Lectures 33-34. Greenhouse gases and global warming.

Objectives:

1. Greenhouse gases.
2. Global warming.

Readings: Turco: p. 365-386; Brimblecombe: p.184-189

1. Greenhouse gases.

Greenhouse effect is a trapping of the earth's thermal radiation by the clouds and greenhouse gases (such as H_2O, CO_2, O_3, CH_4, etc.) and re-emitting it back to the surface.

- Various human activities result in additional loading of greenhouse gases with potential of global warming (or climate change).
- That the concentrations of greenhouse gases have been increasing over the past century is indisputable, a problem is how to identify their effects on climate.

Some history of global warming:

1896: Arrhenius proposed that continued coal combustion might increase the amount of CO_2 causing the global warming.

1938: G.Callendar stated that atmospheric CO_2 level increased by 10% since 1890s.

1955: G.Plass showed that CO_2 absorption lines don't overlie H_2O absorption lines. Thus adding of CO_2 to the atmosphere lead to interception of more infrared radiation.

1956: R.Revelle showed that, because of the chemistry of seawater, the ocean surface layer has limited uptake of CO_2

1957: C. Keeling detected a rise of CO_2 after two years of measurements.

Table 33.1 Greenhouse gases whose concentrations have been increasing by human activities.

Compound	**Preindustrial concentrations (ppbv)**	**Present concentrations (ppbv)**	**Rate increase (%/yr)**	**Lifetime (yr)**
CO_2	**275,000**	**356,000**	**0.4**	**100-200** (hard to estimate)
CH_4	**800**	**1714**	**0.8**	**11**
N_2O	**290**	**310**	**0.2**	**150**
O_3 (in the troposphere)	**10**	**10-200**	**1**	**few hours**
HALOCARBONS				
$CFCl_3$ (CFC-11)	**0**	**0.3**	**5**	**50**
CF_2Cl_2 (CFC-12)	**0**	**0.5**	**5**	**102**
CF_3Cl (CFC-13)	**0**	**0.005**	**5**	**139**
CF_2HCl (HCFC-22)	**0**	**0.1**	**7**	**13**
CH_3CCl_3 (methyl chloroform)	**0**	**0.16**	**7**	**5.4**
CF_3Br (Halon-1301)	**0**	**0.002**	**20**	**65**
$C_2F_3Cl_3$ (CFC-113)	**0**	**0.082**	**10**	**85**
$CF_2Cl_3CF_2Cl$ (CFC-114)	**0**	**0.02**	**5**	**300**
C_2F_5Cl (CFC-115)	**0**	**< 0.01**	**5**	**1700**
CH_3Br (methyl bromide)	**about 0**	**0.0015**	**15**	**1.5**

CO_2 is the most important greenhouse gas.

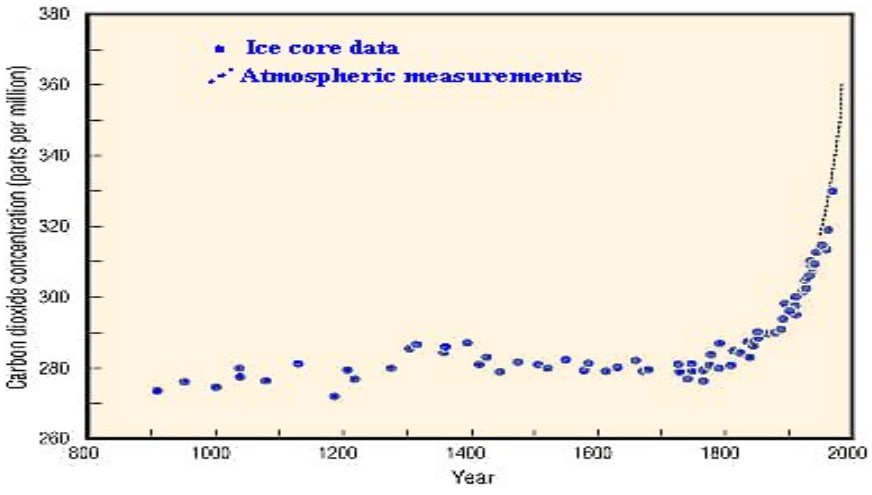
- Atmospheric lifetime for CO_2 is hard to determine because the cycling of carbon in the terrestrial biosphere and ocean occurs over timescales of decades to thousand of years.

Table 33.1 Global CO_2 budget (IPCC 1995).

	CO2 (Gt(C) /yr)
Sources	
Fossil fuels combustion	5.5 +/- 0.5
Deforestation and land use changes	1.6 +/- 1.0
Total known sources	**7.1 +/- 1.1**
Sinks	
Oceanic uptake	2.0 +/- 0.8
Uptake by Northern Hemisphere forest regrowth	0.5 +/- 0.5
Retained in the atmosphere	3.2 +/- 0.2
Total known sinks	**5.7 +/- 1.0**
Net imbalance	**1.4 +/- 1.5**

- Accounting for the missing sink is a major research problem in the global CO_2 budget.

Figure 33.1 Long-term trend of atmospheric CO_2 concentrations.



CH_4: shows a rapid growth since about 1900, and is currently increasing of about 1%/yr.

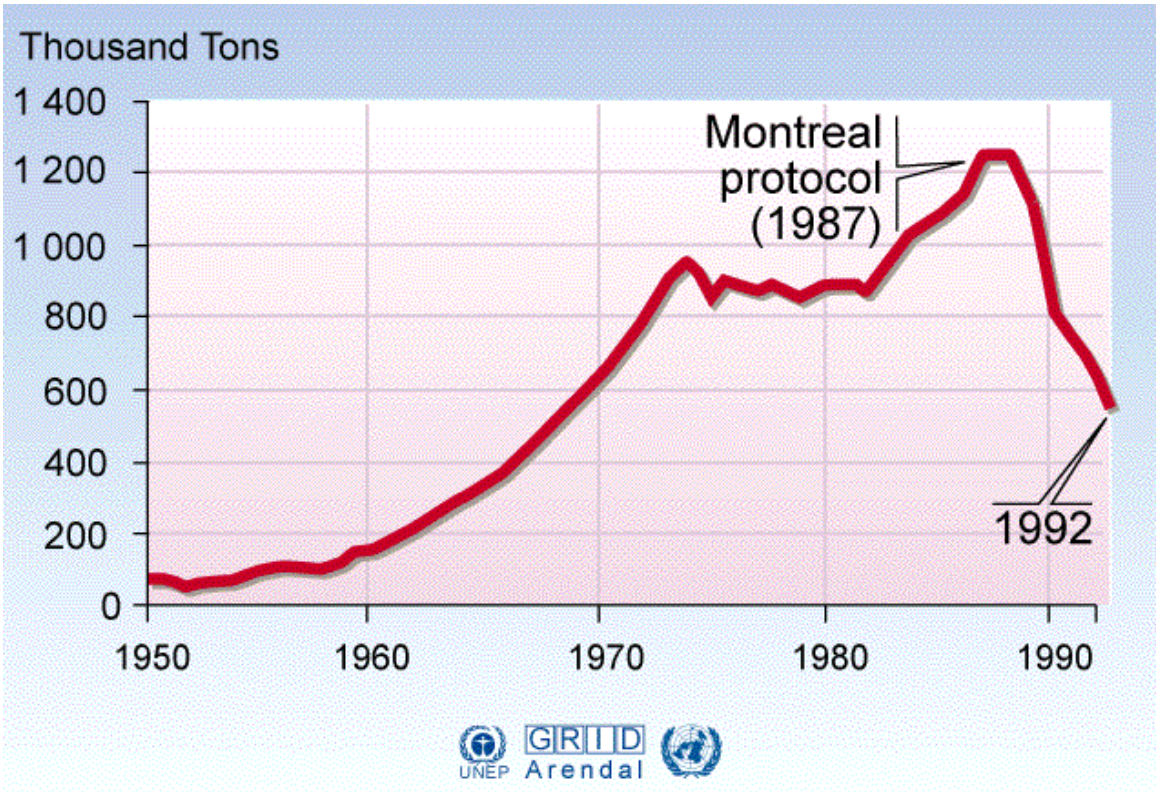
NOTE: Table (Lecture 12) shows natural and anthropogenic sources of CH_4.

N_2O: has currently lower concentrations, but shows steady increase of 0.2%/yr and has very long lifetime of 150 years.

NOTE: Table 11.1 (Lecture 11) shows natural and anthropogenic sources of N_2O.

CFCs

Figure 33.2 CFCs global production.



2. Global warming.

The **radiative forcing** is defined as the change in net irradiance (in W m^{-2}) due to a change of a given species (for example, due to change in greenhouse gas concentration).

Estimation of the climate forcings from about 1850 to 1990 (IPCC, 1995):

CO_2: +1.56 W m^{-2}

CH_4: +0.47 W m^{-2}

N_2O: +0.14 W m^{-2}

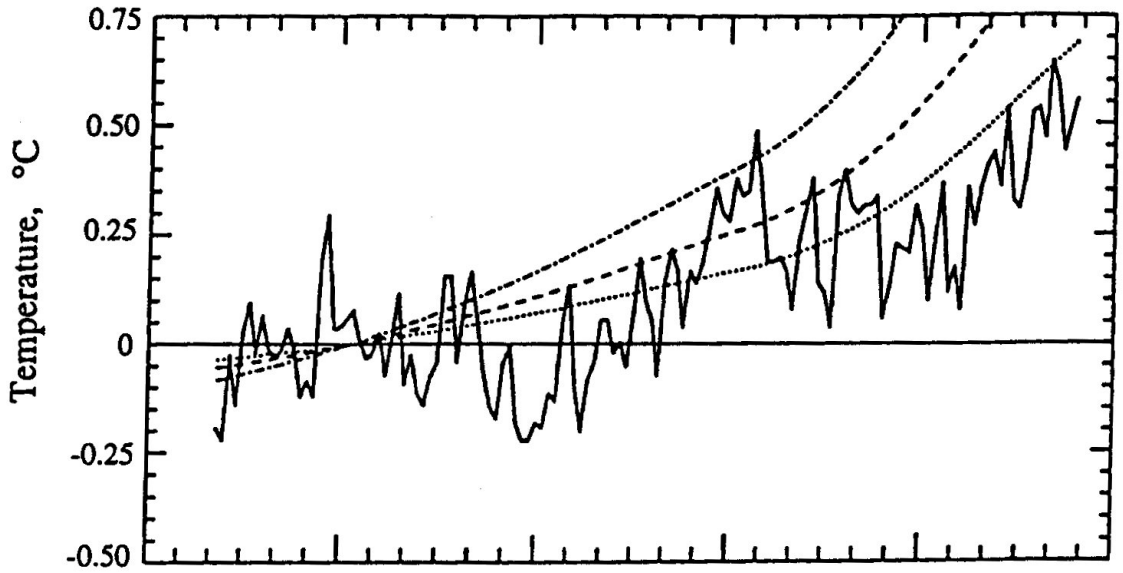
$CFCl_3$ (CFC-11): +0.06 W m^{-2}

CF_2Cl_2 (CFC-12): +0.14 W m^{-2}

(CCl_4 + HCFC-22 + CFC-113): +0.08 W m^{-2}

TOTAL: +2.45 W m^{-2}

Figure 33.3 Comparison of observed (solid line) and modeled global mean temperatures (dashed lines). Modeled temperatures were predicted by the model assuming CO2-doubling scenario for three values of climate sensitivity.



Two major problems:

1) greenhouse gases give too much warming (about 1.5^0 to 4.5^0C compare to the observed temperature change of about 0.5^0);
2) radiative forcing due to greenhouse gases can not explain the pattern of global temperature change;

NOTE: accounting for the effects of anthropogenic aerosols we can explain better the observed temperature (will be discussed in Lectures 39-41).