Mantle convection modeling with depth-dependent viscosity – Effects on the convective planform and plume behavior

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While it is commonly accepted that mantle plumes do exist, their spatial and temporal dynamics is a matter of debate. It seems clear, that plumes are largely influenced by the rheology of the mantle material, i.e. by the dependence of the viscosity on temperature and pressure.
Recent work, based on joined inversion, has indicated a stronger viscosity increase in the lower mantle due to the effect of pressure than previously expected [1]. They, in fact, suggest a viscosity increase by a factor up to 1000.
We have employed a two dimensional model of mantle convection, based on a finite volume discretization. In this 2D numerical study we analyze the effect of depth-dependent viscosity on convective planform and in particular on plume behavoir. The value of the surface Rayleigh number is set to $Ra = 10^7$. In order to minimize boundary effects, the aspect ratio of the computational domain is set to 12. We employed an exponential depth dependence of viscosity ranging from 3 to 1000.
In general, depth-dependent viscosity increases the wavelength of mantle flow. It allows for longer aspect ratio cells to form as the viscosity contrast is increased and convection typically reaches a quasi-stationary state. Buoyancy is focused into a few strong upwellings which are virtually fixed in the bottom boundary layer. Smaller boundary layer instabilities travel within the boundary layer until they fed one of the major upwellings. Horizontal and vertical velocities are analyzed as well as plume thickness and temperature.

References

[1] Forte, A.M. and J.X. Mitrovica, 2001. Deep-mantle high-viscosity flow and thermochemical structure inferred from seismic and geodynamic data, *Nature*, **410**, 1049-1056.