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The 2009 Antarctic Ozone Hole Summary: Tuesday 10 November 2009

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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 utilized 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, 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 August, the ozone minimum in the Antarctic ozone hole had dropped rapidly to 160 DU (similar to 2008), about 1 week earlier than 2006 and 2007, and 1-2 weeks later than in the 2005 hole. By the third week of September the ozone minimum continued to drop rapidly to 115 DU, similar to 2007. By the last week of September the ozone minimum dropped below 100 DU, deeper at this time than any of the past 4 ozone holes. The ozone minimum stayed below 100 DU for about a week, returning to above 100 DU at the beginning of October. By October 3, the ozone minimum had recovered to 103 DU and by October 11 to 109 DU. During the third week of October the ozone minima rose sharply to be at approximately 140 DU by 17 October. This rapid ozone recovery was short-lived, with ozone falling to below 120 DU in late October, before steadily increasing to above 130 DU in early November, lower than any recent ozone hole at this time, except for the exceptionally low ozone hole of 2006. By the end of the first week in November the ozone minimum had touched 140 DU before dropping again to 135 DU. This looks like a very normal ozone recovery. The below 100 DU period in late September defined the ozone minimum for this year, with an ozone minimum of 96-97 DU. Only the record low ozone in 2006 in early October (84 DU) has been lower in recent years (Figure 1, top panel).

The 2009 Antarctic ozone hole is very 'deep', but not 'record breaking' in terms of ozone hole area (Figure 1, bottom panel). During the first and second weeks of September, the ozone hole area remained in the 22-23 million km^2 range, which is very similar to the 2007 hole during the same date range, and about 4 million km^2 smaller than the 2005, 2006 & 2008 holes at the end of the second week of September. By the third week of September the ozone hole area had risen to about 24.5 million km^2, about 3 million km^2 smaller than the 2005, 2006 & 2008 holes at the same time and has stayed at that area for the past week. The ozone hole area achieved by mid-September (24.5 million km^2) was the maximum ozone hole area for this year. By October 7 the ozone hole area declined significantly to 17 million km^2, recovering to 19 million km^2 by October 11 and subsequently dropping rapidly again to 13-14 million km^2 by October 17. The ozone hole area then increased rapidly to 19 million km^2 during the last week of October, falling to 17 million km^2 by early November, staying approximately at that level during the first week of November. Ozone hole area has been quite variable at this time of the year for the past 5 years, varying from 12 million km^2 (2005, 2007) to 22 million km^2 (2006). This year's hole sits in the middle of this range.

Figure 2 (top panel) shows that the estimated daily ozone deficit by the end of the third week of September had reached 33 million tonnes, which was larger than the 2007 & 2008 ozone holes, but less than the 2005 & 2006 ozone holes at the same time. The ozone deficit continued to grow, reaching 36 million tonnes in the last week of September, larger than the past 4 ozone holes, except for the record deficit (45 million tonnes) achieved in 2006, at the same date. By the end of the first week of October, the ozone deficit in the hole declined significantly to 22 million tonnes, recovering to 25 million tonnes by October 11, followed by a dramatic drop to around 12 million tonnes by October 17. The ozone deficit rose to 20 million tonnes by late October and then declined to 17 million tonnes by early November, remaining at 16-17 million tonnes during the first week of November, which is about the average for recent ozone holes at this time of the year.

The average ozone amount in the hole (averaged column ozone amount in the hole weighted by area, Figure 2 bottom panel) dropped rapidly to a minima of about 155 DU during the third week of September, similar to 2005 & 2006 ozone holes and about 13 DU lower than the 2007 & 2008 ozone holes at the same time. By the last week of September the minimum dropped to 150 DU, very similar at this time to 2005 and 2006, lower than 2007 and 2008. The average ozone in the hole stayed at this 150 DU level for over a week, before showing signs of a rapid recovery to 157-158 DU by October 3 and increasing to 157-161 DU by October 11. During the third week of October the average ozone in the hole showed a very rapid recovery to be at 180 DU by October 17, followed by a sharp decline in late October to 170 DU, remaining below 175 DU into early November and recovering to 175 DU by the end of the first week of November. This is lower than all recent ozone holes except the exceptional 2006 hole.

Total column ozone data over Australia and Antarctica for 27 October – 7 November are shown in Figure 3. The vortex appears relatively symmetrical, and therefore likely cold and stable, up to 21 September, with a significant elongation towards the Indian Ocean during 22-26 September. The elongation weakened around September 29-30 before elongating again in the Indian Ocean/African direction by October 3, weakening again by October 5. This elongation was very pronounced and all of the Antarctic coast south of Australia experienced unusually high ozone levels since the beginning of October. During that week the vortex looked one of the least stable vortices for this time of the year. However, during 6-13 October, the vortex became more symmetrical (and presumably stable), but the Antarctic coast south of Australia remained outside the hole. Subsequently, during 14-17 October, the vortex again became very elongated and reduced in size, and by 17-18 October was centred off of the South Pole towards the Atlantic Ocean/South Africa. This explains the sudden changes in the above mentioned ozone hole metrics. However, by October 20, the severe elongation of the vortex declined, becoming more symmetrical, and remaining symmetrical for the next 2 weeks. By early November the vortex centre was located over the pole, and looking quite stable. By November 3, the ozone hole started to distort again, this time with the major axis towards Australia. This is unusual. On November 5 the ozone hole passed quite close to Macquarie Island – it will be very interesting to look at sonde data if available during this period. By November 5 the lobe of the distorted vortex was orientated toward the Tasman Sea, with its northern extension at about 55°S. By November 6-7, the distortion flipped 180° to be pointing towards the South Atlantic. During the period October 27 – November 1 all of the Australian Antarctic stations were under the hole.

The ridge of ozone that formed to the south and west of Australia during 6-9 September, intensified and moved east to be situated south of Australia on 11-12 September. The maximum ozone in this ridge (> 500 DU) is the highest that has been seen for many years. This ridge dissipated during 14-15 September, with another intense ridge forming south of Australia during 16-25 September, dissipating on 26 September. The ridge reformed over the southern Indian Ocean on 30 September, and intensified and moved to the south of Australia by 3 October. It is very intense with areas of ozone levels above 500 DU over the Antarctic coast, very unusual to be this far south and this intense. The ridge weakened after October 5, before intensifying SE of New Zealand during 10-13 October. As of 16-17 October this ridge, now in the 400-450 DU range, covered a very large area around the Antarctic coast from south of Australia to the tip of South America. By October 20, the ridge began to dissipate, coinciding with the return to a more symmetrical vortex. By The end of October, the ridge had disappeared, and the ozone distribution from 30°S to 60°S, showed rare zonal uniformity at about 325-375 DU. No significant ozone ridge had reformed by the end of the first week of November.

Summary

The 2009 ozone hole is a very normal, deep ozone hole. Of the 30 holes for which we have data since 1979, the 2009 hole ranked

13th:	15-day average area	8th:	15-day average minimum ozone
15th:	daily maximum area	8th:	daily minimum ozone
9th:	daily ozone deficit	8th:	daily min average ozone amount in the hole

Once the ozone hole has recovered for this year, we will then be able to rank the 2009 ozone hole for the integrated ozone deficit metric.

Literature

In June 2009, the US National Academy of Science hosted a major meeting in Washington to celebrate 20-years of the NASA Earth System Science Program.

Many eminent scientists in the NASA program presented, including Richard Stolarski (NASA) who reported that the ozone hole is estimated to begin decreasing in the 2020s and be fully recovered by 2070.

Australian Judith Lean (US Naval Research Laboratory) discussed natural and anthropogenic influences on global surface temperatures. Lean concluded that the lack of warming over the past decade can be attributed in part to declining solar radiation from 2002 to the current (2009) solar minimum. Natural drivers account for <15% of the observed warming since 1890 (GHGs and aerosols drive 85% of temperature changes since 1890). Lean suggested that global surface temperatures will increase over the next 5 years due to the anticipated increase in solar irradiance during this period, perhaps to new record global temperatures.

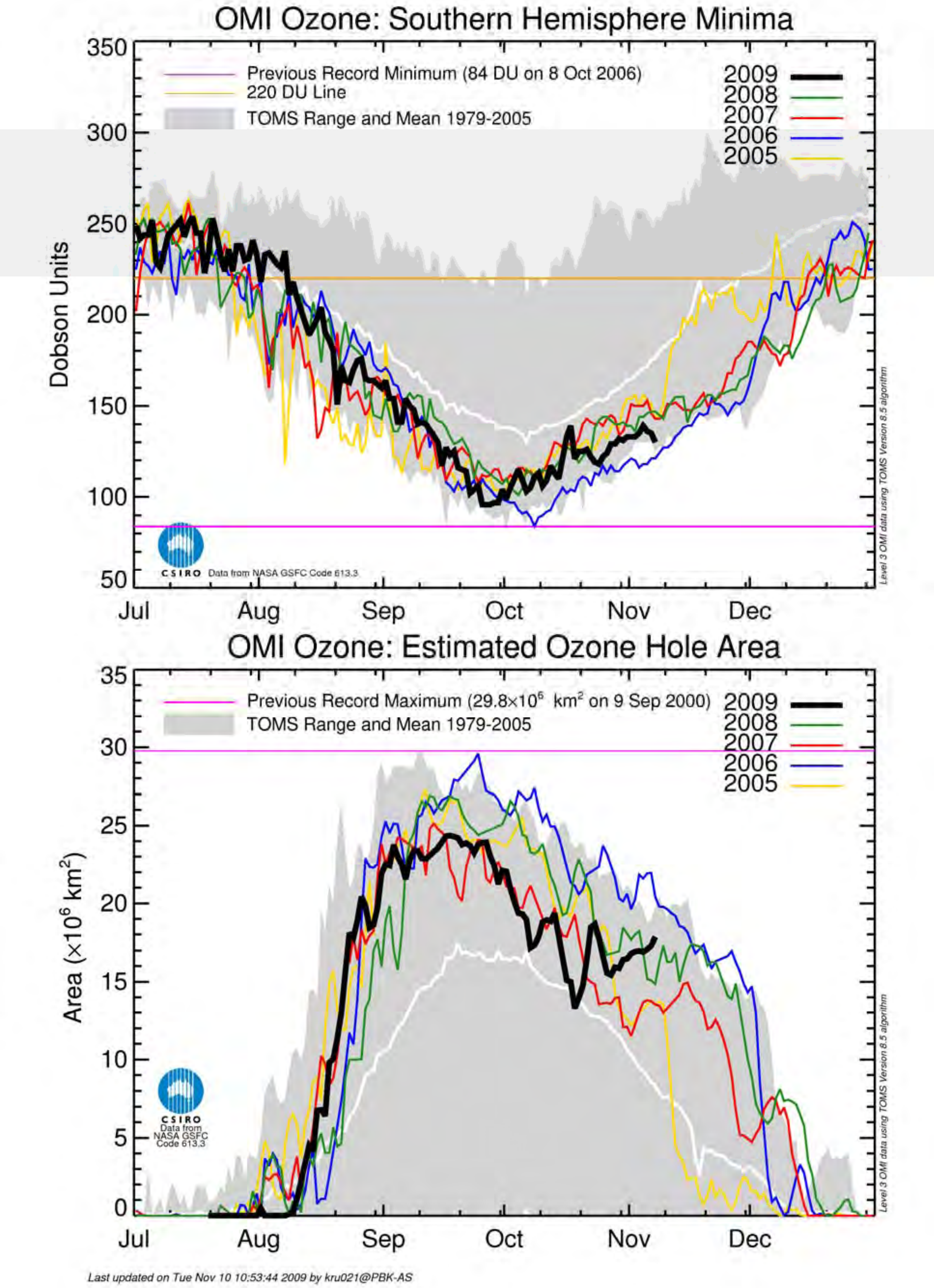

Figure 1: Ozone hole depth (top panel) and area (bottom panel) based on OMI satellite data, as of 7 November 2009.

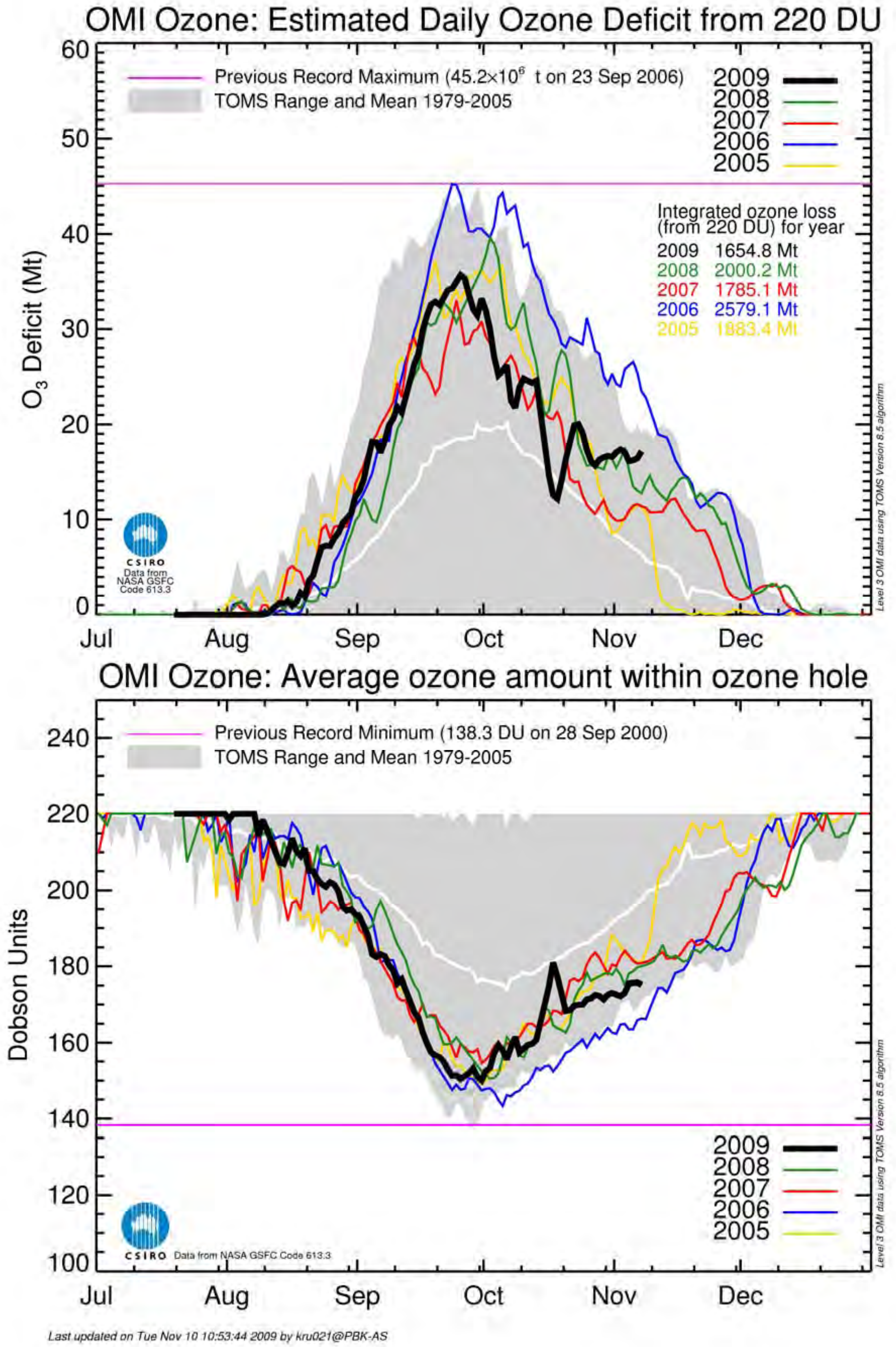

Figure 2: Estimated daily ozone deficit (top panel) and average ozone amount within the ozone hole (bottom panel) based on OMI satellite data, as of 7 November 2009.

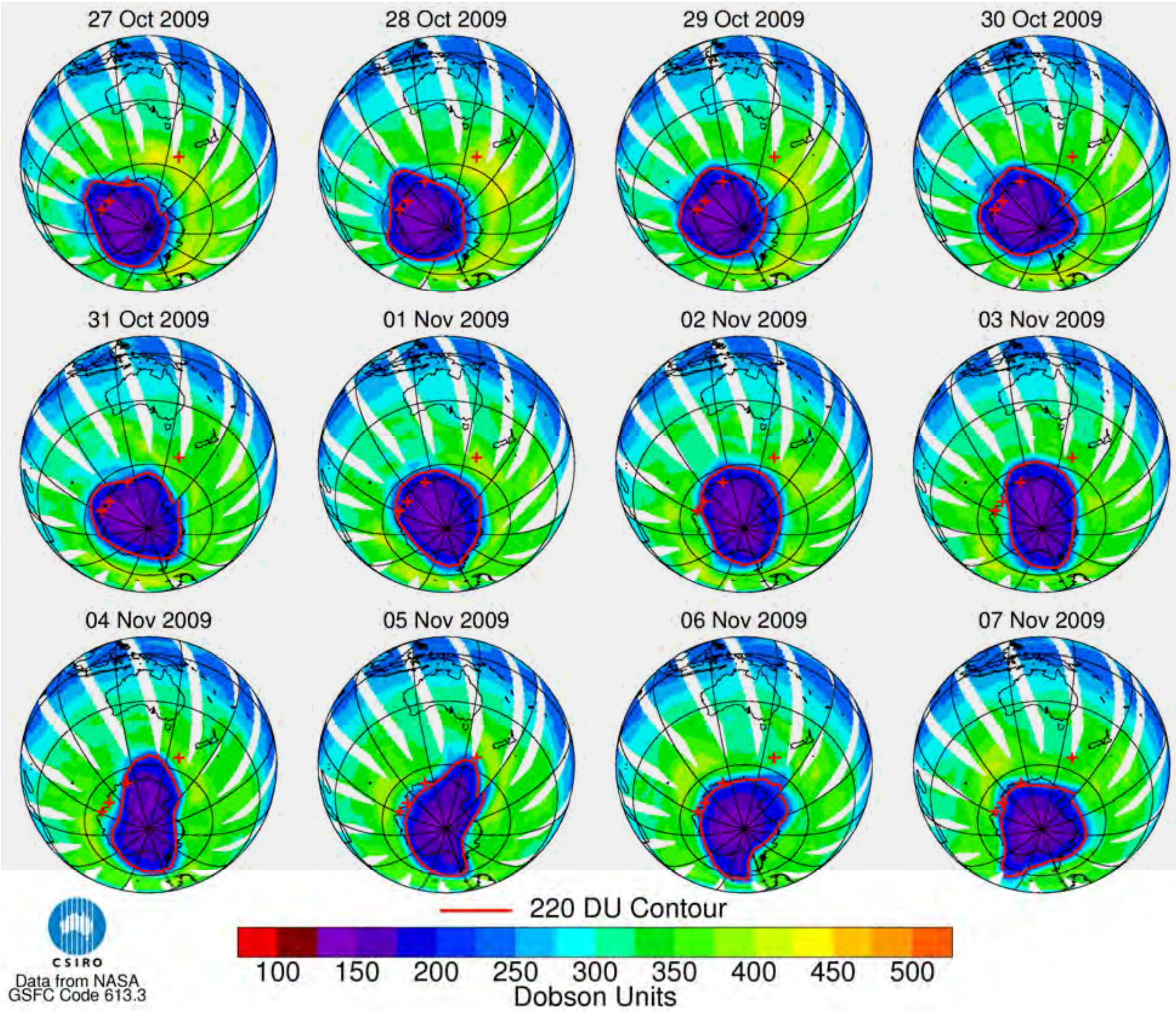

Figure 3: OMI ozone hole images for 27 October to 7 November 2009; the ozone hole boundary is indicated by the red 220 DU contour line. The Australian Antarctic (Mawson, Davis and Casey) and Macquarie Island stations are shown as red plus symbols. The white stripes are bad/missing data due to a physical obstruction in the OMI instrument field of view.

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 to 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°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°C) inside the vortex.

PSCs: polar stratospheric clouds are formed when the temperatures in the stratosphere drop below -78°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

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