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A consistent geodynamic model for predicting the velocity and plate-internal deformation of Eurasia

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The motion and deformation of tectonic plates is driven by gravity and resisted by frictional forces. In principle it should thus be possible to build mechanical models that reproduce plate velocities and surface deformation. Here we present a new approach that overcomes many of the previous obstacles to achieving this goal. Our approach to quantify the forces is based on mechanical equilibrium of the whole Eurasian plate, meaning that an increase in, for instance collision, forces must be matched by other plate tectonic forces. We first focus on present-day Eurasia. We include basal tractions from a global convection model, lithospheric body forces, and edge forces resulting from the interaction of the Eurasian plate with neighboring plates. The resulting force distribution is constrained by observed plate motion and by stress observations.
Eurasia's stress field turns out to be most sensitive to the distribution of collision forces on the plate's southern margin and, to a lesser extent, to lithospheric density structure and normal pressure from mantle flow. Stress observations require collision forces on the India-Eurasia boundary of 7.0 - 10.5 TN/m.

A similar analysis is performed for Eurasia at 20 Ma and 40 Ma. Plate geometry is taken from the global Lausanne (Stampfli) reconstruction, as are plate velocities and oceanic ages. Lithospheric body forces are accounted for in a simplified way because we lack detailed enough information on the plate scale topography. For the Miocene, we find ∼1.2 TN/m for the collision force on the India-Eurasia boundary. In the Eocene, the collision force we find is ∼0.4 TN/m.

We conclude that the magnitude of the collision force on Tibet increased significantly after 20 Ma: from 40-20 Ma, the plate contact force on the India/Tibet plate boundary segment was of the same order of magnitude as resistive forces on subduction plate boundaries elsewhere. Our timing of the collision force on Eurasia, is substantially younger than the often quoted collision age of ∼50Ma.

Forces (and the corresponding stresses) drive permanent deformation on both geological time scales and short time scales, e.g., earthquakes. Low stress magnitudes may result in strain if the material is weak, high stresses may give no strain in strong materials. Our next step therefore is to use geological information on the strength of the lithosphere.

We show new results of our work on using estimates of the mechanical properties of the lithosphere to predict surface deformation.