**Chapter 14 Pleistocene Glaciations**

**What does an ice age look like?**

- Details still contested, especially the sea ice edge
- Reconstruction of land and sea ice 21,000 years ago

**Fig 14-4** δ¹⁸O from ocean sediments = Proxy for (1) ocean temperature and (2) ice volume on land

- More ice = less ice
- **100,000 yr “glacials”**
- The Pleistocene

**Fig 1-9** δ¹⁸O from ice cores tell us about temperature

- Condensation and rainfall preferentially remove heavy isotopes from clouds - even more so when air is cold (never mind the details)

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**CLIMAP reconstruction**

- February
- July

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Milankovitch cycles, Milankovitch curves, Milankovitch insolation, Milankovitch theory, Milankovitch hypothesis...

Earth's orbit varies over time due to influence of the Sun, Jupiter, and the Moon.
• **Eccentricity** (ellipticity) 
  \( \approx 100 \text{ kyr}, 400 \text{ kyr} \)
• **Obliquity** (tilt) 
  \( \approx 41 \text{ kyr} \)
• **Precession** (wobbly top) 
  \( \approx 19, 23 \text{ kyr} \)

Milutin Milankovitch (1879 - 1958)

“Summer insolation minima in the Northern Hemisphere lead to ice sheet advances”

How an ice sheet works (roughly):
• *Net accumulation* creates surface slope
• Surface slope causes ice to flow towards edges
• Accumulation (and mass flow) is balanced by ablation and/or calving

Ice sheets are very sensitive to summertime temperatures!
• Ice sheet has parabolic shape.
• line represents melt zone
• small warming increases melt zone a lot because of shape!

Furthermore temperature has a powerful influence on melting
Accumulation

Greenland - average accumulation ~30 cm/year.
Antarctica - average accumulation ~10 cm/year.

• moisture content of air decreases with height (temp)
• ice sheets experience a strong negative feedback on their vertical growth

Compilation of $\delta^{18}O$ from about 20 deep sea cores

Ice volume and June insolation at 65N (upside down)

Wiggles do not match well - ice volume has too much 100k yr cycle
Best match when ice volume is shifted by 6 kyr (6,000 years), as above, but no good reason for it!

In defense of Milankovitch

Gerard Roe,
Earth and Space Sciences, UW

Shouldn’t we be thinking about how insolation changes ice growth or melt NOT ice volume?

Old/Wrong idea? - Instant relationship between ice volume and insolation
New/Right idea? - Turn up the sun and ice melts

Ice ablation/accumulation
and June insolation at 65N (upside down)

Wiggles match quite well
No phony shift in time!
Summary - 1

• Waxing and waning of global ice volume strongly controlled by high latitude, northern hemisphere insolation
  (i.e., Milankovitch’s original idea, sort of)

• Reason for deglaciation still unknown

• Changes the question from does orbital forcing affect global ice volume (it does), to what causes the big deglaciations?

Summary - 2

• Another question - Why are the southern hemisphere climate variations nearly the same as in the northern hemisphere, yet the insolation curves are quite different?

Read text on glacial climate feedbacks (p279-287) on your own.