Summary so far

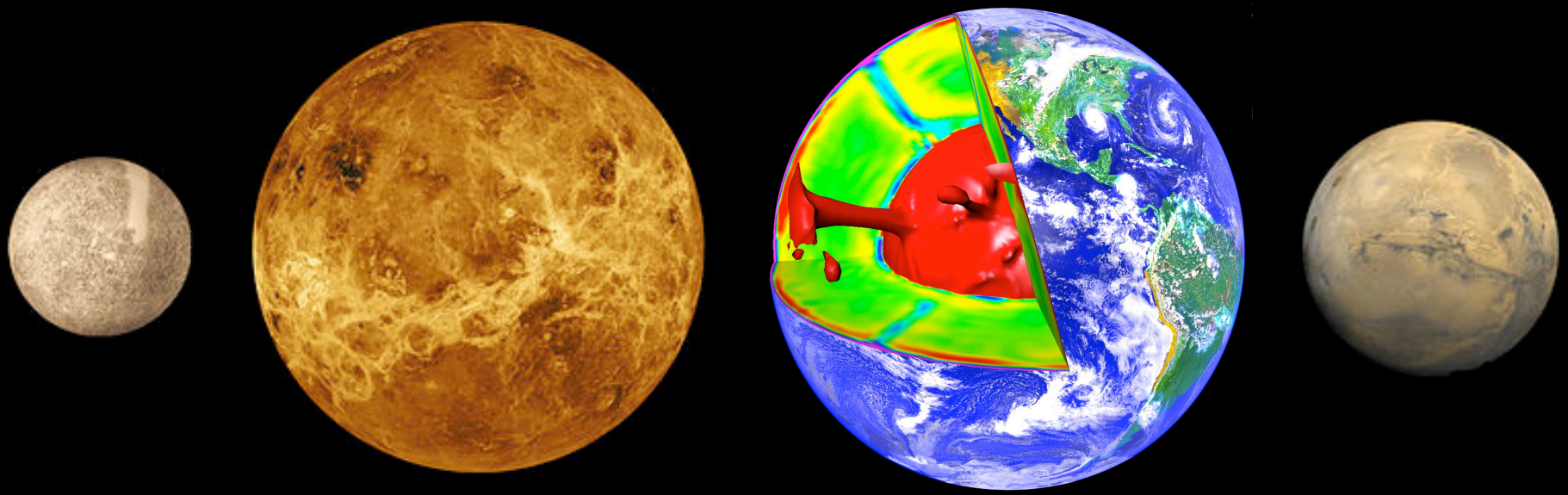
- ‘Effective’ strength of the lithosphere ~100 MPa (or similarly, effective friction coefficient <0.1). Lower than ‘laboratory’ values.
- Weak ‘asthenosphere’ increases ‘plateness’
- Both plastic yielding and ‘damage’ can cause plate boundaries
- Successes
  - Linear 'subduction'
  - Linear passive spreading centers+rifts
  - Toroidal:Poloidal ratio realistic (sometimes)
- Failures
  - Subduction double-sided
  - No pure strike-slip margins
  - Yield stress too low

One-sided Subduction in Self-Consistent Models of Global Mantle Convection: The Importance of a Free Surface and Weak Crustal Layer

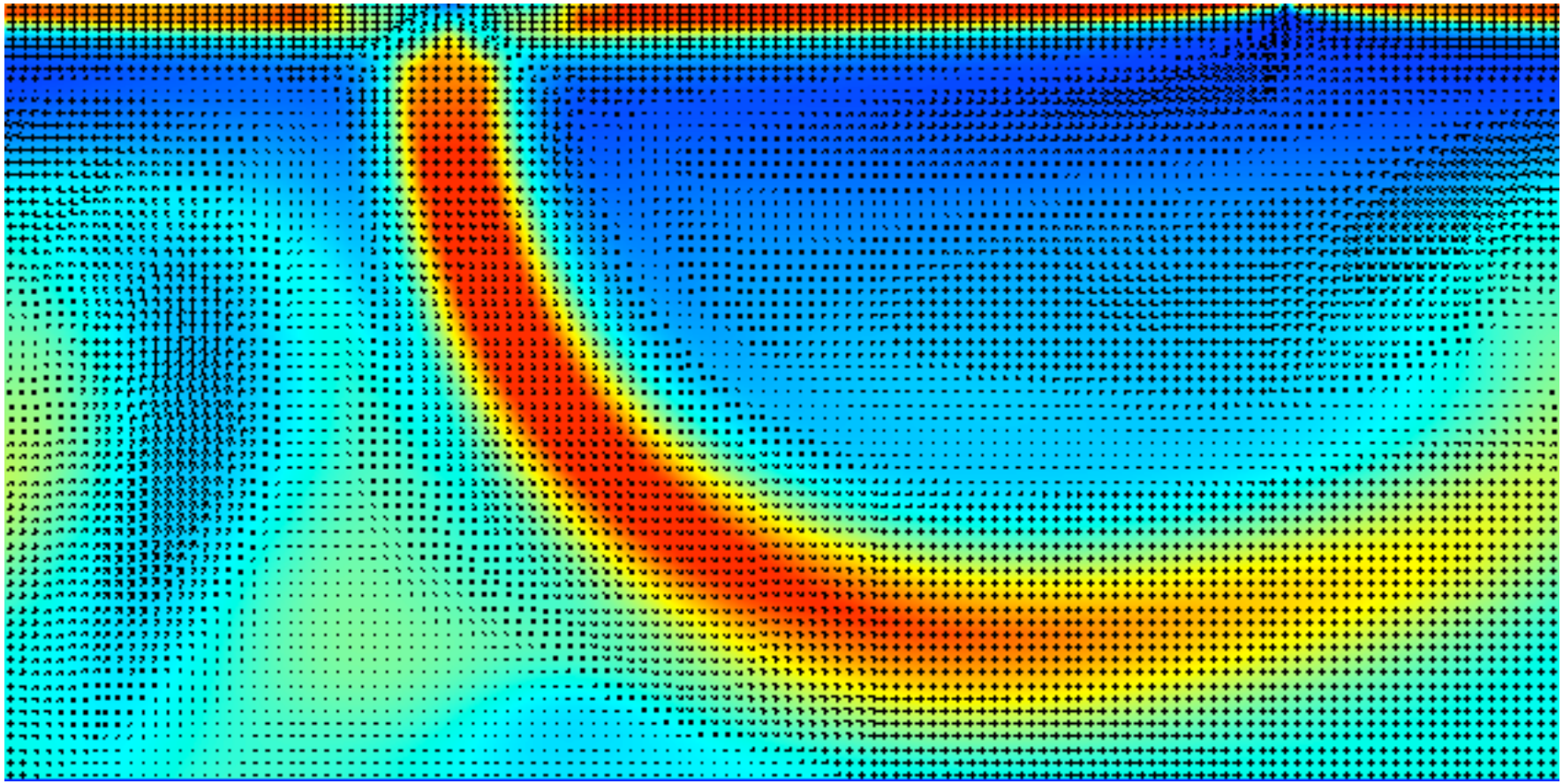
Paul Tackley,

F. Meilick, F. Crameri, T. V. Gerya, B. Kaus, T. Keller

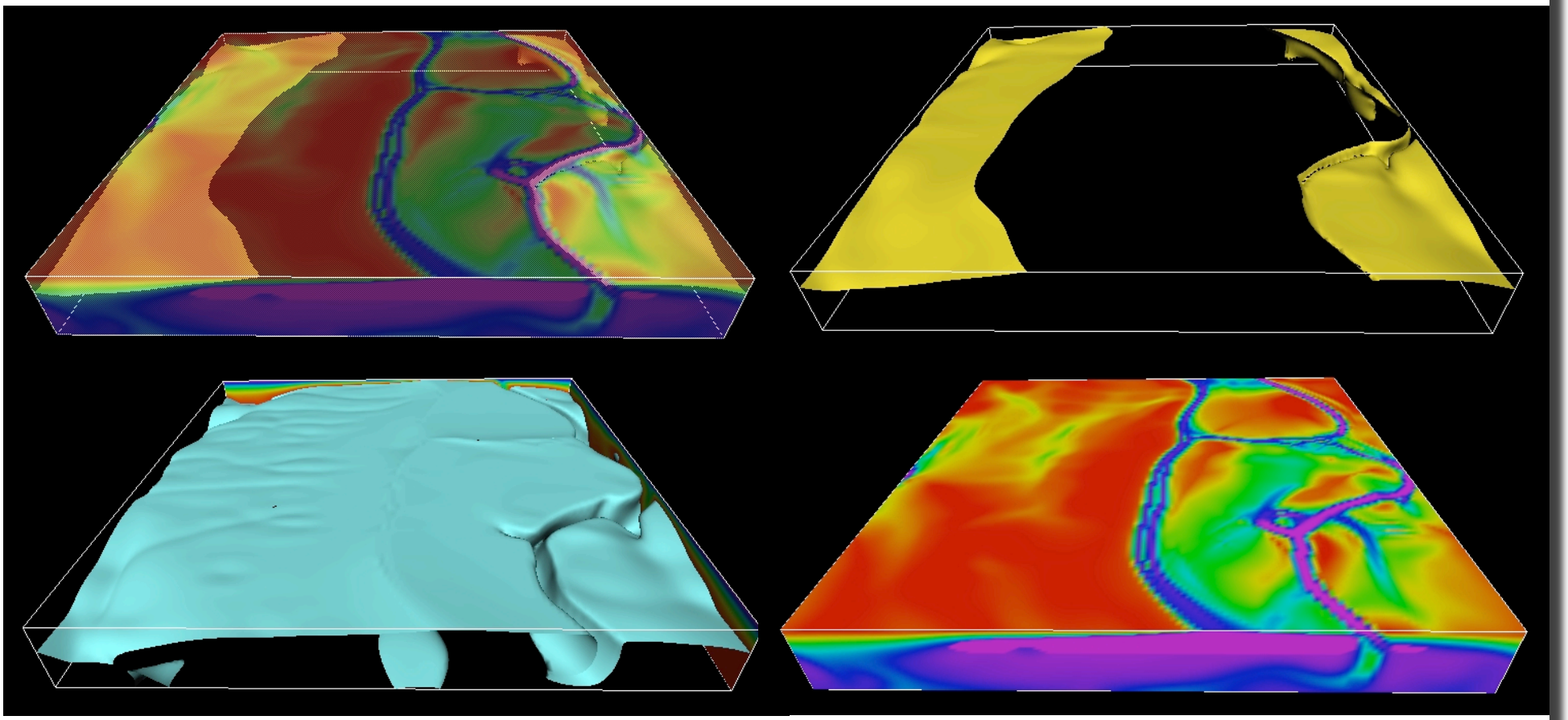
Institut für Geophysik, ETH Zürich



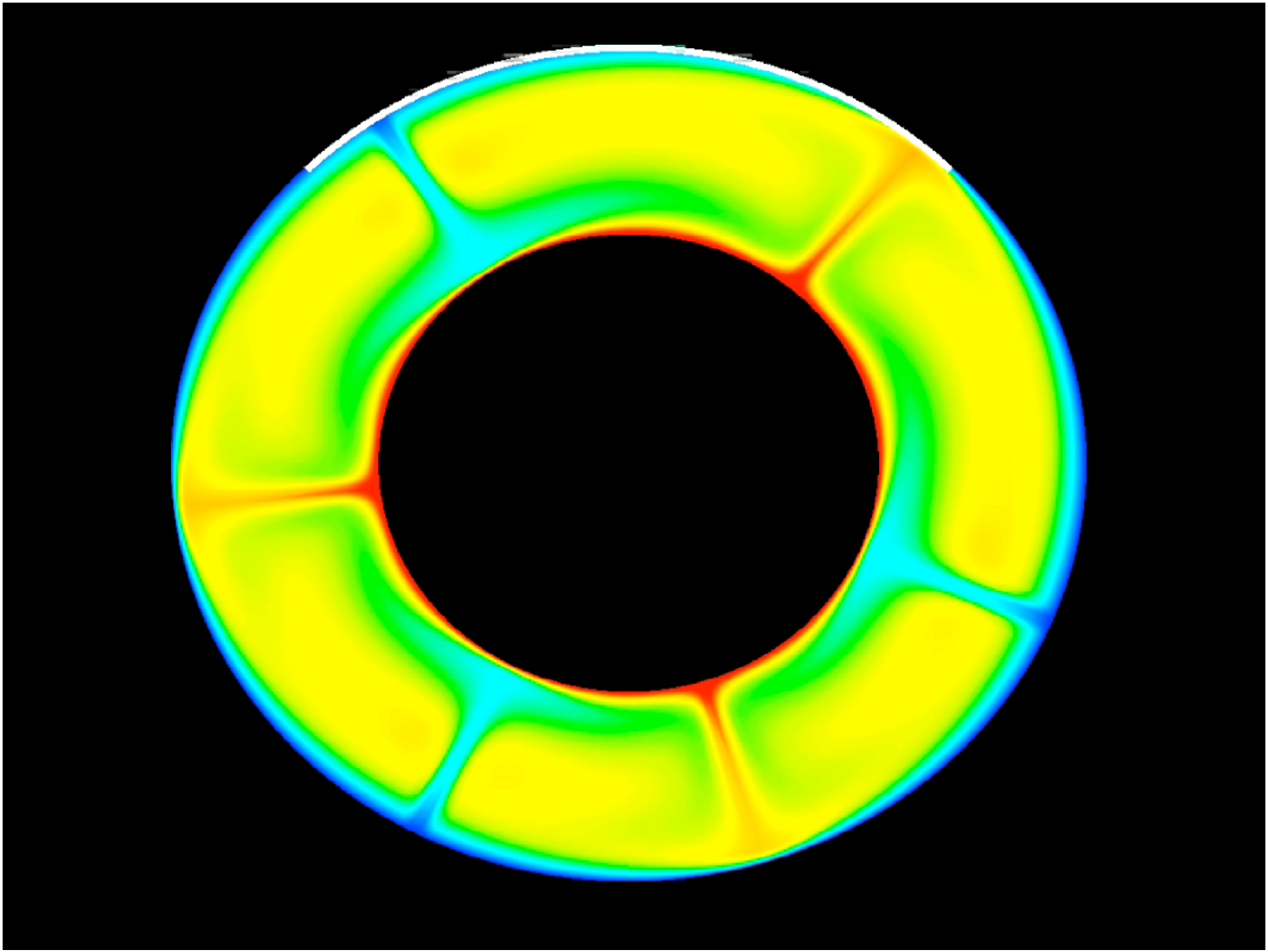
The problem: 2-sided subduction!



One solution: asymmetry due to continents



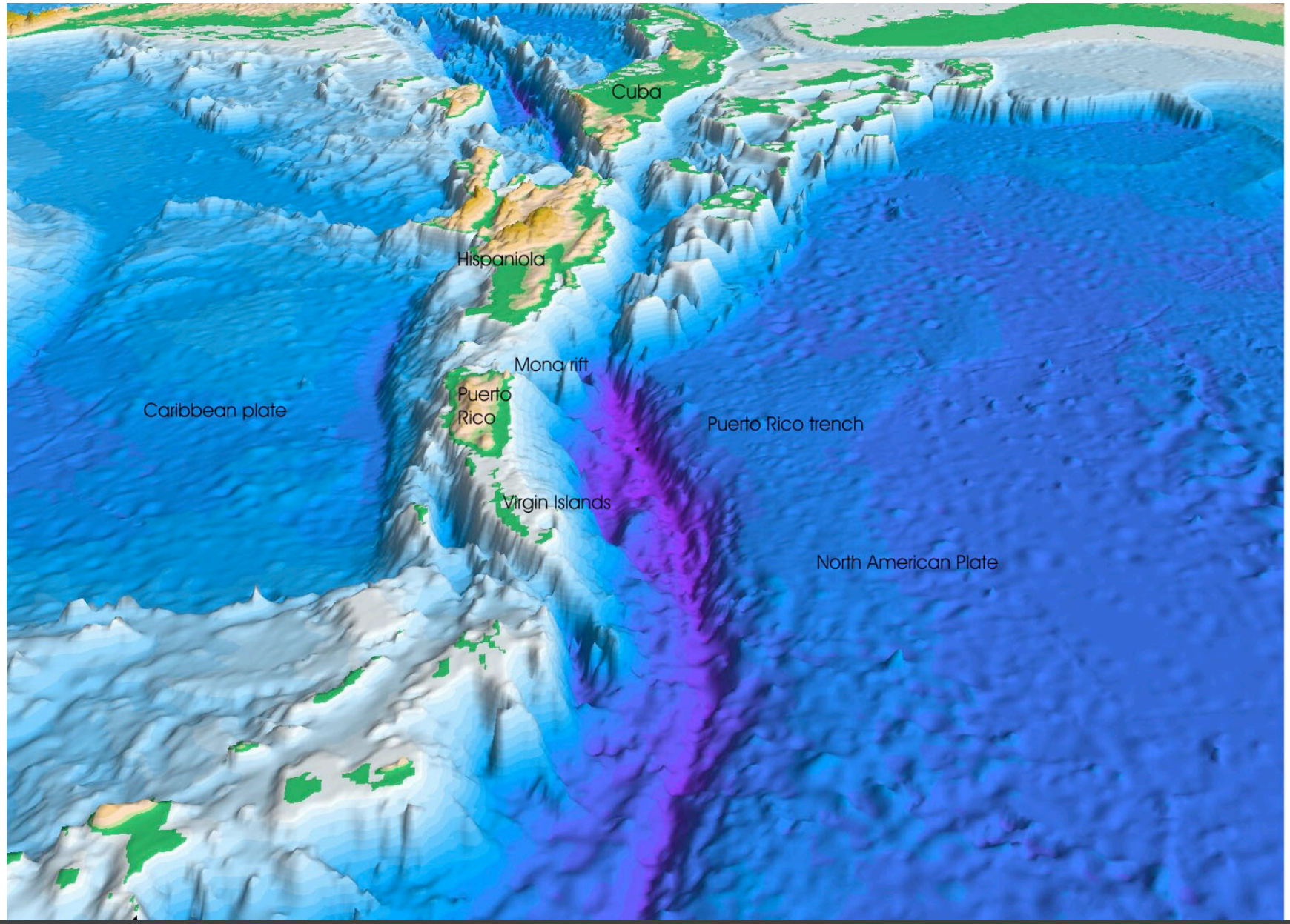
But on Earth, 1-sided ocean-ocean subduction also exists



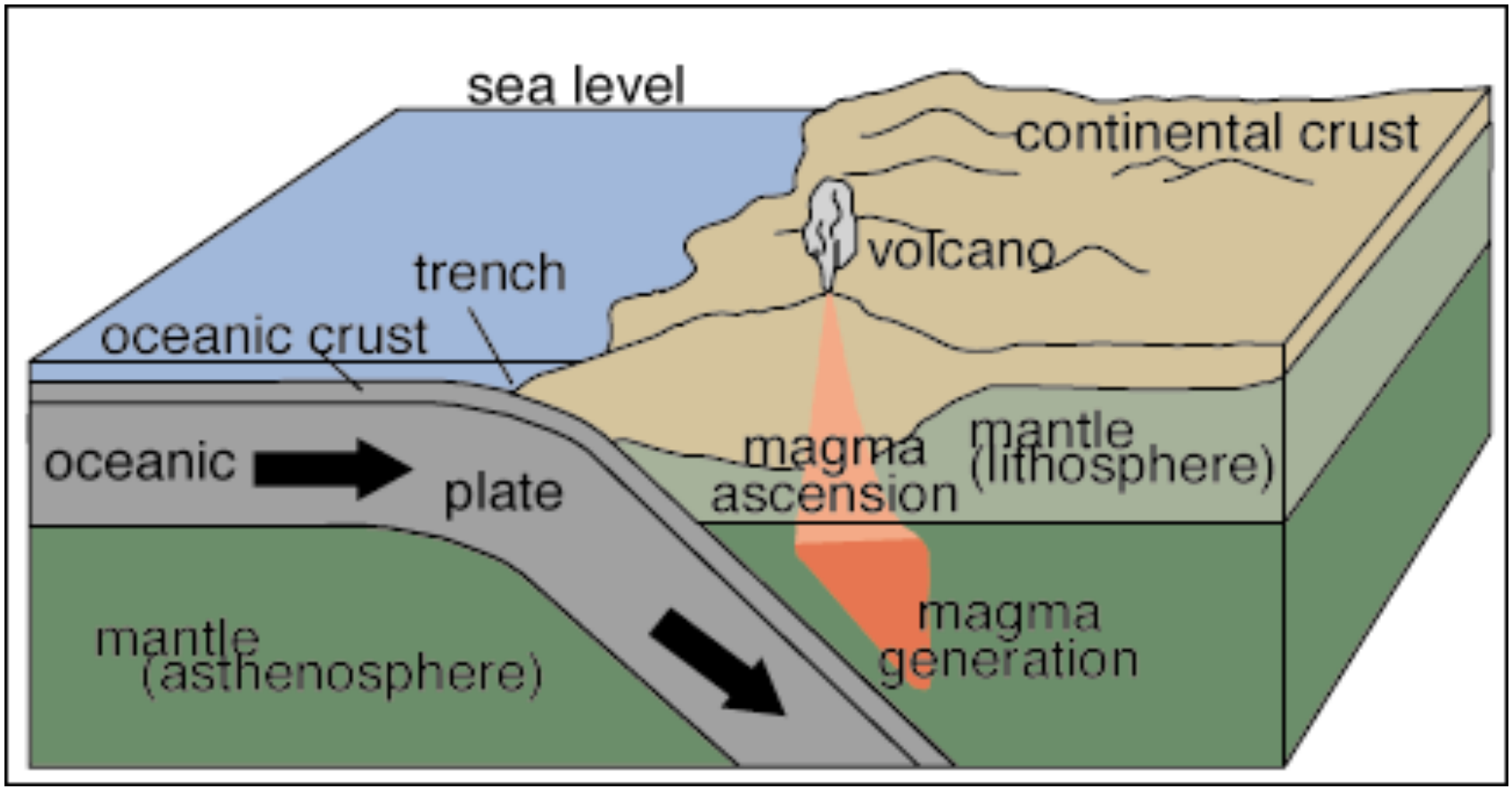
Mantle convection codes assume a free-slip boundary condition: surface is FLAT

- Zero shear stress but finite normal stress, proportional to what the topography would be if allowed.
- But this may create unnatural geometries at subduction zones….

Real subduction zone: NOT FLAT



Trench due to bending



Numerical models with a free surface: also get a trench

Physics of the Earth and Planetary Interiors 171 (2008) 198–223

A benchmark comparison of spontaneous subduction models—Towards a free surface

H. Schmeling[a,*], A.Y. Babeyko[a,b], A. Enns[a], C. Faccenna[c], F. Funiciello[c], T. Gerya[d], G.J. Golabek[a,d], S. Grigull[a,e], B.J.P. Kaus[d,g], G. Morra[c,d], S.M. Schmalholz[f], J. van Hunen[h]

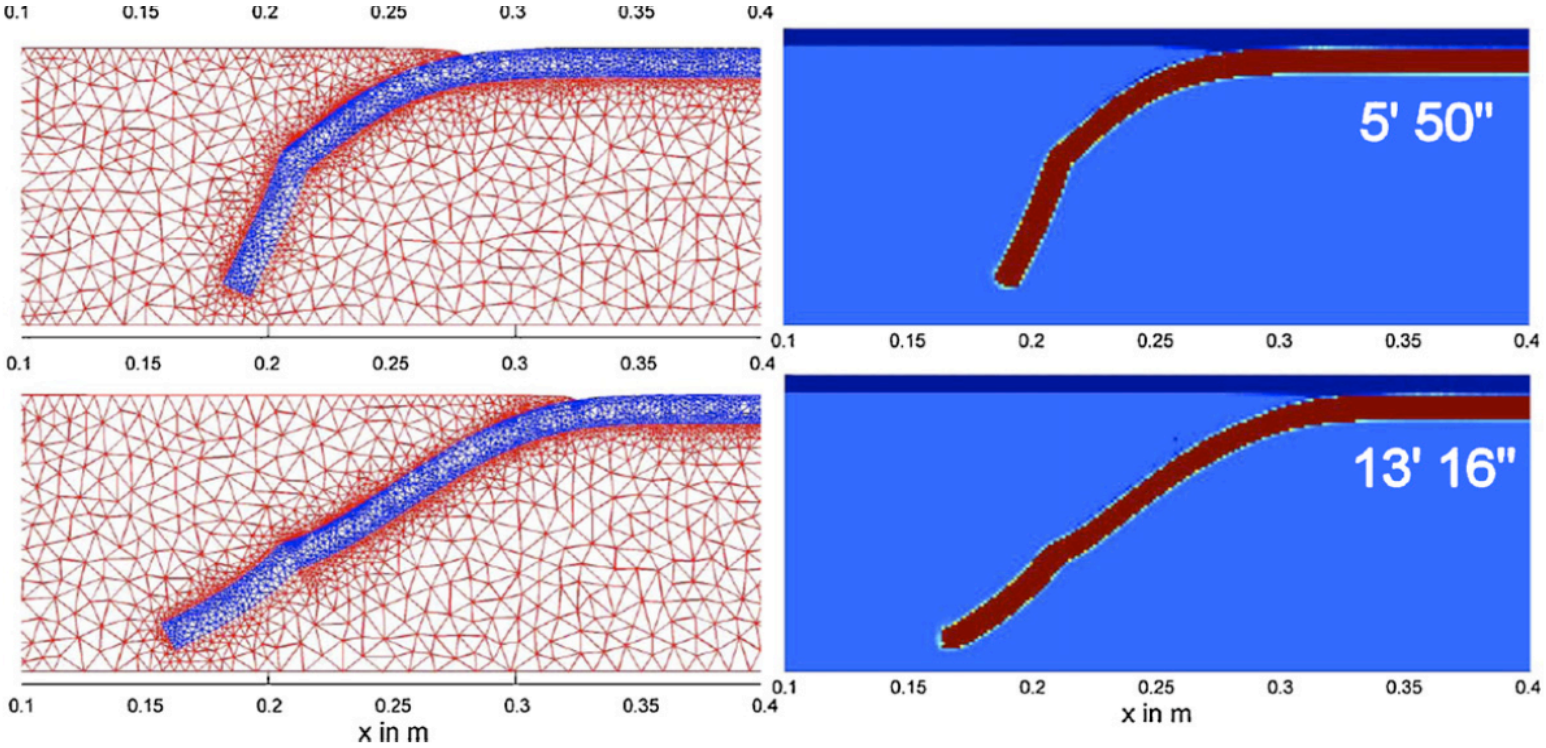


Fig. 16. Zoom in for viscosity snapshots of the FEMS-2D (left), FDCON (right) numerical models for times 57s, 5′ 50″, and 13′ 16″ which are comparable to the time steps presented for the laboratory experiment. For FDCON the harmonic mean for viscosity is used.

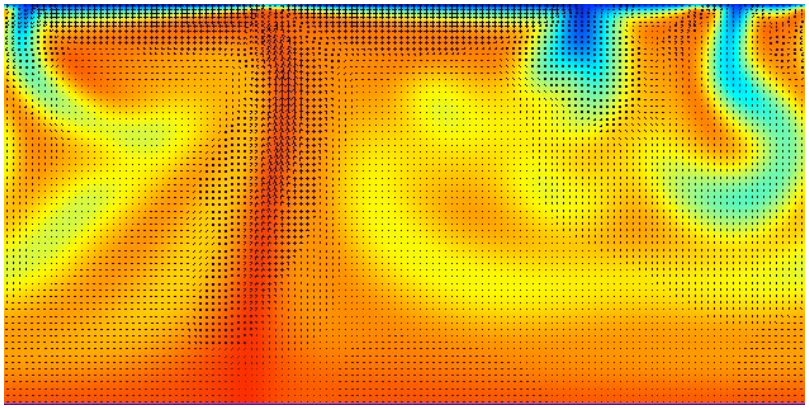
"Sticky-air" method gives same result as true free surface

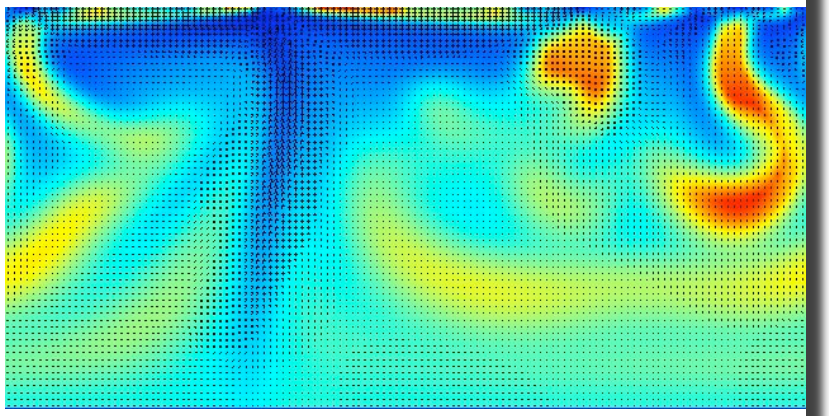
What effect does a free surface have on free convection with "self-consistent" plate tectonics?

- Run simple, Boussinesq convection models with strongly T-dependent viscosity
  - E_act for wet olivine, plus variable V_act
- …and depth-dependent (Byerlee's law-type) plastic yield stress,
  - Drucker-Prager yield criterion (2^{nd} invariant)
  - Specify friction coefficient
- Truncate to 9 orders of magnitude variation

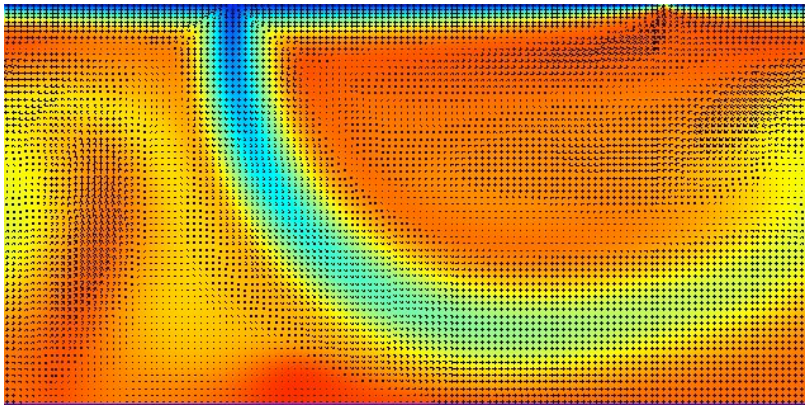
Free-slip (flat) upper boundary

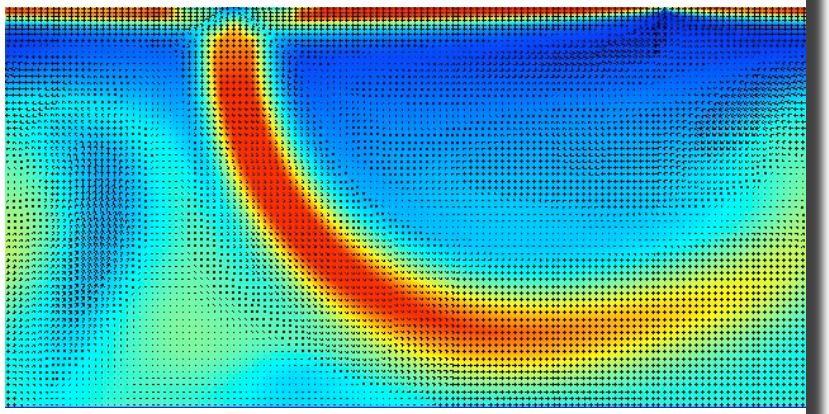
Friction=
0.03



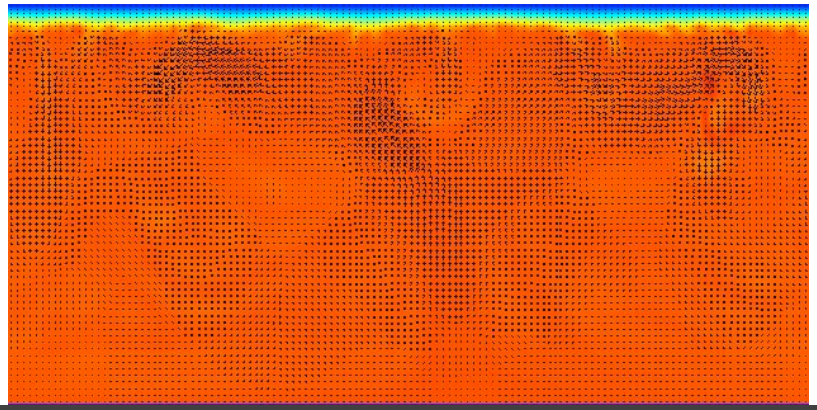


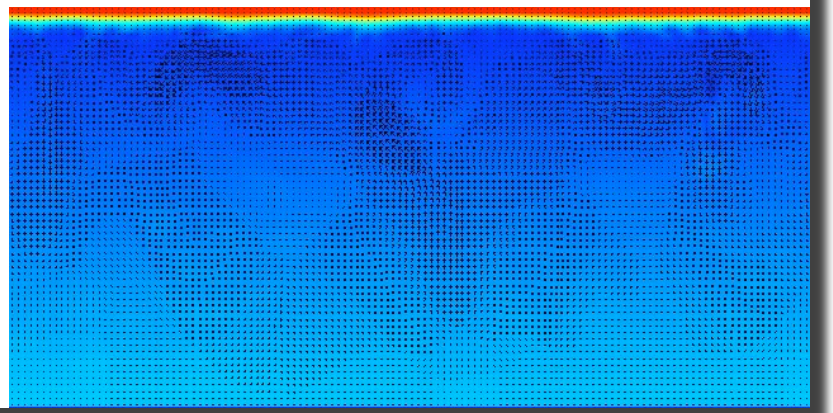
0.09





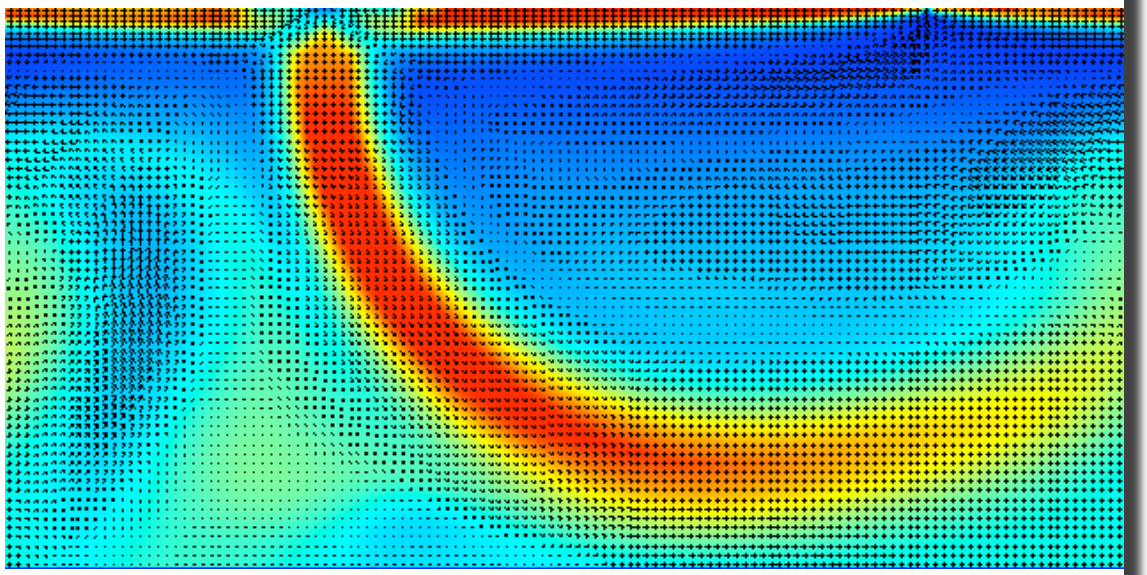
0.15



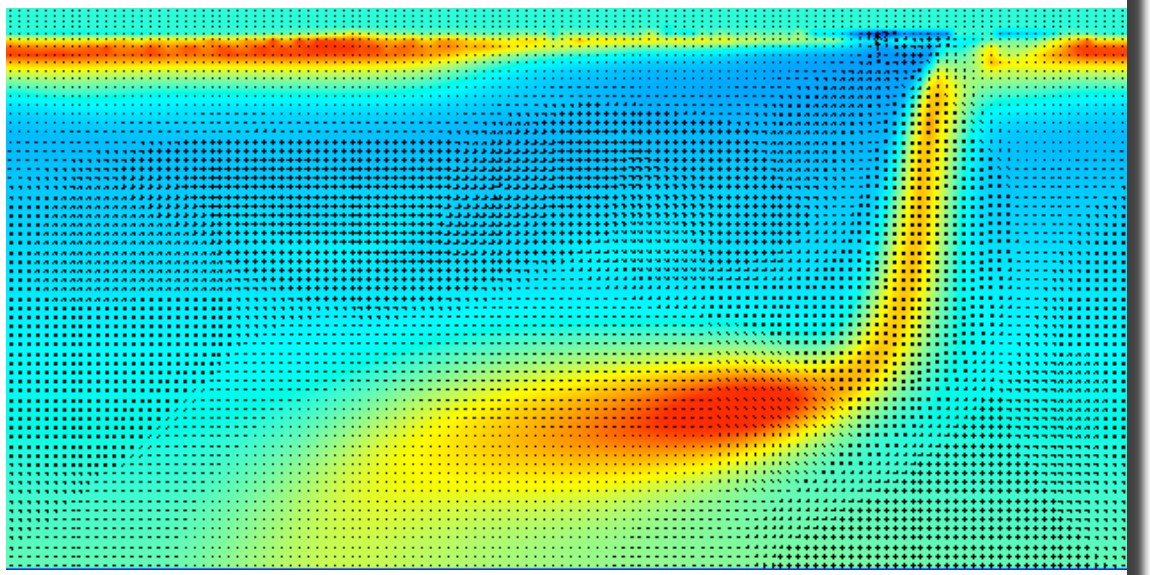


Free-slip to free comparison

Free-slip



Free surface



Single sided subduction!