Closed-loop tests of a regional gravity field modelling approach using radial basis functions

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We consider different spectral and spatial resolutions. GOCE data contribute the most in the regional gravity field modelling. We test different combinations of geophysical data sets (disturbing potential T on geographic grids, GRACE or GOCE data) which have been used in the past. In general the closed-loop tests give information on the external accuracy of our regional gravity field modelling strategy. This helps to understand the interactions and relationships between different parametrisations and applications (see Schmidt et al., EGU2014-12952/poster 8770).

Simulation of different gravity field solutions

Validation data sets

Differences

Comparison of different basis functions (synthesis)

Results

We use series expansions in terms of radial basis functions (scaling functions) based on Legendre polynomials acting as low-pass filters in the frequency domain. The maximum degree \( j \) of the series expansion is related to a specific resolution level \( \ell \). It defines the cut-off frequency of the low-pass filter and thus the spectral resolution \( \ell \). In the synthesis step we use Blackman scaling functions (multiplied with the estimated coefficients \( d_j \)). We model functional expansions of the gravitational potential \( \Phi \) with a Legendre polynomial \( \Phi(P_{lM}) \) or an observation \( \Phi_{obs} \) to avoid edge effects. The higher the resolution level, the sharper the decline of the functions, the denser the grid points (see Figures below: Reuter grids at \( j = \ell \) vs. \( j = 11 \) and data distribution for two study areas in Europe).

Motivation

Since many high-resolution observations, e.g. from terrestrial gravimetry or GOCE, are only available in regional areas, regional gravity field modelling becomes more and more important as an extension of the traditional global modelling of the Earth’s gravitational potential. However, a lot of open questions have to be answered and problems concerning a consistent model combination and application have to be cohered. In contrast to global approaches using spherical harmonic functions, the choice of the set of basis functions for regional analysis is a central question. In the context of inter-comparing different approaches within the IAG (CCT JSG 3*), we set up a closed-loop simulation using an approach based on radial scaling functions. All results are compared with validation data sets (disturbing potential T) on geographic grids to synthesize a posteriori results in study areas for data in Europe (I) and South America (SA).

Observation equations

We set up observation equations for each observation type \( \Delta T, T_{ij}, \) subtracted by a background model \( T_{\text{back}} \). We define an extended Gauß-Markov model and calculate the unknown scaling coefficients \( d_j \) by variance component estimation. In this analysis step we use Shannon scaling functions \( \Phi_{\text{Sh}}(P_{lM}) \) with appropriate Legendre coefficients \( \Phi_{lM} \).

The functions are located on a Reuter grid (area of computation). The area of investigation is the smallest area. The area of observations should be larger to avoid edge effects. The higher the resolution level, the sharper the decline of the functions, the denser the grid points (see Figures below: Reuter grids at \( j = \ell \) vs. \( j = 11 \) and data distribution for two study areas in Europe).

Notes:

- We use the simulated gravity field solutions \( \Phi_{\text{sim}} \) for different spectral and spatial resolutions.\( \Phi_{\text{sim}} \) is defined as the model solution without the estimated coefficients \( d_j \).
- Testing different combinations of geophysical data sets (disturbing potential T on geographic grids, GRACE or GOCE data) which have been used in the past.

Legend: \( T \) = disturbing potential, GRACE = GRACE, GOCE = GOCE, GOCO03s = GOCO03s, EGM2008 = EGM2008, IAG = International Association of Geodesy, ICCT = International Centre for Coastal and Territorial Studies, GRACE = Gravity Recovery and Climate Experiment, GOCE = Geodetic Observations for Geophysical and Climate Exploration, GOCO03s = Global Geopotential Model 2003, EGM2008 = Earth Gravitational Model 2008, T = disturbing potential, \( T_{ij} \) = gravitational potential, \( \Phi_{\text{obs}} \) = observation, \( \Phi_{\text{sim}} \) = simulated.