Geophysical Research Abstracts
Vol. 20, EGU2018-16509, 2018
EGU General Assembly 2018

Characterizing thermochemical piles and their influence on deep mantle behavior using a grain-size dependent viscosity

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Seismic studies show two antipodal regions of lower shear velocity at the core-mantle boundary (CMB) which are called Large Low Shear Velocity Provinces (LLSVPs). They are thought to be thermally and chemically distinct and thus might have a different density and viscosity. Whereas there is some general consensus about the density of the LLSVPs the viscosity is still a very debated topic.
In this study we attempt to shed light on the influence of a grain size-dependent viscosity on the evolution and characteristics of thermochemical piles in geodynamic models. Our approach is based on the theory developed by Rozel et al. (2011) and implemented in the self-consistent convection model StagYY.

We consider a primordial layer and a time-dependent basalt production at the surface to dynamically form the present-day chemical heterogeneities, similar to earlier studies, e.g by Nakagawa & Tackley (2014). With this model, we perform a parameter study which includes different densities and viscosities of the imposed primordial layer. Further, we detect possible thermochemical piles based on different criterions, compute their average effective viscosity, density, rheology and grain size.

Our results show that a higher density and/or viscosity of the piles is needed to keep them at the CMB. Relative to the ambient mantle, grain size is high in the piles but due to the temperature at the CMB the viscosity is not remarkably different than the one of plumes. We can though report two different internal phases of the detected piles: in the first one the average viscosity is more dominated by temperature whereas in the second it is mainly dominated by grain size. Overall we observe that the final average characteristics of the piles is to a wide extent independent of the parameters of the initial primordial layer. This means that for a certain range of parameters the initial composition of LLSVPs might not be that relevant for their composition nowadays.

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