Motivation: Satellite gravimetry allows to study mass displacements in the Earth system on the basis of observed gravity field changes. These mass variations as derived from the dedicated gravity field mission GRACE and Satellite Laser Ranging (SLR) can be used as an information source about mechanisms of polar motion excitation. Polar motion excitation series are mostly determined from geometric space observations and modelled mass variations in the Earth’s subsystems. Here we discuss the potential of satellite gravimetry for studies of the underlying physical processes in the Earth system by computing time series of the mass-related part of the excitation functions from observed gravity field changes. The results are compared with geometrically observed and modelled excitations. Since geometrical space geodetic methods are sensitive to the integral effect of mass redistribution and motion, the motion component is reduced using models prior to our comparisons. The analysis strategy is shown in Fig. 1.

Comparison: All time series agree quite well with respect to signal characteristics and amplitudes (Fig. 2). In Fig. 3 the RMS differences and correlations of the gravimetric and modelled mass excitation series are compared with the mean of the geometrical solutions (reduced by modelled motion effects). While RMS differences and correlations for gravimetric and modelled excitations are in a similar range in the case of \( \chi_1 \), the model time series perform better in the case of \( \chi_2 \) where the respective RMS differences are smaller.

Combination: An adjusted set of gravimetric mass excitation functions is computed from the individual solutions GFZ RL04, CSR RL04, JPL RL04, ITG-Grace03, GRGS and SLR. The time series are weighted according to the corresponding RMS differences (Fig. 3, left) w.r.t. the mean of the two geometrical solutions. The adjusted time series show higher agreement with the geometric solutions than any of the individual gravimetric or modelled excitation series (cf. the dark blue bars in Fig. 3).

Conclusions: The weighted adjustment of several gravimetric solutions for polar motion mass excitations significantly increased the concordance with geometrically determined excitations. The agreement between the adjusted solution and the geometric time series is clearly better than the agreement between the geophysical model solutions and the geometrical observations.

Of course the models used for the reduction of the motion term from the geometrical observations are not free of errors either. But nevertheless the study reveals the importance of gravimetical methods for the analysis of polar motion observations: Satellite gravimetry allows for an independent quantification of the mass generated fraction of the observed polar motion excitations which appears to be more reliable than geophysical models.

Fig. 1: Three different computation strategies for the mass-related part of the polar motion excitation functions and the datasets which are applied throughout this study.

Fig. 2: Comparison of polar motion mass excitation functions determined from geometric observations reduced by modelled motion effects, gravimetric observations (GRACE, SLR) and geophysical models. For each method at least two solutions are shown.

Fig. 3: RMS differences (left) and correlations (right) of the individual gravimetric, modelled and adjusted gravimetric results w.r.t. the mean geometric solution for the mass-related part of the polar motion excitation functions.

Acknowledgments: The authors thank J.-M. Lemoine, R. Schmidt and T. Mayer-Gürr for providing gravity solutions from GRACE and LAGEOS data. NCEP Reanalysis data was provided by the NOAA/OAR/ESRL PSD. ECCO data is a contribution of the Consortium for Estimating the Circulation and Climate of the Ocean.