S18p-160: Constrain density, temperature, and composition of Antarctic lithosphere by gravity inversion along with seismic tomography

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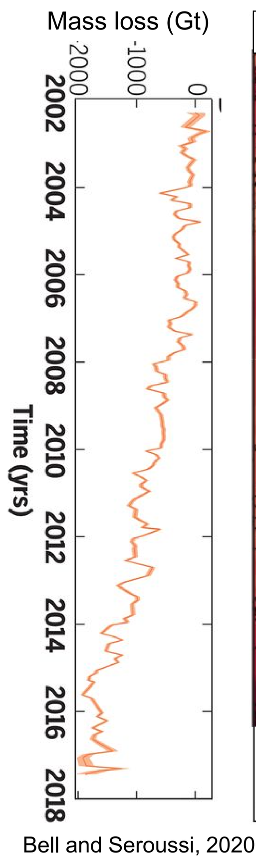
Introduction

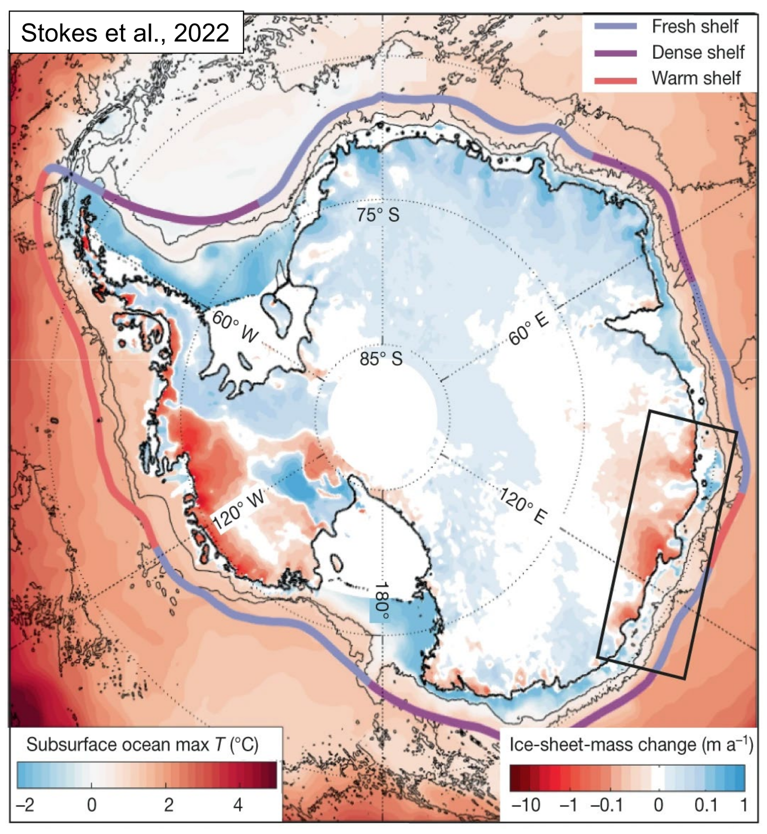
Antarctica preserve the largest ice sheet on earth, and the mass loss in Antarctica is accelerating. The capacity to prediction future ice mass change is limited by the incomplete knowledge of basal processes and basal boundary condition for ice sheet flow.

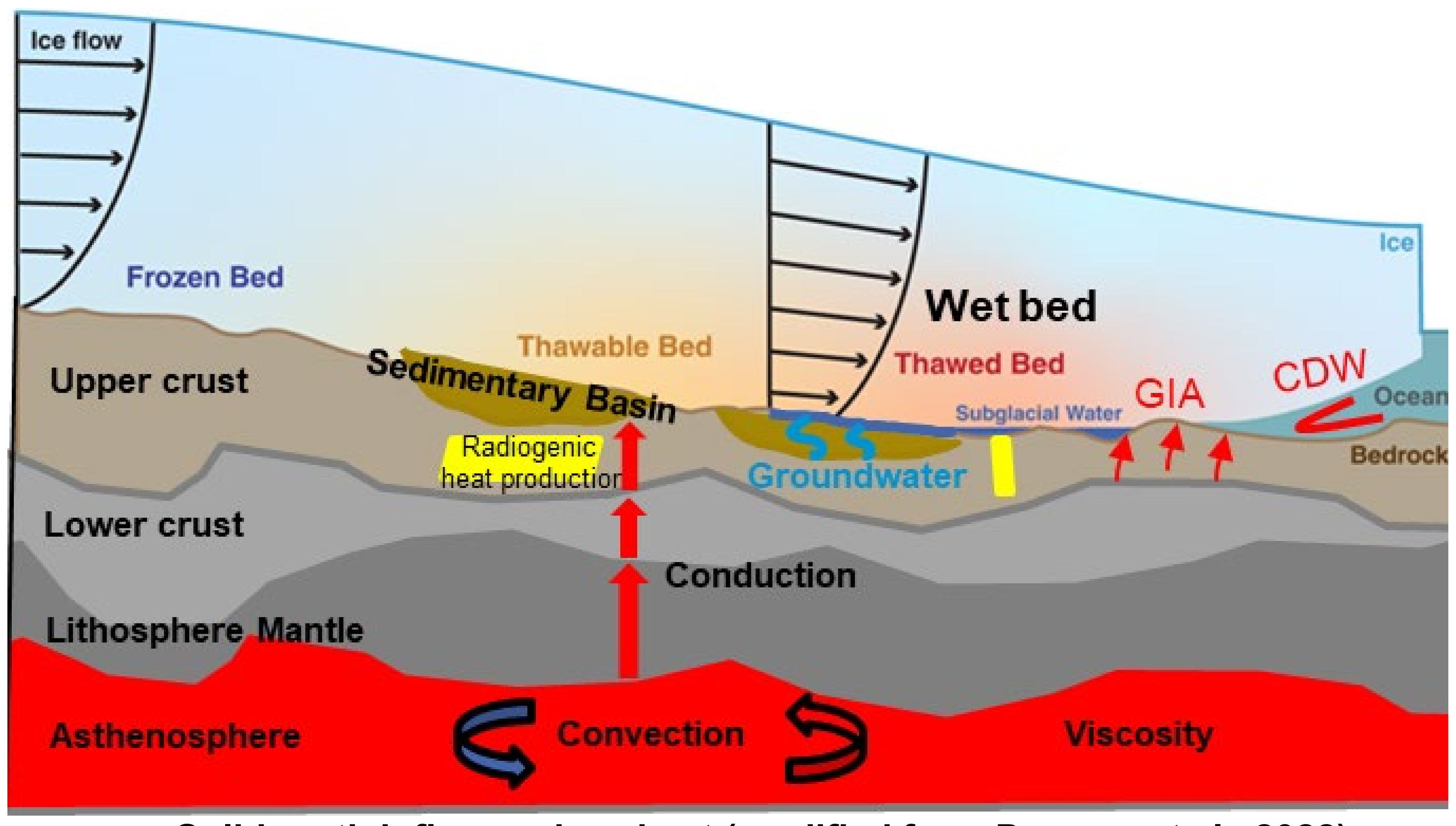
Solid-earth provide important basal boundary conditions for governing ice sheet flow. For example, water and sediment could reduce basal friction cause basal sliding. Glacial isostatic adjustment (GIA) could recouple ice sheet and bed to stabiles ice sheet retreat.

Understanding these impacts require knowledge about geothermal heat flow and mantle viscosity. But how?



Bell and Seroussi, 2020



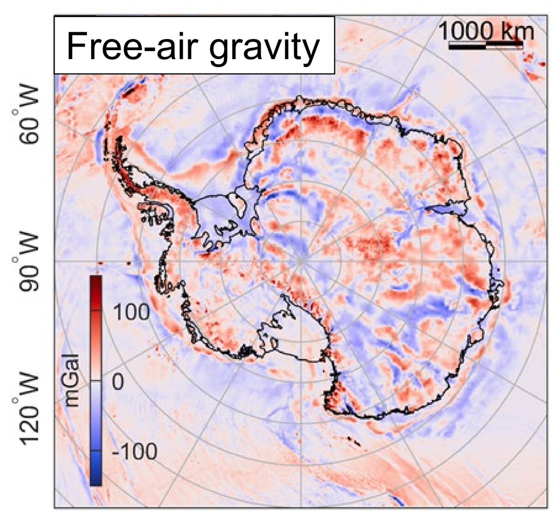


Solid-earth influence ice sheet (modified from Dawson et al., 2022)

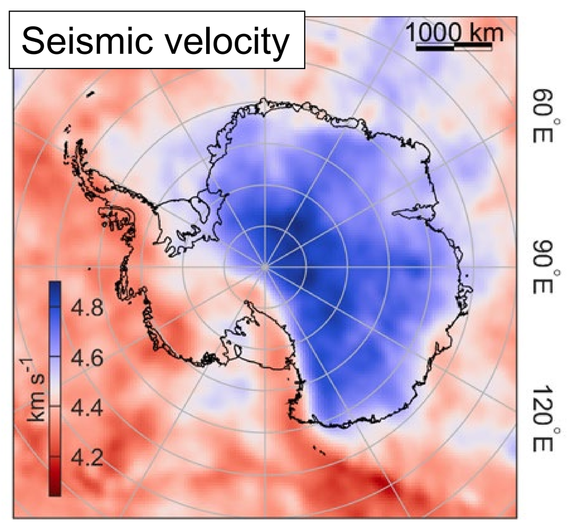
Know more details

Data & Method

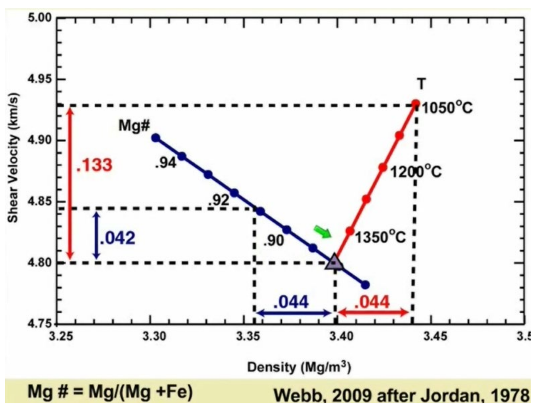
Seismic velocity mainly sensitive to temperature change, but compositional impact is also important. Gravity inversion as constrain (mantle density) for estimate mantle temperature and composition.



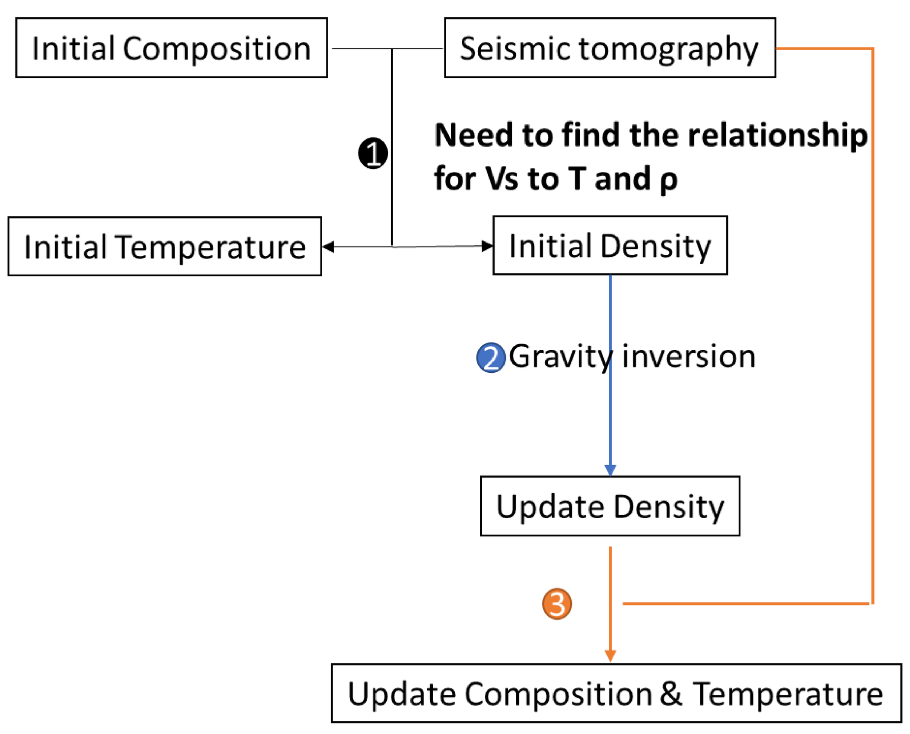
ANTGG+ (Scheinert et al., 2016)



ANT-20 (Lloyd et al., 2020)

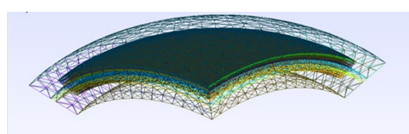


Workflow



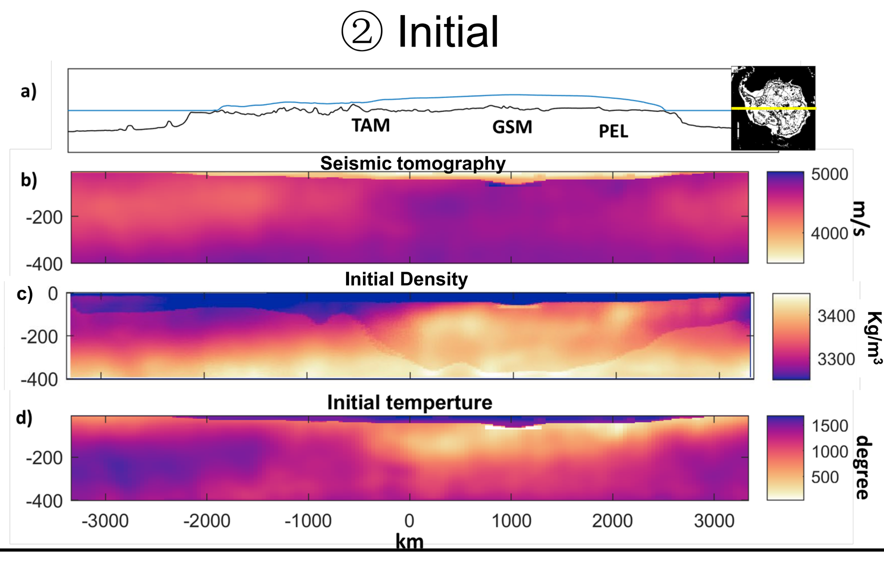
① We use a Mineral physical approach (Goes et al., 2000) to convert Vs to Temperature and density

Then we build our initial model with a 10 km resolution curved Earth. ② The inversion is solved using **esys-escript** by combining I-PCG with discrete solver AMG-PCG (Codd et al., 2021)

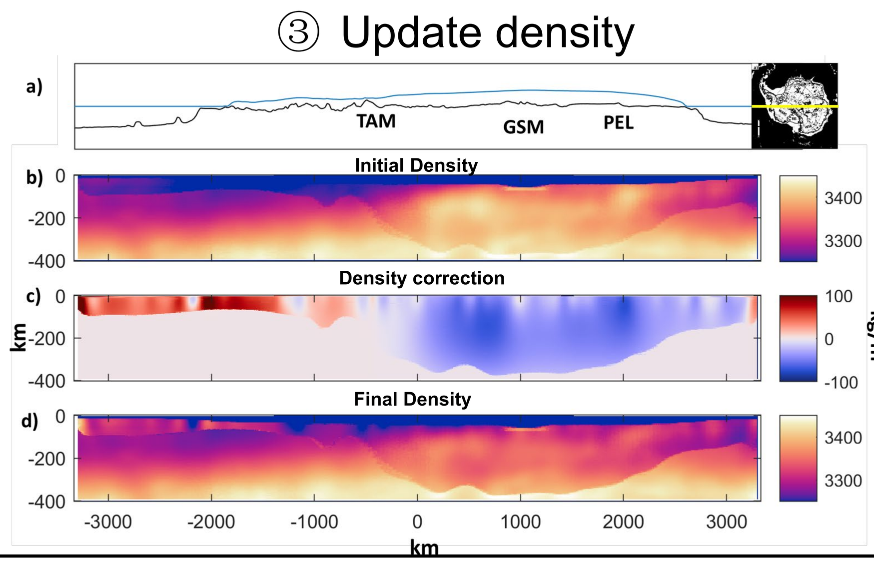


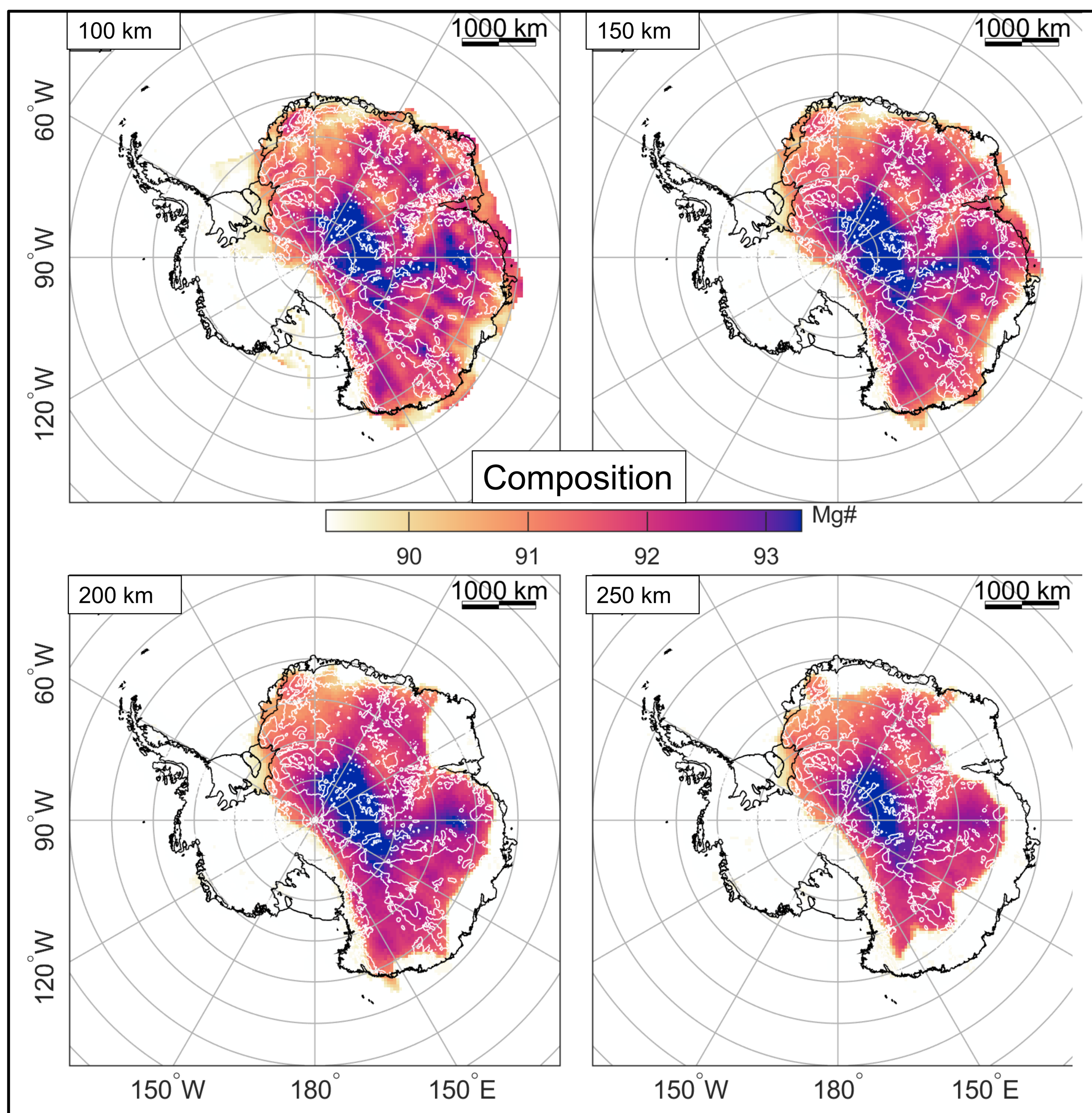
esys-escript

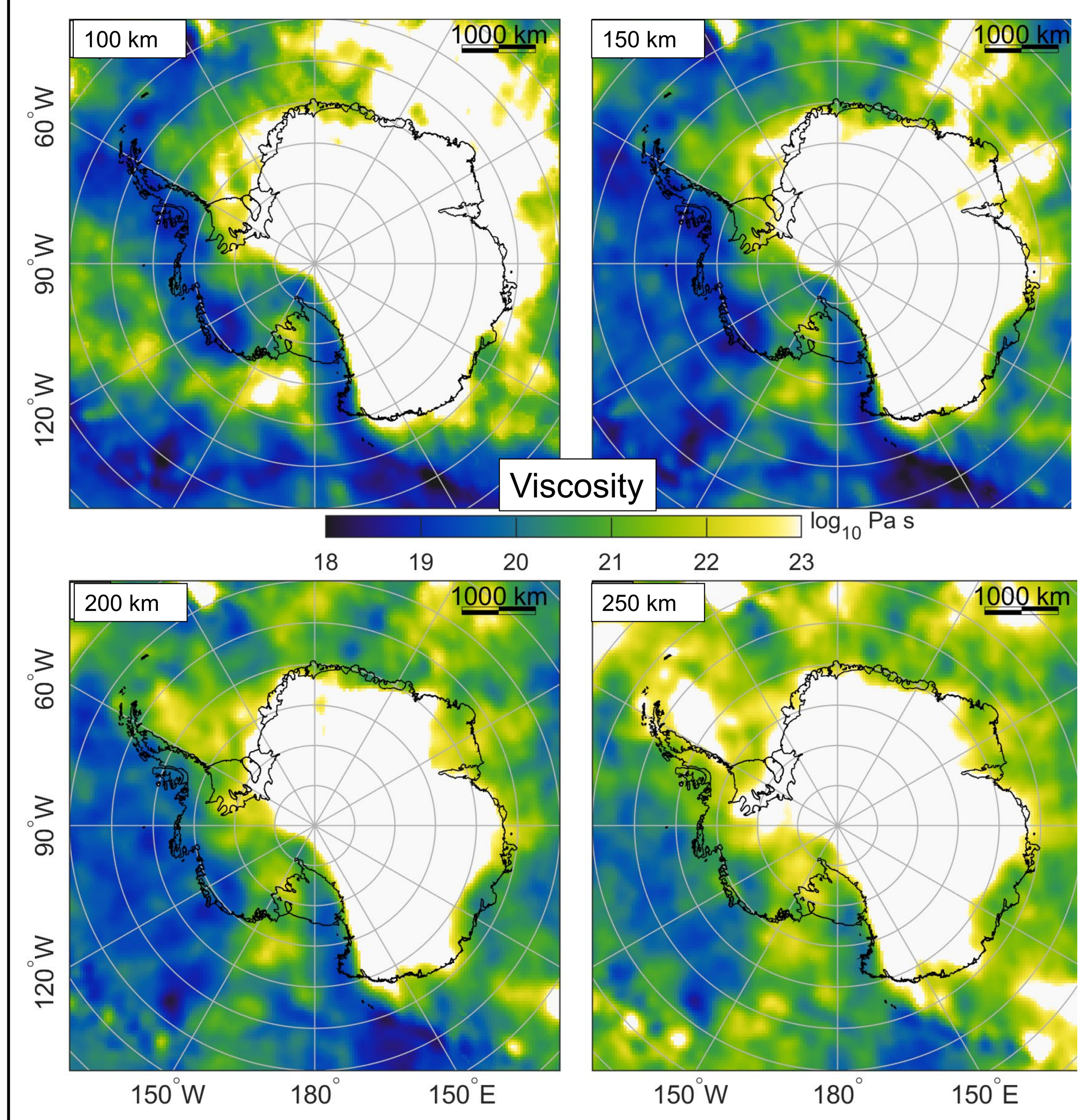
② Initial



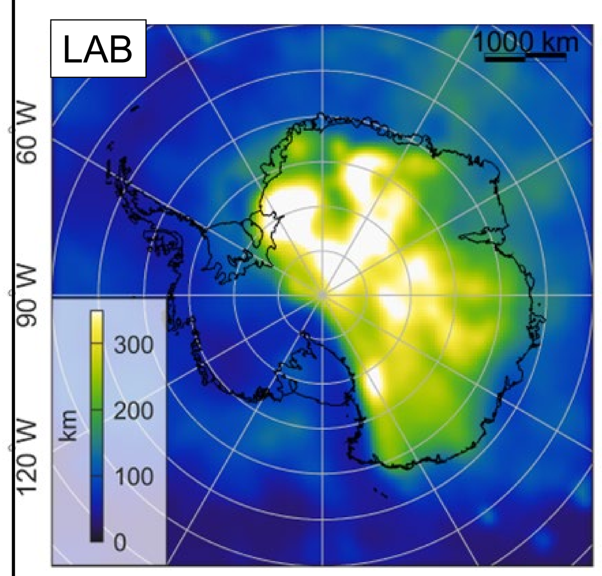
③ Update density

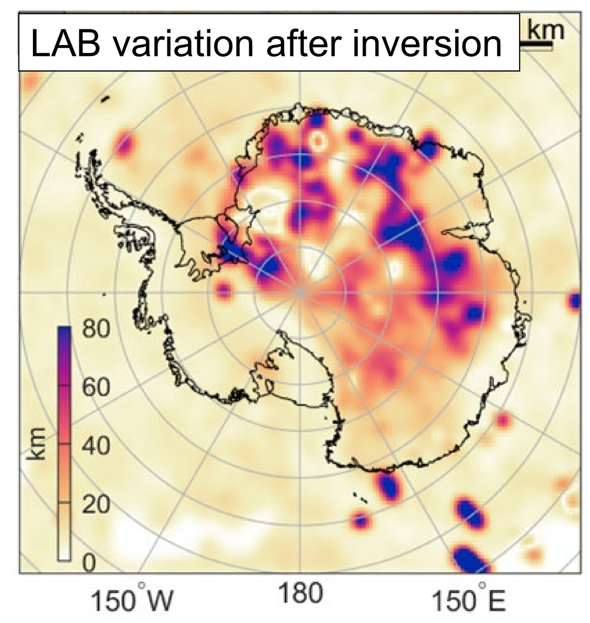


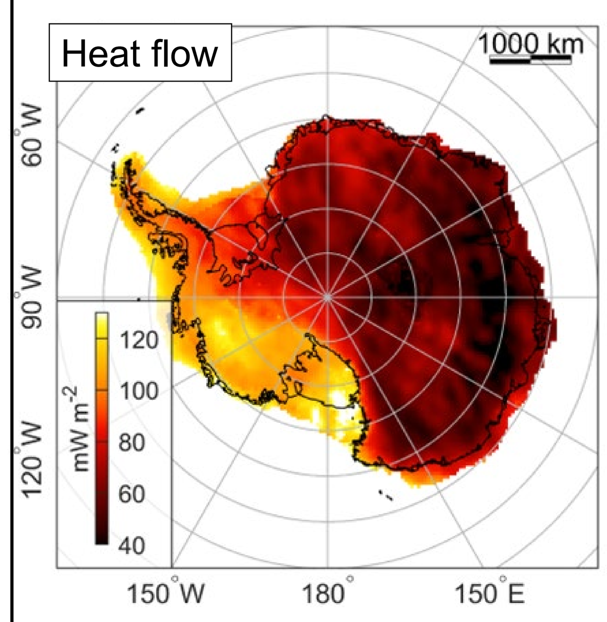




We calculated the **lithosphere thickness** (at 1200°C isotherm) and **geothermal heat flow** based on mantle heat flow. In areas with depleted mantle, the resolved LAB could be shallower by up to 80 km compared to the initial assumption.



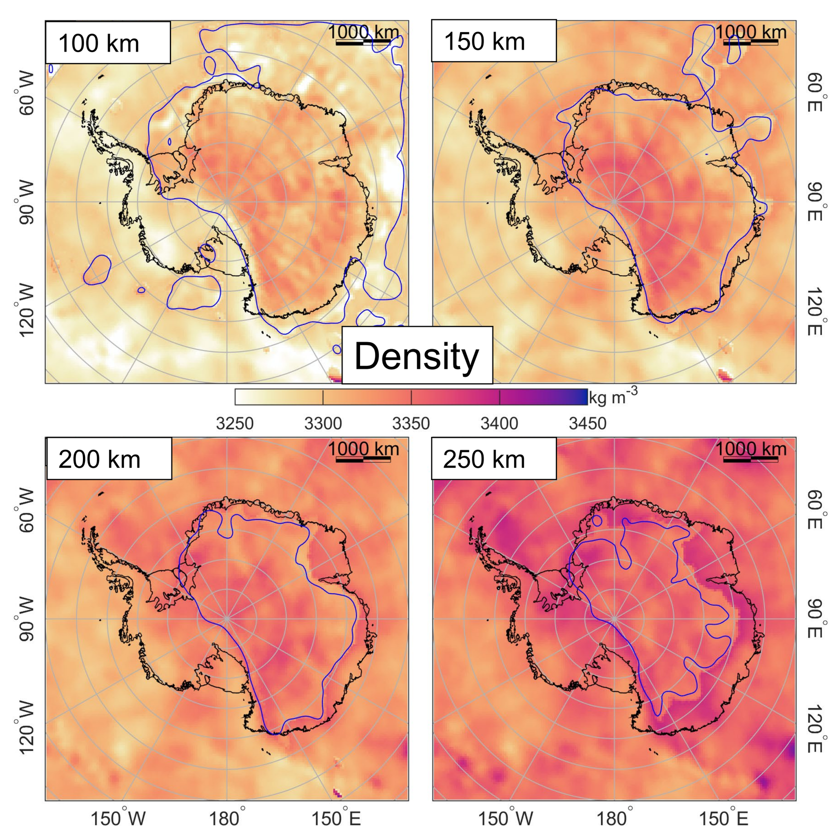


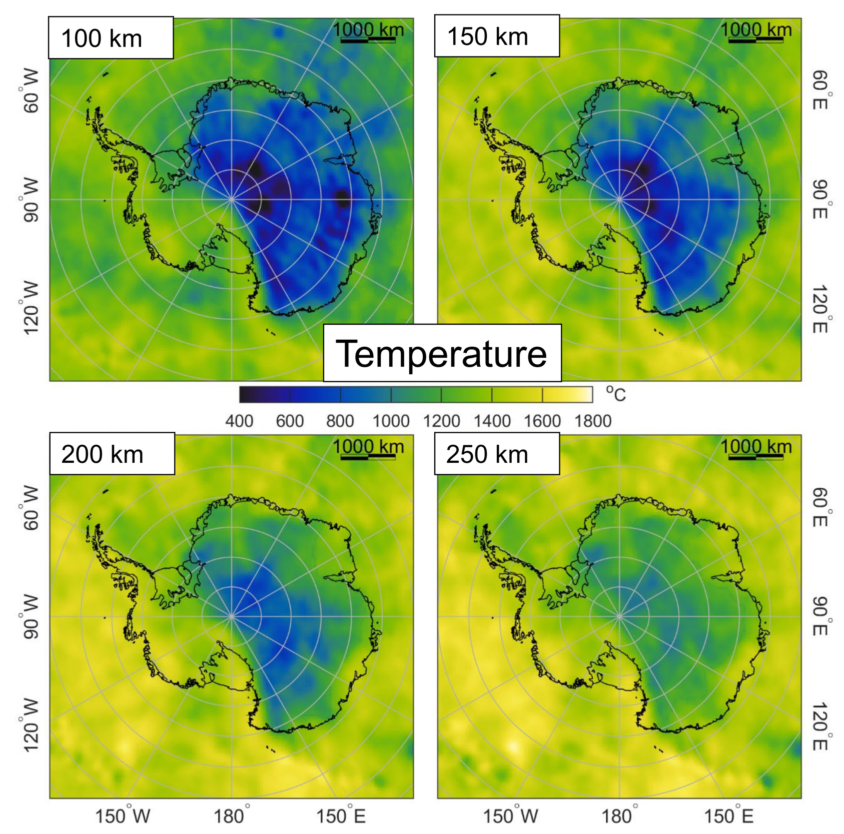


Result and Discussion

Based on the inversion result, we can estimate temperature, composition of Antarctic lithosphere. By considering compositional change, the estimated temperature in East Antarctica is up to 150℃ higher, compare with a uniform primitive type mantle.

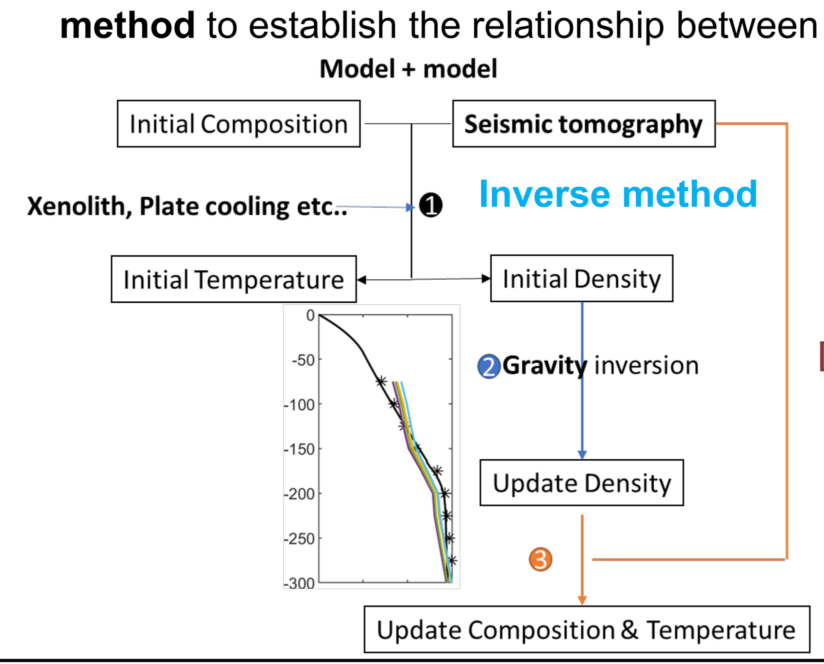
New structures provide constrain for **mantle density, temperature, composition and viscosity.**

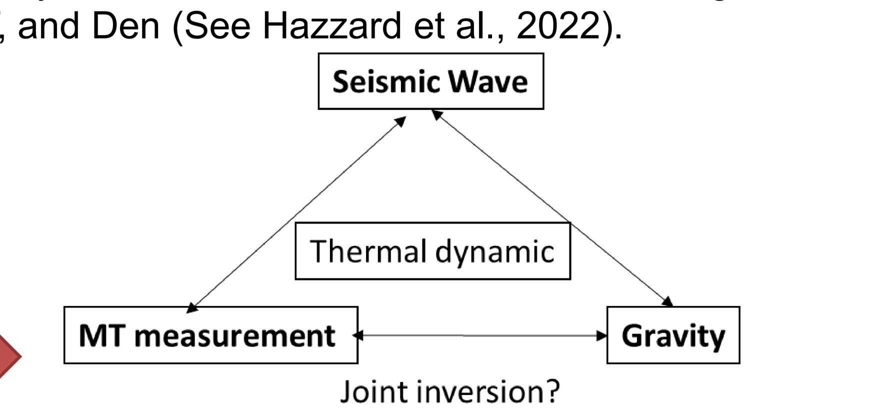




How do we move forward?

Temperature is the primary factor influencing seismic tomography, while composition plays a secondary role. Additional uncertainty arises due to seismic attenuation. Instead of employing a mineral physical approach to convert Vs to temperature and density, an alternative method involves using **inverse method** to establish the relationship between Vs, T, and Den (See Hazzard et al., 2022).





Currently, our understanding is based on the initial tomography model, and each model suggests different structural interpretations. It may be necessary to consider rebuilding the model from observation, which would require significant computational power…

Conclusion

- We provide a new lithosphere model to constrain basal boundary conditions.
- Resolving Antarctic mantle composition suggests a warmer East Antarctica.
- West Antarctica especially Amundsen Sea Embayment show low mantle viscosity and high geothermal heat flow.

Reference

[1] Bell, R. E. & Seroussi, H. History, mass loss, structure, and dynamic behavior of the Antarctic Ice Sheet. *Science* 367, 1321-1325 (2020). **[2] Stokes**, C. R. et al. Response of the East Antarctic Ice Sheet to past and future climate change. *Nature*, 608(7922), 275-286 (2022). **[3] Lloyd**, A. J. *et al.* Seismic structure of the Antarctic upper mantle imaged with adjoint tomography. *JGR. Solid Earth* 125 (2020). **[4] Scheinert**, M. *et al.* New Antarctic Gravity Anomaly Grid for Enhanced Geodetic and Geophysical Studies in Antarctica. *GRL.* (2016). **[5] Dawson**, *et al*. Ice mass loss sensitivity to the Antarctic ice sheet basal thermal state. *Nat Commun*, 13(1), 4957. (2022). **[6] Codd**, A. *et al*. Fast multi-resolution 3D inversion of potential fields with application to high-resolution gravity and magnetic anomaly data from the Eastern Goldfields in Western Australia. *Computers & Geosciences* (2021). **[7] Goes**, S. *et al.*, Shallow mantle temperatures under Europe from P and S wave tomography. *JGR: Solid Earth* (2000). **[8] Hazzard**, J. *et al*. Probabilistic Assessment of Antarctic Thermomechanical Structure: Impacts on Ice Sheet Stability. *JGR: Solid Earth*, (2022)

Acknowledgments

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