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# Numerical simulations of coupled core-mantle evolution of Earth and other terrestrial planets

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Mantle convection controls the heat flux out of the core and lateral variations in that heat flux. Therefore, in order to understand the thermal evolution of the core over planetary history, including whether enough heat is extracted to facilitate a dynamo at different times and possible growth of the inner core, it is necessary to understand the thermal and compositional evolution of the mantle. Because parameterized models do not capture the full complexity of mantle dynamics, we present numerical simulations of mantle convection that include strongly temperature-dependent viscosity, a plastic yield-stress that facilitates the formation of different tectonic regimes (plate tectonics, episodic plate tectonics, rigid lid), chemical differentiation through melting-induced crustal formation, and composition-dependent phase transitions. The core is represented by a parameterized heat balance based on Buffett et al. (JGR 1996) and Lister (PEPI 2003). Applications to Earth and Mercury are here highlighted.

On Earth, the challenge is to understand how CMB heat flux can have remained high enough to generate a dynamo over at least the last 3.5 billion years without growing the inner core too large. The main findings from our published results (Nakagawa and Tackley Gcubed 2005; EPSL 2004) are that isochemical models display too-large CMB heat flux, resulting in a too-large inner core, while models with a global, compositionally-distinct dense layer above the CMB have a CMB heat flux that is too low for a geodynamo. Models with 'piles' of dense material above the CMB separated by exposed patches are the only ones to produce viable core thermal evolutions, although the addition of radiogenic potassium to the core relaxes these requirements. Lateral variations in CMB heat flux are substantial, with a peak-to-peak variation larger than the mean value, which according to published geodynamo simulations is expected to exert a strong influence on the dynamo process.

On Mercury, the proximity to the Sun, lack of an atmosphere and spin-orbit resonance leads to a lateral variation of $\sim$250 K in time-averaged surface temperature. Numerical simulations are being performed to test whether this can exert a significant influence on the mantle, and whether this in turn can lead to long-lived lateral thermal heterogeneity at the CMB that could drive weak dynamo action on Mercury with no internally-driven core convective motions.

Additional applications to Mars and Venus are being studied and will be reported if time permits.