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HYDROLOGICAL EFFECTS ON POLAR MOTION COMPARED TO GRACE OBSERVATIONS.

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Abstract. The influence of the continental hydrologic signals on the polar motion is not well known. Different models have been developed to evaluate and compare these effects to geodetic observations. Previous studies have shown large disagreements mainly due to the lack of global measurements of related hydrological parameters. The recent Gravity Recovery and Climatic Experiment (GRACE) mission allows us to compute excitation functions ($\chi_1 + i\chi_2$) of polar motion due to unmodelled variations like hydrological processes. We have compared this gravimetric-based excitation to the excitation estimated from a hydrological model and from geodetic observations for the period February 2003 to December 2006. The residuals of the geodetic excitation are not fully explained, neither by the hydrological model nor by the gravimetric data. However, considering annual variations, there is a good agreement between geodetic and gravimetric excitations especially in amplitude. The hydrological model-based excitation has significant discrepancies for the real component of the excitation χ_1. We found that all series show common interannual oscillations of nearly 1.3 year period coinciding with Amazon's water storage variations (Schmidt et al. 2007).

1 Introduction

The excitation of polar motion is to a large extent related to the mass redistribution of geophysical fluids. The importance of atmospheric and oceanic angular momentum signals at monthly and seasonal periods are well known. The role of the continental hydrologic signals, originated from land water, snow, and ice, is however less known. A number of previous studies have estimated hydrological excitation from climatologically measurements, numerical climate models and global hydrology models based upon the observed distribution of surface water, snow, ice and soil moisture (Kuehne & Wilson 1991; Chen et al. 2000). The hydrological part of polar motion excitation, can also be obtained, as a residual series, by removing atmospheric and oceanic signals from the mass term of the geodetically determined excitation of polar motion. The general conclusion of these studies is that the change in continental water storage plays a major role in the seasonal polar motion. However, the results do not agree among themselves and with the observed polar motion (Chen & Wilson 2005). This is mainly due to the lack of global measurements of related hydrological parameters.
Thanks to the Gravity Recovery and Climate Experiment (GRACE) mission, the mass redistribution is determined over the period February 2003 to December 2006. Data are tide free and non-tidal atmospheric and oceanic effects have been taken into account in the processing of the data. That means that gravity field solution is mostly of hydrological nature. This allows us to compare "gravimetric"-based excitation to the existing hydrological models, differences being possibly due to other Earth phenomena, for example, earthquakes.

2 Data and Methodology

2.1 Gravimetric excitation of polar motion

The determination of the GRACE satellites data is provided by four centres: Center for Space Research (CSR), GeoForschungsZentrum (GFZ), Jet Propulsion Laboratory (JPL) and Groupe de Recherche de Géodésie Spatiale (GRGS) in the form of normalized spherical harmonic coefficients.

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We use the latest version of the gravity field solution. All series are tide free. The non-tidal atmospheric and oceanic effects have been removed from the gravimetric data as a part of the de-aliasing. Then gravimetric-based excitation reflects variations from hydrological processes, post-glacial rebound, earthquakes and maybe unknowing Earth's geophysical phenomena. However, GRGS uses a barotropic oceanic model then baroclinic oceanic signal is as well in the data.
The "gravimetric" polar motion excitation is directly related to the (2,1) Stokes coefficients of the gravity field and off-diagonal inertia moments of the Earth in the terrestrial frame. The "gravimetric" citation is computed using the formula given by Chen et al. (2004).

2.2 Modeled hydrological excitation of polar motion

The Special Bureau for Hydrology of the International Earth Rotation and Reference System Service (IERS) provides the grids of the continental water storage estimated by the Climate Predicted Center (CPC). Hydrological excitations functions can be computed from these fields of using the formulation given by Chen & Wilson (2005).

2.3 Geodetic excitation of polar motion

The geodetic polar motion excitation in polar motion can be written as:

$$\chi = \chi_1 + i\chi_2 = p + i\frac{\dot{p}}{\sigma_c} \tag{2.1}$$

where $p = x - iy$ is the complex pole coordinate obtained from the Earth Orientation Parameters (EOP) series C04 (Gambis 2004) and σ_c is the frequency of the Chandler pulsation ($2\pi/433$ rad/days) with quality factor of 175. Polar motion derivative has been numerical approximated.
We have then to remove atmospheric and oceanic effects. For this purpose we use the Atmospheric Angular Momentum (AAM) series of the National Center for Environmental Prediction and National Center for Atmospheric Research reanalysis (Salstein et al. 1993) and the Oceanic Angular Momentum (OAM) series obtained from Estimating the Circulation and Climate of the Ocean model (Gross 2008).

2.4 Sampling and filtering of the excitation series

The different excitation functions used in our study have sampling comprised between 6 hours and one month. Applying Vondrak smoothing we make the series spectrally consistent. All those solutions are also interpolated

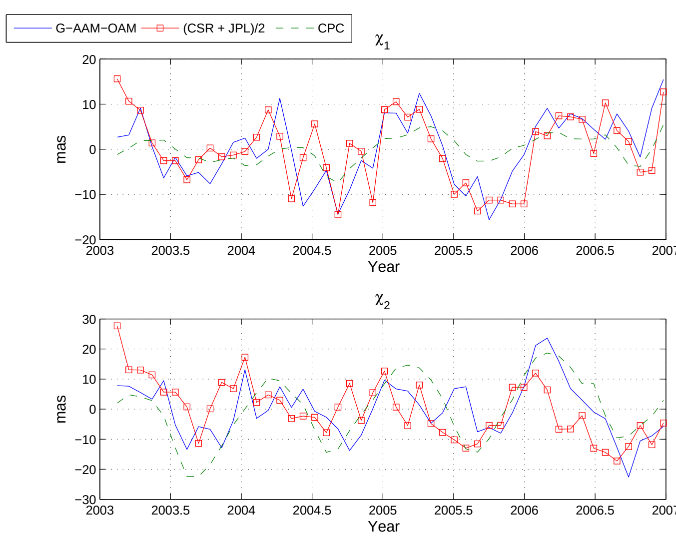

Fig. 1. Hydrological excitation from geodetic observations, CPC model and mean CSR and JPL gravimetric solutions

	χ_1		χ_2	
	Amplitude mas	Phase degree	Amplitude mas	Phase degree
G-AAM-OAM	6.9 ± 1.4	67.3 ± 12.0	9.2 ± 1.5	78.4 ± 9.3
CPC	3.6 ± 0.4	89.6 ± 6.8	13.6 ± 0.6	70.1 ± 28.5
CSR	4.7 ± 2.8	70.7 ± 34.9	8.6 ± 2.5	23.8 ± 16.7
GFZ	2.2 ± 2.4	20.8 ± 63.6	8.2 ± 2.3	10.8 ± 15.6
JPL	7.4 ± 1.4	78.3 ± 10.6	7.0 ± 1.2	31.8 ± 9.6
GRGS	5.3 ± 3.2	341.5 ± 34.7	13.0 ± 2.6	10.3 ± 11.2

Table 1. Annual variations of hydrological excitations.

at 30 day intervals.
We must be careful especially with the correlation significance because temporal span is not long enough (only 48 points). According to the Student-t test, critical value for 90% significance level of correlation is 0.18.

3 Analysis and Results

We compared gravimetric and modeled hydrological excitations to geodetic observations after removing atmospheric and oceanic contributions.
Considering correlations (not shown) with geodetic observations we find that CPC model-based, CSR and JPL gravimetric-based excitations have higher values than the critical value of the correlation coefficient. Fig. 1 shows hydrological excitation estimated from geodetic observations, CPC model and mean of CSR and JPL. We note that gravimetric excitation functions differ from geodetic observations up to 10 mas. Hence any difference between gravimetric and geodetic quantities can be associated to the inaccuracy of the gravity field solution or to the mis-modelling of the atmospheric and oceanic effects.
Table 1 shows annual variations of the different hydrological excitation series. We note that the annual oscillations of real component of the equatorial excitation (χ_1) computed from CSR and JPL gravity field observations agree in amplitude and phase with geodetic residuals whereas the hydrological excitation from CPC has not enough power. χ_2 amplitudes of all series are in agreement with geodetic one, but there are phase discrepancies. Only CPC series provide an correct phase.

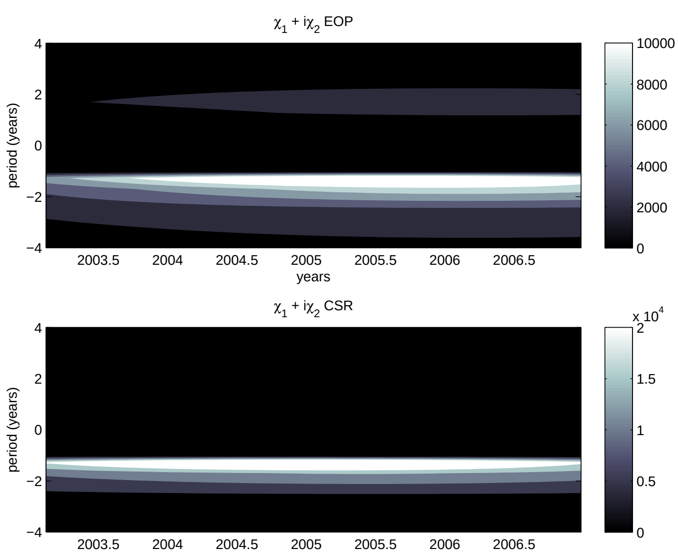

Fig. 2. Wavelet analysis for geodetic observations and CSR series of long period variations (longer than 1 year)

We also notice interannual period variations (greater than 1 year) in polar motion excitation functions: band-

pass filter of cut-off frequencies 1/4 and 1 cpy is applied to all series and wavelet analysis (Fig. 2) shows the existence of interannual oscillations with a maximum energy at the period of 1.3 year in the gravimetric observations as well as in the geodetic and in the modeled excitation (not shown). Over the same time span, February 2003 to December 2006, Schmidt et al. (2007) have as well detected the oscillations of 1.3 year period over the Amazon using GRACE's geoid computed by GFZ. We confirm that water storage variations in the Amazon or even in other world's basin have a significant influence in polar motion excitation.
Further improvements of GRACE or any other gravimetric mission data might help in the validation of hydrological signals due to center data processing computed from the hydrological models.
Interesting facts were found at long periods. We should confirm these results in the future using longer series of GRACE data.

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