Lecture 12. Global biogeochemical cycles of carbon.

Objectives:
1. Global biogeochemical cycle of carbon.
2. Important carbon-containing compounds.

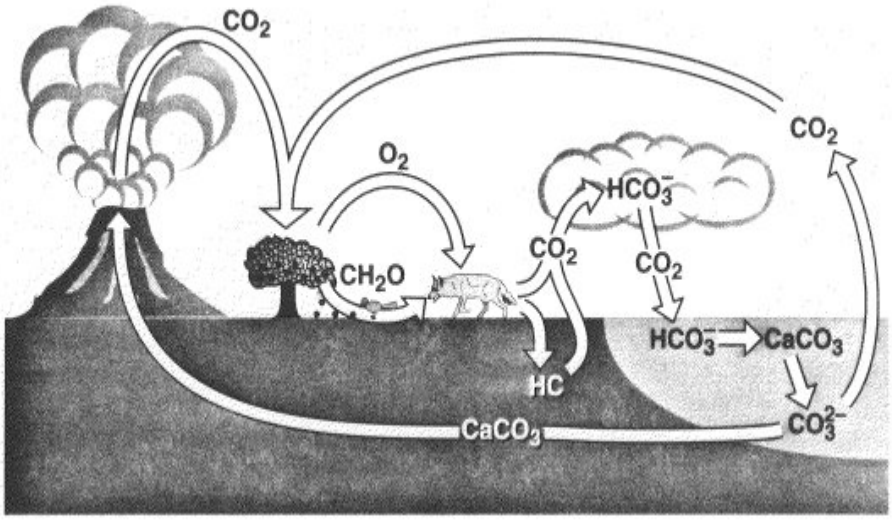
Readings: Turco: p. 307-316; Brimblecombe: p. 21-23, 37 (20-41)

1. Global biogeochemical cycle of carbon

Principal carbon compounds in the atmosphere:

CO_2 , CO, CH_4, carbonates (e.g., $CaCO_3$), organic compounds (e.g., CH_2O)

Figure 12.1 The simplified illustration of transfer of carbon through the biosphere and geosphere (Turco 1997).



NOTE: find major differences in Figure 10.14 from Turco (1997) and Figure 2.1 from Brimblecombe (1996)

The carbon cycle on Earth can be divided on the primary (**fast**) processes and the secondary (**slow**) processes.

Major primary (**fast**) carbon transfer processes:

* Atmosphere/land-biomass exchange of carbon dioxide by **photosynthesis** and **respiration**, 80Gt-C/yr.
* Atmosphere/ocean exchange of CO_2 by **dissolution** and **evaporation**, 50Gt-C/yr.
* Surface-ocean/deep-ocean exchange of carbonate by **sinking** and **upwelling** of ocean water, 25Gt-C/yr.
* Surface-ocean/water-biomass exchange of CO_2 by **photosynthesis** and **respiration**, 5Gt-C/yr.

Major secondary (**slow**) carbon transfer processes:

* Sediment/atmosphere transfer of carbonate as CO_2 by silicate mineral reconstruction and **volcanism**, 0.05Gt-C/yr.
* Sediment/ocean transfer of carbonate by **weathering** and **runoff** from land, 0.2Gt-C/yr.
* Ocean/sediment transfer of carbonate by **sedimentation** and burial of tests, 0.25Gt-C/yr.
* Sediment/atmosphere transfer of fossilized organic carbon by oxidation during **weathering** of uplifted sediments, 0.05Gt-C/yr.
* Ocean/sediment transfer of organic carbon by **sedimentation** and burial of detritus, 0.05Gt-C/yr.

2. Important carbon-containing compounds:

CO_2 , CO, CH_4, carbonates (e.g., $CaCO_3$), organic compounds (e.g., CH_2O)

- Carbon dioxide is the single most important trace constituent from the standpoint of global climate change causing global warming (will be discussed in Lectures 33-34). CO_2 levels have increased from about 280 ppm in 1800 to 356 ppm in 1993.

- Carbon monoxide has a chemical lifetime of 30 to 90 days on the global scale of the troposphere. Tropospheric CO mixing ratios range from 40 to 200 ppb.

Table. Estimated sources and sinks of CO typical of the last decade (IPCC 1995).

Sources	**Range (Tg(CO) yr^{-1})**
Technological	**300-550**
Biomass burning	**300-700**
Biogenics	**60-160**
Oceans	**20-200**
Methane oxidation (by OH)	**400-1000**
NMHC oxidation	**200-600**
Total sources	**1800-2700**
Sinks	
OH reaction	**1400-2600**
Soil uptake	**250-640**
Stratospheric loss	**~100**
Total sinks	**2100-3000**

- Carbonates:

$CaCO_3$ (calcium carbonate) is an important carbon-containing compound in rocks and in ocean sediments.

- Methane is the most abundant hydrocarbon in the atmosphere.

Table. Estimated sources and sinks of methane (IPCC 1995).

Identified sources	Individual estimate ($Tg(CH_4)\ yr^{-1}$)
Natural	
Oceans	**10 (5-50)**
Wetlands	**115 (55-150)**
Termites	**20 (10-50)**
Other	**15 (10-40)**
Total natural sources	**160 (110-210)**
Anthropogenic	
Fossil-fuel related sources:	
natural gas	**40 (25-50)**
coal mines	**30 (15-45)**
petroleum industry	**15 (5-30)**
coal combustion	**? (1-30)**
Total fossil-fuel related sources	***100 (70-120)***
Biospheric carbon:	
enteric fermentation	**85 (65-100)**
rice paddies	**60 (20-100)**
biomass burning	**40 (20-80)**
landfills	**40 (20-70)**
animal waste	**25 (20-30)**
domestic sewage	**25 (15-80)**
Total biospheric	***275 (200-350)***
Total anthropogenic sources	**375 (300-450)**
Total identified sources	**535 (410-660)**
Sinks	
Troposheric OH	**445 (360-530)**
Stratosphere	**40 (32-48)**
Soils	**30 (15-45)**
Total sinks	**515 (430-600)**
Total global burden	**4850 Tg (CH_4)**

- Volatile organic compounds (**VOCs)** denote the entire set of vapor-phase atmospheric organics.

Table. Global biogenic VOC emission rate estimates by source (Tg/yr).

Source	Isoprene	Monoterpenes	Total VOC
Woods	**372**	**95**	**821**
Crops	**24**	**6**	**120**
Shrub	**103**	**25**	**194**
Ocean	**0**	**0**	**5**
Other	**4**	**1**	**9**
Total	**503**	**127**	**1150**

Table. Estimated global **anthropogenic** emission of nonmethane organic compounds.

Activity	Emission (Tg yr^{-1})
Fuel production/distribution:	
petroleum	**8**
natural gas	**2**
oil refining	**5**
gasoline distribution	**2.5**
Fuel consumption	
coal	**3.5**
wood	**25**
crop residues	**14.5**
charcoal	**2.5**
dung cakes	**3**
road transport	**36**
chemical industry	**2**
solvent use	**20**
uncontrolled waste burning	**8**
Other	
Total	**142**