CIG's Activities in and Impact on Mantle Convection Studies

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Outline

1) Community-building/driven Activities (workshops, working groups, and codes).

2) Impact on mantle convection studies (25 one-pagers).

3) Challenges and future outlook.

Community-building/driven activities:Workshops

- ***Mantle convection workshop at CU-Boulder in June, 2005 (organized by Kellogg, Lenardic, Parmentier & Zhong).***

  Defined the community needs (codes, benchmark, ...)
- ***Compressible mantle convection at Purdue in April, 2006 (organized by King & Zhong).***
- ***Mantle/lithospheric dynamics workshop at UC-Davis in July, 2008 (organized by Billen, Becker, King, & van Wijk).***
- ***Adaptive mesh refinement at CU-Boulder in October, 2007 (organized by Bangerth & Zhong).***

Community-Driven activities: Working groups

- ***On compressible mantle convection (King, van Keken, Gurnis, Moresi, Tan, Zhong, …).***
- ***On development of 1-D analytical codes (Becker, Steinberger and others).***
- ***On acquisition of various convection codes.***

Mantle Convection Codes: Available at CIG

- ***CitcomS (3D spherical convection: compressibility, thermochemical, and non-Newtonian rheology, …)***

  Latest release version 3.0.3 in September, 2008

- ***CitcomCU (3D Cartesian and regional spherical)***

  Latest release version 1.0.2 in May, 2007.

- ***Ellipsis3d (3D Cartesian)***

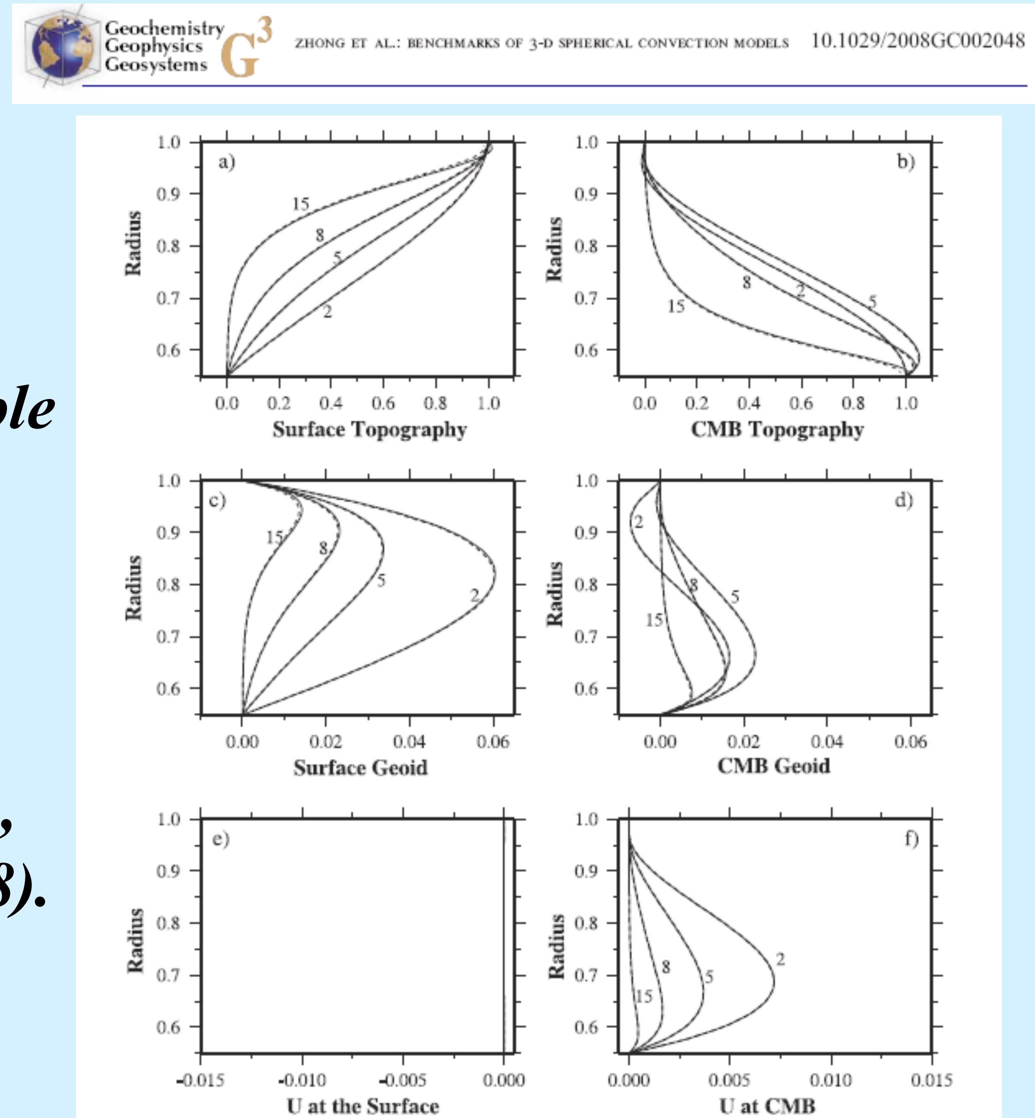
  Latest release version 1.0.2 in April, 2007.

- ***ConMan (2D Cartesian)***

  Latest release in September, 2008.

Community-Driven activities: Benchmark efforts

- ***Extensive benchmark of incompressible CitcomS (Zhong et al., G^3, 2008).***
- ***Benchmark of compressible CitcomS (Tan et al., in preparation).***
- ***Cartesian 2-D/3-D compressible convection (King, and other 5 groups, a poster at Fall AGU 2008).***



Outline

1) Community-building/driven Activities (workshops, working groups, and codes).

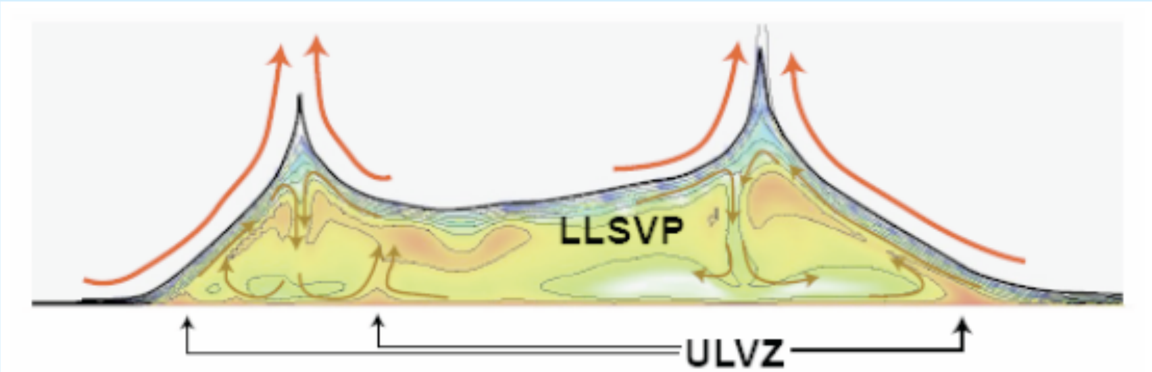
2) Impact on mantle convection studies (25 one-pagers).

3) Challenges and future outlook.

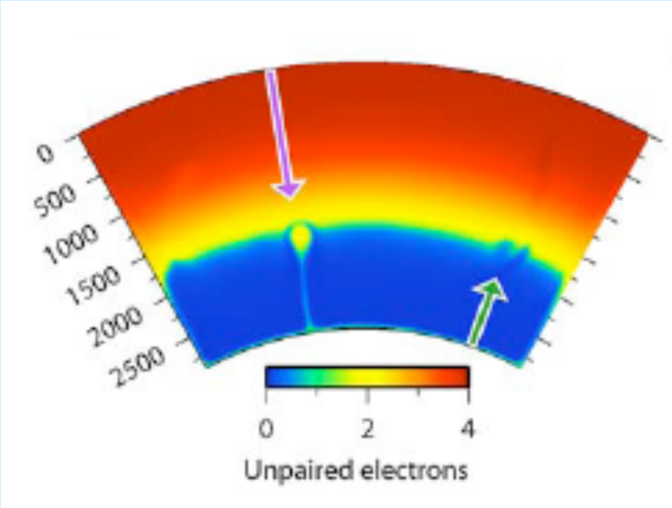
1) Enabling (direct) linkage between mantle convection and seismic observations and mineral physics

- **Bower, D.J., M. Gurnis, J.M. Jackson, and W. Sturhahn,** ***Enhanced Convection and Fast Plumes in the Lower Mantle Induced by the Spin Transition in Ferropericlase***
- **Bull, A., A. McNamara, and J. Ritsema,** ***Synthetic tomography of plume clusters and thermochemical piles***
- **Conrad, C., and M. Behn,** ***Global Mantle Flow and the Development of Seismic Anisotropy***
- **Garnero, E., T. Lay, and A. McNamara,** ***Implications of lower mantle structural heterogeneity for existence and nature of whole mantle plumes***

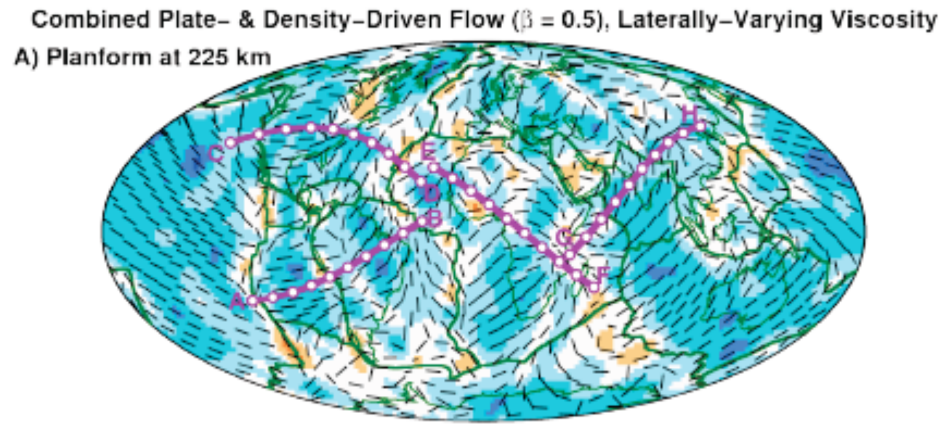
Examples: Enabling (direct) linkage between mantle convection and seismic observations and mineral physics



Garnero, Lay, and McNamara

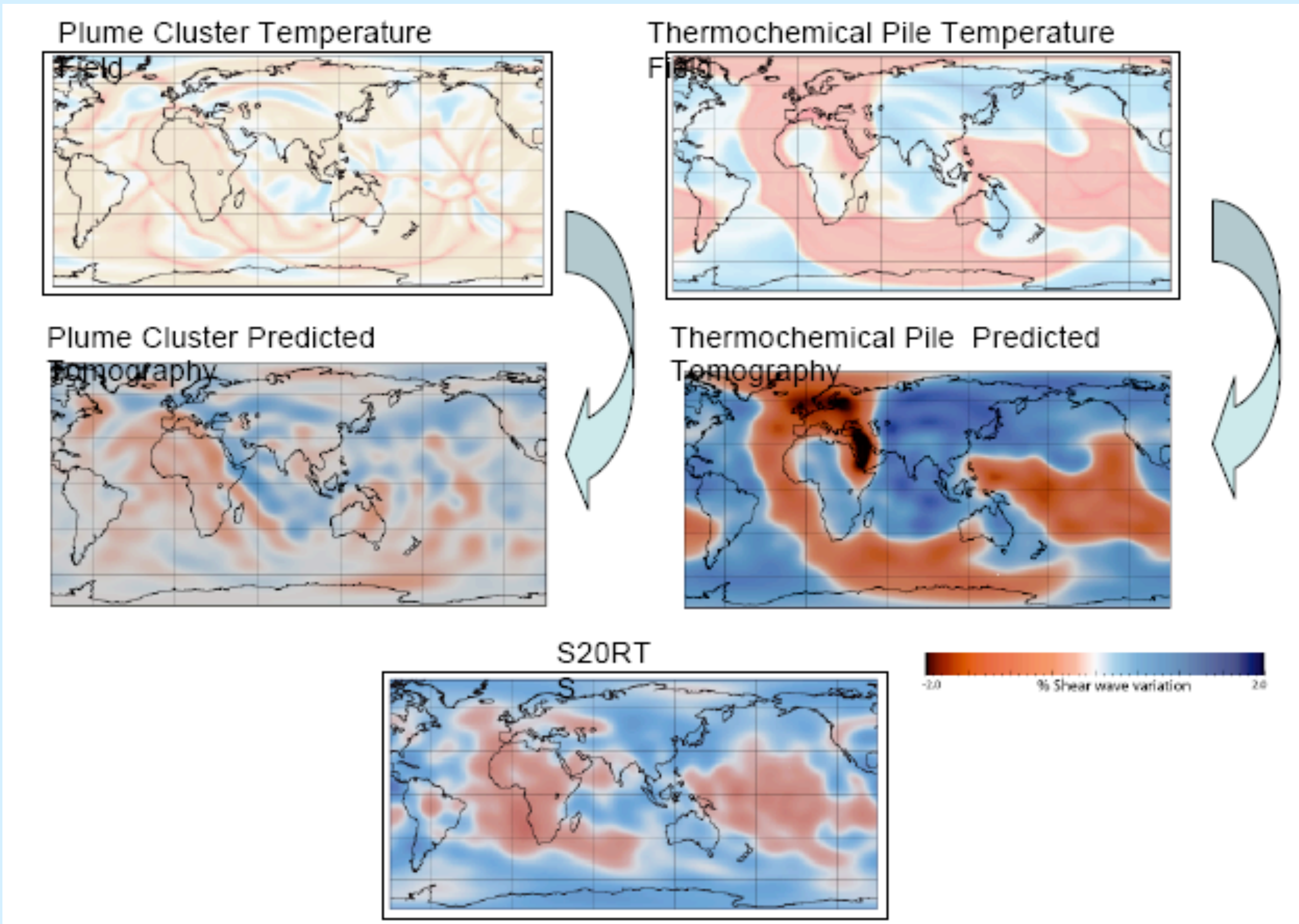


Bower et al.



Conrad and Behn

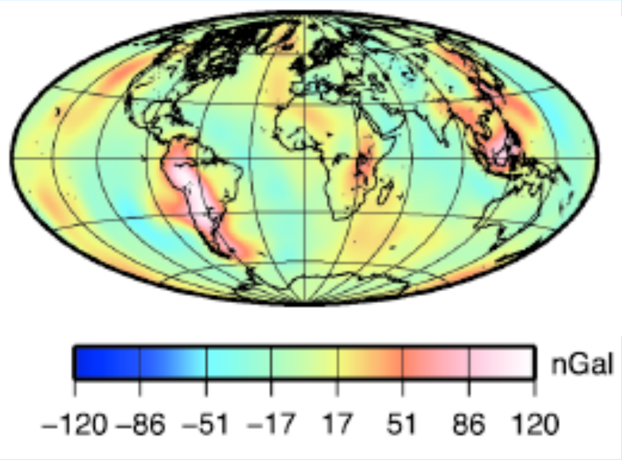
Examples: Enabling (direct) linkage between mantle convection and seismic observations and mineral physics



Bull, McNamara and Ritsema

2) Mantle convection and Earth's tides and gravity

- **Métivier, L., and C. Conrad,** ***Body Tides of a Convecting, Laterally Heterogeneous, and Aspherical Earth*** →



- **Ghosh, A., T. Becker, and S. Zhong,** ***Effect of lateral viscosity variations on mantle flow and the geoid***

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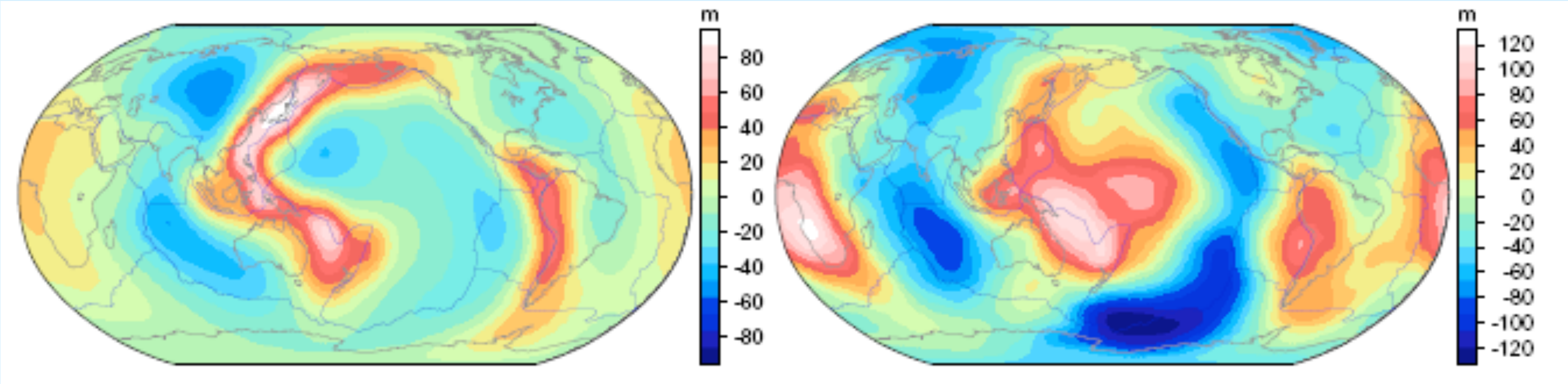
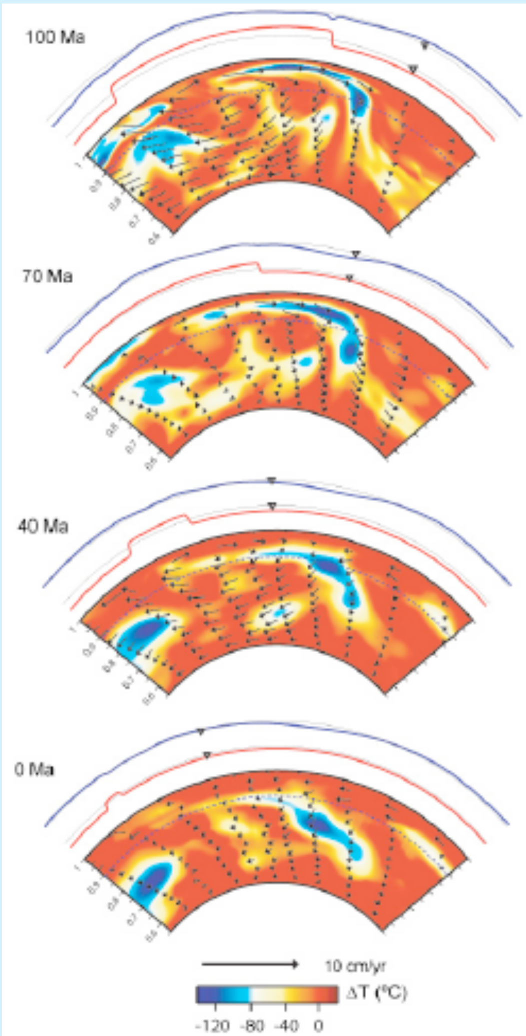


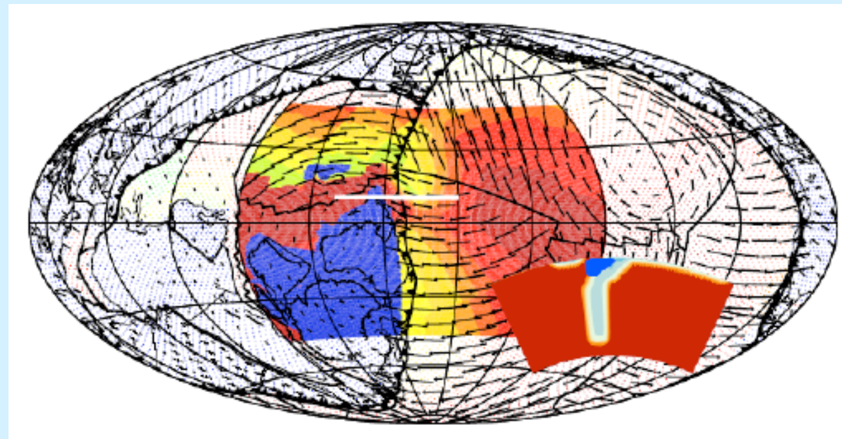
3) Mantle convection and geological history of dynamic topography and sea level change

- **Conrad, C., and L. Husson***, Influence of Dynamic Topography on Sea Level and its Rate of Change*
- **DiCaprio, L., M. Gurnis, R.D. Müller, and E. Tan***, History of the Australian region since the Cretaceous: Assimilation plate tectonic data into a regionally-globally coupled geodynamic model*
- **Liu, L., S. Spasojevic, and M. Gurnis***, Reconstructing Farallon Plate Subduction beneath North America back to the Late Cretaceous*
- **Liu, L., and M. Gurnis***, Simultaneous inversion of mantle properties and initial conditions using an adjoint of mantle convection*
- **Spasojevic, S., M. Gurnis, and R. Sutherland,** *Inference of mantle properties with an evolving dynamics model of the Antarctica-New Zealand region*
- **Spasojevic, S., L. Liu, and M. Gurnis***, North America regional sea level since the Late Cretaceous from adjoint convection models*

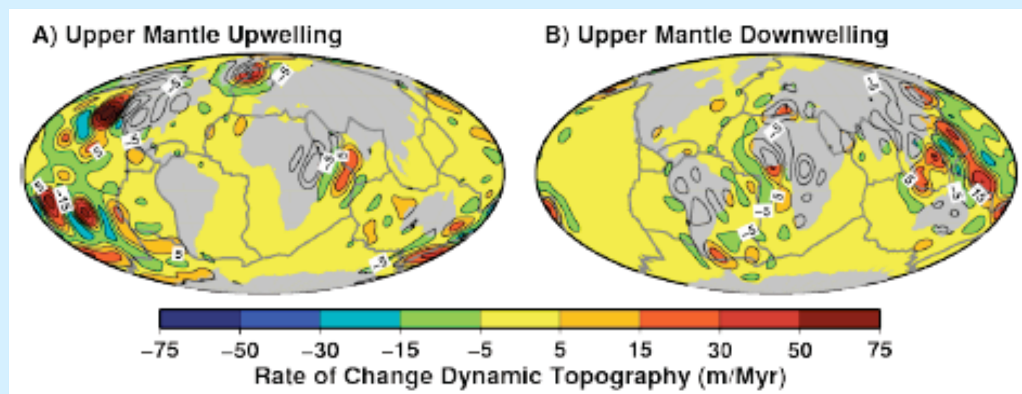
Examples: Mantle convection and geological history of dynamic topography and sea level change



Liu, Spasojevic, & Gurnis



DiCaprio, Gurnis, Müller, Tan

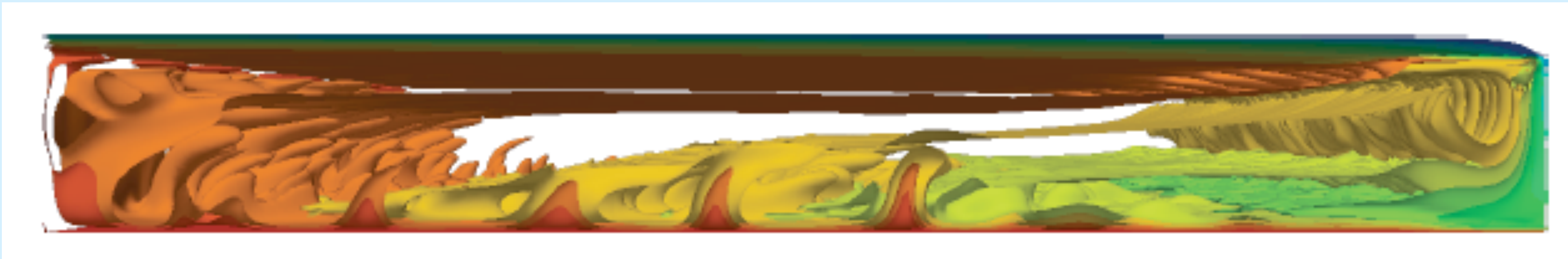


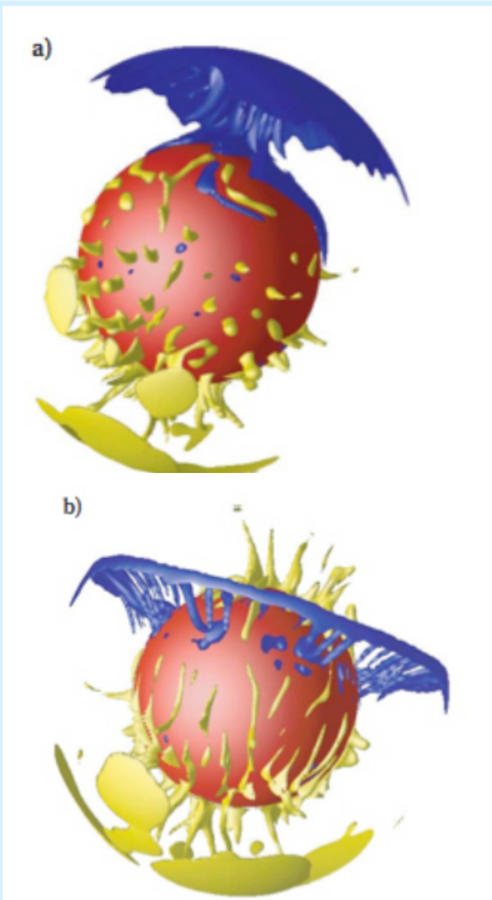
Conrad & Husson

4) Planform of mantle convection and dynamics of plate tectonics

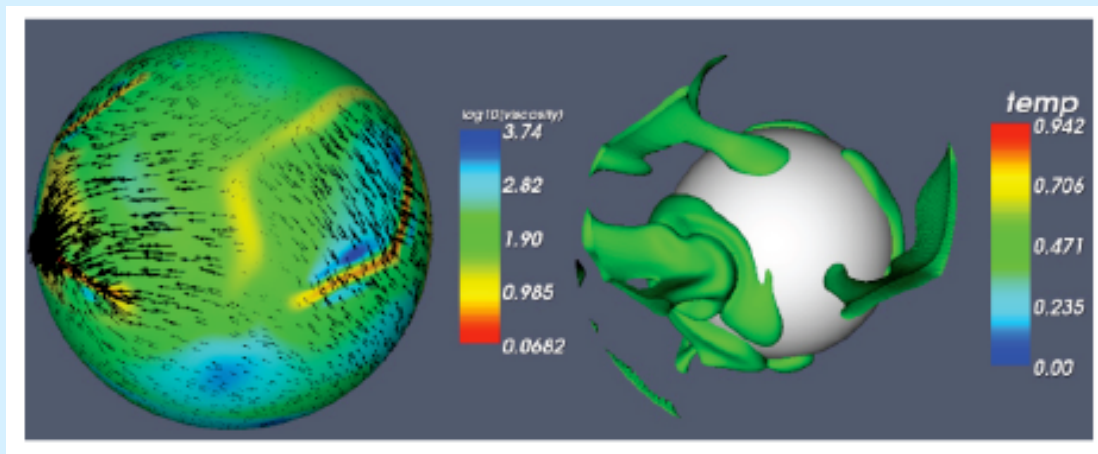
- **Conrad, C., and C. Lithgow-Bertelloni,** ***Influence of Continental Roots and Asthenosphere on Plate-Mantle Coupling***
- **Foley, B.J., and T.W. Becker,** ***Generation of Plate Tectonics and Mantle Heterogeneity from a Spherical, Visco-plastic Convection Model***
- **Höink, T., and A. Lenardic,** ***Three-dimensional mantle convection simulations with a low-viscosity asthenosphere***
- **Tan, E., W. Leng, S. Zhong, and M. Gurnis,** ***The convection planform of a dense chemical layer with higher bulk modulus***
- **Zhong, S.J., N. Zhang, Z.X. Li, and J.H. Roberts,** ***Very Long-wavelength Convection, True Polar Wander and Supercontinent Cycles***

Examples: Planform of mantle convection and dynamics of plate tectonics





Höink & Lenardic

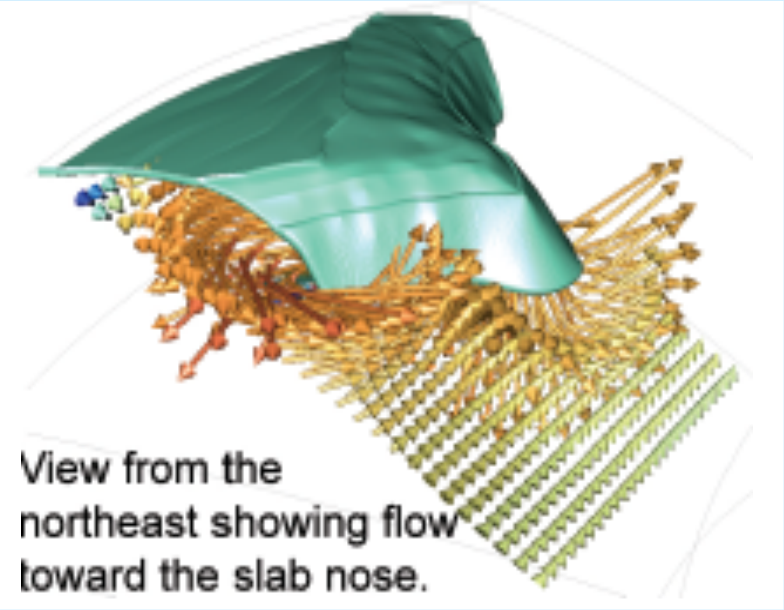


Foley & Becker

Zhong, Zhang, Li, & Roberts

5) Dynamics of downwellings and upwellings

- **Burkett, E., and M. Billen*, 2D Dynamics of Slab Detachment Due to Ridge-Trench Collision***
- **Jadamec, M., and M. Billen, *Mantle Flow at a Subduction-Transform Plate Boundary***
- **Manea, V., and M. Gurnis, *Reconstructing of Flat Slab Subduction and Detachment beneath Central Mexico***
- **Zhong, S.J. and W. Leng*, Constraints on thermochemical convection of the mantle from plume heat flux, plume excess temperature and upper mantle temperature***

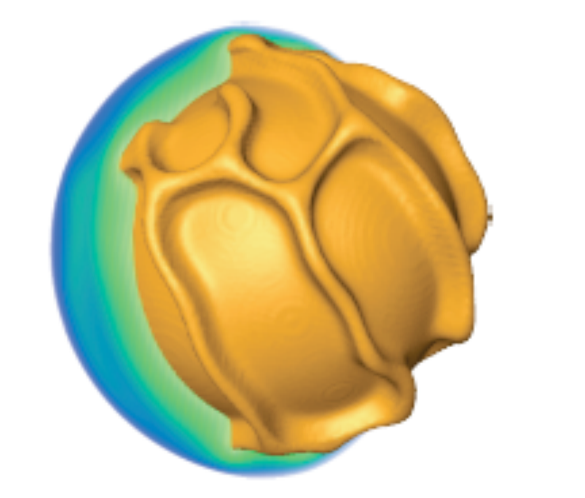


Jadamec and Billen

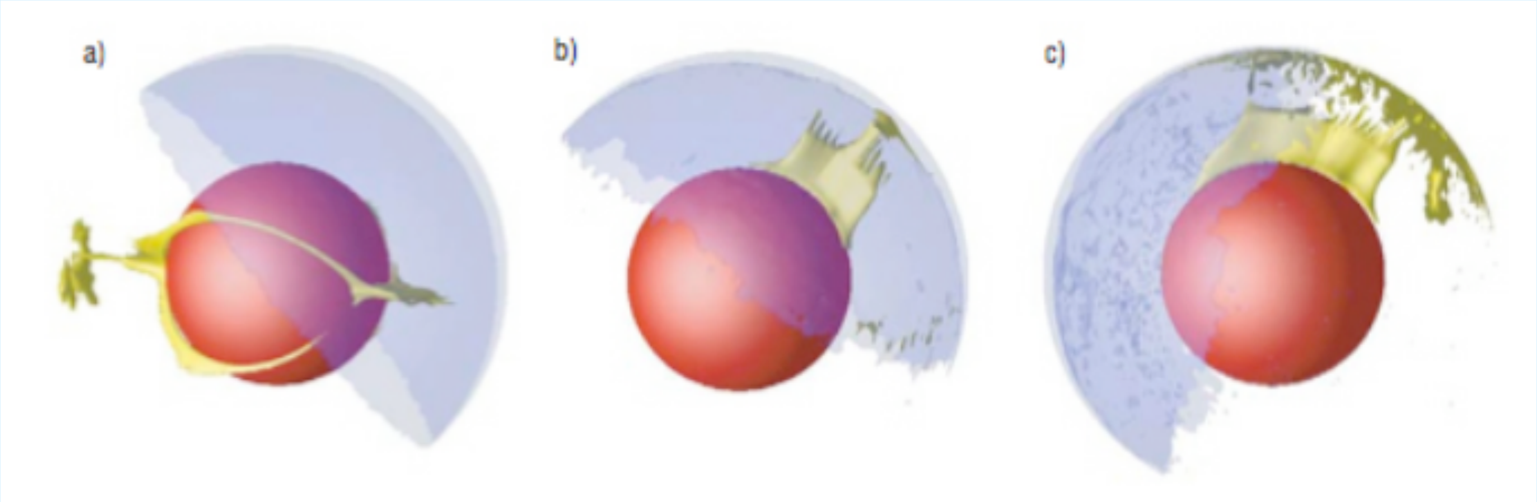
6) Other Planets (Mercury & Mars)

- **King, S.D.,** ***More Thoughts on Tharsis Rise Mars and Small-Scale Convection***
- **King, S.D.,** ***Unusual Pattern of Convection in a Thin Mantle Shell and the Connection to Tectonics on Mercury***
- **Roberts, J.H., R.J. Lillis, and M. Manga,** ***Giant impacts on early Mars and the cessation of the Martian dynamo***
- **Zhong, S.J.,** ***Migration of Tharsis volcanism on Mars caused by differential rotation of the lithosphere***

Examples: Other planets



King



Zhong

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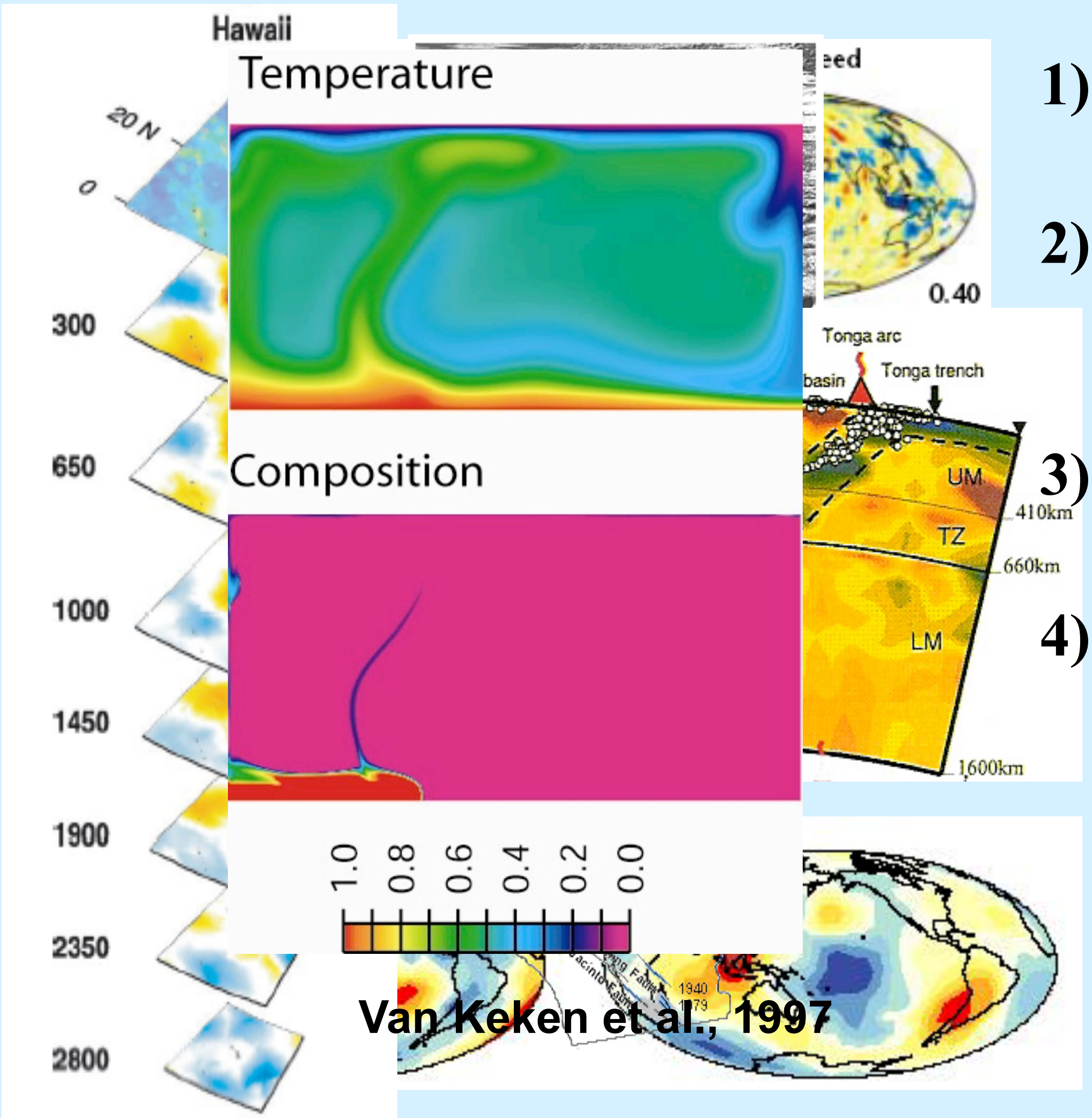
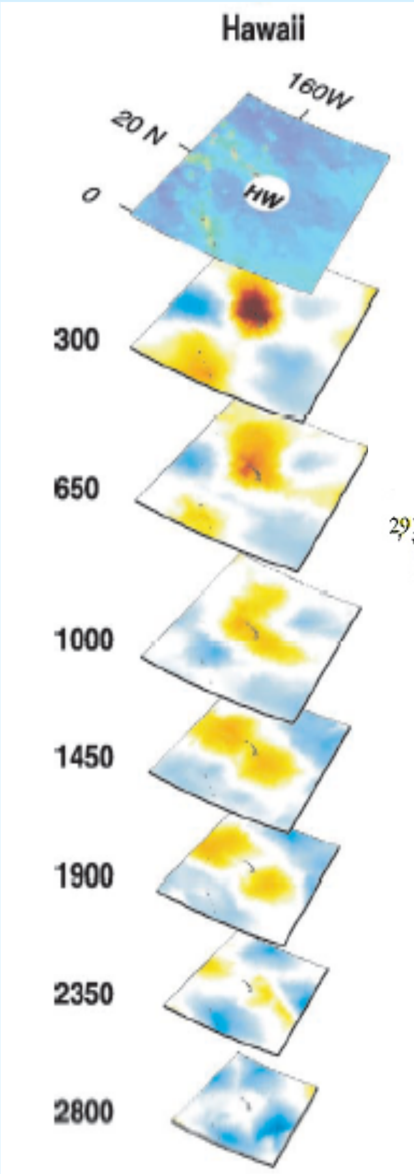
Multi-scale (from 10^0 km to 10^4 km) Physics

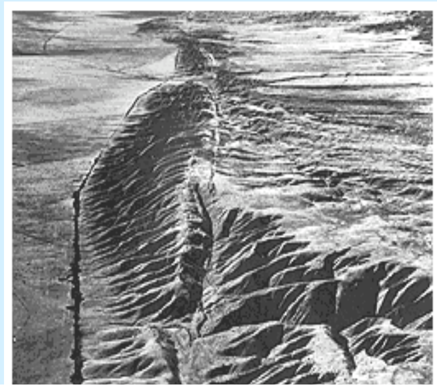


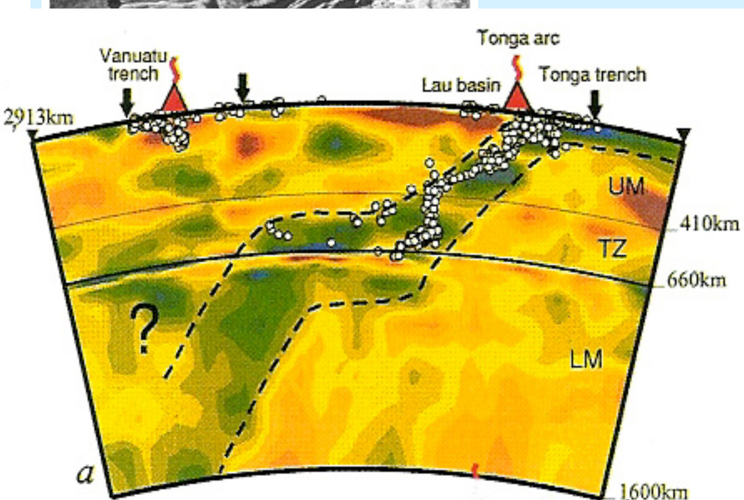
Van Keken et al., 1997

1) **Plate margins and faults:** ~1- 10^2 km.
2) **Upwelling and downwellings:** ~ 10^2 km.
3) **Chemical entrainment:** ~ 1-10^2 km.
4) **Plate scales:** ~ 10^3-10^4 km.

Nonlinear and Highly Variable Rheology





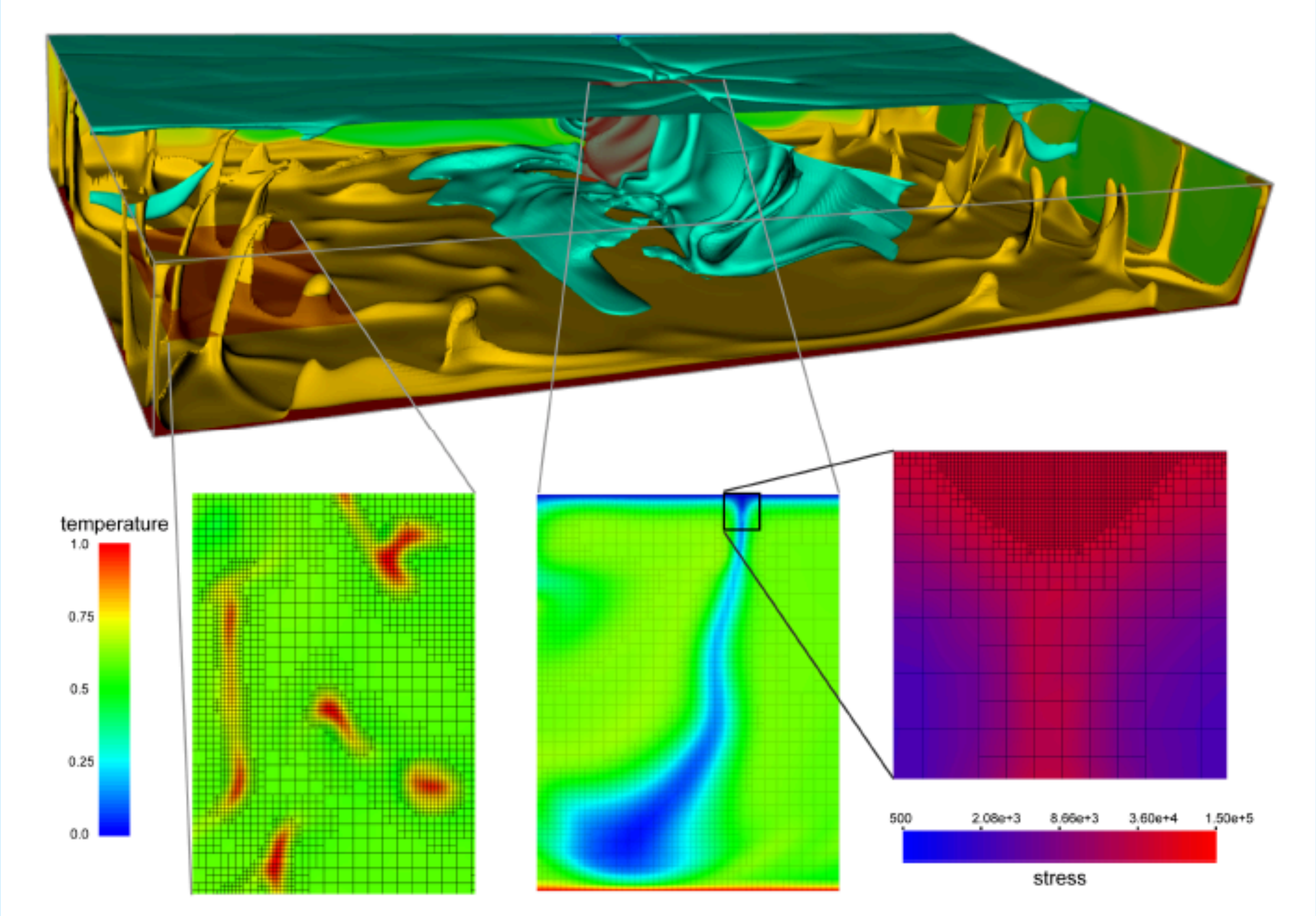


1) **Faulting and Plastic deformation: nonlinear**
2) **Highly temperature-dependent viscosity for silicate mantle (up to 3 orders of magnitude variations in plumes and downwellings).**

Ongoing and Future Developments

- ***Better treatment of multi-scale processes (both physics and numerics).***
- ***Adaptive mesh refinement (AMR) [Davies & Davies, 2008; Leng & Zhong, 2008 – 2D studies; Bangerth's deal-II].***
- ***Efficient AMR on ~60K cores [Burstedde et al., 2008 – a collaborative effort by UT-Austin, Caltech, & UC-Boulder]***
- ***…***

A new code: Rhea (octree-based AMR & massively parallel; local resolution to 1.5 km!)



Burstedde et al. [2008]