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Thermo-chemical plumes in the Earth's mantle

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In order to understand behavior of plumes in the heterogeneous mantle, we have conducted laboratory experiments on a thermo-chemical plume generated from a thermal boundary layer which is stratified in composition. We present a new quantitative visualization technique which allows us to simultaneously visualize temperature, composition, and velocity fields. The behavior of the thermo-chemical instability depends on the initial buoyancy ratio B_0, the ratio of the stabilizing chemical buoyancy to the destabilizing thermal buoyancy. When the $B_0 = 0$, a purely thermal plume which has a large plume head and a narrower conduit is produced. For large B_0 (larger than 1), the thermal density anomaly cannot counterbalance the compositional anomaly and convection develops above the compositional interface. For intermediate B_0, the interplay between the thermal and compositional effects generates complicated morphologies. From temperature and compositional fields, we can calculate the local buoyancy ratio B_l in the plume. As the thermo-chemical plume material rises, it cools down and looses its buoyancy. Therefore the compositionally denser blob rises only up to the level of neutral buoyancy, where it stops, then sink back down. We will show scaling laws for the thermo-chemical plume behavior based on quantitative measurement.