COMPARISON OF THE HYDROLOGICAL EXCITATION FUNCTIONS HAM OF POLAR MOTION FOR THE PERIOD 1980.0-2007.0

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ABSTRACT. In this study we compared contributions of polar motion excitation determined from hydrological models and harmonic coefficients of the Earth gravity field obtained from Gravity Recovery and Climate Experiment (GRACE). Hydrological excitation function (hydrological angular momentum - HAM) has been estimated from models of global hydrology, based on the observed distribution of surface water, snow, ice and soil moisture. All of them were compared with observed Geodetic Angular Momentum (GAM), excitations of polar motion. The spectra of these excitation functions of polar motion and residual geodetic excitation function G-A-O obtained from GAM by elimination of atmospheric and oceanic excitation functions were computed too. Phasor diagrams of the seasonal components of the polar motion excitation functions of all HAM excitation functions as well as of two GRACE solutions: CSR, CNES were determined and discussed.

1. ANALYSIS AND RESULTS

Hydrological angular momentum have been estimated from several models of global hydrology: NCEP/ NCAR (National Centers for Environmental Prediction/National Centers for Atmospheric Research), CPC (Climate Prediction Centre), GLDAS (Global Land Assimilation Data System), NOAA (National Oceanic and Atmospheric Association). They are available in the Special Bureau of Hydrology of Global Geophysical Fluids Center (GGFC) of the International Earth Rotation and Reference Frame Service (IERS). The HAM GFZ (GeoForschungZentrum) and WGHM CRU (WaterGAP Global Hydrology Model Climate Research Unit) were delivered by personal communication.

In recent years many studies on the impact of land hydrology on the polar motion excitation were carried on (Shuanggen et al. 2010, Brzezinski et al. 2009, Chen and Wilson, 2005; Nastula et al. 2007; Seoane et al. 2009). Investigations of influence of HAM on the polar motion in different part of spectra show that consideration of the HAM data not improve agreement of the geophysical excitation of polar motion containing contributions from atmosphere, oceans and hydrology with geodetic excitation function GAM (Nastula and Kolaczek, 2005).

Since 2002 satellite GRACE (Gravity Recovery and Climate Experiment) mission has delivered precise data of time gravimetric variations and has allowed to determined mass-gravimetric polar motion excitation function. Due to the GRACE mission and in a lesser extent LAGEOS missions, the geophysical fluids mass variability can be determined from gravity field observations. The coefficients of the second degree and of the first order of the Earth gravity field are proportional to variations of equatorial components χ_1, χ_2 of the series of gravimetric excitation function of polar motion. This gravimetric function can be compared with the mass term of geodetic excitation function of polar motion. Several centers, GeoforschungZentrum (GFZ), Center for Space Research (CSR), the Jet Propulsion Laboratory (JPL), Centre National d'Etudes Spatiales /the Groupe de Recherche en Géodésie Spatiale (CNES/GRGS) computed coefficients of series of time variable gravitation and of adequate layer of water storage (Brzezinski et al. 2009, Chen and Wilson, 2005; Nastula et al. 2007; Seoane et al. 2009).

Hydrological excitation functions were computed by the following formula (Eubanks, 1993):

$$\begin{bmatrix}\chi_1^{mass}\\ \chi_2^{mass}\end{bmatrix} = -\frac{1.098R_e^2}{C-A}\iint \Delta q(\phi,\lambda,t)sin(\phi)cos(\phi)\begin{bmatrix}cos(\lambda)\\ sin(\lambda)\end{bmatrix}dS \qquad (1)$$

where $\Delta q(\phi, \lambda, t)$ represents the changes in water storage in unit area (in kgm^{-2}), R_e is the Earth's mean radius, dS is the surface elements area, C and A are the Earth's principal moments of inertia.

The gravimetric excitation of polar motion was computed from harmonic coefficient of the Earth gravity field based on formula (Chen and Wilson, 2005):

$$\begin{bmatrix} \chi_1^{mass} \\ \chi_2^{mass} \end{bmatrix} = -\frac{1}{(1+k_2')\sqrt{\frac{3}{5}}\frac{C-A}{1.098 R_e^2 M}} \begin{bmatrix} \Delta C_{21} \\ \Delta S_{21} \end{bmatrix} \tag{2}$$

where M and R_e are the mass and mean radius of the Earth, respectively, C and A are the Earth's principal moments of inertia, is the degree-2 Love number (-0.301) accounting for elastic deformational effects on gravitational change. ΔC_{21}, ΔS_{21} are Stokes coefficients of the gravity field.

The IERS provides time series of Geodetic Angular Momentum (GAM) with one day sampling, the series are available for the period 1962-2010 from the IERS website. The geodetic excitation function is obtained from the IERS C04 series of polar motion (Bizouard, Gambis, 2007).

Comparison of the equatorial components of GRACE gravimetric excitation polar motion functions with the geodetic residuals excitation function G-A-O and hydrological ones CPC and NCEP/NCAR are shown in Fig. 1. The gravimetric excitation functions are fairly consistent with the geodetic residuals excitation function. Some compatibility of the CPC data with GRACE CNES and CSR can be seen at the Fig. 1, but only for χ_2.

Spectra of the complex-valued components of (χ=χ_1 + iχ_2) of hydrological excitation functions as well as of geodetic residuals G-A-O using Fourier Transform Band Pass Filter (FTBPF) (Kosek, 1995) in the broad band with 200 and 600 days cutoff were computed (Fig. 2). The spectra of all these considered models show oscillations with annual, semiannual and 120 day periods both in the prograde and retrograde band, but the annual oscillations are the strongest ones. It is easy to see that amplitudes of the spectra of these models are different in different models. Subtracting from geodetic excitation function GAM the impact of the atmosphere and ocean does not remove the annual and semiannual oscillations (Fig.2). Retrograde annual oscillations of the NOAA and NCEP/NCAR functions have similar amplitude to those of the geodetic residuals G-A-O. Annual oscillations of the CPC data are stronger than those of geodetic residuals G-A-O.

In order to check agreement of activity of the hydrological and gravimetric excitation functions of polar motion we computed also the prograde and retrograde components of annual and semiannual oscillations of complex polar motion excitation functions, for each hydrological excitation functions and for geodetic residuals G-A-O using LSQ method (Brzezinski, 1992, Brzezinski et al. 2009). The model comprising the second order polynomial and a sum of complex sinusoids with periods 365.25 and 180 days was computed by LSQ method. Amplitudes and phases of these oscillation are presented in terms of phasor diagrams shown in Figure 3. On the basis of phasor diagrams shown in Figure 3, can be concluded, that the hydrological excitation functions have different amplitudes and phases, furthermore, no function is close to the geodetic residuals in prograde and retrograde annual oscillations. In retrograde annual oscillations three hydrological functions have a similar phases: GFZ, CPC, NOAA, and the GFZ and CPC have similar amplitudes. Errors of phases and amplitudes, which are drawn as a circle, have different sizes. In the case of the annual prograde and annual retrograde oscillations errors are smaller than the determined vectors. But in semiannual prograde and semiannual retrograde oscillations errors for GLDAS excitation function exceeded determine vectors.

Figure 3 shows, that the phasor diagrams of the GRACE gravimetric excitation functions of polar motion computed by CNES and CSR show disagreement of amplitudes and phases of their vectors as well as of G-A-O and NCEP/NCAR, CPC vectors. In prograde annual oscillations the phase and amplitude for the vectors of GRACE excitation functions and for CPC excitation function are similar (Fig. 3). For the retrograde annual oscillation only the vector of GRACE CNES excitation function follows in the same direction as the vector of CPC excitation function.

2. CONCLUSIONS

Phasor diagrams of annual and semiannual oscillations of polar motion show that different models of HAM excitation functions differ significantly in amplitudes and phases and temporal characteristics in their spectra. None of the HAM functions do close the budget of the needed global geophysical excitation function of polar motion. The gravimetric excitation functions of polar motion based on GRACE data also do not close this budget.

Spectra of seasonal oscillations of geophysical fluids excitation functions mainly annual and semiannual are different too. The annual oscillation is the strongest one. Prograde annual and semiannual oscillations of geophysical fluids excitation functions are smaller than those of geodetic ones.

The models of land hydrology are still under development. At present it is difficult to say, which hydrological model is the best for improvement the agreement with geodetic excitation function GAM.

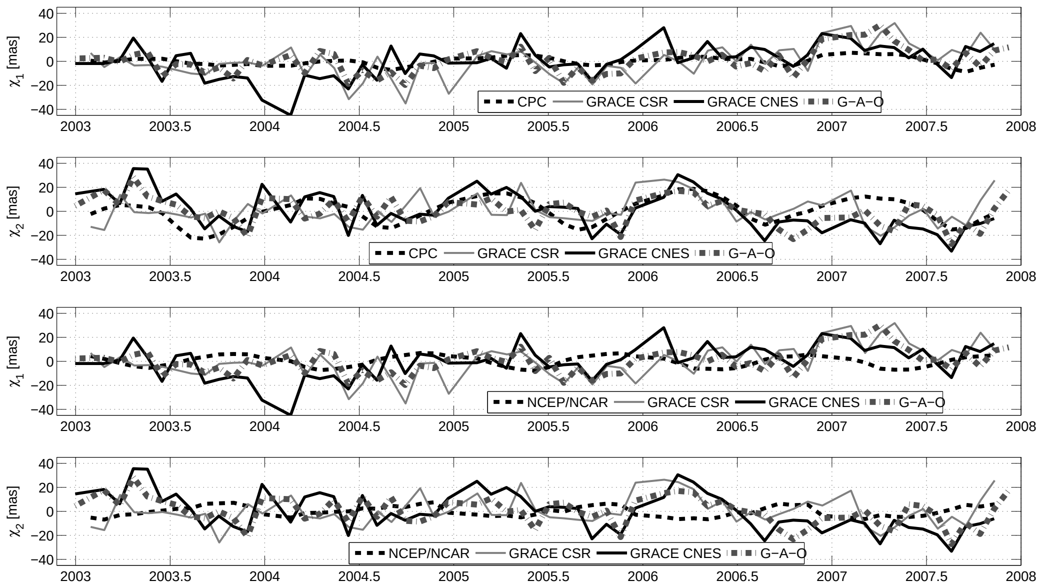

Figure 1: Comparison of χ_1, χ_2 components of: gravimetric excitation polar motion (GRACE CNES, GRACE CSR), residuals of the geodetic excitation function G-A-O and hydrological excitation functions CPC and NCEP/NCAR.

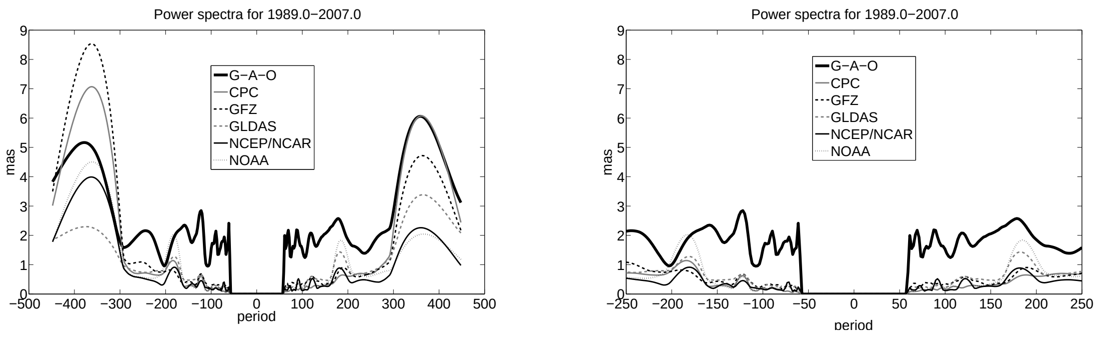

Figure 2: FTBPF amplitude spectra of the different complex geophysical excitation functions of the polar motion.

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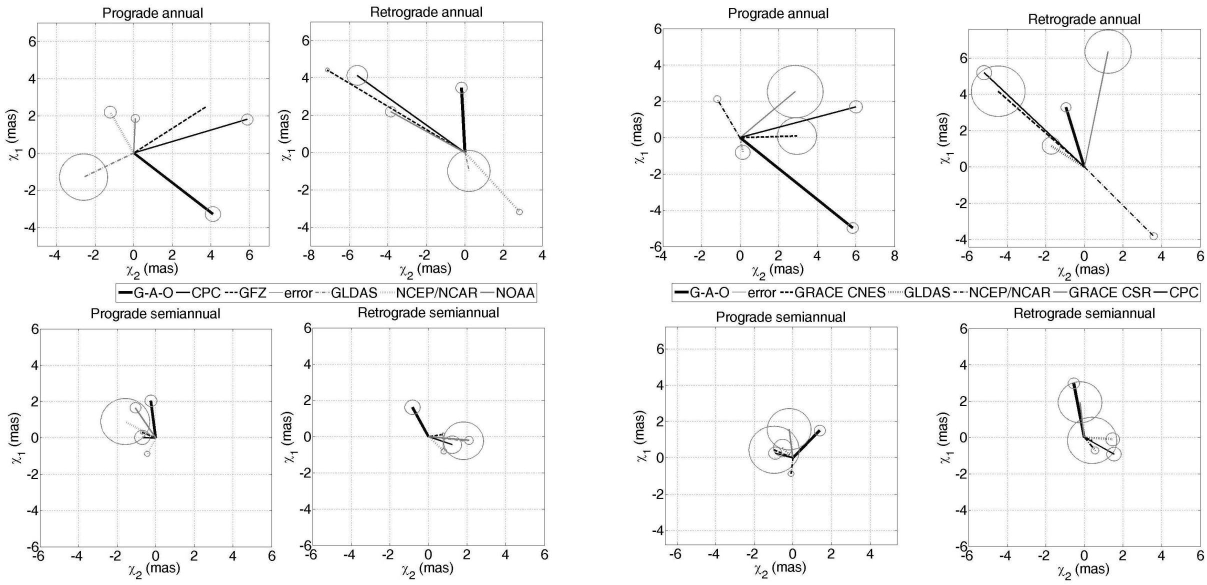

a) b)

Figure 3: Phasor diagrams of the seasonal components of the residual of the **a)** geodetic excitation function (G-A-O) and different hydrological excitation functions (CPC, GFZ, GLDAS, NCEP/NCAR, NOAA); analysis is done over the period 1989.0-2007.0 (at left) and **b)** phasor diagrams of the seasonal components of the residual of geodetic excitation function (G-A-O), gravimetric excitation functions GRACE CNES and GRACE CSR and different hydrological excitation function. Analysis is done over the period 2003.0-2008.0 (at right)

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