LAGEOS-ETALON solutions using the Bernese Software

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ABSTRACT

During the last three years, the Bernese Software has been extended with the capability to analyze SLR data to geodetic satellites, e.g., LAGEOS and ETALON. SLR data to LAGEOS and ETALON have been processed to obtain weekly solutions including station coordinates, satellite orbits, Earth rotation parameters (ERPs) and range biases.

Different a priori models and parameterization are used in the analysis and their impact on the weekly solutions is studied. The models of interest are, e.g., ocean tidal loading (OTL) or atmospheric tidal loading (ATL). The impact of OTL was found to be larger than the impact of ATL. The differences in the LAGEOS orbits are at the level of 4 mm and 1 mm when ignoring OTL or ATL, respectively.

In addition, different parameterizations of the ERPs have been tested and compared: the standard ILRS parameterization using constant pole offsets per day (resulting in jumps at the day boundaries), and the piece-wise linear parameterization used in the Bernese Software for the GNSS solutions (including continuity at the day boundaries). When comparing with the IERS-08-C04 series, the RMS of the differences is smaller by almost 10% if a piece-wise-linear parameterization is chosen for the ERPs instead of a piece-wise-constant parameterization.

1 Introduction

The Bernese Software (Dach et al., 2007) recently has been extended with the capabilities of analyzing SLR observations to spherical satellites, e.g., LAGEOS and ETALON satellites. We processed five years of data to these satellites (2006 - 2010) and generated weekly solutions following the recommendations of the ILRS Analysis Working Group (AWG). The observations to LAGEOS and ETALON are weighted against each other by a factor of 9 using a priori sigmas for the observations of 1 cm and 3 cm, respectively.

SLR station coordinates are estimated together with satellite orbits for LAGEOS and ETALON, daily Earth Rotation Parameters (ERPs), i.e., polar motion and universal time / length of day (LOD), as well as range biases for a few selected SLR sites.

The weekly satellite orbit is represented by six osculating elements valid at the first epoch of the weekly arc, and five empirical parameters: a constant acceleration in along-track direction, and once-per-revolution accelerations (represented as sine and cosine terms) in along-track and cross-track direction. The empirical parameters are valid for the entire orbital arc of 7 days.

2 Impact of a priori models

A priori models have a big impact on the solution generated. As the orbits of spherical satellites like LAGEOS and ETALON can be modeled rather simple so that only a few empirical parameters have to be estimated (see Sec. 1), the SLR solutions are well suited to test the impact of several a priori models.

The impact of different Earth's gravity field models on the LAGEOS solutions has been presented by Jäggi et al. (2011).

The impact of applying or ignoring ocean tidal loading (OTL) and atmospheric tidal loading (ATL) is analyzed for weekly solutions of the year 2008. The weekly RMS of the observation residuals are displayed in Fig. 1 (left). Comparing the different solutions reveals that ATL has almost no impact on the solution, whereas omitting OTL slightly decreases the quality of the solution, i.e., about 10% of the RMS value itself.

We also studied the impact of OTL and ATL on the estimated LAGEOS orbits and compared the orbits with each other. Taking the orbit of the solution with both, i.e. OTL and ATL, applied as a reference, Fig. 1 (right) shows the RMS of the orbit differences for each weekly comparison. Table 1 summarizes the median of the weekly RMS values of the orbit comparisons for the entire year. Generally speaking, the impact of OTL and ATL in terms of RMS of orbit differences are at the level of several millimeters. Similar to the RMS of the observation residuals, the impact of ATL on the resulting orbits is clearly smaller than the impact of OTL, i.e., about 1 mm and 4.5 mm, respectively.

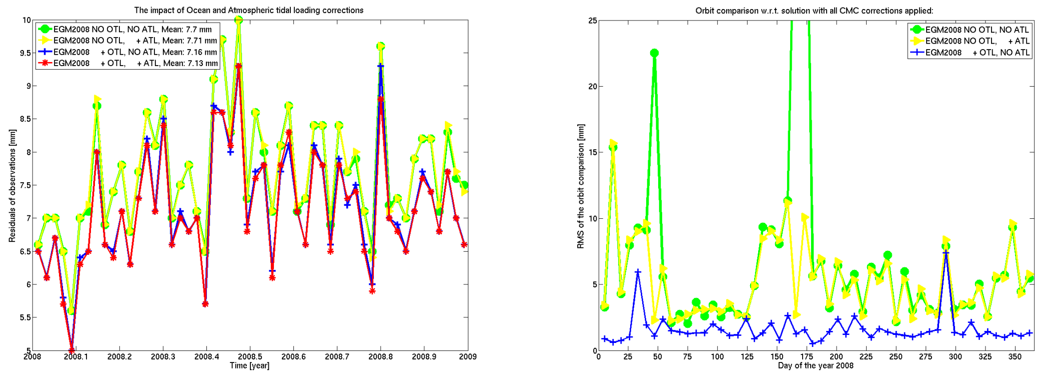

Figure 1: Impact of ocean and atmospheric tidal loading on the SLR solutions. Left: RMS of the observation residuals; Right: RMS of orbit comparison w.r.t. the solution with OTL and ATL applied.

	No OTL, + ATL	+ OTL, No ATL	+ OTL, + ATL
No OTL, No ATL	1.17	4.43	4.96
No OTL, + ATL		4.06	4.54
+ OTL, No ATL			1.33

Table 1: Impact of ocean and atmospheric tidal loading on the SLR solutions: Median values of RMS of orbit differences for weekly orbit comparison (given in [mm]).

3 Impact of different parameterizations of ERP

We tested different parameterizations for the ERPs. First, the standard parameterization as it is used within the ILRS AWG was chosen, i.e., piece-wise-constant daily polar motion estimated, fixed UT1-UTC values and daily LOD estimates. The disadvantage of this parameterization is that the resulting time series of ERPs have discontinuities at the day boundaries, whereas the orbit is parameterized as continuous arc over the entire week. Therefore, a second parameterization was chosen: piece-wise-linear (PWL) with offset and drift parameters per day for polar motion and UT1-UTC and additional continuity conditions at the day boundaries. The first value of UT1-UTC is fixed to the IERS-08-C04 series. This type of parameterization is similar to that used in the GNSS data analysis at the IGS Analysis Center CODE (Center for Orbit Determination in Europe).

The comparison of both SLR-based polar motion series w.r.t the IERS-08-C04 series is shown in Fig. 2, and the corresponding mean and weighted RMS values are given in Table 2. The comparison is done for the epochs at 12:00 UTC. It can be seen that the agreement with the IERS-08-C04 series is slightly better for the SLR-derived polar motion series using the piece-wise-linear parameterization than the piece-wise constant parameterization.

Additionally, a polar motion series based on microwave GNSS observations is compared to IERS-08-C04. The GNSS series results from the weekly analysis performed at the IGS analysis center CODE. The ERPs are parameterized as piece-wise-linear polygons with polygon values estimated at 00:00 UTC. For the comparison with IERS-08-C04, the polygon values are interpolated to the epochs 12:00 UTC. We can see from Fig. 2 as well as from Table 2 that the polar motion series derived from GNSS observations is much more stable than the polar motion series based on SLR data. The difference is about a factor of 10 in terms of RMS.

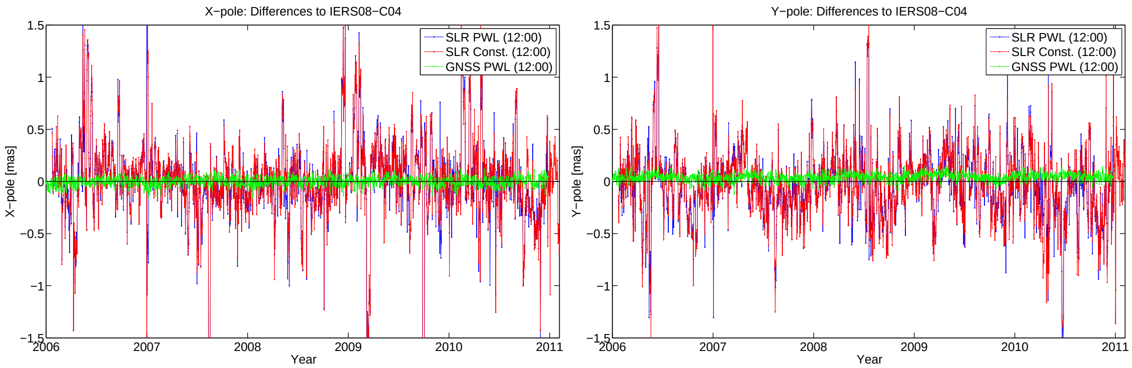

Figure 2: Comparison of polar motion derived from SLR and GNSS solutions with the IERS-08-C04 series at 12:00 UTC epochs. Left: X-pole; Right: Y-pole.

		LAG+ETA: constant ERP	LAG+ETA: pwl ERP	GNSS: pwl ERP
Mean Bias	**X-pole [µas]**	13.8	-4.1	-0.1
	Y-pole [µas]	-37.7	-41.4	40.5
Weighted RMS	**X-pole [µas]**	459.9	428.9	41.0
	Y-pole [µas]	371.3	334.7	36.6

Table 2: Comparison of polar motion derived from SLR and GNSS solutions with the IERS-08-C04 series at 12:00 UTC epochs: Mean bias and weighted RMS.

4 Impact of ETALON observations on ERP

The number of SLR observations to ETALON satellites is clearly smaller than to LAGEOS, i.e., in average the amount of ETALON observations is only about 10% of the amount of LAGEOS data. But due to different orbital characteristics of the ETALON satellites, they could stabilize the ERP estimates. Therefore, we wanted to study the impact of the ETALON observations on the ERP time series. For the comparison of the ERP series derived from LAGEOS-only solutions and the ERP series derived from combined LAGEOS+ETALON solutions we choose the piece-wise-linear parameterization as explained and analyzed in Sec. 3.

The differences for the polar motion and LOD estimates are shown in Fig. 3. As expected, the impact of the ETALON observations on LOD is larger than the impact on polar motion. The mean difference in the polar motion time series is negligible, although the differences can reach up to 0.1 mas for some epochs. The differences in LOD seem to be rather systematic with a mean bias of about 0.348 ms/d.

5 Conclusions

The impact of a priori models for ocean and atmospheric tidal loading has been tested for weekly LAGEOS solutions of the year 2008. We found that neglecting OTL slightly degrades the solution by increasing the RMS of the observation residuals by about 10%, whereas there is almost no negative impact on the RMS seen when neglecting ATL. The differences in the estimated orbits are at the level of several millimeters when neglecting OTL or ATL, with OTL having a bigger impact on the orbit.

Concerning the ERP derived from SLR solutions we studied several aspects: the comparison of the SLR-derived ERPs with the IERS-08-C04 series, the impact of different parameterizations for the ERPs and the impact of ETALON observations on the ERP estimates.

We have seen an agreement of the SLR-based polar motion series with IERS-08-C04 at the level of 0.3 – 0.4 mas in terms of weighted RMS. The RMS of the differences w.r.t. IERS-08-C04 is smaller by almost 10% if a piece-wise-linear parameterization is chosen for the ERPs instead of a piece-wise-constant parameterization.

A systematic impact on the LOD estimates is seen when additionally including ETALON observations. The polar motion series shows no systematic differences between LAGEOS-only and combined LAGEOS-ETALON solutions.

We intend to extended the time series of combined LAGEOS-ETALON solutions in order to approve the findings described in this contribution.

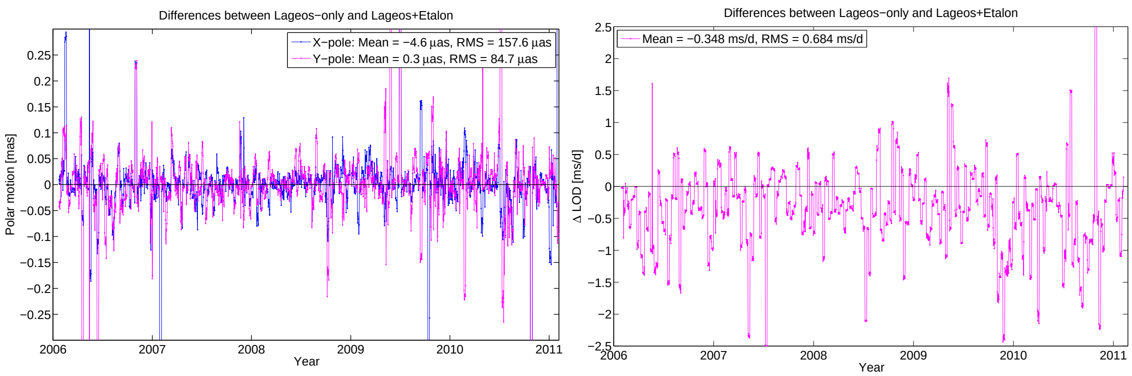

Figure 3: Comparison of ERP derived from LAGEOS-only solutions and combined LAGEOS+ETALON solutions. Left: Polar motion; Right: LOD.

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References

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