Christian-Albrechts-Universität zu Kiel

Importance of the Solid Earth structure for understanding the evolution of the Greenland ice-sheet

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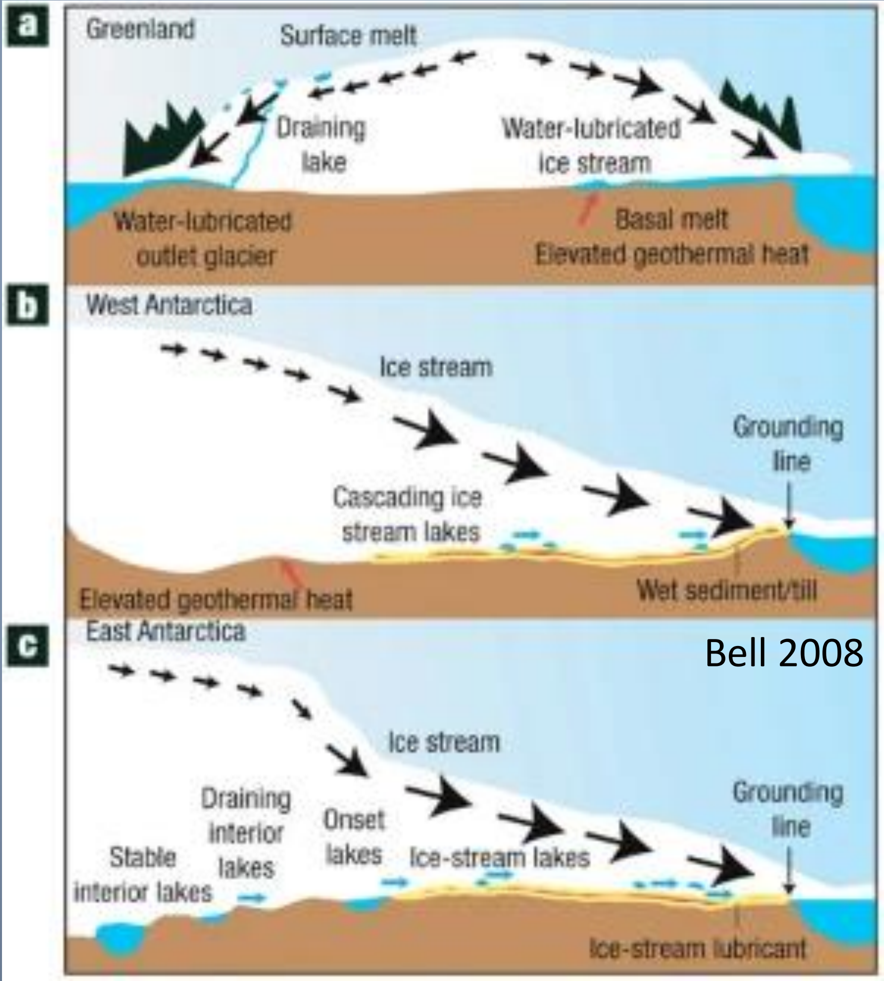
Deutsche Forschungsgemeinschaft

European Space Agency

4DGreenland

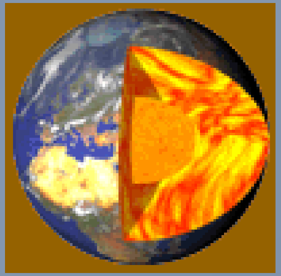
Motivation

- Bell (2008) described the role of sub-glacial conditions for the evolution of the Polar ice sheets



Bell 2008

Motivation



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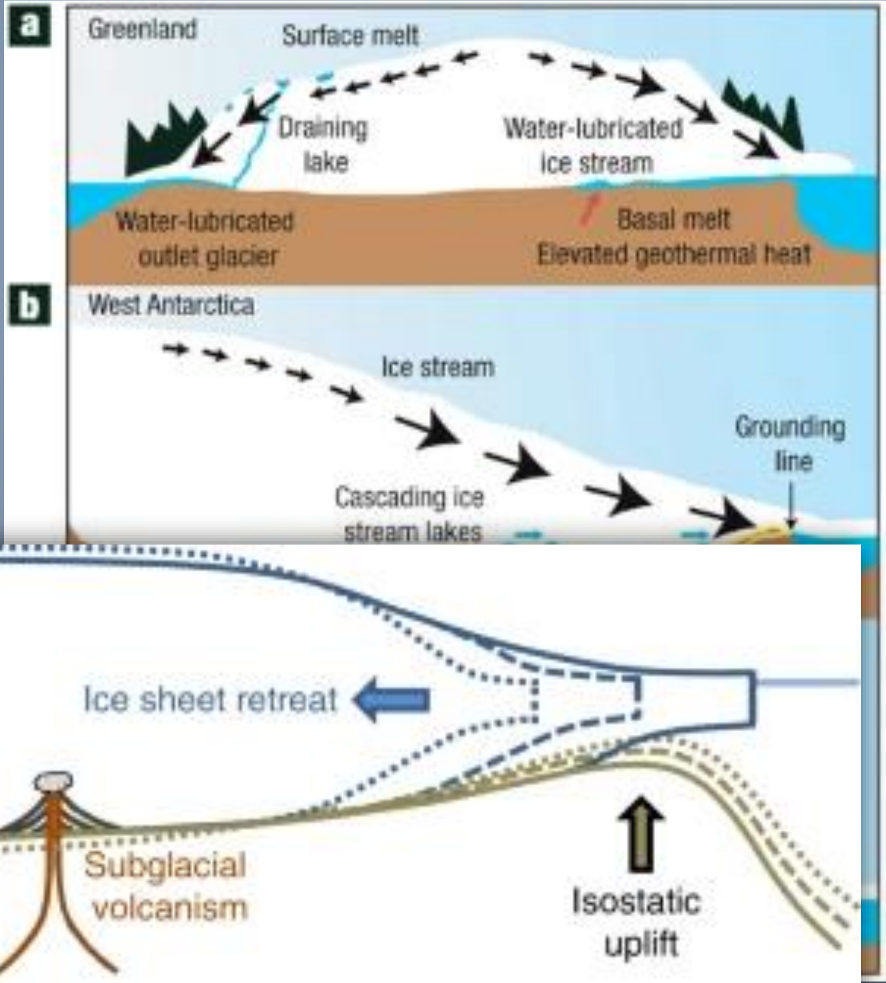
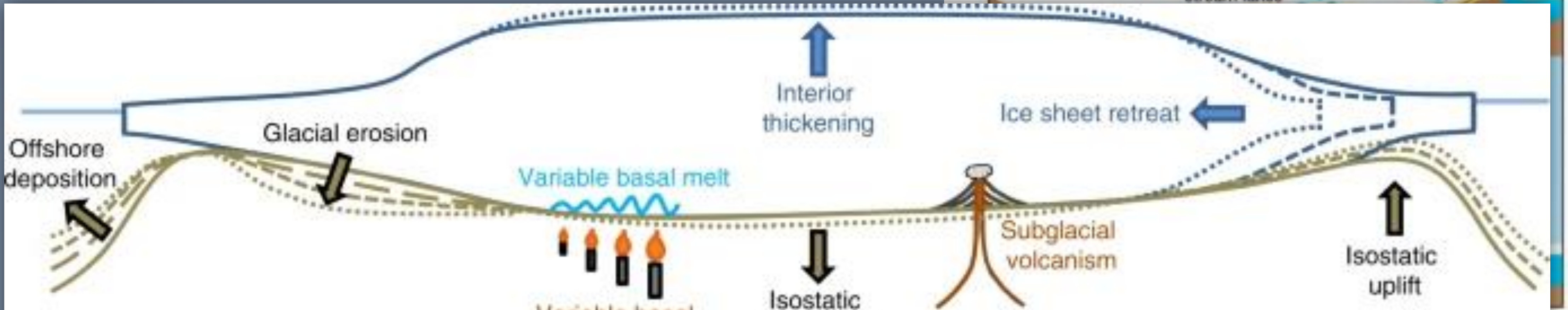
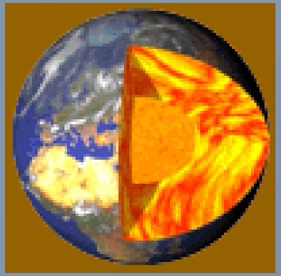
- Whitehouse et al. (2019) extended the description of Solid Earth parameters described the key ingredients affecting the (Antarctic) Ice Sheets

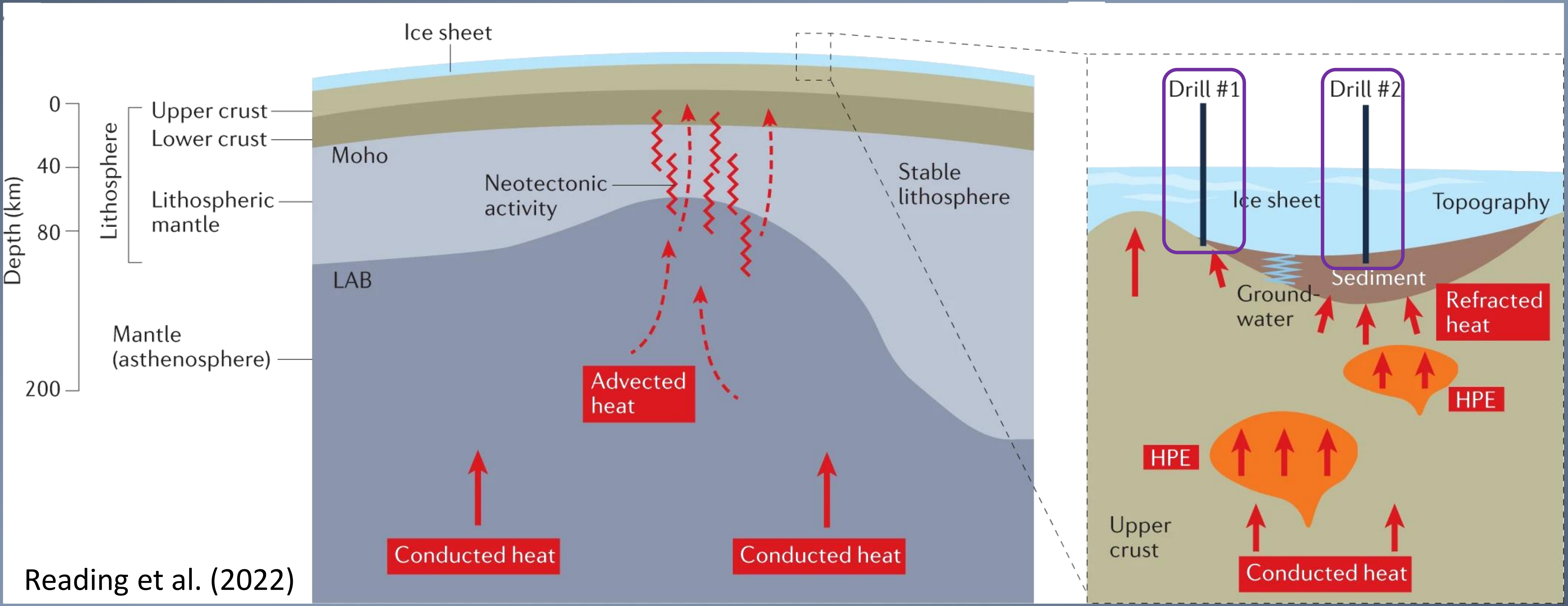




Whitehouse et al 2019

Regional and local contributions to GHF

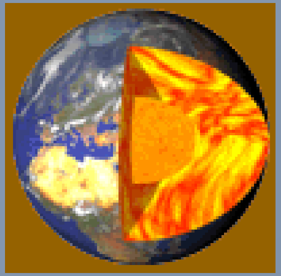




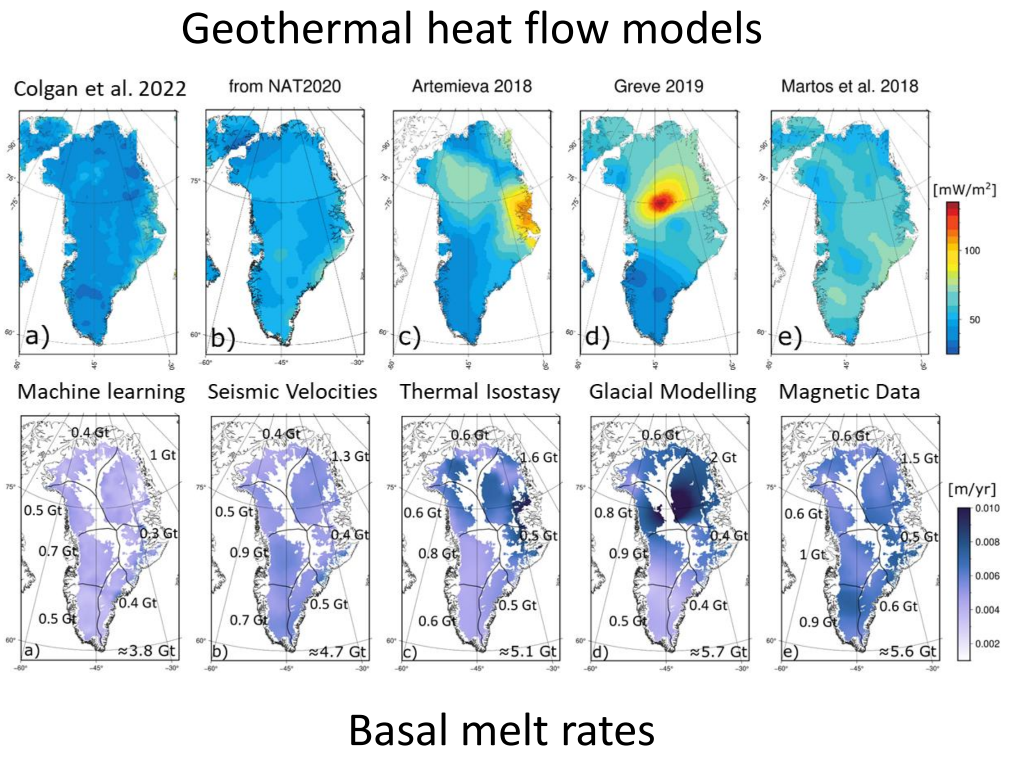
Reading et al. (2022)

- Regional scale: Crustal and upper mantle sources
- Local scale: radiogenic heat production (RHP) in upper crust

Motivation

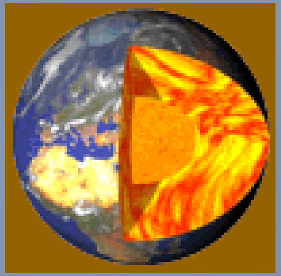


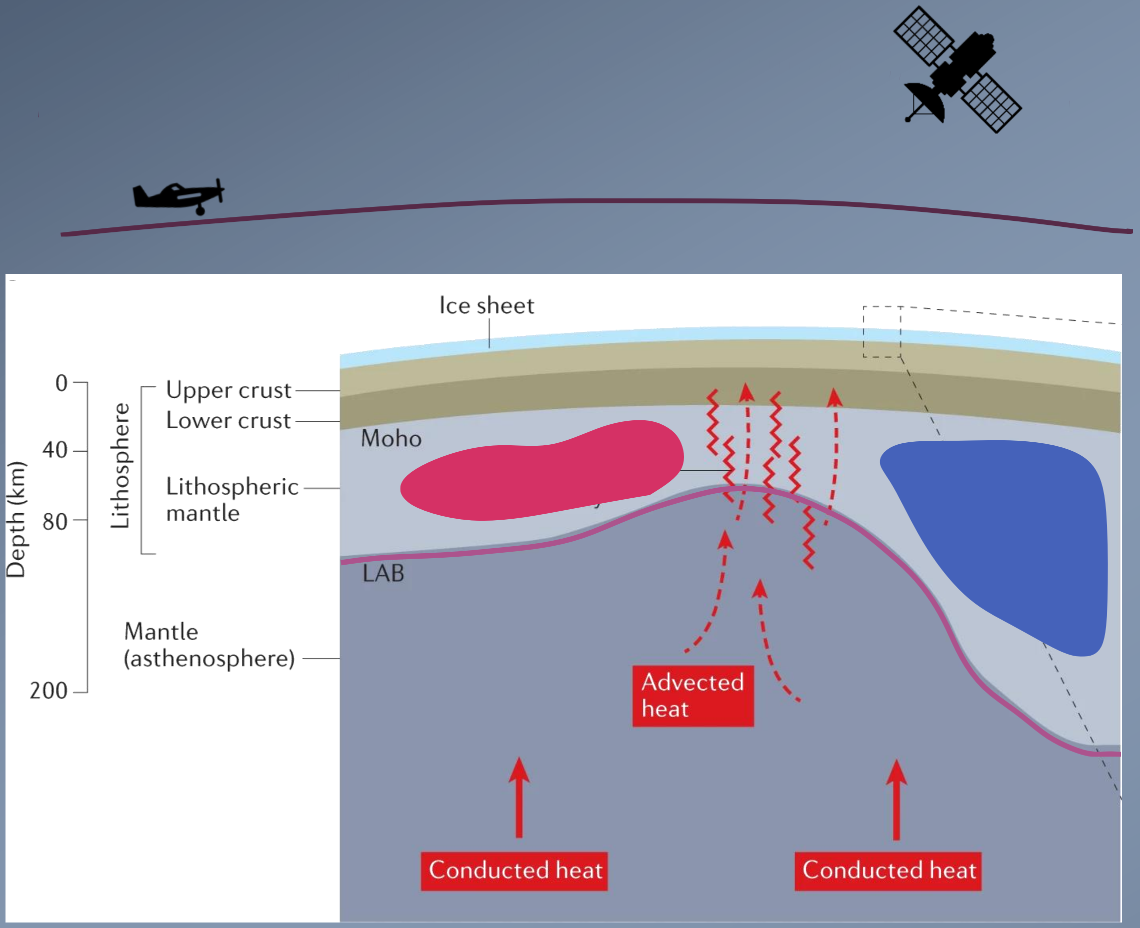
- Bell (2008) described the role of sub-glacial conditions for the evolution of the Polar ice sheets
- Whitehouse et al. (2019) extended the description of Solid Earth parameters described the key ingredients affecting the (Antarctic) Ice Sheets
- Geothermal heat flow (GHF) has been identified as one key parameter, but also one of the largest sources of uncertainty (see Reading et al. 2022, Colgan et al. 2022)
    - ➢ Contribution of GHF to basal melt rates is c. 25 % of total volume
    - ➢ However, uncertainty of estimates is ~20%, mainly related to GHF



Wansing (2024), following Karlsson et al. (2021)

Contributions to GHF and evolution of the ice-sheets and how to geophysically resolve this



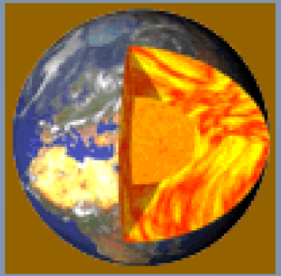


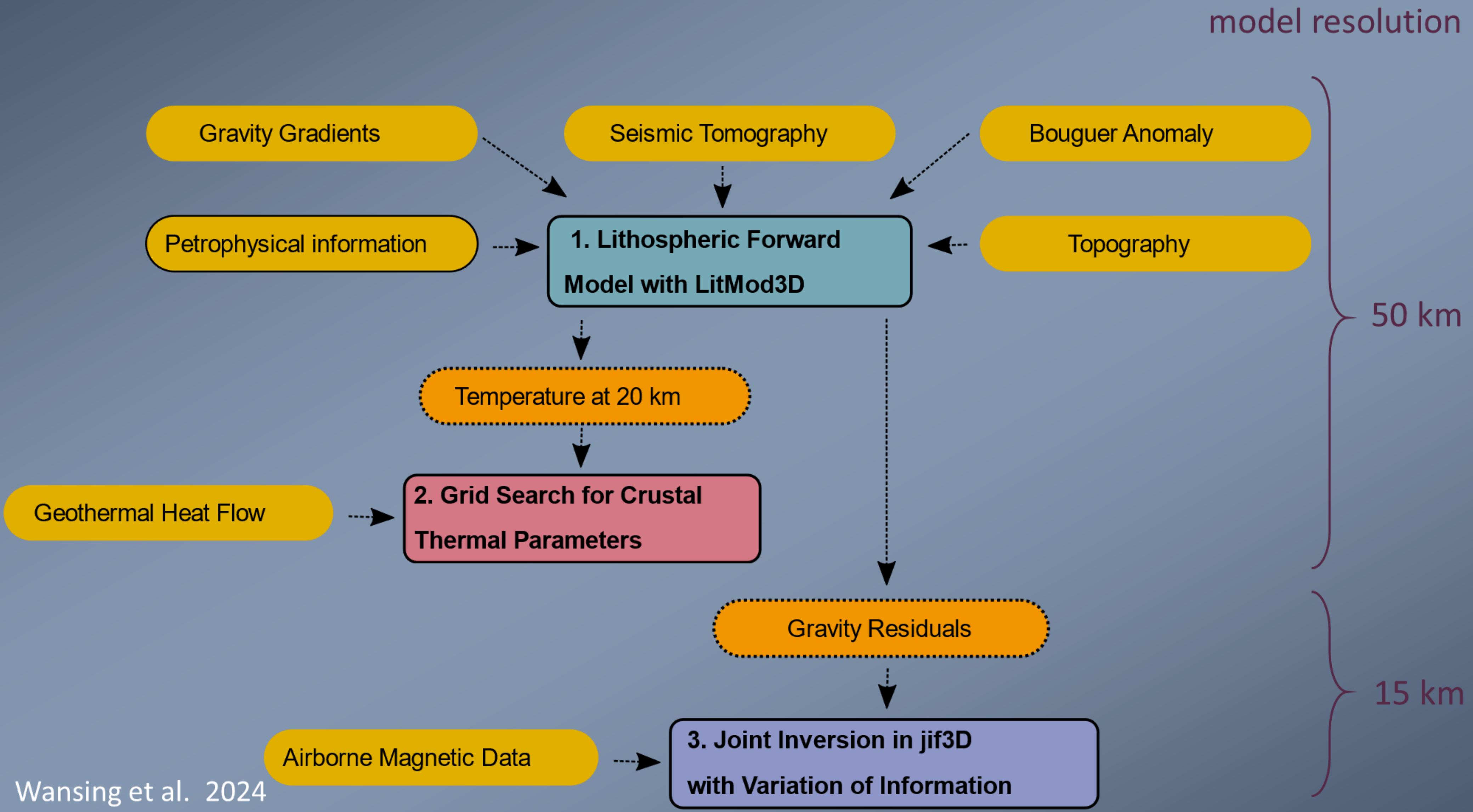
Crustal thickness: Airborne & Satellite gravity data, Seismic data

Lithospheric thickness and architecture: Seismic tomography, Gravity data, Magnetotellurics

Key parameters: Composition and temperature -> Viscosity

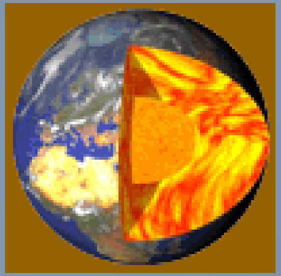
Workflow for a complete lithospheric model



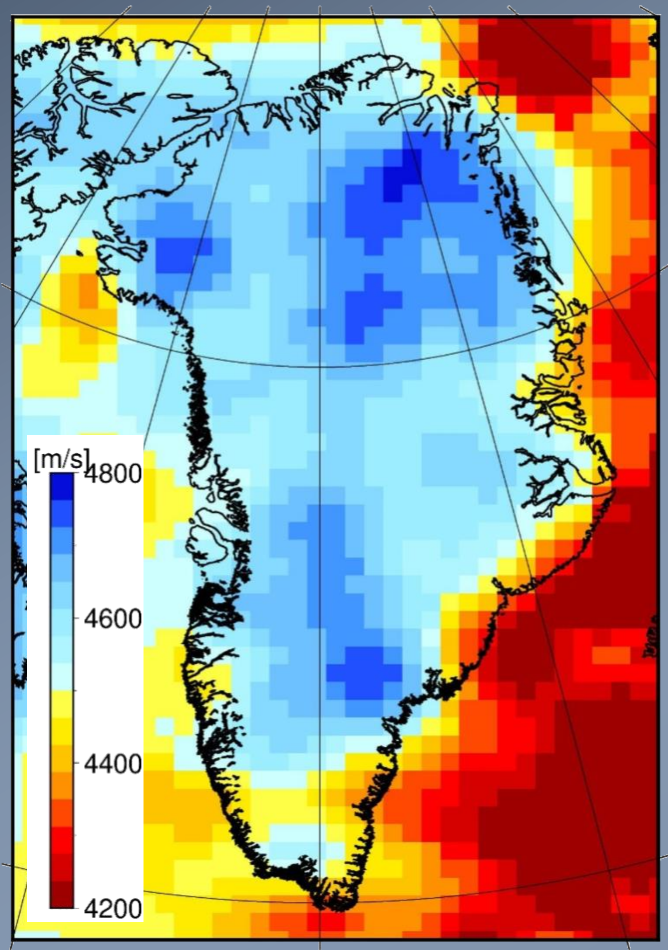


Wansing et al. 2024

3D structure of the Greenland lithosphere

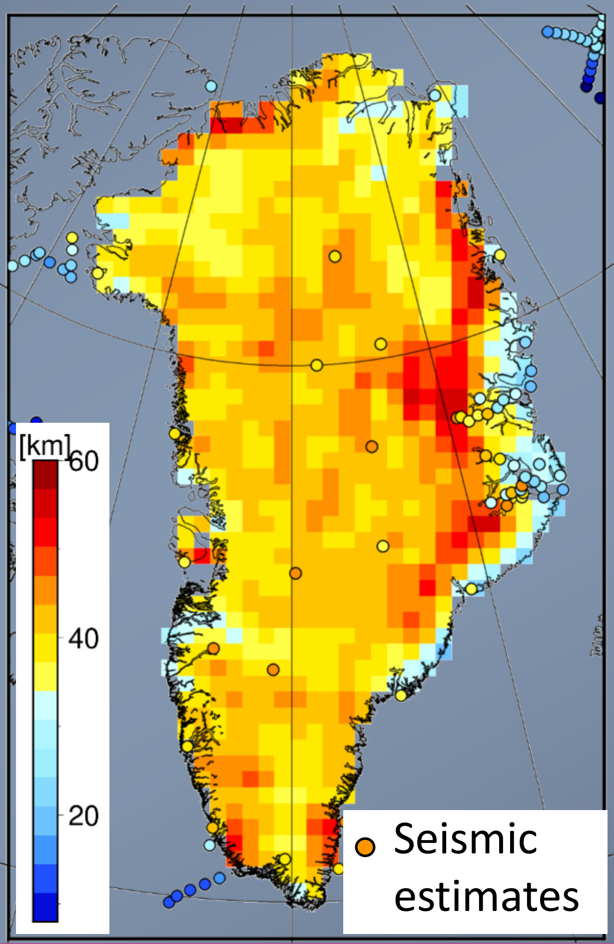


Vs at 130 km depth



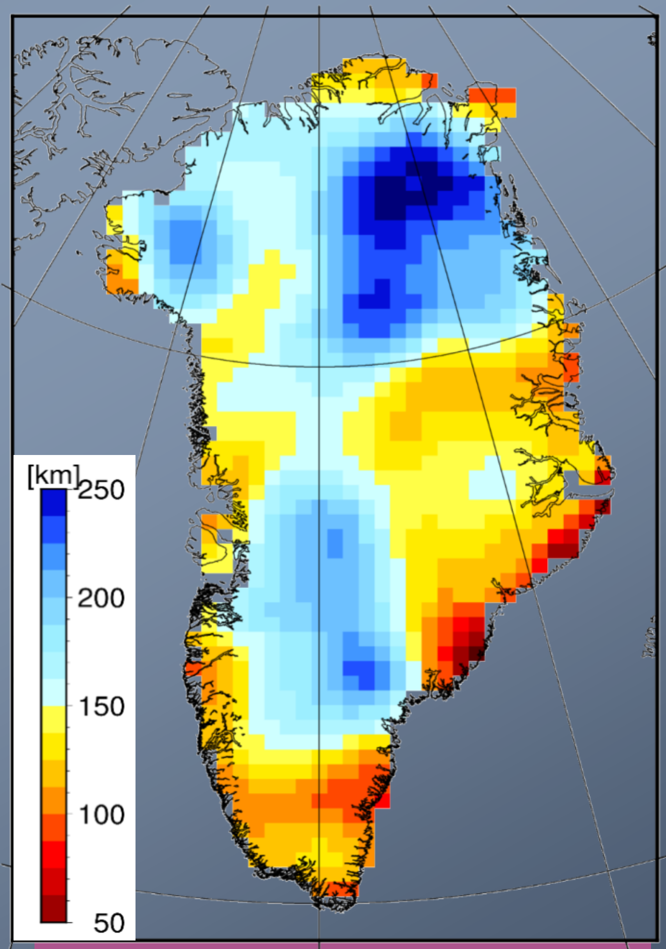
NAT2021, Celli et al. 2021

Moho depth



39 km mean Moho depth

LAB depth



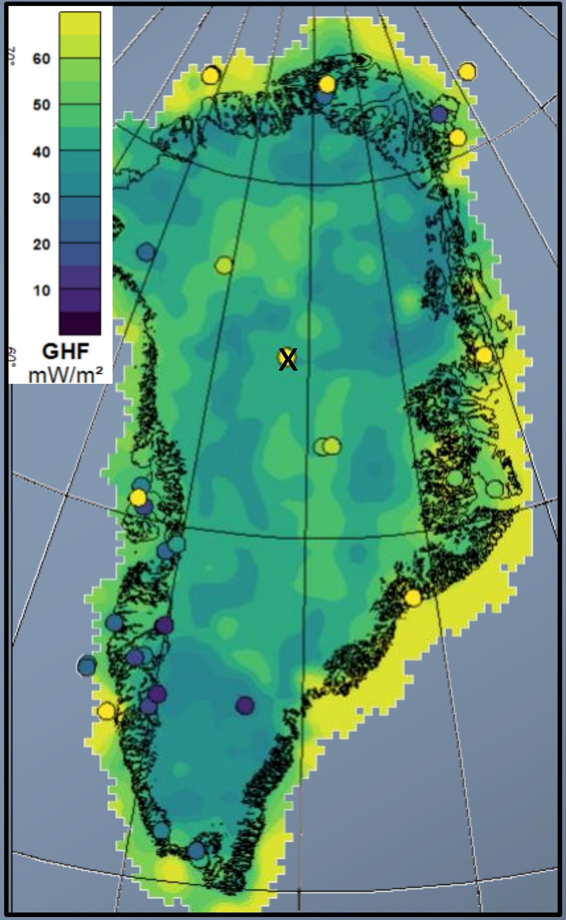
151 km mean LAB

3D structure of the Greenland lithosphere

Model predicts significant lithosphere thickness of > 140 km depth in the interior of Greenland

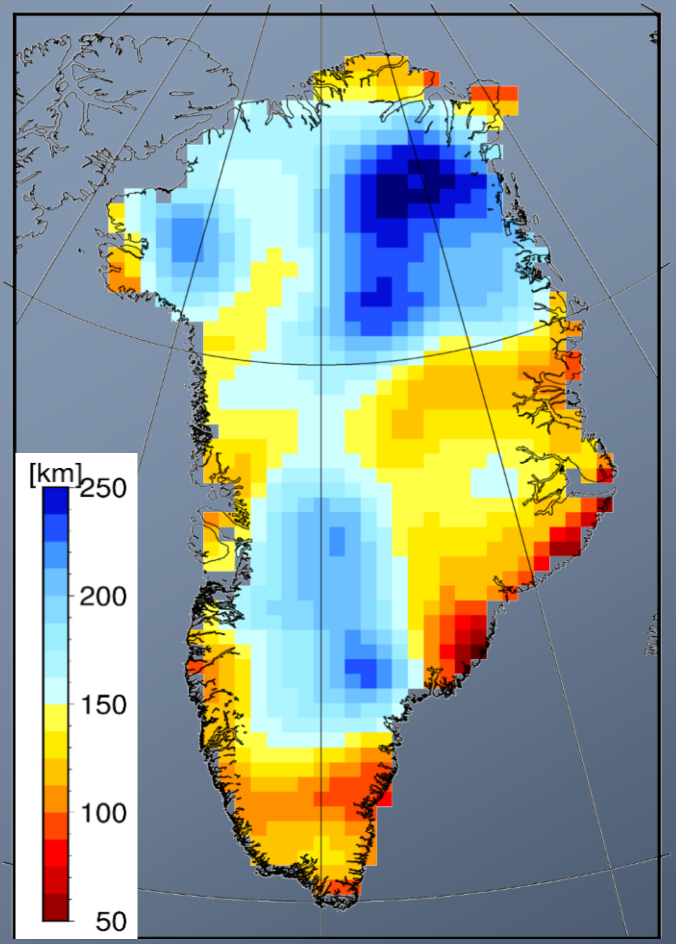
- Little indication of increased GHF
- in agreement with Colgan et al. (2022)

GHF



Colgan et al. 2022

LAB depth



Wansing et al. 2024

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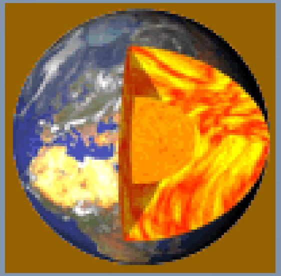

Model predicts significant lithosphere thickness of > 140 km depth in the interior of Greenland

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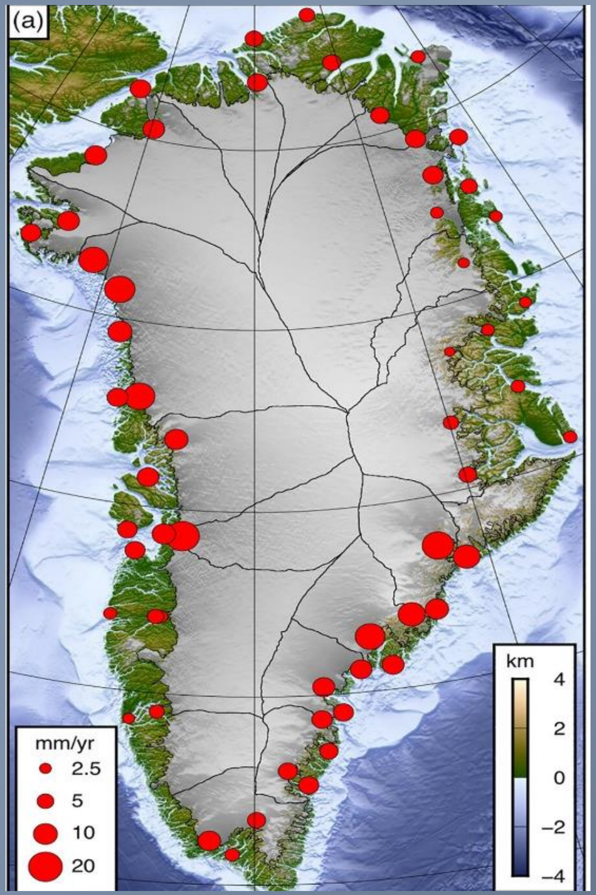
However, thinner lithosphere corresponds with areas of higher uplift rates

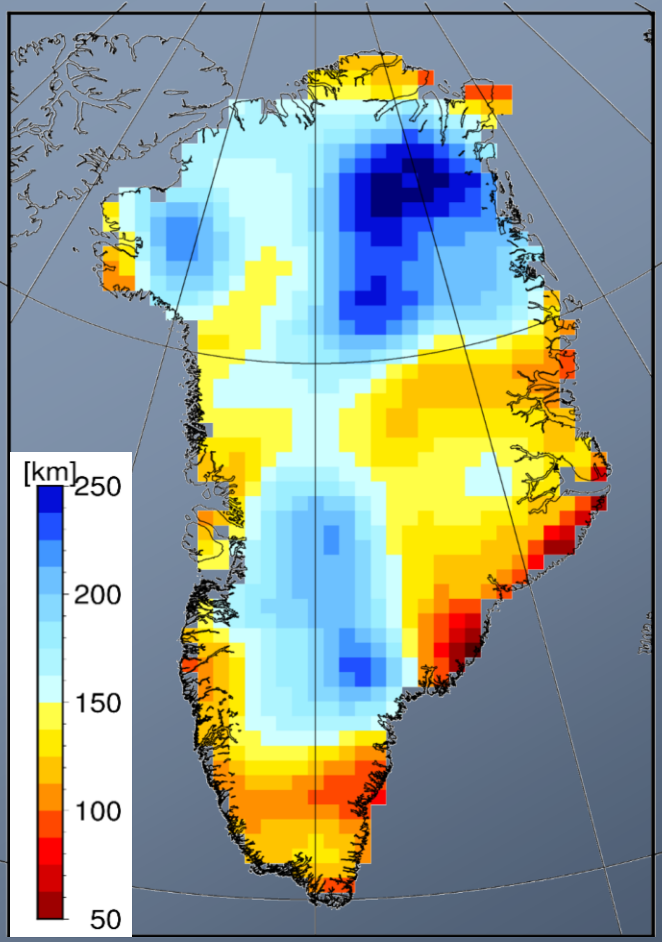
- Lateral variations important: E.g. lateral variations in (3D) viscosity

Relative uplift rates



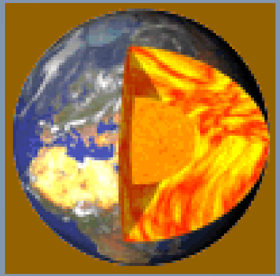
Paxman et al. 2023

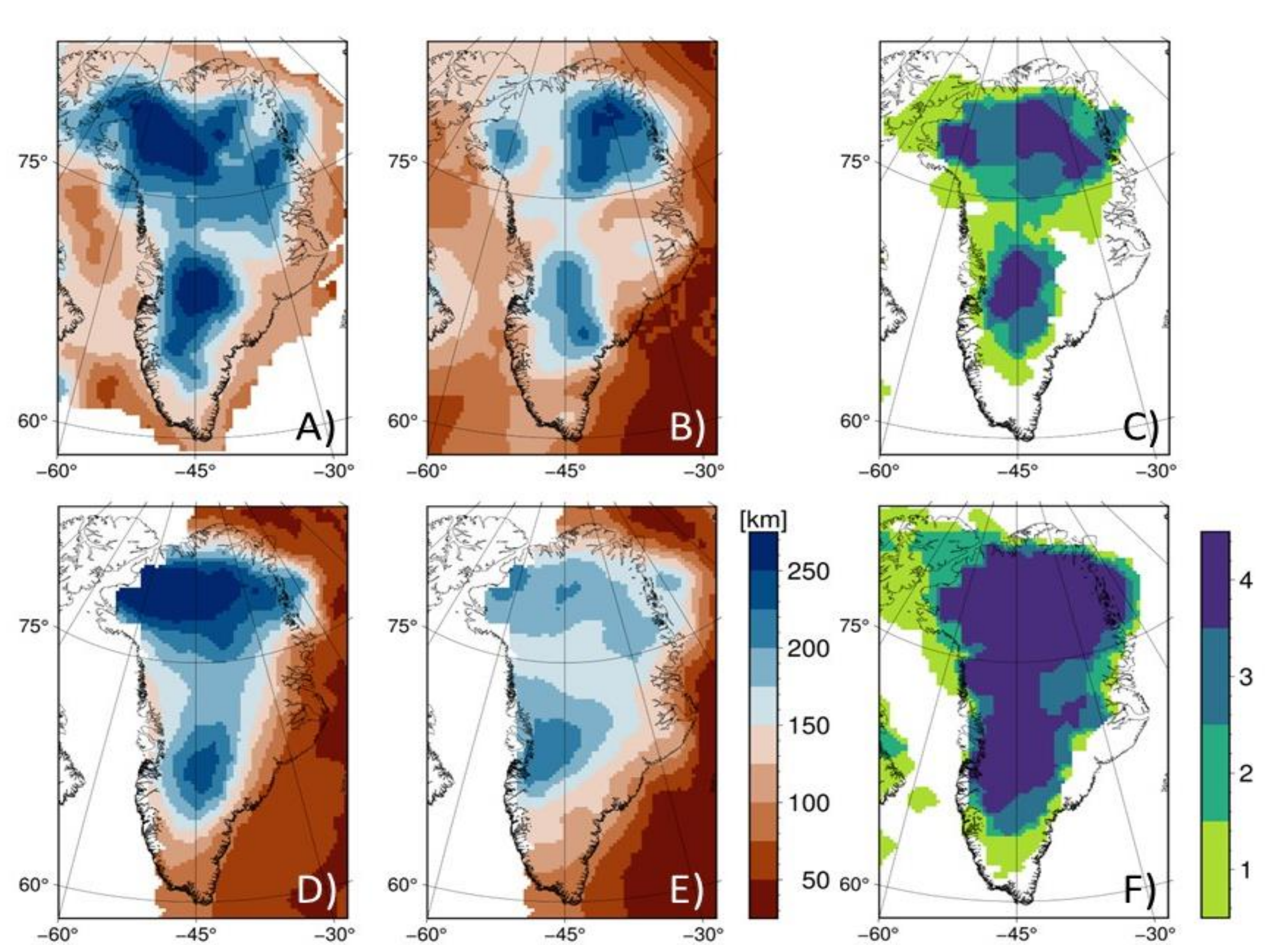
LAB depth



Wansing et al. 2024

The stable continental interior of Greenland?





Afonso et al., EOS, in press

Four recent models (A, B, D, E) of the thermal structure of the lithosphere.

All models are based on joint inversions/modelling of multiple, yet different, seismic and non-seismic datasets by different research groups.

Panels C and F highlight the agreement between these models in terms of their predicted depths to the thermal lithosphere-asthenosphere boundary (LAB); C) number of models predicting LAB > 180 km depth. F) number of models predicting LAB > 140 km depth

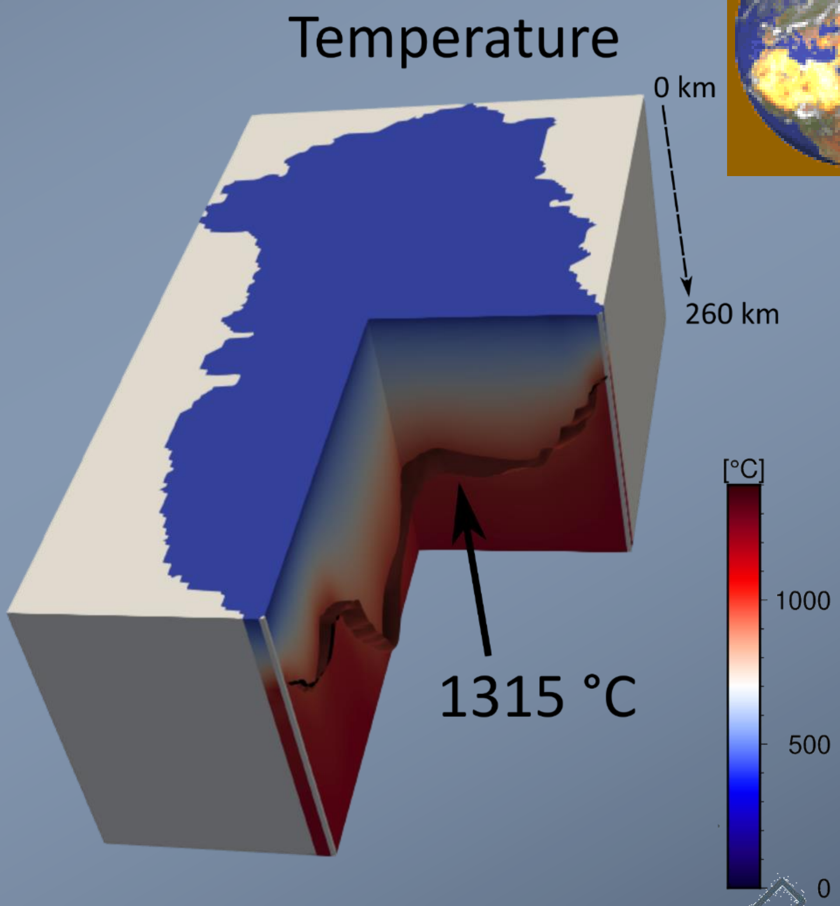
Conclusions and outlook

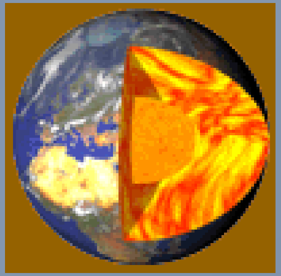
Solid Earth structure affects the Greenland ice-sheet at different levels:

- High surface heat flow would accelerate ice melting, but most lithospheric scale models and data predict a stable continental interior
  - Still, role of crustal heterogeneities must be further explored to link models and pointwise observations
  - Important to link Ice temperature models (from SMOS and CryoRad satellite missions) to Solid Earth Models
- Areas with thin lithosphere have elevated thermal gradients, leading to higher surface heat flow and mechanically weaker tectonic plates

  ⇒ Affects coastal areas of Greenland, especially adjacent to Iceland plume

  ⇒ Deep Earth structure must be considered for a complete understanding of the Greenland Ice Sheet





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