Executive summary

Since the last WMO Antarctic Ozone Bulletin 14 days ago, the area where temperatures are below the threshold for formation of PSCs of type I (nitric acid trihydrate, NAT) has continued to decrease and is now close to zero. This area has been close to the 2003 values and well above the 1995-2004 average throughout the month of September and the first week of October. The area where the total ozone column is less than 220 DU is now on the way down after reaching its maximum around 20 September. Although the ozone hole area has remained nearly constant during the last two weeks, it is now being filled up with ozone, and minimum values, as seen by satellites, are now around 125 DU, after being down to 106 DU on 30 September. Ground-based observations from Belgrano showed a total ozone column of 94 DU on 4 October, which is the lowest ever measured at that station. The maximum observed UV index at Antarctic stations has increased since the previous Bulletin from 4.4 to 6. At Ushuaia, Argentina, the UV index reached 8 on 8 October, which is unusually high for this time of the year.
Introduction

For background information on the Antarctic ozone hole and ozone loss in general the reader is referred to the first 2005 issue of this Bulletin, which can be found here: [http://www.wmo.int/web/arep/ozone.htm](http://www.wmo.int/web/arep/ozone.htm)

More background information is also found here: [http://www.wmo.int/web/arep/O3_summaries/O3_summaries_afischer.htm](http://www.wmo.int/web/arep/O3_summaries/O3_summaries_afischer.htm).

Meteorological conditions

During the 14 days since the last bulletin, minimum temperatures at the isentropic level of 500K in the south polar vortex have increased, but remained below or near the 1995-2004 average, as can be seen from Figure 1. Looking at the overall development during the last week of August, the four weeks of September, and the first two weeks of October, minimum temperatures have been relatively low compared to the last decade.

The area where $T < T_{NAT}$ has continued to decrease during the last two weeks, which is normal for this time of the year, as seen in Figure 2. This area has been between zero and 5 Mkm$^2$ the last days and is expected to drop to zero within the next two weeks.

Analyses of the vortex area at the isentropic level of 450K (about 17 km), made by the Climate Prediction Center at NCEP/NOAA, show that the area of the vortex has hovered around 30 Mkm$^2$ throughout September, but has now (6 Oct.) decreased to 28 Mkm$^2$. At 550 K (approximately 25 km) the vortex area reached a maximum of 32 Mkm$^2$ in the beginning of September and has now decreased to 27 Mkm$^2$. At 650 K (about 28 km) the vortex area reached a maximum of approximately 40 Mkm$^2$ in early August and is now (6 October) down to 28 Mkm$^2$. Throughout most of the winter the vortex area has been very close to the 1995-2004 average at all three of these levels. Graphics showing this development are updated regularly and available at the web sites referred to below in the "Acknowledgements and links" section.

**Figure 1.** Time series of ECMWF daily minimum temperatures at the 500K isentropic level southward of 30°S. The thick red curve shows 2005 (until 11 October). The blue line shows 2004 and the green line 2003. The average of the 1995-2004 period is shown for comparison in grey. The error bars represent ±2σ (standard deviations). The two horizontal green lines at 195 and 188 K show the thresholds for formation of PSCs of type I and type II, respectively.

**Figure 2.** Time series of the area where ECMWF temperatures are low enough for the formation of PSCs of type I at the 500K isentropic level. This corresponds to an altitude of approximately 20 km. The thick red curve shows 2005 (until 11 October). The blue curve represents 2004 and the green curve 2003. The average of the 1995-2004 period is shown for comparison in grey. The error bars represent ±2σ (standard deviations).

**Figure 3.** Total ozone map for 8 October 2005 based on data from the Ozone Monitoring Instrument (OMI) on board the AURA satellite.
Ozone observations

Satellite observations

On 8 October the ozone hole affected the southern tip of South America, as shown by the AURA/OMI map in Figure 3. Similar images can also be obtained from NASA/TOMS and ESA/SCIAMACHY by visiting the links given at the end of the Bulletin. The low ozone column on 8 October led to unusually intense UV radiation in Ushuaia, Argentina, as described below in the section on UV radiation.

Minimum ozone column values, as observed by the SCIAMACHY instrument on ENVISAT, reached values around 106 DU on 30 September. During the first two weeks of October, the minimum ozone columns from SCIAMACHY have stabilised around 115-127 DU as shown in Figure 4. Comparing with data from the last few years, one expects that the minimum ozone columns now have reached the bottom and will begin to increase again.

Ozonesonde observations

Ozonesondes launched in early October by the University of Wyoming from the GAW/NDSC station at McMurdo (77.9°S, 166.6°E) show nearly complete ozone destruction in the 14-19 km altitude interval, in particular on 3 October.

Ozone soundings from the GAW/NDSC Amundsen-Scott base at the South Pole show that the partial ozone column between 12 and 20 km decreased rapidly during the first three weeks of September from 100 to 15 DU. The last 2-3 weeks the partial column has stabilised around 15-20 DU. Time series of the partial column for the 12-20 km altitude range, based on South Pole ozonesonde observations, are given in Figure 5. The total ozone column, as calculated from the sonde profiles, has decreased from 266 DU on 7 August to 110 DU on 28 September, which amounts to a decrease of 59%. The ozone soundings carried out after 28 September show an increase in the total ozone column, which reached 181 DU on 9 October.

Ozonesondes are launched from the GAW/NDSC station at Neumayer several times per week. The progression of ozone depletion at this stations is illustrated in Figure 6.

Figure 5. Partial ozone columns at the South Pole for the 12-20 km height interval. This is the altitude region where most of the ozone loss takes place. The brown diamonds show the 2005 measurements. It can be seen that on several days in September the partial ozone column has been lower than any of the earlier years at the same date. In early October the partial column has stabilised around 15-20 DU.

Ground-based observations

Low total ozone values have also been observed from the ground. The Global Atmosphere Watch (GAW) stations at Rothera (67.6°S, 68.1°W), Faraday-Ver-
nadsky (65.2°S, 64.2°W) and Halley (75.6°S, 26.7°W) report ozone columns around 150 DU or below during
the latter half of September and first week of October. At Halley, the observations show that ozone values
fell rapidly during September and reached 107 DU on 27 September, which is the second lowest value
ever recorded for the month of September at this site. After that, total ozone has increased somewhat and
is now around 130 DU. At Rothera, total ozone has increased during the first week of October and is now
around 170 DU.

The Argentinian GAW stations at Marambio (64.2°S, 56.7°W), San Martin (68.1°S, 67.1°W) and Belgrano
(77.9°S, 34.5°W) are all well inside the ozone hole and report total ozone values in the 94-161 DU range

Figure 8. Total ozone maps synthesised by the World Ozone and UV Data Centre at Environment Canada. Panel A
shows the situation on 27 September 2005 and panel B shows the situation on 11 October 2005. It is clearly visible that
the area with a total ozone column inferior to 125 DU (light grey) has shrunk significantly during this 14-day period.
during the 3-12 October time period. Since the last Bulletin on 29 September, the ozone column at Ma-rambio has varied between 275 DU on 1 October and 116 DU on 7 October. At San Martin, the column has varied between 125 DU on 7 October and 170 DU on 10 October. Belgrano, which is located deeper inside the polar vortex, started the observations on 13 September, and ozone columns have continued to decrease since the last Bulletin. The lowest values were observed on 1 and 4 October, with 95 and 94 DU, respectively. These are the lowest total ozone columns ever measured at Belgrano. The previous low is 95.4 DU, which was measured on 27 September 2003. Zenith sky measurements showed 88 DU on 6 October, but this measurement is not as reliable as the direct sun measurements. The GAW station at Ushuaia (54.5°S, 68.3°W), usually outside the polar vortex, has been located under the edge of the vortex during several days in September and October. Most recently, the ozone column was below 220 DU during 7-9 October, with a minimum of 161 DU on 8 October (see Figure 3). This led to enhanced UV radiation, as described in the UV section below. The long-term norm for early October is around 330 DU at Ushuaia.

The GAW/NDSC station at Arrival Heights (77.8°S, 166.7°E) started this season’s Dobson measurements on 15 September and the ozone columns have varied between 156 (20 September) and 401 DU (9 October), depending on the position of the station relative to the edge of the polar vortex. This station is less affected by ozone loss than Belgrano (see above), which is located at the same latitude, but further west. This is partly due to the fact that Arrival Heights on many days has been closer to the edge of the vortex, but also because ozone depletion has been more intense in the 30-150°W sector.

The GAW station Syowa (69.0°S, 39.6°E) started this season’s total ozone measurements on 14 August and the column values were close to or above 200 DU during August and early September. From 5 September the ozone column has decreased more or less gradually and it reached its lowest value so far this year (136 DU) on 4 October. This is 56% below the 1964-76 pre-ozone hole norm.

The GAW station at Novolazarevskaja (70.8°S, 11.9°E) has reported ozone columns below 150 DU during the last week, and the column dropped to 109 DU on 23 September. The last days of September and the first days of October, total ozone has remained low and has varied between 111 and 126 DU.

The GAW station at Zhong Shan (69.4°S, 76.4°E) started the total ozone measurements on 22 August, and the ozone column has varied between 267 DU (2 September) and 164 DU (30 September). The ozone observations at this site has been influenced by the location of the polar vortex. On 26 September, Zhong Shan was under the vortex edge and an ozone column of 240 DU was measured. Four days later, the column was down to 164 DU, as the station then was inside the vortex.

**WOUDC maps**

Total ozone column maps synthesised by the World Ozone and UV Data Centre at Environment Canada, using surface-based WMO/GAW network observations and satellite data, show that the ozone hole area (defined as the region where total ozone is less than 220 DU) has not changed much during the last two weeks. However, as shown in Figure 8, the hole has been filled up with ozone and the area inside the 150 and 125 DU contours have decreased considerably from 27 September to 11 October.

**Ozone hole**

**Daily ozone hole area**

The area where the ozone column is less than 220 DU reached a peak of 26.9 Mkm$^2$ on 19 September according to the analysis carried out by the Royal Netherlands Meteorological Institute (KNMI). Since then, the ozone hole area has been around 24-25.5 Mkm$^2$. The last few days the area has dropped to about 22 Mkm$^2$ (see Figure 9). The ozone hole size, as calculated by the US Climate
Prediction Center, using SBUV/2 data, has been in the 21-24 Mkm$^2$ range during all of September and the first week of October, but has dropped to 19 Mkm$^2$ during the last few days.

Plots of the ozone hole area, deduced from ESA/SCIAMACHY, NOAA/SBUV/2 and NASA/EP-TOMS, can be found at the web sites given in the section on "Acknowledgements and links" below.

The area where total ozone is less than 220 DU has passed its maximum, and based on data from GOME and SCIAMACHY, the ozone hole of 2005 ranks as the third largest ever recorded after the ones of 2000 and 2003.

**September climatology**

The average total ozone column for the month of September for the years 2000-2005 is shown in Figure 10. One can see the weak ozone hole of 2002, when the vortex split in two parts in mid-September. One can also see that the 2004 ozone hole was less severe than the other years shown here. Most of the years the ozone hole is shifted somewhat towards South America. This is also the case in 2005.

**UV radiation**

The US National Science Foundation funds a network for the monitoring of ultraviolet radiation at stations scattered around the globe. There are several stations in Antarctica and the southern part of South America. UV Bulletins are issued regularly by Biospherical Instruments Inc. Their third Antarctic UV Bulletin of 2005 reports on the 27 September to 10 October time period and states the following:

The 2005 ozone hole affected UV levels at all austral network sites according to NASA's Earth Probe TOMS. UV levels at McMurdo Station and the South Pole remained low since prevailing solar elevations

![Figure 10. Mean total ozone for the month of September for the years 2000-2005. These maps are based on data from Earth Probe TOMS until 2004 and on AURA/OMI data for 2005.](image-url)
were still small. When the ozone hole extended to South America between October 7 and 10, UV indices of 6 and 8 were measured at Palmer Station and Ushuaia, respectively. These indices were amongst the highest measured at these sites during this part of the year.

McMurdo Station, Antarctica

Solar elevations at McMurdo Station were still below 19° and UV levels remained low. McMurdo Station was close to the edge of the ozone hole until 5 October. When the shape of the ozone hole became elongated on 6 October, the station was outside the ozone hole area and total ozone increased to values above 370 DU. This led to a marked reduction in UV. Between 27 September and 5 October, the daily maximum UV index varied between 0.9 and 1.4. It remained below 0.8 after 7 October.

Palmer Station, Antarctica

Palmer Station was affected by the ozone hole during most of the reporting period. Exceptions are 30 September and 1 October. UV levels were highly variable. Much of the variability was caused by changes in cloudiness. The maximum daily UV Index ranged between 0.5 (30 September) and 6 (8 October). Typical summer-time values are about 8.

South Pole, Antarctica

Solar elevations at the South Pole were still below 7° and UV levels remained low. The maximum UV index was 0.3.

Ushuaia, Argentina

Ushuaia was affected several times by the ozone hole. According to TOMS, total ozone dropped below 220 DU on 27 September and between 7 and 10 October. The lowest ozone concentration (161 DU) was measured on 8 October when the ozone hole had an elongated shape and extended to South America. The maximum daily UV index stayed below 5 until 6 October and rose to about 8 on 8 October. A UV index of 8 is exceptionally high for Ushuaia during this part of the year.

Distribution of the bulletins

The Secretariat of the World Meteorological Organization (WMO) distributes Bulletins providing current Antarctic ozone hole conditions beginning mid-August of each year. The Bulletins are distributed via the WMO Global Telecommunication System (GTS) and are also available through the Global Atmospheric Watch programme web page at http://www.wmo.ch/web/arep/ozone. html. In addition to the National Meteorological Serv-

ices, 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 Is and Davis), China/Australia (Zhong Shan), France (Dumont D'Urville and Kerguelen Is), Germany (Neumayer), Japan (Syowa), New Zealand (Arrival Heights), Russia (Mirny and Novolazarzavreska), Ukraine (Vernadsky), UK (Halley, Rothera), Uruguay (Salto) and USA (South Pole, McMurdo). More detailed information on these stations can be found at the GAWSIS web site (http://www.empa.ch/gaw/gawsis).

Satellite ozone data are provided by NASA (EP TOMS and AURA/OMI) (http://toms.gsfc.nasa.gov/epptomv8.html, http://jwocky.gsfc.nasa.gov/epptom/dataqual/ozone.html), NOAA/TOVS (http://www.cpc.ncep.noaa.gov/products/stratosphere/tvstol/), NOAA/SBUV/2 (http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/) and ESA/Sciamachy (http://envisat.esa.int). 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 (http://www.nilu.no/projects/nadir/o3hole). Meteorological data from the US Climate Prediction Center 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.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) and by the Royal Netherlands Meteorological Institute (http://www.temis.nl/protocols/O3global.html). UV data are provided by the U.S. National Science Foundation’s (NSF) UV Monitoring Network (http://www.biospherical.com/nsf).

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The next WMO Antarctic Ozone Bulletin is planned for Thursday 27 October.