

CANADA

OBSERVATIONAL ACTIVITIES

The Meteorological Service of Canada (MSC), part of Environment Canada, is the Canadian government department responsible for atmospheric ozone research. Its column ozone and UV monitoring programme is based on Brewer spectrophotometer measurements made at nine sites. Ozonesondes are flown at least weekly from six of these sites and from four new, recently established stations. Column abundances of other molecules important to understanding ozone chemistry and climate change are measured by Fourier Transform Spectroscopy (FTS) at two locations. The World Ozone and UltraViolet radiation Data Centre is operated by the MSC on behalf of the World Meteorological Organization WMO.

Although intense resource pressures and a protracted re-organization are taking place within Environment Canada, the MSC continues to support an extensive range of activities in the fields of ozone and ultraviolet radiation research and monitoring.

Column Measurements of Ozone and Other Gases

Brewer spectrophotometers are currently being operated at 9 stations in Canada (Saturna Island, British Columbia; Stoney Plain, Alberta; Bratt's Lake, Saskatchewan; Churchill, Manitoba; Resolute Bay, North West Territories; Alert and Eureka, Nunavut; Toronto, Ontario; Goose Bay, Labrador). This reflects the closing of three relatively recently established observing sites (Winnipeg, Manitoba; Montreal, Quebec; and Halifax, Nova Scotia) as a result of resource pressures. The instruments are programmed to make total ozone measurements on the sun, moon and zenith sky. Near-real time total ozone data is used with the Canadian Weather Prediction model to generate public forecasts of the UV-index; real time UV scan data are used for public information and validation of the UV forecasts. The raw data from the Brewers are processed in the Brewer Data Management Centre, which is also used to process data from several Brewer instruments operated in other countries. The Canadian sonde data as well as ozone and UV data from the Brewers are archived and made available to all users through the World Ozone and UV Radiation Data Centre (WOUDC).

Profile Measurements of Ozone

Ozonesondes are flown at 6 of the column ozone measuring stations (Stoney Plain, Churchill, Resolute Bay, Alert, Eureka, and Goose Bay, Labrador) and at four new stations (Kelowna, British Columbia; Bratt's Lake, Saskatchewan; Egbert, Ontario; Yarmouth, Nova Scotia) where the primary goal is the measurement of ozone in the troposphere. The Brewer Spectrophotometers also make Umkehr measurements of the vertical profile of ozone.

UV Measurements

Broadband measurements

Narrowband filter instruments

Environment Canada does not support these measurement types.

Spectroradiometers

The Brewer Spectrophotometers at all Canadian column ozone stations also make spectral scans of the horizontal UV irradiance. The data are reported in the WOUDC data base. Some stations are now equipped with double monochromator versions of the Brewer (Mark III). The instruments are re-calibrated on a two-year refurbishment and re-calibration cycle and an active life

cycle management programme is underway to replace the present network instruments with MK III Brewers at the rate of one per year

Calibration Activities

Toronto is the WMO/GAW Brewer Spectrophotometer Ozone Calibration Centre. The ozone calibration reference is a group of three single monochromator Brewers, the Brewer 'Triad',

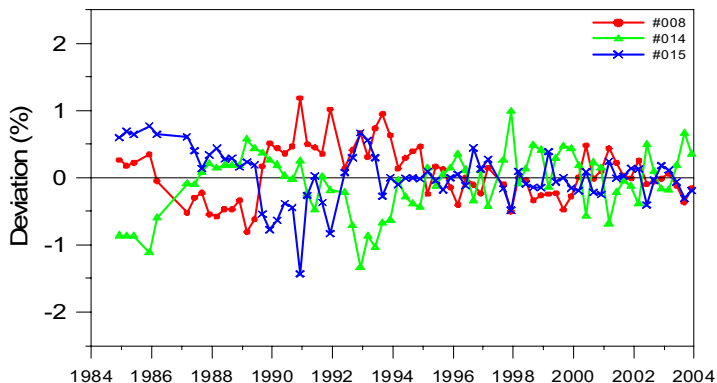


Figure 1: Deviations of ozone values of individual triad Brewers from the mean of the three instruments. Each point on the graph represents a 3-month average.

that are characterized regularly and taken approximately every two years to a high altitude, low-latitude station (Mauna Loa) in order to track their extra-terrestrial readings; except for these trips they remain in Toronto. Figure 1 demonstrates that the Triad is maintaining a long-term reference accuracy better than 1 %. Most field Brewer calibrations are done on site by bringing another Brewer (a 'Travelling Standard') to the station and making simultaneous measurements there. The Travelling Standard will normally be one of three instruments that are compared at least twice per year against the reference

Triad in Toronto. Besides maintaining the reference and travelling instruments and a Dobson spectrophotometer, the Calibration Centre continues work on ozone metrology such as the relationships between ozone measurements made at different wavelengths and with different viewing geometries from the ground or space and the effects of temperature on ozone measurements. A double as well as a single Brewer are operated permanently by the MSC at the NDSC Mauna Loa station for research purposes as well as to provide a comparison for instruments being transported to Mauna Loa for absolute calibration.

MSC participated in the first use of the European Brewer Reference Standard from Izana, Spain in September, 2005. The new reference which consists of a Triad of double monochromator Brewers maintained at Izana, Tenerife in the Canary Islands will provide a redundant, independent reference for Brewer calibration in Europe. It is intended that the Toronto Triad and the Izana Triad will be maintained in agreement to high precision through comparisons like the one held in Mazagon, Spain in September.

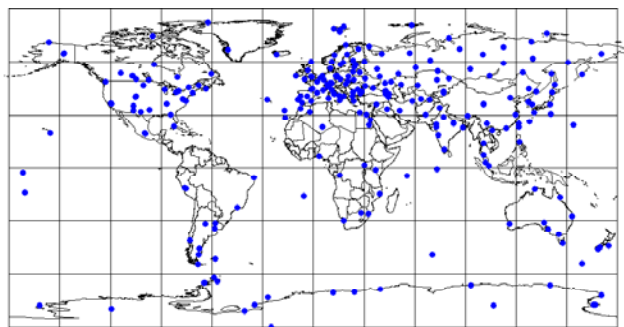


Figure 2: Stations reporting total column ozone data to the WODC. August, 2005.

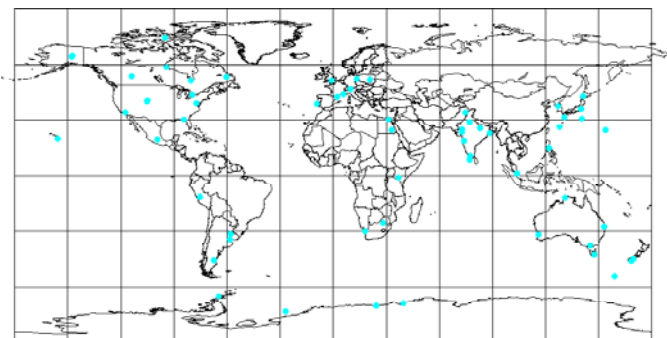


Figure 3: Stations reporting Umkehr observations to the WODC. August, 2005.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The MSC operates the WODC on behalf of the WMO. The availability of all types of data from the WODC and their value depends to a considerable extent on the prompt submission of data from those agencies throughout the world that make ozone and UV measurements. Generally the submission of data is highly satisfactory. There are minor exceptions such as the lack of some ozonesonde data sets and spectral

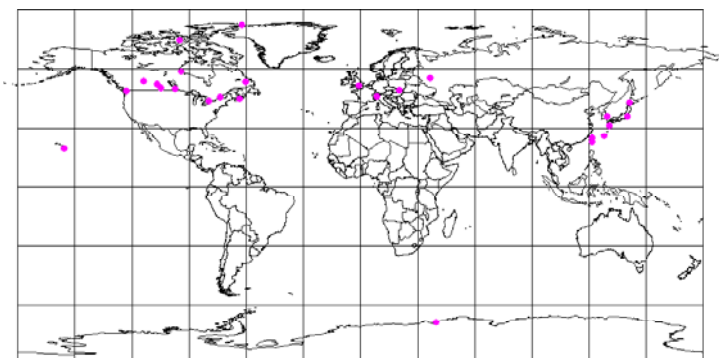


Figure 4: Stations reporting spectral UV data to the WOUDC. August, 2005

UV data from some countries in Europe. However, the current volume of spectrally-resolved UV data in the WOUDC is approximately 400 station-years, which may be more than 75% of what could be made available. Figures 2 through 5 indicate the kinds of data and numbers of stations reporting to the WOUDC. During the past six years the WOUDC has moved towards making products that assist the originators and users of UV and ozone data with quality control. The centre now accepts ozone and UV data in near real time and posts

current maps of column ozone obtained from current ground-based and satellite instruments. Daily hemispheric and global maps (Figures 6 and 7) are available for all periods during the past forty years. Also various forecasts maps of ozone (at present KNMI, NCEP and MSC) are posted on the site. Data from the new OMI satellite instrument will soon be included to replace the now unreliable EP-TOMS data. The Centre is still struggling to increase the amount of 'raw' Brewer data (so-called B-files) that are submitted.

Analyses from the data centre are contributed to the Ozone Assessment process and for the preparation of the WMO Ozone Bulletins.

THEORY, MODELLING, AND OTHER RESEARCH

The Canadian Middle Atmosphere Model (CMAM), collaboratively developed over the last decade by scientists from Canadian universities and Environment Canada, is a middle atmospheric climate general circulation model (GCM) stretching from the ground to ~95 km, or ~0.001 hPa. This model incorporates complex, online gas-phase and heterogeneous chemistry for the middle atmosphere. The CMAM was involved in the last WMO intercomparison aimed at assessing current middle atmospheric GCMs capabilities for describing the current and future states of the stratosphere and the impact of greenhouse gases and chlorine loading upon the ozone layer in particular. A new WMO scenario experiment is currently underway involving similar work with newer model versions intended to continue this task. The currently running simulation using CMAM covers 1960-2050+ as part of the latest SPARC/WMO assessment.

Stratospheric chemistry has also been coupled to a version of the Canadian Global Environmental Multiscale Model (GEM) for weather forecasting extended to 0.1 hPa. This has been done for the ESA-funded project 'Coupled Chemical-Dynamical Data Assimilation'. This project, led by Environment Canada in collaboration with The Belgian Institute for Space Aeronomy (BIRA) and York University, is a study of ozone chemistry, dynamics, and their interactions in a data assimilation context.

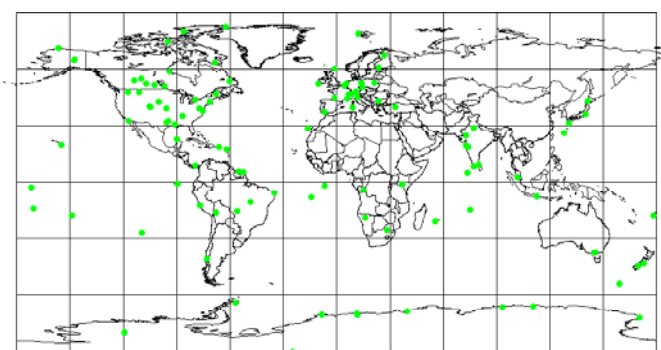


Figure 5: Stations reporting ozonesonde profile data to the WOUDC. August, 2005.

Both of these models, CMAM and GEM, are being employed in data assimilation mode using the Environment Canada 3-D variational system (3DVar). 3DVar has been adapted to allow the assimilation of species observations. To support this, the preparation of a database of ozone-related observations from various sources has been undertaken. Short-term preliminary assimilations of ozone observations have been performed using data from the OSIRIS, SBUV/2, TOMS, and GOME-2 instruments.

The Canadian Space Agency and Environment Canada are supporting the CMAM Facility for Data Assimilation and Modelling (CMAM-FDAM). Its principal objective is to provide support to the Canadian atmospheric measurement community. In that context, species products relying on assimilated dynamics are being provided for sites and periods of interest. This is to eventually incorporate products from species assimilation.

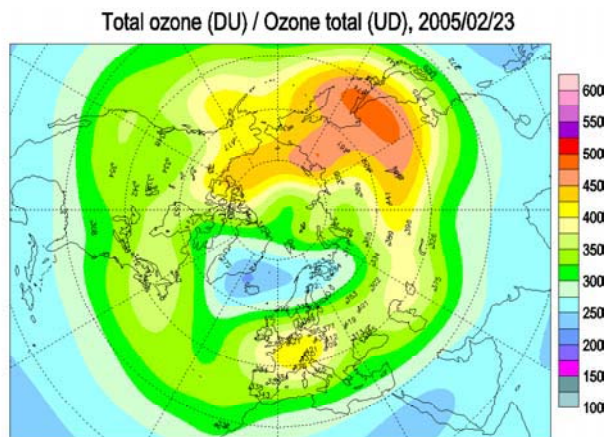


Figure 6: Total ozone map from the WOUDC for February 23, 2005 showing low ozone off the coast of Greenland.

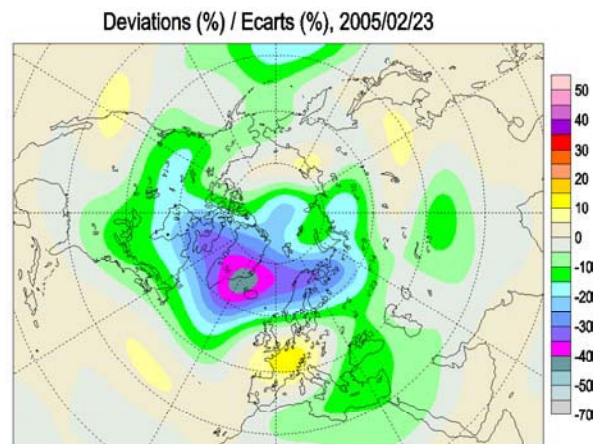


Figure 7: The same data as in Figure expressed as a departure from historically normal levels. Note that depletions reached more than 40%.

DISSEMINATION OF RESULTS

Data Reporting

Canadian column ozone measurements, ultraviolet radiation measurements and ozonesonde profiles are all submitted to the WOUDC on a regular basis by the MSC.

Information to the Public

Canada developed a UV Index in April, 1992. Since then Canadian public weather forecasts and reports have included the UV Index. Surveys indicate that there is a widespread public awareness of the Index and the data suggest that the majority of the public have modified their behaviour in response to the information provided. Six years ago MSC and Health Canada cooperated to develop a special programme to educate school children about UV exposure. It is called the "Children's UV-Index Sun Awareness Programme" and was initially directed toward primary school children but now includes high school students as well. Part of the programme is World Wide Web (WWW) based and involves the students making and reporting measurements.

Addresses:

World Ozone and UV Data Centre
 Maps and real time measurements
 Children's UV-Index Sun Awareness Programme

<http://www.woudc.org/>
<http://exp-studies.tor.ec.gc.ca>
<http://www.msc-smc.ec.gc.ca/uvindex>

Information on the state of the ozone layer is released on the WWW each week. It includes a comparison of the current two-week average ozone values over Canadian stations with estimates of un-depleted ozone data based on an analysis of historical records.

Ozone maps that are prepared for scientific use as indicated in Section 2, are also freely available to the general public on the WWW (Figures 6 and 7). Figures 8 and 9 compare satellite based estimated of UV irradiance to Brewer network measurements.

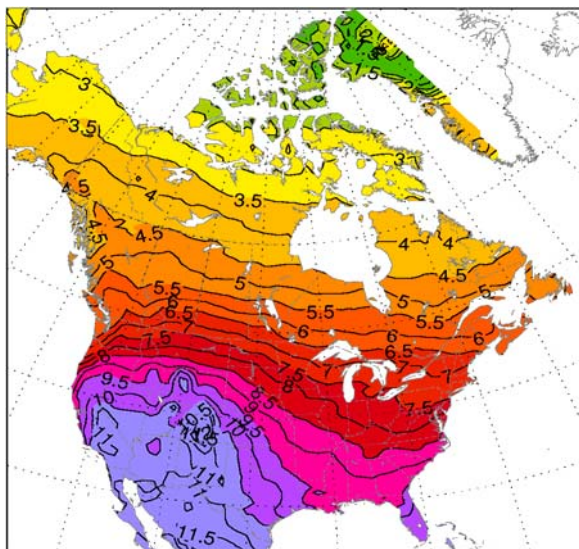


Figure 8: Map of mean noon (11 am-1 pm) UV index values for July estimated from TOMS.

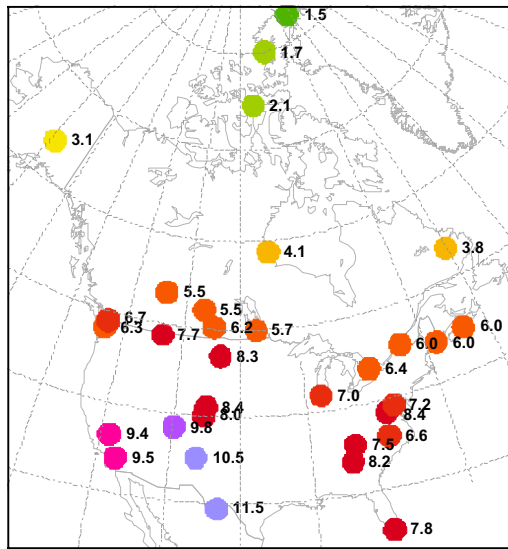


Figure 9: The same as Figure 8 but estimated from Brewer measurements.

PROJECTS AND COLLABORATION

WMO/GAW Biennial Brewer Users' Workshops

Canada supports the Global Ozone Observing System through organizing and Chairing the Brewer Users' Workshops. These are held in different host countries every two years and are intended to improve the consistency and quality of ozone observations through the sharing of knowledge concerning the operation and maintenance of the Brewer instrument. They also provide a mechanism for the propagation of scientific information to encourage a wider range of measurements to be made and to provide feedback on a scientific level to improve operations. Canada hosted the Seventh Brewer users' meeting in Toronto in September, 2002. The most recent meeting was hosted by the Brewer Spectrophotometer's manufacturer, Kipp & Zonen B.V., in Delft, the Netherlands, in June, 2005. Between 4 and 6 MSC staff organize and participate in these meetings.



Figure 10: The PEARL observatory. The Eureka research facility is undergoing a full-scale upgrade, including the installation of a 128 kbs⁻¹ satellite communications link.

Arctic Ozone Research

The Arctic Stratospheric Ozone Observatory (ASTRO) at Eureka, Nunavut (80°N) was established in 1992 as a contribution from Canada to the WMO/GAW Network for the Detection of Stratospheric Change (NDSC). The observatory instrument complement included Raman (added in 1996) and Rayleigh lidars for the measurement of ozone, water vapour, density and aerosols; FTIR spectrometers both for atmospheric thermal emission and for solar and lunar occultation; and various UV/Vis spectrometers, including modified Brewer spectrometers. However, since the 2002 Ozone Assessment, which led policy-makers to the conclusion that the ozone depletion issue was solved based on the observed decline in regulated, ozone-depleting chemicals, resourcing of the stratospheric science programme has decreased significantly, resulting in the Eureka observatory being at first moth-balled and then ceded to the university community in 2004.



Figure 11: Two sea containers were insulated and equipped in Toronto and airlifted to Eureka by a C-130 Hercules. They are situated near sea level at the site of the Eureka weather station.

In 2005, the university consortium - the Canadian Network for the Detection of Atmospheric Change (CANDAC) - was successful in gaining 5-year funding to re-establish an atmospheric research facility at Eureka. The new laboratory is called the Polar Environment Atmospheric Research Laboratory (PEARL) and is operated by that consortium. It includes partners from a number of Canadian Universities and from other countries. Within Canada it is supported by funding from nine different federal and provincial organizations. The major contributors are: the Canadian Foundation for Innovation (CFI), the Canadian Foundation for Climate and Atmospheric Science (CFCAS) and the Natural Sciences and Engineering Research Council (NSERC). There are

also contributions in kind from the MSC. It is hoped that some research involvement from the MSC can be maintained.

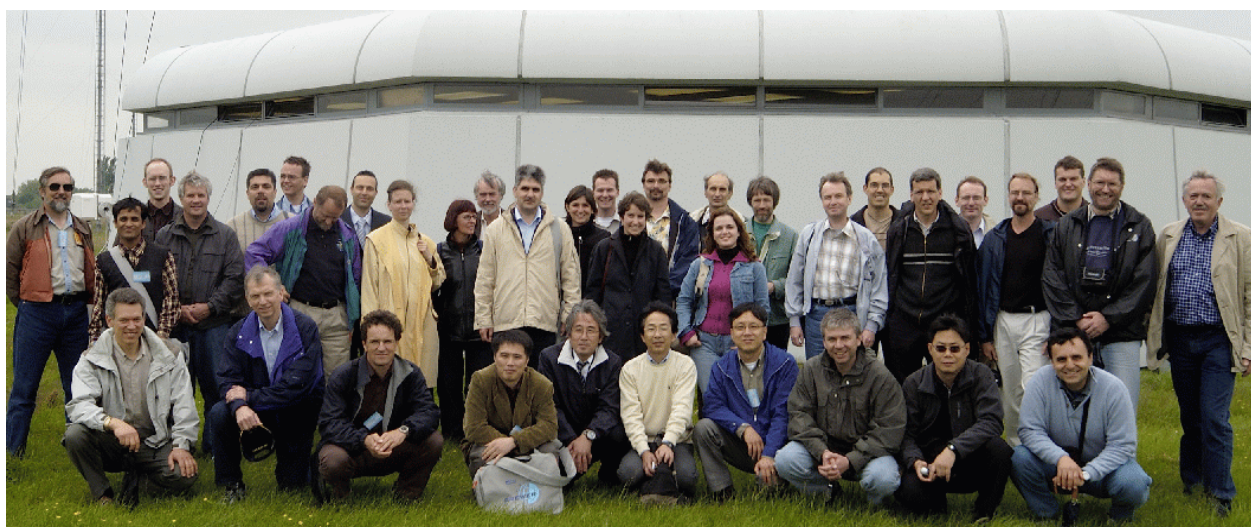


Figure 12: Attendees at the 2005 Brewer User's Workshop in Delft. The photo was taken at the bottom of the Netherlands' 200 m flux tower. Photo courtesy of Ben Dieterink, Kipp & Zonen B.V.

The overall objective of the new PEARL laboratory encompasses air quality, climate change and ozone studies. The laboratory will be fully functional by 2007 in time to participate in the International Polar Year (IPY). The instrumentation of the former laboratory has been maintained and upgraded to enable the continuation of previous datasets and new observations are planned for the study radiation, clouds and aerosols in the lower atmosphere, and composition and waves in the upper atmosphere.

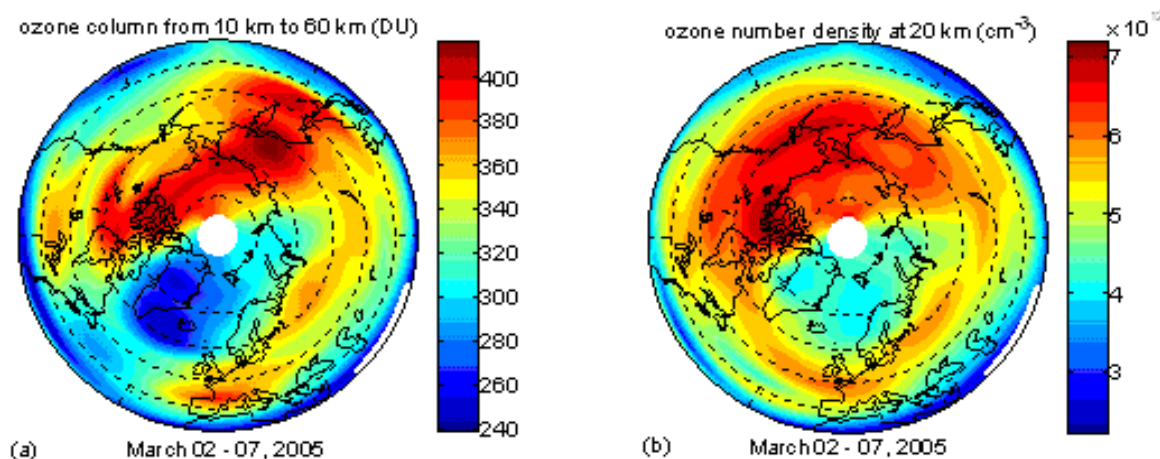


Figure 13: The total ozone column from 10 to 60 km and the ozone number density at 20 km as measured by OSIRIS. The structures seen in these plots indicate a minor northern hemisphere ozone depletion event in spring 2005.

OSIRIS Instrument on the ODIN Satellite

The OSIRIS instrument team is led by a principal investigator from the University of Saskatchewan in Saskatoon. OSIRIS was launched in March, 2001 on the Swedish satellite ODIN in an international collaboration that also involves French researchers. The OSIRIS spectrometer has been producing limb radiance spectra since it was commissioned in August, 2001. Ozone and NO₂ vertical profiles are available from these measurements. These have exceptionally high vertical and spatial resolution. The Canadian Space Agency renewed funding for the OSIRIS project in the spring of 2005, so data will continue to be available for at least two more years.

Atmospheric Chemistry Experiment (ACE)

The Canadian Space Agency funded the development of the Atmospheric Chemistry Experiment (ACE) satellite, also called SCISAT, to make atmospheric measurements relevant to ozone depletion, primarily focussed on the Arctic wintertime and early springtime stratosphere. This satellite mission is based on a proposal submitted by a mission scientist from the University of Waterloo. SCISAT was launched on August 12, 2003 and is currently making valuable occultation measurements with an infrared Fourier transform spectrometer (FTIR) and an MSC-developed diode-array spectrometer operating in the UV/visible/NIR wavelength range. The data will provide concentration profiles of more than ten trace gases as well as information about the



Figure 14: SciSat undergoing final assembly at the David Florida Laboratories in Ottawa. The satellite was subsequently shipped to Vandenberg AFB to be launched on a Pegasus launch vehicle.

characteristics and occurrence of polar stratospheric clouds. The science team of ACE reflects substantial collaboration with teams in Belgium, France and the USA.

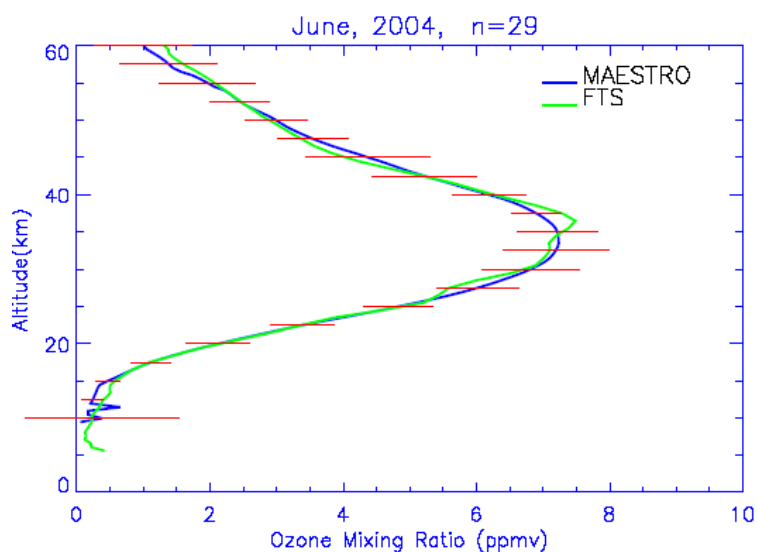


Figure 15: The mean of 29 ozone profiles taken with ACE-FTS (Green) and MAESTRO (Blue). The 'error bars' indicate the standard deviation of the 29 profiles. (Courtesy of J. Kar, U. Toronto).

TOMS3F

MSC participated in a NASA-led project in spring, 2001 to improve our understanding of the relationship between satellite-based (TOMS) measurements of ozone and measurements made by ground-based instruments at high latitudes. The TOMS3F campaign provided measurements from the Fairbanks Dobson instrument, one double monochromator Brewer owned by NASA/Goddard, and one single and one double Brewer provided and operated by MSC as well as ozonesonde and Microtops data. The data have not yet been published, but preliminary assessment has indicated that the agreement between double Brewer instruments and TOMS observations is very good while systematic errors in Dobson and single Brewer measurements contribute a significant discrepancy in comparison with the satellite results. MSC is attempting to arrange participation in a follow-on campaign in Sodankyla, Finland in the Winter of 2005 - 2006.

Brewer Spectrophotometer Manufacture and Maintenance

After a period of uncertainty, that the supply of Brewers for the global ozone observing network has been assured by the demonstrated, continuing interest of Kipp & Zonen, B.V. of Delft, the Netherlands, the Brewer manufacturer, and the signing of a multi-year license agreement between Environment Canada and Kipp & Zonen. Maintenance and calibration services for the Brewers is also available, with both the manufacturer and International Ozone Services of Toronto supporting instruments in service at Brewer observing locations around the world. Environment Canada is actively participating in this process through the Brewer workshops as well as by providing consulting services and calibration support to both companies.



Figure 16: The Canadian contingent present at Vandenberg AFB for the launch of SciSat on August 12, 2003. Left to right: Peter Bernath (Mission Scientist, U. Waterloo), Randy Shelly (Bus Manager, CSA), Roger Colley (Director General, Space Science, CSA), Tom McElroy (MAESTRO Principal Investigator, MSC), Wally Eliuk (Bristol Aerospace), Reg Colin (Université Libre de Bruxelles, Belgium). The white cylinder with 'Canada' marked on it is the Pegasus rocket that carried the satellite into space after being dropped over the Pacific Ocean from the L-1011 aircraft on which it is mounted as shown in this photograph.

FUTURE PLANS

MSC is continuing, within resource constraints, to work on improving the basic scientific foundation for spectroscopic measurements of ozone and solar radiation. The scope of this work ranges from technical issues related to instrument performance as well as scientific studies related to optimizing the analysis of data collected in the Brewer observing network. The development of new instruments with superior performance for atmospheric remote sounding is also being addressed. For example, the MAESTRO spectrophotometer on SCISAT was developed and the flight model constructed at the MSC. MSC is attempting to arrange participation in a TOMS3F follow-on campaign in Sodankyla, Finland in the Winter of 2005 - 2006.

NEEDS AND RECOMMENDATIONS

(a) It is imperative to improve the ground-based network to a capability of detecting a 1% per decade trend in the ozone recovery rate so that a turnaround comprising a recovery in the ozone layer may be detected in less than several decades. With the failure of the TOMS instrument and its replacement by new systems such as OMI, a high quality surface network is crucial to maintain a consistency of observations both between satellites and over the life-time of an individual instrument. The development and maintenance of such a crucial network cannot be accomplished with the reduction in resources being experienced by many of the meteorological agencies within the WMO.

(b) Those responsible for decisions concerning the implementation of the Montreal Protocol and Vienna Convention on Ozone Depleting Substances within national governments must be made aware of the need for long-term consistent high-quality observations. The present belief among many policy analysts is that network observations can be easily reconfigured as a short-term cost-saving measure. They must be convinced of the importance of long-term monitoring of atmospheric trends and the enormous damage inflicted in the determination of such trends when observing sites are decommissioned.

(c) Heads of meteorological agencies within the WMO should be apprized of the potential of assimilating ozone observations, made both from the surface and from space, as a means of significantly improving weather and air quality forecasts.

Relevant Scientific Papers

Papers published in 2002-2005:

- Arola, A., J. Kaurola, L. Koskinen, A. Tanskanen, T. Tikkanen, P. Taalas, J. R. Herman, N. Krotkov, V. Fioletov, A new approach to estimating the albedo for snow-covered surfaces in the satellite UV method, *J. Geophys. Res.*, 108, 4531, 10.1029/2003JD003492, 2003.
- Fioletov, V.E., J.B. Kerr, L.J.B. McArthur, D.I. Wardle, and T.W. Mathews, Estimating UV Index climatology over Canada, *J. Appl. Meteorol.*, 417-433, 2003.
- Fioletov, V.E., and T.G. Shepherd, Seasonal persistence of midlatitude total ozone anomalies, *Geophys. Res. Lett.*, 30, 1417-1421, 2003.
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- Fioletov V. E., M. G. Kimlin, N. Krotkov, L. J. B. McArthur, J. B. Kerr, D. I. Wardle, J.R. Herman, R. Meltzer, T. W. Mathews and J. Kaurola, UV index climatology over the US and Canada from ground-based and satellite estimates, *J. Geophys. Res.*, 109, 22,308, 10.1029/2004JD004820, 2004.
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- McElroy, C.T., and D.F. Francis, Eds., *Beyond the Breaking Point*, BTT Communications, Toronto, Canada, 34p, 2004.
- Penghui, M., J.A. Dobrowolski, F. Lin, C. Midwinter, and C.T. McElroy, Long-wavelength polarizing cut-off filters for the 275-550 nm spectral region, *Applied Optics*, 41, 3218-3223, 2002.
- Tarasick, D.W., V.E. Fioletov, D.I. Wardle, J.B. Kerr, Changes in the vertical distribution of ozone over Canada from ozonesondes: 1980-2001, *J. Geophys. Res.*, 110, 2,304, 10.1029/2004JD004643, 2005.

CHILE

INTRODUCTION

Chile is located on the extreme southwestern coast of South America. Several different scientific groups and institutions are engaged in the investigation of ozone depletion and ultraviolet radiation. The majority are studying changes in incident UV using several types of instruments, mostly broad band.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

Instruments	Institution	Station	LAT. LONG.	Period of observations
Brewer MKIV 068	University of Magallanes	Punta Arenas	53S;70.9W	1992-2000
Brewer MKIII 180	University of Magallanes	Punta Arenas	53S;70.9W	2002 - today

Profile measurements of ozone

Type	Institution	Station	LAT. LONG.	Period of observations
Umkehr	University of Magallanes	Punta Arenas	53S;70I.9	2002 - today
Ozone sondes	University of Magallanes	Punta Arenas	53S;70I.9	Campaigns spring time 1995-1996-1997-2001-2005
Ozone sondes	DMC	Isla de Pascua	27S;109W	1996

DMC: Dirección Meteorológica de Chile (National Meteorological Service)

UV measurements

Broadband measurements

Instruments of the groups of research.

Instruments	Institution	Station	LAT. LONG.	Period of observations
Solar Light 501	University of Atacama	Arica	18S;70W	1998 - today
Solar Light 501	University of Santiago	Antofagasta	23S;70W	2000 - today
Solar Light 501	University of Santiago	Santiago	33S;70W	1999 - today
Solar Light 501	University Federico Santa María	Valparaíso	33S;70l.9	
Solar Light 501	University of Magallanes	Puerto Natales	51S;72W	1997 - today
Solar Light 501	University of Magallanes	Punta Arenas	53S;71W	1997 - today
Solar Light 501	University of Magallanes	Puerto Porvenir	53S;70W	1997- 2002
Solar Light 501	University of Magallanes	Puerto Williams	55S;68 W	1997 - 2004
Solar Light 501	University of Magallanes	Bernardo O'Higgins	63S; 57W	2005 -

Network of DMC.

Instruments	Institution	Station	LAT. LONG.	Period of observations
Pyranometer UVA-B	DMC	Iquique	20S;70W	1998 - today
Pyranometer UVA-B	DMC	La Serena	29S;71W	2003 - today
Pyranometer UVA-B	DMC	El Tololo	30S;70W	1997 - today
Solar Light 501	DMC	Valparaíso	32S;71W	2002 - today
Pyranometer UVA-B	DMC	Pudahel	33S;70W	1992 - today
Pyranometer UVA-B	DMC	Concepción	36S;73W	2002 – today
SUV 100	DMC	Valdivia	39S;73W	1998 - today
Pyranometer UVA-B	DMC	Puerto Montt	41S;73W	2001 - today
Pyranometer UVA-B	DMC	Coyhaique	45S;72W	2001 - today
Pyranometer UVA-B	DMC	Punta Arenas	53S;70l.9	2001 - today
Pyranometer UVA-B	DMC	Base Presidente Eduardo Frei	62S;58W	1992 - today

Narrowband filter instruments

Instruments	Institution	Station	LAT. LONG.	Period of observations
GUV 511	University of Chile	Santiago	33S; 70W	1995 - today
GUV 511	University Austral	Valdivia	39S;73W	1995 - today
GUV 511	University Magallanes	Punta Arenas	53S;70l.9	1993 - today
NILU UV	University Magallanes	Base Prof. Julio Escudero	62S;58W	2005 -

Spectroradiometers

Instruments	Institution	Station	LAT. LONG.	Period of observations
SUV 100	University Austral	Valdivia	39S;73W	1997 - today
Brewer MKIII 180	University of Magallanes	Punta Arenas	53S;70.9W	2002 - today

O₃ Surface

Instruments	Institution	Station	LAT. LONG.	Period of observations
PM 10	University of La Serena	Cerro Tololo	30S; 70W	1995 - today

Calibration activities

The instruments of the DMC are compared and calibrated at least every two years in Valdivia. GUV 511 instruments are calibrated annually with a standard instrument sent from the factory and are part of the project Latin American, "Enhanced ultraviolet-B radiation in natural ecosystems as an added perturbation due to ozone depletion". This project is directed by Maria Vernet (Scripps Institution of Oceanography, La Jolla, California) and financed by the Inter American Institute for Global Research, (IAI), this project concluded in 2004, is possible that a new project will be approved during 2005 and starting in 2006.

Both the Brewer and the SUV spectroradiometers possess self calibration mechanisms which are constantly checked and updated by the respective scientific group. Additionally, the Brewer is calibrated monthly with an external lamps to verify the stability of the measurements. The last calibration of the Brewer No.180 from the factory was in December, 2004. The instruments Solar Light of the group of the University of Magallanes are calibrated once per year with the instrument Brewer.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Some Results of Studies at Punta Arenas Chile (Lat. 53S, Long. 70W)

The Brewer instrument No. 068 was operational at Punta Arenas from May 1992 until November 2000 thanks to a cooperative agreement between INPE, Brazil (Brazilian National

Institute for Space Research) and UMAG, Chile (University of Magallanes), a new Brewer (No. 180) was bought by the Magallanes Regional Government and was installed in 2002. The Figure 1 shows the variation of the ozone column measured by Brewer from 1992 until 2005 (June). Part [a] refers to the daily averages (solid line refers to the running average, $n=30$).

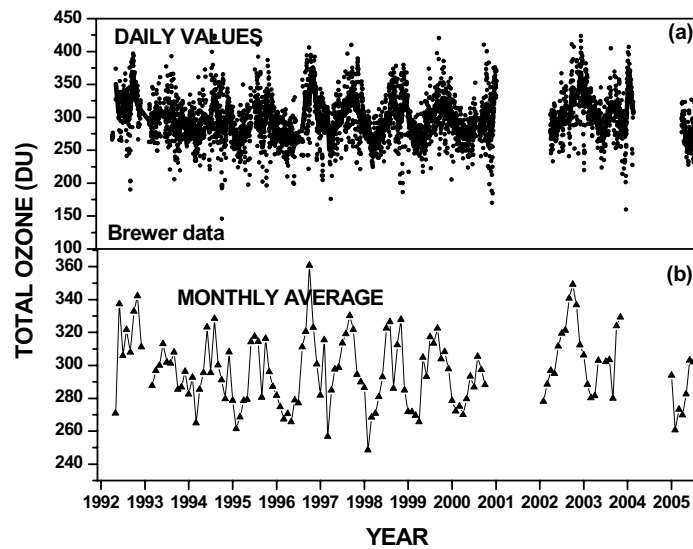
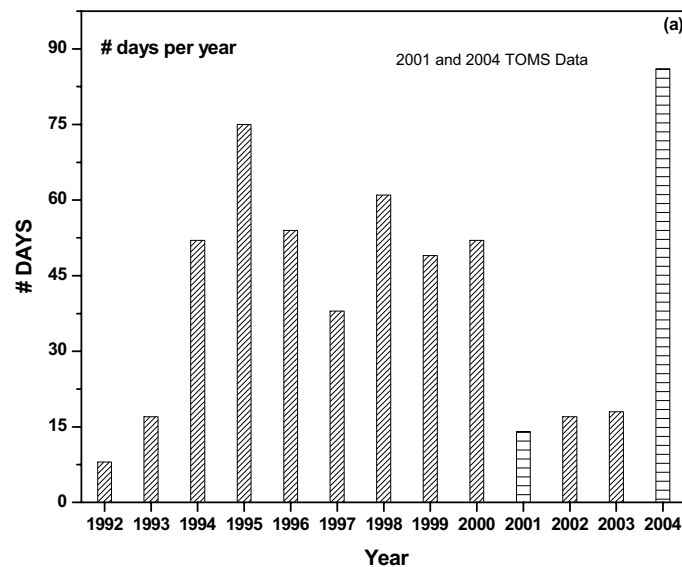


Figure 1: Daily and monthly mean values of total column ozone over Punta Arenas Chile 1992-2000 obtained with Brewer spectroradiometer (No 068 and No. 180).

The number of days in which the AOH has been over the Magallanes region varies from year to year. Figure 2 shows the number of events of low ozone to Punta Arenas. The criteria for defining an event of low ozone is that ozone column (daily average) must be lower than the reference (mean monthly climatological values for Punta Arenas from TOMS overpass data for the period 1978-1987), minus twice the standard deviation of the mean (mean monthly - 2σ). The number of days per year is shown in part (a), after 1995 the higher frequency occurred in February of 1998 with 27 days. In the period of 1994-1999 there were many days of low ozone events during summer time. Between 2001 and 2003 there were fewer significant days showing a possible recuperation of the ozone over Punta Arenas. However, during 2004 the days began to increase again. From there we ask the question: Which is the situation of the recovery (if it exists) of the layer of ozone at mid latitudes. The answer to this question must wait some years until much more data is collected.



DISSEMINATION OF RESULTS

Data reporting

- GUV-Network: The database of the GUV instruments are stored and maintained by each group, also exists an archive of all data (IAI) from all stations.
- The UV-B data from DMC network and vertical profile from Isla de Pascua are being regularly sent to the World Ozone Data Centre, Canada.
- The data from Brewer 180 in the course of this year will be sent to the WOUDC.

Information to the public

- The National Meteorological Service gives UV-Index forecast for all the stations shown in 2.3.1.
- Since the summer of 1999 the Ozone Laboratory and RUV of the University of Magallanes provides a UV index daily forecast during spring and summer time.

Relevant scientific papers

- Abarca, J.F., C. Casiccia, F. Zamorano, "Increase in sunburns and Photosensitivity Disorders at the Edge of Antarctic Ozone Hole, Southern Chile, 1986-2000", *J. Am. Acad. Dermatol*, 46(2):193-199, 2002.
- Abarca J.F.; C. Casiccia, "Skin cancer and ultraviolet-B radiation under the Antarctic ozone hole: southern Chile, 1987-2000", *Photodermatology photoimmunology & photomedicine*, 18(6):294-302, dec. 2002.
- Casiccia, C.; Kirchhoff, V.W.J.H ; Torres, A C., "Simultaneous measurements of ozone and ultraviolet radiation: spring 2000, Punta Arenas, Chile", *J. Atmos. Env.* 37(3):383-389, 2003.
- Aranibar D, Ligia, Cabrera S, and Honeyman M. "Menores quemados por el sol y su relación con la radiación ultravioleta y la cubierta de ozono, durante seis veranos (1996 a 2001) en Santiago de Chile (33,5°S)". *Rev. méd. Chile*, sep. 2003, vol.131, no.9, p.1011-1022. ISSN 0034-9887.
- Lovengreen vd M, C., Alvarez J., Fuenzalida, H., Aritio, M. "Radiación ultravioleta productora de eritema en Valdivia: Comparación entre inferencias satelitales, modelo de transferencia radiativa y mediciones desde Tierra". *Rev. méd. Chile*, Ene 2002, vol.130, no.1, p.17-25. ISSN 0034-9887

FUTURE PLANS

- A new campaign of ozone sonde launchings at Punta Arenas during spring time 2005.

NEEDS AND RECOMMENDATIONS

We would like to carry out the following activities but funds are needed.

- Construct a network of instruments to measure ozone and ultraviolet radiation along the total length of Chile using the country's unique geographical features and scientific installations, with two or three additional Brewer Spectroradiometers in the northern and central regions.
- Implement a long term programme of continuous balloon sonde measurements to establish a profile of stratospheric ozone concentrations over Punta Arenas.
- Is imperative to implement a plan of calibration of instruments.

CZECH REPUBLIC

INTRODUCTION

In the Czech Republic (CR) monitoring and research of ozone and UV-B solar radiation are mostly carried out in the Czech Hydrometeorological Institute (CHMI). Scientific activities are performed also by the Institute of Atmospheric Physics of the Czech Academy of Science and by the Department of Meteorology of the Charles University in Prague. While the monitoring is fully funded by the CHMI the research projects are supported also by grant agencies or by EC programmes. In recent years the extensive assistance has been provided by CHMI experts to the ozone part of the Global Atmosphere Watch Programme (GAW) of WMO.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

Daily observations of total ozone (DS and ZS) have been performed with the Dobson and Brewer spectrophotometers collocated at the Solar and Ozone Observatory of CHMI in Hradec Kralove (SOOHK) since 1962 and 1994, respectively. The observations are stored in the ozone database of CHMI and submitted to partner institutions. Both total ozone data series have been re-evaluated and re-deposited into WOUDC in 2005 [1], [2].

Profile measurements of ozone

Balloon-borne ECC ozone sondes are launched three times per a week in January - April at the Aerological Observatory (AOPH) of CHMI in Prague. The vertical profiles of ozone are stored in the ozone database of CHMI, WOUDC and NDSC, as well.

UV measurements

Broadband measurements

The broad-band UV Solar Light-Biometers are operated at three CHMI stations (Hradec Kralove, Kosetice and Labska Bouda) that are located in typical climate and geographical regions of CR (lowlands, rural land and mountains). The observations are used for the UV public information system and for research activities - see next parts of this Report.

Narrowband filter instruments

No narrowband UV radiometers are currently operated in CR.

Spectroradiometers

Spectral measurements of UV-B solar radiation (298-325 nm) and calculation of erythema DUV irradiances have been performed with the single (MKIV) and double (MKIII) Brewer spectrophotometers at SOO-HK since 1994 and 2004, respectively. The observations are accompanied by measurements of other auxiliary radiation fluxes (global, diffuse, reflected).

Calibration activities

The above mentioned instruments are regularly calibrated towards regional or world standards of the GAW calibration centres (RDCC-E, Hohenpeissenberg, MSC/IOS Brewer Triad) and they are operated according to SOPs defined in GAW manuals. Therefore the data sets are consistent with observations from other GAW stations and they are given in relevant world calibration scales.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The observations taken at SOO-HK have been used for data quality assessment, estimation of long-term ozone trends and analyses of relation between ozone and UV in the territory of CR in several recent and current international research projects joined by Czech teams - see the paragraph 5. Attention is paid mainly to investigation of relation between simultaneous Dobson and Brewer total ozone observations and between ground and the latest satellite data sets (TOMS-8, GOME/WFDOAS). The results show significant seasonal variations of differences that exceed 1% calibration accuracy of the spectrophotometers and thus they could influence the estimation of ozone trends if combined or non-homogenized data series are used - see Figures 1, 2 and [2], [3]. The quality assessment of UV spectral measurements taken with Brewers confirmed that the UV scans need to be filtered and correct (e.g. for spikes spikes) before they are deposited into data bases and used for statistical analyses.

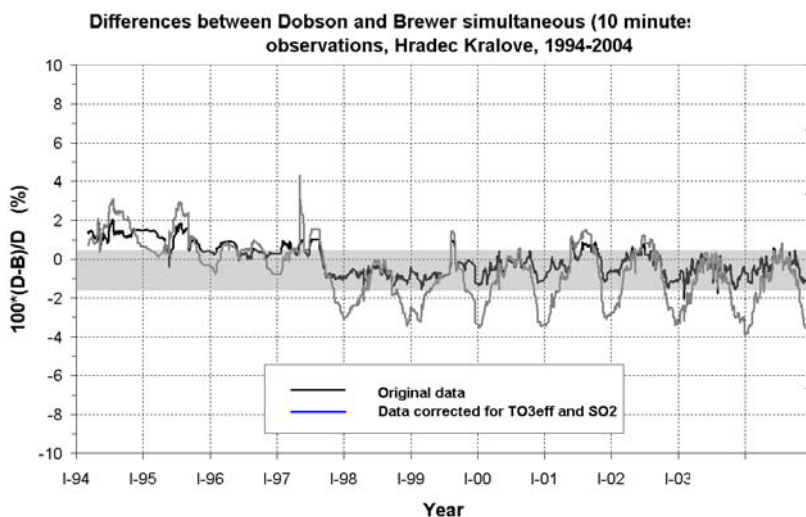


Figure 1: Differences between simultaneous DS Brewer and Dobson total ozone observations in Hradec Kralove - original data and data corrected for ozone effective temperature and total SO_2 .

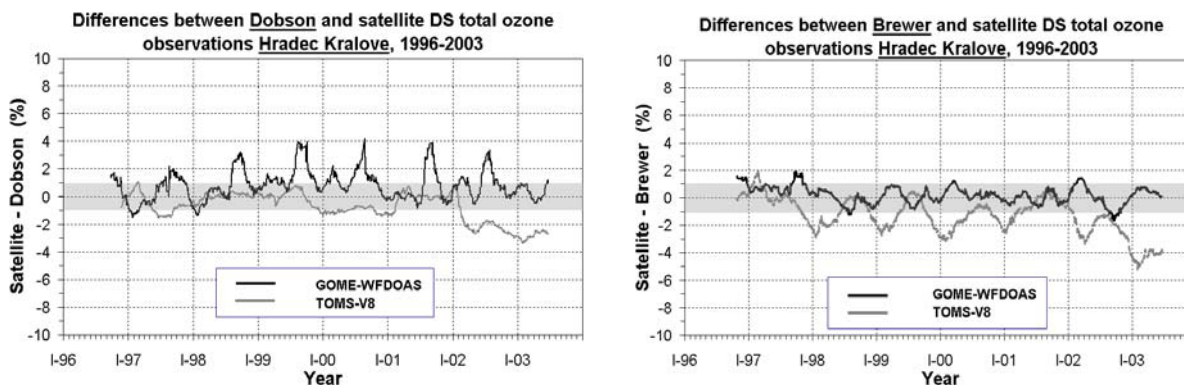


Figure 2: Relative differences between simultaneous DS Brewer, Dobson and satellite (TOMS-8, GOME/WFDOAS) total ozone observations in Hradec Kralove.

THEORY, MODELLING, AND OTHER RESEARCH

Neural technologies have been used to simulate long-term ozone and UV changes by specialists from CHMI. The chemically induced part of the decadal ozone change was estimated by the neural model that was developed within the project CANDIDOZ and run with ERA-40, solar flux, circulation indices and AOD proxies in the European region [4]. The results showed that the magnitude of the chemical component of ozone losses has been increasing since the early sixties in the region but it depends on the latitude - see Fig. 3. While in the southern part (45° N) of the region its influence is almost negligible in high latitudes (over 50° N) the ozone losses have

reached 30-40 DU (8-12%) during last four decades. Similar neural model has been developed to simulate UV spectral irradiances and UV erythemal doses by total ozone, clearness indices and AOD at Hradec Kralove. The model is now tested by re-evaluated total ozone data series from SOO-HK and it is to be used for estimation of the UV climatology in the territory of CR during last five decades - see the project COST-726

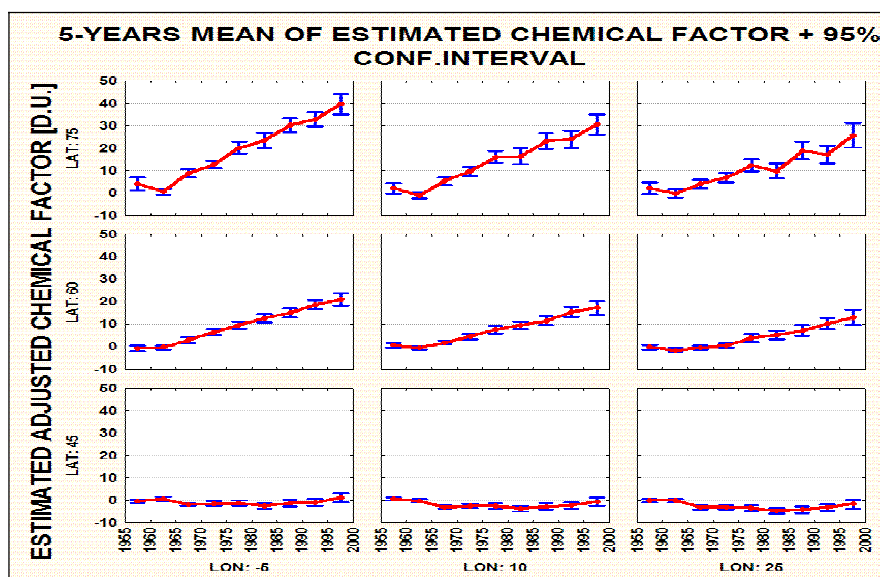


Figure 3: Time evolution of the estimated chemical component of decadal total ozone change in the European region - simulation with the neural model of CHMI, EC project CANDIDOZ [5].

DISSEMINATION OF RESULTS

Data reporting

All ozone observation taken in CR are regularly submitted into the WOUDC, Toronto and also to other partner institutions and projects - e.g. the Ozone Mapping Centre of MSC, NDSC data base, GAW cooperating stations in Central Europe, MATCH campaigns and satellite validating teams. UV observations that have been carried out under projects funded by EC (COST-713, COST-726, SUVDAMA, EDUCE, SCOUT) are reported to the European UV data base maintained by FMI.

Information to the public

A public ozone and UV information system has been implemented and operated by CHMI since 1999. Reports on actual and forecasted UV Indices and variation of ozone are issued for the territory of CR and disseminated to mass media daily. The system is supported by information campaigns that are also joined by medical experts [5]. The internet component of the system that is linked with international centres (e.g. TEMIS/KNMI the Netherlands and ECUVF/DWD, Germany) is located at the address: <http://www.chmi.cz/meteo/ozon/hk-e.html>.

Relevant scientific papers

- [1] Vanicek K.(2003), *Calibration History of the Dobson 074 and Brewer 098 ozone spectrophotometers*, Publication of the Czech Hydrometeorological Institute, Prague, 2003, ISBN:80-86690-08-3
- [2] Vaníček., Dubrovský M. and Staněk M., *Evaluation of Dobson and Brewer total ozone observations from Hradec Králové, Czech Republic, 1961-2002 (2003)*, Publication of the Czech Hydrometeorological Institute, Prague, 2003, ISBN: 80-86690-10-5
- [3] Vanicek K. (2005), *Results of the Work Task 4. The final Report of the CANDIDOZ Project*, Brussels - in print.

- [4] Metelka L., Kliegrova S. and K. Vanicek (2005), *Application of Neural Models for Simulation of Total Ozone in the European Region, Deliverable 12 of the CANDIDOZ Project, Publ. of the Czech Hydrometeorological Institute, Prague, ISBN:80-86690-30-X*
- [5] Vaníček, K. , Janouch M. a K. Ettlér (2001): *UV-Index for the Public. Deliverable of the COST-713 Project, Publ. of the Czech Hydrometeorological Institute, Praha (in Czech)*
- [6] Koehler U.H. and K. Vanicek (2000): *The new European Dobson Calibration Center at Hohenpeissenberg and Hradec Kralove. Proceedings of the Quadrennial Ozone Symposium, Sapporo, NASDA Publ., July 2000, p.483*

PROJECTS AND COLLABORATION

The Czech scientific community is involved in several research and development projects that are focused mainly on analyses of ozone and UV observations taken by national monitoring facilities and their relations to external data sets. Attention is also paid to modeling of UV radiation with the aim to the ozone change and regime of cloudiness. The long-term cooperation is pursued between CHMI and the GAW Programme of WMO. Following are the chief ongoing collaborations and projects that should be mentioned.

CANDIDOZ

“Chemical and Dynamical Influences on Decadal Ozone Change”. EC FP-5, 2002-2005. Experts from CHMI and from the Department of Atmospheric Physics of the Czech Academy of Sciences investigate:

- Differences between simultaneous total ozone data sets originated with different instruments (Dobson, Brewer, satellite - TOMS-8, GOME/WFDOAS) and their impacts on ozone trends
- Estimation of the chemical component of ozone changes in the European region using neural-models and ERA-40 proxies.
- Relation between occurrence of ozone laminae and trends in ozone profiles in NH mid latitudes.

SCOUT-O3

“Stratospheric-Climate Links with Emphasis on the UTLS”. EC FP-6, 2004-2009. The CHMI specialists are involved in its UV part. High-quality UV spectral and broadband measurements taken at Czech stations are provided to SCOUT partners. Development and tests of a CHMI’s neural UV model and its application on reconstruction of the UV climatology in CR are the goals of the Czech team. The activities follow up the previous participation of CHMI in the project EDUCE.

COST-726

“Long term changes and climatology of UV radiation over Europe”. The EC coordinated, 2004-2008. Definition of the climatology of UV radiation and selected biologically effective UV radiation doses in the territory of CR by UV models are the chief tasks of the Czech scientists in the project. The models will be tested and applied to derive UV radiation data for long time period and places without UV measurements.

GAW Ozone

For a decade experts of CHMI contribute to maintenance of the GAW ozone monitoring network. The activities are focused mainly on implementation of new technologies and calibration of instruments at stations in developing countries (Capacity Building) and on cooperation with GAW central facilities. The following missions and achievements have been realized in the recent years.

- Technical service on ozone spectrophotometers (WMO IC in Dahab, Egypt, 2004)
- Re-installation and upgrade (semi-automation) of ozone spectrophotometers at GAW stations (Botswana, Egypt, Kenya, South Africa in 2004/2005)
- Training of operators from ozone stations - annual campaigns (15 trainees in 2003-2005)
- Assistance in realization of calibration campaigns of the Regional Dobson Calibration Centre - Europe, Hohenpeissenberg, Germany
<http://www.chmi.cz/meteo/ozon/dobsonweb/eurdcc.htm>
- Assistance in establishment of the Regional Brewer Calibration Centre - Europe, Izana, Spain
- Maintenance of the Dobson Web
Site:<http://www.chmi.cz/meteo/ozon/dobsonweb/welcome.htm>
- Donation of the software packages for Dobson and Brewer data management at GAW stations
- Participation in GAW scientific groups (SAG-Ozone, Dobson and Brewer Committees)

Currently the above activities are mostly sponsored by the Czech governmental project: "Maintenance of the Network for Monitoring the Ozone Layer in Developing Countries" established by the Ministry for Environment of CR for the period 2004-2006.

FUTURE PLANS

- The long-term monitoring of ozone and UVB radiation will be pursued in CR as specified above. Attention will be paid mainly to maintenance of calibration condition of the instruments and to implementation of updated SOPs, so that observations from the Czech facilities keep the highest achievable quality. Further establishment of new stations is not planned.
- Participation in the ongoing projects mentioned in this Report will continue. Future activities will be focused on the Czech contribution to building up the IGACO system in the regional scale. This includes the assistance to the Regional Dobson and Brewer Calibration Centres and on testing new technologies for Brewer spectrophotometers, above all.
- The UV simulation model developed at SOO-HK will allow CHMI experts to reconstruct the UV climatology of the last 5-6 decades. The results are expected to be applied in Czech and international integrated environmental projects.

NEEDS AND RECOMMENDATIONS

- Quality of assimilated ozone observations from the integrated ozone monitoring system should generally reach the calibration accuracy of the ground system so that recovery of the ozone layer is reliably identified and documented in the future.
- Accuracy of ground and satellite ozone observations in high latitudes needs to be better understood and improved through analyses of available records or by experimental missions.
- Analyses and modeling of the Arctic ozone losses and their relation to the stratospheric dynamics should get the highest priority in research projects in order to estimate a possible influence of the climate change on the state of the ozone layer.
- The WMO/GAW Programme and the UNEP should continue their key role in the capacity building and in the international coordination of ozone monitoring and research.
- Sustainable quality of UV spectral measurements in the global network requires establishment of global/regional references and implementation of standard calibration procedures for particular types of UV radiometers.

DENMARK

Stratospheric ozone monitoring

Daily observations of total ozone are performed by the Danish Meteorological Institute (DMI) in Denmark and Greenland:

Station	Location	Instrument	Start of observations
Copenhagen	56°N, 12°E	Brewer Mark IV	May 1992
Sondre Stromfjord (Kangerlussuaq)	67°N, 51°W	Brewer Mark II	September 1990
Thule Air Base (Pituffik)	77°, 69°W	SAOZ UV-vis 1024 diode array	September 1990

On non-regular basis, total ozone has also been measured from Qaanaaq in Greenland (78°N, 69°W), using the DMI Dobson #92 instrument since early 2000. One reason for moving the instrument to this location is the possibility to measure total ozone in the polar night in winter time using the Moon as the light source.

Weekly ozone soundings have been performed using balloon-borne ECC sensors from Scoresbysund (Illoqqortoormiut, 71°N, 22°W) since January 1993. Additional ozone soundings have also been performed on campaign basis from Scoresbysund and Thule each winter since January 1992 and occasionally from Copenhagen. Many of these ozone soundings have been used in European Match-campaigns to assess the chemical ozone depletion in recent Arctic winter/spring seasons.

The measurements are reported to databases under Network for the Detection of Stratospheric Change (NDSC) and World Ozone and UV-radiation Data Center under the WMO-programme Global Atmosphere Watch.

Thule and Sondre Stromfjord are primary Arctic stations within the Network for the Detection of Stratospheric Change (NDSC). Scoresbysund is a complementary NDSC-station. In addition to the DMI-instrumentation, aerosol lidars are operated at Thule and Sondre Stromfjord by the University of Rome (Italy) and SRI International (USA), respectively, together with an FTIR spectrometer at Thule, operated by National Center for Atmospheric Research (USA). A long series of balloon-borne backscatter soundings of polar stratospheric clouds (PSCs) and aerosol have been performed from Thule, Sondre Stromfjord, and Scoresbusund by DMI in collaboration with the University of Wyoming (USA). DMI also collaborates with Service d'Aeronomie du CNRS (France) for daily total ozone measurements by a SAOZ UV-vis spectrometer at Scoresbysund.

Ozone research

DMI has participated in all major European/US Arctic ozone research campaigns since the beginning the 1990'es such as EASOE, SESAME, THESEO, THESEO-2000/SOLVE and VINTERSOL. DMI has also participated in the HIBISCUS campaign from Bauru, Brazil, in February 2004, investigating cirrus formation and transport of water vapour in the tropical tropopause. In addition, DMI has participated in numerous past and ongoing research project, funded by the European Commission and Danish research agencies. DMI currently participates in the integrated EU-projects "Stratosphere-Climate links with emphasis on the UTLS" (SCOUT-O3), "Quantifying the climate impact of global and European transport systems" (Quantify), and "Global Earth-System monitoring using satellite and in-situ data" (GMES-GEMS). DMI will be CO-PI together with the Alfred Wegener Institute (Germany) in coordinating bi-polar stratospheric ozone and UV research in connection with the International Polar Year 2007-2008 (IPY).

The ozone research at DMI relates to:

- Transport studies of stratospheric ozone, including dilution effects at mid-latitudes from Arctic ozone depletion. In this research domain filling trajectory calculations, based on meteorological analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF), are applied together with available observations of total ozone and ozone profiles. This modelling concept is expanded to include microphysical and chemical modules.
- DMI has also been involved in studies of the accuracy of stratospheric temperatures in ECMWF and other analyses products, used for stratospheric research.
- Studies of polar stratospheric clouds (PSCs) by microphysical simulations and balloon-borne experiments from Greenland and Northern Scandinavia. For several years, the DMI has been collaborating with the University of Wyoming on balloon-borne backscatter soundings of stratospheric aerosols and PSCs from Greenland. This collaboration has been extended into a European/US collaboration on balloon-borne in-situ measurements of chemical and physical properties of PSC particles, performed from Northern Scandinavia.
- Microphysical modelling of cirrus clouds, including the formation of sub-visible cirrus in the tropics of relevance for transport of water vapour to the stratosphere.
- Studies of the effects of aircraft on cirrus formation and their radiative properties in the upper troposphere.
- Climate modelling, relating to the influence of ozone on the stratospheric circulation and climate. DMI operates climate models which include the effects of changes in stratospheric ozone.
- The DMI participates in several scientific and validation studies to utilise data from ESA's Envisat and other satellites, both on ozone, other trace gases, and aerosol measurements.
- Ozone and UV trend assessments. The DMI has contributed to the latest WMO/UNEP and European assessments on stratospheric ozone and to the Arctic Climate Impact Assessment Report and have taken part in the review process of assessment reports. DMI is currently involved in preparing a SPARC-assessment report on PSCs.

Ultraviolet radiation

Daily measurements of the surface UV-B radiation are performed by DMI at Thule, using a high resolution spectroradiometer, since summer 1994. The instrument has been intercompared to a NIWA instrument to become NDSC classified.

The DMI participates in EUMETSAT's Satellite Application Facility on Ozone Monitoring, aiming at the development of operational UV-index products, based on satellite measurements of the ozone layer.

UV-B index forecasts, based on Danish total ozone measurements, were initiated at DMI in summer 1992. This public service runs every summer season, made public on the Internet and in several media.

Further information

Further information on the stratospheric ozone research and monitoring at DMI, including publication lists and lists of past and ongoing research projects can be obtained on the Internet at http://www.dmi.dk/eng/index/research_and_development/the_division_fo.htm

General information about DMI can be obtained at www.dmi.dk
