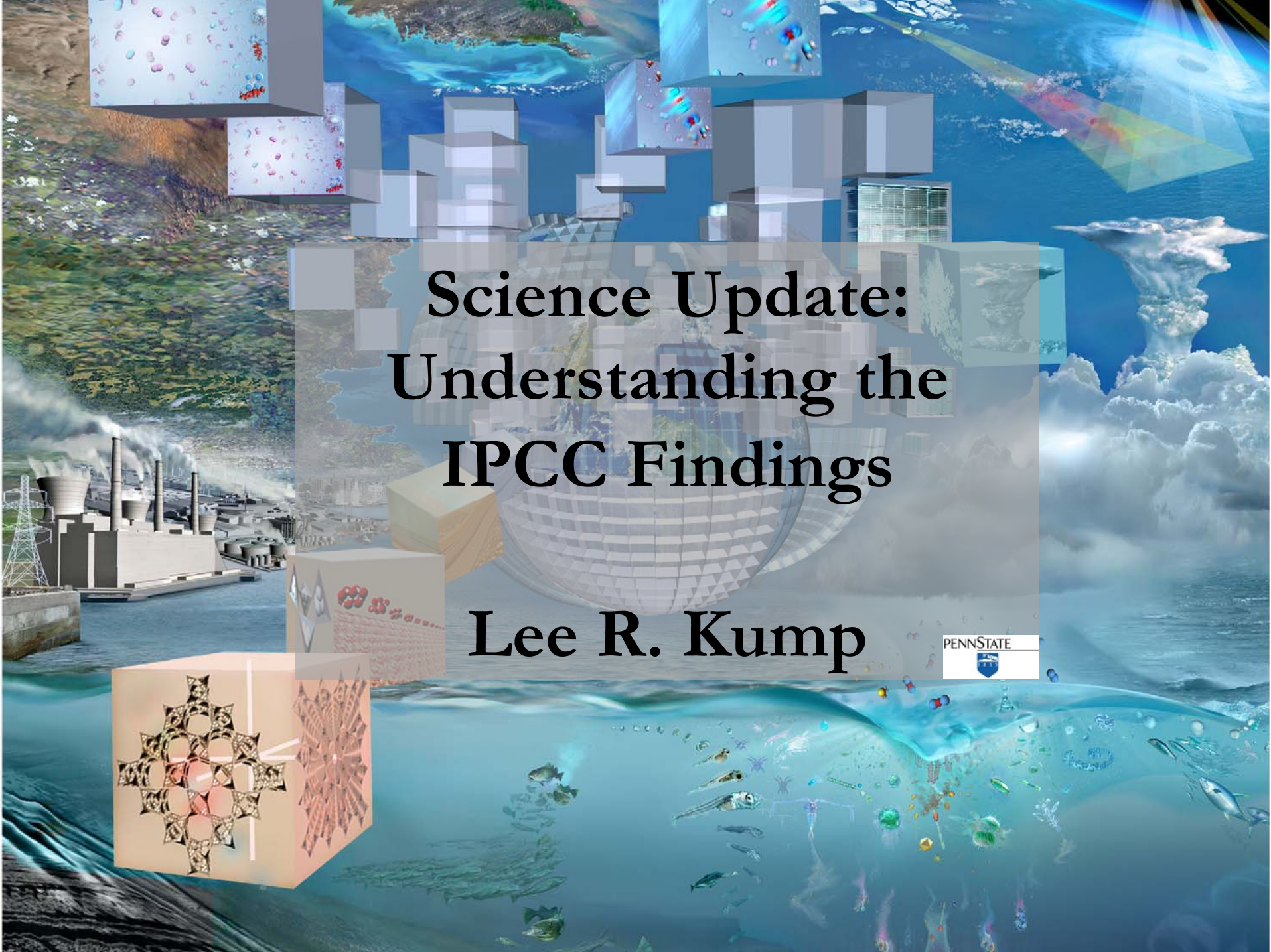


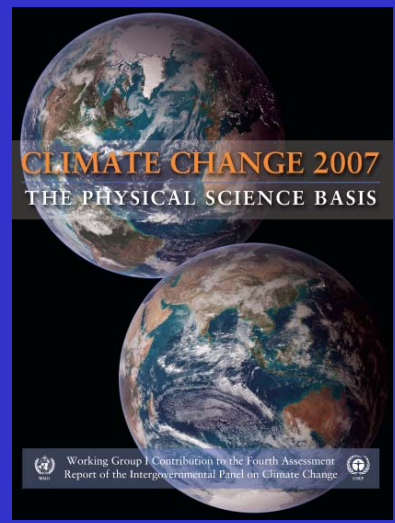
Science Update: Understanding the IPCC Findings

Lee R. Kump

PENNSTATE

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

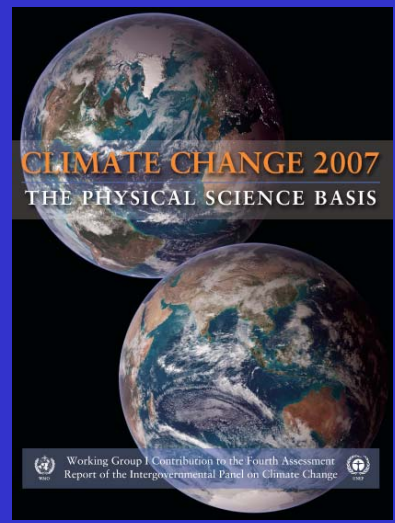
"Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations"



Intergovernmental Panel on Climate Change (United Nations), Fourth Assessment Report, 2007

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

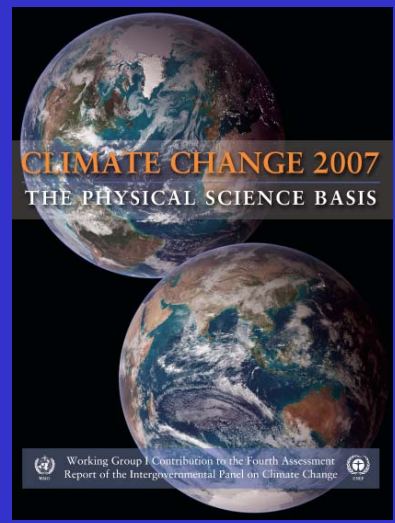
"Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending on the rate or magnitude of climate change"



IPCC Chairman Pachauri Speech to World Economic Forum, Davos, January 2008

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

"As global average temperature increases exceed 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe"



IPCC Chairman Pachauri Speech to World Economic Forum, Davos, January 2008

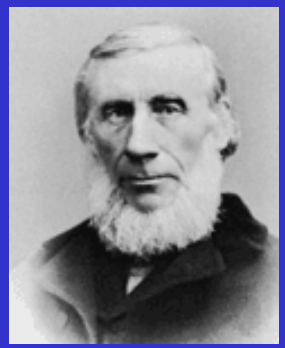
Overview of Talk

- What is the greenhouse effect?
- Why the fuss over CO_2 when water vapor does so much more?
- What do we know about high CO_2 worlds?
- What else is happening to the climate system?
- Can we trust models? What do they predict?
- What's ocean acidification?
- Where are the critical gaps in scientific understanding needed for policy decisions?

Discovery of the Greenhouse Effect

Joseph Fourier (1827)

Recognized that gases in the atmosphere might trap the heat received from the Sun.

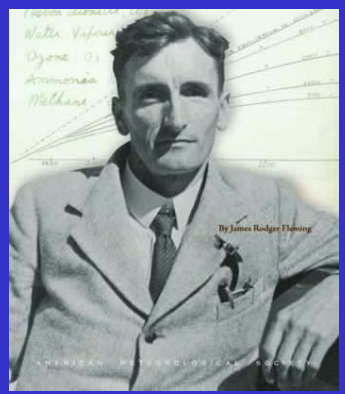


James Tyndall (1859)

Careful laboratory experiments demonstrated that several gases could trap infrared radiation. The most important was simple water vapor. Also effective was carbon dioxide, although in the atmosphere the gas is only a few parts in ten thousand.

Svante Arrhenius (1896)

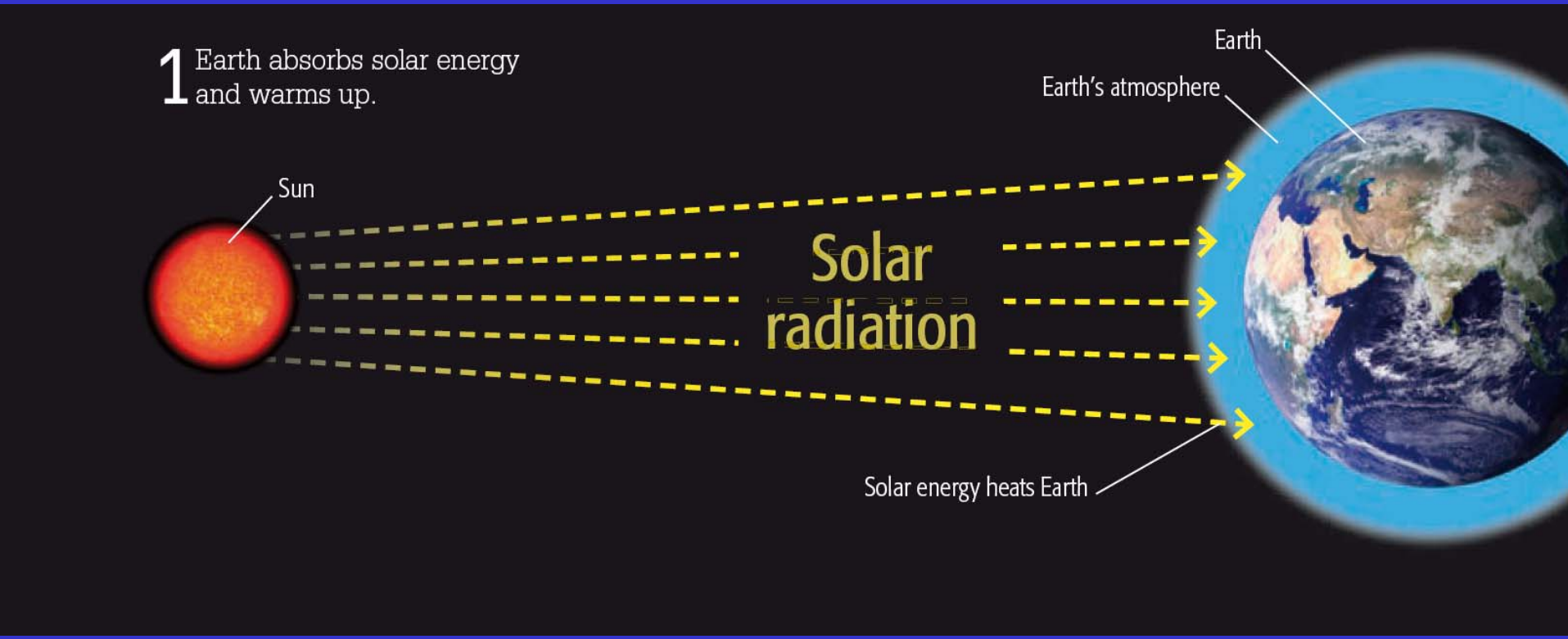
Performed numerical calculations that suggested that doubling the amount of carbon dioxide in the atmosphere could raise global mean surface temperatures by 5-6°C.



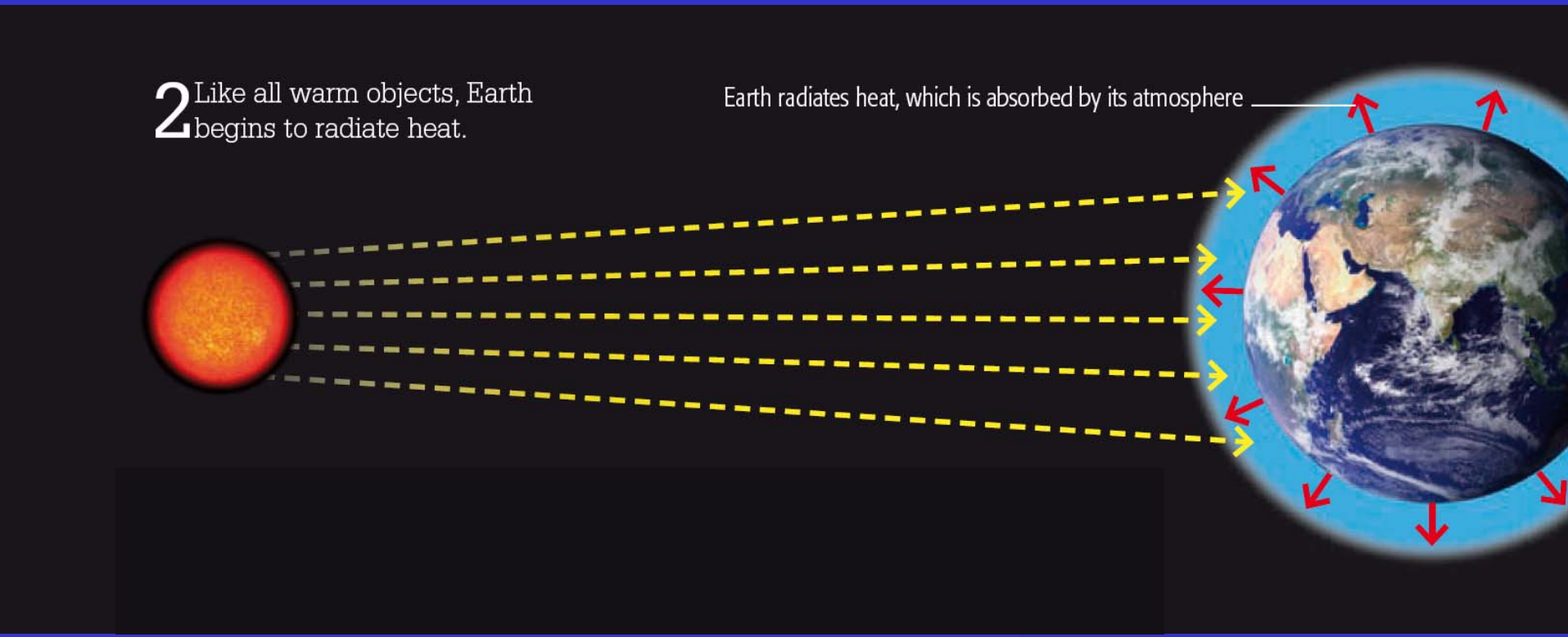
Guy Callendar (1939)

Argued that rising levels of carbon dioxide were responsible for measurable increases in Earth surface temperatures. Estimated that doubling the amount of CO_2 in the atmosphere could raise global mean surface temperatures by 2°C.

What is the "Greenhouse Effect"?

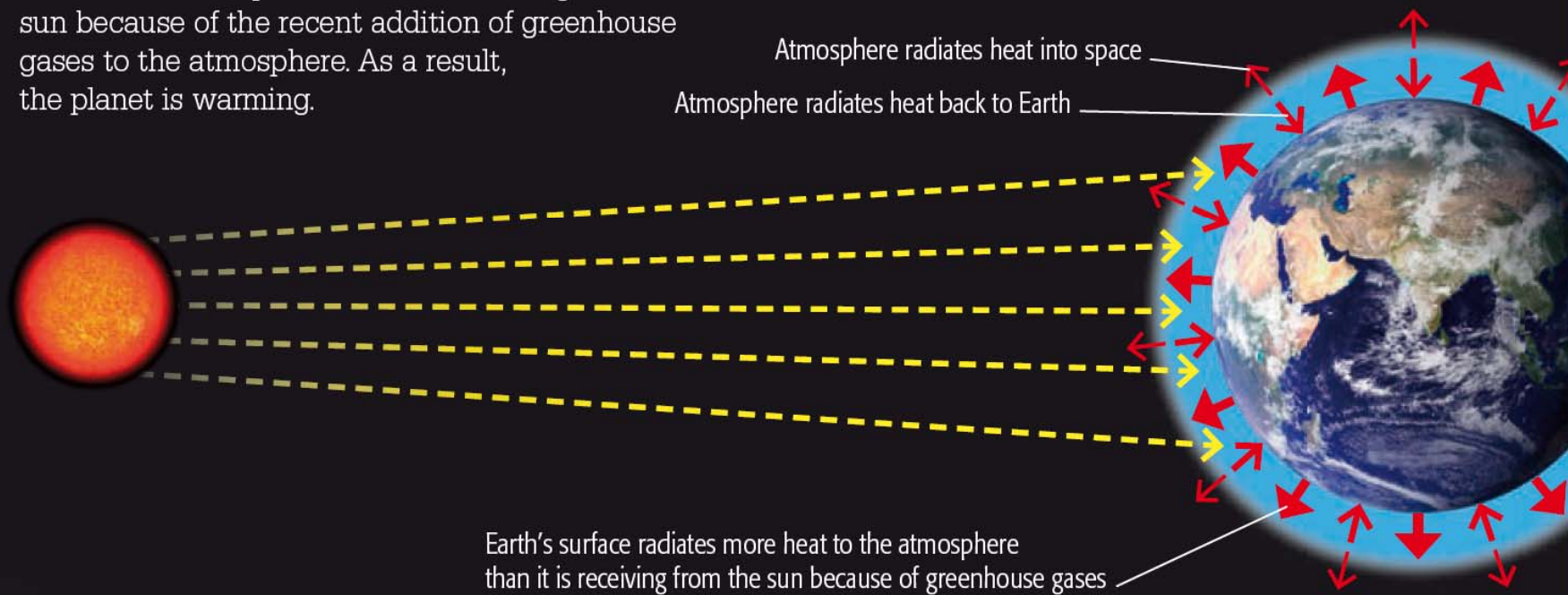


Mann and Kump (*Dire Predictions*, 200



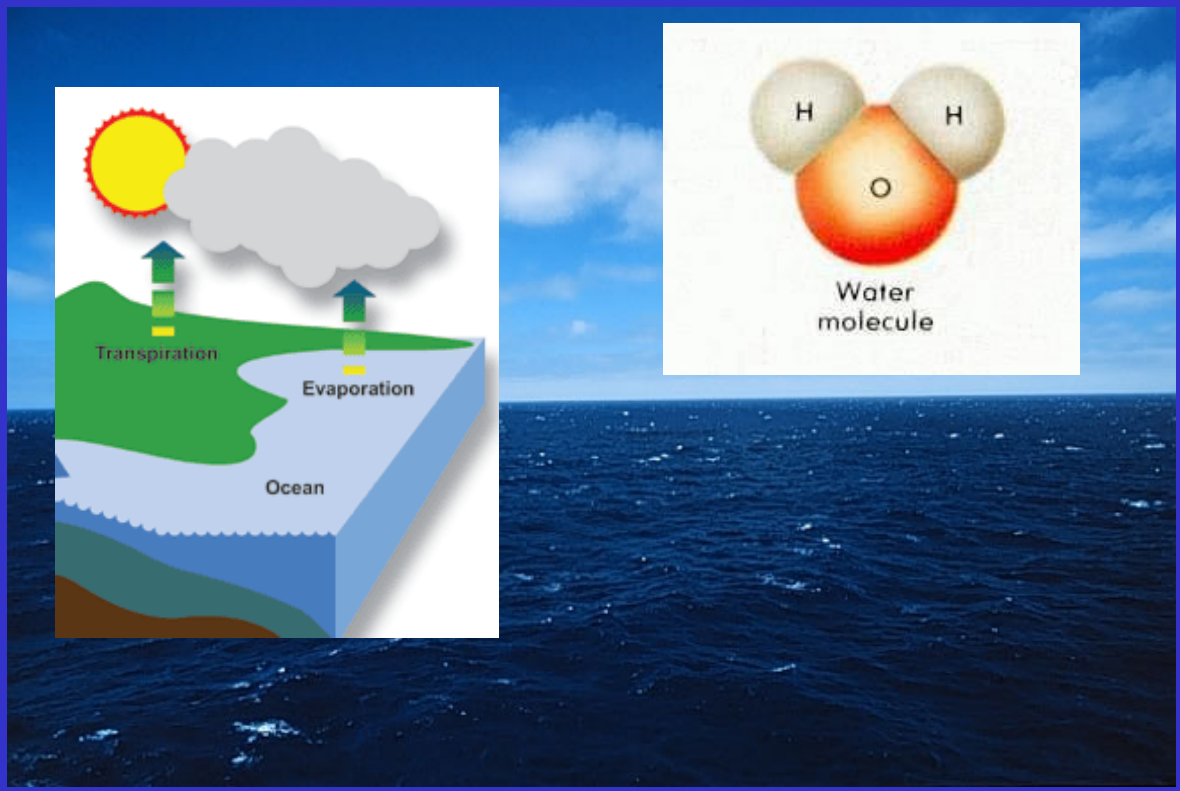
Mann and Kump (*Dire Predictions*, 200

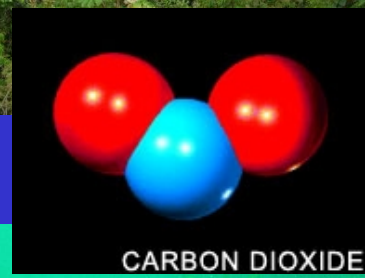
3 Heat radiating from Earth encounters greenhouse gas molecules in the atmosphere, and is absorbed. The atmosphere warms, and as a result, it too radiates heat. Some of this heat is radiated out into space, but the rest is radiated back to the Earth's surface. This extra energy warms Earth even more than the initial solar energy. In previous eras, the energy radiated to space more nearly balanced the solar energy absorbed by Earth. Currently however, Earth is radiating less radiation to space than it is receiving from the sun because of the recent addition of greenhouse gases to the atmosphere. As a result, the planet is warming.

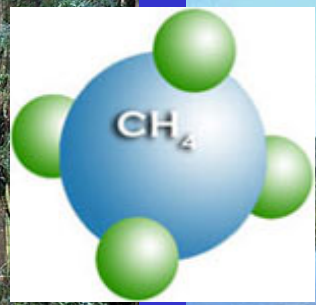


Mann and Kump (*Dire Predictions*, 200

NATURAL GREENHOUSE EFFECT



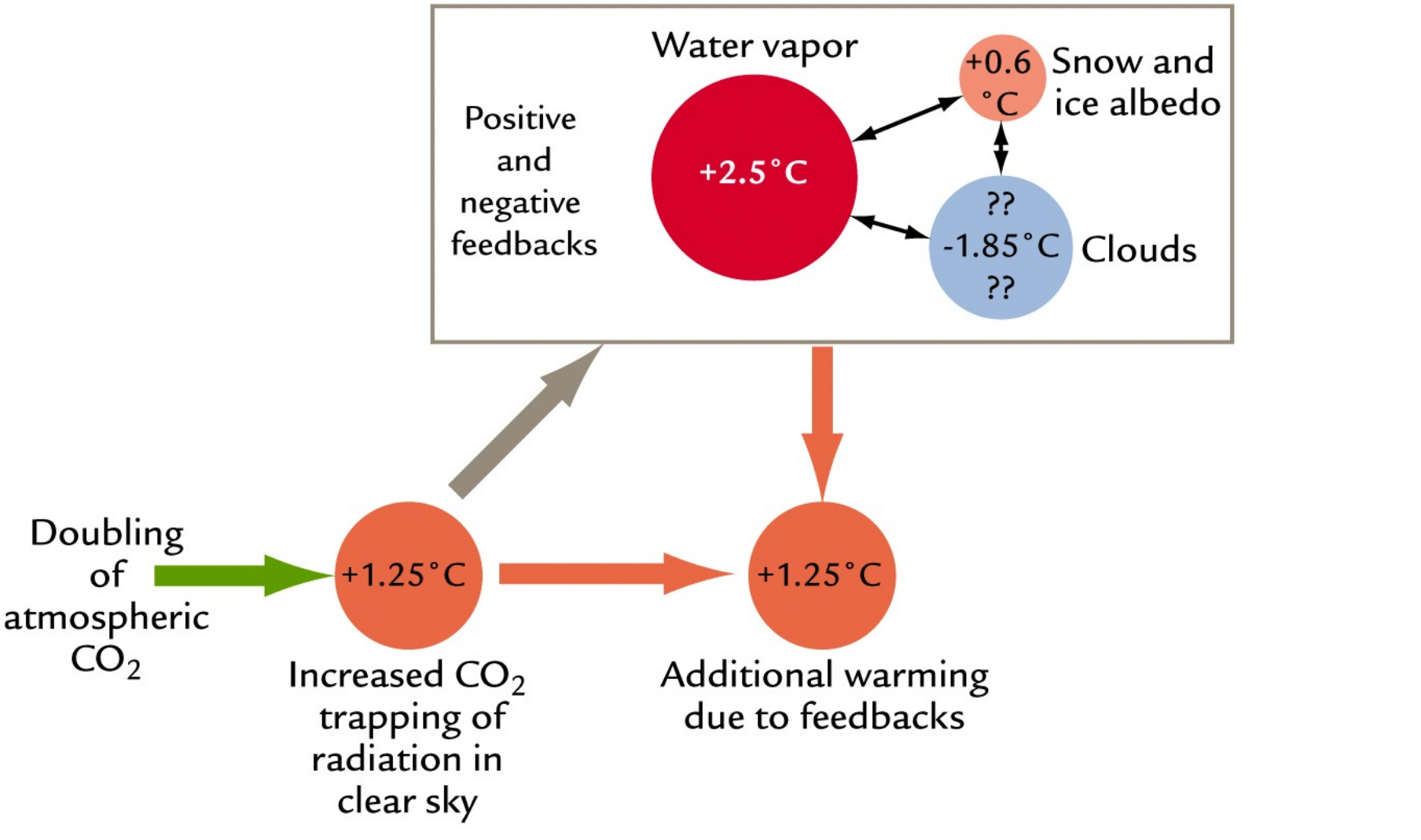




57°F vs. 0°F

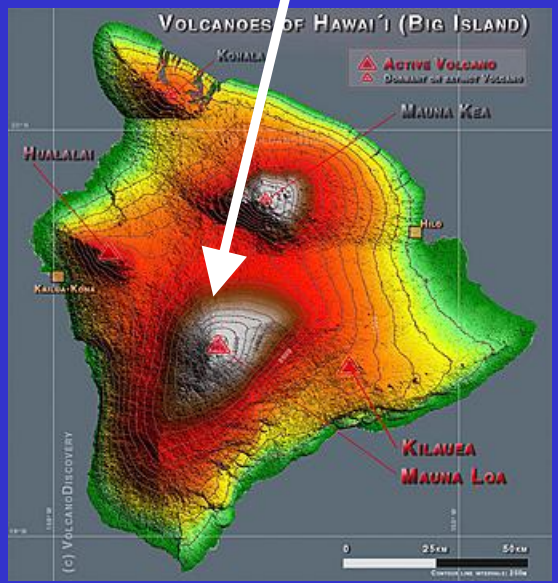
Anthropogenic GREENHOUSE EFFECT

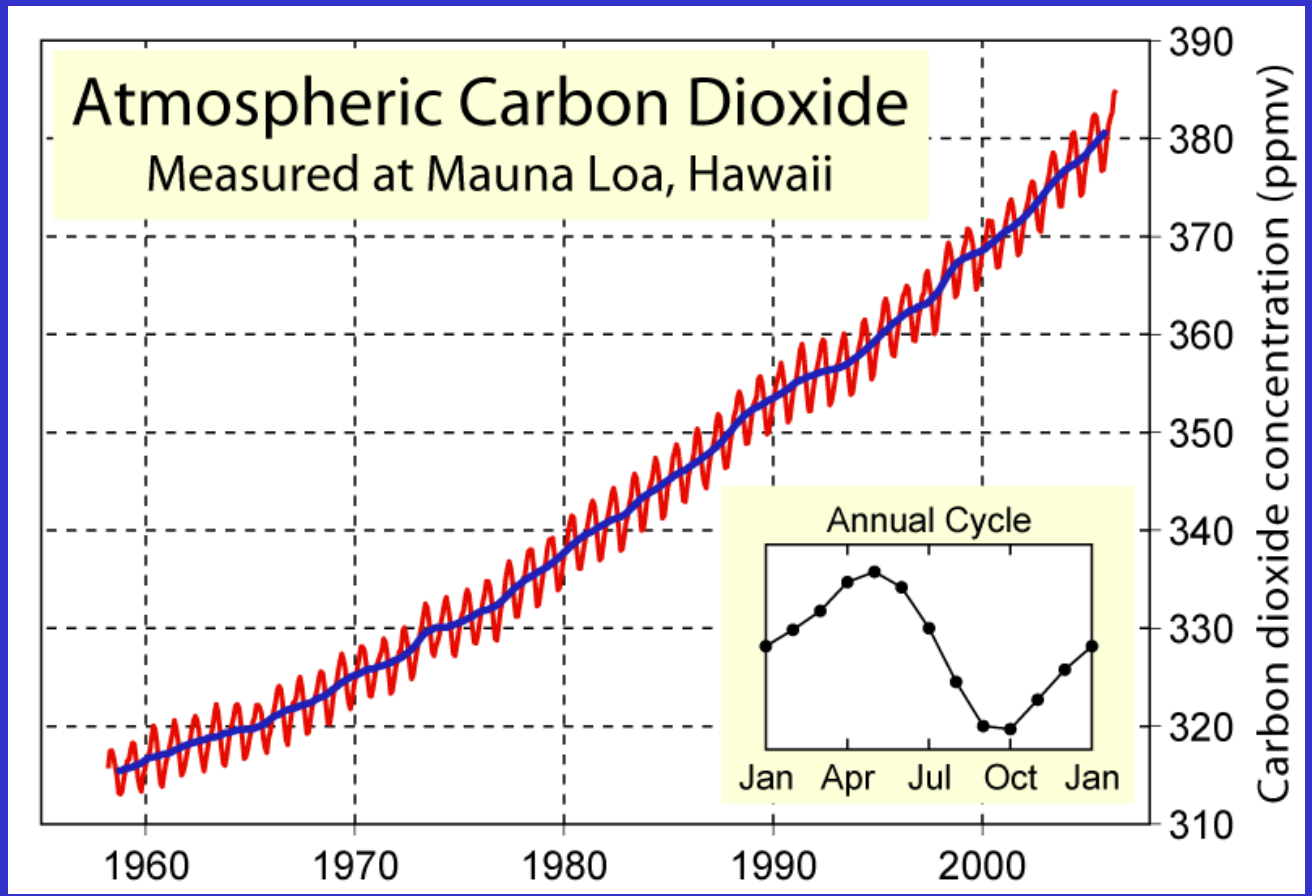
Anthropogenic CO_2 forces climate; water amplifies



Mann and Kump (*Dire Predictions*, 200

Historical CO_2 measurements

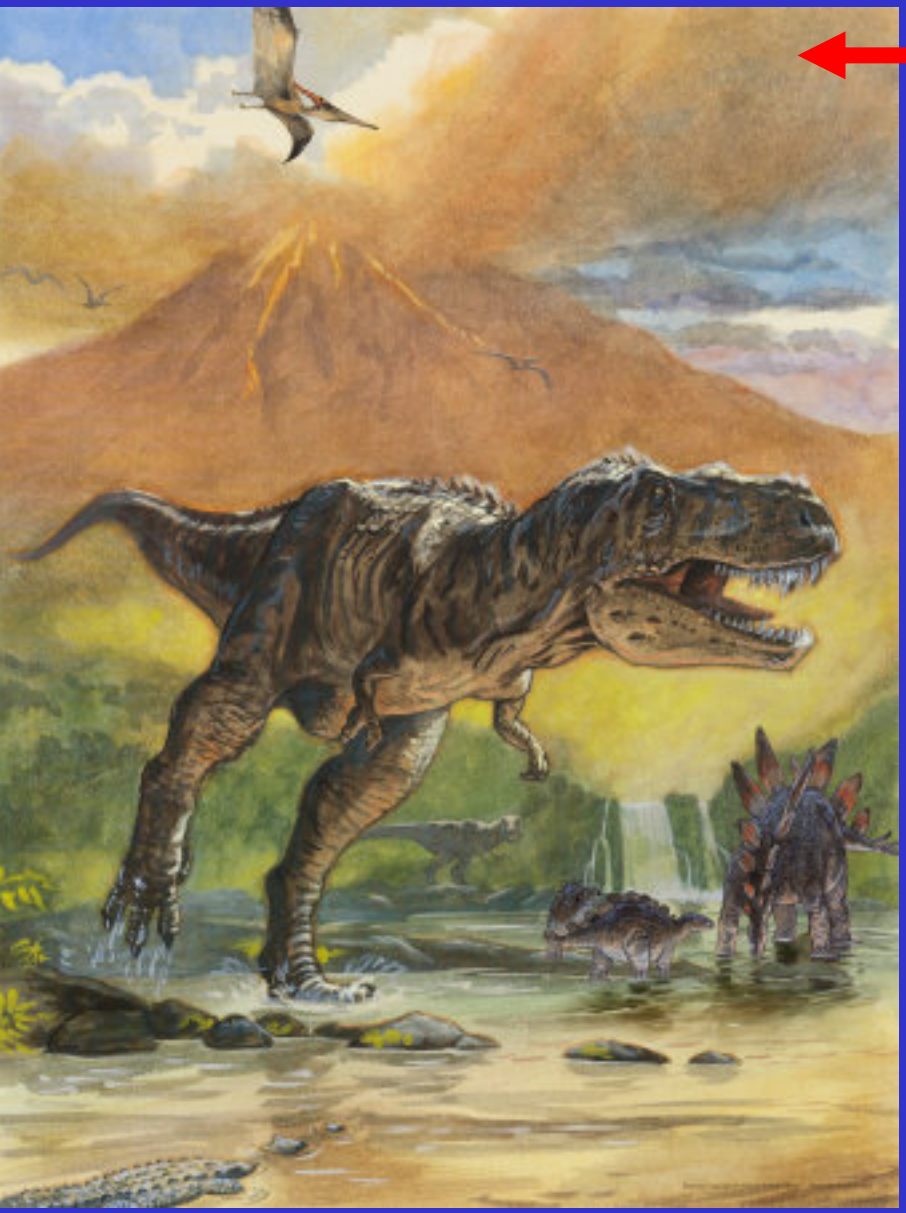


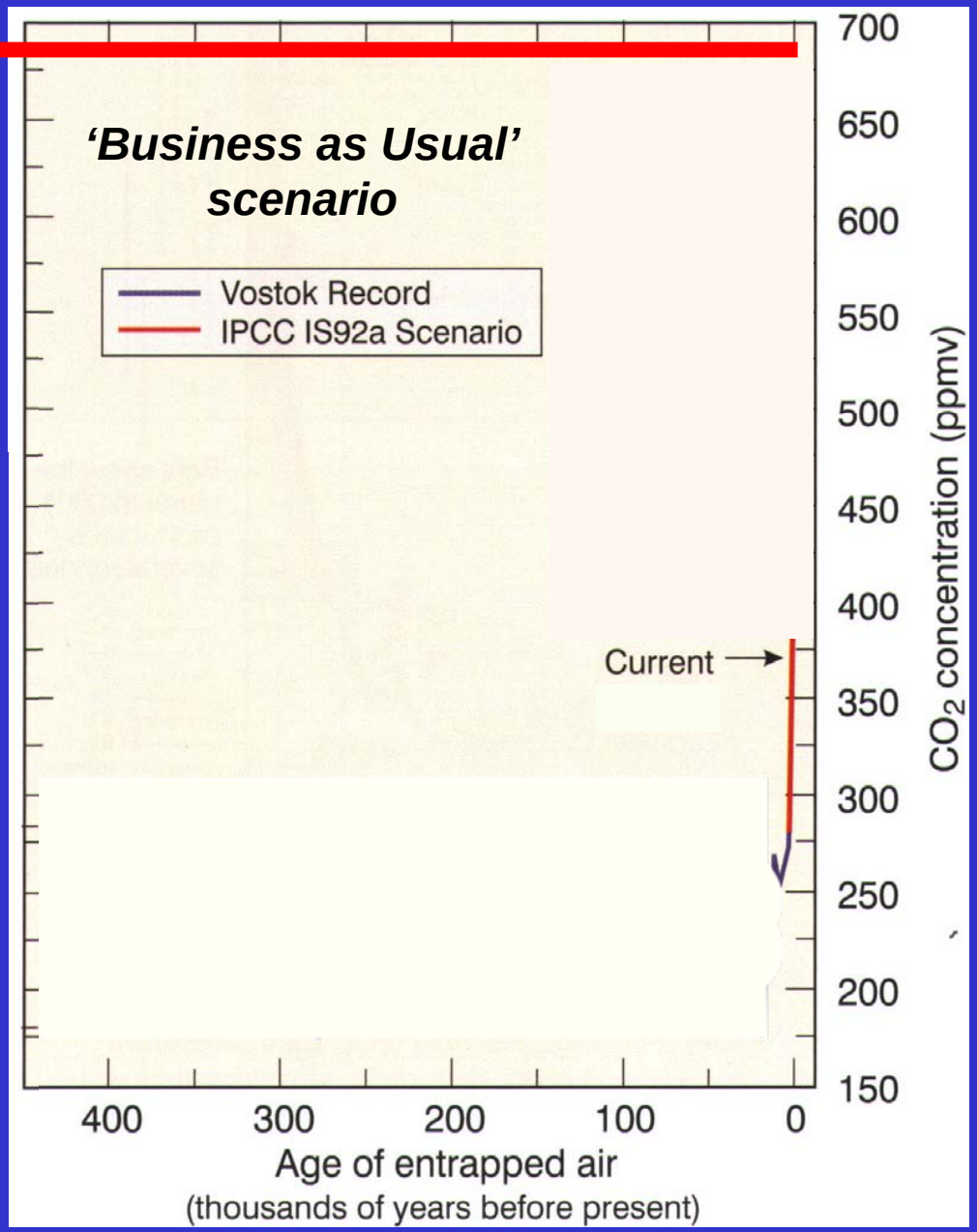


Began in 1958

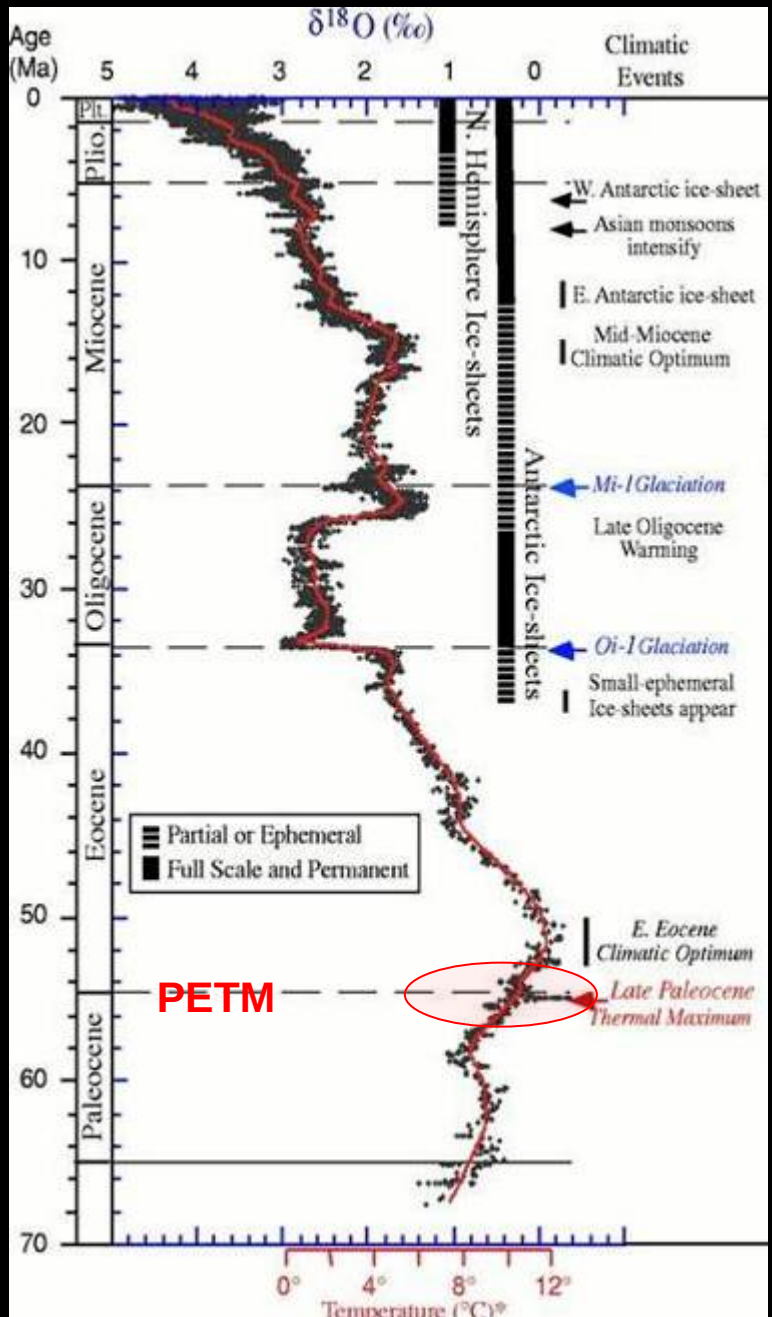
We know this is anthropogenic

Prehistoric Greenhouse Gas Measurements

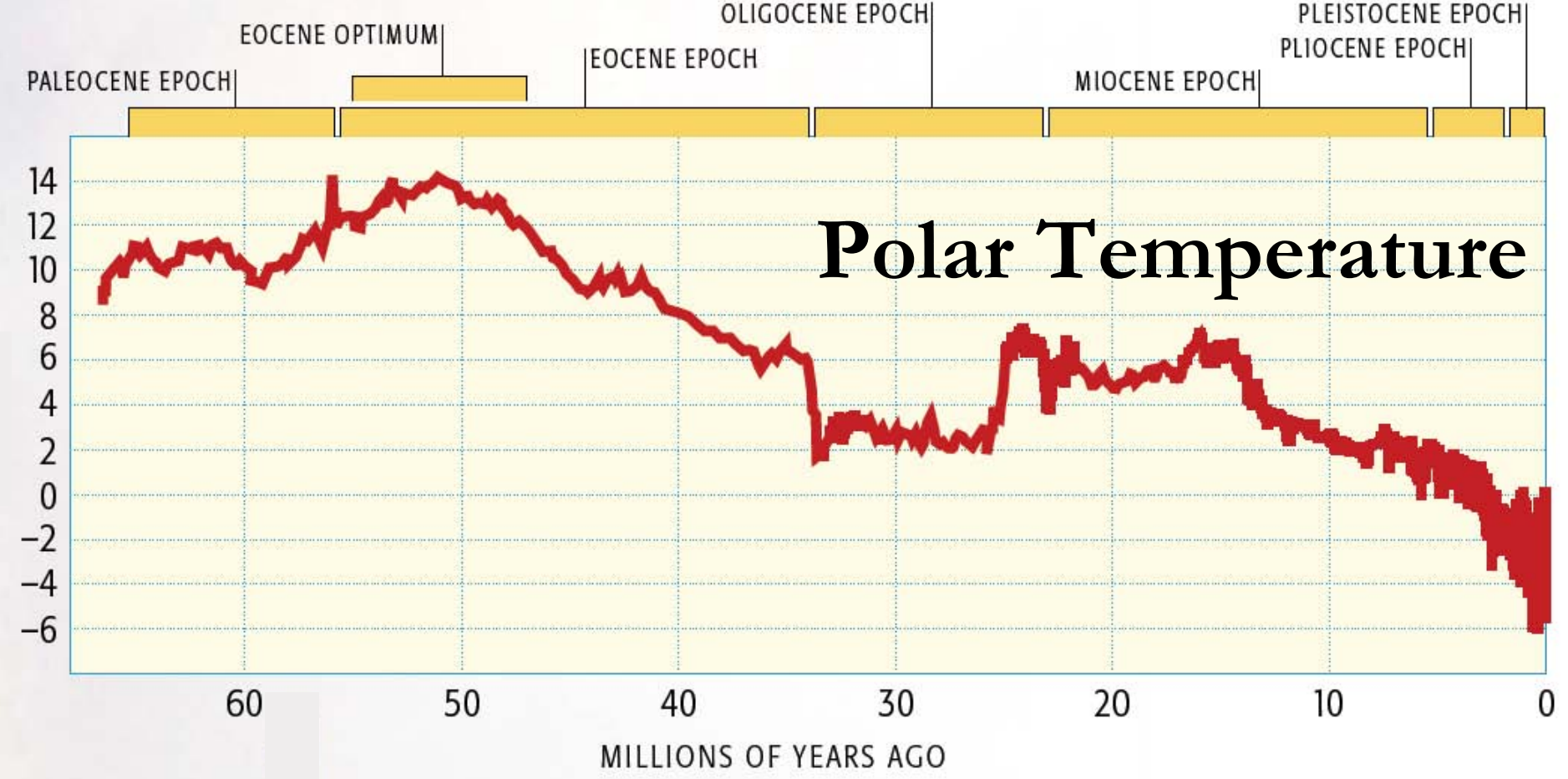


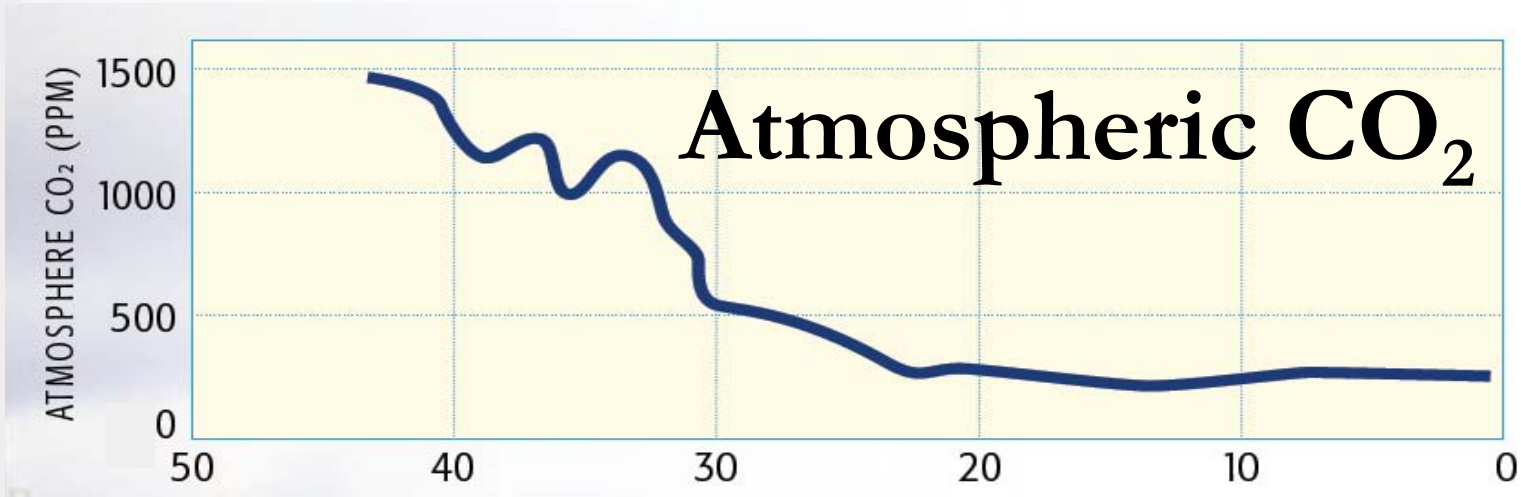


Polar temperatures for the last 65 million years

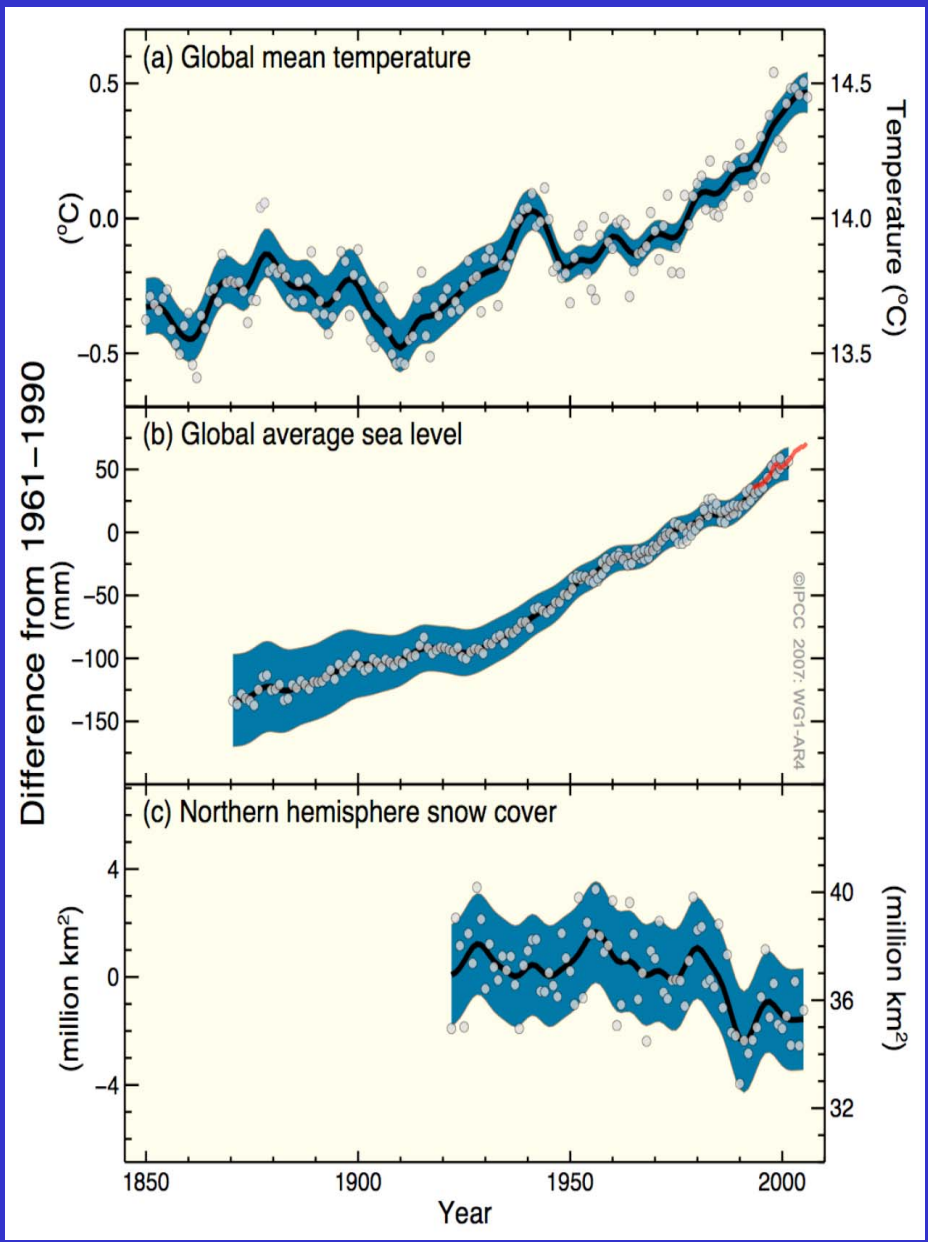


Zachos et al. (2001, *Science* 292: 686-693)

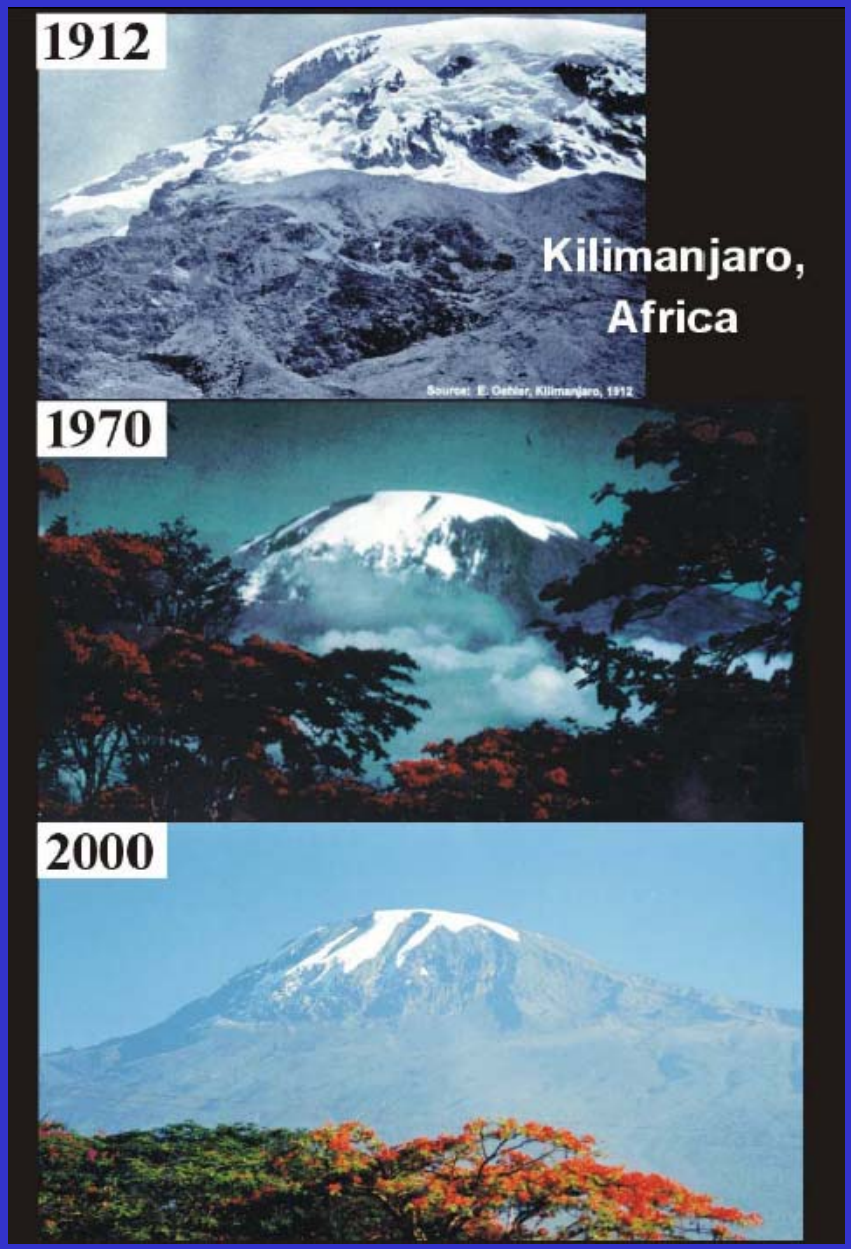

PALEOCENE EPOCH
EOCENE OPTIMUM
EOCENE EPOCH
OLIGOCENE EPOCH
MIOCENE EPOCH
PLIOCENE EPOCH
PLEISTOCENE EPOCH
Polar Temperature
14
12
10
8
6
4
2
0
−2
−4
−6
60
50
40
30
20
10
0
MILLIONS OF YEARS AGO


Atmospheric CO_2
ATMOSPHERE CO_2 (PPM)
1500
1000
500
0
50
40
30
20
10
0

Historical Trends

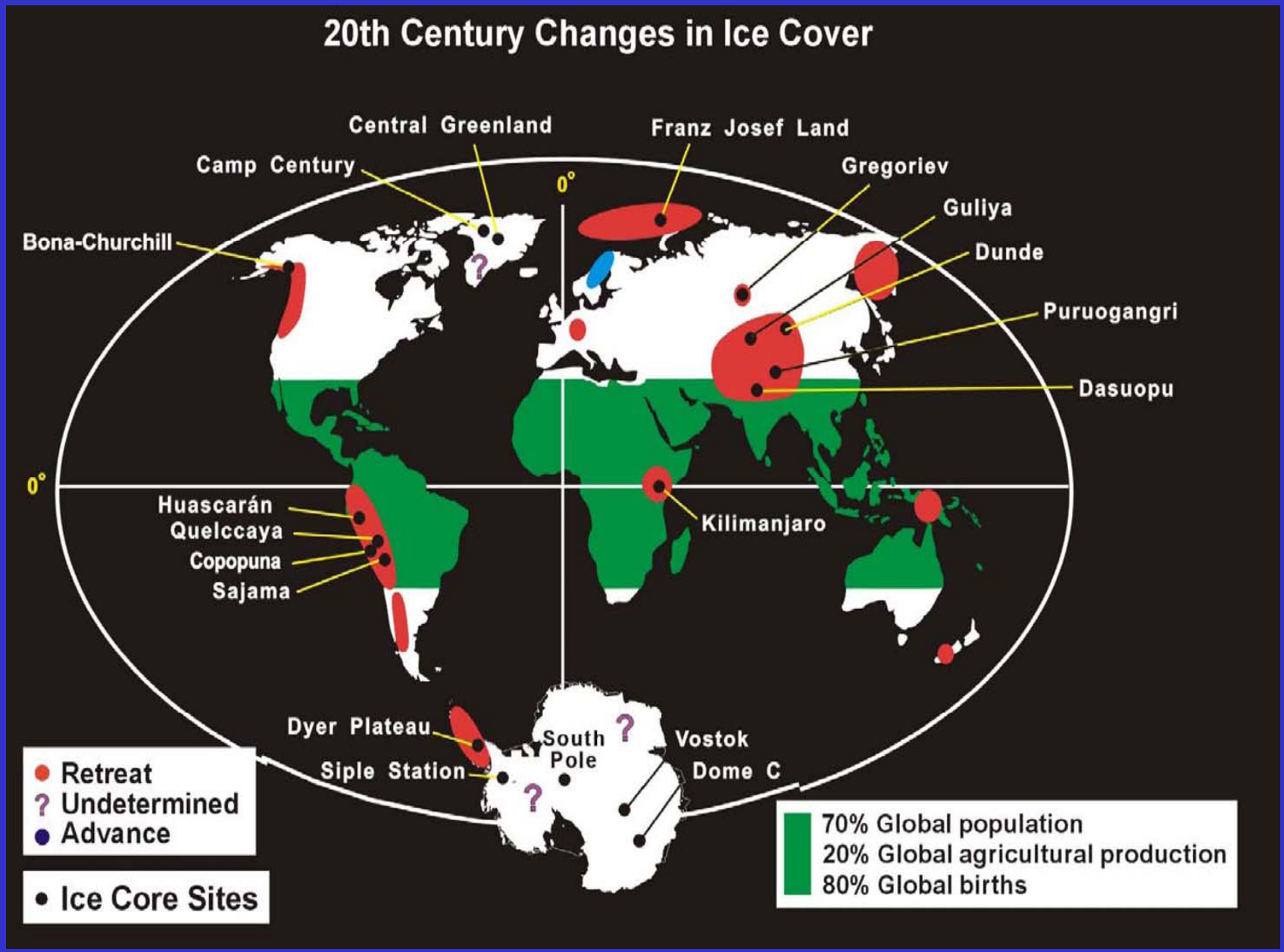


Glacial Retreat

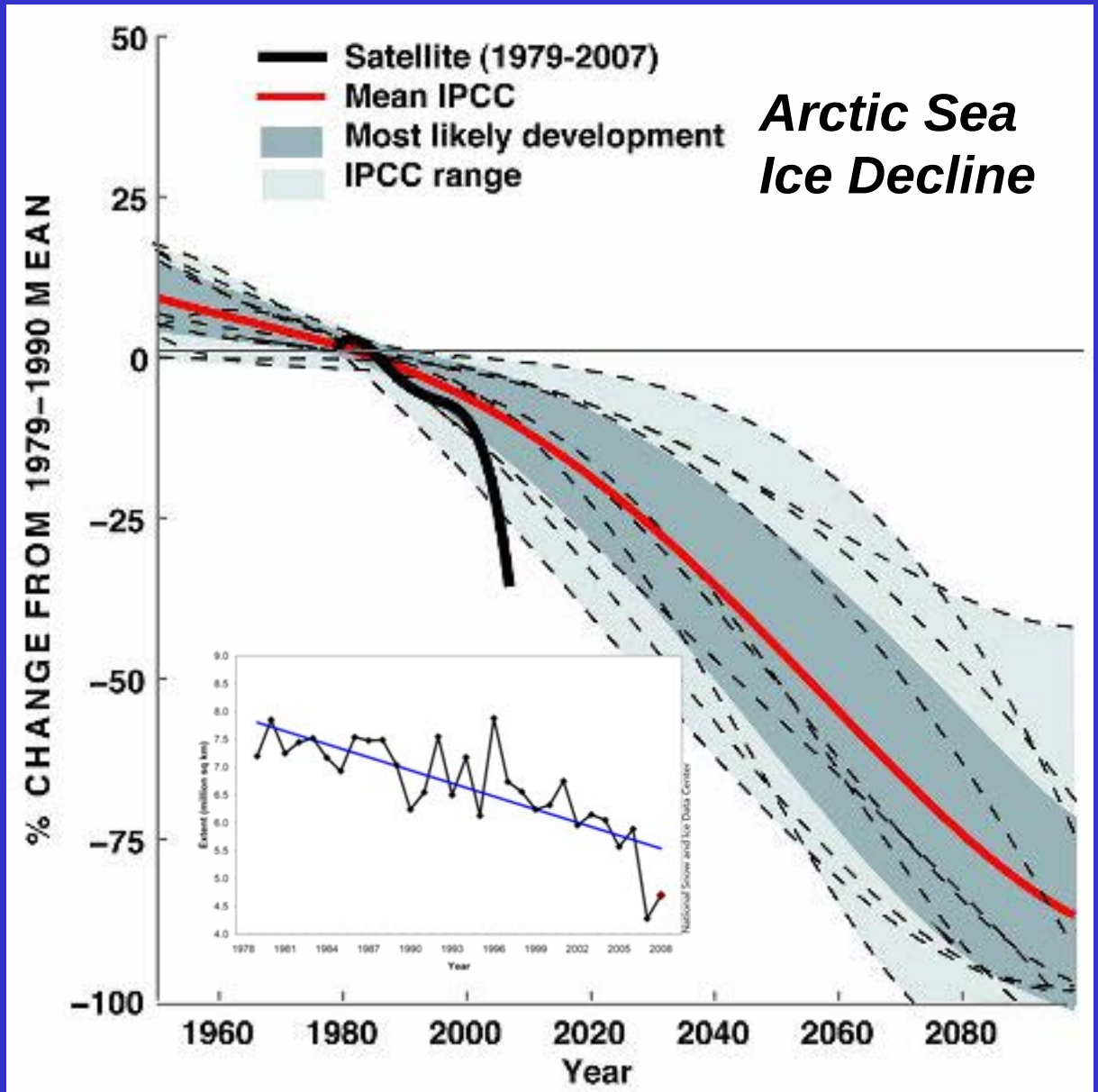


2007

Glacial Retreat

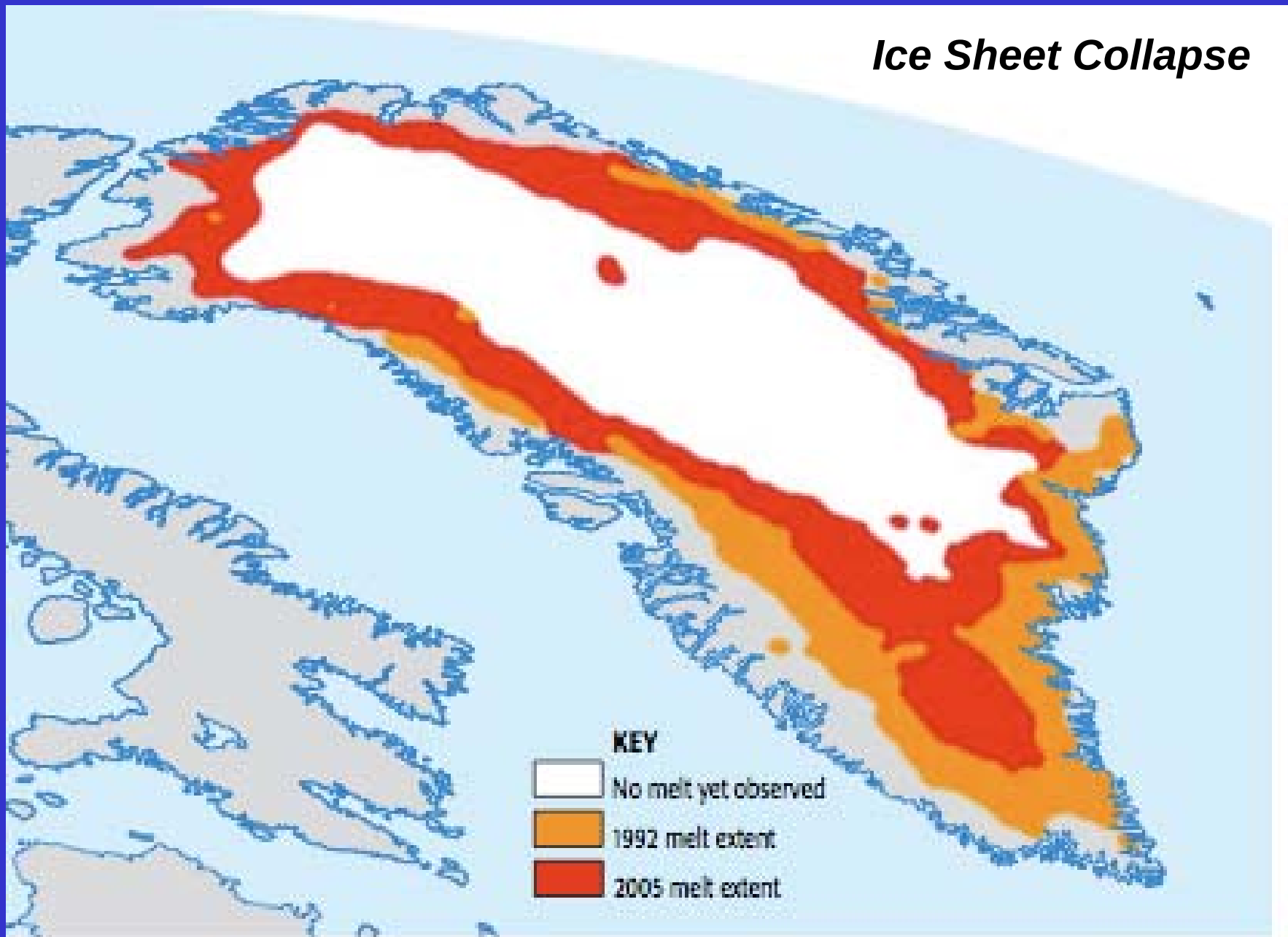


Tipping Points

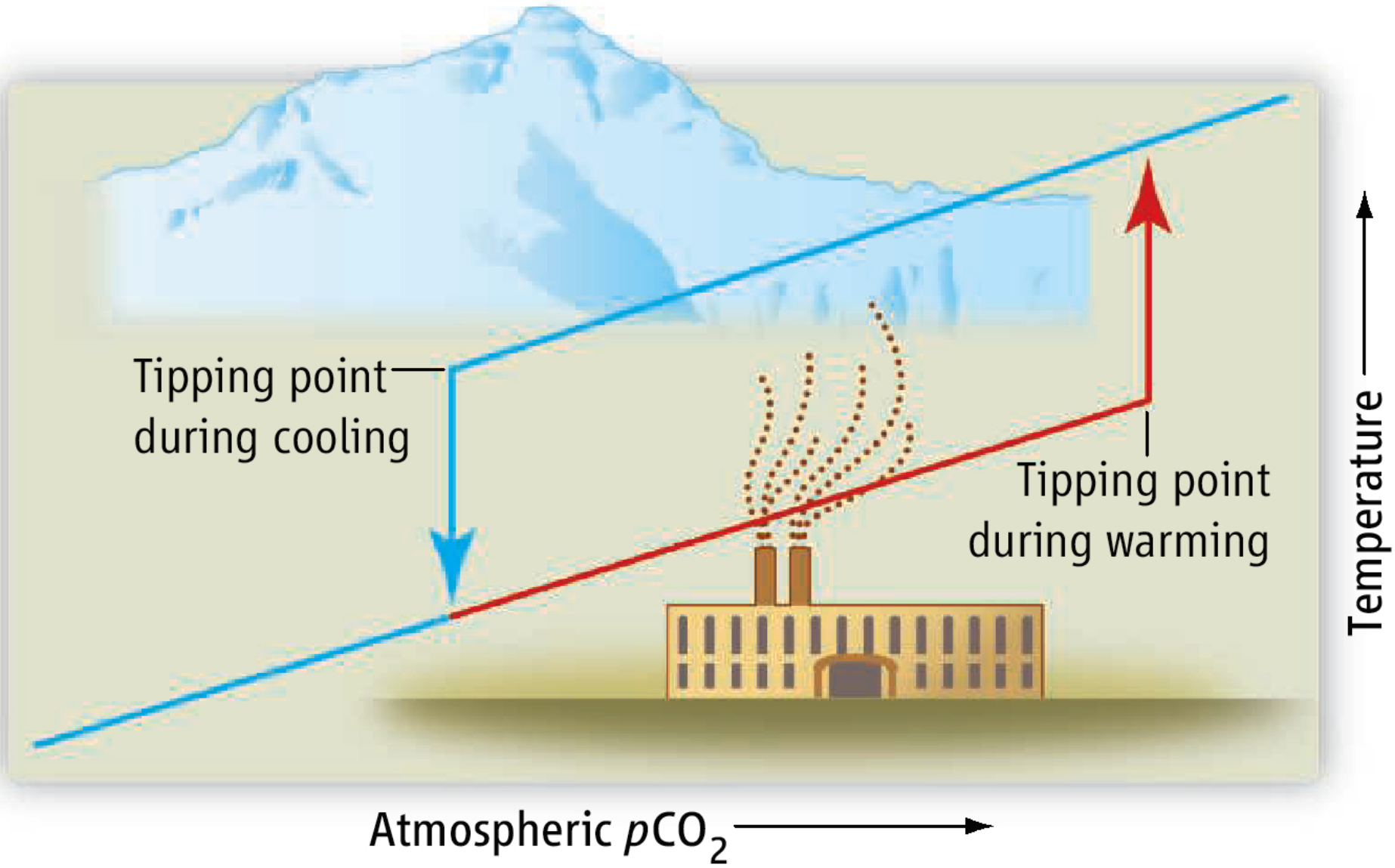


Tipping Points

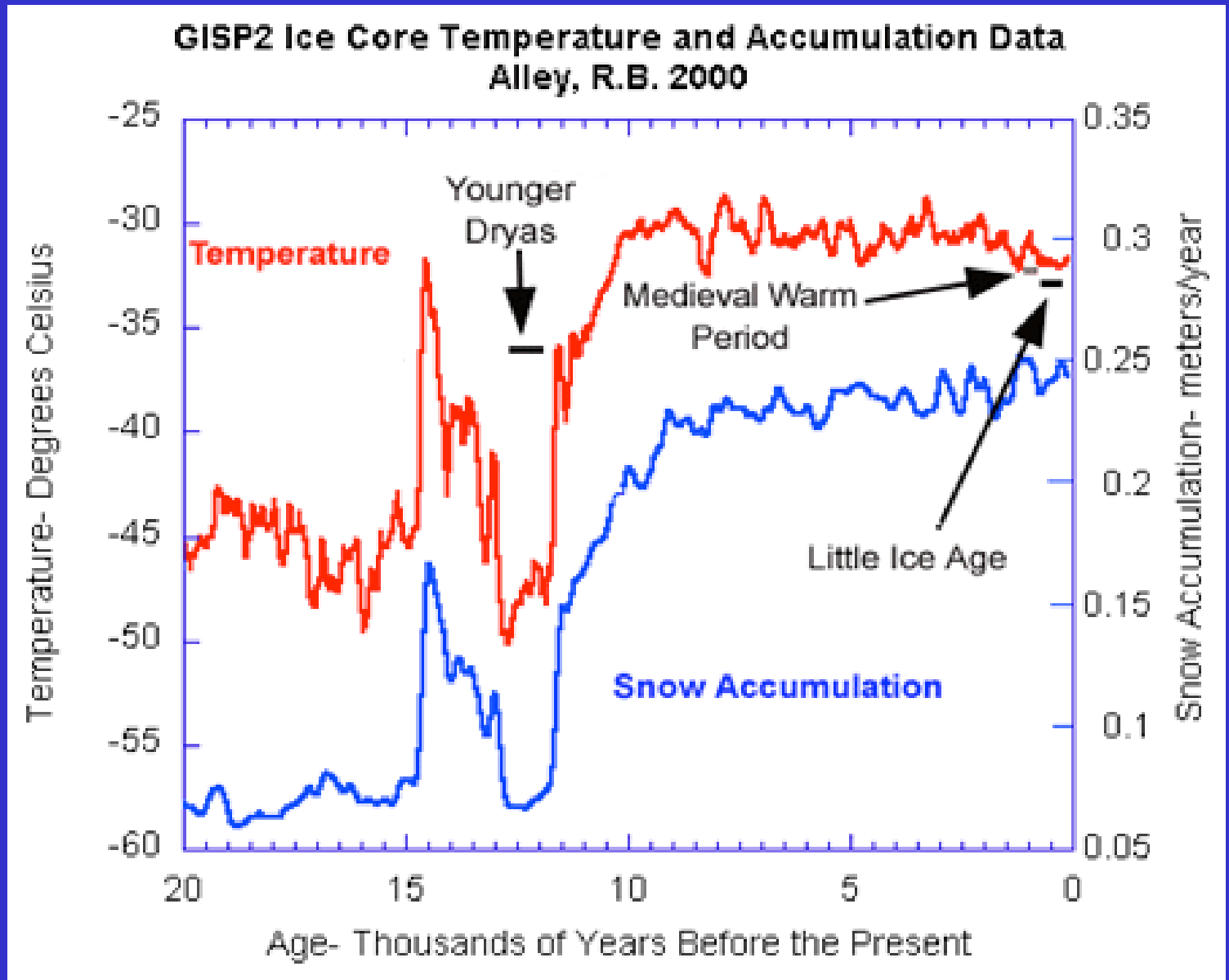
Ice Sheet Collapse



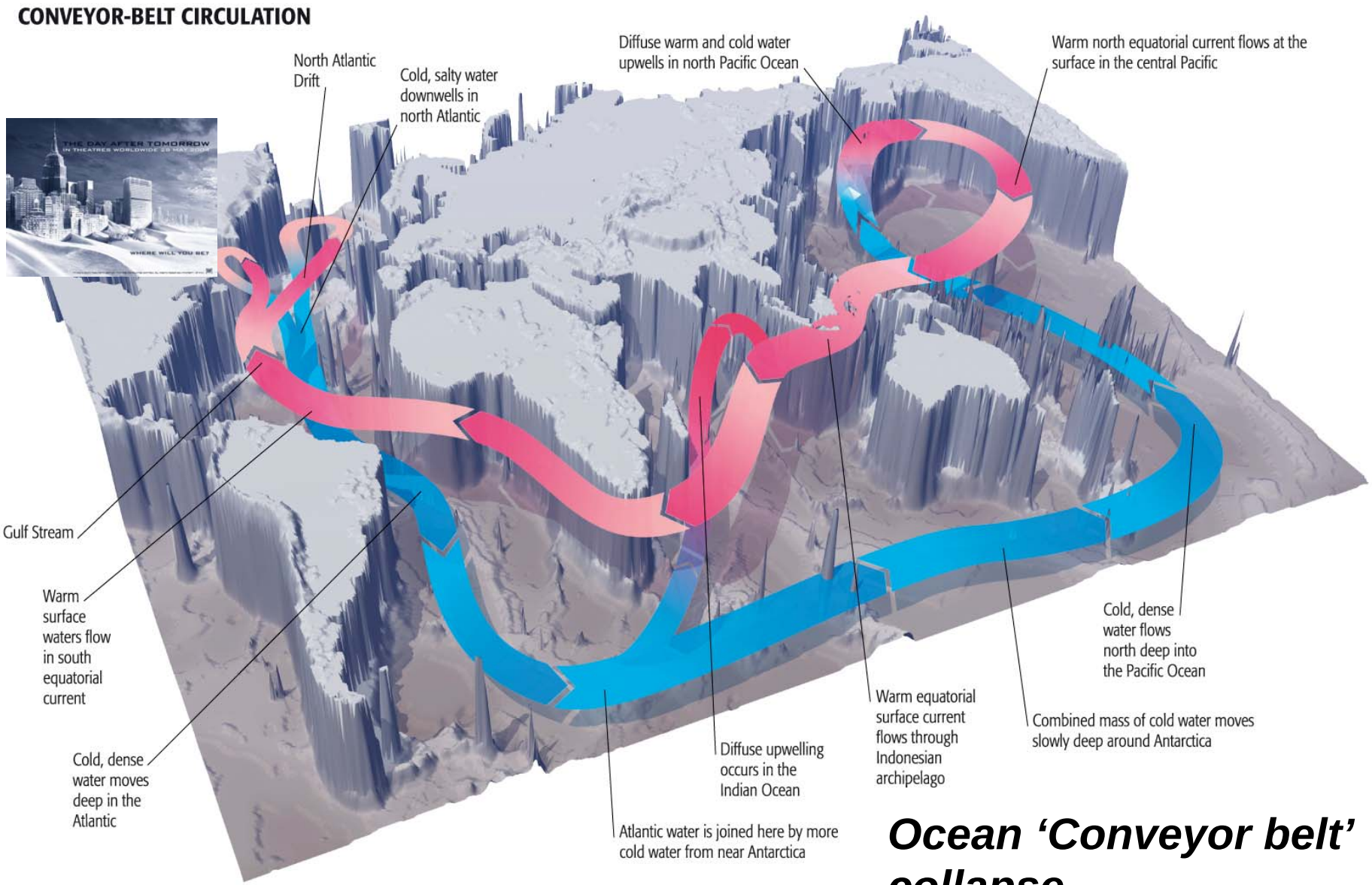
Tipping Points



Tipping Points

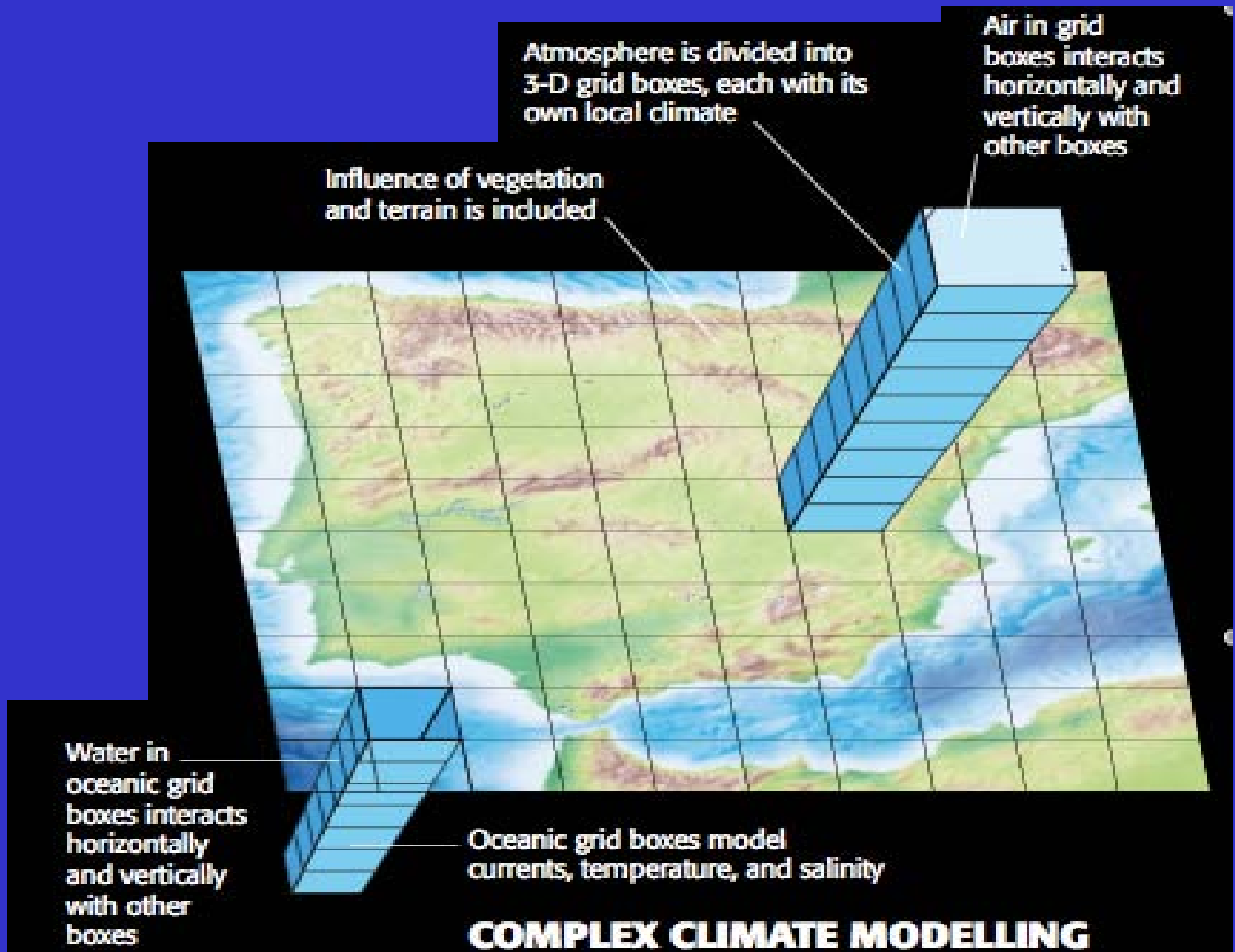


Tipping Points



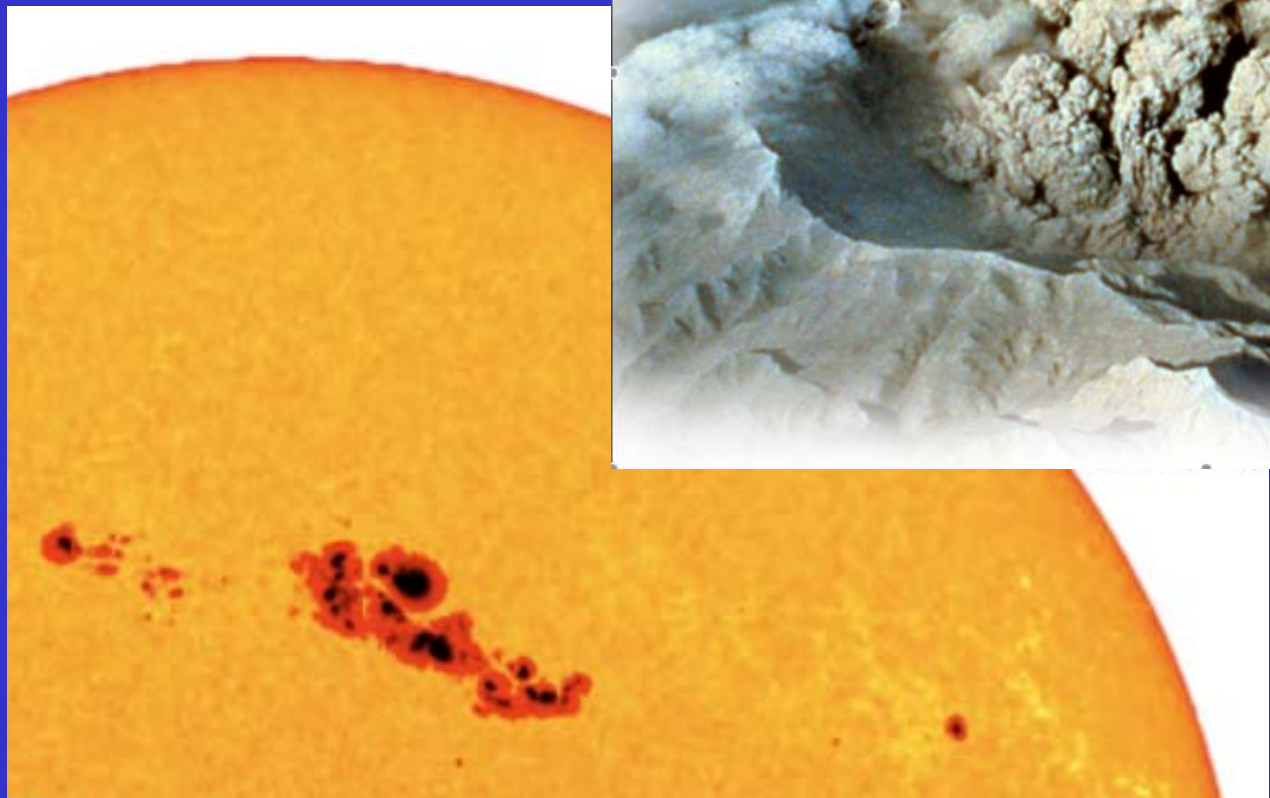
Ocean 'Conveyor belt' collapse

Should We Trust Climate Models?



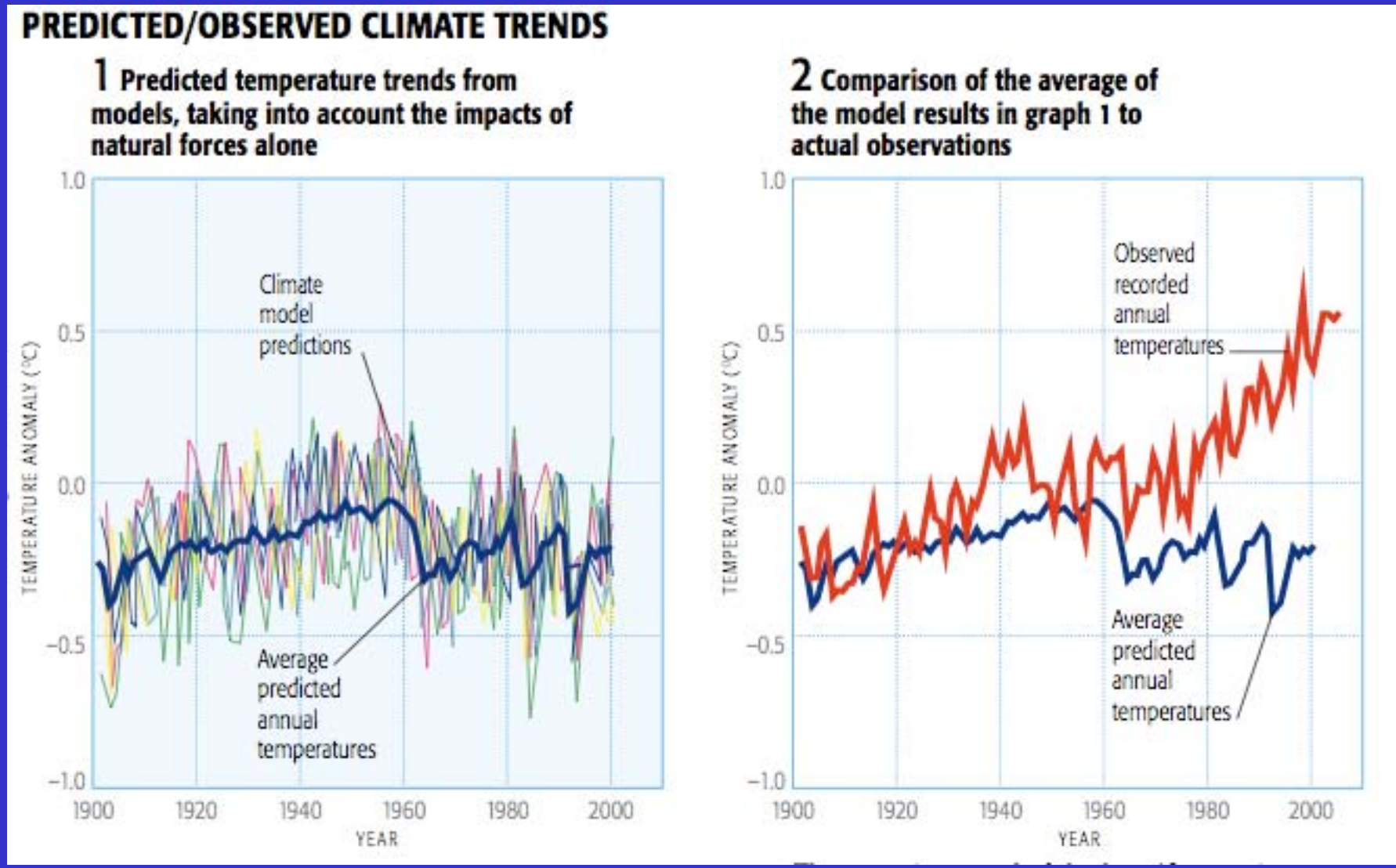
Should We Trust Climate Models?

Natural Factors



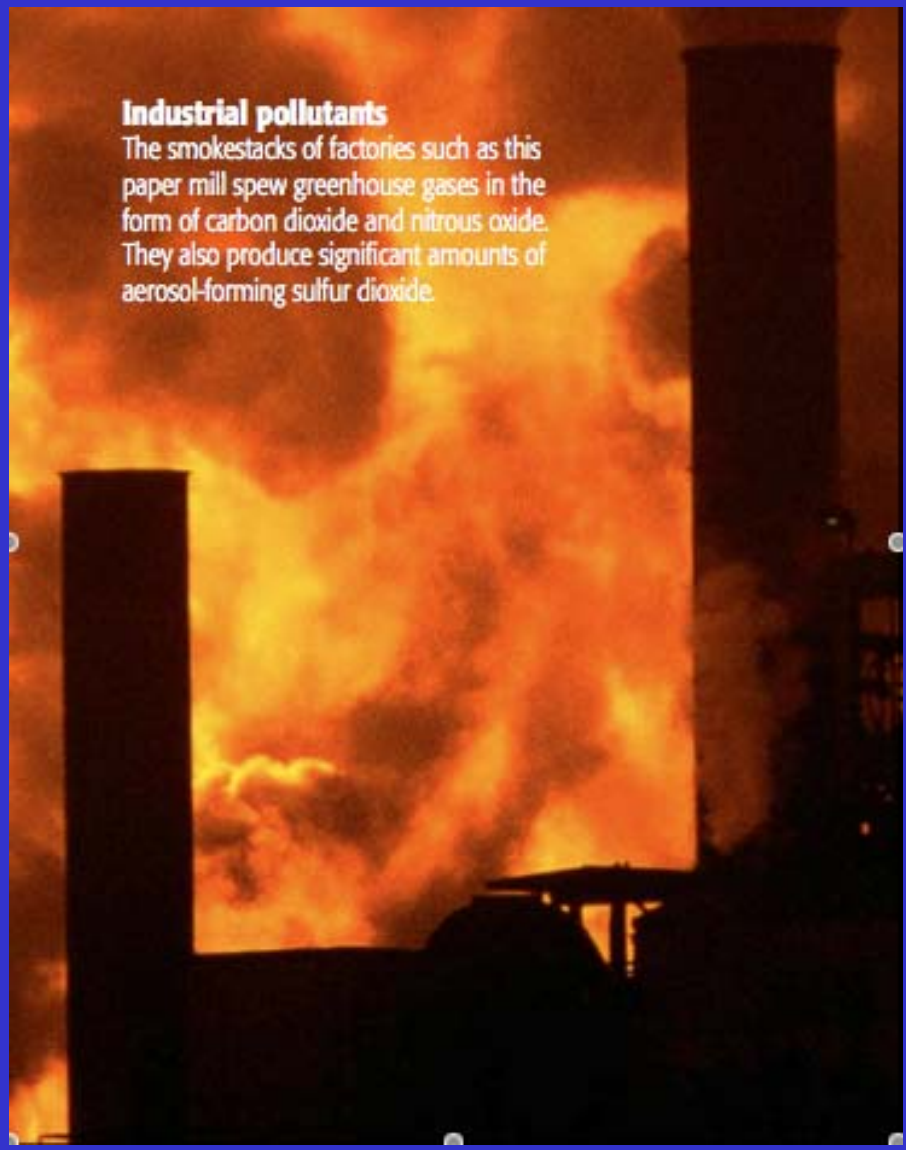
Should We Trust Climate Models?

Natural Factors



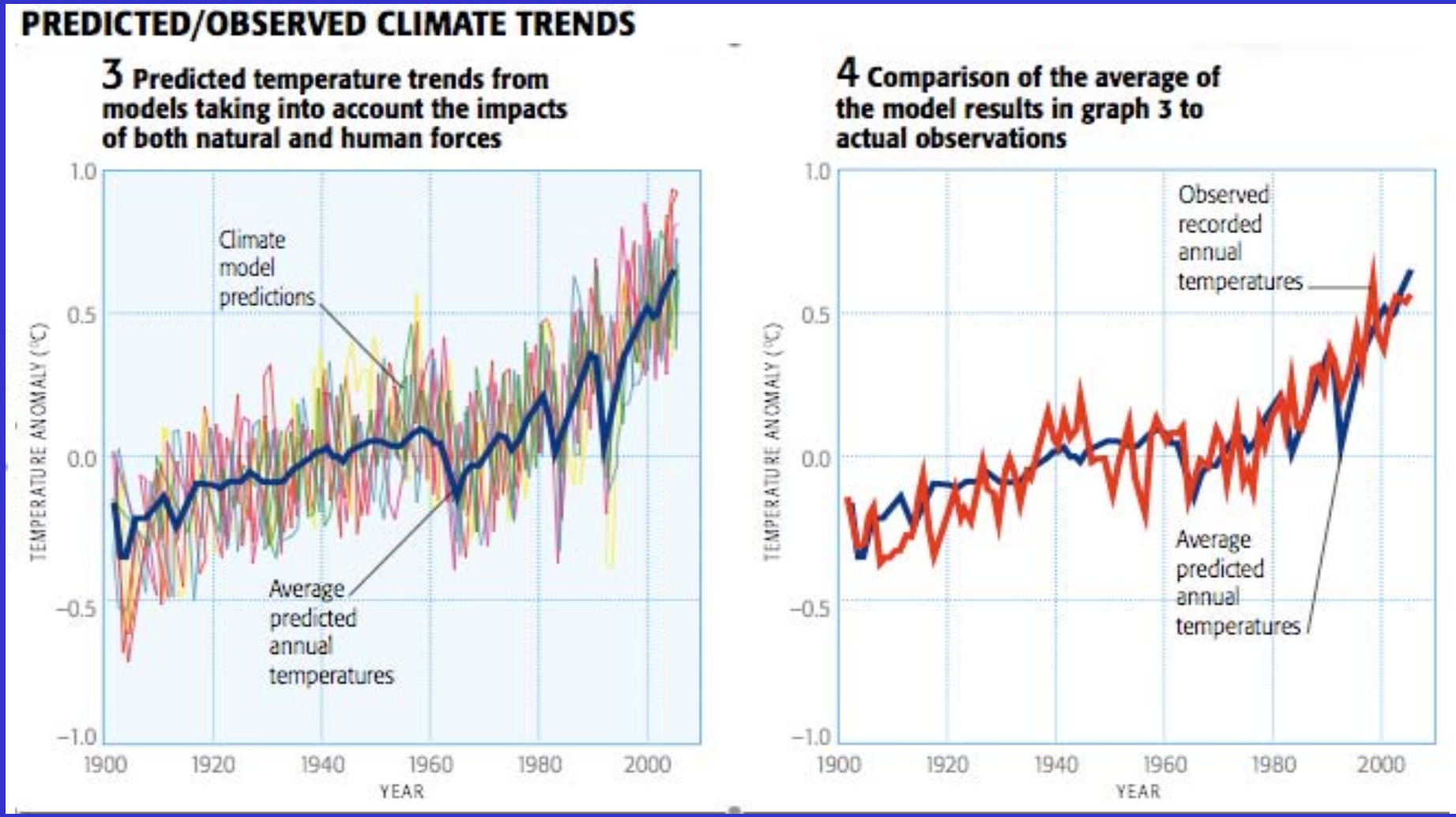
Should We Trust Climate Models?

Human Factors

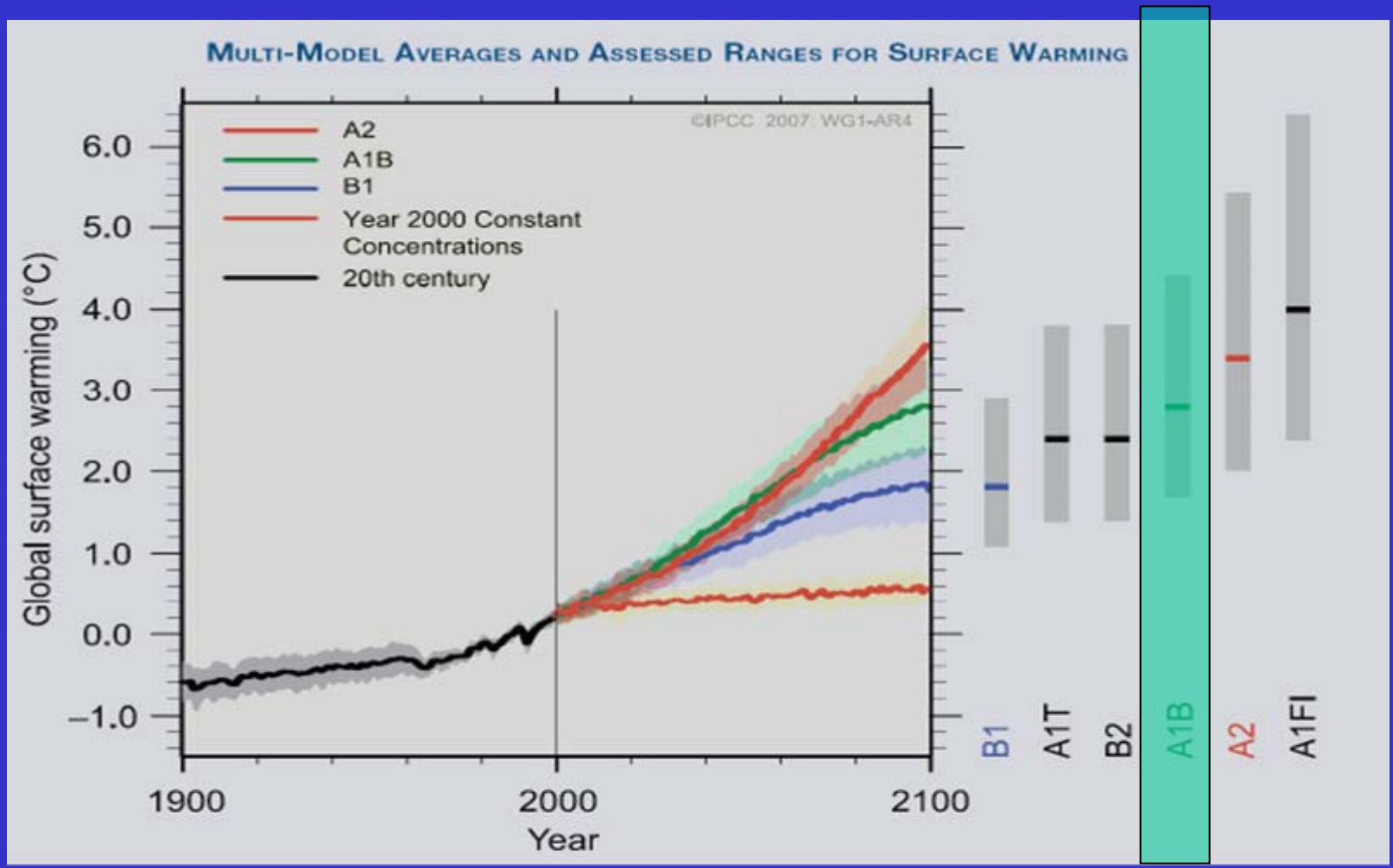


Should We Trust Climate Models?

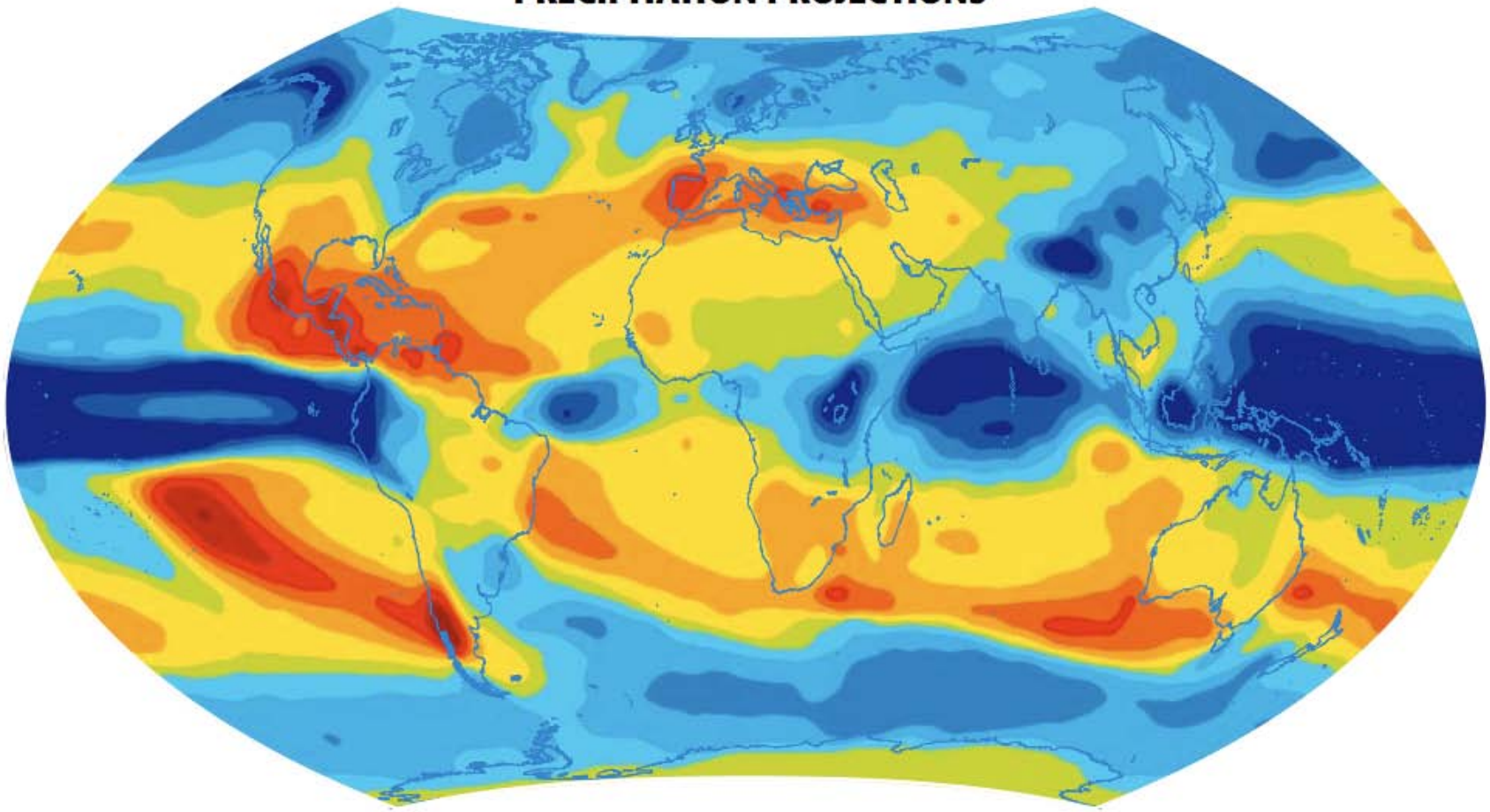
Natural and Human Factors



Projected Future Warming

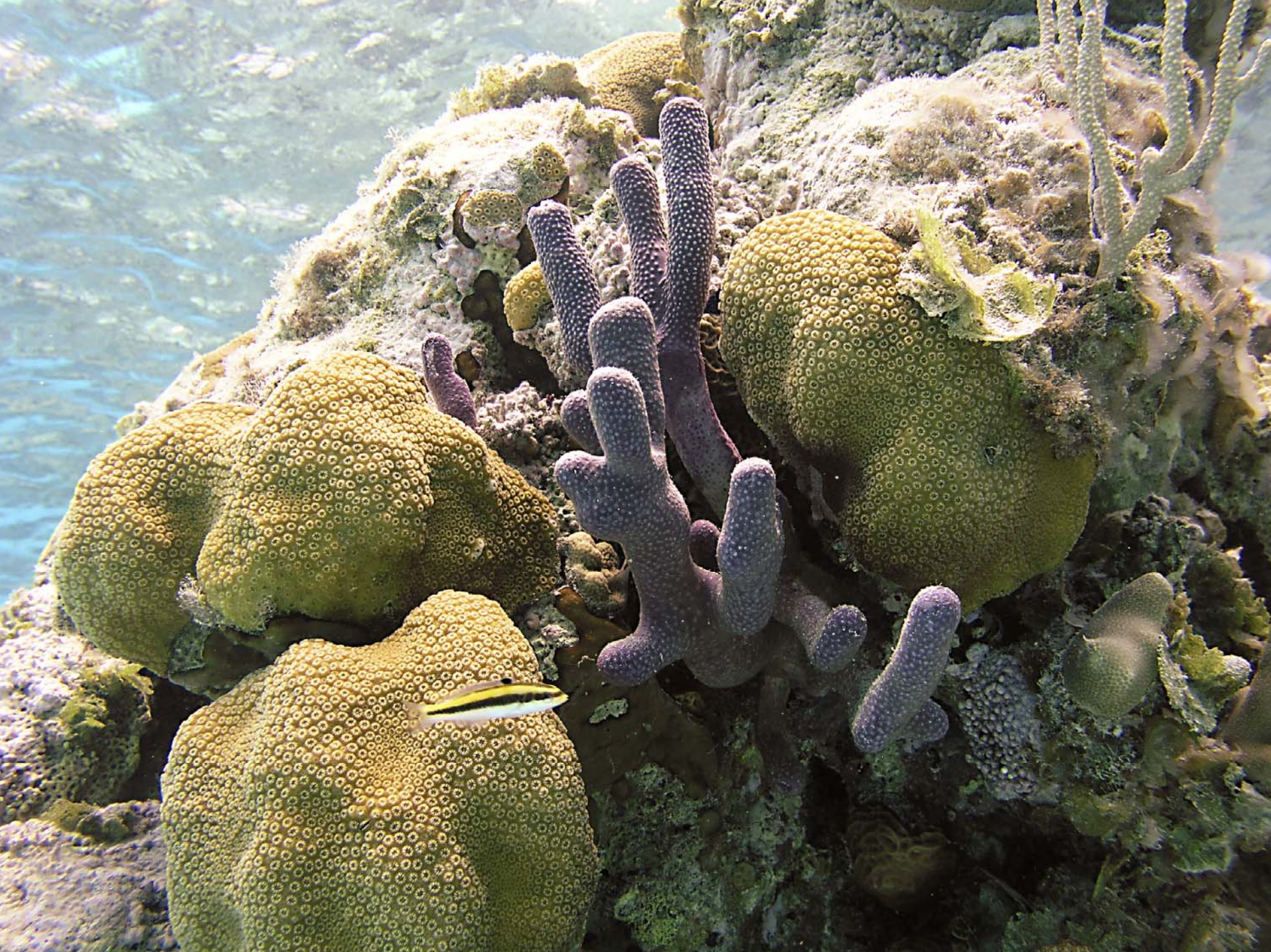


PRECIPITATION PROJECTIONS



< −0.5 −0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4 0.5 >

AVERAGE MODEL-PROJECTED CHANGES IN PRECIPITATION
(MM PER DAY) FOR 2080–2099 RELATIVE TO 1980–1999.



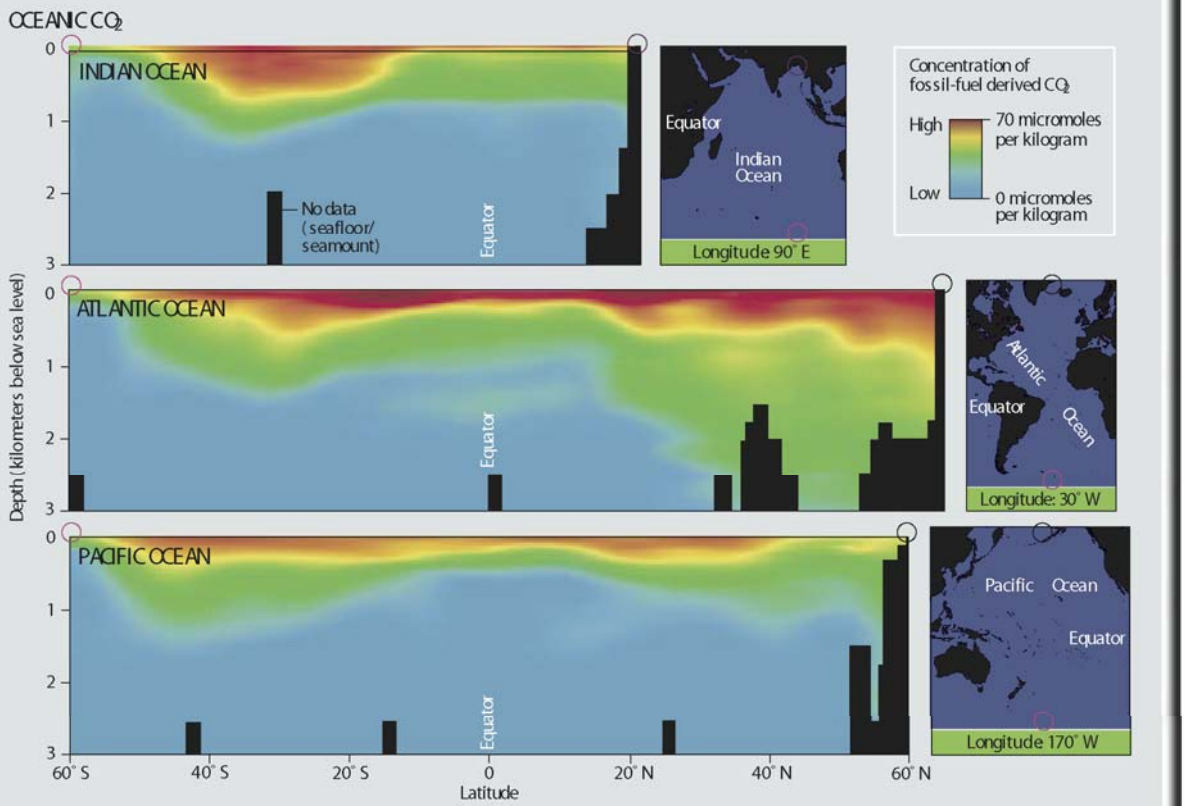
Live coral coverage in Florida Keys

decreasing at 10% per decade . . . why?

This large star coral (*Montastrea annularis*) was being attacked by black band disease in 1988 and was mostly dead by 1998. (Courtesy E. Shinn)

A number of stressors, including warming, nutrients, disease, but also CO_2

Fossil Fuel CO_2 Uptake by Ocean



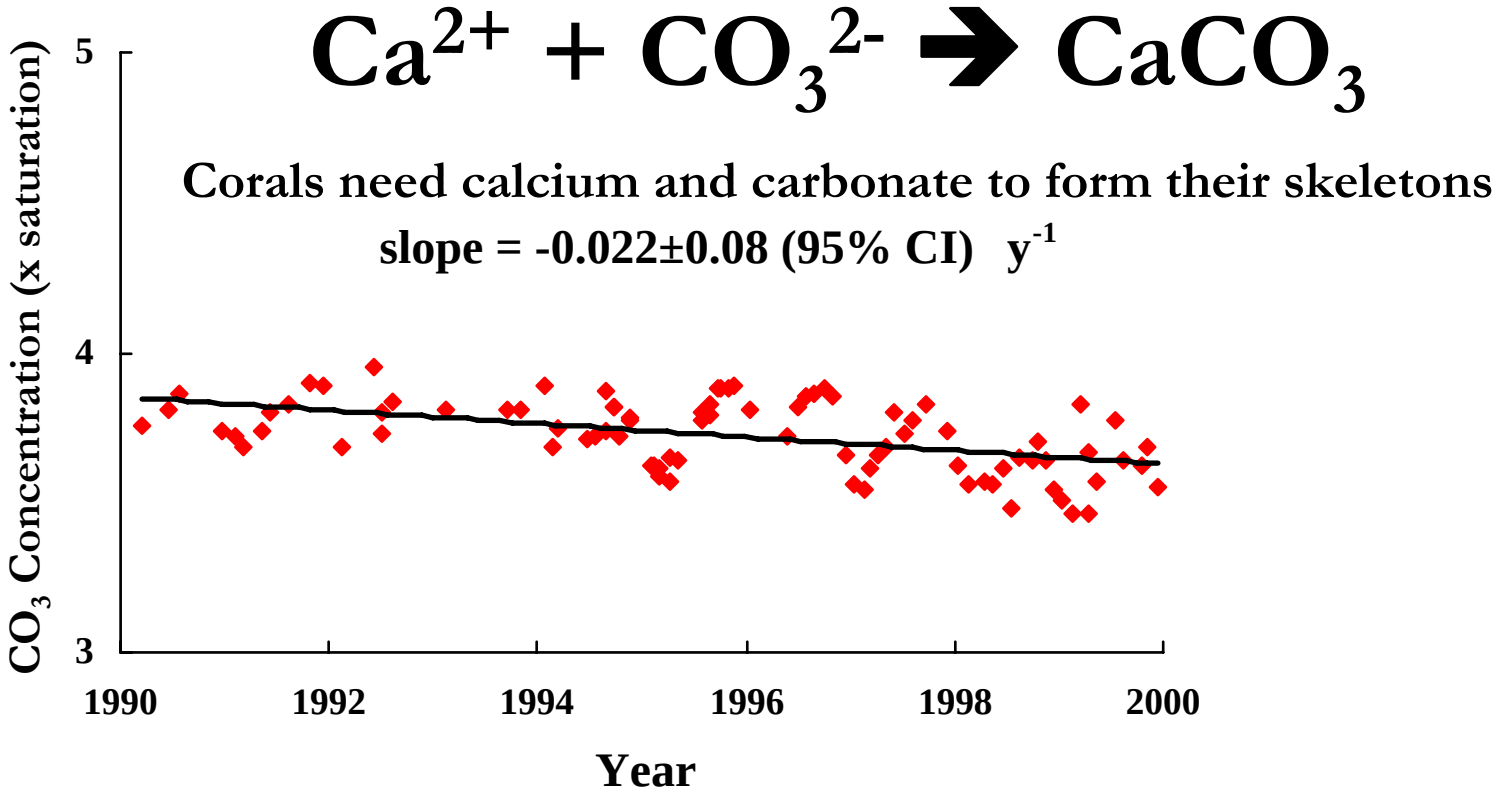
Doney (2006)

Carbon Chemistry in Seawater

$$CO_2 + CO_3^{2-} + H_2O \rightarrow 2\ HCO_3^-$$

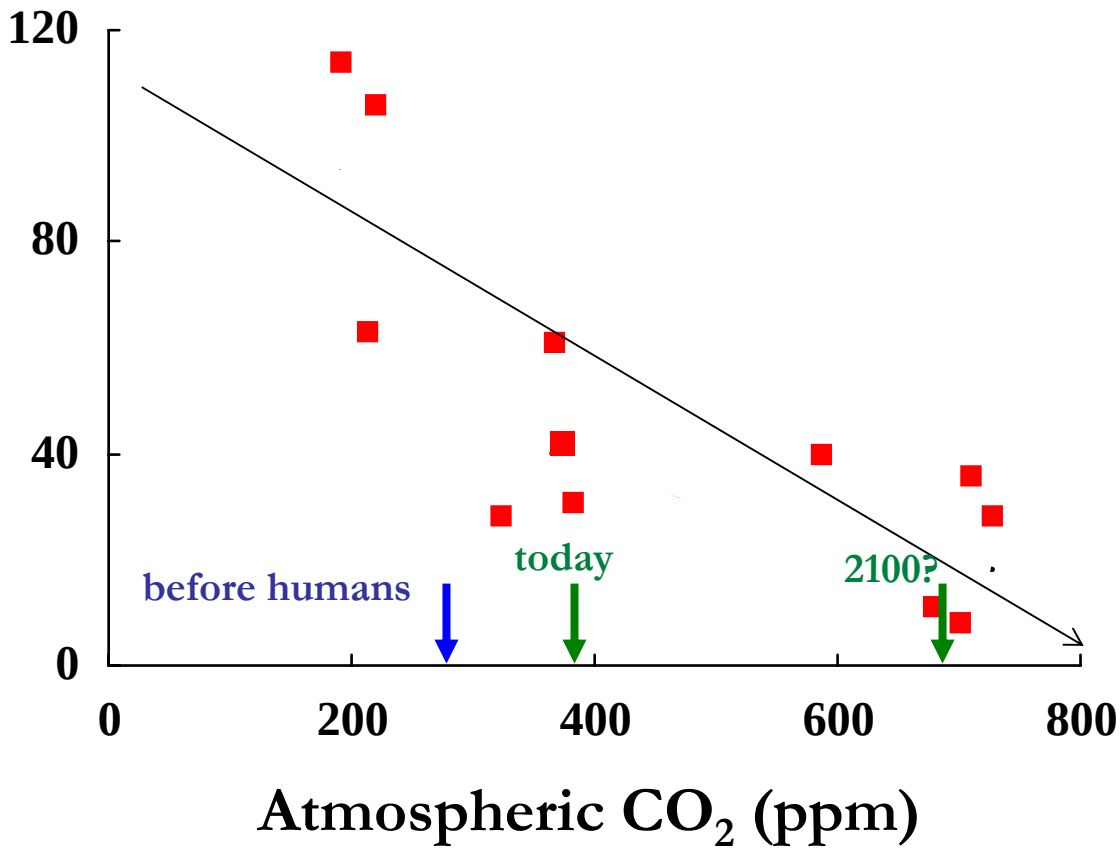
Carbon dioxide reacts with carbonate in water to form bicarbonate

Observations at the Hawaii Ocean Times Series Station



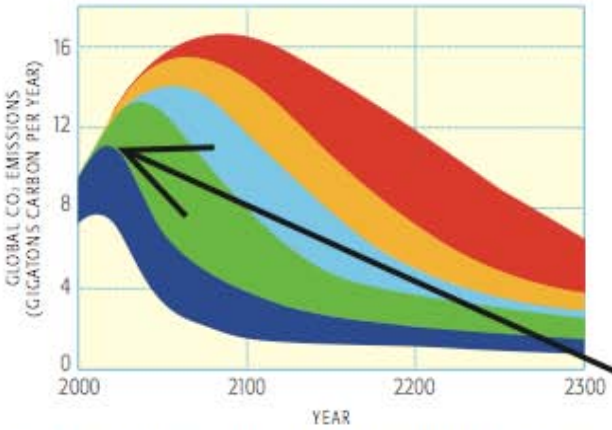
Chris Langdon

Effect of atmospheric CO_2 on community calcification (Biosphere 2)



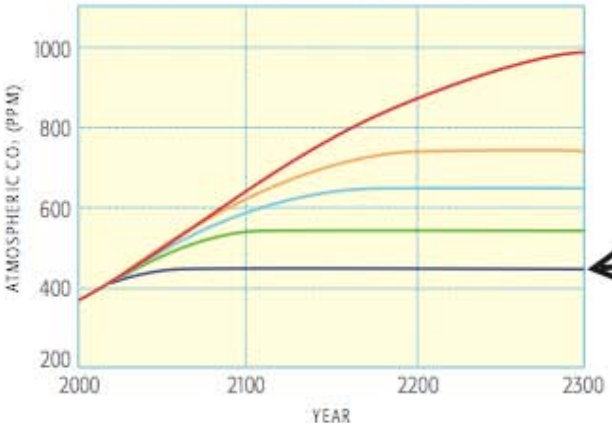
Chris Langdon

EMISSIONS SCENARIOS FOR CO_2 STABILIZATION



The level at which emissions peak determines the level at which atmospheric CO_2 stabilizes.

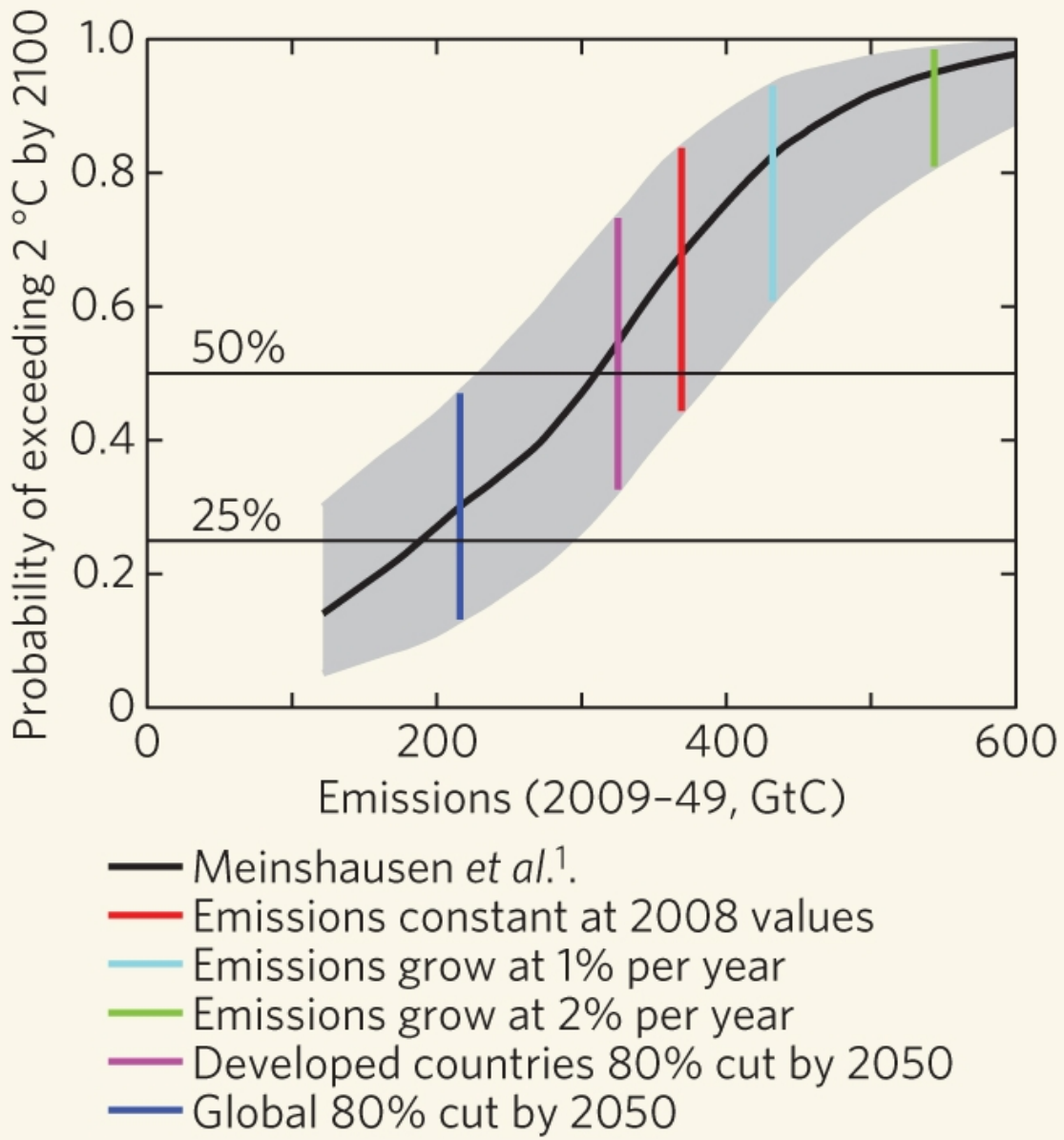
CO_2 STABILIZATION TARGETS



To stabilize atmospheric CO_2 levels at 450 ppm, **fossil fuel use needs to peak by 2020**

With atmospheric CO_2 levels at 450 ppm, global temperature increases by about 2°C and sea level rises by half a meter or more

Stabilization?



Conclusions

- Greenhouse effect is real, always had it, just intensifying it
- Atmospheric CO_2 and temperature have co-varied through Earth history
- Climate models best tool we have to project future climate; key gaps: nonlinearities, downscaling
- Tipping point behavior a real risk, not clear where tipping points reside. Key observations?
- Ocean acidification likely consequence of CO_2 buildup. Need *in situ* experiments.