Lecture 35 Past Climate Variations (ATMS 211)

Study of past natural climate variations (**paleoclimatology**) is context for understanding anthropogenic climate changes, and fascinating as well.

- Past 100 years - temperature records around world
- To probe further into past, use datable indirect climate measures(*proxies*).

Some proxies:

Tree rings (1000+ yrs before present (BP)): thickness⇒precip/temperature

Historical records of crops, weather events

Fossil pollen (10000+ yrs BP): ecosystem ⇒ climate.

(C^{14} dated pollen from tundra plants

⇒ Arctic climate in New England 10000 yrs BP)

Glacial ice cores (100,000+ yrs BP): O isotope ratios ⇒ surface temp.

Mid-ocean sediment cores (1 million yrs+ BP)

Comprised largely of shells of tiny marine organisms from near surface.

Many species have narrow temperature ranges: Shell types ⇒ sea temp., O isotope ratios ⇒ ice volume.

Geology (1 billion+ yrs BP)

Evidence of past ice ages (moraines, old shorelines, coral reefs etc.)

Fossil ecosystems

Oxygen isotope proxies (quite ingenious!)

- 1 in 1000 oxygen molecules are heavy *isotope* O^{18}.
- When ocean H_2O evaporates, water with heavier O^{18} gets left behind.

Oceans	→	Water Vapor	→	Snow	→	Glacial Ice
		(Evaporation)		(freezing)		
O^{18}/O^{16} higher		O^{18}/O^{16} lower		O^{18}/O^{16} ⇒ snow formation temp.		

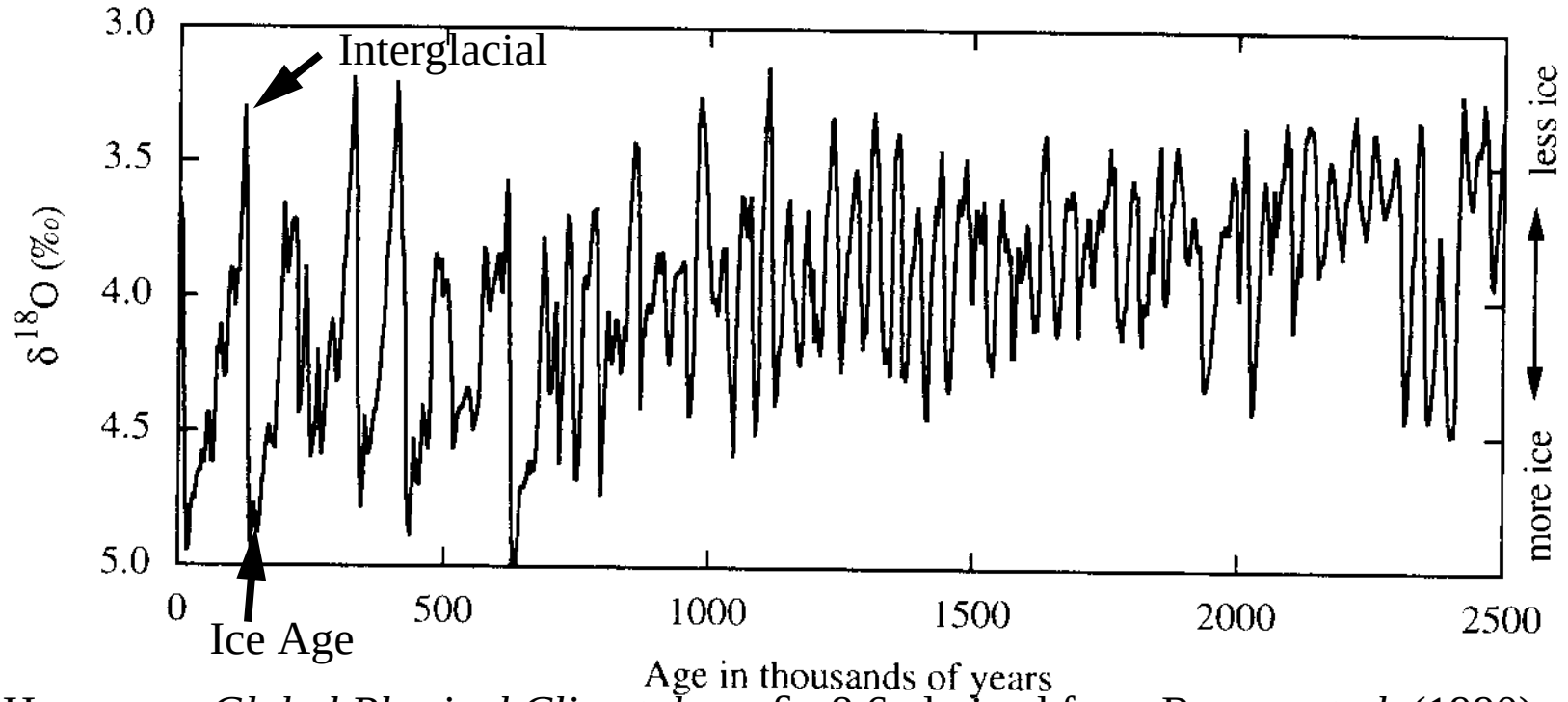
- More glacial ice⇒ more evaporated ocean water

  ⇒ ocean sediment core O^{18}/O^{16} high
- High ice core O^{18}/O^{16} ⇒ Warmer temperatures.

Climate Through Geologic Time

- Brief glacial periods 700 million years ago (mya), 300 mya. In last 500 mya, mostly warmer than now.
- 100 mya: Fossil redwoods on AK North Slope suggest Earth's midlatitude/ polar climate, deep ocean temps. up to 15 C warmer than today. Could be due to CO_2 levels 5x present associated with extensive volcanism.
- Last 50 mya: Deep oceans cooled from 15-20 C to 4 C. Glacial ice sheets formed on Antarctica 15 mya.
- Last 3 mya: Greenland ice sheet forms. Periodic ice ages.

Glacial ice mass in last 2.5 mya from deep sea core

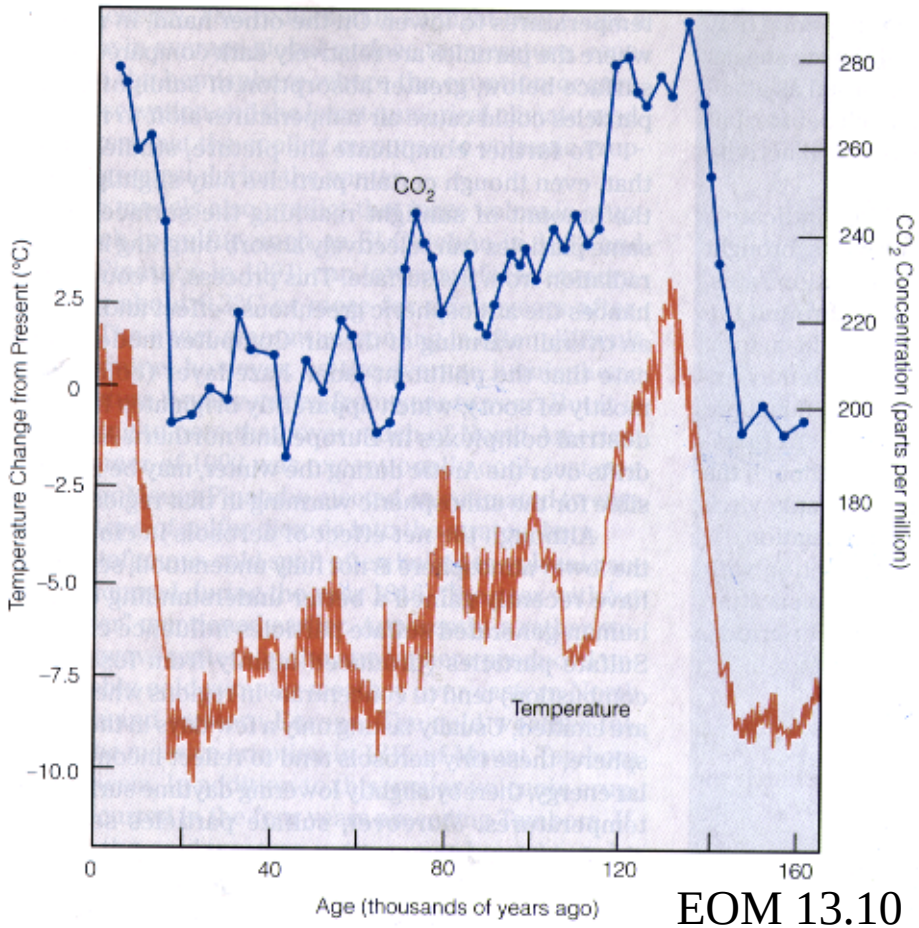


Hartmann, *Global Physical Climatology,* fig 8.6, derived from Raymo *et al*. (1990).

- Ice ages have occurred roughly every 100,000 yrs for last 700,000 yrs.
- Before that, smaller ice ages occurred every 40,000 yrs.

The last 100,000 years

Ice core from Vostok, Antarctica



EOM 13.10

Temperatures up to 10 C colder, CO_2 levels 30% lower 20,000 yrs ago than in current interglacial.

Ocean temperatures 18,000 yrs ago from foram distributions

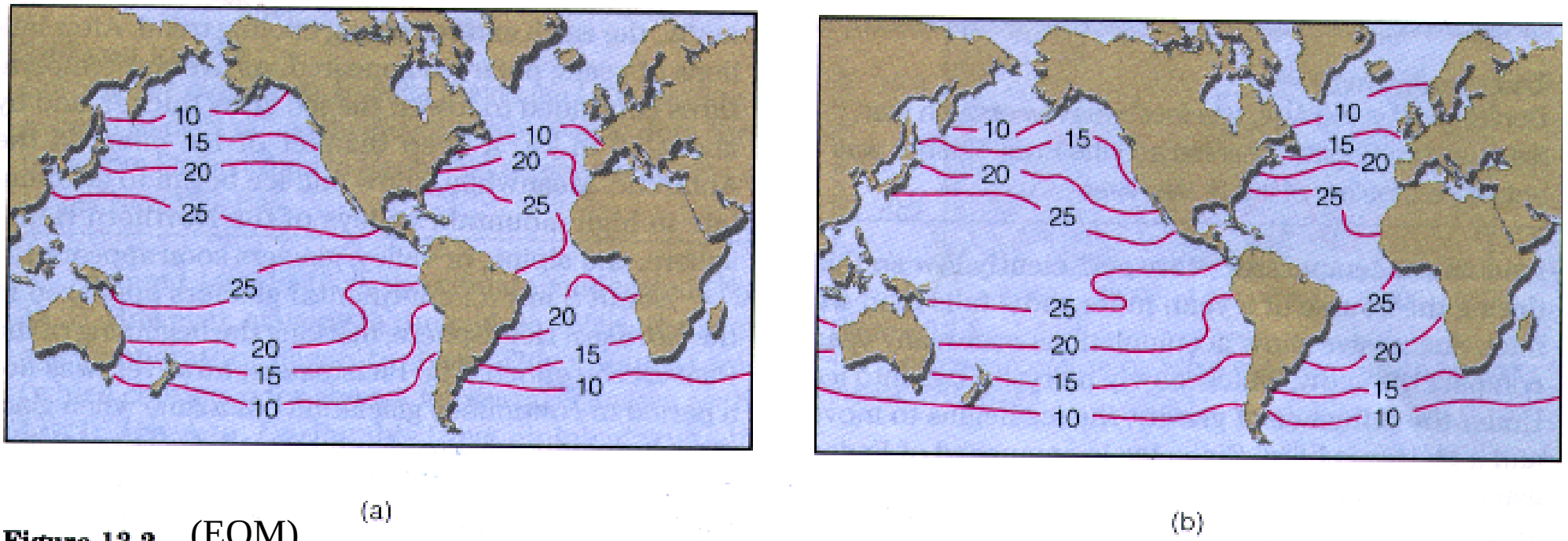
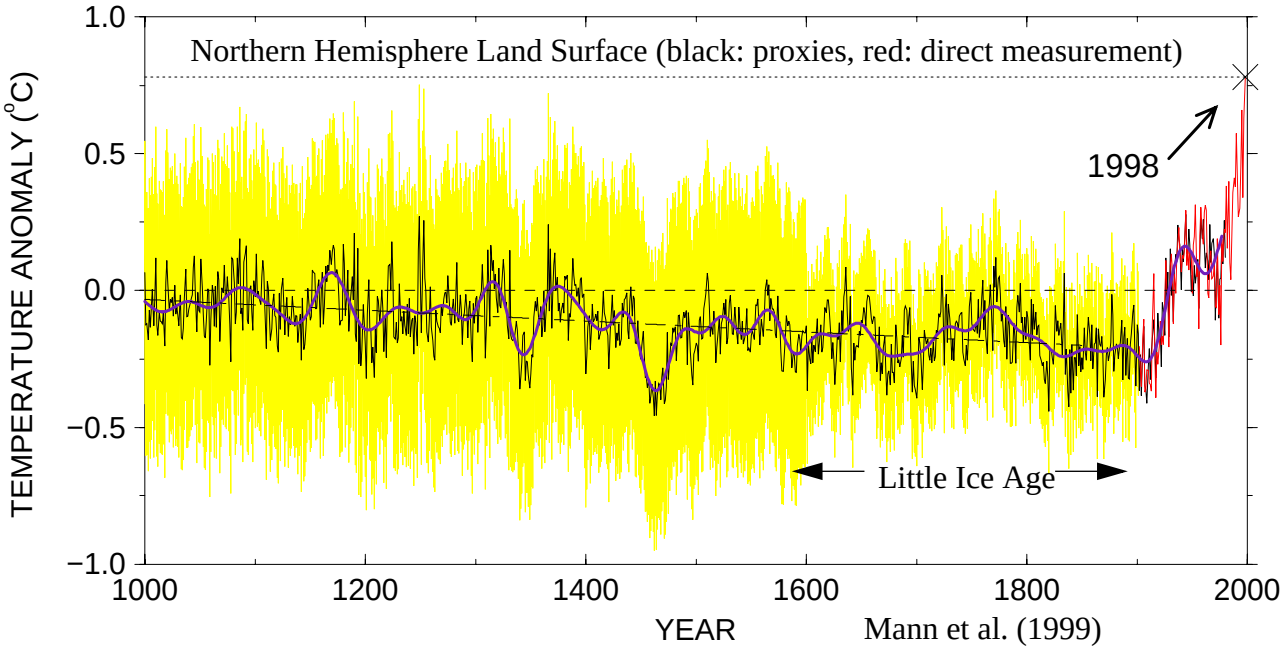


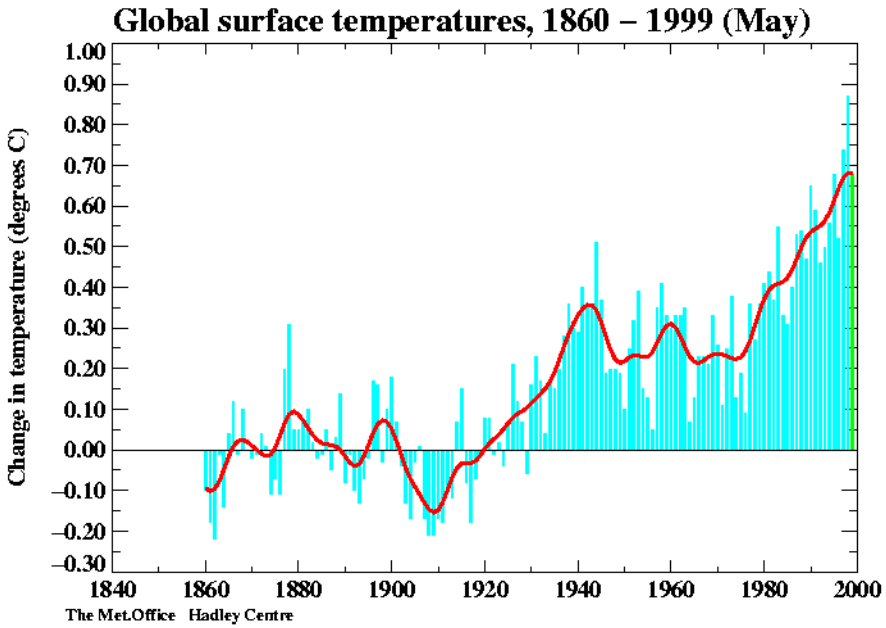
Figure 13.2 (EOM)
(a) Sea surface isotherms (°C) during August 18,000 years ago and (b) during August today.

- Largest cooling in N Atlantic.
- It is now thought that these maps underestimate the tropical cooling during the last ice age, perhaps as a result of slow evolution of the temperature ranges of different species.

The Last 1000 years



The Last 100 years



- Is the warming of the last century solely due to human effects?

Orbital (Milankovitch) Theory of Ice Ages

- Idea (developed 1910-1940): Small periodic changes in earth's tilt, orbit affect seasonal, geographic distribution of solar radiation.
- Ice ages when less radiation in NH summer to melt winter sub-polar snow.
- Three cycles:
  - Eccentricity (100 myr period)
  - Precession (23 myr period)
  - Obliquity (41 myr period)
- Partially agrees with observations, but still many puzzles.
- A convincing deterministic model of how orbital cycles produce ice age climate variations is still lacking
- Important feedbacks include:
  - Ocean circulation
  - Enhanced reflectivity of snow/ice
  - Greenhouse gases (CO_2, CH_4)
  - Dust

Rebound of land masses after ice sheets melt.

Eccentricity (0-9%difference in r_{max}/r_{min})

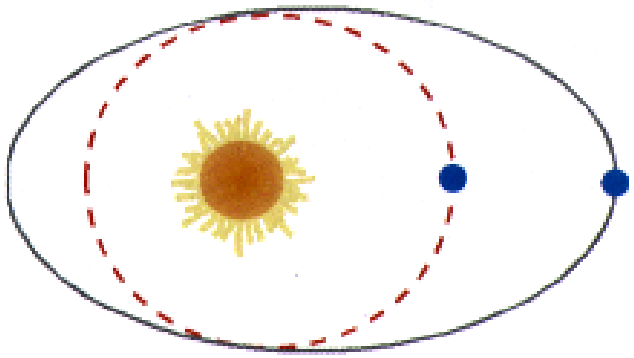
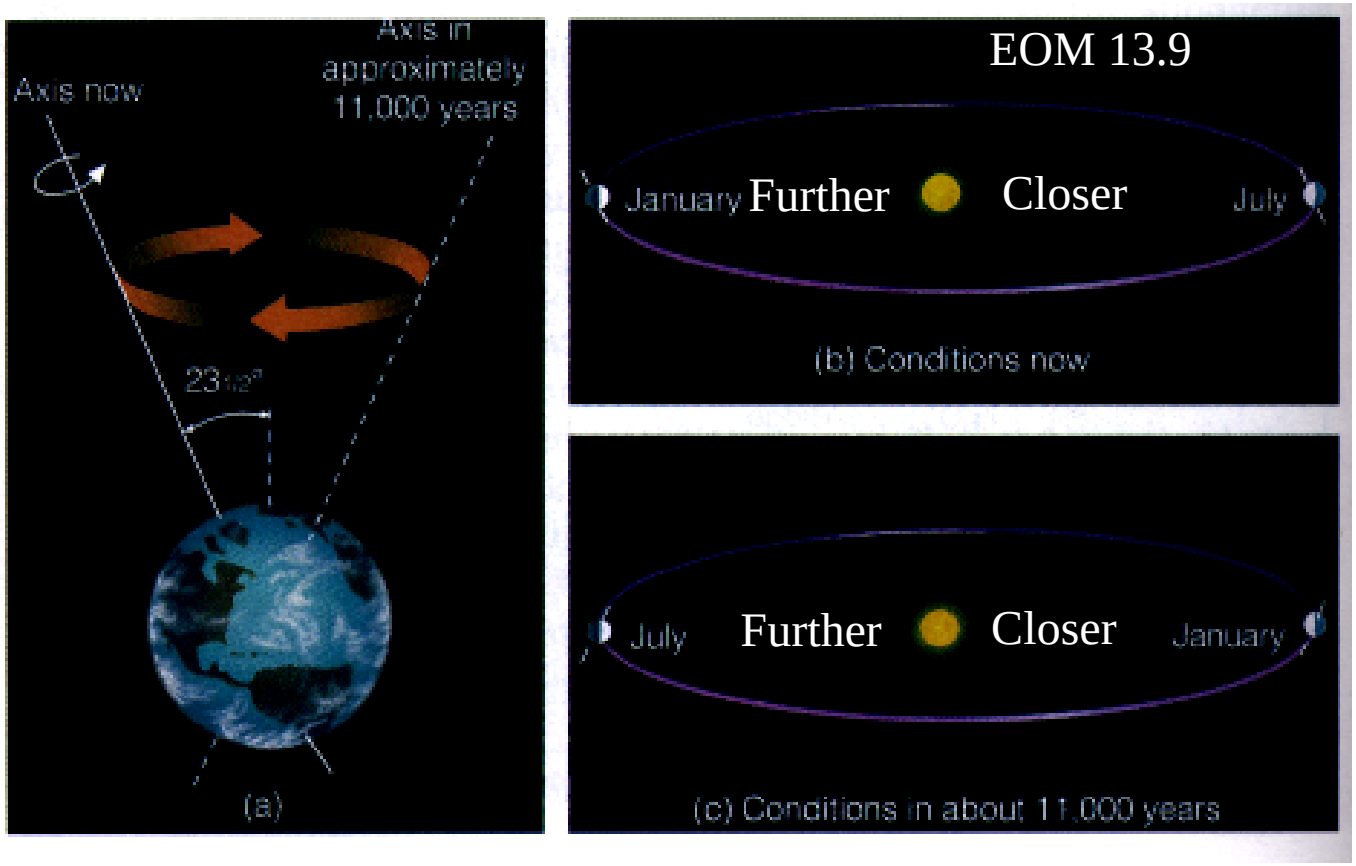


Figure 13.7 EOM 13.8
For the earth's orbit to stretch from nearly a circle (dashed line) to an elliptical orbit (solid line) and back again takes nearly 100,000 years. (Diagram is not to scale.)

Precession (Rotation axis slowly spins)



Obliquity (axis tilt varies from 22 to 24.5°).

Less tilt ⇒ Less seasons ⇒Cooler summer,less melt