Global gravity field determination with regional refinements by the analysis of GOCE-level-1b data (GLOREGOCE)

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Summary

In this contribution, we present regionally refined gravity field models from GOCE data only using the short arc processing. For easy comparison, regional solutions calculated on small patches all over the globe have been merged and transformed to a spherical harmonic expansion by means of quadrature methods. The power of the regional approach is demonstrated by comparison to the previously calculated ITG-Goce01/ITG-Goce02 spherical harmonic models, which are based on exactly the same processing strategy, standards and data time span. We show, that these global models are comparable in accuracy with respect to the official ESA time-wise models. Second, we verify the gain of regional modelling with respect to our global models: Compared to EGM08 cut to the oceans, using a land/ocean adjustment of regularisation reduces the global noise by 11%. A more tailored choice of the regularisation areas tested for the South Sandwich Trench reveals the significant improvement of 18%.

GOCE analysis using the Short Arc Approach

Input data SGG

- tensor main diagonal elements, star camera and reduced dynamic orbits for orientation in space
- data low pass filtered on 5sec

Input data SST

- kinematic orbits, common mode acceleration as measured by the gradiometer
- data low pass filtered on 10sec

Background models

- reference field
- direct, earth, ocean tides
- dealiasing products

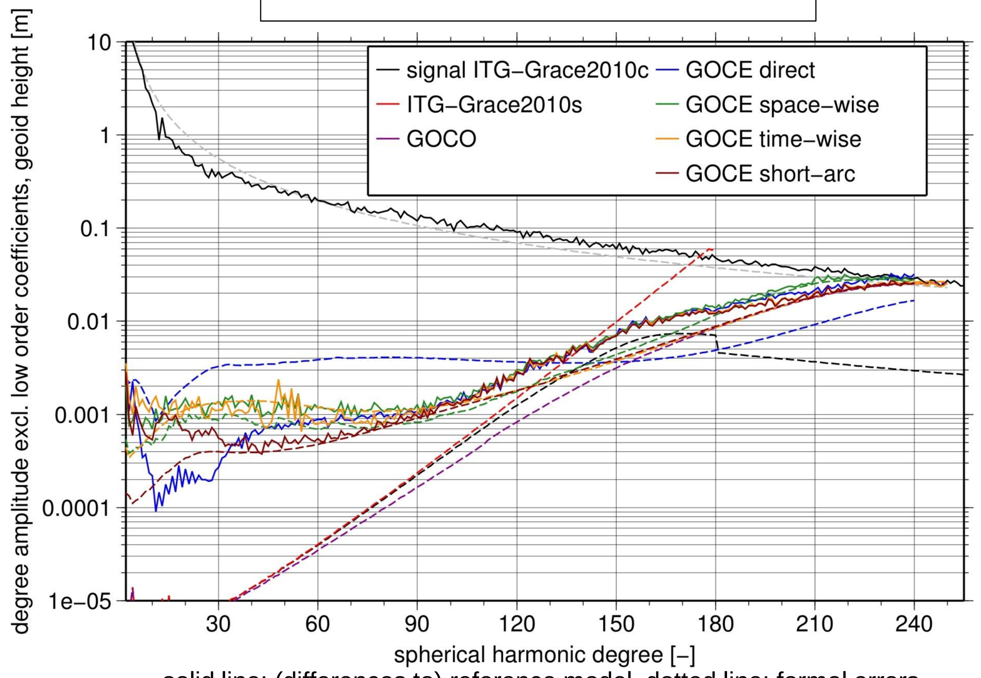
Stochastic model

- emp. covariance matrices per arc
- offset per arc and tensor element

Processing strategy

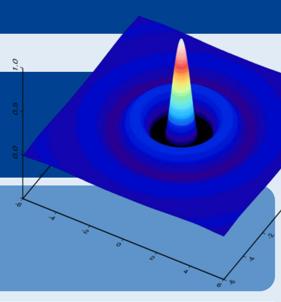
- major outliers flagged using a threshold value procedure
- arcwise reweighting of observations
- arcwise assembling of normal equations
- least squares solution
- regularisation using Kaula's rule

Comparison between the 7month ITG-Goce02 model and the official ESA GOCE solutions



solid line: (differences to) reference model, dotted line: formal errors

Regional GOCE analysis



What for?

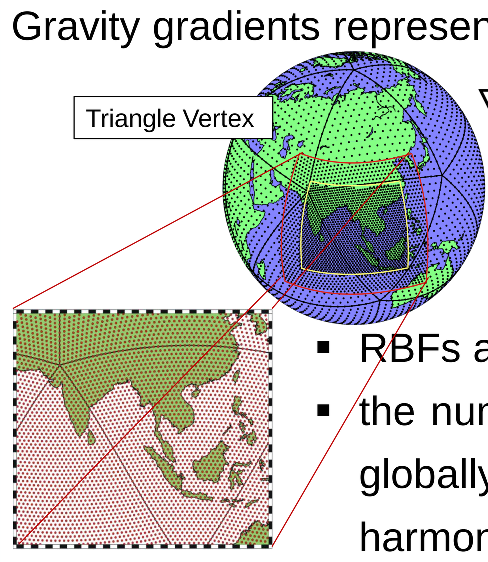
Compared to spherical harmonics, space localising basis functions provide the advantage to be more flexible in modelling data of differing density and variability, as it is the case in gravity field analysis. Particularly,

- regionally adjusted regularisation enables optimal damping of both, regions featuring rough signal and rather smooth areas, at the same time. This is of special interest for GOCE because of its strength in observing higher frequencies of the gravity field.
- data gaps, such as GOCE polar regions, can easily be dealt with by skipping the refinement in the respective areas.

Regionally limited, but high resolution gravity models are based on a comparatively small number of parameters. This fact is of practical relevance, because it reduces significantly the computation effort for gravity analysis and synthesis.

Regional Representation by Radial Basis Functions RBFs

Gravity gradients represented by RBFs



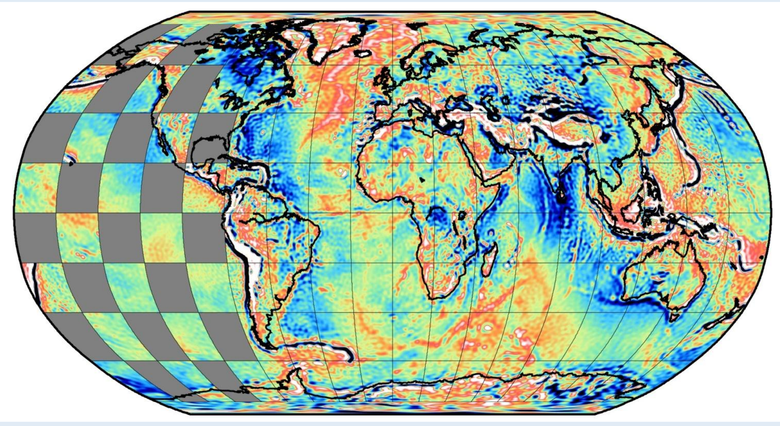
$$\nabla\nabla V(\mathbf{r}) = \sum_{i=1}^{I} \alpha_i \nabla\nabla\phi_i(\mathbf{r})$$

$$\phi_i(\mathbf{r}) = \frac{GM}{R}\sum_{n=2}^{N}\left(\frac{R}{r}\right)^{n+1} k_n P_n(\mathbf{r},\mathbf{r}_i)$$

- RBFs arranged on a Triangle Vertex grid
- the number of base functions is chosen to globally match the number of spherical harmonics with comparable resolution
- design of RBFs is derived from the covariance function of the gravity signal
- in practice, residual signal is approximated
- thus, the shape is chosen from the formal errors of the reference solution and from Kaula's rule for higher degree

Conversion into Spherical Harmonics

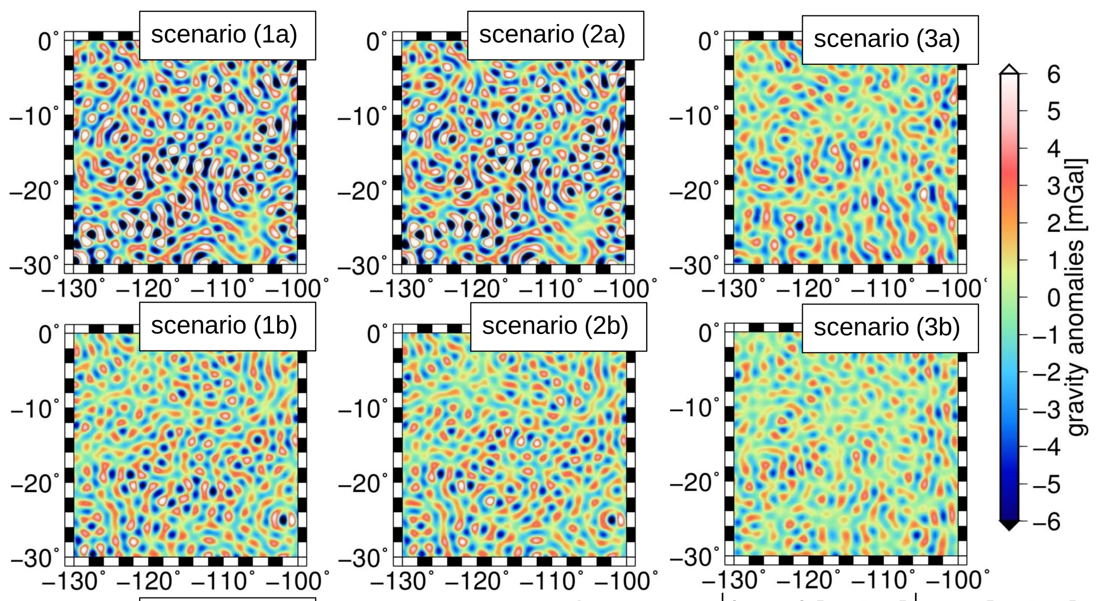
- regional solution with global coverage can be merged into a global solution and converted to spherical harmonics by Gauss-Legendre quadrature
- thus, the solutions can be investigated in the frequency domain as well

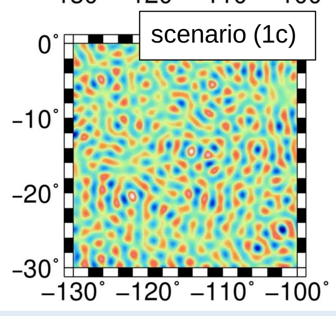


Validation of/by GOCE models in space domain

Over the open ocean

Deviations from EGM08 (d/o 200)

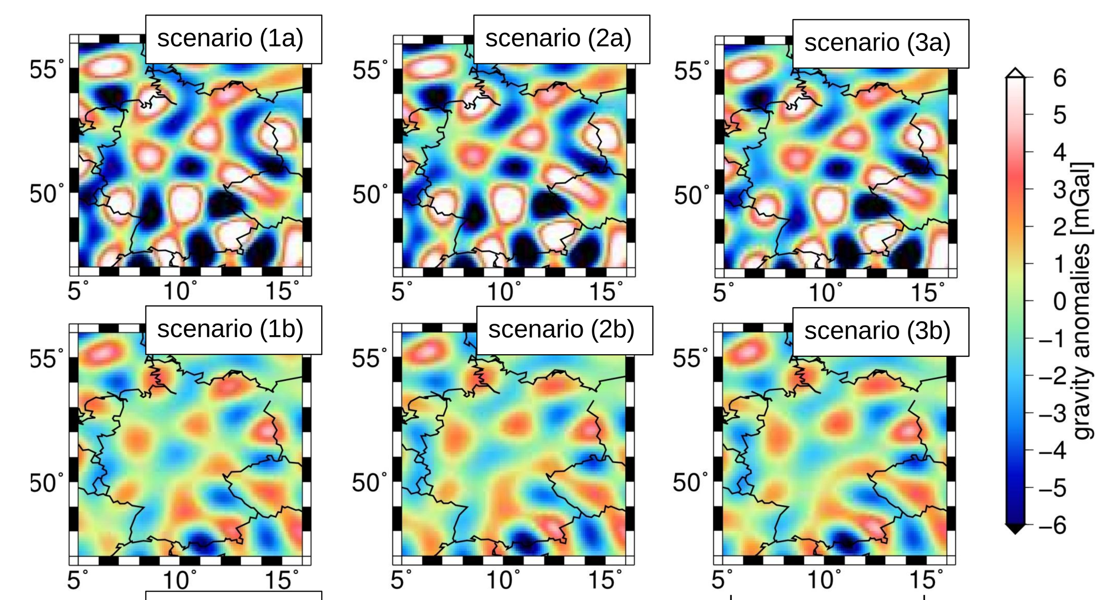


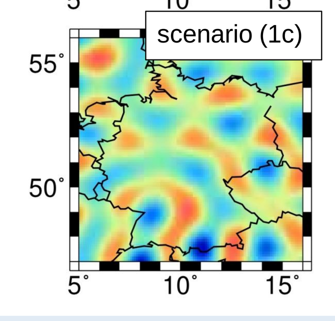


scenario		|max| [mGal]	rms [mGal]
GOCE	(1a) 72days	14.393	3.177
time-wise	(1b) 7months	8.671	1.956
	(1c) 12months	5.965	1.497
ITG-Goce	(2a) 72days	13.018	3.121
	(2b) 7months	7.605	1.844
ITG-Goce	(3a) 72days	7.396	1.765
RBFs	(3b) 7months	5.235	1.385

In Germany

Deviations from EGM08 (d/o 200)

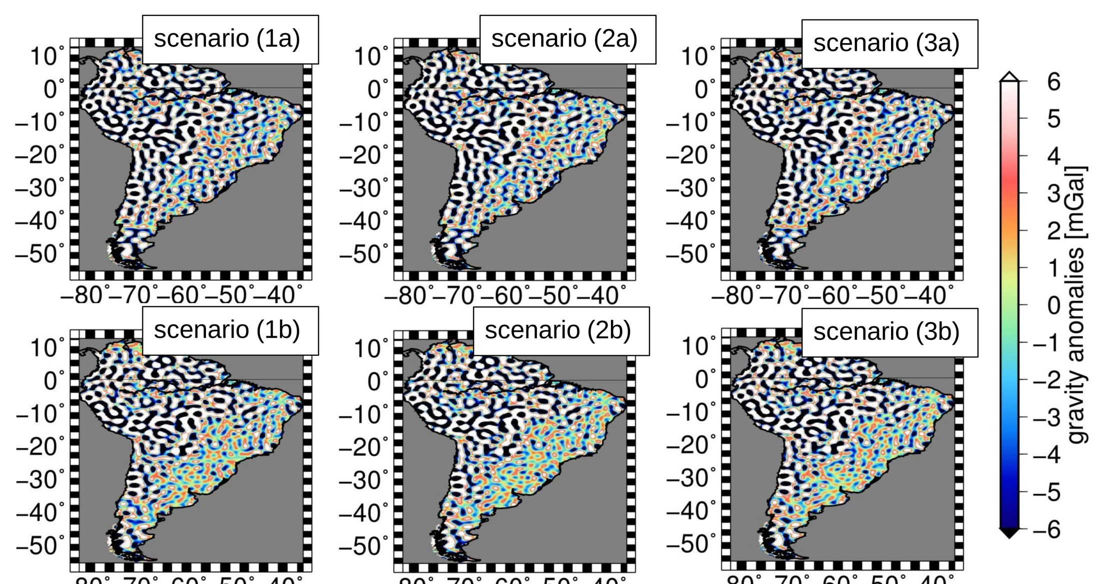


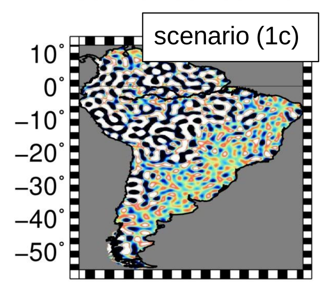


scenario		|max| [mGal]	rms [mGal]
GOCE	(1a) 72days	12.240	3.983
time-wise	(1b) 7months	6.138	1.701
	(1c) 12months	5.021	1.429
ITG-Goce	(2a) 72days	12.022	3.853
	(2b) 7months	6.665	1.740
ITG-Goce	(3a) 72days	12.189	3.606
RBFs	(3b) 7months	6.680	1.738

In South America

Deviations from EGM08 (d/o 200)

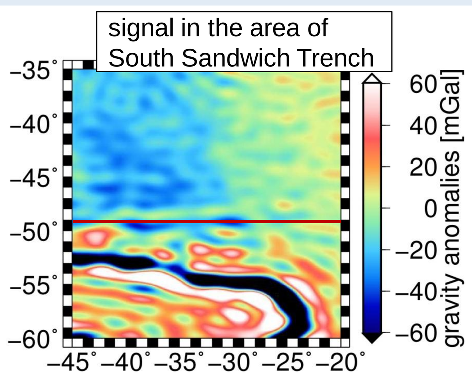


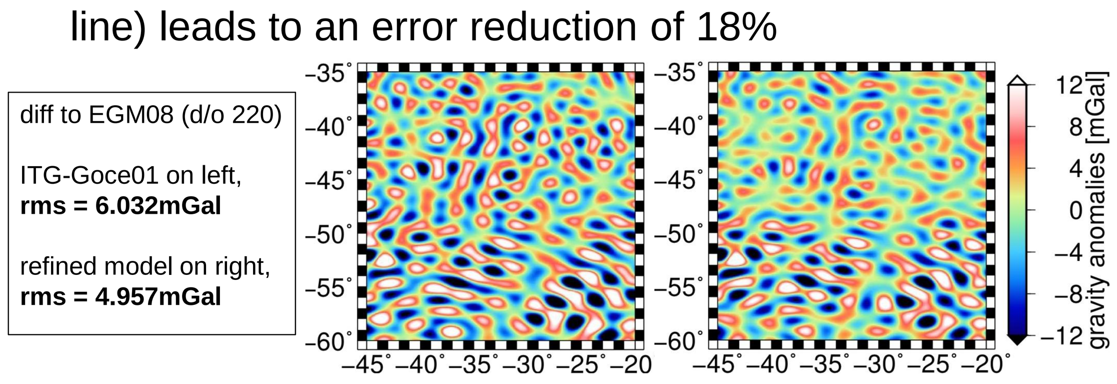


scenario		|max| [mGal]	rms [mGal]
GOCE	(1a) 72days	66.346	8.790
time-wise	(1b) 7months	64.718	8.403
	(1c) 12months	65.357	8.311
ITG-Goce	(2a) 72days	66.080	8.824
	(2b) 7months	63.970	8.374
ITG-Goce	(3a) 72days	67.086	8.815
RBFs	(3b) 7months	65.058	8.400

Towards a more tailored regularisation

- so far, regularisation factors for land and ocean are estimated
- for the heterogeneous patch displayed on the right, this may not be the best choice
- by doing so, any improvement is achieved compared to the global model
- contrary, subdividing the ocean into two areas of differently smooth gravity signal (indicated by the red line) leads to an error reduction of 18%



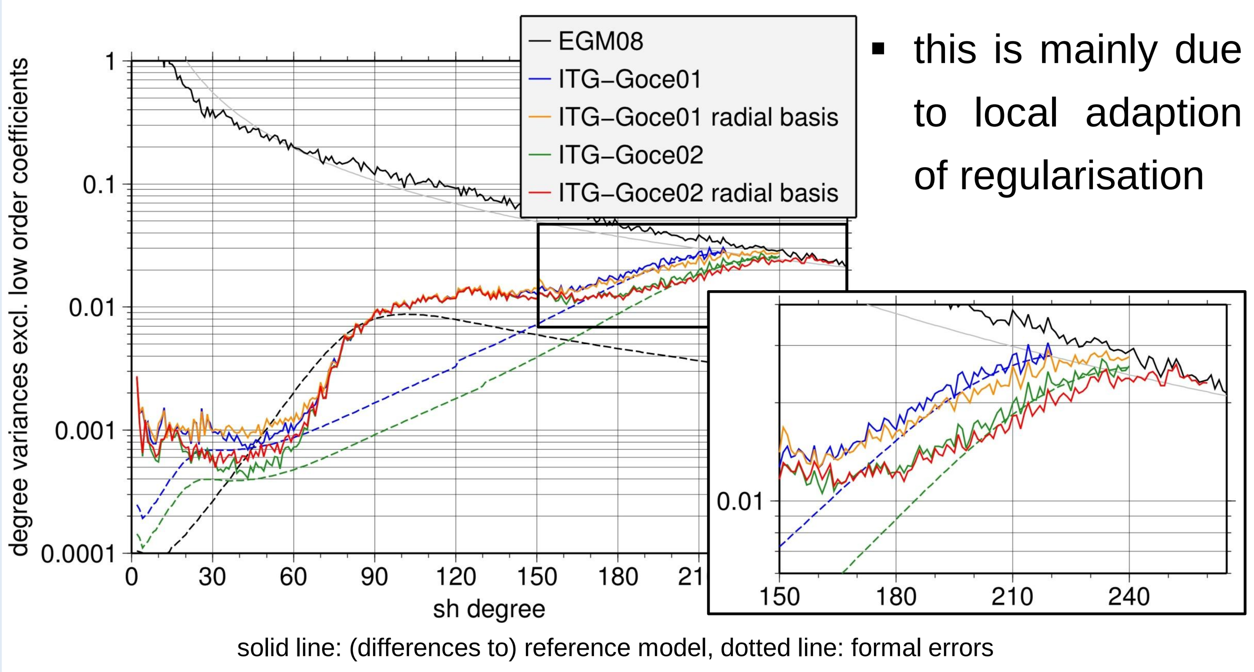


Setup

- regional refinements calculated from gradiometer data
- to ITG-Goce01 (d/o 150) up to d 240, using a triangle vertex grid of level 76 (59292 global parameters)
- to ITG-Goce02 (d/o 160) up to d 260, using a triangle vertex grid of level 82 (68892 global parameters)
- on small patches of 20°x20°, polar areas have been skipped and filled up by the reference models before transforming to spherical harmonics
- using land/ocean adaption of regularisation

Validation in frequency domain

- both ITG-Goce01 and ITG-Goce02 show smaller differences in the low frequencies compared to their refined version
- an improvement of the refined models in the long wavelengths may be achieved by more careful treatment of the transitions between neighbouring patches
- for higher frequencies, the opposite is true, better performance above d 160 (for 72days solution) or d 180 (for 7months solution)



- this is mainly due to local adaption of regularisation

solid line: (differences to) reference model, dotted line: formal errors

Eicker, A. (2008) Gravity Field Refinement by Radial Basis Functions from In-situ Satellite Data, PhD thesis, Bonn University, Bonn.

Mayer-Gürr (2006) Gravitationsfeldbestimmung aus der Analysis kurzer Bahnbögen am Beispiel der Satellitenmissionen CHAMP und GRACE, PhD thesis, Bonn University, Bonn.

Schall, J. et al. (2011) A global gravitational field model from GOCE gradiometer observations, Proceedings of the 4th International GOCE User Workshop, ESA Publication SP-696.

Publication of the ITG-Goce models and the regional refinement technique using the example of GOCE in preparation

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