

Global Warming (I): Earth in Deep History

- *historical perspectives to global warming*
- *is now warmer than the past?*
- *what does 1°C rise matter?*

- *climate as a character*

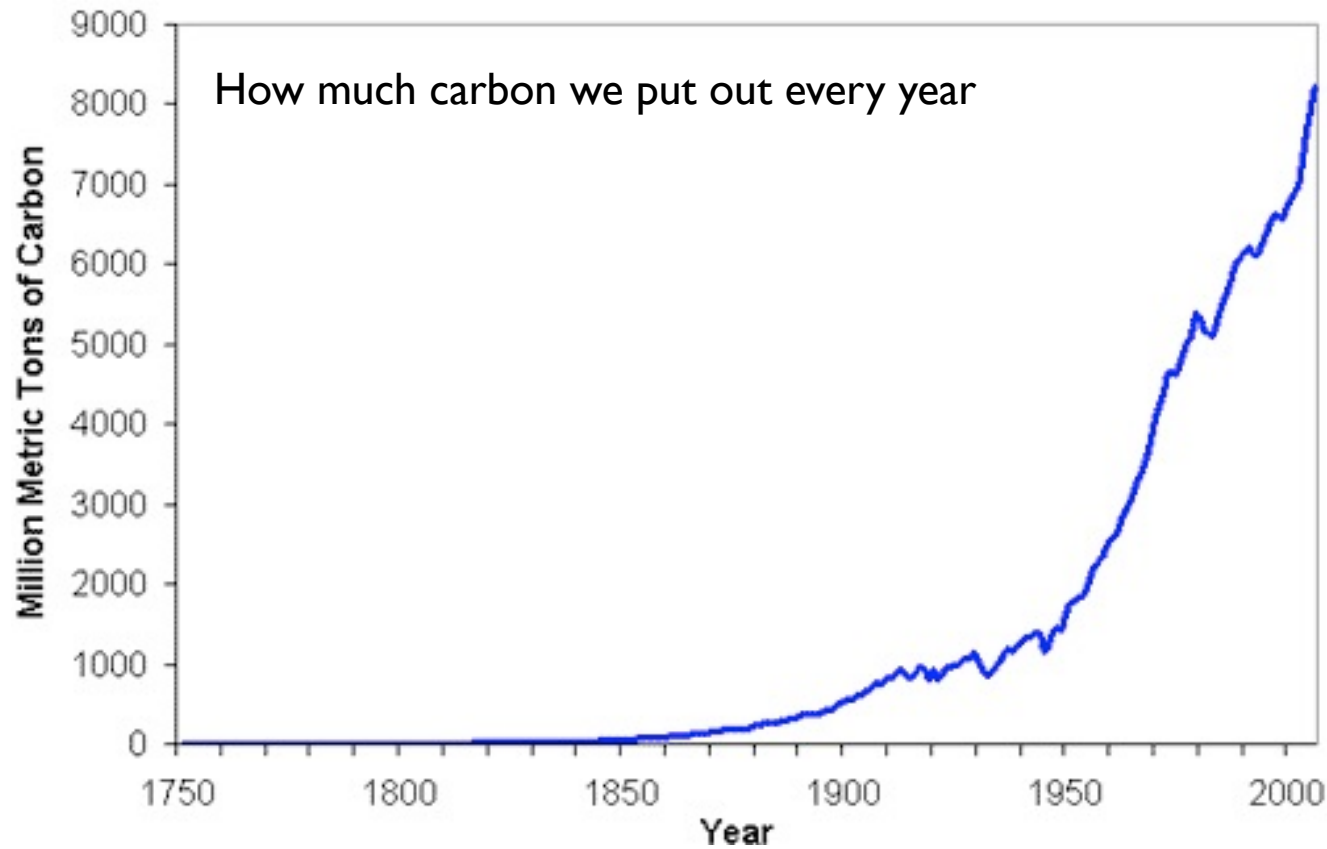


Readings for this and next week:

- 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>)

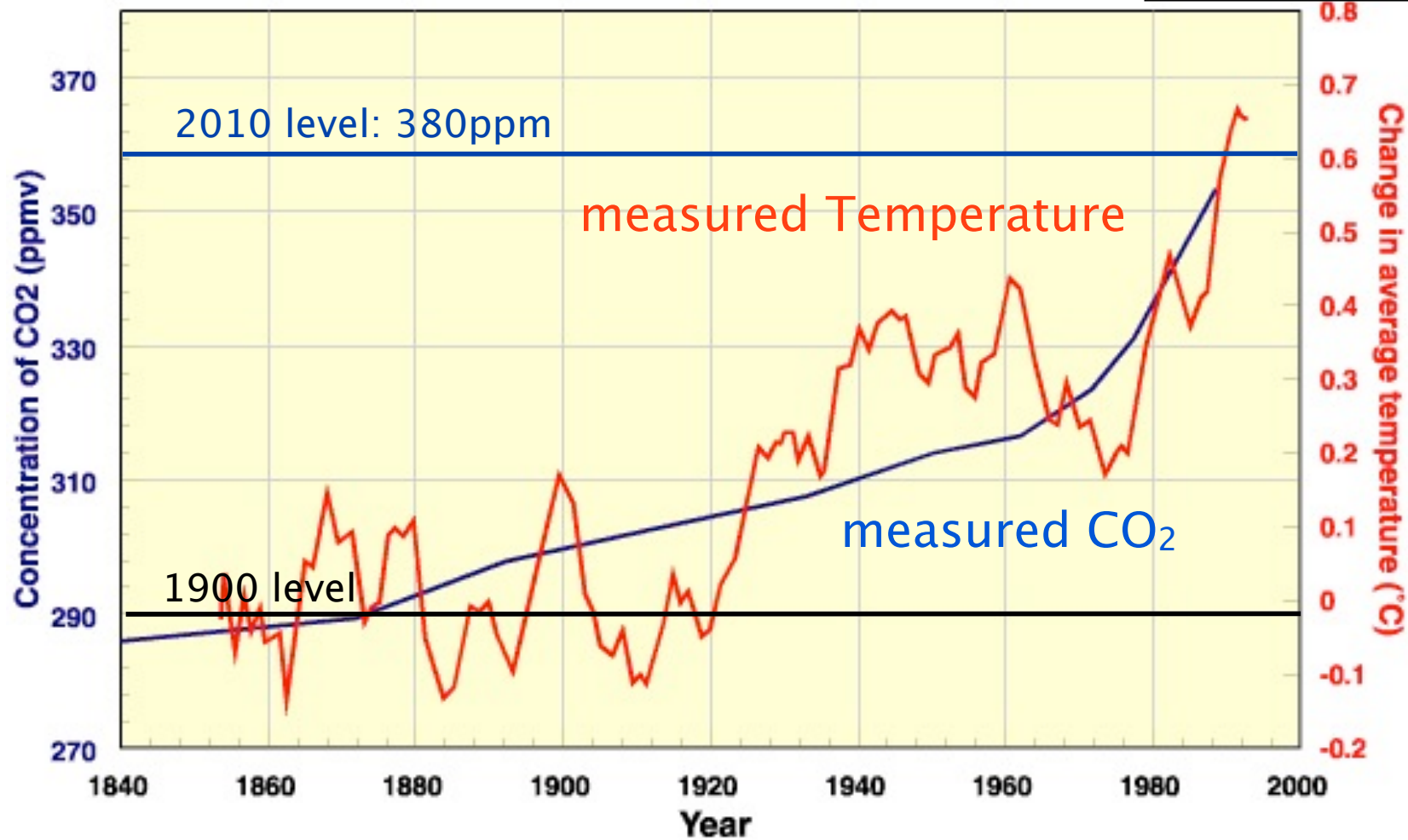
Our CO₂ emission

~ One kilogram of CO₂ for every hour of your fridge



Over the past 100 years, we have observed rises in both global **temperature** and atmospheric **CO₂**

PPM: part per million.
380 ppm = 0.038% .
Air = Nitrogen (78%) + Oxygen (21%) + Water vapor (~0.2%) + CO₂ (0.038%) + ...



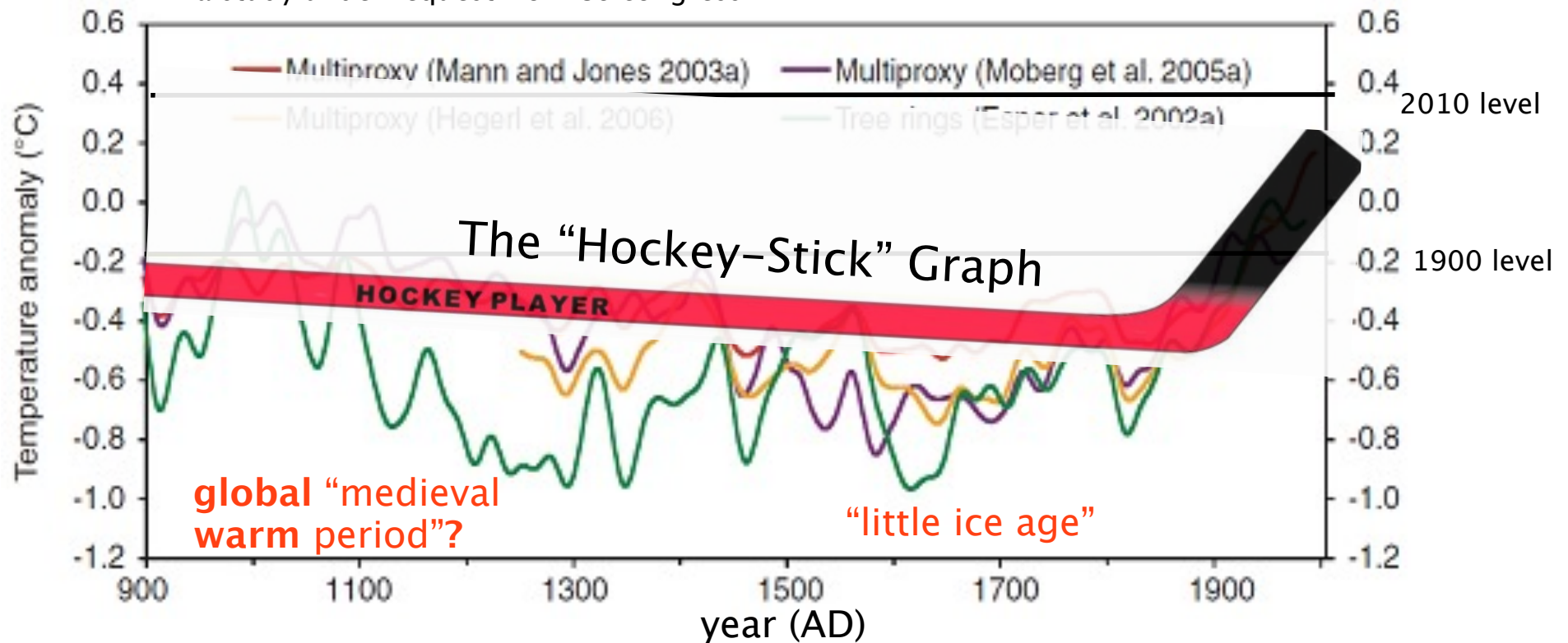
- .2013 Yale survey: 50% american believe warming is man-made
- .Has such warming occurred in the past? if so, what was the damage?

Temperature over the past 1000 years:

first thermometer: 1720
before that: "a can of worms"



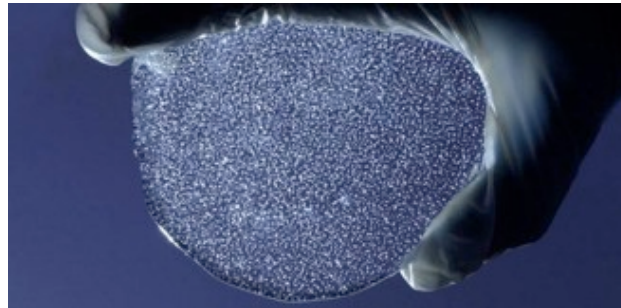
National Academy of Sciences '06;
a study under request from US congress



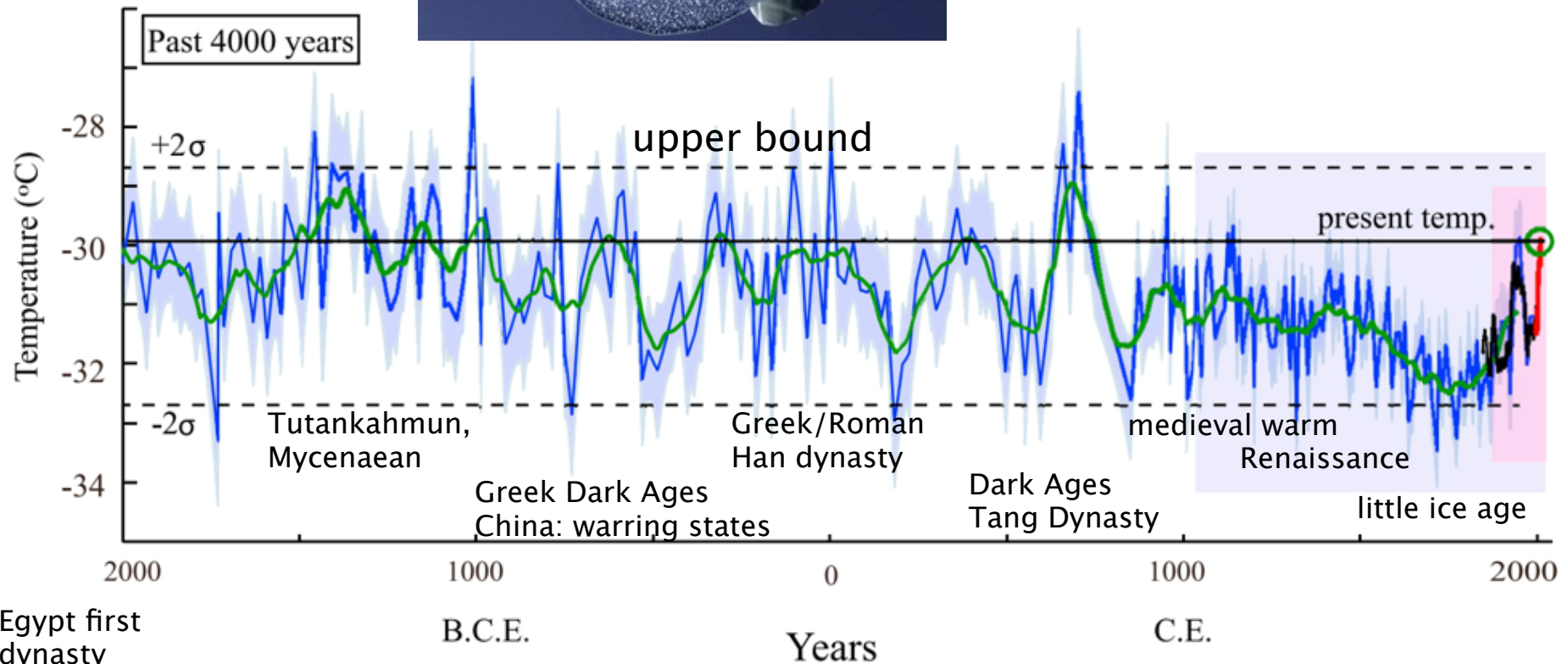
- . Reconstructed using 'proxies': tree rings, ice-cores, boreholes, glacier length records, historical documents. Proxy not precise. Large uncertainties further back in time.
- . Erratic variations $< 1^{\circ}\text{C}$
- . Current warming appears unusual
- . what was the damage? -- tutorial this week

Greenland temperature for the past 4000 years (using trapped bubbles in ice core)

Kobashi et al, GRL, '11

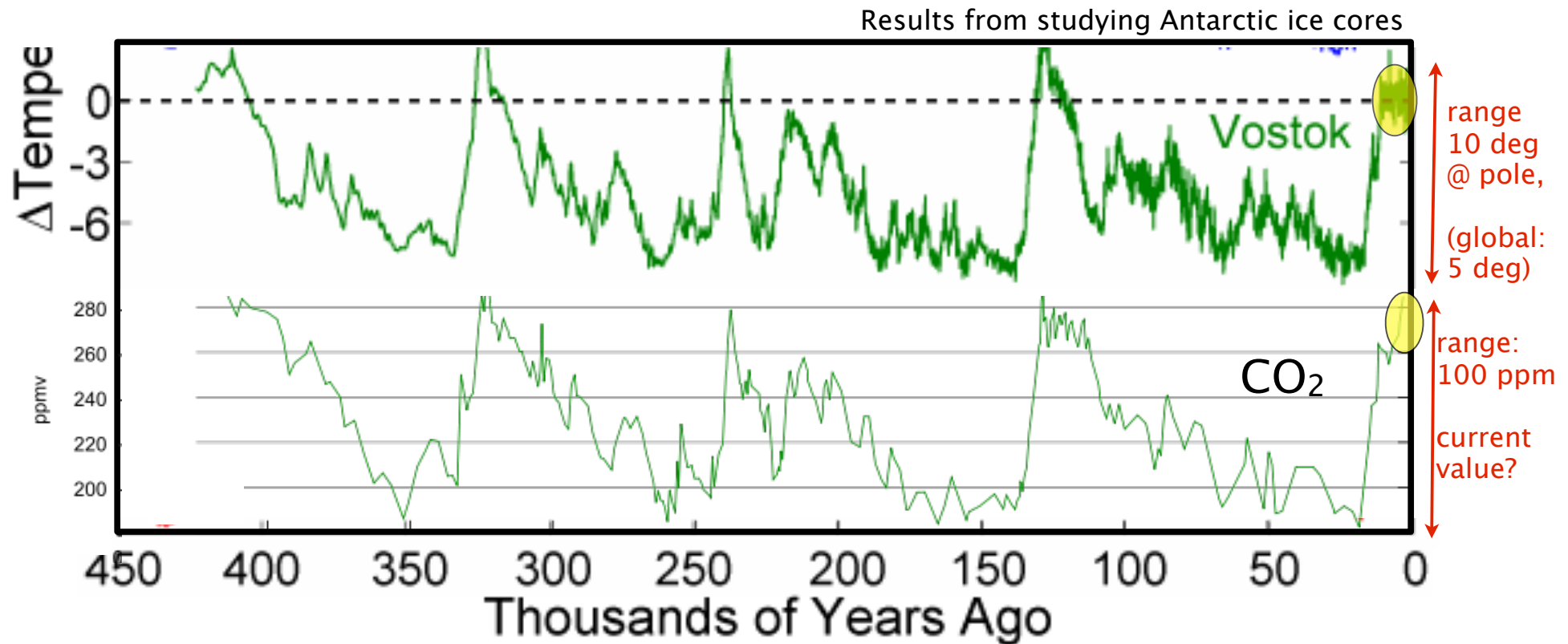


.need further collaborative evidences.
.this is in Greenland, not elsewhere,
not global



.erratic variations, globally $\sim 1^\circ\text{C}$
.What are the connections with civilization?

the “ice age” -- variations up to 5°C

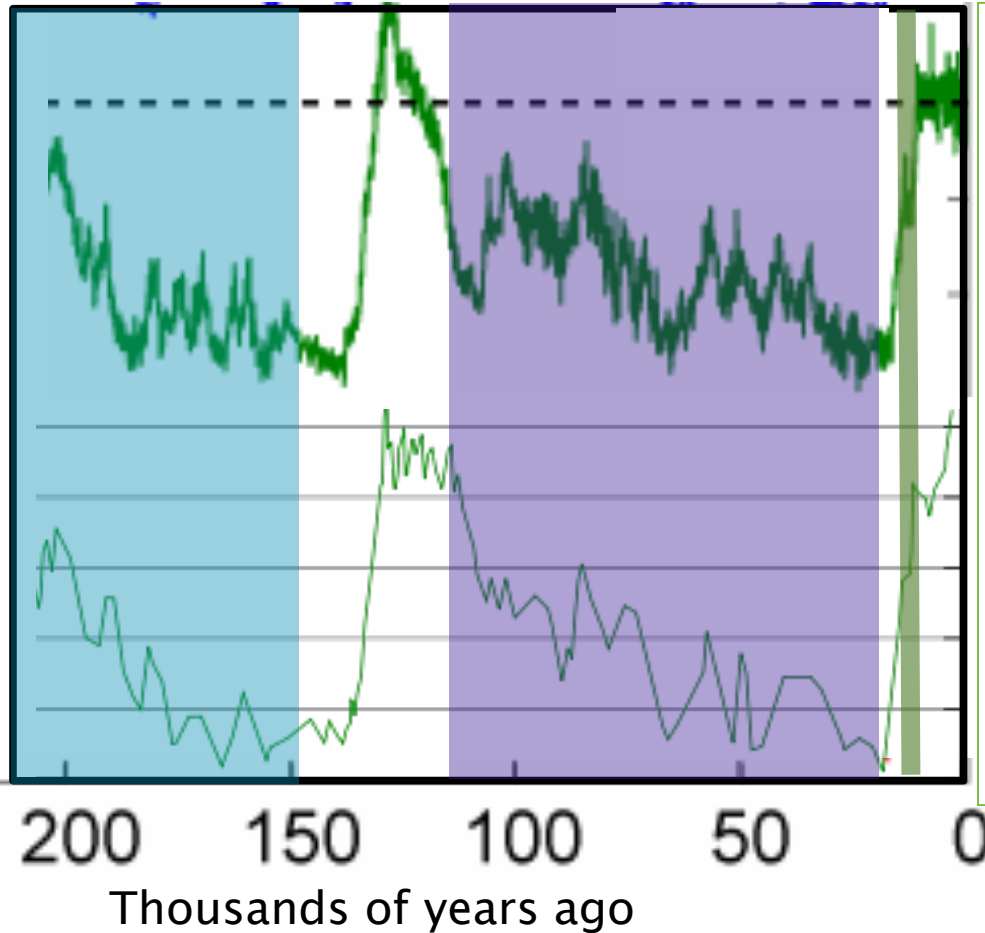


- . further back in time, even greater temperature swings
- . periodic swings, repeat ~ every 100,000 yrs
- . atmospheric CO₂ uncannily follows
 - long lasting ice ages ('glacial'), low CO₂;
 - short warm phases ('interglacial'), high CO₂;
 - Is CO₂ the 'driver' or the 'follower' for these climate changes?
- . **What is going on?**

You are standing at a glacial spot

- . up till 14,000 years ago, HERE is covered by ice sheets 3–4 km thick.
- . The Great Lakes -- big scratches by glacier; Ontario/Quebec hydro-electricity
- . North of Toronto, the 'Canadian Shields', soil scrubbed by glacials -- the 'cottage country'

Modern human matured during the last ice-age.
Modern civilization within the warm period.



Ice-age and Man-kind

. ~200,000 yrs ago, anatomically modern human appeared in E. Africa

. mega-droughts during last glacial period (cold = dry), near extinction, migration out of Africa, 70,000 yrs ago migration to N. America, 15,000 yrs ago

. 13,000 yrs ago, rapid transition to wet and warm interglacial, invention of agriculture. Prosperity.

We are now in the warm phase, high CO₂.

BIG idea?

BIG HISTORY



Woolly mammoth, ice age, Cave Rouffignac, France

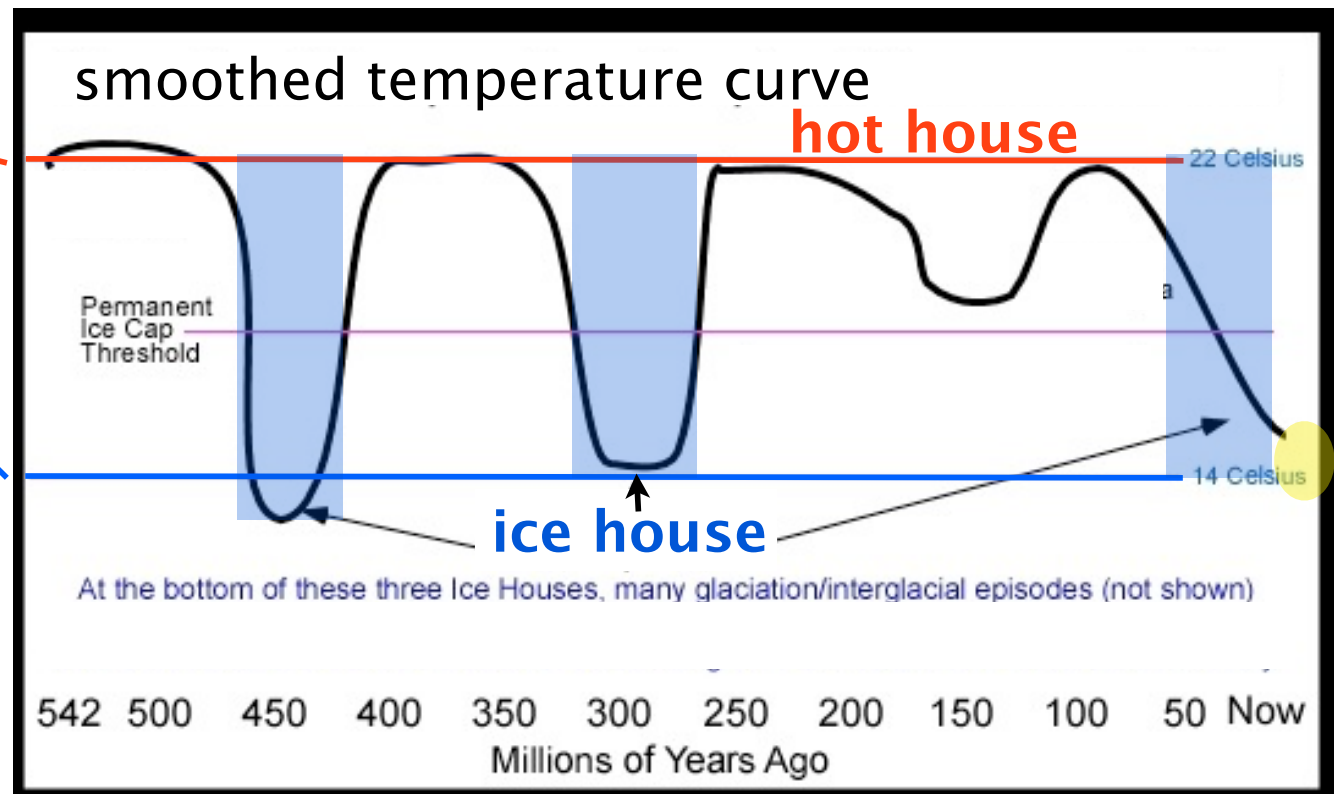
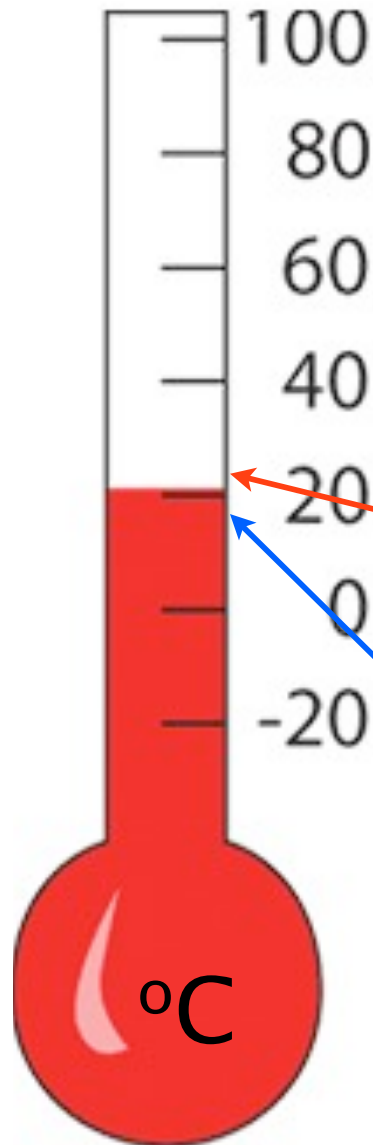
Going further back in time, are temperature swings getting larger?

We are currently in an 'ice house'

- now in interglacial, annual average $\sim 14^{\circ}\text{C}$,
- but **cooler than most other times** in Earth history
- geological average $\sim 18^{\circ}\text{C}$, hot and humid
(no permanent ice-cap; summers difficult for human)

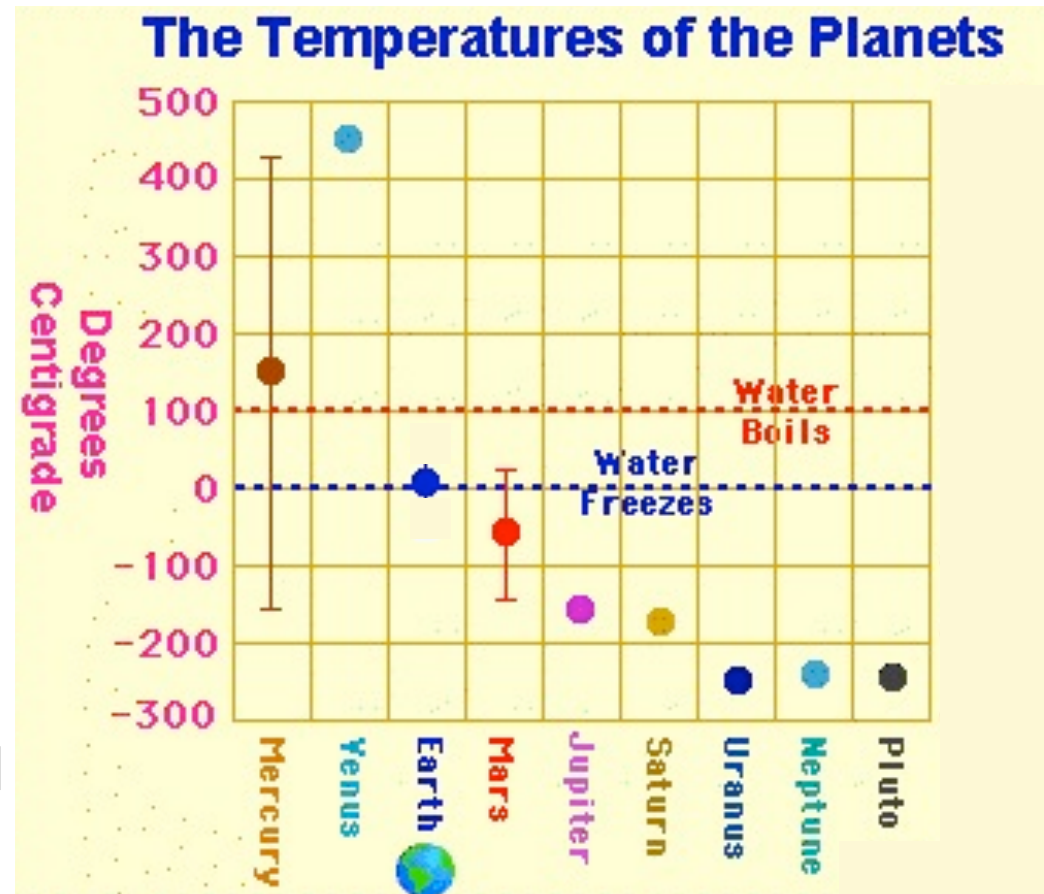
Global temperature on Earth is relatively **stable**.

- between ice houses and hot houses, difference $< 10^{\circ}\text{C}$



Who is keeping guard?

- The amount of heat received from the Sun largely sets the mean temperature of a planet.
- The Earth is in the so-called 'Goldilocks' zone.
- However, there could be wild swings and large deviations.
- On Earth, there is a planetary thermostat acting to stabilize climate, making Earth habitable.

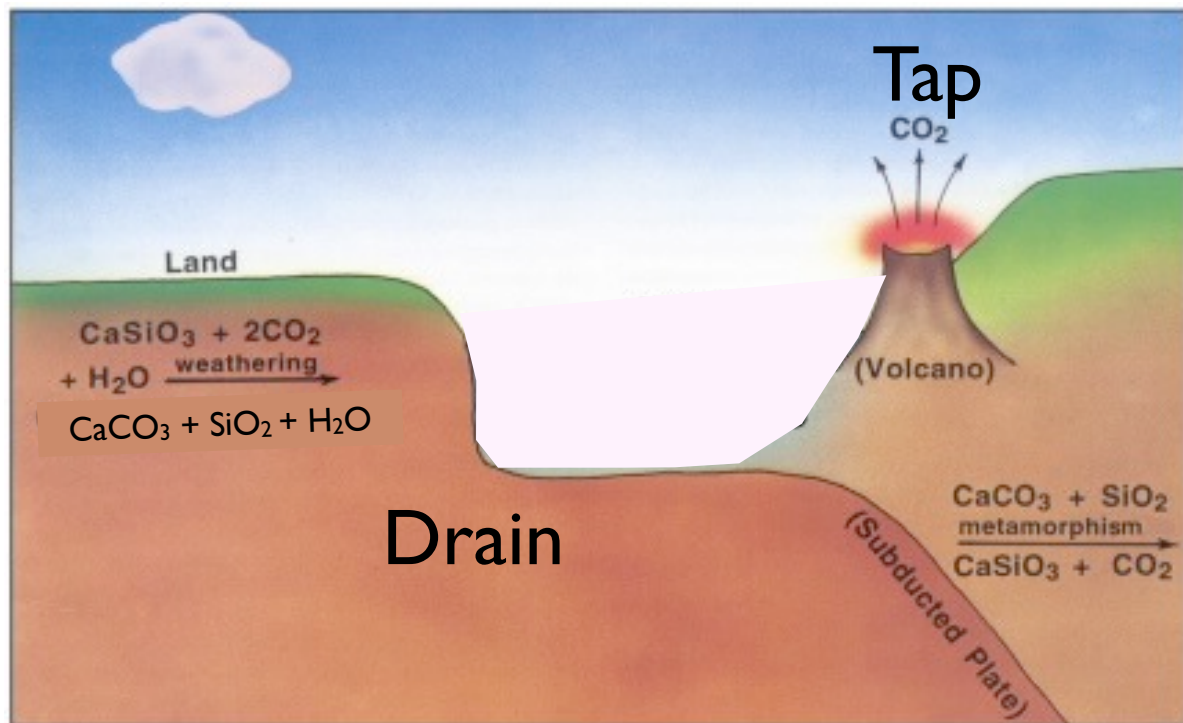
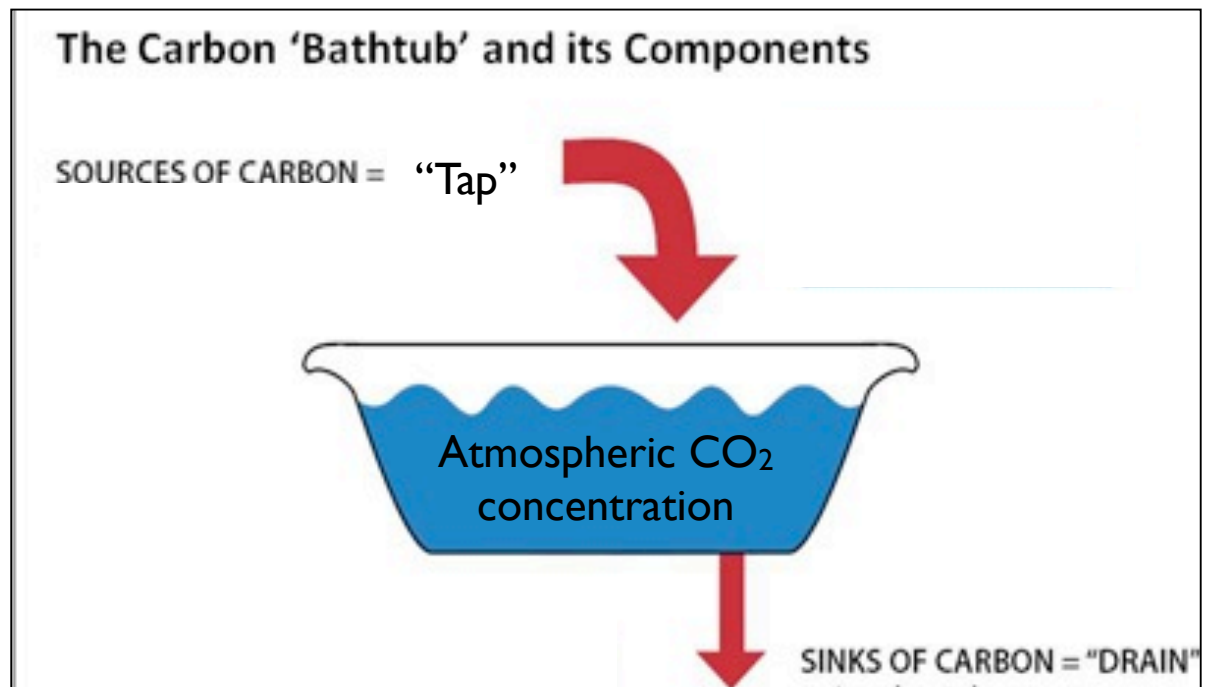


Thermostat: a control that senses and maintains the system's temperature near a desired set-point.

a small deviant can be cancelled out.

To find the thermostat, let's take a look at the atmospheric CO₂.

Carbon on Earth is continuously recycled -- the **Carbon Cycle**



one component of the global carbon cycle

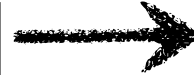
Rock Breathing

Imagine turning up the tap a bit:

more CO₂ in atmosphere



temperature rise



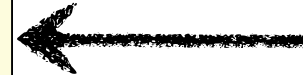
more evaporation of ocean



air humidity rises



water rained out



warm/wet allows more CO₂ to be absorbed into rock -- the drain turned up



temperature drop

~1 million yrs

On a million year timescale, **rock breathing** acts as a thermostat.

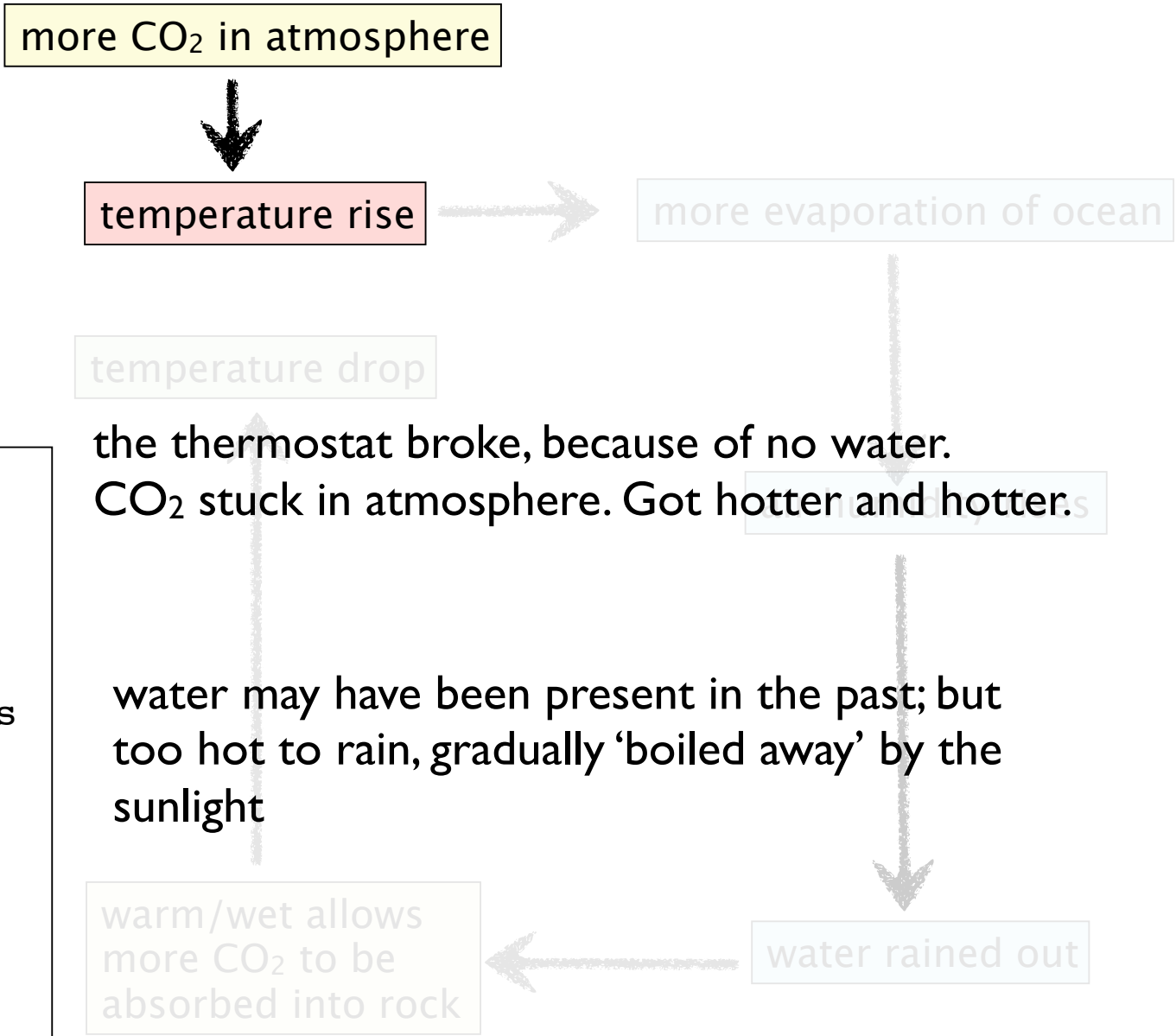
It regulates the atmospheric CO₂ level, and by association, stabilizes Earth's climate, to within a few degrees of the mean (18°C).



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

What is up with that?

Venus ♀
2nd planet from Sun
closer by 30%
roughly same size as Earth
surface Temp. 464°C
atmosphere:
96% CO₂ (92 bar)
0.002% water vapor



Why not Earth? **'Goldilocks Earth'**