Simulation of Earth Mantle Convection

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Abstract

Much of the geological activity of the Earth is due to the fact that heat is transported from the interior of the planet to the surface in a planet-wide slow convection of the Earth's mantle. Understanding these mantle processes is a fundamental problem in the Earth sciences and is also of direct practical relevance because of its impact on the evolution of sedimentary basins.

On geological time scales of several million years, the Earth mantle behaves like a viscous fluid moving with velocities of a few centimeters per year that can be modeled by variants of the Stokes system. Mathematically this leads to a saddle point structure that is coupled to an energy transport equation.

The Earth Mantle has a volume of approximately 10^{12} cubic kilometers, and thus resolving the full volume with a resolution of 1km will require approximately 10^{12} finite elements. In this talk we will present progress towards solving finite element systems of such size. Clearly this requires maximal computing power, as it can be delivered by massively parallel supercomputers on the peta scale (or more). However, tackling systems of such size also requires a careful algorithmic design and efficiency aware software structures. Here we will discuss the experiences gained from the first prototype of the new TerraNeo Mantle convection simulator that uses fast scalable multigrid methods implemented with hierarchical hybrid grid data structures.

References

1. Jens Weismüller and Björn Gmeiner and Siavash Ghelichkhan and Markus Huber Lorenz John and Barbara Wohlmuth and Ulrich Rüde and Hans-Peter Bunge. Fast asthenosphere motion in high-resolution global mantle flow models. Geophysical Research Letters 42 (2015), 7429–7435.