



Australian Government

Department of the Environment, Water, Heritage and the Arts

## The 2009 Antarctic Ozone Hole Summary: Thursday 27 August 2009

Paul Krummel and Paul Fraser  
Centre for Australian Weather and Climate Research  
CSIRO Marine & Atmospheric Research  
Aspendale, Victoria

### Instrumentation

Data from the Ozone Monitoring Instrument (OMI) on board the Earth Observing Satellite (EOS) Aura, that have been processed with the NASA TOMS Version 8.5 algorithm, will be utilised again this year in our weekly ozone hole reports. OMI continues the NASA TOMS satellite record for total ozone and other atmospheric parameters related to ozone chemistry and climate.

In 2008, stripes of bad data began to appear in the OMI products, apparently caused by a small physical obstruction in the OMI instrument field of view. NASA scientists guess that some of the reflective Mylar that wraps the instrument to provide thermal protection has torn and is intruding into the field of view. On 24 January 2009 the obstruction suddenly increased and now partially blocks an increased fraction of the field of view, leading to the larger stripes of bad data that are seen in current OMI images. Affected data have been flagged and removed from the images. NASA thinks that some of the data may be recoverable but a fix may take months to create and test. However, once the polar night reduces enough then this should not be an issue for determining ozone hole metrics, as there is more overlap of the satellite passes at the polar regions which essentially 'fills-in' these missing data.

Lastly, all of the OMI ozone data have been reprocessed/updated and were released in June 2009. These have now been reprocessed by CSIRO, which has resulted in small changes in the ozone hole metrics we calculate, and as such, these metrics may be slightly different for previous years for OMI data (2005-2008).

### The 2009 ozone hole

The OMI data show that the ozone minimum dropped below 220 DU in early August, about two weeks later than in 2005-2008, and about a week later than the 1979-2005 mean. By the end of the third week of August, the ozone minimum in the Antarctic ozone hole had dropped rapidly to 160-170 DU (similar to 2007), about 1 week earlier than 2006 and 2008, a week later than in the 2005 hole, and about 3 weeks earlier than the 1979-2005 mean (Figure 1, top panel).

At this stage the 2009 Antarctic ozone hole is heading for the 'deep' category (as have all ozone holes since the early 1990s except for 2002). By the end of the third week of August, the ozone hole area reached over 18 million km<sup>2</sup> (Figure 1, bottom panel), which is similar to the 2005 and 2007 holes at the same date, and about 5 million km<sup>2</sup> larger than the 2006 and 2008 holes at the corresponding date. The 1979-2005 average ozone hole was only 6-7 million km<sup>2</sup> by this date.

Figure 2 (top panel) shows that the estimated daily ozone deficit by the end of the third week of August had reached 7 million tonnes (similar to 2007, less than 2005), while the average ozone amount in the hole (averaged column ozone amount in the hole weighted by area, Figure 2 bottom panel) shows a minima of about 200 DU at the same time (similar to 2006 and 2007, less ozone deficit than in 2005). The really rapid ozone decline in 2005, 2006, 2007 and 2008 did not start until early September – presumably this will be the case for 2009.

Total column ozone data over Australia and Antarctica for 13-24 August are shown in Figure 3. The Antarctic polar night region still covers most of Antarctica, with the 220 DU contour being virtually completely exposed by 23 August. An ozone maximum has formed in the ridge immediately south of Australia.

It should be noted that until the polar night reduces to be smaller than the ozone hole, the above metrics are subject to noise and inaccuracies.

## **WMO Ozone Bulletin #1 (21 August 2009)**

WMO have just released the first of their comprehensive Bulletins on the Antarctic Ozone Hole for 2009. The polar vortex is primed for rapid ozone loss, once illumination is sufficient to release reactive chlorine and bromine radicals from the 'bank' of chlorine and bromine that has accumulated in the vortex from the usual PSC-catalysed chemistry during the winter.

### **Vortex Temperatures**

The daily minimum temperatures in the Southern Hemispheric polar (50°S-90°S) lower stratosphere have been close to or below the 1979-2008 average throughout the winter. The vortex is very cold, the minimum temperature achieved at 50 hPa (lower stratosphere) was -93°C in early August, 2°C warmer than the minimum in 2008, and nearly the coldest temperature ever achieved in the vortex from 1979 to 2008. The coldest vortex temperature ever recorded is -96°C.

Nitric acid-type polar stratospheric clouds (Type I PSCs:  $\text{HNO}_3 \cdot 3\text{H}_2\text{O}$ ) form below -78°C and Type II below -85°C. Since late June, temperatures low enough for the formation of Type 1-PSCs have covered an area of about 20 million  $\text{km}^2$ , 85% of the polar vortex area.

Rather than look at the Type 1-PSC area at a specified level, it makes more sense to look at the volume within which Type-1 PSCs can form. This new metric - the volume of the region where temperatures are low enough for the formation of Type I PSCs:  $\text{HNO}_3 \cdot 3\text{H}_2\text{O}$ , has been calculated and plotted. This volume peaked in early July at 300  $\text{Mkm}^3$  compared to 320  $\text{Mkm}^3$  in mid-July 2008, which was close to the record volume over the 1978-2008 period (325  $\text{Mkm}^3$ ). Since early July this volume has declined to 280  $\text{Mkm}^3$ , a level at which it has stayed from mid-July through late-August, at which time it was at near record volumes.

### **Polar Vortex Stability and the Onset of Ozone Loss**

At present, the vortex is not as concentric (circular) than at the same time in 2008. This has led to (due to sun exposure at the edges of the vortex) an onset of ozone depletion that is much earlier than the long-term average

The flux of heat from mid-to-polar latitudes is a measure of vortex stability. Since mid-July this heat flux has been below normal (the 1979-2008 average), indicating a stable vortex.

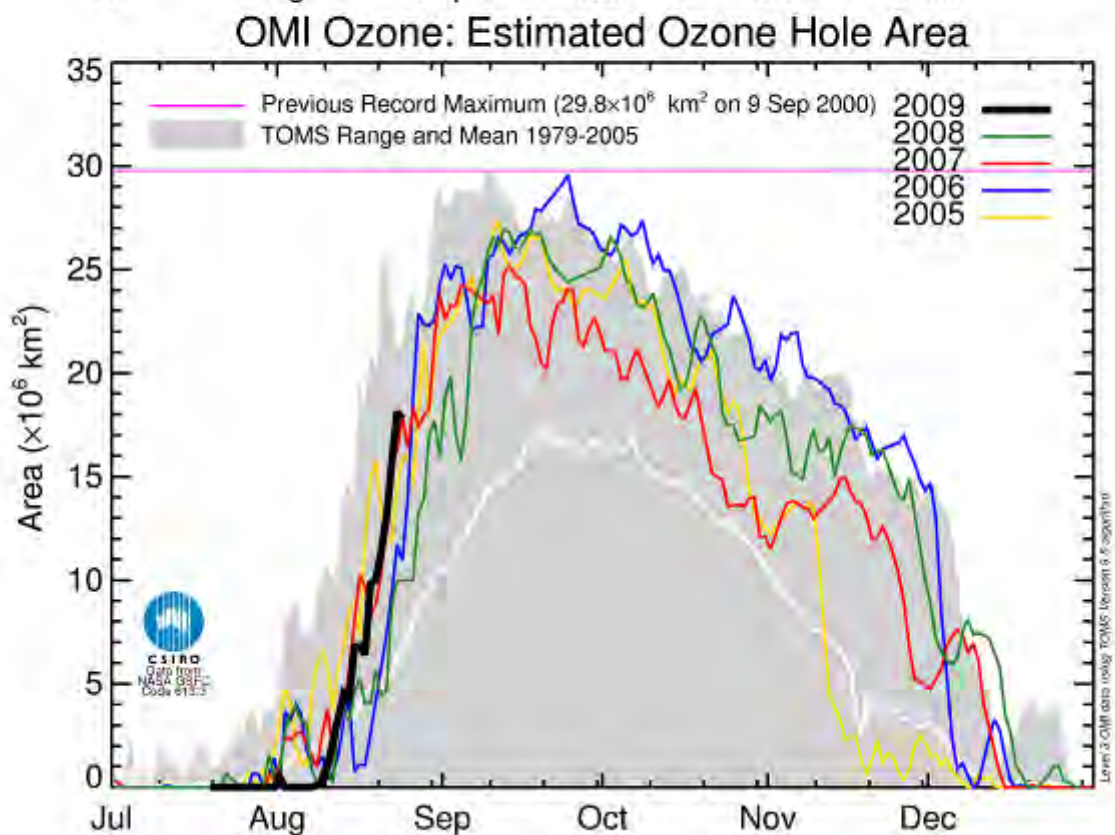
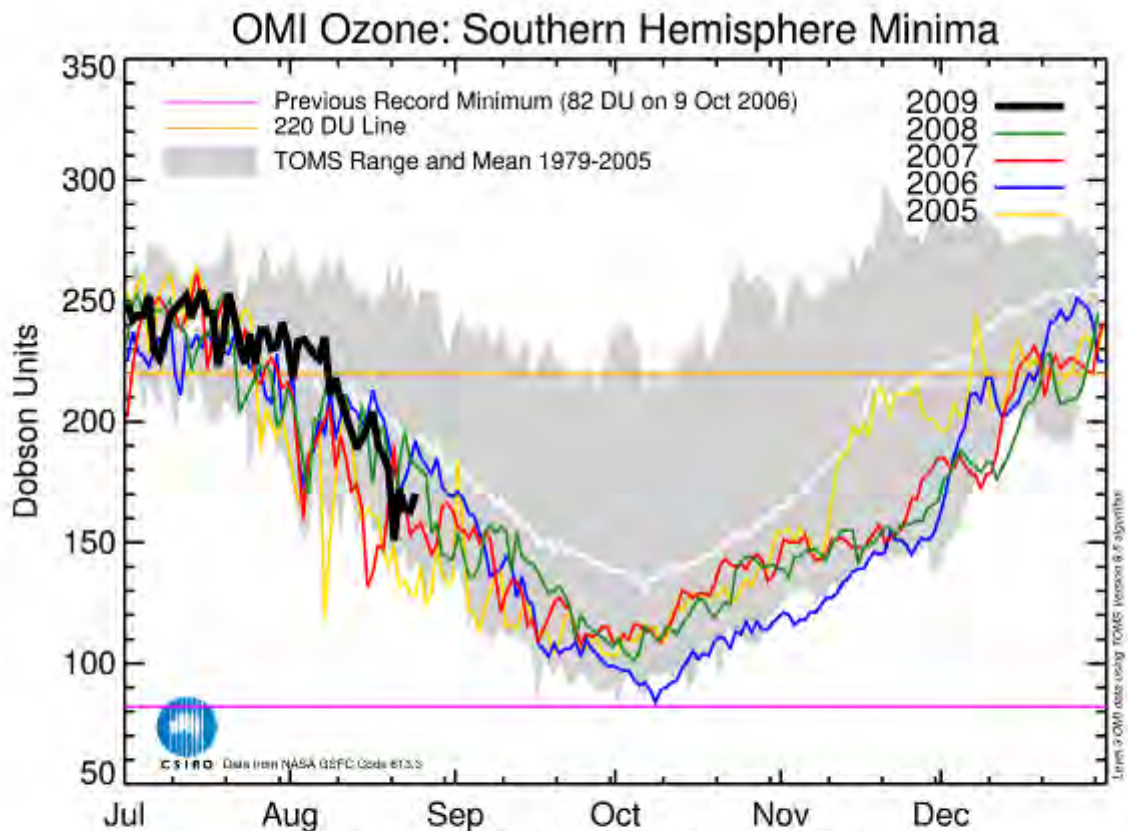
### **Chemical Activation of the Vortex**

During the winter the chlorine present inside the vortex (hydrochloric acid and chlorine nitrate from the photo-dissociation of ODSs the previous summer) are converted to reactive chlorine ( $\text{Cl}_2$ ). NASA Aura-MLS satellite data show that by mid-August 2009 all HCl inside the vortex has been converted, ready for the first levels of weak Antarctic spring sunlight to trigger the rapid destruction of Antarctic ozone, forming the ozone hole. The area affected by HCl removal is larger in 2009 at this time compared to 2008. As the sun exposes the vortex, at the sun-lit edge,  $\text{Cl}_2$  is converted to Cl which rapidly reacts with ozone to form ClO, beginning the catalytic ozone destruction cycle. By 17 August, Aura-MLS data show ClO levels exceeding 1.8 ppb, indicating nearly all chlorine at the day/night terminator is present as the ozone destructive form. Because this year's vortex is currently more distorted than in 2008, it has been exposed to more sunlight and as a consequence ClO levels are higher.

### **From the Literature**

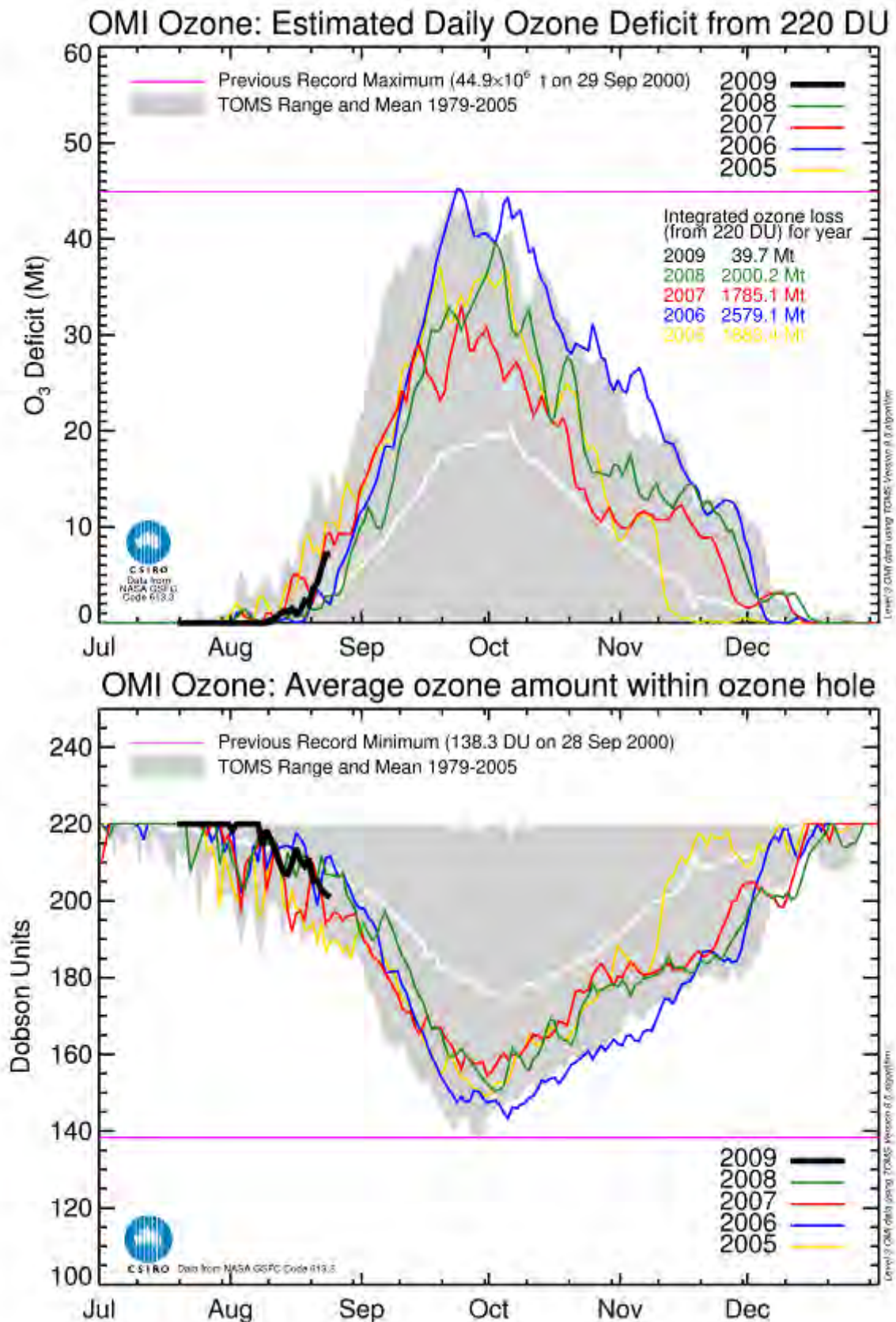
In 2007, Pope *et al.* reported that the  $\text{Cl}_2\text{O}_2$  photolysis rate was almost an order of magnitude lower than needed to explain the rate of ozone loss over Antarctica in late winter. This result challenged the widely-accepted model of chlorine-induced ozone destruction. A recent paper by Chen *et al.* (2009) suggests that the Pope *et al.* result was due to some impurities in the preparation of  $\text{Cl}_2\text{O}_2$  for their kinetics experiments. The Chen *et al.* method avoids possible impacts of contaminants and generates the high photolysis rates for  $\text{Cl}_2\text{O}_2$  that are the cornerstone of Cl-catalysed ozone destruction.

Ravishankara *et al.* (2009) have calculated a pre-industrial ozone Depletion Potential (ODP) for nitrous oxide (N<sub>2</sub>O) of 0.026 and a current value of 0.017, close to the ODPs of some HCFCs regulated under the Montreal Protocol.



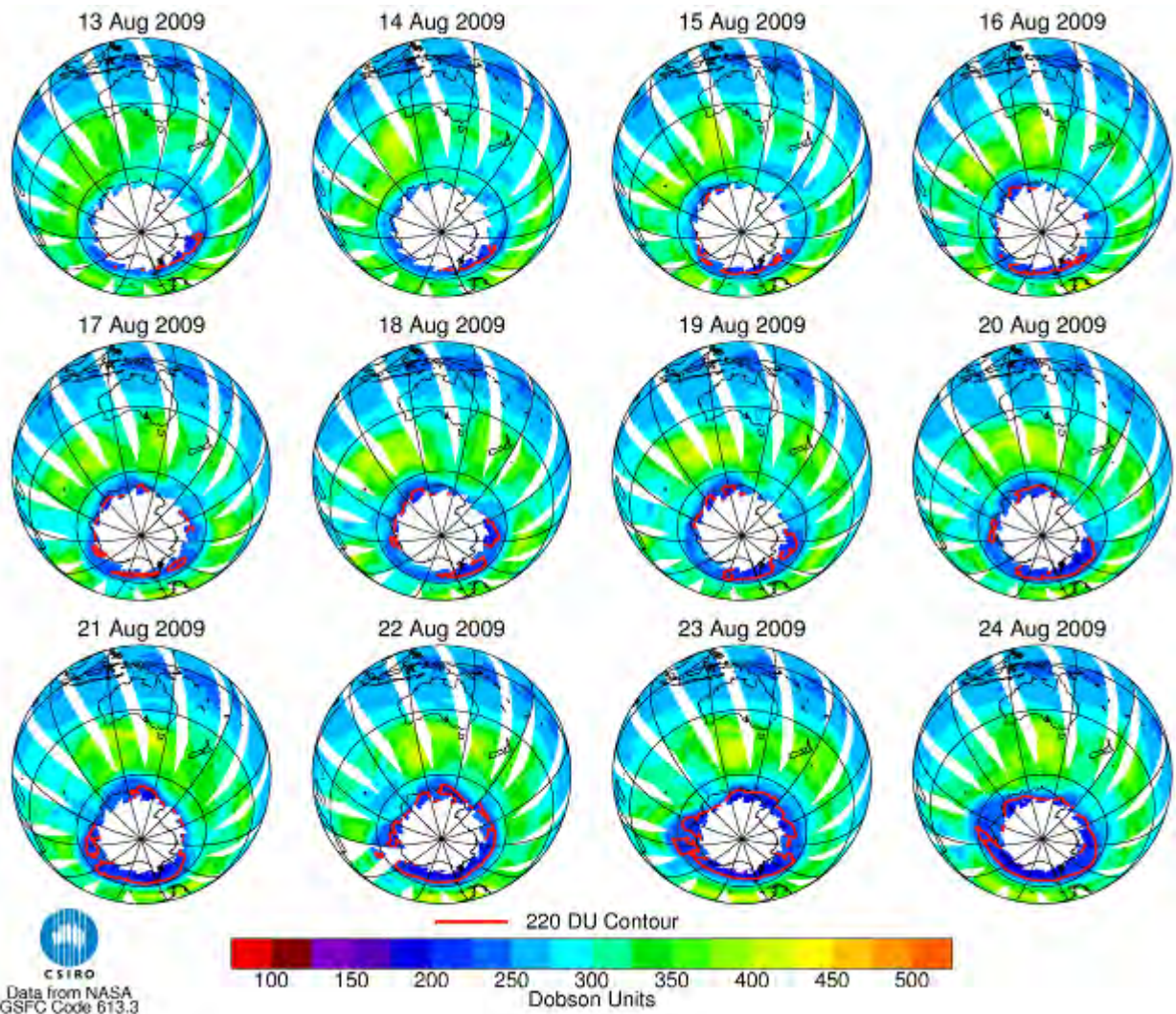
Last updated on Thu Aug 27 14:15:41 2009 by iku021@PBK-A5

**Figure 1:** Ozone hole depth (top panel) and area (bottom panel) based on OMI satellite data, as of August 24 2009.

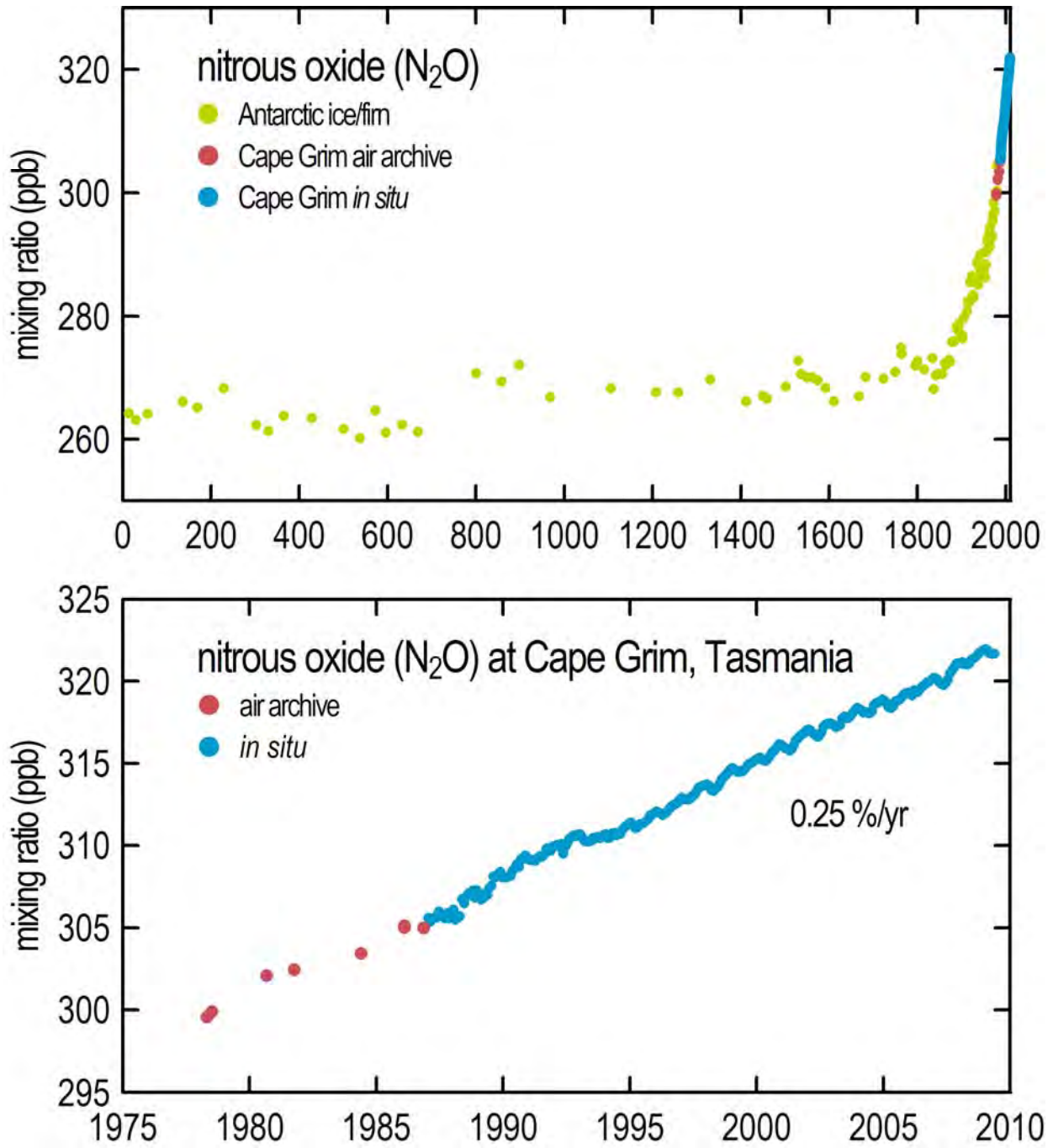


Last Updated on Thu Aug 27 14:15:41 2009 by kru021@PHBK.AS

**Figure 2:** Estimated daily ozone deficit (top panel) and average ozone amount within the ozone hole (bottom panel) based on OMI satellite data, as of August 24, 2009.



**Figure 3:** OMI ozone hole images for 13 to 24 August 2009; the ozone hole boundary is indicated by the red 220 DU contour line. The white area over Antarctica is missing data and indicates the approximate extent of the polar night. The OMI instrument requires solar radiation to the earth's surface in order to measure the column ozone abundance. The white stripes are bad/missing data due to a physical obstruction in the OMI instrument field of view.



**Figure 4:** Nitrous oxide at Cape Grim, Tasmania, since 1978 and over the past 2000 years, from Cape Grim atmospheric and Antarctic ice/firn measurements (MacFarling-Meure *et al.*, 2007; Huang *et al.*, 2008).

## Definitions

CFCs: chlorofluorocarbons, synthetic chemicals containing chlorine, once used as refrigerants, aerosol propellants and foam-blowing agents, that break down in the stratosphere (15-30 km above the Earth's surface), releasing reactive chlorine radicals that catalytically destroy stratospheric ozone.

DU: Dobson Unit, a measure of the total ozone amount in a column of the atmosphere, from the earth's surface to the upper atmosphere, 90 of which resides in the stratosphere at 15–30 km.

Halons: synthetic chemicals containing bromine, once used as fire-fighting agents, that break down in the stratosphere releasing reactive bromine radicals that catalytically destroy stratospheric ozone. Bromine radicals are about 50 times more effective than chlorine radicals in catalytic ozone destruction.

Ozone: a reactive form of oxygen with the chemical formula  $O_3$ ; ozone absorbs most of the UV radiation from the sun before it can reach the earth's surface.

Ozone Hole: ozone holes are examples of severe ozone loss brought about by the presence of ozone depleting chlorine and bromine radicals, whose levels are enhanced by the presence of PSCs (polar stratospheric clouds), usually within the Antarctic polar vortex. The chlorine and bromine radicals result from the breakdown of CFCs and halons in the stratosphere. Smaller ozone holes have been observed within the weaker Arctic polar vortex.

Polar night terminator: the delimiter between the polar night (continual darkness during winter over the Antarctic) and the encroaching sunlight. By the first week of October the polar night has ended at the South Pole.

Polar vortex: a region of the polar stratosphere isolated from the rest of the stratosphere by high west-east wind jets centred at about  $60^\circ S$  that develop during the polar night. The isolation from the rest of the atmosphere and the absence of solar radiation results in very low temperatures (less than  $-78^\circ C$ ) inside the vortex.

PSCs: polar stratospheric clouds are formed when the temperatures in the stratosphere drop below  $-78^\circ C$ , usually inside the polar vortex. This causes the low levels of water vapour present to freeze, forming ice crystals and usually incorporates nitrate or sulphate anions.

TOMS & OMI: the Total Ozone Mapping Spectrometer & Ozone Monitoring Instrument, are satellite borne instruments that measure the amount of back-scattered solar UV radiation absorbed by ozone in the atmosphere; the amount of UV absorbed is proportional to the amount of ozone present in the atmosphere.

UV radiation: a component of the solar radiation spectrum with wavelengths shorter than those of visible light; most solar UV radiation is absorbed by ozone in the stratosphere; some UV radiation reaches the earth's surface, in particular UV-B which has been implicated in serious health effects for humans and animals; the wavelength range of UV-B is 280-315 nanometres.

## Acknowledgements

The TOMS and OMI data are provided by the TOMS ozone processing team, NASA Goddard Space Flight Centre, Atmospheric Chemistry & Dynamics Branch, Code 613.3. The OMI instrument was developed and built by the Netherlands's Agency for Aerospace Programs (NIVR) in collaboration with the Finnish Meteorological Institute (FMI) and NASA. The OMI science team is lead by the Royal Netherlands Meteorological Institute (KNMI) and NASA.