Ultra-High Resolution and Composite Rheology in Global Mantle Flow

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Abstract

A full understanding of the dynamics of plate motions requires numerical models with a realistic, nonlinear rheology and a mesh resolution sufficiently high to resolve large variations in viscosity over short length scales. We suspect that resolutions as fine as 1 km locally in global models of the whole mantle and lithosphere are necessary. We use the adaptive mesh mantle convection code Rhea to model convection in the mantle with plates in both regional and global domains. Rhea is a new generation parallel finite element mantle convection code designed to scale to hundreds of thousands of compute cores. It uses forest-of-octree-based adaptive meshes via the p4est library. With Rhea,’s adaptive capabilities we can create local resolution down to ,àº1 km around plate boundaries, while keeping the mesh at a much coarser resolution away from small features. The global models in this study have approximately 220 million elements, a reduction of ,àº2000x compared to a uniform mesh of the same high resolution.

Since plate velocities and ”plateness” are dynamic outcomes of numerical modeling, we must carefully incorporate both the full buoyancy field and the details of all plate boundaries at a fine scale. The models are constructed with detailed maps of the age of the plates and a thermal model of the seismicity-defined slabs which grades into the more diffuse buoyancy resolved with tomography. A composite formulation of Newtonian and non-Newtonian rheology along with yielding is implemented; plate boundaries are modeled as very narrow weak zones. The effect of variations in rheology parameters on plate velocities and viscosity in the hinge of the subducting plate is examined. The instantaneous dynamic global mantle convection models predict plate velocity, state of stress, viscosity and energy dissipation. These models are tested by assessing the plateness of the surface velocity field, and its misfit with measured surface velocities. The global mantle flow models will allow us to address the cause of changes in plate motions and the distribution of energy dissipation within the convective system.