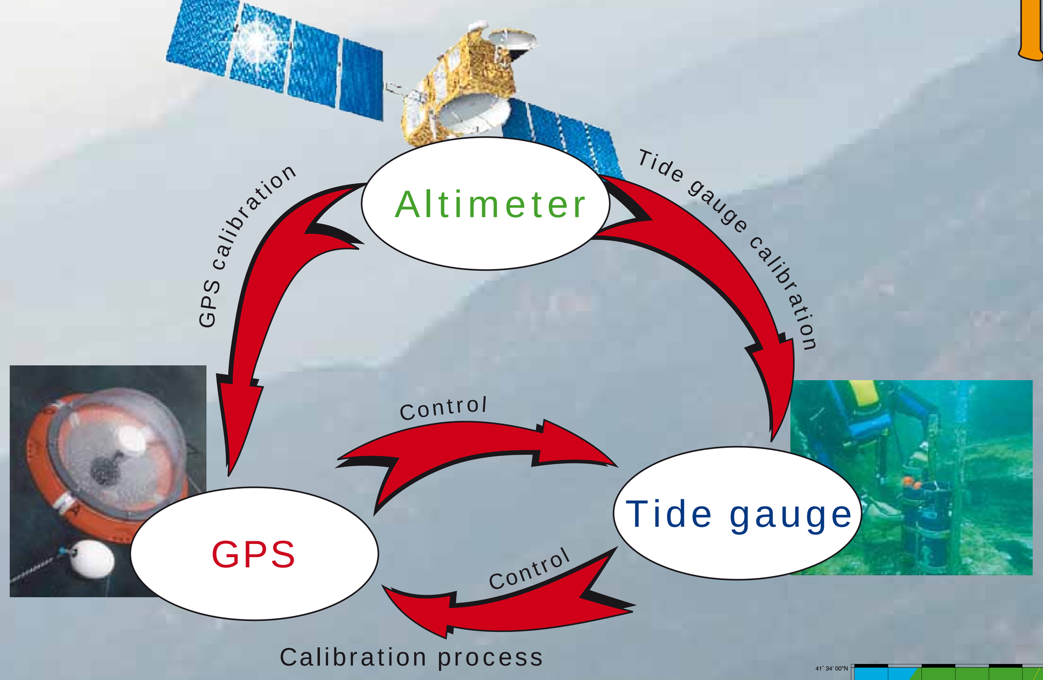
Absolute Calibration of Jason-1&2 and TOPEX/Poseidon Altimeters in Corsica

P. Bonnefond, P. Exertier, O. Laurain, F. Pierron, OCA/GeoAzur, Grasse, France
G. Jan, NOVELTIS, Ramonville, France

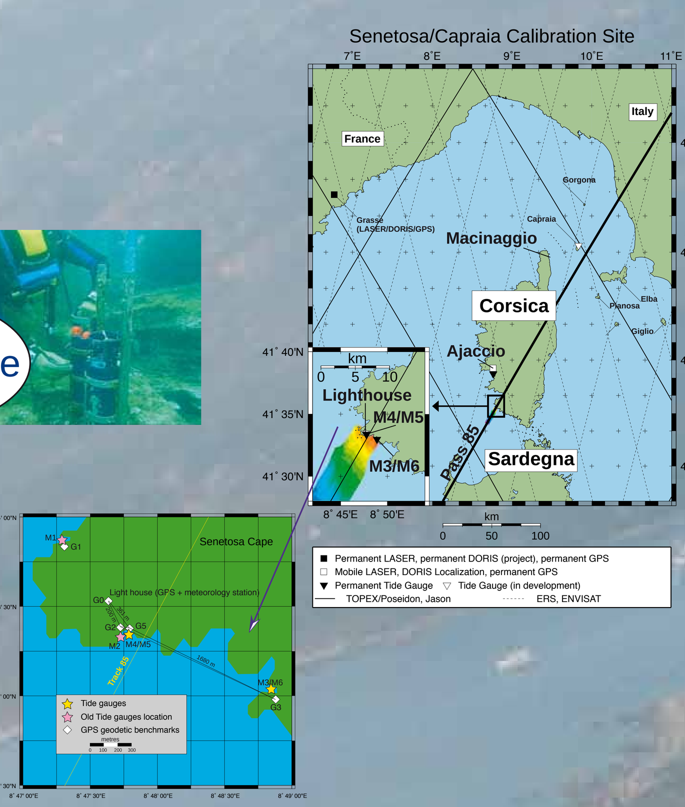


Calibration process

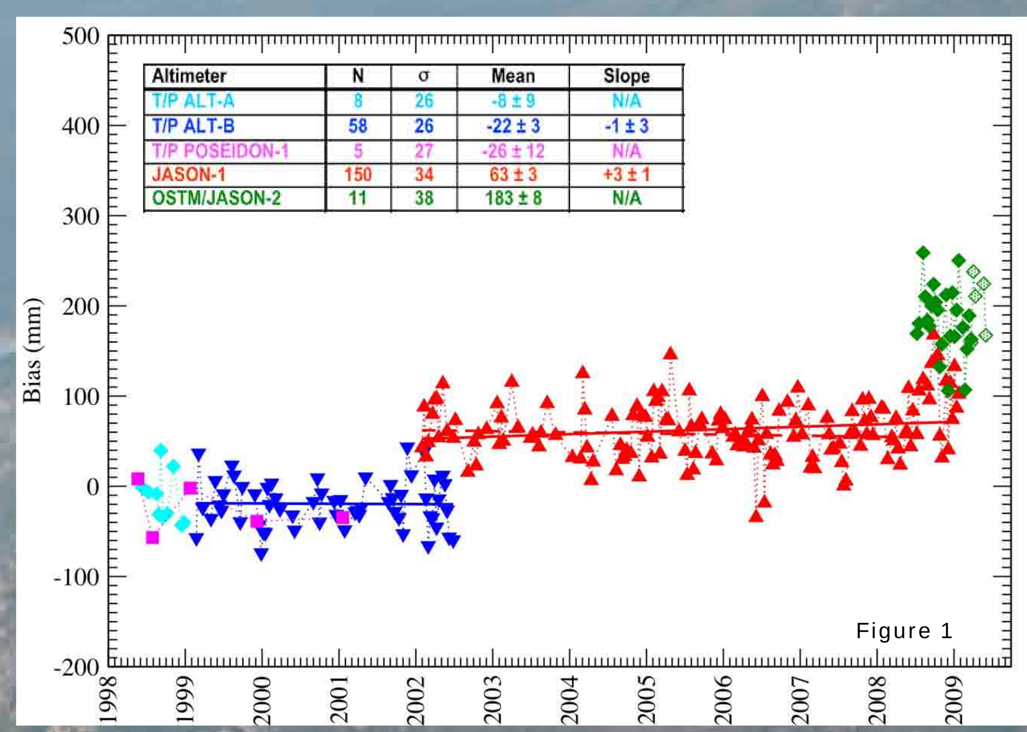
The calibration principle is to compute the difference between the sea surface height (ssh) measured with the altimeter and the ssh recorded by the tide gauge. These two ssh are located at two distant points. The link between the two ssh is partly the geoid slope from offshore altimetric measurement 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. Details can be found in Bonnefond et al. (2003a and 2003b).

Bonnefond, P., P. Exertier, O. Laurain, Y. Menard, A. Orsoni, G. Jan, and E. Jeansou, Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica, Special Issue on Jason-1 Calibration/Validation, Part 1, Marine Geodesy, Vol. 26, No. 3-4, 261-284, 2003a.

Bonnefond, P., P. Exertier, O. Laurain, Y. Menard, A. Orsoni, E. Jeansou, B. Haines, D. Kubitschek, and G. Born, Leveling Sea Surface using a GPS catamaran, Special Issue on Jason-1 Calibration/Validation, Part 1, Marine Geodesy, Vol. 26, No. 3-4, 319-334, 2003b.



TOPEX/POSEIDON (MGDR+) JASON-1 AND JASON-2 (I/GDR-C) ALTIMETER BIASES



Altimeter	N	σ	Mean	Slope
T/P ALT-A	8	26	-8 ± 9	N/A
T/P ALT-B	58	26	-22 ± 3	-1 ± 3
T/P POSEIDON-1	5	27	-26 ± 12	N/A
JASON-1	150	34	63 ± 3	+3 ± 1
OSTM/JASON-2	11	38	183 ± 8	N/A

Figure 1

The above Figure shows TOPEX/Poseidon, Jason-1 and Jason-2 altimeter bias determination for the three tide gauges settled at Cape Senetosa. Jason-1 cycle 239 corresponds to the first Jason-2 over flight (cycle 0, July 5th, 2008). Jason-1 cycle 259 corresponds to the last over flight (cycle 20 for Jason-2, January 19th, 2009). The presented times series has been obtained using the best products available that are close to the future reprocessing except for retracking on T/P and for SSB and ionospheric correction for the three satellites:

- TOPEX/Poseidon: MGDR products with the TMR replacement product and the GSFC TVG orbits based on ITRF 2005-rescaled. This will be named $MGDR^+$ in the following.
- Jason-1: GDR-C products (cycle 1 to 259, ~45 cycles are missing but are in process to be delivered).
- Jason-2: GDR-C products (for cycle 0 to 26) and IGDR-C products (for cycle 27 to 33, light green diamonds)

The Corsica experiment is providing a very accurate bias time series for almost ten years which enable also to monitor possible drifts. The drift observed for Jason-1 (~3 mm/yr, plain red line) seems to be due to some high values at the end of the series: when data since Jason-2 launch are excluded, the drift is not statistically significant (~1 mm/yr, dashed red line); this have to be updated when all the Jason-1 cycles will be available.

JASON-1 AND JASON-2 FORMATION FLIGHT PHASE ANALYSIS

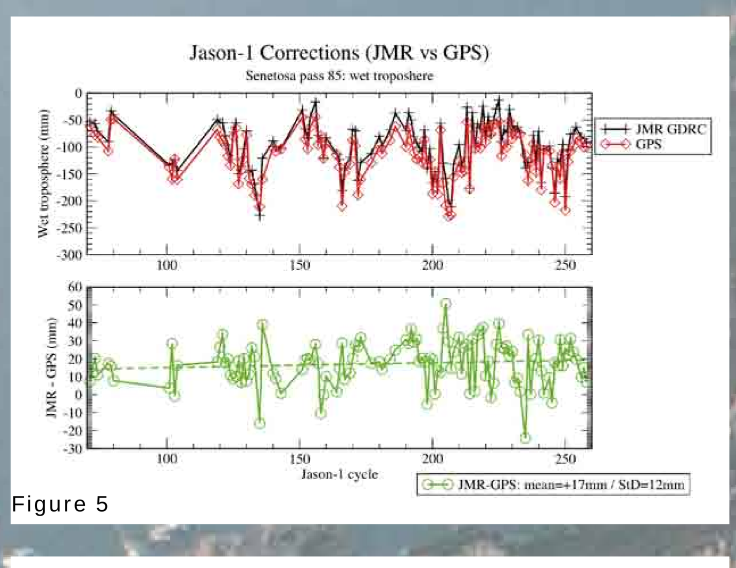


Figure 5

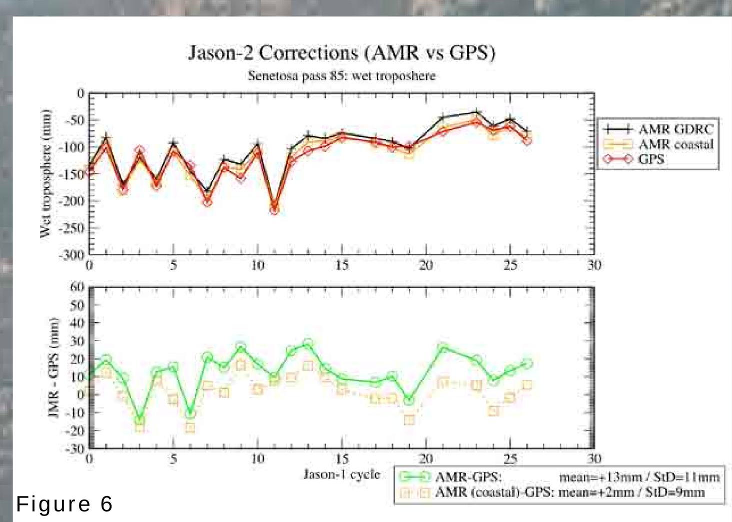


Figure 6

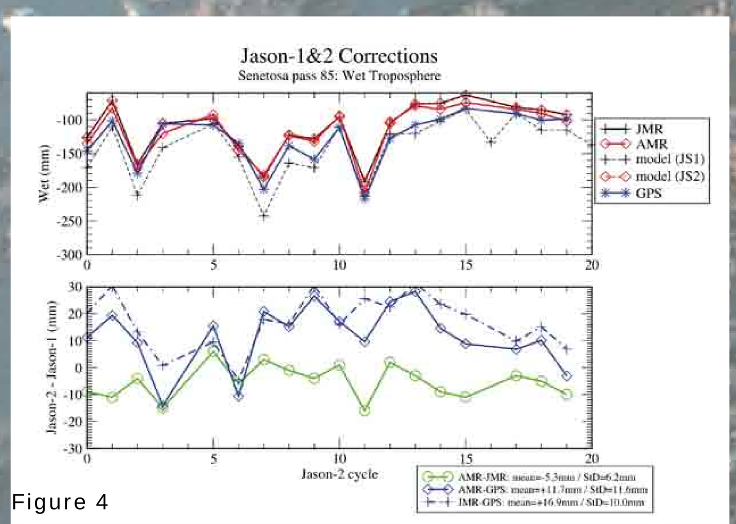


Figure 4

Jason-2 – Jason-1 (corrections):

Correction	Mean (mm)	Standard Deviation (mm)
Dry Tropo.	-0.1 (-0.2)	2.7 (2.9)
Wet Tropo. (radiometer)	-5.6 (-11.3)	6.0 (6.5)
Wet Tropo. (ECMWF)	0.0	0.5
AMR - ECMWF	*23.8*	*15.1*
JMR - ECMWF	*29.4*	*14.4*
AMR – GPS	*11.7*	*11.6*
JMR - GPS	*16.9*	*10.0*
Iono. (dual frequency)	+7.6 (+9.4)	23.6 (22.1)
Iono. (GIM)	0.0	0.0
JS2 - GIM	*-5.6*	*19.1*
JS1 - GIM	*-13.2*	*17.6*
SSB	-2.7 (-2.4)	5.8 (4.9)
Solid Tides	+0.1	0.7
Loading	0.0	0.0
Pole Tide	0.0	0.0
Total	**-0.7**	

(from IGDR)

Main contribution comes from Wet tropo (~-6 mm) and iono (~+8 mm)

Other environmental parameters:
- SWH: Mean = -1.2 cm StD = 23.0 cm
- Wind Speed: Mean = +0.6 m/s StD = 0.6 m/s

The above table shows the differences between the Jason-2 and Jason-1 corrections

Main contribution comes from Wet tropospheric (~-6 mm) and Ionopheric (~+8 mm) corrections

When compared to the wet tropospheric correction derived from our on site permanent GPS, both JMR and AMR show a bias respectively of +17 mm and +12 mm (Figure 4); these values are consistent over the whole JMR (+17mm, Figure 5) and AMR (+13mm, Figure 6) time series. However, the new correction for coastal application (AMR coastal, orange line in Figure 6) shows a highly better consistency with GPS (+2 mm, Figure 6). These biases are related to the radiometer land contamination and are detailed in the "WET TROPOSPHERIC CORRECTION AT THE COAST APPROACH" section.

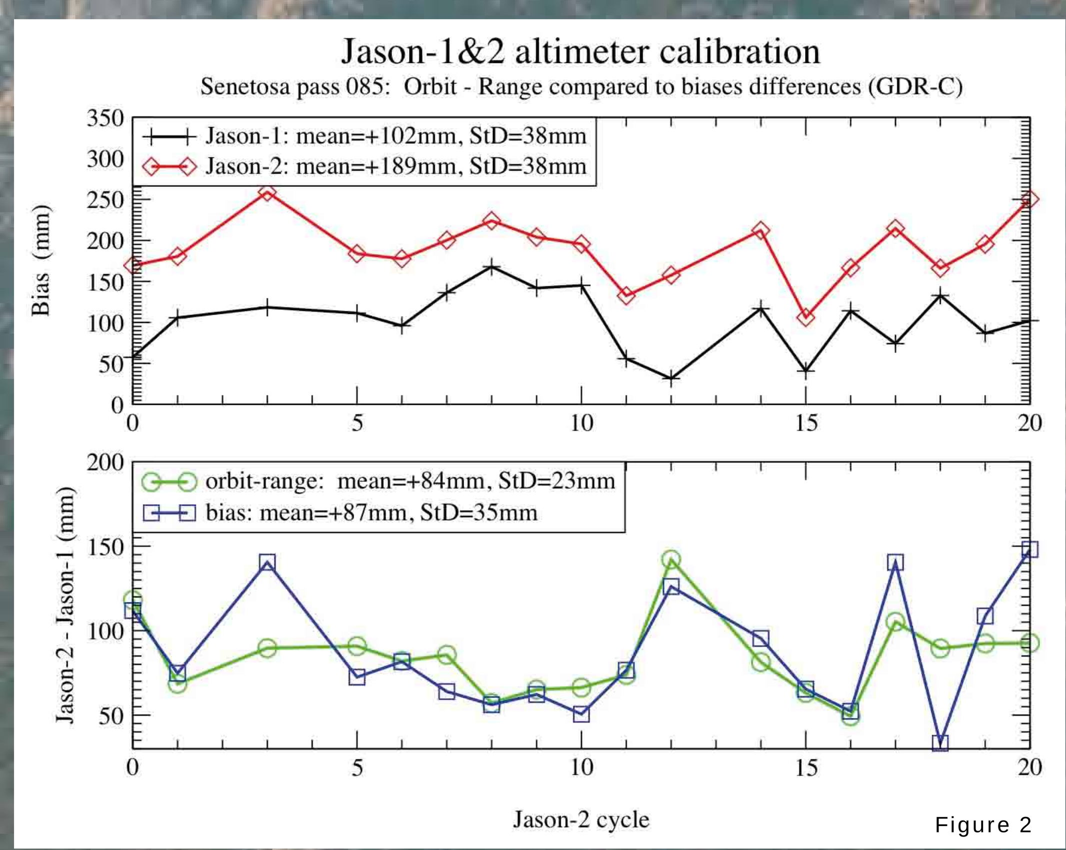


Figure 2

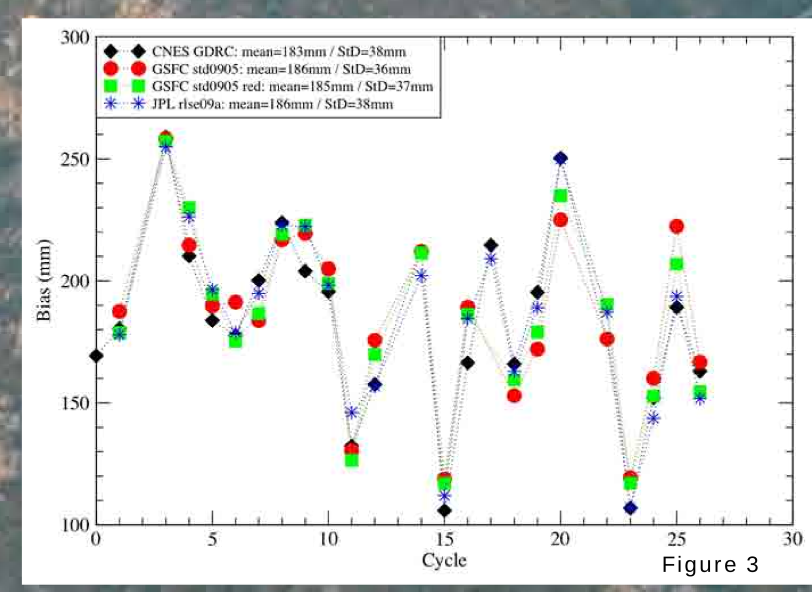


Figure 3

Figure 3 (above) shows the Jason-2 absolute altimeter bias computed from different POE orbits:

- CNES GDRC: CNES standard POE in the GDR-C
- GSFC std0905: GSFC POE (SLR+DORIS+GPS)
- GSFC std0905 red: GSFC POE (GPS reduced dynamic)
- JPL rlse09a: JPL POE (GPS reduced dynamic)

The impact on the bias is not significant (few mm)

Orbit-Range and Bias differences (Figure 2) give coherent results for the relative bias between Jason-1 and Jason-2 due to the fact that the corrections differences are compensated. Moreover, the results are in relatively good agreement with the relative bias derived from JPL global analysis (~77 mm). Results on the biases are given below:

Absolute biases (cycle 0 to 20):

Jason-1/Poseidon-2: +102 mm ±9 mm
Jason-2/Poseidon-3: +189 mm ±9 mm

Relative biases (cycle 0 to 20, common cycles):

Bias differences (Poseidon-3) - (Poseidon-2): +87 mm ± 8 mm
Orbit-range differences (Poseidon-3) - (Poseidon-2): +84 mm ± 5 mm

During the Formation Flight Phase between T/P and Jason-1 the relative bias was:
Bias differences (Poseidon-2) - (ALT-B): +85 mm ± 9 mm

WET TROPOSPHERIC CORRECTION AT THE COAST APPROACH

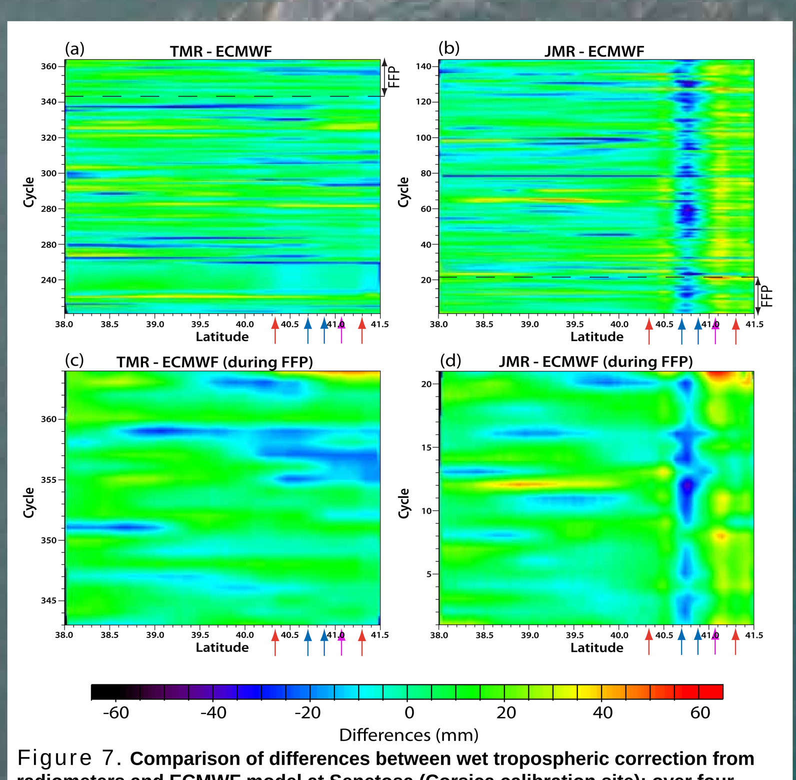


Figure 7. **Comparison of differences between wet tropospheric correction from radiometers and ECMWF model at Senetosa (Corsica calibration site); over four years of data for (a) T/P (TMR, cycle 221 to 364) and (b) Jason 1 (JMR, cycle 1 to 144); over the Formation Flight Phase (FFP) for (c) T/P (TMR, cycle 343 to 364) and (d) Jason 1 (JMR, cycle 1 to 21). The colored arrows on the latitude axis correspond to the lines defined in Figure 9.**

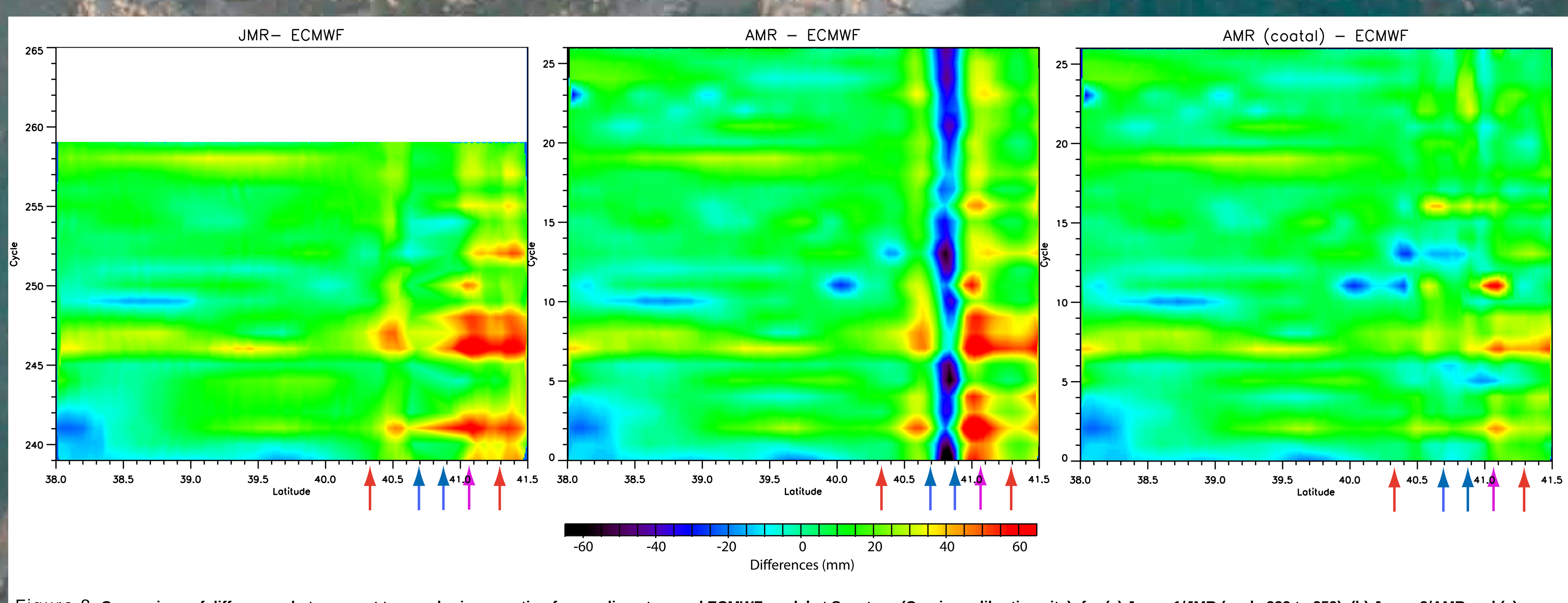
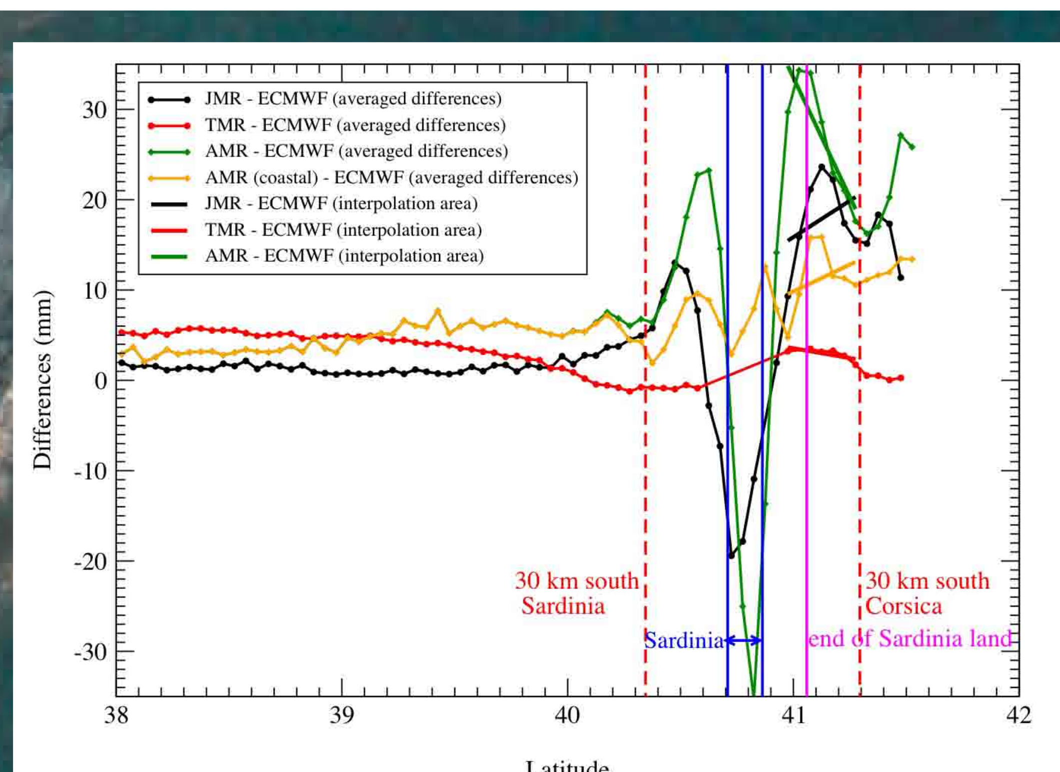


Figure 8. **Comparison of differences between wet tropospheric correction from radiometers and ECMWF model at Senetosa (Corsica calibration site); for (a) Jason 1/JMR (cycle 239 to 259), (b) Jason 2/AMR and (c) Jason 2/AMR coastal (cycle 0 to 26); the Formation Flight Phase (FFP) correspond for Jason 1 of cycle 239 to 259 and for Jason 2 to cycle 0 to 20. The colored arrows on the latitude axis correspond to the lines defined in Figure 9.**

The wet tropospheric correction (path delay with a negative sign) is an important source of geographically correlated bias. Indeed, it is mainly linked to radiometer land contamination, with differences existing between calibration sites depending on the distance from the coast and the orientation of the satellite approach to the land. For example, at the Corsica site, for the calibration pass #85 (Figure 9) the satellite first overflies Sardinia and then enters over a channel where the maximum distance to the coast is about 40 km.

Figures 9 shows that the radiometer behavior is different for T/P (TMR) while it is similar for Jason 1 (JMR) and Jason-2 (AMR) when flying over Sardinia and crossing the Sardinia-Corsica channel. The TMR contamination seems to not really affect the wet path delay corrections, but most of the data are missing over Sardinia. For Jason 1 and Jason 2, the JMR and AMR behavior is more complex: the correction is decreasing (in absolute value) when approaching the coast (Sardinia and then Corsica) and increasing when moving away from coast. This effect implies that, in the area where the correction is interpolated, its value is stable for T/P (Figure 9, red line) while for Jason 1 and Jason 2 (Figure 9, respectively black and green line) it will be overestimated by 10 to 15 mm (even using classical criteria that suggest to maintain data no nearer than 30 km from the coast).

AMR coastal (Figure 9 in orange, cycle 0 to 26) is a new correction which has been developed for coastal applications (distance below 25 km); the complex behaviors exhibited by both JMR and AMR have been considerably reduced even if some oscillations remain between Sardinia and Corsica. Thanks to this improvement, data very close to the coast (~10 km) seem to be useable. Results of comparisons between AMR coastal and GPS (+2 mm, Figure 6) confirm that this correction is better suited for coastal studies.
In Figure 8, the (a), (b) and (c) maps show the differences between wet path delay data from both JMR and AMR radiometers with respect to the ECMWF model when Jason 1 and Jason 2 were in formation flight (July 2008 to January 2009) and clearly illustrates the big improvement thanks to the new AMR coastal correction: before Sardinia (open ocean) there's a relatively good correlation in the patterns showing a good consistency between both radiometers and revealing some coherent signatures over few cycles which are probably due to model inconsistencies for some meteorological conditions. Similar study is presented in Figure 7 for T/P and Jason 1.



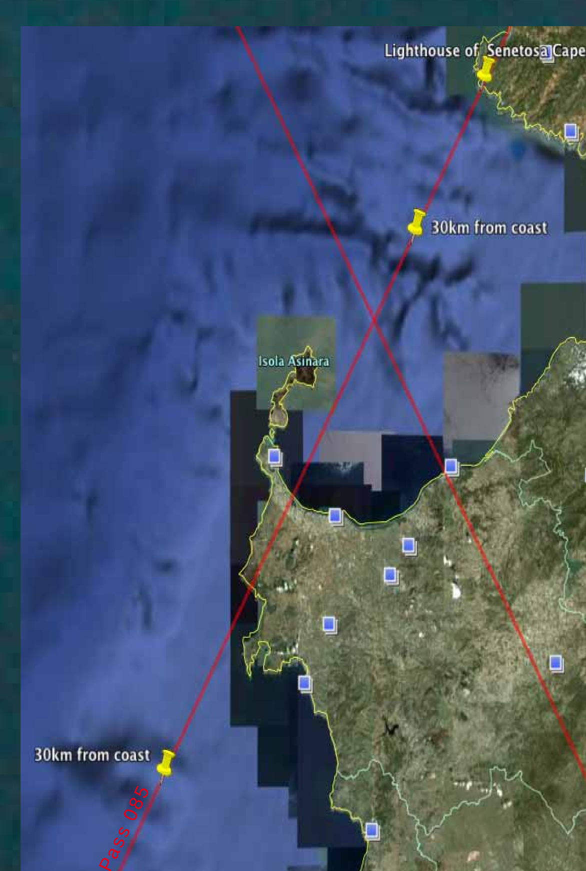


Figure 9. **Comparison of averaged differences (every 5 km) between wet tropospheric correction from radiometers and ECMWF model for Jason 1 (JMR, in black, cycle 1 to 144), T/P (TMR, in red, cycle 221 to 364) and Jason 2 (AMR and AMR coastal, respectively in green and orange, cycle 0 to 26) at Senetosa (Corsica calibration site). "End of Sardinia land line" corresponds to the end of the small Asinara Island.**

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. 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 drifts.
The expected outputs of this on site verification experiment are dedicated obviously to the determination of the calibration bias of TOPEX/Poseidon and Jason-1. On the other hand, it is also an opportunity to contribute to the orbit tracking of oceanographic and geodetic satellites and to the analysis of the different error sources, which affect altimetry. In the field of positioning, we expect to contribute also to the decorrelation between the possible vertical displacements of our site (Earth crust) and the Mediterranean mean sea level.
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 altimeters from 1998, and the Jason 1&2 ones since the beginning of the missions. 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. Following the previous 2002 and 2005 campaigns, the French Transportable Laser Ranging System is settled at Aspretto since beginning of July until December 2008. Preliminary results of this campaign, in term of calibration, are presented.
At Senetosa cape, permanent geodetic installations have been installed since 1998 and different campaigns have been conducted in view of Jason-1 mission. Four tide gauges are installed at the Senetosa Cape and linked to ITRF using GPS and leveling. In parallel, since 2000, a GPS buoy is deployed during overflights at Senetosa (10 km off-shore). Moreover, since 2003, a permanent GPS has been installed to monitor possible vertical displacements of our site. In addition, using a local weather station, we derived the wet tropospheric path delay from GPS measurements which are compared to the Radiometer ones (TMR, JMR and AMR) at the overflight times.
The presented results will be focused on the Formation Flight Phase (also called tandem phase) of Jason-1 and Jason-2 and based on the I-GDR and GDR products. The full set of Jason-1 and Jason-2 GDR-C available will be also analyzed to be validated at the OSTST. Updated values of the altimeter biases for both Jason-1 and Jason-2 will be presented as well as detailed studies on the various corrections. In our presented results, continuity of the long biases time series for T/P and Jason 1 will not be forsaken...
Our semi-permanent experiment is planned to last over several years in order to detect any drift in the space borne instruments.