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Revealing stress and density variations in the upper mantle of the Alpine region by joint gravity-tomography inversion and geodynamic modeling.

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The Alps is a part of the Alpine-Himalayan orogenic belt formed as a result of the collision of the African and Eurasian plates during the Cenozoic Era. This collision formed a compound tectonic structure characterized by complex geology. To better understand geology and tectonics of the Alps, additional knowledge on density distribution, stress state and rheology of the crust and upper mantle are essential.

The mantle convection is actively involved in the plate tectonics and interacts with the lithosphere at its base, greatly affecting the stress distribution and deformation in the lithosphere. On the other hand, the basal traction forces caused by the mantle flow do not only affect the stress field in the lithosphere, they also induce geoid, dynamic topography and gravity anomalies.

To understand how the mantle flow affects the deformation of the lithosphere in the Alpine region, a numerical geodynamic model on a continental or even global scale in 3D is required. However, the model setup needs in additional data such as distribution of the density, viscosity and temperature within the modeling domain.

In our study we have developed a global mantle convection model based on the refined density model and viscosity distribution derived from tectonic, rheological and seismic data. The global density model of the upper mantle is refined for Europe based on the new high-resolution 3D model. This model, based on joint inversion of the residual gravity and topography, provides much better resolution of the 3D density structure compared to the global model based solely on seismic tomography. The refined density model and the viscosity distribution calculated using a homologous temperature approach provide an initial setup for further numerical calculations. The present-day snapshot of the mantle convection is computed using the numerical code ProSpher 3D, which takes into account strong lateral variations of viscosity (Petrunin et al., 2013). The setup includes weak plate boundaries, while the measured GPS velocities are used to constrain the solution.

As a result of the modeling we present maps of density, viscosity and stress distribution. These results allowed us to more accurately locate subducted slabs in the upper mantle in the Alpine region and its surroundings. We also demonstrate a map of maximum principal stress orientation as a proxy for polarization of seismic waves and stress state (compressional or extensional environment) of the lithosphere that can be used for further geodynamic modeling.

Petrunin, A. G.; Kaban, M. K.; Rogozhina, I., and Trubitsyn, V. (2013). Revising the spectral method as applied to modeling mantle dynamics. Geochemistry Geophysics Geosystems (G3), EDOC: 21048.