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Transitions in Tectonic Mode based on Calculations of self-consistent Plate Tectonics in a 3D spherical Shell

H.J. van Heck and P.J. Tackley
Institute of Geophysics, ETH Zurich, Switzerland (hvanheck@erdw.ethz.ch)

In the past decade, several studies have documented the effectiveness of plastic yielding in causing a basic approximation of plate tectonic behavior in mantle convection models with strongly temperature dependent viscosity, strong enough to form a rigid lid in the absence of yielding. The vast majority of such research to date has been in either two-dimensional, or three-dimensional cartesian geometry. Also, scalings for mixed internally and bottom heated convection are not well established.

In the present study, mantle convection calculations are done to investigate the planforms of self consistent tectonic plates in three-dimensional spherical geometry. Several diagnostics are used to analyze how successful each model is in producing tectonic plates. We study the proposed transitions in tectonic mode (e.g. changes in plate size, rigid lid convection to tectonic plates, smoothly evolving plates to more episodic, time dependent, tectonics) as a function of yield stress envelope and heating mode. Cases with zero bottom heat flux are compared to cases which have both internal heating and bottom heating.

This enables us to investigate which tectonic mode prevails as function of lithospheric yield stress, Ra and heating mode. The results are compared to analytical scalings for boundary regimes as well as scalings for heat flux. This allows us to scale to different planets of different sizes and can be applied to the evolution of Earth, Mars and Venus as well as terrestrial extra-solar planets.