Lecture 12

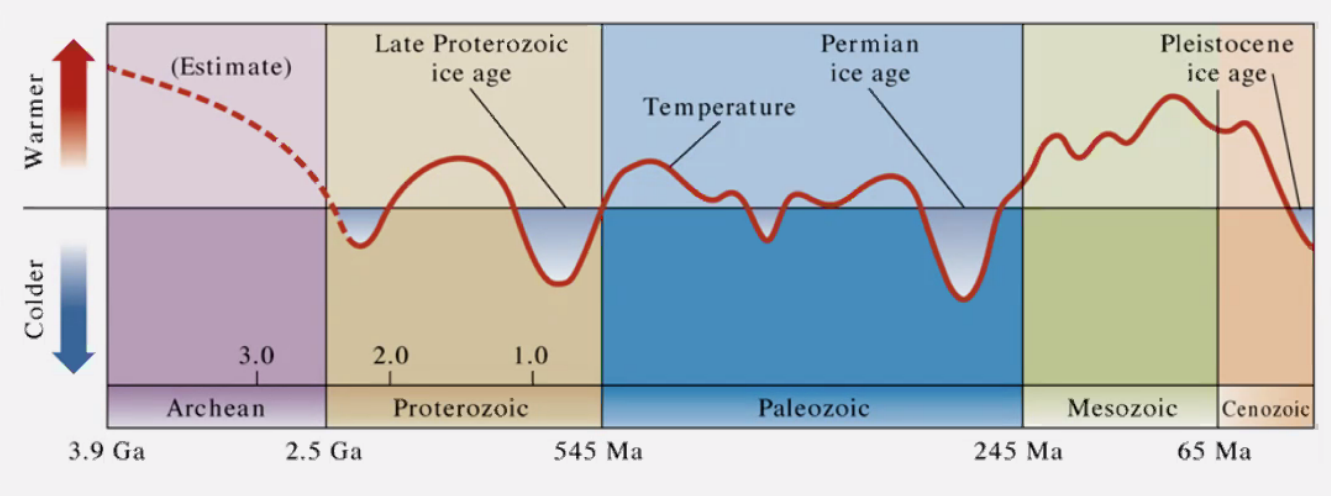
GLY102

3/11/2021

Paleoclimatology & Ice Cores

Review

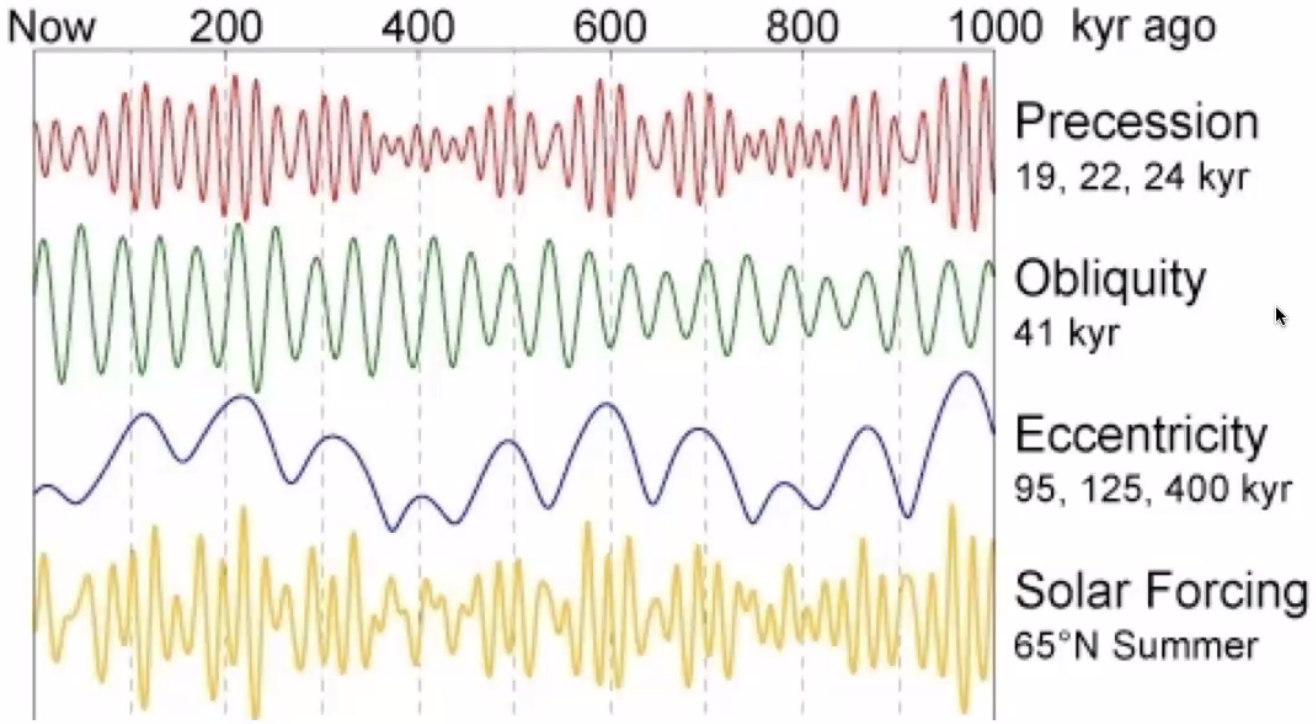
Major Climate Change in Earth History



Two Factors that lead to Ice Ages:

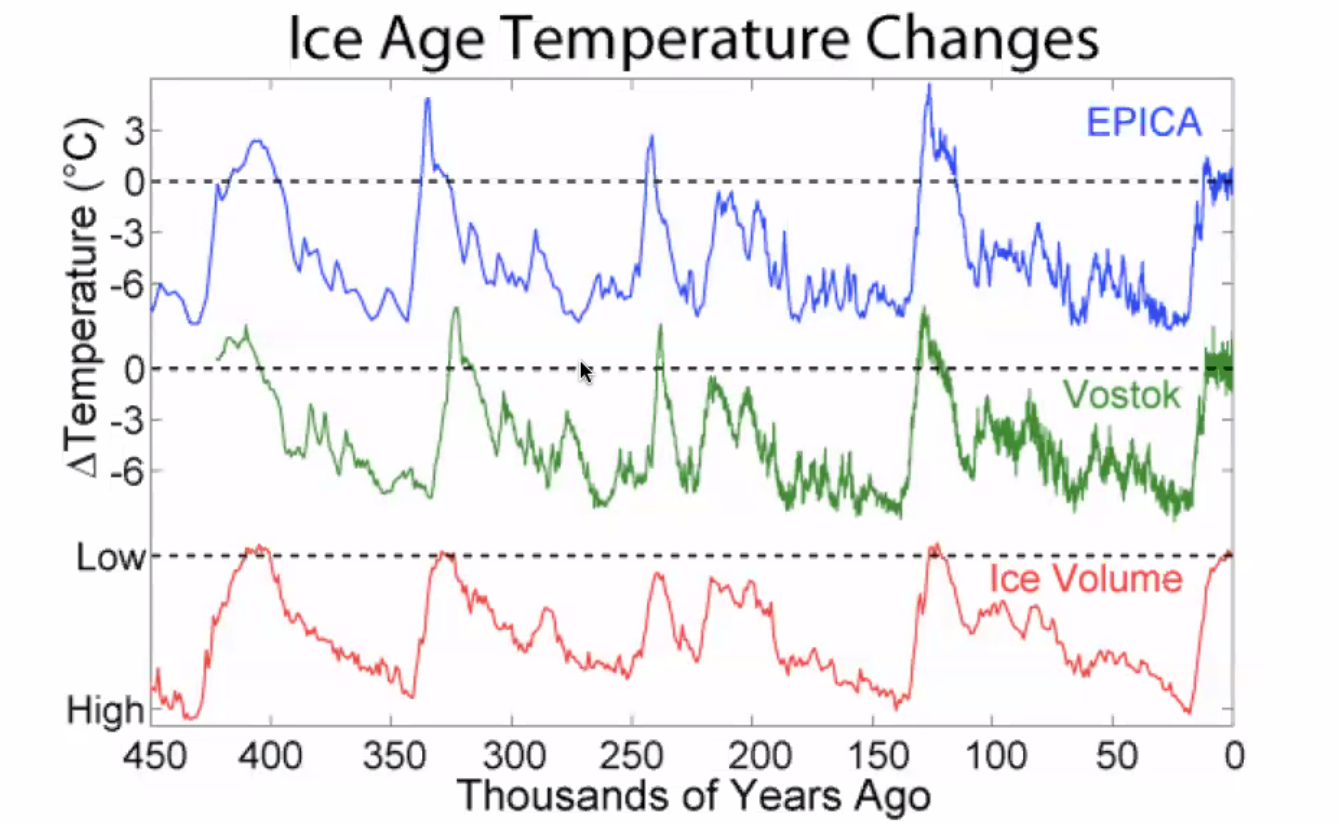
- Plate Tectonics
  - Need plates for ice to grow, ice growing means more albedo, albedo means cooler temp, cooler temp means more ice
- CO_2
  - Big source is volcanoes

Milankovitch Cycles

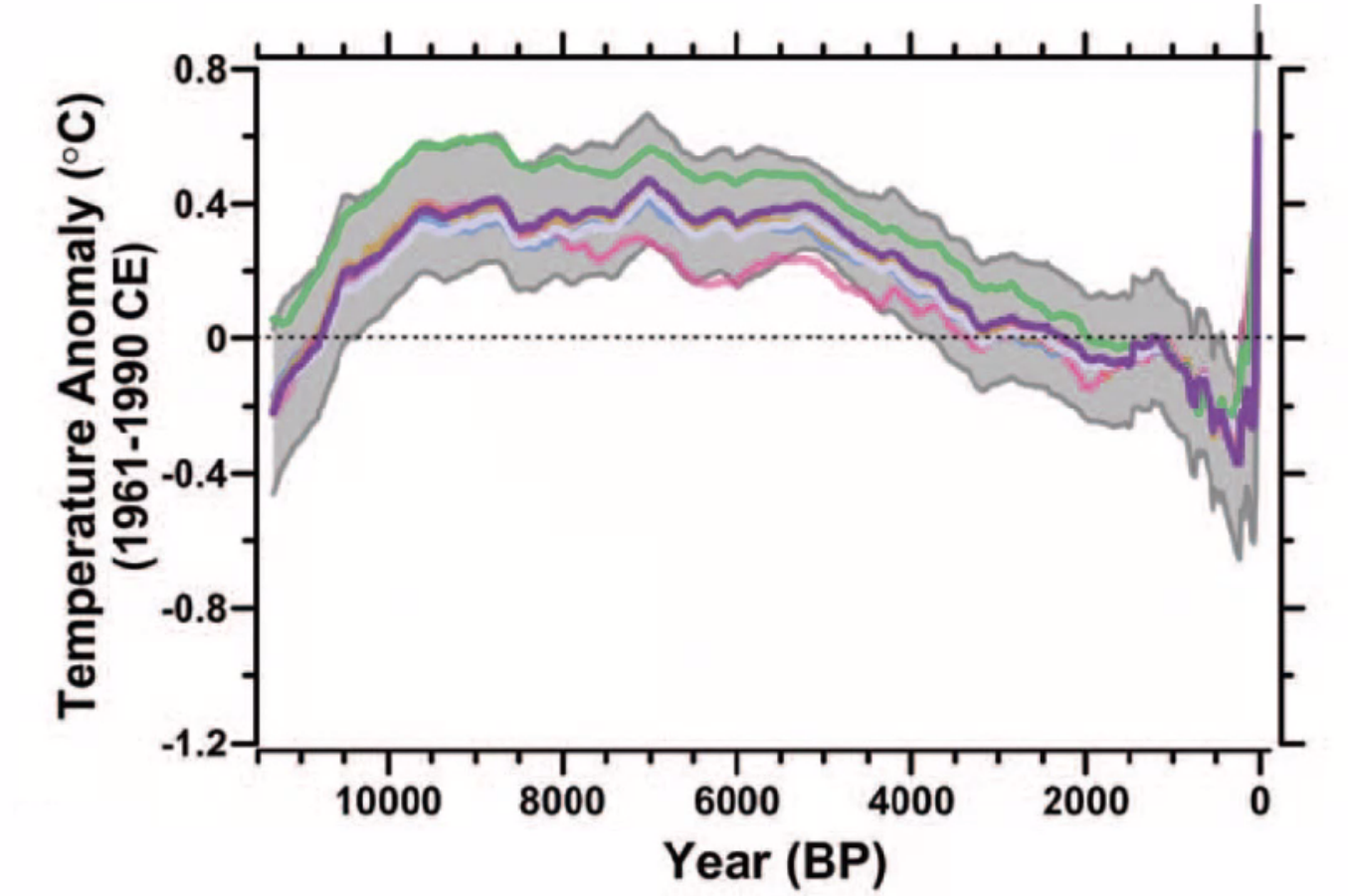


- Obliquity = Tilt
- Eccentricity = Circularity of Orbit
- Precession = Changing Date of Perhelion, when Earth is closest to the sun

As a result, we get the varying "Solar Forcing" or varying levels of Incoming Solar Radiation



Earth's temperature has changed naturally in the past due to orbital changes. We were in a cooling process before the Industrial Revolution but after, we have affected the Earth's temperature directly.



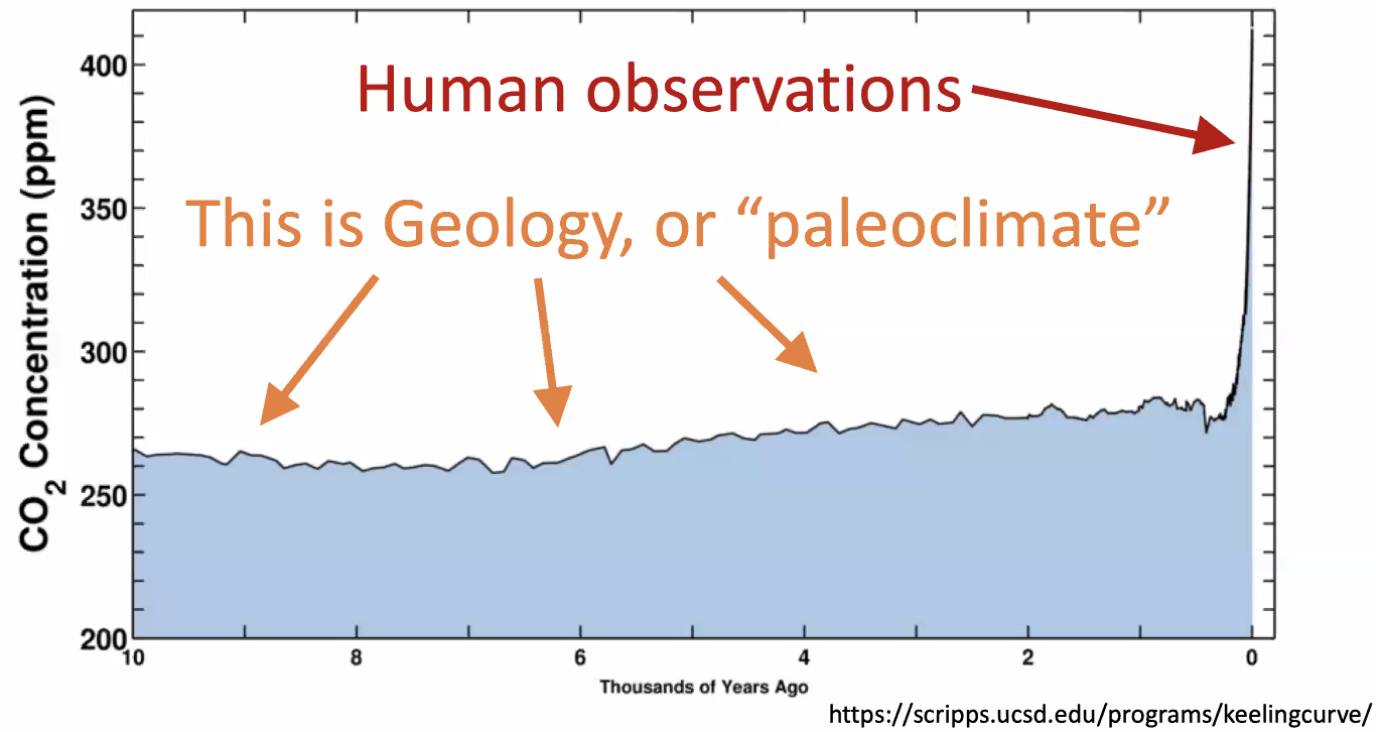
How do we get this data for temperature anomalies throughout history?

- Ice Cores
- Types of Rocks

This is what we will discuss throughout the next couple classes.

Paleoclimatology: The study of Earth's climate history

Trees are just one source of this information. Their rings can tell us about the temperature in their environment and how old they are.



https://scripps.ucsd.edu/programs/keelingcurve/

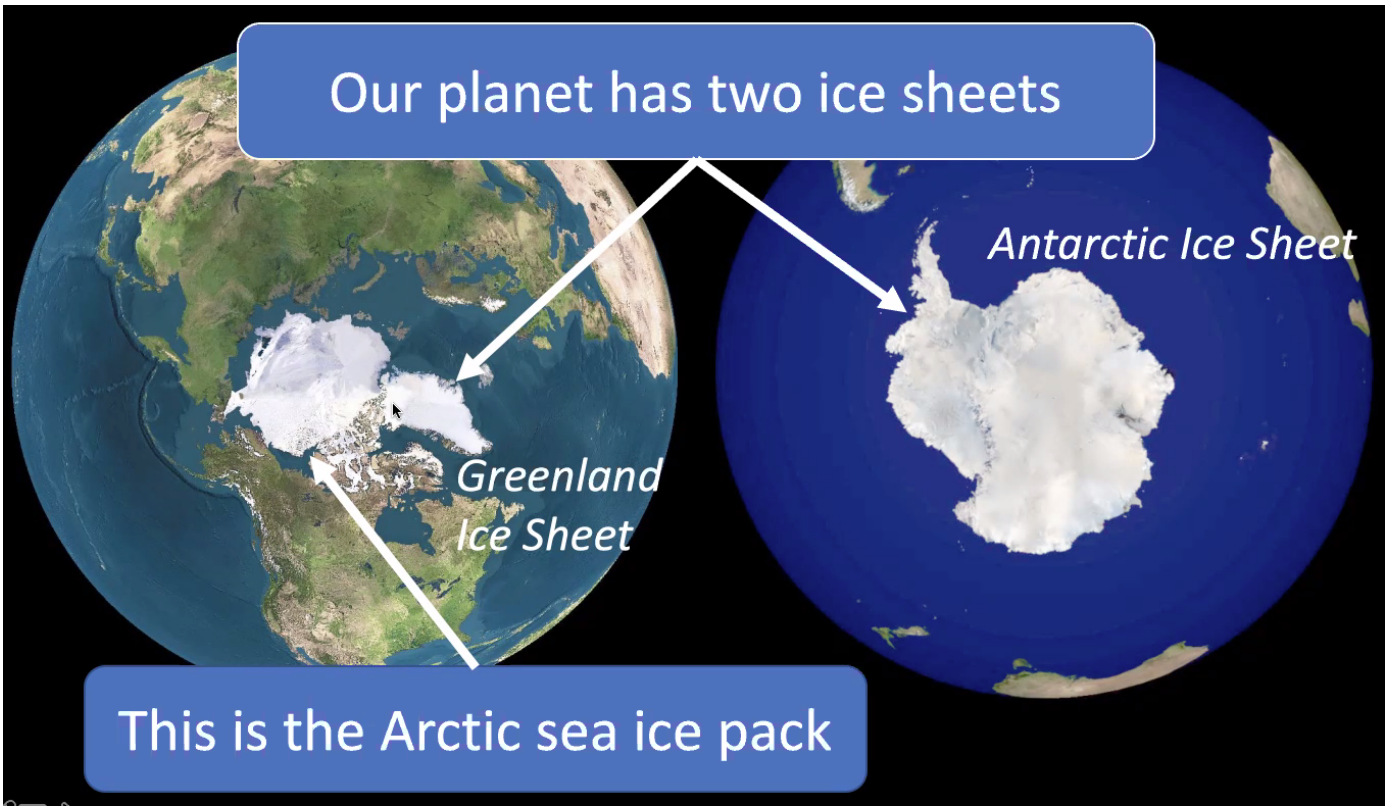
Ice Sheets and Project: Iceworm

How do Ice Sheets form?

Ice sheets are made up of years of snow that has compacted into ice. Ice sheets are just a result of snowfall and pressure.

What about Buffalo?

No ice sheets form in Buffalo because our snowfall melts every year. In places like Greenland, the snow doesn't melt as easily and it's more likely you'd find ice sheets there than in Buffalo.



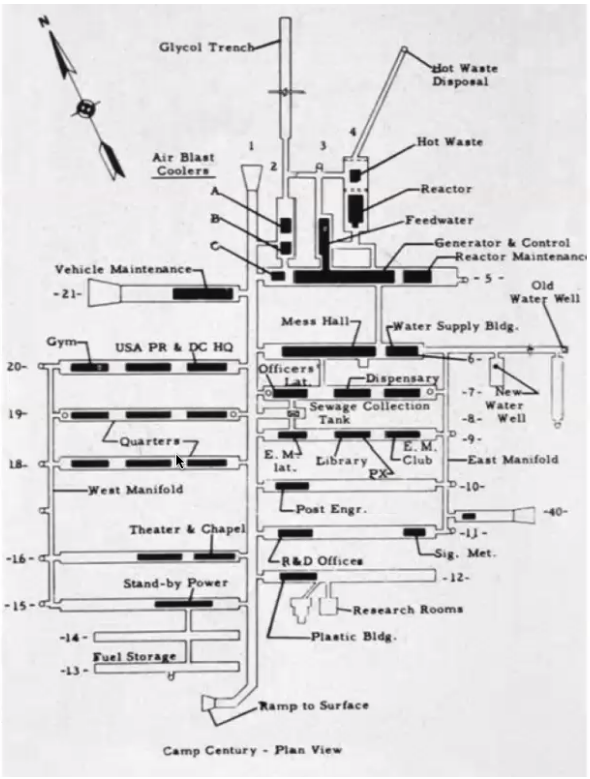
One in the Northern Hemisphere, the Greenland Ice Sheet, and one in the Southern Hemisphere, the Antarctic Ice Sheet.

Ice Coring: It all started with Camp Century and "Project Iceworm"

This was a secret military installation. It was originally planned to hide nuclear projects in the ice sheets in Greenland

during the Cold War.

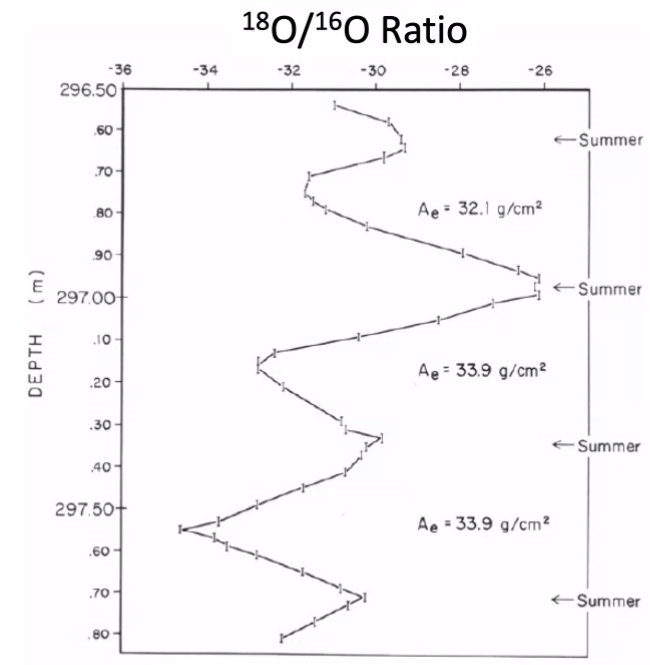
A map of the base:



They figured out quickly that it was not stable there, because glaciers can deform thanks to gravity.

Separately, some were drilling into the ice.

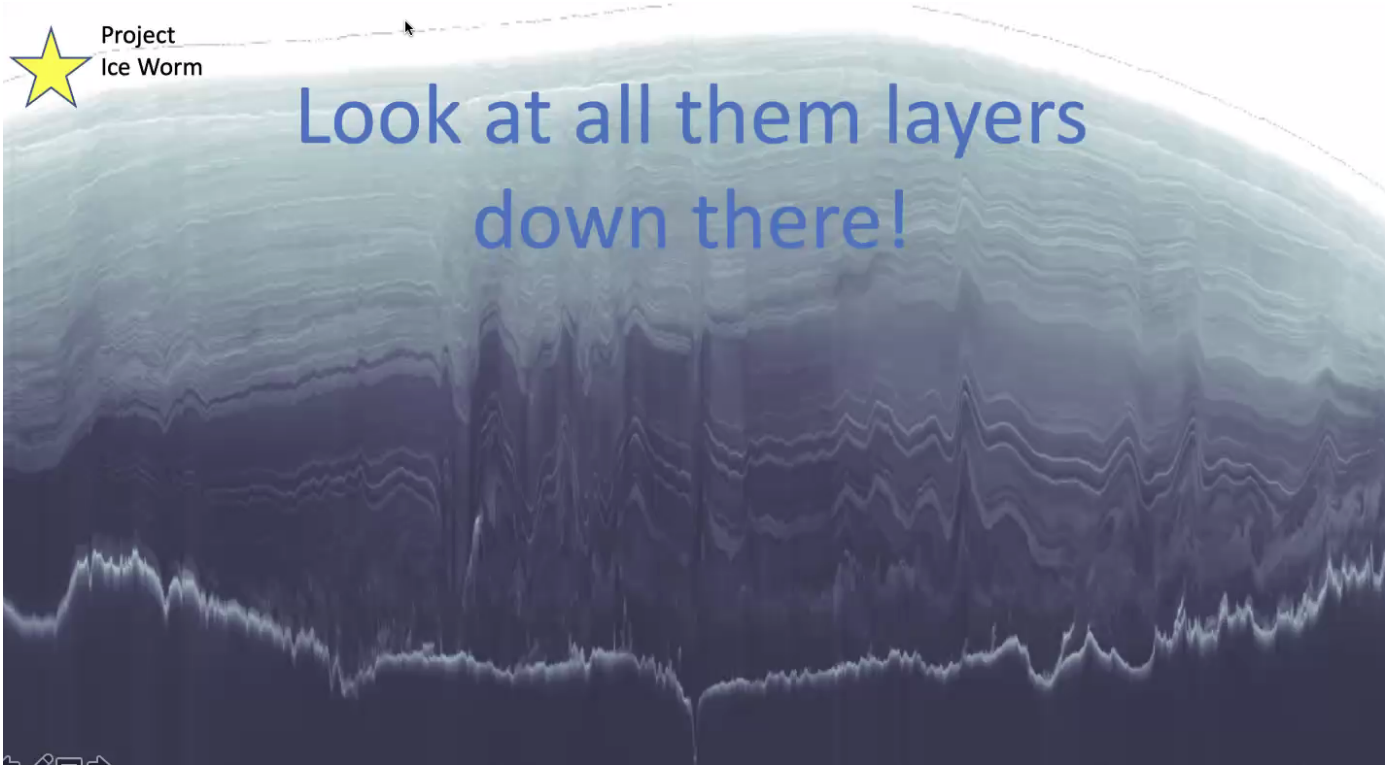
As a result of the drilling, they found that there were oscillations of isotopes of oxygen in the layers.



These oscillations in the different isotopes of Oxygen represent seasonal cycles of temperature over 4 years.

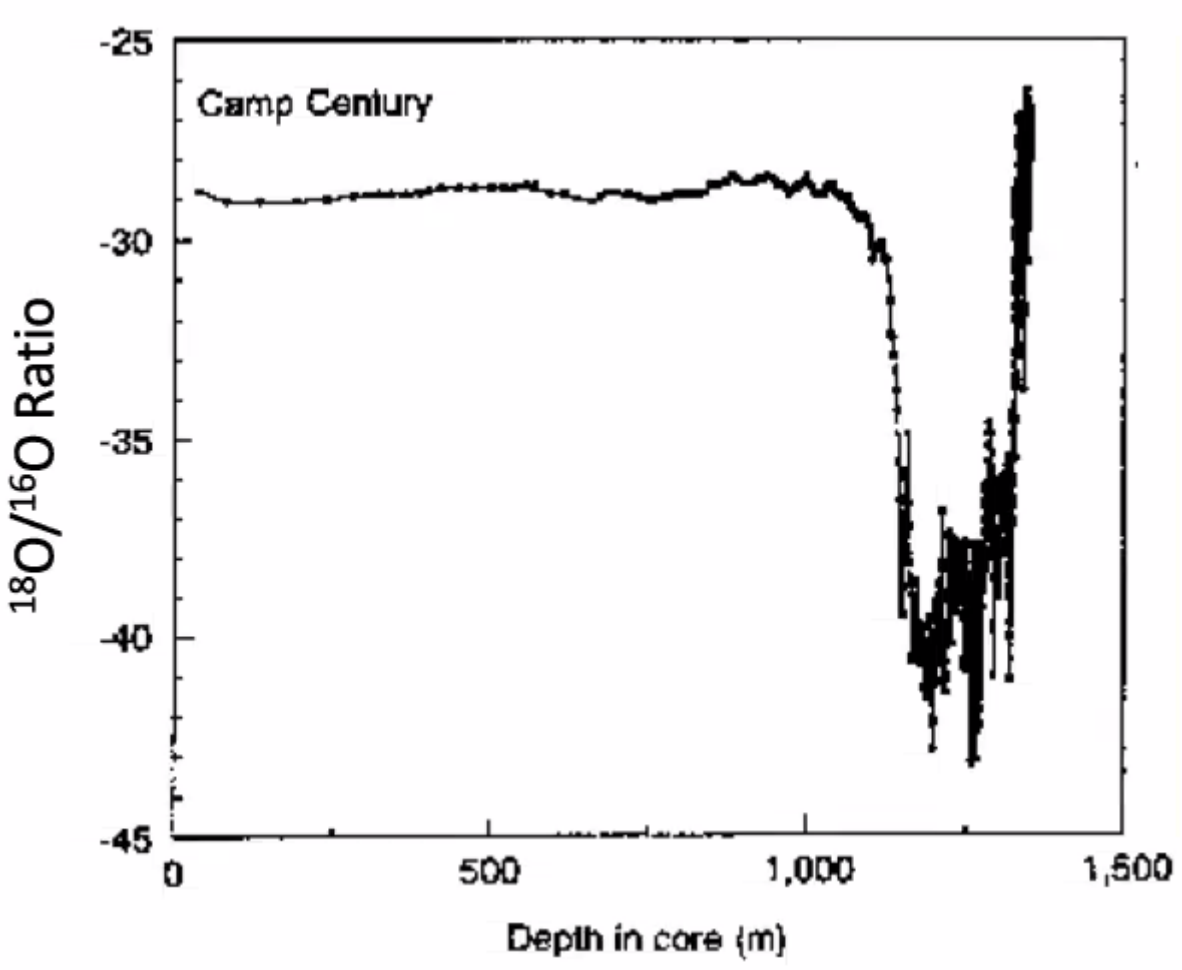
If these chart seasonality, perhaps we can learn about Earth's history through these oscillations!

It turns out this was true.



This is taken by an ice penetrating radar.

Next step, drill down to bedrock, > 1km, to observe:



From this, we can observe:

- Down at about 1200m, there is a big dip
- At the very bottom, it rises again at around 1350m
- The top 1000m are fairly constant

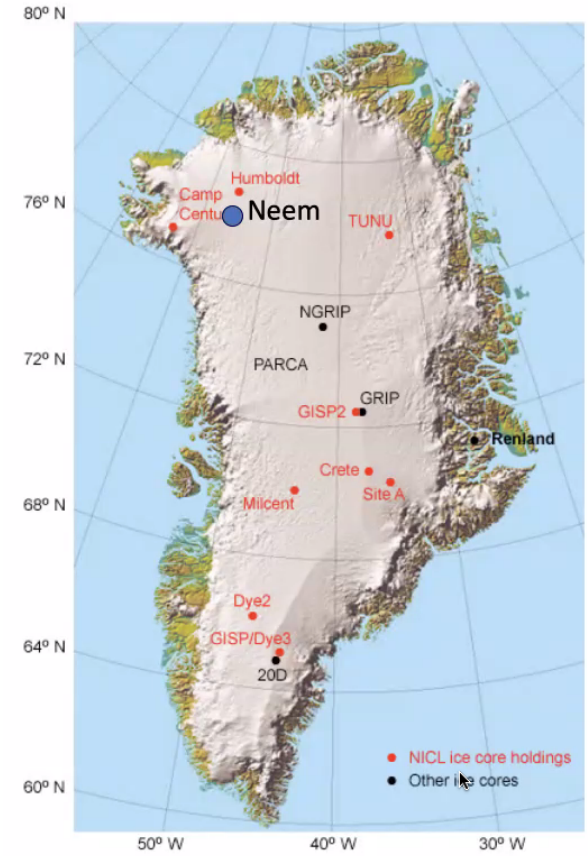
Figure 26. Dansgaard, Langway, and Oeschger in the science trench at Dye 3 shortly after bottom ice was reached at 2037 m on August 15, 1981. (Photo by J. Murray Mitchell, NOAA.)

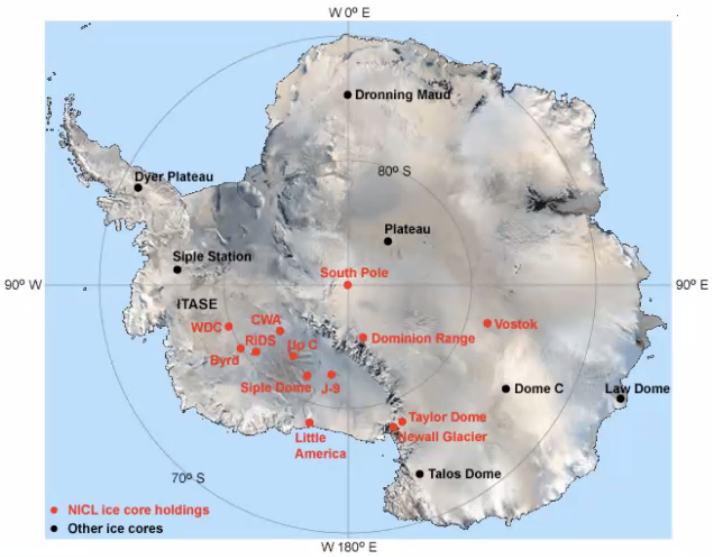
Next stop: Vostok, Antarctica

The Antarctic ice Sheet, thicker than Greenland AND with lower accumulation rates, contains much more TIME than Greenland = a much longer ice core record

Now, we have many more sites!

All Ice Core Sites





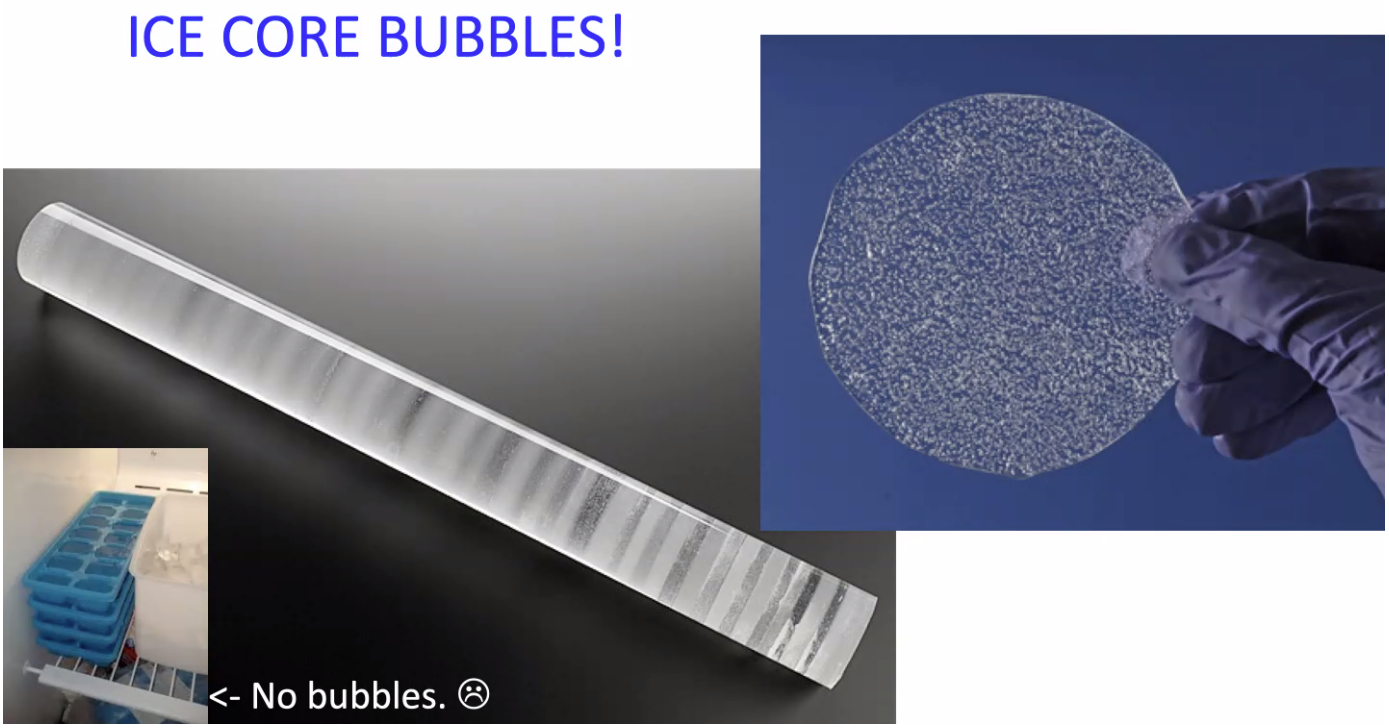
Where do we keep all this ice?

The US has a federal facility to store all the Ice Cores. Before this was created, all the Ice Cores were stored *in Buffalo!*

What Ice Cores Record

1. Past levels of greenhouse gasses in the atmosphere (to be elaborated: **CO_2**)
2. Water isotopes (H and O) record changes in temperature and water source area (to be elaborated: **Radio Isotopes**)
3. Ice layer thickness is a function of past precipitation amounts

4. Ice layers contain dust and volcanic ash
5. Melt layers record extreme summer warmth

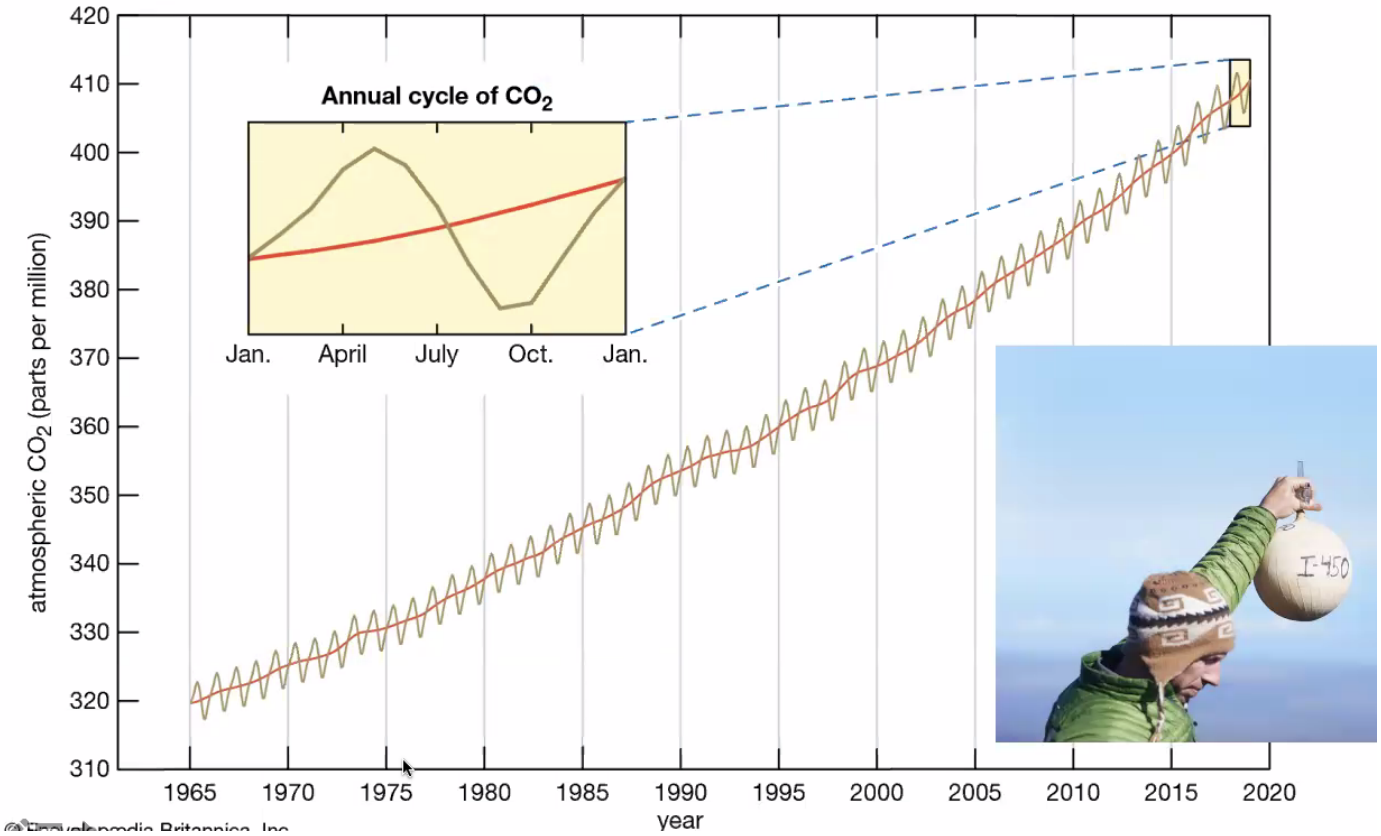


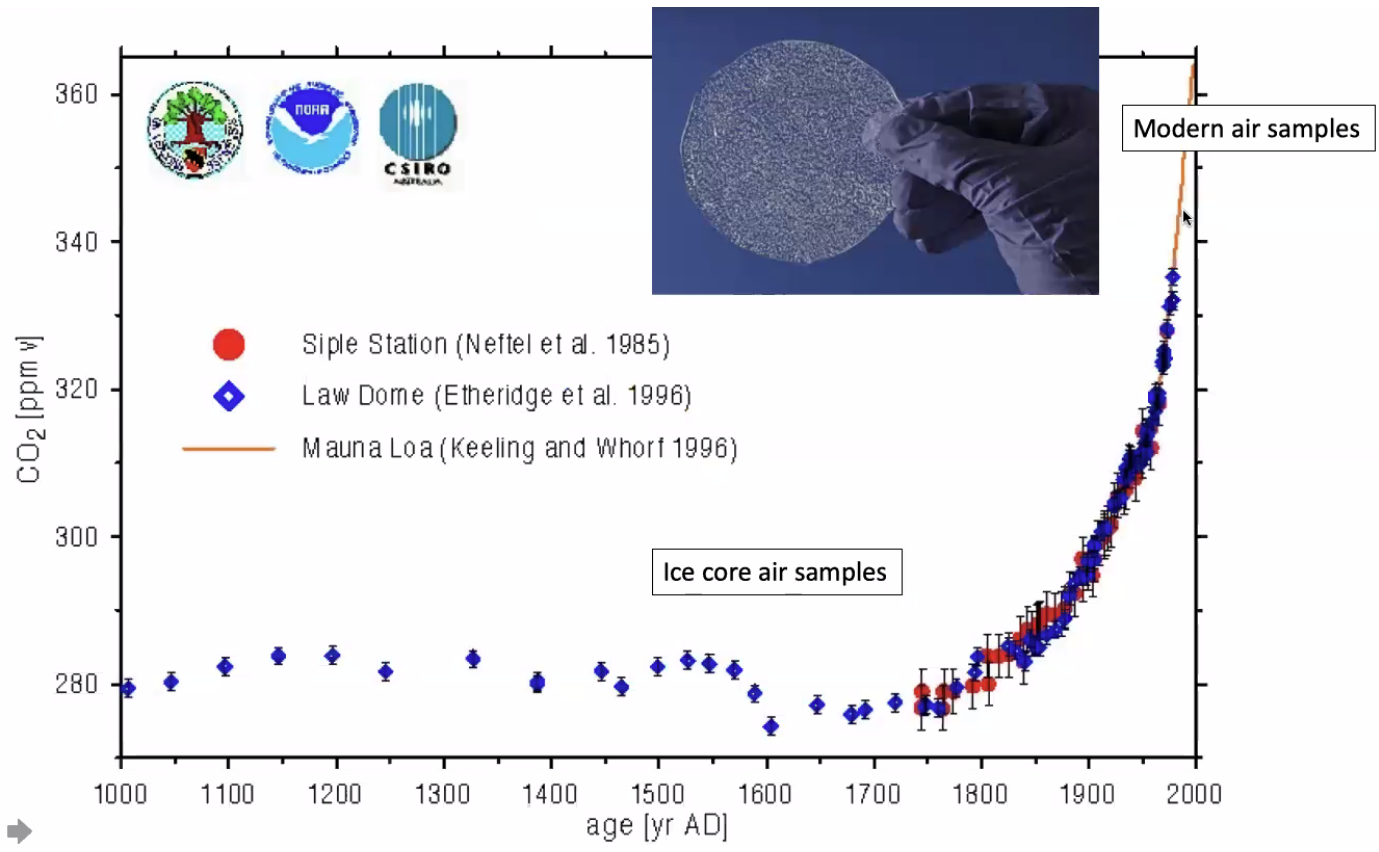
If you compact snow until it turns to ice, it will contain several bubbles. However, water turned to ice will not.

So, all those Ice Core bubbles contain the atmosphere of the past!

What Ice Cores Record: CO_2

The Keeling Curve

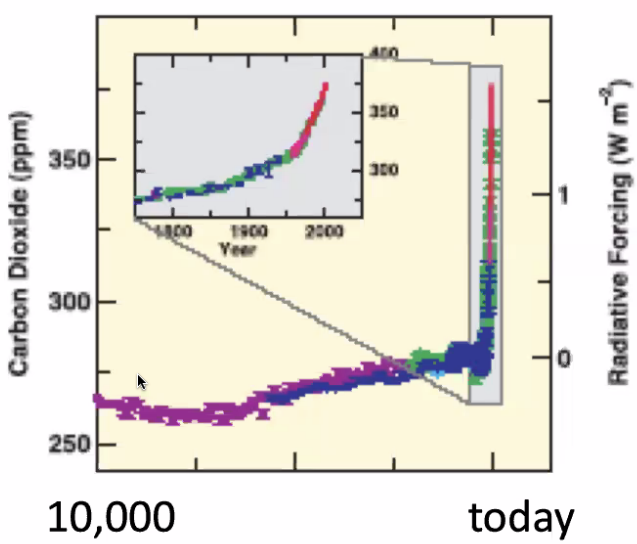


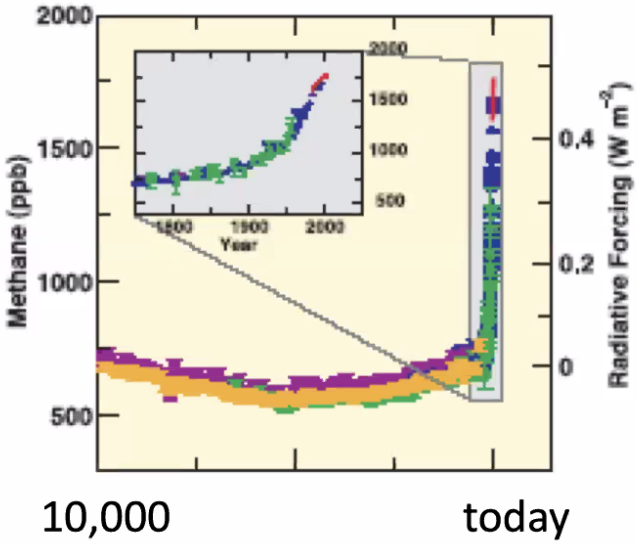


We can get the ppm of CO_2 from these Ice Core Bubbles

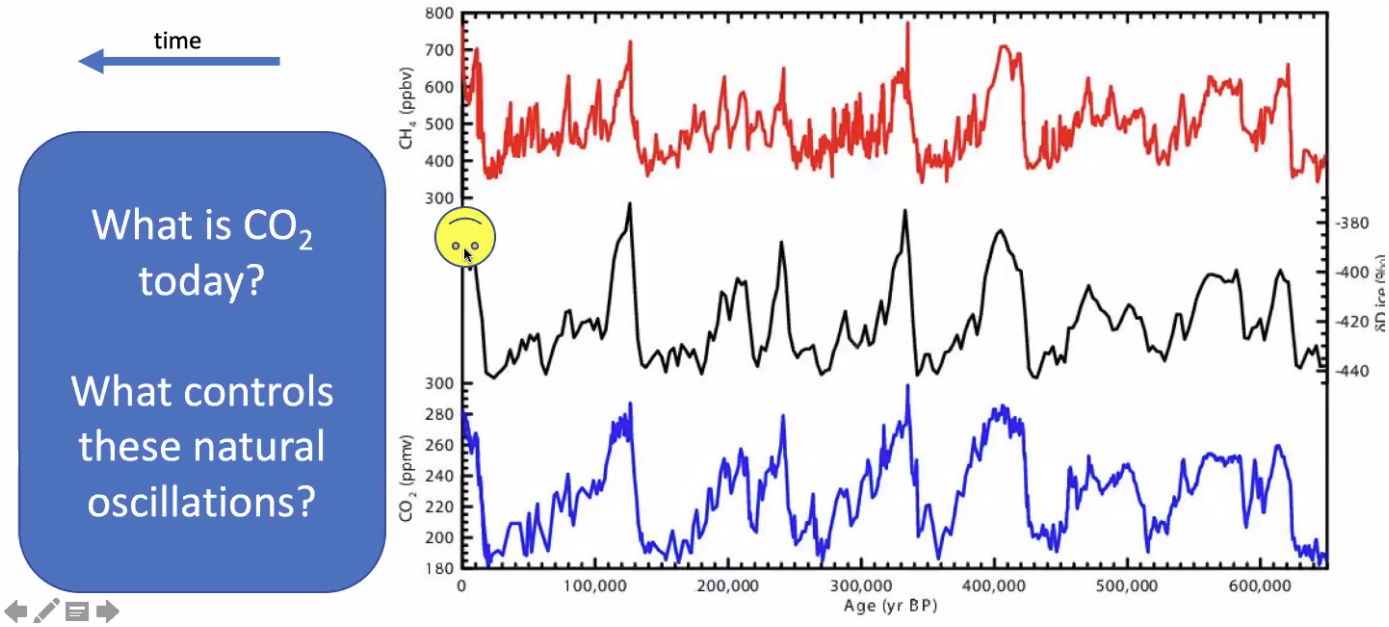
The amount of CO_2 in these graphs aligns with what we've seen in previous classes, with different graphs.

Greenhouse gas levels are at an ALL TIME high!





We have LONG records of greenhouse gas levels from Antarctic ice cores

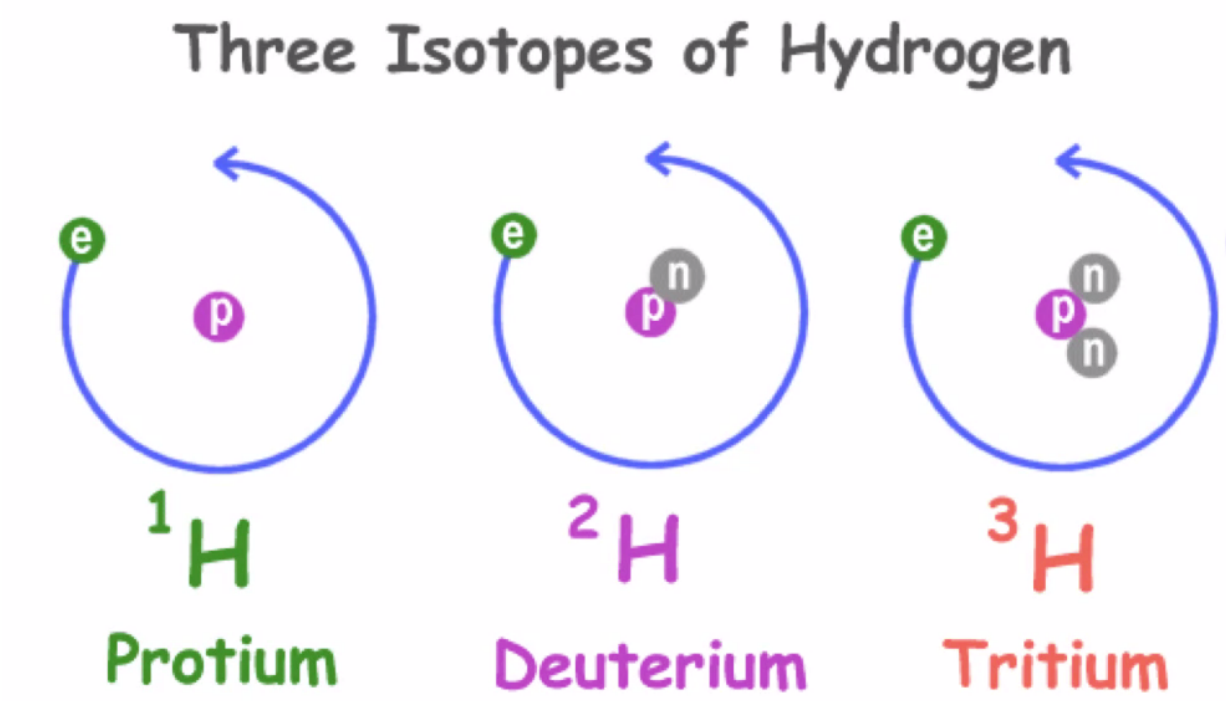


The natural variability is caused by the Milankovich cycles.

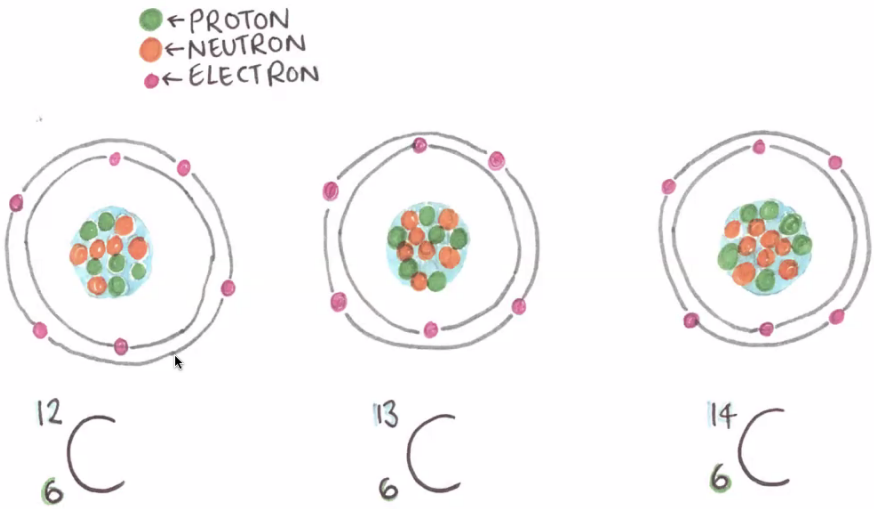
CO_2 is the blue curve. Currently, we're at the upside-down smiley face (415ppm).

What Ice Cores Record: Radio Isotopes

What is an isotope?

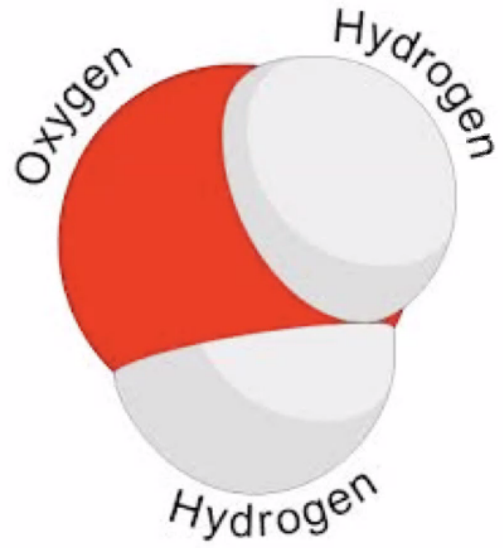


As another example, here are 3 isotopes of Carbon



Each element has a set amount of protons, but their isotopes may vary in the amount of neutrons.

There are also different isotopes within the WATER molecule: Oxygen and Hydrogen

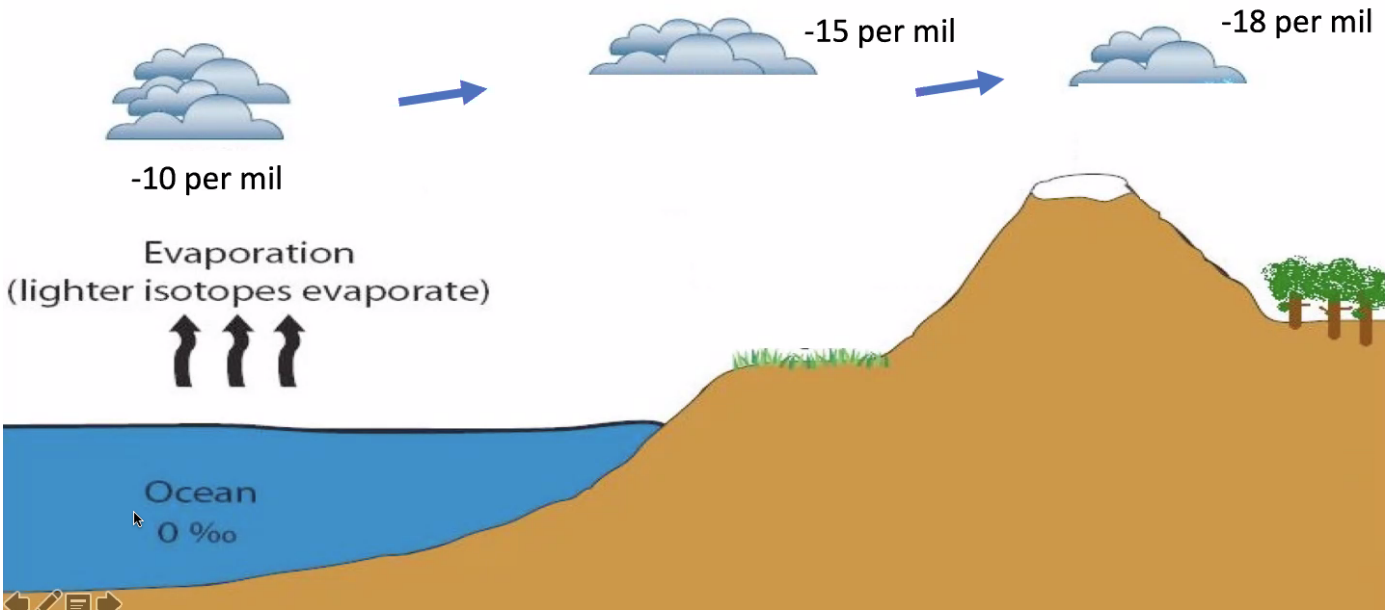


Oxygen has isotopes:
^{16}O, ^{17}O, ^{18}O

Hydrogen has isotopes:
^{1}H and ^{2}H

That means a water molecule can be different weights.

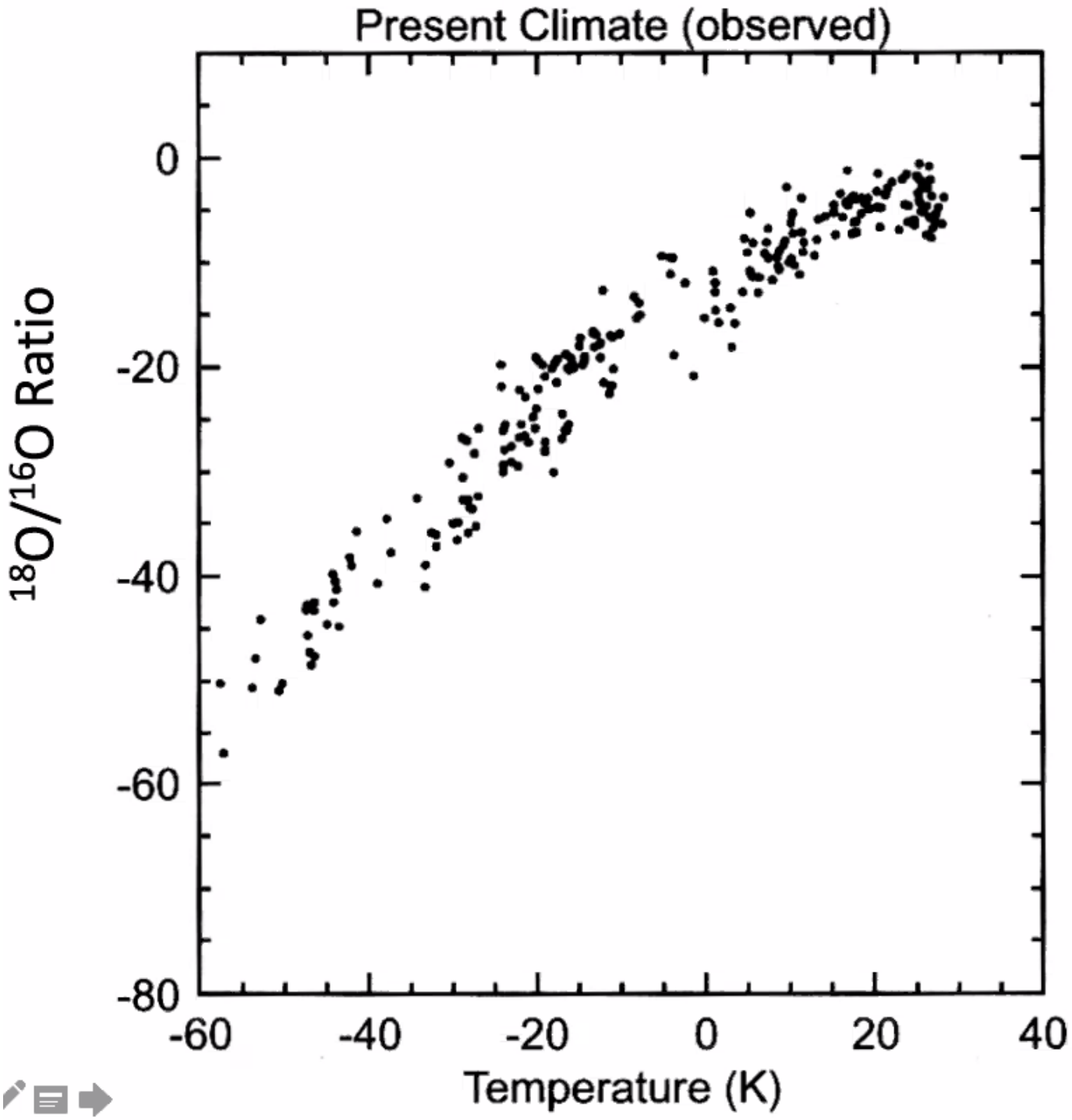
We measure how much of the rare ^{18}O is in the water molecule using per mil notation.



So, 0 per mil in the oceans is the starting point (that's the standard). By the time you form a cloud, evaporation favors ^{16}O more than ^{18}O, so you are at -10 per mil.

Then, as the air mass travels to higher latitudes and gets colder, it gets lighter and lighter (more ^{16}O because the ^{18}O that is there preferentially rains out).

Paleoclimatologists use this relationship and apply it to ancient ice core samples:

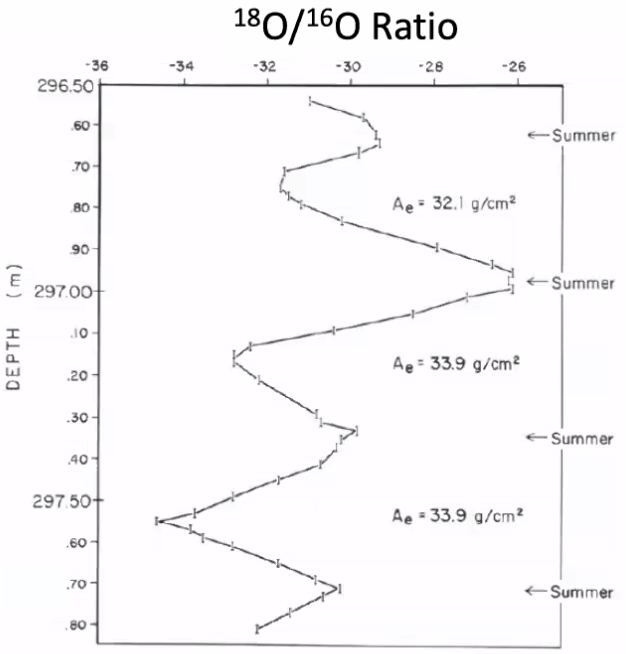


Lighter isotopes during colder times!

Remember this?

Higher (less negative) values = warmer.

Lower (more negative) values = colder.



So, these isotopes directly correlate to what we've seen in class previously.

Therefore, the Greenhouse Effect is REAL! Temperature and greenhouse gas levels all fluctuate together!