

**Australian National Report
for the 9th WMO/UNEP Ozone Research Managers Meeting
14-16 May 2014, 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).

NIWA operates a zenith viewing spectrometer at Macquarie Island for NO₂ column and profile information as part of NDACC.

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 conducted weekly from May to November and monthly from December to April. Since early 2014, the Chinese Academy of Meteorological Sciences (CAMS) has been collaborating in this programme, which now also involves information exchange and research associated with atmospheric chemistry measurements at China's Zhongshan station (near Davis). In conjunction with some of these ozonesonde flights, the AAD has operated a Rayleigh/Mie/Raman lidar at Davis to measure temperature and aerosol loading in the stratosphere (the lidar operated from 2001-2012 and is anticipated to collect further data from 2016).

Coarse vertical resolution profiles from Dobson Umkehr measurements have been made at BoM Dobson network sites dating back to 1962. Umkehr observations are still made at Brisbane, Darwin and Perth. (Stone et al., in preparation for AMT).

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.

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. ARPANSA also currently measures solar UVR using a Bentham spectroradiometer at Davis Station in the Antarctic.

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, most recently in Boulder in August 2013. 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).

1.5 Ozone Depleting Substances

Australian activities in ODS research are focused on *in situ* observations at the WMO Baseline Station at Cape Grim, Tasmania (funded and managed by the Australian Bureau of Meteorology), at the CSIRO laboratory at Aspendale, Victoria, and on air samples collected for the Cape Grim Air Archive and from the CSIRO Australian and global flask sampling networks. Australian activities also include ODS modeling, and all ODS observational and modeling research involve collaborations with AGAGE (Advanced Global Atmospheric Gases Experiment) and other colleagues in the USA, Europe and Japan.

ODSs monitored and modeled in the Australian program include species from all the major ODS groups – CFCs (chlorofluorocarbons), HCFCs (hydrochlorofluorocarbons), halons, chlorocarbons, bromocarbons and nitrous oxide.

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.

The Melbourne Dobson record from 1978-2012 was analysed in Tully, Klekociuk and Rhodes (2013) who found total ozone has been closely tracking mid-latitude EESC over this period.

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 et al., 2011; Klekociuk and Tully, 2007; Innis and Klekociuk, 2006; see also https://secure3.aad.gov.au/proms/public/projects/report_project_public.cfm?season=1112&project_no=737 and https://secure3.aad.gov.au/proms/public/projects/report_project_public.cfm?season=1213&project_no=4012)
- 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).

Gies et al 2013 studied a low ozone event observed over southern Australia in August 2011, which led to anomalously high UV exposure for this time of year.

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 . (Lemus-Deschamps and Making 2011).

Australian ODS research made a major contribution to the WMO/UNEP *Scientific Assessment of Ozone Depletion: 2010* and is currently making a major contribution to the 2014 Assessment.

ODS contributions to Equivalent Effective Stratospheric Chlorine (EESC) and global radiative forcing (RF) have been derived from Cape Grim and other global AGAGE stations, from the Cape Grim Air Archive and from Antarctic firn air (Rigby et al., 2013, 2014; Fraser et al., 2014a).

Global and Australian regional estimates of HCFC-22 and CCl₄ emissions have been derived for these important ODSs from Cape Grim and global AGAGE data (Xiao et al., 2010a; Saikawa et al., 2012; Fraser et al., 2014b).

Global emissions of the four major halons in the atmosphere have been derived from Cape Grim Air Archive data (Newland et al., 2013).

Several new ODSs, some of which are growing in the background atmosphere, have been identified in the Cape Grim Air Archive and their emissions and lifetimes have been estimated (Laube et al., 2014).

AGAGE data, including Cape Grim, have been used to derive a revised estimate of the sources and sinks of atmospheric methyl chloride, the most abundant natural ODS in the atmosphere (Xiao *et al.*, 2010b).

Cape Grim and AGAGE global *in situ* nitrous oxide (N₂O) data and N₂O data from the CSIRO global monitoring network have been used to substantially advance the understanding of the sources and sinks of this important ODS and the cause of its long-term increase in the background atmosphere (nitrogenous fertilizers) (Nevison *et al.*, 2010; Park *et al.*, 2012; Thompson *et al.*, 2013, 2014a,b,c).

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 is being 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.

- Specific simulations are being performed for the 1st Chemistry-Climate Model Initiative (CCMI-1). This work operates under project q90 of the National Computational Infrastructure, and Project 4012 of the Australian Antarctic Science (AAS) scheme (https://secure3.aad.gov.au/proms/public/projects/report_project_public.cfm?season=1213&project_no=4012).
- AAS Project 4012 (Polar Feedbacks of Ozone Recovery on Climate in the Southern Hemisphere) is using the model output to investigate the influence of ozone zonal asymmetries on Antarctic surface climate.

Siddaway *et al.* (2013) examined the timing of the return to pre-ozone hole conditions in spring and summer ozone recovery using model simulations from the 2nd Chemistry-Climate Model Validation activity (CCMVal-2), finding that recovery is slower in the later months.

Arblaster, Meehl and Karoly (Arblaster *et al.* 2011) have studied the impact of ozone depletion and recovery on Southern Hemisphere climate.

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 2011).

Using ground-based and satellite instruments, Innis and Klekociuk (2006) and Alexander *et al.* (2011, 2013) have quantified the effects of planetary waves and orographic gravity waves, respectively, on the formation of Polar Stratospheric Clouds.

CIO data from microwave measurements made at Scott base have been used to examine the chlorine dimer ozone loss kinetics (Kremser, Schofield *et al.*, 2011).

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.

Cape Grim and AGAGE global ODS data, and N₂O data from the CSIRO global flask monitoring network are regularly archived at the WMO World Data Center for Greenhouse Gases (WDCGG) in Japan: <http://ds.data.jma.go.jp/gmd/wdcgg/>

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 are diagnosed with 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. (This system currently uses GFS ozone forecasts and ACCESS meteorological fields as input to the UV radiation code to forecast UV Index. Aerosols and UV surface albedo effects are also included).

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>

The Melbourne of Melbourne Earth Sciences' website provides five-minute UV index updates for Melbourne <http://www.earthsci.unimelb.edu.au/weather-station-data>

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

During spring of each year, CSIRO provides a weekly update on the status of the ozone hole, based primarily on satellite data from OMI and TOMS, which is posted on the Department of Environment website and publicly available.

4.3 Relevant scientific papers (those published since 2011 or otherwise referenced in this report)

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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 Environment, which has led to increased co-operation between agencies and institutions.

A number of Australian scientists contributed as lead-authors, co-authors, contributors or reviewers of the 2010 and 2014 Scientific Assessment of Ozone Depletion, supported by the Department of Environment. David Karoly is a member of the Scientific Steering committee for the 2014 Scientific Assessment of Ozone Depletion, again supported by the Department of Environment.

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.

ARPANSA has an ongoing collaborative project with the Australian Antarctic Division entitled Determination of the ultraviolet radiation environment at the Australian Antarctic Stations using broadband and spectral instrumentation (AAS 4115).

6. FUTURE PLANS

- Chemistry-climate simulations using the ACCESS model will be archived for the CCMI-1 project.
- The historic Umkehr Dobson record is to be reanalysed for the Australian region (BoM – University of Melbourne).
- The BoM is planning to purchase a number of new instruments to operate alongside network Dobsons as well as continuing to develop new UV spectral radiometers.

7. NEEDS AND RECOMMENDATIONS

Support for ongoing long term observational programs.