Spectral-finite element approach to present-time mantle convection

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We present a spectral-finite element approach to the forward modelling of present-time mantle convection. The differential Stokes problem for an incompressible viscous flow in a spherical shell is reformulated in weak sense by means of a variational principle. The integral equations obtained are then parametrized by vector and tensor spherical harmonics in the angular direction and by piecewise linear finite elements over the radial direction. The solution is obtained using the Galerkin method, that leads to the solution of a system of linear algebraic equations. The earth-viscosity structure is described using a two-dimensional spherical grid, that allows us to treat various kinds of lateral variation, with viscosity contrasts of several order of magnitude.

The method is first tested for the case of a one-dimensional viscosity structure. After prescribing the internal load in the form of a Dirac-delta, Green's functions for the surface topography, core topography and geoid are computed and compared with those obtained by solving the problem with the traditional matrix propagator technique.

The approach is then applied to two different axisymmetric viscosity structures consisting either of one or two highly viscous cratonic bodies embedded in the upper mantle. We compute the corresponding Green's functions, showing and discussing the non-linear coupling of various spherical-harmonic modes, and the resulting angular dependence of the flow velocity.