Geophysical Research Abstracts
Vol. 13, EGU2011-9471-1, 2011
EGU General Assembly 2011

Geodynamic modelling using finite difference and finite element methods on massive parallel computers.

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3D geodynamic modelling of lithospheric-scale deformation remains a challenge as it requires scalable multilevel preconditioners which perform well in the presence of large and abrupt jumps in viscosity. In recent years, we have developed LaMEM (Lithosphere and Mantle Evolution Model), which is a finite element code, that can be combined with a marker-and-cell method (to model large strains) and can be used in an Eulerian, Lagrangian or ALE manner. LaMEM is built on top of the parallel PETSC package (http://www.mcs.anl.gov/petsc), which allows us to access a large repertoire of smoothers, iterative solvers, as well as algebraic multigrid preconditioners such as ML. We can use either Q_1P_0, stabilized Q_1Q_1 or Q_2P_{-1} elements (all configurable from the command-line). Recently, we have also added a staggered grid finite difference discretisation. Here, we will compare the relative performance of the FD versus the FEM method for a few selected benchmark cases. In addition, we have ported LaMEM to massive parallel machines (Cray XT5 and IBM Bluegene). Using up to 2048 cores, we obtain $\sim 70\%$ efficiency in weak scaling tests, thereby enabling problems with more than 500 million degrees of freedom to be solved.