Impact of Geological Surface Density Information and Seismic 3D Density Models for High Precision Regional Geoid Computation

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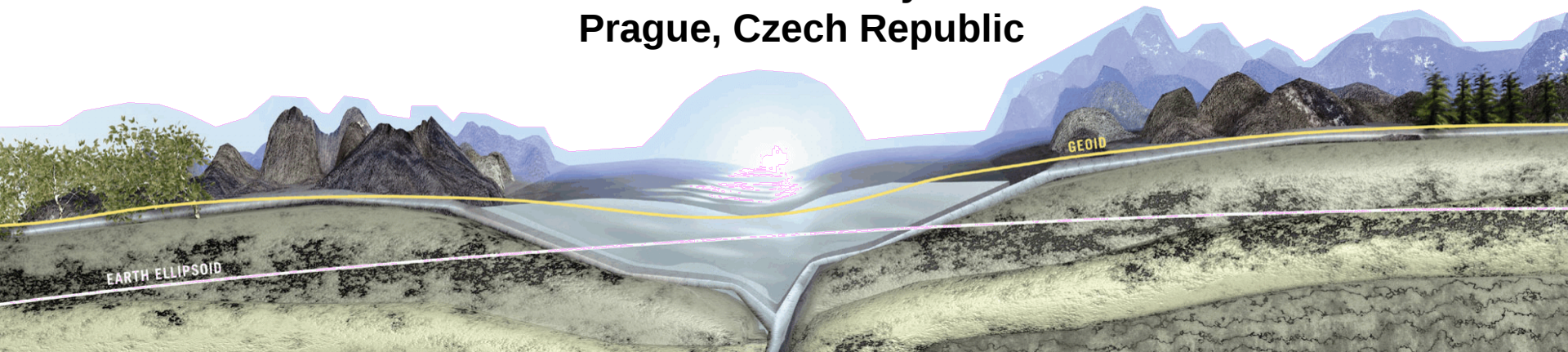


Introduction

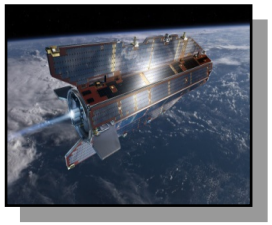
- Focus of investigations:
  - **Density information**
  - **How does this data type can contribute to an improved geoid?**
  - **Different validation approaches**
- Investigations are embedded in the current Austrian geoid initiative *"Geoid for Austria - Regional gravity FIELD improved" (GARFIELD)* - P25222-N29

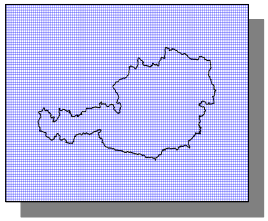
- ***Question:***
  - ***Used computation parameters?***

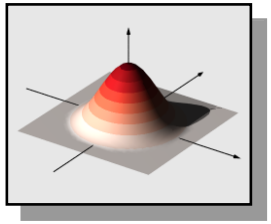
Computation Parameters

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

  Used for validation
- Global gravity field model:
  - **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



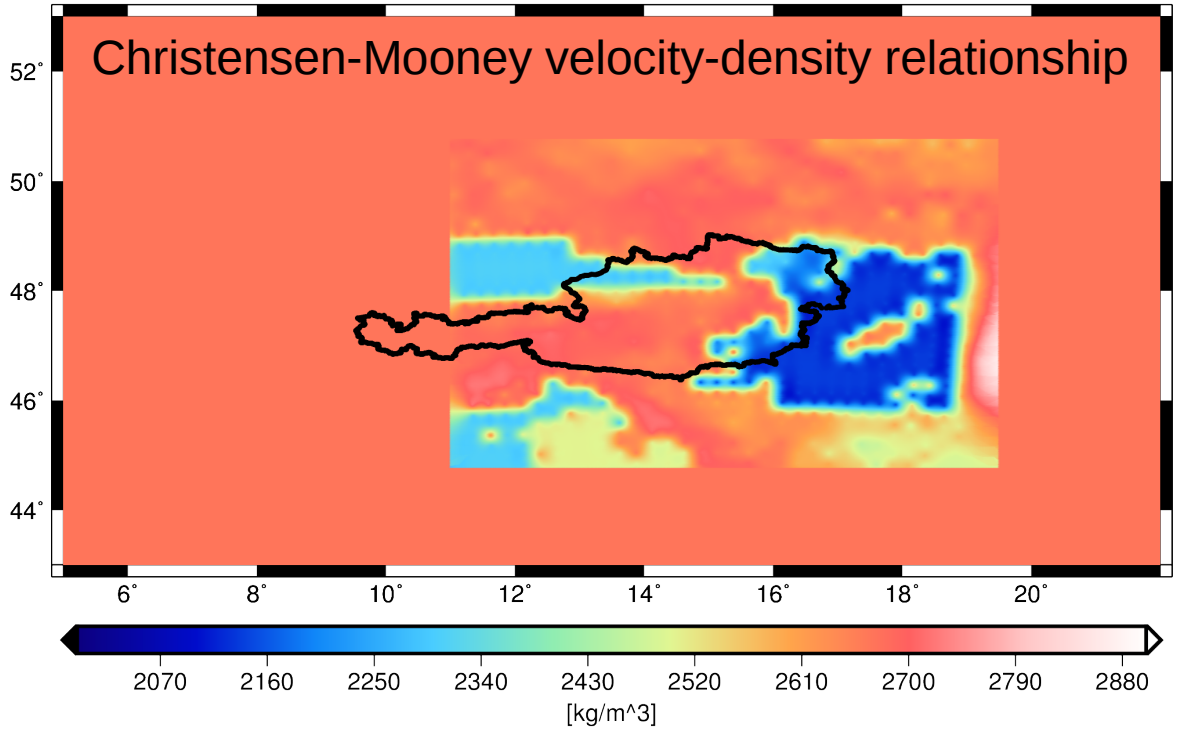




Density Models (1)

- **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

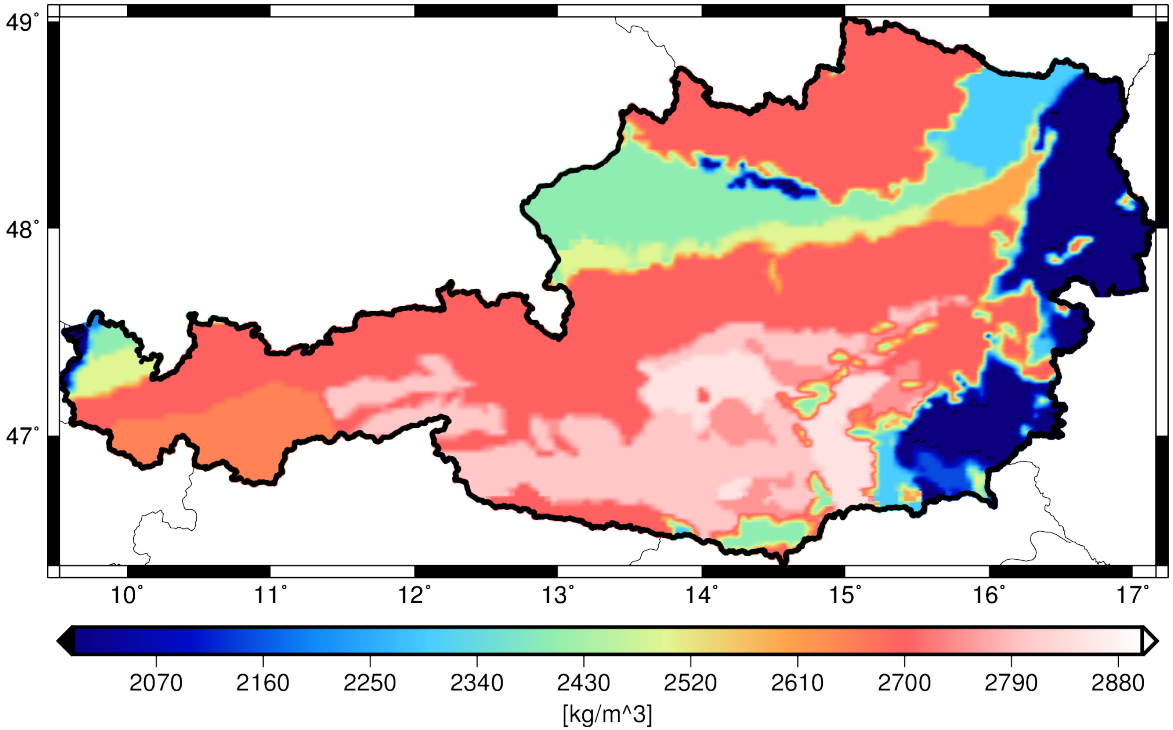
[kg/m^3]	min	max	mean
	2102.70	2870.60	2628.60



Density Models (2)

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

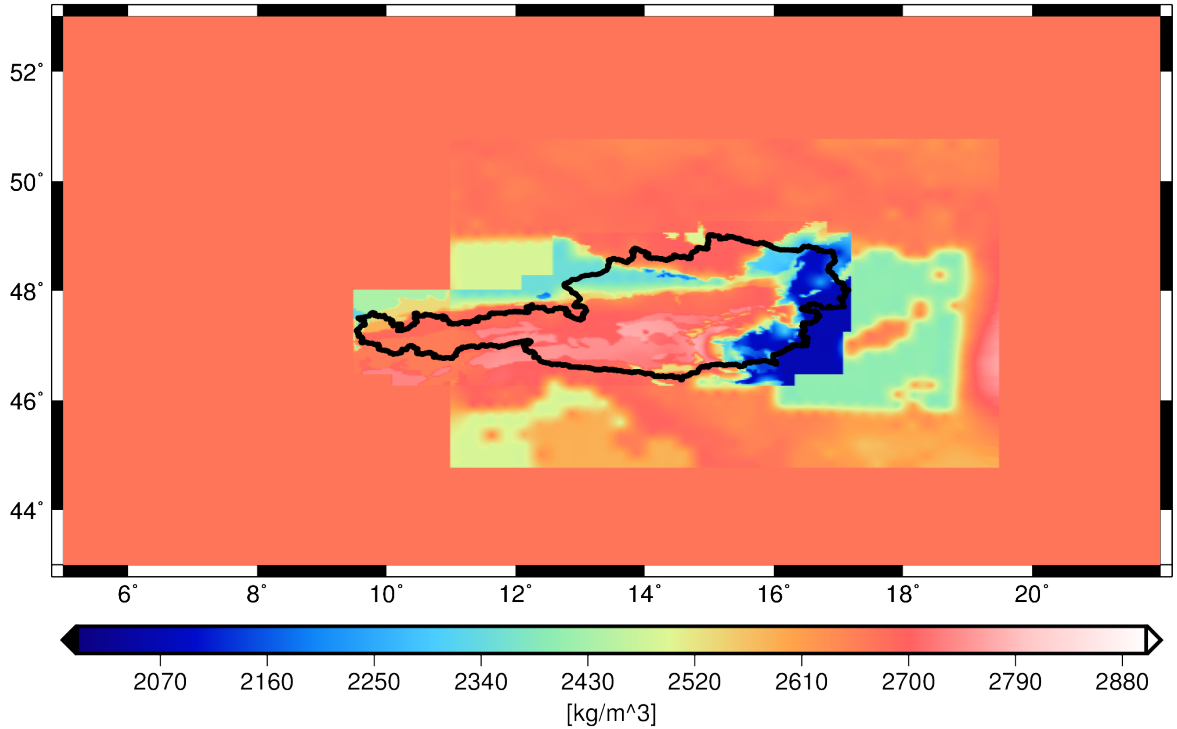
[kg/m^3]	min	max	mean
	2000.00	2852.00	2575.60



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}

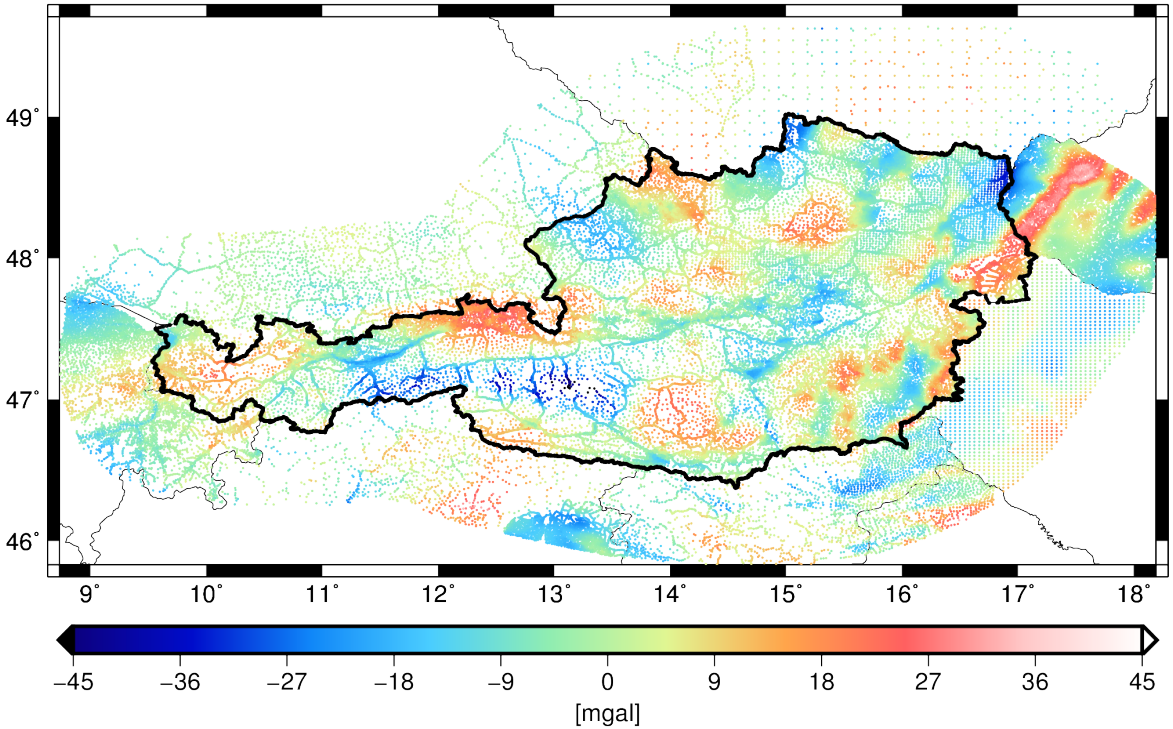
- ***Questions:***
  - ***Significant improvements throughout the reduction step?***
  - ***Is any of these density models improving the geoid solution?***
  - ***Which density assumption performs best compared to GPS/Leveling and geopotential numbers?***

Remove Step (1)

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

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

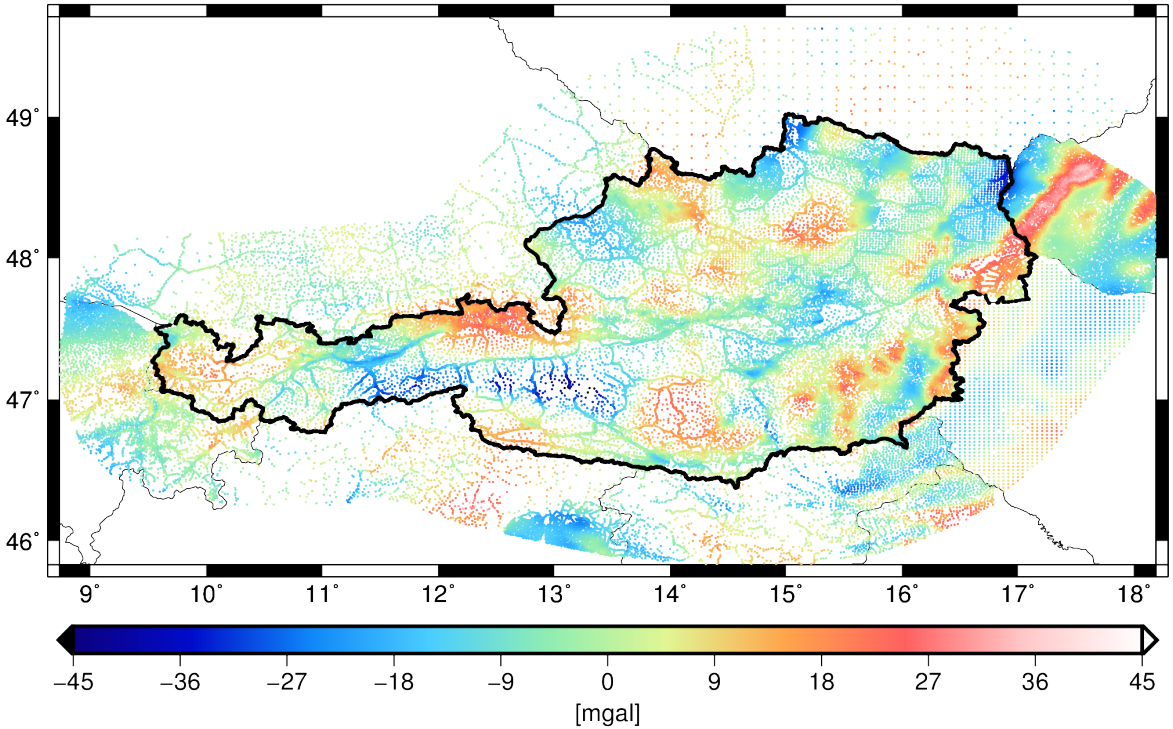
[mgal]	min	max	mean	rms
	-48.49	39.44	-1.10	11.70



Remove Step (2)

- **Input data:** gravity, number of data points: 72327
  - Hybrid density $\rho_{hyb} = \frac{\rho_{seis} + \rho_{geo}}{2}$

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

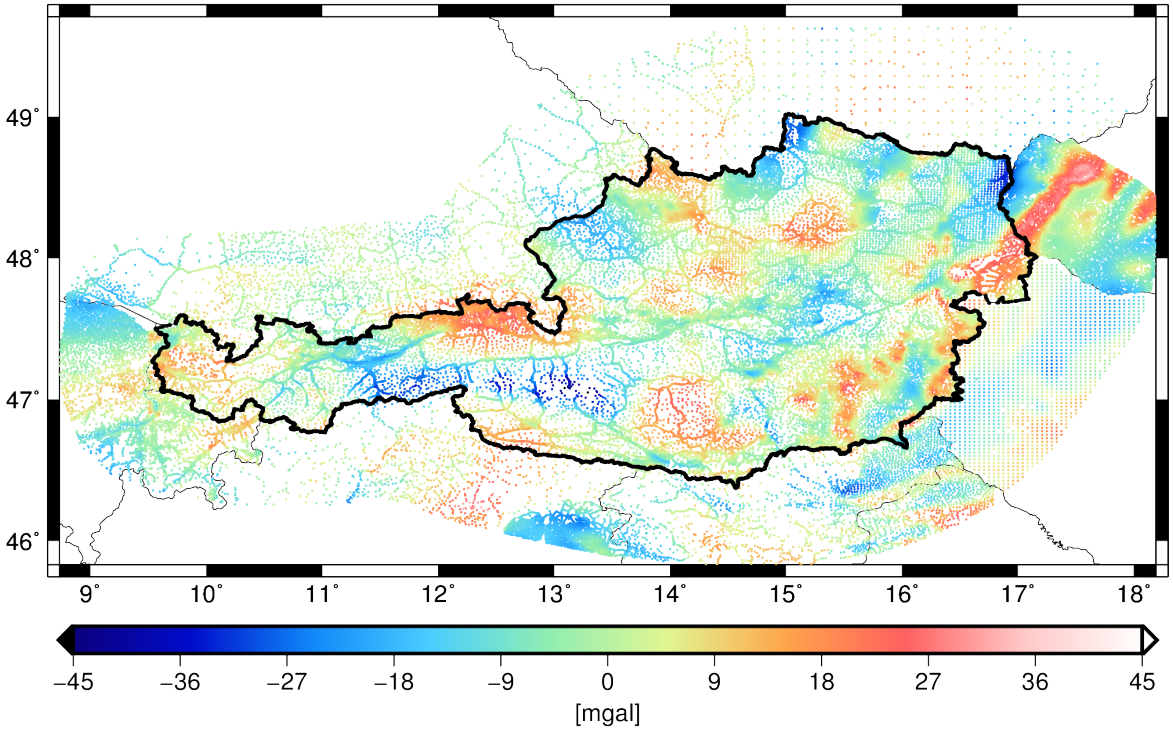


Remove Step (3)

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

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

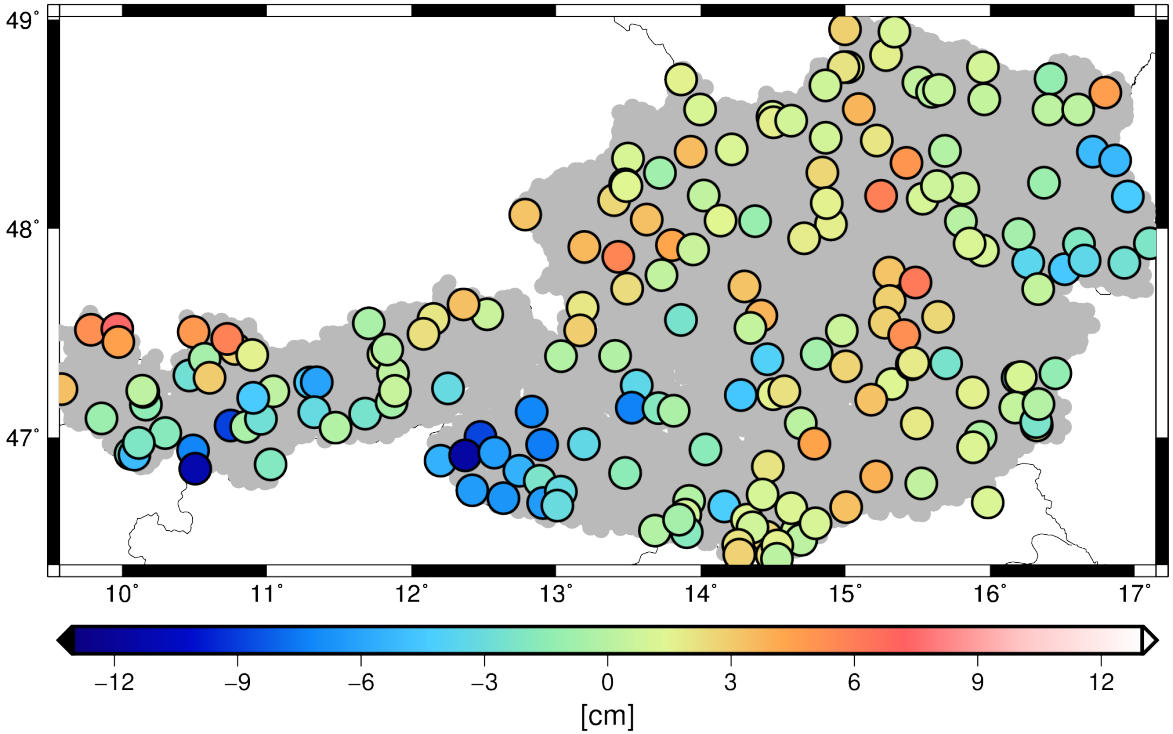
[mgal]	min	max	mean	rms
	-49.48	37.35	-0.85	11.40



Absolute Validation (1)

- **Geoid validation with 192 GPS/Leveling observations**
  - Standard crustal density $\rho = 2670\ kg/m^3$

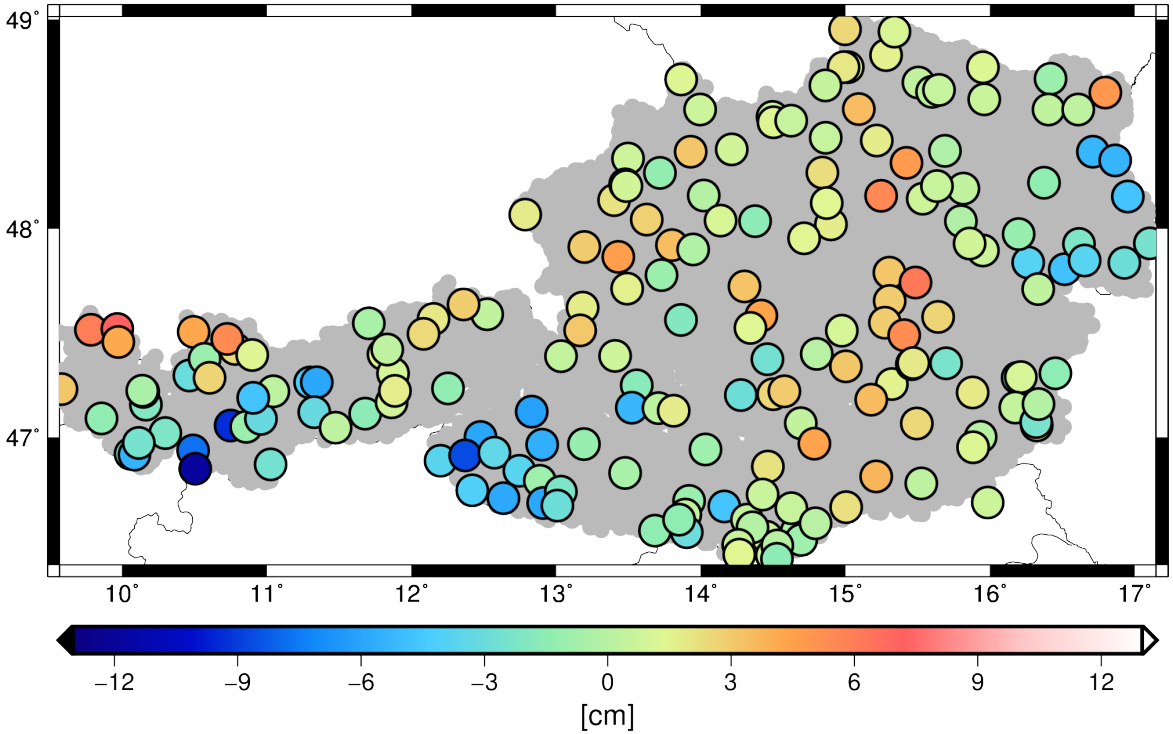
[cm]	min	max	rms
	-11.68	7.43	3.33



Absolute Validation (2)

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

[cm]	min	max	rms
	-11.82	7.21	3.05

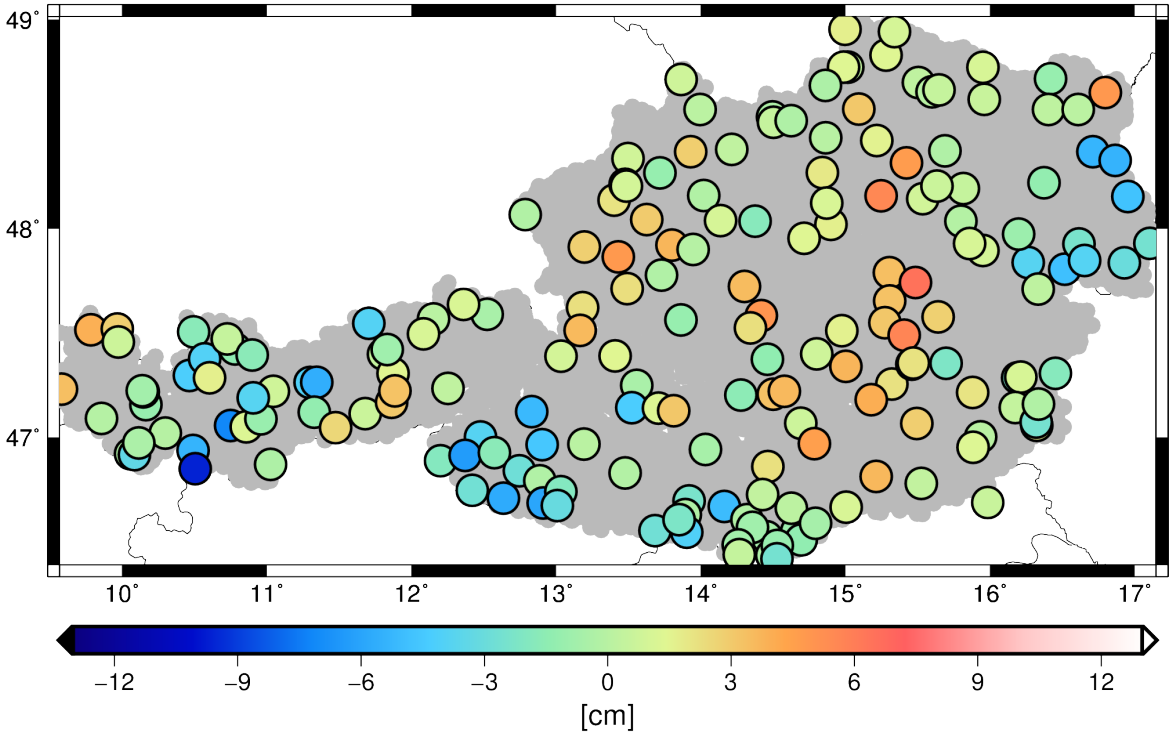


Absolute Validation (3)

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

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

[cm]	min	max	rms
	-9.62	6.46	2.75

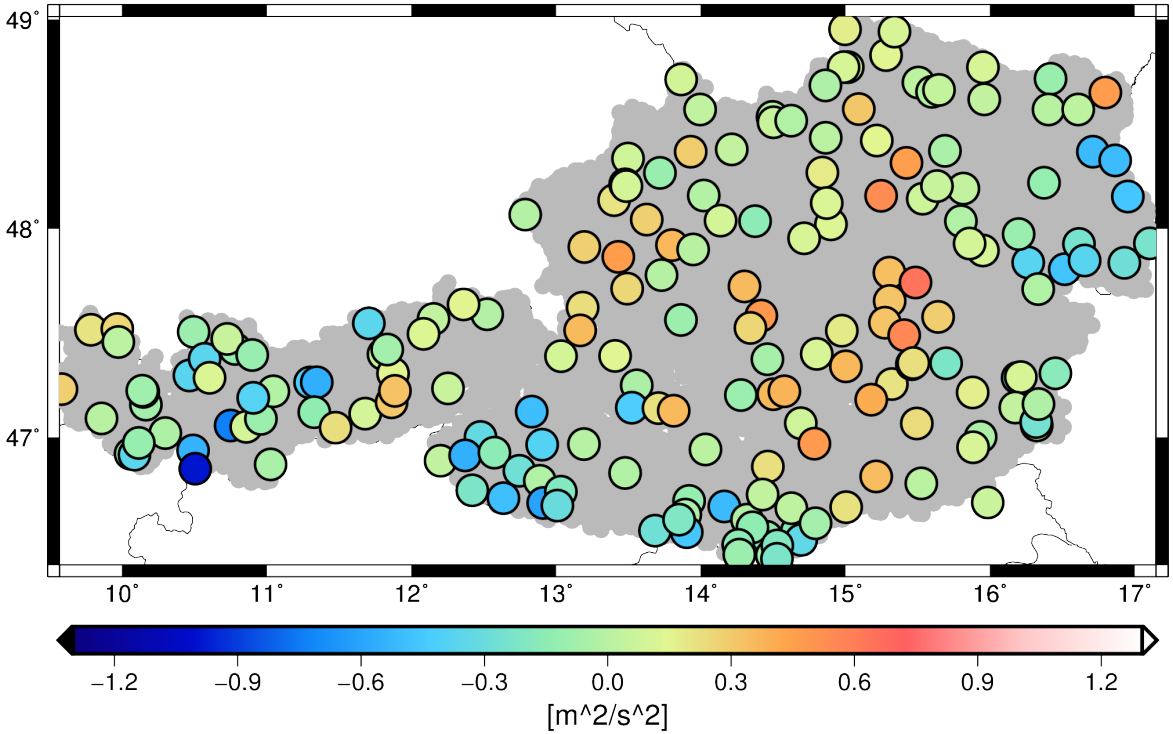


Validation with Geopotential Numbers

- **Validation with 192 geopotential numbers**

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

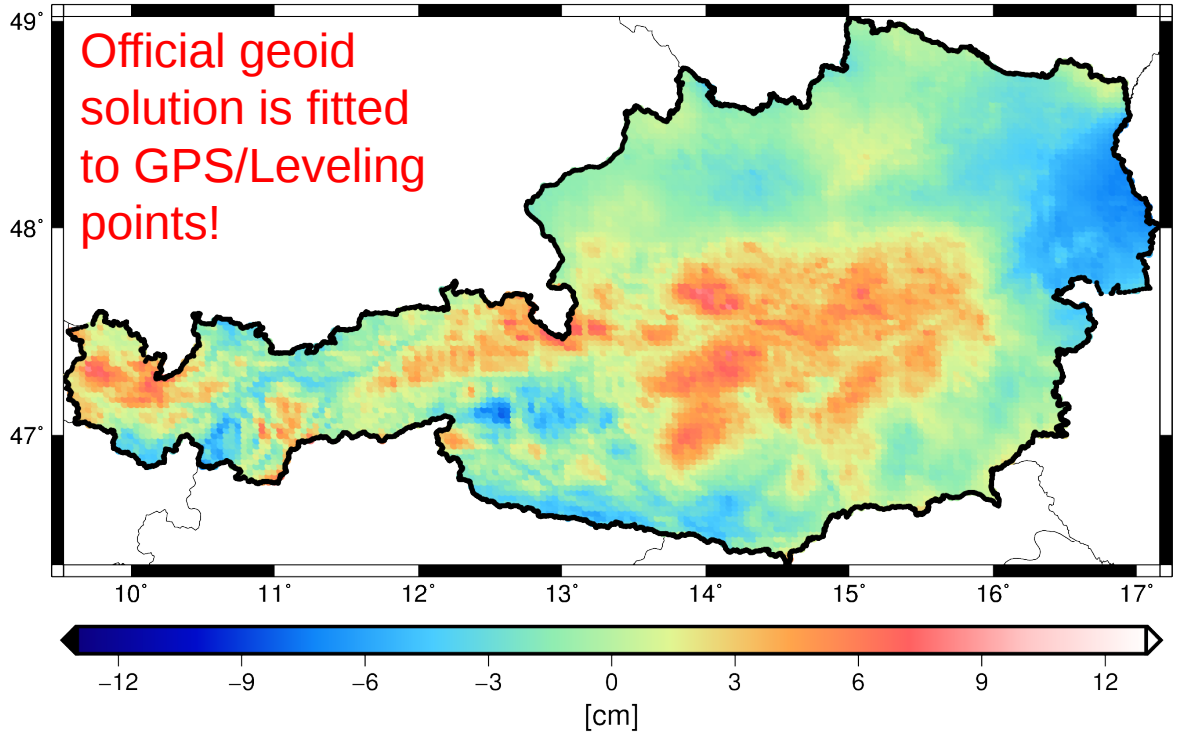
[m²/s²]	min	max	rms
	-0.99	0.65	0.27



Validation with Austrian Geoid Solution

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

[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

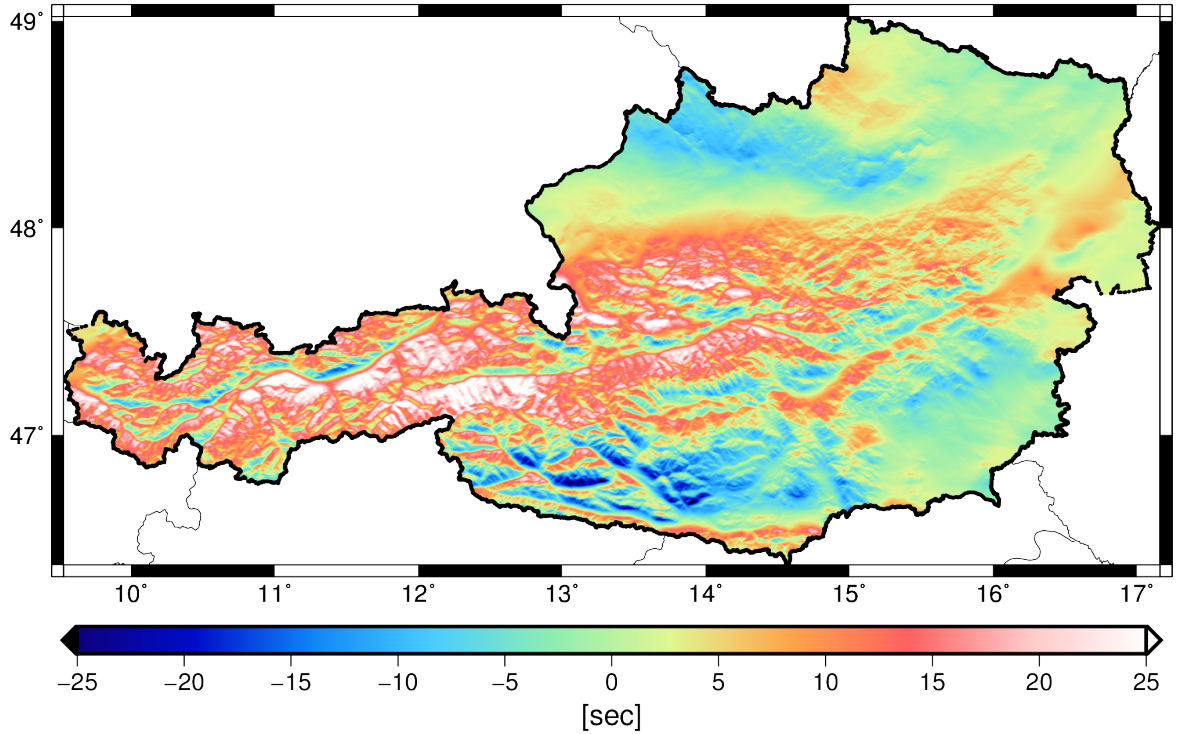
- ***Answers:***
  - ***Significant improvements throughout the reduction step? → Yes***
  - ***Is any of the density models improving the geoid solution? → Yes***
  - ***Which density assumption performs best compared to GPS/Leveling and geopotential numbers? → Surface density***

Further Validation with Deflections (1)

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

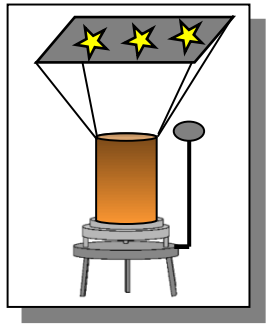
  - Input data: 72327 gravity points, ρ_{geo}, GOCO05s → ***quality of solution?***

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

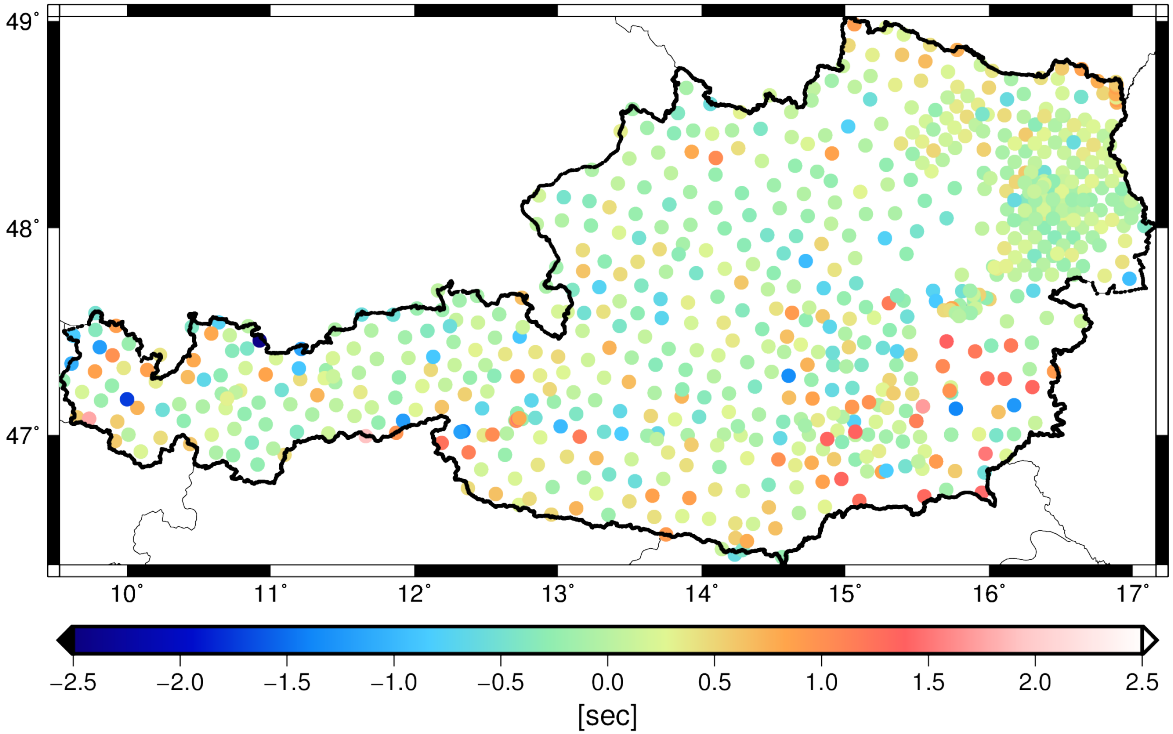


Further Validation with Deflections (2)

- **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

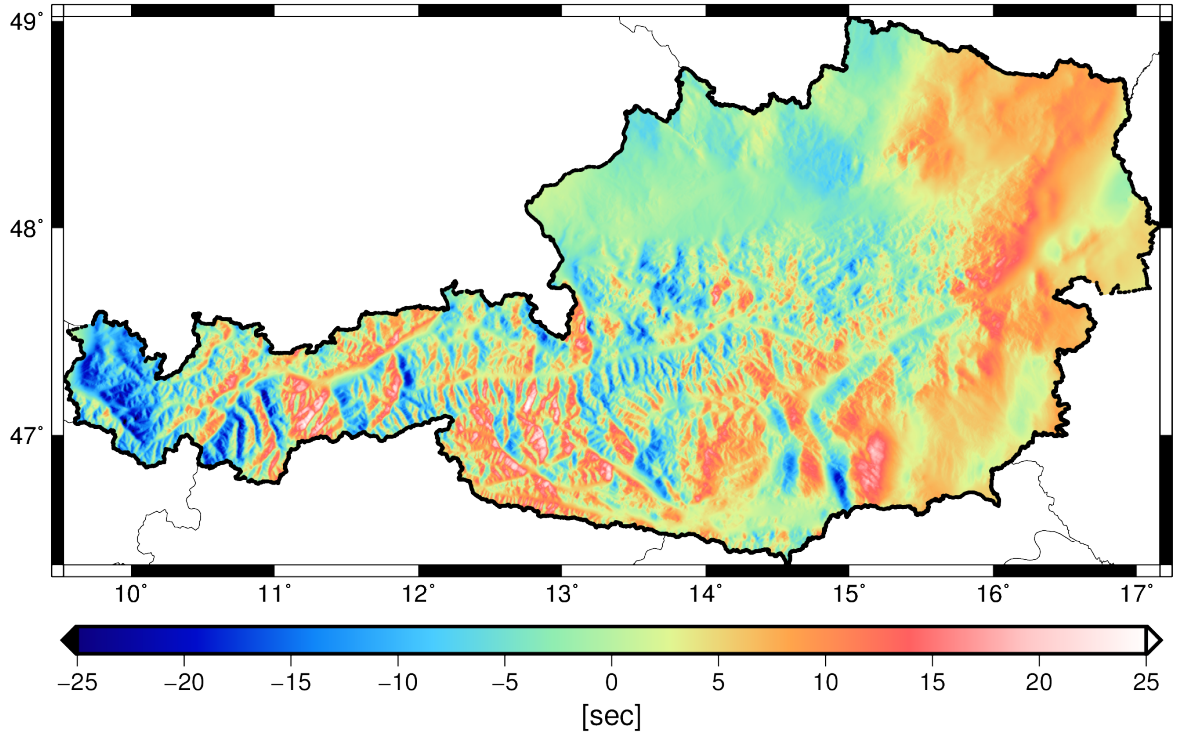


Further Validation with Deflections (3)

- **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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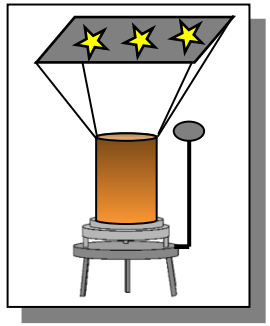
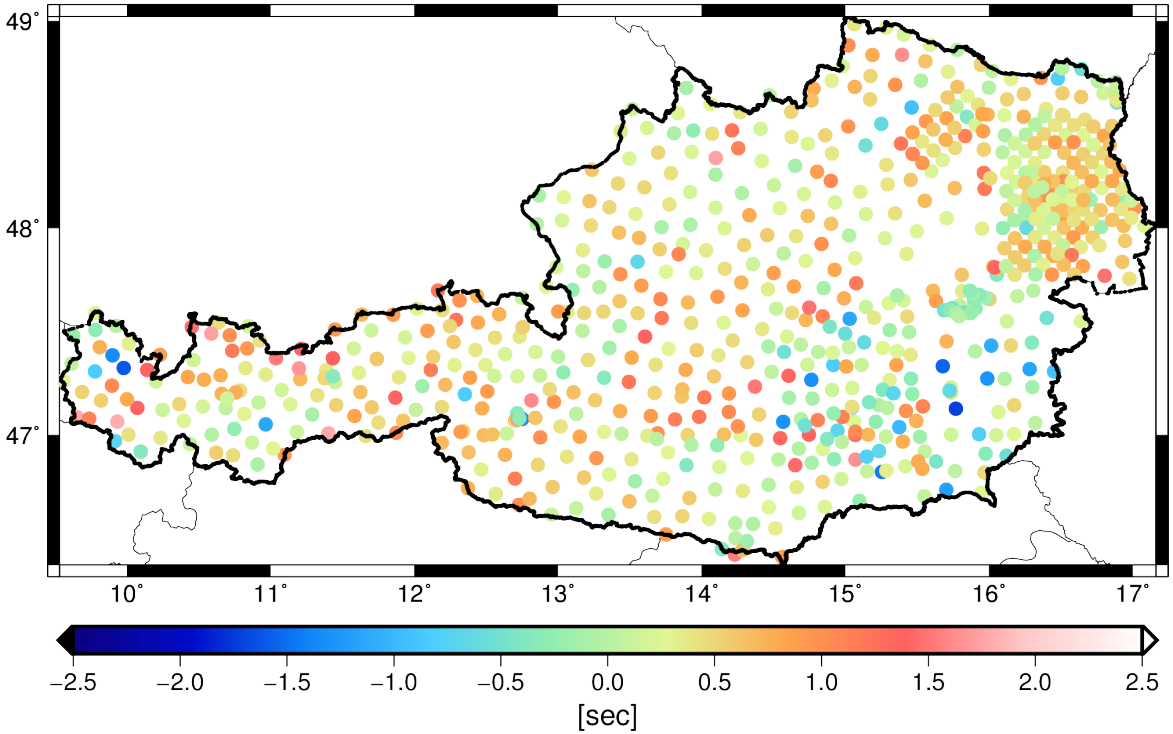


[']	min	max	mean	rms
	-1.71	1.80	0.35	0.63



Summary

- **Take away messages:**
  - **Density information improves** the entire **geoid computation**
  - **Density models** perform **better** compared to **standard crustal density**
  - **Improvements** also for **deflections of the vertical & geopotential numbers**
  - **Best gravimetric geoid solution** is based on **surface density & GOCO05s**
  - **Latest GOCO model also contributes to an improved geoid**

- **Problems:**
  - Rms values < 3 cm possible → **Quality of 192 GPS/Leveling observations?**
    → **Quality of density information?**

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