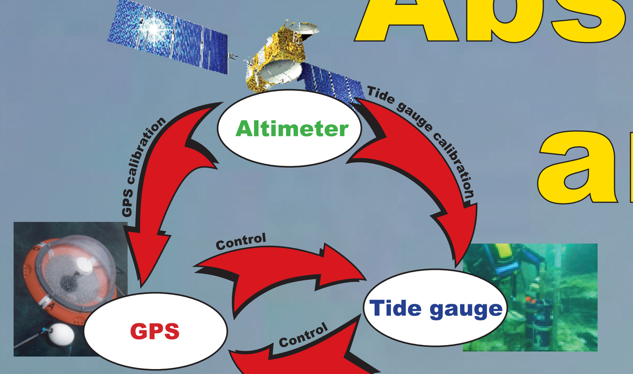
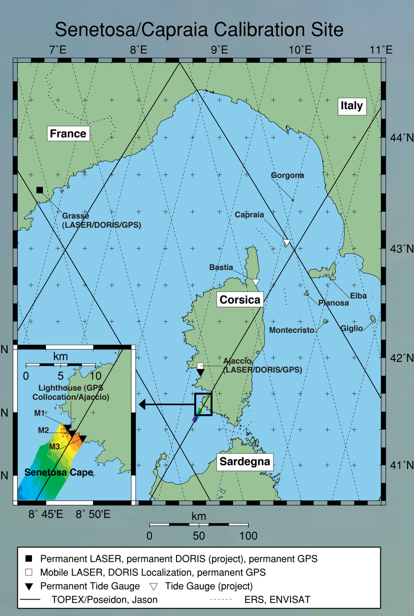
# Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica


P. Bonnefond, P. Exertier, O. Laurain
OCA/GEMINI, avenue N. Copernic, F-06130 Grasse
Y. Ménard
CNES, avenue E. Belin, F-31055 Toulouse
F. Boldo, A. Orsoni
IGN-CNES, avenue E. Belin, F-31055 Toulouse
E. Jeansou, G. Jan
NOVELTIS, 2 av de l'Europe, F-31520 Ramonville


## General Overview

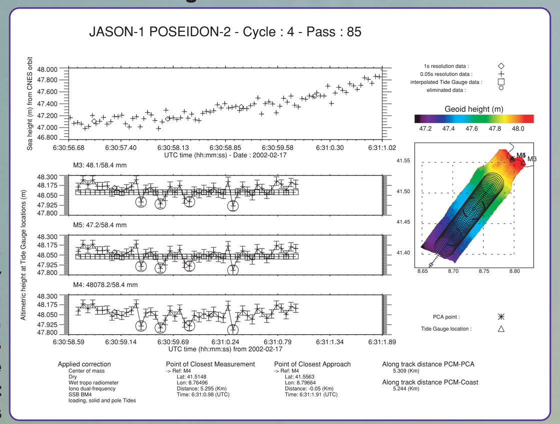
### Calibration process




**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.**

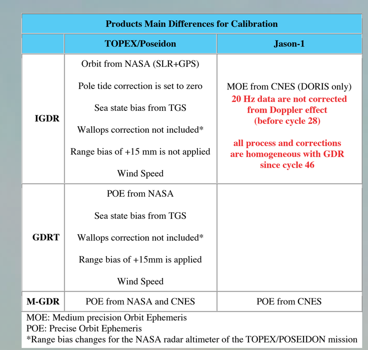
**The calibration principle is to compute the difference between the sea surface height (ssh) measured with the altimeter and the ssh recorded by the tide gauge. These two ssh are located at two distant points. The link between the two ssh is partly the geoid slope from offshore altimetric measurement to tide gauges locations. The situation of the Corsica calibration site implies to take it into account. This slope is 6 cm/km on average and a specific GPS campaign has been realized in 1999 in order to determine a geoid map of about 20 km long and 5.4 km wide centered on the satellites ground track.**

**In a first step, high-rate (10 Hz for T/P and 20 Hz for Jason-1) altimetric sea heights (see upper panel of the Figure) are corrected from geoid slope by computing the geoid 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 (right panel) which size is defined by the formula given in Chelton et al. (1989).**




**In a second step, tide gauges data are interpolated at the high-rate altimetric data time using a linear regression over a time span of 30 min centered on the time of closest approach. The mean values of sea height differences, and the associated standard deviations, are then computed (Haltimeter - Htide gauges) for each tide gauge. Same process for geoid slope correction is used for the GPS buoy but the location of the buoy is about 10 km off shore: the altimetric sea heights are then compared to filtered GPS sea heights.**

### Definitions on products and processes




**The sea-height bias is thus defined by the following difference: altimeter sea height - in situ sea height. For example, a positive sea-height bias means that the altimetric sea height is erroneously high or the altimeter is measuring too short. Statistical computations for the sea-height bias have been realized using the following rules: (i) the bias for each overflight is obtained by averaging all the bias determinations from available tide gauge data, and (ii) the overall bias for each radar altimeter (POSEIDON-2, ALT-A, ALT-B and SSALT) corresponds to the mean (or median) of the estimates computed from all participating overflights (i.e, cycles).**

**For all analyses, we have chosen to use data products provided by the T/P and Jason-1 projects. The principal assumptions are summarized below:**

**Jason-1:**

- **Adopt Jason-1 GDR product as baseline**
- **Other orbits (GPS Reduced Dynamic from JPL and short-arc orbits from GEMINI) have been used for comparisons only.**

**TOPEX/Poseidon:**

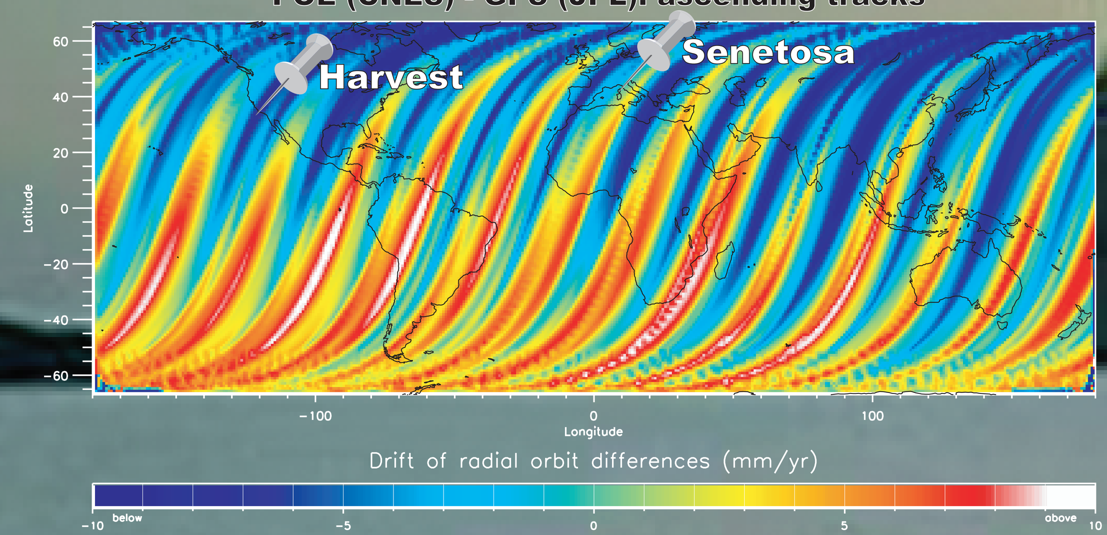
- **T/P M-GDR product is baseline. NASA precise orbit ephemeris has been chosen (Satellite Laser Ranging and DORIS data are used)**
- **Correct for drift in TOPEX Microwave Radiometer (TMR) data from 18-GHz channel instability [Ruf and Brown, 2002]**

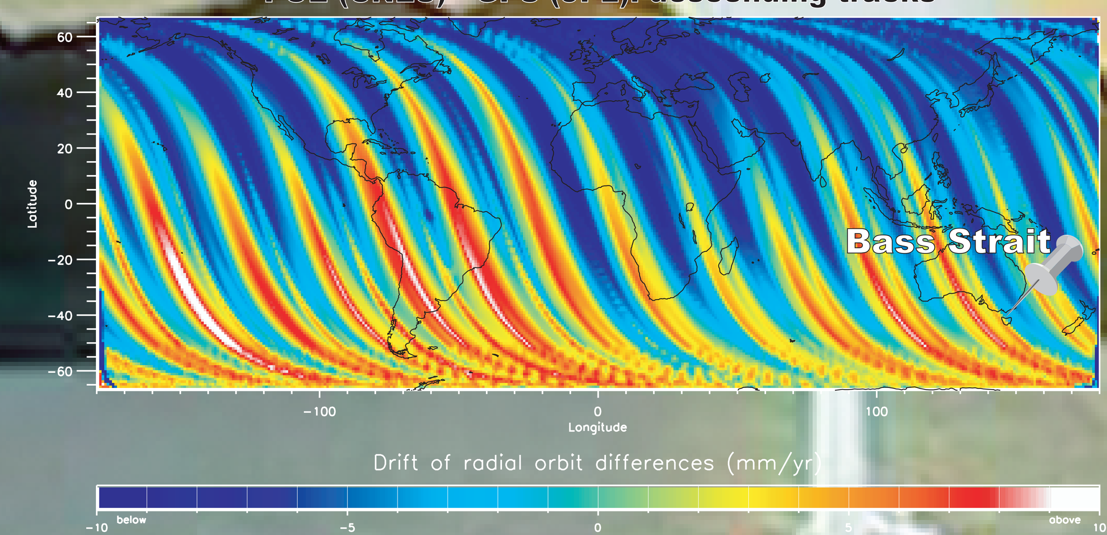
**Finally, the altimeter bias time series are obtained after applying two-selection criterion :**

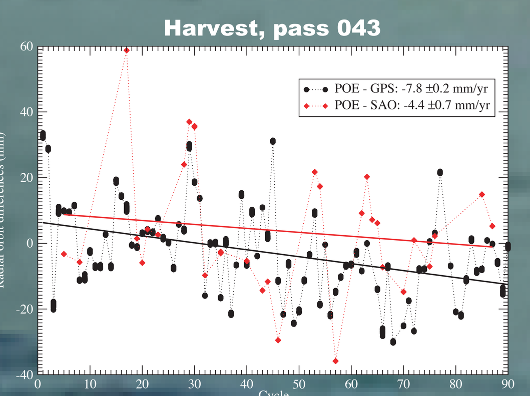
**Only overflights with a sigma naught below 14 dB (16.26 dB for Jason-1) are kept avoiding a possible sigma bloom effect (see Figure below) . This criteria leads to reject about 27% of the ALT (T/P), 36% of SSALT (T/P) and 24% of POSEIDON-2 (Jason-1) altimeters data.**

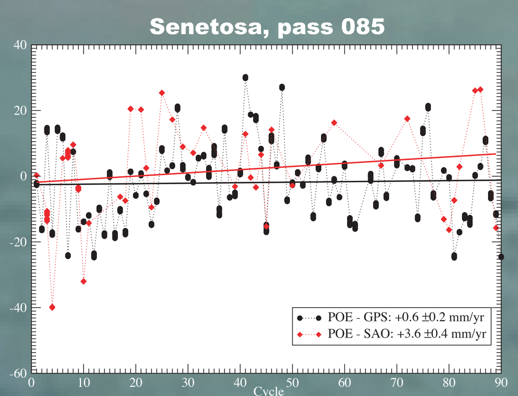
**To avoid erroneous tide gauges data, all cycles for which the standard error (issued from the averaging of tide gauges determinations) is higher than 10 mm are rejected (about 10%). This threshold has been chosen taking into account that the individual tide gauge measurement precision is better than 10 mm.**

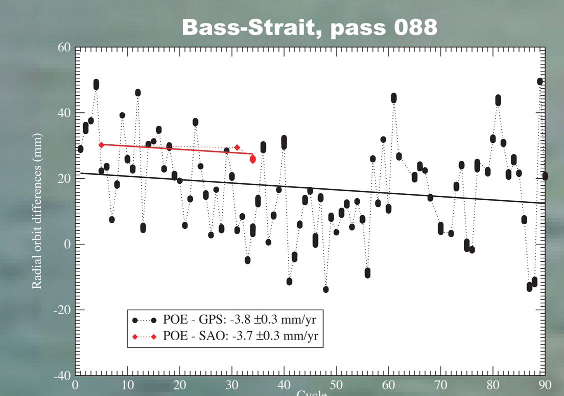
## Impact of Orbit on Calibration




**The POE orbits (CNES) were compared to the GPS-based Reduced dynamic orbits (JPL) from cycle 1 to 88. The radial orbit differences were then mapped at 1°x1° resolution for each cycle and a drift was computed at each node for the whole studied period. The maps above show the results respectively for the ascending and the descending tracks. They clearly exhibit geographical patterns up to +/-10 mm/yr.**

**This "unexpected" result induced that for specific calibration sites the altimeter bias series can be altered by an orbit dependant trend. While the pass used for the Corsica calibration site (#085) is located in an area where the drift is close to zero (see results in the "correction analysis" section), it is not the case for Harvest (#043) and Bass Strait (#088) were the effect reaches respectively -8 and -4 mm/yr.**

**These results are confirmed by our analysis using the LASER-based Short-Arc Orbits (SAO). Even if they are less statistically significant (especially for Bass Strait due to the loss of Mount Stromlo SLR station), these results confirm the general trend for the calibration sites.**

**The geographically correlated drift between the POE and GPS orbits seems to be mainly due to the 1 cycle per revolution orbit error. However, the maps also exhibit a global North-South pattern which can be due to a Z drift of the reference frame.**

**For more information on this see POD posters and splinter.**

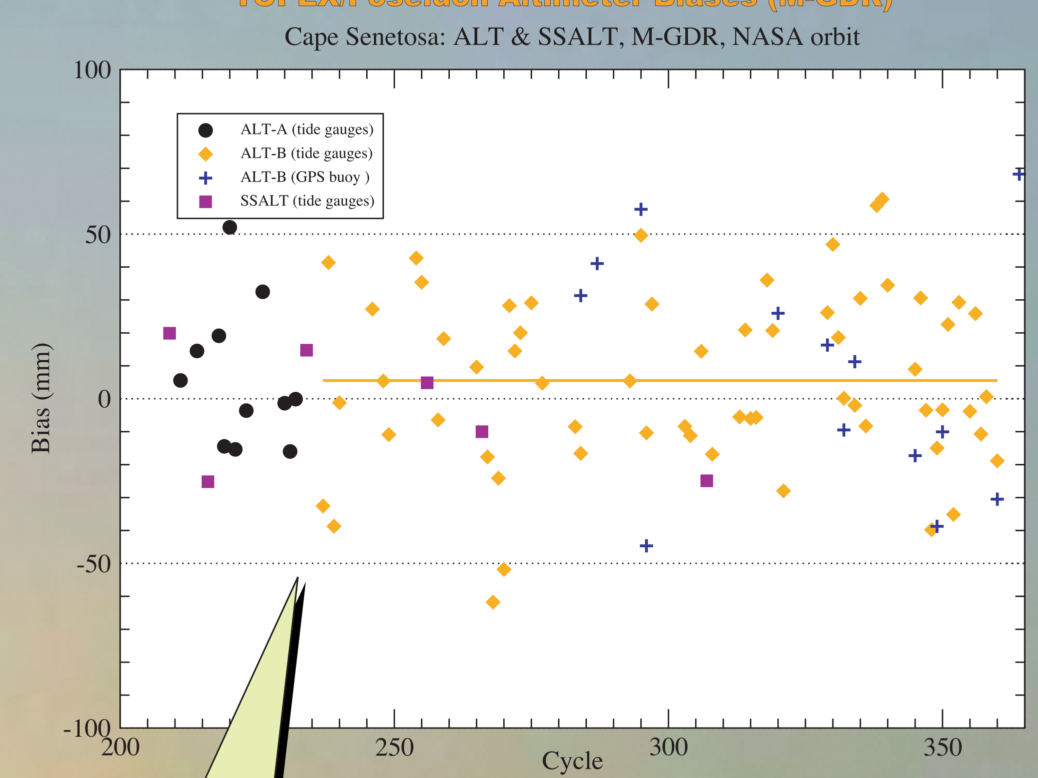
**The whole calibration process (Tide gauges and GPS buoy) have been validated with TOPEX/Poseidon over 4 years of data. For Jason-1 all the GDR (90 cycles) have been analysed:**

- **TOPEX/Poseidon (ALT-A): +7 ±7 mm**
- **TOPEX/Poseidon (ALT-B): +6 ±3 mm**
- **TOPEX/Poseidon (SSALT): -3 ±8 mm**
- **Jason-1 (POSEIDON-2): +99 ±4 mm**

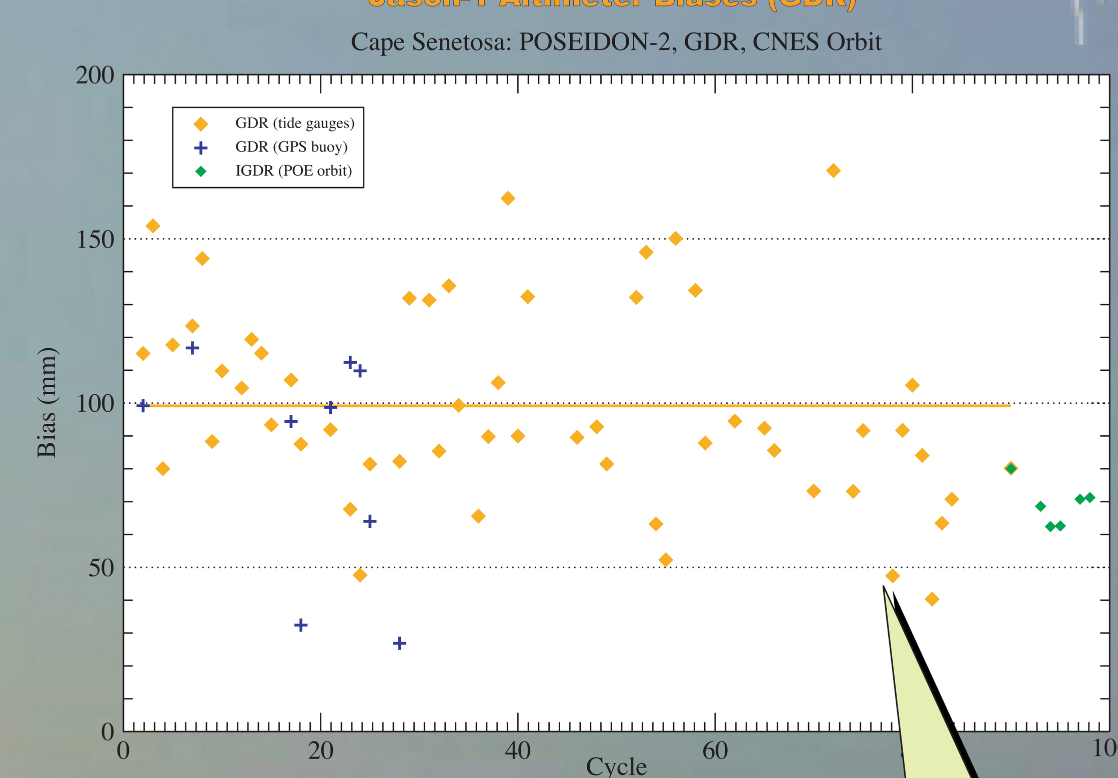
**However, the Jason-1 altimeter bias exhibits a drift of -13 mm/yr which leads to a bias of 114 mm at 2002.0 epoch. This drift is mainly due to the JMR which seems also to be biased in the coastal areas. As a result, when using ECMWF model the bias at 2002.0 epoch is 127 mm with no statistically significant drift.**

## Altimeter Biases Time Series

### TOPEX/Poseidon Altimeter Biases (M-GDR)




### Jason-1 Altimeter Biases (GDR)




**TOPEX/Poseidon altimeters (ALT-A and ALT-B) have been calibrated from 1998. Results show a great coherence between both altimeters +7 ±7 mm, +6 ±3 mm and -3 ±8 mm for ALT-A, ALT-B and SSALT respectively. Moreover, results are very consistent with those obtained from the Harvest Platform (differences of few millimeters).**

**For the 10 cycles in common, the tide gauges and GPS buoy determinations are respectively +2 ±7 mm and -3 ±10 mm. Results obtained by the two techniques thus show a very high consistency at the millimeter level, within the error bars.**

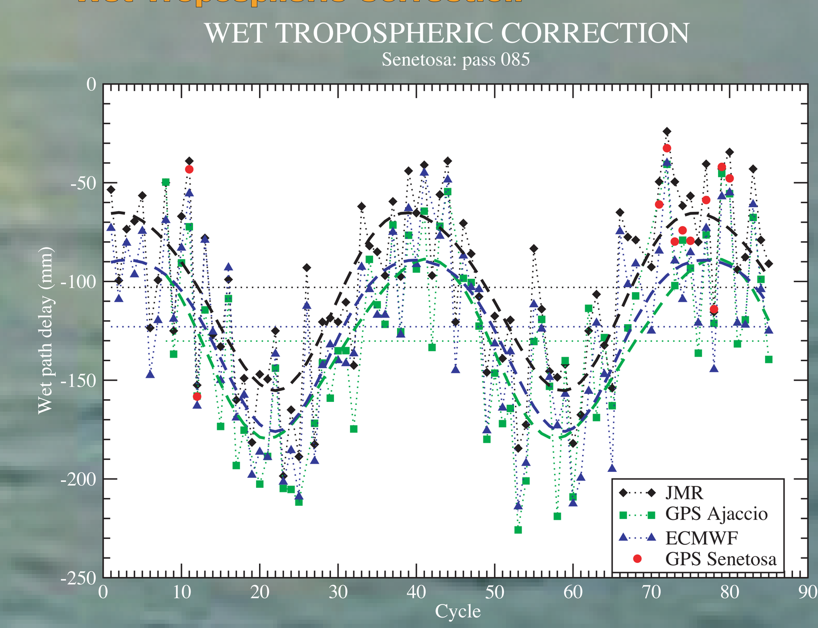
**POSEIDON-2 altimeter bias is +99 ±4 mm (cycle 1 to 90, GDR products). Consistency of both techniques appears to be lower than for T/P. However, this effect is only due to the time distribution of the GPS buoy: half of the set is during relatively low values of Jason-1 altimeter bias (cycle 20 to 25). Indeed, when comparing the time series on common cycles, tide gauges determination only differ by few millimeters (5 mm higher). Thus, once again GPS buoy determination appears to be a very promising and powerful technique.**

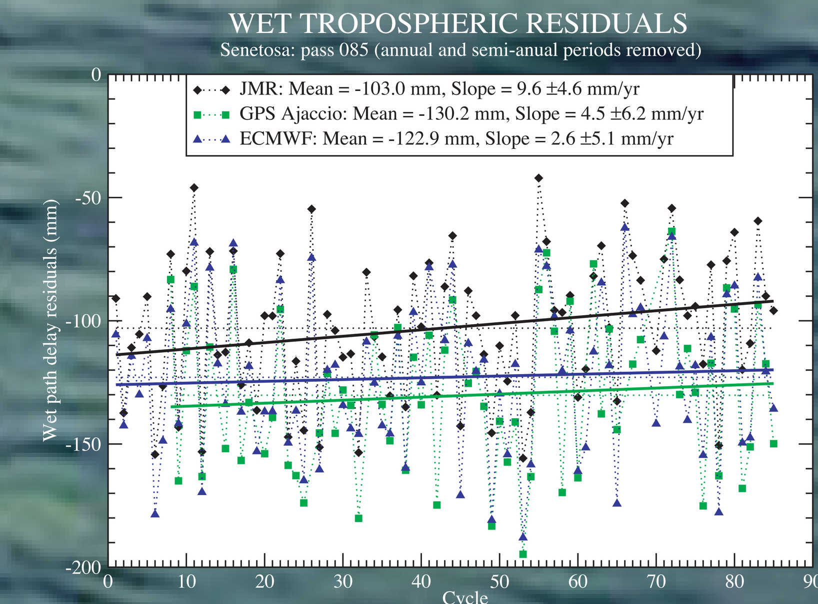
**While the whole TOPEX/Poseidon (ALT-B) altimeter bias series does not exhibit any significant trend, the Jason-1 (POSEIDON-2) one shows a drift of -13 ±6 mm/yr.**

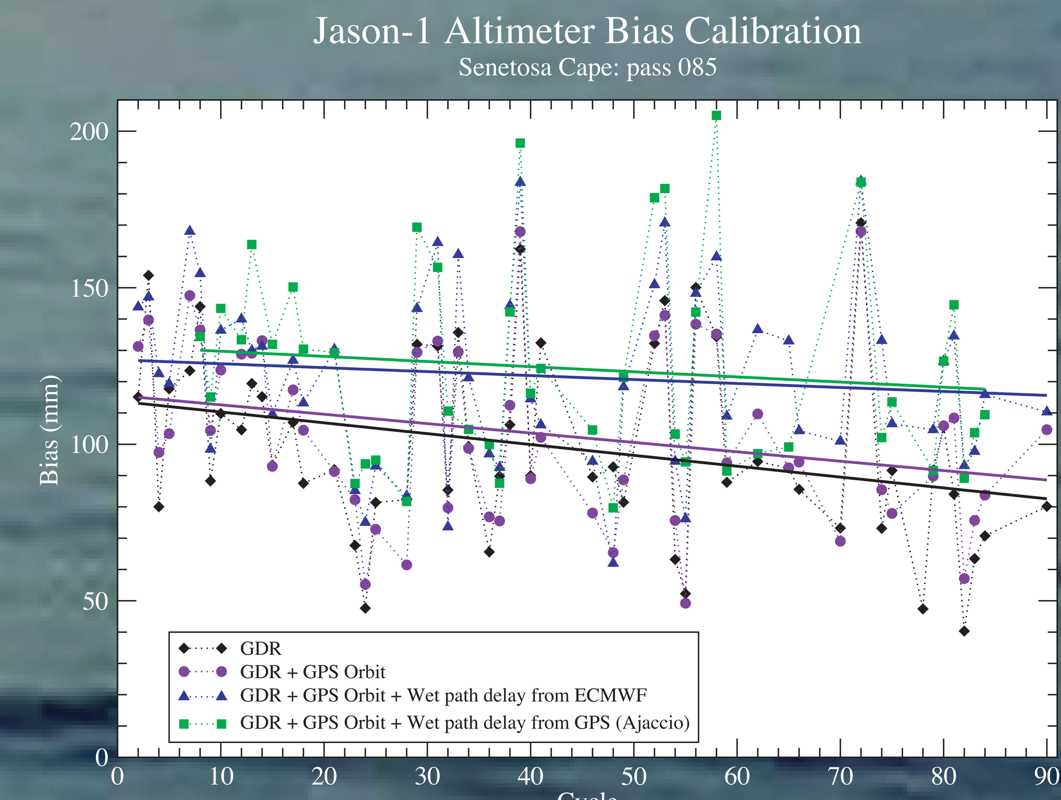
**The origin of this trend (mainly due to JMR) is discussed in the "correction analysis" section.**

## Analysis of Jason-1 Altimeter corrections

### Wet Tropospheric Correction




**JMR path delay has been compared to the ECMWF (GDR model, blue triangles) and GPS derived tropospheric corrections. For the GPS solution the total path delay is extracted from the GAMIT software processing. The dry contribution is then computed from local meteorological data and substracted to the total path delay to deduce the wet contribution. We have used the continuous measurements from the Ajaccio permanent receiver (green squares) but also data from specific campaigns at Cape Senetosa (red dots). They are both in very good agreement but we have now installed a quasi-permanent GPS receiver at Senetosa to avoid any possible behaviour differences (Ajaccio is 40 km North Senetosa).**

**GDR**
**Bias 2002.0 = 114 ± 7 mm**
**Slope = -13 ±6 mm/yr**

**GDR + GPS Orbit**
**Bias 2002.0 = 116 ± 7 mm**
**Slope = -11 ±5 mm/yr**

**GDR + GPS Orbit + Wet path delay from ECMWF**
**Bias 2002.0 = 127 ± 7 mm**
**Slope = -5 ±6 mm/yr**

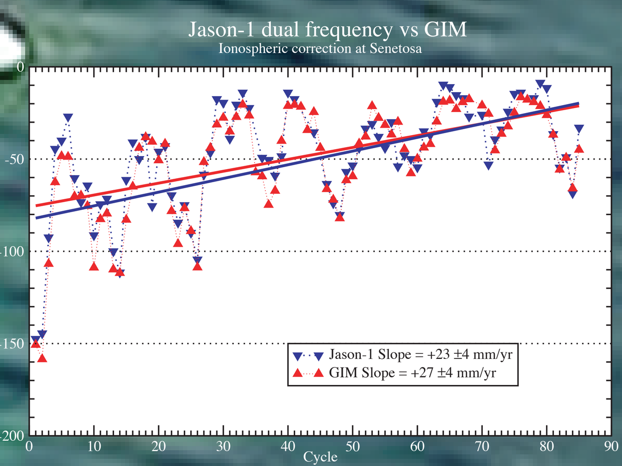
**GDR + GPS Orbit + Wet path delay from GPS (Ajaccio)**
**Bias 2002.0 = 131 ± 10 mm**
**Slope = -6 ±8 mm/yr**

**Altimeter bias results are given at the 2002.0 reference epoch along with the corresponding slope.**

**Comparisons from both ECMWF and GPS clearly show a drift of the JMR correction at the level of -6 mm/yr. The remaining slopes for ECMWF and GPS are within the error bar and so not statistically distinguishable from zero.**

**Moreover, JMR exhibits a mean bias of about 20 mm (JMR correction is under evaluate) compared to ECMWF which induces a difference of 11 mm at the 2002.0 epoch. This bias seems to affect the whole Mediterranean Sea and the coastal areas. It is then a problem for the calibration sites for which results should differ from global comparisons.**

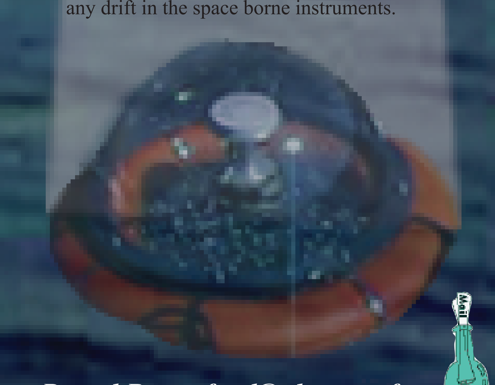
### Ionospheric Correction




**The Jason-1 dual frequency ionospheric corrections has been compared to those extracted from the Global Ionosphere Maps (GIM, derived from GPS data). Results are very coherent and show the same trend due to the solar cycle.**


### 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.
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). 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.
T/P altimeter calibration has been performed from cycle 208 to 365. All the produced Jason-1 GDR cycles have been also analyzed in the altimeter calibration process. In addition, JMR path delay has been compared to the ECMWF and GPS derived tropospheric correction.
Our semi-permanent experiment is planned to last over several years in order to detect any drift in the space borne instruments.


Pascal.Bonnefond@obs-azur.fr