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Long-term gravity field changes from SLR data and the combination with GRACE for improving low-degree coefficients

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In recent two decades, monitoring of changes in the Earth's gravity field has been carried out mainly by the Gravity Recovery And Climate Experiment (GRACE) and its successor GRACE Follow-On. However, before the GRACE era, very little information is available on the temporal evolution of the Earth's gravity field prior to that date. Moreover, through these missions, we have many gaps between 2010 and 2019. Fortunately, GRACE and GRACE Follow-On are not the only missions that can be used to recover variations in the Earth's gravity field. For the recovery of the mass redistribution processes on a large scale, we may employ precise Satellite Laser Ranging (SLR) observations.

We propose a set of long-term, continuous solutions based on SLR data. In our solutions, we use observations from spherical geodetic satellites. The gravity field is expanded up to a degree and order 10 with a monthly resolution from 1/1995 to 10/2021. The main solution has been decomposed into solutions expanded to degree and order 4, 6, 8, and 10 and stacked, taking advantage of the stability of the low-degree expansion and the better resolution of the high-degree expansion. The results show the reduction of the correlations between obtained parameters, stabilization of the ice mass estimates in polar regions – in Greenland and Antarctica, and a reduction of the noise over oceans by a factor of four.

In the GRACE and GRACE Follow-On datasets, the replacement of the spherical harmonics C_{20} and C_{30} with SLR-derived data is necessitated by suboptimal quality resulting from thermal effects impacting satellites and accelerometer malfunctions. In both SLR and GRACE solutions, coefficients of the same order and parity exhibit strong correlations. Merely replacing two specific coefficients could introduce bias into the solution. Therefore, we propose a comprehensive approach, combining GRACE with SLR solutions up to a degree and order of 10x10. This strategy ensures a proper consideration of the sensitivity of each technique to gravity field coefficients. The combined solution exhibits reduced noise compared to standard GRACE COST-G solution and effectively address the distinct sensitivities of SLR and GRACE techniques to low-degree time-variable gravity field coefficients.