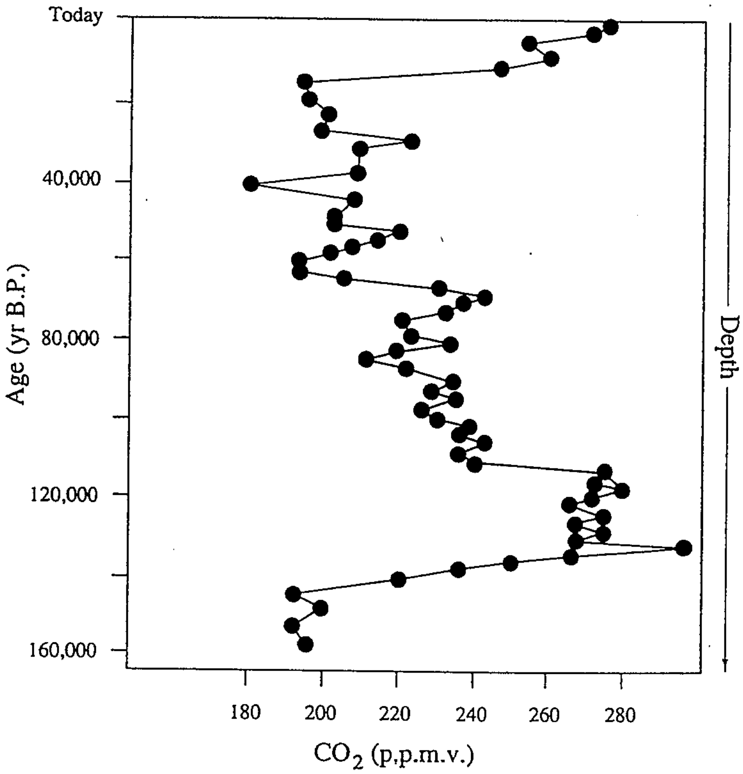
Teacher Background Information: The Enhanced Greenhouse Effect

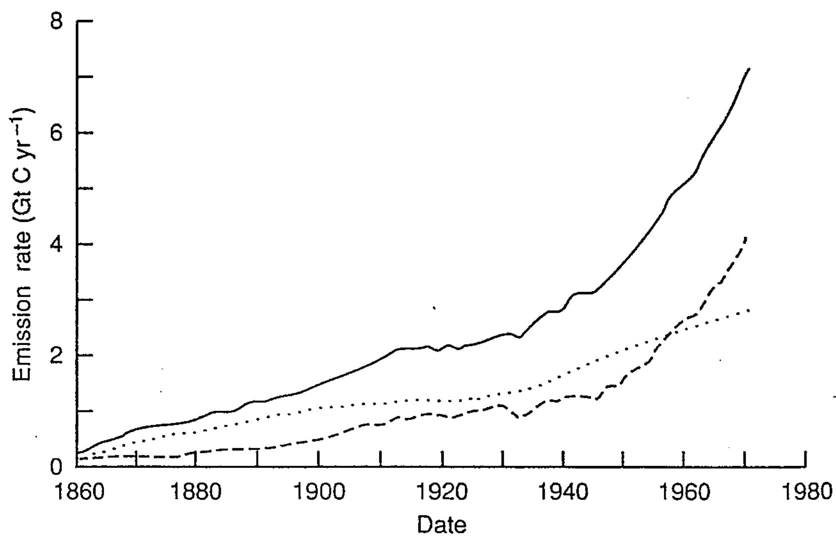
The Earth's atmosphere has never been free of change: its composition, temperature and self-cleansing ability have all varied since the planet first formed. Yet the pace in the past two centuries has been remarkable: the atmosphere's composition in particular has changed significantly faster than at any time in human history.



Record of atmospheric CO_2 during the last 160,000 years derived from analysis of gas bubbles trapped in the Antarctic ice core.

The increasingly evident effects of these ongoing changes include acid deposition by rain and other processes, corrosion of materials, urban smog and a thinning of the stratospheric ozone shield which protects the surface of the Earth from harmful ultraviolet (UV) radiation. Atmospheric scientists also expect that the planet will eventually warm, causing potentially dramatic climatic shifts through an "enhanced" greenhouse effect - human activity is altering the mixture of gases responsible for the heating of the Earth by absorbing infrared radiation from the warmed surface of the planet and then returning it to Earth.

This important phenomena does not stem from a modification in the atmosphere's major constituents. Excluding the widely varying content of water vapor, the concentrations of the gases that make up 99.9 percent of the atmosphere - N_2, O_2 and the noble gases (Argon, Neon, etc.,) - have been relatively constant for much longer than humans have been on Earth. Rather, the effects are caused in large part by changes, mainly increases, in the levels of several of the atmosphere's minor constituents, or trace gases. Rising levels of carbon dioxide, methane, nitrous oxide and the CFCs are enhancing the natural greenhouse effect. While some fluctuation in the concentrations of atmospheric constituents can certainly derive from variations in rates of emissions by natural sources, the fact remains that the activities of human beings account for most of the rapid changes of the past 200 years. Such activities include the combustion of fossils fuels (coal and petroleum) for energy, other industrial and agricultural practices, biomass burning (burning of vegetation) and deforestation.

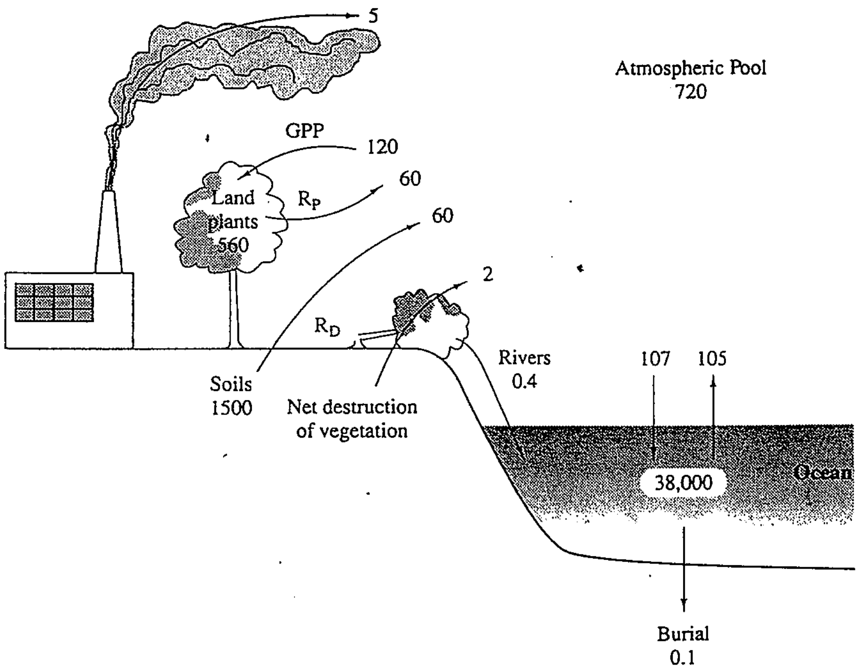


Emissions of carbon to the atmosphere from natural sources in the biosphere (dotted line) and from fossil fuel consumption (dashed line) for the period 1860 - 1970.

Which human activities generate which emissions? How do altered concentrations of trace gases give rise to certain consequences? How much has the problem grown and what are the consequences for the planet? Although complete answers to these and other questions are still forthcoming, multidisciplinary efforts by chemists, meteorologists, solar and space physicists, geophysicists, biologists, ecologists, social scientists and others are making good headway.

Multidisciplinary collaboration is crucial because the factors influencing the fate of gases in the atmosphere and their interaction with the biosphere are complex and incompletely understood. For instance, the chemical reaction a gas undergoes in the atmosphere can vary depending on the local mixture of gases and particles, the temperature, the intensity of the Sun, the presence of different levels and types of clouds or precipitation and patterns of airflow. The reactions in turn influence how long a gas remains in the atmosphere, and whether the gas or its end products have a global or local effects on the environment.

Among the fruits of the investigations has been an improved understanding of the emissions produced by specific human activities. The combustion of fossil fuels is known to yield substantial amounts of sulfur dioxide (particularly from coal), nitrogen oxides (which form when N_2 and O_2 in the air are heated) and carbon dioxide. If the burning incomplete it also yields carbon monoxide (CO), a variety of hydrocarbons (compounds of C and H) including methane, and soot (carbon particles). Other industrial activities release additional sulfur dioxide (smelting is an example) or inject such substances as chlorofluorocarbons (CFCs) or toxic metals (lead) into the air.



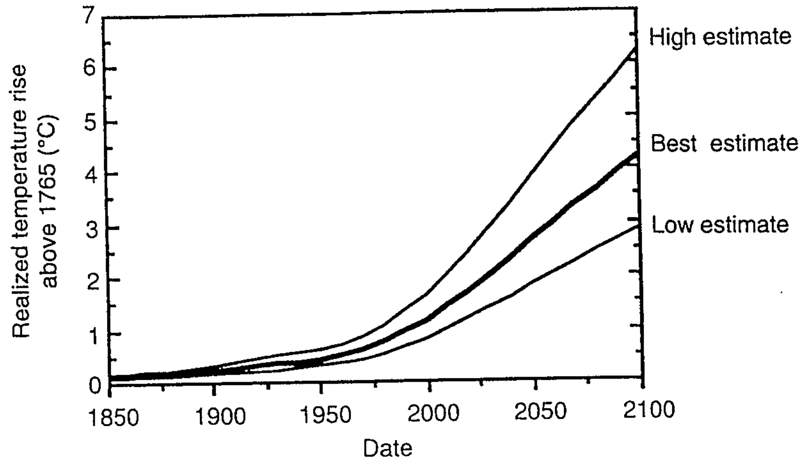
The present day global carbon cycle. All reservoirs of C are expressed in 10^{15} g C and all fluxes in units of 10^{15} g C/yr.

Agricultural practices lead to the emissions of several gases as well. The burning of forests and savanna grasses in tropical and subtropical regions to create pastures and croplands yield additional large amounts of carbon monoxide, methane and nitrous oxides. In addition, soils exposed after forests are cleared emit nitrous oxide as do nitrogen-rich fertilizers spread over fields. The breeding of domestic animals is another major source of methane from anaerobic (oxygen-shunning) bacteria in the digestive tracts of cattle and other cud-chewing animals, as is the cultivation of rice, which is a staple food for millions of people in the tropics and subtropics.

Source or Sink	CH_4 (10^{12} g CH_4/yr)
Sources	
Natural wetlands	115
Open freshwaters	5
Rice paddies	110
Animals	80
Termites	40
Oceans	10
Anthropogenic	
Biomass burning	55
Landfills	40
Coal mining	35
Natural gas	45
Methane hydrate	5
Total sources	540
Sinks	
Reactions with OH	490
Soil microbes	10
Atmospheric increase	40
Total sinks	540

The Atmospheric Methane Budget

While the depletion of global ozone appears to be the handiwork of primarily a single class of industrial products - the CFCs, several different emissions combine to raise the specter of an *enhanced greenhouse effect* for the Earth. Exactly how high the global temperatures might climb in the future is not clear. What is clear is that the levels of infrared-absorbing trace gases such as CO_2, CH_4, and N_2O have mounted drastically in the past decades, making some degree of heating inevitable.



The annual surface warming (in *C) for "business as usual" greenhouse gas emissions, which consider a variety of climate sensitivities, ocean heat uptake and other variables.