Numerical Methods for Variable Viscosity Mantle Convection

C. Köstler, M. Müller, U. Walzer and R. Hendel
Institut für Geowissenschaften, Friedrich-Schiller-Universität Jena

Viscosity in the Earth's mantle varies by several (probably more than 10) orders of magnitude, dependent on temperature, pressure, grain size and phase transformations. Modeling these variations realistically in three-dimensional mantle convection simulations has been a long-standing problem.

We present various approaches to increase the robustness of the solution process in a spherical shell. Emphasis is on the finite-element discretization and on the iterative solution of the Stokes equations, which are the central part in the high-viscosity convection calculations. An inf-sup stable grid refinement as a result of theoretical analysis is given and two iterative solvers, namely preconditioned MINRES and coupled multigrid are introduced. For the existing code, parallel performance results are shown.

Moreover, we present results of a 3-dimensional spherical model with chemical differentiation and redistribution of incompatible elements in a convective Earth's mantle heated mostly from within and slightly from below. These results include the preservation of geochemical heterogeneity in spite of more than 4500 Ma of convection and the episodic growth of continents and oceanic plateaus.