GRAVIMETRIC EXCITATION FUNCTION OF POLAR MOTION FROM THE GRACE RL05 SOLUTION

J. NASTULA
Space Research Centre of the PAS
Bartycka 18a, 00-716 Warsaw, Poland
e-mail: nastula@cbk.waw.pl

ABSTRACT.Impact of land hydrosphere on polar motion excitation is still not as well known as the impact of the angular momentum of the atmosphere and ocean. Satellite mission Gravity Recovery and Climate Experiment (GRACE) from 2002 provides additional information about mass distribution of the land hydrosphere. However, despite the use of similar computational procedures, the differences between GRACE data series made available by the various centers of computations are still considerable. In the paper we compare three series of gravimetric excitation functions of polar motion determined from Rl05 GRACE solution from the Center for Space Research (CSR), the Jet Propulsion Laboratory (JPL) and the GeoForschungsZentrum (GFZ). These data are used to determine the gravimetric polar motion excitation function. Gravimetric signal is compared also with the geodetic residuals computed by subtracting atmospheric and oceanic signals from geodetic excitation functions of polar motion. Gravimetric excitation functions obtained on the basis of JPL data differ significantly from the geodetic residuals while and the series obtained from CSR and GFZ are more compatible.

1. INTRODUCTION

Satellite mission Gravity Recovery and Climate Experiment (GRACE) is a source of data on temporal changes in Earth's gravity field. These data are available, in the form of changes in the coefficients C_{mn} S_{mn} - the so-called Level 2 gravity field product, include the GSM coefficients, estimated from satellite data, and the GAB, GAC, and GAD non tidal coefficients from atmosphere, atmosphere plus ocean, and ocean bottom pressure geopotential coefficients, respectively [Tapley et. al., 2004)]. Since 2002 there are have been a number of attempts to better process releases of these GRACE data. Here we use the most recently updated solution of Release 5 (Rl05) processed by three centers: Center for Space Research (CSR), the Jet Propulsion Laboratory (JPL) and the GeoforschungsZentrum (GFZ). The $\triangle C_{21} \triangle S_{21}$ coefficients of the newest Level 2 gravity field product are used here to compute gravimetric excitation functions of polar motion which reflect mainly the influence of the land-based hydrosphere (Hydrological Angular Momentum - HAM). We first explore the extent of agreement among the three Rl05 gravimetric excitation functions. We estimate also how well residual polar motion is explained with these newest gravimetric excitation functions.

2. DATA AND METHOD

The GSM coefficients reflect mainly the influence of the land-based hydrosphere, and to a lesser extent ice mass, and from seismic events, and do not include atmospheric and oceanic signals. This functions are also affected by errors of atmospheric and oceanic model approaches. To obtain information about the impact of all three geophysical fluids: land-based hydrosphere, atmosphere and oceans, the GAC coefficients should be added back to GSM. Atmospheric and oceanic model approaches however are certainly not error-free and the generation of the needed de-aliasing coefficients depends on several initial assumptions, as, e.g., a simplified two-year mean. The equatorial components of the polar motion excitation functions available for transfer of the fluid angular momentum to the solid Earth have been formalized as the χ_1 and χ_2, components, towards longitudes 0^o and 90^o E, respectively [Barnes, et al., 1983; Eubanks, 1993].

The equatorial components of the gravimetric polar motion excitation functions (χ_1 and χ_2) can be simply estimated directly from GRACE degree-2 and order-1 coefficients [Eubanks, 1993; Chen and

Wilson,2005;Chen et al.,2012; Nastula et al., 2007].

$$\chi_1 = -\sqrt{\tfrac{5}{3}}\tfrac{1.098a_E^2 M}{C-A}\triangle C_{21}, \chi_2 = -\sqrt{\tfrac{5}{3}}\tfrac{1.098a_E^2 M}{C-A}\triangle S_{21}$$

where M and a_E are the mass and mean radius of the Earth, respectively, C and A are the Earth's principal moments of inertia.

In the paper we use the following data:

1. GSM product - coefficients $\triangle C_{nm}$, $\triangle S_{nm}$ from RL05GRACE solutions developed by the CSR, JPL, and GFZ centers. The coefficients do not include the effects of atmosphere and ocean (http://icgem.gfz-potsdam.de/ICGEM/). The χ_1 and χ_2 components of gravimetric excitation functions computed from the GSM coefficients reflect mainly the influence of the land-based hydrosphere.

2. GAC de-aliasing product - coefficients $\triangle C_{nm}$ $\triangle S_{nm}$ of the gravitational field from atmospheric pressure (ECMWF) and from ocean bottom pressure (OMCT), prepared by CSR, JPL, and GFZ. (http://icgem.gfz-potsdam.de/ICGEM/). The χ_1 and χ_2 components of excitation functions computed from the GAC coefficients reflect mainly the matter term of the atmospheric and oceanic angular momentum in polar motion excitation.

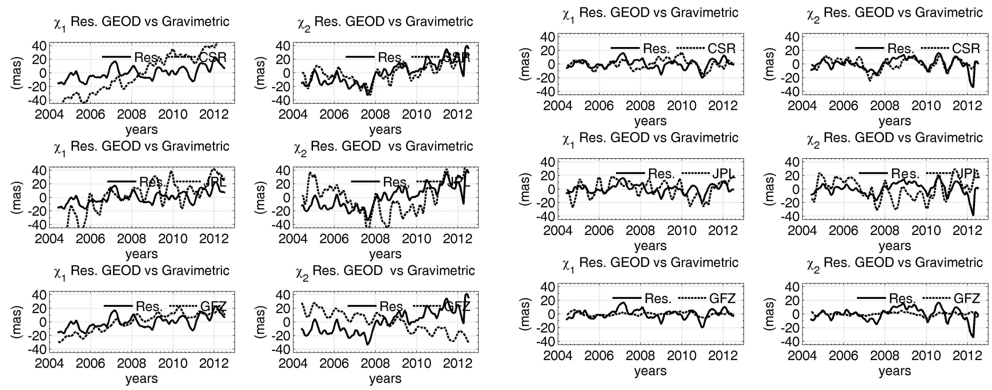
3. GEOD - Geodetic polar motion excitation χ_1 and χ_2 function, computed from x, y pole coordinates from the IERS C04 combined solution [Gambis, 2004]. Additionally, the motion term including atmospheric winds (NCEP) and oceanic currents (ECCO) are removed from the series by the IERS (http://hpiers.obspm.fr/eop-pc/). The data are daily from 1963 to the present, and also averaged into monthly intervals. GEOD–AAM– OAM - χ_1 and χ_2 components of geodetic residuals GEOD–AAM–OAM containing the hydrological part of polar motion excitation obtained by removing from the geodetic excitation functions merged atmospheric and oceanic excitation computed from the GAC coefficients from the three centers. In this way we obtained three types of residuals GEOD–GACCSR, GEOD–GACJPL, GEOD–GACJPL.

3. RESULTS

Figure 1a compares the variability of χ_1 and χ_2 components (solid – lines)of gravimetric excitation function of polar motion computed from the GSM coefficients. Figure 1b shows similar comparisons after removal of trends and seasonal oscillations; these are estimated by a least–square fitting model, comprised of a 1st order polynomial and a sum of sinusoids with periods 1, $\frac{1}{2}$, $\frac{1}{3}$ years. We should emphasize significant differences between the series obtained from the same solution RL05 from the three data centers. Despite the use of similar procedures, differences among GRACE–related values from models processed by different data centers are still considerable, making their use in interpreting polar motion difficult. The series obtained from the GFZ data is the smoothest while the series received from JPL shows the largest variation (Fig. 1b).

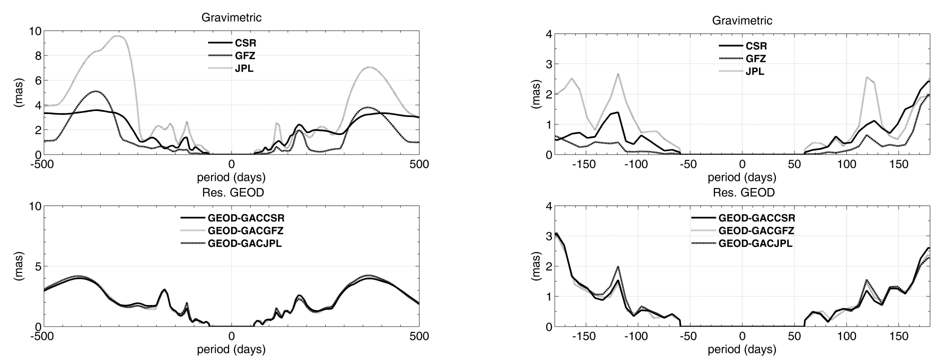
Next, in order to verify which of computed gravimetric series, is compatible with geodetic excitation we compared gravimetric excitation series with geodetic residuals GEOD–AAM–OAM. Diagrams of these gravimetric residuals are also illustrated in Figure 1. As it can be seen from Figure 1a, all gravimetric functions calculated from gravity data show a trend that is not present in the geodetic residuals. From visual inspection of Figures 1 a,b one can see that relatively good agreement between gravimetric excitation functions and the geodetic residuals is obtained from the CSR data, especially for χ_2. This conclusion is confirmed by results shown in both parts of Table 1., which shows correlation coefficients and variances of differences between geodetic residuals and gravimetric excitations.

Comparison of the spectra of the analyzed excitation functions are presented in Figure 2 while Figure 3 shows the phasor diagrams of the most important oscillation which is the annual oscillation. As in Figure 1, one can see the large differences f the results obtained from the data of the three centers. The spectra confirm the largest degree of smoothing in the data from the GFZ, and the relatively best agreement between gravimetric excitation functions computed from the CSR data and the geodetic residuals. Comparing the amplitude of the annual oscillation vectors we can easily see the correspondence between



(a) (b)

Figure 1: a) Comparison of gravimetric excitation function computed from GSM coefficients from CSR, JPL, GFZ with geodetic residuals GEOD-GACCSR, GEOD-GACJPL, GEOD-GACGFZ , b) comparison of the series shows with trend and seasonal oscillations (annual, semi-annual, 120 days) removed.



(a) (b)

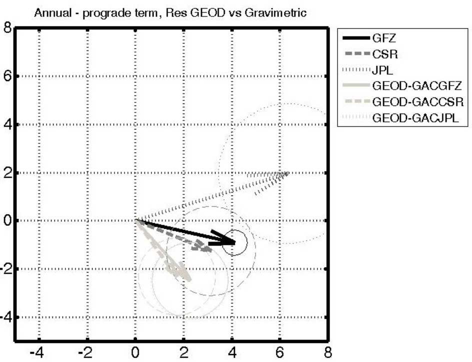
Figure 2: Comparison of spectra of gravimetric excitation function computed from GSM coefficients (CSR, JPL,GFZ), with spectra of geodetic residuals GEOD-GACCSR, GEOD-GACJPL, GEOD-GACGFZ.

the values determined from the geodetic residuals and from the CSR data, in both prograde and retrograde parts of spectra. In terms of the direction the closest to the vectors of geodetic residuals is the CSR vector in the prograde part while the GFZ vector in the retrograde part.

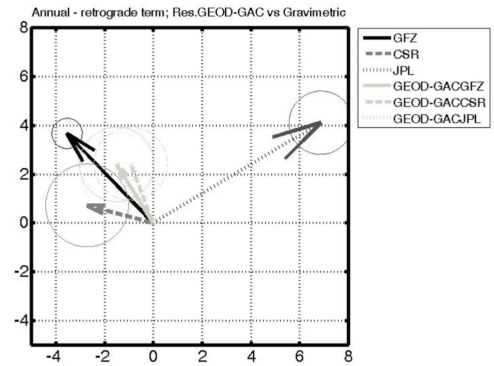
4. CONCLUSIONS

GRACE data are a useful tool to determine time-variable geophysical mass fields, and in particular that of the changing land-based hydrology, which is estimated otherwise only with complex hydrological models. We found that these gravimetric–hydrological excitation functions, based on the most recent GRACE RL05 release, obtained by the three processing centers, JPL, GFZ, CSR, may differ significantly. One difference is that a greater degree of smoothness is exhibited by GFZ than the JPL and CSR ones. Analyses show that the use of these new data to compare with geodetic residuals, does not bring significant new results from to previous studies [Seoane et al., 2009, Jin et al.,2012, Chen and Wilson, 2005; Chen et al., 2012, Nastula, et al.,2007, 2011]. Overall, though, the best agreement between gravimetric–hydrological excitation functions and geodetic residuals was obtained for the CSR data series, and this may be due to some attributes in the processing.

Acknowledgements. The author expresses his sincere thanks for the travel grant provided by the Local Organizing Committee of the Journées 2013. This work was supported by the Polish national science foundation NCN under grant No. DEC-2012/05/B/ST10/02132.



(a)



(b)

Figure 3: Phasor of annual oscillations of gravimetric excitation functions (GFZ,JPL,CSR) and geodetic residuals(GEOD-GACJPL, GEOD-GACJPL, GEOD-GACCSR),(units are mas).

Table 1: Comparison of gravimetric excitation functions, with geodetic residuals in terms of correlation coefficients and variances of differences.

Data	Detrended				Non seasonal			
	Corr. Coeff		Variance Diff. (mas^2)		Corr. Coeff		Variance Diff. (mas^2)	
	χ_1	χ_2	χ_1	χ_2	χ_1	χ_2	χ_1	χ_2
Res. Geod vs JPL	0.31	0.53	256	398.2	0.32	0.23	62.7	256.7
Res. Geod vs GFZ	0.33	0.32	56.3	103.8	0.30	0.20	134.2	84.6
Res. Geod vs CSR	0.22	0.72	82.6	65.1	0.18	0.58	40	62.7

5. REFERENCES

Barnes, R.T.H., Hide R., White A.A., Wilson C.A., 1983, Atmospheric angular momentum fluctuations, length-of-day changes and polar motion. Proc. R. Soc. London, Ser. A 38731-73, doi:10.1098/rspa.1983.0050.

Chen, J.L., and Wilson C. R. ,2005, Hydrological excitation of polar motion, 1993-2002, Geophys. J. Int. 160, 833-839, doi:10.1111/j.1365-246X.2005.02522.

Chen, J.L., Wilson, C.R., Zhou, Y.H., 2012, Seasonal excitation of polar motion, J. Geodyn., 62, 8-15, doi: 10.1016/j.jog.2011.12.002.

Eubanks, T.M., 1993, Variations in the orientation of the earth. In: Smith, D.E., Turcotte, D.I., (Eds.), Contributions of Soace Geodesy to Geodynamics-Earth Dynamics, Geodyn. Ser., vol 24, AGU, Washington, D.C., pp. 1-54.

Gambis, D., 2004, Monitoring Earth orientation at the IERS using space-geodetic observations, J. Geod., 78, 295-3-2.

Jin, S.G., Hassan A.A., and Feng G.P. ,2012, Assessment of terrestrial water contributions to polar motion from GRACE and hydrological models, J. Geodyn., 62, 40-48, doi: 10.1016/j.jog.2012.01.009.

Nastula, J., R. M. Ponte, and D. A. Salstein , 2007, Comparison of polar motion excitation series derived from GRACE and from analyses of geophysical fluids, Geophys. Res. Lett., 34, L11306, doi:10.1029/2006GL028983.

Nastula, J., Pasnicka M., Kolaczek B. ,2011, Comparison of the geophysical excitations of polar motion from the period:1980.0-2009.0, Act Geophys, 59(3):561577.

Seoane, L., Nastula J., Bizourad C., Gambis D. ,2009, The use of gravimetric data from GRACE mission in the understanding of polar motion variations Geophys. J. Int. 178, 614-622.

Tapley, B.D., Bettadpur S., Ries J.C., et al. ,2004, GRACE measurements of mass variability in the Earth system. Science 3055683:503-505 doi:10.1126/science.1099192