

Geochronology and Ice Cores

A short introduction to dating landscape and climate processes

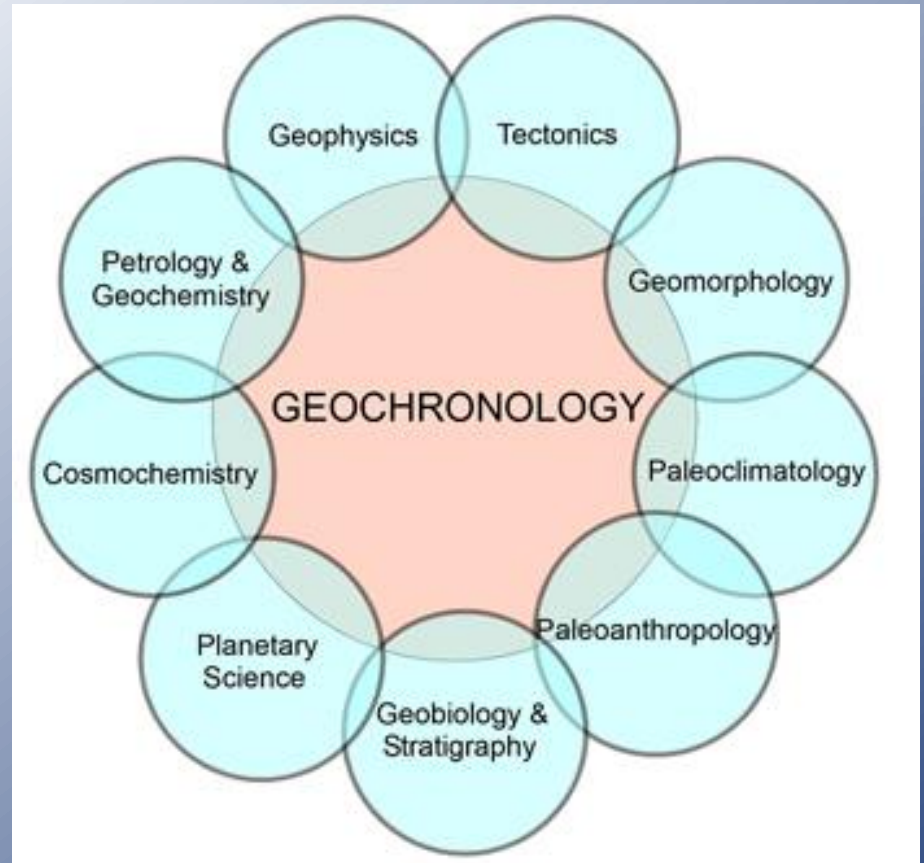
Dr Alissa Flatley
ACNA4007 – Physical Landscape and the Geosphere



Prifysgol Cymru
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University of Wales
Trinity Saint David

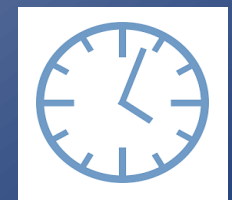
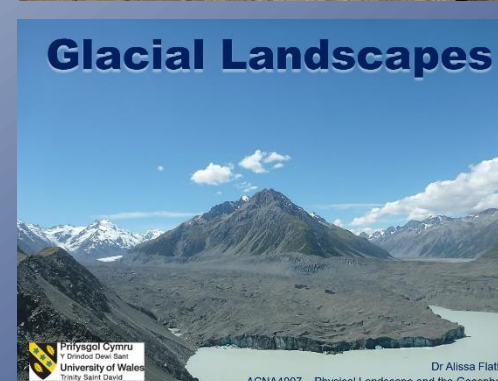
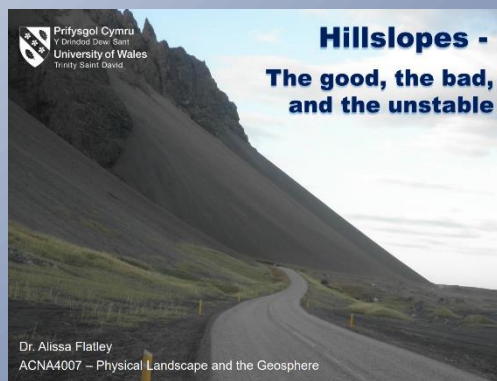
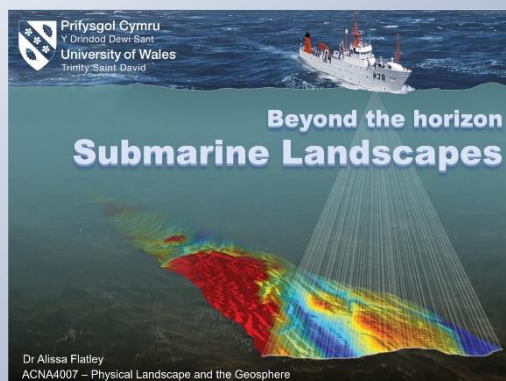
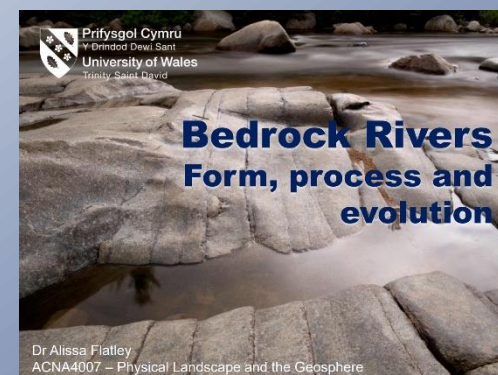
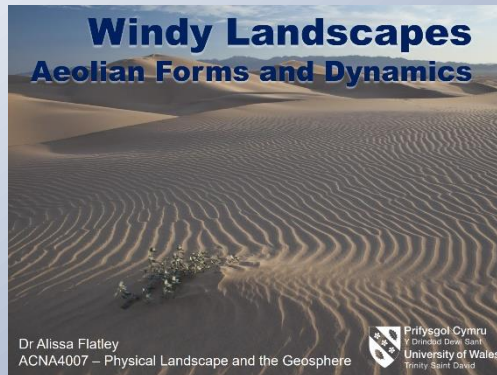
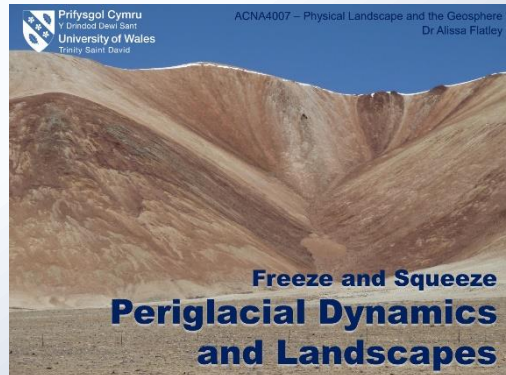
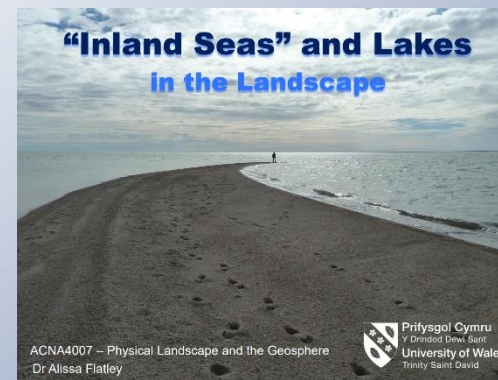
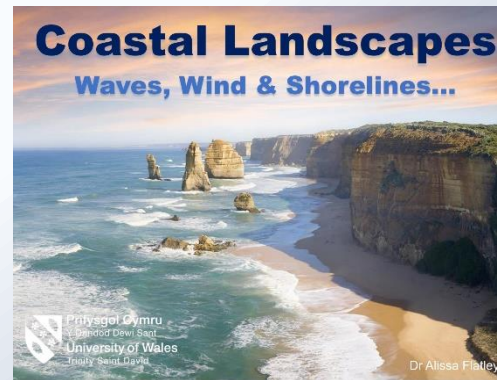
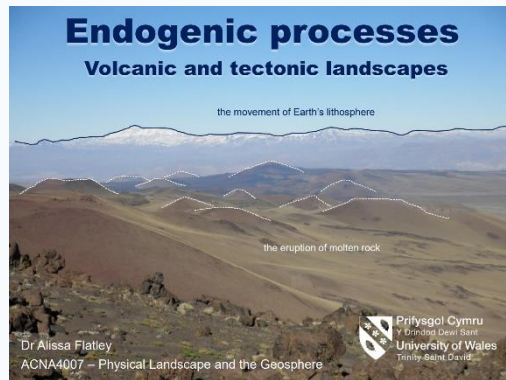
Geochronology is the science of applying dates in the past to rocks. These rocks receive dates because they contain constituents that can be used as chronometers

[Geochronology: It's About Time - Eos](#)



[Geological Basics: the difference between chronology and stratigraphy | Highly Allochthonous \(all-geo.org\)](#)

- Modern landscape processes vs landscape evolution
 - **rates and dates** needed...



???

- Modern landscape processes vs landscape evolution
– rates and dates needed...

Introduction

When did erosion event happen?

3

How long are transport times?

4

1

How fast and when are rocks forming?

How fast are landscapes weathering?

2

How fast are landscapes eroding?

When sediment deposition happen?

5

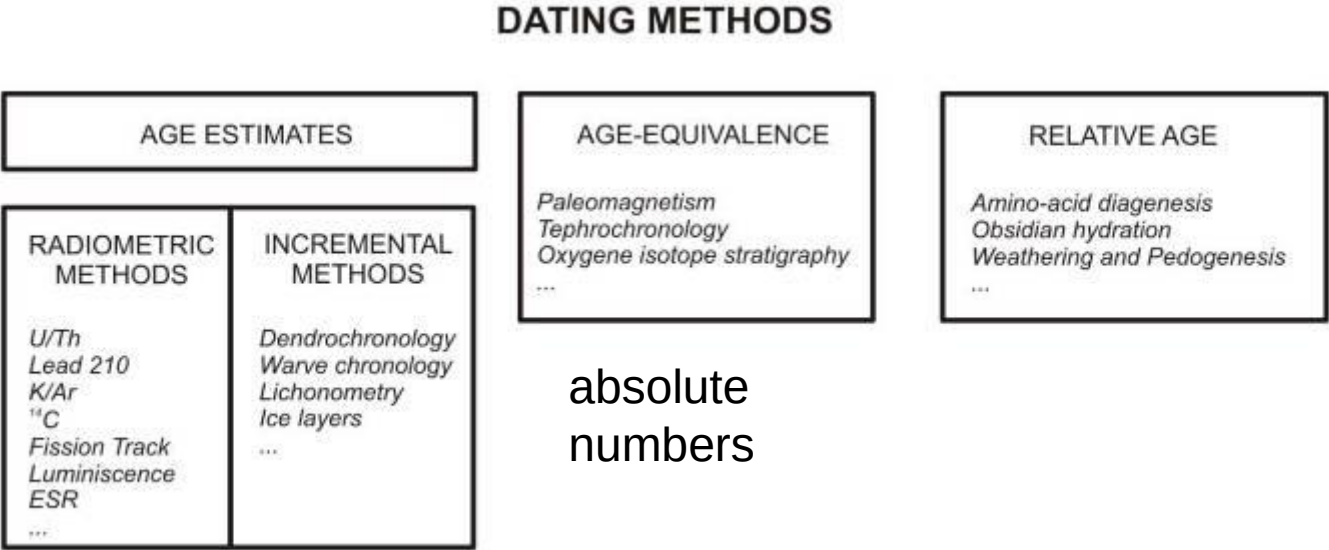
When did organism die?

1. Rocks...
2. Weathering
3. Erosion
4. Transport
5. Deposition

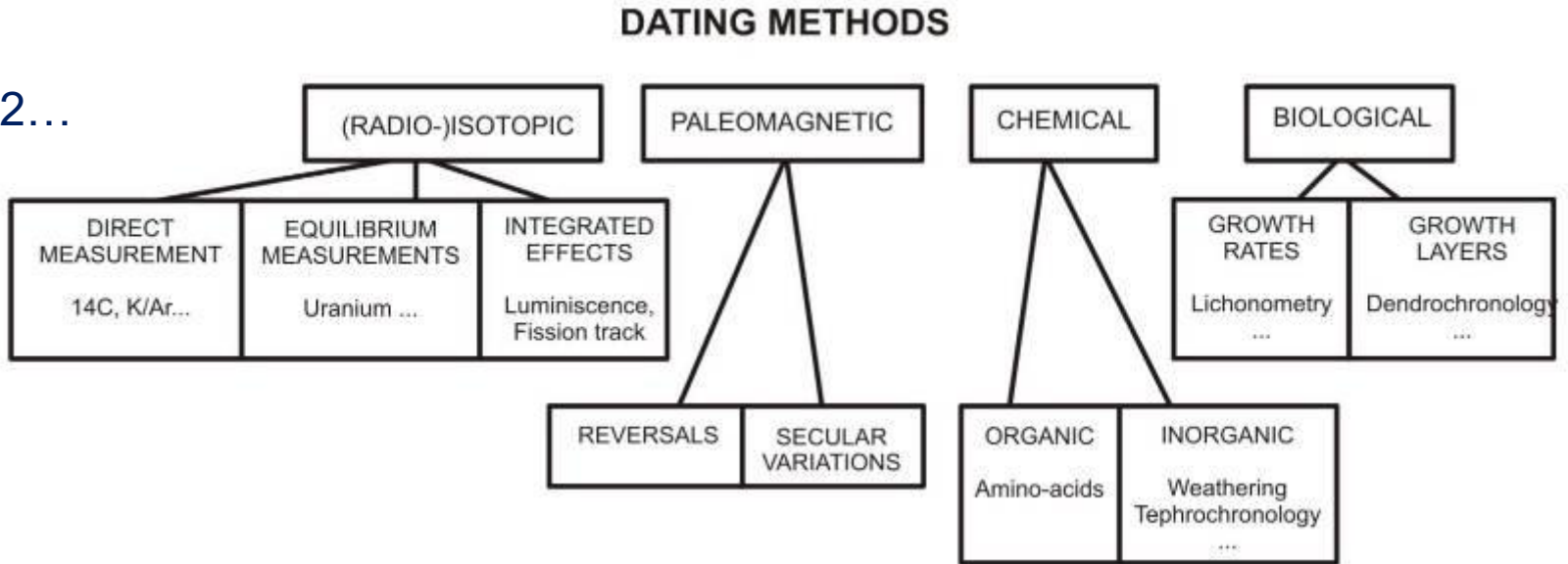
↓
geochronology
toolbox



1...



2...



Introduction



neither
accurate nor
precise



accurate but
not precise

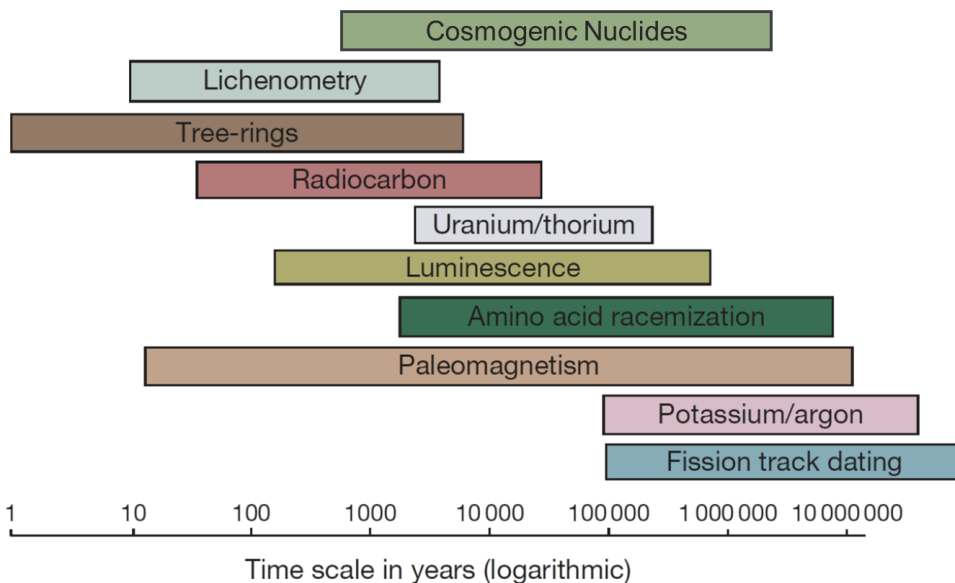
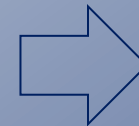


not accurate
but precise



accurate and
precise

1. How good is the date – how large is the error... ?
(accuracy vs precision)



2. How good is the record
(temporal resolution)...

3. Is my timescale covered...



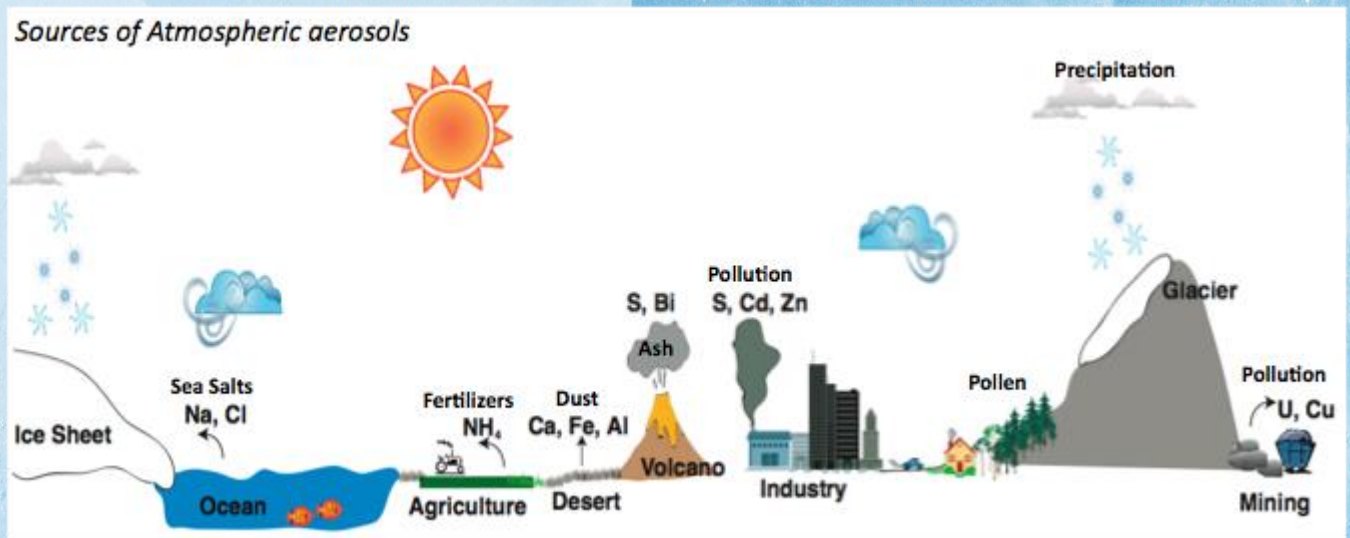
Tree-rings of
Huon Pine,
Tasmania

Climate records from ice cores

What is ice chronology? Why ice cores?

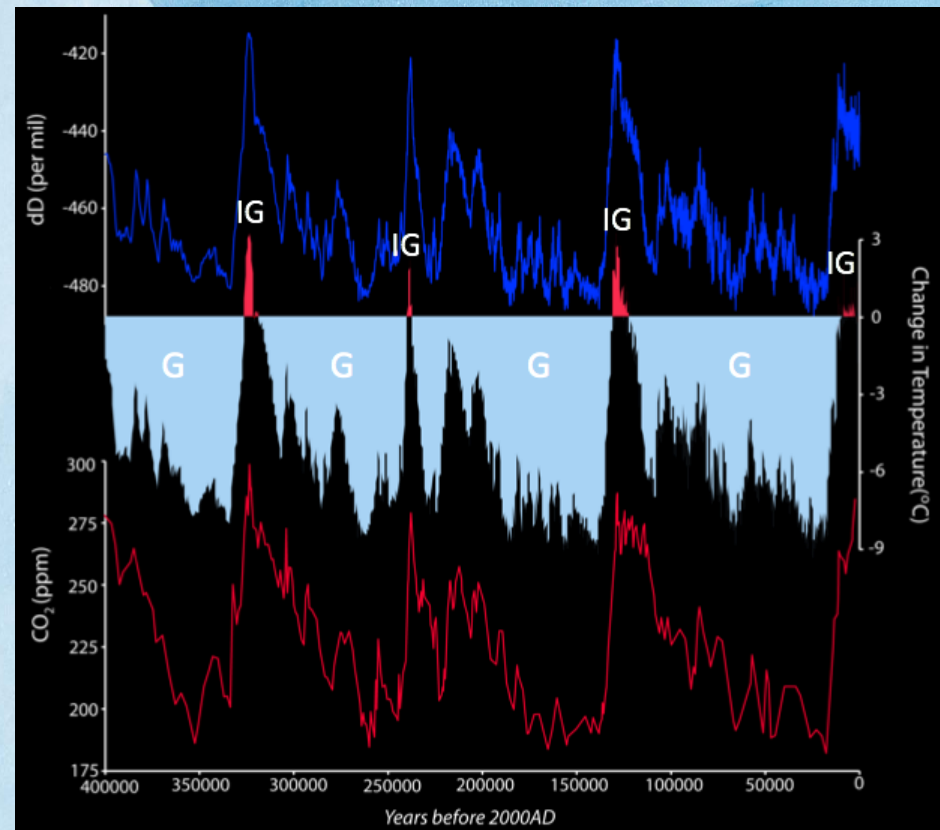


- Ice core records provide the most direct and detailed way to investigate past climate and atmospheric conditions.
- Snowfall that collects on glaciers each year captures atmospheric concentrations of dust, sea-salts, ash, gas bubbles and human pollutants.

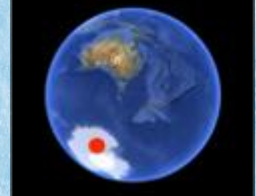


Climate records from ice cores

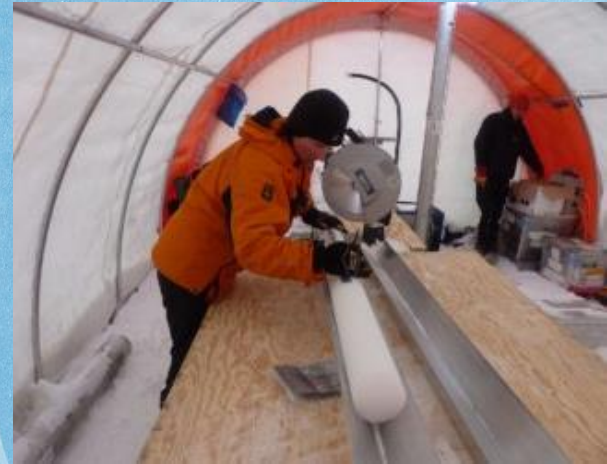
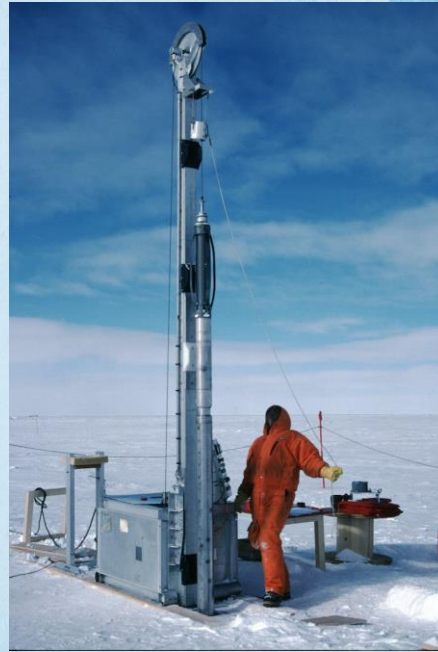
- Ice sheets contain a record of hundreds of thousands of years of past climate, trapped in the ancient snow.
- Scientists recover this climate history by drilling cores in the ice, some of them over 3,500 meters (11,000 feet) deep.



Vostok Ice Core



Collecting ice cores

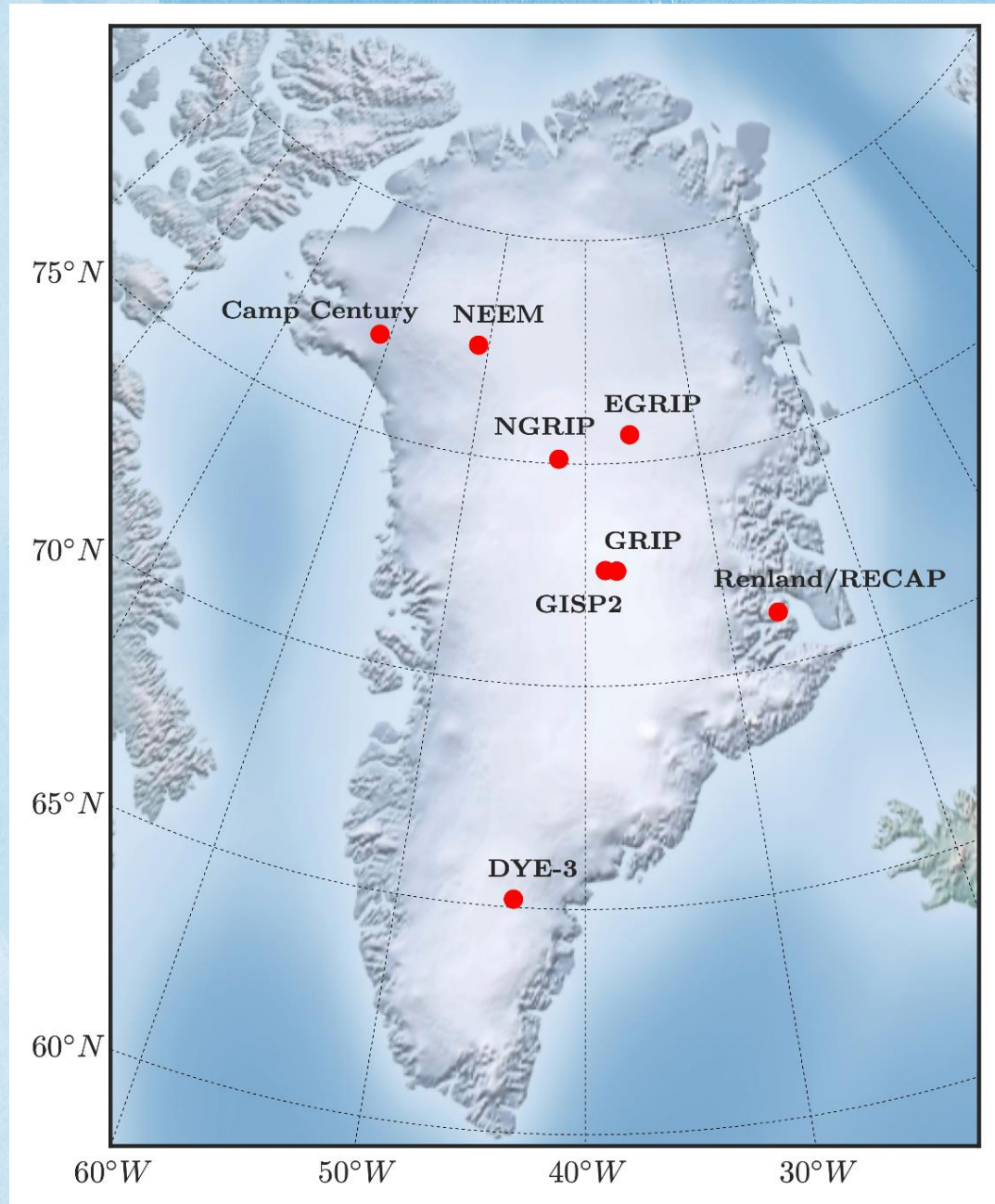


Ice core records

Greenland



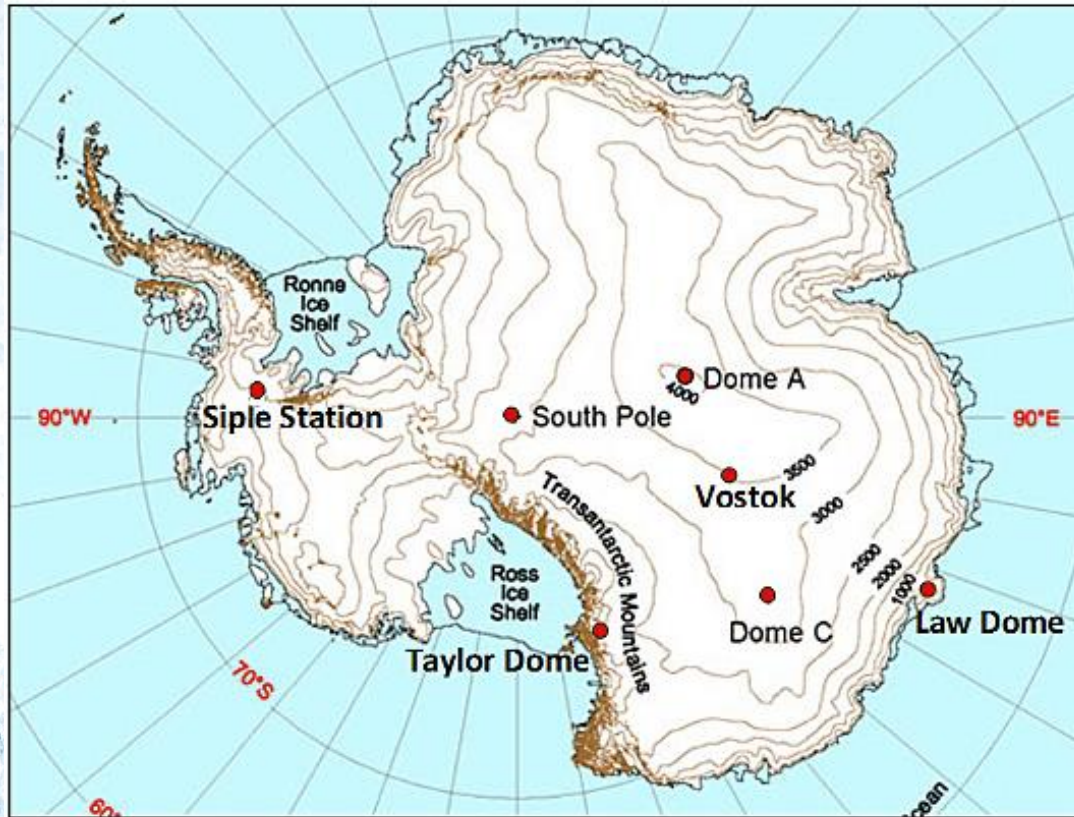
Back to 123,000 years (the last interglacial), around 3 km long



Ice core records

Antarctica

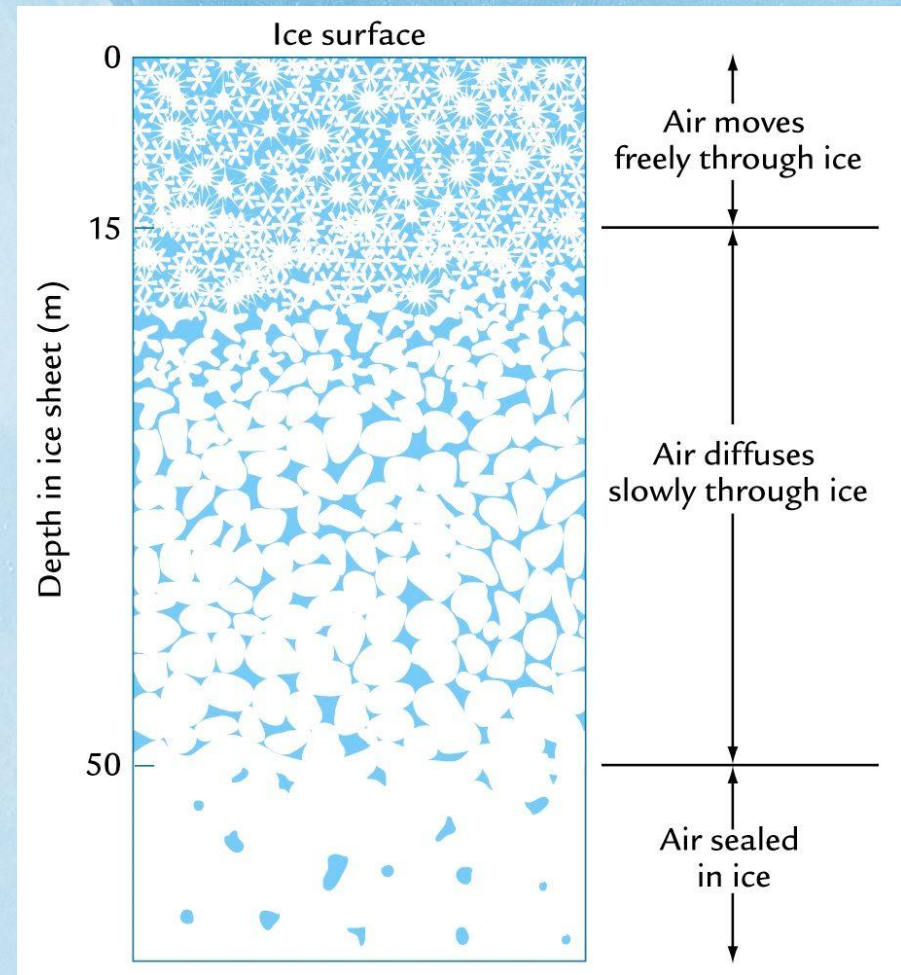
- Currently back to 800,000 years
- Soon to be 1.5 million years!
- Multiple glacial-interglacial cycles



Also mountain glaciers in the Andes, Himalaya, Rockies, Alps, going back 10,000s years

Climate records from ice cores

- Snow accumulates layer by layer in ice sheets and glaciers
- Preserves air bubbles and water that fell as snow



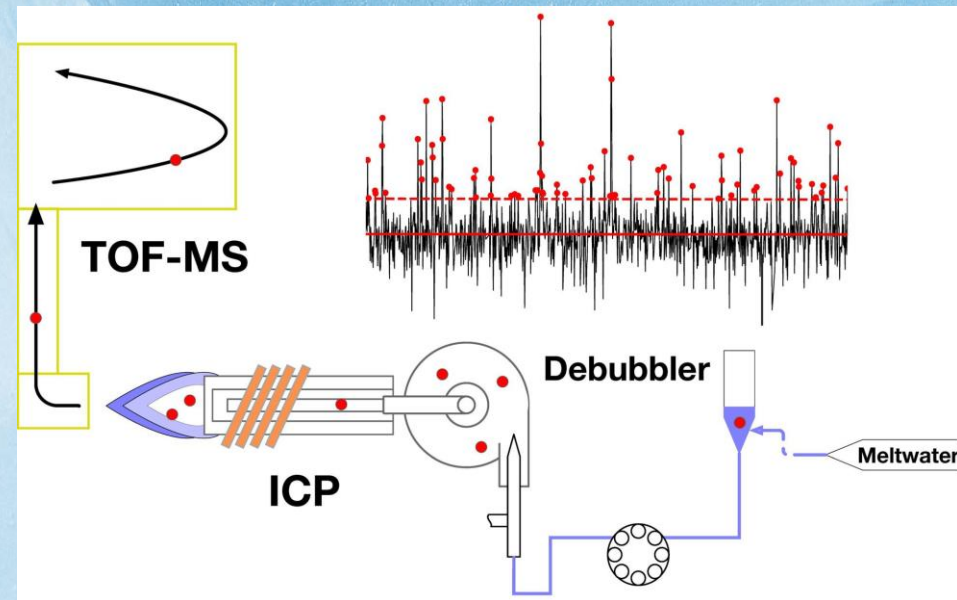
Air bubbles are younger than the ice

[Putting the time in time machine: Methods to date ice cores | PAGES \(pastglobalchanges.org\)](https://pages.pastglobalchanges.org/)

Climate records from ice cores

The measurement of the gas composition is direct: trapped in deep ice cores are tiny bubbles of ancient air, which we can extract and analyze using mass spectrometers.

<https://youtu.be/0KwFpICNV08>



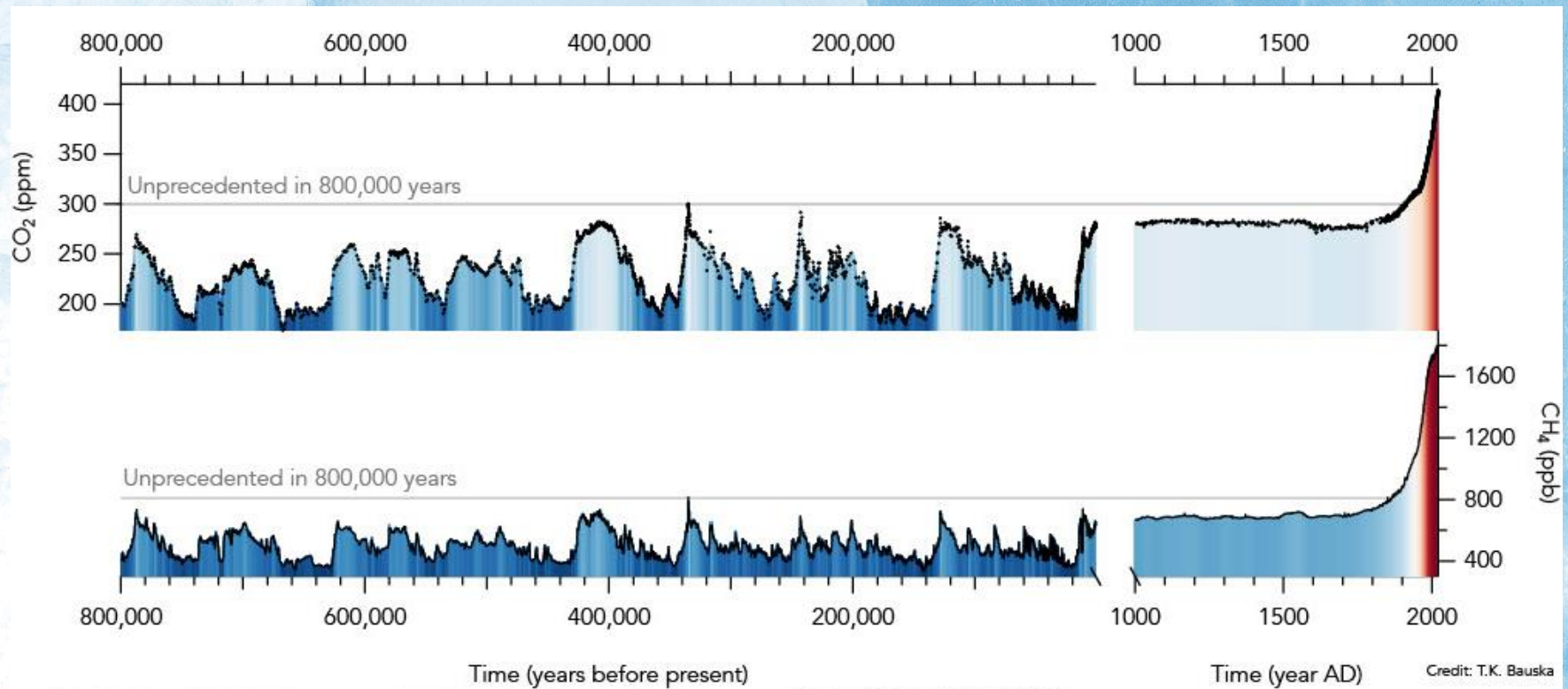
Climate records from ice cores



Air bubbles in ice

What is happening in the atmosphere at that time?

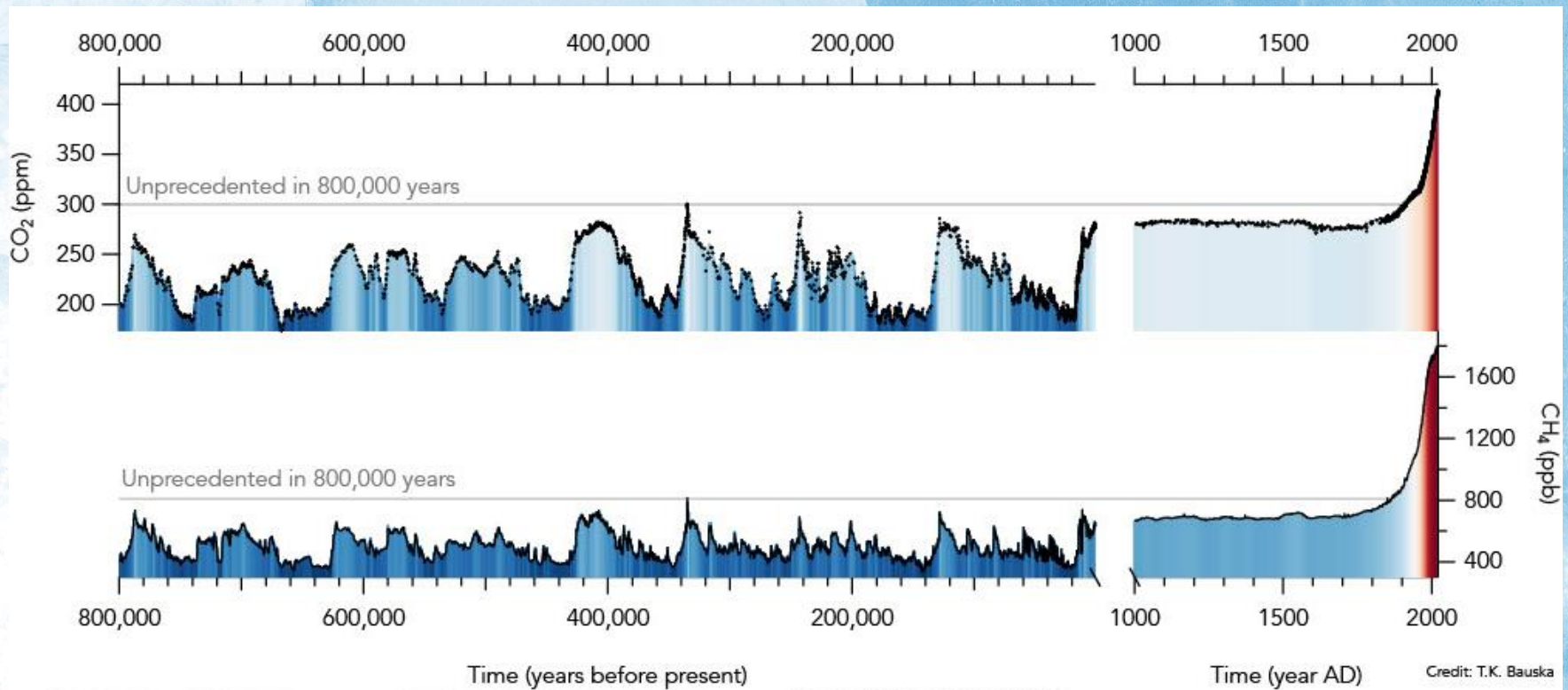
- Air bubbles in the ice preserve a sample of the past atmosphere
- A direct measure of past CO₂ and methane CH₄



[Ice cores and climate change - British Antarctic Survey \(bas.ac.uk\)](http://bas.ac.uk)

Air bubbles in ice

- Air bubbles in the ice preserve a sample of the past atmosphere
- A direct measure of past CO_2 and methane CH_4



[Ice cores and climate change - British Antarctic Survey \(bas.ac.uk\)](http://bas.ac.uk)

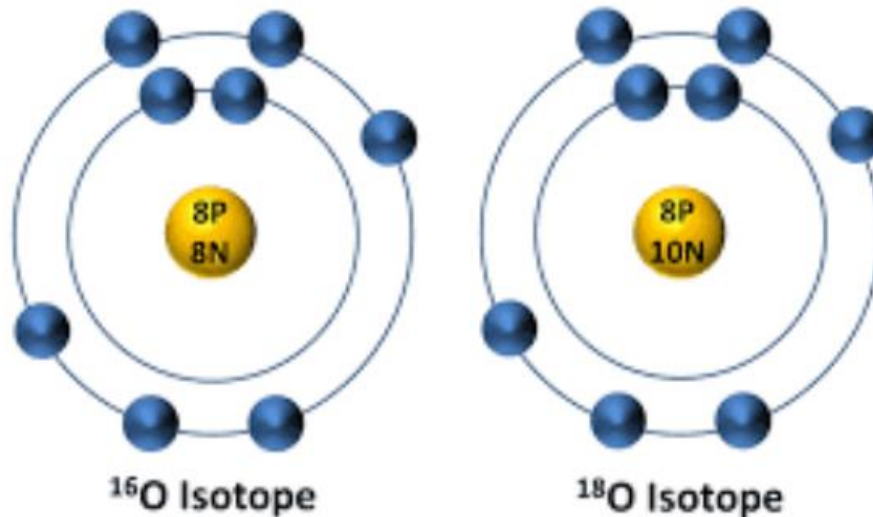
What about temperature?

Proxy Data and Past Climate

Another type of proxy data from ice cores is the chemical composition of the water itself. Temperature, in contrast, is not measured directly, but is instead inferred from the **isotopic composition of the water molecules** released by melting the ice cores.

Oxygen isotopes contain different numbers of neutrons in the atom nucleus that make them lighter or heavier.

Oxygen Isotopes



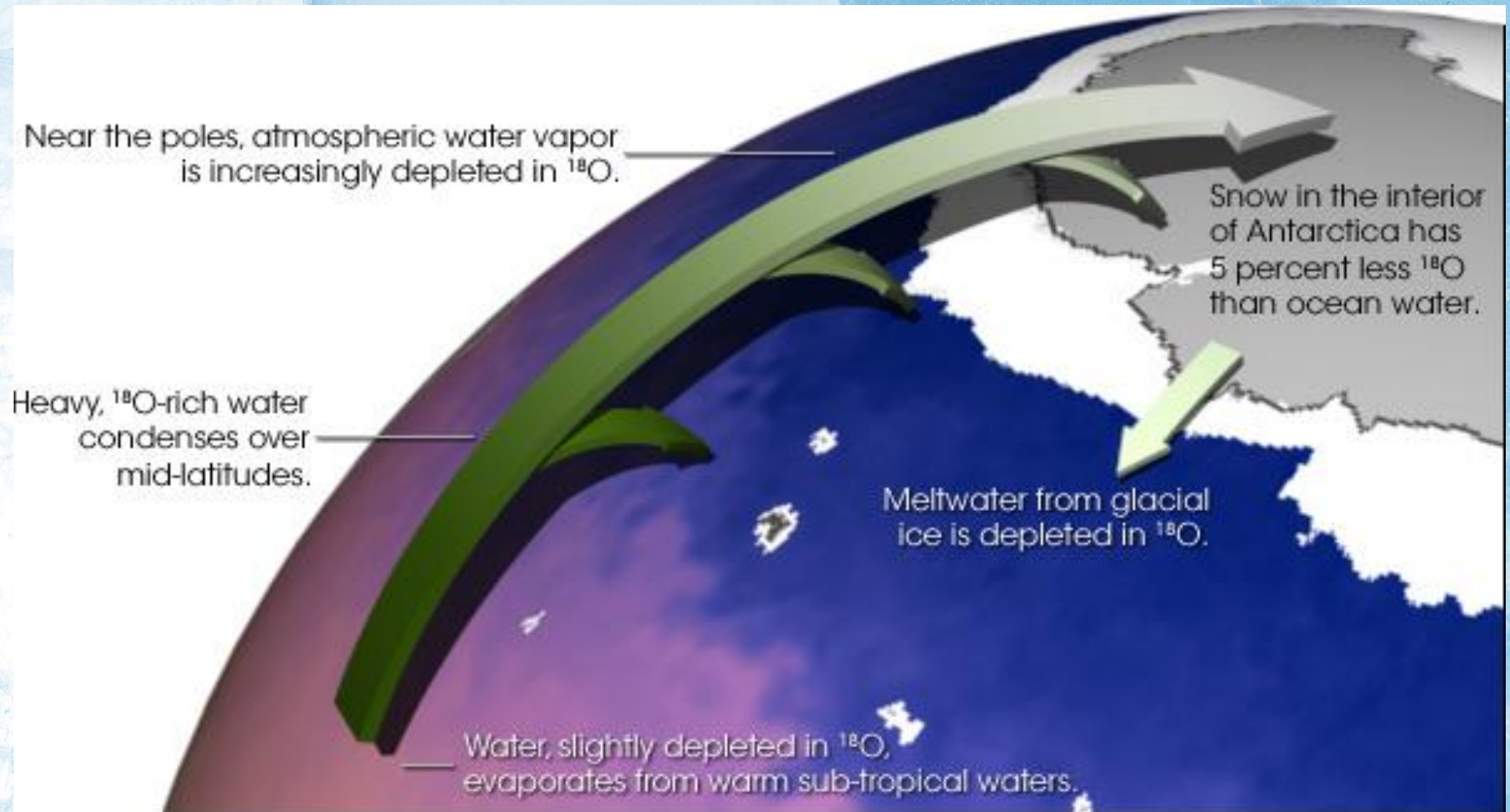
Lighter = ^{16}O

^{18}O = Heavier

- Past temperature records have been constructed entirely from the relative amounts of oxygen-16 and oxygen-18 *isotopes*

Proxy Data and Past Climate

- It has been shown that the relative amounts of the different isotopes vary depending on the temperature of the oceans at the time the snow fell.

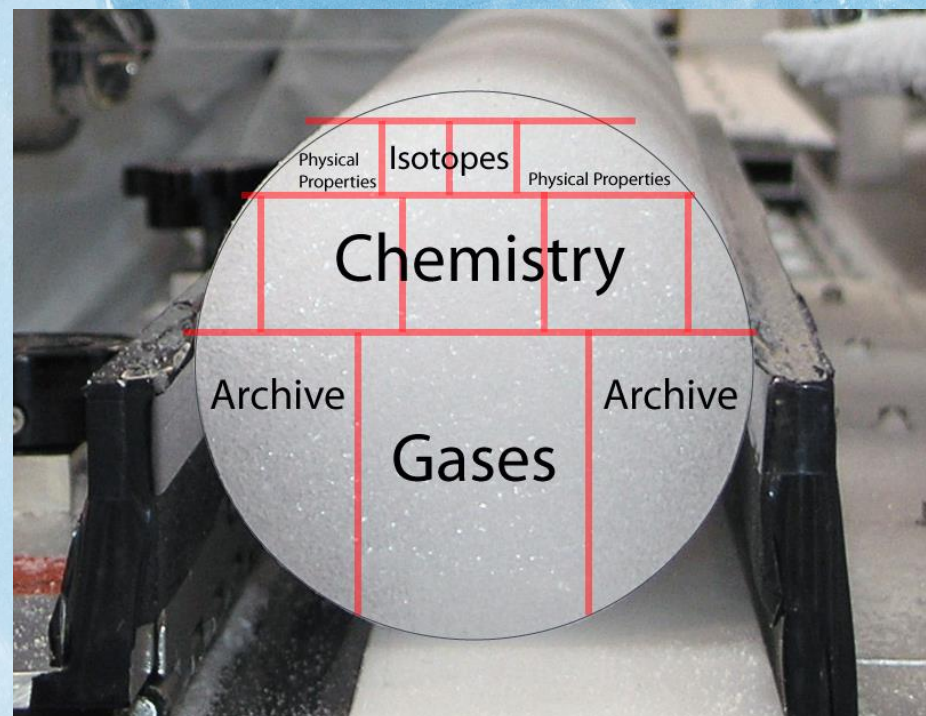


Climate proxies in ice cores

- Oxygen isotope ratio
 - Temperature at the time the snow fell
- Sulphur concentration
 - Volcanic events
- Calcium concentration
 - Atmospheric dust
- Layer thickness
 - Amount of precipitation

Ice cores preserve up to seasonal level signals

Typical CPL cut plan for a large multi-investigator ice coring project. —[Credit: NICL-Science Management Office](#)

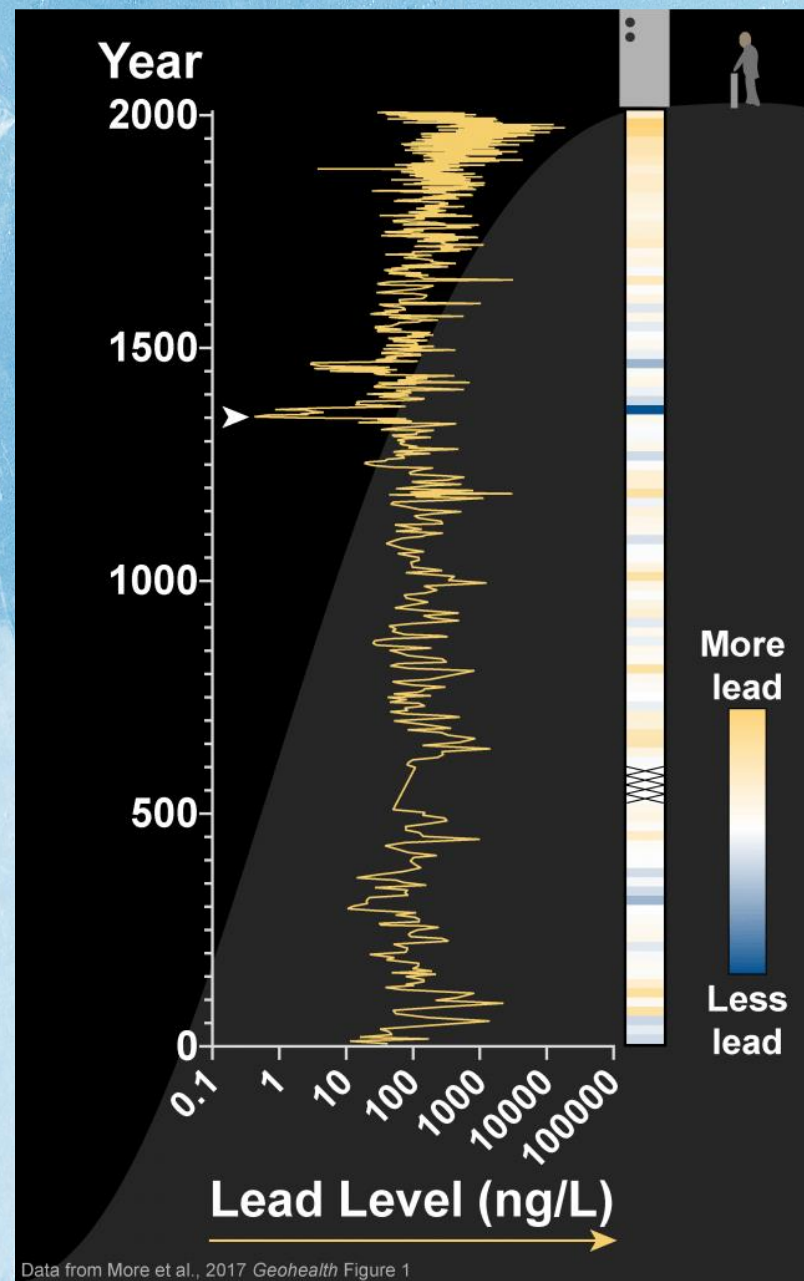
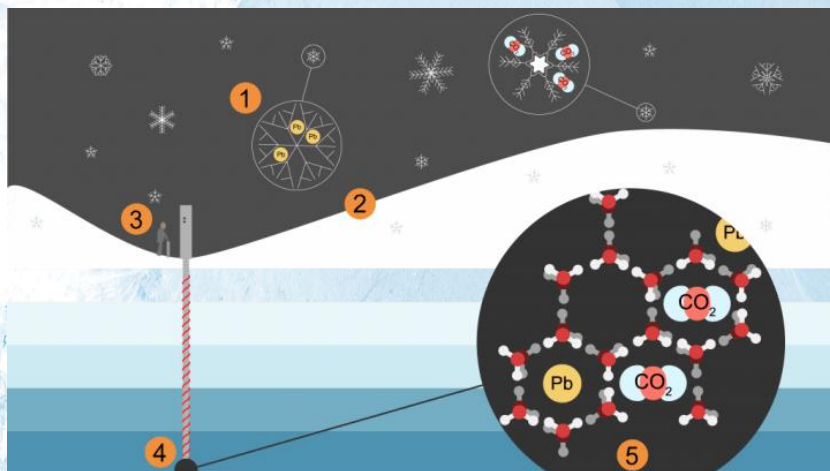


Lead Concentrations and Romans / Middle Ages

- Lead Concentration

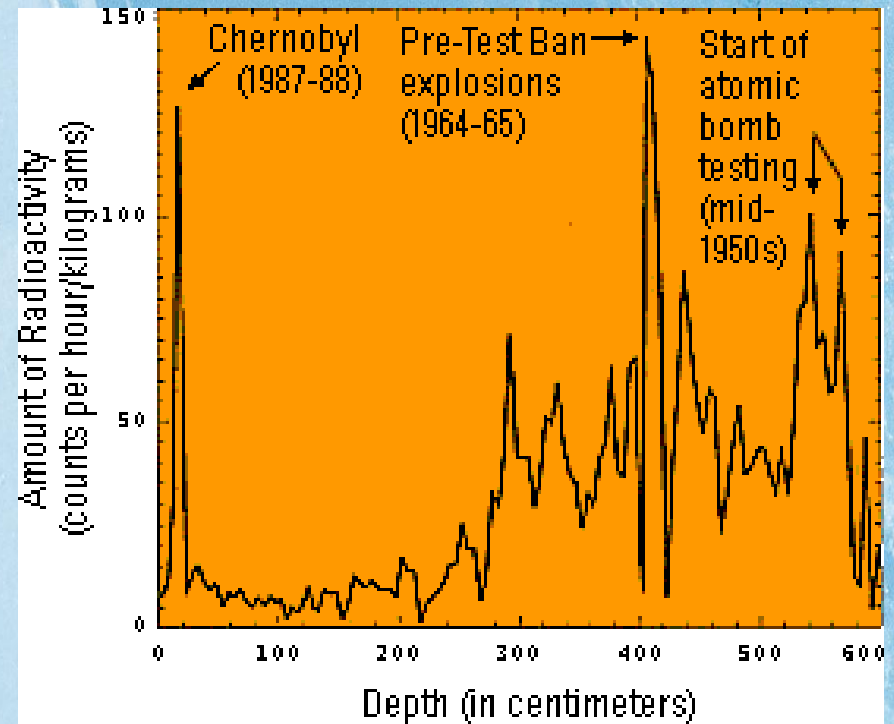
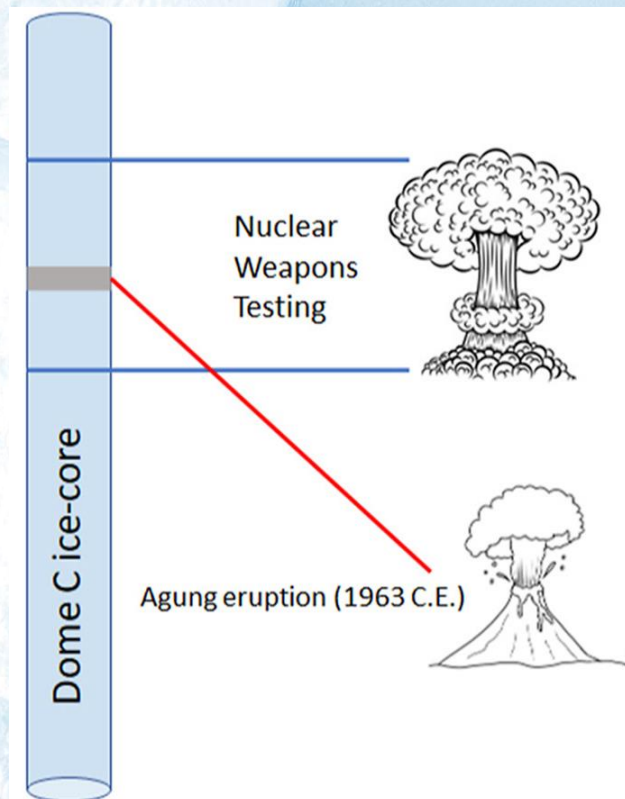
Lead pollution and climate in the Middle Ages

[Ice Cores and Roman Lore: Modern climate science helps scientists and historians piece together the past - Science in the News \(harvard.edu\)](#)



Climate proxies in ice cores

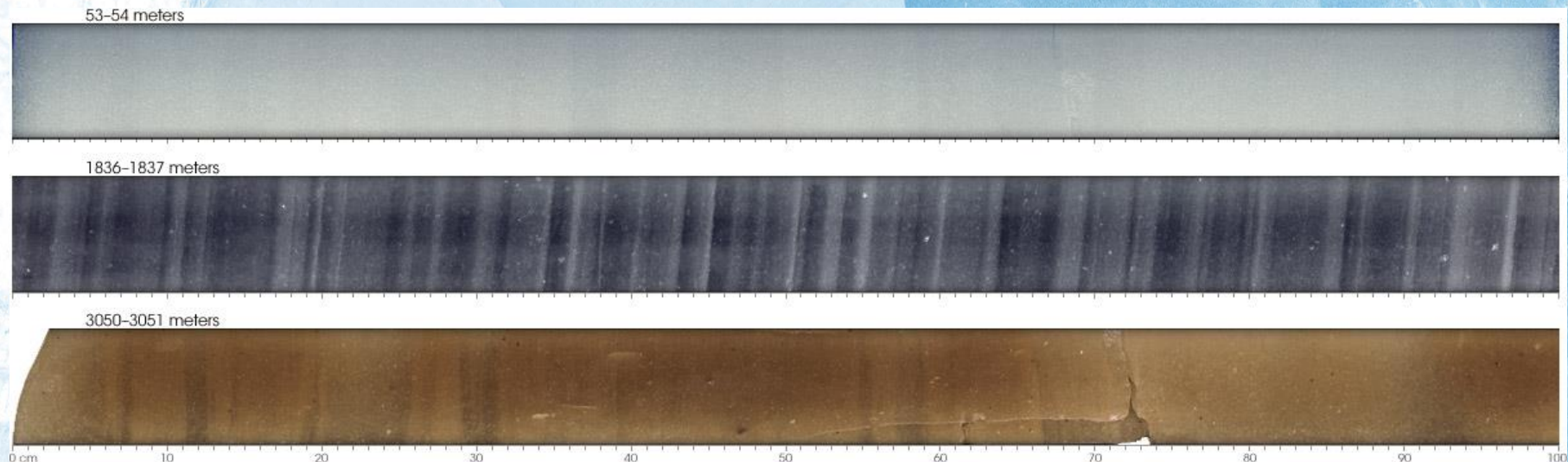
- One such test is an analysis of the strontium-90 (^{90}Sr) and cesium-137 (^{137}Cs) content. These radioactive elements were part of the nuclear fallout during the 1950's nuclear bomb testing in the Pacific Ocean.
- By pinpointing the depth in the ice of high levels of strontium-90 and cesium-137, scientists can in turn date the ice at that point as being the year of the nuclear testing (1955).



[what's up with the weather: stories in the ice \(pbs.org\)](http://www.pbs.org/what's_up_with_the_weather/stories_in_the_ice)

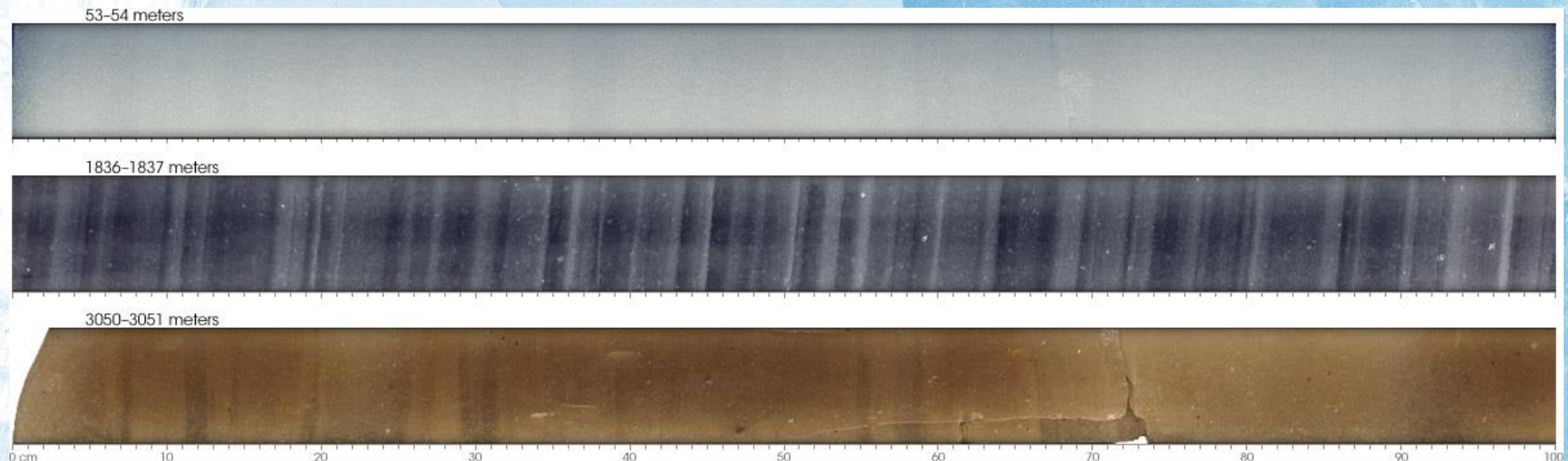
Annual Layer Counting

- A method to develop an ice chronology is via annual-layer counting, where seasonally varying compounds or properties of ice can be used to identify yearly cycles.
- Water isotopes, dust, and conductivity are commonly used to achieve this.
- Physical properties of ice also aid in this stratigraphy, such as visually distinct winter and summer layers due to extreme polar seasons.



Annual Layer Counting

- Snowfall differs depending on whether it falls in summer (when snow is comparatively warm and moist) or winter (when snow is cold and dry).
- These differences mean that when snow turns into ice, on the surfaces of glaciers and ice sheets, it is possible to see distinct annual layers.
- The layers are in a sense similar to tree rings: thick annual layers mean high snowfall, and thin annual layers mean low snowfall.



Annual Layer Counting

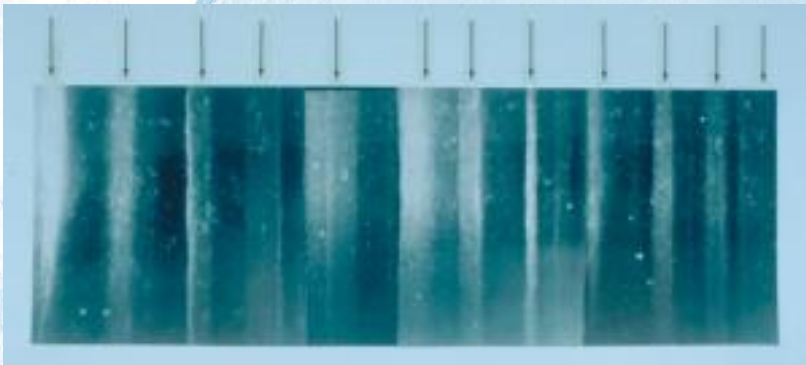
Summer snow tends to be coarser, creating layers that are less tightly packed

Winter snow tends to be more fine-grained, and so it is more easily compacted by overlying snow or wind.

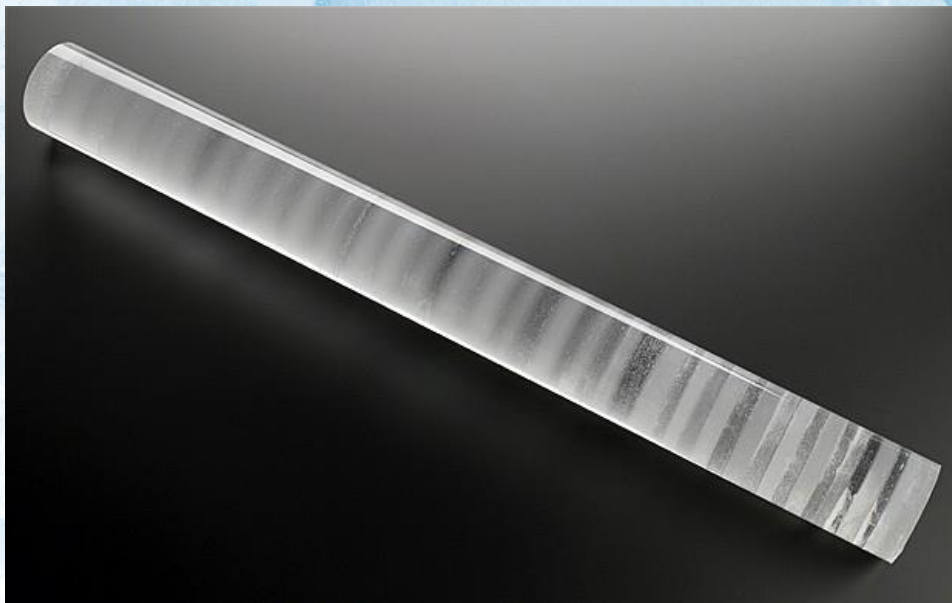
Because of the compaction, winter snow layers tend to be darker than summer layers.

Lighter layers = summer

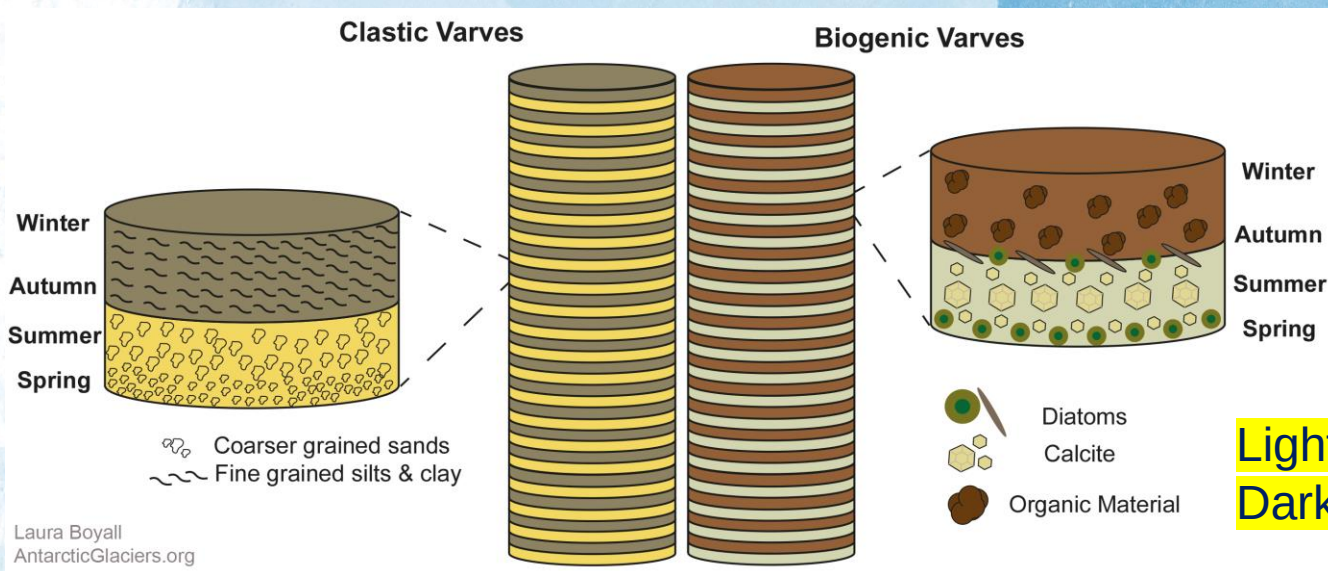
Darker layers = winter



Annual Layer Counting - Thickness



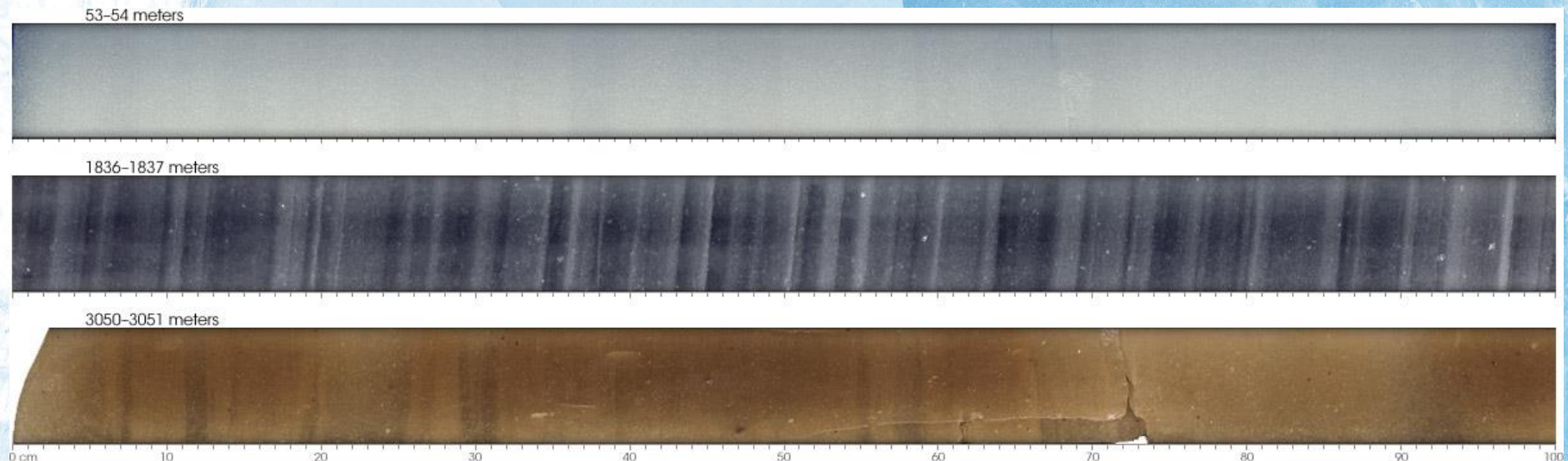
Thickness of annual layers in an ice core is a simple proxy for moisture in the atmosphere at the time snow fell. This is because more snow forms and falls when the air is more moist. A thicker layer means more snow fell, so the atmosphere must have been wetter to form and hold the increased snow before it fell. A thinner annual snow layer would imply the opposite.



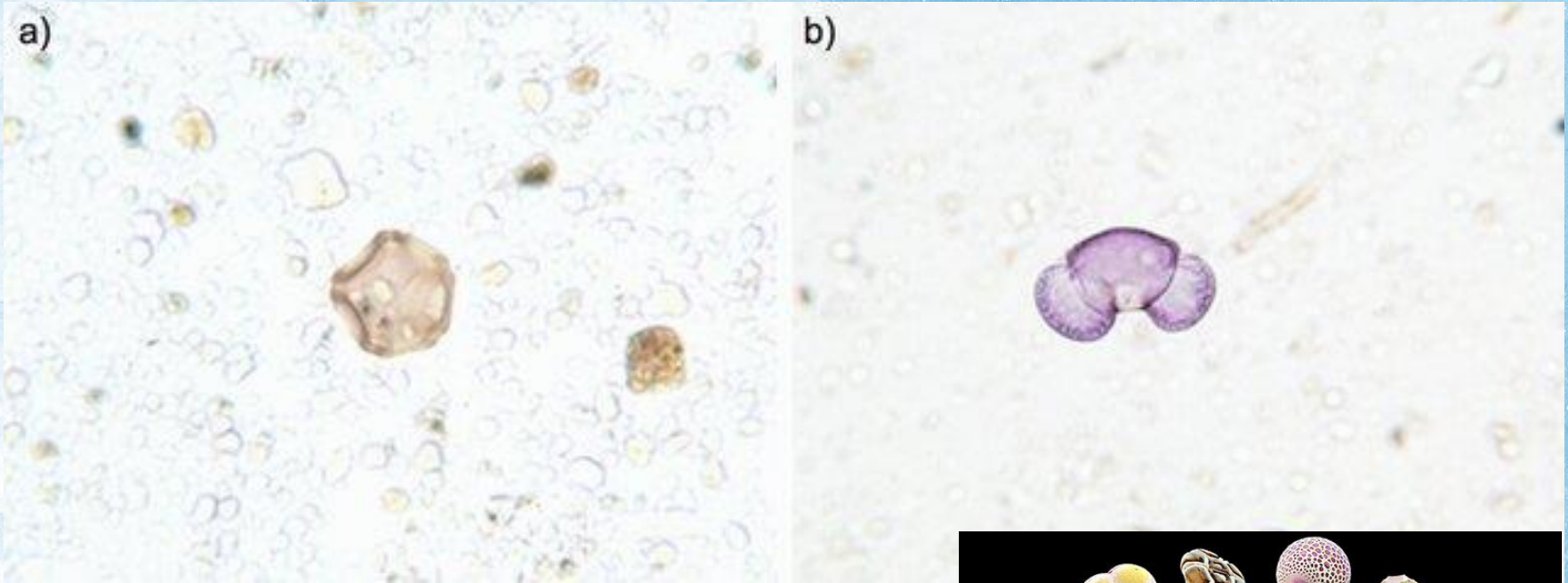
Annual Layer Counting

Annual layers become thinner with depth due to large-scale ice flow, reducing temporal resolution. Deep within an ice sheet, just a few meters can contain thousands of years of snowfall.

Here, other techniques must be used as annual layers become indiscernible and dating becomes challenging.



Proxy Data and Past Climate



There are also many other types of proxy. For example, the types of pollen found in glacier cores, ancient lake and ocean sediments are a proxy for the temperature and rainfall in the area at the time the plants grew.



Ash Layers

- Multiple methods
 - Counting annual layers
 - Modelling ice flow
 - Synchronising to other records
 - Ash layers (tephra) from known volcanic events



Volcanic ash layer

10 km

Ash Layers

Ash from volcanic eruptions becomes trapped in ice sheets along with snow and dust. Scientists use the volcanic ash found in ice cores to date the cores and to estimate the intensity of past volcanic activity.



Volcanic ash (Iceland)

10 km

Summary

- Large ice sheets in Antarctica and Greenland, as well as mountain glaciers, accumulate layer by layer, preserving air bubbles and frozen water
- Climate proxies that can tell us about past temperature, atmospheric greenhouse gas concentration, dustiness and volcanic events for example
- Ice cores can span back to 800,000 years, at up to seasonal resolution
- Ice cores can be dated through a variety of methods, but for older ice this is more complex
- Chronologies are critical to placing ice-core records into a global context, enabling direct comparisons between natural greenhouse-gas variations and records of environmental change in other archives.

Watch

- [Learn about the Australian Antarctic Division's project to collect 1 Million year old ice](#)
- [See how scientists analyse an ice core in the lab](#)
- [Learn all about drilling the new EGRIP ice core in Greenland](#)



Easy reading

- [What are ice cores?](#)
- [Ice-core basics](#)
- [Paleoclimatology: The Ice Core Record \(nasa.gov\)](#)

2 minutes...





Antarctic Lab.pdf

[Evidence | Alfred Wegener: Building a Case for Continental Drift - University of Illinois at Urbana-Champaign](#)

Next week: Geofuture (45mins) and Course recap (1hr)

Geofuture

What will happen to the geosphere in the future?

Dr Alissa Flatley
ACNA4007 – Physical Landscape and the Geosphere



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