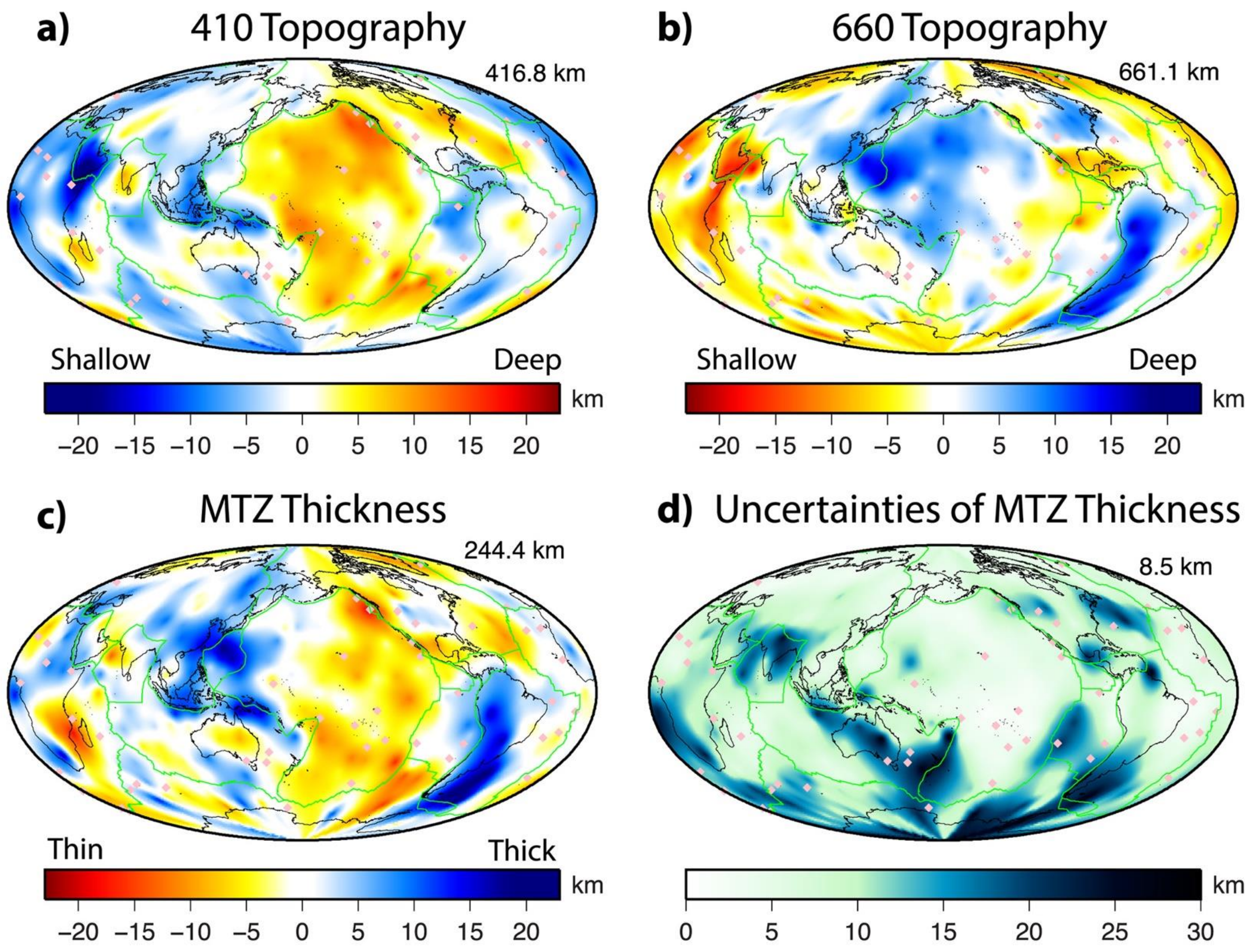
Displaced and Faded:

How thermodynamics and kinetics collude to complicate seismic structures in Earth's mantle

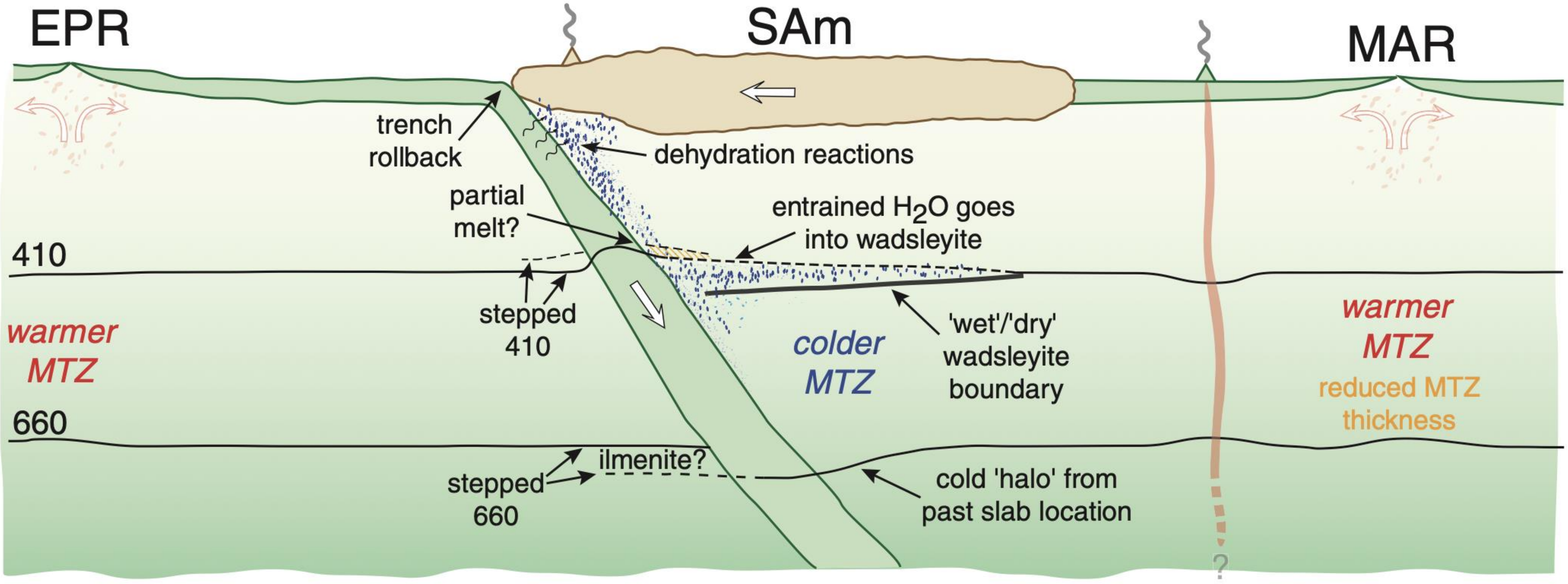
B. Kerswell, J. Wheeler, R. Gassmöller

Seismic discontinuities show global variability



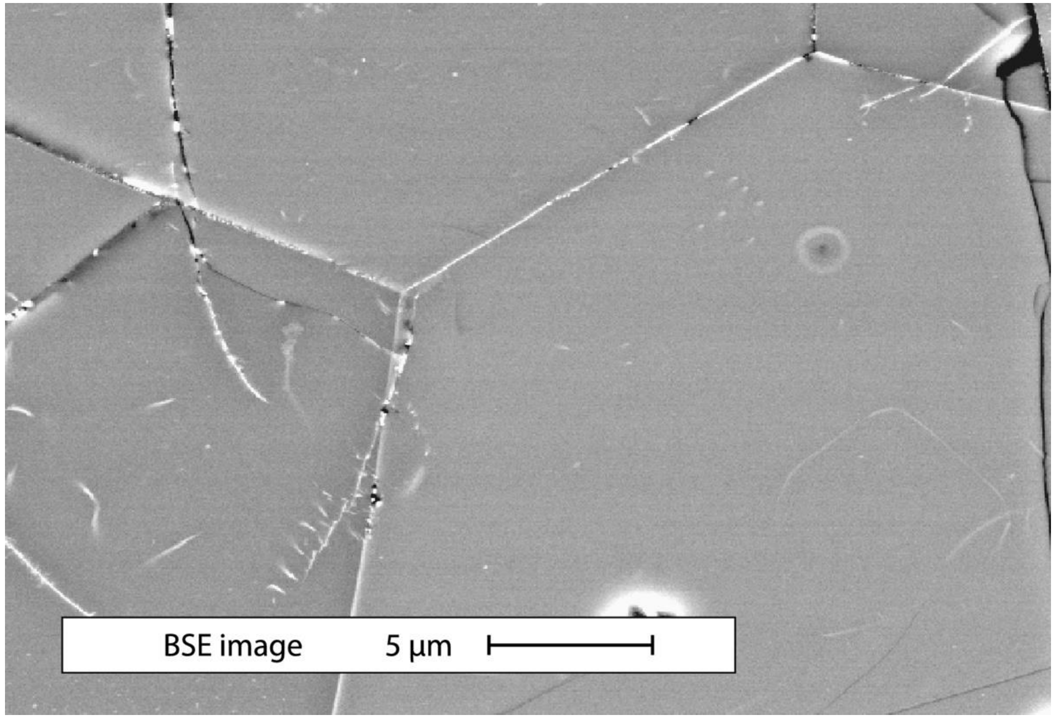
Huang et al. (2019)

Thermodynamics cannot explain the seismic variability alone

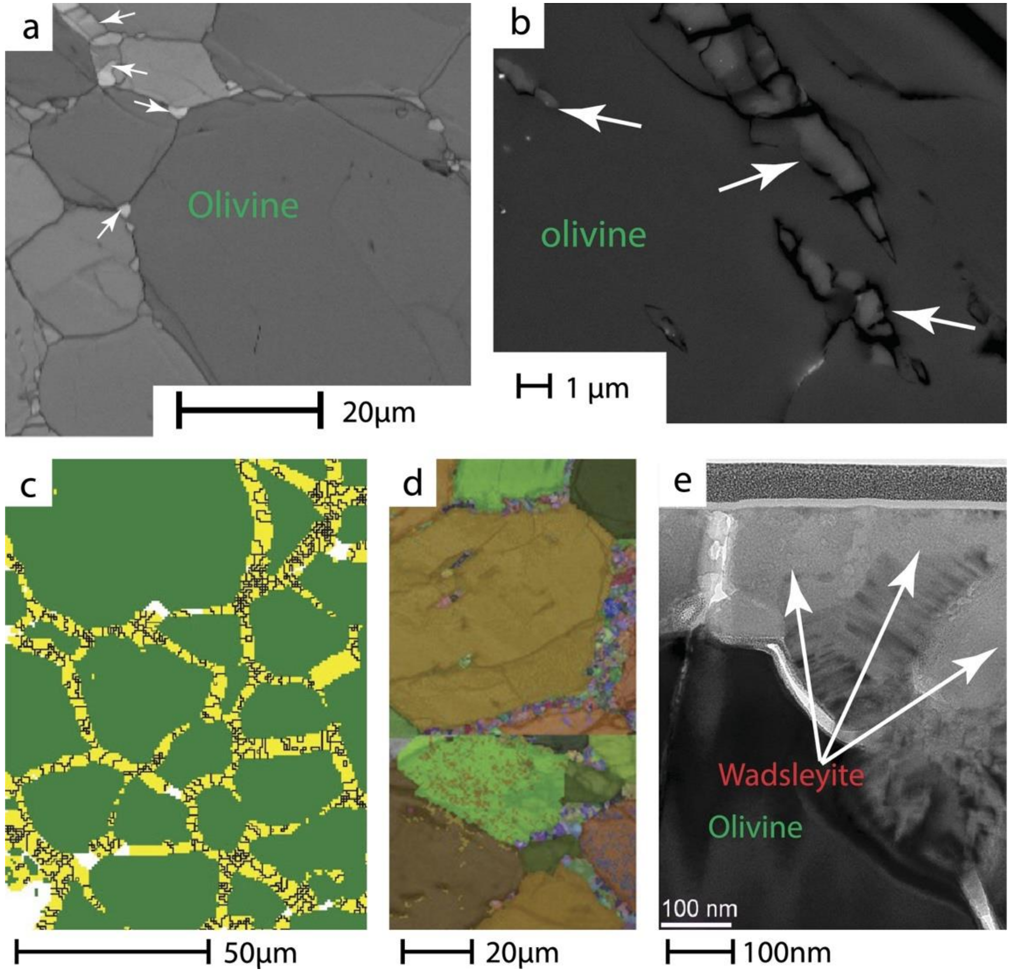


Schmerr & Garnero (2007)

Mantle phase transitions are rate-limited



Growth-limited after rapid nucleation saturation



Mohiuddin & Karato (2018)

Research question

What is the impact of stress, microstructures, and mineral-scale kinetics on mantle-scale seismic structures (and dynamics)?

Hypothesis

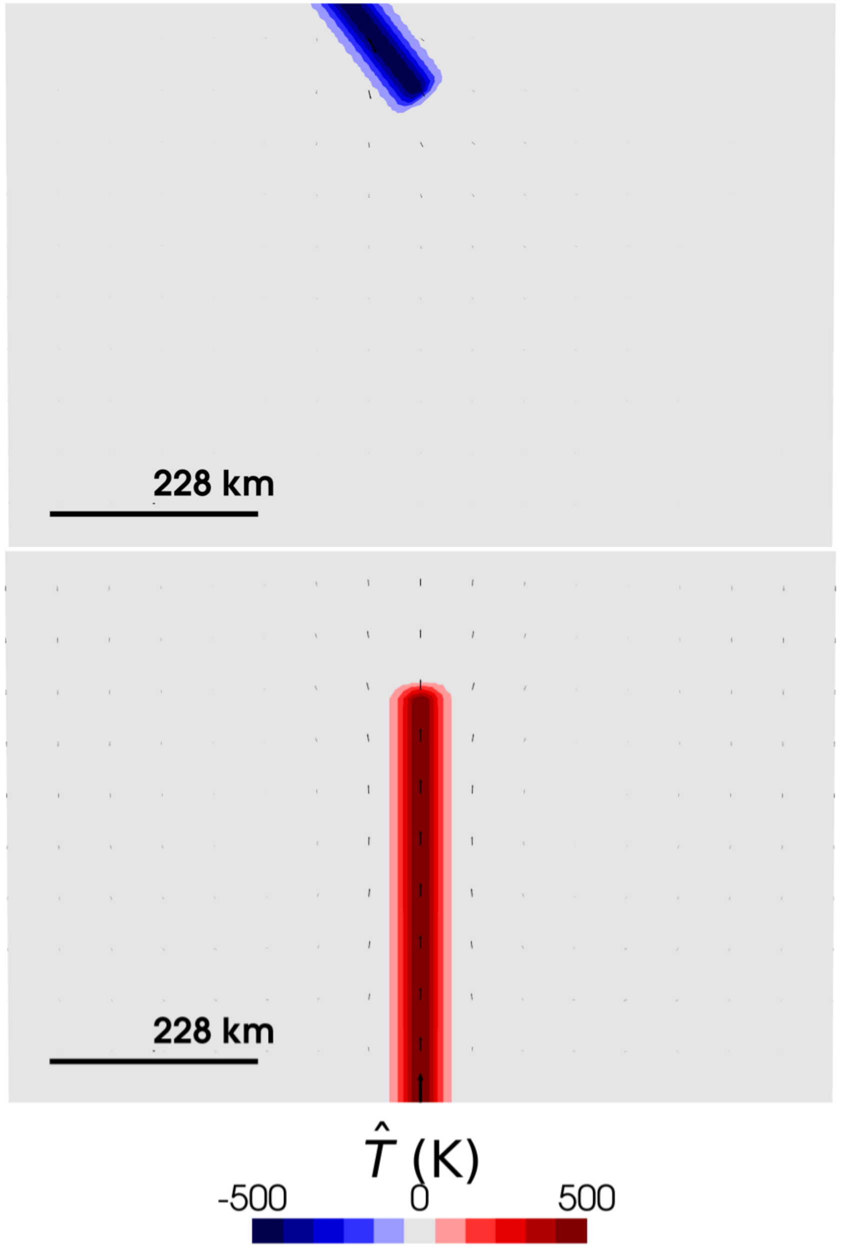
Variable olivine ⟷ wadsleyite growth rates in slabs and plumes are consistent with observed seismic variability

We simulate plumes and slabs using ASPECT with a compressible mantle

Bangerth et al. (2025), and others

$$\nabla P - \nabla \cdot \sigma' = \rho\, g \qquad \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho\, \vec{u}) = 0$$

$$\rho\, \bar{C}_p \left(\frac{\partial T}{\partial t} + \vec{u} \cdot \nabla T \right) - \nabla \cdot \left(\bar{k}\, \nabla T \right) = \cdots heating$$



Kerswell et al. (in prep)

Growth rate depends on kinetic factors, dynamic PT, and saturation

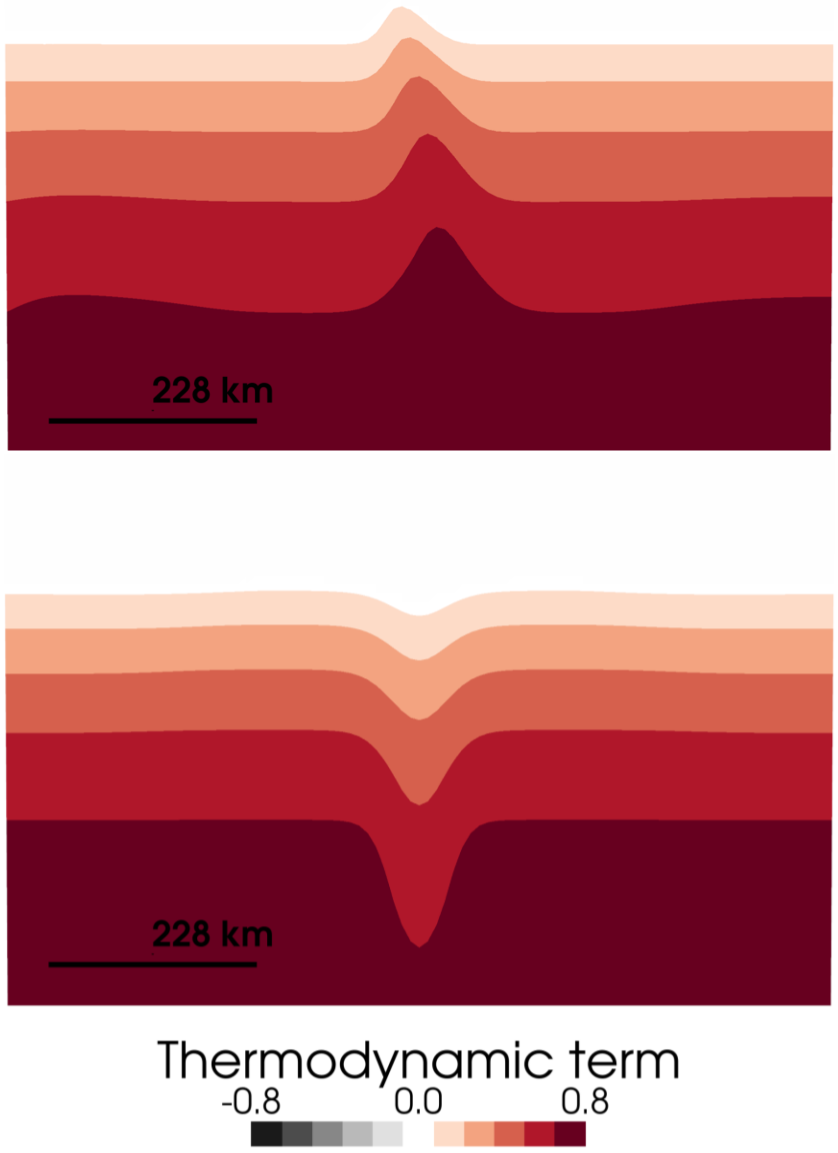
Hosoya et al. (2005), and others

$$\frac{dX}{dt} = Z\, T \exp\left(-\frac{H^{*}+PV^{*}}{R\,T}\right)\left(1-\exp\left[-\frac{\Delta G}{R\,T}\right]\right)(1-X)$$

$$Z = \frac{6.67}{d} A\, C_{OH}^{n}$$

$$\Delta G = \Delta\bar{G} + \hat{P}\Delta\bar{V} - \hat{T}\Delta\bar{S}$$

$$\hat{P} = P - \bar{P} \qquad \hat{T} = T - \bar{T}$$



Kerswell et al. (in prep)

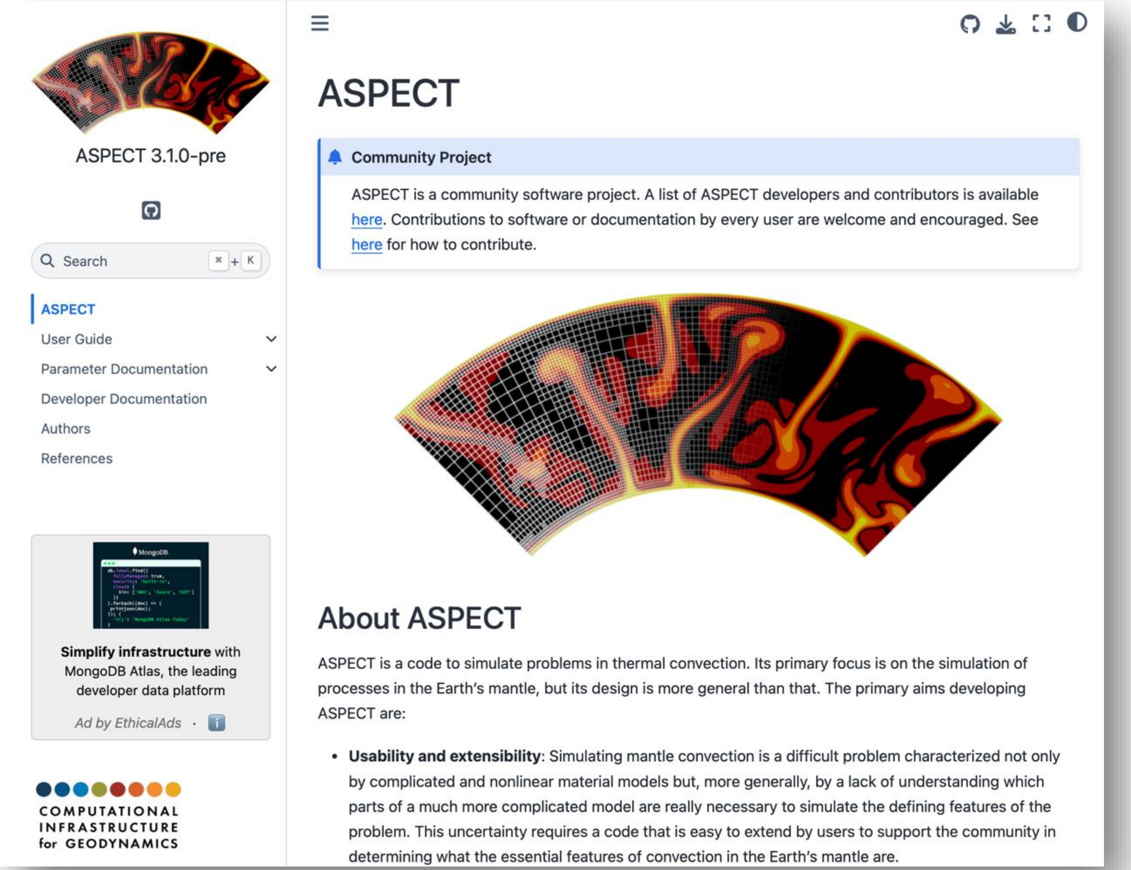
ASPECT Hackathon 2025

ASPECT is a community software project

COMPUTATIONAL INFRASTRUCTURE for GEODYNAMICS

National Science Foundation
WHERE DISCOVERIES BEGIN

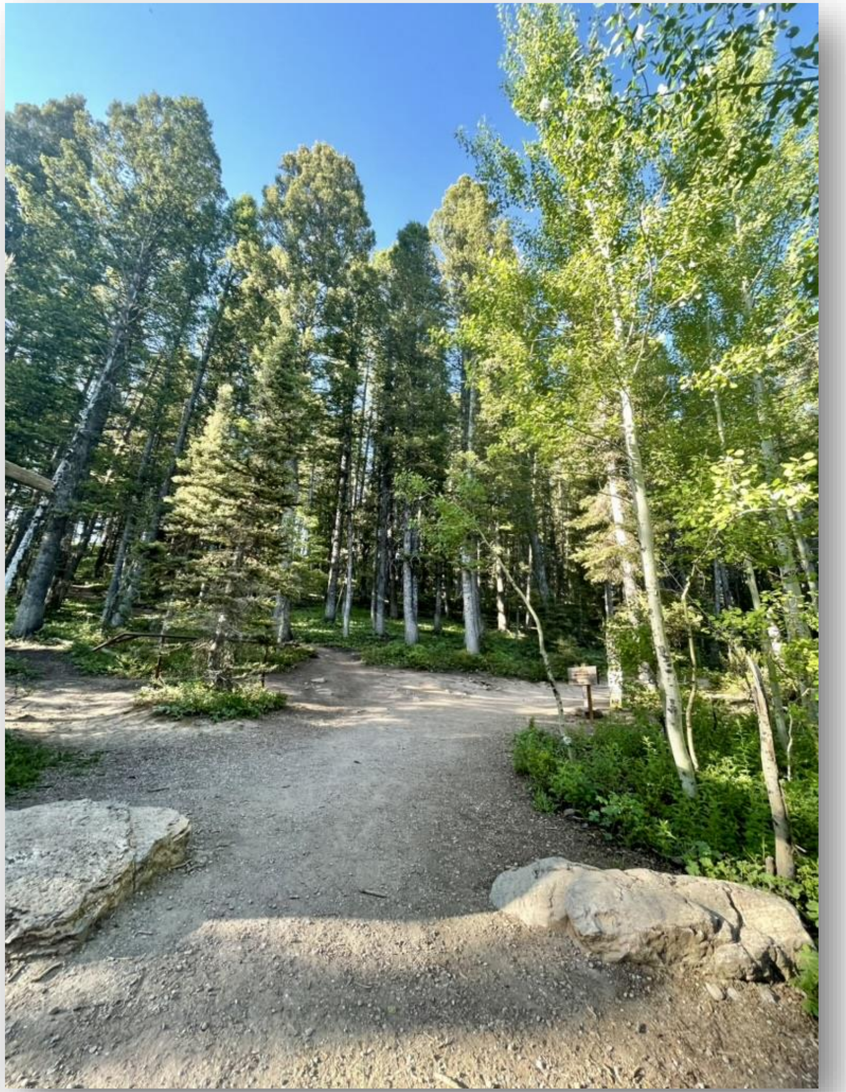
GEOMAR
Helmholtz Centre for Ocean Research Kiel



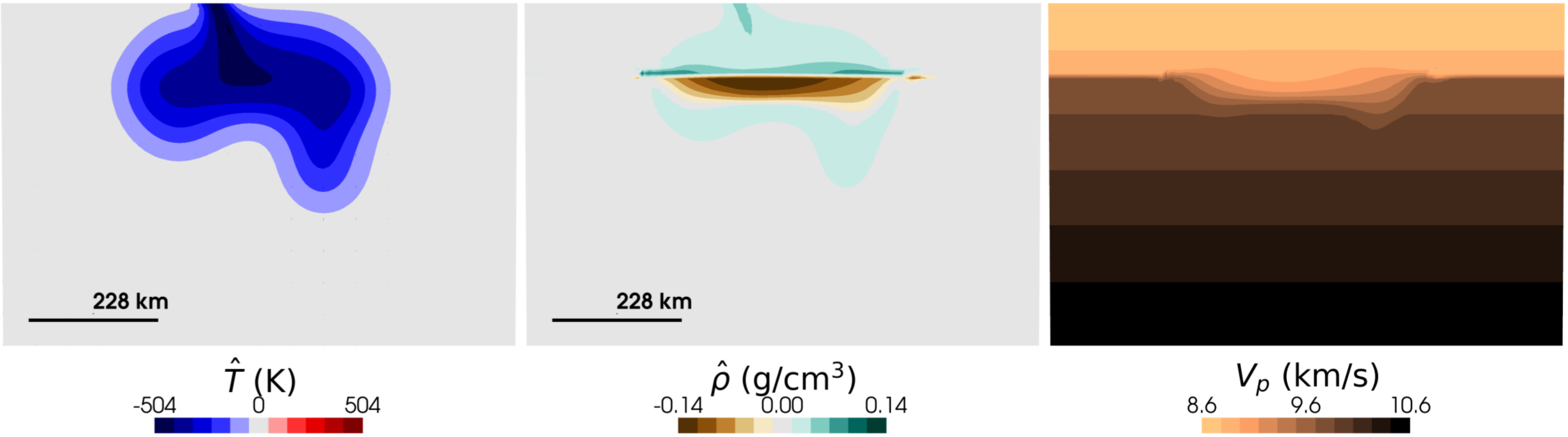
ASPECT Hackathon 2025

Bear Lake, Utah

ASPECT Hackathon 2025

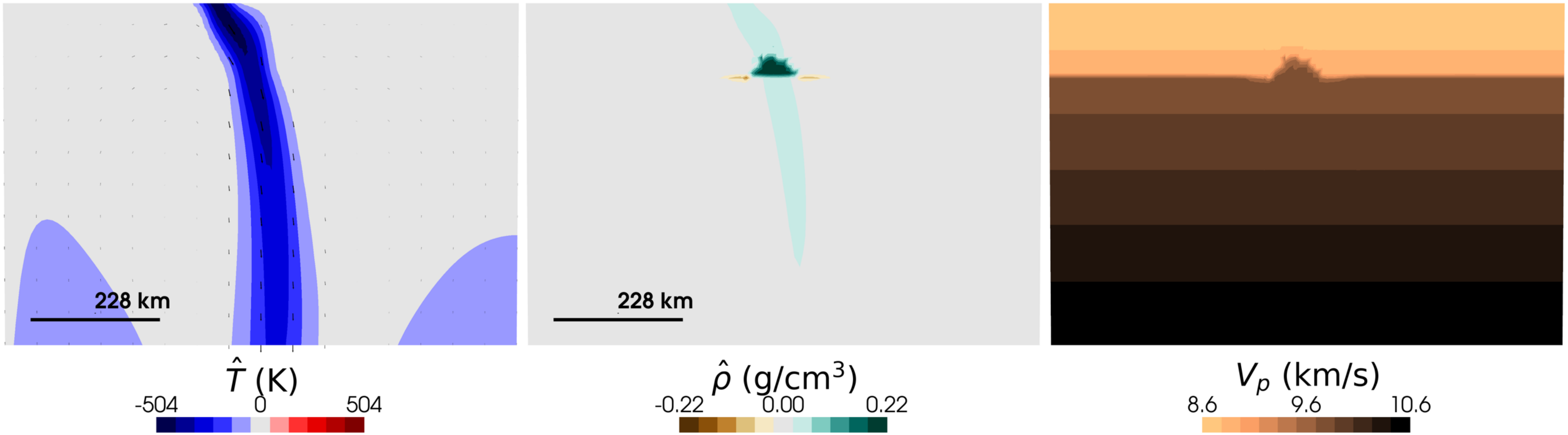


Sluggish kinetics in slabs promote ponding and large metastable olivine regions



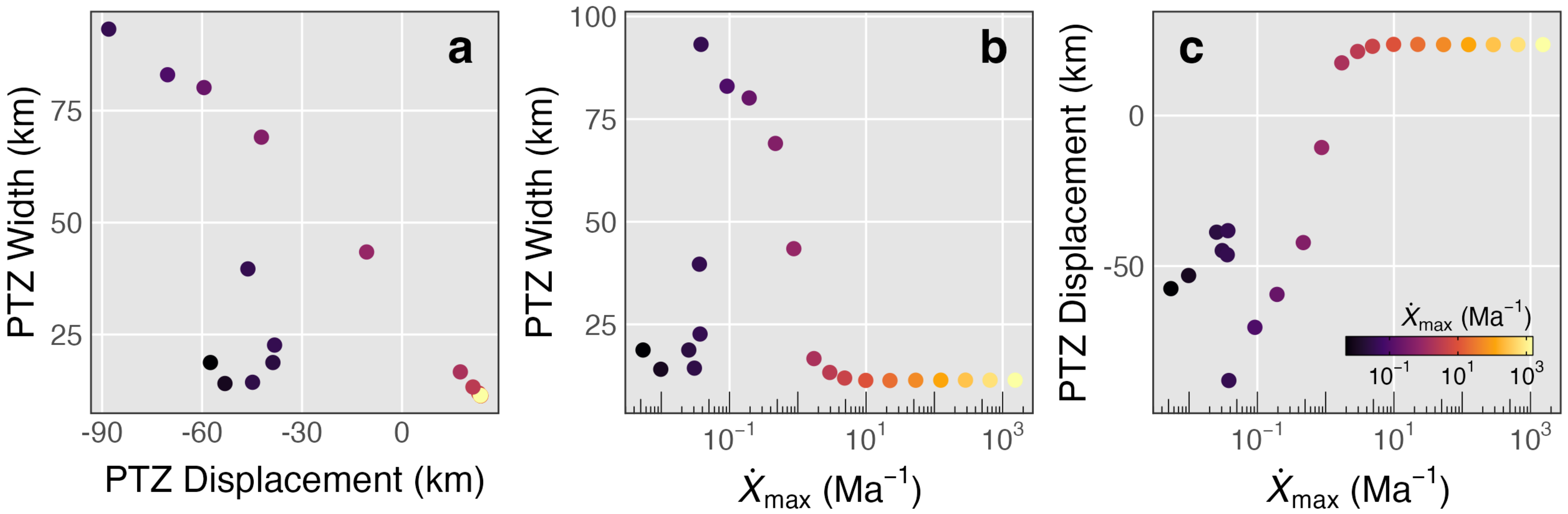
Kerswell et al. (in prep)

Faster kinetics sharpen the slab phase transition and enable penetration



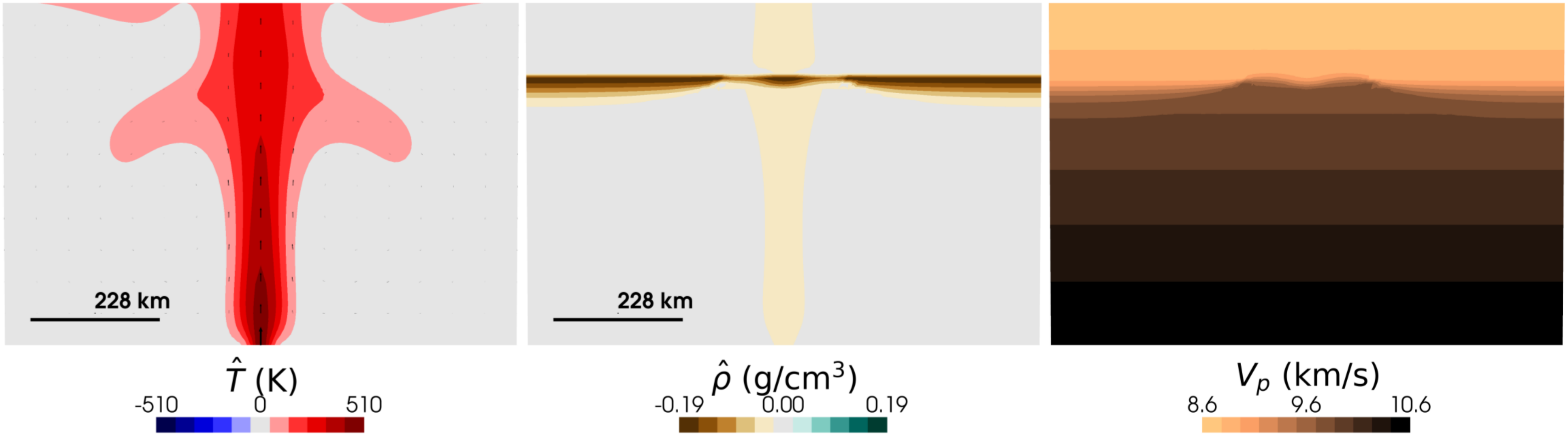
Kerswell et al. (in prep)

Slabs exhibit log-linear relationships between kinetics and PTZ structure (with thresholds)



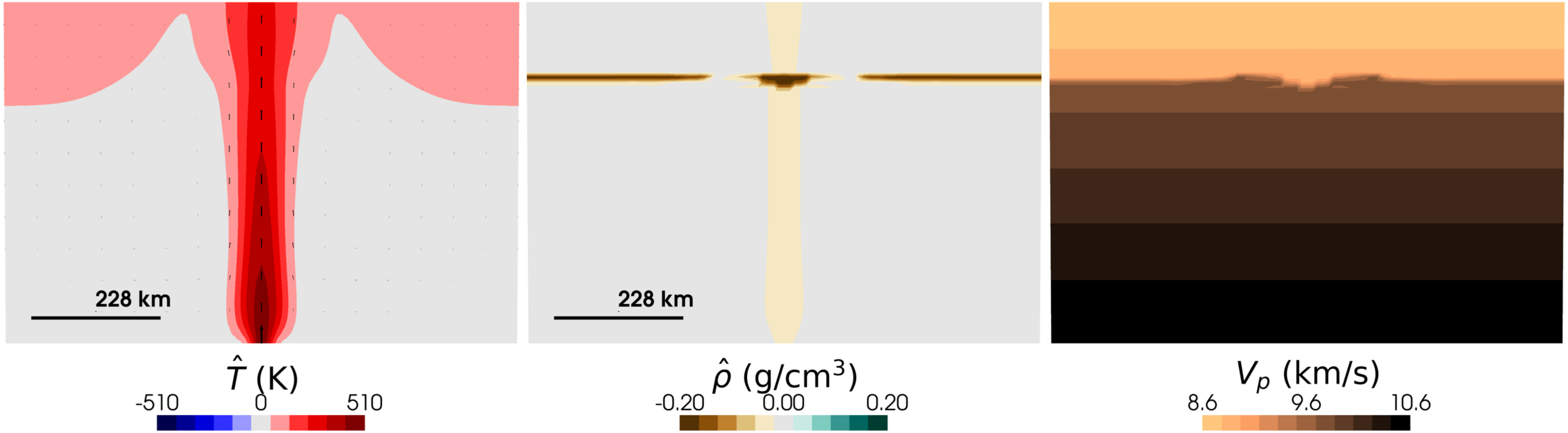
Kerswell et al. (in prep)

Sluggish kinetics in plumes promote *negligible* stagnation and 410 uplift



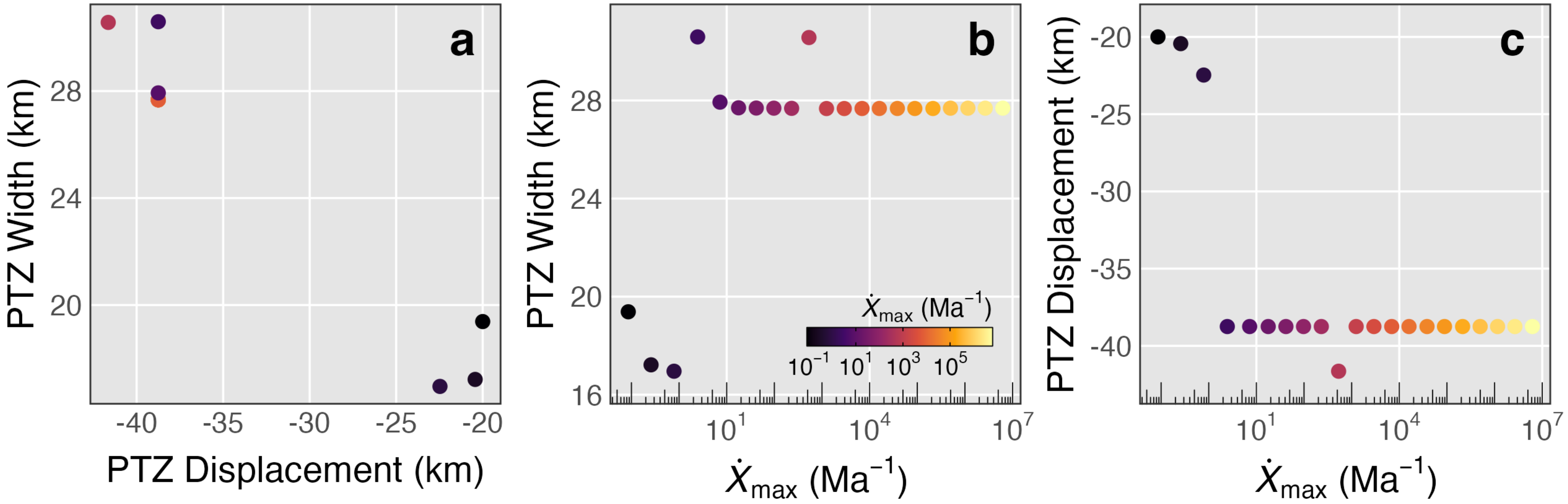
Kerswell et al. (in prep)

Kinetic rates are always high in plumes: the 410 remains at its predicted equil. depth



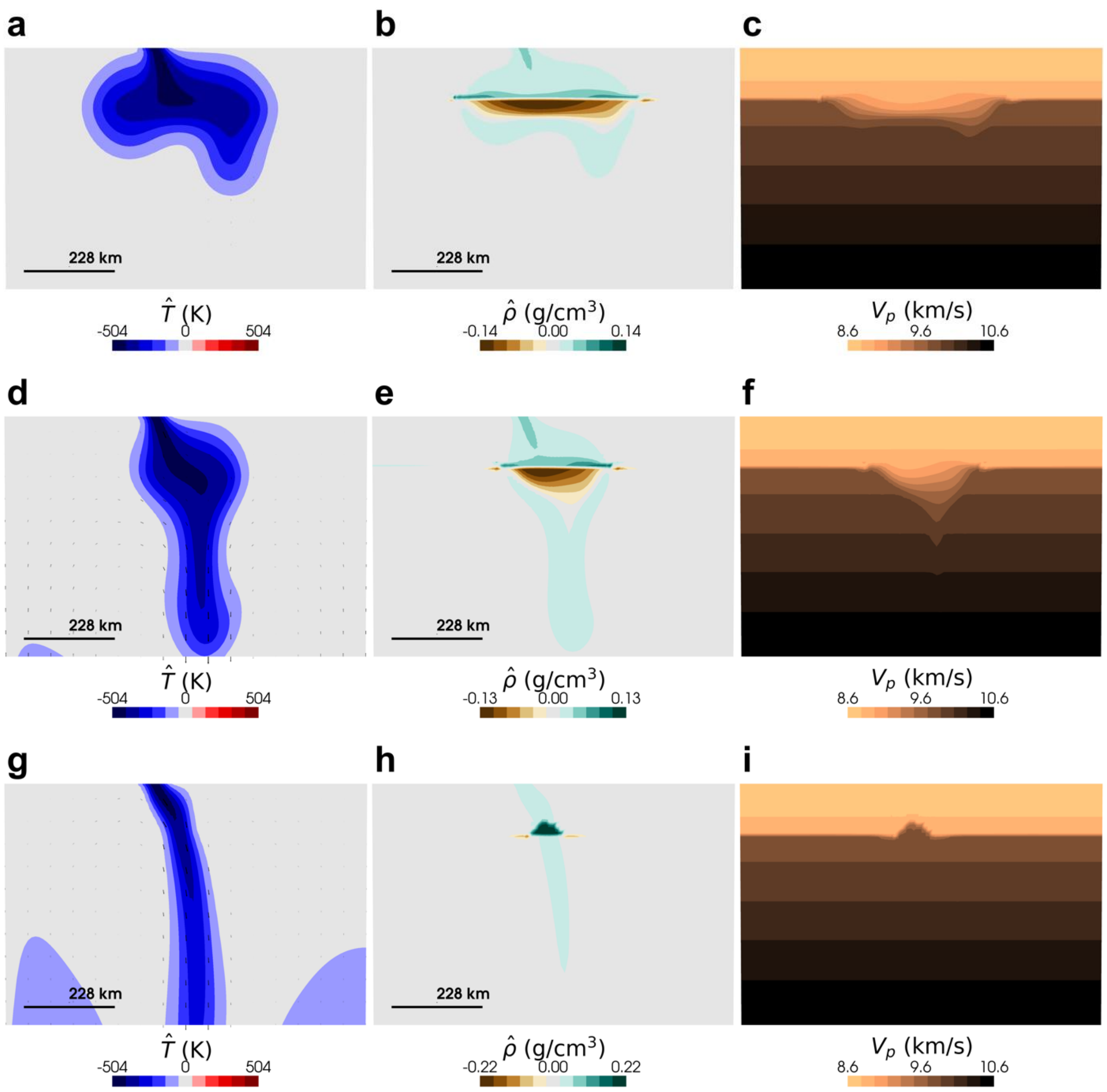
Kerswell et al. (in prep)

Plumes show no scaling between kinetics and PTZ structure (with a few outliers)



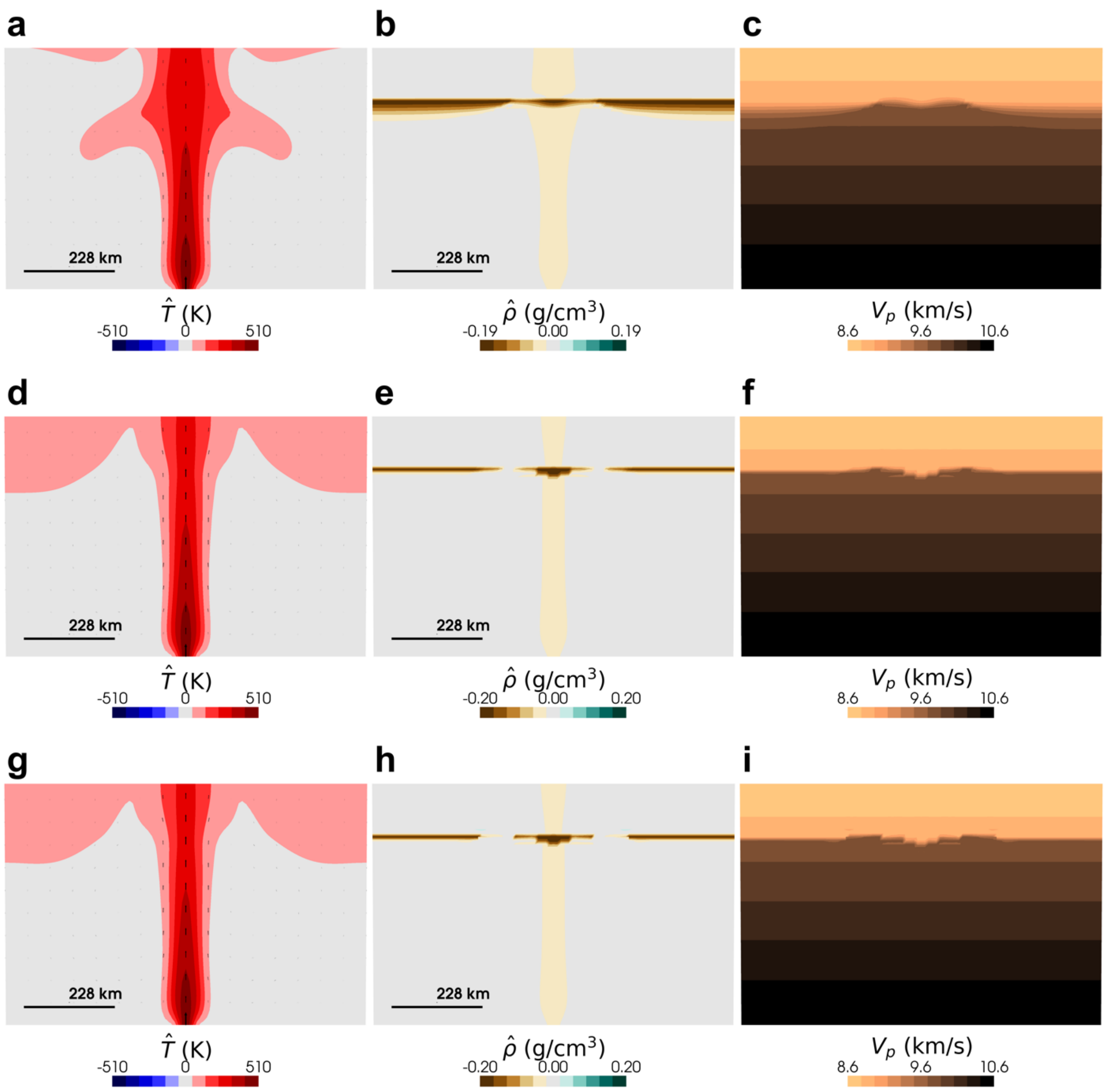
Kerswell et al. (in prep)

Kinetics explain slab stagnation, deep EQs, and variable seismic signals



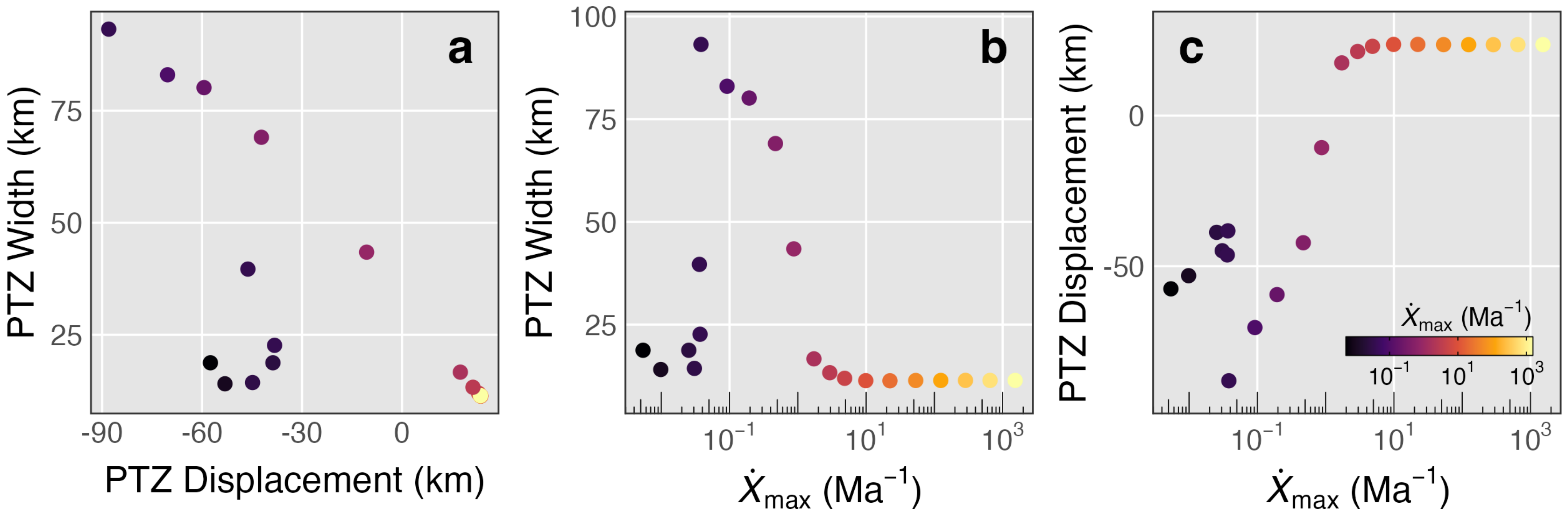
Kerswell et al. (in prep)

Kinetics cannot explain uplifted and/or weak 410 signals near hotspots



Kerswell et al. (in prep)

Seismic observables can constrain phase transition rates in slabs (?)



Takeaways from Kerswell et al. (in prep)

- 410 is uniform in plumes, but slabs show displacement and fading
- Kinetics can explain slab dynamics and unusual seismic observations
- Kinetics cannot explain unusual seismic signals near plumes
- Seismic discontinuities are probes of phase transition rates