Characterising the Antarctic Ice Sheet
– through time and space –

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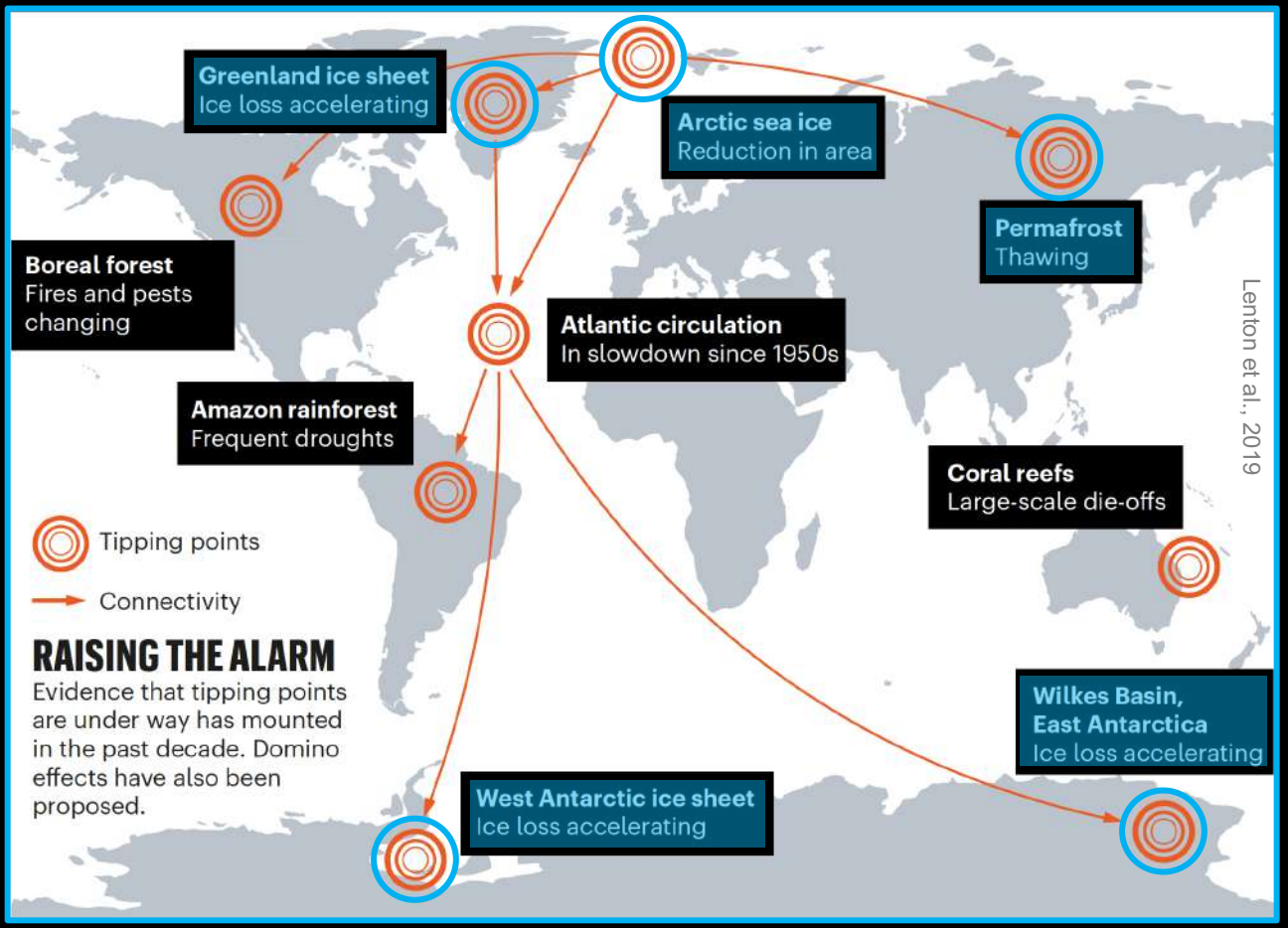
Germany

Why? Climate tipping points



How much is it to insure the climate system?

risk = probability x damage

emergency = risk x urgency

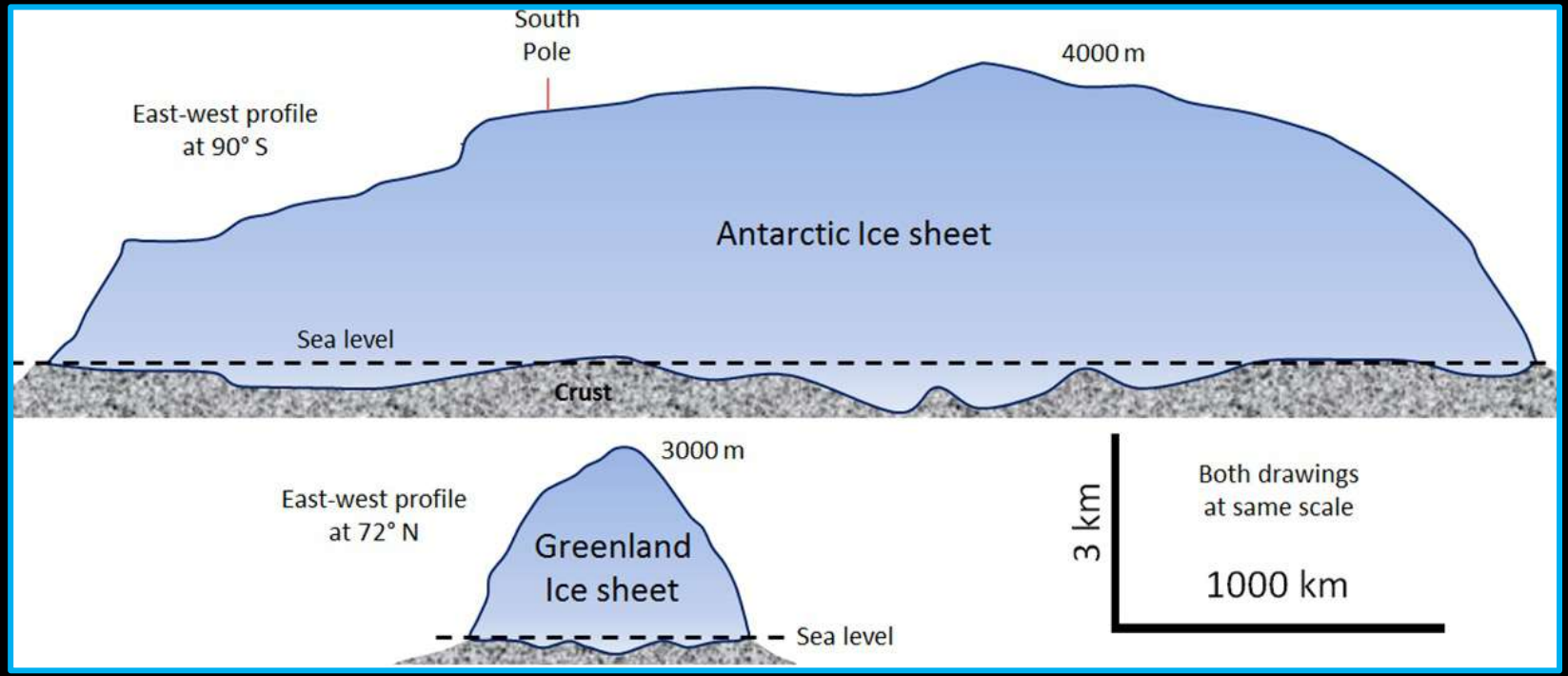
$$= \text{risk} \times \frac{\text{reaction time}}{\text{intervention time}}$$

$$E = R \times U = p \times D \times \tau / T$$

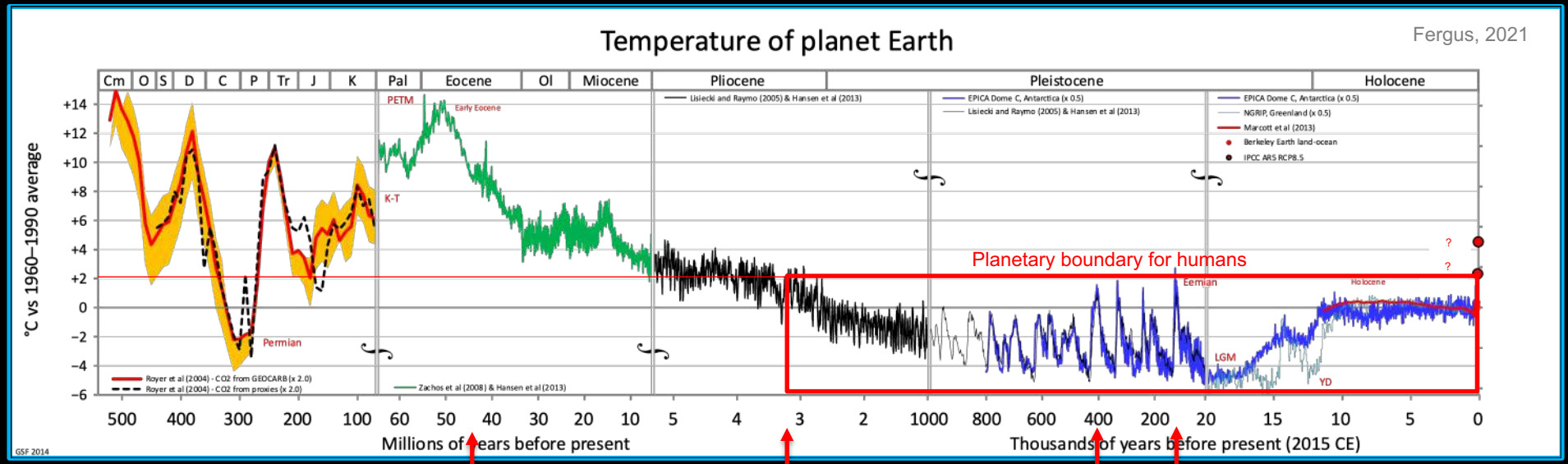
If reaction time is longer than the intervention time left ($\tau / T > 1$),

we have lost control.

Ice sheets


South
Pole
4000 m
East-west profile
at 90° S
Antarctic Ice sheet
Sea level
Crust
3000 m
East-west profile
at 72° N
Greenland
Ice sheet
Sea level
3 km
Both drawings
at same scale
1000 km

A brief history of Earth‘s climate



+70–76 m

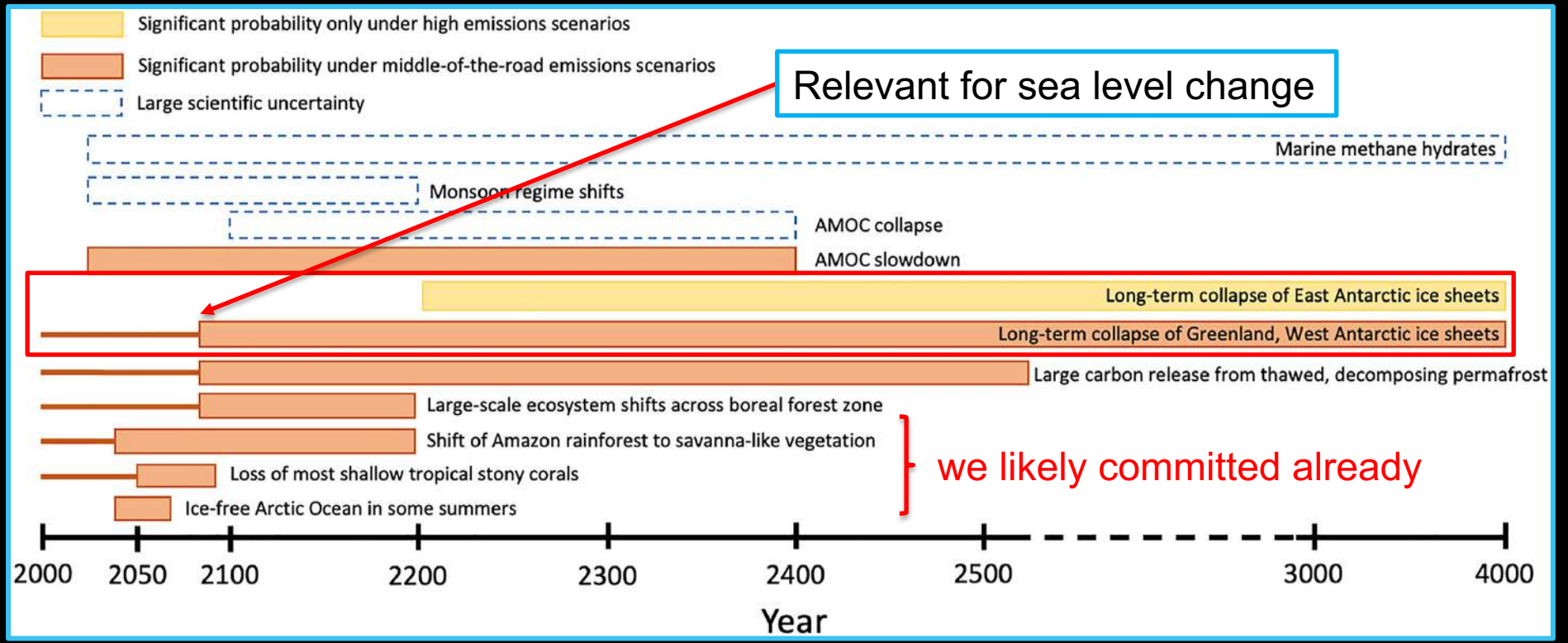
+5–25 m

+6–13 m

+5–10 m

Sea level from palaeo reconstructions w.r.t. 1900 (IPCC AR6)

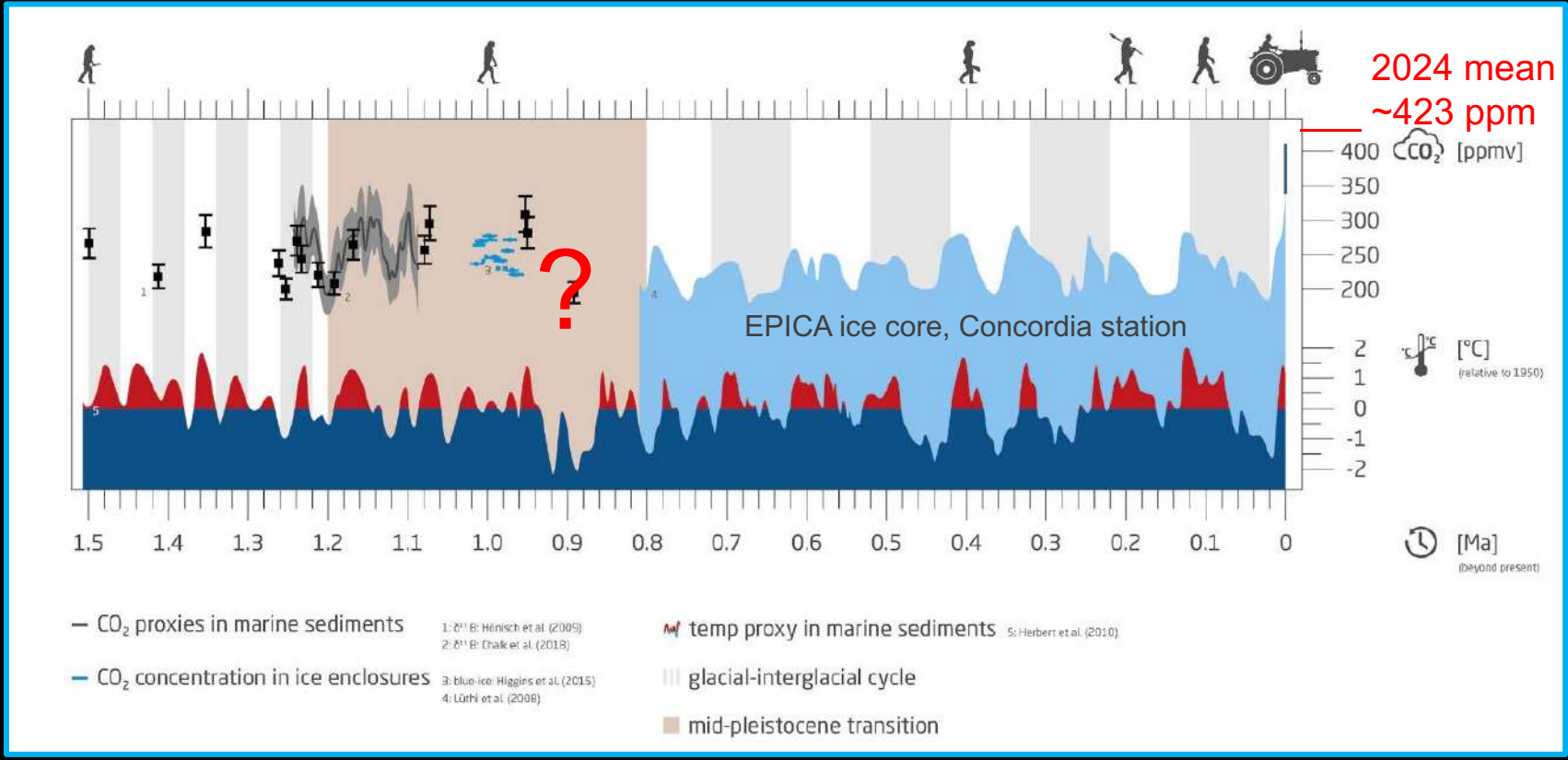
Why do we have to think long-term?



Want et al.,2023

Why are ice sheets important?

Unique paleo-climate archive



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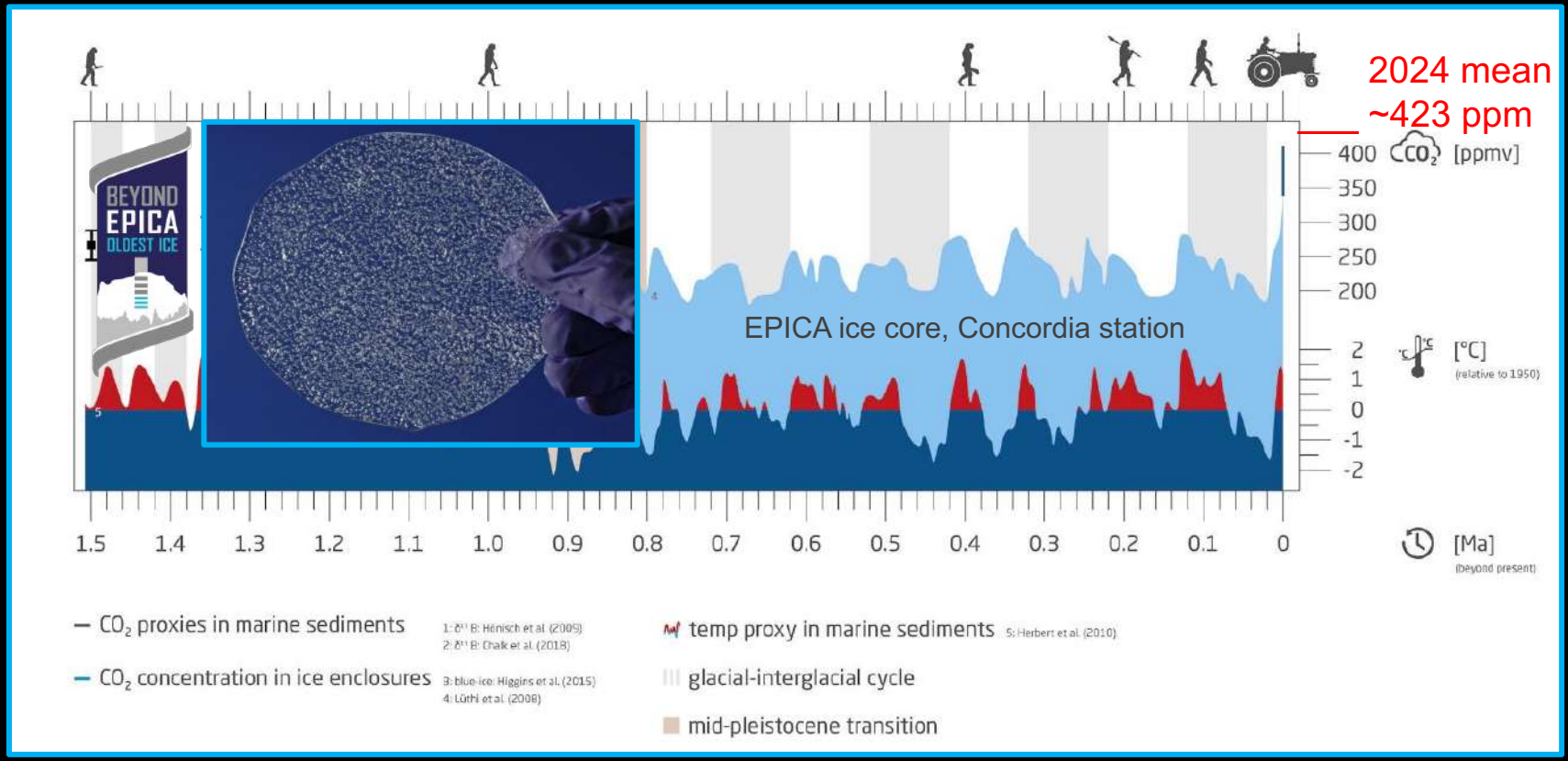

Why are ice sheets important?

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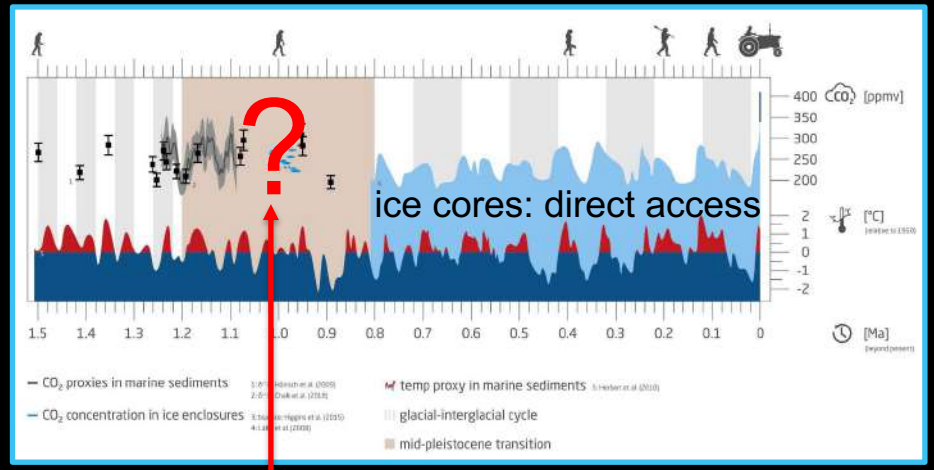
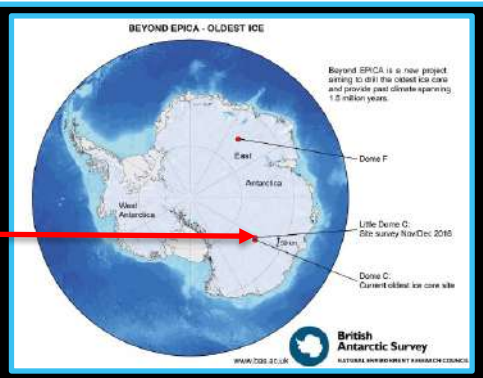
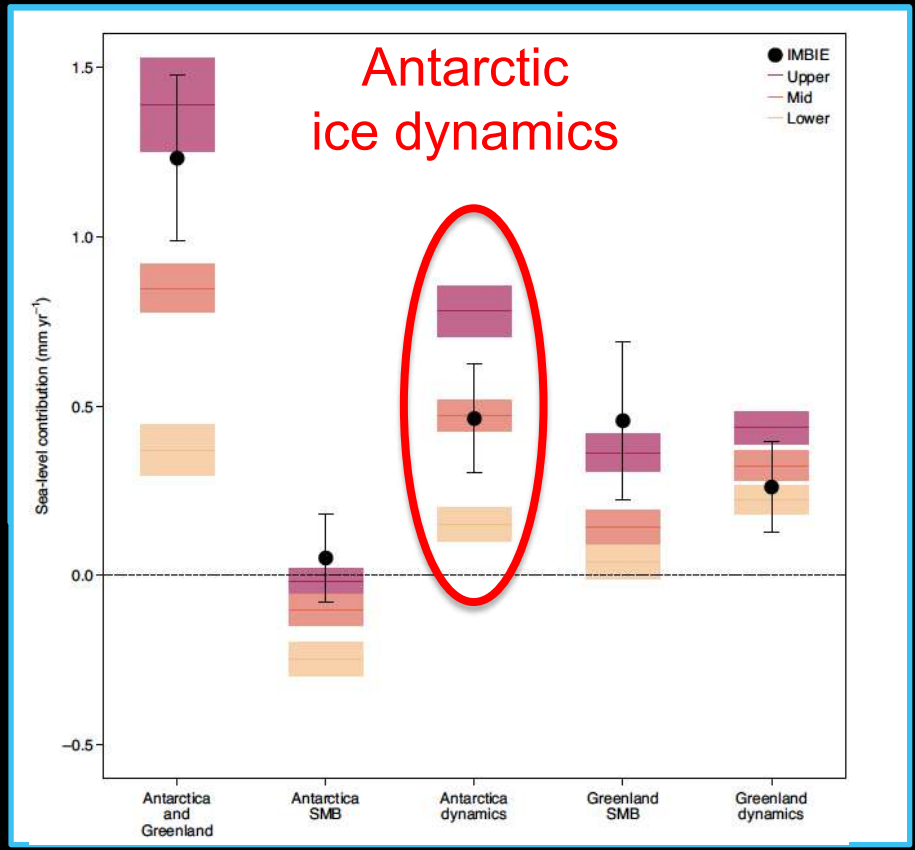




Beyond EPICA, 2019

2. Sea level change



Slater et al., NCC, 2020

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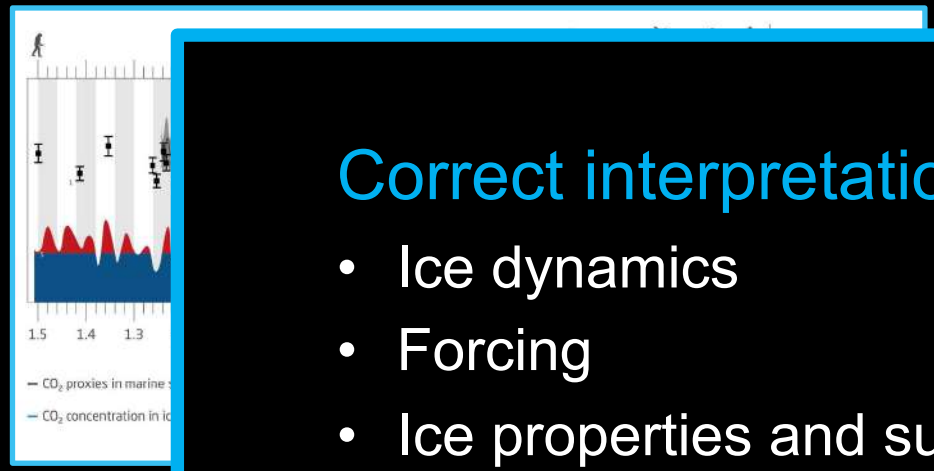
2. Sea level change

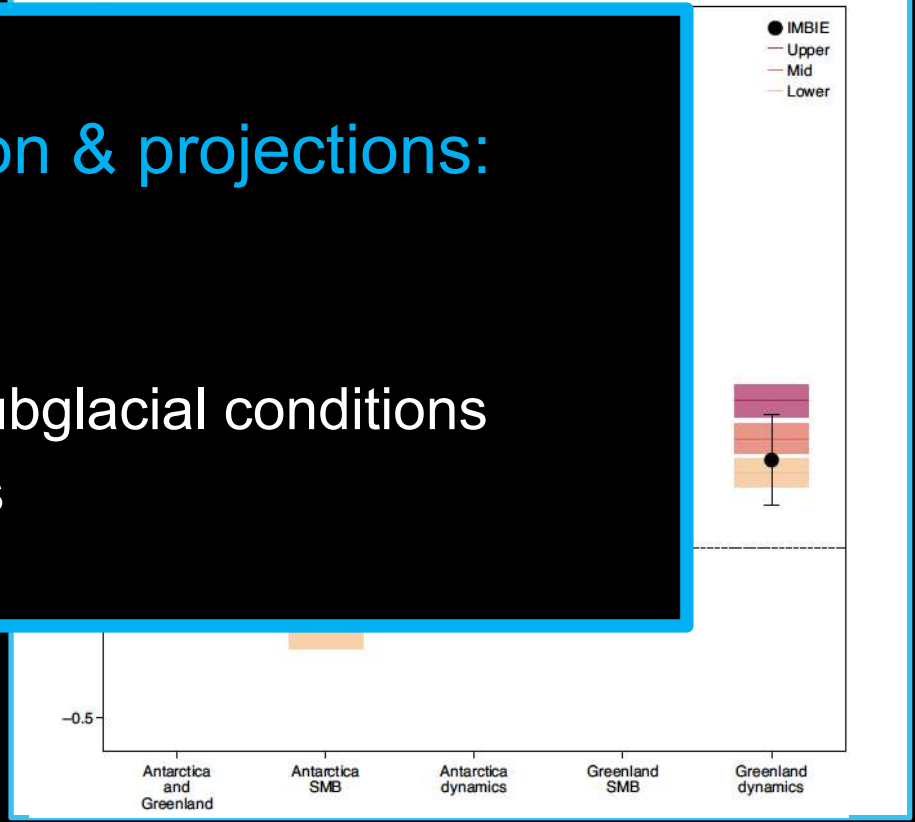


Correct interpretation & projections:

- Ice dynamics
- Forcing
- Ice properties and subglacial conditions

⟶ on-site observations

Beyond EPICA, 2019



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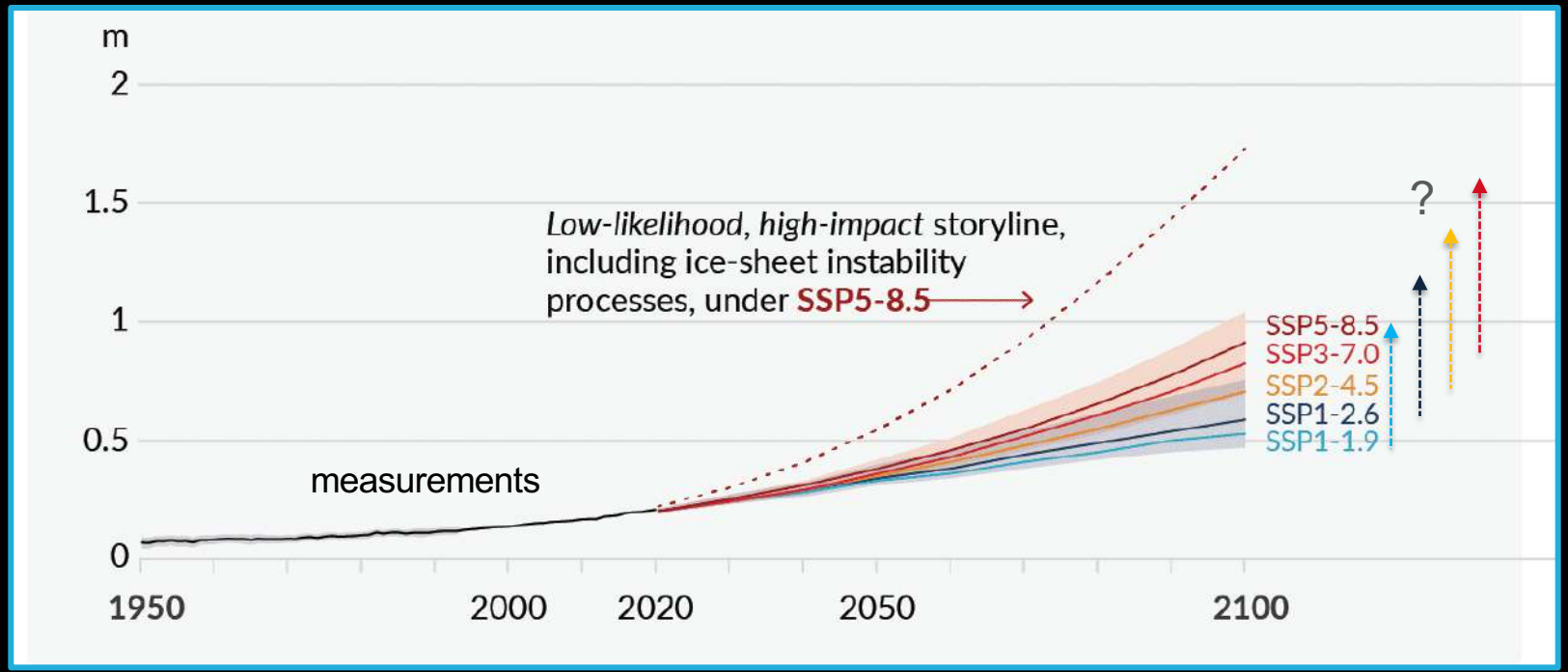
Why are ice sheets important?

Sea level change

(relative to 1900)



IPCC, AR6, 2021

Single events – compound effects

low likelihood

Quelle: RND, DPA (Vaggelis Kousioras), RND

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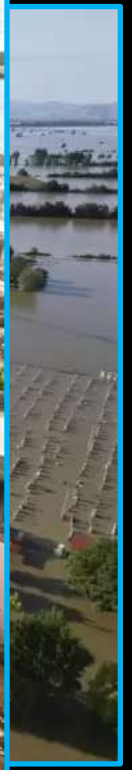
low likelihood



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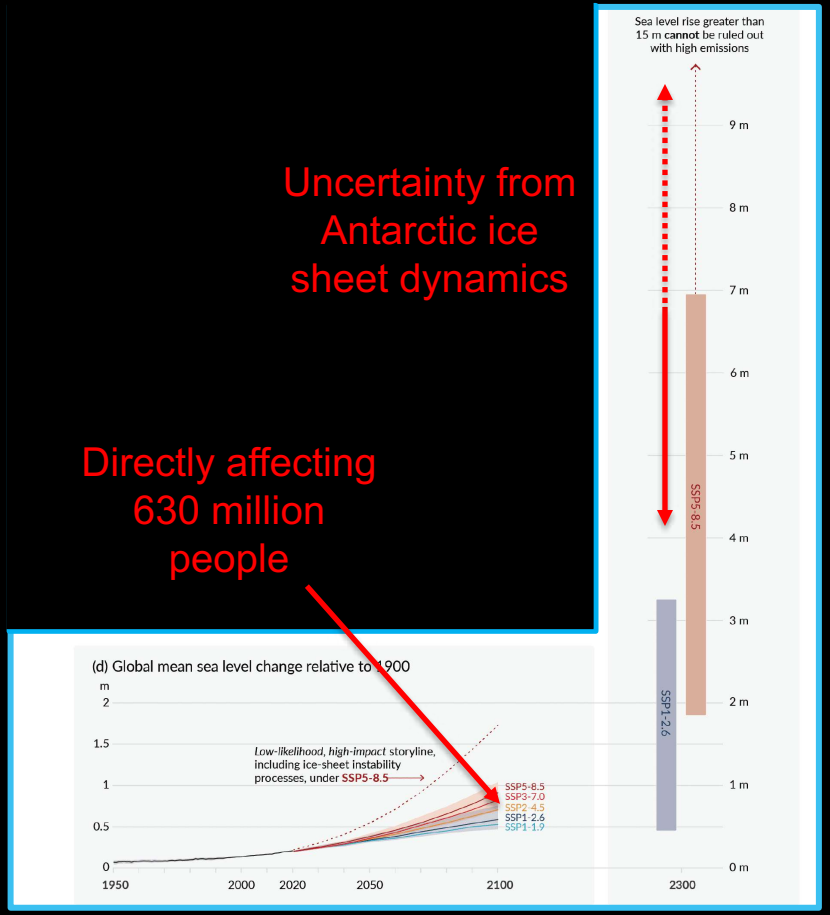
Why are ice sheets important?

Sea level change

(relative to 1900)

Uncertainty from Antarctic ice sheet dynamics

Directly affecting 630 million people



IPCC, AR6, 2021

How to characterise an ice sheet

When?

past

present

future

What?

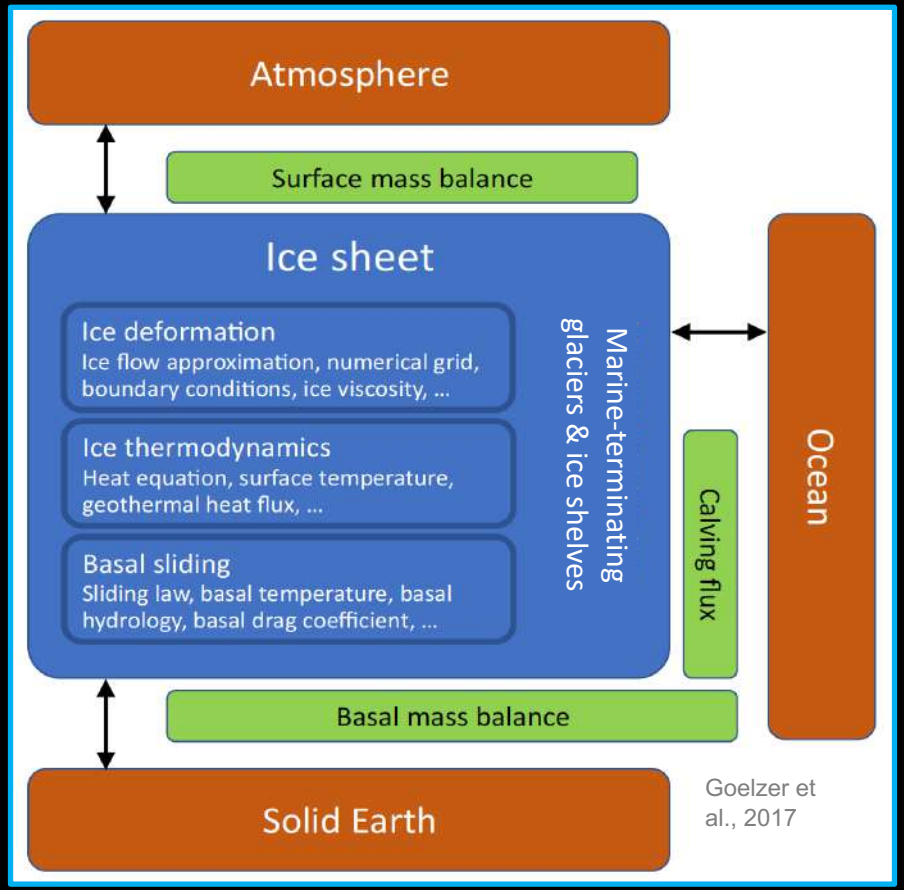
reconstructions

observations

projections

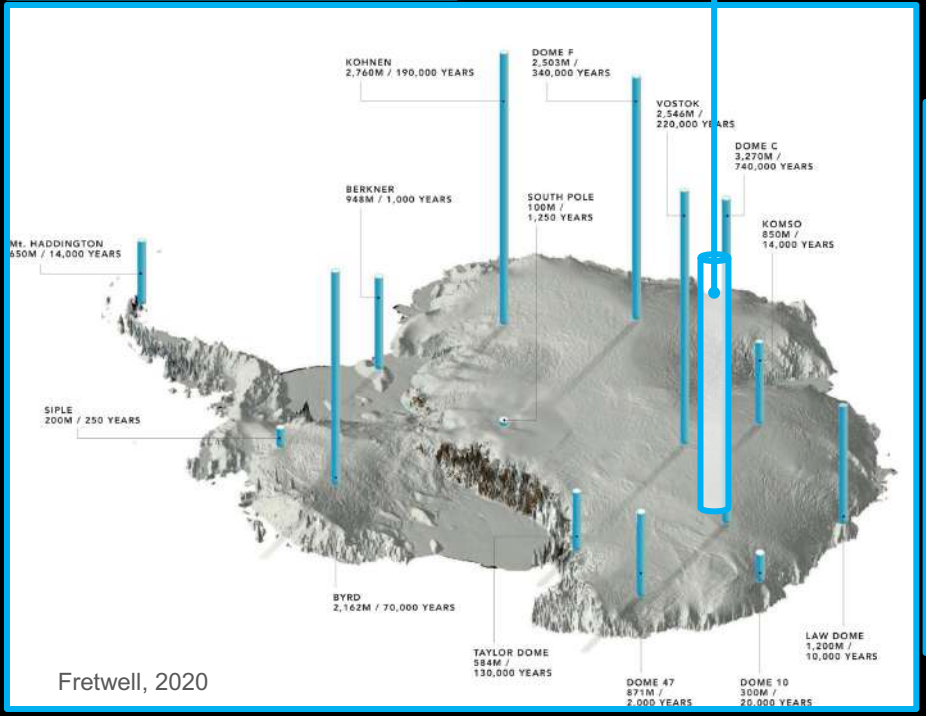
How?

ice cores
in-situ measurements
remote sensing
modelling
…



Beyond EPICA, Little Dome C, Antarctica

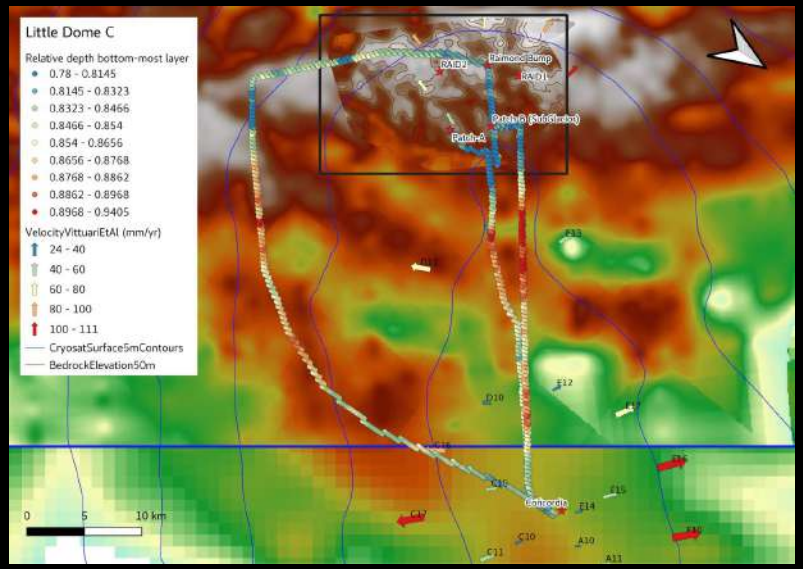
Elevation: 3233 m
Ice thickness: 2764 m
Age: >1,200,000 years

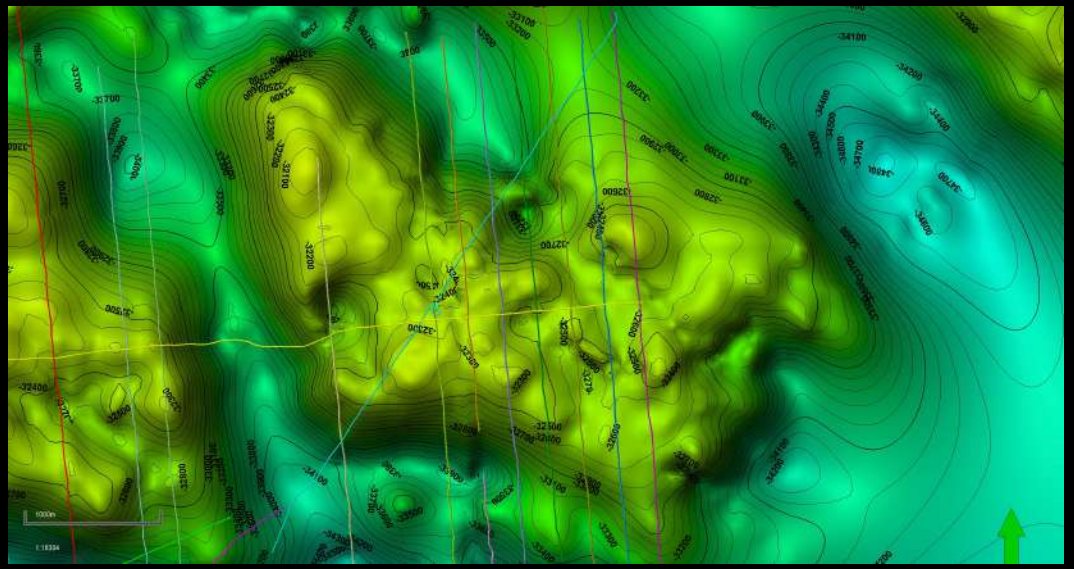


Fretwell, 2020

Pre-site survey: 2017 – 2020
Ice-core drilling: 2021 – 2025
Scientific analysis: 2026 – 2030
Working conditions: Nov. – Jan.
(–50 to –35 °C)

Beyond EPICA – best reconnaissance

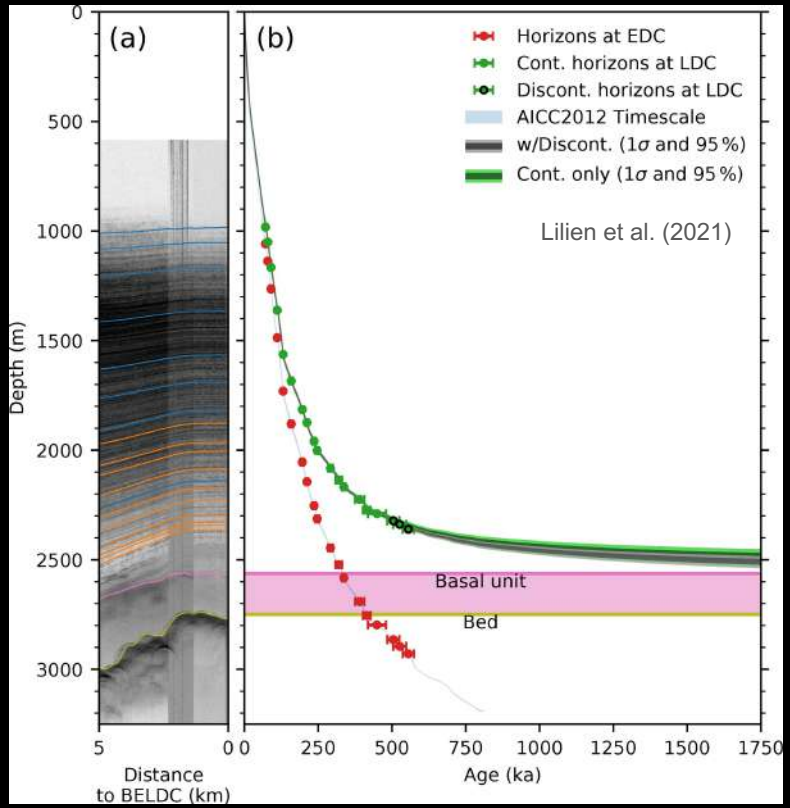




- Staggered airborne radar surveys (thickness, layering)
- Ground-based surveys (repeat for vertical displacement & horizontal velocity with pRES & GNSS, radar polarimetry for fabric)
- Rapid Access Ice Drilling (quick sampling)
- Modelling

News on ice dynamics: fabric & basal unit

- Lower part (250 m) of ice sheet does not participate in dynamics
- Orientation of crystals different for glacials & interglacials



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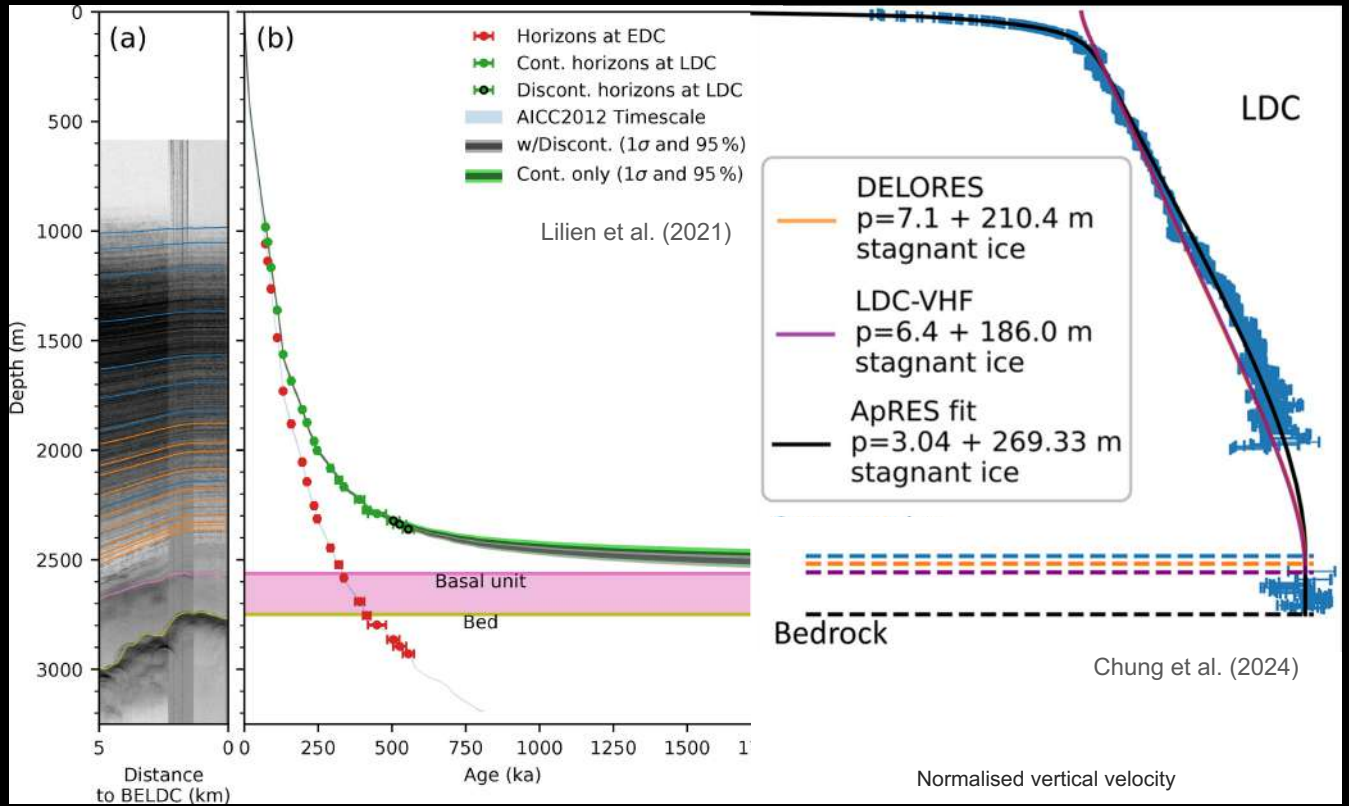

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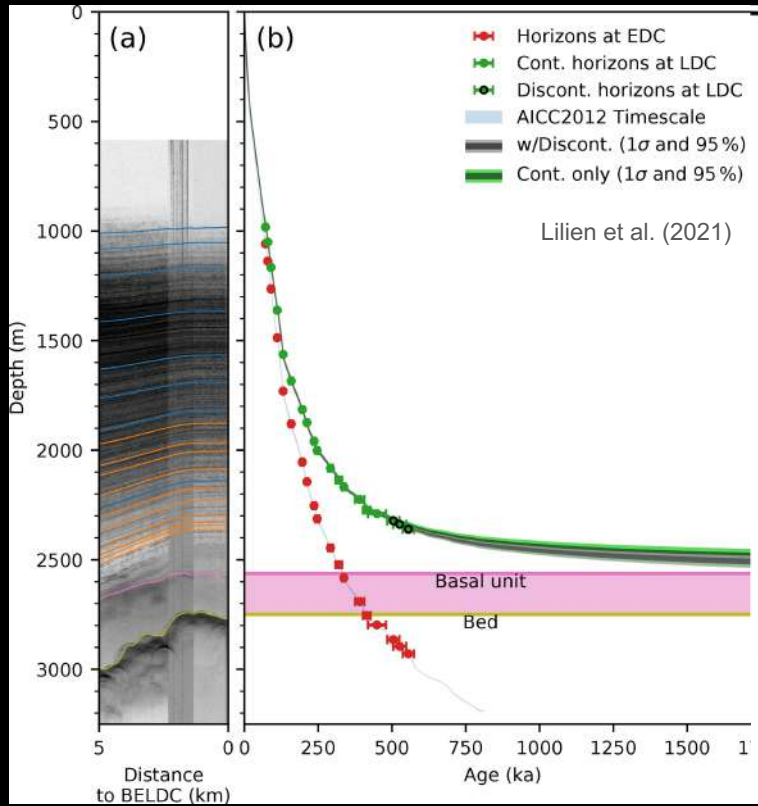
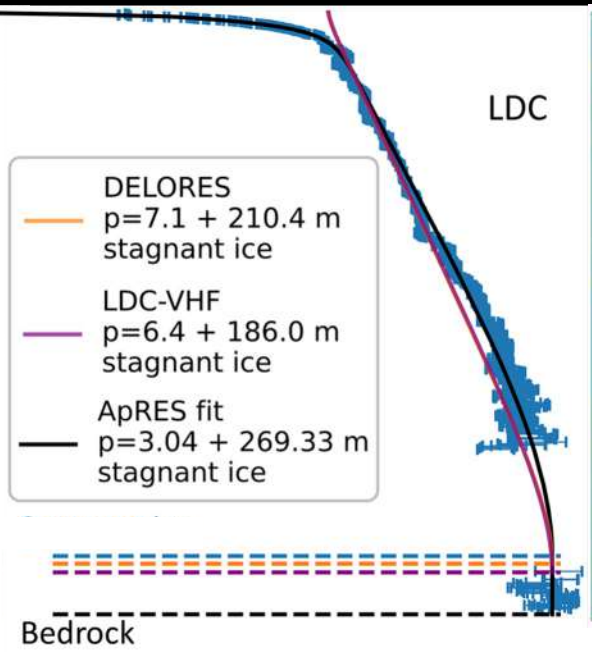
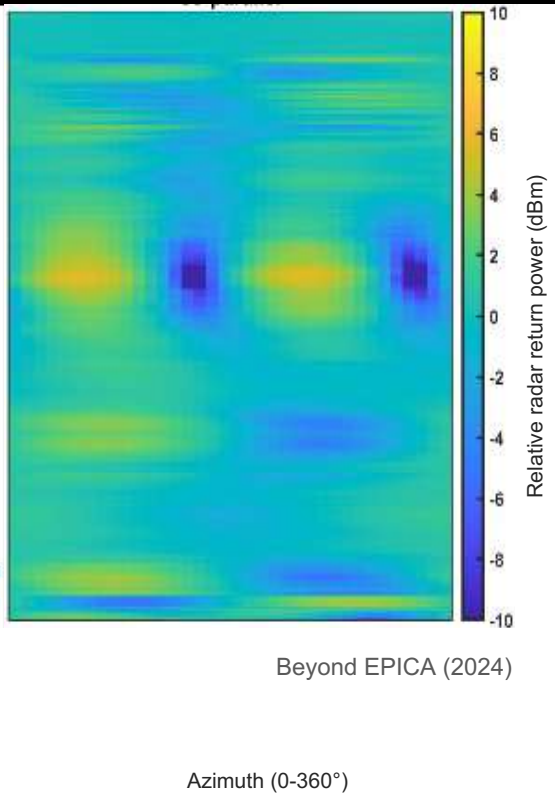


Lilien et al. (2021)

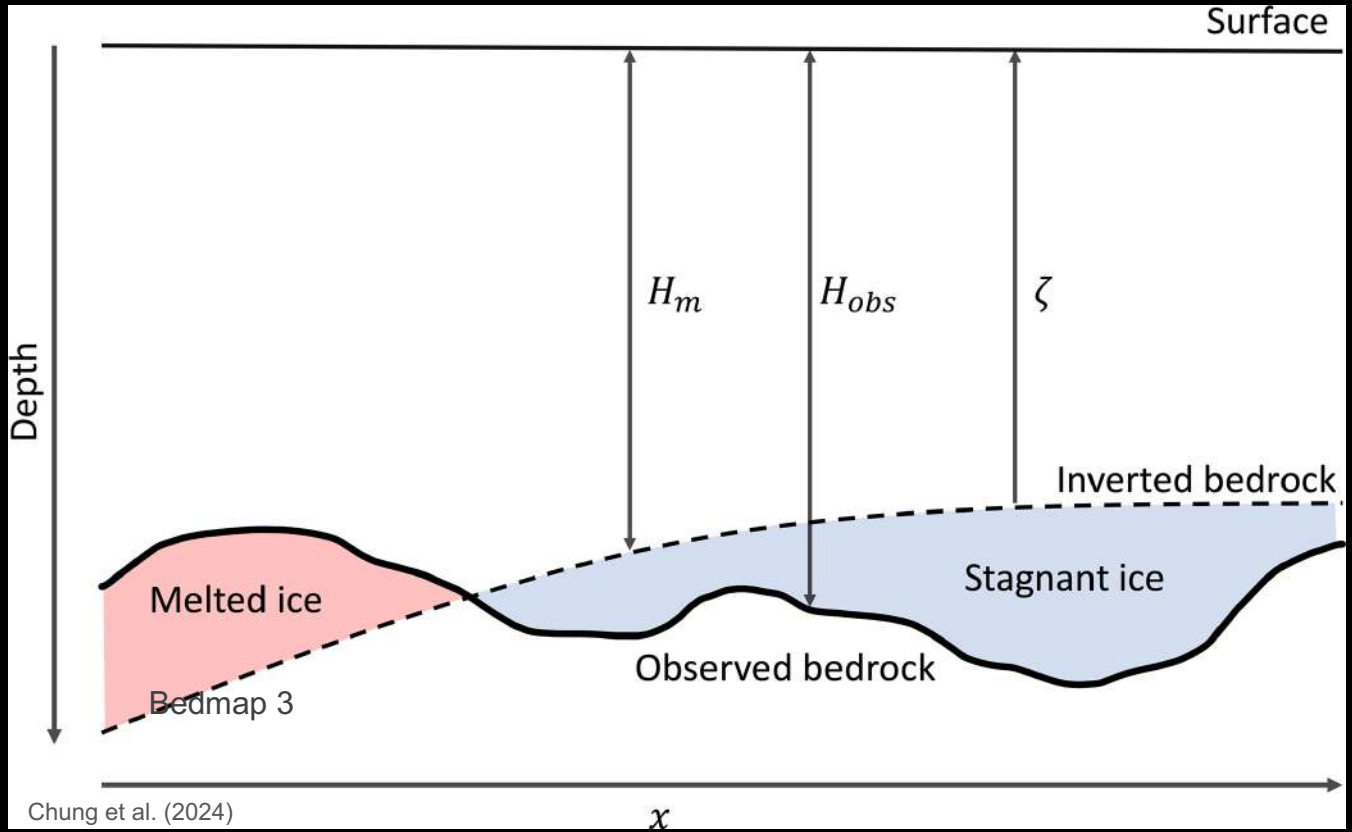


Chung et al. (2024)



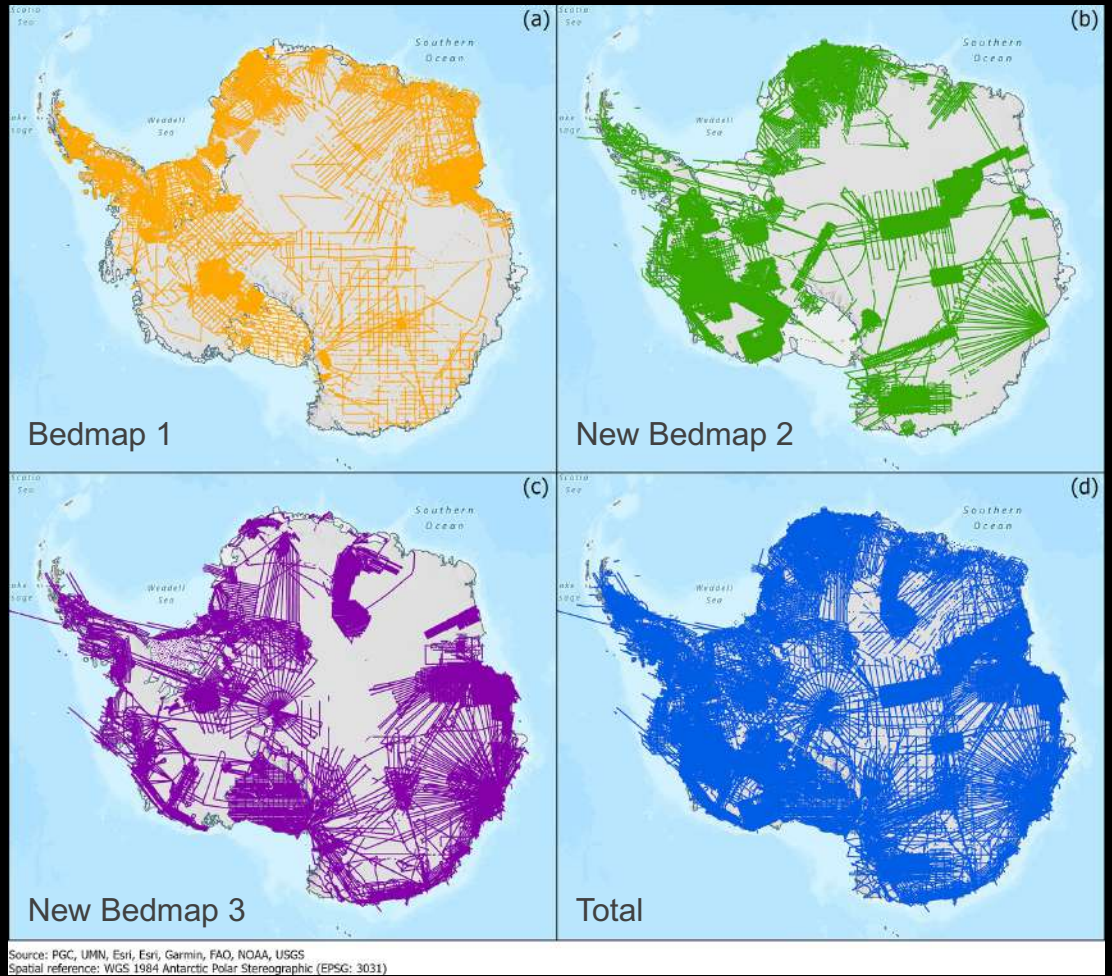
Beyond EPICA (2024)

What does it look like elsewhere? And does it matter?



Chung et al. (2024)

As good as it gets … SCAR Bedmap3



Frémand et al. (2023)

What does it look like elsewhere?

Remote observations?

✓ Airborne & ground-based radar

(regionally low, locally high resolution)

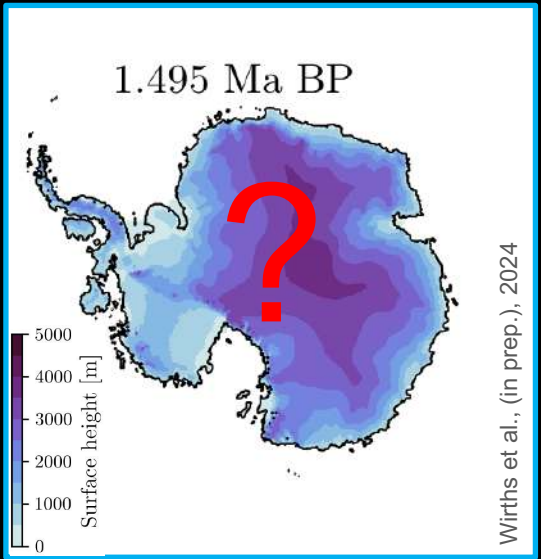
Full continental coverage high resolution?

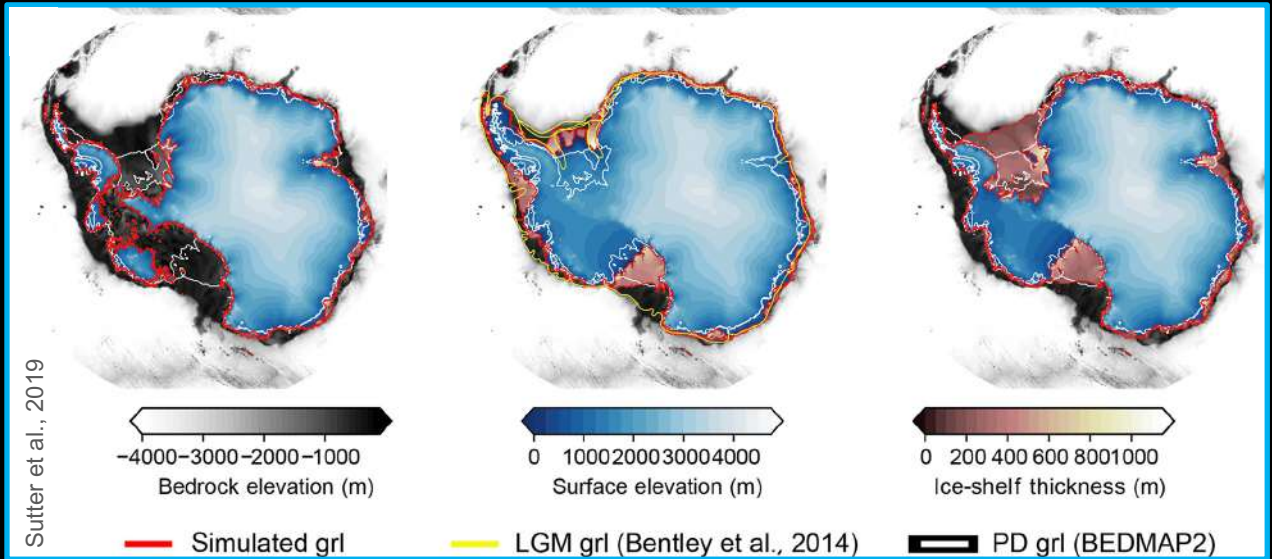
✗ Satellite observations for ice thickness & stratification: still missing

(concepts developed repeatedly since 2004, but not implemented)

Needed: from LIG to pre-MPT
– at high quality & resolution –

1.5 Ma BP | 120 ka BP | 20 ka BP | today





CO_2 vs SH ice sheet/sea ice
Reliable Earth system forcing needed!

Some open questions:

Large-scale ice dynamics: stratigraphy

- How widespread are basal units in Antarctica? Are they important for SLR?

Large-scale ice dynamics: fabric

- How does that change ice flow dynamics and large-scale behaviour (MISI)?

Modelling

- How well do models fit to observations (ice core, paleosurface, stratigraphy)?
- All relevant processes incorporated in models? Boundary conditions? Drivers?

Observations: ice-sheet scale needed!

- Can we map thickness & internal stratigraphy of ice sheets from space?

Open questions:

Larges-scale ice dynamics: basal unit

- How widespread are basal units in Antarctica?
- How important are they for ice dynamics, especially w.r.t. SLR?
- They have so far been ignored, what does that mean for recent large-scale behaviour?
- What are basal units made of? Refrozen ice? Old, stagnant ice?
- Do they contain paleoclimate records, which could be dated?

Fabric

- Why does fabric change between glacial and interglacial units?
- How does that change ice flow dynamics?
- Does this need to be considered for modelling ice-sheet dynamics over time?

Modelling

- How well do models fit to the ice-core based age of the ice?
- Are all relevant processes incorporated in models?
- How important are external drivers compared to model performance, are they sufficiently considered?

Beyond EPICA – Oldest Ice