Splash Plumes - Plumes Rooted in Mid-Mantle

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A new class of thermal upwellings have been discovered in mantle convection simulations. The important point is that they are not rooted in thermal boundary layers, but are rooted at varying depths in the mantle and could explain minor hot spots.

These are high resolution, Earth-like vigour thermal convection calculations in three-dimensional spherical geometry. The models are for compressible convection, with decreasing coefficient of thermal expansion with depth, as observed in laboratory experiments. The models have $\sim$ chondritic (spatially uniform) rates of internal heating; and varying bottom heating that straddle estimated Earth values. Some of the models have included transition zone phase transitions. The models have depth dependent viscosity; with a viscous lithosphere and a lower mantle approximately 40 times more viscous than the upper mantle. The plate motion history of the past 120 Myrs is applied as a surface velocity boundary condition.

Passive, localised and shallow upwellings are generated beneath the spreading ridges. The planform of downwellings is linear at the surface and become cylindrical as they descend into the mantle. Similarly upwellings at the base of the mantle start linearly but become more cylindrical rising from the junctions of the linear features. In the simulations described here these features are rare and weak.

There are also upwellings that are not rooted at the base of the mantle. They develop as follows. Regions which have not suffered recent subduction become hotter than average and tend to form horizontal sheets that rise passively and slowly. Downwellings from the surface fall onto the sheets and make them into bowls as the hot material is forced up around the sides. The rims of the bowls can become unstable producing cylindrical upwellings (plumes). Since they look a bit like water droplet splashes, I have abbreviated "plumes not rooted in thermal boundary layers" as "splash plumes". The splash plumes originate at a range of depths. In fact the downwellings can push the sheets all the way to the core mantle boundary in certain cases where it is then difficult to tell splash plumes from "traditional plumes".

The sorts of hot-spots that "splash plumes" might be an explanation for, include magmatism behind arcs on continents; e.g. Korea and NE China; magmatism beneath slow-moving continental plates; e.g. Tibesti, Hoggar and Darfur in Africa; Eifel and Massif Central in Europe; and magmatism around lake Baikal beneath Asia.

Other models have been run which are similar in all respects, except for different upper boundary conditions. These models have a comparatively small number of very strong and stable plumes arising from the thermal boundary layer at the core mantle boundary and no splash plumes. This shows that a proper understanding of the relationship between the surface and convection will be critical for evaluating the importance of splash plumes for the actual mantle.

The best test for splash plumes will be seismic imaging. Their thin plumes and narrow bowls very near fast downwellings will require high resolution. These "plumes" also have implications for fixity, temperature contrast, and lifespan which can all be tested.