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Transient mantle plumes: hot heads and cold stems

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Recent petrological studies show evidences for secular cooling in mantle plumes: the source temperature of oceanic plateaus could be 100^oC hotter than the source temperature of volcanic island chains. In terms of mantle plumes, it would mean that the temperature of the plume head is hotter than that of the plume stem. This is at odd with a model where a plume head would entrain so much ambient mantle on its journey towards the Earth's surface that it would end up being considerably colder than its narrow stem.

So we revisited the problem using laboratory experiments and new visualization techniques to measure in situ simultaneously the temperature, velocity and composition fields. At time t=0, a hot instability is created by heating a patch of a given radius at constant power or constant temperature. The fluids are sugar syrups , with a strongly temperature-dependent viscosity. Rayleigh numbers were varied from 10^4 to 10^8, and viscosity ratio between 1.8 and 2000. After a stage where heat transport is by conduction only, the hot fluid gathers in a sphere and begins to rise, followed by a stem anchored on the hot patch. In all cases, temperatures in the head start with higher values than in the subsequent stem. However, the head also cools faster than the stem as they rise, so that they will eventually have the same temperature if the mantle is deep enough. However, our scaling laws predict that Earth's mantle plumes can indeed have hot heads and colder stems. Presence of chemically denser material on the bottom of the mantle would only increase this trend. Moreover, all the material sampled by partial melting in the plume head or stem would be coming from the heated area around the deep source, and very little entrainment from the ambient mantle is predicted.