Kazan Federal University

CAU Christian-Albrechts-Universität zu Kiel

INVERSE AND FORWARD GRAVITY MODELING FOR REVEALING THE CRUSTAL STRUCTURE OF VOLGA-URALIAN SUBCRATON

Igor Ognev (1), Jörg Ebbing (2), Peter Haas (2)
(1) Kazan Federal University, Russia. (2) Department of Geosciences, Kiel University, Germany
Contact: ognev.igor94@gmail.com

KIEL 2021 DGG A-234

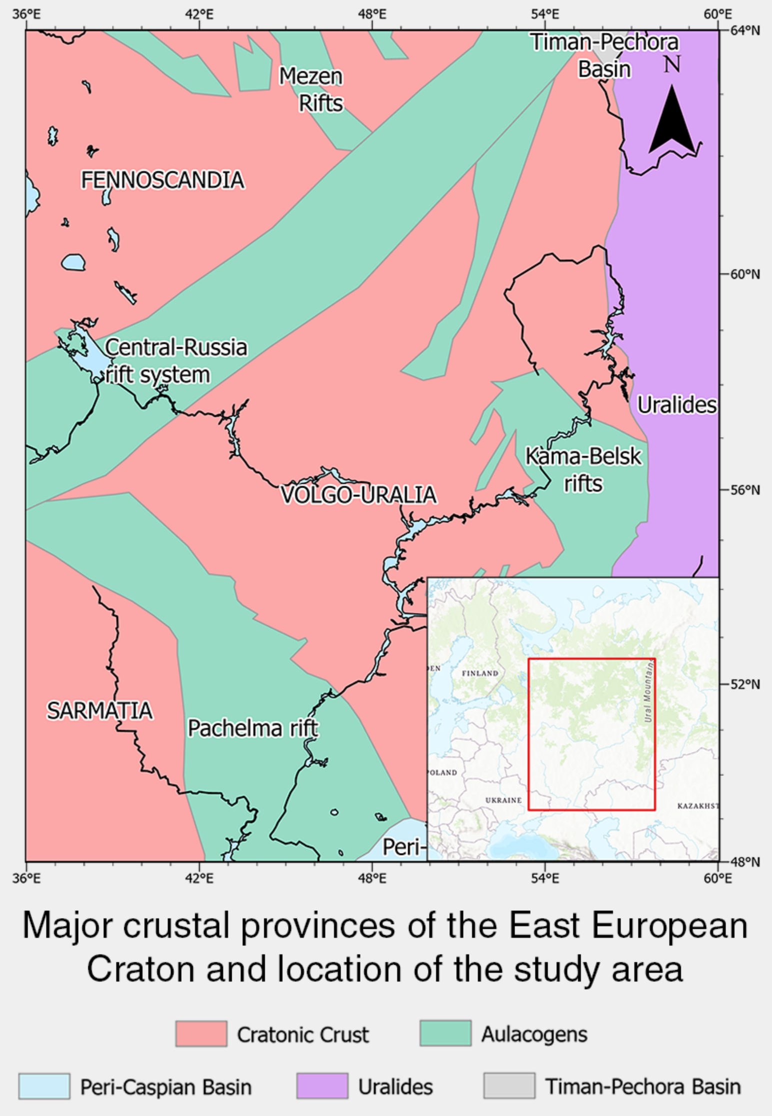
INTRODUCTION

Volgo-Uralia is a Neoarcean subcraton of the East European Craton, located on its East. It is separated from the adjacent subcratons by the large Proterozoic rift systems.

Recent regional seismic investigations performed on the territory of Volgo-Uralia made it possible to better reveal its structural features and were included in the several seismic-based regional structural models (Artemieva & Thybo, 2013; Mints, et al., 2015).

Nowadays with the advent of satellite gravimetry it became possible to conduct a more complex study of the crustal structure of Volga-Uralian subcraton which is based on both seismic and gravity constraints. Therefore, the main objectives of this study are:

- Perform a gravity field inversion for determining the Moho depth of Volga-Uralian subcraton;
- Modify and enhance the obtained crustal model by adding new crustal layers in the process of forward gravity modeling.

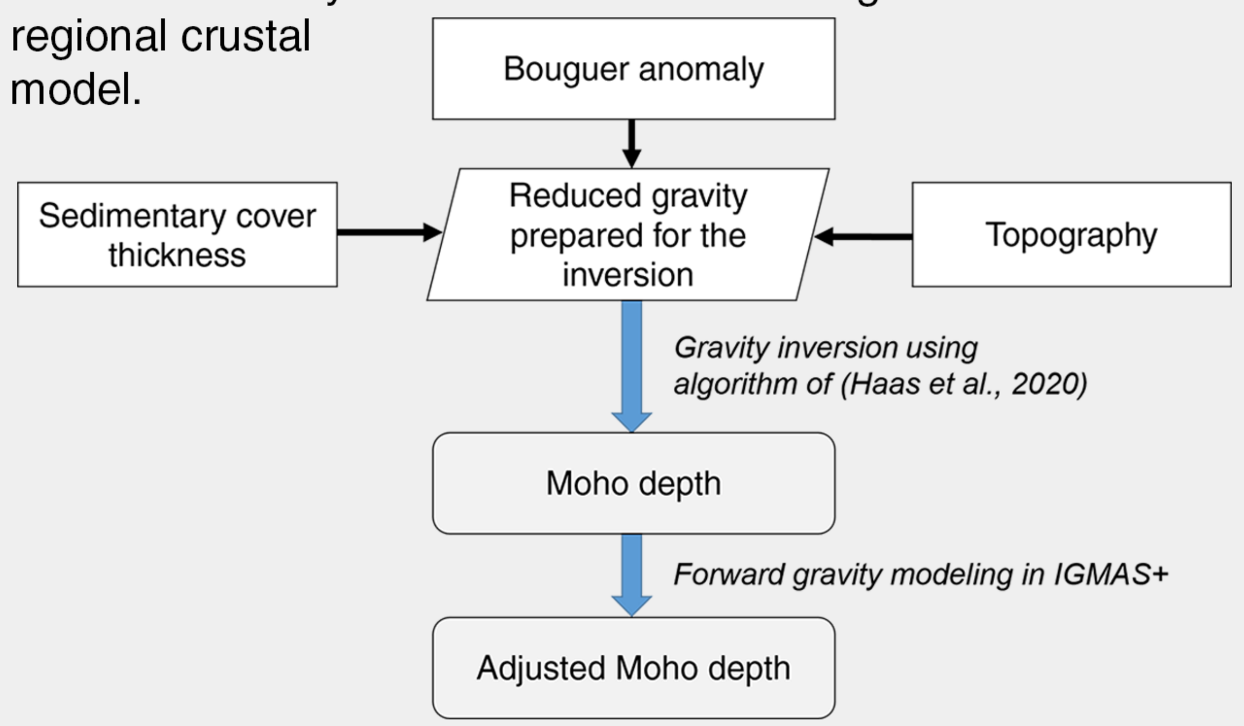


Major crustal provinces of the East European Craton and location of the study area

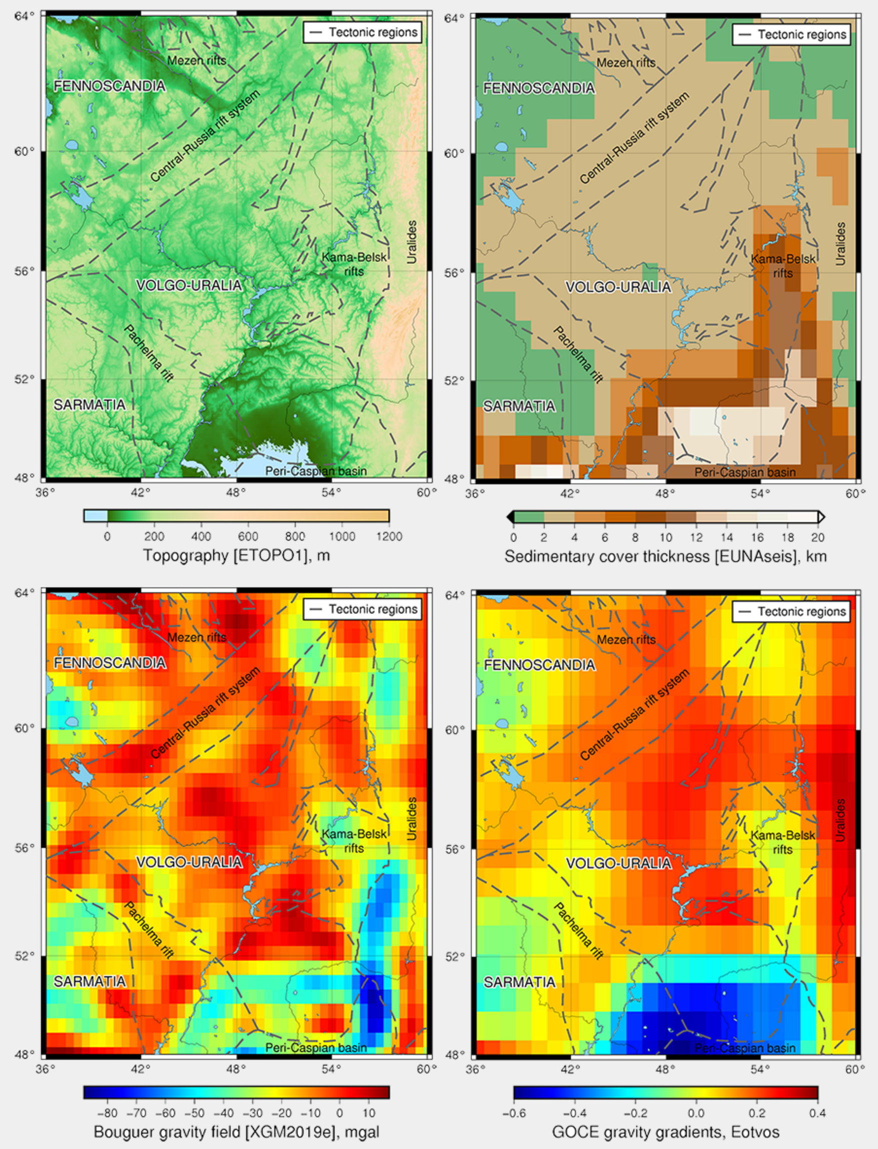
DATA AND METHODOLOGY

The following main data were used for the modeling:

1. Depth to Moho according to the USGS global seismic catalog with addition of several recent seismic profiles;
2. Gravity data in the form of satellite gravity gradients and global gravity field models;
3. Topography according to the ETOPO1;
4. Sedimentary cover thickness according to the EUNAseis regional crustal model.



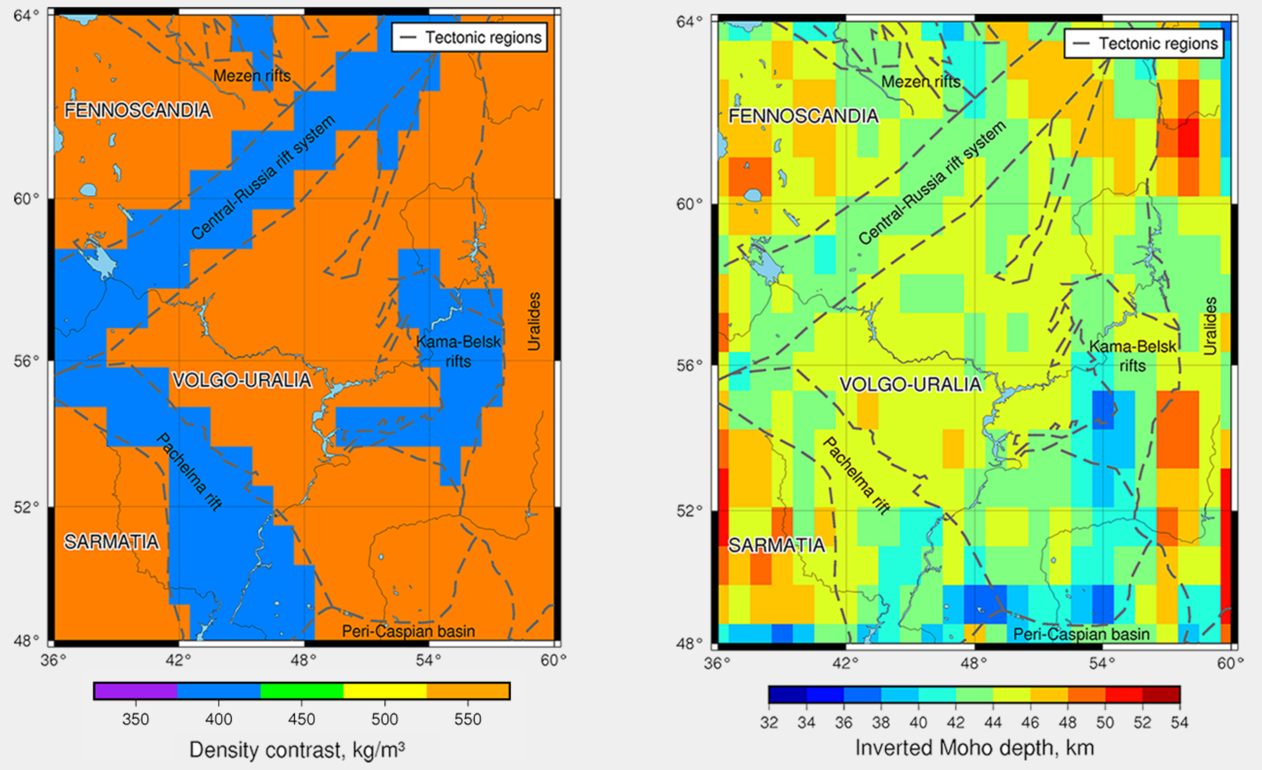
Schematic workflow of the study



GRAVITY FIELD INVERSION

We performed gravity field inversion to get a primary estimate of the Moho depth for Volga-Uralian subcraton:

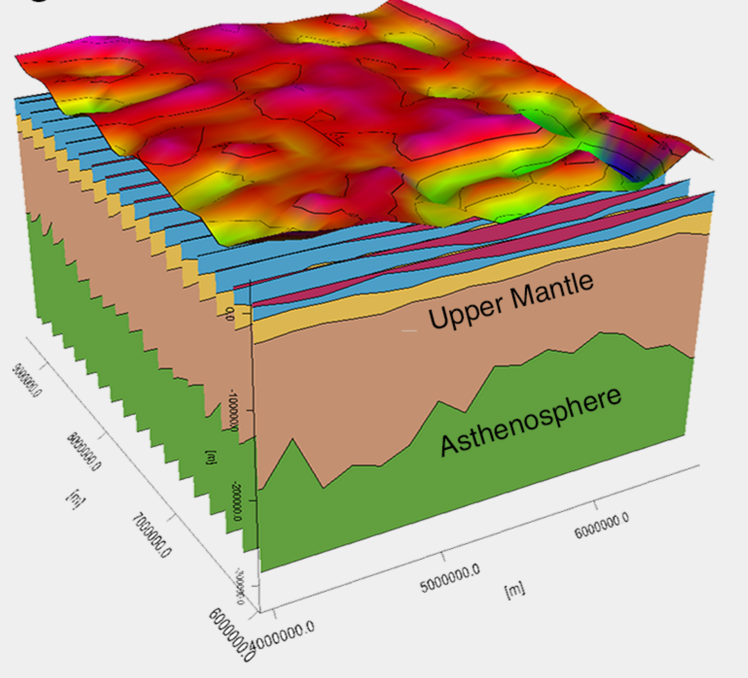
- We used approach of (Haas et al., 2020) for gravity inversion which allows using laterally variable density contrasts and takes Earth sphericity into account with tesseroids;
- Sedimentary cover gravity effect was calculated with tesseroids, GOCE gravity gradients were used for the inversion in the process of Moho depth determination;
- Density contrasts between crust and mantle were varied laterally according to the main tectonic provinces present in the region;
- The model was constrained by the available seismic data including receiver function studies, and deep reflection and refraction profiles.



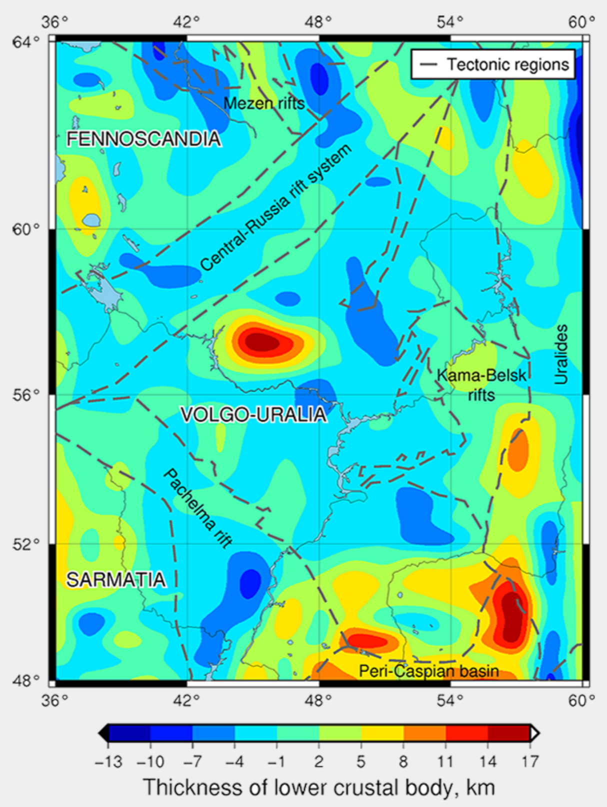
FORWARD GRAVITY MODELING

Forward gravity modeling was performed in IGMAS+ software :

- Initially the model contained five layers: (1) Sedimentary cover, (2) Upper crust, (3) Lower crust, (4) Upper Mantle, (5) Asthenosphere;
- During the adjustment of the model to seismic data, gravity misfit of ca. 100 mgal was found in the center of Volga-Uralia subcracton. We attributed this misfit to underplated body of 3100 kg/m³ density;
- We confirmed our finding by the isostatic calculations based on Pratt's model. It gave us average thickness of the underplated body of ca. 10 km.



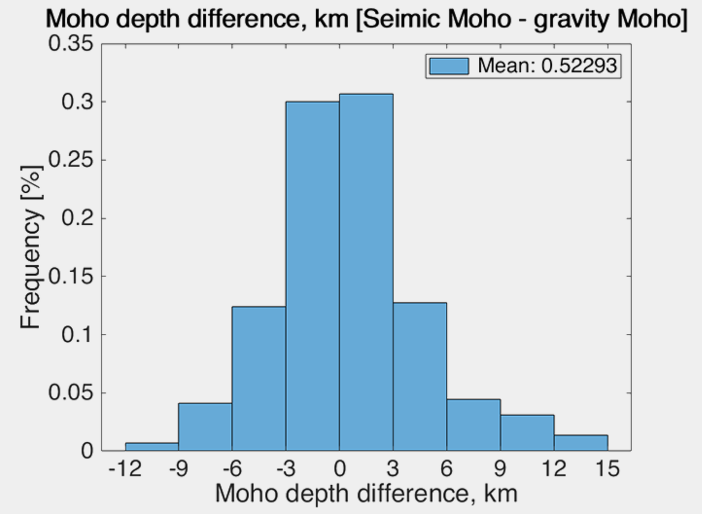
3D view of lithospheric model in IGMAS + with Bouguer gravity placed on the top

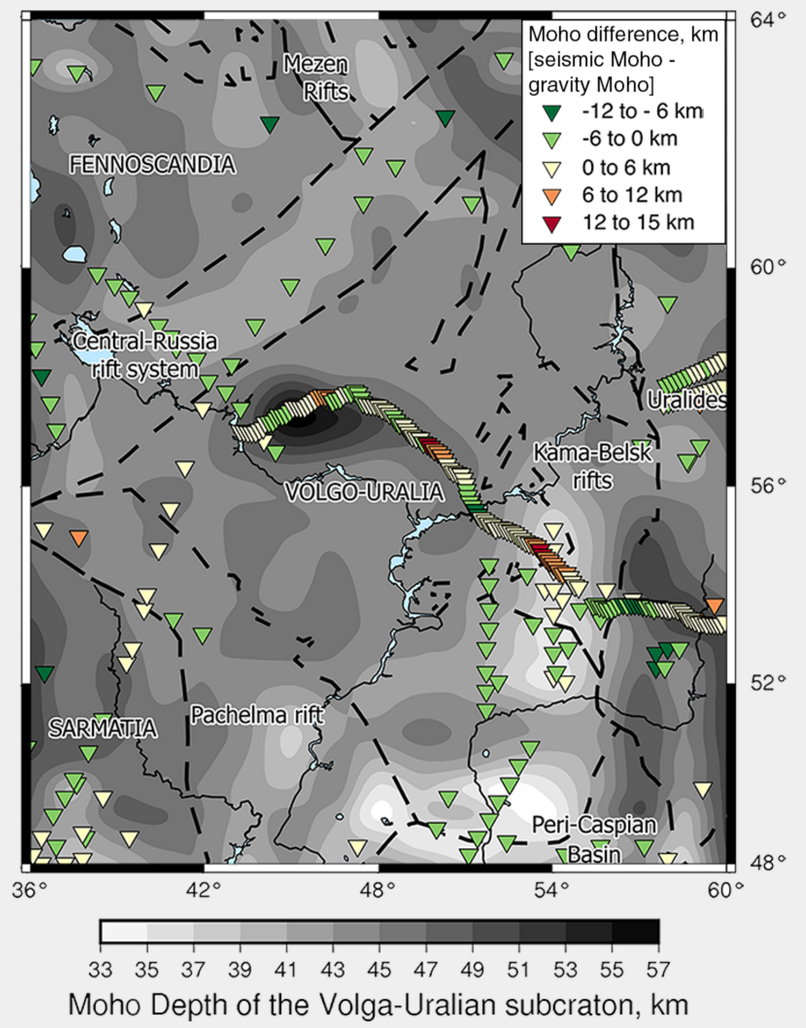


RESULTS

As a result, crustal model of the Volga-Uralian subcraton was obtained:

- The model showed crustal thickness variation from 34 to more than 55 km in some areas;
- The thinnest crust with the thickness below 40 km appeared on the Pericaspian basin which corresponds to the thickest sedimentary column;
- A relatively thin crust was found along the central Russia rift system;
- The thickest crust is located underneath Ural Mountains as well as in the center of the Volga-Uralian subcraton. In both domains it exceeds 50 km.





CONCLUSION AND FUTURE PLANS

1. We presented a new crustal model of the Volga-Uralian subcraton obtained using gravity inversion and thorough forward gravity modeling with seismic constrains. It respects all the main geological features of the Volga-Uralian subcraton and its surroundings;
2. The 3D forward gravity modeling reveals a considerable gravity misfit in the central part of the study area which supports the hypotheses of underplated body located on the top of the Moho (Artemieva & Thybo, 2013);

The obtained crustal model will serve as a basis for further basin analysis and geothermal modeling.

ACKNOWLEDGEMENT

The presented work has been supported by the German Academic Exchange Service (DAAD)

REFERENCES

1. Amante, C. & Eakins, B.W. (2009) 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS, NGDC-24, National Geophysical Data Center, NOAA. 25 pp.
2. Artemieva, I. M., & Thybo, H. (2013). EUNAseis: A seismic model for Moho and crustal structure in Europe, Greenland, and the North Atlantic region. Tectonophysics, 609, 97–153.
3. Bogdanova, S. V., Gorbatschev, R., & Garetsky, R. G. (2016). EUROPE|East European Craton. Reference Module in Earth Systems and Environmental Sciences.
4. Götze, H. J., & Lahmeyer, B. (1988). Application of three-dimensional interactive modeling in gravity and magnetics. Geophysics, 53(8), 1096-1108.
5. Haas, P., Ebbing, J., Szwillus, W. (2020). Sensitivity analysis of gravity gradient inversion of the Moho depth — a case example for the Amazonian Craton. Geophysical Journal International 221(3):1896-1912
6. Mints M.V., Dokukina K.A., Konilov A.N., … Zamozhnyniaya N.G. (2015) East European Craton Early Precambrian History and 3D Models of Deep Crustal Structure. The Geological Society of America (GSA) Boulder, Colorado, USA. 433 p.
7. Mooney, W. D. (2015). Crust and Lithospheric Structure - Global Crustal Structure. Treatise on Geophysics, 339–390.
8. Schmidt, S., Anikiev, D., Götze, H. J., Gomez Garcia, À., Gomez Dacal, M. L., Meeßen, C., Plonka, C., Rodriguez Piceda, C., Spooner, C., & Scheck-Wenderoth, M. (2020, May). IGMAS+-a tool for interdisciplinary 3D potential field modelling of complex geological structures. In EGU General Assembly Conference Abstracts (p. 8383).
9. Thybo, H., & Artemieva, I. M. (2013). Moho and magmatic underplating in continental lithosphere. Tectonophysics, 609, 605–619.
10. Zingerle, P., Pail, R., Gruber, T., Oikonomidou, X. (2019) The experimental gravity field model XGM2019e. GFZ Data Services.