JASON-1 CALVAL EXPERIENCES IN CAPE OF BEGUR AND IBIZA ISLAND

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ABSTRACT

The direct and indirect calibration experiences made at the Cape of Begur area in 1999, 2000 and 2002, for Topex/Poseidon and at the Ibiza island in 2003 have contributed to the international campaigns made at Harvest (USA), Corsica (France) and Bass (Australia).

The main objective of IBIZA 2003 campaign has been the determination of the instantaneous sea surface/marine geoid gradient along Jason-1 tracks using a GPS catamaran and a network of GPS located in Portinatx and Ibiza and San Antonio harbours. The marine geoid will be used to relate the tide gauge coastal data with the altimeter data. We present the first results obtained with static and kinematic analysis of the data using different softwares.

Keywords: altimetry, calibration, tide gauges, GPS

RESUMEN

Las experiencias realizadas en las zonas del Cabo de Begur en 1999, 2000 y 2002 , e Ibiza en 2003 dentro del marco internacional de calibración altimétrica directa e indirecta de los satélites Topex/Poseidon y Jason-1 han tenido como finalidad la contribución a las campañas realizadas a nivel internacional en Harvest (Estados Unidos), Córcega (Francia) y Bass (Australia).

El principal objetivo de la campaña IBIZA2003 ha sido la determinación de la superficie instantánea del mar/gradiente del geoide a lo largo de las trazas del Jason-1 usando un catamarán GPS asi como un conjunto de sistemas GPS situados en Portinatx y en los puertos de Ibiza y San Antonio proximos a los mareógrafos permanentes en donde se ha realizado una nivelación óptica. El geoide marino servirá para relacionar los datos costeros de los mareógrafos situados en los puertos de Ibiza y San Antonio con los datos altimétricos. Se ha realizado el procesado de los datos GPS, estático y cinemático con diferentes softwares presentándose los primeros resultados.

Palabras clave: altimetria, calibración, mareógrafos, GPS

1. Introduction

In the framework of a project of the Spanish Space Program related to the JASON-1 CNES/NASA mission, a Spanish campaign, with French support, was conducted on June 9-17, 2003, in the Absolute Calibration Site of Ibiza Island (NW Mediterranean Sea). The objective was to determine the local marine geoid slope under the ascending (187) and descending (248) Jason-1 ground tracks, in order to allow a better extrapolation of the open-ocean altimetric data to on-shore tide gauge locations and thereby improve the overall precision of the calibration process. A technical Spanish contribution to the calibration experience has been the design of GPS buoys [3,8] and GPS catamaran taking in account the previous University of Colorado at Boulder and GEMINI/CNES designs. For the mapping of the extended calibration areas centered on satellite ground tracks, the catamaran was tracked by the Patrol Deva, from the Spanish Navy. An additional absolute altimeter direct calibration was performed on June 14 near the crossover point north of the island. Complementary data came from five GPS reference stations deployed at Ibiza city, San Antonio and Portinatx, and from vertically-referenced tide gauges located at Ibiza and San

Antonio. Here we present preliminary results on the GPS-based marine geoid processing, for which the accuracy is estimated to be better than 3 cm at crossovers. Moreover, the geodetic activities (e.g., GPS, leveling) 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). Improved geoid surface has been obtained using the MOG2D ocean model data. The IBIZA 2003 campaign and its logistics has been a major contribution for a possible implementation of a complementary calibration site at the Ibiza island to the permanent sites of Harvest [4], Corsica [2], Bass strait [15], Gavdos island [11] and Lake Eire [14]. It has followed a JASON-1 campaign made at Cape of Begur in August 2002 [9].

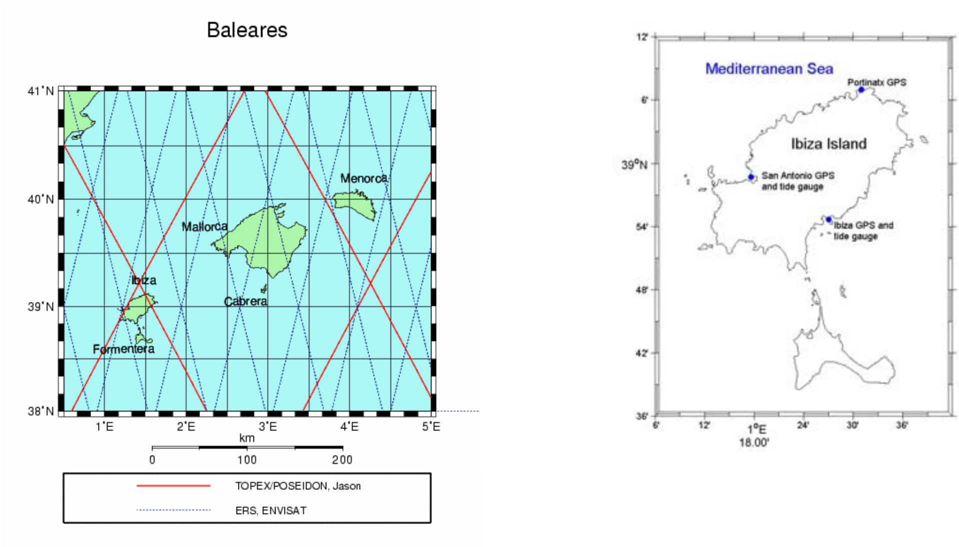

FIGURE 1. Geographical area of the Ibiza 2003 campaign (a) and GPS Reference stations and tide gauges on Ibiza Island (b).

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The Western Mediterranean is quite a complex area from different points of view: due to the presence of several islands, coastal lines, shallow waters and a peculiar hydrologic equilibrium due to its proximity to the Atlantic water exchange area. This makes the estimation of the gravity field and the geoid slope a quite difficult task.

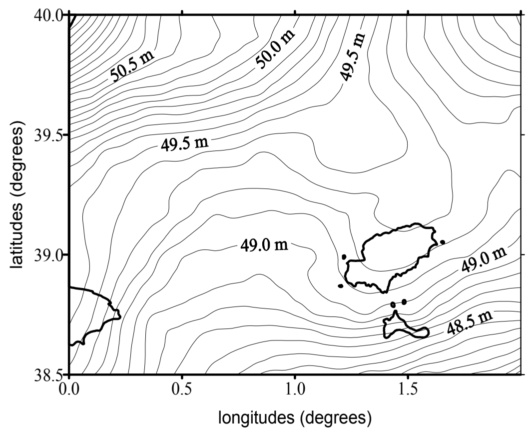

FIGURE 2. Level lines of the gravimetric geoid. Contour interval: 10 cm.

There are some results for the local/regional gravimetric geoid, which have been built up using different techniques such as least squares collocation (LSC) and spectral methodology (fast Fourier transform; [13]. In all cases, the classical remove-restore technique has been employed, taking into account the long wavelength part of the gravity field by means of sets of coefficients of the geopotential EGM96 model and the topography effect or contribution of high frequencies to the gravity field. The result is a fairly smooth surface, with a range of variation around the Island of about one meter , from 48,5 m to 49,5 m. The isolines of one of this geoid are depicted in Figure 2. When gravimetric geoids are compared to each other they show a good match, with only small discrepancies found to the South of Ibiza Island.

2. The instruments and the data set

2.1 GPS Reference Stations

Five GPS reference stations were deployed on Ibiza Island: one at Portinatx, two at San Antonio and two at Ibiza (see Figure 1 and Tables 1 and 2). An additional Trimble antenna and receiver were also installed at Ibiza harbour during a few hours (on 06/16/2004). For IBIA, SANA and SANB stations, the raw data set covered 6 days (11-16 June 2003), whereas for IBIB and PORT stations it covered only 5 days. The ample rate was fixed to 30 seconds except during the Catamaran/Buoy measurements, during when it was set to 1 second.

TABLE 1 Location and time of observation for each GPS station.

Marker Name	Location	From	To
IBIA	Ibiza (hotel roof)	11/06 18h58	16/06 24h00
IBIB	Ibiza (hotel roof)	12/06 08h29	16/06 24h00
SANA	San Antonio (nautical club roof)	11/06 12h49	16/06 07h53
SANB	San Antonio (nautical club roof)	11/06 13h24	16/06 07h32
PORT*	Portinax (room roof)	10/06 15h49	15/06 24h00
Buoy	Ibiza, San Antonio, Calibration (North)	11/06 15h33	16/06 07h37
CATR	Ibiza, San Antonio, Calibration (North)	11/06 15h34	16/06 07h37
CATL	Ibiza, San Antonio, Calibration (North)	12/06 08h24	16/06 09h48

*Data lack on 11/06 from 08h09 to end of day

TABLE 2 Antenna height, type of antenna and type of receiver for each GPS station.

Marker Name	ARP Height	Antenna Type	Receiver Type
IBIA	0.8447	TRIMBLE: 4000 ST/SST	ASHTECH: XII Z-12
IBIB	1.1510	LEICA: AT502	LEICA: SR530 3.02
SANA	0.6385	SHTECH: Choke Ring	ASHTECH: iCGRS Z-12
SANB	0.1438	TOPCON: Choke ring ant CR-3	TOPCON: LEGACY-E L1/L2
PORT	0.9510	LEICA: AT502	LEICA: SR530 3.02
Buoy	-0.0078	TRIMBLE:Compact L1/L2	TRIMBLE: 4000SSI
CATR*	0.4640	LEICA: AT502	LEICA: SR530 3.02
CATL*	0.9510	TRIMBLE: Compact L1/L2	TRIMBLE: 4000SI

* Height relative to the water line

2.2 Catamaran description

A catamaran equipped with two GPS antennas to perform continuous sea level measurements at a convenient velocity was built up using two wind-surf boards and a metallic structure onto which the antennas were fixed (Figure 3a). The design followed the model used in Senetosa measurements [1], and is stable enough to be towed by a boat (in this campaign the Patrol Deva P29, from the Spanish Navy, Figure 3b) at a convenient speed without stopping GPS data acquisition. Two radomes for protection were placed above the two GPS antennas, a Trimble (CATL), and a Leica (CATR). Two GPS receivers, Trimble and Leica, were used aboard the Deva and linked to the antennas of the catamaran by cables independent of the towing rope at a distance about 30 m. Measurements were made in the harbours of San Antonio and Ibiza, with the catamaran close to the GPS buoy (Figure 3c) and simultaneously to tide gauge records.

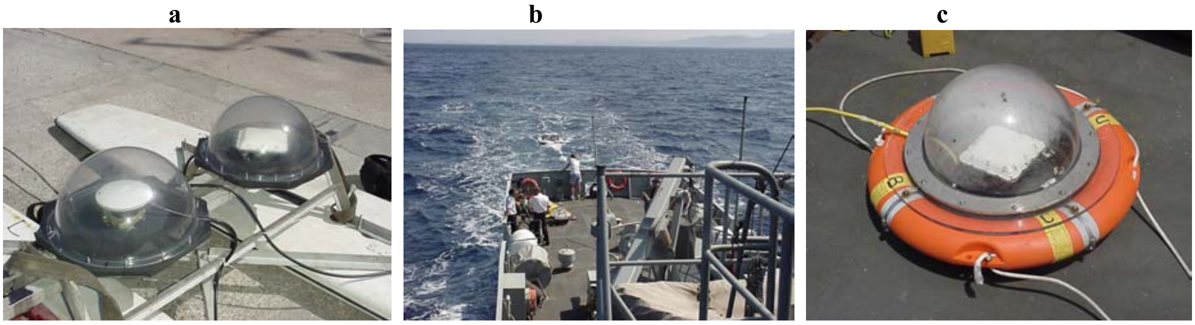

FIGURE 3. GPS Catamaran (a), Patrol Deva from the Spanish Navy towing the GPS Catamaran (b) and GPS Buoy (c).

2.3 Description of the tide gauges

The tide gauges used to complement GPS and altimetric data are installed in Ibiza city and San Antonio (see Figure 1 for a general location and Figure 4 for details).

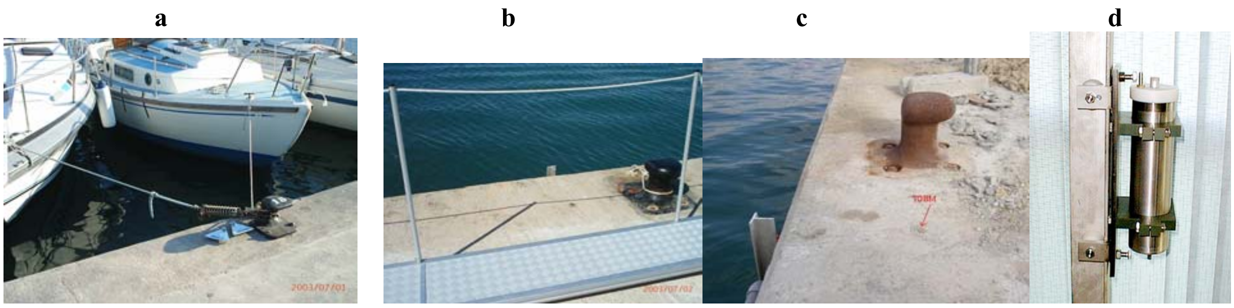

FIGURE 4. Detail of the locations of the tide gauges in San Antonio harbour (a), Ibiza (b), tide gauge bench mark (TGBM) at Ibiza harbour (c) and Ibiza pressure sensor container attached to the metallic timber (d)

The Spanish Port Authority “Puertos del Estado” installed the tide gauge station of Ibiza harbour in January 2003. The station belongs to the REDMAR network, composed at this moment by 21 stations distributed along the whole Spanish waters. The tide gauge deployed in Ibiza also belongs to the European Sea-Level Service (ESEAS) network. The instrument, an Aanderaa water level/temperature sensor (3796 A) with compensating unit for atmospheric pressure, was installed at the Golondrinas pier (Figure 4a). In 2004 a permanent GPS station funded by ESEAS-RI EU project has been collocated with the tide gauge in a building in front of the tide gauge peer.

The San Antonio tide gauge (Figure 4b), an Aanderaa WLR7, was deployed by IMEDEA by the beginning of 2002. It was funded by the European Space Agency (ESA) in the framework of the calibration and validation activities of the ENVISAT radar altimeter RA-2. From the beginning of 2003 onwards, the station has been funded by the ESEAS-RI EU Project.

In the framework of the Ibiza 2003 campaign (on the 1st and 2nd of July 2003), the levelling of both tide gauges to the respective GPS markers was repeated. The classical high precision automatic level Zeiss-Ni1 (with parallel plate micrometer) was used and the method was double run levelling with observation in the middle point to avoid systematic errors. In order to avoid and detect bounder and accidental errors, each line was observed twice by the double run method. The loop misclosures in any case exceeded 1 mm. The results are shown in the Tables 3 and 4.

TABLE 3. Leveling at San Antonio	
Marker	**Height (m)**
SANA	8,2431 ± 0.0008
SANB	8,2320 ± 0.0008
Top of the iron bar	0,0000 ± 0.0008
Pressure sensor	-1.998

TABLE 4. Leveling at Ibiza	
Marker	**Height (m)**
IBIA	10,5805 ± 0.0008
IBIB	10,5631 ± 0.0008
Top of the iron bar	0,0000 ± 0.0008
Tide Gauge Bench mark (TGBM)	0,0001 ± 0.0008
Pressure sensor	-0.884

In order to check the quality of the data of both tide gauges, especially during the dates of the campaign, a comparison has been made between both, Ibiza and San Antonio tide gauges (Figure 5), for the period 24th of May to 20th of September. Data from San Antonio are sampled each 10 minutes. Apart from some important differences in the higher frequency data (Figure 5, left), due to the different response of each harbour, the daily averaged values show a good agreement for this period (Figure 5, right).

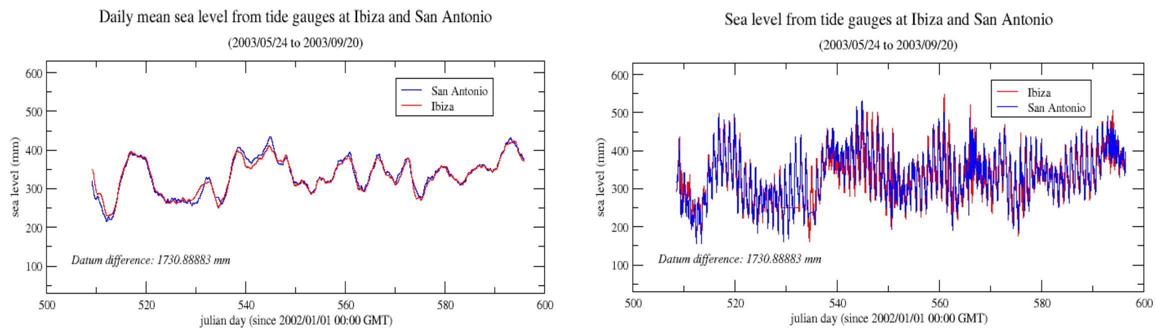

FIGURE 5. Comparison between tide gauge data at Ibiza and San Antonio (IMEDEA); the mean difference for the period has been subtracted for comparison. Left: raw data (5 min Ibiza, 10 min San Antonio). Right: moving average of 1 day applied to raw data.

3. GPS Data Processing

The GPS data processing can be divided into two parts: first we need very accurate absolute positions (particularly in the vertical component) in a global reference frame coherent with the one commonly used for T/P and Jason-1 mission (ITRF2000). In a second part, these reference stations will define the datum for the kinematic processing of the GPS catamaran and buoy data but will be also used to determine the absolute sea level heights derived from tide gauges data.

3.1Reference Station Analysis

For this analysis, we have used three software/methodology: Bernese (computation by ICC), GIPSY-OASIS II (computation by ROA) and GAMIT/GLOBK (computation by OCA-GEMINI). All these solutions are based on 30 s time sampling GPS data. These three solutions will be described and compared.

<u>OCA-GEMINI Solution</u>

The reference stations are processed using the GAMIT [7] and GLOBK [5] suites developed at the Massachusetts Institute of Technology.

The GPS station processing has been realized in two steps: we have used the GAMIT “Relax” mode for the reference stations (SANA, SANB) with antenna compatible IGS standards and the GAMIT “Baseline” mode for the others (IBIA, IBIB, and PORT). For the two reference stations processed in the GAMIT “Relax” mode, a regional network based on the most accurate GPS station of EUREF network has been chosen (Figure 6): Ajaccio and Grasse (France) - Cagliari, Matera and Medicina (Italy) - Ebre and San-Fernando (Spain) - Wettzell (Germany). With six daily solutions the weighted root mean square (wrms) values for SANA and SANB were 3.8 mm and 2.4 mm.

SANA and SANB have then been fixed and the three other stations have been determined using the GAMIT "Baseline" mode to reduce the impact of the heterogeneous antenna types. With four daily solutions the weighted

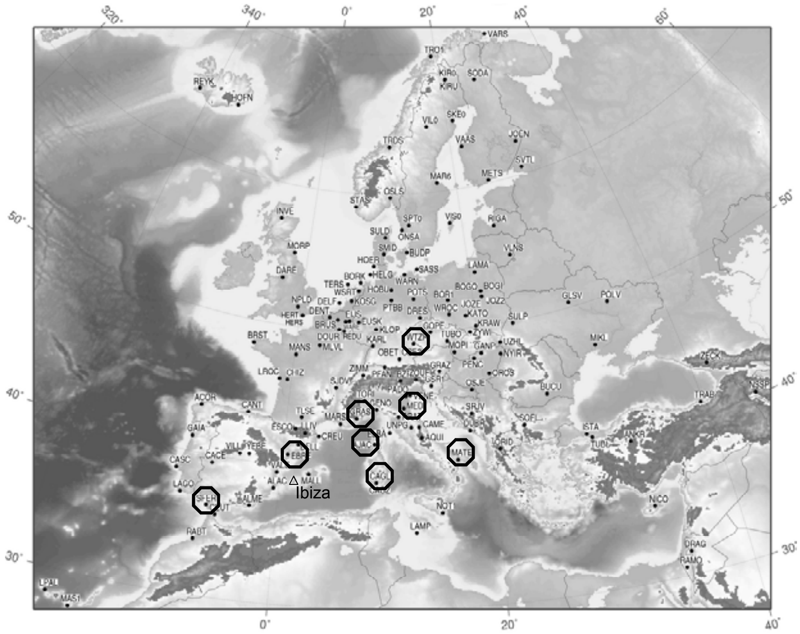

FIGURE 6. Network used for the GAMIT "Relax" mode for SANA and SANB determination.

root mean square values for IBIA, IBIB and PORT were 5.0 mm, 3.5 mm and 18.2 mm. In order to estimate the quality of the local network used during this campaign we have compared the height differences to the optical leveling (Table 3 and 4). The very good agreement (Table 6) for the reference station (2 mm) and the relatively good agreement between the other station (5 mm for IBIA-IBIB) make us confident on the quality of the Ibiza network. Cartesian coordinates of the GPS stations are given in Table 7 at the epoch 2003.456 as well as their heights above GRS80 ellipsoid (semi major axis of 6378137 m and an inverse flattening of 298.257222101).

ICC Solution

The Cartographic Institute of Catalonia (ICC) estimated coordinates of the 5 GPS stations placed in Ibiza (IBIA, IBIB, SANA and SANB) using Bernese v4.2 software. The strategy followed by ICC consisted in computing, for every session, baselines from 3 GPS permanent stations of the European Reference Frame network (EUREF). These stations were Mallorca (MALL), Observatori de l'Ebre (EBRE) and Alacant (ALAC) to each Ibiza station (Figure 7). Coordinates for EUREF stations (Ray et al. 2004) were obtained from the weekly combined solution published by EUREF for the week of data collection (Eur12227.snx file), which are in ITRF2000 epoch 2003.45.

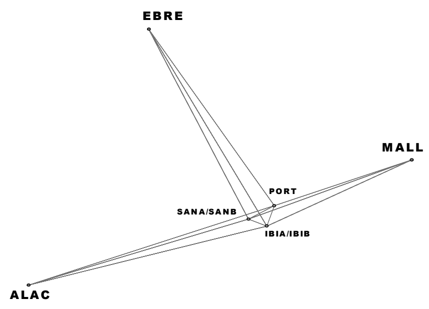

FIGURE 7. Baselines from Ibiza network

Coordinates for the 5 GPS Ibiza stations were obtained as a result of a network adjustment (using GeoTeX software, developed by ICC) combining all baselines computed by Bernese software and fixing EUREF stations coordinates.

As stated before, the height differences between stations pairs SANA-SANB and IBIA-IBIB were also determined by leveling and results agree well. The comparison of the GPS height component obtained in the ICC computation with differences obtained by leveling can be observed in Table 7.

ROA Solution

San Fernando Naval Observatory (ROA) analysed the data files produced by the static GPS station deployed at San Antonio, Ibiza and Portinatx, by using the GIPSY-OASIS II software, developed by the Jet Propulsion Laboratory (JPL). The strategy used was the precise point positioning approach (PPP). In such strategy orbits, polar motion, earth orientation parameters, and satellite clocks behavior files are issued by the JPL. The non fiducial approach has been chosen. Each station data daily data file is processed in an independent way of the rest of the set of the station data files. Once the solution has been obtained in the non fiducial reference frame, a Helmert seven parameters transformation is applied in order to align it with the ITRF2000 reference frame. Transformation parameters are also issued by the JPL analysis center. In such a way the solution errors are in the same order of magnitude of a conventional network analysis approach. Ambiguities have not been fixed.

3.2 Comparison

The differences in planimetry are below 3-4 mm, but a 29 mm offset was detected in height for the ICC solution (Table 5). Although the reason of the offset is not clear it can be due to the fact that the reference frame used in the ICC and GEMINI solution were not exactly the same. As mentioned before, ICC used the EUREF combined weekly solution for week 1222 (Eur12227.snx file), while GEMINI used the primary combination of all solutions also published by EUREF (ITRF2000_EUROPE.SSC file).

Comparing the station coordinates used by GEMINI of these two files (transformed to epoch 2003.45), some height differences were found. For example, SFER station showed a height discrepancy of 30 mm, EBRE 12 mm and CAGL 16 mm. A possible explanation may be the high constraints (1 mm level) that EUREF applies to some fiducial stations (WTZR, MATE…) in its weekly combined solution and that may create a internal inconsistency within the overall frame.

Concerning the ROA solution, the height of PORT and IBIB seem to be affected by a bias of ~1 cm. Because these two markers were equipped with the same antennas we are suspecting an offset in the antenna phase center that is not good in the GIPSY-OASIS II parameters. Part of this bias is retrieved when comparing to leveling (Table 6).

TABLE 5 Height differences for GPS stations between ICC, ROA and GEMINI solutions

Markers	GEMINI-ICC (m)	GEMINI-ICC – mean (m)	GEMINI-ROA (m)
IBIA	0.028	-0.001	0.004
IBIB	0.033	0.004	0.011
PORT	0.025	-0.004	0.012
SANA	0.028	-0.001	-0.002
SANB	0.032	0.003	0.001
	mean = 0.029		

TABLE 6 Height differences between GPS results and leveling

Marker1->Marker2	δH GPS (m)			δH Leveling (m)	Difference Leveling – GPS (m)		
	GEMINI	ICC	ROA		GEMINI	ICC	ROA
SANA-SANB	-0.013	-0.017	-0.016	-0.011	+0.002	+0.006	+0.005
IBIA-IBIB	-0.012	-0.017	-0.019	-0.017	-0.005	0.000	+0.002

As the altimetry satellite orbits are computed in the ITRF2000 reference frame, for the catamaran trajectory computations the IRTF2000 realization was used (GEMINI solution, Table 7) instead of using the EUREF realization (ICC solution) [12].

TABLE 7 Cartesian coordinates and heights above GRS80 ellipsoid at epoch 2003.456

Marker	X (m)	Y (m)	Z (m)	H (m)
SANA	4 963 596.226	112 798.208	3 990 492.996	57.438
SANB	4 963 597.316	112 793.093	3 990 491.772	57.425
PORT	4 953 996.022	130 706.294	4 001 814.258	76.430
IBIA	4 968 004.124	125 818.741	3 984 658.110	60.311
IBIB	4 968 002.892	125 818.607	3 984 659.621	60.299
IBIC	4 968 038.013	125 898.520	3 984 630.257	57.438*

*height is deduced from the levelling and the IBIA height.

4. Kinematic Analysis

The kinematic solutions are based on the high rate GPS data (1 Hz). The mobile receivers (Catamaran and buoy) ellipsoidal heights are solved relatively to the coordinates of the reference stations chosen in the previous section (OCA-GEMINI solution). This processing has been realized independently by ICC (POSGPS Software) and OCA-GEMINI (TRACK software).

OCA-GEMINI Solution

The kinematic solution has been processed using TRACK software developed at MIT, [6]. In order to reduce the impact of distance in the kinematic GPS processing SANA, IBIB and PORT have been chosen as reference stations (fixed) and CATL and CATR have been processed independently. IBIB has been chosen instead of IBIA because it was equipped with the same antenna/receiver than CATR. However, there were lots of data gap for the Leica receiver (CATR) and also lots of satellite lost so the solution was very difficult to process and results were very uncertain because of too few fixed ambiguities. We have then decided to use only the CATL solution for processing the GPS sea level map.

ICC Solution

For computing GPS kinematic sessions ICC used POSGPS v4.02 software, from Applanix. The computation of each trajectory was done in three steps: a forward filtering (positive in time), a backward filtering (negative in time) and a final combination of the two previous processes (smoothing), assigning weights at each epoch according to certain quality parameters. This software has also the possibility to combine different solutions computed from several GPS permanent stations.

In this way, two preliminary quality controls for the estimated trajectory can be done:

1. Differences between the solution of forward filtering process and the solution of backward filtering process (nearly independent),
2. Agreement between all trajectories computed using different GPS reference stations.

The strategy adopted in the kinematic processes was the following: for each kinematic receiver (buoy or catamaran), a set of trajectories was computed from 3 or 4 different GPS permanent stations (IBIA, IBIB, PORT, SANA or SANB). The two best trajectories (determined by the quality controls explained before) were combined to obtain a final solution. The combination uses weights that the software assigns to each one, depending on some internal quality parameters (number of satellites, ambiguities fixed, distance from rover to reference station, standard deviation...). We can also force the process to not use one solution in some time period (then software gives weight 0 to this one).

The accuracy of trajectories obtained in these processes showed some variability depending on quality of data collected. For most of buoy sessions, some time periods showed a large number of important satellite occlusions as can be observed in Figure 8 showing the number of locked satellites during a session.

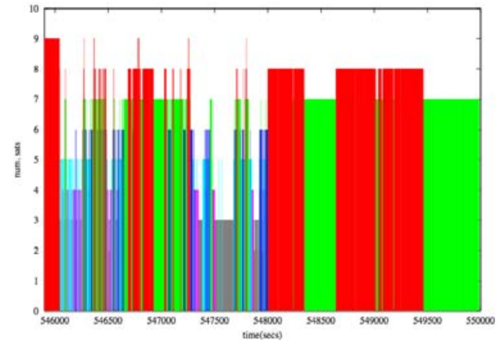

FIGURE 8. Satellite visibility in buoy for day 165 (06/14/2003).

As a consequence, in these periods, no position can be obtained for the buoy and the data around them were also too bad for obtaining acceptable results. Despite this, in time intervals with a good number of satellites (for example from time 548000 to the end of the session in Figure 8), estimated accuracy for buoy trajectory was below few centimeters. Figure 9, shows the comparison between two solutions of the buoy trajectory computed from two different stations (SANA and SANB stations).

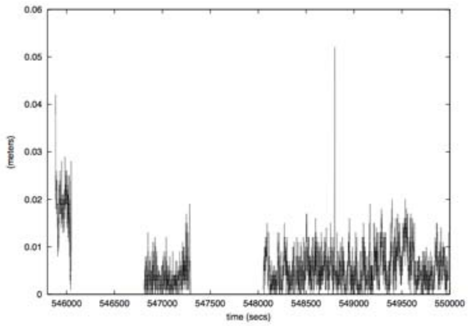

FIGURE 9. Absolute value of height difference between solutions from SANA and from SANB to buoy for day 165 (06/14/2003).

For the processes of the kinematic catamaran trajectories, data collection in both receivers also showed some short time intervals with less than 4 satellites (lasting for 3 or 4 seconds) that also caused a bad estimation of the trajectory. Figure 10 shows the difference between forward and backward filtering processes for session 163 of antenna placed in the left side of the catamaran. It can be observed some spikes that were caused by these interruptions of satellite signals (checked observing raw data from receivers). Moreover, there are some persistent differences for up to 20 cm, that may be caused by a wrong resolution of ambiguities in one of the processes (after lost of satellites, ambiguities are solved again), taking into account that distance to reference station was longer than 20-30 km. It must be noted that the accuracy of the solution can be much better than values shown by these differences (one of both processes may be better than the other in some time intervals). Figure 11 shows differences in the trajectory of this session computed from two different reference stations.

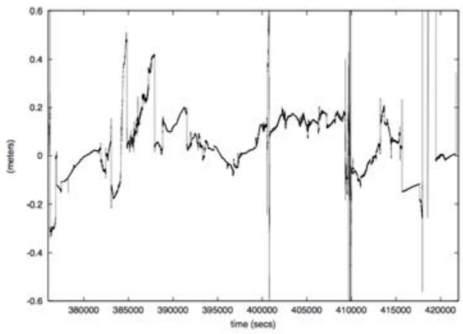

FIGURE 10. Height difference between forward and backward solutions from IBIB to catamaran for day 163 (06/13/2003).

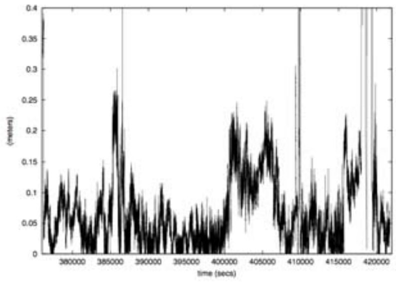

FIGURE 11. Absolute values of height difference between solutions from IBIB and SANA to catamaran for day 163 (06/12/2003).

It has to be noted that the problems with the data quality are very localized, and despite may exist some persistent differences (for example up to 15-20 cm around time 400000 seconds in previous plot), it is well known that they are caused by problems in the process from one of the reference stations chosen (in this case from SANA). Then, in final trajectory, this bad solution is discarded in this time interval. All catamaran kinematic sessions are very long (around 10 hours or more), hence, for most part of the trajectories the quality is acceptable (below few centimeters). Moreover, the final trajectories (combining two solutions computed from different GPS reference stations) allowed a redundancy increase and a quality improvement leading to a final trajectory determination accurate enough for the aim of this project. Figure 12 shows the coherence of a catamaran trajectory determination from two GPS reference stations, notice that most of the difference is around 5-6 cm during the 12.5 hour session.

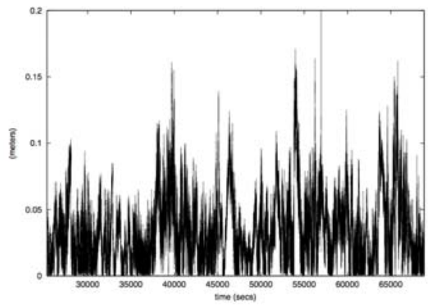

FIGURE 12. Absolutes values of height difference between solutions from IBIB and SANA to catamaran for day 166 (06/15/2003).

5. Sea Height Processing

Methods used to derive the sea level map from kinematic GPS solutions can be found in [1,10]. Figure 13 shows the sea level map derived from the GPS catamaran campaign.

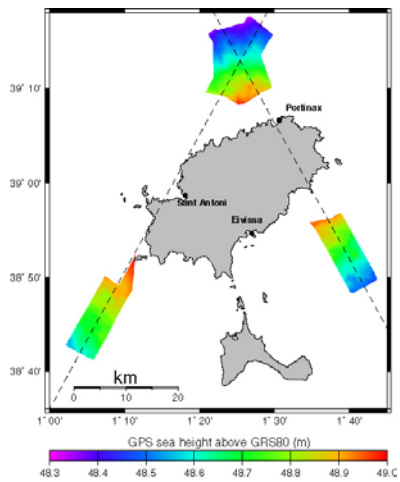

FIGURE 13. Contour Map of the gridded GPS sea surface heights (weighted mean). Dashed lines represent the Jason-1 passes: ascending N°187 (South West – North East) and descending N°248 (North West –. South East).

Conclusion

The main objective has been to test the value of Ibiza Island as a possible permanent calibration site in the western Mediterranean Sea, complementary to the Corsica/Senetosa site. Leveling the marine sea surface using a GPS catamaran had been proved to be useful in defining the local marine geoid slope between the coast and offshore area. This allows to apply the kinematic GPS methodology expanding significantly the geographic coverage of the survey and mapping the marine sea surface very fast when is towed by a convenient and powerful ship as this case with Patrol Deva.

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References

[1].Bonnefond, P., P. Exertier, O. Laurain, Y. Menard, A. Orsoni, E. Jeansou, B. Haines, D. Kubitschek, and G. Born. 2003a. Leveling Sea Surface using a GPS catamaran, *Marine Geodesy*, 26(3-4), 319-334.

[2].Bonnefond, P., P. Exertier, O. Laurain, Y. Menard, A. Orsoni, G. Jan, and E. Jeansou. 2003b. Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica, *Marine Geodesy*, 26(3-4), 261-284.

[3].Born, G.H., M.E. Parke, P. Axelrad, K.L. Gold, J. Johnson, K.W. Key and D.G. Kubitscheck. 1994. Calibration of the TOPEX altimeter using a GPS buoy. *J. Geophys. Res.* 99(C12), 24517-24526.

[4].Haines, B.J., D. Dong, G.H.Born and S.K.Gill. 2003. The Harvest experiment: Monitoring Jason-1 and TOPEX/POSEIDON from a California offshore platform, *Marine Geodesy*, 26(3-4), 239-259.

[5].Herring, T. A..2002. Global Kalman filter VLBI and GPS analysis program, Version 10, Massachusetts Institute of Technology, Cambridge.

[6].Herring, T. A.. 2002. TRACK GPS kinematic positioning program, Version 1.07, Massachusetts Institute of Technology, Cambridge.

[7].King, R. W., and Y. Bock. 2000. Documentation for the GAMIT GPS Analysis Software, Release 10, Massachusetts Institute of Technology, Cambridge.

[8].Kruizinga, G.L. 1997. Validation and applications of satellite radar altimetry. Ph.D. Dissertation, the University of Texas at Austin.

[9].J.J. Martinez Benjamín, M.A. Ortiz Castellon, M. Martinez Garcia, A. Nuñez, S. Gonzalez, J. Talaya, G. Rodríguez, M. Sevilla, B. Perez, E. Alvarez, J. Martin Davila, J. Garate, J.M. Ferrandiz y M.I. Vigo Aguiar:".2003.Campañas de calibración altimétrica del Topex/Poseidon y Jason-1 en la zona del cabo de Begur e isla de Ibiza". Revista del Instituto de Navegación de España, nº 17, pp. 11-17.

[10]. J.J. Martinez-Benjamin, M. Martinez, S. Gonzalez, A. Nuñez, F. Buill, M. Espino, J. Lopez, J. Martin Davila, J. Garate, C. Garcia, P. Bonnefond, O. Laurain, A. Baron, M.A. Ortiz, J. Talaya, B. Perez, E. Alvarez, G. Rodríguez, D. Gomis, M. Marcos, Y. Menard, G. Jan, E. Jeansou, F. Lyard and L. Roblou, "Ibiza Absolute Calibration Experiment: Survey and Preliminary Results, Marine Geodesy, Vol 27, pp.1-25, Taylor&Francis, Diciembre 2004, (ISSN 0149-0419 print/1521-060X online).

[11].Pavlis,E.C., and the GAVDOS Team.2002.Absolute sea level monitoring and altimeter calibrationat Gavdos, Crete. Proceedings of the Jason-1 SWT Meeting, 10-12 June 2002, Biarritz, France.

[12].Ray, J., D. Dong, Z. Altamini. 2004. *IGS references frames: status and future improvements*. IGS 2004 Workshop. March 1st, Berne, Switzerland.

[13].Rodríguez-Velasco, G. and M. J. Sevilla. 2000. Geoid Model in the Western Mediterranean Sea. *Physics and Chemistry of theEarth (A)* 25, n1. pp: 57-62.

[14].Shum, C.K., Y. Yi, K. Cheng, C. Kuo, A. Braun, S. Calmant and D. Chambers. 2003. Calibration of JASON-1 Altimeter over Lake Eire, *Marine Geodesy*, 26(3-4), 335-354.

[15].Watson C., R. Coleman, N. White, J. Church. And R. Govind. 2003. "Absolute Calibration of TOPEX/Poseidon and Jason-1 using GPS Buoys in Bass Strait, Australia", *Marine Geodesy*, 26(3-4), 285-304.