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The effect of rheological approximations on the dynamics and topography in 3D subduction-collision models

Adina E. Pusok, Boris J. P. Kaus, and Anton A. Popov
Institute of Geosciences, Johannes Gutenberg University, Mainz, Germany (puesoek@uni-mainz.de)

Most of the major mountain belts and orogenic plateaus are found within the overlying plate of active or fossil subduction and/or collision zones. Moreover, they evolve differently from one another as the result of specific combinations of surface and mantle processes. These differences arise for several reasons, such as different rheological properties, different amounts of regional isostatic compensation, and different mechanisms by which forces are applied to the convergent plates.

Previous 3D geodynamic models of subduction/collision processes have used various rheological approximations, making numerical results difficult to compare, since there is no clear image on the extent of these approximations on the dynamics.

Here, we employ the code LaMEM to perform high-resolution long-term 3D simulations of subduction/continental collision in an integrated lithospheric and upper-mantle scale model. We test the effect of rheological approximations on mantle and lithosphere dynamics in a geometrically simplified model setup that resembles a tectonic map of the India-Asia collision zone. We use the “sticky-air” approach to allow for the development of topography and the dynamics of subduction and collision is entirely driven by slab-pull (i.e. “free subduction”).

The models exhibit a wide range of behaviours depending on the rheological law employed: from linear to temperature-dependent visco-elasto-plastic rheology that takes into account both diffusion and dislocation creep. For example, we find that slab dynamics varies drastically between end member models: in viscous approximations, slab detachment is slow following a viscous thinning, while for a non-linear visco-elasto-plastic rheology, slab detachment is relatively fast, inducing strong mantle flow in the slab window. We also examine the stress states in the subducting and overriding plates and topography evolution in the upper plate, and we discuss the implications on lithosphere dynamics at convergent margins.

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