Gravity effect of Alpine slab segments based on geophysical and petrological modelling

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Mountain Building Processes in 4D

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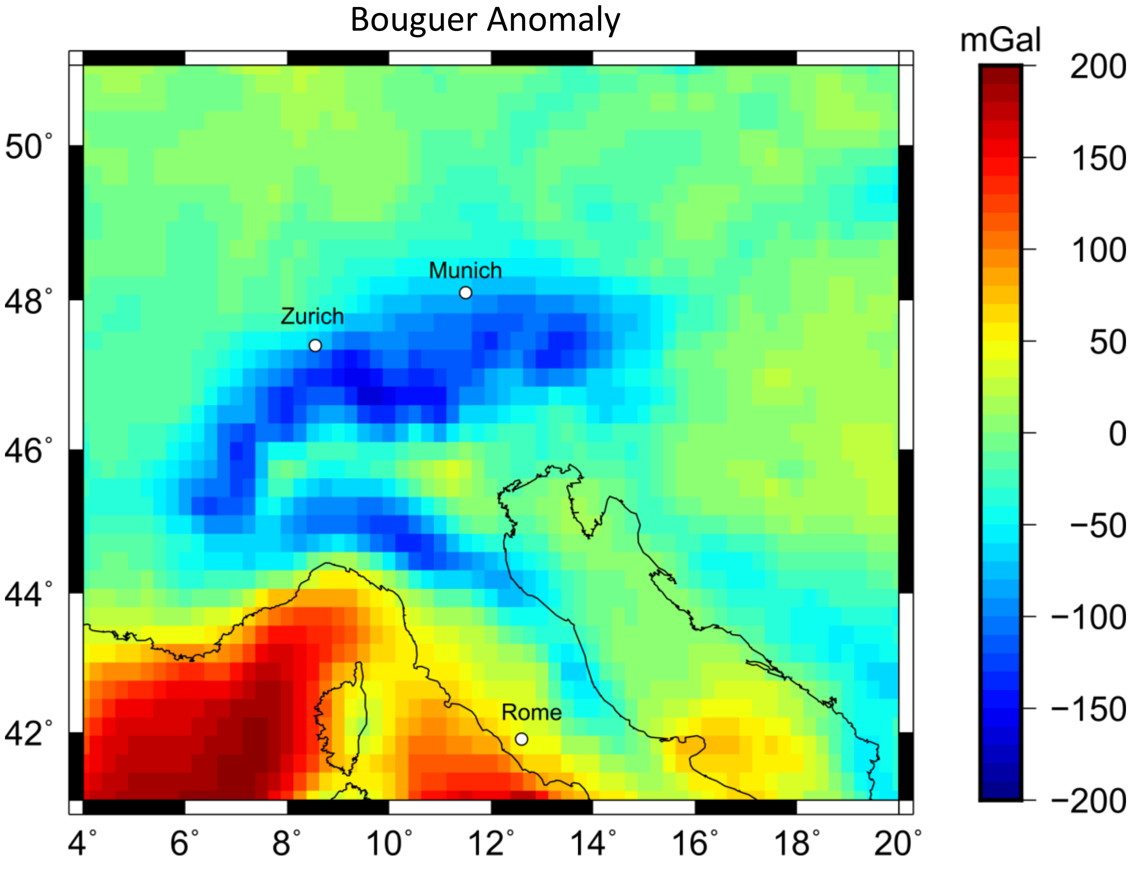
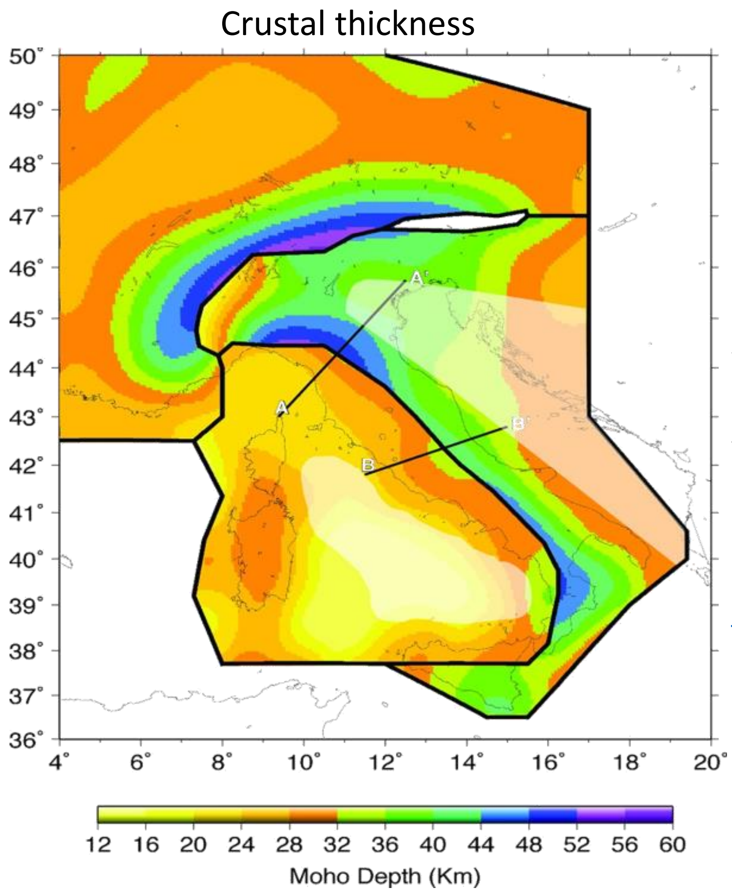
- Bouguer anomaly is dominated by crustal thickness.





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https://doi.org/10.1093/gji/ggt148

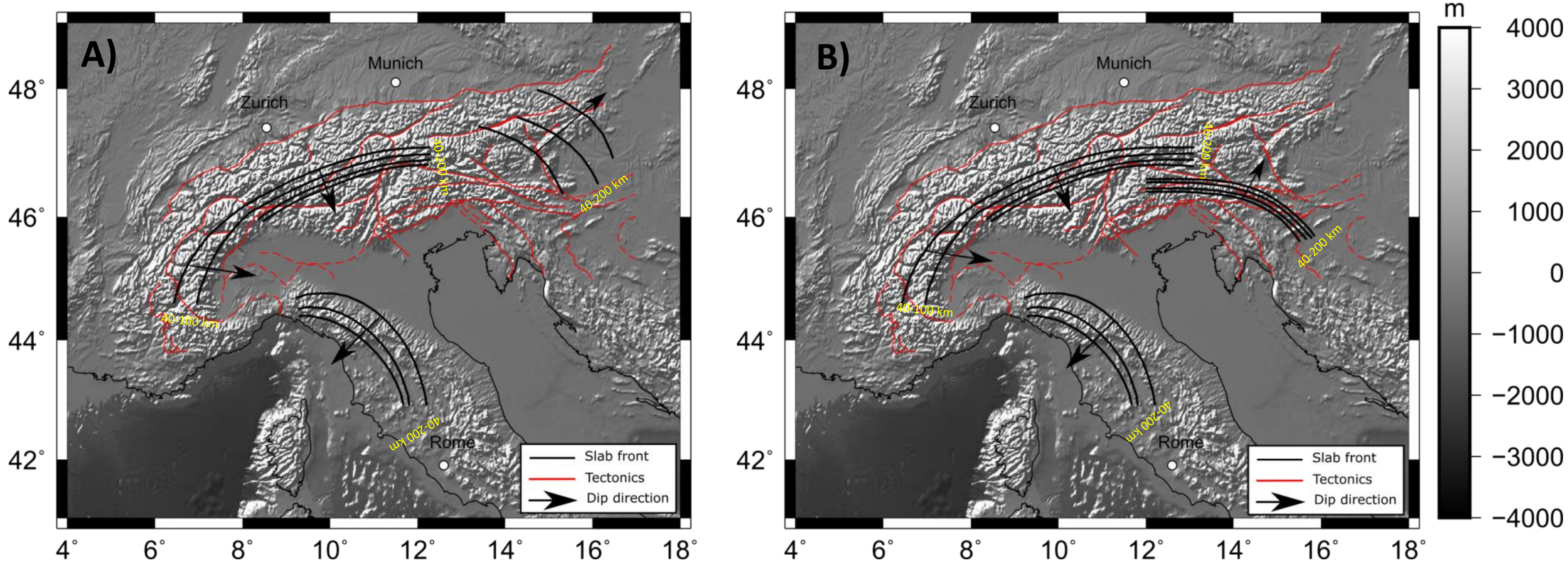
- But: How large is the gravity contribution to the Alpine gravity field caused by a subducting slab?

Slab models

We use seismic crustal depth estimations and different upper mantle tomographies to define hypotheses for the geometry of the subducting slab segments.

- **A) Hypothesis 1** includes a west Alpine slab up to 100 km (Kästle et al. (2018)), a short central Alpine slab and an eastern Slab segment subducting north east (Lippitsch et al. (2003)) with a slab gap separating central and eastern Alps.

- **B) Hypothesis 2** based on a new surface wave tomography (El-Sharkawy, (2019)), including a long Eurasian slab in the central Alps and bivergent subduction in the eastern Alps. In addition, we consider the south-dipping slab segment beneath the northern Apennines.

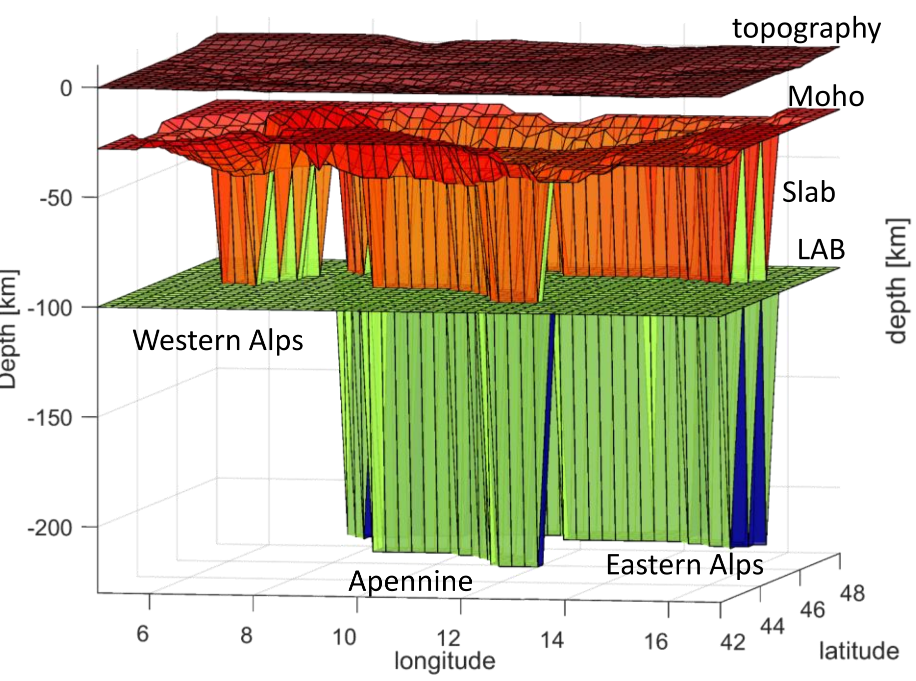


Faults in red after Schmid et al. (2004)
Topography from ETOPO 1 Amante, C., & Eakins, B. W. (2009)

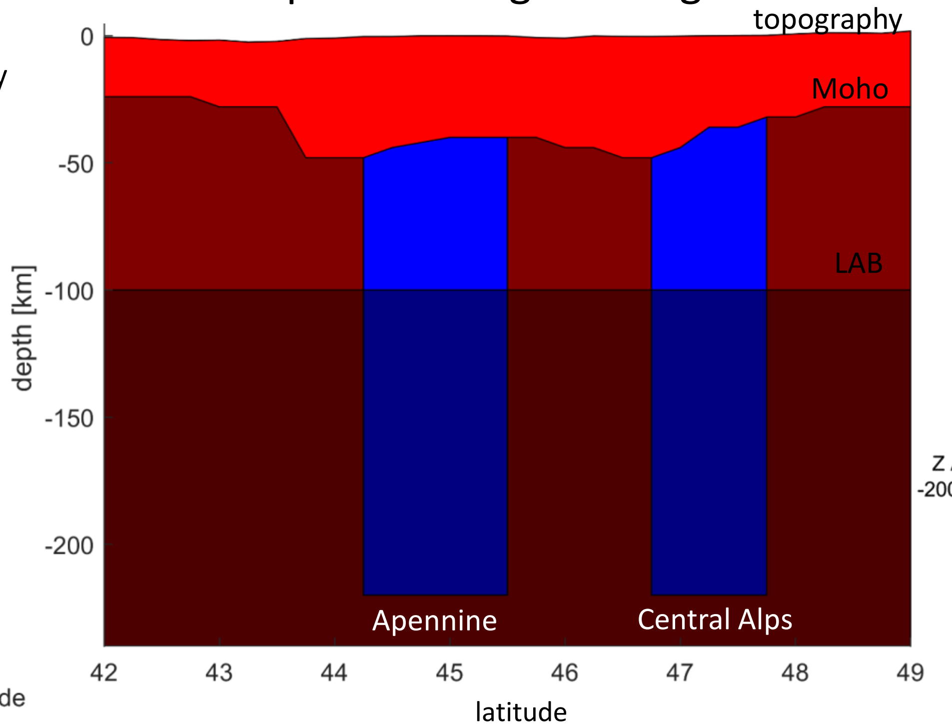
Model setup

- LitMod 3D by Fullea et al. (2009) is used for slab modelling.
- Calculates gravity based on density distribution depending on temperature, pressure and composition on a finite element grid.
- Slabs are divided into a lithosphere and a sub lithosphere domain.

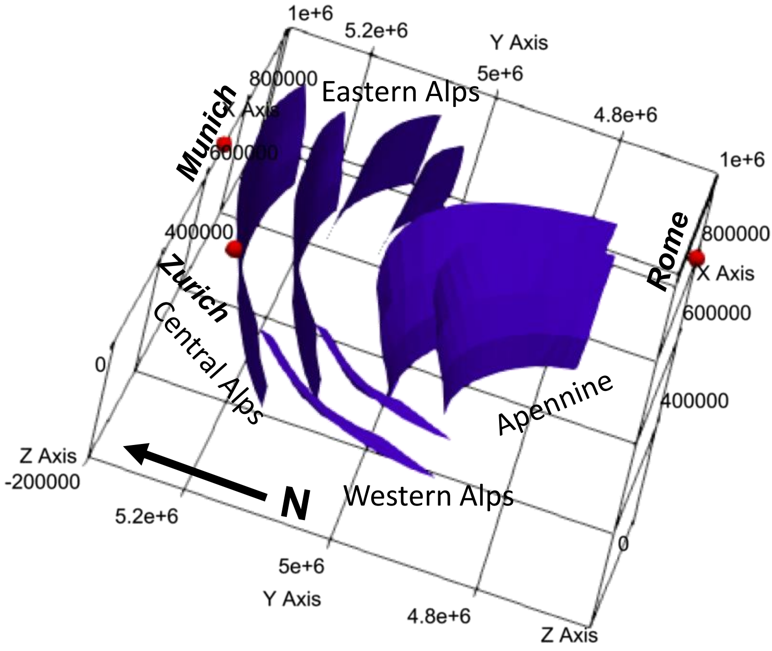
Model configuration containing slabs in the lithosphere and sub lithosphere



Model profile along 11° longitude



Slab configuration hypothesis 2



Model composition

- We use phanerozoic compositions for the lithosphere and the subducting slab segments.
- depleted mid-oceanic ridge basalt mantle (DMM) and primitive upper mantle (PUM) are used for the sub lithospheric domain.
- Note those compositions are a first order test and serve as a starting point. They do not necessarily represent the compositional mantle environment in the Alps.
- Additional to the density contrast within the sub lithosphere, a temperature anomaly of – 100 ° K is added.

Table 1 : Compositional difference between lithosphere mantle and subducting slab material.

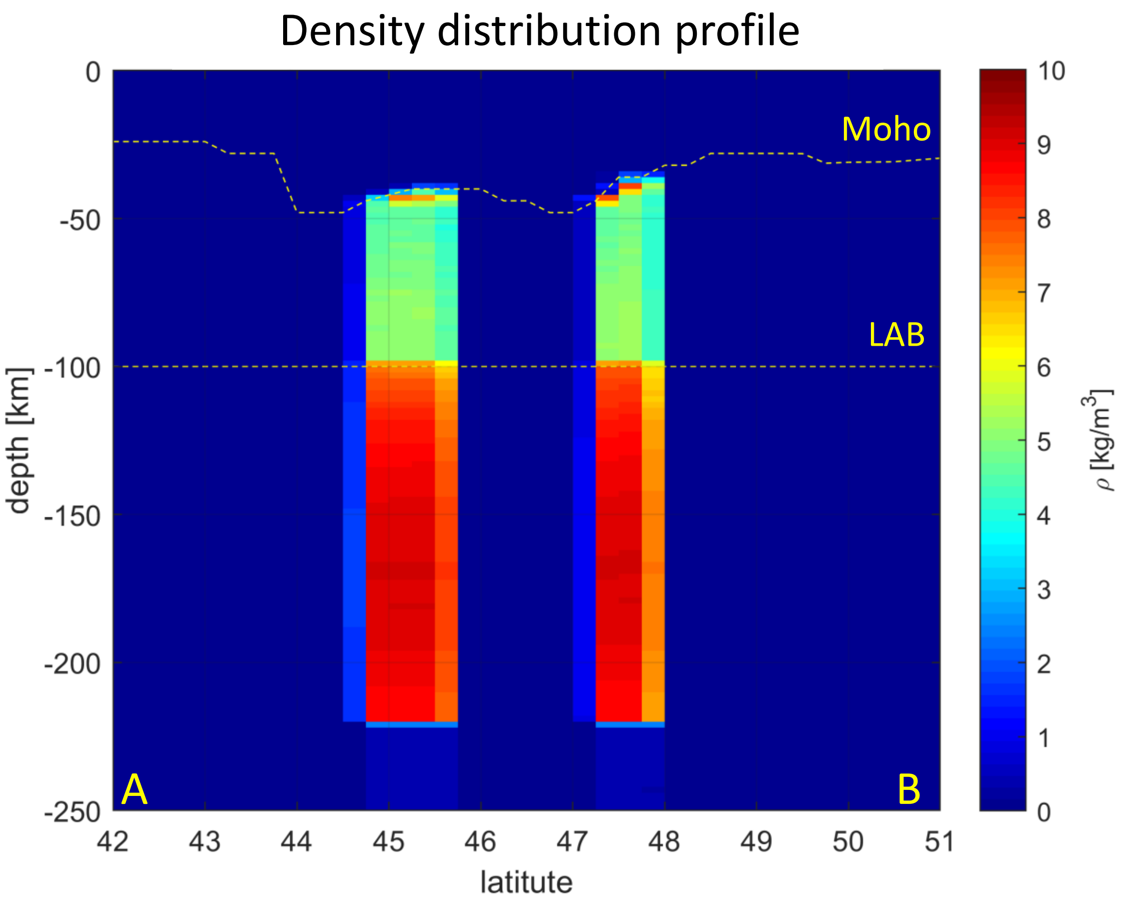
Major Oxide Compositions	Aver. Tecton Gnt. SCLM [a]	Aver. Tecton Gnt. Peridotite [a]	Differences
SiO_2	44.5	45	-0.5
Al_2O_3	3.5	3.9	0.4
FeO	8	8.1	-0.1
MgO	39.8	38.7	1.1
CaO	3.1	3.2	-0.1
Na_2O	0.26	0.24	0.04

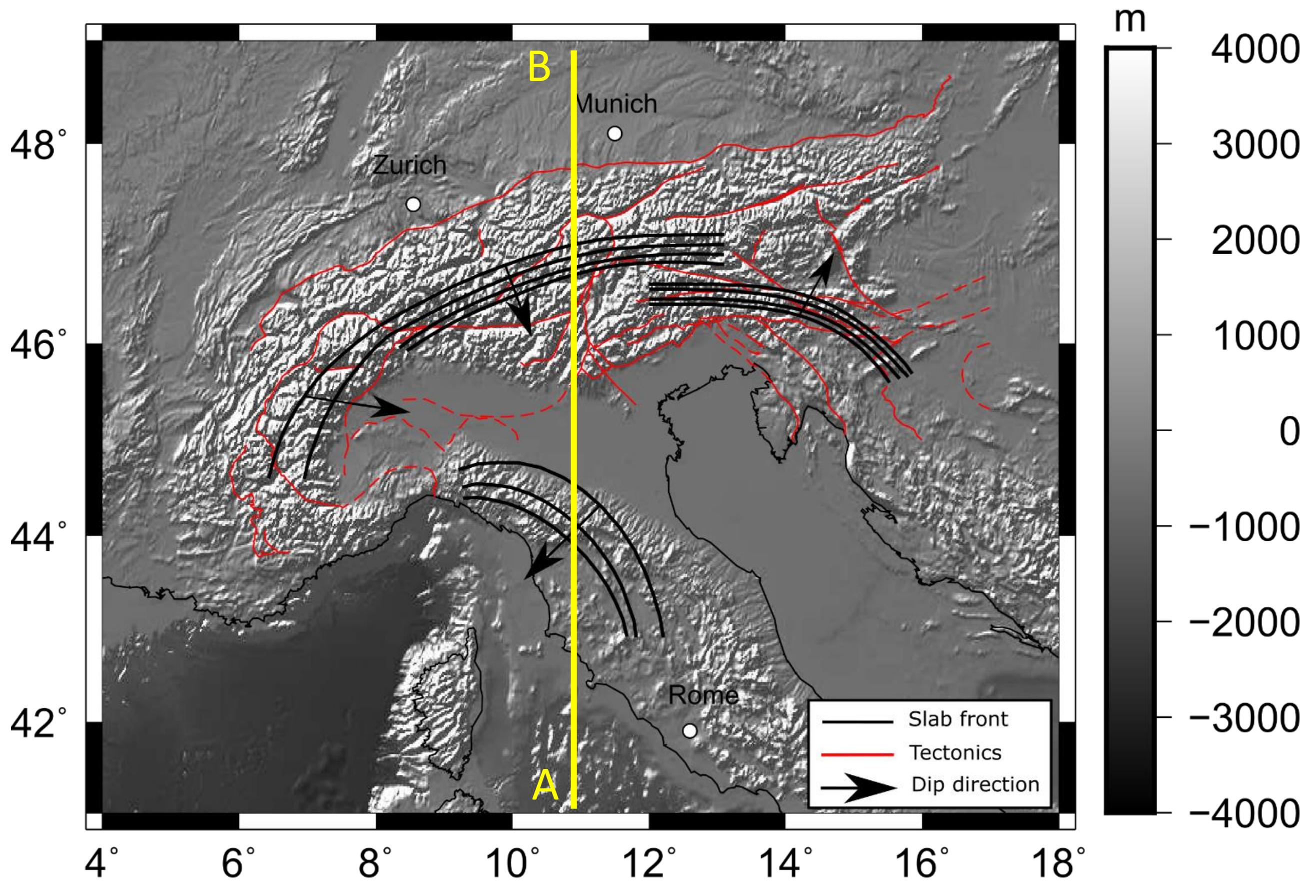
Table 2 : Compositional difference between sub lithosphere mantle and subducting slab material.

Major Oxide Compositions	PUM [b]	DMM [c]	Differences
SiO_2	45	44.7	0.3
Al_2O_3	4.5	3.98	0.52
FeO	8.1	8.1	0
MgO	37.8	37.8	0
CaO	3.6	3.17	0.23
Na_2O	0.36	0.13	0.25

[a] Classifications according to Griffin et al. (1999b), [b] McDonough & Sun (1995), [c] Workman & Hart (2005)

Density contrast within the subducting slab to the ambient mantle





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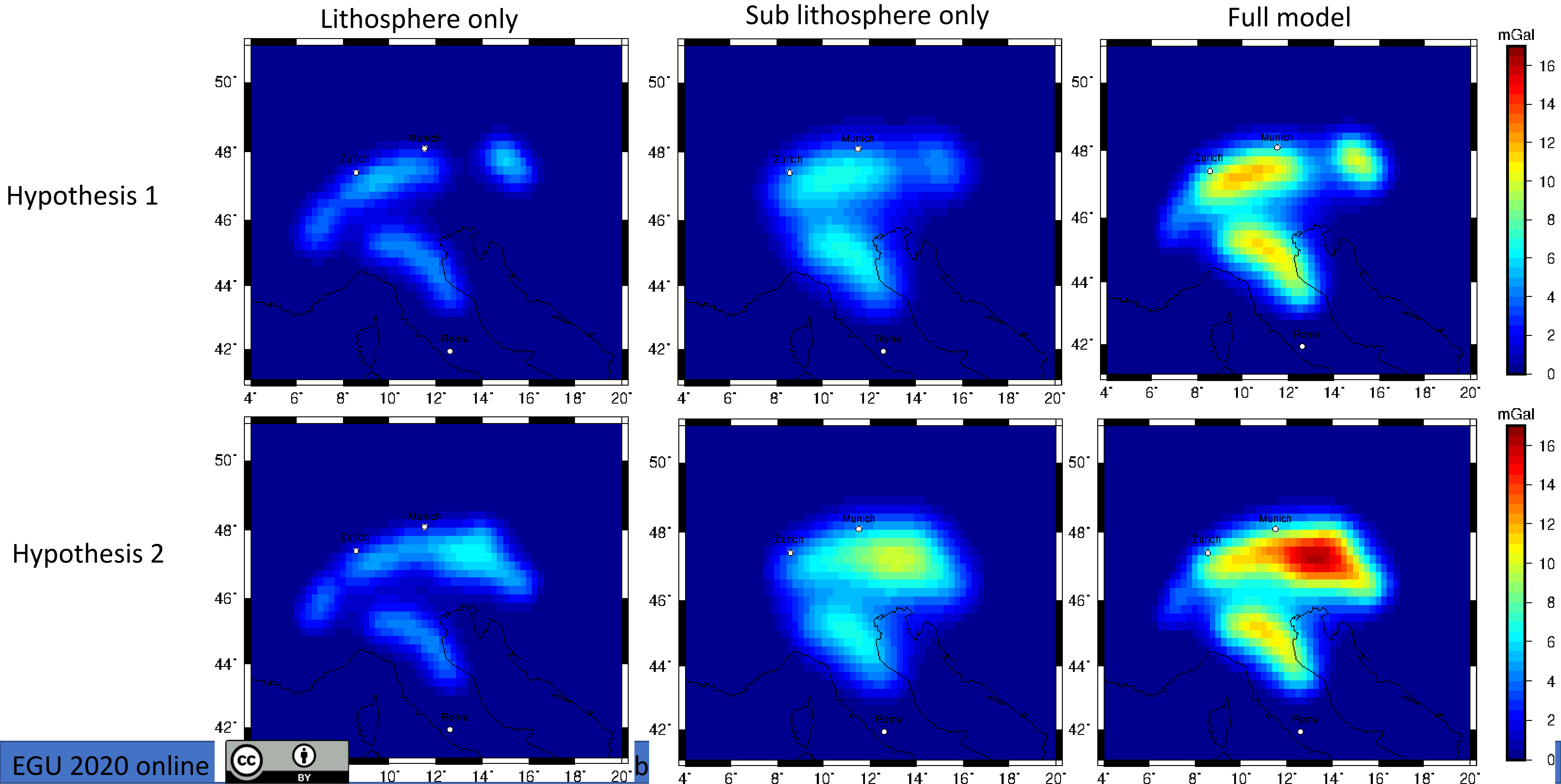
Calculated gravity effect g_z at surface height



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Summary, Conclusion and Outlook

Summary

- We can model the gravity signal of subducting lithosphere taking composition, temperature and pressure distributions into consideration using the LitMod 3D algorithm. Furthermore, we can estimate those quantities separately for the lithosphere and sub lithosphere.
- The density contrast between the slab segments and the ambient mantle is for the lithosphere in the order of 5 kg/m^3 and for the sub lithosphere in the order of 10 kg/m^3.
- The gravity signal for the gz component at surface height is in the order of 12 to 17 mGal.

Conclusion

- Different slab hypotheses configurations can be distinguished by gravity modelling at surface station height.
- The gravity signal of a subducting slab in the Alpine region is in the order of 20 mGal compared to the overlaying negative Bouguer Anomaly of about - 200 mGal.
- The gravity signal of the slabs can be compensated by slight changes to the Moho depth and or LAB depth within the estimated uncertainty ranges.

Outlook

- The next step could be: more complex LitMod models with increased resolution in the crustal domain, to cross validate with geodynamics.
- Calculated seismic velocities can validate slab models by comparing to seismic velocities measured by the AlpArray.

Acknowledgement: This study is part of the project "Surface Wavefield Tomography of the Alpine Region to Constrain Slab Geometries, Lithospheric Deformation and Asthenospheric Flow in the Alpine Region" funded by DFG in the SPP Mountain Building Processes in 4D.

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Lowe, M., Ebbing, J., El-Sharkawy, A., Meier, T,

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