The Transient Nature of Mantle Plumes

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The morphology of convective features in the Earth's mantle is still heavily debated. Classical Rayleigh-Bénard convection at high Rayleigh numbers (typically $> 10^6$ as the whole mantle) in an homogeneous fluid produces "plumes", which are mushroom-shaped 3-D ephemeral structures. It has been proposed that "hotspots" (Wilson 1963) were created by mantle plumes originating from a deep thermal boundary layer (Morgan 1971). While this simple model does well explain the characteristics of a number of hotspots (Hawaii, La Réunion, Louisville...), an increasing number of observations on other hotspots cannot be explained in this framework.

My intention is to investigate and understand mantle plume dynamics consistently with fluid mechanic constraints. The aim of the experiments carried out in our laboratory is to study the characteristics of plumes: morphology, geometry, height, duration, temperature anomaly, velocity field. Our experiments focus on the temperature and velocity fields. The fluid is a Newtonian, incompressible, thermo-viscous sugar syrup, which is seeded whith two kinds of particles. First thermo-liquid crystals allow us the see the thermal structure of the plume. Then, microscopic hollow glass spheres brighten as tracers of the motion in the fluid. Hence we get information about the temperature and the dynamics of the convection.

The simplest case is a plume issued from a punctual heat source (source of buoyancy). We will compare the results with the analytical scaling laws. Then we will try to determine to what extent those scalings laws derived from an isolated plume can be valid for instabilities from a thermal boundary layer.

References:

Davaille A., Vatteville J. On the transient nature of mantle plumes. Geophys. Res. Lett., 32, 2005.