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Modelling Antarctica's lithospheric structure

and testing the West Antarctic mantle plume hypothesis

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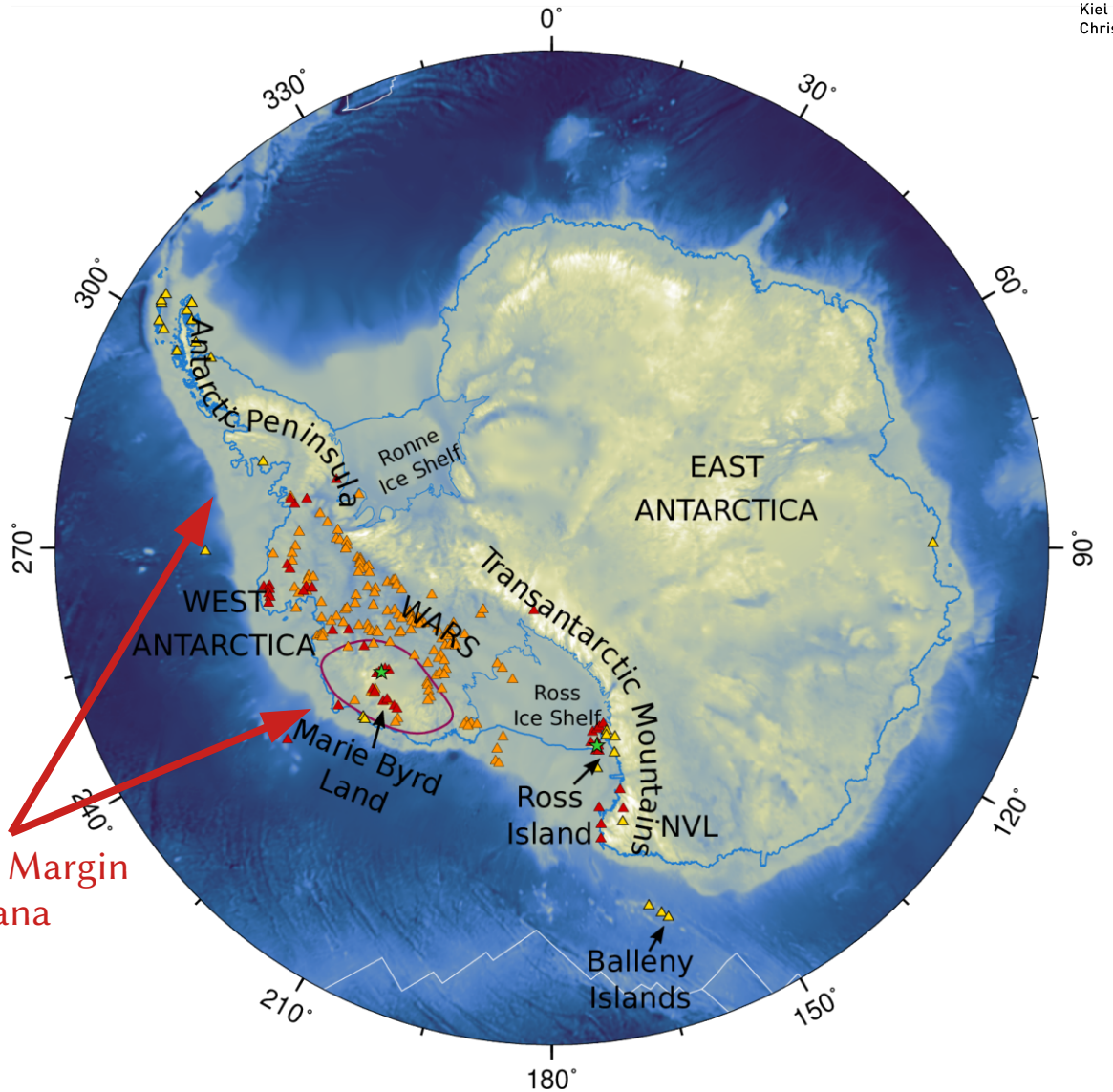
- Competing hypotheses about the origin of the Marie Byrd Land (MBL) dome:
  Uplift driven by a plume
  vs.
  Hydrous mantle wedge
- One of the world's largest volcanic provinces (coloured triangles).



Modelling Thermal Anomalies beneath Marie Byrd Land

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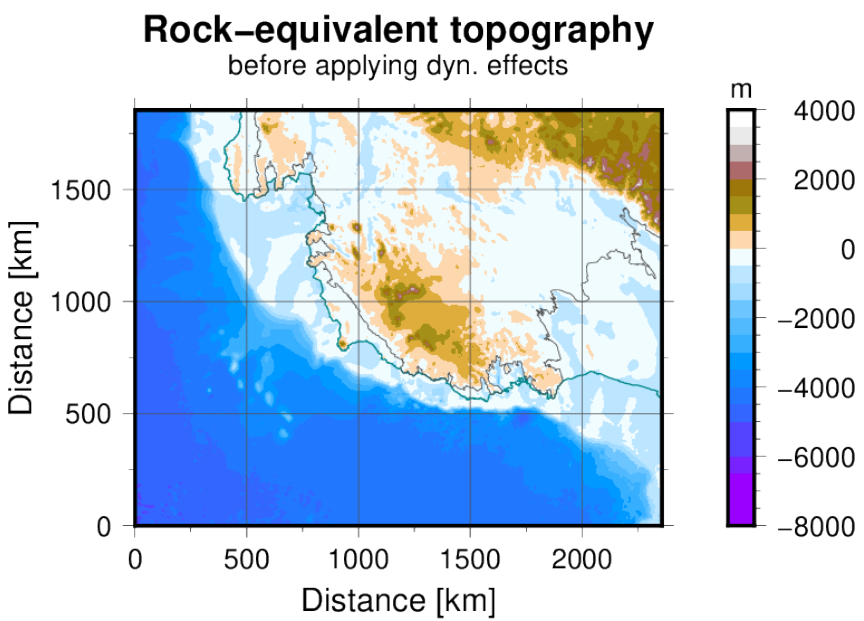
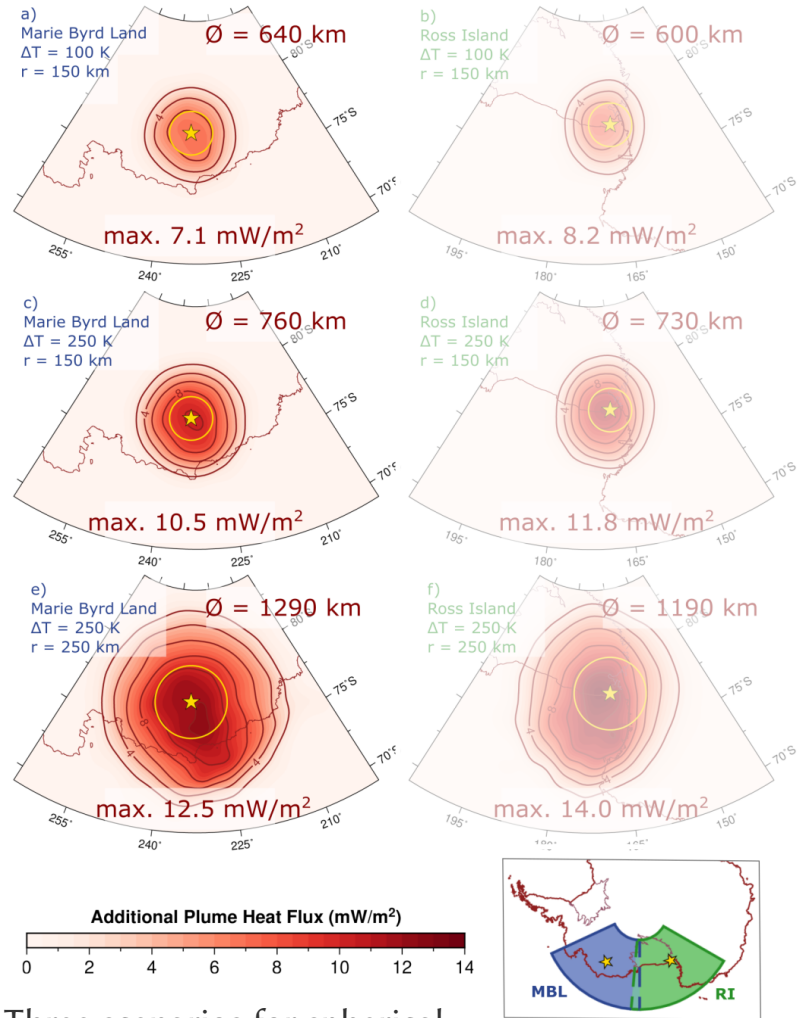
Testing the plume hypothesis by modelling thermal anomalies in the upper mantle beneath MBL:

- increased surface heat flow,
- decreased density in the lithosphere and the sub-lithospheric upper mantle,
- buoyancy force ⟶ dynamic topography,
- reduced seismic wave velocities.





Three scenarios for spherical thermal anomalies in the upper mantle beneath MBL

Dynamic Topography Effect Caused by Thermal Anomalies

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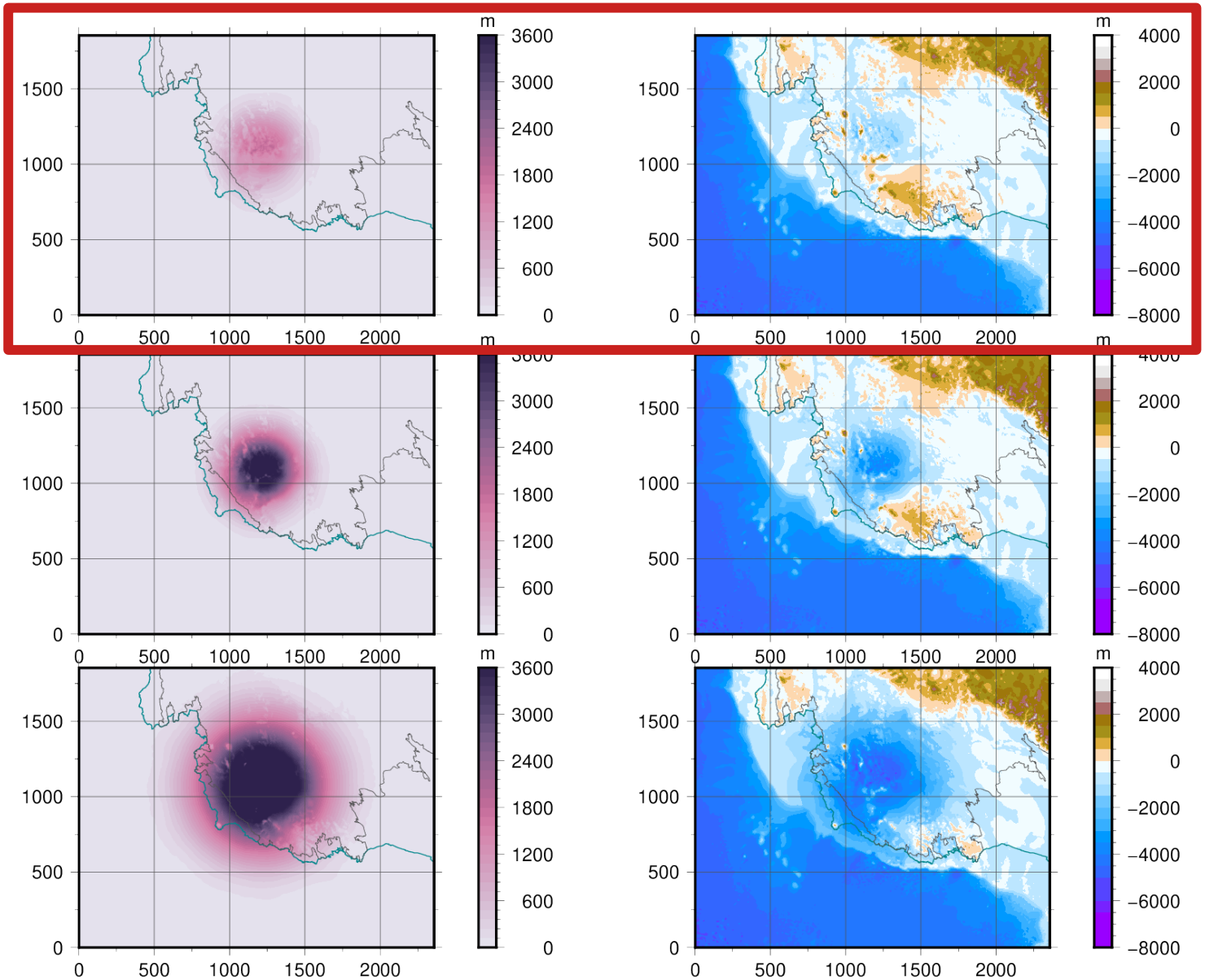
Dynamic topography effect



Reduced topography

Scenario with ~1 km dynamic topography effect is chosen for further modelling.

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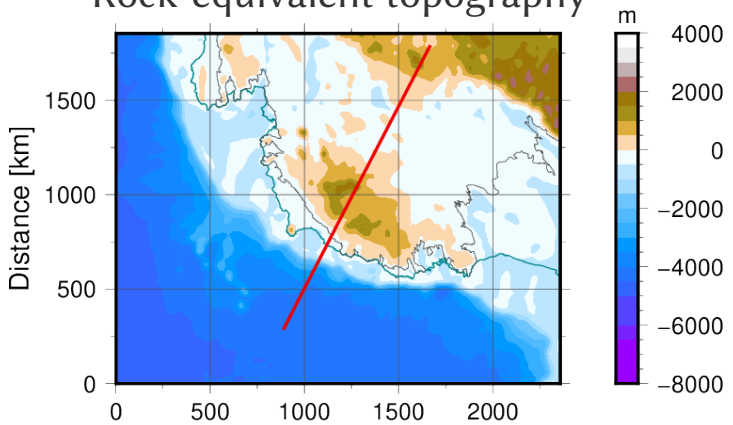
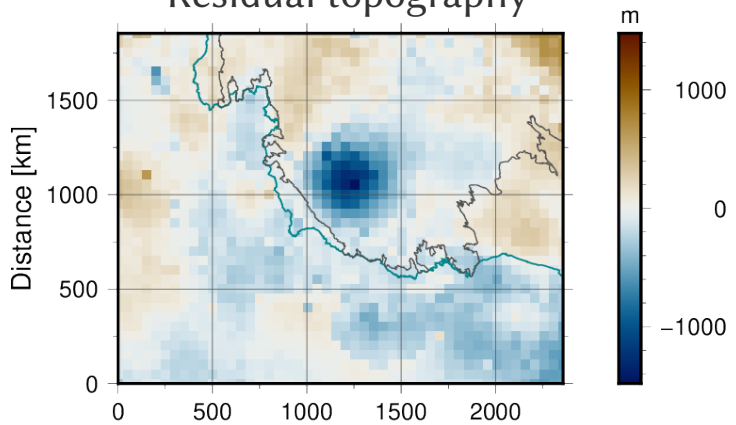
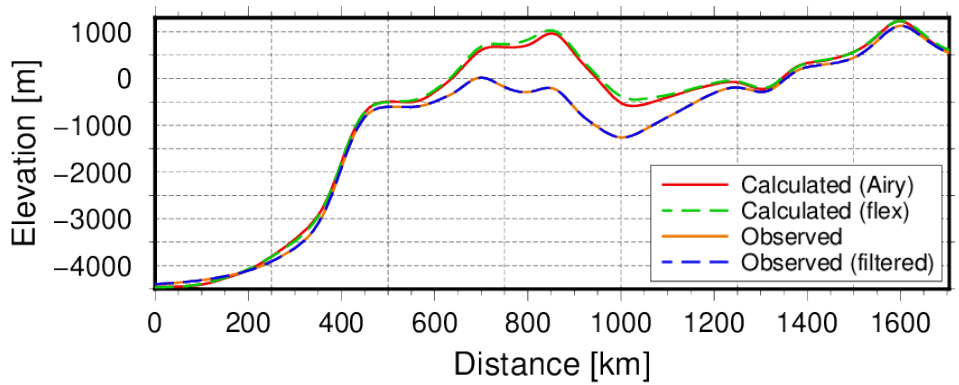
- Modelling software LitMod3D (Fullea et al., 2009),
- basic model (whole Antarctica) from Pappa et al. (2019) ⟶ cut out MBL,
- fit model to reduced topography by varying Moho / LAB depth,
- evaluate effect on observables (e.g. seismic velocities, gravity).

Rock-equivalent topography



Residual topography





Fit Model by Changing the Moho Depth

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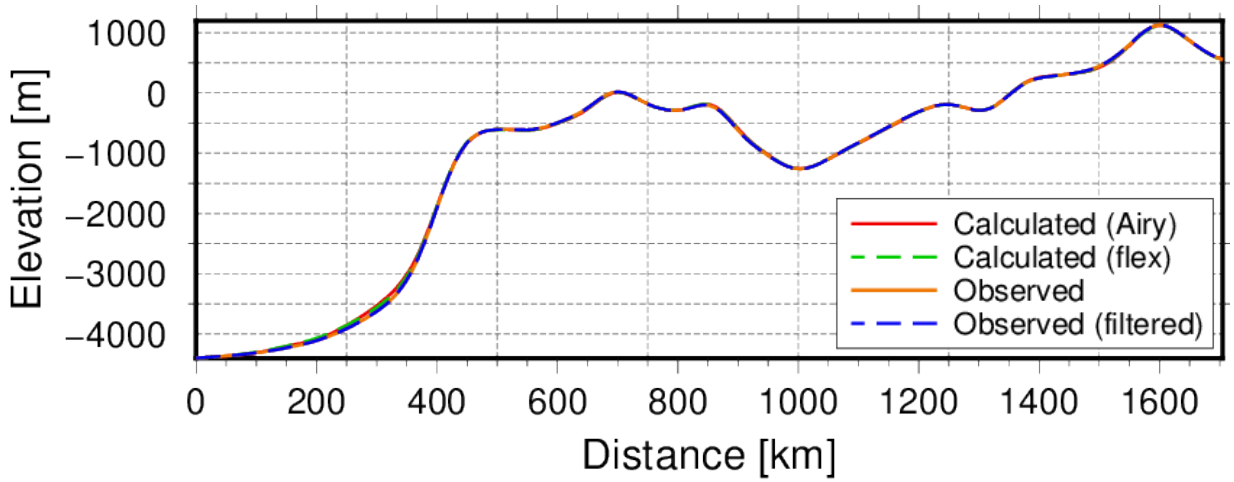

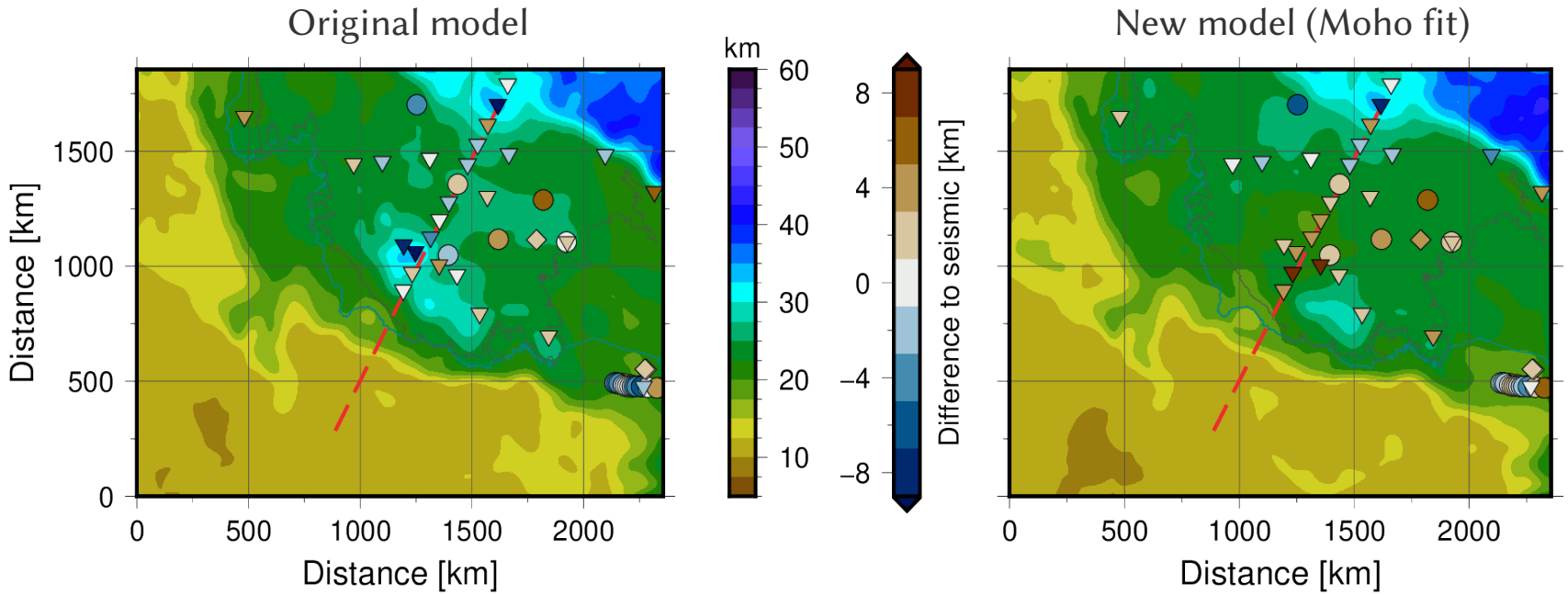

Fit Model by Changing the LAB Depth

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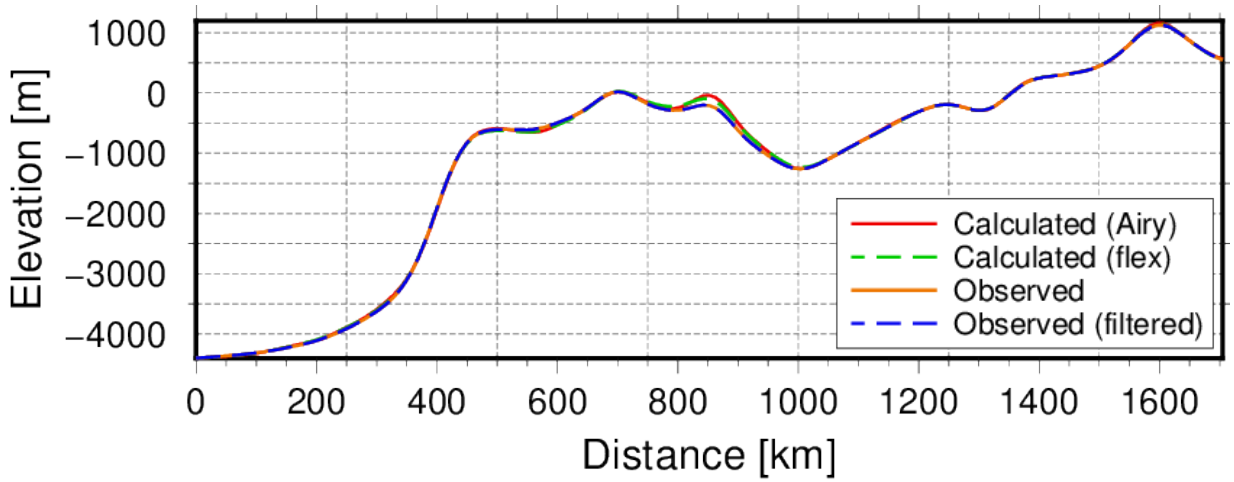

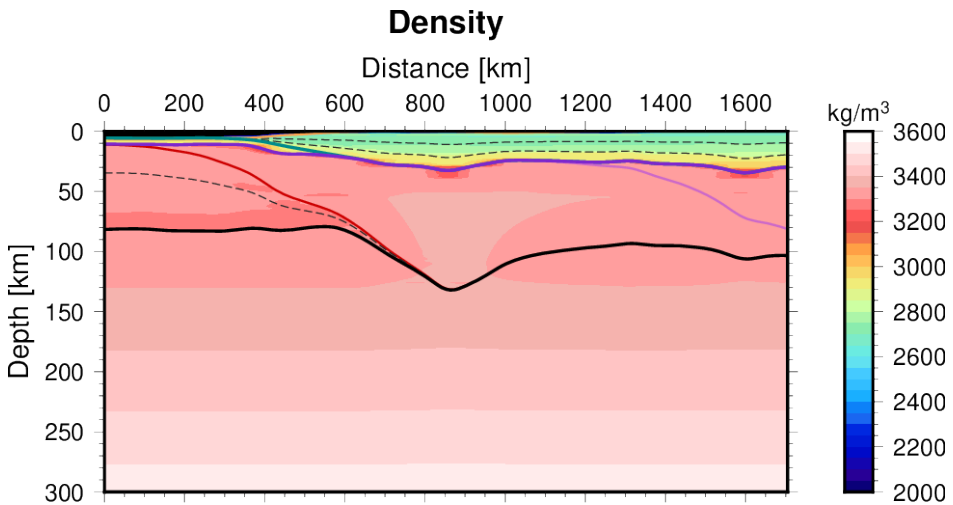

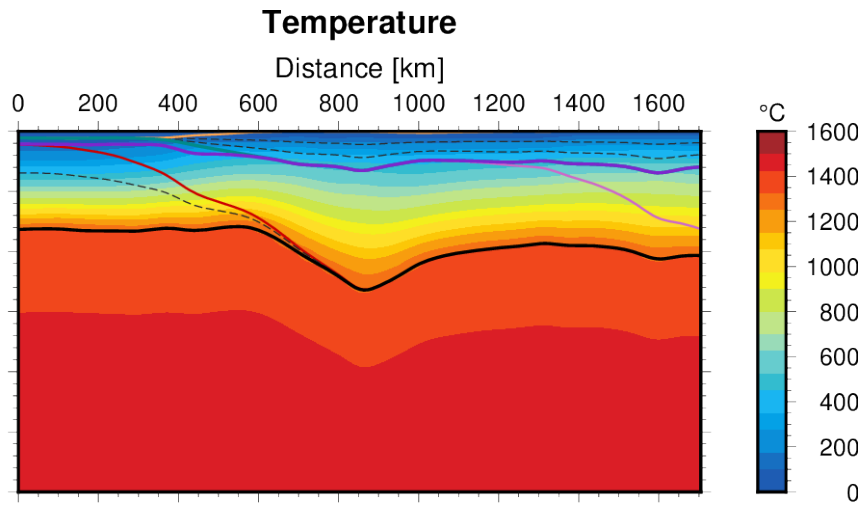

Evaluating Seismic Velocities

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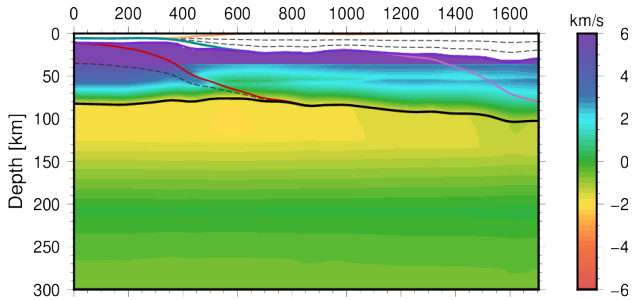
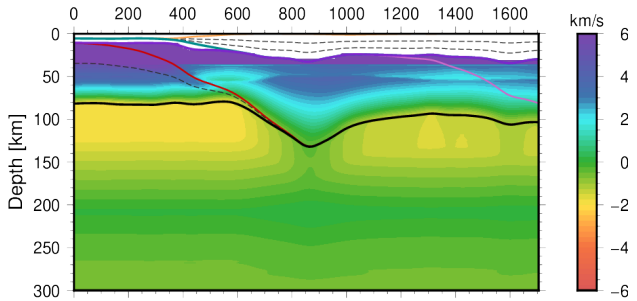
Compare seismic S-wave velocity anomaly along profile D–D' from Lloyd (2018), Figure 12, p.98.



New model from Moho fit



New model from LAB fit

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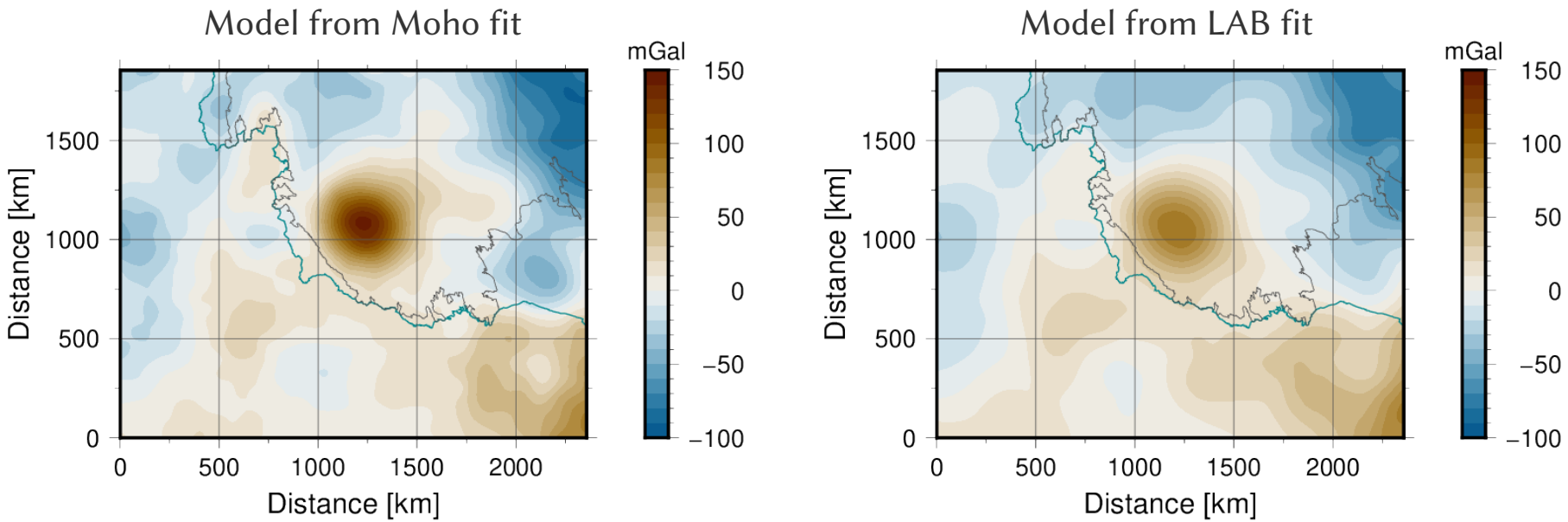

- Estimated dynamic topography effect from thermal anomaly compensated by
  - a) thinner crust: strong gravity effect, small effect on seismic velocities
  - b) thicker lithospheric mantle: contradicts observed seismic velocities
- LitMod3D models inconclusive (dynamic forces not explicitly modelled)

  → seismic anomaly $\stackrel{?}{=}$ thermal anomaly $\stackrel{?}{=}$ density anomaly

  → seismic anomaly $\stackrel{?}{=}$ hydrated mantle

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Fullea, J., Afonso, J. C., Connolly, J. A. D., Fernàndez, M., García-Castellanos, D., & Zeyen, H. (2009). LitMod3D: An interactive 3-D software to model the thermal, compositional, density, seismological, and rheological structure of the lithosphere and sublithospheric upper mantle. Geochemistry, Geophysics, Geosystems, 10(8). https://doi.org/10.1029/2009GC002391

Lloyd, A. J. (2018). Seismic Tomography of Antarctica and the Southern Oceans: Regional and Continental Models from the Upper Mantle to the Transition Zone. PhD thesis, Washington University. https://doi.org/10.7936/4r3g-rn34

Pappa, F., Ebbing, J., Ferraccioli, F., & van der Wal, W. (2019). Modeling Satellite Gravity Gradient Data to Derive Density, Temperature, and Viscosity Structure of the Antarctic Lithosphere. Journal of Geophysical Research: Solid Earth. https://doi.org/10.1029/2019JB017997

