Section C: Carbon Cycle

Outline

C.1 Introduction
C.2 The global carbon cycle
C.3 Human perturbations to the carbon cycle
C.4 Global carbon budget

Learning outcomes

- explain the major stocks of the global carbon cycle
- understand the major sources and sinks of the carbon cycle and the time scales over which they operate
- describe the human perturbations to the carbon cycle and where the emitted carbon is going

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Carbon fluxes
Net Primary Productivity

Forest disturbances and the C cycle

Cumulative impact: equivalent to 5 years of emissions from Canada’s transportation sector

Sea-to-Air Carbon Flux

cdiac.ornl.gov/oceans/LDEO_Underway_Database/pco2_flux_rate_maps.html
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Global Climate Change

Prof. J. Hicke

www.esrl.noaa.gov/gmd/ccgg/trends/
dougrobbins.blogspot.com/2012/04/modeling-global-co2-cycles.html

Annual cycle of atmospheric CO2

Northern Hemisphere CO2 Cycle, 2005 - 2006
Northern Hemisphere Seasons

Fossil Fuel and Cement Emissions

Global fossil fuel and cement emissions: 36.1 ± 1.8 GtCO2 in 2013, 61% over 1990

Projection for 2014: 37.0 ± 1.9 GtCO2, 65% over 1990

Estimates for 2011, 2012, and 2013 are preliminary

Source: CDIAC; Le Quéré et al. 2014; Global Carbon Budget 2014

Uncertainty is ±5% for one standard deviation (IPCC “likely” range)
Observed Emissions and Emissions Scenarios

Emissions are on track for 3.2–5.4°C “likely” increase in temperature above pre-industrial. Large and sustained mitigation is required to keep below 2°C.

Over 1000 scenarios from the IPCC Fifth Assessment Report are shown.

Source: Fuss et al. 2014; CDIAC; Global Carbon Budget 2014

Top Fossil Fuel Emitters (Absolute)

The top four emitters in 2013 covered 58% of global emissions:
- China (28%), United States (14%), EU28 (10%), India (7%).

Bunkers fuel used for international transport is 3% of global emissions.

Statistical differences between the global estimates and sum of national totals is 3% of global emissions.

Source: CDIAC; Le Quéré et al. 2014; Global Carbon Budget 2014

Top Fossil Fuel Emitters (Per Capita)

China’s per capita emissions have passed the EU28 and are 45% above the global average.

Source: CDIAC; Le Quéré et al. 2014; Global Carbon Budget 2014
Size of country proportional to total CO2 emissions in 2009

CO2e emissions by sector (source)

Global CO2 Emissions


US emissions by consumers of fossil fuels

IPCC, AR4, 2007

IPCC, AR5, 2013

IPCC, AR5, 2014
Global Climate Change

Tropical deforestation

Deforestation patterns

Arc of deforestation (red) in Amazon
### Historical Emissions from Land Use Change

#### Carbon Emissions from Tropical Deforestation

- **Africa**
- **Latin America**
- **S. & SE Asia**
- **SUM**

#### 2000-2007
- 1.5 GtC yr⁻¹ (16% of emissions)

### Land-Use Change Emissions

Global land-use change emissions are estimated 3.3 ± 1.8 GtCO₂ during 2004–2013. The data suggests a general decrease in emissions since 1990.

Three different estimation methods have been used, indicated here by different shades of grey.

Land-use change also emits CH₄ and N₂O which are not shown here.


### Total Global Emissions by Source

Land-use change was the dominant source of annual CO₂ emissions until around 1950. Coal consumption continues to grow strongly.

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Balancing the global carbon budget

Fate of Anthropogenic CO₂ Emissions (2004-2013 average)

Global carbon budget

Table 1: Global anthropogenic CO₂ budget, expressed in the form of the net change on carbon inventory (Gt C) from 1750 to 2010 and 1990 to 2010, assuming a linear trend of 1.73% per year in the 19th century and a constant rate of 1.0% per year from 1950 to 2010 (and 0.5% per year from 1970 to 2010 for land-use change). The values are based on a global carbon inventory of 781 Gt C in 2010.

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Net Change</th>
<th>1950-2010</th>
<th>1970-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houghton et al. 2012</td>
<td>1750-2010</td>
<td>781 Gt C</td>
<td>781 Gt C</td>
<td>781 Gt C</td>
</tr>
</tbody>
</table>

Emissions are partitioned between the atmosphere, land, and ocean.
Global Carbon Budget

The cumulative contributions to the Global Carbon Budget from 1870
Contributions are shown in parts per million (ppm)

Figure concept from Shrink That Footprint

North American carbon budget

Figure 15.1 North American carbon sources and sinks (fettneq tonnes of carbon per year) in 2000. A dark blue indicates a best estimate for net carbon exchange between the atmosphere and the indicated element of the North American carbon budget. Sources and CO2 (net change in atmospheric carbon mass) are in blue. Source: Sinks indicate the uncertainty in these estimates, and define the range of values that include the actual value with 95% certainty. Data from the North American Carbon Budget Project for details and disaggregation on these sources and sinks.

Oceans: Sinks, with small uncertainties
Land: Sinks, with uncertainties

Large uncertainties in model results for uptake of carbon on land

Large uncertainties when modeling future vegetation type

columns: different GCMs
rows: different assumptions about vegetation (amount of CO2 and its effect on photosynthesis)
Carbon stocks and fluxes