Gravimetric excitation function of polar motion from the GRACE RL05 solution

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Outline

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- Data
- Comparison of gravimetric excitation functions.
- Comparison of gravimetric excitation functions with geodetic residuals computed by removing atmospheric and oceanic signals from geodetic excitation functions of polar motion.
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 $\Delta C_{mn}$ $\Delta S_{mn}$ - the so-called Level 2 gravity field product.

$\chi_1$, $\chi_2$ - Gravimetric excitation functions are determined from $\Delta C_{21}$, $\Delta S_{21}$ coefficients from the following formulas (Gross, 2013):

$$\chi_1 = -\sqrt{\frac{5}{3}} \frac{1.098 a_E^2 M}{(C - A)} \Delta \tilde{C}_{21}$$
$$\chi_2 = -\sqrt{\frac{5}{3}} \frac{1.098 a_E^2 M}{(C - A)} \Delta \tilde{S}_{21}$$

$M$ - mass of the Earth
$a_E$ - average equatorial radius of the Earth
$C, A$ - principal moments of inertia
**Data used**

**GSM product** - coefficients $\Delta C_{21}, \Delta S_{21}$ from RL05 GRACE solutions developed by three centers, the Center for Space Research (CSR), the Jet Propulsion Laboratory (JPL) and GeoForschungsZentrum (GFZ). These coefficients reflect mainly the impact of the land mass of the hydrosphere on the gravitational field changes. To a lesser extent, they reflect changes in ice mass, and changes from seismic events. However they do not include information about the influence of the atmosphere and ocean.

**GAC dealiasing product** - coefficients $\Delta C_{21}, \Delta S_{21}$ of gravitational field from atmospheric pressure (ECMWF) and from pressure of the ocean (OMCT), prepared by CSR, JPL, GFZ.

**GEOD** - Geodetic polar motion excitation function estimated by the International Earth Rotation and Reference Systems Service (IERS) based on the C04 series of $x,y$ coordinates of the pole. *From this function motion term is removed.*
Gravimetric ~ hydrological (HAM) excitation function of polar motion - computed from the GSM coefficients $\Delta C_{21}$ and $\Delta S_{21}$. This function represents primarily change of the excitation function due to changes in land mass of the hydrosphere.

**AAM+OAM** - merge atmospheric and oceanic excitation function of polar motion - computed from the GAC coefficients $\Delta C_{21}$ $\Delta S_{21}$. This function represents primarily excitation due to atmospheric and oceanic mass changes.

**GEOD** - (AAM+OAM) - Geodetic residuals computed by removing atmospheric and oceanic signals AAM+OAM (computed from the GAC) from the geodetic excitation function.
Comparison of gravimetric - hydrological excitation functions
$\chi_1$ and $\chi_2$

**Fig. 1** Gravimetric excitation function (HAM) computed from GSM coefficients from CSR, JPL, GFZ (top panel), joint atmospheric and oceanic excitation function computed from GAC coefficient from CSR, JPL, GFZ (middle panel), joint atmospheric oceanic and gravimetric excitation function AAM+OAM+HAM (bottom panel).
\( \chi_1 \) and \( \chi_2 \) - non seasonal changes

Fig. 3 Gravimetric excitation function (HAM) computed from GSM coefficients from CSR, JPL, GFZ (top panel), joint atmospheric and oceanic excitation function computed from GAC coefficient from CSR, JPL, GFZ (middle panel), joint atmospheric oceanic and gravimetric excitation function AAM+OAM+HAM (bottom panel). Seasonal oscillations are removed.
Comparison of gravimetric (HAM) excitation functions with geodetic residuals (GEOD-GAC)
Geodetic residuals (GEOD-GAC) vs HAM

Fig. 4 Comparison of gravimetric excitation function HAM computed from GSM coefficients (CSR, JPL, GFZ), with geodetic residuals GEOD-GAC.
Fig. 4 Comparison of gravimetric excitation function HAM computed from GSM coefficients (CSR, JPL, GFZ), with geodetic residuals GEOD-GAC.
Fig. 6 Comparison of gravimetric excitation function HAM computed from GSM coefficients (CSR, JPL, GFZ), with geodetic residuals GEOD-GAC. Seasonal oscillations are removed.
Fig. 7 Comparison of spectra of gravimetric excitation function HAM computed from GSM coefficients (CSR, JPL, GFZ), with geodetic residuals GAM-GAC spectra. (FTBPF, lambda=0.02).
Fig. 8 Phase diagrams of annual oscillations of gravimetric excitation functions HAM computed from EWT (GFZ, JPL, CSR) with phase diagrams of annual oscillations of geodetic residuals computed by removing atmospheric and oceanic signals using GAC coefficients from geodetic excitation function.
### Table 1a Correlation coefficients HAM

<table>
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<tr>
<th>Series</th>
<th>$\chi_1$</th>
<th>$\chi_2$</th>
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<tbody>
<tr>
<td>CSR/GFZ</td>
<td>0.62</td>
<td>0.24</td>
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<tr>
<td>CSR/JPL</td>
<td>0.30</td>
<td>0.54</td>
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<tr>
<td>JPL/GFZ</td>
<td>0.08</td>
<td>0.01</td>
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### Table 1b Variance of differences HAM (mas$^2$)

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<tr>
<td>CSR/GFZ</td>
<td>31.7</td>
<td>61.2</td>
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<tr>
<td>CSR/JPL</td>
<td>137.6</td>
<td>165.2</td>
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<td>JPL/GFZ</td>
<td>148.8</td>
<td>232.4</td>
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### Table 2a Correlation coefficients HAM vs. Geodetic residuals

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<td>JPL</td>
<td>0.32</td>
<td>0.23</td>
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<tr>
<td>GFZ</td>
<td>0.30</td>
<td>0.20</td>
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<tr>
<td>CSR</td>
<td>0.18</td>
<td>0.58</td>
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### Table 2b Variance of differences HAM – GEOD Res (mas$^2$)

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<tbody>
<tr>
<td>JPL</td>
<td>62.7</td>
<td>256.7</td>
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<tr>
<td>GFZ</td>
<td>134.2</td>
<td>84.6</td>
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<td>CSR</td>
<td>40.0</td>
<td>62.7</td>
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Conclusions

- Gravimetric-hydrological excitation functions obtained from the GSM coefficients from RL05 solution from three data centers JPL, GFZ, CSR differ significantly.

- GFZ solution exhibits a greater degree of smoothness than JPL and CSR.

- The best agreement between gravimetric-hydrological excitation functions and geodetic residuals was obtained from the CSR data series.
Fig. 2a. Differences among the EWT maps computed from GAC coefficients in Figure 5a (units meters$^2$/grid).

Fig. 2b. Differences among the EWT maps computed from GSM coefficients in Figure 5b (units meters$^2$/grid).
Fig. 2 Gravimetric excitation function (HAM) computed from GSM coefficients from CSR, JPL, GFZ (top panel), joint atmospheric and oceanic excitation function computed from GAC coefficient from CSR, JPL, GFZ (middle panel), joint atmospheric oceanic and gravimetric excitation function AAM+OAM+HAM (bottom) panel. Combination of annual, semiannual and 120-day oscillations.
Fig. 5 Comparison of gravimetric excitation function HAM computed from GSM coefficients (CSR, JPL, GFZ), with geodetic residuals GEOD-GAC. Combination of annual, semianual and 120 day oscillations.
Fig. 9a Phase diagrams of semiannual oscillations of gravimetric excitation functions HAM computed from EWT (GFZ, JPL, CSR) with phase diagrams of annual oscillations of geodetic residuals computed by removing atmospheric and oceanic signals using GAC coefficients from geodetic excitation function.
Fig. 9b Phase diagrams of semiannual oscillations of gravimetric excitation functions HAM computed from EWT (GFZ, JPL, CSR) with phase diagrams of annual oscillations of geodetic residuals computed by removing atmospheric and oceanic signals using GAC coefficients from geodetic excitation function.