SF2A 2008
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LONG TIME SERIES OF THE LOW WAVELENGTHS OF THE EARTH'S GRAVITY FIELD, FROM SLR-ONLY DATA: 1992-2008

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Abstract. We use SLR data tracked by the ILRS network to derive long time series of the low wavelenghts of the Earths gravity field. The work is based on post-fit residuals analyses, performed with the computation of orbit of geodetic satellites (LA-1 and LA-2 in particular). Osculating orbital arcs are propagated over short periods of time and adjusted on tracking data. Normal matrices are deduced from that adjustment, and then mixed. We give here a time series of the J_2 and J_3 coefficients, where variations, to be analyzed by geophysicists, can be linked to mass transfer inside the Earth: post-glacial rebound, 18.6 year tide, El Niño Southern Oscillation events.

1 Introduction

As an official Analysis Center (AC) of ILRS, GRGS (Groupe de Recherche en Géodésie Spatiale) provides every week station positions, site velocities, Earth Orientation Parameters (EOP), deduced from a post-fit analysis of LAGEOS-1 and LAGEOS-2 orbits, adjusted on SLR data tracked by SLR stations. This is the prime objective of the International Laser Ranging System (ILRS) (Pearlman et al., 2002). In parallel, the group is currently developing an operational service providing time series of the low wavelenghts of the Earth's gravity field based on SLR data: even if methodological developments are still required to ensure the best decorrelation of the different parameters, the level of residuals is good enough, since many years, to enlighten in time series temporal variations linked to mass transfer within the terrestrial system.

In fact, SLR geodetic satellites are still extremely used to determine the very-long wavelengths part of Earth gravity field models, even since the launch of the GRACE mission in 2002. One of the first impressive results was given by (Yoder et al. 1983), enlightening the effects induced by the post glacial rebound on the orbit of LAGEOS-1. In 2008, geodetic satellites still give an unique information on some parameters of geophysical interest, such as time variations of the Earth's oblateness, which can be now determined over a very long period of time (about 30 years, in 2008). This long term history of the SLR measurements makes it possible for geodesists to determine the changes over time in polar ice sheets and sea level change. It is the part of astronomy for Earth's Sciences.

2 Post-fit analysis of Satellite Laser Ranging (SLR) Data

Five geodetic satellites were used in this study to derive time series of spherical harmonics coefficients: LAGEOS-1 and LAGEOS-2, but also ETALON-1, AJISAI, STARLETTE.

Figure 1 (resp. Figure 2) shows the estimated variations of $C_{2,0} = -J_2$ (resp. of $C_{3,0} = -J_3$) for each 10-day interval over the period 1992-2008, on the basis of a weighting procedure (ie the Helmert's method) using the SLR data avaiable during each orbital arc, propagated every week. Each figure contains as well a running average of the time series, in order to enlighten secular, tidal and seasonal variations of the coefficients.

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More than two coefficients of the geopotential have in fact to be routinely determined, to ensure the accuracy of the two first coefficients. Since we focuse only on the main temporal variations of the gravity field, they are not shown here.

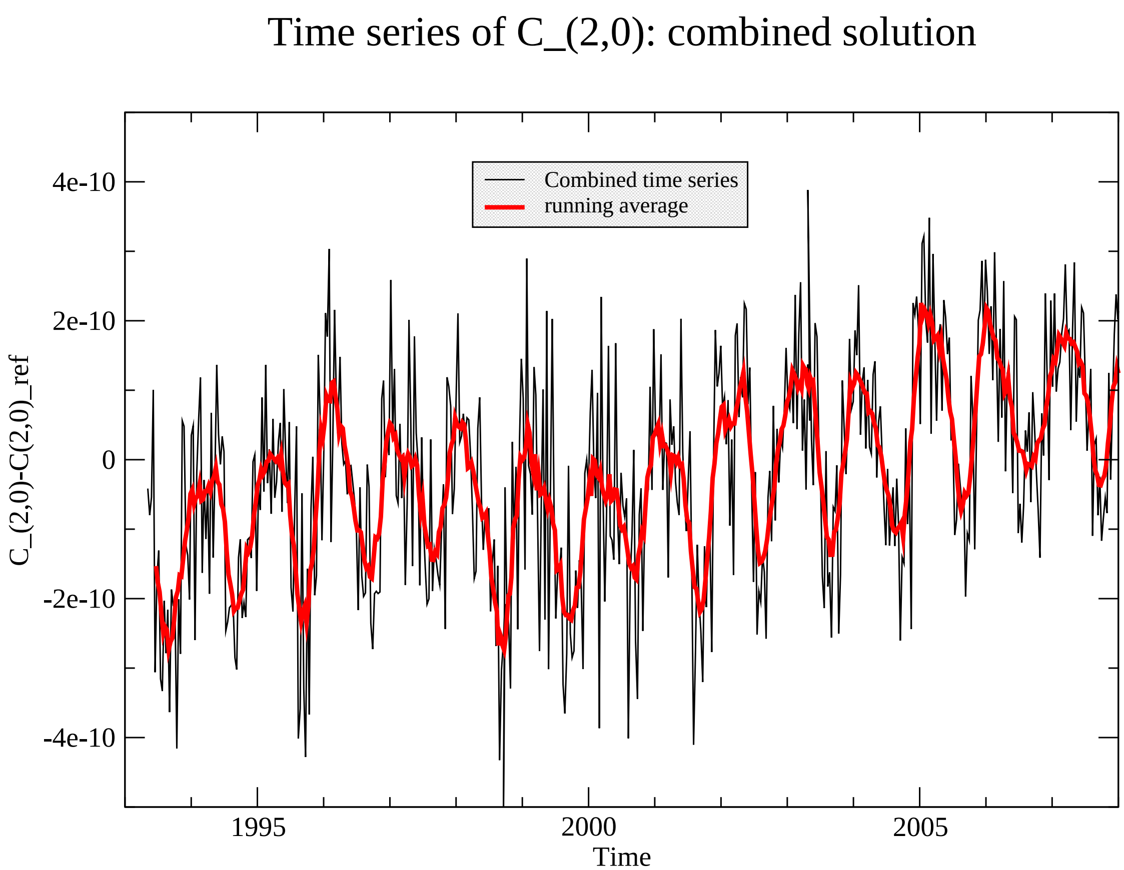

Fig. 1. Times series for the $C_{2,0} = -J_2$ coefficient.

3 A first analysis

The $C_{2,0} = -J_2$ and $C_{3,0} = -J_3$ time series contain a broad spectrum of signals.

Concerning J_2, the secular trend and annual variations appear to be the strongest. A large interannual variation is related to the strong El Niño Southern Oscillation event during the period 1996-2002, and was studied by many authors (in particular (Cazenave & Nerem 2002), (Cox & Chao 2002), and, in the framework of mean orbital motion (Deleflie et al. 2003)).

As far as the J_3 time series is concerned, a secular and an annual part should have been expected as well, but, it seems not to be the case. In particular, the strong variations during the 1998 El Niño Southern Oscillation event suggest that most of the signal induced on J_3 corresponds to a mass redistribution linked to such events. A detailed study devoted to a possible correlation will be the subject of a forthcoming paper. Nevertheless, such a correlation seems to be visible with naked eye between the $C_{3,0} = -J_3$ time series, and the Sea Level Anomaly shown Figure 3. Moreover, on the basis of the $C_{3,0} = -J_3$ time series, it is not reasonable to try to

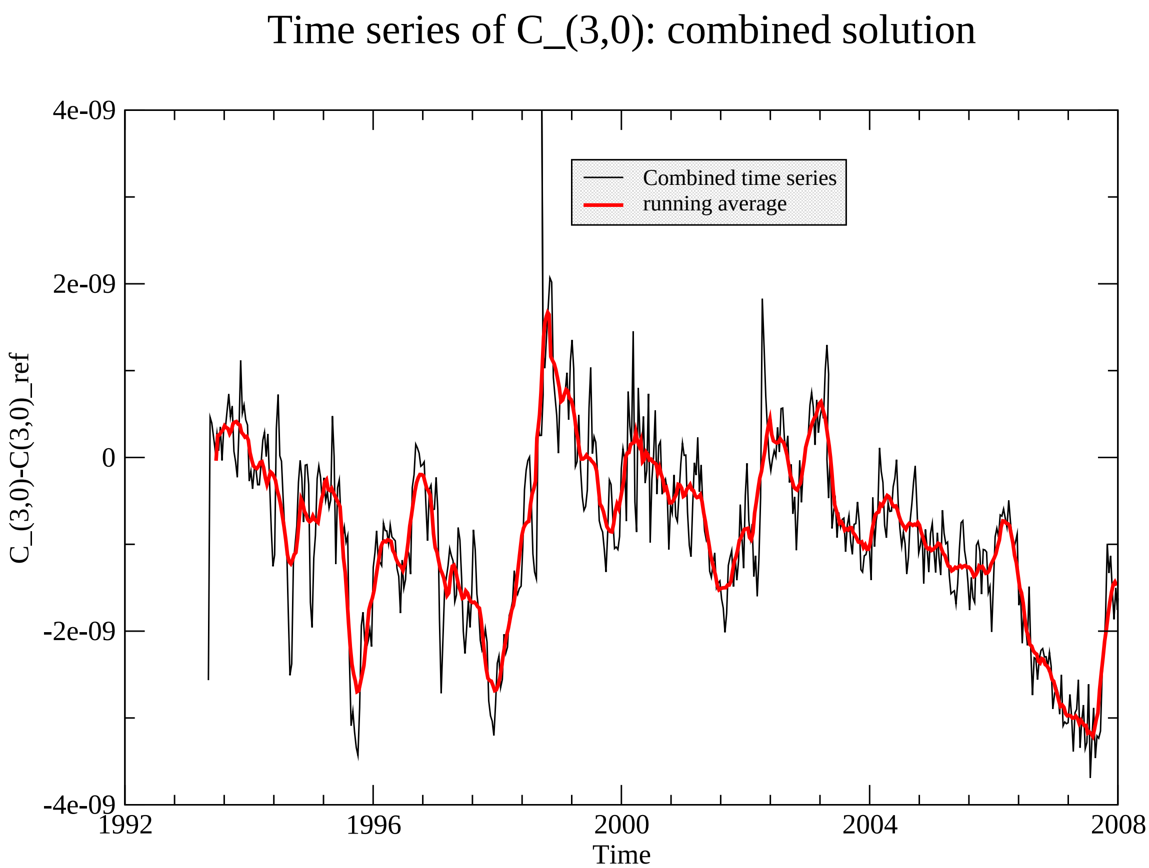

Fig. 2. Times series for the $C_{3,0} = -J_3$ coefficient.

determine a coefficient $\dot{J}_3$, standing for a secular variation of J_3.

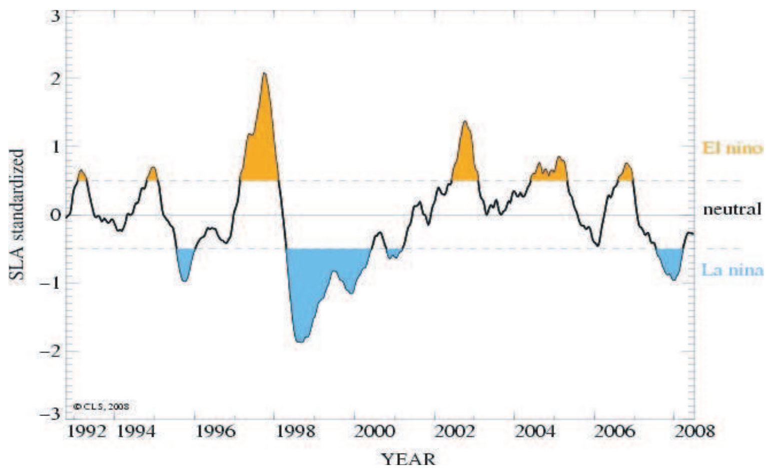

Fig. 3. El Niño and La Nina Southern Oscillation events, deduced from sea level anomaly (SLA), from 1992 to 2008. From http://www.aviso.oceanobs.com/

4 Conclusion

As a conclusion, SLR geodetic satellites still gives an information on temporal variations of the gravity field with a high level of quality, and it is likely to continue over the next years. These variations, as well as those of the main tesseral coefficients, should be used as a constraint in geophysical models.

These time series have to be analyzed in terms of mass transfer within the system Earth, even over a longer period of time. Such an analysis will aim at carefully determining, over 30 years, the 18.6 year tide, the 9.3 year tide, and other periods, such as an interannual cycle suggested by (Cheng & Tapley 2002) which started in 2002, and the secular variation. What happens for odd coefficients will be very challenging, even more than for even coefficients, whose variations are well known.

We should reinforce the role played by the SLR technique among other ones to permanently observe the Earth and its space environment. Because of the limitations in coverage due to weather conditions and anisotropy of the laser network, it is not possible to compare the SLR technique to GNSS, for example. But, they are complementary, for the determination of terrestrial reference frames as well as for the deterination of the gravity field.

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