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The Eurasian stress field: important role of topography and mantle flow

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The large-scale lithospheric stress field results from lithospheric body forces (including topography), from interaction with adjacent plates, and from tractions at the base of the tectonic plates. Here we constrain these three categories of forces for the Eurasian plate and evaluate our results using the stress field.

We recently established (Warners-Ruckstuhl et al., 2010) that tractions from an actively convecting mantle are required to mechanically balance the Eurasian plate. We use SEATREE (Milner et al., 2009) to a priori compute mantle flow tractions for a wide range of forcings and radial viscosity profiles. Radial tractions influence Lithospheric body forces. On geological time scales and large horizontal length scales, pressure differences due to topography and the density structure of the lithosphere are expected to be counteracted by radial stresses due to mantle flow. We compute lithospheric body forces for two end member models fulfilling this requirement: Model 'mantle' includes normal pressures from mantle flow models and computes corresponding crustal thicknesses, model 'crust2.0' includes observed crustal thicknesses and computes corresponding normal pressures at the base of the lithosphere. Directions of edge forces are assumed parallel to relative motion directions. Edge force magnitudes follow from solving the torque balance equations. Stresses are calculated in a spherical elastic shell containing major faults.

The net shear of the different mantle flow models varies considerably. Only those that are forced by mantle densities from published S-wave tomographic models mechanically balance Eurasia for a certain ratio range of magnitude of convective shear versus shear due to plate motion. The intra-plate stresses corresponding with these balanced models turn out to be mostly sensitive to uncertainties in lithospheric body forces. Dynamic topography contributes to the stress field of Eurasia. Stresses in Europe fit the observations best if we assume compensation of topography according to model 'mantle', whereas observed stress orientations in the Tibetan plateau are significantly better explained by model 'crust2.0'.