Modelling the Global Geodynamic & Seismological Consequences of Different Phase Boundary Morphologies

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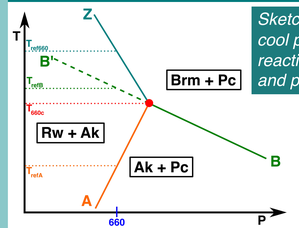
Chanyshev et al (2022) and others suggest that post-spinel reactions via **Akimotoite** in sub-Adiabatic mantle, with extremely negative Clapeyron slopes, could **stagnate downwellings**.

Branching Phase Transitions



Sketch phase diagram of cool post-spinel reactions, with reactions and points labelled.

- Potential dynamics illustrated with 3D incompressible convection models in TERRA (lateral resolution ~45km, isoviscous).
- Implement stresses as

$$\Delta\sigma_{660} = \begin{cases} \gamma_Z \cdot \frac{\Delta\rho_Z}{\rho}(T_{660} - T_{ref660}) & T_{660} \geq T_{660C} \\ \gamma_A \cdot \frac{\Delta\rho_A}{\rho} \cdot (T_{660} - T_{refA}) + \gamma_B \cdot \frac{\Delta\rho_B}{\rho} \cdot (T_{660} - T_{refB}) & T_{660} < T_{660C} \end{cases}$$

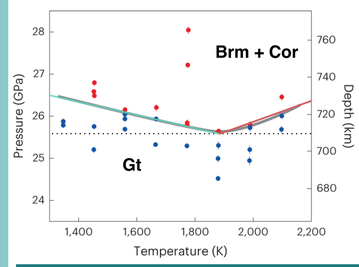
- Only for extreme γ_B & cross over Temperature (T_{660C}) is significant effect seen → modes with some slab stagnation ('S') and most slabs stagnating ('MS'), distinct from symmetrical transitional mode 'T' – 2Gyr visualisations ↓.
- However, ΔS and ΔV must be conserved at triple points, ∴ choice of values for γ_A & γ_B is not independent. So for our implementation:

$$\Delta\sigma_{660} = \begin{cases} \frac{(\Delta S_Z)}{V} \cdot (T_{660} - T_{ref}) & T_{660} \geq T_{660C} \\ \frac{(\Delta S_A + \Delta S_B)}{V} \cdot (T_{660} - T_{ref}) & T_{660} < T_{660C} \end{cases}$$

→ **Impossible** for **branching** phase boundaries to **effect global dynamics except** on **smallest** scale

Ishii *et al* (2023) suggest that a **sharper, curved Post Garnet** phase transition (PGt) could make upwellings and **downwellings more buoyant**.

Curving Phase Transitions



After Ishii et al *(2023); curved phase PGt phase transition & linear approximation.*

- We adapt our implementation of the branching phase boundaries to model the curving PGt boundary as two lines with slopes γ_{COOL} & γ_{WARM}:

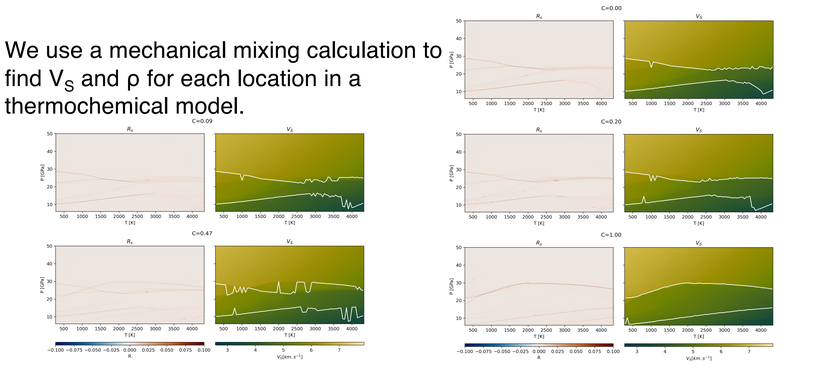
$$\Delta\sigma_{710} = \begin{cases} \gamma_{warm} \cdot \frac{\Delta\rho_{PGt}}{\rho}(T_{710} - T_{ref710}) & T \geq T_{710C} \\ \gamma_{cool} \cdot \frac{\Delta\rho_{PGt}}{\rho} \cdot (T_{710} - T_{ref710}) & T < T_{710C} \end{cases}$$

- This is thermodynamically permissible as volume changes are strongly temperature dependent, which varies γ.
- Except for extreme values of γ_{COOL}, no significant effect is observed with incompressible convection models (lateral resolution ~45km, isoviscous).
- Proposed density change too low for significant effect in Earth.

Seismic **discontinuity topography** is sensitive to **Temperature** and **Composition** – making it a plausible **constraint on MCMs**

Thermochemical Predictions of Seismic Discontinuities

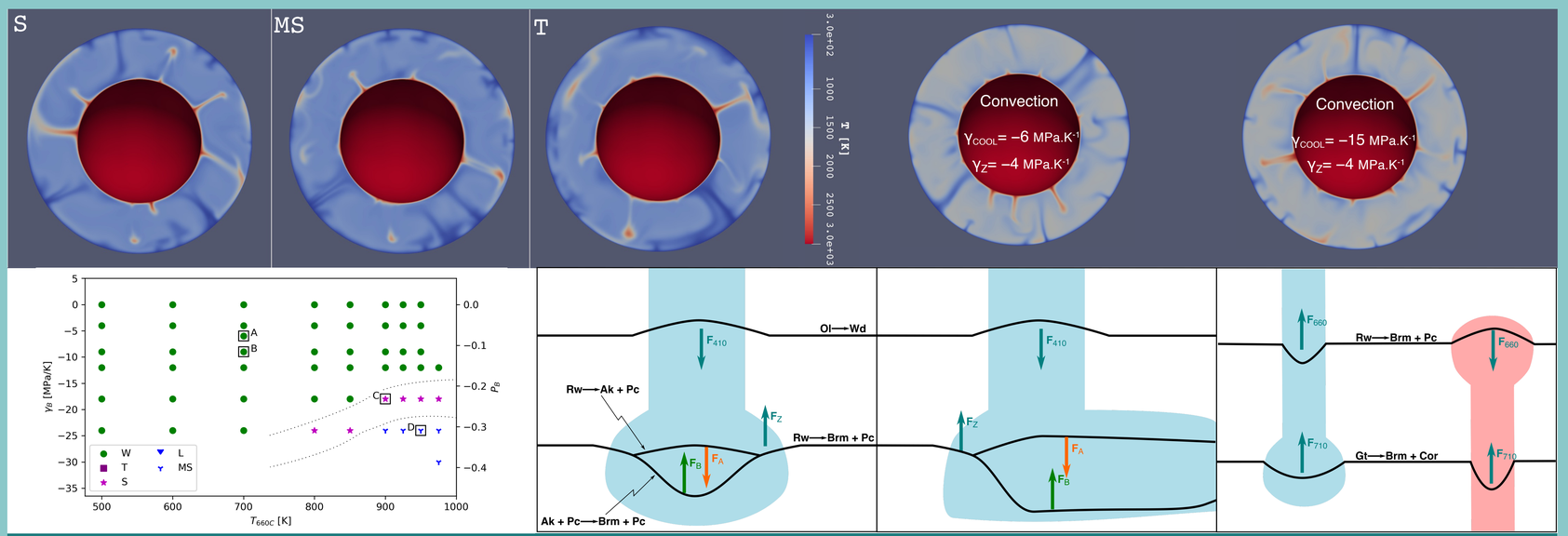
- We use the temperature and chemistry structure of geodynamic simulations to model the reflectivity structure – and pick the peaks as our discontinuity depth.
- Papanagnou *et al* (2023) develop a similar workflow for isochemical mantles.
- We use a mechanical mixing calculation to find V_S and ρ for each location in a thermochemical model.



Reactions via **Akimotoite** **cannot** have a **large effect** on global **mantle dynamics**

A **curving** phase transition **can** have a **significant effect** on global mantle dynamics, for **PGt** this is **unlikely**

We **compute** seismic velocity **discontinuity topography** of **thermochemical** mantle circulation models (MCMs)

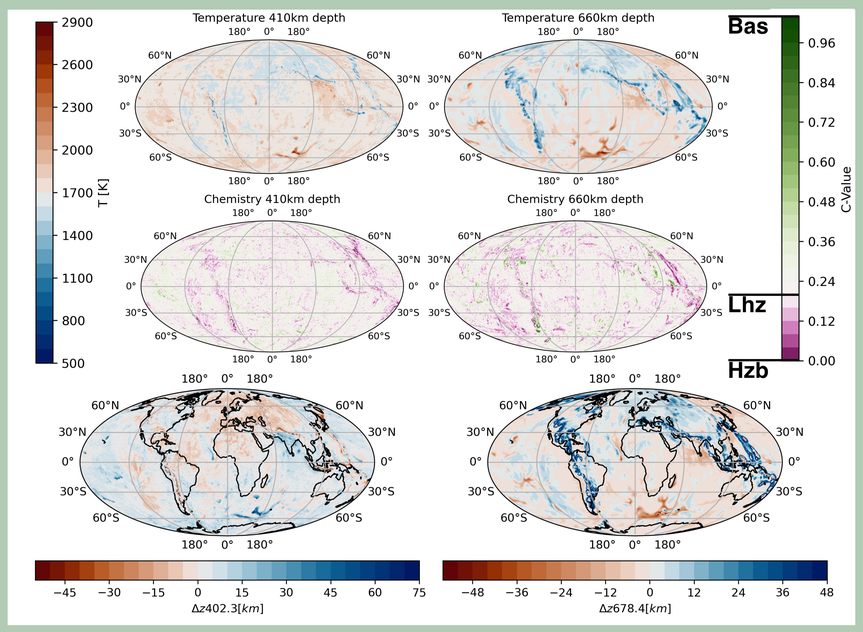


Regime diagram varying γ_B and T_{660C} – modes T, MS and S are visualised above. (W: whole mantle convection; L: layered convection)

Force balance in a vertical downwelling for post-spinel reactions.

Force balance in a stagnating downwelling for post-spinel reactions.

Phase boundary buoyancy forces in the lower MTZ for Post-Garnet simulations.



Acknowledgments

This work is associated with the MC^2 NERC large grant
GTM's PhD is funded by the College of Physical Sciences and Engineering, Cardiff University
This work used the ARCHER2 UK National Supercomputing Service (https://www.archer2.ac.uk).

References

Chanyshev, A. *et al.* (2022) 'Depressed 660-km discontinuity caused by akimotoite–bridgmanite transition', *Nature*, 601(7891), pp. 69–73.
Ishii, T., Chanyshev, A. and Katsura, T. (2022) 'A New Approach Determining a Phase Transition Boundary Strictly Following a Definition of Phase Equilibrium: An Example of the Post-Spinel Transition in Mg_2SiO_4 System', *Minerals*, 12(7), p. 820.
Papanagnou, I., Schuberth, B.S.A. and Thomas, C. (2023) 'Geodynamic predictions of seismic structure and discontinuity topography of the mantle transition zone', *Geophysical Journal International*, 234(1), pp. 355–378.

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Abstract