Paleoclimatology

ATMS/ESS/OCEAN 589

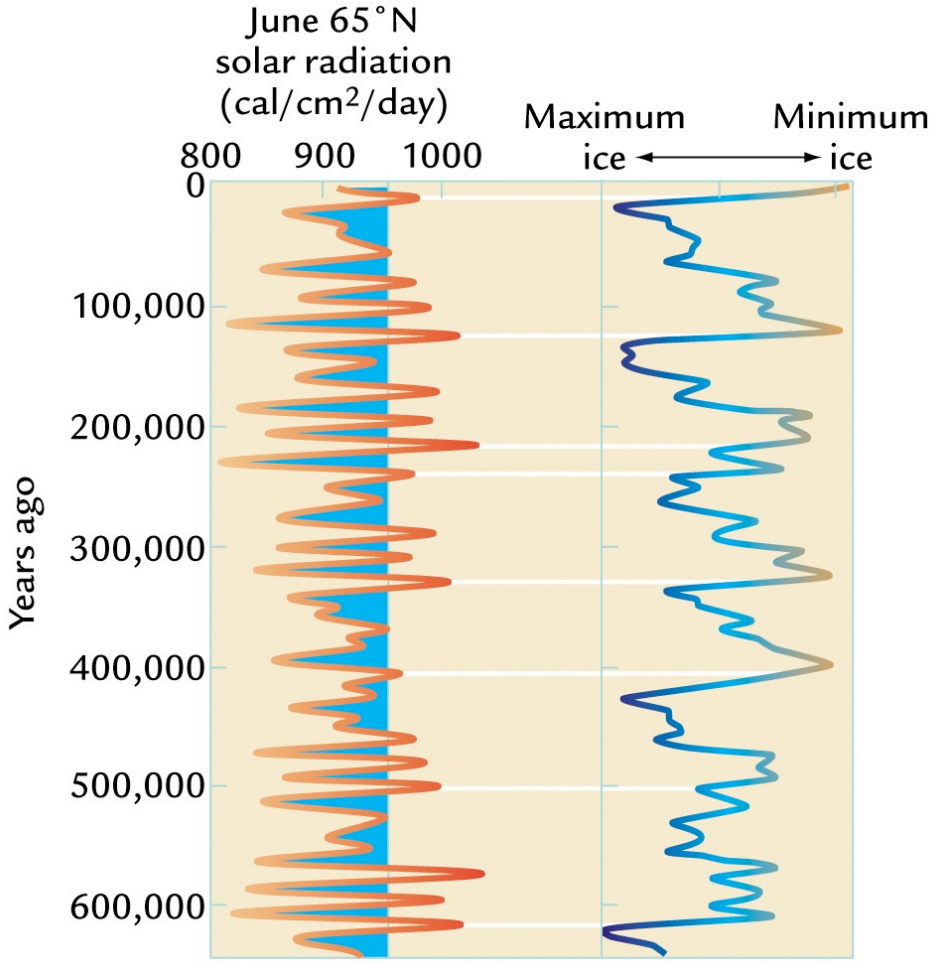
- **Ice Age Cycles**
  - Are they fundamentaly about ice, about CO2, or both?
- **Abrupt Climate Change During the Last Glacial Period**
  - Lessons for the future?
- **The Holocene**
  - Early Holocene vs. Late Holocene
  - The last 1000 years: implications for interpreting the recent climate changes and relevance to projecting the future climate.

Website: faculty.washington.edu/battisti/589paleo2005

Class email: ess589a_au05@u.washington.edu

Theory of the Ice Ages:

Orbital induced insolation changes and global ice volume

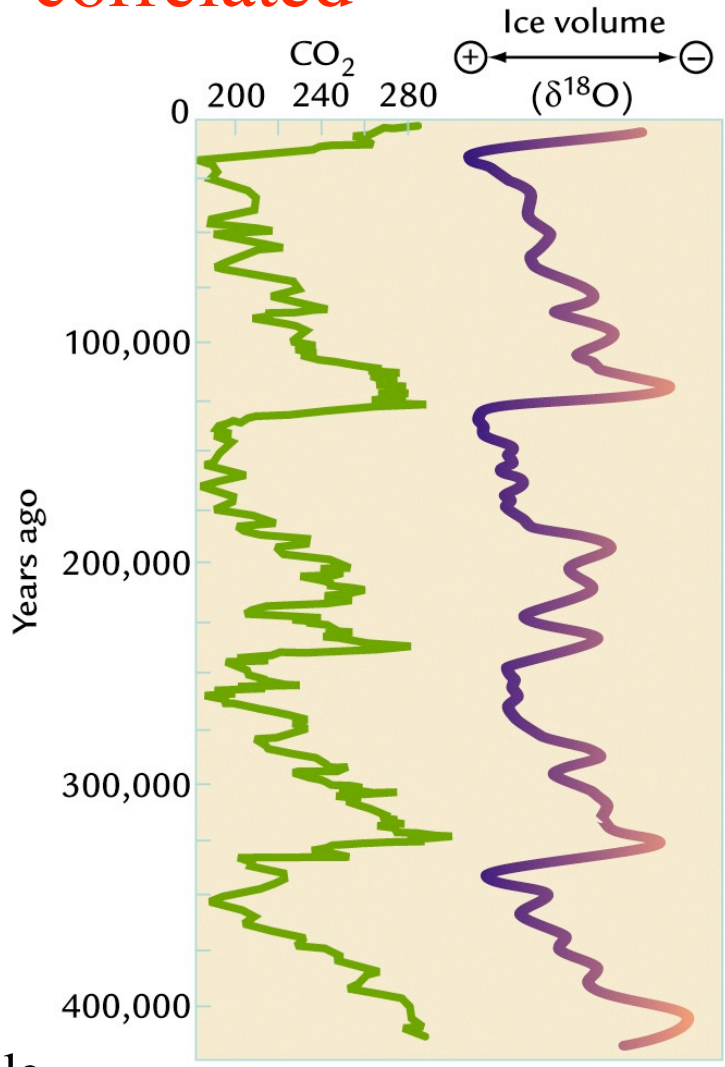


"Strong summer insolation peaks pace rapid deglaciation"

Theory of the Ice Ages:

Ice Volume and Atmospheric Carbon Dioxide are highly correlated

- Summer (NH) insulation tends to lead ice volume.
- Ice Volume and Carbon Dioxide seem to be in phase (except for in rapid deglaciation, when Ice volume leads Carbon Dioxide)



CO_2 measured at Vostok, South Pole

The Ice Age Cycles:

Some big unsolved questions we will examine

- Is the Ice Age cycle fundamentaly about cycles in ice volume induced by high latitude insolation changes (with CO_2 being a weak positive feedback)?
- Or, is the Ice Age cycle fundamentally about changes in CO_2 that are driven by insolation changes (with weak positive feedbacks associated with ice albedo feedbacks)?
- Why do (high latitude) insolation changes cause changes in atmospheric CO_2? Why is it CO_2 so highly correlated with ice volume?

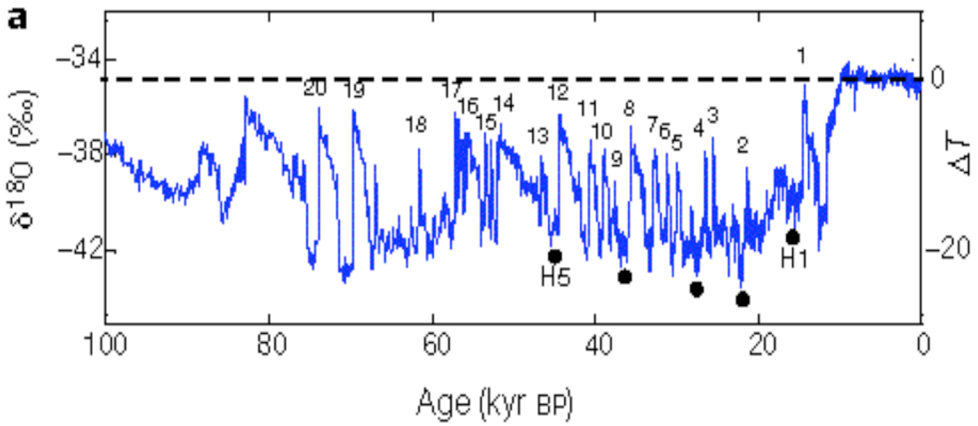
Abrupt Climate Change during the Last Glacial Period

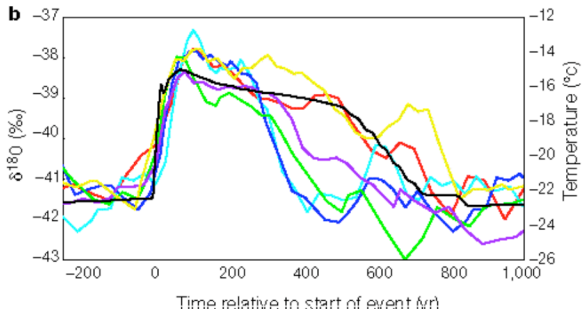
During Glacial stages, the climate system featured large rapid rearrangements.

Dansgaard/Oeschger (D/O) events show:

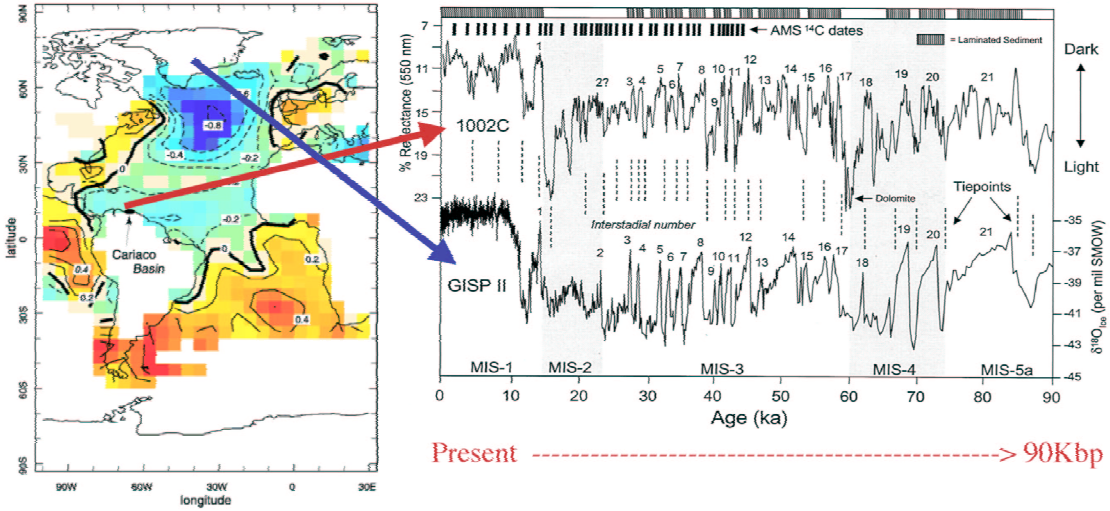
- Rapid onset of warming at Greenland (10 K in < 30 years!)
- Long-lived (~ 200 - 600 years)

Greenland Temperature





Tropical-Extratropical Linkages during Glacial Times: Extratropics forcing Tropics



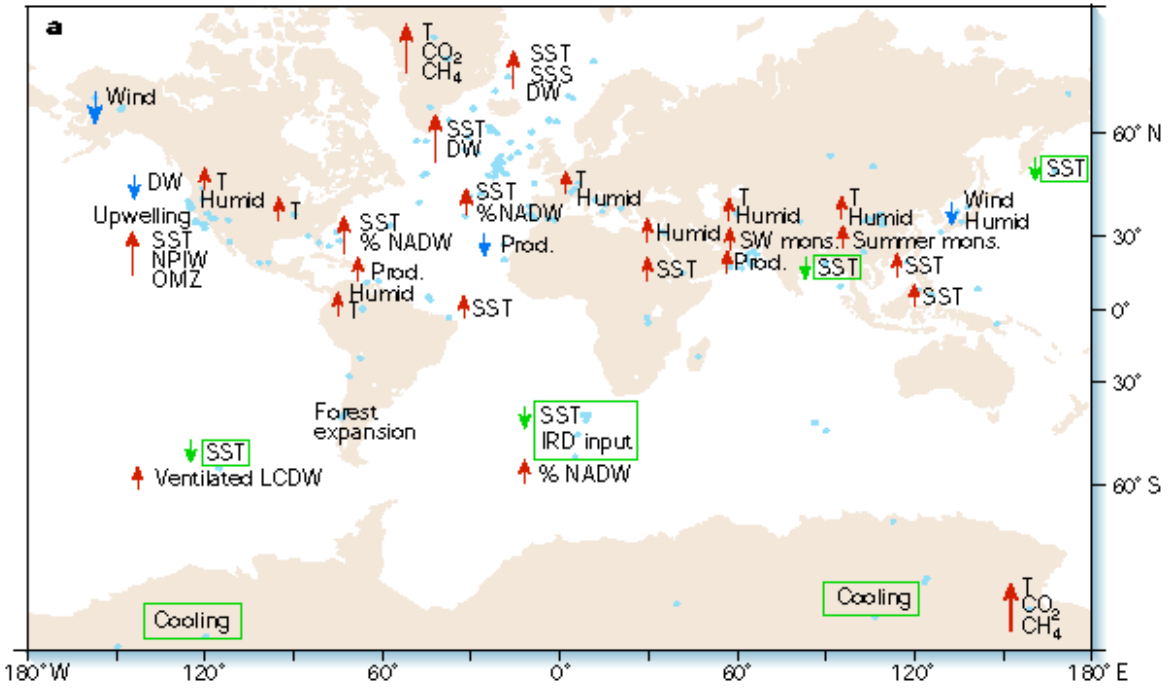
Black et al. 1999

Peterson et al. 2001

- Paleo data show strong linkages between the millennial variability in the North Atlantic, the tropical Atlantic and the Northern Hemisphere during the last Glacial Period.
- Thermohaline changes have been implicated as the cause.

Abrupt Climate Change during the Last Glacial Period (cont)

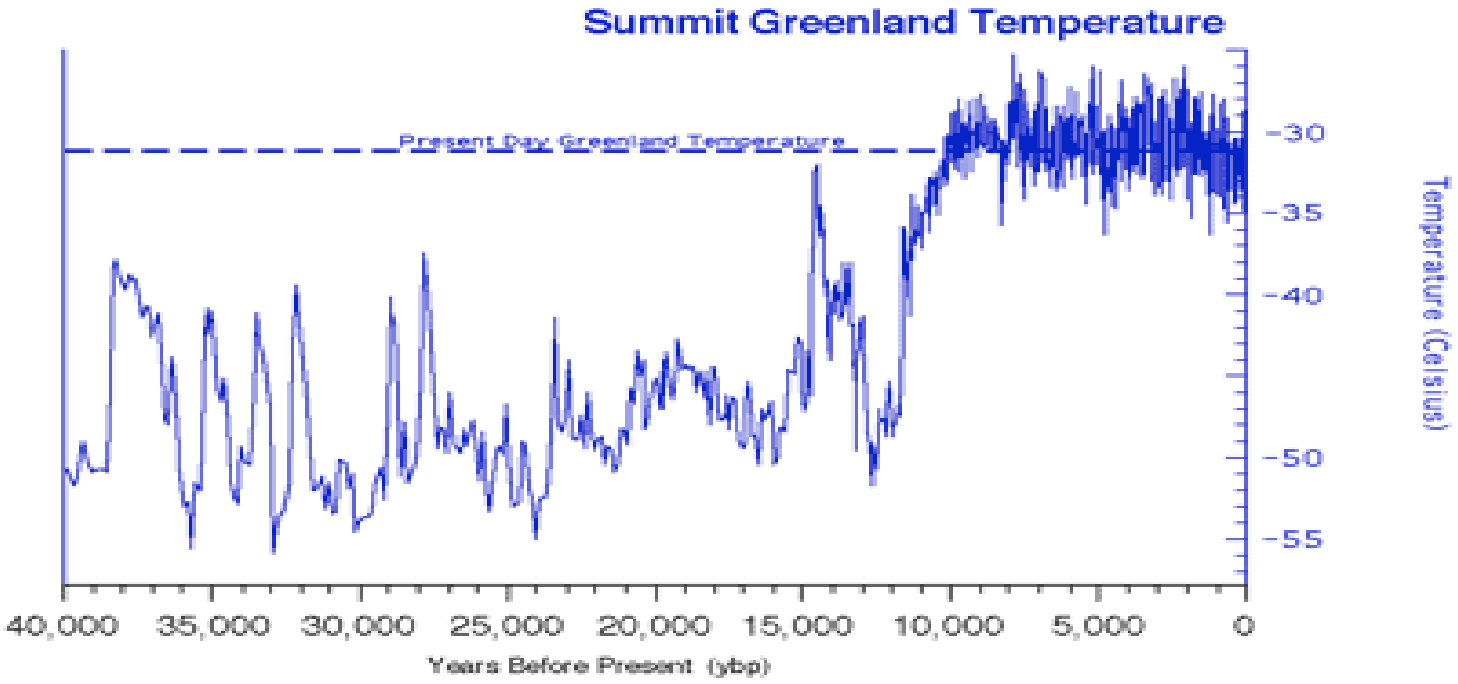
Dansgaard/Oeschger (D/O) events have a footprint throughout (at least) the Tropics and Northern Hemisphere



Why are there abrupt, global scale climate changes in the last glacial period? Is there evidence for abrupt climate changes in the Holocene (interglacial) period?

Climate of the Early Holocene (5-10kyr BP)

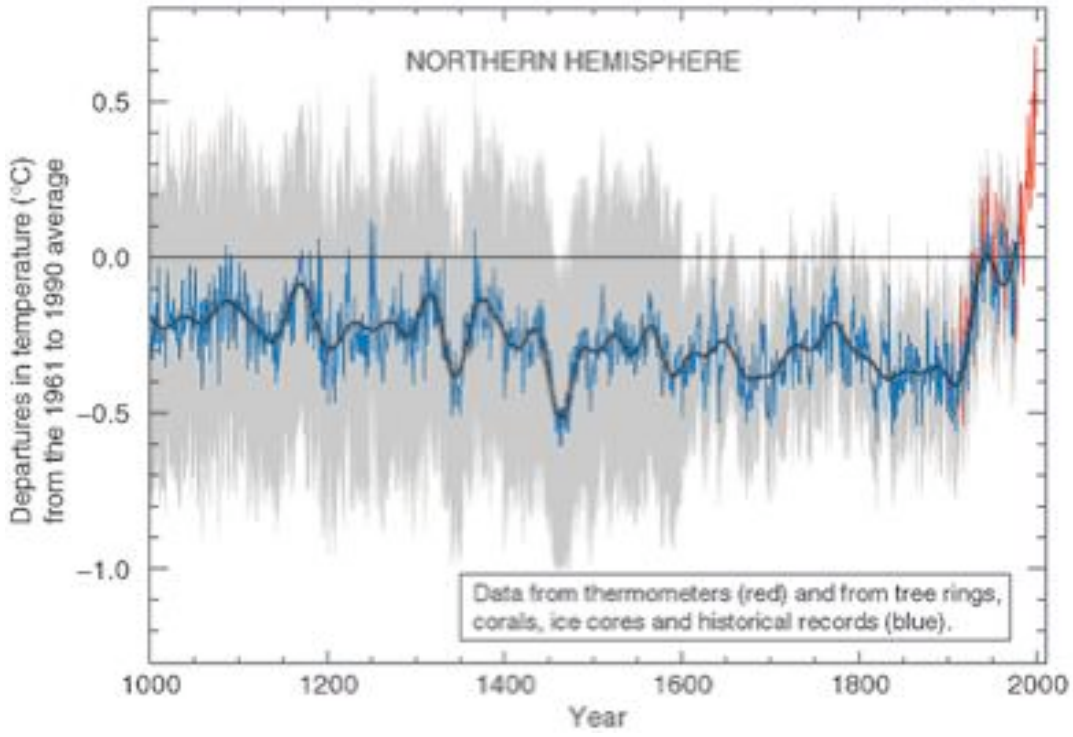
Is the Holocene climate as dull as is commonly believed?



- A green Sahara …
- Large millennial scale variability in African lakes an in Amazon rainfall (Cariaco Basin) ….

Climate of the Past 1000 years

- How well do we know the climate record of the past 1000 years?
  - E.g., what do we know about the character of climate variability on the centennial time scale?
  - To what extent is the variability natural or externally forced (solar, volcanic, greenhouse gas)?
- What do the proxy records tell us about the trends in climate over the 20th Century? About the future climate?



Brief History of Orbital Theory of the Ice Age Cycles

- Agassiz (1840)
  - Summarized geologic evidence for an ice age
- Adhemar (1842)
  - First to attribute ice age to orbital changes of Earth around Sun
  - Highlighted precession and # of hours of daylight
- Croll (1864)
  - Postulated winter was key: high eccentricity & winter hemisphere near aphelion promoted ice accumulation
  - Theory dropped when prediction of timing of glacial conditions didn't match evidence
- Milankovitch (1911)

Milankovitch (1911)

- Koppen suggested to M. that summer insolation was the key to the ice ages
  - Winter: too cold to get much accumulation
  - Summer: low-insulation summers produce less melt in Fall and Spring, allowing winter snow to persist.
- M. calculated summer insolation at 65N vs time
- At the time, proxy data did not support predicted timing of glacial vs interglacial conditions
- In the 1970's, new data from ocean sediment cores (and new dating methods, e.g. U/Th) clearly showed the ice ages went in cycles, and matched pretty well with summer insolation at 65N