Evaluation of PGM2007A by comparison with globally and locally estimated gravity solutions from CHAMP

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Introduction

This poster shows results of the evaluation of the preliminary gravity field model PGM2007A with CHAMP data. It will focus on the low to medium degree part of the spectrum due to the restricted spatial and spectral solvability of the CHAMP mission. Three different data sets will be considered in the comparison. Besides the PGM2007A, the GRACE-only solution GGM02s provided by UTCSR and a two year CHAMP-only solution will be used. PGM2007A incorporates GRACE-data and thus an evaluation with, e.g., GGM02s is biased. One of the best available independent data sources for low to medium degrees till 70 is consequently the CHAMP data. It is known that the accuracy of the CHAMP solutions is approximately one order of magnitude worse than GRACE-only solutions but the CHAMP solutions might still serve as an indicator since also discrepancies between the PGM2007A and the GGM02s occur.

Data Processing

The CHAMP solutions are derived in two steps. First the measured positions, velocities and accelerations are converted into pseudo-potential observations values along the orbit using the energy balance approach:

\[ T + c = E_{kin} - U - Z - \int \left( f + \sum_{k} g_k \right) dx \]

- \( T \) = disturbing potential
- \( c \) = integration constant
- \( E_{kin} \) = kinetic energy
- \( U \) = normal gravitational potential
- \( Z \) = centrifugal potential
- \( \int f dx \) = dissipative energy
- \( \int \sum_{k} g_k dx \) = time variable changes

Subsequently, a global spherical harmonic analysis on the sphere is performed in order to derive the global satellite-only solution by a brute-force method. In areas of higher data densities, e.g., near the poles, or of special interest a local refinement can be attempted in order to better indicate the tendency of the CHAMP data towards one of the two other models. For this, the framework of a Slepian analysis will be introduced. The motivation for local refinements using Slepian functions in polar areas can be seen from the following figure.


Local refinement using Slepian functions

The basic concept of the Slepian functions is to maximize the ratio between the spacelimited (R) and the unlimited norm (\( \Omega \)) of a spatial function \( S \) and thus the spatial concentration of the bandlimited function in the area of interest:

\[ \lambda = \frac{\int_{R} S^2 d\Omega}{\int_{\Omega} S^2 d\Omega} = \text{maximum} \]

The solution of the spatial localization problem is found as the solution of an algebraic eigenvalue problem forming an orthogonal set of base functions. A gravity functional can then be expressed as a series of Slepian base functions, e.g., the potential:

\[ T = \frac{GM}{R} \sum_{i=1}^{(L+1)^2} \beta_i S_i = \frac{GM}{R} \sum_{i=1}^{(L+1)^2} \beta_i \sum_{l=0}^{L} \sum_{m=-l}^{l} \left( \frac{R}{r} \right)^{l+1} g_{lm} Y_{lm} \]

where \( \beta_i \) Slepian coefficients \( q_i \) eigenvectors \( S_i \) Slepian base function \( Y_{lm} \) spherical surface harmonic

The eigenvalue indicate the spatial concentration inside the area of interest.

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Global Evaluation

In the spectral domain, the difference between GGM02s and PGM2007A wrt. CHAMP is almost identical. Obviously and for all degrees, the difference between PGM2007A and GGM02s is smaller than the difference to CHAMP – a first hint that the quality of the CHAMP solution is too poor. The spatial plots also do not show significant differences. Only the statistics show slight but not significant tendency towards GGM02s.

<table>
<thead>
<tr>
<th></th>
<th>GGM02s</th>
<th>PGM2007A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>1.342 m</td>
<td>1.326 m</td>
</tr>
<tr>
<td>Min</td>
<td>-1.338 m</td>
<td>-1.364 m</td>
</tr>
<tr>
<td>RMS</td>
<td>0.326 m</td>
<td>0.329 m</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.028</td>
<td>0.038</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.199</td>
<td>0.299</td>
</tr>
</tbody>
</table>

Local comparisons

The CHAMP solution is refined for a latitude band from 60 to 85. The recovered residual signal has a strength of 10 cm. However, in the spatial domain again no significant differences are visible and both pictures are dominated by the deficiencies in the CHAMP data.

<table>
<thead>
<tr>
<th></th>
<th>GGM02s</th>
<th>PGM2007A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>1.014 m</td>
<td>1.032 m</td>
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<tr>
<td>Min</td>
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<td>-1.217 m</td>
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<tr>
<td>RMS</td>
<td>0.314 m</td>
<td>0.318 m</td>
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<tr>
<td>Skewness</td>
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<td>-0.035</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.605</td>
<td>0.589</td>
</tr>
</tbody>
</table>

Conclusions

In conclusion, one can at best say that the global CHAMP solution compares slightly better to GGM02s. The local refinement recovers residual signal but yields no further insight. The tendency towards GGM02s is not visible. Overall, the poorer quality of the CHAMP data is preventing a real statement about the quality of the PGM2007A.

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