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Consequences on lower-mantle plume dynamics with the post-perovskite phase change and strongly depth dependent thermodynamic and transport properties

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We have carried out numerical simulations of 2-D mantle convection specifically with the deep phase change from perovskite (pv) to post-perovskite (ppv). Using the extended Boussinesq approximation for a fluid with both temperature and pressure dependent viscosity, we have performed an extensive sensitivity analysis of the post-perovskite phase parameters and investigated their effects on the convective planform, heat transport and mean temperature profiles. Since the rheology of ppv is expected to be relatively weak with respect to pv (Ohta et al., 2008; Hunt et al., 2009) and to have a large thermal conductivity (Hofmeister, 2007), we assume that the transition from pv to this ppv phase is accompanied by both a reduction in viscosity by 1 to 2 orders of magnitude and by an increase in thermal conductivity by a factor of 2. Furthermore, we investigate the combined effects of decreasing pressure-dependent thermal expansivity, by considering the most recent findings by Katsura et al. (2009), and steeply increasing thermal conductivity (Hofmeister, 2008, Tang and Dong, 2010). As long as the thermal expansivity and conductivity are constant, ppv exerts a small but measurable effect on mantle convection: it destabilizes the D" layer and causes focusing of the heat-flux peaks and an increase of the average mantle temperature and also of the temporal and spatial frequency of upwellings. When depth dependent thermal expansivity and the latest thermal conductivity models are introduced, the effects of ppv are dramatic. On the one hand, without ppv, we obtain a very sluggish convective regime characterized by a relatively cool mantle dominated by large downwellings that tend to stagnate beneath the transition zone. With ppv, on the other hand, we observe an extremely significant increase of the average mantle temperature due to the formation of large sized and vigorous upwellings that in some cases tend to cluster, thus forming superplumes. If a very large thermal conductivity at the core-mantle boundary is assumed ($k \sim 20$ W/Km) we obtain a quasi-steady state regime characterized by large and very stable plumes with long lifetimes. The combination of strongly depth dependent expansivity and conductivity is a viable mechanism for the formation of long-wavelength, long-lived structures in the deep mantle (Torsvik et al., 2008;Dziewonski et al., 2010).