Geophysical Research Abstracts
Vol. 14, EGU2012-4524-1, 2012
EGU General Assembly 2012

Numerical Modeling of the Deep Mantle Convection: Accuracy of the Tracer Methods

E. Mulyukova (1), M. Dabrowski (2), and B. Steinberger (1)

(1) GFZ German Research Center for Geosciences, Potsdam, Germany, (2) University of Oslo, Physics, Physics of Geological Processes, Oslo, Norway

One of the most robust results from tomographic studies is the existence of two antipodally located Large Low Shear Velocity Provinces (LLSVPs) at the base of the mantle. Results from the reconstruction studies (Torsvik et al., 2006) have led to inferences that the LLSVPs are stable and long-lived. The negative correlation between the bulk sound velocity and the shear velocity within the LLSVPs suggests that these anomalies are not of purely thermal origin.

In this numerical study we investigate the effect of the entrainment of the LLSVPs by convective mantle flow on their longevity. We have developed a two-dimensional FEM code to model thermal convection in the deep mantle with presence of chemical heterogeneities. There exists a variety of numerical methods for the discretization of the compositional field. We focus on the methods that use tracers. The long simulation time that is required in order to study the inferred long-term stability of the LLSVPs poses a stringent constraint on the errors of the numerical model. Our goal is to determine whether the tracer methods produce accurate modelling results for the entrainment rate of a heterogeneous fluid that is vigorously convecting over billions of years.

One of the advantages of using tracer methods for modelling the dynamics of heterogeneous fluids is that they offer a sub-grid scale resolution of the compositional field. The effects of the grid resolution and the interpolation scheme on the accuracy of the these methods has been previously studied, e.g. (Deubelbeiss and Kaus, 2008; Duretz et al., 2011). Some of the disadvantages associated with the tracer methods are tracer settling and artificial small-scale instabilities due to tracer discretization noise. These problems may be avoided to a large degree by using the so-called 'tracer-ratio' method, as was proposed by (Tackley and King, 2003). However, in the same study it was shown that the tracer-ratio method underestimates entrainment, and an improvement of the method is required in order to obtain physically correct entrainment rates. Another well-known numerical artifact of the tracer methods is the formation of spurious sub-grid scale structures at the material interfaces, which can be difficult to distinguish from the geophysical structure (Suckale et al., 2010).

We study how the numerical errors of the solution obtained with the tracer method accumulates with each time step, taking into account the accuracy of the mechanical and thermal solvers, and accuracy of the advection and interpolation schemes. We compare the numerical results to known analytical solutions, where possible. Our numerically derived entrainment rate is compared to those obtained by experimental studies, e.g. (Davaille, 1999), and to the one recently proposed by (Deschamps et al., 2011), which was based on the isotopic signatures of the ocean island basalts.

We show how the value of the solution gradient, the spatial resolution, and the order of the shape functions affect the accuracy of the solution. We argue that using the tracer method for discretization of the compositional field results in accuracy gain, despite the lower resolution of the other fields.