Geophysical Research Abstracts
Vol. 19, EGU2017-9465-3, 2017
EGU General Assembly 2017

Techniques and Software for Monolithic Preconditioning of Moderately-sized Geodynamic Stokes Flow Problems

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Geodynamics simulations typically involve the repeated solution of saddle-point systems arising from the Stokes equations. These computations often dominate the time to solution. Direct solvers are known for their robustness and "black box" properties, yet exhibit superlinear memory requirements and time to solution. More complex multilevel-preconditioned iterative solvers have been very successful for large problems, yet their use can require more effort from the practitioner in terms of setting up a solver and choosing its parameters.

We champion an intermediate approach, based on leveraging the power of modern incomplete factorization techniques for indefinite symmetric matrices.

These provide an interesting alternative in situations in between the regimes where direct solvers are an obvious choice and those where complex, scalable, iterative solvers are an obvious choice. That is, much like their relatives for definite systems, ILU/ICC-preconditioned Krylov methods and ILU/ICC-smoothed multigrid methods, the approaches demonstrated here provide a useful addition to the solver toolkit.

We present results with a simple, PETSc-based, open-source Q2-Q1 (Taylor-Hood) finite element discretization, in 2 and 3 dimensions, with the Stokes and Lamé (linear elasticity) saddle point systems. Attention is paid to cases in which full-operator incomplete factorization gives an improvement in time to solution over direct solution methods (which may not even be feasible due to memory limitations), without the complication of more complex (or at least, less-automatic) preconditioners or smoothers.

As an important factor in the relevance of these tools is their availability in portable software, we also describe open-source PETSc interfaces to the factorization routines.