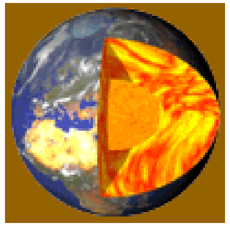
3D Earth – Greenland

Start nov 2020



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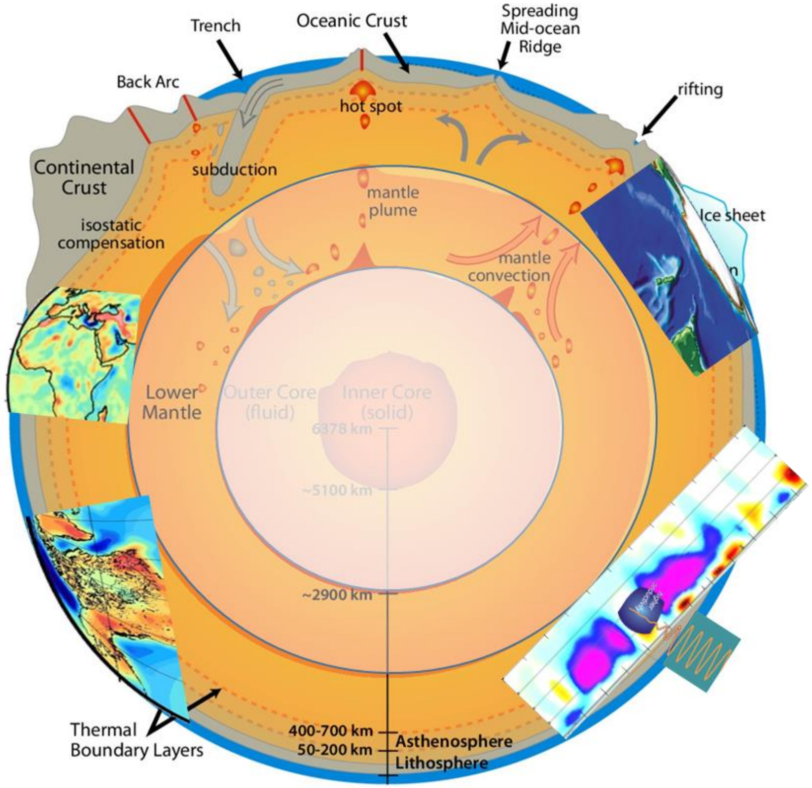

Gravity

Magnetic anomaly

Seismology

Heatflow

Mantle plume

Glacial isostatic adjustment

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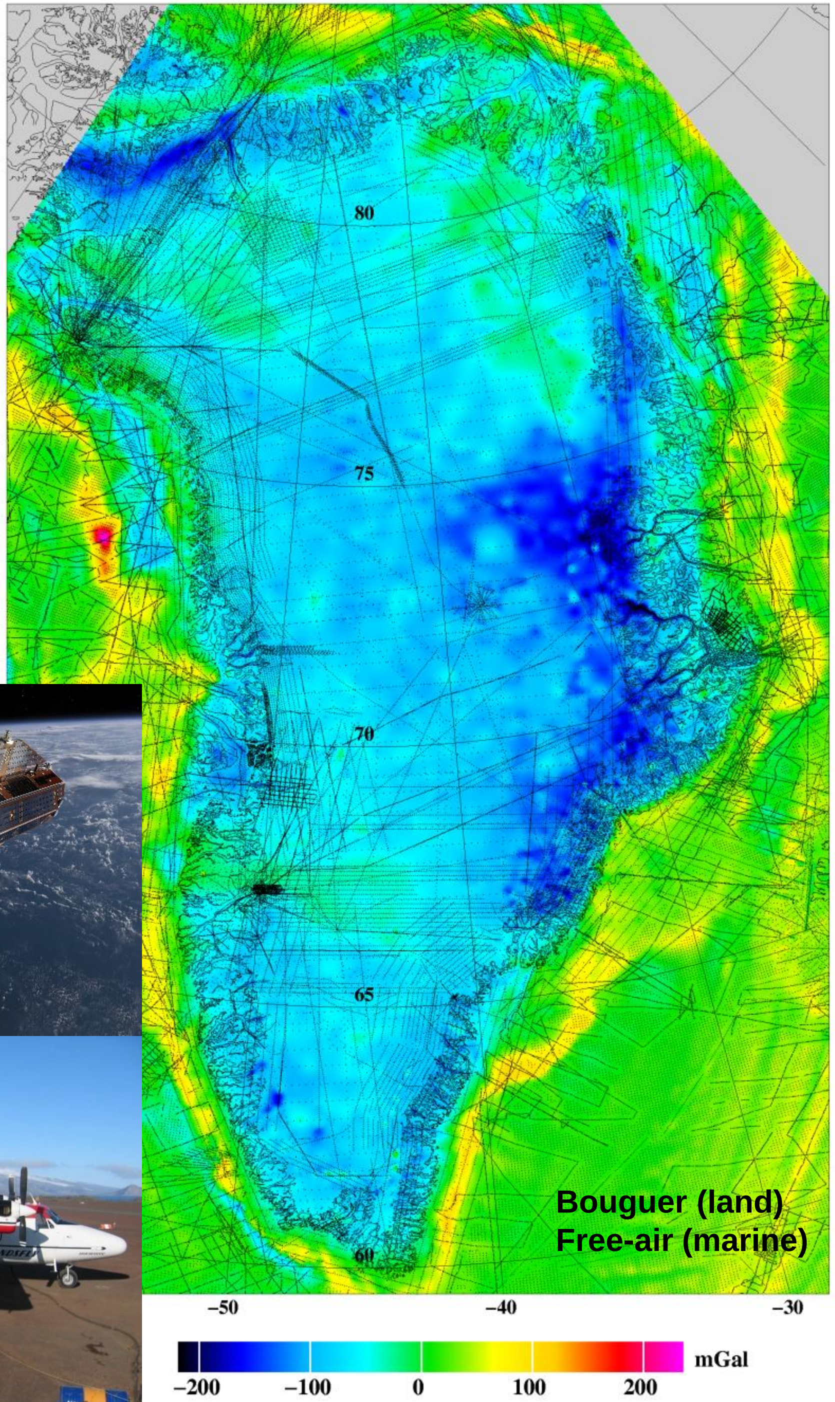
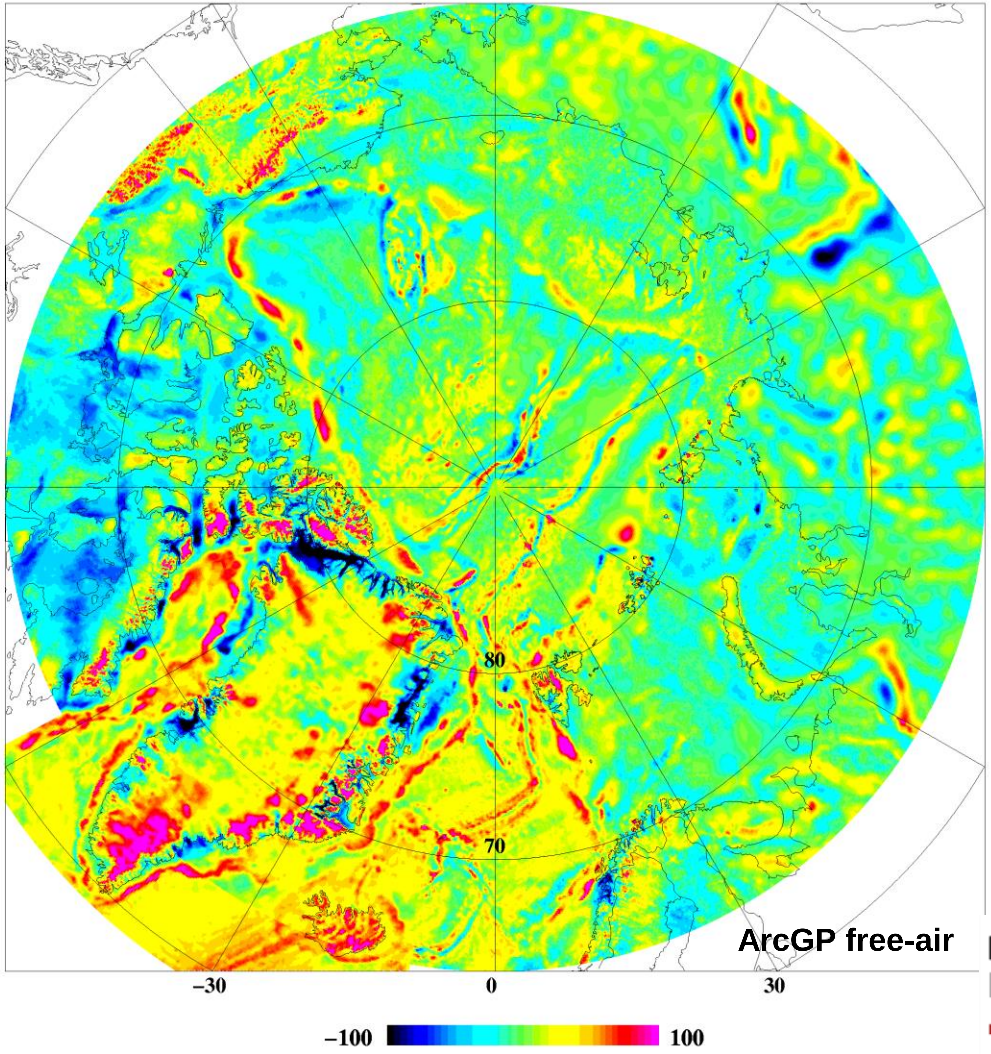
Compilation – 3D Greenland update

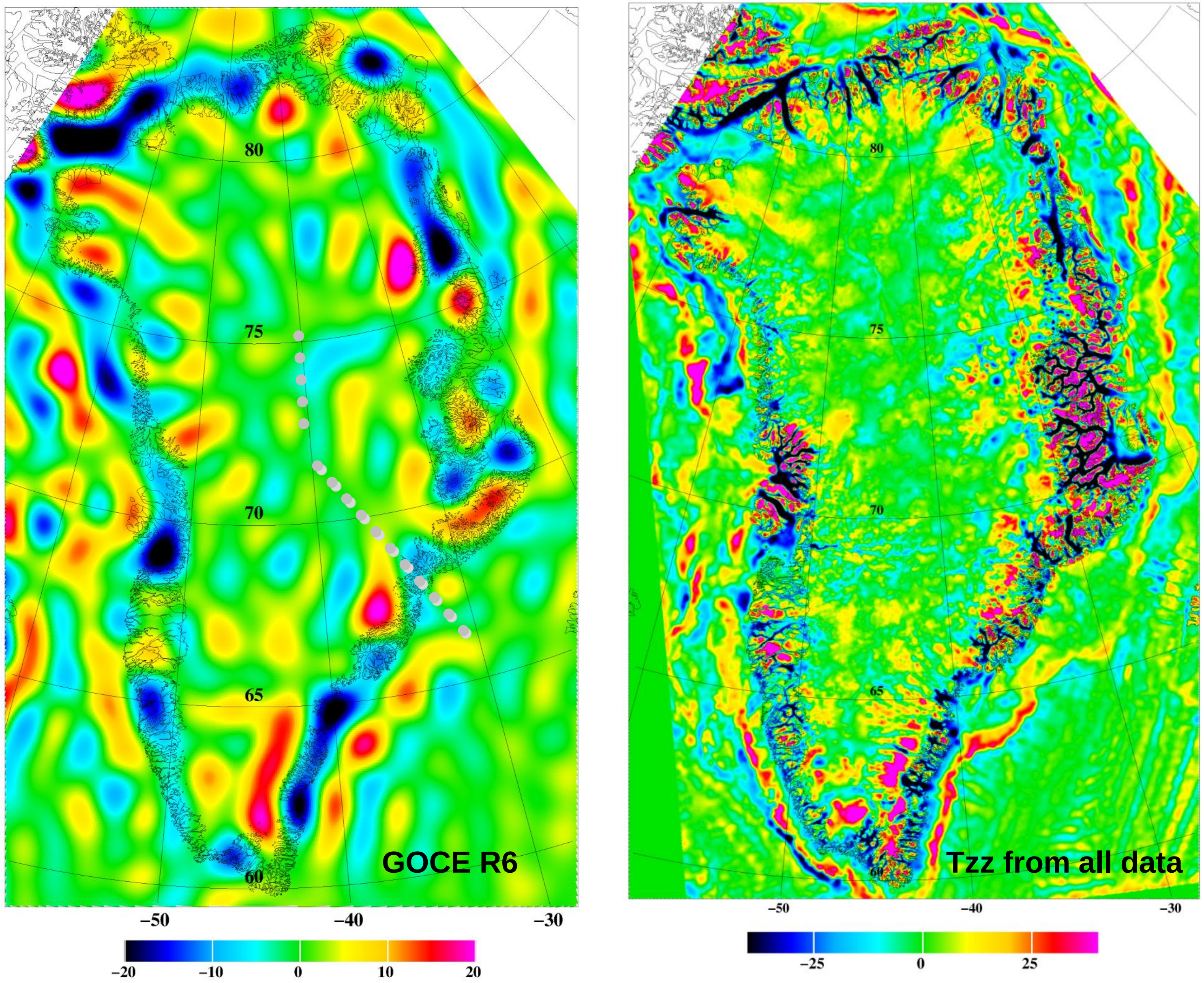
- *More data, GOCE R6, satellite altimetry (DTU 17)*
- *Improved ArcGP (Arctic gravity grid for EGM2020)*
- *New DEMs, new ice thickness grids (Bamber) =>*
  new improved Bouguer anomaly grid





Vzz Gradient (Eotvos)

by FFT transformation of Free-air grid



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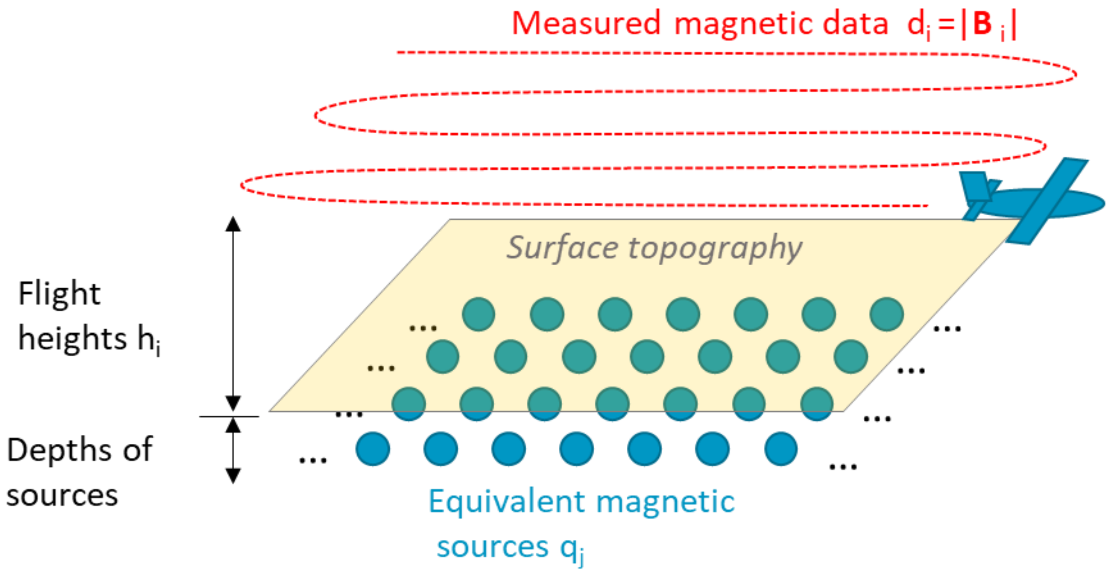
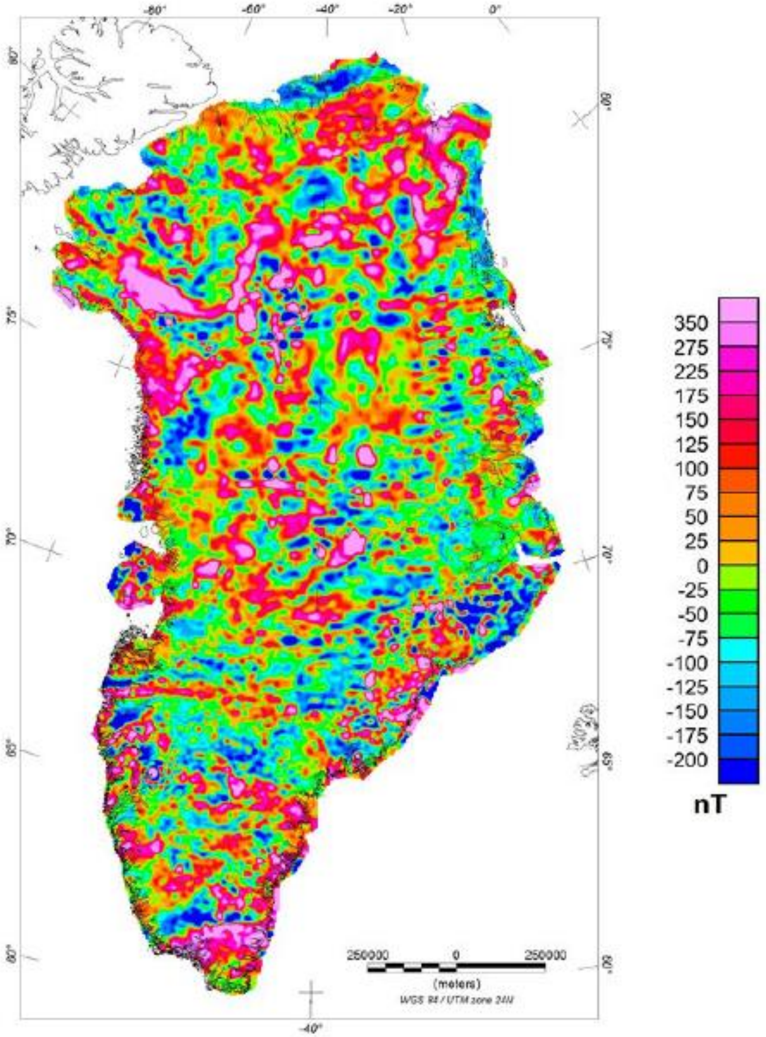
New magnetic anomaly



For each equivalent source q_j, an ”apparent” susceptibility value is assigned by means of inversion :

Magnetic responses (Data)	Inversion $F^{-1}(\Delta d)$	Equivalent sources (Model with $\mathbf{F(m)} = \mathbf{d}_{calc}$)
$\mathbf{d}_{obs}$	$\rightarrow$	$\mathbf{m}$

Magnetic anomaly in 5km heights



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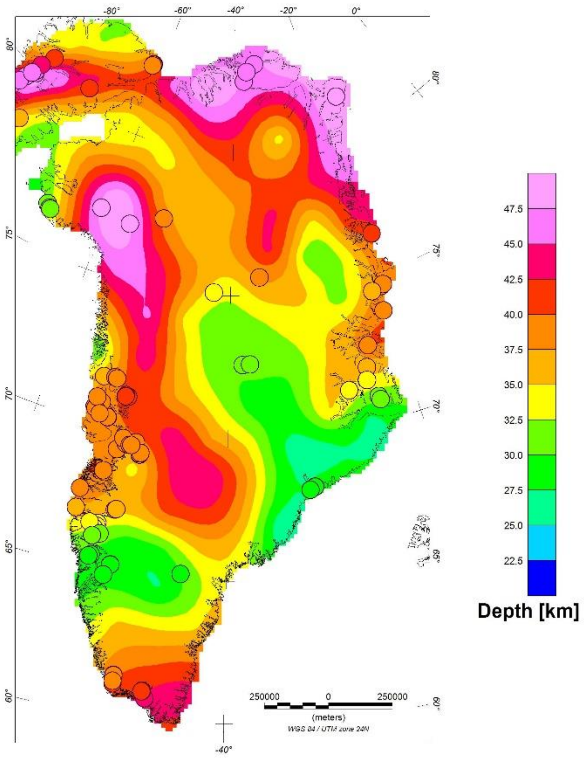
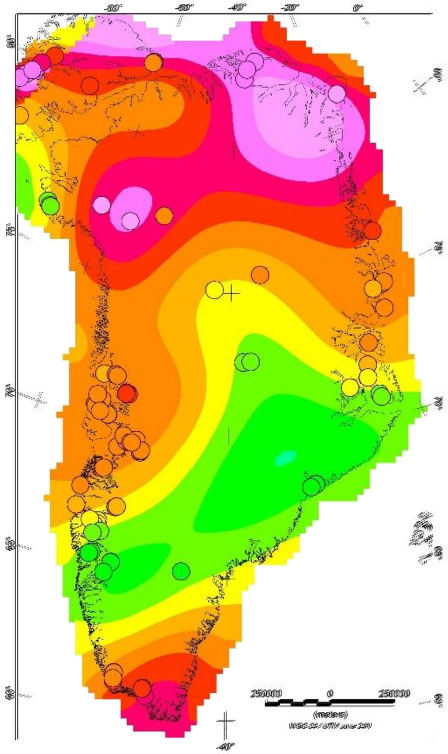
Application using constraints from Martos et al. 2018

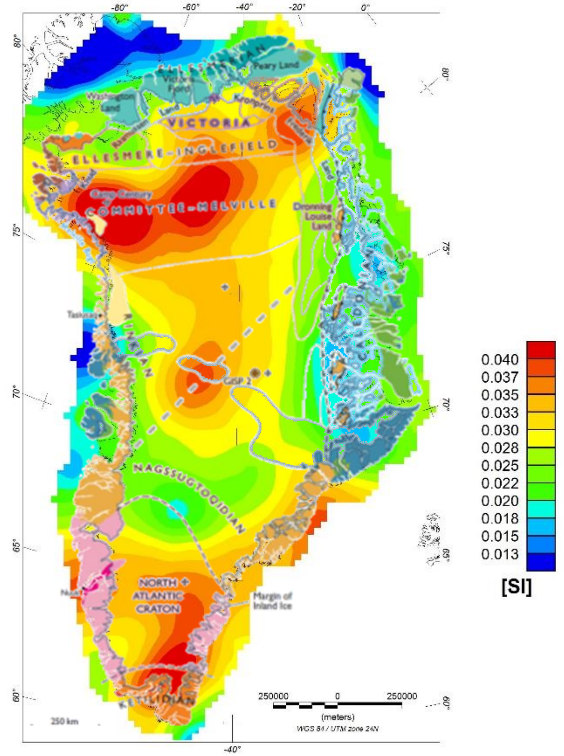
Spatial variability from magnetic data?



Curie isotherm depth from Martos et al. 2018



Curie isotherm depth from Linearized Bayesian inversion



Susceptibility model from inversion

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NAT2021: new tomographic model of the North Atlantic

Earth and Planetary Science Letters 569 (2021) 117048

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The tilted Iceland Plume and its effect on the North Atlantic evolution and magmatism

Check for updates

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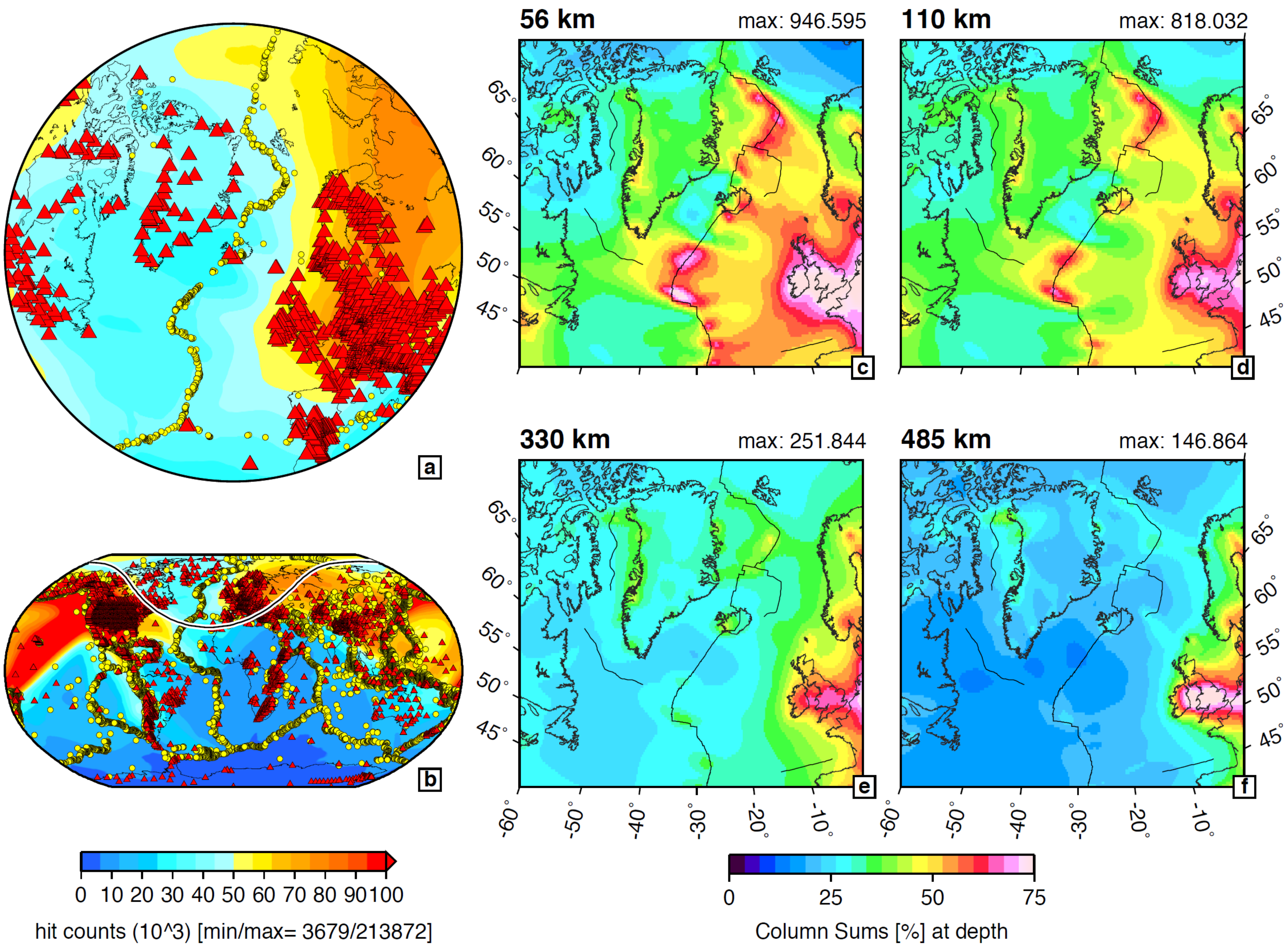

- 1.2 million global and regional seismograms from over 27000 events and 6000 stations
- The densest sampling of the region with seismic data

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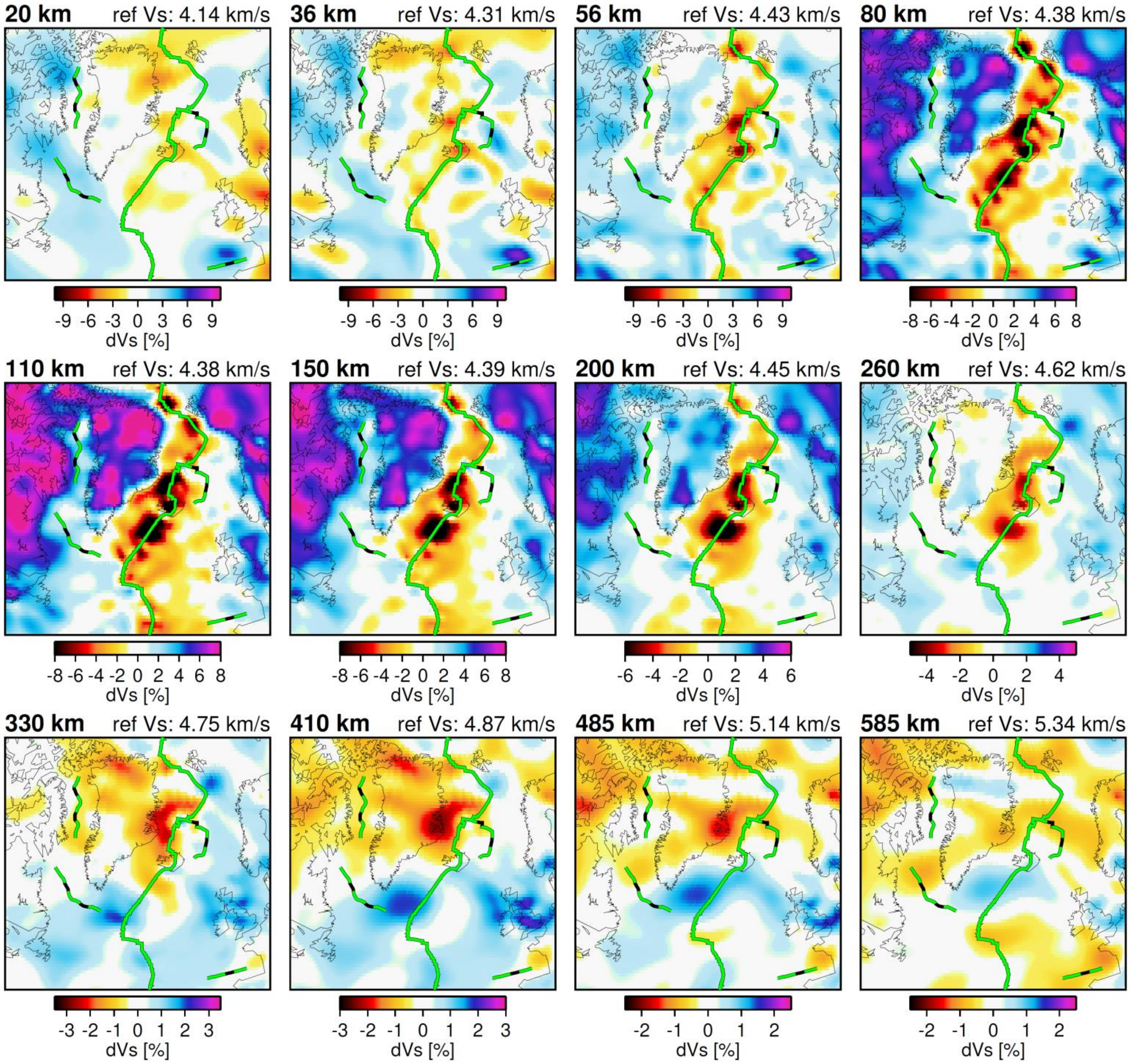

- The model spans from the upper crust to the bottom of the mantle transition zone (660 km).
- Crustal structure was inverted for (more accurate than assumptions or crustal corrections).
- S-wave velocity, P-wave velocity, azimuthal anisotropy.

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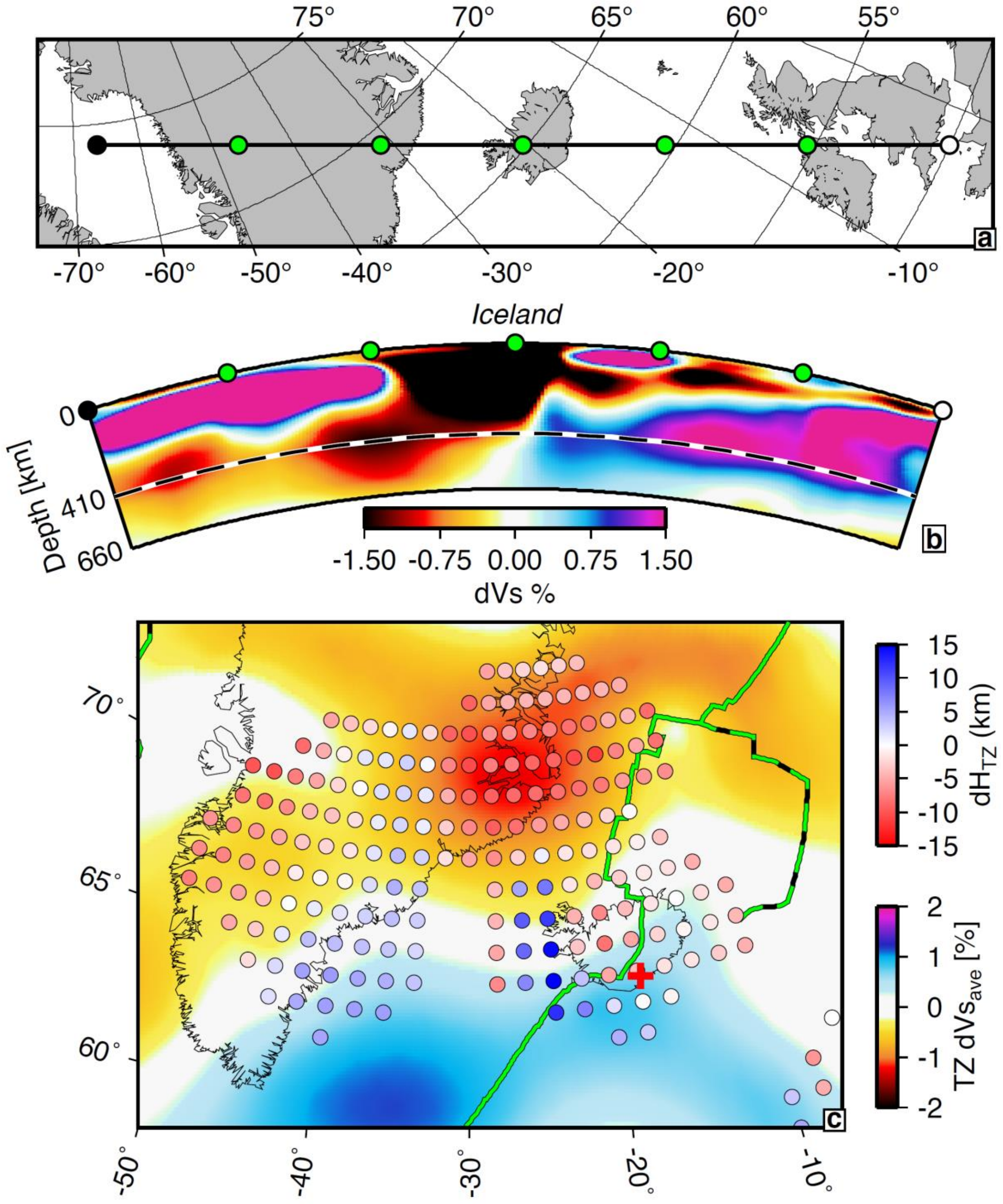


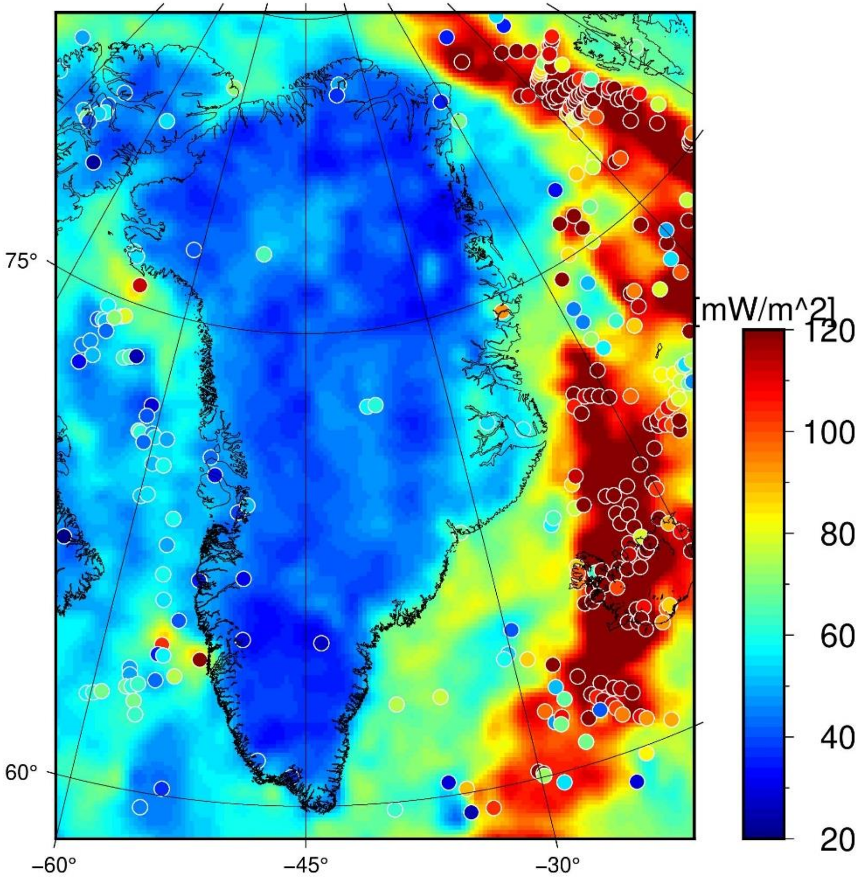
- Receiver functions indicate thin transition zone (410-660 km) and, thus, high temperatures beneath eastern Greenland at 410-660 km depth.

- Important independent confirmation of the large high-temperature anomaly beneath eastern Greenland.

- Beneath Iceland, the transition zone shows small scale hot can cold anomalies, possibly due to the small scale convection including lithospheric cooling and dripping.

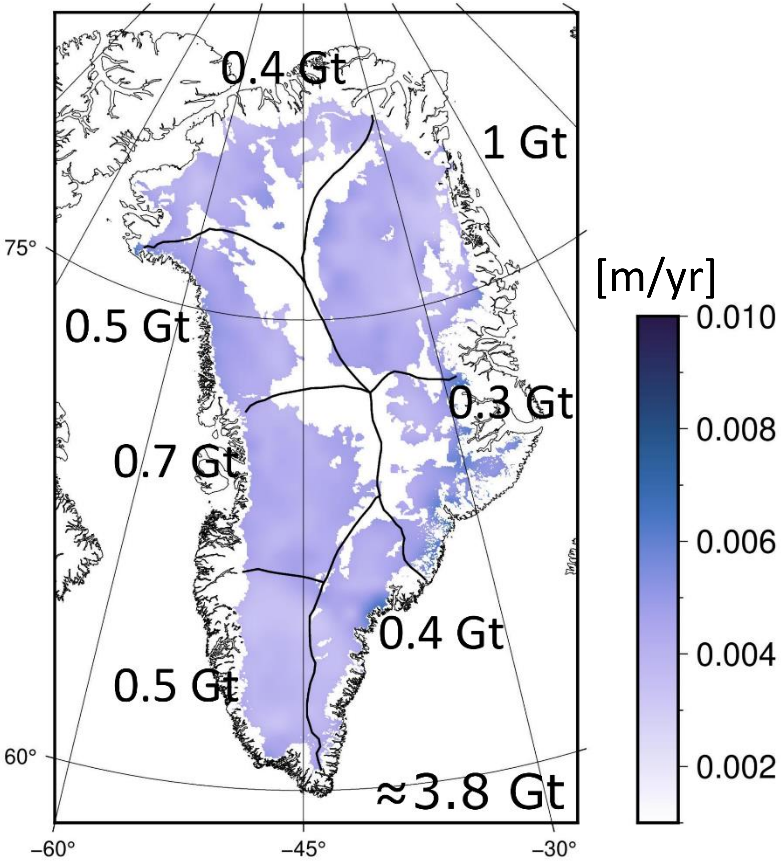
Geothermal heat flow – a new database & map for Greenland

GHF from machine learning



d on top

Basal melt rates



areas considered as frozen at the ice-bed interface are blanked out

- Greenland Geothermal Heat Flow Database and Map - **Colgan et al. in review :** https://essd.copernicus.org/preprints/essd-2021-290/
- covers in total 419 sites, 129 which have not been reported by IHFC previously https://doi.org/10.22008/FK2/F9P03L
- applied a machine learning algorithm to the data (following the method in Lösing and Ebbing 2021 for Antarctica)
- calculated mass loss from basal melt due to geothermal heat flow (following method from Karlsson et al. 2021)

	Mean onshore GHF	Mass loss per year
This study	44 [mW/m²]	3.8 [Gt]
Artemieva (2019)	58 [mW/m²]	5.1 [Gt]
Martos et al. (2018)	60 [mW/m²]	5.6 [Gt]
Greve (2019)	62 [mW/m²]	5.7 [Gt]

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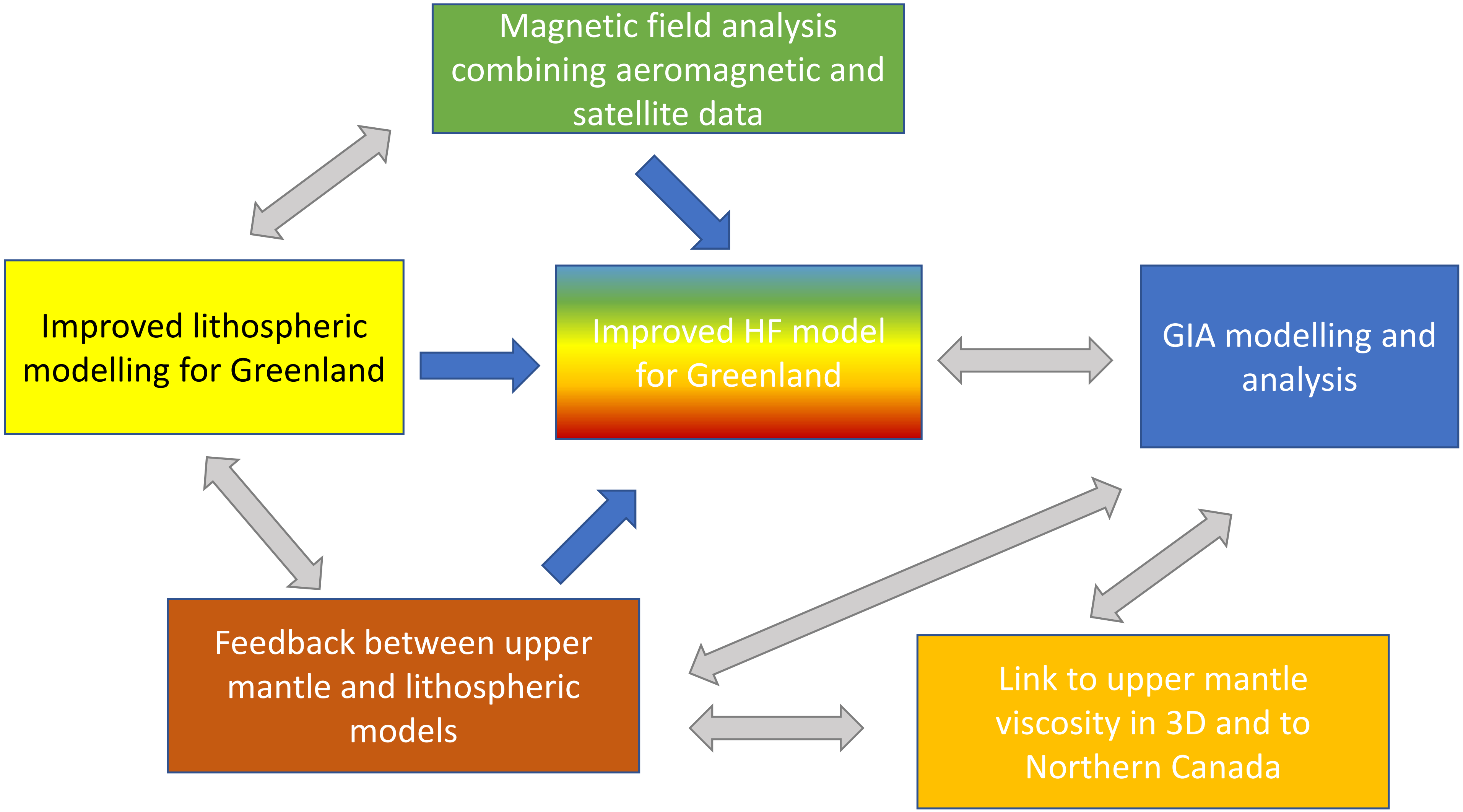
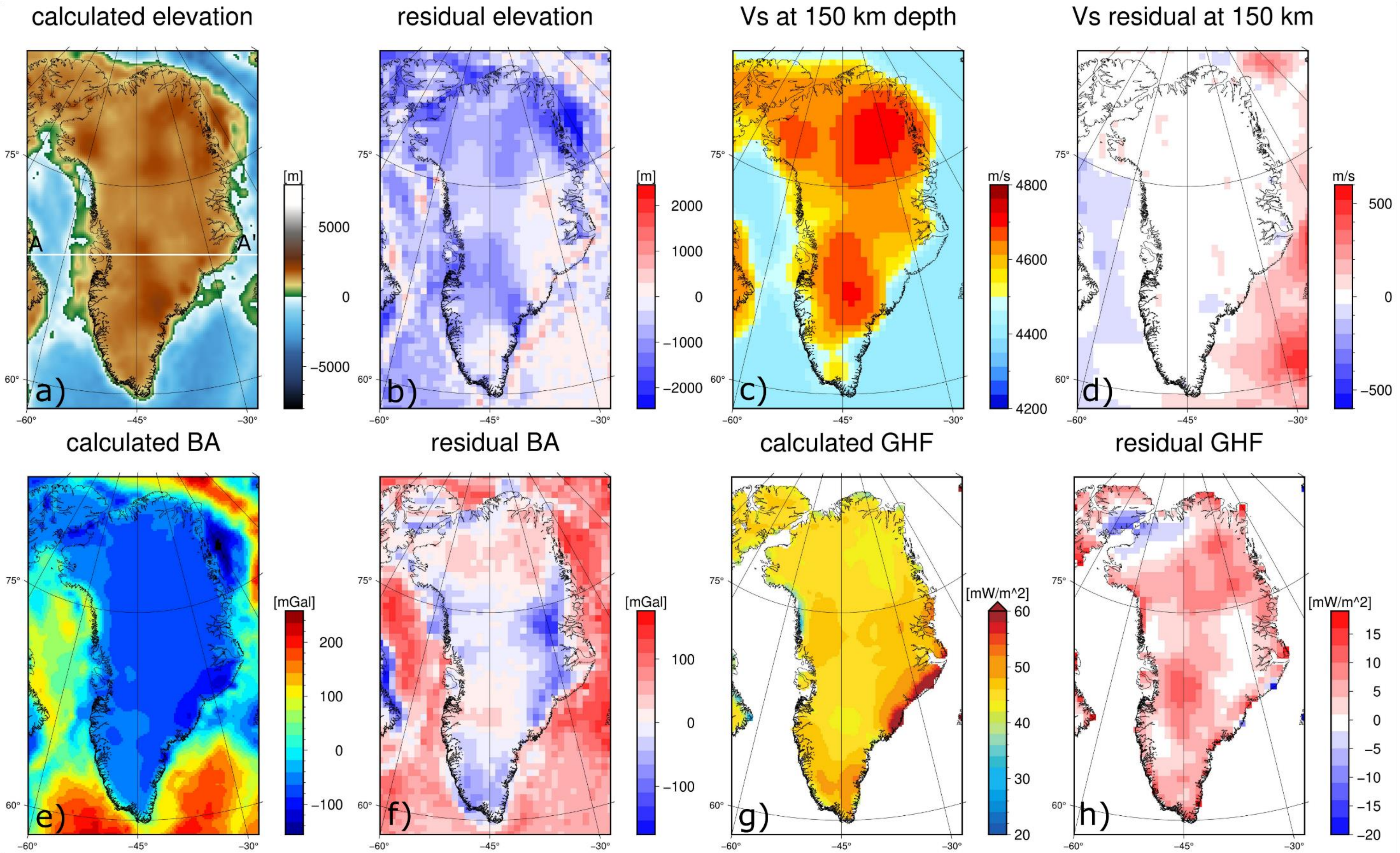

Magnetic field analysis combining aeromagnetic and satellite data
Improved lithospheric modelling for Greenland
Improved HF model for Greenland
GIA modelling and analysis
Feedback between upper mantle and lithospheric models
Link to upper mantle viscosity in 3D and to Northern Canada

Lithospheric model – Archean composition II

res. elevation > 0 : to much masses
res. BA > 0 : mass deficit



- Vs residual is low
- residual GHF is towards the one from the similarity analysis with NAT2020 → also low enough → both methods are consisted
- high residuals for BA and isostatic elevation

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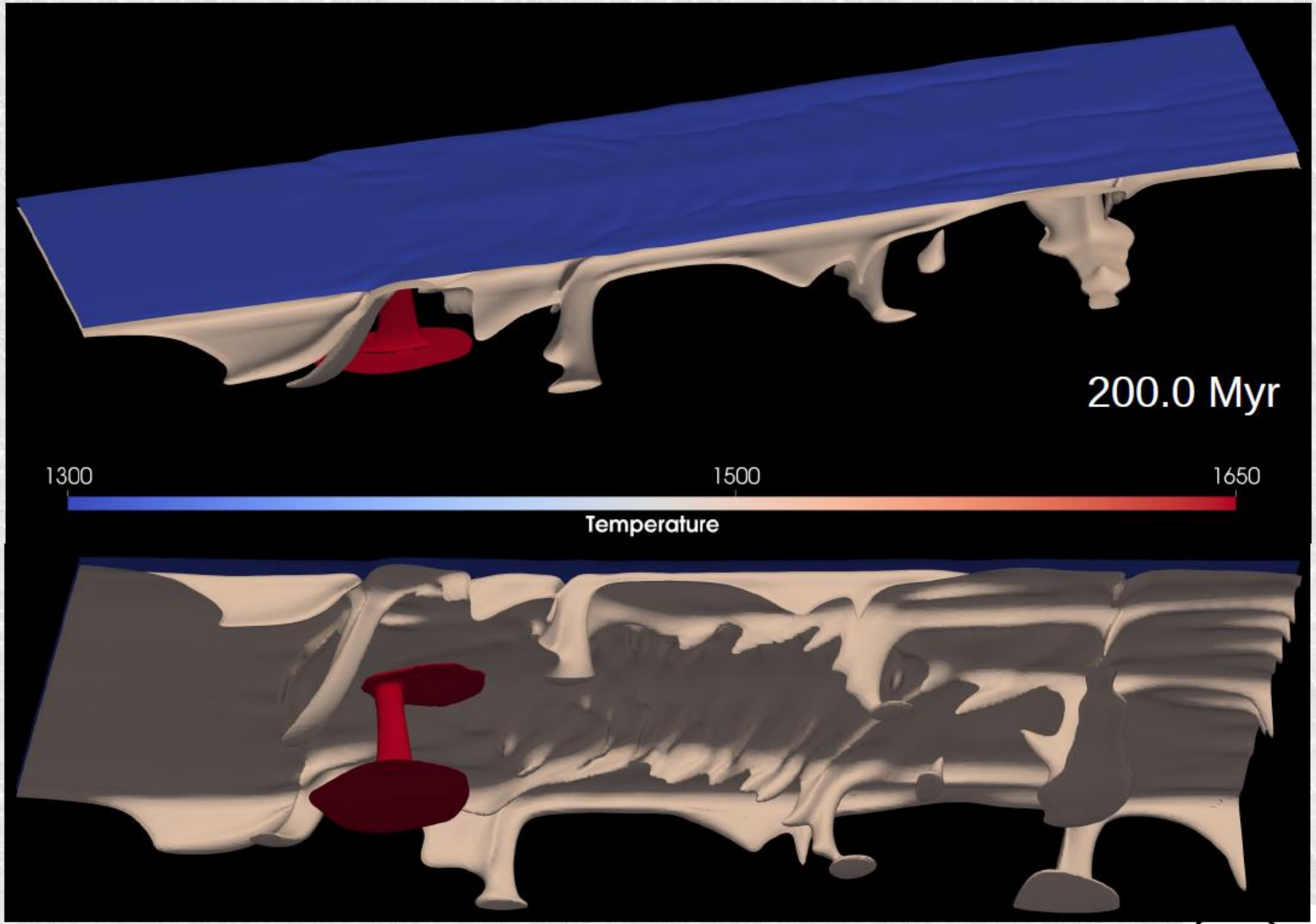
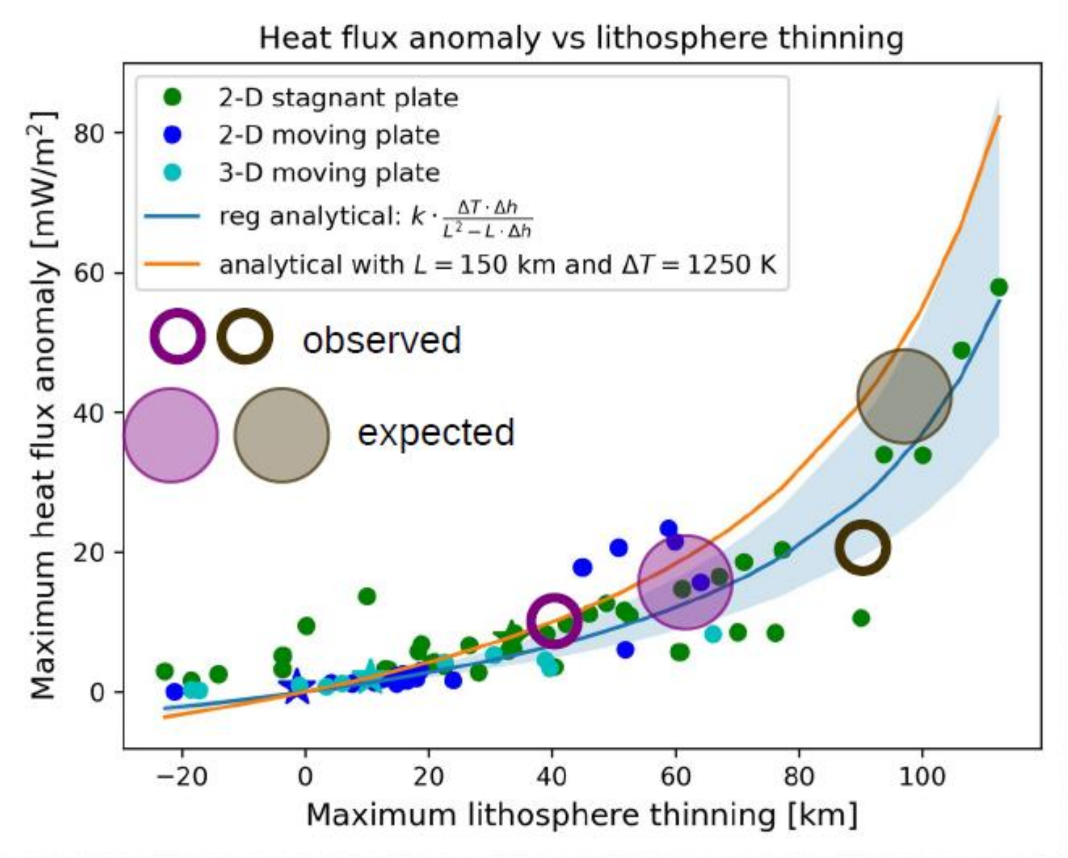
3-D moving plate – Reference case

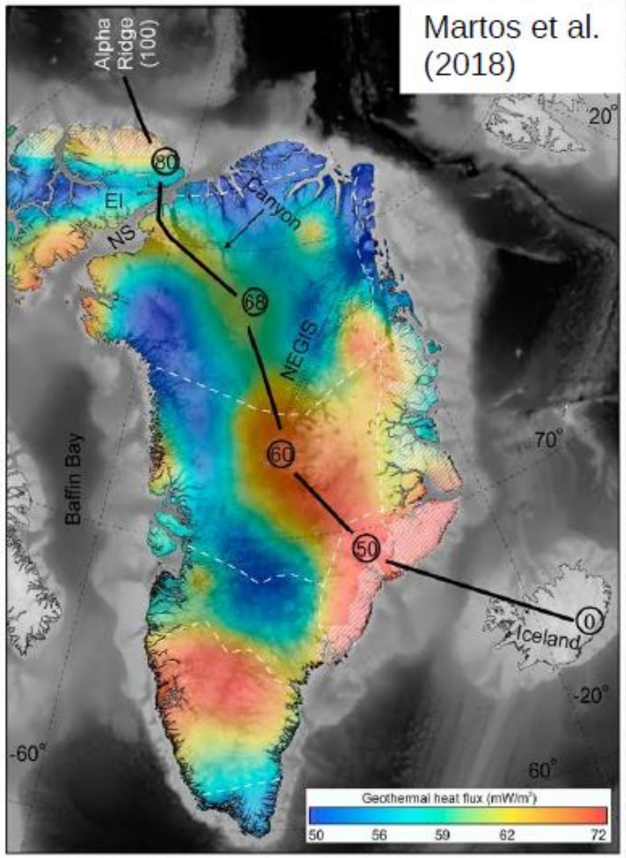
- Isotherms:
  - 1300 K
  - 1500 K
  - 1650 K

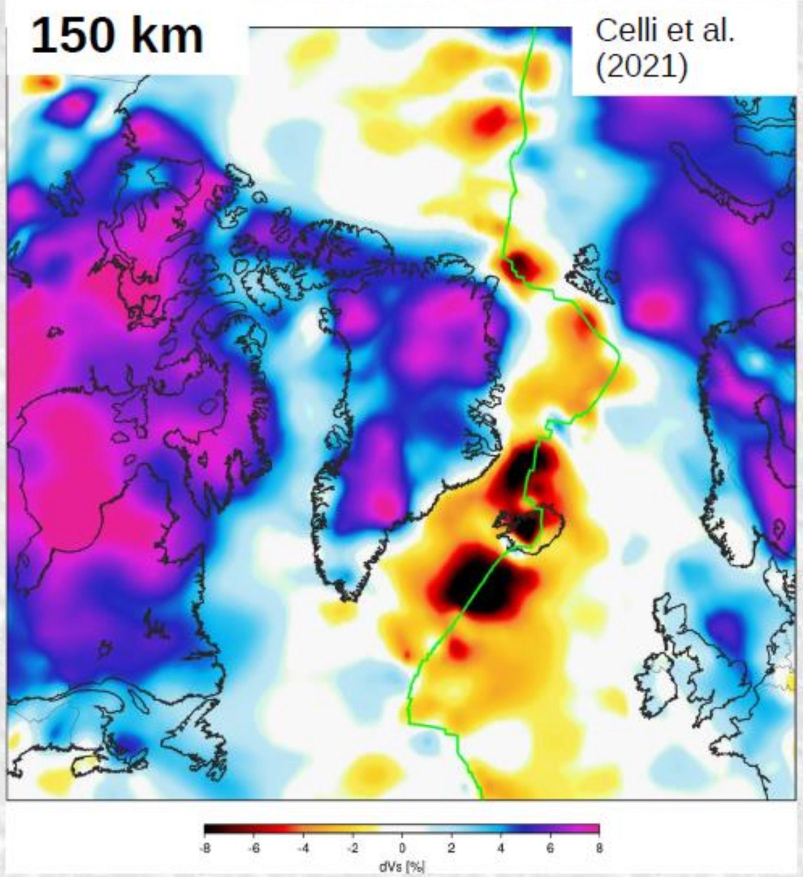
- Downstream:
  - **plume track**
  - **drips next to plume track**



Anomaly values for Greenland







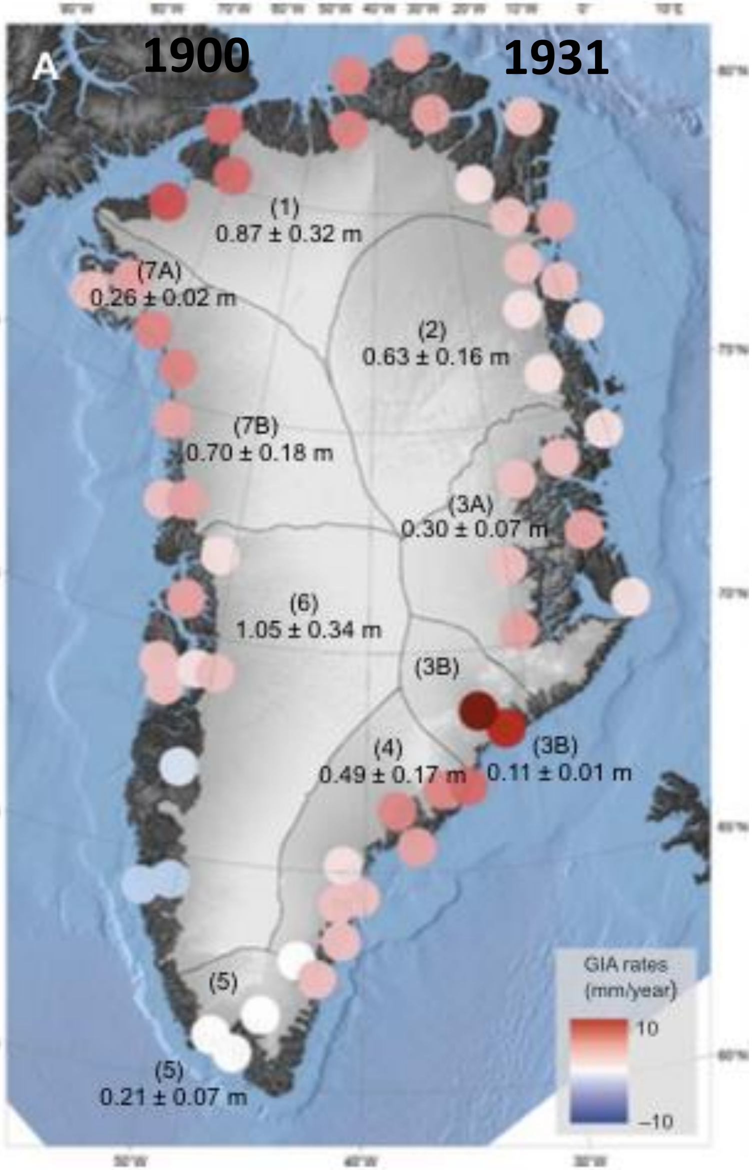
Northern part:

- Heat flux anomaly ~10 mW/m²
- Lithosphere thinning ~40 km

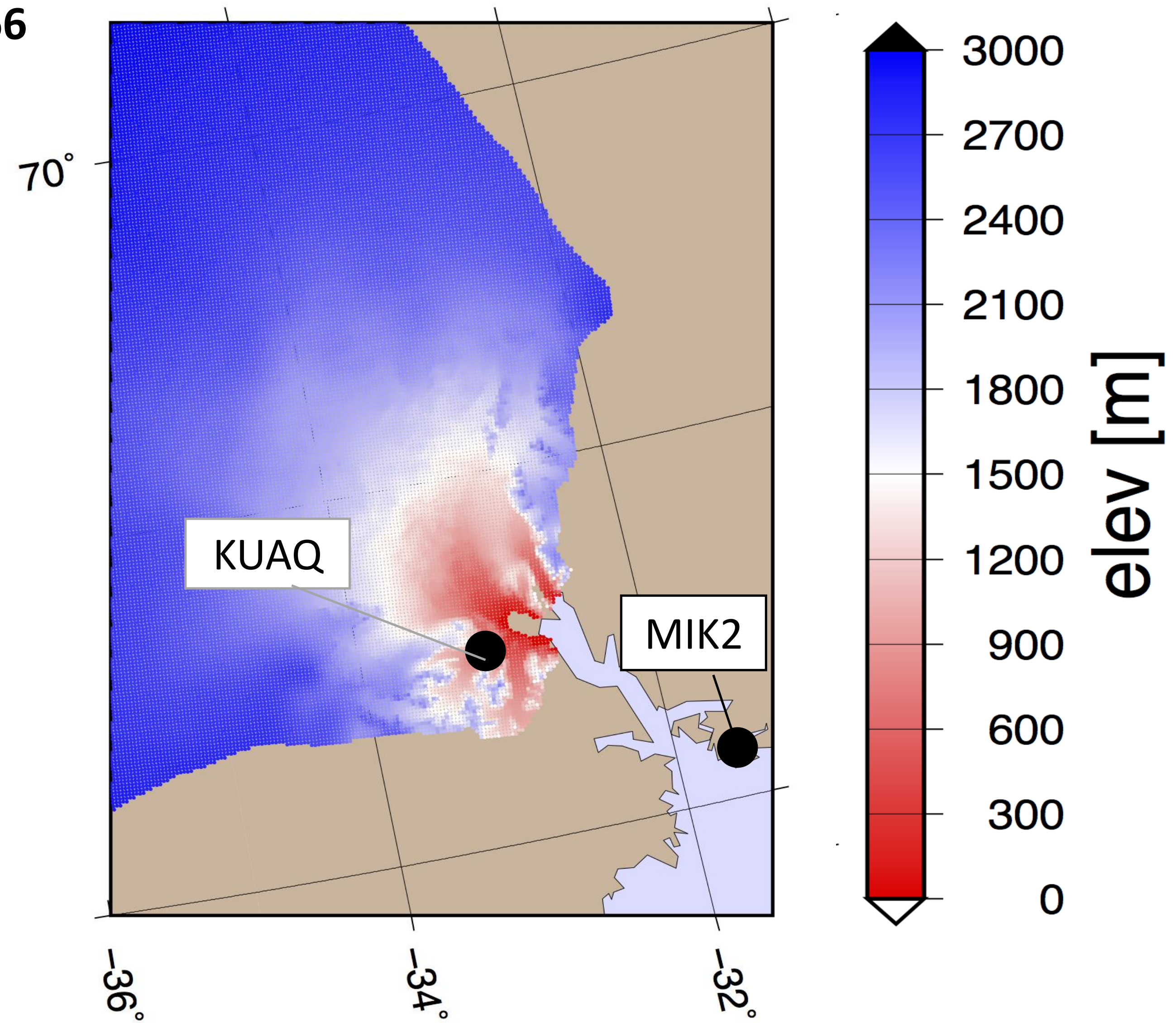
Southern part:

- Heat flux anomaly ~20 mW/m²
- Lithosphere thinning ~90 km

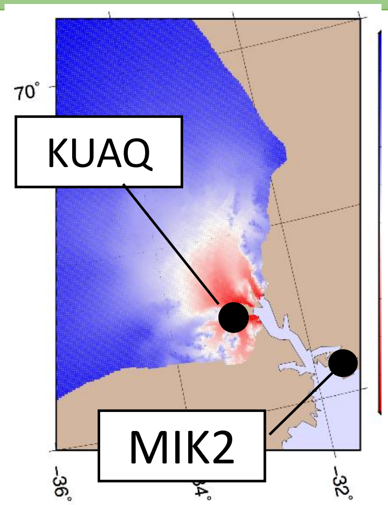
1966



From ESA Glaciers CCI



3 Possible combinations of parameters

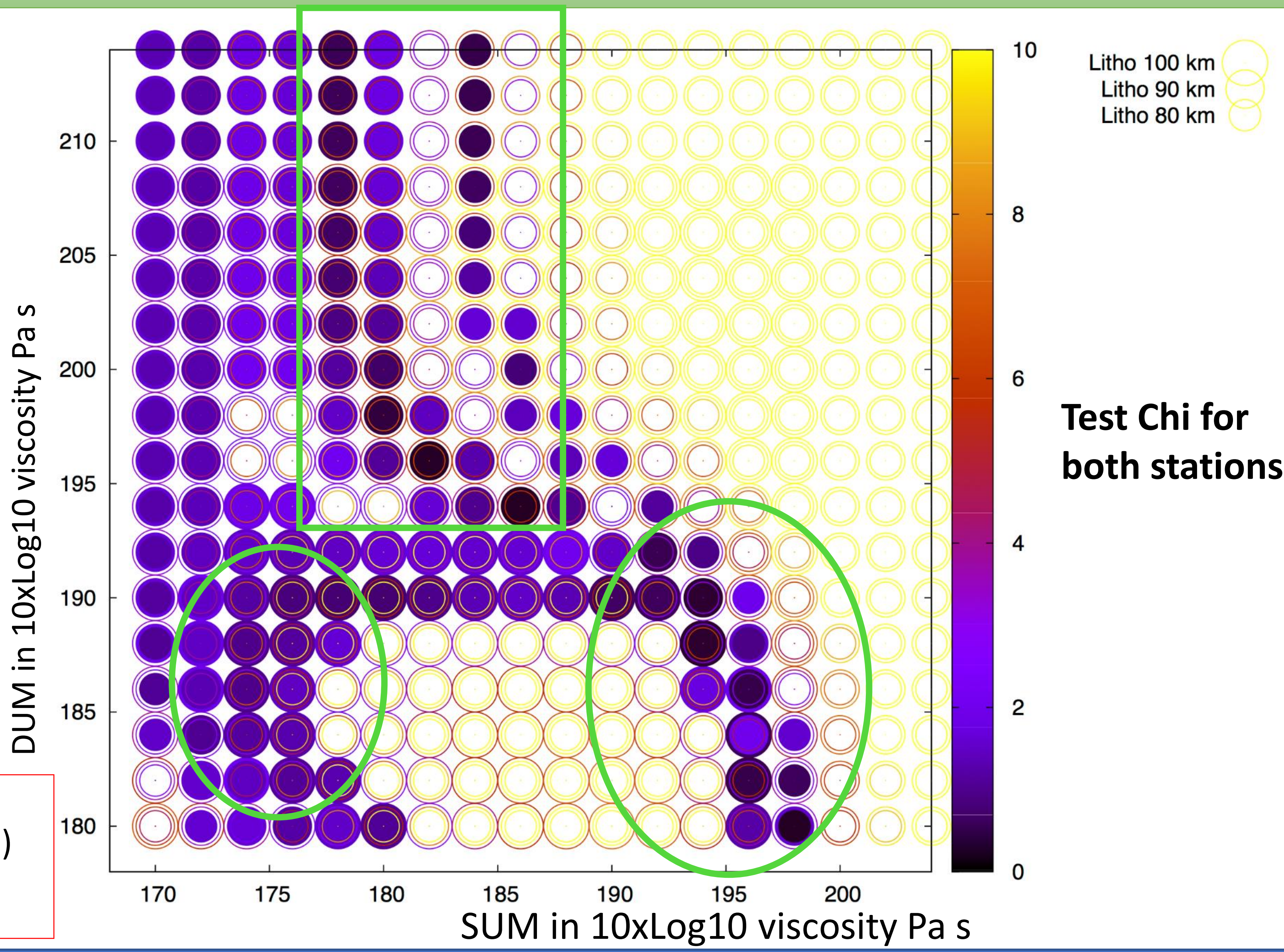


3 possibilities:

80-90 km LT
with SUM low viscosity

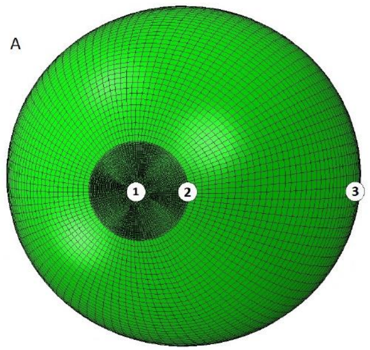
100 km LT
SUM & DUM low viscosity

80-90-100 LT
DUM low visco (0.1-1x10^{19} Pa s)
SUM around 4x10^{19} Pa s

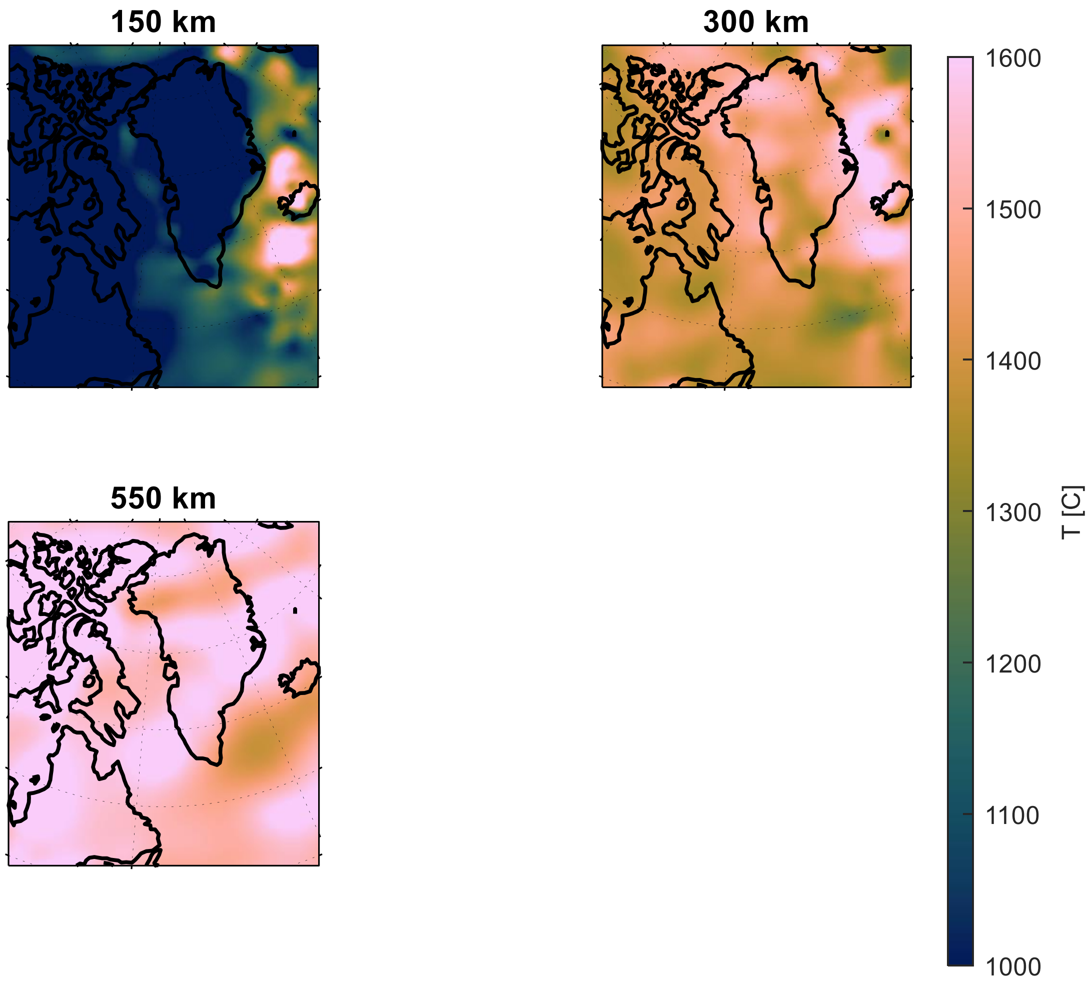


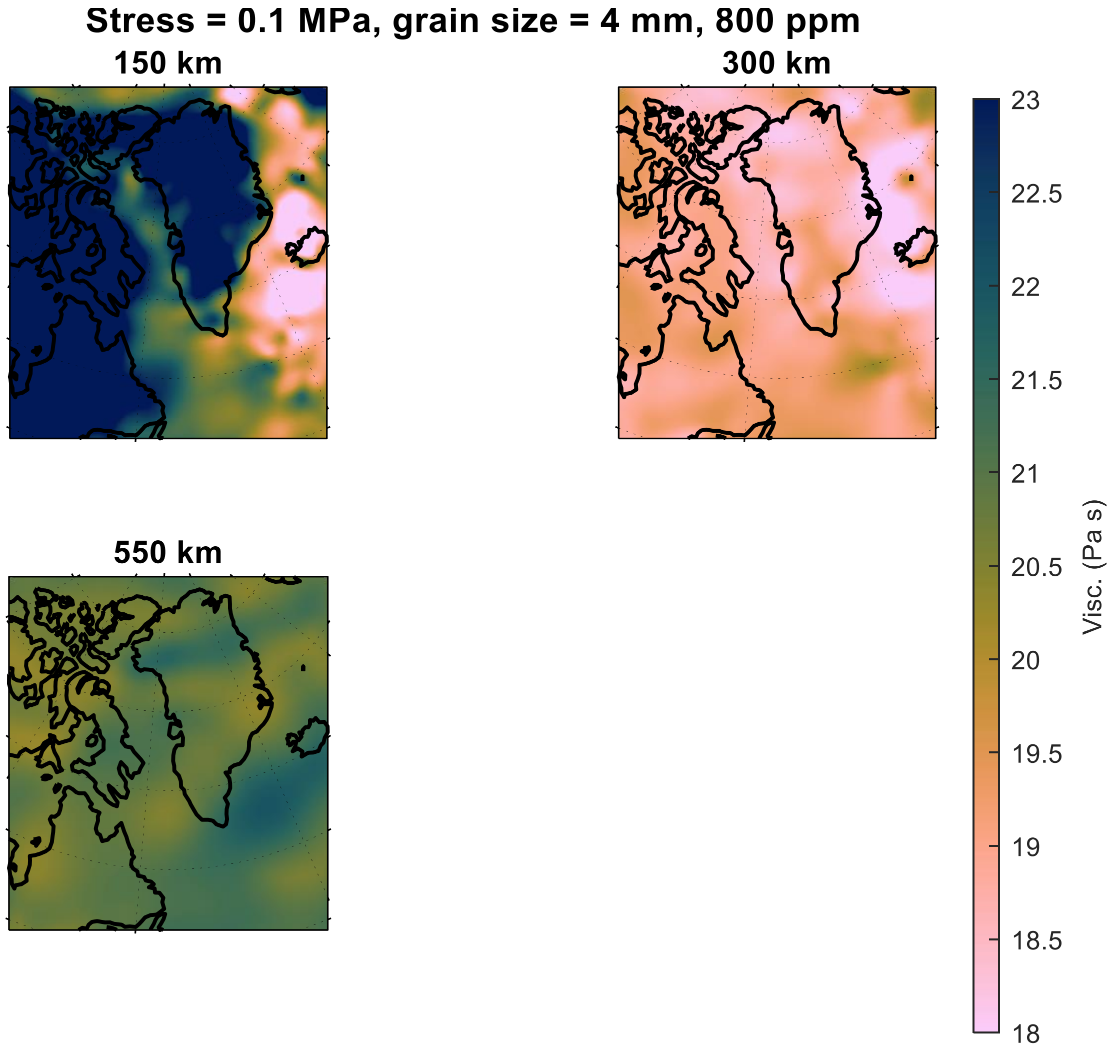
Test Chi for both stations

Postglacial rebound

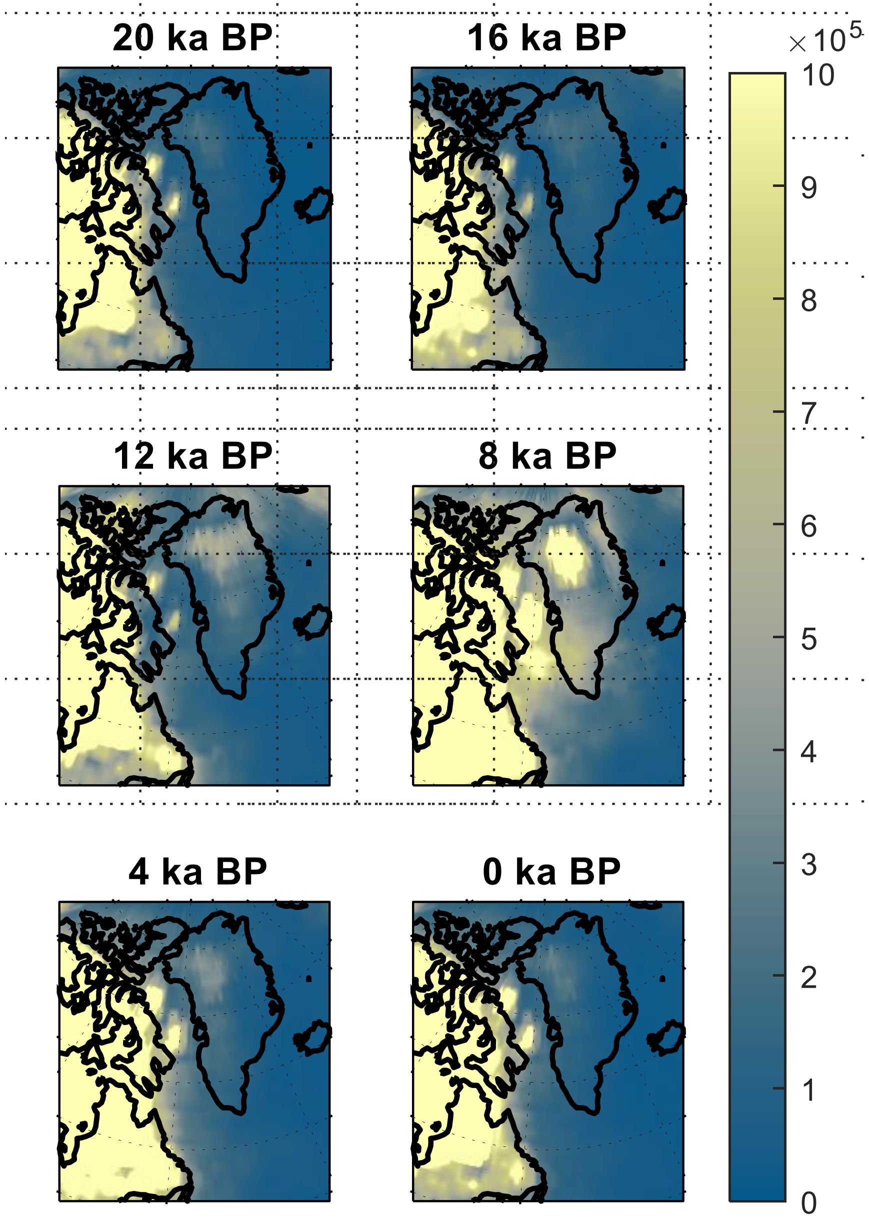


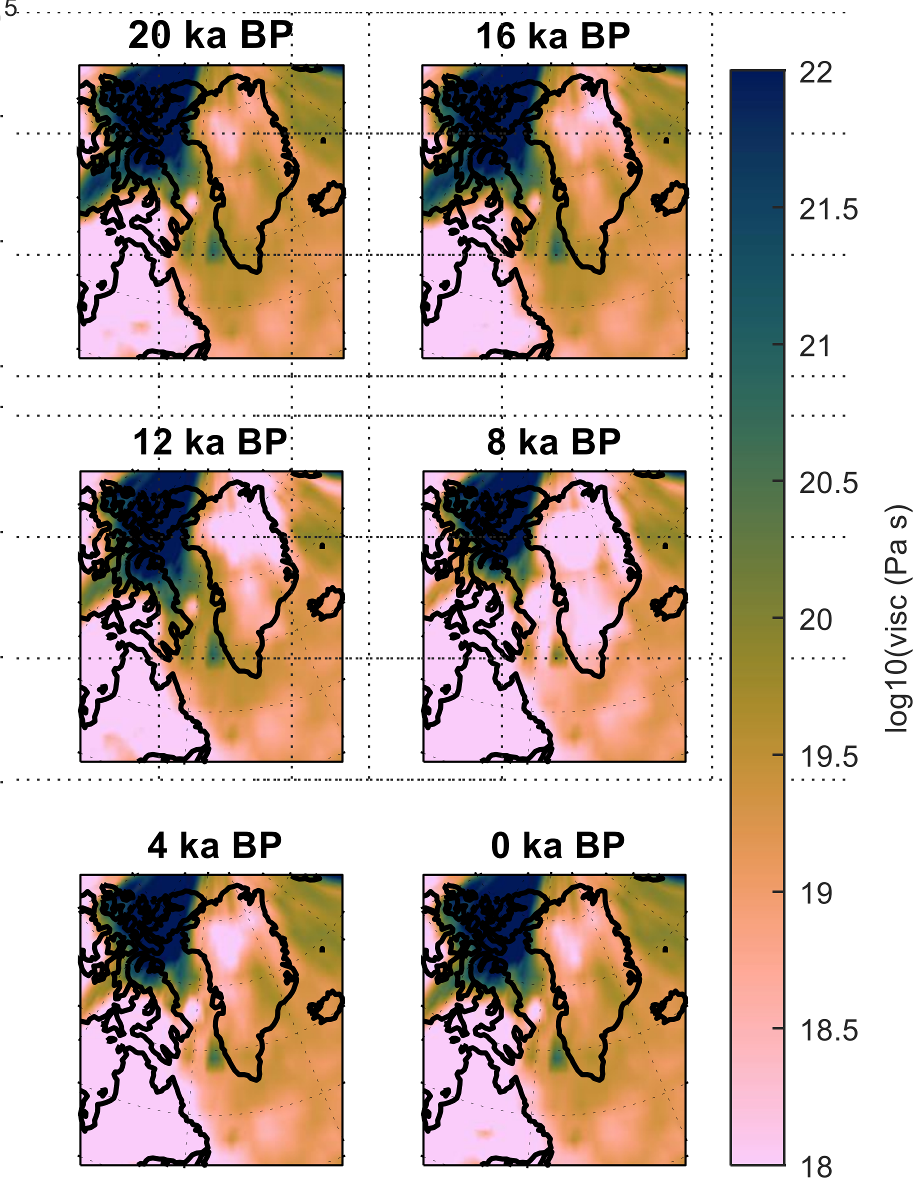
NAT2020 (Celli et al. 2020)





Stress-dependent viscosity





WINTERC-G

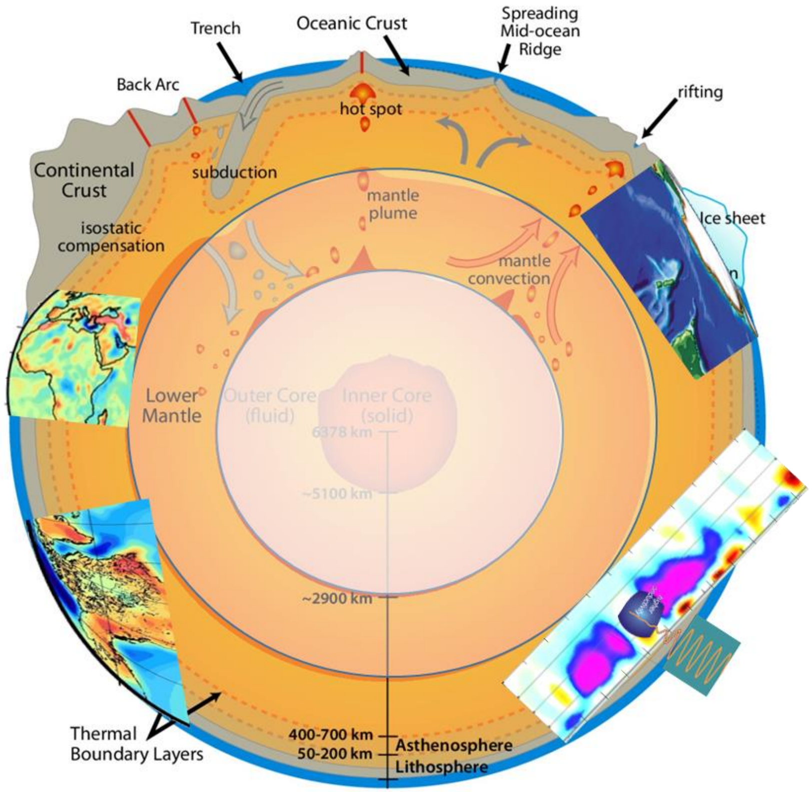
7 mm 300 ppm

200 km depth

Conclusions

- New data compilations: gravity, magnetic anomalies, seismic, heatflow
- New interpretations: sub-ice geology, lithosphere structure, mantle plume, postglacial rebound

→ interaction with ice sheet



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Publications

Accepted/published

- Celli, N.L., S. Lebedev, A.J. Schaeffer, C. Gaina, 2021. The tilted Iceland Plume and its effect on the North Atlantic evolution and magmatism. EPSL, 569, doi.org/10.1016/j.epsl.2021.117048.
- Martinec, Z., Fullea, J., Velimsky, J., Sachl, L. A new integrated geophysical-petrological three-dimensional model of upper mantle conductivity validated by the Swarm M_2 tidal magnetic field. Geophysical Journal International, Volume 226, Issue 2, August 2021, Pages 742–763, https://doi.org/10.1093/gji/ggab130.

In review

- Dilixiati, Y., Baykiev, E., Ebbing, J. Spectral consistency of satellite and airborne data: Application of an Equivalent dipole layer for combining satellite and aeromagnetic data sets. Geophysics, revised.
- Kolyukhin D., Minakov, A., "Statistical modeling of Earth's mantle heterogeneity" (International Journal of Geomathematics)
- Minakov, A., Gaina, C. "Probabilistic linear inversion of satellite gravity gradient data applied to the northeast Atlantic" (JGR Solid Earth)
- Moorkamp, M., Fullea, J. Aster, R.C., Weise, B., Inverse Methods, Resolution and Implications for the Interpretation of Lithospheric Structure in Geophysical Inversions, submitted to PEPI.
- Sebera, J., Bezdek, A., Ebbing, J., Satellite magnetic anomalies with a smooth spectral transition to long wavelengths. Physics of the Earth and Planetary Interiors.