GREENHOUSE EFFECT

[*For an introduction to* Greenhouse Effect, *see articles on* Carbon Dioxide *and* Global Warming.]

A Scientific Analysis

The term *greenhouse effect* refers broadly to the partial trapping by the atmosphere of radiation from the Earth's surface, leading to a surface temperature that is larger than would be the case without the atmosphere. While the atmosphere is relatively transparent to shortwave radiation (sunlight), it is nearly opaque to infrared radiation, owing to the presence of certain trace gases and of clouds. Much of the infrared radiation passing upward from the Earth's surface is absorbed and reradiated, both upward and downward. Because the surface therefore receives not just solar radiation but also infrared radiation from the atmosphere and clouds, it is much warmer than it would be in the absence of the atmosphere. (Actual greenhouses work mostly by preventing the upward *convection*—not radiation—of heat received from the sun, so that the term *greenhouse effect* is something of a misnomer.)

The most important greenhouse gas in the atmosphere is *water vapor.* Along with clouds, composed of water drops or ice crystals, water vapor plays a key role in trapping outgoing terrestrial radiation. But because water vapor responds rapidly to changing conditions, water is treated as a feedback in the climate system, not an external forcing. It is generally believed that water vapor and clouds are the most important feedbacks in the climate system, at least on time scales of thousands of years or less. [*See* Clouds; *and* Water Vapor.]

Next to water in all its phases, the important greenhouse substances in the atmosphere include *carbon dioxide, methane, nitrous oxide, ozone,* and various *chlorofluorocarbons* (CFCs). The CFCs are entirely of anthropogenic origin. Carbon dioxide is thought to respond to changes in sources and sinks over a time scale of from forty to several hundred years, while methane has an inherent time scale of about eight years. The ozone concentration peaks in the middle stratosphere, where it filters out most of the harmful, very shortwave (ultraviolet) radiation from the sun. Although its lifetime is short, ozone's concentration is affected by the presence of other trace gases, notably chlorine, which is in turn related to the chlorofluorocarbons, which have very long lifetimes. Analysis of gas bubbles trapped in polar ice shows that carbon dioxide and methane had somewhat lower concentrations during the ice ages but had quite stable concentrations from the end of the last major glaciation until the beginning of the Industrial Revolution. The carbon dioxide concentration of the atmosphere has been increasing since the early nineteenth century, owing to our consumption of fossil fuels and to deforestation, and is expected to reach twice its natural, postglacial value sometime in the twenty-first century. [*See* Deforestation.]

The concentration of methane increased even more rapidly over the past two centuries (but now seems to be stabilizing), for reasons that are less clear but possibly related to the influence of human activities, which are also affecting the concentrations of ozone, nitrous oxide, and the chlorofluorocarbons. Because of the important role these gases play in the greenhouse effect, it is feared that their increasing concentrations may lead to noticeable global warming. [*See* Carbon Dioxide;