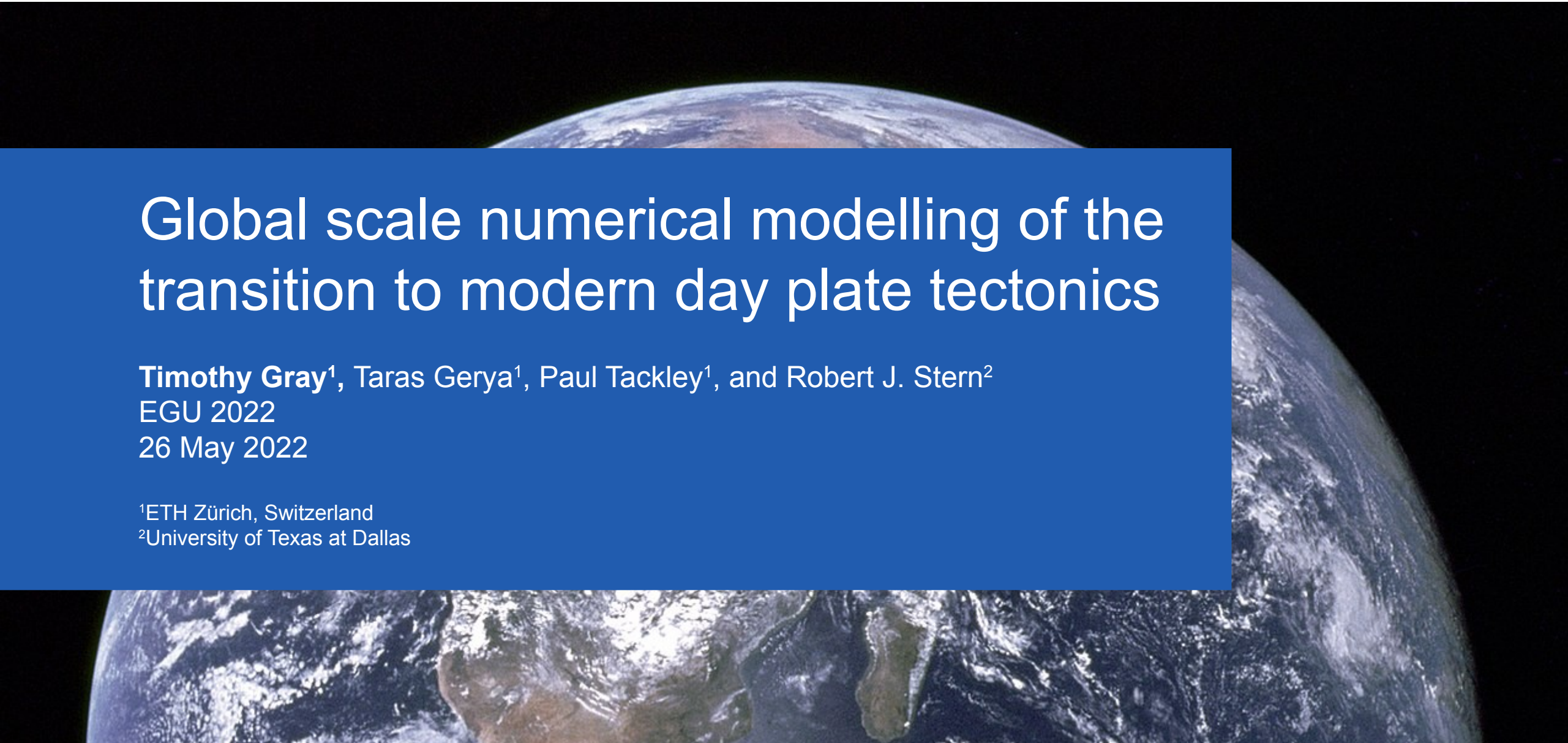
ETH zürich



Global scale numerical modelling of the transition to modern day plate tectonics

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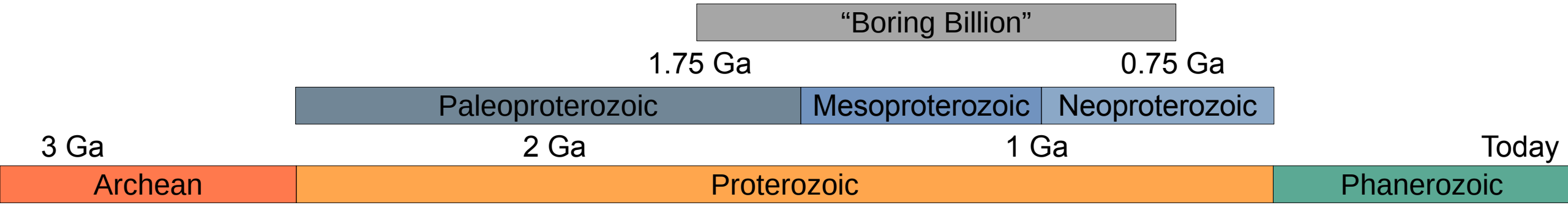
A big change – Transition to modern plate tectonics

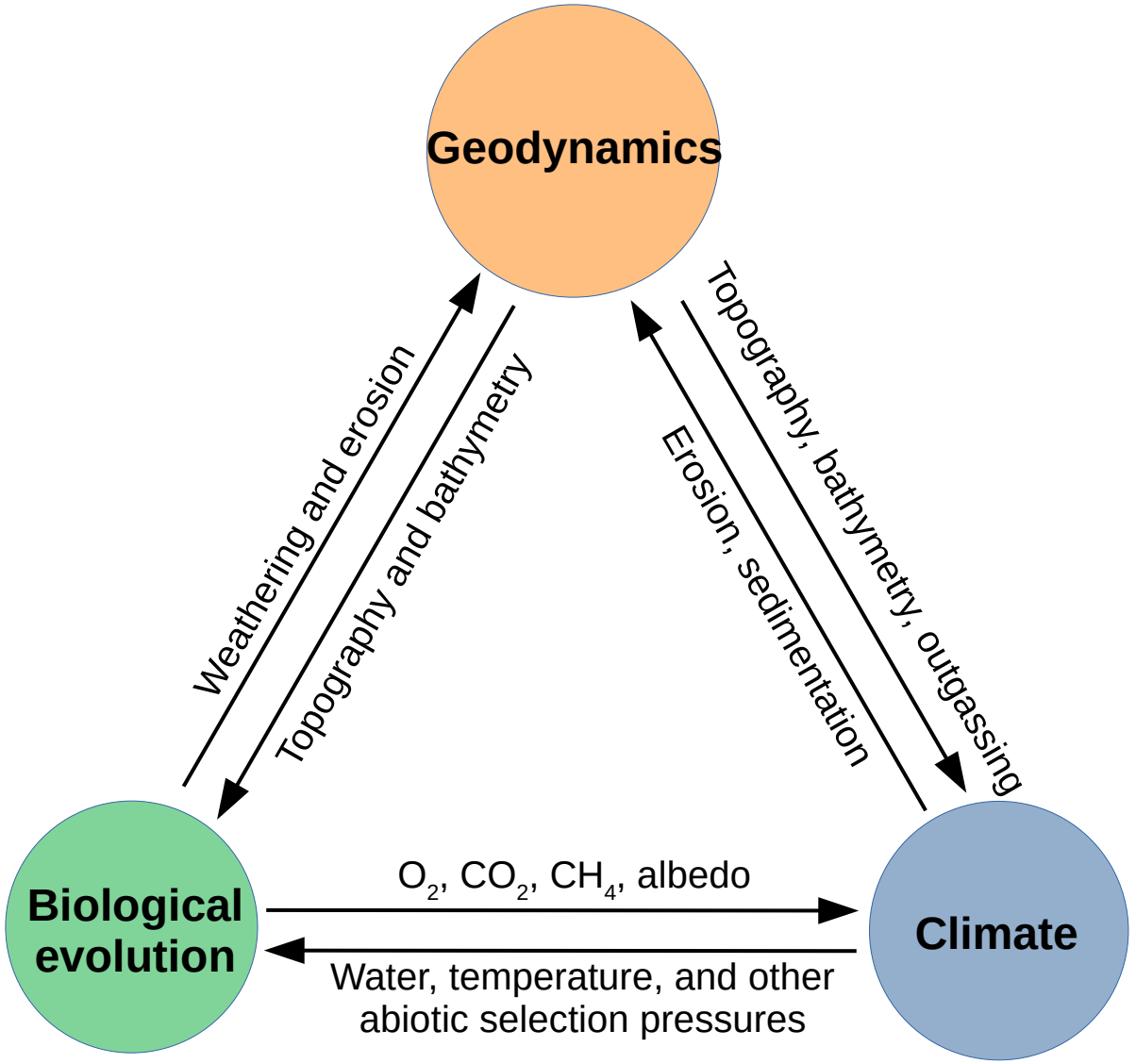


Neoproterozoic transition to modern style PT?

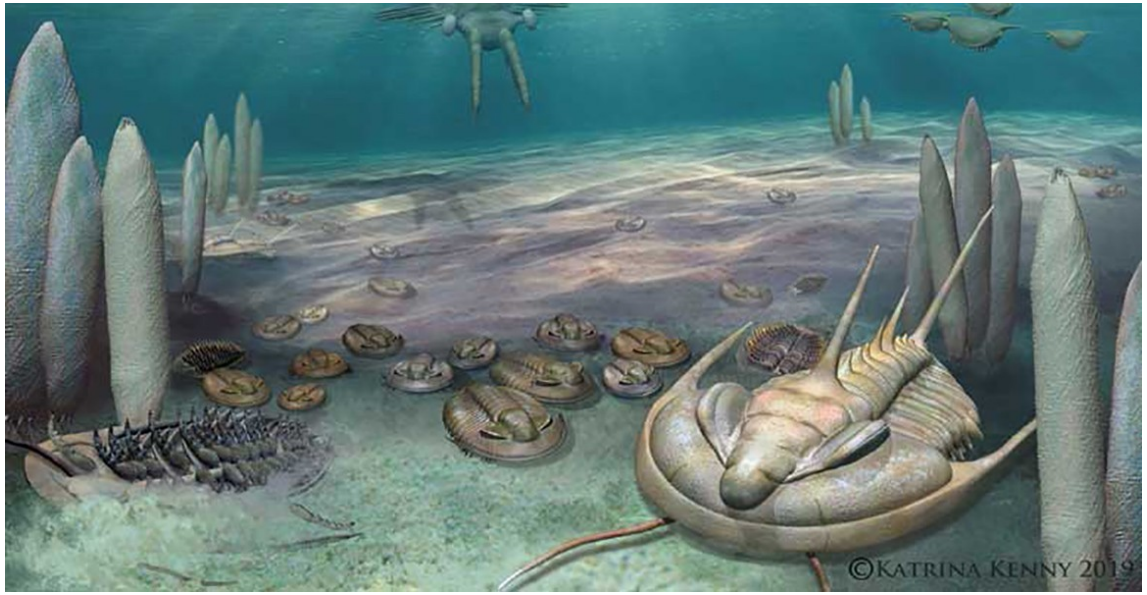
Evidence:
- Ophiolites
- Secular cooling of the mantle
- Geochemical markers

Stern, 2008

Motivation – Coupled earth systems

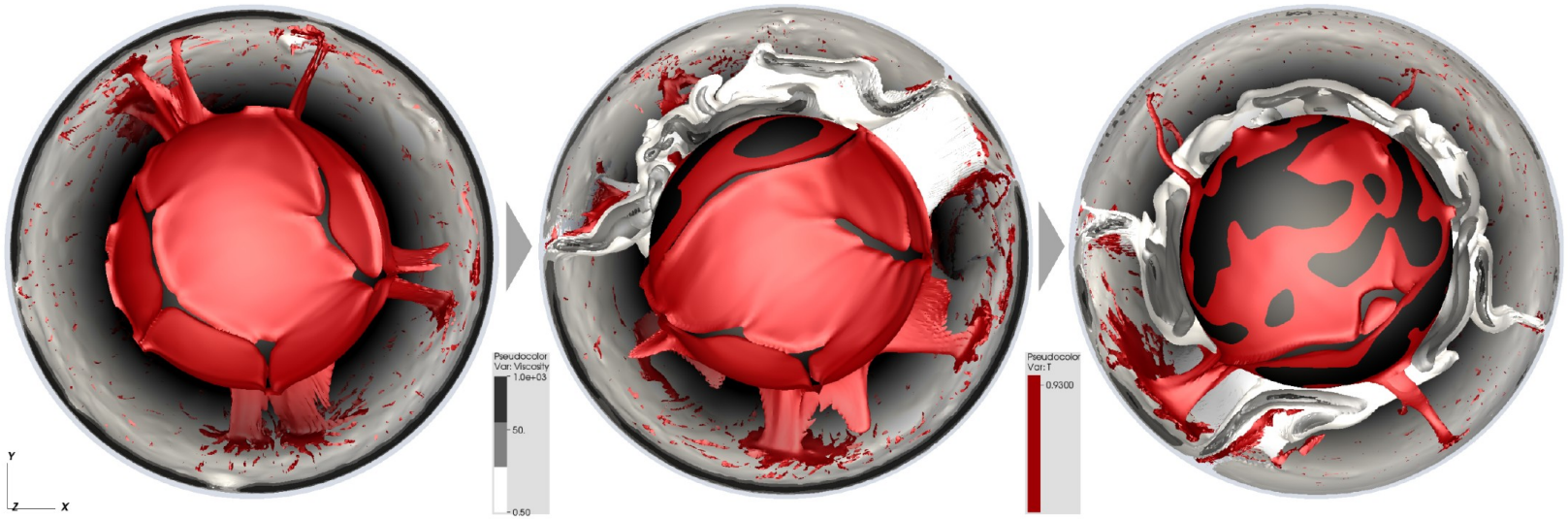


- Coupled study of geodynamic, climactic, and biological processes
- Emerging field with large research potential
- Cambrian explosion or snowball earth associated with transition to modern day plate tectonics?

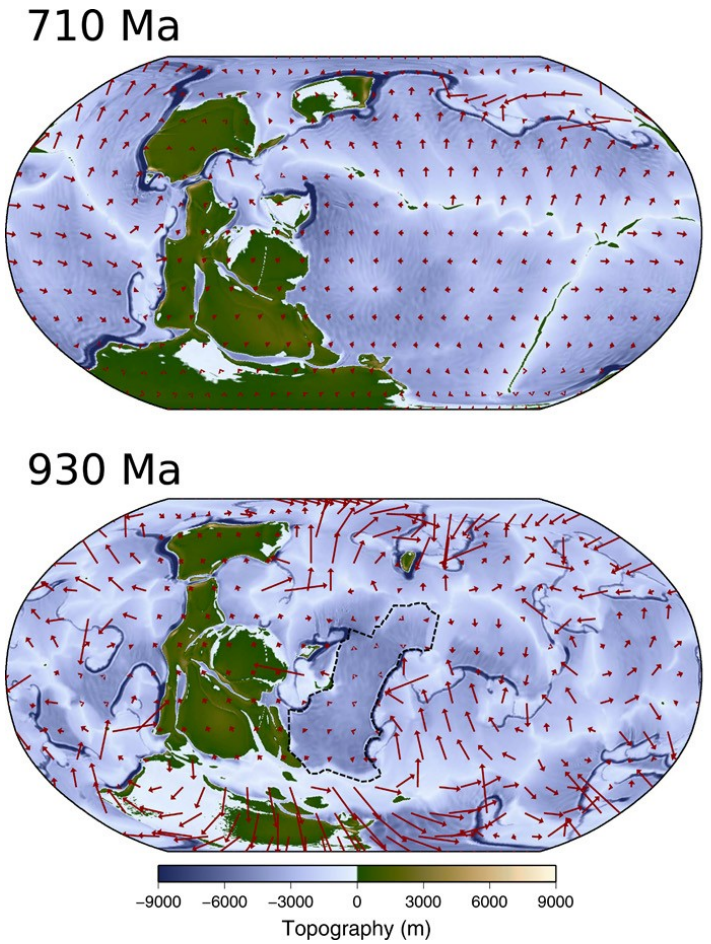


Global scale mantle convection models

Global scale geodynamic models have developed significantly in recent years.

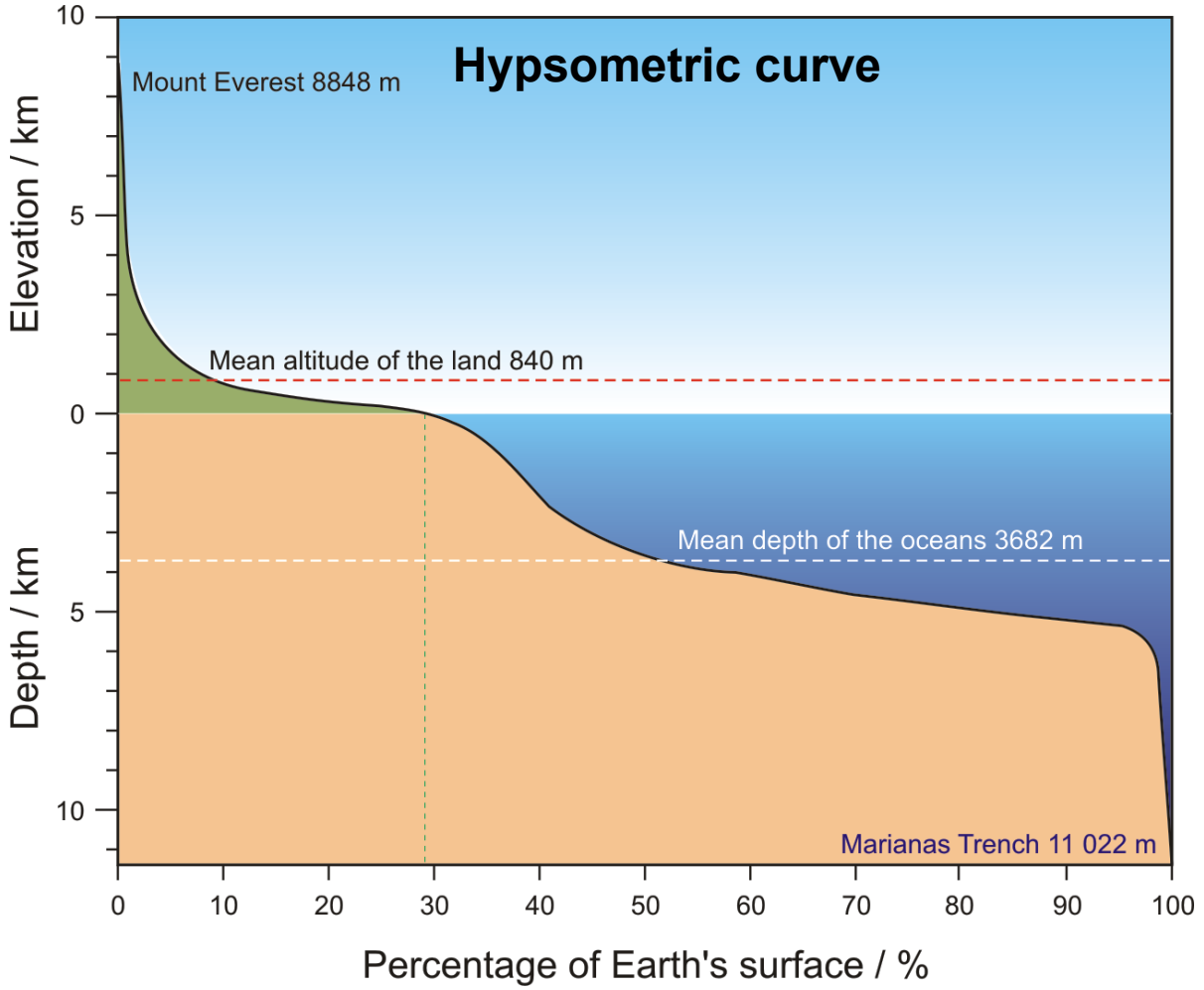


Subduction initiation from a stagnant lid and global overturn: new insights from numerical models with a free surface.
Crameri and Tackley, 2016



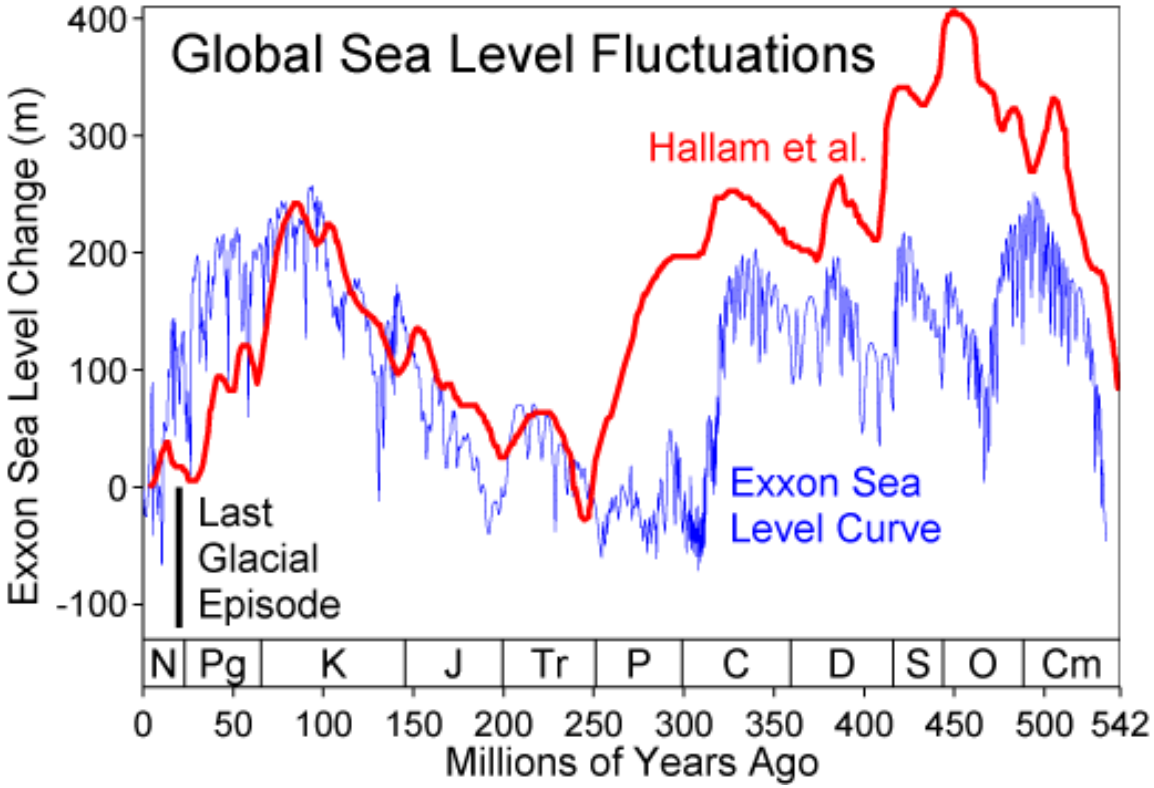
What drives tectonic plates?
Coltice et al. Science 2019

The role of the surface in coupled earth systems



https://www.periodni.com/gallery/hypsometric_curve.png

Topography and bathymetry are key outputs for models of climate and biological evolution

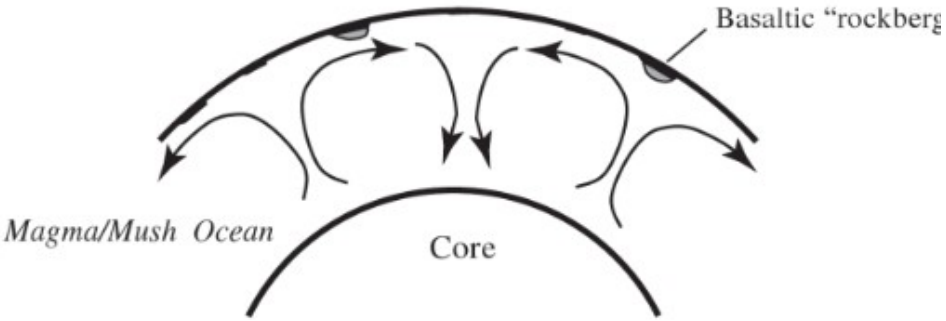


Hallam et al. (1983)
Haq et al. 1987, Ross & Ross 1987, Ross & Ross 1988

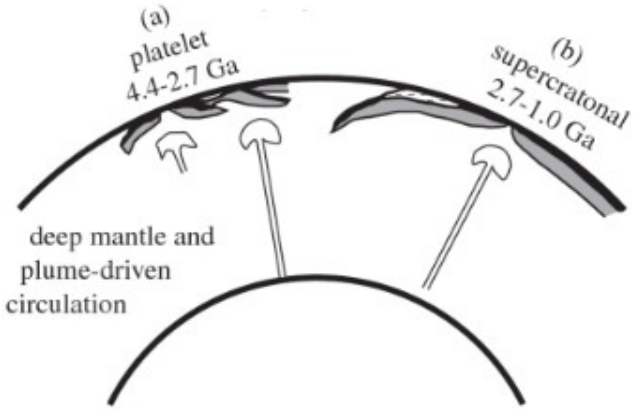
Modelling strategy

Produce a **suite of numerical models** using global mantle convection code **StagYY** (Tackley, 2008)
Finite volume marker in cell technique, compressibility, melting, **free surface**, and more.

Early Earth
hot mantle,
Plume dominated

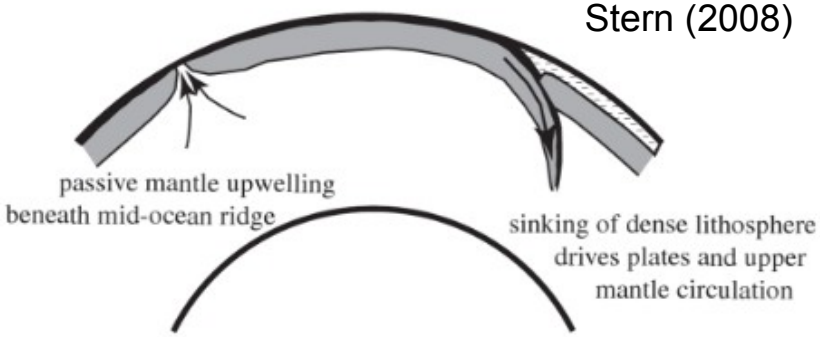


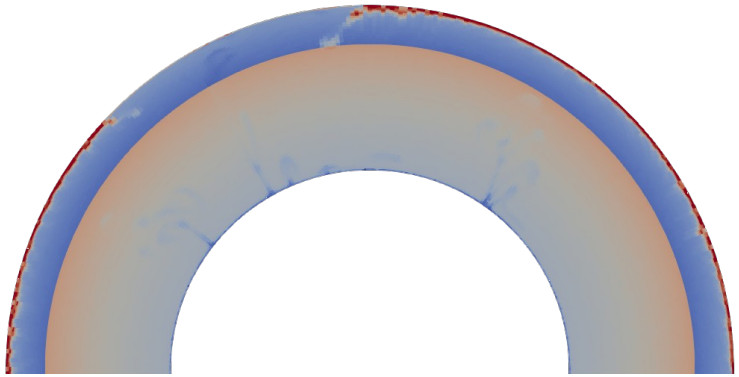
Middle-age Earth
(Boring billion)

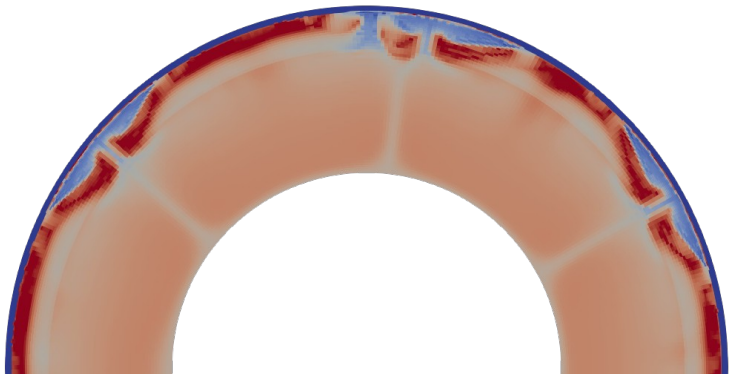


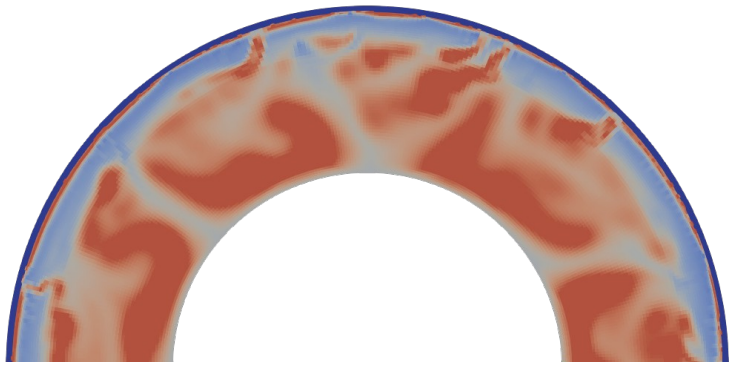
Modern Earth
Stable plate tectonics

Stern (2008)



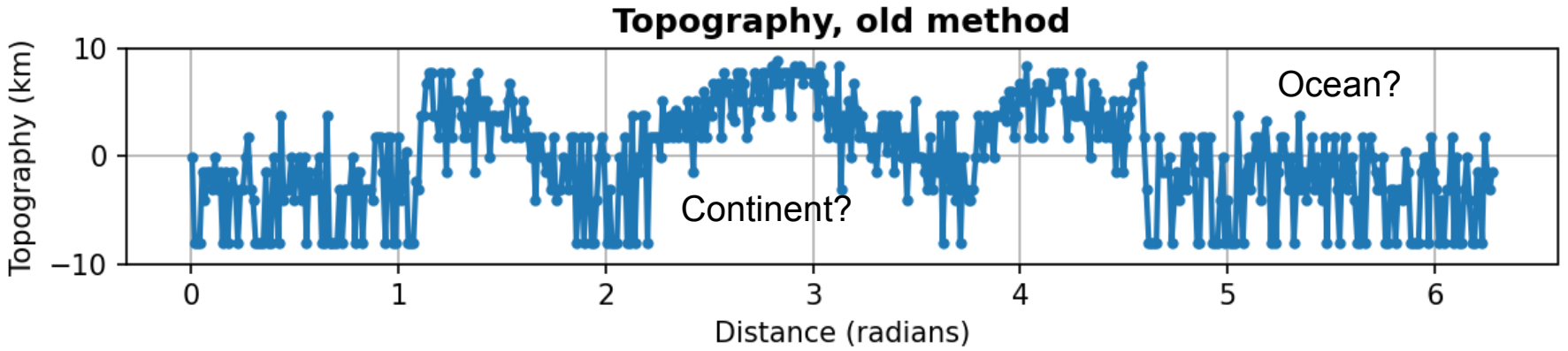






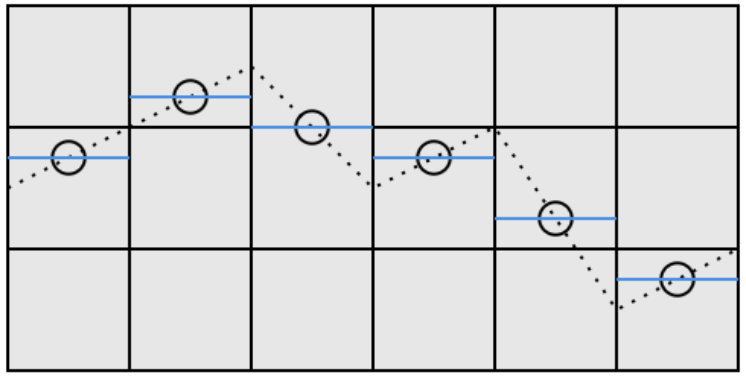
Free surface modelling

The current method (“sticky air” with composition tracking) lacks the required surface resolution

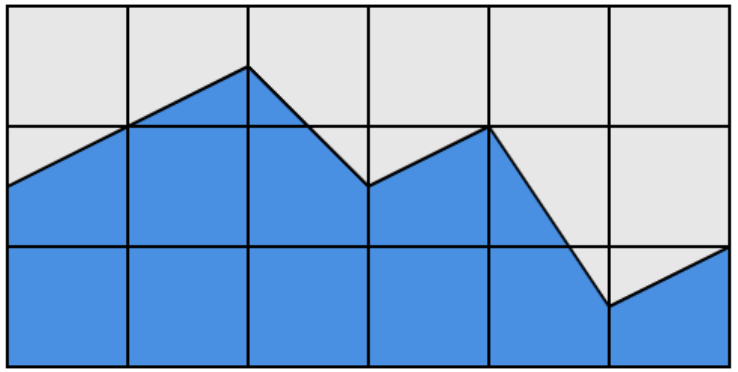


Mainstream computational fluid dynamics codes use a variety of methods to track interfaces between fluids:

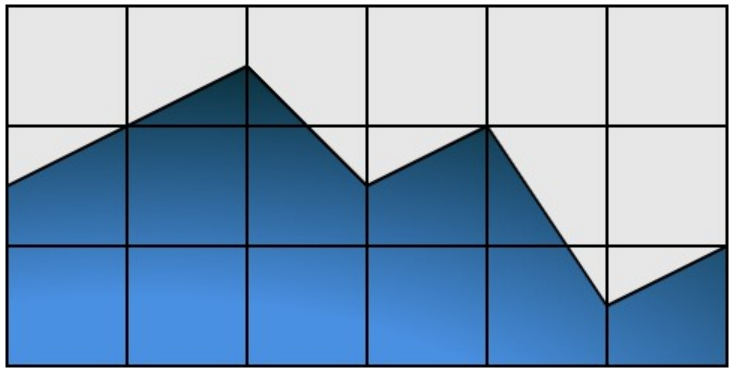
Surface marker chain



Volume of fluid method



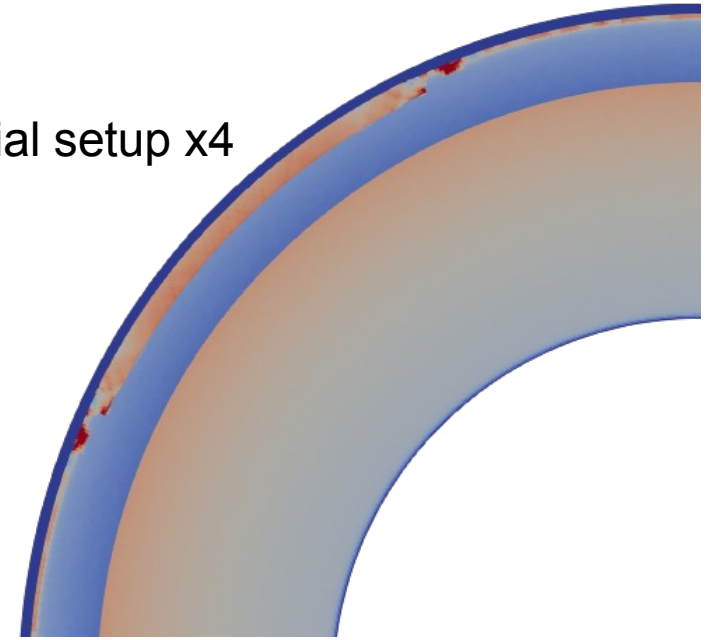
Level set method

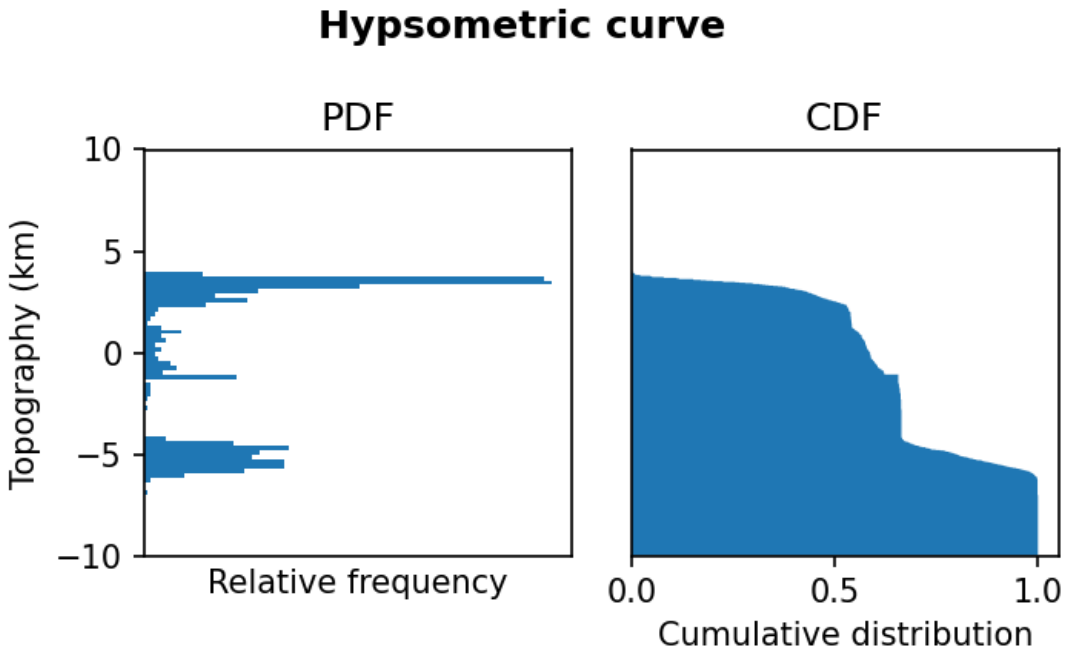


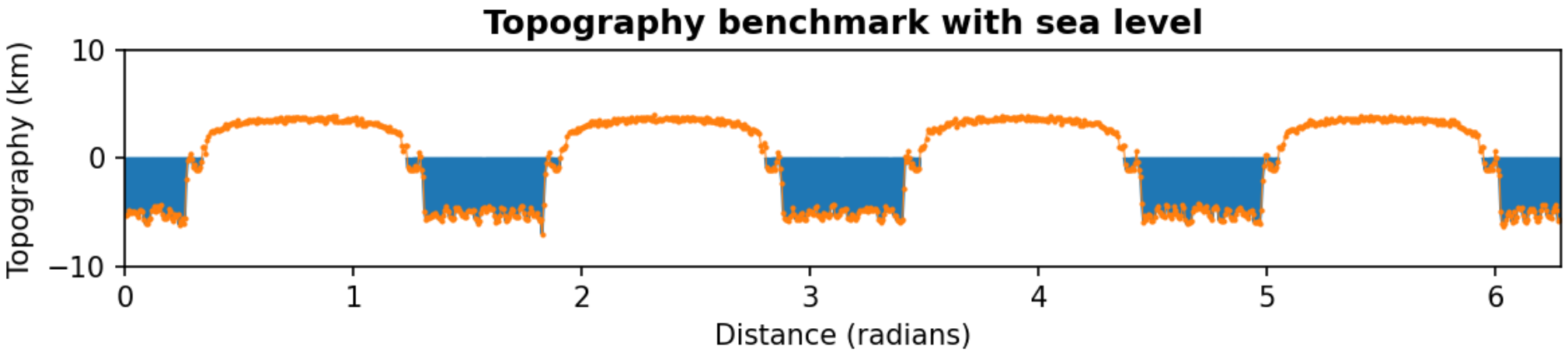
Prototyping and testing using julia

Preliminary results – 2D benchmarking

Initial setup x4

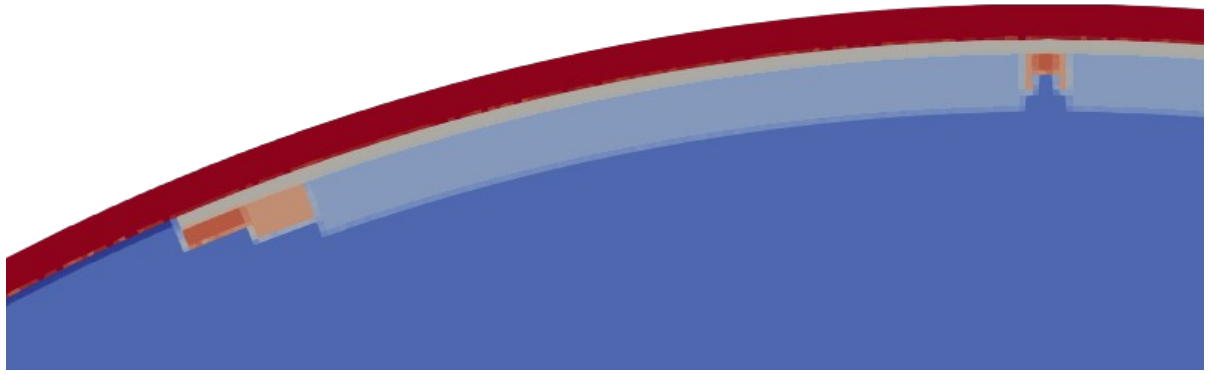




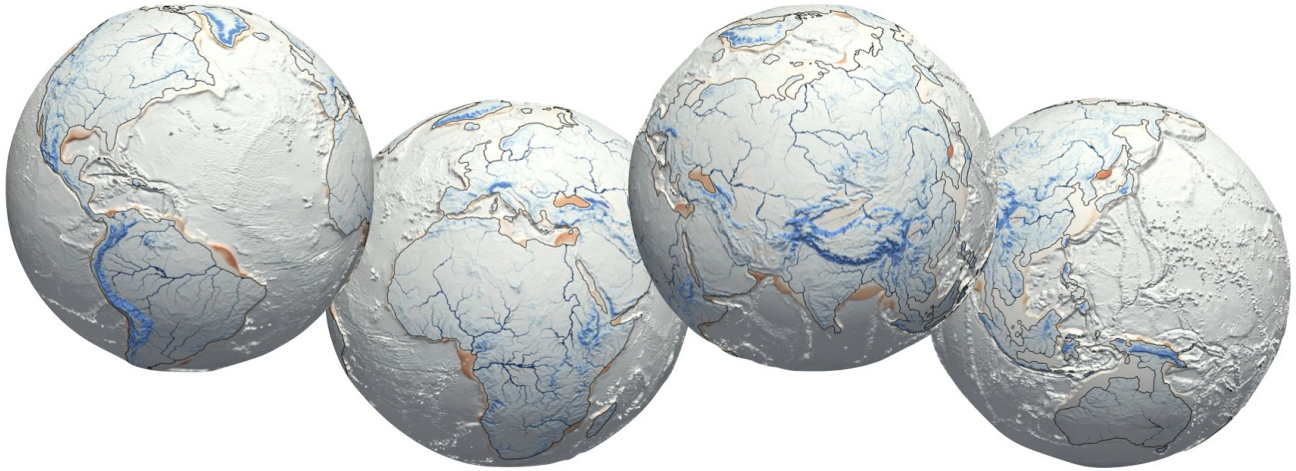


Future directions

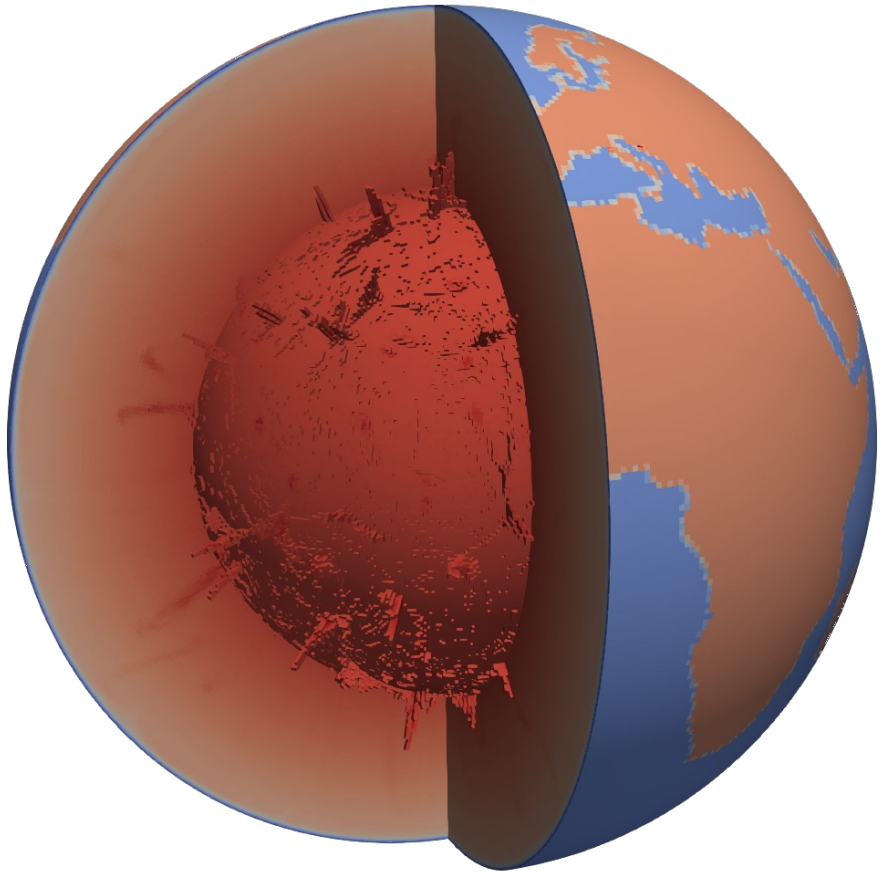
- Self consistent continental rheology e.g. Jain et al. (2018)



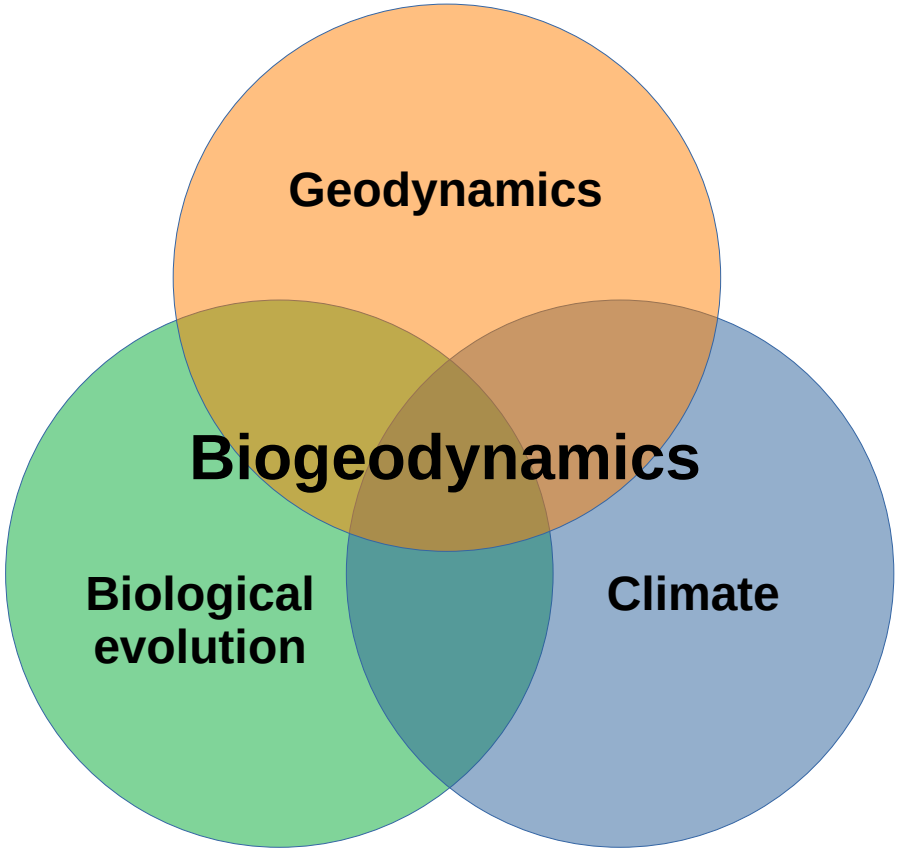
- Potential for coupling with surface process models e.g. GOSPL



Extension to 3D



Take home messages



- The **Neoproterozoic** was a period of radical change in multiple coupled Earth systems
- We propose to study this period through a **suite of models** representing the transition to modern plate tectonics
- **Topography and bathymetry** are the key outputs
- Newly implemented methods for **tracking the free surface** at a sub-grid resolution in StagYY are implemented.

Biogeodynamics project website:
http://jupiter.ethz.ch/~dstemmler/

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