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Slab-mantle interactions in simulations of self-consistent mantle convection with single-sided subduction

F. Crameri (1), P.J. Tackley (1), I. Meilick (1), T.V. Gerya (1), B.J.P. Kaus (1,2)

(1) ETH Zürich, Institute of Geophysics, Earthscience, Switzerland (fabio.crameri@erdw.ethz.ch), (2) Johannes Gutenberg University Mainz, Institute of Geosciences, Germany

Subduction zones on present-day Earth are strongly asymmetric features (Zhao 2004) composed of an overriding plate above a subducting plate that sinks into the mantle. Our recent advances in numerical modelling allow global mantle convection models to produce single-sided subduction self-consistently by allowing for free surface topography on and lubrication between the converging plates (Crameri et al., 2012). Thereby, they are indicating important mantle-slab interactions.

The increase of viscosity with depth is an important mantle property affecting the dynamics of subduction: a large viscosity increase on the one hand favours an immediate stagnant lid because the slab cannot sink fast enough, while a small increase on the other hand does not provide enough resistance for the sinking slab and therefore facilitates an immediate slab break-off.

While in the mobile lid (plate tectonic like) regime, our model also shows that single-sided subduction in turn has strong implications on Earth‘s interior such as its rms. velocity or its stress distribution. The arcuate trench curvature is such a feature that is caused by single-sided subduction in 3-D geometry. The pressure difference between the mantle region below the inclined sinking slab and the region above it causes a toroidal mantle flow around the slab edges. This flow of mantle material is responsible for forming the slabs and subsequently also the subduction trenches above it towards an arcuate shape.

For this study we perform experiments in 2-D and global spherical 3-D, fully dynamic mantle convection models with self-consistent plate tectonics. These are calculated using the finite volume multi-grid code StagYY (Tackley 2008) with strongly temperature and pressure-dependent viscosity, ductile and/or brittle plastic yielding, and non-diffusive tracers tracking compositional variations (the ’air’ and the weak crustal layer in this case).

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