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Earth-atmosphere interaction torques and their use in studying polar motion variability

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Perturbations in Earth rotation due to dynamical processes in the atmosphere are usually investigated based on the principle of angular momentum conservation within the entire Earth system, including the solid and fluid portions of our planet, with the exception of some well-known tidal terms that can be accounted for. This method can be complemented by analyzing the set of Earth-atmosphere interaction torques, which embraces mountain torques from differential normal forces at irregular topographic features, friction torques from tangential surface stresses, and ellipsoidal torques related to mass-induced forces on the equatorial bulge. The main objective of this study is to assess the performance and reliability of state-of-the-art atmospheric torque estimates for the purpose of modeling excitation signals in seasonal and intraseasonal polar motion. Specifically, time series of both atmospheric angular momentum (AAM) as well as Earth-atmosphere interaction torques are computed from the output of two established atmospheric analysis systems: ERA-Interim of the ECMWF (European Centre for Medium Range-Weather Forecasts) and MERRA (Modern Era-Retrospective Analysis for Research and Applications) of NASA's GMAO (Global Modeling and Assimilation Office). Term-to-term intercomparisons of both models based on coherence and phase lag plots reveal excellent agreement between ERA-Interim and MERRA with respect to all equatorial torque terms. In particular, the level of coherence found for mountain and friction torques (larger than 0.9) exceeds that of the AAM motion term (0.7–0.9 at seasonal and intraseasonal periodicities) and indicates that torque series can be reliable quantities in the frame of Earth rotation studies. This result is further supported by a successful numerical verification of the equatorial AAM budget equation for the ERA-Interim and MERRA models, both with and without the dominant effect caused by the ellipsoidal torque. Applied to the modeling of geodetic polar motion, torque-based atmospheric excitation values are shown to be of similar quality as excitation values derived from conventional angular momentum series. Additional but non-negligible polar motion contributions due to oceanic mass and motion terms are incorporated into the time and frequency domain comparisons.