PLANS FOR HIGH ACCURACY COMPUTATIONS OF EARTH ROTATION/POLAR MOTION EXCITATIONS

D.A. SALSTEIN
Atmospheric and Environmental Research, Inc.
131 Hartwell Ave., Lexington, MA, 02421, USA
e-mail: salstein@aer.com

ABSTRACT. Knowledge from atmospheric analyses and/or models is very important for calculations of the excitations of the Earth, including length of day, polar motion, and nutation, and has further consequences for understanding of the geophysical structure of the Earth's interior, that is, mantle and core. With some of the nutation parameters especially dependent on the diurnal variability of the atmosphere's equatorial angular momentum, it is important to seek the best series for such terms. We are grateful to the winners of the Descartes Prize for their nutation studies with having chosen our team for an award to study the relevant excitation functions.

1. TEAM MEMBERS

Ben Chao, NASA GSFC, Greenbelt, MD, USA Rui Ponte, Atmospheric and Environmental Research, Inc., Lexington, MA, USA Jianli Chen, Center for Space Research, University of Texas, Austin, TX, USA Yonghong Zhou, Shanghai Astronomical Observatory, Shanghai, China, and Atmospheric Environmental Research, Inc., USA

2. SPECIAL BUREAU FOR THE ATMOSPHERE ISSUES

The Special Bureau for the Atmosphere (SBA) of the Global Geophysical Fluids Center of the International Earth Rotation and Reference Systems Service, has been calculating, accessing, archiving, and distributing data for the atmospheric excitation of Earth rotation and polar motion. During the more than 15 years of this bureau and its predecessor, the Sub-Bureau for Atmospheric Angular Momentum, a number of weather centers have supplied the SBA with atmospheric data, including both operational and reanalysis series. the other geophysical fluid, the ocean, has diurnal terms as well, relevant to nutation. These terms are only now starting to be estimated using ocean models and much work is needed to assess their quality and usefulness for nutation studies. Plans for a postdoctoral fellow to help in these data improvement endeavors are presented.

Subdiurnal values for the atmospheric excitation function for polar motion are the heart of the project. Atmospheric weather analysis systems typically produce values every 6 hours, largely because that is the frequency of many of the best observations that are assimilated by the system. Some systems have produced a limited number of meteorological parameters, in this case, the surface variables, every 3 hours. We will consider if this, or even higher temporal resolution, based upon the independence of the analyses, is worthwhile.

Because the atmosphere is a major excitation source for Earth rotation and polar motion, we turn to its analyses to determine global excitation values of these excitations, based on winds and mass (surface pressure). Also, torques that dynamically effect momentum transfer are calculated. Outlined here is the basic three-step process by which analyses are performed: modeling, data assimilation, initialization; also they assimilate a variety of heterogeneous observed data

As high frequency atmospheric data (retrograde diurnal) are required for nutation studies, at present 6 hourly data are available. In this project we explore the issue of obtaining or determining such excitation values with any accuracy on higher frequency. Values from the SBA (Special Bureau for the Atmosphere) of the IERS (International Earth Rotation and Reference Frames Service), currently based on the Barnes et al. (1983) formulation, need updating. For example, the particular constants, some approximations that have been used, and methods of organization will be reviewed, well as data handling at the SBA for all our products, including a full notation of all angular momentum data archives. Ocean angular momentum at short time scales requires modeling with a variety of improvements.

Torque is the dynamic mechanism that transfers angular momentum across the atmosphere's lower boundary. Three main torques can be computed (for axial), with a fourth for equatorial: (1) The mountain torque against topography, based upon normal forces, (2) the friction torque, from the tangential stress term; (3) a gravity wave torque, based on the subgrid scale friction-like process over topography, and (4) the gravitational torque arising from the impact of uneven mass, acts principally from bulge of Earth on equatorial torque (de Viron et al. 1999). We will analyze torque and angular momentum balances.

3. ATMOSPHERIC ANALYSES FROM A METEOROLOGICAL FORECAST -ANALYSIS SYSTEM

To appreciate what is needed to improve the data sets in the SBA it is necessary to have an understanding of how the analysis-forecast systems produce meteorological information relevant to the variations in the Earth Orientation Parameters (EOP).

Meteorological centers have access to the huge amount of information from in situ (radiosonde), aircraft-based, and information from a variety of weather satellites. The information from this heterogeneous set is assembled and combined with output from a weather forecast model. Such a model advances the state of the atmosphere in time, typically by six hours, from which the forecasted fields of atmospheric parameters are obtained. The combination is performed with specific data assimilation techniques that combine the various observations within a time window in an optimal way, based upon the error characteristics of both the data sources and the forecast model. A third step is often needed, known as initialization, that makes analysis usable as initial state for the forecast model.

The result is a full set of atmospheric parameters including temperature, moisture, pressure and winds. Surface pressures and winds are needed by the formulas for excitations of Earth rotation and polar motion. The present formulations, based on Barnes et al. (1983) will be updated in new procedures, as noted above.

Thus, we need to make improvements in the atmospheric data as follows: We wish to improve the representation of AAM at short periods, essentially sub-daily. An issue arises, however, when attempting either possibility: the characteristics of forecast and analysis fields are not the same, and so great care must be used if one is to combine information from these different time steps. This effort will require either accessing the intermediate time steps of a model-assimilation system, or running such a system ourselves, and we are investigating both options. As another possibility, we may access the intermediate time steps of a general circulation model without benefit of data-in this case more understanding about the characteristics of higher temporal frequency data, such as spectral resolution, will be apparent.

First we examine suggested improvements to the Barnes et al. simulation that have been published (e.g., Eubanks 1993; Wahr, 1982, Wahr, 2004). Second, we investigate better distribution/archiving procedures those present in the SBA and GGFC websites. Included are closer examinations of the calculations of the excitation terms, including issues of the integration including vertical limits near bottom topography. We also investigate the torques, which effect the changes of angular momentum. The torque and angular momentum approaches need to be more consistent: the torque values are derived from the forecast models, and angular momentum from analyses.

4. IMPROVEMENTS NEEDED FOR THE OCEAN-RELATED STUDIES

A number of steps must be taken to enhance the usefulness of ocean-related products for use in studying Earth rotation issues. The major relevant issue to consider here is the representation of OAM at short periods (daily and shorter). Also, the uncertainties in ocean results must be reduced to the extent possible. Achieving these ends will require efforts in the following areas: (1) Obtaining more frequently sampled and/or better representation of daily cycle in atmospheric forcing fields, as the atmospheric fields form boundary conditions for an ocean model. The fields include the winds and surface pressures. (2) Use of truly global ocean models, including effects of semi-enclosed seas and the Arctic. (3) Tuning ocean model parameterizations of friction, which will help in the overall angular momentum balance., (4) Use of state estimation techniques to better constrain short period variability in ocean models, (5) Accounting for the effects of self-attraction and loading in calculations of non-tidal effects, and (6) Attempting to ensure consistency in modeling non-tidal and tidal effects, with regard to radiational and gravitational effects (Ponte and Ray 2002) .

5. GLOBAL GEOPHYSICAL FLUIDS CENTER

The User community is served by the Global Geophysical Fluids Center, a product center of the IERS. The SBA has eight different special bureaus, namely, those for the atmosphere, oceans, hydrology, tides, mantle, core, gravity/geocenter, and loading. Activities of the whole GGFC are centered at the NASA Goddard Space Flight Center. Information about the GGFC and IERS can be found on its website. We will address issues of commonality to the special bureaus and attempt to unify the data sets resident at the GGFC that are derived from the various special bureaus.

6. HIGH RESOLUTION ATMOSPHERIC ANGULAR MOMENTUM

We are attempting to produce AAM at the high subdaily resolution. This is important when one considers the strong diurnal and semidiurnal tides that influence the wind terms in such a way as to strongly impact the equatorial term. Hsu and Hoskins (1989), for example have shown that such tides are caused by thermal effects of radiation, and are, moreover, seasonally modulated. Thus we will make an effort to use atmospheric models, as noted above, to produce the wind terms necessary to calculate the excitation terms at the highest resolution. It should be noted though, that at such high frequencies, the excitation terms, such as mentioned in Barnes et al. are not subject to the full set of approximations used in that formulation.

As noted above, the integrations at the weather centers are organized so that data are archived typically at 6 hour intervals. The equations of motion of the atmospheric models have time steps that are far shorter, as little as 15-seconds for very high spatial resolution. So atmospheric parameters are produced at that very high frequency, but these are very rarely saved or used for any other purpose. Because the nutation studies would benefit from data at the 1-hour resolution, our goal in this project and succeeding efforts is to investigate the characteristics and usefulness of such information.

7. REFERENCES

Barnes, R.T.H., R. Hide, A.A. White, and C.A. Wilson, 1983: Atmospheric angular momentum fluctuations, length of day changes, and polar motion. Proc. R. Soc. Lond., 387, 31-73.

deViron, O., C. Bizouard, D.A. Salstein, and V. Dehant, 1999: Atmospheric torque on the Earth and comparison with atmospheric angular momentum variations. J. Geophys. Res., 104, 4861-4875.

Eubanks, T.M., 1993: Variations in the rotation of the Earth. In Contributions of Space Geodesy to Geodynamics - Earth Dynamics, Geodyn. Ser. Vol 24, edited by D.E. Smith and D.L. Turcotte, pp. 1-54, AGU, Washingthon, DC.

Hsu, H.H., and B.J. Hoskins, 1989. Tidal fluctuations as seen in the ECMWF data. Quart. J. Roy. Meter. Soc., 115, 247-264.

Ponte, R.M. and Ray, R.D., Atmospheric pressure correction in geodesy and oceanography: A strategy for handling air tides, Geophys. Res. Let., vol. 29, (24), 2153, doi:10.1029/2002GL016340, 2002.

Salstein, D.A., D.M. Kann, A.J. Miller, and R.D. Rosen, 1993: The Sub-bureau for Atmospheric Angular Momentum of the International Earth Rotation Service, Bull. Amer. Meteorol. Soc., 74, 67-80.

Wahr, J.M., 1982: The effects of the atmosphere and the oceans on the Earth's wobble. -1. Theory, Geophys. J. R. astr. Soc., 70, 349-372.

Wahr, J.M.,2004: Polar motion models: Angular momentum approach. Proceedings, Chandler Wobble Workshop. April 2004, European Center for Geodynamics and Seismology,