Global Climate Change Program

By Degrees

Illinois State Water Survey • 2204 Griffith Drive • Champaign, IL • 61820 • 217-333-2210

What Are the Greenhouse Gases?

Greenhouse gases are *not* the most abundant constituent of the atmosphere (less than 1 percent of all gases), but collectively they are critical to heating the atmosphere and maintaining life as we know it The principal greenhouse gases are water vapor (H_2O), carbon dioxide (COj), methane (CH*), nitrous oxide (N_2O), and to a lesser degree ozone (O_3). While transparent to incoming solar (short-wave) radiation, each greenhouse gas has selective wavelengths at which most outgoing terrestrial (long-wave) radiation is absorbed and prevented from escaping to space (figure 1). This absorption effect and the re-radiation of some of this "trapped heat" back to the earth's surface is the driving force of the greenhouse effect.

While not considered greenhouse gases, other trace gases contribute either to their buildup or their removal. For example, carbon monoxide (CO) reacts chemically to form $C0_2$; volatile organic compounds (VOCs), nitrogen oxide radicals (NOx), and nonmethane hydrocarbons (NMHCs) all react to form O_3 in the lower atmosphere; and hydroxyl radicals (OH) react chemically to remove CH_4. Still other gases, such as sulfur dioxide (SO_2) and sulfate particles, may contribute to a cooling effect while chlorofluorocarbons (CFCs) have competing effects.

Climatic warming predictions are generally based on the doubling or the equivalent doubling of CO_2 over pre-industrial values. The "equivalent doubling" takes into consideration the global warming potential (GWP) of all greenhouse gases. The GWP depends on three factors: their atmospheric concentration, their lifetime in the atmosphere, and their effectiveness in absorbing outgoing terrestrial radiation. For example, a molecule of CH_4 is about 25 times more effective in trapping radiation than CO_2. But CH_4 is less concentrated and has a shorter lifetime in the atmosphere, giving it a smaller GWP. Thus, CH_4 accounts for about 15 percent of the enhanced warming in the last century, compared to about 60 percent for CO_2.

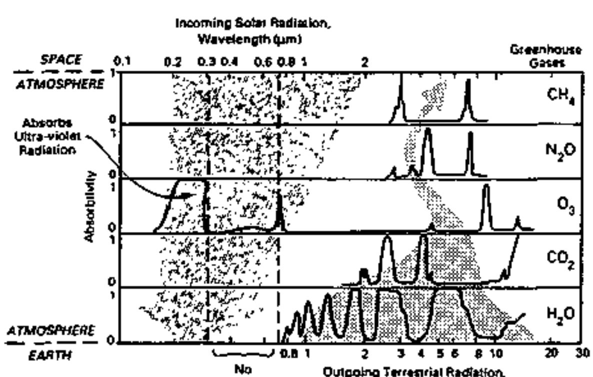

Figure 1. Greenhouse gases are transparent to incoming solar (short-wave) radiation but trap outgoing terrestrial (long-wave) radiation.

With the exception of CFCs, greenhouse gases are a natural constituent of the atmosphere. Concern about these gases is not their presence but their growing levels in the atmosphere due to human activities. The principal human sources of greenhouse gases are fossil fuel combustion (primarily CO_2, but CH4 is released by natural gas leakage), land-use changes (primarily deforestation, which releases stored CO_2 and limits future intake by photosynthesis), agricultural activities (ruminant animals and rice Fields release CH4, and nitrogen fertilizers release N_2O), and other sources (e.g., landfills and coal mines release CH_4).

Ozone (O_3)

The role of O_3 as a greenhouse gas depends on whether it is found in the upper atmosphere (stratosphere) or the lower atmosphere (troposphere). Stratospheric ozone absorbs ultra-violet radiation, preventing incoming solar radiation from reaching the earth (cooling effect). Tropospheric ozone is a more effective greenhouse gas than stratospheric ozone, acting as other greenhouse gases, which contribute to tropospheric warming. Model calculations show that a 50 percent increase of tropospheric ozone may lead to a surface warming of 0.5 °F.

Water Vapor (H_2O)

Water vapor is the most abundant and powerful of all greenhouse gases. It is not a primary factor in the enhanced greenhouse warming, as its abundance in the atmosphere has remained relatively constant

Characteristics of Key Greenhouse Gases

Parameter	CO_2	CH_4	N_2O
Pre-industrial levels (pre-1880) (ppm)	280	0.8	0.288
Present levels in the atmosphere (ppm)	353	1.7	0.310
Rate of increase per year (percent)	0.5	0.9	0.2
Life time in the atmosphere (years)	120	10	150
Global Warming Potential (× CO_2)	1	25	200
Contribution to greenhouse warming (percent)	60	15	7
U.S. share of emissions (percent)	20	10	no estimate

But H_2O may be important in other ways. For example, increasing temperatures may raise the water content of the atmosphere and thus its influence on global warming. Increased cloud coverage could either serve as an insulating layer absorbing outgoing terrestrial radiation (warming effect) or shade the earth by reflecting incoming solar radiation (cooling effect). Some scientists estimate that shifting 10 percent of the clouds from daytime to nighttime will have a greater warming effect than doubling the greenhouse gases. Others see the dual role of water vapor and clouds as a natural thermostat preventing runaway greenhouse warming.

Sulfur Dioxide (SO_2)

Particles formed from sulfur dioxide (SO_2) emissions reflect and absorb incoming solar radiation and increase the brightness (reflectivity) of clouds, producing a cooling effect. Volcanic eruptions (figure 2) also have a cooling effect by releasing SO_2 to the stratosphere, which reacts with water vapor to form sulfur particles. These particles envelope the globe within months and block some of the incoming solar radiation. The eruption of Mt Pinatubo is estimated to reduce temperatures by 0.8 degrees over the next few years — possibly enough to mask a global warming signal.

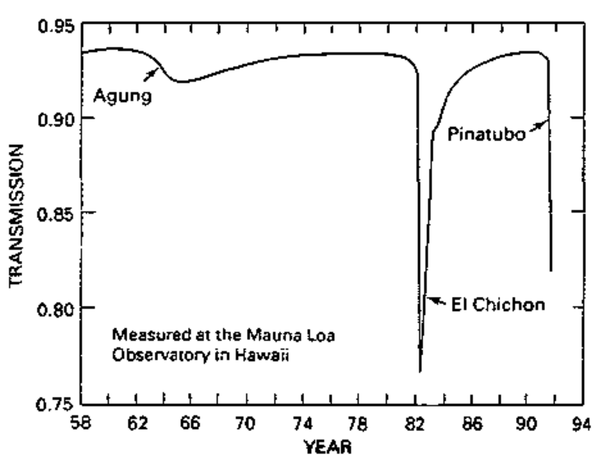

Figure 2. Particles released to the stratosphere from major volcanic eruptions can reduce the transmission of incoming solar radiation that reaches the earth's surface (cooling effect).

Chlorofluorocarbons (CFCs)

CFCs are man-made chemicals that were first used in the 1930s. Over the past decades, atmospheric levels of CFCs have increased more rapidly than levels of other greenhouse gases. Due to concerns about their destruction of the ozone layer of the stratosphere, CFCs will be phased out by international agreement (Montreal Protocol). Originally thought a potent greenhouse gas (trapping 10,000 times as much heat per molecule as CO_2), recent research suggests CFCs have a neutral effect — depleting ozone in the lower stratosphere, a cooling effect that offsets radiative warming by CFCs.

Hydroxyl Radicals (OH)

The chemical reaction between OH and CH_4 is an important removal process for atmospheric CH_4. The rate of removal may be slowing down due to decreasing concentrations of OH in the air from the removal of OH by other polluting chemicals. The implication is to increase the GWP of CH_4 by giving it a longer lifetime in the atmosphere and amplify the greenhouse warming.

Further Reading

Climate Change: A Global Concern. Chap. in *World Resources 1990-91.* New York: Oxford University Press, 1990.

Schneider, Stephen H., "The Changing Climate," *Scientific American* 261 (September 1989):70-79.

U.S. Congress, Office of Technology Assessment, *Changing by Degrees.Steps to Reduce Greenhouse Gases,* OTA-O-482. Washington, DC: U.S. Government Printing Office, 1991.