GEOG 401
Climate Change

Biogeochemical Feedbacks in Contemporary Climate Change

Carbon-Cycle Feedbacks

• 55% of anthropogenic emissions are taken up by land and ocean processes
• Increasing CO2 concentration leads carbon cycle feedbacks
  – Higher air-sea CO2 concentration gradient increases ocean uptake of CO2
  – Higher atmospheric CO2 concentration stimulates terrestrial photosynthesis (CO2 fertilization)

CO2 Fertilization
CO2 Fertilization

Carbon-Cycle Feedbacks

• CO2 fertilization
  – The 20- to 30-year residence time of carbon in terrestrial ecosystems means that these systems are not in equilibrium, i.e. photosynthesis may be greater than respiration for decades or more
  – That imbalance results in a net uptake of CO2 into biomass and soils
  – This is a major negative feedback: “CO2-concentration-carbon-cycle feedback”

Carbon-Cycle Feedbacks

• Climate-Carbon-cycle interaction
  – Changing climate is expected to reduce the ability of oceans and terrestrial ecosystems to take up excess CO2 from the atmosphere
  – The “climate-carbon-cycle feedback” (positive feedback) will cause more warming by offsetting the “CO2-concentration-carbon-cycle feedback” (negative feedback)

Carbon-Cycle Feedbacks

• Climate-Carbon-cycle feedback
  – Ocean: warming surface causes increased stratification, reducing export of carbon from surface waters to deep ocean. Surface water CO2 concentration builds up, limiting uptake from atmosphere
Carbon-Cycle Feedbacks

• Climate-Carbon-cycle feedback
  – Land: warming increases rate of decomposition in soils (heterotrophic respiration)

• Carbon-Nitrogen interaction
  – CO2 fertilization in N-limited systems
  – Complex effects on decomposition
  – Accounting for nitrogen effects in models reduces the climate-carbon-cycle feedback, but leads to more CO2 in the atmosphere, resulting in greater warming

Carbon-Cycle Feedbacks

• Using observations to “constrain” effects of climate-carbon-cycle feedback
  – ENSO provides a means of connecting climate variability with fluctuations in atmospheric CO2 growth
  – El Niño: higher release of terrestrial carbon; only partly offset by higher ocean uptake
Carbon-Cycle Feedbacks
• Using observations to “constrain” effects of climate-carbon-cycle feedback
  — Tropical ecosystems appear to lose more carbon during El Niños: about 40 Pg C loss per degree of warming
  — This finding is contradicted by the work of Dr. Litton in Hawai’i, based on spatial temperature differences, which found no net effect of temperature on carbon storage

Methane (CH$_4$) Feedbacks
• Wetlands accumulate carbon because the saturated conditions slow down organic matter decomposition
• Conditions also favor production of methane
• Wetlands are the largest source of atmospheric methane
• Methane is a potent greenhouse gas

Methane (CH$_4$) Feedbacks
• CO2 concentration feedback links to a wetlands CH4 feedback through terrestrial ecosystem productivity
• Climate warming also produces CH4 feedbacks
  — Northern wetlands and peatlands take up CO2 and have significant carbon stores
  — Warming and other human-related activities may reduce the sink strength or flip them from sinks to sources
## Fire Feedbacks

- Fire has major effects on climate through:
  - Release of greenhouse gases
  - Direct effect on albedo
  - Change in vegetation – with albedo and energy partitioning effects
  - Release of aerosols from smoke – with effects on radiative balance, clouds, precipitation, etc.

## Fire Feedbacks

- Fire is extremely sensitive to climate
  - Fire incidence increases with increasing temperature
  - Fuel availability and fuel moisture affected by precipitation change
  - Droughts are strongly associated with greater fire occurrence