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Positioning of the French Transportable Laser Ranging System (FTLRS) in Corsica over the 2002 and 2005 campaigns

By

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1 Introduction

The Ajaccio Site (Corsica) is the main calibration site of the satellite altimeters in the Mediterranean area.

Goals of the Corsica Mission:

- Absolute sea level monitoring, altimeter calibration and orbit validation (CAL/VAL) of the Topex/Poseidon, Jason-1 and Envisat satellites from the Ajaccio site (Corsica - FRANCE).
- Estimation of the satellite altimeters biases and drifts

Objective:

Carrying out an accurate SLR positioning from the geodetic satellites observations

Notice:
Altimeter calibration = precisely compare
- **altimeter data**
- **satellite altitude above the sea level**

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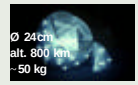
1 Introduction

➔ **Positioning with 4 geodetic satellites :**

LAGEOS-1
LAGEOS-2

STARLETTE
STELLA



✓ Multi-satellite Combination
✓ Adoption of an accurate gravity field model for the LEO computation

➔ **Methodology :**

– Orbit computation
– Positioning of the FTLRS Station

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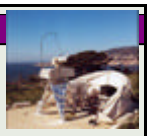
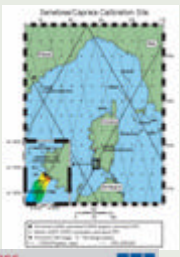
2 LASER campaigns in Corsica



Geographical situation :
- Naval base at Aspretto (**Ajaccio**)
- *In situ* instruments at **Senetosa** Cape : Tide gauges, GPS buoys, meteo station,..



02 Laser campaigns :
- January – September 2002 (**10 months**)
- May – October 2005 (**5 months**)
- 4 satellites used : **Lageos-1&-2, Starlette and Stella**

Instrument :
French Transportable Laser Ranging System **(FTLRS)**

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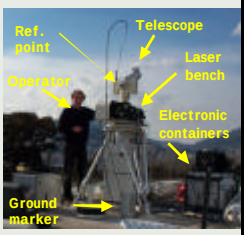
FTLRS : French Transportable Laser Ranging System

The smallest SLR system in operation
– 350 kg
– Ø tel = 13 cm (emission/reception)
– Time = GPS steered rubidium
– LEO satellites to Lageos-1&-2



Applications

- ✓ Satellite Altimeter Calibration
- ✓ Reference Frame
- ✓ Charge Effects
- ✓ Co-localisation Mono or Multi-techniques

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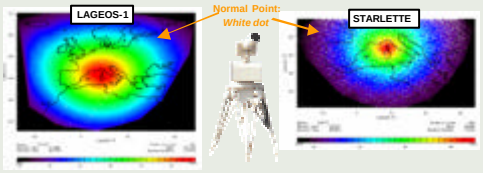
Maps of the range data distribution during the 2005 campaign (05 months) above Ajaccio site



LAGEOS-1 & -2 :

- Few measurements on LAGEOS satellites, particularly at low elevation (40°), and non regularly distribution of these data over the Ajaccio site
- Are difficult to reach by the FTLRS laser (high altitude)
- Low number of normal points collected : not enough to perform 3D geocentric positioning (σ >>±1cm)

Starlette / Stella :

- Ten times more range data on Starlette/Stella relative to LAGEOS, and homogeneous distribution of the range data over the Ajaccio site.

3 Orbit Computation

- **GINS software (*developed by CNES*)**
- **Dynamical Models used :**

Model	Designation
Gravity field	*Grim5-c1 or Eigen-Grace03s*
Atmospheric pressure	*ECMWF*
Solar flow	*Accs02*
Atmospheric Density	*Dtm-94bis*
Ocean tides	*Fes-2002*
Planets	*De403bdff.ad.ibm*
Earth Orientation Parameters	*Eop-c04*

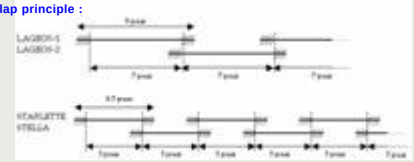
- **Terrestrial reference frame : ITRF2000**

3 Orbit Computation

- **Computation by successive arcs with overlapping periods (Coulot, 2005)**

Nom du satellite	Longueur de l'arc (jours)	Recouvrement début + fin d'arc (jours)	Durée de l'arc concerné (jours)	Nombre de révolutions du satellite par arc	Nombre d'arcs pour la campagne 2005	Pas d'intégration (secondes)
LAGEOS-1	9	1 + 1	7	63	22	60
LAGEOS-2	9	1 + 1	7	63	22	60
STARLETTE	4,5	0,75 + 0,75	3	50	41	60
STELLA	4,5	0,75 + 0,75	3	50	41	60

- **Overlap principle :**



- Overlap periods allow to control the orbits quality of successive arcs
- Improve the arc computation

3 Orbit Computation

- **Effect of the gravity field model on the quality of the orbits :**
  - Grim5-c1 (Gruber et al., 2000)
  - Eigen-Grace03s (Reigber et al., 2005)

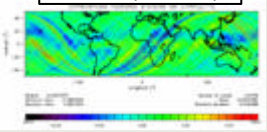
Radial orbit differences :

$RMS_{Starlette}$ = +/- 15 mm

RMS_{Lageos} = +/- 5 mm

☞ The Mediterranean area seems to be less affected by a permanent effect

STARLETTE (32 arcs / 2005)



Mean Radial orbit differences (m) geographically correlated of Starlette orbits

- **RMS (mm) of satellites orbits :**

☞ LAGEOS orbits are more precise & less affected by the change of the gravity field model

☞ Eigen-Grace03s: improvement of the Starlette / Stella orbits precision (+/- 5mm)

Satellite	2002 campaign		2005 campaign	
	GRim5-c1	Eigen-Grace03s	Grim5-c1	Eigen-Grace03s
LAGEOS-1	13	-	11	11
LAGEOS-2	10	-	10	09
Starlette	23	18	23	18
Stella	23	19	21	16

4 Positioning of FTLRS Station

- **MATLO software (*developed by OCA*), (Coulot, 2005):**
  - Dedicated to laser positioning (coordinate updates + range bias/satellite)
  - Multi-Satellite Combination
  - Global solution & Time series solution :

- **Position based on** [illegible] and range biases are estimated over th[illegible]

X (m)	Y(m)	Z (m)	ITRF-yy
4696993.369	724001.714	7239672.762	ITRF-97
4696993.311	724001.825	7239672.837	ITRF-02

- **Position estimated** [illegible] sed const.) remain estimated over the whole data period – *Temporal decorrelation method*

Satellite	2002 Campaign	2005 Campaign
LAGEOS-1	301	377
LAGEOS-2	323	235
Starlette	3413	5294
Stella	1731	2068
TOTAL	5768	7975

☞ Objective : **Reduce the correlation between the range biases and the vertical component (dh)**

5 Adjusted FTLRS Parameters

Adjusted FTLRS parameters *(2005 Campaign)*

Range bias	$B_{LAGEOS-1}$ (mm)	$B_{LAGEOS-2}$ (mm)	B_{STAR} (mm)	B_{STEL} (mm)
Glob. Sol. (1)	+12.0	+12.2	-3.9	-6.4
Glob. Sol. (2)	+6.8	+6.6	-4.9	-4.9
7d. Sol. (1)	+11.7	+13.8	-4.6	-5.4
7d. Sol. (2)	+6.9	+3.3	-5.6	-4.3

Gravity field models :

(1): Grim5-c1

(2): Eigen-Grace03s

Coordinate updates	*dx* (mm)	*dL* (mm)	*dh* (mm)	Pos-bias (%)
Glob. Sol. (1)	+4.3 ± 0.6	-10.1 ± 0.6	+11.7 ± 1.8	94.4
Glob. Sol. (2)	+4.3 ± 0.5	-3.6 ± 0.4	+3.0 ± 1.4	94.4
7d. Sol. (1)	+4.4 ± 0.8	-8.6 ± 0.5	+13.8 ± 0.6	55.4
7d. Sol. (2)	+4.1 ± 0.4	-2.9 ± 0.4	+4.0 ± 0.4	55.4

- **Glob.Sol :** Correlation remains too high between biases and *dh* (94%) - Some part of the bias may move to dh and vice versa
- **7d.Sol :** Correlation decreases significantly (55%) → This solution is held
- Statistically, the estimates of coordinates updates with Eigen-Grace03s model are better than those with Grim5-c1 model.

Adjusted FTLRS Parameters

Adjusted FTLRS parameters *(over 2005 & 2002 Campaigns)*

Coordinate updates	dφ (mm)	dλ (mm)	dh (mm)	R.m.s.dev. (%)
2002	-0.8 ± 0.7	+1.6 ± 0.7	+0.2 ± 0.8	55.8
2005	+4.1 ± 0.4	-2.9 ± 0.4	+4.0 ± 0.4	55.4

With:
- ☑ Time Series Sol.
- ☑ Eigen-Grace03s

Range Bias

	Lageos-1 (mm)	Lageos-2 (mm)	Mean Lageos-1&2 (mm)	Starlette (mm)	Stella (mm)	Mean Starlette/Stella (mm)	Global mean (mm)
2002	-5	-7	-6	-13	-13	-13	-10
2005	+5	+3	+4	-5	-5	-5	0

- Differences between Lageos & Starlette/Stella biases : target response and FTLRS detection process
- More surprising effect is the variation of the adjusted values of the FTLRS range bias between 2002 and 2005 (increase of +10 mm on the global mean for all satellites) :
  - Remaining correlation (~ 50%) between the range bias and the altitude update
  - Internal and/or external calibration of the FTLRS + Instrumental evolution (2002-2005)
- New coordinates (from 2002 & 2005 data sets) along with -5 mm mean range bias : validating the latest Jason-1 precise orbits (Bonnefond et al., 2006)

Adjusted FTLRS Parameters

Geographical coordinates differences from (Exertier et al., 2004) solution

Coordinates differences	Δφ (mm)	Δλ (mm)	Δh (mm)
2002	+0.5 ± 0.7	+2.7 ± 0.7	-1.2 ± 0.8
2005	+4.1 ± 0.4	-2.9 ± 0.4	+4.0 ± 0.4

3D-position RMS : Stability

Campaign	Number of solution	s j (mm)	s? (mm)	s h (mm)	s (mm)
2002	28	14.6	13.1	10.5	12.9
2005	20	7.5	12.3	10.5	10.3

- Global mean of bias (-5mm): very close to the published one (-7mm) (Exertier et al., 2004)
- Coordinate updates values for 2002 and 2005 are at 3mm level in average relatively to (Exertier et al., 2004) solution.
- Coordinates differences are very small at level of residuals errors in the ITRF2000 velocities
- No significant differences between 2002 and 2005 coordinates (at level of the tectonic movement): FTLRS point is locally stable.

Conclusions & Prospects

Conclusions :

- ✓ Multi-satellite combination has allowed to palliate the lack of measurements on the high satellites (LAGEOS),
- ✓ The improvement of the dynamical models, notably of the terrestrial gravity field (with GRACE satellite data: *Eigen-Grace03s*) has permitted a precise computation of the orbits, in particular for the low satellites, and so a more precise geographical positioning,
- ✓ Considerable decorrelation (*~ 50%*) is obtained between the range bias and the station vertical component, using the time series solution (MATLO),
- ✓ The station position is stable between the two observation campaigns,
- ✓ FTLRS has allowed a sub-millimetric terrestrial positioning. That confirms its importance for the absolute calibration process of oceanographic satellites.

Conclusions & Prospects

Prospects :

For future campaigns, and parallel to the technological progress of the FTLRS instrumentation (Nicolas et al., 2002), ideas were discussed between the OCA and the different French partners for planning the development of a new telescope of 25 cm diameter. This will permit to greatly improve the tracking particularly at mean and low elevations, as for high geodetic targets as for satellites equipped with small laser retro-reflectors. Thus, this will contribute to the importance of the role of SLR technique for altimeter calibration missions as for space geodesy and so in the realization of the ITRF.

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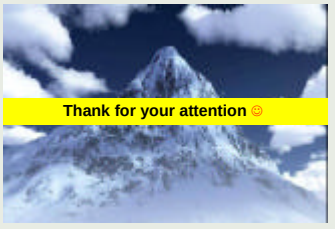

1 Introduction

Problematic ?

➔ Quality of the Laser Measurements (FTLRS positioning) depends on the accuracy of the orbits.

➔ Starlette / Stella : More sensitive to remaining uncertainties in the dynamical models (gravitational & non gravitational effects).

Solution :

✓ Since few years: Improvement of the gravity field model (GRACE mission)

✓ Adoption of an accurate gravity field model for the LEO computation

✓ Multi-satellite Combination