TIME SERIES OF SATELLITE LASER RANGING STATION POSITIONS

D. Coulot (1-2), P. Berio (2), P. Exertier (2) and O. Laurain (2)
(1) IGN/ENSG/LAREG, 6 et 8 av. B. Pascal, F-77455 Marne la Vallée
(2) OCA/site de Grasse, av. N. Copernic, F-06130 Grasse
david.coulot@obs-azur.fr /+33-04-93-40-53-84/Fax:+33-04-93-40-53-33

Abstract

The International Terrestrial Reference System is the current positioning reference for all geodetic computations. Its computation is evolving through the use of time series of terrestrial station positions together with time series of Earth Orientation Parameters. As a first step, we study here a processing strategy to determine position time series by the Satellite Laser Ranging technique (ranging measurements -from the international tracking network- and precise orbit determination for LAGEOS satellites). We show that, owing to improvements in orbit computation, physical signals clearly appear in the position time series determined in a free network approach.

Introduction

The underlying of physical phenomena by experiments implies the use of measurements. The computation of a model based on these measurements requires to link them to a given reference. It is always the case in geodesy, science with a great amount of data. Therefore, terrestrial reference systems are of great importance. The International Terrestrial Reference System (ITRS) is the current positioning reference for all geodetic calculations. The computation of its representation (the International Terrestrial Reference Frame - ITRF) is evolving. Indeed, it will no more be based on single sets of coordinates and velocities of terrestrial stations but station position and Earth Orientation Parameter (EOP) time series. These time series are in better agreement with geodynamical phenomena and allow the computation in the same process of the terrestrial reference frame and the EOPs. In this context, to participate in the pilot project of the International Laser Ranging Service (ILRS) and to provide the International Earth Rotation and Reference System Service (IERS) with a French solution, we study a processing strategy to determine position time series by the Satellite Laser Ranging (SLR) technique. These time series should also allow us to underline and study geodynamical phenomena such as oceanic and atmospheric loading effects. In practice, the SLR technique limits inevitably the sampling of such time series (inability to track several satellites at the same time and no tracking with bad meteorological conditions). On the other hand, with its present sub-centimetric precision, this technique should be able to explain variations of station positions under the centimetric level. Therefore, to analyse accurately the geodynamical phenomena acting on the station movements and to participate in the ITRF calculation, our aim is to obtain time series with a reasonable sampling (ten days typically) and an accuracy better than 5 mm.

Processing Strategy

A geometrical approach

The method of computation of SLR station position time series typically used is a geometrical one (see [Nicolas 2001] and [Coulot et al 2002]). This method uses the two geodetic satellites LAGEOS-1 and LAGEOS-2. These two satellites are of great interest in SLR. Indeed, due to their high altitude (about 6000 km), they are less sensitive to Earth's gravity field and to non gravitational forces. So they represent the most stable targets for SLR positioning. In a first step, orbital arcs of ten days are computed for both satellites. The ten-day length is a good compromise between a good distribution of SLR measurements with time and space and a good quality of the orbits. The average of mean weighted residuals of these computed arcs is about 2 cm for both satellites. In a second step, SLR measurements are used with orbital arcs to compute SLR station position offsets in a least-squares adjustment process. We assume that these offsets are constant over ten days to keep a reasonable distribution of the two LAGEOS measurements which are so cumulated. These offsets are given with respect to the position of the station given in ITRF2000 [Atamimi et al. 2002] corrected for Earth tides and the polar tide according to IERS96 conventions[McCarthy 1996]. The least-square residuals ("measurement minus model") of such adjustment are shown on Figure 1. We can clearly see a signal remaining in the residuals for one satellite pass. The model used for computation is not satisfactory and position offsets must be inaccurate. Indeed, there are two sources of inaccuracy on these offsets: the residual orbital errors and the mismodelling of the crustal movements.

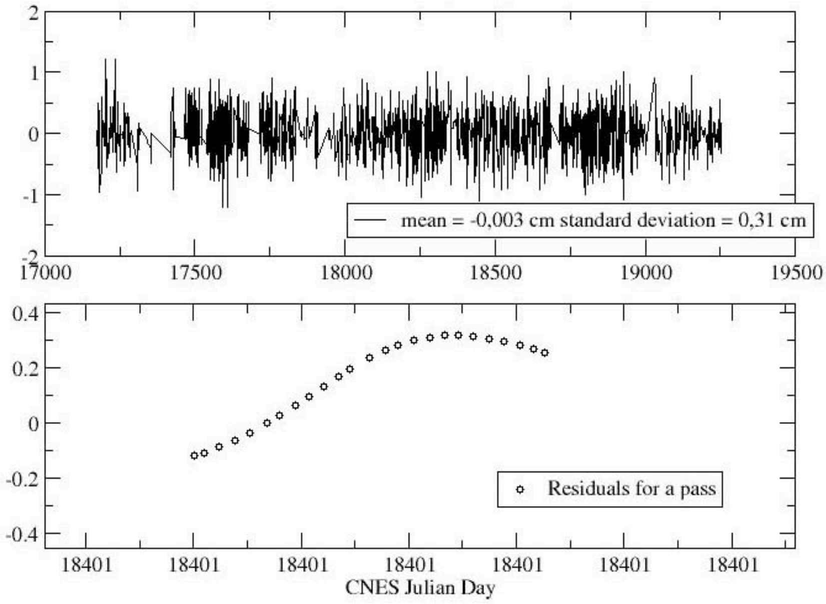

Figure 1. Least-square residuals for LAGEOS-1. Station 7835 (Grasse). The unit is cm.

Although they are of great quality, the orbital arcs are not perfect: physical models used for numerical integrations have limits and the SLR global tracking network is deficient in the southern hemisphere. Our simulations show that these residual orbital errors can induce inaccuracies at the centimetre level. The model used for station position variations (ten-day constant offsets) implies to suppose that phenomena like atmospheric loading can be averaged on ten days. Furthermore, with this constant model, we suppose that computed offsets represent the means of geodynamical signals on ten days. Our simulations show that it is not necessarily the case. Indeed signals are averaged not only temporally speaking but through the design matrix too. This averaging by the design matrix (matrix of partial derivatives of the measurements with respect to station position offsets) can induce inaccuracies at the level of few millimetres.

Improvements

To obtain position time series with an accuracy better than 5 mm, we have to reduce the impact of orbital errors and to use a satisfactoring model for station position variations. Regarding orbital errors, the approach used is semi-dynamical. Hill's theory gives a physical model for orbital errors (periodical and constant functions in acceleration) [Crétaux et al. 1994]. By integrating second-order differential equations for satellite motion, we can obtain an empirical error function for the spatial position of the satellite. Using this empirical model, we can adjust orbital errors with station positions. But doing this gives rise to strong correlations between the various parameters estimated in the least-square process. To avoid for this, we first compute the orbital errors alone for each satellite using a minimal network. Then, orbital errors and station positions are computed together for this minimal network, orbital errors being constrained to their previous values. Finally, the orbital errors updated are fixed and position time series are computed for the whole SLR network. Figure 2 shows such time series for stations located in the USA.

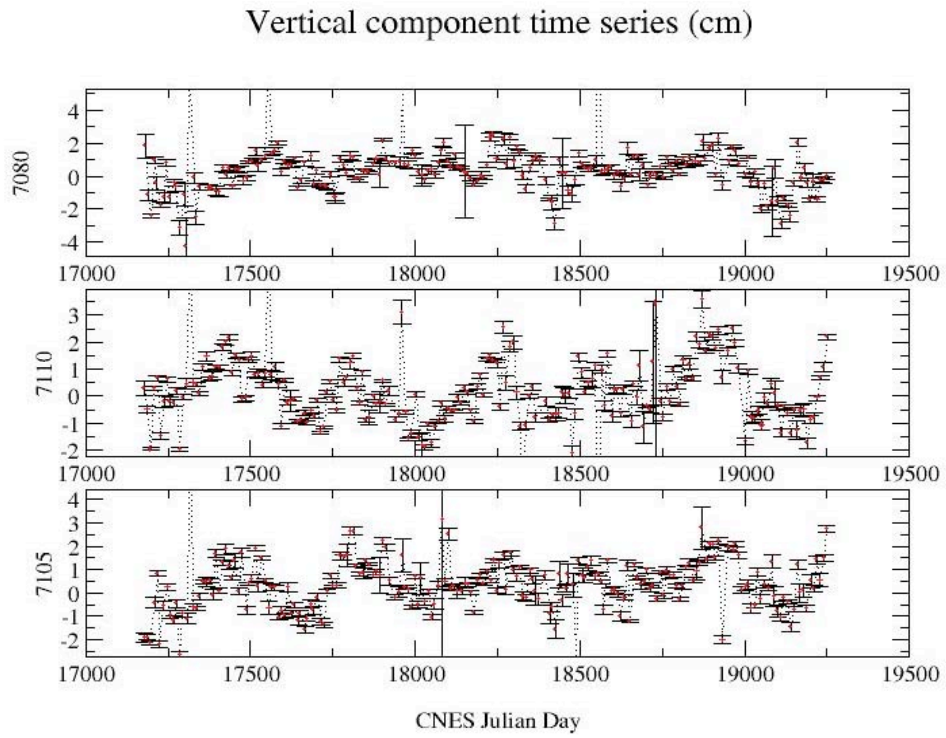

Figure 2. Vertical component time series. 7080: Mc Donald, 7110: Monument Peak and 7105: Greenbelt.

These time series still correspond to constant offsets over ten days. They clearly show periodical variations certainly linked to geodynamical phenomena such as loading effects. To better represent these physical signals and to reduce the average through the design matrix, we test alternative series such as periodical models or decompositions in wavelet basis. Range biases are also sources of inaccuracies on estimated station vertical components. To avoid for the great correlation (99%) between these biases and the vertical components, we use a method to “temporally decorrelate” these quantities. Indeed, biases are estimated over a month or more and station positions are still computed with a ten-day sampling. Moreover we estimate not one bias but a range bias per satellite. Doing this, correlations between biases and vertical components are not greater than 50%.

Conclusion and prospects

Our semi-dynamical method allows us to compute SLR station position time series with an accuracy of about 5 mm. We think that alternative models for station positions will allow us to reach a better accuracy and, furthermore, to give a better representation of geodynamical phenomena we are interested for. Another way to obtain this is to reduce the sampling of time series. We could so determine station positions by combining measurements on several satellites like LAGEOS-1 and -2 ("classical approach") and STELLA and STARLETTE (low geodetic satellites: altitude of about 800 km). The new challenge will then consist in reducing the orbital errors for STELLA and STARLETTE, which are greater than for both LAGEOS.

References

Altamimi, Z., Sillard, P. and C. Boucher, Journal of Geophysical Research, 107, B10, 2210-2214, 2002.

Coulot, D., Nicolas, J. and P. Exertier , Bulletin d'Information de l'IGN, 73, B14, 2002.

Crétaux, J.-F., Nouël, F., Valorge, C. and P. Jannière, Manuscripta Geodetica, 19, 135-156, 1994.

Mc Carthy, D.D., IERS Conventions, IERS technical note 21, 1996.

Nicolas, J., La Station Laser Ultra Mobile. De l'obtention d'une exactitude centimétrique des mesures à des applications en océanographie et géodésie spatiales, thèse de doctorat, 2000.