Deformation patterns in relation to the deep configuration of the lithosphere of the Alps and their forelands – DEFORM

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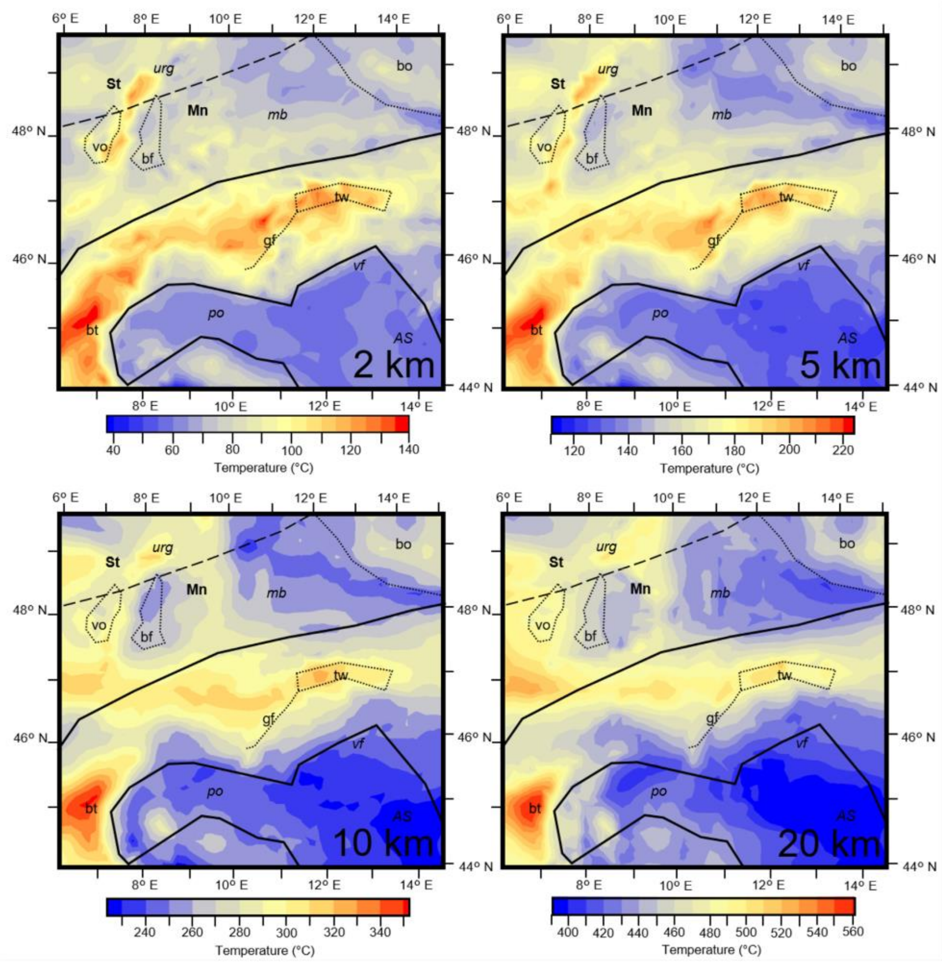
The present-day physical state of the Alps and their forelands is still a matter of debate due to observed variations of surface deformation and seismicity. Due to our limited knowledge of the internal structure of the lithosphere in relation to the present-day stress field, this leads to contradictory interpretations on which first order mechanisms are dominantly controlling present-day processes. In particular, the question of how the shallow domains of the crust are coupled or decoupled from deeper crustal levels and the mantle, is open. Results obtained in phase I of the SPP confirm that the internal structure of the lithosphere is characterized by a strong lateral and vertical variation in lithology from the orogen to the forelands indicated by the distribution of densities and seismic velocities. This variation in physical properties also results in a highly variable thermal field and a heterogeneous rheological zonation. The main objective of DEFORM is to test the hypothesis that different processes controlling recent deformation can be isolated and their relative contributions quantified if first-order characteristics of lithosphere configuration are considered together with physical processes.

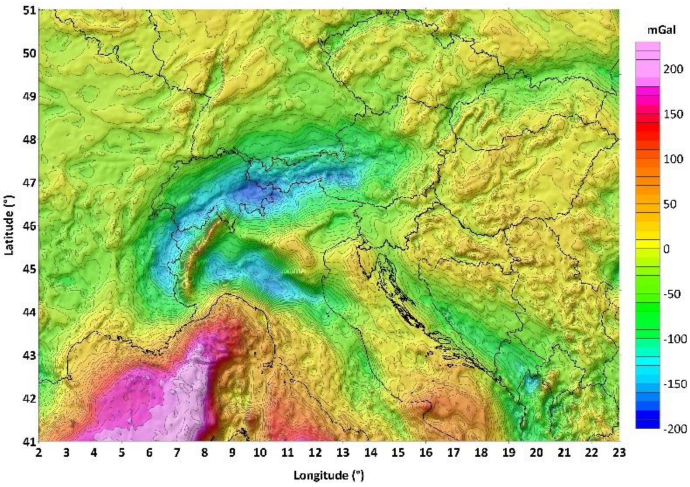


Temperature maps at different depths below sea level (Spooner et al., 2020). Abbreviations: urg – Upper Rhine Graben; mb – Molasse Basin; po – Po Basin; vf – Veneto Friuli plane, st – Saxothuringian Variscan domain; mn – Moldanubian Variscan domain; bo – Bohemian Massif; vo – Vosges Massif; bf – Black Forest Massif; tw – Tauern Window; gf – Giudicarie Fault; bt – Brianconnais Terrane

To test this hypothesis we aim to quantitatively assess how the data-derived internal lithospheric configuration deforms in response to plate boundary forces on the one hand and vertical loading or unloading over a glacial cycle on the other. In our project INTEGRATE running in phase I of the SPP we find a strong positive correlation between crustal density contrasts and present day deformation vectors from geodetic measurements as well as the distribution of large seismic events. To evaluate if there is a systematic and across scales relationship between the distribution of observed deformation and the rheological configuration of the lithosphere, we will use an updated rheological model as a base for simulations of coupled thermo-mechanical processes. Therefore, we propose to link thermomechanical models of large-scale deformation on geological timescales with regional thermomechanical approaches that can resolve the human time scale and account in a consistent way for the multi-physics coupling among the different deformation mechanisms controlling the bulk behavior of the lithosphere. In the simulations, the static rheological and thermal models are considered as initial conditions, the present-day deformation field at the surface as upper boundary condition and the deformation field of the uppermost asthenosphere derived from large-scale dynamic models will be extracted as lower boundary condition.

The project contributes to Theme 2 (Surface and crustal responses to changes in mountain structure on different time scales) of the SPP MB-4D. It links to many other partners in the SPP to ensure the integration of new results in the rheological model and to validate the simulation predictions.

The AlpArray Gravity Research Group focuses on compiling a homogeneous gravity dataset across the Alpine area, on creating related gravity products and using them for various studies from small to regional to continental scales, as well as for joint inversion with other datasets. The gravity working group is managed by Hans-Jürgen Götze and György Hetényi.



The new AlpArray Gravity map of the Alp and adjacent areas (Zahorec et al. under review in Copernicus´ "Earth System Science Data, ESSD, open discussion)

Publications

Spooner, C., Scheck-Wenderoth, M., Götze, H.-J., Ebbing, J., Hetényi, G. (2019): Density distribution across the Alpine lithosphere constrained by 3-D gravity modelling and relation to seismicity and deformation. - Solid Earth, 10, 2073-2088. https://doi.org/10.5194/se-10-2073-2019.

Spooner, C., Scheck-Wenderoth, M., Cacace, M., Götze, H.-J., Luijendijk, E. (2020): The 3D thermal field across the Alpine orogen and its forelands and the relation to seismicity. - Global and Planetary Change, 193, 103288. https://doi.org/10.1016/j.gloplacha.2020.103288

Spooner, C., Scheck-Wenderoth, M., Cacace, M., Anikiev, D. (2020): 3D-ALPS-TR: A 3D thermal and rheological model of the Alpine lithosphere. https://doi.org/10.5880/GFZ.4.5.2020.007

Pavol Zahorec, Juraj Papčo, Roman Pašteka, Miroslav Bielik, Sylvain Bonvalot, Carla Braitenberg, Jörg Ebbing, Gerald Gabriel, Andrej Gosar, Adam Grand, Hans-Jürgen Götze, György Hetényi, Nils Holzrichter, Edi Kissling, Urs Marti, Bruno Meurers, Jan Mrlina, Ema Nogová, Alberto Pastorutti, Matteo Scarponi, Josef Sebera, Lucia Seoane, Peter Skiba, Eszter Szűcs, and Matej Varga (2021):

The first pan-Alpine surface-gravity database, a modern compilation that crosses frontiers. essd-2020-375, under review at: https://essd.copernicus.org/preprints/essd-2020-375/#discussion.