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Combining floating continents and a free surface in a 3D spherical mantle convection model with self-consistent plate tectonics

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The dynamics of the Earth's lithosphere and mantle are strongly influenced by its upper mechanical boundary condition. For instance, our previous work has shown that a necessity for the evolution of Earth-like, single-sided subduction is a free surface, which allows for vertical movement of the two converging plates, i.e. the development of surface topography [Crameri et al (2012), in press]. Single-sided subduction has an important effect on the evolution of self-consistent plate tectonics, e.g. by shaping subduction trenches.
However, due to the usage of a homogeneous, i.e. purely oceanic, lithosphere these models tend to favour the rigid lid mode of plate tectonics for a realistic strength of the lithosphere, which is in contradiction to the present-day Earth. In contrast, our previous work with a pre-existing heterogeneous structure of the lithosphere has shown that the presence of continents floating at the top of the mantle may play an important role in the evolution of plate tectonics. Convective stresses may be focussed at the rheological boundary between continent and ocean, which facilitates the formation of plate boundaries and makes the Earth-like, mobile lid mode of plate tectonics easier to observe [Rolf & Tackley (2011)]. However, in these models subduction is single-sided when one oceanic and one continental plate converge, but double-sided in the case of two converging oceanic plates.
Taking the previous findings as a motivation, we now combine both ingredients: the free surface and the heterogeneous lithosphere, in one self-consistent model. We approximate the free surface by using a „sticky air" layer [Schmeling et al, 2008; Crameri et al., submitted] and the continents by strong Archaean cratons, which can resist recycling on long timescales [Rolf & Tackley (2011)].
Such a model might produce single-sided subduction that is continuously evolving supported by the presence of continents. Performing global-scale self-consistent mantle convection and using constraints from geological observations and laboratory experiments will further allow for constraining the conditions - in particular the rheological and properties of oceanic and continental lithosphere - that allow for Earth-like evolution of plate tectonics.

References:

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