THE GREENHOUSE EFFECT

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WHAT IS THE GREENHOUSE EFFECT?

The “greenhouse effect” is the warming of climate that results when the atmosphere traps heat radiating from Earth toward space. Certain gases in the atmosphere resemble glass in a greenhouse, allowing sunlight to pass into the “greenhouse,” but blocking Earth’s heat from escaping into space. The gases that contribute to the greenhouse effect include water vapor, carbon dioxide (CO2), methane, nitrous oxides, and chlorofluorocarbons (CFCs).

Life on Earth depends on energy coming from the Sun. About half the light reaching Earth’s atmosphere passes through the air and clouds to the surface, where it is absorbed and then radiated upward in the form of infrared heat. About 90 percent of this heat is then absorbed by the greenhouse gases and radiated back toward the surface, which is warmed to a life-supporting average of 59 dedrees Fahrenheit (F) (15 degrees Celsius (C).

On Earth, human activities are changing the natural greenhouse. Over the last century the burning of fossil fuels like coal and oil has increased the concentration of atmospheric CO2. This happens because the coal or oil burning process combines carbon (C) with oxygen (O2) in the air to make CO2. To a lesser extent, the clearing of land for agriculture, industry, and other human activities have increased the concentrations of other greenhouse gases like methane (CH4), and further increased (CO2).

The consequences of changing the natural atmospheric greenhouse are difficult to predict, but certain effects seem likely:

* On average, Earth will become warmer. Some regions may welcome warmer

temperatures, but others may not.

* Warmer conditions will probably lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others dryer.

* A stronger greenhouse effect will probably warm the oceans and partially melt glaciers and other ice, increasing sea level. Ocean water also will expand if it warms, contributing to further sea level rise.

* Meanwhile, some crops and other plants may respond favorably to increased atmospheric CO2, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns may change the areas where crops grow best and affect the makeup of natural plant communities.

INCREASES IN ATMOSPHERIC (CO2)

Human Activities Add to Atmospheric (CO2)

Atmospheric CO2 has increased about 25 percent since the early 1 800s. Climatologists at NASA's Goddard Space Flight Center, Greenbelt, Md., estimate the increase since 1958 has been about 10 percent. Currently, the level of atmospheric C 2 is increasing at a rate of about 0.4 percent a year.

Human beings add CO2 to the atmosphere mainly by burning fossil fuels like coal and oil. Deforestation is the second major way we increase atmospheric CO2. Felled timber releases CO2 as it burns or decays, and disturbed soils produce CO2 from burned organic matter. Forests give way largely to annual crops that store CO2 for only a season, or to cities with little vegetation at all.

Natural Processes Affect the Amount of Atmospheric (CO2)

Human activities add appreciably to atmospheric CO2, but natural processes are fundamental in regulating the amount of CO2 in the atmosphere and elsewhere.

Besides the atmosphere, Earth has several other reservoirs of CO2 including vegetation and the oceans. Through photosynthesis, plants take up (CO2) and store it in their leaves, fruit, stems, and roots. Oceans constitute by far the largest reservoir, however. Atmospheric CO2 dissolves into surface waters, and over time, ocean circulation carries it to great depths and distant locations. Eventually, biochemical processes may turn it into shells and sediments that drift toward the bottom of the oceans.

THE RISE OF GREEN HOUSE GAS LEVELS

Because high levels of greenhouse gases may have a significant effect on climate, vegetation, and other aspects of our lives, it is important to determine when major increases will occur. The concentration of atmospheric CO2 will certainly continue to rise so long as fossil fuels remain our principal source of energy; but pinpointing the rate of future increases is difficult, due mostly to uncertainties about future human behavior and technological developments.

Predictions become more complicated when they take other greenhouse gases into account. While increasing CO2 is expected to be the main factor in enhancing Earth's atmospheric greenhouse, gases like methane, nitrous oxide and the CFCs almost certainly will contribute to changing climate as well. How quickly these gases will increase is also uncertain.

Predictions From the GISS Model

The NASA Goddard Institute for Space Studies' (GISS) computer model has been used to calculate the temperature increase during the next 50 years in response to gradual increases in greenhouse gas concentrations. The simulation shows a change of 35.6 degrees F (2degrees C), which would make Earth warmer than it is thought to have been at any point in history.

HOW INCREASING ATMOSPHERIC (CO2) MAY AFFECT CLIMATE

Globally, as the concentration of atmospheric (CO2) rises, temperatures will increase and other climate characteristics will probably change as well:

* On average, surface air temperature around the world will increase. When the climate has adjusted to a doubling of the CO2 concentration, researchers estimate a global average temperature increase of 3 to 8 degrees F (-13.3 to 16.1 degrees C). The GISS computer model is close to the higher end of this range.

* Overall, rain and perhaps snow at high altitudes may increase, but this trend may not appear everywhere.

* Snow cover may recede.

Changes in worldwide averages interest most of us less, however, than shifts in regional and local climate. Conditions locally may differ from global averages in temperature, amounts of rain and snow, frequency or severity of major

storms. Local conditions like these profoundly influence the quality of our lives, and they certainly affect important activities like agriculture. Farmers need to know, for example, whether the amounts of soil moisture available for their crops will increase or decrease and whether they should worry more or less about frosts. In some regions, concerns for safety and property could require measures to deal with more frequent flooding, more severe storms, or the like. Scientists know how important these concerns are. Nevertheless, they cannot yet produce good estimates of future changes in regional climate because their tools are not yet sophisticated enough to forecast changes in regional conditions.

IS THE GREENHOUSE EFFECT AT WORK?

To determine the effects produced from greenhouse gases, scientists look for changes such as warmer weather, warmer ocean temperatures, and a cooler stratosphere. The ability to predict these effects presents many difficulties because the Earth's temperature fluctuates for a variety of reasons. Instruments and techniques used to measure changes have not always been consistent. Although it is difficult to determine how much of the warming effect is man-made, it is fairly certain that humans have contributed to the growth of atmospheric CO2. The increase in CFCs is entirely man-made. The cause of the increase in methane is less well understood.

There is evidence that average surface air temperature has increased worldwide by nearly 1 F (-1 7.2 C) since 1850. Given the increase of about 25 percent in atmospheric CO2 between the early 1800s and the present, it might be concluded that the greenhouse effect is producing a global warming.

However, there has been little increase in the last 50 years, which raises questions about whether we really have experienced the effect of increasing CO2. The pattern of changing global temperatures suggests that there may be other factors influencing climate. There is also the possibility that the sensitivity to greenhouse gases is less than what most climate models indicate. Scientists feel an increase of 1degree F (-17.2 degrees C) in 140 years is not necessarily outside the range of natural climate variability.

HOW GREENHOUSE EFFECTS ARE PREDICTED

Goddard scientists use computer models to simulate the known workings of Earth's environment in response to increases in certain gases. Computer models divide the planet into hundreds of parts that scientists commonly refer to as "boxes." Each box is represented by mathematical equations for such variables as wind, temperature, incoming and outgoing radiation. Each of the boxes are linked to neighboring boxes so they can respond to changing conditions around them with changes of their own. Thus, scientists can enter variables into the model such as increased levels of certain atmospheric gases to see what changes these cause.

Computer models of Earth's environment have some problems. For example, scientists do not yet completely understand the relationship that clouds play in the heating and cooling process of the Earth's atmosphere. Also, the role of the ocean in this process is not completely understood. However, scientists continue to use the models while these difficulties are being studied .

FUTURE GREENHOUSE STUDY

Two NASA projects, managed by the Goddard Space Flight Center, which will contribute to further study of the greenhouse effect, are the Upper Atmosphere Research Satellite (UARS), which will look at the role of the stratosphere, and the Earth Observing System (EOS).

UARS, launched in September 1991, is providing NASA and a broad, international scientific community with comprehensive data sets on the upper atmosphere's chemistry, energy and dynamics, including data crucial to expanding our understanding of the ozone layer. It is the spearhead of a long term international program of space research into global atmospheric change. The UARS program is designed to carry out the first systematic, detailed satellite study of Earth's upper atmosphere, establish the comprehensive data base needed for an understanding of stratospheric ozone depletion, and bring together scientists and governments from around the world to assess the role of human activities in atmospheric change. The mission will also lay the foundations for a broader study of upper atmosphere influence on climate and climatic variations.

EOS is a planned NASA program for observing Earth from space using a new generation of spacecraft called polar orbiting platforms. EOS will collect data to help us understand the processes which control our global environment and to determine which natural events can be predicted, what things humans influence, and the consequences of these activities.