Agronomy 406

March 20, 2018

Climate data sources.

Causes of natural climate changes.

View the Alley video and turn in the exercise at **start of class Thursday.** Linked from course schedule.

Complete plagiarism tutorial and "Post-Test Your Knowledge" quiz by start of class next Tuesday (March 27). **Do not take the quiz before doing the tutorial.**

Plagiarism tutorial

Plagiarism tutorial post-test is due by start of class (9:30 a.m.) on Tuesday, March 27. Linked from course schedule.

This is a brief but excellent tutorial that will help you avoid plagiarism, even accidental plagiarism.

Remember – **you will have a letter grade deducted from your climate report if you do not achieve a passing score (at least 8/10) on the post-test by the deadline.**

Retaking the post-test can be difficult, so **do not take the post-test before completing the tutorial.**

Climate data sources

Instrumental measurements

- Quantitative data, but still need quality control and analysis.
- Short record from a climate point of view (about 40-150 years depending on type of measurement).

Proxy data

- Can be difficult to relate to climate in a quantitative way.
- Potentially very long record (centuries to billions of years).

Surface measurements

Surface weather elements:

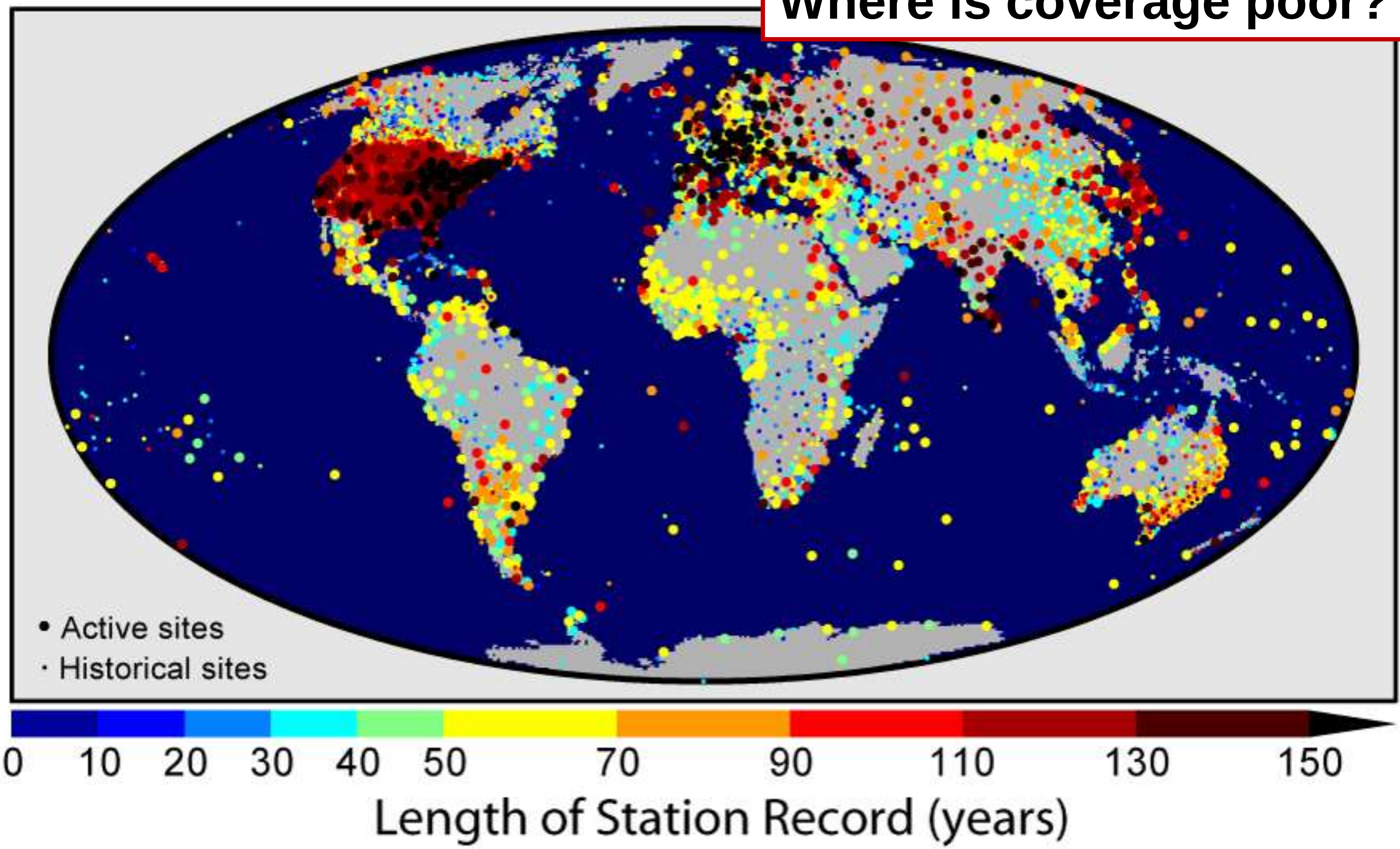
> Daily max/min temperature and rainfall have the longest and most complete coverage.
>
> Pressure, winds, etc. have less coverage in space and shorter record.

Good coverage over most land areas, less coverage and poorer quality over water until very recently.

50-200+ years of data depending on location.

Global Climate Network Temperature Stations

Where is coverage good?
Where is coverage poor?



map created by Robert Rohde, Berkeley Earth

Radiosondes

Balloon-borne instrument packages that measure from near the surface into the lower stratosphere:

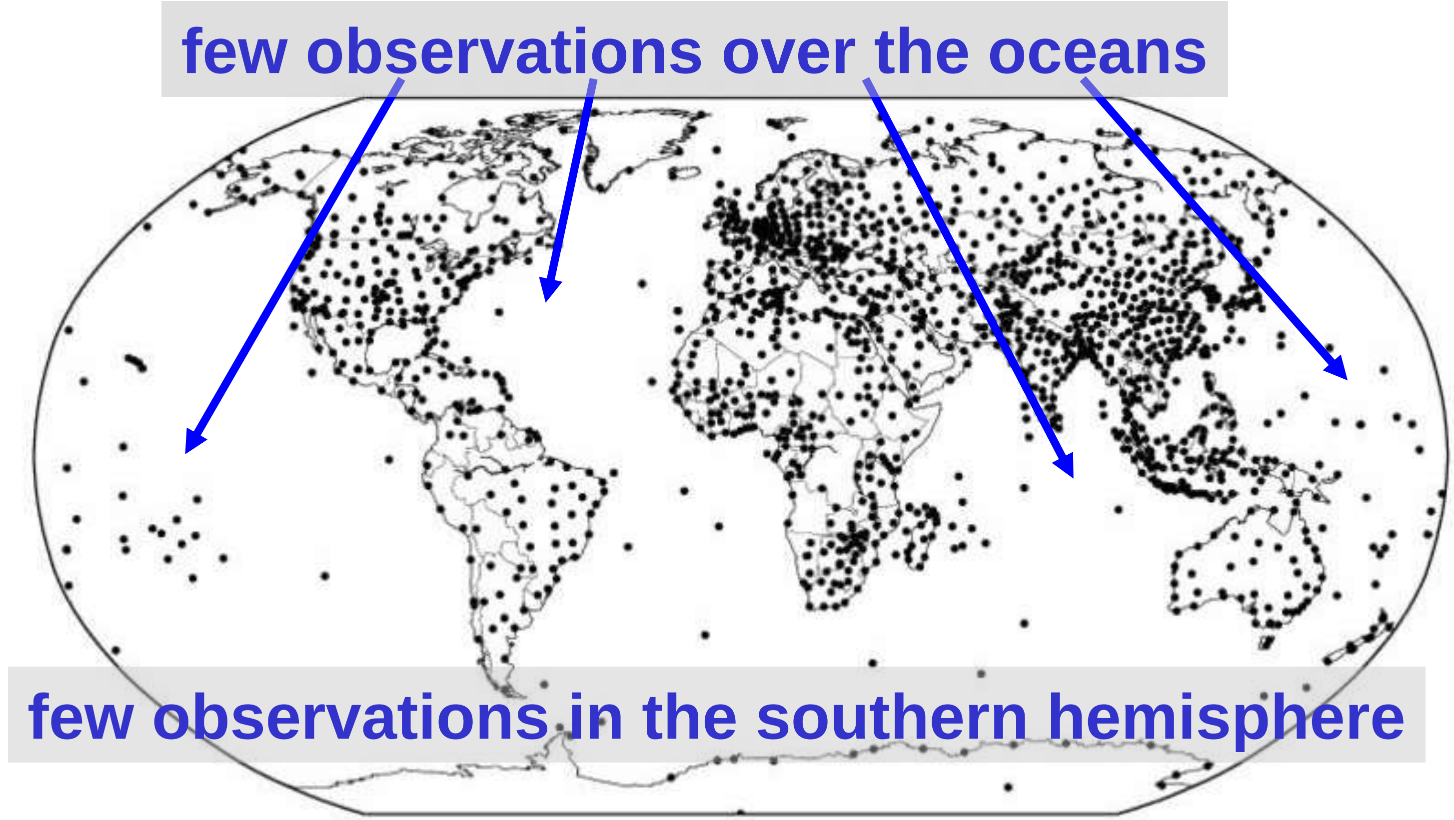
- Measure temperature, pressure, relative humidity, and usually winds (ra**win**sondes).
- Released once or twice a day at standard times (00 and 12 UTC).

Good coverage over Northern Hemisphere land, poor to fair coverage elsewhere.

- About 60-70 years of data.
- Amount of data increases markedly after 1958.

image from http://cliffmass.blogspot.com/2012/10/how-high-do-weather-balloons-rise.html

Stations in the Integrated Global Radiosonde Archive



Number of stations peaked around 1980.

Only about 2/3 of stations report regularly. Stations in tropical Africa and South America are especially likely to be missing.

For details see https://www.ncdc.noaa.gov/data-access/weather-balloon/integrated-global-radiosonde-archive

Satellites

Measure both atmosphere and surface.

Near-uniform global coverage.

Some satellites do not measure near the poles, especially **geostationary** satellites.

Remember, sensors on satellites measure radiances.

Mathematical algorithms use radiances to **estimate** temperature, precipitation, etc.

Less than 40 years of data on atmospheric profiles.

Began in late 1978 (TIROS-N satellite).

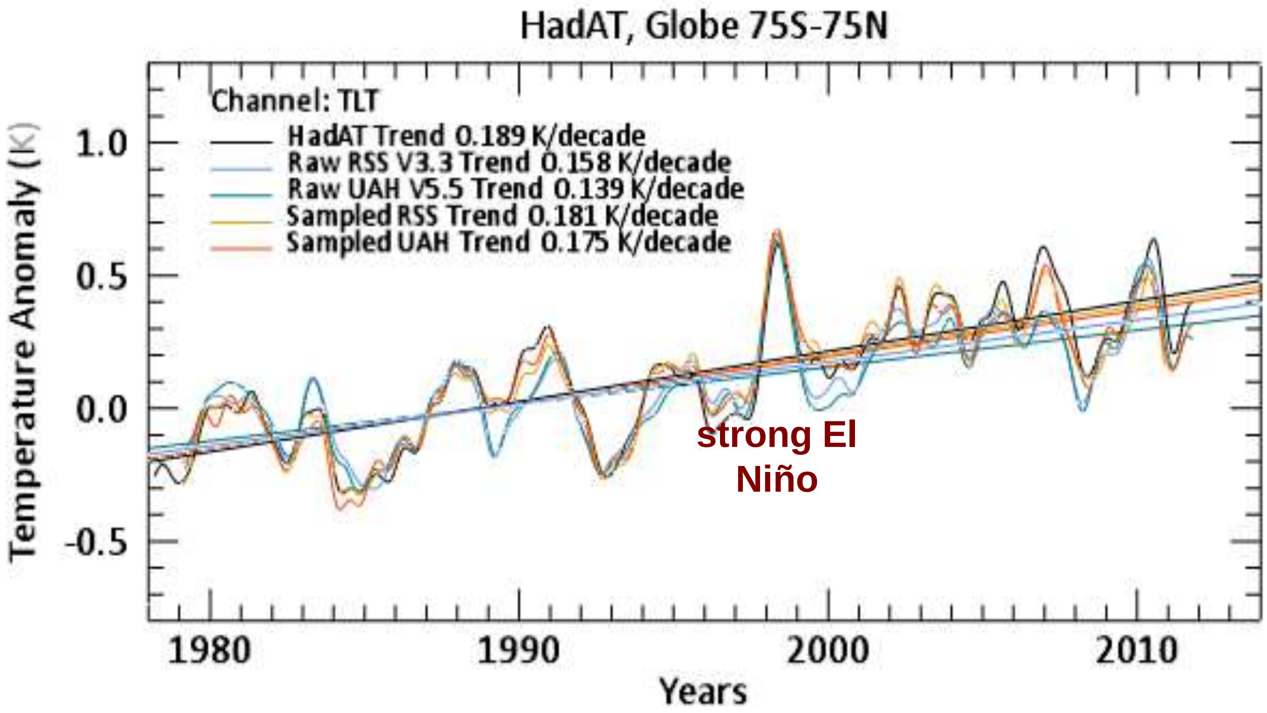
Earlier satellites produced images and infrared temperature measurements (e.g., cloud top temperature or sea surface temperature) but no profiles.

Satellite and radiosonde data for the lower troposphere agree fairly well

Black curve: radiosondes

Colored curves: different versions of satellite data.

Yellow and orange curves show satellite data only for locations that also are measured by radiosondes.



from http://www.remss.com/measurements/upper-air-temperature/validation

Problems with instrumental data

Not enough data coverage both in space and time.

Instrument problems:

Failure, miscalibration, poorly installed.

Instrument changes:

Change of instrument type or location (including orbital decay of satellites).

Change of environment around the instrument, such as growth of urban areas.

Human error: Transposition of numbers, filling in the wrong blank, etc. Sometimes ship reports are given for locations on land!

Data must undergo extensive **quality control** to detect and (ideally) correct problems.

Proxy climate data

The instrumental data record is short.

Proxy data let us make inferences about climate before instrumental measurements became available.

Proxy climate data

These are not measurements of climate variables but are **related** to climate in some way.

Geophysical proxy data:

Physical or biological phenomena are related to climate. The Alley video discusses some of these. Examples: tree ring widths, isotope measurements from ice cores.

Documentary proxy data:

Records of human activities or qualitative observations of climate phenomena (not measurements).

Less direct relation to quantifiable climate elements.

Some sources of geophysical proxy data

Ice cores:

Isotopes are atoms of an element with differing numbers of neutrons. Isotope ratios in ice cores can be used to infer climate.

Other measurements such as sulfur deposited from volcanoes, or dust layers implying transport by wind.

Tree rings:

Climate inferences based on width of rings.

Deep-sea and lakebed sediments:

Examples include pollen types or isotopic content of shells.

Geological evidence of glacier advances and retreats.

How old is it?

Suppose you have a sample from an ancient spruce tree in a place where palm trees now grow. This means climate was colder in the past – but when?

Radiometric dating is based on the principle of radioactive decay.

> Isotopes that undergo radioactive decay are called **radioisotopes.** Decay of radioisotopes occurs at a known rate.
>
> Not all isotopes are radioactive! Non-radioactive isotopes are called **stable isotopes**.
>
> Changes in the ratio of a given radioisotope to a stable isotope of the same element can give an idea of how old a sample is.

Radiometric dating

Best known example: Carbon-14 dating of material having a biological origin. [Video.]

Source of ^{14}C is the atmosphere (about 1 in 1 trillion CO_2 molecules contains ^{14}C). Atmospheric ^{14}C was roughly constant until about 1950.

Living organisms take CO_2 from the atmosphere, or consume other organisms that take up CO_2.

At time of death, terrestrial organisms have the same ratio of ^{14}C to total carbon as the atmosphere.

Over time ^{14}C in the dead organism decays so the ratio decreases.

Half-life of ^{14}C is 5730 years: Every 5730 years, half of the remaining ^{14}C decays away.

Radiometric dating

The **half-life** of ^{14}C is 5730 years: every 5730 years, half of the remaining ^{14}C decays away.

After one half-life (5730 years) 1/2 of the original ^{14}C is left.

After two half-lives (11,460 years) 1/4 of the original ^{14}C is left.

Continue reducing the fraction by 1/2 for every 5730 years.

Radiometric dating: example

The **half-life** of ^{14}C is 5730 years: i.e., every 5730 years, half of the remaining ^{14}C decays away.

Suppose you have a sample from an ancient spruce tree in a place where palm trees now grow (implying climate was colder in the past).

The sample has **1/10** the ^{14}C ratio compared with the atmosphere.

How old is your sample? Work the problem individually and in your teams.

> You do not need to give an **exact** answer, but try to give a good estimate.

Radiometric dating

One answer:

After 5730 years, 1/2 of the original ^{14}C is left.

After (2 x 5730 = 11,460) years, 1/4 is left.

After (3 x 5730 = 17,190) years, 1/8 is left.

After (4 x 5730 = 22,920) years, 1/16 is left.

So the time when 1/10 of the ^{14}C is left would be more than 17,190 years but less than 22,920 years.

A more precise answer

We know

$$\text{fraction remaining} = 1/2^{N}$$

where N is the number of half-lives.

If N = 1 then half of the ^{14}C is left, if N = 2 then 1/4 is left, and so on.

We can solve for the exponent by taking the **natural logarithm** of both sides of this equation.

Then: $ln\ (\text{fraction remaining}) = N\ ln\ (1/2)$

or: $ln\ (\text{fraction remaining}) / ln\ (1/2) = N$

The fraction is 1/10, and *ln* (0.1) is -2.303.

Likewise *ln* (0.5) = -0.692. This gives us

$$N = -2.303 / -0.693 = 3.32 \text{ half-lives}$$

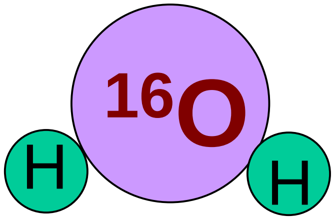
So the age is 3.32 x (5730 years) = **19,038 years.**

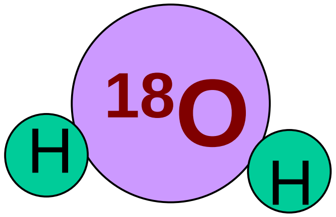
Stable isotopes

Stable isotopes do not decay radioactively.

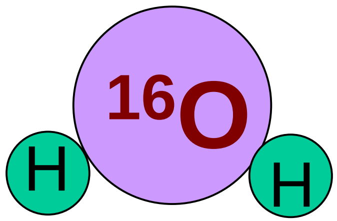
Since they do not decay, they persist indefinitely and can be used to make inferences about the far-distant past.

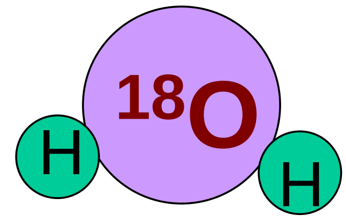
Example: Water can contain either ^{16}O ("normal" oxygen) or ^{18}O.





Stable isotopes can be used to infer temperature





^{18}O is a **stable isotope** of oxygen.

Some water molecules contain ^{18}O instead of ^{16}O. Their molecular weight is about 20 (=1+1+18) instead of 18 (=1+1+16).

Because water with ^{18}O is a little heavier, it responds differently to temperature.

Temperature inferences from stable isotopes

One index is $\delta^{18}O$:

$$\delta^{18}O = 1000 \times \frac{(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{standard}}{(^{18}O/^{16}O)_{standard}}$$

$$= 1000 \times \frac{\text{(ratio in sample) - (ratio in standard)}}{\text{ratio in standard}}$$

$^{18}O/^{16}O$ ratio for **standard mean ocean water** (SMOW) is 0.002005 (about 1/500)

Discuss: Do you think a sample from a polar ice core with a large **negative** $\delta^{18}O$ would imply a **warm** climate, or a **cold** climate? Why?

Two effects separate the isotopes

Distillation (evaporation): A water molecule with ^{18}O is heavier than one with ^{16}O, so more energy is needed to evaporate it.

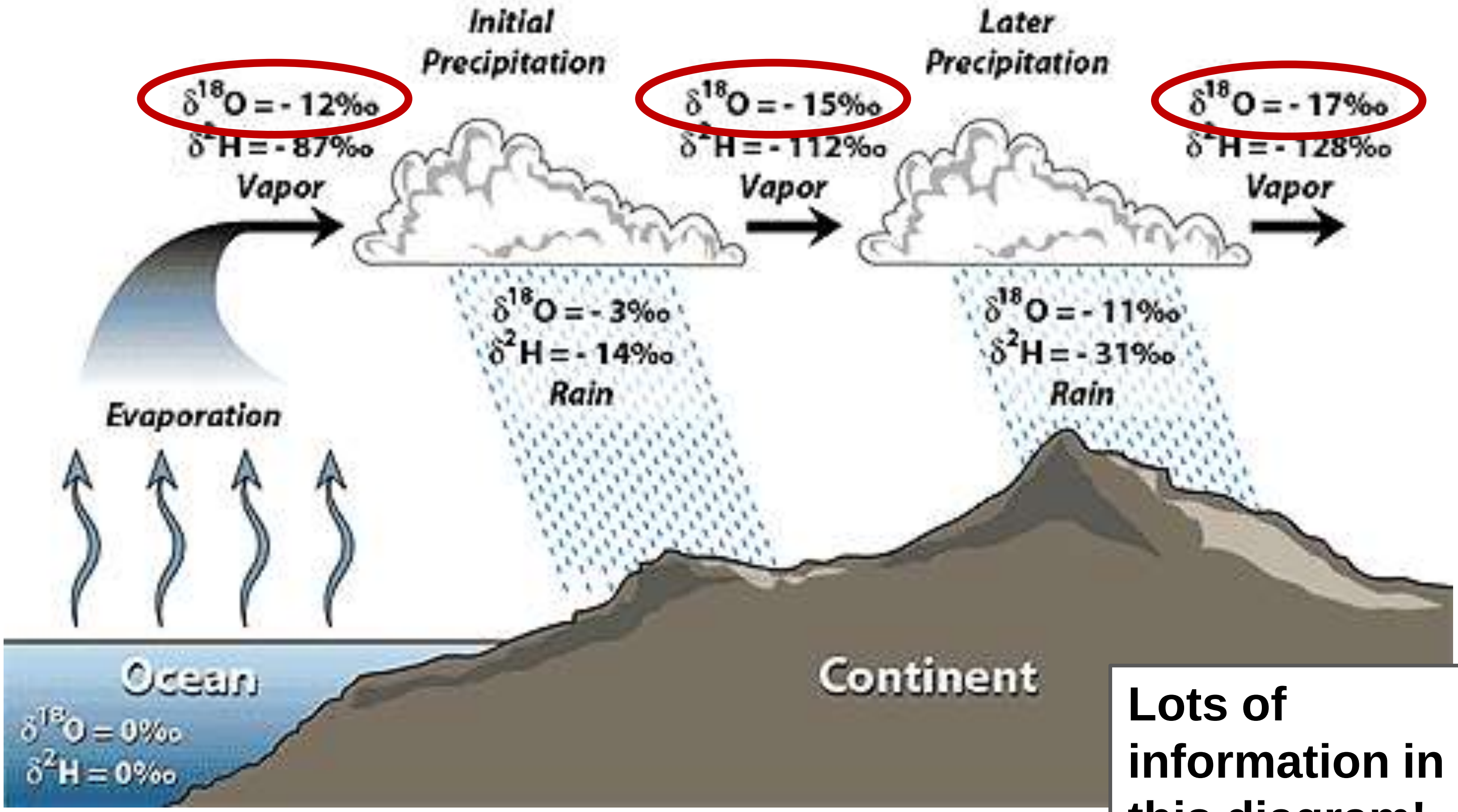
Precipitation: Water with ^{18}O condenses out faster.

These relationships come from basic thermodynamics.

So:

- **Water vapor will have less ^{18}O than the ocean.**
- Water vapor with ^{18}O will tend to precipitate earliest.
- Water that precipitates later will have a lower concentration of ^{18}O.
- **The longer distance that vapor is transported, the less ^{18}O it will contain.**

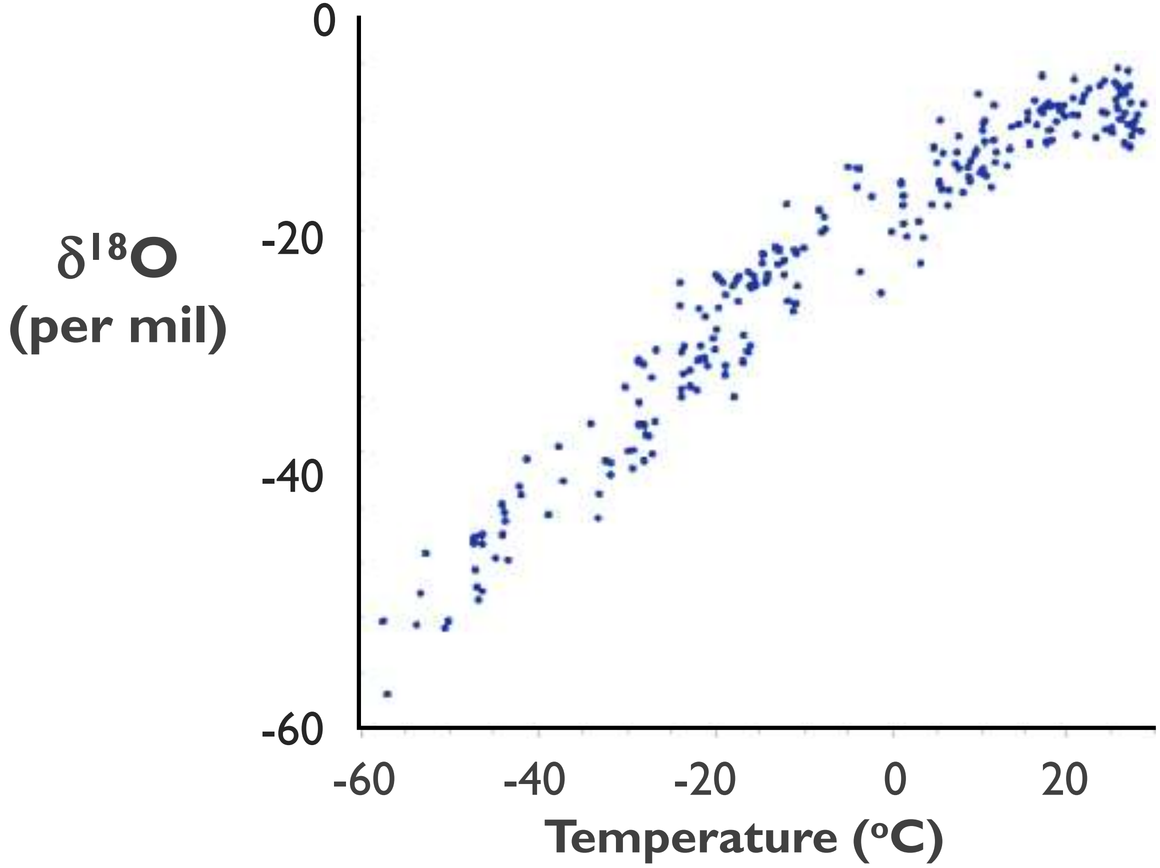
As water vapor travels, it loses ^{18}O when moisture falls out (precipitates)



Lots of information in this diagram!

from http://web.sahra.arizona.edu/programs/isotopes/oxygen.html

Oxygen isotope ratio ($\delta^{18}O$) in precipitation is almost linear with temperature



adapted from http://earthobservatory.nasa.gov/Features/Paleoclimatology_OxygenBalance/

Inferring climate from polar ice cores

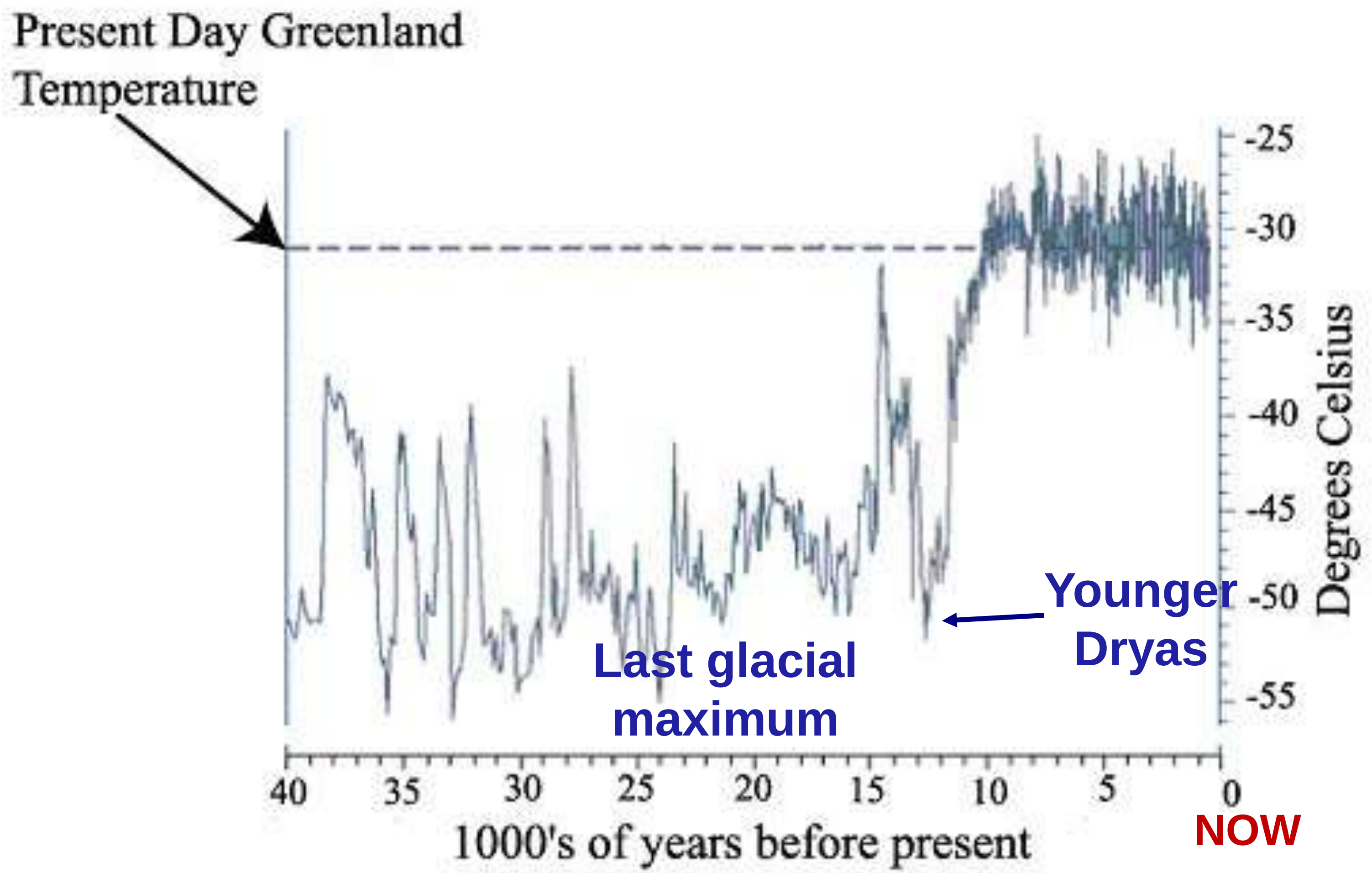
In practice the **precipitation** effect tends to dominate for polar ice cores.

In a **cold climate**,

- Warm water doesn't extend as far toward the poles.
- This means water vapor has to **travel farther** before reaching the ice caps.
- This gives **more time for water vapor with ^{18}O to fall out** before getting to the ice caps.

Thus **in a cold climate, snow that falls on the ice caps is relatively depleted in ^{18}O.**

Temperature reconstructed from Greenland ice core



adapted from figure by Mark Williams, Univ. of Colorado