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Separation of atmospheric, oceanic and hydrological polar motion excitation mechanisms by a combination of geometric and gravimetric space observations

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Redistribution and motion of masses within and between the individual subsystems of the Earth cause variations of the orientation of the Earth axis with respect to an Earth-fixed reference frame (polar motion and length-of-day variations). Whereas the integral effect of Earth rotation is precisely measured by geometric space techniques, such as Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), Global Navigation Satellite Systems (GNSS) and Doppler Orbit determination and Radiopositioning Integrated on Satellite (DORIS), the separation into individual excitation mechanisms remains a challenge. Commonly, individual geophysical excitation mechanisms of Earth rotation are derived from geophysical models. Due to the fact that geophysical models are afflicted with uncertainties, results derived from different model show large discrepancies. Here we present an adjustment model which allows to combine precise observations from space geodetic observation systems (SLR, VLBI, GNSS, DORIS, satellite altimetry and satellite gravimetry) in order to separate geophysical excitation mechanisms of the Earth rotation. Time variable gravity field solutions from GRACE (Gravity Recovery and Climate Experiment) are used to determine not only the integral mass effect but also the oceanic and hydrological mass effects by applying suitable filter techniques and land-ocean-masks. Furthermore the oceanic mass effect is determined from sea level anomalies as observed by cross-calibrated multi-mission altimetry. Due to the fact that sea level anomalies are not only caused by mass variations but also by volume changes (steric effect), these steric sea level anomalies need to be reduced using appropriate models. We show that through the combination weaknesses of the individual processing strategies can be compensated and the technique specific strengths can be optimally accounted for. This way, excitation functions of atmospheric, oceanic and hydrological mass effects and of the integral motion effect can be determined. The formal errors of our results are significantly smaller than the RMS differences of the solutions based on geophysical models. Thus the presented approach is suitable for the computation of improved excitation time-series and means a step forward with respect to the understanding of individual contributions of the subsystems to Earth rotation variations.