

Lower mantle dynamics and the role of pressure-dependent thermodynamic and transport properties

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We have carried out numerical simulations of large aspect-ratio 2-D mantle convection that feature pressure-dependent thermal expansivity and conductivity along with the major mantle phase transitions, including the deep phase change from perovskite (pv) to post-perovskite (ppv). The rheological law is Newtonian and has both temperature- and pressure-dependences, while the extended Boussinesq approximation is assumed for the energetics. We have analyzed the combined effects of a strongly decreasing thermal expansivity, according to the diffraction experiments on pv by Katsura et al. (2009), and steeply increasing lattice thermal conductivity based on different models obtained from experiments (Ohta, 2010) and first principles (de Koker, 2010; Tang and Dong, 2010). Since ppv is expected to have a relatively weak rheology with respect to pv (Hunt et al., 2009; Ammann et al., 2010) and a large thermal conductivity (Ohta, 2010), we have also assumed that the transition from pv to ppv is accompanied by both a reduction in viscosity by 1 order of magnitude and by a 50% increase in conductivity.

As long as the thermal expansivity and conductivity are constant, ppv exerts small but noticeable effects: it destabilizes the D" layer, causes focusing of the heat flux peaks and a slight increase of the average mantle temperature and of the temporal and spatial frequency of upwellings. The destabilizing character of ppv is strong enough to affect the stability of mantle plumes even in the presence of a large decrease of the thermal expansivity which otherwise, without ppv, delivers remarkably stable large upwellings. However we have found that if a sufficiently large thermal conductivity near the core-mantle is also accounted for, lower mantle plumes are stabilized for a geologically long time-span in excess of billion of years, even in the presence of the disturbances induced by the pv-ppv transition. Preliminary results confirm the validity of these findings even for thermo-chemical piles in the framework of thermo-chemical convection with important implications for the understanding of the large low shear velocity provinces (Dziewonski et al., 2010; Torsvik et al., 2010).

The combination of strongly depth-dependent expansivity and conductivity is a viable mechanism for the formation of long-wavelength, long-lived thermo-chemical anomalies in the deep mantle, even if a low-viscosity ppv atop the core-mantle boundary is included.