Pleistocene Climate

Alan R. Rogers

February 20, 2014

To understand how we measure ancient temperature, you need to know about oxygen isotopes

- There are several types of oxygen atoms, called *isotopes*
- The common isotope ^{16}O has atomic mass 16.
- A rare isotope ^{18}O has atomic mass 18.

But what do these have to do with ancient temperatures?

Oxygen isotopes measure temperature for two separate reasons

1. At any given time, precipitation in cold places has less ^{18}O than that in warm places.
2. In any given place, precipitation has less ^{18}O when the earth is cold than when it is warm.

- The isotopes in *you* reflect those in the water you drink.
- We can measure oxygen isotope ratios in ancient fossils or ancient sediment.
- The colder it was, the lower the ratio of ^{18}O to ^{16}O.

To understand these facts, we need to think about clouds and rain.

Clouds, rain, and oxygen isotopes

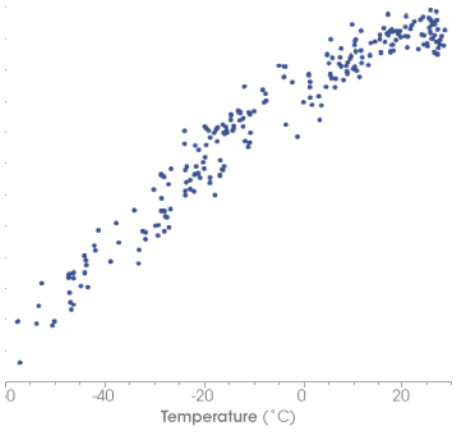
- Each water molecule has a single oxygen atom.
- Water molecules with ^{16}O evaporate more easily.
- In clouds, water molecules with ^{18}O condense more easily into rain.

Bottom line: Water with ^{18}O evaporates more slowly but condenses faster.

Why $^{18}O/^{16}O$ is lower in cold climates at any given time

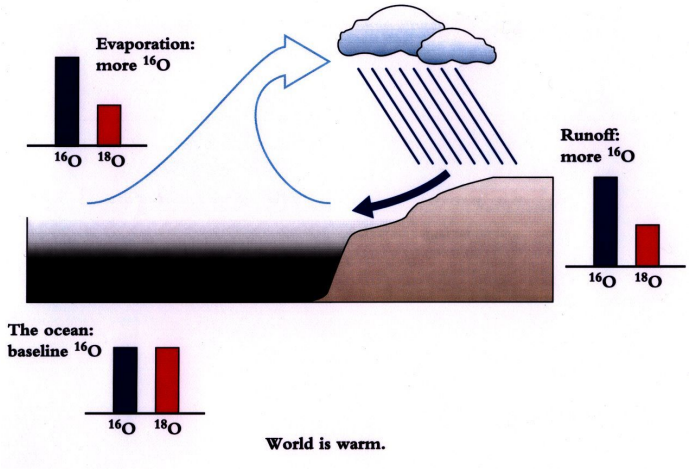
- Most clouds form in the tropics, then travel toward the poles.
- Along the way, they lose water as rain.
- Water molecules with ^{18}O rain out faster than those with ^{16}O.
- Rain (or snow) that falls in cold climates has less ^{18}O.

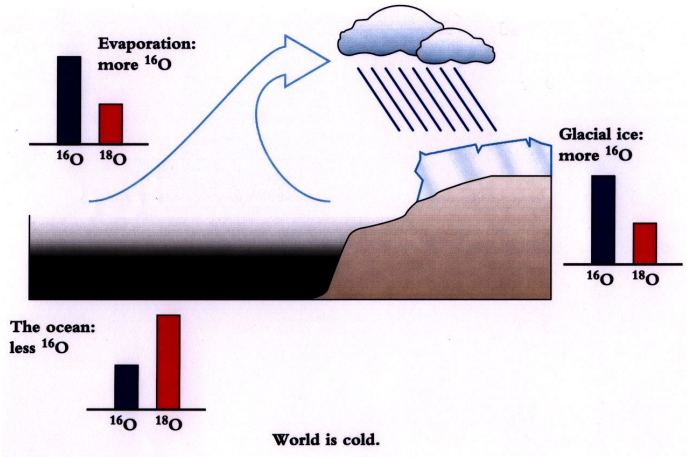
Rain that falls in warm places has more ^{18}O relative to ^{16}O.



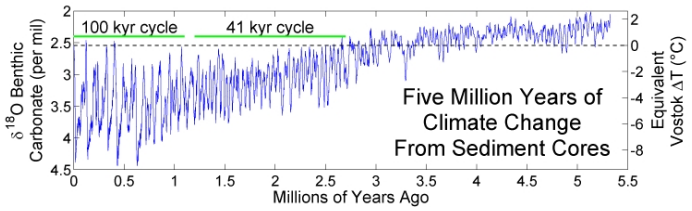
Ancient temperature and oxygen isotopes

- Water with ^{16}O evaporates faster than that with ^{18}O.
- If atmosphere is warm, the water flows back into the ocean, so nothing changes.
- If atmosphere is cold, the water gets trapped as ice.
- Less and less ^{16}O in ocean.
- Less and less ^{16}O in ice deposited on land.

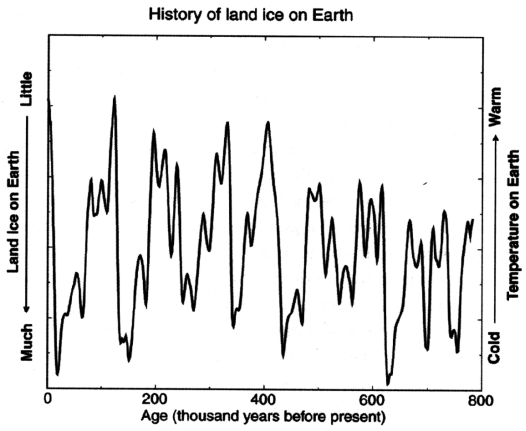




Global temperature during past 5 Myr

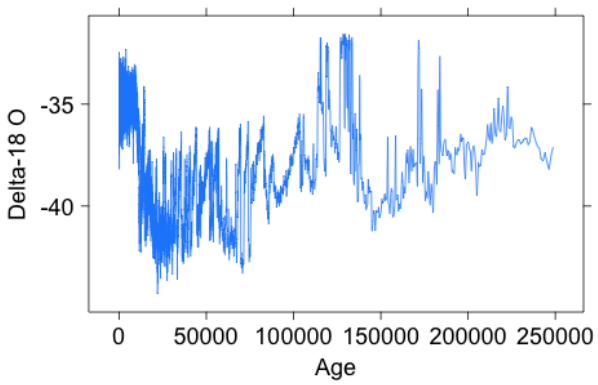


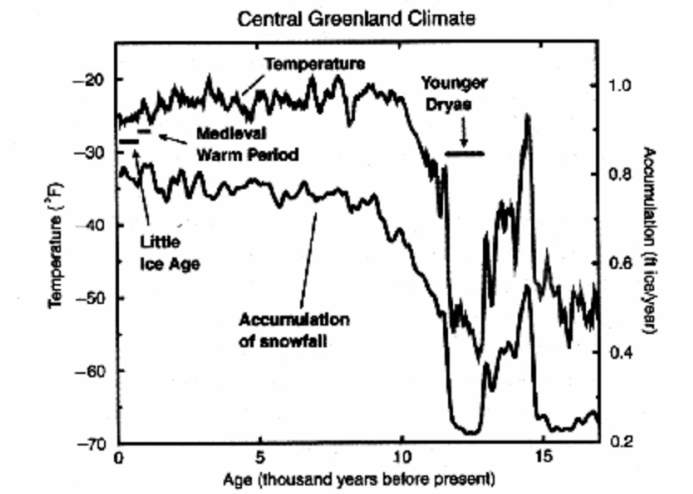
Global temperature during past 800,000 y



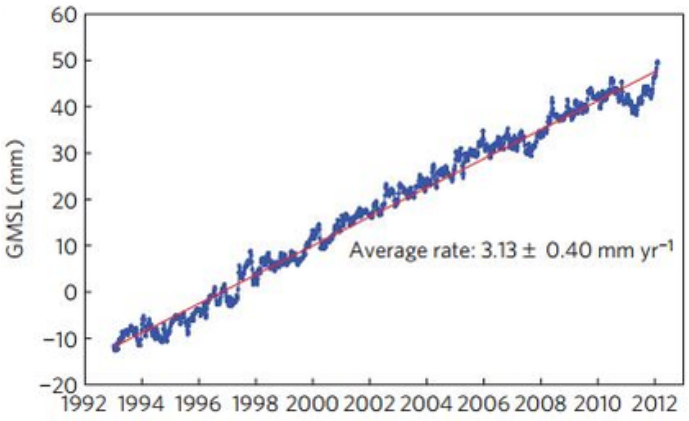
Major cold periods roughly 100ky apart.

Greenland temperature over past 250,000 y

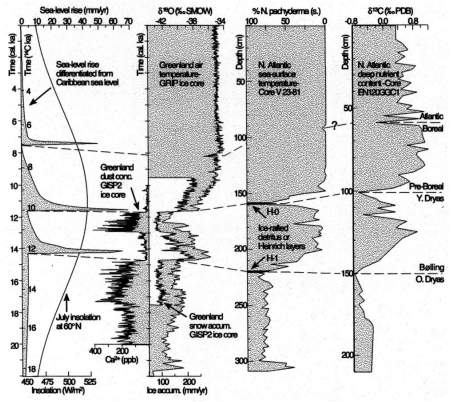




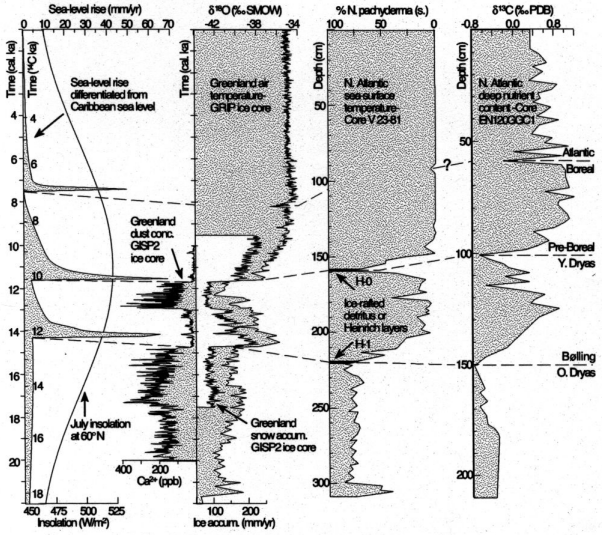
Sea level rises as polar ice melts



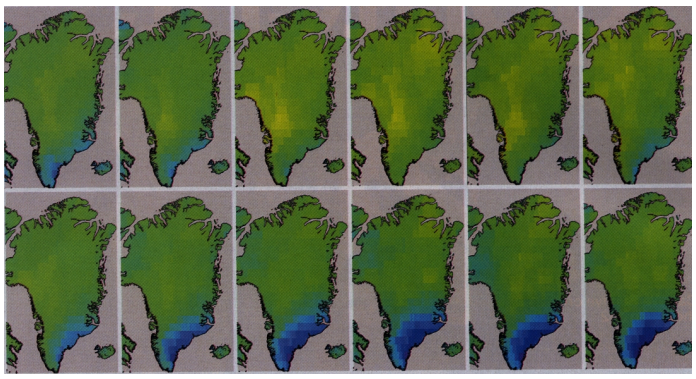
Changes in sea level can be sudden and catastrophic

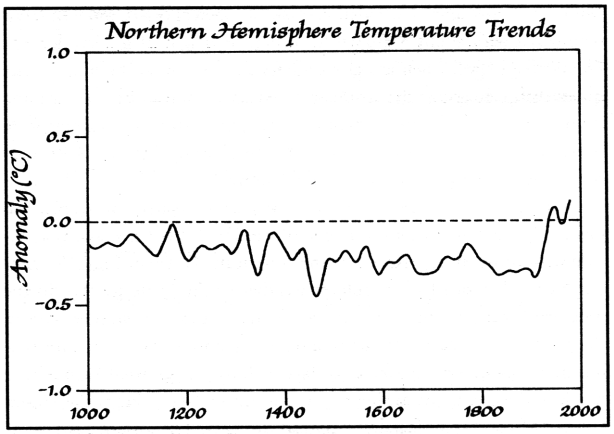


1. warming caused sudden collapse of ice sheets at 14.2, 11.5, & 7.6 kyr
2. huge fleets of icebergs
3. sea level ↑ by 44, 25, & 21 feet
4. duration: $<$ 290, 160, & 140 yrs



Greenland lost 38 cubic miles of ice during 2005





Northern Hemisphere temperature trends based on ice-core and tree-ring records, also instrument readings after c. 1750. This is a generalized compilation obtained from several statistically derived curves.

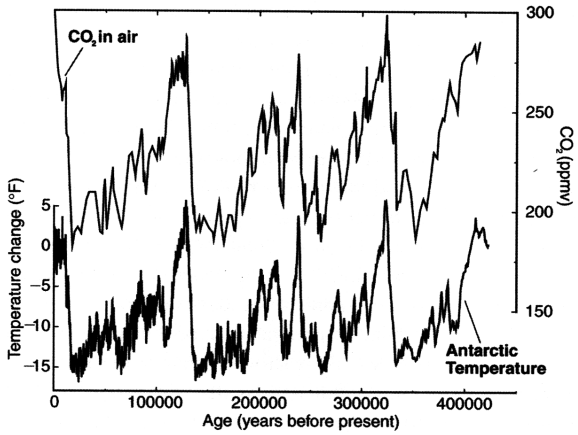


FIGURE 11.1
The ice-isotopic history of temperature in central East Antarctica at Vostok, and the history of CO_2 from air bubbles in the Vostok core,

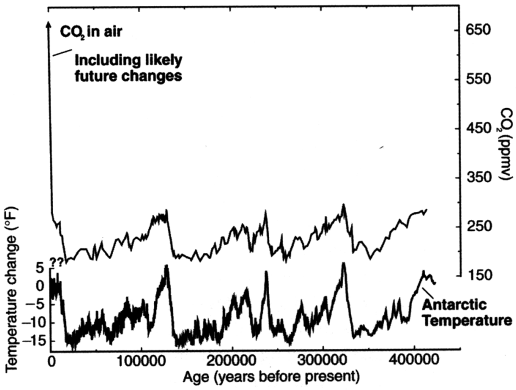
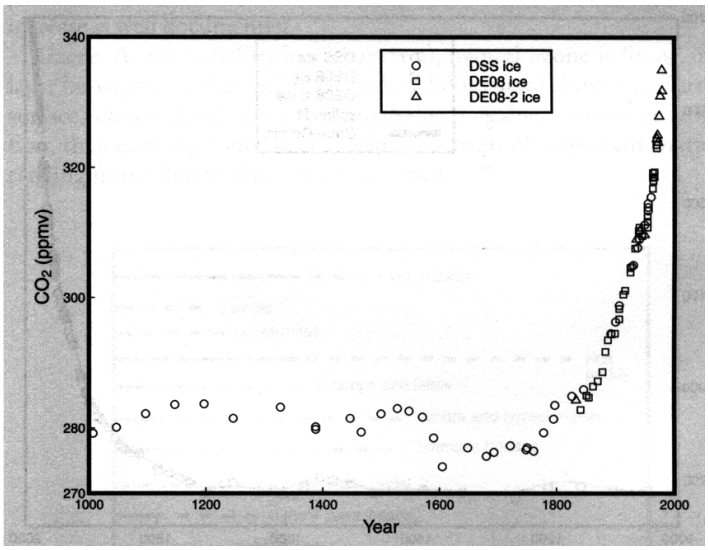
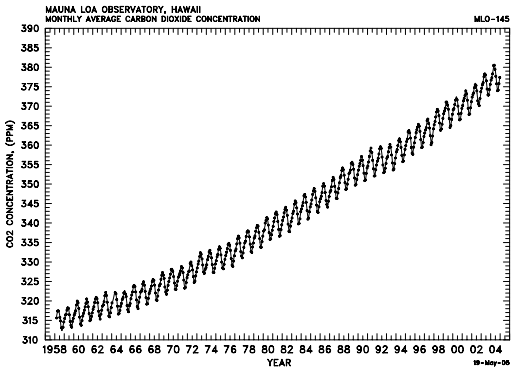
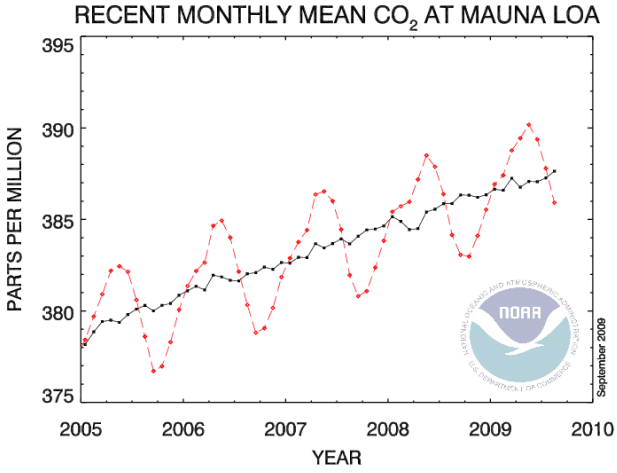


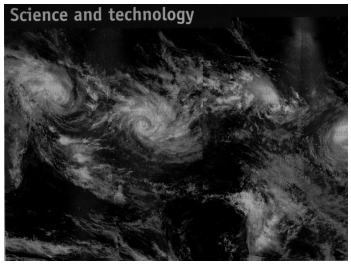
FIGURE 11.2
The history of temperature and CO_2 from Vostok, as in the previous figure, but with the scale changed to show what humans are likely to do to CO_2 within the next centuries. The question marks for future temperature pose some interesting questions for us.





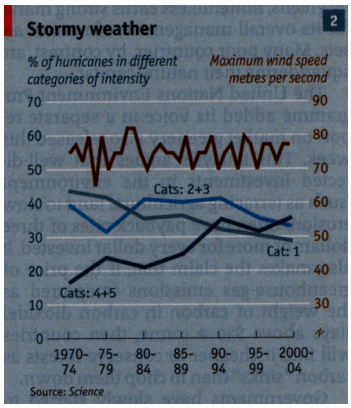


Hurricanes



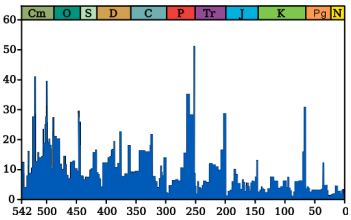
- Only in tropics, where water is warm.
- Speed up when passing over warm water.

Webster et al. (2005) Changes in tropical cyclone number, duration, and intensity in a warming environment



- In past 30 years, no increase in number of hurricanes
- Big increase in fraction in categories 4 & 5
- This idea still controversial.

Global warming: the worst case scenario



- Numerous mass-extinction events in the earth history.
- Cretaceous/Eocene event caused by comet

Others caused by global warming.

How global warming causes extinctions (Peter Ward. 2007. *Under a Green Sky*)

1. Massive volcanism releases lots of CO2
2. Climate grows warm
3. Shuts down current that carries oxygen to deep ocean
4. Without oxygen, only anaerobic bacteria can live there
5. Anaerobic respiration releases a poison: hydrogen sulfide (rotten egg smell)
6. Hydrogen sulfide rises, killing oceanic life.
7. Invades atmosphere, killing land plants and animals.

Marine extinctions at end of Permian

Group	Genera extinct
Foraminifera	97%
Radiolaria (plankton)	99%
Sea anemones, corals, etc.	96%
Bryozoans	79%
Brachiopods	96%
Bivalves	59%
Snails	98%
Cephalopods	97%
Crinoids	98%
Blastoids	100%
Trilobites	100%
Eurypterids	100%
Ostracods	59%
Acanthodians	100%

- During most recent mass extinction event, peak CO2 level was 800 ppm.
- We are now at nearly 400 ppm.
- But 800 was the *peak* level. The extinction may have started at a much lower level.
- We may be close to the critical level—there is no way to know.

Summary

- The Pleistocene was alternately cold and warm.
- During the cold (glacial) periods, sea level dropped because much of the earth's water was frozen on land.
- We live in a warm (interglacial) period.
- Climate change can be sudden.
- Carbon dioxide traps heat inside the atmosphere and raises the earth's temperature.
- The last hundred years have seen an enormous increase in atmospheric carbon dioxide.
- Hurricanes may be getting stronger: it is hard to tell.
- Global warming may cause mass extinction.