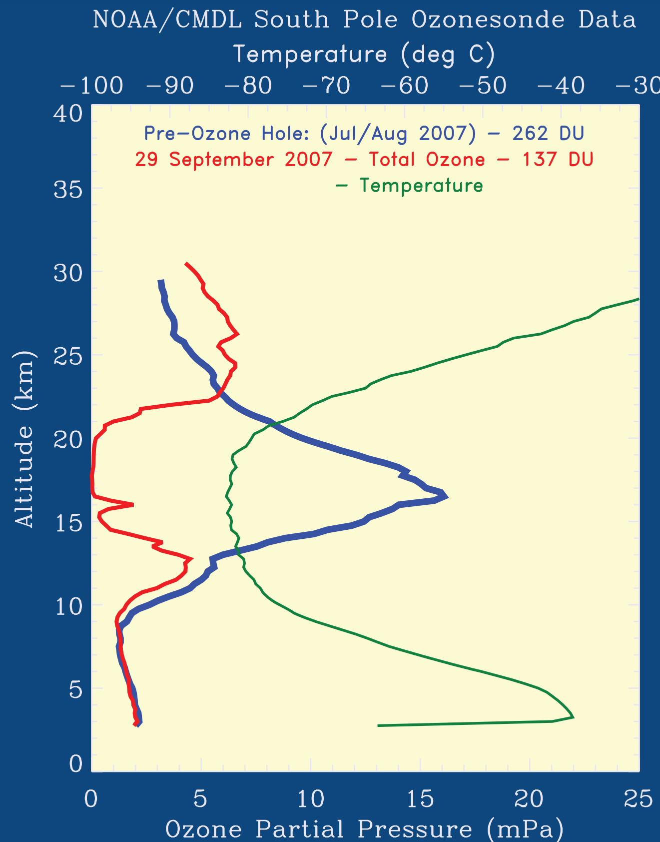
Antarctic Ozone Bulletin

No 3/2007



Ozonesonde profile measured at the NDACC-GAW Amundsen-Scott station at the South Pole. The observations are carried out by the National Oceanic and Atmospheric Administration (NOAA).
The profile shown is from 29 September (red curve). On this date the partial ozone column from 12-20 km reached it minimum so far this season. One can see that ozone depletion is nearly complete in the 16-20 km height range. In comparison, an average profile for July and August 2007 is shown (blue curve). The plot is downloaded from the Earth System Research Laboratory web site of NOAA.

World Meteorological Organization
Weather • Climate • Water

2 Oct. 2007

Global Atmosphere Watch

Executive Summary

During the April-late June 2007 time period, 50 hPa temperatures averaged over the 60-90°S region have been close to, or somewhat below, the 1979-2006 average. From late June until late July this mean temperature was above the average. Since late July, the mean temperature has been oscillating around the 1979-2006 mean. Since the last Bulletin, the 50 hPa temperatures averaged over the 60-90°S region have warmed up and are now above the 1979-2006 average.

Minimum temperatures in the vortex at 50 hPa are quite similar to those of 2006, but at 10 hPa the August minimum temperatures were lower this year than last year. In September, the 10 hPa minimum temperatures have increased and are now warmer than at the same time last year, but still colder than the 1979-2006 average.

Since the onset of NAT temperatures in mid-May the NAT area was larger than the 1979-2006 average until late June. From early July to mid July the NAT area was lower than the 1979-2006 average, but from mid July to mid August, the NAT area has been somewhat above the long-term mean. After mid August the NAT area has been significantly above the 1979-2006 average, but still well below the area of 2006. A warming event in mid September caused the NAT area to drop rapidly, but it picked up again and is still well above the 1979-2006 average.

The ozone hole area reached a maximum of 25 million km^2 in mid September. In comparison the ozone hole covered more than 29 million km^2 in the record years of 2000 and 2006.

The ozone mass deficit reached 28 megatonnes on 23 September. In comparison it reached more than 40 megatonnes in the beginning of October 2006, which was a record year. Since 1998 only 2002 and 2004 experienced less severe ozone loss than 2007. Since we are still only at the very beginning of October, the ozone mass deficit might pick up again, but it is not very likely that it will pass the 28 megatonnes reached on 23 September. The next Bulletin, which is due on 18 October, will bring the final numbers for maximum daily ozone hole area and maximum daily ozone mass deficit.

The relatively modest ozone loss seen so far in 2007 is related to the temperature conditions in the stratosphere. Although minimum temperatures have been quite similar to those of 2006, the average temperature in the 60-90°S region has been warmer, and the area cold enough for existence of polar stratospheric clouds (NAT) has been smaller, than in 2006. There is still more than enough halogens present in the stratosphere to cause total destruction of ozone in the 14-21 km altitude range. The severity of the ozone hole will for the coming 1-2 decades depend on the meteorological conditions.

WMO and the scientific community will use ozone observations from the ground, from balloons and from satellites together with meteorological data to keep a close eye on the development during the coming weeks and months.

Introduction

The meteorological conditions in the Antarctic stratosphere found during the austral winter (June-August) set the stage for the annually recurring ozone hole. Low temperatures lead to the formation of clouds in the stratosphere, so-called polar stratospheric clouds (PSCs).

The amount of water vapour in the stratosphere is very low, only 5 out of one million air molecules are water molecules. This means that under normal conditions there are no clouds in the stratosphere. However, when the temperature drops below -78°C, clouds that consist of a mixture of water and nitric acid start to form. These clouds are called PSCs of type I. On the surface of particles in the cloud, chemical reactions occur that transform passive and innocuous halogen compounds (e.g. HCl and HBr) into so-called active chlorine and bromine species (e.g. ClO and BrO). These active forms of chlorine and bromine cause rapid ozone loss in sun-lit conditions through catalytic cycles where one molecule of ClO can destroy thousands of ozone molecules before it is passivated through the reaction with nitrogen dioxide (NO_2).

When temperatures drop below -85°C, clouds that consist of pure water ice will form. These ice clouds are called PSCs of type II. Particles in both cloud types can grow so large that they no longer float in the air but fall out of the stratosphere. In doing so they bring nitric acid with them. Nitric acid is a reservoir that liberates NO_2 under sunlit conditions. If NO_2 is physically removed from the stratosphere (a process called denitrification), active chlorine and bromine can destroy many more ozone molecules before they are passivated. The formation of ice clouds will lead to more severe ozone loss than that caused by PSC type I alone since halogen species are more effectively activated on the surfaces of the larger ice particles.

The Antarctic polar vortex is a large low-pressure system where high velocity winds (polar jet) in the stratosphere circle the Antarctic continent. The region poleward of the polar jet includes the lowest temperatures and the largest ozone losses that occur anywhere in the world. During early August, information on meteorological parameters and measurements from ground stations, balloon sondes and satellites of ozone and other constituents can provide some insight into the development of the polar vortex and hence the ozone hole later in the season.

The situation with annually recurring Antarctic ozone holes is expected to continue as long as the stratosphere contains an excess of ozone depleting substances. As stated in the recently published Executive Summary of the 2006 edition of the WMO/UNEP Scientific Assessment of Ozone Depletion, severe Antarctic ozone holes are expected to form during the next couple of decades.

For more information on the Antarctic ozone hole and ozone loss in general the reader is referred to the WMO ozone web page: http://www.wmo.int/pages/prog/arep/gaw/ozone/index.html.

Meteorological conditions

Temperatures

Meteorological data from the National Center for Environmental Prediction (NCEP) in Maryland, USA, show that stratospheric temperatures over Antarctica have been below the PSC type I threshold of -78°C since mid May and below the PSC type II threshold of –85°C since early June, as shown in Figure 1. This figure also shows that the daily minimum temperatures at the 50 hPa level have been close to (mainly below) the 1979-2006 average. The development of the minimum temperatures in 2007 is quite similar to the development in 2006. In mid September there was a rapid warming at higher levels, such as 10 hPa. This warming also penetrated down to 50 hPa, but was much less pronounced here.

Data from NCEP, made available through the Ozonewatch web page of NASA (see section on Acknowledgements and links at the end of the Bulletin), show that during the April-late June 2007 time period, 50 hPa temperatures averaged over the 60-90°S region have been close to, or somewhat below, the 1979-2006 average. From late June until late July this mean temperature was above the long-term average. Since late July, this polar cap mean temperature has been oscillating around the 1979-2006 mean. During the last few

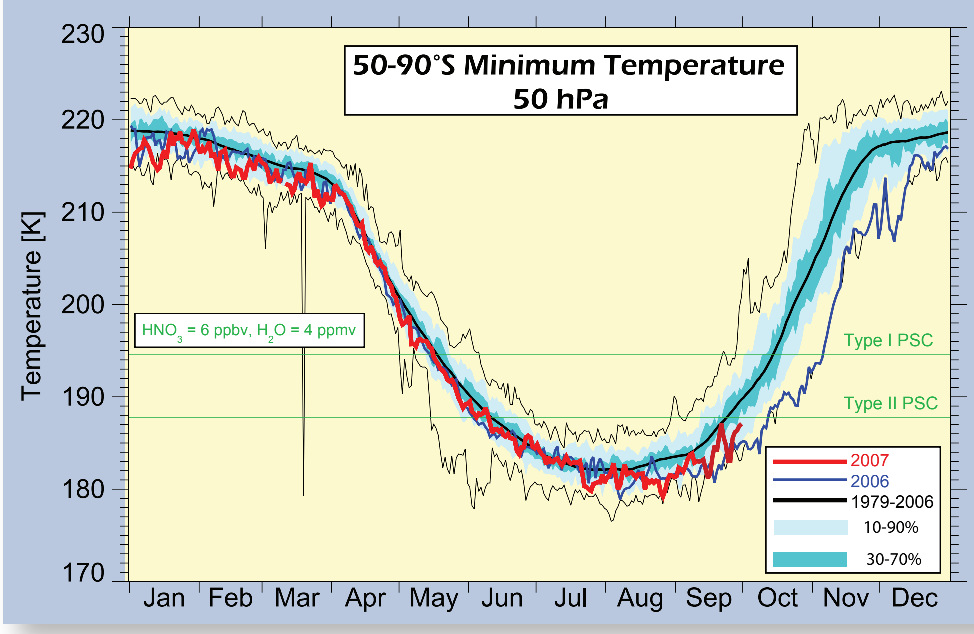


Figure 1. Time series of daily minimum temperatures at the 50 hPa isobaric level south of 50°S. The red curve shows 2007 (until 30 September). The somewhat darker red section of the curve shows the development since the previous Bulletin (10 September). The blue line shows 2006. The average of the 1979-2006 period is shown for comparison in black. The thin black lines represent the highest and lowest daily minimum temperatures in the 1979-2006 time period. The light blue-green shaded area represents the 10th and 90th percentile values and the dark blue-green shaded area the 30th and 70th percentiles. The two horizontal green lines at 195 and 188 K show the thresholds for formation of PSCs of type I and type II, respectively. The plot is adapted from a plot downloaded from the Ozonewatch web site at NASA and based on data from NOAA/NCEP.

weeks, the 50 hPa temperature in the 60-90°S region has been approx. 2 K warmer than at the same time last year. Since the last Bulletin (10 August), the 50 hPa temperatures averaged over the 60-90°S region have increased rapidly and are now well above the 1979-2006 average for this time of the year. A similar development is also seen at 10, 30, 70, 100 and 150 hPa, but much less pronounced at the two lower levels.

The mean temperature at 50 hPa in the 55-75°S region also experienced the warming seen in the 60-90°S region and temperatures are now somewhat warmer than the 1979-2006 average.

PSC Area

Since mid-June, temperatures low enough for nitric acid trihydrate (NAT or PSC type I) formation have covered an area of more than 20 million square kilometres, or about 70-75% of the vortex area. This is less than in 2006 when the NAT area in late July corresponded to approx. 90% of the vortex area. The temporal development of the NAT area is shown in Figure 2. Since the onset of NAT temperatures

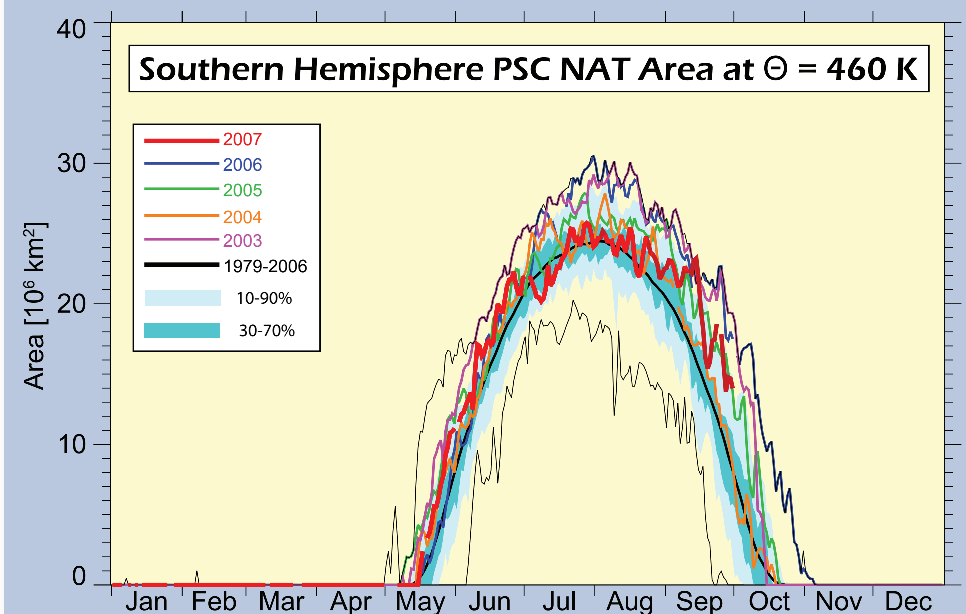


Figure 2. Time series of the area where temperatures are low enough for the formation of nitric acid trihydrate (NAT or PSCs of type I) at the 460 K isentropic level. This corresponds to an altitude of approximately 18 km. The red curve shows 2007 (until 30 September). The somewhat darker red part of the curve shows the development after the last Bulletin (10 September). The blue, green, orange and magenta curves represent 2006, 2005, 2004 and 2003, respectively. The average of the 1979-2006 period is shown for comparison in black. The two thin black lines show the maximum and minimum PSC area during the 1979-2006 time period for each date. The light blue-green shaded area represents the 10th and 90th percentile values and the dark blue-green shaded area the 30th and 70th percentiles. The plot is adapted from a plot downloaded from the Ozonewatch web site at NASA and based on data from NOAA/NCEP.

in mid-May the NAT area was larger than the 1979-2006 average until late June. From early July to mid July the NAT area was lower than the 1979-2006 average, but from mid July to mid August, the NAT area has been somewhat above the long-term mean. The mid September warming event described above can also be seen in the NAT area data in Figure 2, but the NAT area still remains above the 1979-2006 average.

The area with temperatures low enough for the existence of PSCs is directly linked to the amount of ozone loss that will occur later in the season, but the degree of ozone loss depends also on other factors, such as the amount of water vapour and HNO_3.

Ozone observations

Satellite observations

Figure 3 shows minimum ozone columns as measured by the SCIAMACHY instrument on board ENVISAT in comparison with data for the nine previous years (SCIAMACHY and GOME). The red dots show the development from 1 August 2007. The minimum column has now dropped from to around 115 DU. During August and the first half of September the minimum ozone columns were close to the average for the last ten years, but the last two weeks it has been somewhat larger than this average.

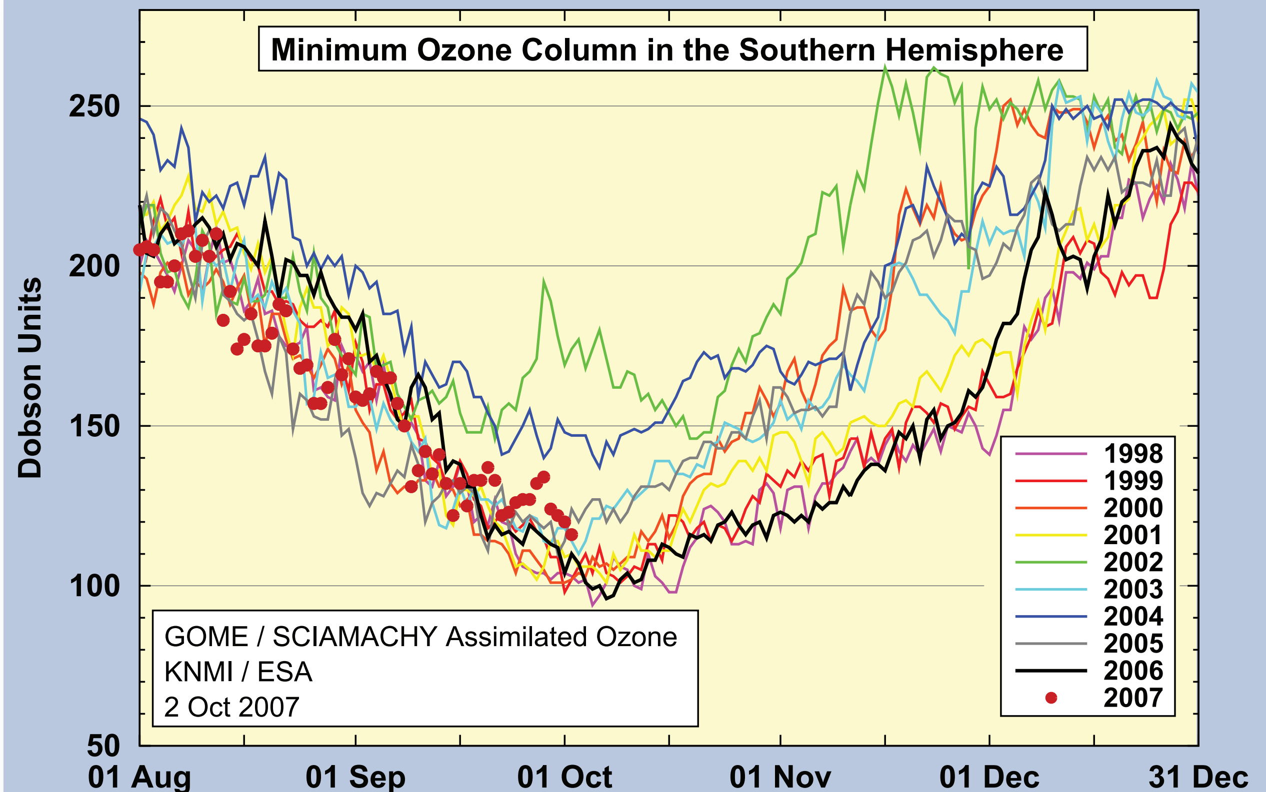


Figure 3. Daily minimum total ozone columns in the Southern Hemisphere as observed by GOME, and SCIAMACHY. The red dots show the SCIAMACHY observations for 2007. The data now show minimum ozone columns down to 115 DU. The plot is provided by the Netherlands Meteorological Institute (KNMI).

Figure 4 shows minimum ozone as measured with the OMI instrument on board the AURA satellite. These data are similar to the SCIAMACHY measurements. Note however that the SCIAMACHY data are a few days more up to date than the OMI data, so the last decline in the minimum columns seen in the SCIAMACHY data do not show up in the OMI plot.

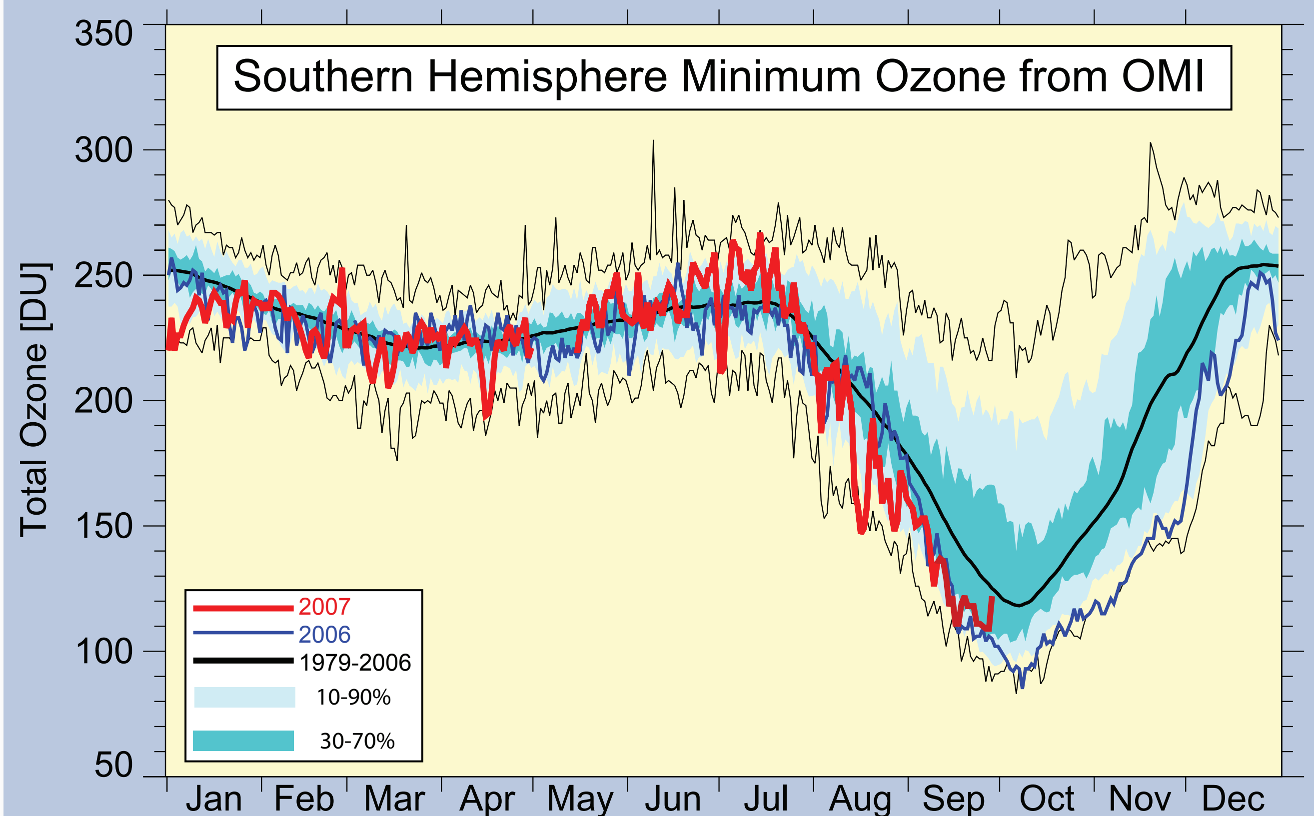


Figure 4. Daily minimum total ozone columns in the Southern Hemisphere as observed by OMI and TOMS. The red curve show the OMI observations for 2007 until 30 September. The development since the previous Bulletin (10 September) is shown in darker red. Minimum columns went down to around 110 DU during the last two weeks of September. The plot is adapted from a plot downloaded from NASA's ozone watch web site.

Ozone hole area and mass deficit

The region where total ozone is less than 220 DU (ozone hole area) as deduced from the OMI instrument on AURA is shown in Figure 5. The area reached 25 million km² in mid September. The last two weeks the ozone hole area has varied between 21 and 24 million km². It is considerably smaller than last years ozone hole area, which reached more than 29 million km² in late September.

Figure 6 (next page) shows the ozone mass deficit as deduced from the GOME and SCIAMACHY satellite instruments. On 23 September, the mass deficit was close to 28 megatonnes. Since then the ozone mass deficit has varied between 22 and 27 megatonnes. It is unlikely that it will climb above 25 megatonnes later in the season. Thus, it looks as if the 2007 ozone hole will be the third weakest

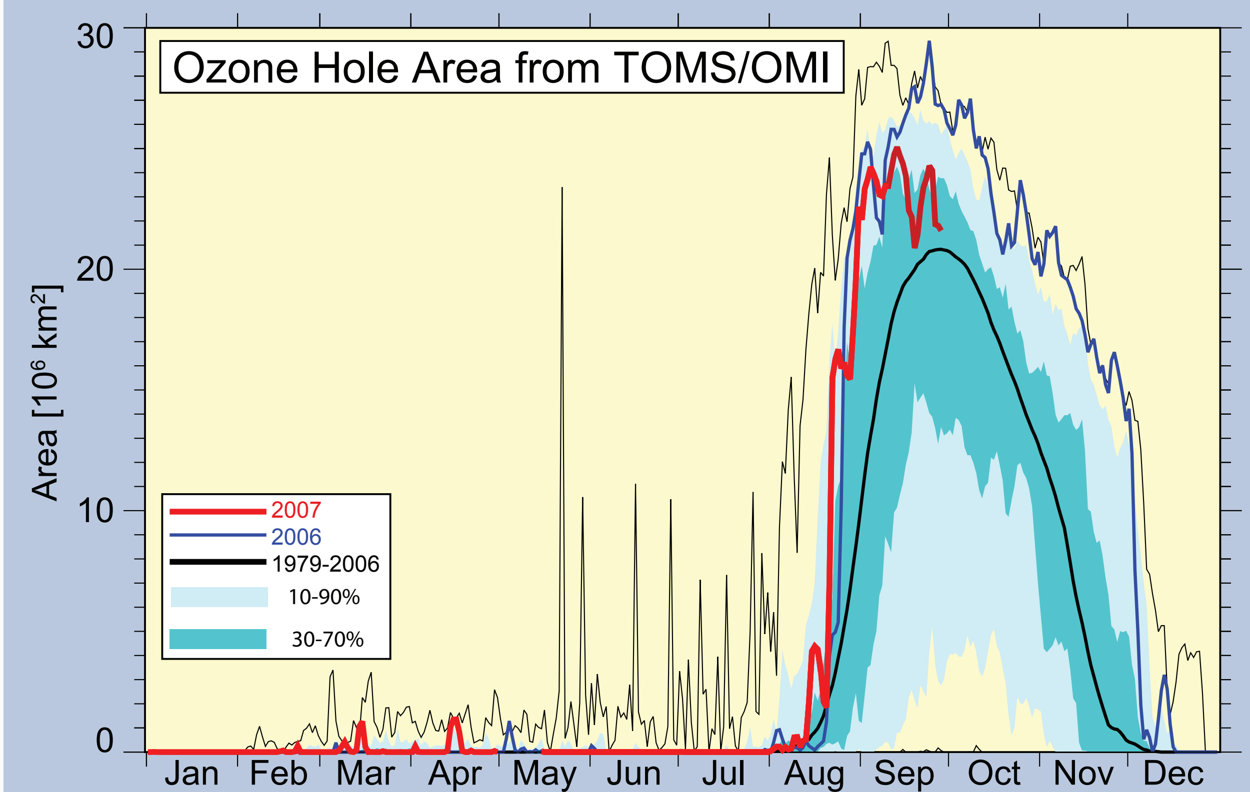


Figure 5. Area (millions of km²) where the total ozone column is less than 220 Dobson units. 2007 is showed in red (until 30 September). The time period after the last bulletin (10 September) is shown in darker red. 2006 is shown in blue. The smooth black line is the 1979-2006 average. The dark green-blue shaded area represents the 30th to 70th percentiles and the light green-blue shaded area represents the 10th and 90th percentiles for the time period 1979-2006. The graph is adapted from a plot downloaded from the NASA Ozonewatch web site and is based on data from the OMI instrument on AURA and various TOMS instruments.

since 1998, with the ozone holes of 2002 and 2004 as the only ones with less ozone mass deficit.

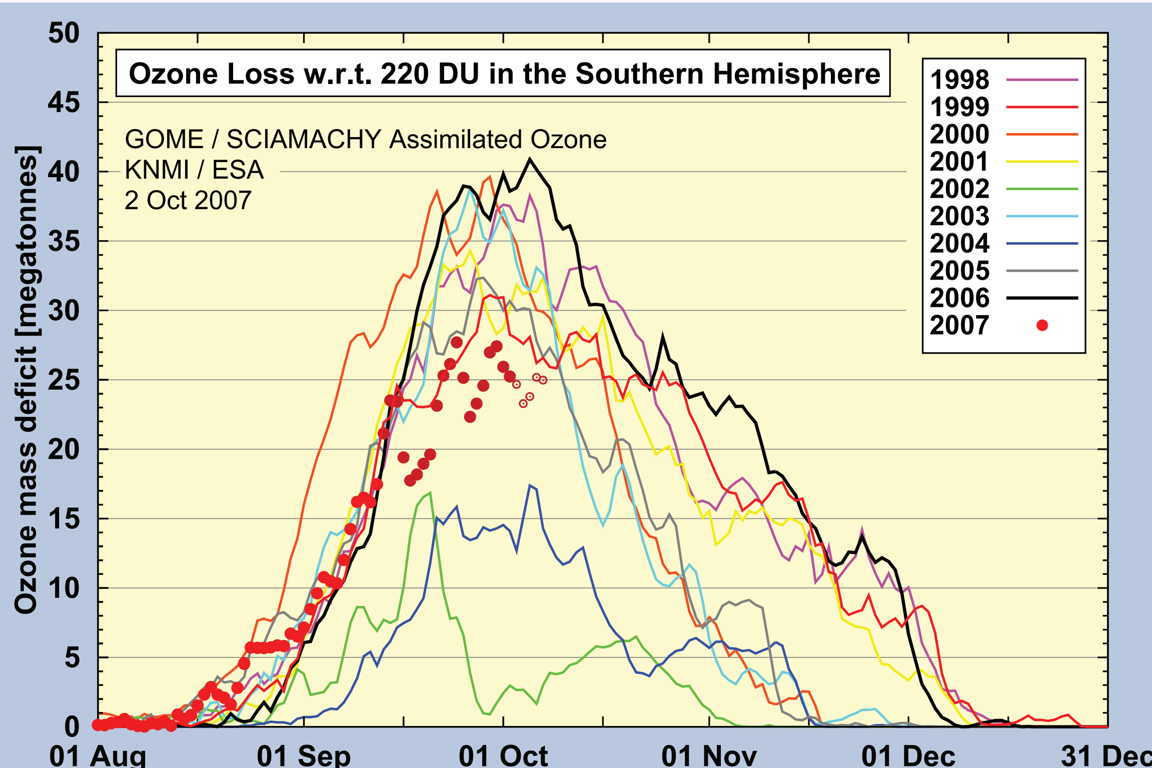


Figure 15. Ozone mass deficit (megatonnes) for the years from 1998 to 2007 (red dots). Data after the previous Bulletin are given in dark red. The open red circles are forecasts. The mass deficit is the amount of ozone that would have to be added to the ozone hole in order to bring the total column up to 220 DU in those regions where the total column is below this threshold. This plot is produced by KNMI and is based on data from the GOME and SCIAMACHY satellite instruments.

UV radiation

UV radiation is measured by various networks covering the southern tip of South America and Antarctica. There are stations in Southern Chile (Punta Arenas), southern Argentina (Ushuaia) and in Antarctica (Belgrano, Marambio, McMurdo, Palmer, South Pole). No station has yet measured a UV index superior to 2 so far during the current season. As the sun rises in the sky and ozone gets depleted, higher UV indices are expected. Links to sites with data and graphs on UV data are found in the "Acknowledgements and Links" section at the end of the Bulletin.

Distribution of the bulletins

The Secretariat of the World Meteorological Organization (WMO) distributes Bulletins providing current Antarctic ozone hole conditions beginning around 20 August of each year. The Bulletins are available through the Global Atmosphere Watch programme web page at http://www.wmo.int/pages/prog/arep/gaw/ozone/index.html. In addition to the National Meteorological Services, the information in these Bulletins is made available to the national bodies representing their countries with UNEP and that support or implement the Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol.

Acknowledgements and links

These Bulletins use provisional data from the WMO Global Atmosphere Watch (GAW) stations operated within or near Antarctica by: Argentina (Comodoro Rivadavia, San Martin, Ushuaia), Argentina/Finland (Marambio), Argentina/Italy/Spain (Belgrano), Australia (Macquarie Island and Davis), China/Australia (Zhong Shan), France (Dumont D'Urville and Kerguelen Is), Germany (Neumayer), Japan (Syowa), New Zealand (Arrival Heights), Russia (Mirny and Novolazarevskaja), Ukraine (Vernadsky), UK (Halley, Rothera), Uruguay (Salto) and USA (McMurdo, South Pole). More detailed information on these sites can be found at the GAWSIS web site (http://www.empa.ch/gaw/gawsis).

Satellite ozone data are provided by NASA (http://ozonewatch.gsfc.nasa.gov), NOAA/TOVS (http://www.cpc.ncep.noaa.gov/products/stratosphere/tovsto/), NOAA/SBUV/2 (http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/) and ESA/Sciamachy (http://envisat.esa.int). Satellite data on ozone, ClO, HCl and a number of other relevant parameters from the MLS instrument on the Aura satellite can be found here: http://mls.jpl.nasa.gov/plots/mls/mls_plot_locator.php.

Potential vorticity and temperature data are provided by the European Centre for Medium Range Weather Forecasts (ECMWF) and their daily T_{106} meteorological fields are analysed and mapped by the Norwegian Institute for Air Research (NILU) Kjeller, Norway, to provide vortex extent, PSC area and extreme temperature information. Meteorological data from the US National Center for Environmental Prediction (NCEP) are also used to assess the extent of PSC temperatures and the size of the polar vortex (http://www.cpc.ncep.noaa.gov/products/stratosphere/polar/polar.shtml). NCEP meteorological analyses and climatological data for a number of parameters of relevance to ozone depletion can also be acquired through the Ozonewatch web site at NASA (http://ozonewatch.gsfc.nasa.gov/meteorology/index.html).

Ozone data analyses and maps are prepared by the World Ozone and UV Data Centre at Environment Canada (http://exp-studies.tor.ec.gc.ca/cgi-bin/selectMap), by the Royal Netherlands Meteorological Institute (http://www.temis.nl/protocols/

O3global.html) and by the University of Bremen (http://www.doas-bremen.de/). UV data are provided by the U.S. National Science Foundation's (NSF) UV Monitoring Network (http://www.biospherical.com/nsf).

UV indices based on the SCIAMACHY instrument on Envisat can be found here: http://www.temis.nl/uvradiation/

Ultraviolet radiation data from the Dirección Meteorológica de Chile can be found here: http://www.meteochile.cl

Data on ozone and UV radiation from the Antarctic Network of NILU-UV radiometers can be found here: http://polarvortex.dyndns.org

The Executive Summary of the 2006 WMO/UNEP Scientific Assessment of Ozone Depletion can be found here: http://www.wmo.int/web/arep/gaw/gaw_home.html

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The next Antarctic Ozone Bulletin is planned for 18 October 2007.