Lecture 30

THIS WEEK:

-The human-perturbed carbon cycle (Ch. 16 & some of Ch. 8)

-Aerosols and global warming (guest lecture); Homework #5

-Future Projections & Impacts on the biosphere (Ch. 16)

-Arguments of the global warming denier “skeptics” (handout)

NEXT WEEK:

-Global warming impacts in the Pacific Northwest

- Why should we be concerned? (handout)

- Solutions and government policies/lack of policies

Thermohaline catastrophe movie coming to theaters near you…

In recent years, researchers have uncovered evidence that the "conveyor belt" of ocean heat and salt circulation repeatedly broke down during prehistoric times, disrupting global climate…

Some scientists, notably climate guru Wallace Broecker of Columbia University, speculate that present global warming might bring another breakdown in thermohaline circulation in the foreseeable future.

Where scientific speculators tread, Hollywood is rarely far behind. In the forthcoming science-fiction thriller "The Day After Tomorrow," due in theaters in late May, a breakdown of thermohaline circulation figures in the onscreen climatic catastrophe.

from March 1, 2004, *San Francisco Chronicle*

Global warming overview

"Global warming" definition:

A warming of the Earth’s surface and troposphere due to an anthropogenic enhancement of the greenhouse effect. The principle mechanism of change is enhanced CO_2 caused by burning of fossil fuels. The primary index of change is rising global-mean surface temperature.

"Global warming" BIG questions:

1. Is it real? (science)
2. Is it a serious problem? (consequences)
3. What should we do about it? (response)

Is it real?

1. Is Global Warming real?

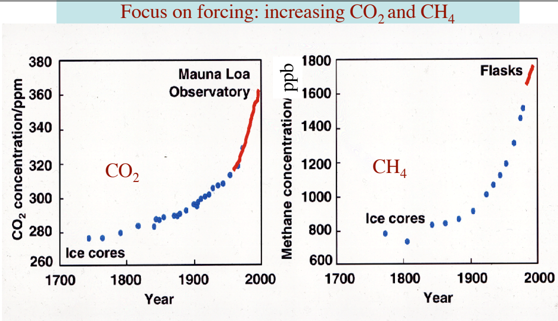
- Are we forcing the climate system?
- Is the energy balance theory of climate change correct?
- How well can we forecast the climate system response?
- Has the warming already been detected?

$$\Delta T_s = \lambda \Delta F$$

ΔF = forcing (changes to energy balance)
ΔT_s = temperature response (predicted or measured)
λ = climate sensitivity (from models or empirical tests)

Global warming debate has tended to focus on detection of the response, ΔT_s. First, we ask whether or not we are forcing the climate system (i.e. ΔF). Our fundamental focus should be on the carbon cycle to look at this question.

Focus on forcing: increasing CO_2 and CH_4



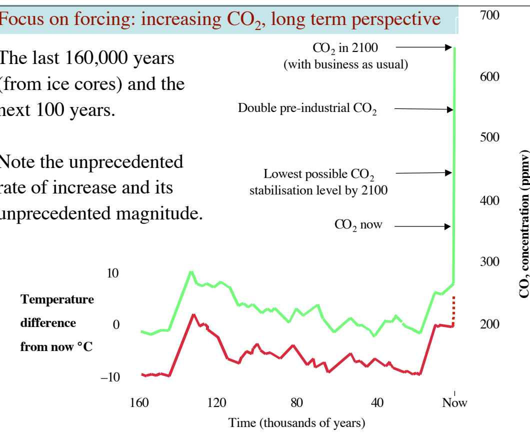
CO_2 was 371 ppmv in 2001 compared to pre-industrial 280 ppmv
Why? Due to the burning of fossil fuels and deforestation.

CH_4 was 1.8 ppmv in 2001 compared to pre-industrial 0.8 ppmv
Why? Intensive agriculture (cattle flatulence, rice paddies), landfills, coal/oil/gas production

Focus on forcing: increasing CO_2, long term perspective

The last 160,000 years (from ice cores) and the next 100 years.

Note the unprecedented rate of increase and its unprecedented magnitude.



Carbon cycle basics

Basic unit of measure:

Gton C: Gigatons of carbon atom
Gton = 10^9 metric tons (or 10^{15} g = 1 "petagram")
metric tonne = 1000 kg ~ 2205 lbs or roughly 1 British ton
(1 British ton is defined as 2240 pounds)

Biological reservoirs
- land biomass is a large reservoir: ~2200 Gton C
- ocean biomass is a tiny reservoir: ~3 Gton C

Qu.) Why so different?

Biological fluxes
- very large fluxes with atmosphere, but no net change in atmospheric CO_2 unless...
  1. land biomass changes (fast, temporary)
  2. ocean biological pump changes (fast, longer lasting)

- ocean biological pump is organic matter sinking to deep ocean or ocean bottom

Concept of residence time

$$\text{Residence time} = \frac{\text{reservoir size at any time}}{\text{inflow rate or outflow rate}}$$

= average time a substance spends in a given reservoir that is at steady state

Example) Oceans contain 39123 Gtons of carbon.
In the long-term geological carbon cycle, volcanic carbon fluxes replenish carbon lost as carbonate/organics in sediments.

Rate of production of carbon from volcanoes = 0.06 Gtons/year
What's the residence time of carbon in the ocean?

$$\text{Residence time} = \frac{\text{reservoir size at any time}}{\text{inflow rate or outflow rate}} = 39123/0.06 = 0.65 \text{ m.y.}$$

Carbon cycle: reservoirs and couplings

Coupling	Reservoir	Amount (Gton,C)	Coupling
1	Atmosphere	760	
1	Land (plants, soil)	2200	
1	Ocean Mixed Layer	1023	2
3	Deep Ocean	38,100	2
3	Carbonate Rocks	40,000,000	

1: Coupled by biological processes and CO_2 solubility... fast

2: Coupled by thermo-haline circulation (and other mixing, upwelling processes) ... slow

3: Coupled by geological processes... very slow

Fossil fuels (oil, nat. gas, coal): 4000-6000 Gton C

Carbon Cycle: Reminder of Chemistry

Inorganic carbon cycle:

weathering $CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2$

metamorphosis $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

Organic carbon cycle:

photosynthesis $CO_2 + H_2O$ + solar energy $\rightarrow CH_2O + O_2$

respiration/burning $CH_2O + O_2 \rightarrow CO_2 + H_2O$ + energy

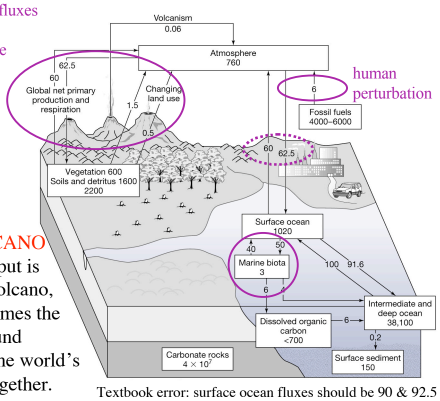
Global Carbon Cycle: Fig 16-1

Major atmospheric fluxes associated with the organic carbon cycle

Qu.) Is the atmosphere gaining/losing carbon in this diagram?

HUMAN VOLCANO

Human CO_2 output is like a gigantic volcano, producing 100 times the natural background emission of all the world's volcanoes put together.

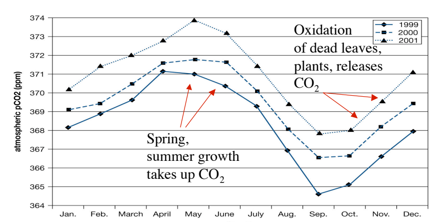


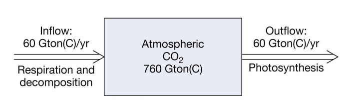
Textbook error: surface ocean fluxes should be 90 & 92.5

"Breathing of the Biosphere"

Annual cycle of CO_2 of monthly averages at Mauna Loa.

Note: year-by-year increase of CO_2 (Fig 8-4)





natural annual cycle: big flow, but not net change (Fig 8-5)

What is the time for atmospheric C to flux through the biosphere based on these fluxes?

Forests:
"Mature forests are a reservoir of carbon, not a source or sink."

Clearing of forests results in a substantial release of carbon into the atmosphere, both from the trees themselves and from the soil beneath them.
Twigs, leaves, branches decay to CO2
Soil carbon oxidies to CO2
(Forests often burnt for clearing or the wood is subsequently burnt).

"Deforestation of North America during the 19th century, the ***pioneer effect***, was responsible for most of the rise in atmospheric CO2 between 1800 and 1850." [p.321, Kump]

Forests:
"Mature forests are a reservoir of carbon, not a source or sink."

~~Earth in the Balance by Al Gore:~~
~~"By rapidly destroying the [tropical] forests…, we are damaging [the earth's] ability to remove excess CO2." [p. 293]~~

↑
Science VIOLATION !!!

There are valid reasons for not cutting down tropical forests:
-CO_2 is released to the atmosphere
- numerous species have gone/are going extinct
- natural beauty of the tropics is vandalized

Forests:
"Mature forests are a reservoir of carbon, not a source or sink."

Consider three land owners, each with a mature forest containing 100 tons/acre of carbon locked up in the biomass of the trees.

#1: leaves it alone

#2: burns it down and starts a farm

#3: logs it and replants with trees

Which one removes or adds the most CO2 to the atmosphere?
(a) Immediate effect?   (b) after 100 years?

Draw graphs to explain your answers.

Human input of carbon

Currently, about 6.1 GtC/year (fossil fuel) and increasing.
Also 2 GtC/yr from deforestation/land use
75% (6.1 GtC) from industrial and transportation sources (below)
25% (2 GtC) from deforestation and biomass burning (not shown)

Global, Regional and National CO_2 emissions