Contribution of space techniques to Jason-1 altimeter calibration

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With uncertainties currently running at around a few millimetres per year, it is hard for space geodesy to identify signatures of oceanographic phenomena of interest and, at the same time, drift and/or inherent errors (biases) in a complete space system, i.e., including orbit models and measuring instruments. The large amount of effort already expended on the TOPEX/POSEIDON mission shows the difficulty of conducting long-term altimetry at the millimetre-per-year level. In this respect, radar altimeter calibration and orbit validation work undertaken for altimetry projects is extremely important.

Introduction

Over the last 30 years, we have developed techniques to measure the position, velocity, and acceleration of objects orbiting the Earth that today offer high levels of accuracy and repeat spatial and temporal coverage. In that time, space geodesy research has defined innovative measurement techniques, including laser ranging, Doppler tracking, and radar altimetry, which have been implemented by major space projects such as space oceanography missions: TOPEX/POSEIDON (T/P), European Remote sensing Satellite (ERS), Geosat-Follow-On (GFO), and shortly Jason-1.

These achievements are the result of a long-term strategy. Over a 20-year period — from the 1970s to the 1990s — satellite tracking techniques all improved by several orders of magnitude, both in terms of quality (measurement precision and accuracy) and quantity (number and rapid availability of data, and spatial and temporal coverage). During the 1990s, applications of radioelectric systems such as DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) developed by CNES, France, and GPS (Global Positioning System), developed by the US, progressed to a point where they are now operating within a global network and have attained the same level of performance as another proven technique: satellite laser ranging (SLR). At the same time, SLR has benefited from the emergence of new technologies which have enabled us to achieve one-centimetre range accuracy over space distances of 350 kilometres to the Moon.

While all space-based measuring techniques have become more accurate over time, they have also found their own special applications in geodesy, geophysics, and oceanography.

The advantage of SLR lies in its simplicity—the concept is based on measuring the round-trip time of a laser beam—and accuracy. It relies on relatively low-cost retroreflectors onboard satellites. Its main drawback is its reliance on weather conditions and the need for specialist personnel on the ground. In this sense, SLR is in many ways the opposite of radioelectric techniques such as DORIS and GPS, which provide an all-weather capability, are very easy to set up and use in the field, and for which it is the spaceborne technologies used that are very costly. In addition, the properties of laser targets appear to have perfect stability in space with an unlimited lifetime at the human scale. This is not the case with the other techniques. That makes the laser technique an unrivaled tool for observing slowly-varying geodynamic phenomena and for establishing an accurate terrestrial reference system with a very large grid, i.e., covering several thousand kilometres [Tapley et al., 1993]. Moreover, SLR provides an absolute scale factor for orbit determination and for space oceanography, by calibrating radar altimeters in particular.

The calibration experiment

The role of laser ranging systems during calibration campaigns is to achieve centimetre accuracy locally

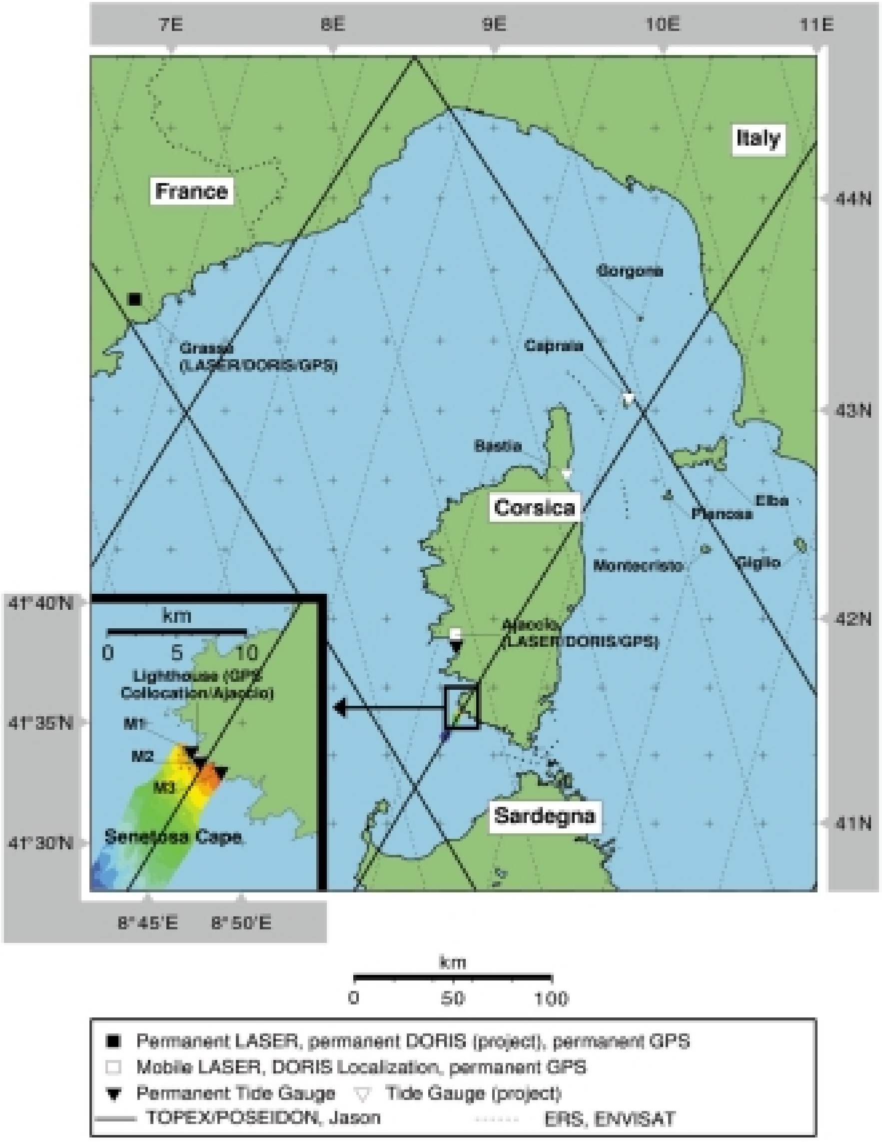

Figure 1: Senetosa/Capraia calibration site. The surface in color, near Cap Senetosa (southern Corsica), represents the geoid determined with a Catamaran GPS.

for the altimetry satellite orbit [Bonnefond et al., 1995]. For radar altimeter calibration to be successful, campaigns must be performed if possible under the satellite track in zones where the slope of the geoid is smooth, away from the coast (on an island or offshore platform) and in a region where the logistics involved are not prohibitively expensive.

Absolute calibration of radar altimeters based on the SLR technique has been used previously for numerous missions such as Seasat in Bermuda (1978), for ERS-1 in Venice (1991), for POSEIDON in Lampedusa (1993), and for TOPEX on the Harvest platform (CA) [Francis, 1992; Mitchum, 1994; Christensen et al., 1994; Ménard et al., 1994]. These “conventional” experiments proved very troublesome to implement, given the remoteness of the sites and the complex combination of satellite-based, geodetic surveying and tide gauge techniques.

With these aims and future space oceanography missions such as Jason-1 in mind, we have set up a semi-permanent site in Corsica with the lowest possible installation and monitoring costs [Bonnefond et al., 1997]. In addition, the French space agency CNES, the French mapping and survey agency IGN, and OCA-CERGA have developed a new SLR concept from the 1990s called the French Transportable Laser Ranging Station (FTLRS). The idea behind this project was to build a very small SLR station (telescope 13 centimetres in diameter, weighing 300 kilograms) that is easily transportable and can be installed, for example, in oceanic zones on islands and oil drilling platforms [Nicolas et al., 2000]. The main objective is to play a leading role in space oceanography in the early 2000s, via satellite tracking, centimetre calibration of radar altimeters, positioning, and geodynamics.

The ultra-mobile FTLRS system, which is under technological development at OCA-CERGA, France, in order to achieve centimetre accuracy, will be deployed in Corsica in 2001 first for the Jason-1 validation phase. For the reasons explained above, this kind of experiment is planned to continue if possible for several years to detect any drift in the spaceborne instruments.

Conclusion

The quality of space geodesy and Earth science research depends to a large extent on our ability to obtain numerous, accurate measurements covering a wide spatial and temporal spectrum.

All calibration experiments thus far have attempted to decorrelate the drift of altimeters and associated devices (e.g., water vapor radiometer) from the long-term variability of the mean sea level, at a level of one millimetre per year at least.
The many absolute calibration sites worldwide and the range of calibration techniques now used are of great value for monitoring satellite altimetry performance at this level of accuracy, because each site and each technique brings its own systematic errors. Further, these concepts, which aim to improve the permanent vertical positioning of tide gauge sites used for altimetry, using GPS or DORIS [e.g., Cazenave et al., 1999], also have a major role to play in establishing a uniform and identical vertical reference frame for oceanography missions, stable to within one millimetre per year.

References

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. of Geophys. Res.*, 100(C12), 25365-25382.

Bonnefond P., P. Exertier, Y. Ménard, E. Jeansou, G. Manzella, S. Sparnocchia, F. Barlier, 1997: Calibration of Radar Altimeters and Validation of Orbit Determination in the Corsica-Capraia Area, in *Proceedings of the 3rd ERS Symposium*, Florence, Italy; Vol. 3, pp. 1525-1528.

Cazenave A., K. Dominh, L. Soudarin, F. Ponchaud, Ch. Le Provost, 1999: Sea level changes from TOPEX/POSEIDON altimetry and tide gauges, and vertical crustal motions from DORIS, *Geophys. Res. Lett.*, 26(14), 2077-2080.

Christensen E.J. et al., 1994: Calibration of TOPEX/POSEIDON at Platform Harvest, *J. of Geophys. Res.*, 99(C12), 24265-24485.

Francis C.R., 1992: The height calibration of the ERS-1 radar altimeter, in *Proceed. of the first ERS-1 Symp. - Space at the Service of our Environment*, ESA Spec. Pub., ESA SP-359(1), pp. 381-393.

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

Mitchum G.T., 1994: Comparison of TOPEX sea surface heights and tide gauge sea levels, *J. Geophys. Res.*, 99(C12), 24541-24553.

Nicolas J., F. Pierron, M. Kasser, P. Exertier, P. Bonnefond, F. Barlier, and J. Haase, 2000: French Transportable Laser Ranging Station: Scientific objectives, technical features, and performance, *Applied Optics*, 39(3), 402-410.

Tapley B.D., B.E. Schutz, R.J. Eanes, J.C. Ries, M.M. Watkins, 1993: Lageos laser ranging contributions to geodynamics, geodesy, and orbital dynamics, in *Contributions of Space Geodesy to Geodynamics: Earth Dynamics, Geodyn. Ser.*, 24, pp. 147-174.

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