Importance of Terrestrial Surface Density Information and Satellite-Aided Global Gravity Field Models for High Precision Regional Geoid Computation

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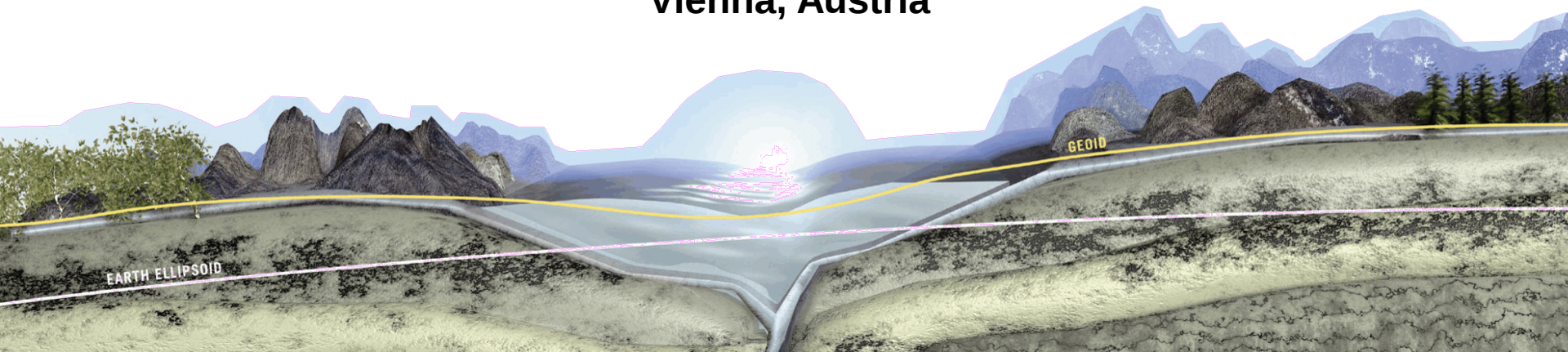
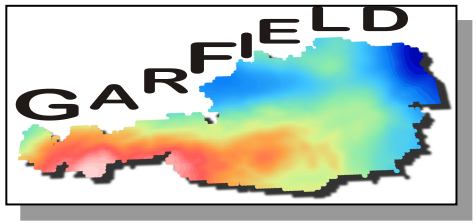


Introduction

- Focus of investigations:
  - **Density information & global gravity field models (GOCO series)**
  - **How does this data contribute to an improved geoid**
  - **Validation**
- Investigations are embedded in the current Austrian geoid initiative *"Geoid for Austria - Regional gravity FIELD improved" (GARFIELD)* - P25222-N29



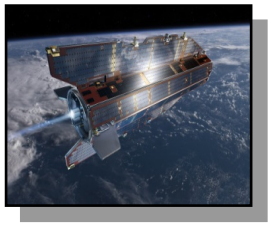
- ***Question:***
  - ***Used computation parameters?***

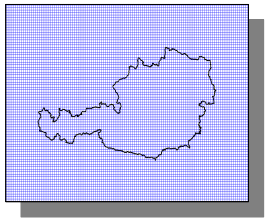
Computation Parameters

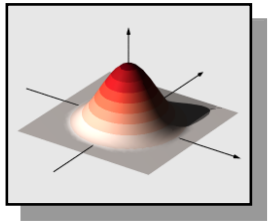
- **Remove-Compute-Restore** technique
- Terrestrial data:
  - **72327** gravity measurements
  - **735** deflections of the vertical
  - **192** GPS/Leveling observations

  } Used for validation
- Global gravity field models:
  - GOCO02s, GOCO03s and **GOCO05s** up to d/o 250

  Topographic reduction: **Prism formula**
  - DTM 176 x 196 m within central Europe
  - **3 density models** interpolated to DTM spacing
- Computation: **Least squares approach**
  - Radial basis function parametrization



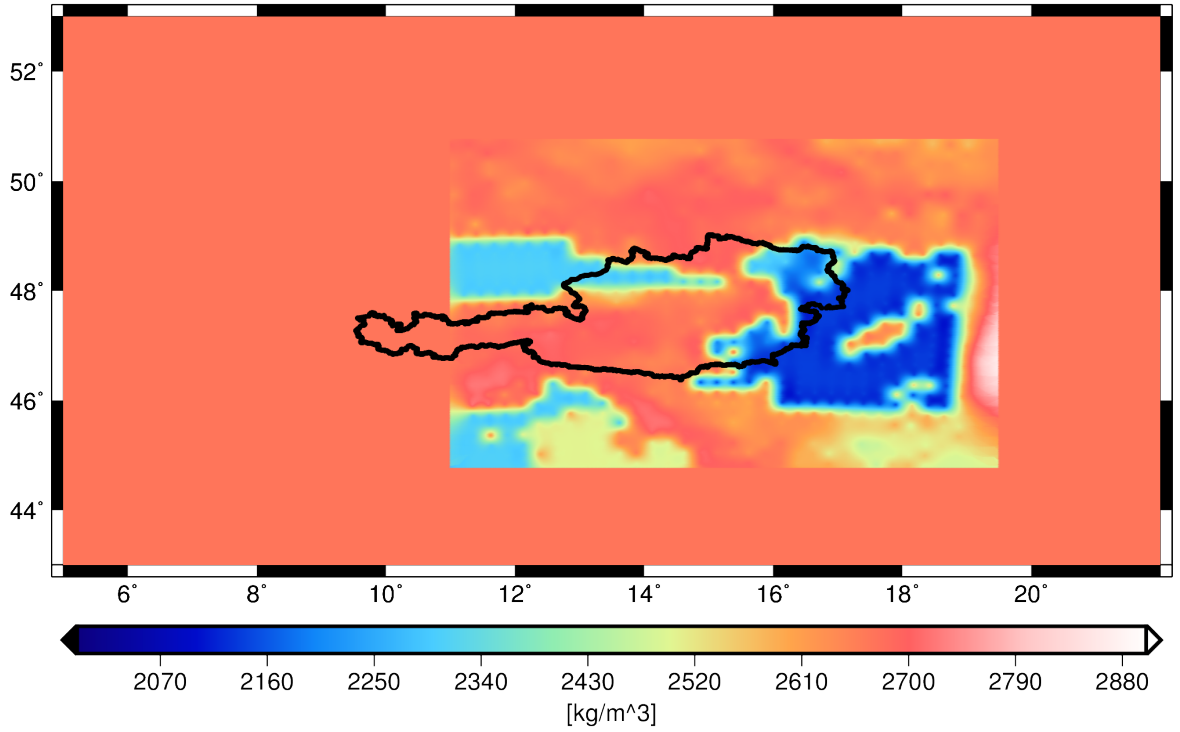




Density Models (1)

- **3D seismic data ρ_{seis}: 11 layers (0 to -10 km), 1 km vertical spacing**
  - Top layer refers to sea level → used as lower boundary in combination with surface density

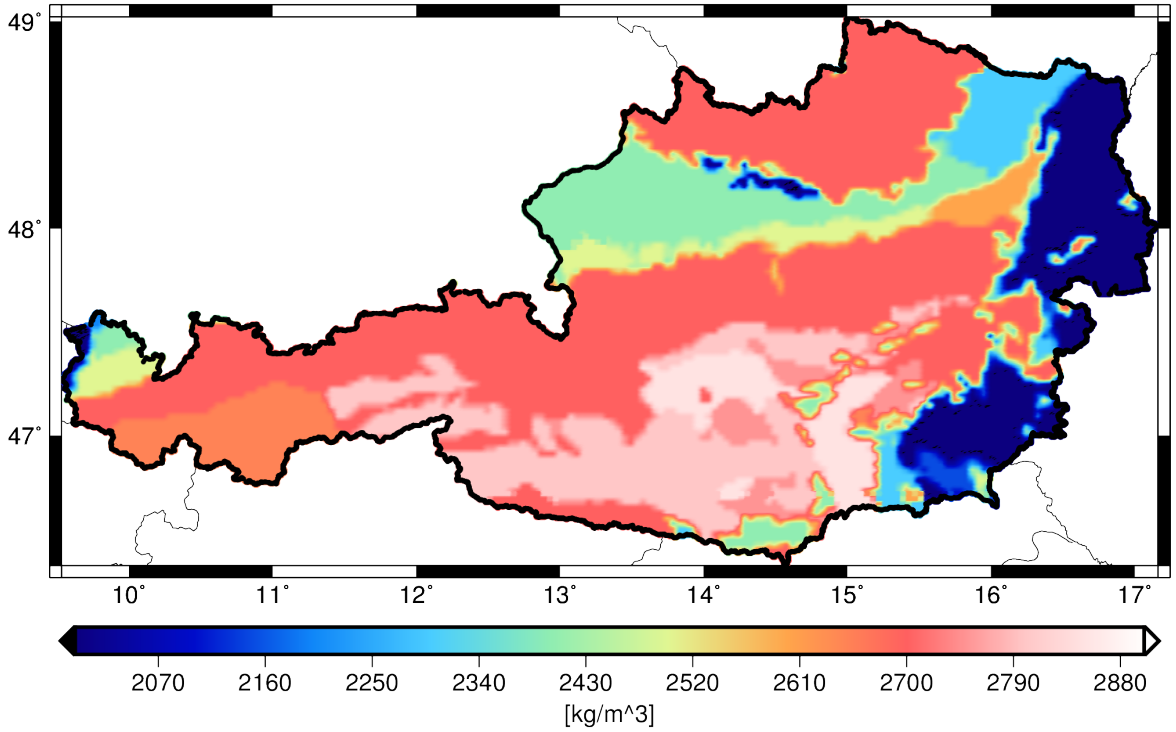
[kg/m^3]	min	max	mean
	2102.70	2870.60	2628.60



Density Models (2)

- **Geological observations ρ_{geo}: 1 layer → surface density model**
  - Historically grown (1950-1983), but still up to date

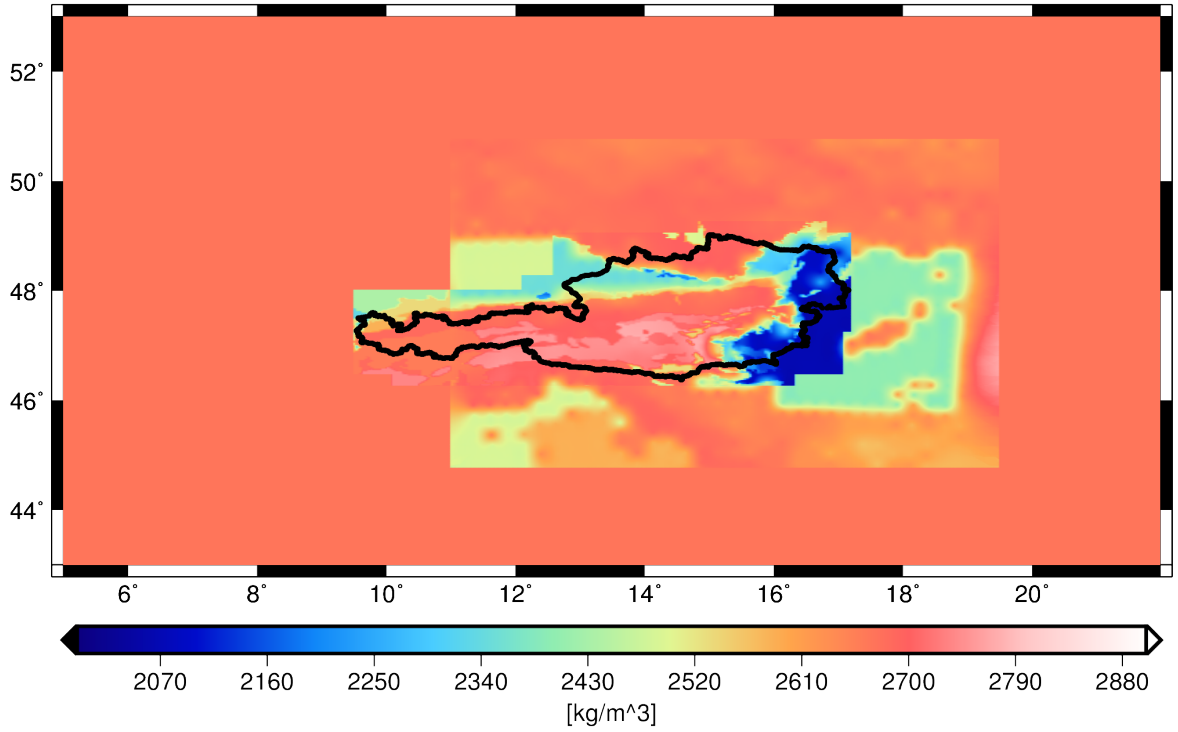
[kg/m^3]	min	max	mean
	2000.00	2852.00	2575.60



Density Models (3)

- **Hybrid model as trivial combination of both data types**
  - $\rho_{hyb} = \frac{\rho_{seis} + \rho_{geo}}{2}$

[kg/m^3]	min	max	mean
	2054.34	2775.27	2651.07



Density Models (4)

- **Three different density assumptions:**

  1.) Constant standard crustal density → $\rho = 2670\ kg/m^3$

  2.) Hybrid density model → $\rho_{hyb} = \frac{\rho_{seis} + \rho_{geo}}{2}$

  3.) Surface density model → ρ_{geo}

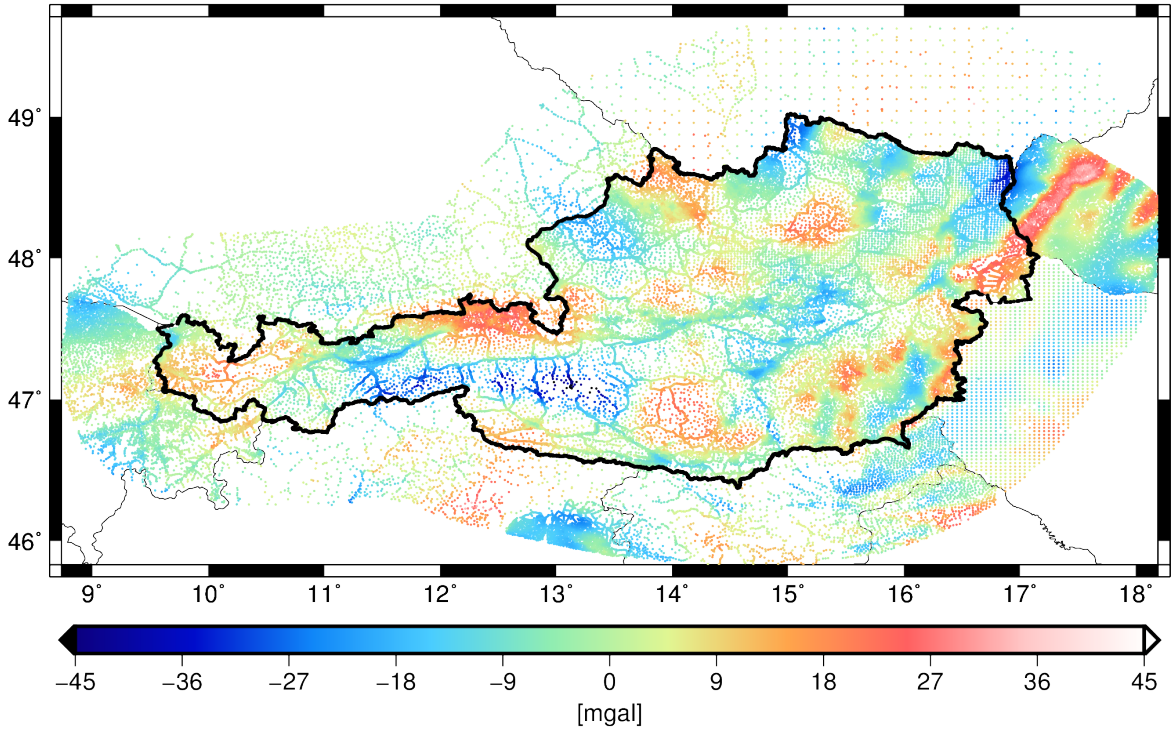
- ***Questions:***
  - ***Significant improvements throughout the reduction step?***
  - ***Is any of the density models improving the geoid solution?***
  - ***Which density assumption performs best compared to GPS/Leveling?***

Remove Step (1)

- **Input data:** gravity, number of data points: 72327

  - Standard crustal density $\rho = 2670\ kg/m^3$, GOCO05s

[mgal]	min	max	mean	rms
	-48.49	39.44	-1.10	11.70

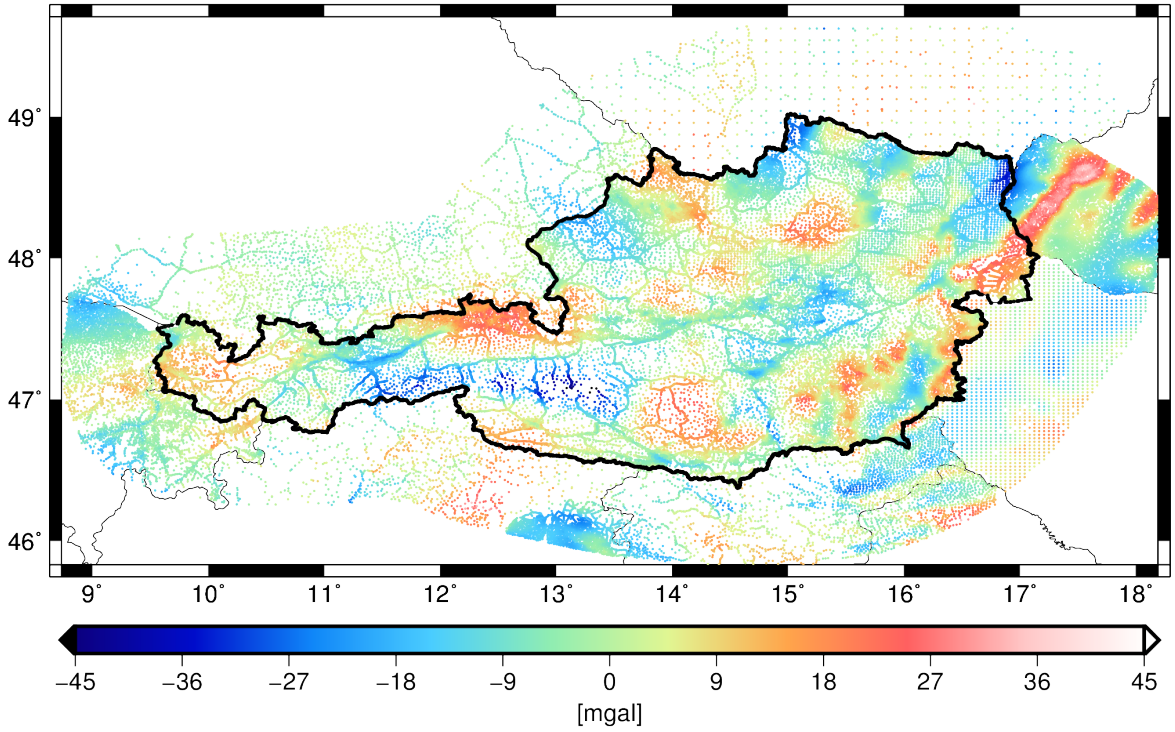


Remove Step (2)

- **Input data:** gravity, number of data points: 72327

  - Hybrid density $\rho_{hyb} = \frac{\rho_{seis} + \rho_{geo}}{2}$, GOCO05s

[mgal]	min	max	mean	rms
	-48.10	38.66	-1.02	11.57

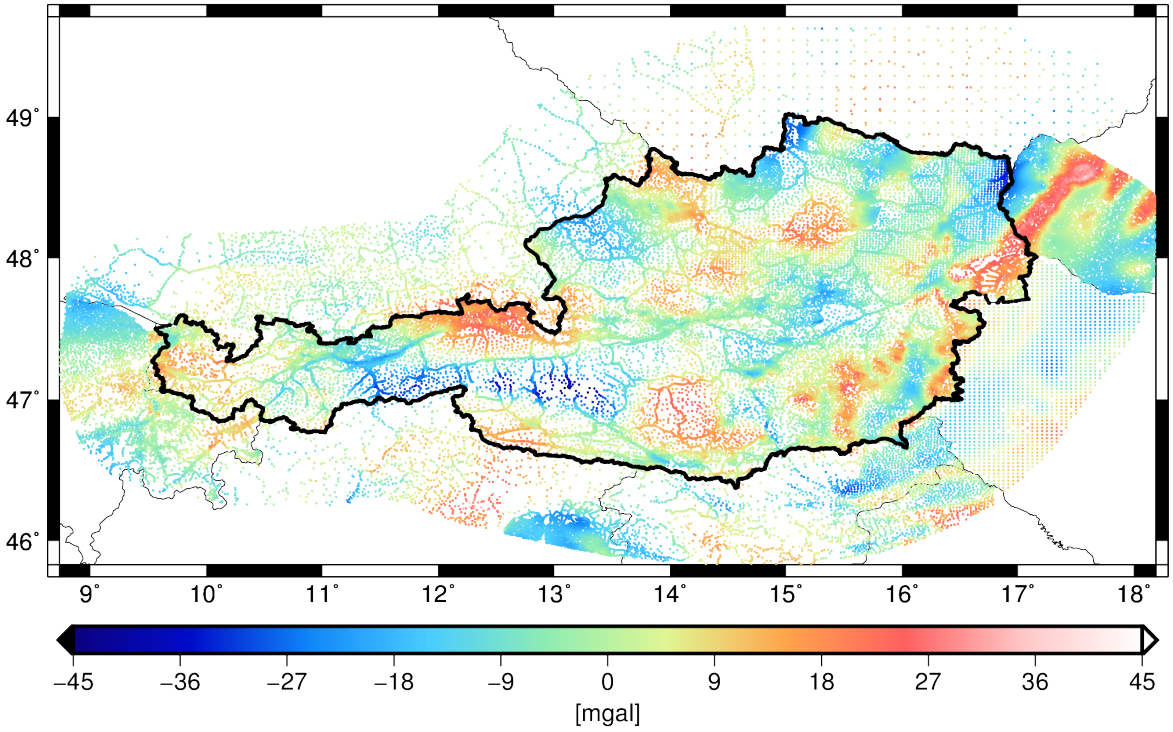


Remove Step (3)

- **Input data:** gravity, number of data points: 72327

  - Surface density ρ_{geo}, GOCO05s; performs best → rms

[mgal]	min	max	mean	rms
	-49.48	37.35	-0.85	11.40

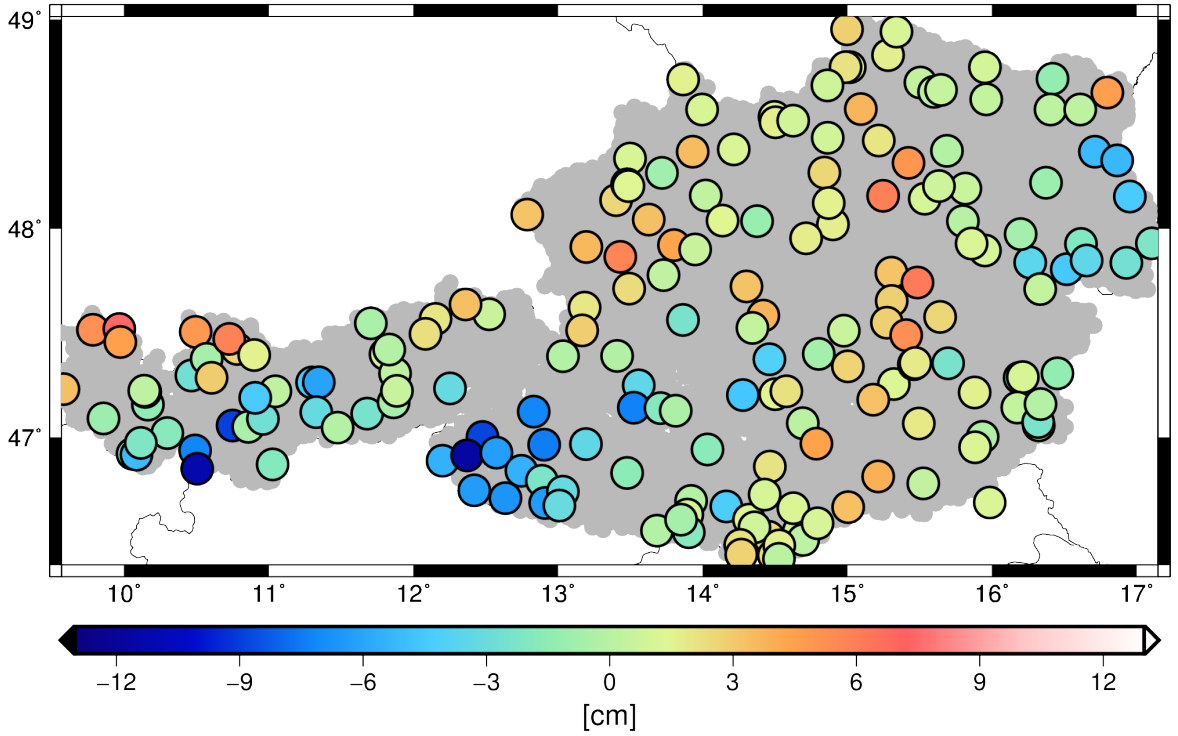


Absolute Validation (1)

- **Geoid validation with 192 GPS/Leveling observations**

  - Standard crustal density $\rho = 2670\ kg/m^3$, GOCO05s

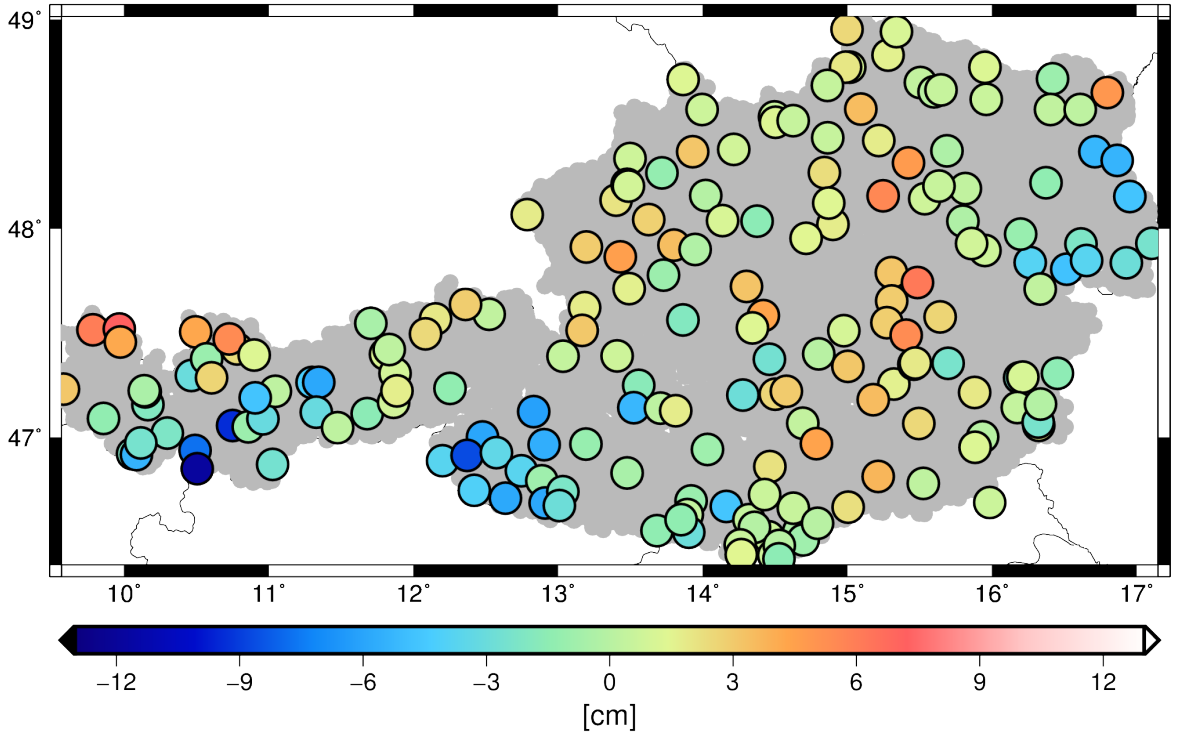
[cm]	min	max	rms
	-11.68	7.43	3.33



Absolute Validation (2)

- **Geoid validation with 192 GPS/Leveling observations**
  - Hybrid density model $\rho_{hyb} = \frac{\rho_{seis} + \rho_{geo}}{2}$, GOCO05s

[cm]	min	max	rms
	-11.82	7.21	3.05

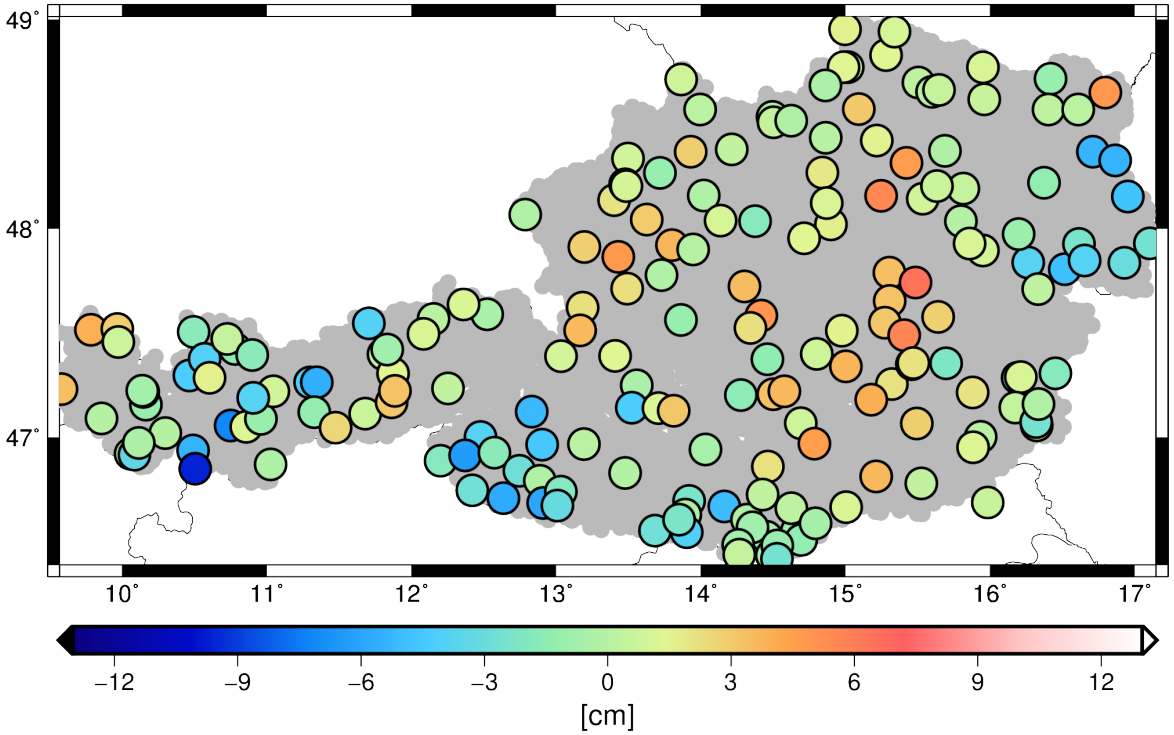


Absolute Validation (3)

- **Geoid validation with 192 GPS/Leveling observations**

  - Surface density model ρ_{geo}, GOCO05s; performs best → rms

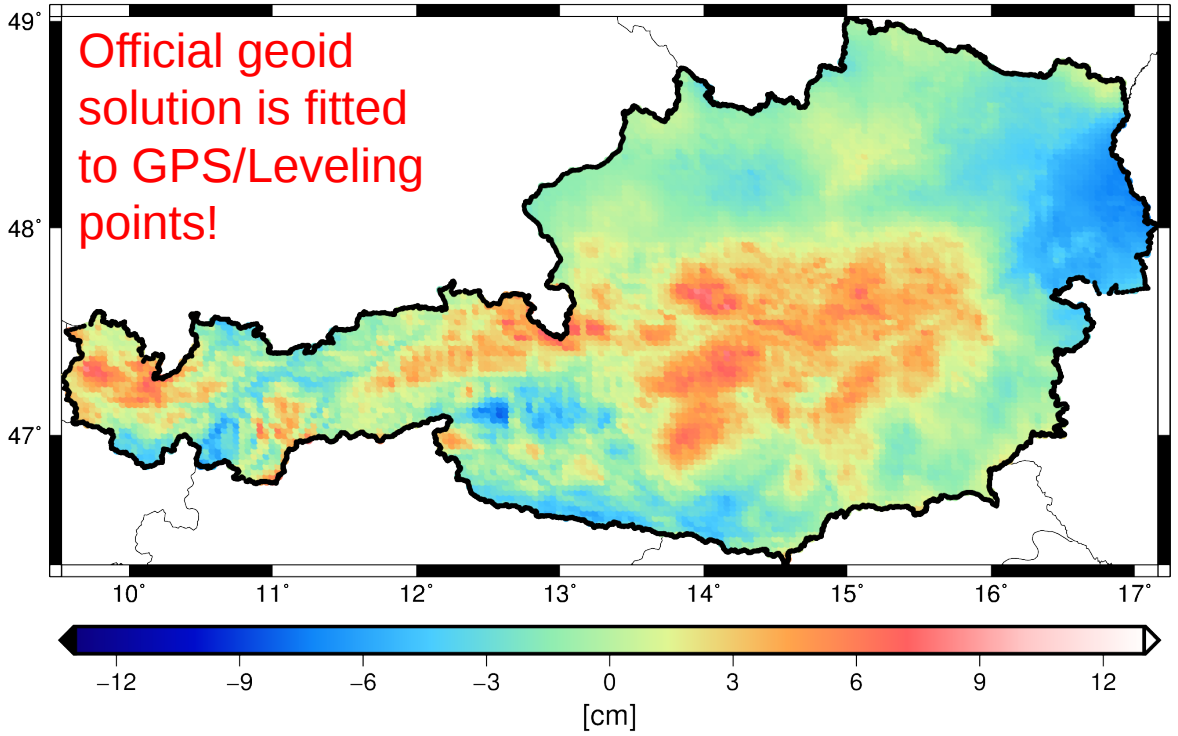
[cm]	min	max	rms
	-9.62	6.46	2.75



Validation with Austrian Geoid Solution

- **Compared to present official Austrian geoid solution → 3x3 km grid**
  - Surface density model ρ_{geo}, GOCO05s

[cm]	min	max	rms
	-8.19	8.38	2.80



Validation Gravimetric Geoid - Summary

REMOVE Density Model	min [mgal]	max [mgal]	mean [mgal]	rms [mgal]
Standard	-48.49	39.44	-1.10	11.70
Hybrid	-48.10	38.66	-1.02	11.57
Surface	-49.48	37.35	-0.85	11.40

Decreasing rms values

RESTORE Density Model	min [cm]	max [cm]	rms [cm]
Standard	-11.68	7.43	3.33
Hybrid	-11.82	7.21	3.05
Surface	-9.62	6.46	2.75

Decreasing rms values

- ***Answers:***
  - ***Significant improvements throughout the reduction step? → Yes***
  - ***Is any of the density models improving the geoid solution? → Yes***
  - ***Which density assumption performs best compared to GPS/Leveling?***

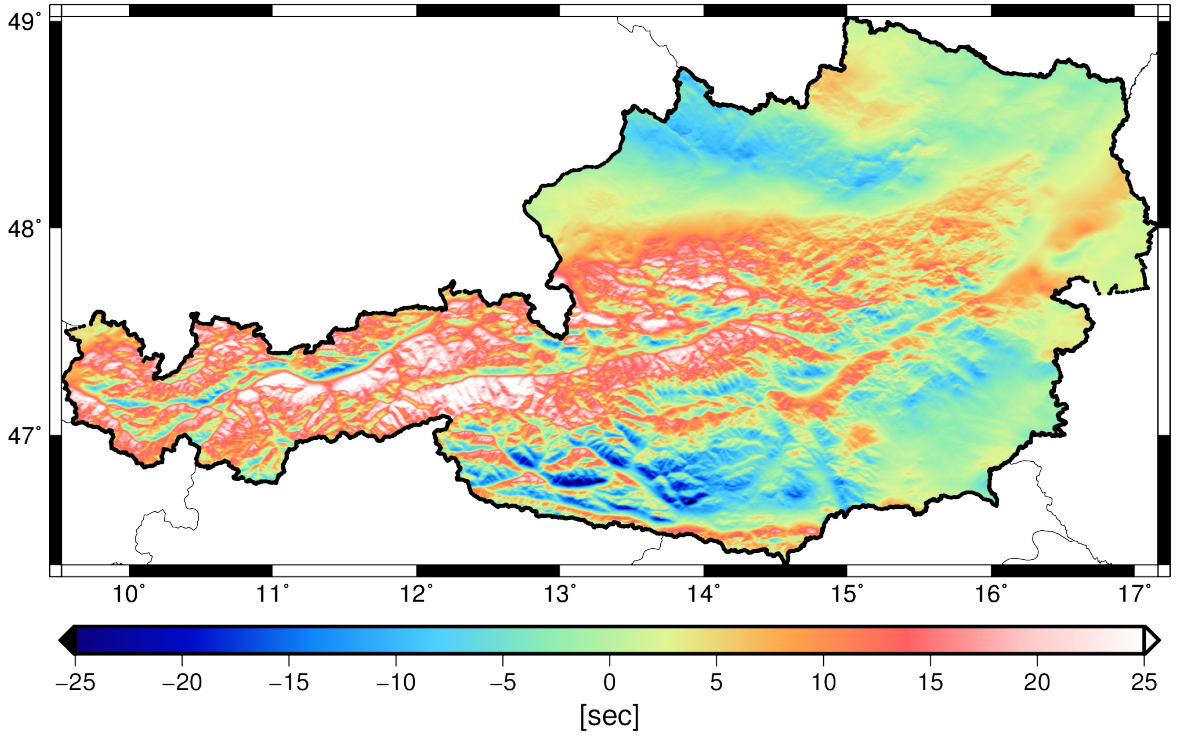
    → Surface density

Further Validation with Deflections (1)

- **Map of deflections of the vertical → ξ component**

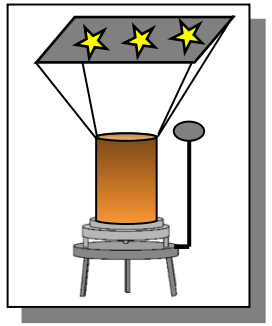
  - Input data: 72327 gravity points, ρ_{geo}, GOCO05s → ***quality of solution?***

[']	min	max	mean	rms
	-26.70	39.07	3.67	8.80

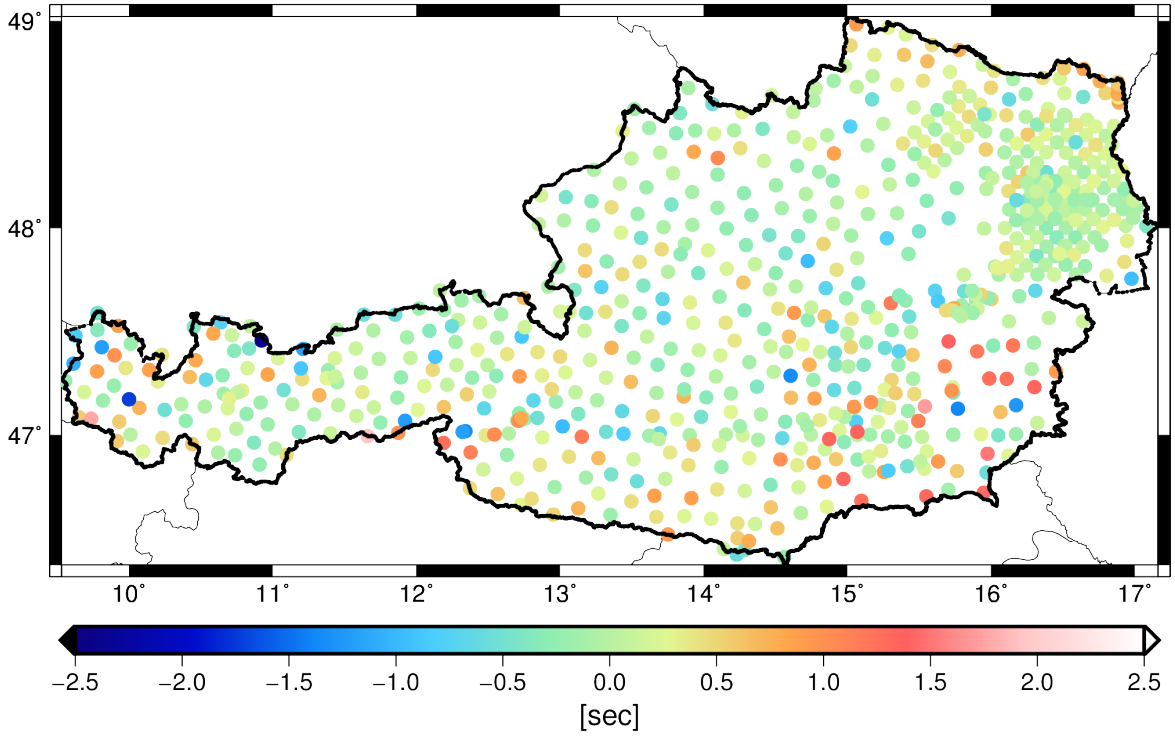


Further Validation with Deflections (2)

- **Measured deflections of the vertical are used for validation**
  - Validation ξ map → 735 deflections of the vertical



[']	min	max	mean	rms
	-2.44	1.91	0.08	0.49

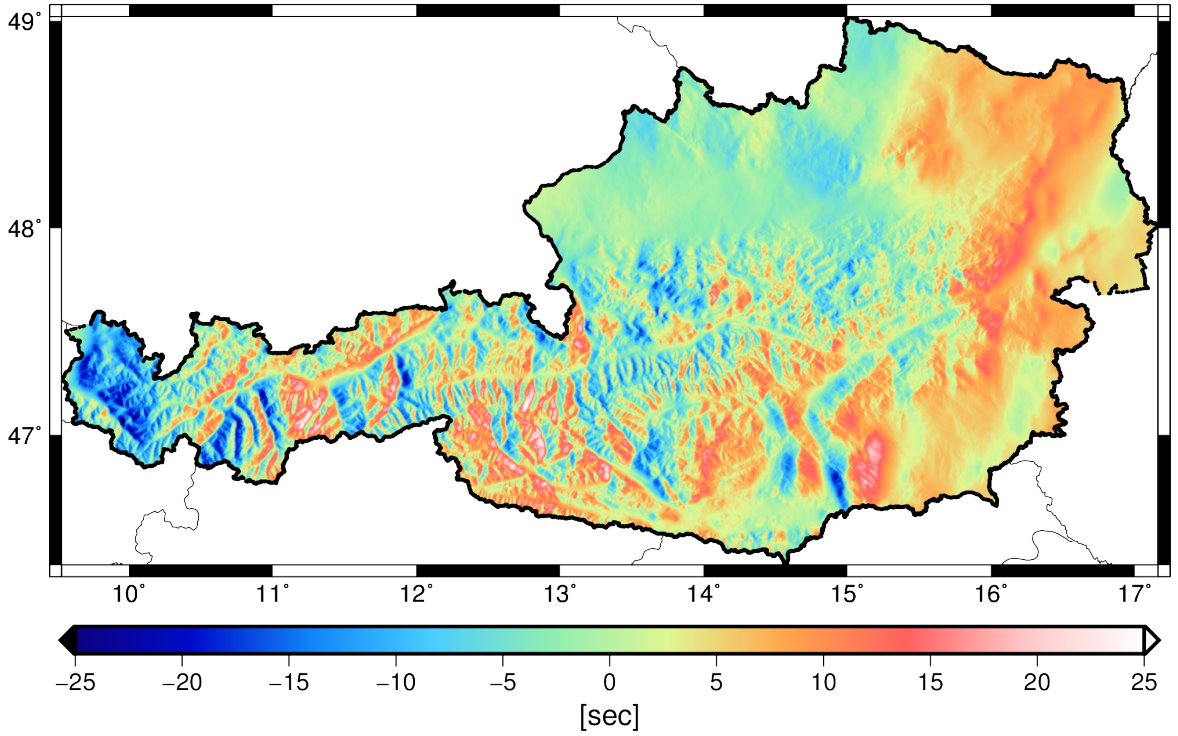


Further Validation with Deflections (3)

- **Map of deflections of the vertical → η component**

  - Input data: 72327 gravity points, ρ_{geo}, GOCO05s → ***quality of solution?***

["]	min	max	mean	rms
	-27.37	26.65	1.51	6.58



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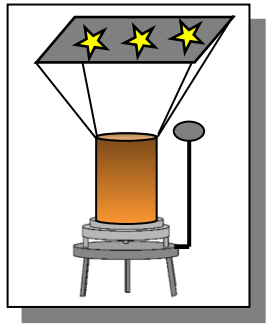
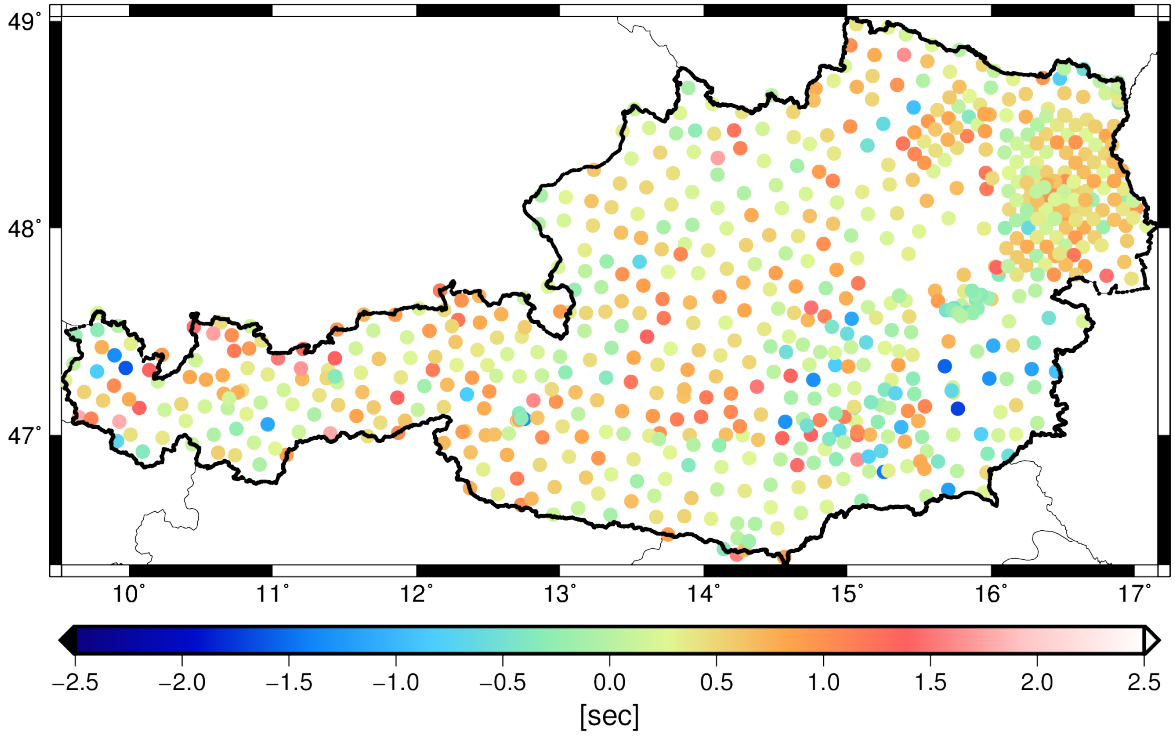


[']	min	max	mean	rms
	-1.71	1.80	0.35	0.63



Global Gravity Field Models - Results

- **Contribution to geoid improvements:**
  - Surface density model ρ_{geo}, in combination with different GOCO models
  - Comparison of **72327** gravity measurements & **192** GPS/Leveling points

REMOVE GOCO Model	min [mgal]	max [mgal]	mean [mgal]	rms [mgal]
GOCO02s	-50.55	42.75	-0.84	11.92
GOCO03s	-49.83	41.50	-0.94	11.55
GOCO05s	-49.48	37.35	-0.85	11.40

Decreasing rms values

RESTORE GOCO Model	min [cm]	max [cm]	rms [cm]
GOCO02s	-12.63	8.31	3.41
GOCO03s	-12.49	8.28	3.30
GOCO05s	-9.62	6.46	2.75

Decreasing rms values

Up to date model contributes significantely to geoid improvements!

Summary

- **Take away messages:**
  - **Density information improves** the entire **geoid computation**
  - **Density models** perform **better** compared to standard crustal density
  - **Continuous improvements** also **for deflections of the vertical**
  - **Up to date** global gravity field models **improve** the **geoid solution**
  - **Best** gravimetric geoid **solution** is based on **surface density & GOCO05s**
- **Problem:**
  - Rms values < 3 cm possible → **Quality of 192 GPS/Leveling observations?**

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