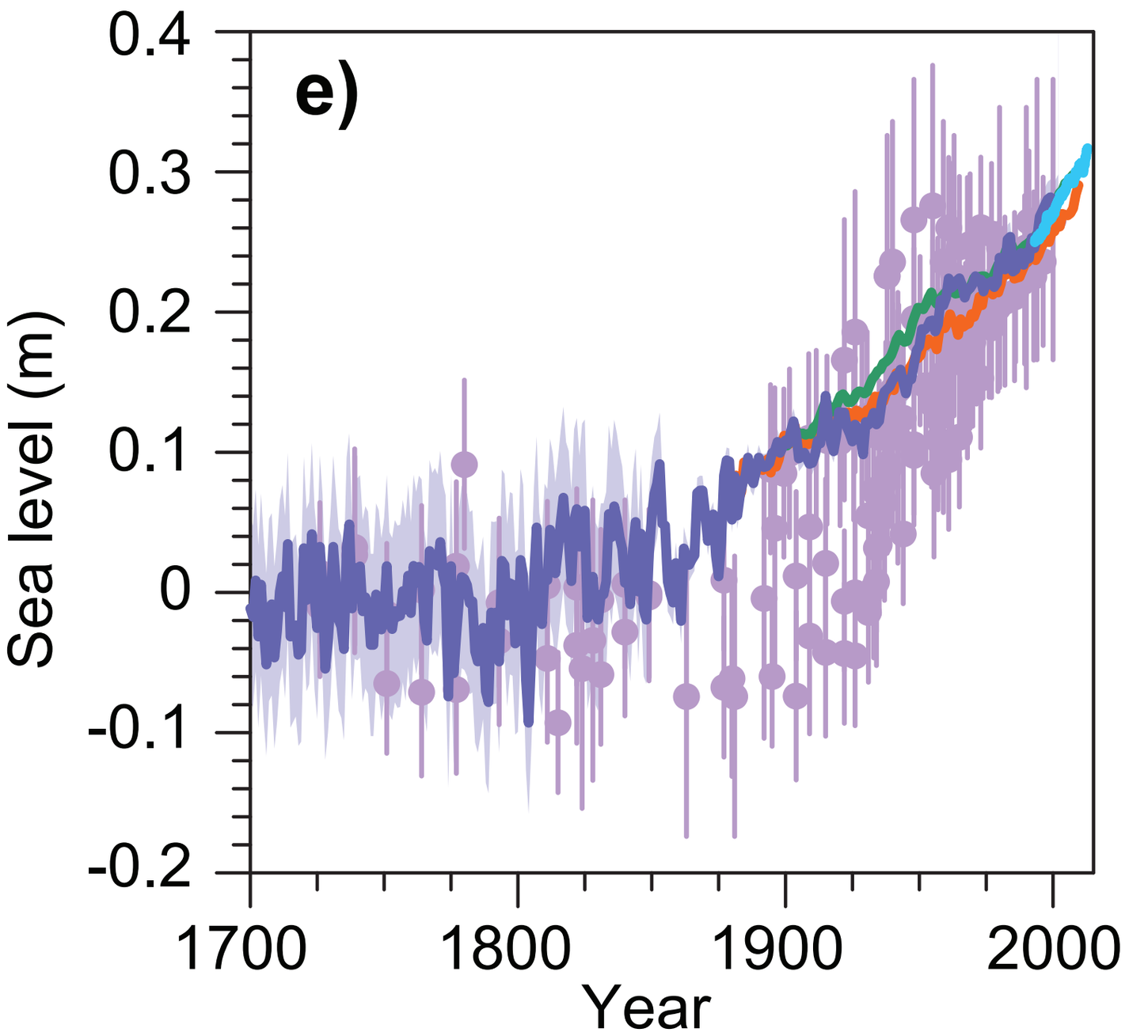
A (Brief) History of Sea Level Change

Recent sea level change

IPCC 2013 Report

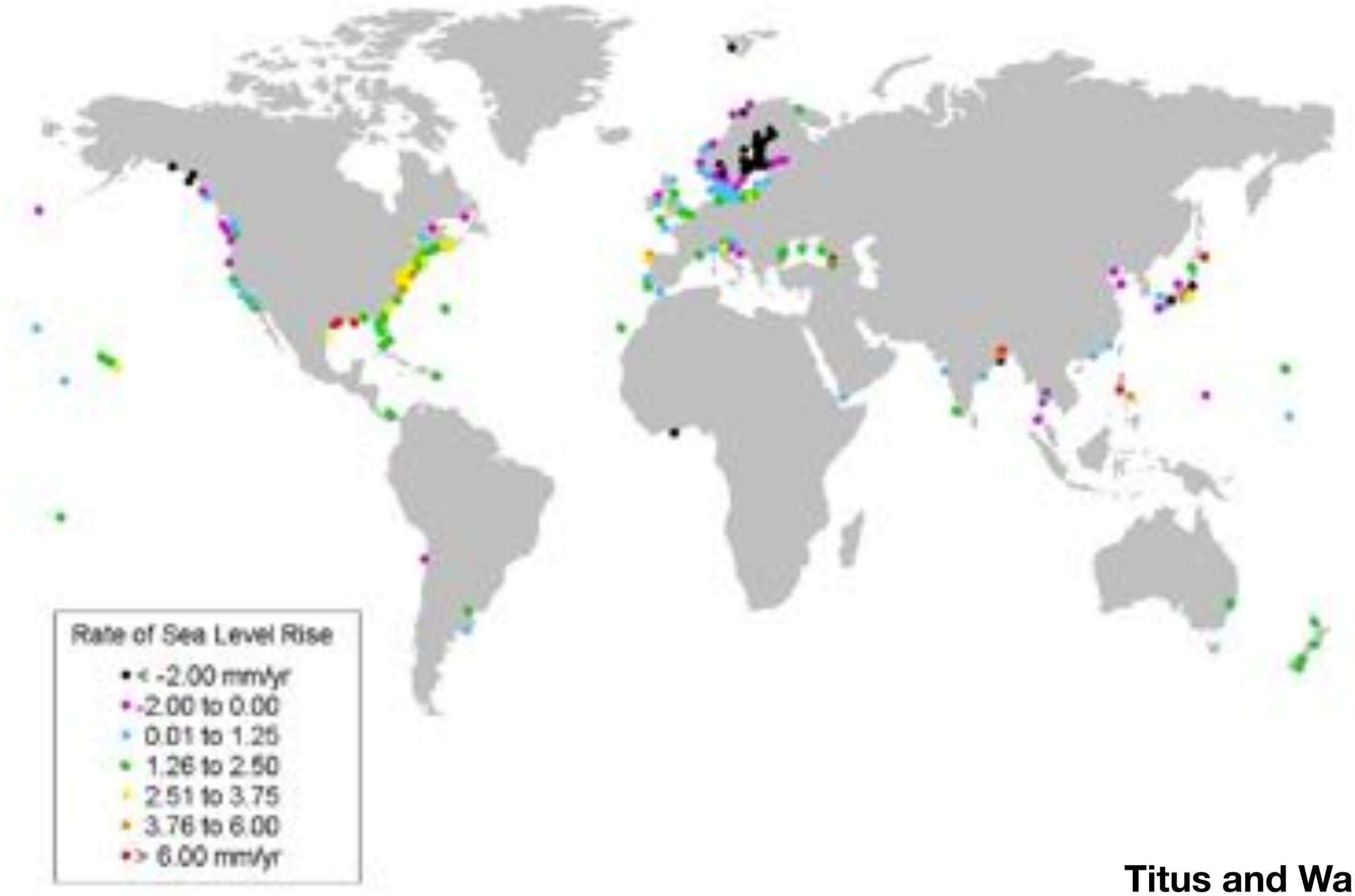


Averaged tide gauges (three different methods)
Altimetry

Since ~1900 global mean sea level has been increasing at a rate of 1.5-2 cm/ decade.

Recent sea level change

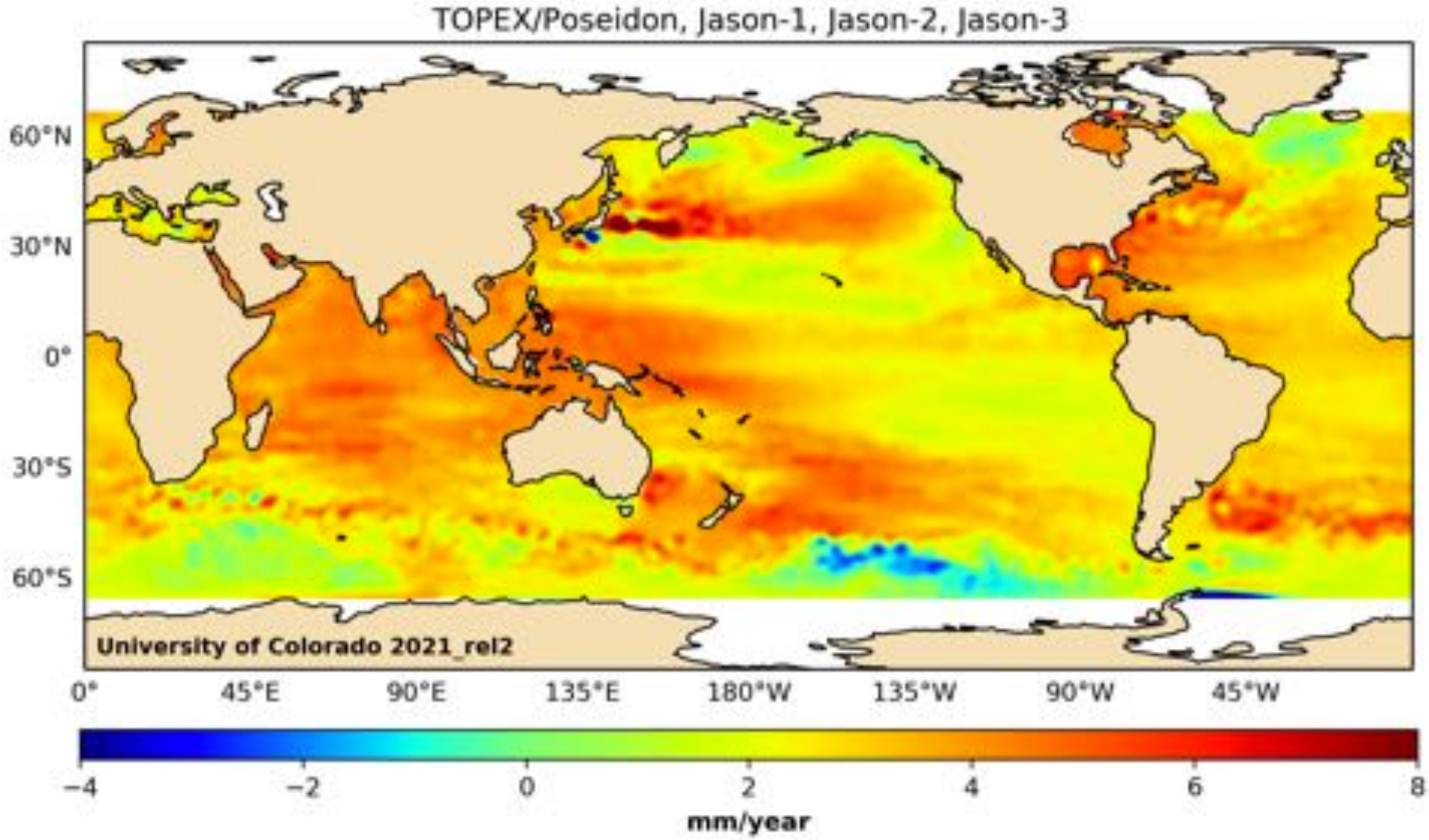
Trends from tide gauges over last 50 years



Titus and Wang 2008

Recent sea level change

Trends from altimetry satellites over last 30 years



Data from https://sealevel.colorado.edu/trend-map

Recent sea level change

Trends from altimetry satellites over last 30 years

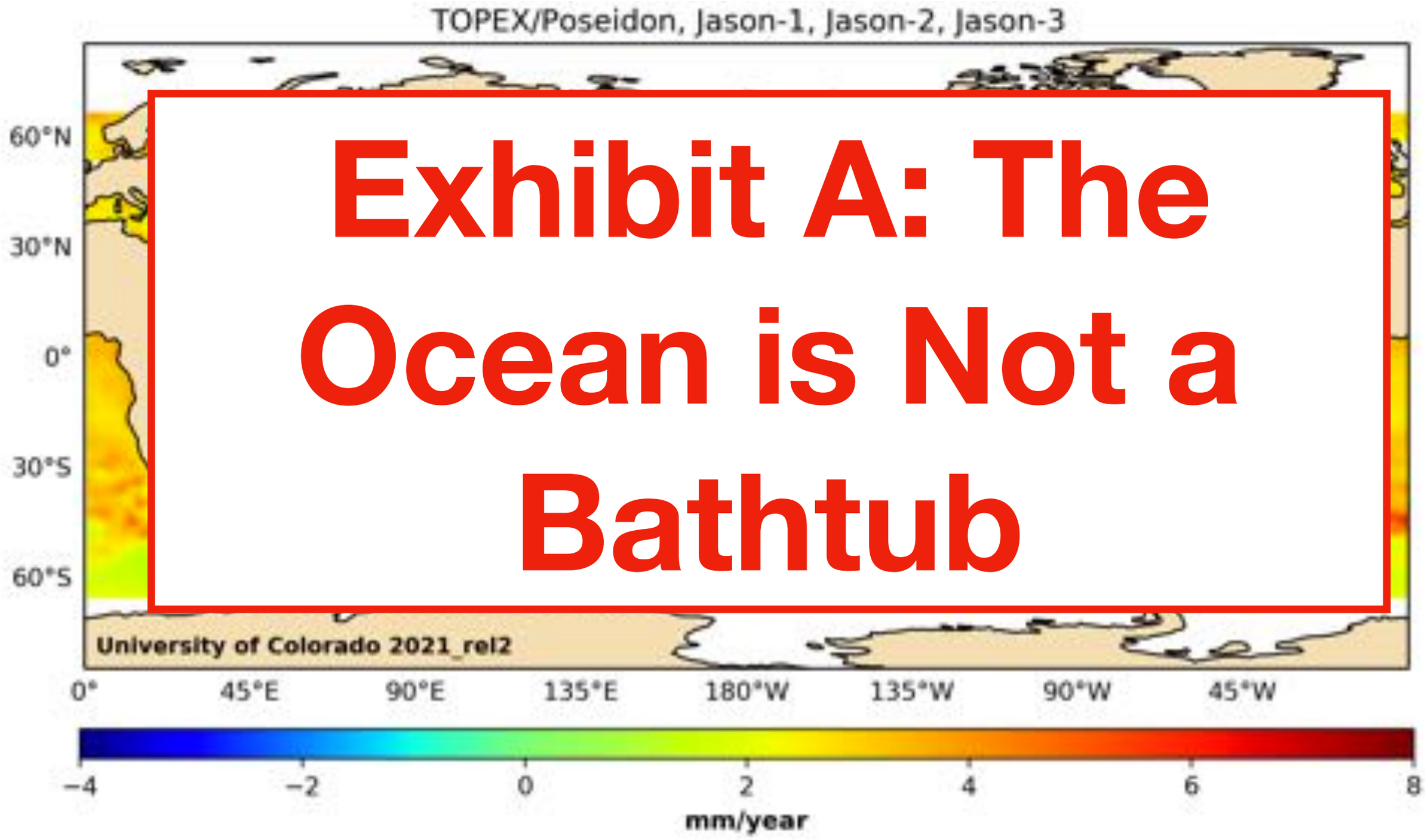
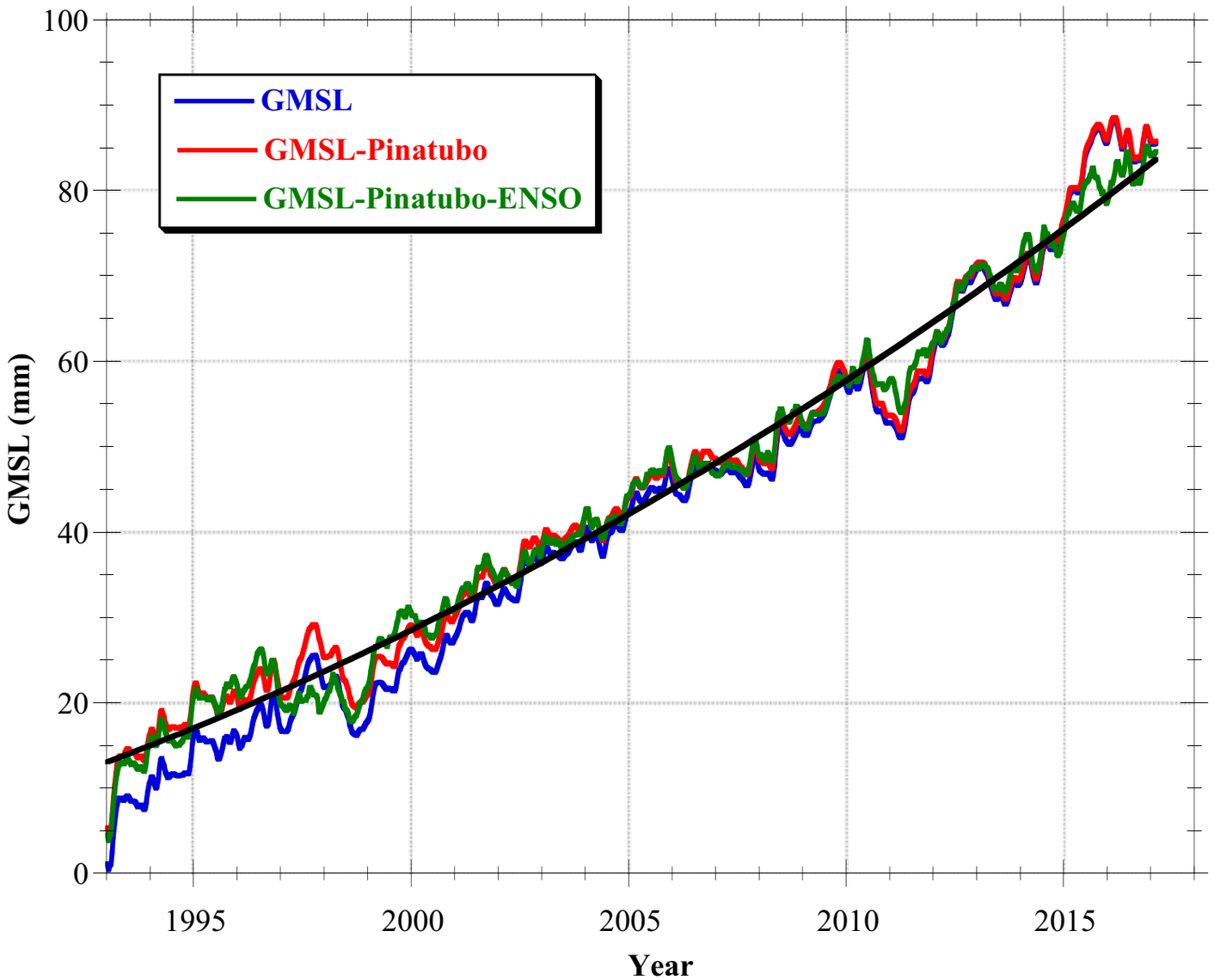


Exhibit A: The Ocean is Not a Bathtub

Data from https://sealevel.colorado.edu/trend-map

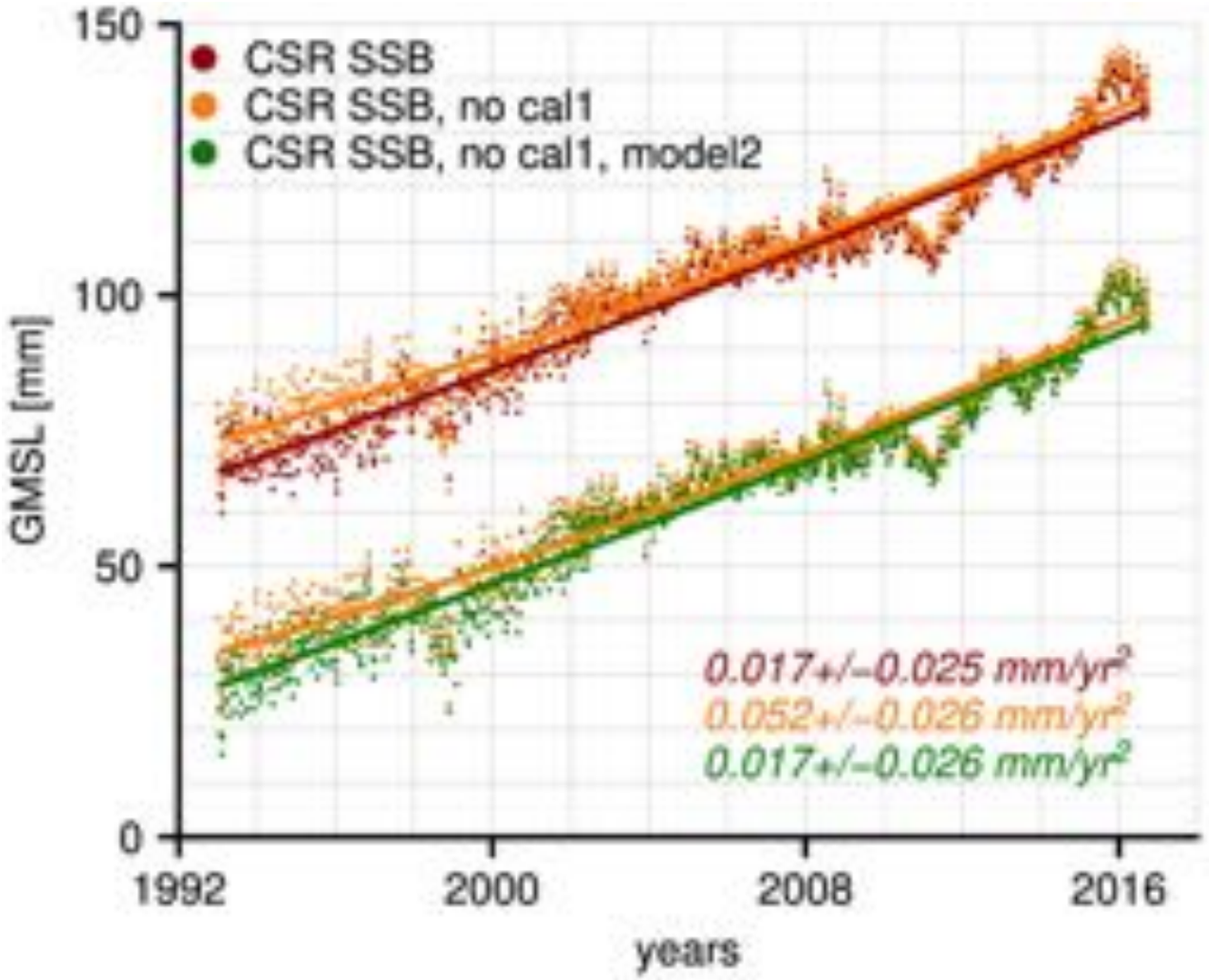
Recent sea level change



Nerem et al. 2018

Since ~1990 global mean sea level has been increasing at a rate of ~3 cm/ decade.

Recent sea level change



Kleinherenbrink et al. 2019

Or has it?
(wonky: when corrected for inter-mission altimeter bias)

Recent sea level change

Table 2. Validation of acceleration estimate

Component	Time period	Rate, mm/y; Epoch 2005.0	Acceleration, mm/y^2
Greenland	2002.3–2017.0	0.66	0.0236
Antarctica	200.32–2017.0	0.19	0.0332
Mountain glaciers and small ice caps	2002.3–2017.0	0.51	0.0094
Thermosteric*	1993.0–2016.0	1.65	0.0076
Components total		3.01	0.074
Altimeter observed	1993.0–2017.0	3.1	0.097
Altimeter observed*	1993.0–2017.0	2.9	0.117
Altimeter observed†	1993.0–2017.0	2.9	0.084

*Corrected for Pinatubo.
†Corrected for Pinatubo and ENSO effects (climate-change–driven acceleration).

Nerem et al. 2018

Still: pieces of sea level budget (what goes into setting sea level) have accelerated since 1990

Recent sea level change

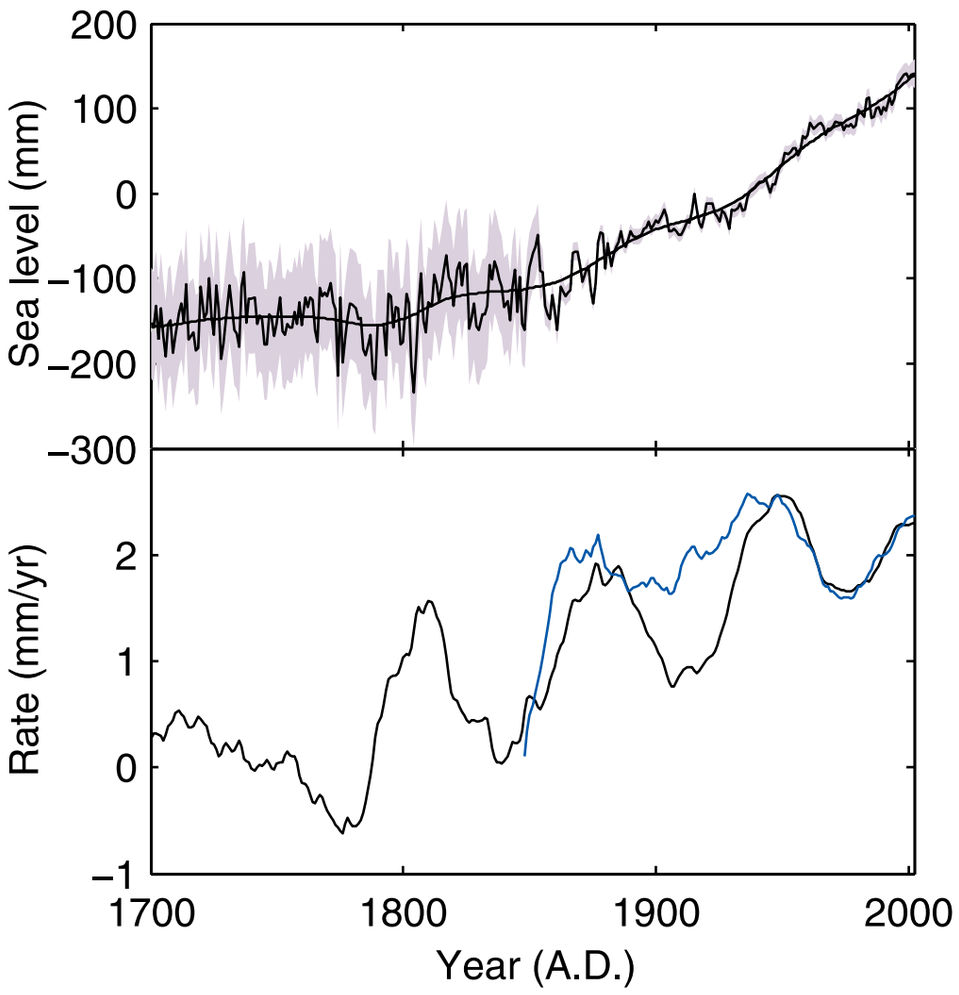
GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L08715, doi:10.1029/2008GL033611, 2008

Recent global sea level acceleration started over 200 years ago?

S. Jevrejeva,[1] J. C. Moore,[2,3] A. Grinsted,[2] and P. L. Woodworth[1]

Received 12 February 2008; revised 19 March 2008; accepted 28 March 2008; published 30 April 2008.

(Dark blue line in previous slide)

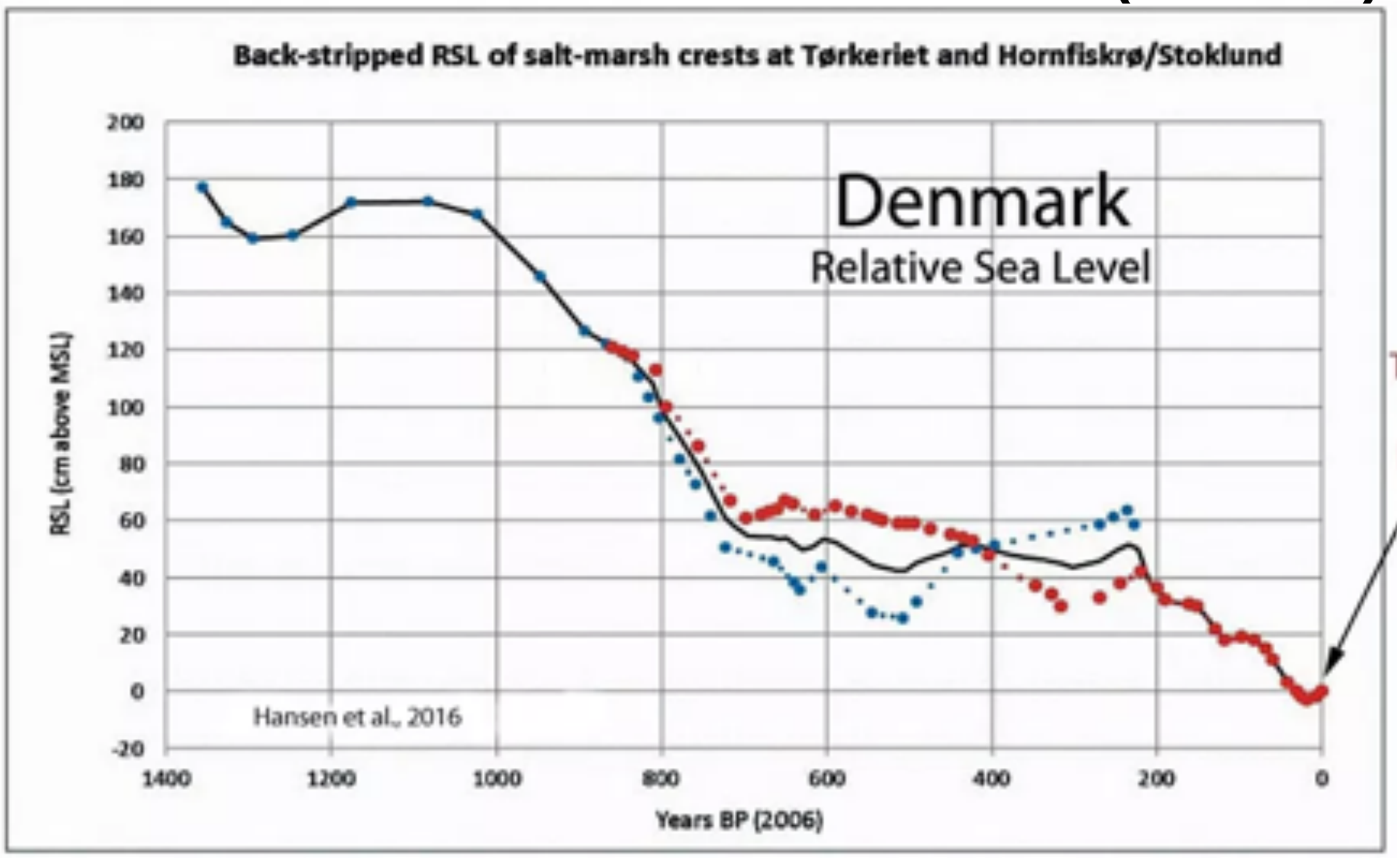


Modern sea level rise probably started in the 1800s - as long as the climate has been changing, so has sea level.

How do we measure sea level before the instrumental era? (~1700)

As local sea level changes, the distribution of corals, salt marshes and beaches changes, leaving behind an archive of past sea level

How do we measure sea level before the instrumental era? (~1700)



As local sea level changes, the distribution of corals, salt marshes and beaches changes, leaving behind an archive of past sea level

How do we know about sea level before the instrumental era? (~1700)

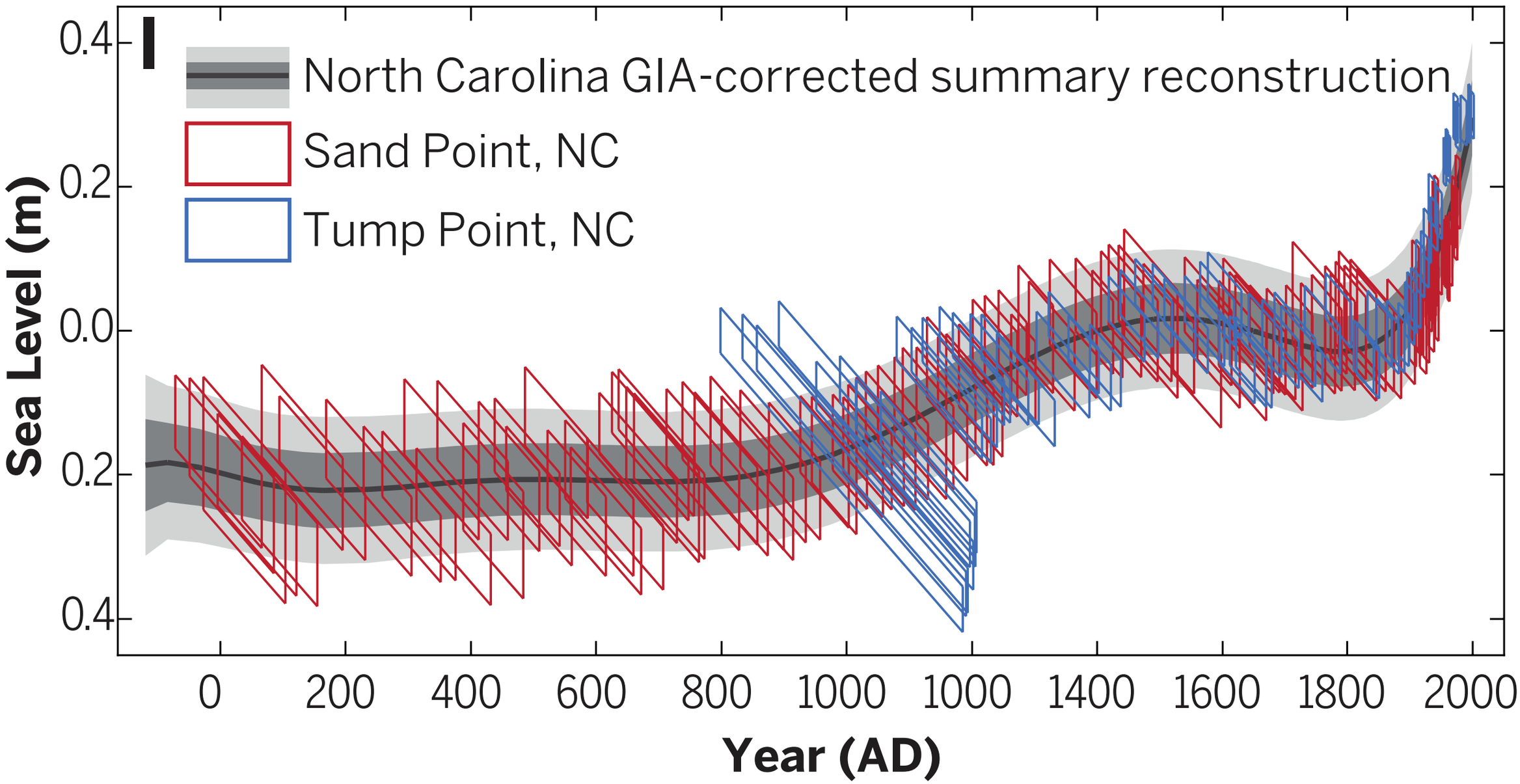
Ancient shorelines leave behind evidence of past beaches, deposits and different elevation - can be dated

How do we measure sea level before the instrumental era? (~1700)

Corals!

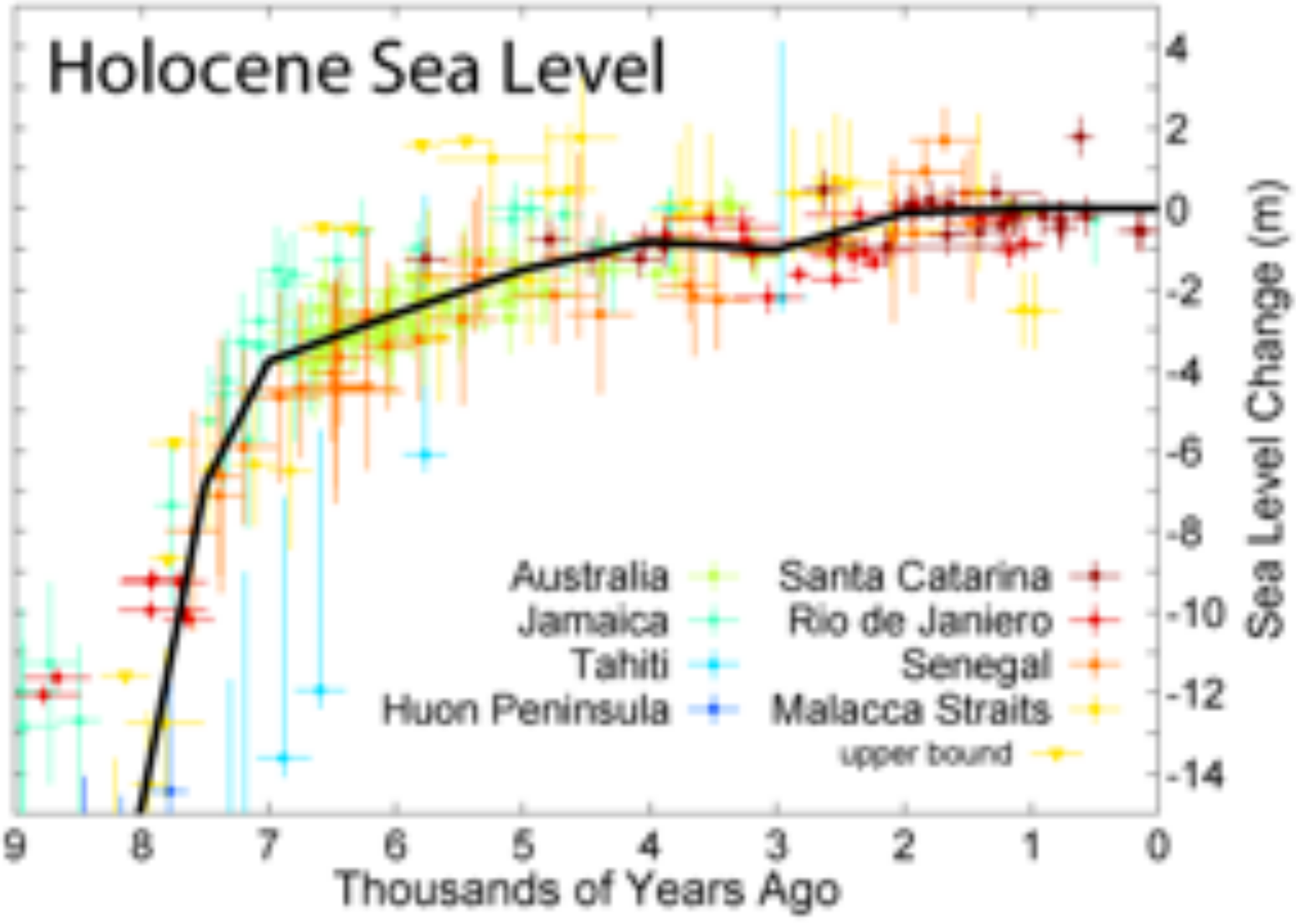
"…corals occupy a narrow vertical depth range and have good geological preservation potential."
-Woodroffe & Webster 2016

Less recent sea level change

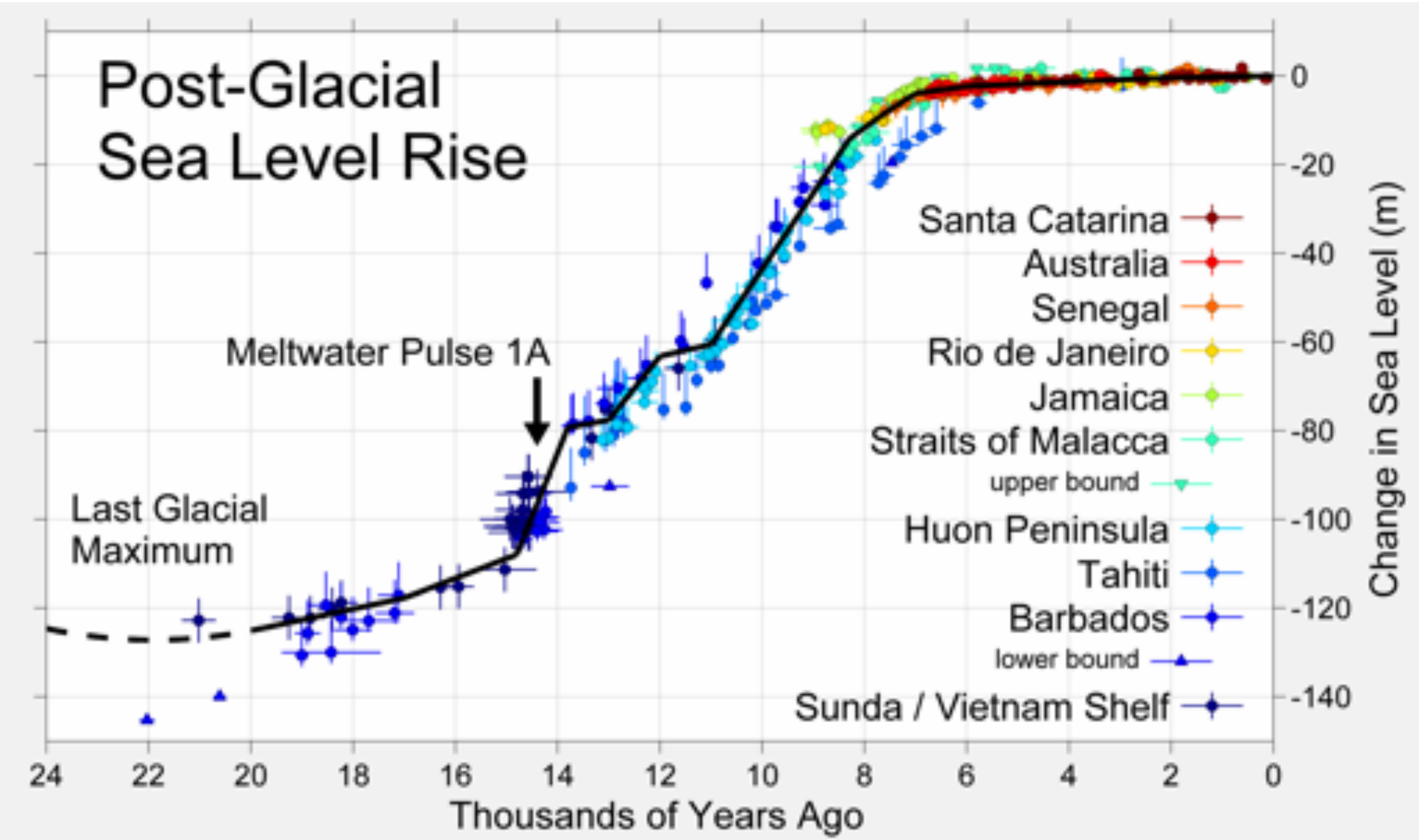


Dutton et al. 2015

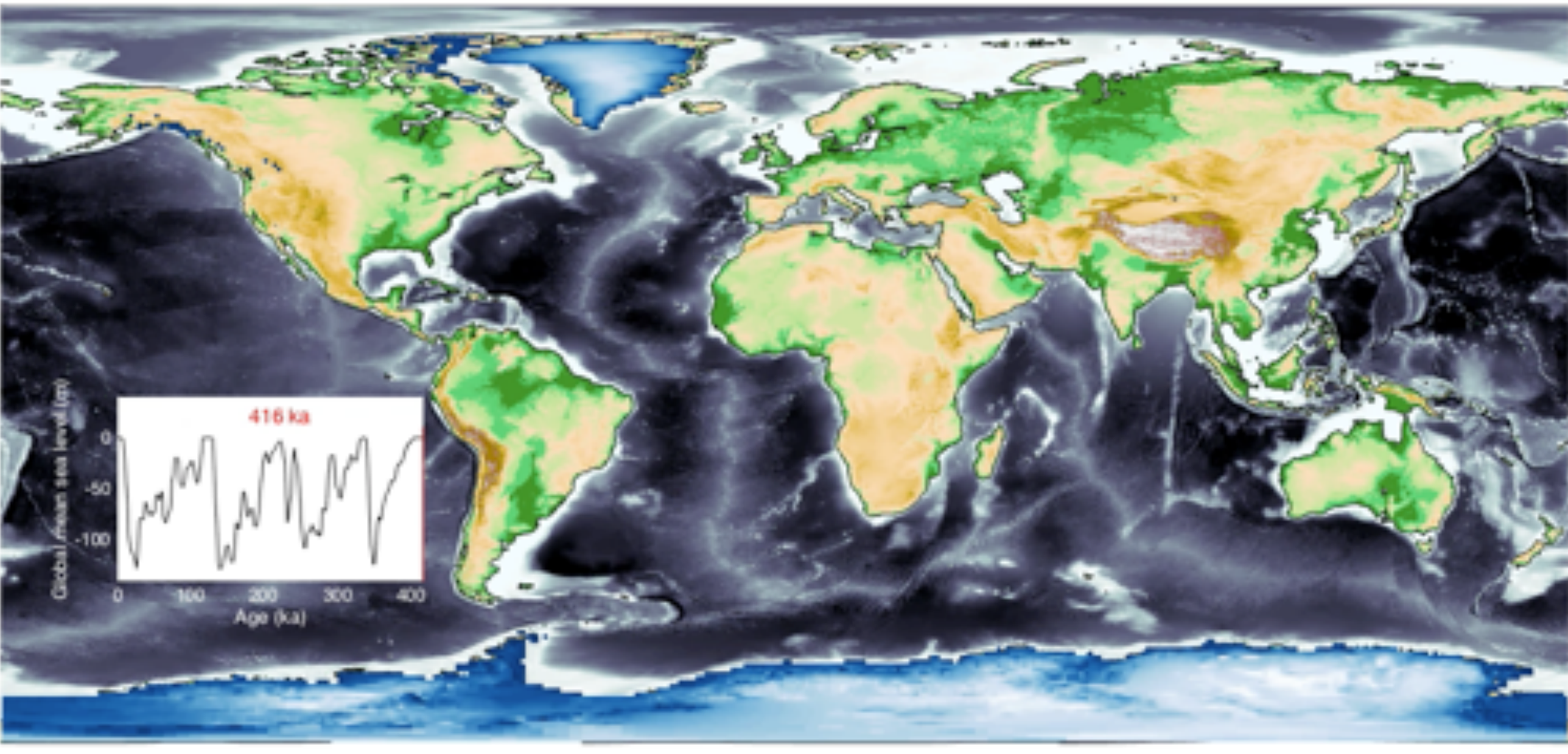
Less recent sea level change



Less recent sea level change

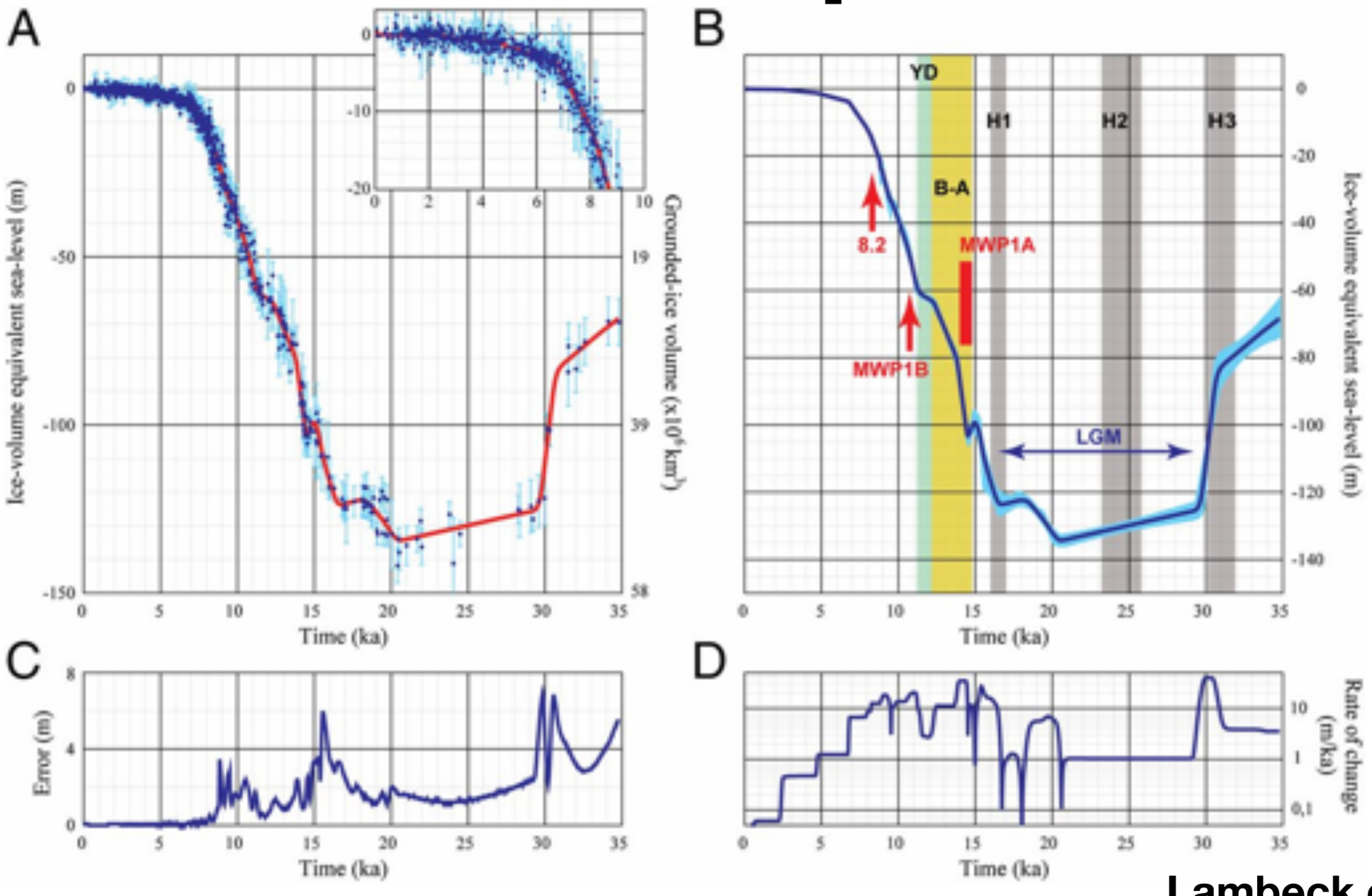


Ice ages



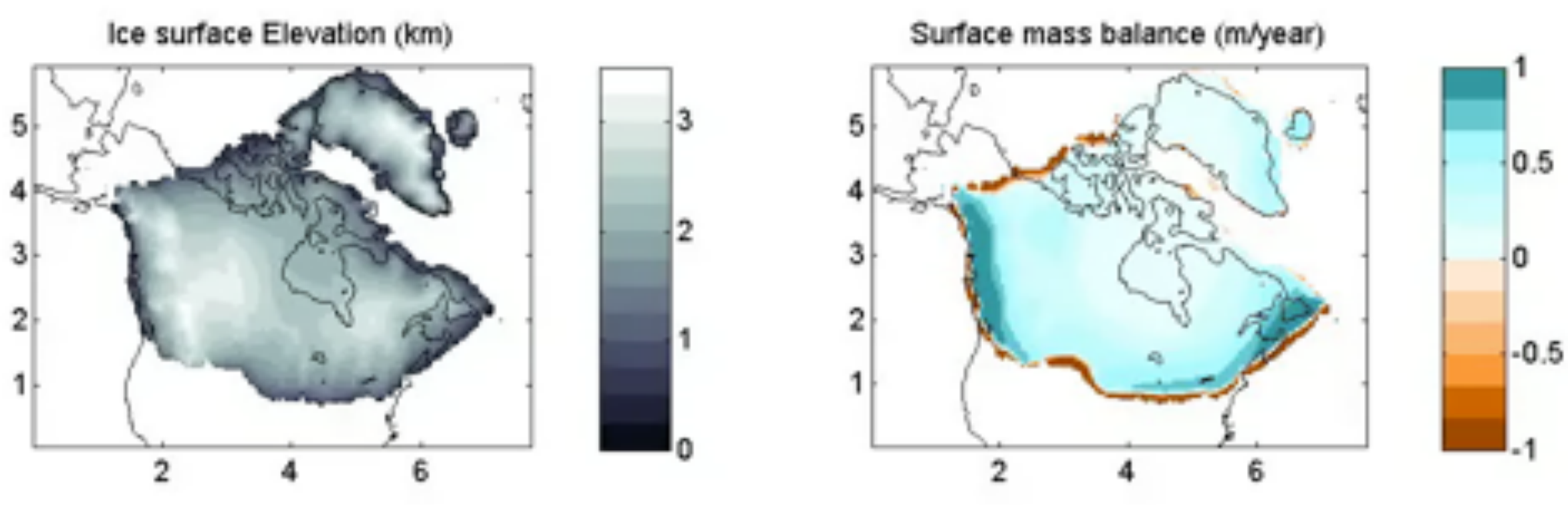
Dendy et al. 2017

Meltwater pulses

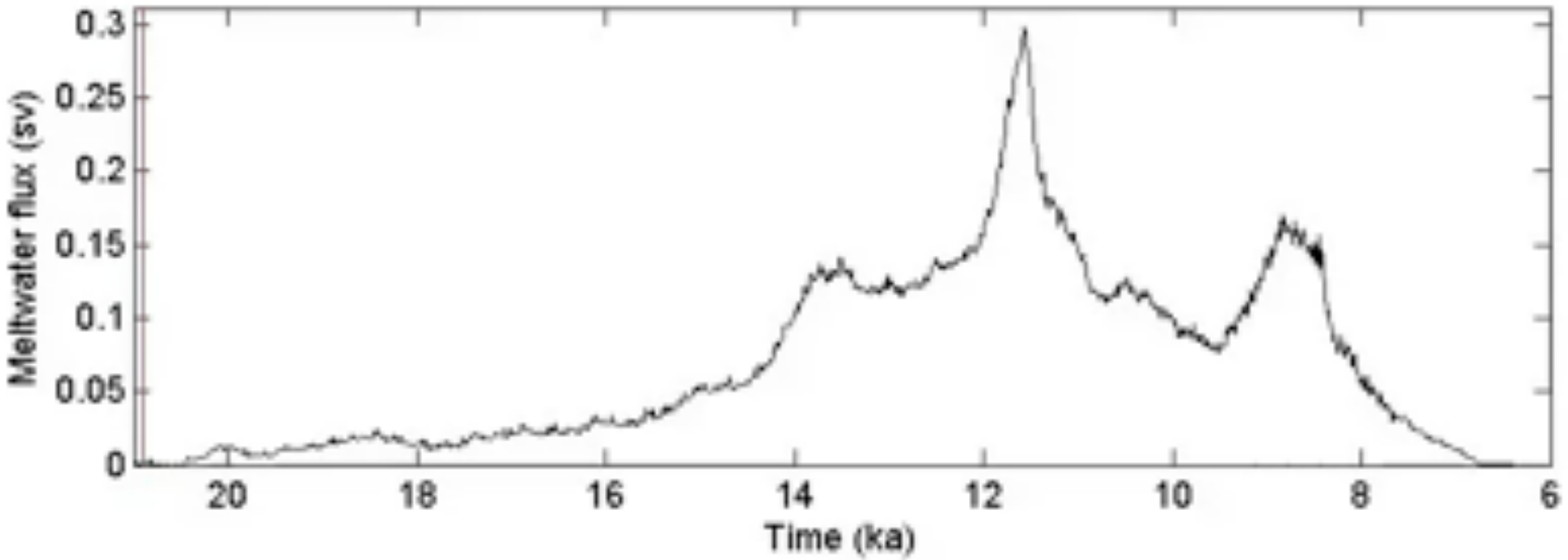


Lambeck et al. 2014

Meltwater Pulse 1A - Corals, ancient beaches and many other proxies show that 14,600 years ago global mean sea level jumped by 10-20 meters in <500 years - this is 10x faster than current sea level rise

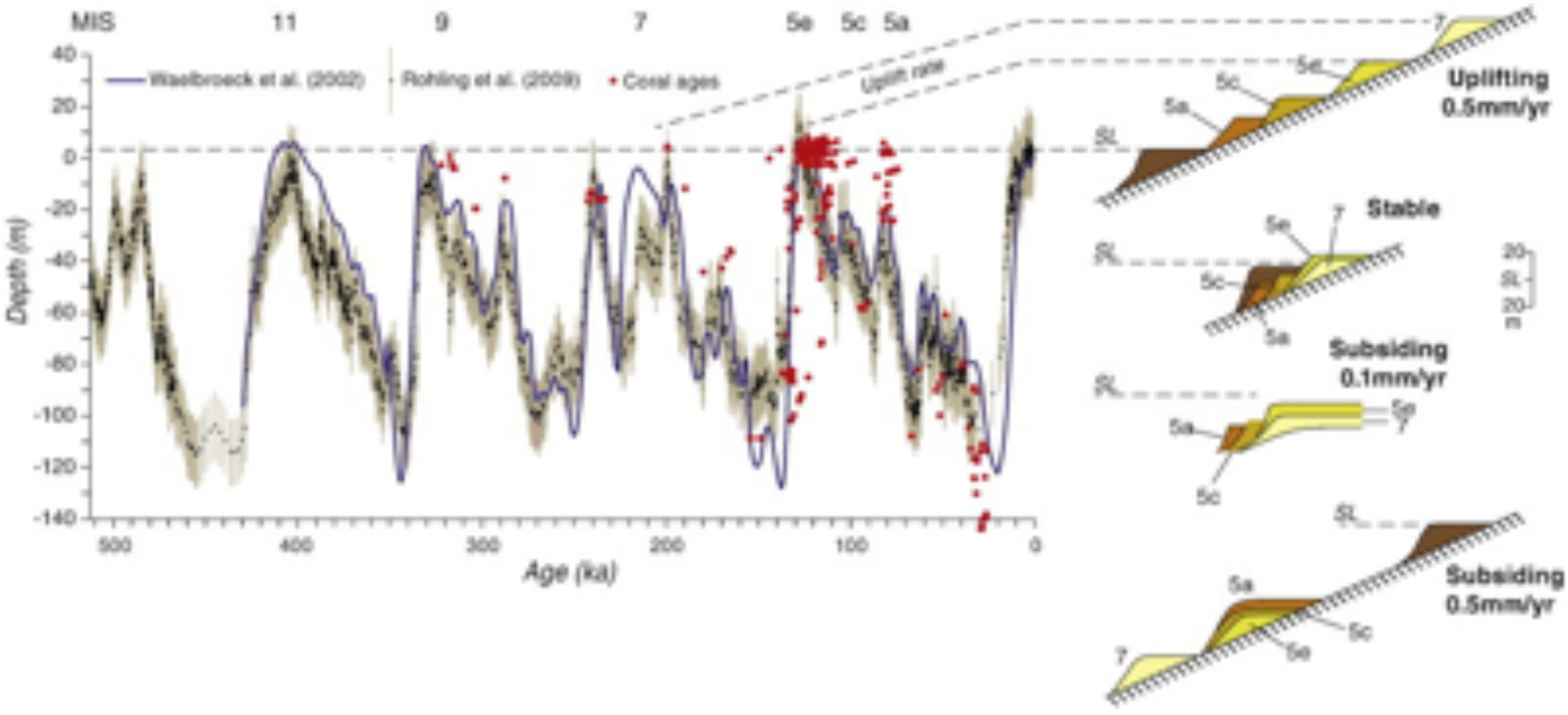


Many theories about where this MWP came from - still being debated



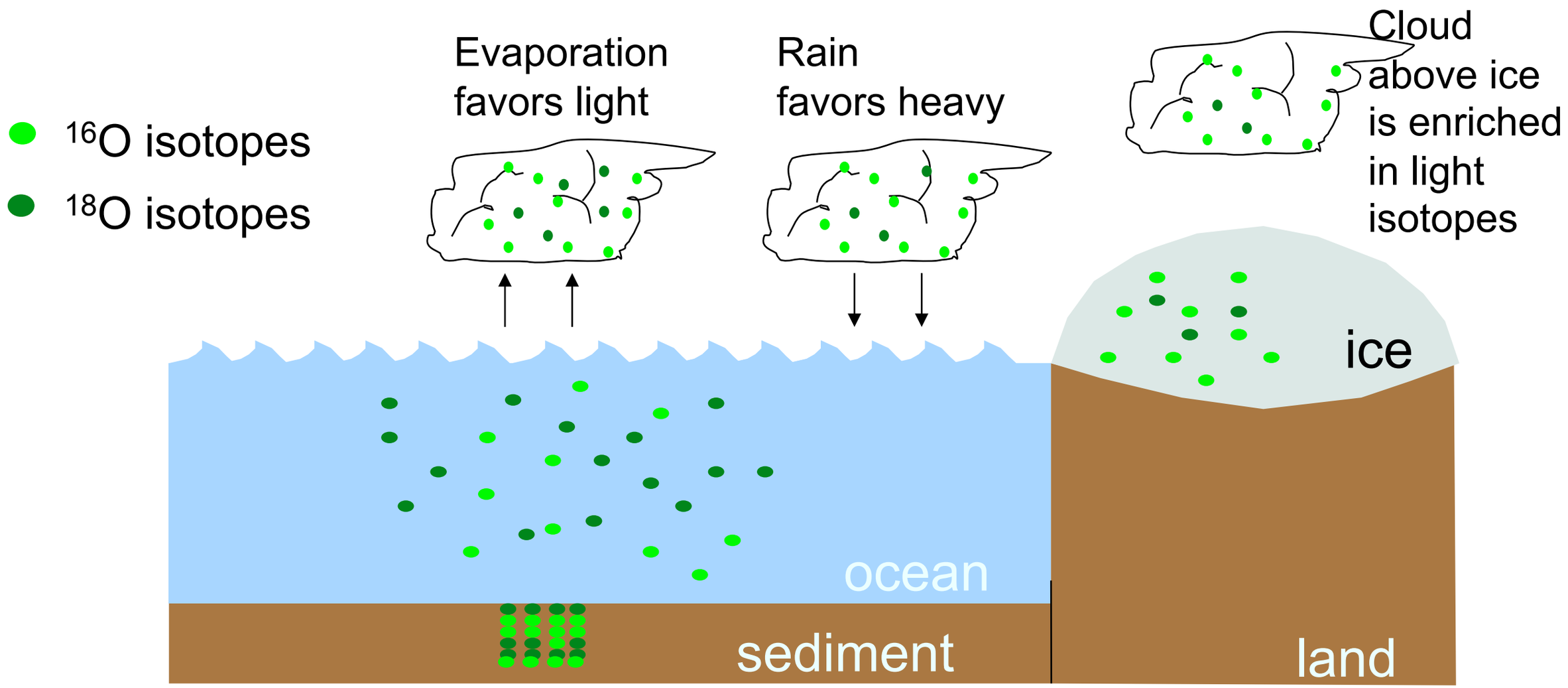
Gregoire et al. 2012

Ice Ages


MIS
11
9
7
5e
5c
5a
Waelbroeck et al. (2002)
Rohling et al. (2009)
Coral ages
Uplift rate
Depth (m)
Age (ka)
Uplifting
0.5mm/yr
Stable
Subsiding
0.1mm/yr
Subsiding
0.5mm/yr
SL
20 m

How do we know about sea level before the instrumental era? (~1700)

$\delta^{18}O$ from ocean sediments as proxy for ice volume

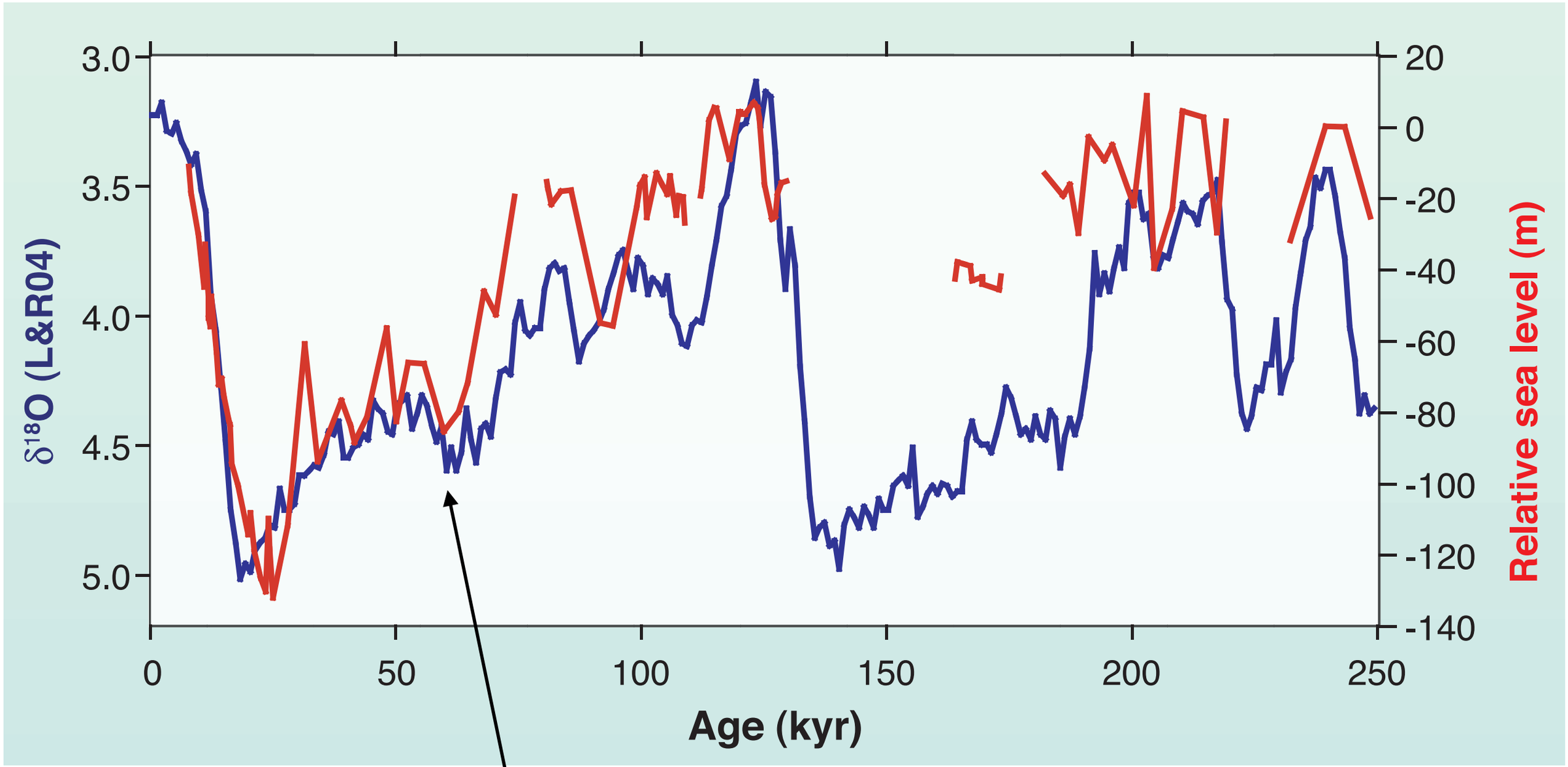


When water evaporates from the ocean, it preferentially takes light oxygen isotopes with it, its leaves heavier oxygen in the ocean. When the water is precipitated as snow, it deposits H20 with light oxygen. The H20 left in the ocean has more heavy oxygen (it is enriched).

Schematic from C. Bitz

$$\delta^{18}O = \left(\frac{\left(\frac{^{18}O}{^{16}O}\right)_{sample}}{\left(\frac{^{18}O}{^{16}O}\right)_{standard}} - 1 \right) * 1000\ {}^{o}/_{oo}$$

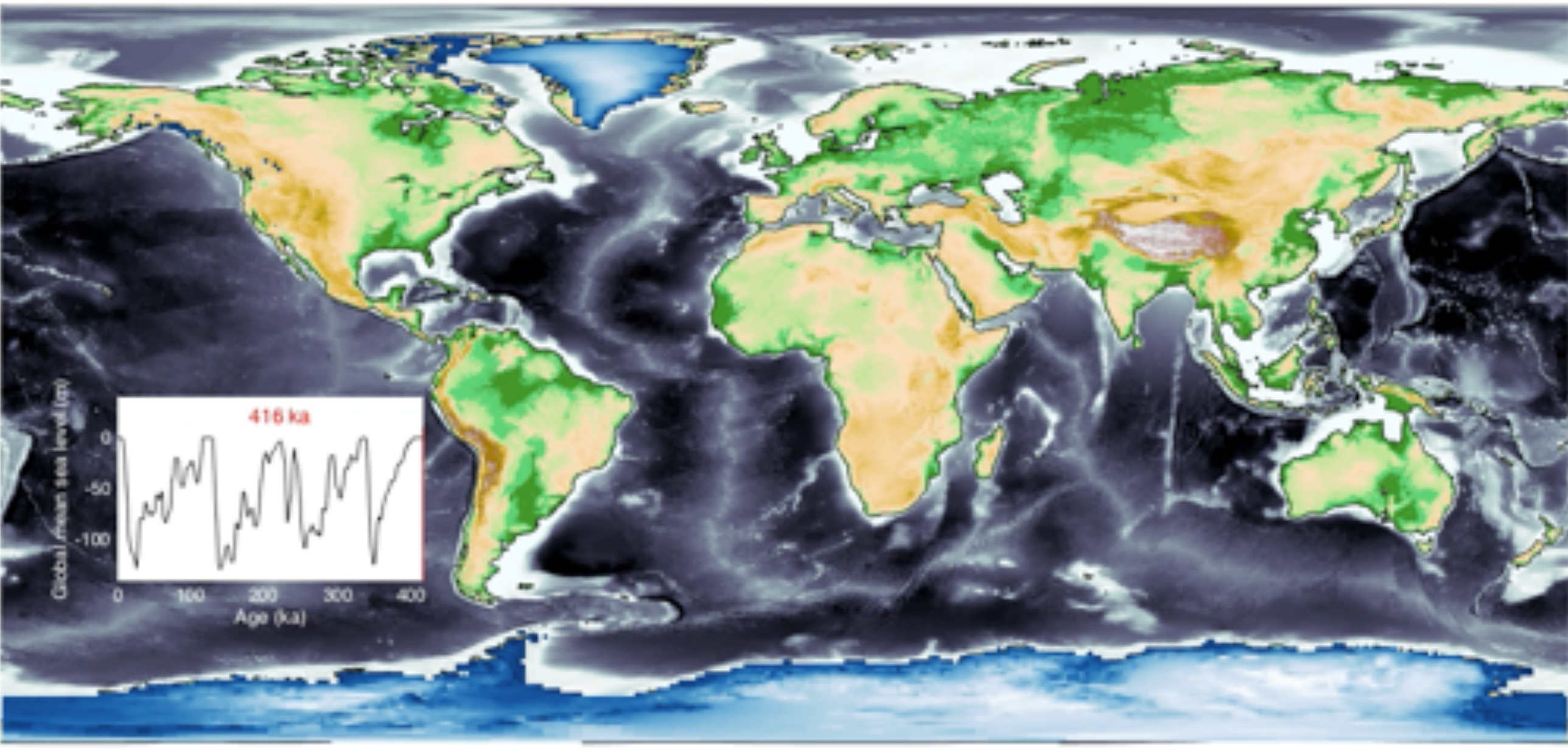
Heinrich Events



Heinrich events - Northern Hemisphere ice sheets spit out a bunch of ice into N. Atlantic causing 0.5 m GMSLR

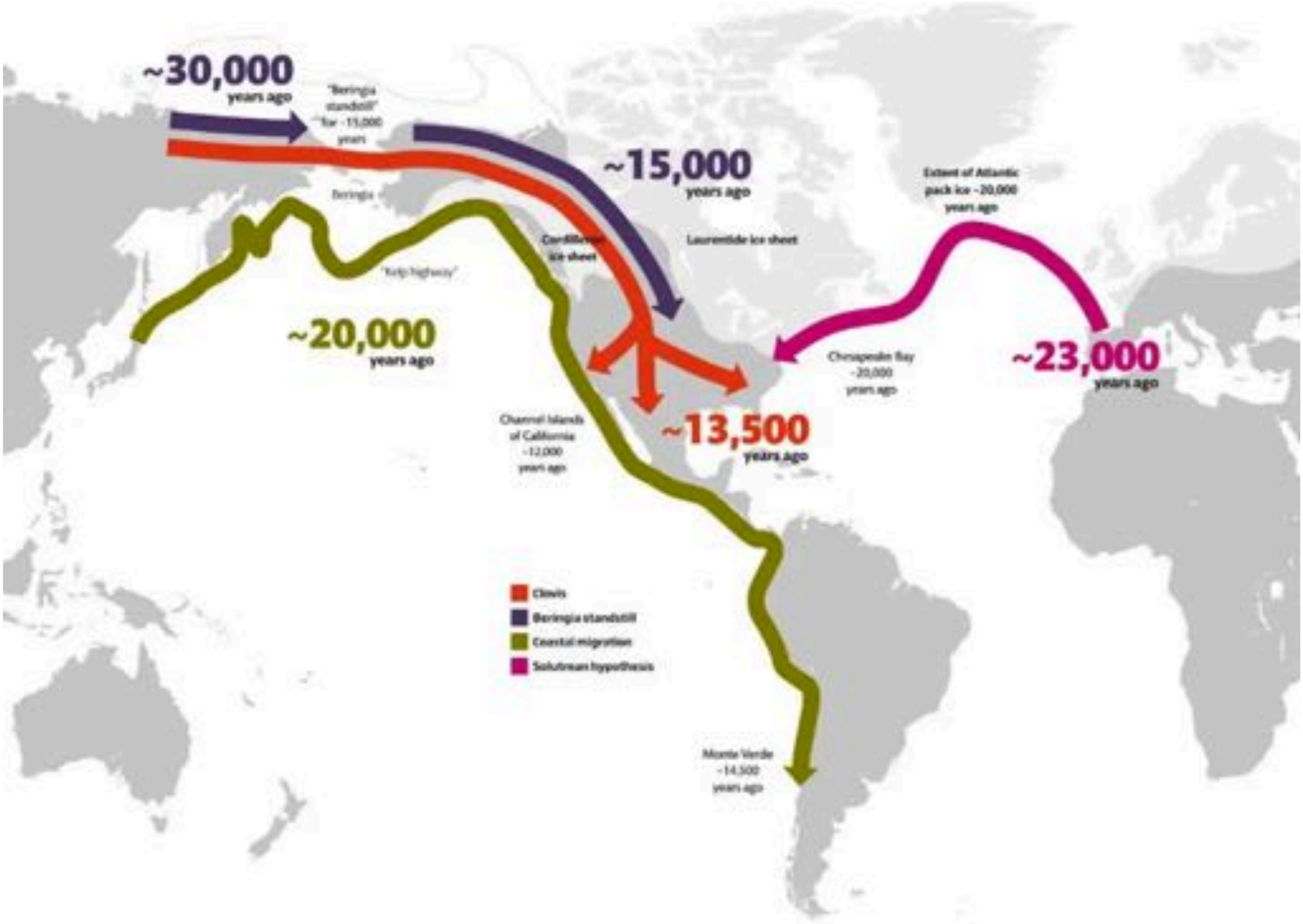
Denton et al. 2010 (from LR05)

Ice ages

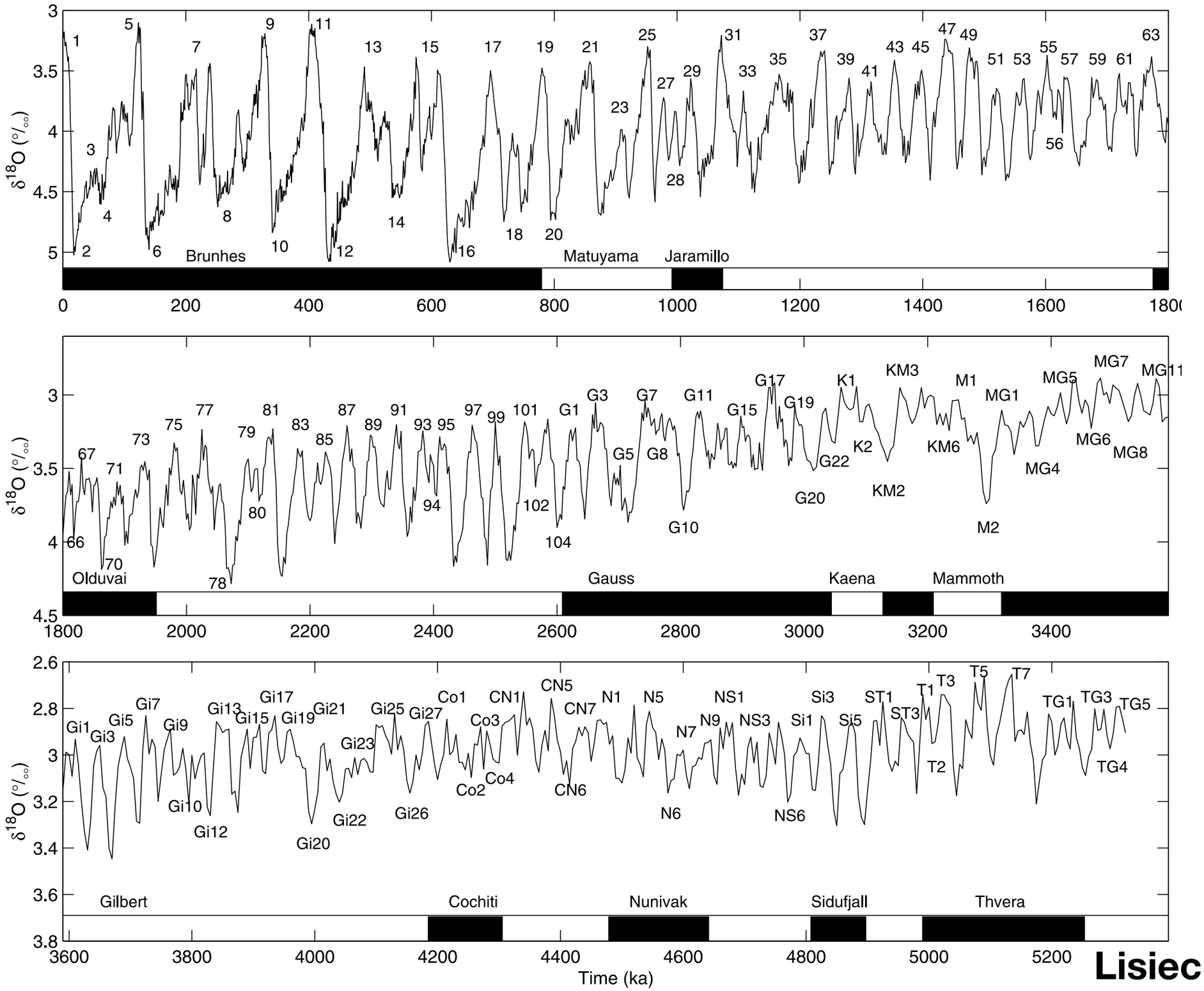


Dendy et al. 2017

Sea Level and Human Migration

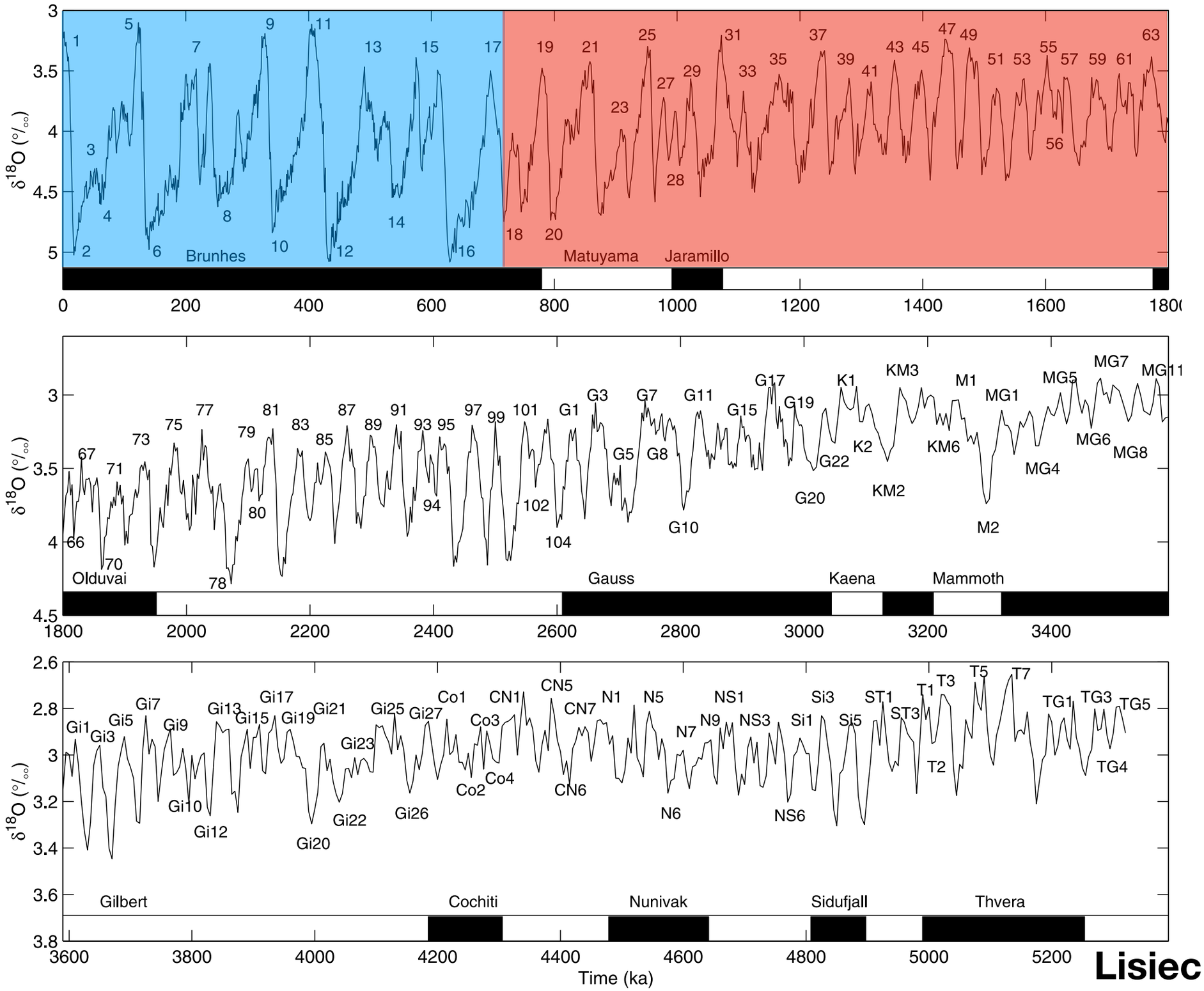


Pleistocene - period during which we had Northern Hemisphere ice sheets



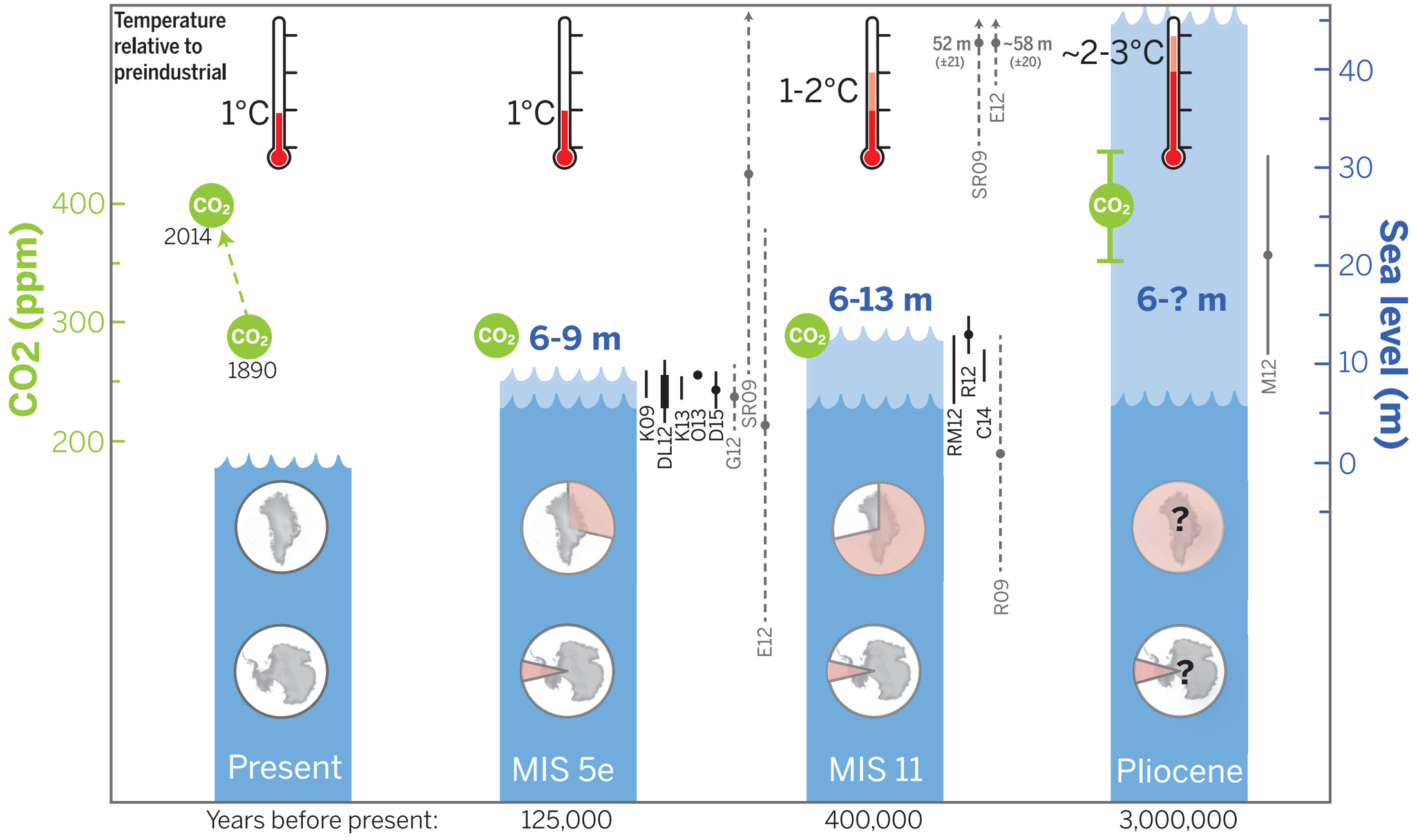
Lisiecki & Raymo 2005

Pleistocene - period during which we had Northern Hemisphere ice sheets



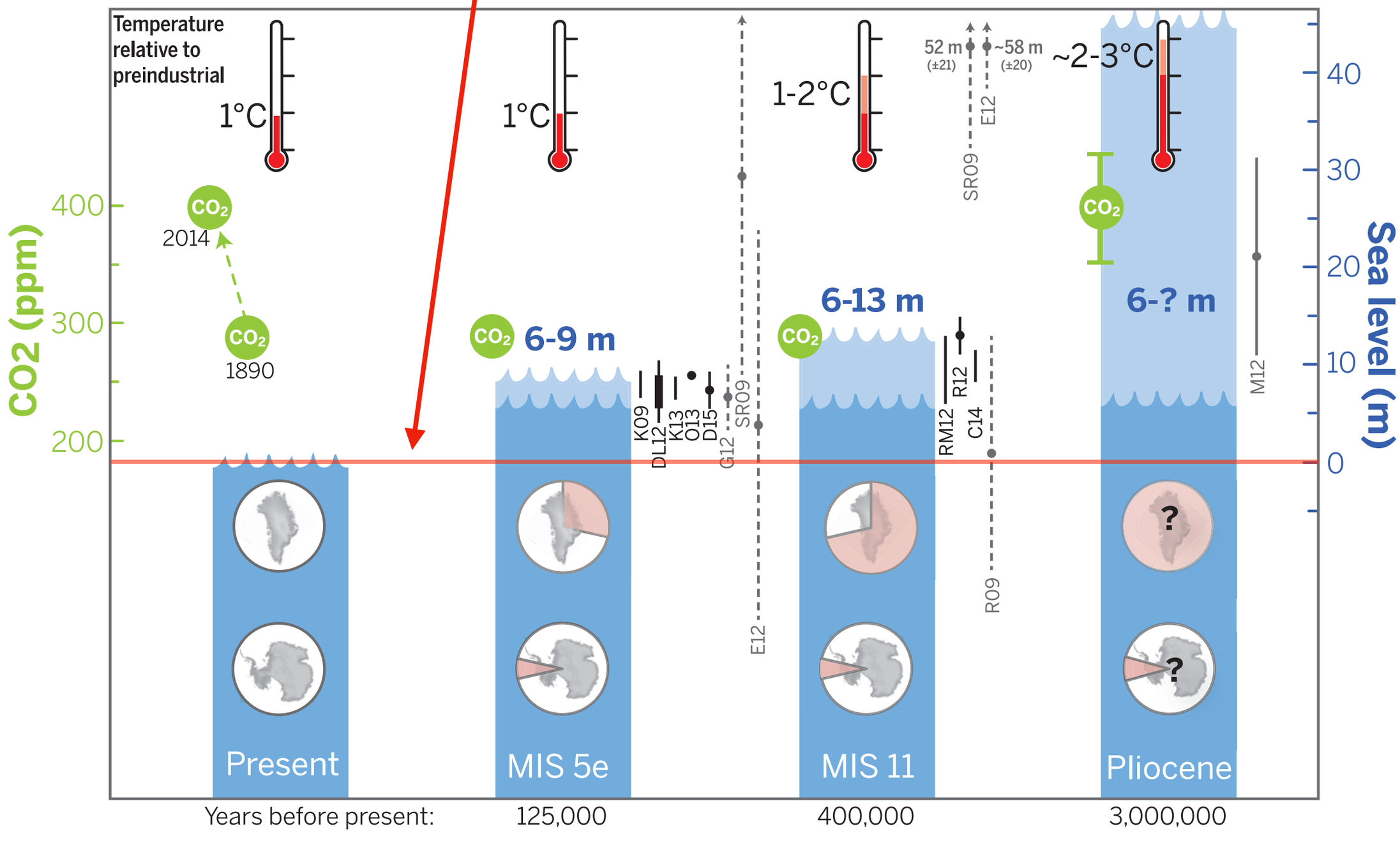
Lisiecki & Raymo 2005

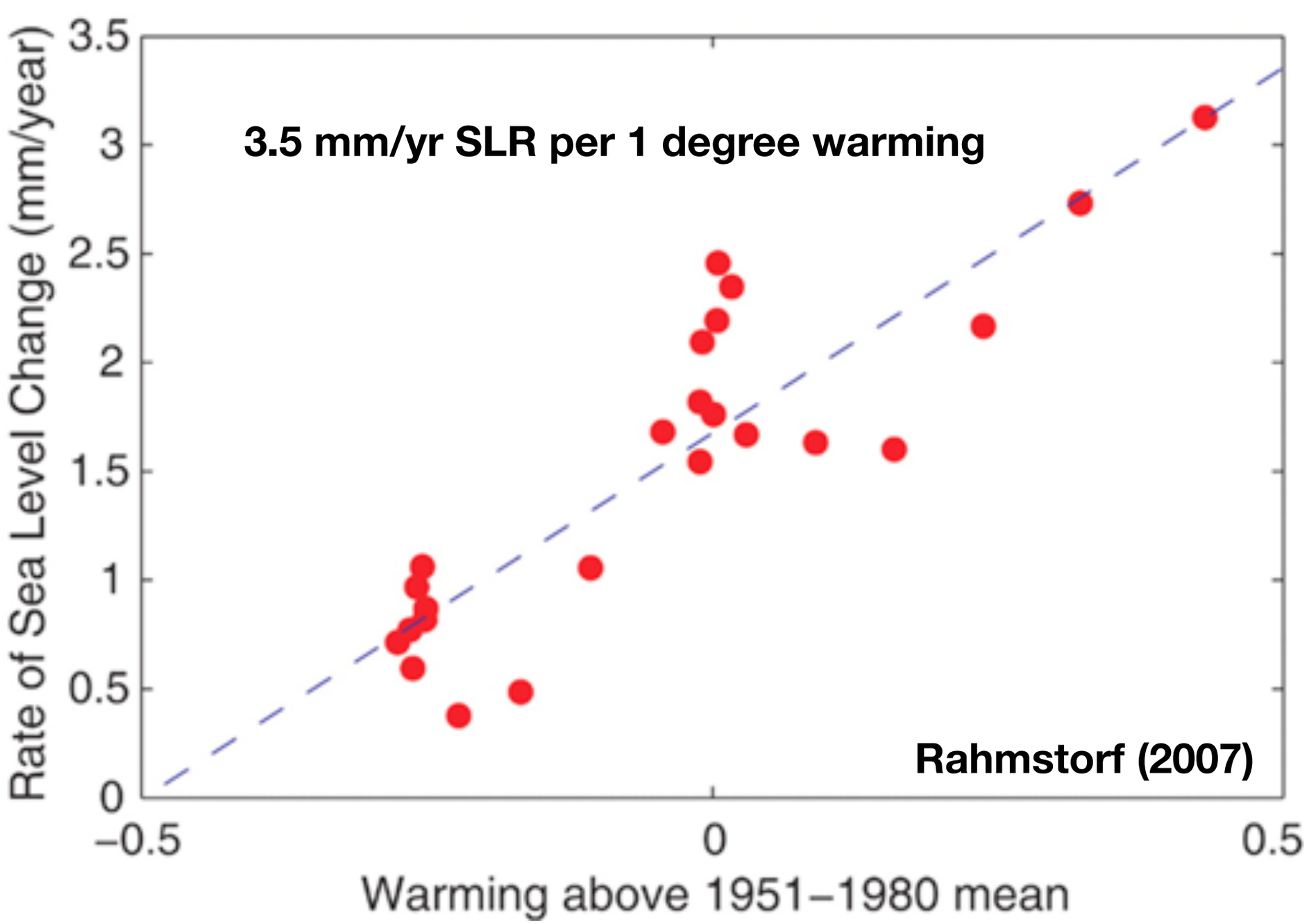
Sea level during past warm periods in Earth's climate



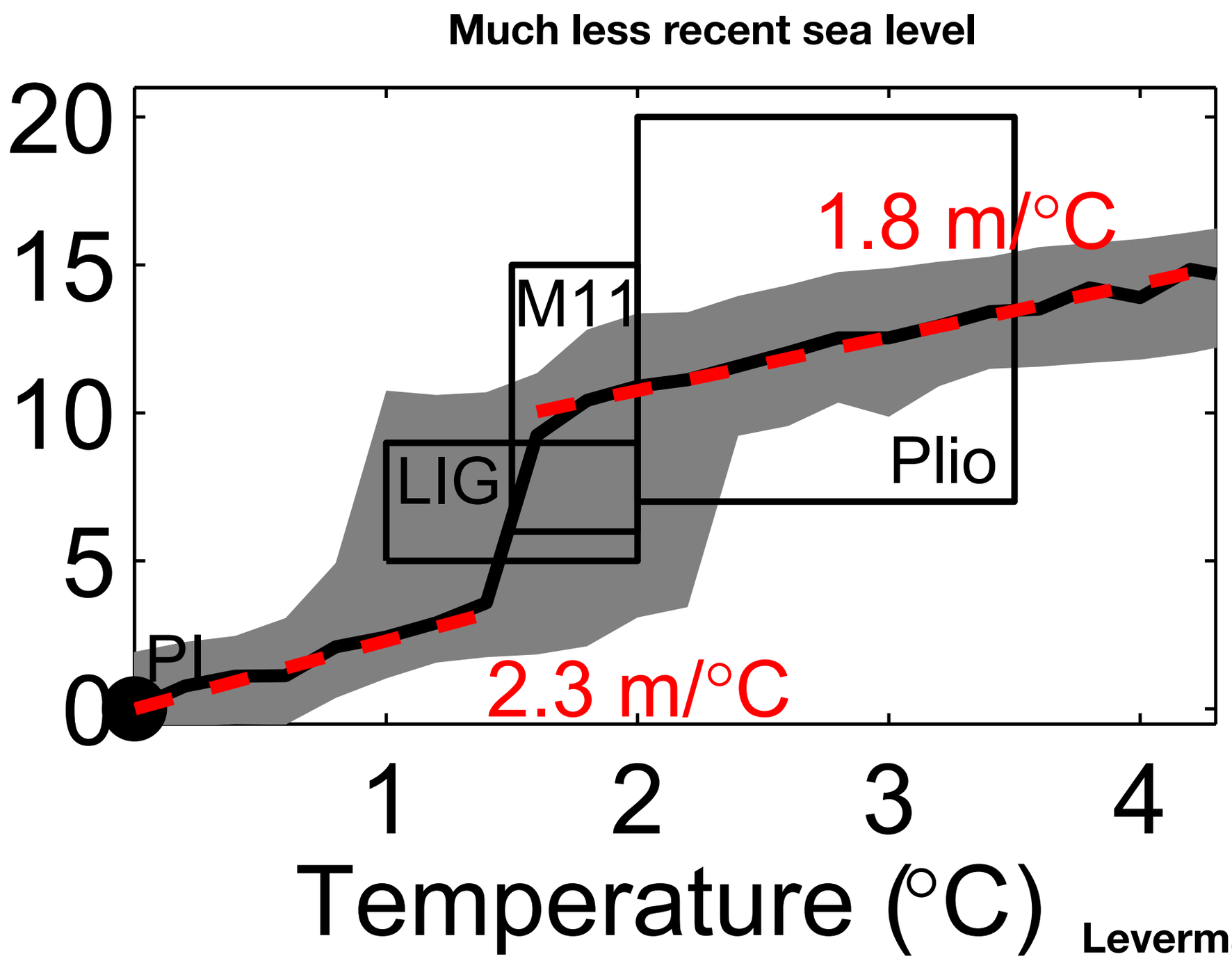
Dutton et al. 2015

Modern sea level measurements have only spanned this range





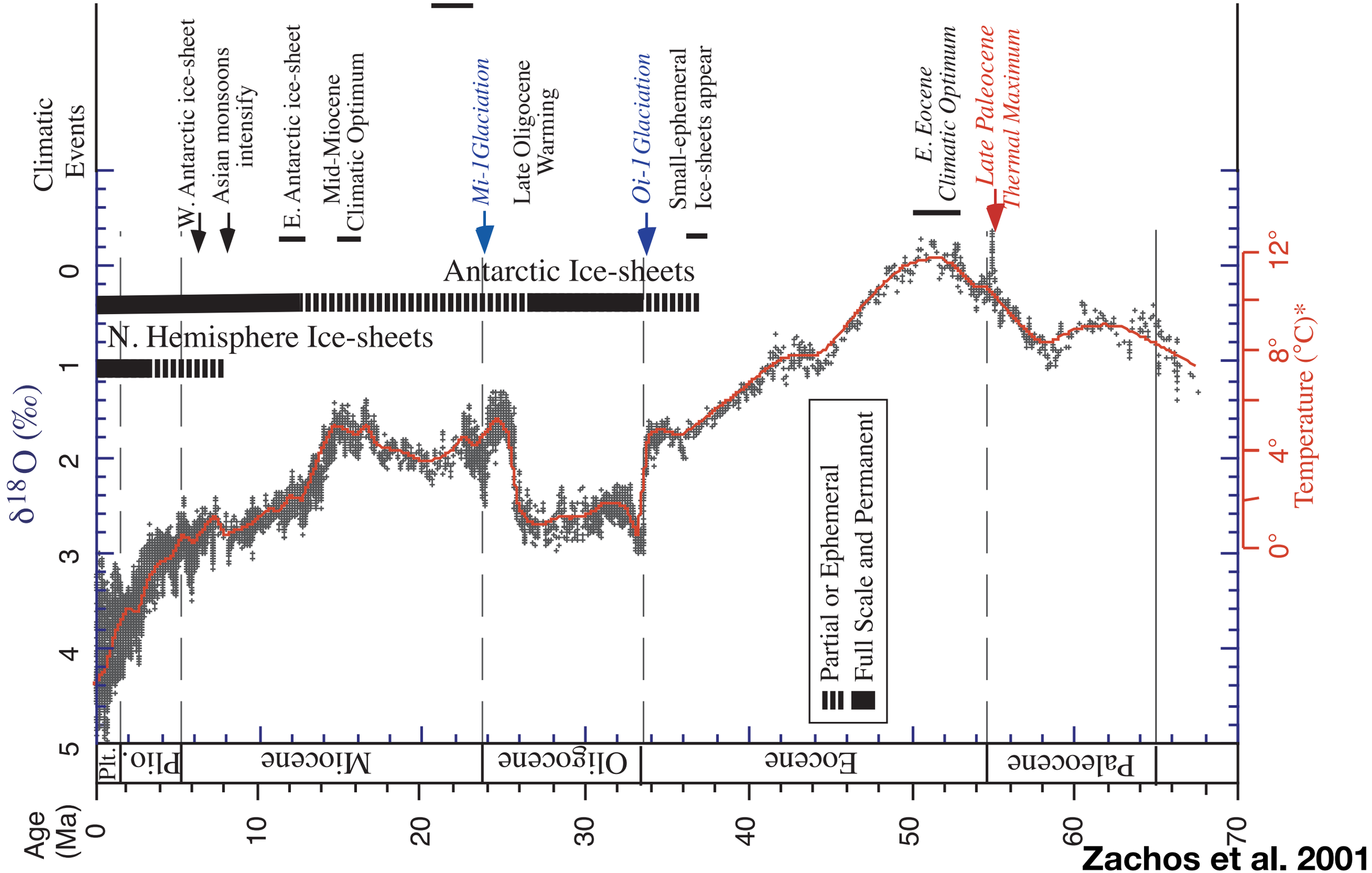
Understanding the drivers of sea level during warmers time deep in Earth's history is the only analogue we have for future sea level



Levermann et al (2013)

Understanding the drivers of sea level during warmers time deep in Earth's history is the only analogue we have for future sea level

As far back as we can go



Zachos et al. 2001

Eocene - No Ice in Antarctica

(Not actual picture of Antarctica…but it looks cool)