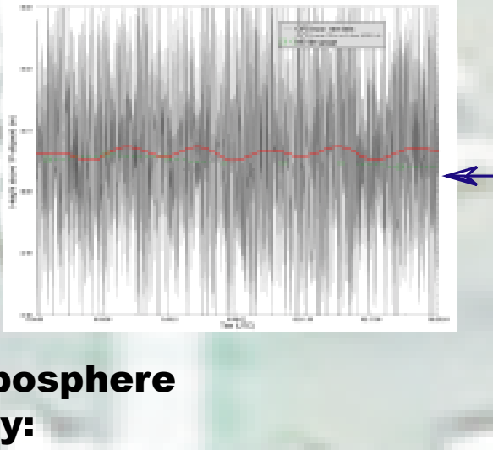
Computation from Ajaccio permanent GPS are also given for illustration but the distance from Senetosa (40 km) can induce differences at the level of 1-2 cm.

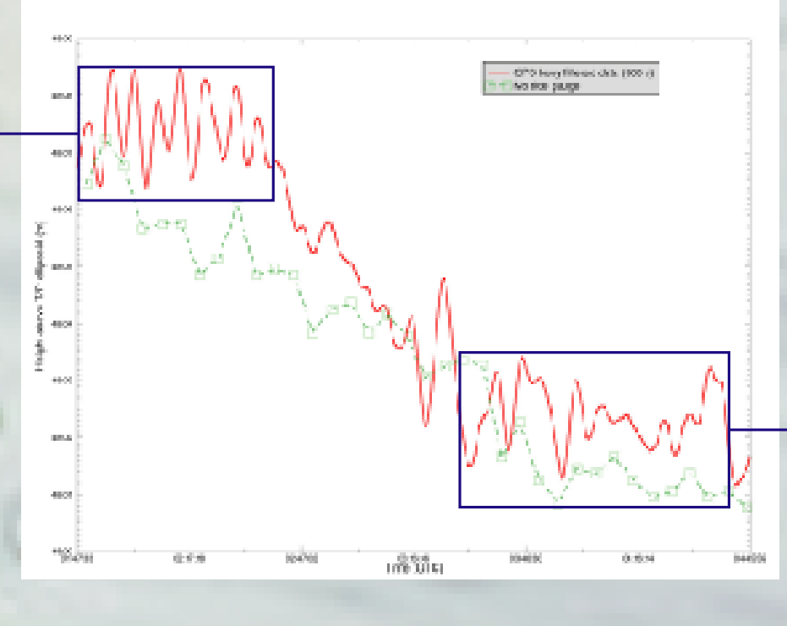
Results shows a good agreement with TMR (T/P radiometer). Correlation between both estimations is 96% when using a simple linear regression (slope=1.02 and constant=-2.2mm).

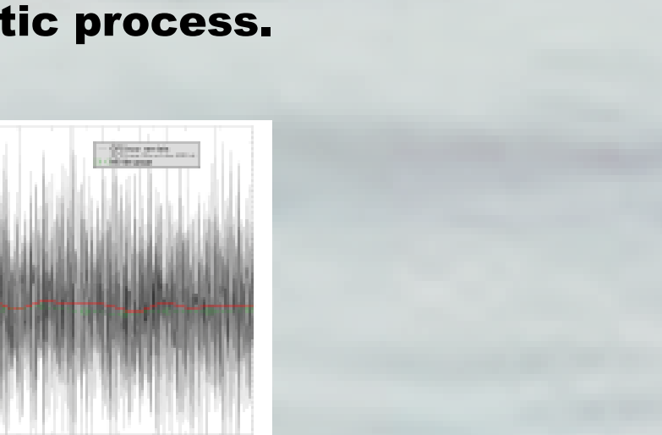
Results for Jason-1 are not significant due to the small number of cycle processed corresponding to a GPS determination. However, for the 9 computed cycle JMR and TMR give a difference of 11.4 mm (JMR path delay smaller than for TMR).

GPS BUOY AND TIDE GAUGES COMPARISONS









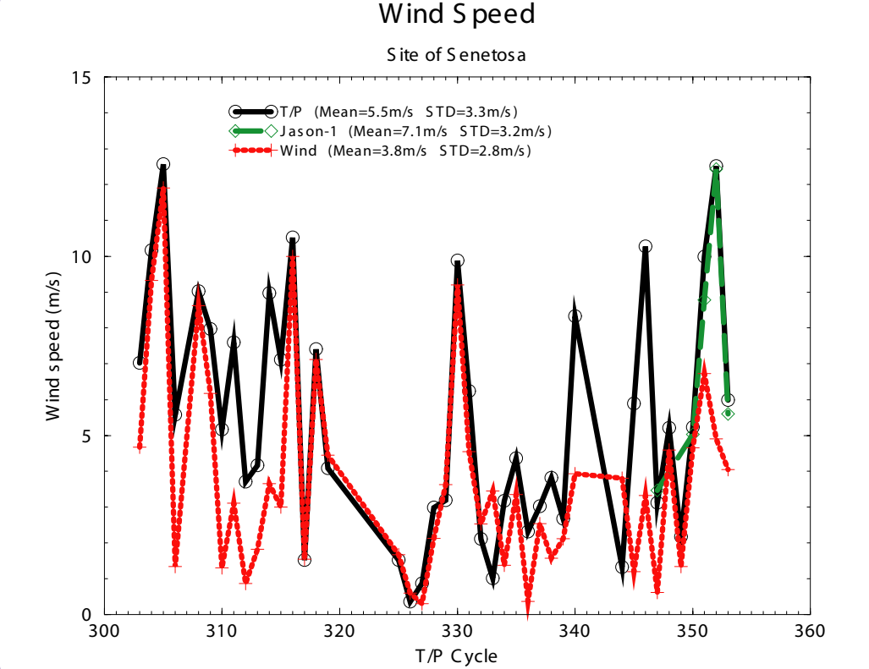
Before and/or after each calibration passes the GPS buoy is deployed at tide gauges locations to make direct comparisons of seal level determination. Differences for the two tide gauges (M3 and M5) is at the millimeter level. During, each control phase tide gauge and GPS buoy seal level have a different behavior due to measurement process. An example is given for T/P cycle 350 where we can see undulations on the sea level deduced from GPS which seems to be linked to GPS data and/or kinematic process.

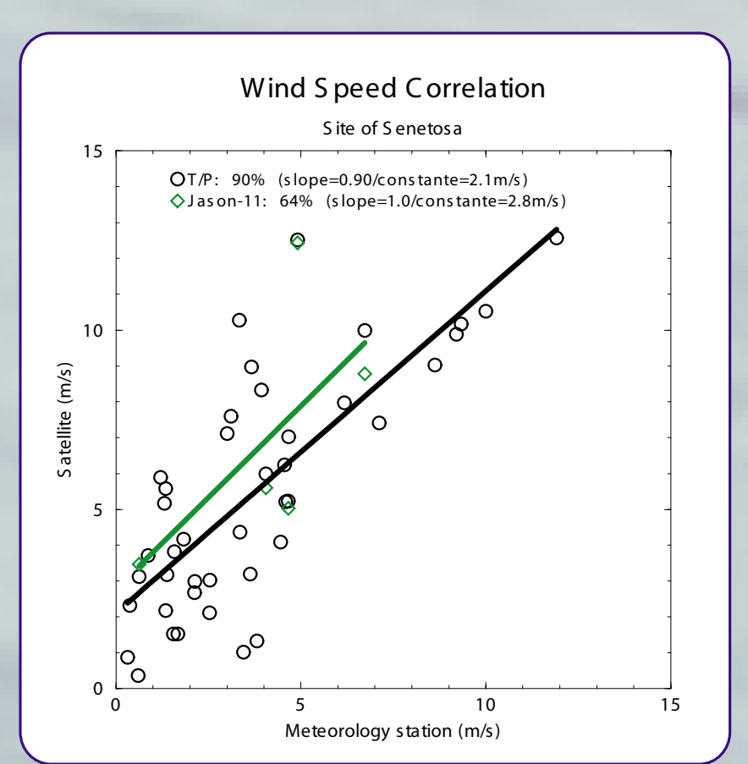
WIND SPEED CALIBRATION

Wind Speed from meteorology station has been compared to T/P wind speed values in GDR (using Wind Speed from Witter and Chelton (1991) formulation, AVISO standards)

Results shows a good agreement with T/P SWH of the GDR products: the main part of differences may be linked to the location of the meteorology station (altitude ~90m near the light house) where winds can be different than off-shore. Correlation between both estimations is 90% when using a simple linear regression (slope=0.90 and constant=2.1m/s).

Results for Jason-1 are not significant due to the small number of cycle processed.





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

Thanks to improvement of TOPEX/Poseidon IGDR altimeter biases can then be directly compared to Jason-1 ("normal IGDR"):

- TOPEX/Poseidon (ALT-B): -4.4 ±11.9 mm
- Jason-1 (POSEIDON-2): +53.3 ±10.4 mm
- Jason-1 - TOPEX/Poseidon: +57.7 ±9.0 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/

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 future. 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.

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 in the altimeter bias determination is at the same level considering buoy or tide gauges; the GPS data also provide an estimation of the wet tropospheric path delay and significant wave height that are compared to T/P and Jason-1 measurements.

T/P altimeter calibration has been performed from cycle 344 to 357, and Jason-1 calibration has been performed from cycle 4 to 12 using IGDR products; all parameters (orbit, corrections,...) are listed and discussed in the poster. Results for ALT-A and ALT-B biases are estimated to be +2.8 mm ±4.5 mm and +1.0 mm ±3.1 mm respectively (using GDRM from AVISO). 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.

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