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Subduction Initiation from a Stagnant Lid: New Insights from Numerical Models with a Free Surface

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Subduction initiation is key in understanding the dynamic evolution of the Earth and its fundamental difference to all other rocky planetary bodies in our solar system. Despite recent progress, the question about how a stiff, mostly stagnant planetary lid can break and become part in the global overturn of the mantle is still unresolved.

Here, we present results on subduction initiation obtained by dynamically self-consistent, time-dependent numerical modelling of mantle convection and single-sided subduction (Crameri et al., 2012b) using the finite-difference, multigrid code StagYY (Tackley 2008).

We show that the stress distribution and resulting deformation of the lithosphere is strongly controlled by the top boundary formulation: A free surface enables surface topography and plate bending, increases gravitational sliding of the plates and leads to more realistic, lithosphere-scale shear zones. As a consequence, subduction initiation induced by regional mantle flow is significantly favoured by a free surface compared to the commonly-applied, vertically-fixed (i.e. free-slip) surface.

In addition, we present global, three-dimensional mantle convection experiments (see e.g. Crameri and Tackley, 2014) that employ basal heating that leads to narrow mantle plumes. Narrow mantle plumes impinging on the base of the plate cause locally weak plate segments and a large topography at the lithosphere-asthenosphere boundary. Both are shown to be key to induce subduction initiation.

Finally, our model self-consistently reproduces an episodic lid with a fast global overturn due to the hotter mantle developed below a former stagnant lid. We conclude that once in a stagnant-lid mode, a planet (like Venus) thus preferentially evolves by temporally discrete, global overturn events rather than by a continuous recycling of lid.

REFERENCES

Crameri, F, Tackley, P.J, Meilick, I, Gerya, T.V, Kaus, B.J.P (2012) A free plate surface and weak oceanic crust produce single-sided subduction on Earth. Geophys. Res. Lett. 39(3), 03306.

Crameri, F, Tackley, P.J (2014) Spontaneous development of arcuate single-sided subduction in global 3-D mantle convection models with a free surface. J. Geophys. Res. Solid Earth 119(7), 5921–5942.

Tackley, P.J (2008) Modelling compressible mantle convection with large viscosity contrasts in a three-dimensional spherical shell using the yin-yang grid. Physics of the Earth and Planetary Interiors 171(1–4), 7–18.