DI11A-2574 Probing seismically melting induced mantle heterogeneities in thermal-chemical convection models

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NERC SCIENCE OF THE ENVIRONMENT

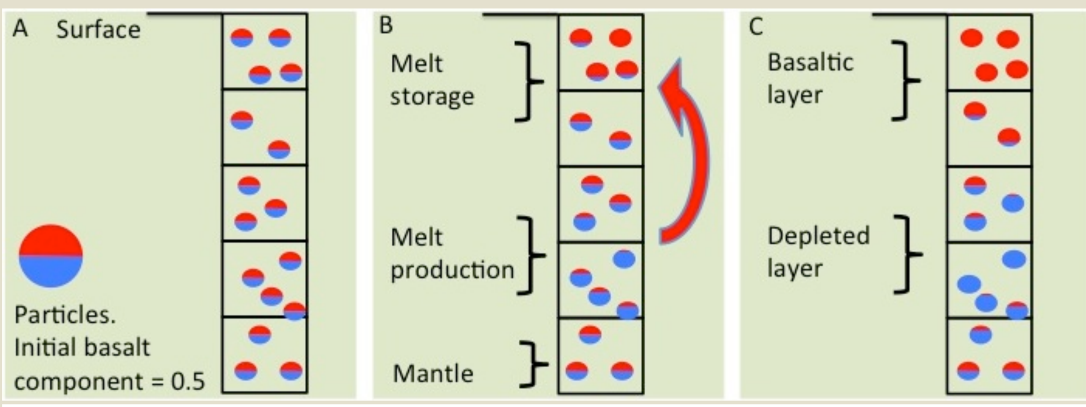
Mantle GeoDynamics

Introduction

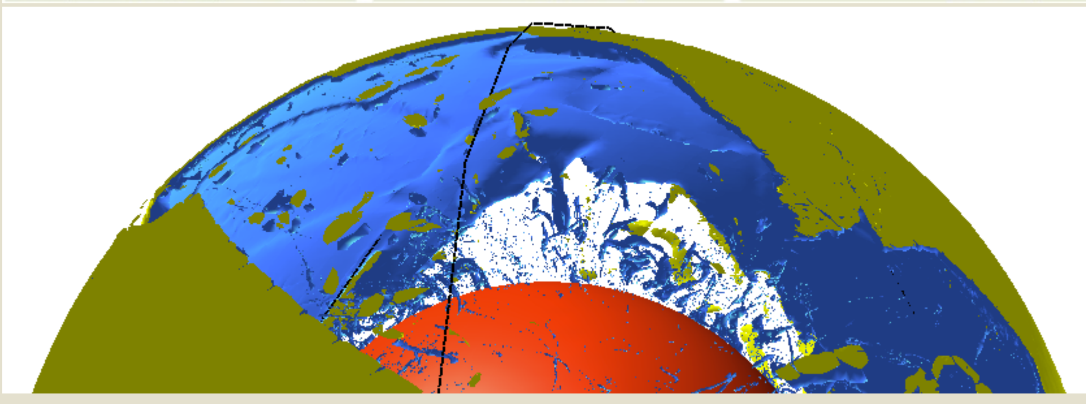
Structure, composition and dynamics of LLSVPs:
* Purely thermal convection.
* Thermo-chemical with a dense primordial layer at the base of the mantle.
* **Thermo-chemical where heterogeneity is generated at mid-oceanic ridges.**

Melting via particles

van Heck et al., GMD, in review



Sketch illustrating how melting (solidus depending on composition) separates a basaltic and depleted layer.



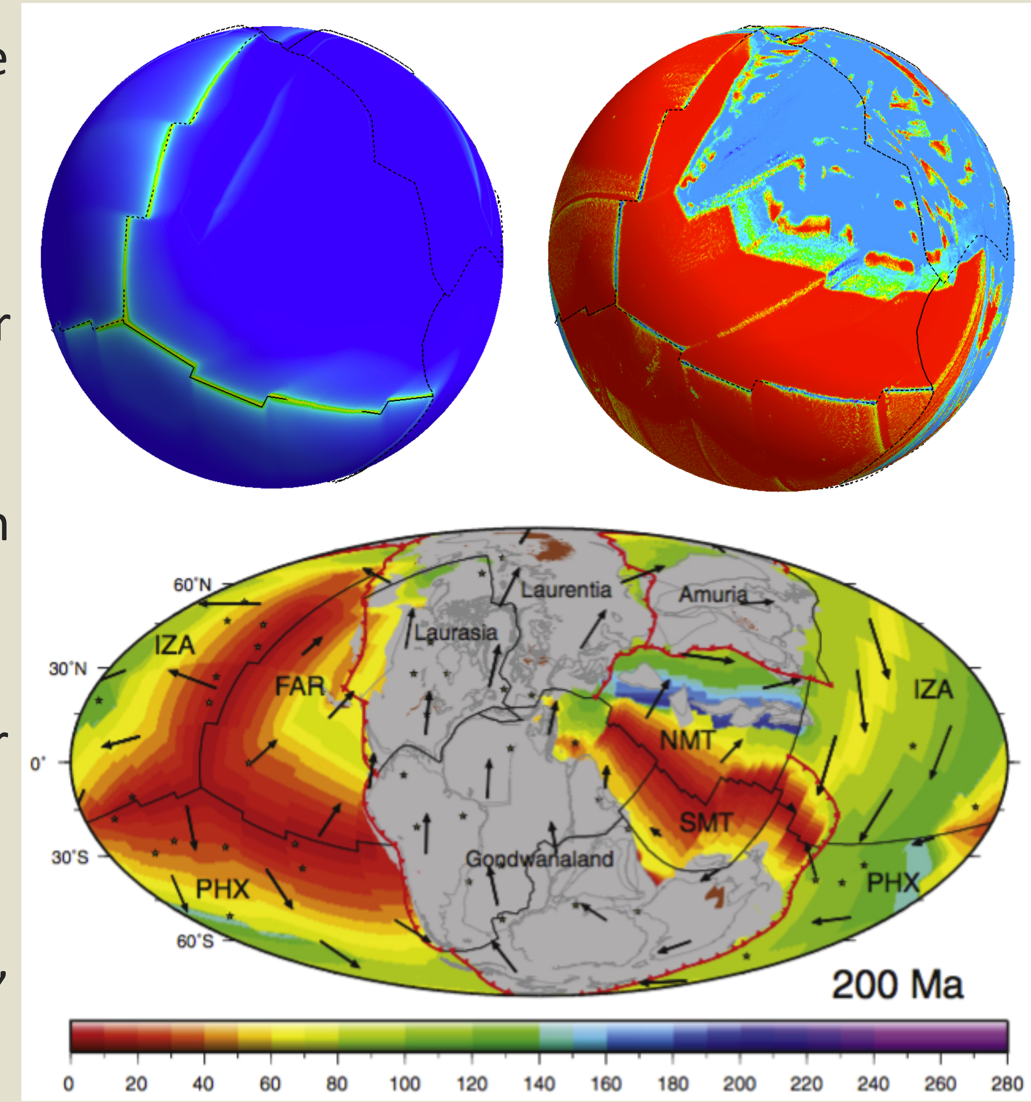
Example composition separation.
Blue: depleted composition
Yellow: enriched composition
(c=0.2 vs c=0.6)
Red: core-mantle boundary.

Calculation setup / Initial condition

3D-spherical finite element code (TERRA) to model convection. With particles to track bulk composition. We use a compressible setup with a upper mantle viscosity of $2*10^{21}$, an increase of 30 in the lower mantle and an increase of 100 in the top 100 km.

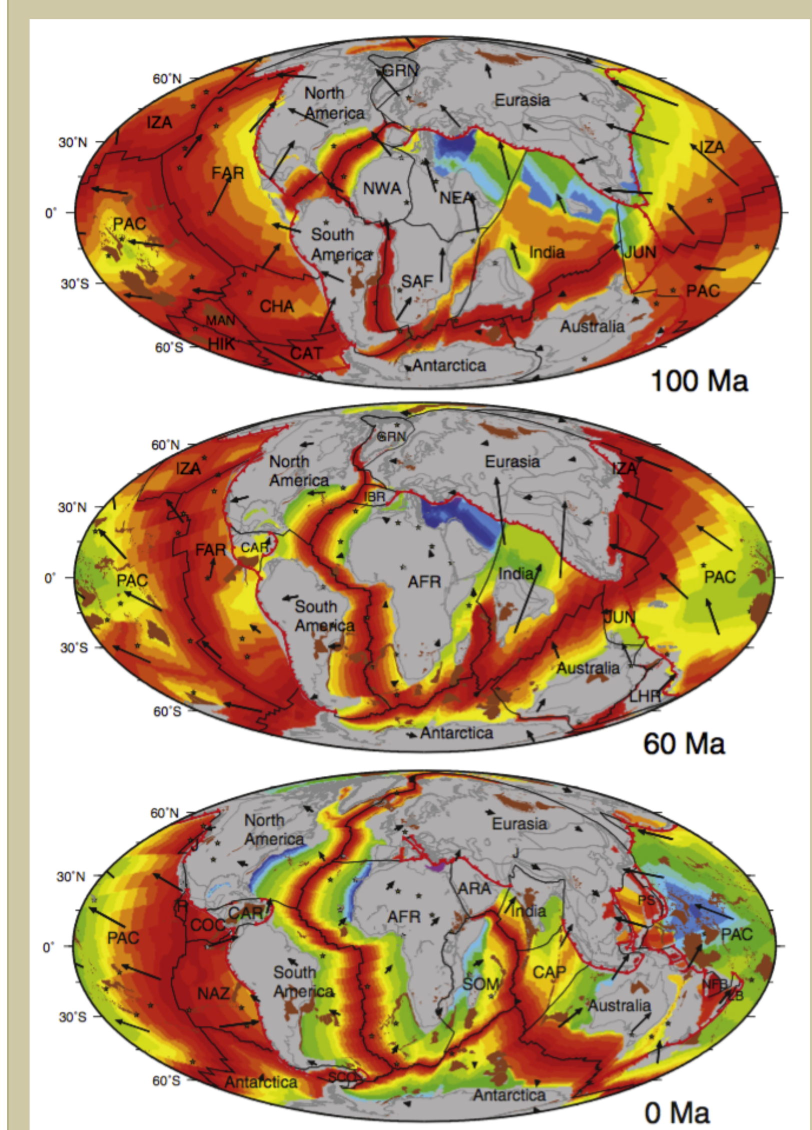
Grid resolution is in the order of 20 km with max. 35 particles per cell.

Initial condition: Homogeneous composition of pyrolite (c=0.25), small temperature perturbations, plate stage 200 Ma. Ran for ≈ 60 Myear.



TOP: Initial temperature and bulk composition.
BOTTOM: Initial velocity field (*Seton et al, 2012*).

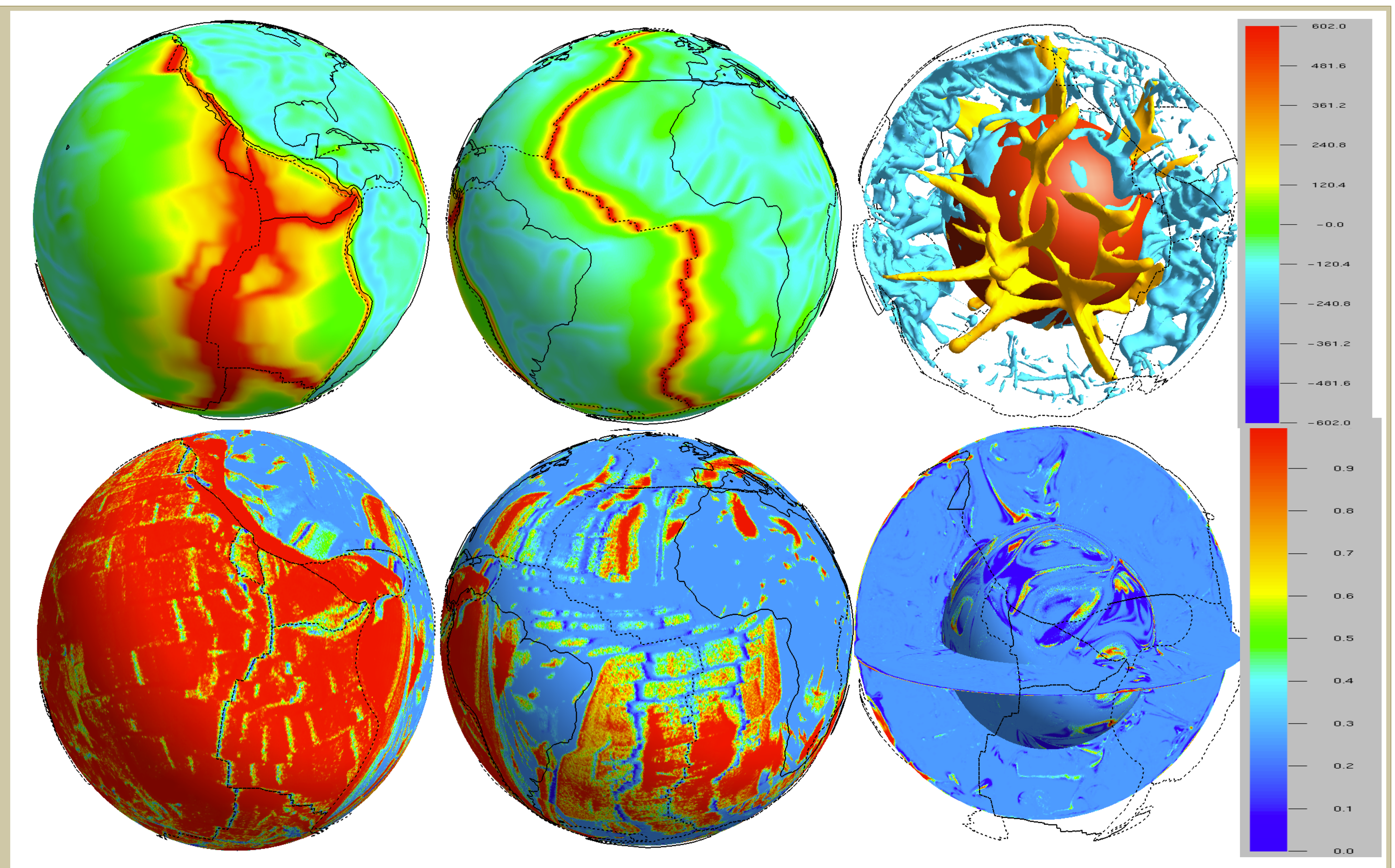
1. Plate driven convection with melting



Seton et al., ESR, 2012.

- The surface velocity field is imposed.
- Changes every 1 MY.
- Scaled down by a factor of 5 to match higher viscosity.
- Melting happens when-/wherever material crosses its solidus.

Results:
- Melt is produced at spreading ridges.
- Fast spreading ridges produce a lot of melt, slow ones less.
- Basalt/Harzburgite structures easily reach the CMB.
- Structure can be used to investigate lower mantle dynamics.

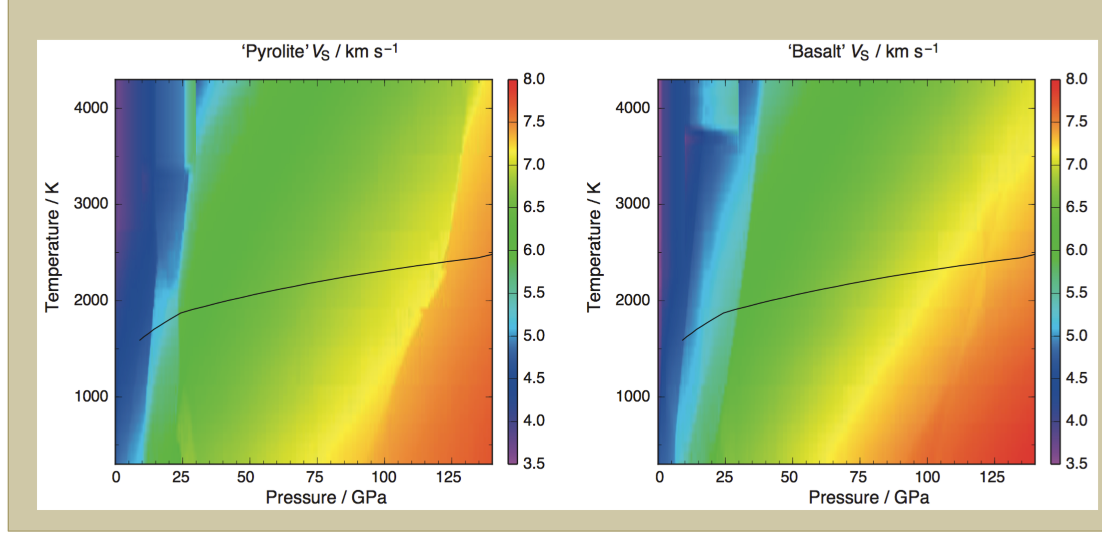


TOP: Temperature; BOTTOM: Bulk composition. After 200 MYear (present day).

2. Conversion to seismic properties

We use the thermodynamic database of Stixrude and Lithgow-Bertelloni (GJI, 2005, 2011)
Temperature, Pressure and Composition are taken from the convection model.
C=0: Hartzburgite; C=0.25: Pyrolite; C=1: Basalt,
Linear interpolation for intermediate values.
Generates: Vp, Vs, density and attenuation (Qs).
Using the Q4 model of Goes et al (EPSL, 2004)

Component	*Pyrolite*	*Basalt*	*Hartzburgite*
SiO_2	38.71	51.75	36.04
MgO	49.85	17.94	56.54
FeO	6.17	7.06	5.97
CaO	2.94	13.88	0.79
Al_2O_3	2.22	10.19	0.65
Na_2O	0.11	2.18	0.00

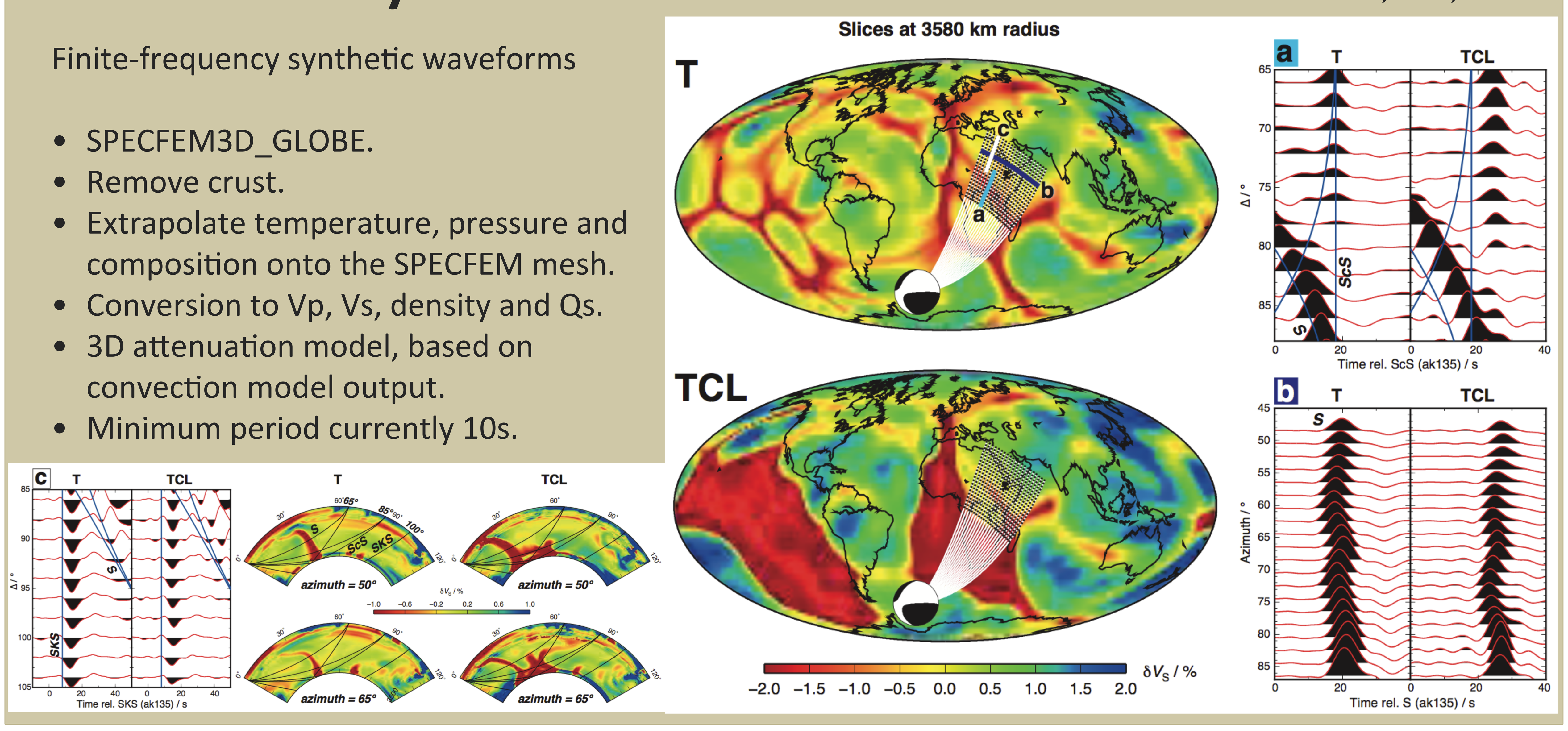


3. Preliminary seismic calculations

Based on Davies et al., EPSL, 2012

Finite-frequency synthetic waveforms

- SPECFEM3D_GLOBE.
- Remove crust.
- Extrapolate temperature, pressure and composition onto the SPECFEM mesh.
- Conversion to Vp, Vs, density and Qs.
- 3D attenuation model, based on convection model output.
- Minimum period currently 10s.



References / See also:

Davies et al., Reconciling dynamic and seismic models of Earth's lower mantle: The dominant role of thermal heterogeneity,EPSL, 2012.
Seton et al., Global continental and ocean basin reconstructions since 200 Ma, ESR, 2012.
Stixrude and Lithgow-Bertelloni, Thermodynamics of mantle minerals I.-Physical properties, GJI, 2005
Stixrude and Lithgow-Bertelloni, Thermodynamics of mantle minerals I.-Phase equilibria, GJI, 2011
Van Heck, Davies, Elliott, Porcelli, Global scale modeling of melting and isotopic evolution of Earth's mantle, GMD, under review.
AGU Poster DI31A-2553 (Wednesday): Davies et al., Dynamic coupling of bulk chemistry, trace elements and mantle flow.