The Greenhouse Effect and Global Climate Change

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The greenhouse effect in its natural form has existed on the planet for hundreds of millions of years and is essential in maintaining the Earth's surface at a temperature suitable for life. Without it, we would all freeze.

The sun's radiant energy, as it falls on the earth, warms its surface. The earth in turn re-radiates heat energy back into space in the form of infra-red radiation. The temperature of the earth establishes itself at an equilibrium level at which the incoming energy from the sun exactly balances the outgoing infra-red radiation.

If the earth had no atmosphere, its surface temperature would be approximately minus 18°C, well below the freezing point of water. However our atmosphere, whilst largely transparent to incoming solar radiation in the visible part of the spectrum, is partially opaque to outgoing infra-red radiation. It behaves in this way because, in addition to its main constituents, nitrogen and oxygen, it also contains very small quantities of 'greenhouse gases'. Put simply, these enable the atmosphere to act like the panes of glass in a greenhouse, allowing the sun to enter but inhibiting the outflow of heat, so keeping the earth's surface considerably warmer than it would otherwise be. The average surface temperature of the earth is in fact around 15°C, some 33°C warmer than it would be without the greenhouse effect.

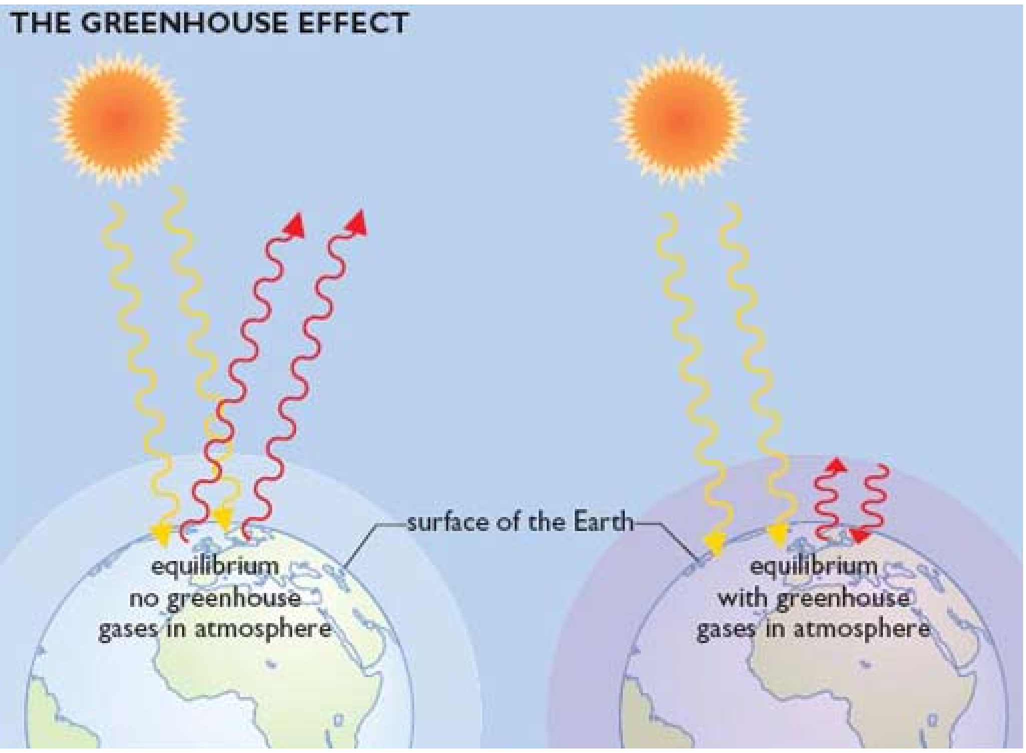

Figure 1: A simplified depiction of how the greenhouse effect raises the earth's temperature

The most important greenhouse gases are water vapour, carbon dioxide and methane, though other gases such as the chlorofluorocarbons (CFCs) also play significant but lesser roles.

Water vapour evaporating from the oceans plays a major part in maintaining the natural greenhouse effect, but human activities have very little influence on the vast processes through which water cycles between the oceans and the atmosphere.

Carbon dioxide (CO_2) is also primarily generated by natural processes. These include the process of respiration, in which organisms 'breathe out' carbon dioxide; and the emissions of CO_2 that occur when organisms die and the carbon compounds of which they are composed decay. But since the industrial revolution, the burning of fossil fuels by humanity has been adding substantial quantities of CO_2 to our atmosphere. The fossil fuels are essentially compounds of carbon and hydrogen. Coal consists mostly of carbon, the chemical symbol for which is C. Natural gas, the chemical name for which is *methane*, consists of carbon and hydrogen. Each carbon atom is surrounded by four hydrogen atoms, so in chemical shorthand its symbol is CH_4. Oil is a more complex mixture of many different hydrocarbon molecules. When any of these fuels is burned, carbon dioxide is produced, along with water.

The concentration of CO_2 in the atmosphere in pre-industrial times was around 280 parts per million by volume (ppmv) but levels have been steadily rising since then, reaching some 360 ppmv in 2000.

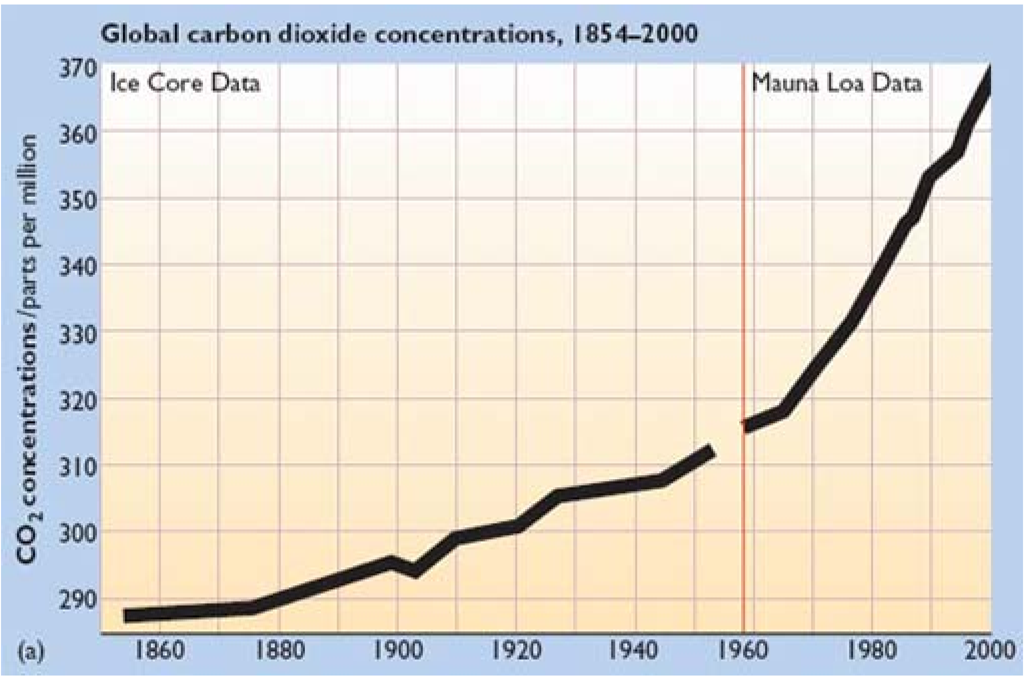

Figure 2: Atmospheric concentrations of carbon dioxide (CO_2), 1854–2000. Carbon dioxide data from 1958 were measured at Mauna Loa, Hawaii; pre-1958 data are estimated from ice cores

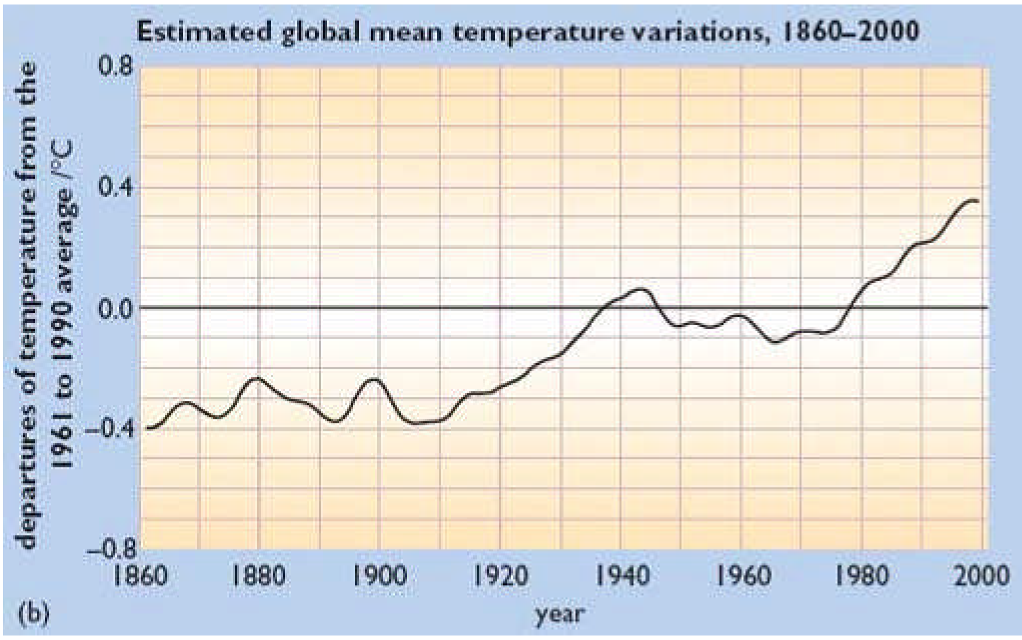

Figure 3: Estimated global mean temperature variations, 1860–2000

The other main greenhouse gas, methane, is given off naturally when vegetation decays in the absence of oxygen – for example, under water. However various human activities, including increasing rice cultivation, which causes methane emissions from paddy fields, and leaks of fossil methane from natural gas distribution systems, have caused the levels of methane in the atmosphere to increase sharply. Concentrations have risen from about 750 parts per billion by volume (ppbv) in pre-industrial times to around 1750 ppbv in 2000.

These additional emissions of carbon dioxide and methane are the main causes of the so-called *anthropogenic* – that is, human-induced – greenhouse effect. Unlike the operation of the natural greenhouse effect, which is benign, the anthropogenic greenhouse effect is almost certainly the cause of a global warming trend that could have very serious consequences for humanity. Though a small minority dissents, the majority of scientists now believe that the anthropogenic effect, acting to enhance the natural processes, has already caused the mean surface temperature of the earth to rise by about 0.6°C during the twentieth century (Intergovernmental Panel on Climate Change, 2001). Moreover, if steps are not taken to limit greenhouse gas emissions, atmospheric CO_2 levels will probably rise by 2100 to between 540 and 970 ppmv (depending on the assumptions made). These levels would be between two and three times the pre-industrial CO_2 concentration, and would be likely to lead to rises in the earth's mean surface temperature of between 1.4 and 5.8°C by the end of the century. Such temperature rises would be unprecedented since the ending of the last major Ice Age, more than 10,000 years ago.

These temperature rises would be very likely to result in significant changes to the earth's climate system. Such changes would probably include more intense rainfall, more tropical cyclones, or long periods of drought, all of which would disrupt agriculture. Moreover, ecosystems might be damaged with some species unable to adapt quickly enough to such rapid changes in climate.

In addition, due to thermal expansion of the oceans, sea levels would be expected to rise by around 0.5 metres during the twenty-first century, sufficient to submerge some low-lying areas and islands. In the longer term, further sea level rises would result if the Antarctic ice sheets were to melt significantly.