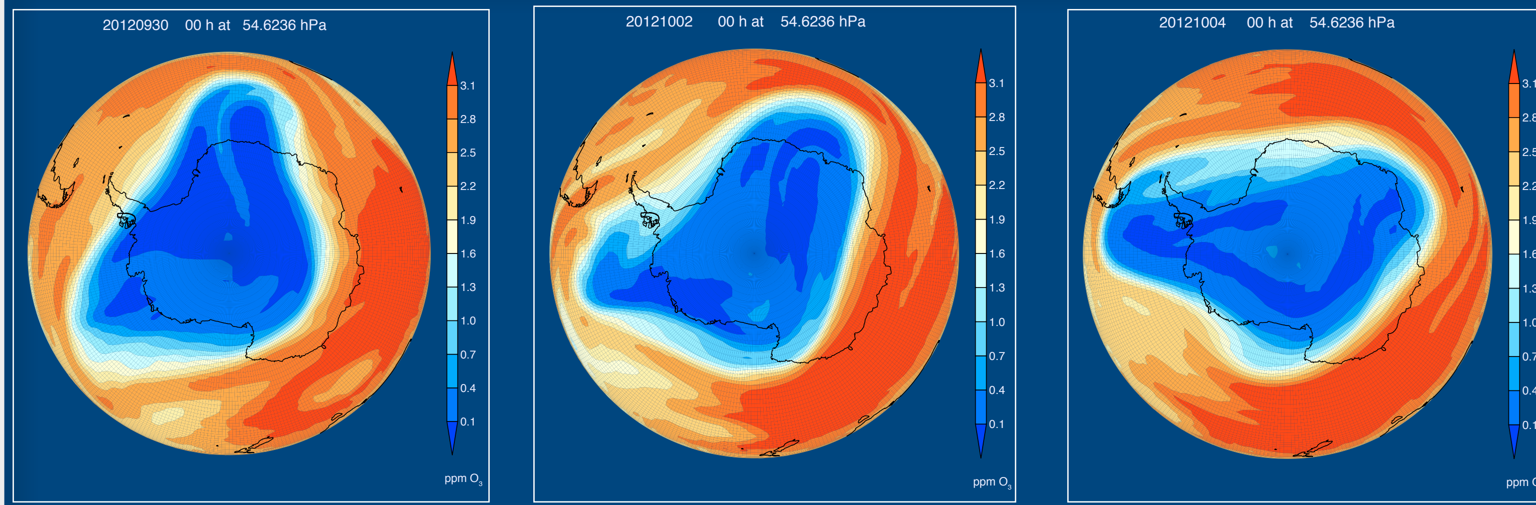
Antarctic Ozone Bulletin

No 3/2012



One, three and five day forecasts of the ozone mole fraction at 54.6 hPa from the atmospheric chemistry model used in the MACC-II project. The images show how the ozone hole will move over the southern tip of the South American continent at midnight on 4 October. More information on the MACC-II project and model products can be found on page 58.

WMO OMM

30 September 2012

Global Atmosphere Watch

GAW

Executive Summary

The daily minimum temperatures at the 50 hPa level have been close to or below the 1979-2011 average since April. In July and August the minimum temperature was below the long term mean but relatively warm compared to recent years. In September the minimum temperature has increased more rapidly than the average, and is now (on 28 September) near the long term mean.

The average temperature over the 60-90°S region was quite close to or below the long-term mean until the middle of August. During the latter half of August a minor warming led to a temperature increase of approx. 5 K. Towards the end of August the temperature decreased again, but since early September the polar cap mean temperature at 50 hPa has been near or above the average for the season.

Since the onset of NAT temperatures in mid May the NAT area was close to or above the 1979-2011 average until early July. The NAT area reached a peak above 25 million km^2 on 12 July. Then the NAT area stayed well below the 1979-2011 average until late August, but after that and until now (28 Sept.) has been close to or somewhat below the long-term average.

The NAT volume has been close to or below the 1979-2011 average throughout the winter. From early July until now the PSC volume has been significantly lower than the long-term mean and also near and even below the 1979-2011 minimum on some days. In late September it is still below the long-term mean.

During May and June the 45-day mean of the heat flux was lower than or close to the 1979-2011 average. From early July, the heat flux increased somewhat and remained larger than the 1979-2011 average until late August. After mid September the heat flux increased and by the end of September it is near the long-term mean.

At 46 hPa (altitude of ~19 km), HCl is less depleted now (21 September) than on 11 September. This is a sign that the vortex is about to get deactivated. Although there remain areas where the HCl mixing ratio is clearly depleted, there are also large areas where HCl is reforming. Compared to recent years, the HCl recovery in 2012 is similar to that seen in 2009 and 2010, but less depleted than on the same date in 2011.

In 2012 the vortex seems somewhat more activated (more active chlorine, ClO) than in 2010, but less activated than in 2009 and 2011. However, the activated area only covers the part of the vortex facing the Atlantic and Indian Oceans, where as the Pacific sector has much less ClO.

During the first half of August, the area where total ozone is less than 220 DU ("ozone hole area") increased more slowly than during the same time period in many of the recent years. However, from mid August the increase has more or less followed the same development as in 2011. As of 28 September, the ozone hole area is 20.8 million square kilometres, after passing through a maximum of 21.2 million square kilometres on 22 September. This is less than the 24.3 million square kilometres reached on 28 September last year, and also less than the 21.7 million square kilometres reached on 28 September 2010. In fact, one has to go back to 2004 to find a smaller ozone hole area on 28 September (18.1 million km^2). The final peak reached in

September has varied between 22 and 28 million square kilometres the last seven years.

Measurements with ground based instruments and with balloon sondes show that ozone depletion has come far at many sites, also the South Pole. In this issue data are reported from the following stations: Arrival Heights, Belgrano, Dôme Concordia, Dumont d'Urville, Davis, Halley, Macquarie Island, Marambio, Mirny, Neumayer, Novolazarevskaya, Río Gallegos, Rothera, South Pole, Syowa, Ushuaia, Vernadsky and Zhong-shan.

As the sun now has returned to all of Antarctica after the polar night, ozone destruction will continue as long as there is active chlorine present. It is still too early to give a definitive statement about the development of this year's ozone hole and the degree of ozone loss that will occur. This will, to a large extent, depend on the meteorological conditions. However, the temperature conditions, the extent of polar stratospheric clouds and the development of the ozone hole area and the ozone mass deficit so far this year indicate that the degree of ozone loss will be smaller than in 2011, possibly also somewhat smaller than in 2010, which was a year with a relatively perturbed vortex.

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). See **Figure 1** on the next page for details.

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 Executive Summary of the 2010 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.

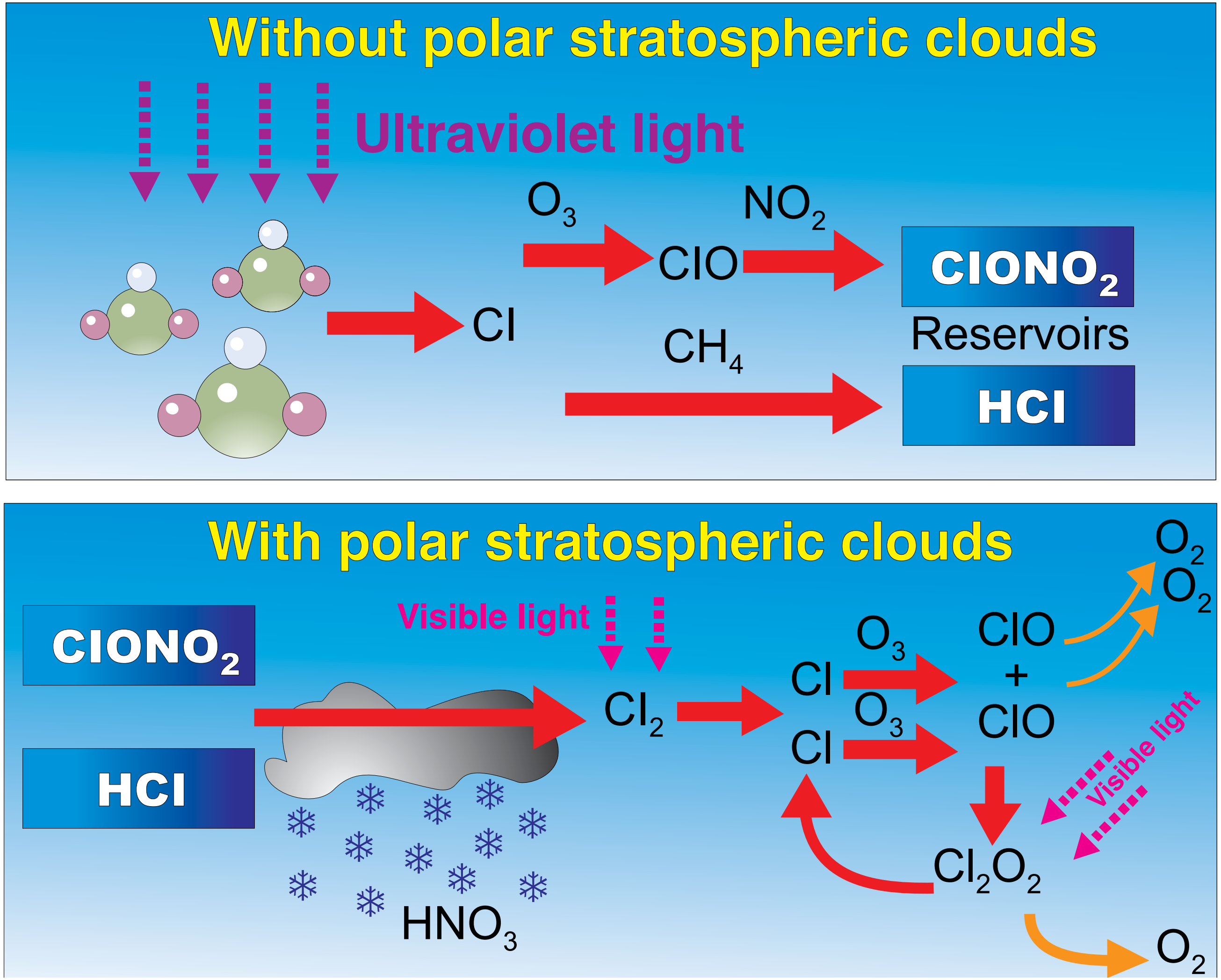


Figure 1. Diagram showing the effect of polar stratospheric clouds on ozone loss. The upper panel shows the situation when there are no polar stratospheric clouds. Ozone depletion takes place only in the gas phase (homogeneous chemistry). The lower panel shows the situation when there are polar stratospheric clouds present. The reservoir gases hydrochloric acid and chlorine nitrate react with each other on the surface of the PSC particles through a red-ox reaction and liberate elementary chlorine (Cl_2). Elementary chlorine is easily photolysed by sunlight and forms atomic chlorine, which reacts fast with ozone to form chlorine monoxide (ClO, active chlorine) and oxygen (O_2). ClO dimerises and forms Cl_2O_2, which is easily photolysed, liberating atomic chlorine again. Due to this catalytic cycle, one atom of Cl can destroy thousands of ozone molecules before it is passivated through reaction with NO_2, methane or other substances. This explains why a few ppb of chlorine can destroy several ppm of ozone. In addition, PSC particles can grow large enough to sediment, thereby removing HNO_3 from the stratosphere. This means that there will be limited amounts of NO_2 present to quench the active chlorine, and the ozone depleting process can continue for several weeks. The diagram has been made by Finn Bjørklid, Norwegian Institute for Air Research (NILU).

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 2**. This figure also shows that the daily minimum temperatures at the 50 hPa level have been close to or below the 1979-2011 average since April. In July and August the minimum temperature was below the long term mean but relatively warm compared to recent years. In September the minimum temperature has increased more rapidly than the average, and is now (on 28 September) near the long term mean.

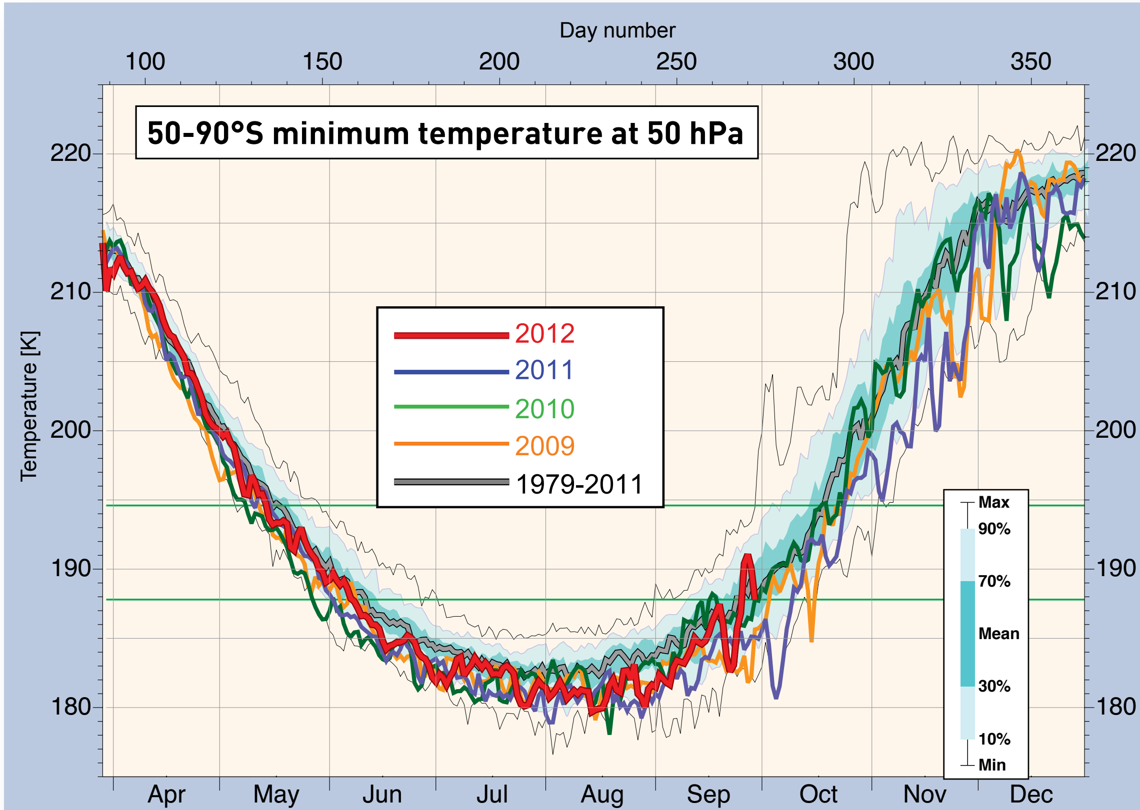


Figure 2. Time series of daily minimum temperatures at the 50 hPa isobaric level south of 50°S. The red curve shows 2012 (until 28 September). The blue line shows 2011, the green line 2010 and the orange line 2009. The average of the 1979-2011 period is shown for comparison in grey. The thin black lines represent the highest and lowest daily minimum temperatures in the 1979-2011 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 made at WMO based on data downloaded from the Ozonewatch web site at NASA, which are based on data from NOAA/NCEP.

Figure 3 (left panel) shows temperatures averaged over the 60-90°S region at 50 hPa. It can be seen from the figure that the average temperature was quite close to or below the long-term mean until the middle of August. During the latter half of August a minor warming led to a temperature increase of approx. 5 K. Towards the end of August the temperature decreased again, but since early September the polar cap mean temperature at 50 hPa has been near or above the average for the season.

At 10 hPa (**Figure 3**, right panel), the 60-90°S mean temperature was below or near the long term mean until the end of June. After that the

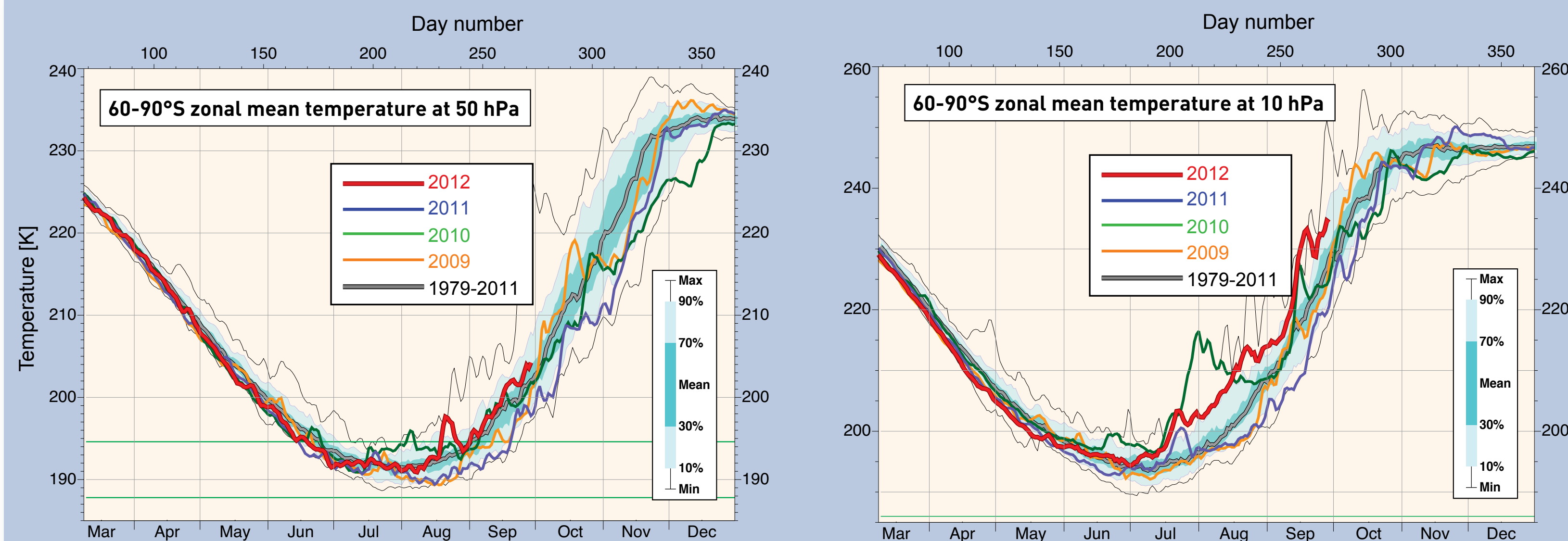


Figure 3. Time series of temperature averaged over the region south of 60°S at the 50 hPa level (left) and at 10 hPa (right). The red curve shows 2012 (until 28 September). The blue, green and orange curves represent 2011, 2010 and 2009, respectively. The average of the 1979-2011 period is shown for comparison in grey. The two thin black lines show the maximum and minimum average temperature for during the 1979-2011 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 made at WMO based on data downloaded from the Ozonewatch web site at NASA, which are based on data from NOAA/NCEP.

mean temperature has risen more or less gradually and on most days since the latter half of July it has been above the 90th percentile (which means that 90% of the winters during the 1979-2011 time period have been colder during this time of the year at 10 hPa). In late August the 10 hPa temperature stabilised and even decreased a bit but was still well above the long-term mean. In September the temperature has been rising again and is still higher than the long-term average. On some days in September the 10 hPa temperature has even been above the long term (1979-2011) maximum.

The mean temperature over the 55-75°S region has behaved quite similarly to the temperature averaged over the 60-90°S region at all levels from 10 to 150 hPa.

PSC Area

Since the end of 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 at the 460 K isentropic level (**Figure 4**). Since the onset of NAT temperatures in mid May the NAT area was close to or above the 1979-2011 average until early July. The NAT area reached a peak above 25 million km^2 on 12 July. Then the NAT area stayed well below the 1979-2011 average until late August, but after that and until now (28 Sept.) has been close to or somewhat below the long-term average.

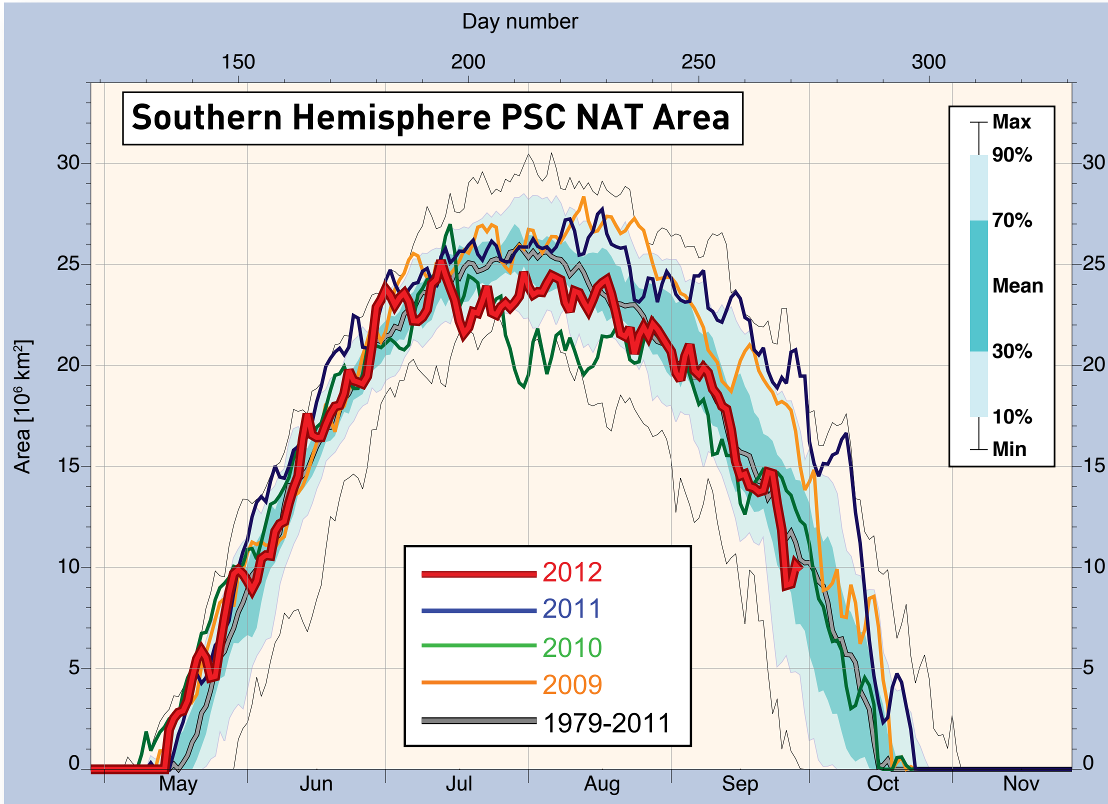


Figure 4. Time series of the area of the region where temperatures are low enough for the formation of nitric acid trihydrate (NAT or PSCs of type I) at the 460 K isentropic level. The red curve shows 2012 (until 28 September). The blue, green and orange curves represent 2011, 2010 and 2009, respectively. The average of the 1979-2011 period is shown for comparison in grey. The two thin black lines show the maximum and minimum PSC area during the 1979-2011 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 made at WMO based on data downloaded from the Ozonewatch web site at NASA, which are based on data from NOAA/NCEP.

PSC Volume

Rather than looking at the NAT area at one discrete level of the atmosphere it makes more sense to look at the volume of air with temperatures low enough for NAT formation. The so-called NAT volume is derived by integrating the NAT areas over a range of input levels. The daily progression of the NAT volume in 2012 is shown in **Figure 5** in comparison to recent winters and long-term statistics. Since the onset of PSCs in mid May, the NAT volume was close to or below the 1979-2011 average throughout the winter. From early July until now the PSC volume has been significantly lower than the long-term mean and also near and even below the 1979-2011 minimum on some days. In late September it is still below the long-term mean. The area or volume 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. Based upon the historical meteorological record it is expected that the extent of the region with temperatures below the NAT threshold will continue to decrease now as the sun is back all over Antarctica. The relatively small NAT area and NAT volume since July give reason to foresee that ozone depletion in October will be relatively moderate in comparison to recent years.

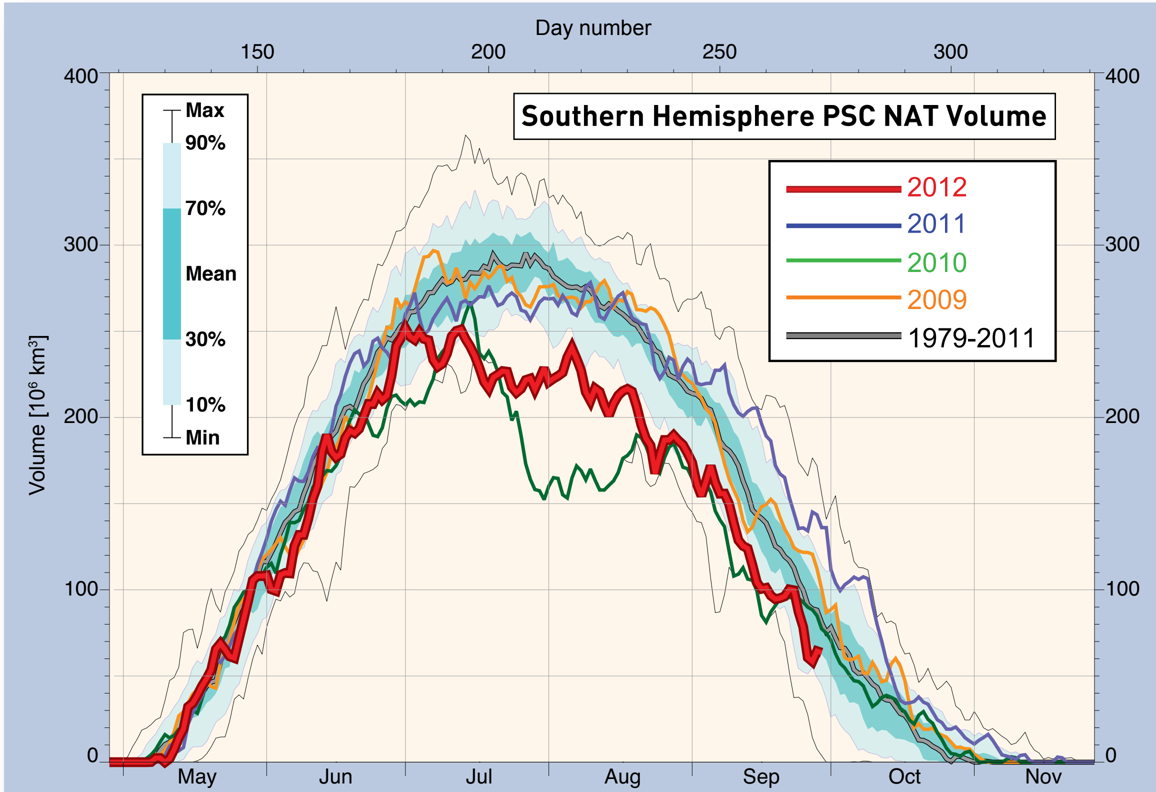


Figure 5. Time series of the volume of the region where temperatures are low enough for the formation of nitric acid trihydrate (NAT or PSCs of type I). The red curve shows 2012 (until 28 September). The blue, green and orange curves represent 2011, 2010 and 2009, respectively. The average of the 1979-2011 period is shown for comparison in grey. The two thin black lines show the maximum and minimum PSC area during the 1979-2011 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 made at WMO based on data downloaded from the Ozonewatch web site at NASA, which are based on data from NOAA/NCEP.

Vortex stability

The longitudinally averaged heat flux between 45°S and 75°S is an indication of how much the stratosphere is disturbed. During May and June the 45-day mean of the heat flux was lower than or close to the 1979-2011 average. From early July, the heat flux increased somewhat and remained larger than the 1979-2011 average until late August. In September it has been somewhat smaller than or equal to the average. The development of the heat flux is shown in **Figure 6.** One can see that the heat flux from mid July to mid September was smaller in 2012 than in 2010 (green curve), which was a year of a relatively perturbed vortex. After mid September the heat flux increased and by the end of September it is near the long-term mean.

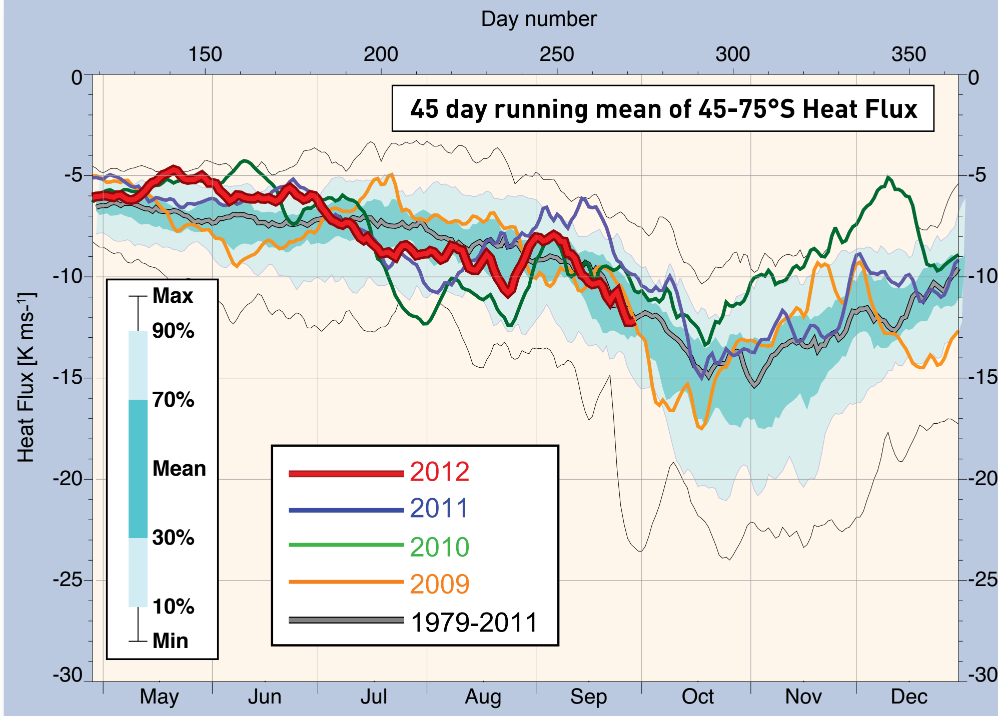


Figure 6. Time series of the meridional heat flux averaged over the 45-75°S region. The red curve shows data for 2012 (updated until 28 September). Please note that a large negative number means a large heat flux. Values closer to zero means a small heat flux. The plot is made at WMO based on data downloaded from the Ozonewatch web site at NASA, which are based on data from NOAA/NCEP.

Ozone observations

Satellite observations

Most of Antarctica is now exposed to sunlight, and ozone loss is taking place at a rapid rate. Satellite data show that depletion is occurring in most of the vortex. **Figure 7** shows minimum ozone columns as measured by the GOME-2 instrument on board MetOp-A in comparison with data for recent years back to 2005 (SCIAMACHY and GOME-2). In the middle of August the minimum columns were about average for the time of the year in comparison to the seven most recent years. After that the minimum columns have been relatively large in comparison to the other years shown here. The minimum ozone columns are expected to level out now at the beginning of October. The lowest value seen so far this year is 126 DU on 21 September.

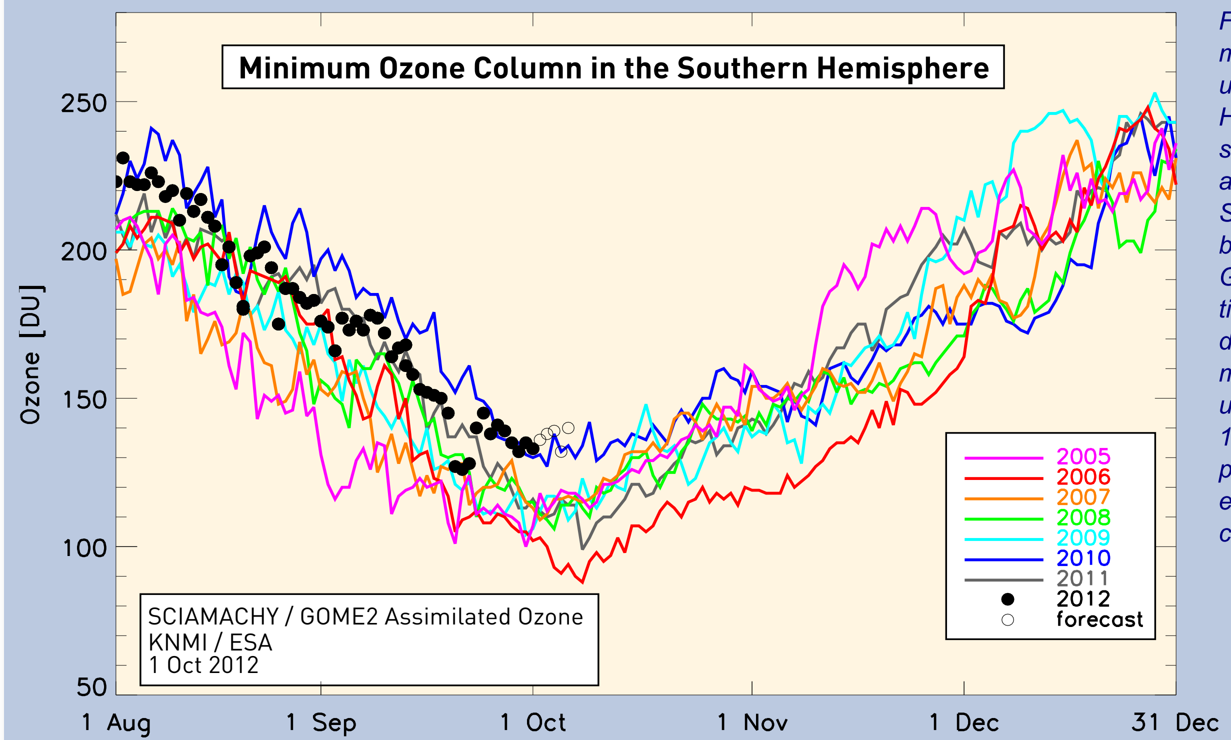


Figure 7. Daily minimum total ozone columns in the Southern Hemisphere as observed by GOME-2, and in the past by SCIAMACHY. The black dots show the GOME-2 observations for 2012. The data now show minimum ozone columns down to about 130 DU. The plot is provided by the Netherlands Meteorological Institute (KNMI).

Figure 8 shows satellite maps from GOME-2 for 30 September for the years 2006 - 2012. On the map for 30 September 2012 one can see that ozone depletion affects the whole polar vortex. It is evident, however, that ozone depletion covered a larger area in all the other years shown here, at this time of the season.

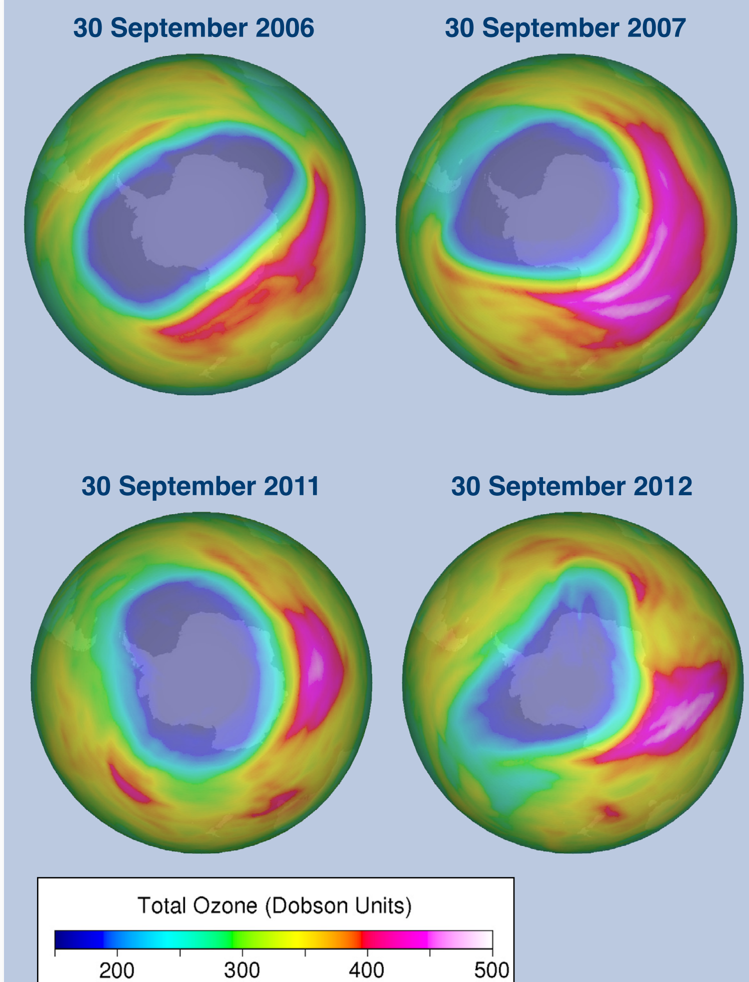


Figure 8. Total ozone maps for 30 September 2006, 2007, 2008, 2009, 2010, 2011 and 2012 based on data from GOME-2 on board MetOp-A. The data are processed and mapped at KNMI.

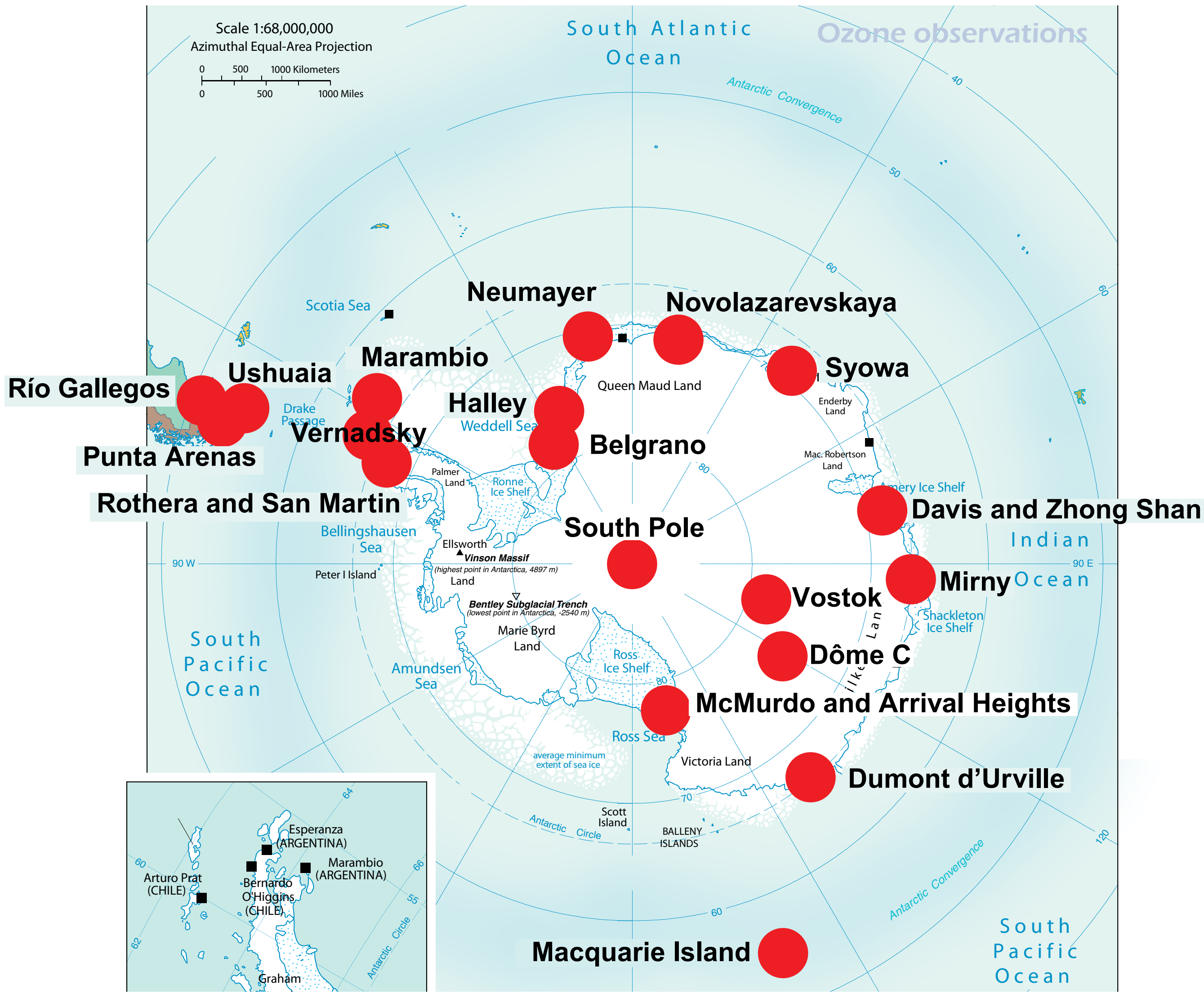
Ground-based and balloon observations

It is still early in the ozone hole season and the degree of ozone loss is still very modest. Some stations, though, show some first signs of ozone depletion. All the stations are now reporting data and are presented in this issue. On the next page is a map showing the location of the stations that provide data during the ozone hole season. The table to the right shows the lowest ozone values observed so far at the individual stations, measured by remote sensing (Dobson, Brewer, SAOZ or filter instruments) or in situ by ozonesondes.

Station Statistics. Lowest ozone values observed at Antarctic stations

Station name	Lowest Total Ozone (Dobson, Brewer, SAOZ)	Lowest Total Ozone from Sonde	Lowest 12-20 km partial column
Arrival Heights	181 DU (26 Sep)		
Belgrano		122 DU (26 Sep)	17 DU (26 Sep)
Davis		220 DU (13 Sep)	
Dôme C	224 DU (13 Sep)		
Dumont d'Urville	243 DU (12 July)		
Halley	133 DU (23 Sep)		
Marambio	152 DU (21 Sep)	154 DU (22 Sep)	39 DU (22 Sep)
Mirny	224 DU (11 Sep)		
Neumayer		141 DU (8 Sep)	35 DU (24 Sep)
Novolazarevskaya	160 DU (19 Sep)[1]		
Rothera	145 DU (22 Sep)		
South Pole		150 DU (26 Sep)	43 DU (26 Sep)
Syowa	176 DU (23 Sep)	191 DU (23 Sep)	39 DU (23 Sep)
Ushuaia		169 DU (22 Sep)	46 DU (22 Sep)
Vernadsky	150 DU (21 Sep)		
Zhong Shan	211 DU (24 Sep)		
Minimum	**139 DU**	**122 DU**	**17 DU**

[1] From satellite overpass data. This is the lowest OMI observation over Novolazarevskaya on that day.



Ozone observations
Scale 1:68,000,000
Azimuthal Equal-Area Projection
0 500 1000 Kilometers
0 500 1000 Miles
South Atlantic Ocean
Antarctic Convergence
Scotia Sea
Neumayer
Novolazarevskaya
Syowa
Marambio
Ushuaia
Río Gallegos
Halley
Vernadsky
Belgrano
Punta Arenas
Rothera and San Martin
Queen Maud Land
Enderby Land
Mac. Robertson Land
Drake Passage
Weddell Sea
Palmer Land
Ronne Ice Shelf
Amery Ice Shelf
Davis and Zhong Shan
Indian Ocean
South Pole
Bellingshausen Sea
Ellsworth Land
Vinson Massif
(highest point in Antarctica, 4897 m)
90 W
90 E
Peter I Island
Mirny
Vostok
Bentley Subglacial Trench
(lowest point in Antarctica, -2540 m)
Shackleton Ice Shelf
Marie Byrd Land
Ross Ice Shelf
Dôme C
South Pacific Ocean
Amundsen Sea
McMurdo and Arrival Heights
Ross Sea
average minimum extent of sea ice
Victoria Land
Dumont d'Urville
Antarctic Circle
Scott Island
BALLENY ISLANDS
Esperanza (ARGENTINA)
Marambio (ARGENTINA)
Arturo Prat (CHILE)
Bernardo O'Higgins (CHILE)
Graham
Macquarie Island
South Pacific Ocean

Arrival Heights

The New Zealand GAW/NDACC station at Arrival Heights.

The GAW/NDACC station Arrival Heights (77.845°S, 166.67°E), operated by New Zealand, started the regular observations of total ozone after the polar night on 17 September. On 17 September, total ozone was 202 DU. Total ozone has been above the 220 DU threshold on two days since the measurements started (20 and 21 September), otherwise it has been under this threshold. The minimum total ozone value observed so far this year is 181 DU on 26 September.

Time series of total column ozone for the years 2006 until 2012 are shown in **Figure 9** together with long term statistics.

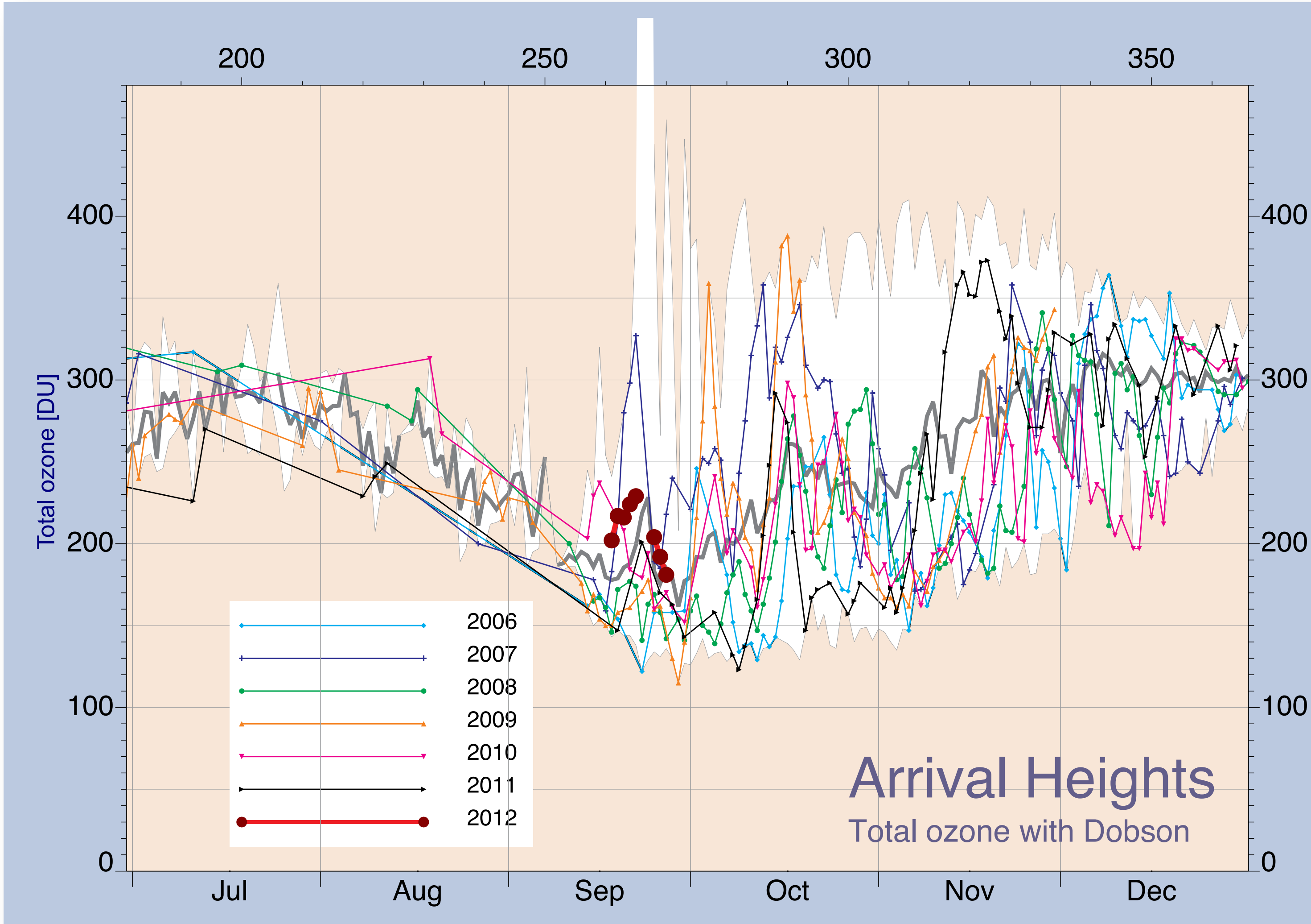
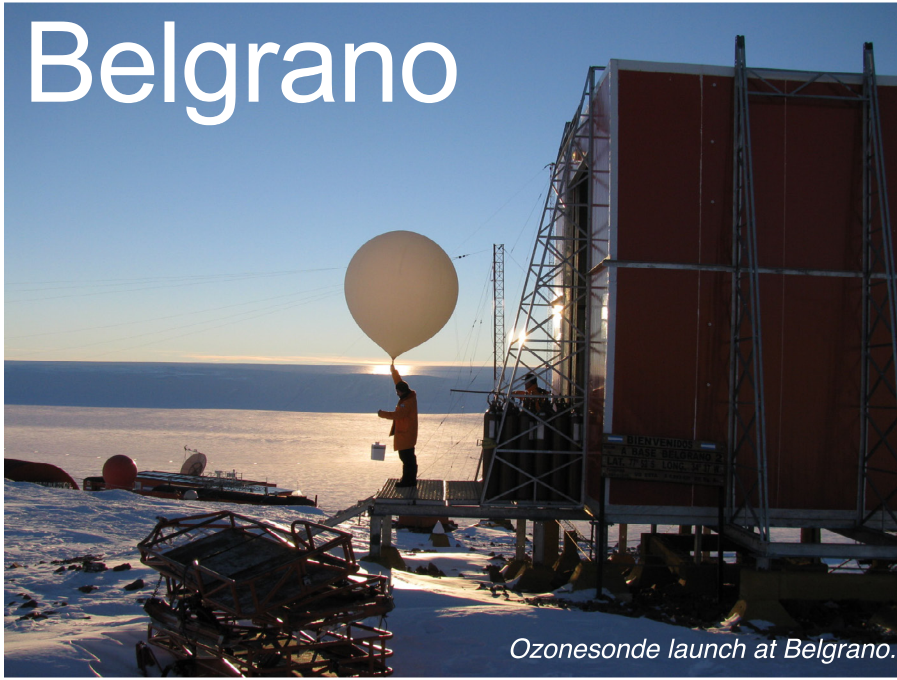


Figure 9.Time series of total ozone measured at the New Zealand station Arrival Heights. Data from 2006 until 2012 are shown. The white shaded region represents the range from maximum to minimum values measured during the time period from 1988 to 2011. The thick grey line is the average value for the same time period.



Ozonesonde launch at Belgrano.

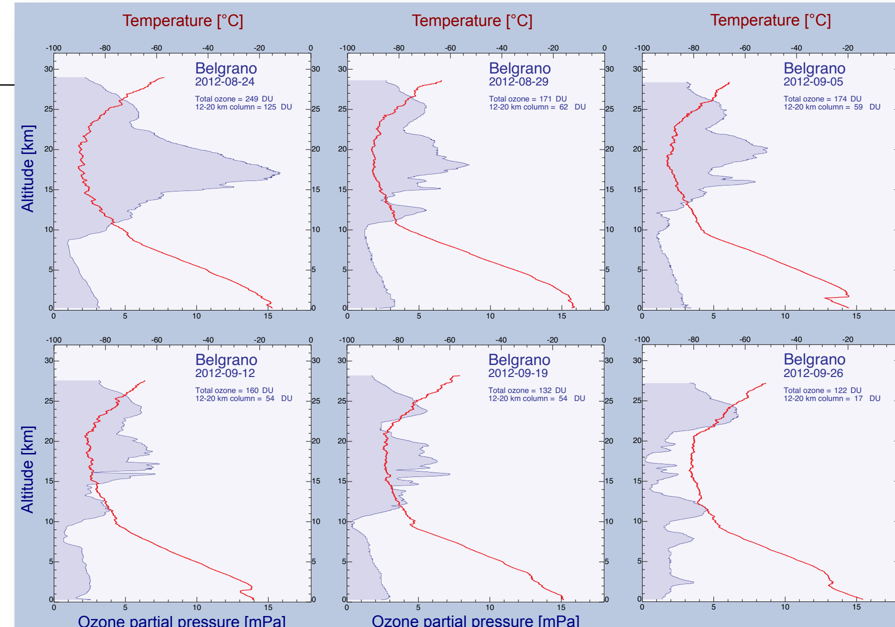


Figure 10. Ozonesonde observations at the GAW station Belgrano carried out from 24 August to 26 September. The plots are made at WMO based on data received from INTA, Spain.

The vertical distribution of ozone is measured at the Argentine GAW station Belgrano (77.88°S, 34.63°W) with electrochemical ozonesondes. **Figure 10** shows the six soundings carried out so far this spring. It can be seen that the both the total column as well as the 12-20 km column dropped considerably from 24 August to 26 September. It can be seen that there is substantial depletion in the 21-23 km height range in the profiles from 12 and 19 September. The profile measured on 26 September shows massive ozone depletion over the 14 to 21 km height range. The 12-20 km partial ozone column is 17 DU, which is the lowest measured at any station so far this year. The GOME-2 maps shown in **Figure 11** show that Belgrano was influenced by relatively ozone rich air on 24 August and by ozone poor air 5 days later. Overpass data from the OMI instrument on board the AURA satellite confirm this decrease although the total ozone values show some disagreement. The figure also shows that Belgrano was inside the ozone hole on 19 and 26 September. **Figure 12** shows maps from the MLS satellite

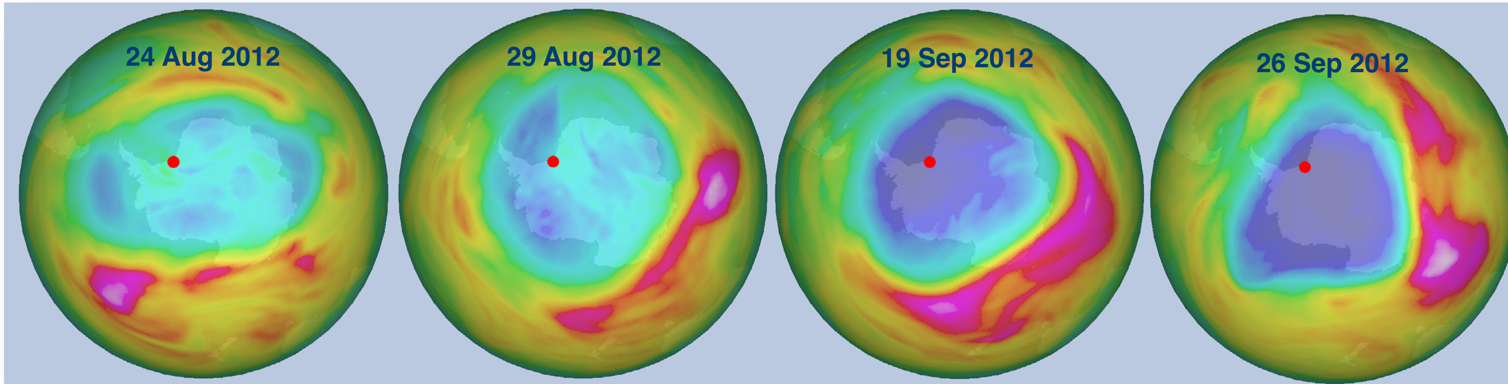


Figure 11. Total ozone from the GOME-2 instrument on 24 and 29 August and 19 and 26 September. The position of Belgrano is marked with a red circle. The plots are downloaded from the TEMIS web site (http://www.temis.nl)

instrument and from a MACC-II model run that shows that Belgrano was in a region of very poor ozone at the 55 hPa level. The figure shows that Belgrano was inside a region where the ozone mole fraction was less than 0.1 ppm at the 55 hPa level. The level corresponds to the 17-18 km region in the profile from 26 September, and that shows the largest "bite-out" of the ozone profile.

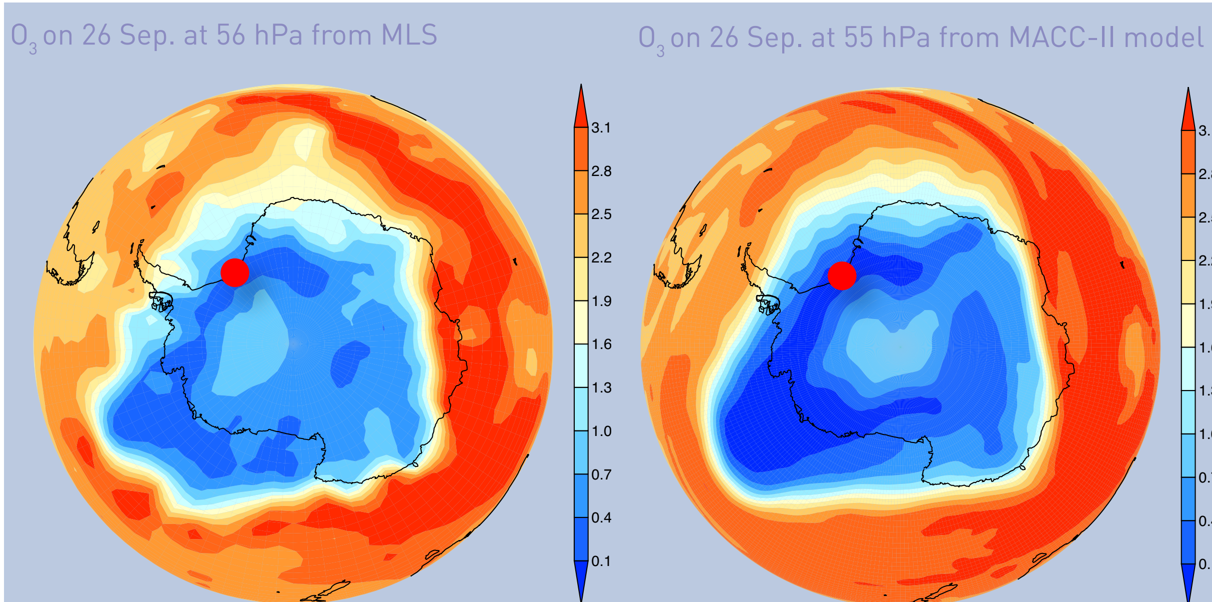


Figure 12. Ozone mole fraction at 56 hPa from the MLS instrument on the AURA satellite and at 55 hPa from the MACC-II model. This shows that Belgrano is located in a region where the ozone mole fraction is below 0.1 ppm (according to the model) at this level. The MLS data show somewhat higher mole fractions inside the vortex, but the regions with most ozone depletion look very similar in the two cases.

Ozonesonde launch at Davis.

From the Australian GAW site Davis (68.58°S, 77.47°E, 15 masl) ozonesondes are launched weekly. The measurement programme is run in partnership by the Australian Bureau of Meteorology and the Australian Antarctic Division. **Figure 13** shows ozone profiles measured between 16 August and 21 September. One can see a clear and progressive decline of the ozone partial pressure in the 16-21 km height range. **Figure 14** shows the time series of the 12-20 km partial ozone column calculated from ozonesonde measurements. During September, the partial column has dropped, but is close to the maximum, observed during the last decade (2003-2011).

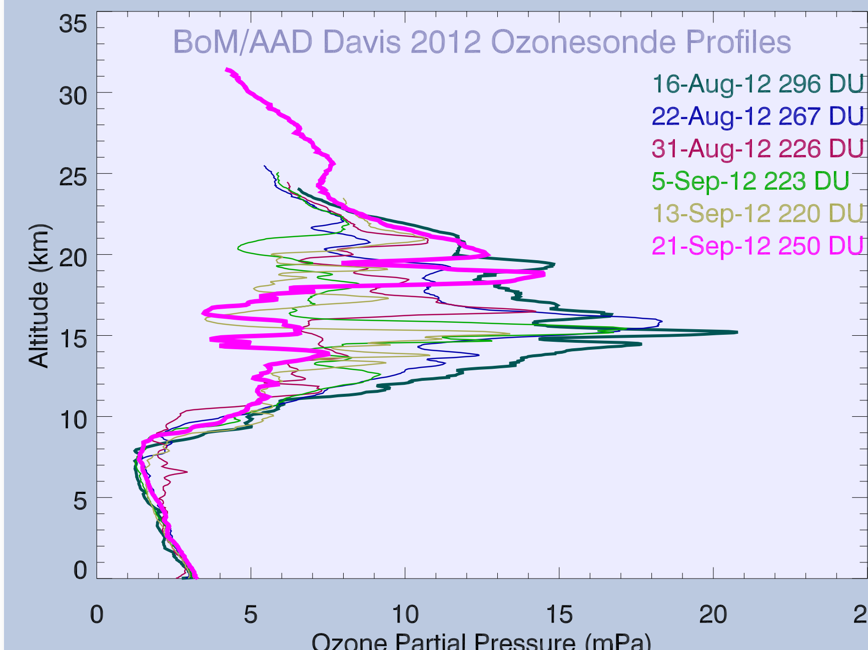


Figure 13. Ozonesonde observations at the Australian GAW station Davis. The plot has been provided by Matt Tully, Australian Bureau of Meteorology.

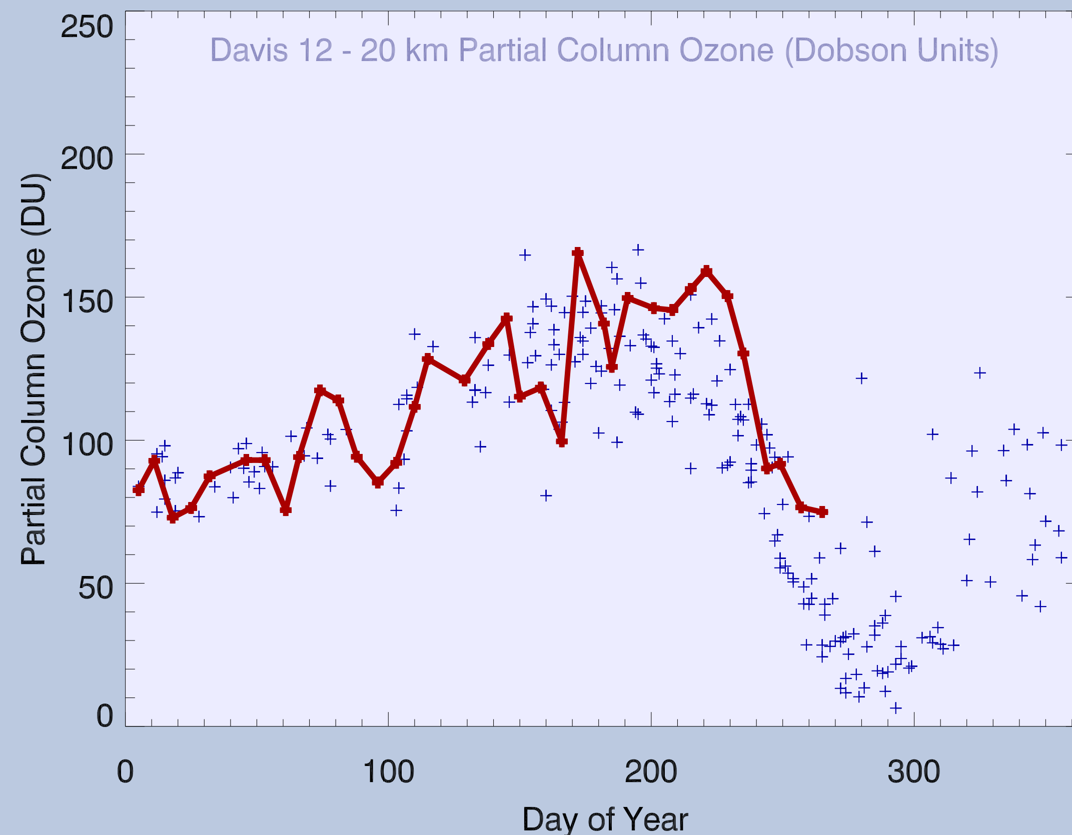


Figure 14. Partial ozone columns between 12 and 20 km from soundings at Davis. The thick red curve shows the data from 2012. The blue crosses show all data from 2003-2011. The plot has been provided by Matt Tully, Australian Bureau of Meteorology.

The twin buildings at Dôme Concordia. Photo: Marco Maggiore.

Total ozone is measured with a SAOZ spectrometer at the French/Italian GAW/NDACC station at Dôme Concordia (75.0998870°S, 123.333487°E, 3250 masl) on the Antarctic ice cap. The measurements started up again after the polar night on 1 August. During August total ozone varied between 239 and 354 DU. In September total ozone has dropped from 285 DU on 1 September to 227 DU on 11 September. Figure 15 shows the time series of total ozone measured at Dôme Concordia. Daily averaged total ozone has remained above the 220 DU threshold so far this season. After the previous Bulletin, total ozone has remained relatively low, but has still not dropped under the 220 DU threshold.

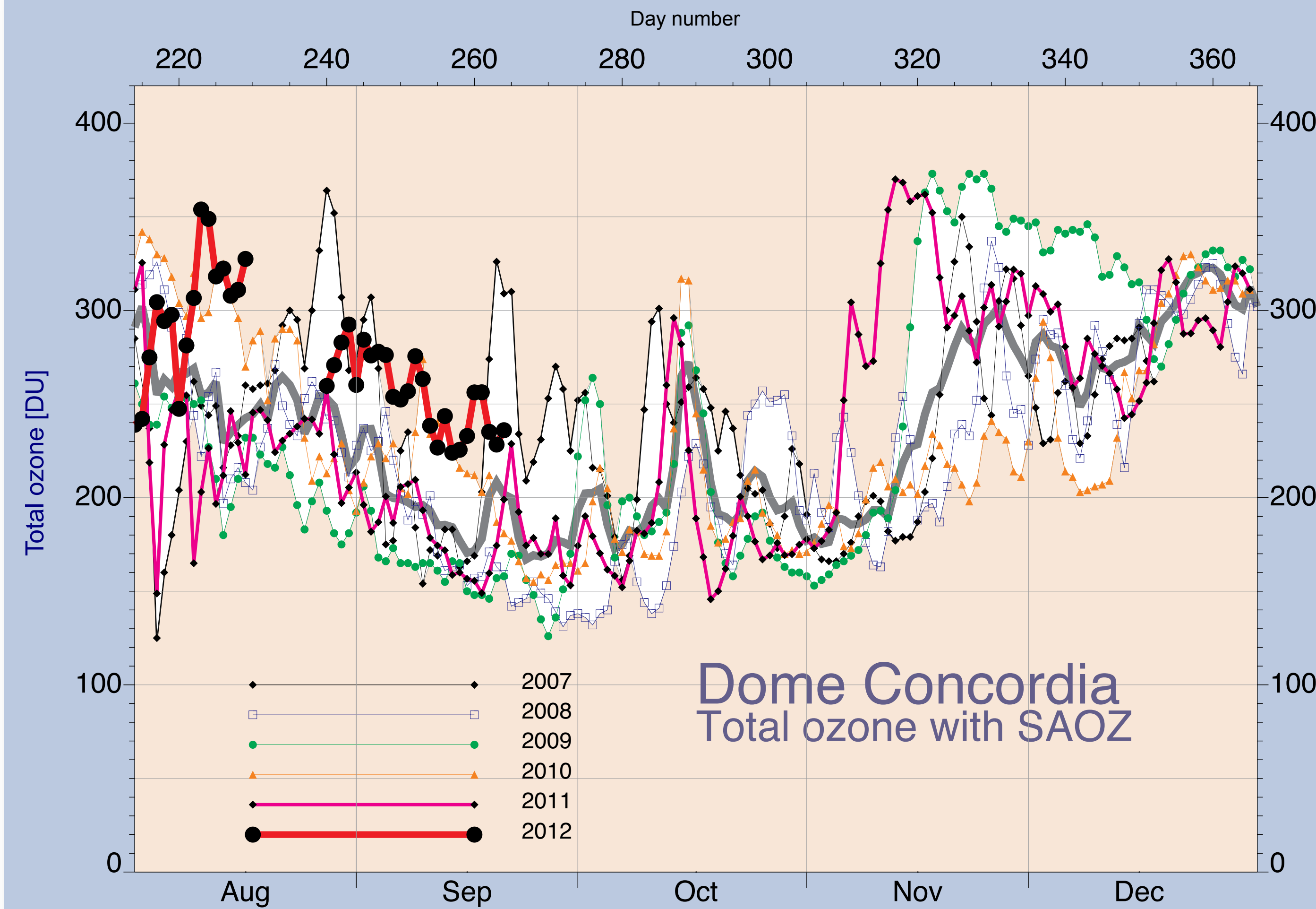


Figure 15. Time series of total ozone measured with the SAOZ spectrometer at Dôme Concordia on the Antarctic ice cap. The plot is produced at WMO based on data downloaded from the SAOZ web site at CNRS.

Dumont d'Urville

Panorama photo showing a 360° view of the Dumont d'Urville station.

The French GAW/NDACC station Dumont d'Urville (66.662929°S, 140.002546°E) is located at the polar circle, which allows for SAOZ measurements around the year. From the beginning of August daily averaged total ozone has varied between 255 DU and 455 DU. **Figure 16** shows the progression of daily averaged ozone until 23 September. The most striking is the large day-to-day variability, as the polar vortex moves back and forth above the station. The daily average value is calculated as the mean of the total ozone values at sunrise and sunset. On some days the difference between the sunrise and sunset values can reach several tens of DU. Daily averaged total ozone has not yet dipped below the threshold of 220 DU.

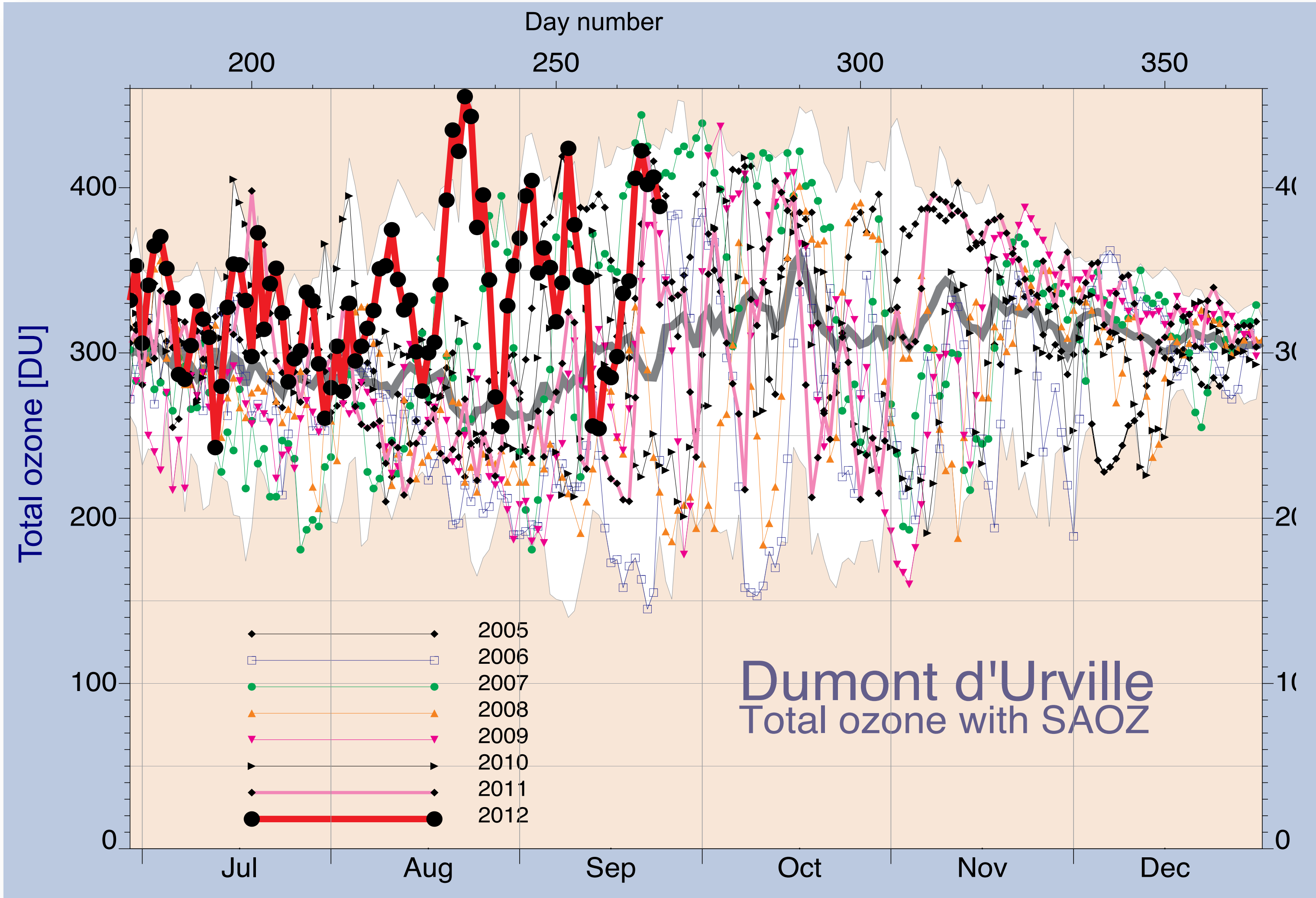
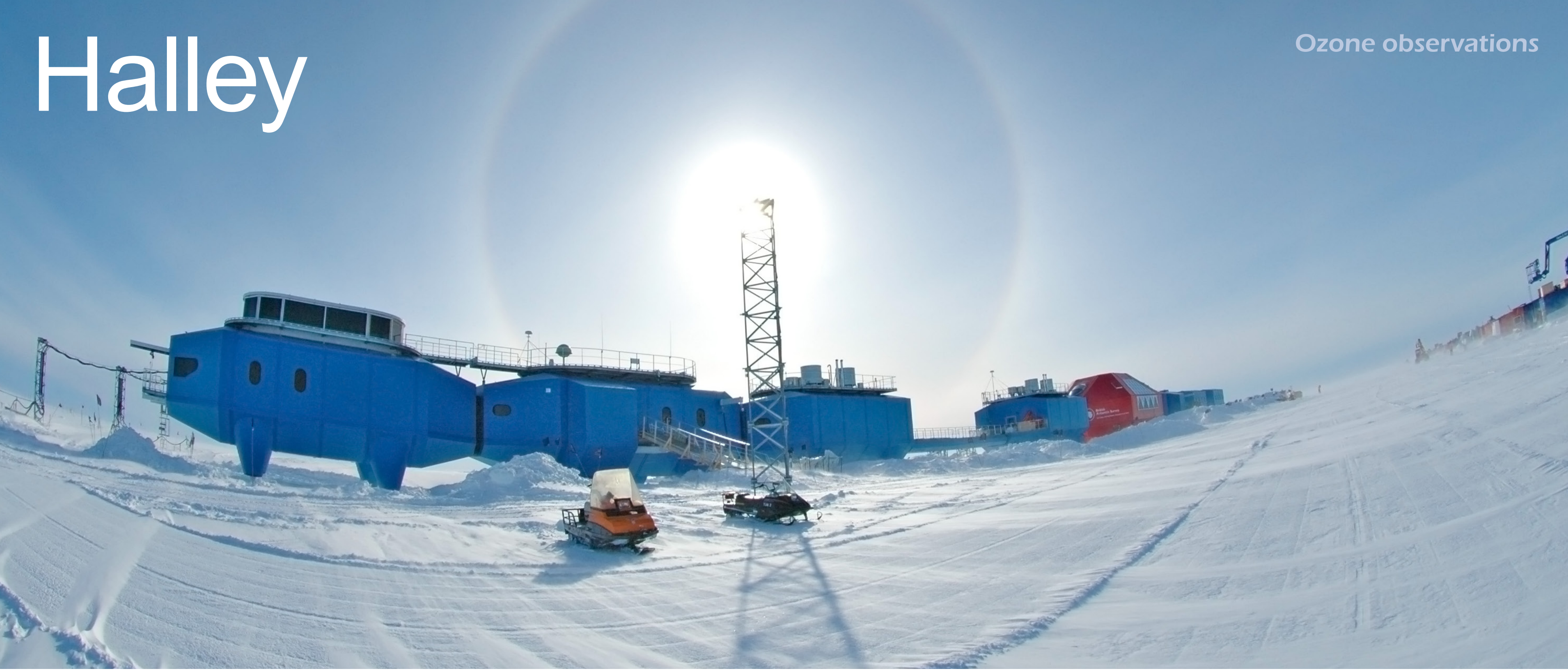


Figure 16. Time series of daily mean total ozone in 2012, in comparison to earlier years, as measured by a SAOZ spectrometer at Dumont d'Urville. The plot is produced at WMO based on data downloaded from the SAOZ web site at CNRS.

Halley



Total ozone is measured with a Dobson spectrophotometer at the UK GAW station Halley (75.58°S, 26.71°W). The measurements started up again on 27 August after the polar winter. Figure 17 shows the total ozone time series at Halley for the most recent years together with long term statistics (1957-2011). From 27 to 31 August total ozone was above 220 DU, but from 1 September total ozone dropped below this threshold and has remained there until now (27 September). The lowest total ozone value observed so far this year is 133 DU, measured on 23 September.[1]

[1] Personal communication from Jonathan Shanklin after a recent revision of the observations.

The new Halley Research station (Halley VI). Photo: Jonathan Shanklin, British Antarctic Survey. More information about the new Halley Station can be found at: http://en.wikipedia.org/wiki/Halley_Research_Station

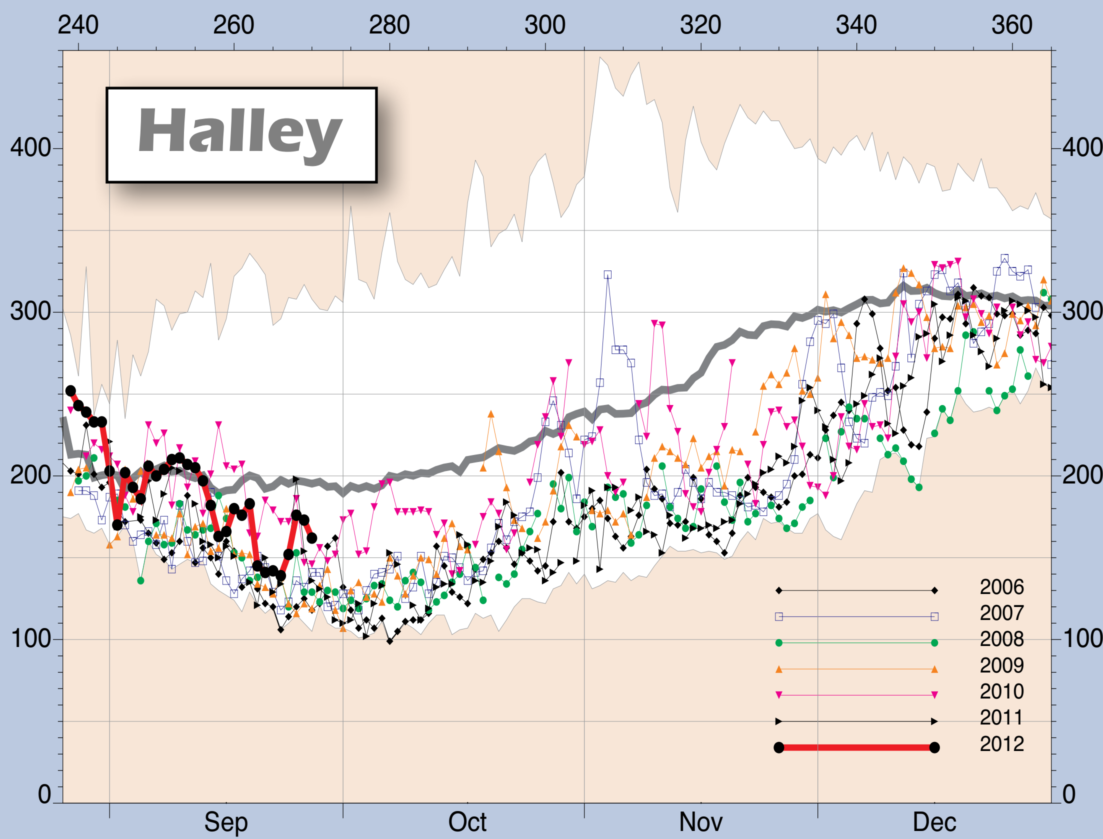


Figure 17. Time series of daily mean total ozone in 2012, as measured by a Dobson spectrophotometer at Halley. The thick grey line shows the average ozone column for the 1957-2011 time period. The white shaded area shows historical maxima and minima calculated for the 1957-2011 time period. The plot is produced at WMO based on data downloaded from WOUDC and from Jonathan Shanklin's Antarctic web site at British Antarctic Survey.

Macquarie Island

Ozonesonde launched by Bureau of Meteorology observer Ashleigh Wilson at Macquarie Island. Photo: Leon Hamilton.

The GAW/NDACC station Macquarie Island is located at 54.499531°S and 158.937170°E. Dobson observations of total ozone have been made there since 1957.

Matt Tully of the Australian Bureau of Meteorology has sent the following report:

Total ozone values have mostly been around average at Macquarie Island so far this spring. In early September some very high values were observed, the highest single observation being 455 Dobson Units on the 4th of September. At this time the ozone hole had moved off the pole towards South America causing very high ozone values south of Australia. (On the plot, the red line is 2012 data, the dark blue line is the 1987-2011 mean, and the light blue and medium blue bands are the 10th-90th and 30th-70th percentile ranges respectively).

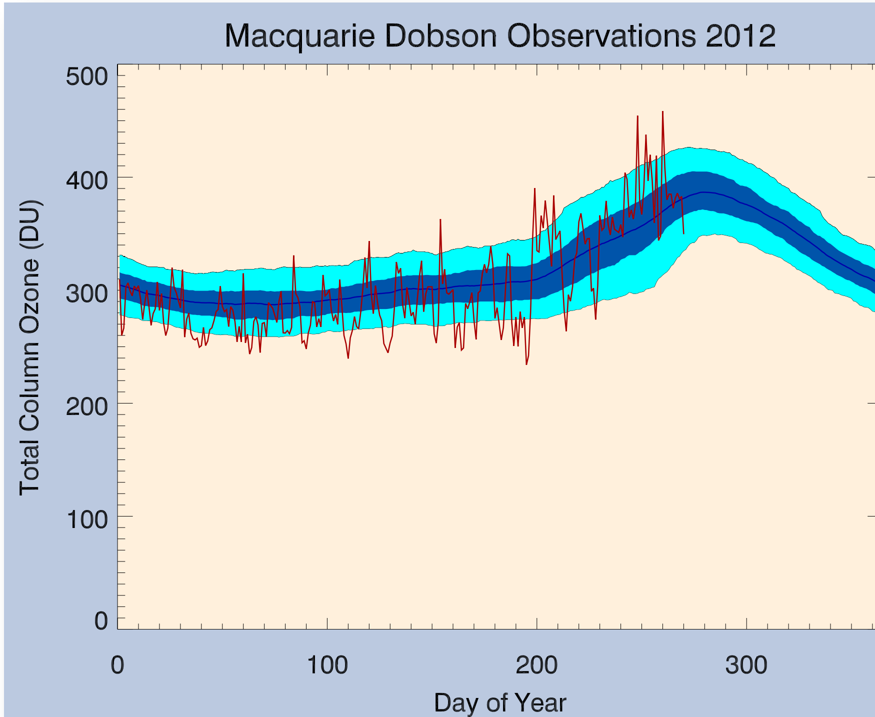
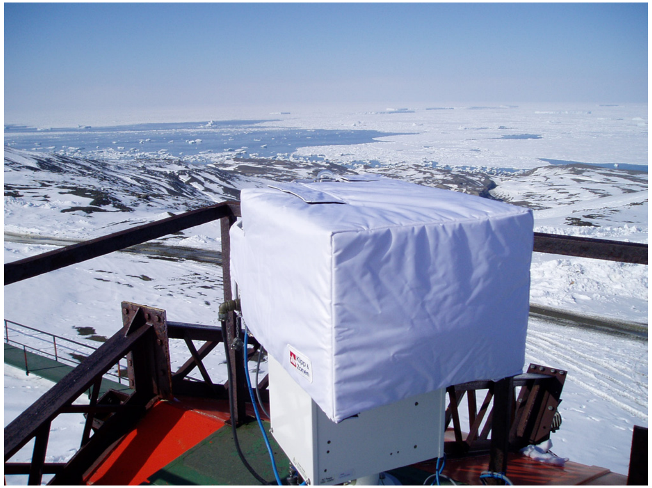


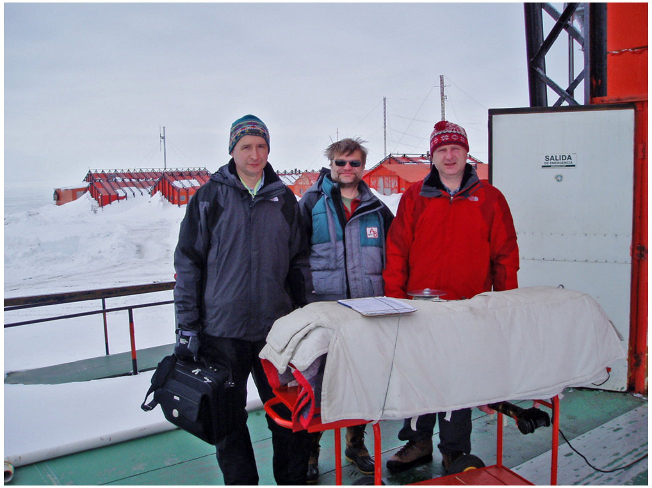
Figure 18. Time series of total ozone in 2012, as measured by a Dobson spectrophotometer at Macquarie Island. The blue line in the middle shows the 1987-2011 mean. The dark blue band shows the 30th-70th percentile, and the light blue band the 10th-90th percentile.

Marambio

Panorama photo showing a 360° view of the Marambio station.



The Brewer spectrophotometer MARK III No. 199, Marambio Antarctic Station – yearly inspection. Photo: Michal Janouch.



Research group from CHMI, Ing. Martin Staněk, RNDr., Michal Janouch, Ph.D and Ing. Ladislav Sieger, CSc. from CTU.

Total ozone is observed at the Argentine GAW station Marambio (64.2°S, 56.6°W) with a Dobson and Brewer MkIII spectrophotometer. The measurements started up after the winter on 10 August. Ozone profiles are observed with ozonesondes. Soundings are carried out once to twice per week. Six ozonesondes were launched in June, six in July and nine in August. So far in September nine sondes have been launched. The lowest total ozone value observed so far this year with the Brewer instrument was 152 DU on 21 September (see **Figure 19**). Also the day after suffered very low ozone with 154 DU. This value is confirmed by the ozonesonde launched on that day. Also with the ozonesonde one deduces a total ozone column of 154DU on 22 September (**Figure 20**). During the same time period the 12-20 km partial ozone column has dropped from about 140 DU to 39 DU on 22 September, i.e. a reduction of 72%.

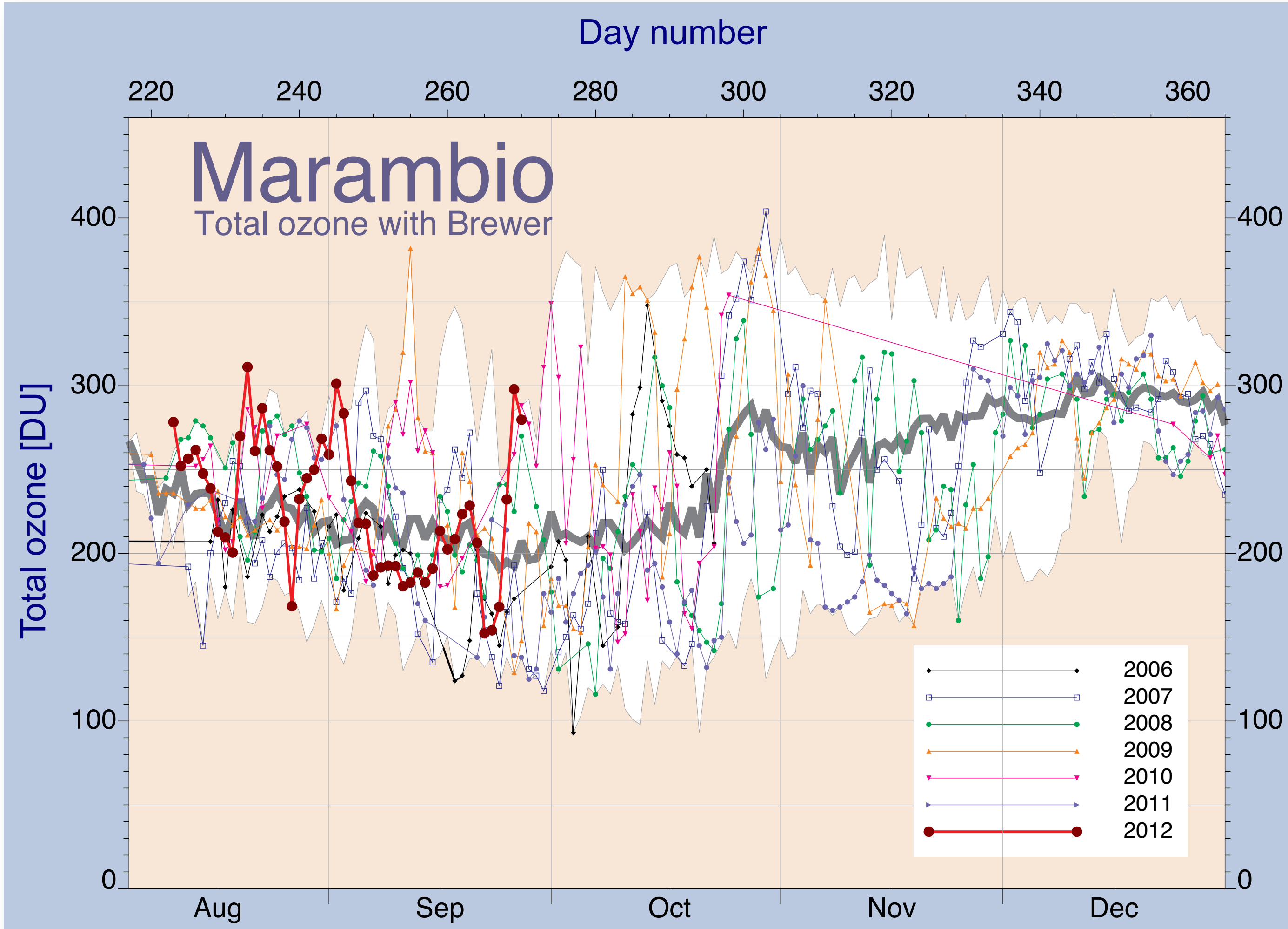


Figure 19. Total ozone over Marambio as measured by Dobson and Brewer spectrophotometers. The plot is up to date until 26 September. The thick grey curve represents the long-term mean (1987-2011) and the white shaded area represents the historical maxima and minima for the same time period. The plot is produced at WMO based on Dobson data from WOUDC and Brewer data for 2012 submitted by Instituto Antarctico Argentino and the Czech Hydrometeorological Institute.

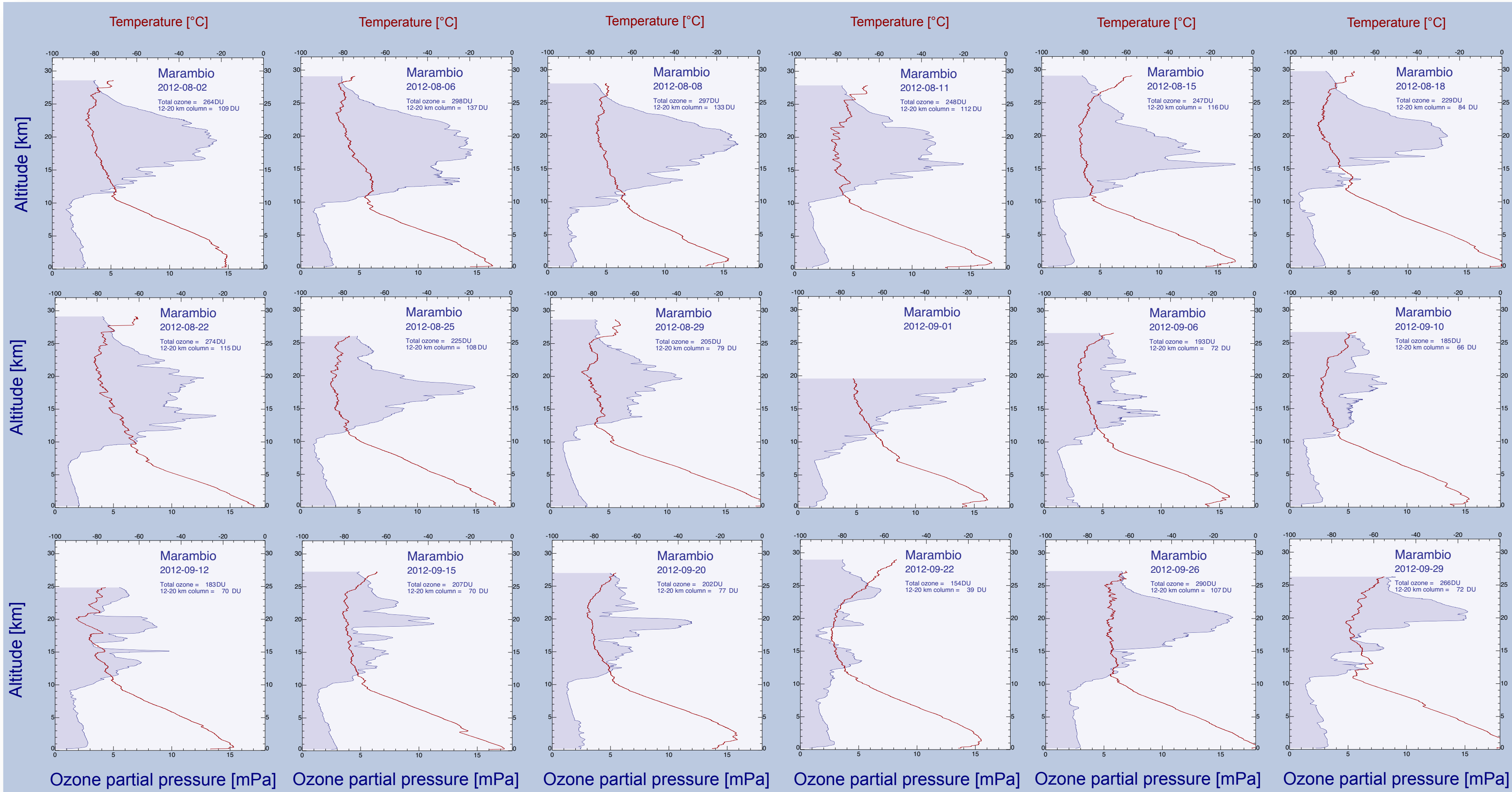


Figure 20. Ozone profiles measured with electrochemical ozonesonde launched from the Argentine GAW station Marambio from 2 August to 22 September. The plots are produced at WMO with data submitted by the National Meteorological Service of Argentina.

Mirny

The Russian GAW station Mirny.

At the Russian GAW station Mirny (66.558270°S, 93.001017°E) total ozone is measured with a filter instrument (M-124). The data are submitted by Elena Sibrus of the Arctic and Antarctic Research Institute, St. Petersburg, and are up to date as of 30 September. During August total ozone varied quite a lot with a maximum of 484 DU on 19 August and a minimum of 234 DU on 25 August. In September total ozone has varied between 224 (11 Sep) and 448 DU (28 Sep). The minimum observed so far this season was 224 DU on 11 September. The values obtained with the filter instrument agree quite well with satellite overpass data from OMI on board the AURA satellite. These overpass data also show that during September the station has been influenced by middle latitude air masses. So far in 2012, total ozone at Mirny has not been below the threshold of 220 DU.

Neumayer

Preparing an ozonesonde for launch at the Neumayer station.

The vertical distribution of ozone is measured with ozonesondes from the German GAW/NDACC station at Neumayer (70.65°S, 8.26°W). Sondes were launched on 1, 10 15, 18, 22, 26 and 31 August. These sounding are shown in **Figure 21** together with the first two soundings of September. The sounding of 3 September shows clear signs of ozone depletion with a total ozone column of 200 DU and a 12-20 km partial ozone of 76 DU, down from 130 DU on 31 August.

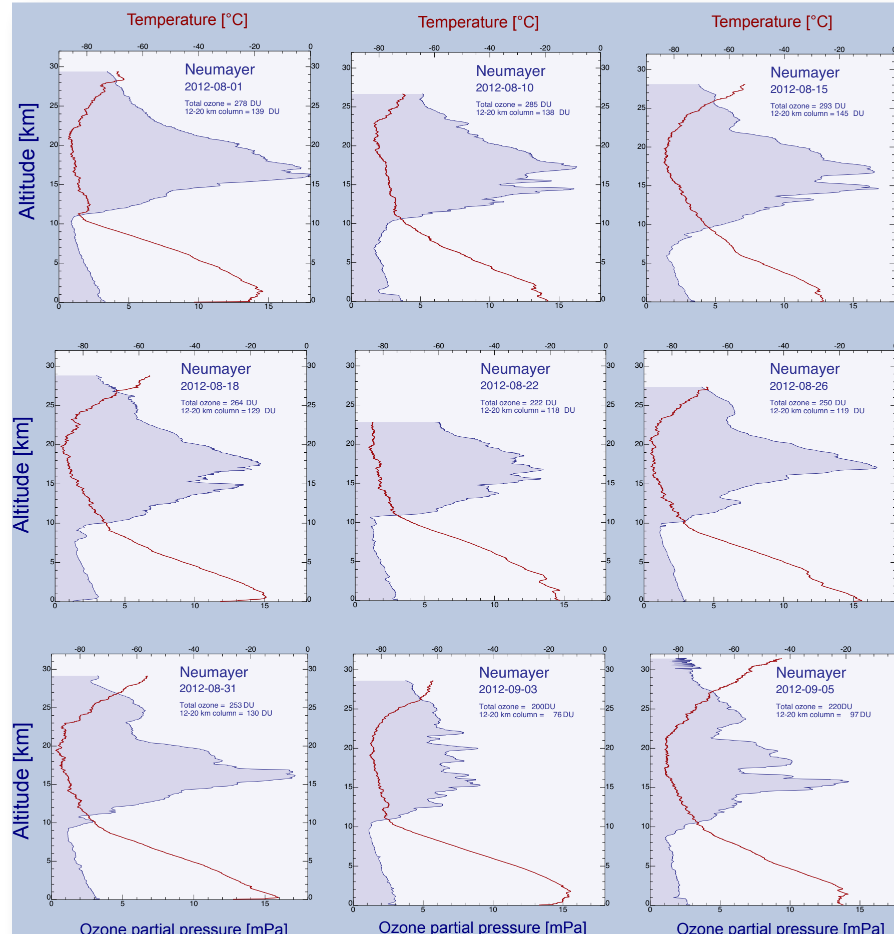


Figure 21. Ozone profiles measured with electrochemical ozonesonde launched from the German GAW station Neumayer from 1 August to 5 September 2012. It can be seen how the 12-20 km partial ozone column is coming down towards the end of August and into the beginning of September.

Figure 22 shows soundings carried out from 8 to 26 September. The September profiles show clearly that ozone depletion has progressed far with 12-20 km partial ozone columns down to 35 DU (24 September), which is the lowest observed so far this year at any of the ozonesonde stations in Antarctica. The sounding performed on 28 September shows a large "bite-out" of ozone over the 15-20 km height range.

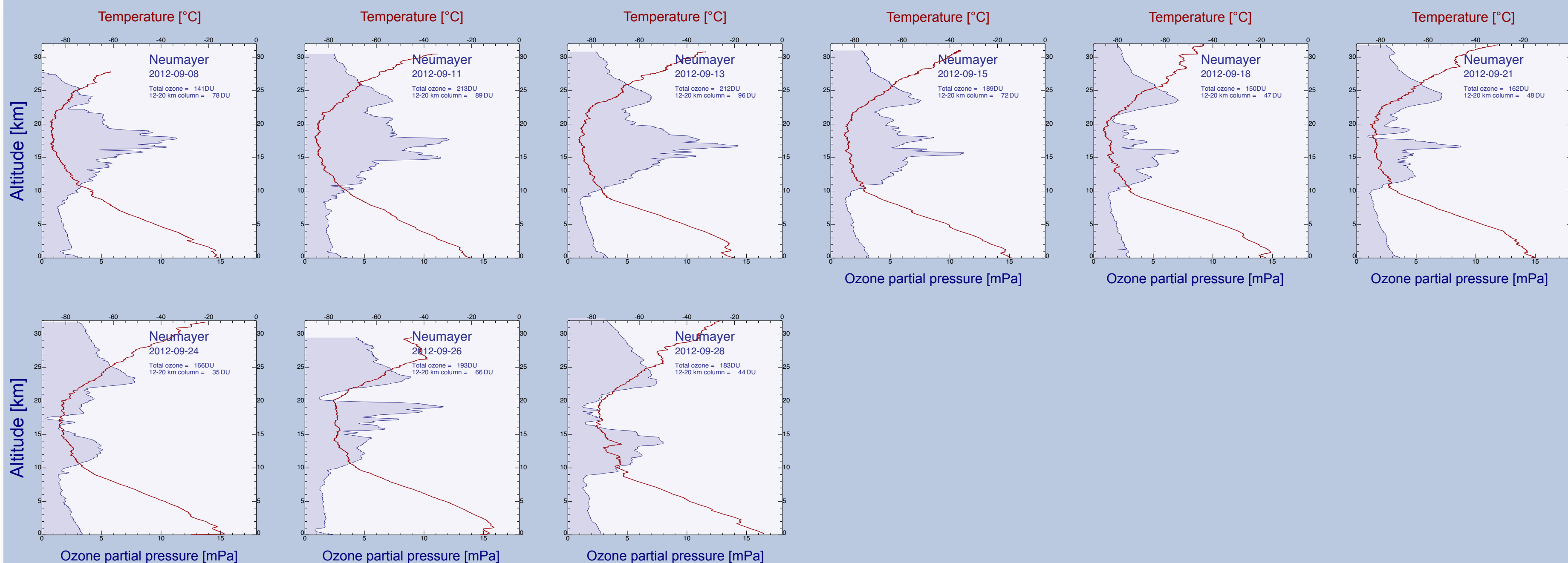


Figure 22. Ozone profiles measured with electrochemical ozonesonde launched from the German GAW station Neumayer from 8 until 18 September 2012. Ozone depletion is now well under way as can be seen from 12-20 km partial ozone columns well below 100 DU. The plots in this and the previous figure are produced at WMO based on data sent directly from the Neumayer station.

The ozone hole above Neumayer III Station, Antarctica

Kathrin Höppner (Air chemist of the overwintering crew 2012), Thomas Schmidt (Meteorologist of the overwintering crew 2012), Gert König-Langlo (Scientific manager of the Meteorology Observatory of Neumayer III Station), Contact: gert.koenig-langlo@awi.de, kathrin.hoeppner@dlr.de

The 2012 ozone hole season has started for the entire Antarctica and the overwintering crew at the Neumayer III Station (Photo 1) now performs in addition to the daily radiosonde releases also ozone soundings up to 3 times a week (up from 1 per week). The data are available in near-real time (NRT) and are submitted to the GAW-World Ozone and Ultraviolet Radiation Data Centre (WOUDC) and to the WMO Global Telecommunication System (GTS), in future to the WMO Information System (WIS). Neumayer III acts as a global GAW station and is additionally included in the NDACC and BSRN networks.

Three to seven days prior to the sonde release the ozonesonde (using currently ECC 6A sensors mounted on Vaisala RS92 radiosondes) is prepared following standard operating procedures developed by the GAW Programme. On the day of release the sonde is again thoroughly tested including e.g. comparison with a calibration sensor, measurement of background sensor current and sensor response test (see Photo 2). The sondes are launched from the roof of the building (Photo

Photo 1: The German Antarctic Research Station Neumayer III at the Ekström Shelf Ice in the north-eastern Weddell Sea (70°40'S, 08°16'W) started routine operation in 2009. The building is situated on a platform above the snow surface integrating scientific research (meteorology, air chemistry and geophysics), operational and accommodation facilities in one building, and it is connected to a garage in the snow. The red hall located at the center of the roof is the platform for launching weather balloons. The picture was taken during polar night in June 2012. © Kathrin Höppner.

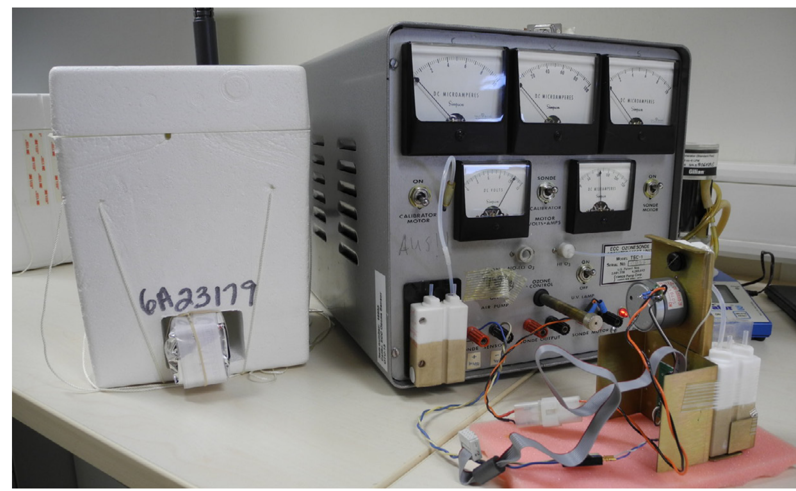


Photo 2: Preparation of an electrochemical ozone sonde (in the foreground) in the ozone laboratory of Neumayer III station. The calibration unit (in the background) is used to make different performance tests prior to the release. © Kathrin Höppner.

1) even during adverse wind conditions up to about 30-35 knots (see Photos 3 and 4).

The ozone profiles obtained from the last five releases at Neumayer III between 29 August and 08 September, 2012 are shown in **Figure 23**. The stratospheric ozone depletion between 15 and 20 km has started, and further decline in ozone concentration is expected.

Photo 3: The balloon launching hall located on the roof of the Neumayer III building. Copyright Kathrin Höppner.

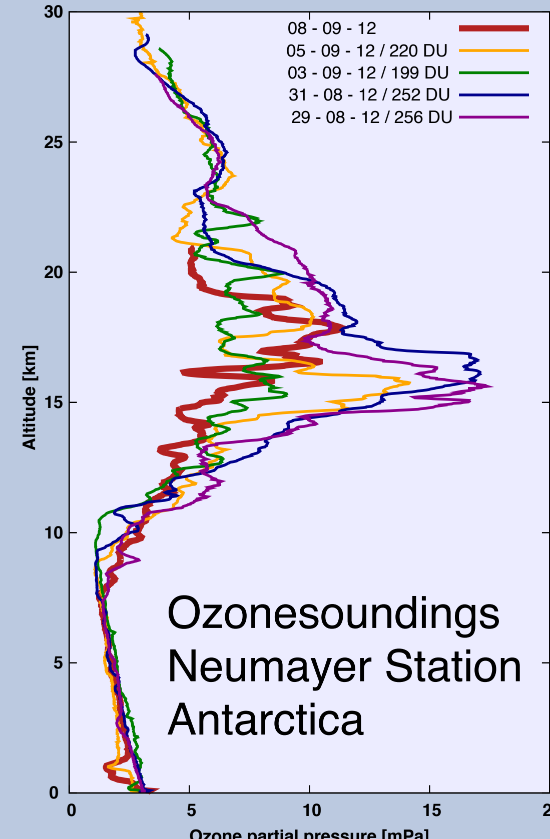


Figure 23. Ozone profiles measured with electrochemical ozonesondes at the Neumayer III station on 29, 31 August, 03, 05 and 08 September, 2012. Also indicated is the total ozone amount (in Dobson units) of each release. Due to the low burst height on 08 September the total ozone amount was not calculated for this release.

Photo 4: *Thomas Schmidt, meteorologist of this year's overwintering crew, launching an ozonesonde from the roof of the Neumayer III station during stormy weather conditions on 5 September, 2012. © Stefan Christmann.*

The observed total ozone for these five profile measurements is in the typical range of about 200 to 250 Dobson units (DU) as expected at the beginning of the ozone hole season. Compared to the long-term average it is sometimes even slightly higher (see **Figure 24**).

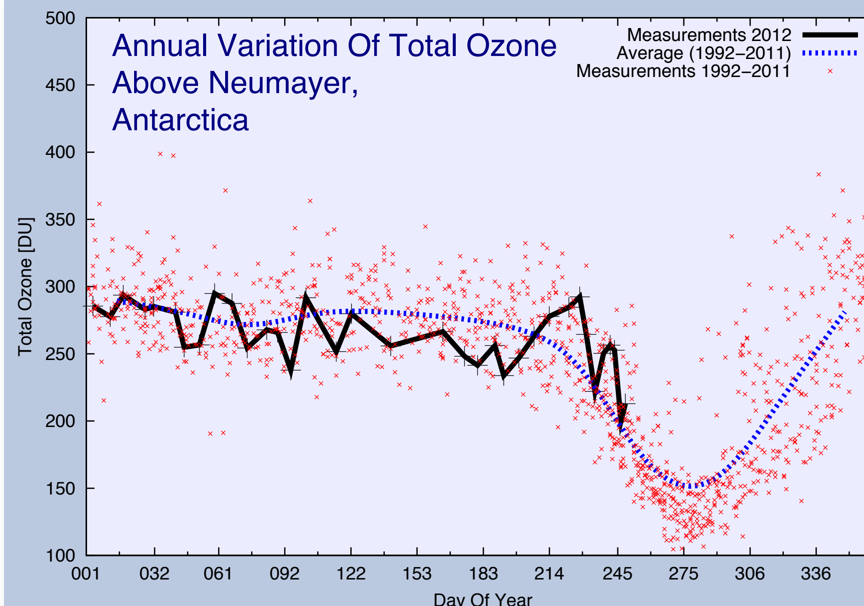


Figure 24. Annual variation of total ozone (in Dobson units) above Neumayer III station (shown in black). The blue dotted line shows the average over 1992-2011, the red crosses dedicate all measurements from 1992-2011.

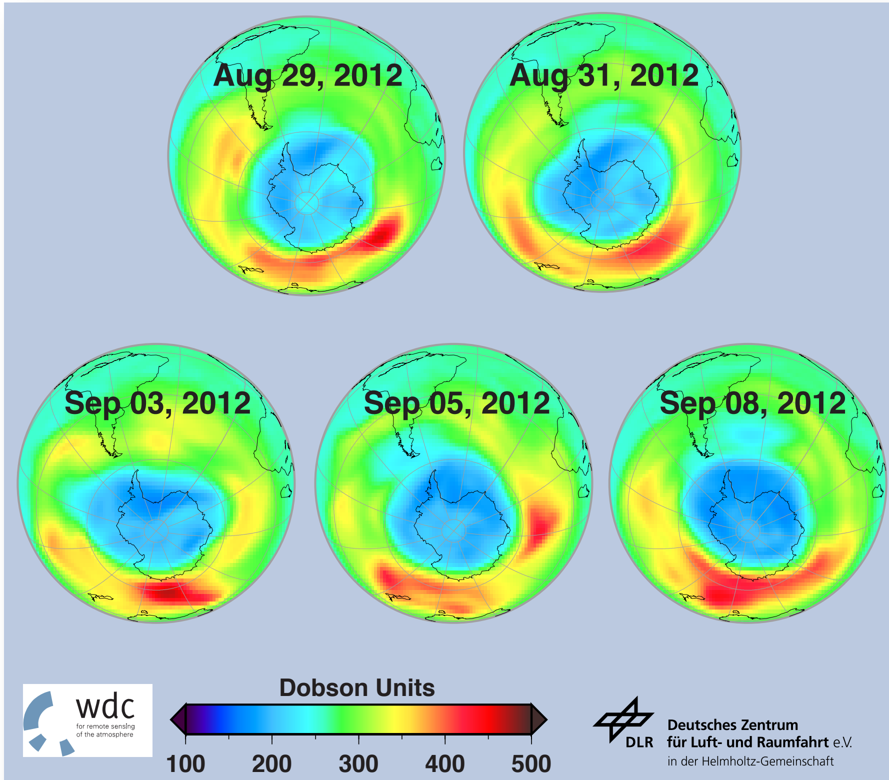


Figure 25. Sequence of total ozone maps from 29 August to 08 September, 2012 based on data from the GOME-2 instrument aboard the MetOp-A satellite. Shown are assimilated data using the ROSE/DLR model. Data are available at the WMO World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT).

Satellite based measurements of ozone vertical column density (**Figure 25**) derived from the ROSE/DLR model based on GOME-2 data also indicate low values in the range of 200 to 250 DU over Neumayer during the same time period.

From 1985 to 1992 regular ozone soundings have been performed at the German Georg Forster Station (70°46'S, 11°41'E). In 1992, this ozone sounding programme was moved to the Neumayer II Station (70°39'S, 8°15'W), which is located at the same latitude 750 km further west. Since February 2009 the programme is ongoing at the Neumayer III station built 6 km south of the Neumayer II Station. The results of all three stations can be regarded as one time series, as shown in **Figure 26**.

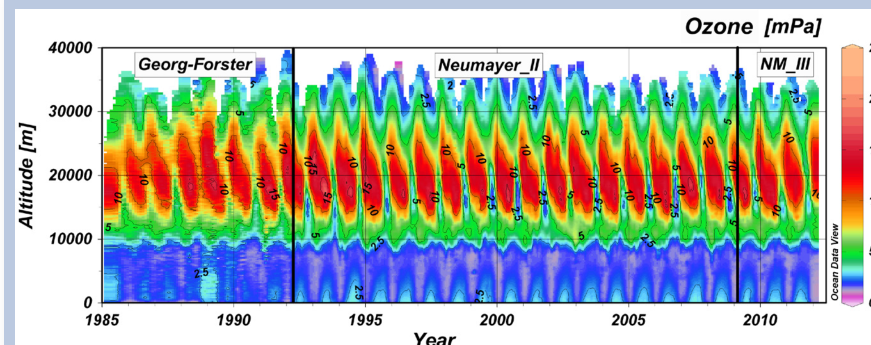


Figure 26. Time-height sections of ozone partial pressure above Georg Forster Station (1985-1992), Neumayer II Station (1992-2009) and Neumayer III Station (2009-2011). Clearly seen is the typical annual variation in the stratospheric ozone.

Within the last 20 years the seasonal averaged ozone partial pressure at 70 hPa shows a remarkable trend during Antarctic spring (September - November). In close correlation to this ozone depletion the stratospheric temperatures are decreasing. During Antarctic autumn (January - March) no comparable trends are observed (see Figure 27).

Neumayer III is committed to continue the research and monitoring programmes designed to document changes in the chemical composition of the atmosphere that are attributable to anthropogenic activities. Of special importance are the long-term ozone profile measurements contributing to the investigation of the Antarctic ozone hole and documenting its predicted recovery.

References

Gert König-Langlo and Bernd Loose, 2007. The Meteorological Observatory at Neumayer Stations (GvN and NM-II) Antarctica. Polarforschung 76 (1-2), 25-38.

Meteorology Observatory of Neumayer III Station: http://www.awi.de/en/infrastructure/stations/neumayer_station/observatories/meteorological_observatory/

World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT), the most recent data center in the WMO-WDC family: http://wdc.dlr.de

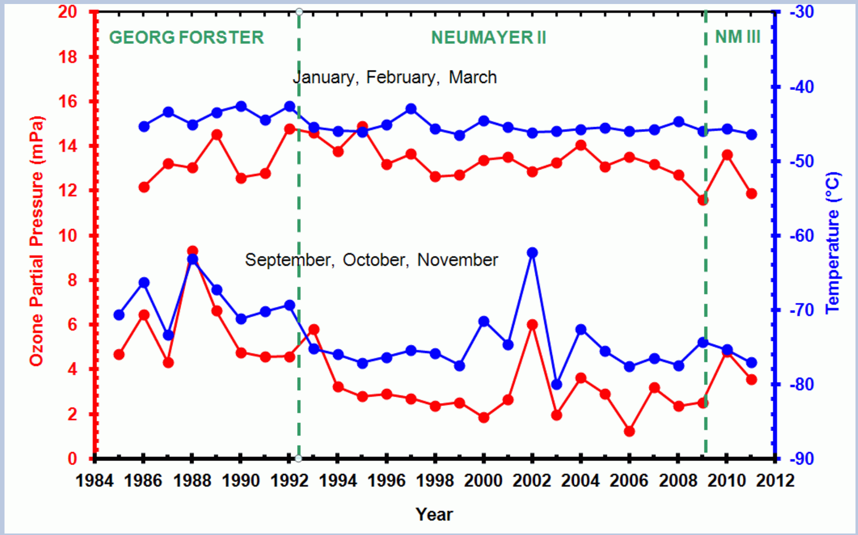


Figure 27.Figure 9: Time series of the seasonally averaged stratospheric parameters at 70 hPa. Shown is the coupled time series of Georg Forster Station (1985-1992), Neumayer II Station (1992-2009) and Neumayer III Station (2009-2011).

Novolazarevskaya

At the Russian GAW station Novolazarevskaya (70.776739°S, 11.822138°E) total ozone is measured with a filter instrument. The data are submitted by Elena Sibrus of the Arctic and Antarctic Research Institute, St. Petersburg. The measurements started on 14 August and are up to date until 30 September. On 14 August total ozone was 290 DU, which is the highest value measured so far this season. From 21-23 August, total ozone was under the 220 DU threshold with a minimum of 192 DU on 21 August. Since 3 September, total ozone has been below the 220 DU threshold, with a minimum of 157 DU on 19 September. OMI satellite overpass data show that the station has remained inside the ozone hole most of September, with a minimum ozone column of 160 DU on 19 September, in good agreement with the ground based observations .

An overview of the Novolazarevskaya station. Photo: Maks Kupec.

Río Gallegos

The lidar system in operation at Río Gallegos. Photo: CONICET.

The NDACC station "Observatorio Atmosférico de la Patagonia Austral" in Río Gallegos (51.600496°S, 69.31946°W) is equipped with a differential absorption lidar (DIAL) for the measurement of profile ozone and with a SAOZ spectrometer for the measurement of total ozone and NO_2. A GUV-541 filter radiometer measures UV radiation. The station is operated by the Lidar Division of CEILAP (Laser and Applications Research Center) and belongs to UNIDEF (MINDEF, (Ministerio de Defensa) and CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina)). It is supported by JICA. CEILAP is associated with LATMOS through a collaboration agreement. The University of Magallanes, Chile, collaborates with the ozone measurements and the Nagoya University has a millimetric wave radiometer for ozone profile measurement operating at the station. The following report has been written by the scientists at the station.

Ozone monitoring in Río Gallegos NDACC Station, Santa Cruz, Argentina

J. Salvador, E. Wolfram,F. Orte, R. D'Elia, D. Bulnes, E. Quel
email contact jacosalvador@gmail.com

September 2012

As a part of systematic observation of ozone layer in southern Patagonia, total ozone column taken with SAOZ spectrometer and stratospheric ozone vertical profiles (14-45 km) with lidar were measured in the Río Gallegos NDACC Station.

The total ozone columns over Río Gallegos present typical fluctuation around mean values for this time of the year. On September 6 (day of year 250), the ozone hole pass over Río Gallegos station, and total ozone column drops to 260DU (**Figure 28**). These ground based ozone column measurements were taken with SAOZ and each single point in the figure corresponds to the average of sunrise and sunset daily measurement.

During the first days of September, four ozone vertical profiles were measured with the Differential Absorption Lidar operative at OAPA. In average, the integration time of each lidar experiment was around 3 hour. The measured stratospheric ozone profiles are presented in

Figure 28. The approximation of polar vortex to vertical of Río Gallegos produces reduction of ozone profile in the middle stratosphere (profile Sep 3) clearly visible in comparison with typical ozone profile on Sep. 1. Reductions in all altitudes are observed in the ozone profile measured on September 6, when ozone hole reach the vertical of Río Gallegos, as confirmed by OMI/AURA satellite image (**Figure 30**). Rapid recovery of total ozone happens after this day as a consequence of the polar vortex movement away from the station. **Figure 30** shows the sequence of images of the total ozone column measured by the OMI instrument aboard the AURA platform.

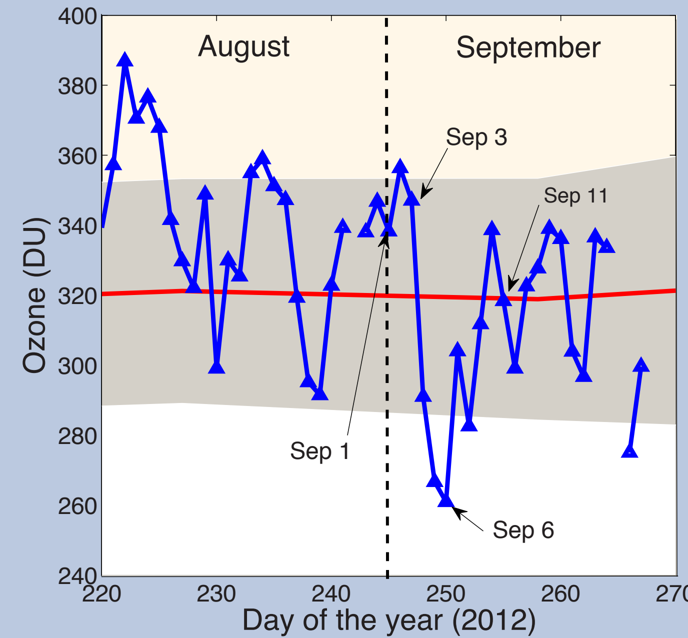


Figure 28. Evolution of the total ozone column over Río Gallegos. Measurements were taken with SAOZ spectrometer. Each point corresponds to the mean of daily sunrise and sunset observations.

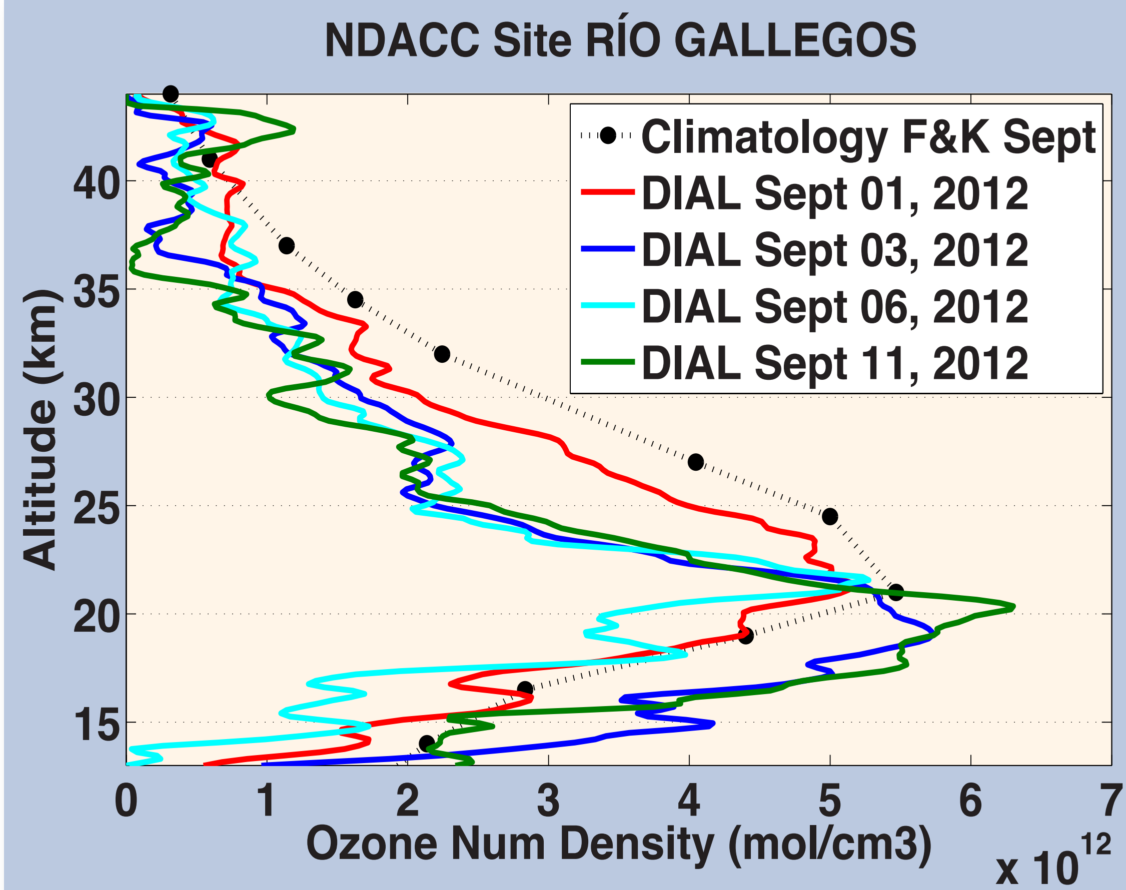


Figure 29. DIAL measurements of stratospheric ozone profile during four different days at the Río Gallegos NDACC site together with the Fortuin & Kelder climatologic profile for this latitude belt (45 - 55 S).

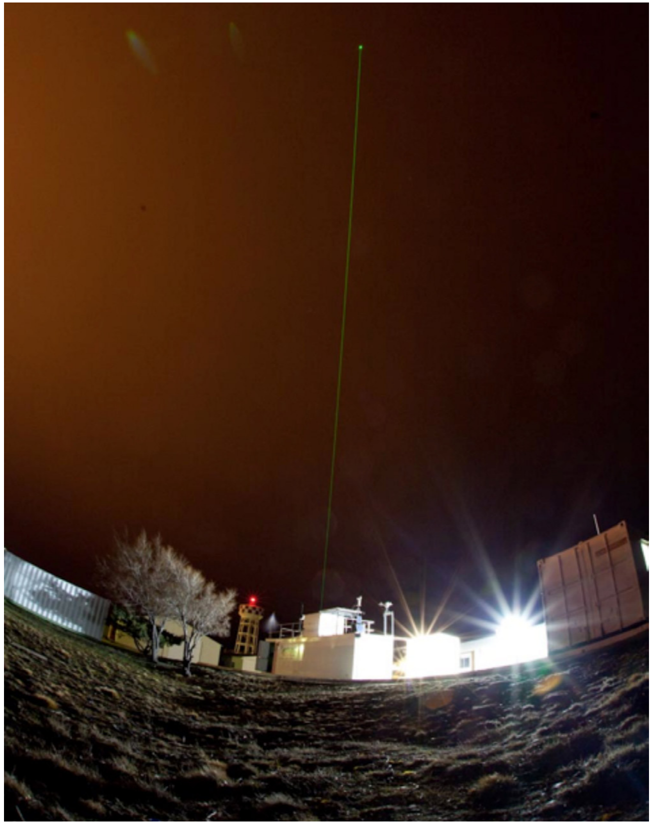


Photo 1. The differential absorption ozone lidar at Río Gallegos.

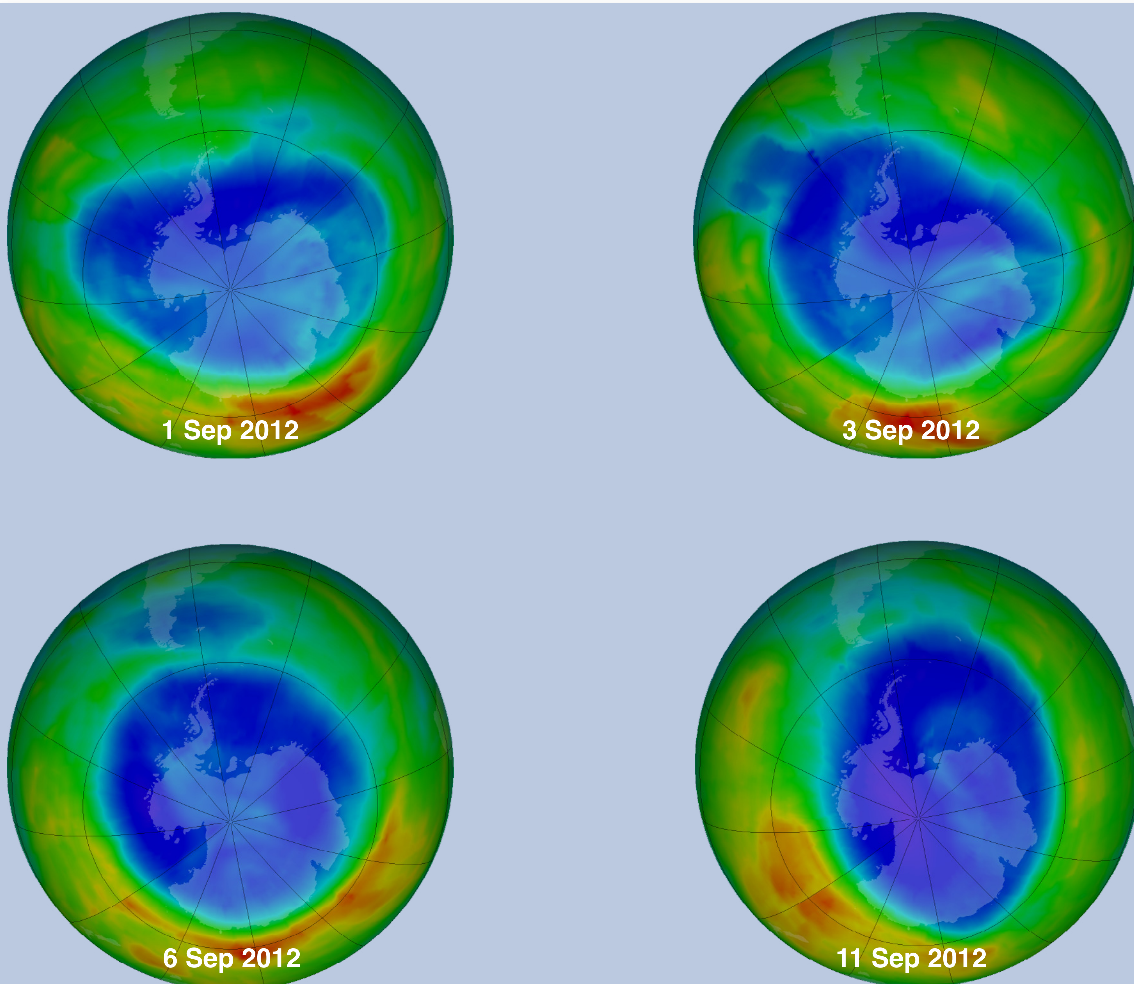


Figure 30. Sequence of ozone maps measured with the OMI satellite instrument on 1, 3, 6 and 11 September.

Rothera

The approach to the Rothera Research Station. Photo: Beth Simmons.

At the British GAW/NDACC station Rothera (67.5695°S, 68.1250°W) total ozone is measured with a SAOZ spectrometer. Since the station is close to the polar circle, and the SAOZ observes with the sun near the horizon, observations can be carried out around the year. **Figure 31** shows the 2012 data in comparison to earlier years and long term statistics. Total ozone was oscillating between 250 and 350 DU in June, July and early August. On 16 and 17 August total ozone dropped to 199 and 175 DU, respectively as air masses with somewhat depleted ozone passed over the station. On 18 and 19 August, the ozone column increased again and reached 266 and 298 DU, respectively. After that total ozone dropped again and reached 155 DU on 26 August. Then total ozone increased again and reached 273 DU on 2 September. Then followed a new dip in total ozone to 185 DU on 6 September. During September there has been a more or less gradual decrease of total ozone, and a minimum so far this season was reached on 22 September with 145 DU. The large and rapid variations in total ozone are due to the fact that Rothera is located close to the vortex edge. Relatively small movements of the vortex can cause large variations in ozone, depending on whether the station is located inside or outside the vortex. After that total ozone showed a rapid increase and reached 291 DU on 26 September. A new drop brought total ozone down to 211 DU on 28 September.

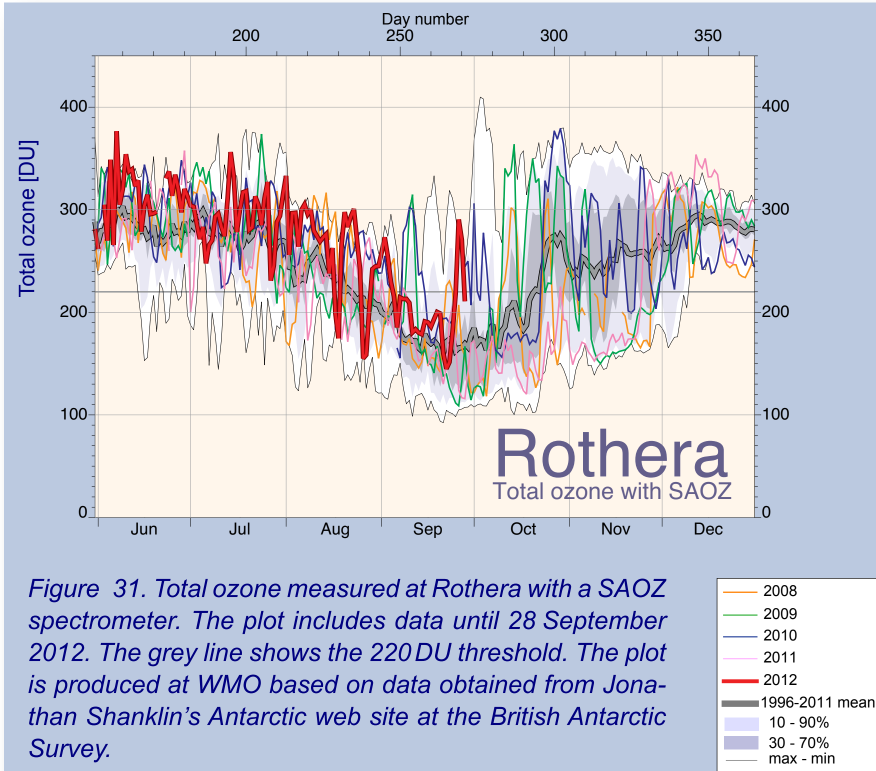


Figure 31. Total ozone measured at Rothera with a SAOZ spectrometer. The plot includes data until 28 September 2012. The grey line shows the 220 DU threshold. The plot is produced at WMO based on data obtained from Jonathan Shanklin's Antarctic web site at the British Antarctic Survey.

South Pole

Ozonesonde launch at the South Pole

The vertical distribution of ozone at the GAW/NDACC station at the South Pole (Amundsen-Scott base) has been measured by NOAA/ESRL with electrochemical concentration cell (ECC) ozonesondes since 1986.

Total ozone, as estimated from ozonesonde flights in August and until 26 September, has declined from 276 to 150 DU (see **Figure 32**). The partial ozone column over the 12-20 km altitude dropped from 150 DU at the end of August to 43 DU on 26 September. This is shown in **Figure 33**. The figure shows that the 12-20 km column has been stable around 140-150 DU during August, but the seven soundings thus far in September show a rapid drop in the partial ozone column. **Figure 34**

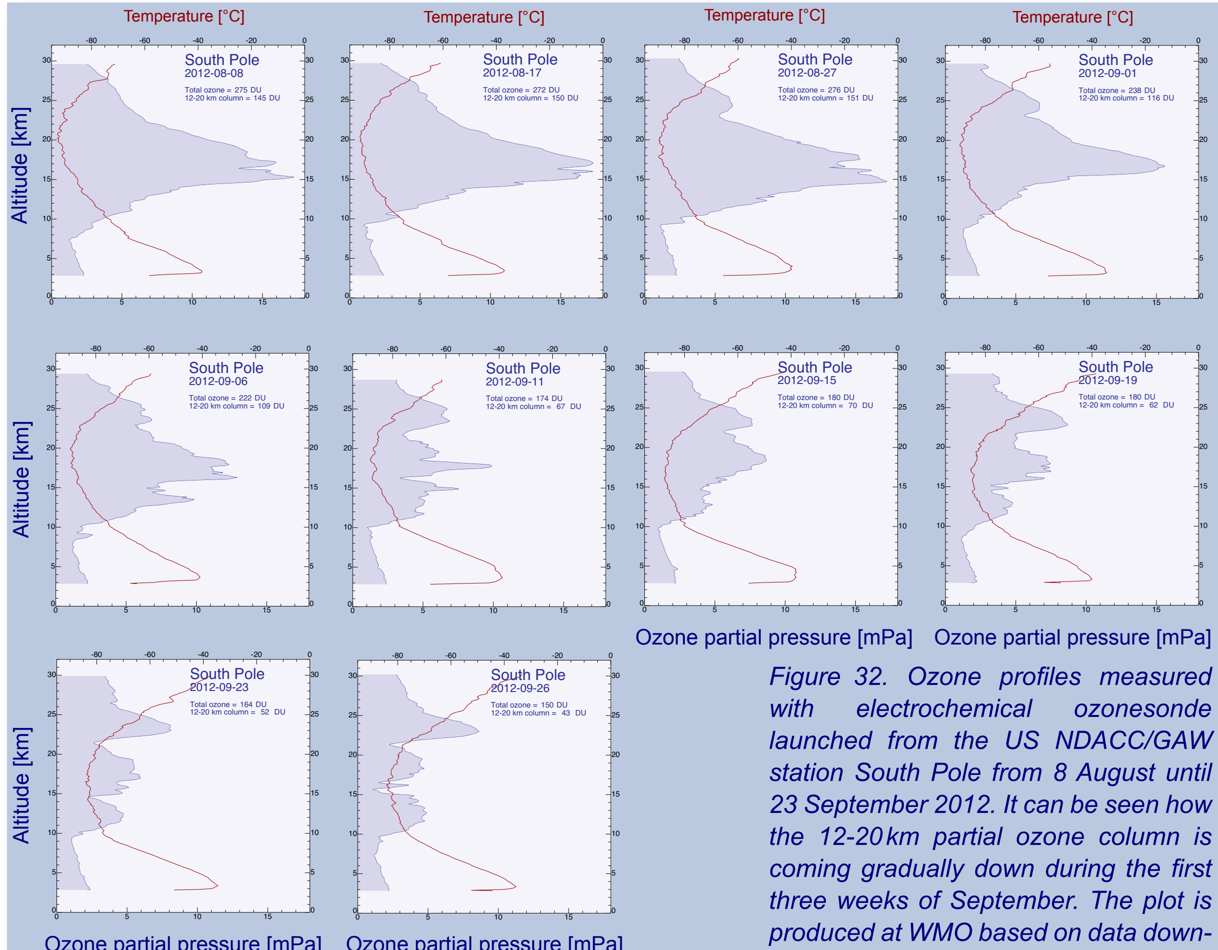


Figure 32. Ozone profiles measured with electrochemical ozonesonde launched from the US NDACC/GAW station South Pole from 8 August until 23 September 2012. It can be seen how the 12-20 km partial ozone column is coming gradually down during the first three weeks of September. The plot is produced at WMO based on data downloaded from the NOAA/ERSL/GMD ftp server.

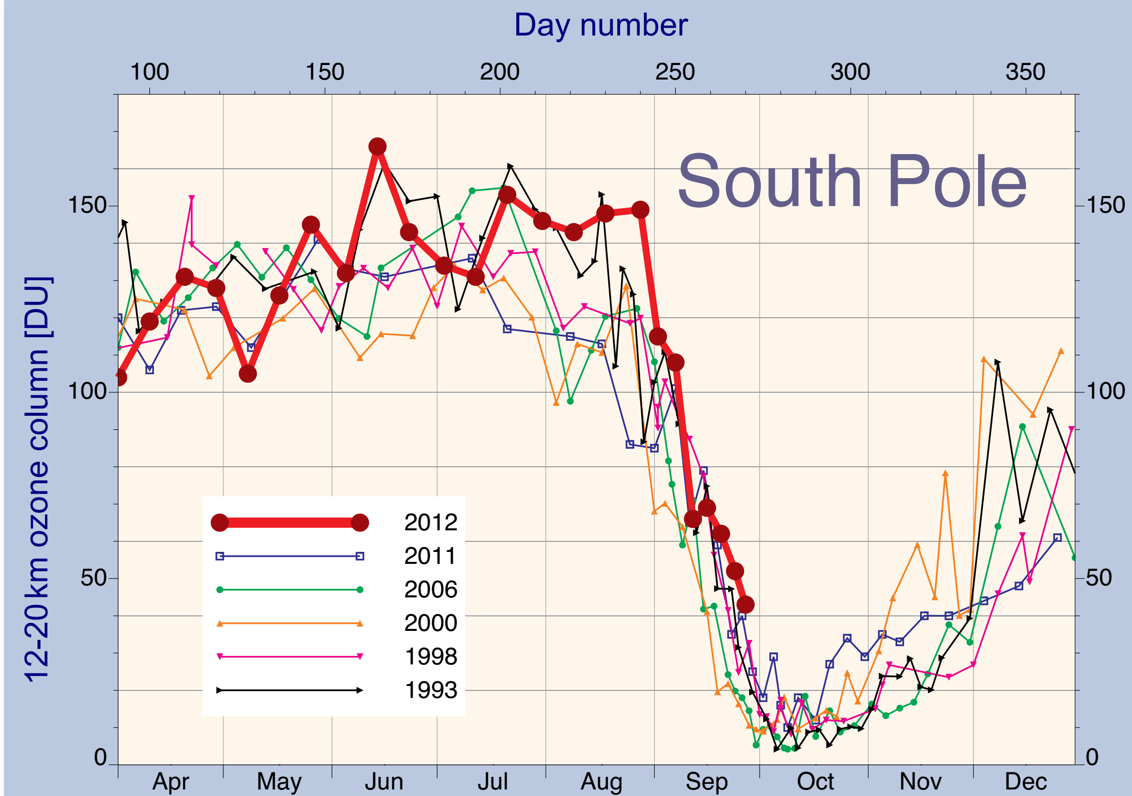


Figure 33. The 12-20 km partial ozone column (DU) based on ozonesonde measurement from the US NDACC/GAW Amundsen-Scott station at the South Pole. The plot is produced at WMO based on data published on the NOAA/ERSL/GMD ftp server. The 12-20 km partial ozone column has dropped to 52 DU as of 23 September.

shows the long term development of the 12-20 km partial ozone column from 1986 until present. The largest ozone loss observed at the South Pole happened in 1993 and 2006 when the partial column reached 4.2 DU in both cases.

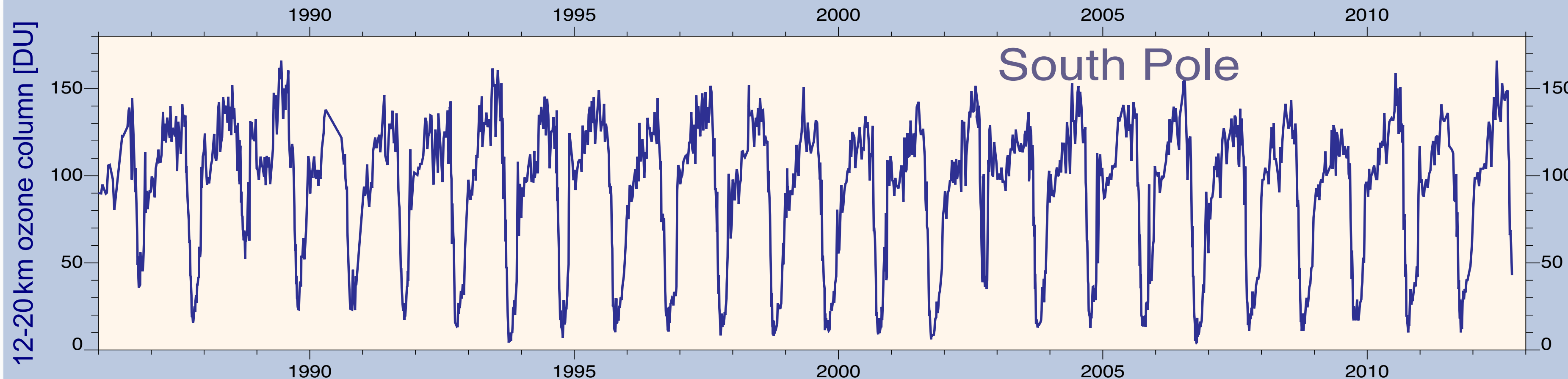


Figure 34.Time series of the 12-20 km partial ozone column deduced from ozonesonde measurements at the South Pole from 1986 until now. The recurring nature of the ozone hole is clearly seen. One can also see that 1993 and 2006 are the years when the 12-20 km partial ozone column reached the lowest values ever observed at this station, with 4.2 DU in both cases.

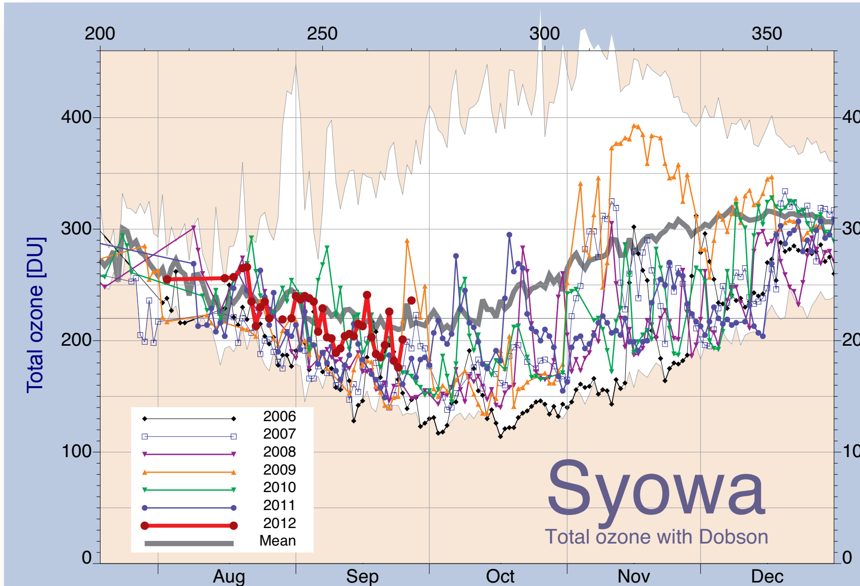


Figure 35.Time series of total ozone measured at the GAW station Syowa. The thick grey curve shows the 1961-2011 average. The data are updated until 26 September. The plot is produced at WMO based on data submitted by the Japanese Meteorological Agency.

Total ozone is measured at the Japanese GAW station Syowa (69.0°S, 39.6°E) with a Dobson spectrophotometer. These measurements have been carried out since 1961. Measurements started up on 2 August after the winter. The total ozone value measured with the Dobson spectrophotometer on that day showed 255 DU. During August the total ozone values varied between 219 and 266 DU. During September total ozone has decreased from around 240 DU at the beginning of the month to 189 DU on 9 September. After that total ozone has varied up and down as the polar vortex moves over the station. A minimum so far this season occurred on 23 September with 176 DU. This is shown in **Figure 35**.

Ozonesondes have been launched from Syowa since the early 1960s, as well. **Figure 36** on the next page shows the ozone profiles measured in August and so far in September. It can be seen from the figure that the 12-20 km partial column has decreased from about 130-140 DU around 20 August to 39 DU on 23 September. This is the same as observed at Marambio on 22 September.

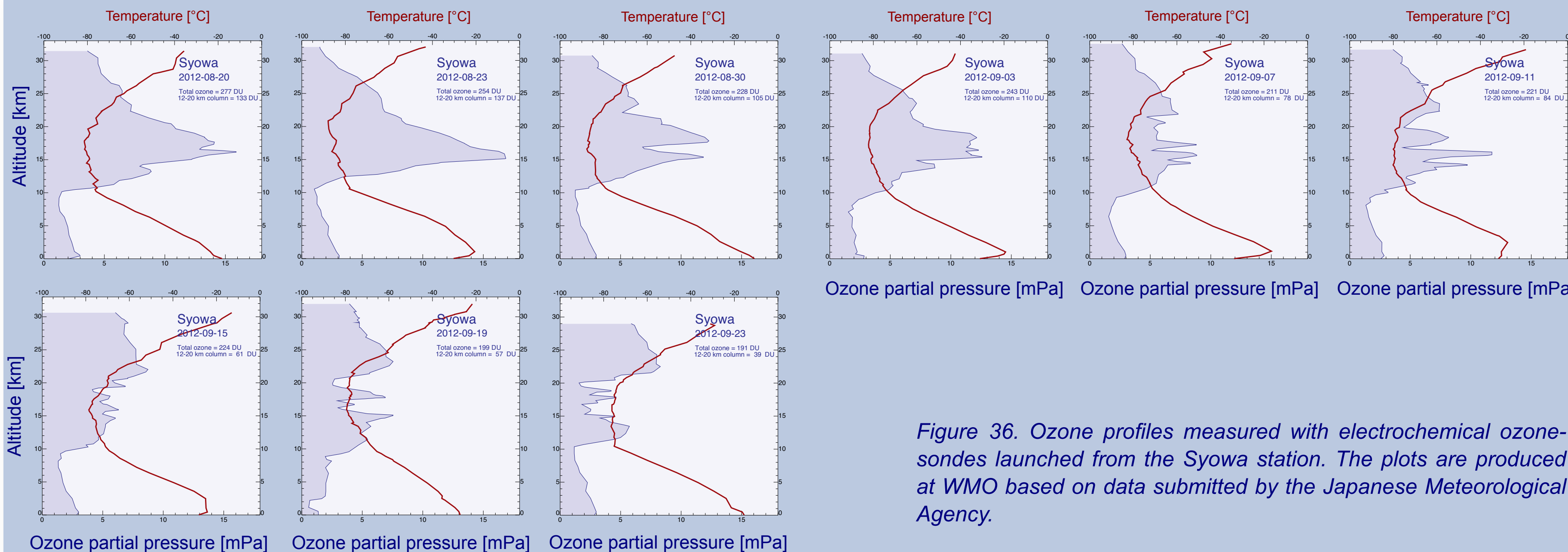


Figure 36. Ozone profiles measured with electrochemical ozone-sondes launched from the Syowa station. The plots are produced at WMO based on data submitted by the Japanese Meteorological Agency.

Ushuaia

Ozonesonde launch at Ushuaia

The global GAW station Ushuaia (54.848334°S, 68.310368°W) is operated by the Servicio Meteorológico Nacional of Argentina. This station is mainly influenced by middle latitude air masses, but on certain occasions the south polar vortex sweeps over the southern tip of the South American continent. On such occasions Ushuaia can be on the edge of or even inside the ozone hole. Ozone profiles measured with electrochemical ozonesondes are shown in **Figure 37**. The profile measured on 5 September shows that the station was influenced by ozone poor air with a 12-20 km partial ozone column of 76 DU. The sounding carried out on 22 September shows clear signs of ozone depletion in the 15-21 km range. The satellite images on the next page shows that the station was under the edge of the ozone hole on this day. On 26 September, the ozone hole had again moved away from the station.

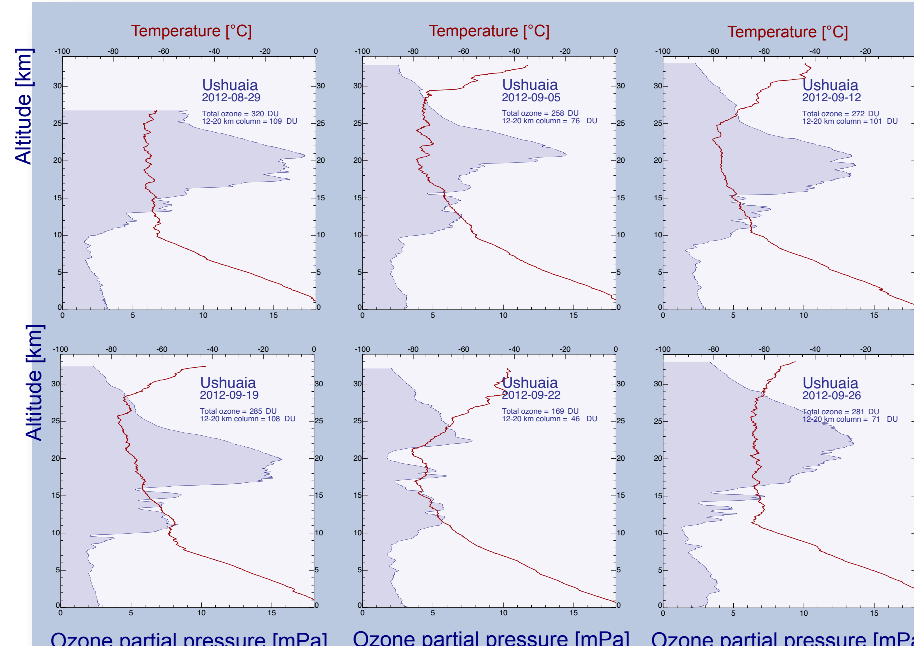


Figure 37.Ozonesonde profiles measured at the Argentine GAW station Ushuaia between 29 August and 26 September. The plots are produced at WMO based on data submitted by the National Meteorological Service of Argentina.

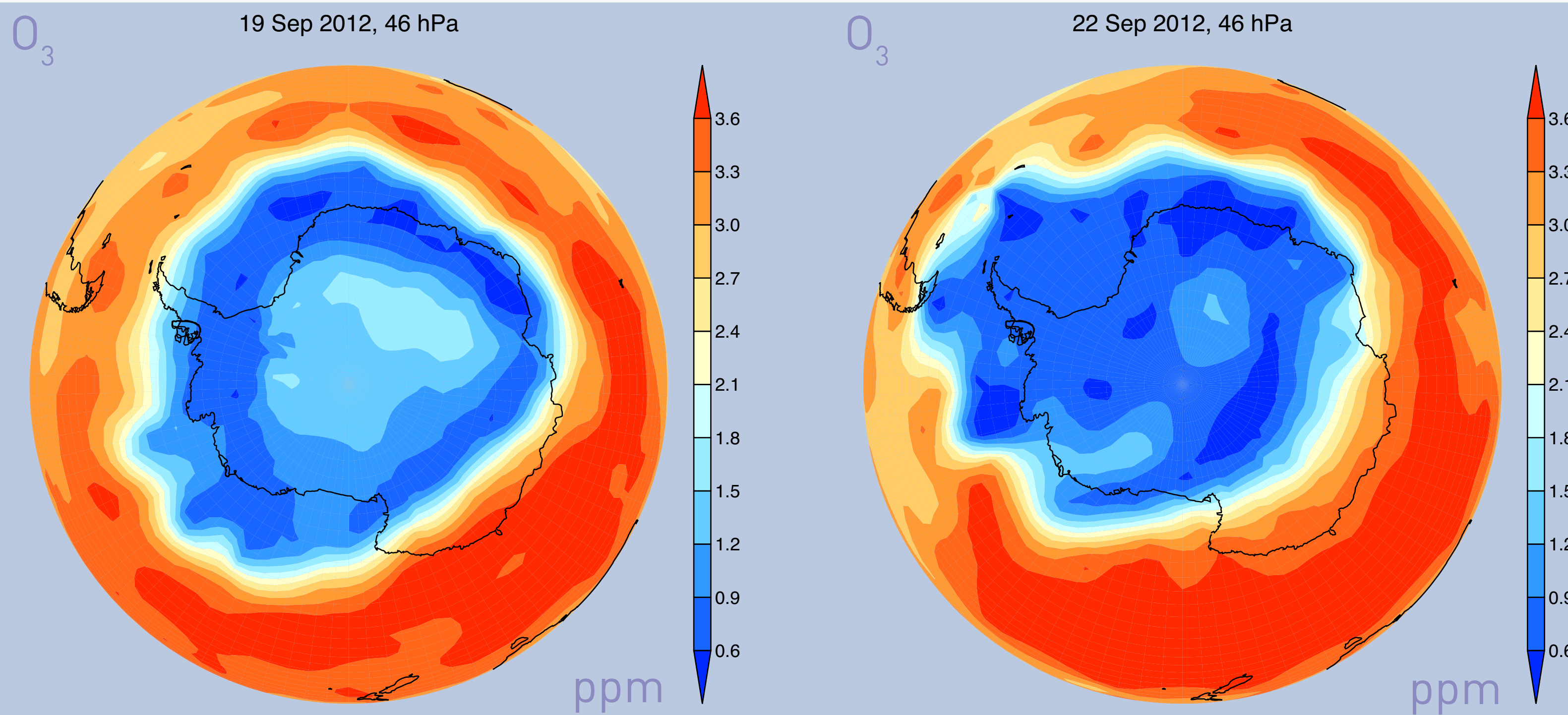


Figure 38.Ozone mixing ratio (ppm) at 46 hPa on 19 Sept 2012 and 22 September 2012. Data are from the MLS instrument on the AURA satellite. The data are downloaded from the Goddard Earth Sciences Data and Information Services Center (GES DISC) and plotted at WMO.

Vernadsky

The Vernadsky station seen from the sea.

Vernadsky station (65.2458°S, 64.2575°W) is run by the National Antarctic Scientific Centre of Ukraine. Total ozone is measured with a Dobson spectrophotometer. Observations recommenced after the polar night on 21 July, with initial results around 260-280 DU. During August total ozone values oscillated between 316 (19 Aug) and 203 DU (25 Aug). From 1 to 10 September total ozone dropped from 293 DU to 169 DU. After an increase to 240 DU on 18 September, total ozone dropped again and reached a minimum so far this season of 150 DU on 21 September. After that total ozone increased again and reached 299 DU on 25 September.

Zhong Shan

The Zhong Shan station.

At the Chinese GAW station Zhong Shan (69.373770°S, 76.373770°E) total ozone is measured with a Brewer spectrophotometer. The observations started up on 13 August after the polar night. The first direct sun measurement was carried out on 17 August. The total ozone value on that day was 291 DU. After that, total ozone showed a gradual decline and on 11 September it was 214 DU. Then total ozone increased and reached 276 DU on 16 September. Between 16 and 30 September total ozone has varied between 211 DU (24 September) and 358 DU (30 September). The station is often close to the vortex edge, and this can lead to large changes in total ozone, as a function of the location of the station relative to the vortex edge. **Figure 39** on the next page shows this for two days when total ozone was high (424 DU on 19 August) and when total ozone was low (223 DU on 9 September).

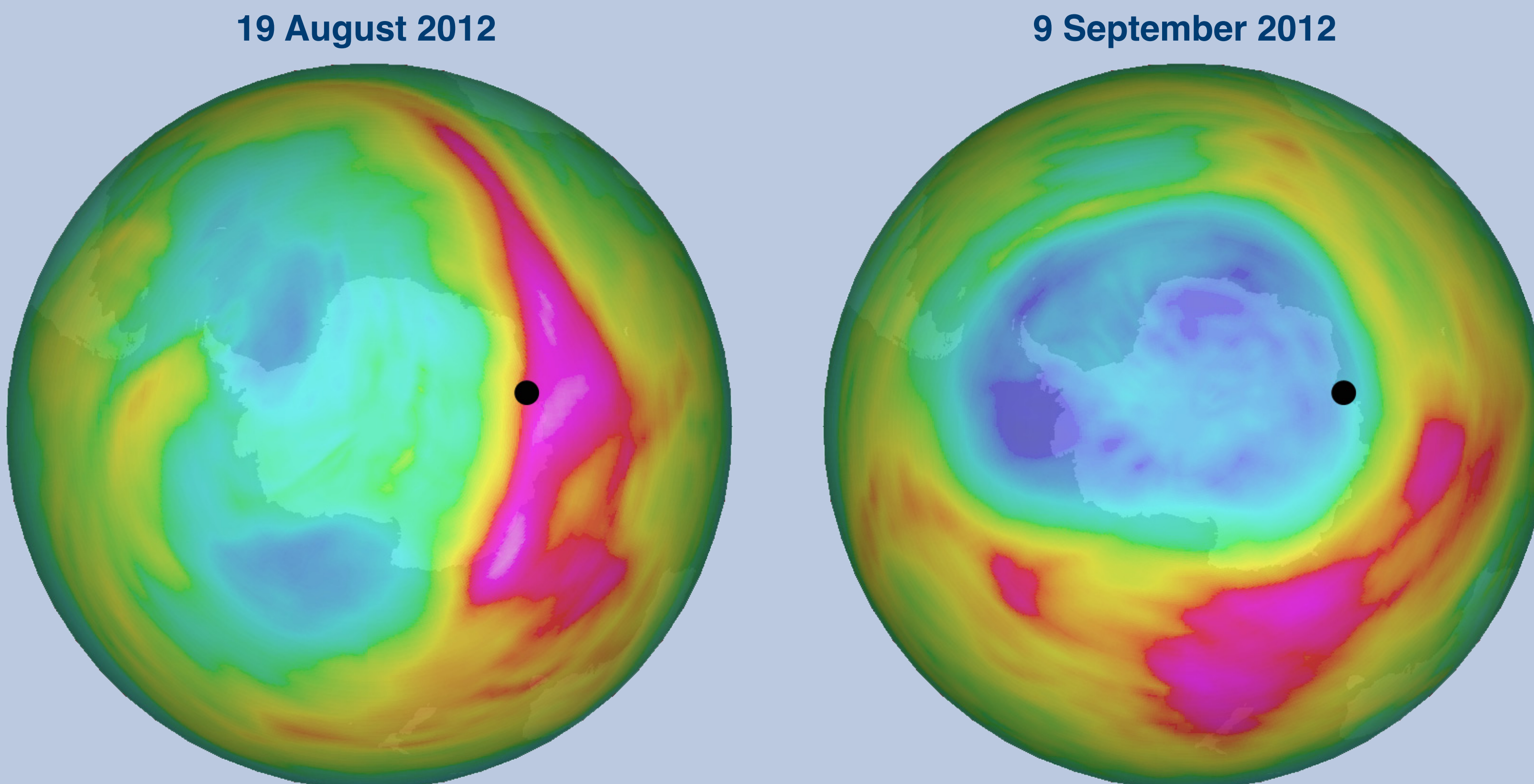


Figure 39. Satellite images of total ozone from the GOME-2 satellite instrument on board MetOp-A on 19 August and 9 September. The satellite images have been downloaded from the TEMIS web site at KNMI and the location of the Zhong Shan station has been added.

Chemical activation of the vortex

Satellite observations

The south polar vortex is still activated and primed for ozone depletion. The sun is now back over the Antarctic continent after the polar winter and ozone depletion is near its maximum for the season.

Figure 40 (upper row) shows the extent of removal of hydrochloric acid (HCl), which is one of the reservoirs for active chlorine, on 21 September 2012 and on the same date the three previous years. If one compares this figure with the corresponding figure in Bulletin no. 2 one can see that the region with very low HCl is smaller now than on 11 September. This is a sign that the vortex is about to get deactivated. However, compared to 21 September in recent years, the vortex is still comparatively devoid of HCl.

Another indicator of vortex activation is the amount of chlorine monoxide (ClO). It should be noted, however, that ClO dimerises and forms $(ClO)_2$ in darkness. The dimer is easily cracked in the presence of sunlight. ClO will therefore be present in the sunlit parts of the vortex, whereas the dark areas will be filled with $(ClO)_2$, which is not observed by Aura-MLS. **Figure 40** (lower row) shows the mixing ratio of ClO on the same dates as above. It can be seen from the figure that the degree of activation was more complete in 2011 than in the other years on this date. In 2012 the vortex seems somewhat more activated than in 2010, but less activated than in 2009 and 2011. However, the activated area only covers the part of the vortex facing the Atlantic and Indian Oceans, where as the Pacific sector has virtually no ClO.

Figure 41 (upper row) shows the amount of nitric acid (HNO_3) in the polar vortex. Removal of gaseous HNO_3 is an indication that this compound is condensated in the form of polar stratospheric clouds (nitric acid trihydrate, $HNO_3 \cdot 3H_2O$). It can be seen from the figure that the area of depleted HNO_3 is somewhat smaller in 2010 than in the other years and that in 2012 this area is smaller than in 2009 and 2011.

Figure 41 (lower row) shows the mixing ratio of ozone at the 490 K isentropic level. A collar of enhanced ozone can be seen just outside the polar vortex. Most of the polar vortex is now affected by ozone depletion. The area affected by low ozone on this date at the 490 K isentropic level is similar for all the four years shown here.

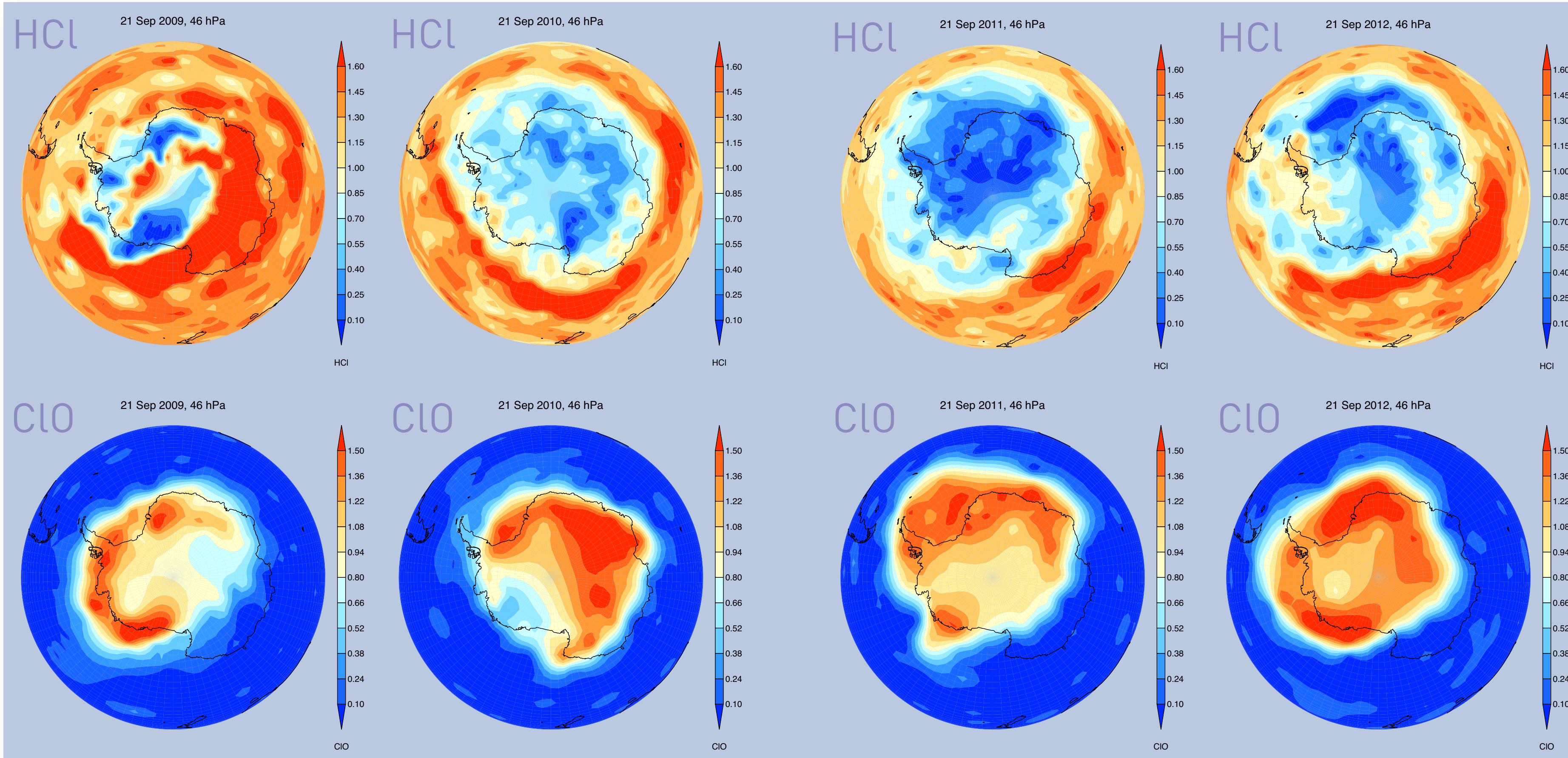


Figure 40. Upper row: Mixing ratio of HCl on 21 September of 2009, 2010, 2011 and 2012 at 46 hPa. Lower row: Mixing ratio of ClO at the same level and on the same four dates as above. The maps are made at WMO and based on data downloaded from the Goddard Earth Sciences Data and Information Services Center (GES DISC).

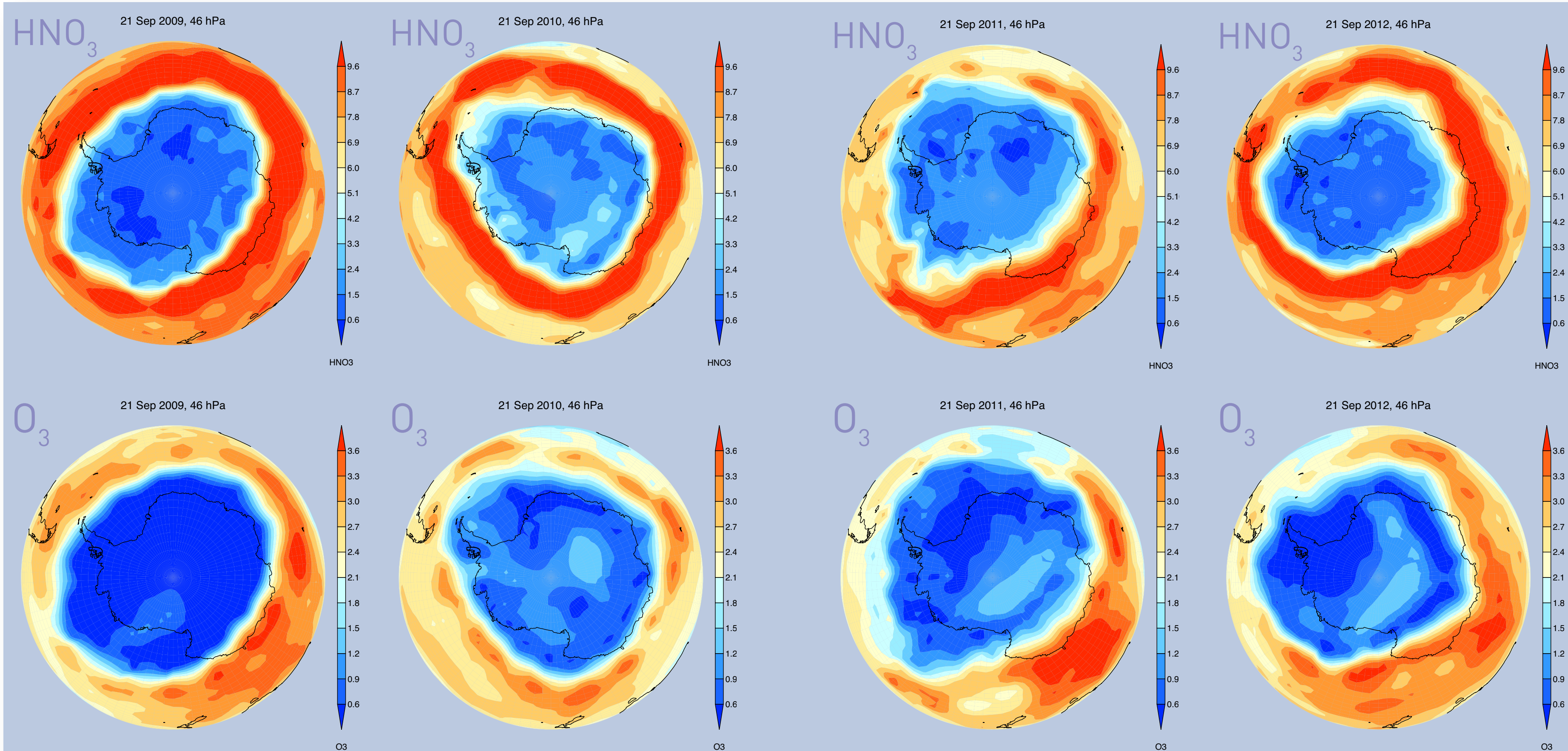
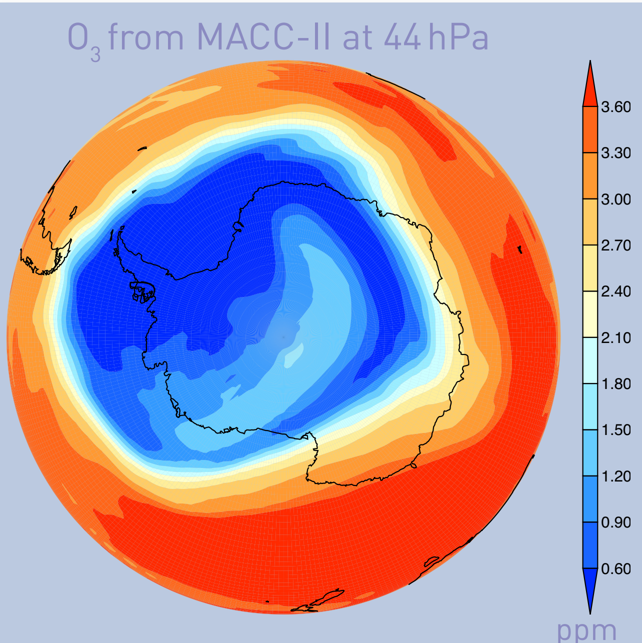


Figure 41. Upper row: Mixing ratio of nitric acid (HNO_3) on 21 September of 2009, 2010, 2011 and 2012 at 46 hPa. Lower row: Mixing ratio of ozone (O_3) on the same level and on the same four dates as above. The maps are made at WMO and based on data downloaded from the Goddard Earth Sciences Data and Information Services Center (GES DISC).

Modelling

The MACC-II project (Monitoring Atmospheric Composition and Climate - Interim Implementation) is the current pre-operational atmospheric service of the European GMES programme. MACC-II provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. MACC-II combines state-of-the-art atmospheric modelling with Earth observation data to provide information services covering European Air Quality, Global Atmospheric Composition, Climate, and UV and Solar Energy. More information about the MACC-II project can be found here: http://www.gmes-atmosphere.eu/. Model output from the MACC-II project includes some stratospheric variables, such as mole fractions of ozone, methane, nitric acid and other chemical species, as well as temperature. **Figure 42** shows the ozone mole fraction (in practice the same as mixing ratio for small mole fractions, i.e. in the ppm and ppb range) for 21 September 2012 at 44 hPa from the MACC-II model (left). Comparing this to the ozone field measured by MLS on the 46 hPa surface (right), shows a good agreement.



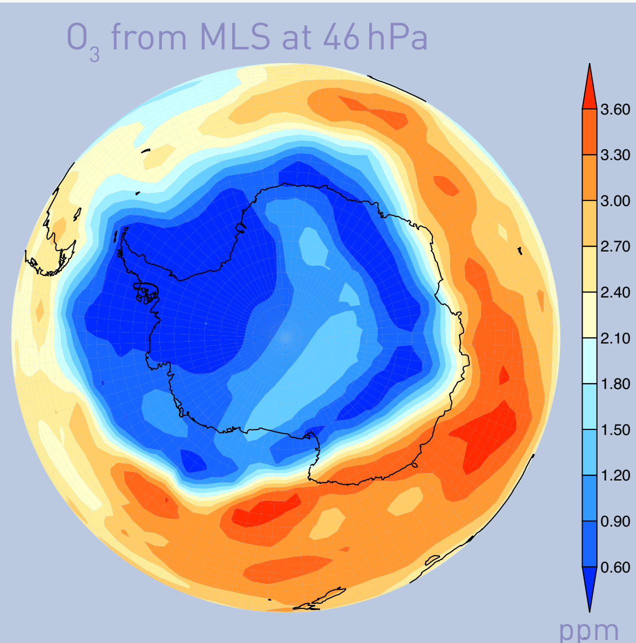


Figure 42. Ozone at 44 hPa from the model used in the MACC-II project (left) and ozone at 46 hPa measured by MLS aboard AURA (right). The model overestimates the amount of ozone at middle latitudes, but the ozone depletion inside the vortex is quite well reproduced.

Ozone hole area and mass deficit

Ozone hole area

The area of the region where total ozone is less than 220 DU ("ozone hole area") as deduced from the GOME-2 instrument on Metop-A (and SCIAMACHY on Envisat in the past) is shown in **Figure 43**. During the first half of August, the area increased more slowly than at the same time in many of the recent years. However, from mid August the increase has more or less followed the same development as in 2011. As of 1 October, the ozone hole area is just above 16 million square kilometres. This is less than the 22.5 million square kilometres reached on the same date last year, and also less than the 21 million square kilometres reached on 1 October 2010. It can be seen from the figure that the speed of the onset of ozone depletion in August varies a lot from year to year. However, the final peak reached later in the season has varied between 22 and 28 million square kilometres the

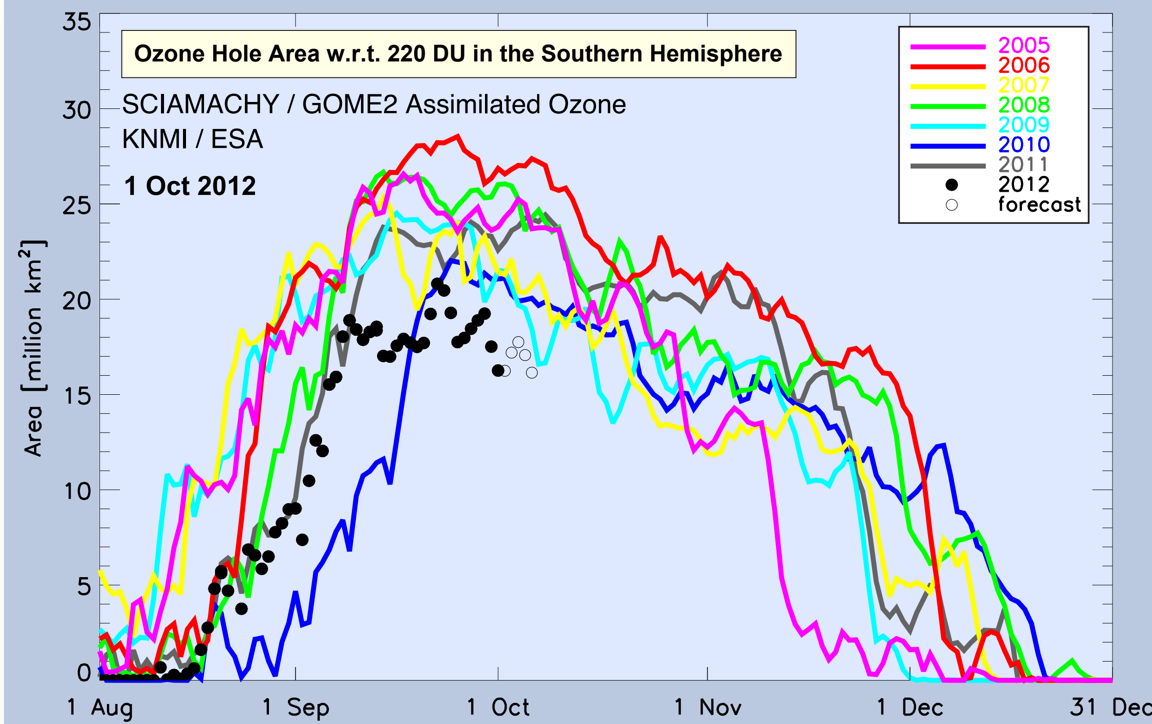


Figure 43. Ozone hole area for the years from 2005 to 2012 (black dots). The ozone hole area is the area of the region where total ozone is below 220 DU. The open circles represent a forecast for the five next days. This plot is produced by KNMI and is based on data from the GOME-2 and SCIAMACHY satellite instruments.

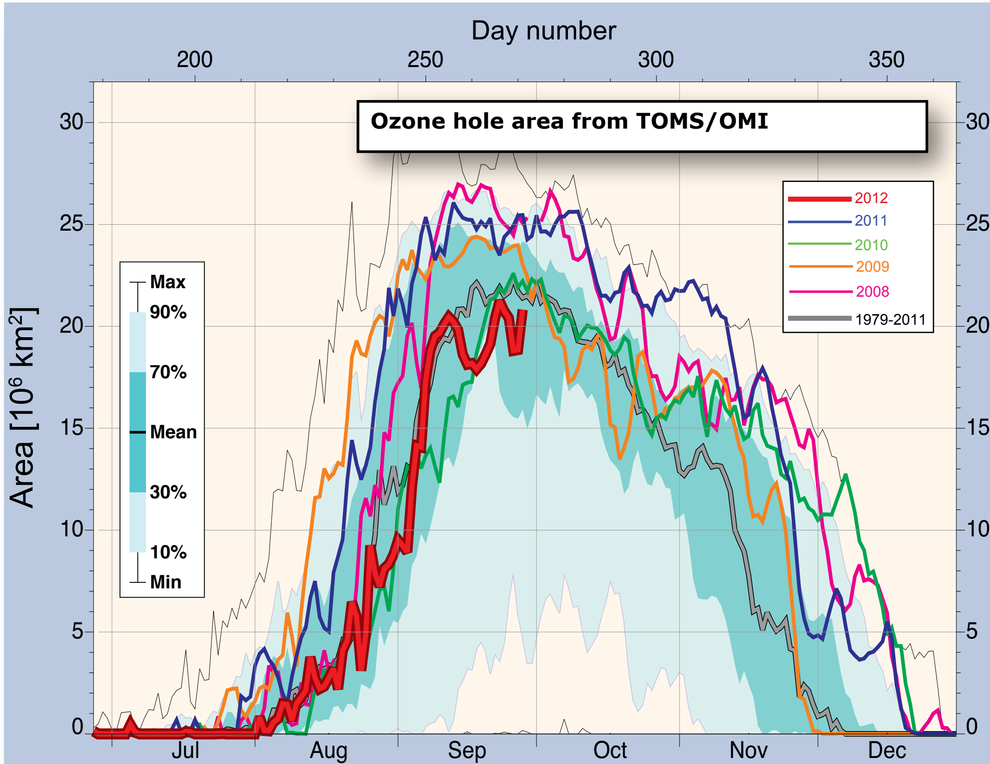


Figure 44. Area (millions of km²) where the total ozone column is less than 220 Dobson units. 2012 is showed in red (until 27 September). 2011 is shown in blue, 2010 in green, 2009 in orange and 2008 in violet. The smooth grey line is the 1979-2011 average. The dark green-blue shaded area represents the 30th to 70th percentiles and the light green-blue shaded area represents the 10th and 90th percentiles for the time period 1979-2011. The ozone hole area on 19 August is approx. 4.3 million km². The plot is made at WMO based on data downloaded from the Ozonewatch web site at NASA, which are based on data from NOAA/NCEP.

last seven years.

Figure 44 shows the ozone hole area as deduced from the OMI satellite instrument. Here it can be seen that the 2012 ozone hole had a slightly later start than in the other years shown here. From late August the ozone hole area has increased rapidly and as of 27 September it is 20.8 million square kilometres. Again, as we saw on the previous figure, based on GOME-2 data, this area is smaller than at the same date both in 2011 and 2011.

Ozone mass deficit

Figure 45 shows the ozone mass deficit as deduced from the OMI satellite instrument. It can be seen that the ozone mass deficit has followed the development of 2010 (green curve) quite closely. The ozone mass deficit reached a temporary maximum of 22.1 megatonnes on 22 September. After that it made a dip down, but it now on the way up again. With the exception of 2010, the ozone mass deficit is much lower than in other recent years.

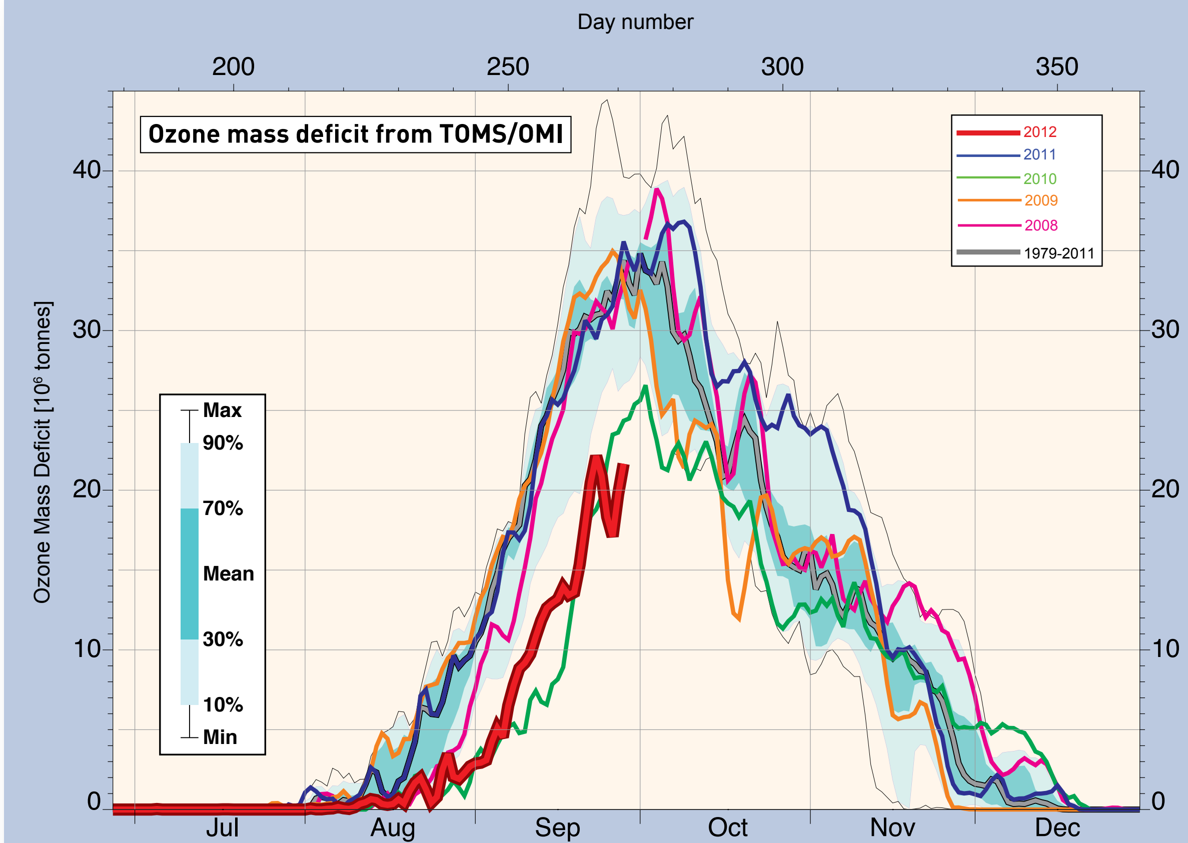


Figure 45. Ozone mass deficit (megatons) inside the Antarctic ozone hole for the years from 2008 to 2012 together with 1979-2011 statistics. Data for 2012 are shown in red (until 27 September). The ozone mass deficit is defined as the mass of ozone that would have to be added to the ozone hole in order to bring the total ozone column up to 220 DU in those areas where total ozone is less than 220 DU. The plot is made at WMO based on data downloaded from the Ozonewatch web site at NASA.

Figure 46 shows the ozone mass deficit based on data from SCIAMACHY and more recently from GOME-2. This plot is a few days more up to date than the one in Figure 45. It shows that the ozone mass deficit has been decreasing during the last few days of September and is now around 15 megatonnes. One has to go back to 2004 in order to find a similarly low ozone mass deficit for this time of the year, and it less than half of what was observed in 2003, 2005, 2006, 2008 and 2009 on this date.

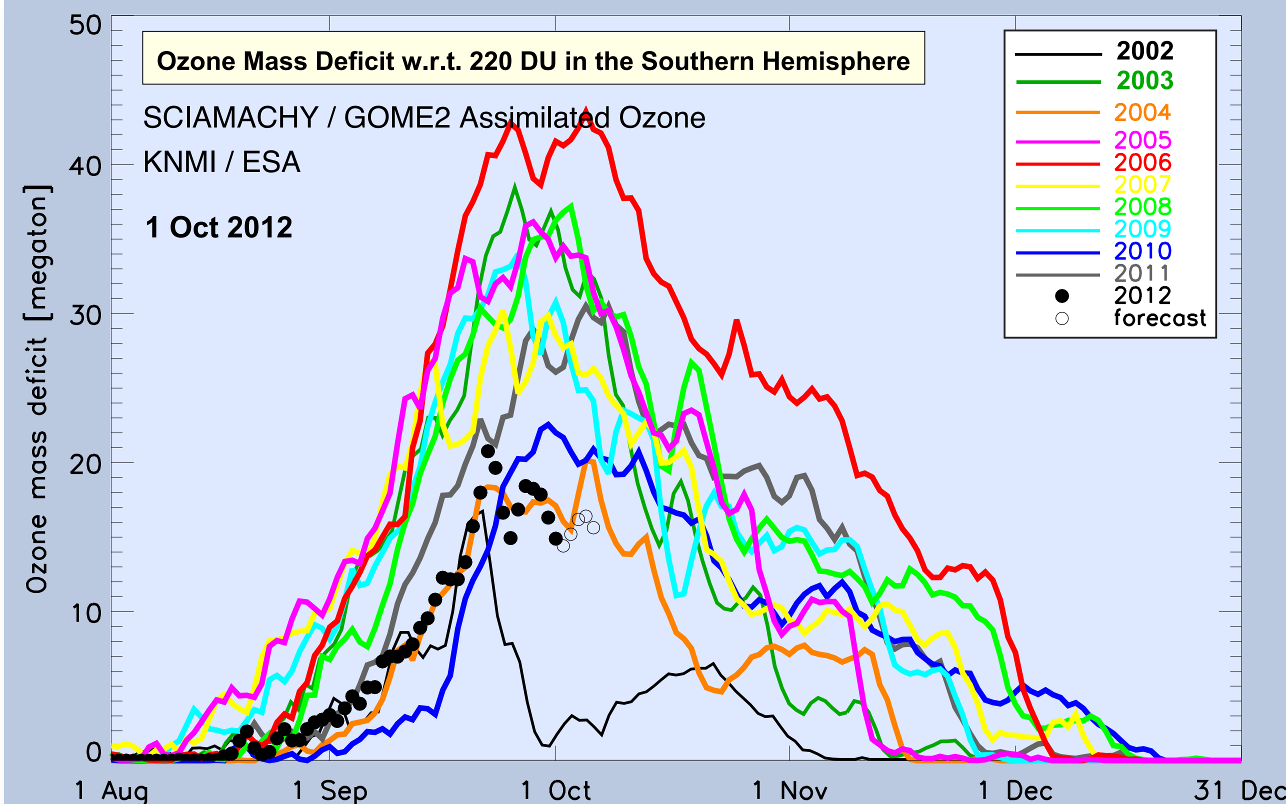


Figure 46. Ozone mass deficit (megatons) inside the Antarctic ozone hole for the years from 2002 to 2012. Data for 2012 are shown as black dots (until 1 October). The ozone mass deficit is defined as the mass of ozone that would have to be added to the ozone hole in order to bring the total ozone column up to 220 DU in those areas where total ozone is less than 220 DU. This plot is produced by KNMI and is based on data from the GOME-2 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). Reports on the UV radiation levels will be given in futures issues when the sun comes back to the south polar regions. 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).

SAOZ data in near-real time from the stations Dôme Corncordia and Dumont d'Urville can be found here: http://saoz.obs.uvsq.fr/SAOZ-RT.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 2010 WMO/UNEP Scientific Assessment of Ozone Depletion can be found here: http://www.wmo.int/pages/prog/arep/gaw/ozone_2010/ozone_asst_report.html

Questions regarding the scientific content of this Bulletin should be addressed to Geir O. Braathen, mailto:GBraathen@wmo.int, tel: +41 22 730 8235.

The next Antarctic Ozone Bulletin is planned for 12 October 2012.