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GLOBAL ATMOSPHERE WATCH

WMO Global Ozone Research and Monitoring Project

Report No. 36

WMO/NOAA MEETINGS ON OZONE DATA RE-EVALUATION AND USE OF DOBSONS AND BREWERS IN THE GO$_3$OS

Puerto de la Cruz, Tenerife, June 1994

1996

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

Puerto de la Cruz, Tenerife, Canary Islands, Spain
June 23 - 26, 1994

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

Edited by: C.T. McElroy

Organized by: J.B. Kerr, C.T. McElroy, E. Cuevas, and C.R. Jimenez

Chairperson C.T. McElroy

FOREWORD

There are now about 120 Brewer Ozone Spectrophotometers of different types in the Global O_3 Observing System. At this point in time, since the introduction of regulations to control the use of Ozone Depleting Substances (ODS), the Brewer network is ideally placed to make the observations necessary to confirm the efficacy of those controls. The Brewer network has the capability to provide the very-high-quality data needed to help verify the changes in the ozone layer expected in the next decade as a result of changes in the usage pattern of ODS.
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
1996

Table of Contents

1. Opening of the Meeting and Election of a Chairman and Rapporteurs

1.1 Brewer User's Working Group

The Brewer User's Working Group is supported by the World Meteorological Organization, the International Ozone Commission, and Environment Canada. The goal of the Working Group is to improve the overall level of performance of the Brewer Ozone Spectrophotometer global measuring system through the informal exchange of information, ideas and scientific results. The first meeting of the Working Group series took place in 1990 in Arosa, Switzerland in conjunction with an international intercomparison of Dobson and Brewer Spectrophotometers. It is intended that the working group meet every four years in conjunction with the Quadrennial Ozone Symposium and also in the interval between at the same time as another significant event in the ozone community such as an ozone instrument intercomparison. The emphasis of the Working Group is particularly focussed on the exchange of the scientific and technical knowledge required to properly operate a Brewer ozone station for the collection of high-quality ozone data and to discuss and promote the enhancement of the Brewer observing system.

1.2 Official Opening by the Permanent Representative of Spain and Local Authorities

1.3 Opening remarks by Rumen Bojkov, WMO

1.4 Opening remarks by the Chairman, C.T. McElroy

The Working group is indebted to the Permanent Representative to the WMO for Spain and the local organizers for the warm welcome received in Tenerife. In particular, E. Cuevas and C.R Jimenez worked very hard to prepare for the Working Group sessions and have made all of the attendees welcome.

The Brewer working group meetings are intended to exchange information to ensure that all of the Brewers in the global network will provide data of the highest quality. The Brewer network began in 1979 with the introduction of the prototype instrument #004 in Toronto. The number of instruments in service has increased by about 1/3 since 1990. Since the introduction of the Brewer it has already become an important contributor to the global ozone data set and is becoming a significant source of UV-B data.

While presenting scientific results from the Brewer network is not the primary goal of the Working Group meetings, it supplies a mechanism for starting the discussion process and provides an extra incentive to new users of the Brewer by demonstrating the capabilities of the instrument. Since the acquisition of scientific data about the atmosphere is the final goal of operating the Brewer in the global network, it is important that the quality of the final output data produced be the subject of stringent quality controls.

2. Review of the Recommendations by the Virginia Consultation

The recommendations from the previous Working Group meeting were reviewed and a number of open issues were passed forward for inclusion in the discussion of recommendations at the end of the current sessions.

3. Total Ozone Measurements

[J.Kerr, rapporteur]

3.1 Re-evaluation of Brewer #005 Ozone Data from 1982 to the Present

A. Bais of the University of Thessoloniki in Greece presented results of a re-analysis of the total ozone record for Thessoloniki measured with Brewer instrument #005. The ozone record, which started in March 1982, is one of the longest records made using the Brewer instrument. For the first three years the instrument was operated manually and in 1985 the instrument was automated. In general, the instrument was found to be more stable after automation after which time the instrument was left outside all the time. The data record was divided into several intervals separated at times when changes in the instrument were known to have taken place. Standard lamp measurements were used to carry the calibration of the instrument from one period to another. Variations in the lamp record suggested that there would be changes of up to -5% in total ozone.

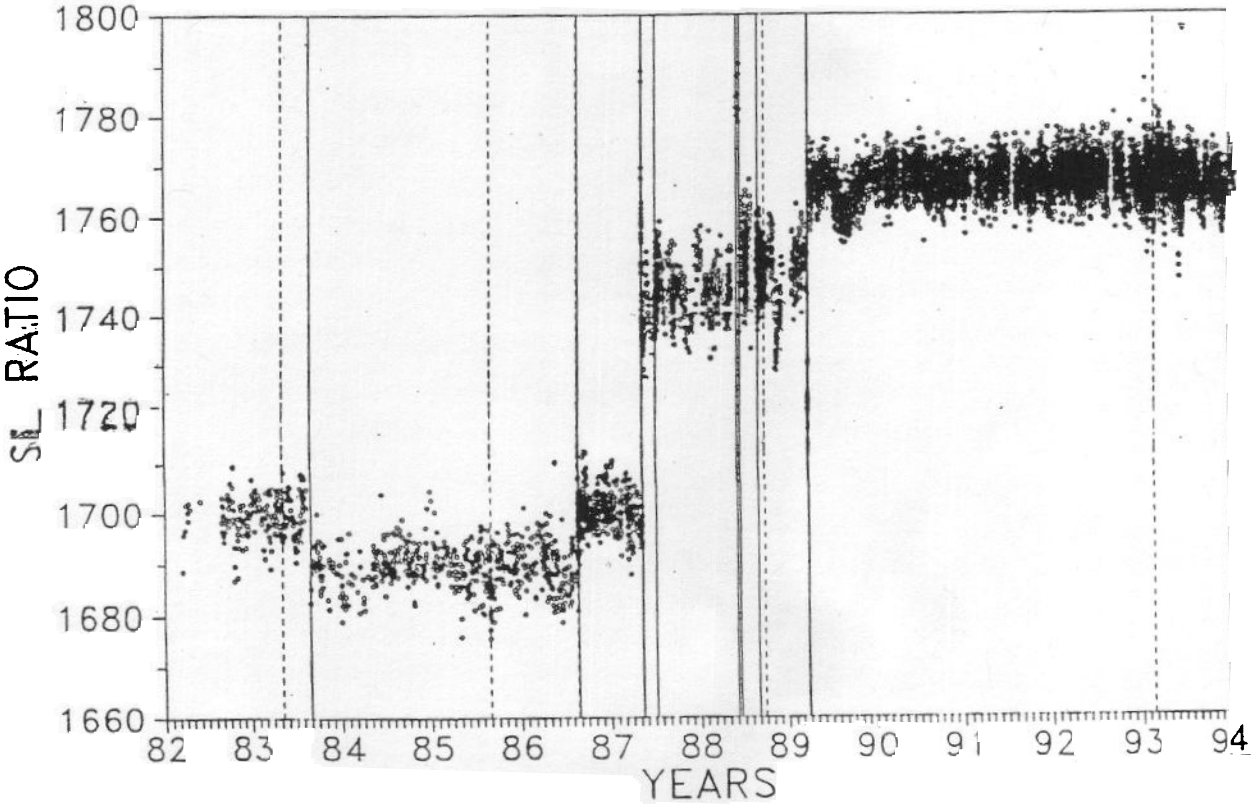

Figure 3.1.1 Ozone Standard Lamp ratios for instrument #005.

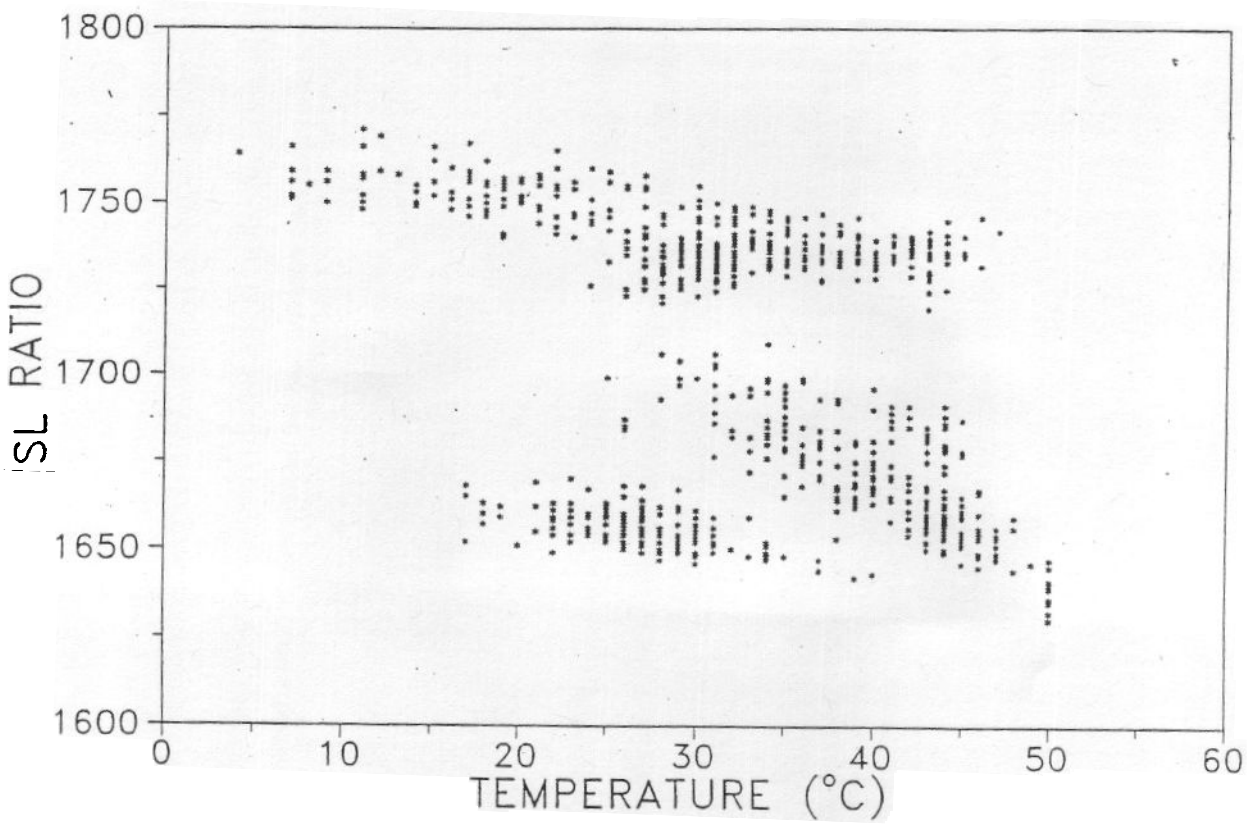

Figure 3.1.2 Standard lamp ratios as a function of temperature. Note more than one relationship.

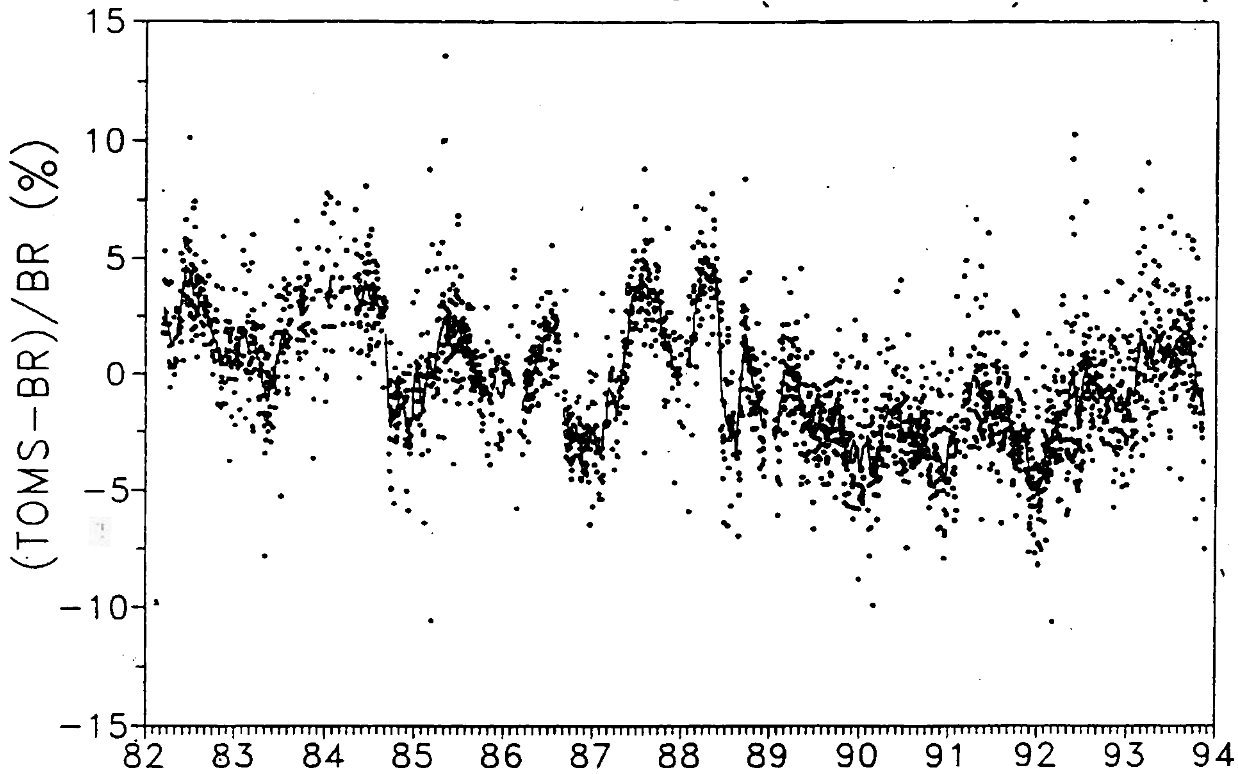

Figure 3.1.3 Uncorrected time series of #005 ozone data compared to TOMS.

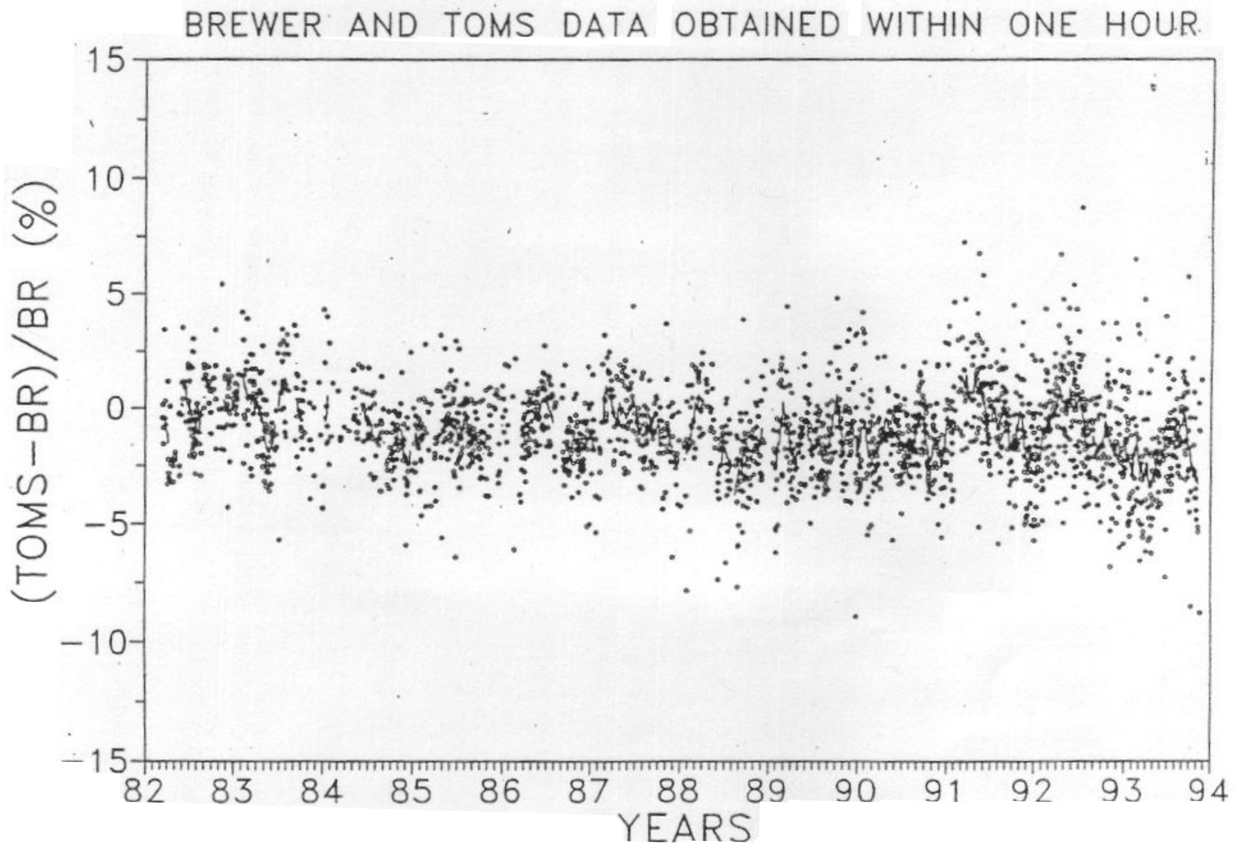

Figure 3.1.4 Comparison of corrected ozone data from #005 and TOMS results.

The temperature response of the instrument was also determined from the lamp record and was found to change as a function of time. The reanalysis of the data included the effects of changes in the instrument's extraterrestrial values and the instrument's temperature dependence as determined from the standard lamp record. The revised data set shows improved agreement with the TOMS satellite record for Thessaloniki.

In the discussion following the presentation, it was noted that this is a good example of how data records should be reanalyzed. The question of changes in temperature response of the instrument with time should be considered for a thorough re-evaluation.

3.2 The Measurement program at Valentia Observatory

G. Murphy of the Irish Meteorological Service presented an overview of the ozone observation program that began recently at the Valentia observatory (51.95°N, 10.25°W) on the south-west coast of Ireland. Since February 1993 ground-based ozone, SO_2, NO_2, Umkehr and UV-B irradiance measurements with Brewer instrument #088 and ozonesonde profile measurements have been made on an operational basis.

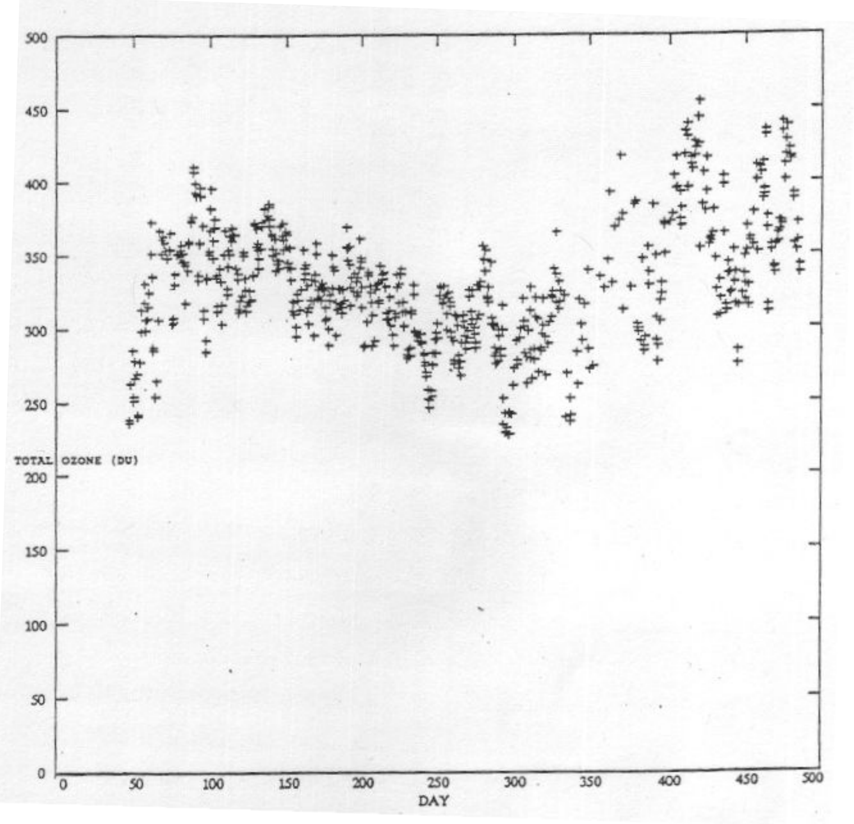

Figure 3.2.1 Total Ozone measured at Valentia 1993.

The Brewer instrument has been operating on a winter schedule from November to March and a summer schedule from April to October. Results of the operation to date indicate that 40% of direct sun measurements are of good quality and no good direct sun measurements were made obtained 25% of the days. Including zenith sky data in the record is important since the humid Maritime conditions at the station result in many totally overcast days. The measurement record date shows significantly more ozone in 1994 than in 1993.

Future plans for operations at the observatory include sending all ozone data to the WODC and using the measurements in a UV forecast program.

3.3 The Temporal Behaviour of Ozone over Italy in the Period 1992-1994

Ozone measurements have been made routinely with Brewer instrument #067 at the University of Rome (41.9° N, 12.5° E) since May 1991 and with instrument #066 at Ispra (45.8° N, 8.6° E) since September 1991. UV-B measurements at Rome were started in January 1992.

Instrument performance has been carefully monitored over the period of operation. Generally the instruments have operated within acceptable tolerance limits except for the instrument in Rome during summer. It is suspected that high humidity has caused variable R5 and R6 standard lamp values which are, therefore, used to correct the ETC values used for deriving total ozone.

Coefficients for zenith "sky chart" observations were derived at both sites and significant improvement was found when the 9 coefficients were changed from the Toronto values.

The ozone records from Rome and Ispra indicate that there were low ozone s during the winters of 1991/92 (10% below normal) and 1992/93 (12% below normal). Ozone values for winter 1993/94 were near normal. Higher UV-B values were seen during winter 1992/93 and lower values seen during 1993/94.

3.4 Diurnal Ozone Variations at Toronto and Edmonton

J.B. Kerr of the Atmospheric Environment Service in Canada presented results of total ozone measurements since 1984 made at Toronto with Brewer instrument #015 and at Edmonton with instrument #013. The measurements at both sites indicate a similar diurnal variation in total ozone. Ozone increases slowly during the morning and peaks in late afternoon. The peak in the afternoon is typically between 1% and 2% higher than the early morning value.

Figure 1a. Total ozone time series at Rome for the year 1992.

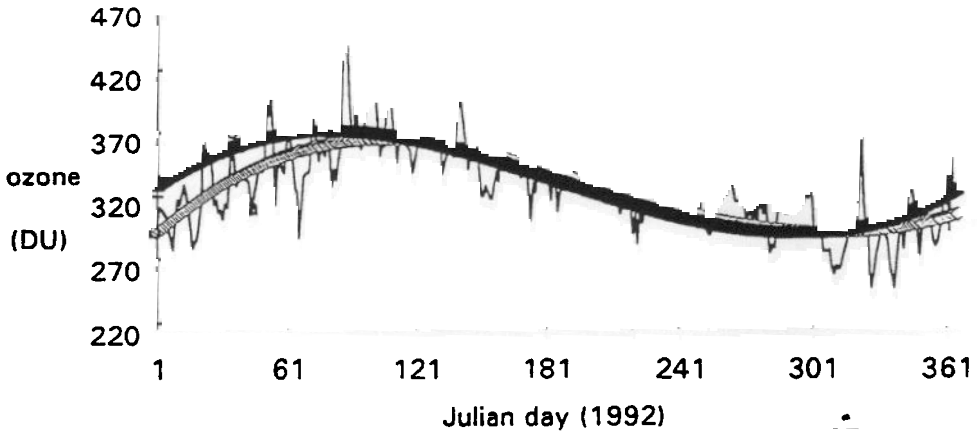

Fig.1b. - Total ozone time series at Rome for the year 1993.

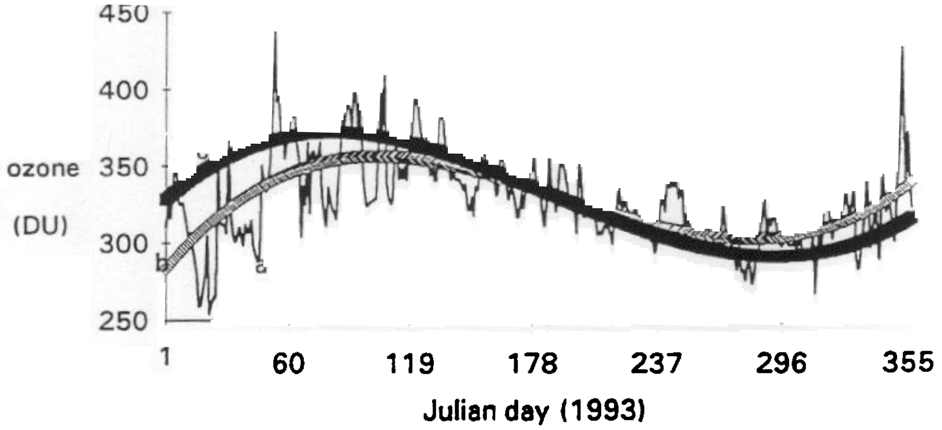

Fig. 1c. - Total ozone time series at Rome for the year 1994.

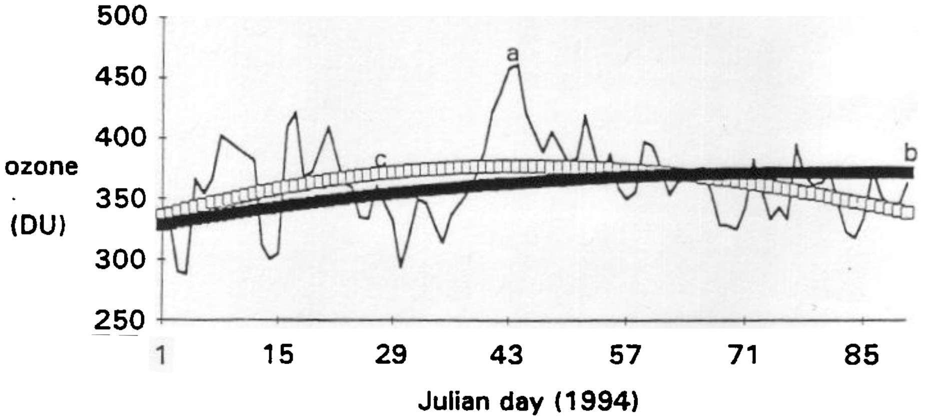

Figure 3.3.1 Total ozone measurments made in Rome in 1992-1994.

The cause of the diurnal variation is most likely variations in ground level ozone. Results of surface ozone concentration measurements at a site 4 km from the Toronto Brewer instrument show a similar diurnal behaviour with average ozone concentrations increasing to a peak in the afternoon that is about 30 ppbv more than the early morning value. Edmonton ozonesonde data also suggest that the diurnal variation is caused by low level ozone. When 00:00 GMT (18:00 local standard time) flights are compared with 12:00 GMT (6:00 AM local time) there is an average of about 3 DU less ozone in the troposphere in the morning than there is in the evening during the summer months (May to August). All of this difference is seen in the lowest 3 or 4 km.

4. Data Comparisons [E.Hare, rapporteur]

4.1 Brewer/Dobson/TOMS ozone measurements: Daily and annual variations of the differences

U. Köhler of the German Weather Service presented a comparison of the Brewer instrument #10 and the Dobson #104 at the Hohenpeissenberg, Germany. The difference was only 0.7%, indicating no trend between them. Only simultaneous observations (i.e.within 10 minutes) were compared. The Brewer measures more ozone than the Dobson during the winter, this work is a relative difference comparison. For large m values (i.e. low sun angles), the Brewer yielded higher ozone values than the Dobson and for low m values (i.e. high sun angle) the opposite relationship exists.

A comparison between TOMS and both the Brewer and Dobson indicated a downward linear trend over the last ten years. The diurnal variations of ozone from the Brewer and Dobson at noon show the Dobson to measure higher ozone amounts (AM to early PM), but then yields lower ozone amounts at the fringe points where m is less than or equal to 2.7. There is a phase shift with TOMS data: it measures more ozone in the summer and less in winter.

The seasonal variation in total ozone amount between the years1984-1994 from both the Brewer and Dobson indicated low ozone values during winter with a distinct shift indicated from the last 10 years when compared with measurements from the 1960's and 1970's. Annual trends indicated that for the period April - November these trends were quite small and largest in March.

The number of observations per day from the Dobson has decreased from 20, in the early 1970's to below 15 since 1985, while the Brewer maintains greater than 20 observations per day. It was suggested that missing Dobson data be replaced with Brewer data by using "interpolated difference values" from days before/after the missing days of Dobson data. It was stressed, however, that the Brewer is not to replace the Dobson but is considered a valuable data supplement.

4.2 A comparison of observations made by the Brewer, TOMS and SAOZ

E. Kyrö of the Finnish Meteorological Institute (FMI) presented the results of the total ozone monitoring program using Brewer #037 which has been in operation since April of 1988, and UVB measurements since June 1990. Beginning in February 1990, FMI added observations using the SAOZ instrument which measures in the visible band, centered at 510 nm. In general, only zenith sky observations have been made, but on occasion focused sun and moon observations are made. TOMS data are also available for comparison.

Time series analysis of TOMS, Brewer and SOAZ at 67° N were compared between the years1988-1994. The observing program was from the beginning of March until the end of October provided that the solar zenith angle was less than 80°. Moon observations were used at other times.

A comparison was made of the ratios of the Brewer ozone amounts divided by the TOMS values. During October up to 10% difference was observed with the largest differences occurring at the fringe of the above mentioned temporal range. During summer only about 2% difference was observed. Regression analysis indicated a slope of approximately unity with an intercept of about zero. The R^2 value was about 87%.

A similar comparison of the Brewer to SAOZ was conducted for March 1992 (after Pinatubo), but the SAOZ was greatly affected and, therefore, the 1992 data were omitted and only 1990, 1991, and 1993 data were used. Regression analysis yielded the following representative equation: $y = 0.009 + 1.275x$ with $R^2 \sim 24\%$. It was suggested that the reason for strong seasonal dependence is based on the temperature dependence of UVB, SZA and m dependence. The SOAZ and

Brewer instruments supplement each other, but neither instrument is viewed as a standalone

4.3 A comparison of Dobson No. 61 and Brewer #025 ozone measurements made at Boulder between October 1991 and January 1994

G. Koenig, representing NOAA, presented a comparison of ozone data from Brewer #025 and Dobson #61 over the period of October 1991 and January 1994. Data were used from days where the following three criteria were met: the standard deviation was less or equal to 2.5, the m value less or equal to 3.2 and both the Dobson and Brewer instruments have values.

The seasonal time series regression analysis for these three periods indicated the relative difference between the instruments as follows: up to 1993 the difference was ~1%, for 1993 ~3% and 1993-94, ~1%. The data from the Dobson observations represented the best measurement of the day while the Brewer data represented daily averages of many observations. This potential difference in the time of observation which can be as large as 8 hours, did not affect the data enough to explain this 3% difference in 1993. The Dobson did consistently read lower than the Brewer, by as much as 5 Dobson units (DU), or about 1.5%, as a diurnal difference.

Brewer #025 and Dobson #61 were compared with the world standard Dobson #83; the Brewer showed good and Dobson #61 poor correlation. Brewer #025 was then compared with both Dobson #83 and the secondary standard, Dobson #65. Various aspects were examined which included: lamp conditions, difference versus ozone amount, daily values at selected times, sulphur dioxide amount, lamp intensity and the high voltage power supply for the PMT.

4.4 Intercomparison of Dobson and Brewer ozone measurements made at low sun angles

S. Nichol from the National Institute of Water and Atmospheric Research , New Zealand presented data observed in the Antarctica. The summertime observation schedule from September 15 to March 21 is primarily direct sun measurements. The Brewer schedule can change throughout this period, but the Dobson schedule remains fixed at 4 observations near Local Apparent Noon (LAN). The winter season is restricted to moon observations.

The Scott Base is a high-latitude station and, therefore, produces predominantly low sun measurements. When the ozone destruction begins in late winter and early spring, moon and large-SZA observations are used, which unfortunately are less reliable and the least accurate. Results indicate that, in summer, the values are about 300 DU versus about 150 D.U. in the spring, in late October.

Daily average data from the Brewer versus LAN values from the Dobson agree to within 5%. For the years 1991-1993, direct sun values observed within ten minutes of each other were represented as a ratio: (Dobson-Brewer) / Dobson. The results showed agreement to within 5% for small m values (<2.5), 10% for m values of 3-5 and >15% for m values of 5-6. Instrumental stray light problem associated with the very low angle causes these large errors..

Observations from 2 days in October 1992 at LAN (~ 1300 hrs local time) resulted in values that were too low because of the stray light problem. Full-moon periods offer reasonably good observations. .Daily moonlight observations under these conditions provided agreement of 5-9% for the (Dobson-Brewer) / Dobson ratio of simultaneous moon observations. Results indicated a steady decrease in ozone amount from 320 to 180 D.U. and agree to within 3% for airmass values up to 3.0.

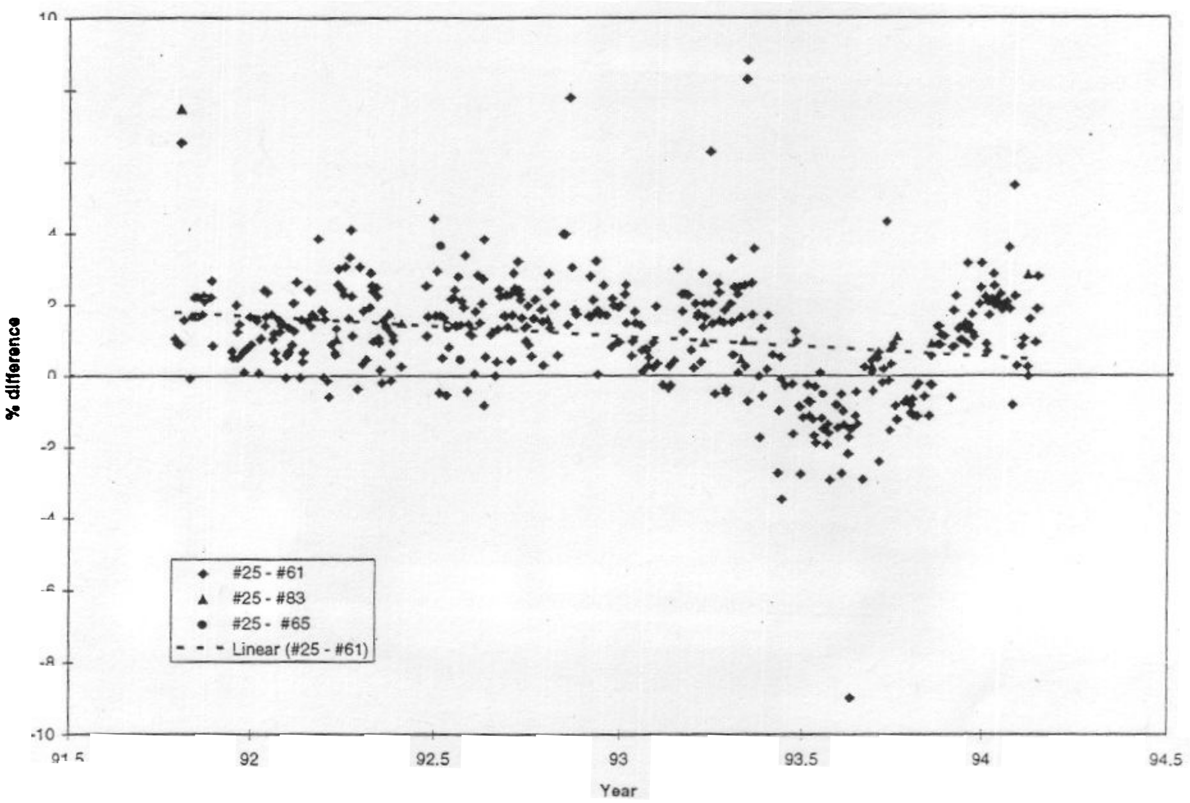

Figure 4.3.1 Comparison of ozone measurements by Brewer #025 and Dobsons 61, 65, and 83.

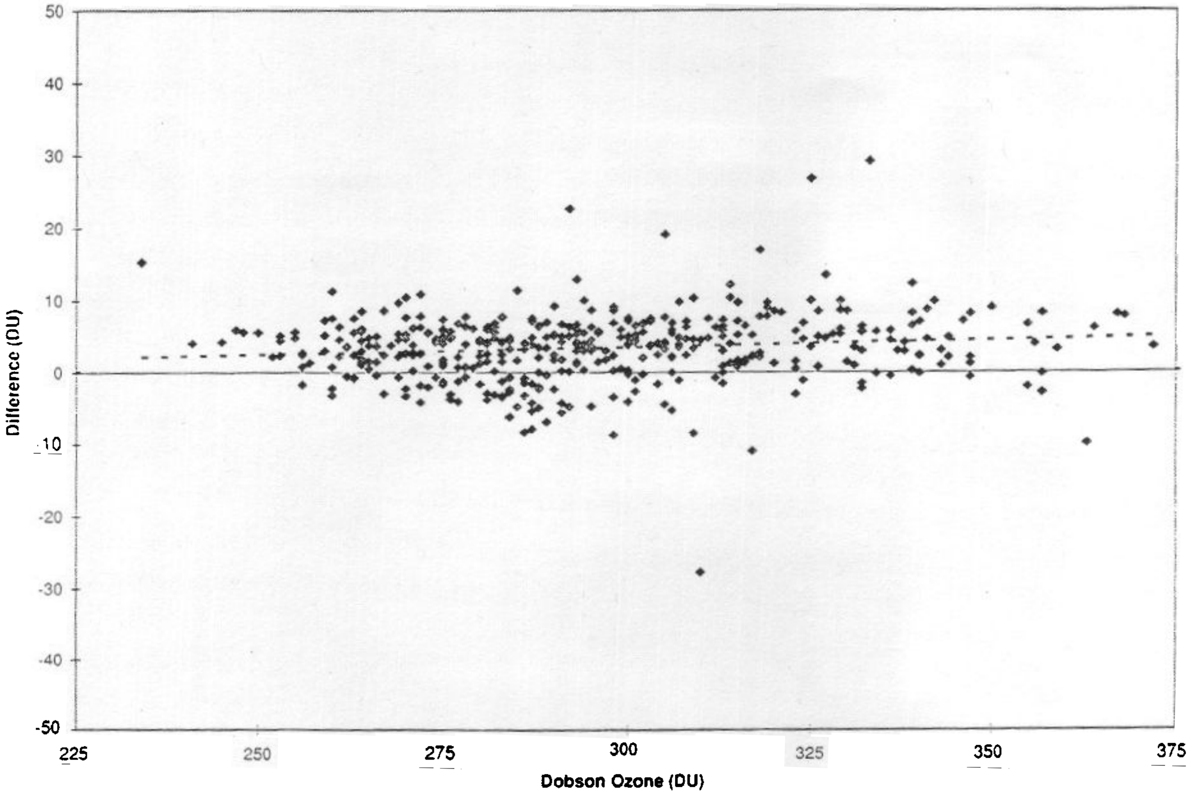

Figure 4.3.2 Difference plot comparing the Dobson and Brewer total ozone data.

4.5 Comparison of Brewer ozone data with over-passing satellite measurements

V. Fioletov of Environment Canada presented a comparison of TOMS data with data from several Brewer sites. The analysis indicated that TOMS had instrumental problems for latitudes > 78°. The fact that the TOMS instrument was available on two satellites (Nimbus-7 and Meteor-3) with different orbits was discussed. In addition to TOMS data, ground-based total ozone data available from the World Ozone Data Centre (WODC) were used in the analysis. Brewer data from Rome University, and Dobson data from Vigna di Valle were used as a comparative example of the difference between two ground reference stations.

The differences between the TOMS and Brewer and Dobson instruments were discussed. Taipei showed large differences between direct sun and zenith sky measurements and there was about 3-4% difference in the Brewer data from Thessaloniki and Hohenpeissenberg compared with TOMS. Using only the best data (i.e. direct sun), the comparison of the Brewer-TOMS data indicated a relative difference of 2% in winter and about 0.5% in summer, while the Dobson-TOMS was consistently around 0.5%. This difference is likely to be due to the different temperature coefficients for the ozone absorption cross-sections for the different instruments.

The final presentation concerned ground-based instruments in general, compared to TOMS data during the period 1979-90. The results are given in the following table. The percentage figure in parentheses indicates the fraction of total data available from the station which was available for the comparison as a result of using only direct sun ozone values in the analysis.

Table 4.5.1 Comparison of Brewer, Dobson and Filter Instrument data with TOMS.

Measurement type	Dobson (>20 stations)	Brewer (10 stations)	Filter instrument (9 Stations)
(%) Direct Sun	(60%) 2.3%	(80%) 3%	(60%) 4.1%

4.6 A comparison of Brewer data with TOMS and Dobson ozone measurements

J.B. Kerr of Environment Canada presented an analysis of TOMS data compared with Brewer data from Toronto and Edmonton for the period 1984-1993 including an examination of Dobson versus Brewer data for stations at Toronto, Edmonton, Goose Bay and Churchill.

The first comparison was for Toronto data for the years 1984-1993. Toronto Brewer #015 / TOMS data plotted against TOMS SZA yielded about a 2% difference. For solar zenith angles from 20°-50° the TOMS data show a larger difference, however for SZA's > 55°, the difference with TOMS is smaller. For comparisons made with data collected within a 1/2 hour of the TOMS overpass, the standard deviation is about 1.3%. Similar results were shown from Edmonton. In summer, Toronto (TOMS SZA < 40°) and Edmonton (TOMS SZA < 50°), shared a TOMS reflectivity dependence, while in winter where the TOMS SZA's are > 60° and > 70°, respectively, much of the reflectivity is due to snow cover. In general there is good agreement despite some systematic reflectivity dependence. It was stressed that TOMS detects these reflectivity effects which the Brewer does not.

Analysis of the ratio of TOMS / Brewer#015 data versus time (at LAN) showed very good correlation with standard deviation. TOMS was greater than the Brewer in the morning to just past LAN then falls off in late afternoon and evening.

A similar standard deviation dependence was seen in the Edmonton data along with the 1% systematic difference between TOMS and the Toronto and Edmonton Brewers. The difference between TOMS and the Brewer as time moves away from LAN (up to 24 hours in the summer) is between 2 and 6%.

Daily mean ozone values reported in the Redbook do not necessarily attempt to synchronize with a TOMS overpass, but are affected by diurnal variations which increase the standard deviation to about 3%. If data more than 2 hours away from LAN are removed, then the standard deviation becomes 2.3% for Toronto and 2.5% for Edmonton. This eliminates about 30% of the data, but greatly improves the results. If ground reflectivity is less than 0.5 (non-water) the standard deviation is slightly less again. Combining all these effects, the Toronto standard deviation becomes about 1.8%.

Dobson and Brewer data through the years 1984-1994 for Toronto, indicated a correlation of 0.994 for daily averages from Dobson / Brewer with a standard deviation of 0.019 with both instruments on the Bass-Paur scale. Edmonton data for the years 1984-88 had a 1% difference, with a standard deviation of 0.016. This comparison of TOMS / "simulated Dobson" data from Edmonton takes into account the diurnal and seasonal variation. Other stations like Goose Bay and Churchill show similar results.

4.7 Measurements of ozone in 1993 in Malaysia

A discussion of the performance of the first Malasian Brewer was presented by C.P. Leong of Malaysia.

5. High Latitude Measurements

[A.Bais, rapporteur]

5.1 Measurements of Ozone and NO_2 made by Brewer Instruments and by SAOZ in Eastern Siberia

V. Dorokhov reported on the investigation, using Brewer and SAOZ instruments, into the Eastern Siberia region of the Northern Hemisphere, which showed increased total ozone values, unlike the other two regions where low ozone values were seen. A Brewer MK-II spectrophotometer is installed in Yakutsk (62° N, 13° E) for total ozone observations and high-quality direct sun measurements for the validation of satellite ozone data. A SAOZ UV-VIS spectrophotometer is operated in Zhigansk (67° N, 123° E) for monitoring O_3 and NO_2. The advantage of using the visible spectral region is that it makes it possible to make year-round ozone and nitrogen dioxide observations at the latitude of the Arctic circle.

The total ozone and NO_2 data collected during 1992 to 94 revealed some characteristics of ozone layer behaviour in Eastern Siberia:

a) A total ozone decrease of up to 15% below normal was detected in Yakutsk by the Brewer instrument in July and August of 1992 and 1993;

b) For the first time the stratospheric NO_2 column was measured in Siberia by the SAOZ UV-VIS spectrophotometer and the annual cycle of NO_2 variations was observed;

c) It was found that, on average, in winter the NO_2 column near the Arctic circle in Zhigansk is larger by a factor of 3 than in Scandinavia at the same latitude (67° N);

d) A total NO_2 reduction by 30% due to the Pinatubo aerosol in spring and summer 1992 compared to 1993 was observed,

e) Comparisons of TOMS, Brewer #045 and SAOZ total ozone data in 1993 indicated that there was good agreement between all instruments when measurements are made during the cold part of the year. At warmer temperatures in the low stratosphere, TOMS and Brewer data were closer than SAOZ. A correlation between the 50mb temperature and the ratio TOMS / SAOZ displayed a temperature dependence of 4.2 x 10^{-3} per °C.

It is planned that SAOZ and Brewer observations be continued in Siberia in 1994-1995 for ozone layer monitoring and the validation of satellite data from TOMS / METEOR-3, ERS-2 and ADEOS (1996) and to start ECC ozone sonding in Yakutsk in late 1994 during the SESAME campaign.

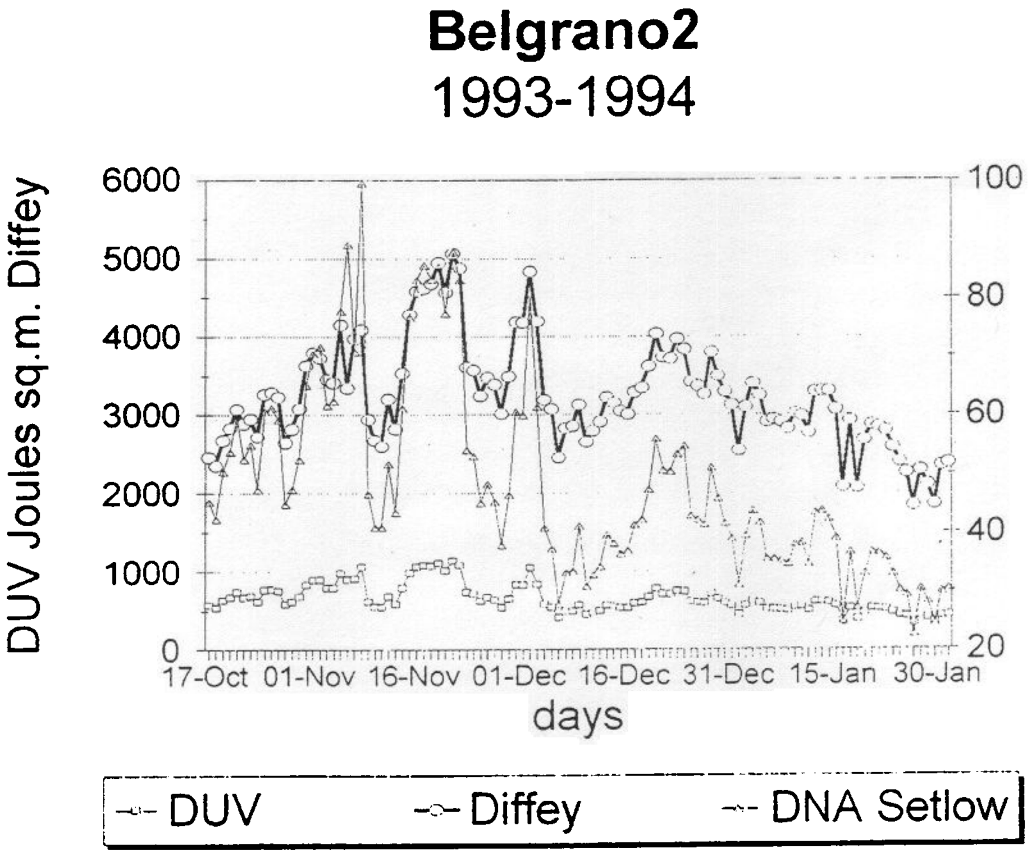

Figure 5.2.1 Ozone measurments made in the Antarctic at Belgrano2 station in 1993-94.

5.2 Brewer data taken during the Antarctic ozone hole in 1993

L. Ciatagglia summarized the results of data taken from the two MK-IV Brewers, #035 and #050, at the Belgrano2 station and Scott base. Belgrano2 station (77.8° S ,34.6° W) is situated in the southernmost part of the Weddel Sea. Scott base (77.8° S, 165.6° E) is in the Ross sea area, making the two sites almost on opposite sides with respect to the South Pole. The ground-based measurements of ozone and other minor stratospheric constituents were carried out with a good level of efficiency, mainly during the period September to March each year when the Sun elevation angles were convenient for these types of observations. Despite weather conditions, which are sometimes very harsh, both instruments provided good records of total ozone, nitrogen dioxide and UV-B and, on some occasions, also Umkehr profiles. A third instrument, #099, was purchased for use during campaigns in remote areas (for instance Ushuaia, Tierra del Fuego) or as a traveling standard.

It was reported that, during October-November 1993, there was an opportunity to get some Umkehr profiles with the Brewer instrument installed at Scott base using the program set up by C.T. McElroy. During this period a fast growth of Ozone appeared and for days 23, 30 and 31 October 1993, the vertical profiles were reconstructed taking advantage of atmospheric conditions very suitable for this kind of observation. Contemporary values of O_3 at Belgrano and especially the TOMS maps confirmed that the Antarctic vortex and the Ozone Hole were shifted towards the Weddel Sea. Total Ozone values were very close to TOMS data thus confirming the validity of monitoring the Ozone hole either from the ground or by satellite .

UV-B measurements were also taken during the whole year, showing a clear relationship with the depletion of the Ozone layer. DUV and action spectrum (Diffey, DNA Setlow, and Erythemal components) quantities, if examined into detail, appeared higher during October and November than during December and

January when on the other hand the Sun is at a higher elevation angle.

5.3 Brewer Ozone Spectrophotometer observations made at high Arctic latitudes (Heiss Island) 1989-94

V. Dorokhov presented the results of ground-based observations of total ozone, using a Brewer spectrophotometer, at high latitudes in the Arctic European sector at Heiss Island (81° N, 58° E) in 1989-1994. These results complimented the overall pattern of the atmospheric ozone field of the Northern Hemisphere both before and following the Pinatubo eruption.

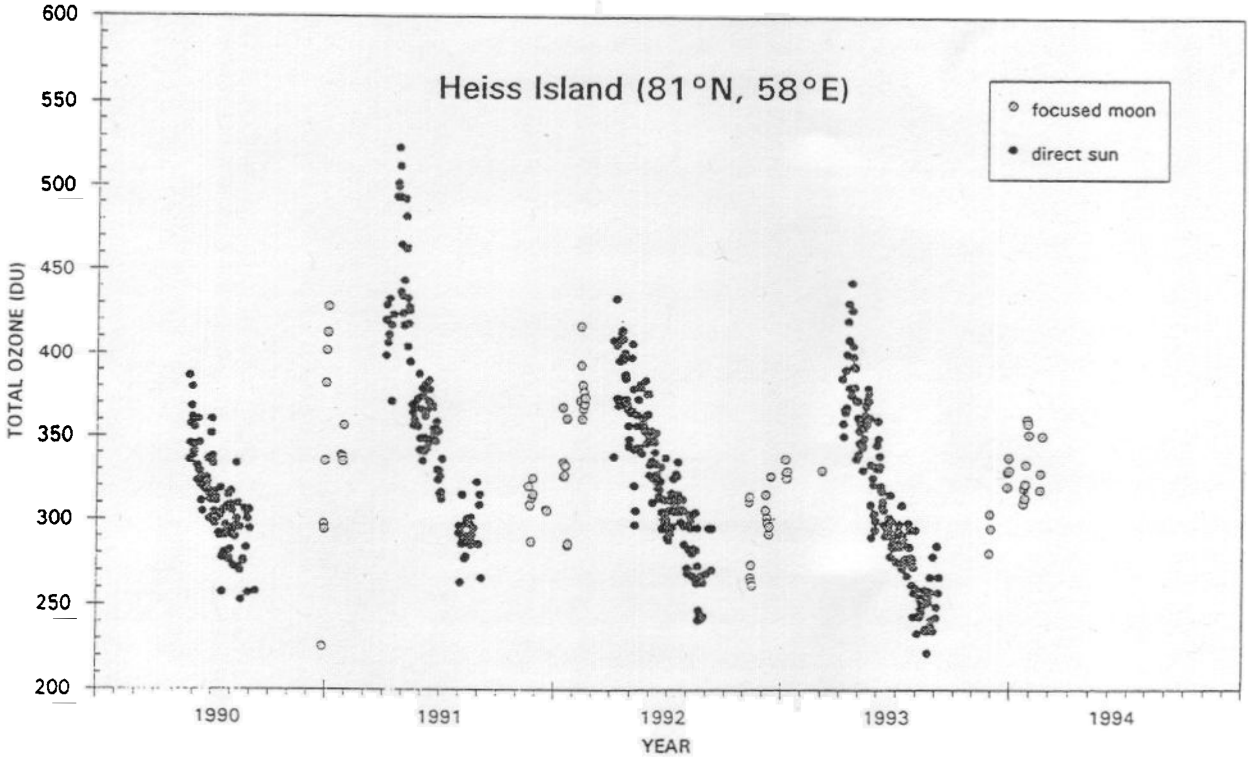

Figure 5.3.1 Daily ozone over Heiss Island in 1990-1994.

The results of the investigation showed:

a) In the winter seasons of 1989-1994, under low of solar illumination in the lower stratosphere, no long periods were marked by significant depletion of ozone content in the atmosphere at 81o N;

b) During the polar day in 1992 and 1993, a record low total ozone values were detected at Heiss Island latitude as compared to the climatic norm; maximum ozone decrease of 16.7% was observed in August 1993. On average the April-September 1993 ozone values were 13.2% below normal;

c) During the summer periods of 1992 and 1993, at high polar latitudes, total ozone decrease agreed with that at the middle latitudes of the Northern Hemisphere.

5.4 Measurements of ozone and UV with Brewer #053 in Greenland

P. Eriksen presented ozone and UV measurements from the MKII Brewer #053 operated by the Danish Meteorological Institute since September 1990 at Sondre Stromfjord, Greenland (67° N, 51° W). Dobson #92 has also been used occasionally at the same site, but on sunny days only, and was used for comparisons with the Brewer, having been calibrated at the WMO Intercomparison in Arosa in 1990. The comparisons between the instruments showed an agreement to within 4 DU, or slightly more than one percent, with measurements restricted to air mass less 3 and with measurements taken within 30 minutes.

The period in which reliable measurements can be achieved is approximately from mid February through late October. The site at Sondre Stromfjord is on a small hilltop 300 metres above sea level and is characterized by very clean air and an almost perfect horizon. At midsummer, measurements can almost be taken around the clock since reliable focused sum measurements can be done down to air mass 7, only limited by the shade cast by the window frame.

Because of the eruption of Mt. Pinatubo in June 1991, DS measurements were used on clear days to infer the aerosol optical depth at 310-320 nm during the period 1990-1994. The aerosol optical depth can be inferred by starting with the Beer-Lambert law for a specific wavelength, viz. one of the standard Brewer wavelengths, and splitting up the total optical depth into a Rayleigh, an aerosol and an ozone optical depth, and using the raw photon counts for that wavelength, corrected for dark count and dead time and converted to a count rate. If DS measurements separated by a MU-value (1/cos for air masses less than about 3) of 1.5-2.0 are used, the aerosol optical depth can be inferred. Before Pinatubo the optical depth was about 0.08, increasing to about 0.25 in September 1991, about 0.2-0.25 in summer 1992, decreasing to about 0.1 in April 1993. The aerosol optical depth in 1992 compared fairly well with aerosol optical depths using other techniques. This method worked because of the very clean air and lack of interference from tropospheric aerosols (city pollution).

From TOMS measurements (version 6) between 1979 and 1988, an overall trend of about 5.5% per decade was seen at Sondre Stromfjord. If monthly averages are considered from March through September, using TOMS data before 1991, a steady decline in the summer months (June, July and August) and the spring months was observed, the latter showing a more dramatic decline approaching 1994. Of all months, September 1993 showed the lowest monthly means, but 1994 values were well above the lows observed in 1993. The low ozone values of 1993 were easily observed in a corresponding increase in the UV, independent of the weather conditions, especially when considering March 1992-1994.

The DMI was constructing a database for ozone, UV and weather data, but had not yet put in all of the data. The database was hoped to able to be used to infer the influence of various cloud types and cloud cover on the UV levels, and for different solar zenith angles to infer the radiative amplification factor for different wavelengths or for different action spectra, thus documenting the Arctic UV climatology.

5.5 Comparison of total ozone measurements from Brewer, Dobson and high resolution direct sun UV spectra at Arosa

P.P. Viatte reported on the high resolution spectral measurements of direct solar UV irradiance together with spectral measurements of global solar UV irradiance performed at the Light Climatic Observatory in Arosa, with a double monochromator. Swiss data was collected on Dobson 101 since 1967. In 1992, Dobson 15 was replaced by Dobson 62 (Canadian), and the D15 data was converted to D62 data. Two independent measurement programs were possible due to the Brewer #040 / #072 compliment.

The total atmospheric ozone amount and optical depth were determined by fitting model calculations to the spectral measurements of direct solar irradiance. These results were compared to the data from Dobson and Brewer spectrometers routinely operated in Arosa. As entirely different calibration procedures are used for the UV-spectrometer and for the Dobson and Brewer instruments, this comparison allows the evaluation of the absolute accuracy of the total ozone determination from spectral measurements of direct solar irradiance and from the commonly-used ground-based total ozone instruments.

On 21 days in February and March 1993, more than 1200 spectra of direct solar irradiance were taken from 290 nm to 350 nm with steps of 0.5 nm.

The comparison of a typical diurnal change of total ozone measured by all three instruments clearly showed that the total ozone amount determined from the spectral measurements agreed with that from the Brewer instrument within 2 DU, whereas the total ozone amount from the Dobson instrument was about 5 DU high in the morning. Whereas the same temporal changes were found for spectrometer and Brewer results, the relatively small number of Dobson measurements prevented a detailed comparison of the diurnal course.

When comparing quasi-simultaneous measurements for the entire period, total ozone amount determined from spectral measurements of direct solar irradiance differed from the results of the Brewer instrument only by -0.4±0.7% and from those of the Dobson instrument by -1.1±0.90%. The difference to the Dobson instrument did not show any significant correlation with the total ozone amount and the solar elevation. On the contrary, the difference to the Brewer instrument showed a small but significant ozone dependence of 0.81 % per 100 DU and of 0.53 per 10^0 solar elevation.

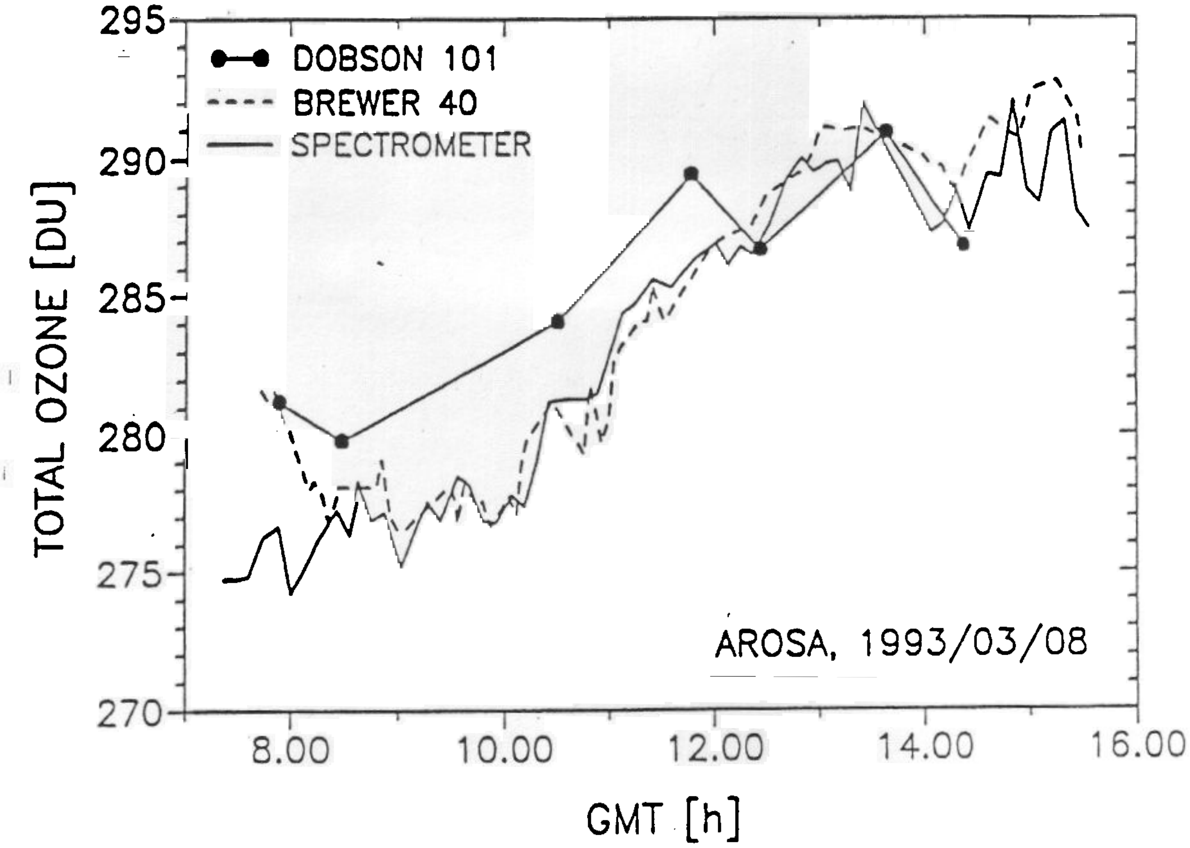

Figure 5.5.1 The diurnal variation of ozone as determined from spectral measurements of the direct, solar irradiance and from Dobson and Brewer measurements at Arosa, Switzerland (1840 m a.s.l.) March 8, 1993.

5.6 On the Brewer Intercomparisons at Izaña, 1993

E. Cuevas and A. Bais reported on the results of the 1993 intercomparison of ozone instruments at Izaña, Spain.

5.7 UV-B and ozone measurements in Central and Southern Greece

C. Varatsos spoke on the results of surface-level measurements of atmospheric ozone in Athens, Greece, from the beginning to the end of the twentieth century. These results were used to estimate the UV-B level and determine changes in the ozone producing potential.

Regular total ozone measurements made using Dobson spectrophotometer No. 118 were started in 1988 and now form part of the data published by the WMO, World Ozone Data Center. This data set has been used to examine the consistency of TOMS data with the corresponding Dobson data on a daily basis. The results show that Athens Station may be used as a ground-truth for satellite-based total ozone measurements and also to provide reasonably accurate total ozone values for southeastern Europe.

The reprocessed daily ozone observations made by the TOMS on Nimbus-7 over Athens (38° N, 24° E), Sofia (42.4° N, 23.3° E), Dundee (56.5° N, 3° W), St. Petersburg (60° N, 30° E), Cairo (30° N, 31° E), Vigna di Valle (42° N, 12° E) were analyzed from November 1978 to January 1994 to investigate the temporal and spatial variations of both total ozone and UV-B radiation over this geographical area.

A number of vertical ozone profiles up to 35 km in height were measured using the method of free balloon launch (ozonesondes), at the Athens Station from 1989 as part of various EC projects (TOASTE, TOR-EUROTRAC, EASOE, OCTA, SESAME) to investigate, among other things, stratosphere-troposphere ozone exchange, the lamination of ozone profiles and the horizontal transport of ozone. Further, the dependence of the Radiative Amplification Factor of the erythermally active UV on the changes of the vertical ozone profile was attempted.

Broad-band and spectral SUVR measurements were obtained at the central and southern Greece since 1986 by using three Eppley radiometers and the YES UV-B1 radiometer. In collaboration with the Photobiology Units of Dundee and Athens Universities, the indoor and outdoor MED were also measured using the polysulphone film method.

6. New Developments [P.Erikson, rapporteur]

6.1 Design elements of the Brewer double monochromator

C.T. McElroy talked about the Double Brewer Spectrophotometer. The instrument was designed with the slit function being determined by the first half, and the stray light being rejected by the second half. Independent motors speed the alignment and assembly. The instrument halves are kinematically connected, with a 5-slit mask and motor for Brewer-type ozone measurement. Most of the regular Brewer software is compatible with the double monochromator The slit function is determined by the mid-line slits.

When it comes to alignment and operation, the two halves are independently aligned with visible light. The system is then assembled and the alignment is fine-tuned. A white light source is used to co-align the gratings of the two halves. The relationship between the two gratings is used to make a wavelength scan for calibration. All commands which adjust the grating use this relationship between the two halves.

The double monochromator can be used for accurate UV monitoring and measuring ozone to very large paths. It can also be used for measuring the performance of the Brewer, and as a reference instrument.

6.2 Performance of the double monochromator

6.3 Brewer spectral irradiance measurements used to infer total ozone

Arne Dahlback talked about spectral irradiance measurements made with the Brewer. The most accurate measurements of total ozone with the Brewer are obtained using direct sun measurements if the sky is clear and the solar zenith angle (SZA) is not too large. In cloudy weather one has to rely on zenith sky measurements. Measurements at Oslo (60° N) indicated that zenith sky measurements are sensitive to cloud cover for large solar zenith angles. A radiative transfer model was used to show that zenith sky measurements are sensitive to cloud cover. A cloud layer with optical depth 50 between 2 and 4 km lead to an overestimation of 10 DU at 70° SZA if zenith sky measurements are used. This overestimation increased to 25 DU at 80° ZSA.

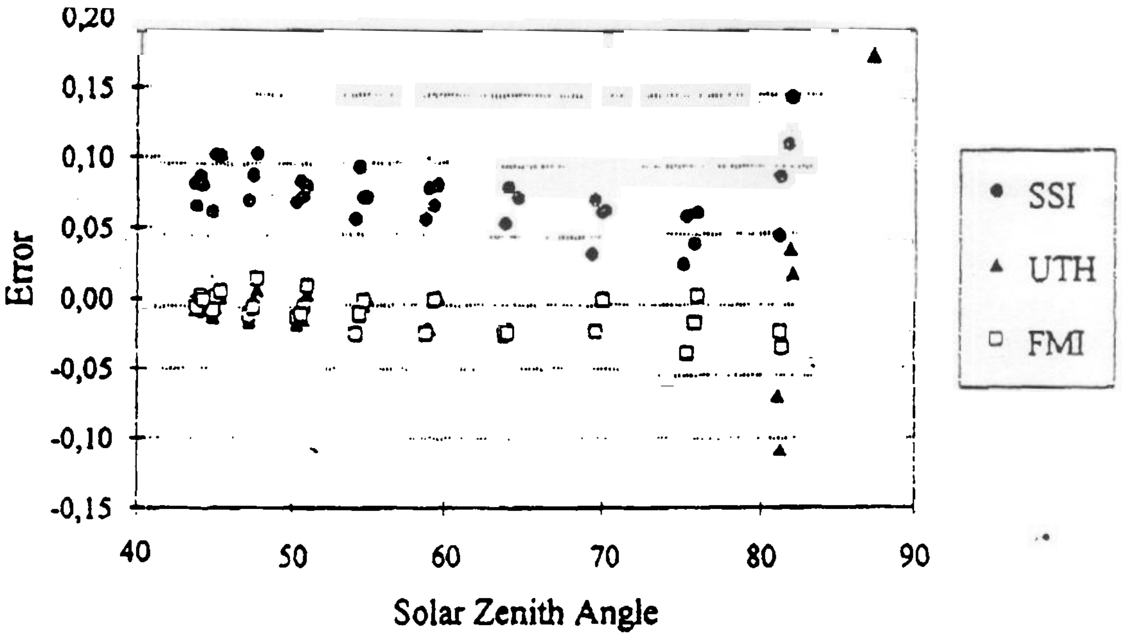

Figure 6.3.1 Ozone calculated from irradiance spectra (320 nm / 306 nm) measured on days 307 and 308 by two Brewers (UTH and FMI) and one Optronics Spectrophotomter (SSI) are compared to the the total ozone determined by Brewer #017 using the standard algorithm.

Stamnes et al., 1991, showed that global irradiances provide a reliable means of inferring total ozone for clear as well as for cloudy skies. Total ozone is determined by comparing measured irradiance ratios at two wavelengths in the ultraviolet part of the spectrum with a synthetic chart of this ratio computed with various ozone amounts and various SZAs. Computer simulations were used to show that the 320 nm / 306 nm irradiance ratio is nearly insensitive to cloud cover. A cloud layer with optical depth 50 between 2 and 4 km lead to an error in ozone determination of less than 2 DU for SZA < 90°.

In addition to cloud cover, zenith sky measurements are also sensitive to the ozone profile for SZA > 60-70° (the Umkehr effect). The irradiance ratio 320 nm / 306 nm is also sensitive to the ozone profile for large SZA, although less sensitive than zenith sky measurements. However, if the 320 nm / 316 nm ratio is used instead, the sensitivity to ozone profile is smaller than using 320 nm / 306 nm. The cloud effect on this ratio is larger than the 320 nm / 306 nm ratio, approximately 20 DU for the same cloud layer as mentioned above for 75^p < SZA < 85°. However, this cloud layer represents a relatively thick cloud layer and the cloud effect should normally be smaller.

The irradiance ratio technique was used on Brewer irradiance measurements carried out at Izaña, Tenerife, during the Nordic Ozone Group Intercomparison October/November 1993. The ozone determined from irradiance ratios were in very good agreement with ozone determined with standard direct sun measurements.

6.4 On possible improvements to the Brewer software

N.F. Elansky reported on the results of investigations into ways to improve the Brewer instrument for measuring NO_2 and the aerosol vertical profile.

The optical model of the twilight atmosphere and a numerical model of NO_2

measurement by scanning and by using the Brewer instrument were created. The influence of the main factors (Shift, Stretch, Ring effect correction, etc.) on the accuracy of NO_2 measurements were also studied. The difference between the two types of instruments were shown. The use of the scanning spectrophotometer makes it possible to compensate numerically for the action of these factors and to obtain NO_2 data with small errors. The use of the Brewer instrument demands that the specific effect of each factor for each instrument be known. The knowledge of all these effects can be used as the basis for working out special programs to minimize the errors. It was clear that up-to-date accuracy of NO_2 measurements can be improved.

A study of the polarimetric method for the aerosol vertical profile retrieval showed that, when realized on the Brewer instrument, it can give satisfactory information about the atmospheric aerosol distribution. The investigation of the features of microphysics of aerosol and other parameters influencing the retrieved profile were made. The program of aerosol observation by Brewer MKIV instrument was worked up as well and an example of such a retrieval made with the use of Brewer #007 was presented.

6.5 The Composition and Photodissociative Flux Measurement experiment on ASHOE/MAESA

T. McElroy reported on a new diode array spectrophotometer developed to make ozone and atmospheric radiation measurements from on board the NASA ER-2 high-altitude research aircraft.

7. Data Management [H. De Backer, rapporteur]

7.1 The Brewer data management system

E. Hare explained the structure of the Brewer Data Management System (BDMS). Different entries are introduced into the database in order to be capable of handling different instruments at the same location as well as data from single instruments which are moving around. The purpose is to store the raw data files (so called b-files), the files with the calibration data and the UVB data. If ozone data are requested, they are recalculated using the most recent calibration data. For security the data are archived on two different media(digital tape and optical disks). All of the data received amounts to about 1GB for one calendar year.

The data also has to be entered into the WODC, which also contains other ozone data (Dobson, Lidar, ozonesondes). The method of data transmission from the station to the data centre is mostly by forms (with a smaller portion by disk, and a still smaller fraction by email). It was proposed to make a yearly CD-ROM to facilitate the distribution to the users. Access is also available through ftp.

In order to avoid communication problems it was suggested that regional data centers be installed around the world, which can be used to consult the database. (There may be however a conflict with the requirements of WMO, who request the data should be transmitted directly to one data centre). The structure of the WO3DC database is comparable to the BDMS, but contains only ozone values(no raw data). The delay due to the changeover is currently becoming smaller.

7.2 Automatic data reporting in the Canadian Brewer ozone network

J. Kerr and C.T. McElroy presented on an automated ozone and UV-B reporting system. Since in Canada UVB index forecast are discriminated, nearly real time access to the Brewer data is requested. Therefor, the 11 Canadian

Brewers are connected with modems to the national data collection network. Every hour the Brewer data are transferred by telephone lines. This allows for UV-Index forecasting based on the relation between weather patterns and total ozone. The prediction of ozone maps has a capability of ±10 DU. The system can be extended transfer all the Brewer data (including calibration, UVB, ...) and even in the other direction it is possible to download new versions of software and schedules to the Brewer (working in the field) from a remote place.

8. Umkehr Measurements

[H. De Backer, rapporteur]

8.1 Umkehr observations with data collected by the York / ISTS / AES Lidar in Toronto

J.Hahn and C.T. McElroy presented results on the comparison of Lidar ozone profile measurements with Umkehr profiles obtained with the Brewer instrument. It appears that both techniques agree quite well, except during periods with high aerosol loading. After aerosol correction of both (Lidar and Umkehr) the correspondence is much better (within 10% which is within the expected error bars). Therefore the aerosol correction can be trusted if the aerosol loading is not too high. It should be kept in mind, however that the Umkehr measurements may be biased by the climatology used in the first guess. The use of measured ground ozone data can improve the quality of Umkehr profiles but it was the speaker's feeling that the aerosol loading is a more important error source.

8.2 A survey of total ozone measurements in China

L. Chao showed some results from the ozone measurements from four Brewer and two Dobson stations in China, which have been in operation since 1979. Comparison with satellite data showed good agreement (5%) although some systematic deviations are discernible.

9. Other Trace Gasses

[H. De Backer, rapporteur]

9.1 Correlations between SO_2 and NO_2 surface level measurements and Brewer SO_2 and NO_2 determinations

F. Cappellani presented the results of his investigation (in conjunction with A. Bielli) into whether averages performed over some tens of days (typically 30 days) could be significant for giving a correct trend for the tropospheric SO_2 and NO_2 pollution using the data measured by standard analytical techniques by a colocal EMEP station as a reference of reliability.

Single values or daily-averaged SO_2 and NO_2 data measured by the Brewer spectrophotometer are by far less accurate than ozone data, especially in the case of SO_2, where the standard deviation of each determination (coming from a set of five measurements) or of the daily mean value can be as high as 100%. The large inaccuracy inhibits the use of daily data for providing a daily mapping of $S0_2$ and NO_2 pollution.

The Brewer zero level for the SO_2 measurements had to first be corrected for. The results of a linearity test for SO_2 with an absorption cell for concentrations up to 1600 ppm confirmed good linearity. The comparison between the corrected columnar SO_2 amounts (m-atm-cm) from the Brewer with the surface level SO_2 concentrations ($\mu g/m^3$) smoothed with a thirty-day filter showed a good degree of correlation with EMEP data. The comparison between the tropospheric morning

NO_2 columns as measured by the Brewer with the ground NO_2 data taken at the same hours at the EMEP station (all the data smoothed with a thirty days filter) showed a qualitative agreement.

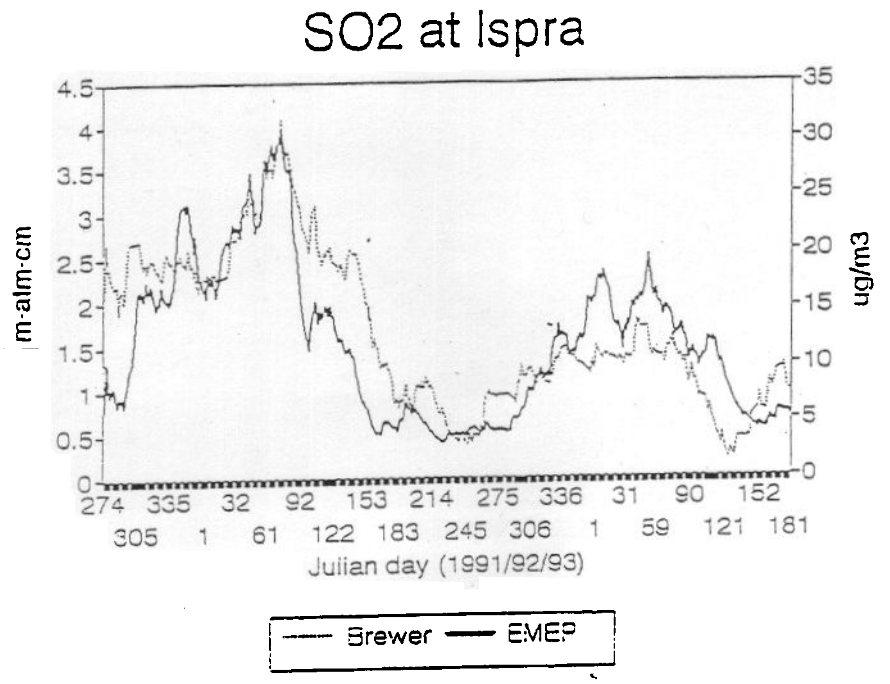

Figure 9.1.1 Measurements of surface SO_2 compared with Brewer column SO_2 measurements made at ISPRA.

Thus the measurements and the comparisons with the EMEP data above reported indicate that the Brewer spectrophotometer can provide reliable tropospheric trends of pollutants like NO_2 and SO_2 on a mean monthly basis.

9.2 Total ozone and NO_2 measurements using a SAOZ spectrometer and validation by comparison to other instruments: Brewer, Dobson, TOMS and other UV-visible spectrometers

F. Goutail and J.P. Pommereau explained the principle of the SAOZ instrument. This instrument works in the visible spectrum (3 nm resolution) and has some advantages compared to the Brewer and Dobson spectrophotometers. No calibration lamps are needed since the wavelength is calibrated by comparing the results with the known solar spectrum, which has only a small influence from pollutants and is only sensitive to stratospheric ozone. The instrument reveals weaknesses when dealing with high aerosol load or with dense Polar Stratospheric Clouds (PSCs).

Comparisons with the Dobson and Brewer shows good agreement at low latitudes, but a seasonal cycle with differences of about 5% at high latitudes. This may be due, in part, to the temperature dependence of the ozone absorption coefficients in the UV-B, or due to error in the calculations. At high latitude, the difference becomes 10-15%.

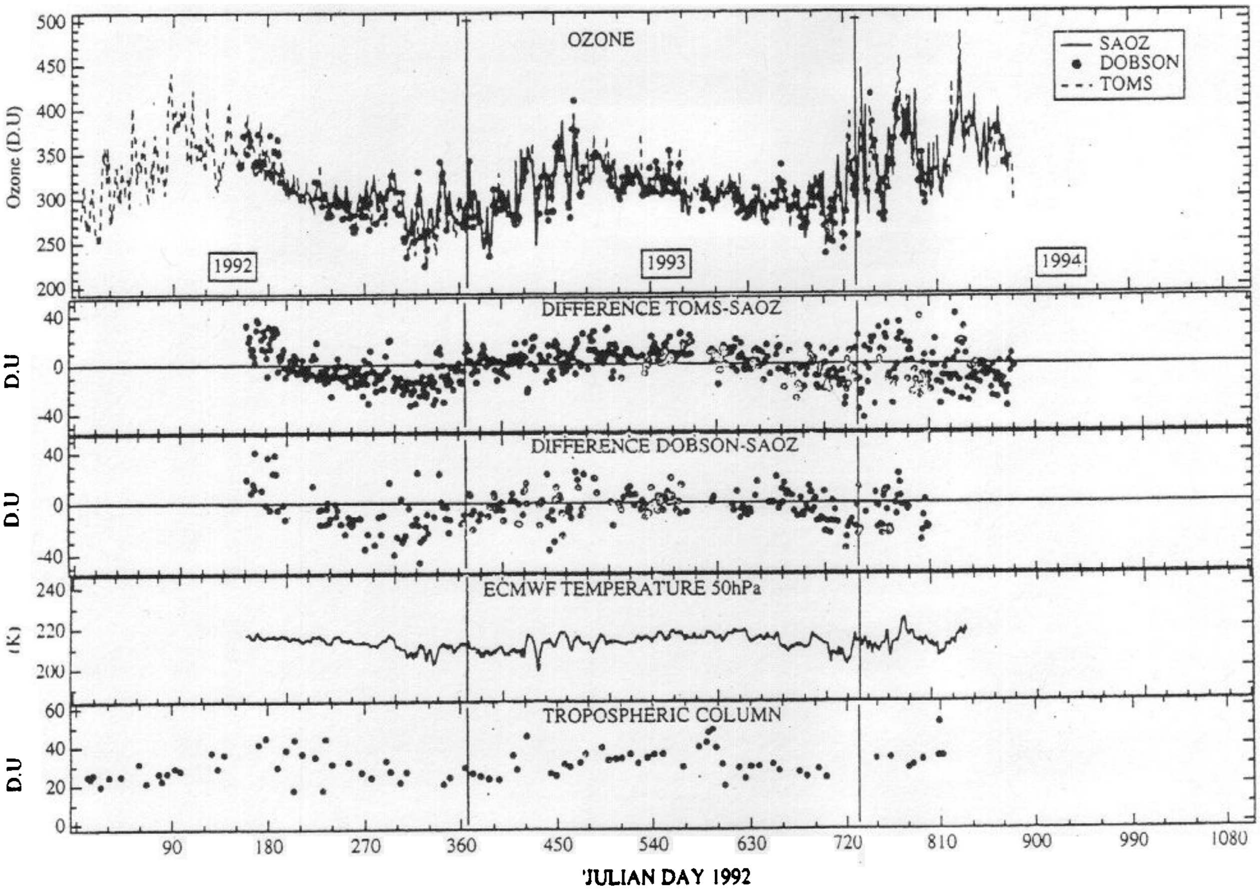

Figure 9.2.1 Two years of data collected by the SAOZ spectrometer at OHP are compared to Dobson and TOMS data. An annual modulation of the differences is a result of the annual temperature variation of the stratosphere. Also observable is the influence of variations in tropospheric ozone to which SAOZ is not sensistive.

Comparison with TOMS data revealed large differences (up to 30%). This is attributed to errors induced in the TOMS data, at high latitude, by an error in the climatology of the ozone profiles used for the retrieval of the satellite data. This will be taken into account in the next version of the TOMS data set.

10. UV-B Measurement

[B.Barnard, rapporteur]

10.1 Upward trend detected in solar UV-B series

R. Basher reported on the results of UV-B monitoring in New Zealand.

10.2 Trends in ozone and UV-B as measured in Toronto

Jim Kerr talked about the measurement of UV-B in Canada. He presented a brief history of UV-B research and spoke about various topics including its initial investigations in 1989, the development of the Canadian UV Index, the effects of aerosols on UV transmission, and concluded by showing the definite link between ozone depletion and increased levels of UV-B.

He compared actual spectra taken by the Brewer instrument to model solar spectra derived by John Frederick. Noting specific differences at the shorter wavelengths, he explained that these were caused by stray light within the Brewer monochrometer.

His talk then switched to the history and development of the UV Index. He discussed how the Brewer spectra can be convolved with the Diffey erythymal response curve, resulting in the amount of UV radiation necessary to produce a reddening of the skin. He further explained how UV flux could be predicted by looking at the relationship of UV-B and ozone at various zenith angles. From this relationship and the previous day's ozone value, a UV Index value for a solar noon, clear sky day can be derived.

After determining values for I_0 for Brewers #014 and #015 he made optical depth measurements in Toronto for the period 1989-1994. Optical depth values averaged near one for most of the first year with many peaks going beyond, almost reaching 2. Values in 1993 clearly showed the effects of the eruption of Mt.

Penitubo on the stratosphere, attenuating almost half of the direct sun's intensity.

He ended his talk by referring to an award-winning paper [1995 Norbert Gerbier-Mumm Award] authored by himself and Tom McElroy and published in Science [1993]. Using UV-B and ozone data collected from 1989-1993, he illustrated conclusively the direct correlation between ozone depletion and the resultant increase in UV-B radiation.

10.3 Results of UV-B measurements

Alkis Bais spoke briefly about some specialized UV-B data collected between 1990 and 1994 at a zenith angle of 63 ±1 degree. A study of cloud cover coincident with UV-B readings taken at this zenith angle showed that cloudiness greater than 3 parts out of eight would greatly decrease the UV-B levels at the surface. The UV-B data, collected simultaneously with column ozone at Thessaloniki, was also used to show increases in UV-B attributable to ozone decreases. There was a 12.6% per year increased intensity at 305 nanometer for the study, but only a 2.8% increase per year at 325 nanometer, a wavelength not much affected by ozone absorption.

10.4 UV-B Measurements with the Brewer at Hohenpeissenberg

W. Vandersee addressed the results of UV-B measurements at Hohenpeissenburg from 1991-1993, comparisons between specific types of calibration lamps, and a comparison between a Bentham double monochromator and the Brewer. He also presented data comparing Brewer spectral scans to the STAR model from the University of Munich.

By comparing Brewer DUV scans for clear days in April 1991 with similar days in 1993 he showed not only an increase of 30% in DUV for this time frame, but a definite linear correlation between UV-B levels and total column ozone.

10.5 Evidence of diurnal variations of total ozone correlated with solar activity

S. Perov used various techniques, including ozone sondes, rocket sondes, ground-based ozone instruments and Brewer #044, in an attempt to show the wave-like structure of the varying ozone concentrations at certain locations within Russia, as well as a brief attempt with the Izaña data. Using a Brewer, he made a series of 3-hour full-moon ozone observations before and after the daylight hours of 3/20/90. Data from this time period, one day and two nights, was used to show that ozone varied in a wave-like manner. He produced graphs showing the solar activity that had a periodicity that he also attempted to correlate with variations in the total column ozone concentrations.

He further corroborated his findings by showing graphs of wind velocities, atmospheric temperature variations, and other meteorological parameters that showed a wave-like nature

10.6 Comparison of Brewer UV-B measurements with data from the Robertson-Berger Meter at Belsk

M. Degorska presented graphs with over 700 daily values of RB meter and Brewer UV-B readings from July 1992-May 1994. These data had a correlation coefficient of .98 for the entire period. When only clear sky values from each instrument were selected the correlation for the linear fit of the data increased to 0.99.

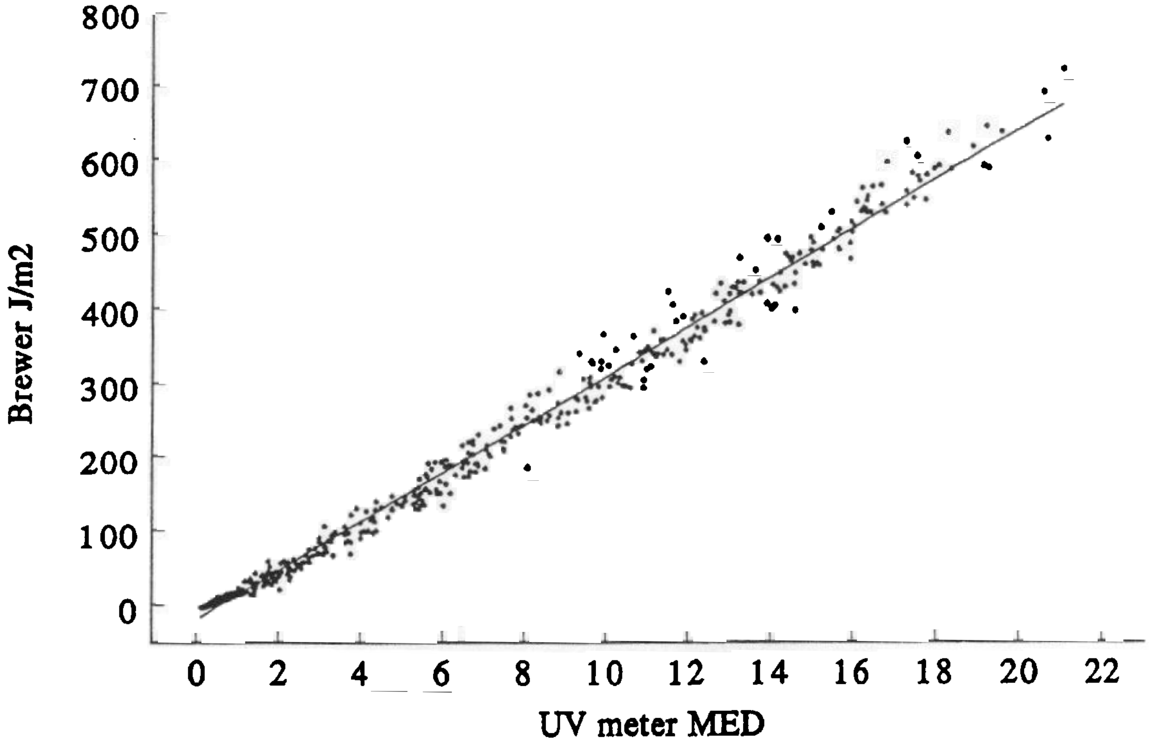

Figure 10.6.1 A comparison of the readings from a Robertson-Berger meter with UV-B data calculated using Brewer UV scans. The measurements were made in Belsk, Poland.

Ozone comparisons between a Brewer and Dobson instruments showed only fractional deviations between the two.

10.7 UV-B monitoring satellite validation program (GOME)

10.8 The United States EPA UV-B Program

W. Barnard presented the U.S. Environmental Protection Agency's (EPA) program to develop and operate a monitoring network to measure ultraviolet (UV) radiation flux at the earth's surface and to provide for public awareness of exposure to UV radiation through adaptation and publication of a predictive UV "exposure

Index." This "Index", similar to the one developed and publicized by Canada in 1992, is being developed in conjunction with the National Weather Service for possible public distribution in the current year. Plans call for a 15-site monitoring network to measure UV intensities on a spectrally-resolved basis, together with other parameters (e.g., total column ozone, cloud cover, interfering tropospheric pollutants, etc.) that affect UV flux. Eleven urban sites will provide data to validate the "Index" predictions in proximity to ~25% of the U.S. population. The combination of urban (polluted) and four rural (less polluted) sites would enable EPA to improve the algorithms upon which the "index" predictions are based. A series of instrumental intercomparisons with other agencies were also planned to ensure comparability of data and good quality assurance/quality control. EPA's intent was to coordinate its efforts with other Federal Agencies and with the international community.

Ozone data from the Research Triangle Park, North Carolina Brewer site dating back to its original date of operation to May of 1994 was presented as well. A comparison of a National Weather Service predictive UV Index values and the UV Index values obtained from the Brewer at solar noon were also presented for 1992 and 1993.

10.9 Stratospheric monitoring of NO_2 and ozone

11. 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 steps be taken to achieve the goal stated in the last working group meeting of having calibration visits or intercomparisons for all Brewer instruments at least every two years.

2. It is recommended that a working group be convened under the auspices of the International Ozone Commission to create a draft handbook of information concerning the operational, maintenance and data reporting procedures to be presented at the next Brewer Users' Working group meeting.

3. Brewer Spectrophotometer calibration and maintenance records should be documented at Brewer stations and regularly submitted to the WODC. The WODC will define information exchange standards and co-ordinate this activity.

4. All Brewer Spectrophotometer operators should be strongly encouraged to collect and submit data, including Umkehr observations, within 60 days of their acquisition. The WODC should be encouraged to follow up on the submission records of the stations.

5. Brewer Spectrophotometer operators should take the necessary steps to upgrade their instruments to collect ultraviolet spectral (UV-B) data and provide proper calibration for the UV observation mode.

6. It is recommended that all Brewer station operators reprocess their data and

make it available on an annual basis.

7. It is desirable that all stations monitor surface/tropospheric ozone concentrations to improve the Umkehr analysis and the estimate of the stratospheric column ozone.

8. It is recommended that another Brewer Workshop be held at the time of the 1996 Quadrennial Ozone Symposium.

12. Participant List

Participant	Institution/Address	Telephone/Fax/Email
Alves, J.	INPE-Natal C. Postal 130 Natal, Rn, Brazil	Tel: 5584 231 4733 Fax: 5584 231 4941
Ashbridge, A.	9 Lehar Crescent Willowdale, Ontario Canada, M2H 1J4	Tel: 1 416 494 2622 Fax: 1 416 496 9190
Bias, A.F.	Lab. Of Atmospheric Physics Aristotle University of Thessaloniki 54006 THESSALONIKI Greece	Tel: +30 31 998184 Fax: +30 31 283 752 bais@olymp.ccf.auth.gr
Barnard, W.F.	U.S. EPA MD-44 Research Triangle Park North Carolina 27711 USA	Tel: 919541.2205 Fax: 919541.0239
Bhartia, P.K.	NASA/Goddard Space Flight Center Mail Code 916 Greenbelt, MD, 20771 USA	Tel: 301-286-4094 Fax: 301-286-1662 bharta@chapman.gsfc.nasa.gov

Basher, R.E.	NIWA Climate P.O. Box 3047 Wellington New Zealand	Tel: +64 4 4729966 Fax: +64 4 4969411 basher@award1.kelburn.cri.nz
Bojkov, R.D.	c/o WMO p.o Box 2300, Geneva-2 Switzerland	Tel: 4122 7308 455 Fax: 4122 7400 984 rumen.bojkov@itu.ch
Cappellani, F.	Commission EC/JRC Environment Institute I-21020 ISPRA Italy	Tel: 332 789228 Fax: 332 785837 Francesco.Cappellani@ei.jrc.it
Chmelik, M.	Dept. of Aerology and Ozone Measurements Slovak Hydrometeorological Institute Poprad-Ganovce, Slovakia	Tel: 42 92 32136 Fax: 42 92 36616
Ciattaglia, L.	CNR-Via Tiburtina 770 00159 Roma Italy	Tel: 39 6 4075 871 Fax: 39 6 4075 807 chamard_p@eca401.enea.casacia.it
Cisneros, J.M.	Instituto Nacional De Meteorología Apdo. 285 Madrid 28071 Spain	Tel: +34 1 5819773 Tel: +34 1 5819767

Colombo, T.
Camm M. Cimone
Dott Tisiano Colombo
Via Delle Ville 100
41028 Sestola
Italy

Cuevas, E.
Izaña GAW STATION/INM
c/s. Sebastián 77
38071-Sta. C, Tenerife
Spain
Tel: 34 22 373878
Fax: 34 22 373720
ecuevas@ull.es

Dahlback, A.
NILU
P.O. Box 100
N-2007 Kjeller
Norway
arne@nilu.no

De Backer, H.
K.M.I.
Ringlaan 3
B-1180 Brussels
Belgium
Tel: +32 2 3730594
Fax: +32 2 3751259
hugo@oma.be

De La Morena, B.
INTA (Est. Sondeos Atmosféricos)
El Arenosillo
Mazagon 21130-Huelva
Spain
Tel: 34 59 536003
Fax: 34 59 376294
Telex: 75537

Degorska, M.
Institute of Geophysics
Polish Academy of Sciences
Ks. Janusza St. 64
01-452 Warsaw
Poland
Tel: 48 22 379820
Fax: 48 22 370522

Dorokhov, V.
Central Aerological
Observatory
Pervomayskaya Str. 3
141700 Dolgoprudny, Moscow
Russian Federation
Fax: 7 095 5763327
vvcao@sovam.com

Elansky, N.F.
Institute of Atm. Physics
Pyzhevsky per. 3
Moscow, 109017
Russian Federation
Fax: 7 095 233 1652
root@iaph.msk.su

Eriksen, P.
DMI, Research & Development
Department
Lyungbyvej 100
DK-2100 Copenhagen 0
Denmark
Tel: +45 39 157418
Fax: +45 39 157460
pe@dmi.min.dk

Evans, R.
CIRES, University of Colorado
c/o NOAA-CMDL-R/E/CGI
325 Broadway
Boulder, CO 80303
USA
Tel: 1 303 497 6679
Fax: 1 303 497 6290
bevans@cmdl.erl.gov

Fioletov, V.	AES/ARQX 4905 Dufferin Street Downsview, Ontario M3H 5T4 Canada	Tel: 1 416 739 4915 Fax: 1 416 739 4281 vfioletov@dow.on.doe.ca
Frolov, A.D.	Department of Meteorology 2213 Computer & Space Science Bld. University of Maryland College Park, MD 20742-2425 USA	frolov@atmos.umd.edu
Ginzburg, M.	Servicio Meteorológico Nacional 25 de Mayo 658 1002 Buenos Aires Argentina	Tel: 541 522 1122 Fax: 541 311 3968
Giovanelli, G.	CNR Fisbat Institute Via Gobetti 101 40129 Bologna Italy	
Goutail, Ms. F.	Service d'Aeronomie BP 3 Verrieres le Buisson 91371 France	Tel: 33 1 6447 4289 Fax: 33 1 6920 2999 florence.goutail@aerov.jussieu.fr

Hare, E.W.
AES
4905 Dufferin Street
Downsview, Ontario
M3H 5T4 Canada
Tel: 416 739 4635
Fax: 416 739 4281
ehare@dow.on.doe.ca

Hassan, G.K.Y.
The Meteorological Authority
of Egypt
Koubry-El-Quoppa
P.O. Box 11784
Cairo, Egypt
Telex: 94293 METEGH UN
Fax: 202 2849857

Henriques, D.
Instituto de Meteorología
Rua C, Aeroporto de Lisboa
1700 Lisboa
Tel: 351 1 8483961
Fax: 351 1 802370

Hudson, R.D
Department of Meteorology
2215 Computer & Space
Sciences Bld.
University of Maryland
College Park, MD, 20784
USA

Kerr, J.B.
AES
4905 Dufferin Street
Downsview, Ontario
M3H 5T4 Canada
Tel: 1 416 739 4626
Fax: 1 416 739 4281
jkerr@dow.on.doe.ca

Karamanian, G.
Servicio Meteorológico Nacional
25 de Mayo 658
Buenos Aires
Argentina
Tel: 541 311 7476
Fax: 541 311 3968

Koenig, G.L.	Department of Commerce NOAA/ERL/CMDL-R/E/CG1 325 Broadway Boulder, CO 80303 USA	Fax: 303 497 6290 koenig@cmdl1.cmdl.erl.gov
Köhler, U.	Deutscher Wetterdienst Meteorologisches Observatorioum Albin-Schwaiger-Weg 10 82383 Hohenpeissenberg Germany	Tel: 49 8805 920021 Fax: 49 8805 920046
Komhyr, W.D.	NOAA/CMDL-R/E/CGI 325 Broadway Boulder, CO 80303 USA	Tel: 1 303 497 6331 Fax: 1 303 497 6290
Kulmala, A.J.	W.M.O. P.O. Box 2300, Geneva-2 Switzerland	Tel: 4122 7308 455 Fax: 4122 7400 984 wmo.ozone@omnet.com
Kuik, F.	KNMI P.O. Box 201 3730 AE de Bilt The Netherlands	Tel: +31 30 206482 Fax: +31 30 210407 kuik@knmi.nl
Kyrö, E.	FMI Met. Observatory at Sodankyla FIN-99600 Sodankyla Finland	Tel: +358 693 610072 Fax: +358 693 610105 esko.kyro@fmi.fi

Lamb, K.C.
International Ozone Services, Inc.
43 Lehar Crescent
North York, Ontario
Canada, M2H 1J4
Tel: 1 416 494 4382
Fax: 1 416 494 7179
klamb@istar.ca

Leong, C.P.
Malaysian Meteorological
Service
Jalan Sultan
46667 Petaling Jaya, Selangor
Malaysia
Tel: 603 756 9422
Fax: 603 756 0964

Luo, C.
Institute of Atm. Chemistry
Chinese Academy of Met. Science
State Meteorological Admin.
No. 46, Baishiqiao Road
Beijing 100081
Peoples Republic of China
Fax: 86 1 834 7390

McElroy, C.T.
AES
4905 Dufferin Street
Downsview, Ontario
M3H 5T4 Canada
Tel: 1 416 739 4630
Fax: 1 416 739 4281
tmcelroy@dow.on.doe.ca

Murphy, G.
Valentia Observatory
Cahirciveen
CO. Kerry
Ireland
Tel: +35 366 72939/72176
Fax:+35 366 72442

Muthama, N.J.	Cattedra di Meteorologia Dipartimento di Fisica Università "La Sapienza" Piazzale Aldo Moro 2-1-00185 Rome Italy	Tel: +396 499 13479 Fax: +396 446 3158
Nichol, Ms. S.E.	P.O. Box 31-311 Lower Hutt New Zealand	nichol@award1.kelburn.cri.nz
Palmieri, S.	University "La Sapienza" Department of Physics P. Le Aldo Moro 2 00185 Rome Italy	Tel: +396 499 13479 Fax: +396 446 3158 palmieri@sci.uniromat.it
Pastor, A.	Servicio de Análisis e Investicagión del Clima Instituto Nacional de Meteorología Spain	Tel: 91 5819 690 Fax: 91 5819
Peláez, J.C.	Apartado 17032 Habana 17, C.P. 11700 Cuba	Tel: +537 338010 Fax: +537 617168

Perov, S.P. Central Aerological Observatory
Tel: 095 4086150
141700 3, Pervomayskaya str.
4087771
Dolgoprudnii 9166258
Moscow Region
2552284 (Office)
Russia
2490217 (Home)
Fax: 095 5763327
vvcao@sovam.com

Pommereau, J.P. Service d'Aeronomie Tel: 33 1 6447 4288
BP3, Verriers le Buisson Fax: 33 1 6920 2999
91371 France

Rajewska-Wiech, B.
Institute of Geophysics
Polish Academy of Sciences
Ks. Janusza St. 64
01-452 Warsaw
Poland

Ramos, O.B. Servicio Nacional de Tel: 5114 71 7287
Meteorologia Fax: 5114 71 7287
Hidrología (SENAMHI)
Casilla Postal 1308
Lima 11
Perú

Ravegnani, F.
CNR-Fisbat Institute
Via Gobetti 101
40129 Bologna
Italy
Tel: +39 51 6399589
Fax: +39 51 6399652
fabrizio@03.fisbat.bo.cnr.it

Savastiouk, V.
357741 Kislovodsk Box 1
GAS IPhA
Russia
Fax: 7 095 233 1652
andron@comprog.msk.su

Shalamyansky, A.
Main Geophysical Observatory
7 Karbysheva Str.
St. Petersburg
Russian Federation
Tel: 78 122 459303
Fax: 78 122 478661

Siani, Ms. A.M.
Department of Physics
University of "La Sapienza"
P. le Aldo Moro 2
00185 Rome
Italy
Tel: +396 49913479
Fax: +396 4463158

Soubrier, F.
INTA (Sondeos Atmosféricos)
El Arenosillo
Mazagón 21130, Huelva
Spain
Tel: 959 5366003
Fax: 959 376294

Stanek, M.
Solar and Ozone Observatory
Hvezdarna 456
50008 Hradec Kralove 8
Czech Republic
Tel: +42 49 24906
Fax: +42 49 25458

Starodubtsev, Y. Main Geophysical Observatory
7 Karbysheva Str. Tel: 781 224 59303
St. Petersburg Fax: 781 224 78661
Russian Federation

Tonnessen, F. University of Oslo Tel: +47 22 8555673
Department of Physics Fax: +47 22 855671
P.O. Box 1048
Blindern N-0316 Oslo
Norway

Valenti, C. IFA-Piazza L. Sturzo, 31 Tel: +396 5910941
00144 Rome Fax: +396 5915790
Italy

Vandersee, W. Met. Observatorium
Hohenpeissenberg
Albin-Schwaiger-Weg 10
82383 Hohenpeissenberg
Germany

Vanicek, K. Solar and Ozone Observatory
Hvezdarna 456 Tel: +42 49 24906
50008 Hradec Kralove 8 Fax: +42 49 25458
Czech Republic

Varotsos, C. University of Athens
Department of Applied Physics
Lab. of Meteorology
33 Ippokratous Str. 10080, Athens
Greece

Viatte, P.
Institut Suisse de Meteorologie
Tel: +41 37 626111
Station Aerologique Les
Invuardes
CH-1530 Payerne
Switzerland
Fax: +41 37 621194
pvi@sap.sma.ch

Zerefos, C.
Aristotle University of Thessaloniki
Lab. of Atmospheric Physics
54006 Thessalonii
Greece

13. Program:

Session 1 - Opening and Introduction

Official Opening by the Permanent Representative of Spain and Local Authorities

Introductory remarks by the Chairman of the Scientific Organizing Committee
R.D. Bojkov.

Remarks by the Consultation Co-Chairman
C.T. McElroy.

Session 2 Total Ozone Measurement

Re-evaluation of Brewer #005 Ozone Data from 1982 to the present
[Alkis Bais, Greece]

Measurement program at Valentia Observatory
[G. Murphy, Ireland]

The temporal behaviour of ozone over Italy in the period 1992-1994
[N.J. Muthama, A.M. Siani and S. Palmieri, Italy]

Diurnal ozone variations at Toronto and Edmonton
[J.B. Kerr, Canada]

Session 3 Data Comparisons

Brewer/Dobson/TOMS ozone measurements: Daily and annual variations of the differences [U. Köhler, Germany]

A comparison of observations made by the Brewer, TOMS and SAOZ
[E. Kyrö, Finland]

A comparison of Dobson No. 61 and Brewer #025 ozone measurements made at Boulder between October 1991 and January 1994 [G. Koenig, USA]

Intercomparison of Dobson and Brewer ozone measurements made at low sun angles [S.S.E. Nichol, New Zealand]

Comparison of Brewer ozone data with overpassing satellite measurements
[V. Fioletov and R.D. Bojkov, Canada]

A comparison of Brewer data with TOMS and Dobson ozone measurements
[J.B. Kerr, Canada]

Measurements of ozone in 1993 in Malaysia
[C.P. Leong, Malaysia]

Session 4 High latitude Measurements

Measurements of Ozone and NO_2 made by Brewer Instruments and by SAOZ in Eastern Siberia [V. Dorokhov, Russia]

Brewer data taken during the Antarctic ozone hole in 1993
[L. Ciatagglia, Italy]

Brewer Ozone Spectrophotometer observations made at high Arctic latitudes (Heiss Island) 1989-94 [V. Dorokhov, Russia]

Measurements of ozone and UV with Brewer #053 in Greenland
[P. Eriksen., Denmark]

Comparison of total ozone measurements from Brewer, Dobson and high resolution direct sun UV spectra at Arosa [P.P. Viatte, Suisse]

On the Brewer Intercomparisons at Izaña, 1993
[E. Cuevas, Spain, and A. Bais, Greece]

UV-B and Ozone measurements in Central and Southern Greece
[C. Varatsos, Greece]

Session 5 New Developments

Design elements of the Brewer double monochromator
[C.T. McElroy, Canada]

Performance of the double monochromator Brewer Spectrophotometer
[Alkis Bais, Greece]

Brewer spectral irradiance measurements used to infer total ozone
[A. Dahlback, Norway]

On possible improvements to the Brewer software
[N.F. Elansky, Russia]

The Composition and Photochemical Flux Measurement experiment on ASHOE/MAESA [C.T. McElroy, Canada]

Session 6 Data Management

The Brewer data management system
[E. Hare, Canada]

Automatic data reporting in the Canadian Brewer ozone network
[J.B. Kerr and C.T. McElroy, Canada]

Session 7 Umkehr Measurements

Umkehr observations with data collected by the York/ISTS/AES Lidar in Toronto
[J. Hahn and C.T. McElroy, Canada]

A survey of total ozone measurements in China
[L. Chao, China]

Session 8 Other Trace Gasses

Correlations between SO_2 and NO_2 surface level measurements and Brewer SO_2 and NO_2 determinations [F. Cappellani, Italy]

Total ozone and NO_2 measurements using a SAOZ spectrometer and validation by comparison to other instruments: Brewer, Dobson, TOMS and other UV-visible spectrometers [F. Goutail and J.P. Pommereau, France]

Session 9 UV-B Measurement

Trends in ozone and UV-B as measured at Toronto
[J.B. Kerr and C.T. McElroy, Canada]

Upward trend detected in solar UV-B series
[R. Basher, New Zealand]

Results of UV-B measurements
[A. Bais and C. Zerefos, Greece]

UV-B Measurements with the Brewer at Hohenpeissenberg
[W. Vandersee, Germany]

Evidence of diurnal variations of total ozone correlated with solar activity
[S.P. Perov, Russia]

Comparison of Brewer UV-B measurements with data from the Robertson-Berger Meter at Belsk [M. Degorska, Poland]

UV-B monitoring satellite validation program (GOME)
[P.C. Simon, Belgium]

The United States EPA UV-B Program
[W. Barnard, USA]

Stratospheric monitoring of NO_2 and ozone
[P.C. Simon, Belgium]

Session 10 Closing Activities

Preparation of meeting recommendations and closing of the meeting.