On use of Starlette and Stella laser measurements in determination of SLR stations' coordinates and Earth Orientation Parameters (EOP)

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SUMMARY

The present work deals with the computation of Laser stations coordinates and Earth Orientation Parameters (EOP) based on observations of Low Earth Orbit (LEO) satellites, namely Starlette (STL) and Stella (STA) together with measurements of both LAGEOS satellites (LA1 & LA2) which their derived solution is considered as standard solution. This subject is at the forefront of the researches currently carried out in the framework of the activities of the Analysis Working Group (AWG) of ILRS.

The objective is to achieve good quality on the geodetic products by inter-satellite combination of Low and High satellites Laser data.

We compare two series of solutions (between 2002 and 2005): LA1+LA2 (**LL**) only, and a four-satellite combination based on LA1+LA2+STL+STA (**LLSS**), in terms of quality of the weekly stations positions, daily EOP and weekly Geocenter variations. The results presented show that the data obtained from LEO satellites such as Starlette and Stella can be successfully applied for precise determination of the SLR geodetic products.

Key words: SLR • Starlette • Stella • LAGEOS-I/-II • LEO • EOP • Geocenter

METHODOLOGY

- **Orbit restitution** of different tracked satellites is performed by **GINS** software (GRGS, France) with consideration of a recent GRACE gravity model (Eigen_Grace-03s) in the processing, for a period of four years (between January 2002 and December 2005).
- **Estimation of stations coordinates updates and EOPs residuals**, is performed using **MATLO** software **[Coulot, 2005]**. This estimation provides weekly time series of stations positions and daily time series of EOPs. In order to express these parameters in same reference frame **ITRF2000**, the parameters of transformation were calculated using **CATREF**. The analysis of the time series of these products permits the geophysical study of the behaviour of stations positions, Geocenter variations and pole motion.
- **Analysis of time series of SLR geodetic products** according to different combinations based on (i) ***frequency analysis*** by **FAMOUS** software **[Mignard, 2005]**, and (ii) noise estimation by ***Allan variance method*** **[Feissel-vernier et al., 2007]**.

Algorithm of developed program : ANASS

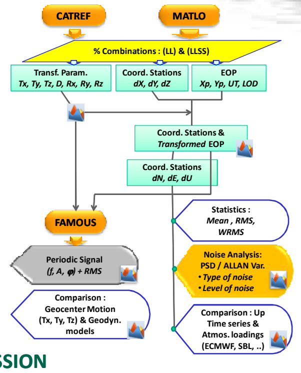
ANASS : *ANAlysis of Statistical and Spectral of SLR time series (Geodetic Products)*

Program Language : *IDL v.6*

Realised at : *Space Geodesy Division (CTS - Algeria) & GEMINI (OCA – France) on 2006/2007.*

Features:

- *Statistical Analysis*
- *Frequency Analysis*
- *Noise Analysis*
- *Graphical representation of results*
- *Interaction with other softwares : CATREF, MATLO & FAMOUS*



RESULTS AND DISCUSSION

According to Table 1, it is clear that the orbits of the high satellites (LAGEOS-I/-II) have a better precision than those of the low satellites (Stella and Starlette), because they are less perturbed. This phenomenon is related to the difficulty of modelling with accuracy of the physical forces acting on the LEO satellites.

Table 1: Length of arcs and weighted RMS of orbital arcs residuals

Satellite	Length of the arc *(days)*	WRMS *(mm)*
LAGEOS-1	7	11.1
LAGEOS-2	7	9.5
Starlette	3.5	16.1
Stella	3.5	15.5

The SLR time series of positions expressed in the local coordinates (NEU); from LL and LLSS combinations; are projected on ITRF2000. The results revealed that these series are statistically equivalent, according to table (2). The addition of the low satellites to the high satellites did not deteriorate the results quality, in particular for the estimates of Earth orientation parameters and of transformation parameters, see table (3). In spite of the inaccuracy of the low satellites orbits (Starlette and Stella) due to the effects of the non-gravitational forces as well as the gravity field, one is now able to use them in complementary with the LAGEOS orbits; for two reasons :

(**a**) important quantity of the low satellites data which can contribute to well constraint the calculation of the ILRS network.

(**b**) good quality of the recent dynamical models (gravitational as ***Eigen-Grace-03s*** and non-gravitational) which allows an improvement of LEO satellites.

Combination	N *(mm)*	E *(mm)*	U *(mm)*
LL solution	-20±35	21±23	-6±26
LLSS solution	-21±36	20±21	-5±28

Table 2: Mean and weighted RMS of NEU coordinates updates,of 34 Laser stations

Combination	Xp *(mas)*	Yp *(mas)*	TX *(mm)*	TY *(mm)*	TZ *(mm)*	RX *(mas)*	RY *(mas)*	RZ *(mas)*	Δ *(ppb)*
LL solution	-0.12±0.32	0.30±0.32	-1±6	1±5	1±7	-0.13±0.41	0.01±0.36	-0.18±0.19	-0.37±1.03
LLSS solution	-0.10±0.30	0.33±0.32	0±6	1±5	1±7	-0.13±0.46	-0.01±0.49	-0.21±0.16	-0.31±0.93

Table 3: Statistics the pole coordinate updates (Xp, Yp) and the Transformation parameters time series

Pole variations

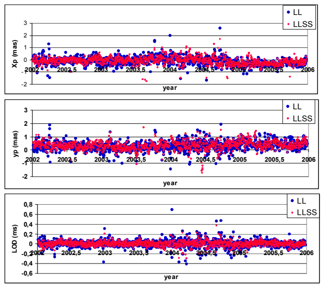
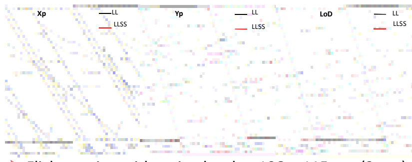


Fig. 1: Pole variations (coordinates & LOD w.r.t. EOPC 04) % LL & LLSS solutions (2002-2005).

- Estimation of pole parameters is satisfactory for the SLR technique and the obtained values are coherent with published values of IERS **[Gambis, 2004]**.

Parameter	Term	LL solution	LLSS solution
Xp (µas)	Interannual	146.9	125.2
	Annual	81.7, 48.1*	54.0*
	Short period	43.7 – 68.3	48.5 – 61.0
Yp (µas)	Interannual	–	–
	Annual	–	69.8*
	Short period	42.7 – 54.6	50.9 – 72.3
LOD (µs)	Interannual	–	–
	Annual	12.6*	10.7 , 10.0*
	Short period	9.1 – 10.0	6.7 – 8.9

- Amplitudes of pole coordinates (% LL & LLSS) are very closed (diff. < 22µas or 0.7mm). Amplitudes ~ few mm.
- LOD : Average amplitude ~ 10µs (5mm).
- These values remain very smalls because they describe the residual signals of the geophysical phenomena.



- Flicker noise with noise level ~ 106 - 115µas (3mm), for pole coordinates and ~ 11 and 16 µs (6 and 8mm), for LOD, according to LL & LLSS solutions.

Geocenter variations

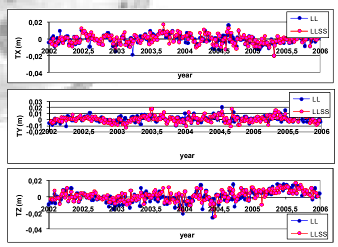
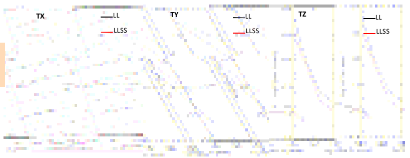


Fig. 2: Geocenter variation components w.r.t. ITRF2000 % LL & LLSS solutions (2002-2005).

	LL solution	LLSS solution	Dong et al. 1997	Chen et al. 1999
TX A(mm)	2.9 ± 0.8	2.6 ± 0.8	4.2	2.4
φ (°)	139 ± 15	131 ± 18	224	244
TY A(mm)	2.3 ± 0.5	4.1 ± 0.6	3.2	2.0
φ (°)	168 ± 22	183 ± 16	339	270
TZ A(mm)	2.3 ± 2.6	1.9 ± 2.1	3.5	4.1
φ (°)	246 ± 67	218 ± 71	235	228

- Coherence in annual amplitudes for LL & LLSS solutions and in comparison with geodynamical signals.



- White noise for TX & TY with noise level ~ 1.8 mm (% LL & LLSS solutions but it is ~ 2.3 mm for TY of LLSS).
- Z-component is affected by a flicker noise ~ 2.8 mm.

Stations positions variations

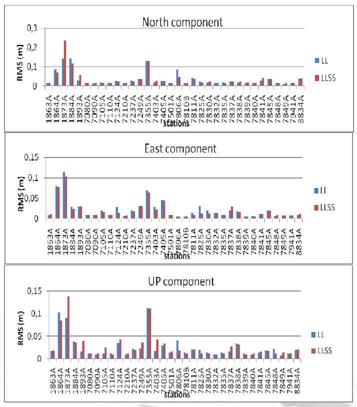


Fig. 3: Average RMS of NEU coordinates of 34 Laser Stations %LL & LLSS solutions (2002-2005).

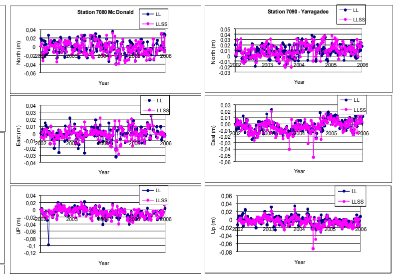


Fig. 4: Example of Time series of McDonald (7080) and Yarragadee (7090) stations.

- Seasonal signals with mm amplitudes on Up component (which represents 2/3 station motion) of stations.
- Signals detected are probably related to residual atmospheric loading effects.

CONCLUSION

This study has showed, in one hand, the feasibility of precise calculation of a SLR network, Earth orientation parameters (EOP) and Transformation parameters, by using four years observations of low satellites namely Starlette and Stella, and in other hand, the methodology of analysis adopted for this work.

It will be useful and interesting to consider more observations of LEO satellites (such as, Ajisai, TopexPoseidon, Jason-1&-2, with Starlette and Stella), during a long period, for the following:

- Contribution to the realisation of new SLR reference frame and SLR solution for future version of ITRF;
- Analysis of geodetic products variations (Stations motions, EOP, Geocenter, ..) with the adopted methodology.

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