Advances in the geodynamic modelling code ASPECT

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The last years have seen a significant advancement in the evolution of geodynamic modeling, both in the size of performed models and the complexity of modeled processes. Several factors have been driving this change: Increased availability of data, increasing availability of high-performance computing, improved numerical algorithms like linear solvers and preconditioners, and a better understanding of how to engineer and manage geodynamic modeling software.

In this contribution I will present software development strategies and applications using the mantle convection software ASPECT, which is developed as a modular, massively parallel, open-source code for the geodynamic modeling community. In particular, I will discuss techniques that allow different linear systems (based on equations describing different physical processors), solvers, and solver schemes to coexist in a single software. This has a number of advantages, for example:
(1) It allows direct comparisons between different methods in the same code.
(2) The influence of models specifications like the geometry, dimension (2d vs. 3d), size of the domain (regional vs. global) or boundary conditions on the model result can be tested directly.
(3) The software can be used to model very different applications such as mantle convection, magma dynamics, lithosphere deformation, planetary evolution, dynamics of icy satellites and inner core convection and growth.

I will illustrate these advantages using different examples and application cases. This includes ASPECT’s new solver for large-scale models of coupled magma/mantle dynamics and its application to mid-ocean ridge modelling. In addition, I will compare a number of approximations for the compressible Stokes equations and evaluate the limits of the commonly used anelastic liquid approximation, which is based on a reference-profile, in the presence of local temperature or density perturbations, such as caused by phase transitions or superadiabatic temperature gradients. Beyond that, I will showcase how a modular software design allows us to easily build realistic geodynamic models with increasingly complex boundary conditions, and a freely deformable surface.

Finally, I will discuss some of the future plans for ASPECT, including the coupling of software packages, and the verification of increasingly complex models.