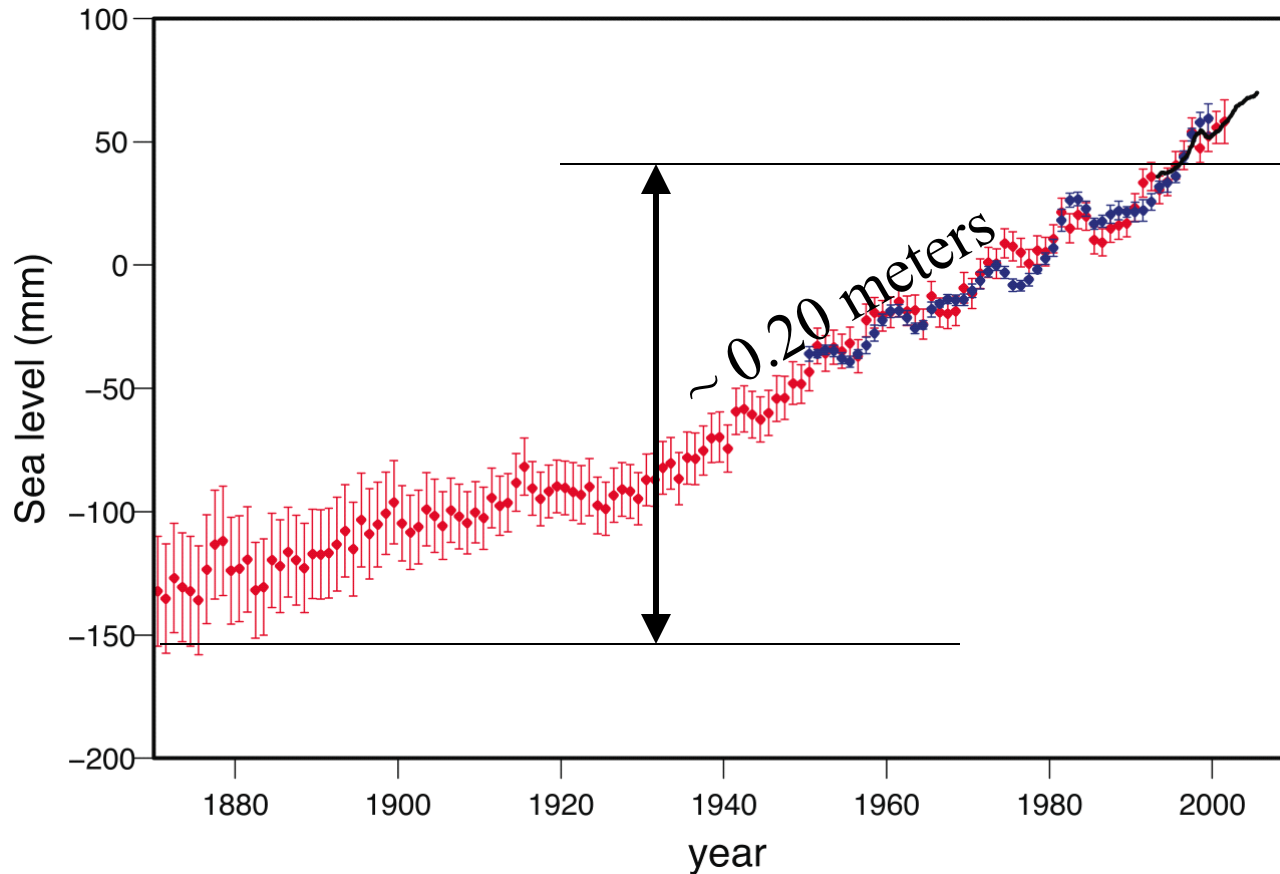


Sea level, and it's rise

(IPCC big conclusions)



Red=reconstructed sea level fields

Blue=coastal tidal gauge measurements

Black=satellite altimetry

Figure 5.13

Good agreement
between datasets

IPCC report, Figure 5.13, 2007

From last time

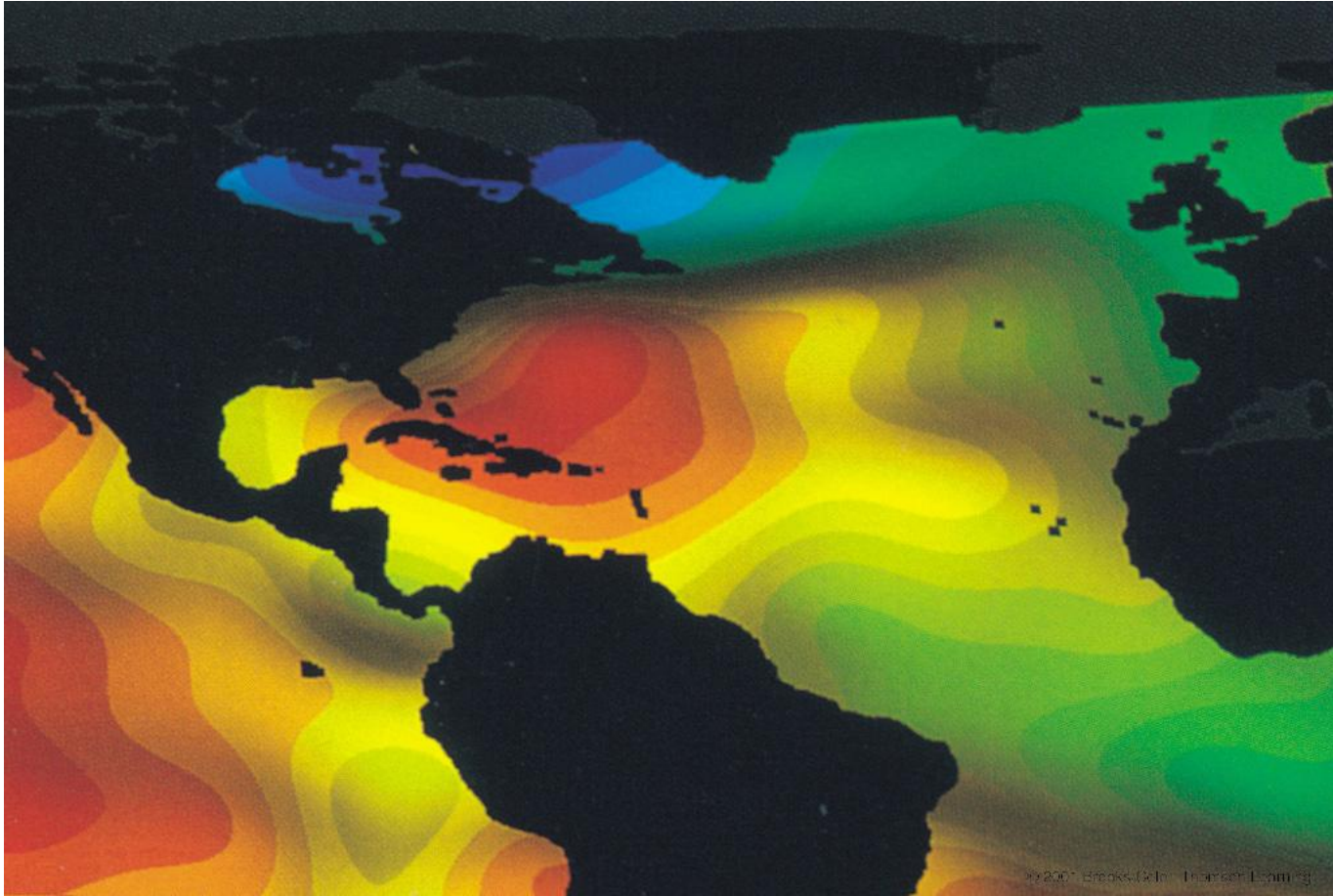
- Lack of sea ice changes the production of deep water in the North Atlantic
- But also temperature can change density.

- What about sea level...
- Surely melting will cause sea level change?

Sea level

- As we know sea level changes from day to day and with weather systems
- Also tides!
- *Average depth of the ocean*

Average sea level elevation seen from space



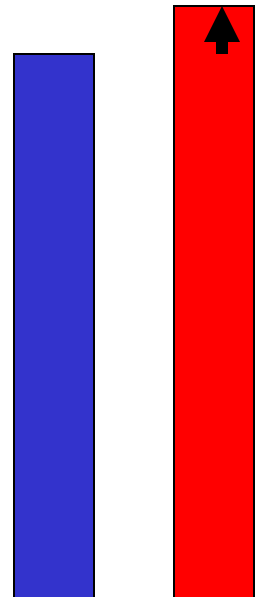
Ekman transport allows water to “pile up” in center of ocean basin

This forces geostrophic currents on the large scale

These are the anticyclonic ocean gyres

Recall, altimetry and SST

- Warm water expands
- Coefficient of expansion $0.33 \times 10^{-3} / \text{K}$
- So for every 1 K warming in the upper 1 km of water, change in depth of 1 km of ocean is 0.33 meters by thermal expansion ($0.33 \text{ meters} / \text{K}$)
- Have observed about 0.20 m of sea level rise with about 0.5 K warming. ($0.40 \text{ meters} / \text{K}$)
- Can conclude most of the sea level change seen to date is due to thermal expansion.



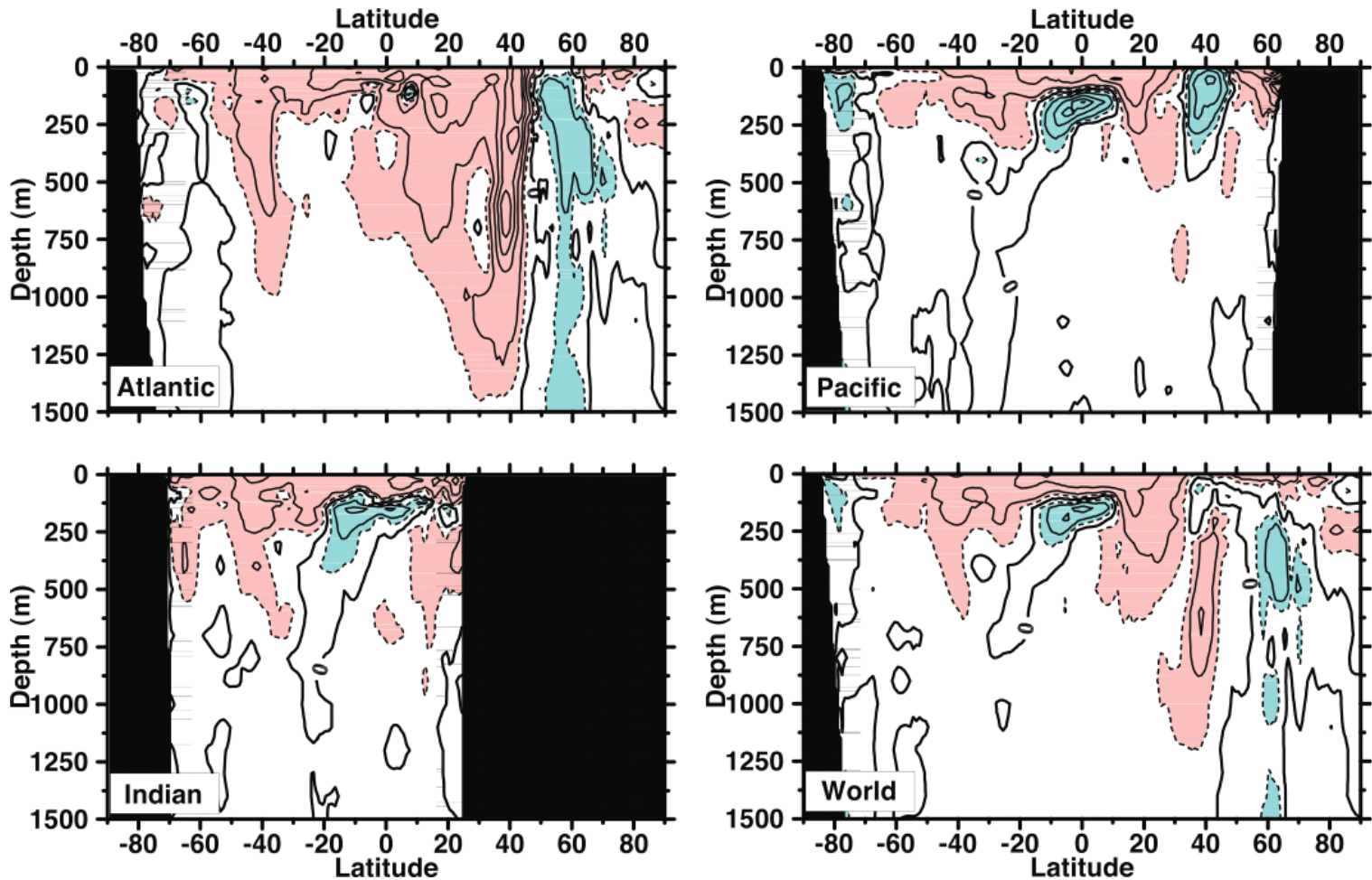


Figure 5.3. Linear trend (1955–2003) of zonally averaged temperature in the upper 1,500 m of the water column of the Atlantic, Pacific, Indian and World Oceans. The contour interval is 0.05°C per decade, and the dark solid line is the zero contour. Red shading indicates values equal to or greater than 0.025°C per decade and blue shading indicates values equal to or less than -0.025°C per decade. Based on the work of Levitus et al. (2005a).

Figure 5.3

Sea level change due to thermal expansion

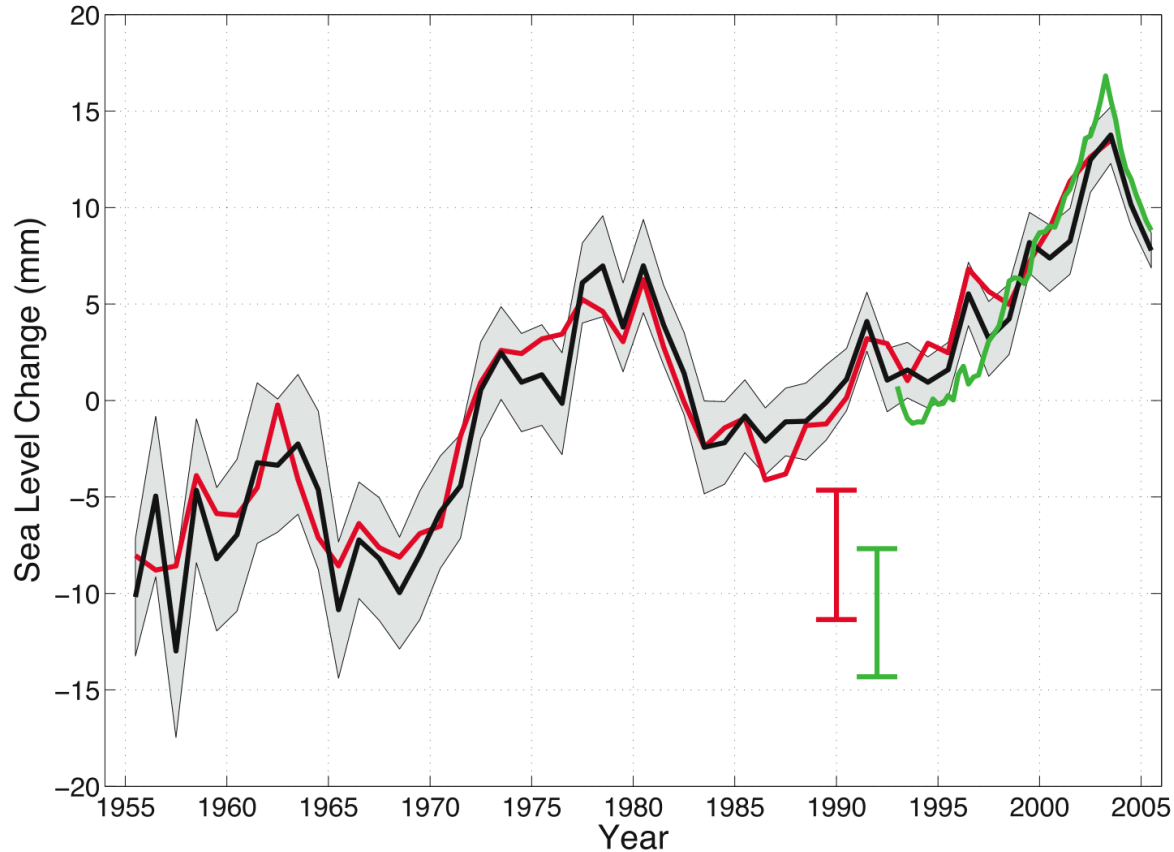


Figure 5.19. Global sea level change due to thermal expansion for 1955 to 2003, based on Levitus et al. (2005a; black line) and Ishii et al. (2006; red line) for the 0 to 700 m layer, and based on Willis et al. (2004; green line) for the upper 750 m. The shaded area and the vertical red and green error bars represent the 90% confidence interval. The black and red curves denote the deviation from their 1961 to 1990 average, the shorter green curve the deviation from the average of the black curve for the period 1993 to 2003.

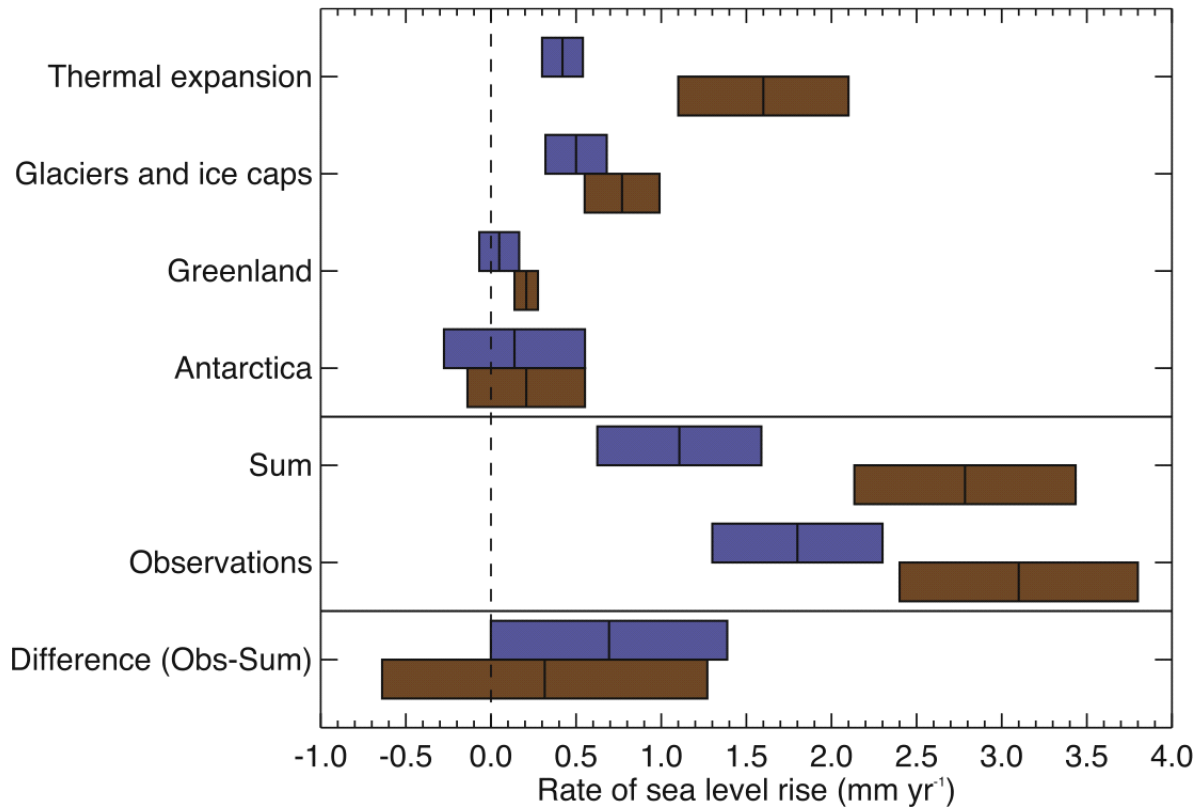
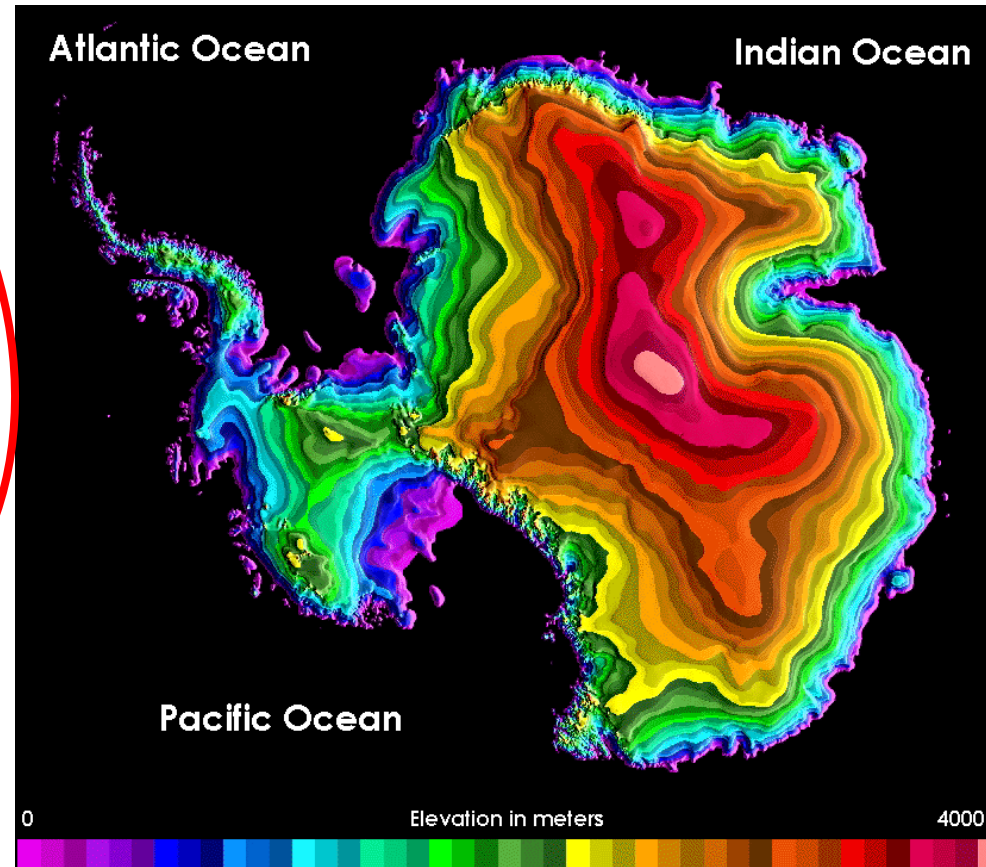
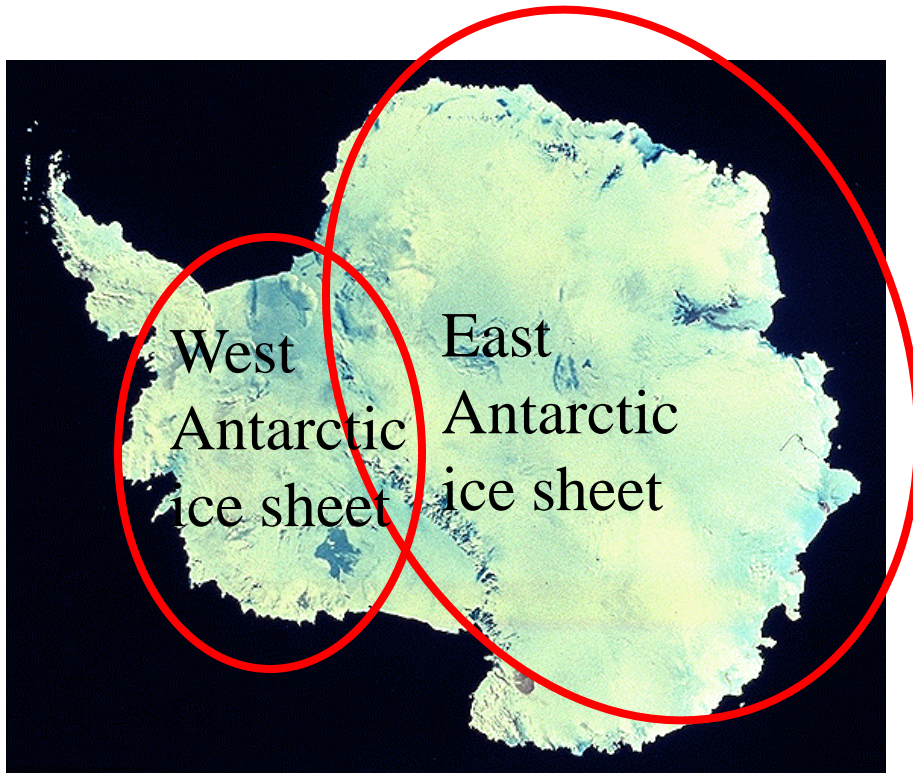


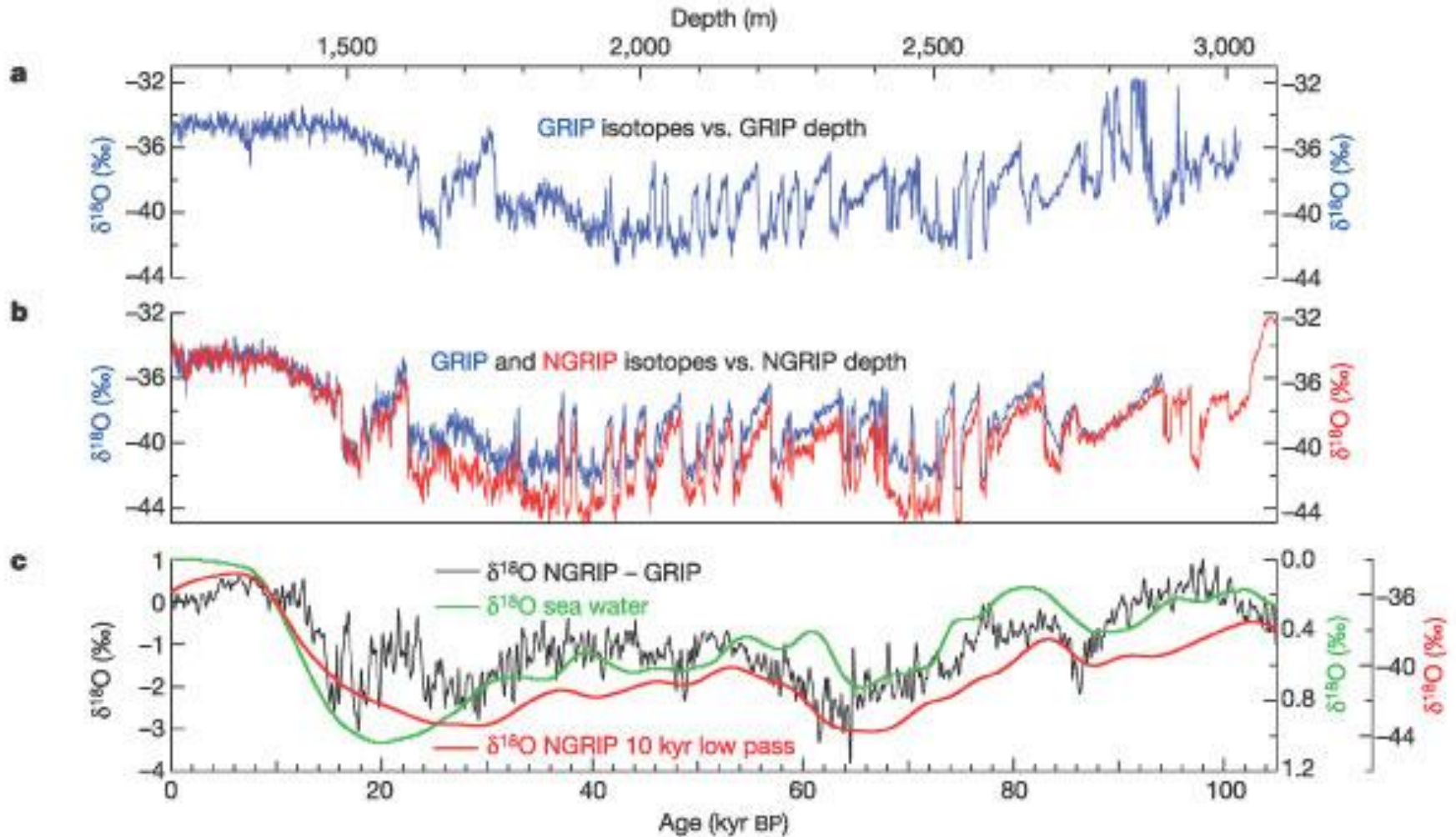
Figure 5.21. Estimates of the various contributions to the budget of the global mean sea level change (upper four entries), the sum of these contributions and the observed rate of rise (middle two), and the observed rate minus the sum of contributions (lower), all for **1961 to 2003 (blue)** and **1993 to 2003 (brown)**. The bars represent the 90% error range. For the sum, the error has been calculated as the square root of the sum of squared errors of the contributions. Likewise the errors of the sum and the observed rate have been combined to obtain the error for the difference.

Antarctica



Ice piled up on continental bedrock

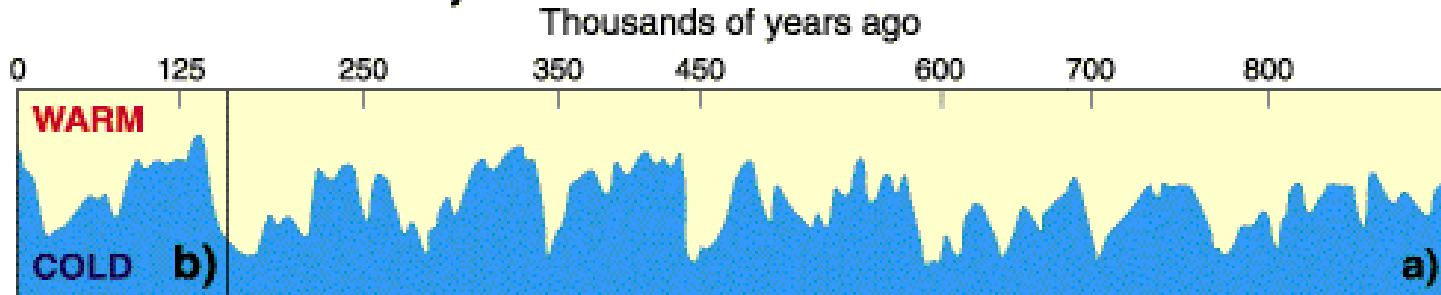
Ice cores from Greenland



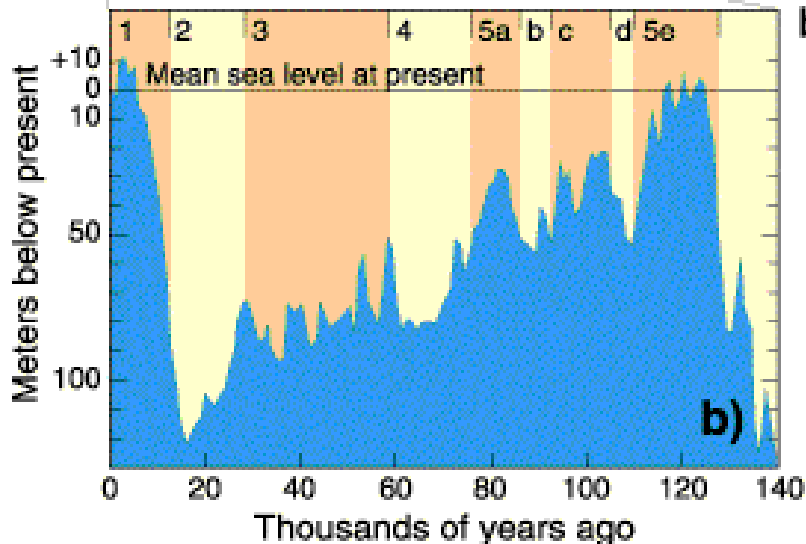
Notice sea water scale OPPOSITE ice sheet scale.

Long term sea level

a. Global climate history



b. Late Quaternary sea-level history



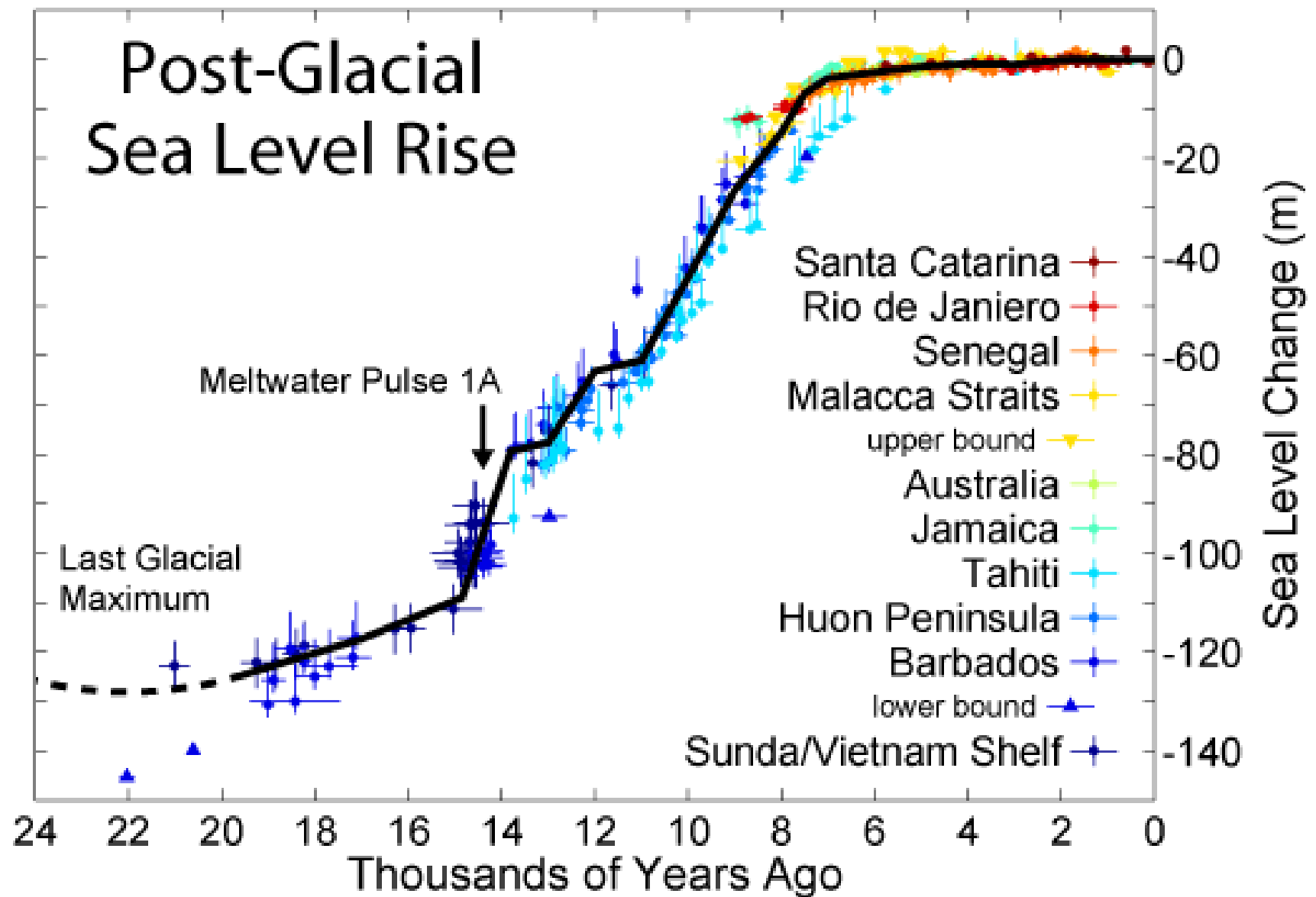
Note – looks quite like the Vostok Ice core record!

When isotopes not in ocean, they are on in the ice sheets. Thus isotopes also tell about sea level

Last ice age (21000 years ago)

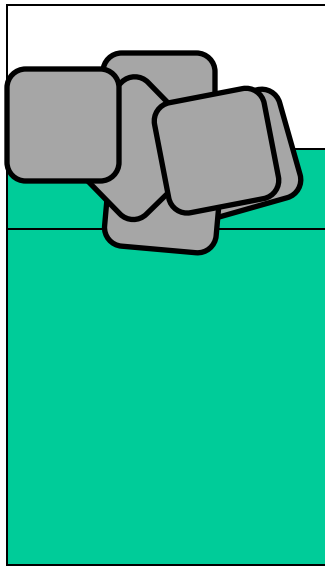


Post-Glacial Sea Level Rise

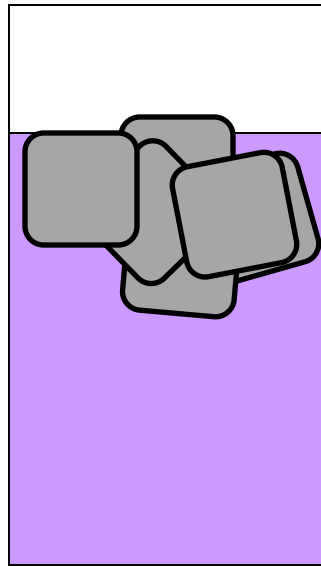


Recall Scott's "cool aid"

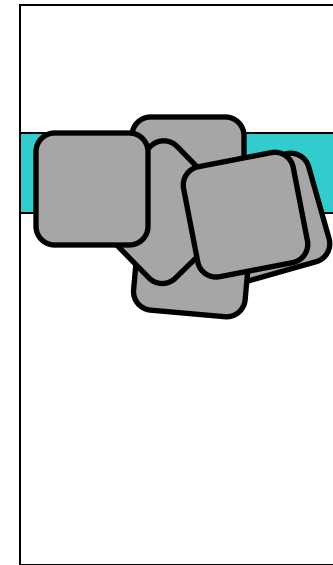
3 cases...



Freshwater
"ice sheet" with
grounded ice

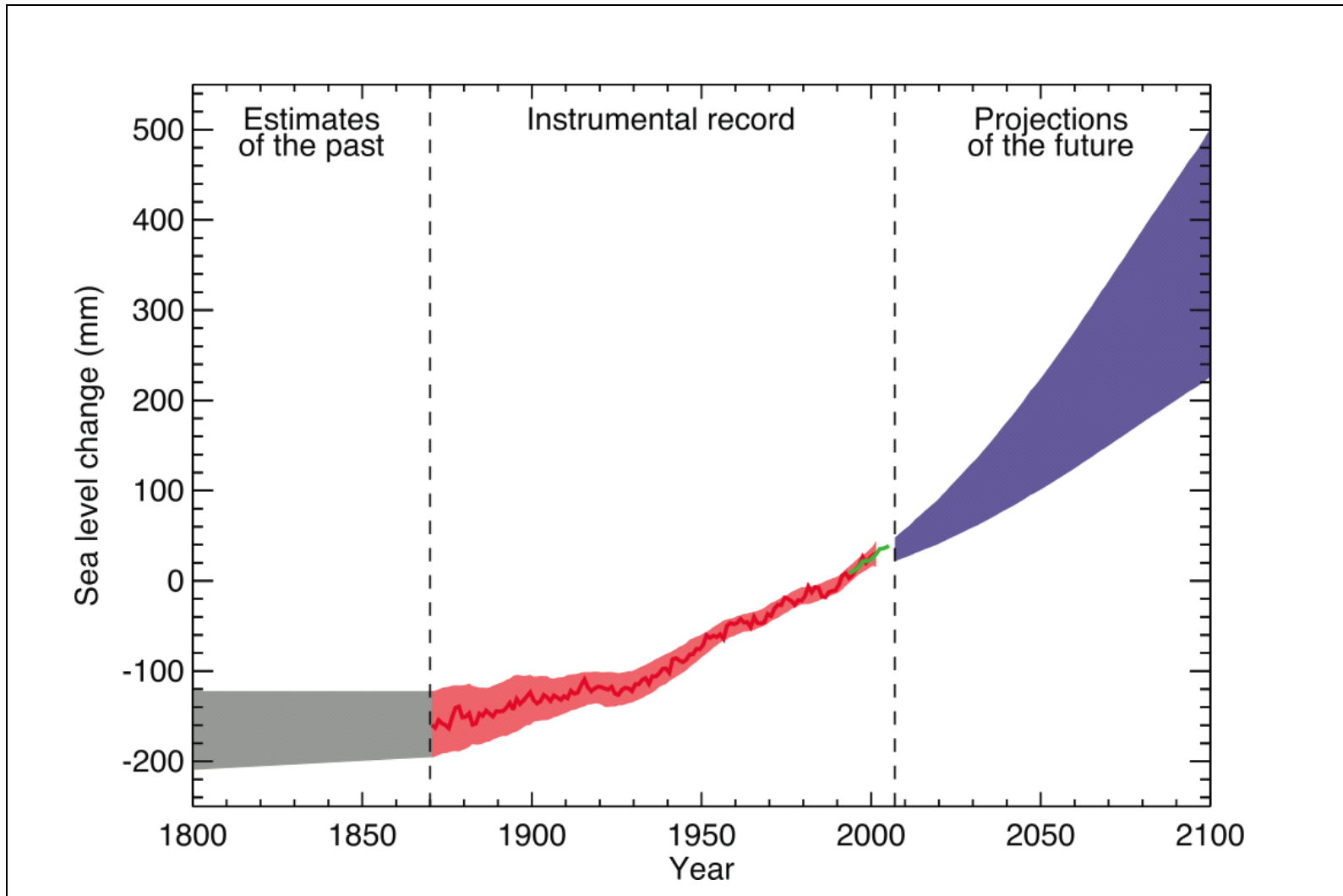


Freshwater "well
mixed" with
convection
(no sea level rise)



Salty water "stratified"
with freshwater
discharge
(like melt pulse)

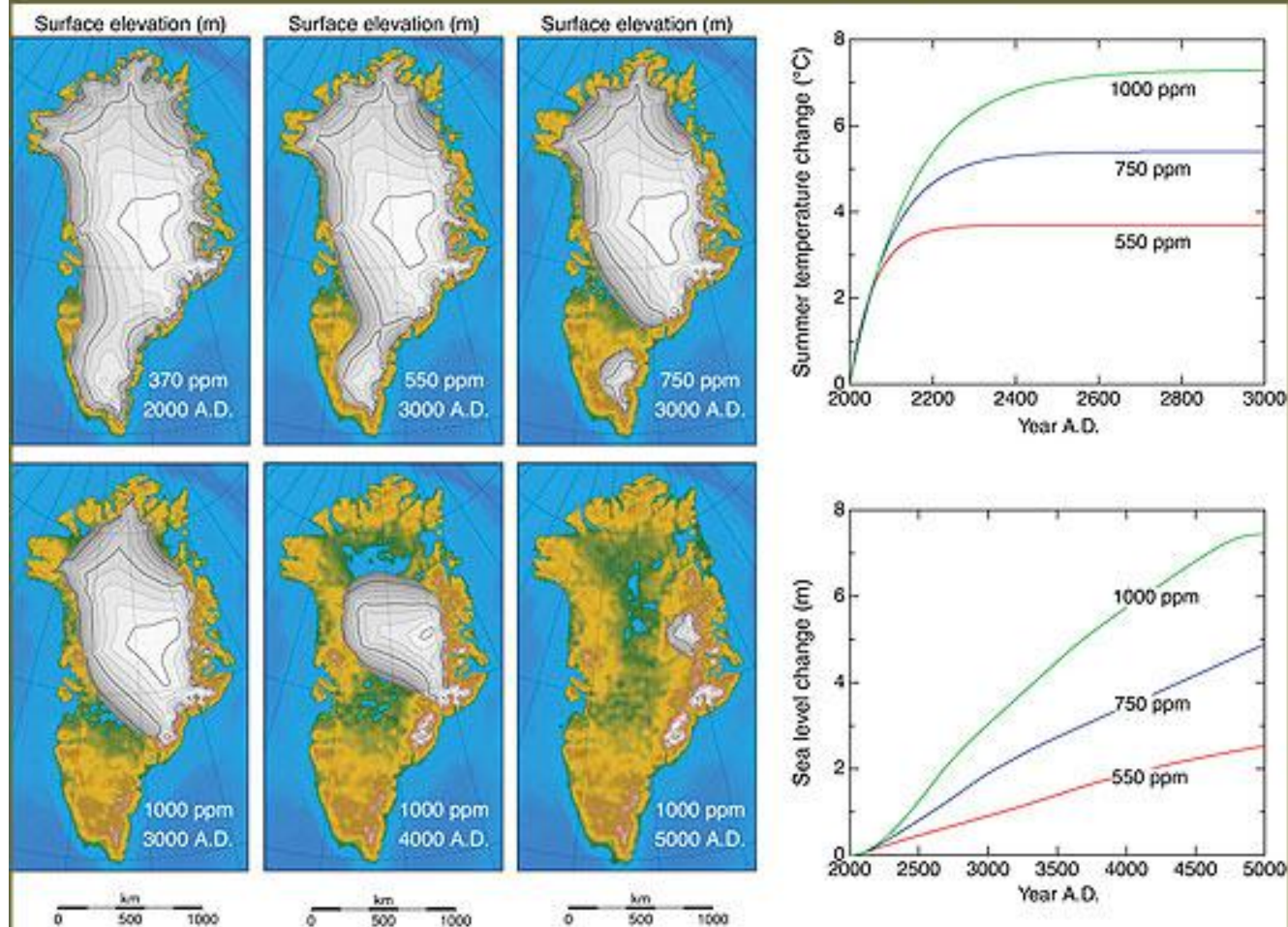
Future sea level?



Some suggest could be much more if
Greenland melts faster than expected.

FAQ 5.1, Figure 1

Future evolution of the Greenland Ice Sheet



Note: Future evolution of the Greenland Ice Sheet calculated from a 3D ice-sheet model forced by three greenhouse gas stabilization scenarios. The warming scenarios correspond to the average of seven Intergovernmental Panel on Climate Change (IPCC) models in which the atmospheric carbon dioxide concentration stabilizes at levels between 550 and 1000 ppm after a few centuries and is kept constant after that. For a sustained average summer warming of 7.3°C (1000 ppm), the Greenland Ice Sheet is shown to disappear within 3000 years, raising sea level by about 7.5 m. For lower carbon dioxide concentrations, melting proceeds at a slower rate, but even in a world with twice as much CO₂ (550 ppm or a 3.7° C summer warming) the ice sheet will eventually melt away apart from some residual glaciation over the eastern mountains.

Source: Alley, Richard B, et al. "Ice-Sheet and Sea-Level Changes." *Science* 310(5747): 456-460 (21 October 2005).

Works with 100 meters sea level rise



Greenland and Antarctica melted

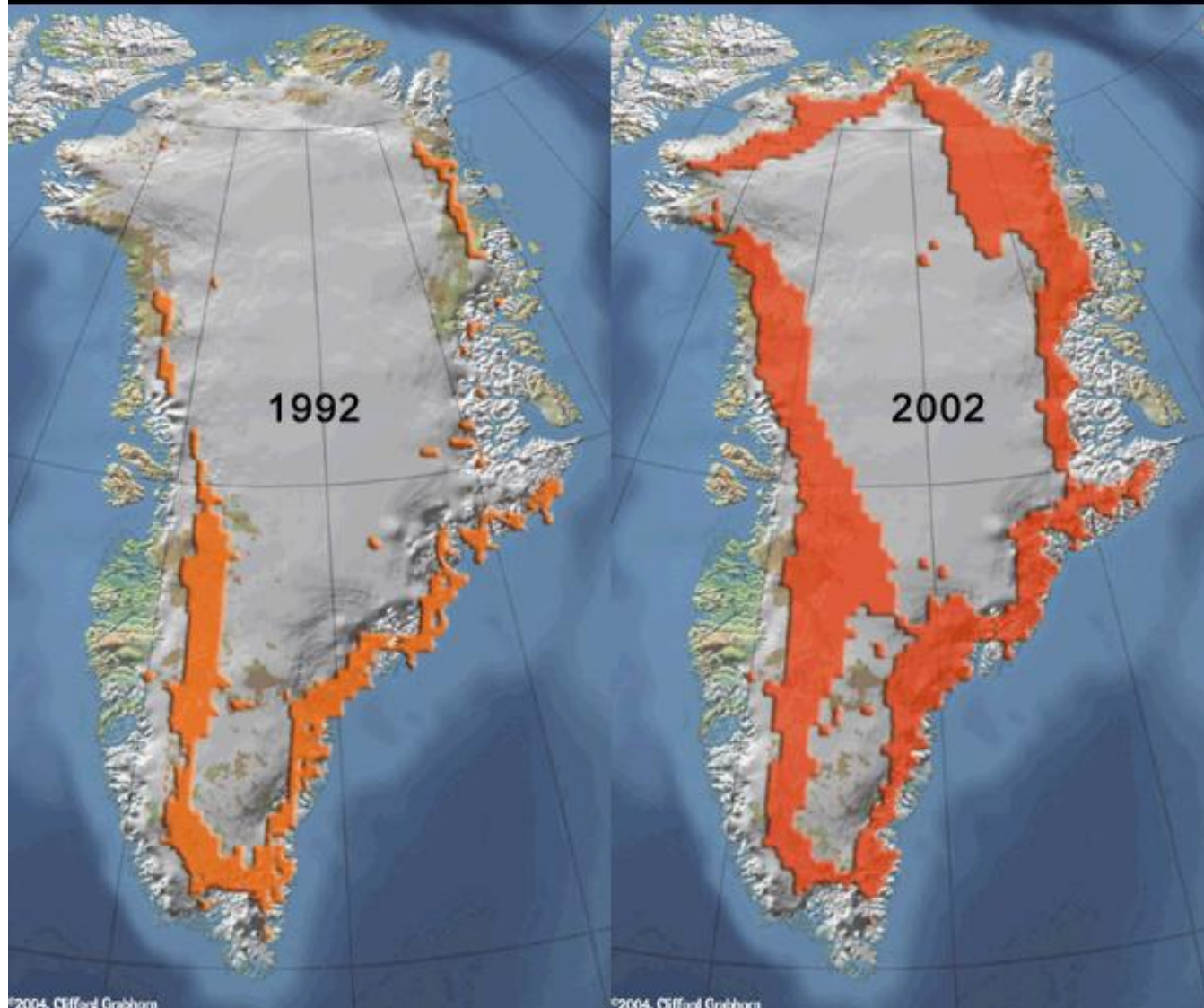


100 meters sea level rise
not likely!

But acts to remind us
that the 7 meters stored
in Greenland would be
quite catastrophic for
coastal communities.

Recent melting of Greenland

Greenland Ice Sheet Melt 1992 to 2002



Based on
work done
at CU in
CIRES!



Rapid collapse of Greenland if water acts as a lubricant at the base of the ice sheet. The Greenland ice sheet and the West Antarctic ice sheet might just “slide off” into the ocean.

A moulin in Greenland.

Key points

- Sea level rises with water previously stored on the continents (ice sheets, glaciers) melting.
- No sea level change with sea ice melt, since it is floating (*recall buoyancy and displacement!*)
- Sea level change due to thermal expansion.
- *Warmer water expands!*
- *Most of sea level change to date due to thermal expansion.*

- If Greenland ice sheet melts, could result in 7 meters of sea level rise.
- If West Antarctic ice sheet melts, another 12 or so meters
- *In unlikely case that all of Antarctica melts, 100-180 meters of sea level rise!*

- Sea level rise will have substantial consequences for nations at low elevations, and coastal locations.
- Recent suggestions are that there will be about 1 meter of sea level rise over the next 100 years.
- Many scientists suggest there is evidence that the IPCC report vastly underestimates the possible sea level rise, because of the lack of “fast ice” processes