Wednesday, December 2, 2010
Chapters 14 – Glacial Climate Feedbacks

**CO₂/biological pump (p 281)**

- Shelf-nutrient (p 281-282)
- Iron fertilization (p 282-283)
- Coral reef (p 283-285)

**Cloud/albedo (see text, p 285-287)**
Before Fall Break we saw that the ice ages (at least for the last million years or so) have occurred at times when Earth’s orbit favored the build up of ice in the northern hemisphere.

Three factors contributed to this – precession, obliquity, and eccentricity. However, we noted that the climate signal at 100,000 years (the eccentricity mode) was far larger than expected based on changes in sunlight. We already know that CO₂ abundances and temperatures have correlated strongly during the current ice age epoch (the Pleistocene). How does CO₂ vary with temperature?
What is needed to amplify the signal from the 100,000 year cycle? Some kind of positive feedback loop!

**CO₂/biological pump (p 281)**

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The biological Pump – recall that nutrients come from both land (river runoff) and sea (upwelling)
Shelf Nutrient Hypothesis

Mechanism - Sea levels rise during a warm interglacial period, trapping nutrients underwater on the continental shelf.

Photosynthesis is reduced, and less CO₂ is removed from the atmosphere.
Shelf Nutrient Hypothesis

When sea levels fall (as ice builds up again), nutrients in the continental shelves are exposed, and photosynthesis increases, once again removing $\text{CO}_2$ from the atmosphere.
**Shelf Nutrient Hypothesis**

Nutrients in ocean – balance between input by river and loss by sedimentation of organic matter

If $\text{CO}_2$ in atmosphere was lower during a glaciation, either input from rivers was down, or there was more loss by sedimentation

Glaciers $\uparrow$ sea level $\downarrow$ weathering $\uparrow$ phosphate $\uparrow$ $\text{CO}_2$ $\downarrow$

Problem – in seawater, abundances of another element ($\text{Cd} = \text{cadmium}$) track those of phosphate, but measurements of Cd in fossil shells show that it wasn’t higher during glacials – implies that phosphate wasn’t higher either!
Shelf Nutrient Hypothesis

Overall positive

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Iron Fertilization Hypothesis

Iron abundances limit primary productivity (new growth) in certain regions of the ocean (where the other limiting nutrients are plentiful). Iron is supplied by wind-blown dust (Sarahan, Gobi deserts – wait until next week or the week after!)

Lower CO$_2$ during glaciations would imply more wind-blown dust, so either dryer climate or greater average winds.

Surface temp $\downarrow$ temp gradient $\uparrow$ winds $\uparrow$ iron $\uparrow$ CO$_2$ $\downarrow$

Evidence supports this feedback – windblown dust in ocean sediments is higher during glacials
Iron Fertilization Hypothesis

Positive feedback

Atmospheric carbon dioxide content → Global average surface temperature

Equator-to-pole temperature gradient

Intensity of oceanic biological pump

Delivery of iron to ocean via aerosols

East-West wind speeds

Figure 14-15
Coral Reef Hypothesis

Formation of coral increases atmospheric CO$_2$

$$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$$

Problem – growth can keep up with changes in sea level, but dissolution of limestone is slow, so if this occurs, the process may be unbalanced – CO$_2$ release may be faster than CO$_2$ uptake (we call this hysteresis)
Coral Reef Hypothesis

Note – the hard piece of this feedback cycle to remember is that when coral reefs grow, they increase the ocean acidity, which increases the diffusion of dissolved CO$_2$ back to the atmosphere – see page 165.

Positive feedback (if temperatures go down, glacial ice volume goes up)
Cloud condensation nuclei, formed by gases produced by marine plants, are higher during cold periods than warm ones.

Increased nutrients to ocean during cold periods increases growth of algae which promote additional cloudiness, which further cools the earth.

Methane sulfonic acid is a proxy for clouds.

Figure 14-18
One negative feedback: Changes in terrestrial biomass

Warm periods
Smaller ice sheet, more land for plants and trees
Less arid – rainforests are larger, more biomass in tropics.
Both result in additional uptake of CO₂ from the atmosphere

Tropical rainforests expand during warm periods

Figure 14-16
For Monday – what do the high-resolution ice core records tell us about climate stability?

Hint – Glacial periods tend to be unstable (relatively warm periods mixed in with extremely cold periods) (p 288-290)