Geophysical Research Abstracts
Vol. 17, EGU2015-11179, 2015
EGU General Assembly 2015

LaMEM: a massively parallel 3D staggered-grid finite-difference code for coupled nonlinear themo-mechanical modeling of lithospheric deformation with visco-elasto-plastic rheology

Anton Popov and Boris Kaus
Johannes Gutenberg Universität Mainz, Institute for Geosciences, Mainz, Germany (popov@uni-mainz.de)

This software project aims at bringing the 3D lithospheric deformation modeling to a qualitatively different level. Our code LaMEM (Lithosphere and Mantle Evolution Model) is based on the following building blocks:

* Massively-parallel data-distributed implementation model based on PETSc library
* Light, stable and accurate staggered-grid finite difference spatial discretization
* Marker-in-Cell pedictor-corector time discretization with Runge-Kutta 4-th order
* Elastic stress rotation algorithm based on the time integration of the vorticity pseudo-vector
* Staircase-type internal free surface boundary condition without artificial viscosity contrast
* Geodynamically relevant visco-elasto-plastic rheology
* Global velocity-pressure-temperature Newton-Raphson nonlinear solver
* Local nonlinear solver based on FZERO algorithm
* Coupled velocity-pressure geometric multigrid preconditioner with Galerkin coarsening

Staggered grid finite difference, being inherently Eulerian and rather complicated discretization method, provides no natural treatment of free surface boundary condition. The solution based on the quasi-viscous sticky-air phase introduces significant viscosity contrasts and spoils the convergence of the iterative solvers. In LaMEM we are currently implementing an approximate stair-case type of the free surface boundary condition which excludes the empty cells and restores the solver convergence.

Because of the mutual dependence of the stress and strain-rate tensor components, and their different spatial locations in the grid, there is no straightforward way of implementing the nonlinear rheology. In LaMEM we have developed and implemented an efficient interpolation scheme for the second invariant of the strain-rate tensor, that solves this problem.

Scalable efficient linear solvers are the key components of the successful nonlinear problem solution. In LaMEM we have a range of PETSc-based preconditioning techniques that either employ a block factorization of the velocity-pressure matrix, or treat it as a monolithic piece. In particular we have implemented the custom restriction-interpolation operators for the coupled Galerkin multigrid preconditioner. We have found that this type of algorithm is very robust with respect to the high grid resolutions and realistic viscosity variations. The coupled Galerking geometric multigrid implemented with the custom restriction-interpolation operators currently enables LaMEM to run efficiently with the grid sizes up to 1000-cube cells on the IBM Blue Gene/Q machines.

This project is funded by ERC Starting Grant 258830
Computer facilities are provided by Jülich supercomputer center (Germany)