Canadian 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

The Canadian Brewer Ozone Spectrophotometer network consists of 8 real-time reporting stations that provide data directly to the Canadian Meteorological Centre in support of operational requirements. Each of the southern network stations operates two Brewer Spectrophotometers and the Arctic stations have three instruments on site. The additional instruments provide redundancy to reduce overall travel costs, especially in the Arctic, should an instrument fail; provides a means of optimizing the observation of both columnar ozone and UV spectral irradiance; and provides extra data for quality assurance purposes. The Arctic instruments are scheduled to perform moon observations during the Arctic night. Over the last several years Environment Canada has embarked upon an aggressive Life Cycle Management program as part of their ISO 9001 certification. The Brewer network has benefited from this program so that MK III Brewers (double Brewers) are installed at each of the network sites.

The Richmond, BC (Vancouver) site was established in 2010 and following an appropriate overlap period will probably replace the present Saturna Island location. Two reasons for this change are the overall increase in efficiencies associated with travel and maintenance costs, and the improved location of the instrument to provide real-time UV Index information to a major Canadian population area.

Besides the operational network, efforts are underway to establish Brewer Spectrophotometers at each ozonesonde location where the networks are not presently collocated. This will improve the overall quality of the ozonesonde profiles through corrections of the integrated ozonesonde column to the Brewer ozone column observations. Presently, Kelowna, BC and Egbert, ON have collocated Brewers for this purpose and installation at the last station, Yarmouth, NS, is underway.

Canada, in collaboration with the U.S. National Oceanic and Atmospheric Administration (NOAA), maintains a Brewer instruments at the Mauna Loa Observatory, Hawaii and at South Pole Station, Antarctica. There are a number of other Brewers operated by Canadian universities for research purposes that do not report data on a regular basis.

Table 1. Locations of the Canadian Operational Brewer Network. The date the site was established represents the when column ozone observations commenced.

NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	ESTABLISHED
Alert	82.50	62.30	1989
Churchill	58.75	94.00	1964
Edmonton (Stony Plain)	53.55	114.10	1957
Eureka	80.05	86.43	1992
Goose Bay	53.32	60.30	1962
Regina (Bratt's Lake)	50.21	104.67	1994
Resolute Bay	74.72	94.98	1957
Saturna Island	48.78	123.13	1990
Toronto (Downsview)	43.78	79.47	1960
Richmond (Vancouver)	49.182	123.078	2010

1.2 Profile measurements of ozone

Environment Canada launches ozonesondes at 10 locations across Canada once per week using Ensci Inc. sondes. Eight of these stations are operated using the facilities of the Meteorological Service of Canada,[1] while 2 are located at Science and Technology Branch facilities. Sondes are launched from appropriate stations with higher frequency during campaigns such as Match (Alfred Wagner Institute, Bremerhaven, Germany) and for short-term process studies within North America (e.g., BORTAS (see below).

Table 2. Locations of the Canadian Ozonesonde Network.

NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	ESTABLISHED
Alert	82.50	62.30	1987
Churchill	58.75	94.00	1973
Edmonton (Stony Plain)	53.55	114.10	1970
Egbert (Centre for Atmospheric Research	44.23	79.78	2003

[1] Environment Canada completed a reorganization of functions in 2007 whereby a new Science and Technology (S&T) Branch was created and atmospheric science research was separated from the more operational aspects of weather and environmental monitoring which remained as the Meteorological Service of Canada (MSC). The ozone monitoring program straddles these two branches.

Experiments)			
Eureka	80.05	86.43	1992
Goose Bay	53.32	60.30	1969
Kelowna	49.94	119.40	2003
Regina (Bratt's Lake)	50.21	104.67	2003
Resolute Bay	74.72	94.98	1966
Yarmouth	43.87	66.11	2003

Environment Canada operated a stratospheric ozone LIDAR at Eureka, NU until 2009, when its laser failed. In summer 2009 a new laser was installed, but because of electronics problems the LIDAR could not be returned to functionality. Because of the obsolescence of the electronics and operating system of this LIDAR, this instrument has yet to be returned to operation. A second stratospheric LIDAR is being developed approximately 80 km north of Toronto at the Centre for Atmospheric Research Experiments (CARE) using the same laser system as the arctic instrument. Once this second system is completed and tested, the expectation is to have a duplicate set of pre-tested electronics installed at Eureka.

1.3 UV Measurements

1.3.1 Broadband measurements

Broadband observations are not made by Environment Canada, however commercial forecasting companies such as the Weather Network have developed their own broadband UV network for observing erythemal-weighted UV at major Canadian cities.

The United States Department of Agriculture (USDA) UV-B Monitoring and Research Program network is collocated with two Canadian Brewer Spectrophotometer sites in Canada – Bratt's Lake Observatory and Toronto. As part of their measurement program they obtain erythemal-weighted UV-B irradiance using a Yankee Environmental Systems UVB-1 Pyranometer. Further information can be found at: http://uvb.nrel.colostate.edu/UVB/index.jsf

1.3.2 Narrowband filter instruments

Similarly, narrowband filter instruments are not used in Canada other than at the two stations operated in conjunction with the USDA UV-B Monitoring and Research Program.

1.3.3 Spectroradiometers

Observations of spectral UV-irradiance are made using Brewer Spectrophotometers. Because of the dual purpose of these instruments, the number of observations of ozone and spectral UV irradiance are optimized by location and time-of-year. Approximately 5 UV spectra are obtained each hour. A single spectrum, consisting of a forward and backward scan across the grating is obtained in about 8 minutes.

1.4 Calibration Activities

Canada continues to host the World Brewer Ozone Triad and supports the European Brewer (MK III) Ozone Triad located at El Arenosillo Atmospheric Sounding Station, Spain. To date, Environment Canada has sent a double Brewer and two scientists to participate in the bi-annual calibration event and to ensure that the reference maintained in Spain remains in concert with the reference Triad in Toronto.

The World Brewer Ozone Triad is maintained through regular calibration trips to Mauna Loa, Hawaii where Environment Canada maintains a Mark III Brewer Spectrophotometer. Through the maintenance of this single instrument and the calibration of multiple Brewer instruments brought, including one from the Triad, the overall reference Triad is continuously evaluated and maintained. With the overall up-grading of the Canadian network, a number of Mk III Brewers are being evaluated to eventually upgrade the Triad to the Mk III instruments,

The standard and UV lamps of network instruments are monitored constantly to ensure proper operation of each instrument. Should information being reported from the lamp tests or other instrument diagnostics fall outside acceptable levels the instruments are either serviced on site or sent to Toronto for servicing, or removed from network operations (for Arctic stations). Following any servicing of an instrument that might impact the quality of the observations, calibrations are completed as part of the servicing operation. Should an instrument not require servicing sooner, it undergoes a complete on-site service once every two years by Environment Canada technicians. As part of this overhaul, both ozone and UV calibrations are undertaken before and after any work is undertaken on the instrument. Information calibration and servicing methods can be found at: ftp://ftp.tor.ec.gc.ca/documentation/SOP_Documents

2 RESULTS FROM OBSERVATIONS AND ANALYSIS

- **Ozone trend studies**. Fioletov was nominated as one of the two Lead authors of the WMO/UNEP 2006 Ozone Assessment, Chapter 3, “Global Ozone: Past and Present” and as one of two Coordinating Lead Authors of the WMO/UNEP 2010 Ozone Assessment, Chapter 2, “Stratospheric Ozone and Surface Ultraviolet Radiation.” This was largely in recognition of his contribution to estimating and understanding long-term ozone trends. Ozone Assessments are prepared every 4 years and provide the scientific basis for political decisions made by the Parties to the United Nations Montreal Protocol.

- **"Ozone memory" studies.** Fioletov and Shepherd, 2003, GRL paper, demonstrated that summertime total ozone anomalies are strongly linked to springtime anomalies. This and the subsequent papers give a way to predict summertime ozone (and therefore summertime UV) from springtime ozone levels. Subsequent studies by. S. Tegtmeier, a PDF under Fioletov's supervision, found a similar link between winter and summer concentrations of ozone and other trace gases in the lower and upper stratosphere over low and middle latitudes that can be used for long-range forecasts of the stratospheric composition.

- **Ozone network performance study.** One of the outcomes of the Ozone Assessment-2006 was the identification of the need to improve the quality of ground-based total ozone observations. The world ground-based network is comprised of stations from more than 100 different agencies. Operational procedures, calibration histories, etc., are somewhat different among them resulting in a difference in the quality of the data. Fioletov et al., 2008, evaluated the performance of all individual station instruments. This study represents the common view of the WMO SAG-Ozone technical panel comprised of experts in ground-based and satellite total ozone observations.

- **UV Climatology over the US and Canada, erythemal and vitamin D action spectra-weighted UV study**. The UV Index is based on the erythemal action spectrum which expresses the dependence on wavelength of the effectiveness with which radiation produces sunburn. Solar UV radiation is also the main natural source of vitamin D, which is essential for bone and musculoskeletal health, etc. Canadian and US Brewer spectral UV irradiance measurements were used to study the relationship between erythemal and vitamin D action spectra-weighted UV and to estimate Ultraviolet exposure levels for a sufficient vitamin D status in North America.

- **ARC-IONS (2008) Ozonesonde campaign: ~380 profiles.** Cooperation with NASA project Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS), April and July 2008 over northern Canada. Objectives: (1) evaluation of the role of stratosphere/troposphere exchange (STE) in the spring buildup of tropospheric ozone; (2) studies of boundary layer ozone depletions resulting from halogens released from sea salt deposited on Arctic sea ice; (3) the contribution to the tropospheric ozone budget from boreal forest fires and the extent of fire emission influence on a trans-continental scale and beyond; (4) validation of Aura (TES, OMI) at high latitudes; of GEM-MACH, for ozone & STE, and forest fire models.

- **BORTAS-A (2010) Ozonesonde Campaign: ~ 210 profiles.** Cooperation between Universities of Edinburgh, York and Leeds, Environment Canada, Dalhousie University, NASA, several other European, Canadian and US universities. Objectives: Study ozone production from boreal fires; quantify the impact of boreal biomass burning on the global tropospheric composition using data from satellite sensors. Rationale: tropical biomass burning is well known, and observed from satellites; the potential atmospheric impact of boreal fires is larger, as both fuel consumption and intensity of boreal fires are typically an order of magnitude larger than for savanna fires; emissions are carried higher, making long-range transport an important consideration. However, previous measurements in smoke plumes show highly variable ozone amounts.

BORTAS-A involved an ozonesonde intensive field study, along with aerosol optical depth and aerosol lidar network intensives, surface measurements at Halifax, and NO2 and CO (plume-tracking) data from AIRS, TES, MOPITT, IASI. Extensive modeling using GEOS-Chem, GEM-FLEXPART, HYSPLIT.

BORTAS-B (2011) will add sampling of the biomass burning outflow of boreal fires from North America toward Europe with the FAAM146 aircraft, in order to quantity the impact of boreal forest fires on oxidant chemistry over the Atlantic with a 3-D chemistry transport model, constrained by field measurements.

3 THEORY, MODELLING AND OTHER RESEARCH

- **New Brewer ZS algorithm.** This new algorithm was developed to improve the quality of Brewer observation under cloudy conditions. Unlike the present algorithm that is based on an empirical relationship, the new algorithm is based on radiative transfer calculations with just a small adjustment that accounts for properties of individual Brewer instruments. (Fioletov, V.E., C. A. McLinden , C. T. McEloy, and V. Savastiouk, New method for deriving total ozone from Brewer zenith sky observations, *J. Geophys. Res*., 2011.)

- **Research into Ozone and temperature trends.** When ozone trends are computed using profiles measured in different units, differences should be expected due to simultaneous trends in background air number density and layer thicknesses brought about by climate change. The long-standing difference between SAGEI+II and SBUV ozone trends in the upper stratosphere can be largely reconciled when this is taken into account. When SAGE profiles (originally number density on a constant altitude grid) are converted to SBUV-like units (partial column on a pressure grid) differences of 4-6%/decade are reduced to <5%/decade. Any such unit conversion requires that the long-term temperature trend be captures by the temperature profiles used in the conversion. Temperatures from reanalysis are generally not suitable as due to differing data densities and instrumental biases being fed into the assimilation system lead to incorrect trends.

This result has implications for ozone turnaround as instruments measuring in different units/co-ordinates will identify the onset of turnaround at different times – perhaps by as much as ten years difference.

- **OSIRIS BrO and Bry.** OSIRIS (Optical spectrograph and Infrared Imager System) UV limb scattered sunlight measurements (345-365 nm) have been inverted to yield vertical profiles of BrO between 16-36 km at 3-4 km resolution. To reduce noise radiances are averaged daily with a given latitude band. Profile precision is estimated at 30%. Ten years of data are averaged to create a monthly-mean climatology, the first such vertically resolved climatology of BrO. Photochemical was modeling used to derive monthly values of total inorganic bromine, Bry. For each month and latitude band a photochemical model, constrained with observed values ozone, temperature, and total reactive nitrogen was used to calculate the fraction of Bry present as BrO at the local mean time of the OSIRIS measurement. By scaling OSIRIS BrO by the inverse of this fraction, a measure of Bry is obtained. OSIRIS find 21 pptv of Bry, implying about 5 pptv originating from very short lived bromine-bearing substances (VSLS).

  The correlation between OSIRIS Bry and monthly-mean N_2O measured by the SMR (Submillmetre and Millimetre Radiometer) is similar to correlations obtained by insitu measurements of Bry source gases (that do not account VSLS) except it is shift by 5-6 pptv across the range of N_2O. This suggests that whatever is source is missing from the in situ-derived correlation is, in fact short-lived, or there would be more variation with N_2O.

- **Stratospheric Ozone Data Assimilation.** Data assimilation consists of incorporating information from observations into a model state to produce improved estimates of the state variables. Three research projects have been undertaken over the last several years; two projects make use of the Global Environmental Multiscale (GEM) NWP model with addition of a simplified on-line stratospheric photochemical module (LINOZ), while the third utilizes the Canadian Middle Atmosphere Model Data Assimilation System (CMAM-DAS).

  The first project is on the implementation and evaluation of dynamically varying ozone and aerosols in the EC global forecast model. Assimilations of MLS-Aura ozone profiles, SBUV/2 partial column ozone profiles with use of averaging kernels, and GOME-2 total column ozone were conducted for two periods, the Summer of 2008 and the Winter of 2008/09. MLS-Aura data expectedly yielded the most beneficial impact on the quality of the ozone field. The evaluation of the impact from radiative coupling is in progress.

  The second project is a subtask of the PREMIER (PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation) Impact Study led by Forschungszentrum Jülich, Germany, and funded by the European Space Agency (ESA/ESTEC). PREMIER is a candidate of the ESA Earth

Explorer Core Mission. The EC contribution was to assess the possible impact of PREMIER ozone, water vapour and temperature observations on NWP using observation system simulation experiments (OSSEs). The assimilation and medium range forecasting products are being assessed with a final subtask report being prepared for submission this Spring. It was demonstrated, as example, that the PREMIER IRLS (InfraRed Limb Sounder) instrument should very notably improve the troposphere to lower stratosphere ozone analyses and forecasts as compared to MLS in addition to SBUV/2.

The third project was to conduct ozone assimilation with the Canadian Middle Atmosphere Model Data Assimilation System (CMAM-DAS) using OSIRIS and MLS ozone profiles as part of the Canadian SPARC[2] (C-SPARC; 2006-11) project. Phase one focussed on determining ozone zonal mean biases between OSIRIS, MLS and ozonesondes through direct comparisons and through the intermediate use of ozone analyses obtained through MLS ozone assimilation. These results were used to correct for biases between the two satellite instruments and ozonesondes in the lower stratosphere and for OSIRIS in the middle stratosphere and lower mesosphere. The second phase of the project is to use the de-biased data in assimilation.

- **The Atmospheric Chemistry Experiment.** The Atmospheric Chemistry Experiment (ACE) is a small satellite developed by the Canadian Space Agency containing a Fourier Transform Spectrometer (ACE FTS) and a UV-Vis spectrometer (MAESTRO, Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation) for the observation of stratospheric ozone and its associated chemistry. Details can be found at: http://www.ace.uwaterloo.ca/index.html including links to data products and publications. The satellite was launched in 2003 and continues to provide information on polar stratospheric chemistry. Approximately 70,000 profile measurements have been made to date and the satellite health remains excellent.

4 DISSEMINATION OF RESULTS

4.1 Data Reporting

Column ozone and UV-spectral observations are reported to the Canadian Meteorological Centre of the Meteorological Service of Canada in real-time and are used in the Canadian UV-Index forecast and for validation purposes.

[2] Stratospheric Processes And their Role in Climate, a project of the World Climate Research Programme

Data from both the Canadian Ozonesonde and Brewer Spectrophotometer networks is directed to the World Ozone and UV Data Centre following quality assurance procedures. Following the implementation of ISO 9001 protocols and assessments of data from multiple Brewer instruments at each location, data quality control has become significantly more complicated and the overall uncertainty of the Brewer data greater than originally calculated. Multiple Brewer instruments have also led to the discovery that very small changes in wavelength can have significant impacts on the spectral irradiance curves, although not significant enough to alter UV-Index calculations. Because of these issues, which continue to be assessed, co-located Brewers can show single wavelength spectral differences in the order of 5%. As Canadian ozone and spectral UV irradiance data is processed together for inclusion in the WOUDC, several years have passed since data of what is deemed an appropriate quality have been submitted to the WOUDC. Data from the Canadian Ozonesonde network is approximately one year behind schedule in its submission to the WOUDC.

4.2 Information to the public

Near real-time observations are also provided to the public through the web at: http://exp-studies.tor.ec.gc.ca and then http://exp-studies.tor.ec.gc.ca/clf2/main.html. These include both ozone and UV-Index based on Brewer observations.

This website also displays maps of ozone concentrations and deviations of these concentrations from mid-1980 levels.

Each year, based on springtime Arctic ozone levels, a summer seasonal forecast is provided to the public through the Meteorological Service of Canada website: http://www.ec.gc.ca/uv/default.asp?lang=En&n=C28590EA-1. The forecast normally comes out before Canada's May 24 (Victoria Day) long weekend as this is the 'first' long weekend of summer in Canada and many individuals are prone to extended hours outdoors for the first time since winter.

Canada provides daily UV-Index forecasts for values greater that 2 through the Meteorological Service of Canada regular forecasts: http://www.weatheroffice.gc.ca/canada_e.html. Private sector forecasts of the UV-Index are also provided by such organizations as the Weather Network: http://www.theweathernetwork.com/uvreport/canuv_en/?ref=topnav_homepage_uvreport

World Ozone and UV Data Centre. Data continues to be submitted to the WOUDC, although budget constraints in many nations are being reflected in lower frequencies of submission. Regular data contributors are reported each week on the WOUDC web site at: http://woudc.org/currentcontributors_e.html.

There are **131 Agencies from 75 Countries representing 500 platforms** (stations) that have in the past or continue to contribute data to the WOUDC.

Data Category	Platforms	Number of Files	Temporal Range	Number of New Platforms	Data Increase Since Last Report (%)
Lidar	2	~700	1991-1998	0	No Change
Ozonesonde	139	~65,000	1962-2011	15	16%
Total Column ozone (Daily)	287	~64,000 (monthly)	1924-2011	7	9%
Total Column Ozone (Hourly)	22	~43,000	1984-2011	12	46%
Umkehr	64	~10,000 monthly records, >50,000 retrievals	1951-2011	0	No Change

Personnel from Environment Canada/WOUDC participated in the following WMO related meetings and activities which have a direct connection to the role and activities of the WOUDC in its capacity to serve the ozone scientific communitiy as well as support the capacity building initiative of the WMO-GAW Programme.

- **Science Advisory Group for Ozone** - Three meetings (2008, 2009 & 2010) with participation from Environment Canada//WOUDC staff. Critical discussion of ozone cross-sections, data citation and new, expanded data formats were the focus.
- **Quadrennial Ozone Symposium** - 2008, Tromso, Norway
- **Biennial Brewer Workshop** – 2009, Aosta, Italy - Was coordinated and chaired by EC/WOUDC staff
- **ET-WDC meeting** – 2009, Geneva, Switzerland - Part of the WMO-GAW 20th anniversary celebration where the data centre is seens a the longest serving centre in the WMO-WDC "family"
- **ET-WDC meeting** – 2010, Toronto, Canada - Environment Canada hosted the 2010 ET-WDC meeting where other world data centre experts attended and progress was made in better collaboration efforts between the ground-based centres and those centres hosting satellite data.
- **Dobson Data Workshop** - Feb 2011 – Hradec Kralove, Czech Republic - Environment Canada scientists participated and lead discussion on issues of data quality and long-term data archiving

The WOUDC continues to produce daily (NRT) ozone and UV maps as well as time series of totals column ozone, ozone sonde and UV index graphs. Ozone information is also made available to the WMO for the Antarctic ozone bulletins and the data archive provides enhanced web tools for searching for data and mapping the results of these searches

The WOUDC continues to release the ***Ozone Data for the World*** "red-books" on DVD. The latest DVD will be released later in 2011. The WOUDC Data Archive continues to be the leading source of total column and profile ozone data as used in large international research projects, modelling efforts, satellite data validation and was used extensively in the 2010 UNEP Ozone Assessment), and remains a key source of metadata for the WMO-GAWSIS.

The WOUDC quality-assurance procedures continue to assist ozone and UV data providers to improve the measurement and dissemination of their data.

Environment Canada will celebrate 50 years of operations and management of the WOUDC in 2012.

5 **RELEVANT SCIENTIFIC PAPERS** (from last meeting)

Kerr, J. B., and V.E. Fioletov, 2008: Surface ultraviolet radiation, *Atmos.-Ocean*, 46, 159–184 doi:10.3137/ao.460108.

Fioletov, V.E., 2008: Estimating the 27-day and 11-year solar cycle variations in tropical upper stratospheric ozone. *J. Geophys. Res,* 114, D02302, doi:10.1029/2008JD010499.

Fioletov, V.E., 2008: Ozone climatology, trends, and substances that control ozone, *Atmos.-Ocean*, 46, 39–67, doi:10.3137/ao.460103.

Fioletov, V. E., G. J. Labow, R. Evans, E.W. Hare, U. Koehler, C. T. McElroy, K. Miyagawa, A. Redondas, V. Savastiouk, A.M. Shalamyansky, J. Staehelin, K. Vanicek, and M. Weber, 2008: The performance of the ground-based total ozone network assessed using satellite data, *J. Geophys. Res*., D14313.

Tegtmeier, S., V. E. Fioletov, and T. G. Shepherd, 2008: Seasonal persistence of northern low and middle latitude anomalies of ozone and other trace gases in the upper stratosphere, *J. Geophys. Res.*, D21308.

Cooper, O.R., D.D. Parrish, A. Stohl, M. Trainer, P. Nédélec, V. Thouret, J. P. Cammas, S.J. Oltmans, B.J. Johnson, D. Tarasick, T. LeBlanc, I.S. McDermid, D. Jaffe, R. Gao, J. Stith, T. Ryerson, K. Aikin, T. Campos and A. Weinheimer, 2009: Increasing ozone above western North America during springtime, *Nature*, *463*, 344-348, doi:10.1038/nature08708.

de Grandpré, J., R. Ménard, Y. J. Rochon, C. Charette, S. Chabrillat, A. Robichaud, 2009: Radiative Impact of Ozone on Temperature Predictability in a Coupled Chemistry–Dynamics Data Assimilation System. *Mon. Wea. Rev.*, **137**, 679–692. doi: 10.1175/2008MWR2572.1

Fioletov, V.E., 2009: Estimating the 27-day and 11-year solar cycle variations in tropical upper stratospheric ozone. *J. Geophys. Res,* 114, D02302, doi:10.1029/2008JD010499

Liu G., D. W. Tarasick, V.E. Fioletov, C. E. Sioris, and Y. Rochon, 2009: Ozone correlation lengths and measurement uncertainties from analysis of historical ozonesonde data in North America and Europe. *J. Geophys. Res,.* 114, D04112, doi:10.1029/2008JD010576.

McLinden, C. A., Tegtmeier, S., and Fioletov, V., 2009: Technical Note: A SAGE-corrected SBUV zonal-mean ozone data set, *Atmos. Chem. Phys.*, 9, 7963-7972.

Parrington, M., D.B.A. Jones, K.W. Bowman, A.M. Thompson, D.W. Tarasick, J. Merrill, S.J. Oltmans, T. Leblanc, J.C. Witte, and D.B. Millet, 2009: Impact of the assimilation of ozone from the Tropospheric Emission Spectrometer on surface ozone across North America, *Geophys. Res. Lett.*, 36, L04802, doi:10.1029/2008GL036935.

Boxe, C.S., J.R. Worden, K.W. Bowman, S.S. Kulawik, J.L. Neu, W.C. Ford, G.B. Osterman, R.L. Herman, A.Eldering, D.W. Tarasick, A.M. Thompson, D.C. Doughty, M.R. Hoffmann and S.J. Oltmans, 2010: Validation of northern latitude Tropospheric Emission Spectrometer stare ozone profiles with ARC-IONS sondes during ARCTAS: sensitivity, bias and error analysis, *Atmos. Chem. Phys., 10*, 9901-9914, doi:10.5194/acp-10-9901-2010.

Fioletov V. E., J. B. Kerr, and A. Fergusson, 2010: The UV Index: definition, distribution, and factors affecting it, *Canadian Journal of Public Health.*, 101(4):15-19

Fioletov, V.E, L. J. B. McArthur, T.W. Mathews, and L. Marrett, 2010: Estimated Ultraviolet exposure levels for a sufficient vitamin D status in North America. *Journal of Photochemistry and Photobiology,* B: Biology 100 (2010) 57–66.

Makar, P.A., W. Gong, C. Mooney, J. Zhang, D. Davignon, M. Samaali, M.D. Moran, H. He, D.W. Tarasick, D. Sills and J. Chen, 2010: Dynamic adjustment of climatological ozone boundary conditions for air-quality forecasts, *Atmos. Chem. Phys., 10*, 8997-9015, doi:10.5194/acp-10-8997-2010.

Oltmans, S.J., A.S. Lefohn, J.M. Harris, D.W. Tarasick, A.M. Thompson, H. Wernli, B.J. Johnson, P.C. Novelli, S.A. Montzka, J.D. Ray, L.C. Patrick, C. Sweeney, A. Jefferson, T. Dann, J. Davies, M. Shapiro and B.N. Holben 2010: Enhanced ozone over western North America from biomass burning in Eurasia during April 2008 as seen in surface and profile observations, *Atmospheric Environment, 44*, (35) 4497-4509, ISSN 1352-2310, doi: 10.1016/j.atmosenv.2010.07.004.

Pan, L.L., W. J. Randel, J. C. Gille, W.D. Hall, B. Nardi, S. Massie, V. Yudin, R. Khosravi, P. Konopka, and D. Tarasick, 2010: Tropospheric intrusions associated with the secondary tropopause, *J. Geophys. Res., 114*, D10302, doi:10.1029/2008JD011374

Robichaud, A., Ménard, R., Chabrillat, S., de Grandpré, J., Rochon, Y. J., Yang, Y., and Charette, C., 2010.: Impact of energetic particle precipitation on stratospheric polar constituents: an assessment using monitoring and assimilation of operational MIPAS data, *Atmos. Chem. Phys*., 10, 1739-1757.

Tarasick, D.W., J.J. Jin, V.E. Fioletov, G. Liu, A.M. Thompson, S.J. Oltmans, J. Liu, C.E. Sioris, X. Liu, O. R. Cooper, T. Dann and V. Thouret, 2010: High-resolution tropospheric ozone fields for INTEX and ARCTAS from IONS ozonesondes, *J. Geophys. Res., 115,* D20301, doi:10.1029/2009JD012918

Tegtmeier, S., V. E. Fioletov, and T. G. Shepherd, 2010: Seasonal persistence of ozone and zonal wind anomalies in the equatorial stratosphere, *J. Geophys. Res,.* 115, D18118, doi:10.1029/2009JD013010, 2010

Tegtmeier, S., V. E. Fioletov, and T. G. Shepherd, A global picture of the seasonal persistence of stratospheric ozone anomalies, *J. Geophys. Res.,* 115, D18119, doi:10.1029/2009JD013011.

Thompson, A.M., S.J. Oltmans, D.W. Tarasick, P. von der Gathen, H.G.J. Smit and J.C. Witte, 2010: Strategic Ozone Sounding Networks: Review Of Design And Accomplishments, *Atmospheric Environment*, ISSN 1352-2310, DOI: 10.1016/j.atmosenv.2010.05.002.

Vyushin, D. I., T.G. Shepherd, and V.E. Fioletov, On the statistical modeling of persistence in total ozone anomalies, *J. Geophys. Res,.* 115, D16306, doi:10.1029/2009JD013105, 2010.

Walker, T.W., R.V. Martin, A. van Donkelaar, W.R. Leaitch, A.M. MacDonald, K.G. Anlauf, R.C. Cohen, T.H. Bertram, L.G. Huey, M.A. Avery, A.J. Weinheimer, F.M. Flocke, D.W. Tarasick, A.M. Thompson, D.G. Streets and X. Liu, 2010: Trans-Pacific transport of reactive nitrogen and ozone to Canada during spring, *Atmos. Chem. Phys., 10*, 8353-8372, doi:10.5194/acp-10-8353-2010.

Binyman, J., J.A. Davies, B. McArthur, 2011 : Validation of spectral and broadband UV-B (290-325 nm) irradiance for Canada, *Atmos. Clim. Sci., accepted*.

Fioletov, V.E., C. A. McLinden , C. T. McEloy, and V. Savastiouk, 2011: New method for deriving total ozone from Brewer zenith sky observations, *J. Geophys. Res*., *accepted*.

He, H., D.W. Tarasick, W.K. Hocking, T.K. Carey-Smith, Y. Rochon, J. Zhang, P.A. Makar, M. Osman, J. Brook, M. Moran, D. Jones, C. Mihele, J.C. Wei, G. Osterman, P.S. Argall, J. McConnell and M.S. Bourqui, 2011: *Atmos. Chem. Phys., 11,* 2569-2583, doi:10.5194/ acp-11-2569-2011.

McLinden, C. A., and V. E. Fioletov, 2011: Quantifying stratospheric ozone trends: Complications due to stratospheric cooling, *Geophys. Res. Lett*., *accepted*.

6 FUTURE PLANS

In 2010, Canada renewed its commitment to the sponsorship of the WMO Brewer Trust Fund for a further 5 years. This fund provides $30,000 U.S. per year to support the development of Brewer observations through instrument calibrations and capacity building.

Under an agreement between Canada and the WMO, and a Memorandum of Understanding between China and Canada, the 13th Biennial Brewer Users Group Meeting is tentatively planned for 12 – 16 September 2011 in Beijing, China. A link to the 12th meeting at Aosta, Italy, 2009 can be found on the WOUDC website. Further information on the 13th meeting will be found on the website as plans are finalized.

The 2012 Quadrennial Ozone Symposium will be held in Toronto, Canada with sponsorship from Environment Canada, the Canadian Space Agency and several Canadian universities.

7 NEEDS AND RECOMMENDATIONS

There is a continued need to emphasize the importance of monitoring the health of the stratospheric ozone layer. While the recent Arctic spring time depletion was the largest ever recorded, many governments continue to reduce monitoring efforts as indicated by the frequency of data being submitted to the WOUDC.

The number of satellites now observing vertical distributions of ozone are dwindling and, at present, there appears to be no new satellites ready to replace those that are aging. The information provided by such satellites is critical, and nations with the capability to build and/or launch such space-borne instruments should be encouraged to cooperate to ensure a continuous space-based monitoring program of the vertical ozone distribution of the upper atmosphere.

A number of weather centres are exploring the use of assimilating surface, space-based and ozonesonde data for improved weather forecasts. Such ongoing use of this data should be encouraged as a means of aiding in the long-term stability of the global ozone monitoring programme.

The two-way link between ozone and climate change must continue to be emphasized.