GLOBAL WARMING

Global warming is evidenced by a steady rise in average global temperatures, changing climate, the fact that snow cover has decreased 10% over the past half-century and that glaciers have begun melting and sea levels are rising.

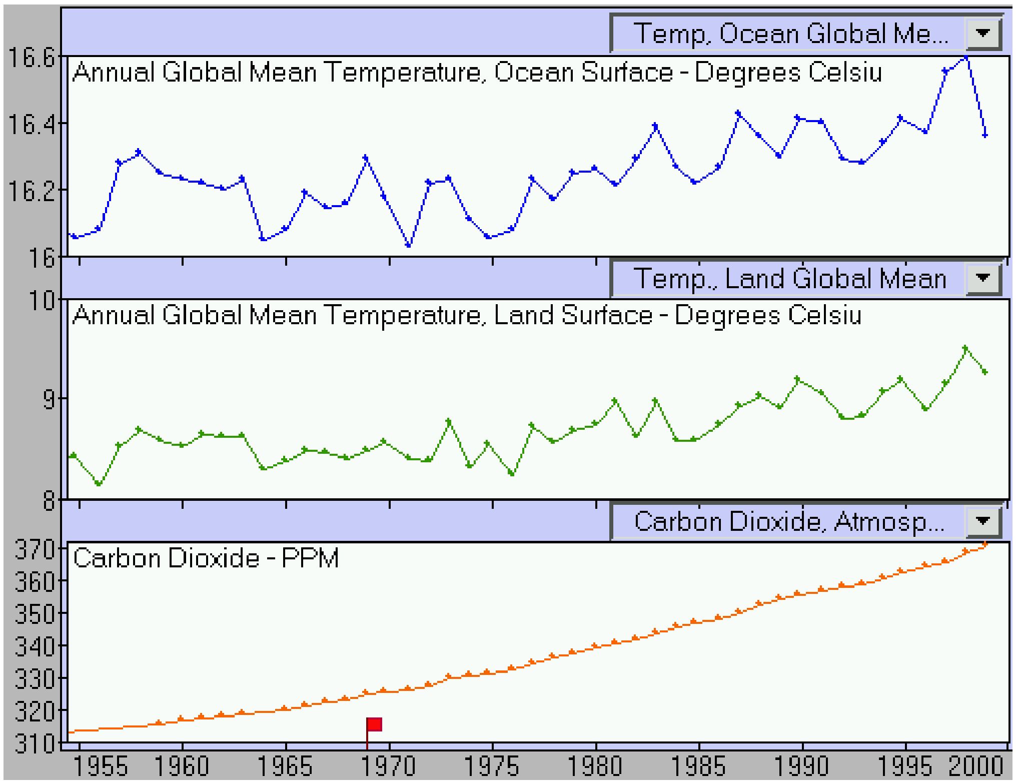

Figure 1 - Global Temperatures - A plot from the EarthScience Centre at http://www.riverdeep.net/earthscience/data/globalwarming/research_desk.html#

Scientists are convinced that the main cause is the steady rise in greenhouse gases (GHGs) in our atmosphere such as carbon dioxide resulting in an increase in the greenhouse affect.

The Greenhouse Affect

Short wave solar radiation strikes the Earth as it travels from the Sun. Some is reflected back into space while the remainder is absorbed. Because the earth is significantly cooler than the sun, the energy the earth re-radiates has a longer wavelength and is partially absorbed by greenhouse gasses in the atmosphere such as CO_2 and transformed into kinetic energy (heat).

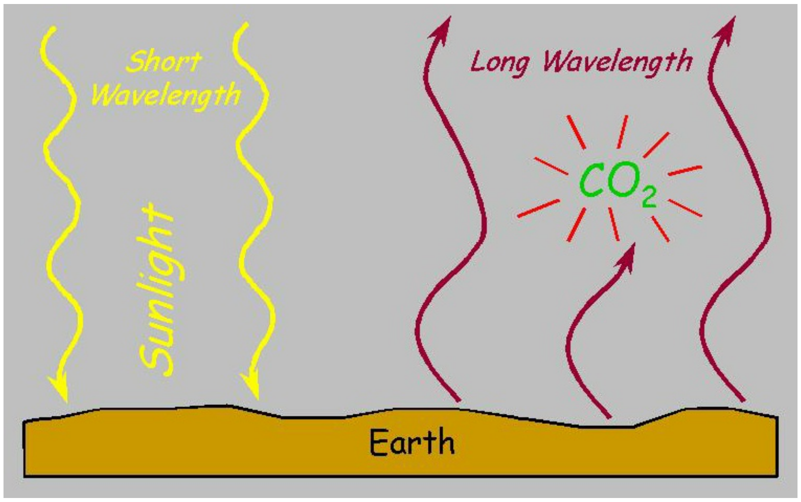

Figure 2 - The Greenhouse Affect (Source - International Energy Agency at http://www.ieagreen.org.uk/.)

Greenhouse gases differ in their ability to absorb the radiation leaving the Earth. The ability of a gas to trap heat depends on its capacity to absorb and re-emit radiation and on how long the gas remains in the atmosphere. In order to compare emissions from different sources, the global warming potential of each gas is equated to the global warming potential of carbon dioxide. For example, the global warming potential of one tonne of methane is 21 times more potent than one tonne of carbon dioxide over a 100 year period (Table 1).

Table 1 - Global Warming Potentials

Gas	**Relative Global Warming Potential (CO_2 Equivalent)**
Carbon Dioxide Methane Nitrous Oxide	1 21 310

Contributors to Global Warming

The major GHGs in our atmosphere are water vapor, carbon dioxide (CO_2), methane (CH_4), halocarbons, which are used as refrigerants, and nitrous oxide (N_2O). Modern industry and lifestyles have led to elevated levels of existing GHGs such as carbon dioxide, methane and nitrous oxide, and in some cases, completely new GHGs such as halocarbons (Figure 1).

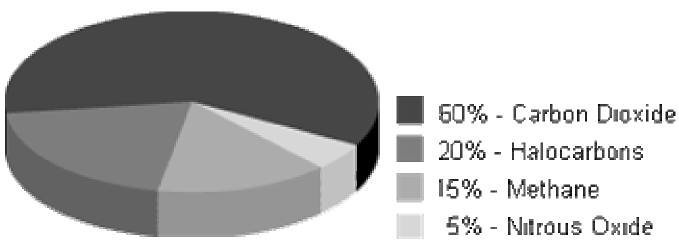

Figure 3 – The Approximate contribution of Greenhouse Gases to the Enhanced Greenhouse Affect

Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth's atmosphere.

Carbon dioxide is by far the biggest contributor simply because of the volumes involved. Nearly all modern industries rely, at least in part, upon the combustion of fossil fuels - sources of energy that include oil, natural gas, and coal. While the specific chemical composition of each energy source is variable, for the purposes of this discussion consider all three to simply be a general form of organic matter (CH_2O).

$$CH_2O + O_2 \rightarrow H_2O + CO_2$$

Burning is a relatively simple chemical reaction known as oxidation. The products of this reaction are carbon dioxide and water vapour.

The Carbon Cycle

Carbon is very important in energy cycles. Many living plants and animals extract carbon from their nonliving environment to build themselves and their environment.[1] Plants capture energy from the sun by photosynthesis whereby carbon is fixed in their structures. Animals consume food produced in this way releasing the stored up energy and CO_2.

Carbon exists in the nonliving environment as:

- carbon dioxide in the atmosphere and dissolved in water (forming HCO3-)
- carbonate rocks (limestone and coral - CaCO3)
- deposits of coal, petroleum, and natural gas derived from once-living things.
- dead organic matter, e.g., humus in the soil

Carbon enters the biotic world through the action of autotrophs:

- primary photoautotrophs, like plants and algae, that use the energy of light to convert carbon dioxide to organic matter.
- and to a small extent, chemoautotrophs - bacteria and archaeans that do the same but use the energy derived from an oxidation of molecules in their substrate.

Carbon returns to the atmosphere and water by respiration (as CO2)

- burning
- decay (producing CO2 if oxygen is present, methane (CH4) if it is not.

[1] The concentration of carbon in living matter (18%) is almost 100 times greater than its concentration in the earth (0.19%).

Prior to the industrial revolution a long term equilibrium existed between these processes.

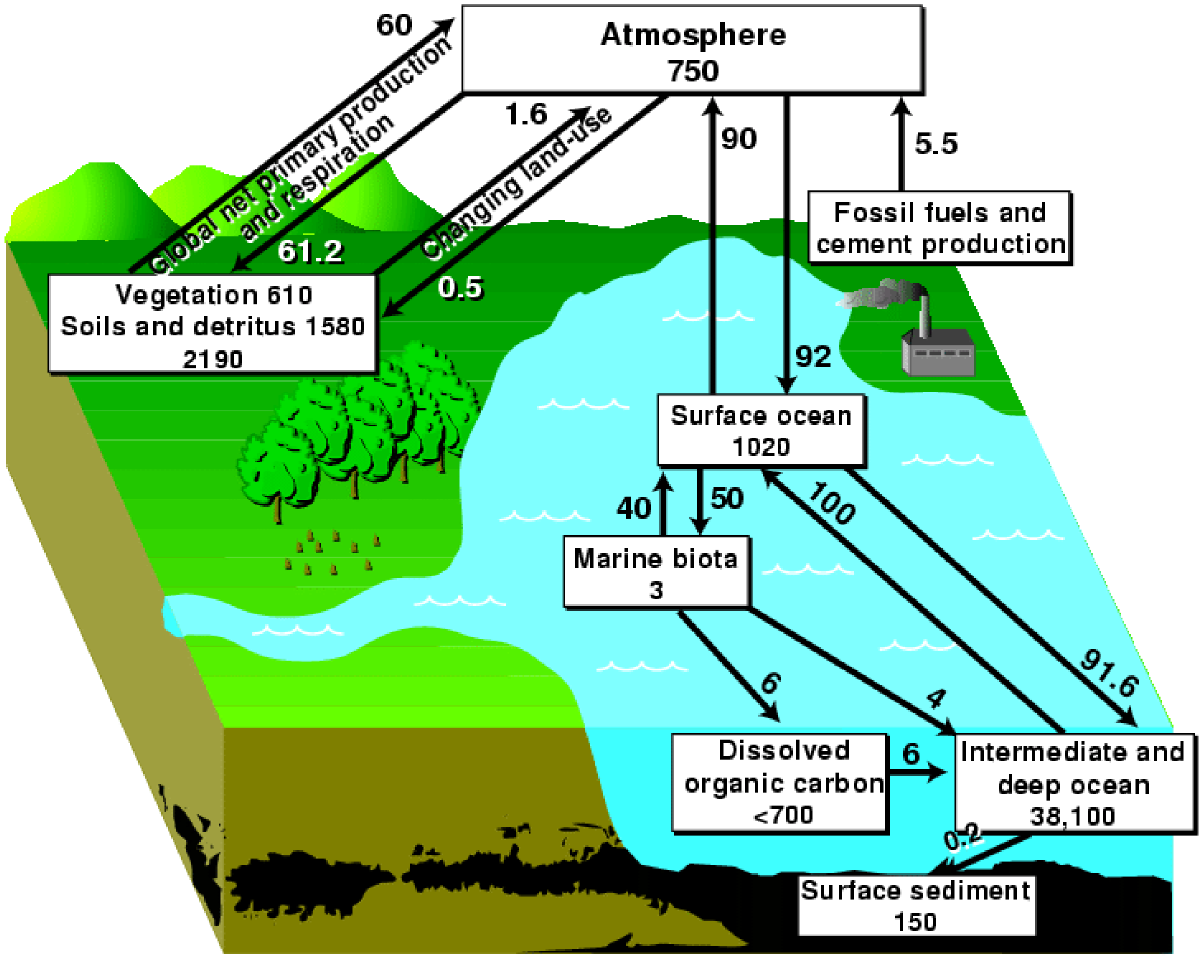

Figure 4 - The Carbon Cycle (From from Schimel, et al. 1995. CO2 and the carbon cycle.)

Samples of air trapped over the centuries in the glacial ice of Greenland show virtually no change in CO2 content until 300 years ago.

The main natural sinks available for removing CO_2 from the atmosphere are the slow, long-term, fluxes associated with the balanced pre-industrial carbon cycle and so the CO_2 concentration in the atmosphere is increasing.

Since measurements of atmospheric CO2 began late in the nineteenth century, it's concentration has risen around 30%. This increase is most likely "anthropogenic"; that is, caused by human activities such as:

- burning fossil fuels (coal, oil, natural gas) which returns to the atmosphere carbon that has been locked within the earth for millions of years.
- clearing and burning of forests, especially in the tropics. In recent decades, large areas of the Amazon rain forest have been cleared for agriculture and cattle grazing.

Fortunately increases in atmospheric CO_2 are only about one-half of what would have been expected from the amount of fossil fuel consumption and forest burning.

Research has shown that increased CO_2 levels lead to increased net production by photoautotrophs. There is some evidence that the missing CO_2 has been incorporated by

- increased growth of forests, esp. in North America.
- increased amounts of phytoplankton in the oceans.

Putting Numbers to the Carbon Cycle

Summary totals presented by the Wood's Hole Institute for carbon in the carbon cycle during the decade ending 1990 (in billion metric tonnes or petograms) are:

Atmospheric increase	=	Emissions from Fossil fuels	+	Net emissions from changes in land use	-	Oceanic uptake	-	Missing carbon sink
3.3(±0.2)	=	5.5(±0.5)	+	1.6(±0.7)	-	2.0(±0.8)	-	1.8(±1.2)

Converting to tonnes CO_2 this is:

Atmospheric increase	=	Emissions from Fossil fuels	+	Net emissions from changes in land use	-	Oceanic uptake	-	Missing carbon sink
12.07 (±0.73)	=	20.152 (±0.1.83)	+	5.86 (±2.56)	-	7.32 (±2.93)	-	6.59 (±4.39)

In general agreement with other research there appears to be a discrepancy which is believed to be because there has been a greater than measurable amounts taken up by living plant sinks (We may also be increasing the overall size of our atmosphere! – ed.)

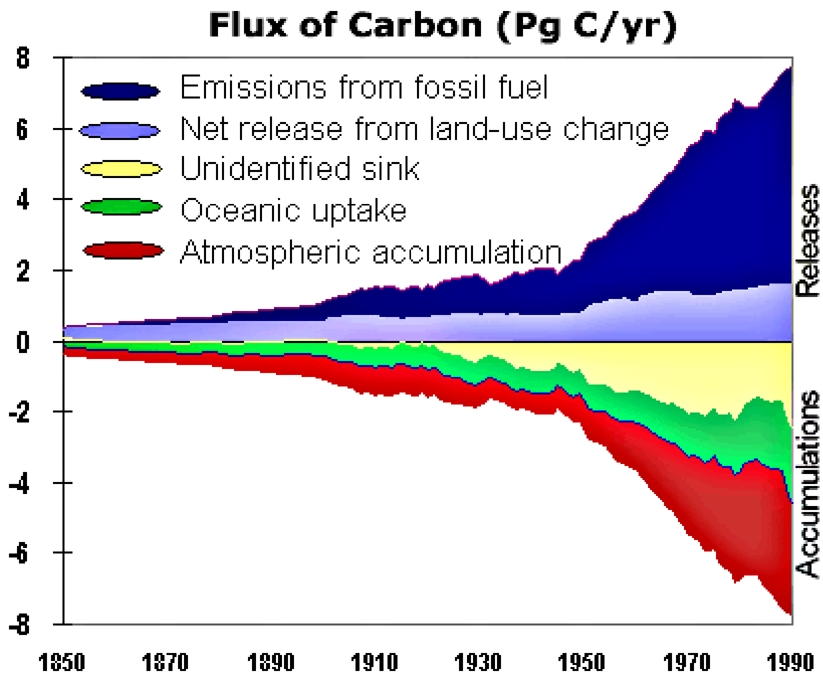

Figure 5 - Sequestration and Emission of Carbon Dioxide (from the Woods Hole Institute web site at http://www.whrc.org/science/carbon/carbon.html).

Other Side Affects

The earth's surface temperature is influenced by more than carbon dioxide. Coupled with CO_2 is the complex feedback systems associated with water vapour in the atmosphere. Water is one of the two products of the combustion of organic mater; however, this source of H_2O is small compared to the magnitude of evaporation fluxes in the water cycle. As such, water sourced from combustion is not particularly significant; yet, water vapour does play a major role in our study of global warming.

An interesting and important property of our atmosphere is that the amount of water vapour that it can contain is a function of the air's temperature. Warm air is able to hold more moisture than is cold air. The result of this is that as temperatures rise, due to the long wavelength absorption associated with CO_2, ever more water vapour is held in the atmosphere.

Water vapour in the atmosphere influences global temperatures through two different feedback systems. Water is, like CO_2, is a weak greenhouse gas. As such, more water vapour in the atmosphere results in the absorption of more long wavelength radiation and an additional increase in global average temperature. This relationship is a strongly positive feedback loop. Conversely, more atmospheric water vapour causes the formation of more clouds. The white colour of clouds reflects incoming short wavelength sunlight back into space before it has a chance to warm the Earth. This decrease in the input of solar energy by cloud-top reflection is a negative feedback loop. Thus, more water vapour in the atmosphere can result in both warming and cooling. Considerable debate remains within the scientific community as to which of these two feedback systems is the most significant . One of the most active areas of atmospheric research is the description of changes in the global distribution of cloud cover.

Global warming and the concentration of atmospheric CO_2 represents one of the most complexly interrelated Earth Systems. Because scientists do not, as yet, fully understand all of the fluxes and feedback loops that control global average temperature, it is extremely difficult to predict future changes with any certainty.

There is no question, however, that industrially driven CO_2 increases are forcing the Earth's atmosphere out of its pre-industrial equilibrium.