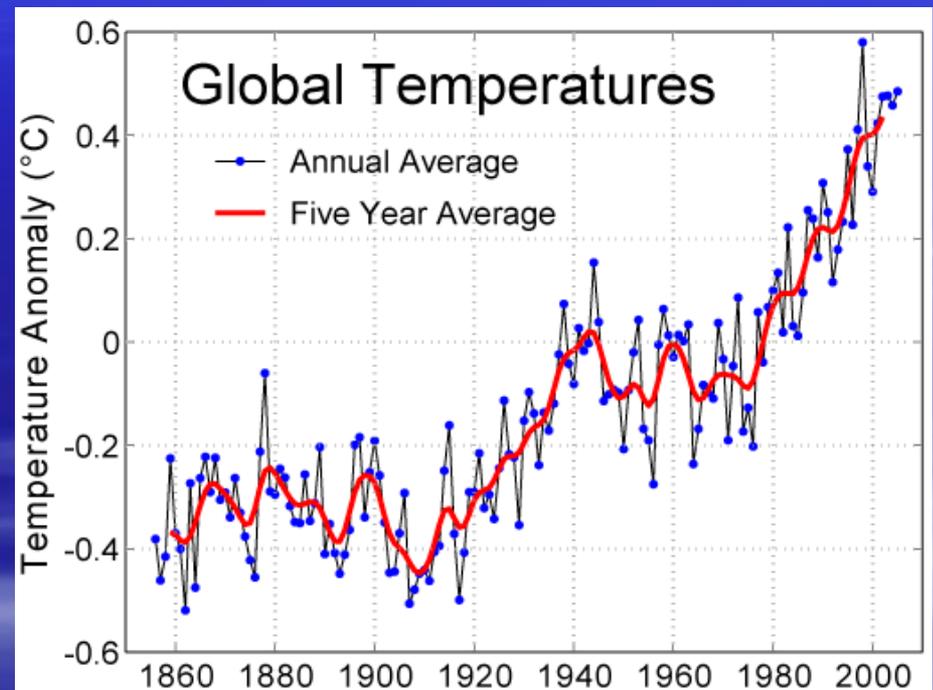


Are We Getting Warmer?

Original slides provided by Dr. Daniel Holland

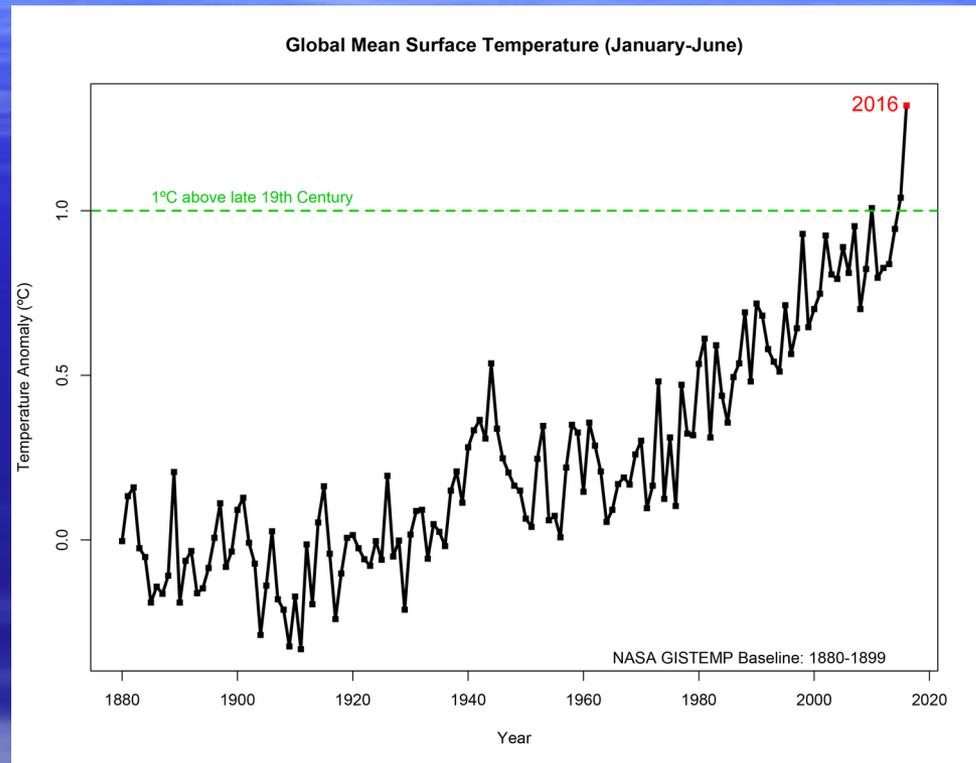
How do you take a planets temperature?

- If you have them, then thermometers spread around the earth can tell us the average temperature.
- These record go back to the mid 19th century.
- Earlier records not standardized so they have more uncertainty.



[Audio Link](#)

The reference point on the temperature axis may change on different Temperature graphs, but the message is the same.



<https://www.ncdc.noaa.gov/sotc/global/201713>

RANK 1 = WARMEST PERIOD OF RECORD: 1880-2017	YEAR	ANOMALY °C	ANOMALY °F
1	2016	0.94	1.69
2	2015	0.90	1.62
3	2017	0.84	1.51
4	2014	0.74	1.33
5	2010	0.70	1.26
6	2013	0.67	1.21
7	2005	0.66	1.19
8	2009	0.64	1.15
9	1998	0.63	1.13
10	2012	0.62	1.12

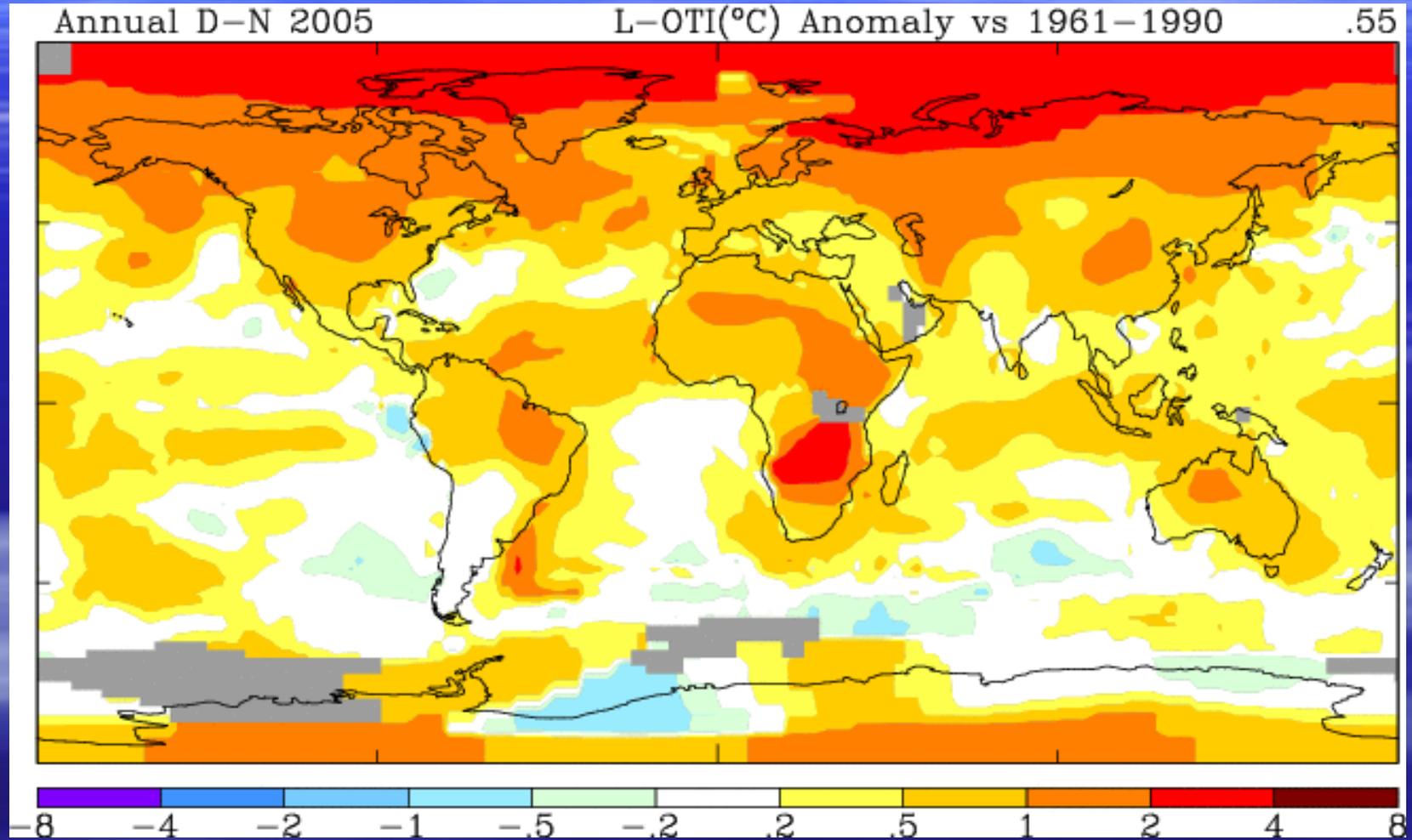
<https://www.ncdc.noaa.gov/sotc/global/201713>

- Records must account for Sea Surface temperature, heat islands around cities, land use changes.
- Usually want to determine “anomalies” rather than absolute values

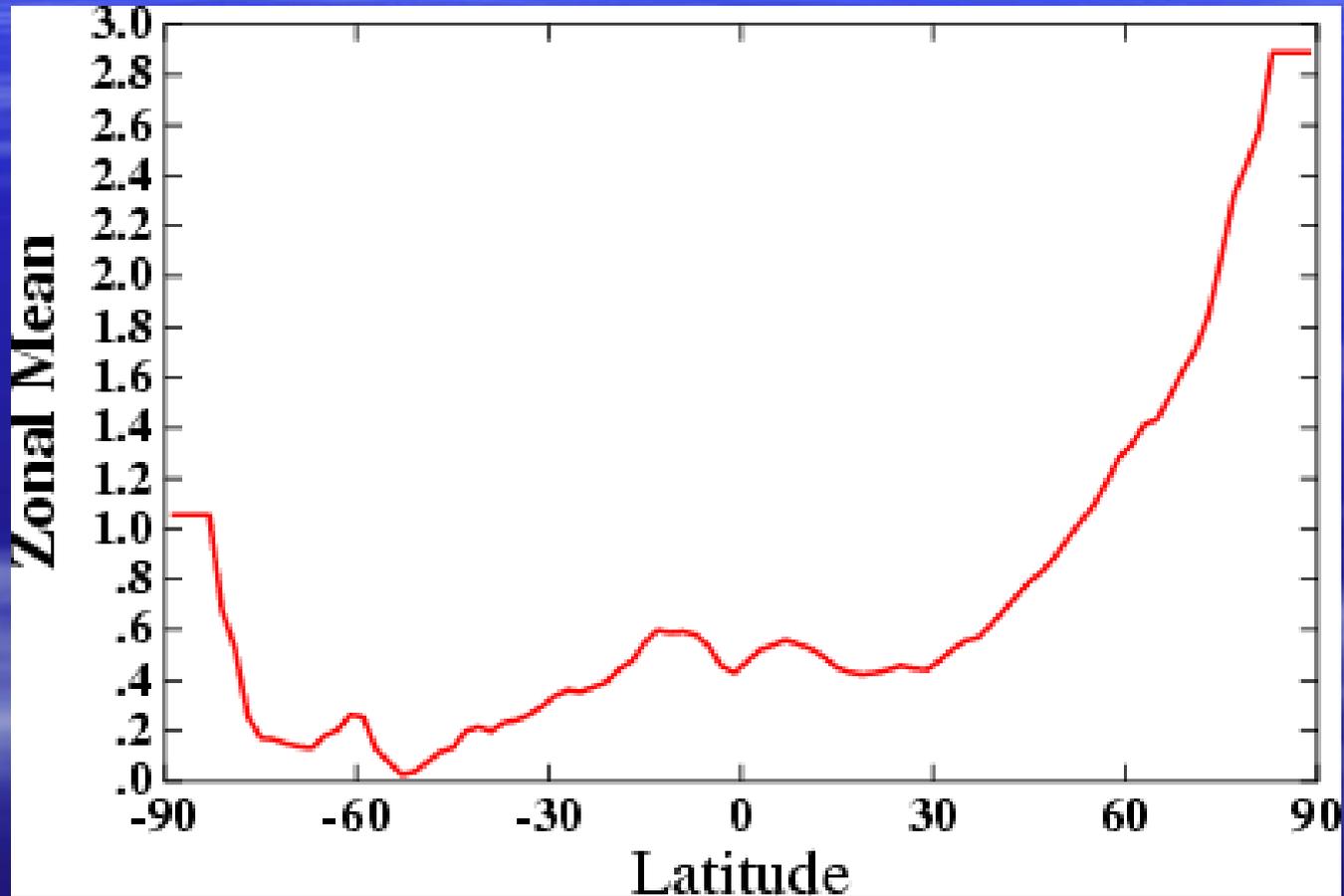
Regional Patterns

- Warming is greater on land than in oceans (specific heat)
- Warming is larger in northern hemisphere (more land and more GHG)
- Arctic has warmed at twice the global rate (ice-albedo feedback, lower evaporation so more energy absorbed at the surface)

Regional Temperature Anomolies



Zonal Mean Temperature Anomalies



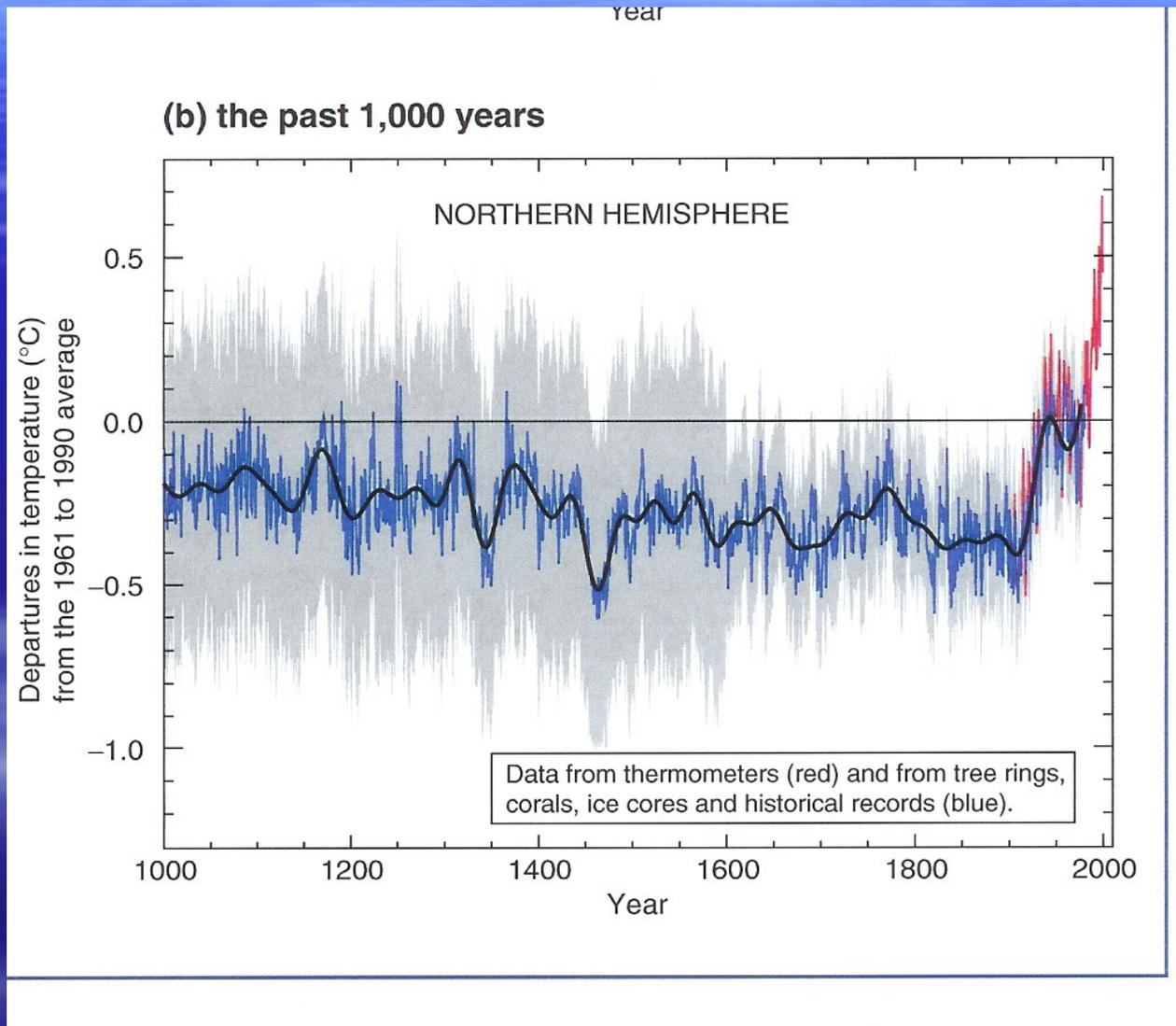
Is the temperature rise unusual

- Before 1850 we have very little direct thermometric data so we use “proxies” for measuring the temperature from long ago.
- Examples: tree rings, lake sediments, bleaching of coral reefs, isotope ratios

A real life disaster story:

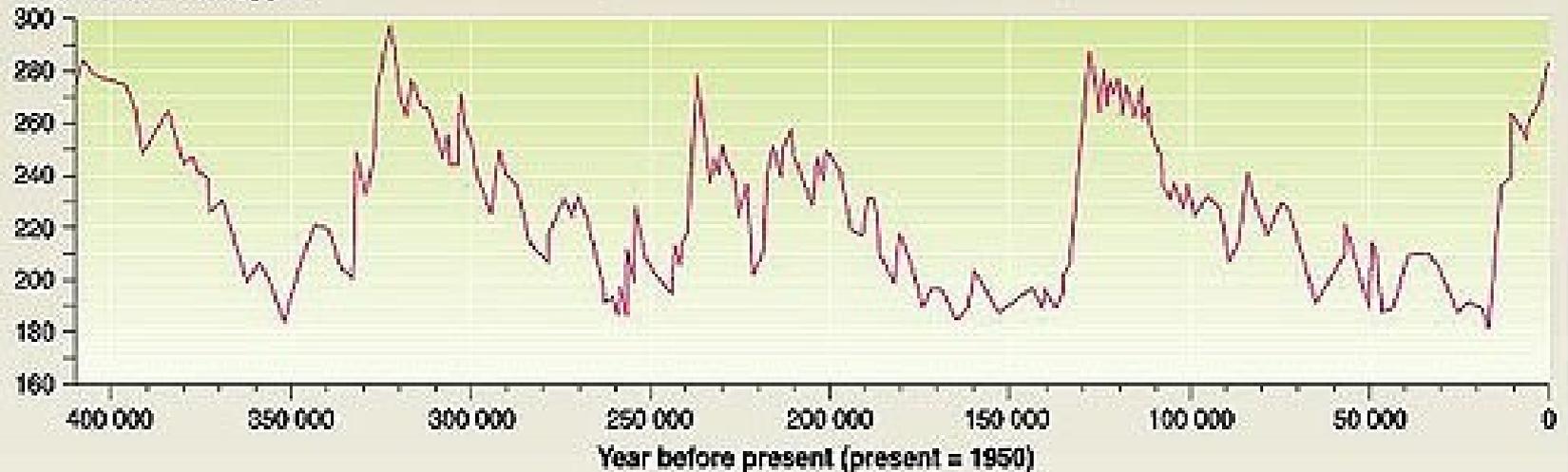
<http://www.ipcc.ch/report/ar5/wg1/>

Temperature for 1000 years.

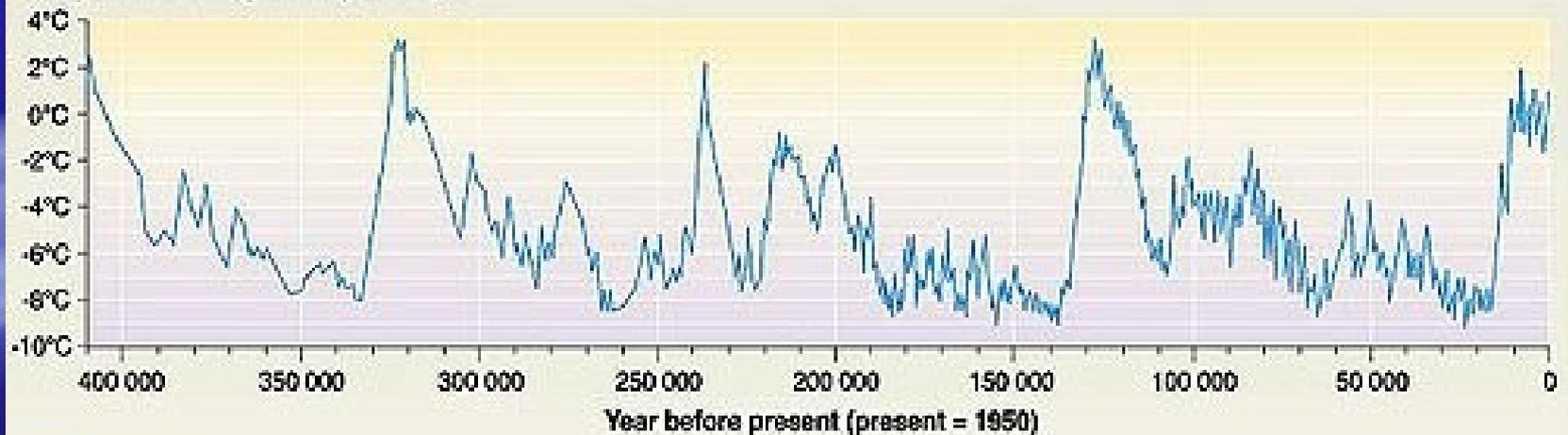


Temperature and CO₂ concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)

CO₂ concentration, ppmv



Temperature change from present, °C



GRIP
Arendal UNIP

GRAPHIC DESIGN : PHILIPPE PENNACARD

Greenland Ice Cores

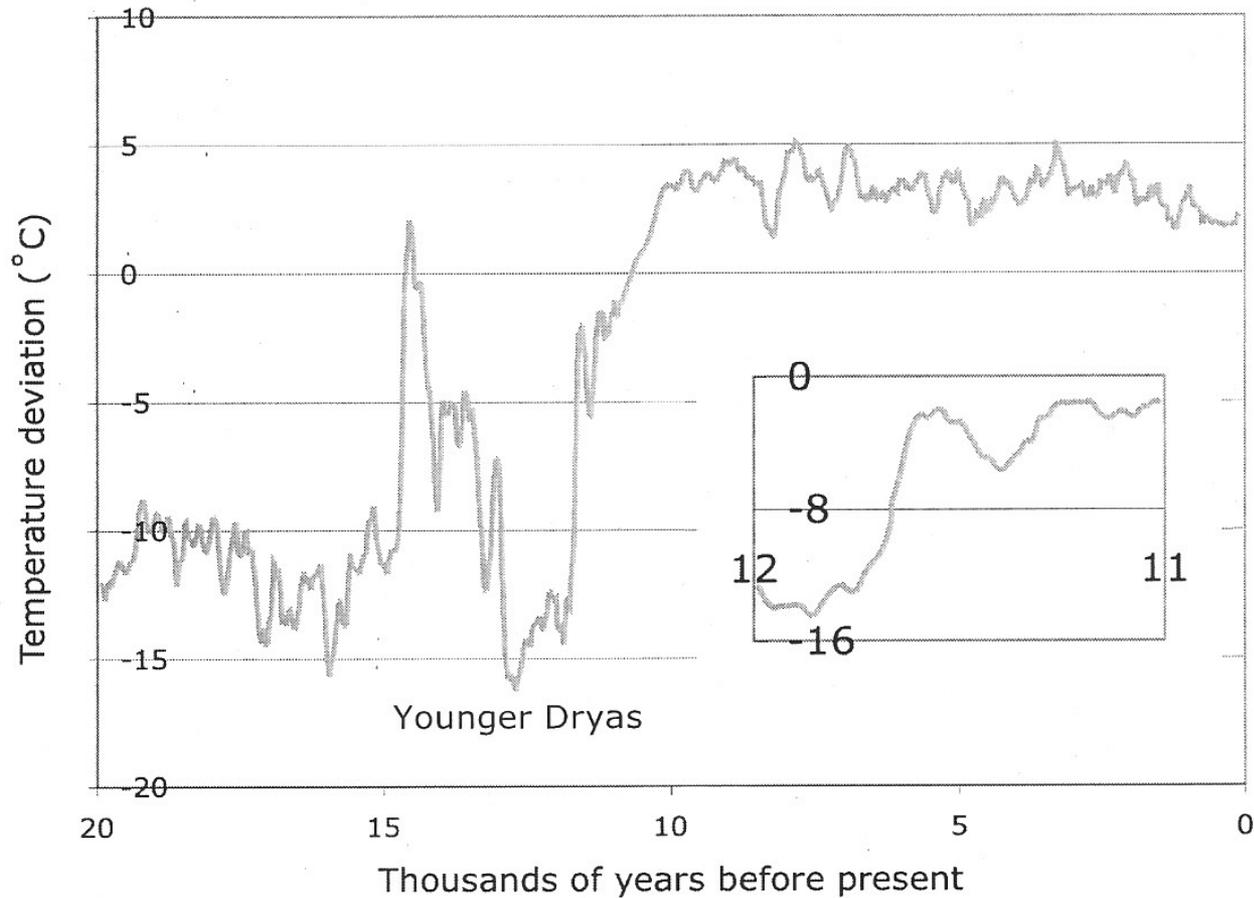


CO₂ and Temperature are strongly correlated.

- Probably not simple cause and effect.
- Small changes in temperature are caused by small orbital changes.
- A small increase in sea surface temperature cause some CO₂ to come out of solution.
- More CO₂ in the air cause further warming.

- Using Isotope ratios we can go back millions to billions of years to find temperatures.

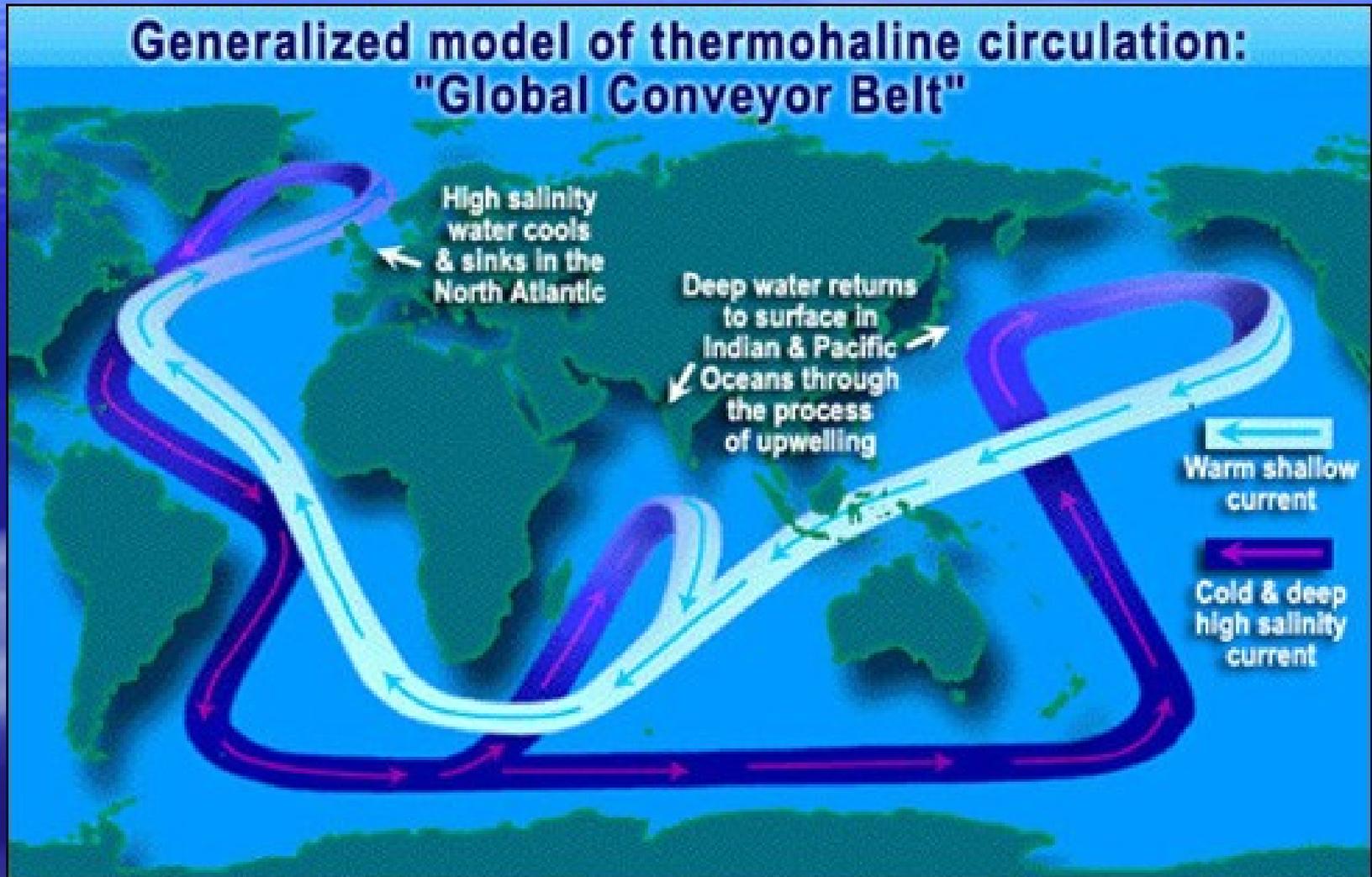
Evidence for Rapid Temperature Changes in Greenland Ice Core



- Approximately 15,000 ybp the ice core data shows a relative “brief” period which abruptly swung back to ice age conditions
- These are believed to be nonlinear effects that occur due to changes in ocean circulation when there is a large influx of fresh water from glacial melting.
- Fresh water in the North Atlantic cause warm current to “sink” further south.

Ocean Currents

Generalized model of thermohaline circulation: "Global Conveyor Belt"



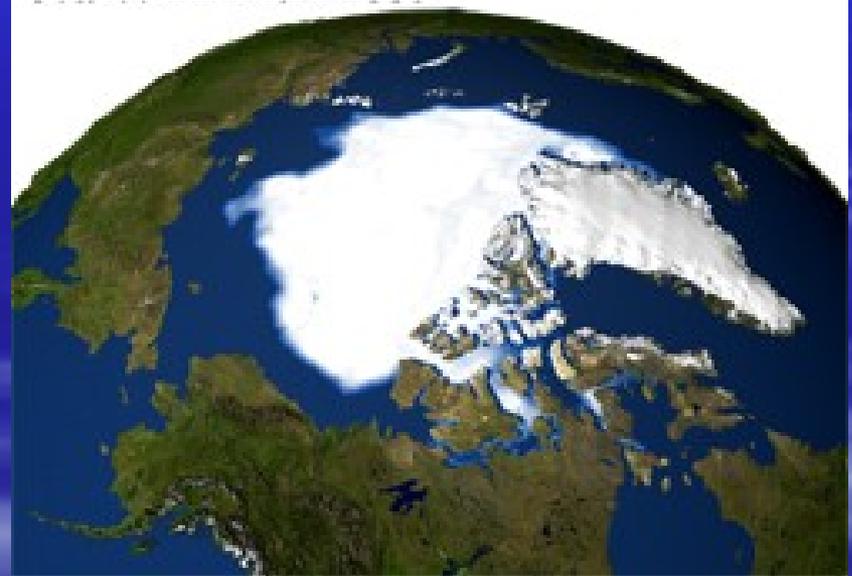
- Caution: The rapid fluctuation in the **Younger Dryas** is an example of Arctic temperatures which exaggerate global climate changes.
- It is there, but not so obvious in other proxies from other regions of the world.
- The rapid changes that we are experiencing now are global. They are also more exaggerated in the polar regions.

Reduction in Sea Ice 1979-2005

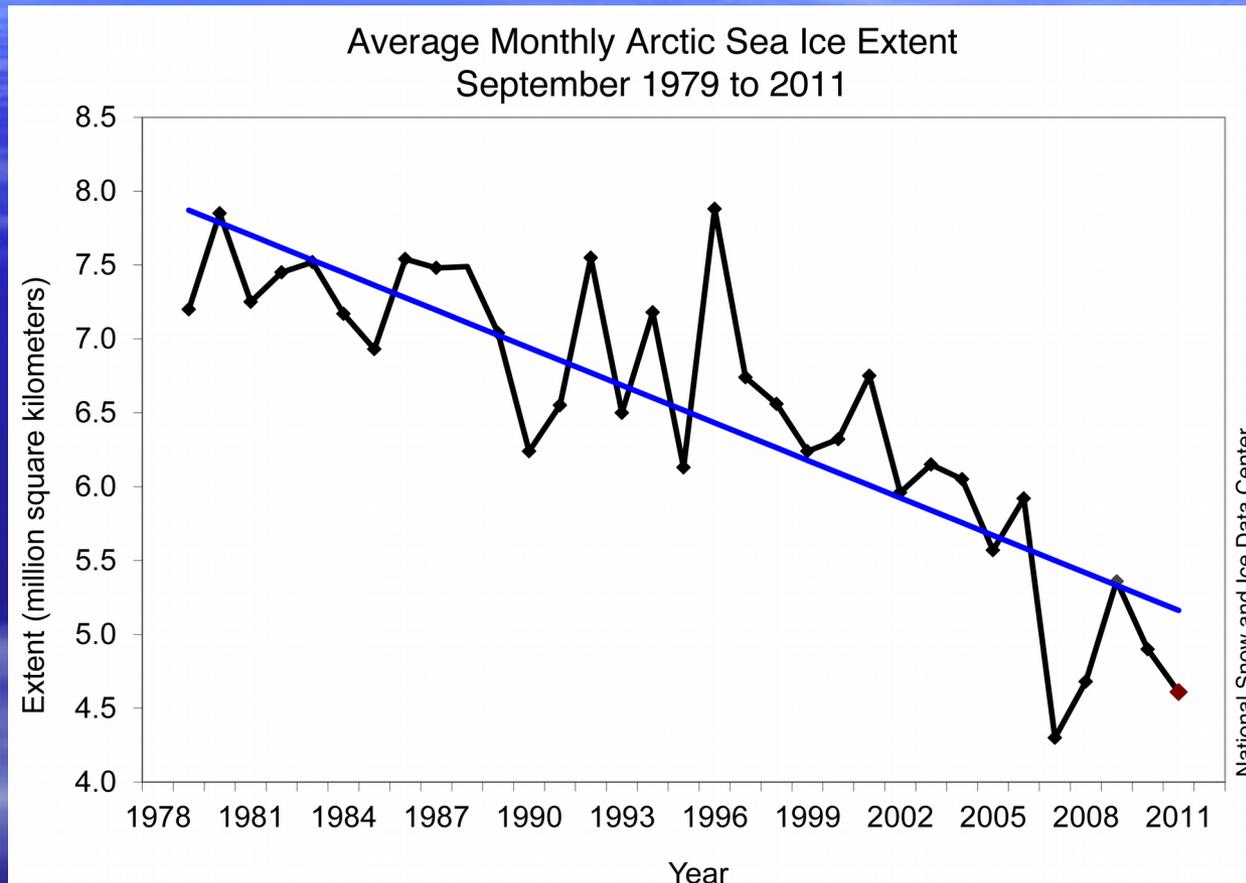
Sea Ice Minimum 1979



Sea Ice Minimum 2005

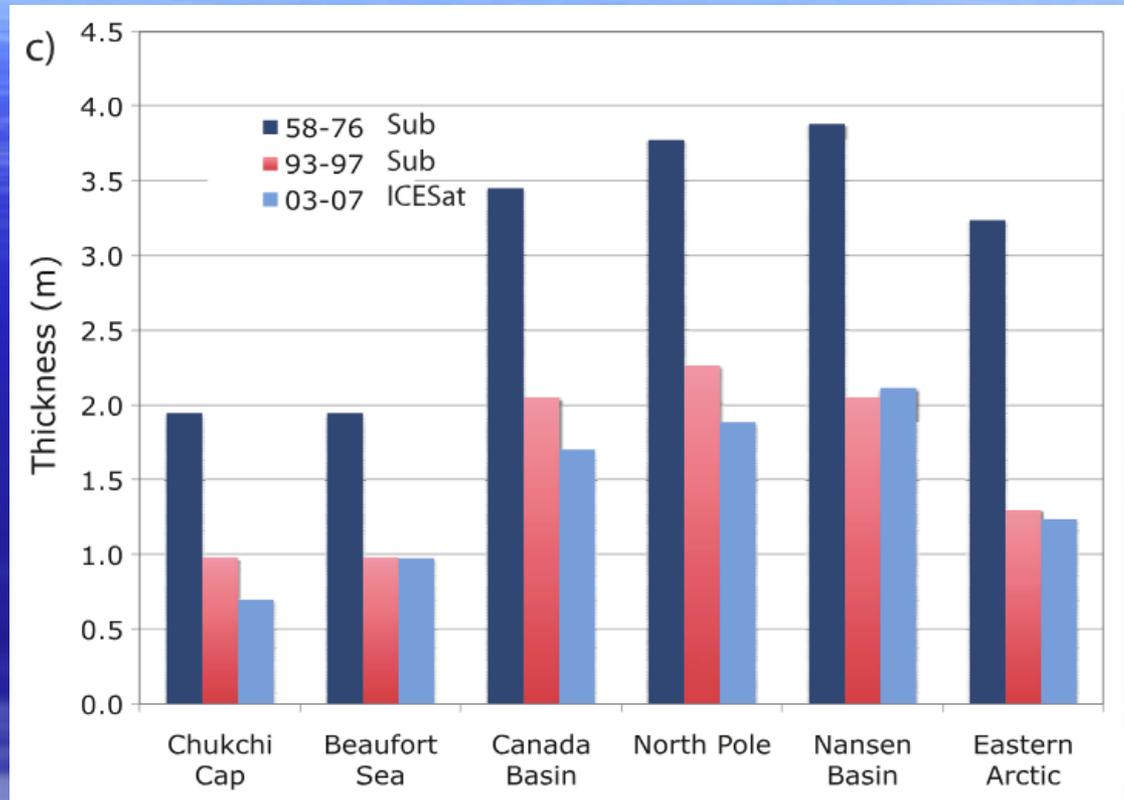


Decline in Sea Ice



<https://climatesight.org/2012/08/15/a-bad-situation-in-the-arctic/>

- Not only is there less area of sea ice, it is also thinner.



R. Kwok and D. A. Rothrock, Decline in Arctic sea ice thickness from submarine and ICESat records: 1958–2008, *Geophysical Research Letters* 36, L15501. Doi:10.1029/2009GL039035

Melting Glaciers



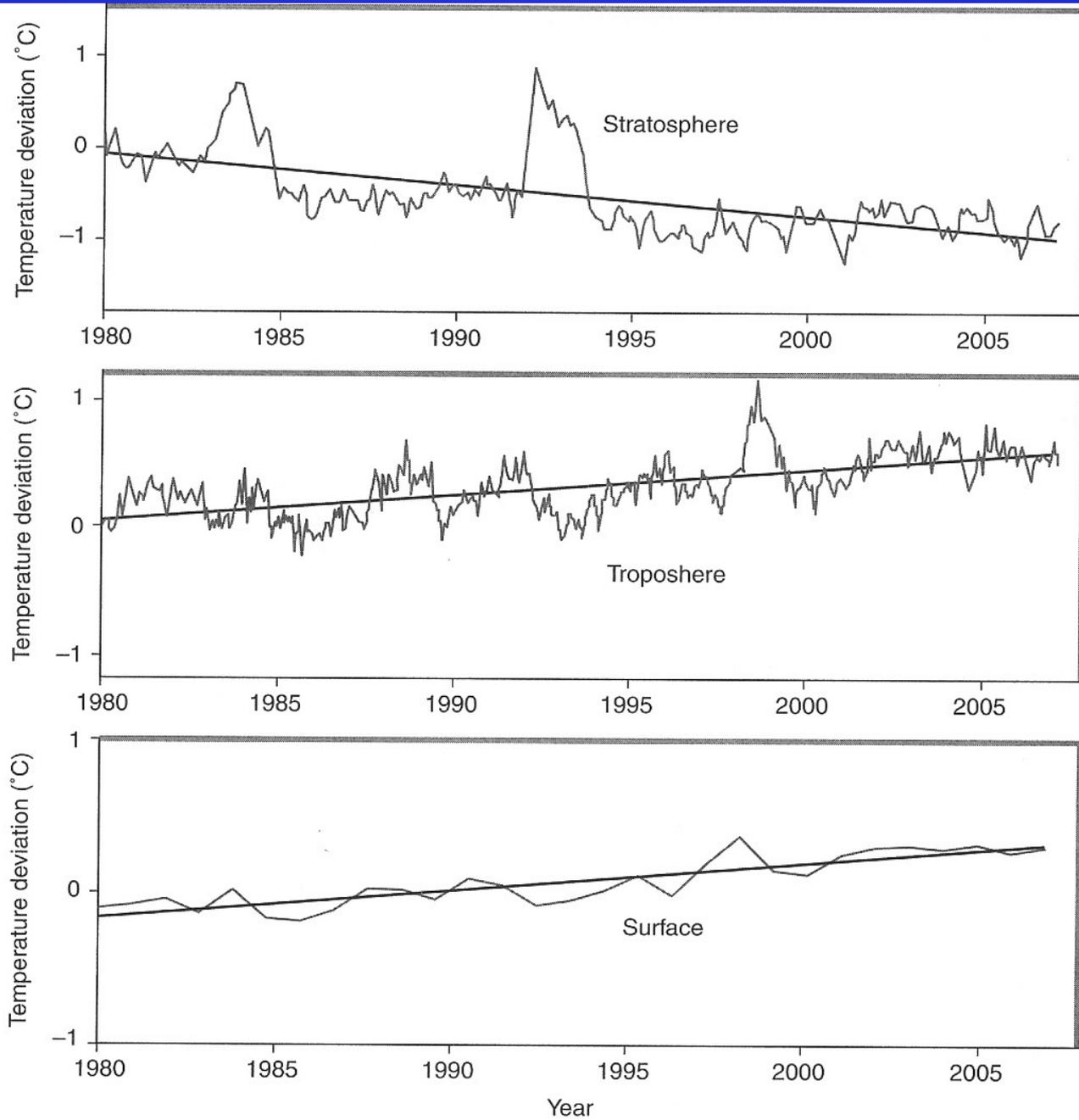
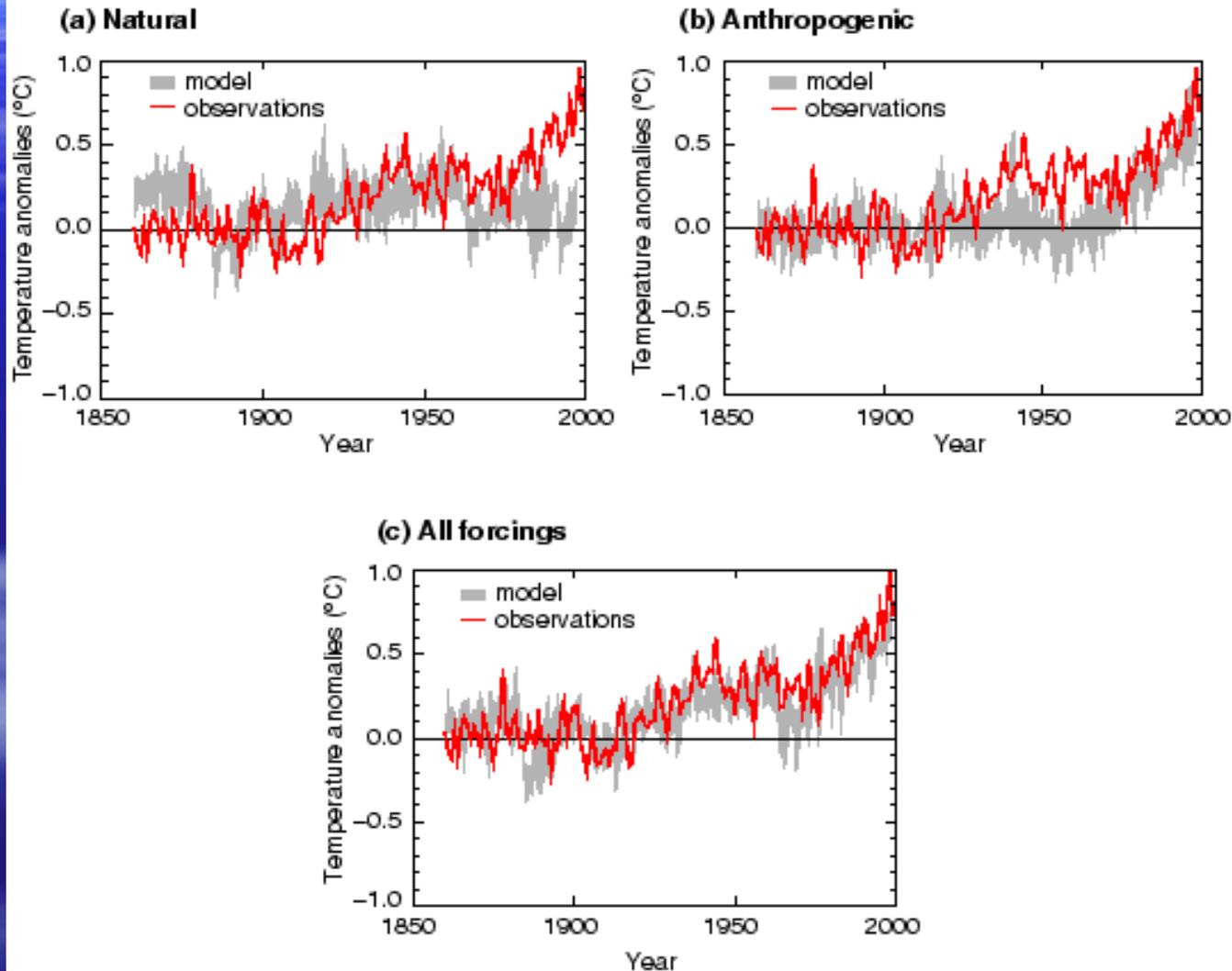


Figure 14.4

Is the Warming Anthropogenic?

Simulated annual global mean surface temperatures



- Skeptical "Science"

Take a look at the Skeptical "Science Link". If you remember nothing else from it, remember that 97% of climate scientists agree that global warming is real. There is no longer a scientific debate. There is no scientific controversy to teach, because there is no scientific controversy.

<https://www.skepticalscience.com/global-warming-scientific-consensus-intermediate.htm>

... accepts its responsibility to keep working with dili-
... ers do not resolve it.
hdellios@tribune.com

Study finds 'classic global warming' over Antarctica

Los Angeles Times

In the winter sky over Antarctica, scientists have detected a vast cap of steadily warming air, in the first sign that record levels of greenhouse gases in the atmosphere may be trapping heat above the ice sheets of the South Pole.

The temperature of the winter air over Antarctica has been rising at a rate three times faster than the world as a whole, the researchers reported Thursday in the journal *Science*.

By analyzing 30 years of high-altitude weather balloon records, meteorologists at the British Antarctic Survey in Cambridge concluded that temperatures in the polar troposphere, the dense layer of air reaching from the surface to an altitude of about 5 miles, have risen by 3.6 degrees Fahrenheit since the early 1970s.

"We have the largest regional warming on Earth at the tropospheric level," said climate spe-

cialist John Turner, who led the research team.

In their study, Turner and his colleagues drew on daily temperature records from 1971 to 2003 kept by eight international research stations that rim the continent and the U.S. station at the South Pole. It was the first time anyone had been able to collate all the high-altitude atmosphere readings.

When the researchers examined the data, they not only saw evidence of winter season warming throughout the troposphere, but a cooling in the stratosphere above, a layering effect that researchers predict as a consequence of greenhouse warming.

"We have the classic global warming signal," Turner said. "It is like the blanket on the bed: When we wrap the Earth with a blanket of greenhouse gases like carbon dioxide and methane, we trap heat under it at the expense of the atmosphere above, which then cools."

Chicago Tribune

31 March 2006