Calibration of Radar Altimeters and Validation of Orbit Determination in the Corsica-Capraia Area

P. Bonnefond, P. Exertier, and F. Barlier — Observatoire de la Côte d'Azur - CERGA, Av. Copernic, F-06130 Grasse, France

bonnefond obs-azur.fr

http://wwwrc.obs-azur.fr/cerga/EMChomepage.html

Y. Ménard, E. Jeansou — Centre National d'Etudes Spatiales, 18 av. Ed. Belin, F-31055 Toulouse Cedex, France

G. Manzella, S. Sparnocchia — ENEA, Marine Environment Research Centre, P.O. Box 316 - 19100 La Spezzia, Italy

Abstract

Recent events have shown the importance of monitoring the absolute calibration to make certain a correct interpretation of altimeter data in terms of secular rise of the mean sea level or in terms of seasonal or interannual variations. The accuracy of an absolute local calibration, as made permanently in Harvest or in the past in Lampedusa is only a few centimeters and this fact makes the direct detection of a possible drift of an altimeter at the level of few mm/year over a few years difficult. The problem also is to monitor the absolute altimeter calibration at as low a cost possible. For doing that a probationary experiment is presently carried out between Grasse (France), Corsica (France) and Capraia (Italy) to show that with a fundamental geodetic station as Grasse, with some tide gauges well located in a homogeneous system, it is possible to monitor properly the absolute altimeter calibration in using short-arc techniques. A Mobile Laser Station (FTLRS) has been used with the Grasse laser station as well as GPS and DORIS to allow a control of the calibration with a reliable error budget. In the future, the idea is to extend the principle of this experiment in using tide gauges under the repetitive tracks of satellite in other regions around the world covered by laser tracking, or if necessary to use transportable tracking systems like the FTLRS. Cooperative actions will be carried out with different countries (e.g. at Ibiza, Tahiti, ...). As there are systematic errors at each site, one may hope that in averaging the data, a better accuracy will be obtained.

Keywords: short-arc technique - radar altimeter calibration - geodetic collocation.

Introduction

With the TOPEX/Poseidon (T/P) and ERS satellites, altimetry is entering a new era thanks to the exceptional performance of these systems (orbitography, altimeter measurement, various corrections) [*Fu et al.*, 1994]. It would be of great interest for satellite altimetry data analysis to have an altimeter calibration at the level of 1 cm (or less if possible), taking into account the other associated error sources [*Bonnefond et al.*, 1995]. The on-site external calibration was a part of the project-supported activities. The ERS-1 altimeter was calibrated over an oceanographic platform in bay of Venice [*Francis*, 1992]. For T/P it was decided that CNES and NASA would support two sites, the Harvest oil platform off the Californian coast and the Italian island Lampedusa in the Mediterranean Sea south of Sicily, respectively [*Christensen et al.*, 1994; *Ménard et al.*, 1994]. These two sites were selected with respect to criteria such as laser tracking support, adequate environmental conditions, and no contamination of the altimetric signal due to the site overflight. During the last years, complementary altimetric missions have notably permitted to compare the instruments: relative calibrations have been achieved, global statistics and results show the power of such a technique [*Benveniste*, 1997]. However, recent problems have been discovered both in the algorithms and the instruments: the SPTR and USO drift corrections for ERS [*Benveniste*, 1997] and the oscillator drift corrections for TOPEX/Poseidon [*AVISO*, 1996]. This reinforces the interest of regular absolute calibration campaigns to detect such problems in near real time. Beyond the calibration of the altimeters, the calibration sites also are very useful in assessing the various components of the altimetric systems, even if it is only a single-point verification. The calibration sites are equipped with a complete system of in situ instruments which have the capability of measuring very accurately the environmental parameters interfering in the altimetric measurement: sea state, sea level, etc. The orbit itself can be locally evaluated at these sites, as a dense tracking network of the satellites is available there. The objective of the Corsica-Capraia experiment is threefold: (i) to calibrate the ERS2 and TOPEX/Poseidon radar altimeters, (ii) to collocate the DORIS, GPS and laser tracking systems and (iii) to validate the various precise orbit solutions (NASA, CNES, Delft University of Technology). This experiment is mainly a feasibility study in order to develop a new concept of monitoring absolute calibration at low costs. Such an experiment requires a dedicated site and instruments which often represent lots of money as in the case of Harvest/Lampedusa and Venice calibration campaigns. Using

the French Transportable Laser Ranging Station (FTLRS), developed in cooperation with Institut Géographique National (IGN), Centre National d'Etudes Spatiales (CNES) and Observatoire de la Côte d'Azur / Centre d'Etudes et de Recherches en Géodynamique et Astronomie (OCA/CERGA), we have carried out at Ajaccio a short campaign (~3.5 months), easily repeatable and with a relatively small budget (<200000 F). The aim of this paper is to describe the various instruments used, their installation as well as the course of operations from October 1996 to February 1997.

Site and Instruments

The choice of the site is of course very important for such an experiment because laser station and tide gauges have to be close to the altimetric measurements to be calibrated. If a small island is theoretically better in order to avoid altimeter problems during the overflight, it often requires complicated logistics. Near Corsica, the ERS and T/P ground track configuration as well as the implantation possibility have conducted to the choice of a double site (Figure 1). First, the island of Capraia (Italy) is very closed to T/P and ERS2 crossover points and benefits of an existing tide gauge. On the other hand, Ajaccio (Corsica) is a better site concerning the administrative authorizations and the geographical access, and so minimizing the costs. The FTLRS has been installed at the air and sea base of Aspretto (~2 km from Ajaccio) on a small hill. This military base offers classical logistic infrastructure and has a small private port with relatively small traffic. The MORS tide gauge (EPSHOM, Brest) has been immersed at this place to be close to a descending ERS2 ground track (number 130). The closest T/P ground track is ascending (number 85) and located at 40 km south. An AANDERAA tide gauge (CNES, Toulouse) has been immersed at the Senetosa cap.

The FTLRS of course plays a dominating role in this experiment, concerning principally the operating and budget levels as well as the quality of the results. It was also the first operational experiment with this instrument, except tests made at Grasse, notably on T/P. These tests have permitted to demonstrate the precision level of about 2 cm. Moreover, a collocation campaign with the DORIS tracking system has been planned. CNES and IGN have collaborated on this campaign by installing the DORIS beacons and by positioning the reference points with GPS respectively. During this experiment, due to the proximity of the main DORIS beacon (Toulouse), it was necessary for the DORIS ground segment to use the Kourou site as main beacon.

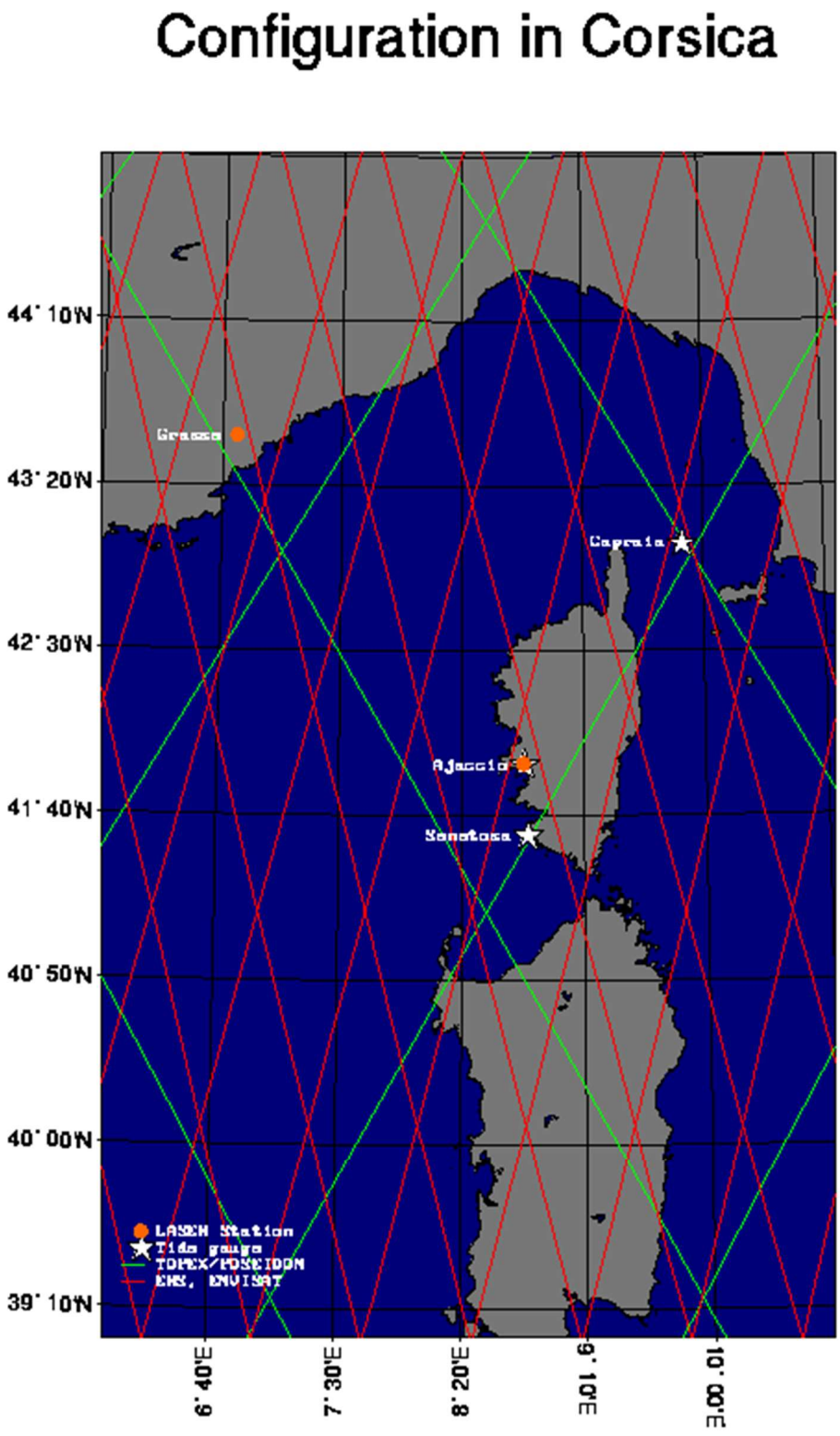

Figure 1. *Configuration of the Corsica-Capraia experiment.*

Operations

Geodetic links. The FTLRS, the DORIS beacons and the tide gauges have been installed in October (Table 1)**.** Various GPS links have been established just before the campaign. A reference point has been established with 15 days of GPS measurements between Grasse and Aspretto (Ajaccio). The FTLRS has then been placed at this location. Other secondary points have been determined notably for the DORIS beacon (few decameters from the reference point). A preliminary analysis of the data from Aspretto and Grasse DORIS beacons have been performed at Collecte Localisation Satellites (CLS)/CNES, Toulouse. GPS points have also been determined near each tide gauge, using about 20 hours of measurements. The tide gauges leveling has also been performed using two different methods: (i) at Senetosa direct leveling using a surveyor's rod fixed on the tide gauge and (ii) at Aspretto (Ajaccio) indirect leveling using a tide scale fixed on the wharf. For the second method, 40 sea heights have also been read regularly on the tide scale in order to link it to the tide gauge measurements: standard deviation of the determined constant is about 1 cm. All the GPS links and the leveling have been performed and then will be analyzed by IGN.

Instruments	Begin	End	Data sampling* (min.)
FTLRS, 7848, Ajaccio†	96/10/02	96/12/11	
FTLRS, 7848, Ajaccio‡	97/01/16	97/02/10	
fixed SLR, 7835, Grasse	96/10/01	97/02/28	
DORIS Beacon, Ajaccio	96/10/01	97/02/28	
DORIS Beacon, Grasse	96/10/01	97/02/28	
Tide gauge (MORS), Ajaccio†	96/11/06	96/12/30	2
Tide gauge (MORS), Ajaccio‡	97/01/20	97/04/11	2
Tide gauge (AANDERAA), Senetosa	96/10/23	96/12/19	5
Tide gauge (AANDERAA), Capraia	96/10/05	97/02/11	20

Table 1. *Date of operations for the various instruments.*

†First period of observations.

‡Second period of observations.

*For tide gauges.

SLR data acquisition. During the campaign (Table 1) about 430 satellite passes have been observed (Figure 2). The lack of Lageos data concerning (except a few experimental data) is due to the actual configuration of the FTLRS. It appears that the divergence of the beam has to be reduced and that the tracking system has to be improved to acquire a high orbiting satellite in an operational mode with the relatively small telescope (130 mm). Another possibility is to use another wavelength (green instead of infrared) in order to increase the signal-to-noise ratio of the detector. All these improvements are under investigation. It is of great importance, because the SLR Lageos data guarantee the quality of the station coordinates determination [*Boucher et al.*, 1996; *Noomen et al.*, 1993], thanks to the satellite altitude and the high precision of the orbit (at the level of 3 cm). However, coordinates adjustment using multiple satellites of medium altitude (Stella, Starlette, Ajisai, notably) should be achieved with a precision below 2-3 cm. A first test has been performed using the T/P CNES precise orbits from Service d'Orbitographie DORIS [*Nouël et al.*, 1994]. It shows that a preliminary stable solution can be achieved with about two months of data (cycles 149 to 156). The formal error is very small (below 1 cm) but some comparisons and tests show that the accuracy is probably at level of 3-4 cm. This is only an example, because SLR data on T/P will only be used for short-arc orbit on the calibration passes.

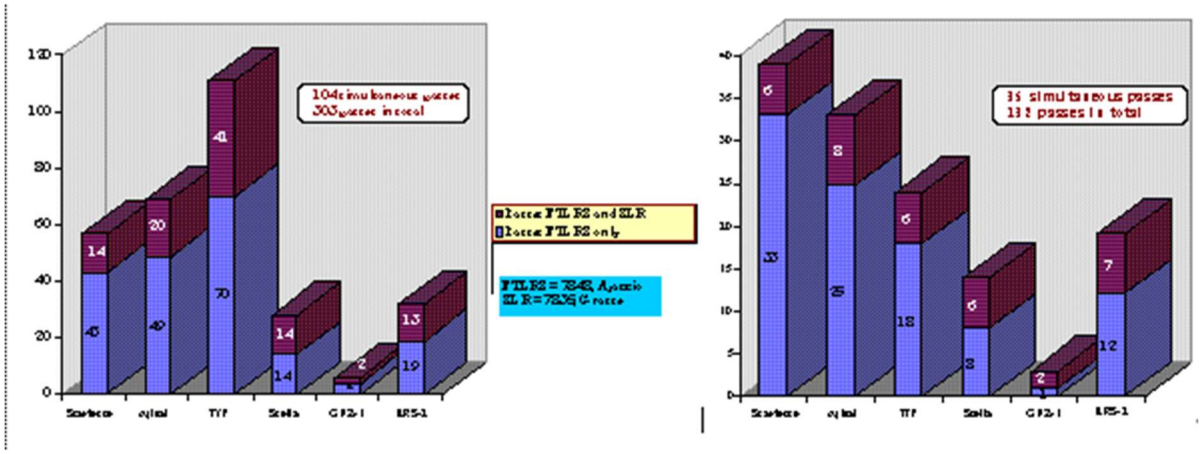

Figure 2. *Statistics on the satellites passes acquired by FTLRS (7848) and also for simultaneous tracking with Grasse (7835): (a) for the first period and (b) for the second (Table 1).*

Altimeter and tide gauges data acquisition. The 10 Hz altimeter data will be used for T/P and ERS-2, in order to obtain sea height measurements close to the tide gauges (Figure 3). These data are delivered regularly by AVISO (T/P) and CERSAT (ERS). Concerning the tide gauge data, they have been collected on each site and are under analysis at CNES (Toulouse), EPSHOM (Brest) and ENEA (La Spezia, Italy) for the Senetosa, Ajaccio and Capraia sites respectively.

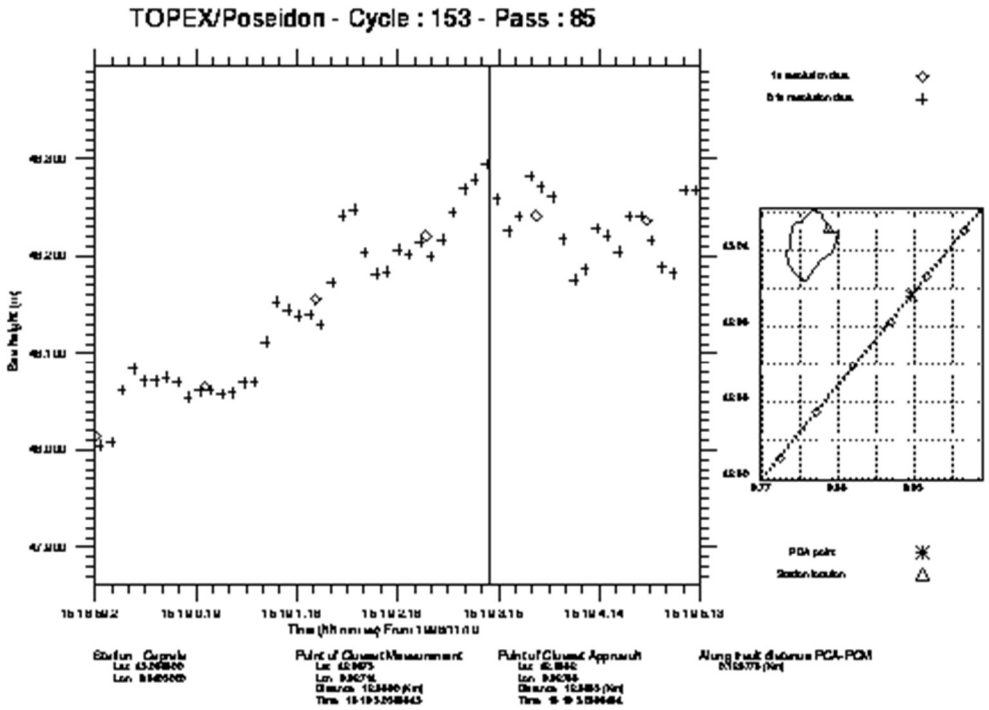

Figure 3. *TOPEX/Poseidon 1O Hz altimeter data for cycle 153 and pass 85, near Capraia island.*

Conclusion

Absolute calibration campaigns remain very important particularly for monitoring long term sea level variations. On the other hand, it is also necessary to monitor very accurately, at the same time, the vertical reference system, materialized by tracking systems such as SLR, DORIS and GPS. Campaign

such as the Corsica-Capraia experiment permit to realize such objectives with relatively low costs. Moreover, this work can be easily repeatable on a regular basis.

The FTLRS has operated almost nominally except for the Lageos tracking. Its small size has permitted to reduce the costs considerably: for example, the station was installed in 2 days. Moreover, the DORIS and GPS tracking measurements will allow a good opportunity to realize a geodetic collocation.

The data analysis is in progress. In the next future the FTLRS coordinates will be determined using a multiple satellite solution. Then, altimeter calibrations will be performed using short-arc orbit adjustment for the ERS2 and T/P calibration passes [*Bonnefond et al.*, 1995]. A total and reliable error budget will be determined as soon as the different components will be available and analyzed.

Acknowledgments. First we want to thank the whole OCA/CERGA SLR team directed by F. Pierron for the very good work they have done during and after the campaign (E. Cuot, JL. Hatat, M. Laplanche, J. Paris, A. Spang). We are also very grateful to O. Laurain and HG. Stoufs for the help given in the data analysis. We also want to thank EPSHOM for the lending of MORS tide gauges and the data analysis. The cooperation with IGN was particularly fruitful and we especially want to thank A. Orsoni and H. Fagard. This work was supported by CNES, CNRS and mainly financed by the Plan National de Télédétection Spatiale (PNTS).

References

Archiving, Validation, and Interpretation of Satellite data in Oceanography, 1996:
AVISO User Handbook, Merged TOPEX/POSEIDON Products (GDR-Ms), 3rd ed., Publ. *AVI-NT-02-101-CN*, Cent. Natl. d'Etudes Spatiales, Toulouse, France.

Benveniste, J., 1997:
ERS2 Altimetry Calibration, *in Proceedings of the 3rd ERS Symposium*, same issue.

Bonnefond, P., P. Exertier, P. Schaeffer, S. Bruinsma and F. Barlier, 1995:
Satellite Altimetry From a Short-Arc Orbit Technique: Application to the Mediterranean, *J. Geophys. Res.*,**100** (C12), 25365-25382.

Boucher, C., Z. Altamimi, M. Feissel, and P. Sillard, 1996:
Results and Analysis of the ITRF 94, *IERS Tech. Note 20*, Int. Earth Rotation Serv., Obs. de Paris.

Christensen, E.J., et al. , 1994:
Calibration of TOPEX/POSEIDON at Platform Harvest, *J. Geophys. Res.*, **99** (C12), 24465-24485.

Francis, C.R. , 1992:
The height calibration of the ERS 1 radar altimeter, *in Proceedings of the First ERS 1 Symposium* - Space at the Service of our Environment, Eur. Space Agency Spec. Publ., ESA SP-359 **(I)**, 381-393.

Fu, LL., et al. , 1994:
TOPEX/POSEIDON mission overview, *J. Geophys. Res.*, **99** (C12), 24369-24381.

Ménard, Y., E. Jeansou, and P. Vincent, 1994:
Calibration of the TOPEX/POSEIDON altimeters at Lampedusa: Additional results at Harvest, *J. Geophys. Res.*, **99** (C12), 24487-24504.

Nouël, F., et al. , 1994:
Precise Centre National d'Etudes Spatiales orbits for TOPEX/POSEIDON: Is reaching 2 cm still a challenge?, *J. Geophys. Res.*, **99** (C12), 24405-24419.

Noomen, R., B.A.C. Ambrosius, and K.F. Wakker, 1993:
Crustal motions in the Mediterranean region determined from laser ranging to Lageos, in Contributions of Space Geodesy to Geodynamics: Crustal Dynamics, *Geodyn. Ser.*, vol. **23**, edited by D.E. Smith and D.L. Turcotte, pp. 331-346, A.G.U., Washington, D.C..