FTLRS support to the GAVDOS project : tracking and positioning

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Abstract

In 2002, the FTLRS system performed a very successful six months campaign in Corsica for the altimeter calibration (CAL/VAL) of the JASON-1 satellite. The results have been presented on last laser workshop in Washington. After a short period of maintenance, this mobile station was again engaged in 2003 in the framework of the European GAVDOS project. The primary objective of this project is the establishment of an absolute sea level monitoring and altimeter calibration facility on the isle of GAVDOS, south of the island of Crete, Greece. The GAVDOS project will determine consistently and reliably (1) the altimeter biases and drifts for each satellite altimetric missions (TOPEX/Poseidon, JASON1, ENVISAT,…) and (2) the bias among different missions. It will also determine the mean sea level and the earth's tectonic deformation field in the region of Crete.

The FTLRS was set up in Crete (from April to October 2003 with a two month stop in July and August to avoid too warm days) in order to provide accurate data for altimeter calibrations, orbit validations and accurate positioning.

In this talk, we will present the observational balance sheet of the FTLRS Crete campaign and the positioning results obtained with a combination of LAGEOS -1, -2, STELLA, and STARLETTE observations. This solution will be compared to a GPS one.

Introduction

GAVDOS is a research project supported by the European community. Its primary objective is the establishment of an absolute sea level monitoring and altimeter calibration facility on the isle of Gavdos, south of the island of Crete, Greece. It will determine consistently and reliably (1) the altimeter biases and drifts for each of these missions and (2) the bias among different missions. It will also determine the mean sea level and the earth's tectonic deformation field in the region of Crete, Greece.

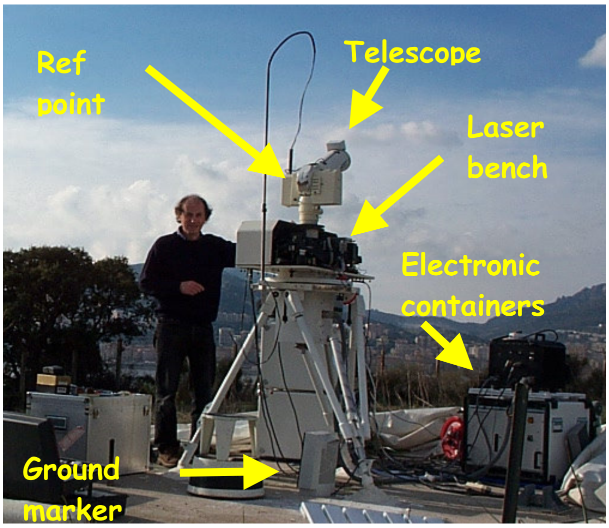
The FTLRS system is one of the instruments deployed for this project. It was set up on the Chania University site in Crete, in the north of the Gavdos Isle. The FTLRS is a highly mobile Satellite Laser Ranging (SLR) system dedicated to the tracking of geodetic satellites equipped with retroreflectors. This instrument was developed by the Observatoire de la Côte d'Azur (OCA) and the Centre National d'Etudes Spatiales (CNES) in collaboration with the Institut National des Sciences de l'Univers (INSU) and the Institut Géographique National (IGN) (Nicolas et al., 2000). The capabilities of this laser ranging system have been greatly enhanced between 1997 and 2001 to meet the 1 cm accuracy level required by the new altimetry missions, and to track the LAGEOS -1 and –2 satellites. In 2002, the FTLRS system performed a very successful six months campaign in Corsica for the altimeter calibration (CAL/VAL) of the JASON-1 satellite (Bonnefond et al., 2003).

The SLR technique is the major contributor to the altimeter calibration : (i) SLR data of the whole network are used to derive ultra precise orbit of altimeter satellites (in combination with DORIS and GPS data) and (ii) FTLRS conducts comparative laser distance measurements between the facility and satellite radar altimeters. The altimeter calibration could be derived from the FTLRS distance measurements only if the FTLRS position is known with a sub-centimetric accuracy.

The purpose of this paper is to present the observational balance sheet of this FTLRS campaign and to explain the method we used to determine the coordinates of the FTLRS. The positioning results obtained from FTLRS data will be compaired to a positioning realized from GPS data only.

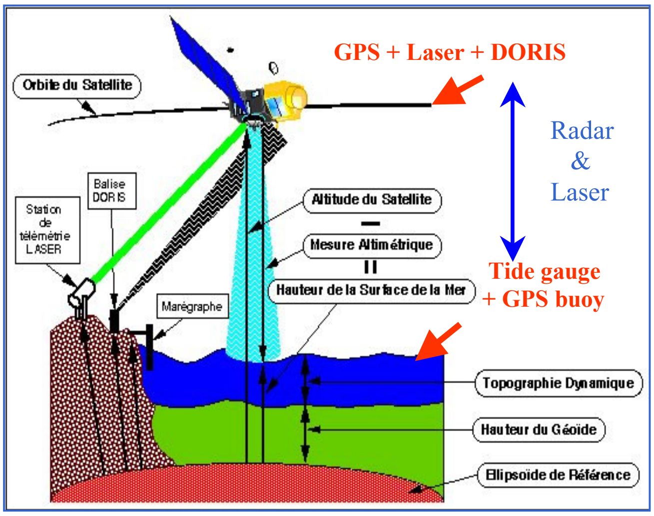
FTLRS technical and operational issues:

<u>Ftlrs specifications</u>:
–Total weight : 350 kg
–Electrical power : 5 KVA
–Laser: Yag frequency doubled 10hz /20 mj
–telescope = 13 cm (emission/reception)
–Time = GPS steered rubidium
–LEO satellites to Lageos
–Time to setup : 48 h

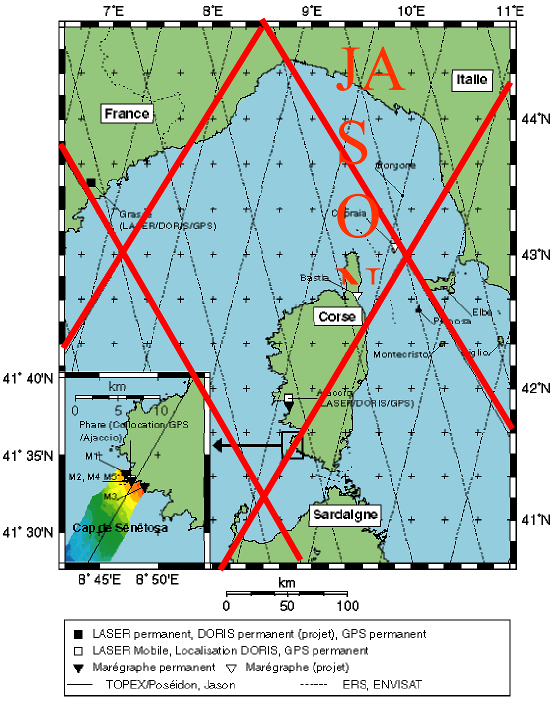


Typical setup of the station (Corsica 2002 for Jason1 calibration)

Previous campaign : Corsica in 2002 for Jason calibration

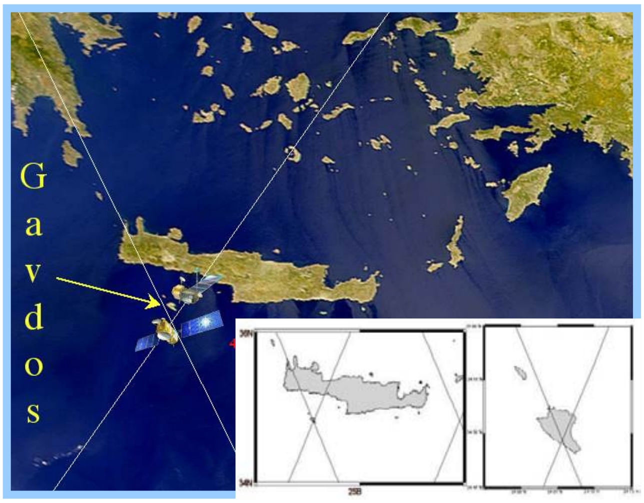


Ftlrs system, after many technical upgrades became really operational with this campaign in 2002 after a three month collocation phase in Grasse observatory with both the fixed slr system and lunar station.
This 6 months campaign in Ajaccio was devoted to positioning and to calibrate Jason1/Topex altimeter.



- JASON-1 absolute calibration and orbit validation (CAL/VAL) in tandem mission with TOPEX/Poseidon
- Precise positioning
- Altimeter calibration = precisely compare : altimeter data - satellite altitude above sea level

Gavdos campaign (April to October 2003) :



In the framework of an European and multi-agencies project, we have set up a semi-permanent site in Crete (Technical University of Chania) with the lowest possible installation and monitoring costs. The ultra mobile FTLRS system (French Transportable Laser Ranging Station, weight 300 kg), has been deployed here during the period from March to November 2003.

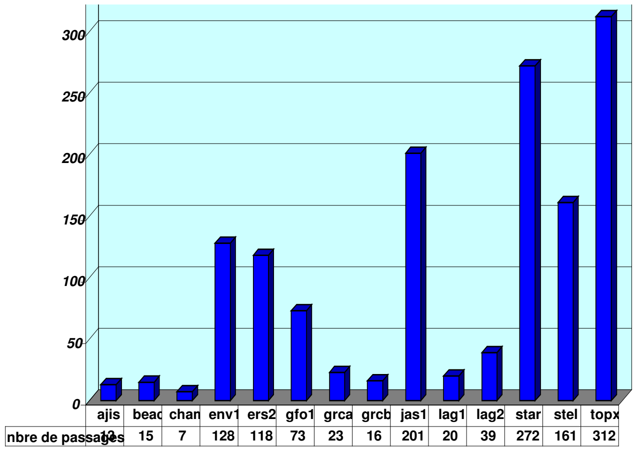
FTLRS system tracked satellite passes during 6 months roughly, in particular both ascending and descending JASON-1 passes which over flight the Gavdos island.

Our team in Chania (2 peoples during 6 months) contributed to observe and to permanently realize adjustments and maintenance of optics, laser, telescope, etc.

The results

This campaigns has been done in very good conditions thanks to the Technical University of Crete staff supplying supports when needed for infrastructure, power and internet lines during theses 6 months.

Observations gathered more than 1400 passes including lageos and with high priorities on Jason1 and Topex.. The accuracy of the positioning finally obtained in solutions were at some millimeter levels.



Data treatment have been achieved at OCA-CERGA and are described in this paper.

- Accurate positioning and short arcs
- Cal/val processing for Jason1/Topex above Gavdos island calibration point.
- GPS treatment and comparison

Laser positioning method

The methodology, based on a geometrical approach, first consisted in computing the orbits as accurately as possible (for the lower altitudes especially). Then, we established the normal matrices for estimating the station geocentric coordinate updates and a range bias value through a least-squares fit.

The orbit restitution process has been performed with the GINS software (GRGS, Toulouse) from a selected subset of SLR stations, apart from the FTLRS. Actually, we considered a kind of "core stations" almost well distributed on the Earth and with high criteria concerning the quality and the quantity of their data. We computed 5-day and 9-day arcs, respectively for STARLETTE and STELLA, and for LAGEOS-1 and -2 satellites, over the 6 months of the campaign. We used in each case the same following dynamical models and reference frame: the GRIM5-S2 Earth gravity field model (Biancale et al., 2000}, the FES99 ocean tides model (Lefevre et al., 2002}, the DTM atmospheric density model (Berger et al., 1998) for STARLETTE and STELLA only, and the ITRF2000 solution. Results, in terms of orbit precisions are (mean RMS over the whole campaign) : RMS_{LA1} = 1.05 cm, RMS_{LA2} = 0.82 cm, RMS_{STA} = 1.98 cm, RMS_{STE} = 2.17 cm.

The FTLRS coordinates are estimated by comparing the FTLRS measurements to the computed orbits. The model fitted to the FTLRS range measurements was the following:

$$D = \sqrt{\sum_{i=1}^{3}\left[X_{i,0} + \Delta X_i + X_{i,pt} + X_{i,et} - X_{i,sat}\right]^2} + B \quad (1)$$

where $X_{i,0}$ are the initial mean coordinates, $X_{i,pt}$ and $X_{i,et}$ are the corrections of the polar and Earth tides following the IERS 96 conventions (Mac Carthy, 1996}, $X_{i,sat}$ are the satellite coordinates expressed in the terrestrial reference frame, B is the FTLRS range bias, and ΔX_i are the updates in the terrestrial reference frame. These updates were estimated in a spherical frame: East, North, and Up (λ, ϕ, and h, respectively). The estimation of ΔX_i and B required to solve the following linear system:

$$\left(A^T \Sigma A\right) X = A^T \Sigma Y \quad (2)$$

where A and Σ are the design and the weight matrices, and X and Y are the parameter and the observation vectors, respectively. We used the JCET solution as initial mean coordinates of the FTLRS (see Table 2).

Range biases were key parameters, when analyzing SLR data. Indeed, the vertical component of station coordinates was strongly correlated to this systematic error present in the SLR measurements (correlation of 0.9 to 1, typically). In addition, it was also strongly correlated to the radial component of the local orbit error. Using a geometrical approach, the difficulty so consisted in separating these different parameters from themselves at the level of 1-2 mm. Naturally, low elevation measurements and simultaneous SLR tracking observations from a regional network (short-arcs) were fundamental to reduce the correlations between range bias, vertical positioning, and radial orbit error. We have also developped specific data processing strategies for reducing the correlation between range bias and vertical component. The first one consisted in estimating one range bias per satellite. This was fully justified since the four geodetic satellites had different signatures. The second one consisted in estimating the range bias per satellite over the whole campaign whereas the coordinates updates are estimated each week. In such a way, the range bias was temporally decorelated from the vertical updates.

Laser positioning results

Table 1showed the FTLRS positioning and range bias values obtained. The multi-satellite solution has been obtained with two different methods. The first one (typed 1) consisted in estimating mean coordinate updates and a range bias value per satellite over the whole campaign. As a consequence of estimating two constant and correlated parameters at the same time, we obtained a too high correlation coefficient C (0.93) between the vertical component and the range bias values. The second method (typed 2) so consisted in estimating weekly solutions for the coordinate updates whereas the range bias values were still estimated over the whole campaign. The weekly solutions are then averaged to obtain the mean FTLRS pcoordinates over the whole campaign. This allowed to decrease C to 0.57, which can be considered as a limit, and also to decrease the standard error of h.

	$d\phi$ (cm)	$d\lambda$ (cm)	dh (cm)	B_{LA1}	B_{LA2}	B_{STA}	B_{STE}
Method 1	-0.59±0.1	0.25±0.1	0.03±0.3	-1.97±0.4	-2.06±0.3	-2.24±0.2	-2.83±0.2
Method 2	-0.58±0.3	0.16±0.3	1.25±0.3	-0.96±0.2	-0.97±0.2	-1.57±0.1	-2.02±0.1
GPS proc.	-0.58±0.1	0.48±0.1	1.13±0.3				

Table 1 : Results of the FTLRS positionning . The method 1 and 2 correspond to the laser processing.

GPS positioning

The GAMIT software has been used (with IGS precise orbits), as in the JCET solution (E. Pavlis, June, 1, 2004). Observations have been made over two periods :

- March 12th –15th and 20th – 24th 2003 (9 days)
- January 28th – February 9th 2004 (13 days)

We estimated the FTLRS updates with respect to the JCET solution for each day of observations. The results are presented in figure 1. Then, GPS coordinates have been corrected from estimated plates motions and brought back to the laser measurements average date (July 16th 2003). Results are presented in Table 1.

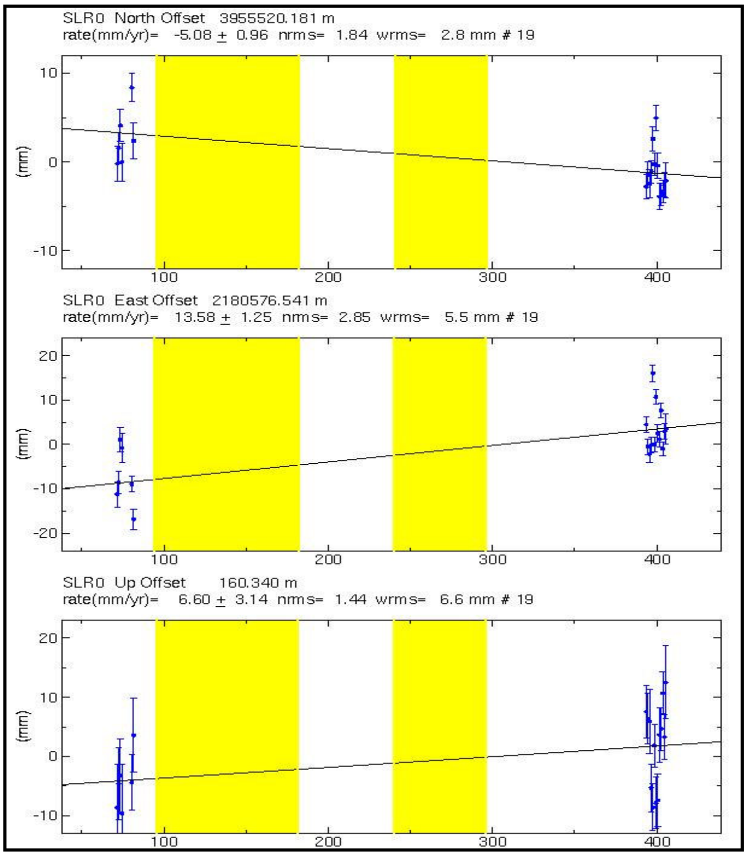


Fig : Results of the GPS processing. Each point represented a daily updates with respect to the JCET solution. The yellow areas represented the observation dates of the FTLRS.

Discussion

Considering the laser processing, our final solution was those obtained by applying method 2. Our choice is motivated by the weak coorelation between range bias and the vertical component. However, two remarks could be done considering the range bias values. The expected bias of the FTLRS was about 5mm. This value has been determined during the Corsica campaign in 2002 (Exertier et al., 2004). The value of 10mm found for this campaign could be explained by the fact that:

- the local tie of the calibration target was determined within 10mm
- the accuracy of chronometer on short time flight was not better than 5mm.

Considering the relative high value estimated for the STELLA bias, several tests have been realized. These tests consisted in a geometrical computing of STELLA's orbits with the short-arc technique from at least 3 European laser tracking station, observing at the same time a satellite pass. With 17 computed short arcs, we showed that permanent and radial orbit error of STELLA orbit existed and was at a level of 10 mm. It certainly explained the greater value obtained for the STELLA bias (of –2.02 cm) relative to LAGEOS ones.

The GPS and Laser results were in very good agreement (see Table 1). The difference between both solutions were lower than 5mm. Finally, The coordinates of the FTLRS in the IRTF2000 reference frame was:

	X (m)	Y(m)	Z(m)
JCET solution	4744552.5533	2119414.5451	3686245.1363
Laser solution	4744552.5636	2119414.5525	3686245.1388
GPS solution	4744552.5614	2119414.5550	3686245.1381

Table 2 : Coordinates of the FTLRS.

Conclusion

After a very succesfull campaign in Corsica for the altimeter calibration of the JASON-1 satellite, the FTLRS confirmed and validated its performances. Moreover, the success of this campaign in Crete has been obtained in the context of a European joined project.

The method of estimating the FTLRS coordinates has been used succesfully. In particular, this method allowed to decorrelate the range bias values and the vertical component of the coordinates. The accuracy of our solution was at the millimeter level and has been validated from a GPS solution.