The Ninth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting

(Delft, The Netherlands, 31 May to 3 June 2005)
THE NINTH BIENNIAL WMO CONSULTATION ON BREWER OZONE AND UV SPECTROPHOTOMETER OPERATION, CALIBRATION AND DATA REPORTING

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FOREWORD

The 9th Brewer Workshop is the second to be held since the timing of the workshops was changed to avoid the years when the Quadrennial Ozone Symposium (QOS) is held. It was also the first meeting to run for a full four days. The attendance and the level of participation in the meeting have clearly demonstrated both the need for the workshop within the community and the utility of having the meeting disassociated from the QOS so that people can allot more time to the workshop activities.

The importance of the Brewer Ozone Spectrophotometers within the WMO/GAW Global Ozone Network is increasing. The system-wide performance is also improving, particularly as a result of the improved level of calibration effort being expended in many countries. The recent introduction of the Brewer support fund at WMO as a result of the contribution from Environment Canada is helping this effort with respect to countries which have inadequate resources for these activities. In order for the effects of those improved efforts to flow through to provide the highest quality data for the future assessment of the ozone layer and ultraviolet environment, it is essential that the data collected by individual instruments, including test and inter-comparison results, be archived in the WMO World Ozone and Ultraviolet radiation Data Centre (WOUDC). This will guarantee that accurate and detailed retrospective analyses can be uniformly carried out on the data from all stations in the Global Observing System in the future.

The inclusion of tutorials sessions at the Brewer meetings, which were re-introduced at the 8th meeting after an absence, was well received and was continued at the 9th meeting. Scientific presentations continue to be an important part of the workshop and have been accommodated partly by extending the length of the meeting and partly by including poster sessions. However, informal meetings conducted outside the scheduled sessions remain a significant and essential feature of the meetings.

The highly successful meeting this year was held in Delft, The Netherlands was hosted by Kipp & Zonen, the licensed manufacturer of the Brewer. The Brewer community is indebted to Ben Dieterink, Els Schinkel and all the other staff of Kipp & Zonen whose professional support and warm personal assistance were an integral component of the success of the Workshop.

The community was also well-served by International Ozone Services which arranged for the attendance of Vladimir Savastiouk at the meeting. His contributions regarding new science opportunities, insights into Brewer operations and servicing, and software support were invaluable.

The Brewer Workshop meetings are a crucial part of the process of ensuring that all Brewers are properly operated, that instrument calibrations are tightly traceable to international standards and that highly reliable data are lodged with the WOUDC. As we all move forward toward the new WMO-Integrated Global Atmospheric Chemistry Observations (IAGCO) framework, these meetings will become increasing more important.

I look forward to seeing you again at the next workshop.

C.T. McElroy
June 2005
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1. **WELCOME AND INTRODUCTION BY THE LOCAL HOSTS** (B. Dieterink)

B. Dieterink of Kipp & Zonen B.V., The Netherlands, opened the meeting by informing everyone that this is a special year for Kipp & Zonen, it is the 175th anniversary since the company was established. Dieterink gave a brief history of Mr. Kipp’s company and its contribution to Dutch society through many of his inventions. He mentioned that Zonen means “sons”. Around 1920, Kipp and Zonen began doing solar radiation measurements. When the thermopile was invented, Kipp & Zonen, purchased one to further develop this technology.

Dieterink gave a brief overview of Delft and wished everyone a good meeting.

2. **OPENING ADDRESS BY THE MEETING CHAIRMAN** (C. T. McElroy)

C.T. McElroy of the Meteorological Service of Canada (MSC), welcomed everyone and acknowledged Ben Dieterink and the staff at Kipp & Zonen (Els Schinkel, Martin Veenstra, Kristian Boot and Clive Lee) for their support and thanked them for hosting of the meeting.

He mentioned that it has been 23 years since the delivery of the first commercial Brewer (BR#005) to Thessaloniki, Greece and then BR#006 to Sweden. Although it is not 175 years, it is approaching a quarter century. One of the most important aspects of these Brewer meetings are the interactions that occur during poster sessions and coffee breaks. This is a key strength of these workshops.

3. **PLENARY WMO SESSION**

3.1 **WMO-GAW Programme** (L. Barrie)

L. Barrie of the World Meteorological Organization, Switzerland opened his presentation by identifying the motivation behind such a workshop. This motivation is based upon a need for a better understanding of:

- Stratospheric Ozone Depletion and Surface UV Enhancement: Are Halocarbon controls working? How is human health and the biosphere affected?
- Climate, Climate Change and Climate Prediction;
- Improved Weather Forecasting: By Including Ozone, Dynamics Are Improved;
- Air Pollution Forecasting, Effects, Long-Range Transport and Deposition;

What is less appreciated is that ozone is a greenhouse gas that it is now being predicted in forecast models. It is also important for understanding the planets UV environment and is related to the air quality and long range transport issues. It also delivers information on the oxidation capacity of the atmosphere. The mission of GAW is three fold:

- **Systematic Global Monitoring** Of Chemical Composition of the Atmosphere;
- Analysis and Assessment in Support of **International Conventions**;
- Development of Air Pollution and Climate **Predictive Capability**.

Examples of how the global Brewer network of data are integrated into the WMO scheme is evident by the importance of trend analysis as well as the ozone bulletins for the Antarctica. Eventually, arctic bulletins will also be incorporated into these WMO-GAW products.

The structure of the GAW programme is given in Figure 1.
He illustrated the “build out” of a primary standard with the goal of linking operating and quality assurance standards to these primary standards, supporting the quality assurance and submission of data to world data centres and oversight advisory groups of experts for all aspects of the network.

The various GAW networks and their role or contribution to the community were summarised in the question: “How are these data and communities coming together in an integrated way?” IGAGO is the response to this question. Figure 3.1.2 refers to the IGACO system components. The community is challenged to deliver integrated data products in real time for forecast models, other related applications and for the various users of the data. There are four foci of IGACO: ozone depletion climate, greenhouse gases, air quality and climate change.

In conclusion, Barrie reinforced the idea of how important this Brewer community is to this newly evolving IGACO scheme and to the overall WMO-GAW process.
K. Vanicek from the Czech Hydrometerological Institute, Czech Republic began by explaining the role of the Science Advisory Group (SAG_Ozone) for Ozone. The SAG_Ozone serves as a scientific body nominated by the WMO Committee for Atmospheric Sciences (CAS) working group that assists in management and implementation of the ozone component of the GAW programme. Within this structure each component part of the ozone community is represented. Of interest to the Brewer community are the objectives relevant to the operation and maintenance of the global Brewer network.

He outlined the objectives of the SAG with respect to the Brewer Network:

- Advanced successor of the Dobson spectrophotometer.
- Widely used at GAW stations – nearly 200 instruments manufactured.
- Multi-functional: total column O$_3$, SO$_2$, NO$_2$, UV spectra, O$_3$ profiles (Umkehrs) and Aerosol Optical Depth (AOD).
- Important ground-based contributor to the IGACO system.
- Perspectives for further technical development.

Recent achievements include:

- The World Reference Triad has been established.
- The Brewer calibration scale is defined.
- The majority of instruments are regularly calibrated.
- Instructions for operation of instruments are available.
- A big experience gathered by experts and the community.
- The Brewer network of the MSC (CBN) is a good example for GAW.

He also mentioned gaps and needs, mostly notably, calibrations that are commercially dependent (except for the MSC), calibration metadata that are not freely accessible to data users, the capacity for Umkehr observations is underestimated and problems with the operation of instruments in some countries still exist.

In addition, recommendations and realizations of the past three SAG_Ozone meetings (Toronto, 2002; Prague, 2003 and Boulder, 2004) were highlighted to illustrate that despite some of these gaps, many issues are moving forward.

- The Primary Brewer Reference Triad (*The MSC continues maintenance the PBRT*).
- The Standard Operating Procedures (SOPs) for Brewer spectrophotometers (*As a dynamical web document by the end of 2005*).
- The GAW Regional Brewer Calibration Centre for RA-VI (*RBCC-E established at Izana, Spain in 2004*).
- Collection of calibration metadata into WOUDC (*Expert group of GAW to create templates and the web site in 2005*).
- Analysis of calibration histories of Brewer instruments in GAW (*Expert group of GAW to follow up the above task, Report of GAW*).
- Submission of primary data (level 0 files) from stations to the WOUDC (*The Brewer Data Management System available in MSC to run the data*).
- Investigation of relation between Dobson and Brewer total ozone (*The GAW Report No.142, analyses continue*).
- Upgrade of the algorithm for Brewer Umkehr observations (*Development of a new Umkehr code started in 2004*).
- Expansion of Brewer Umkehr observations at GAW stations (*Implementation the new algorithm into the Brewer operating software*).
- Assistance to Brewer stations in developing countries (*Establishment of the WMO-MSC Trust Fund for calibration missions*).
Vanicek concluded by remarking that the recommendations and initiatives of the SAG_Ozone will only have an impact if the Brewer community actively assists the WMO/GAW in this realisation. He also thanked all those volunteers who have assisted the SAG_Ozone in recent years.

SPECIAL SESSION ON THE GLOBAL BREWER NETWORK, WHERE DO WE GO FROM HERE?

3.3 The Role of the Global Brewer Network in Ozone/UV Trends Studies (V. Fioletov)

V. Fioletov from the Meteorological Service of Canada presented his view of the status of the global Brewer network for ozone and UV studies. He emphasised the importance of the ground-based network in satellite and model validation, to monitor ozone recovery and assist in the analysis of ozonesonde data. He showed that sondes, that are not “normalised” to total ozone measurements, have an uncertainty of about 7% versus the normalised data which has about a 3% uncertainty. Another important use of ground-based data is to monitor ozone at high latitudes.

With specific regard to the Brewer instrument, the ozone requirements are:

- Low systematic errors and uncertainties.
- Data that we can trust (2 or more instruments at the site, ozone from different types of measurements: DS, ZS, UV, red Brewer, etc.).
- Capable of measuring ozone at high zenith angles.
- Near-real time data.

The Brewer instrument is also part of a composite picture of the UV radiation field as illustrated in Figure 3. Data from Brewer instruments along with pyranometers and space-based simulation can provide this composite representation, especially for mean summer daily erythemal irradiation values.

![Composite plot of Brewer, pyranometer and TOMS data for Toronto.](image)

A comparison of ground-based data from several Brewers to NASA TOMS v7 data illustrated the difference for erythemally weighted UV irradiance and for UV irradiance at 305, 310, and 324 nm. as given in Figure 4. These data represent summer noon values for mostly clear-sky conditions (TOMS reflectivity <0.2).
Fioletov concluded by stating the Brewer UV issues that he feels are important and assigned them a priority: Satellite data validation (High), Studying aerosol effects (High), UV trend detection (Moderate), Total ozone derivation (Moderate) and UV forecasting (Low).

3.4 The Need for Integrated Data Sets for Long-term Monitoring (C.T. McElroy)

McElroy began with the goals that should be considered when discussing long-term monitoring. These include:

- Improve measurement accuracy.
- Increase re-calibration rate.
- Improve access to southern hemisphere data.
- More measurement types:
  - Aerosol
  - \( \text{NO}_2 \)
- Raw data storage in the WOUDC.
- Full tracking of instrument calibration information in the WOUDC.
- Uniform re-processing.

There are also new applications for the network such as the use of the ‘red Brewer’ (MK V) to improve the reliability of measurements at very large solar zenith angles (i.e. Polar regions and possibly elsewhere), the MK IV & MK V to extend the aerosol measurement wavelength range, the use of co-located instruments to improve access to high-quality data and the exchange of data via the Global Telecommunication System (GTS).

There still exist several areas in need of improvement, namely:

- Better tracking of instrument calibration information.
- New measurement types.
• Stray light characterization and correction.
• Wavelength-dependent neutral density filter characterization.
• European Brewer reference and calibration capability.

More recently, tropospheric studies have become increasingly more important and relevant to the Brewer community. Data assimilation of Brewer data may have an impact on forecasting and tropospheric studies are complementary to Brewer and other array instrument data.

There are several challenges facing the community. This includes the recent retirements of Jim Kerr and David Wardle, the funding for the Brewers in Toronto is becoming precarious, the MSC is going through another re-organization exercise and McElroy has become more involved in other projects such as the ACE-MAESTRO satellite instrument.

3.5 The Central Calibration Centre for Brewers – the Reference Triad (V. Fioletov)

The Brewer triad, as the name implies, comprises three Brewer instruments (serial numbers 8, 14, and 15) and was established at the MSC headquarters, Toronto in 1984. A calibration history of the triad, for visits to the Mauna Loa Observatory (MLO), Hawaii are summarized in Table 1.

<table>
<thead>
<tr>
<th>Brewer #008</th>
<th>Brewer #014</th>
<th>Brewer #015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar. 1999</td>
<td></td>
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The following statistical model was applied to the ozone data processed by each instrument on each day:

$$\Omega=A_8I_8+A_{14}I_{14}+A_{15}I_{15}+B\cdot(t-t_0)+C\cdot(t-t_0)^2$$  \hspace{1cm} (1)

Where \(\Omega\) is an ozone measurement by any instrument, \(t\) is the time of the measurement and \(t_0\) is the time of local solar noon. \(I_8\) is an indicator function of Brewer 8. It is set to 1 if the ozone value \(\Omega\) is measured by Brewer 8 and to 0 otherwise. \(I_{14}\) and \(I_{15}\) are indicator functions for Brewers 14 and 15 respectively. The coefficient \(A_8\) (or \(A_{14}, A_{15}\)) for a particular day can be interpreted as an average of all measurements on that day from Brewer 8 (or 14, 15) with diurnal ozone variations relative to the noon ozone value removed. The average of the three coefficients \(A=(A_8+A_{14}+A_{15})/3\) can be used as a benchmark to estimate the performance of individual instruments.

Fioletov explained the various uncertainties of individual direct sun (DS) measurements and relative systematic errors in the extraterrestrial coefficients (ETCs) and the ozone absorption...
coefficients and the problems these factors present when analyzing the data. There are temperature coefficients estimated from the standard lamp (SL) values and the effects of not correcting these data. Figure 5 illustrates the corrected versus non-corrected effects.

Figure 5: Temperature coefficients for Brewers 8, 14 and 15 extracted from standard lamp data.

There are also differences in comparison with satellite data such as the NASA-TOMS. For example, the average difference between Nimbus 7 TOMS and the triad is -0.8%, between Earth Probe TOMS and the triad is -2.9%. Similarly, the triad was compared with the travelling standard Brewer #017 as illustrated in Figure 6.

In summary, the standard uncertainty of the triad Brewers is 0.6% for daily values and 0.5% for seasonal averages. The standard deviation of random errors of individual measurements is ~0.5% and for the Brewer-TOMS difference, can be less than 2%. Even better results can be obtained by considering the stray light, neutral density filters and dead time.

Figure 6: Difference between Brewer 17 and the triad. The data are smoothed to a one-month running mean.
U. Köhler asked the question about the air-mass always being calculated for a layer centred 22km. V. Savastiouk responded that this issue is being investigated. M. Allaart asked about determining the Brewer’s temperature dependence: how stable is the internal standard lamp (SL)? Savastiouk answered that temperature tests done on a shorter time scale produce better results. SL ratios change illustrating temperature dependence.

3.6 The Travelling Standard (Brewer #017) and Brewer Calibrations (V. Savastiouk)

V. Savastiouk of International Ozone Services (IOS) Inc., Canada gave an overview of the performance of the travelling standard Brewer #017, the triad and other references. A Brewer calibration usually includes service (or maintenance) to ensure adequate instrument performance along with the actual calibration to determine the values of several parameters that characterise the instrument. These two components affect the quality of the data and often the ability of the instrument to perform a particular type measurement. In most cases the data collected with an un-calibrated instrument can be reprocessed later, after the instrument is calibrated. In other cases it is impossible. Tracking problems often leads to irrecoverable loss of data. For example, wrong dispersion coefficients result in UV data that is difficult to interpret, yet in some instances, one can recover information such as the Extraterrestrial Coefficients (ETC), which can then used to reprocess the data.

There are many elements in the data processing pathway that must be considered. For example, in the process of a calibration, some instrument parameters, such as the shutter delay and the dead time, are determined by running specific tests on the instrument being calibrated. Other parameters require a reference. Such references range from an external spectral lamp for the dispersion test to a travelling Brewer standard for the determination of the extraterrestrial constant. Doing calibrations is only one part of the process that leads to a good-quality Brewer network. An important part is keeping a detailed record of all calibration information and test results.

Certainly, there are other factors that affect data quality. These include software and hardware performance, the schedule composition and the ability of the operator to take appropriate measures to respond to the needs of a malfunctioning Brewer.

Education of the users is a very important part, especially for establishing instrument observing schedules. Sometimes there are disconnects between the instrument operators/technicians and the scientist or principal investigator. Savastiouk emphasised the important role each plays to ensure that observing routines are run properly.

The Primary Brewer Reference is the Brewer Triad in Toronto, Canada. A recent analysis by MSC staff showed the Triad data to be consistent to within 1% over 20 years. Brewer #017 continues to serve as the travelling standard that IOS uses for the ozone calibrations. Regular comparisons to the Triad and careful monitoring of the instrument performance ensure that the instrument can be used as a travelling standard. The UV 1000 Watt calibration lamp unit built by IOS is used to provide UV calibrations to the many Brewers around the world.

A summary of various instrument calibrations and travelling standard visits are available from the IOS web site (www.io3.ca). Figure 7 is a sample of the web summary.
Some common problems affecting Brewer data were outlined and these include:

- Tracking errors: refer to slide for expansion.
- High humidity (defective instrument seals).
- Poorly designed schedules.
- Poor software control (sometimes the software makes a “poor” decision or lists poor diagnostics for how the user can respond.
- Motor problems, micrometer settings and HG or SL lamp replacement.

The most common servicing problems include the azimuth tracker, damage due to humidity and communication errors from computer failures because of RF interference. Problems have also been traced to the new Brewer electronics and problems with power supply failures.

Three recommendations are:

1. Cooperation between WMO and the calibration providers.
2. Brewer user’s education.
3. Improvements in the Brewer operating software.

A question was asked regarding the replacement of the Hg lamp leading a change in the wavelength settings. Savastiouk replied that the “hot spot” (i.e. the brightest part of the discharge) of the lamp, if it is tilted, can cause problems. It is necessary to do a sky scan to sort this out (or use Hg line 296.7nm) and re-reference the instrument to the solar spectrum extreme point. It has been used with good success. M Allaart offered that sun scans are ineffective. Savastiouk suggested that T. Grajnar will address this issue.

3.7 Brewer Standard Operating Procedures (T. Grajnar)

T. Grajnar from the MSC presented an update on the status of both the Brewer Operating Procedures (SOPs) and the Brewer Users web site. Regarding the web site, existing information
on the www.Brewerinfo.org site will moved to a new location. The new location will be announced after the completion of move.

A draft of the SOPs has now begun and seven of eleven topics have been written. Many of these chapters have been reviewed by V. Savastiouk with his comments implemented. At present, there are about 40 pages completed with another 60 or so pages of notes prepared for remaining sections. Primary SOP topics are:

1. Safety issues.
2. Prevention of damage to instrument.
3. Introduction.
4. Hardware installation.
5. Software installation and configuration.
7. Diagnostics.
8. Data Acquisition.
10. Data Analysis and Interpretation.

Although the SOPs process is well underway, there still needs to be a review by the Brewer sub-committee and SAGs before the document is made available for release. And once posted, it is expected that the document will be “dynamic” in nature and include updates from ongoing feedback from the community.

Some highlights of the various sections include:

- **Safety Issues**: electrical safety, protecting eyesight, handling of the brewer and placement of cables or tripod.
- **Prevention of Damage to Instrument**: such as photomultiplier tube, excess moisture, optical surfaces and lubricants.
- **Hardware installation**: system requirements, site selection, assembly instructions, levelling the tripod and optical frame, protective covers and computer system installation and connection, software installation configuration for automatic startup, setting the buffer delay (if required), time-keeping options, location, date and time, sighting and scheduled operation.
- **Maintenance**: Brewer log form, weekly, bi-weekly, bi-monthly and unscheduled maintenance such as lamp replacement.
- **Diagnostics**: daily error checks, weekly diagnostic checks and monthly measurement checks.

Remaining topics include data acquisition, calibrations, data analysis and interpretation and data quality assurance.

### 3.8 Brewer Data Management System and the WOUDC (E. Hare)

E. Hare from the MSC presented the current status and updates of the Brewer Data Management System (BDMS). The primary function of the BDMS is to archive Level 0 Brewer data as a sub-component of the World Ozone and Ultraviolet radiation Data Centre (WOUDC). However, some misperceptions concerning the BDMS still exist. The BDMS is a special part of the WOUDC because it deals initially with Level 0 data. No other data within the WOUDC have both Level 0 and Level 1 (processed data). Archiving Level 0 data is essential for the long-term security of the data set.

Some recent developments of the WOUDC are:
Following both the Toronto 2002 and El Arenosillo 2003 meetings, two key recommendations were tabled:
- The need for more information about the calibration histories
- Brewer Standard Operating Procedures (SOP).

Examination of the BR#017 and Brewer triad records to build a global calibration picture;
A progress report was given at the 2004 Brewer sub-committee meeting (during the Quadrennial Ozone Symposium, Kos, Greece – June 2004).
The IOS Inc. web site posted a table of all instruments indicating when each was calibrated;
At the October 2004 SAG Ozone meeting, the collection of Level 0 data (for both archiving and traceability) was further endorsed.
A mock-up calibration report form to be part of the SOPs.
Updated the BDMS database to report more information about each file type.
Data inventory summaries are loaded weekly as part of the routine WOUDC data processing and are accessible using the new on-line BDMS search form.
Logs are generated and sent to data originators ONLY IF problems arise.

He also mentioned that work has begun on the extensive inventory (~20 gigabytes) of data in order to process these log files and report them back to the data originators. Typical problems that have been encountered are:

Types of errors:
- Redundant data.
- No core data or no DH tag.
- Multiple locations or Latitude/Longitude/Height out of range.
- Error parsing data date or metadata data (Example: Julian day 367).
- Existing file is different.

Problems:
- Data volume is limiting – want to build up the information correctly so that the system can be automated.
- Cannot be as “proactive” with large volumes of legacy data – it is easier to handle weekly submissions.
- Non-unique files.

Figure 8 shows the locations reporting Level 0 data to the BDMS.

Figure 8: Locations reporting Level 0 data to the BDMS.
Special Session: The Brewer Sub-committee General Meeting

The fifth meeting of the WMO-GAW Brewer sub-committee was held as a general meeting during the WMO plenary session. The summary report is presented in Annex C and is also available for download from the WOUDC-BDMS web site at http://www.woudc.org/bdms/reports_e.html.

3.9 Regional Brewer Calibration Center – Europe (RBCC-E): Results and First Test-Campaign (A. Redondas)

A. Redondas from the National Meteorological Institute of Spain presented an overview of the Izaña Regional Brewer Calibration Centre for Region VI. He began with a brief history:

• There have been about 50 Brewer spectrophotometers installed at 42 stations located in the European region up to 2004.
• Creation of an internationally structured Brewer calibration system, under the GAW programme, with Quality Assurance (QA) procedures similar to those of the Dobson system.
• Izaña was recommended to become a Regional Brewer Calibration Center for WMO Region VI (Europe) at the WMO/GAW SAG-Ozone meeting in Toronto, September 2002.
• Brewer meetings held under the umbrella of the GAW Programme in September 2003 (Mazagon, Spain) and in 2004 (Kos, Greece) confirmed the above plan.
• In November 2003 Izaña was officially recognised as RBCC-E by WMO.

There are three Brewers in operation at Izaña: BR#157, BR#183 and BR#185 and the centre has facilities for dark room calibration, ozonesonde flights, UV-Vis-FTIR and CIMEL’s for aerosol measurements. The location site is good for absolute calibrations using the Langley plot method and has a web-oriented database (http://www.rbcc-e.org) that makes RBCC-E data available to the RBSG-E members. It also has a tool for Brewer triad routine operation and real-time data processing. Figure 9 gives a panoramic view from the observatory.

Recent results indicate that ETC’s transferred from the travelling standard BR#017 and ETC’s from the Izaña Langley-plot derivations agree to within 1% for the period 1998-2002. Redondas continued by showing the calibration pathway and transfers from the travelling standard. Absolute calibrations will be performed by the Izaña triad as well as comparison visits with BR#017 that may eventually lead to inter-comparisons with the World Standard Triad in Toronto.

The first GAW Regional Brewer Calibration Center-Europe inter-comparison campaign of Brewer spectrophotometers will occur at the El Arenosillo, Atmospheric Sounding Station, INTA (Huelva, Spain) 9-18 September 2005. At present, five Spanish network Brewers, one Brewer from Portugal and possibly one from Morocco as well as two reference instruments (Br#017 and Br#185) are scheduled to participate. The programme calls for ozone calibrations to be made against both the RBCC-E travelling reference (B185) and against travelling reference (Brewer #017) managed by IOS Inc. along with minor servicing and refurbishment of the instruments to be

Figure 9: Panoramic view from atop the RBCC-E, Izaña, Tenerife, Spain.
performed also by IOS. UV QA by QASUME unit, compilation of the calibration histories of the instruments and Aerosol Optical Depth (AOD) calibration against the RBCC-E reference instrument.

Future activities include:

- Cooperation with Morocco.
- Cooperation with Uruguay.
- III Operator course
  - Spain, Portugal, Morocco and Uruguay.

He concluded with the recent terms of reference for the RBCC-E and the RBSG-E outlining these:

- Establishment and maintenance of Regional Brewer Reference Spectrophotometers.
- Perform calibration campaigns (El Arenosillo, Arosa and other sites?).
- Calibration histories of instruments.
- Relation between the Dobson and the Brewer calibration scales.
- UV Calibration of Brewer spectrophotometers (second level calibrations).
- Measurements of UV Aerosol Optical Depth with Brewer spectrophotometers.

3.10 IBERONESIA (A. Redondas)

Redondas presented IBERONESIA a web-oriented database for administration of a Brewer network and it began as a project to allow access to the RBCC members to the data. It is a tool for routine operation and real-time data processing for the three triad Brewers at Izaña and can be extended to include other instruments. The RBCC-E and the network share the same database and the application runs with two web pages: http://www.rbcc-e.org and http://www.iberonesia.com. At present IBERONESIA is a Brewer network of 11 brewers from Spain and Portugal.

There are three levels of access to data (Administrative, Operator and Guest), two databases (one for raw files (B-file databank) and the other a relational database). It was developed using free software with an open source philosophy (O/S Linux, Database engine: MySQL, Web engine Apache/PHP). Data are collected in real time and checked for format and any problems are relayed to operators immediately and then data are put into the database and posted on the web. He illustrated how the data are displayed and queried from the web site. Langley data are displayed and Redondas indicated how these data are integrated with the instrument data. A sample of the web display is given in Figure 10.

Figure 10: Web display from IBERONESIA.
Finally, a question was asked regarding the AOD measurements. The primary focus of the AOD work is from a funded study to examine the transport of Sahara Desert dust.

4. PLENARY SESSION I: LONG TERM STUDIES, TRENDS AND COMPARISONS


To access a copy of this presentation, refer to the WOUDC-BDMS web site topics list: either Tutorials or Meetings/Delft. The BDMS web site is:

http://www.woudc.org/bdms/index_e.html

Following the tutorial a question and answer period occurred.

Question: What effect does using 22 Km as the ozone layer height have on the measurements? Answer: The use of 22 Km for the height for the ozone layer will need to be reviewed as it may not be accurate enough for high-latitude stations using measurements at large solar zenith angles (SZA). It is also an issue for aerosol optical depth measurements. Currently, 5 Km is being used as the layer height for air and aerosol and this is not an accurate enough approximation a large solar zenith angles.

Question: Were the wavelengths chosen specifically for ozone absorption? Answer: The approximation wavelengths were chosen to minimise changes in the ozone with regard to wavelength shift.

Question: Does the Dobson have this problem? Answer: Not to our knowledge.

4.1 25 Years of Satellite & Ground-based Total Ozone Comparisons: What we have learned and what issues still remain? (G. Labow)

G. Labow of the NASA-Goddard Space Flight Center (GSFC), USA began with a TOMS image from 1983 (Figure 11) giving a brief history of the discovery of the ozone hole by reflecting on how the two communities (satellite and ground-based) were not in agreement. The 2001 EP_TOMS data were displayed that indicated a major mirror degradation (cross-track bias problem) that was detected by observing the differences with the ground-based data.

Figure 11: TOMS image from 1983 showing the beginnings of the ozone hole development.
Further, differences observed in terms of cloud/snow reflectivity problems related to the retrieval algorithm were removed in the TOMS Version 8. In a comparison of 30 Northern Hemisphere stations versus EP-TOMS shows that up to January 2002, the data sets compared well. However, after that there is a degradation that may be related to the diffuser, but each wavelength is degrading at different rates. A SZA correction was applied that helped reduce these differences. This is illustrated in Figure 12a,b. The composite of different TOMS instruments was shown and the first data from the OMI charge-coupled device spectrometer.

![Figure 12a,b: Comparison of non-corrected (a) versus SZA corrected data (b) with N-16 SBUV.](image)

The main foci of the “first 25 years” were:
- An iterative process correcting instrument and/or algorithm problems;
- Satellites- Series of TOMS & SBUV's 1978 to Present:
  - Cloud vs. Snow/Ice Corrections;
  - Cross-track biases;
  - Instrument (EP-TOMS) degradation;
- Ground-based instrumentation-Dobson & Brewers:
  - Airmass dependences;
  - Stray light effects;
  - a-priori assumptions;
  - Station-to-station comparisons using TOMS as a transfer standard.

So what is left to do? The new focus is on the Brewer – Dobson comparison. Examples from Hohenpeissenberg, Uccle and New Delhi were presented. The New Delhi data showed quite a noticeable difference. The slopes of the difference were then plotted against latitude. The plenary session attendees were asked for some ideas. Suggestions ranged from effects of Aerosol Optical Depth (AOD), airmass to tropopause height. Labow contends that the accuracy of the climatology is adequate, but leaves open the possibility that it could still be a problem?

Finally, a description of some hardware changes to Brewer #171 such as the new entrance window and depolarizer were presented. Now residual polarization <2% for all wavelengths. Some enhancements were described as well as some new routines developed at GSFC such as:
- Improved Total Ozone measurements.
- Improved SO$_2$ Measurements ($6 \lambda$).
- NO$_2$ retrievals.
- UV Aerosol retrievals.
- DS AOD at 18 wavelengths.
- 60 & 70 SZA almucanter.
• Principle plane (every 45 min).
• Variable field-of-view DS for forward scattering.
• ZS at 18λ without polarisation (compare to R/T).
• Sun Search routine to center sun in FOV.
• ZS during Umkehr measurements.

In conclusion, a suggestion of a future “for all data” includes satellite retrievals (determine the source of total ozone dependence, maintain long-term calibration, improve retrievals under cloudy conditions), ground-based retrievals (study airmass dependence, polarization effects, stray light and forward scattering effects, iteratively de-convolve SO2 from ozone, expand the scope of the Brewer beyond O3 and UV and add SO2, NO2, Aerosols etc. to help with the validation of the new generation of hyper-spectral, space-based instruments. An inter-comparison suggestion was made. An intercomparison should be done where ozone is NOT 310-340 DU.

P. Eriksen made a comment that at high SZA angles, very small things can be very important, such as the ZS calculation within the operating software. There are differences in the Brewer ozone to TOMS at high sun angles especially with single Brewers. Fioletov suggested that some of these differences are probably real.

4.2 Analysis of 25 years (TOMS+Brewer) Total Ozone Data over the Iberian Peninsula (J.L. Camacho)

J.L. Camacho from the National Meteorological Institute of Spain (INM) began with a list of objectives of the ozone programme in Spain. The suite of data and instruments were presented:

• Baseline for total ozone levels over Iberian Peninsula and basic statistics to reference ozone minimum cases in the future.
• Daily and seasonal behaviour.
• Spatial relationships between peninsular Brewer sites.
• Compare Brewer and TOMS total ozone data.
• Quality control for Madrid ozonesoundings.

In addition, several TOMS satellite data sets were examined: Nimbus-7, Meteor-3 and Earth-Probe. Initially, version 7 TOMS data were examined, but later comparisons with Version 8 showed significant differences. Ozone soundings from Madrid (1992-2002) and Brewer spectrometers running in Madrid (1993-2002), Murcia (1995-2002), La Coruña and Zaragoza (both only 2002) make up the suite of ground-based instruments within the INM network. Data comparisons with TOMS were made form 1978-1993 with these five continental sites which included the Madrid and Murcia sites, plus El Arenosillo, Lisbon, Portugal, Mont-Louis, France and one from Tenerife, Canary Islands. It is important to note the altitude effect for the Madrid and Mont-Louis series because the total ozone amount will be systematically lower than the other stations. For Madrid, the correction was estimated to be 2-3 DU and 7-9 DU for Mont-Louis.

Mean differences from the median values for the peninsular stations were 5-6 DU versus only 2 DU for Izaña. This is likely the result of the probability distribution not matching a normal (Gaussian) distribution. Daily average analysis made for each Julian day show a great variability for the individual values and for the consecutive days giving a noisy figure. These daily values showed significant diurnal variation. Spatial distribution issues over the Iberian peninsula were also shown.

A comparison of TOMS Version 7 and 8 was presented with the following factors considered:

• Sunglint correction.
• Aerosol correction.
• Murcia site was 200 km to the East v.7.
• Improvement in summer.
• GHOST has been smoothed.

Also a comparison with the Brewer instruments and the E-P and Nimbus-7 TOMS data were presented and is illustrated in Figure 13. The plot shows that the Brewer seems to underestimate the ozone at the seasonal maximum in early spring as compared to the TOMS data.

![Figure 13: Brewer data compared with E-P and Nimbus-7 TOMS data.](image)

A brief presentation of the ozonesonde programme completed the presentation. In conclusion:

1. Satellite ozone data show a variable throughout the along year and day. Comparison and evaluation of total ozone coming from different sources justifies the existence of spectrometer networks in order to know and study its regional behaviour and for satellite data validation purposes.

2. This work establishes the total ozone levels for Madrid. The annual maximum in two-weekly averaged ozone for the whole of the Iberian peninsula occurred during the April second fortnight. The annual minimum occurred during November. Using the TOMS series from Madrid, a gradual fall in averaged values was observed during the 1980’s TOMS ozone levels are lower than the Brewer measurements and this agrees with WMO information.

3. Ozone sounding data supply a primary information source about the vertical ozone atmosphere distribution. The study made using Madrid data shows that the seasonal ozone behaviour is similar at mid-latitudes. The vertical ozone profiles evolution in the course of the years analysed seems to indicate a minimum ozone amount in autumn, the season where the amount of stratospheric ozone is least.

4.3 Comparison of Brewer and Recent Satellite Total Ozone Observations at Selected Northern Hemisphere, Mid-high Latitude Stations (K. Vanicek)

Vanicek began his presentation by outlining the work plan and objective of the study: a Northern mid-latitude, long-term trend analysis using a homogenization of the 40-year record of total ozone observations of Hradec Kralove using Dobson, Brewer and satellite observations. The
objective was to see if a combination of different data sets introduces an instrumental signal into decadal total ozone trends and to follow up previous studies:

- WMO/GAW Report No. 149, Geneva, 2003 (Staehelin et al.).

The question of seasonal variations of differences between Brewer and satellite observations were investigated through several data sets by examining the daily averages of DS total ozone observations taken on the same days. Two satellite data sets were used: TOMS-V8 and GOME-WFDOAS. These data were compared to Dobson and Brewer instrument data from Hradec Kralove, CHMI as well as Brewer data from Sodankyla, Finland and measurements from the Brewer instrument at Tromso/Andoya, Norway.

The 1996-2004 study of the Hradec-Kralove, Brewer and Dobson data compared to the satellite data yielded the following results.

The satellite minus Brewer showed:

- Seasonal differences negligible for GOME.
- Seasonal differences evident for TOMS.
- Shift of TOMS data after 2001 confirmed.
- Seasonal course below 1% for GOME.
- Seasonal course 1-3% in winter for TOMS.

The satellite minus Dobson showed:

- Seasonal differences negligible for TOMS
- Seasonal peaks of differences for GOME.
- Shift of TOMS data after 2001 confirmed.
- Seasonal course below 1% for TOMS.
- Seasonal course 1-2% in winter for GOME.

Thus, the conclusions for Hradec Kralove were:

- The Dobson data fit better with TOMS observations than with GOME measurements.
- The Brewer data agree better with GOME observations than with TOMS measurements.
- Does the reason come from the satellite algorithms?

Next, the question of how well the Brewer instruments compared with satellite at high latitudes was presented. The yearly differences for the years 1997-2003 were investigated. And the conclusions were:

- Very good fit with GOME for all stations and the whole period.
- Good agreement with TOMS till 2001, then a big shift at all stations.

In addition, the conclusions for the Sodankyla and Tromso/Andoya sites were:

- Better agreement between GOME and Brewer observations at both stations.
- For TOMS a 1-3 % shift appears, probably due to technical problems after 2001.
- How well do GOME and TOMS agree with each other?

In conclusion, a plot of the TOMS-V8 minus GOME-WFDOAS along with ground-based data from Hradec Kralove, Sodankyla, and Tromso/Andoya for the years 1995-2001 was shown and discussed. Refer to Figure 14.
P. Eriksen commented that the Brewer measures more ozone for lower sun angles, at least in the arctic where the air is clean. One can measure up to μ 5 or 6 (if the ozone is not too large) with a MKIII and even a MKII can measure it. There is still a problem with the airmass calculation at larger SZA. M. Allaart commented that GOME may have corrected for temperatures whereas the measurements from other instruments are sensitive. Vanicek replied that Jim Kerr had proven that the Brewer temperature problem had been resolved. Likely GOME is temperature independent and the next release will confirm this point. McElroy also commented that the B-P temperature dependence is not quite correct and will lead to errors at extreme temperatures. Slight changes in wavelength settings can cause differences in the temperature dependence from one Brewer to another. The seasonal effect is likely contributed by instrumental stray light.

4.4 Two Decades of Brewer Operation at Hohenpeissensberg (U. Köhler)

U. Köhler from the German Weather Service (DWD) presented a two-decade review of the Brewer operation at the Hohenpeissensberg site.

Only direct sun measurements were examined and there were many days (~20) per month where DS observations were possible and after the DWD halted weekend and holiday observations, only 15-20 days were collected for Dobson. Improvement of measurement frequency was done by creating a Dobson & Dobson normalized - Brewer total ozone record. This required a two step process. The first step was the determination of a correction coefficient c using a simple linear regression function:

\[ c = a + b \times \mu \]

where \( c = (\text{TOCDob-TOCBrew})/\text{TOCDob} \) for all simultaneous observations in each individual month. The second step was the calculation of a Dobson-normalized Brewer total ozone value:

\[ \text{TOCBrewnorm} = \text{TOCBrew} + c \times \text{TOCBrew} \]

Both Dobson and Brewer data sets were combined in order to gather a larger number of days of observations per month. "Mini ozone holes have been observed during the late winter and
early springtime of late. Figure 15 depicts this effect. Also, the new TOMS version 8 data, at least for Hohenpeissenberg, is not considered an improvement as seen in Figures 16a,b,c.

In summary,

1. The Brewer is a valuable addition to the total ozone monitoring network.
2. Versatility and automated operation of Brewers complements the long-term stability of the Dobson’s.
3. Two independently calibrated systems like Dobson and Brewer provide excellent data sets for satellite validation.
4. But even long-term records of more than 20 years are not sufficient for reliable trend analyses.

Both Dobson and Brewer operation will continue at Hohenpeissenberg in hopes of providing high quality data that in the future will combine the advantages of both systems.

A final comment suggested that because Hohenpeissenberg sits on the top of a mountain where there is snow and the surrounding TOMS footprint would see the lower levels where snow
does not exist, reflectivity problems may be introduced because it does not take the snow-free region into account.

5. PLENARY SESSION II: ULTRAVIOLET STUDIES

Tutorial: Brewer UV Measurements (V. Fioletov)

To access a copy of this presentation, refer to the WOUDC-BDMS web site topics list: either Tutorials or Meetings/Delft. The BDMS web site is:

http://www.woudc.org/bdms/index_e.html

Following the tutorial a question and answer period occurred.

Question: Have you investigated the cause of the spikes? Answer: possibility the Photomultiplier (PM) tube, but McElroy commented that it may be a communication error. Someone suggested it may be cosmic rays, but this would only affect one wavelength.

5.1 Modelling UV Index in Hong Kong (T.K. Chan)

T. K. Chan from Hong Kong University gave a presentation on the modelling of UV in Hong Kong. He has used a modified Canadian UV regression expression by adding an AOD portion, one for AOD < 0.8 and one for AOD >0.8. He displayed several time series for several different AOD values. Clear-sky days were used for testing and he explained the rational behind the classification of “clear sky” days.

Clear Sky Day = True IF (A > 95% AND B > 70% AND C < 2%)

Where:

A is the number of 'measured' / ideal number of DS scans for that day (where 'measured' are DS scans not aborted due to clouds suddenly moving across the sun);

B is the number of 'good' / the number of measured DS scans (where 'good' is defined as those scans having a standard deviation of ozone variation < 2.5 DU);

C is the TOMS reflectivity.

Cloud types were also considered and their respective transmission amount as was the effect of rain. Results from February 2004 were shown and are depicted in Figure 17. TUV is a radiative transfer model.

![Figure 17: Plot of measured and modelled UV data for Hong Kong, February 2005.](image-url)
Question: How are the optical depths being measured? Answer: Using the AOD from the 300 and 320nm.

Question: How is the instrument calibrated? Answer: It has been calibrated by IOS six times since 1995.

Question: What is the rapid increase after 2000? Answer: Likely the change in industry in Hong Kong.

5.2 Ozone and UV Monitoring in the UK (J. Rimmer)

J. Rimmer from University of Manchester (UManchester), UK presented an overview of the ozone and UV programme at the university. In the past, the UK Met Office (UKMO) was responsible for the measurement and analysis of ozone data. Today there is now a consortium headed by the Department for Environment, Food and Rural Affairs (DEFRA) consisting of the UK Net Centre (NetCen), UKMO, UManchester and Imperial College in London. A brief history of the programme and the temporal range of the data series data were presented as given in Table 2. Several changes were reported as well. The Camborne Dobson ozone measurements ceased at the end of 2003. The site was transferred to Reading where Brewer #075 was installed in 2001 and has been calibrated twice (May 2002 and April 2004). The emphasis is on co-location of ozone and UV measurements. Trend analysis will still be viable from Valencia Observatory, Ireland. Brewer #172 was installed at UManchester in June 2000. It was calibrated in May 2002 and April 2004. However, recently it suffered damage as the result of a January 2005 storm and is currently awaiting repair.

Table 2: Ozone and UV measurements in the UK.

<table>
<thead>
<tr>
<th>Location and Parameter</th>
<th>Time Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lerwick ozone</td>
<td>1957 – date</td>
</tr>
<tr>
<td>Camborne ozone</td>
<td>1957 – 1967</td>
</tr>
<tr>
<td>Bracknell ozone</td>
<td>1967 – 1989</td>
</tr>
<tr>
<td>Camborne ozone</td>
<td>1989 - 2003</td>
</tr>
<tr>
<td>Reading ozone</td>
<td>2001 - date</td>
</tr>
<tr>
<td>Manchester ozone</td>
<td>2000 - 2004</td>
</tr>
<tr>
<td>Reading spectral UV</td>
<td>1993 – date</td>
</tr>
</tbody>
</table>

Data from the recent low ozone events which occurred over the UK and northern Europe during the March 2005 was presented next. On the 19th of March the lowest departure of ozone from the long-term mean was observed at both Lerwick and Reading. The Lerwick mean March column ozone was 322 DU, the lowest in the past 25 years. This low is largely explained by tropospheric meteorological conditions, but about 10% is considered a chemical effect. The January to March 2005 data yield an average of 313 DU which is very close to the low of 309 DU recorded in 1996. The polar ozone map given in Figure 18 illustrates this event.

Finally, he briefly discussed UV index forecasting with some emphasis on the alternatives to cloud modification factors. He calculated the UV index from Reading spectral data along with the theoretical clear sky UV index using the TUV (NOAA) radiative transfer model and simultaneous total ozone from Brewer #075. He then calculated the solar transmissivity from observed broadband solar flux. The comparison of the observed to the forecast UV values yielded a correlation factor of 0.94.

Question: What value was the clear sky transmissivity? Answer: The value of 0.9 was used.
Figure 18: Low ozone event over Northern Europe in March 2005.

5.3 Effects of Cloud and Snow Surface on Surface UV Irradiance (J. Kim and B.Y. Lee)

J. Kim from Yonsei University, Korea gave a presentation on the effects of cloud and snow on UV measurements. The motivation for this study is:

1. Clouds, aerosols and surface snow cover affect UV radiation measurements.
2. The effect of aerosol is minimized for the measurements in the Antarctic region.
3. Ground-based measurements of total ozone are still affected by clouds.
4. Can we estimate quantitatively the effect of clouds and snow cover on the spectral measurements in UV?
5. Do clouds and snow cover affect the Brewer measurements of UV and thus ozone?

The objectives were:

1. To study the spectral radiation amplification factor of ozone.
2. To understand the spectral variation of cloud transmission in UV.
3. To understand the effect of surface snow cover on the spectral UV radiation.

A brief history of the ozone and UV monitoring programme in Korea was presented which included the three stations in Korea and one in the Antarctica. There are several instruments including a Dobson, three Brewers, a lidar and ozonesonde throughout these sites. Unusually low ozone values (<90) were shown for the Antarctica (King Sejong) station, where Brewer #122 is in operation, these values were almost twice as low as the TOMS values. Kim admitted that some of these values were the result of an interpolation of points from the rim of the vortex to the station location. Cloud effects were examined and the effects and the errors increased below 300nm. This was observed for snow free surfaces and SZA of 50-70 degrees.

In summary,

1. The agreement between Brewer and TOMS Version 8 is reasonably good at the King Sejong Station in Antarctica.
2. The radiation amplification factor (RAF) of ozone shows a peak at 295 nm - 300 nm and decreases as the wavelength increases. As the cloudiness increases from clear to overcast. The RAF decreases from 7.7 to 2.7 accordingly.
3. The transmission of clouds shows distinct difference ranging from 10 to 80 % for a SZA of 60 degrees. The attenuation of radiation for cloud conditions is highly variable. Surface snow cover affects the transmission additionally. For further study, measurement of cloud optical depth and cloudiness are desirable.

4. EUV irradiance is enhanced when the ground is covered by snow because of multiple reflections between the ground and the atmosphere. On clear-sky days the enhancement is about 50% at 300 nm for 50º SZA.

Hare commented that the unusually low ozone values reported in 2000 seem to correlate with the high snow/cloud reflectance values. Fioletov added that the zenith sky algorithm does not work near or in the ozone hole. This is due to significantly different ozone vertical profiles during the ozone hole event. With additional snow on the ground it will make this effect even worse.

6. PLENARY SESSION III: NEW METHODS, TECHNOLOGIES AND ALGORITHMS


To access a copy of this presentation, refer to the WOUDC-BDMS web site topics list: either Tutorials or Meetings/Delft. The BDMS web site is: http://www.woudc.org/bdms/index_e.html

Following the tutorial a question and answer period occurred.

**Question:** Is the factor that you can open the iris up to, about 3? **Answer:** Yes.

**Question:** Mode-1 is this used for the moon? **Answer:** Yes, but also for low sun angles. It can be programmed in the schedule like any other routine.

**Question:** Will the Hg test fail if it is out of focus? **Answer:** In principle yes, but most instruments will not be that badly away from the optimal position. The micrometer is moved in units of 10 steps and tests against the stored image by correlation ... it then interpolates the between the step positions to find the best point. **The one thing that goes wrong that really affects the ozone value is if the wavelength shifts.** There are 0.007 nms per step.

**Question:** Whose ozone cross-section absorption coefficients are being used? **Answer:** Bass and Paur. As a community we may need to change this, but for the Brewer this is not a practical issue at the moment.

**Question:** With all the problems with the nickel-sulphate filter, will it be replaced? **Answer:** Yes, we have investigated this with a research optical company but it is quite a complex procedure and so we have not had much success.

**Question:** Which line from the mercury lamp is used? **Answer:** This is done on the double doublet, the temperature of the discharge and the age of the lamp can affect this. Savastiouk added the HG routine has been changed to accommodate any shifts when a lamp is replaced.

6.1 Ozone at High Latitude and High SZA: what μ? (P. Eriksen)

P. Eriksen of the Danish Meteorological Institute, Denmark presented the effects of measuring ozone at high latitudes with an introduction into the Sondestrom station, Greenland. When comparing TOMS (version 7 & 8) to the Brewer data there is a slight shift between the v7 to v8 with a seasonal variation. This is was similar to the Czech results, although the Czech results were normalized to a different point. The Brewer ozone values are higher than those derived from TOMS v.7 for large SZAs, yet less then TOMS v.7 during the summer. Similarly, the Brewer ozone values are higher than those derived from TOMS v.8 for large SZAs, however, the values remain higher then the TOMS v.8 data during the summer thus producing less pronounced seasonal variation. Thus, the Brewer #053 data as compared to TOMS v.8 gives better seasonal agreement than TOMS v.7. In addition, Brewer #053 is not the only Brewer that measures higher ozone than TOMS for large SZAs.
So why is this observed? Are the Brewer SZAs calculated correctly? The instrument tracks the sun well, so this is not the problem. So, is the $\mu$ value calculated correctly or is it a stray light feature in the MKII? Is there a stratospheric temperature effect?

In comparing the method for SZA determination, the Dobson approximation does not take into account the refractive index of the atmosphere to that at the ground. It seems that we should use the apparent SZA instead of the true SZA. This is taken into account by the tracking software, however what about the $\mu$ values? The Brewer uses different values from those of the Dobson. Thus, the values at 19km are slightly different from those generated at 22km. Refer to Table 3.

**Table 3:** The height of the ozone maximum versus latitude. The 22km height is used because it is centred over mid-latitudes.

<table>
<thead>
<tr>
<th>lat</th>
<th>± 0</th>
<th>± 10</th>
<th>± 20</th>
<th>± 30</th>
<th>± 40</th>
<th>± 50</th>
<th>± 60</th>
<th>± 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>26</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
<td>21</td>
<td>20</td>
<td>19</td>
</tr>
</tbody>
</table>

The Brewer software calculates the $\mu$ value from the true SZA instead of the apparent. After examining this, it runs out that the use of the apparent $\mu$ value still yields approximately the correct $\mu$ and so the seasonal effect still exists and thus it is difficult to correct for. What’s the implication at Kangerlussuaq (67N) – using $h = 19$ km rather than 22 km? Table 4 shows the different $\mu$-values for various SZA’s.

**Table 4:** $\mu$ values compared with SZA for heights 19 and 22 Km respectively.

<table>
<thead>
<tr>
<th>$\mu$-values</th>
<th>SZA</th>
<th>22km</th>
<th>19km</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>2.885</td>
<td>2.892</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>3.772</td>
<td>3.787</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>5.456</td>
<td>5.505</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>5.983</td>
<td>6.049</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>6.615</td>
<td>6.706</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>7.382</td>
<td>7.509</td>
<td></td>
</tr>
</tbody>
</table>

In conclusion, the v.375f calculates SZA correctly, but calculates $\mu$ incorrectly. By chance this does not explain the seasonal difference between B53 and TOMS. One suggestion is to have everyone use the same layer height according to latitude (as for the Dobsons) and change the calculation of $\mu$ in v.375f.

**Question:** It seems not to make as much a different at your station, but does it make any different elsewhere? **Answer:** Yes, at even higher latitudes or sea level equatorial stations.

### 6.2 New Brewer Algorithm for a Single-Pair (I. Petropavlovskikh)

Irina Petropavlovskikh of NOAA, USA began with a brief history of the Brewer and Dobson Umkehr algorithm developments.

- Brewer data at Arosa station since 1988 along side of Dobson.
- Zenith-sky measurements at 10 wavelengths, between 70 and 90 SZA.
- Ozone profile RT: T. McElroy algorithm, similar to Dobson Umk-92, but for three pairs (“short Umkehr” technique by J. DeLuisi).
- Difference between Dobson and Brewer ozone profiles.
- New algorithm developed for Dobson Umkehr at C-pair measurements (UMK04).
The new algorithm is mostly optimized to study monthly mean anomalies (MMA) or trend in the data. The a priori profiles have no impact on the MMA, which are influenced only by the MMA of the radiances. The algorithm is more linear, hence it preserves the probability distribution function of the layer ozone which could otherwise bias the monthly means. The measurements are given more weight than in the UMK92 algorithm, which improves the information content, particularly in the lower layers.

Trend analysis was performed comparing the UMK92 versus UMK04 algorithms with a better agreement with the “expected” profile. Figure 19 shows this comparison.

![Figure 19: Comparison of the UMK92 to UMK04 algorithms.](image)

The Brewer retrieval algorithm is based on the following elements:

- Dobson UMK04 is modified for Brewer single pair measurements (310 and 326 nm).
- New multiple scattering tables and Jacobians.
- New refraction corrections.
- Measurement noise is half of Dobson.
- Still has no cloud detection capabilities.

By using the Dobson data to screen Brewer data for clear sky conditions, this was to account for the lack of information provided by the Brewer instrument. The averaging kernels were shown to compare with those of the Dobson. These show that the retrieved amount at one level also depends on the amount in the adjacent levels.

A study was done, using synthetic ozone profiles to simulate Dobson and Brewer measurements. This also incorporated statistical noise (0.25 N-value). The profiles were retrieved by using the same inverse model and then results were compared to the synthetic data.

Next a test data set from Arosa was used. The approach was to use a single wavelength pair from Brewer data from the years 1988 to 2004. The data were chosen to be co-incident with Dobson measurements to assure the elimination of clouds. The retrieved profiles were compared against the Dobson record (about 1500 measurements) and with SBUV results.

The time series examined layer 8 where ozone recovery would be expected to be observed. Also, layer 0 +1 (approximately the first 10 kms) were analysed. The SBUV comparison with Arosa Dobson data was done as an (SBUV-umk)/avg(SBUV+umk) where similar trends were observed.

In conclusion:

- Brewer algorithm development can improve our understanding of Dobson measurements.
• Dobson algorithm UMK04 was modified to adopt to Brewer Umkehr measurements at 310 and 326 nm.
• Brewer data have more ozone in layers 4-8 and less ozone in layers 0-3 as compared to Dobson.
• Brewer mean ozone in layers 8 and 7 agrees better with SBUV than Dobson.
• Total ozone used in Brewer RT is 2% higher than in Dobson and could cause some differences in retrievals (up to 4%).

Future plans involve:

• Simulate Dobson Umkehrs using Brewer retrieved ozone and assess measurement noise in Dobson data.
• Develop correction procedures to reduce errors from the “internally scattered light” in Dobson measurements.
• Assess profile information contained in other Brewer wavelengths (306, 313, 323, 329 nm).
• Develop methods to screen for clouds in Brewer measurements.

Question: There seems to be a Mt. Pinatubo effect toward the end of 1991 to 1992. Answer: Agreed. At this point it is only a single pair, but if more then one pair is used, then the effect is not as prominent.

Question: Have you compared these Umkehr profiles with those of the ozonesondes from Payerne. Answer: No, but we have noticed that there is a large variability in the lower levels of the sonde profiles so it is a bit of a difficult task since it did not come directly from the station, even though they are near one another. It is in layer 6 is where the differences are seen.

McElroy commented that he was surprised that there was little difference between the aerosol effect on the Dobson and Brewer data.

6.3 Measurements of Nitrogen Dioxide (NO₂) in Washington, DC Using a Brewer Spectrometer (A. Cede)

A. Cede from NASA Goddard Space Flight Center, USA presented the results of NO₂ measurements from Washington, DC. He began with a brief review of the absorption spectrums and the optical depths for the measurement. He positioned the slit mask for the NO₂ spectra and used all 6 slits (wavelengths) in the range 349 to 363 nm.

There are 5 sets of 10 slit mask cycles, which is about half the usual cycle time. A series of plots for O₃, SO₂, AOD and NO₂ was shown along with other data sets (TOMS, OMI, AREONET). The DOAS instrument was described and when measuring NO₂, high SZAs are desired to observe through a long path length. The “Boot strap” method was introduced and discussed. A data set of approximately 5000 points was used initially and after applying an error of <0.2 DU as a selection criterion, the remaining data set was about 2000 points. Within a polluted environment like the Washington, DC area “we lifted the negative data” (i.e. the boot strap method) out of the data set. If data were collected from a cleaner site, then the number of “bad” values would be less.

A comparison of the Brewer data with SCIAMACHY (<200km) looking at daily means and a 30-day-window moving average was then presented. The influence of aerosol absorption was then considered. Why do we get this very high aerosol absorption? Part of this may be caused by NO₂. Re-calculating the aerosol but eliminating the absorption by NO₂, reduced this value. The time of the week and seasonal patterns in the NO₂ distribution were shown. The analysis of uncertainty in the Brewer measurements is presented in Table 5.
Table 5: Uncertainty Levels for the various parameters.

<table>
<thead>
<tr>
<th>Uncertainty (2σ-level)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise (instrument, atmosphere) Old routine</td>
<td>0.1 to 1DU (α 1/m)</td>
</tr>
<tr>
<td>Noise (instrument, atmosphere) New routine</td>
<td>0.1 to 0.4DU (α 1/m)</td>
</tr>
<tr>
<td>Bootstrap selection</td>
<td>0.04 to 0.2DU (α 1/m)</td>
</tr>
<tr>
<td>Stratospheric Background</td>
<td>~0.1DU</td>
</tr>
<tr>
<td>Other atmospheric gases ± 1DU HCHO</td>
<td>~0.04DU</td>
</tr>
<tr>
<td>Other atmospheric gases ± 0.002DU BrO</td>
<td>~0.01DU</td>
</tr>
<tr>
<td>X-sections, temperature</td>
<td>~0.06DU</td>
</tr>
<tr>
<td>Total Old routine</td>
<td>0.2 to 1.0DU</td>
</tr>
<tr>
<td>Total New routine</td>
<td>0.2 to 0.5DU</td>
</tr>
</tbody>
</table>

The "Direct Sun technique is a very useful method to derive daily courses of NO2 in polluted areas."

Question: What do you actually retrieve? Answer: I have 6 wavelengths and I fit 4 parameters, 2 for ozone with a constant and linear term. The remaining strong term is the NO2.

Question: What SCIAMACHY product are you using? Answer: Level 2 overpass data of the selected area within 200 km of Washington, DC.

6.4 AOD Measurements with the Canadian Brewer Network (V. Savastiouk)

Savastiouk presented some results of an updated Aerosol Optical Depths (AOD) calculation. The calculation uses the 5 operating wavelengths with each DS measurement and displays the AOD at slit 5 (320 nm) on screen in real time and saves an AOD summary in to the B-file for easy access.

What is the change? The changes include:

- DS.RTN is updated so no changes to the schedules are required.
- A new routine for characterization of the 'neutral' density filters has been introduced. The routine runs every 5 days on the Canadian Brewer network, but it can be custom fit to each Brewer. The output is used in the AOD calculations.
- The main programme has been changed to output the 320 nm AOD on the screen and to implement the improved method of calculating the air mass factors (only for AOD calculations at present).

Next, what are the requirements?

- Absolute calibration at the operating wavelengths (WO):
  - this can be done either by the Langley plots.
  - or by transferring the calibration from a reference instrument.
  - the calibration values are the absolute ETC for the operating wavelengths.
- A recent dispersion test’s output file (LF-files) to establish the ozone and SO2 absorption at each OW.
- DS commands in the schedule.
- Absolute temperature coefficients.

An example of the AOD constants file is given in Example 1.
Example 1

0 82350 80952 82673 81744 80602
3.1805  1.7963  1.0070  0.6800  0.3740  0.2958
10.0240  6.3764  1.9213  1.8379  0.9919  0.5487
32103  9  1   1  3 49836  +32 59799   +0 60039   +0 60337  +18 59626  +26 58466   +0 2   3  3
4531 +12 4534 ...

The file has more records: 36 records with std. in total (6 positions of FW2 times 6 slits)
Example 2 illustrates the actual screenshot of the software running one of the triad instruments, Brewer #008, in Toronto.

Example 2

<table>
<thead>
<tr>
<th>DS 03</th>
<th>320.3</th>
<th>322.4</th>
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</thead>
<tbody>
<tr>
<td>ZS 03</td>
<td>322.5</td>
<td>321.0</td>
</tr>
<tr>
<td>DS S02</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>AOD320</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>DUU at 12:26:59</td>
<td>23.7</td>
<td></td>
</tr>
<tr>
<td>SL R6 at 12:02:00</td>
<td>1922</td>
<td></td>
</tr>
<tr>
<td>Last HG at 11:50:23</td>
<td>23°C</td>
<td></td>
</tr>
<tr>
<td>Current temperature</td>
<td>22°C</td>
<td></td>
</tr>
</tbody>
</table>

The software is available upon request.

**Question:** Does the update include the polarization problem correction? **Answer:** No.
**Question:** Are the wavelengths used different from those used in the NO₂ study. **Answer:** Yes, because the wavelengths used for the NO₂ study are larger then those used for ozone.
**Question:** What is the temperature dependence? **Answer:** Approximately 10 units per degree (0.01% per degree).

7. **PLENARY SESSION IV: TECHNICAL ISSUES AND KNOWLEDGE TRANSFER**

7.1 **IOS and the Brewer Community (V. Savastouk)**

Savastouk presented an update of activities at International Ozone Services (IOS) Inc., Canada. IOS also been actively involved in the following areas:

- Operating software developments.
- Data processing software developments.
- Hardware developments.
- Efforts towards better understanding of the UV calibration.
- Brewer calibration database development.

These updates also included recent changes or upgrades to the Brewer operating software. The following list is a brief description of these upgrades.

- Various bugs fixed.
- The following routines now save data in the b-files:
  - HG.RTN, HP.RTN, SC.RTN, DT.RTN, RS.RTN, CZ.RTN and UV (DUV).
- The new HG.RTN calls HP.RTN automatically if MKIII:
  - It will check to test if HP has been just done.
  - It only calls HP if ran from a schedule or a command sequence, i.e. it is still possible to do only HG from the menu.
• QL.RTN now does an SL-type measurement before and after the scan:
  - To track the absolute calibration.
  - To collect info on temperature dependence.
• MAIN programme now calls (HP) HG if instrument reset was required to establish communication.
• GS.RTN collects data on all slits now and the processing software optimizes the GI/GS constants to have the best performance with slit 1 for \( \text{wl}<350 \text{ nm} \) and with slit 5 for \( \text{wl}>350 \text{ nm} \).

Savastiouk finished by inviting the community to send suggestions about how the operating software can be further improved. IOS Inc. can be contacted at either Info@io3.ca or Volodya@io3.ca.

**Question:** What is your policy for distributing the software?  **Answer:** Things are quite new, so once the testing is completed the updates will be available on the IOS web site.

**Tutorial:** Brewer Ozone Spectrophotometer: Mechanical Design Principles  
(C.T. McElroy)

To access a copy of this presentation, refer to the WOU DC-BDMS web site topics list: either Tutorials or Meetings/Delft. The BDMS web site is:

http://www.woudc.org/bdms/index_e.html

Following the tutorial a question and answer period occurred.

**Tutorial:** Analysis of Stray Light in a Brewer Spectrophotometer  
(C.T. McElroy)

To access a copy of this presentation, refer to the WOU DC-BDMS web site topics list: either Tutorials or Meetings/Delft. The BDMS web site is:

http://www.woudc.org/bdms/index_e.html

Following the tutorial a question and answer period occurred.

**Question:** What is the difference between the MKII and MKIV?  **Answer:** A second order versus third order grating.

**Question:** Are you intending to work with the Dobson community and apply the stray light correction as well?  **Answer:** The stray light problems are different and until the Brewer is solved there have been no discussions as yet.

**Question:** Would the model change if analysed on ZS measurements?  **Answer:** Whatever error you see in the Umkehr would likely be small.

### 7.2 Kipp & Zonen and the Brewer Community  
(C. Lee)

C. Lee of Kipp and Zonen B.V., Netherlands described the relationship of the company with the Brewer community by presenting a brief history of how the Brewer manufacturing was moved from Saskatoon, Canada to Delft, Netherlands. He emphasized how this aspect (manufacturing) makes Kipp and Zonen's relationship to the Brewer community different from that of IOS Inc., mostly due to this manufacturing business plan.

Most customers seem interested in measuring UV and UV-B, but not ozone. Thus, the MKIII is the most suitable. Of course, ozone is still an important an integral parameter to be considered.

The main product lines are solar instruments and atmospheric science instruments. Kipp and Zonen is the only company where you can purchase all the instruments to operate a Baseline
Surface Radiation Network (BSRN) compatible station. This also applies to the Brewer community. In both cases, operating as part of a network may not be the primary motivation, but the customers want the “best” product. Moving into the atmospheric science realm is motivated by interest in remote sensing. There are “synergies” of the Kipp and Zonen product line with the Brewer instrument. These are:

- Solar Radiation Monitoring.
- UV Index Network Reference.
- Aerosol and Particulate Distribution.
- Total Ozone Column Measurement.
- Ground-truthing satellite data.
- Climate change, global dimming and warming.
- Remote sensing ‘super-sites.

The point was made that production of the Brewer will continue and that Brewer parts will continue to be supplied. Kipp and Zonen, as a manufacturer, is not in a position such as IOS to be able to react quickly to new software upgrades because of testing issues and approval required by the patent holders in Canada. This is quite a different relationship than that of IOS which of course can react more quickly and is not constrained in this manner. He further emphasised the Brewer operating software and hardware updates for the Brewer would be supported by Kipp and Zonen.

A brief discussion took place on the fact that changes to communication ports (from the old RS232 to newer ones like USB or Firewire) is leading to problems. The issue that remains is the communication protocols.

8. POSTER SESSIONS - ABSTRACTS

Retrieval of AODs with the Langley Plot Method from Data of 10 Brewer Spectrophotometers
Anne Cheymol, Hugo De Backer, René Lemoine, Andy Delcloo
Royal Meteorological Institute of Belgium, Belgium

Abstract: The first part of this study is to compare AODs corresponding to individual DS data from a single (#016) and a double monochromator (#178) settled at Uccle (Belgium). Figure 1 presents the results of this comparison on 8428 individual data points. The AODs from these 2 instruments are well correlated and there is no offset between the data from these 2 instruments. The 2 instruments at Uccle measure similar AODs. The method was also applied to 8 Brewer spectrophotometers at different sites all over the world. Three geographical classes were arbitrary chosen:

- High latitudes sites: Belgrano (Antarctica), Resolute Bay (Canada) and Norrkoping (Sweden).
- Middle latitude sites: Toronto (Canada), Uccle (Belgium) and Arosa (Switzerland).
- Low latitudes sites: Yonsei (Korea) and Petaling Jaya (Malaysia).

Some conclusions stood out from this preliminary study. There is a clear seasonal cycle at Uccle (Belgium), at Resolute Bay (Canada), at Norrkoping (Sweden) and at Seoul (Korea) with a large amplitude of about 0.5. On the contrary, at Toronto (Canada) and at Arosa (Switzerland), there is no seasonal cycle and the amplitude of AODs is very low, of about 0.2 for these stations. Highest values of AODs are in low latitudes and the lowest ones are in the high latitudes sites.

Quality of the Ground-based Total Ozone Network over Europe: Implications for Searching for the Ozone Recovery
Bonawentura Rajewska-Więcek, Janusz W. Krzyścin, Janusz Jarosławski,
Institute of Geophysics, Polish Academy of Sciences, Poland
Abstract: The first stage of ozone layer recovery, i.e. the lessening of the negative trend, has been found over Europe (Krzyścin et al., 2005). It seems possible that the increase of the ozone mean level since 1994 of about 1-2% is due to superposition of “natural” processes. Comparison of the total ozone ground-based network (the Dobson and Brewer spectrophotometers) and satellite (TOMS, version 8) data over Europe shows the small bias in the mean values for the period 1996-2004, but the differences between the daily ozone values from these instruments are not trendless. That may hamper the identification of the next stage of the ozone recovery over Europe.

Total Ozone Observations with Spectrophotometers at Uccle (Belgium)
Hugo De Backer, Anne Cheymol and René Lemoine
Royal Meteorological Institute of Belgium, Belgium

Abstract: At Uccle (50°48’N, 4°21’E) total ozone has been observed with different spectrophotometers. Dobson spectrophotometer #40 was in use since 1971. In 1983 a single monochromator Brewer (#016) was installed. In 2001 a double monochromator Brewer (#178) was put into operation. Quasi-simultaneous direct sun observations are compared (not shown here). To get an idea of the relative behaviour of the different instruments on a longer time scale the running annual means were examined. Based on the frequency of observations with the different instruments, a total ozone time series can be composed with the Dobson #40 data from 1971 until the end of 1989, and Brewer #016 data from 1990 onwards.

Difference of Total Ozone Measurements between Dobson and Brewer MKIII Spectrophotometers in JMA Network
Mahito Ito and Koji Miyagawa
Japan Meteorological Agency, JMA, Japan

Abstract: In atmospheric ozone monitoring careful data quality control plays an essential role for correct analysis and evaluation of the long-term ozone trend. In this connection, the first WMO summary report on the comparison of total ozone measurements of Dobson and Brewer spectrophotometers (WMO: 2003) says that the simultaneous operation of Dobson and Brewer instruments at the same station is highly recommended to improve the reliability of the total ozone measurements of the station. A problem in this measurement redundancy, however, is the present situation that no officially authorized calibration mechanism exists for Brewer, while Dobson is standardized in the solid calibration hierarchy established by the GAW/WMO. As an approach to this problem in the Brewer MKIII UV observation network of the Japan Meteorological Agency (JMA), we have developed the calibration system for Brewer DS O₃ measurement on the basis of the total ozone comparison between Dobson and Brewer performed under the most appropriate clear atmospheric conditions. For Brewer DS SO₂ measurement, which is needed to evaluate the influence of SO₂ on the Dobson total ozone measurement, a field Brewer MKIII traceable to one of the Brewer standards maintained by the Meteorological Service of Canada (MSC)/ Kipp & Zonen was used as the working calibration reference for other field Brewers. The Japanese Brewer MKIII UV observation network is run concurrently with the Dobson ozone network comprised of Sapporo, Tsukuba, Kagoshima, Naha, and Syowa Antarctica (Figs.1 2, and 3, Photo.1). These overlapped networks continue to store quasi-simultaneous total ozone comparison data as well as SO₂ since 2002. Long-range data accumulation into the future with these networks is expected to offer valuable data set to further enrich the understanding of the difference between Dobson and Brewer, which will lead to more accurate and sensitive ozone trend monitoring at these stations.

Routine Observation of Reflected Spectral UVB at the Ground Surface using Modified Brewer MKII Spectrophotometer at Tsukuba, Japan
Mahito Ito
Japan Meteorological Agency, JMA, Japan

Abstract: A modified Brewer spectrophotometer and the calibration method for observing reflected
spectral UVB on the ground surface were developed at the Aerological Observatory, Tsukuba. In this paper, the details of the Brewer modification for use at reverse position, the calibration procedure to ensure the instrument factors of modified Brewer at reverse position, and the results of spectral UVB reflectivity measurement of the ground under some typical surface conditions in winter season are presented. Using the modified Brewer system reflected spectral UVB measurement of the grass field was made from December 2003 to January 2005 to characterize the seasonal variation. The measurement was carried out in parallel with the routine global UVB observation on the rooftop.

**Improved Entrance Optics for Global Irradiance Measurements with a Brewer Spectrophotometer**

*Josef Schreder*
*Calibration Measurements Software Solutions, Austria*

**Abstract:** A new input optic for measuring the spectral UV irradiance with the Brewer spectrophotometer was first installed in 2002 in a MKIII, serial number 163. The system provides considerably improved measurement accuracy in comparison with traditional flat input optic. The direct cosine error of this system is less then 5% for incidence angles between 0 and 80 degrees. The integral cosine error for isotropic radiation is less then 2.4% with an uncertainty of +/- 1%. This system was replaced in 2004 by the further improved and now commercially available system UV-J1015.

**Thirteen Years of Measurements by Brewer #067 at Rome**

*G.R. Casale, N. Bono, A.M. Siani*
*University of Rome “La Sapienza”, Italy*

**Abstract:** Brewer MKIV #067 has been working continuously since January 1st 1992 at Rome (41.9°N, 12.5°E). Its position in the city centre (60 m a.s.l.) is essential for characterizing the urban environment. More than thirteen years of O3, SO2, NO2 and UV (290-325 nm) data are now available. Routine tests and checks are carried out to guarantee the accuracy and quality of observations (Casale et al., *J. Geophys. Res.* 105, D4, 4895-4901, 2000). The database needs continuous inspection and this is achieved by running software tools on site and making comparisons with the Brewer modified MKII #024 (Vigna di Valle, 50 km apart from Rome) and the Brewer MKIV #066 (Ispra, 45.8°N, 8.6°E, 240 m a.s.l.). TOMS data are also used as an additional reference. Results of statistics on Brewer #067 O3 and UV data up to December 31st 2004 are reported. The distribution of UV measurements versus solar zenith angle is presented: the peak in the number of spectral measurements occurs at 66°. The time sequence of daily total ozone from 1992 to 2004 is plotted together with the climatological reference pattern of the Vigna di Valle long time series: the lowest ozone value (221.4 DU) in the series was observed at the end of November 2000 (Galliani et al., *Opt. Eng.* 41(2), 3082-3089, 2002), the highest one (500.5 DU) on February 2nd 1999. The measured daily UV index around 11.00 UTC is reported, too. Ultraviolet data were used to build maps of ambient irradiances over Italy (Meloni et al., *Photochem. Photobiol.* 71, 6, 681-690, 2000) and for comparisons with different instruments, such as a multi-channel moderate-band radiometer (Di Menno et al., *Rad. Prot. Dos.* 102, 3, 259-263, 2002). Recently, NO2 data were compared to GOME satellite retrievals (Francesconi et al., *Il Nuovo Cimento*, 27C, 4, 383-392, 2005).

**Aerosol Optical Depth in the UV Spectral Region at the Italian Brewer Stations**

*P. Sellitto¹, A.M. Siani¹, A. di Sarra², J. Groebner³*

¹University of Rome “La Sapienza”, Italy
²ENEA, Italy
³Physikalisch-Meteorologisches Observatorium, Switzerland

**Abstract:** Several studies have pointed out the important role of aerosols in the Earth’s atmosphere and their impact on global climate. Few long-term series of aerosol optical properties
are available and there is no satisfactory worldwide spatial coverage. Recently methodologies that allow the retrieval of aerosol optical depth (AOD) from Brewer direct sun measurements in the UV and visible regions have been developed. Here an improvement on the Langley plot calibration method is presented and applied to the Brewer stations of Rome (#67) and Lampedusa (#123). A comparison between the AOD retrieved values at 320.1 nm and MFRSR and AERONET CIMEL data is also presented. In addition, AOD values from Brewer #066 at Ispra are presented, giving a nationwide overview of AOD measurements at the Italian Brewer stations.

A Portable Device for Characterizing the Angular Response of UV Spectroradiometers
A. Bais1, S. Kazadzis1, K. Garane1, N. Kouremeti1, J. Gröbner2, M. Blumthaler3, G. Seckmeyer4, A.R. Webb5, T. Koskela6, P. Görtz7, J. Schreder8
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4University of Hannover, Germany
5University of Manchester, United Kingdom
6Finnish Meteorological Institute, Finland
7National Institute of Public Health and the Environment (RIVM), The Netherlands
8CMS – Calibration Measurement Software Solutions, Austria

Abstract: This paper introduces a device that was developed for measuring the angular response of UV spectroradiometers in the field. This device is designed to be used at the operating position of the spectroradiometers, thus the derived angular response includes also any effects from imperfect levelling of the diffuser, and corresponds to the actual operational angular response. The design and characterization of the device are presented, as well as results from its application on 11 different spectroradiometers that operate at different European UV stations. Various sources of uncertainties that were identified result in a combined uncertainty in determining the angular response which ranges between about 1.5% and 10%, depending on incidence angle and the characteristics of the diffuser. For the 11 instruments, the error in reporting the diffuse irradiance ranges between 2% and -13 %, assuming isotropic distribution of the downwelling radiances.

Effective Temperature of Ozone Layer Using Spectral Data
R. Stübi
MeteoSwiss, Switzerland

Abstract: The differences between Dobson and Brewer spectrophotometers have been observed since the beginning of the coincident measurements. The causes of the differences have been analysed in many publications and the temperature of the stratospheric ozone certainly contributed to this effect. Presently no change can be implemented in the data processing since no method is available to get the so-called effective temperature. In this study, an attempt is made to evaluate this parameter from the spectral data of the Brewer.

Revision of the Historical DS data Observed by Using Brewer#054
Zheng Xiangdong, Qi Donglin
Chinese Academy of Meteorological Sciences, P.R.China

Abstract: All the daily summery SL test (29790-36504) results show that Brewer #054 has two periods with high frequency of large temporal variations of SL tests. The first period is before April 1999 when an aging UV filter was used for the instrument; another period is in 2001 when the motor driving FW#2 was not working well. Individual abnormal SL test results often occurred on the day when the instrument just recovered operation after it had been out of operation for at least 10-days in the first period, while the case occurred when the SL was scheduled to run at SZA larger than 100 degrees in the second period, particularly in the summer of 2001. The individual abnormal SL test in each B file was manually eliminated and the revised time series of daily
summery R6 results suggest that Brewer#054 works in a stable status after the UG 11 filter was replaced.


McElroy thanked the local hosts at Kipp and Zonen for their participation and organization of the meeting. In particular, he thanked Ben Dieterink, Els Schinkel, Martin Veenstra and Kristian Boot. Anyone who was willing to host the next meeting (the 10th workshop) was encouraged to contact McElroy with his or her proposal.

****
## List of Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation1</th>
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Group Photo of Participants at the 9th Biennial Brewer Workshop, Cabaux Atmospheric Research Facility, The Netherlands.
9th Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting

(Delft, The Netherlands, 31 May - 3 June 2005)

Final Agenda

Tuesday, May 31, 2005

09:00-09:30 Welcome by Meeting Chairman (C.T. McElroy) and by the Local Hosts (Zipp and Zonen: B. Dieterink et al.)

09:30-17:30 Plenary Sessions

WMO Session

The Role of Brewer Observations in an Integrated Global Ozone Observation System: GAW and IGACO – L. Barrie
WMO SAG Ozone Report – K. Vanicek

Special Session: The Global Brewer Network, Where do you go from here?

The role of the global Brewer network in ozone/UV trends studies – V. Fioletov
The need for integrated data sets for long term monitoring – C.T. McElroy

WMO Session continued …

The Central Calibration Centre for Brewers- The Brewer reference Triad – V. Fioletov
The travelling standard (Brewer#017) and Data Transfer – V. Savatiouk
Brewer Standard operating Procedures – T. Grajnar
Brewer Data Management System and the WOUDC – E. Hare

Brewer Sub-committee and general business meeting

Draft recommendations to forward onto the SAG Ozone and UV

16:30-17:30 Poster Session

- Comparison of Brewer and Dobson Total Ozone – B. Scarnato, R. Stübi, J. Staehelin and H. Schill
- Development of the adjustment for DS-ZS measurements on INM’s peninsular Brewers (sky-charts) – I. Gomez
- Difference of total ozone measurements between Dobson and Brewer MKIII - spectrophotometers in JMA network – M. Ito
- Routine observation of reflected spectral UVB on the ground surface using modified Brewer MKII spectrophotometer at Tsukuba, Japan – M. Ito
- 14 years of Brewer AOD measurements at Belsk, Poland – J. Jaroslawski
- Total ozone observations with spectrophotometers at Uccle – H. De Backer, A. Cheymol and R. Lemoine
- Improved entrance optics for global irradiance measurements with a Brewer spectrophotometer – J. Schreder
- Total Ozone Over Kathmandu using Brewer Spectrophotometer – B. Dhakal
- Ozone Measurements at Matrouh, Egypt – W. Sharobiem
- Retrieval of AODs with the Langley Plot Method from data of 10 Brewer spectrophotometers – A. Cheymol, H. De Backer, R. Lemoine and A. Delcloo
- Modelling UV Index in Hong Kong – T.K. Chan
- Quality of the ground-based total ozone network over Europe: Implications for searching for the ozone recovery – B. Rajewska-Wiech, J.W. Krzyscin and J. Jaroslawski
- Aerosol Optical Depth In The UV Spectral Region At The Italian Brewer Stations - P. Sellitto, A.M. Siani, A. di Sarra and J. Groebner
- Thirteen Years of Measurements By Brewer #067 At Rome - G.R. Casale, N. Bono and A.M. Siani
- Revision of the historical DS data observed by using Brewer#054 – XD Zheng, DL Qi
- Effective temperature of ozone layer using spectral data - R. Stübi

18:30-21:00  Reception – Hosted by Kipp & Zonen

Wednesday, June 1, 2005

09:00-16:30  **Plenary Sessions**

**WMO Session continued ...**

Regional Brewer Calibration Center – Europe: Results and first test-campaign – A. Redondas
IBERONESIA – A. Redondas

**Session I  Long Term Studies, Trends and Comparisons**

**Tutorial:** Ultraviolet Spectrophotometers: Principles of operation – I – C.T. McElroy

25 Years of Satellite & Ground-based Total Ozone Comparisons: What we have learned and what issues still remain. – G. Labow
Analysis of 25 years (TOMS+Brewer) total ozone data over the Iberian Peninsula. – J.L. Camacho
Comparison of Brewer and recent satellite total ozone observations at selected NH mid-high latitude stations – K. Vanicek
Two Decades of Brewer Operation at Hohenpeissenberg – U. Koehler

**Session II  Ultraviolet Studies**

**Tutorial:** Brewer UV Measurements – V. Fioletov

Modelling UV Index in Hong Kong – T.K. Chan
Ozone and UV monitoring in the UK – J. Rimmer
16:30-17:30  Poster Session & Concurrent Meeting of the Brewer Regional Calibration Centre for RAVI

Thursday, June 2, 2005

09:00-12:30  Plenary Sessions

Session III  New Methods, Technologies and Algorithms


Ozone at high latitude and high SZA: what μ? – P. Eriksen
New Brewer Algorithm for a single-pair – I. Petropavlovskikh

13:30-17:30  Excursion to Cabauw, Experimental Site for Atmospheric Research

Friday, June 3, 2005

09:00-12:00  Plenary Session

Session III  New Methods, Technologies and Algorithms continued ...

Measurements of Nitrogen Dioxide in Washington DC Using a Brewer Spectrometer – A. Cede
AOD measurements with the Canadian Brewer network – V. Savastiouk

Session IV  Technical Issues and Knowledge Transfer

IOS and the Brewer Community – V. Savastiouk

Tutorial: Brewer Ozone Spectrophotometer Mechanical Design Principles - C.T. McElroy
Tutorial: Analysis of Stray Light in a Brewer Spectrophotometer - C.T. McElroy

Kipp & Zonen and the Brewer Community – C. Lee

Closing of the meeting

13:30-17:00  Tour of Kipp and Zonen facility with a presentation by B. Dieterink followed by a cocktail hour
Report of the 5th Meeting of the WMO Brewer Sub-Committee  
(Delft, The Netherlands, 31 May – 3 June, 2005)

Chairman: C. T. McElroy  
Rapporteur: E.W. Hare

Executive Summary

The fifth meeting of the WMO Brewer Sub-committee was held during a special plenary session of the 9th Brewer Users Group meeting in Delft, Netherlands, 31 May – 3 June, 2005. There were approximately 55 people in attendance.

List of Sub-Committee Members

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Agenda and Discussion Items

1. **NDSC Brewer expert position to be filled**

McElroy opened the discussion about the need for a replacement from the Brewer community to serve as an expert on the NDSC. He mentioned that he has served on this committee for several years and was looking for a replacement. Outcome: no one volunteered to serve on the committee so McElroy will continue in this capacity.

In addition, data exchange issues with NDSC were discussed. Hare mentioned that some of the NDSC ozonesonde data sets had been sent, but there were some outstanding issues such as the most current versions of data and that such exchanges can lead to confusion. McElroy emphasized that it has always been the WOUDC position that data should be first, or at least be...
sent, concurrently, to the WOUDC archive. L. Barrie suggested that the NDSC may be best viewed as a near-real time repository for “preliminary” data, but that all “final” versions (or at least quality-assured versions) be forwarded to the WOUIDC as soon as possible.

2. **Tom McElroy has replaced Jim Kerr on the SAG Ozone**

McElroy announced that since Jim Kerr has retired, he has vacated his position on the WMO SAG Ozone. In the interim, McElroy will be his replacement.

3. **Progress reports**

Updates on the progress of several key reports were discussed.

a. **Brewer Standard Operating Procedures (SOPs)**

T. Grajnar gave a brief overview of the status of the Brewer (SOPs). Many chapters have been written in draft form and that the document is meant to be dynamic in nature and everyone within the community is invited to contribute to the text of the document.

The draft version of the SOPs will be made available from the WOUDC-BDMS web site.

b. **Brewer calibration report form**

Hare gave a brief overview of the status of a proposed Brewer Calibration and Service Report form. The intention is to have this form be available on the web for ease of access and it should take only 10-15 minutes to complete the form following a calibration or maintenance visit. The data would then be stored directly into a calibration database. It is intended to be cross referenced and linked with data reports housed at the IOS web site.

The draft of form is presented in Appendix A.

**Recommendation and Action Item:** send out this report to everyone and solicit responses from those who volunteer.

c. **Brewer web sites**

A brief discussion regarding the various web sites focused mostly on the temporary closure of the brewerinfo.org site. The main point of this discussion item was to determine the best way to deliver the information to the community. The brewerinfo.org issue will be resolved, but in the interim, information will be made available at either the MSC web sites or at IOS Inc. web site.

4. **Update on the US-EPA Brewer network**

P. Disterhoff from NOAA gave an update on the status of the former US EPA Brewer network briefly outlining the plans for these instruments. Highlights of the talk were:

- The original EPA network consisted of 21 sites within the US and its territories
- Six sites have been chosen across the continental United States reduced from the original 21; two of these are from the original network
- The sites were chosen because of local atmospheric conditions and collocation with ancillary instrumentation
• Emphasis of the network will be on the measurement of UV irradiance
• Other measurements may include ozone, aerosol optical depth, NO2 and SO2

The main emphasis of the original EPA network was on UV and this will continue with the addition of air quality issues especially aerosols, but the typical ozone/UV issues will not be the focus as in the traditional Brewer network.

The plan also includes the establishment of a triad along with a travelling standard. The other instruments will be used for extra parts and supporting this smaller network.

For a more complete summary of Disterhoff’s presentation, refer to the 9th Biennial Brewer Workshop Report.

5. Other issues

Discussion about the collection and distribution of calibration information and consistent operating software resulted in a recommendation to the SAG Ozone.

Recommendation to SAG ozone: Establish a set of characteristics that constitute a proper calibration history of each instrument and encourage data contributors to supply this information to the WOUDC so any re-processing of the data, if needed, can be done at the WOUDC which should undertake the development of the required capacity to carry out this task.

Regarding current software issues: V. Savastiouk reported that updates are available from the IOS web site. However, B. Dieterink expressed concern that a new Brewer should be delivered with a standard set of operating software. Another aspect is if a user needs an upgrade or software support, Kipp &Zonen is not in the position to supply such software. Dieterink is willing to make available the operating software version that is considered standard by Kipp & Zonen on the Kipp & Zonen web site. IOS will continue to supply updates on its web site. Savastiouk will report back on a possible collaboration on this issue among IOS, MSC and Kipp&Zonen.

6. Next meeting

Participants were invited to offer to host the next Brewer meeting, tentatively scheduled for approximately two years. A decision will be made within a year to allow time to prepare.
APPENDIX A

BREWER CALIBRATION AND REPORTING FORM

Template of an Abbreviated Brewer Instrument Service and Calibration Report Form

E.W. Hare, V. Savastiouk, E.J. Carthy, T. Grajnar, V.E. Fioletov, K. Lamb and C.T. McElroy

NOTE: This report is intended to be available as an online, web-based form.

Instructions

This report is intended to be a quick summary of your recent Brewer instrument service and calibration activities. It is expected that other reports and documentation may exist that describe in more detail the events outlined in this summary. If such reports exist, then you are encouraged to submit them to the WOUDC for archiving purposes. If you are presently registered with the WOUDC (and BDMS) any additional reports can be sent to your personal WOUDC ftp account.

Preamble - Questions and Answers

Who should submit this report?
Preferably, the person responsible for performing a service or calibration. This may be a PI or a third party consultant.

When should this report be completed?
It should be completed after a service and/or calibration visit or after a major event such as the instrument being moved. In addition, if something about the site changes (the field of view, affects of local industry, the instrument is disrupted or affected by a natural event such as a wind, sand or snow storm etc.).

Why should this report be deposited at the WOUDC?
To preserve as much information about the long term stability of the instrument characteristics in a central repository.

Who will use the information contained within this report and why is it important?
At present, the intended audience will be the staff of the WOUDC, the members of the WMO Brewer sub-committee and WMO Science Advisory Groups (SAGs) for ozone and UV and possibly the Brewer community at large. The information will assist in the efforts to report on the status of the global ground-based ozone and UV monitoring programmes.

Where will this information be stored?
In a separate, non-public database operated by the WOUDC. The information would only be accessible by the aforementioned groups, but could be made available to a broader audience through a strict security protocol. This protocol will involve permission being granted by the originator of the data and any potential user of the data.

If you are already registered with the WOUDC you simply use your WOUDC agency ID as a reference. If you are a new user, please register your agency by visiting the WOUDC web site and completing the on-line forms: http://www.woudc.org/data/UsingArchive_e.html#Forms
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<td>yyyy-mm-dd to yyyy-mm-dd</td>
</tr>
<tr>
<td>Start and End Date</td>
<td></td>
</tr>
</tbody>
</table>

## Service Section

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of last service</td>
<td>yyyy-mm-dd</td>
</tr>
<tr>
<td>Any major repairs?</td>
<td>y/n</td>
</tr>
<tr>
<td>Details</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name and contact information of the person who performed the service</td>
<td></td>
</tr>
<tr>
<td>Is a summary Report available?</td>
<td>y/n</td>
</tr>
</tbody>
</table>

## Calibration Section

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of calibration.</td>
<td>Ozone, UV or both</td>
</tr>
<tr>
<td>(Choose either ozone, UV or both)</td>
<td></td>
</tr>
<tr>
<td>Is this a scheduled calibration or an emergency call?</td>
<td>Scheduled or emergency</td>
</tr>
<tr>
<td>Calibration Method (see list of options )</td>
<td></td>
</tr>
<tr>
<td>Refer to the section titled Instrument Re-location Summary</td>
<td></td>
</tr>
<tr>
<td>If a travelling standard was used, report Instrument model and number</td>
<td>Model Serial #</td>
</tr>
<tr>
<td>Date of last major calibration</td>
<td>yyyy-mm-dd</td>
</tr>
<tr>
<td>Date of current calibration</td>
<td>yyyy-mm-dd</td>
</tr>
<tr>
<td>Name and contact information of the person who performed the calibration</td>
<td></td>
</tr>
<tr>
<td>Is a summary Report available?</td>
<td>y/n</td>
</tr>
</tbody>
</table>

## For Ozone calibration

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL ratios and ETCs prior to calibration</td>
<td>R5/R6 ETC O3 ETC SO2</td>
</tr>
<tr>
<td>SL ratios and ETCs after calibration</td>
<td>R5/R6 ETC O3 ETC SO2</td>
</tr>
<tr>
<td>Were new constants installed?</td>
<td>y/n</td>
</tr>
<tr>
<td>Absorption coefficients</td>
<td>y/n</td>
</tr>
<tr>
<td>Table of Contents</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td>Dead time</td>
<td>y/n</td>
</tr>
<tr>
<td>Dispersion</td>
<td>y/n</td>
</tr>
<tr>
<td>Temperature coefficients</td>
<td>y/n</td>
</tr>
<tr>
<td>Shutter motor delay</td>
<td>y/n</td>
</tr>
<tr>
<td>Cal step</td>
<td>y/n</td>
</tr>
<tr>
<td>ICF file before calibration</td>
<td>ICFjjjyyyy.iii</td>
</tr>
<tr>
<td>ICF file after calibration</td>
<td>ICFjjjyyyy.iii</td>
</tr>
<tr>
<td>Is there a need to re-calculate past data?</td>
<td>y/n</td>
</tr>
</tbody>
</table>

**For UV calibration**

<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and serial number of lamp(s) used</td>
</tr>
<tr>
<td>UVR file before calibration</td>
</tr>
<tr>
<td>UVR file after calibration</td>
</tr>
<tr>
<td>% Difference</td>
</tr>
<tr>
<td>Is there a need to re-calculate past data?</td>
</tr>
</tbody>
</table>

**Instrument Re-location Summary**

<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Was the instrument moved for the calibration?</td>
</tr>
<tr>
<td>If yes, details. Include Site name, Country, Latitude, Longitude, Height</td>
</tr>
<tr>
<td>Has your instrument been moved for any other reason? Please provide details (indicate the name and co-ordinates of the site where the instrument was moved). Use the guide below as a reference.</td>
</tr>
<tr>
<td>1.1 Regular calibration at a national site</td>
</tr>
<tr>
<td>1.2 Regular calibration at a designated WMO-GAW Brewer calibration site</td>
</tr>
<tr>
<td>1.3 Inter-comparison at an external site</td>
</tr>
<tr>
<td>1.4 Routine re-location at a different national site or another permanent re-location</td>
</tr>
<tr>
<td>Date of Move</td>
</tr>
<tr>
<td>Date of Return (if applicable)</td>
</tr>
</tbody>
</table>

**Additional Information**

<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have there been any changes to the site characteristics such as new structures, obstructions or roadways? If yes, specify.</td>
</tr>
<tr>
<td>If log files are generated, indicate the frequency</td>
</tr>
<tr>
<td>Are the primary (level 0) data files (refer to file list) being archived?</td>
</tr>
<tr>
<td>Are any of the following reports available through the Internet (web or ftp)?</td>
</tr>
<tr>
<td>Have re-calculated data been submitted to the WOUDC?</td>
</tr>
</tbody>
</table>
GLOBAL ATMOSPHERE WATCH REPORT SERIES


8. Review of the Chemical Composition of Precipitation as Measured by the WMO BAPMoN by Prof. Dr. Hans-Walter Georgii, February 1982.


14. Effects of Sulphur Compounds and Other Pollutants on Visibility by Dr. R.F. Pueschel, April 1983.


19. Forecasting of Air Pollution with Emphasis on Research in the USSR by M.E. Berlyand, August 1983.


26. Sulphur and Nitrogen in Precipitation: An Attempt to Use BAPMoN and Other Data to Show Regional and Global Distribution by Dr. C.C. Wallén. April 1986 (WMO TD No. 103).


29. Recommendations on Sunphotometer Measurements in BAPMoN Based on the Experience of a Dust Transport Study in Africa by Dr. Guillaume A. d'Almeida. September 1985 (WMO TD No. 67).


43. Recent progress in sunphotometry (determination of the aerosol optical depth). November 1986.


58. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the years 1986 and 1987 (WMO TD No. 306).


62. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the year 1988 (WMO TD No. 355).


69. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1989 (WMO TD No. 400).


72. Integrated Background Monitoring of Environmental Pollution in Mid-Latitude Eurasia by Yu.A. Izrael and F.Ya. Rovinsky, USSR (WMO TD No. 434).


75. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1990 (WMO TD No. 447).


77. Report of the WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques, Lake Arrowhead, California, 14-19 October 1990.


84. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at GAW-BAPMoN sites for the year 1991 (WMO TD No. 543).
85. Chemical Analysis of Precipitation for GAW: Laboratory Analytical Methods and Sample Collection Standards by Dr Jaroslav Santroch (WMO TD No. 550).
89. 4th International Conference on CO₂ (Carqueiranne, France, 13-17 September 1993) (WMO TD No. 561).
91. Extended Abstracts of Papers Presented at the WMO Region VI Conference on the Measurement and Modelling of Atmospheric Composition Changes Including Pollution Transport, Sofia, 4 to 8 October 1993 (WMO TD No. 563).
97. Quality Assurance Project Plan (QAPjP) for Continuous Ground Based Ozone Measurements (WMO TD No. 634).
104. Report of the Fourth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the First Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE, Garmisch-Partenkirchen, Germany, 13 to 17 March 1995 (WMO TD No. 689).


113. The Strategic Plan of the Global Atmosphere Watch (GAW) (WMO TD No. 802).


120. WMO-JUMP Workshop on Broad-Band UV Radiometers (Garmisch-Partenkirchen, Germany, 22 to 23 April 1996) (WMO TD No. 894).


124. Fifth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, (Geneva, Switzerland, 7-10 April 1997) (WMO TD No. 898)

125. Instruments to Measure Solar Ultraviolet Radiation, Part 1: Spectral Instruments (lead author G. Seckmeyer) (WMO TD No. 1066)

126. Guidelines for Site Quality Control of UV Monitoring (lead author A.R. Webb) (WMO TD No. 884).


129. Guidelines for Atmospheric Trace Gas Data Management (Ken Masarie and Pieter Tans), 1998 (WMO TD No. 907).


131. WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia (Singapore, 2 to 5 June 1998) (Gregory R. Carmichael). Two volumes.


133. Workshop on Advanced Statistical Methods and their Application to Air Quality Data Sets (Helsinki, 14-18 September 1998) (WMO TD No. 956).


135. Sixth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Zurich, Switzerland, 8-11 March 1999) (WMO TD No.1002).


139. The Fifth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Halkidiki, Greece, September 1998)(WMO TD No. 1019).


146. Quality Assurance in monitoring solar ultraviolet radiation: the state of the art. (WMO TD No. 1180).


149. Comparison of Total Ozone Measurements of Dobson and Brewer Spectrophotometers and Recommended Transfer Functions (prepared by J. Staehelin, J. Kerr, R. Evans and K. Vanicek) (WMO TD No. 1147).

150. Updated Guidelines for Atmospheric Trace Gas Data Management (Prepared by Ken Maserie and Pieter Tans (WMO TD No. 1149).


154. WMO/IMEP-15 Trace Elements in Water Laboratory Intercomparison. (WMO TD No. 1195).


159. IGOS-IGACO Report - September 2004 (WMO TD No. 1235)


170. WMO/GAW Expert Workshop on the Quality and Applications of European GAW Measurements (Tutzing, Germany, 2-5 November 2004) (WMO TD No. 1367).


172. WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008 – 2015 (WMO TD No. 1384)


174. World Data Centre for Greenhouse Gases Data Submission and Dissemination Guide (WMO TD No. 1416).