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Modeling rapid Earth rotation variations – where are we going next?

Michael Schindelegger
University of Bonn, Institute of Geodesy and Geoinformation, Bonn, Germany (schindelegger@igg.uni-bonn.de)

Non-tidal Earth rotation variations at intraseasonal periods are almost exclusively driven by mass redistributions within the atmosphere and ocean. Our capacity to model these signals has advanced over the past decades, but differences between the observed and modeled portions of the planetary angular momentum budget are still as large as 1–5 cm when expressed as axis displacement at the Earth's surface. A likely source for these significant errors is the ocean, poorly sampled with observations and thus not amenable to the sequential data assimilation machinery developed for the atmosphere. Moreover, the recent delineation of basin-wide ocean mass exchanges associated with the Madden-Julian Oscillation (MJO) in a high-resolution baroclinic model emphasizes that a revisit of standard forward modeling choices (e.g., grid spacings of □100 km) may be in order to better describe rapid, large-scale oceanic mass motions. In this contribution, I provide a brief overview of recent progress in the field and suggest that dynamically consistent model-data syntheses, as practiced by the consortium on Estimating the Circulation and Climate of the Ocean (ECCO), are a viable route to mitigate deficiencies in present oceanic angular momentum (OAM) series on intraseasonal (but also longer) time scales. As ocean state estimates continue to be refined by the central ECCO production, I assess the benefits of higher model resolution with OAM series from an eddy-permitting (1/6°) forward simulation, descending from the current ECCO release in its discrete setup. The resulting mass and motion terms indeed provide smaller Earth rotation residuals than other available OAM estimates, possibly due to the model resolving important topographic interactions and the dynamic response to MJO in the 30–80-day band. However, these improvements come at disproportionally large computational costs, and iteratively fitting an eddy-permitting general circulation model to oceanographic observations may still be prohibitive in the near future. Instead, efforts should be devoted to extending the present coarser-resolution ECCO framework to new data constraints and shorter adjustment intervals. Of particular interest in the context of Earth rotation are non-standard daily GRACE gravity field solutions, which contain realistic information on oceanic mass-field variability below the nominal GRACE Nyquist period of 60 days.