What is being done to address ozone depletion? Is it helping?

- Faced with the scientific community's findings that ozone depletion was real and due to human-produced ozone-depleting substances, nations throughout the world agreed to the Montreal Protocol. The Protocol went into effect in 1987 and was one of the first international agreements to address a global environmental problem. Since that time, several amendments and adjustments, including the 1990 London Amendment, the 1992 Copenhagen Amendment, and the 1999 Beijing Amendment, have been made to strengthen the original Protocol.
- The Protocol established legally binding controls for developed and developing nations on the production and consumption of gases known to cause ozone depletion. The harmful ozone-depleting substances, which are mainly CFCs and certain gases that contain bromine, were gradually replaced by hydrochlorofluorocarbons (HCFCs), which remove fewer ozone molecules, and by hydrofluorocarbons (HFCs), which do not contribute to ozone depletion at all because they have no chlorine or bromine.
- Since these changes were made in response to the Montreal Protocol, total global emissions of ozone-depleting substances have declined substantially. By 2005, total production of ozone-depleting substances and the amount used had declined 95 percent from peak amounts produced and used in the late 1980s.
- Assuming continued compliance with the Protocol, ozone-depleting substances are expected to decline back to their pre-1980 levels by about the middle of this century.

Ozone-depleting substances are expected to decline back to their pre-ozone-hole levels by about the middle of this century.

What will happen to the ozone layer in the future?

- Ozone is projected to recover as the amounts of ozone-depleting substances in the atmosphere decline over the next few decades. If the nations of the world continue to adhere to the Montreal Protocol, ozone-depleting substances should have an insignificant effect on ozone in all regions by 2070 and beyond.
- Projections of a changing climate have added a new dimension to the issue of the stratospheric ozone layer and its recovery. Climate change is expected to alter the timing of the recovery of the ozone layer.
- In the future, U.S. emissions of ozone-depleting substances, like those from other developed nations, will be largely determined by the size of *banks* of ozone-depleting substances. Banks refer to ozone-depleting substances that are already produced, but not yet released into the atmosphere. The expected future decline in emissions of ozone-depleting substances from the United States will aid in reducing the effect on climate from these substances.
- While the Montreal Protocol has had a large beneficial effect on current and projected ozone depletion, there are additional options for the United States and other countries to reduce ozone depletion arising from ozone-depleting substances over the coming decades. The greatest reduction possible would be obtained from ending all future emissions of ozone-depleting substances, including emissions from banks and future production.

The Montreal Protocol and the "World Avoided"

Without the Montreal Protocol, the levels of ozone-depleting substances in the atmosphere would likely be more than 50 percent larger than currently predicted by the end of this century. The increases in ozone-depleting substances would have already caused substantially greater ozone depletion, and large depletions would have continued to occur. Large increases in UV radiation at the Earth's surface and the associated impacts on human health and ecosystems also likely would have occurred.

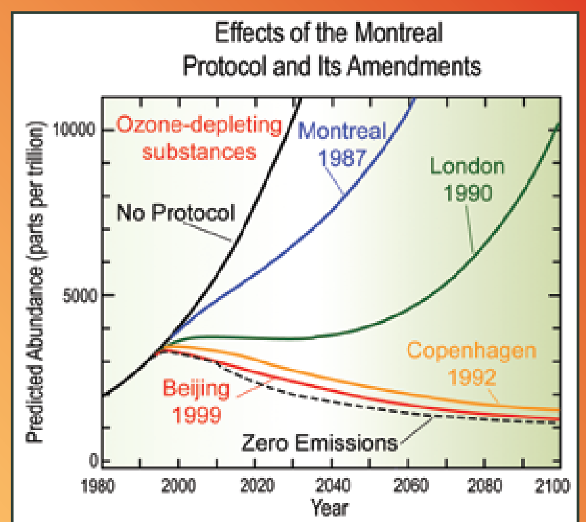
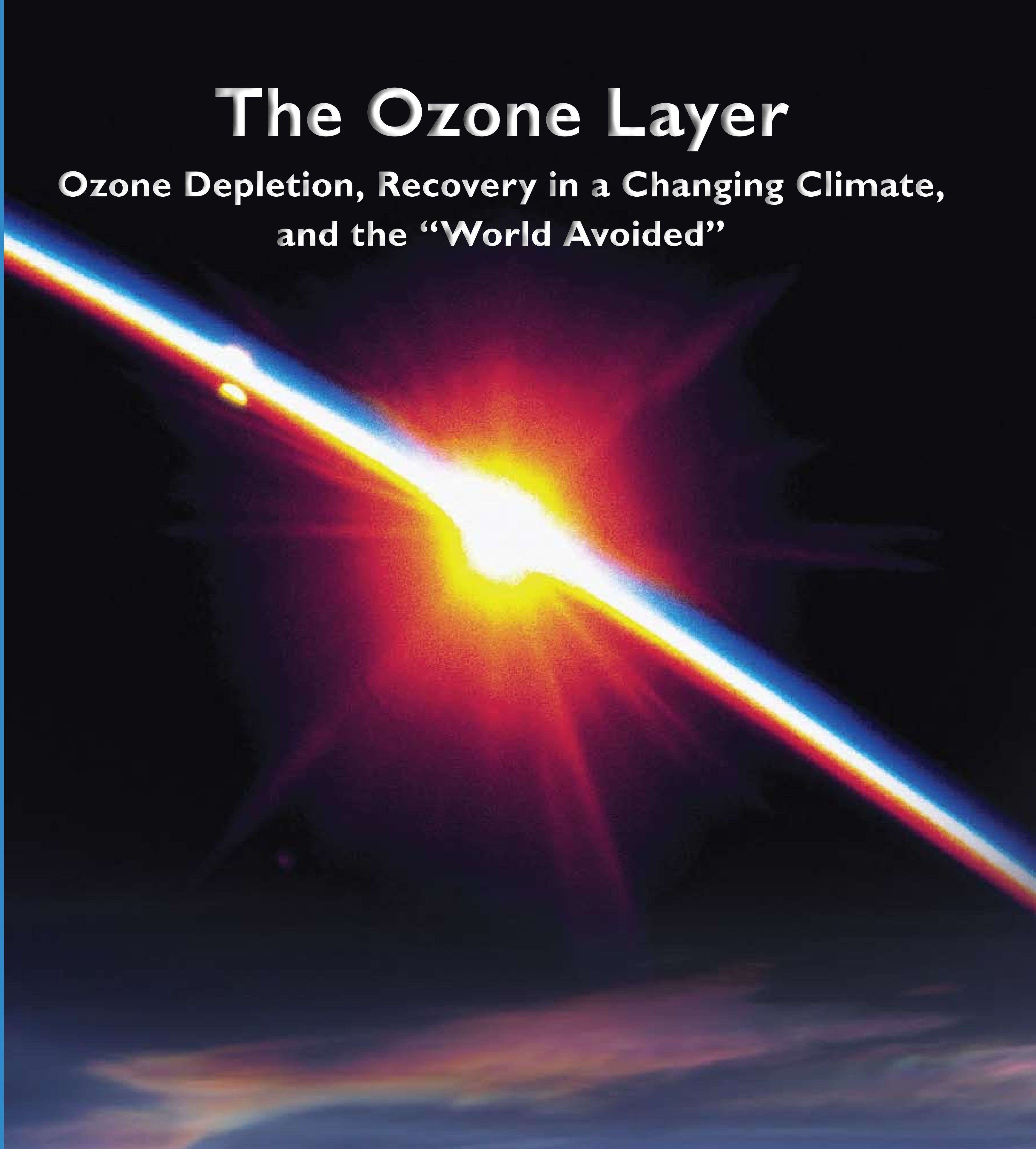


Figure 3. The projected future abundance of ozone-depleting substances in the stratosphere, with and without the Montreal Protocol and its various Amendments.

The Ozone Layer

Ozone Depletion, Recovery in a Changing Climate, and the "World Avoided"



Findings and Summary of the U.S. Climate Change Science Program
Synthesis and Assessment Product 2.4

Trends in Emissions of Ozone-Depleting Substances, Ozone Layer Recovery, and Implications for Ultraviolet Radiation Exposure

Ozone layer depletion, like climate change, is a global issue with regional impacts. The depletion of the ozone layer is mainly caused by emissions of human-produced ozone-depleting substances.

What is ozone and why is it important?

Ozone is a gas that is naturally present in our atmosphere. About 90 percent of ozone is found in the stratosphere, a region that begins about 9 miles above Earth's surface and extends up to about 28 miles in altitude. Most ozone resides in the lower stratosphere in what is commonly known as the "ozone layer." The remaining 10 percent is found in the troposphere, which is the lowest region of the atmosphere, between Earth's surface and the stratosphere.

The ozone layer acts as a protective shield, preventing most of the Sun's harmful ultraviolet (UV) radiation (energy) from reaching the surface. The depletion of the ozone layer can therefore lead to an increase of the UV radiation that reaches the Earth's surface.

Human exposure to UV increases the risk of skin cancer, cataracts, and a suppressed immune system. Exposure to UV can also damage plant life, aquatic ecosystems, and physical materials. In addition, the ozone layer and its changes can alter how temperature changes with height in the Earth's atmosphere as well as weather- and climate-related air circulation patterns.

> The ozone layer prevents most of the Sun's harmful UV radiation from reaching the Earth's surface.

How do emissions from human activities cause ozone depletion?

In the mid-1970s, it was discovered that certain human-made gases could cause stratospheric ozone depletion. These gases contain chlorine or bromine and are called ozone-depleting substances. Chlorofluorocarbons (CFCs) used as coolants in refrigeration and air conditioning systems are an important example of chlorine-containing gases. Ozone-depleting substances have also been used as fire-extinguishing chemicals, as solvents to clean electronic components, as blowing agents in the production of plastic foams, and as propellants in aerosols.

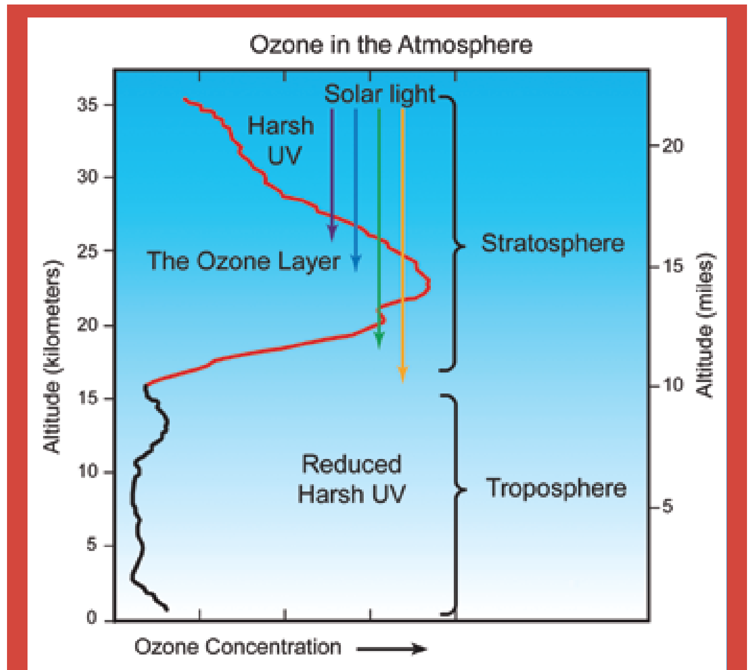


Figure 1. The location of ozone in the atmosphere.

Contributions to the total global amount of ozone-depleting substances vary by regions and countries. Once they are released into the atmosphere, most ozone-depleting substances remain there for years. This means that they become well mixed throughout the lower atmosphere around the globe and can be transported to the stratosphere by air motions. Ozone-depleting substances are harmless in the lower part of the atmosphere, but in the stratosphere they are broken apart by UV radiation from the Sun, releasing chlorine and bromine in forms that can then react with the ozone layer. These reactive gases have caused depletion of stratospheric ozone over the entire globe except in tropical regions. Because they remain in the atmosphere for such long periods of time, ozone-depleting substances can be a global threat, regardless of where they have been emitted in the world.

What are the connections between ozone depletion and climate change?

Over the past 20 years, the connections between the depletion of ozone in the stratosphere and climate change issues have become clearer:

- Ozone-depleting substances and many of the chemicals that have replaced them are potent greenhouse gases that influence Earth's climate by trapping heat that would otherwise escape to space.
- Ozone itself is a greenhouse gas. The ozone layer warms the stratosphere and lower troposphere and is an important component that affects climate.
- The recovery of the ozone layer is influenced not only by the decreases in ozone-depleting substances, but also by changes to climate and changes in the amounts of various gases in the Earth's atmosphere.

What are the connections between the ozone depletion issue and the United States?

It is not possible to make a simple connection between emissions of ozone-depleting substances from the United States and the depletion of ozone above the country. However, it is possible to describe ozone depletion over various regions of the United States and the contribution of emissions of ozone-depleting substances from the United States.

- Above the continental United States, as well as other regions that are about 60° north in latitude, there was a decrease in ozone levels, with the lowest amount occurring around the mid-1990s, and a slight increase since that time.
- Emissions of ozone-depleting substances from the United States have been significant, accounting for between 15 and 39 percent of the overall amount of these gases measured in the atmosphere between 1994 and 2004.
- The United States has also contributed significantly to reductions in the emission of ozone-depleting substances. This has helped efforts to achieve the expected recovery of the ozone layer and to prevent large changes in UV at the Earth's surface.

Ozone and Ultraviolet Radiation

The amount of ultraviolet (UV) radiation reaching the ground is mainly controlled by cloud cover, pollution, and the amount of atmospheric ozone. If all other factors remain the same, UV at the Earth's surface increases as the amount of total ozone decreases, because ozone absorbs UV radiation.

Except for Antarctica, changes in surface UV due to ozone depletion have not been clearly noticeable in most locations around the globe because the Montreal Protocol—an agreement created in 1987 between nations of the world to reduce emissions of gases that deplete the ozone layer—has prevented large increases in surface UV radiation, reducing the effects due to ozone depletion. As a consequence, changes in UV attributable to ozone depletion have been much smaller than the UV changes due to other factors. As the ozone layer recovers over the next few decades, factors such as changes in clouds and air pollution will be the dominant factors influencing future UV changes.

The Antarctic "Ozone Hole"

The severe depletion of stratospheric ozone that has occurred every year since the 1980s during Antarctic springtime is known as the "ozone hole." This hole is created by the reactive gases containing chlorine and bromine that destroy ozone. The ozone hole was discovered in the early 1980s by researchers making ground-based measurements of the ozone above this region. The depletion of the Antarctic ozone layer occurs because of the interactions of ozone-depleting substances in the unique weather conditions that exist only in this region. The very low temperatures of the Antarctic stratosphere create ice clouds called polar stratospheric clouds (PSCs). Special reactions that occur during springtime on these clouds, along with the relative isolation of polar stratospheric air, allow chlorine and bromine reactions to produce the ozone hole.

Amounts of ozone are often described in terms of the thickness of ozone in a column of air that stretches from the Earth's surface to the top of the atmosphere. The most common measurement of total ozone values in the column are called Dobson units (DU). One DU is equal to the number of molecules of ozone that would be needed to create a layer of pure ozone 0.01 millimeter thick. Typical amounts vary between 200 and 500 DU around the world. The total ozone value of the ozone hole is only 100 DU. This is equivalent to a layer of pure ozone gas on Earth's surface having a thickness of only 1 millimeter (less than one sixteenth of an inch).

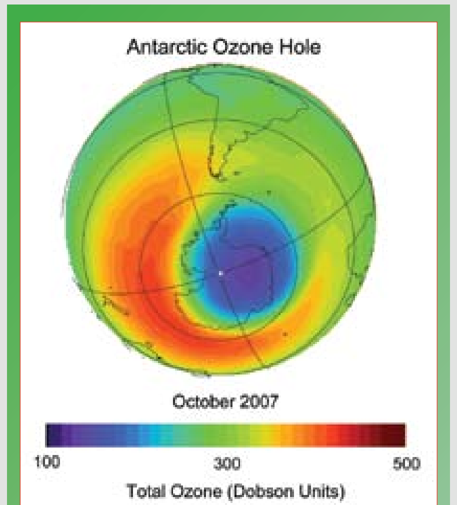
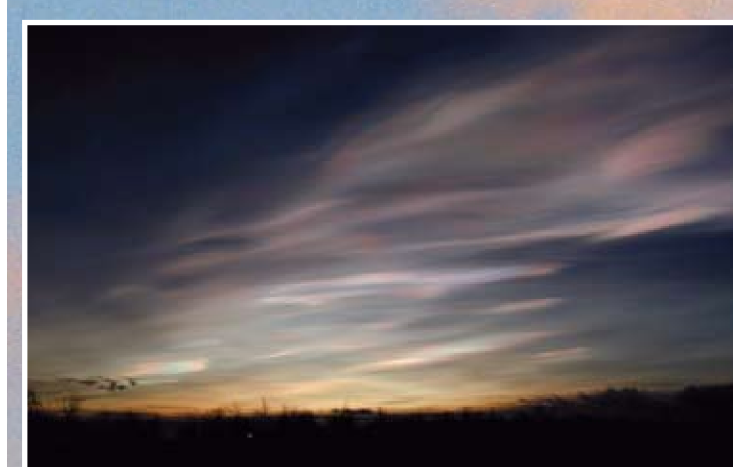


Figure 2. Satellite observations of the springtime Antarctic ozone hole.


Polar Stratospheric Clouds