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SECOND WMO CONSULTATION ON OZONE MEASUREMENTS BY BREWER SPECTROPHOTOMETER

Charlottesville, Virginia, 1-3 June 1992

C.T. McElroy, Editor

WMO CONSULTATION ON BREWER OZONE SPECTROPHOTOMETER

OPERATION, CALIBRATION AND DATA REPORTING

University of Virginia, Charlottesville
June 1-3, 1992

Report on the WMO Meeting on Brewer Ozone Spectrophotometer Operation, Calibration and Data Reporting

Edited by: C.T. McElroy

Organized by: R. Bojkov, J. Staehelin, J.B. Kerr, and C.T. McElroy

Chairperson: J.B. Kerr

FOREWORD

The WMO Global Ozone Monitoring and Research Project was established in the mid-1970's to enable WMO to provide advice to Members, to the United Nations and to other organizations on: 1) the extent to which man-made pollutants, especially CFC's and nitrogen oxides might be responsible for stratospheric ozone reduction, 2) the possible impact of ozone changes on climate and the UV-B reaching the Earth's surface and 3) maintaining the basis for the long-term monitoring of trends.

Since the International Geophysical Year (IGY), WMO has had in existence the Global Ozone Observing System (GO_3OS) which is now part of the WMO Global Atmosphere Watch (GAW). While the system was originally instrumented with Dobson Ozone Spectrophotometers, there are now a large number (about 80) of Brewer Ozone Spectrophotometers in service. These instruments represent a significant new resource for acquiring accurate ozone data over a wide geographical area. In the past, the coordination of intercomparisons of Dobson instruments has always been a priority task among the internationally coordinated activities within the GO_3OS. In collaboration with the International Ozone Commission of IAMAP, the WMO has coordinated the exchange of data, scientific and technical information, and facilitated calibration trips for the maintenance of calibration standards for the GO_3OS.

As part of these efforts of WMO and the Ozone Commission, a regular program of Brewer Users' meetings was started with the first meeting in Arosa, Switzerland in 1990. This report contains a record of the discussions related to ozone measurement which were conducted at the second bi-annual WMO Consultation on Brewer Ozone Spectrophotometer Operation, Calibration and Data Reporting held at the University of Virginia in Charlottesville, Virginia in 1992.

With the rapid growth in the numbers of Brewer instruments and with the new roles in which it is being employed, such as UV-B monitoring, it is essential that the calibration, operational programs, and data archiving for the instruments in the GO_3OS be carefully coordinated. It is for this reason that this important series of workshops is being supported by the WMO and will continue to provide a significant medium for the exchange of technical and scientific information for the operators of Brewer instruments in the GO_3OS.

C.T. McElroy
Member, International Ozone Commission, IAMAP

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

Opening of the Meeting and Election of a Chairman and Rapporteurs

Brewer User's Working Group

The Quadrennial Ozone Symposium was held in Charlottesville, Virginia in June of 1992. The Brewer User's working Group took the opportunity to have their bi-annual meeting in conjunction with the Symposium in accordance with the principals set down by the group at the time of the founding meeting held in Arosa, Switzerland in connection with a Dobson Spectrophotometer intercomparison in July and August of 1990. The 1992 meeting was attended by more than 30 ozone experts and Brewer operators from 20 countries and was hosted by the University of Virginia, the World Meteorological Organization and Environment Canada.

1.2 Opening remarks by Rumen Bojkov

The meeting was opened by Rumen Bojkov. He said that he was pleased to open this second WMO Consultation on Brewer Ozone Spectrophotometer Operation, Calibration and Data Reporting and, on behalf of the Secretary-General, Prof. Obasi, to welcome all who were present. Within the framework of the WMO Global Ozone Observing System and Ozone Project great importance is given to data quality, on which all the assessments and scientific deductions depend. WMO has worked in close collaboration with the International Ozone Commission for 35 years to establish the methodology and standardization, calibration and intercomparison of instruments, formerly only the Dobson, in order to respond to the high demand for consistent measurements.

Now, more and more Brewers are being installed, and it is hoped that the ozone research community will soon have timely access to their data through the World Ozone Data Centre. After the Brewer consultation meeting at Arosa two years ago, Tom McElroy, Alkis Bais and Christos Zerefos prepared a beautiful report for the WMO on the activities of the Brewer Users Working Group.

There are some advantages to the Brewer instrument, however they must be used everywhere or those advantages will remain only "paper advantages". These advantages include:

a) the automatic Umkehr
b) the UV-B measurement

as well as other abilities such as measuring NO_2 and SO_2. However, this meeting should have as its aim the implementation of a) and b). Within less than 1 year all Brewer-equipped stations in the Global Ozone Observing System should be reporting data regularly.

Recommendations were made at the last meeting and a number of these have been implemented. New ozone absorption coefficients based on the work of Bass and Paur have been adopted. Brewer #039 has been used a travelling calibration reference. There is not yet a systematic use of zenith sky measurements within the Brewer community, and it is anticipated that scientists at the AES will provide guidance in the use of this technique. The University of Thessaloniki and the specialists at the Academy of Sciences in Moscow have co-operated to provide near-real-time data exchange, but more needs to be done. That is why the Secretary- General has provided support for this meeting and why all of you are here.

1.3 Opening remarks by the Chairman,

James Kerr of Environment Canada was elected as the Chairman of the Brewer Users meeting. In his opening remarks he reminded the participants of the significance of the work being done by those present in order to monitor the stratosphere and understand the impact of changes in ozone on the UV environment on Earth. He noted that there are now more than 80 Brewers in use around the world, and that as the use of the Brewer Spectrophotometers increases and the length of the record becomes longer, the Brewer will play an increasingly important roll in the Global Ozone Observing System. Kerr lead the selection of rapporteurs for the meeting, and the election of the editor of the proceedings.

2. Recommendations of the Last Meeting

1. Recommendation concerning ozone coefficients for the Brewer and Dobson.

   As of January 1, 1992 WMO called for the adoption of the Bass and Paur [1985] ozone absorption coefficient scale for both Dobson and Brewer Spectrophotometers. Instructions concerning this recommendation were formally distributed among the contributing members of the GO_3OS.

2. Calibration visits.

   Sci-Tec Instruments Limited is making regular trips to visit Dobson and Brewer observing sites to compare operational instruments to travelling standard Brewers #017 (AES) and standard #039 (WMO). The calibration references return frequently to Toronto for comparison with the AES Brewer calibration reference triad. The recalibration interval is variable from station to station and the goal of having visits every two years has not been universally met.

3. Reporting Brewer Moon Measurements.

   Some stations have instituted moon observation programs; however, many more instruments could still be included in this program. These measurements are of particular interest in the polar night.

4., 5. Zenith Sky Observations

   This report contains information concerning the proper used of zenith sky data.

8., 9. UV-B Observations

   A number of additional UV-B stations are now measuring UV-B. The old ACGIH-NIOSH scale has been replaced by the McKinley-Diffey algorithm which appears to be a likely candidate for an international standard for erythemal dose estimation.

10. Regular Meetings.

The next meeting was held at Charlottesville, Virginia in connection with the Quadrennial Ozone Symposium in 1992, as recommended in Arosa in 1990. It appears that the value of the Brewer Users' meetings is such that they will continue to be convened every two years.

11. Real-Time Ozone Data Reporting

Near-real-time ozone data were collected by a data collection centre operated by the University of Thessaloniki in connection with the European Arctic Stratospheric Ozone Experiment. Data were submitted by European nations, countries of the Commonwealth of Independent States and by Canada. Maps of the ozone distribution were provided to participants and interested parties.

3. Measurement of Total Ozone [U. Köhler, rapporteur]

3.1 Total column ozone measurements at Izaña Observatory

E. Cuevas reported on the recently-started total ozone observation program at the Izaña-Observatory on Tenerife (Canary Islands, Spain). Brewer #033 has been in operation at about 2360 m height a.s.l. since April 1991, but, due to some humidity problems at the beginning, the various measurements and tests made between May 20, 1991, and May 19, 1992 are presented. The weather conditions were mostly good with clear days, with foggy days mainly occurring during wintertime. Occasionally there was a problem with dust from the Sahara desert. The record of standard lamp tests revealed that the spectral sensitivity of the instrument was not always stable. Especially in the fall of 1991 the R5 and R6 values exhibited a large change. The mercury lamp tests showed a strong decrease in the light intensities caused by a degradation of the mercury lamp. The results of the DS (direct sun) measurements are nevertheless of a very reliable quality. A reasonable annual oscillation was measured with a minimum of 260 D.U. in

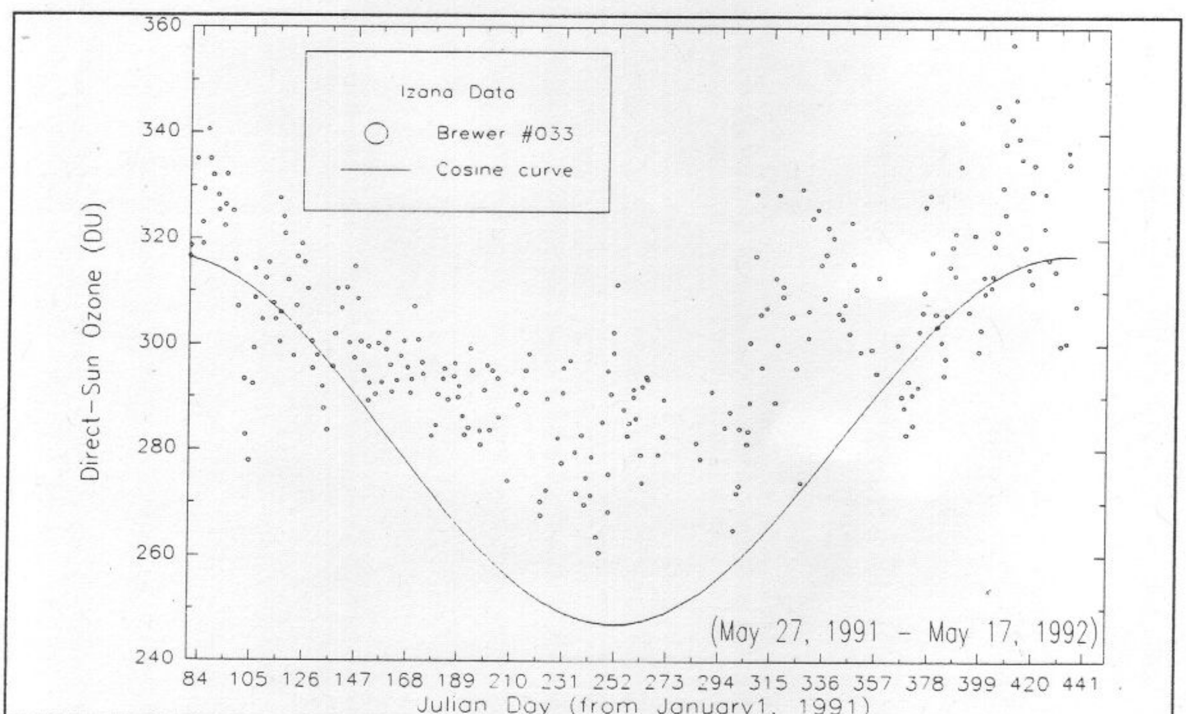

Figure 3.1: Direct sun total ozone measurements made at Izaña Observatory.

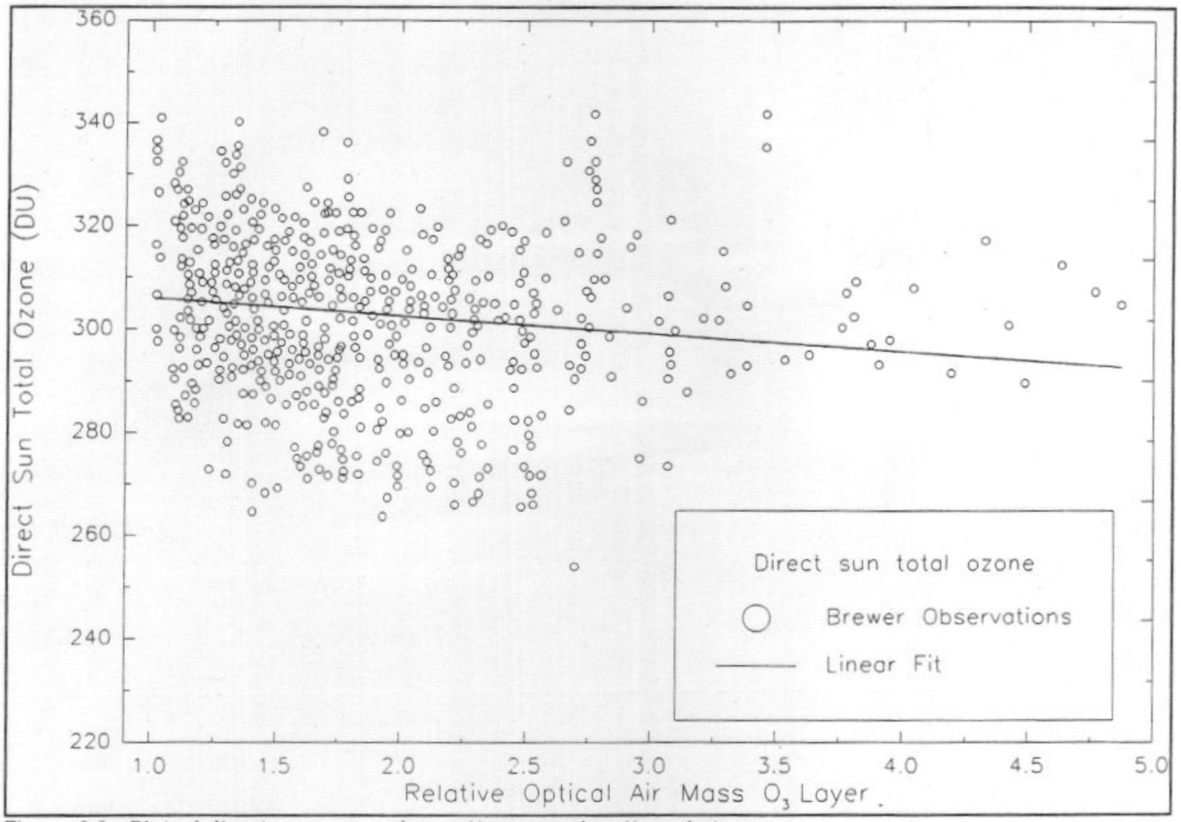

Figure 3.2: Plot of direct sun ozone observations as a function of airmass.

November 1991 and a maximum of 357 D.U. in April 1992 (see Figure 3.1). The observations showed a slight, not unusual μ-dependency (Figure 3.2).

Measured SO_2 values were slightly negative at the beginning, but later on their mean values were around 1 milli-atm-cm with maximum values up to 6 milli-atm-cm. A possible reason for this upward trend could be instrument drift as suggested by the behaviour of the R5 value from the standard lamp test, as no corrections to the extraterrestrial constants have been applied based on the lamp test results. The comparison of DS and FM (focussed moon) observations showed very good agreement, but with a large standard deviation for the FM measurements. Similar results have already been presented at the first Brewer Workshop in Arosa in 1990. The original set of ZS (zenith sky observation) coefficients, determined in Canada for instrument #015, turned out to be unsuitable for instrument #033, with differences of about 7% compared to normal DS observations. A successful determination of a new coefficient set for different types of cloud cover improved the quality of the ZS observations.

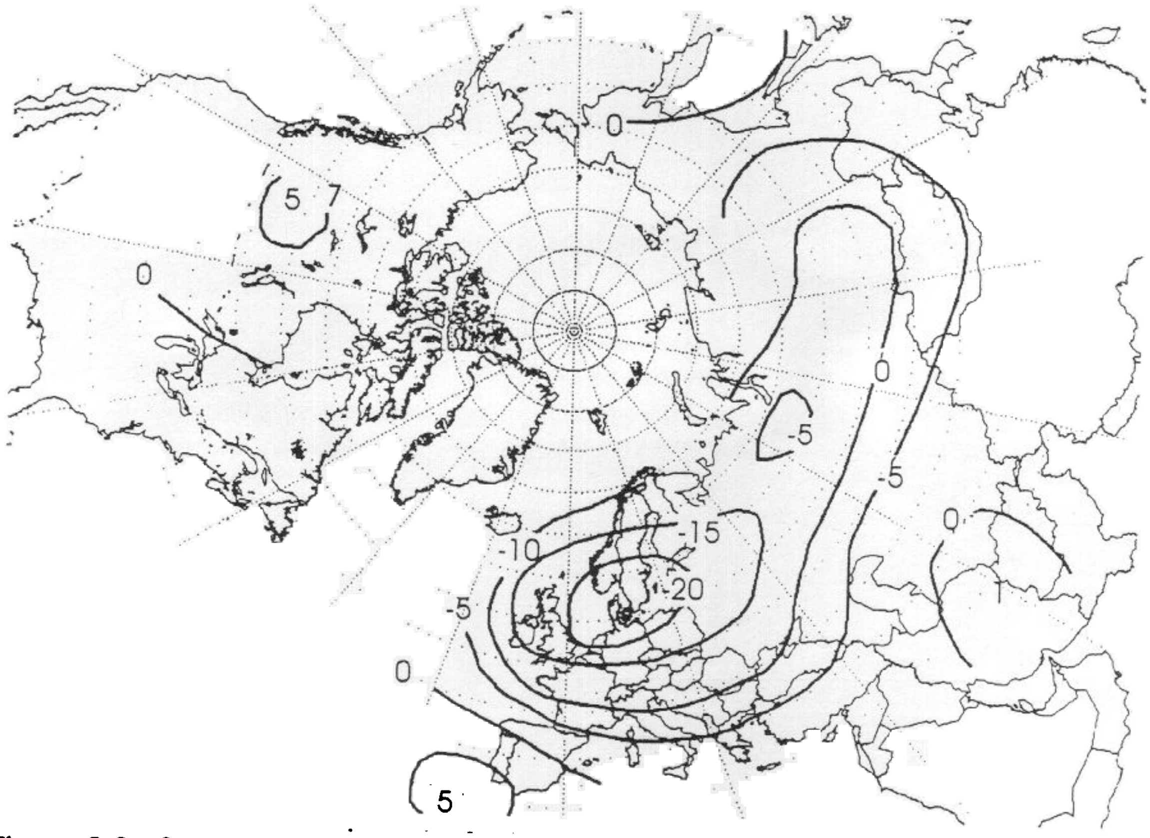

Figure 3.3 Ozone deviations from historical levels for January, 1992.

3.2 The zenith sky algorithm for total ozone measurements

J. Kerr gave guidelines for determining a "Sky Chart" function from near-simultaneous DS and ZS observations. The following equation describes the relationship between the Brewer ozone absorption function F, which is calculated using zenith sky light, the total ozone amount, measured nearly simultaneously by DS observations and the airmass μ:

$$(F - F_0) = A + B\mu + C\mu^2 + DX + EX\mu + FX\mu^2 + GX^2 + HX^2\mu + IX^2\mu^2$$

where F_0 is the extraterrestrial constant ETC

X is the DS-total ozone value

μ is the relative airmass

A,B,... I   are 9 regression constants

At least several hundred sets of near simultaneous (within 10 minutes) DS and ZS observations are necessary to determine the 9 constants of this empirical function by a least square fit of all the data to sufficient accuracy.

Whereas E. Cuevas applied this method for three different zenith sky observations (clear sky, dust and thin clouds), J. Kerr reported, that the constants should be determined only for clear sky. The effects of clouds were determined by calculating the ratio of daily average zenith sky total ozone values to that for the direct sun as a function of cloud cover. It was found that as cloudiness increases from 0 to nearly 100 % (overcast) the ratio of zenith to direct sun ozone values increases from 1 to 1.04.

3.3 Results of the WMO/GO$_3$OS synoptic ozone mapping project

A. Bais reported on the EASOE-campaign of the winter 1991-92, during which the daily means of total ozone observations of Brewer, Dobson and Filter instruments were sent to Thessaloniki from a large number of stations. He clearly described the problems with telecommunication, the time problem between the measurements in Canada and Siberia, and with the schedules of some stations, which made it difficult to send the data in time. Because of these problems, the mapping centre was not able to construct total ozone maps as quickly as it was hoped. The availability of the maps at the NILU data centre was within a 24 hour delay, similar to that for TOMS data. A further problem in constructing the charts was the different types of instruments each with different accuracies and calibration standards. Therefore the data are only preliminary and Thessaloniki could and will not replace the World Ozone Data Centre in Toronto. The total ozone maps were nevertheless of high quality and were of great value to the EASOE-campaign. Some results, e.g.: the monthly mean deviations from long term means, were very impressive (Figure 3.3), which shows the extraordinary ozone reduction of up to 20 % over a wide area during a large period in this winter. A. Bais promised for the next campaign in the winter of 1993/94 to have a much better telecommunications link.

3.4 Measurements of ozone at Oslo

In the investigation of F. Tonnessen and S.H.H. Larsen direct sun observations of total ozone from Brewer #042, Dobson No. 56 and TOMS at Oslo (60 N) for the period of May 1990-1992 were compared (direct sun measurements are not possible during winter season at this latitude). Brewer #042 yielded about 3% lower values in spring and fall, whereas values in summer were similar. The difference was slightly more pronounced comparing A wavelength pair observations with Brewer #042.

Stronger seasonal variations in the difference were found comparing Brewer #042 with the daily overpasses of TOMS, with an amplitude of about 6% (higher values of TOMS in summer). Similar but more pronounced was the difference between TOMS and Dobson No. 56 (AD). The best agreement was found between TOMS and Dobson No. 56 (C).

3.5 The daytime course of the total ozone content

A.G. Ishov presented data that indicated that during 3 years of Brewer observations, only a few day exists on which the diurnal amplitude is smaller than 1 %. As an example he showed the measurements of Brewer No. 44 at a tropical station in India. The total ozone amount oscillated between about 270 - 260 - 270 DU with the minimum at noon. He assumed that real atmospheric processes cause this diurnal variation and not an instrumental miscalibration. This was confirmed by A. Asbridge, who checked their Brewer after the campaign. This behaviour of the total ozone is in contrast to the observed diurnal variations in the moderate and northern latitudes

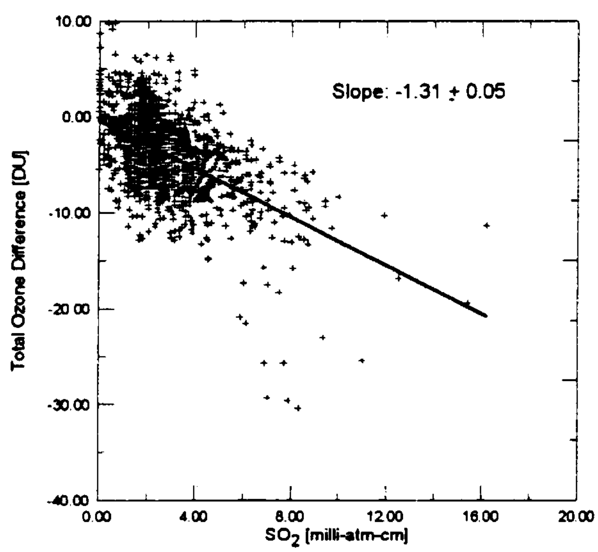

Figure 3.4: The difference between the amount of ozone measured by the Dobson and Brewer Spectrophotometers as a function of SO_2 amount.

with a maximum near noon.

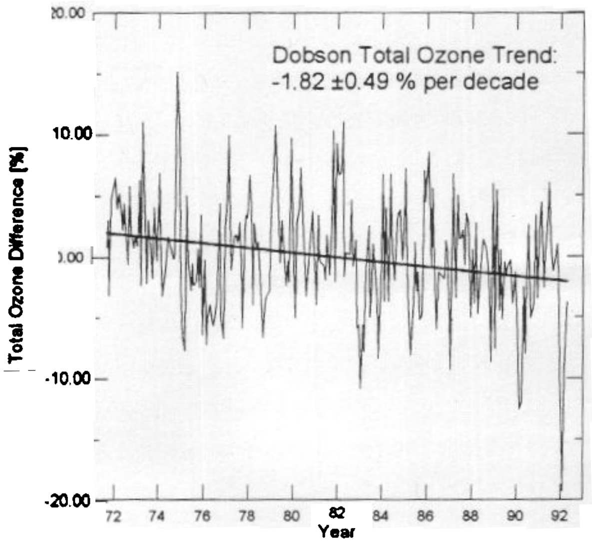

Figure 3.5: The trend in total ozone at Uccle.

3.6 Analysis of eight years of ozone and SO_2 Brewer measurements at the Meteorological Institute of Belgium

D. DeMuer presented a comparison between Brewer #016 and Dobson No. 40 at the Meteorological Institute of Belgium in Brussels since 1983. He showed that an excellent agreement exists between these instruments when the Brewer 1.3 times the SO_2 column is added to the Brewer total ozone (Figure 3.4). This factor is somewhat higher than that recommended by AES (1.06). He proved that the apparent total ozone trend of about -1.82% per decade as measured with his Dobson since 1971 (Figure 3.5), is in reality caused by the decrease of the total column amount of SO_2. This downward trend, measured with the Brewer (Figure 3.6), is of the same order as the results of the measurements of SO_2 near the surface (Figure 3.7). When the Dobson total ozone data are corrected for SO_2, the remaining small trend is no longer statistically significant (Figure 3.8). The comparison between DS and ZS observations shows very good agreement with annual oscillations, which are deduced from the change of the ozone profile during the winter, and which were very strong this year [1992].

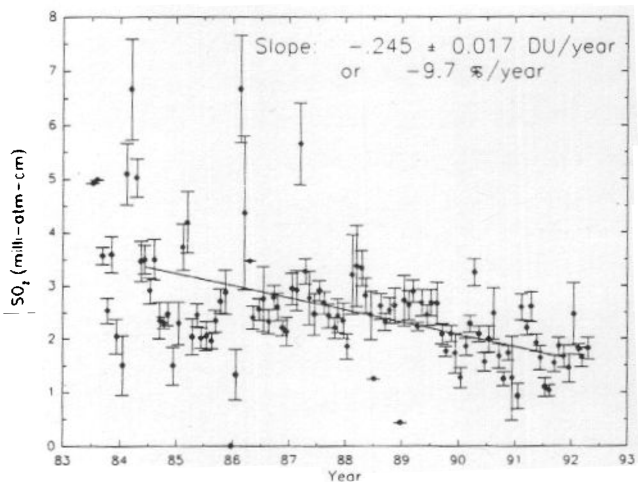

Figure 3.6: SO_2 measurements made in Uccle.

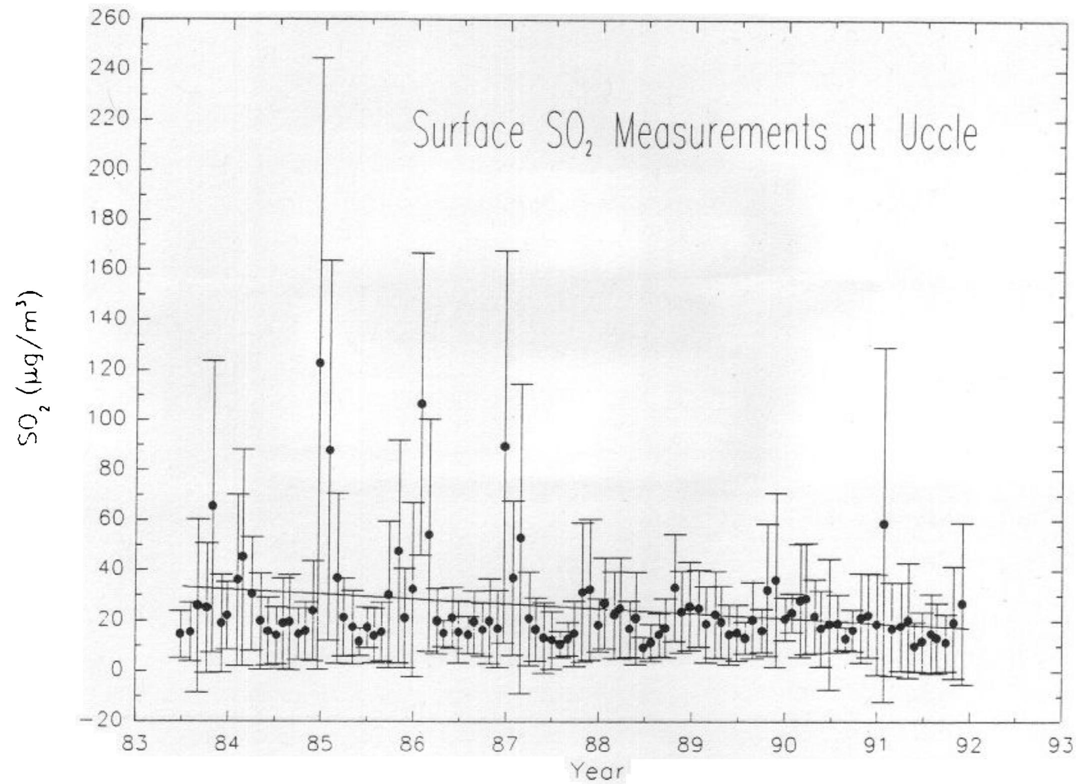

Figure 3.7: Surface SO_2 measurments made at Uccle. These should be compared to the Brewer measurements shown in Figure 3.6.

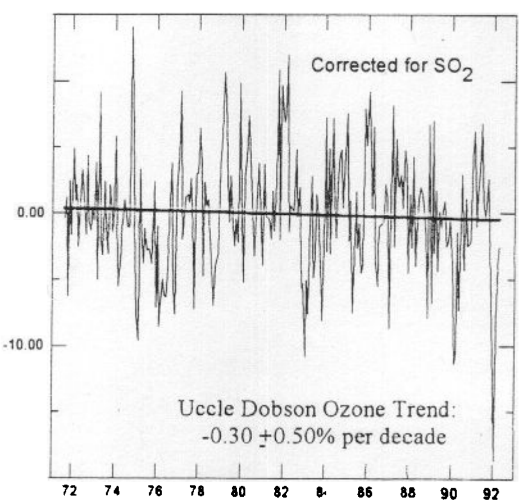

Figure 3.8: Dobson total ozone trend at Uccle.

3.7 Measurements of ozone and SO_2 at Kislovodsk observatory

N. P. Elansky presented the results of ozone and SO_2 measurements at Kislovodsk with the Brewer #043. The most interesting feature of the ozone observations is the deviation from the latitudinal mean especially during summer and fall, when the total ozone amount is significantly lower than it should be. He assumed the strong continental effect to be responsible for this phenomenon. During the summer season tropical airmasses drift to the north, driven by a high pressure system, which causes low ozone.

3.8 The Canadian OZONE WATCH program

J. Kerr gave a short survey of the Canadian Ozone Watch Program for the public, which has become a very important service with regard to the events during the winter 1991/92 and the anticipated, future trend of total ozone and UV-B irradiance. He showed the trend investigation of the total ozone observations in Toronto in the period 1960-91, which revealed essentially no trend within the first 20 years, but then a sharp drop of the annual means since 1982/83. This coincides with the eruption of El Chichon in 1982 in Mexico. This downward trend has continued until the present with a small recovery in the middle of the nineteen-eighties. Another large ozone loss is expected in 1992, as already indicated in the monthly means of January - April (Figure 3.9). An investigation of the deviation of the 60-day smoothed Brewer total ozone from the long term mean (1960 -1980) has shown that the main reduction is during winter and spring (Figure 3.10).

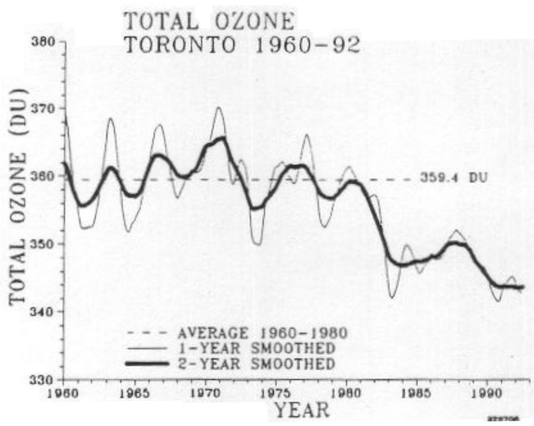

Figure 3.9: Total ozone record from Toronto showing a downward trend since 1980.

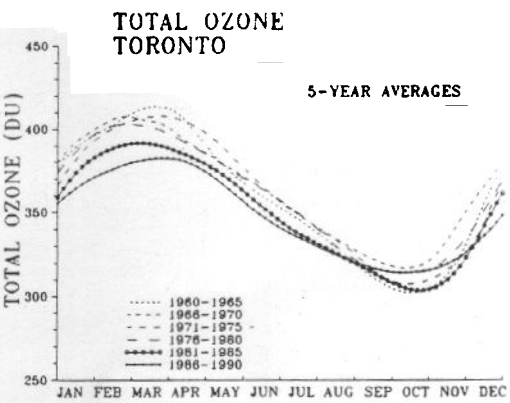

Figure 3.10 Annual cycle of totol ozone in Toronto.

4. Total Ozone Intercomparisons [J. Staehelin, rapporteur]

The intercomparison of total ozone measurements from instruments at the ground (Brewer and Dobson) and from satellites (e.g. TOMS) is an important task because these measurement form the data bases, which are or will be available for global trend analysis. The different instruments provide either complementary information (satellite versus ground based measurements) or they have different instrumental design and different calibration history (Brewer versus Dobson). Five contributions dealing with different data sets have been presented at this meeting including measurements from 60 N to the antarctica. It is worth to mentioning that other papers from another session of the meeting (De Muer: Analysis of the eight years of ozone and Brewer Measurements at the Meteorological Institute of Belgium) or presented at the Quadrennial Ozone Symposium are related to the same topic.

4.2 Intercomparison of Dobson, ozonesonde, TOMS and Brewer measurements made in Greece

In the presentation of C. Varatsos and P. Kalabokas, ozone measurements performed at local noon during May 1991 at Athens were compared with those made by the Brewer instrument in Thessaloniki. The Brewer data tended to be rather higher (correlation coefficient 0.78). The measurements of Dobson No. 118 agreed well with the daily overpasses of TOMS (correlation coefficient 0.96). From 29 balloon ascents, performed with ECC sondes during the EASOE campaign, 13 ascents could be compared with total ozone from Dobson No. 118. The integrated amount from the soundings agreed well with the measured total ozone values.

4.3 Intercomparison of Brewer #010 with Dobson No. 104 and TOMS

U. Kohler presented data from Hohenpeissenburg (Germany), from where one of the world's longest data sets for the intercomparison of Brewer and Dobson measurements is available. Good agreement of the measurements was found in the period between 1986 and 1991, when from both of the instruments good data could be obtained. During this period the deviation of the monthly mean values of the two instruments was in the range of approximately 1% showing a typical seasonal variation with higher Brewer than Dobson values in winter. The comparison of Brewer #010 measurements with TOMS overpasses showed larger seasonal variations in the differences which may have been the result of errors in the TOMS measurements at large solar zenith angles.

The data comparisons consistently showed a small but systematic seasonal variation in the difference of Brewer and Dobson measurements, which presently seem not to be fully understood [Ed. this has been observed elsewhere an is probably due to the annual variation of the ozone-weighted mean temperature above the observing station causing an annual cycle in the difference in the effective ozone absorption coefficients between the two instruments].

4.4 Airmass dependence of the Brewer #064 and the Dobson No. 84 total ozone measurements

B. Rajewska-Wiech presented the comparison of measurements of Brewer #064 and Dobson No. 84 from Poland. The group of Poland modelled the influence of aerosols and stray light on Dobson No. 84 measurements using the procedure proposed by Basher (1982). A similar behaviour with respect to dependence, in particular with noon decline, was found in the measurements of Brewer #064 and Dobson No. 84.

4.5 Ozone measurements in the Antarctic

The contribution of L. Ciattaglia and C. Valenti included the intercomparison of total ozone from Brewer #035 (focused moon observations) with the New Zealand Dobson at Scott base in Antarctica which yielded quite satisfactory agreement. Also the comparison of the Brewer results with the integrated amount from balloon ozone soundings from Scott base, including measurements from 1991, was reasonable. Umkehr measurements were performed at Roma providing good results. Umkehr measurements in Antarctica are restricted to a few days after the beginning of October because of the low solar elevation angle and small range of angles in polar regions.

5. Umkehr Measurements [E.W. Hare, rapporteur]

5.1 The Brewer Umkehr analysis and results from Edmonton

Table 5.1: Sample setup file for the Umkehr preprocessor.

```
ozoavg89.039
0999 TMO 34.383 117.683

/* station number, header code, latitude
and longitude */
```

C.T. McElroy presented a brief history of the mathematics and physics of the Umkehr effect, which has been known for approximately sixty years, and discussed in detail the Umkehr inversion technique, particularly as it applies to Brewer Ozone Spectrophotometer Umkehr measurements. Eight discrete wavelengths are measured with the Brewer Umkehr program. The Umkehr algorithm utilises the standard five "short" wavelengths used for total ozone observations as well as three additional "long" wavelengths obtained by offsetting the diffraction grating to longer wavelengths which allows an overlap of the last two short and first two long spectral positions. Measure-ments are made in the strong polarization direction, but will include some multiple scattered light.

The source radiation is attenuated by air and aerosols and is different for the various Umkehr layers dependent upon the pressure. The mean scattering height is about 20 Km at a zenith angle equal to approximately 60°. There is attenuation of light through the layer and along the vertical path (between the bottom of the layer and the observing point on the surface) in the nadir direction. Ozone removes most of the radiation in the 295-98 nm region.

The most probable solution method developed by Clive Rodgers is used in the "short Umkehr", developed by J. DeLuisi and C. Mateer. The Umkehr method utilizes the log-intensities at the various heights whereby twelve angles are measured with the ratios of three wavelengths (ie. 6 of the 8), the shortest being 306.3 nm and the longest 323.2 nm. It is the difference in the various ratios which yields the information about the height distribution.

The preprocessor reads an OZOAVG file which contains the daily mean total column ozone values, one for each Umkehr observation day. A PRESETUP file contains station location information and is given in Table 5.1. The program produces actual intensity values for a given set of generated zenith angles. Measurements are made at a large number of angles and interpolated to standard angles. A complete Umkehr preprocessor output record is illustrated in Table 5.2 for one AM and one PM measurement. Standard Umkehr angles are used for both AM/PM observations.

Table 5.3 is an example of a sample output record from the Umkehr analysis program (TOMKEHR). The TOMKEHR program requires an UMKSETUP file as input which contains

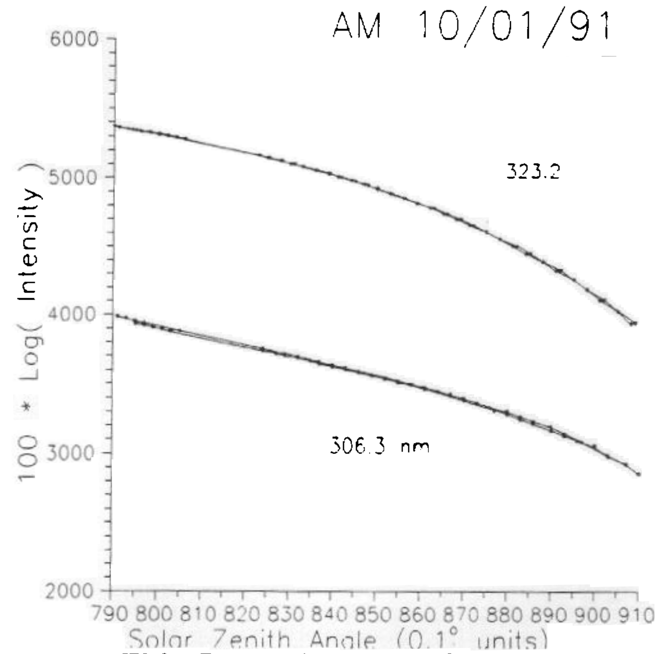

Figure 5.1: This figure shows the fitted curve and the raw data points output by the preprocessor for the longest and shortest wavelengths observed by the Brewer.

Table 5.2: Preprocessed records for input to the Umkehr analysis program.

TMO	24	789	11	2915035482945454245	398037163492	33553250312830272902	999
TMO	24	789	12	2915397525450524823	459443053976	37613617346933563222	999
TMO	24	789	13	2915784567055095323	513248784544	42894099391137823636	999
TMO	24	789	14	2915899581356905549	540352034921	46724450420840413862	999
TMO	24	789	15	2915860578356735546	541452334975	47414523427440933898	999
TMO	24	789	16	2915667560555175416	531251664958	47664580434641583943	999
TMO	24	789	17	2915630557755015413	532251975017	48514690448143094102	999
TMO	24	789	18	2915372532352535173	509049744810	46564507431541553960	999

instrument dependent coefficients and a representative model chosen to reflect the climatology. An ozone partial column amount is produced for each Umkehr layer and the sum of the partial column is compared with an independent measure of the total ozone. Output files which yield layer concentrations in summary and plot format are used to monitor data quality and integrity with respect to the model fitting procedures.

Figure 5.1 represents Edmonton, Alberta Umkehr data which includes both morning and evening as well as short and long wavelengths. With the Rodger's method, the averaging kernels yield information about the vertical resolution and validate the sounding methodology. First quarter data for the years 1984-92 from Edmonton are represented in Table 5.4. The Umkehr inversion has contributed about as much information as the climatology at middle levels and there is no statistically significant change from year-to-year for a given layer.

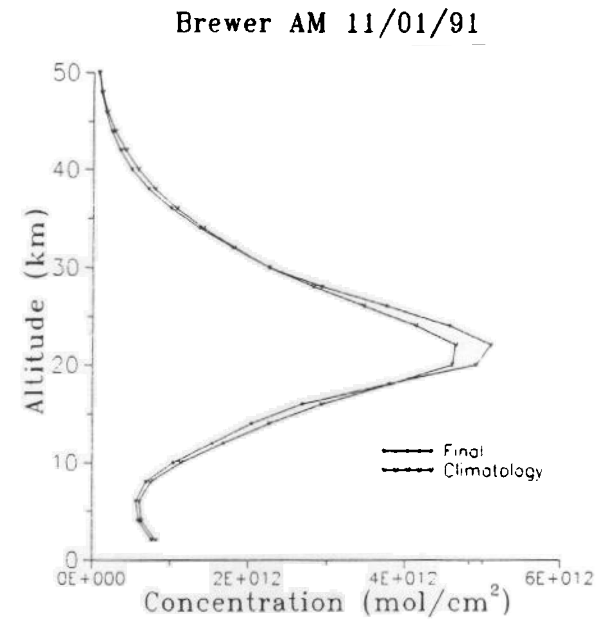

Figure 5.2: Sample output from the inversion algorithm. Both the climatological "first-guess" and the retrieved profile are shown.

Program testing was conducted on data collected at Table Mountain, California during July, 1989. An Umkehr profile derived from Brewer data is given in Figure 5.1. The most "probable" profile based upon the observed data and the climatology lies between the "real profile" (probably close to the one observed by the independent profiling instruments) and the climatological profile.

In conclusion, McElroy indicated the use of the second Umkehr to recover the higher level profiles and yield information about the aerosol distribution, is under investigation. Umkehr solutions will be poor if the total ozone amount is changing rapidly near sunrise or sunset.

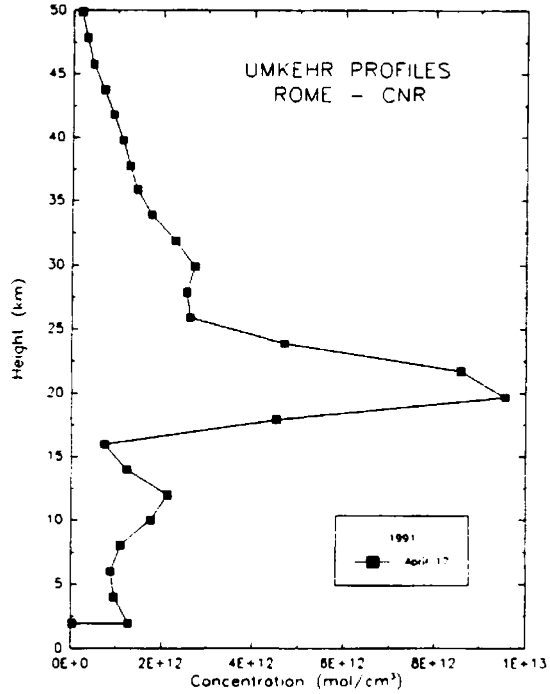

Figure 5.3: A sharp increase observed in the ozone at 20-22 km in Rome.

5.2 Umkehr results from Scott Base, Antarctica

The Italians are working with data from two Brewer stations in the Antarctica: Brewer #50 at Scott Base and Brewer #35 in co-operation with New Zealand and Argentina respectively. Umkehr observations were collected during October, 1991 at Scott Base, however, there were no successful profiles generated due to a date/time stamp problem involving the Julian date and AM/PM recording.

Data collected at the Consiglio Nazionale delle Ricerche (CNR) in Rome, Italy have been processed and Umkehr profiles generated. April 17, 1991 data indicates a sharp rise in the

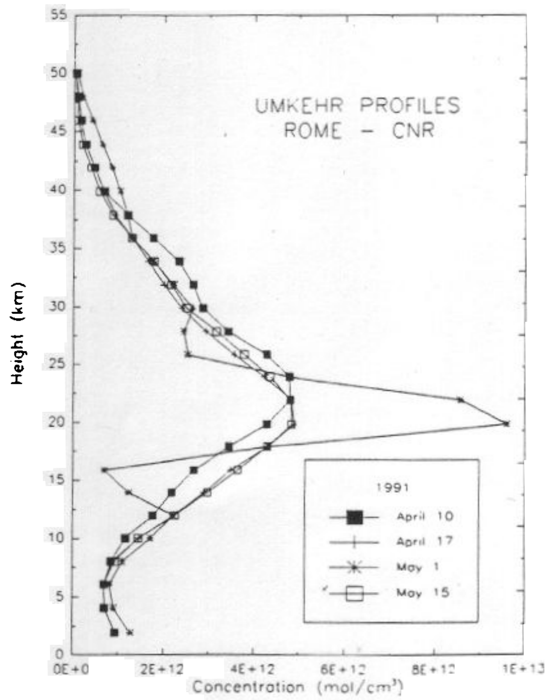

Figure 5.4: Ozone Umkehr profiles collected at the CNR in Rome.

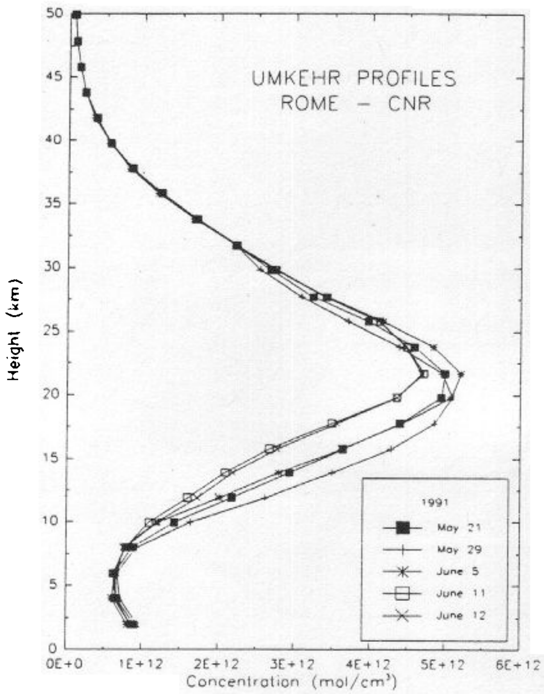

Figure 5.5: Ozone profiles measured at the CNR in Rome in May and June, 1991.

ozone concentration at 20-22 Km as seen in Figure 5.3 and there is still uncertainty about the explanation. Profiles which have been plotted and given in Figures 5.4 and 5.5 were obtained between April 10 and June 12, 1991. Ozonesonde data collected at a site near Bologna, Italy have revealed a maximum concentration of ozone at 18 Km. Ozonesonde data collected on June 6 and 20, 1991 are to be compared with Umkehr measurements made at CNR in Rome. In addition, total O_3 and SO_2 are to be reported as well and included in the data comparison, despite the distance between the Rome and Bologna stations.

5.3 Comparison between the "classical" Umkehr and the Brewer Umkehr

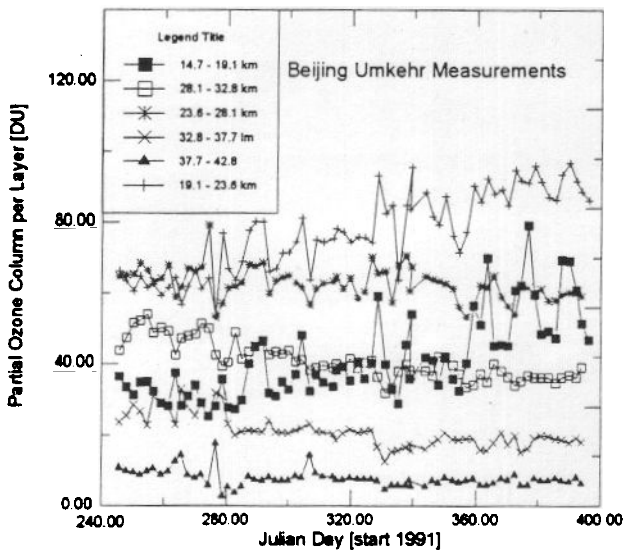

Figure 5.6: Stratospheric Umkehr layer results from Beijing observations.

A comparison of Dobson No. 51 and Brewer #040 at Arosa, Switzerland has been undertaken for Umkehr profiles. Total ozone was measured by the Brewer and by Dobson instrument No. 15. Phenomenological cloud cover descriptions were made each day and 25 data sets were preprocessed with 15 Brewer ozone profiles actually being analyzed using the TOMKEHR program. The Dobson Umkehr analysis employed the new program by Mateer and DeLuisi (1992) to provide single profiles and monthly means from both methods

The effects of cloud were reported to be large; therefore, the unusually large ozone values observed are not considered reliable. Yet clear sky data also indicated unacceptably large ozone values suggesting a program "collapse" had occurred. From September 1990 to December 1991 a total of 336 Umkehr measurements have been made. January and June 1991 indicated good monthly mean ozone comparison results with best the agreement in layer 4. The upper layers, such as layer 7, show the Brewer method estimating higher ozone values than were reported for the Dobson. Total ozone measurements form the Brewer were also noted to be larger than the Dobson values.

It was suggested that the percentage difference of ozone measurements from each instrument can be determined and compared by running the Dobson data through the Brewer Umkehr analysis program (with appropriate changes).

5.4 Aerosol corrections for Umkehr measurement

There are currently two Brewer instruments operating in the PRC: one near Beijing and another in the north Central interior at Qinghui at an elevation of 3300 m. There are two Dobson instruments at the northern site and two more Brewer instruments have been ordered.

Data collected at the Beijing site from September 1991 to January 1992 have been analyzed using the AES Umkehr data processing software. Plots for layers 3 to 8 are given in Figure 5.6 which are derived from data analyzed by the TOMKEHR program with acceptance criteria: rmsres values of < 1.1. An aerosol correction has been applied to these data. Total ozone values from the Qinghui site for the period September 1991 to February 1992 are given in Figure 5.7. Brewer and Dobson data collected at the Beijing site (November 1990 to January 1991) showed good correlation with about an average of 6% difference between instruments as seen in Figure 5.8.

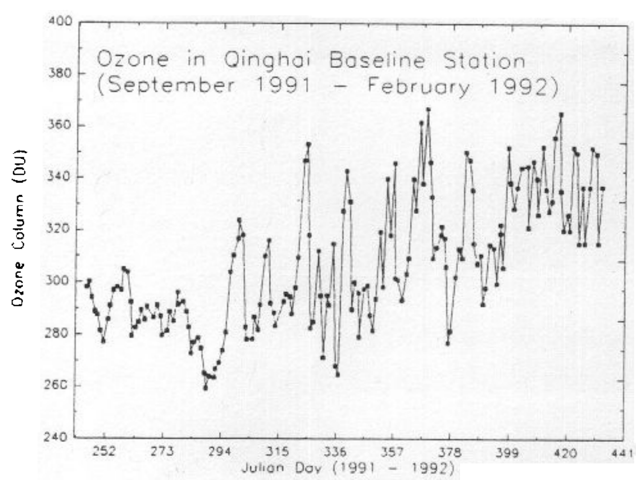

Figure 5.7: Total ozone values measured at the Quinghai site in 1991 and 1992.

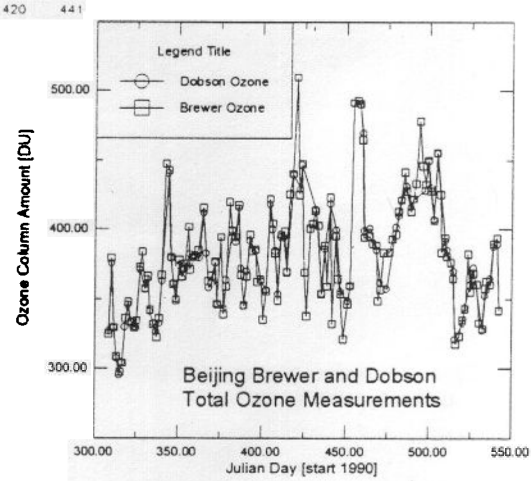

Figure 5.8: A comparison of total ozone at Beijing as measured by both the Brewer and Dobson Spectrophotometers.

Further data analysis using the aerosol correction method is

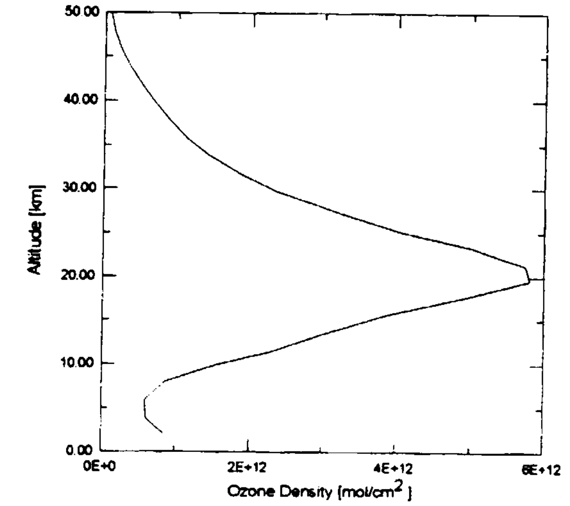

Figure 5.9a:

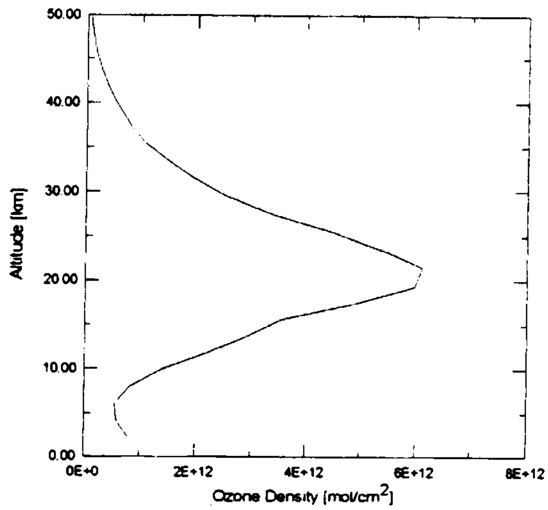

Figure 5.9b:

shown in the four plots in Figure 5.9 where the first plot indicates the first guess, the second is the AES software derived result, and the last plot includes the appropriate aerosol corrections. Table Mountain, California data is also presented indicating the effect of the aerosol correction given in Figure 5.9.

The aerosol correction uses the stratospheric optical depth of aerosol plus the mid-latitude ozone profiles. These input parameters are then used to solve the radiative transfer equation assuming first-order scattering (single scattering model). A first guess profile along with the refractive index of aerosols are also used as inputs to the calculation. Six plots for morning and evening profiles are shown in Figure 5.10.

It was recommended that the aerosol profiles be measured to ensure that the aerosol optical depths used as input are, in fact, representative of the stratosphere and not ground-level aerosols.

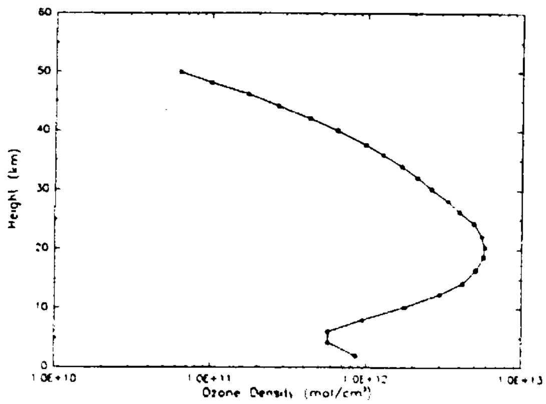

Figure 5.9c:

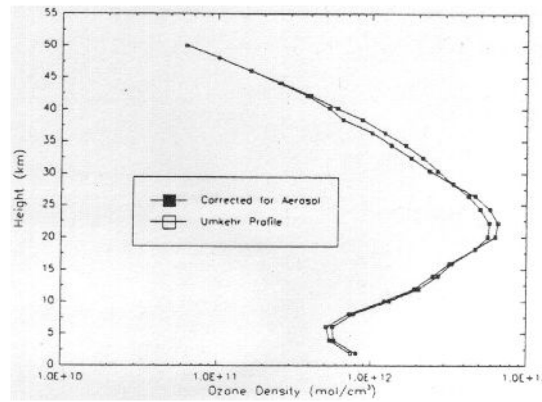

Figure 5.9d:

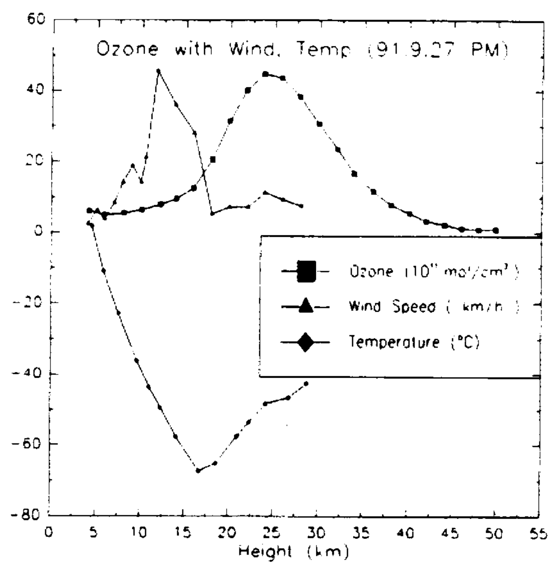

Figure 5.10a:

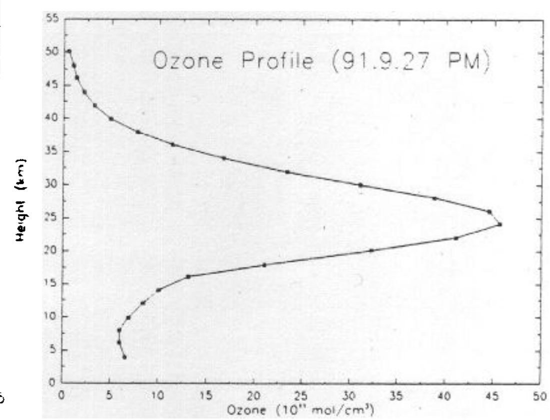

Figure 5.10b:

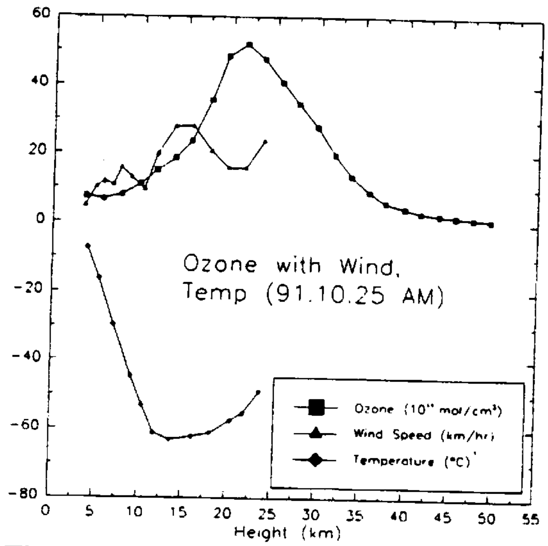

Figure 5.10c:

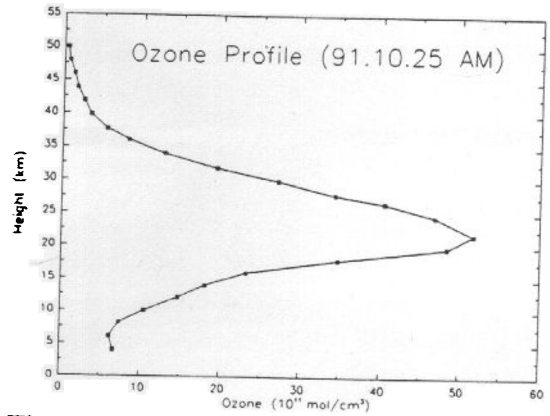

Figure 5.10d:

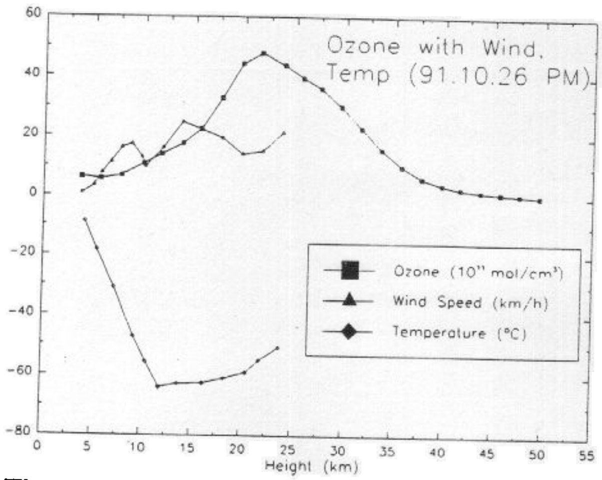

Figure 5.10e:

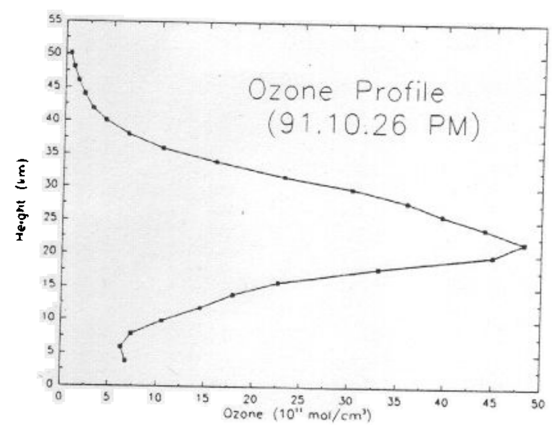

Figure 5.10f:

6. UV-B Measurements [W. Josefsson, rapporteur]

6.1 Preliminary results of UV-B measurements with Brewer #064

Preliminary results from UV-B measurements made with Brewer #064 were presented by M. Degrorska. The instrument is sited at Belsk where observations of UV radiation have been recorded since 1975 using a Robertson-Berger (RB) meter. Three months of daily UV observations for the period April to June 1991 from the Brewer were compared to the corresponding data recorded by the RB meter. The correlation coefficient was about 0.92 and the daily values from the Brewer included about 20 scans which were weighted by the ACGIH-NIOSH action spectrum. The absolute calibration of the Brewer was based on exposures to a lamp unit supplied by Sci-Tec.

Spectral data from two clear days were compared with measurements of Bener and with model-computed values by Green, Dave and Halpern and Schippnick-Green.

6.2 Three years of UV-B measurements at Toronto compared with model results

J. Kerr presented the results of a three-year study of UV-B made by the Brewer instruments in Toronto. The instruments were calibrated once a week using a set of 1000 W DXW halogen lamps traceable to NIST.

Kerr also reportd on an intercomparison on the 6th of Nov 1990 between a number of different spectroradiometers including the Brewer. The presented agreement of the spectra within the UV-B was surprisingly good. The comparison data were taken close to local noon.

Daily values of weighted UV irradiation based on the action spectrum given by McKinley and Diffey were presented. The annual variation for the years 1989 to 1991 revealed the strong influence of the solar elevation and cloudiness.

The McKinley-Diffey weighted values are denoted here by DFY and have been plotted versus the total ozone for different cloud categories. A set of clear days were extracted from the total data set and the DFY was plotted as a function of the total ozone with the solar zenith angle as parameter. The result was a set of grouped data points. Using a simple regression model, a set of curves were fitted to the points showing a good agreement.

This verification of the empirical model shows that it can be used to compute clear-day values of DFY. It can also be used for simulation as was shown in a plot presenting the yearly average daily DFY based on pre-1981 total ozone data compared to the actual measured 1991 DFY values. The relatively small effect of the springtime low values of total ozone was evident. The model also illustrated the so-called radiation amplification factor (RAF; the ratio of the percentage UV change to the percentage ozone change causing it) which was a little larger than 1. The noon-time flux can be computed for any latitude assuming a clear sky. Using TOMS data, it is possible to do a global map of the Diffey flux.

Canada has a program called the Green Plan which includes a UV-B advisory program. On a daily basis, a forecast of an ultraviolet index is given to the public. It is based on a predicted field of ozone calculated from meteorological fields and adjusted using Brewer total ozone data. The model relating UV-B to ozone amount is used to determine the clear-sky UV radiation which is then converted to a suitable index in the range 0 to 10.

6.3 Comparison of UV-B measurements performed with a Brewer Spectrophotometer and a new Robertson-Berger detector

A. Bais presented a comparison of data collected by a Brewer Ozone Spectrophotometer and a new Robertson-Berger (RB) meter. The Brewer was calibrated using a calibration lamp unit supplied by Sci-Tec and UV spectra were collected five times per day. The spectra were convolved with the action spectrum recommended by ACGIH-NIOSH [Parish] and also the spectral response of the RB meter. The latter showed a very good correlation (0.997) with the measurements of the RB meter.

A brief presentation of the intercomparison of spectroradiometers within the STEP UV measurement project was also included. Some very large discrepancies were shown. A probable explanation is errors in the spectrophotometer wavelength settings. A new intercomparison is planned to take place in the summer of 1992.

6.4 UV-B - measurements applied to studying marine biology

A. Roberge presented the results of some UV-B measurements as applied to the study of marine biology. A study of the growth of algae in a river in British Columbia (51°N) as a function of UV-B was the impetus for a new application of Brewer data. About 30 scans per day, roughly corresponding to two observations per hour, were taken along with observations of the total ozone column.

The action spectrum of Setlow was applied to the measured spectra and they were also converted to photons per unit area per seconds. The latter is a unit often used for the photosynthetically active radiation (PAR) which also was measured at the site.

7. NO_2 Measurements [J.B. Kerr, rapporteur]

7.1 Results of NO_2 intercomparisons.

Tom McElroy reported on an instrument intercomparison which was carried out under the auspices of the World Meteorological Organization. Environment Canada hosted the comparison of visible light spectrophotometers at Mt. Kobau, British Columbia in August of 1991. Instruments from four countries were involved. The intercomparison results have indicated that some significant differences exist in the response of the various instruments, and have provided a basis for the comparison of the historical data sets which currently exist as a result of the independent researches carried out in the past in the former Soviet Union, New Zealand and Canada.

Measurements of the amount of stratospheric nitrogen dioxide were first reported by Ackerman and Muller and were based on balloon observations of the solar spectrum in the infrared from high-altitude balloons. Shortly afterward, Brewer, Kerr and McElroy published the first ground-based results using visible light spectroscopy in the 430 to 450 nm region. Observations of the brightness of the zenith sky were analyzed by comparison with the results of a single-scattering model to give an estimate of the amount of NO_2 in the stratosphere.

The Mt. Kobau intercomparison was organized in order to evaluate the performance of visible light spectrophotometers which have been in use for some time for the monitoring of stratospheric nitrogen dioxide (for example the work of Brewer et al., Noxon, Pommereau, Platt et al., McKenzie and Johnston and Mount et al.). It is of considerable scientific importance to compare those instruments which have a long, independent record of measurements, particularly the Canadian and New Zealand instruments. The groups which were represented at the intercomparison included the Academy of Sciences (AS) of the Soviet Union, the University of Heidelberg, Germany, the Atmospheric Environment Service (AES) of Canada, and the Department of Scientific and Industrial Research (DSIR) of New Zealand.

The DSIR instrument is a mechanically scanned monochromator. The AES NO_2 instrument is a Brewer spectrophotometer and the University of

Heidelberg spectrometer is a cooled, diode array device. The Academy of Sciences group used a mechanically-scanned grating instrument. The detailed descriptions of these instruments, and the results of the comparison, will be published during 1992 as a WMO report.

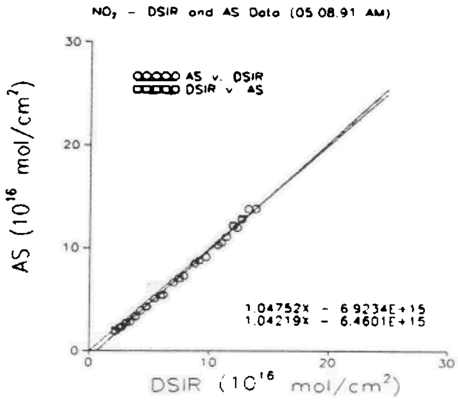

Figure 7.1: Comparison of the slant column amount of NO_2 observed at different times by two instruments.

Data from a total of 10 sunrises or sunsets are available for comparing at least one pair of instruments. At the other extreme, four day's worth of data were collected which permit the comparison of sunset data from all four instruments and 2 sunrises were available during which all instruments collected data. In the comparisons which follow, a detailed analysis of 4 mornings and 4 evenings is presented, since three of the four instruments were operating on all of those days. The comparison is of somewhat lower precision for the sunrise data in the case of the Heidelberg instrument because only 2 days' data were available.

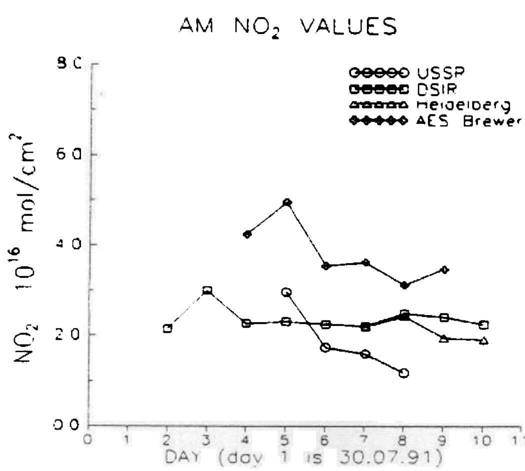

Figure 7.2: The morning apparent slant column amount of NO_2 measured by each instrument at 84° solar zenith angle.

The vertical column amounts which are reported by different groups based on zenith sky, twilight observations is totally dependent on the model or algorithm used to reduce slant column data to vertical column amounts. Therefore, if vertical column data were directly compared, the results would include the effects of the differences in the analysis methods. Model results have shown that the process of scattering radiation from the sun toward an instrument looking at the zenith sky is relatively independent of wavelength for the spectral interval 400 to 500 nm. It is therefore useful in the investigation of the relative behaviour of the NO_2 measurement systems to compare the differential sensitivity of the various measurement devices to changes in the apparent NO_2 slant column in the zenith sky light which occur because of the variability of NO_2 and the progression of the solar zenith angle throughout the day.

Figure 7.2 shows the apparent slant column amount of NO_2 measured by each instrument at approximately 84° solar zenith angle each morning. The relationship between the AES and DSIR instruments is markedly different. It may be that there is an interfering effect which makes the DSIR and AES data behave differently in the morning. Since it is known that the Brewer may be experiencing some interference from residual Ring effect contributions and possibly water vapour, the variation in the other column amounts retrieved (say by the DSIR intsrument) should be examined in light of the information in Figure 7.2.

The general consistency of the results would suggest that all instruments are achieving a precision on the order of a few percent. The offset indicated between the AES instrument and the others may be a significant feature of the comparison. The offsets between the other pairs of instruments generally seem to be somewhat smaller. Since the Brewer data analysis technique is different from that which is used for the analysis of all the other data, this may indicate a systematic difference between the two analysis methods. This will require further investigation.

7.2 Seven years of NO_2 measurements at Toronto

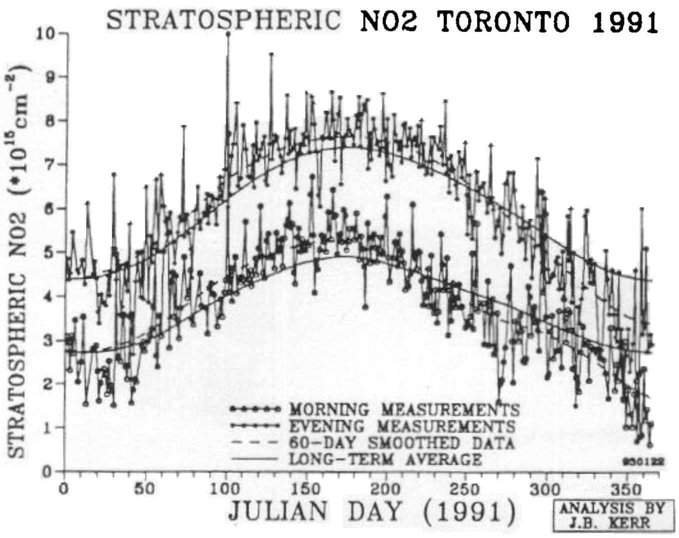

Figure 7.3: Stratospheric AM and PM NO_2 column amounts during 1991.

J.B. Kerr presented results of NO_2 measurements made at Toronto with Brewer instrument #022 since 1985. Figure 7.1 shows morning and evening column amounts of stratospheric NO_2 for 1991 with the long-term (1985-1992) annual averages shown as solid lines and the short-term (60-day) running averages shown as dashed lines. Toward the end of 1991 both morning and evening column amounts of NO_2 were observed to decrease to values less than those observed in previous years. The lower values of NO_2 continued during early and mid 1992 as shown in Figure 7.2. Kerr stated that the observed decrease in NO_2 was likely due to effects from the Mount Pinatubo volcanic debris which arrived at northern mid-latitudes around the same time. However, it is not clear whether the observed decrease is a real decrease in stratospheric NO_2 or an apparent decrease resulting from the volcanic aerosols causing an optical effect on the inversion.

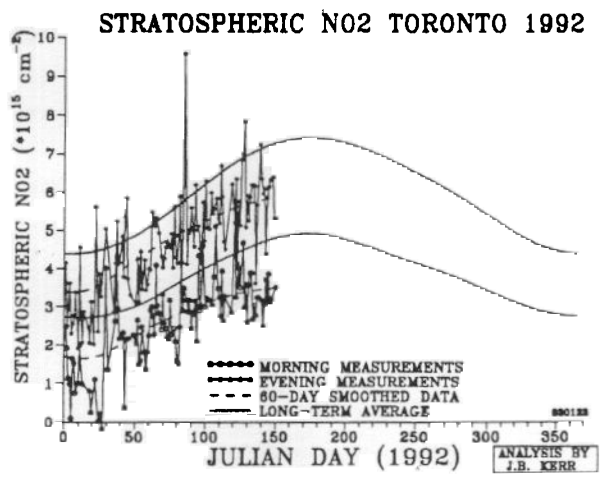

Figure 7.4: Same as Figure 7.3 but for 1992. NO_2 values are about 25% below normal.

Figure 7.3 summarizes the 7 year record of total NO_2 (from

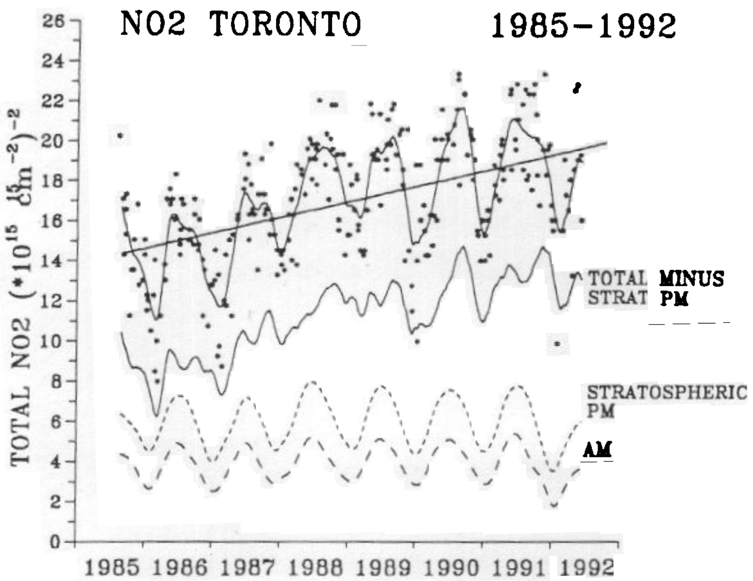

Figure 7.5: Summary of total column stratospheric and tropospheric NO_2 from direct sun and twilight measurements.

direct sun measurements) and morning and evening stratospheric column amounts (from twilight zenith sky measurements). It is apparent that the total column NO_2 is significantly larger than the stratospheric column amount. It is also evident that the total column NO_2 has been increasing with time, whereas, the stratospheric amount remained relatively constant until the recent decline in late 1991.

8. Data Analysis and Archiving [Alkis Bias, rapporteur]

8.1 The NO_2 vertical profile inversion technique.

Tom McElroy reported on the development of software to retrieve vertical profiles of NO_2 from apparent slant column amount measurements made using light from the zenith sky in the blue part of the visible spectrum. The apparent amount of NO_2 in spectra taken at large solar zenith angles is determined by either the Brewer NO_2 algorithm or the spectral fitting of the spectrum of light relative to a reference spectrum taken near noon. The growth of the apparent slant column amount is the result of light taking a long, slanting path through the upper atmosphere as the solar zenith angle increases.

The precise path of the light through the atmosphere is determined by the radiative transfer process and is dependent on the amount of air and aerosol at each level in the atmosphere. Since the absorption coefficients for absorption by NO_2 ozone and other significant substances are not large (maximum <10%) even in the long twilight slant path, the path of scattered light in the atmosphere is independent of the amounts of these absorbers. As a result, a quasi-linear model of the scattering process can be used to produce a useful profile inversion method. Some results of this technique have been reported in the literature, notably by McKenzie et al.

8.2 Brewer Database Management System (BDMS)

Ed Hare presented a general overview of the Brewer Database Management System (BDMS) by first giving a brief history of the development of the system by illustrating the contents of the Canadian Brewer data along with several international data sets currently being processed.

Hare then proceeded to discuss the development of the Oracle database which is a multi-environment, relational database, by illustrating the logical model used for data table creation. Parsing software will be used to disseminate data from the B and # files in order to generate ascii text files which in turn get uploaded into the database. UV data tables are currently being designed. Figure 8.1 shows the logical model for Brewer tables.

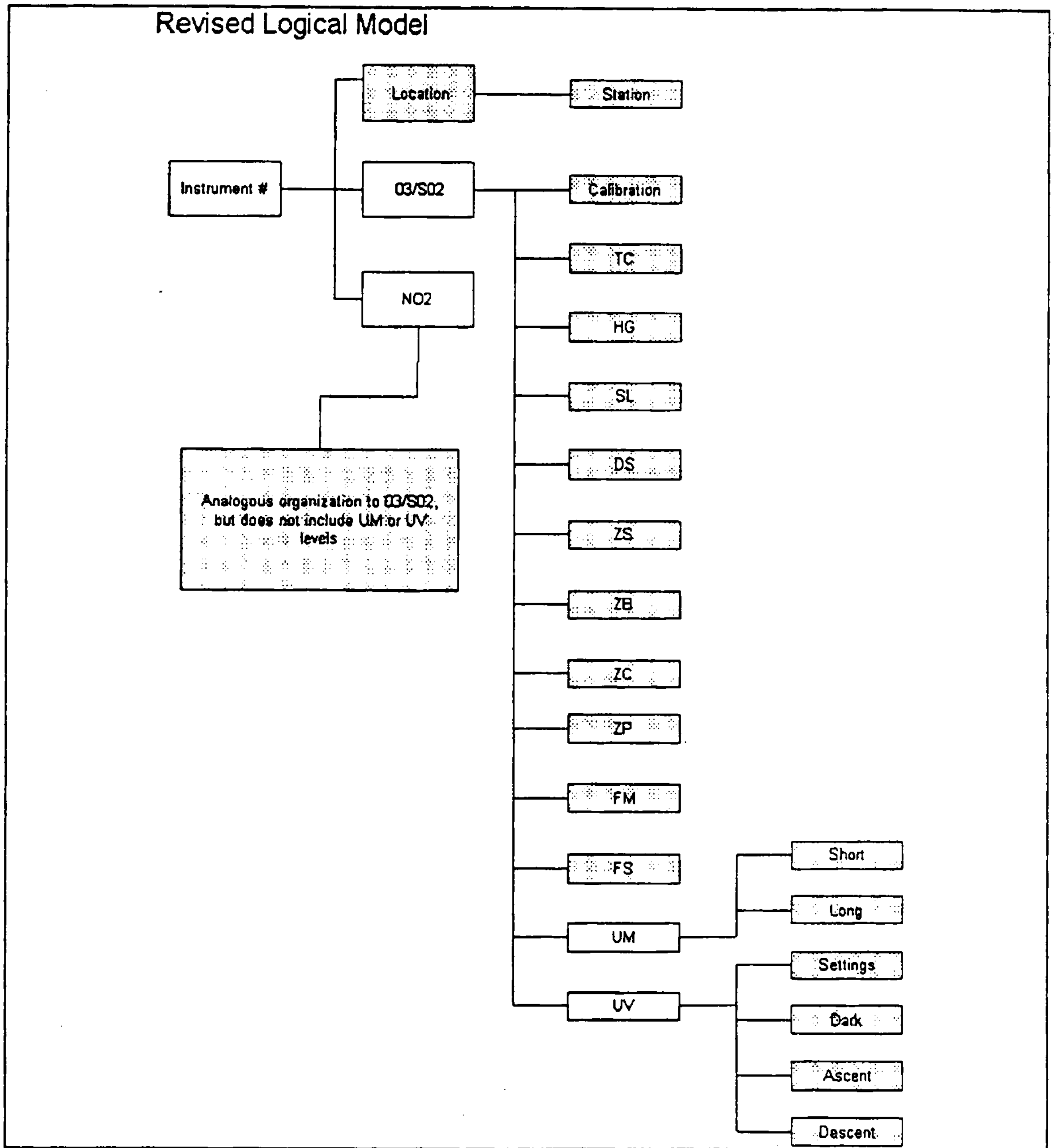

Figure 8.1: The Brewer Database organizational structure.

9. New Instrument Hardware and Software Developments

[A. Roberge, rapporteur]

9.1 Ozone Measurements at Large Solar Zenith Angles

Weine Josefsson has developed a technique for the Brewer which extends the direct sun ozone monitoring capability to larger solar zenith angles. The technique is known as a corrected Focused Sun observation. Focused sun observations were originally developed for the Dobson Spectrophotometer.

The measurement is done by taking a reading of both an offset and a focused sun image on the entrance slit of the Brewer. The signal from the offset position is taken as the scattered light component of the focused signal. In theory, the observations at higher solar zenith angles include much more scattered signal compared to a direct sun measurement at a smaller zenith angle.

The relation:

$$I'(WL) = I(WL) + \Delta I$$

where WL is wavelength
I is intensity

shows the relation between what is measured by the Brewer [I'(WL)] along with the direct component [I(WL)] and the difference between the previous two components [ΔI] which represents the signal read when the sun's image is offset from the entrance slit. The Figure 9.1 demonstrates the relationship between the sun's image offset angle and the relative intensity value for both the longest and shortest Brewer wavelengths.

{graph} relative signal value v. image offset angle 9.1

Figure 9.2 demonstrates the difference between the conventional DS Brewer measurements and the new FS measurement which subtracts out the scattered skylight component of the signal. The FS method can give reasonably accurate results down to 85 deg. SZA compared to 75 deg. for DS measurements. The rolloff will be dependent on sky conditions and the ozone value as is demonstrated in the Figure.

{graph} mu vs. ozone for DS and FS msmnts. 9.2

The higher the ozone, the less reliable the FS results are as increased ozone decreases the direct component and increases the scattered component of the signal.

9.2 New developments in instrument software

Ken Lamb of SCI-TEC Instruments discussed several aspects of the Brewer software and hardware. Recent hardware improvements to the Brewer include a redesigned weatherproof cover that no longer has an opening door on the top and uses a tubular gasket seated in an aluminum groove that makes a better seal to the Brewer base. Now that the top window is sealed, the siting switches have been moved to along side the azimuth connector on the Brewer base. No changes have been made to the siting technique. A lightning arrestor has been added as a modular connection to the base of the tracker. As well, a surge suppression adaptor has been added to the computer end of the RS232 communications cable. Software improvements have been made for both instrument control as well as graphical presentation of near-real-time Brewer instrument performance and atmospheric data.

Two commercial software packages have been tested running in conjunction with the Brewer control software. They are:

DESQVIEW V2.41 (Quarterdeck Office Systems)

- this package is a true multitasking system that can control up to nine operations/windows at one time. The operations may be any combination of Brewers, DOS operations or other commercial software packages such as WordPerfect,

LOTUS

CLOSE-UP V4.0 (Norton Lambert)

- this package is a remote terminal control system that allows Brewer, DOS or any other application operation from another computer provided both machines are connected by modem.

Sci-Tec is currently developing some data processing software which can display, with a very small number of key strokes, any number of graphs at once of Brewer instrument performance or atmospheric data. The style and structure of the graphs are defined by the operator. The name of the software is BREWVIEW. BREWVIEW, along with DESQVIEW, can turn a dedicated Brewer control computer into a multitasking work station that is capable of running more than one Brewer and other programs, as well as displaying in near-real-time previously-recorded Brewer data. Quality improvements have been directed toward improved GWBASIC Brewer software that eliminates most communication difficulties.

9.3 Turbo-based software development for Brewers

P. Eriksen described the successful conversion of some of the Brewer control software to operate in the compiled mode using a Turbo-Basic compiler. This development permits the faster operation of the observing system and quicker post-processing of data which have been collected by the measuring system.

9.4 Development of the Brewer Double Monochromator

Tom McElroy presented preliminary results and discussed the construction of a double monochromator Brewer. This Brewer has been constructed to test the stray light rejection capability of the single monochromator Brewer. The need for accurate scan information is driven by sophisticated atmospheric radiation models, instrument specifications as well as the life sciences. Since ground based spectral measurements are influenced by ozone (implies very little signal) it is assumed the single monochromator Brewer is sufficiently accurate for wavelength scans.

The goals of the characterizations tests are to:
- better understand the single monochromator Brewer,
- test the double monochromator.

It was shown that the throughput of radiation after each pass through a

Brewer monochromator is 20% of the signal (e.g.: 2nd pass 20% of 20%). The double monochromator gives a higher performance in rejecting stray light compared to a single monochromator, where the quality figure for the double instrument is the square of that for a single monochromator. In a graph showing the irradiance values for simultaneous UV scans with both a single and double monochromator good agreement was seen between 300-325 nm as shown in Figure 9.3.

9.5 Development of the red-light Brewer for ozone measurements at 600 nm

Andre Roberge presented and discussed the progress to date on the MKV Brewer. The MKV Brewer will have the capability of measuring ozone in both UV and visible wavelengths. Wavelengths centred around the peak (580 to 610 nm) in the absorption spectrum of ozone in the Chappuis band (450 to 750 nm) will be used for visible-light ozone measurements. The use of the visible absorption band will extend the useful monitoring period in the winter, at high-latitude observing stations, since the absorption sue to ozone is smaller than in the region used by the conventional Brewer UV measurement, the light level is higher in the visible, and Rayleigh scattering is smaller.

The MKV Brewer design is based on the design of the MKIV Brewer. Hardware differences that distinguish the two are outlined in Table 9.1. Wavelength selection for $O_3/SO_2/NO_2$ in the MKIV and O_3-UV/O_3- vis. is accomplished by using different diffraction gratings and differeent order-sorting filters located in front of the cathode of the PMT. Changes have been made in the electronics in the MKV to achieve higher gain, speed and linearity and greater stability in the applied high voltage. Faster pulse rise times and higher counting rates are used with the stronger visible light signal. Comparing the UV and visible wavelength regions to the UV ozone absorption, there is less absorption and a stronger signal in the visible region. To overcome the difficulties with the weaker absorption the following elelments will be included in the design:

a.) restrict wavelengths to those not affected by H_2O or O_2 absorption.
b.) wavelengths cover the visible absorption region where O_3 has the greatest optical depth.
c.) breadth of monitored region is small enough to neglect aerosol

scattering.

d.) calcluate and remove the effects of Rayleigh scattering

e.) apply the most accurate absorption coefficients.

Other instruments that have employed the Chappuis band differential absorption technique have achieved a 4-7% accuracy with both DS and ZS observations. It is believed the Brewer MKV will do equally as well and maintain all of its automation and weather hardening. With the extension of the measured wavelengths to the region between 530 nm and 700 nm it may be possible to measure gasses other than O_3, that absorb in this region.

Table 1: Hardware differences that distinguish the MKIV and MKV Brewers.

COMPONENT	**MKIV**	**MKV**
Optical Filters	UG-11, $NiSO_4$ BG-12 (blue)	OG-530 (orange) sharp cut-off filter
Diffraction Grating	1200 l/mm planar, ruled 1 micron blazing	1800 l/mm planar, holographic 600 nm blazing
Sensor	9789QA Bialkali PMT	9863/350 S20 PMT
type	bialkali	S20
Multiplier Structure	venetian blind	linear focused
Dynodes	13	14
Surface	CsSb	BeCu
Discriminator		
Propagation Delay	14 ns	2.5 ns
Pre-Scaler	Schottky TTL /2 (fixed)	ECL /2,/4,/8,/16
H.V. Supply	1500 Vdc	1950 Vdc

9.6 Special Applications

Tom McElroy reported on the following new developments in Canada:

- a Stellar Brewer which would have a 30-40 cm. telescope for use in the Arctic. Stars were first used as light sources for the measurment of ozone in the 1960's by D. Wardle with a spectrophotometer similar to the Brewer. This project is in the conceptual design phase at this time.

- SunPhotoSpectrometer (SPS) for SPEAM II. This is a hand-held instrument to designed to fly on the US Space Shuttle in the fall of 1992. The instrument uses a 1024-pixel Reticon diode array detector and a concave holographic grating (400-800 nm in second order and 200-400 nm in the first order). The system weighs 2.8 kg with batteries for 6 hours of operation. A space-qualified PC computer has been built as well to store data on ROM (1 MB credit card size). There is also another instrument which will fly along with the SPS to make airglow measurements.

10. Recommendations from the Attendees of the Meeting

As part of the concluding discussions of the Brewer Users' Workshop, a number of recommendations concerning ozone measurements and the operation of Brewer Spectrophotometers in the Global Ozone Observing System were agreed upon by the working group members.

1. It is recommended that all Brewer Spectrophotometers have calibration and servicing visits as frequently as possible and not less than once every two years. Furthermore, steps should be taken to co-ordinate the calibration activities at various sites to reduce the cost of the calibration trips.

2. All Brewer Spectrophotometer operators should be strongly encouraged to collect and submit data, including umkehr observations, within 60 days of their acquisition.

3. Brewer Spectrophotometer operators should take the necessary steps to upgrade their instruments to collect ultraviolet spectral (UV-B) data.

4. Regular UV-B calibration activities should be organized in order to properly calibrate all the Brewer UV-B monitoring instruments in the world network. These calibrations could be co-ordinated with the regular Brewer Spectrophotometer ozone calibrations.

5. It is recommended that measurements of the two linear polarization components of the zenith sky light be included as part off the Brewer Umkehr. Both the component of light polarized parallel to the instrument-sun vector and the perpendicular component should be measured. Currently, only the perpendicular (strong) component is being measured at most observing stations. As a minimum, ozone Umkehr observations

6. It is recognized that the WMO has supported the continuation oft eh near-real-time ozone reporting and mapping system which was operated jointly by Greek and Russian scientific groups for the purpose of providing ozone information for planning during the European Arctic

Stratospheric Ozone Experiment (EASOE). It is recommended that the reporting system be operated throughout the whole year until such time as the World Ozone Data Centre (WODC) can provide near-real-time quality assessment of contributed ozone data. Rapid collection and dissemination of ozone data encourages timely submission of data and provides for the early detection of instrument problems.

The working group further recommends that the WODC develop, as soon as is practical, the ability to automatically collect ozone data from field stations. Preparations for the establishment of such a system should be made so that the matter can be pursued at the next Brewer Workshop.

Guidelines should be developed and published, along with case histories, to serve as an operational guide to the successful use of the Brewer Spectrophotometer in the Global Ozone and ultraviolet radiation observing system.

The Users Group recommends that the WODC organize an on-line software and information dissemination system that can be used to co-ordinate the activities of the Brewer Ozone measuring network, and thereby shorten the delays in making new observation techniques and software available to the observing stations operators.

Appendix i) - List of Participants

Participant	Institution	Telephone/Fax
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Appendix ii)

WMO CONSULTATION ON THE OPERATION OF THE BREWER OZONE SPECTROPHOTOMETER

University of Virginia, Charlottesville
June 1-3, 1992

Program

Chairman: J.B. Kerr

1. Opening of the Meeting and Election of a Chairman and Rapporteurs ... [R.D. Bojkov]

2. REVIEW OF THE RECOMMENDATIONS BY THE AROSA 1990 CONSULTATION

3. MEASUREMENT OF TOTAL OZONE

   i) Total column ozone measurements at Izana Observatory. [E. Cuevas]

   ii) The zenith sky algorithm for total ozone measurements. [J.B. Kerr]

   iii) Results of the WMO/GO_3OS synoptic ozone mapping project. [A. Bais and C. Zerefos]

   iv) Measurements of ozone at Oslo. [S.H.H. Larsen]

   v) The daytime course of the total ozone content [A.G. Ishov]

   vi) Analysis of eight years of ozone and SO_2 Brewer measurements at the Meteorological Institute of Belgium. [D. De Muer]

   vii) Measurements of ozone and SO_2 at Kislovodsk observatory. [N.P. Elansky]

viii) The Canadian OZONE WATCH program. [J.B. Kerr]

4. TOTAL OZONE INTERCOMPARISONS

i) Comparison of Brewer and Dobson measurements at Sondrestrom, Greenland. [P. Eriksen]

ii) Intercomparison of Dobson, ozonesonde, TOMS and Brewer data over Greece [C. Varotsos]

iii) Intercomparison of Brewer 10 with Dobson 104 and TOMS. [U. Koehler]

iv) Airmass dependence of the Brewer No. 64 and the Dobson No. 84 total ozone measurements. [B. Rajewska-Wiech]

v) Ozone measurements in the Antarctic [L. Ciataglia and C. Valenti]

5. UMKEHR MEASUREMENTS

i) The Brewer Umkehr analysis and results from Edmonton. [C.T. McElroy]

ii) Comparison between "classical" Umkehr and Brewer Umkehr measurements. [J. Staehelin, P. Viatte and B. Hoegger]

iii) Aerosol correction for Umkehr measurements [G. Song]

6. UV-B MEASUREMENTS

i) Preliminary results of UV-B measurements with the Brewer No. 64. [M. Degrorska]

ii) Three years of UV-B measurements at Toronto compared with model results. [J.B. Kerr and D.I. Wardle]

iii) The Canadian UV-B Advisory program. [J.B. Kerr]

iv) Comparison of UV-B measurements performed with a Brewer spectrophotometer and new Robertson detectors. [A. Bais]

v) UV-B measurements applied to studying marine biology. [A. Roberge and K. Lamb]

7. NO_2 MEASUREMENTS

i) Results of NO_2 intercomparisons. [C.T. McElroy]

ii) Seven years of NO_2 measurements at Toronto [J.B. Kerr]

8. DATA ANALYSIS AND ARCHIVING

i) The NO_2 vertical profile inversion technique. [C.T. McElroy]

ii) High altitude ozone profile measurements using the second umkehr. [K. Gioulgkidis and C.T. McElroy]

iii) Measuring procedures, quality control and data :hiving of Brewer measurements at the Meteorological Institute of Belgium. [H. De Backer]

iv) Software for total ozone mapping and analysis. [V. Fioletov]

v) The Brewer data management system. [J.B. Kerr and E. Hare]

9. NEW INSTRUMENT HARDWARE AND SOFTWARE DEVELOPMENTS

i) Focused sun observations using the Brewer ozone spectrophotometer. [W. Josefsson]

ii) New developments in instrument software. [K. Lamb and A. Roberge]

iii) Turbo based software development for Brewers. [P. Eriksen]

v) Development of the Brewer double monochromator. [C.T. McElroy and D.I. Wardle]

vi) Development of new Brewer instruments for special applications. [C.T. McElroy]

10. FORMULATION OF RECOMMENDATIONS AND CLOSING OF THE MEETING

Appendix iii) - List of Brewer Ozone Spectrophotometer Locations (June 1994)

(Courtesy SCI-TEC INSTRUMENTS)

S/N	COUNTRY	LOCATION	LAT.	LONG.	CONTACT	REMARKS
05	GREECE	THESSALONIKI	40.52	-22.97	C. ZEREFOS	82 O3/SO2/UVB MKII
06	SWEDEN	NORRKOPING	58.61	-16.12	W. JOSEFSSON	82 O3/SO2/UVB MKII
07	CANADA	MOSCOW			T. MCELROY	82 O3/SO2/NO2/UVB MKIV
08	CANADA	TORONTO	43.78	79.47	J. KERR TRIAD	82 O3/SO2 MKII
09	CANADA	TORONTO	43.78	79.47	T. MCELROY	82 O3/SO2/NO2/UVB MKIV
10	GERMANY	HOHENP'BERG	47.8	-11.02	U. KOHLER	82 O3/SO2/UVB MKII
11	CANADA	SASKATOON	52.11	106.71	R. ADIE	87 O3/SO2/UVB MKII
12	CANADA	ALERT	82.5	62.3	J. BELLEFLEUR	83 O3/SO2/UVB MKII
13	CANADA	STONY PLAIN	53.55	114.1	J. BELLEFLEUR	83 O3/SO2/UVB MKII
14	CANADA	TORONTO	43.78	79.47	J. KERR TRIAD	83 O3/SO2/UVB MKII
15	CANADA	TORONTO	43.78	79.47	J. KERR TRIAD	83 O3/SO2 MKII
16	BELGIUM	BRUSSELS	50.8	-4.35	D. DEMUER	83 O3/SO2/UVB MKII
17	CANADA	TORONTO	TRAVELING STD.		J. KERR	84 O3/SO2/UVB MKII
18	CANADA	GOOSE BAY	53.32	60.3	J. BELLEFLEUR	84 O3/SO2/UVB MKII
19	CANADA	GRANDORA	52.14	107.06	J. BELLEFLEUR	84 O3/SO2/UVB MKII
20	CANADA	LONDON	U.OF W. ONT.		B. LOWE	85 O3/SO2/UVB MKII
21	CANADA	TORONTO	43.78	79.47	T. MCELROY	85 O3/SO2/UVB MKIII
22	CANADA	TORONTO	43.78	79.47	J. KERR	85 NO2 STANDARD
23	TAIWAN	TAIPEI	25.02	-121.31	HSIU-WU CHANG	85 O3/SO2/UVB/NO2 MKIV
24	ITALY	VIGNA'VALLE	42.08	-12.22	S.GIANNOCCOLO	85 O3/SO2/UVB MKII
25	USA	BOULDER	40.01	105.15	G. KOENIG	86 O3/SO2/UVB MKII
26	CANADA	CHURCHILL	58.75	94.07	J. BELLEFLEUR	85 O3/SO2/UVB MKII
27	CAN.	ICELAND	FOR EASOE		A. BAIS	85 O3/SO2/UVB/NO2 MKIV
28	CANADA	TORONTO			R. OLAFSON	86 SHUTTLE
29	CANADA	TORONTO			J. KERR	86 CLO3 EVALUATION
30	GERMANY	POTSDAM	52.36	-13.05	U. FEISTER	87 O3/SO2/UVB MKII
31	CANADA	RESOLUTE	74.72	94.98	J. BELLEFLEUR	86 O3/SO2/UVB MKII
32	CANADA	ALERT	82.5	62.3	J. KERR	87 NO2 ONLY
33	SPAIN	IZANA CAN.IS.	28.29	16.49	E. CUEVAS	87 O3/SO2/UVB MKII
34	JAPAN	SYOWA	-69	-39.58	T. ITO	87 O3/SO2/UVB MKII
35	ITALY	ANTARCTICA	-77.87	34.627	L. CIATTAGLIA	87 O3/SO2/UVB/NO2 MKIV
36	GREECE	THESSALONIKI	40.5	-22.4	F. VOSNIAKOS	88 O3/SO2/NO2 MKIV
37	FINLAND	SODANKYLA	67.4	-26.6	ESKO KYRO	88 O3/SO2/UVB MKII
38	CANADA	SASKATOON			T. MCELROY	88 CCD TEST
39	WMO	TORONTO	TRAVELING STD.		A. ASBRIDGE	88 O3/SO2/UVB MKII
40	SWITZERLAND	AROSA	46.78	-9.67	B. HOEGGER	88 O3/SO2/UVB MKII
41	GREECE	KOZANI	40.27	-21.77	N. STAMNOUS	88 O3/SO2/NO2 MKIV
42	NORWAY	OSLO	59.91	-10.72	S. LARSEN	89 O3/SO2/UVB/NO2 MKIV
43	RUSSIA	KISLOVODSK	43.73	-42.66	N. ELANSKY	88 O3/SO2/UVB MKII
44	RUSSIA	OBNINSK	55.5	-36.2	A. ISHOV	88 O3/SO2/UVB MKII
45	RUSSIA	YAKUTSK	62.08	-129.75	V. DOROKHOV	88 O3/SO2
46	CANADA	SASKATOON			A. ROBERGE	88 O3/SO2
47	PORTUGAL	TERCEICA IS.	38.66	27.22	D. HENRIQUES	88 O3/SO2
48	PORTUGAL	MADEIRA IS.	32.64	16.89	D. HENRIQUES	88 O3/SO2
49	RUSSIA	HEISS IS.	80.62	-58.1	V. DOROKHOV	90 O3/SO2

BREWER SPECTROPHOTOMETER LOCATIONS (JUNE/94) SCI-TEC INSTRUMENTS

S/N	COUNTRY	LOCATION	LAT.	LONG	CONTACT	REMARKS
50	ITALY	SCOTT BASE	-77.8	-165.6	C. VALENTI	89 O3/SO2/UVB/NO2 MKIV
51	MOROCCO	CASABLANCA	33.57	7.67	B. LOUAKED	89 O3/SO2/UVB MKII
52	JAPAN	TATENO	36.05	-140.1	T. ITO	89 O3/SO2/UVB MKII
53	DENMARK	SONDRESTROM	67.	50.5	P. ERIKSEN	89 O3/SO2/UVB MKII
54	CHINA	GONGHE	36.27	-100.62	GUO SONG	90 O3/SO2/UVB MKII
55	CANADA	SATURNA B.C.	48.78	123.13	J. KERR	90 O3/SO2/UVB MKII
56	BRAZIL	CUIABA	-15.5	56.05	V. KIRCHHOFF	89 O3/SO2/UVB MKII
57	JAPAN	TOKYO	35.67	-139.75	H. INOUE	90 O3/SO2/UVB MKII
58	JAPAN	SAPPORO	43.05	-141.3	T. ITO	90 O3/SO2/UVB MKII
59	JAPAN	KAGOSHIMA	31.6	-130.6	T. ITO	90 O3/SO2/UVB MKII
60	JAPAN	OKINAWA	26.2	-127.67	T. ITO	90 O3/SO2/UVB MKII
61	TAIWAN	CHENGKUNG	23.1	-121.37	HSIU-WU CHANG	90 O3/SO2/UVB/NO2 MKIV
62	ITALY	BRINDISI	40.65	-17.95	MET. SERVICE	90 O3/SO2/UVB/NO2 MKIV
63	ITALY	SESTOLA	44.22	-10.77	T. COLOMBO	90 O3/SO2/UVB/NO2 MKIV
64	POLAND	BELSK	51.84	-20.79	M. DEGORSKA	90 O3/SO2/UVB MKII
65	ITALY	MESSINA	38.2	-15.55	MET. SERVICE	90 O3/SO2/UVB/NO2 MKIV
66	ITALY	ISPRA	45.80	-8.63	G. RESTELLI	91 O3/SO2/UVB/NO2 MKIV
67	ITALY	U. OF ROME	41.9	-12.52	S. PALMIERI	91 O3/SO2/UVB/NO2 MKIV
68	CHILE	PUNTA ARENAS	-52.5	71.0	V. KIRCHHOFF	91 O3/SO2/UVB/NO2 MKIV
69	CANADA	EUREKA	80.	85.93	A. ROBERGE	91 O3/SO2/UVB/ MKV
70	SPAIN	MADRID	40.45	3.72	J. CISNEROS	91 O3/SO2/UVB/NO2 MKIV
71	CANADA	TORONTO	43.78	79.47	J. KERR	91 O3/SO2/UVB/NO2 MKIV
72	SWITZERLAND	AROSA	46.78	-9.68	B. HOEGGER	91 O3/SO2/UVB/MKII
73	BRAZIL	RIO BRANCO	-9.97	67.81	V. KIRCHHOFF	91 O3/SO2/UVB/NO2/MKIV
74	CHINA	ZHONGSHAN	-69.37	76.37	GUO SONG	91 O3/SO2/UVB/NO2/MKIV
75	ENGLAND	CAMBORNE	50.22	5.32	P. HUGHES	91 O3/SO2/UVB/NO2/MKIV
76	CHINA	LONGFENGSHAN	44.75	-127.6	GUO SONG	91 O3/SO2/MKII
77	CHINA	LINAN	30.3	-119.73	GUO SONG	91 O3/SO2/MKII
78	GERMANY	LINDENBERG	52.21	-14.12	U. LEITERER	91 O3/SO2/UVB/NO2/MKIV
79	CANADA	TORONTO	43.78	79.47	J. KERR	92 O3/SO2/UVB/NO2/MKIV
80	CANADA	MONTREAL	45.5	73.6	J. BELLEFLEUR	91 O3/SO2/UVB/NO2/MKIV
81	BRAZIL	SANTA MARIA	-29.69	53.73	V. KIRCHHOFF	91 O2/SO2/MKII
82	DENMARK	COPENHAGEN	55.72	-12.57	P. ERIKSEN	92 O3/SO2/UVB/NO2/MKIV
83	CANADA	WINNIPEG	49.91	97.24	J. BELLEFLEUR	92 O3/SO2/UVB/NO2/MKIV
84	CANADA	BEDFORD	44.73	63.66	J. KERR	92 O3/SO2/UVB/NO2/MKIV
85	CANADA	TORONTO	43.78	79.47	T. MCELROY	92 O3/SO2/UVB/MKIII
86	GREECE	THESSALONIKI	40.52	-22.97	A. BAIS	92 O3/SO2/UVB/MKIII
87	USA	RES.TRI-PARK	35.9	78.86	B. BARNARD	92 O3/SO2/UVB/NO2/MKIV
88	IRELAND	VALENTIA OBS.	51.93	10.25	G. MURPHY	92 O3/SO2/UVB/NO2/MKIV
89	INDIA.	NEW DELHI	28.58	-77.2	S. SRIVASTAV	93 O3/SO2/UVB/NO2/MKIV
90	MALAYSIA	PETAL'G JAYA	3.1	-101.65	L. CHOW PENG	92 O3/SO2/UVB/MKII
91	JAPAN	SYOWA	-69.0	-39.58	T. ITO	93 O3/SO2/UVB/MKII
92	INDONESIA	WATUKOSEK	-7.57	-112.65	T. OGAWA	93 O3/SO2/NO2/MKIV
93	AUSTRIA	SONNBLICK	47.05	-12.95	I. DIRMHIRM	93 O3/SO2/UVB/NO2/MKIV
94	INDIA	KODAIKANEL	10.67	-77.47	S. SRIVASTAV	93 O3/SO2/UVB/NO2/MKIV

BREWER SPECTROPHOTOMETER LOCATIONS (JUNE/94) SCI-TEC INSTRUMENTS

S/N	COUNTRY	LOCATION	LAT.	LONG.	CONTACT	REMARKS
95	KOREA	POHANG	36.03	-129.38	B-SUN KIM	93 O3/SO2/UVB/MKII
96	JAPAN	MARCUS ISL.	24.3	-153.96	T. ITO	93 O3/SO2/MKII
97	SLOVAKIA	POPRAD-GAN.	49.03	-20.32	M. CHMELIK	93 O3/SO2/UVB/NO2/MKIV
98	CZECH RP.	HRADEC KRAL.	50.18	-14.83	C. VANICEK	93 O3/SO2/UVB/NO2/MKIV
99	ITALY	ROME	41.9	-12.52	C. VALENTI	93 O3/SO2/UVB/NO2/MKIV
100	NETHERLANDS	DE BILT	52.00	-5.18	F. KUIK	93 O3/SO2/UVB/MKIII
101	USA	ATHENS, GA.	33.95	83.38	J. RIVES	94 O3/SO2/UVB/NO2/MKIV
102	PORTUGAL	LISBON			D. HENRIQUES	94 O3/SO2/UVB MKII
103	USA	BOSTON	43.33	71.10	G. ALLEN	94 O3/SO2/UVB/NO2/MKIV
104	NORWAY	TROMSO	69.65	-18.95	T. SVENOE	94 O3/SO2/UVB/MKIII
105	USA	GAITHERSBURG			A. THOMPSON	94 O3/SO2/UVB/NO2/MKIV
106	USA	RES.TRI-PARK			B. BARNARD	94 O3/SO2/UVB/NO2/MKIV
107	FINLAND	SASKATOON			P. TAALAS	94 O3/SO2/UVB/MKIII
108	USA	RES.TRI-PARK			B. BARNARD	94 O3/SO2/UVB/NO2/MKIV
109	USA	SASKATOON			B. BARNARD	94 O3/SO2/UVB/NO2/MKIV
110	BRAZIL	SASKATOON			V. KIRCHHOFF	94 O3/SO2/UVB/NO2/MKIV
111	CANADA	SASKATOON			J. KERR	94 O3/SO2/UVB/MKIII
112	USA	SASKATOON			B. BARNARD	94 O3/SO2/UVB/NO2/MKIV
113	JAPAN	SASKATOON			T. ITO	94 O3/SO2/UVB/MKII