Experiences on Altimeter Calibration at Ibiza Island and Cape of Begur (Spain)

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ABSTRACT/RESUME

Three preliminary campaigns for TOPEX/POSEIDON (T/P) were made in March 1999 and July 2000 and for JASON-1 in August 2002, in the NW Mediterranean Sea at the Begur Cape area. Direct absolute altimeter calibration, and mapping of the sea surface, were made in these campaigns from direct overflights using GPS buoys with a toroidal design performed at the ICC based in the original design of the University of Colorado at Boulder and a estimation of the TOPEX Alt-B bias was made.

A Spanish JASON-1 geoid gradient campaign with Fench support has been made in June 2003 at the Ibiza island in the NW Mediterranean Sea. The main objective has been to map with a new designed, builded and calibrated GPS catamaran, the local geoid gradient in three areas around Ibiza island under the ascending (187) and descending (248) Jason-1ground tracks. The catamaran equipped with two GPS antennas to perform continuous sea level measurements was towed by the Patrol Deva from the Spanish Navy. Five GPS reference stations were deployed on Ibiza island: one in Portinatx, two in San Antonio and two in Ibiza. The marine geoid has been used to relate the coastal tide gauge data from Ibiza and San Antonio harbours to off-shore altimetric data. In the framework of the campaign, the levelling of the Ibiza and San Antonio tide gauges to the respective GPS markers was performed.

We present synthesis of the results obtained from Topex/Poseidon and the first results on Jason-1 altimeter calibration using the direct measurements from GPS buoys and the derived marine geoid. The Ibiza results agree relatively well with results obtained at Corsica, Harvest and Bass Strait calibration permanent sites. Moreover, the geodetic activities (e.g., GPS, levelling) has permitted to build a very accurate (few mm) local network linked to the European one, with a reference frame compatible with the satellite altimetry missions (ITRF2000). The GPS kinematic data were processed using two different softwares allowing to check the consistency of the solutions. A perspective of a new Jason-1, including Envisat, Ibiza campaign to be made around 2007 will be presented.

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1. METHODOLOGY

A comparison of the instantaneous sea surface height (SSH) estimated by two independent techniques at the same geographical location and time was the methodology followed [1]. This technique is the so-called direct calibration method. The instantaneous SSH derived from the JASON-1 measurements, that is, the difference between the satellite orbit height (h_{orbit}) and the altimeter measurement (h_{alt}), which represents the corrected basically raw range of the media delays, troposphere and ionosphere, the sea state bias and the instrumental delay:

$$SSH_{JASON} = h_{orbit} - h_{alt} \quad (1)$$

is compared with the same magnitude $SSH_{tide\ gauge}$, which can be considered a 'true' measurement of the instantaneous sea level, estimated from the measurements of the GPS buoys placed underneath the ascending T/P satellite ground track. The bias of the altimeter is obtained from this comparison :

$$BIAS = SSH_{JASON} - SSH_{tide\ gauge} \quad (2)$$

However, because off-shore altimetric data are affected by the geoid slope, the Sea Level map derived from both the GPS catamaran campaign (Ibiza 2003) or the

GPS buoy campaign (Begur 2000 and 2002) is used to correct them. Such a method is described in detail in [Bonnefond et al., 2003b].

2. CALIBRATION CAMPAIGNS

2.1. Begur calibration campaigns

The instrumentation consists on the reference station at the coast and the GPS buoys. The near tide gauge is only used when performing the indirect method. The reference station close to the satellite ground track is needed in order to achieve kinematic buoy solutions within centimeter accuracy level, which is the typical error assumed for the range measurement of the altimeter [3].

In all the campaigns, the buoy solution has been computed by using a differential kinematic strategy with short baselines, assuming common atmosphere corrections (ionosphere and specially troposphere) between the fix receiver and the rover. The mean value of the baselines is of 14.3 km and 14.9 km in 1999 and in 2000, respectively, and of 22.4 km in 2002. Previously, the coordinates of the fiducial site at the coast (triangles in Fig. 1) have been fixed by computing the free-network solution [7] that involves several permanent IGS-ITRF stations of the ICC in Catalonia (squares in Fig. 1).

Apart of the tide gauge at l'Estartit, two ancilliary sensors were temporally installed at Llafranc harbor in 1999 in order to study the spatial and temporal variability of the tides in that area from the simultaneous records.

In the 1999 and the 2000 campaigns the direct estimation of the altimeter bias was realized during the overflight of the TOPEX/POSEIDON onto a point marked as TOP-08 and in the 2002 campaign the overflight occurred onto TOP-11, in Fig.1. Overflight times have an uncertainty of about 10 sec.

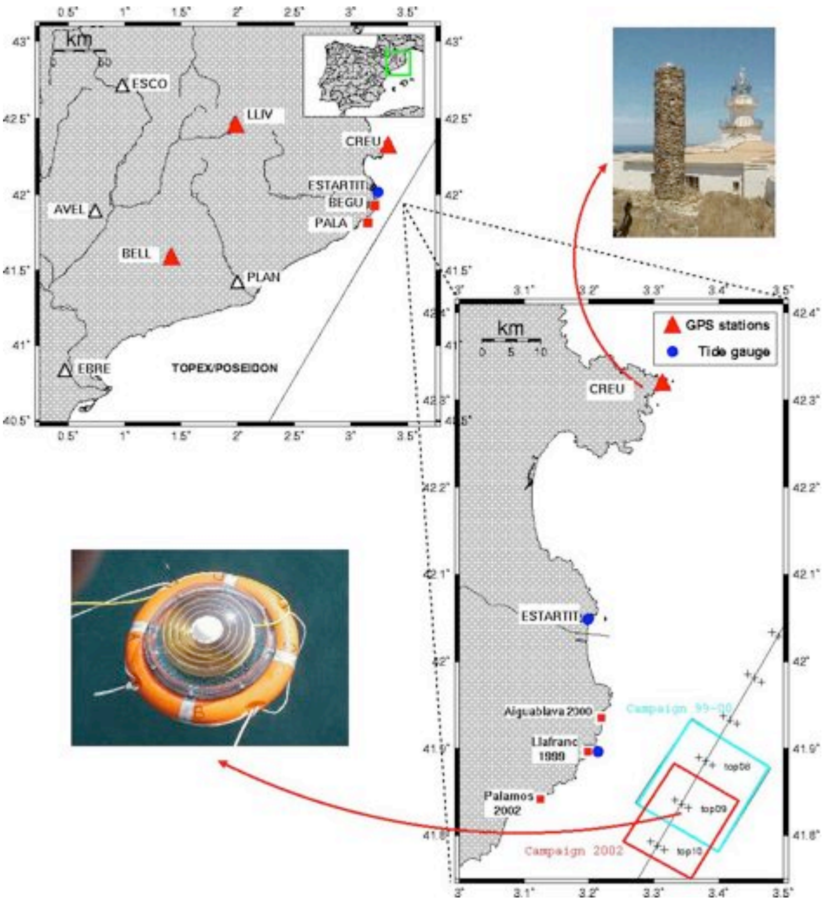

Figure 1. General distribution of Begur calibration site. The GPS network of the ICC in Catalonia and the calibration area offshore Begur Cape indicating the surveying points on both the 1999-2000 and the 2002 campaigns. It is represented the nominal T/P ground track in the center and the parallel internal and the external ground tracks for the mapping of the sea surface.

2.2. Ibiza 2003 campaign

The determination of the marine geoid by GPS catamaran technique was objective. This marine geoid will be used to rely the coastal tide gauge data and the off of coast Jason-1 altimeter data. The GPS catamaran was designed at ICC taking in account the one used in Senetosa/Corsica campaigns [2]. Also a toroidal GPS buoy was used. GPS reference stations were located at Ibiza, San Antonio and Portinatx (Fig. 2). Data from tide gauges at Ibiza and San Antonio have been used and a spirit levelling was performed in these two places.

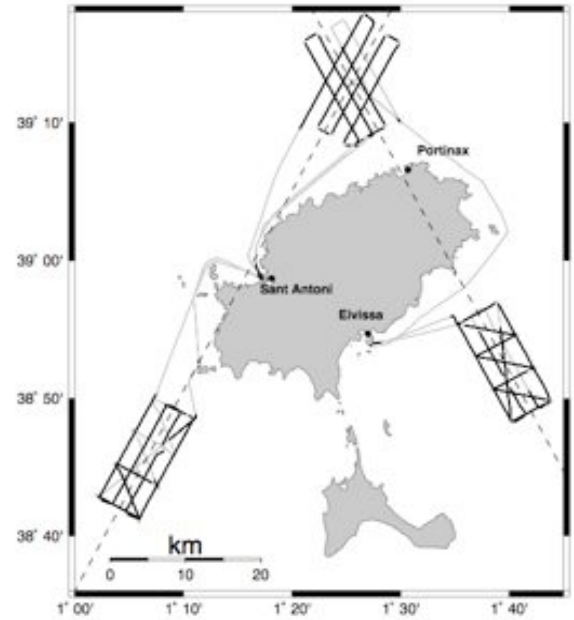

Figure 2. GPS data collected (gray) and kept (black). Dashed lines represent the Jason-1 passes: ascending N°187 (South West – North East) and descending N°248 (North West –. South East).

3. CALIBRATION RESULTS

3.1. Begur campaings

The GPS data have been processed with the GIPSY/OASIS-II software (JPL). In the three campaigns the GPS data processing has been split in two parts: First, positioning of the reference station at the coast near the calibration area (free-network solution) and, second, differential positioning of the buoy respect to the reference (fiducial) site off the coast (differential kinematic solution).

In the direct calibration the SSH measured by the altimeter at the overflight is compared with the same magnitude derived from the buoy solution. Thus the range bias is computed in Tab. 1 and example of the kinematic solution at 2000 campaign is given in Fig.3.

The significant wave height (SWH) computed from GPS as described in the section before is compared with the simultaneous radar altimeter measurement. Tab. 2 shows very good agreement between both measurements, thus GPS measurements are very accurate descriptors of SWH because it is the stardard deviation from the mean value of the sea surface.

Also the altimeter bias computed by the mapping of the sea surface and correcting the sea level anomaly from the time serie of l'Estartit tide gauge give closer values to the ones given in the literature and their associated rms have decreasing respect to the values obtained in the single point calibrations or direct methods where the buoy is physically present (Tab. 3).

Campaign	Overflight (UTC time)	Cycle	SSH_{GPS} (m)	SSH_{alt} (m)	SHH_{BIAS} (cm)	Alt. product
1999	18/03 at 08:45:41	T/P 239	49.12 ± 0.319	49.05 ± 0.04	6.50 ± 32.10	M-GDR TOPEX-B
			49.09 ± 0.323	49.05 ± 0.04	3.70 ± 32.60	
2000	07/07 at 07:34:47	T/P 287	49.24 ± 0.074	49.21 ± 0.04	+3.43 ± 7.96	M-GDR TOPEX-B
2002	28/08 at 15:37:07	J 23	49.29 ± 0.061	49.18 ± 0.08	+10.52 ± 10.35	I-GDR Jason-1

Table 1. SSH_{BIAS} estimation by single point experiments over point TOP-08 (figure 1) for TOPEX-B and over point TOP-11 for Jason-1 radar instruments. The two values in 1999 correspon to both similar GPS buoys used simultaneously at that campaign (UPCB and JPLB buoys, respectively).

3.2. Ibiza campaign

Jason-1 altimetric data was analyzed from cycle 9 (beginning of San Antonio tide gauges data) to cycle 62. Fig.4 and 5 shows the time series of the Jason-1 altimetric bias for pass 187 (left) and 248 (right) from Ibiza and San Antonio tide gauges.

Campaign	SWH_{GPS}(cm)	SWH_{alt}(cm)	WS(km/h)
1999 UPCB	128.0	130.0	31.0
1999 JPLB	129.0	130.0	31.0
2000	21.0	20.0	17.0
2002	27.5	28.0	10.0

Table 2. SWH at the overflight and the in-situ wind speed.

Date	Cycle	# averaged points	SHH_{BIAS} (cm)	Altimeter product
2000	T/P 287	6	+ 2.13 ± 6.55	M-DGR TOPEX-B
2002	J 23	4	+10.12 ± 6.23	I-DGR Jason-1

Table 3. SSH_{BIAS} estimation by the indirect method for TOPEX-B and Jason-1altimeter in only one pass.

The statistics of this analysis are summarized in table 4. The bias found at San Antonio is very close to that found at other calibration sites notably the Corsica one where the geographically correlated errors should be comparable (orbit, sea state,..): +138 ± 7 mm at Harvest (Haines et al., 2003), +120 ± 7 mm at Corsica (Bonnefond et al., 2003b) and +131 ± 11 mm at Bass Strait (Watson et al., 2003).

However, the one derived from Ibiza tide gauge data exhibit a difference of about +50 mm. This confirms the difference of 48 mm found in the GPS sea height versus tide gauge sea level at Ibiza (Tab.4). Moreover, the mean sea heights of tide gauges (Tab.5) exhibits a difference of 95 mm while the geoid height difference should be close to 50 mm. It seems that there should be an error of about 50 mm either in the leveling or the height between the pressure sensor and the Tide Gauge Bench mark. These measurements have to be redone to find the error source

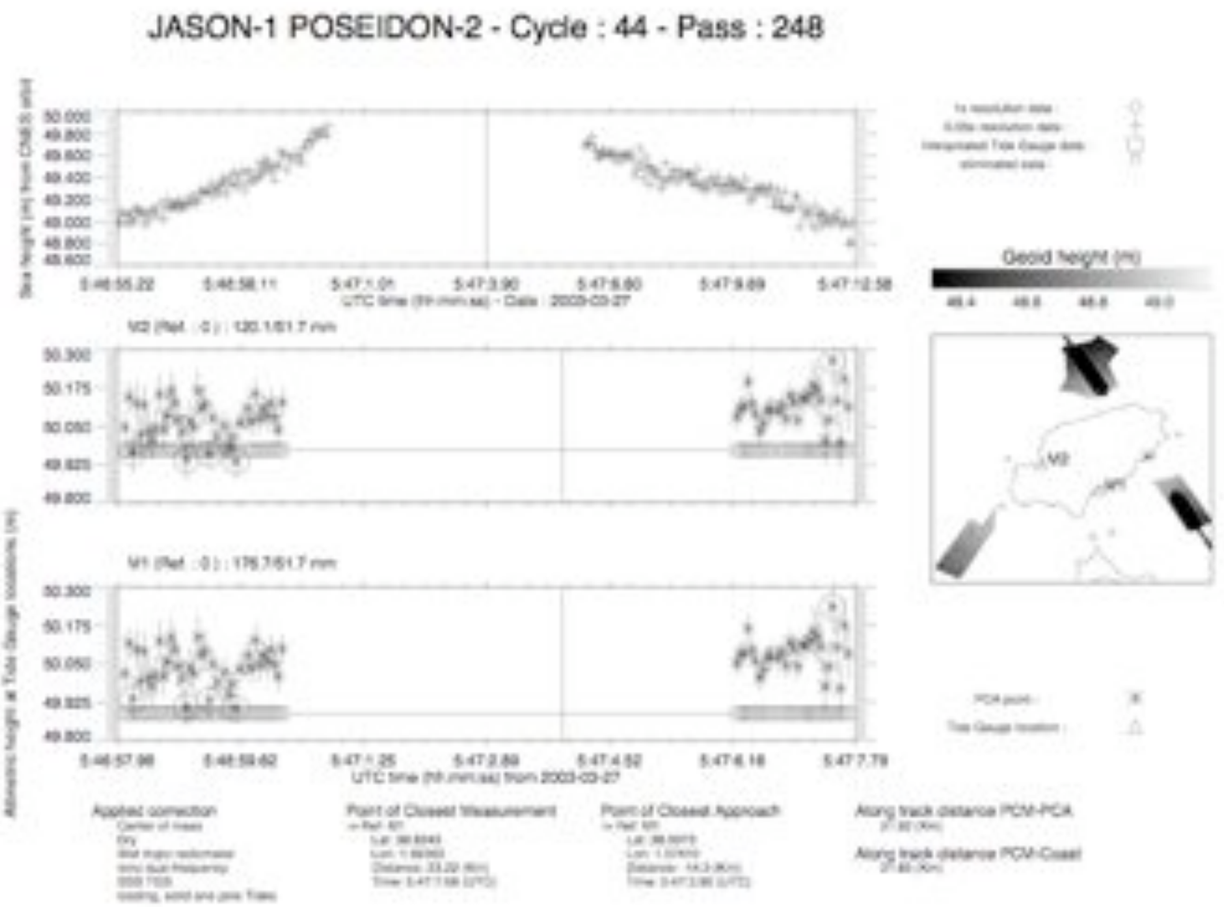

Figure 4. Jason-1 altimeter calibration process for pass 248 and cycle 44.

	Ibiza		San Antonio	
Pass	Mean (mm)	σ (mm)	Mean (mm)	σ (mm)
187	169.0	33.4	119.0	23.4
248	177.0	24.5	122.0	27.4

Table .4. Statistics of the Jason-1 altimeter bias for passes 187 and 248 using Ibiza and San Antonio tide gauges.

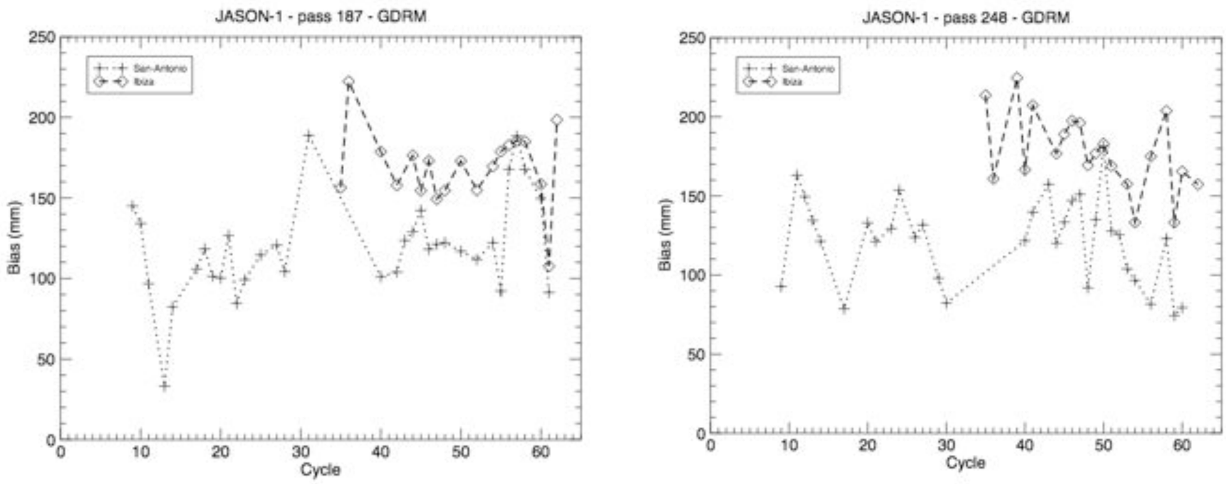

Figure 5. Time series of Jason-1 altimeter bias for pass 187 (left) and 248 (right). Crosses and diamonds represent the determination from San Antonio and Ibiza tide gauges respectively.

Figure 6. Direct JASON-1 absolute altimeter calibration on 14 June 2003

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