

Meltdown – Evidence of Climate Change from Polar Science

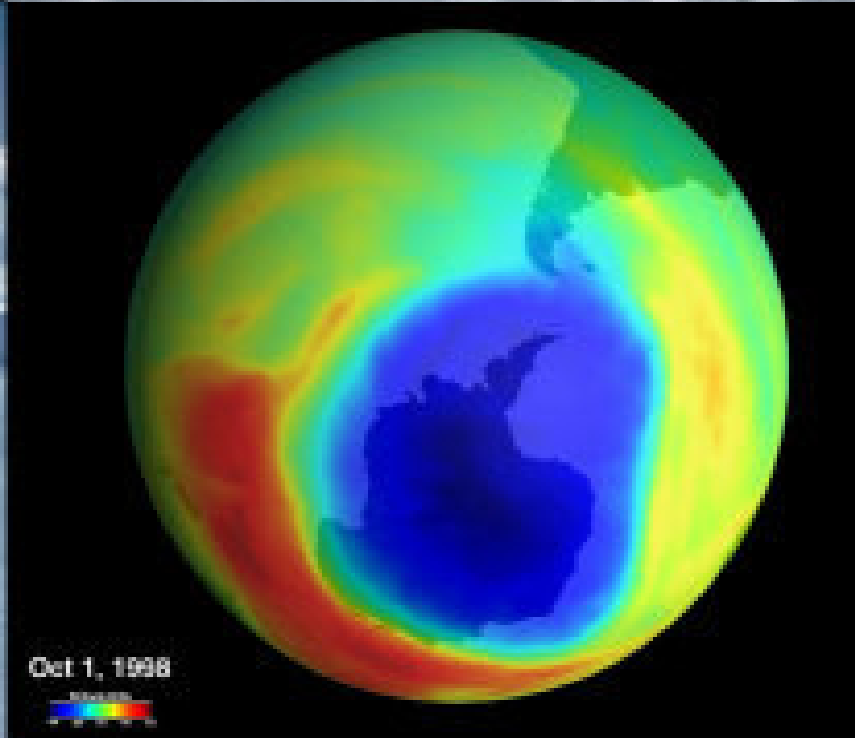
Eric Wolff

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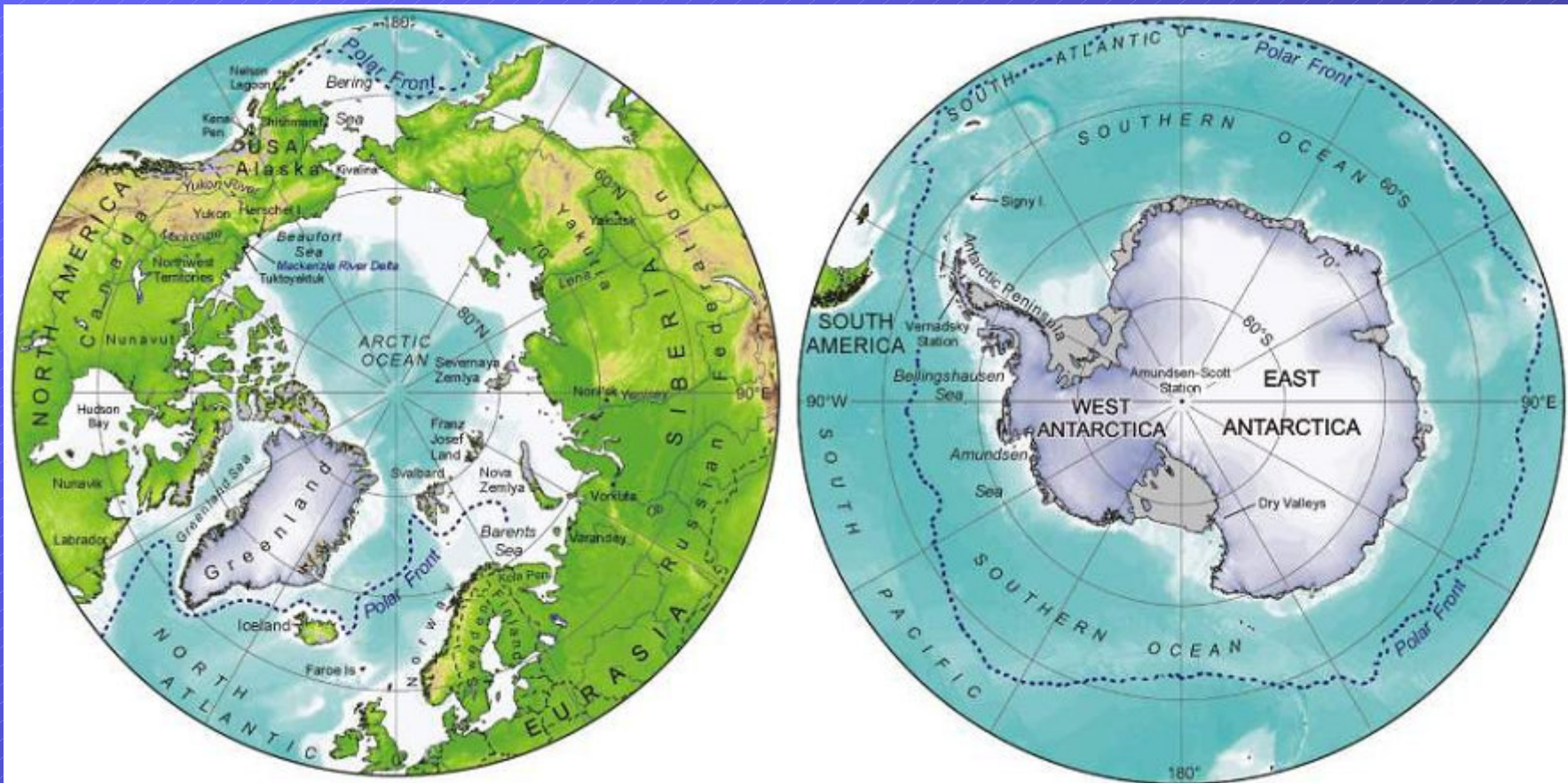


**British
Antarctic Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

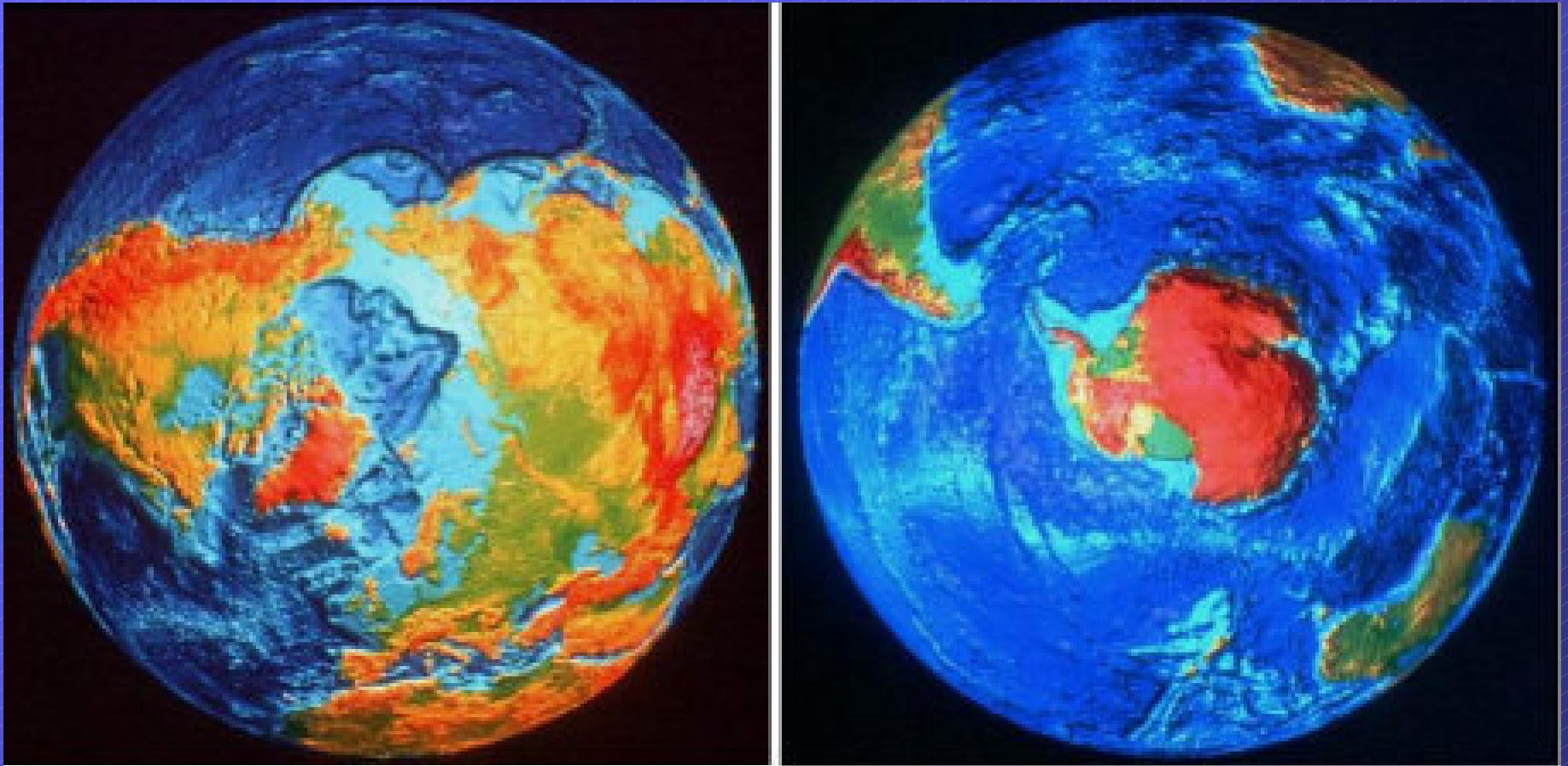


Why are the polar regions important for climate?



Heat engine

Why are the polar regions important for climate?



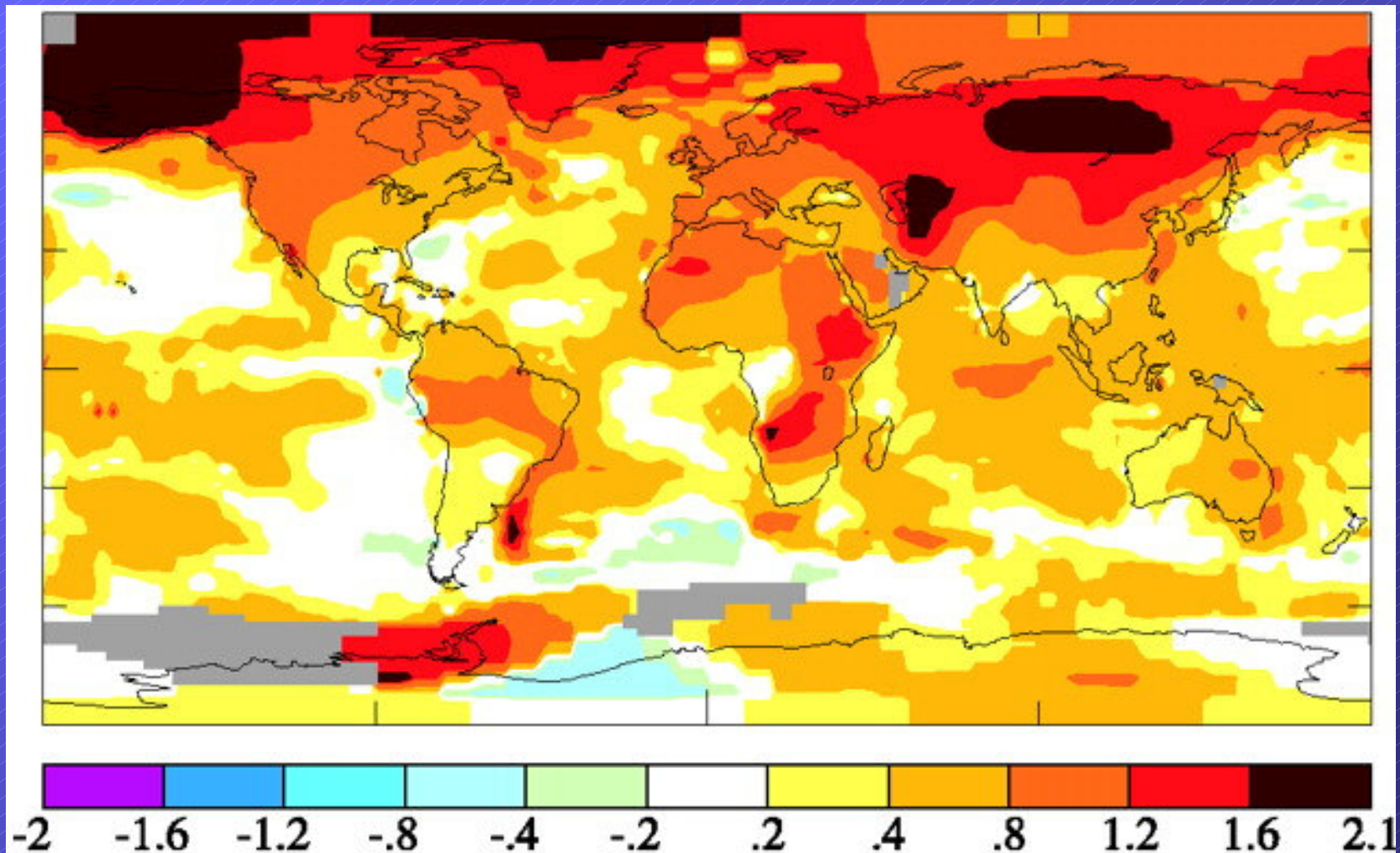
Heat engine

The colour of the Earth

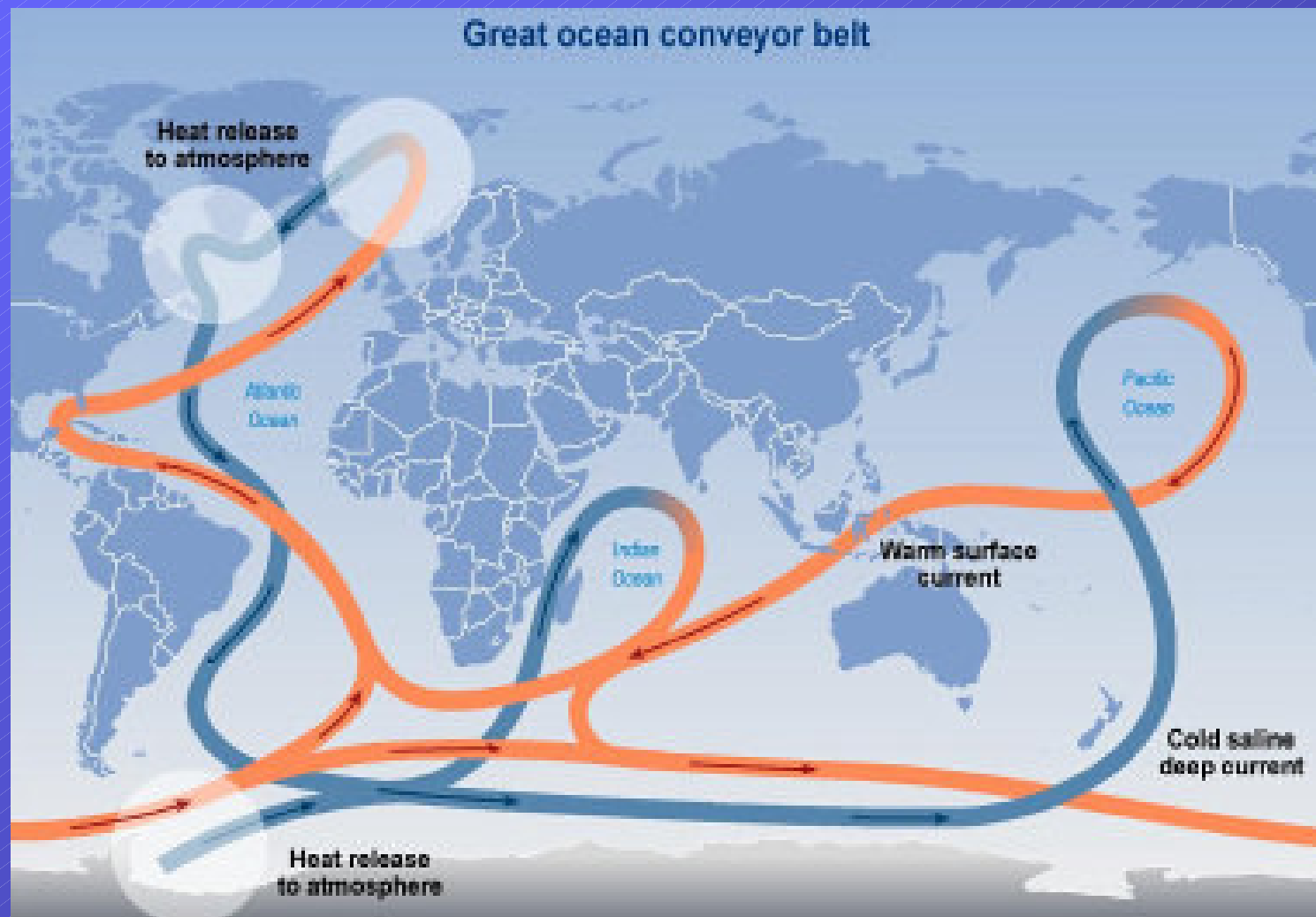


Polar amplification

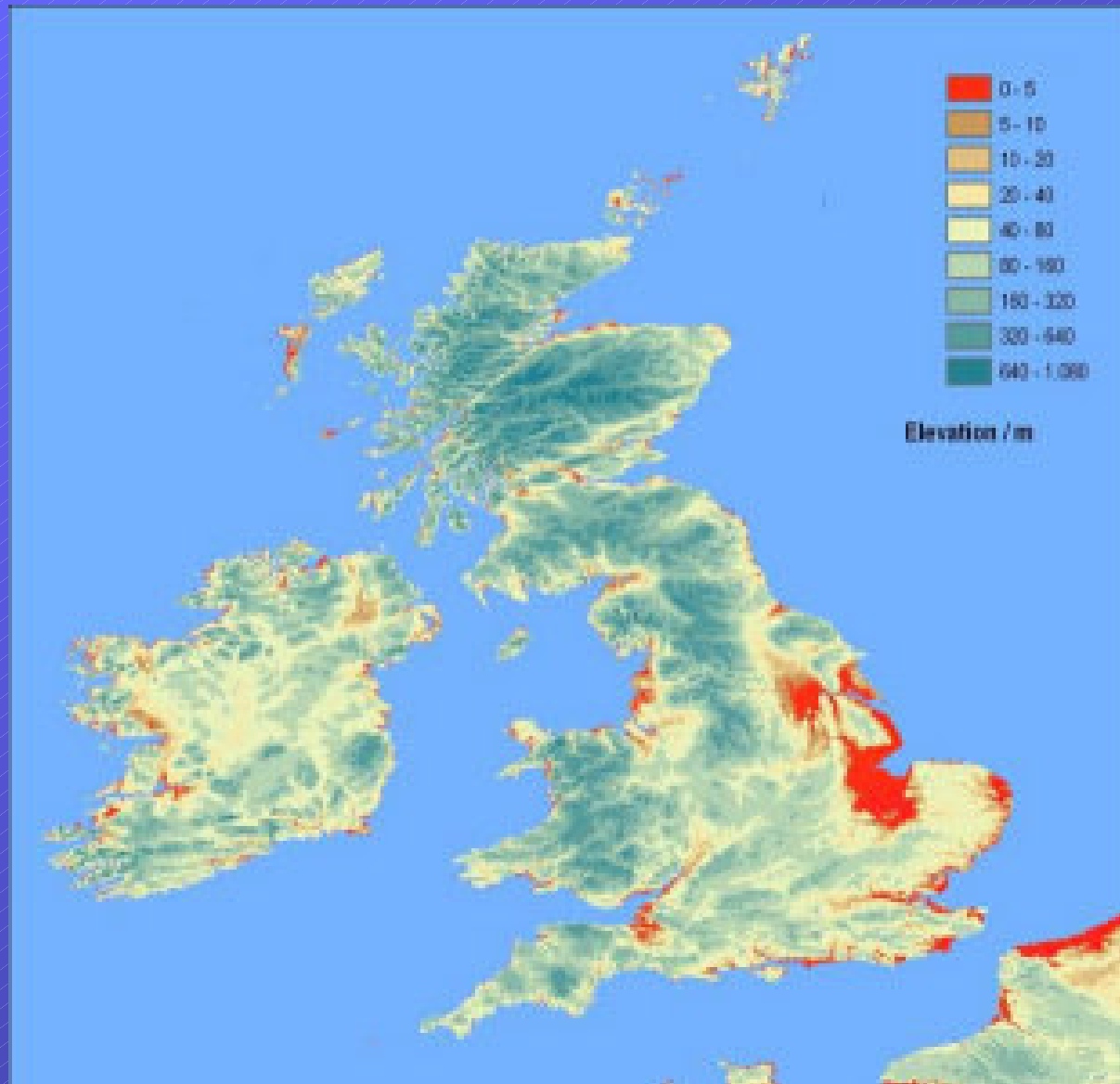
Temperature (°C) 2000-2005 relative to 1951-1980 (Hansen et al., 2006)



Ocean heat transport



Sea level





Past climate
from ice cores

Part I: Learning from the past – ice cores

Part II: Climate change in the polar regions



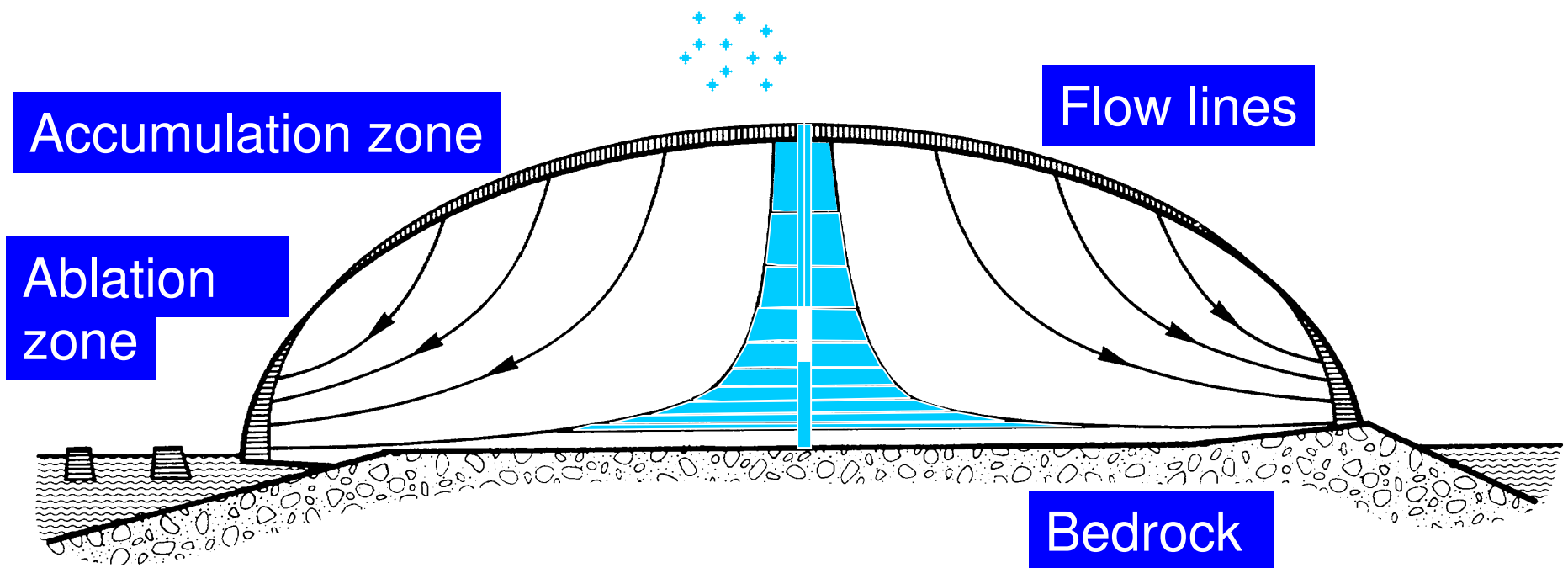
If we use the past to understand the processes, then we can hope to have correct models to predict the future

The ice core record

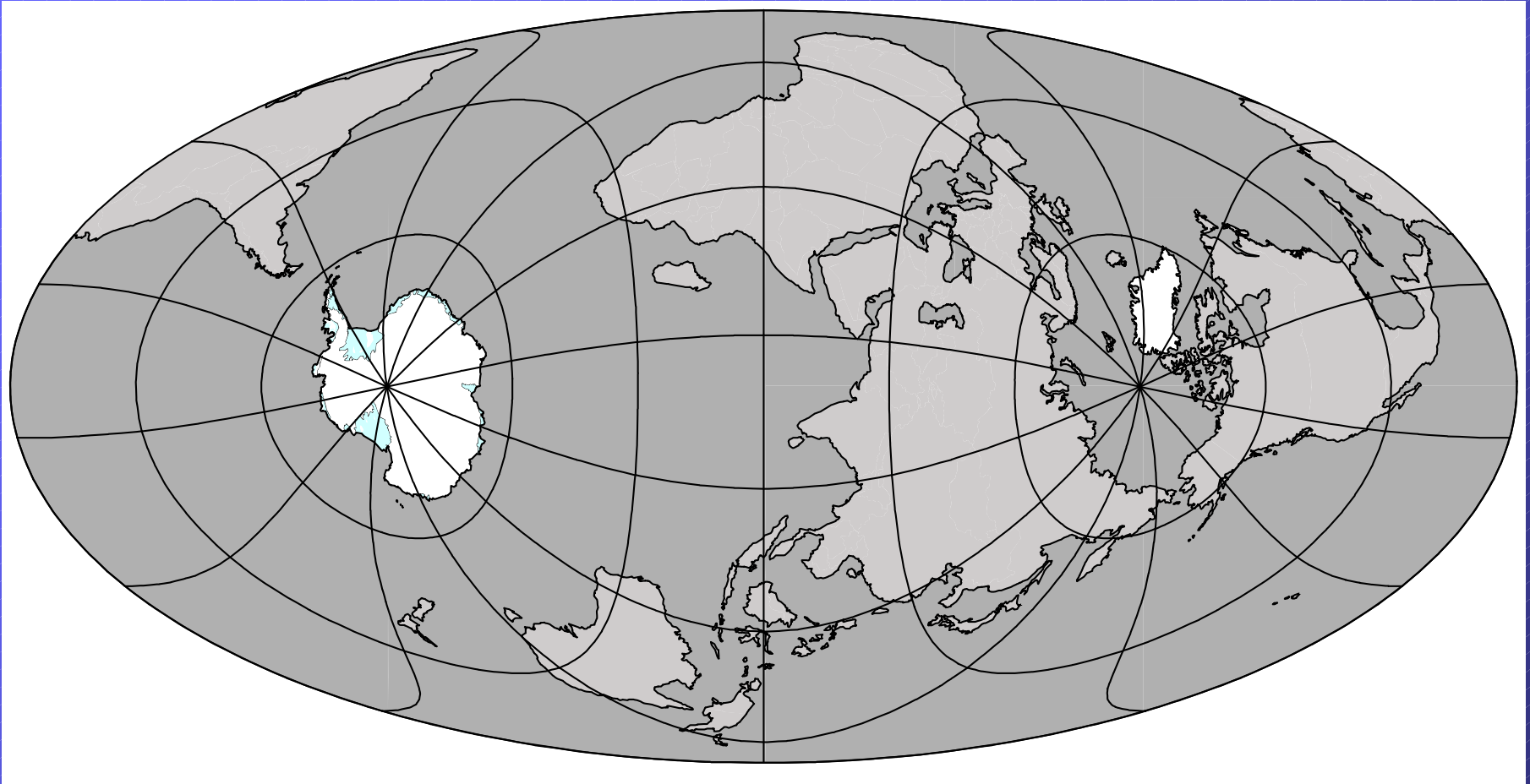
One of many sedimentary records

Very good at recording the atmosphere

800,000 years (Antarctic) and 123,000 years (Greenland)



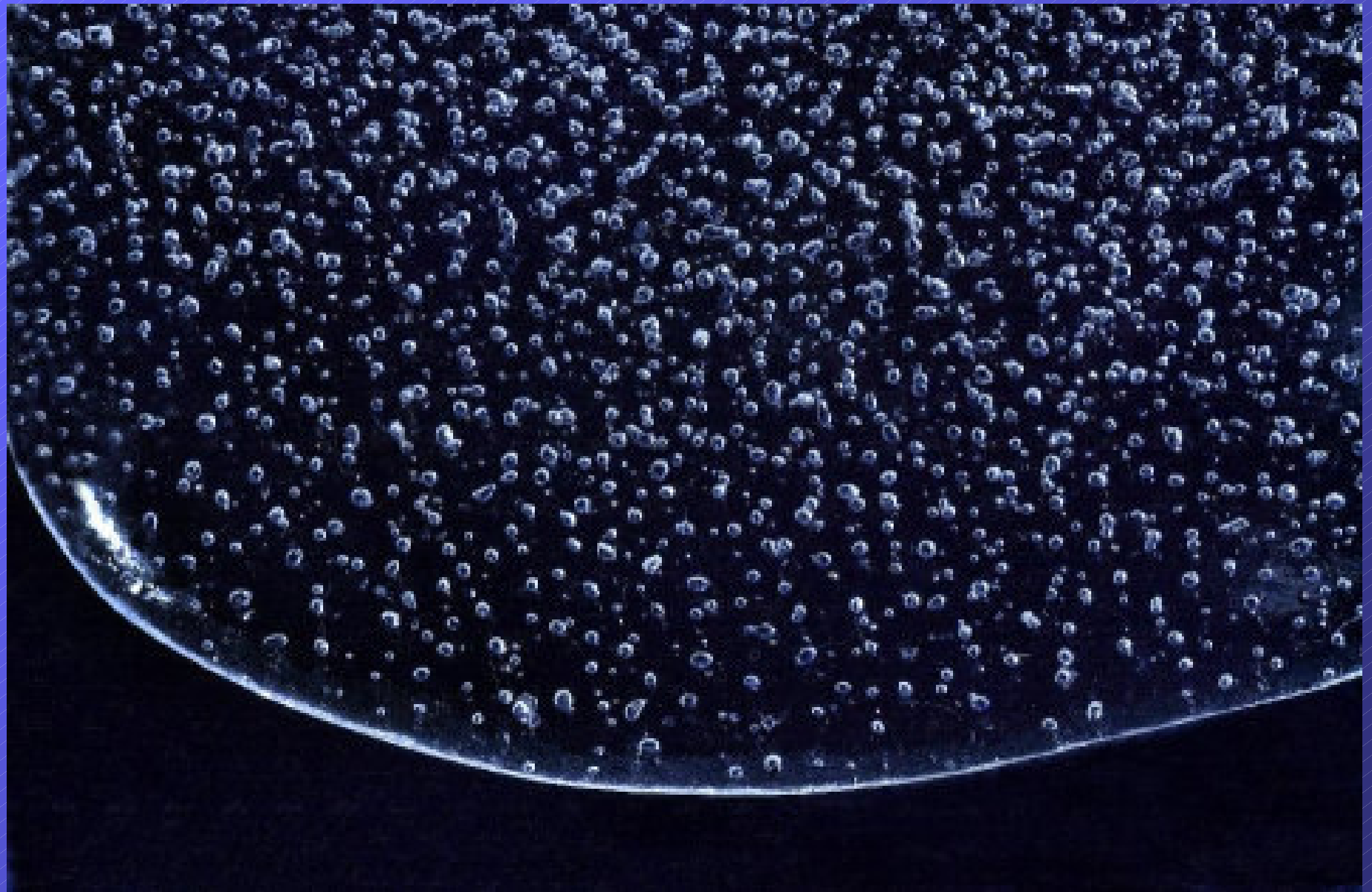
Main drawback: geographical restriction



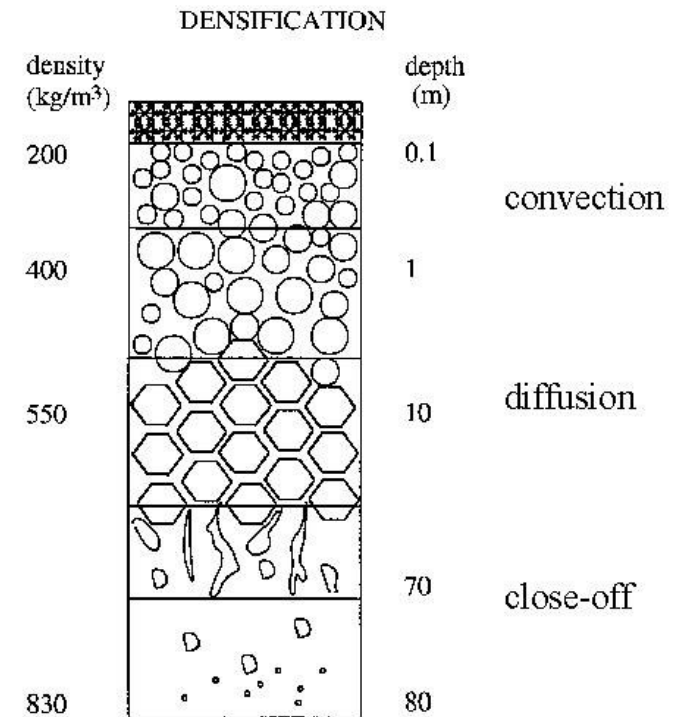
Requirements: Permanent ice cover, no significant melting, positive snow accumulation
⇒ Polar regions, high altitude mountain glaciers

Signals in ice cores

- Temperature and amount of snowfall imprinted in the snow itself
- Many chemicals deposited with the snow, recording e.g. volcanic eruptions, sea salt, atmospheric dust,...
- Oxygen, nitrogen, CO₂,....(all the stable molecules in the air) trapped in bubbles



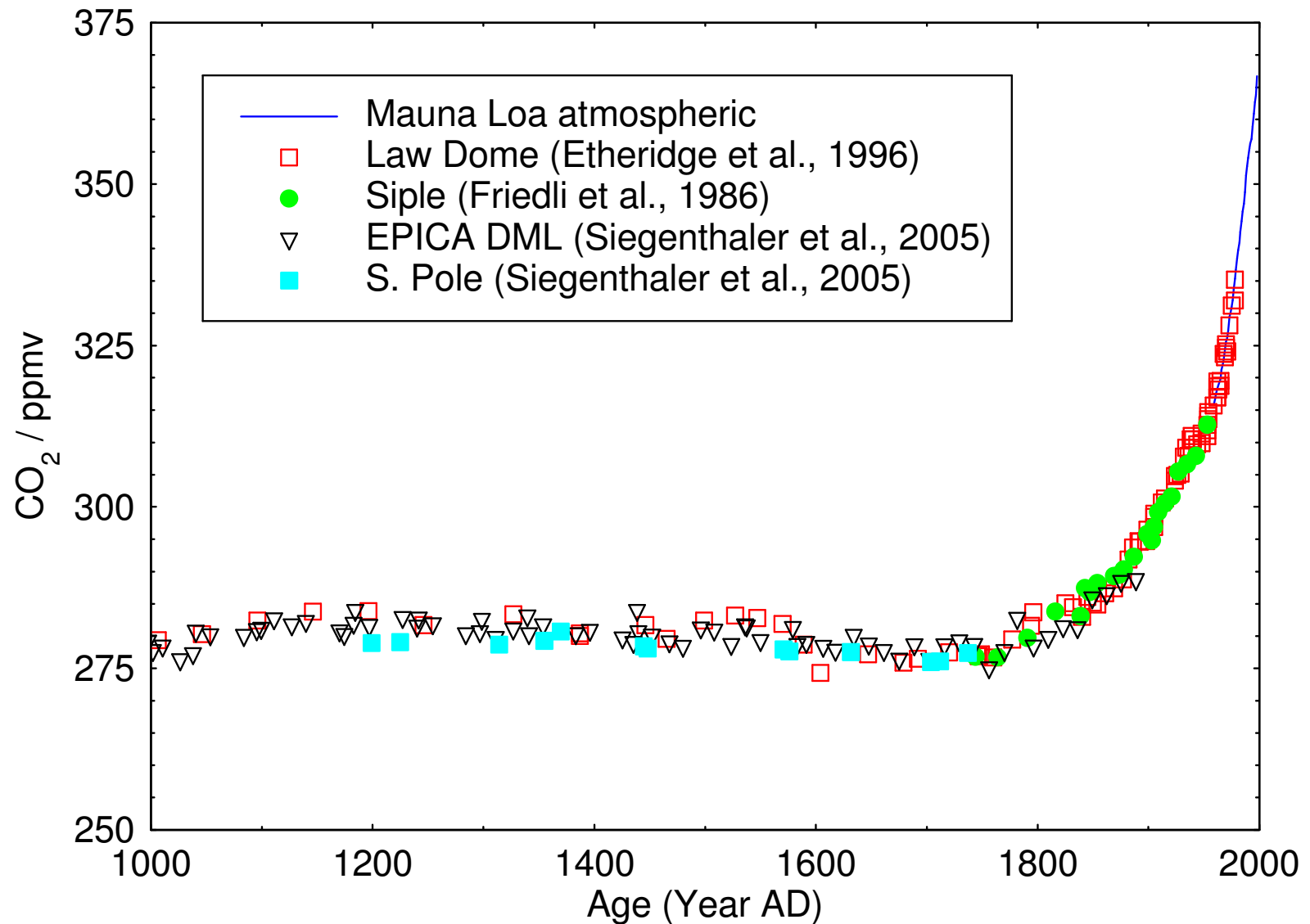
3. As the snow gets deeper, pressure turns loose snow into solid ice with trapped air bubbles. The bubbles contain a sample of stable gases from the atmosphere: e.g CO₂



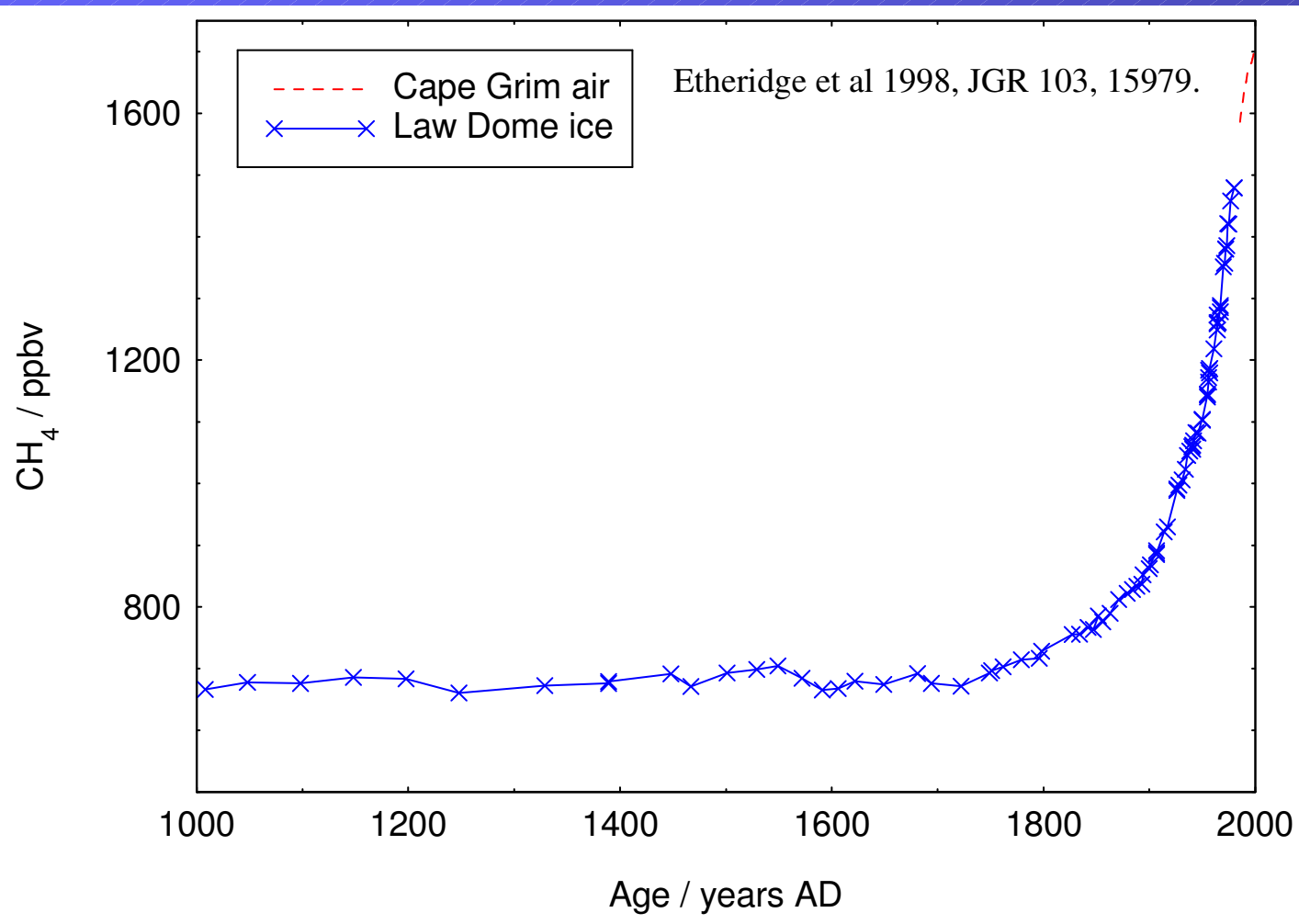
The basic argument of greenhouse warming

- The concentration of major greenhouse gases has increased significantly due to human activities
- Physics tells us that increasing the concentrations of greenhouse gases traps heat and causes climate on average to warm

Recent past – CO₂



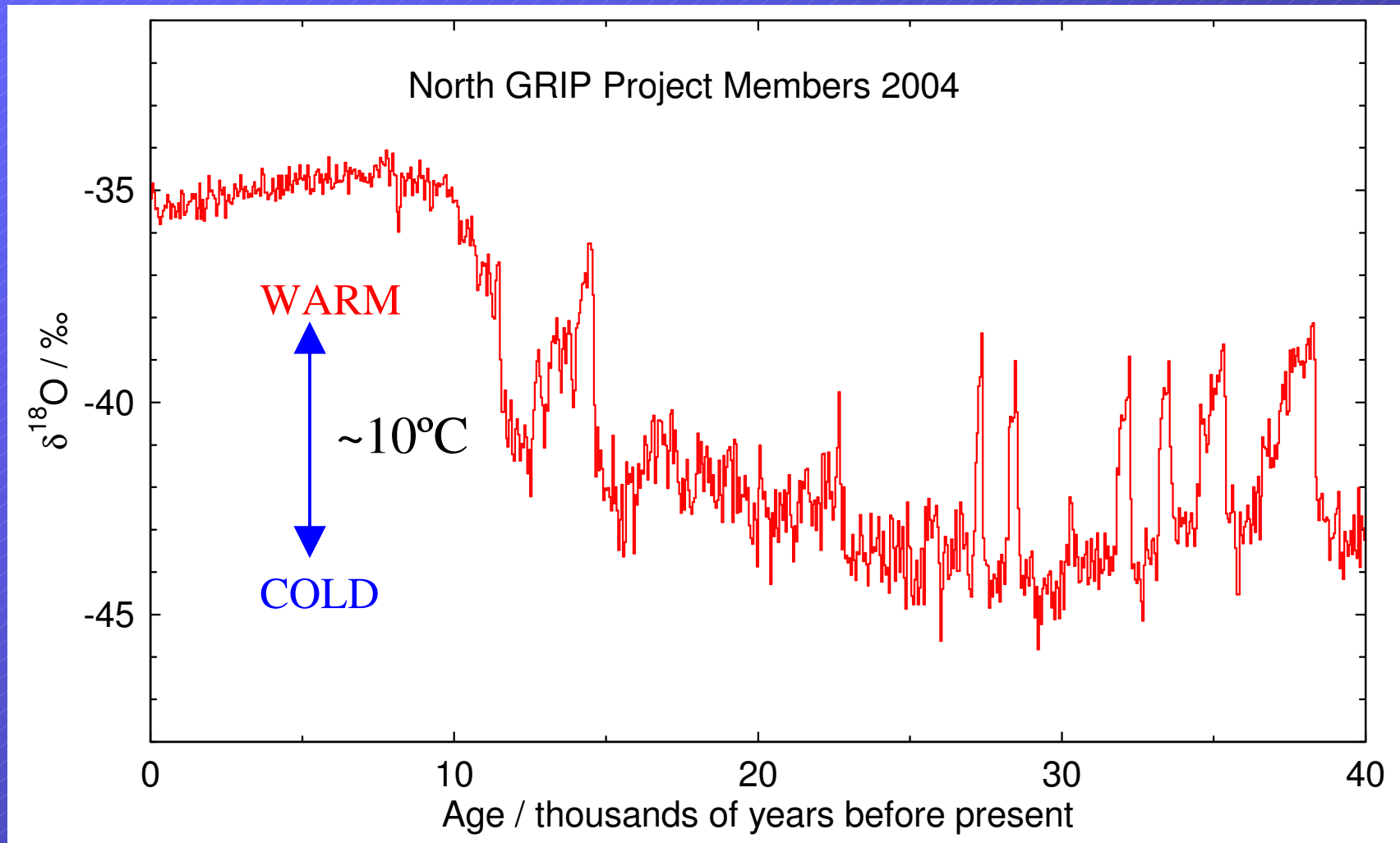
Recent changes - methane



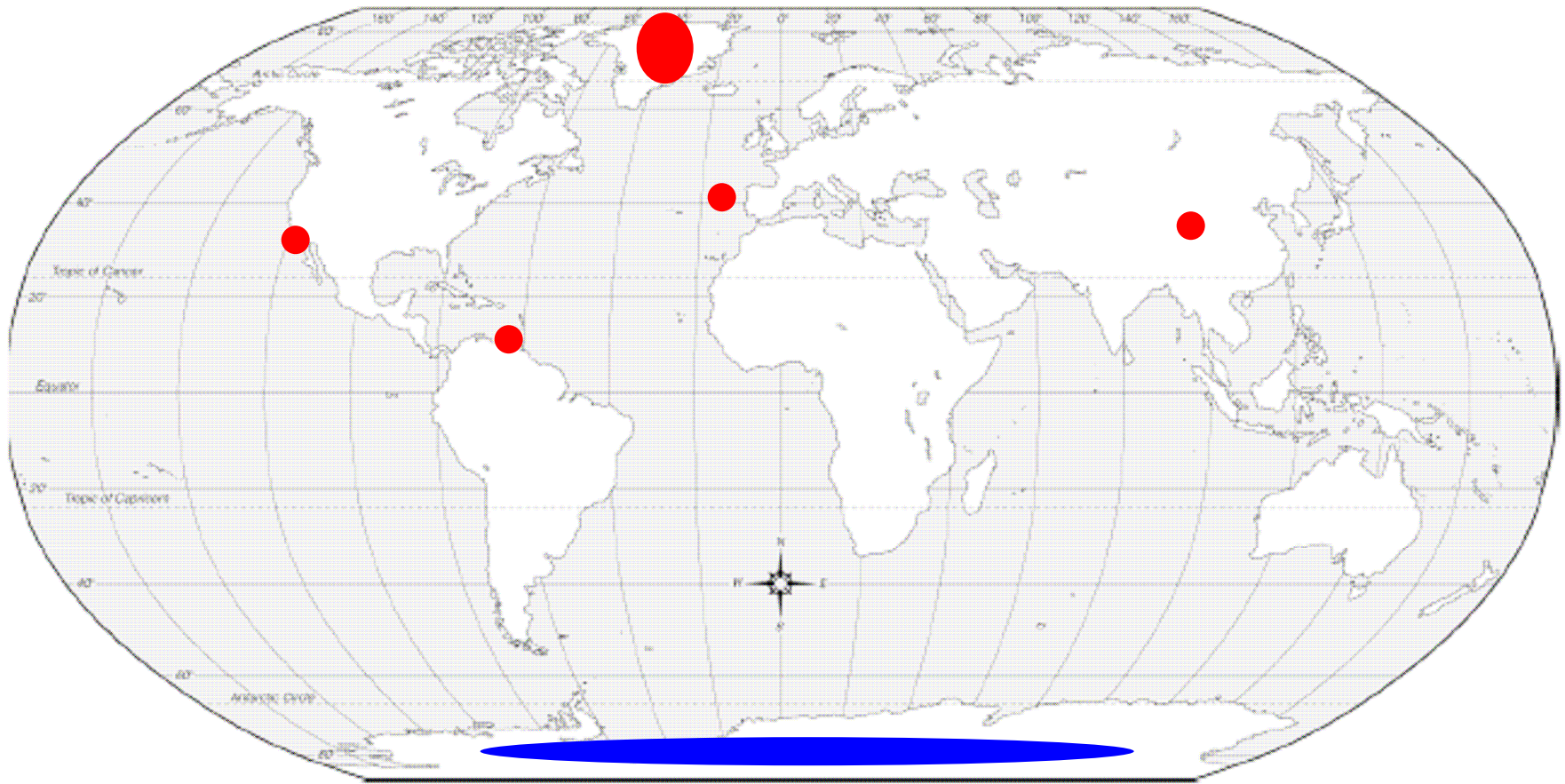
Time's arrow!



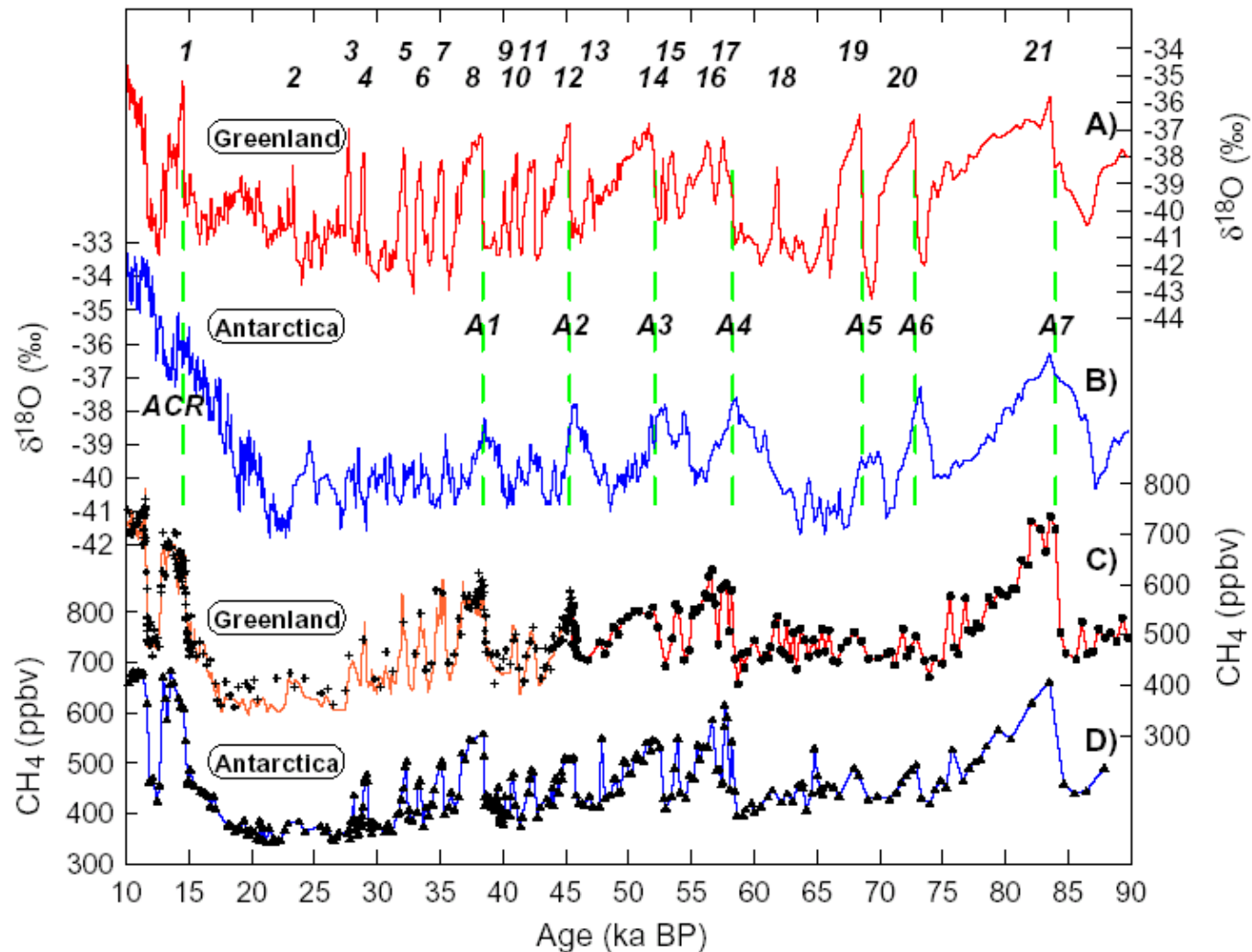
Discovery of rapid (in a human lifetime) climate shifts from a Greenland ice core



Footprint of these events throughout northern hemisphere

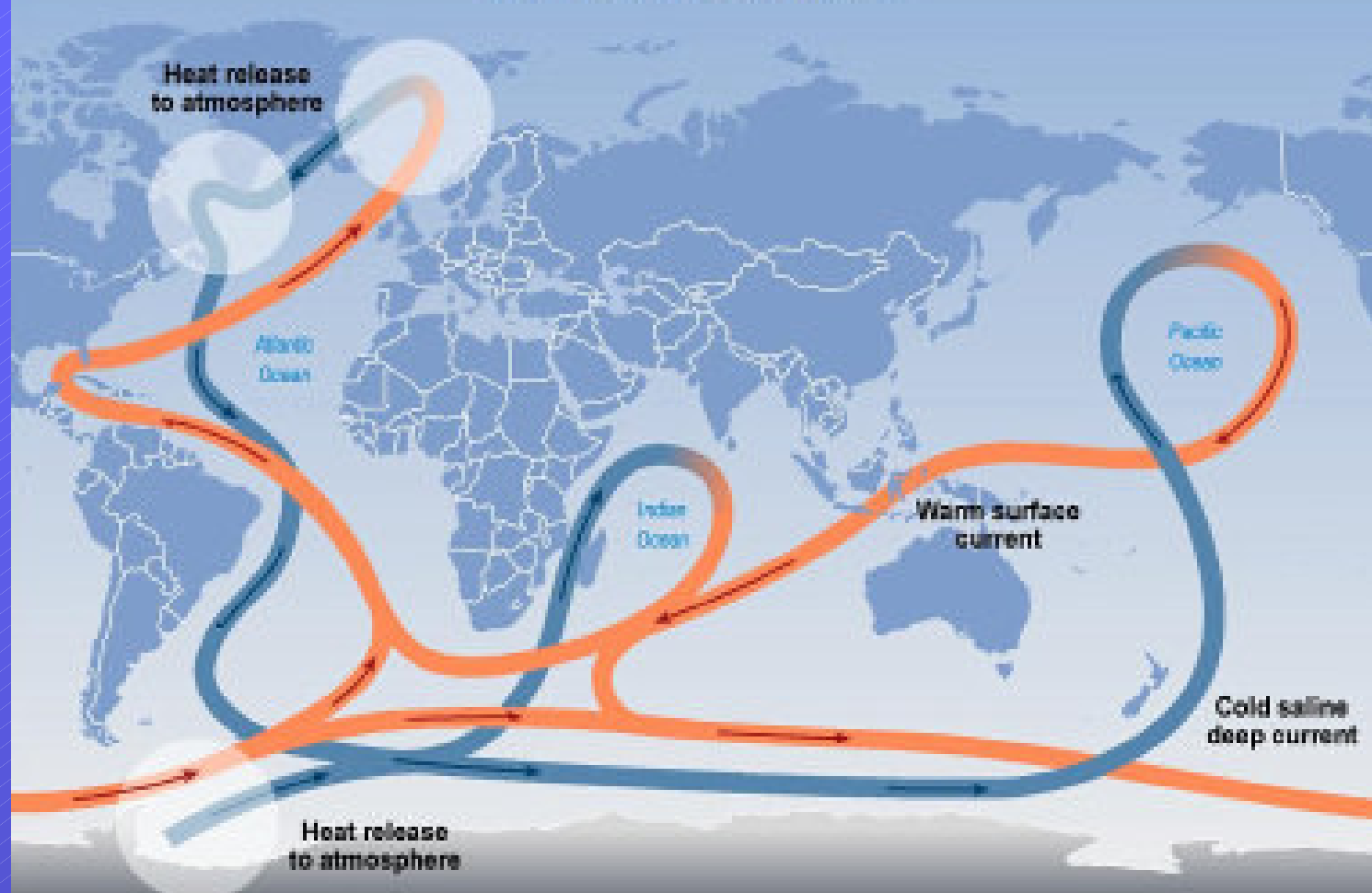


Clues to the mechanism



Antarctica vs the north

Great ocean conveyor belt

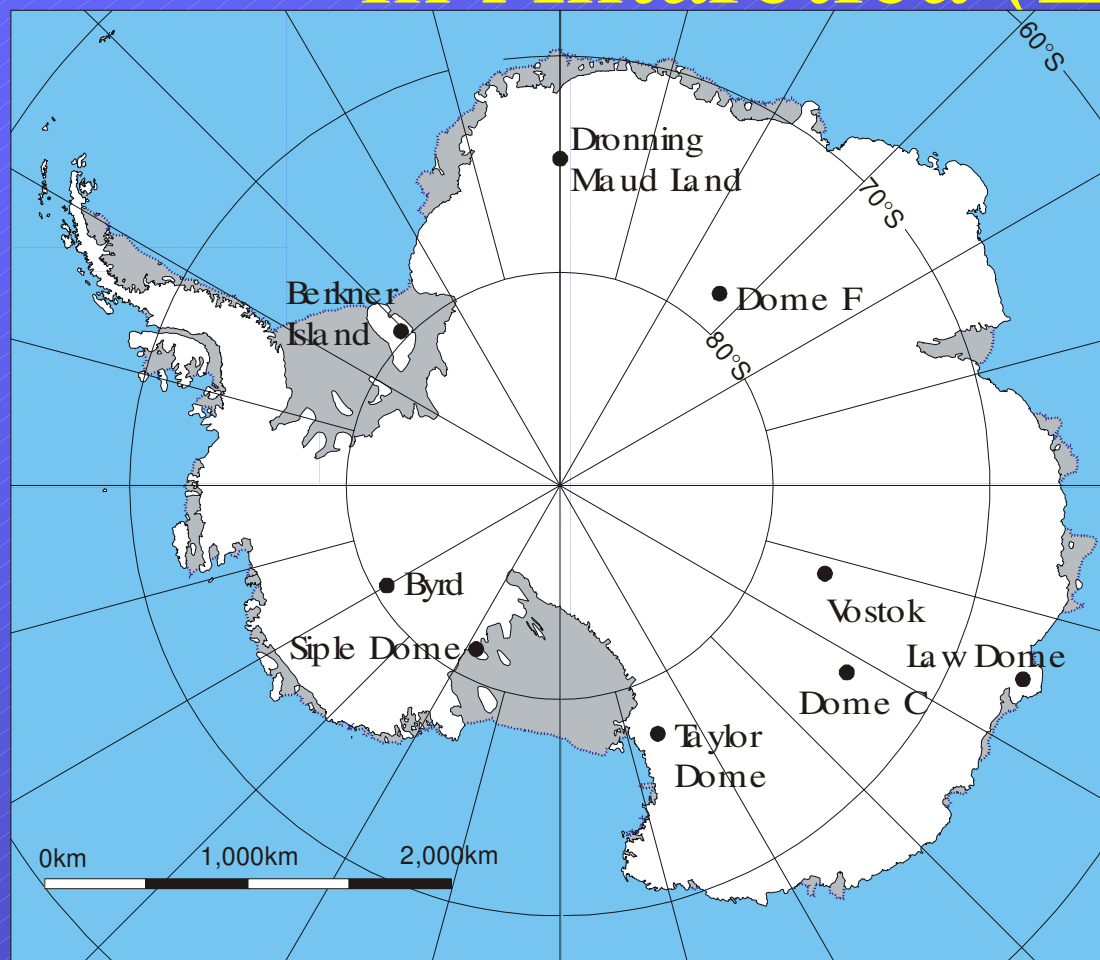


Significance of D-O events

- Rapid change has occurred in the past, but as far as we know only when there are large ice sheets
- But models for the future do suggest changes in thermohaline circulation
- Need to better understand past changes and test models against them



European Project for Ice Coring in Antarctica (EPICA)



Dome C

75°S

3233 m asl

$\sim 25 \text{ kg m}^{-2} \text{ yr}^{-1}$

Mean T: -54.5°C

DML

75°S

2892 m asl

$\sim 64 \text{ kg m}^{-2} \text{ yr}^{-1}$

Mean T: -44.6°C



Dome C

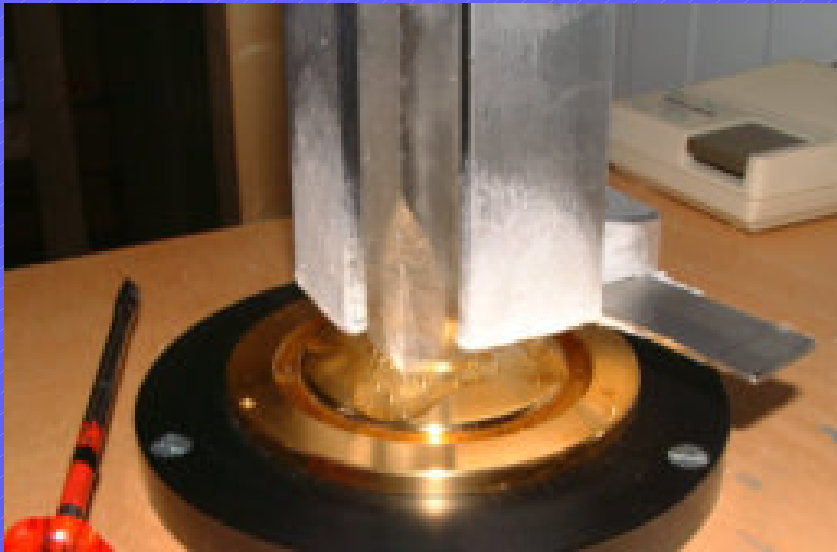


- Depth reached 3270 m (bedrock 3275 m)
- Best estimate of useable age ~800 kyr
- Final 70 m drilled in December 2004

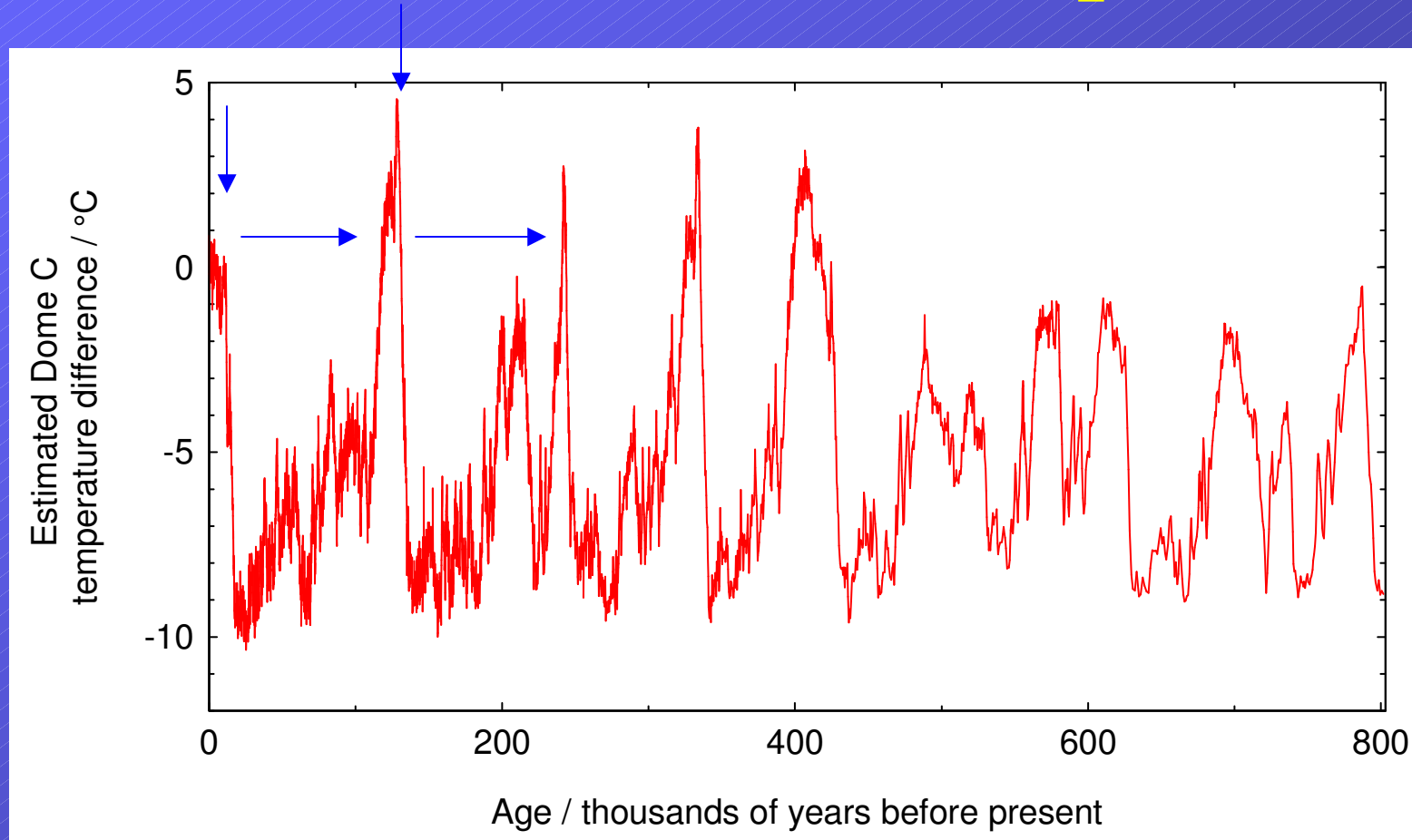




After drilling, the core must be stored and transported frozen back to analytical laboratories

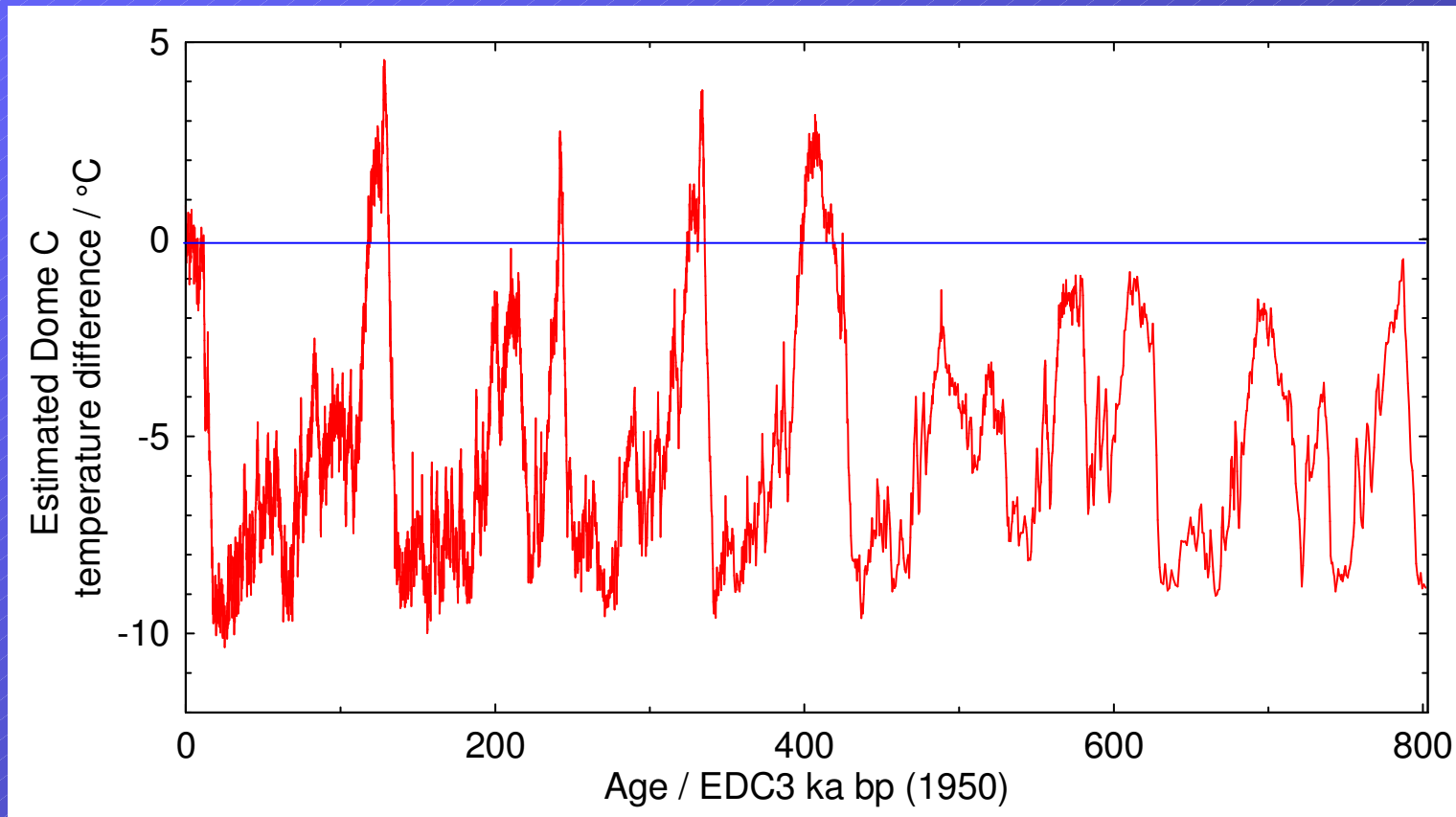


Estimated Antarctic temperature



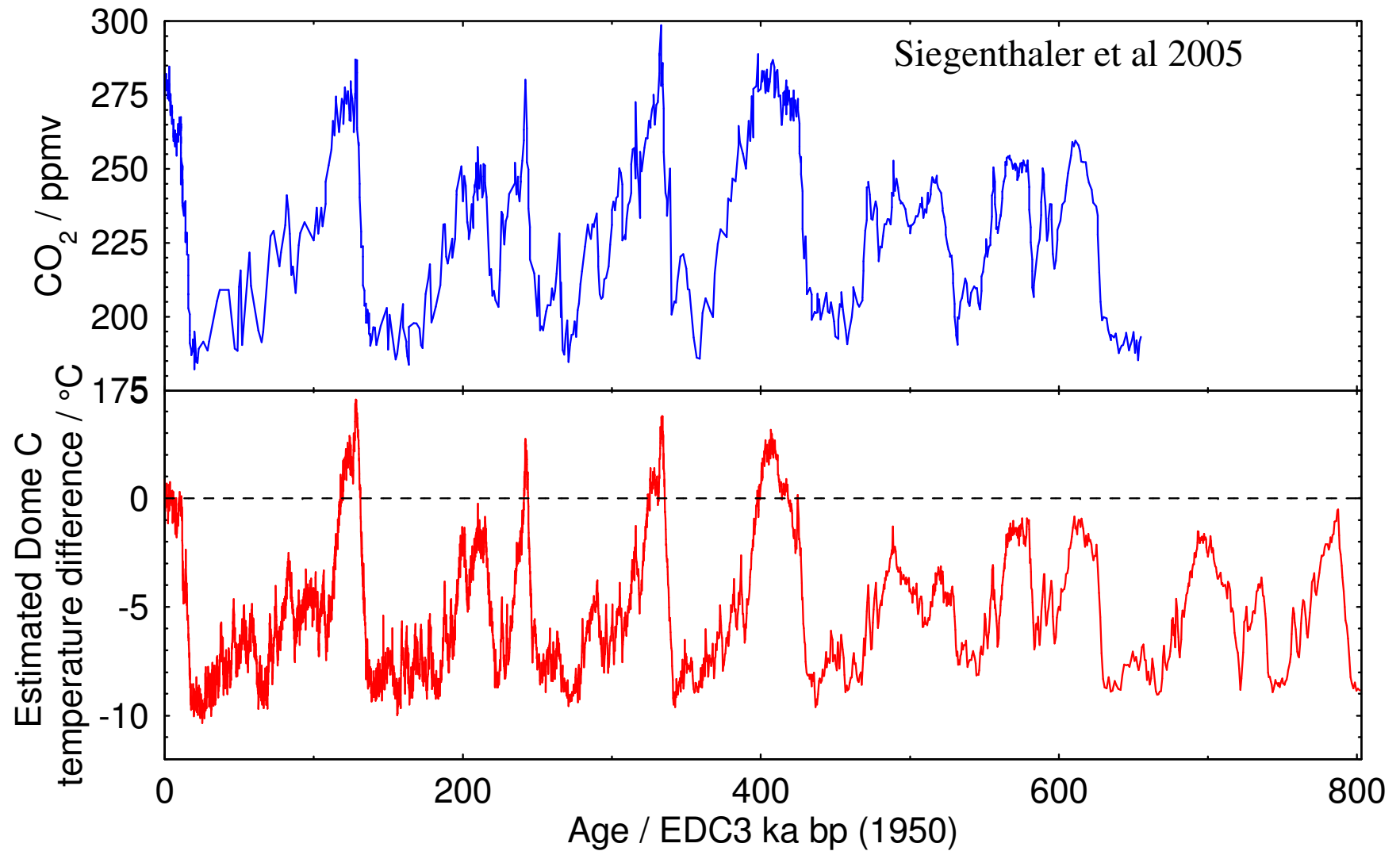
EPICA Community Members, *Nature*, 429, 623-628, 2004;
Jouzel et al., *Science*, 2007

Estimated Antarctic temperature

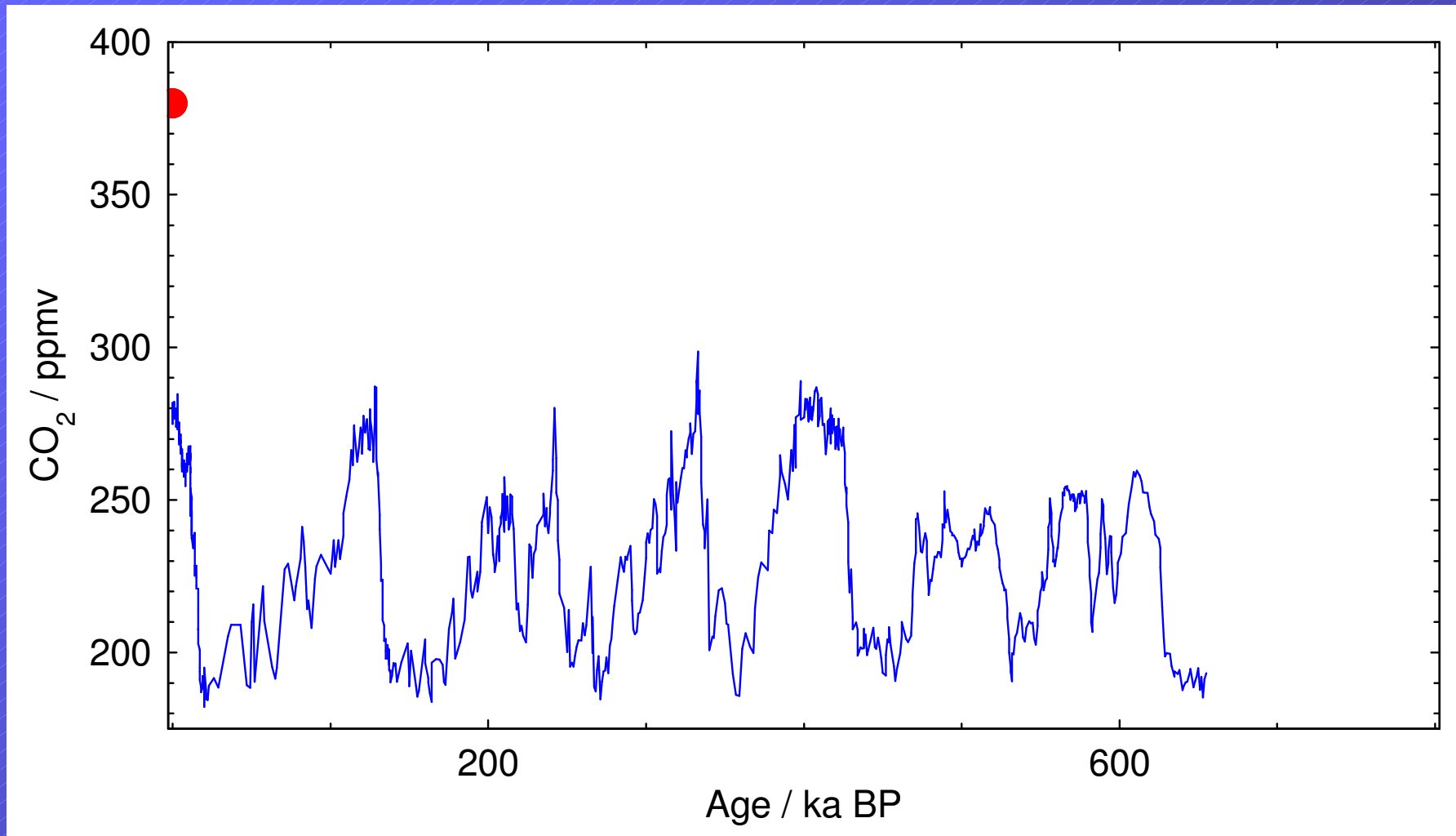


EPICA Community Members, *Nature*, 429, 623-628, 2004;
Jouzel et al., *Science*, 2007

What does CO₂ do in a changing climate?

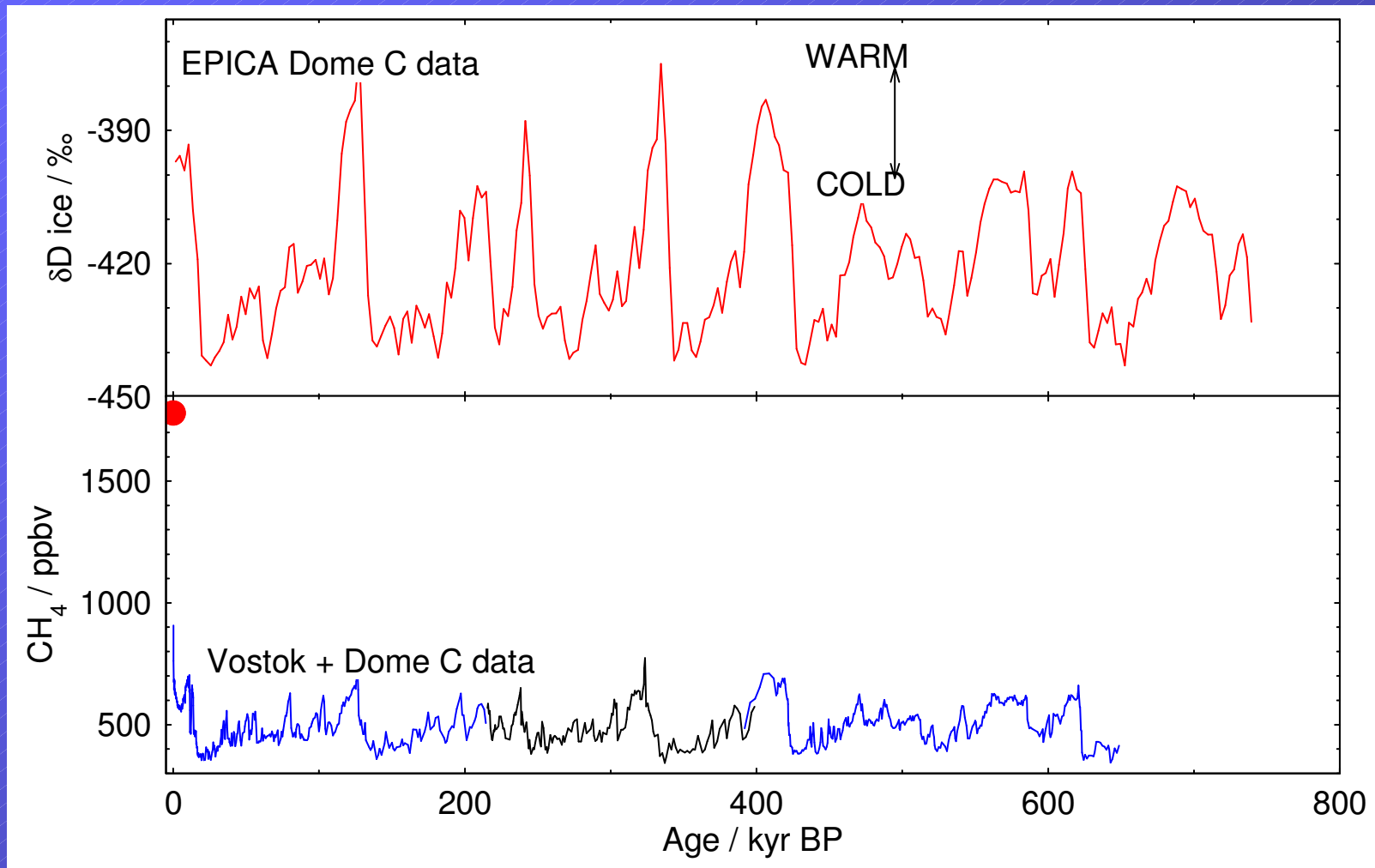


But we are out of the range of the last 800 kyr



Siegenthaler et al., Science 2005 (EPICA gas consortium)

For CH₄ (methane) also



Spahni et al., Science 2005, EPICA gas consortium

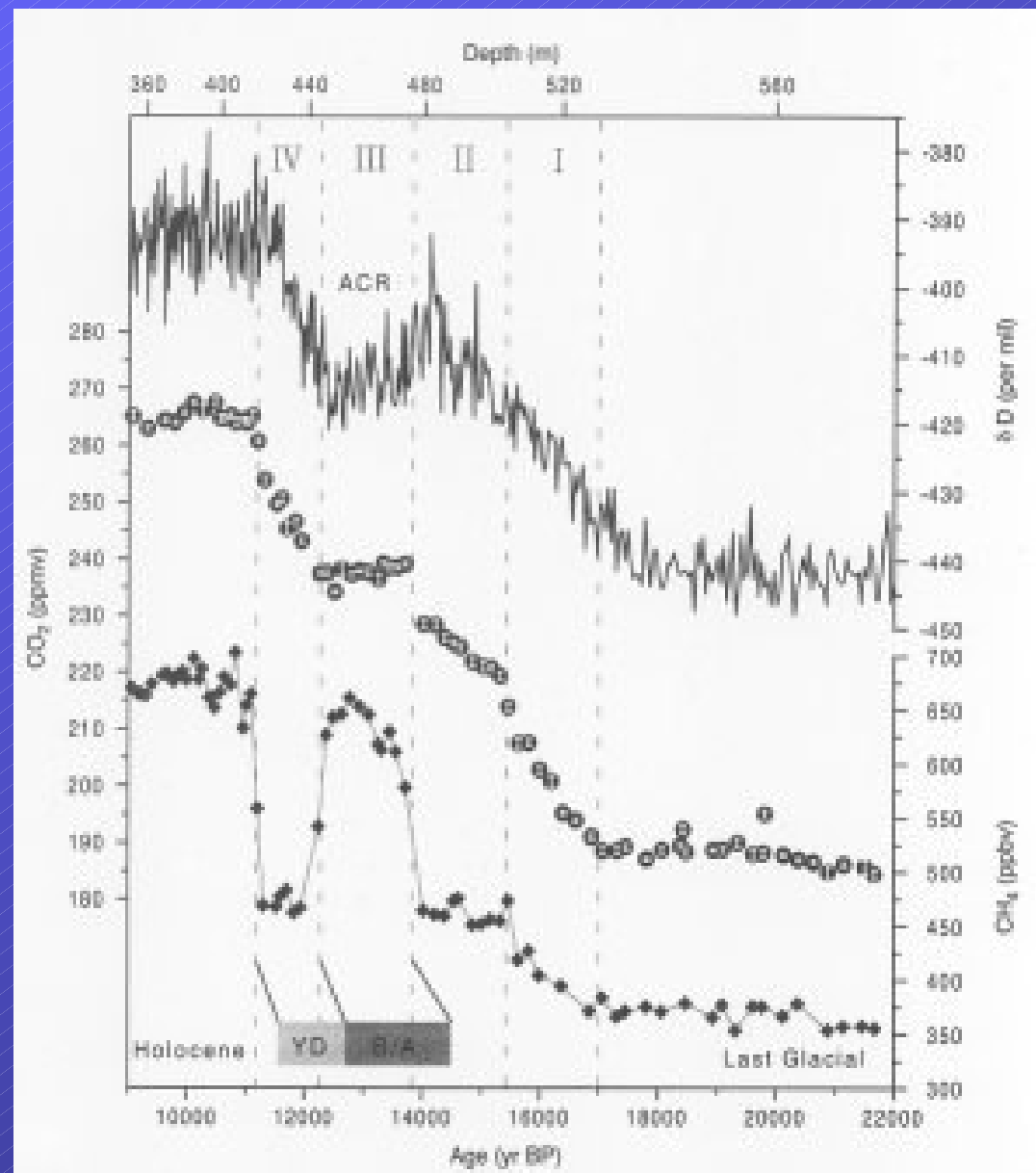
Dome C detailed CO₂

Monnin et al (2001)

Science 291, 112-114

Phasing is
consistent with CO₂
as an amplifier

(NB latest papers
suggest we should
bring CO₂ forward
a few hundred
years)

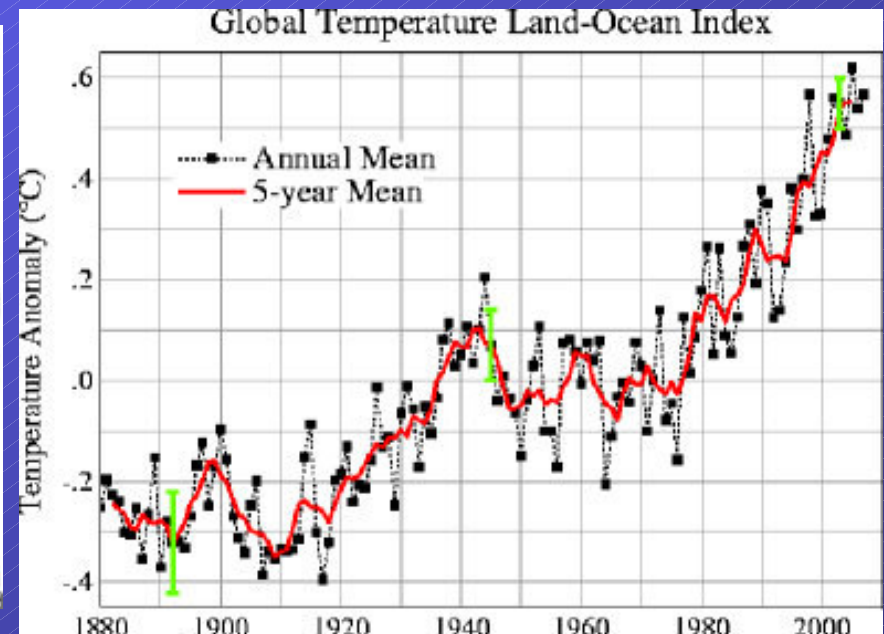
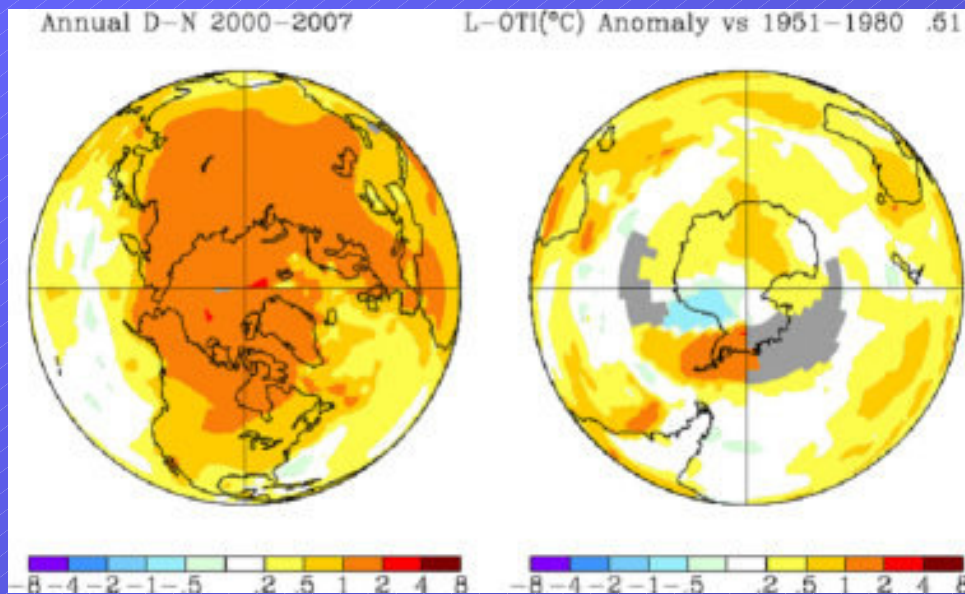


Summary – ice core records

- A fantastic archive of our past
- Have provided our only clear record of recent greenhouse gas increases
- Over longer periods shown strong link between climate and greenhouse gases
- Revealed existence of past rapid climate change
- Shows us how Earth works: needed for future prediction

Part I: Learning from the past – ice cores

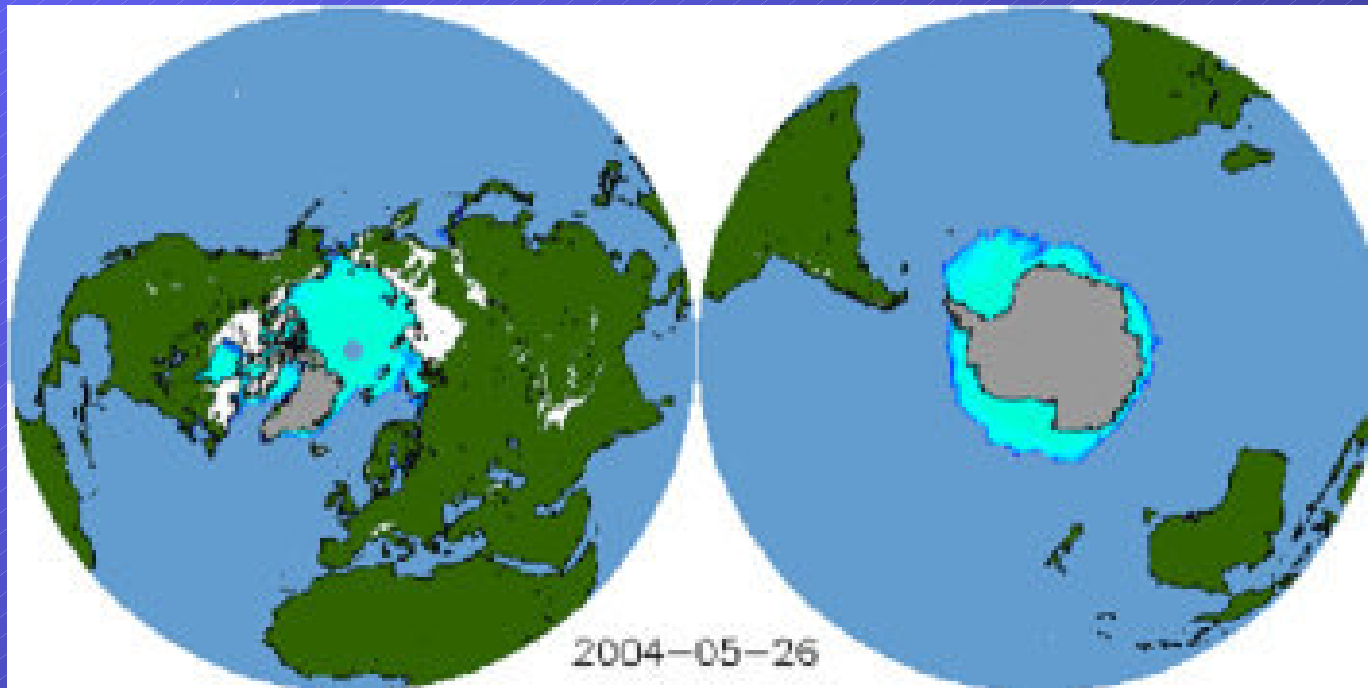
Part II: Climate change in the polar regions



Courtesy of NASA/GISS

The cryosphere

The cryosphere is the portion of the Earth's surface where water is in a solid form, usually snow or ice. This includes sea ice, freshwater ice, snow, glaciers, and frozen ground (or permafrost).

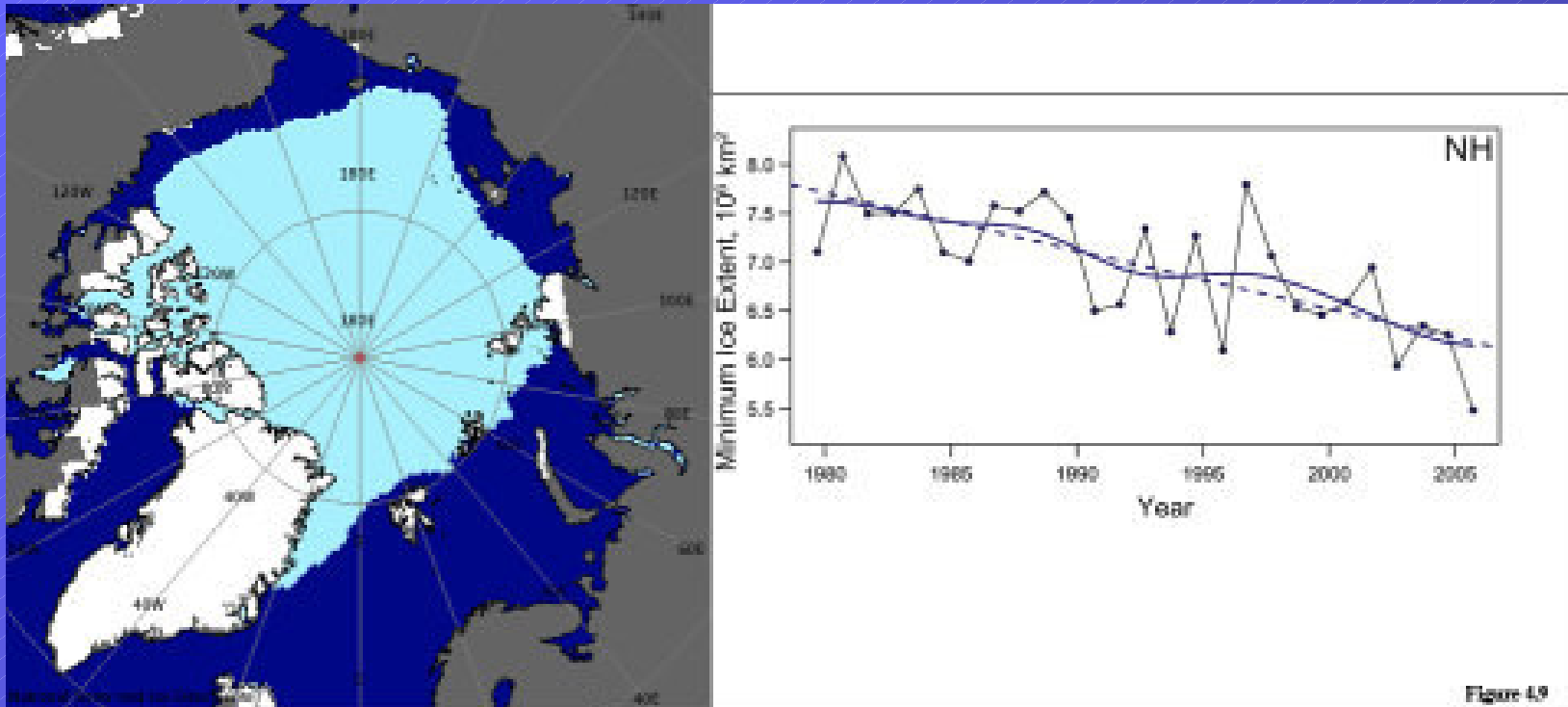


NISE product, courtesy NSIDC

The cryosphere today

	Area / 10^6 km^2	Volume / 10^6 km^3	Sea level equiv / m
Arctic sea ice	14 (winter)		
Antarctic sea ice	17.1 (winter)		
NH snow cover	44 (winter)		
Glaciers/ice caps	0.5	0.1	0.30
Greenland ice	1.7	2.9	7.3
Antarctic ice	12.3	24.7	56.6

Recent trends – Arctic sea ice



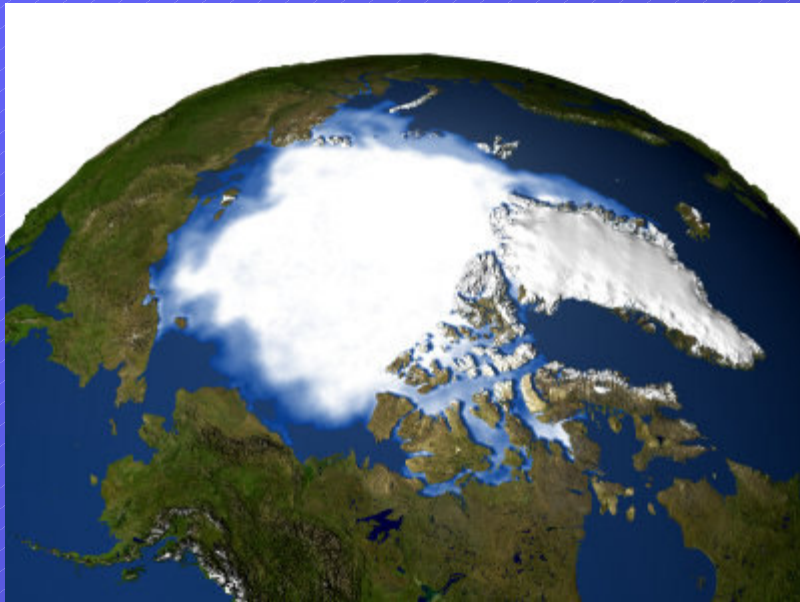
IPCC AR4, 2007

Reduction of 7% per decade
Reductions in thickness also reported (but
somewhat controversial)

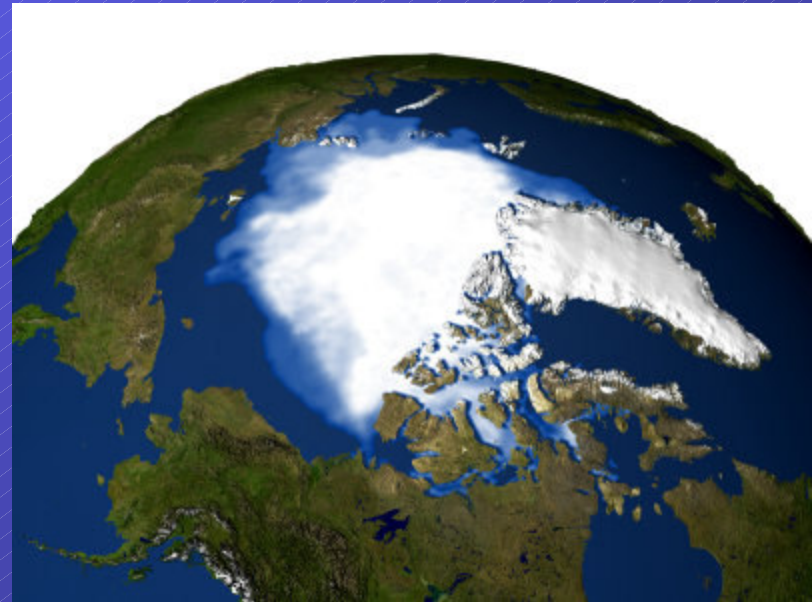
Sea ice

NASA

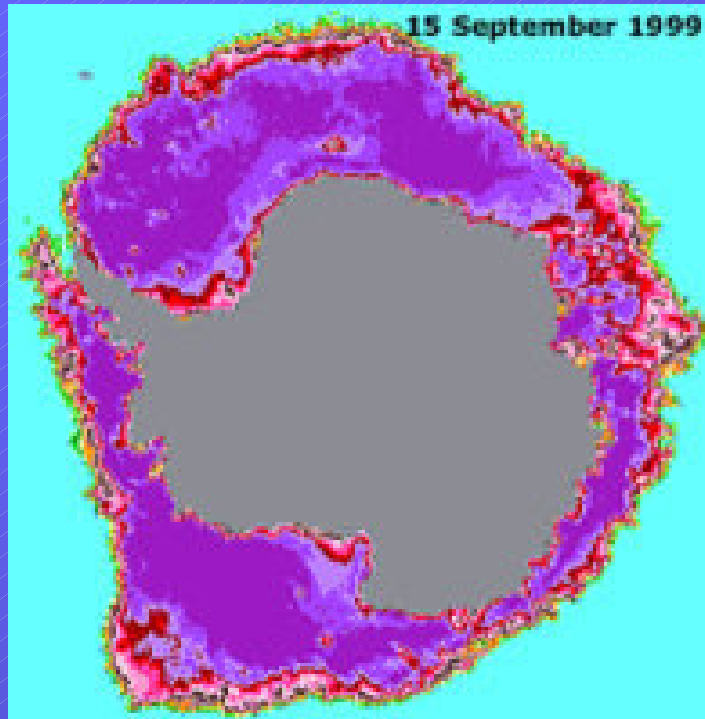
1979-1981



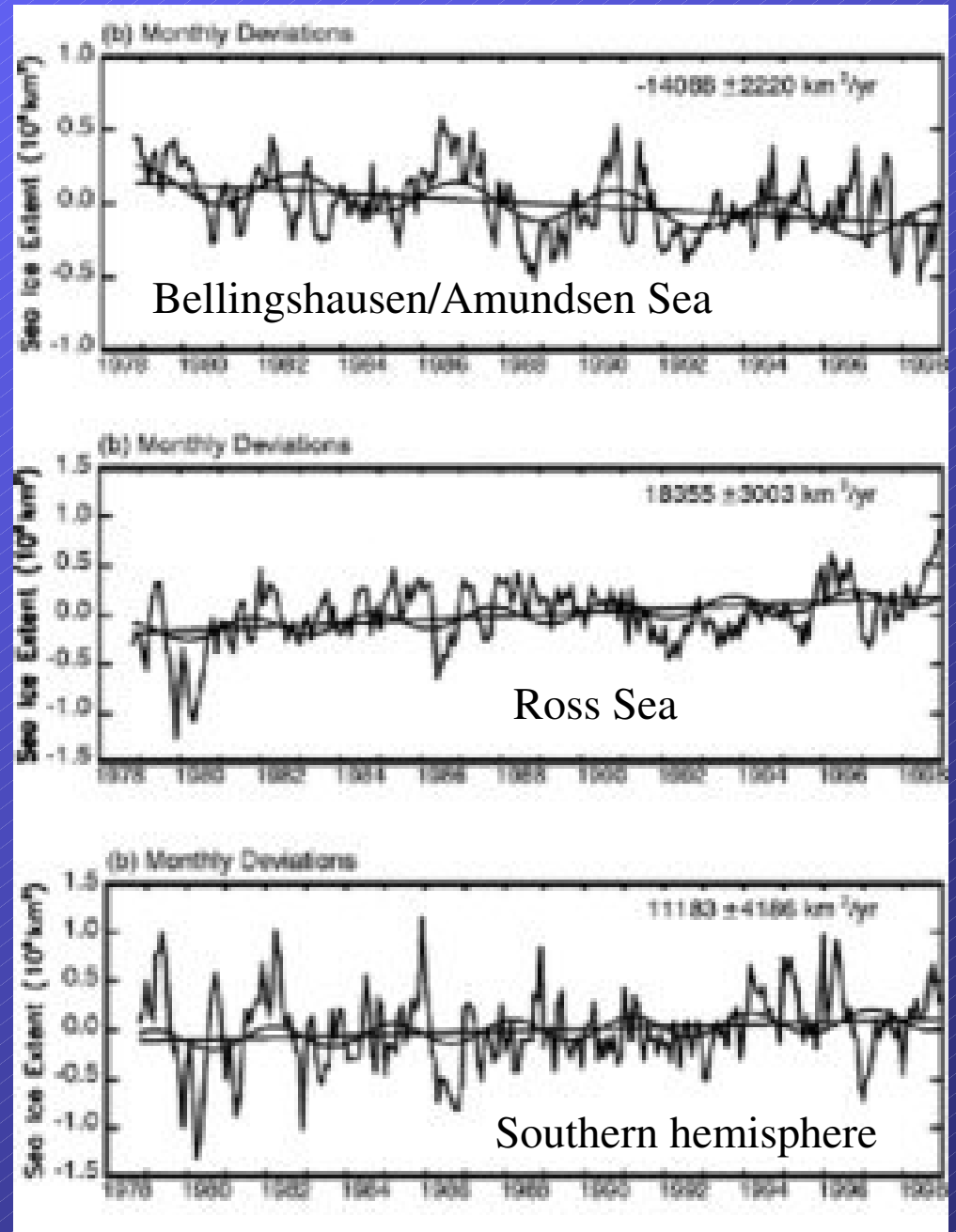
2003-2005



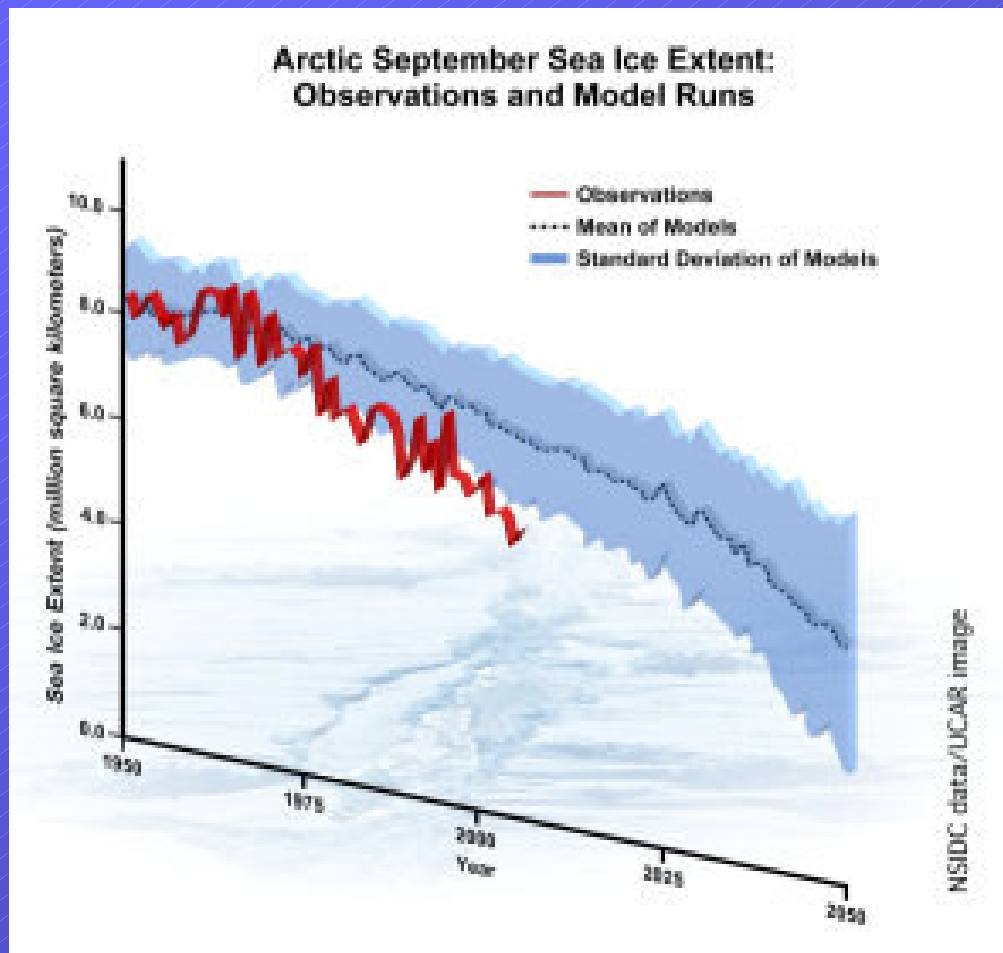
Antarctic sea ice



Regional variations;
little net change



Predicting future sea ice



Ice sheets and sea level

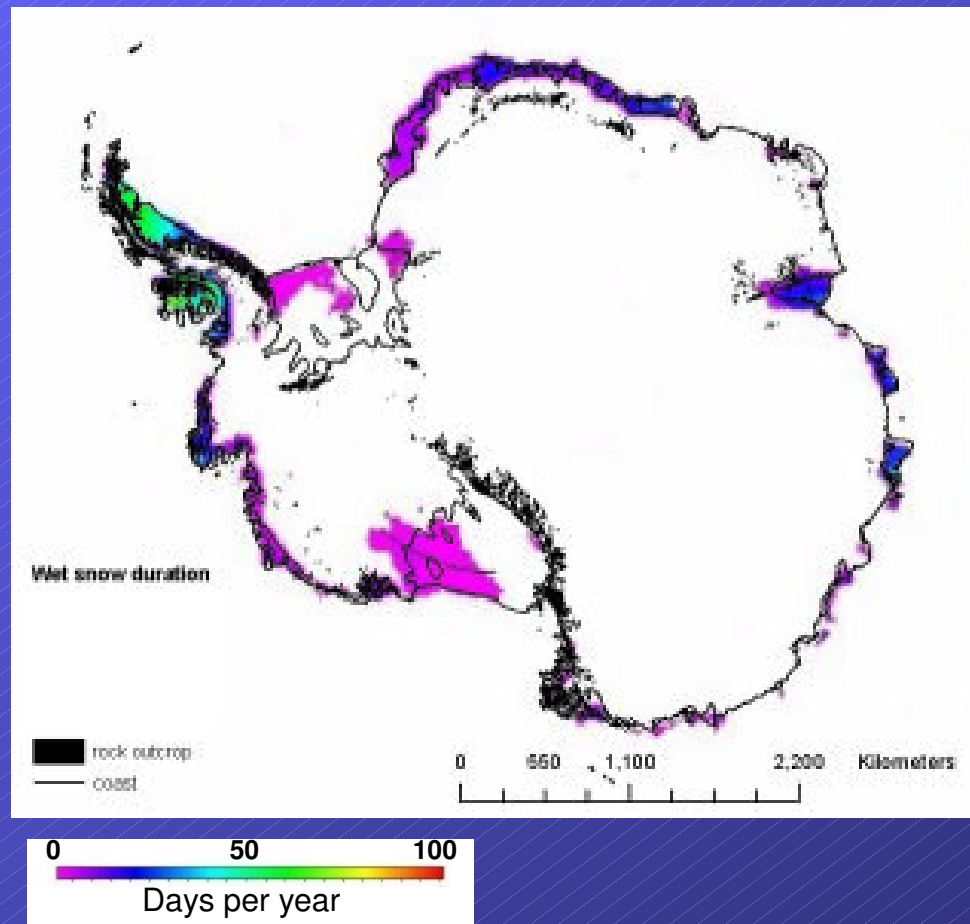
- Greenland ice contains 7 m of sea level
- Antarctic ice contains 60 m of sea level
- IPCC (4th AR) projects 18-59 cm of sea level rise by 2100
- But ignores contributions from ice flow instabilities (no basis for quantifying)
- And this figure takes no account of later sea level rise that we will soon commit to

Ice sheets

- Within uncertainties, the Antarctic ice sheet has been close to being in balance in recent decades
- Most obvious change in Antarctica has been the loss of Antarctic Peninsula ice shelves
- West Antarctic glaciers showing retreat and ice loss than is not yet explained
- Some parts of inland Greenland may have thickened in recent years; some coastal regions show thinning

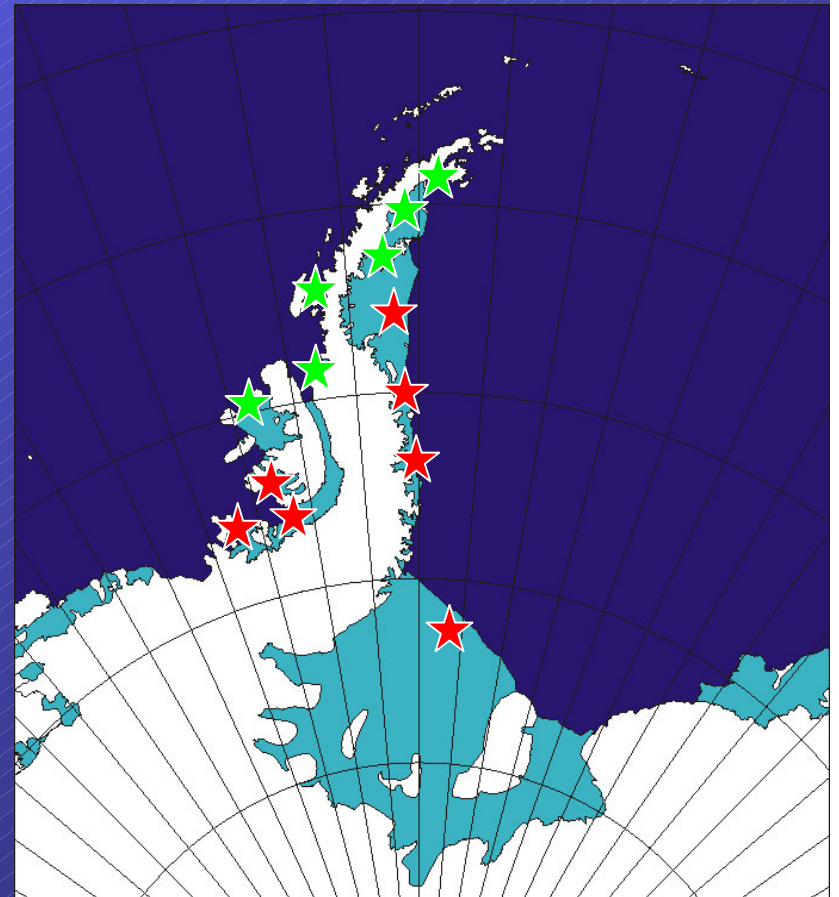
East Antarctica –mainly cold and stable to significant warming

From passive
microwave
measurements



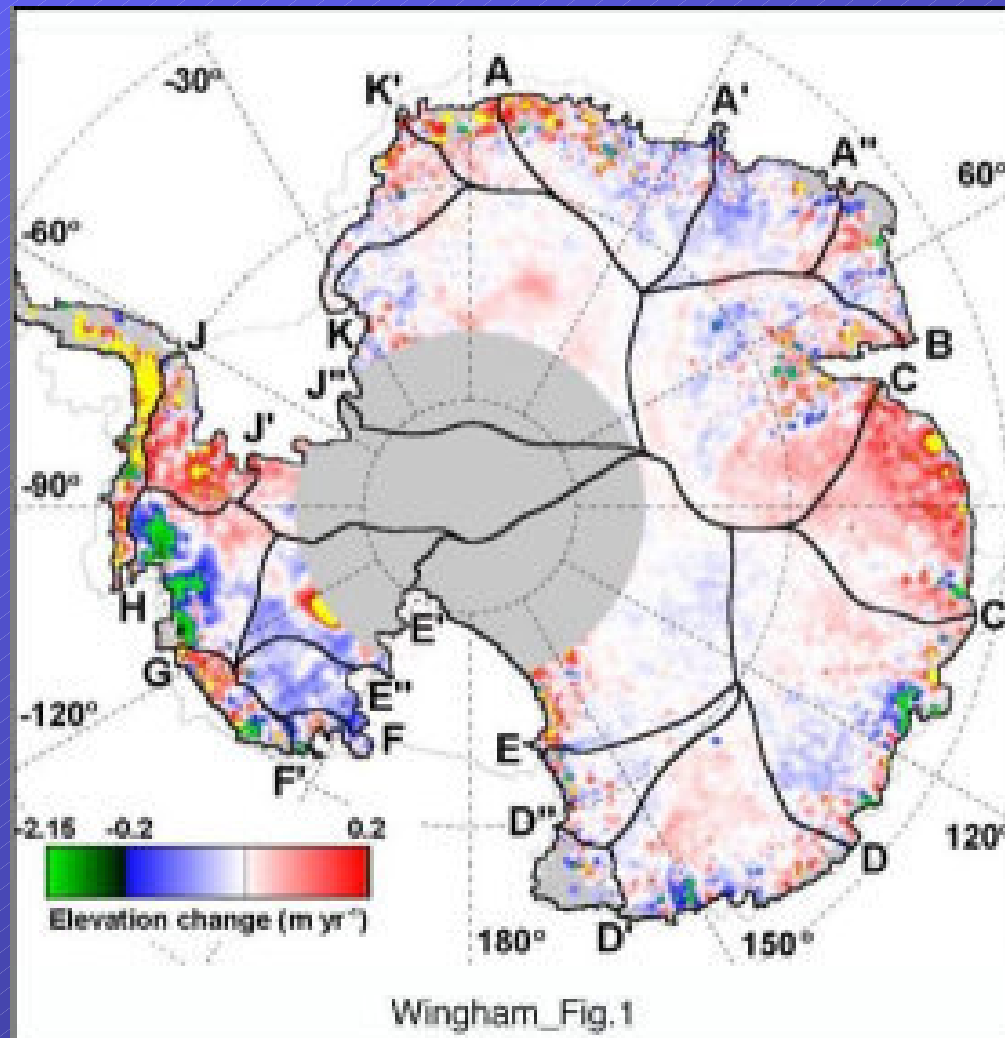
Source: O. Torinesi, M. Fily,
C. Genthon, *J. Clim.* **16**, 1047
(2003).

Antarctic Peninsula: Ice shelf loss in response to regional warming



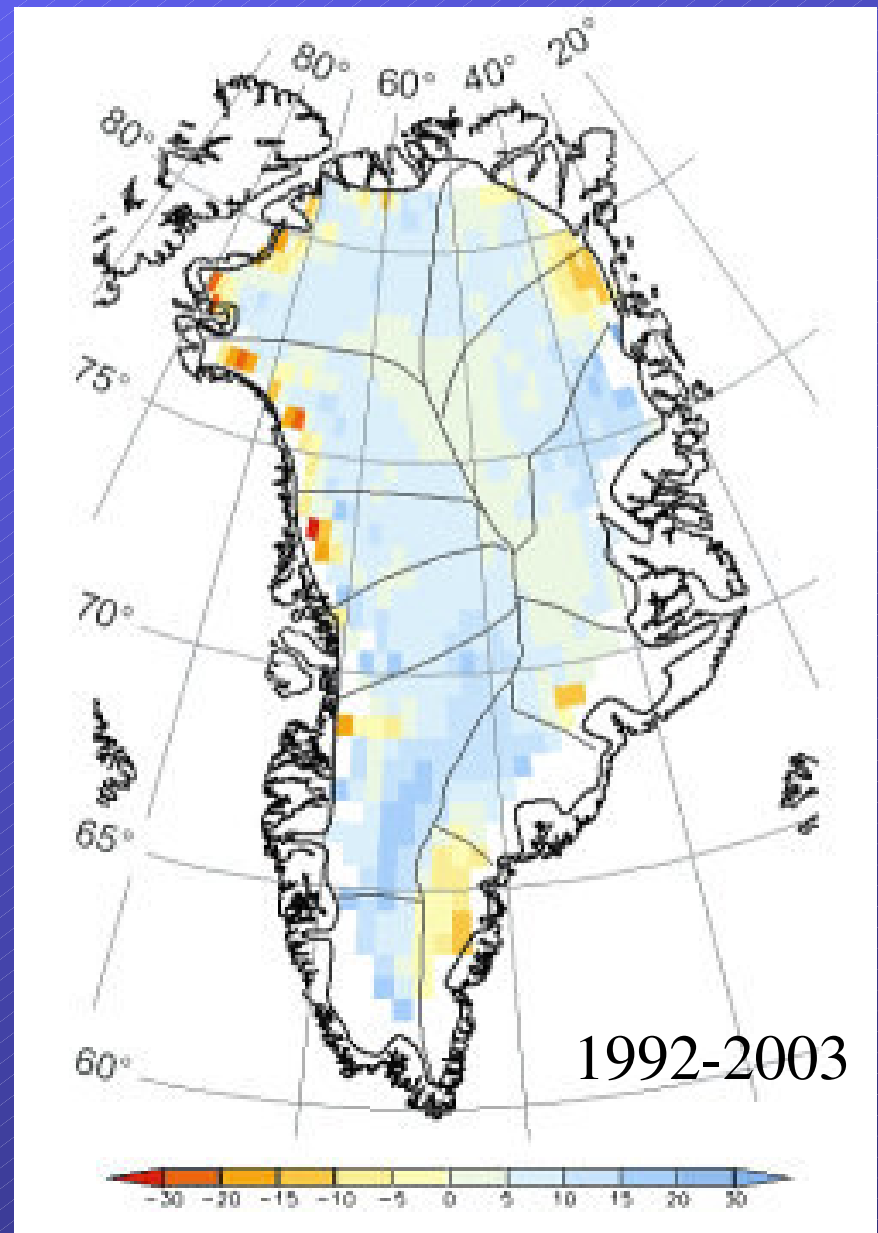
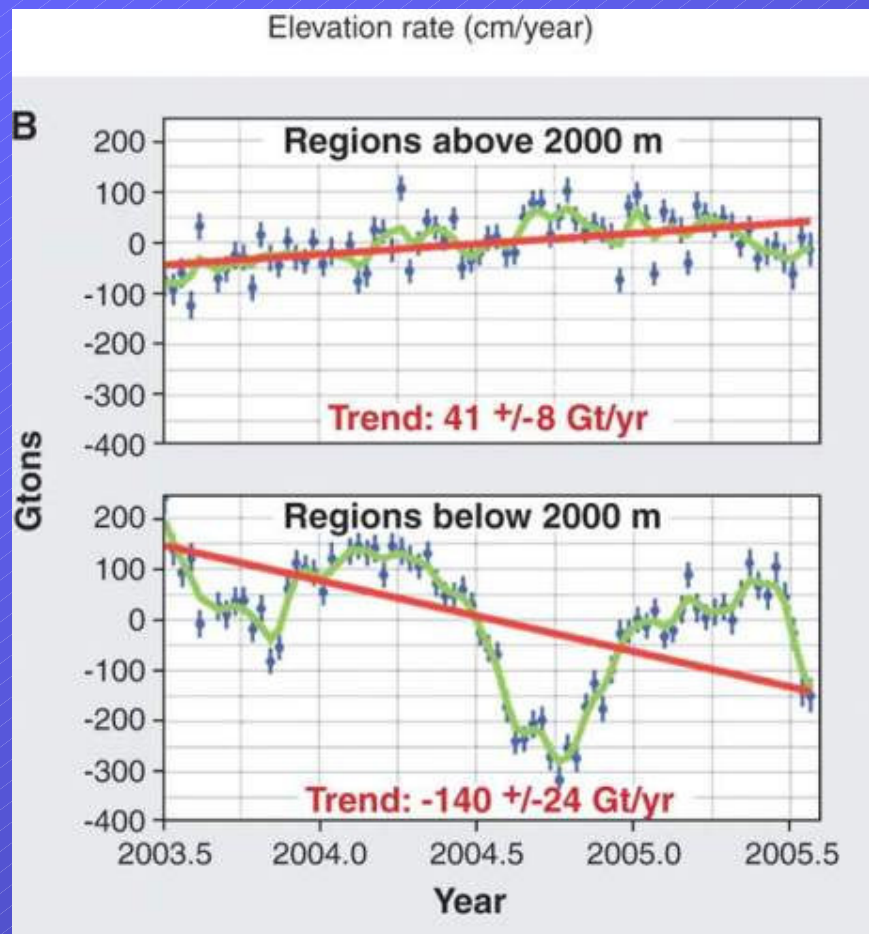
West Antarctic thinning

Ice thickness
changes
1992-2003

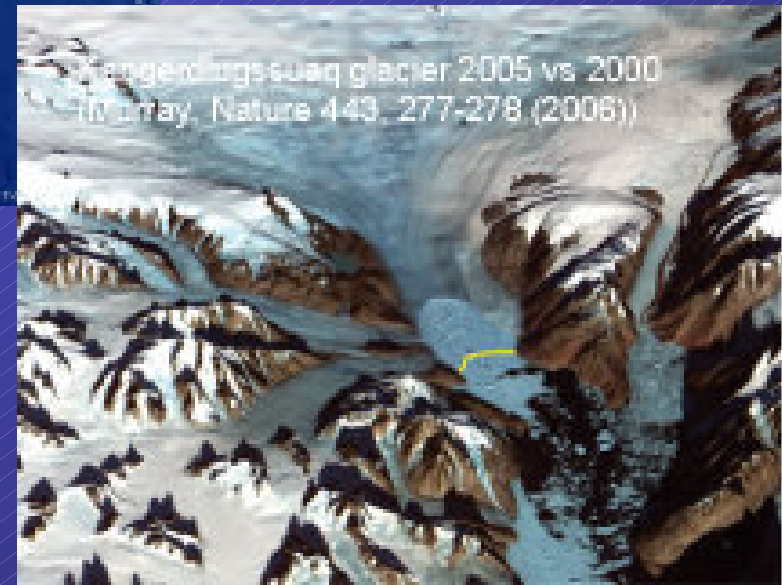
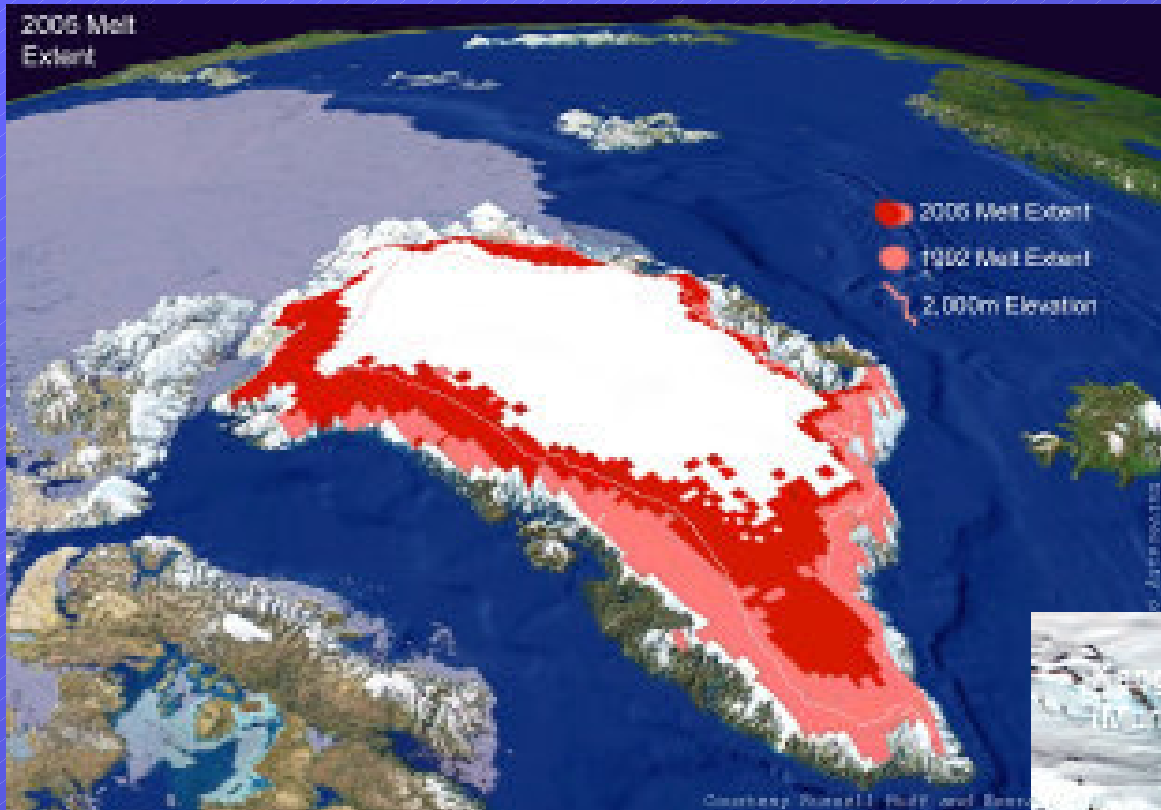


Source: Wingham et al., 2006

Greenland: coastal retreat

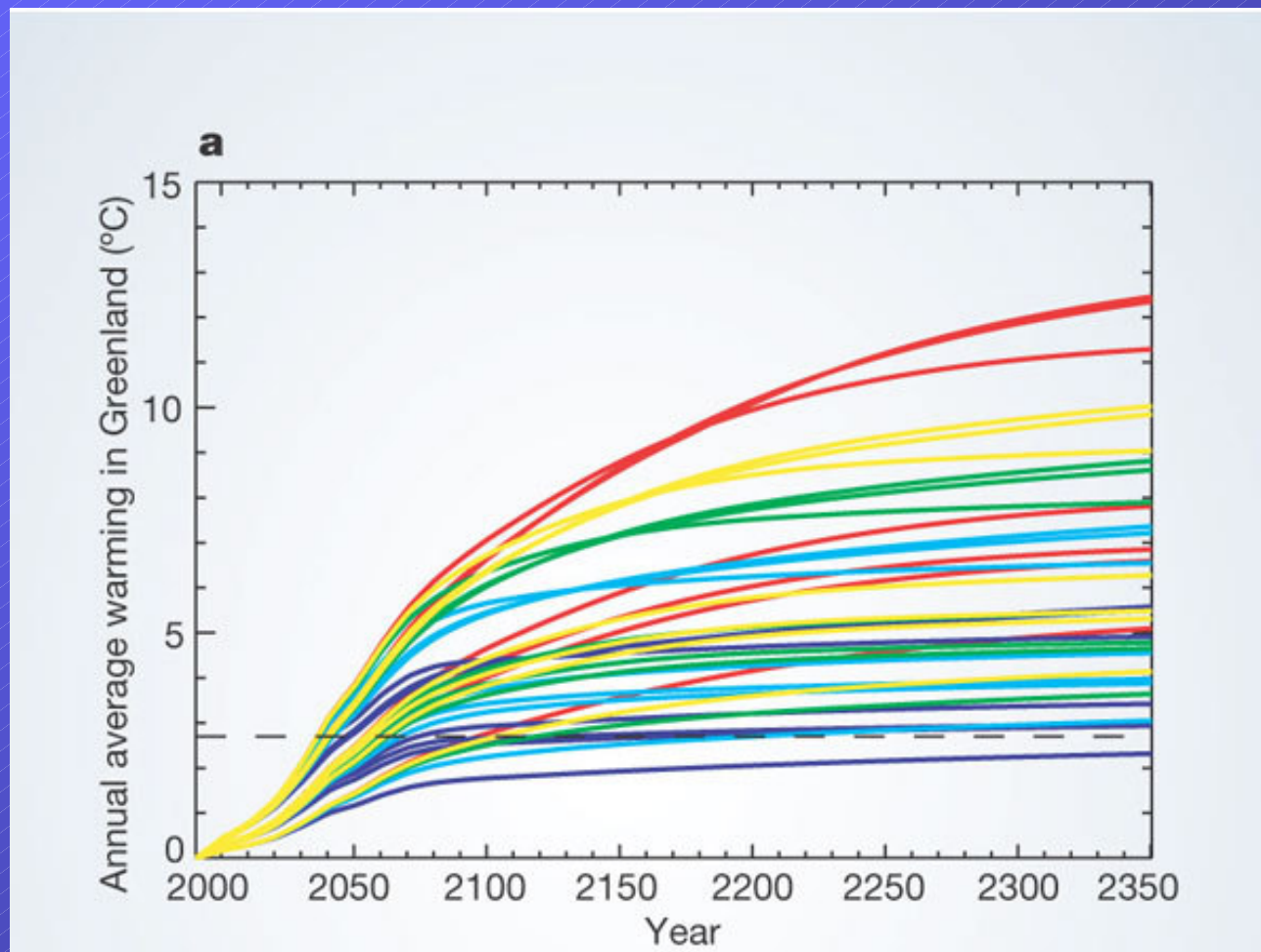


Greenland



At warming somewhere between 1.9 and 4.6°C, net ablation exceeds net accumulation and eventual loss of ice sheet appears inevitable

Greenland: long-term



A 3° warming might imply a commitment to up to 6 m sea level rise

Longer-term prognosis

- Continued warming beyond next century likely to remove most small glaciers and most Arctic sea ice
- East Antarctica is so cold that significant surface melting cannot occur; should be stable unless ice dynamics surprises
- West Antarctica – prognosis somewhat unclear
- Greenland – prognosis poor

Summary

- The polar regions are important for many aspects of climate change
- Ice cores tell us that greenhouse gas concentrations really have risen, that very fast climate change is possible, and show us how the Earth's climate system works
- The polar cryosphere is shrinking, and there are many aspects of that which we don't yet understand

Of course it might be worse than
I think!



Thank you

