Geophysical Research Abstracts
Vol. 16, EGU2014-11182-1, 2014
EGU General Assembly 2014

Progress in developing the ASPECT Mantle Convection Code - New Features, Benchmark Comparisons and Applications

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Since there is no direct access to the deep Earth, numerical simulations are an indispensible tool for exploring processes in the Earth's mantle. Results of these models can be compared to surface observations and, combined with constraints from seismology and geochemistry, have provided insight into a broad range of geoscientific problems.

In this contribution we present results obtained from a next-generation finite-element code called ASPECT (Advanced Solver for Problems in Earth's ConvecTion), which is especially suited for modeling thermo-chemical convection due to its use of many modern numerical techniques: fully adaptive meshes, accurate discretizations, a nonlinear artificial diffusion method to stabilize the advection equation, an efficient solution strategy based on a block triangular preconditioner utilizing an algebraic multigrid, parallelization of all of the steps above and finally its modular and easily extensible implementation. In particular the latter features make it a very versatile tool applicable also to lithosphere models. The equations are implemented in the form of the Anelastic Liquid Approximation with temperature, pressure, composition and strain rate dependent material properties including associated non-linear solvers.

We will compare computations with ASPECT to common benchmarks in the geodynamics community such as the Rayleigh-Taylor instability (van Keken et al., 1997) and demonstrate recently implemented features such as a melting model with temperature, pressure and composition dependent melt fraction and latent heat. Moreover, we elaborate on a number of features currently under development by the community such as free surfaces, porous flow and elasticity. In addition, we show examples of how ASPECT is applied to develop sophisticated simulations of typical geodynamic problems. These include 3D models of thermo-chemical plumes incorporating phase transitions (including melting) with the accompanying density changes, Clapeyron slopes and latent heat effects as well as multiphase subduction models and investigations of true polar wander. An example of the kind of result we will present can be found at http://www.youtube.com/watch?v=dG-ULmcBr1E