POLAR MOTION EXCITATION ANALYSIS DUE TO GLOBAL CONTINENTAL WATER REDISTRIBUTION *

L.I. FERNANDEZ[1,2,3], H. SCHUH[3]
[1] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Argentina.
[2] Facultad de Cs. Astronómicas y Geofísicas. U. N. de La Plata.
Paseo del Bosque s/n. B1900FWA. La Plata. Buenos Aires. Argentina.
e-mail: lauraf@fcaglp.unlp.edu.ar
[3] Institut für Geodäsie und Geophysik. E128/1. Technische Universität Wien.
Gußhausstraße 27-29.A-1040 Wien, Austria.
e-mail: harald.schuh@tuwien.ac.at

ABSTRACT. We present the results obtained when studying the hydrological excitation of the Earth's wobble due to global redistribution of continental water storage. This work was performed in two steps. First, we computed the hydrological angular momentum (HAM) time series based on the global hydrological model LaD (Land Dynamics model) for the period 1980 till 2004. Then, we compared the effectiveness of this excitation by analysing the residuals of the geodetic time series after removing atmospheric and oceanic contributions with the respective hydrological ones. The emphasis was put on low frequency variations. We also present a comparison of HAM time series from LaD with respect to that one from a global model based on the assimilated soil moisture and snow accumulation data from NCEP/NCAR (The National Center for Environmental Prediction/The National Center for Atmospheric Research) reanalysis. Finally, we evaluate the performance of LaD model in closing the polar motion budget at seasonal periods in comparison with the NCEP and the Land Data Assimilation System (LDAS) models.

1. COMPUTATION OF HAM TIME SERIES FROM LaD

The time series of the hydrological excitation of polar motion was computed for the period 1980 till 2004 as estimated from the Land Dynamics (LaD) model for Land Water and Energy Balance (Milly and Schmakin, 2002). The groundwater density redistribution data on a global grid is generated at the U.S. Geological Survey by the Continental Water, Climate, and Earth-System Dynamics Project. The grid is equidistant at 1° and the data outputs are available at monthly intervals. Solving the x and y component of the Liouville equations and replacing the inertia tensor components by the correspondent expression in terms of the second-order Stokes coefficients (C_{21}, S_{21}) yields (Gross et al., 2003; Chen et al., 2000)

$$(\Psi_x + \mathrm{i}\ \Psi_y)^{mass} = -1.098\,\frac{\mathrm{MR}^2}{\text{(C-A)}}\,(C_{21} + \mathrm{i}\ S_{21}) \tag{1}$$

where Ψ are the excitation functions, M and R are the mass and mean radius of the Earth, C and A are the principal moments of inertia. The time series of the Stokes coefficients variations

*Poster presented by Robert Weber

can be expressed by the parameters of the LaD water storage model. Thus, replacing the Stokes coefficients in eq. (1) yields,

$$\left.\begin{array}{l}\Psi_x \\ \Psi_y\end{array}\right\} = \frac{-1.098\ \mathrm{R}^4\ (1+\mathrm{k}_l)}{(\text{C-A})} \sqrt{\frac{3}{5}} \int_S \Delta s(\phi,\lambda)\, cos(\phi)\, sin^2(\phi) \left\{\begin{array}{c} cos(\lambda) \\ sin(\lambda) \end{array}\right\} \mathrm{d}\phi\, \mathrm{d}\lambda \qquad (2)$$

where k_l is the degree 2 load Love number and $\Delta s(\phi, \lambda)$ are the continental water storage values as a function of latitude (ϕ) and longitude (λ).

From eq. (2) we obtained the hydrological excitation functions time series from the LaD model by numerically solving the integral. We prior located the point at the centre of a 4-by-4 sub-block of the grid data. Afterwards, we performed a two-dimensional interpolation by using a polynomial of degree 3 in latitude and the same in longitude. The surface integrals were solved by using twice a ten-point Gauss-Legendre integration.

2. ANALYSIS OF HYDROLOGICAL POLAR MOTION EXCITATION

The equatorial components of the hydrological excitation were computed at annual, semiannual and ter-annual terms and compared with the NCEP,LDAS and LaD models in closing the polar motion budget.

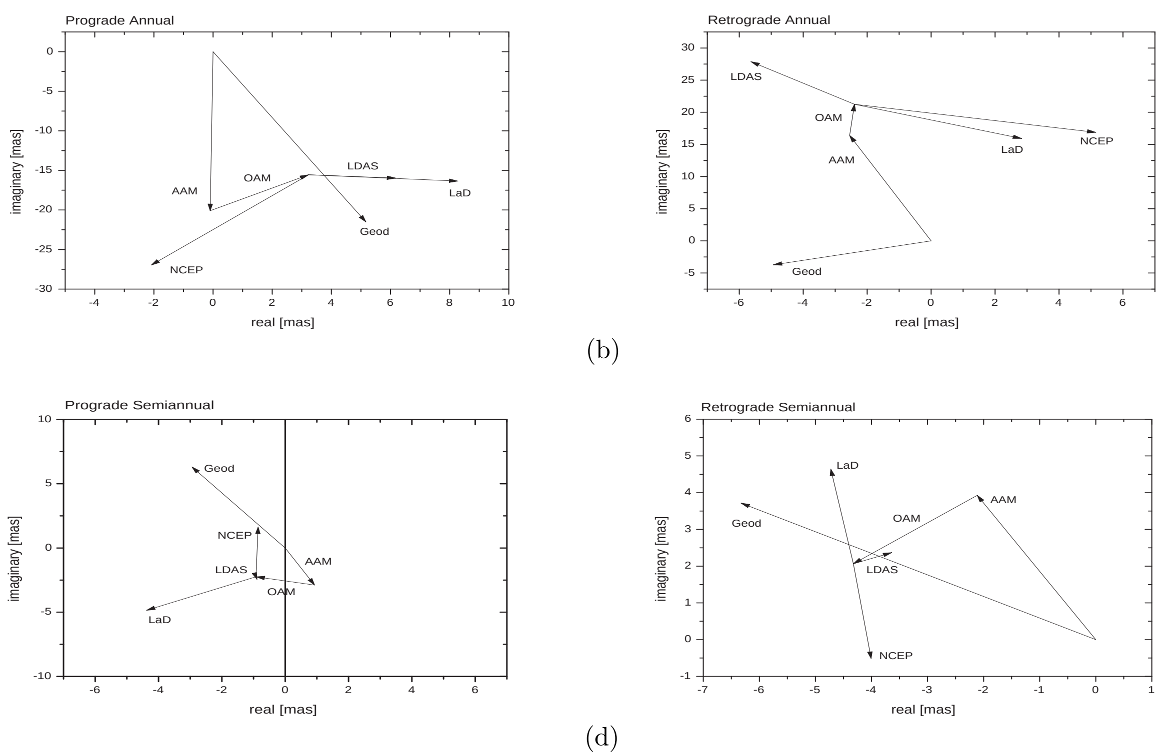

Figure 1: Phasor diagrams for the annual prograde (a), annual retrograde (b), semi-annual prograde (c) and semi-annual retrograde (d) components of the observed (geod), atmospheric (AAM), oceanic (OAM) and hydrological excitations (LaD, NCEP, LDAS)

The interannual hydrological excitation to polar motion was also computed for the whole 24-year period. The geodetic residuals were calculated by subtracting atmospheric plus oceanic contribution to the observed polar motion excitation computed from the IERS C04 series. We eliminated the high frequency components by applying a Vondrák filter (Vondrák, 1977) with ϵ

= 1600 y^{-6}. Afterwards, we applied a wavelet analysis (Schmidt, 2002) in order to compute the squared cross scalogram and the normed coherence.

3. CONCLUSIONS

We computed the equatorial components of a HAM time series as estimated by the LaD model for a period of 24 years at 1-month interval. For the retrograde components, the hydrological influence with a period of 4 years can be seen, which is demonstrated by a normed coherency of .99. However the irregular variations between 5 and 8 years are not clearly explained by hydrological excitation. They should obey to oceanic or atmospheric mis-modelling.

When comparing LaD with other hydrological models at annual periods, LaD seems to overestimate the retrograde component. If one compares LaD with NCEP and LDAS in closing the annual and semi-annual polar motion budget, we can observe that LaD is close to LDAS in phase for all prograde components. Moreover, the LaD contribution approximates better to the polar motion observations in magnitude although differences in phase still exist. Finally, we also performed estimations of the ter-annual hydrological effects on polar motion.

Acknowledgments. We would like to thank M. Schmidt (DGFI) for the FORTRAN codes morlet.f and coherence.f applied in this work for performing the wavelet analysis, as well as for the support and the helpful discussions. L. Fernández is grateful to the Advisory Board of the Descartes Prize "Pinpoint positioning in a wobbly world" for the post-doctoral grant to research at the Institute of Geodesy and Geophysics of TU Wien.

REFERENCES

Chao B.F., O'Connor W.P., Chang A.T.C., Hall D.K., Foster J.L., 1987, "Snow load effect on the Earth's rotation and gravitational field, 1979-1985". J. Geophys. Res. 92 B9, pp. 9415-9422.

Chao B.F., O'Connor W.P., 1988, "Global surface-water-induced seasonal variations in the EarthŠs rotation and gravitational field". Geophysical Journal 94, pp. 263–270.

Chen J.L., Wilson C.R., Eanes R.J., Tapley B.D., 2000, "A new assessment of long-wavelength gravitational variations". J. Geophys. Res. Vol. 105, B7, pp. 16271–16277.

Chen J.L., Wilson C.R., 2005, "Hydrological excitations of polar motion, 1993-2002". Geophys. J. Int. 160, pp. 833–839.

Gross R. S.,Fukumori I., Menemenlis D., 2003, "Atmospheric and Oceanic Excitation of the Earth's Wobbles During 1980-2000". J. Geophys. Res., 108(B8), doi: 10.1029/2002JB002143, 20031992.

Hinnov L. A.,Wilson C. R., 1988, "Estimate of the water storage contribution to the excitation of polar motion", Geophys. J., R. Astr. Soc., 88, pp. 437-459.

Jochmann, H., 1999, "The influence of continental water storage on the annual wobble of polar motion estimated by inverse solution". Journal of Geodyn. 27, pp. 147–160.

Kuehne J., Wilson C. R., 1991, "Terrestrial Water Storage and Polar Motion". J. Geophys. Res., 96, B3, pp. 4337–4345.

Milly P.C.D., Shmakin A.B., 2002, "Global Modeling of Land Water and Energy Balances. Part I: The Land Dynamics (LaD) Model". Journal of Hydrometeorology. Vol. 3, pp. 283–299.

Schmidt, M., 2002, "Wavelet-Analyse von Zeitreihen". Dt. Geod. Komm., München, Reihe A, Nr. 118, pp. 46-56.

Vondrák J., 1977, "Problem of Smoothing observational data II". Bull. Astron. Inst Czech., 28, pp. 84–89.