A MULTI-YEAR SLR SOLUTION

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Abstract

The global Satellite Laser Ranging (SLR) network is fundamental for the realization of the origin (centre of mass) and scale of the terrestrial reference frame. Hence a continuous evolution and improvement of the SLR station coordinates is necessary. Based on SLR tracking data to LAGEOS-1 in the period from January 1981 until May 2004 and LAGEOS-2 in the period from October 1992 until May 2004, a new set of SLR tracking station coordinates and velocities was computed. The basis for the computations were weekly single satellite arcs, which were accumulated to the final solution. Since periodic signals and episodic effects influence the estimation of station positions and velocities we focused on the determination of these non-linear effects in the weekly position time series. Additionally we solved for low degree spherical harmonic coefficients of the Earths gravity field. This paper presents some results from the homogeneously reprocessed twenty-years SLR solution from January 1985 until November 2004.

Introduction and motivation

SLR data to LAGEOS-1 and LAGEOS-2 are a fundamental basis for the establishment and maintenance of a precise terrestrial reference frame. The latest models (e.g. IERS Conventions 2003, McCarthy and Petit, 2004) allow a more precise modelling of the orbital errors. Therefore we have reprocessed all LAGEOS tracking data back to 1981 using the latest version of the DGFI developed software package DOGS (DGFI orbit and geodetic parameter estimation software). More information on the DOGS software is available from http://ilrsac.dgfi.badw.de/dogs/index.html. On the basis of weekly arcs we processed a first solution using 5 years of data (January 1999 – May 2004) to test the new models and to get better estimates for the new SLR tracking stations, which was presented at the ILRS Workshop in San Fernando. Meanwhile we have included data since 1984 (the data before 1984 are significantly less precise, see figure 4) and we have computed a multi-year solution from January 1985 until November 2004. The extended time span significantly improves the velocity estimations for the SLR stations.

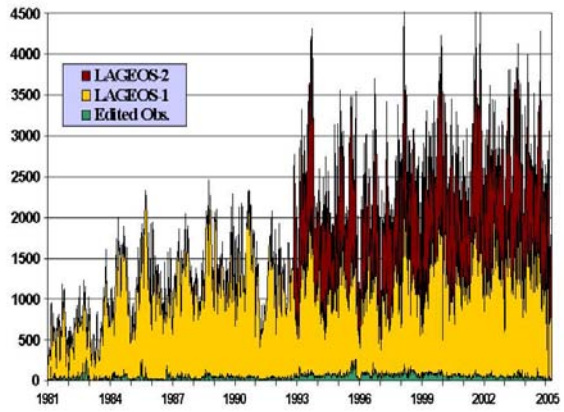

Figure 1: Number of normal points

A major goal of the reprocessing is to compute a consistent multi-year solution, which can serve as reference for various issues, such as the bias estimation for the tracking stations, the operational weekly computations and combinations of SLR solutions within the ILRS, the weekly inter-technique combination in the framework of the IERS Combination Pilot Project,

and for the computation of a refined terrestrial reference frame (see Angermann et al., 2004, Meisel et al., 2004). It is well-known, that the ITRF2000 does not include the newer SLR tracking stations, and furthermore for some stations the ITRF2000 position and velocity estimations are unreliable.

Data processing

We started the processing on the basis of weekly single satellite arcs using models and standards according mostly to the IERS Conventions 2003. We included all SLR data available, also those of stations with poor tracking quality to get a complete SLR network solution. The number of used normal points varies around 1000 to 1500 per satellite and arc from 1985 over the whole period with some fluctuations (see figure 1). Some peeks indicating intensive tracking campaigns can be identified. These weekly arcs were used to detect outliers and biases. During the processing of the weekly arcs we solved for:

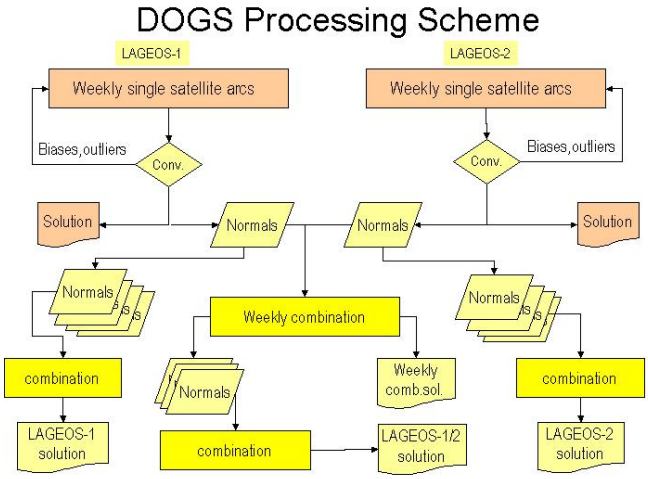

Figure 2: Processing of DGFI SLR solutions

- 6 orbital elements
- 1 revolution dependent parameter (cross and along track)
- 3 empirical along track parameters
- 3 solar radiation pressure parameters
- daily earth orientation parameters
- station coordinates
- potential coefficient J2
- significant pass dependent range and time biases.

The computation of the weekly single arcs was done with the DOGS-OC (orbit computation) module, the processing scheme is outlined in figure 2. The number of biases (either range or time biases) per week is shown in figure 3. In most cases there are only between 5 and 10 biases, with a few weeks containing more than 25. Nearly all biases are not from the core stations. We produced time series of station coordinates to verify the stability of the weekly solutions and to identify non-linear effects (e.g. peridoic signals and discontinuities). Thereby we eliminated stations with less than 10 weeks of tracking and some outliers in the time series. In a final step the weekly normal equations were accumulated to a multi-year solution containing station coordinates and velocities using the DOGS-CS (combination and solution) module. For quality control we computed independent LAGEOS-1 and LAGEOS-2 solutions and a combined solution as the final result, which was compared to the single satellite solutions.

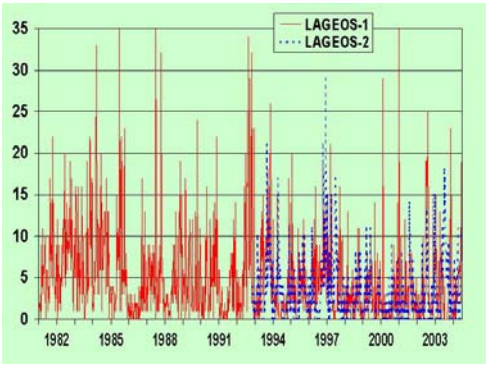

Figure 3: Number of weekly biases

Results

Figure 4 shows the r.m.s. fit of the weekly arcs over the entire data time span. During the first years (1981-1984) the tracking precision improved rapidly. Until 1993 the accuracy level was about 2-3 cm. Since the launch of LAGEOS-2 the 1 cm level was nearly reached, but for some weeks the accuracy was degraded probably due to tracking problems of some stations. Since about 2000 all stations have reached a high tracking performance, so the weekly r.m.s. is below 1 cm for both satellites.

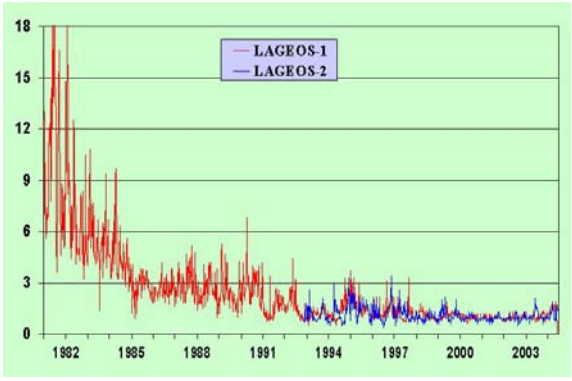

Figure 4: Weekly r.m.s. fit

As a result of the reprocessing two time series for the geopotential coefficient J_2 were generated. Figure 5 shows the weekly estimated J_2 values (relative to J_2 = 0.0010826) independent for LAGEOS-1 and LAGEOS-2. The higher scatter before 1985 can clearly be seen, which is in accordance with the worse orbit precision (see figure 4). In general there is a good agreement between the estimates of both satellites. However, the higher noise after 2000 for LAGEOS-1 and the discontinuity in the year 2000 is not yet clear and subject of further investigations.

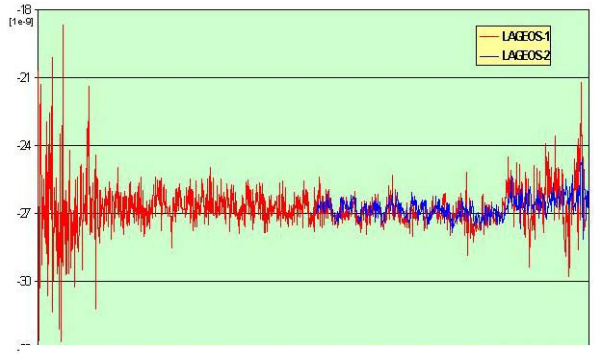

Figure 5: J2 values relative to 1.0826e-03

The time series of station coordinates proved the high stability of the weekly solutions. As an example the time series for Yarragadee, Australia, a station with long tracking history is shown (see figure 6). Each weekly solution has been transformed to the combined SLR solution, using 7 parameter similarity transformation. The offsets in X- Y- and Z-direction are a measure for the stability of the underlying reference frame. The results reflect common (global) variations of the network origin of the weekly SLR solutions w.r.t. the multi-year solution, and are sensitive to the network geometry and to changes of the selected stations used for the transformations. Figure 7 shows the translation parameters for the weekly arcs compared to the combined solution over the whole period.

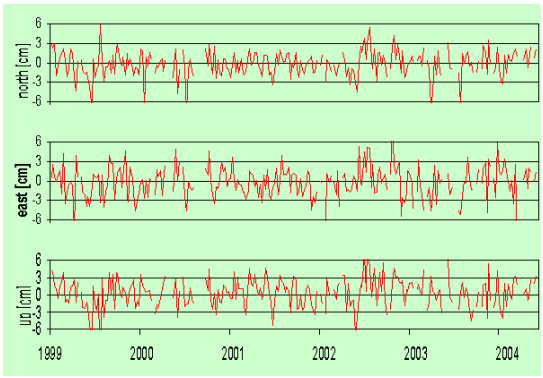

Figure 6: Time series of Yarragadee

Finally the SLR solution was compared with ITRF2000 (Altamimi et al., 2002; Boucher et al., 2004). As an example figure 8 shows the station velocities of both TRF realizations in Europe and parts of Asia. For most of the stations there is a quite good agreement. However there are

some stations with large discrepancies. The Riyad station for example has an improved velocity estimation in this SLR solution, ITRF2000 has only a few weeks of observations.
More results of the combined solution as well as the weekly SLR solutions since 2004, as part of the ILRS analysis working group project, are available from DGFI-Homepage at http://ilrsac.dgfi.badw.de.

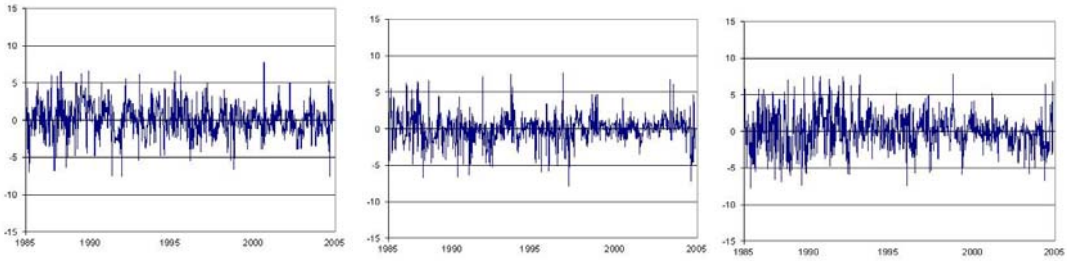

Figure 7: Transformation parameters in x, y and z of the weekly solutions in centimetre

Conclusion and Outlook

This homogeneously reprocessed twenty-years SLR solution includes station positions and velocities of nearly all SLR stations operating since 1984. It serves as a fundamental basis for various scientific issues and in particular for the realization of a refined terrestrial reference frame. Only 1 to 2 per cent of the over all tracking data were edited, see figure 1, which proves the quality of the used models. Using weekly arcs as basis for multi-year solutions helps to detect data problems and outliers and allows to identify periodical signals and discontinuities in the station positions, which are not properly considered (modeled) in recent realizations of the terrestrial reference frame, such as the ITRF2000.

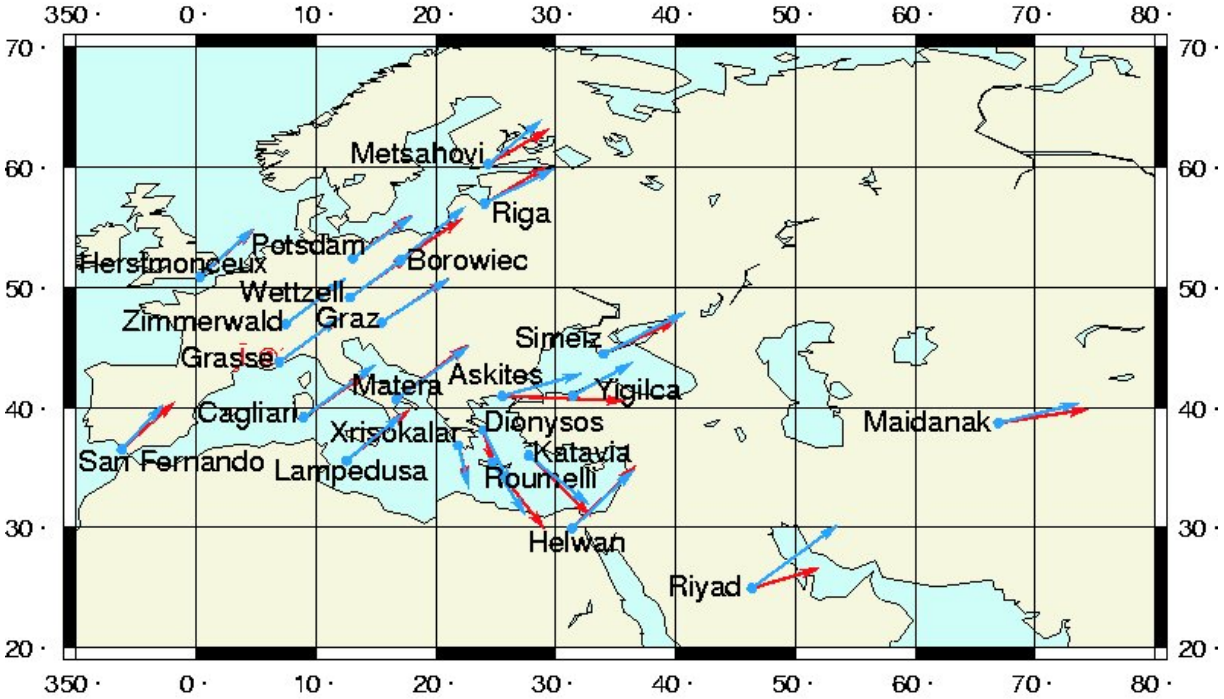

Figure 8: Some station velocities in Europe and parts of Asia (DGFI blue, ITRF2000 red)

We will also add the years 1981 to 1984 to this solution to get better velocities for those stations observing only in the early 80's and we will include ETALON1/2 and recent LAGEOS1/2 tracking data. In response to the call for submission of input data for a new ITRF2004 solution, which has been released by the end of the year 2004, we have provided weekly SLR solutions from January 1993 until the recent week containing station positions and daily Earth orientation parameters according to the guidelines from the ILRS/AWG.

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