STRATOSPHERIC OZONE MONITORING AND ASSESSMENT FOR DETERMINING EFFICACY OF THE MONTREAL PROTOCOL

SUMMARY

Title
Stratospheric ozone monitoring and assessment for determining efficacy of the Montreal Protocol

Service
Regular assessment of the state of the ozone layer (including levels of ozone and ozone-depleting substances, many of which are greenhouse gases)

End users
- International bodies (e.g. UNEP, Meeting of the Parties of the Montreal Protocol)
- National governments
- Environmental agencies
- Compliance monitoring agencies
- Health agencies

Intermediate users
- Research scientists
- Policymakers, economists

Application(s)
- Protocol monitoring and compliance verification
- Scientific assessment

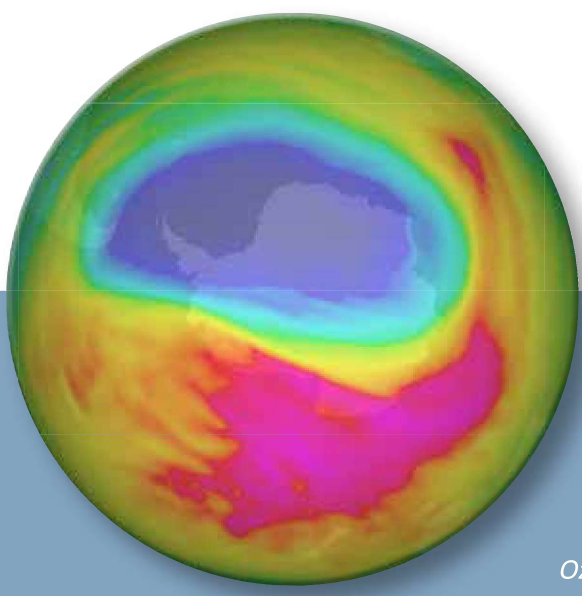
Models used
- Global climate models
- Atmospheric models with coupled chemistry

Climate data records used
- Ozone (total column and vertical profile)
- Long-lived greenhouse gases (e.g. chlorofluorocarbons (CFCs)), other constituents relevant to ozone chemistry (e.g. chlorine and bromine containing gases)
- Methane

Satellite observations used
- Ozone: SBUV, OMI, MLS, GOME-2, Sciamachy, IASI, OMPS-Limb, OSIRIS, SAGE-II, SAGE-III
- Hydrochloric acid: MLS, HALOE
- CFCs: ACE-FTS, TES
- Methane: ACE-FTS, Sciamachy

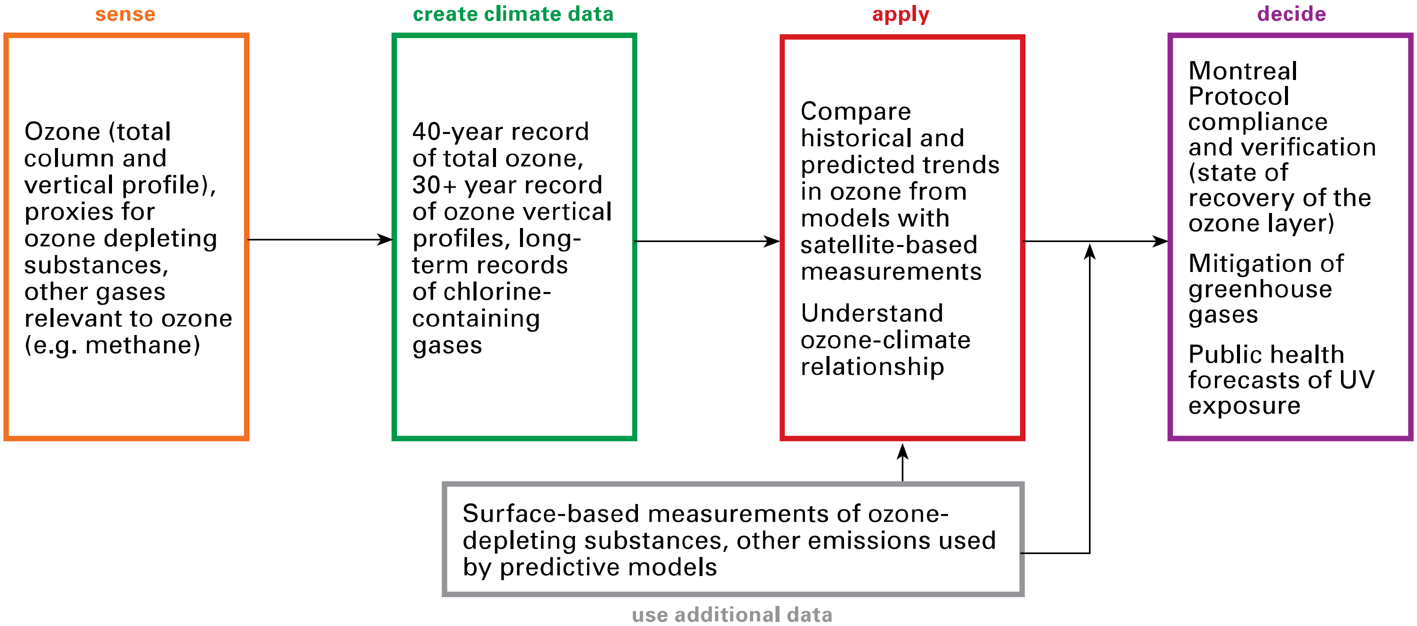
Agencies that produce records
- USA: NASA and NOAA
- Europe: ESA, EUMETSAT

Sustainability of service (demonstration or ongoing)
Satellite measurements of ozone and other constituents relevant to ozone chemistry have been conducted since the 1970s. National space agencies have current and planned missions that will continue the high-quality measurements needed to maintain long-term time series of ozone and shorter records of other important atmospheric constituents needed to improve our understanding of ozone chemistry.



Ozone depletion over Antarctica

INFORMATION FLOW



DESCRIPTION

In 1974, Molina and Rowland first suggested that human-produced CFCs could deplete stratospheric ozone. By the early 1980s, policymakers had taken on the challenge of regulating the production and consumption of these ozone depleting substances and a number of countries had combined their efforts to produce reports on ozone depletion.

In 1985, the atmospheric community was surprised by the published confirmation of a severe downward trend in ozone levels over Antarctica at the British Antarctic Survey's Halley Station (Farman et al., 1985). Figure 1 shows the first image of this depleted Antarctic region (WMO, 1985). This image most likely led to the coining of the term "Antarctic ozone hole." The combination of the strong downward trend of ozone levels over Halley Station and the continental-scale image of this depleted region spawned an immediate scramble by atmospheric scientists to unravel the puzzle of this polar ozone depletion. In the same year, the first major report on ozone depletion "Atmospheric Ozone:

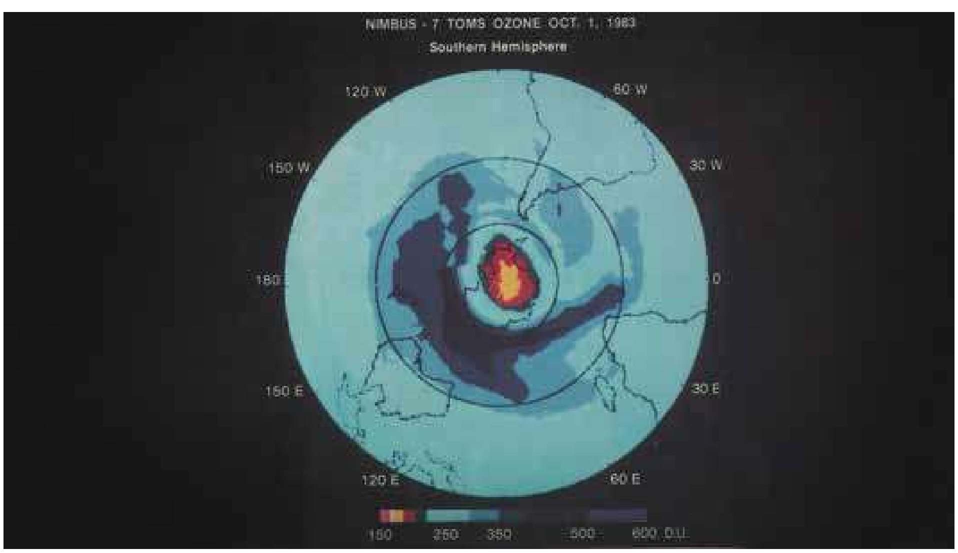


Figure 1. False colour image of total column ozone from the Nimbus-7 satellite's Total Ozone Mapping Spectrometer (TOMS). This is the first image made of the Antarctic ozone hole.

1985" was published under the auspices of the United Nations Environmental Programme and WMO with the assistance of scientists and government science agencies across the world.

The nations of the world responded to the growing body of scientific research by negotiating the Vienna Convention for the Protection of the Ozone Layer. In 1987, the Montreal Protocol on Substances that Deplete the Ozone Layer was finalized. In subsequent years, the Montreal Protocol has been strengthened and CFC production and consumption is now banned throughout the world.

The Montreal Protocol is the primary customer for the scientific assessments of ozone depletion. These assessments are mandated under the Protocol every 4 years (the most recent is "The Scientific Assessment of Ozone Depletion: 2014 (WMO, 2014)"). The terms of reference agreed on by the parties to the Protocol ask for information on amounts of ozone depleting substances, on ozone levels and on general stratosphere-related climate issues. While the Montreal Protocol is primarily a treaty that deals with ozone depletion, CFCs and their substitutes also have a powerful impact on the climate. The Montreal Protocol is therefore evolving as climate issues become a major factor in regulating the consumption and production of fluorinated species such as hydrofluorocarbons.

The ozone depletion issue has now entered an "accountability phase". Scientists predicted large ozone losses from ozone depleting substances, governments acted, and levels of such substances have declined since the mid-1990s. Models have projected that the ozone layer will recover by the middle of the century, but these projections must be verified by observations. Current satellite-based observations of total column ozone and ozone profiles (such as the ozone monitoring and profiler suite, OMPS) are the primary measures for validating these projections, and for observing anomalies (such as volcanic forced ozone losses). Ozone observations in the upper stratosphere show hints of recovery, but these results are preliminary (WMO, 2014).

Projections of future ozone levels are thrown off balance by increasing levels of greenhouse gases. In particular, increasing carbon dioxide levels lead to a cooling of the stratosphere. That cooling slows ozone catalytic cycles and should lead to a more rapid increase of ozone over the course of the 21st century. Observations of greenhouse gases, mid-to-upper stratospheric temperature and ozone are key to separating the effects of ozone-depleting substances and greenhouse gases. Figure 2 shows the future projected ozone levels for various greenhouse gas scenarios. While the decline in levels of ozone-depleting substances will cause ozone levels to increase, stratospheric ozone levels will be strongly affected by future greenhouse gas levels.

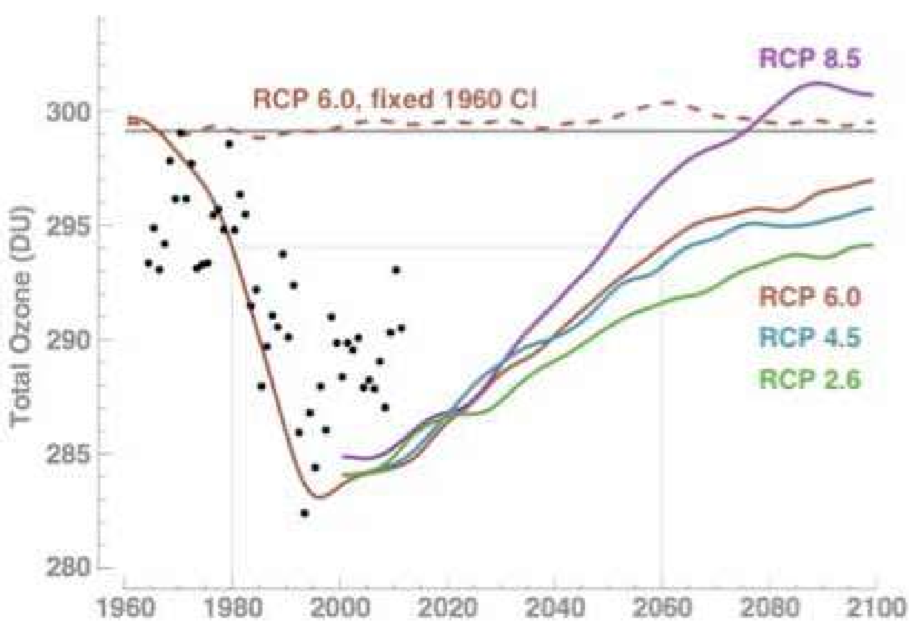


Figure 2. Total column ozone (60˚S–60˚N). Satellite observations in black, with coupled chemistry climate model simulations in colour. The model is forced with various greenhouse gas scenarios, known as representative concentration pathways (RCPs). A low greenhouse gas level is associated with RCP 2.6, while the highest levels of greenhouse gases are with RCP 8.5. The brown solid line (RCP 6.0) shows the model simulation forced by observed levels of ozone-depleting substances and greenhouse gas levels up to 2013, with a "high" greenhouse gas simulation up to 2100. The brown dashed line shows simulated total column ozone under a RCP 6.0 scenario assuming zero emission of ozone depleting substances.

The Montreal Protocol contributed to limiting greenhouse gas levels, since many ozone-depleting substances that have been phased out under the Protocol are potent greenhouse gases. On the other hand, some replacement substances such as hydrofluorocarbons are strong greenhouse gases and their concentration levels have increased rapidly. It is therefore important that the Montreal Protocol develops in order to estimate future greenhouse gas levels and climate projections.

In addition to ozone and temperature data, satellite observations provide key information to the Montreal Protocol on stratospheric water vapour and aerosol levels (key surface radiative forcings). Satellite observations also allow the tracing of stratospheric chlorine levels by observations of hydrochloric acid in the upper stratosphere. Observations by the Atmospheric Chemistry Experiment (ACE) instrument on SCISAT also provide hydrochloric acid observations and include measurements for CFCs and other gases that can be used to trace the annual cycle of stratospheric species and year-to-year changes of the stratospheric circulation.

Satellite observations are key to ensuring that the international regulation of ozone-depleting substances is working correctly. As levels of ozone in the stratosphere control surface ultraviolet levels, changes in ozone are critical for understanding environmental changes of surface ultraviolet as the stratosphere evolves over the 21st century.

References

Farman, J.C., B.G. Gardiner and J.D. Shanklin, 1985: Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. *Nature*, 315:207–210, doi:10.1038/315207a0.

WMO, 2014: *Scientific Assessment of Ozone Depletion: 2014*. Geneva, http://www.wmo.int/pages/prog/arep/gaw/ozone_2014/full_report_TOC.html.