WORLD METEOROLOGICAL ORGANIZATION
GLOBAL ATMOSPHERE WATCH

No. xxx

THE SIXTH BIENNIAL WMO CONSULTATION ON BREWER OZONE AND UV SPECTROPHOTOMETER OPERATION, CALIBRATION AND DATA REPORTING

Tokyo, Japan, July 2000

WMO TD No. xxxx

WMO CONSULTATION ON BREWER OZONE AND UV SPECTROPHOTOMETER OPERATION, CALIBRATION AND DATA REPORTING

Tokyo, Japan
July 10-12, 2000

Edited by: **C. T. McElroy and E. W. Hare**

Organised by: **O. Uchino, C. T. McElroy, T. Sasaki and E. W. Hare**

Chairpersons: **C. T. McElroy and O. Uchino**

Rapporteur: **E. W. Hare**

FOREWORD

There are now over 150 Brewer Ozone Spectrophotometers of different types in the Global O_3 Observing System. While each of these instruments has the potential to make the ozone and ultraviolet radiation measurements crucial to determining the future evolution of the UV radiation environment, some are not performing up to expectations. In order to ensure the availability of the highest quality data for the future assessment of the ozone layer and ultraviolet environment, it is essential that the data collected by individual instruments, including test and inter-comparison results, be archived in the WMO World Ozone and Ultraviolet Radiation Data Centre (WOUDC). Thus, an accurate and detailed retrospective analysis can be uniformly carried out on the data from all stations in the Global Observing System.

The Brewer Workshop meetings are a crucial part of the process of ensuring that all Brewers are properly operated and that instrument calibrations are tightly traceable to international standards.

C.T. McElroy

2000

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Day 1 – Monday, July 10, 2000

1 Formal Introduction of the Meeting and Welcome

O. Uchino of the Japan Meteorological Agency (JMA) officially opened the Sixth Biennial Brewer Workshop with an overview on how the JMA has contributed to the World Meteorological Organization – Global Atmosphere Watch (WMO-GAW) programme by monitoring ozone, UV and other environmental parameters used in the examination of the state of the global atmosphere. He mentioned that the meetings attendees are invited to visit the Tsukuba (Tateno) monitoring site where there are Brewer and Dobson instruments are in operation. The JMA also operates the World Data Centre for Greenhouse Gases (WDCGG) and the Quality Assurance/Science Activity Centre (QA/SAC) for the WDCGG. He wished the participants a successful meeting.

2 Opening Address by the Meeting Chairman

C.T. McElroy of the Meteorological Service of Canada (MSC), Environment Canada, thanked the local hosts O. Uchino, N. Hayashi and T. Sasaki for their efforts in organising the meeting. A common theme with the Brewer meetings is how the number of Brewers has grown. The JMA was specifically recognised for the operation of the second the longest, validated Brewer network, second only to Canada, in terms of the long ozone and spectral UV-B Brewer data records dating back to 1990. In addition, regular submissions of processed data to the WOUDC, is also a contribution that JMA has made to the Brewer and scientific communities.

McElroy stressed the importance of maintaining uniform policy development, international agreements and common methodology in order to respond to the needs of the scientific community.

The next three days will be devoted to some formal lectures in the plenary sessions, but will also provide the opportunity to meet and discuss technical issues.

3 Overview of the WMO-GAW Programme

M. Proffitt representing the WMO-GAW programme, began with an overview of research programmes from an experimentalist's perspective. He explained the importance of tracking, instrument operations, calibrations and data reporting. Problems need to be reported quickly so that the community is immediately aware of the data quality.

An overview of the GAW programme illustrated the importance of the World Data Centres (WDC) and how the GAW programme is built around these centres as depicted in Figure 3.1.1. Proffitt stressed the importance of the GAW regional and global stations and sites. There are also "contributing sites" such as Network for the Detection of Stratospheric Change (NDSC) or the Baseline Solar Radiation Network (BSRN) as well as independent stations or operators that also contribute to the WDCs. Quality Assurance procedures are presently being drafted to assist with the quality control of data from the GAW regional and global sites. The quality control components are: the Scientific Advisory Groups, the calibration Centres (Global and Regional) and the Quality Assurance/Science Advisory Centres (Regional).

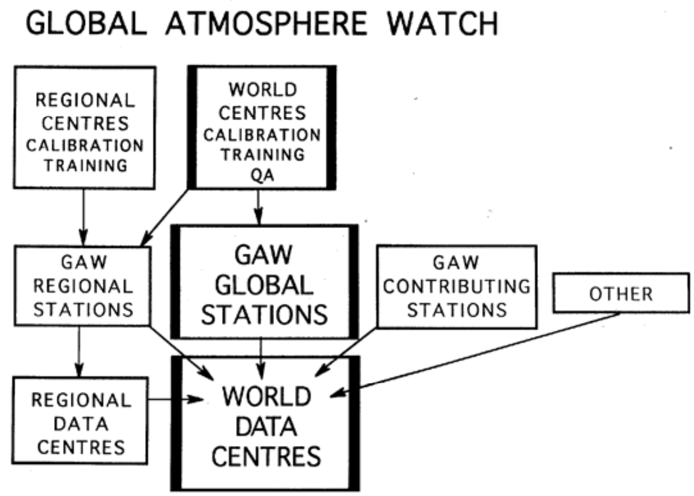

Figure 3.1.1 The World Meteorological Organization - Global Atmosphere Watch Programme

The WMO Science Advisory Groups (SAG) will now be responsible for the establishment of data quality criteria and Standard Operating Procedures (SOP), the promoting of twinning between stations/agencies and to oversee the implementation of data quality procedures. The SAGs then link to the WMO-GAW Quality Assurance/Science Activity Centres (QA/SAC) and the Calibration Centres. These centres provide data quality information to individual stations that is ultimately pointed to the WDCs for data reporting.

Proffitt also mentioned that the WMO-GAW wants to integrate meta-information at the various WDCs, into a centralised database such that users of the data can interrogate this database and be able to link the various measurements housed at the different WDCs.

Proffitt finished his presentation by stressing the importance of the twenty-two WMO-GAW Global stations as illustrated in Figure 3.1.2. The WMO has been very active with the Dobson inter-comparisons and hopes that the Brewer community will embrace some of the same techniques for future meetings. Finally, a new GAW initiative for the monitoring of ozone and UV at the southern hemi-sphere CONE stations located in Argentina, Brazil, Chile, Paraguay and Uruguay was presented. There are also six new stations to be added to the network for monitoring greenhouse gases (including ozone) from Algeria, Argentina, Brazil, China, Indonesia and Kenya.

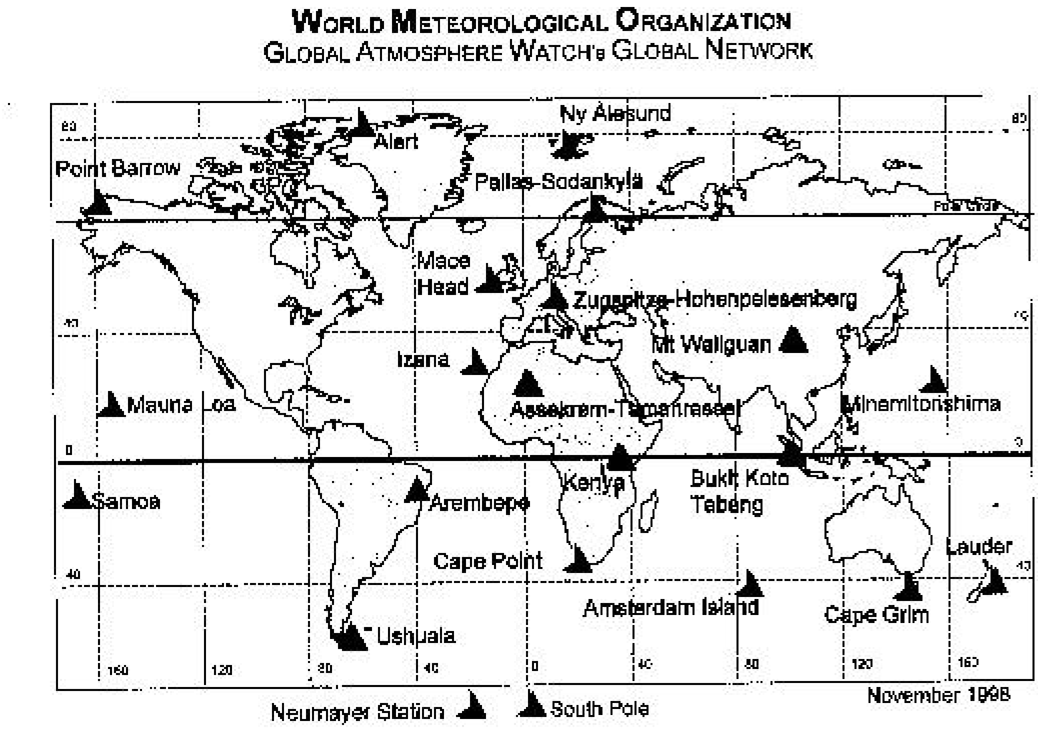

Figure 3.1.2 WMO-GAW Global Stations.

4 Plenary Session I: Brewer Instrument Networks

4.1 Canadian Brewer Spectrophotometer Network – T. Grajnar

T. Grajnar from Environment Canada - Meteorological Service of Canada (MSC) presented an operational overview of the Canadian Brewer instrument network. Three main elements of quality assurance were identified:

1. Basic Mechanical Operation - Daily diagnostics checks
2. Collecting good data – basic instrument maintenance and routine instrument calibrations
3. Collecting as much data as possible

These elements require well-trained site operators and a preventative maintenance schedule.

The staff includes the network manager, a network technologist, students and on-site operators who act as local contacts. Special on-site visits by other site operators plus International Ozone Services (IOS) staff members (K. Lamb and V. Savastiouk) are also arranged.

Canada has 13 monitoring stations within the Brewer network with a total of 18 Brewer instruments and a single Dobson which is housed at MSC headquarters in Toronto. There are also two Brewers located at the MLO, in Hawaii. A map of the Brewer station locations is given in Figure 4.1.1.

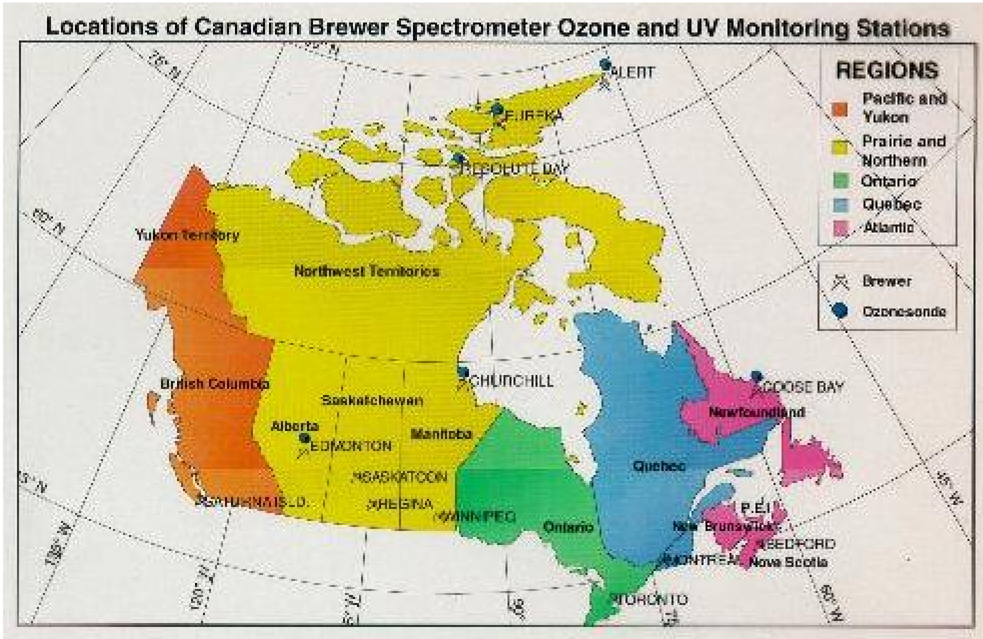

Figure 4.1.1 The Canadian Brewer network.

Station visits occur about once every two years, as a minimum. These visits focus on calibrations, maintenance, repairs and testing. The calibration includes: dispersion, UV, ozone and laser scans for stray light corrections. A field "doghouse" as illustrated in Figure 4.1.2, is used for the radiometric calibrations, that are performed in place, without the need of dismantling the Brewer from its tracker.

Other work includes: maintenance (over 150 checks), repairs (as required) and training of new operators, review and update on procedures. New developments and activities include the installation of new computers systems, digital images (photos) of each site with a panoramic view which are posted on the MSC-Experimental Studies web site and GPS measurements to accurately validate or determine station co-ordinates. There are automated daily downloads of data files, program directories, constants files, data logs and digital camera images. Three to five ozone and UV bulletins are issued every hour.

In order to better process and QA the data, new computer hardware and software has been installed at each station. Each site now uses the same operating system, with time server, spreadsheet and task scheduling programs that can be accessed remotely. There is ongoing customisation of support software and – communications to each site is done through ftp or phone lines.

Future plans include improved instrument characterisation, improved humidity control and monitoring system, an enhanced thermal stabilisation system, on site training or a reference video or DVD for station operators (since most systems will have this capability) and sky and surveillance cameras at all stations.

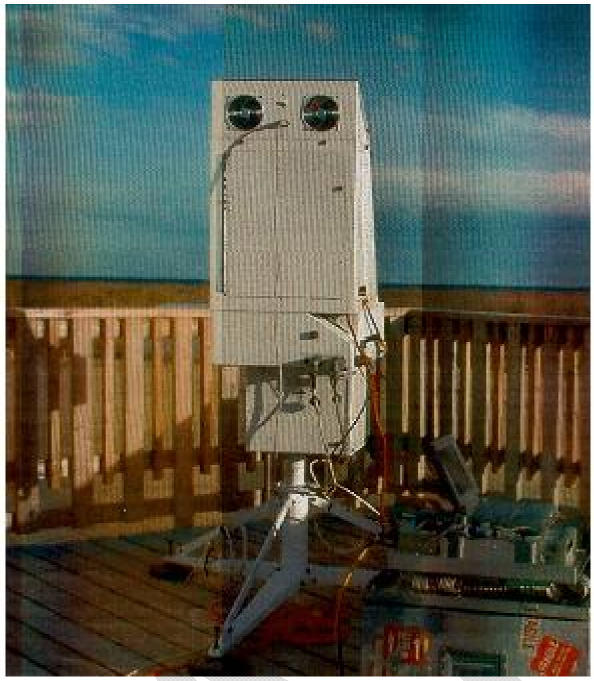

Figure 4.1.2 The Brewer "dog house" for in situ calibrations.

4.2 The Brewer Network at the JMA – K. Yoshimatsu

K. Yoshimatsu of the Japan Meteorological Agency (JMA) presented an overview of the Brewer monitoring network in Japan, operated by the JMA. Each of the five monitoring stations were outlined which included the observation schedules and the types of measurements made: ozonesonde, total ozone, Umkehr and spectral UV. A map of the stations is given in Figure 4.3.1.and station iformation is summarised in Table 4.2.1.

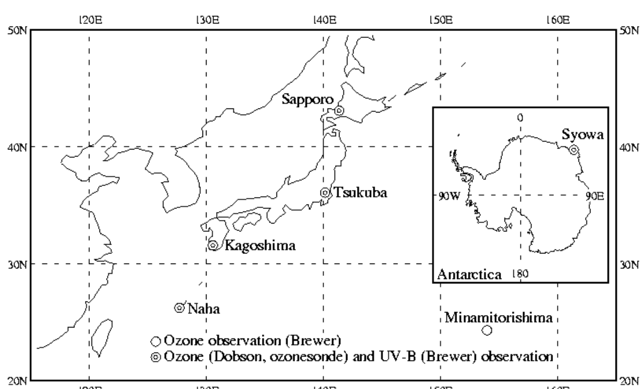

Figure 4.2.1 JMA monitoring stations

A comparison of ozone profiles with Dobson and the Brewer data was done in 1998 and total column ozone amounts from the daily representative value, were also presented for the year 1998. Umkehr data from Minaitorishima were presented. These data have been collected and processed since 1998. The JMA has a long history, dating back to the 1950s, of making Umkehr observations with Dobson instruments, so these Brewer Umkehr records are of interest.. Figure 4.2.2 shows the Umkehr amounts as a function of time for the year 1998.

Station	Ozone(Total, Umkehr)	UV-B	Ozonesonde (RS2-KC96)
Sapporo (43.05N 141.33E)	Dobson 126 Feb. 1958~	Brewer 058(MK-II) Jan. 1991~	Dec.1968~
Tsukuba/Tateno (36.05N 140.13E)	Dobson 125 (Dobson 116: Standard) Jun. 1955~	Brewer 052(MK-II) (Brewer 113(MK-II): Standard) Jan. 1990~	Nov. 1968~
Kagoshima (31.55N 130.55E)	Dobson 128 Mar. 1958~	Brewer 059(MK-II) Jan. 1991~	Dec. 1968~
Naha (26.20E 127.68E)	Dobson 127 Apr. 1974~	Brewer 060(MK-II) Jan. 1991~	Sep. 1989~
Minamitorishima (24.30N 153.97E)	Brewer 096(MK-II) Jan. 1994~	not observed	not observed
Syowa (69.00S 39.58E)	Dobson 119 (Dobson 122: Spare) Mar. 1961~	Brewer 091(MK-II) (Brewer 168(MK-III): Spare) Feb. 1991~	Nov. 1967~

Table 4.2.1 Observation programs at the six JMA monitoring stations.

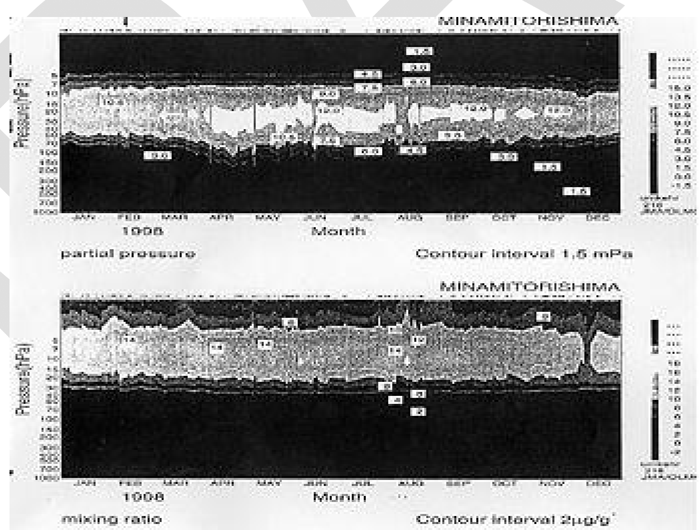

Figure 4.2.2 Umkehr layer amounts for the year 1998 at Minaitorishima station.

Comparisons of the ground-based data (both Dobson and Brewer) with TOMS were along with spectral UV-B data from the four national stations were presented. The relationship between total ozone and UV-B irradiance at the four stations located in Japan along with a plot of the UV-B data measured at the Syowa station, Antarctica was discussed. From 1991 to 1998, the monthly mean total ozone and UV-B data from Syowa, Antarctica for the month of November, illustrates the expected anti-correlation between the higher levels of UV-B irradiance when the total column ozone amounts are lower. This plot is given in Figure 4.2.3. Future research plans include the continued study of the variations of ozone, the effects of clouds and aerosols on the UV-B radiation and the trends of UV-B as related to the ozone amount.

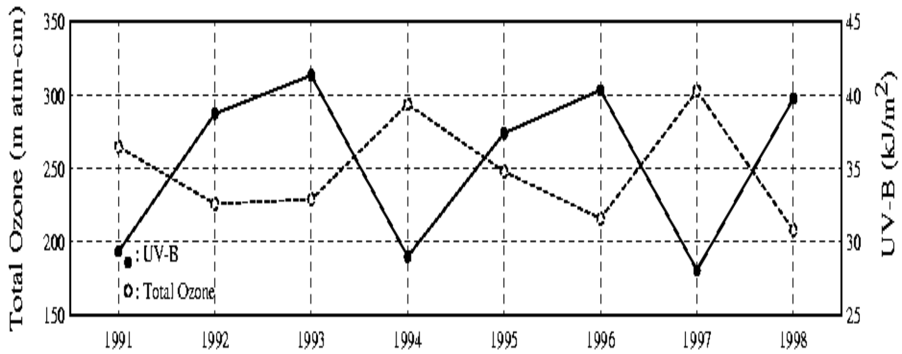

Figure 4.2.3 Time series of monthly mean of UV-B daily accumulation and total ozone in November from 1991 to 1998 at the Syowa station in Antarctica. The solid line is UV-B daily accumulation and dashed line is total ozone.

5. Session II - Retrieval Methods

5.1 Comparison of Information content in the zenith sky content in satellite nadir measurements – P.K. Bhartia

P.K. Bhartia from NASA-GSFC, USA presented the measurement techniques required for zenith-sky (ZS) UV observations and measurements. The technique involved the use of three types of ground-based zenith sky UV instruments: Dobson (manual and automated and the Brewer). For nadir-backscattered measurements, SBUV, GOME and OMI satellite data were used. From this study, a more advanced Umkehr algorithm has been developed. This algorithm is designed to reduce the effect of the *a priori* on trends and inter- annual variability. The algorithm features are:

a. *a priori* has no inter-annual variability and trend
    i. removed total O3 dep. of *a priori*
b. vertical resolution reduced to ~10 km
    i. retrieves in 5 double-Umkehr layers (1, 2+3, 4+5, 6+7, 8+)
c. uses more linear form of the Jacobian
    i. dN/dx instead of dN/dlnx
d. *a priori* covariance matrix is diagonal
    i. 45% rms variation in all 5 layers

The averaging kernel introduced by Rodgers in 1990 was used to locate each kernel's "peak". The traditional C-Umkehr program is very noisy in the lower layers (1 N-value)). The new algorithm has reduced this noise to 0.5 N-value which will improve the layer 1-3 retrievals in the lower stratosphere and the troposphere.

A synthetic data set was created in order to do some comparisons. This was constructed using Hohenpeissenberg ozonesondes (for layer 5 and below) and SAGE (for layer 5 and above). Umkehr N-values were calculated using the best radiative transfer code available. Gaussian noise (σ: 1 n-value) was added and the retrievals were done using the new algorithm.

Using this dataset the differences were shown for each set of layers. Figure 5.1.1a,b illustrates the retrieval for layers 4+5 (15.8-63 hPa). The solid line (___) is the "truth" while the dotted line (…..) is the retrieval. The Hohenpeissenberg ozone sioden versus the Aors Umkehr record for lAYers 4 and 5 are given in Figure 5.1.2.

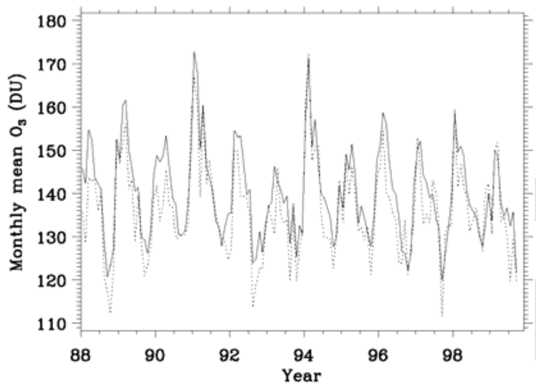

Figure 5.1.1a Layer 4 Retrieval

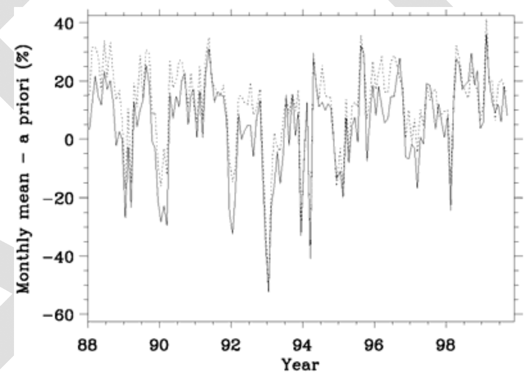

Figure 5.1.1b Layer 5 Retrieval

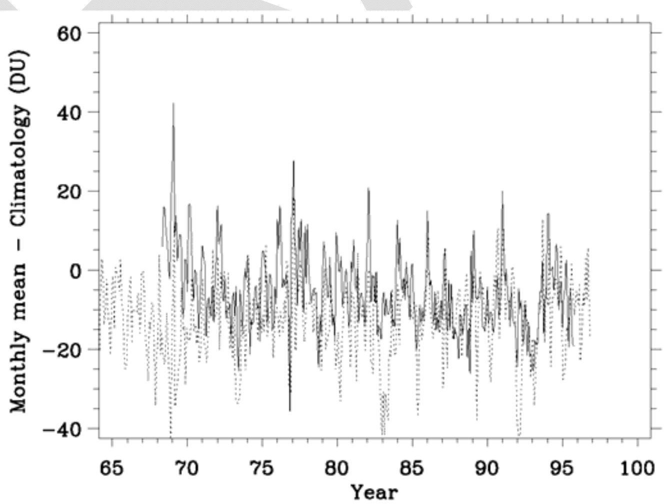

Figure 5.1.2 Ozonesonde (Hohenpeissenberg) versus Arosa Umkehr retrieval.

In conclusion: the Umkehr retrievals can provide reliable ozone profile information between the surface and 1 hPa, but only at ~10 km vertical resolution. The Arosa record shows no significant long-term ozone trend in layer 1 (253 hPa-surface) which is inconsistent with the Hohenpeissenberg sondes.

5.2 Novel Uses of the Brewer Instrument – P.K. Bhartia

The key difference between the Brewer and Dobson instruments in terms of the measurement capability was presented. The Brewer does not measure a ratio of radiances at two wavelengths like Dobson and the Brewer may have "hyperspectral" measurement capability ? Definition: full spectral scan at greater than Nyquist frequency. A disadvantage with respect to the Dobson is much greater cloud noise while the Brewer has the advantage over the Dobson that some applications are feasible that are not with the Dobson. In this regard, Bhartia believes the Brewer instrument is not being utilised to it's full potential, especially with Umkehr data.

Novel uses of the Brewer include that is it is elf-calibrating for total ozone measurements, it provides accurate total ozone, even in cloudy conditions and with high solar zenith angles (SZA). Direct calibration of satellite-measured radiances can be done as well. From the perspective of the self-calibrating mode, Bhartia proposed the following:

1. Run the Brewer in the direct-sun hyperspectral mode at least once a month in cloud-free conditions
2. Wavelength calibration checked by comparing with predicted irradiances using known solar spectrum and O_3 cross-section
3. Instrument calibration checked by examining the residuals (difference between measured and fitted spectra)

In addition, to measure the total ozone in cloudy conditions or with high SZA's:

1. Radiative transfer calculations show that l pairs do not remove cloud effects well from zenith-sky data
2. Profile effects become important at SZA>75˚
3. Use algorithm similar to the recent SBUV/TOMS algorithm to process ground-based zenith-sky data
   - A minimum of 4 single wavlengths are needed
   - 2 Weakly-absorbing wavlengths provide cloud/aerosol info
   - An additional wavlength provides total O_3
   - Shorter wavlengths can be used to correct for profile effects
   - Accurate retrievals close to 90˚ SZA possible

Then there is the direct calibration of satellite radiances.

1. Key similarity (courtesy of Tom McElroy)
   - From a radiation transfer perspective nadir-viewing satellite instruments sense the atmosphere in way very similar to the ground-based zenith-sky instruments

2. Key Difference
   - Effect of total O_3 is different on satellite and ground instruments

This yielded work on regenerating the Jacobian weighting function. A comparison of the Umkehr and SBUV Jacobian is seen in Figure 5.1.1.

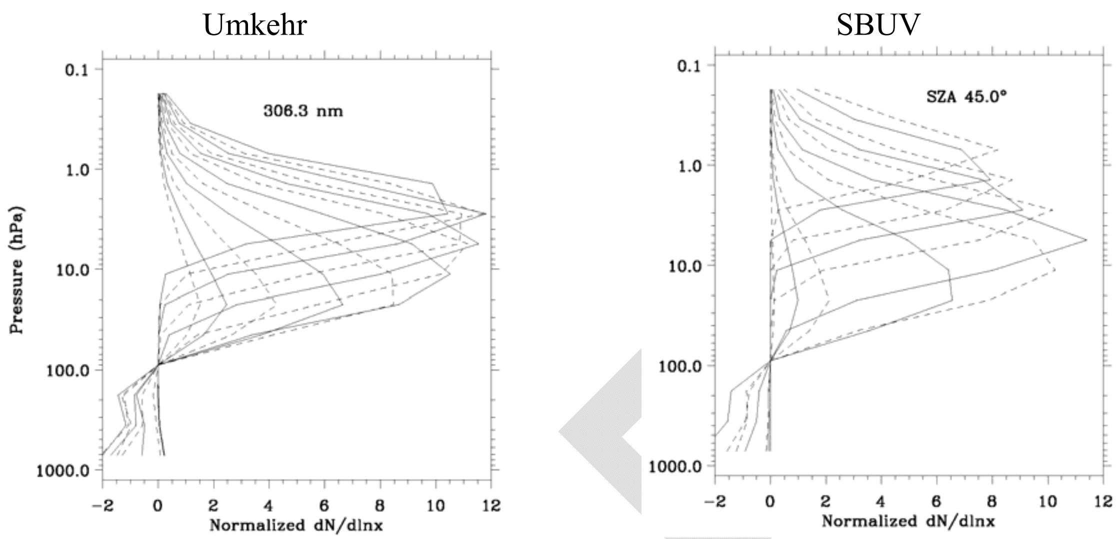

Figure 5.1.1 Comparison of Umkehr and SBUV Jacobian

In conclusion,

1. Periodic hyperspectral observations in clear-sky conditions can provide a "calibration stamp" on direct- sun total O3 measurements.
2. Zenith-sky measurements using 4 wavelengths can provide accurate total O3 in cloudy/dusty conditions using TOMS-like algorithm.
3. Good total O3 measurements up to 90˚ SZA may be possible in the zenith-sky mode.
4. Calibrated zenith-sky data can be used to check the calibration of satellite buv instruments.

6. Session III – Station and Site Studies

6.1 Comparison between Dobson, Brewer and TOMS total ozone measurements at Cairo and Marsa Matrub, Egypt. - A. Gahein

A. Gahein from the Egyptian Meteorological Authority presented results from a comparison of TOMS data to the ground-base data collected from the Brewer and Dobson instruments in Egypt. Some results from the Brewer indicated some problems in the total ozone record. Assistance was requested of the Brewer community to help in determining the cause of a "step function" in the time series. Time series from the Cairo and Aswan stations were also presented. A comparison of Dobson instrument 96 and Brewer instrument 143 compared within 3% and to within 5% with TOMS data.

Poster Session

A poster session was held in conjunction with a "hands-on" tutorial examining the Brewer instrument, which was made available in the poster room. Experts from Environment Canada, SCI-TEC and International Ozone Service were available to answer questions about software, troubleshooting and maintenance related issues.

Following the poster session, C.T. McElroy and J.B. Kerr gave an informal tutorial on the Brewer instrument and general spectroscopy.

Refer to Section 10 for copies of the poster session presentations.

Day 2 Tuesday, July 11, 2000-07-10

6. Session III Station and Site Reports continued …

6.2 Total Ozone and Spectral UV-B Irradiance Measurements by Brewer #148 At Seoul – J. Kim and S. Park

J. Kim and S. Park from Yonsei University, Korea presented results from measurements made at Seoul, Korea using Brewer instrument #148. The objective of the study was to convert ZS to DS data using measurements made from October 1997 to September 1998 and investigate the changes in the surface spectral UV irradiance (SSUVR). Since more detail is required then can be provided by the monthly mean ratios of Brewer ZS to DS measurements, more information about solar zenith angle SZA), cloud types and turbidity is required.

cannot be used for such a determination,

Regular standard lamp tests were performed and are illustrated in Figure 6.2.1.

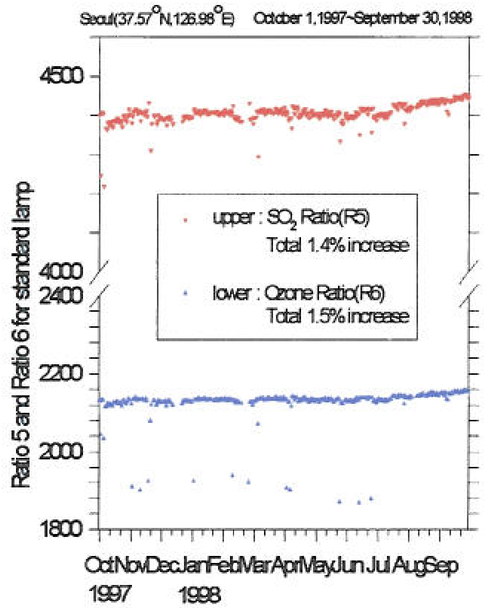

Figure 6.2.1 Daily Standard Lamp test values October 1997 – September 1998

In order to investigate how the changes in total ozone (1%) and the aerosol optical depth (AOD) affect the percentage change in the surface spectral UV irradiance (SSUVR), spectral radiation amplification factor (RAF) was calculated. The RAF is defined by the power law relationship as

$$\mathbf{Y=AX^{(-RAF)}}$$

Where:

Y is surface UV
X is total ozone or AOD
A is a constant
The RAF is also assumed to be constant.

the effect on ozone and UV were monitored – stray light was eliminated. Through the power law relationship:

<u>Comment byV. Fioletov:</u> The RAF does not rely on total ozone or zenith angle.

The spectra was shown in several plots the maximum spectral UV plots were cpmpared and a scatter graph was shown of the comparisons of these maxima???

The spectral RAF for different total ozone and normalized spectral erythemal weighted curve

UV irradiance as a function total ozone and wavelength and the RAF was determined **Figure 3** illustrates these curves

From this procedure the spectral Raf and the normalized spectral erythemal spectra were determined. Figure 4 shows the uv DUV as a function of total ozone and the AOD.

The Brewer at Seoul was determined to being operating fine and it was found that a decrease in ozone of 1% related to a 2.4% increase in erythemal UV irradiance over the 305-311 nm band Future work is imoroving the database and the preceision of calibrations as well as ozone and aerosol changes on the spectral UV and ertyhmal weighted irradiance

6.3 Findings from 17 years of continuous Brewer operation - Ulf Köhler

U. Köhler from the German Weather Service, Meteorological Observatory at Hohenpeissenberg (MOHp) presented an overview of the observation and measurement program at MOHp and a description of the European Ozone Centre (EOC) which is also located at the MOHp. The data set is a comprehensive collection of ozone data and the EOC acts a data archive centre.

Details of the operation of Brewer instrument #010 along with other instruments at the EOC are shown in Figure 6.3.1 as a plot of the time of operations from 1993-2000.

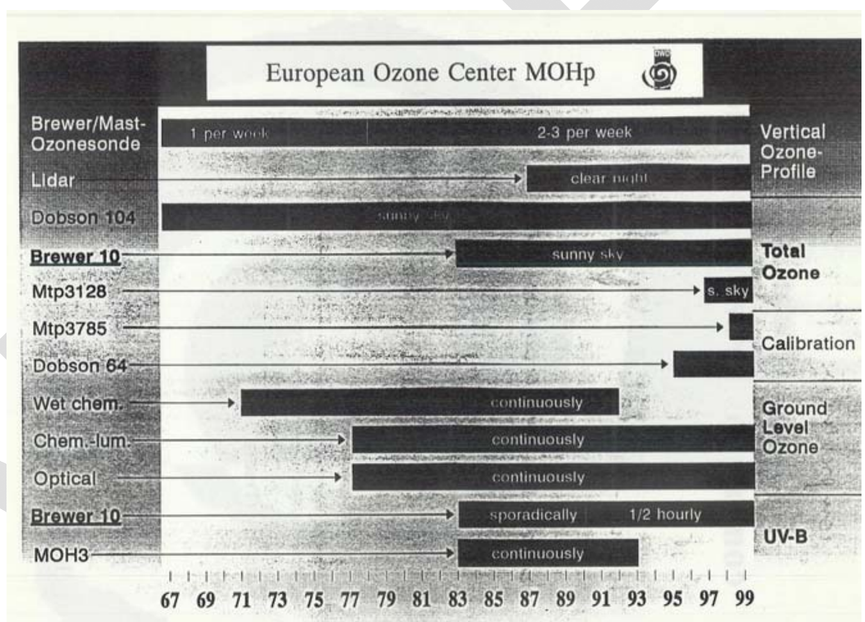

Figure 6.3.1 Summary of the European Ozone Centre MOHp Activities.

A relationship of the temperature of the instrument versus the SL data is given as a time series plot in Figure 6.3.2 where the temperature there does not seem to be any relationship with affects on the SL or photon counts. The Extra Terrestrial Coefficients (ETC) over time are stable – only small changes were necessary to adjust the instrument constants.

A comprehensive calibration history was also presented, where almost every year some form of work had to be done and although not inexpensive, it is necessary in order to maintain the instruments in optimal operational condition. For example, a misaligned prism position caused a cosine response difference. There have been over 4000 daily means out of >61,000 single DS observations from 1984-2000 for Brewer (BR#010). A time series of the Dobson #104 and

Brewer #010 where simultaneous measurements (within 15 minutes) were compared and assumed for a constant temperature coefficient.

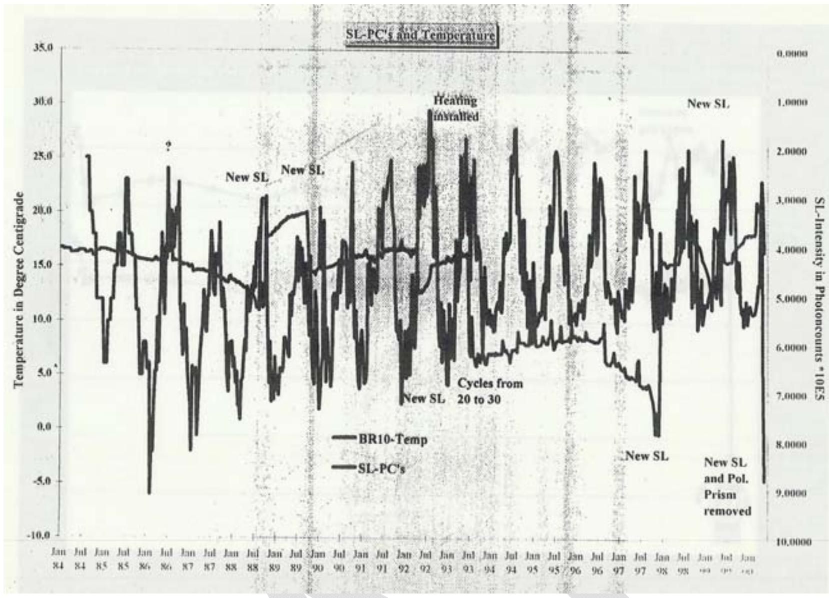

Figure 6.3. 2 The temperature of the instrument versus the SL data

Ozone trends at MOHp were shown where Dobson data trends were compared to those of the Brewer instrument for the years 1998 and 1999 where a slight increase in ozone was observed. If you want to make a good trend assessment, one should have about 30 years of data available, since 17 years does not appear to be enough.
Comment byC.T. McElroy: If this was the case then there would be no ozone trend measured as yet!

Köhler also presented UV observations that are being measured on a regular basis where the UV from ozone monthly means were extrapolated back to view the trends. Some discussion ensued regarding the reflectance from both the building itself and the possible shadowing effect, especially of the diffuse component. Köhler stated that the shaded component of diffuse sky would be less than 5%, but no estimate from the reflected radiation from the building has ever been done.

6.4 Inter-comparison between Dobson and Brewer using Arosa data – R. Stübi

R. Stübi of the Swiss Meteorological Institute (SMI) presented an overview of the various instruments and the measurement programs at the Arosa observatory. Total ozone daily mean values were compared for two Brewers (BR#040 and BR#072) where portions of the record were overlapped during the full time series to compare the instruments directly. The times series compared well due in large part to the regular instrument calibration schedule, approximately every 1-1.5 years. A comparison between BR#040 and BR#156 showed a slight trend of about 1-1.5% over two years, but overall the Brewer instruments compare very well to one another.

The monthly mean records of the Dobson instruments (D015, D051, D062 and D101) were also compared and were considered stable over the several years. Results of "corrections" within the specified temporal ranges showed that some features or offset scans can be adjusted or removed. McElroy presented a brief explanation of the humidity changes within the Brewer and use of the desiccant, as the temperature increases throughout the day so to does the pressure increase and some air will leak out at night as the Brewer cools sometimes by as much as 20^{o}C. A negative pressure builds up inside, thus drawing in cooler, saturated air resulting in liquid water built up. The Brewer needs to be sealed such that the inlet point is the point where the air is drier due to the desiccant so if the box is sealed in this way (knowing that the box will never be a perfect vacuum) then this helps keep the humidity down. If the drier approach is used, than during the day as the air is exhausted some of the desiccant humidity is removed by this process. This will also serve to prolong the life of the desiccant. Care must be taken when changing the desiccant and how and when one chooses to change it. For example, let the instrument reach equilibrium before the cover is removed when changing the desiccant.

Stübi concluded by showing the time series comparison of BR#040 and D062 from 1992 until early 1999. Monthly means with a 12-month running average pf the relative differences were shown and are given in Figure 6.4.1.

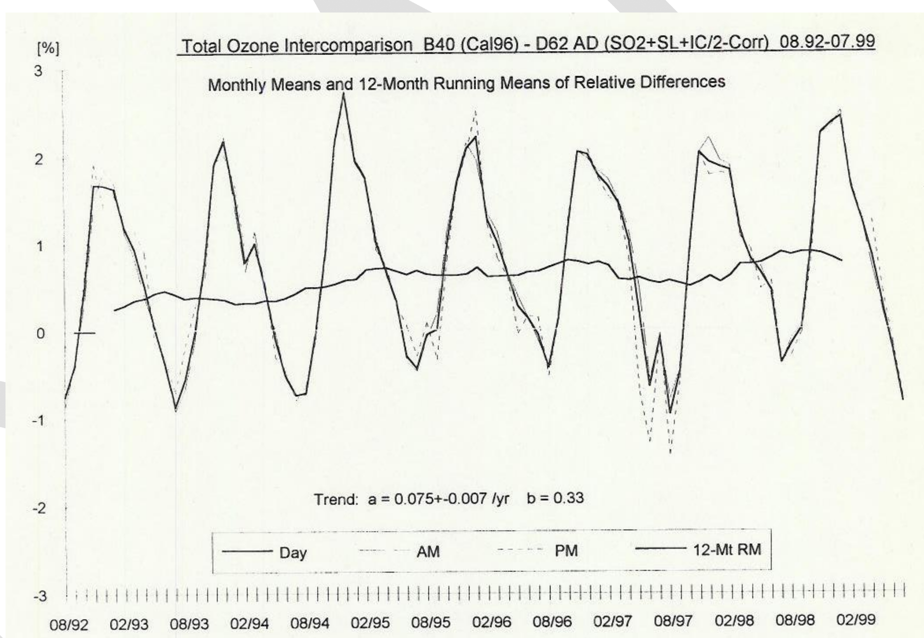

Figure 6.4.1 Comparison of Brewer instrument BR#040 to Dobson D062.

7. Session IV – Issues of Data Quality

7.1 Quality control of Brewer spectral UV measurements – V. Fioletov

V. Fioletov from Environment Canada presented an overview of UV measurements being made as part of the Canadian monitoring effort. A comparison of spectral and pyranometer data was presented. First, a study of the UV-A radiation was examined with the UV radiation at 324nm as compared to the global radiation (300-3000nm) and as a function of attenuation of the global radiation. The derived UV at 324nm was from global spectral irradiance measurements made by Brewer (BR#014). The monthly mean percentage difference between the UV 324nm irradiance measured by the Brewer and estimated from the pyranomter data using the F and S models was shown. The study was for Toronto and Edmonton from Sep-Oct ???

An RT model was compared with a statistical method whereby the relative difference was plotted this was done for clear sky conditions only. Daily comparisons from the Brewer and estimates from satellite TOMS were done for Toronto, Edmonton and Churchill stations. Data taken within +/- 2 hours from the satellite overpass were examined. An estimation of the cloud factor from Brewer observations and monthly mean reflectivity at 360/380 nm values form the TOMS were plotted and presented.

Fioletov noted, that when there is snow on the ground this causes problems (in reflectivity/albedo) between the TOMS and Brewer data and the differences are especially seen in Churchill where the surface is "white" during winter which makes it difficult deriving cloud information when having to differentiate between ground-cover and cloud cover conditions.

7.2 Temperature Dependence Of The Spectral Response For The MKIV Brewers In The UGA/USEPA Network – J.E. Rives

J. Rives from the University of Georgia at Athens (UGA) presented the spectral response to temperature dependence for the US Environmental Protection Agency (EPA) Brewer network. The National UV Monitoring Center (NUVMC), located on the campus of the UGA, is presently under contract with the USEPA to operate the USEPA/UGA network consisting of 21 MKIV Brewer instruments. The 21 sites range from Hawaii to Alaska and Virgin Islands and the data are posted at two web sites, one at the UGA and the other at EPA.

The initial measurements in the laboratory of the temperature coefficient of the Brewer response for three instruments, demonstrated the need to correct for the temperature dependence. The response was measured with a calibrated 1000W FEL lamp operating in a constant temperature environment and at constant current while the temperature of the Brewer was adjusted from -18^{o}C to $+42^{o}$C in a separate temperature controlled atmosphere. Best fits to the data yielded temperature coefficients at 306nm for the three Brewers of –0.17 %, –0.22 % and –0.37 % per ^{0}C. In addition, a wavelength dependence of the response was observed.

The response of Brewer BR#103 to the 50W lamp was examined for temperature dependence and the study showed significant improvement in correlation using temporally corrected adjusted response. The response is plotted in Figure 7.1.1. This lead to a method of using the 50W lamp calibration.

1. Use highly stable current source with small temperature coefficients – very stable
2. Determine the temperature coefficient of the 50W lamp in the lab
3. Use this 50 W for the sites
4. Perform multiple XL scans

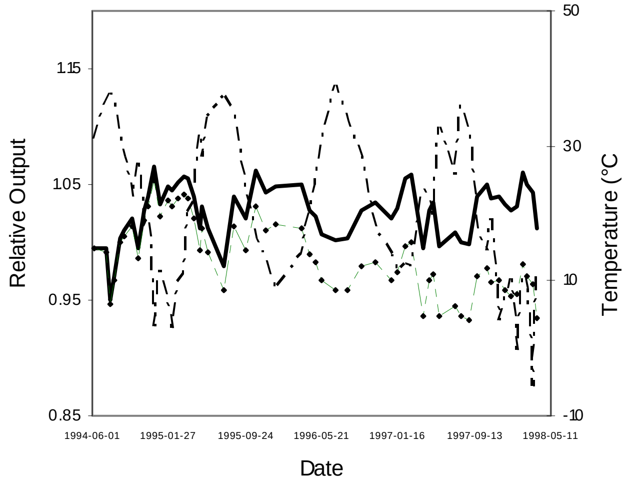

Figure 7.1.1 Response of BR#103 to 50 W lamp.

The temperature dependence of Br#114 comparing the response outside (with a 50 W lamp) to a controlled environment (using a 1000 W FEL) was presented and the plot is given in Figure 7.1.2. If the apparatus is used outside with the Brewer and uses a 50W lamp and also show this as a function of wavelength and so the difference in this should be the temperature coefficients of the 50W lamp, yet it revealed that there is little wavelength dependence of the 50W lamp temperature coefficients. Thus,

1. The temperature dependence of the Brewer UV response function needs to measured for each brewer
2. A 50W lamp properly prepared and operated with ultra-stable current source can be sued in these measurements

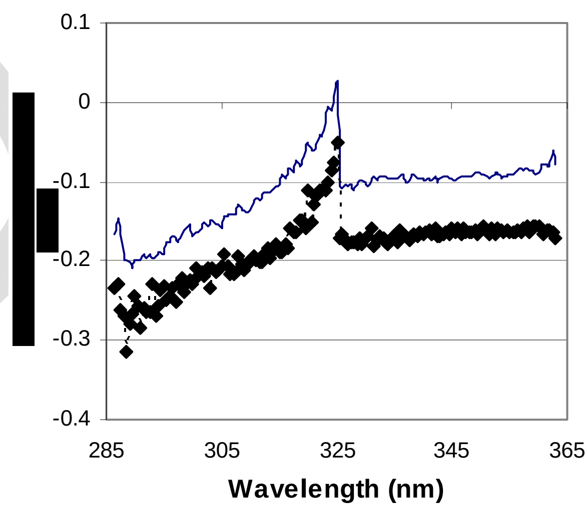

Figure 7.1.2 Temperature dependence of BR#114.

It is intended that a uniform set of electronics and a single 50 W lamp will be used at the sites, but McElroy commented that with a smaller lamp output the inverse square law has a larger error due the short distances involved which enhances these changes which can lead to higher temperature coefficient changes. Rives responded that by using the calculated slope that this should reduce these problems. Köhler mentioned that he uses the SL for measuring any temperature dependency.

7.3 Cosine corrections for ultraviolet radiation data from the USEPA/NUVMC – J. Sabburg

J. Sabburg of the University of Georgia at Athens (UGA) presented the cosine corrections determined for 21 Brewer MKIV spectrophotometers owned by the USEPA and operated and maintained by the NUVMC for ultraviolet radiation data. The methodology involved measuring the cosine response of each Brewer in the laboratory. A cosine correction computer program was written using the Brewer cosine response files as input. These cosine responses were the average of the long and short side measurements made using the irradiance of a standard 1000 W lamp on each Brewer in the laboratory, based on an average of five wavelengths: 306.3, 310.1, 313.5, 316.8 and 320.1 nm, including dark counts. The lamp was rotated over the zenith angle range of –80 degrees to +80 degrees in 10 degree steps. The direct / global irradiance ratio was used in finding the total cosine correction using a semi-empirical UV model. An isotropic, diffuse, skylight distribution was assumed.

Figure 7.3.1 illustrates an example of the cosine response from two Brewers while Figure 7.3.2 presents the corresponding total, cosine correction percentage errors versus SZA using the cosine responses of Figure 7.3.1. The correction is based on a wavelength of 320 nm, ozone amount of 300 DU and an Aerosol Optical Depth (AOD) of 0.5.

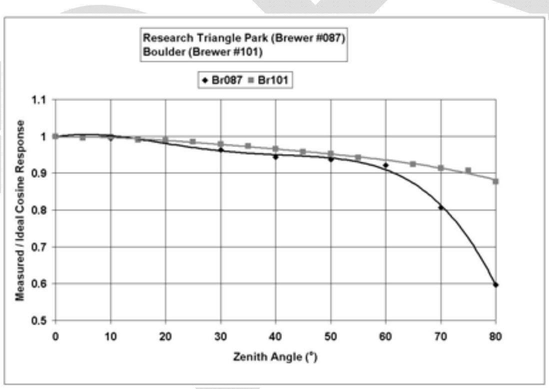

Figure 7.3.1 Cosine response from two Berwers

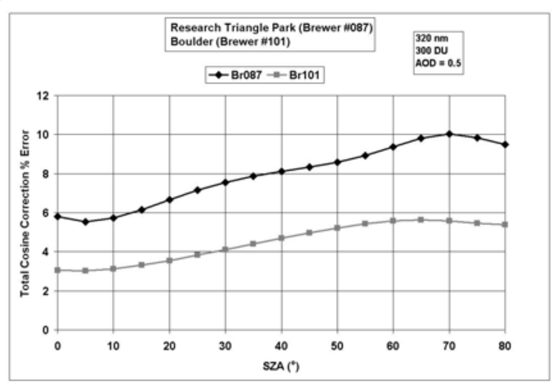

Figure 7.3.2 Cosine correction errors versus SZA.

The direct/global irradiance ratio is required and a semi-empirical clear sky UV model by Rundel was used along with the first approximation of the total cosine correction factor based on the equations of Bais *et al*.See the slide for equations. This model was found to be realistic down to 296 nm and was optimized up to 340 nm over the SZA range of 20 to 80 degrees.

Figure 7.3.3 shows a comparison of the percentage of cosine correction versus SZA of the Brewer located at Research Triangle Park (RTP) for three wavelengths (300, 320 and 350 nm) and Figure 7.3.4 is the percentage of cosine correction versus SZA at RTP for three AOD (0.1, 0.5 and 1.0) with an ozone amount of 300 DU. There are two competing effects that cause the lines of best fit of the data to cross over at a SZA of 60 degrees in both figures 7.3.3 and 7.3.4, rather than at a greater SZA. The effects are an increasing error in the cosine response (direct irradiance) with SZA and a decreasing ratio of direct / global irradiance with SZA.

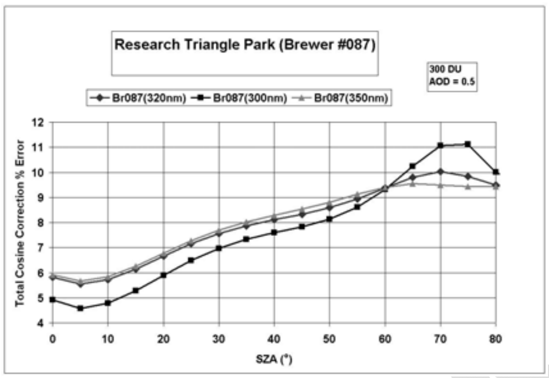

Figure 7.3.3 Comparison of the cosine correction versus SZA at Research Triangle Park for three wavelengths.

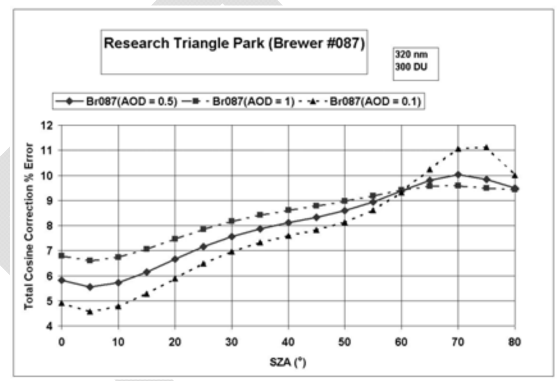

Figure 7.3.4 Comparison of the cosine correction versus SZA at Research Triangle Park for three AOD.

A method for correcting the cosine error due to a no-nideal angular response of the Brewers in the USEPA/UGA network has been presented. The absolute UV irradiance measured by the Brewers should be increased by 3 to 24 % , dependent on wavelength, SZA and cosine response for each Brewer. It is estimated that the uncertainty in the cosine-corrected irradiance is within ± 2 % of the true cosine-corrected irradiance. The uncertainty decreases for moderate to high aerosol loading and shorter wavelengths due to the increased validity of the isotropic sky assumption.

7.4 The ozone measurements using visible part of the spectrum with the Brewer spectrophotometer – V. Savastiouk

V. Savastiouk of International Ozone Services (IOS) Inc. gave a presentation on ozone measurements using visible part of the spectrum with the Brewer. By inspecting the Chappuis band to calculate total column ozone which is located in the visible part of the spectrum (between 400-700 nm) instead of the usual UV region of 310-340nm.

A modified Brewer MKII was developed and renamed a MKV because the diffraction grating with 180 lines/nm produces a UV spectrum from 285-360 in the 2nd order and a red spectrum in the range of 550-630nm in the 1st order. A filter wheel known as FW3 was used to achieve this. The measurement technique that is used is similar to those for DS measurements with the additional effect that after a measurement (with all 7 slits at one position of the micrometer), this position is changed and the measurement with all slits is repeatable. Currently, 28 positions from 510-680 nm region are used over an effective airmass range of 8 to 4.

Data analysis involved a system of linear equations set individually because of the slight difference in SZA and possible changes in the sky conditions. For example, aerosol and molecular components are included within these equations. A graph of the UV versus red approach was shown along with the ratio of the two methods to determine if there were any trends.

In conclusions:

1. Red measurements can extend the observation period (higher airmasses) which is useful at high latitude sites;
2. The time of one scan is shortened because of the reduction of the number of scans;
3. The SL could be measured at the same micrometer position in order to establish temperature coefficients.

8. Poster Session

A Descriptive Statistics of Brewer #067

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Introduction

Brewer #067 (MKIV type) has been working since 1992 at Rome (41.9°N,12.5°E), when first useful data were collected after a trial period in 1991. Its position in the town centre (60 m a.s.l.) adds useful parameters to the description of large urban areas environment. Eight years of O_3, SO_2, NO_2 and UV (290-325 nm) data are now available. Such a large database needs continuous visual inspection, quality control and quality assurance before it can be used for scientific purposes. Operators find benefice in the use of Brewer Data Management System (BDMS) software and data comparison with Brewer instruments collocated nearby in space (Brewer #024, extended MKII, Vigna di Valle, 50 km apart from Rome) or having similar time series (Brewer #066, MKIV, Ispra - 45.8°N,8.6 °E, 240 m a.s.l., working since 1992). TOMS data are also used to get helpful information about O_3 values stability.

Data and results

Table 1 shows the results of a detailed statistics of O_3 data derived from the use of BDMS software. Table 2 is a characterization of UV measurements during the eight years of measurements.

year	***1991***	***1992***	***1993***	***1994***	***1995***	***1996***	***1997***	***1998***	***1999***
Field calibration (with travelling standard #017)	10 Dec (34491)		13-14-15-17 Sep (256-257-258-26093)		29-30-31 May (149-150-15195)	15-16-17 Apr (106-107-10896)	21-22-23 May (141-142-14397)	22-23-24 Jul (203-204-20598)	21-22-23-24 Sep (264-265-266-26799)
Out of work days		42	11	4	115	24	6	10	70
No good daily *zs and* ds data		4	0	0	0	3	3	0	53
Missing ds *and zs* data		46 (13%)	11 (3%)	4 (1%)	115 (32%)	27 (7%)	9 (2%)	10 (3%)	123 (34%)
No good ds data *only*		46	34	34	33	43	33	30	53
Missing ds data *only*		88 (24%)	45 (12%)	38 (10%)	148 (41%)	67 (18%)	39 (11%)	40 (11%)	123 (34%)
Notes	*Start working on May; first useful data on Dec*				*UG11 filter change; stop working from Oct to Dec (lightning?)*				*Power supply burnt; stop working from Nov to Dec*

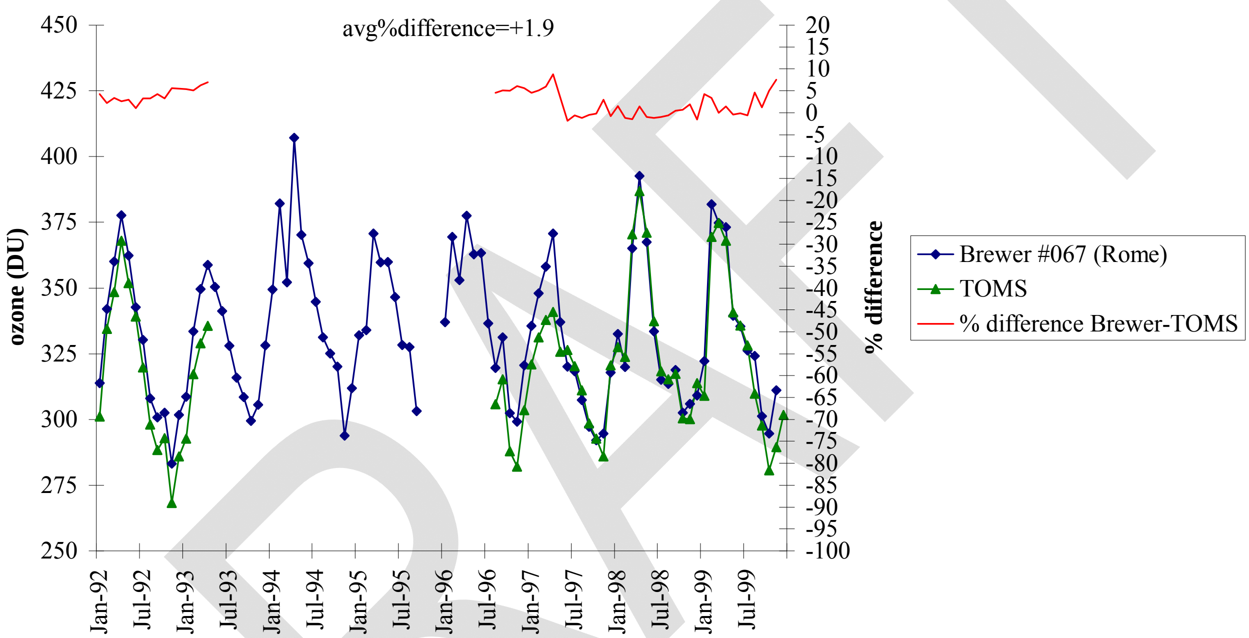
Table 1. Brewer #067 descriptive statistics in O_3 mode

year	***1991***	***1992***	***1993***	***1994***	***1995***	***1996***	***1997***	***1998***	***1999***
Out of work days		17	12	5	114	24	5	8	94
Number of scans		3202	3472	3839	4376	8474	11317	10279	6230
Notes	*Start working on May; first useful data on Dec*				*Stop working from Oct to Dec (lightning?)*				*Power supply burnt; stop working from Nov to Dec*

Table 2. Brewer #067 descriptive statistics in UV mode

The distribution of UV measurements versus solar zenith angle shows two peaks at 47° and 66°, which are frequently used in scientific reports dealing with Rome and Ispra UV data. Figure 1 compares #067 monthly average ozone values with TOMS ones. An average percentage difference Brewer-TOMS of +1.9% is found with a maximum at +8.8% and a minimum at -1.9%. Similar comparisons can be performed with respect to #024 and #066 Brewers, showing respectively the existence of +4.9% and +1.6% average differences.

Figure 1 Comparison between Brewer and Toms monthly average ozone at Rome (Jan 1992-Nov 1999)



Published works dealing with Brewer #067

- Casale G.R., Siani A.M., Palmieri S.: "The Brewer spectrophotometer No.067 in NO_2 mode" *The Fourth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting, Rome, Italy, 22-25 September 1996* Edited by C.T. McElroy and E.W. Hare (1998)
- Casale G.R., Meloni D., Miano S., Siani A.M., Palmieri S., Cappellani F.: "Solar UV-B irradiance and total ozone in Italy: fluctuations and trends" *Journal of Geophysical Research Atmospheres* Vol 105 No D4 pages 4895 - 4901 (February 27, 2000)
- Meloni D., Casale G.R., Siani A.M., Palmieri S., Cappellani F.: "Solar UV dose patterns in Italy" *Photochemistry and Photobiology* Vol 71 No 6 (June 2000)

Projects involving Brewer #067 data

- ♦ SUVDAMA: Solar Ultraviolet Data Management
- ♦ WOUDC: World Ozone & Ultraviolet Data Centre
- ♦ EDUCE: European Database for Ultraviolet Radiation Climatology and Evaluation
- ♦ WMO Northern Hemisphere Daily Ozone Mapping Centre

Temperature dependence of the spectral response for the MKIV Brewers in the EPA/UGA network

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Introduction

The National UV Monitoring Center (NUVMC), located on the campus of the University of Georgia, is presently under contract with the USEPA to operate the USEPA/UGA network consisting of 21 MKIV Brewer instruments. The NUVMC maintains a laboratory that obtains the spectral response of each instrument, and the absolute irradiance of each 50W lamp. It also characterizes each instrument for its spectral bandwidth, stray light level, and deviation from ideal cosine response.

The temperature dependence of the spectral response for λ<325nm has been described previously for one Brewer.[1] It is one of the major limitations of its accuracy as an absolute solar UV irradiance instrument. While it is the dominant instrument worldwide for these measurements, the instrument temperature fluctuates with the ambient at the various sites from about 5 to 50^{o}C. This results in a predicted seasonal variation in the UV irradiance of up to 20%, well beyond the goal of ±3%. This seasonal temperature dependence is seen for Br 103 in Fig. 1 where the integrated signal from a 50W calibration lamp is shown over a four year time period. An annual oscillation of 5% is observed (dashed curve, corrected for the slow decay of the instrument response) to anticorrelate with a 25^{0}C ambient temperature change.

In this paper, we describe a method, using these 50W Brewer calibration lamps operating in a constant current mode, which will allow the local operator at each site to obtain the instrument's temperature dependence.

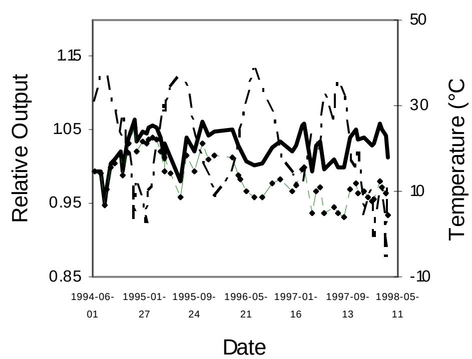

Fig. 1 Response of Br 103 to 50 W lamp. Temperature ----- Relative Output--♦-- Adjusted Relative Output

Initial Laboratory Measurements

Early measurements in the laboratory of the temperature coefficient of the Brewer response for three instruments, demonstrated the need to correct for the temperature dependence. The response was measured with a calibrated 1000W FEL lamp operating in a constant temperature environment and at constant current while the temperature of the Brewer was adjusted from -18^{o}C to $+42^{o}$C in a separate temperature controlled atmosphere. Best fits to the data yielded temperature coefficients at 306nm for the three Brewers of –0.17 %, –0.22 % and –0.37 % per ^{0}C. In addition, a wavelength dependence of the response was observed.

Method of Field Determination of the Brewer Temperature Dependence

Because it is impractical and costly to return each network Brewer to NUVMC in order to measure the temperature coefficients in the manner discussed above, we have developed a plan to obtain these at each site using the 50W lamps.

The operator will perform XL scans throughout a day as the ambient temperature varies in its diurnal cycle. The lamp will be maintained at constant current using a highly regulated DC power source whose current output is kept constant by monitoring the voltage across a low resistance standard resistor in series with the lamp. Both the resistor and the voltmeter will have extremely low temperature coefficients. The only contributions to the temperature dependence of the signal will be from the Brewer and from the 50W lamp.

Once the temperature dependence of the radiance of the 50W lamps is known, the temperature coefficient of the Brewer response can be isolated. XL scans were taken on the same Brewer under two conditions: (1) using a 1000W FEL lamp maintained at constant ambient temperature while the Brewer temperature was varied in a controlled environment and (2) using a 50W lamp where both the lamp and Brewer were in the same fluctuating ambient temperature conditions on the roof. An example of the temperature dependence of the photocurrent counts at λ=310nm with the 1000W FEL lamp is shown in Fig. 2.

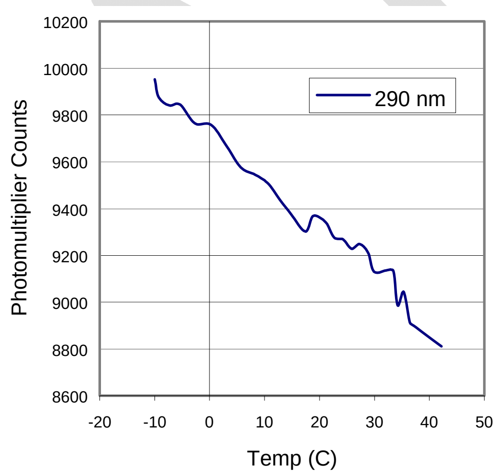

Fig 2   Brewer in controlled temperature environment with 1000 W FEL at room temperature.

The slope determines the temperature coefficient at that λ. The temperature coefficient of the Brewer as a function of λ is shown in Fig. 3 (dotted curve). The $NiSO_4$ filter, which is removed above 325nm, is the main source of the wavelength dependence. In addition, the PMT makes an additional contribution of about -0.2%/^{0}C. Using the 50W lamp, a slightly shifted temperature coefficient is obtained (solid curve in Fig. 3).

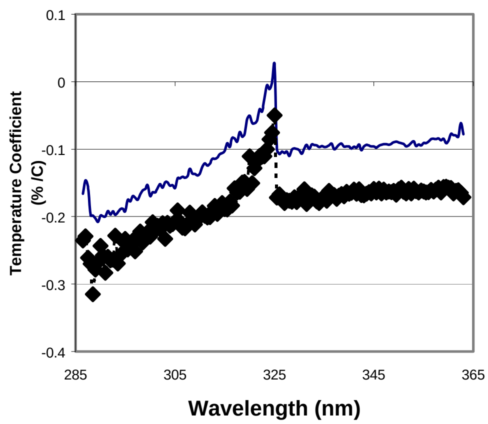

Fig 3 Temperature dependence of Br114. Br outside using 50 W lamp Br in controlled temperature
♦ ♦ ♦ ♦ Environment with 1000 W FEL at room temperature

The difference yields the wavelength independent temperature coefficient of the 50W lamp radiance (0.07%/^{0}C), shown in Fig. 4. We estimate that we can correct, at all λ, at least 70% of the temperature dependent contribution of the instrument response to the measured absolute UV irradiance.

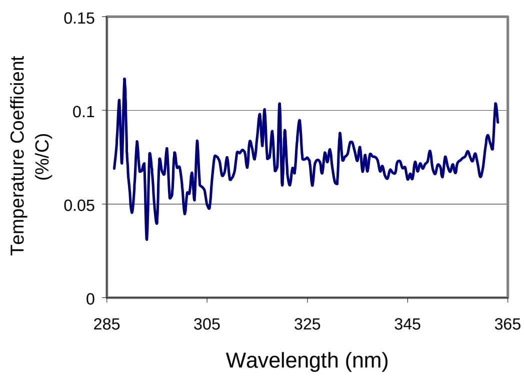

Fig 4. Temperature dependence of 50 W lamp.

Cosine corrections for ultraviolet radiation data from the USEPA/UGA Brewer Network

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Abstract. This paper discusses the cosine corrections that have been determined for 21 Brewer MKIV spectrophotometers owned by the USEPA and operated and maintained by the NUVMC. The methodology involves measuring the cosine response of each Brewer in the laboratory. The direct / global irradiance ratio is used in finding the total cosine correction using a semi-empirical UV model. An isotropic, diffuse, skylight distribution is assumed. It is found that the absolute error due to the nonideal angular response of UV irradiance of the Brewers, range from 3 to 24 %. This range applies for an AOD equal to one, a total column ozone amount equal to 300 DU and the correction is also dependent on wavelength, SZA and the cosine response of each Brewer.

Introduction

The National UV Monitoring Center (NUVMC) has been contracted by the U.S. Environmental Protection Agency (USEPA) to provide quality control for the largest UV network in the world consisting of 21 Brewer MKIV spectrophotometers manufactured by SCI-TEC/Kipp & Zonen. Fourteen of these 21 sites are at national parks and the remaining seven are urban locations. Measurements that can be determined from the retrieved data include erythemal UV (DUV), total column ozone, Umkehr profiles, SO_2, NO_2 levels and aerosol optical depth (AOD).

The contract involves the quality assurance of spectral UV data which, along with the other data, is automatically retrieved from the Brewer network on a daily basis. The absolute calibration of the UV irradiance is required to be less than ± 3 % and traceable to the National Institute of Standards and Technology. However, there are a number of corrections that need to be applied to the data before this accuracy is attainable. These corrections include the cosine errors associated with the nonideal angular response of the full sky diffuser, the temperature dependence of the response of the instruments (Meltzer *et al*., 2000) and the temporal variation in the instrument response due to optical changes in the characteristics of the Brewers. The effects of these corrections on the UV irradiance for some Brewers are quite significant. While for many sites the total corrections amount to less than 10 %, for certain sites they are much larger, in some cases amounting to more than 25 %. This paper only considers the cosine correction.

Instrumentation and Methodology

A cosine correction computer program was written using the Brewer cosine response files as input. These cosine responses were the average of the long and short side measurements made using the irradiance of a standard 1000 W lamp on each Brewer in the laboratory, based on an average of five wavelengths: 306.3, 310.1, 313.5, 316.8 and 320.1 nm, including dark counts. The lamp was rotated over the zenith angle range of – 80 to 80 ° in 10 ° steps.

The program calculates the first approximation of the total cosine correction factor (f_g) based on the equations of Bais *et al*. (1998):

$$f_g = (1 - f_{bg}) * f_d + f_{bg} * f_b \qquad (1)$$

where f_b (the direct correction) is the measured / ideal cosine response and if a diffuse isotropic sky is assumed, then the diffuse correction (f_d) is given by:

$$f_d = 2\int_0^{\pi/2} f_b \cos\theta \sin\theta d\theta \qquad (2)$$

where θ is the solar zenith angle (SZA). The f_{bg} term is the ratio of the direct / global irradiance based on the clear-sky model of Rundel (1986). The model used a sun / earth distance of 1 astronomical unit and a surface albedo of 0 %. Wavelength, AOD, altitude and ozone amount were also input to the model. This model was found to be realistic down to 296 nm and was optimized up to 340 nm over the SZA range of 20 to 80 °.

Results

An example of the cosine response of two Brewers is shown in Figure 1. The corresponding lines of best fit of the cosine responses (f_b) corresponding to Research Triangle Park (RTP) and Boulder respectively, were:

$$f_b = -0.75x^4 + 1.59x^3 - 1.08x^2 + 0.17x + 1.00 \qquad (3)$$

$$f_b = -0.07x^4 + 0.18x^3 - 0.18x^2 + 0.02x + 1.00 \qquad (4)$$

where x is the zenith angle in radians of the direct UV irradiance of the lamp. Figure 2 presents the corresponding total, cosine correction percentage errors versus SZA using the cosine responses of Figure 1. The correction is based on a wavelength of 320 nm, ozone amount of 300 DU and an AOD of 0.5.

Figure 3 shows a comparison of the percentage of cosine correction versus SZA of the Brewer at RTP for (a) three wavelengths (300, 320 and 350 nm) and (b) three AOD (0.1, 0.5 and 1.0) with an ozone amount of 300 DU. There are two competing effects that cause the lines of best fit of the data to cross over at a SZA of 60 ° in both figure (a) and (b), rather than at a greater SZA. The effects are an increasing error in the cosine response (direct irradiance) with SZA and a decreasing ratio of direct / global irradiance with SZA.

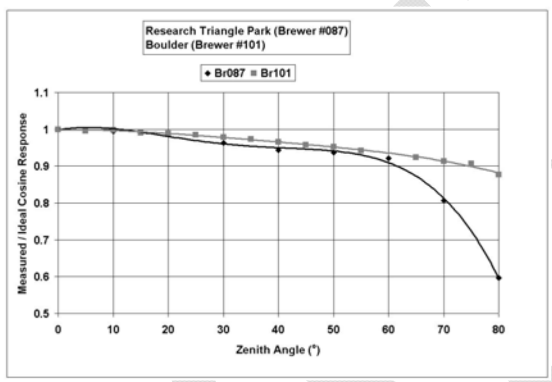


Figure 1. Cosine response of Brewer#087 (RTP) and 101 (Boulder).

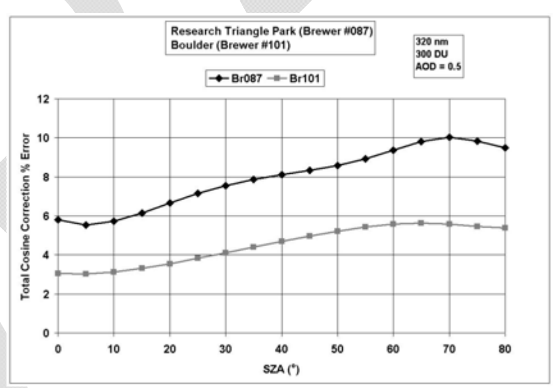
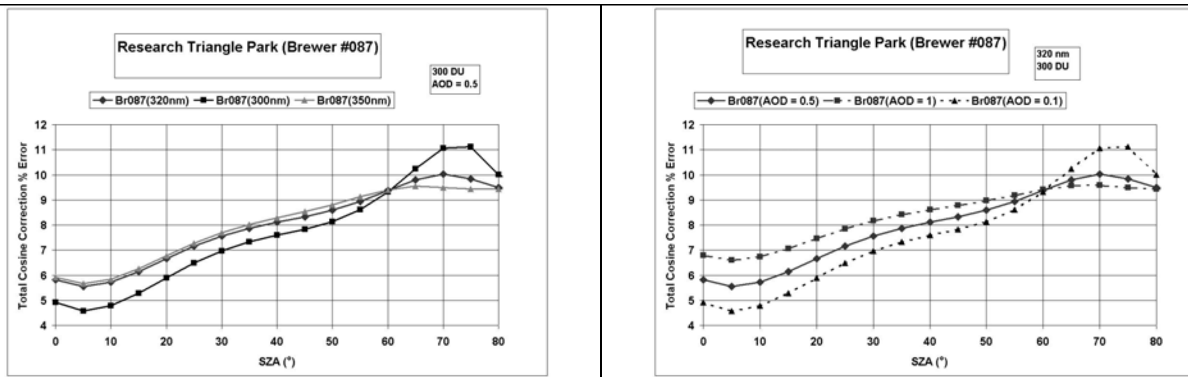


Figure 2. The total cosine correction percentage errors versus SZA using the cosine responses of Figure 1.



(a)	(b)

Figure 3. Comparison of the cosine correction versus SZA at RTP for **(a)** three wavelengths and **(b)** three AOD.

Figure 4 shows the percentage increase of UV irradiance measured at RTP during November 14th 1999 due to the cosine correction. The UV model used an ozone amount of 300 DU and an AOD equal to 1 in calculating the direct / global ratio. The resulting corrected DUV increased by 10.4 %.

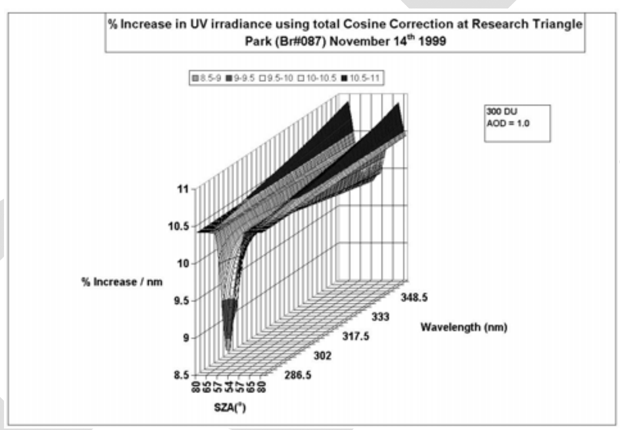


Figure 4. Percentage increase of UV irradiance measured at RTP during November 14th 1999,due to the cosine correction.

Conclusions

A method for correcting the cosine error due to a nonideal angular response of the Brewers in the USEPA/UGA network has been presented. The absolute UV irradiance measured by the Brewers should be increased by 3 to 24 % (Table 1), dependent on wavelength, SZA and cosine response for each Brewer. It is estimated that the uncertainty in the cosine-corrected irradiance is within ± 2 % of the true cosine-corrected irradiance. The uncertainty decreases for moderate to high aerosol loading and shorter wavelengths due to the increased validity of the isotropic sky assumption.

Location	Boulder	Olympic	Canyonlands	Sequoia	Albuquerque	Atlanta	Virgin Islands	Riverside	Everglades	RTP	Denali	Chicago	Acadia	Rocky Mtn	Gaithersburg	Glacier	Great Smoky	Big Bend	Shenandoah	Theodore	Hawaii
Brewer No.	101	147	133	139	109	108	144	112	135	87	141	103	138	146	105	134	132	130	137	131	140
Min %	3	3.2	3.2	4	3.8	4.2	4.8	5	5.2	5.5	5.3	5.1	6.9	5.3	7.1	6.4	7.4	7.3	8.4	10.9	13
Max %	5.6	5.8	6.2	7.5	7.7	7.8	8.6	9.2	9.8	10	10.3	10.4	12.6	12.6	12.8	13.6	14.2	15.6	16.2	20.4	24

Table 1. Range of Cosine Corrections in order of increasing Max % (AOD = 1.0, Ozone amount = 300 DU).

Acknowledgments The authors would like to thank the staff of the NUVMC at UGA as well as USEPA project officers Jack Shreffler and Tom Lumpkin.

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Brewer Spectrophotometer Network in JMA

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JMA started to observe UV-B with the Brewer spectrophotometer at Tsukuba in 1990. Now we use the Brewer to observe UV-B at five stations (Sapporo 43.05N 141.33E; Tsukuba(Tateno) 36.05N 140.13E; Kagoshima 31.55N 130.55E; Naha 26.02N 127.68E; Syowa 69.00S 39.58E) and ozone at Minamitorishima(24.30N 153.97E). We present the Brewer spectrophotometer network in JMA. We will show following some results: the comparison between the Brewer and the Dobson on Umkehr observation, the comparison of total ozone between the TOMS and the Brewer at Minamitorishima, and so on. We will also discuss relations between UV-B and ozone.

1.Observation stations and instruments

1.1 Location of stations in JMA

We present the Brewer Spectrophotometer network in JMA. We started to observe UV-B with the Brewer at Tsukuba (Tateno, see fig1.) in 1990. At the station, both spectral observations and total wavelength observations of UV-B have been operated. The other stations, Sapporo, Kagoshima, Naha and Syowa, make only spectral observations. At Minamitorishima, JMA has observed ozone with the Brewer since January 1994.

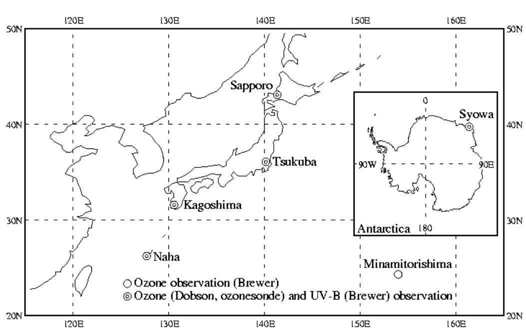

Fig1. Location of the observation stations in JMA. The Brewer is located at five stations for UV-B observation and one station for ozone.

1.2 Calibration

To get the correct UV-B data and keep observing for long time, we need to calibrate adequately these instruments. Although there is not detail explanation about the method in this paper, in JMA, they have been calibrated every three years by Aerological Observatory except Minamitorishima station, at which it has been done every year because of the severe whether.
JMA calibrated the Brewer with the NIST lamp at Sapporo and could confirm the improvement.

2.Total ozone observation at Minamitorishima

2.1 Umkehr observation

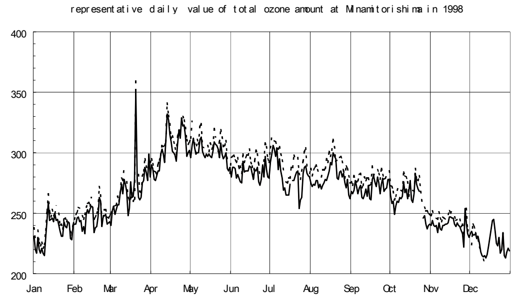

Fig2. Time series of total ozone in 1998. Solid line is the Brewer and dashed line is TOMS.

At Minamitorishima, JMA started the Umkehr observation in 1997. The observation data shows the variation of ozone certainly. We compared the data with the same data of Naha, where is located almost same latitude, by the Dobson. Both ozone profiles were very resembled, although they show the small discrepancy.

2.2 Total ozone observation

Total ozone has also been observed since 1994 (fig.2). In the middle of March, the large peak existed, while it was not observed at Naha. Although it seemed a wrong value, as a result of investigation, it was proved that this phenomenon attributed to the dynamical effect. On 20th March 1998, the air mass over Minamitorishima flowed from higher latitude, in which there is more abundant ozone than lower latitude, while it had come from lower latitude till 19th. TOMS data also showed the phenomenon that the area of rich ozone approached the vicinity of the island temporary. The Brewer could exactly measure the very large variation.

3.UV-B observation

3.1 domestic observation

JMA has observed UV-B with the Brewer since 1990. The time series of daily accumulations of UV-B irradiance show the seasonal variation and the scattered distribution in the same month. To show the relation between ozone and the wavelength of UV-B, we selected the data with constant solar zenith (23 degrees) and clear sky, and plotted UV-B irradiance and total ozone in Fig3. The figure shows the increase of UV-B irradiance corresponding to the decrease of total ozone. The regression for 1 m atm-cm of ozone indicated 1.4% for 300nm and 0.3% for 315nm. The difference for the wavelength was very large.

3.2 Antarctica observation

JMA also observes UV-B at Syowa in Antarctica. The maximum UV-B daily accumulation of these data was observed on 7th December 1995, and it recorded 60.60kJ/m^2. The value is 1.18 times larger than the maximum observed in Japan.

UV-B is strongly affected by the change of ozone, especially ozone hole at Syowa. Fig4 shows the time series of monthly mean of UV-B and total ozone in November from 1991 to 1998. UV-B daily accumulations vary in according to the change of the scale and position of ozone hole.

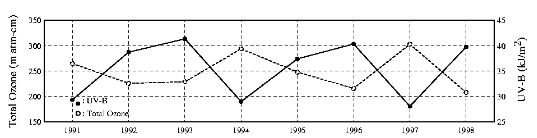

fig.4. Time series of monthly mean of UV-B daily accumulation and total ozone in November from 1991 to 1998 at Syowa in Antarctica. Solid line is UV-B daily accumulation and dashed line is total ozone.

Fig.3 Relation between total ozone and UV-B irradiance of 300nm (the left) and 315nm (the right). Data were observed in 1999 at four stations in Japan under clear sky conditions with a solar zenith of about 23 degrees. Solid lines indicate the regression.

4. Future research plan

In Japan, while the long term trend for ozone is significant at Sapporo only, the short term trends are not obvious since the start of UV-B observation. However UV-B may increase in comparison with 1970s considering the relations of UV-B and total ozone. We should further observe and investigate in order to validate the guess or not. JMA has following future research plan.

At first, we investigate the quantitative effects of ozone, clouds, aerosols and so on for UV B irradiance.

After that, we need to find the tendency of UV-B taking the short observation term into considerations.

10 Closing Activities and Recommendations

J. Kerr gave a brief presentation from the first Brewer Sub-Committee meeting which was held on July 6, 2000 in Sapporo, Japan during the Quadrennial Ozone Symposium. A list of action items and issues arising from the Sub-committee meeting were reported and briefly discussed in the Plenary session of the meeting with attention given to those issues related to the Recommendations. A summary of the Brewer Sub-Committee, which includes a list of the members, may be found in Annex I.

The following list of recommendations were made in addition to the existing recommendation still under review from the 5th Brewer Workshop.

1. **Recommend closer collaboration with the Dobson and satellite communities.**
2. **Preparation of manuals for Standard Operating Procedures (SOPs) and technical issues intended for operators in simple, "easy to use" language.**
3. **The calibration procedures as suggested by Johannes .Staehlen. – the regular submission of reports, calibration data etc to the WOUDC for archiving.**
4. **Data submission of primary (level 0) and processed (level 1) data to the Brewer Data Management System (BDMS) and WOUDC archive respectively.**
5. **Improved hardware and software tools.**
6. **More pyranometer data to support UV measurements.**
7. **Use of the CHMI data processing program for ozone data analysis.**
8. **To include recommendation numbers 3,4,5,8,9,10 and 11 from the 5th Brewer workshop as still outstanding or open issues. (refer to the addendum below).**
9. **A general statement regarding the communication, education and the providing of assistance to site operators through use of web sites, training videos, better documentation and manuals.**
10. **Be aware of hardware improvements/upgrades such as: humidity sensors, faster communications, camera/sky detectors and share this information with the community.**
11. **The collection and submission of more Umkehr data.**

Cited recommendations from the 5th Brewer Workshop in Halkidiki, Greece, September 1998

3. WMO should encourage as many Brewer operators as possible to submit 'raw' data (B-files and other required information) to the WOUDC.
4. To encourage the deposition of 'raw' data into the WOUDC, steps should be taken toward the establishment of a data exchange and security protocol for the inclusion of 'raw' data in the database.
5. After its formation, the Brewer steering committee should move quickly to resolve the issue of what Rayleigh scattering coefficients should be used to evaluate Brewer data. Brewer operators should be encouraged not to make this change until it can be done in a uniform manner.
8. The Brewer workshop members expressed concern that the number of calibration and maintenance events conducted per year within the Brewer network has not increased sufficiently in response to past recommendations.

9. WMO should encourage all Brewer operators to collect and submit Umkehr data to the WOUDC for processing and analysis.
10. Brewer observations should be supplemented by pyranometer measurements performed using WMO-recommended devices.
11. The Brewer workshop participants endorsed the activities of the WMO UV steering committee in developing international UV calibration facilities.

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12 Agenda of the 6th Brewer User's Group Workshop – Tokyo, Japan

Monday, July 10, 2000

Welcome by Local Hosts from the Japan Meteorological Agency	O. Uchino
Introduction by Meeting Chairman	C.T. McElroy
Overview of the WMO/GAW Programme	M.H. Proffitt

Session I – Brewer Networks

The Canadian Brewer Spectrometer Network	T. Grajnar
Brewer Spectrophotometer Network in JMA	K. Yoshimatsu

Session II – Retrieval methods

Comparison of Information content in the zenith sky content in satellite nadir measurements	P.K. Bhartia
Novel Uses of the Brewer Instrument	P.K. Bhartia

Session III – Station and Site Studies

Comparison between Dobson, Brewer and TOMS total ozone measurements at Cairo and Marsa Matruh, Egypt	A. Gahein

Poster Session

A Descriptive Statistics of Brewer #067	G.R. Casale, A.M. Siani and S. Palmieri
Central UV Calibration Facility in Boulder, Colorado	Elizabeth C. Weatherhead
The calibration methods of Brewer spectrophotometers in use at the JMA	Mahito Ito
The Brazilian Network of Brewer Spectrophotometer	Neusa Paes Leme
The Performance of Brewer 090 in Malaysia	Ng.Chee Wah
The Quality Control of Brewer Total Ozone Data at Minamitorishima(Marcus Island)	Yoshiyuki Noto
Analysis of ozone and UVB radiation at Mtruoh, Egypt	Wafik M. Sharobiem
Measurements at Arosa	René Stübi

A Brewer instrument was made available along with experts from Environment Canada, SCI-TEC and International Ozone Service to answer questions about software, troubleshooting and maintenance related issues.

C.T. McElroy and J.B. Kerr gave an informal tutorial on the Brewer instrument and general spectroscopy.

A Reception hosted by the JMA followed the Plenary sessions of Day One.

Tuesday, July 11, 2000

Session III – Station and Site Studies continued …

Total Ozone and Spectral UV-B Irradiance Measurements By Brewer #148 At Seoul	Joon Kim and Sunwook Park
Findings from 17 years of continuous Brewer operation	Ulf Köhler
Inter-comparison between Dobson and Brewer using Arosa data	René Stübi

Session IV – Issues of Data Quality

Quality control of Brewer spectral UV measurement	Vitali Fioletov
Temperature Dependence Of The Spectral Response For The MKIV Brewers In The UGA/USEPA Network	John E. Rives
Cosine corrections for ultraviolet radiation data from the USEPA/NUVMC	Jeff Sabburg
The ozone measurements using visible part of the spectrum with the Brewer spectrophotometer	Vladimir Savastiouk

Group Discussions and Closing of Plenary Session

Report from Brewer ad hoc sub-committee
Recommendations

Wednesday, July 12, 2000

Day excursion to Tsukuba City Research Facilities and the Tsukuba monitoring station.

First Meeting of the WMO Ad-hoc Brewer Sub-Committee
Sapporo, Japan – July 6, 2000

Chairman: J. B. Kerr
Rapporteur: E. W. Hare

Committee members in Attendance: C.T. McElroy (MSC) , J.B. Kerr (MSC), E.W. Hare (MSC), T. Grajnar (MSC), V. Fioletov (MSC), K. Vanicek (CHMI), M. Proffitt (WMO), J. Daniels (SCI-TEC)

Not in attendance: A.. Bais (AUTH), H. DeBacker (RMIB), IOS representative

Guests: A.M. Siani, G. Casale, U. Köhler, J. Gröbner, W.M. Sharobeim, M. Bonitatibus, J. Sabburg, R. Evans, A. Los, R. Stubi, T. Colombo

Agenda and Discussion Items

1. **Introduction – J. Kerr**
2. **SAG_O3 – J. Kerr, M. Proffitt and E. Hare**
3. **Recommendations from the 5th Brewer Meeting, Halkidiki, Greece, 1998 – T. McElroy and E. Hare**
4. **Brewer/Dobson Inter-relationships – J. Kerr and K. Vanicek**
5. **Review of Instruments and Data Reporting – E. Hare**
6. **New Data Analysis Tools for ozone and UV data – K. Vanicek and V. Fioletov**
7. **Ozone Maps – V. Fioletov**
8. **Other Topics**

Meeting Summary

Item 1: J. Kerr opened the meeting by presenting the agenda and re-introducing the group of the function of the sub-committee. Kerr mentioned that at the Fifth Brewer Workshop the members in attendance agreed that a sub-committee should be formed to address issues specific to the Brewer Spectrophotometer community such as: the use and operation of the instrument, data analysis tools and data archiving and retrieval. The recommended committee members are:

J.B. Kerr (MSC) Co-Chairman	C.T. McElroy (MSC) Co-Chairman
V. Fioletov (MSC)	T. Grajnar (MSC)
E.W. Hare (MSC)	M. Proffitt (WMO)
A.. Bais (AUTH)	K. Vanicek/M. Stanek (CHMI)
H. DeBacker (RMIB)	
SCI-TEC representative	IOS representative

Item 2: M. Proffitt (WMO) suggested the need for better communication between Dobson/Brewer groups from the SAG_O3 perspective. He briefly summarised the SAG_O3 meeting and recommendations pertinent to the sub-group. He also suggested that many Brewer users have expressed interest in learning more about the instrument and that this issue needs to be addressed. The advantage of the Dobson inter-comparison includes a workshop and a "class like session" where instruction and tutorials are often part of the agenda. Proffitt suggests that this approach should be investigated from a WMO perspective for the Brewer community.

Item 3: Kerr presented the recommendations and a list of the Steering committee members that were recommended from the meeting of the 5^{th} Brewer Workshop – Halkidiki, Greece. The Canadian influence, in terms of the membership, is expected given the instrument was invented in Canada. Kerr briefly reviewed the recommendations from the 5^{TH} Brewer Meeting. These recommendations are included in Annex I.

Item 4. Kerr suggested that there be inter-comparisons between the Dobson/Brewer communities that are correlated such that there is a sharing of ideas and advantages in instrument detail especially in the maintenance procedures. He mentioned that the MSC has had several training sessions for the Brewer in the past focusing on the Brewer fundamentals – this should be open to the Dobson community as well.

Proffitt mentioned that there is no WMO money to assist in these activities and re-iterated that the MSC should not be expected to pay for travel, but the staff time and facilities are offered free. This is all that MSC can commit. He also suggested that a WMO report summarising the various inter-comparisons from both Dobson and Brewer instruments would be a useful document to both instrument communities.

Kerr proposed that Dobson inter-comparisons (at least the ones involving many instruments) include at least one Brewer. Proffitt furthered this proposal by suggesting that the WMO would like to see these inter-comparisons happen every four years

Item 5: E. Hare reviewed the status of the Brewer Data Management System (BDMS) and emphasised the off-site archive service that MSC continues to offer data originators. The primary (Level 0) data will not be released without the expressed approval of each data originator. He mentioned how several data originators have submitted UV data files and that V. Fioletov has been working with these agencies in the analysis of their data and processed data products that are then submitted on each agency's behalf to the WOUDC. There are over 50 International Brewer instruments contributing to the BDMS archive, the largest single agency being the US-EPA with over 20 Brewers contributing data.

Vanicek asked about the "official" release of the new extended Comma Separated Values (extCSV) format. Hare replied that eventually a letter will be sent by the WOUDC to promote the use of the new format simply for the capability of supporting higher spatial and temporal resolution. Vanicek thought it would be best to have the WMO release the letter "officially".

Item 6: Vanicek informed the group of the representatives from Egypt, Brazil and Thailand have had a Brewer training in conjunction with a Dobson training session. He presented an overview of the latest version of the Czech Brewer Analysis package version 1.5 that is intended to assist operators with several levels of analysis options and provide output options for the various data submissions such as the new extCSV format.

Vanicek suggests that the software will eventually be used as shareware – for testing purposes. He also informed the group that Martin Stanek will replace him on the sub-committee. The committee acknowledged and endorsed this change.

Fioletov mentioned the analysis tools he has developed for the Brewer UV data analysis. This software package can handle the full suite of UV data analysis processing, quality assurance and output formats – data originators can view summary files and plots to make decisions about their data products.

The data processing is in two steps: first, the processed data are placed into a secure ftp account, where the data are available to the originator to review. Once the data have been examined and endorsed by the originator then the second step is the submission of the data to the WOUDC as the "official", sanctioned data set.

Item 7: Fioletov reported on the new near-real-time (nrt) total ozone maps that the MSC has been producing using nrt ground-based, satellite and archived total ozone data. These maps are similar to the ones produced by the WMO Northern Hemisphere Ozone Mapping Centre at the Aristotle University of Thessaloniki (AUTH) located in Thessaloniki, Greece. An agreement has been made between the MSC and the AUTH to co-operatively provide map products – the new mapping software examines the data based on the 30 year maps currently on display at the Exp-studies/ WOUDC web sites.

Vanicek suggested that there is a need for the actual data values for people who require nrt total ozone data. These data can be made available through the use of Global Transmission System (GTS) as the nrt data transport mechanism using the WMO supported CREX encoders/decoders. These CREX packages are available for submitting nrt data using the GTS service. Currently the Czech station at Hradec Kralove, the JMA station Tateno and five Canadian stations post data using the GTS. Vanicek also suggested that the WOUDC should use the GTS so that all users will have access to the data.

Vanicek briefly presented the WMO sanctioned CREX format for total ozone and he re-iterated that the encoding/decoding software is freely available. Fioletov mentioned that the WOUDC will accept data in CREX format for the daily ozone maps.

Item 8: Daniels gave the group an update on the Brewer inter-comparison activities using BR#158. UV calibrations are being done on site. He also mentioned that a new, operational software package will be made available soon, perhaps by October 2000. This new software is intended for use with new, faster computers and so the Brewer software can make use of these capabilities. The main advantage is to indicate the "health" of the Brewer instrument and to assist the operators with maintenance issues. Daniels invited the Brewer users to come up with ideas of what they would like to see in the new software, since he is now the new the software manager.

Daniels also mentioned that another change to the Brewer is the electronics. There will be some conversion required from the single board electronics will likely have to be made as the instruments ages. Proffitt asked about the cost. If the retro-fits are expensive than this will likely be a problem. Daniels last comment on the hardware was that new electronics do not do anything too different than the old except for faster communication. There is also a built in humidity sensor.

Proffitt asked that in the next 5-10 years will all of the approximately 150 active Brewer instruments require conversion? Daniels did not seem to think so, but added that in order to make these existing Brewers to continue for as long as possible may require some form of upgrades or retro-fits. Proffitt suggested to the group that the Brewer community needs to think in terms of decades that this is very important. And that cost is a big factor, one that could be viewed as prohibitive in terms of maintaining an active and reliable global network.

J. Kerr closed the meeting.

Annex I – Recommendations form the 5TH Brewer Workshop, Halkidiki, Greece, 1998

The members of the 5th Biennial Brewer Users' Meeting Recommend:

1. The Brewer workshop participants endorse the formation of a Brewer steering committee which will carry out tasks that will facilitate the operation of and improve the performance of the Brewer global ozone network. This committee should be chaired by a person who is appointed by the WMO Scientific Advisory Group for ozone measurement and who reports directly to the WMO SAG for ozone measurement and the WMO SAG for UV measurements. The tasks and responsibilities of the Brewer steering committee will include the following:
   - certify software for network operation
   - specify the requirements for calibration and maintenance for the global network
   - reference manuals
   - new developments
   - relationship to other total ozone monitoring systems
   - network operations including operating schedules
   - organizing meetings and training activities
   - promote communications with data centres
   - maintain contact with the Brewer manufacturer and service contractors
2. That the appropriate action be taken to hold the next Brewer workshop in conjunction with the QOS in Japan.
3. WMO should encourage as many Brewer operators as possible to submit 'raw' data (B-files and other required information) to the WOUDC.
4. To encourage the deposition of 'raw' data into the WOUDC, steps should be taken toward the establishment of a data exchange and security protocol for the inclusion of 'raw' data in the database.
5. After its formation, the Brewer steering committee should move quickly to resolve the issue of what Rayleigh scattering coefficients should be used to evaluate Brewer data. Brewer

operators should be encouraged not to make this change until it can be done in a uniform manner.

6. WMO should recommend that the global UV-B total ozone routine (gi.rtn) and the collection of direct solar scan data be included in operational schedules throughout the network. The new data should be stored in the B-files.
7. The Brewer workshop members wish to express their disappointment at the closing of the scientific component of the Potsdam Observatory.
8. The Brewer workshop members expressed concern that the number of calibration and maintenance events conducted per year within the Brewer network has not increased sufficiently in response to past recommendations.
9. WMO should encourage all Brewer operators to collect and submit Umkehr data to the WOUDC for processing and analysis.
10. Brewer observations should be supplemented by pyranometer measurements performed using WMO-recommended devices.
11. The Brewer workshop participants endorsed the activities of the WMO UV steering committee in developing international UV calibration facilities.

List of Abbreviations

AOD	Aerosol Optical Depth
BSRN	Baseline Solar Radiation Network
DS	Direct Sun
EPA	US Environmental Protection Agency
ETC	Extra Terrestrial Coefficients
NDSC	Network For The Detection Of Stratospheric Change
SAG	Science Advisory Group
SL	Standard Lamp
SOP	Standard Operating Procedures
SZA	Solar Zenith Angle
QA/SAC	Quality Assurance/Science Activity Centre
WDCGG	World Data Centre for Greenhouse Gases
WMO	World Meteorological Organization
WOUDC	World Ozone And Ultraviolet Radiation Data Centre