HYDROLOGICAL EXCITATION OF POLAR MOTION

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ABSTRACT. First harmonics of the gravity field (C_{21} and S_{21}), derived from the Gravity Recovery and Climate Experiment (GRACE), and processed at different institutes, are used to determine the hydrological equatorial excitation function of polar motion. For that purpose time-variable gravity field solutions are made tidal free and free from modelled non-tidal atmospheric and oceanic effects. The residuals reflect unmodelled variations like hydrological processes, snow cover, post-glacial rebound or possibly earthquakes. They are compared to the hydrological excitation computed from hydrological models. They are also compared to the residual geodetic excitation after removing the atmospheric and oceanic effects. We find that seasonal variations of the excitation computed from gravimetric data and geodetic residuals are in good agreement. Annual signal is not well represented by hydrological models. All series show common biennial oscillations with periods of nearly 1.7 and 2.6 years.

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 signals at monthly and seasonal periods are well known. The role of the continental hydrology, originated from land water, snow, and ice, is however less known. It is possible to estimate the hydrological excitation from global models. 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. It is accepted that the change in continental water storage plays a major role in the seasonal polar motion. However, the models do not agree among themselves and with the observed polar motion. 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 2007. Data are tide free and non-tidal atmospheric and oceanic effects have been taken into account in the processing of the data. It means that gravity field solution is mostly of hydrological nature. This allows to compare "gravimetric"-based excitation to the existing hydrological models, differences being possibly due to other Earth phenomena, for example, earthquakes.

2. METHODOLOGY

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). Polar motion excitation is deduced from the relation between the C_{21} and S_{21} coefficients and off-diagonal inertia moments of the Earth in the terrestrial frame. We have used Chen et al. (2003) formulation for computing excitation from GRACE solutions. Time series of C_{21} and S_{21} are tide free and also corrected from non tidal atmospheric and oceanic signals. The International Earth rotation and Reference systems Service provides combined time series of the Earth Orientation Parameters at daily interval, in particular the pole coordinates x and y, which allows us to compute the "geodetic" polar motion excitation according to $G = \chi_1 + i\chi_2 = p + i\frac{\dot{p}}{\sigma_c}$. Where $p = x - iy$ is the complex pole coordinate and σ_c is the Chandler frequency. Hydrological variations are obtained after removing atmospheric and oceanic signals from geodetic excitation (G-A-O: geodetic - atmospheric - oceanic excitations). We use the atmospheric excitation functions of the NCEP/NCAR reanalysis and oceanic excitation from ECCO. On the other hand latitude-longitude grids providing the charge

	CSR	GFZ	JPL	GRGS	CPC	GLDAS
χ_1 G-A-O	0.54	0.14	0.66	0.23	0.57	0.25
χ_2 G-A-O	0.39	0.49	0.39	0.38	0.63	0.56

Table 1: Correlation coefficients between the residual geodetic observations and the excitation from hydrological models or from gravimetric data.

of continental water by surface unit at monthly intervals are available for the period 2003-2008. By integrating the grids of the Climate Prediction Center (CPC) and Global Land Assimilation System (GLDAS) hydrological models we have reconstituted the hydrological excitation function reduced to its mass term. Time series of the CSR, GFZ and JPL solutions present common sampling of about 30 days, but the GRGS solution is given at approximately 10-day intervals. On the other hand our geodetic excitation function presents variations up to 2 days. Applying Vondrák smoothing, which transmits 95% of the signal at 121 days, we make GRGS, geodetic series and modelled mass excitation spectrally consistent with the CSR, GFZ and JPL solutions. All those solutions are then interpolated at common dates, i.e. at 30 day intervals.

3. RESULTS

In Table 1 we note that CPC leads to the highest correlation for geodetic excitation. The gravimetric-based excitation functions derived from CSR and JPL are also significantly correlated with observations. Hydrological model GLDAS and gravimetric excitation from GFZ and GRGS are poorly correlated with geodetic observations in χ_1. The annual and semi-annual variations of hydrological modelled excitations, gravimetric-based excitations and residual geodetic excitation are show in Tab. 2. The annual signals are the most significant and the semi-annual oscillation is generally determined at the level of their significance. Annual variations of the excitation computed from gravimetric data and geodetic residuals are in agreement, especially for CSR and JPL. But there are phase discrepancies for the annual signal of χ_2. The annual signal amplitude is not well represented by hydrological models. Concerning interannual variations (larger than 1 year), a spectral analysis of all series show common biennial oscillations except for CPC hydrology model. They have a period of nearly 2.6 years possibly corresponding to Amazon and Mississippi water storage variations (Schmidt et al. 2007). We also find an oscillation with a period of 1.7 year period. Further study is required.

	χ_1				χ_2			
	Annual		Semiannual		Annual		Semiannual	
	Amplitude mas	phase degree	Amplitude mas	phase degree	Amplitude mas	phase degree	Amplitude mas	phase degree
G-A-O	7.8 ± 1.3	66.7 ± 9.7	1.2 ± 1.4	129.0 ± 66.7	8.5 ± 1.6	72.4 ± 11.1	3.8 ± 1.3	1.8 ± 20.2
CPC	3.6 ± 0.4	89.6 ± 6.8	1.1 ± 0.6	330.1 ± 28.5	13.4 ± 1.0	70.9 ± 4.2	2.1 ± 1.0	298.4 ± 27.5
GLDAS	2.4 ± 0.6	137.6 ± 15.3	1.0 ± 0.6	340.1 ± 33.6	2.4 ± 0.8	93.7 ± 19.3	1.8 ± 1.0	319.9 ± 32.5
CSR	5.7 ± 2.5	71.9 ± 25.4	3.5 ± 2.8	148.2 ± 44.6	8.7 ± 2.1	4.8 ± 13.6	2.7 ± 2.5	340.1 ± 51.8
GFZ	2.6 ± 2.0	20.1 ± 44.0	2.6 ± 2.1	206.6 ± 46.3	8.7 ± 1.8	3.2 ± 11.7	4.1 ± 2.3	336.2 ± 31.5
JPL	8.6 ± 1.2	87.7 ± 7.9	2.7 ± 1.2	86.9 ± 25.3	6.1 ± 1.3	23.9 ± 11.7	3.1 ± 1.3	300.9 ± 24.6
GRGS	5.5 ± 2.9	16.2 ± 29.0	1.9 ± 2.6	261.0 ± 80.1	15.8 ± 2.2	1.9 ± 7.9	1.7 ± 2.4	277.8 ± 80.1

Table 2: Annual and semiannual variations of hydrological excitations functions

4. REFERENCES

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