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Simulating Mantle Convection using the Spectral Element Method

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We present work undertaken to develop a new mantle convection code that uses the high order spectral element method. High order methods are commonly used in computational fluid dynamics. They frequently produce more accurate results for less computational effort than low order methods such as the finite element method. However to date the spectral element method has not been applied to the mantle convection problem. Through this we hope to be able to simulate mantle convection in models with large lateral variations in viscosity such as are present in Earth's mantle.

Mantle convection requires a numerical grid in a spherical shell. This grid is commonly based on regular polyhedra. We present a new type of computational grid. This grid is based on a range of polyhedrons and allows for greater flexibility in the number of nodes in the grid and easy comparison with existing mantle convection simulators. A further grid is discussed that has no lower boundary and would therefore be suitable for modeling convection in small planetoids.

In our implementation the conservation of mass and momentum equations are solved in one system, rather than iteratively (e.g using an Uzawa algorithm) as done in many other mantle simulators. While for the energy equation we use a straightforward operator splitting method.

We discuss solutions to an initial set of problems on the sphere including Poisson's equation and Stokes' problem. We are advancing this work to undertake solutions to the full mantle convection problem. This is being implemented to work in parallel on message passing clusters, where we will use PETSC to solve the large linear system. The performance of our spectral element method is discussed including demonstration of its results for benchmark problems.