Global Climate Change

1. Natural vs. anthropogenic C fluxes
2. CO_2 removal processes
3. Predicting future climate
   - Changes in sea-level & circulation
   - Effects on ecosystems
4. Consequences of global climate change

Atmospheric CO_2 has increased by 35% since 1800 ?

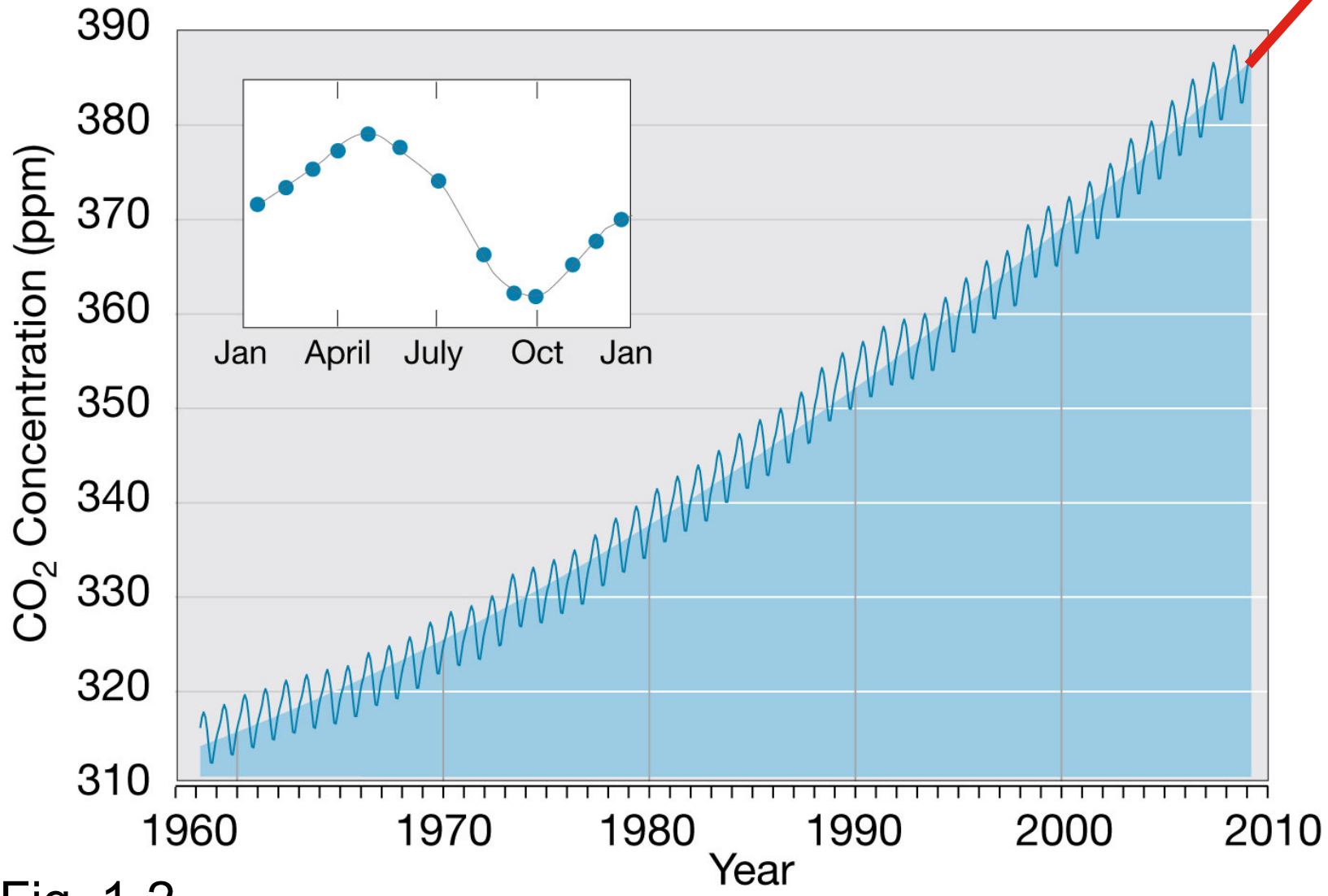
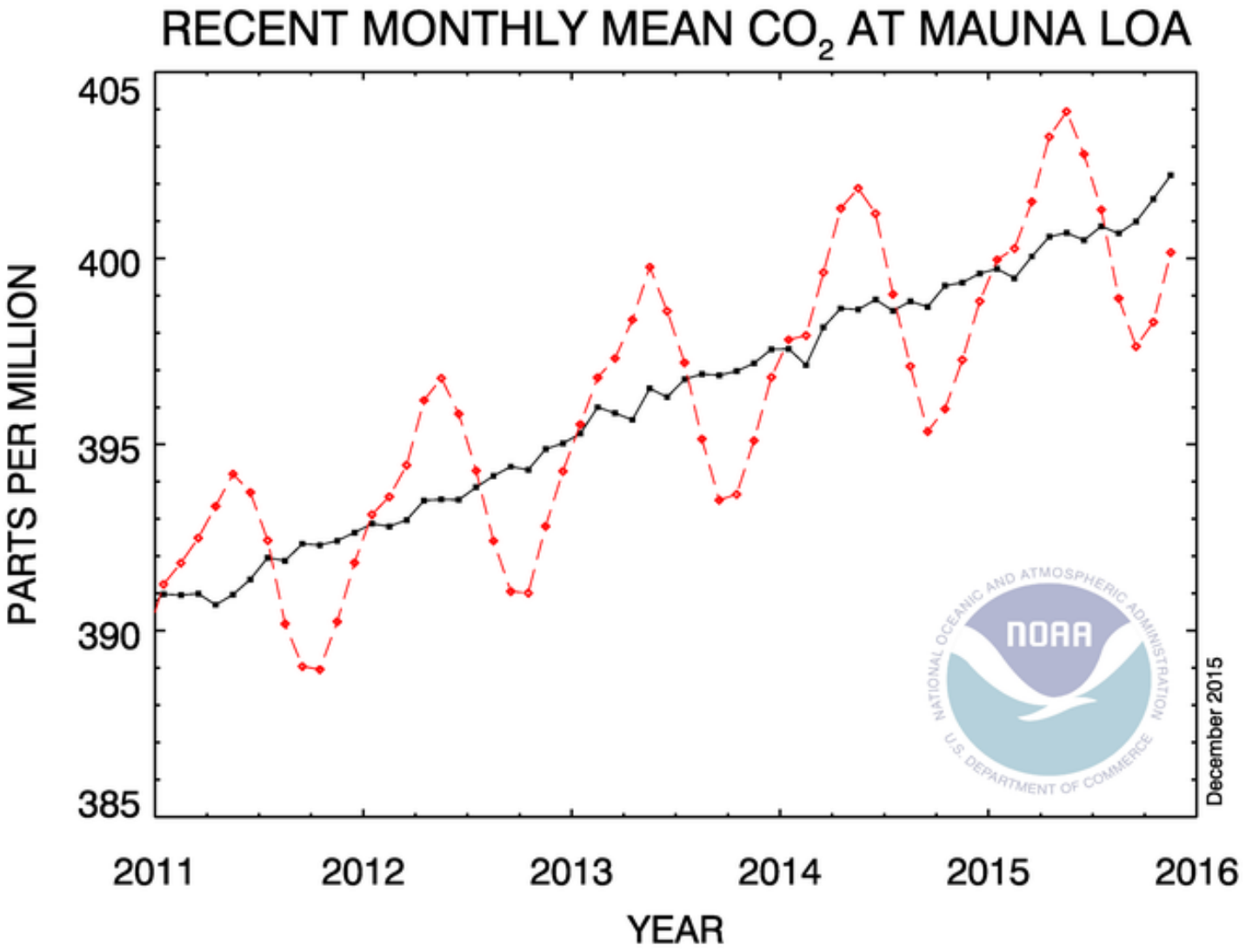
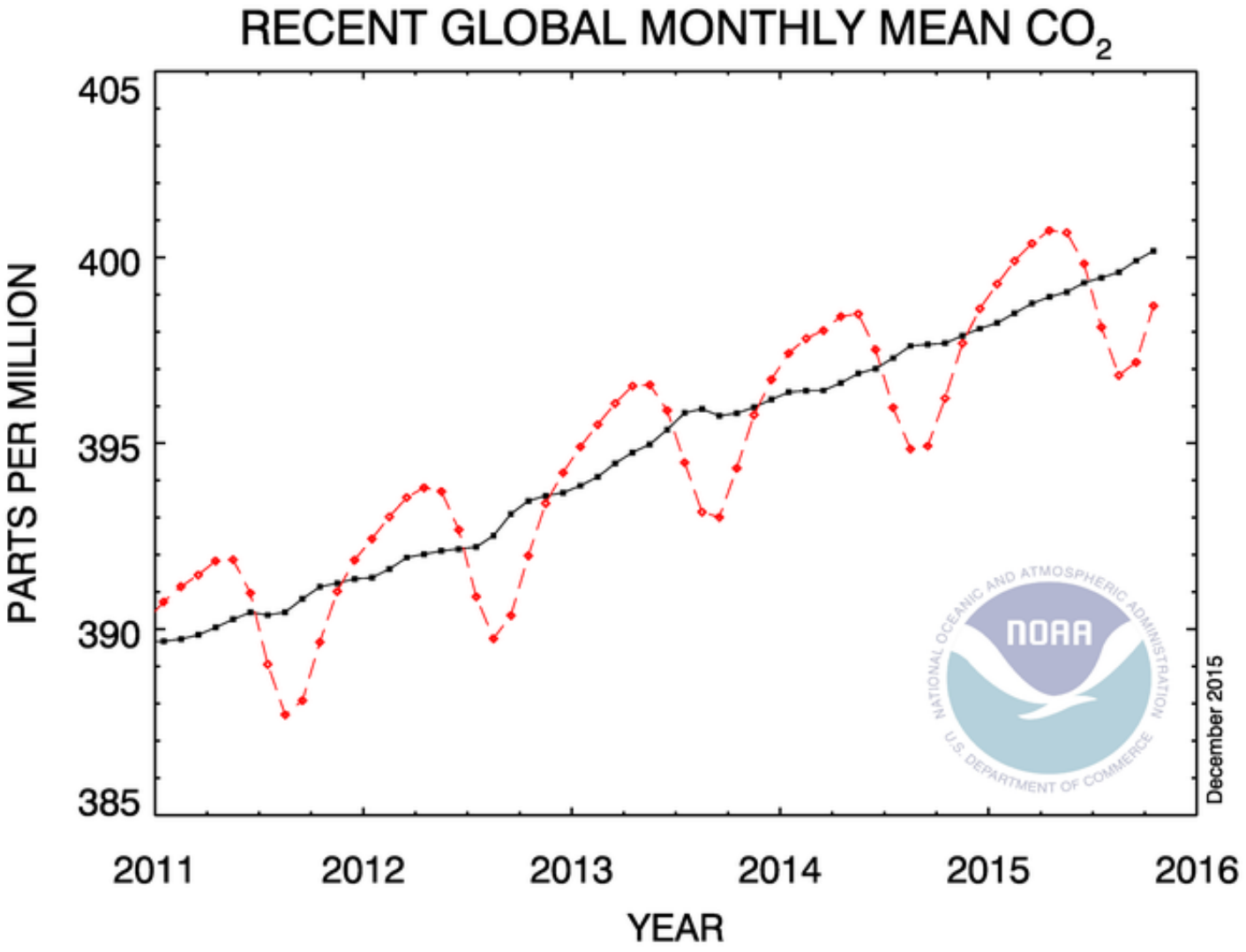


Fig. 1-2

Most recent data available from NOAA web site…



GLOBAL mean, not just Mauna Loa:



This is back in the 2011 class…

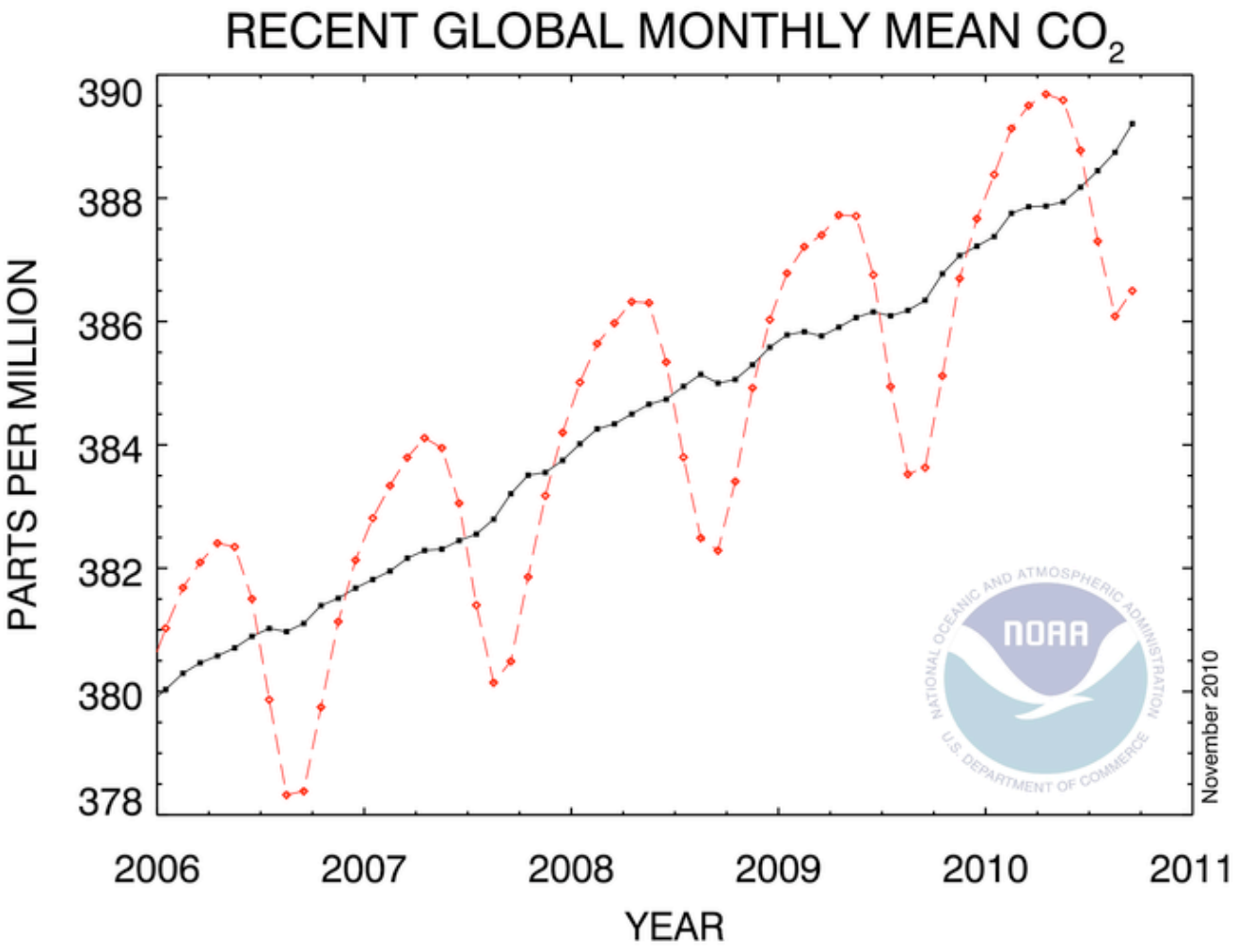


Fig. 1-3a

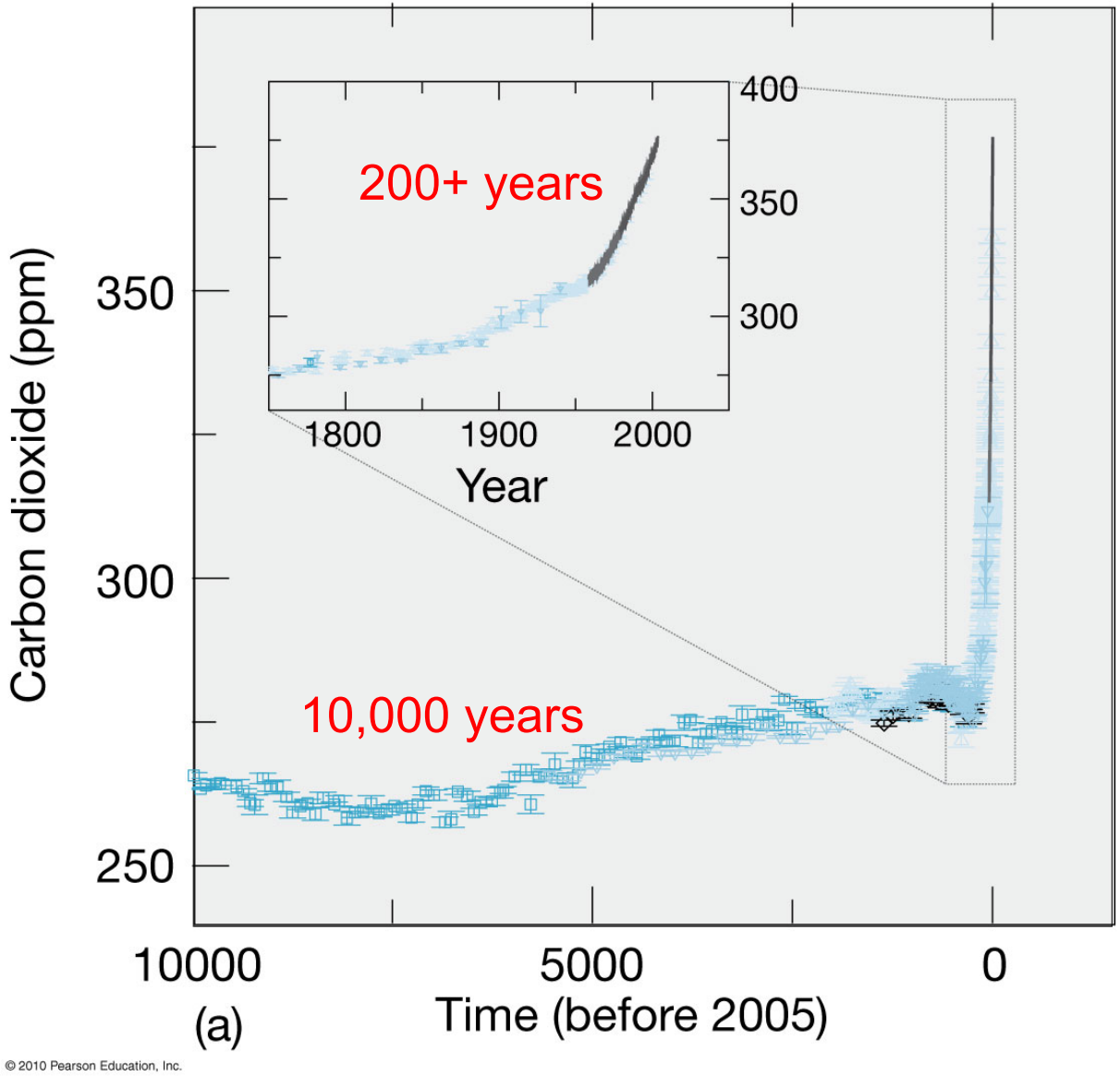


Fig. 1-3b

Not just CO_2…

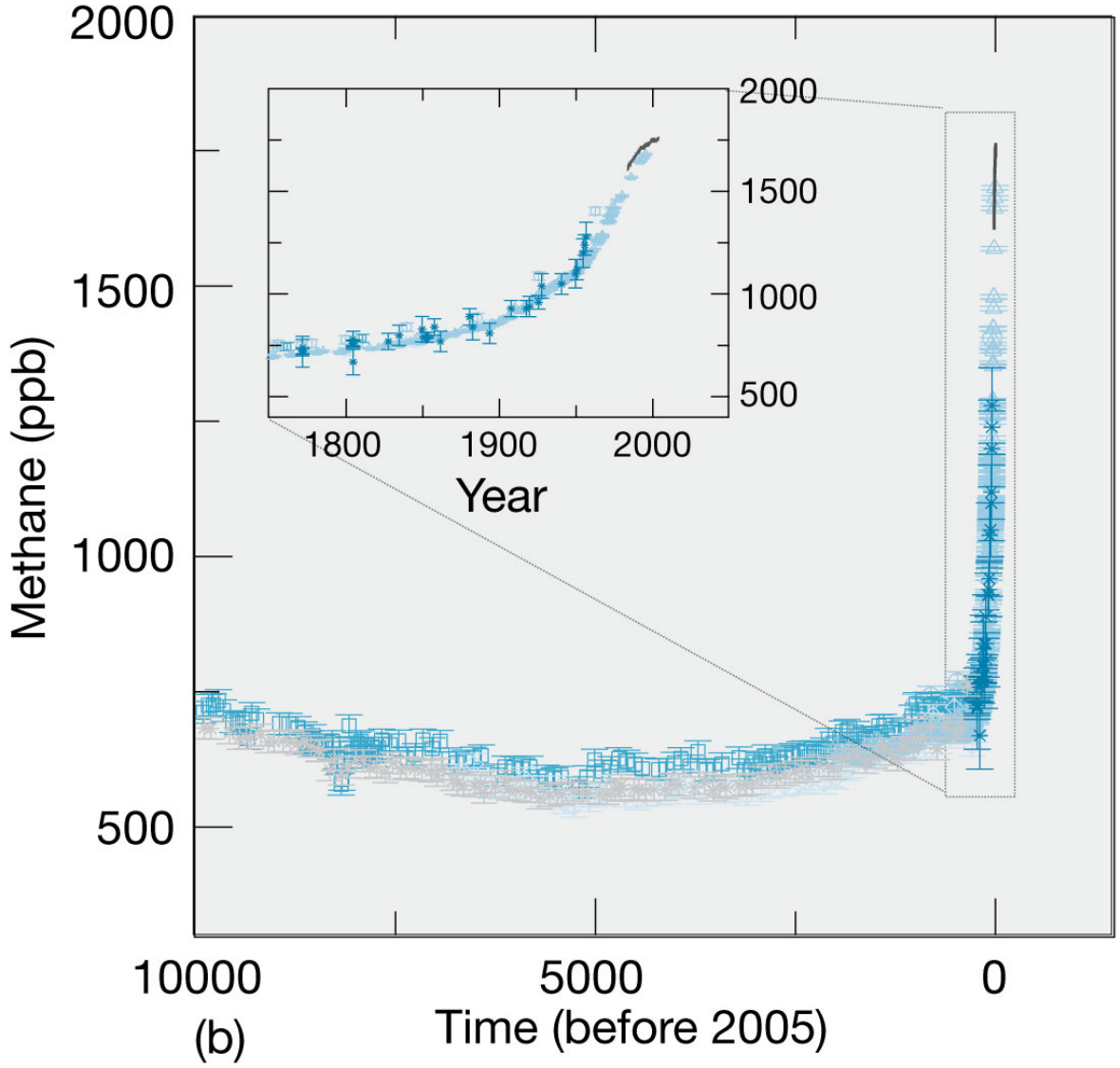
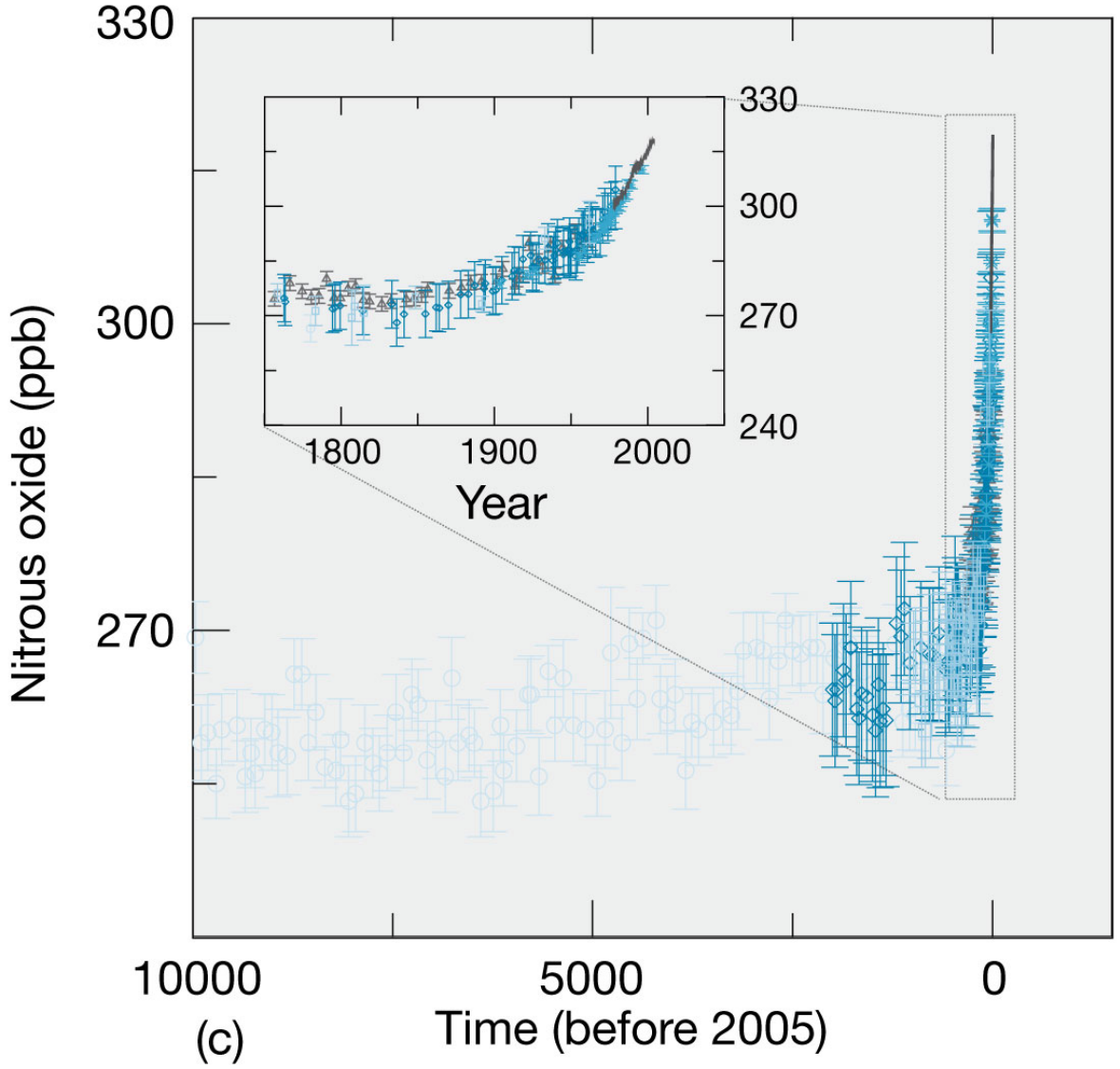
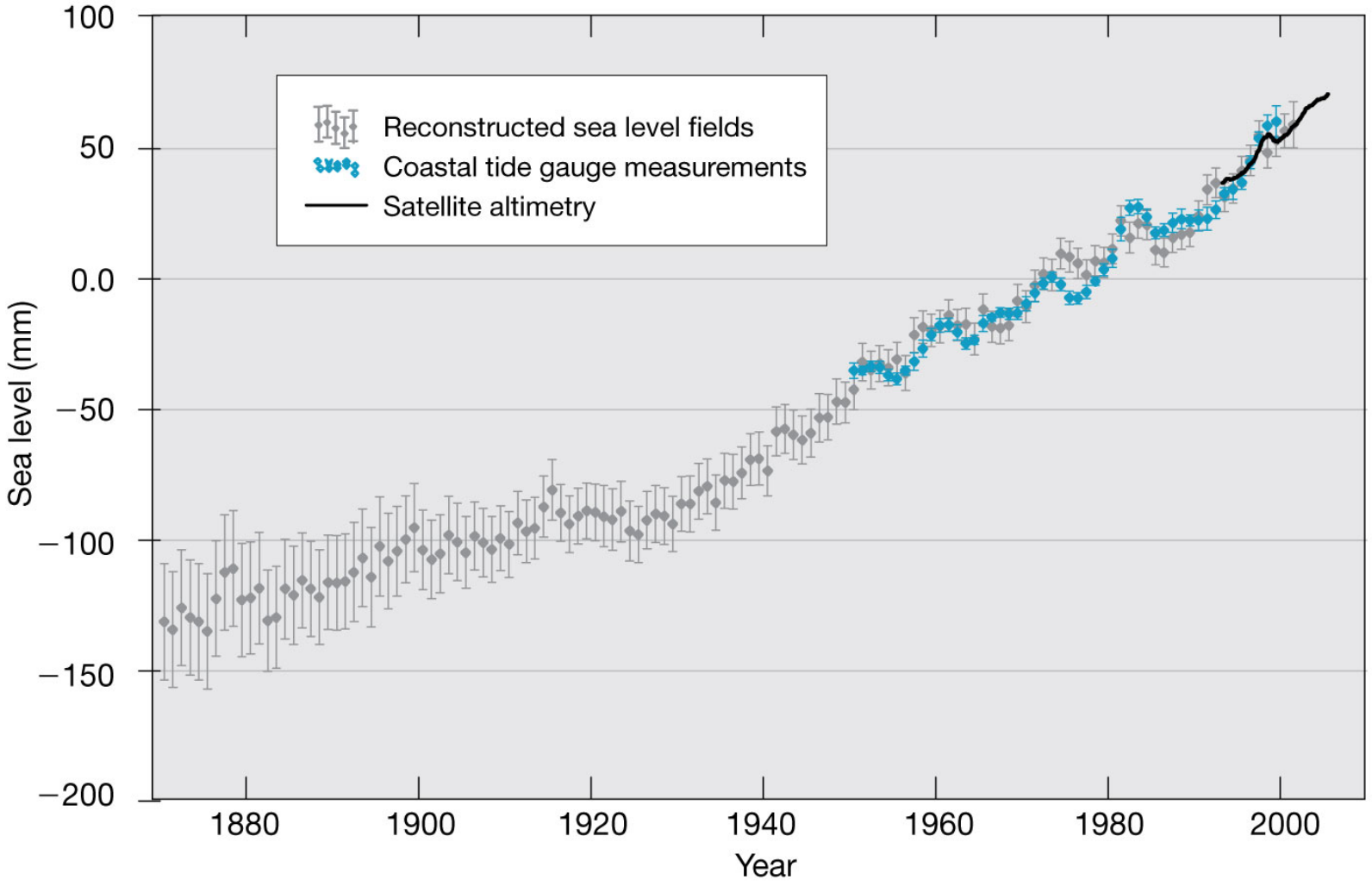


Fig. 1-3c

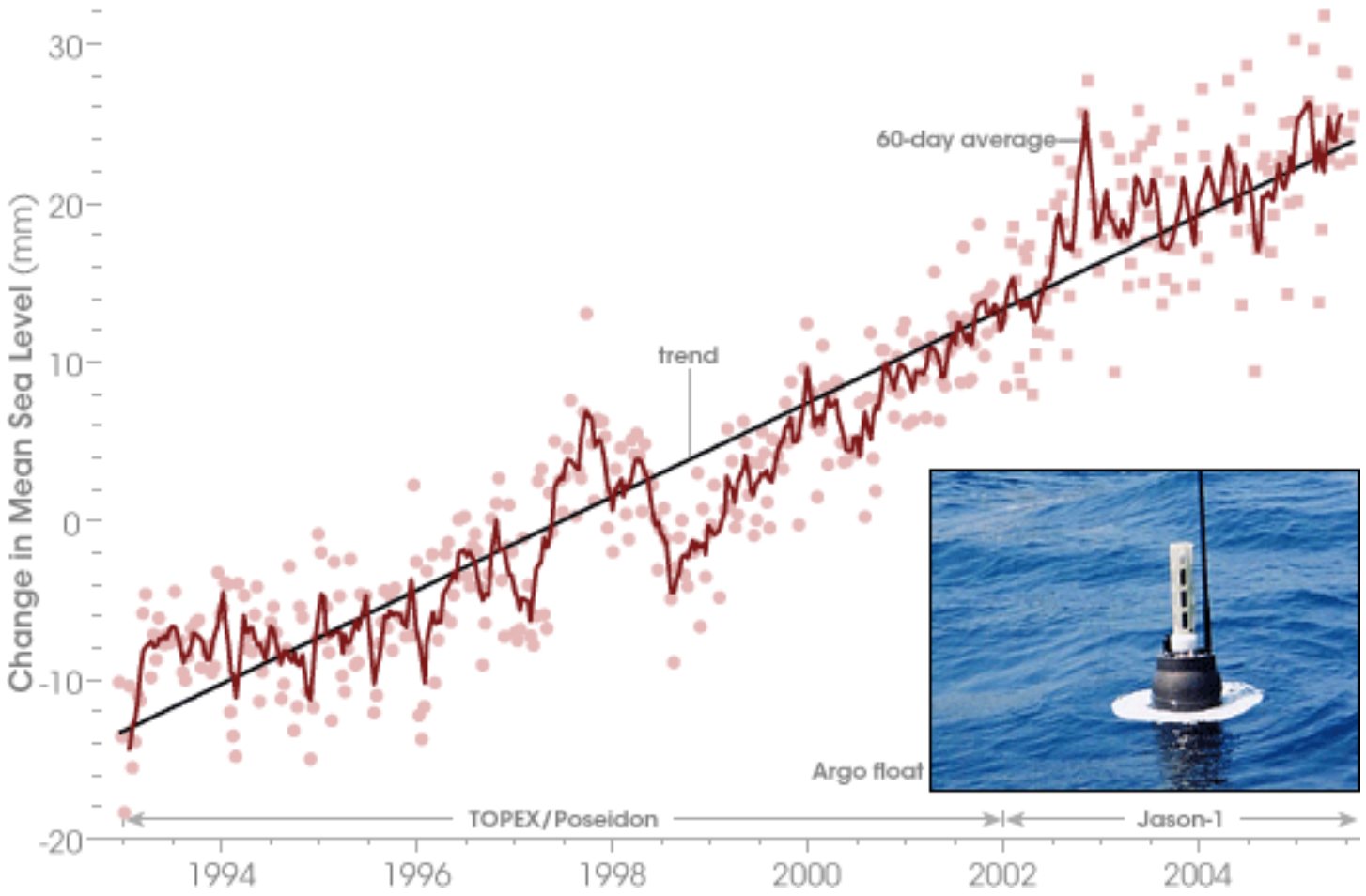


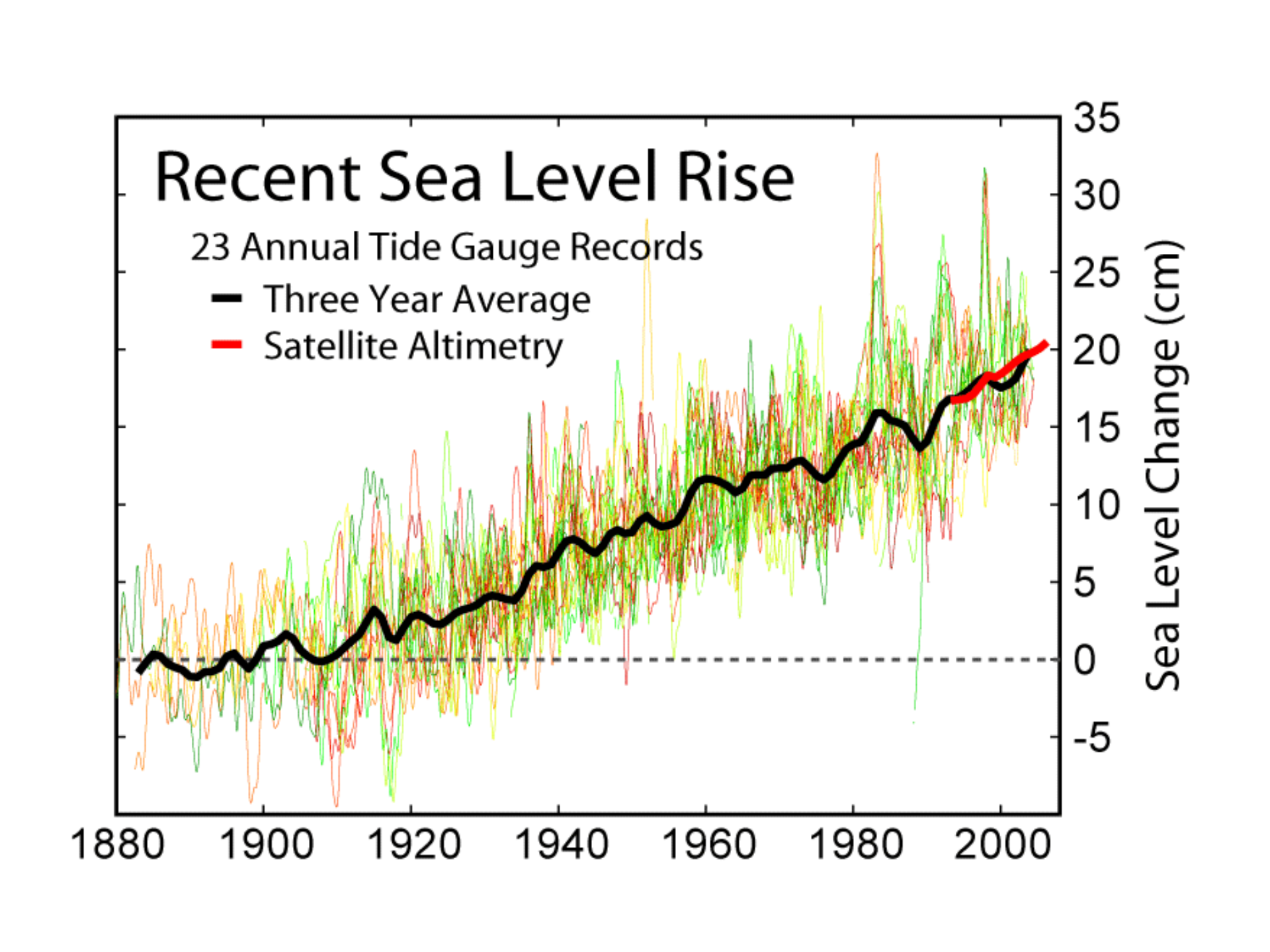


Why does sea level rise?

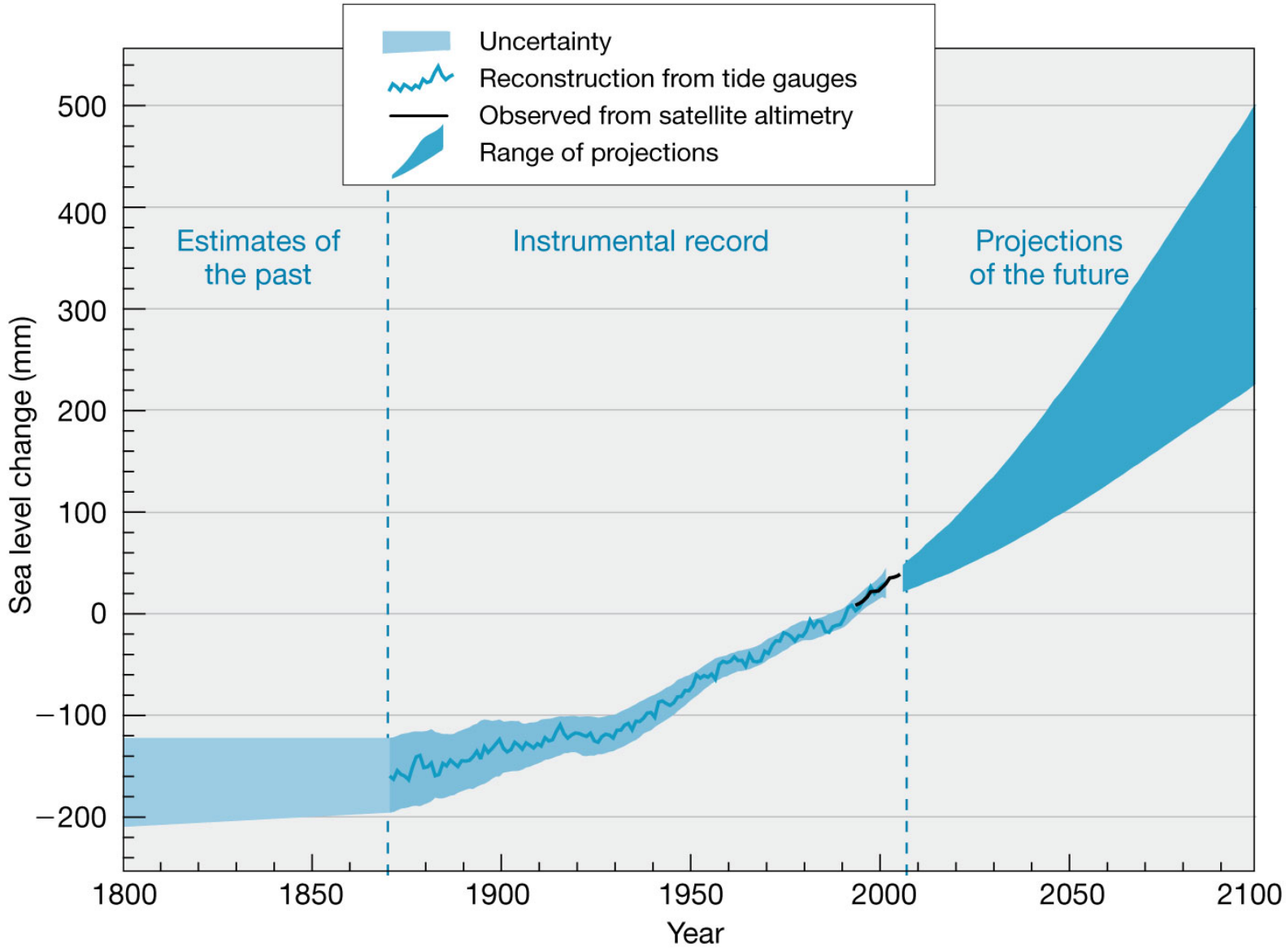
- Warmer water expands, takes up more space
- Sea ice melting? No – no net effect
- Land ice melting? Yes – wasn't in the ocean to start with

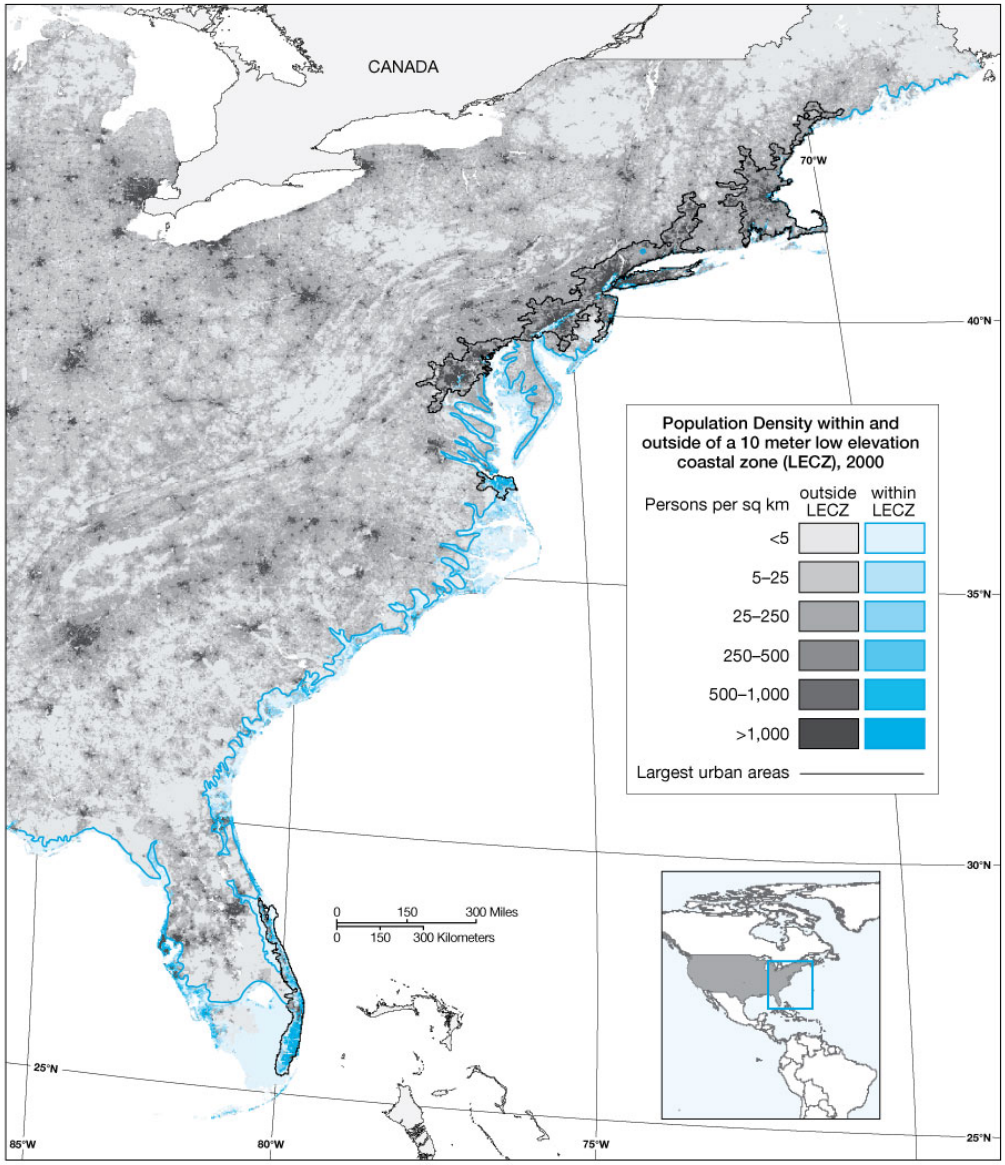
Rising Sea Level…

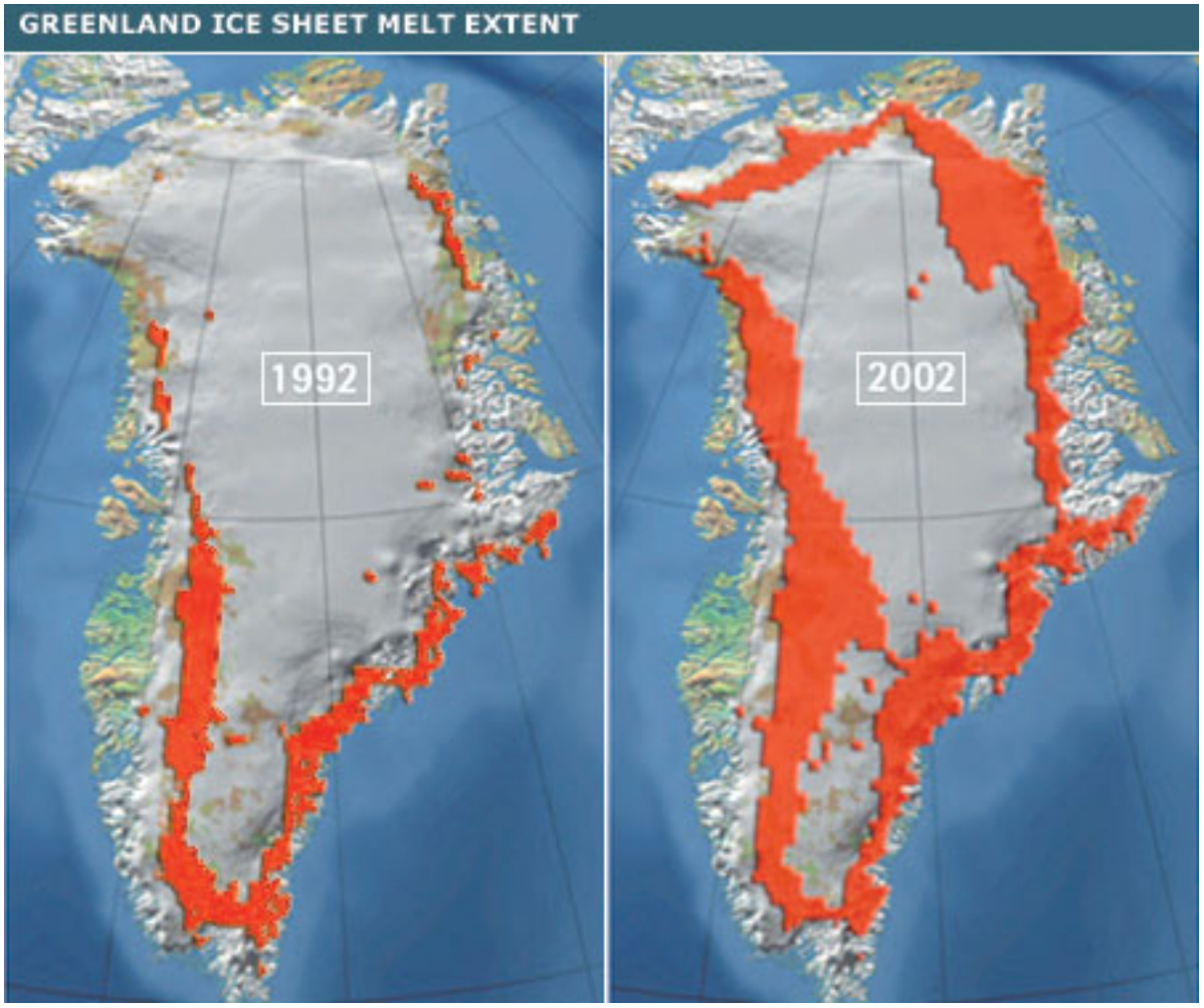



Recent Sea Level Rise
23 Annual Tide Gauge Records
Three Year Average
Satellite Altimetry
35
30
25
20
15
10
5
0
-5
Sea Level Change (cm)
1880
1900
1920
1940
1960
1980
2000

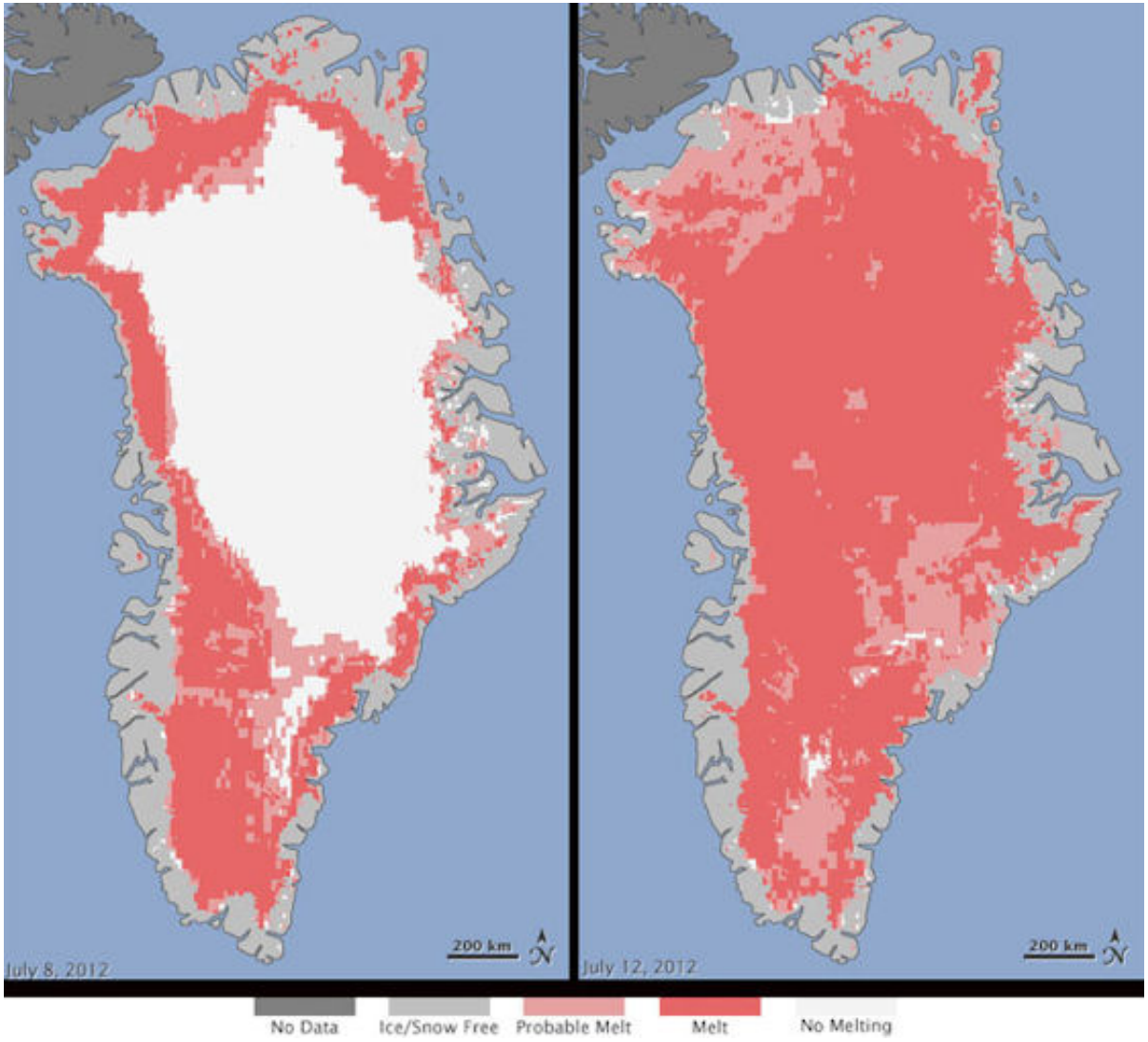
Florida Keys…and much of south Florida!





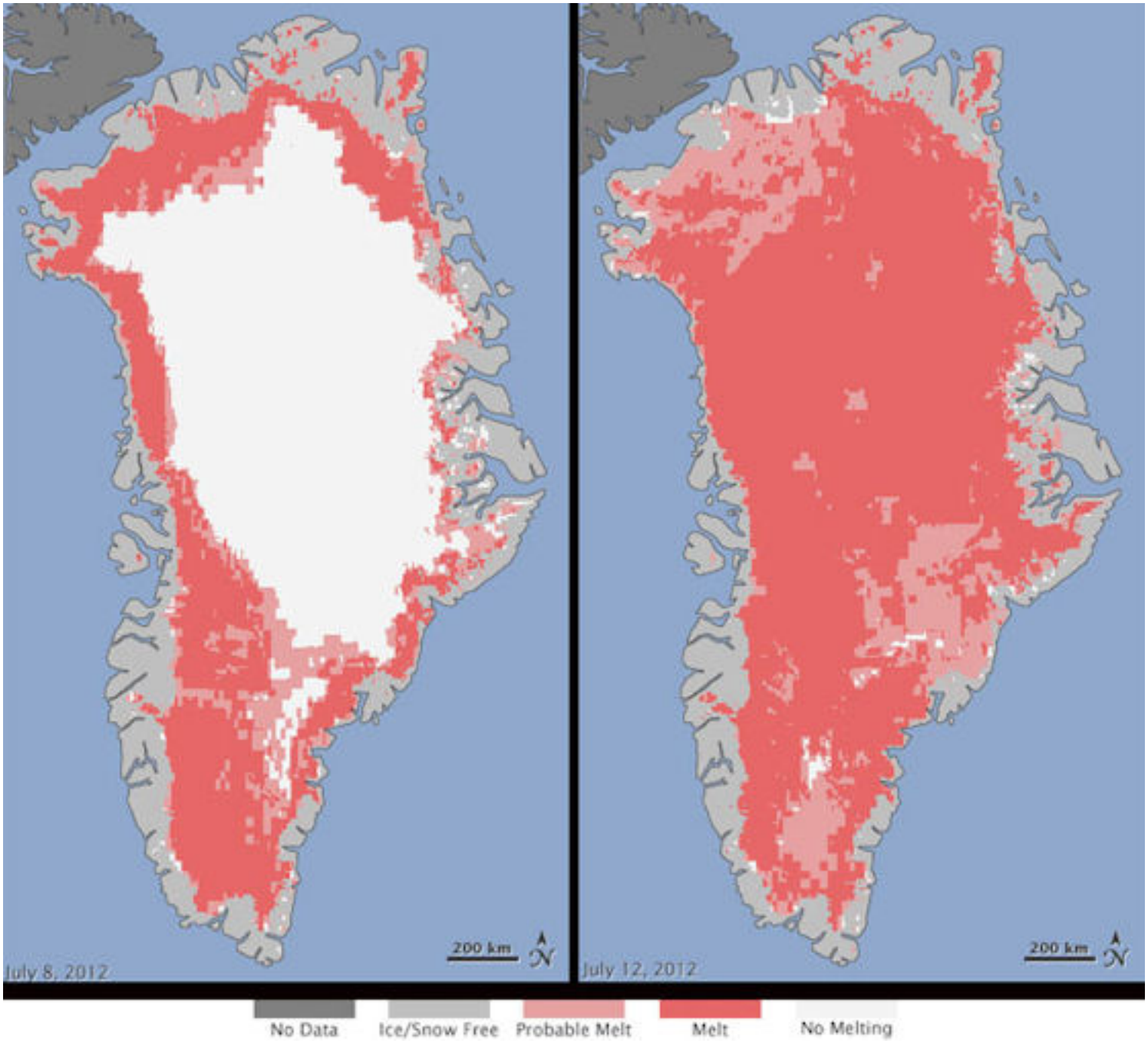

GREENLAND ICE SHEET MELT EXTENT
1992
2002

BBC 25 July 2012, “Satellites reveal sudden Greenland ice melt”



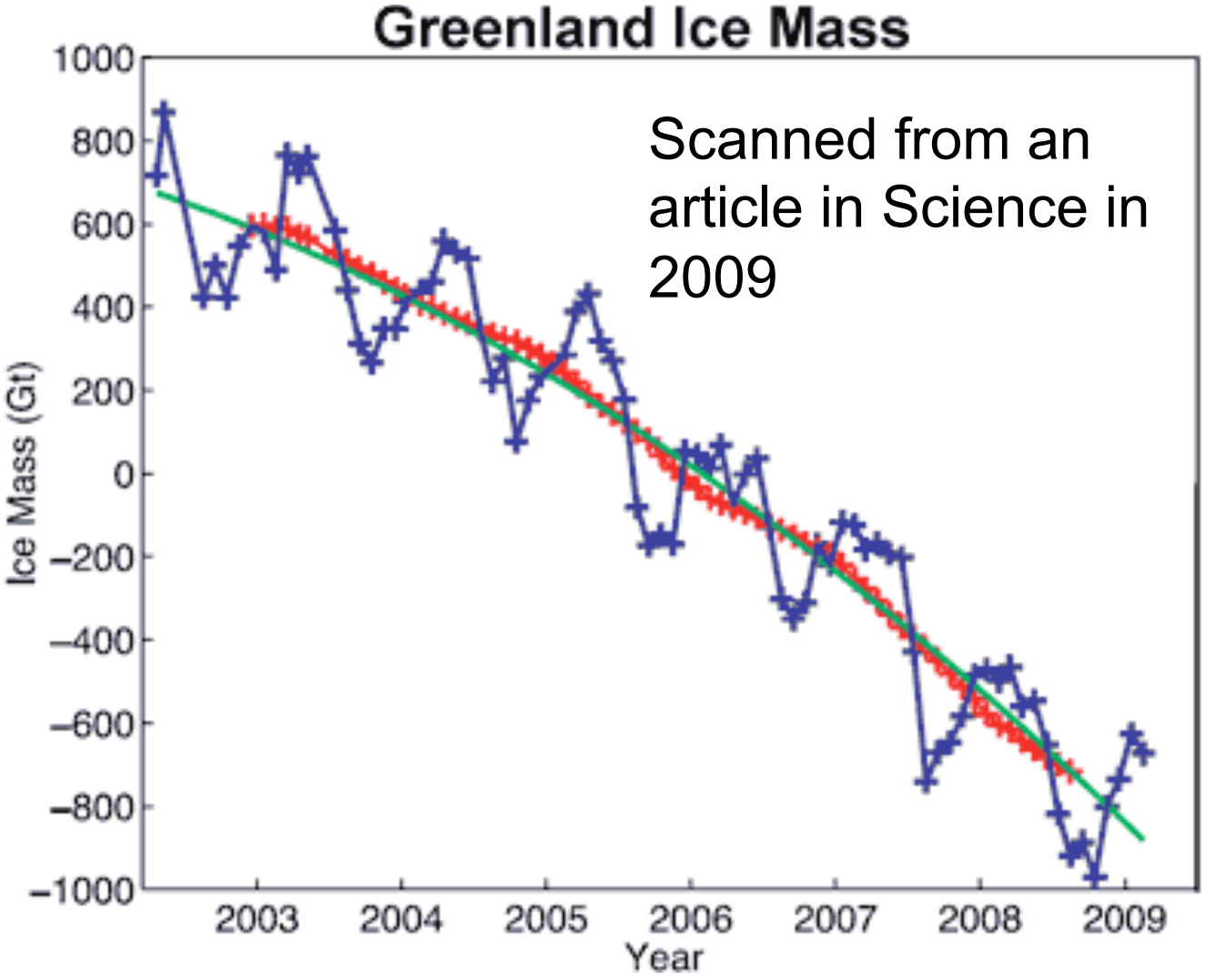
July 8, 2012

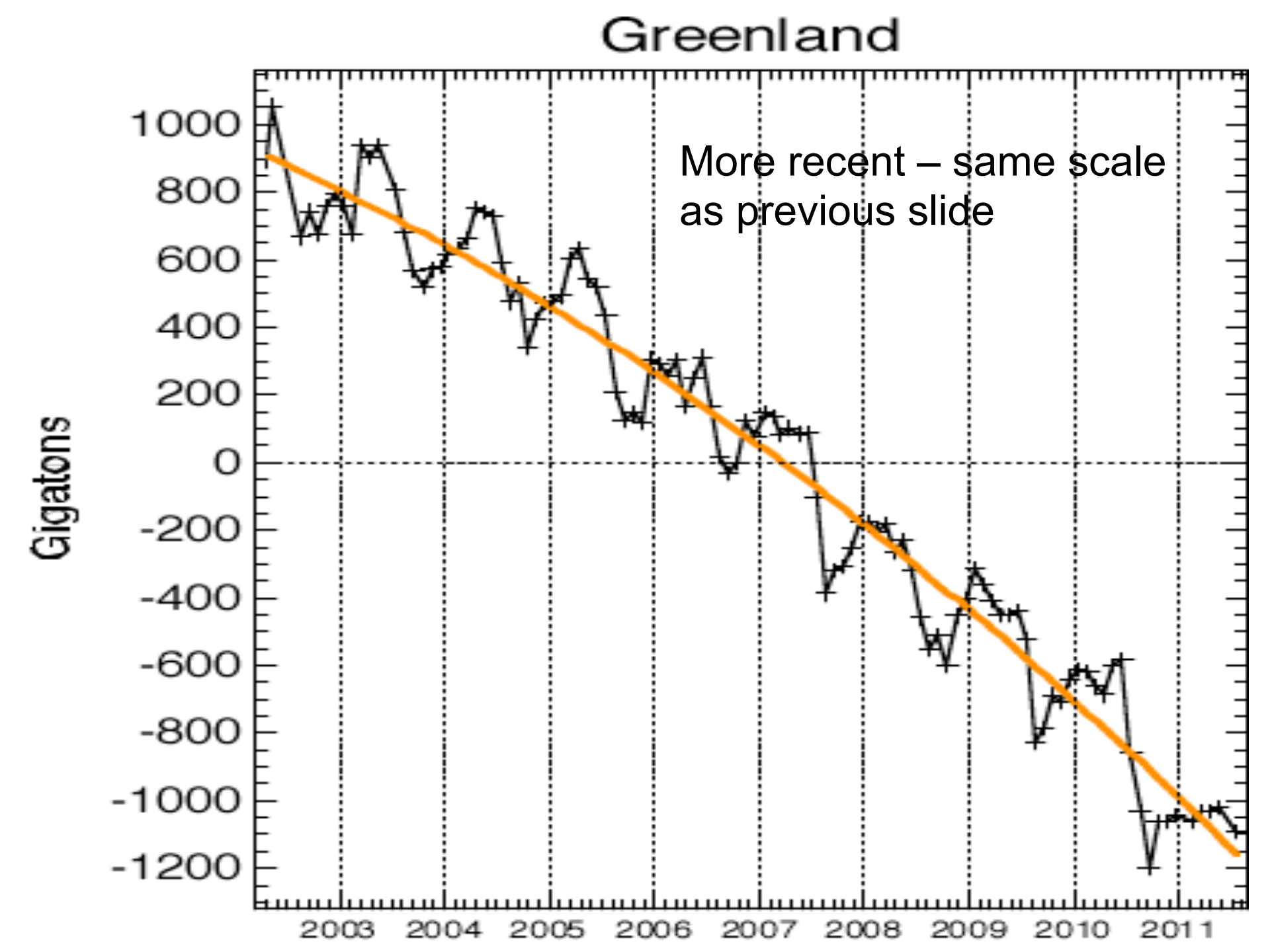
July 12, 2012


July 8, 2012
200 km
N
July 12, 2012
200 km
N
No Data
Ice/Snow Free
Probable Melt
Melt
No Melting

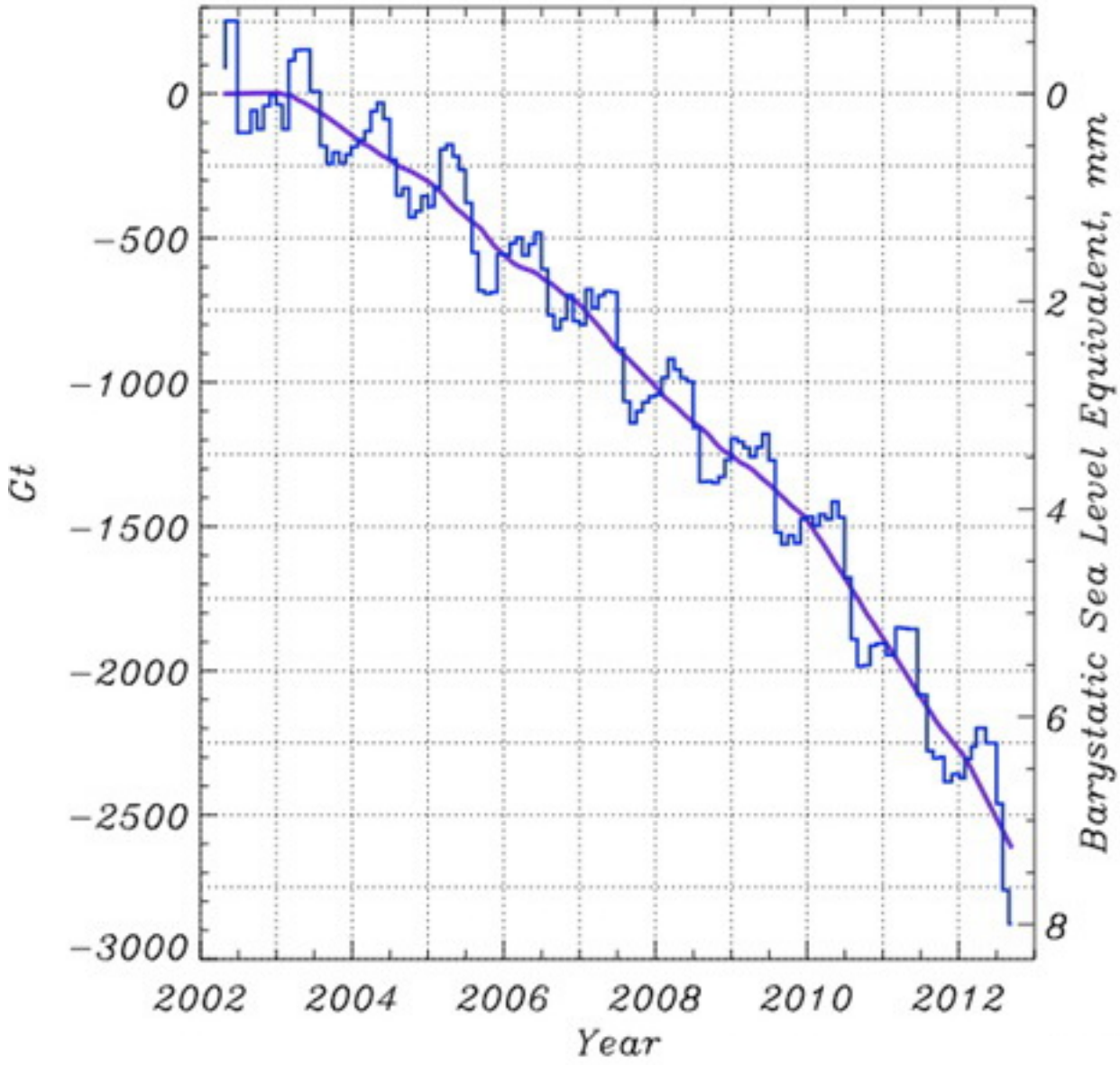
- By **Joe Romm on Jun 17, 2013 at 6:08 pm**
- New research finds that "unusual changes in atmospheric jet stream circulation caused the exceptional surface melt of the Greenland Ice Sheet (GrIS) in summer 2012."
  Prof. Jennifer Francis tells me these changes are consistent with those caused by warming-driven "Arctic Amplification." And that means GrIS may melt faster than climate models have projected.
- Back in May, a study found that by 2025, there is a "50-50 chance" of this unprecedented ice melt happening annually simply based on the continued rapid warming of GrIS.
- This new study, "Atmospheric and oceanic climate forcing of the exceptional Greenland ice sheet surface melt in summer 2012," suggests this kind of melt may become commonplace even sooner.
- As the news release explains, an international team used a computer model and satellite data "to confirm a record surface melting of the GrIS for at least the last 50 years – when on 11 July 2012, more than 90 percent of the ice-sheet surface melted. This far exceeded the previous surface melt extent record of 52 percent in 2010." Weather station data "showed that several new high Greenland temperature records were set in summer 2012."
- The research "clearly demonstrates that the record surface melting of the GrIS was mainly caused by highly unusual atmospheric circulation and jet stream changes, which were also responsible for last summer's unusually wet weather in England."

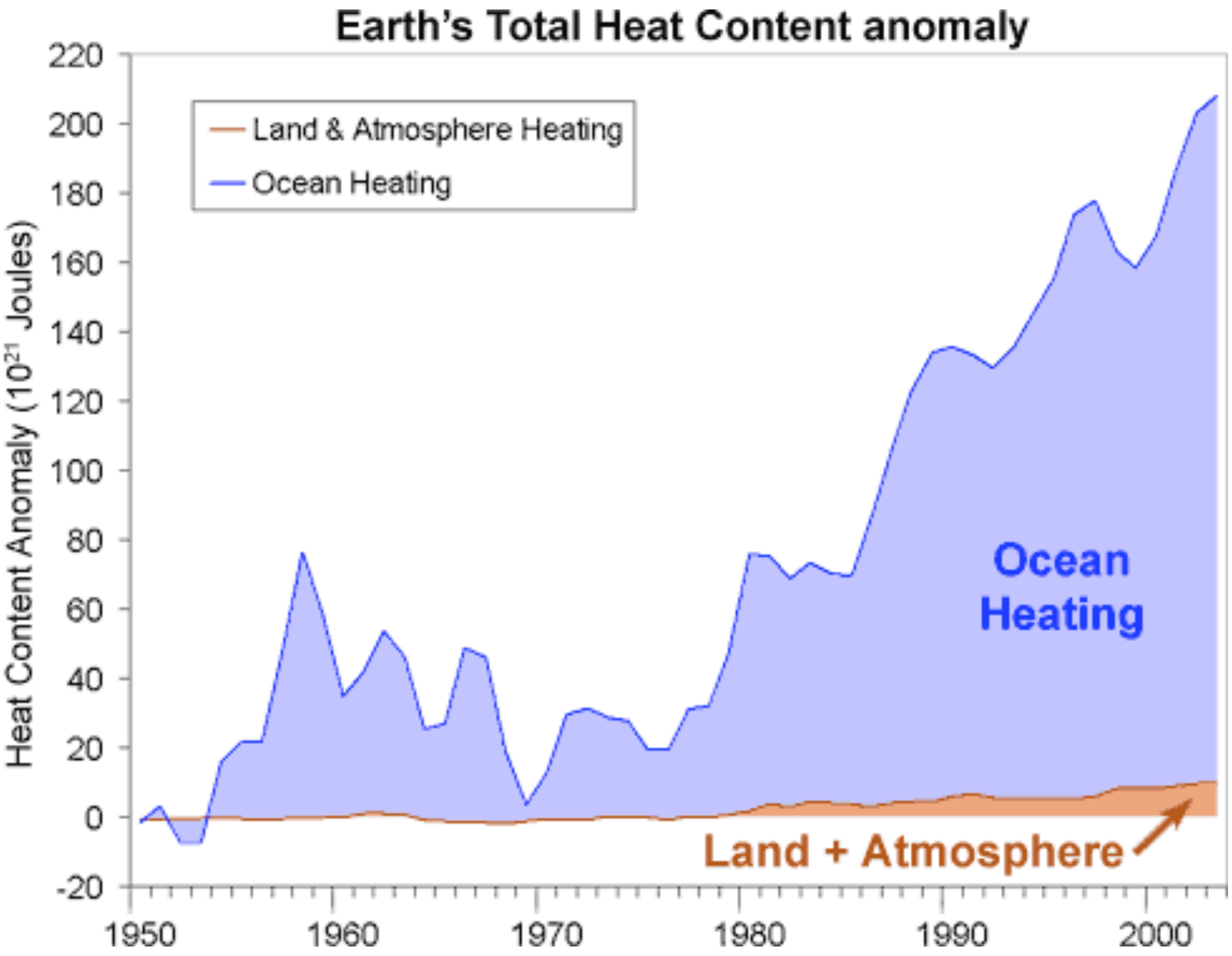
Loss of 1500 Gigatons of ice in 7 years

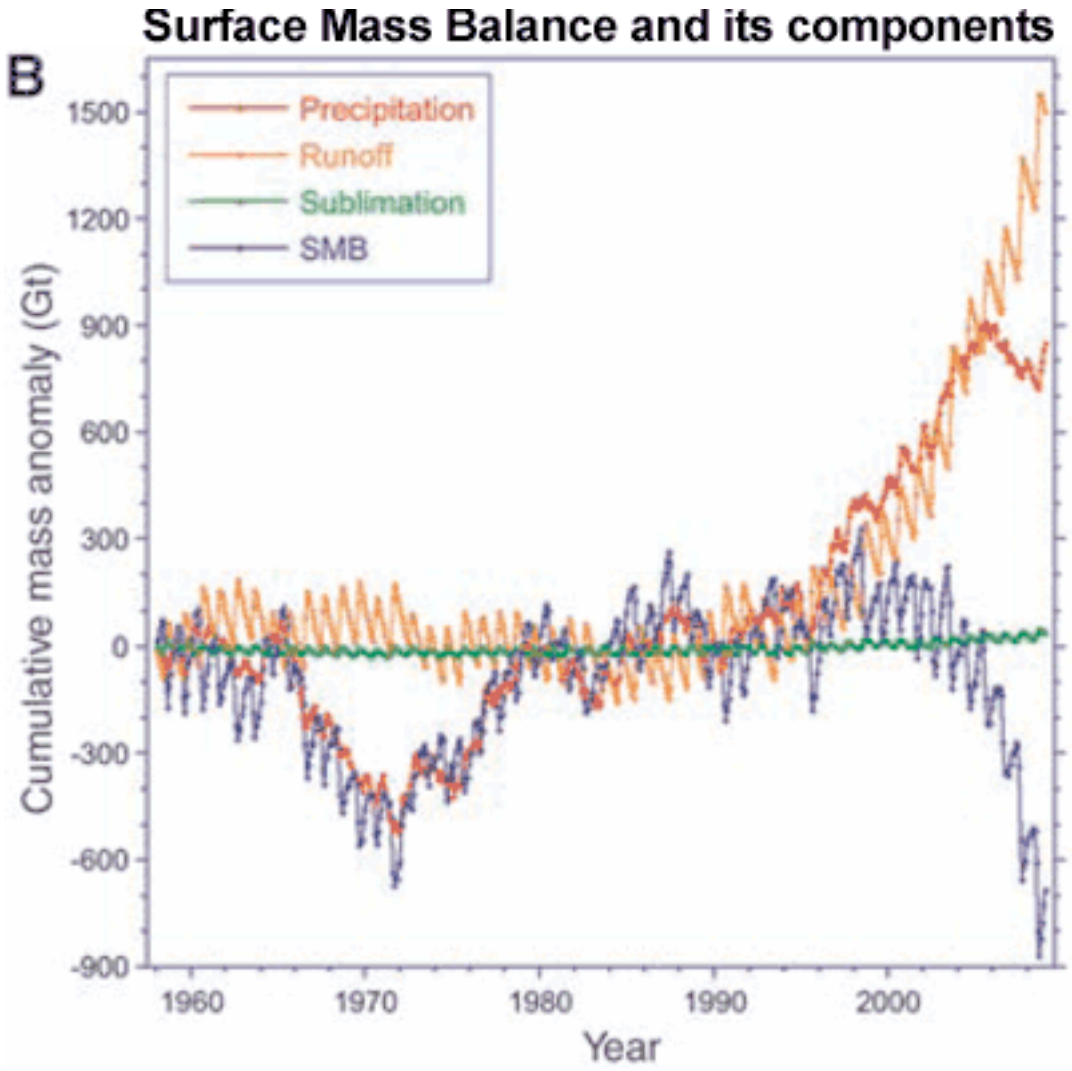



Greenland
More recent – same scale as previous slide
Gigatons
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-1200
2003
2004
2005
2006
2007
2008
2009
2010
2011

Hard to keep up…



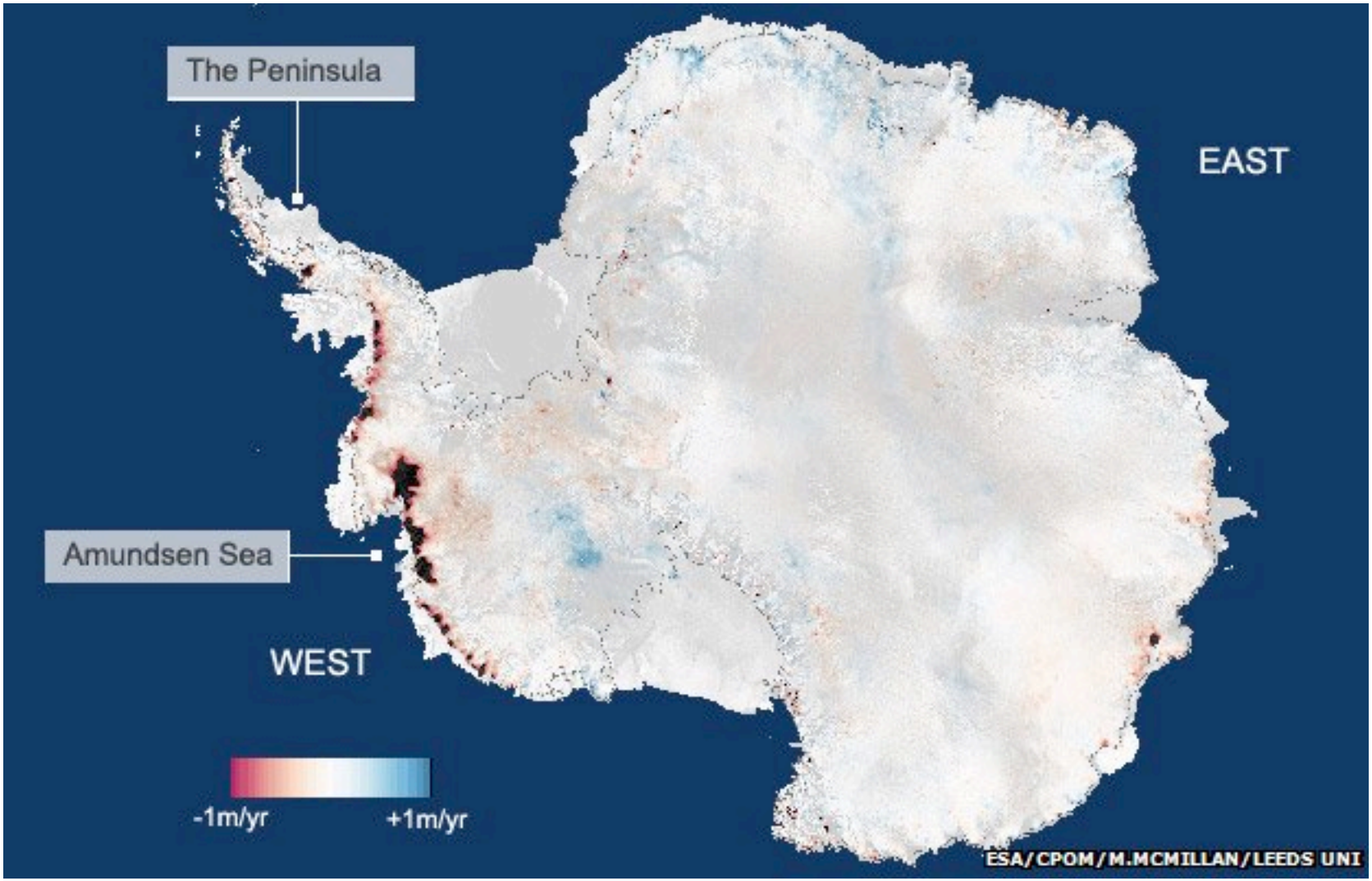

Earth's Total Heat Content anomaly
Land & Atmosphere Heating
Ocean Heating
Heat Content Anomaly (10^{21} Joules)
220
200
180
160
140
120
100
80
60
40
20
0
-20
1950
1960
1970
1980
1990
2000
Ocean Heating
Land + Atmosphere


Surface Mass Balance and its components
B
Precipitation
Runoff
Sublimation
SMB
Cumulative mass anomaly (Gt)
1500
1200
900
600
300
0
-300
-600
-900
1960
1970
1980
1990
2000
Year

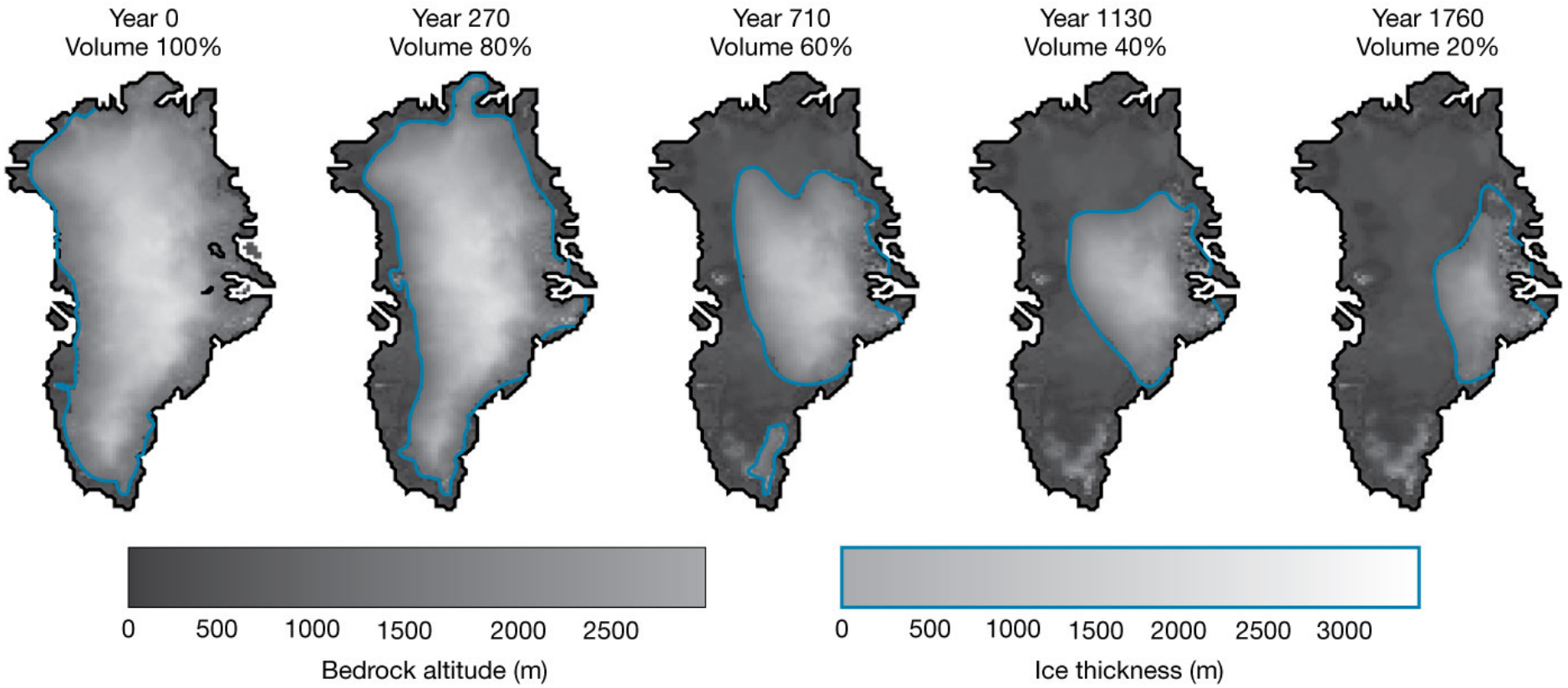
19 May 2014 Last updated at 05:33 ET

Esa's Cryosat mission sees Antarctic ice losses double

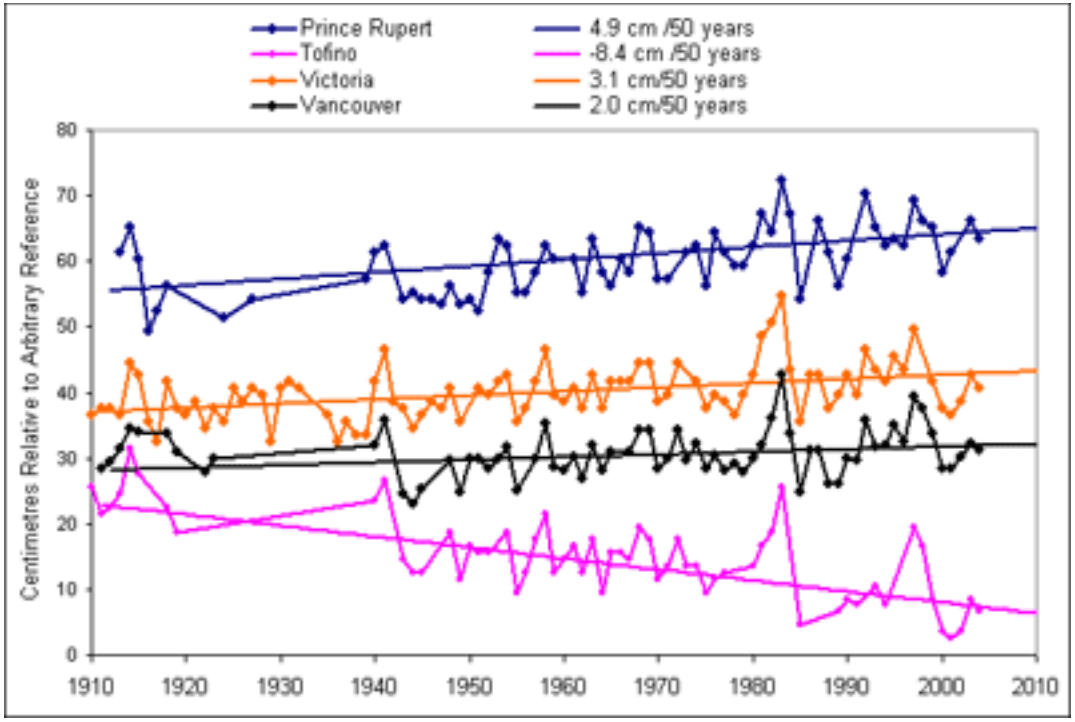
By Jonathan Amos, Science correspondent, BBC News

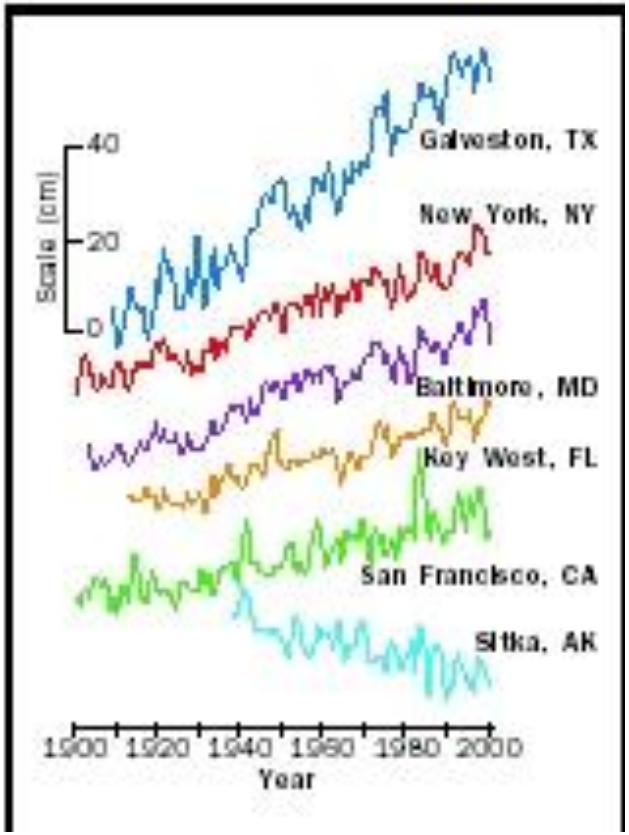


- Antarctica is now losing about 160 billion tonnes of ice a year to the ocean - twice as much as when the continent was last surveyed.
- The new assessment comes from Europe's Cryosat spacecraft, which has a radar instrument specifically designed to measure the shape of the ice sheet.
- The melt loss from the White Continent is sufficient to push up global sea levels by around 0.43mm per year.
- Scientists report the data in the journal Geophysical Research Letters.
- The new study incorporates three years of measurements from 2010 to 2013, and updates a synthesis of observations made by other satellites over the period 2005 to 2010.
- In the three sectors, this equates to losses of 134 billion tonnes, 3 billion tonnes, and 23 billion tonnes of ice per year, respectively.
- The East had been gaining ice in the previous study period, boosted by some exceptional snowfall, but it is now seen as broadly static in the new survey.
- As expected, it is the western ice sheet that dominates the reductions.
- Scientists have long considered it to be the most vulnerable to melting.

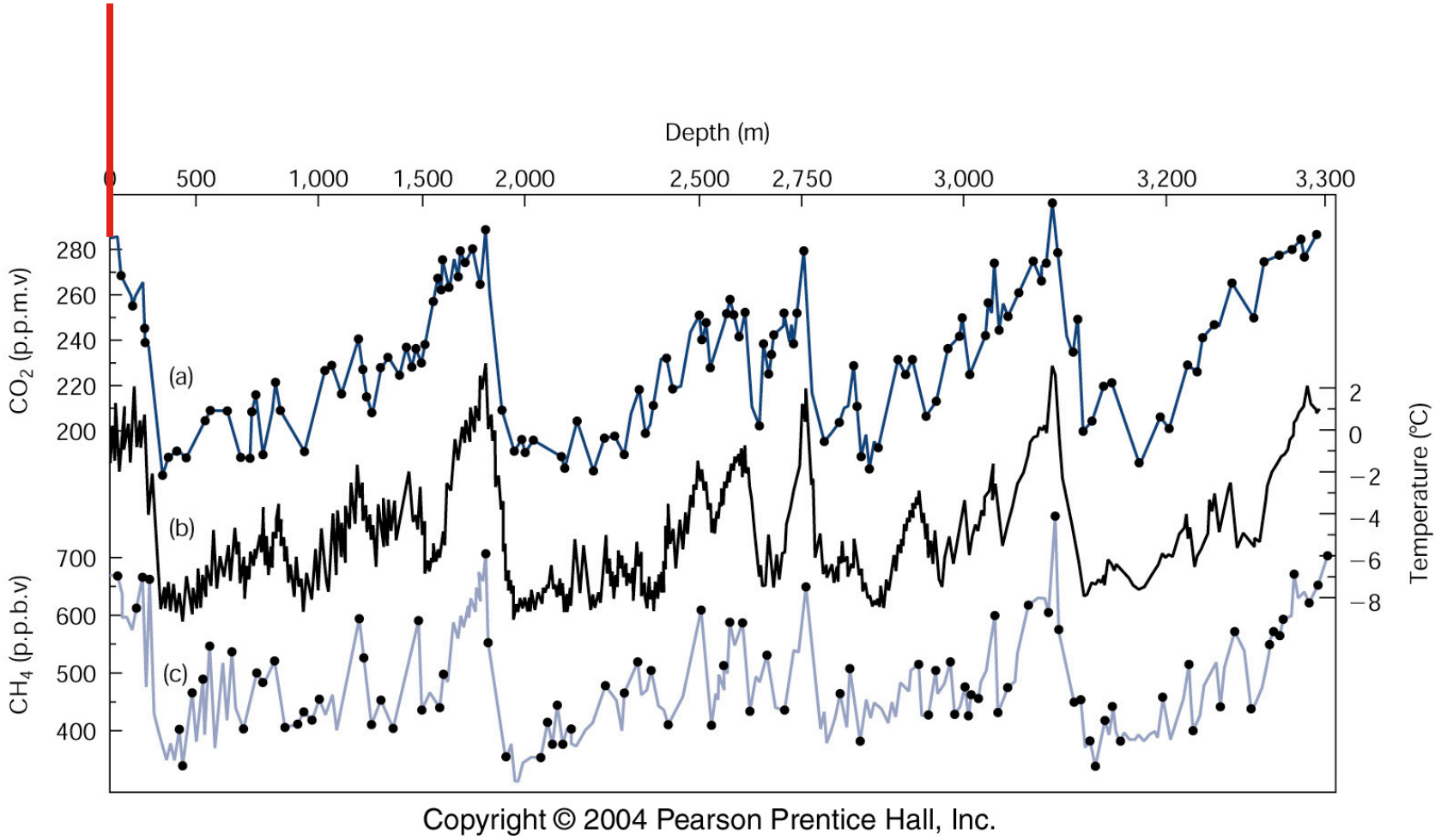


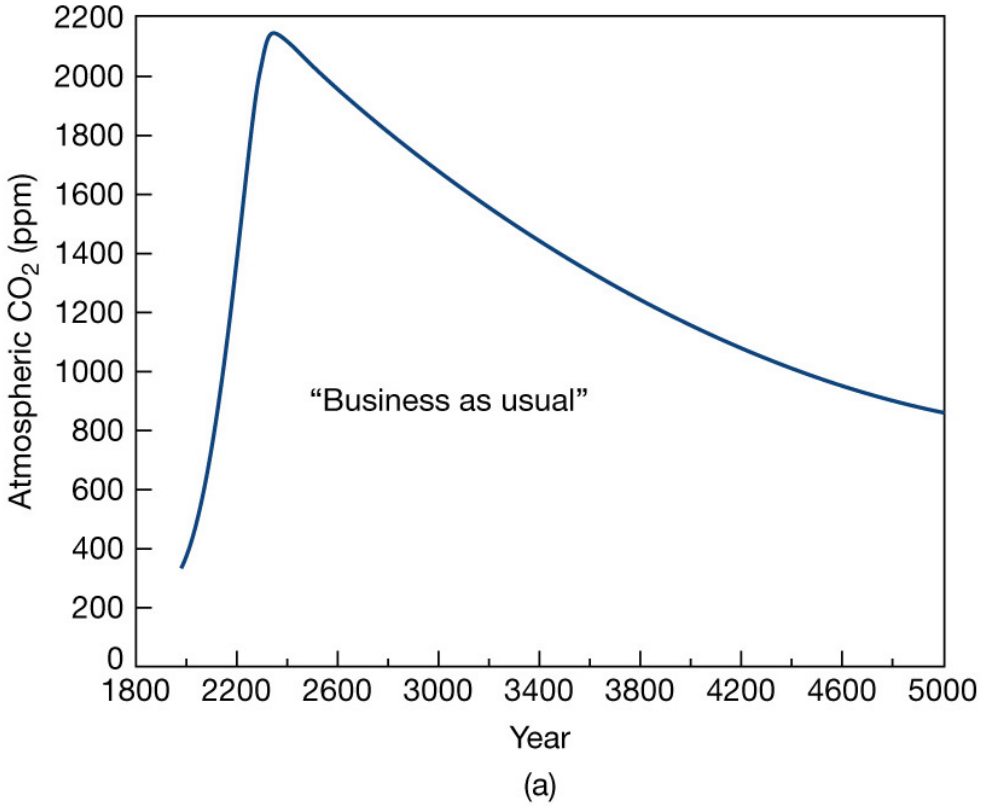
Why is sea level rise not even?

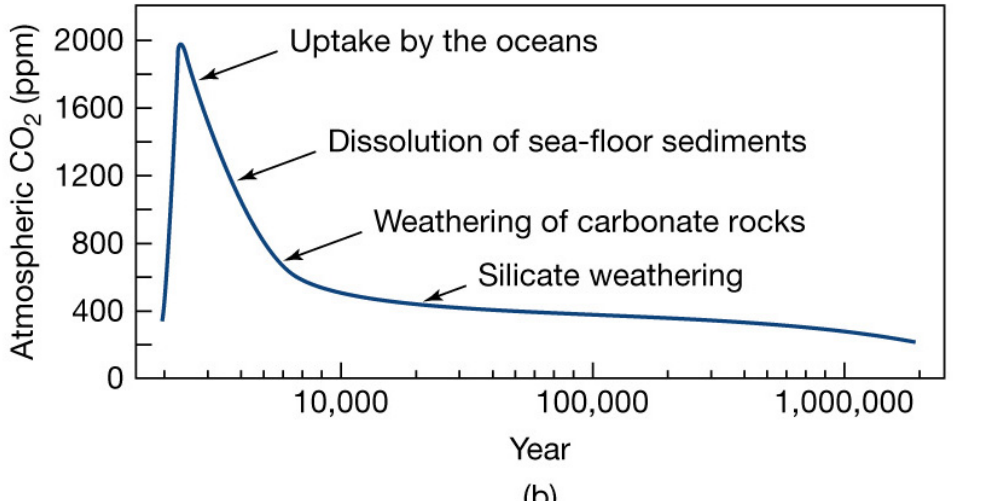




How does an increase from 280 to 380 ppm from industrial time to present compare with the past variations in atmospheric CO_2?




Atmospheric CO_2 (ppm)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
"Business as usual"
1800
2200
2600
3000
3400
3800
4200
4600
5000
Year
(a)


Atmospheric CO_2 (ppm)
2000
1600
1200
800
400
0
Uptake by the oceans
Dissolution of sea-floor sediments
Weathering of carbonate rocks
Silicate weathering
10,000
100,000
1,000,000
Year
(b)

Box 15-3

Effects on ecosystems

Soils good at holding water:

At about 2050, it will be hot enough that soil moisture us generally poor, all trees will have problems

Soils poor at holding water:

(Minnesota Forests)

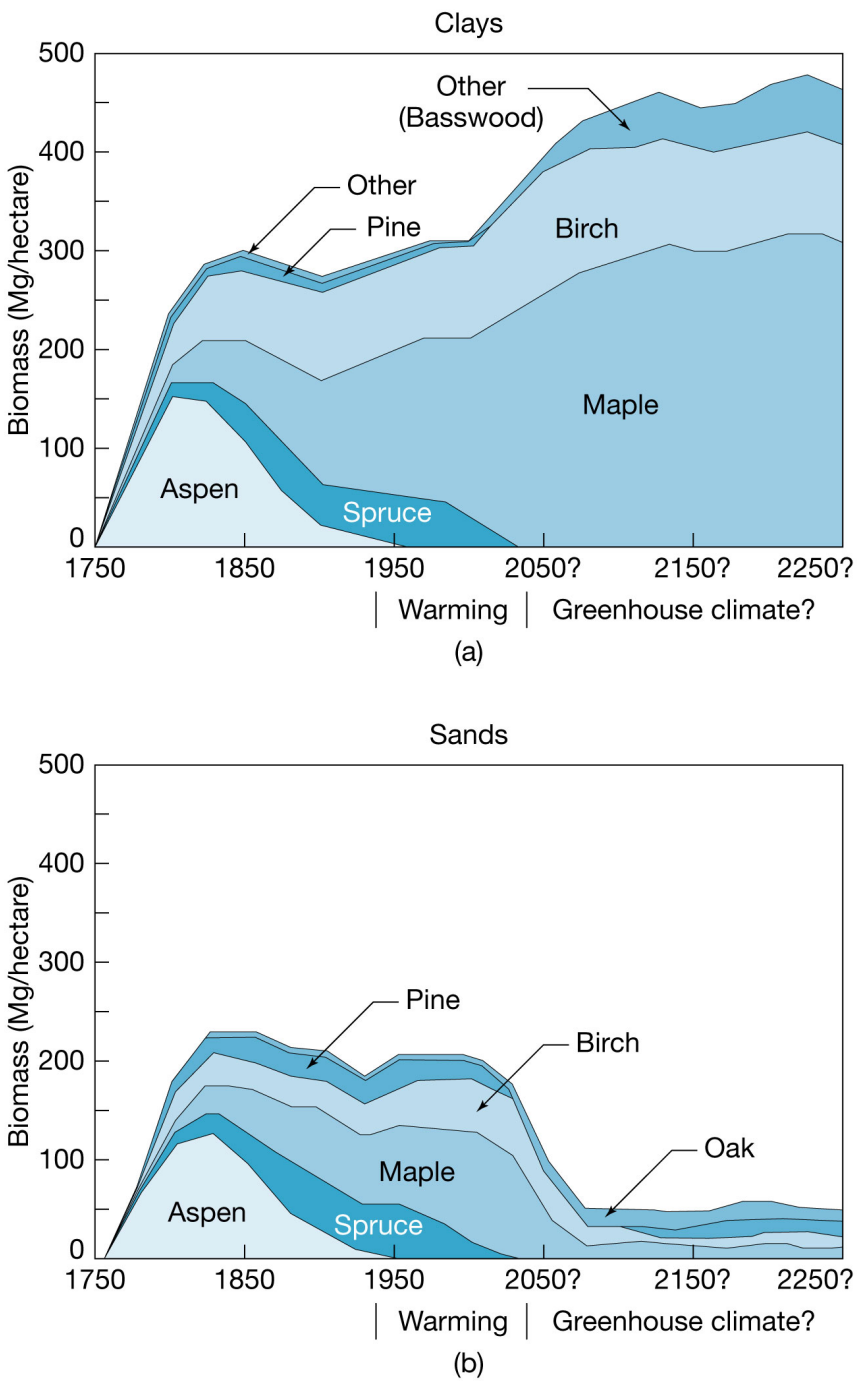
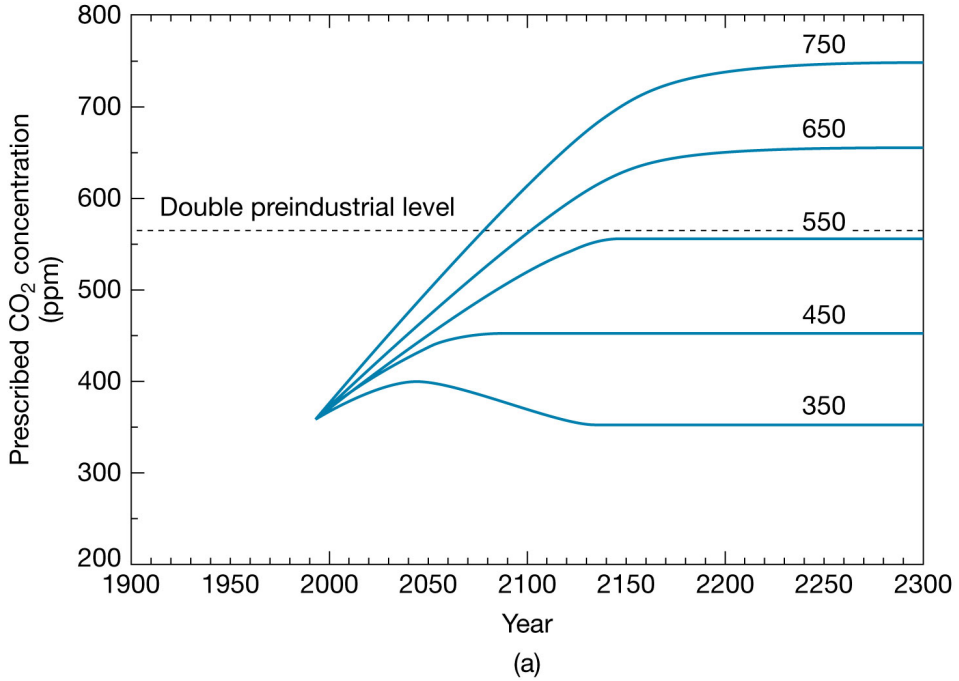


Fig. 16-5



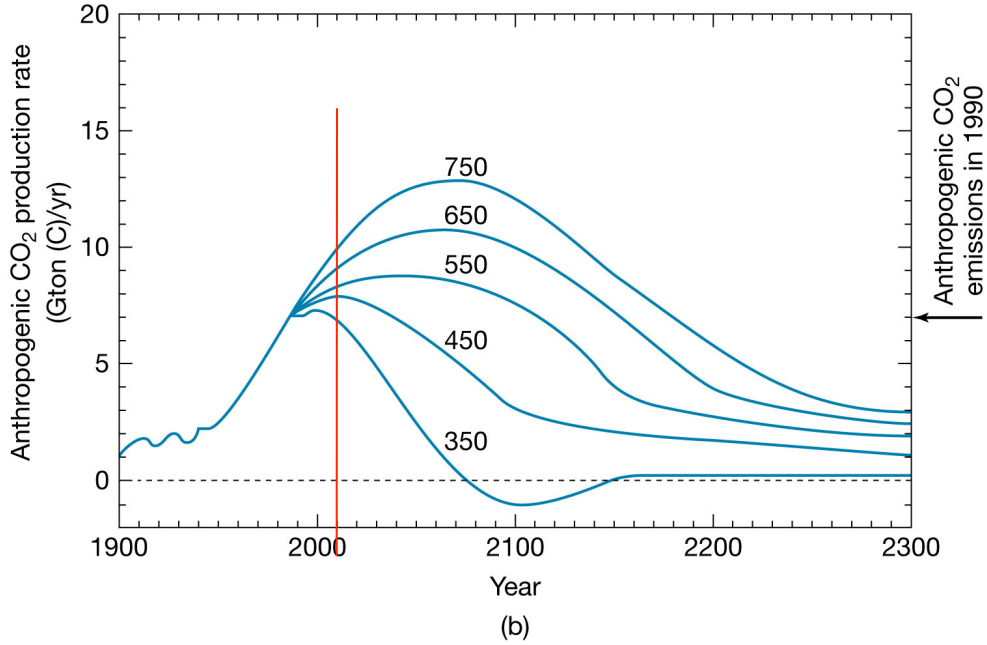


Fig. 16-8

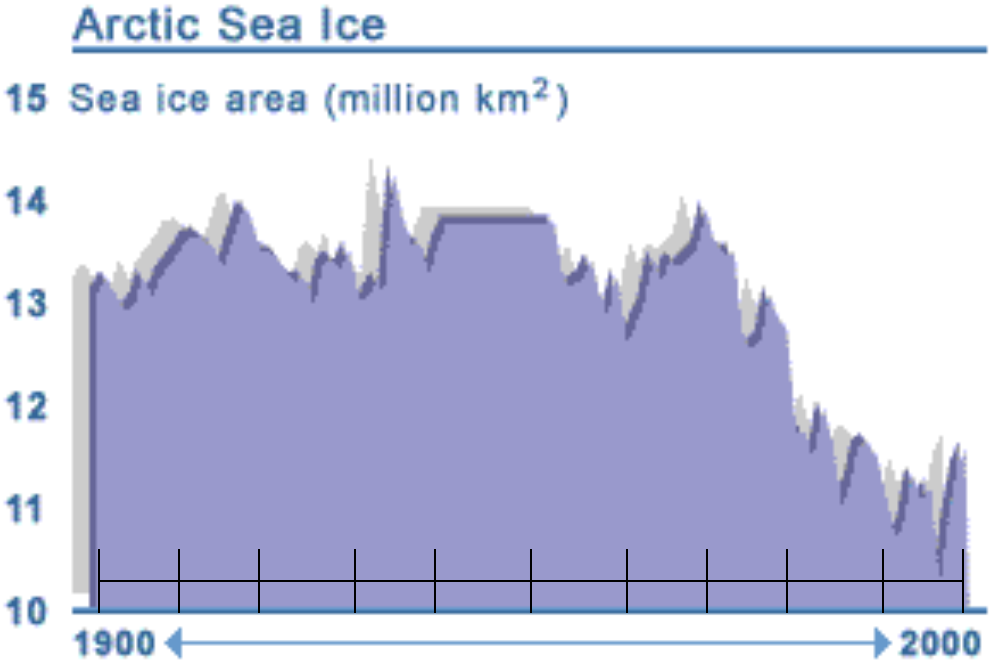
Question:

- When was the National Oceanic and Atmospheric Adminisation (NOAA) founded?
- 1807, by Thomas Jefferson (originally as the “Survey of the Coast” - shortly after the Lewis and Clark expedition.

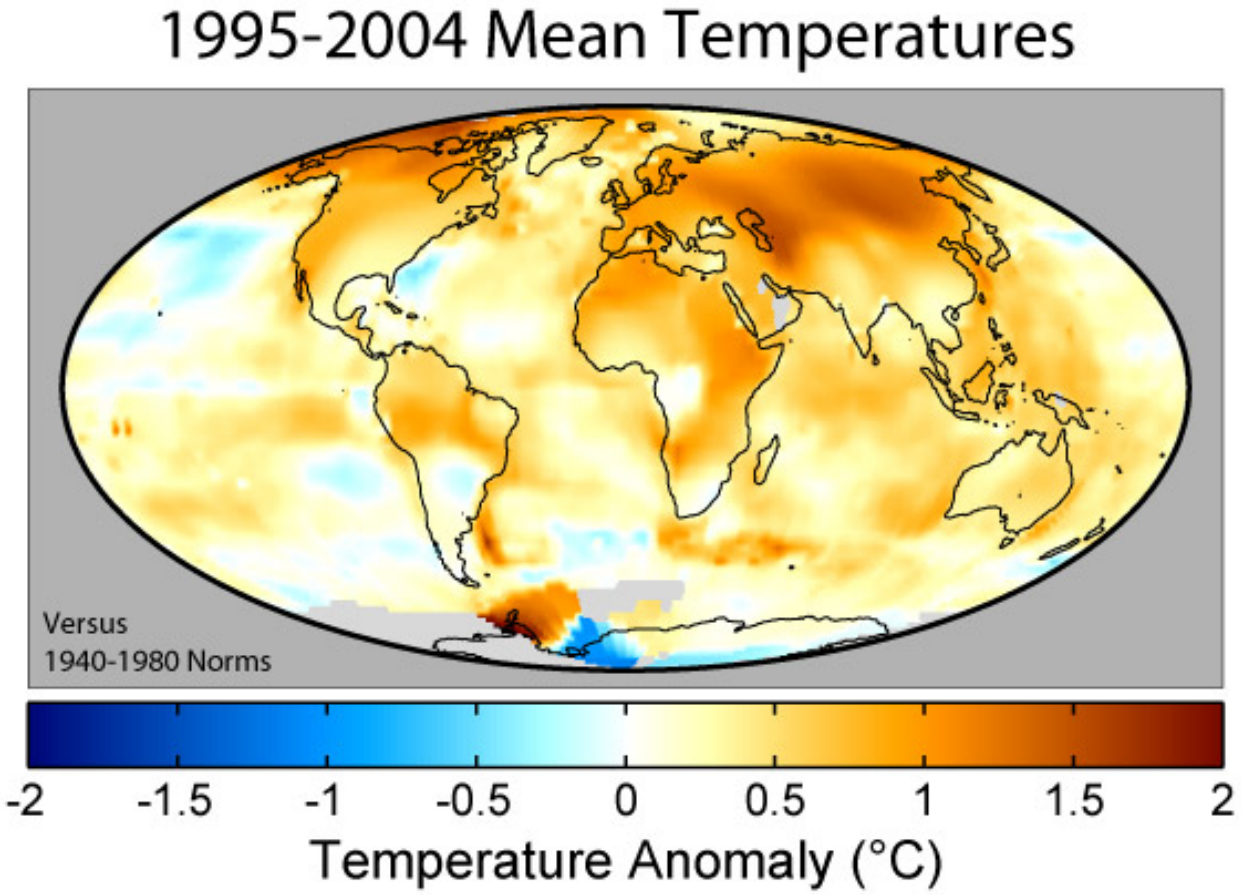
Arctic Sea Ice Extent

It's disappearing faster than even the worst-case scenarios….

- Data from National Snow and Ice Data Center … NASA, NSF, NOAA, CU Boulder,
- and its institute CIRES (Cooperative Institute for Research in Environmental Sciences)



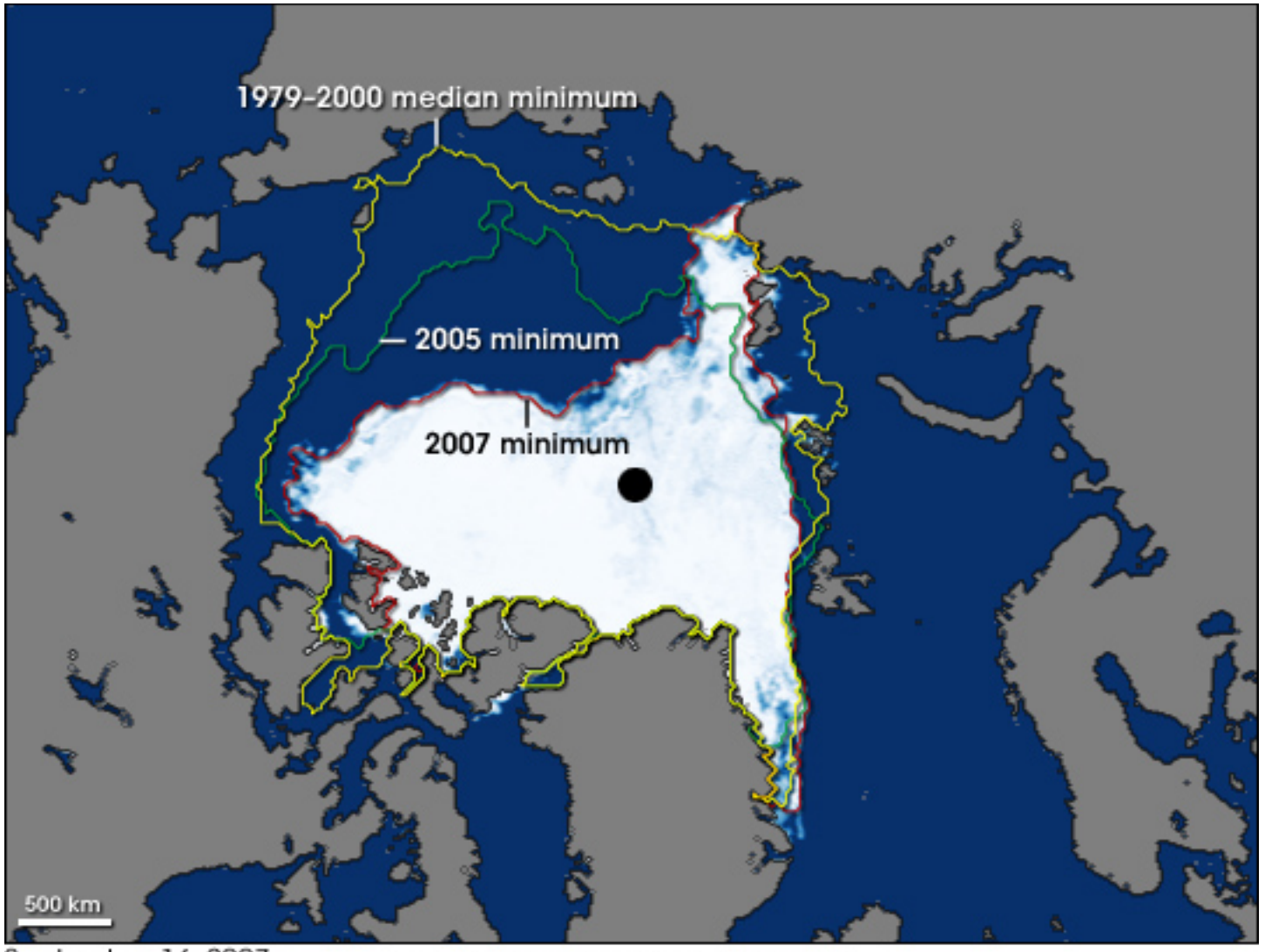
High-latitude regions are warming up more, as predicted



→ a big concern is what will happen to the Arctic sea ice, and a bigger concern regards the Antarctic ice dome

Keep in mind…

- The previous slide is from Bart Geerts, UW atmospheric scientist
- He prepared the slide in the fall of 2005.
- So - what he's saying has proven true in the past few years, perhaps even more than he anticipated!

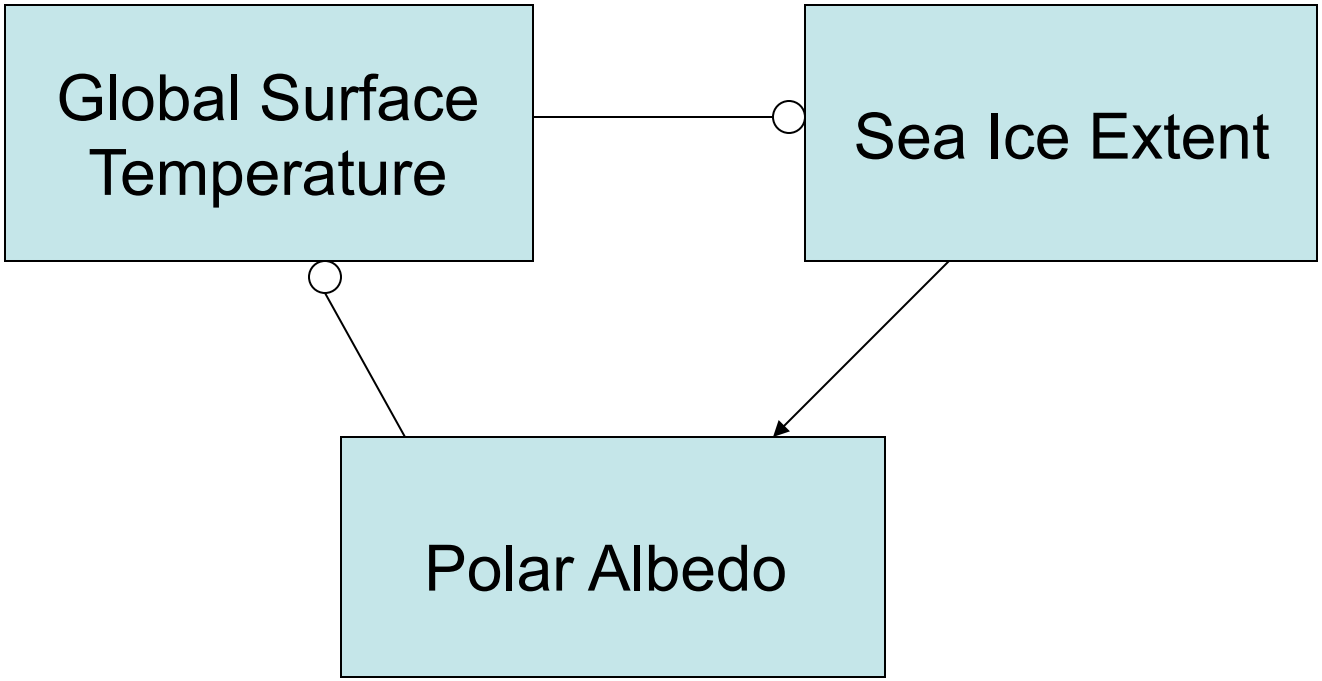


September 16, 2007

Sea Ice Concentration (percent)

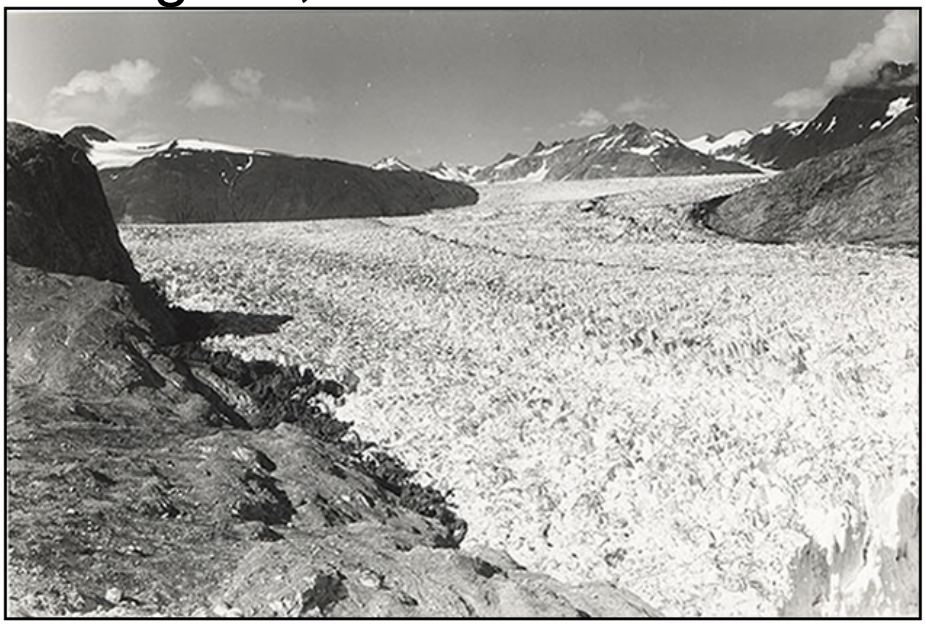
0 50 100

Feedback…



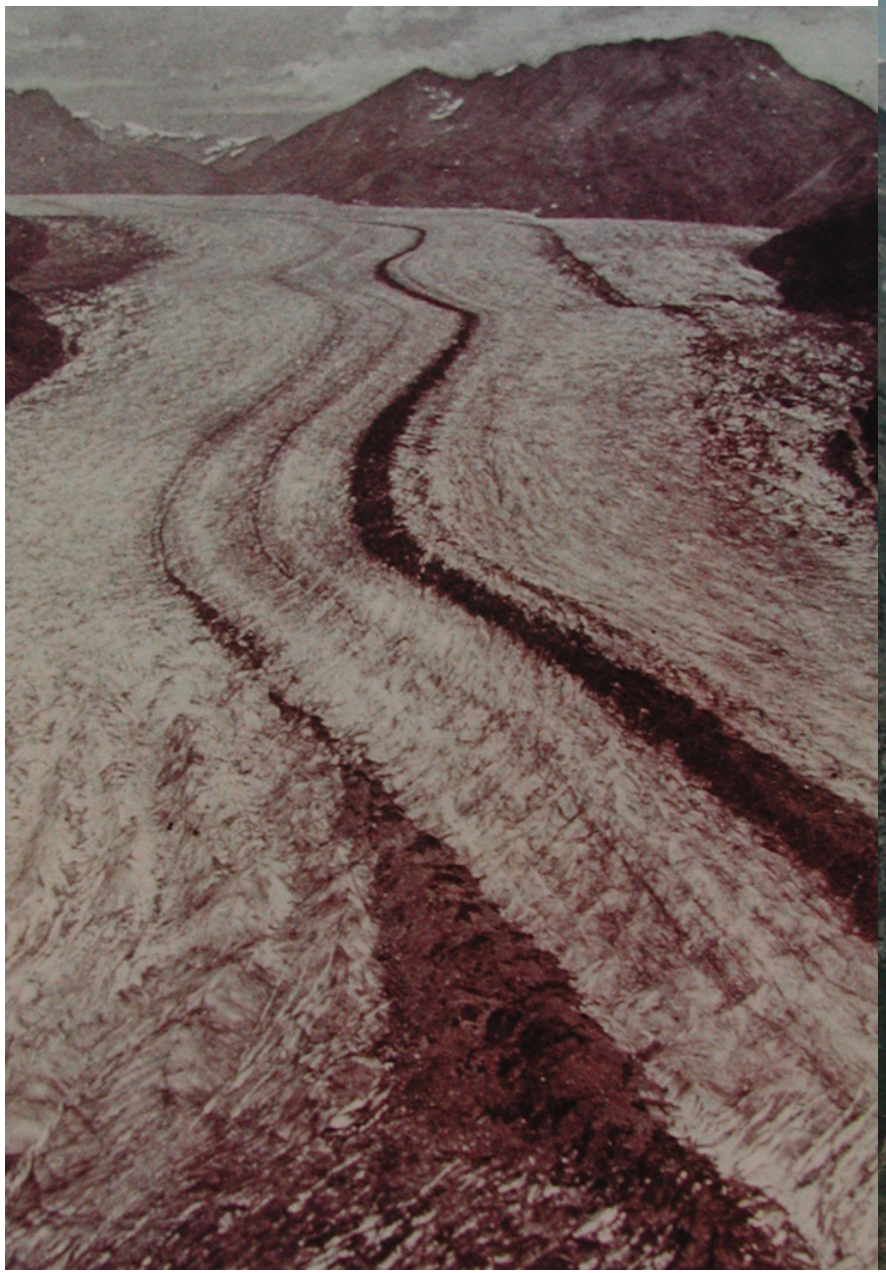
Glacial Retreat…

Aug. 13, 1941



Aug. 30, 2004

Alaska's glaciers are receding at twice the rate previously thought, according to a study published in the July 19, 2002, issue of the journal Science. These two images show Portage Glacier, near Anchorage, Alaska, in about 1950 and in July 2001. The ice has pulled back nearly out of sight, leaving behind a glacial lake.



Coastal Erosion: No sea ice to calm the waves…

Shismaref, Alaska