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The benefits of extended plate motion history in mantle circulation models

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Mantle Circulation Models (MCMs) are mantle convection simulations conditioned with plate motion history. Due to difficulties in reconstructing plate motions beyond $\approx$ 120 Ma, MCMs often only incorporate the most recent 120 Myr of plate tectonic evolution. We find that such models are strongly influenced by initial conditions. The development of a new series of tectonic reconstructions extending back to the Triassic (230 Ma) and including careful reconstruction of the oceanic parts of the plates (modified from Stampfli and Borel, 2004, Stampfli et al. 2008 and references therein) should prove to be of huge importance to MCMs. In this study we present a comparison between the traditionally used 120 Myr and the latest 230 Myr plate motion histories.

We use the three-dimensional spherical mantle convection code TERRA (Bunge et al., 2003) to simulate convection at Earth like vigour. Here we apply the plate motion history as a surface velocity boundary condition to drive the internal convection of an already well-mixed system. The forward models from a chosen starting point to present day yield information on mantle temperature (as well as pressure, velocity and material properties) throughout the volume.

One of the ways to validate our results is to compare these with tomographic models. Seismic tomography provides us with a snapshot of Earth's mantle at present day. Assuming that the mantle is driven largely by thermal convection, we can assume that the seismically fast regions are associated with cooler, denser material. The most significant of these can be interpreted as remnants of subducted slabs (Hafkenscheid et al 2006, van der Meer et al. 2010). We convert the temperatures predicted by the MCM to seismic velocities using the latest techniques (e.g. Cobden et al., 2008) and compare the calculated velocities to a range of seismic tomography models (both P and S wave). This way we can examine the validity of the surface velocity boundary condition and identify areas of weakness in both the MCM and the plate motion history. Two key regions of interest are the fast anomalies beneath North America and South Asia, which represent the subducted Farallon and Tethys plates respectively.

In addition, we can take surface predictions of the model such as heat flow and dynamic topography to compare these to those observed at present day Earth's surface. Accurate predictions of these observable properties provide a further test of model validity.

References

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