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Air and Atmosphere

# Stratospheric Ozone

## Key Findings

- Stratospheric ozone protects the earth's surface from excessive solar radiation, but this protective layer has become thinner, allowing penetration of harmful levels of ultraviolet radiation. Excess levels of ultraviolet radiation are harmful to human health and the environment.
- In response, countries have sought to control production, consumption and trade of ozone-depleting substances (ODS) through an international agreement. By the end of 2005, the parties to the Montreal Protocol had together phased out production and consumption of over 95 percent of ODS—which are used as refrigerants, aerosol propellants and for other purposes.
- Currently the earth's protective ozone layer remains thinner than historical averages; the ozone hole over Antarctica was at its largest and deepest ever observed in 2006.
- Canada, Mexico and the United States have substantially reduced emissions of ODS over the last 20 years, but these substances are still released from various sources in North America and globally. Recovery of the ozone layer is expected by the mid-twenty-first century based on compliance with the international agreement now in place. Reduction in ODS has delivered substantial climate benefits, because some ODS also act as greenhouse gases.

**Ozone is a gas present throughout the earth's atmosphere. *Stratospheric ozone* protects life on earth by absorbing harmful rays from the sun as they pass through the upper atmosphere (the stratosphere). Because the ozone present at the earth's surface is detrimental, ozone is often described as being "good up high and bad nearby."**

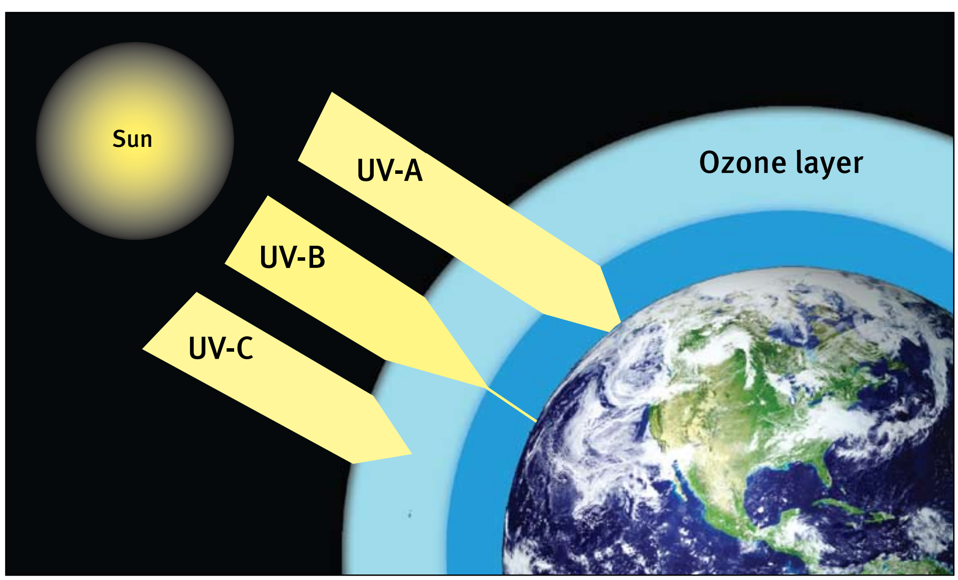
## What Is the Environmental Issue?

Stratospheric ozone protects the earth's surface by absorbing ultraviolet (UV) radiation from the sun (see illustration). It is naturally formed by chemical reactions involving ultraviolet sunlight and oxygen. Approximately 90 percent of ozone is in the stratosphere, the layer of the atmosphere that begins 10–15 kilometers above the earth's surface at the midlatitudes. The ozone in the stratosphere is referred to as the ozone layer.

### Thinning of the ozone layer

The stratospheric ozone layer is now thinner than it has been historically because of certain ozone-depleting substances, such as refrigerants and aerosol propellants. These substances were first produced commercially during the twentieth century and some continue to be produced and used. When released, these chemicals make their way to the upper atmosphere and gradually convert to more reactive gases that destroy ozone. Overall thinning of the ozone layer has been recognized since the 1970s, and the total loss is currently estimated to average 3 percent over the globe, with more thinning occurring toward the polar regions and less near the equator. Above Antarctica, an ozone hole now forms each September. During September 2006, the average area of the ozone hole, at 27.5 million square kilometers, was the largest ever observed (see photo). A little over a week later, instruments recorded the lowest concentrations of ozone ever observed over Antarctica, revealing that the ozone hole was the deepest it had ever been.

**UV protection by the ozone layer**




Source: United Nations Environment Programme.

Because the ozone layer absorbs some of the biologically harmful ultraviolet radiation from the sun, reductions in stratospheric ozone levels allow more UV radiation to reach the earth's surface, where it affects human health, disrupts biological processes and damages materials.

### Ozone-depleting Substances

The substances most responsible for the destruction of the ozone layer are listed in the following table along with their uses in everyday life. Alternatives to these substances include hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). HCFCs, a transitional CFC replacement, are used as refrigerants, solvents and fire extinguishers. HFCs and PFCs are used as refrigerants, aerosol propellants and solvents.

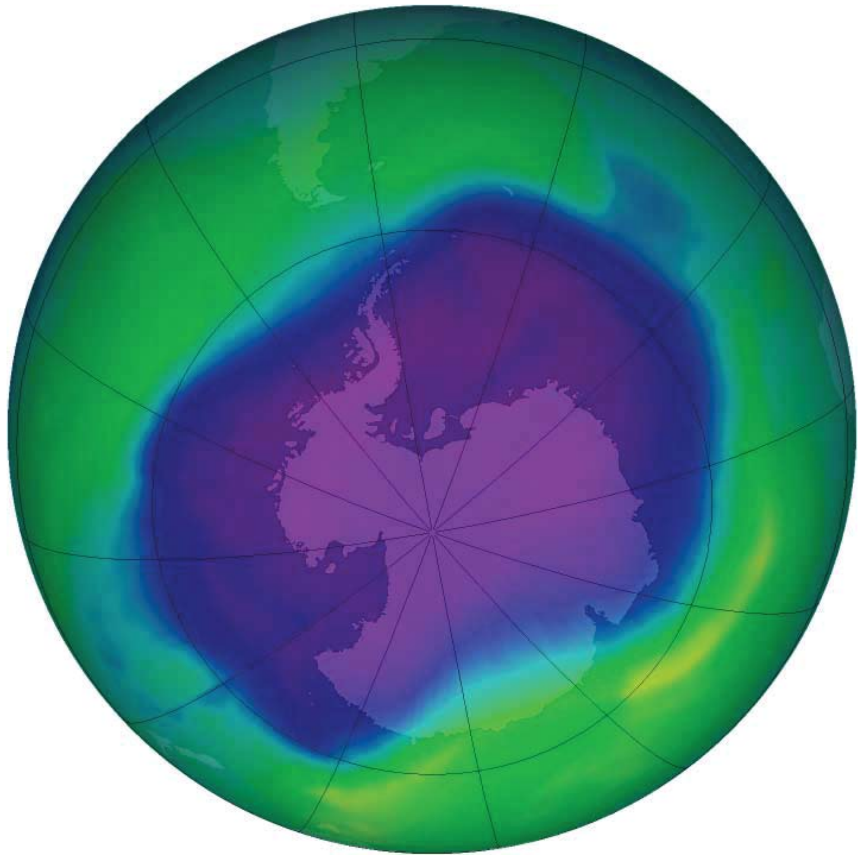
## Why Is This Issue Important to North America?

Ozone depletion has significant health and economic consequences for North America. It is generally worse at latitudes approaching the poles, specifically the northern and Arctic regions in the North American context.

### Effects of UV-B Radiation

Overexposure to UV-B radiation, the most damaging type of ultraviolet radiation, can cause a range of health effects, including skin cancers and premature aging, eye damage (such as cataracts) and suppression of the immune system. The physiological and developmental processes of plants are also affected by UV-B radiation, which can damage sensitive crops such as soybeans and rice and reduce crop yields.

**The Antarctic ozone hole** (21–30 September 2006)



Source: National Aeronautics and Space Administration.

Marine phytoplankton, which serves as the base for the ocean's aquatic food chain, is under stress from UV-B radiation as well. Studies have also found that solar UV-B radiation damages fish, amphibians and other animals in their early developmental stages.

More broadly, increases in solar UV radiation could affect terrestrial and aquatic biogeochemical cycles, thereby altering both sources and sinks of greenhouse and chemically important trace gases.

Finally, synthetic polymers, naturally occurring biopolymers and other commercially useful materials are adversely affected by solar UV radiation. Increases in solar UV-B levels accelerate their breakdown outdoors.

## Common ODS and Their Uses

| Substance | Uses |
| --- | --- |
| Chlorofluorocarbons (CFCs) | Refrigerants, cleaning solvents, aerosol propellants and blowing agents for plastic foam manufacture |
| Hydrochlorofluorocarbons (HCFCs) | Refrigerants, cleaning solvents, aerosol propellants and blowing agents for plastic foam manufacture |
| Halons | Fire extinguishers/fire suppression systems |
| Carbon tetrachloride | Production of CFC (feedstock), solvents |
| Methyl chloroform | Industrial solvents for cleaning, inks, etc. |
| Methyl bromide | Fumigant used to control soil-borne pests and diseases in crops prior to planting |

### Reducing Emissions

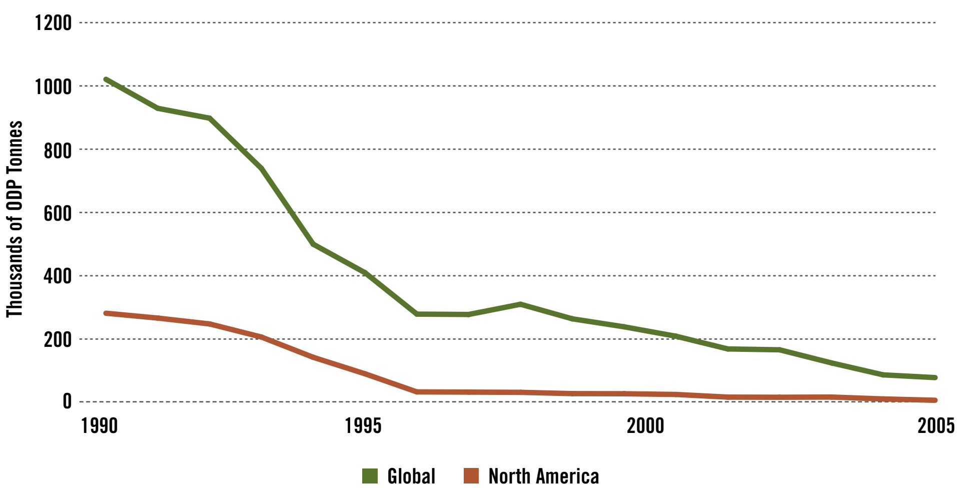
Canada, Mexico and the United States are addressing the destruction of the ozone layer by eliminating the production and consumption of ozone-depleting substances on a schedule determined by the Montreal Protocol on Substances that Deplete the Ozone Layer. This agreement has led to a phase-out of the production and consumption of CFCs and other ODS. Currently, 191 countries and the European Community are parties to the Protocol and are implementing its requirements.

By the end of 2005, the parties had together phased out over 95 percent of ODS, reducing production levels from a 1990 level of over 1 million Ozone Depletion Potential (ODP) tonnes a year to about 93,000 ODP tonnes a year in 2005. North American production and consumption declined from about one-third to under one-fifth of the global total (see graph).

Also through 2005, the production and consumption of ozone-depleting substances in North America fell by almost 97 percent (see graph).

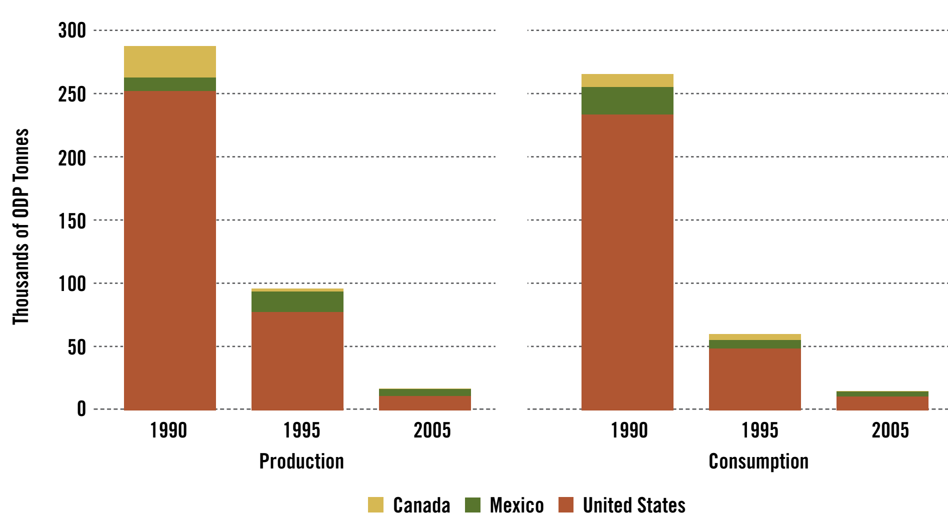
Because of the long time that it takes for ODS to move from ground level to the stratosphere, the impact of their elimination will not be felt for many years. It is estimated that the ozone layer could recover by about 2050, provided that all ozone-depleting substances of anthropogenic origin are eliminated. However, long-term predictions are uncertain because not all of the processes of ozone depletion are understood. The role of very short-lived ODS is still being studied, along with the impact of climate change on the stratosphere and ozone depletion.

### Total reported production of ozone-depleting substances globally and in North America




ODP = Ozone Depletion Potential. Source: United Nations Environment Programme.

### North American reductions in ozone-depleting substances




ODP = Ozone Depletion Potential. Source: United Nations Environment Programme.

### Monitoring Stratospheric Ozone Trends

Over North America, total stratospheric ozone levels began falling in 1965, reaching their lowest levels in 1993. The ozone layer has since begun to recover, but as of 1998–2001 average overall levels were still 3 percent lower than those observed 20 years earlier. Since 1993, ozone levels over North America have been trending upward as result of reduced ODS emissions and reformation of stratospheric ozone.

### Illegal Trade in ODS

Somewhat complicating this picture of progress is the illegal trade in significant amounts of ODS on a global basis. Although all new CFCs are now banned in industrialized countries, millions of refrigerators, automobile air conditioners and other equipment that use CFCs are still in service. Servicing this equipment with CFC replacements is possible, but often more expensive. In addition, used CFC-based equipment is exported to developing countries by countries that have phased out CFCs. These factors create incentives for the illegal trade in ODS, which has been estimated at 10–20 percent of the legitimate global trade. Issues related to the legal trade of equipment and illegal trade of ODS may complicate progress toward the ultimate elimination of ODS on a worldwide basis.

## What Are the Linkages to Other North American Environmental Issues?

Stratospheric ozone depletion has major linkages to other key North American environmental issues—principally climate change and the health of terrestrial and aquatic ecosystems.

### Climate Change

The depletion of the ozone layer and climate change were originally understood to be separate threats. Recently, however, both the Environmental Assessment Panel for the Montreal Protocol and the Intergovernmental Panel on Climate Change stated that there is conclusive scientific evidence that ozone depletion and climate change are linked.

Some ozone-depleting chemicals (CFCs, HCFCs and Halon 1301) and their replacements (HFCs and PFCs) are powerful greenhouse gases. The accumulation of greenhouse gases, including ODS, increases warming of the lower atmosphere, which leads, in turn, to the cooling of the stratosphere. Stratospheric cooling hampers the formation of ozone and favors the development of polar ozone holes. Studies indicate that within two decades climate change may exceed CFCs as the principal cause of overall ozone loss.

Global efforts to phase out ozone-depleting substances have benefited the earth's climate in two ways. First, the net global decline in emissions of ODS has resulted in a drop in greenhouse gas emissions equivalent to several billion tonnes of carbon dioxide. Second, the reductions needed to meet international obligations have frequently required equipment upgrades and more efficient energy practices that reduce greenhouse gas emissions.

### Health of Terrestrial and Aquatic Ecosystems

The linkages between terrestrial ecosystems and the higher levels of UV-B radiation resulting from ozone depletion are complex. The responses of plants and other organisms to increased UV-B radiation are influenced by a variety of environmental factors such as carbon dioxide, water availability, mineral nutrient availability, heavy metals and temperature. Many of these factors are also changing as the global climate is altered.

Higher levels of UV-B radiation damage terrestrial organisms, including plants and microbes. They change patterns of gene activity and affect life cycle timing, as well as change plant shape and the production of plant chemicals not directly involved in primary metabolism. Plant chemicals not only are important in protecting plants from pathogens and insect attacks, but also affect food quality for humans and grazing animals.

The effects of ozone depletion and increased UV radiation on aquatic ecosystems are complex as well. Higher levels of solar radiation have negative impacts on the growth, photosynthesis, protein and pigment content and reproduction of phytoplankton and on the sea grasses that are important biomass producers in aquatic ecosystems.

Zooplankton and other aquatic organisms, including sea urchins, corals and amphibians, are also sensitive to UV-B radiation. Polar marine ecosystems, where the increases in ozone-related UV-B radiation are the greatest, are likely to be the oceanic ecosystems most influenced by ozone depletion.

The linkage between UV-B radiation, aquatic ecosystems and global warming is also important. When these ecosystems are exposed to higher levels of to UV-B radiation, their ability to act as a sink for atmospheric carbon dioxide is reduced.

## Case Study – Phasing Out Methyl Bromide in North America

Methyl bromide (MeBr), a highly toxic, odorless, colorless gas, has been used as an agricultural soil and structural fumigant to control a wide variety of pests. However, because MeBr depletes the stratospheric ozone layer, Canada, Mexico and the United States agreed under the Montreal Protocol to phase out methyl bromide as a crop pesticide by 2005 in the United States and Canada and by 2015 in Mexico. The phase-out allows an exemption for quarantine applications and preshipment applications to eliminate quarantine pests as well as a Critical Use Exemption designed for agricultural users with no technically or economically feasible alternatives.

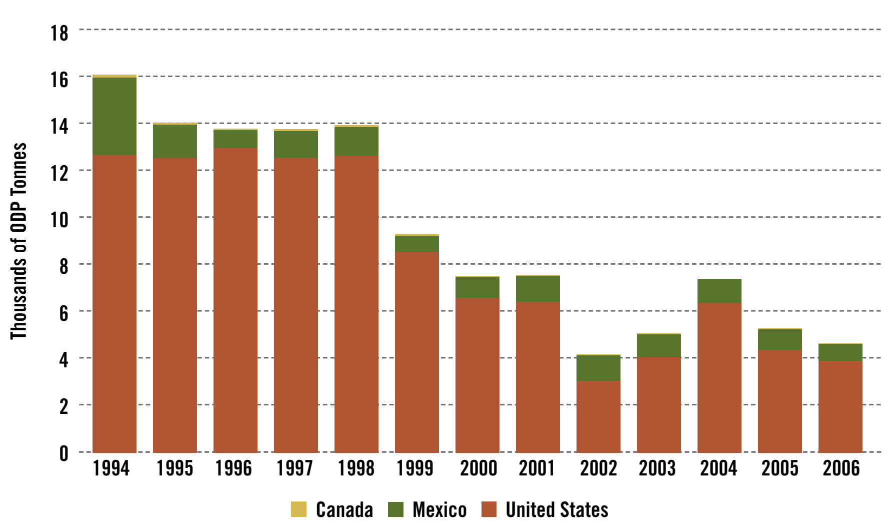
The United States manufactures MeBr and exports it to both Canada and Mexico, because neither country produces MeBr. In all three countries, MeBr is used in growing crops such as strawberry, tobacco, asparagus, flowers, potatoes, tomatoes, peppers and cucumbers. Competition among agricultural producers in the face of different phase-out schedules in the three countries has influenced the ways in which Canada, Mexico and the United States are phasing out MeBr (see graph for these countries' consumption levels of MeBr over the period 1994–2006).

Canada's consumption of MeBr (25 ODP tonnes in 2006) accounts for less than 1 percent of global methyl bromide consumption. The MeBr ban in effect is accompanied by the promotion of alternative technologies emphasizing integrated pest management. Canada has requested a small number of Critical Use Exemptions for the production of strawberry plantlets and fumigation of flour and pasta mills.

With consumption of about 7 percent of the global total, Mexico has the right to a flexible approach as a developing country under the Montreal Protocol. Mexican consumption peaked in 1994 at 3,253 ODP tonnes, falling to 723 ODP tonnes by 2006. Mexico is reducing its MeBr consumption in a stepwise fashion.

The United States remains a significant producer and consumer of MeBr, requesting exemptions for MeBr beyond the original phase-out date in 2005 (see graph). In 2006 the United States produced 6,502 ODP tones of MeBr—55 percent of the global total. That same year, the United States consumed 3,885 ODP tonnes of MeBr—almost 40 percent of the global total. Despite its exemption requests, the United States still reduced MeBr production by over 60 percent and consumption by 75 percent between 1991 and 2006.

**North American consumption of methyl bromide**




ODP = Ozone Depletion Potential. Source: United Nations Environment Programme.