Australian National Report
for the 8th WMO/UNEP Ozone Research Managers Meeting
2-4 May 2011, Geneva, Switzerland

1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss.

The Australian Government's Bureau of Meteorology (BoM) has primary responsibility for monitoring total column ozone.

- The BoM Dobson network consists of stations located at Brisbane, Darwin, Macquarie Island, Melbourne, and Perth (Perth is operated in conjunction with NOAA). Brisbane, Macquarie Island and Melbourne have records stretching back to 1957.

A number of universities also undertake some total ozone monitoring:

- A Brewer spectrophotometer operated by the University of Tasmania (operating costs financed by the BoM).
- Two Mk IV Brewer spectrophotometers operated by the Queensland University of Technology.
- Remote sensing FTIR operated by the University of Wollongong (the measurements are made as part of the Network for the Detection of Atmospheric Composition Change, NDACC).

Measurements of ozone depleting substances (CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride and methyl chloroform) are made by GC-ECD and GC-MS techniques at Cape Grim, Tasmania, and Aspendale, Victoria by CSIRO and BoM.

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

Regular ozonesonde measurements are taken by the BoM at:

- Macquarie Island (weekly flights since 1994)
- Melbourne (weekly flights, with a program having operated from various locations around Melbourne since 1965).
- Davis station, Antarctica, in conjunction with the Australian Antarctic Division (AAD), since 2003. Flights are currently weekly for the whole year. In conjunction with these ozonesonde flights, the AAD operates a Rayleigh/Mie/Raman lidar at Davis to measure temperature and aerosol loading in the stratosphere.

1.3 UV measurements

1.3.1 Broadband measurements

The Australian Radiation and Nuclear Safety Agency (ARPANSA) has maintained a network of UV detectors in capital cities around Australia since 1989. In 1996 the instruments were changed over to Solar Light UVB 501 broadband biometers. Kingston, Tasmania was added in 2007 and more recently Canberra was added as a new site (December 2010). Biometers have also been collecting data at Macquarie Island since 2001 and the Australian Antarctic stations Mawson, since 2002, and both Davis and Casey since 1996. The sites in Antarctica are currently being upgraded with new biometers. The biometers are intercompared at Yallambie before placement in the field. Spectral measurements with traceable calibrations at Antarctic

mainland stations commenced in 2010 at Davis and Mawson. In 2011 a Bentham spectral system was installed at Davis for at least two summers with the aim of providing a longer duration series of calibrated spectral measurements, with the aim to subsequently extend this to both Mawson and Casey as well.

The Queensland University of Technology uses Solar Light 501 UV biometers in Brisbane to provide a live UV Index update to the public, as well as operating a national network of Yankee UVB pyranometers, located in Brisbane, Townsville, Canberra and Hobart.

1.3.2 Narrowband filter instruments

N/A

1.3.3 Spectroradiometers

The BoM owns and operates two NIWA-designed spectroradiometers at Alice Springs and Melbourne.

A UV spectroradiometer generated data at Cape Grim between 1999 and 2006. A repaired spectrometer is awaiting site works for redeployment and a replacement system has been developed at BoM and is undergoing field testing.

ARPANSA currently uses a Bentham spectroradiometer based at the Melbourne site to simultaneously measure solar UVR and transfer a traceable calibration to the biometers before installation. This instrument commenced measurements in December 2008 and has been operating continuously since then.

1.4 Calibration activities

The BoM holds the RA V Dobson standard and operates the Regional Dobson Calibration Centre (RDCC) for Australia. The regional standard Dobson is inter-compared regularly with the world standard Dobson. ARPANSA meets the WMO's instrument specifications and characterization as a health advisory agency that provides the daily UV levels. CSIRO/BoM ODS measurements employ calibration standards supplied by the Scripps Institution for Oceanography (USA) and the data are regular compared to data collected at Cape Grim by NOAA (USA), U. East Anglia (UK) and NIES (Japan).

An Australian Dobson expert attended the WMO Dobson Data Quality Workshop recently held in Hradec Kralove, Czech Republic.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozonesonde and Dobson data from the Bureau network are available through the WOUDC and are frequently used for purposes such as satellite calibrations and trend analysis.

A clear-sky UV Index Climatology (1979-2007) has been developed and is available at: http://www.bom.gov.au/jsp/ncc/climate_averages/uv-index/index.jsp .

Analyses of ozonesonde data from Davis station (Antarctica) are used in the following areas;

- Investigation of polar ozone loss processes and ozone variability through project 737 of the Australian Antarctic program (e.g. Klekociuk and Tully, 2007; Innis and Klekociuk, 2006; see also http://cs-db.aad.gov.au/proms/public/projects/report_project_public.cfm?season=0708&project_no=737)
- Near real-time analyses of ozone in the Southern Hemisphere winter (WMO Antarctic Ozone Bulletins; see http://www.wmo.ch/pages/prog/arep/gaw/ozone/index.html)
- Satellite and instrument validation (e.g. Dupuy et al., 2008).

Existing UVR measurements have had difficulties in detecting any increase in UVR due to the natural variability in solar UVR at the earths surface (Peter Gies et al., 2004).

ODS data collected at Cape Grim have been used in recent international assessments of climate change (IPCC 2007) and ozone depletion (WMO 2011), and are reported biennially in Baseline (Krummel et al., 2007). The data have been used in the Commonwealth Government State of the Environment Report (Beer et al., 2006).

3. THEORY, MODELLING, AND OTHER RESEARCH

Using the UK Chemistry and Aerosols (UKCA) model within the Australian Community Climate and Earth-Simulation System (ACCESS) framework, researchers at the University of Melbourne and CSIRO, along with collaborators at the New Zealand National Institute of Water and Atmospheric Research (NIWA) are developing the capability of a fully coupled atmosphere-chemistry (and eventually ocean) model. The model will be used to simulate the stratospheric ozone layer chemistry and dynamics with the goal of a better understanding of the impacts of the development and recovery of the Antarctic Ozone Hole on the climate of the southern hemisphere.

Recently Arblaster, Meehl and Karoly (Arblaster et al. 2011) have studied the impact of ozone depletion and recovery on southern hemisphere climate.

With the implementation of the ACCESS modelling system, an Ozone and UV forecast (ACCESS-O3+UV) system has been developed to predict the ozone field within the ACCESS framework. The assimilation and forecast system provides extended ozone forecast from 3d variational (3dVAR) assimilation of ATOVS radiances and a modified version of the ACCESS-NWP unified model (UM) (Lemus-Deschamps et al. 2008). The UV and ozone forecast system http://www.bom.gov.au/uv/index.shtml is under continuous development.

Satellite and surface measurements have been used to investigate ozone and UV changes over Australia and skin cancer incidence (Lemus-Deschamps and Makin, 2011; Makin and Lemus-Deschamps, 2011).

Studies of the Antarctic Ozone Hole in recent years have been made in Tully et al. (2008, 2011). Recent analysis by Salby et al. (2011) reports the strong control of inter-annual variability in the size of the Antarctic Ozone Hole by stratospheric dynamics, and the recent unambiguous sign of ozone recovery.

Work by Innis and Klekociuk (2006) and Alexander et al. (2011) has quantified the effects of planetary waves and orographic gravity waves, respectively, on the formation of Polar Stratospheric Clouds.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

Ozonesonde and Dobson data from all Bureau of Meteorology stations are archived at the World Ozone and UV Data Centre (WOUDC).

Measurements of column amounts from the FTIR system at Wollongong are reported via the Network for Detection of Atmospheric Composition Change (NDACC) database (see http://www.ndsc.ncep.noaa.gov/data/), as are spectral UV data from Alice Springs.

4.2 Information to the public

A UV forecast is issued daily by the Bureau of Meteorology. The UV forecast is important because approximately 380,000 Australians still get skin cancer every year. The UV forecast is released to the public by the Bureau of Meteorology regional office in each state and it is provided to the media as part of the weather report (Deschamps et al., 2006). It is also available at http://www.bom.gov.au/uv/index.shtml , and it is extensively used in Australia's SunSmart promotional and educational campaigns.

ARPANSA provide measured real-time UV levels which are updated every minute. A plot of the UV levels for Australian sites is available on the ARPANSA web site at http://www.arpansa.gov.au/uvindex/realtime/index.cfm. Historical UV index data since 2004 is also available on the ARPANSA web site at http://www.arpansa.gov.au/uvindex/monthly/ausmonthlyindex.htm

The Queensland University of Technology's Aus Sun Research Lab maintains a website giving five-minute updates of the UV Index in Brisbane: http://www.uv.hlth.qut.edu.au/community/uvindex.jsp

Ozone analyses and forecasts are used by a number of groups to issue statements on the development of the ozone hole each year.

4.3 Relevant scientific papers

Arblaster, J.M., Meehl, G.A. and Karoly D.J. 2011: Future climate change in the Southern Hemisphere: Competing effects of ozone and greenhouse gases, Geophys. Res. Lett., 38, L02701, doi:10.1029/2010GL045384

Alexander, S. P., Klekociuk, A.R., Pitts, M.C., McDonald, A.J. and Arevalo-Torres, A. 2011: The effect of orographic gravity waves on Antarctic polar stratospheric cloud occurrence and composition, J. Geophys. Res., 116, D06109, doi:10.1029/2010JD015184.

Beer T, Borgas M, Bouma W, Fraser P, Holper P, Torok S 2006: 'Atmosphere', theme commentary prepared for the 2006 Australia State of the Environment Committee, Department of Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/atmosphere/index.html >.

Deschamps L., P. Gies, L. Rikus, R. Dare and K. Strong, 2006: UV Index for Sun Safety. *BMRC Res.Lett.* No4, 34-35.

E. Dupuy, K. A. Walker, J. Kar, et. Al, 2008: Validation of ozone measurements from the Atmospheric Chemistry Experiment (ACE). *Atmos. Chem. Phys. Discuss.*, 8, 2513-2656, 2008

Peter Gies, Colin Roy, John Javorniczky, Stuart Henderson, Lilia Lemus-Deschamps and Colin Driscoli, 2004. Global Solar UV Index: Australian Measurements, Forecasts and Comparison with the UK. *Photochem. Photobiol.* 79, 1, 32-39.

Grytsai, A.V., Evtushevsky, O.M., Agapitov, O.V., Klekociuk, A.R., Milinevsky, G.P. 2007. Structure and long-term change in the zonal asymmetry in Antarctic total ozone during spring. *Annales Geophysicae* 25. 361-374.

Innis, J.L., Klekociuk, A.R., 2006: Planetary wave and gravity wave influence on the occurrence of polar stratospheric clouds over Davis Station, Antarctica, seen in lidar and radiosonde observations. *Journal of Geophysical Research.* 111. D22102, doi:10.1029/.

Klekociuk, A.R.,and Tully, M.B., , 2007: Seasonal variation of ozone above Macquarie Island and Davis *BMRC Research Letters 6.* 12-16.

Lemus-Deschamps, L. and J. Making. 2011: Fifty years of changes in UV Index and skin cancer in Australia: Submitted to Int.J. Biometeorol, 23 March, 2011

Lemus-Deschamps L., 2007: The Ozone and UV Forecasting System, Presented at the *AMOS Conference*, Adelaide, Australia, February 2007.

Lemus-Deschamps L., J. Easson and P. Shinkfield, 2007: Changes in Ozone and UV Index of Australian Cities (1958-2004). Presented at the *AGU Conference*, Acapulco Mexico, May 2007.

Lemus-Deschamps L., B. Tacal, L.Huntington, J. Easson and P. Shinkfield, 2007: Ozone and UV Index over Australia (1958-2004). Presented at the *AMOS Conference*, Adelaide, Australia, February 2007.

Lemus-Deschamps, L., P. Gies, L. Rikus, K. Strong and H. Dixon, 2006: *UV Index: Forecasts and Media Weather Reports. UV Radiation and its Effects,* Report of the NIWA Workshop, Dunedin, New Zealand, April 2006. RSNZ, Miscellaneous series 68,25-26.

Lemus-Deschamps L., L.Rikus, S.Grainger, P.Gies, J.Sisson and Z.Li, 2004: UV index and daily total UV dose distributions for Australia (1997-2001). *Aust.Met.Mag.* 53,239-250.

Lemus-Deschamps Lilia, Lawrie Rikus and Peter Gies, 1999: The operational Australian ultraviolet index forecast 1997. *Meteorol. Appl.* 6, 241-251.

Makin., J. and L. Lemus-Deschamps. 2011: Implications of increases in UV Index (1959-2009) and climate change for skin cancer prevention in Australia: submitted to Australian New Zealand Journal of Public Health, 23 March 2011)

Salby, M., E. Titova, and L. Deschamps. 2011: Rebound of Antarctic ozone, Geophys. Res. Lett., doi:10.1029/2011GL047266, in press.

Siddaway, J. M., and S. V. Petelina. 2011: Transport and evolution of the 2009 Australian Black Saturday bushfire smoke in the lower stratosphere observed by OSIRIS on Odin, *J. Geophys. Res.*, 116, D06203, doi:10.1029/2010JD015162.

Tully, M.B., Klekociuk, A.R., Deschamps, L.L., Henderson, S.I., Krummel, P.B., Fraser, P.J., Shankin, J.D., Downey, A.H., Gies, H.P. and Javorniczky, J. 2008: The 2007 Antarctic Ozone Hole. *Aust. Met. Mag., 57,* 279–98.

Tully, M.B. , A.R. Klekociuk, S.P. Alexander, R.J. Dargaville, L.L. Deschamps, P.J. Fraser, H.P. Gies, S.I. Henderson, J. Javorniczky, P.B. Krummel, S.V. Petelina, J.D. Shanklin, J.M. Siddaway and K.A. Stone. 2011: The Antarctic ozone hole during 2008 and 2009, *Aust. Met. Oceanogr. J., 61,* 77-90.

Wilson, S. R. 2006: The Cape Grim Scanning UV Spectrometer, in *Baseline Atmospheric Program (Australia) 2003-2004*, edited by J. M. Cainey, et al., pp. 9-16, Bureau of Meteorology/ CSIRO Atmospheric Research, Melbourne.

Wilson, S. R. 2007: Effect of temperature on the Cape Grim UV-B records, in *Baseline Atmospheric Program (Australia) 2005 - 2006*, edited by J. M. Cainey, et al., pp. 25-30, Australian Bureau of Meteorology and CSIRO Marine and Atmospheric Research, Melbourne.

5. PROJECTS AND COLLABORATION

Information on Australian activities related to ozone and UV is shared through the *Australian Ozone Science Group,* co-ordinated by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), which has led to increased co-operation between agencies and institutions.

The Bureau of Meteorology has ongoing collaboration projects with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on UV Index validation against surface measurements and with SunSmart (Cancer Council Australia) on the use of the UV Index to promote sun protection; and

The BoM/AAD ozonesonde and AAD lidar measurements at Davis station in Antarctica have contributed to the International Polar Year cluster project ORACLE-O3, and the CONCORDIASI and MATCH campaigns.

A number of Australian scientists contributed as lead-authors, co-authors, contributors or reviewers of the 2010 Scientific Assessment of Ozone Depletion, supported by DSEWPC.

6. FUTURE PLANS

- Total column FTIR measurements of ozone and related trace gases at Davis station are currently being validated by the AAD.
- A low-cost UV spectroradiometer is also being developed by the BoM and is currently being field-tested.

7. NEEDS AND RECOMMENDATIONS

Continued provision and development of international data archival facilities (e.g. WOUDC) and instrument calibration standards and inter-comparisons (e.g. through NDACC and WMO).