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HALOE: Tracking Ozone Loss From Space

NASA Langley Research Center's Halogen Occultation Experiment (HALOE) has been returning critical data about the Earth's ozone layer since it was launched on NASA's Upper Atmosphere Research Satellite (UARS) in 1991. As part of NASA's Mission to Planet Earth program to monitor the health of the Earth's environment from space, UARS carries 10 instruments for studying the chemistry and dynamics of the upper atmosphere (15 to 120 km above the surface of the Earth). HALOE's job is to measure global ozone as well as the chemicals involved in its destruction.

Since the discovery in 1985 of the so-called ozone "hole" - a seasonal loss of ozone in the stratosphere over Antarctica - the world's attention has been drawn to this urgent environmental problem. Because the ozone layer protects life on Earth from the harmful effects of the sun's ultraviolet radiation, it is important to determine the causes and mechanisms of ozone loss, as well as the likelihood that populated regions of the world will be affected.

Ozone Destruction

Ozone in the stratosphere is destroyed when it combines with chlorine, forming oxygen and chlorine monoxide. A single chlorine molecule can destroy 100,000 ozone molecules in its lifetime. Most chlorine comes from the decay of human-made compounds known as chlorofluorocarbons (CFCs). CFCs came into wide use in the 1950s as refrigerants, blowing agents for creating foam insulation, and as industrial cleaning agents.

The loss of stratospheric ozone means that more solar ultraviolet (UV) radiation reaches the Earth's surface. Since UV radiation has been linked to skin cancer, there is a significant human health risk posed by ozone depletion. It has been estimated that a one percent decline in ozone levels can lead to a two percent rise in human skin cancer cases.

In 1987, the nations of the world took action to halt ozone loss by signing the Montreal Protocols, which limited the use of CFCs. Subsequent amendments to the protocols have banned the production of CFCs and other ozone-depleters beginning in 1996. Because chlorine lasts for many years in the stratosphere, however, the positive effects of this ban may not be seen until well into the 21st Century.

Studying the Earth's Ozone Layer

The study of the ozone layer - with instruments based in space, on the ground, on airborne balloons, and on high-flying aircraft - is one of the highest priorities for environmental science in the 1990s. The HALOE experiment is one of the leaders in that effort as the UARS spacecraft continues its ongoing mission to reveal the secrets of the Earth's upper atmosphere.

How Does HALOE Work?

As UARS orbits the Earth, it experiences 15 sunrises and 15 sunsets each day which last only two to three minutes each. During each orbital sunrise and sunset, HALOE measures the amount of ozone and other trace gases in the atmosphere by measuring the amount of sunlight that comes through the atmosphere at different altitudes. The less sunlight that gets through at a specific wavelength, the more a particular gas is absorbing it.

Orbiting at an altitude of nearly 375 miles (600 kilometers), UARS observes almost the entire globe, from 80 degrees north latitude to 80 degrees south latitude. Because each sunrise and sunset occurs over a different point on the Earth, HALOE measures ozone values over the whole globe in three to four weeks.

Besides measuring ozone, HALOE is "tuned" to detect chemical compounds that either indicate ozone destruction or play a role in it. These include hydrogen chloride (HCl), hydrogen fluoride (HF), methane (CH_4), nitric oxide (NO), nitrogen dioxide (NO_2), and water vapor (H_2O). HALOE also measures the amount of small particles (called aerosols) in the upper atmosphere, as well as the temperature of the upper atmosphere.

One of HALOE's key objectives is to measure the concentration of HCl, the main reservoir of chlorine in the stratosphere, and HF. The fluorine-containing HF is produced only by human-made CFCs, whereas HCl is produced by natural sources as well. A careful analysis of the ratio between HCl and HF, and how it varies over time, can reveal how much of the ozone-destroying chlorine in the stratosphere is due to human activities.

What Has HALOE Learned?

The key role of CFCs in ozone loss

HALOE's measurements have settled a crucial scientific issue by confirming that CFCs are responsible for the elevated chlorine levels in the stratosphere that lead to ozone loss. Because chlorine also enters the atmosphere naturally - from sources such as the decay of algae in the oceans and from volcanoes - there had been some uncertainty as to how much of the total amount was due to human activities. Natural chlorine sources are believed to account for only 0.6 parts-per-billion by volume (ppbv), whereas HALOE measured the total amount of chlorine to be 3.2 ppbv at an altitude of 50 kilometers. This measurement showed that most of the chlorine in the stratosphere — more than 80 percent of it — is due to human activities. HALOE is the first instrument that has been able to confirm the influence of human activities on the amount of ozone-destroying chlorine in the stratosphere.

A new transport mechanism in the stratosphere

During the Antarctic winter, an air circulation pattern known as the polar vortex forms in the stratosphere, with high-speed winds surrounding a quiet central region (similar to the structure of hurricanes that form in the lower, tropical atmosphere). Normally, air in the stratosphere remains layered and does not mix vertically, or mixes very slowly. HALOE data show, however, a surprising phenomenon occurring in the center of the Antarctic vortex. Air from very high altitudes descends vertically through the center of the vortex, moving air to lower altitudes over

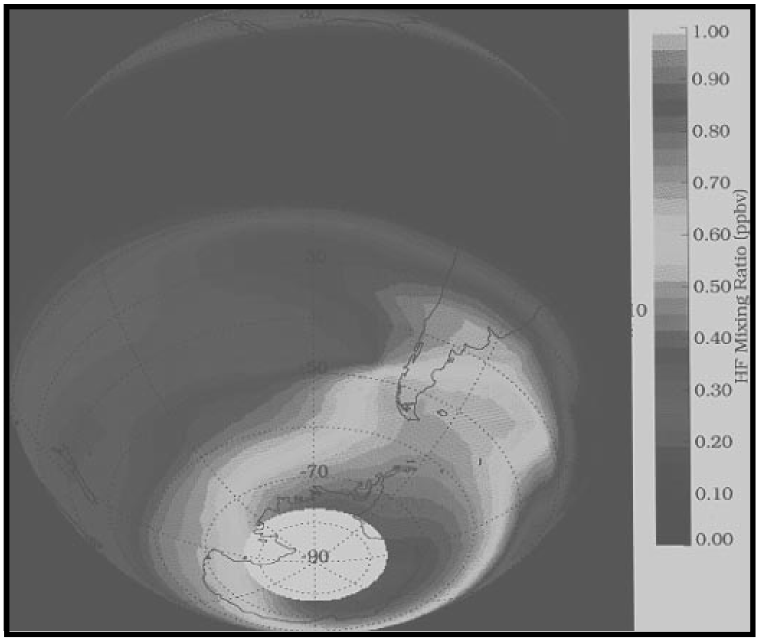

Figure 1a

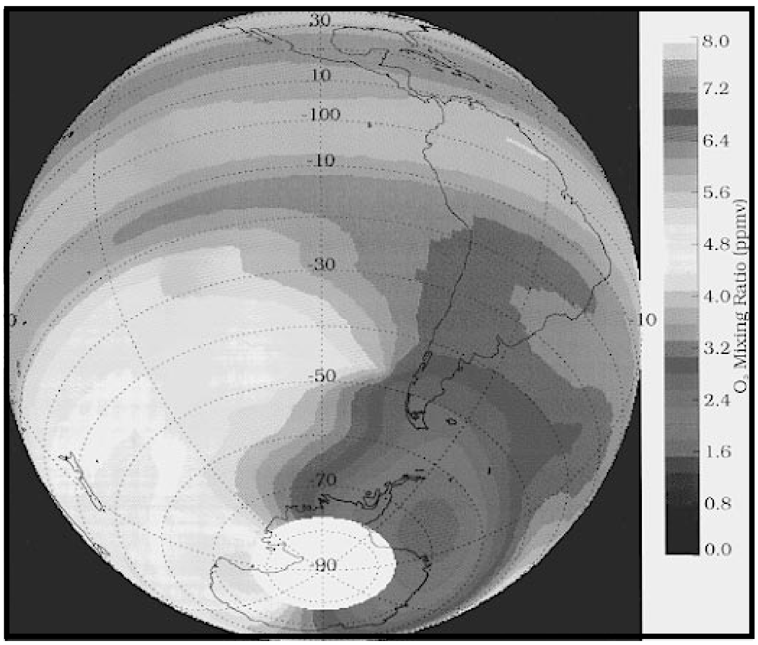

Figure 1b

HALOE Confirms CFCs Cause Antarctic Ozone Hole

Measurements from the Halogen Occultation Experiment (HALOE) showed high values of hydrogen fluoride (HF) (Fig. 1a) and low values of ozone (O3) (Fig. 1b) over the southern polar region and across large areas of the Southern Hemisphere. Low levels of ozone over the Antarctic (Fig. 1b) are indicated by darker gray regions, and represent the region known as the Antarctic ozone "hole." High values of ozone are indicated by the lighter gray regions.

The data in the figures was collected during the 1994 Southern Hemisphere spring, from September 11 to October 11. The white circular area over the South Pole is an area where no HALOE measurements were made.

The ozone hole is in the center of a spiraling mass of air over the Antarctic that is called the polar vortex. The vortex is not stationary and sometimes moves as far north as the southern half of South America, taking the ozone hole with it. Air currents in the upper atmosphere can further extend the effects of the ozone hole into the mid-latitudes and tropics.

several months. One possibility, that will require more study, is that this downward movement of air may represent a way in which the stratosphere can cleanse itself of ozone-depleted air. This important HALOE observation is expected to be a promising area for future research.

Effects on lower latitudes

HALOE also has returned evidence that the effects of the Antarctic stratospheric vortex extend well beyond the South Pole during the Antarctic spring, when the vortex is most vigorous. The HALOE data show that Antarctic-type air, identified by low levels of ozone and other trace chemicals, reaches as far north as 40 degrees south latitude, covering part of the South American continent (Fig. 1b). The effects of the vortex are also extended by air currents into the tropics, to 25 degrees south latitude.

During the 1992 Antarctic Spring, air with low levels of ozone, which also contained chemicals that help ozone destruction, spread northward into latitudes well beyond the Antarctic continent (Figs. 1a and 1b).

These measurements and scientific analyses show that the Antarctic vortex is clearly an important mechanism in global stratospheric chemistry. HALOE data will continue to be used by observers and theoreticians as they study such occurrences in the future.

Evidence of ozone depletion in the Arctic

Stratospheric ozone depletion is not as severe in the Northern Hemisphere polar region because winter temperatures are not as cold as in the Antarctic. Also, the Arctic polar vortex does not remain intact as long as the Antarctic vortex.

HALOE did, however, see evidence of chemical ozone depletion over the Arctic in 1993. During the 1993 Arctic winter, the polar vortex remained intact much longer than in other winters observed by HALOE. While this measured depletion did not constitute an ozone “hole,” it was most likely caused by chemical and physical processes similar to those seen in the Antarctic.

Scientists will continue to monitor stratospheric ozone levels in both the Arctic and Antarctic regions using the continuous global measurements provided by HALOE.

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