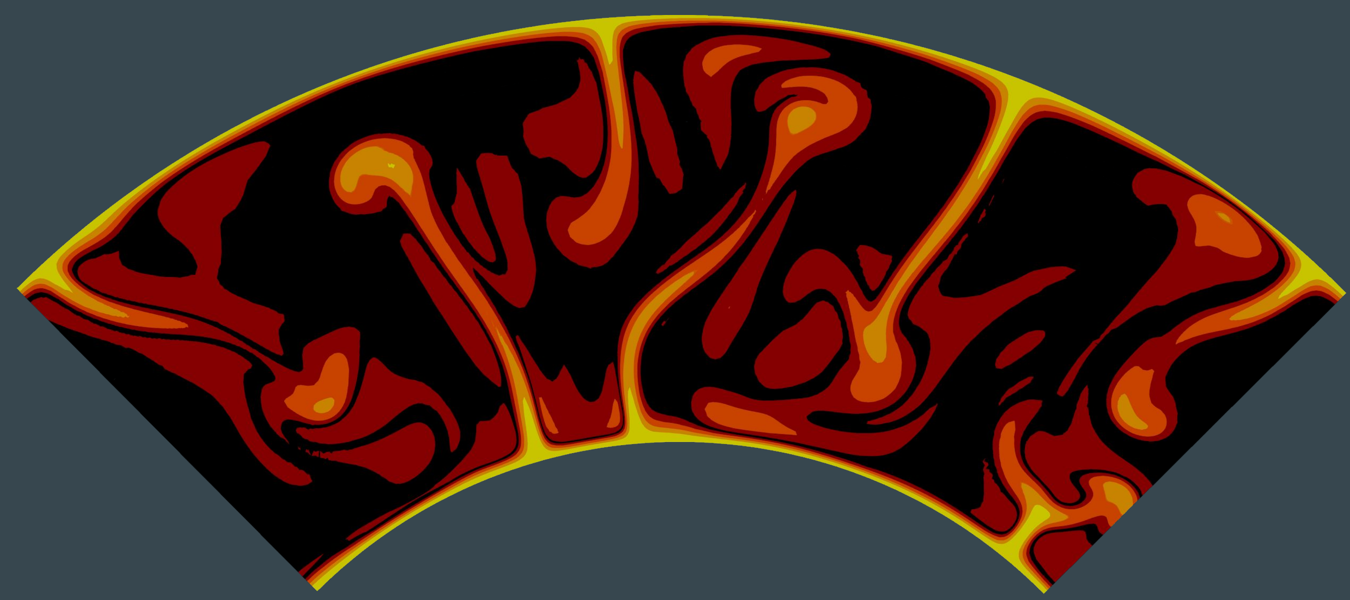


The ASPECT project: What's new?

Wolfgang Bangerth, Juliane Dannberg, Menno Fraters, Rene Gassmoeller, Anne Glerum, Timo Heister *, John Naliboff

About

ASPECT, the Advanced Solver for Problems in Earth's ConvecTion, is an extensible code written in C++ to support research in simulating convection in the Earth's mantle and elsewhere.
See: https://aspect.geodynamics.org

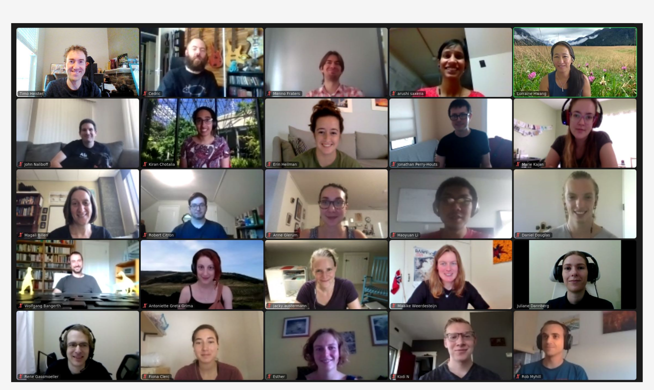
The 2.2.0 release (June 2020)

- Material model for viscoelastic-plastic deformation
- Updated Geodynamic World Builder version 0.3.0.
- New compressible convection formulation called 'projected density approximation
- New matrix-free Stokes solver
- Advection stabilization: improved entropy viscosity method (less artificial diffusion) and new SUPG method
- New "Mesh deformation" framework that includes the "Free surface"
- New benchmarks: entropy equation, viscoelastic cantilever, buoyancy-driven viscoelastic plate stress, advection in annulus, slab detachment benchmark, several advection benchmarks, rigid shear, polydiapirs, surface loading
- ASPECT now requires deal.II version 9.0.0+
- Framework for separate rheology models
- Various bug fixes

More details on this poster!

The 2020 virtual hackathon (Aug 3-14)

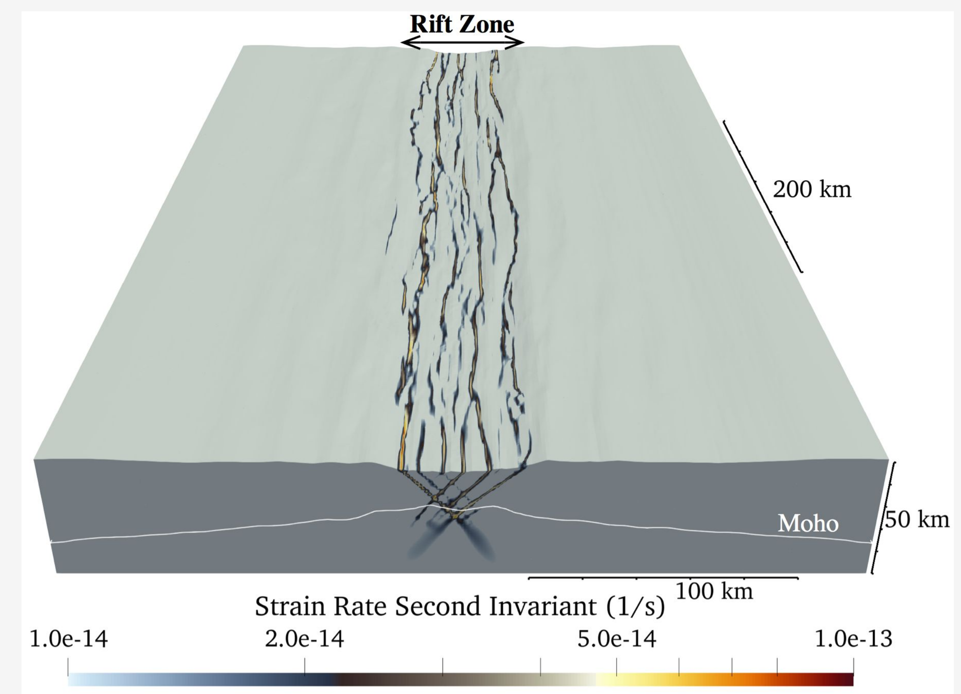
- 25 participants from across the globe, 8 of them principal developers
- Core hours: 9-12 pacific, 1hr rounds
- 3 smaller groups with mentors formed by topic for individual support, separate Zoom rooms for joint work
- 143 pull requests merged (similar to previous years)



Number of commits to the ASPECT repository over time, with peaks showing the dates of hackathons

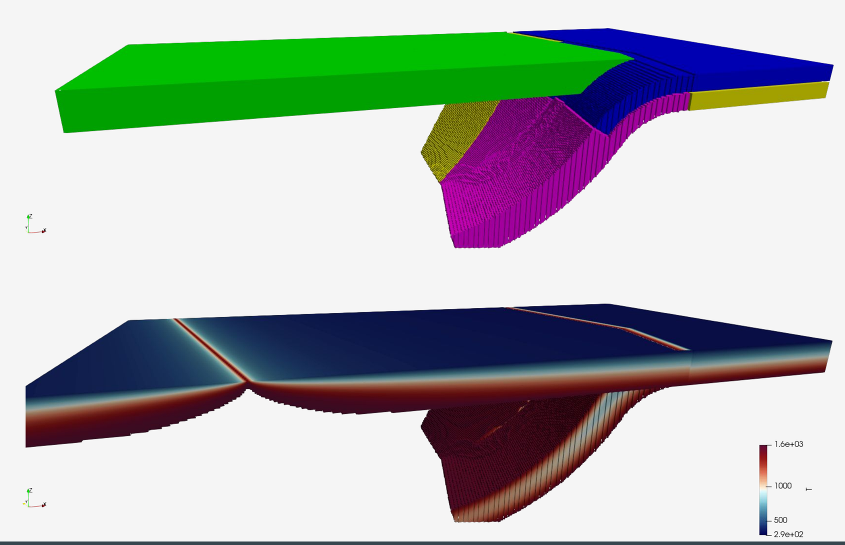
Viscoelastic-plastic deformation

- Viscoelastic-plastic Rheology
  - Drucker Prager Plasticity
  - Diffusion, Dislocation, Peierls
  - Incompressible elasticity
  - Material Tracking: Particles or Fields
  - Phase changes (Density, Flow Laws)
  - Full Integration with Newton Solver
- Active Development
  - Plasticity stabilization
  - Compressible deformation
  - Plasticity with Two-Phase Flow
- For the simulation in the picture see [4]



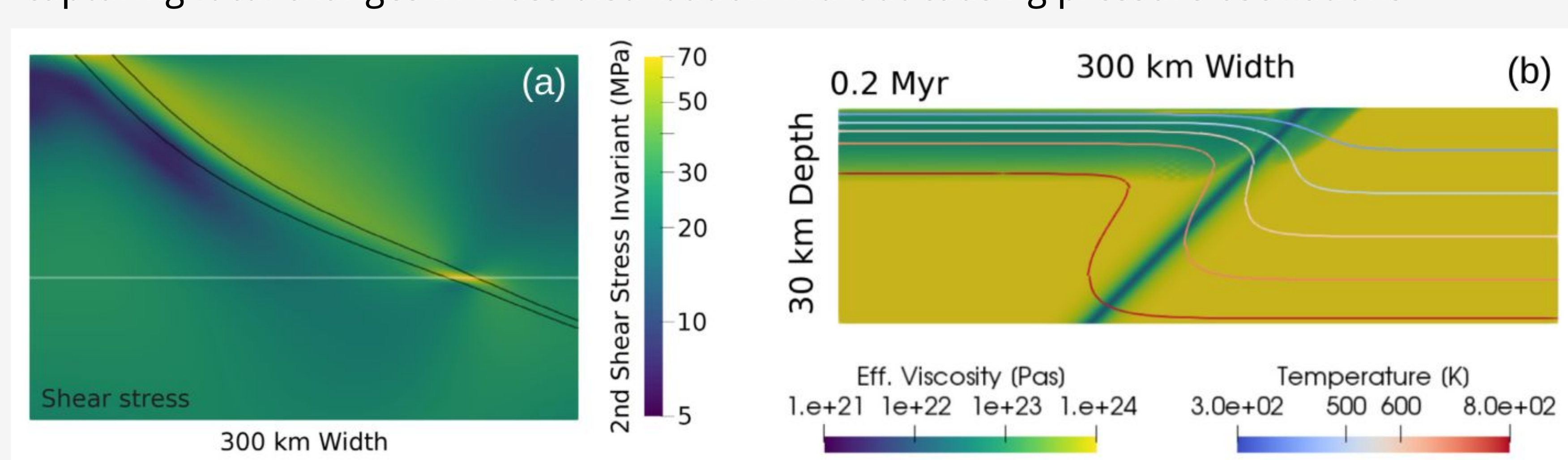
New Geodynamic World Builder (GWB) version (0.3.0)

- An initial conditions generator for geodynamic modeling
- Directly included in ASPECT
- Integration tested by the ASPECT tester
- Contains experimental interface for future Lattice Preferred Orientation (LPO) plugins in ASPECT



New formulation for modeling compressibility

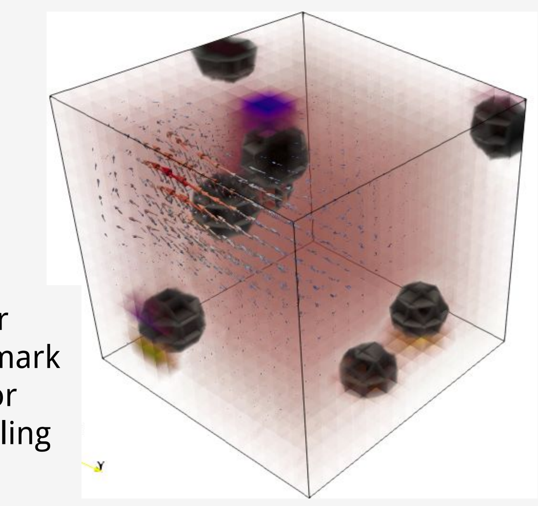
- Many existing approximations of compressible Stokes flow make use of a reference profile.
- This is justified in many applications, but may fail to capture the physical behaviour of interest when deviations from the reference profile are large.
- Examples: when different materials undergo (a) phase transitions, or (b) significant heating or cooling close to boundary layers (see figure below)
- **Solution implemented in ASPECT [2]:**
  New formulation of the continuity equation that includes dynamic density variations caused by temperature and composition, but neglects changes in dynamic pressure (which are of the order of 0.1% or smaller)
- This method allows geodynamic simulations to include the time derivative of the density, capturing local changes in mass distribution without causing pressure oscillations

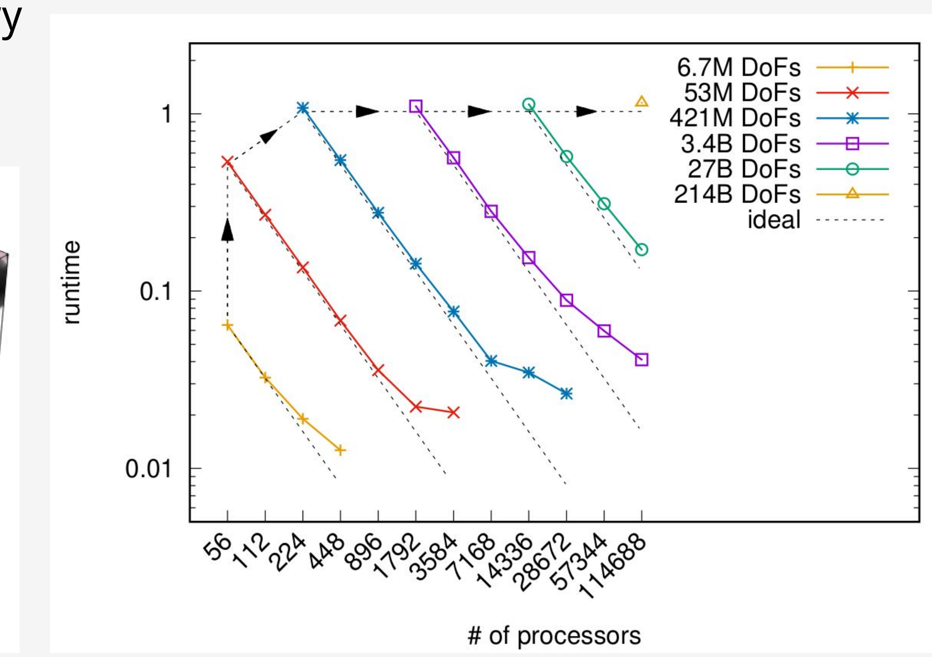


Matrix-free Geometric Multigrid

- Adaptive, matrix-free multigrid for the Stokes system
  - Block solver with velocity block and Schur complement V-cycle
  - Local smoothing with Chebyshev smoother
  - Matrix-free, vectorized residual evaluation
  - IDR(2) short recurrence Krylov method
- Up to 200 Billion unknowns, 114k MPI ranks on Frontera, see [1]
- Compared to Trilinos AMG:
  - 10x reduction in memory
  - 3x faster
  - Slightly more robust

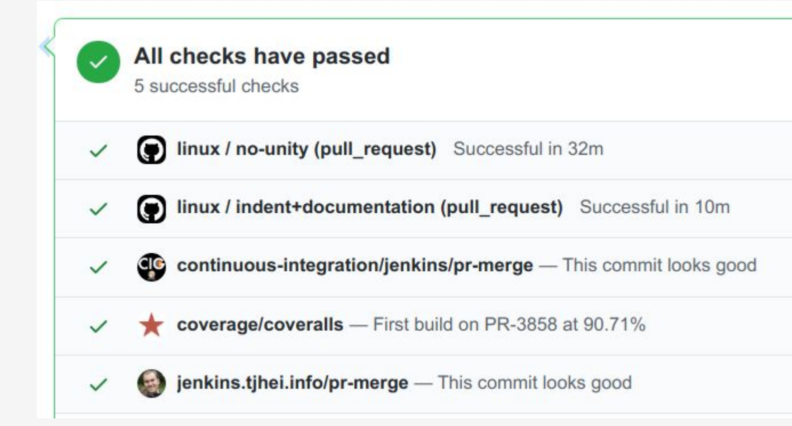
Nsinker benchmark used for the scaling tests





Development process

- Developed in the open on github.com using pull requests
- Detailed code review by a team of 8 principal developers
- Continuous integration with unit tests and integration tests (800+) and compiling in different configurations
- Developer meetings every 2 weeks open to everyone
- Focus on documentation (580 page manual), cookbooks (29), benchmarks (46)



Literature

1. Thomas C. Clevenger, Timo Heister:
   Comparison Between Algebraic and Matrix-free Geometric Multigrid for a Stokes Problem on an Adaptive Mesh with Variable Viscosity
   Submitted, https://arxiv.org/abs/1907.06696
2. Rene Gassmöller, Juliane Dannberg, Wolfgang Bangerth, Timo Heister, Robert Myhill (2020):
   On Formulations of Compressible Mantle Convection. Geophys J Int, 221 (2), 1264–1280
3. T. Heister, J. Dannberg, R. Gassmöller, W. Bangerth (2017):
   High Accuracy Mantle Convection Simulation through Modern Numerical Methods. II: Realistic Models and Problems. Geophys J Int, 210, 833-851.
4. John Naliboff et al. (2020):
   High-Resolution 3D model of continental extension model with a visco plastic rheology. (GRL)

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