Geophysical Research Abstracts
Vol. 16, EGU2014-6313, 2014
EGU General Assembly 2014

Nonlinear rheology in ASPECT: benchmarking and an application to 3D subduction

Anne Glerum (1,2), Cedric Thieulot (1,3), Menno Fraters (1), Wim Spakman (1,2,3)

(1) Utrecht University, Geosciences, Earth Sciences, Utrecht, Netherlands (a.c.glerum@uu.nl), (2) The Netherlands Research Centre for Integrated Solid Earth Science, (3) Centre of Earth Evolution and Dynamics (CEED), University of Oslo, Norway

ASPECT (Advanced Solver for Problems in Earth's ConvecTion) is a promising new code designed for modelling thermal convection in the mantle (Kronbichler et al. 2012). The massively parallel code uses state-of-the-art numerical methods, such as high performance solvers and adaptive mesh refinement. It builds on tried-and-well-tested libraries and works with plug-ins allowing easy extension to fine-tune it to the user's specific needs.

We extended the code by implementing a frictional plasticity criterion that can be combined with a viscous creep rheology, allowing for thermo-mechanically coupled visco-plastic flow. This way we can accommodate for the nonlinear behavior of the Earth's materials and incorporate for instance the localization of deformation through plastic yielding. This has been shown to be of great importance for modelling lithosphere deformation.

Three well-known benchmarks are used to test and validate our implementation of plasticity: the punch benchmark (e.g. Thieulot et al. 2008), which considers the indentation of a perfectly plastic material and allows for comparison with an analytical solution; the brick benchmark (Kaus 2010), performed in both a compressional and tensional regime with shear band angles bounded by results of other codes and theory; and the sandbox experiment by Buiter et al. (2006) modelling the time evolution of the extension of viscous and plastic layers in the presence of a free surface.

We further showcase ASPECT's capabilities with a more geodynamical application: the subduction of an oceanic plate in a three-dimensional thermo-mechanically coupled system. We compare the use of nonlinear rheologies versus that of constant mantle and plate viscosities with an adaptation of the subducting/overriding plate setup of Schellart and Moresi (2013). These models also demonstrate how the adaptive mesh refinement allows for high resolutions locally while the code remains computationally efficient even in the presence of large deformation and large viscosity contrasts.

Buiter, S. J. H. et al., "The numerical sandbox: comparison of model results for a shortening and an extension experiment". Analogue and Numerical Modelling of Crustal-Scale Processes, Buiter, S. J. H. and Schreurs, G. (eds). London: Geological Society, 2006.

Kaus, B. J. (2010), Factors that control the angle of shear bands in geodynamic numerical models of brittle deformation, Tectonophysics, 484, 36-47.

Kronbichler, M., Heister, T. and Bangerth, W. (2012), High Accuracy Mantle Convection Simulation through Modern Numerical Methods, Geophysical Journal International, 191, 12-29.

Schellart, W. P. and Moresi, L. (2013), A new driving mechanism for backarc extension and backarc shortening through slab sinking induced toroidal and poloidal mantle flow: Results from dynamic subduction models with an overriding plate, Journal of Geophysical Research, 118, 1-28.

Thieulot, C., Fullsack, P. and Braun, J. (2008), Adaptive octree-based finite element analysis of two-dimensional and three-dimensional indentation problems, Journal of Geophysical Research, 113.