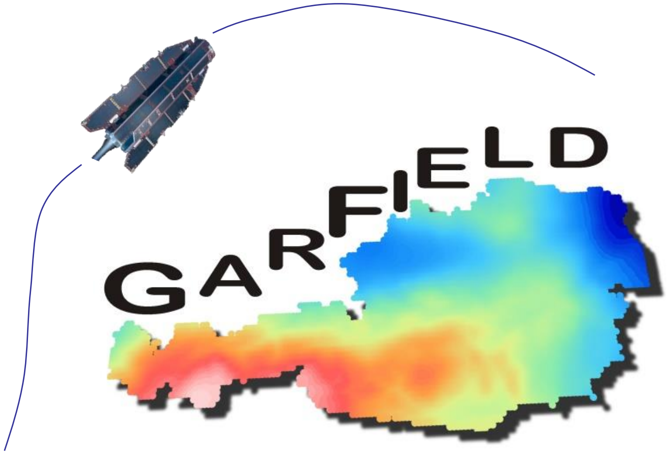
GOCE gravity gradients for a new Austrian Geoid solution - A status report



Daniel Rieser, Christian Pock, Torsten Mayer-Guerr

Institute of Theoretical Geodesy and Satellite Geodesy

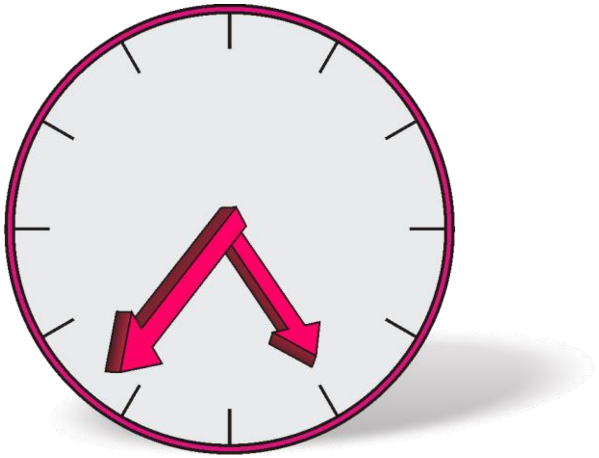
TU Graz

5th GOCE User Workshop 2014

Paris, 27.11.2014

Content

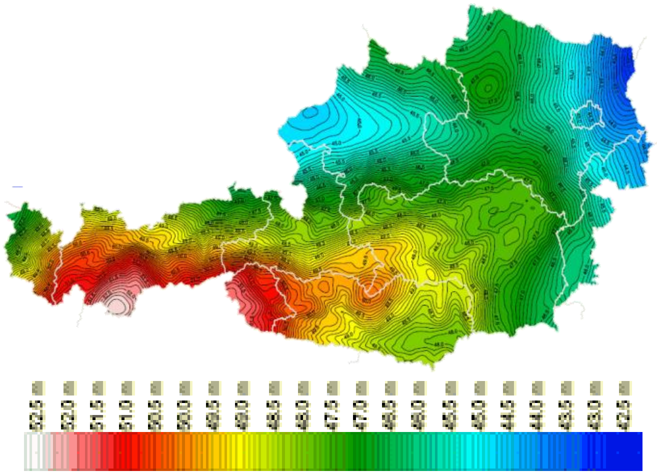
- Introduction / Motivation
- Methods
  - Remove-Compute-Restore
- Data
  - Terrestrial data
  - GOCE gravity gradients
- Results and validation with GPS/Leveling
- Summary and conclusion

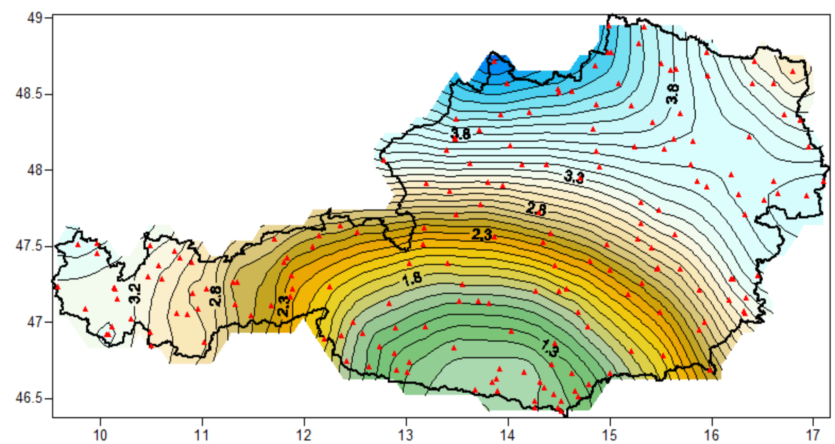


Introduction

State-of-the-art Austrian Geoid solution

- Based on Least Squares Collocation (LSC)
  - 14000 gravity stations
  - 670 deflections
  - 170 precise GPS/Leveling stations
  - EIGEN-GL04S to D/O 70
- Shortcomings
  - *Inconsistencies* between gravimetric Geoid and GPS/Leveling
  - Official solution *forced to match GPS/Leveling* stations





correction surface (several meters)

Introduction

Current research project GARFIELD

(Geoid for Austria – Regional gravity FIELD improved)

- Aims:
  - Optimum combination of global and terrestrial data
  - Use of more (all) available input data
  - Consistent Remove/Restore concept
  - Avoid a correction surface
  - Revised GPS/Leveling points for validation only

Introduction

- Two strategies
  - Gauß-Markov model parametrized with Radial Basis Functions (RBF)
  - Least Squares Collocation (LSC)

Prediction

$$s = C_{sl} \left(C_{ll} + C_{nn} \right)^{-1} l$$

- Aim of this study:

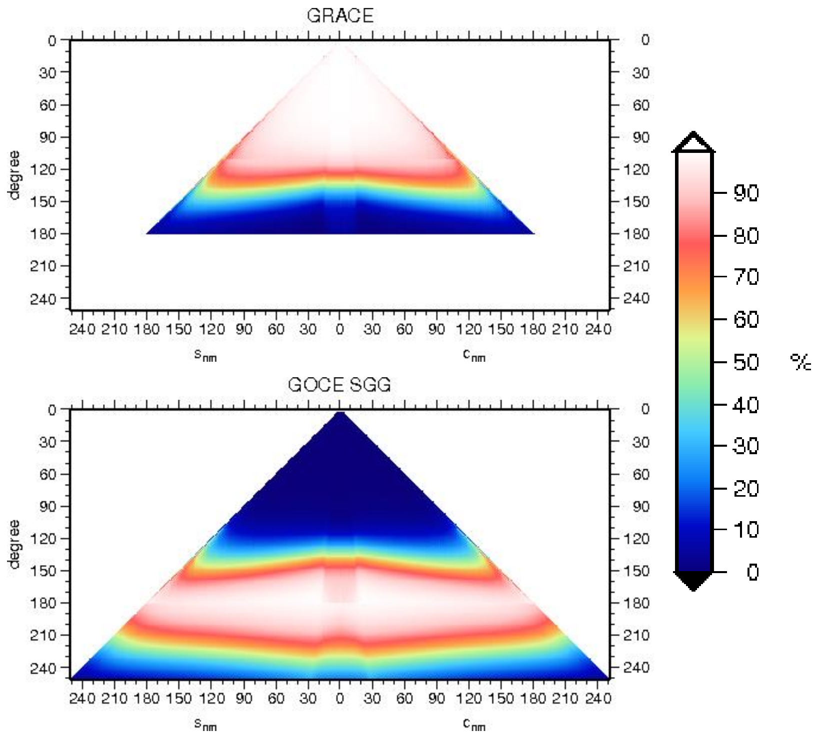
Can GOCE gravity gradients support the gravimetric solution?

Methods

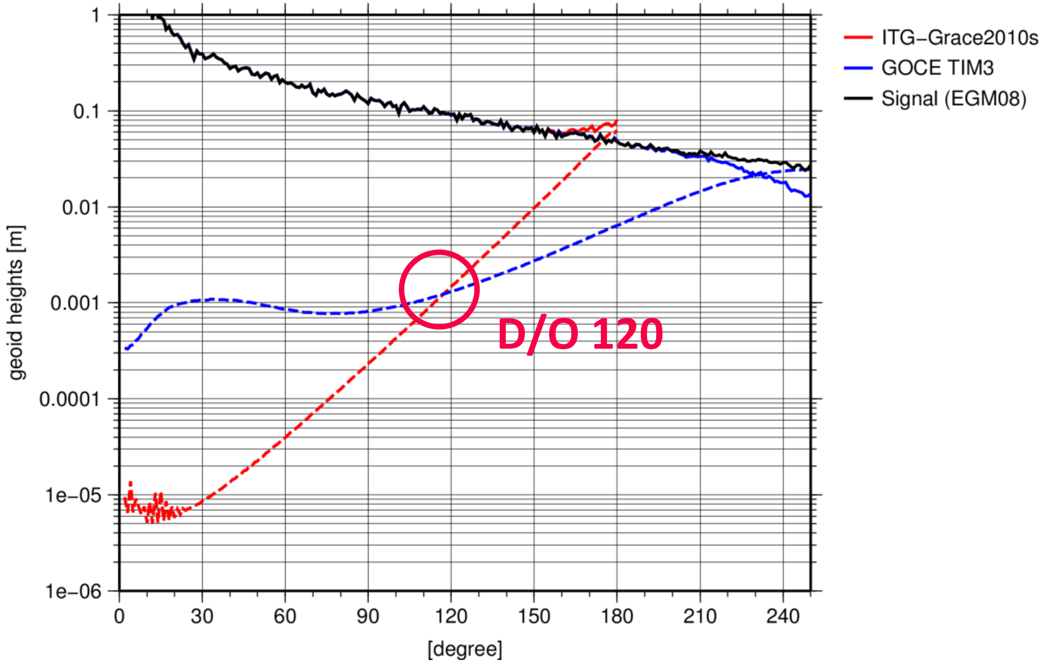
Remove-Compute-Restore

- Long-wavelength effects → GOCO03s → to which degree/order?

Contributions to GOCO03s solution



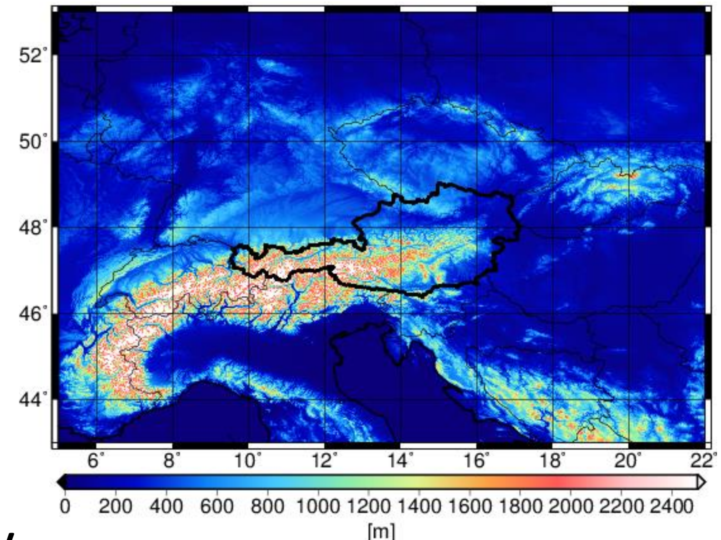
(Error) Degree variances



Methods

Remove-Compute-Restore

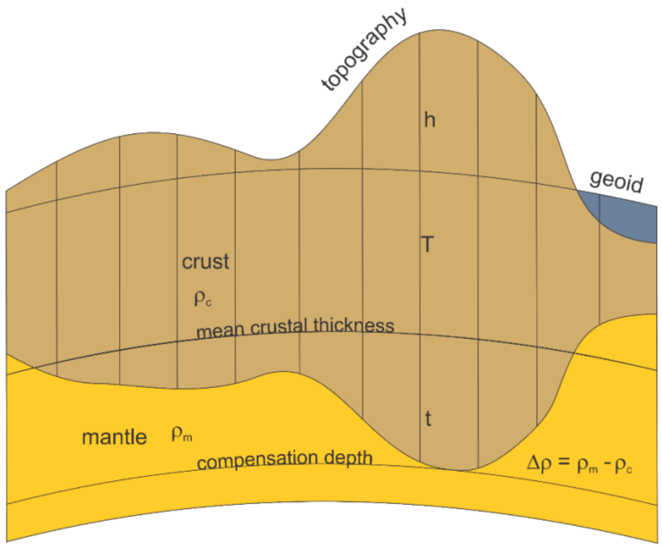
- Short-wavelength effects → topographic reduction
  - Prism formula
  - Input DTM 173x195 [m]
- Double consideration topographic reduction / GOCO03s
  - SHC analysis of topographic effect
  - Add back to D/O 120
- Use GOCO03s instead of normal gravity
  - GOCO03s geoid is reference surface

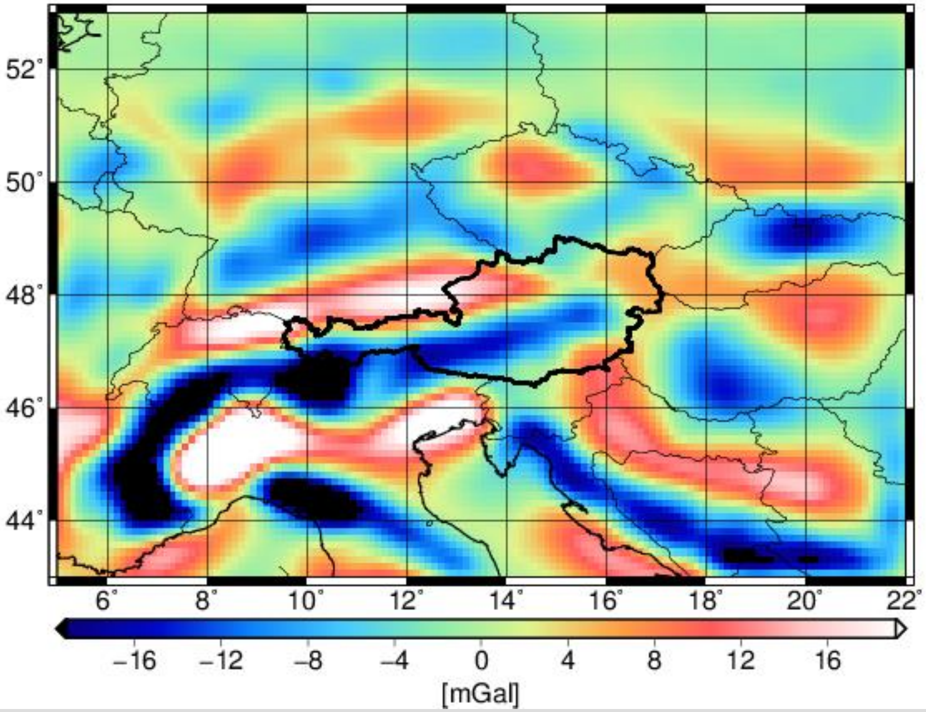


Methods

Remove-Compute-Restore

- Isostatic compensation
  - Airy-Heiskanen model based on DTM with density contrast $\Delta\rho$ = 350 kg/m³, T = 30 km
  - D/O 121 to 720 subtracted

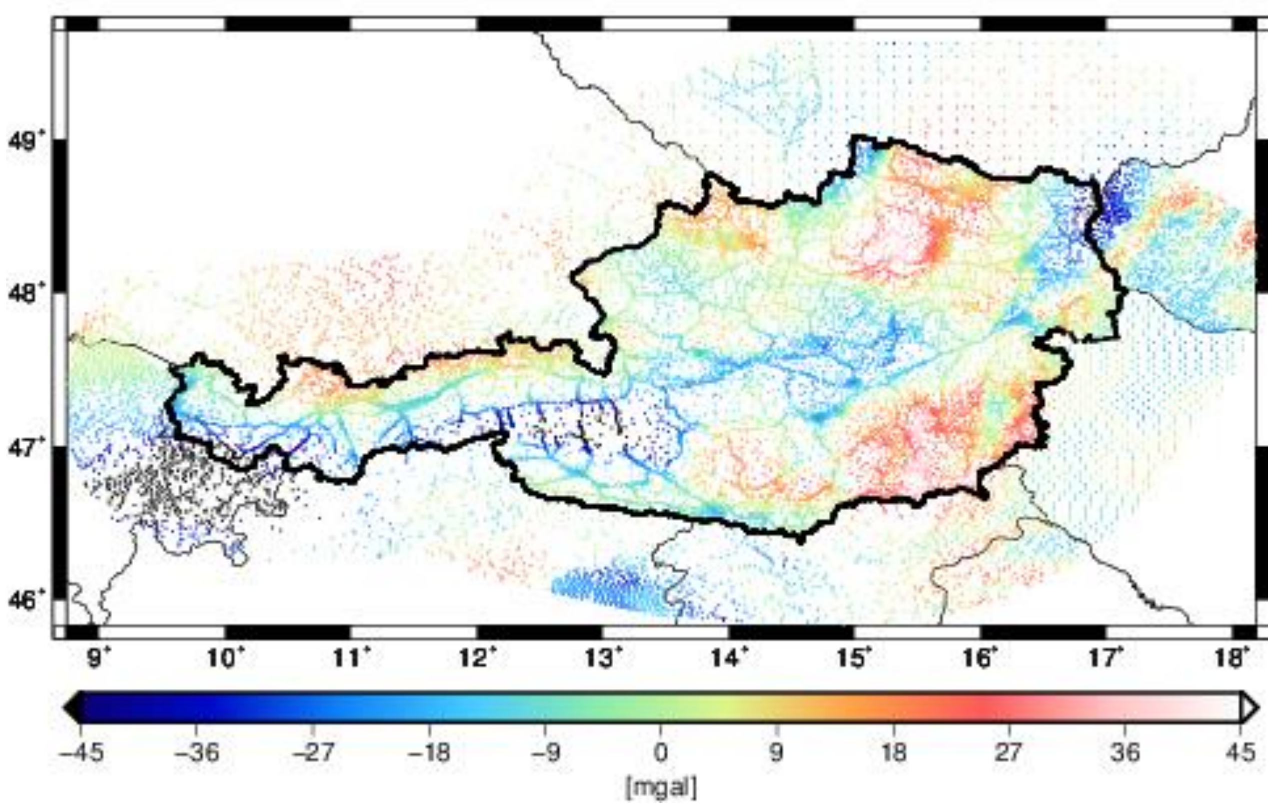




Data - terrestrial

Reduced terrestrial data

- 22841 gravity stations (subset of available data)



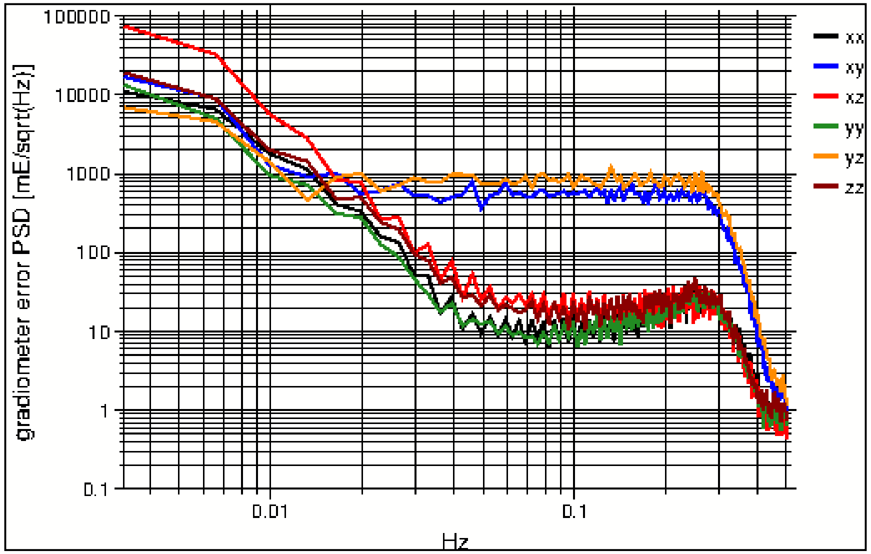
Δg_{red}	[mGal]
min	-60.2
max	45.0
rms	16.5

Data - GOCE gravity gradients

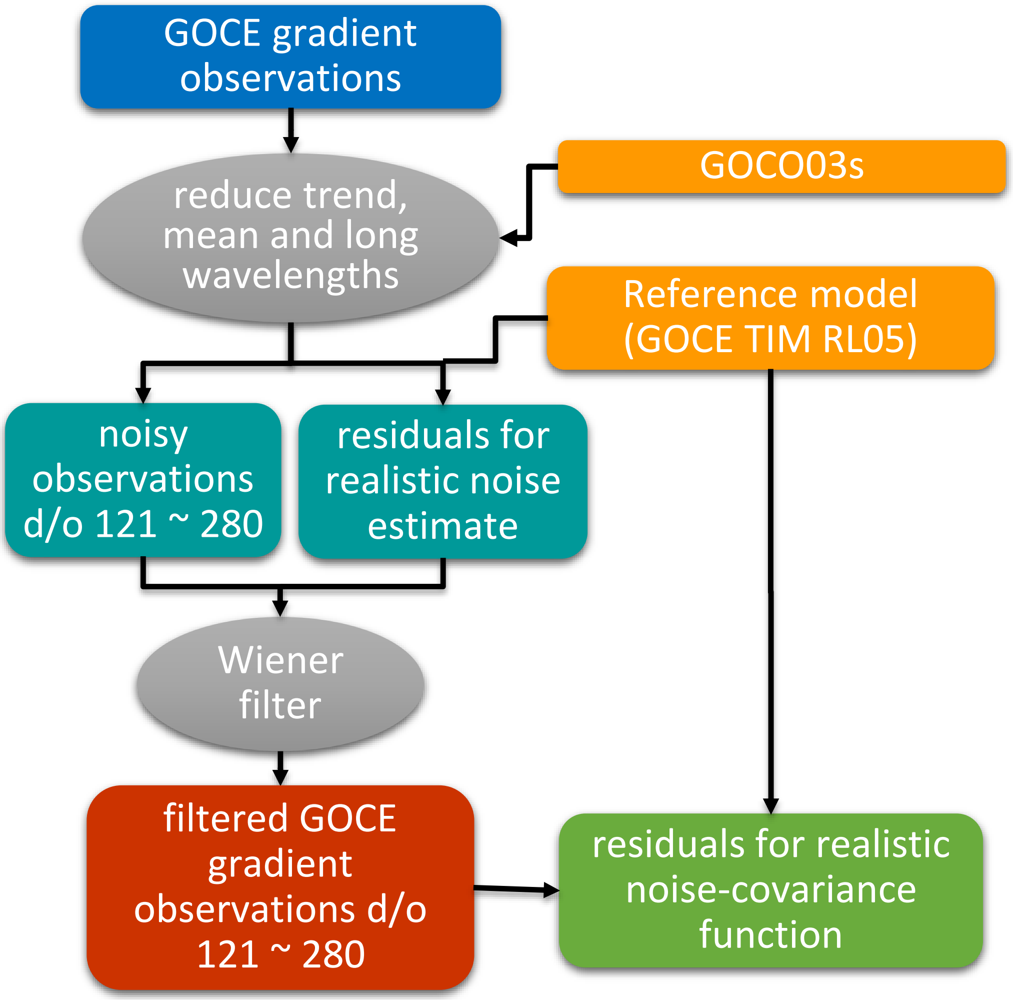
GOCE gravity gradients

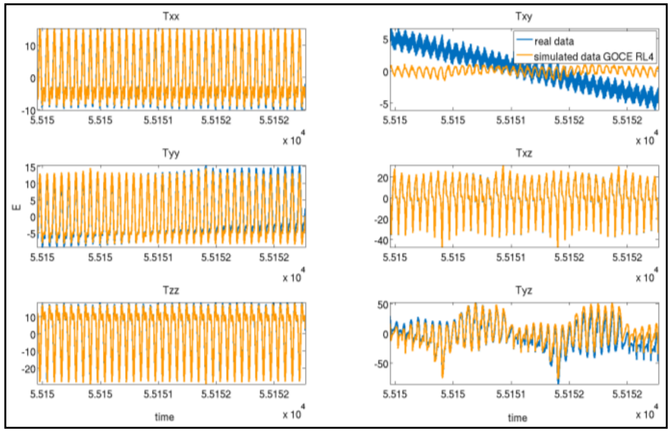
$$\nabla V = \begin{pmatrix} V_{xx} & V_{xy} & V_{xz} \\ V_{xy} & V_{yy} & V_{yz} \\ V_{xz} & V_{yz} & V_{zz} \end{pmatrix}$$

- Level 2 products
  - EGG_NOM_2 gradients (in GRF)
  - SST_PSO_orbits
  - Quaternions
- Preprocessing due to
  - Errors in V_{xy} and V_{yz}
    → only use main diagonal in GRF
  - Colored noise on measurements

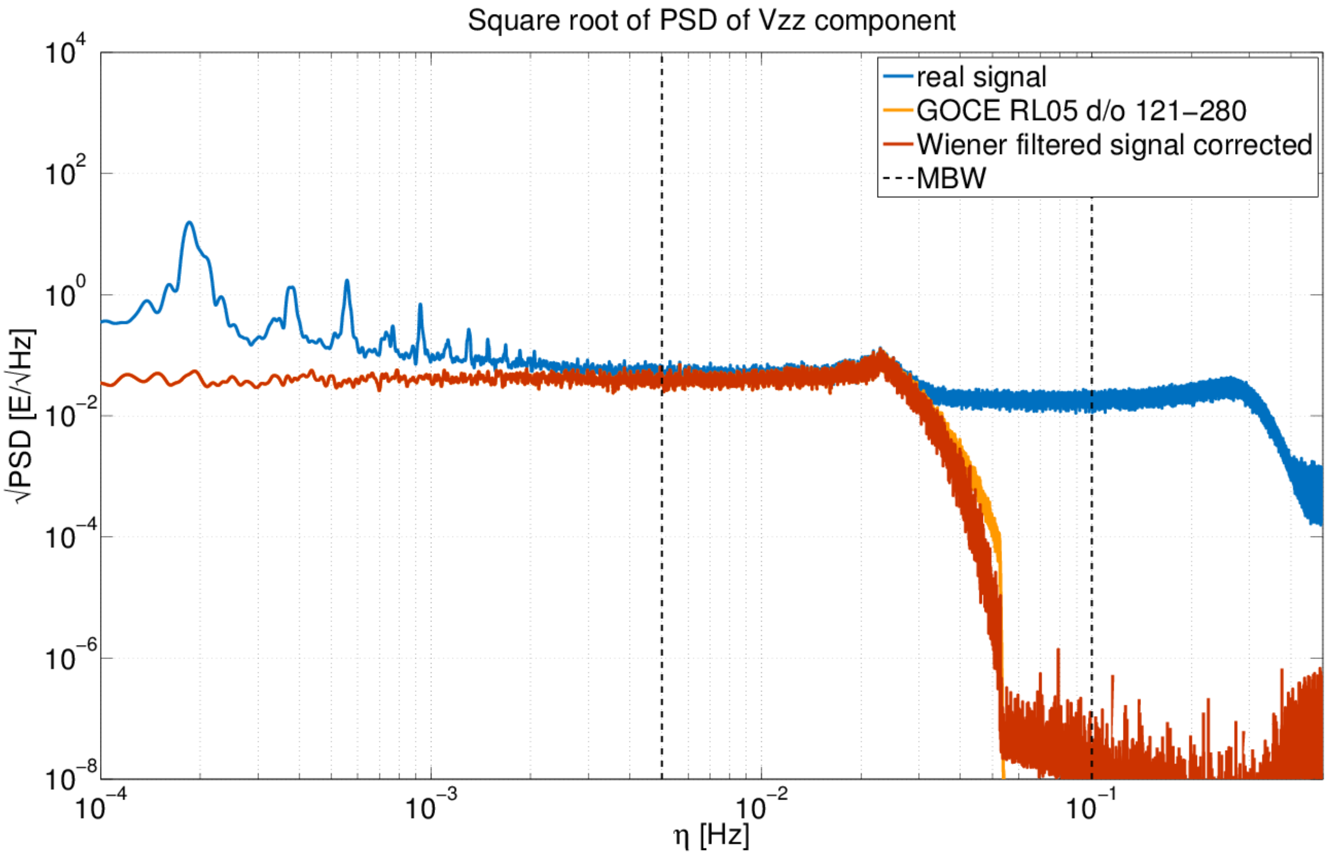


Data - GOCE gravity gradients





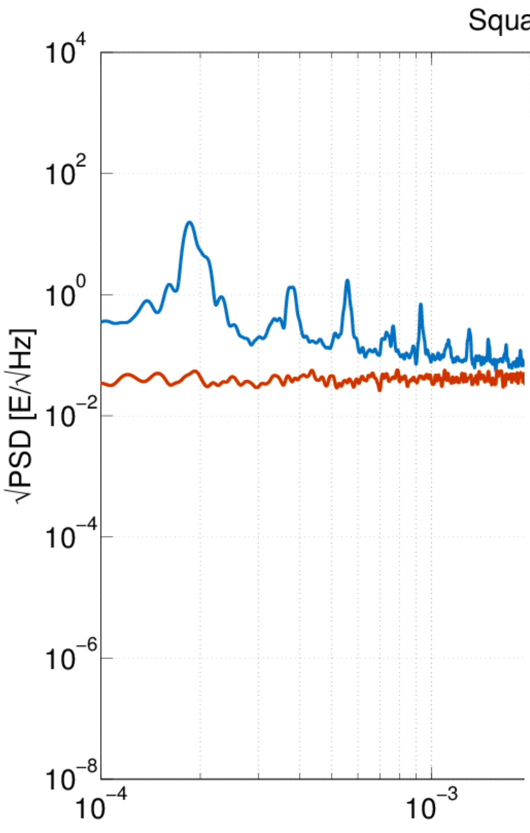
Data - GOCE gravity gradients



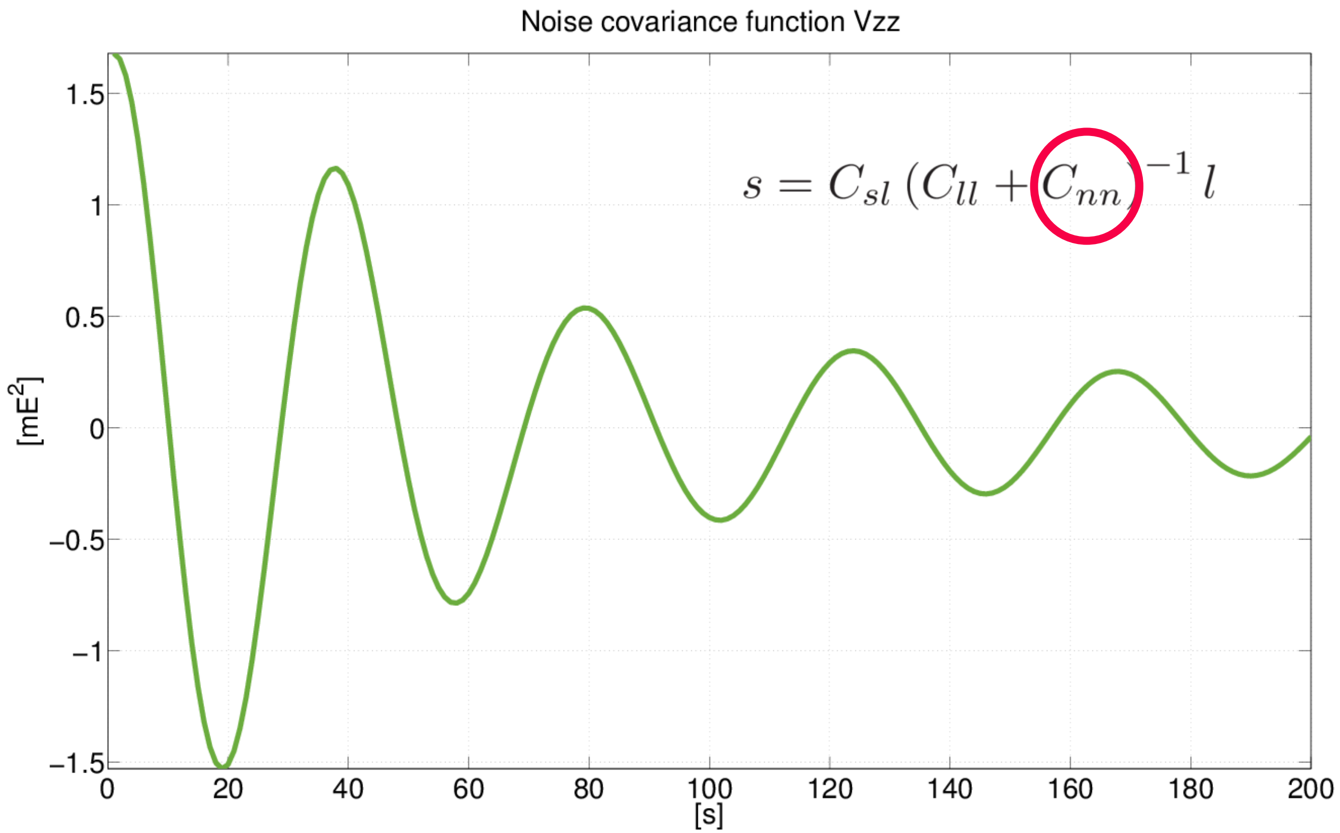
gradient observations d/o 121 ~ 280

noise-covariance function

Data - GOCE gravity gradients



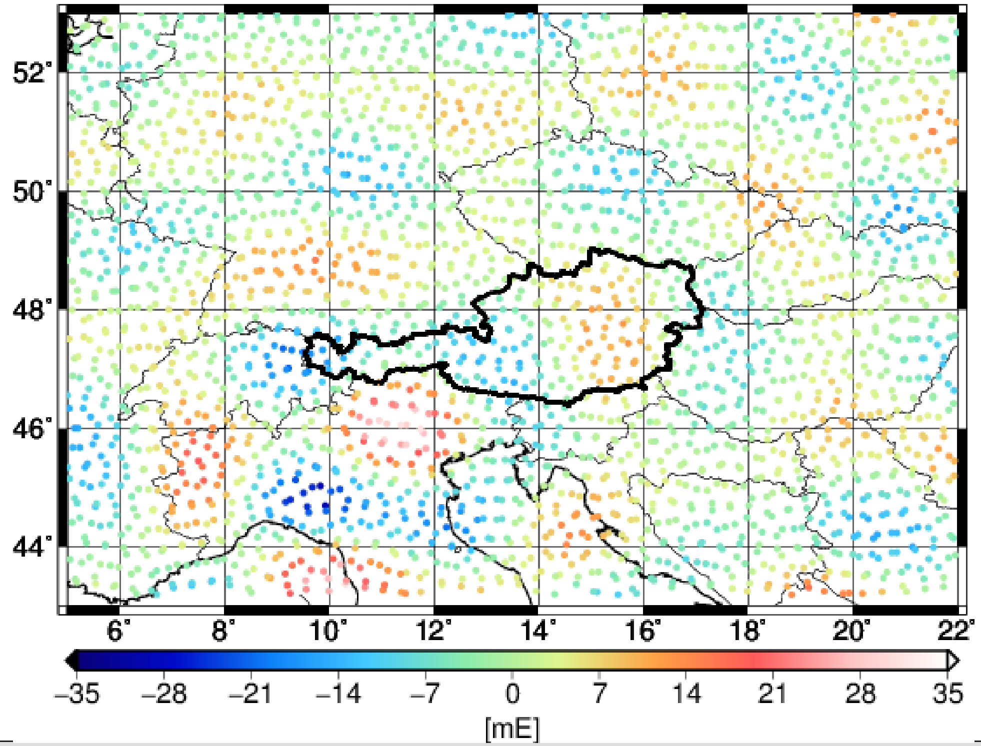
gradient observations d/o 121 ~ 280



Data - GOCE gravity gradients

Reduced GOCE gravity gradients

- Topographic / isostatic effect from d/o 121 to 360 subtracted
- 2804 (x 3) stations (2 months, 5s sampling)



Vzz_{red}	[mE]
min	-28.9
max	31.5
rms	7.4

Data - covariance function

Covariance function (CF) modeling

- Adapted Tscherning-Rapp Model Covariance Function (MCF)

$$C = \sum_{n=2}^{N_{EGM}} \left(\frac{R_b^2}{rr'}\right)^{n+1} \epsilon_n P_n(\cos\psi) + \sum_{n=N_{EGM}+1}^{N_{max}} \left(\frac{R_b^2}{rr'}\right)^{n+1} k_n P_n(\cos\psi)$$

GOCO03s error degree variances

Fitted degree variances

$$\epsilon_n = \sum_m (\sigma^2_{c_{nm}} + \sigma^2_{s_{nm}})$$

$$k_n = \frac{A}{(n-1)(n-2)(n+B)}$$

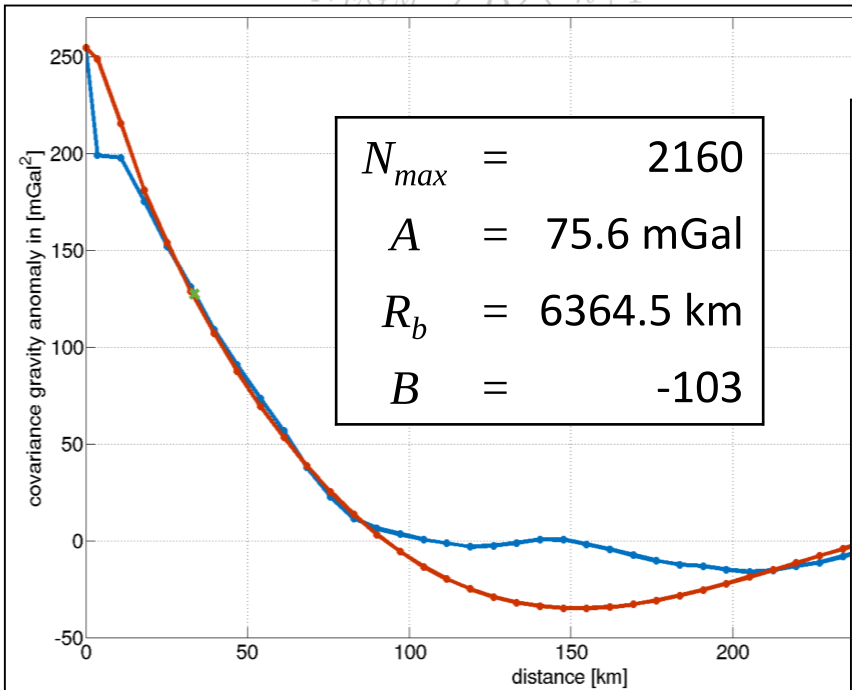
- Fit A, R_b and B to Empirical Covariance Function (ECF) of reduced gravity data

Data - covariance function

Covariance function (CF) modeling

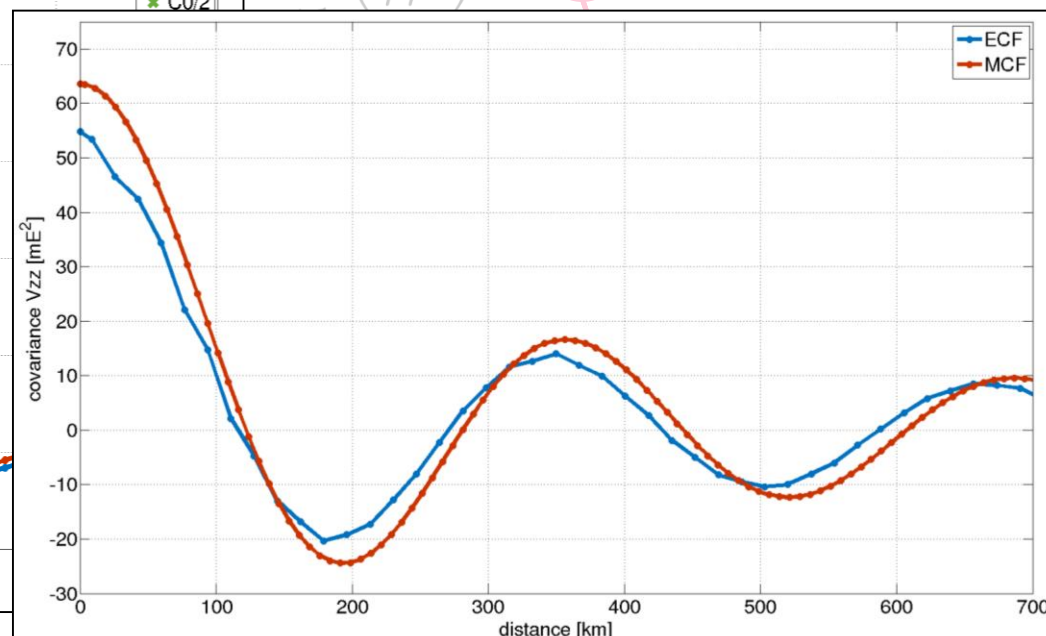
- Adapted Tscherning-Rapp Model Covariance Function (MCF)

CF for gravity anomalies at mean station height



$$N_{max} = 2160$$
$$A = 75.6 \text{ mGal}$$
$$R_b = 6364.5 \text{ km}$$
$$B = -103$$

CF for Vzz at mean orbit height



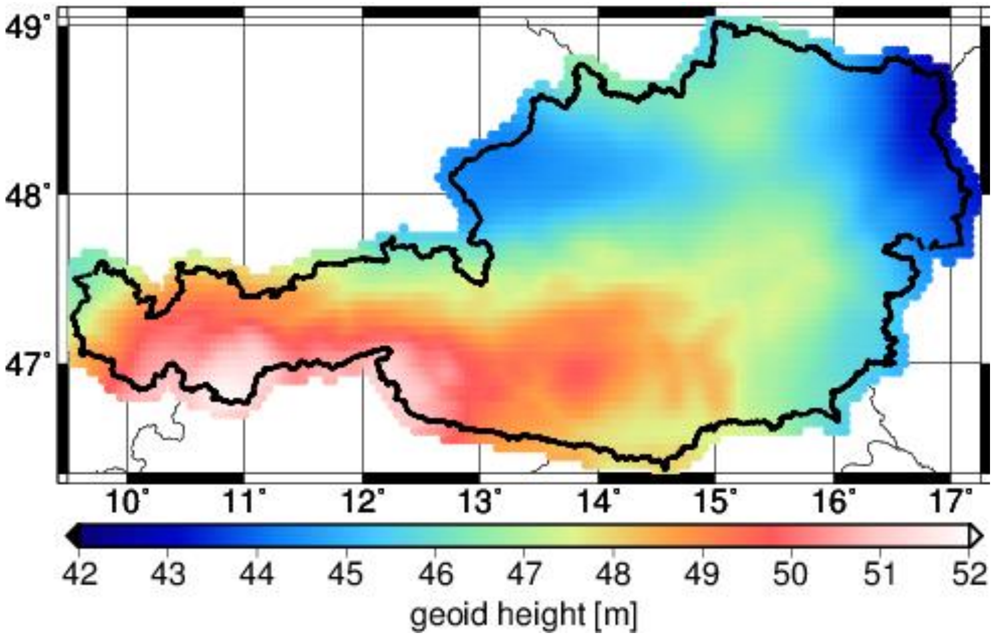
Results and validation

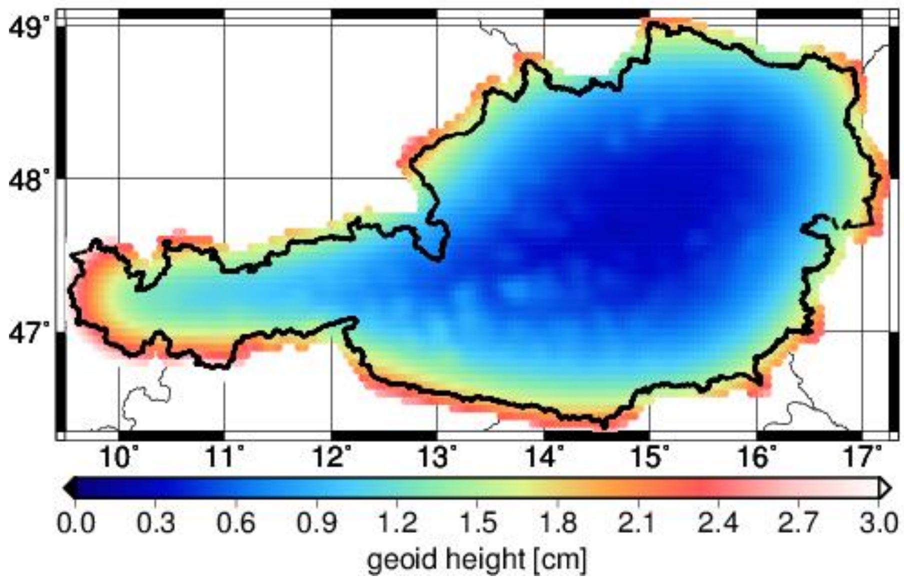
Solution with terrestrial data only

- 22841 gravity stations (σ = 1 mGal)

σ_N	[cm]
min	0.3
max	4.5
rms	1.2

Standard deviations





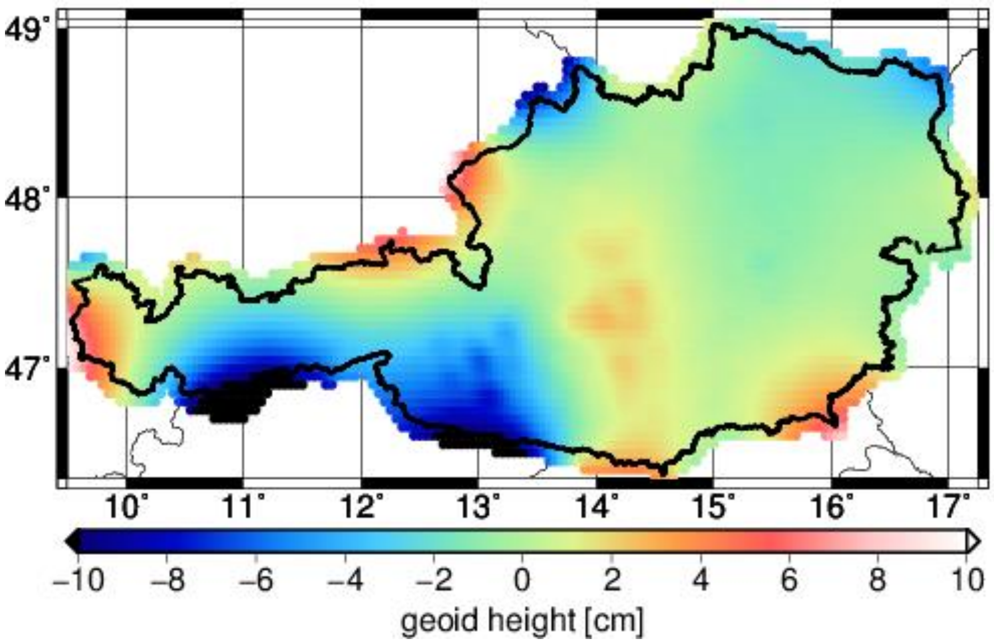
Results and validation

Solution with terrestrial and GOCE gradient data combined

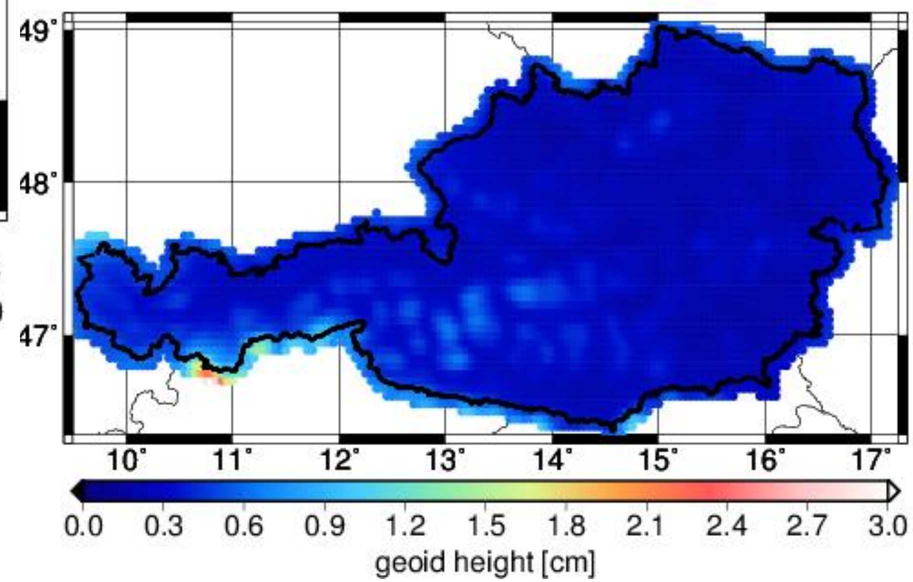
- 22841 gravity stations + 2804 (x 3) gradients

σ_N	[cm]
min	0.2
max	3.1
rms	0.4

Standard deviations



Solution differences

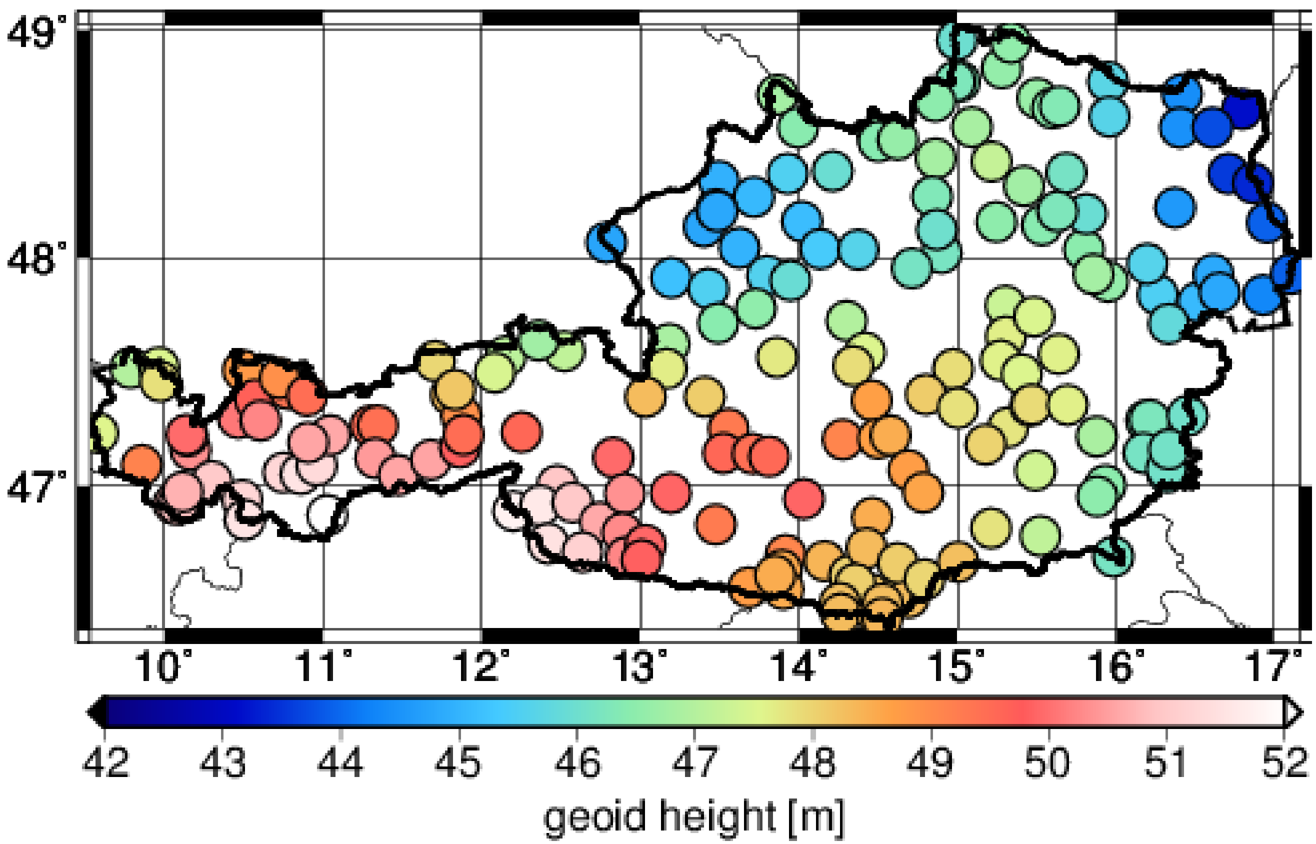


Results and validation

192 precise GPS/Leveling stations from BEV

- Accuracy 2-3 cm (?)

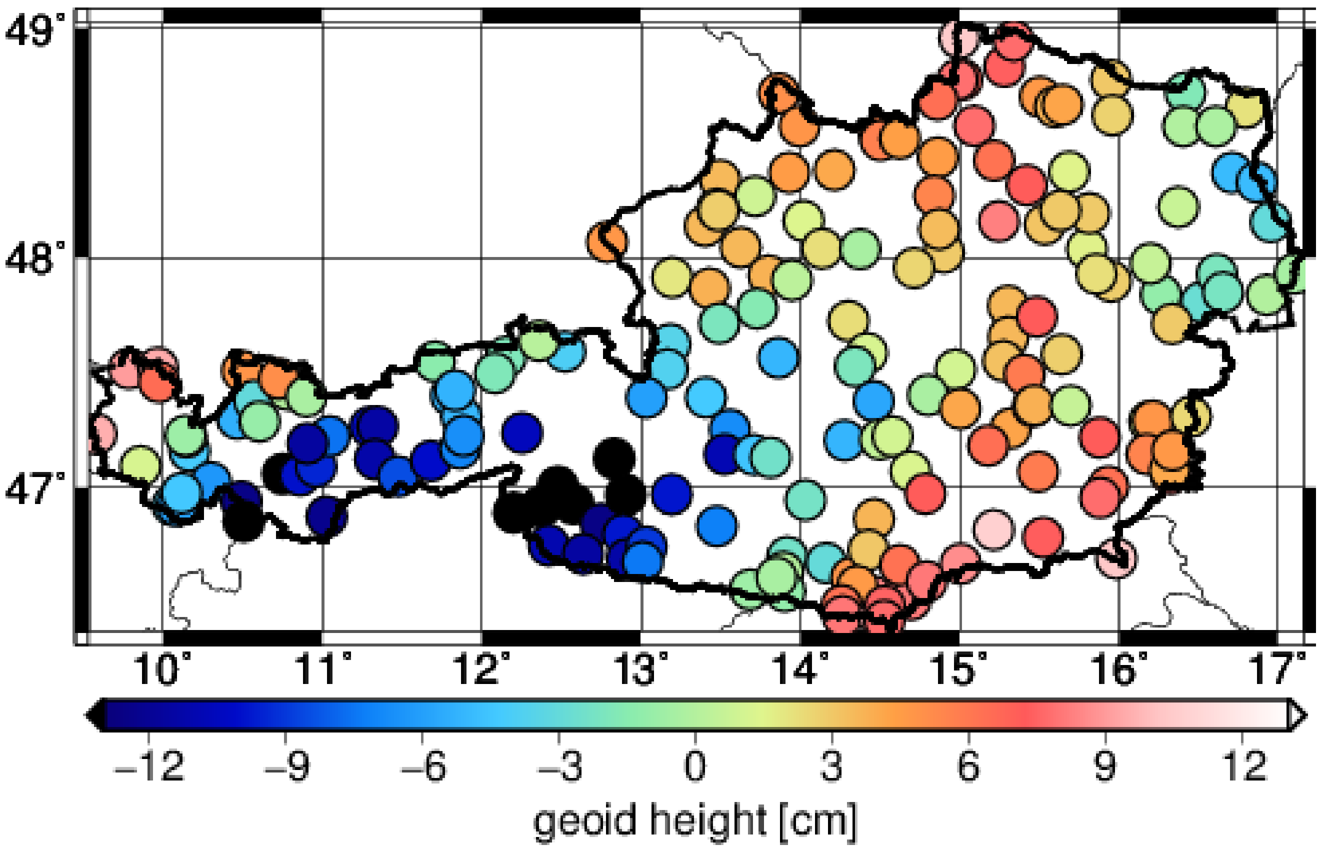
Absolute Geoid heights



Results and validation

Validation with GPS/Leveling - terrestrial data only

Geoid height differences

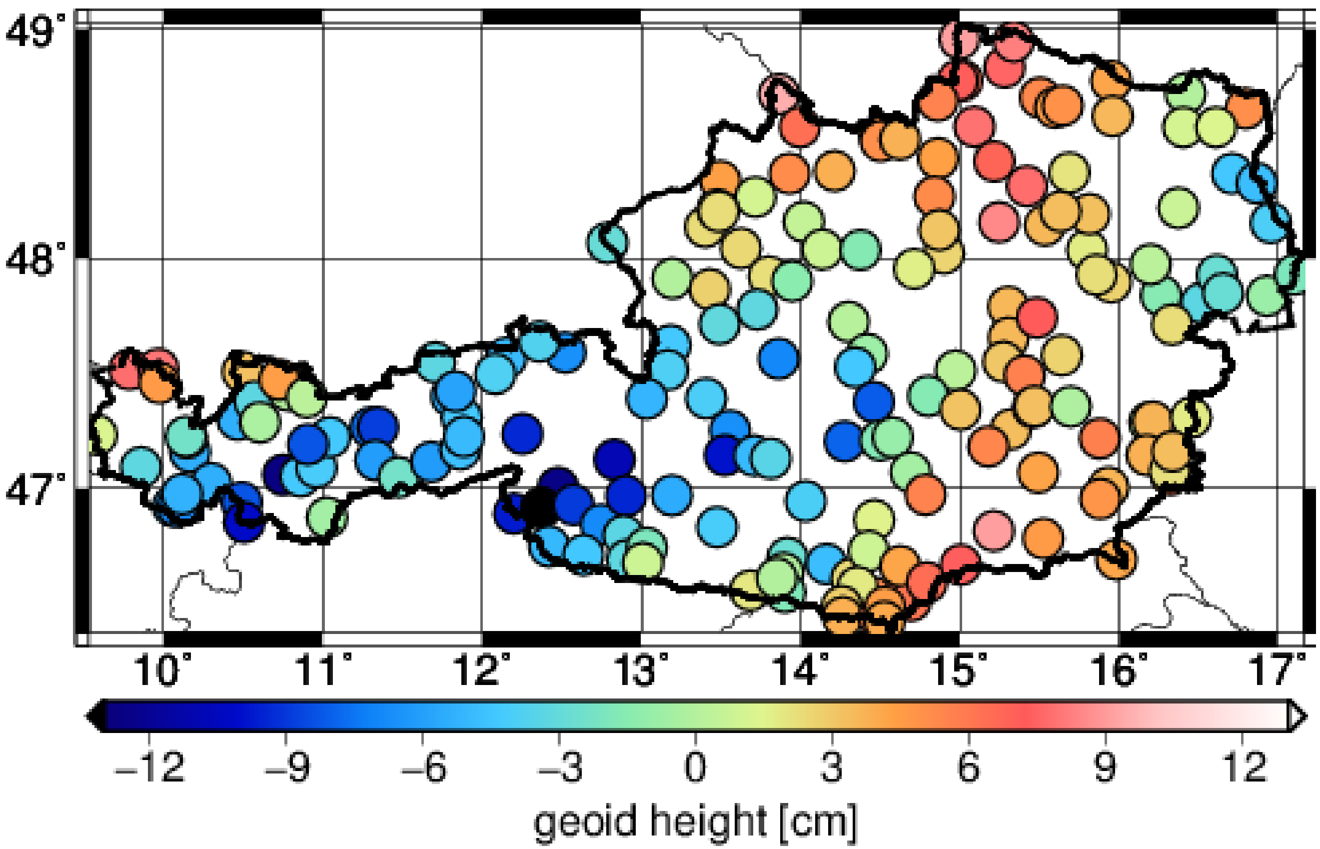


N	[cm]
min	-18.0
max	10.7
rms	6.5

Results and validation

Solution with terrestrial and GOCE gradient data combined

Geoid height differences



N	[cm]
min	-13.6
max	9.5
rms	5.1

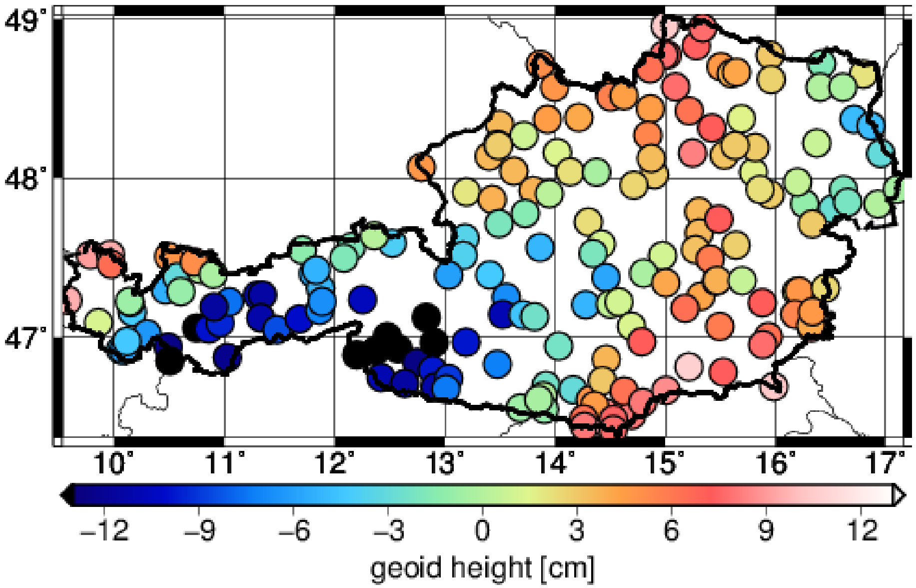
Results and validation

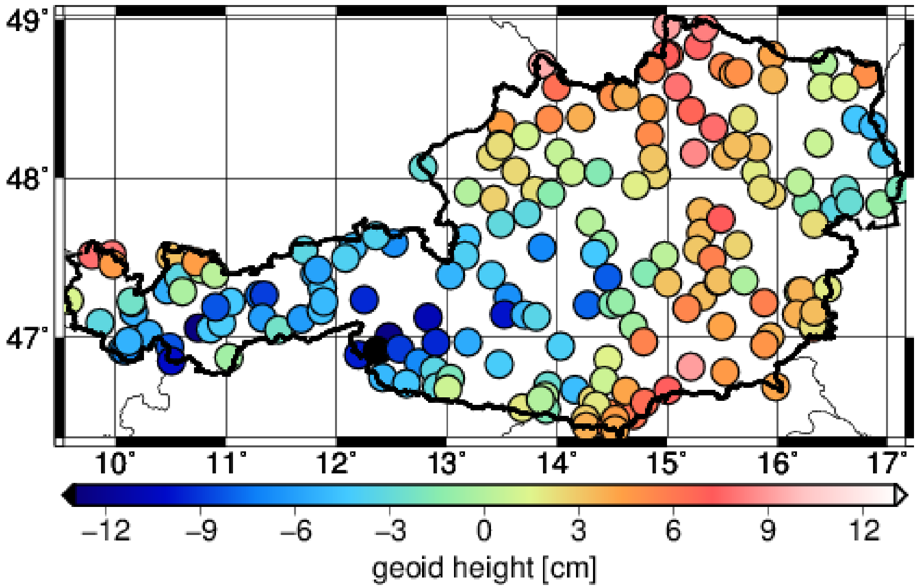
terrestrial only

N	[cm]
min	-18.0
max	10.7
rms	6.5

combined

N	[cm]
min	-13.6
max	9.5
rms	5.1



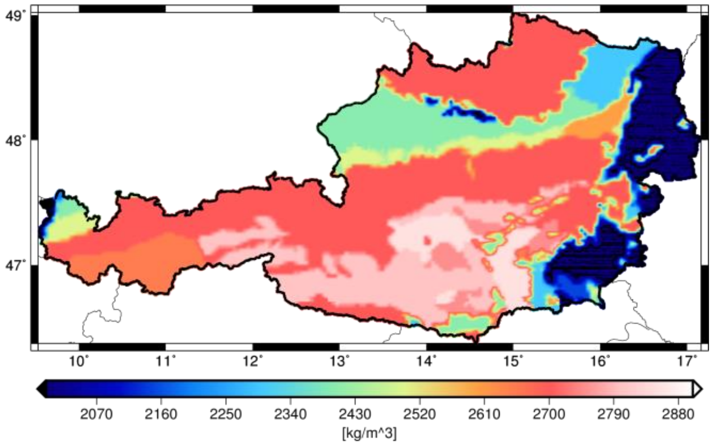


Summary and conclusions

- Incorporating GOCE gradients can improve gravimetric solution
  - proper preprocessing steps necessary
  - covariance function should cover all data types
- Compared to a RBF solution, LSC has high computational costs
  - dimension of C_{ll} ~ number observations
  - currently, LSC resolution is limited to N_{max}=2160
- There are still rather high deviations from GPS/Leveling stations
  - strongly correlated with topography

Outlook / further work

- Achieve better consistency in topographic/isostatic reduction between gradients and terrestrial data
- Improve topographic reduction with density information
- Improve terrestrial data weighting
- Include more data
- …



Thank you for your attention!

Daniel Rieser, Christian Pock, Torsten Mayer-Gürr

Institute of Theoretical Geodesy and Satellite Geodesy
TU Graz

Graz University of Technology

This work was accomplished in the frame of the project GARFIELD (Geoid for Austria – Regional gravity FIELD improved) funded by the Austrian Science Fund (FWF): P 25222-N29

FWF Der Wissenschaftsfonds.