Constraints on lowermost mantle structure from core-mantle boundary dynamic topography

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Mantle flow induces dynamic topography at the core-mantle boundary (CMB), with distribution and amplitude that depend on details of the flow. To assess whether CMB topography can bring constraints on the deep mantle structure, we calculate the CMB dynamic topography associated with different models of mantle convection, including thermo-chemical and purely thermal models. We investigate the influence of key controlling parameters, more specifically the thermal viscosity ratio ($\delta\eta_T$) and, for thermo-chemical models, the chemical density contrast ($\delta\rho_C$) and viscosity ratio ($\delta\eta_C$) between primordial and regular materials. In purely thermal models, plume clusters induce positive topography with an amplitude that decreases with increasing $\delta\eta_T$. In thermo-chemical models with $\delta\rho_C$ around 100 kg/m^3 or more, reservoirs of dense material induce depression in CMB topography, surrounded by a ridge of positive topography. The average depression depth and ridge height increase with increasing $\delta\rho_C$ and $\delta\eta_C$, but decrease with increasing $\delta\eta_T$. We find that for purely thermal models or thermo-chemical models with low $\delta\rho_C$, 90 kg/m^3 and less, the long-wavelength (spherical harmonic degrees up to $l = 4$) dynamic topography and shear-wave velocity anomalies predicted by thermo-chemical distributions anti-correlate. By contrast, for models with $\delta\rho_C$ 100 kg/m^3 and $\delta\eta_C > 1$, long-wavelength dynamic topography and shear-wave velocity anomalies correlate well. This potentially provides a test to infer the nature, thermal or thermo-chemical, of low shear-wave velocity provinces (LLVSP) observed by global tomographic images. The presence of post-perovskite (pPv), provided that the viscosity of this phase is similar to that of bridgmanite, does not alter these conclusions. If the viscosity of pPv is lower than that of bridgmanite by 2 or 3 orders of magnitude, however, more substantial changes may arise.

Keywords: Mantle convection, Core-mantle-boundary topography, Mantle structure

