Low-degree gravity field coefficients from SLR data for the new combined gravity field model GOCO02S

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Introduction

A new global gravity field model–GOCO02S [1]–is to be computed by combining recent GOCE observations with GRACE, CHAMP, SLR, altimetric and terrestrial data sets. This contribution deals with the determination of the very long wavelengths (low degrees) of the Earth's gravity field, which has been accomplished by means of precise orbit determination (POD) of five dedicated SLR satellites. POD and gravity field parameter estimation have been performed with the GEODYN-II [2] and SOLVE software packages.

Satellite Data

The data set consists of normal points (NPs) gathered over a period of five years (2006 to 2010) to five satellites, namely Ajisai, LAGEOS 1 and 2, Stella and Starlette [3]. Their technical and physical parameters and orbital characteristics are summarized in Table 1.

	LAGEOS 1	LAGEOS 2	Ajisai	Stella	Starlette
ID number	7603901	9207002	8606101	9306102	7501001
Launch date	May 1976	Oct 1992	Aug 1986	Sep 1993	Feb 1975
Technical and physical parameters					
Shape	spherical	spherical	spherical	spherical	spherical
Diameter [cm]	60	60	215	24	24
Weight [kg]	407	405	685	48	48
Area to mass ratio [cm^2/kg]	7.0	7.0	53.0	9.4	9.4
Orbital parameters					
Inclination [°]	110	53	50	99	50
Eccentricity [-]	0.005	0.014	0.001	0.206	0.206
Perigee [km]	5 860	5 620	1 490	800	812
Period [min]	225	223	116	100	100
Altitude [km]	5 850	5 625	1 485	815	800

Tab. 1: SLR satellite characteristics

Figure 1 illustrates the spatial coverage of NPs over one day and one month, respectively. As a consequence of the SLR station distribution, there are large data gaps over oceanic areas and polar regions. Additionally, the SLR station network is less dense in the southern than in the northern hemisphere.

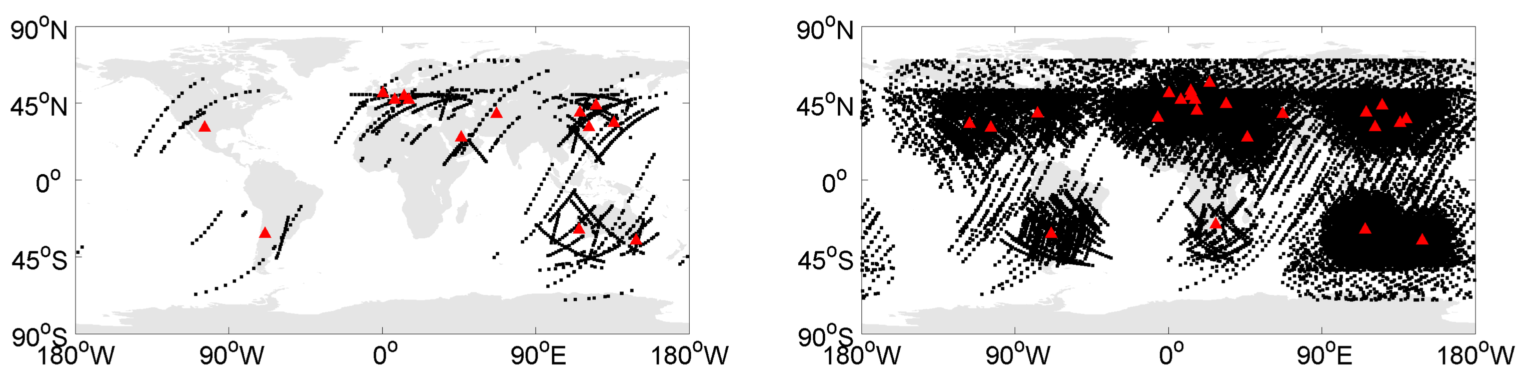

Fig. 1: Observed ground tracks of all five satellites (black squares) during one day (left) and one month (right). Red triangles highlight the involved SLR stations.

Closed-loop Simulation

We conducted a series of closed-loop simulations with EGM2008 as the 'true' model to demonstrate up to which degree and order the gravity field can be resolved by SLR. Noise-free ranges to five satellites (see Table 1) have been generated. Figure 2 shows the reproduced number of digits without leading zeros using one and twelve months of data, respectively. One can see that SLR is especially sensitive to C_{20}, and that a slightly better performance can be achieved by the extended time span. Data of other months provide similar results, suggesting that the inter-annual variation of C_{20} is in the order of 10^{-10}.

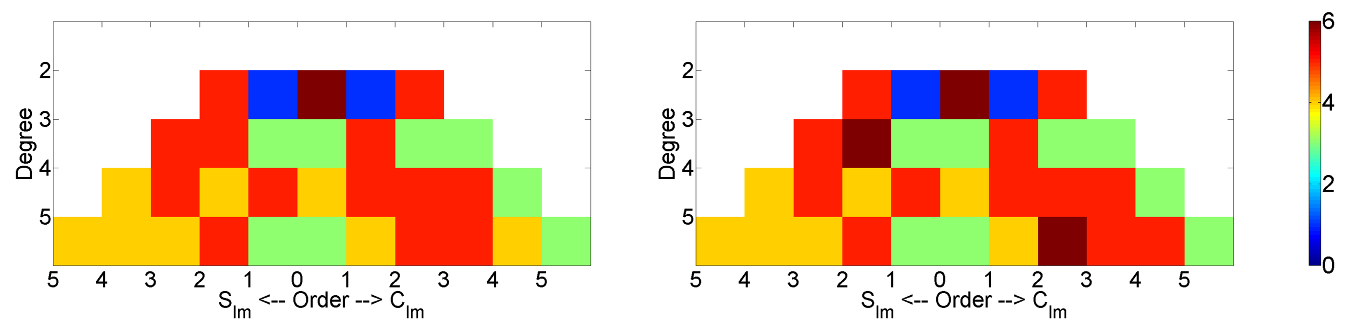

Fig. 2: Number of reproduced digits without leading zeros w.r.t. EGM2008 based on data collected over one month (left) and twelve months (right).

Parameter Settings

The time span of five years has been subdivided into monthly arcs. From data of each arc, a set of arc-dependent parameters such as drag and solar radiation pressure has been estimated. A combination of these arcs yields the global parameters, i.e. gravity field coefficients and station coordinates. The complete list of estimated parameters can be found in Table 2. EIGEN-5S served as a priori gravity field model.

Measurement model
Observations: 120s NPs to LAGEOS and 30s NPs to Ajisai, Stella and Starlette
Tropospheric refraction: Marini-Murray model
Data weighting: 1.0m
Editing criteria:
3.5σ per arc
Cut-off elevation angle of 20°
Minimum number of NPs per station and arc: 50
Estimated parameters
State vector: once per arc
Solar radiation pressure coefficient: once per day
Atmospheric drag coefficient: once per day
Constant acceleration along track, cross track and radial: once per day
Measurement bias: once per station and arc
Gravity field coefficients up to degree and order 5
Station geocentric coordinates

Tab. 2: Measurement model and estimated parameters

Results

One indicator for the precision of the POD process is the RMS of range residuals ($o - c$). The mean RMS over five years for each satellite is listed in Table 3. Due to the long arcs varying between 28 and 31 days, it is not surprising that the fits are at the centimeter level.

	LAGEOS 1	LAGEOS 2	Ajisai	Stella	Starlette
RMS [cm]	4.5	3.9	7.6	10.7	10.3

Tab. 3: Mean RMS of orbital fit

To detect temporal variations, one set of coefficients has been estimated for each month. Annual, semiannual and secular variations of C_{20} are clearly visible in Figure 3 and are indeed in the range of 10^{-10}, as the outcome of the simulation indicates. In order to match the reference epoch of the coefficients estimated from GRACE data, the C_{20} term has been extrapolated to January 1, 2005. The estimated standard deviations of the other coefficients are slightly larger than those resulting from other measurement types.

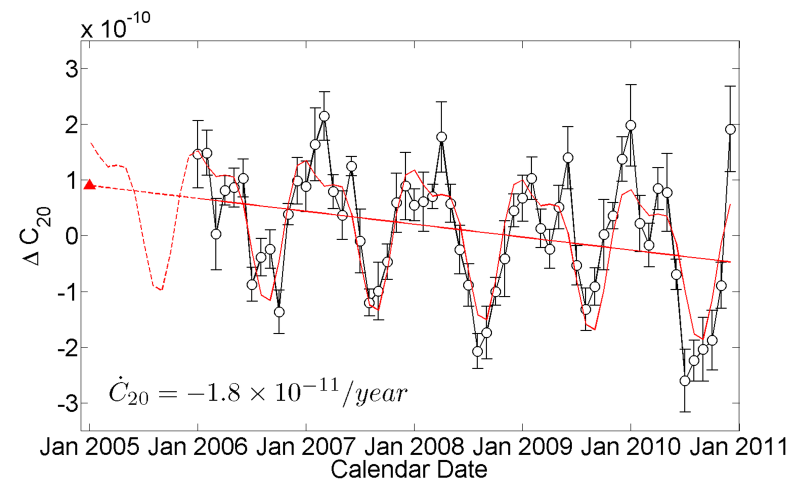

Fig. 3: Monthly values of ΔC_{20} w.r.t. EIGEN-5S (black circles) with standard deviations (black error bars). The variation has been fit by a regression line (straight red line) together with annual and semiannual sinusoids (curved red line). The coefficient has been extrapolated (red triangle) along the extrapolated regression line (dashed red line) to January 1, 2005.

Conclusion & Outlook

SLR data is particularly sensitive to C_{20}. The coefficients of higher degree and order can be detemined more precisely by other measurement techniques. The precision can be increased by including more satellites at different inclinations (e.g. Etalon). Alternatively, it would be worthwhile to extend the time series to further confirm the secular trend.

References

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[3] M Pearlman, J. J. Degnan, and J. M. Bosworth. The International Laser Ranging Service. *Advances in Space Research*, 30(2):135–143, July 2002.

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