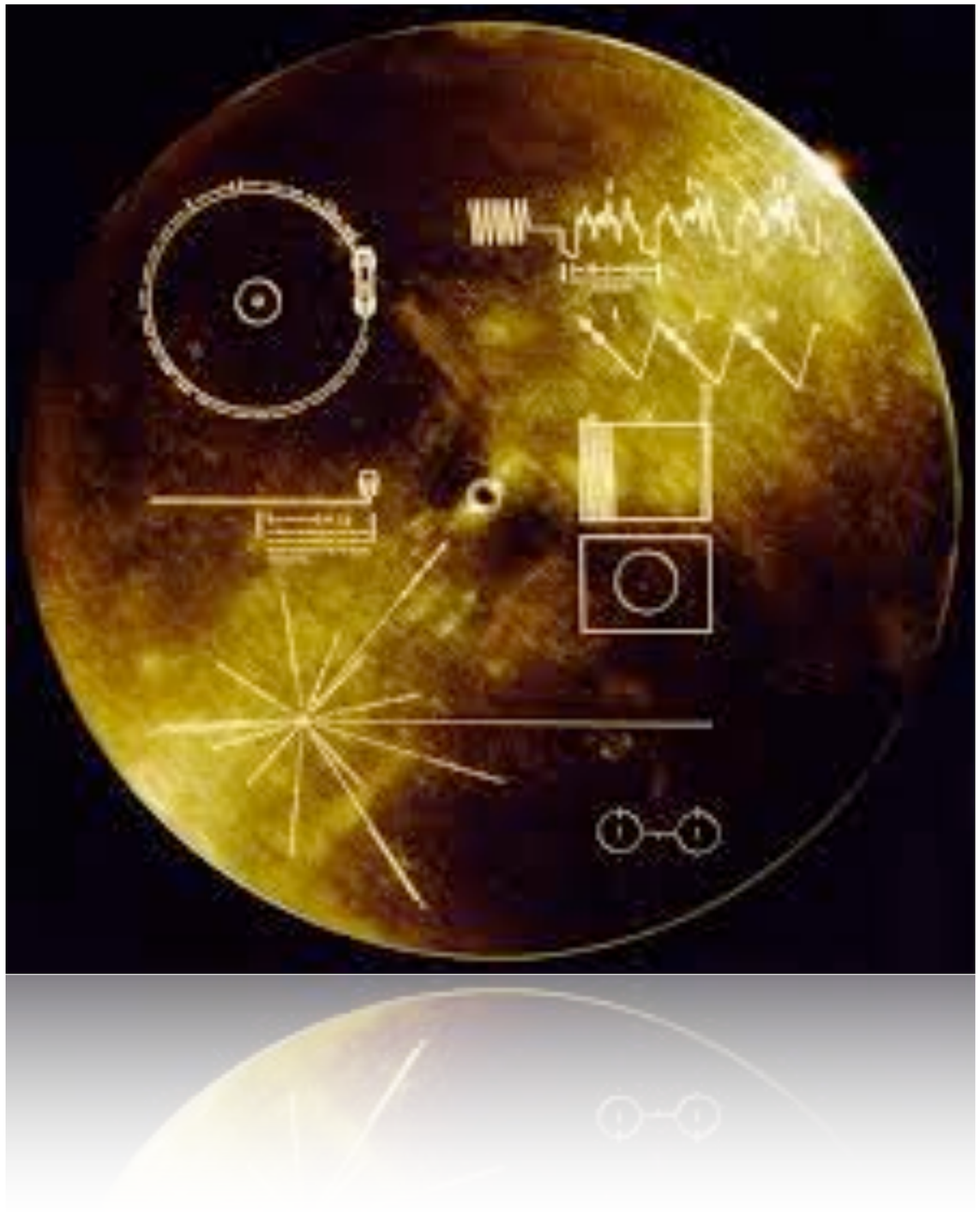
Global Warming (II): us human



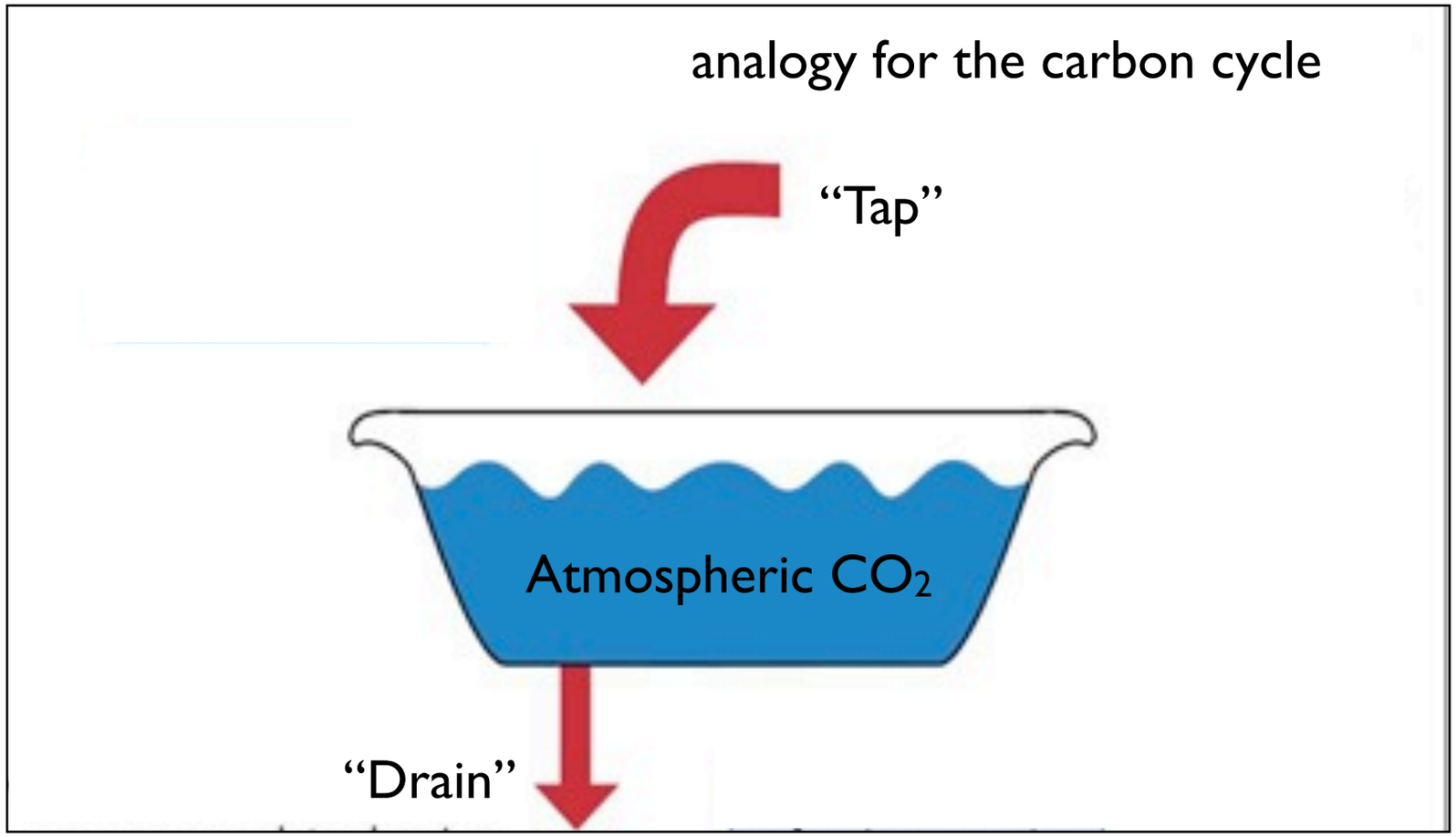
- *the carbon cycle*
- *who is forcing climates*

Readings for the past and this week:

1) Smil, Energy, Beginner's Guide, Chapter 2.
2) Muller, Energy for Future Presidents, Chapter 3
3) David Archer, The Global Carbon Cycle, Chapter 1 (http://press.princeton.edu/chapters/s9379.pdf)

Why is temperature on Earth reasonably constant?

. let's focus on the atmospheric CO_2 -- the more CO_2 in the air, the hotter

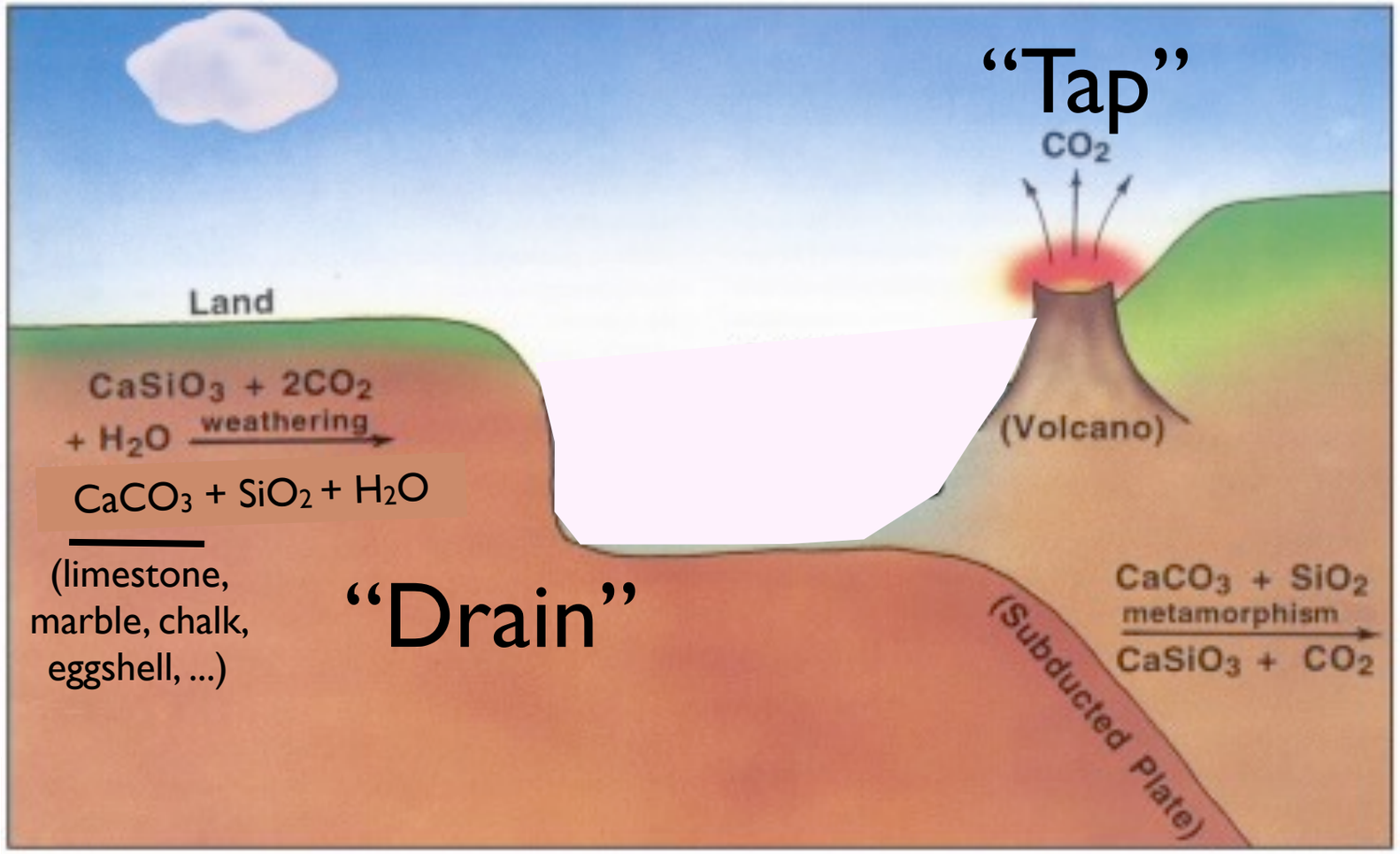


.carbon on Earth continuously loops among air, rock, ocean, life...

-- the **Carbon Cycle**

one component of the cycle

Rock Breathing



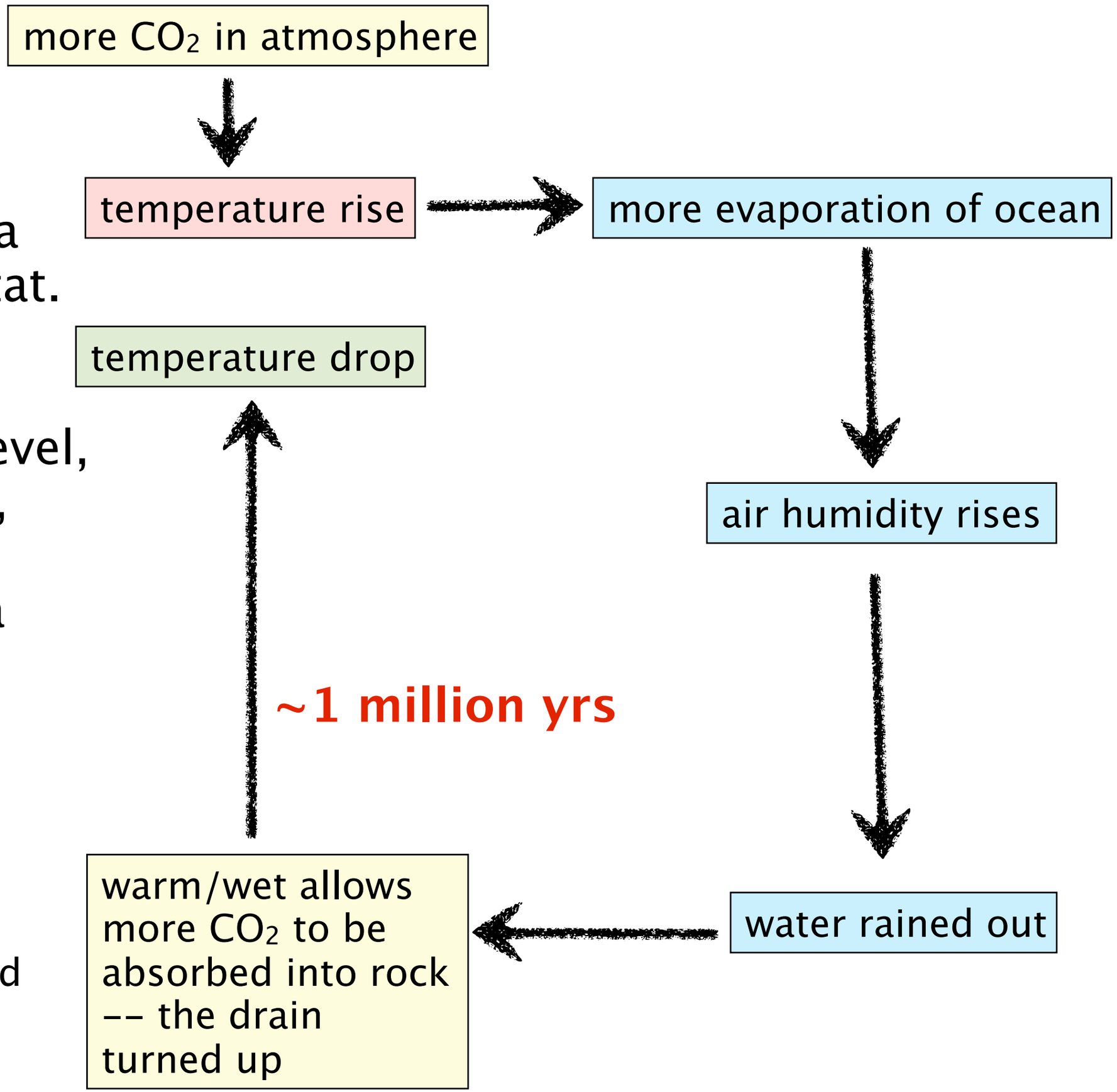
Imagine turning up the tap a bit:

rock breathing is a planetary thermostat.

It regulates the atmospheric CO_2 level, and by association, stabilizes Earth's climate, to within a few degrees of the mean (18°C).

So we are safe?

-- if there is no ocean
-- constantly challenged



a planet that has no ocean --

more CO_2 in atmosphere

temperature rise

more evaporation of ocean

air humidity rises

water rained out

warm/wet allows more CO_2 to be absorbed into rock

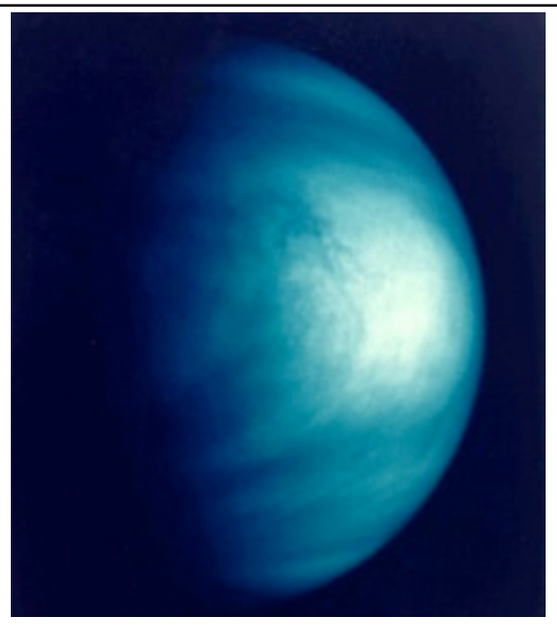
temperature drop

Venus ♀

2nd planet from Sun
closer by 30%;
roughly same size as Earth

surface Temp. 464°C

atmosphere:
96% CO_2 (92 bar)
0.002% water vapor



The thermostat broke. CO_2 stuck in atmosphere.
Got hotter and hotter.

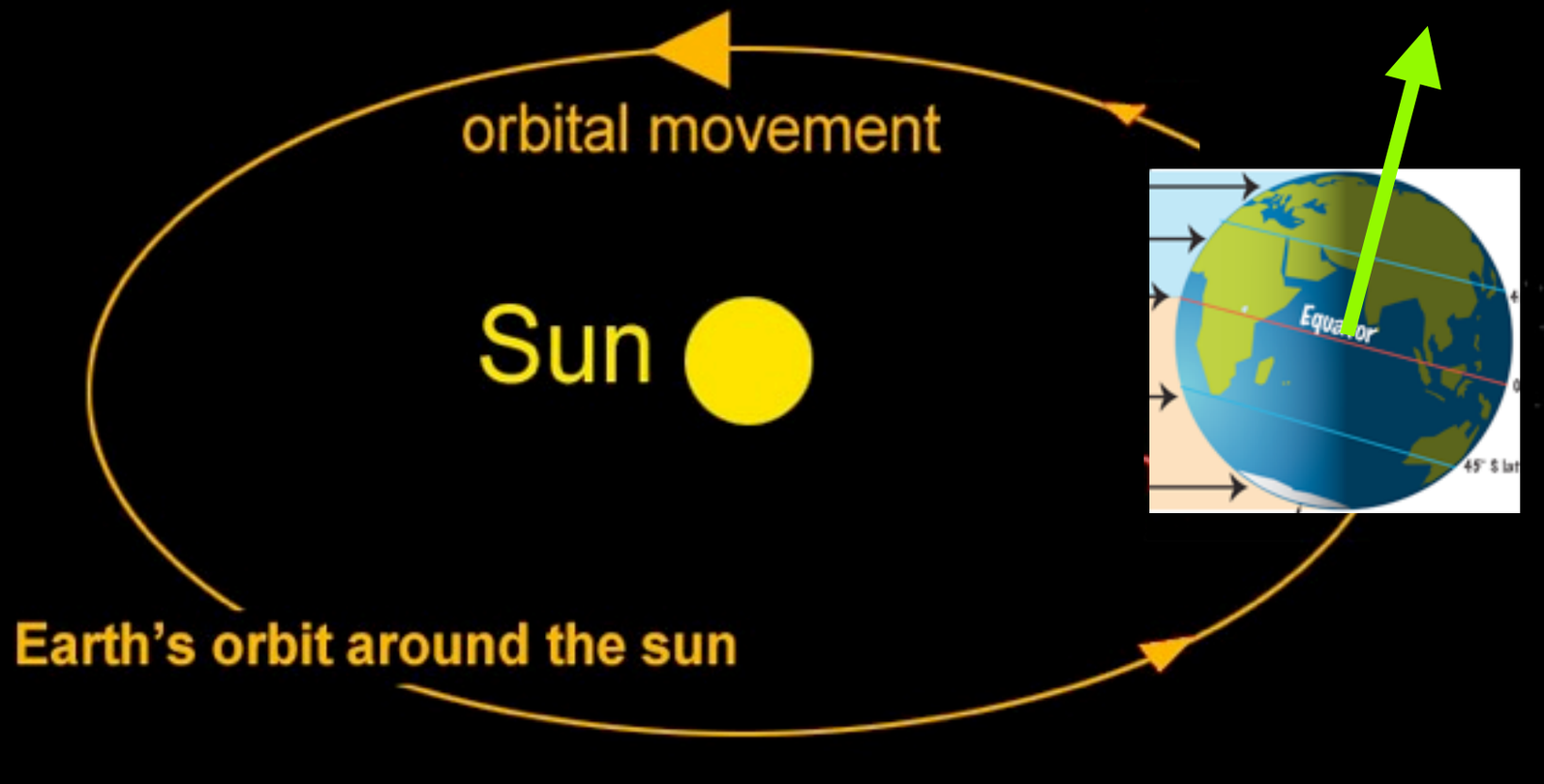
Venus had a **run-away green-house**.

STOCKS

Planets Align for Stock Market Crash in 2013 — If Not Sooner

By DAVID ZEILER, Associate Editor, Money Morning · July 30, 2012

tugging by celestial bodies accumulates over time....



Earth's motion in space are affected by gravity from the Sun, the Moon, and other planets.

Its orbital shape can change from a perfect circle to an ellipse. Its polar axis can wobble around.

These changes are cyclical, with periods: 100,000 years, 41,000 years, 26,000 years. These roughly match the glaciation periods

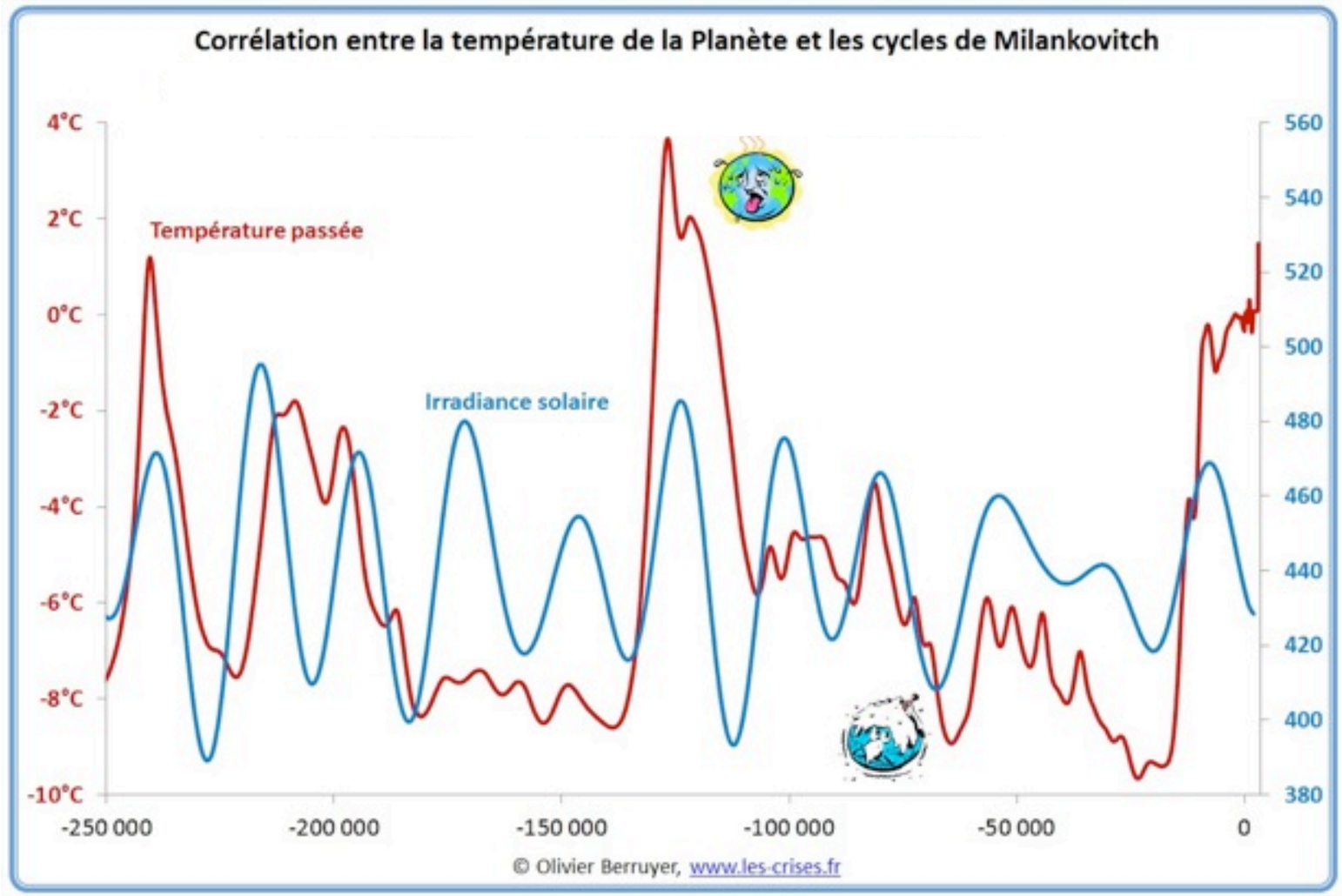
-- Milankovitch 1941."one of the 100 greatest discoveries"

overall sunshine received on Earth varies only by a couple percent, but summer sunshine falling on, say, Stockholm, can vary by 20% (blue curve);

This can be reduced so much that high-latitude regions (Alaska, northern Canada, Siberia) turn cold enough to preserve snow year-round.

Ice in turn reflects more sunshine back to space.... and the ice age descends.

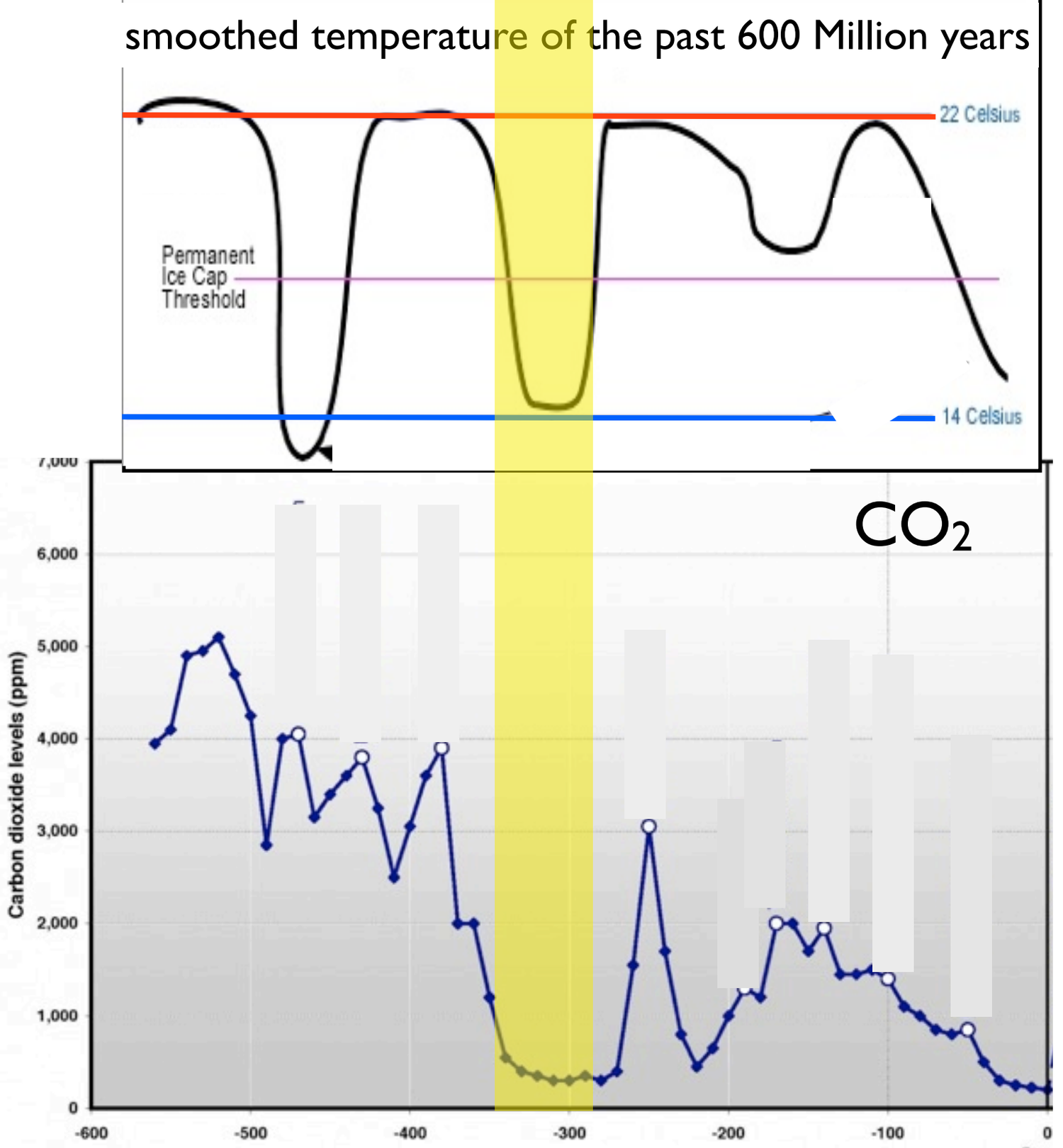
The Milankovitch 'hypothesis'.



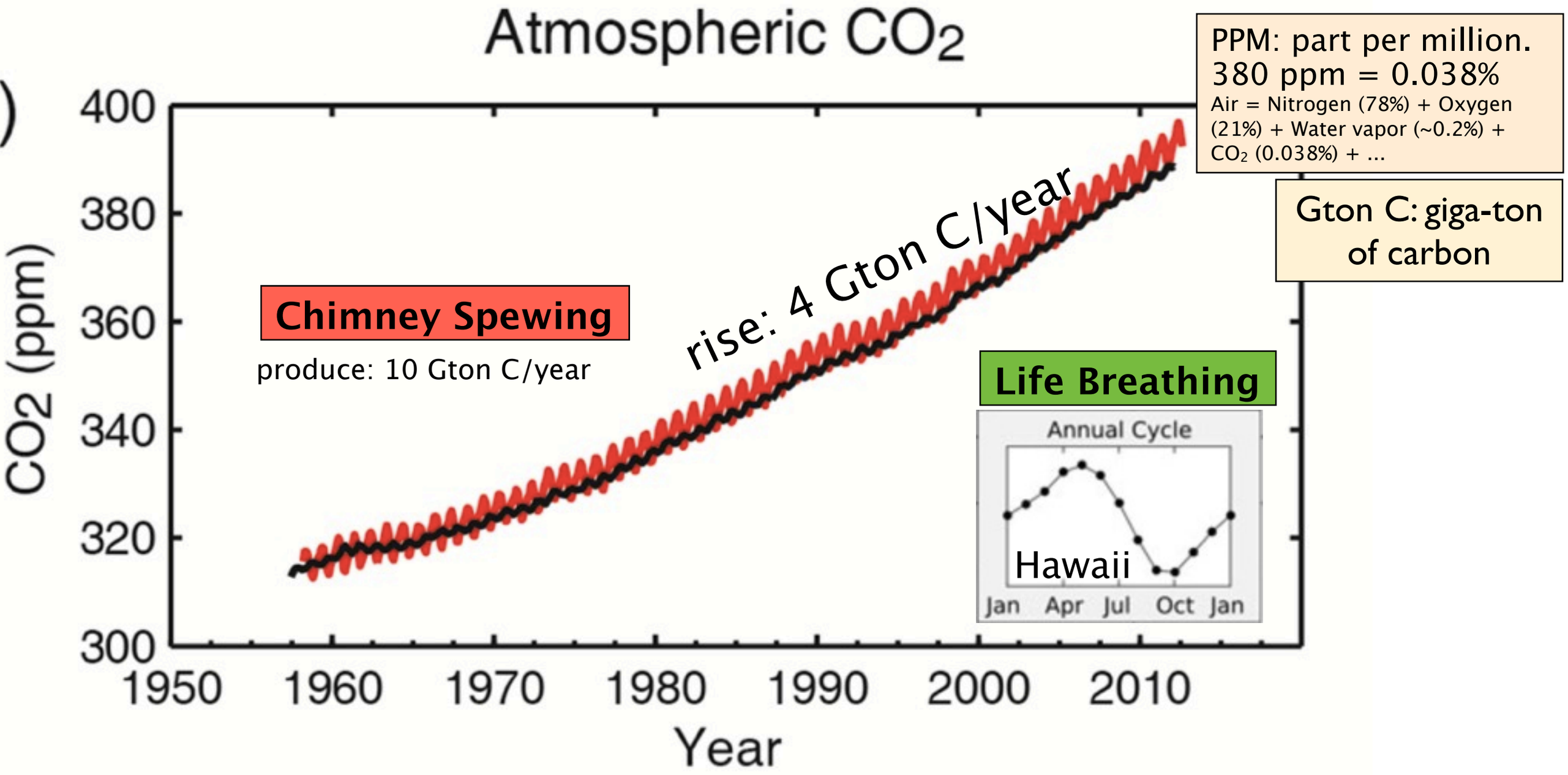
Bacteria can change climates?

life drives climate changes:

one genetic mutation, and an ice house (300 million years ago)



Now
(related)



Only about half of what we released shows up in the atmosphere.

Half of the missing is taken up by ocean, the other half biosphere.

--Biosphere responses complex (growth, decay. ...)

--Ocean ventilates in ~100 year timescale (deeper currents to swell up).

The Global Carbon Cycle

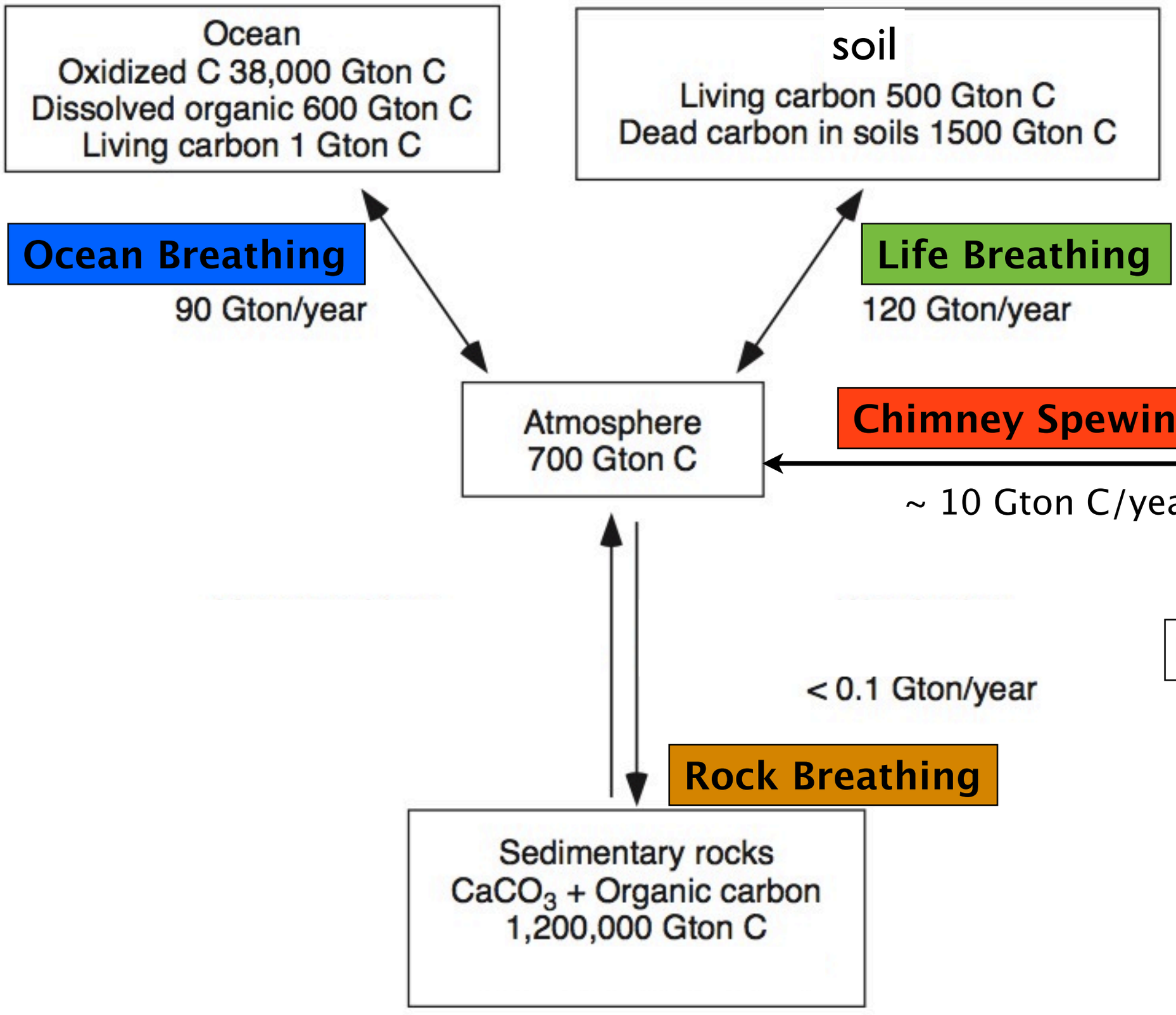
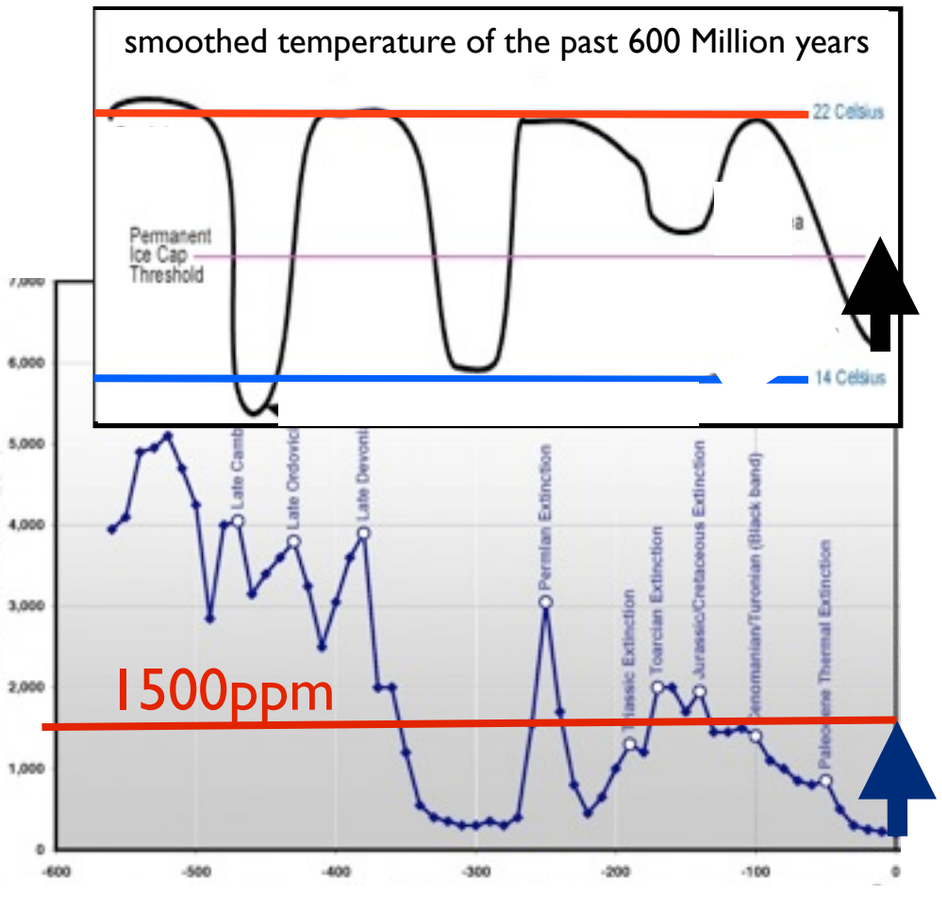


Figure 8-1 Carbon reservoirs on Earth and carbon fluxes between them.

Archer '10



"business as usual":
1500ppm by 2100.

Summary: Earth in Deep History

- we are currently in an 'ice-house';
- climate on Earth is guaranteed stable on long timescales (thermometer: water & rock)
- but short swings unavoidable(nastiness)
- swings can be triggered by...

celestial forces:
Sun, Moon, other planets
(changing Earth's orbit/tilt)
large asteroid impacts...

terrestrial forces:
super-volcanoes, continent shifts,
ocean currents...

life forces:
bacteria evolution, trees, human....

Global Warming (III): the debate

- *correlation vs. causation*
- *hypothesis testing*
- *regression back to the mean*

Questions politicians would like answers for:

Is it human?

How fast? temperature rise per CO_2 doubling

How costly? economic/human impact of warming

What to do? mitigation measures? How to set cap-and-trade? carbon-tax?

Intergovernmental Panel on Climate Change (IPCC)

Nobel Peace prize (2007, shared with Al Gore), all scientists work on voluntary basis

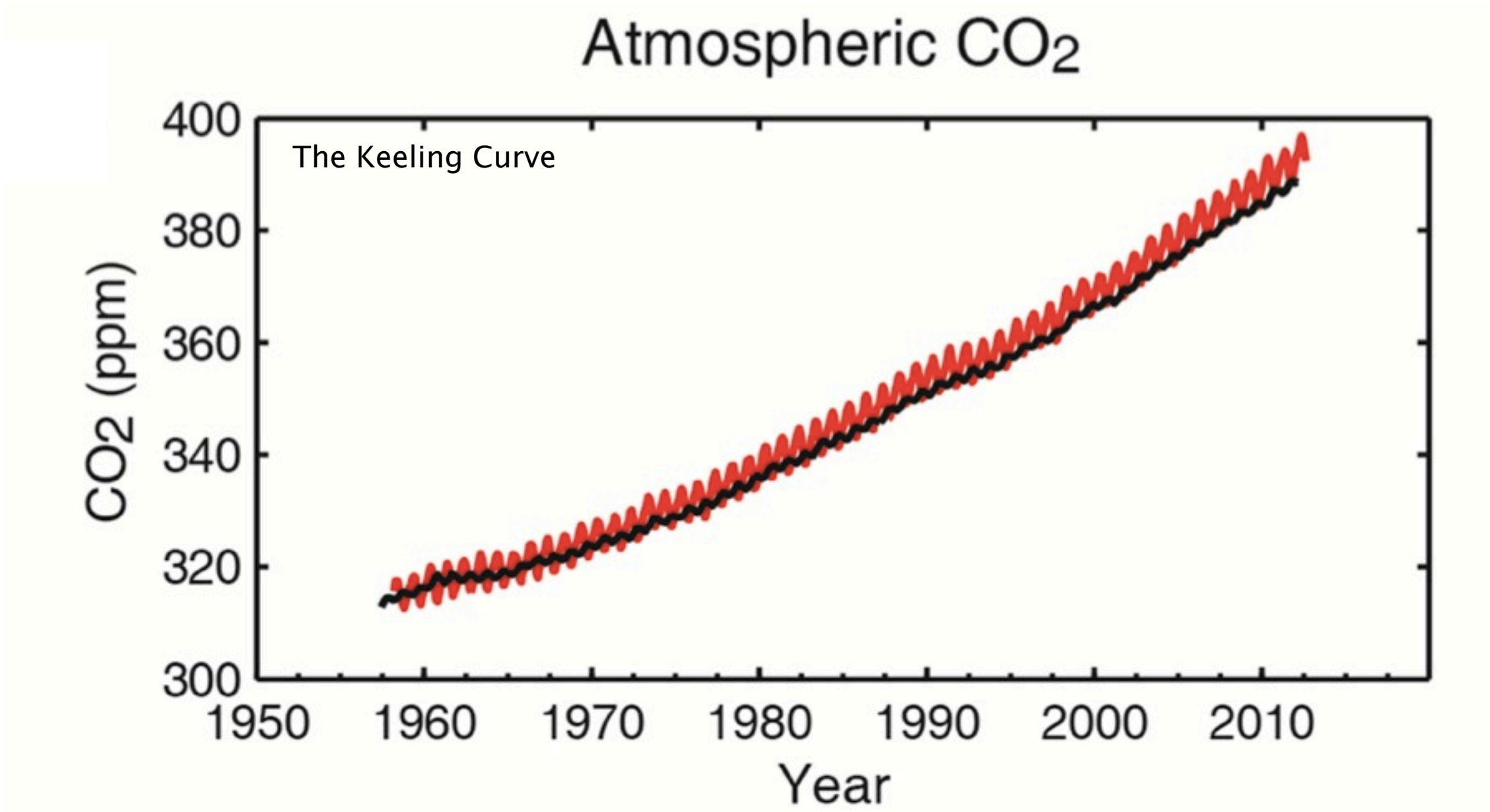
The aims of the IPCC are to assess scientific information

1. Human-induced climate change,
2. The impacts of human-induced climate change,
3. Options for adaptation and mitigation.

Number of review comments on Fifth Assessment Report

		Number of comments	Experts	Governments
Working Group I	First Order Draft	21,400	659	-
	Second Order Draft	31,422	800	26

The rise of CO_2 is incontrovertible

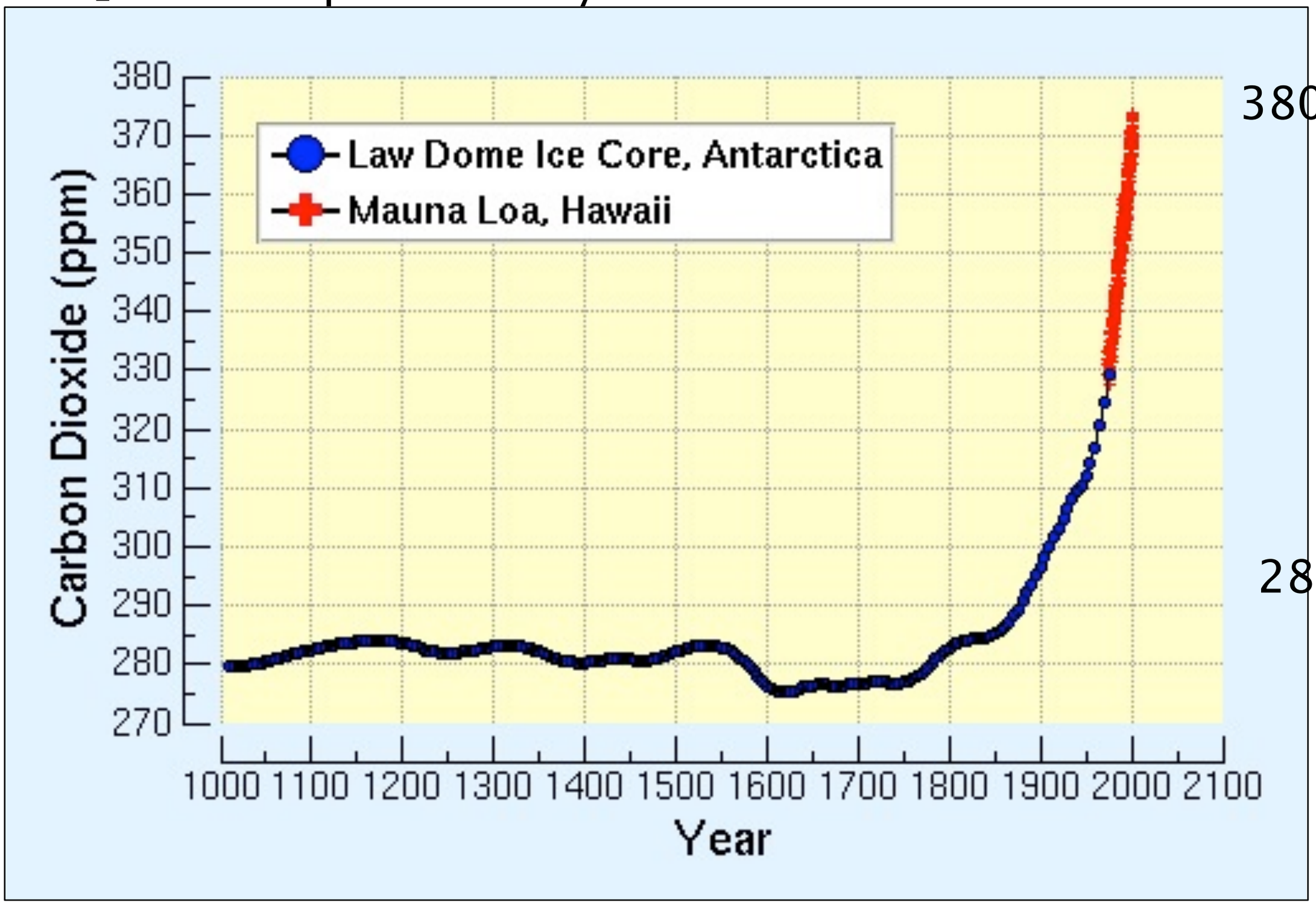


200 yrs of Industrial Revolution coincides with historically high CO_2 level.

This CO_2 rise is caused by human activities

IPCC 2001

CO_2 over the past 1000 yrs



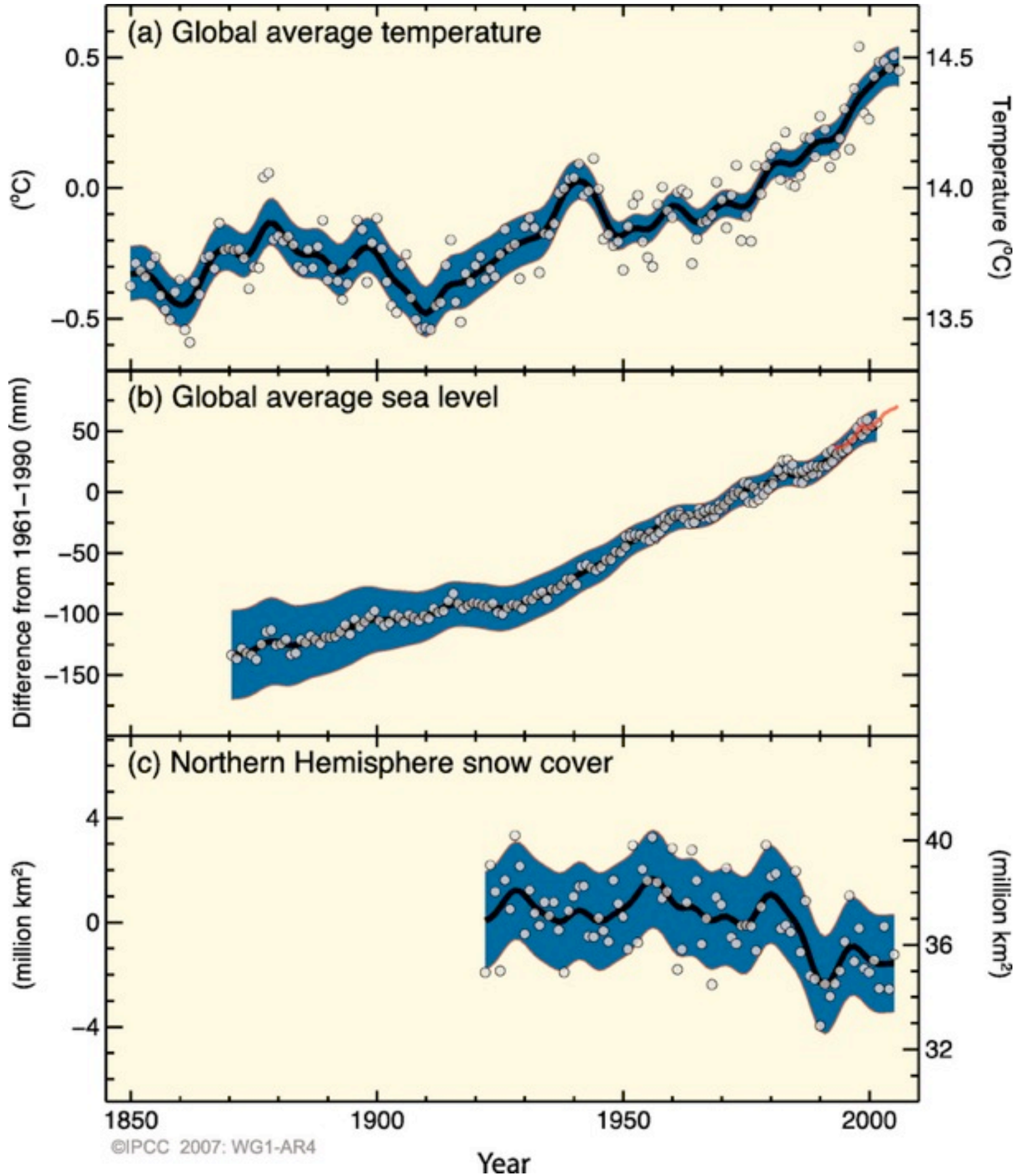
380ppm

280ppm

Warming is ‘unequivocal’

“Warming of the climate system **is unequivocal,** as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level”

IPCC 2007 report



compared with: 70% Americans who believe warming is real.

Warming & anthropogenic CO_2 -- the toughest part!

[Anthropogenic CO2] will enhance the greenhouse effect, resulting in an additional warming of the Earth's surface.

IPCC AR1, 1995: "More likely than not"

There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities. Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years.

IPCC AR3, 2001: "Likely"

"Most of the observed increase in global average temperatures since the mid-20th century **is very likely** due to the observed increase in anthropogenic greenhouse gas concentrations."

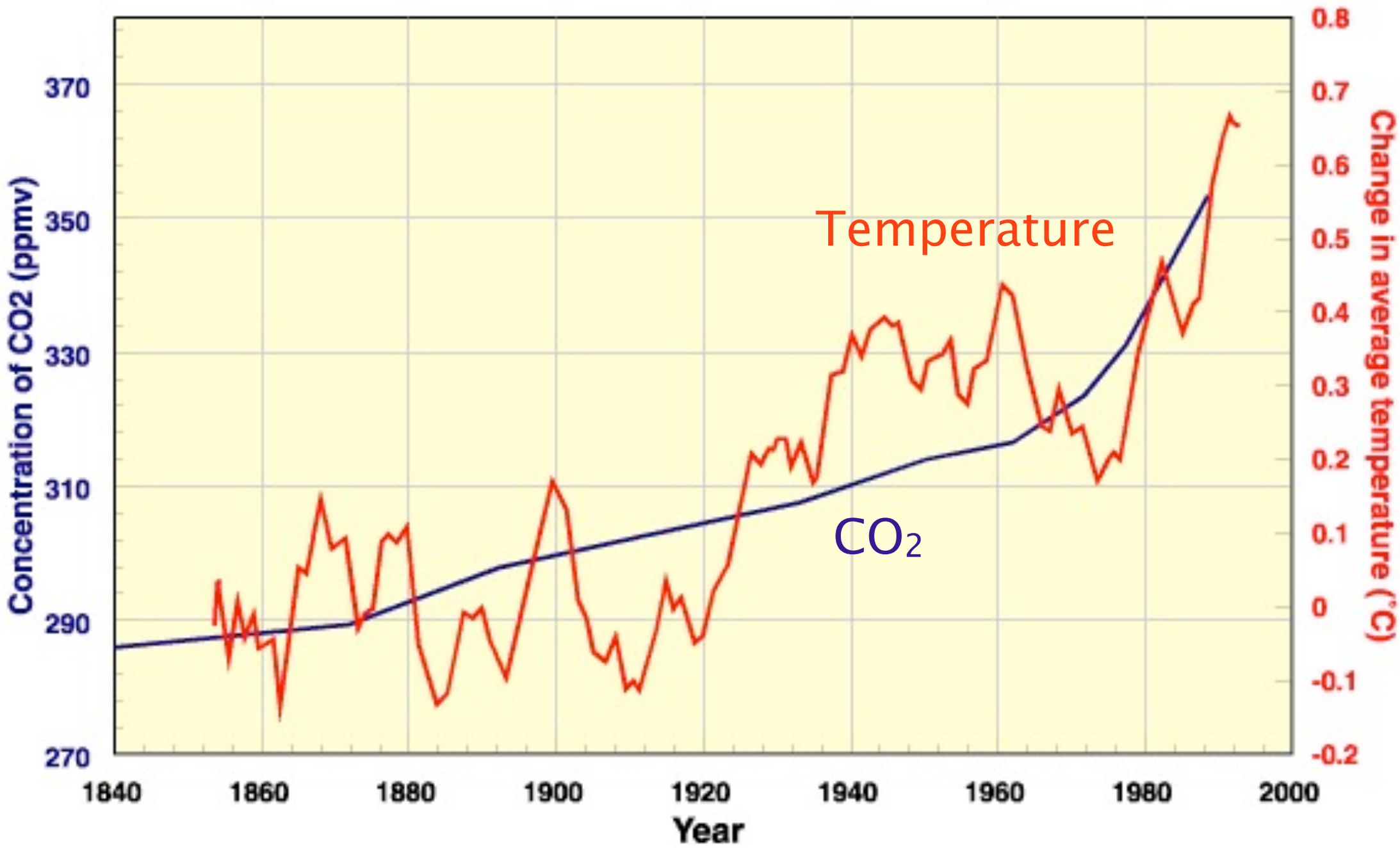
IPCC AR4, 2007: "Very likely"

Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes (Figure SPM.6 and Table SPM.1). This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century. {10.3–10.6, 10.9}

IPCC AR5, Sep 2013, "Extremely likely"

compared with only 50% of American who believe so

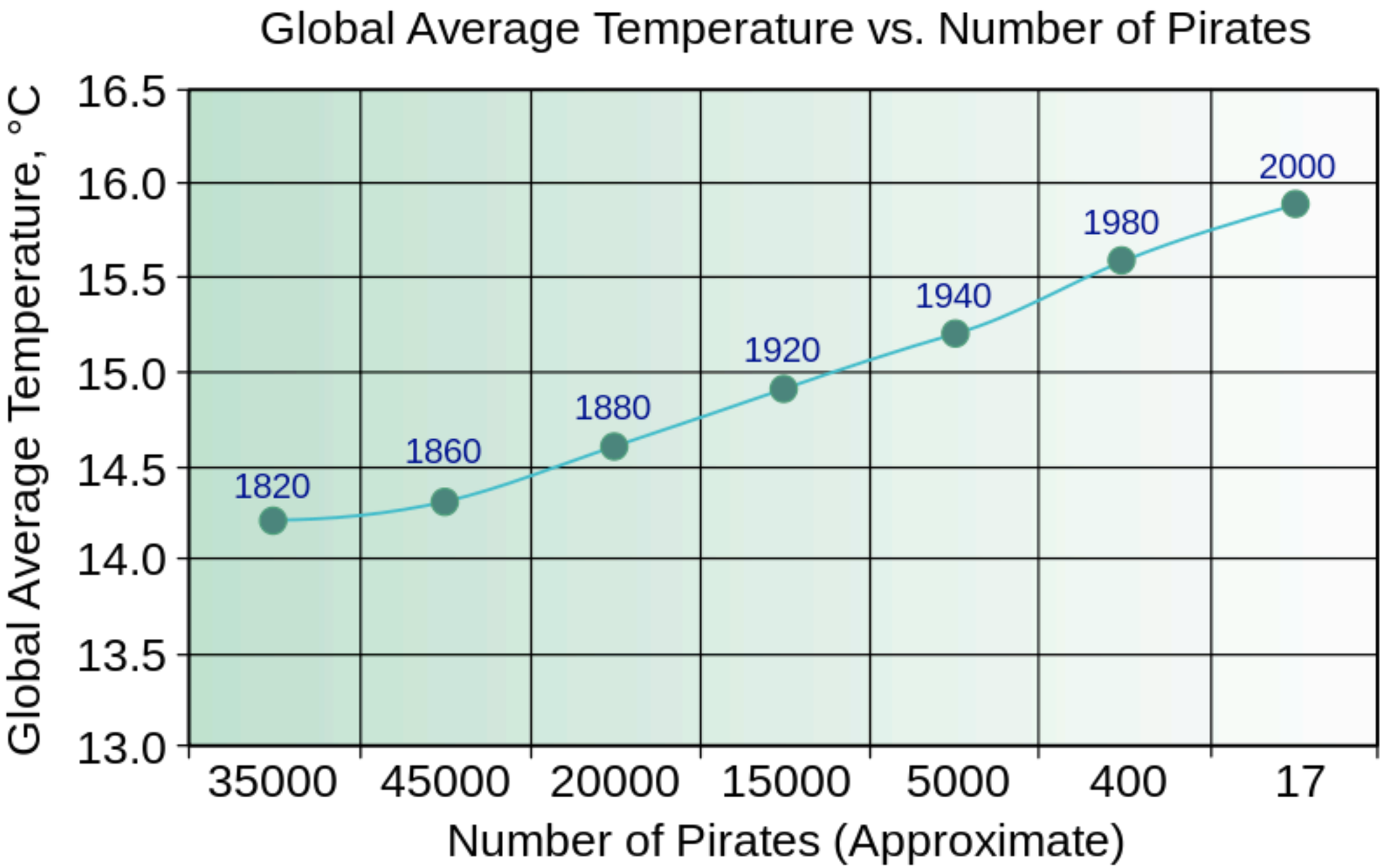
temperature rise strongly correlates with CO_2 rise



Why is it so hard to put two and two together and say that the temperature rise is caused by human-activities?

-- the climate debate

A contrarian example.



Chasing Ice ’05

What is examinable/non-examinable?

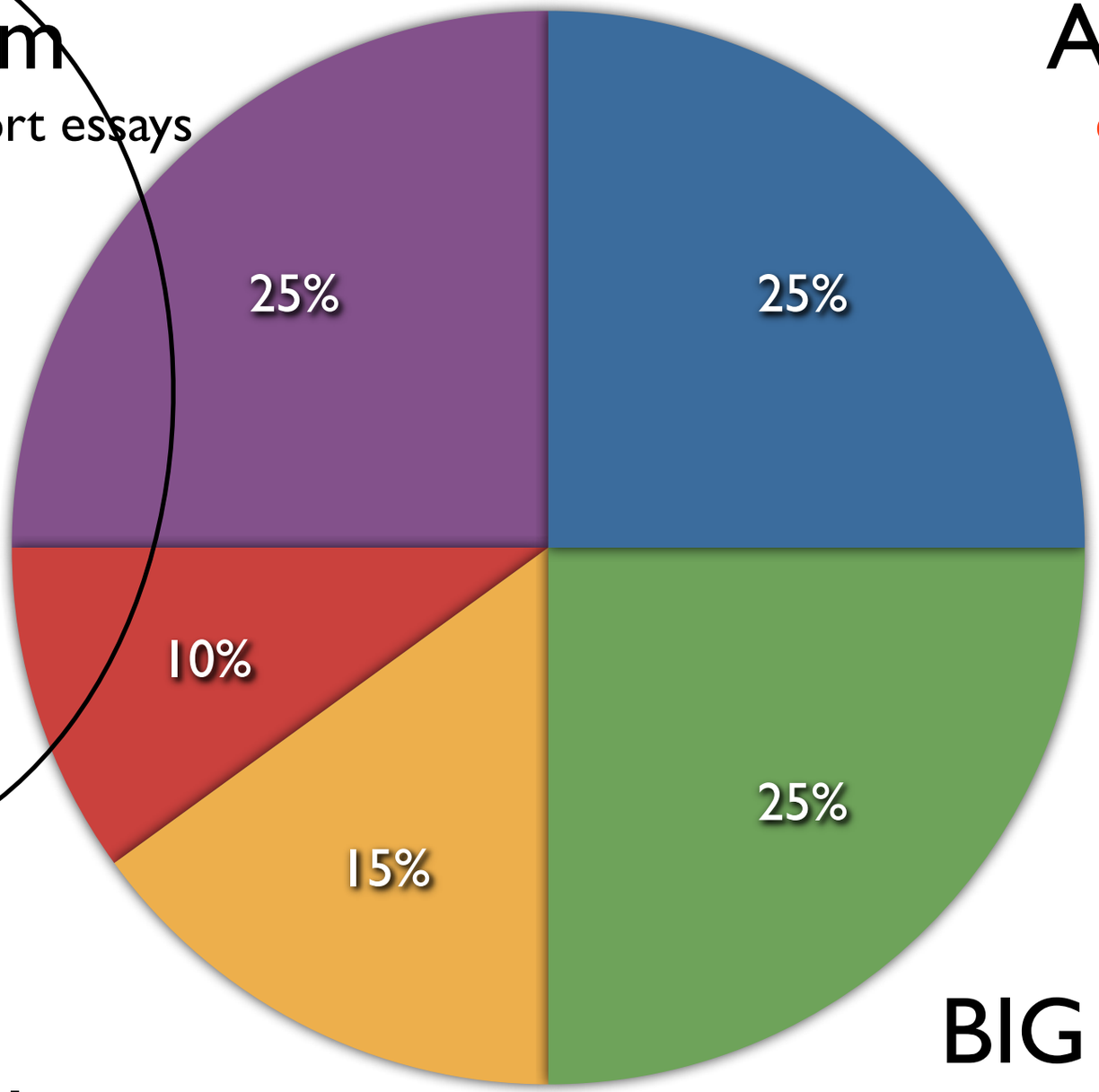
Final Exam

multiple choice + short essays

Term Test

Dec. 4th

multiple choices



Assignments

come to tutorials

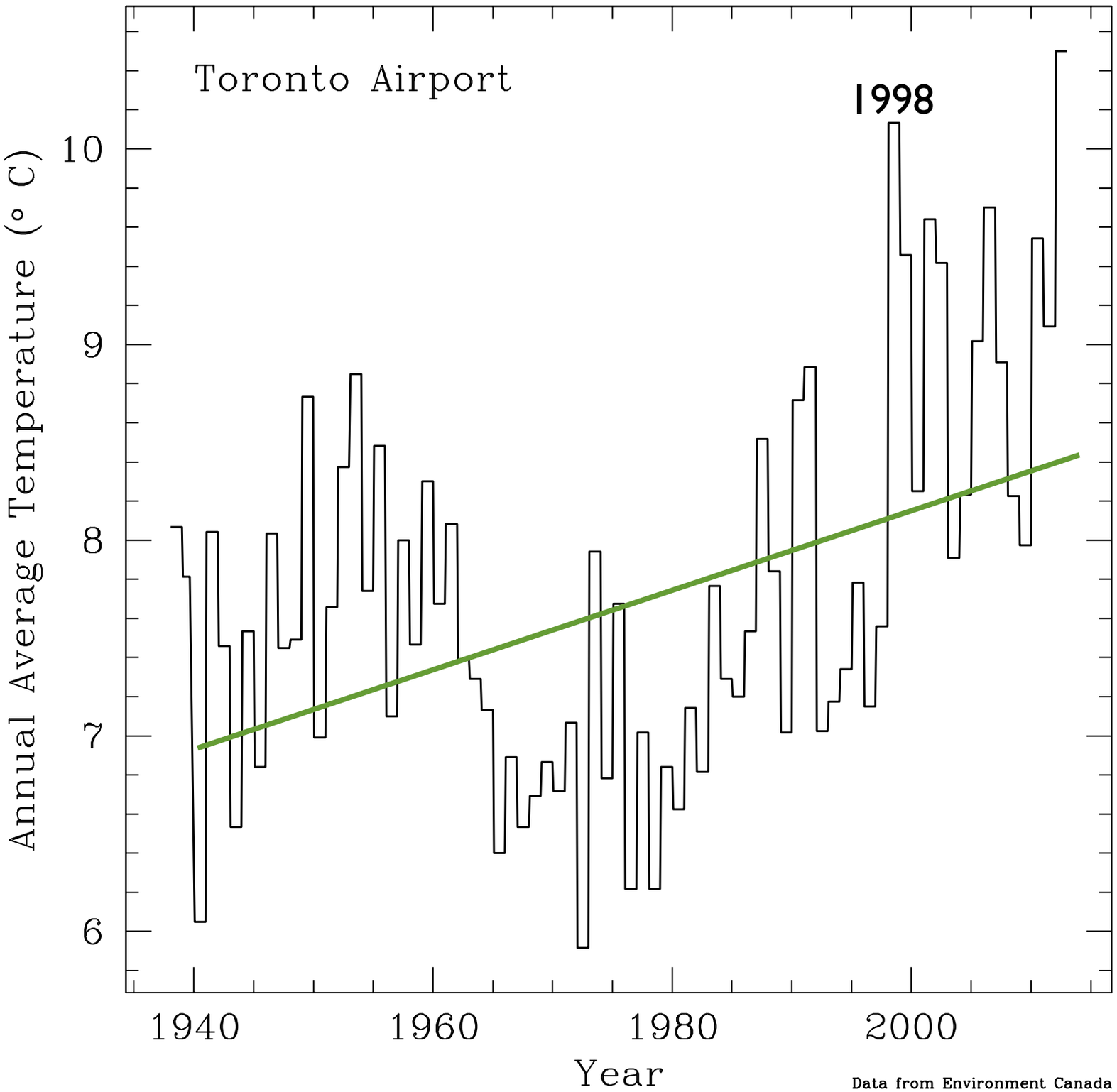
In-class quiz

attend every lecture

BIG project

use your brain hard

How much does an individual experience warming?



Toronto's Annual Average temperatures have increased by 1.5 deg over the past 60 years.

most of this is actually "urban heat-island effect"

Record heat wave bakes Canada's North

Temperatures 10 degrees above normal across Yukon, Nunavut and Northwest Territories

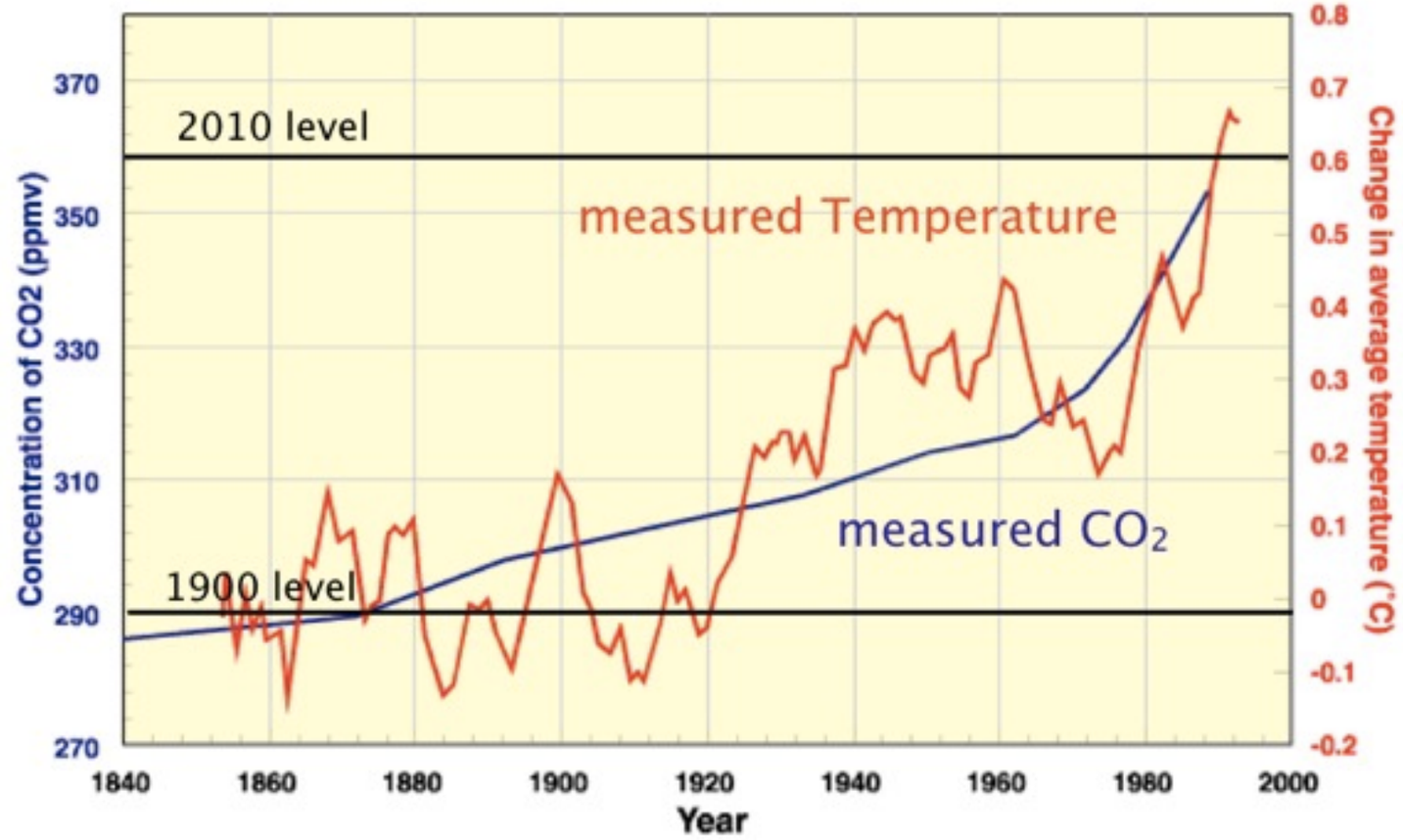
CBC News Posted: Aug 13, 2013 7:28 PM CT | Last Updated: Aug 13, 2013 8:57 PM CT

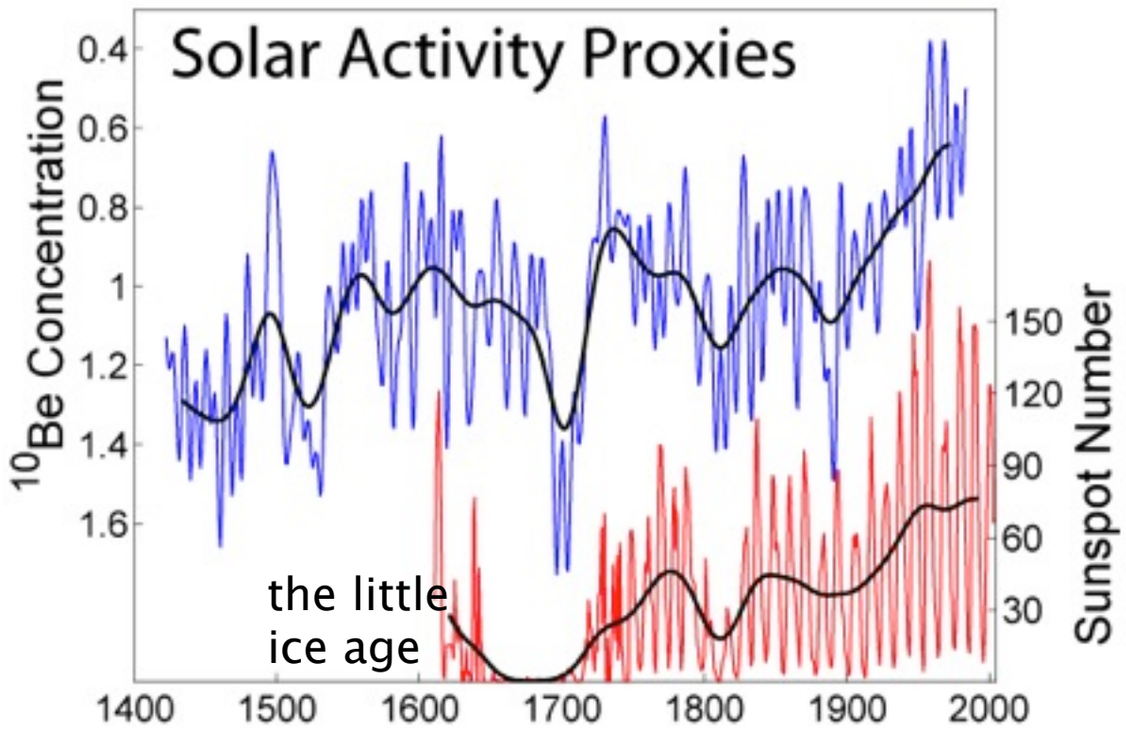
Monday's sunset in Kugluktuk, Nunavut is shown. The town is seeing temperatures more than double the seasonal norms. ((Photo courtesy Ron Tologanak))

Oh-oh, are we seeing effects of global warming?

Maybe Canada will benefit from global warming?

Why is it so hard to put two and two together and say that the temperature rise is caused by human-activities?





one alternative: the Sun has recently become more magnetically active

The NEW ENGLAND JOURNAL of MEDICINE

OCCASIONAL NOTES

Chocolate Consumption, Cognitive Function, and Nobel Laureates

Franz H. Messerli, M.D.

N Engl J Med 2012; 367:1562-1564 | October 18, 2012 | DOI:

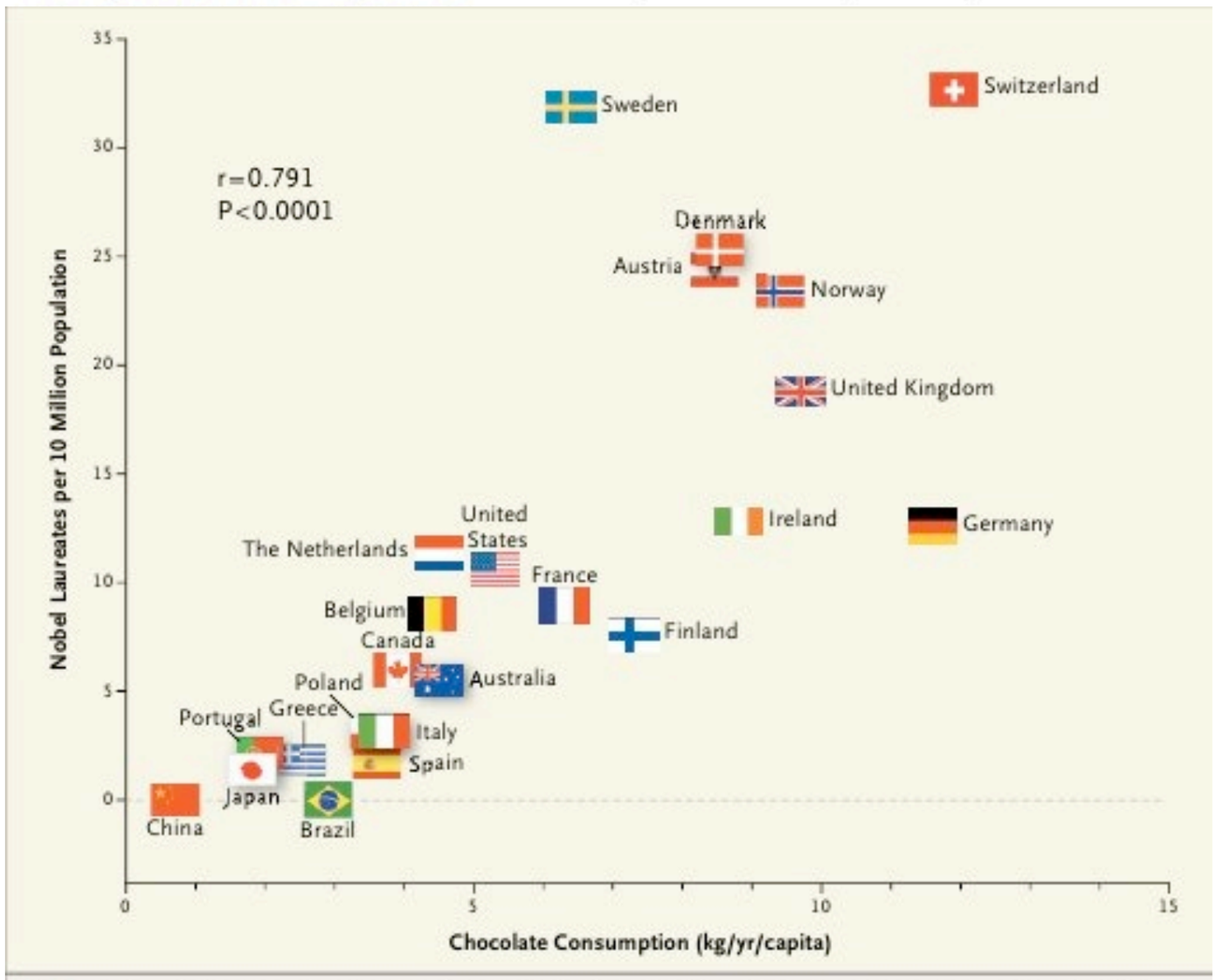


Figure 1. Correlation between Countries' Annual Per Capita Chocolate Consumption and the Number of Nobel Laureates per 10 Million Population.

"correlation ≠ causation"

other examples:
. the smaller your palm, the longer you live.
. people who eat breakfast are less likely to be obese.

if so, what does it take to prove causation?

. Human are too good at pattern finding. Observing a correlation is only the first step in establishing causation.

. You also need a credible mechanism.

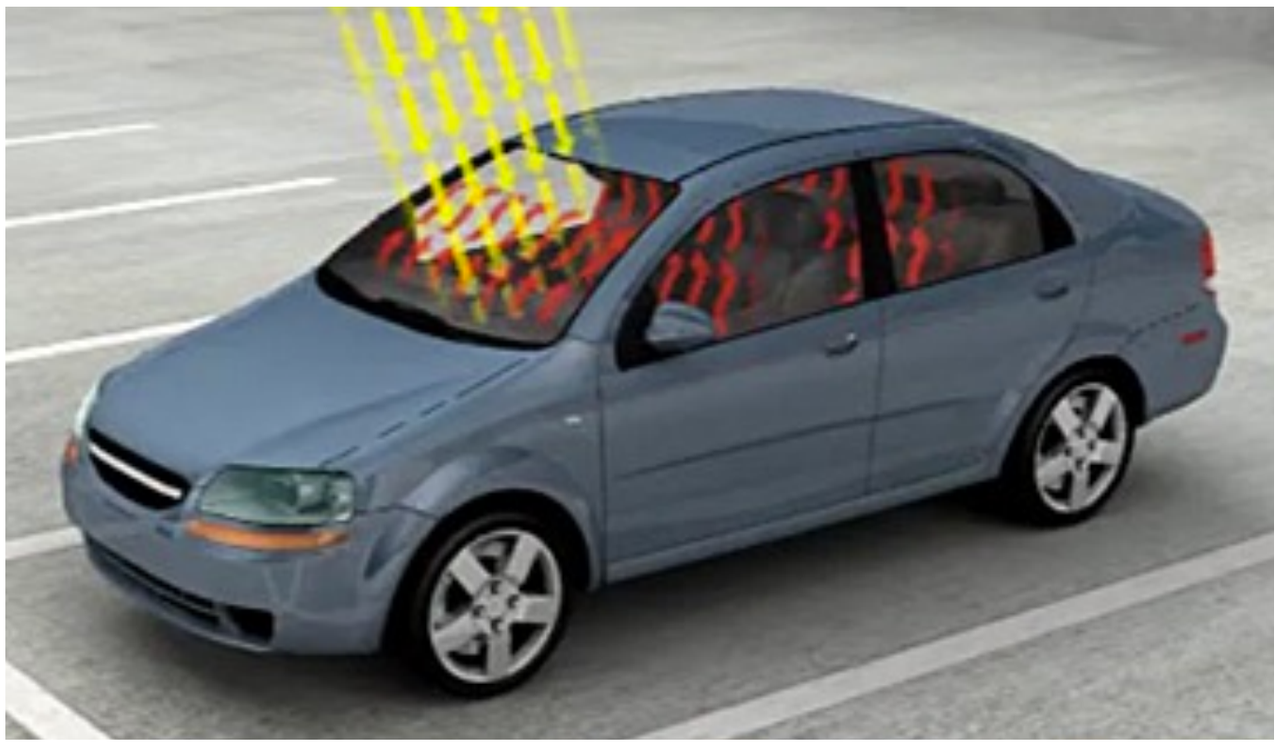
The Greenhouse Effect

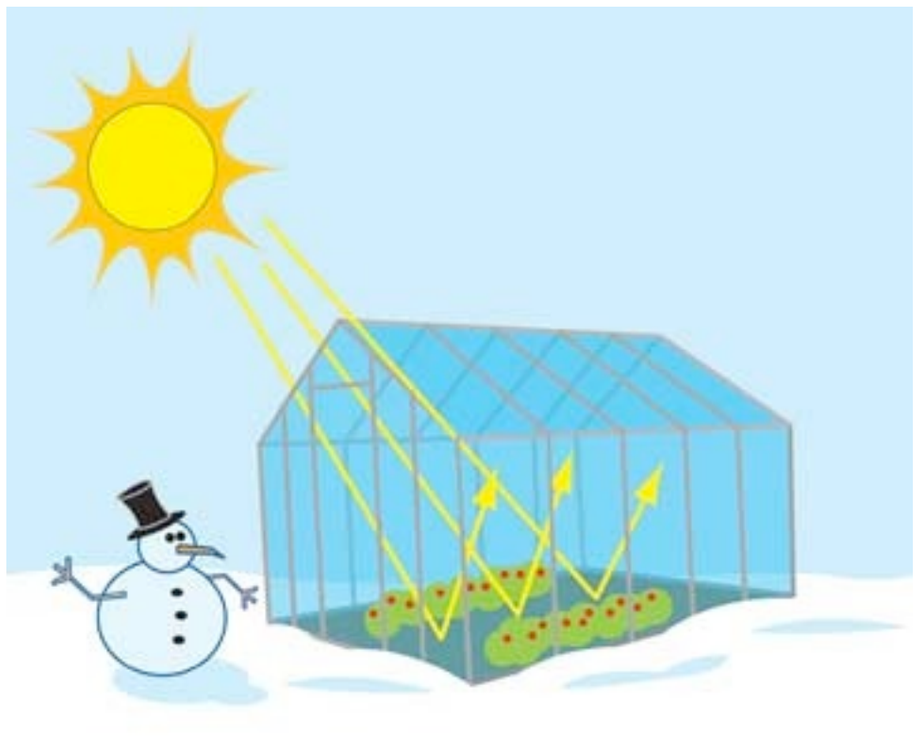
.sunshine (short-wave) streams through the ~~glass~~ atmosphere unhindered.

.~~car interior~~ Earth needs to lose that heat by radiation (long-wave)

.~~glass~~ Atmosphere is opaque to long-wave radiation

.unable to rid of the energy, the ~~car~~ Earth heats up





long-wavelength radiation (infrared light)? what is that

the 100 W bulb

Why CO_2?

Air = Nitrogen (78%) + Oxygen (21%) + Water vapor (~0.2%) + CO_2 (0.038%) + ...

Greenhouse gas is a gas that absorbs radiation in the thermal infrared range (long-wave). Includes H_2O, CO_2, methane...

More greenhouse gas, more blocking of long-wave light. The Earth heats up.

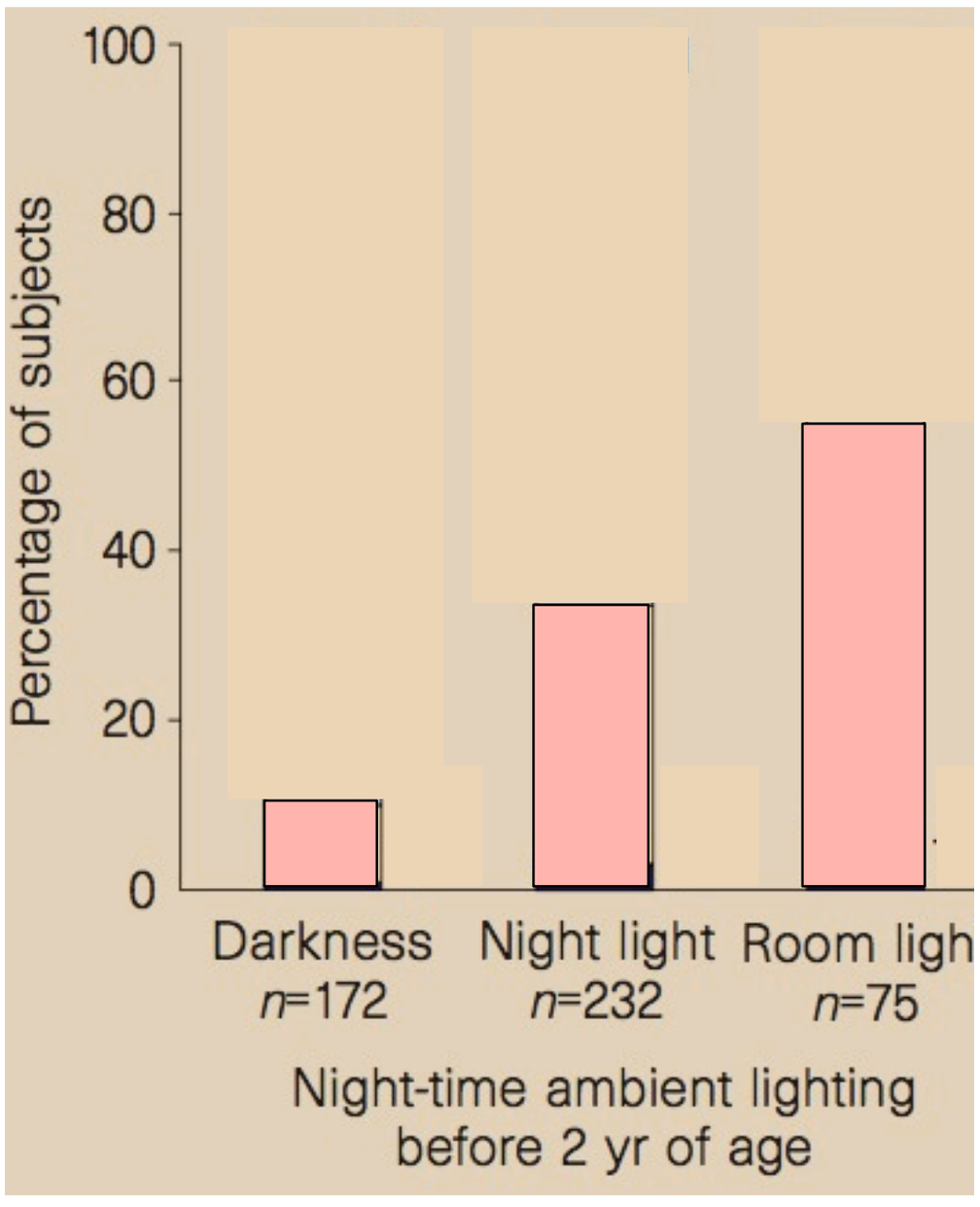
Subtlety: H_2O vs. CO_2?

Be cautious, even when there is a credible mechanism....

--- an example: myopia and night-light

Childhood myopia ... strongly correlated with ambient light during sleep in babies' first two years.

Nature, 1999



a credible mechanism:
"it is known that the growth of the eyes in chicks is influenced by day length: the more light an eye experiences, the larger it grows."

Night-light may lead to nearsightedness

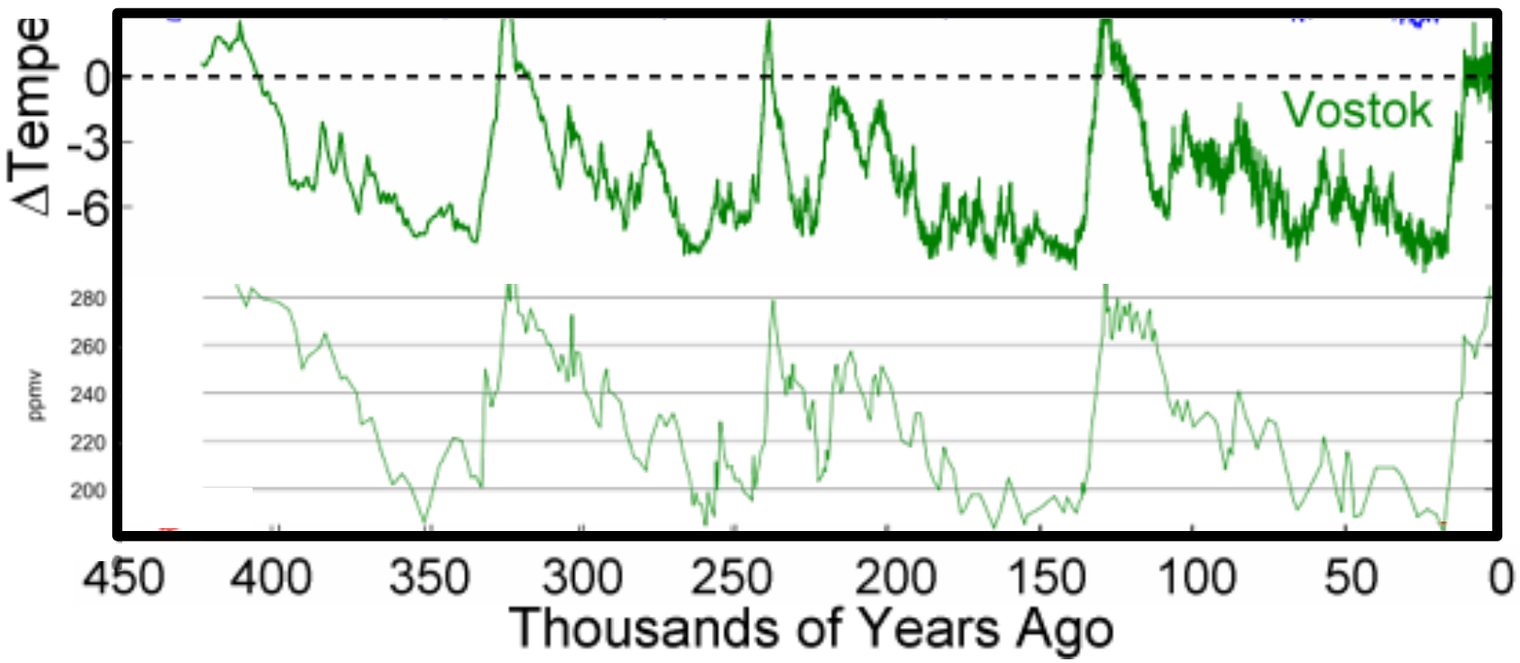
May 13, 1999
Web posted at: 11:38 a.m. EDT (1538 GMT)

(CNN) -- Young children who sleep with a light on may have a substantially higher risk of developing nearsightedness as they get older, says a new study in the journal Nature.

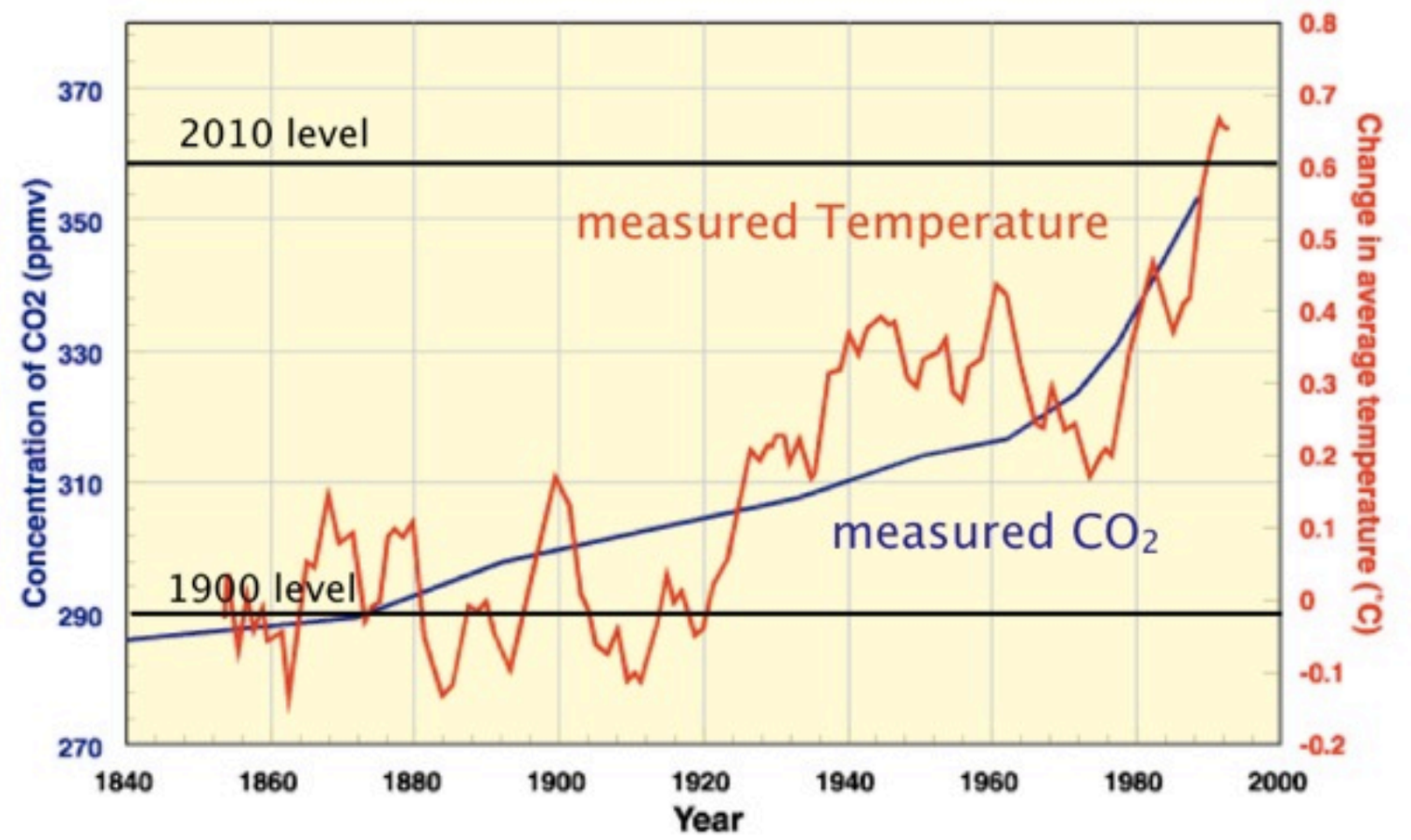
Even scientists may make mistakes.

During the glacial–interglacial cycles, atmospheric CO_2 levels lagged behind temperature swings by a few hundred years.

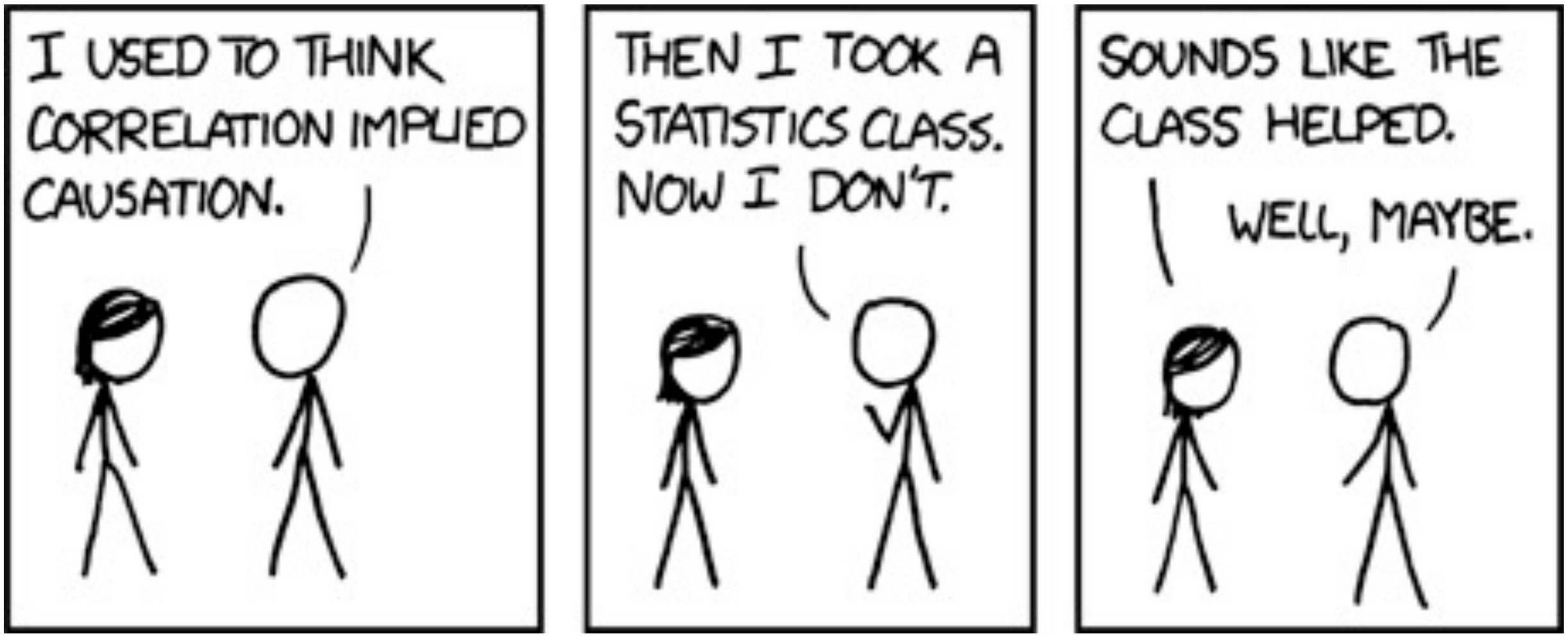
CO_2 did not appear to be the climate driver during these glacial cycles.



What about now?



The peril of Causation



xkcd.com/552

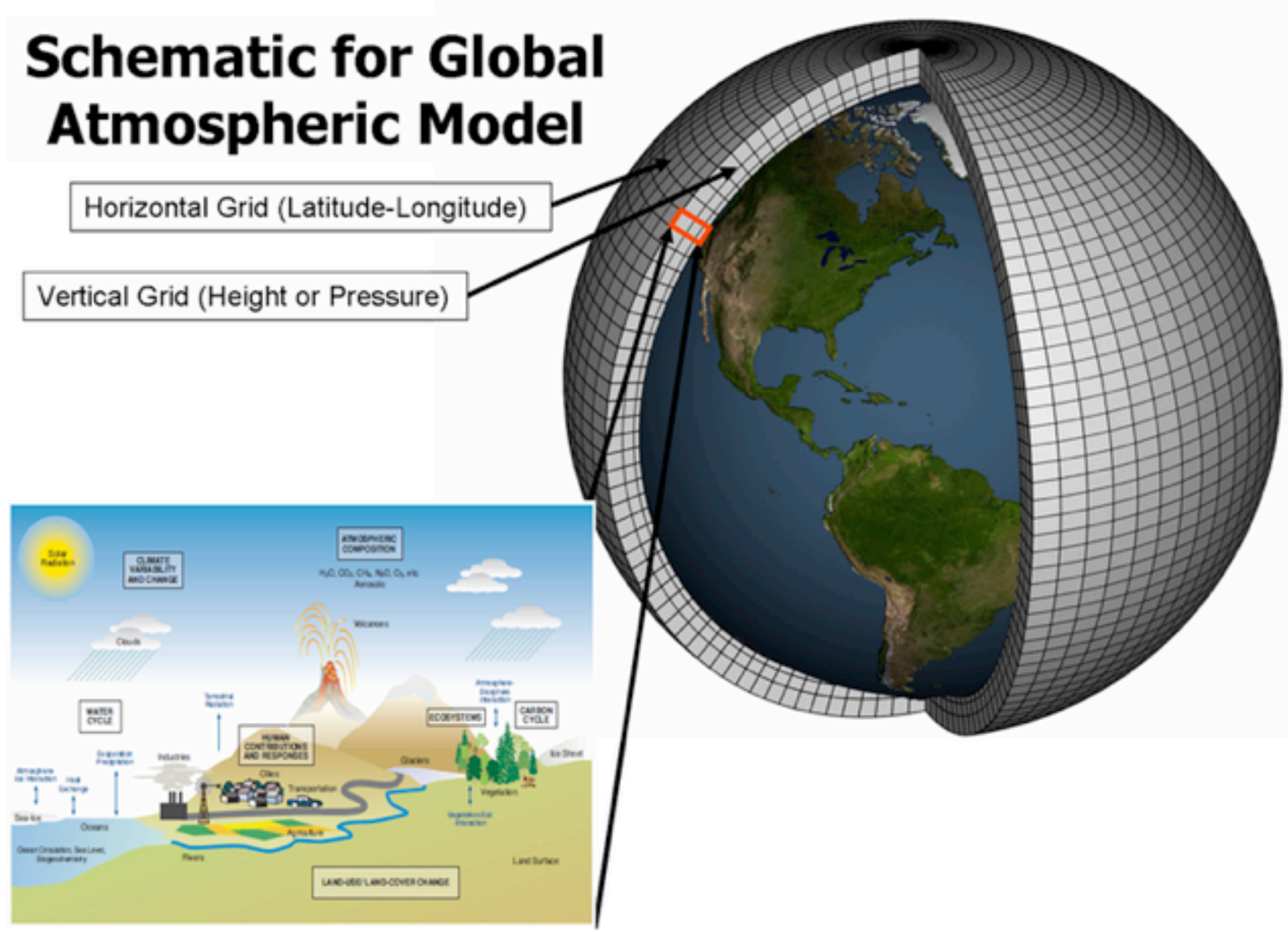
. Observing a correlation is only the first step in establishing a causation.

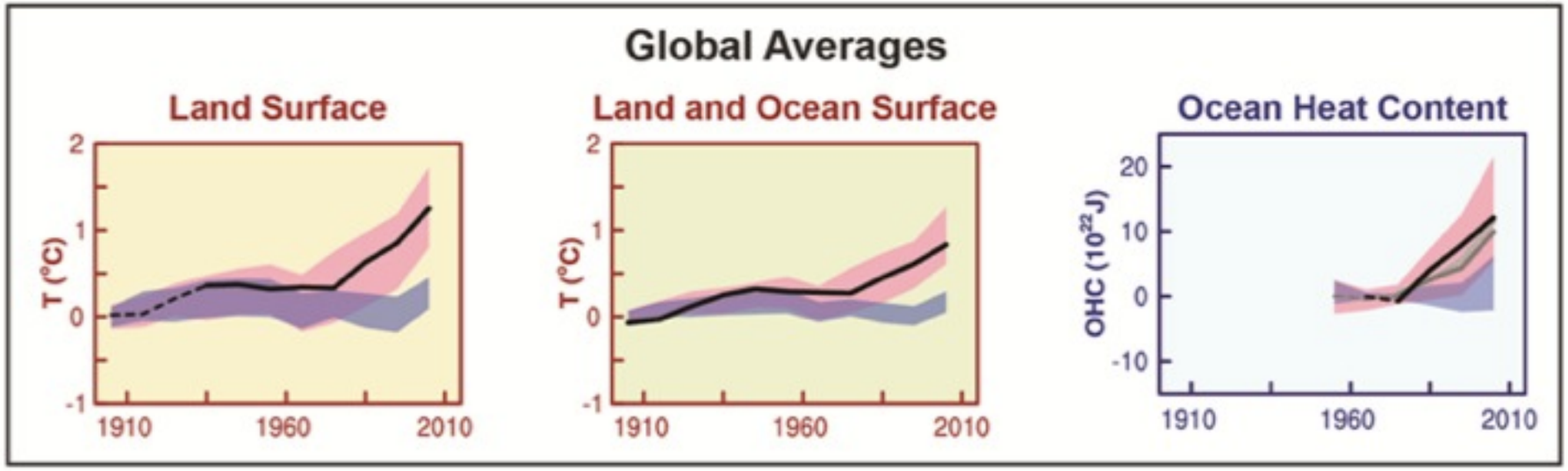
. You also need a credible mechanism.

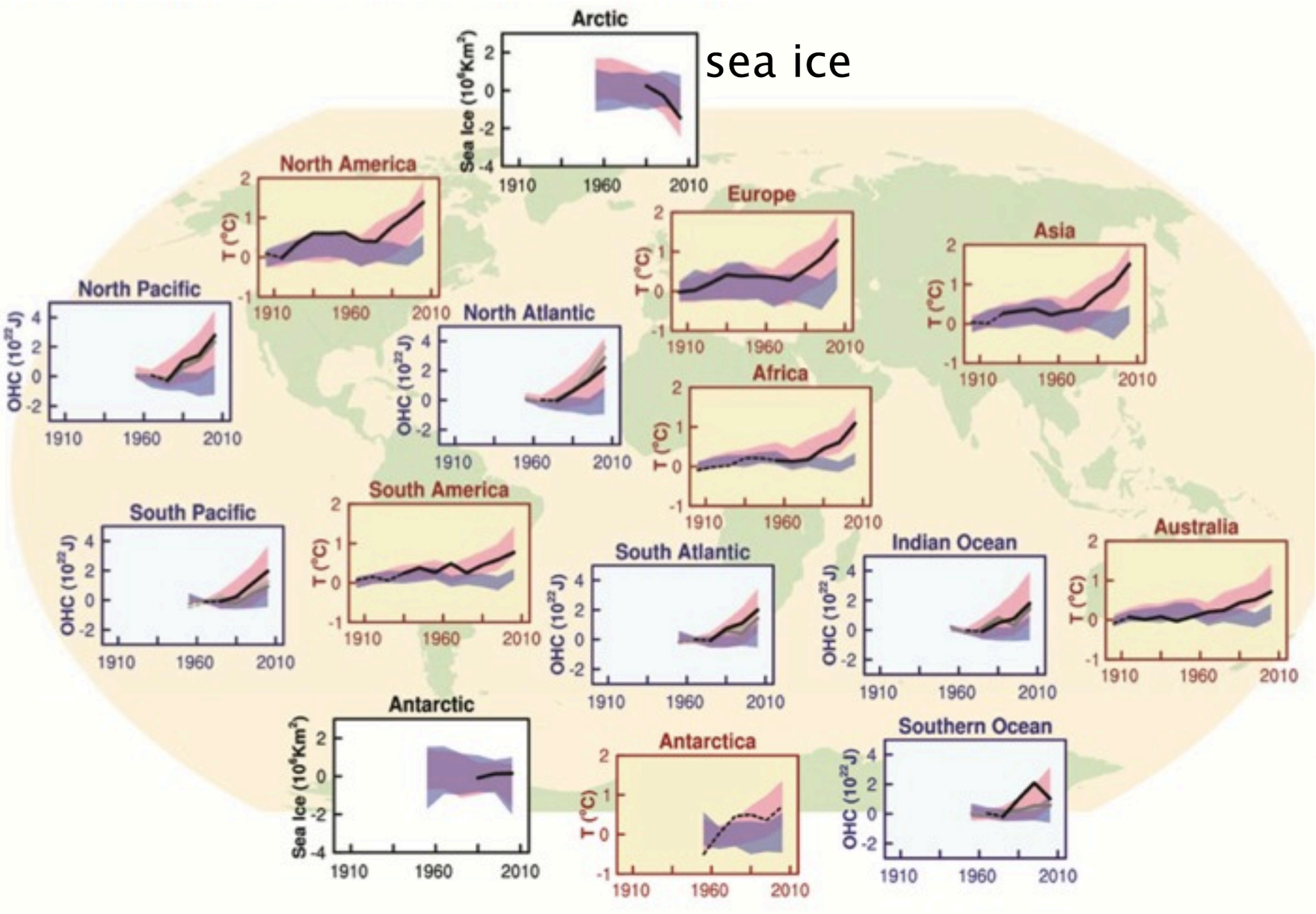
. The mechanism needs to make successful predictions.

General Circulation Model (GCM)

computer simulations of a pixellated Earth; include all known interactions between land, ocean, air,rain, clouds, plants, rock....
-- the greatest video game ever







sea ice

Models reproduce observed data in every continent/ocean.

Counterfactuals: what has not happened

Simulations that include and do not include anthropogenic CO_2 *(counterfactuals)* allow us to distinguish the relative importance of human activities.

This gives credibility to the causal link.

"extremely likely"

IPCC 2013

Is this the end to the climate debate?

If the Earth is enveloped in clouds, will the climate get warmer or cooler?

A) Warmer. Because more heat is retained inside (greenhouse).

B) Cooler. Because more sunlight is reflected out to space.

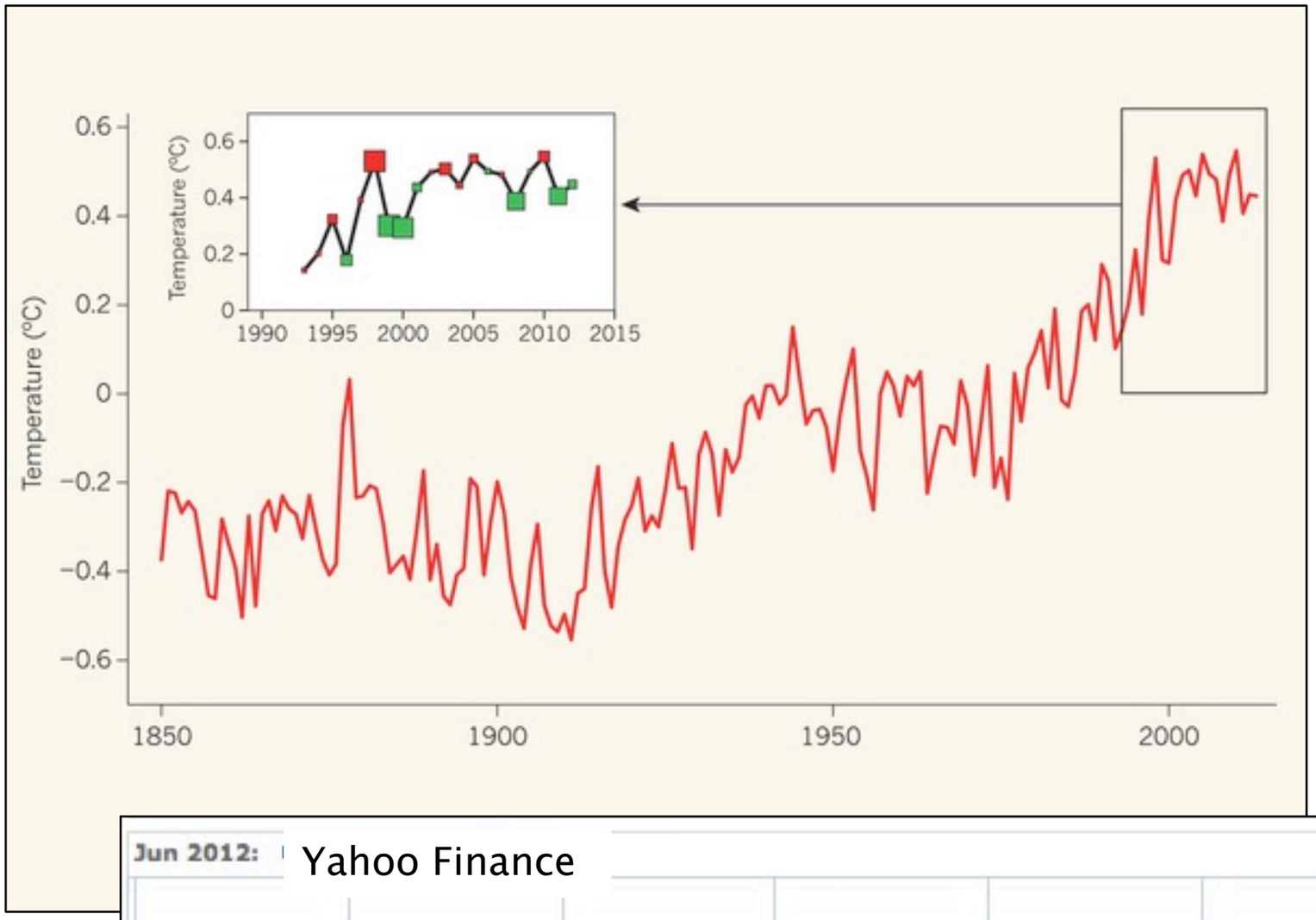
low clouds

high clouds (cirrus)

thick clouds

Model inadequacy: One of the greatest model uncertainties is cloud. No one can yet reliably predict cloud formation

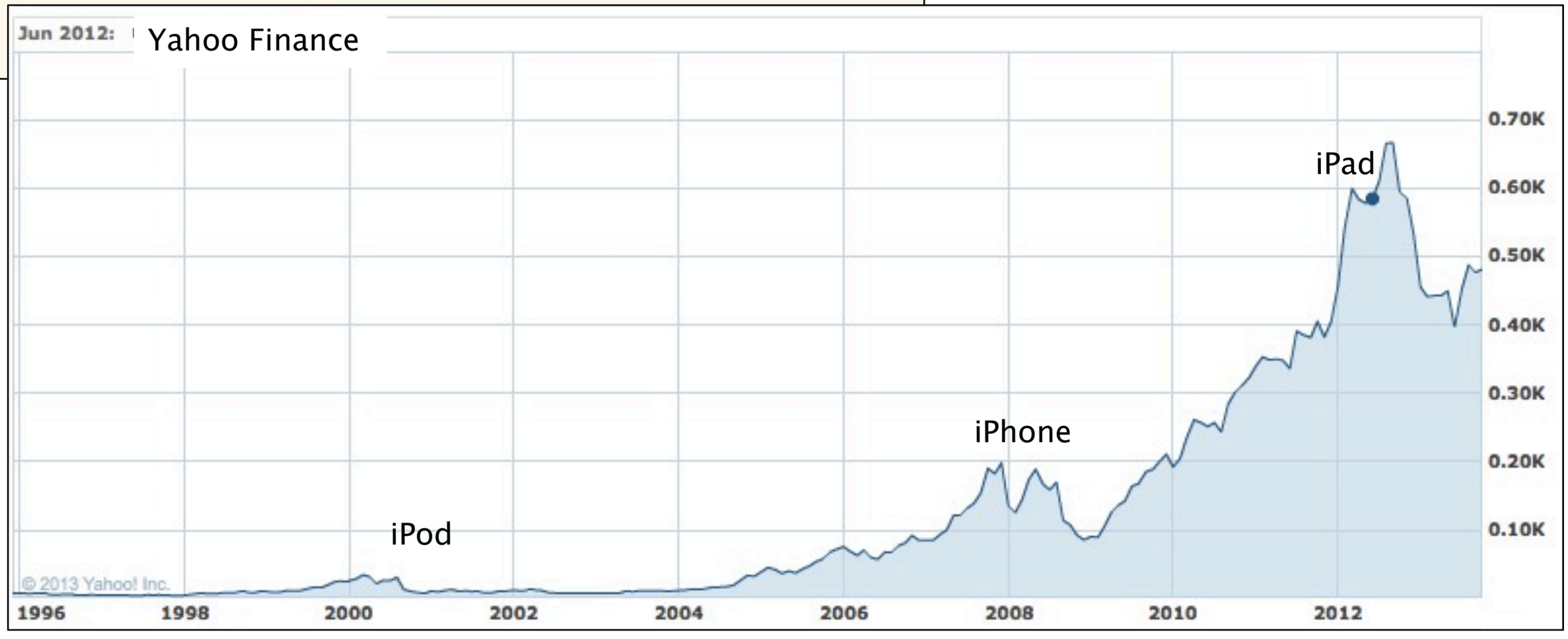
"Both the parameters and the equations contain uncertainties... The choice of which parameter or equation to use is purely arbitrary and left to the judgement of the modellist." www.climatechange101.ca



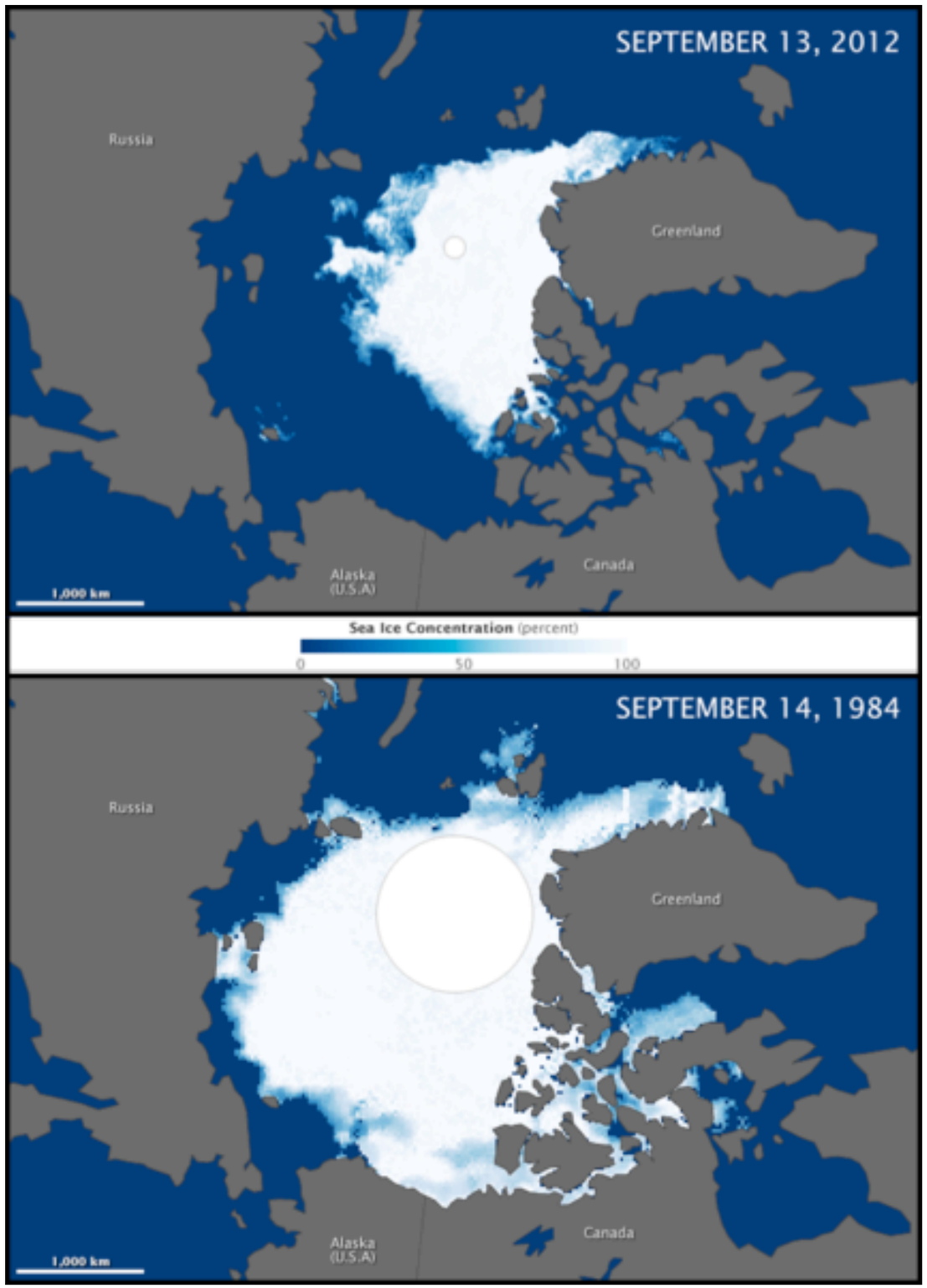
The warming ‘pause’ (1998–2012)....

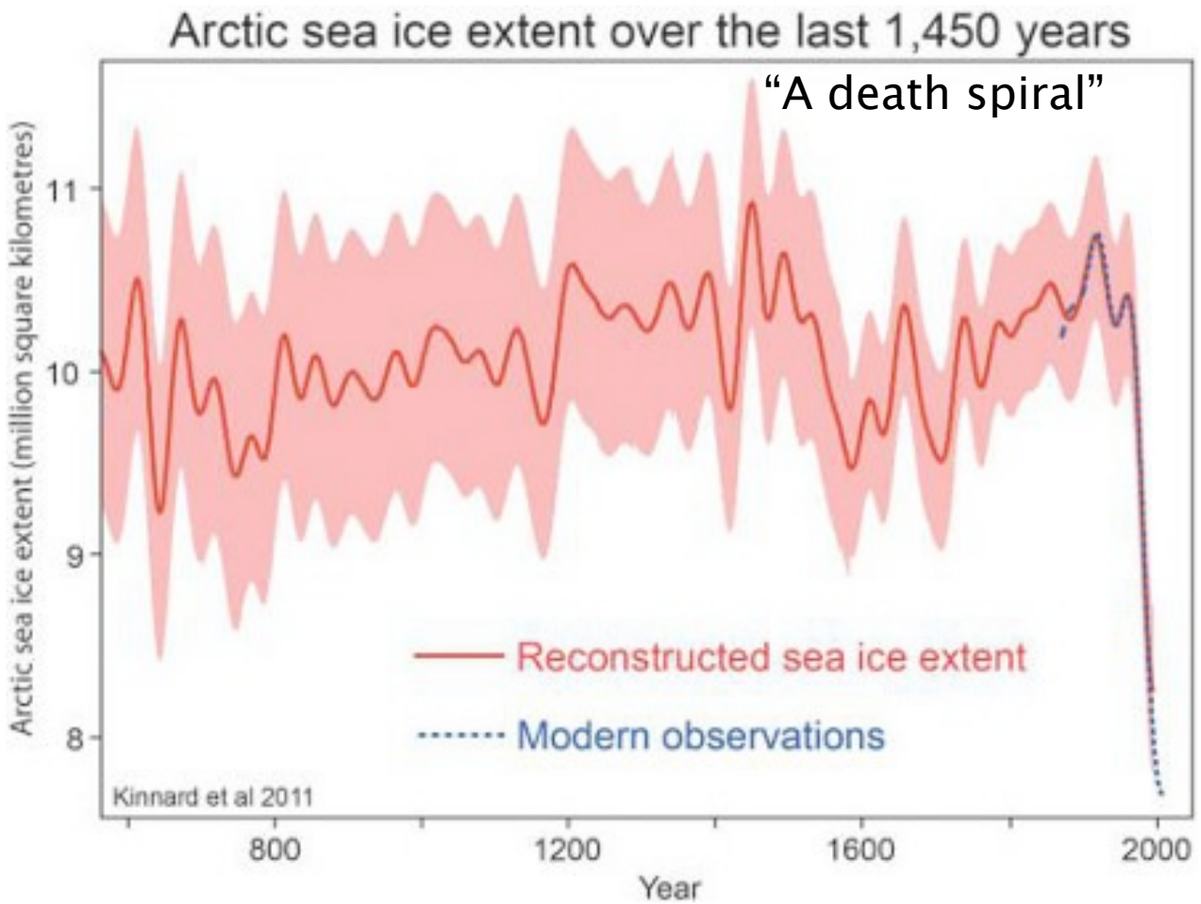
failing of the models?

"Governments are demanding a clear explanation of what are the possible causes of this [pause]." BBC News....



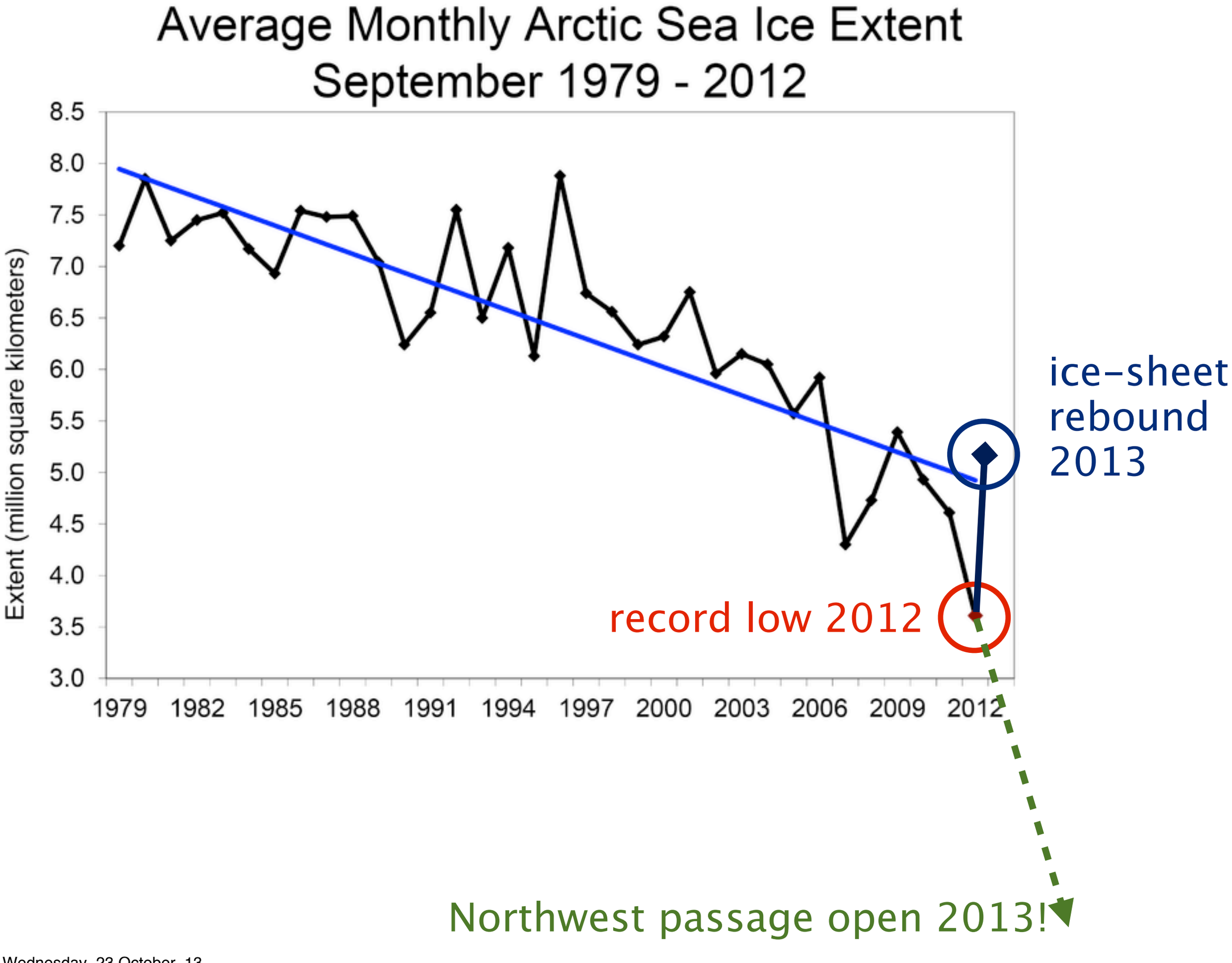
The Arctic sea ice & the opening of the Northwest Passage





http://en.wikipedia.org/wiki/Arctic_shrinkage

Regression back to the Mean

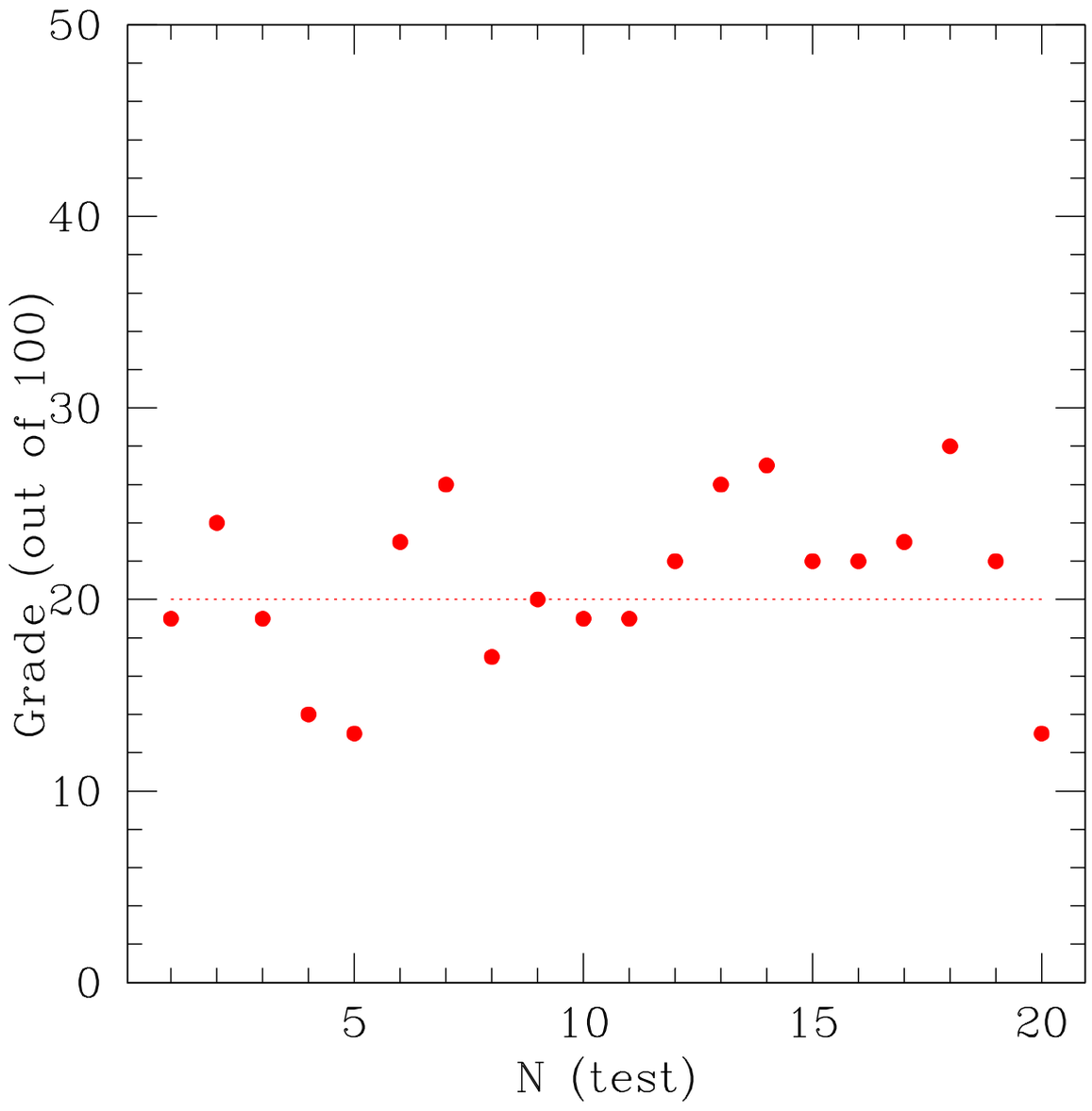


Another example for “regression back to the mean”

Without studying, how well can you do in exams (multiple choice questions)? Can you get lucky?

mean: 20/100 (each question with 5 choices)

lucky this time, unlucky next.



also:
IQ regression,
car accidents,
pilot errors,
lottery ticket,
black-jack...