

# First results with the French Transportable Laser Ranging Station

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## Abstract

The French Transportable Laser Ranging Station (FTLRS) is a very compact (300 kg in 8 containers) and highly mobile satellite laser ranging system (SLR) with a telescope of 13 cm diameter. It was first tested at the Observatoire de la Côte d'Azur (OCA, Grasse, France). It was of great importance to demonstrate the reliability of such a station in real field experiment. The first field campaign was carried out from October 1996 to February 1997 at the Aspretto marine base near Ajaccio on Corsica island, France. The FTLRS was set up and operational less than 2 days after arrival at the site. In 4 months, 430 satellite passes were observed including 120 of TOPEX/Poseidon (T/P). The passes were analysed using precise orbits, with those of T/P provided by CNES and GSFC/NASA especially for the mission, and have a precision of 3-4 cm.

The site position was determined from the laser data with an error budget error of 1.8 cm, which has been verified with collocated measurements using the Global Positioning System (GPS). The standard deviation of the FTLRS residuals is 2 cm rms, with a bias per pass identified at the 3-5 cm level. This last aspect is under technical investigation. Since this experiment, we have made an effort to improve the detection mode of the system. Currently, the FTLRS is being modified (from IR to green wavelength, and single photo-electron detection mode) with the objective of participating in the radar altimeter calibration of Jason-1 and EnviSat (both to be launched in 2000).

## Introduction

The French organisations CNES, IGN, and OCA-CERGA have developed a new concept of satellite laser ranging (SLR) system called the French Transportable Laser Ranging Station (FTLRS). The idea was to realise a very small SLR station (telescope of 13 cm diameter, weight 300 kg), that is easily transportable, for example to make measurements in oceanic zones such as islands or offshore platforms. The technical description of the instrument is described by Pierron et al. (this issue). The main objectives are to participate in space oceanography in the early 2000's, via satellite tracking, centimetric calibration of radar altimeters, precise positioning and geodynamics.

The first laser echoes were obtained with this new system from the TOPEX/Poseidon (T/P) satellite in 1992 from the geodetic site at Grasse, France. Then, a full experiment was carried out in Corsica between 1996 and 1997. During this campaign, geodetic and oceanographic satellite tracking, geocentric positioning, and an attempt at calibration of the TOPEX radar altimeter were carried out. The goal was to demonstrate the feasibility and capabilities of the system under real campaign conditions, that is in continuous use for at least a few months, and outside the OCA laboratory. Taking into account the importance of measurements in the western part of the Mediterranean during the past years in oceanographic and geodetic experiments [Francis, 1992; Ménard et al., 1994], we chose our site near Ajaccio in Corsica. It is near an ascending pass of T/P (25 km to the west) and a descending pass of ERS (5 km to the east).

The FTLRS system operated for 4 months without major technical problems. This paper summarises the first results concerning the satellite tracking of T/P, Ajisai, Starlette, Stella, ERS-2, and GFZ-1 satellites, and the station positioning which is compared to a GPS solution and a DORIS one. We compare in detail the FTLRS laser residuals obtained from precise T/P orbits (CNES precise orbit ephemeris, [Barotto and Berthias, 1996]) with those residuals computed for the Grasse (France), Graz (Austria), and Hertsmonceux (UK) fixed SLR stations during the same period.

## Experiment presentation

The main objective of the Corsica campaign was to test the FTLRS capabilities in view of participating in the absolute calibration of future oceanographic radar altimeter satellites. For altimeter calibration it is necessary to compare precisely the altimetric measurement made by the satellite itself and the satellite altitude above the sea level determined with the satellite laser ranging data, simplified orbit, and tide gauge measurements. Here, the technical capabilities were tested by tracking Topex/Poseidon and ERS-2.

Corsica is a good place for such an experiment because it is an island where the geoid slope is of the order of few cm per km or less along the altimeter ground tracks. In this area the wind and the wave height are also generally minimal. Moreover there is an ERS-2 ground track at 5 km east of the station and a TOPEX/Poseidon track at 25 km (see figure 1). This site allows intercomparison with the regional laser network and has logistical advantages in that it is easy to reach for the Grasse SLR team and there is an existing cooperation with the marine authorities at the site. It was also not very costly.

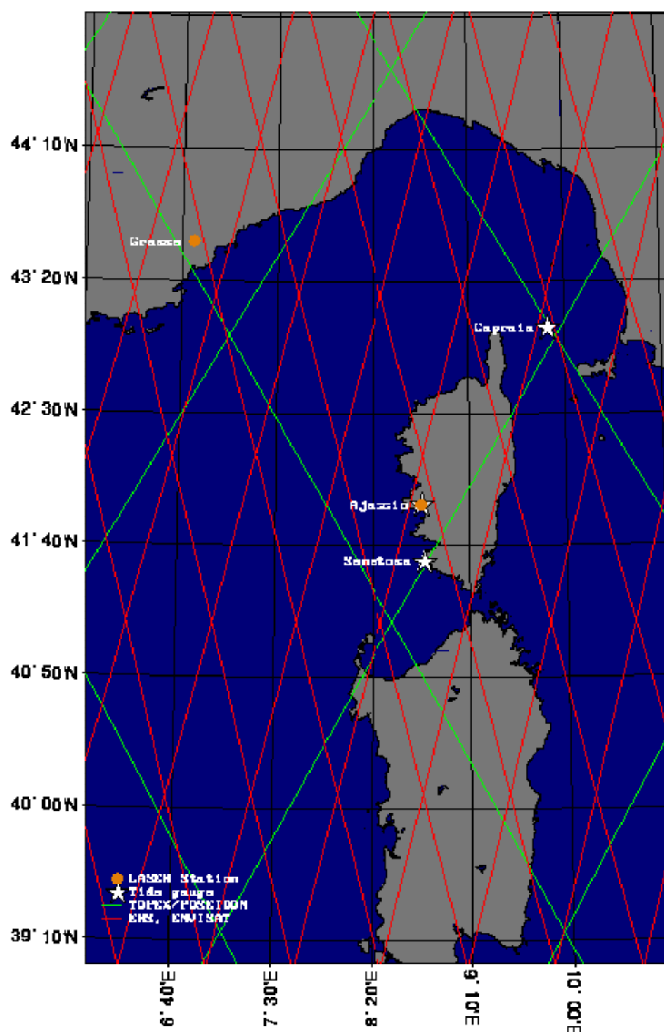


Figure 1 : Configuration of the Corsica experiment (October 1996 – February 1997). The ground tracks of ERS-2 (red) and TOPEX/Poseidon (green), the location of the tide gauges and the Grasse and the FTLRS laser stations are shown.

The sea level is given by 3 tide gauges indicated on the map. Two of them were placed as close as possible to the ground-tracks of ERS-2 and TOPEX/Poseidon for the experiment, one in the port of Ajaccio and another at the Senetosa Cap. The third one was already operating at Capraia Island (Italy) north-east of Corsica. This last point has the advantage of being very close to TOPEX/POSEIDON and ERS-2 ground track cross-over points.

## Data

Figure 2 shows examples of echoes obtained from Topex/Poseidon. There are several detected arrivals separated by a constant distance which corresponds to the laser cavity length because the emitted signal is a semi-train of impulses.

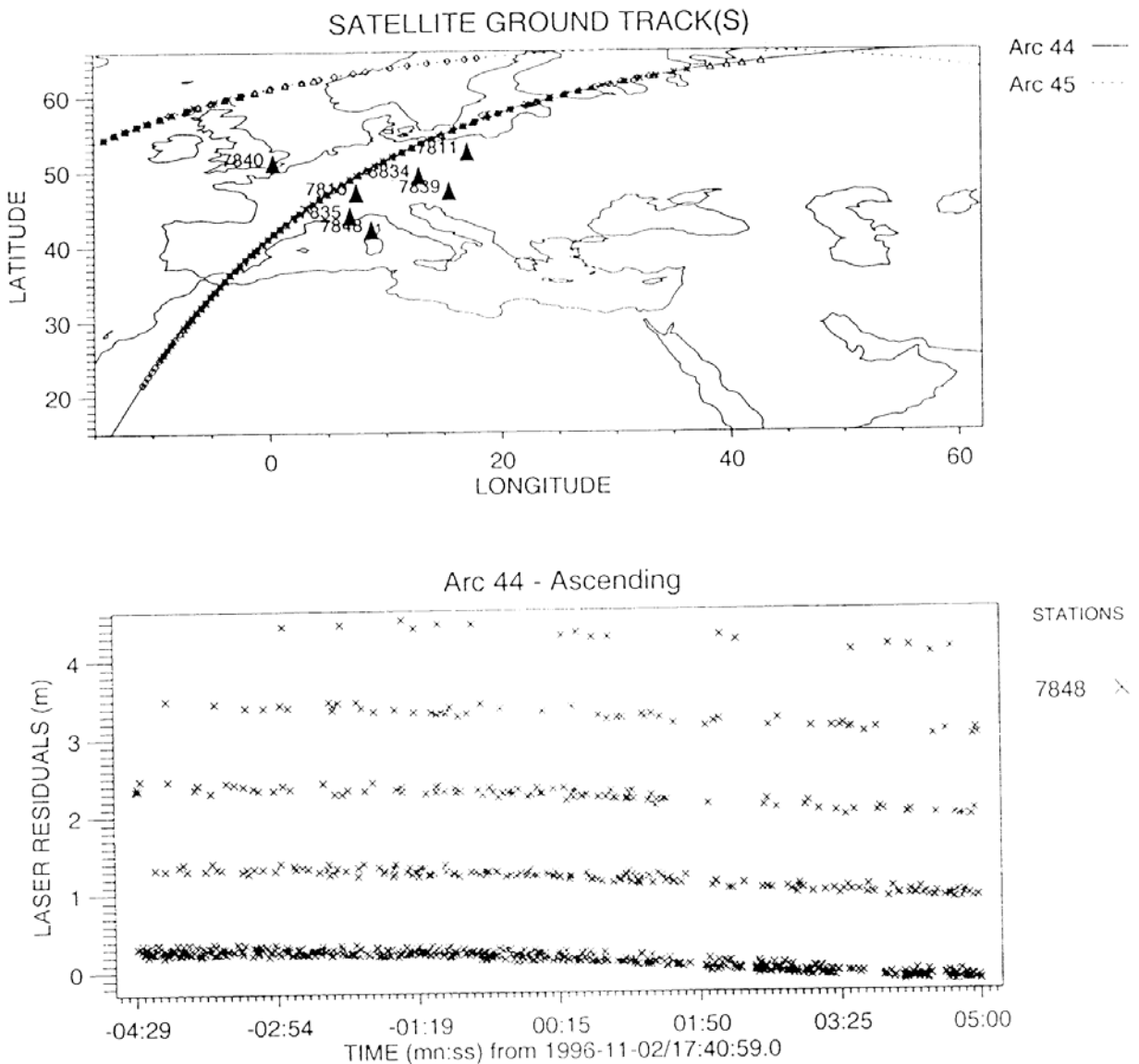


Figure 2 : Example of data acquisition with the FTLRS during the Corsica campaign : echoes obtained from TOPEX/POSEIDON (1996-11/02).

The maximum number of satellites was tracked to increase the accuracy of the positioning and to test the observing capabilities of the station. Priority was given to Topex/Poseidon and ERS-2. Figure 3 shows the number of passes observed for various satellites. It represents about 430 passes with about 7400 normal points.

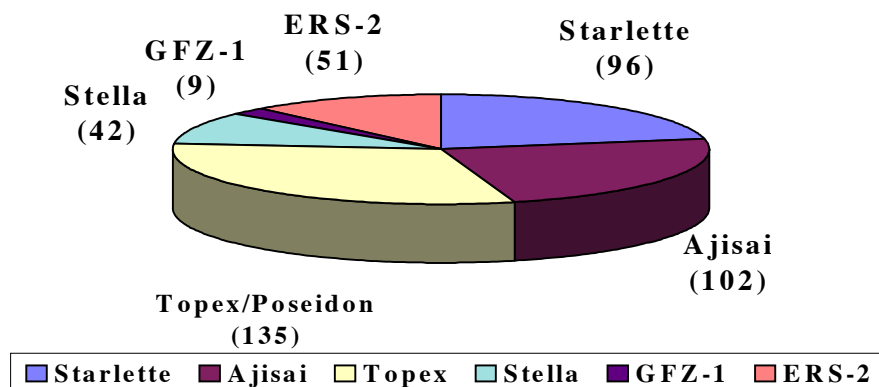


Figure 3 : Statistics of the passes observed during the Corsica campaign

For this campaign, the divergence of the FTLRS infra-red laser beam was optimised for the laser reflector array and altitude of the T/P satellite. A relatively large divergence could be used because of the low altitude of T/P and the sensitivity of the avalanche photo-diode. However, this made the signal too weak to track the much higher LAGEOS satellite (some echoes were obtained but not enough to be considered). In the current configuration, it is not practical to change the divergence from one pass to another, but changes are under investigation on this point.

### TOPEX/Poseidon residual analysis

When we look at the FTLRS data, we can note that there is some variability from one pass to another as regarding the mean laser residuals (figure 4). For estimating the instrumental mean term performance stability, the average residuals per pass have been computed from Topex/Poseidon ELFE precise orbit ephemeris given by the CNES [Nouël et al., 1994].

From figure 4, we can assess that the station quality is not always stable at the mean term when considering several successive passes. The instabilities can reach 6 cm and concern 20% of the data. These residuals are originated by local orbit errors, geodetic coordinates errors, but the main part of the signal is due to accidental fluctuations in instrumental range/time biases. This last point has been identified as the difficulty to obtain an actual single photo-electron detection mode from one pass to another. Of course from a technological point of view this led us to improve this situation by looking at electronic systems able to homogenise the energy level of the return echoes [Prochazka et al., 1996]. But in spite of these instabilities, the precision, which corresponds to the short term stability (few minutes), is of about 2 cm on a pass. It is acceptable in terms of standards but can be improved. The mean bias was estimated below 1 cm during all this campaign.

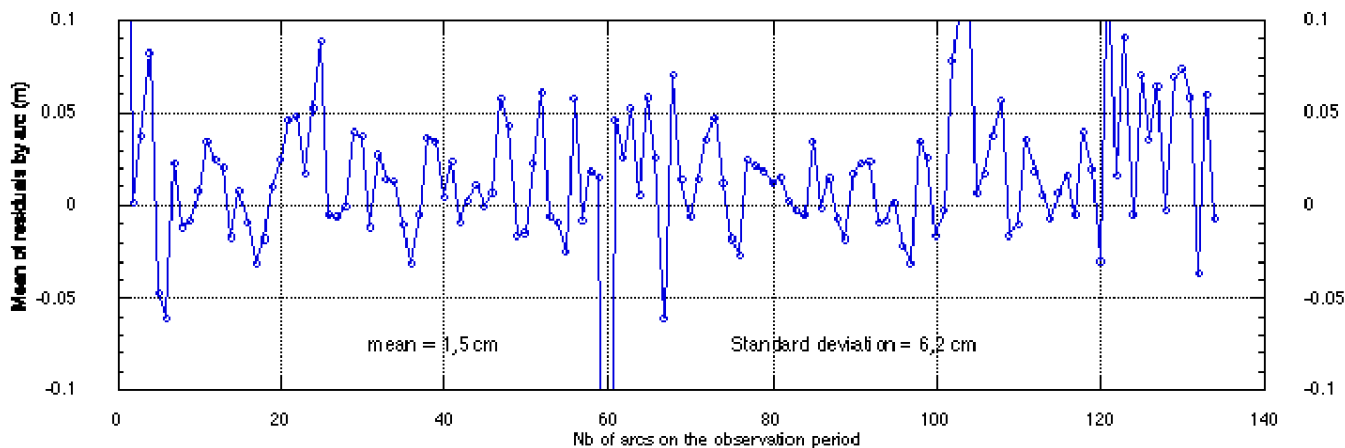


Figure 4 : Temporal evolution of the mean laser residual per pass for TOPEX/POSEIDON.

## Orbitography-Positioning

Figure 5 shows the statistical repartition of the laser residuals for Topex/Poseidon orbits during this campaign for 4 different SLR stations: the fixed stations at Grasse, Grasse, and Herstmonceux and the portable station at Ajaccio. The reference orbit was determined with the Grasse, Grasse and Herstmonceux stations measurements by a short-arc technique without the Ajaccio data. Ajaccio is close enough to these stations that the orbit should have comparable accuracy.

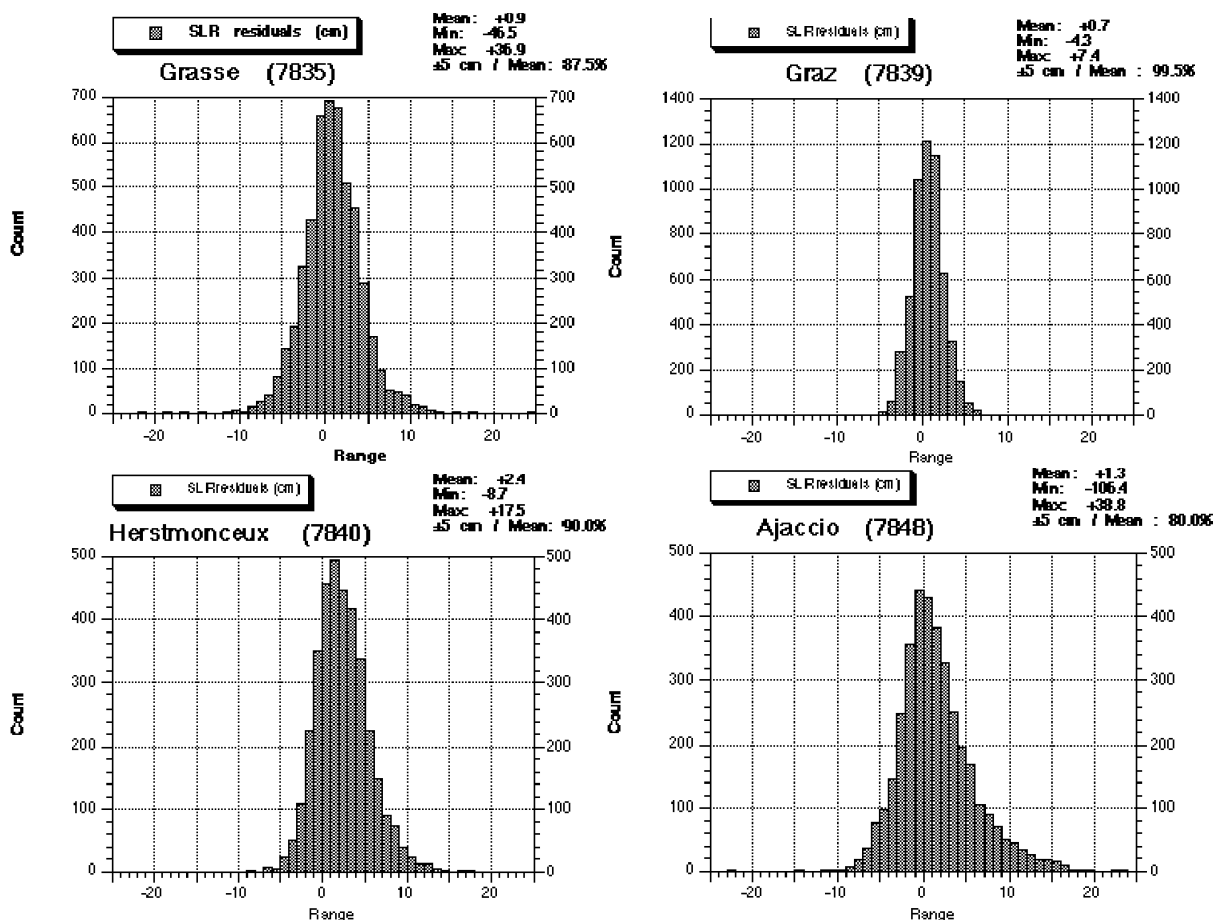


Figure 5 : Statistical repartition of the SLR TOPEX/POSEIDON residuals for different stations (a) Grasse, (b) Graz, (c) Hertsmonceux, (d) the FTLRS at Ajaccio.

The FTLRS histogram is wider but presents the same general shape as the other stations with a systematic difference of about 1.5 cm. It is an encouraging result for the first deployment, but does indicate that some improvements to the station are necessary.

The FTLRS data are used only for the station coordinate determination. The station positioning was carried out with low satellite FTLRS data with two techniques : dynamic and short-arc orbitography. The long term aim is to be able to compute more precise positions with LAGEOS observations. The accuracy of the FTLRS station coordinate determination is evaluated by comparing results from the SLR, GPS and DORIS [Soudarin and Cazenave, 1993] techniques. The IGN/GPS solution corresponds to a campaign carried out in 1993 and the JPL/GPS solution corresponds to a campaign carried out simultaneously with the SLR observations. The DORIS (CNES) campaign was also carried out during the FTLRS observations. The GPS and DORIS positioning determinations constitute an external reference for the station coordinates.

The results are shown in figure 6. Under optimal campaign conditions the GPS technique has a precision on the order of 0.5 mm horizontally and 1.5 cm vertically. The DORIS solution is less precise because of a lack of data (the observation geometry resulted in three time less data than normally expected). We can see that the results are in agreement at the level of 1-2 cm. The difference in the altitude component between the SLR and GPS solution may be due to lower accuracy of the GPS and/or the lack of SLR data near the zenith of the FTLRS station.

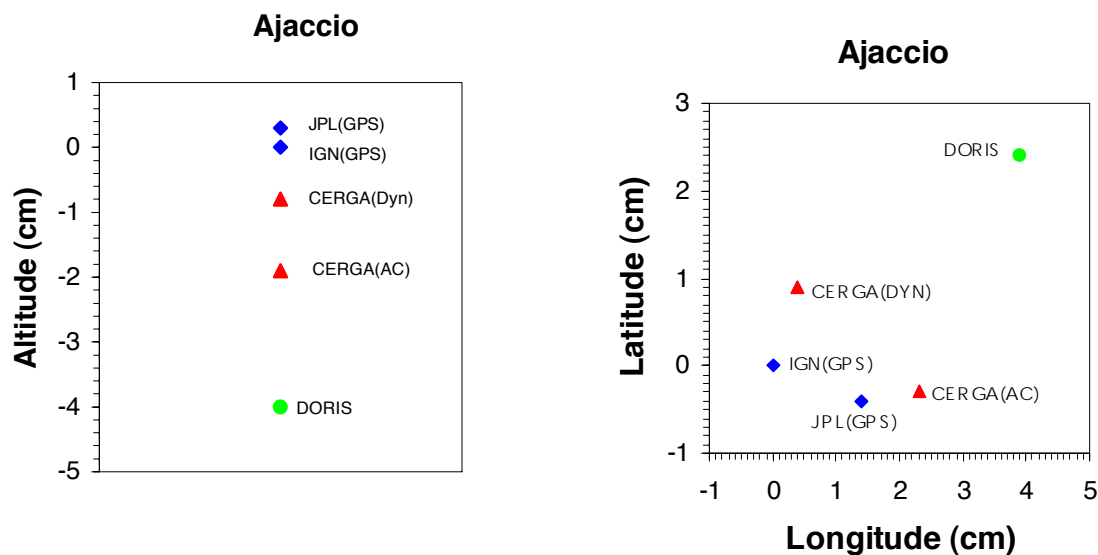


Figure 6 : Positioning results of a collocated measurements of the FTLRS, GPS and DORIS stations. The IGN/GPS solution corresponds to a campaign carried out in 1993 and the JPL/GPS and DORIS measurements were made simultaneously with the FTLRS observation during the Corsica campaign. The CERGA(dyn) points correspond to a dynamic orbitography solution whereas the CERGA(a.c.) points are obtained by a short-arc technique.

## Altimetric Calibration

For altimetric calibration, it is necessary to know the vertical displacement of the FTLRS from the average sea surface measured by the satellite altimeter. The distance from the FTLRS site to the tide gauges on Corsica was determined by the IGN using classical geodetic techniques. There is some variation between the near-shore sea-level measured by the tide gauges and the average sea surface resolved by the altimeter. This is taken into account to first order through the geoid slope.

For TOPEX/Poseidon, there were 9 passes close enough to the zenith to be accepted as a calibration ones observed by the FTLRS. Estimates of the altimetric height which include the connection to the geoid compared to the T/P values show a bias of about  $5.6 \pm 3.9$  cm. For comparison, at the Harvest offshore platform, the bias was found to be  $0 \pm 3$  cm with about 150 arcs [Christensen et al., 1994], [Ménard et al., 1994]. The difference is of a few centimetres and could be explained with the connection to the geoid. Improvements on the geoid slope are under investigation, particularly thanks to a recent campaign with GPS buoys (May 1998). The encouraging result is that the obtained precision is of the same order for both determinations.

No bias determination could have been done for ERS-2 because there was only one calibration pass (satellite track directly overhead) observed.

## Conclusion

During this campaign the FTLRS has demonstrated its capabilities for observation under typical field conditions. The internal accuracy of the instrument is generally (80% of passes) close to 2 cm per pass, but there are sometimes significant variations of the quality with a random time bias of about 1-2 microseconds corresponding to a range bias of about 3-6 cm.

The uncertainties of the geodetic station positioning using only low satellite data are less than about 2 cm.

Concerning the altimetric calibration itself, it could only be evaluated in principle. No bias determination could have been done for ERS-2 because there was only one calibration pass observed. For TOPEX/Poseidon, there were 9 calibration passes observed by the FTLRS. The calibration estimates have a bias of about  $5.6 \pm 3.9$  cm, which may due to problems with the connection to the geoid, but this is an encouraging preliminary result.

Improvements to the station have been carried out and others are also under investigation, as described in another paper of these proceedings [Pierron et al., 1998], in order to understand and correct the instrumental instabilities of the FTLRS, and increase its precision. In the very near future we hope to observe LAGEOS.

Following these developments, future campaigns are foreseen in Grasse (1998-99) and then in Corsica (1999-2000) for a new calibration experiment of TOPEX/Poseidon, Jason-1 (TOPEX/Poseidon follow-on mission to be launched in May 2000) and EnviSat (ERS follow-on mission to be launched in 2000).

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