ESS 203 - Glaciers and Global Change

Wednesday February 17, 2021

Outline for today:

- Highlights of last Friday's class – *Lynn Nguyen*
- Volunteer for today's highlights on Friday – *Brendan Beaudette*

Assignment

Due Today: HW 17

- Chapter 7 from ***Frozen Earth***

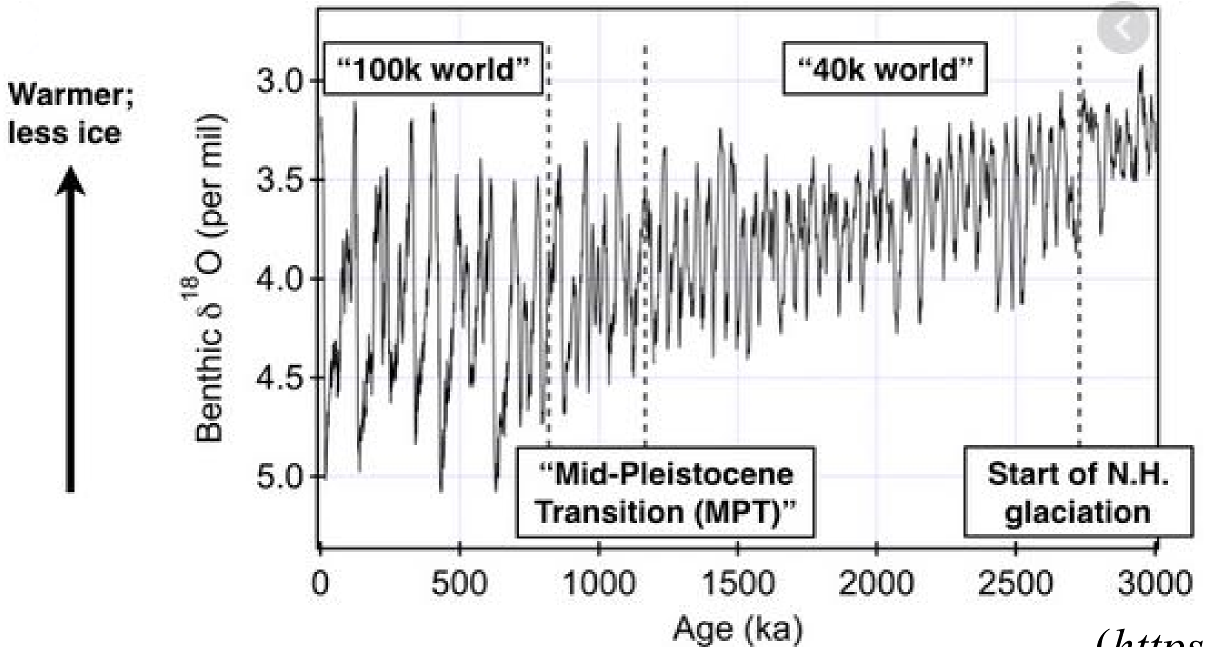
Due Friday: HW 18

- The Mid-Pleistocene Transition (see next slide)

Due Feb 26th:

- Checkpoint 4 (paper outline)

HW 18 – The Mid-Pleistocene Transition (MPT)



(*https://www.yuzheny.com/mpt*)

Ocean-sediment cores show that prior to 1.2 Ma, the ice advanced and retreated roughly every 40 thousand years ("40k world"), but since 1.2 Ma (the Mid-Pleistocene Transition), the cycles changed to every 100,000 years ("100k world"). But ice cores don't go back to 1.2 Ma (yet). What was CO_2 doing?

- See assignment HW 18 on Canvas to address the MPT challenge.

Ice Cores as Paleo-Weather Stations

We're going to focus on three aspects of weather/climate:

1. Temperature ($\delta^{18}O$ proxy)
2. Accumulation Rate (depth-age scale)
3. **Greenhouse gas concentration**

Earth's Atmosphere in the Past

How could we learn about changes in composition of Earth's atmosphere in the past?

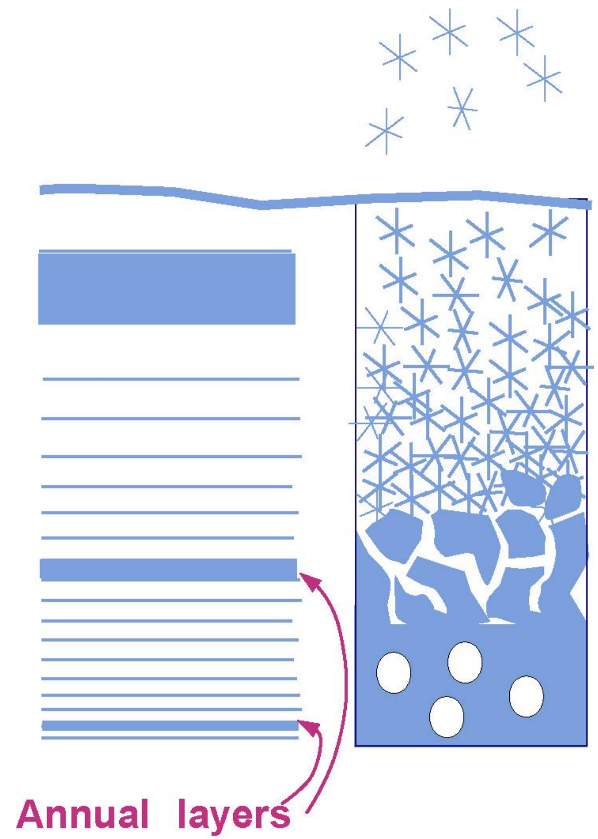
Find bubbles of air trapped in naturally sealed containers.

- Containers must not react chemically with the air.
- Containers must be really well sealed.
- Guess where we can look… Ice Cores!

What can we measure in the air bubbles?

Carbon dioxide: CO_2
(rock weathering, plant growth & decay, ocean uptake)

- Did CO_2 lead or follow temperature changes in pre-industrial times?



Methane: CH_4
(vegetation decay, swamps, termites)

- Why would it change in an Ice Age?

$\delta^{18}O$ of oxygen gas: O_2
(a proxy for plant respiration)

- Respiration removes the lighter ^{16}O in preference to ^{18}O, increasing the relative amount of ^{18}O in the atmosphere.

Global Variation of Records

We know climate changes (e.g. temperature, precipitation, windiness, etc.) and these changes tend to be different at different places on Earth.

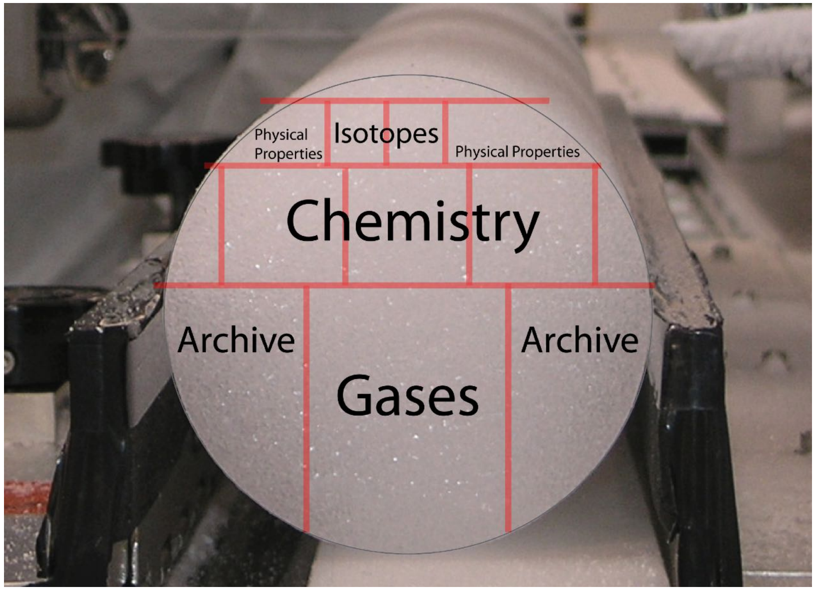
The composition of the atmosphere can also change with time (e.g. CO_2 and CH_4 are rising today), but these changes tend to be relatively uniform across the Earth.

- The atmosphere is well-mixed:
  - CO_2 stays in the atmosphere for 4-200 years
  - CH_4 stays in the atmosphere for ~12 years
  - The atmosphere fully mixes in one year

Why measure gases in every ice core?

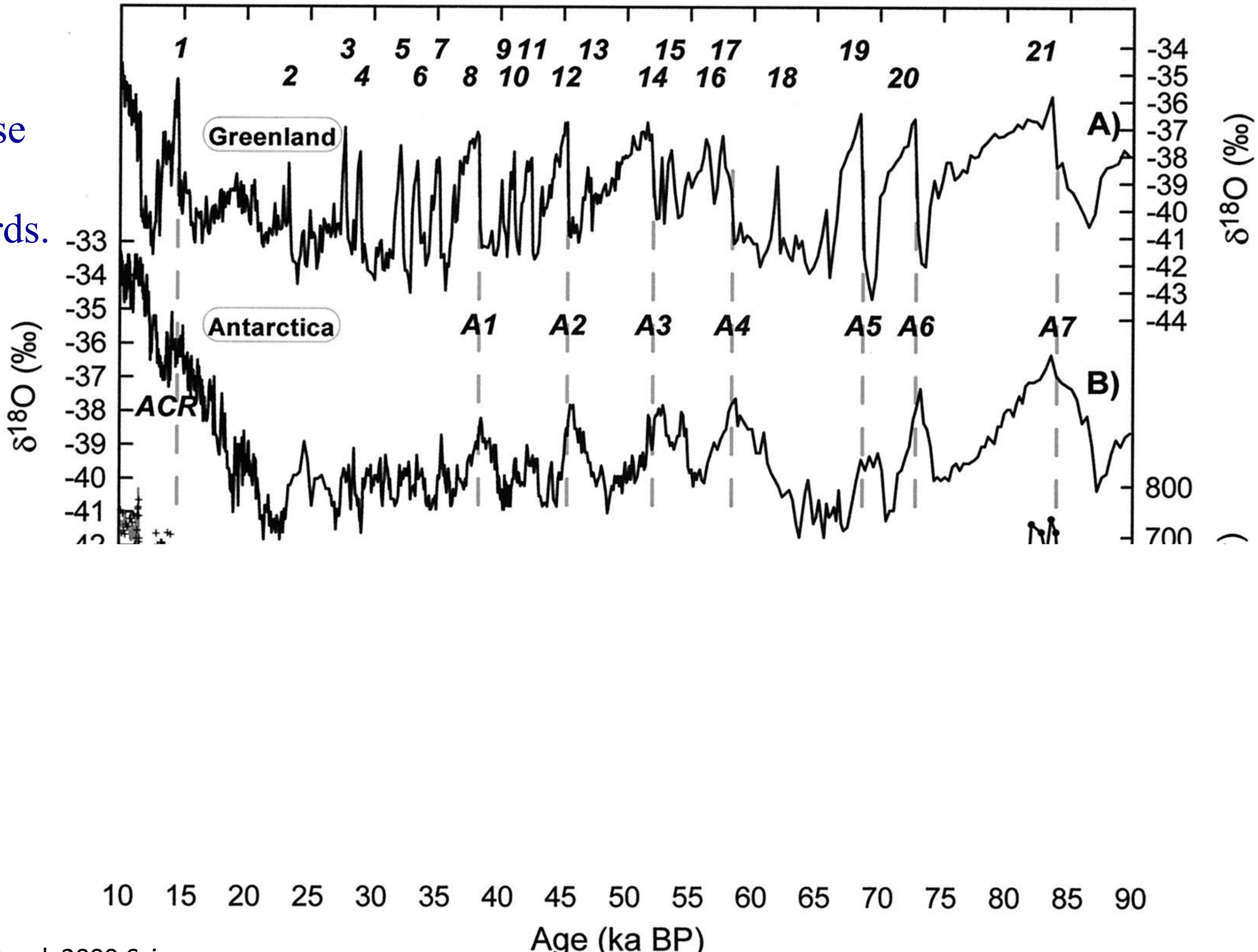
So if you measure gases in one ice core, you know the whole story of Earth's atmosphere.

Yet scientists keep measuring gas from bubbles from more ice cores …



Synchronization of Climate Records

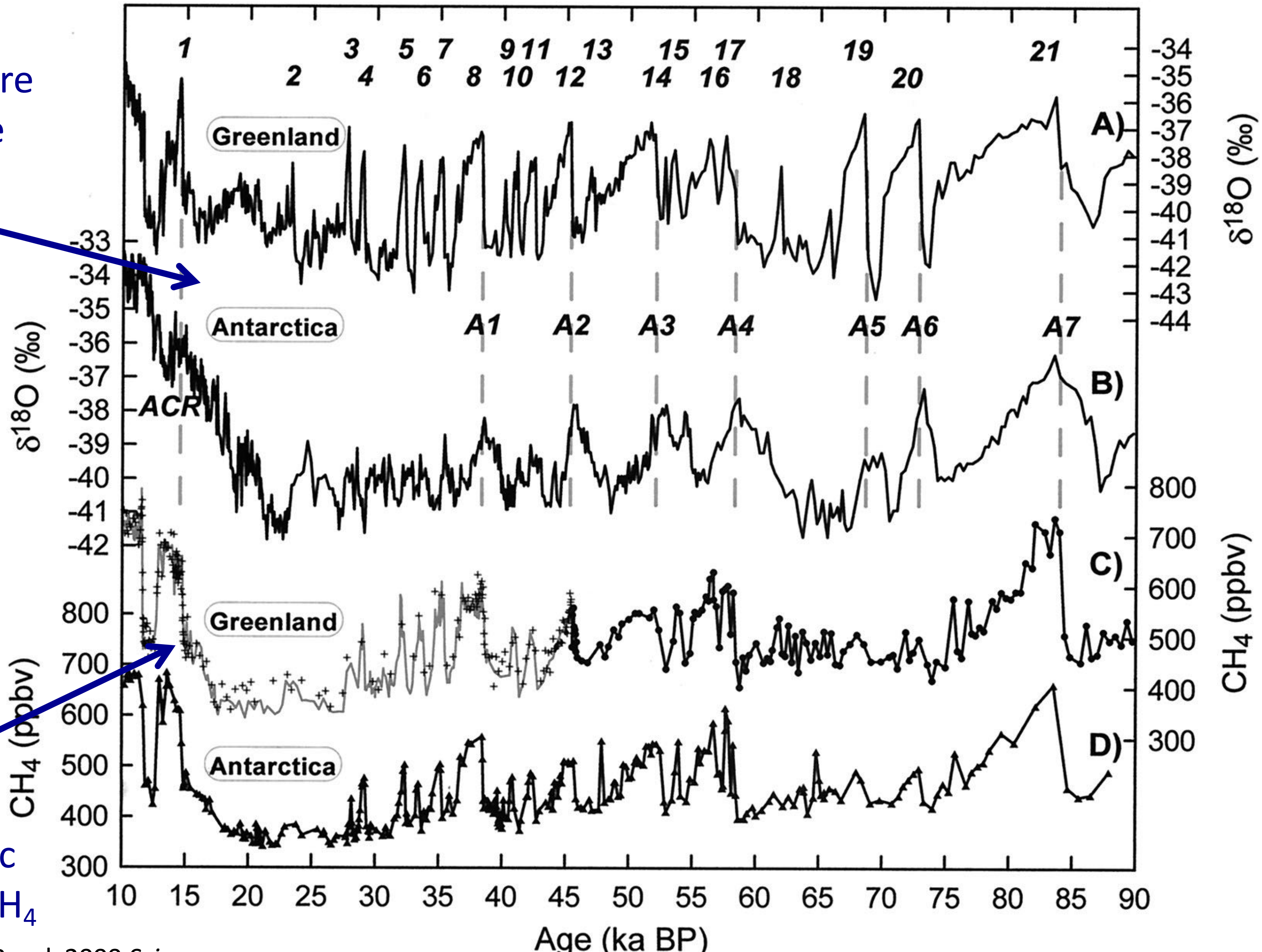
Difficult to compare these two oxygen isotope records.



Blunier and Brook 2000 *Science*.

Synchronization of Climate Records

Then compare temperature records

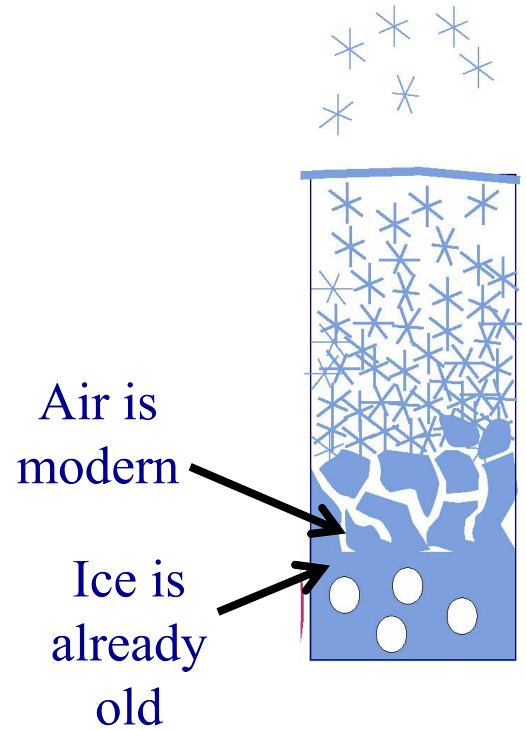


Line up Greenland and Antarctic cores with CH_4

Blunier and Brook 2000 *Science*.

Ice age - Gas age Difference

- The air being trapped today is part of today's atmosphere
- The ice that traps today's air is already old (older than the air)



This offset in age is called the "*ice age-gas age difference*" or *"Δage"* and it can be 100s to 1,000s of years

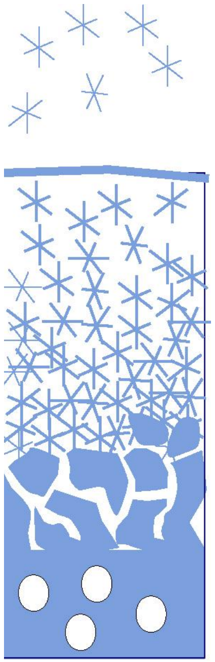
This complicates ice core synchronization because…

If we don't know *Δage*, then synchronizing gas records won't help synchronize the ice records.

How do we learn the age of the gas?

Scientists know:

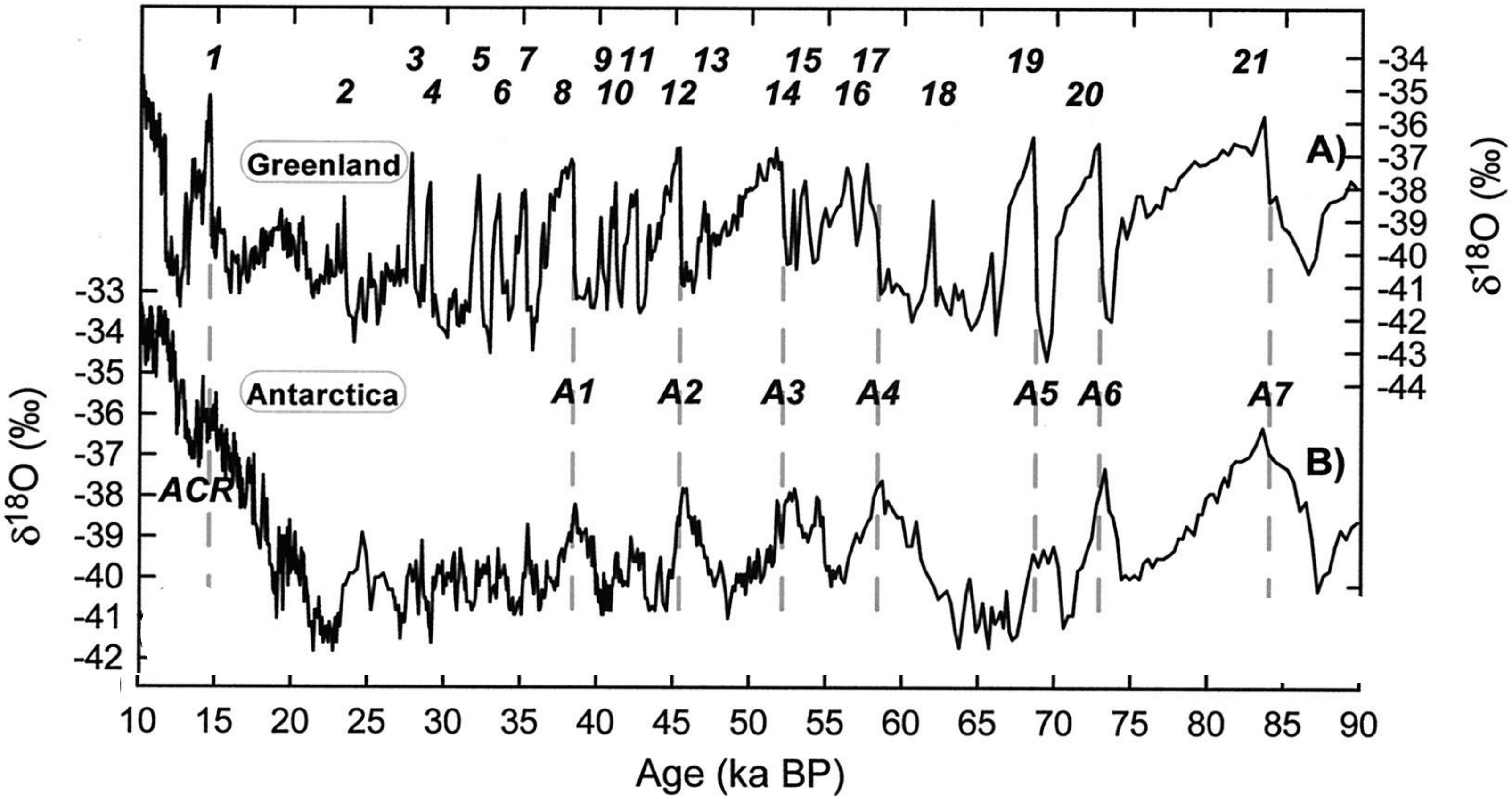
- Δage depends on the speed of snow compression
- speed depends on temperature and accumulation rate



Would you expect Δage to differ between ice ages and interglacial times?

An active area of research is figuring out Δage with a small enough uncertainty to ***understand the timing of climate change between the Northern and Southern hemispheres*** and to ***figure out what aspects of climate change first and "drive" the other changes***.

Gas-based North-South Temperature Correlation



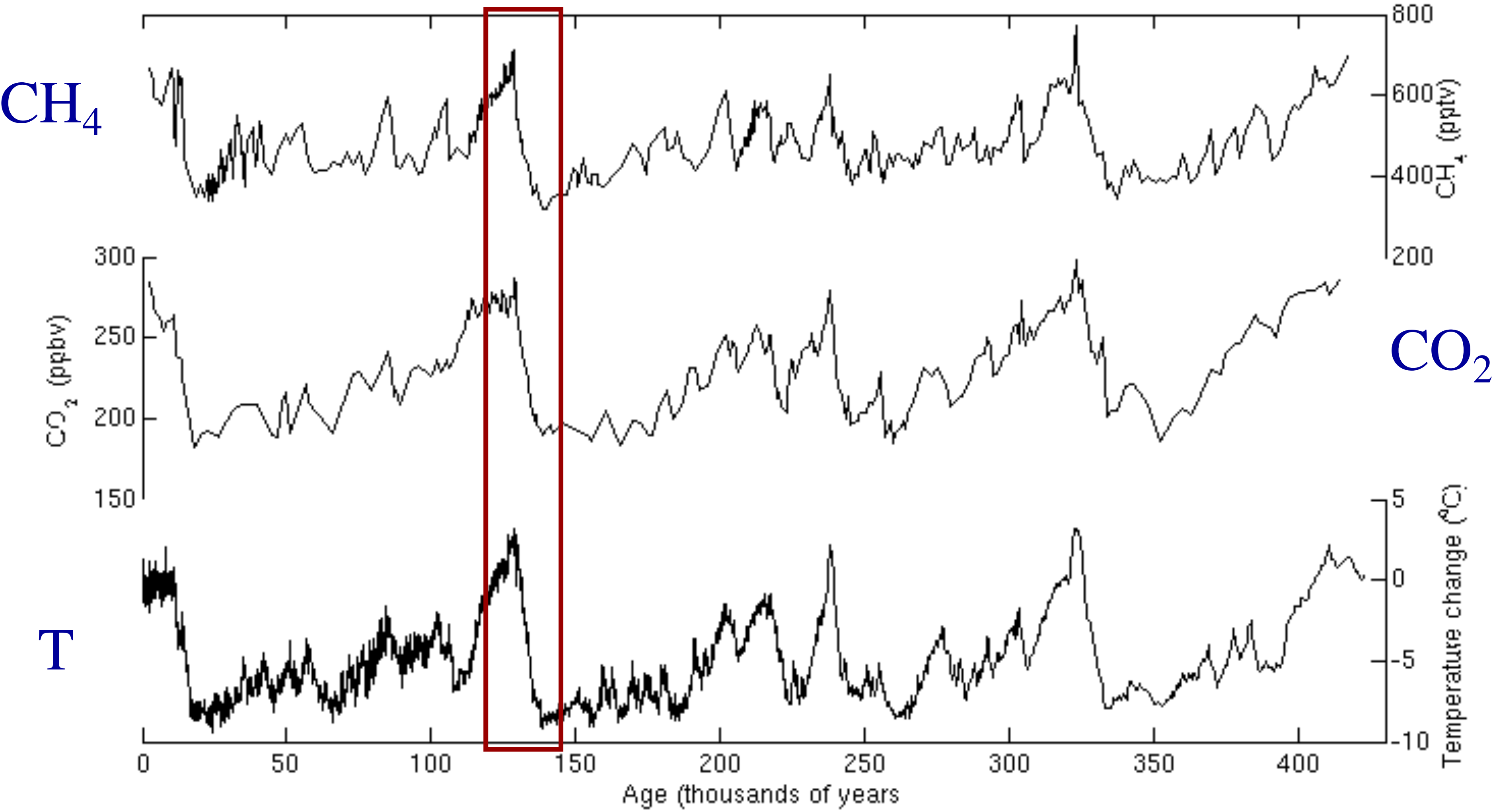
What's the relationship?

- Antarctica warms first.

- Both North and South see the big events.
- Climate changes were faster and larger in Greenland.

Blunier and Brook 2000 *Science*.

Greenhouse Gases and Ice-Age Temperature



Vostok ice core