QDIS: Quantifying Detachment Induced Surface Uplift in the Alps

PIs: Marcel Thielmann (Universität Bayreuth)

The continuously changing surface of the Earth is shaped by tectonic and climatic processes. **Distinguishing the relative importance of these processes is elusive, as their coupled nature makes it difficult to quantify their individual contribution to surface deformation. Being one of the best studied orogens worldwide, the European Alps provide the ideal setting to study these processes.** However, despite the wealth of observational data on surface uplift, the stratigraphic record, exhumation rates and the deep structure, the processes that shaped the Alpine orogen as we know it today are still incompletely understood, as the link between deep tectonic processes, deglaciation and erosion to surface deformation has not been sufficiently quantified. Three main reasons for this missing quantification are (1) the still not fully resolved present-day deep structure of the European Alps and (2) the uncertainties in the rheology of crust and lithospheric mantle and (3) a lack of geodynamic numerical 3D models.

QDIS aims to **quantify the spatiotemporally varying surface and crustal response to tectonic processes** in the European Alps, in particular of lithosphere removal processes (slab detachment, lithosphere delamination). Using **high resolution 3D numerical models**, QDIS will link observed surface deformation patterns to lithosphere and mantle deformation in the last 40 Ma. By comparing numerically predicted surface deformation patterns with results from the first phase of SPP 4D-MB as well as new data from collaborators, it will be possible to constrain the physics and consequences of deep-seated processes (slab detachment, subduction reversal etc.). This will help to 1) **distinguish between the different uplift mechanisms** (horizontal compression, slab rollback/detachment, erosion, deglaciation) shaping the European Alps and 2) answer the question **which of the different mechanisms dominated deformation of the European Alps in the last 40 Ma and today**. The results of this project will be used to determine the stress changes in crust and lithosphere due to the different deep-seated processes and to **explain observed changes in fault system activity and seismicity.**

To achieve these goals, QDIS will employ numerical models to (1) assess the impact of different ductile weakening mechanisms on slab detachment, (2) systematically investigate the role of slab rheology on slab detachment and (3) determine the impact of slab geometry on slab detachment and slab tearing. In a second step, QDIS will determine the characteristic spatiotemporal surface deformation patterns that are indicative of slab detachment and tearing rates as well as of their respective depth. In addition, the contribution of climatic processes on surface deformation will be assessed and their impact on the respective surface deformation patterns quantified. This will result in a "deformation pattern database" that will be used to determine the relative importance of climatic and tectonic processes in shaping the Alpine orogen.

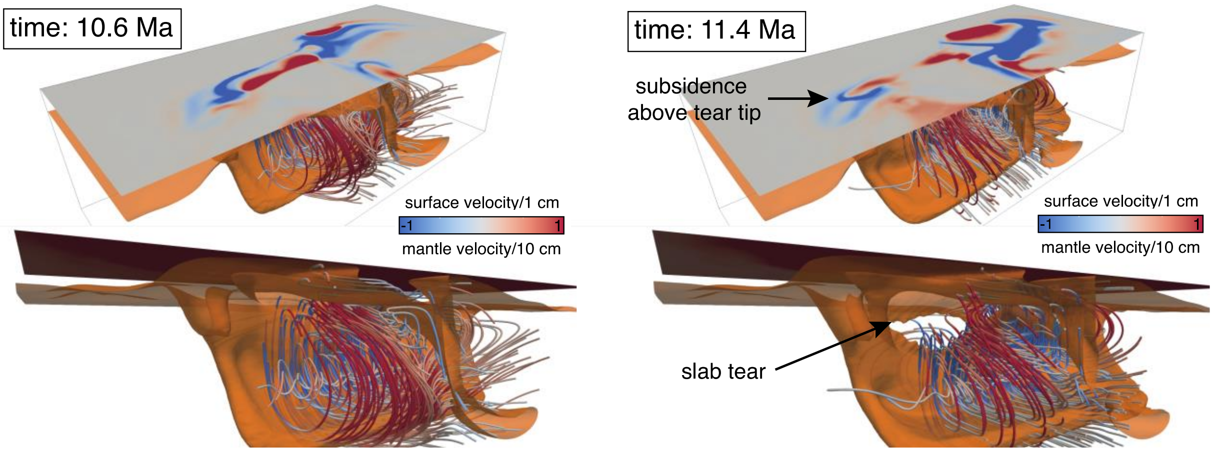

Figure 1*: 3D slab detachment modelled with LaMEM.* ***Left:*** *Slab structure and vertical mantle and surface velocities at 10.6 Ma model time. Vertical surface velocities are shown in the top plane. Mantle velocities are indicated with streamlines, their colour denoting their vertical velocity. The 1000 K isosurface is drawn in orange, thus denoting the slab. Right: Same as in left picture, but at a time of 11.4 Ma. At this time, slab detachment has already started in the middle of the slab and is propagating outwards. This can be observed in the surface uplift pattern, with subsidence occurring above the slab tip, followed by surface uplift.*