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Tracer-based numerical modelling of mantle plumes with constraints from plate reconstructions: Connections to subducted slabs and LLSVPs below the South Atlantic

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The connections between the existence of Large-Low-Shear-Velocity-Provinces (LLSVPs) at the Core-Mantle-Boundary and the regions of plume creation haven been under discussion for several years [1,2,5]. But despite intensive research, the recreation of the observed features in a self-consistent geodynamic model remains challenging [2]. The scope of this work is to determine the interactions between subducted plates and the development of plumes at the Core-Mantle-Boundary. Additionally, we investigate the effects of the continental plate movement history on plume rise. To achieve this we perform three-dimensional modelling of mantle convection and plume uprising coupled with a time-dependent upper boundary inferred from plate reconstructions. We use the geodynamic code CitcomS [3,4], which gives us the opportunity to concentrate on the geodynamic question instead of doing mostly development work. The LLSVPs are considered as chemical and/or thermal anomalies that can be tracked during the model run via the tracer-ratio method [5]. This setup provides the possibility to investigate a well constrained geodynamic model, that can be compared to today measured data like seismic tomography, plate reconstructions, location and properties of Large Igneous Provinces, and geoid data.
With this approach we reverse the idea of mantle plumes influencing plate motion [6,7] and investigates the effects of large-scale mantle-flow visible in subduction and sea-floor-spreading at the surface on the smaller scale of a rising plume. Combining this two aspects leads the way to a model that fully integrates the complex two-way interactions between surface effects and mantle-flow.

References

[1] Torsvik, T. H., Smethurst, M. A., Burke, K. and Steinberger, B. (2006), Large igneous provinces generated from the margins of the large low-velocity provinces in the deep mantle, Geoph. J. Int., 167, 1447–1460.
[2] Tan, E., Leng, W., Zhong, S., and Gurnis, M. (2011), On the location of plumes and lateral movement of thermochemical structures with high bulk modulus in the 3-D compressible mantle, Geochem. Geophys. Geosyst., 12, Q07005, doi:10.1029/2011GC003665.
[3] Zhong, S., Zuber, M.T., Moresi, L.N., and Gurnis, M. (2000), The role of temperature-dependent viscosity and surface plates in spherical shell models of mantle convection. J. Geophys. Res., 105, 11,063-11,082.
[4] Tan, E., Choi, E., Thoutireddy, P., Gurnis, M., and Aivazis, M. (2006), GeoFramework: Coupling multiple models of mantle convection within a computational framework, Geochem., Geophys., Geosyst. 7, Q06001, doi:10.1029/2005GC001155.
[5] McNamara, A.K., and Zhong, S. (2004), Thermochemical structures within a spherical mantle: Super-plumes or Piles?, J. Geophys. Res., 109, B07402, doi:10.1029/2003JB002847.
[6] Cande, S. C. and Stegman, D. R. (2011), Indian and African plate motions driven by the push force of the Reunion plume head, Nature 475, 47-52.
[7] van Hinsbergen, D. J.J., Steinberger, B., Doubrovine, P. V. and Gassmöller, R. (2011), Acceleration and deceleration of India-Asia convergence since the Cretaceous: roles of mantle plumes

and continental collision J. Geophys. Res., 116, B06101.

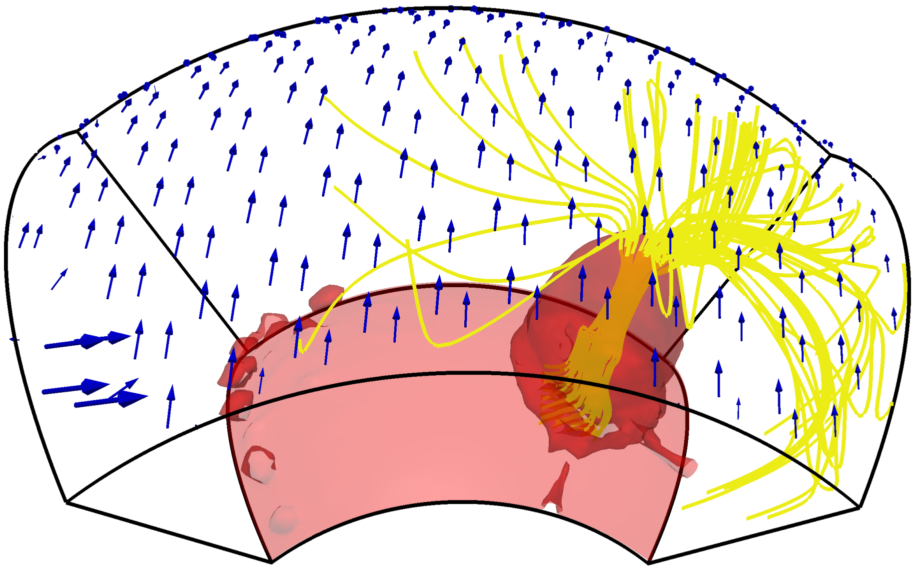

Figure 1: Model snapshot of a rising plume with imposed plate velocity at the surface. Red contour surface is a constant temperature above the average mantle temperature. Blue arrows mark the time-dependent but fixed plate velocity. Yellow streamlines represent the current flow field of material starting at the CMB inside of a thermo-chemical anomaly. The flow is clearly influenced by the plate velocity, instead of a radial outward movement at the surface - the lines are curved in direction of the upper boundary condition.