The Carbon Cycle

I. Introduction: Changes to Global C Cycle (Ch. 15)
II. C-cycle overview: pools & fluxes (Ch. 6)
III. Controls on GPP (Ch. 5)
IV. Controls on NPP (Ch. 6)
V. Controls on NEP (Ch. 6)

Rising atmospheric CO₂

- Atmospheric CO₂ concentration is rising
- Significant effects of biospheric uptake/release

Most major greenhouse gases are increasing in atmospheric concentrations

- CO₂ at highest level in past 650,000 yrs.
- CO₂ increasing faster than any time in past 650,000 yrs
- High atmospheric CO₂ correlated with warmer climates

Global C Cycle
To understand fates of C and potential remediation, we need to understand the controls on C uptake and loss from ecosystems
Major Global C pools
- Atmosphere, land & oceans contribute to cycling over decades–centuries.
- Rocks have the largest pool of C, but changes are small on these time scales
- Main pools on land are organic C (terrestrial biota & SOM) (~3x atmosphere)
- Main pool in oceans is dissolved inorganic C. Aquatic biota are a relatively small pool.

Major global C fluxes
- Terrestrial systems: fires, het resp roughly balance NPP
- Oceans take up ~2 Pg more than they release → deep storage (biol & solubility pumps)
- Humans adding C to atmosphere through fossil fuels & land use change.

Global Carbon Budgeting
How much have we released in fossil fuel burning? Where is it all going?

Sources:
- Fossil Fuel Burning: 5.5 ± 0.5 Pg C yr⁻¹
- Land use change: 1.6 ± 1.0

Sinks:
- Atmospheric accumulation: 3.2 ± 0.2
- Oceanic Uptake: 1.6 ± 1.0

The "Missing Sink": 2.3
Oceanic? Terrestrial? Why?

How do we figure this out?
Partitioning terrestrial and oceanic carbon exchange: a multiple tracer approach

1) Oxygen
   A) Land-atmosphere CO₂ exchange is immediately coupled with O₂ exchange: photosynthesis produces O₂, respiration consumes it
   B) Ocean-atmosphere CO₂ exchange is physical dissolution, so oceanic CO₂ uptake does not influence atmospheric O₂
   C) Thus, the relationship between the CO₂ and O₂ content of the atmosphere provides a fingerprint of terrestrial and oceanic CO₂ exchanges
1) We know how much fossil fuels we’re burning (and that combustion requires O2)

2) But we observe less CO2 increase and O2 decrease than we should based on known fossil fuel emissions

3) We know the O2:CO2 ratio associated with land-atmosphere CO2 exchange, and can use this to constrain land CO2 uptake

4) Ocean CO2 uptake, too can be constrained because we know it’s not associated with ocean-atmosphere O2 exchange

Partitioning terrestrial and oceanic carbon exchange: a multiple tracer approach

2) Carbon Isotopes

A) Terrestrial photosynthesis fractionates against 13C

Overall average fractionation currently estimated at about 18 per mil (‰) - so far, this is a rough global estimate of the combined influences of C3 vs. C4 vs. CAM, water stress, etc.

B) Oceanic CO2 uptake involves very small fractionation effects

C) Thus, changes in the 13C content of the atmosphere indicate the extent to which concurrent CO2 variations can be ascribed to terrestrial or oceanic activity

Potential Terrestrial C sinks

Atmospheric N Deposition Fertilizes Ecosystems, Causing A Large Global Carbon Sink (as much as 1.6 Pg C yr⁻¹)

Townsend et al. 1996, Holland et al. 1999

Global Carbon Budgeting

How much have we released in fossil fuel burning? Where is it all going?

<table>
<thead>
<tr>
<th>Sources:</th>
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<td>Terrestrial Uptake</td>
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<td>CO₂ fertilization</td>
<td>1.0 ± 0.5</td>
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<tr>
<td>Forest Regrowth</td>
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<tr>
<td>Nitrogen Deposition</td>
<td>0.6 ± 0.3</td>
</tr>
<tr>
<td>Other</td>
<td>0.2 ± 2.0</td>
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</tbody>
</table>

Potential Terrestrial C sinks

2. CO₂ fertilization

3. Plant growth from land use change
   - Afforestation: Previously cultivated lands have been abandoned throughout the temperate zone and are becoming forests again.
   - Woody encroachment into deserts and grasslands
   - Suppression of wildfires
   - Changing agricultural practices promotes C storage in soils
   - Wood products are C sinks...

-Long-term behavior of terrestrial sink is unknown
  - What do we need to know about terrestrial C cycling to understand potential changes?
II. C-cycle overview (within-ecosystem C pools and fluxes)

A. Terms
1. Biomass vs. productivity
2. GPP vs. NPP vs. NEP
3. Secondary production

B. C-cycle schematic
1. Simple
2. Complete

Carbon Cycle - The Simple Version

Primary production

C-cycle: the somewhat more detailed version
Main messages

- C flow is linked to energy flow
- C cycles, energy flow is one-way
- Plant production provides the fuel for the entire ecosystem
- GPP > NPP > NEP
- GPP, NPP determine how fast C taken up by ecosystem
- NEP determines how much C stored by ecosystem per unit time