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

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ABSTRACT

The present work deals with the calculation of Laser stations coordinates and Earth Orientation Parameters (EOP) based on observations of Low Earth Orbit (LEO) satellites, namely Starlette (STL) and Stella (STA). The orbits of these satellites are less accurate because they are more affected by the gravitational and non-gravitational forces than those of high satellites as LAGEOS-I (LA1) and LAGEOS-II (LA2). The objective is to achieve good quality on the geodetic products by inter-satellite combination of Low and High satellites data. The orbit computation of the different satellites is performed with GINS software and the laser data processing is carried out by MATLO software, 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). The time series of the results are projected according to ITRF2000, by CATREF software, where the Helmert transformation parameters are obtained. We compare two series of solutions: 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, EOP and Geocentre variations. The results presented show that the data obtained from LEO satellites such as Starlette and Stella can be successfully used for precise determination of the SLR geodetic products.

1 Introduction

Satellite Laser Ranging (SLR) is one of the main techniques of the calculation of the International Terrestrial Reference Frame (ITRF). It contributes to the frame determination by providing time series of laser stations coordinates and Earth Orientation Parameters (EOPs). The laser observations of LAGEOS-I (LA1) and LAGEOS-II (LA2) are generally used for such determination. However, what is the contribution in this determination of other satellites like Low Earth Orbit (LEO) ones?. The twins Starlette (STA) and Stella (STL), orbiting at 800 km altitude, were launched by the CNES, on 1975 and 1993, respectively. The main tasks of these LEO satellites are the determination of Earth's gravity field coefficients, Earth rotation parameters, and investigation of Earth and ocean tides. So, the computation of the laser ranging stations coordinates on the basis of data other than those from LAGEOS-I/-II observations is desirable for the following reasons: (1) significantly increases the number of observations used for determination of the stations coordinates and EOPs, (2) permit verification of results obtained from the LAGEOS-I/-II data, (3) permit determination of coordinates of the stations that cannot range to LAGEOS satellites.

Promising results of the stations coordinates determination were obtained for LEO satellite for short period [Lejba et al., 2008] & [Lejba et al., 2007]. The objective of the study is to check if the laser ranging observations of Starlette and Stella can be used for a precise determination of the laser ranging stations coordinates and EOP, and to investigate the contribution of these LEO data for the geodynamic study of the stations behaviour, pole and Geocenter motions. So, the work concerns the computation of a laser network based on both LAGEOS satellites measurements with those of Starlette and Stella over 04 years period (between January 2002 and December 2005), according to two data combination solutions, namely LA1+LA2 (LL) and LA1+LA2+STL+STA (LLSS).

2 Results Analysis

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. The SLR time series of positions of 34 stations expressed in the local coordinates (NEH); obtained from the LL and LLSS combinations; are projected on ITRF2000 reference frame and are statistically equivalents, 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 EOP and Geocenter parameters, see table (2).

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

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

Combination	N *(mm)*	E *(mm)*	U *(mm)*	Xp *(mas)*	Yp *(mas)*	TX *(mm)*	TY *(mm)*	TZ *(mm)*
LL	-20±35	21±23	-6±26	-0.12±0.32	0.30±0.32	-1±6	1±5	1±7
LLSS	-21±36	20±21	-5±28	-0.10±0.30	0.33±0.32	0±6	1±5	1±7

Table 2: Statistics of stations coordinates' residuals, pole coordinate updates (Xp, Yp) and Geocenter parameters time series.

2.1 Pole motion

The figure (1) illustrates the residuals time series of pole coordinates (X_p, Y_p) and of the Length of Day (LOD), with respect to the standard solution EOPC04 of IERS. In the table (2), the values and their RMS of pole coordinates, according to LL and LLSS solutions are practically the same. In addition, the estimation of pole parameters is satisfactory for the SLR technique and the obtained values are coherent with published values of IERS [Gambis, 2004].

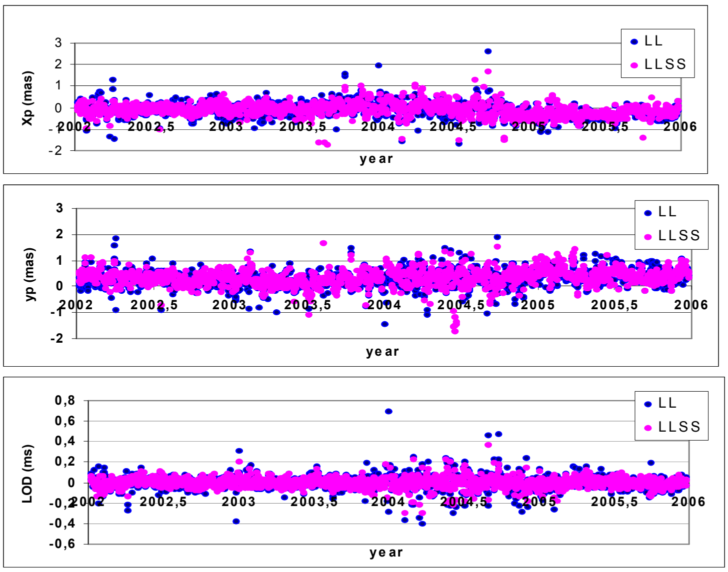

Figure 1: Parameters of pole motion according to LL and LLSS combinations.

The frequency analysis of pole time series is performed by FAMOUS software [Mignard, 2005]. The related periodic signals are decomposed, with respect to three periods [Frède, 1999]: inter-annual, annual and short periods (from few days to few months < 100 days). The amplitude values of pole coordinates, according to LL and LLSS combinations, are very closed, because the maximal difference does not exceed 22µas (i.e., 0.7 mm). In other hand, the amplitudes are small of about few mm. For LOD, the average amplitude is around 10µs (i.e., 5mm). Generally, these values remain very small because they describe the residual signals of the geophysical phenomena. The study of the noise, affecting the pole time series is based on Allan variance method. The dominant noise, for LL and LLSS solutions, is the flicker noise with a slope of the Allan diagram of -0.4 and -0.6. The noise level is of about 106 - 115µas or 3mm, for pole coordinates and it is around 11 and 16 µs (6 and 8mm), for LOD, according to LL and LLSS, respectively.

2.2 Geocenter variations

The Geocenter variations are mainly due to the redistribution of masses in atmosphere, in oceans and also in hydrological reservoirs. Table (3) displays the values of amplitudes and phases of annual terms of our solutions, and of two geodynamic models of (Dong et al., 1997) & (Chen et al., 1999). One can observe a coherence in the amplitudes values for LL and LLSS solutions and in comparison of our solutions with geodynamical ones.

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

Table 3: Annual terms of the Geocenter variations components (TX, TY, TZ) according to the LL and LLSS combinations

The white noise is the dominant noise for the X and Y Geocenter components, with noise level of about 1.8 mm (according to the LL and LLSS combination but it is about 2.3 mm for Y-component of LLSS solution). However, the Z-component is affected by a flicker noise at level of 2.8mm.

2.3 Coordinate updates of SLR stations

Figure (2) shows the average RMS of topocentric coordinates (NEU) of 34 SLR Stations over four years (2002-2005), according to the LL and LLSS combination solutions, which are equivalents.

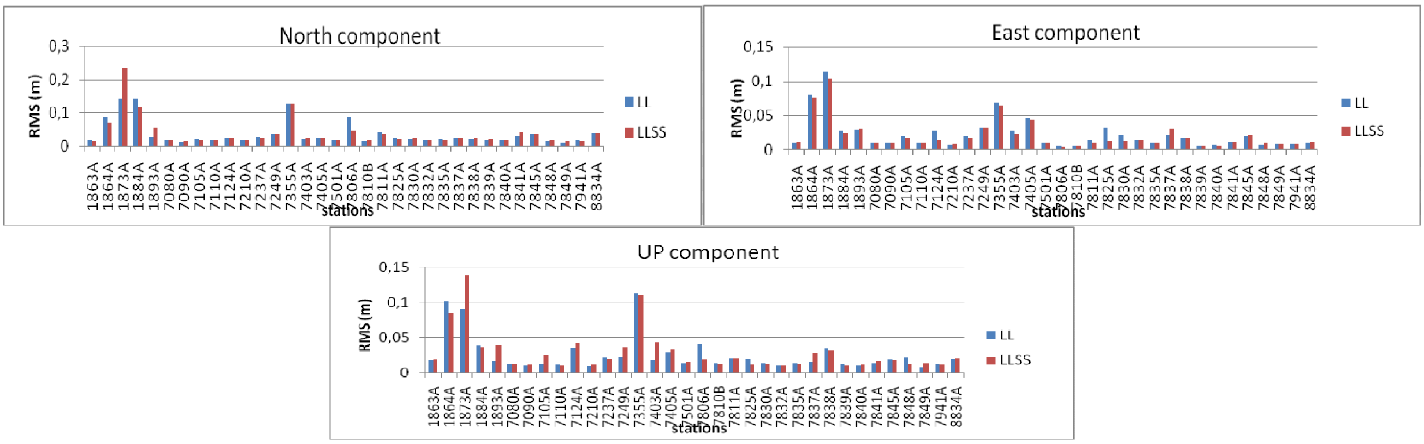

Figure 2: RMS of topocentric coordinates of SLR stations, according to LL and LLSS combination solutions.

Figure (3) shows an example of the position time series of two best stations (7080-McDonald, USA) and (7090-Yarragadee, Australia). We focused on vertical component because it is important for the geodynamical studies since it holds 2/3 amplitude of signals acting on the station motion [Coulot, 2005]. Seasonal signals with amplitudes of about few mm were estimated. Since, the effects of ocean loading were considered in the model a priori of restitution, the signals detected are probably related to residual loading effects, which typically have amplitudes of mm level.

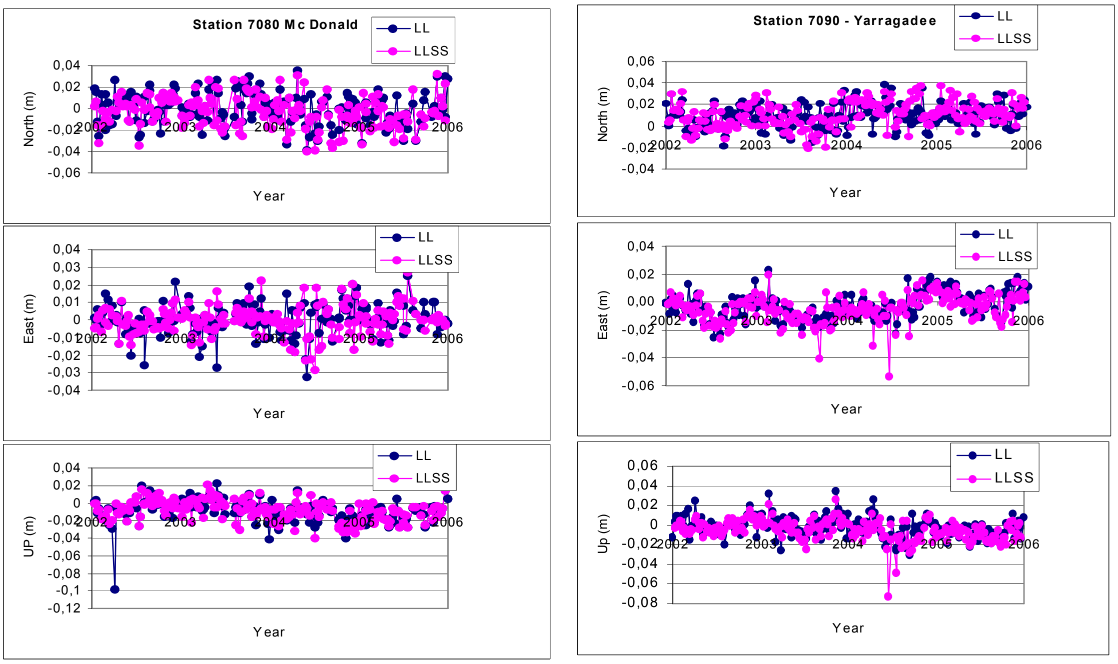

Figure 3: Coordinates Time series of McDonald (7080) and Yarragadee (7090) stations.

3 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,...), during a long period, for: (i) Contribution to the realisation of new SLR reference frame and SLR solution for future version of ITRF, and (ii) Analysis of geodetic products variations (Stations motions, EOP, Geocenter) with the adopted methodology.

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