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Potential Use of Atmospheric and Ocean Angular Momentum Forecasts for Polar Motion Prediction

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Abstract

Significant contributors to the motion of the Earth's axis over the surface of the Earth, called polar motion, are changes in the Atmospheric and Ocean Angular Momentum (AAM and OAM), particularly mass redistribution. AAM as well as OAM forecasts could significantly improve the accuracy of current polar motion predictions. To test this hypothesis, the International Earth Rotation and Reference Systems Service (IERS) Rapid Service/Prediction Center (RS/PC) investigated the possibility that reanalysis and operational data from the National Centers for Environmental Prediction (NCEP) and European Centre for Medium-Range Weather Forecasts (ECMWF) could be used to model polar motion. A model using forecast data was investigated for its ability to generate potentially better polar motion predictions than those currently produced by IERS RS/PC, which are based primarily on analyses of GPS satellite orbits and astronomical observations. The results and their implication for future IERS operations are provided.

Introduction

Accurate predictions of polar motion are necessary to determine the orientation of the Earth in real time. Since the 1980s, it has been known that atmospheric angular momentum excites the Earth's wobble on seasonal time scales. However, there are significant differences between observed polar motion and predictions using AAM alone. The Earth's wobble is also excited by ocean angular momentum. Combining AAM+OAM excitation data to yield polar motion predictions is the scope of this study.

Data

Four possible combinations of two AAM models and two OAM models were studied to determine the best combination to forecast polar motion. The atmospheric models tested were the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) model and the atmospheric general circulation model ECHAM3, produced by ECMWF. The ocean models tested were the Estimating the Circulation and Climate of the Ocean (ECCO), produced by the Jet Propulsion Laboratory (JPL) and the Ocean Model for Circulation and Tides (OMCT), produced by ECMWF. Each model provides excitation functions including motion and mass terms at six-hour intervals, but only the zero-hour data were used. The inverted barometer (IB) mass terms from the AAM excitation functions were used.

Methodology

There are a number of procedures that could be used in combining the data. We describe here the procedure that was found to provide the most accurate results. A polar motion time series *m* based on excitation functions $\chi(t)$ was developed using the first-order differential equation $m(t) + i/\sigma_c \, dm(t)/dt = \chi(t)$, where σ_c is $2\pi F_c(1 + i/2Q)$. Here, we used $F_c = 0.843$ cycles per year and a damping factor Q = 175. For each forecast day, we input the appropriate functions. Comparing the observed polar motion with the generated series provided a set of residuals that we fit with Fourier terms including annual and Chandler frequencies for x and semi-annual, annual, and Chandler frequencies for y. The semi-annual term was not used for x because it reduced the correlation with the geodetic data. The fit was extrapolated and combined with the forecast excitation functions. A linear extrapolation of the past two days of geodetic data was averaged with the above combination. An adjustment is added to the first prediction day value to ensure continuity with observations. These forecasts were combined with the IERS Bulletin A forecasts in a weighted average where the weight of the angular momentum data is 25% of the mean. We used forecast AAM+OAM for prediction days 1-7; forecast polar motion for days beyond 7 were set equal to extrapolated analysis AAM+OAM data. An adjustment was added to avoid a jump from the 7th day to 8th day prediction.

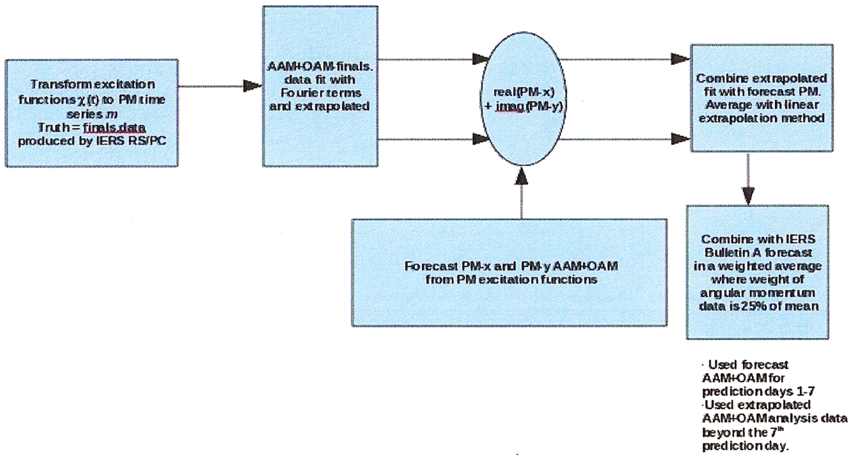

Figure 1: Flow chart of methodology used in this study.

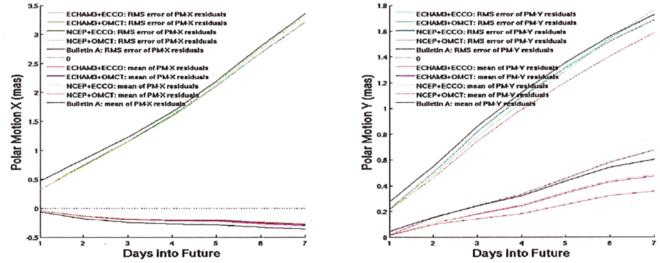

Figure 2: Comparisons of RMS error and mean residuals for all AAM+OAM pairs with respect to current IERS RS/PC polar motion predictions.

Results/Discussion

Figure 2 illustrates the comparison of each combined data set to the current IERS RS/PC polar motion forecasts, and Table 1 shows the improvement in the polar motion predictions using the new algorithm with the most accurate data set combination. Improvements on the order of 50% or better are seen to be possible.

Days of Forecasts

PM-x RMS Error	1 (mas)	2 (mas)	3 (mas)	4 (mas)	5 (mas)	6 (mas)	7 (mas)
IERS Bulletin A	0.450	0.829	1.220	1.635	2.112	2.644	3.162
NCEP + OMCT	0.311	0.721	1.145	1.572	2.066	2.611	3.124
% Improvement	30.90%	13.00%	6.10%	3.90%	2.20%	1.25%	1.20%
PM-x Mean Res.							
IERS Bulletin A	-0.092	-0.210	-0.279	-0.326	-0.370	-0.451	-0.543
NCEP + OMCT	-0.046	-0.144	-0.194	-0.224	-0.257	-0.328	-0.413
% Improvement	50.00%	31.40%	30.50%	31.30%	30.50%	27.30%	23.90%
PM-y RMS Error							
IERS Bulletin A	0.279	0.548	0.855	1.111	1.323	1.522	1.698
NCEP + OMCT	0.216	0.470	0.752	0.991	1.187	1.381	1.559
% Improvement	22.60%	14.20%	12.00%	10.80%	10.30%	9.26%	7.80%
PM-y Mean Res.							
IERS Bulletin A	0.024	0.080	0.106	0.139	0.215	0.281	0.302
NCEP + OMCT	-0.001	0.039	0.034	0.037	0.079	0.119	0.129
% Improvement	104.20%	51.30%	67.90%	73.40%	63.30%	57.70%	57.30%

Conclusions

Polar motion forecasts can be improved using the new algorithm described above that makes use of both AAM and OAM analysis and forecast data. The availability of OAM data limited the tested date range, and more data would be useful. Other sources of AAM and OAM data could be analyzed. Future research would benefit from having additional forecast data available for testing. It would also be beneficial to have OAM forecasts available in real-time. A future study may also consider including hydrological angular momentum (HAM) analysis and forecast data. Additional coding and testing under operational conditions are necessary before this method can be implemented by the RS/PC.

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