The key role of global solid-Earth processes in the onset of Northern hemisphere glaciations

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GFZ
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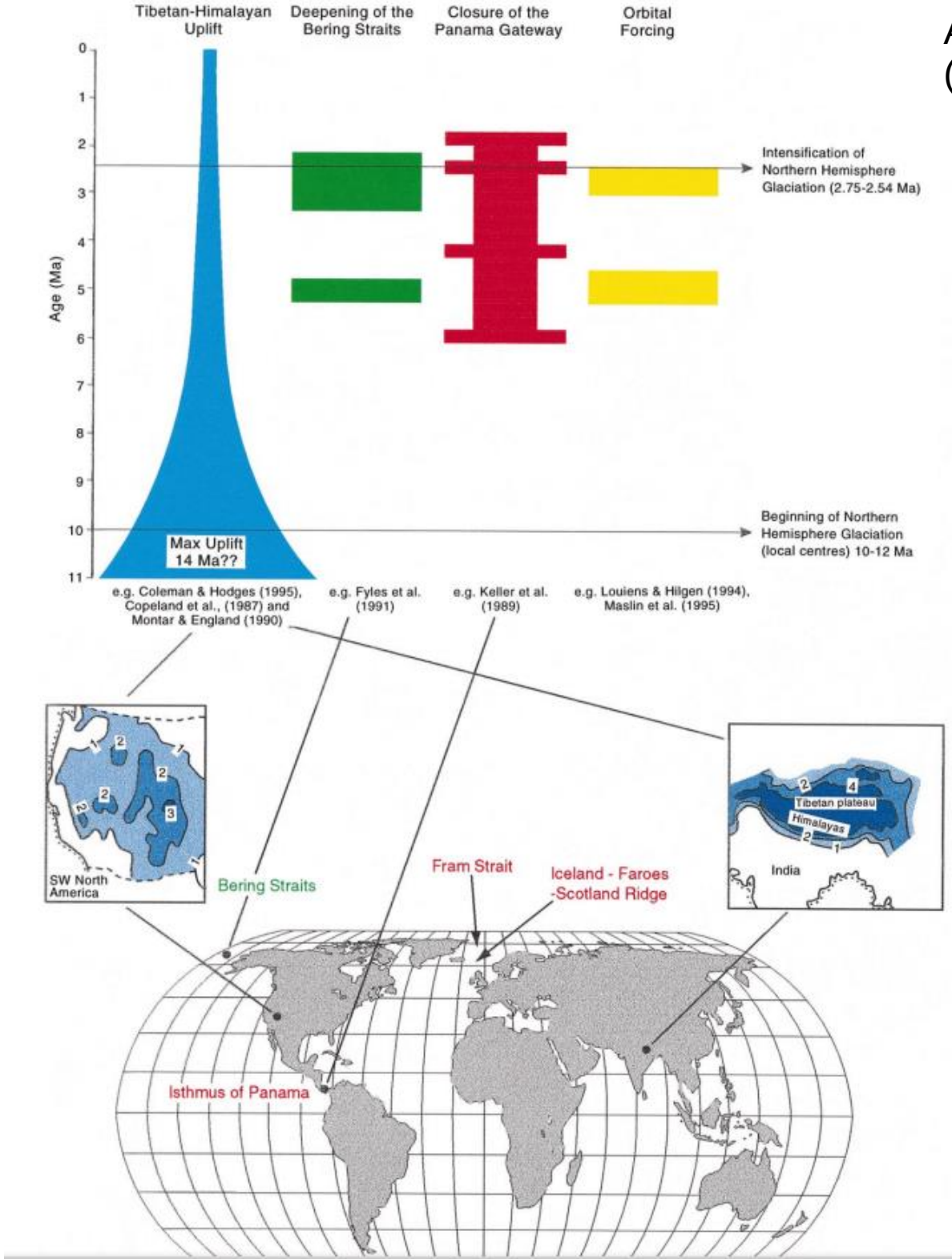
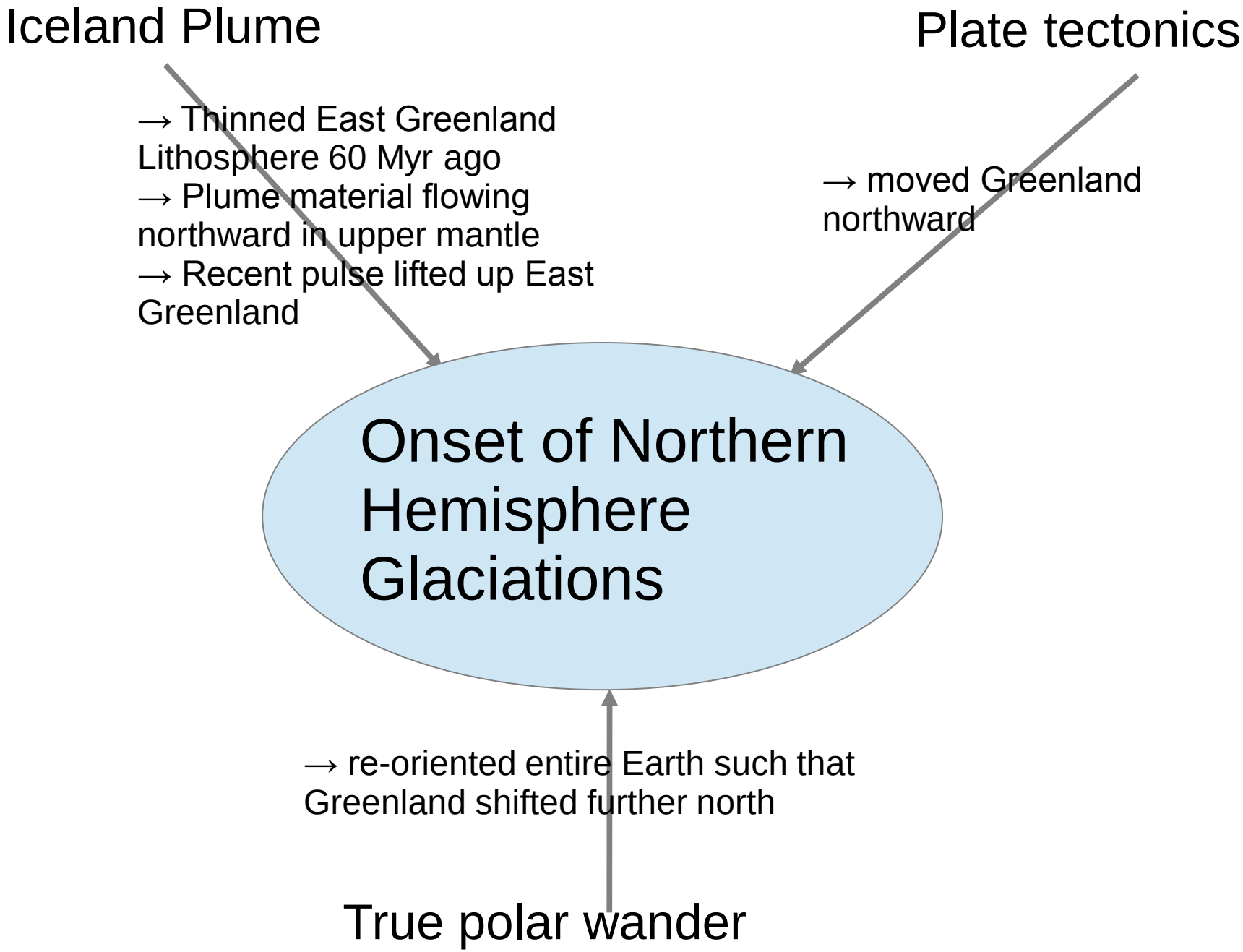
The Centre for Earth Evolution and Dynamics

Atmospheric CO_2
(DeConto et al., 2008)

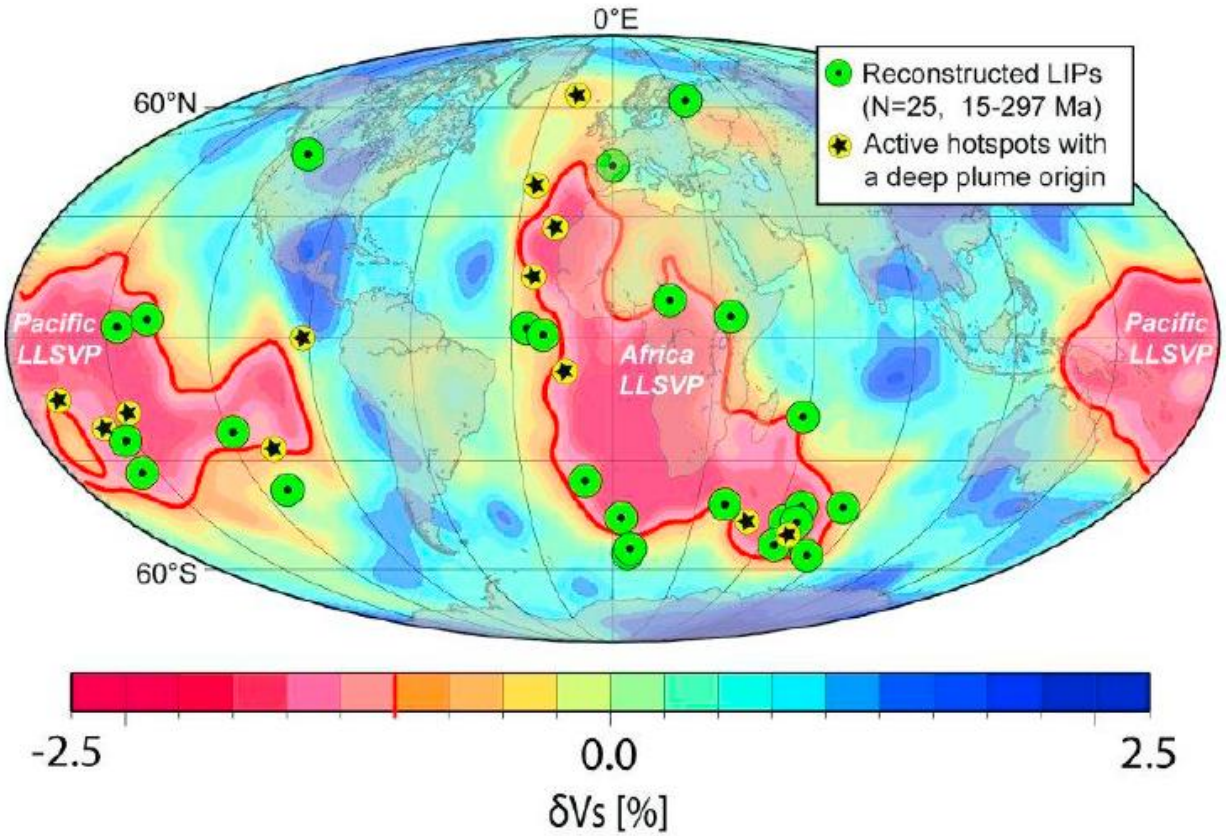


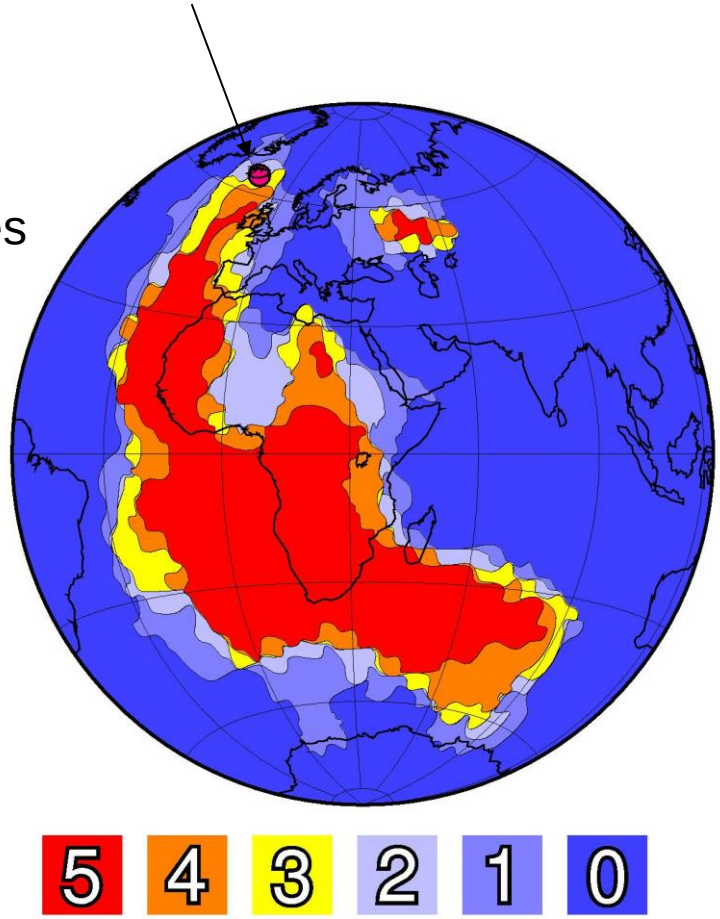
From Maslin et al. (1998)


Iceland Plume
Plate tectonics
→ Thinned East Greenland Lithosphere 60 Myr ago
→ Plume material flowing northward in upper mantle
→ Recent pulse lifted up East Greenland
→ moved Greenland northward
Onset of Northern Hemisphere Glaciations
→ re-oriented entire Earth such that Greenland shifted further north
True polar wander

A deep mantle plume beneath Iceland

Hotspots and reconstructe LIP eruption locations
tend to fall along margins of Large Low Shear Velocity Provinces (LLSVPs) (Torsvik et al.)

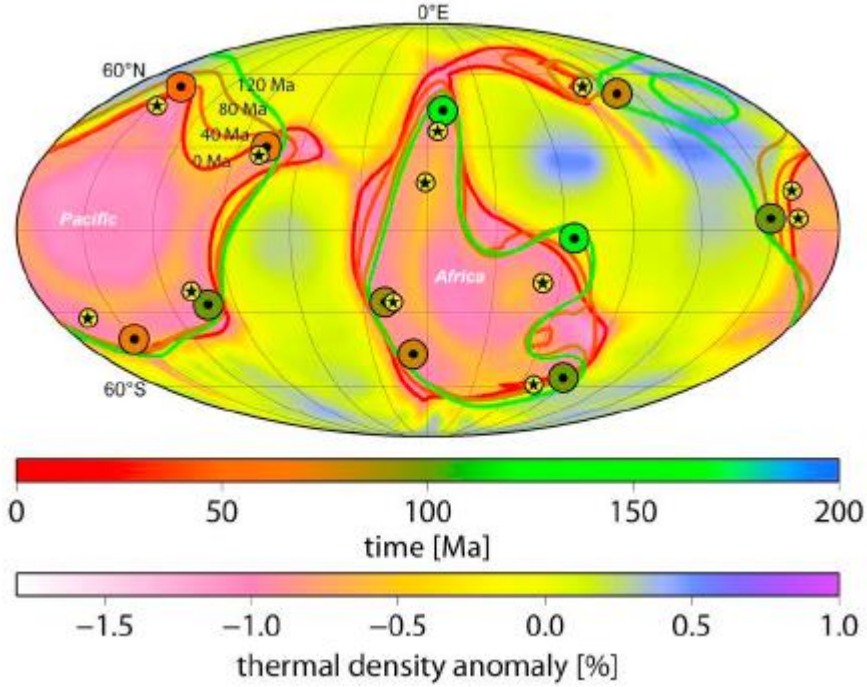


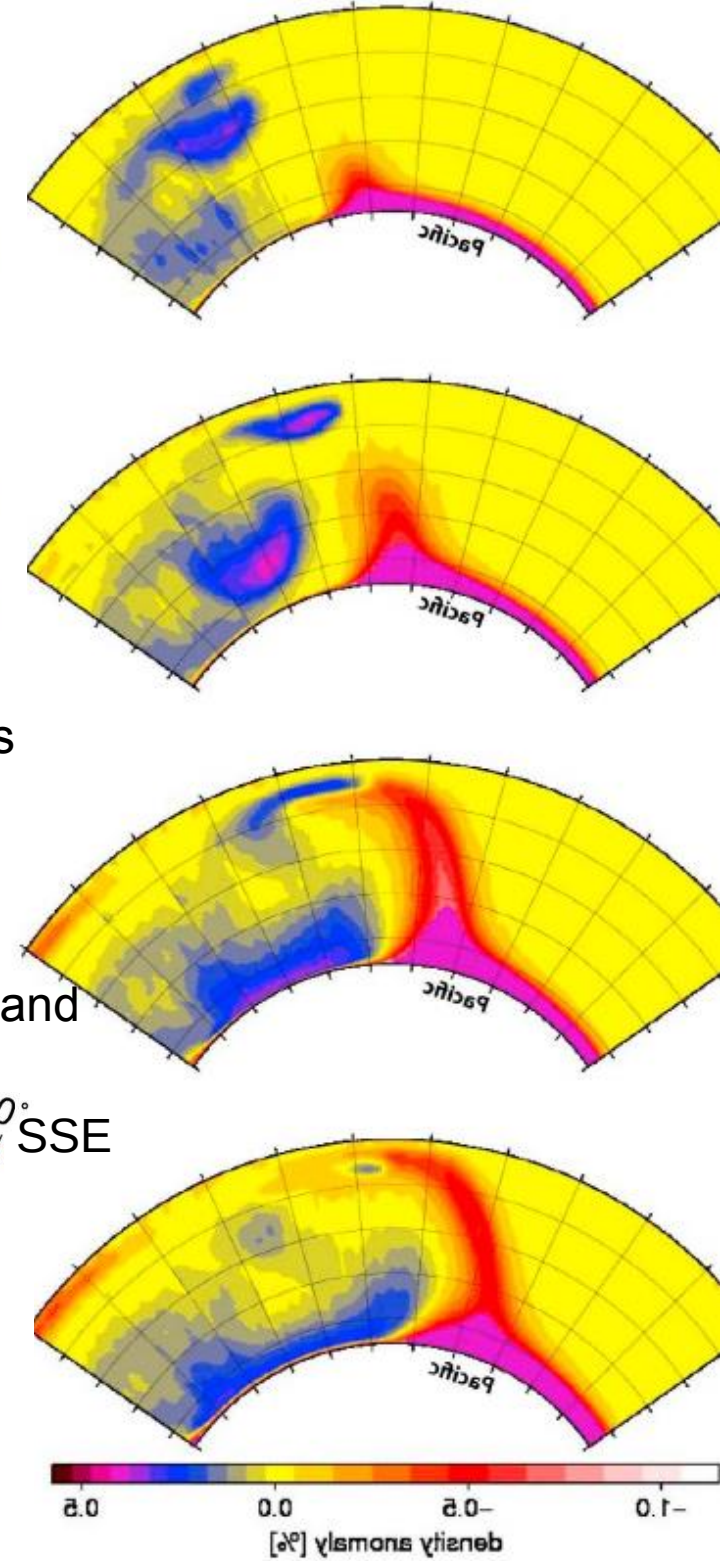


LLSVPs as “voting maps” (from Lekic et al. Cluster analysis)

Iceland fits right into that pattern

A deep mantle plume beneath Iceland



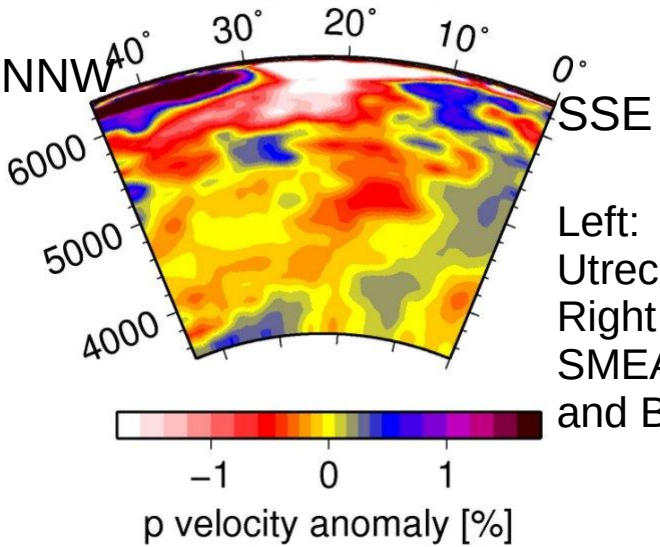


→ A geodynamic model (Steinberger and Torsvik, 2012) explains how plumes get generated at LLSVP margins, particularly at corners

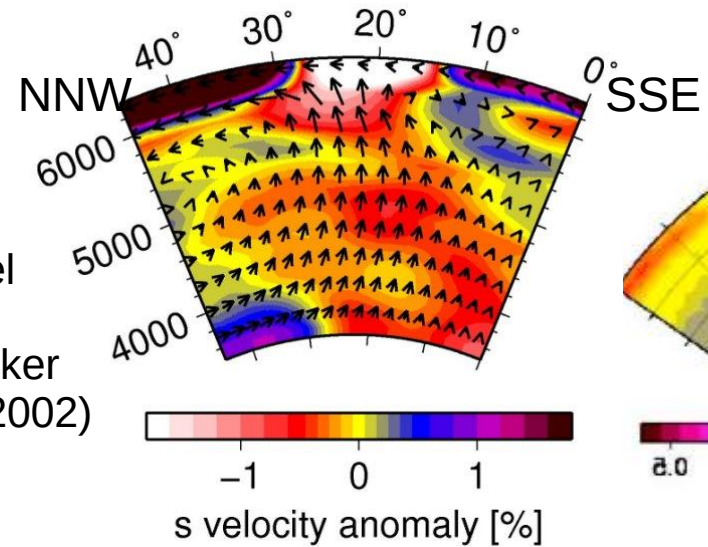
→ Iceland is exactly where a deep mantle plume is expected

→ Geodynamic model predicts tilted plume conduit

→ This is resembled by tomographic cross sections through Iceland



Left:
Utrecht model
Right:
SMEAN (Becker and Boschi, 2002)



Iceland Plume thinned East Greenland lithosphere 60 Myr ago

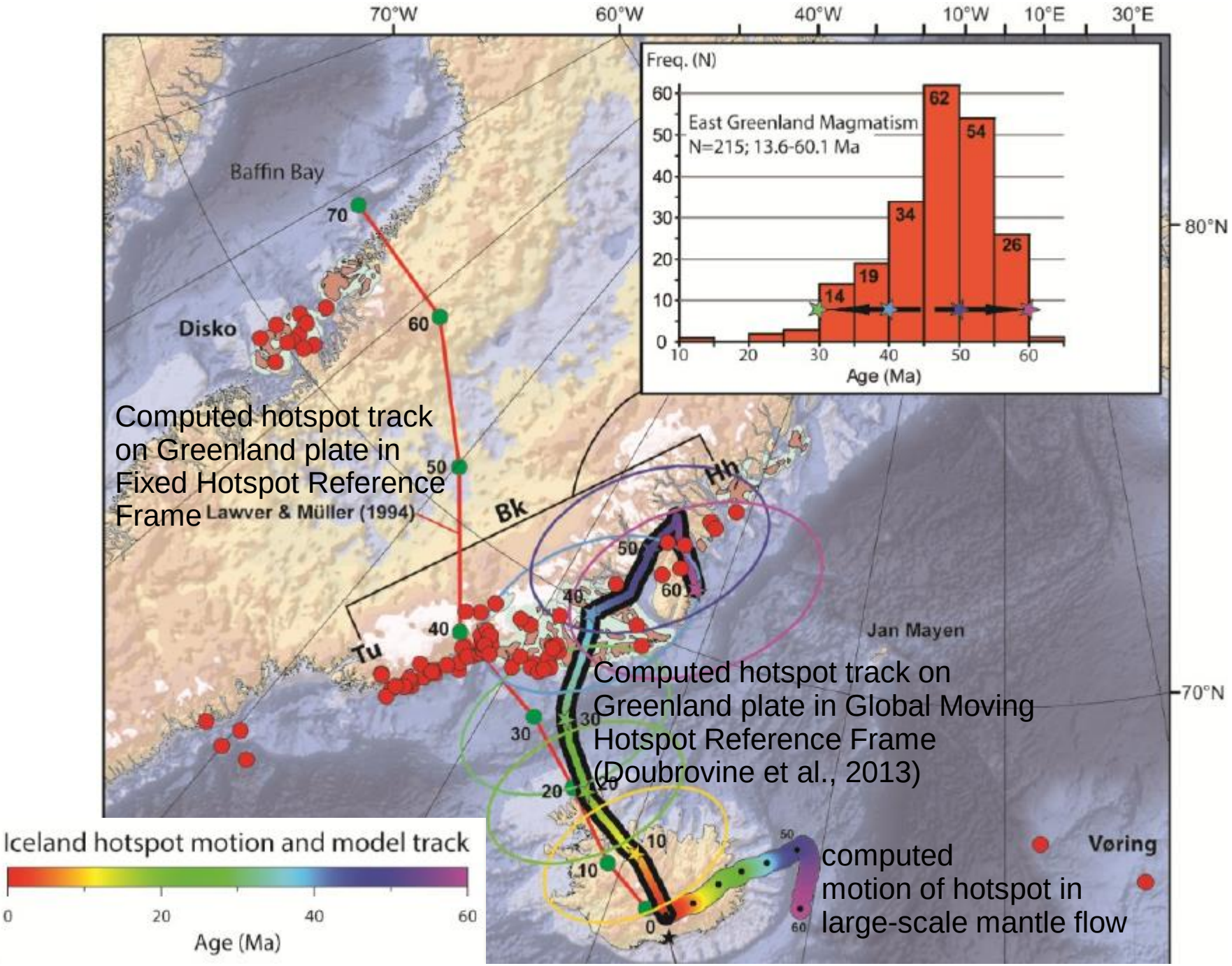


Figure from Torsvik et al. (submitted manuscript)

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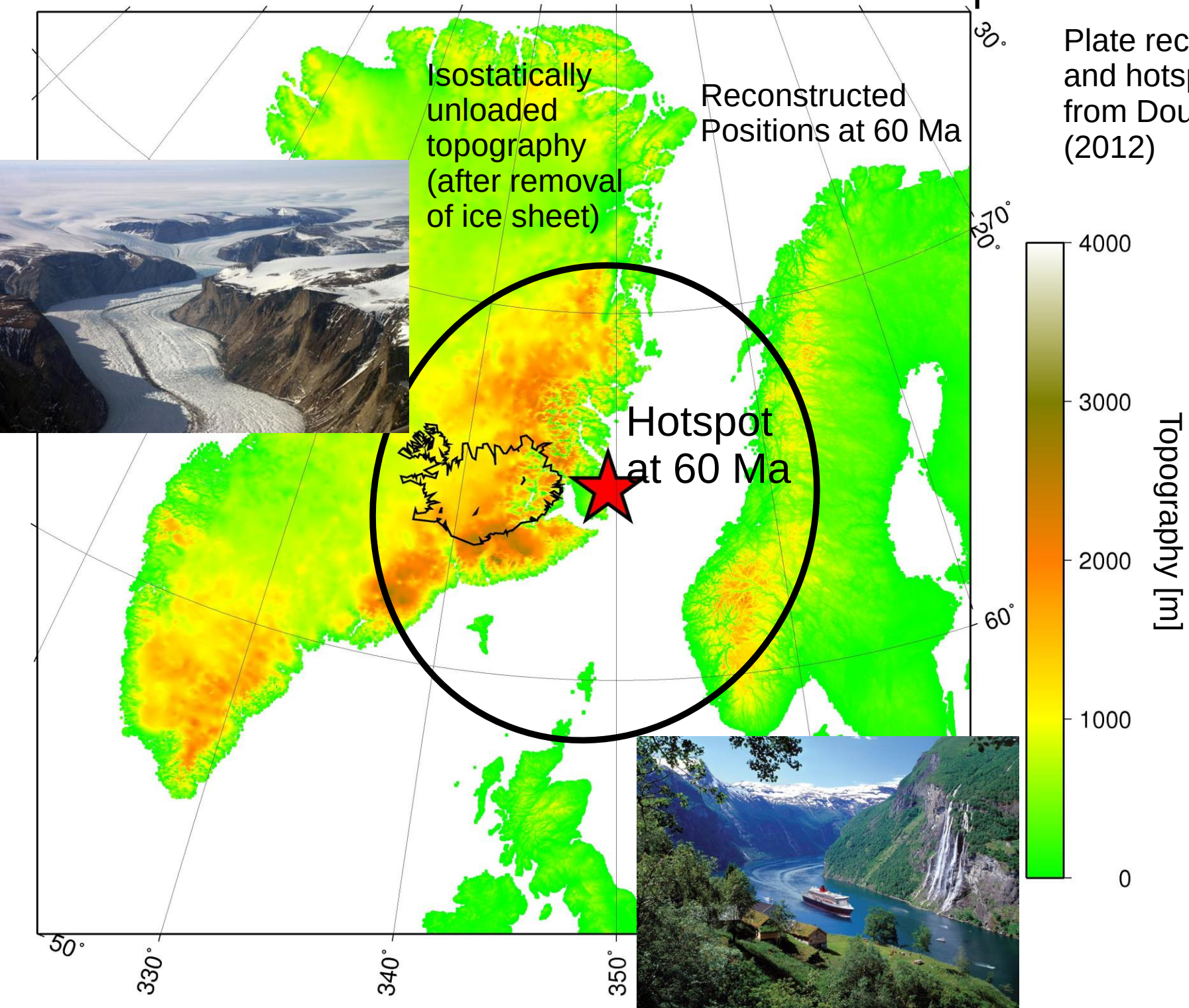
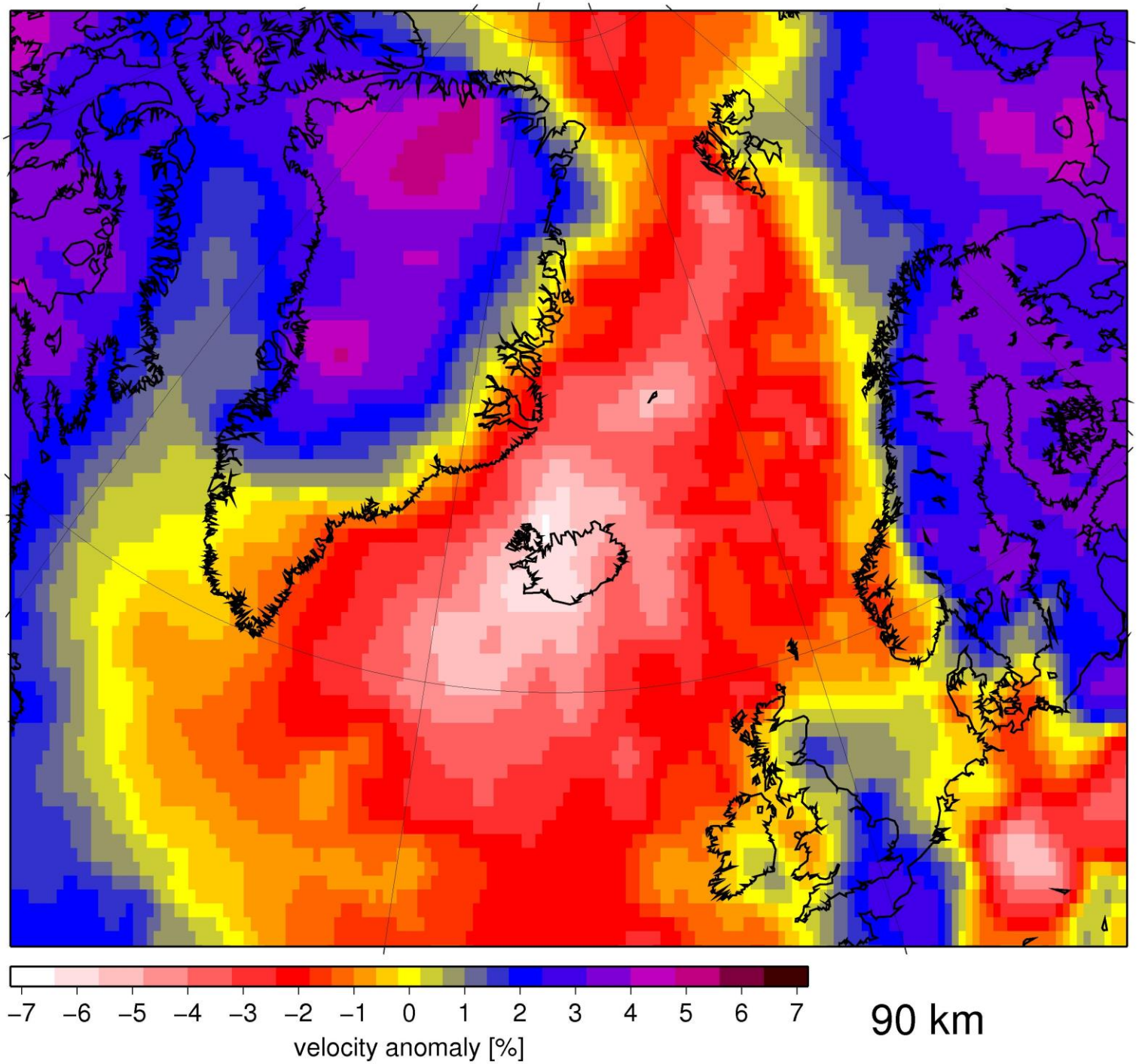


Plate reconstruction and hotspot motion from Doubrovine et al. (2012)

Iceland Plume thinned East Greenland lithosphere 60 Myr ago

UU-P07
Tomography



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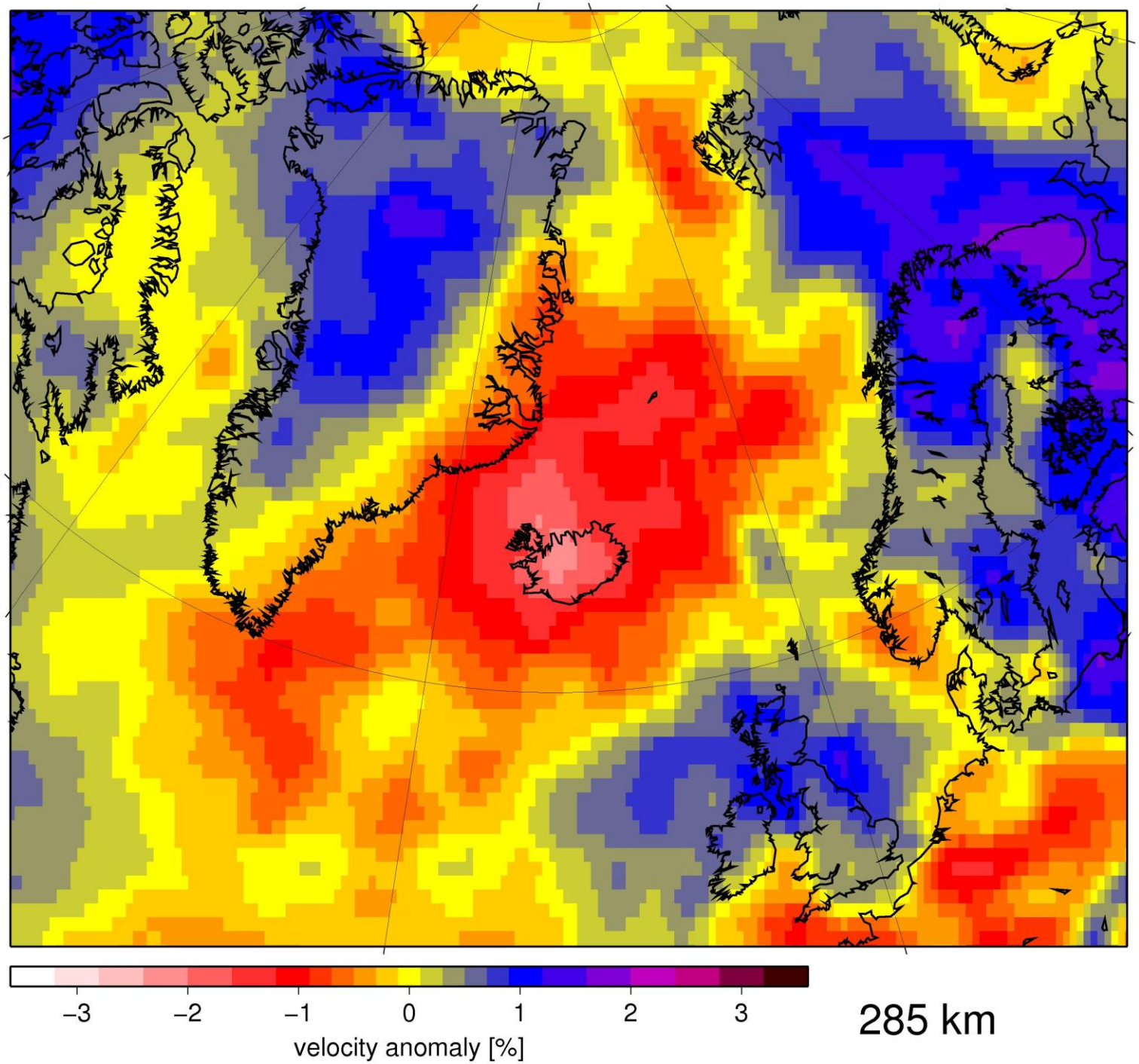
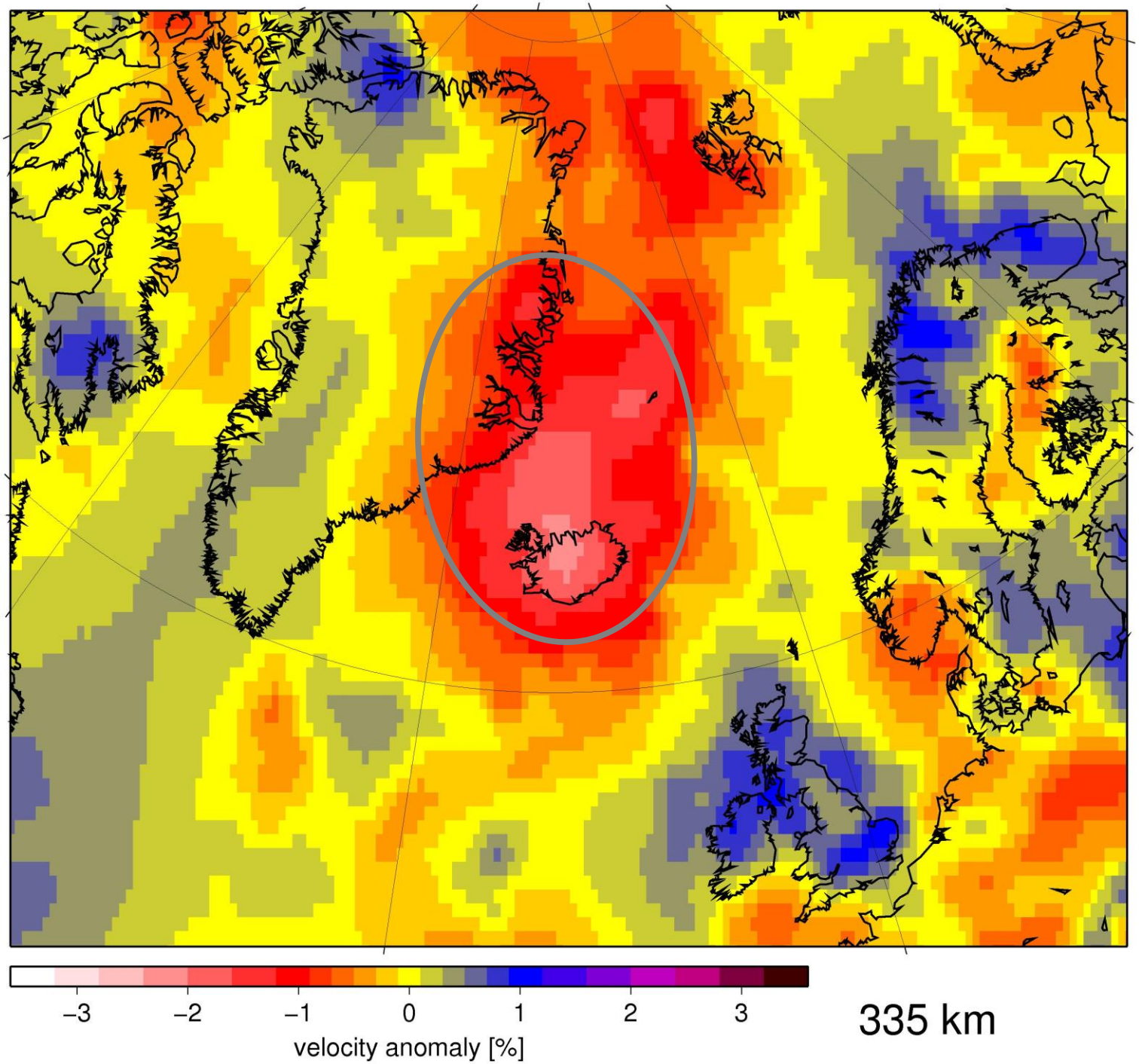


Plume material flowing northward in upper mantle – **recent pulse?**

UU-P07
Tomography



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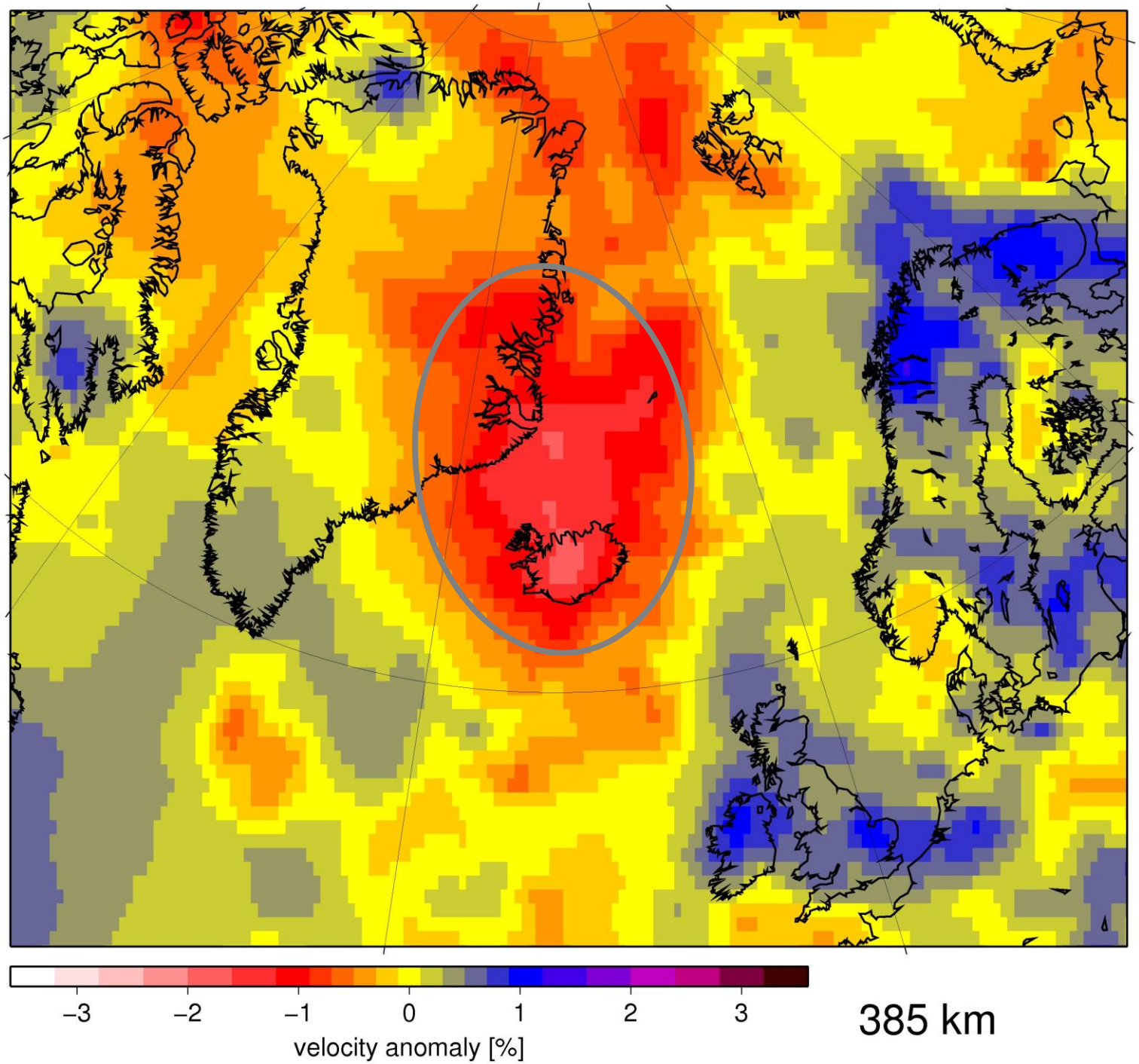
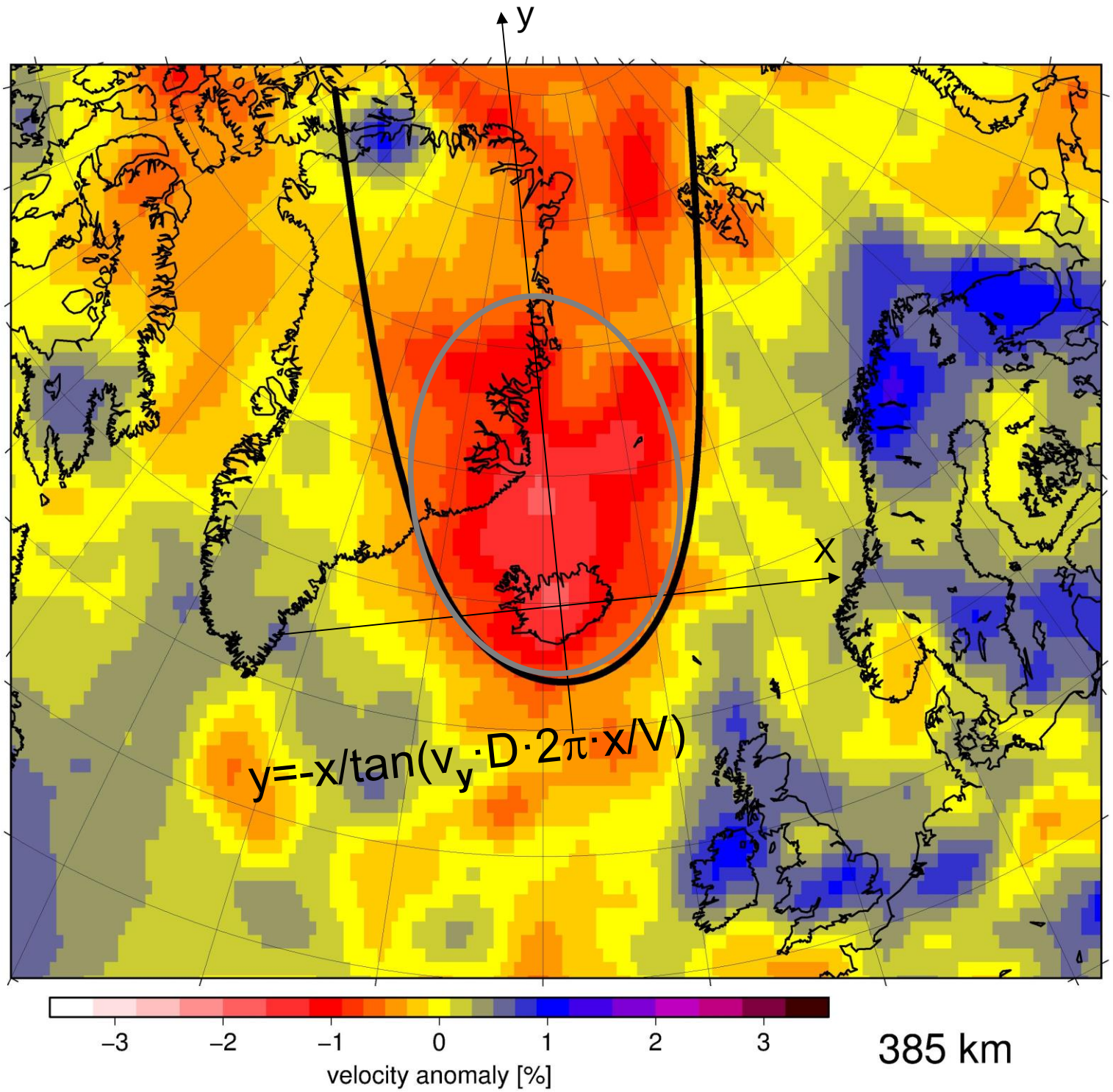


Plume material flowing northward in upper mantle – **recent pulse?**

D = low-viscosity layer thickness

v_y=speed of background mantle flow

V = plume volume flux



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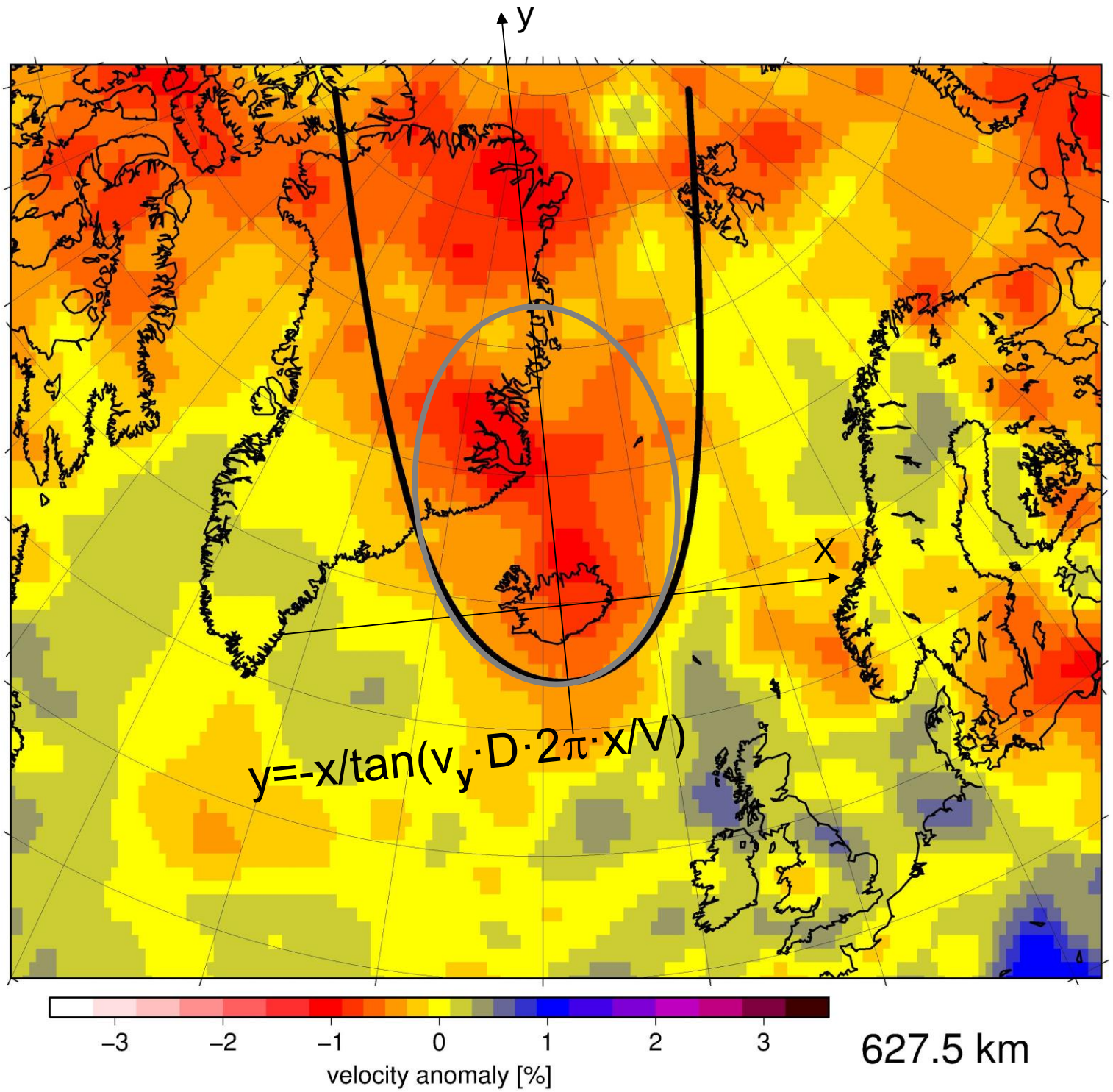
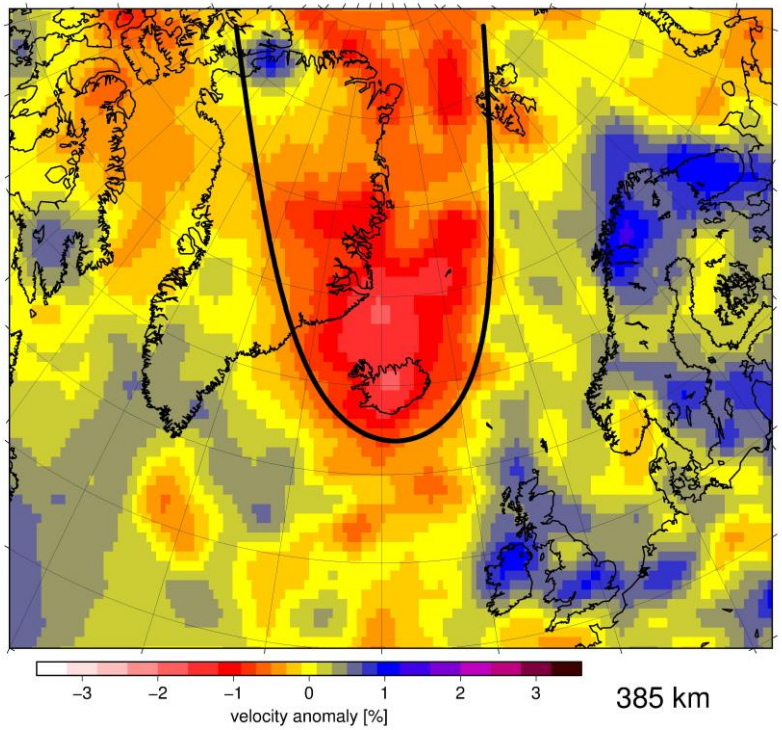
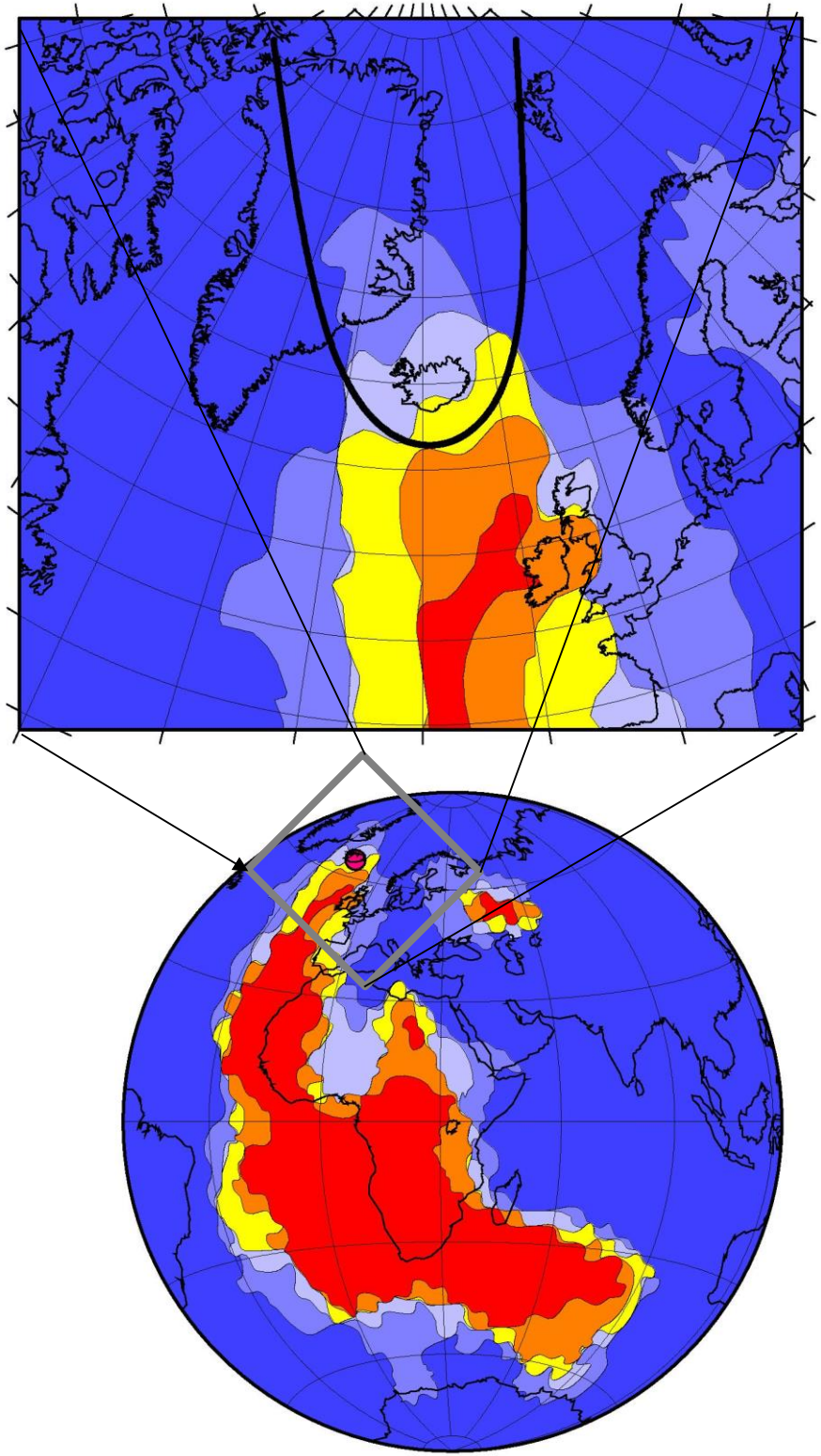






Plume material gets dragged northward
In large-scale upper mantle flow away from
large-scale upwelling above African Large
Low Shear Velocity Province

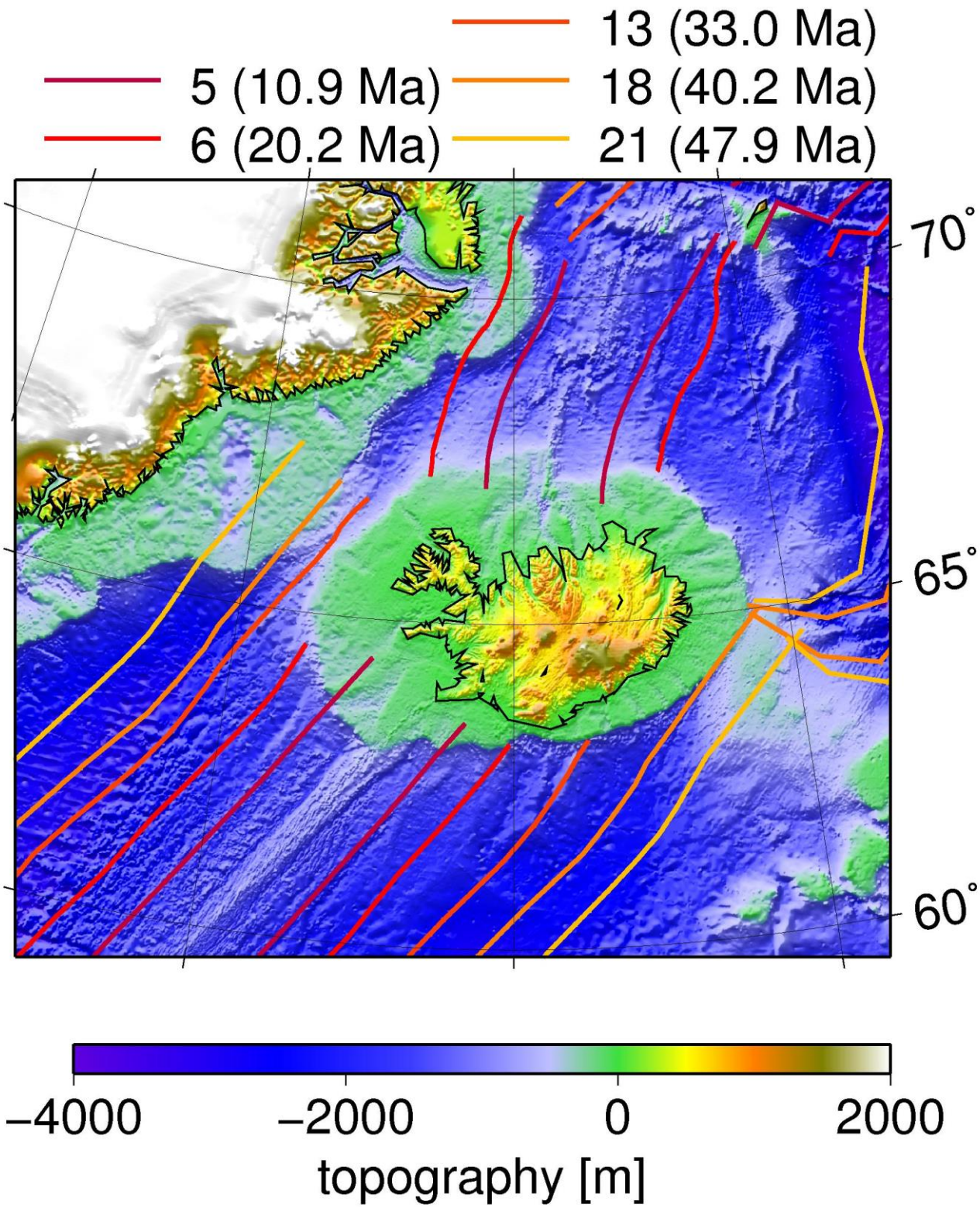
Pulsating mantle plume

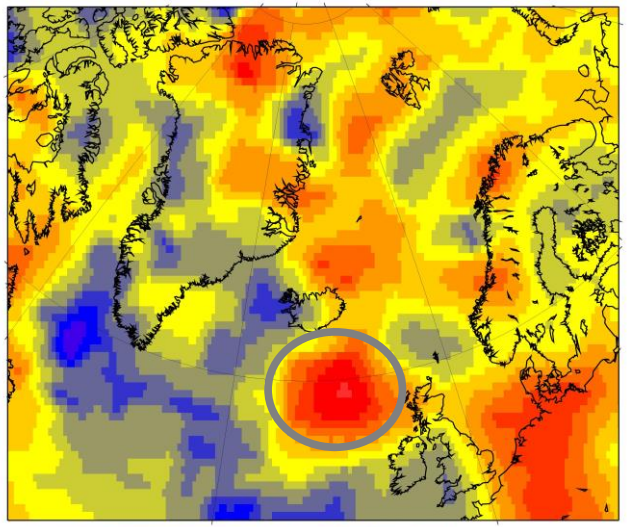
Iceland plateau as evidence for last pulse

→ arriving at surface ~ 25 Myr ago?

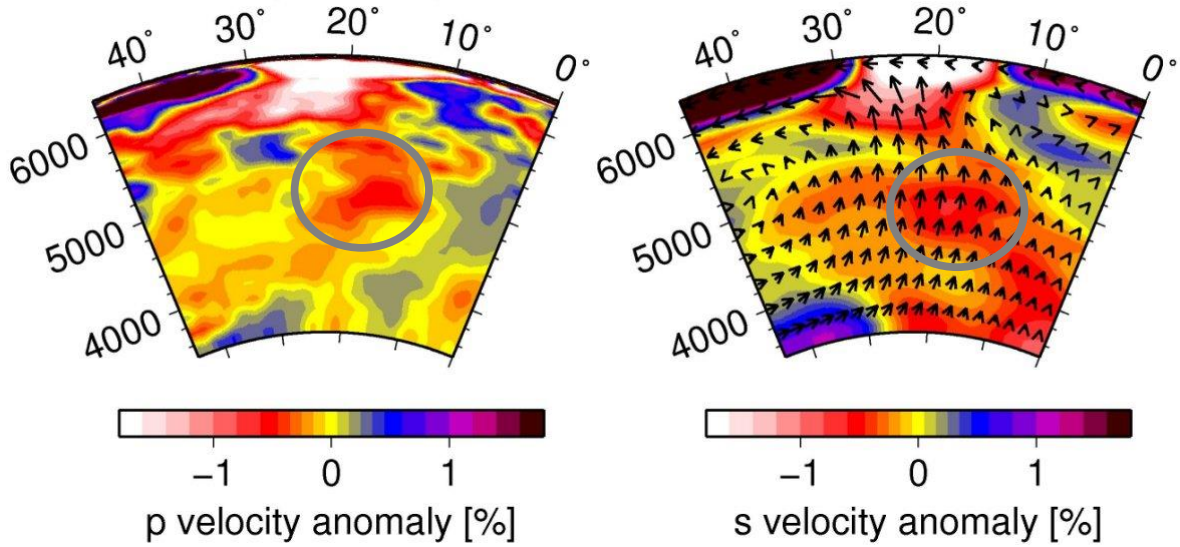
→ spreading northward ~3 cm/yr?

→ arriving at East Greenland (600 km away) ~ 5 Myr ago?





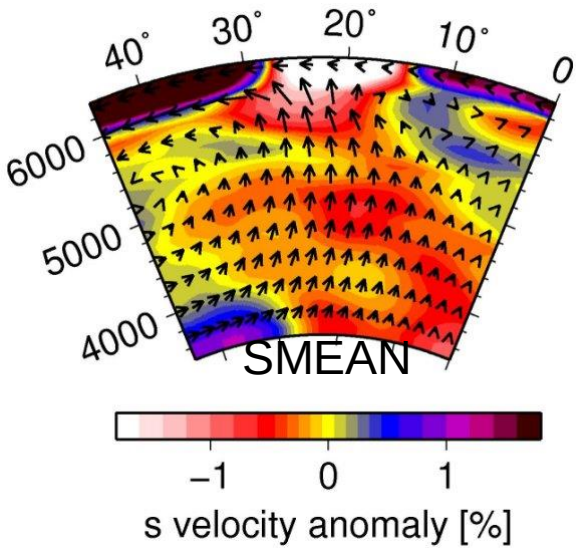
1325 km depth

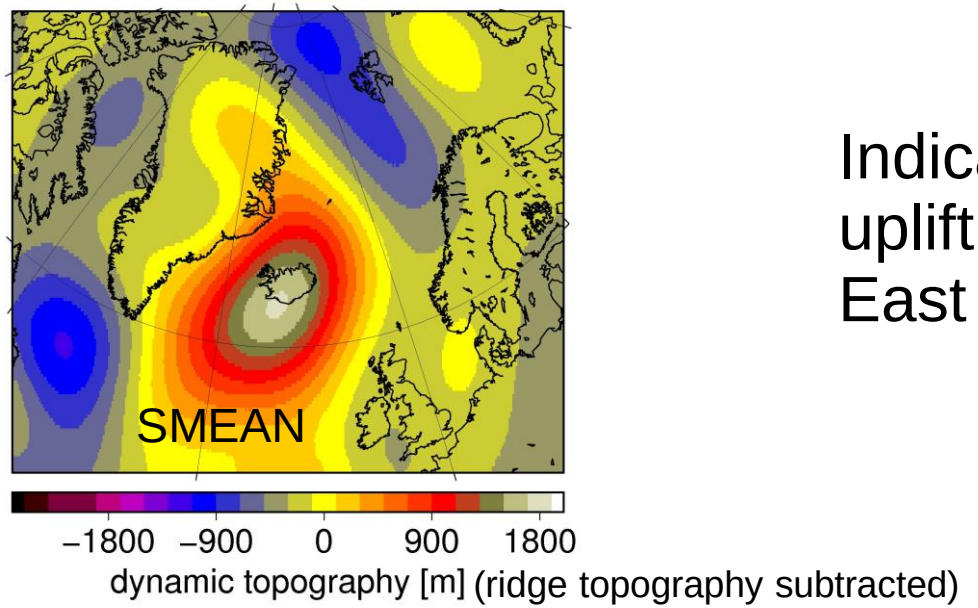


Pulsating mantle plume

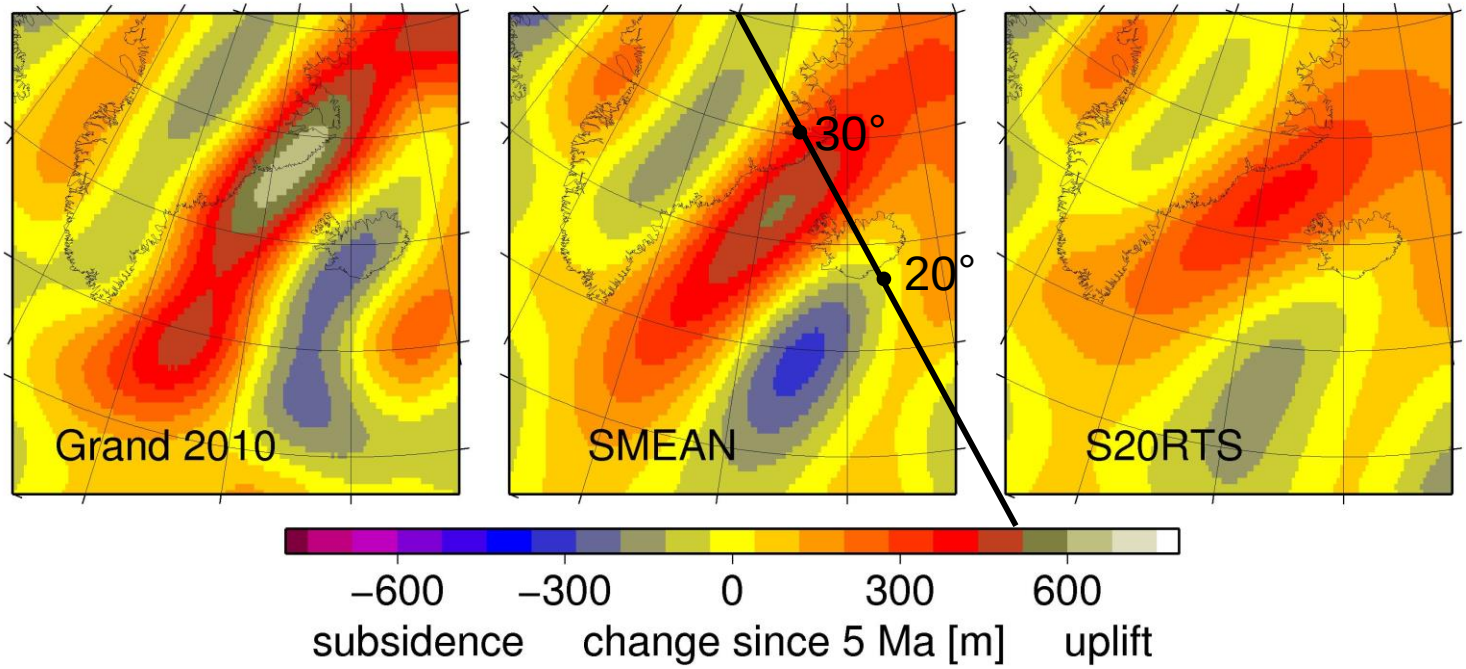
The next pulse on its way up?

Modelling uplift rates
through backward advection of density anomalies in flow



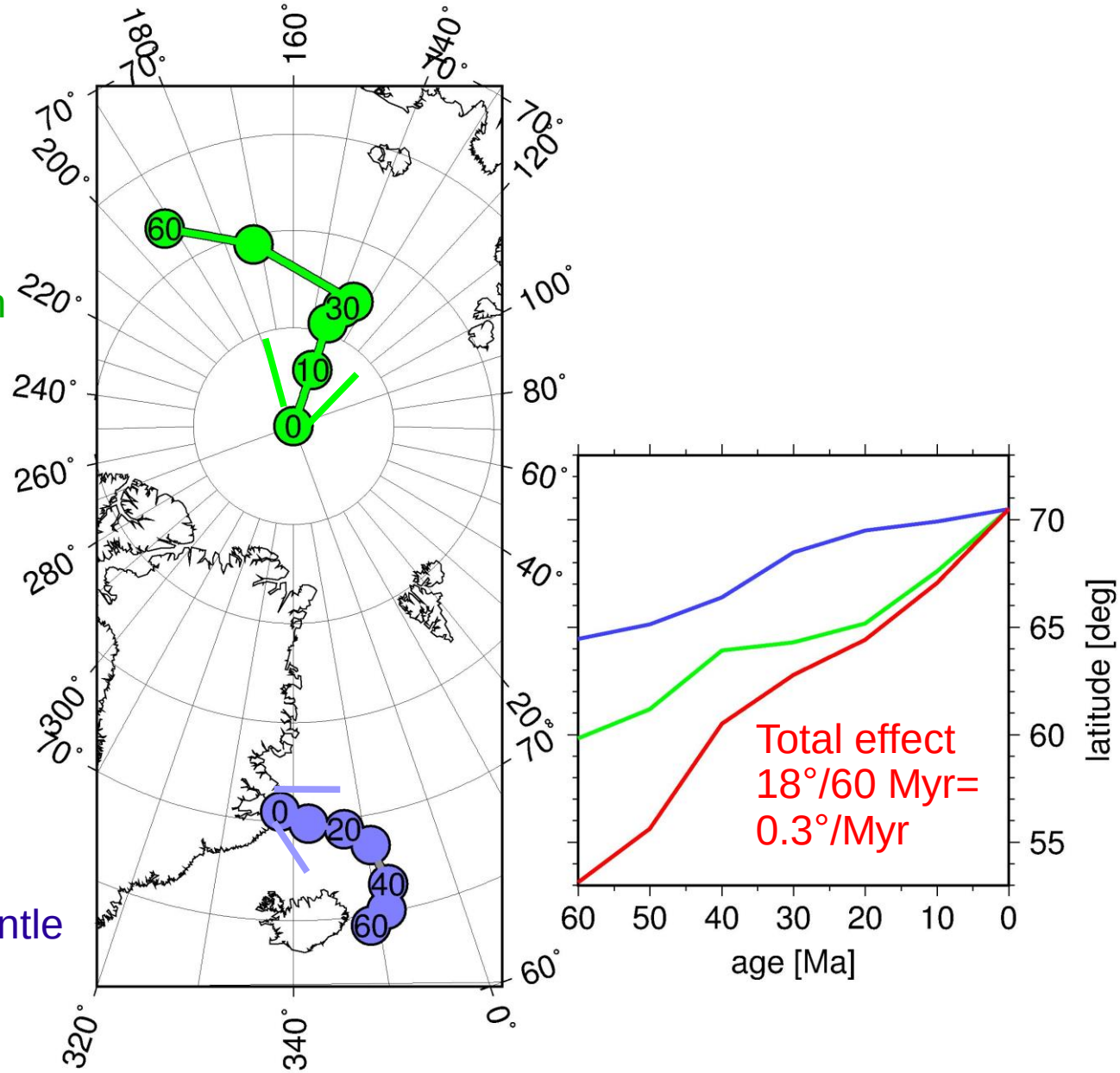


Indicating recent uplift of East Greenland

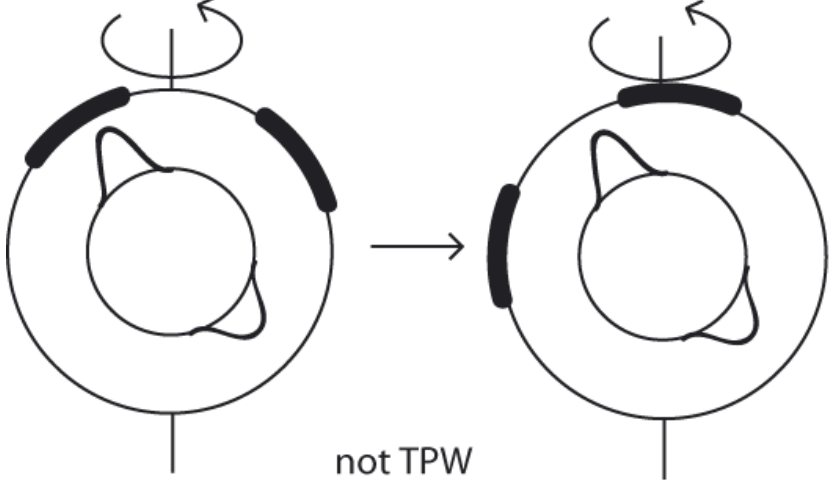


True polar wander reoriented entire Earth such that Greenland shifted further north

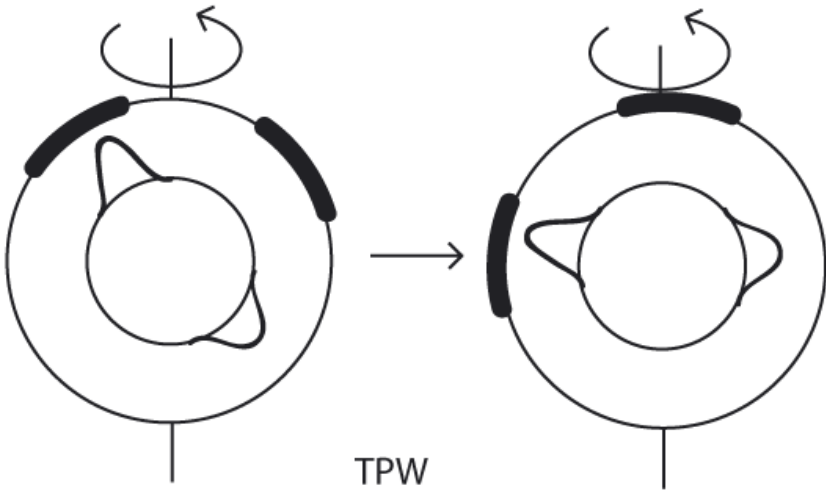
Plate tectonics moved Greenland northward relative to underlying mantle



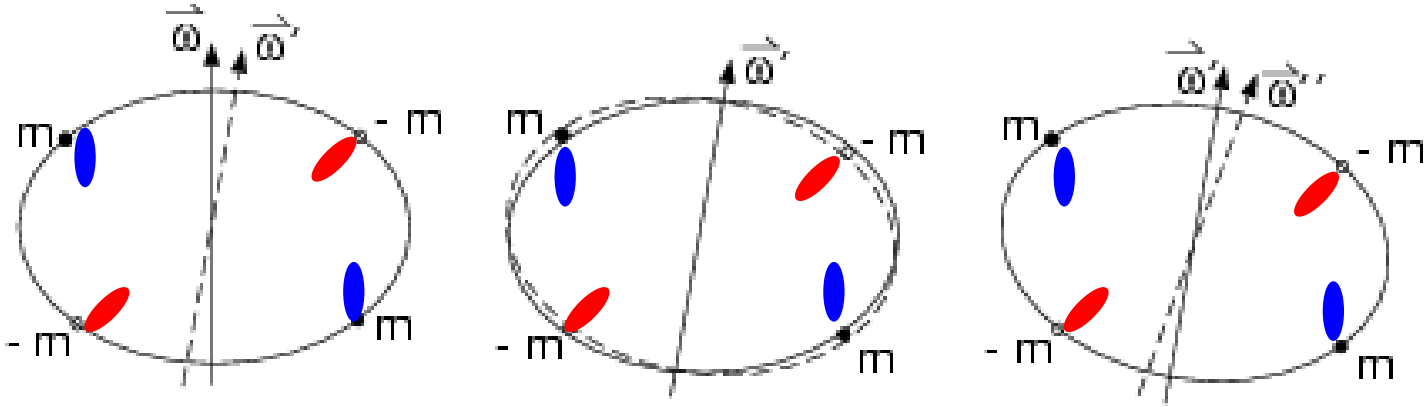
Not true polar wander:
(coherent) motion of plates in mantle (hotspot) reference frame

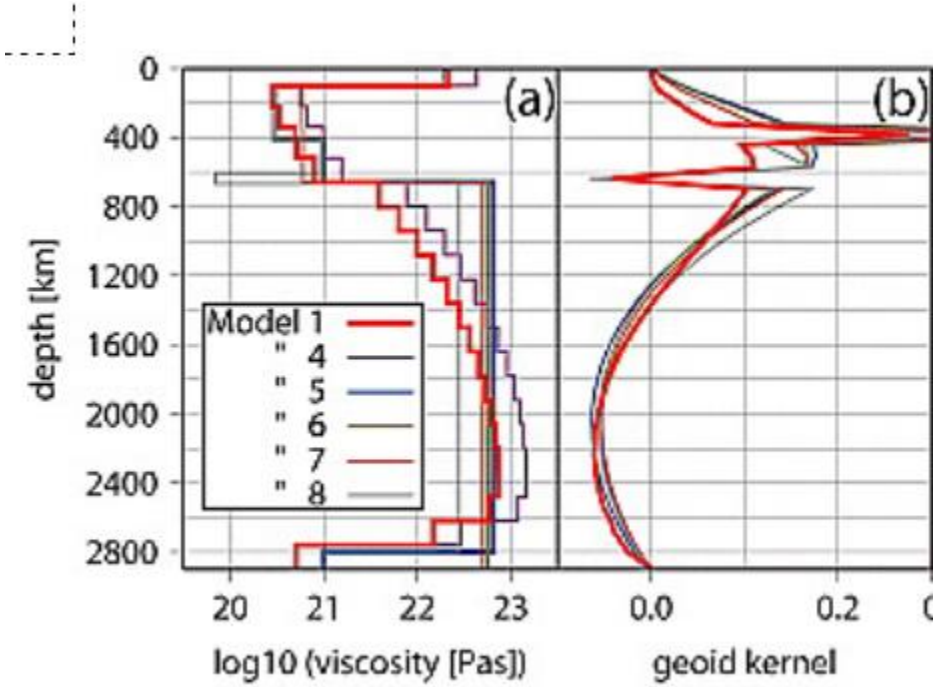


true polar wander:
(coherent) motion of plates relative to pole (determined paleomagnetically) but not in mantle (hotspot) reference frame

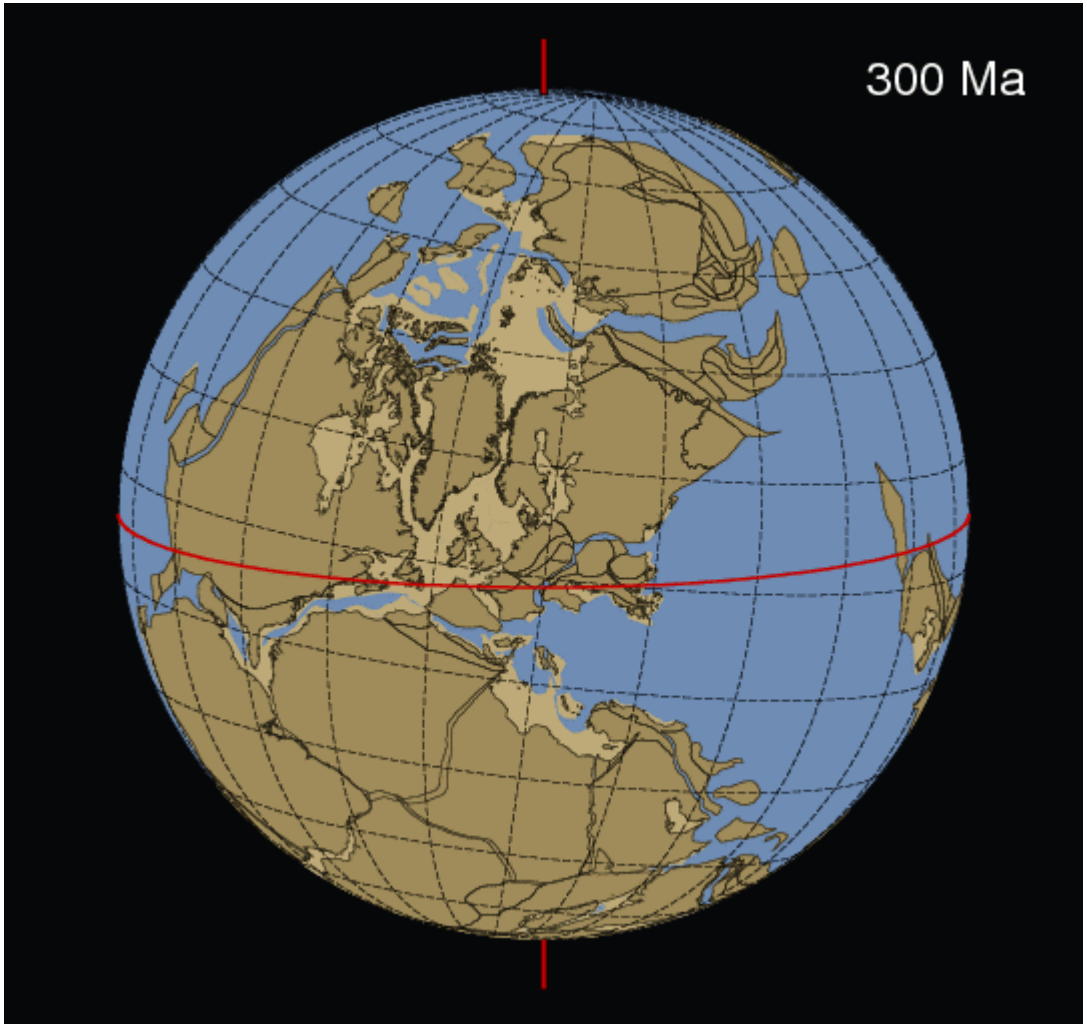


Determine true polar wander by converting (apparent) polar wander paths into mantle (hotspot) reference frame





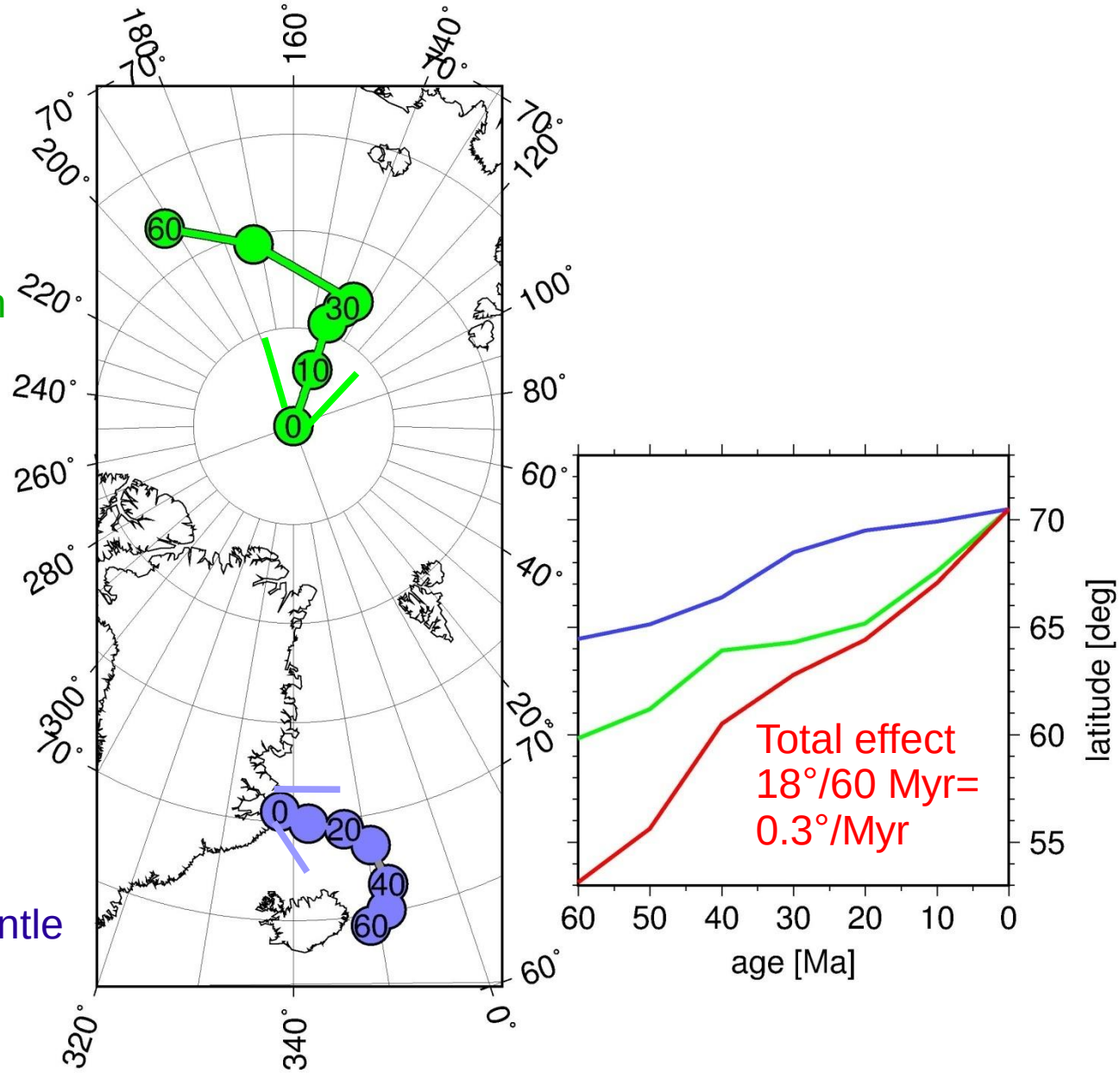
Positive anomalies in upper mantle cause positive geoid at degree 2 – tend to shift to the equator through true polar wander



Mantle reference frame indicated by grid
“True Polar Wander” = motion of pole in mantle reference frame
Model of Doubrovine et al. (JGR, 2012)
Animation made by Pavel Doubrovine

True polar wander reoriented entire Earth such that Greenland shifted further north

Plate tectonics moved Greenland northward relative to underlying mantle



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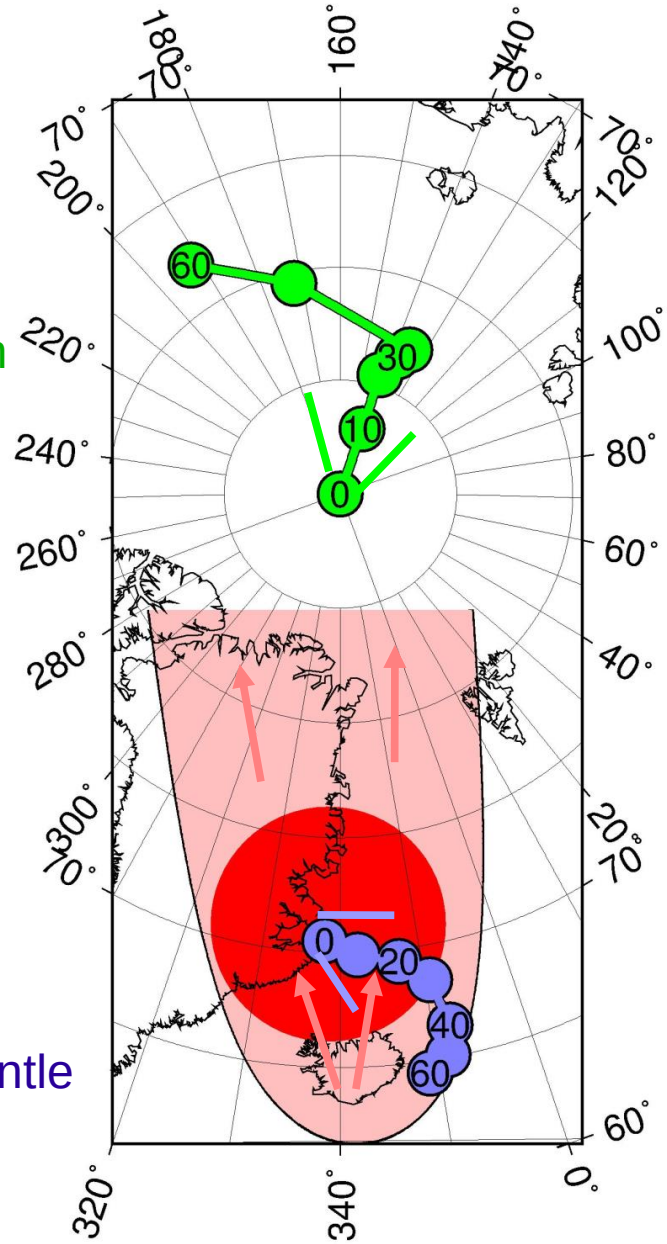

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Iceland plume thinned East Greenland lithosphere 60 Myr ago

Recent pulse lifted up East Greenland

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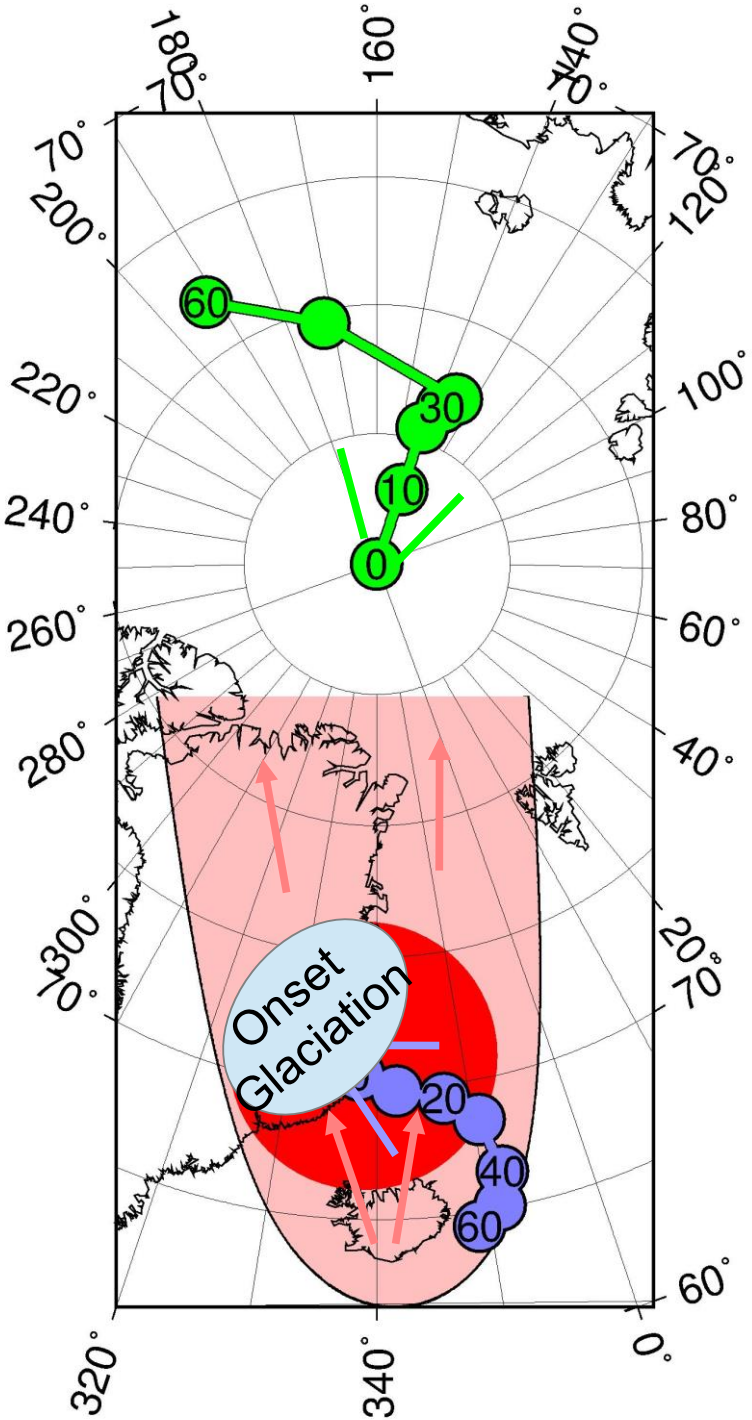

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