Climate Forcing:
Greenhouse Gases & Aerosols
NOAA ESRL Chemical Sciences Division

Certain gases in the atmosphere, such as water, carbon dioxide (CO_2), methane, chlorofluorocarbons (CFCs), and nitrous oxide, absorb infrared light that would otherwise escape to space, radiating it back toward the planet's surface. These "greenhouse gases," as they are called, have always had a critical role in determining the temperature of the Earth's surface and the livability of the planet. Now, with the amounts of CO_2 and other greenhouse gases increasing in the atmosphere due to human activities, the possible implications for climate are the subject of much research.

At CSD, researchers are conducting laboratory experiments and theoretical research to determine the infrared properties and atmospheric lifetimes (how long they "live" in the atmosphere) of molecules that may contribute to the greenhouse effect. The relative roles of these "other" (non-CO_2)greenhouse gases have been evaluated through laboratory experiments that enable calculation of the Global Warming Potential (GWP), a number that compares the warming properties of a given gas to those of carbon dioxide. The GWP gauges the climate impact of a given molecule and hence becomes a crucial piece of information for policymakers, who are faced with decisions about which substances to restrict. Other CSD studies have led to important advances in our understanding of the removal rate of a key greenhouse gas, methane.

An Illustrative Example

An interesting recent contribution was a study of molecules known as "perfluorocarbons", or PFCs for short. PFCs are a class of compounds that were being considered as replacements for the ozone-destroying chlorofluorocarbons (CFCs) in industrial applications such as fire extinguishing, foam blowing, and refrigeration (some of them are also byproducts of aluminum production).

Their suitability as substitutes was clear on one level: they have essentially zero ozone-destroying capacity and can be considered "ozone friendly." However, scientists at CSD recognized that they could have other implications in the atmosphere, in particular that they may be greenhouse gases that could influence the temperature of the surface of the Earth.

With industry poised to produce PFCs, information about their total impact on the global atmosphere was needed. To find out, scientists in CSD's Chemistry and Climate Processes program studied the lifetimes of the PFCs using models and instruments in the laboratory. The atmospheric lifetime is a crucial parameter that is used in the calculation of the Global Warming Potential (GWP) index used by policymakers to gauge each compound's global climate impact.

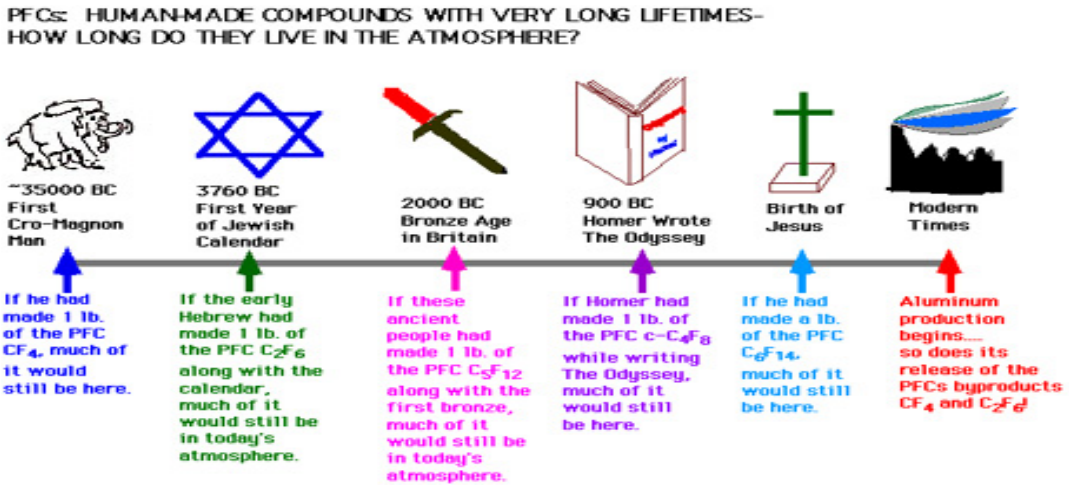
The answer? "Some human-made greenhouse gases could live forever" was the finding of the study, which has subsequently opened up research in this area and also influenced policymaking on the national and international level.

The CSD study was very timely and very comprehensive. Using a concerted laboratory and modeling approach, scientists studied several chemical loss pathways (reaction of the PFCs with trace gases in the atmosphere) and the pathway involving photolytic destruction by ultraviolet light. The research yielded definitive answers for policymakers and industry on six PFCs, finding that each of them had an atmospheric lifetime of more than 2000 years (on the same order of magnitude as human civilization and much longer than the industrial period).

The implications were three-fold for policymakers: 1) emissions of PFCs would accumulate in the atmosphere for tens of centuries; 2) the Global Warming Potentials for these compounds would be very large, and likely much larger than the CFCs they would replace; and 3) it would take the atmosphere an extremely long time to recover from any inputs of these compounds and, in fact, the recovery times would dwarf the century-scale recovery times required in the case of CFCs (see figure below).

The scientific findings of this research had nearly immediate impacts on industry and policy. In the United States, the results caused the Environmental Protection Agency to encourage voluntary efforts to reduce the use of these gases. Internationally, other countries re-evaluated their policies towards such chemicals. The findings were used by the international scientific community to assess Global Warming Potentials and Ozone Depletion Potentials in the recent United Nations Environment Programme-sponsored evaluation of the "state of the science" on ozone depletion (*Scientific Assessment of Ozone Depletion: 1994*).

By averting the use of what would have been very unsuitable substitutes for the CFCs, this research has spared industry a great expense while simultaneously protecting the atmosphere from additional burdens of potent greenhouse gases.



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