Testing Ocean Models With Earth Rotation Measurements

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Abstract. Angular momentum is a fundamental conserved property of dynamical systems. It is an integrated measure of mass motion and redistribution and as such can be used to diagnose the oceans’ changing general circulation. Furthermore, the angular momentum of the oceans is exchanged with that of the solid Earth causing the Earth’s rotation to change. In fact, a number of studies have recently shown the importance of oceanic processes in causing Earth rotation changes, particularly in exciting polar motion, which is the motion of the rotation pole with respect to the Earth’s crust. Because of this demonstrated importance of oceanic processes in exciting polar motion, polar motion observations have the potential to be used as a novel means of testing ocean models. Here, this potential is explored by computing the angular momentum from 15 different ocean model runs of the ECCO consortium that have been forced by surface fluxes from different sources and/or that have assimilated different types and amounts of oceanographic data. Comparing this suite of oceanic angular momentum series to polar motion excitation observations from which atmospheric and tidal effects have been removed shows that, as expected, the angular momentum series from the data assimilative runs are in closer agreement with the observed polar motion excitation series than are those from the runs that have not been constrained by data.

INTRODUCTION

Recent studies using oceanic general circulation models (OGCMs) have shown that oceanic currents due to surface pressure variations are a major source of polar motion excitation. Furthermore, the angular momentum of the oceans is exchanged with that of the solid Earth causing the Earth’s rotation to change. In fact, a number of studies have recently shown the importance of oceanic processes in exciting Earth rotation changes, particularly in exciting polar motion, which is the motion of the rotation pole with respect to the Earth’s crust. Because of this demonstrated importance of oceanic processes in exciting polar motion, polar motion observations have the potential to be used as a novel means of testing ocean models. Here, this potential is explored by computing the angular momentum from 15 different ocean model runs of the ECCO consortium that have been forced by surface fluxes from different sources and/or that have assimilated different types and amounts of oceanographic data. Comparing this suite of oceanic angular momentum series to polar motion excitation observations from which atmospheric and tidal effects have been removed shows that, as expected, the angular momentum series from the data assimilative runs are in closer agreement with the observed polar motion excitation series than are those from the runs that have not been constrained by data.

Earth Rotation Dynamics

OCEANIC ANGULAR MOMENTUM (OAM)

Angular momentum is related to polar motion excitation and length-of-day changes by:

\[ \text{OAM} = \text{length-of-day} \times \text{polar motion excitation} \]

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Summary. The correlations of the OAM series studied here with the observed polar motion excitation residuals range from a low of 0.60 to a high of 0.73, and the observed variances explained by the OAM series range from a low of 35% to a high of 52%. In general, the data assimilative runs are seen to agree better with the observed residual than do the control runs, particularly for nonseasonal excitation and at retrograde (negative) frequencies. The smoothed-wind-driven results (those whose names begin with “dr”) do not agree as well with the observed residuals as do their corresponding Kalman filter runs. Based on these results, additional tests were performed (not shown here) which indicated that there may be problems with the smoother at high latitudes. These results demonstrate the value of using Earth rotation measurements, from which atmospheric and tidal effects have been removed, to test the fidelity of modeled oceanic angular momentum series.