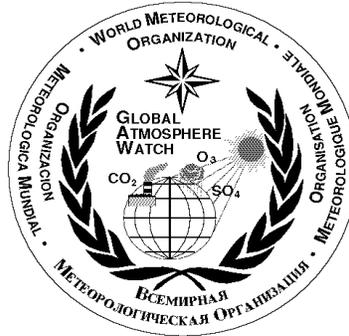


WORLD METEOROLOGICAL ORGANIZATION GLOBAL ATMOSPHERE WATCH



No. 138

REPORTS ON WMO INTERNATIONAL COMPARISONS OF DOBSON SPECTROPHOTOMETERS

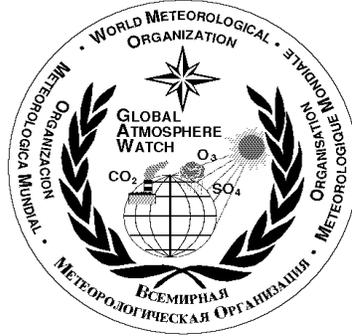
PART I – Arosa, Switzerland (19 - 31 July 1999)

PART II – Buenos Aires, Argentina (29 Nov. - 12 Dec. 1999)

PART III – Pretoria, South Africa (18 March - 10 April 2000)



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WMO TD No. 1016

PREFACE

The World Meteorological Organization has been actively engaged in monitoring atmospheric ozone for several decades. Until the Brewer spectrophotometer became commercially available about 1980 however, the Dobson ozone spectrophotometer, first developed in the 1920s, has been the primary instrument for determining total column ozone in the atmosphere. More than 100 Dobson spectrophotometers are located throughout the world. WMO has assisted in maintaining the integrity of the ozone data from these instruments world-wide by arranging and supporting periodic intercomparisons with a standard reference instrument maintained by the Climate Monitoring and Diagnostics Laboratory located in Boulder, Colorado, USA.

Now, for the first time, WMO has, through its Global Atmosphere Watch programme, staged regional intercomparisons in developing countries in the Southern Hemisphere. In late 1999 and early 2000 Dobson intercomparisons were successfully held in Buenos Aires, Argentina for instruments from South America and in Pretoria, South Africa for instruments in Africa. This publication reports on these events as well as the latest European comparison held in Switzerland in July 1999.

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DEFINITIONS

PART I

WMO/GAW International Comparison of Dobson Spectrophotometers (Arosa, Switzerland, 19 - 31 July 1999)

1. PURPOSE OF THE INTERCOMPARISON

The Intercomparison (IC-99) was organized by WMO Secretariat in close cooperation with and financial assistance of the Swiss Meteorological Institute (SMI). It was a regular event in a campaign to maintain the network of the Dobson ozone spectrophotometers operated in RA VI (Europe), plus Egypt. The Dobson Intercomparison also served as an assurance of the quality of the total ozone data sets created at the GAW ozone stations operated by WMO Member countries. This action is an application of WMO/GAW/QC requirements for monitoring atmospheric total ozone.

The main tasks were:

- The technical inspection and adjustment of the instruments.
- Comparison of the Dobson spectrophotometers with the World Secondary Dobson Standard Instrument (WSSI) No. 65 from NOAA/CMDL, Boulder, CO, USA, to determine the existing calibration level.
- Determination of new calibration constants for each Dobson spectrophotometer, as needed.
- To provide a forum for instruction for operating the Dobson spectrophotometers at home stations, and sharing knowledge concerning the management of an ozone-observing programme.

2. ORGANIZATION

The Intercomparison was held at the Lichtklimatisches Observatorium (LKO) of the Swiss Meteorological Institute in Arosa during the period 19 to 31 July 1999. Its programme was arranged by the Scientific Director, Robert D. Evans (NOAA) and by Technical Director, Bruno Hoegger (SMI) in cooperation with an Executive Team comprising:

Ulf Koehler	DWD	MOHp	Scientific and technical assistance
Karel Vanicek	CHMI	SOO	Scientific and technical assistance
Martin Stanek	CHMI	SOO	Technical assistance
Matthias Lugauer	DWD	MOHp	Technical assistance
Bert Doemling	DWD	MOHp	Technical assistance

The following Swiss experts supported the infrastructure of the Intercomparison:

Kurt Aeschbacher	SMI-LKO
Herbert Schill	SMI-LKO
Reto Wetter	SMI-LKO
Franz Herzog	SMI/LKO

Twenty nine specialists from 13 countries and the WMO Secretariat participated at the Intercomparison – see Part I, Annex A. The following national Dobson spectrophotometers were inspected, adjusted and compared:

<u>Dobson No.</u>	<u>Country</u>	<u>Station</u>
D041	United Kingdom	Camborne
D048	Italy	Sestola
D049	France	Bordeaux
D056	Norway	Oslo
D062	Switzerland	LKO Arosa
D064	Germany	Hohenpeissenberg (Regional Reference Instr.)
D065	USA	Boulder - World Secondary Standard Instr. WSSI
D069	Egypt	Aswan
D074	Czech Republic	Hradec Kralove (Regional Reference Instr.)
D085	France	OHP, Haute Provence
D101	Switzerland	LKO Arosa
D107	Russia	CAO Moscow
D120	Spain	El Arenosillo
M-124 / filter Instr.	Russia	St. Petersburg - on request of WMO

The Intercomparison IC-99 was conducted and all activity arranged in daily schedules according to the weather conditions and with respect to the technical state of the individual instruments. The technical infrastructure of SMI and special facilities from NOAA, Boulder, CO, USA and from the Meteorological Observatory Hohenpeissenberg, DWD, Germany were utilized during IC-99.

The main steps specified below were applied to each Dobson spectrophotometer:

- Unpacking the instrument, an inspection and transport and installation on the roof of the LKO.
- Inspection of the technical condition of the Dobson spectrophotometer and its functioning by means of daily SL and Hg lamp tests.
- Initial comparison against the WSSI to determine the existing calibration level.
- Definition of the technical adjustments and special tests required (wedge calibrations, discharge lamp tests, cleaning and adjustment of the optics, etc.).
- Final comparison against the WSSI.
- Assessment of the results, determination of new calibration constants (Reference R-N tables, Q-table and Reference Standard Lamp Readings).
- Interview by the Scientific Director with the operator in charge on the results of his instrument intercomparison and other calibrations (meta data). At this point, copies of documentation related to the spectrophotometer calibration were given to the operators.
- Packing of the instrument and other technical facilities for transport to home station.
- Preparing the final report of IC-99.

All work done and the results obtained for individual instruments are summarized in Part I, Annex B. This information has been saved in detail by operators and by the Scientific Director of the IC.

The success of the IC was accomplished mainly through the instructions provided by the Scientific and Technical Directors at the regular daily meetings of all participants. These instructions were determined at the daily meetings of the scientific and executive group.

With regard to the goal of sharing knowledge on the operation of the Dobson instruments and the management of an observing programme, the individual participants were required to perform the necessary calibration procedures under the supervision of the scientific staff. For example, almost all wedge calibrations were undertaken by the instrument's own operator.

3. OTHER ACTIVITIES

- At the request of WMO, a filter instrument for measurement of total ozone (M-124) from St. Petersburg took part in IC-99. The measurements will be processed and a calibration constant will be developed by the specialists from the Voieykov Observatory, St. Petersburg, Russian Federation.
- The participants at IC-99 participated in the NDSC Dobson/Brewer Workshop held in Arosa 22 – 23 July 1999 and made several presentations relating to monitoring total ozone, and the functioning of the global ozone monitoring network.
- The updated version of the generalized software for processing Dobson total ozone observations, DOBSON 3.0, created by the CHMI at Hradec Kralove, was also presented. It was also made available to participants, upon request.
- Dr Mike Proffitt, scientific officer, WMO Secretariat, Geneva visited the IC-99 and discussed important issues related to the operation of the GAW total ozone monitoring programme and activities of the WMO/Dobson Ad-Hoc Committee.
- Special morning Umkehr observations on the zenith sky were made by all participating instruments on 26 July 1999 to create a reliable data set for verification of the technologies used for processing these observations in the WMO Global Atmosphere Watch Programme. Ozonesonde balloon flights were also made on this day from Payerne, Switzerland, and Hohenpeissenberg, Germany. Specialists from NASA interested in Umkehr ozone vertical profiles data were present during the observations at LKO.
- Mr David Melkonyan from Armenia, invited by WMO, was present at IC-99 during the period 24 - 31 July 1999 as a potential manager of a proposed Dobson observing programme in his country. He was provided with fundamental scientific literature on the operation of Dobson spectrophotometers and data processing, and took part in all activities of IC-99 thus acquiring basic knowledge on maintenance, operation and calibration of this instrument.
- Mr Archie Asbridge, scientific consultant, assisted in inspection and adjustments of the instruments at the Intercomparison. He also gave a talk on function and special technical tests of the Dobson spectrophotometers. His main task was to introduce a draft of his Dobson manual and to discuss it with Dobson specialists and the WMO representative. Amendments, corrections and additional chapters were recommended and a special, adaptable and open form of publication by WMO was suggested.

4. CONCLUSIONS

All participating instruments left the intercomparison properly calibrated allowing a precision of the ADDS observations less than 1% limit with the WSSI spectrophotometer from the WSSI instrument.

A majority of the instruments that participated at IC-99 arrived with the calibration offset less than 1%. This situation with respect to the Dobson spectrophotometers operated in the WMO RA-

VI Region is a result of previous regular intercomparisons organized by WMO. Nevertheless, continuous attention must be paid to the maintenance of the instruments at all stations.

The results of comparative measurements with the D065 WSSI spectrophotometer confirmed that instruments D064 and D074 fulfill all technical and calibration requirements of Reference Dobson Spectrophotometers of the RA-VI region. Annual calibrations are planned at MOHp in cooperation with SOO-HK and WMO beginning in the year 2000 according to schedules established by the head of the Regional Dobson Calibration Centre (RDCC). The regional standards were compared against the WSSI at both MOHp and LKO, with very similar results, demonstrating the usefulness of the MOHp site.

Because of good weather conditions and no significant technical problems with the Dobson instruments the IC-99 was completed on schedule.

5. FINDINGS AND RECOMMENDATIONS

- Long-term maintenance of the World Primary Standard Dobson Spectrophotometer (WPSS) D083 and the Secondary Standard D065 by NOAA, Boulder, CO, USA has established a well-defined calibration background for the Dobson spectrophotometers worldwide.
- Based on recommendations specified in the Report from the previous Dobson Intercomparison, Arosa 1995 (WMO GAW Report No. 108), a Regional Dobson Calibration Centre (RDCC) for RA-VI has been established to efficiently transfer the calibration scale into the network, and to assist the stations with operational problems. This RDCC will be maintained by the Meteorological Observatory of DWD at Hohenpeissenberg (Germany) in cooperation with the Solar and Ozone Observatory of CHMI at Hradec Kralove (Czech Republic). RDCC began its work in July 1999 with a joint calibration of the Dobson spectrophotometers D064 (MOHp) and D074 (SOO-HK) with the World Secondary Standard Instrument D065 (NOAA Boulder, CO, USA).
- Future intercomparisons of European Dobson spectrophotometers are expected to be held at MOHp using the instruments D064 and D074 maintained as the Regional Reference Dobson spectrophotometers. The specialists from MOHp and SOO-HK have created a suitable infrastructure and have the necessary experience and scientific knowledge to carry out the responsibilities of a RDCC.
- The D064 and D074 instruments will represent new reference instruments that need to be defined by very precise calibration constants. Therefore, it was recommended that a simultaneous absolute calibration of both instruments with the WSSI D065 be conducted in the next 2 years. Both instruments should have all optical parameters, such as slit widths within the published specifications of Dobson instruments.
- The Dobson instruments still show a remarkable variety of electronic circuitry. Some of them are needlessly complicated, and have a problem with missing spare parts and documentation. The IC-99 recommended that WMO standardize the electronic circuits with a simple and effective design using easily available components. To ensure the use of this design, WMO should provide the resources for converting the various instruments to a standardized system.
- The use of personal computers and new communication technologies at the stations could provide a good basis for the development and implementation of unified software tools for processing measurements, data management and data exchange. This would require raising the qualification of the operators. It is expected that the RDCC can assist and in solving problems in individual regions by direct transfer of knowledge as well as by organizing relevant training as has been done at SOO-HK in recent years. WMO's

assistance in this matter was considered essential, mainly under the umbrella of the GAW programme.

- To assess the results of the recent effort undertaken and to maintain the integrity of the global total ozone monitoring network through the RDCCs, it was recommended that a joint meeting of the members of the WMO/Dobson Ad-Hoc Committee be held during the Quadrennial Ozone Symposium in Sapporo, 2000. The Secretariat of WMO was urged to financially support the participation of members of the DAHC at the meeting, if at all possible.
- The Scientific Committee of the IC-99 acknowledged the excellent support and infrastructure provided to the intercomparison by SMI and by the Technical Committee headed by Mr Bruno Hoegger. It also urged WMO to continue organizing the four to five year schedule of RA VI Dobson Ozone Spectrophotometer Intercomparisons.
- An important part of an intercomparison with a large number of participants is the sharing of instrument operations and observing programme experiences. The Technical Committee and participants recommended that WMO organize biennial meetings of the data producers and data users.
- The Scientific Committee of IC-99 discussed the installation of Dobson spectrophotometer D044 in Armenia with Mr David Melkonyan and agreed on the following schedule of work to be completed by the end of 2000:
 - (a) Submission of the questionnaire and station description by Armenian Hydro-Meteorological Institute (Armhydromet) to Hohenpeissenberg DCC by the end of October 1999.
 - (b) A visit to the proposed station by an expert and a WMO representative was recommended before the spring of 2000. The Scientific Committee suggested Arkadi Shalamijanski from the Voieykov Main Observatory, St. Petersburg for this purpose as he is familiar with the use of both Dobson instruments and the M-124 filter instruments used by Armhydromet in the past .
 - (c) Recommendation to WMO and final decision on installation of D044 - before spring 2000.

**WMO/GAW International Comparison of Dobson Spectrophotometers
(Arosa, Switzerland, 19-31 July 1999)**

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**WMO/GAW International Comparison of Dobson Spectrophotometers
(Arosa, Switzerland, 19-31 July 1999)**

Individual Instrument Reports

INSTRUMENT D041 UK (Camborne)

Original Calibration Data:

N-tables from 30 July 1995, Arosa LKO intercomparison.
Reference Standard Lamp values for lamps 41Q3, 41Q4 and 41Q5
Lamp tests used regularly for data processing at home station.

Initial Calibration Results

Adjustments based with the results of Standard Lamp tests included.
27 July 1999

d_Na: -0.6 d_Nc: -0.2 d_Nd: -0.2 d_Nad: -0.4

The d_Nad value implies an average **+0.6% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed:

- Wedge Slides cleaned to remove black coating that was making the R-dial difficult to move.
- The shutter rods were cleaned to remove stiffness in operation.
- New drive belt was installed. This required the removal and replacement of the shutter motor assembly.
- Optical and general cleaning, apart from mirrors.
- Wedge calibration on A wave length to verify that the instrument was reassembled correctly.
- The light mask in front of wedge on right hand side was physically restrained by adding a screw to prevent the mask from being bent down into the light path.

Final intercomparison: Not applied, as the instrument is within calibration limits to D065

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was 0.7% in total ozone.

The instrument was compared to D065 on the 21 July 1999, and repeated the results within 0.5% based on Nad differences. The average of the two intercomparisons still showed the instrument was within 1.0% of the Standard.

Comments

Whilst there were no obvious problems evident in the intercomparison between the instrument and the standard, these features of the instrument are noted for the record only.

- Left hand side mirror has fine vertical scratches.
- Symmetry test fails on S3Q2 vs. S3Q1 – this is repeatable, and has been evident for a number of years.

Recommendation: The apparent shift in R-dial position with change in the gain setting (EHT or High voltage) should be investigated further at the home station.

INSTRUMENT D048

Italy (Sestola)

Original Calibration Data:

N-tables from 25 July 1995, Arosa LKO intercomparison.

Reference Standard Lamp Values for lamps 48/1,48/3,48/5 and 48/6

Lamp tests results used in data processing at home station.

Initial Calibration Results

Adjustments based on the results of Standard Lamp tests included

25 July 1999

d_Na:-0.7 d_Nc:-0.4 d_Nd:-1.1 d_Na:+0.4

The d_Nad value implies an average - **0.6% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Optical Symmetry checked: A small deviation from the expected values was found with respect to S2Q1 versus S2Q2. No change was made in the instrument, as the intercomparison results shown no problem.
- Standard Lamp Power Supply cable was repaired.
- Reference standard lamps UQ1 and UQ7 values were defined for this instrument.

Final intercomparison: Not applied, as the instrument is within calibration limits to D065

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -1.0% in total ozone, at low μ .

The instrument was compared to D065 on three separate days, and repeated the results within 1.0%. The 25 July 1999 intercomparison was chosen, as it was the clearest conditions of three days.

The existing calibration will remain as is, but dated to the 25 July 1999 to document the intercomparison here.

INSTRUMENT D049

France (Bordeaux)

Original Calibration Data:

N-tables from 30 July 1995, Arosa LKO intercomparison
Reference Standard Lamp Values for lamps 49/2H1, 49/3H1 and 49/4H1
Lamp test results are not used for data processing at home station

Initial Calibration Results:

25 July 1999

d_Na: -1.2 d_Nc: -1.0 d_Nd: -1.0 d_Nad: -0.2

The d_Nad value implies an average **+0.3% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Discharge lamp test was performed – the results matched the existing Q-table
- Optical Symmetry checked and found to be in limits.
- Interior and Optics were inspected and found to be very clean.

Final intercomparison: Not applied, as the instrument is within calibration limits to D065

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was +0.6% in total ozone, at low μ .

The instrument was compared to D065 on three separate days, and repeated the results within 0.5% based on the differences in the Nad values. The 25 July 1999 intercomparison was chosen, as it was the clearest conditions of three days.

The instrument has an encoder mounted on the wedge to record the wedge position electronically. For a wedge calibration to be performed, this encoder will have to be removed. This procedure was beyond the facilities and time of this intercomparison. The operators are encouraged to have the wedge calibration checked at the Region VI DCC in Hohenpeissenberg, Germany within the next several years

INSTRUMENT D056

Norway (Oslo)

Original Calibration Data:

N-tables from 22 June 1994 Izana intercomparison
Reference Standard Lamp Values for lamps 56Q2, 56Q3, UQ1
SL tests are not used for data processing at home station.

Initial Calibration Results from 25 July 1999

d_Na: +0.62 d_Nc:-0.11 d_Nd:+0.07 d_Nad:+0.56

The d_Nad value implies an average - **0.9% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge Calibration performed on 20. July 1999 - New G-table created
- Home Q-setting table dated 06 December 1994 corrected for Arosa on 19 July 99 was used for IC-99
- Inspection of the Cobalt filter done on 25 July 1999 – no cleaning necessary
- Optical Symmetry was checked on 24 July 1999 – S3Q2 found out of limits

Final intercomparison: 25 July 1999.

New N-tables and Reference Standard Lamp values defined for 56Q2, 56Q3, UQ1
Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was +0.12% in total ozone.

Recommendations.

Though the results of intercomparisons were very good for the AD pair, a significant offset for CD pair and μ values 2.5-5.0 is permanently persisting. This could not been improved even by the wedge calibration and development of new G-Tables

To perform CD observations at the home station located at 60 deg. N accurate as Much as possible, it is recommended to make systematic CDA sequence of observations for the μ range from 2.5 and higher and investigate relation between AD and CD total ozone values. Based on these analyses a correction factor can be derived for correction of CD observations either for DS, FDS and Zenith measurements.

It is emphasized that Q-setting table Must be corrected when the results of regular Hg tests systematically come over the limit **0.3**.

The UV Cobalt filter was checked on 25 July 99 and found deteriorated in certain places. But the deterioration was not so significant to do any polishing.

INSTRUMENT D062

Switzerland (LKO Arosa)

Original Calibration Data:

N-tables from based on the 1995 LKO Arosa intercomparisons and the 1992 N-table. The "extra-terrestrial constant" in the tables were chosen by station personnel to attempt to make the instrument's ozone values be consistent with other total ozone measuring instruments, and remain at the 1.0% level to the Dobson calibration scale.

Reference Standard Lamp Values for lamps 62v and 62W

Lamp tests results used in data processing at home station.

Initial Calibration Results (Adjustments to the N-values were first made as normal at this station.)

21 July 1999

d_Na: -0.44 d_Nc: +0.31 d_Nd: +0.16 d_Nad: -0.6

The d_Nad value implies an average **0.9% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge Calibration performed, but only for the record.
- Discharge lamp series was performed, results were not applied – existing table not changed.
- Symmetry test was performed, and fails – there is no indication of a problem in the intercomparison results.

No recommendations, as instrument is within one percent of the standard. Note that a recalculation of the 21 July 1999 intercomparison using the full results of the 1995 intercomparison with D065, gives a closer match between the instruments (D_Nad difference of approximately -0.3 or 0.4%)

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was 1.0% in total ozone, at low μ .

The station personnel responsible for the data analyses will have to evaluate these results, and decide what course of action to take, with respect to the calibration level.

INSTRUMENT D064
Germany (Hohenpeissenberg)
Regional reference instrument (Europe)

Original Calibration Data:

N-tables from 22 July 1997. Kalábryta intercomparison
Reference Standard Lamp Values for lamps 64-Q-I and 64-Q-II
Lamp tests results used in data processing at home station.

Initial Calibration Results:

(Adjustments based on the results of Standard Lamp tests included)
17 July 1999

d_Na:0.0 d_Nc:0.0 d_Nd:+0.3 d_Nad:-0.3

The d_Nad value implies an average **+0.4% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge Calibration performed on 15 July 1999, but results not applied.
- Discharge lamp series was performed and new Q-tables produced. The new table is not significantly different from the older table.

Final intercomparison: 17 July 1999.

New N-tables and Reference Standard Lamp values defined for 64Q1, 64Q2, UQ1 and UQ7.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -0.5% in total ozone.

Recommendations and comments.

- The intercomparison held on 17 July 99 at LKO Arosa is in a very good agreement with the previous intercomparison at MOHp on 05. July 1999
- To keep the best fit with the reference D065 and D074 both for AD and CD observations and $\mu= 1.15-3.2$, it was decided to develop new reference N-Tables and SL Readings based on SL tests and IC from 17 July 99. The same decision was made also for D074.
- The instrument will be maintained as a Regional Reference Spectrophotometer for RA-VI, Therefore it is recommended to perform more frequent tests of its optical alignment and absolute calibration.

INSTRUMENT D069

Egypt (Aswan)

Original Calibration Data:

N-tables from 25 May 1993, Hradec Kralove Intercomparison
Reference Standard Lamp Values for lamps 69-Q-I and 69-Q-II
Lamp tests results used in data processing at home station.

Initial Calibration Results

Adjustments based on the results of Standard Lamp tests included.
25 July 1999

d_Na: -1.01 d_Nc: +0.39 d_Nd: +0.69 d_Nad:-1.70

The d_Nad value implies an average **+2.5% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge calibration performed.
- Optical cleaning
- Discharge lamp test performed and a new Q-setting table extended up to 50 C created, dated 23 July 1999.
- Symmetry test performed on 24 July 1999 – S2Q2 and S3Q2 were found out of limits
- Adjustment of position of M2
- New test of symmetry performed on 27. July 1999 – in good limits
- Q-levers removed and cleaned because of their difficult movement. New gaskets mounted and the Q-levers assembled.

Final intercomparison:

25 July 1999

New N-tables and Reference Standard Lamp values dated 25. July 1999 defined for the lamps 69-Q-I, 69-Q-II and UQ7 lamps

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -0.25% in total ozone.

Recommendations:

- Different corrections of the original 1993 N-Tables based on SL tests were found at LKO for A, C, D pairs comparing the results at the station. The operator has been instructed how to investigate the history of SL tests and correction of N-Tables to correct the ozone data sets at Aswan.
- The Q-levers mechanisms are worn, so that metal rubs on metal as the Q-levers are moved. The material of which the Q-lever mechanisms are made has a tendency for “galling” – metal transfer that causes fusing together of the moving pieces. The Q-lever mechanisms were lubricated with Apezeon grease. If the problem of galling appears again, the mechanisms should be repaired by a facility capable of installing new bearing surface.
- To avoid overheating the instrument during the summer season an installation of a shading cover is recommended

INSTRUMENT D074
Czech Republic (Hradec Kralove)
Regional reference instrument (Europe)

Original Calibration Data:

N-tables from 22 July 1997, Kalábryta Intercomparison
Reference Standard Lamp Values for lamp Qj-74-I, Qj-74-II dated 22.July 97
Lamp tests results used in data processing at home station.

Initial Calibration Results:

17 July 1999

d_Na:+0.27 d_Nc:+0.42 d_Nd:+0.05 d_Nad:+0.22

The d_Nad value implies an average - **0.3% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge calibration performed on 14. July 99, New G tables not created.

Final intercomparison: 17 July 1999.

New N-tables and Reference Standard Lamp values defined for QJ/74-1, QJ/74-2, UQ7.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -0.03% in total ozone.

Recommendations and comments.

- The intercomparison held on 17 July 99 at LKO Arosa is in a very good agreement with the previous intercomparison at MOHp on 05. July 1999
- To keep the best fit with the reference D065 and D064 both for AD and CD observations and $\mu=1.15-3.2$, it was decided to develop new reference N-Tables and SL Readings based on SL tests and IC from 17 July 99. The same decision was made also for D064.
- The instrument will be maintained as a Regional Reference Spectrophotometer for RA-VI, Therefore it is recommended to perform more frequent tests of its optical alignment and absolute calibration.
- The instrument is fitted with an encoder/counter linked with a PC for automated reading and real-time data processing

INSTRUMENT D085

France (OHP)

Original Calibration Data:

N-tables from 10 July 1990, intercomparison with D065 at OHP.
Reference Standard Lamp Values for lamps 85Q1, 85Q3, 85Q4, UQ1, UQ2, and UQ8
Lamp tests results used in data processing at home station.

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
25 July 1999

d_Na:-1.6 d_Nc:-0.7 d_Nd:-.5 d_Nad:-1.1

The d_Nad value implies an average **+1.5% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Discharge lamp test series performed – the result table was not used, as it appeared that the lamp series was performed with the instrument not temperature stable.
- Wedge calibration was performed (28 July 1999), but not applied. This instrument is used for automated Umkehr measurements, and the G-function should not be changed without a proper reason. The process of reducing an Umkehr measurement to an ozone profile is more sensitive to the wedge calibration than to the calibration for total ozone.
- Interior and optics were inspected, and no problems were noted. Optics cleaned of dust.
- The symmetry test was performed and the S3Q1 values were out of specification. There was no evidence of a problem in the intercomparison results.

Final intercomparison: 25 July 1999.

New N-tables and Reference Standard Lamp values defined for 85Q1, 85Q3, 85Q4, UQ1, and UQ7.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was 0.6% in total ozone.

Recommendations.

- The existing data set will be reprocessed to account for the calibration drift of 1.5% in nine years. The drift was documented in the results of the 1995 Arosa LKO intercomparison, but was not at the 1% level at that time.
- The symmetry test should be performed at the home station after the instrument is re-installed, and is temperature stable.

INSTRUMENT D101

Switzerland (LKO)

Original Calibration Data:

N-tables from based on the 1995 LKO Arosa intercomparisons and the 1995 G-table from the same intercomparison meeting. The “extra-terrestrial constant” in the tables were chosen by station personnel to attempt to make the instrument’s ozone values be consistent with other total ozone measuring instruments, and remain at the 1.0% level to the Dobson calibration scale.

Reference Standard Lamp Values for lamps 101A and 101B

Lamp tests results used in data processing at home station.

Initial Calibration Results (Adjustments to the N-values were first made as normal at this station.)
25 July 1999

d_Na:-2.08 d_Nc:-1.12 d_Nd:-1.19d_Nad:-0.89

The d_Nad value implies an average **+1.3% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge Calibration performed, but only for the record.
- Discharge lamp series was performed, results were not applied – existing table not changed.
- Symmetry test was performed, and fails – there is no indication of a problem in the intercomparison results.

The instrument is not within one percent of the standard. Note that an analyze of the 25 July 1999 intercomparison using the full results of the 1995 intercomparison with D065, gives a closer match between the instruments (d_Nad difference of approximately 0.0 or 0.0%). The instrument was also intercompared to D065 on 27 July 1999, with very similar results.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was 1.8% in total ozone, at low μ .

The station personnel responsible for the data analyses will have to evaluate these results, and decide what course of action to take, with respect to the calibration level.

INSTRUMENT D107

Russia (CAO Moscow)

Original Calibration Data:

N-tables from 30 July 1995, Arosa LKO intercomparison
Reference Standard Lamp Values for lamps 107-Q-1, 107-Q-2 and 107-Q-4
Lamp tests results used in data processing at home station.

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
25 July 1999

d_Na:-0.7 d_Nc:-1.0 d_Nd:-0.9 d_Nad:+0.2

The d_Nad value implies an average - **0.3% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge Calibration performed – but not used as existing N-table produced very good results with comparison with the standard instrument.
- Discharge lamp test series performed, which verified existing Q-setting table.
- Instrument was cleaned, both optically and in general – producing a pronounced shift in standard lamp readings.

Final intercomparison: Not applied, as the instrument is within calibration limits to D065

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -0.3% in total ozone.

The instrument was compared to D065 on three separate days, and repeated the results within 1.0%. The 25 July 1999 intercomparison was chosen, as it was the clearest conditions of three days.

The existing calibration will remain as is, but dated the 25 July 1999 to document the intercomparison here.

Comments

- Sun Director needs repair. The instrument is also missing the adjusting screws for the leveling of the sun director to the optics of the instrument.
- The R-dial post is dented, and perhaps slightly bent.

INSTRUMENT D120

Spain (El Arenosillo)

Original Calibration Data:

N-tables from 22 June 1994, Izana intercomparison with D065
Reference Standard Lamp Values for lamps 120Q2, 120Q4, 120Q5, UQ1, R51 and R52
Lamp tests results used in data processing at home station.

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
21. July 1999

d_Na: -1.89 d_Nc:-1.22 d_Nd:-0.78 d_Nad:-1.11

The d_Nad value implies an average **+1.6% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units. Application of new G-tables from wedge calibration improves results significantly.

Work Performed:

- Optics checked, and gaskets replaced, inlet window and ground quartz plate cleaned.
- Wedge calibration performed, new G-tables created and used for determination of new N-tables.
- Discharge lamp test series performed, new Q-table not used due to discrepancies with Hg-test after creation.
- Symmetry test was performed, one result (S2Q1 and S3Q1) out of limits. This was not evident in the intercomparison results.

Final intercomparison: 25 July 1999, new R-N-tables used, new calibration level established.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was +0.9% in total ozone, at low μ .

Recommendations/Comments:

- New calibration defined with new R-G-tables.
- Initial calibration with original R-N-tables showed doubtful results, new R-G-tables from wedge calibration improve results significantly, application on the data record backwards has to be decided after reprocessing Izana-IC 1994 with new R-G-tables.
- Correction of original Q-tables from results of the Hg-Test immediately after return to station.
- Performance of regular Symmetry test each 3 months.

PART II

WMO/GAW International Comparison of Dobson Spectrophotometers (Buenos Aires, Argentina, 29 Nov. – 12 Dec. 1999)

1. PURPOSE OF THE INTERCOMPARISON

The Intercomparison (IC/BUA-99) was organized by the World Meteorological Organization (WMO) Secretariat and the Argentine Servicio Meteorológico Nacional (SMN) in close cooperation and with the assistance of the USA National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL). It was a campaign to maintain the network of the Dobson ozone spectrophotometers operated in the South American region. The Dobson Intercomparison also served as an assurance of the quality of the total ozone data sets created at WMO Member stations. This action is a fulfillment of WMO/GAW/QC requirements for monitoring of the atmospheric total ozone.

The main tasks were:

- The technical inspection and adjustment of the instruments. Three of the instruments received new amplifier electronics supplied by the WMO.
- Comparison of the Dobson spectrophotometers with the World Secondary Dobson Standard Instrument (WSSI) No. 65 from NOAA/CMDL's World Dobson Calibration Center (WDCC), Boulder, CO, USA, to determine the existing calibration level.
- Determination of new calibration constants for each Dobson spectrophotometer, as needed.
- To provide a forum for instruction for operation of the Dobson spectrophotometers at home stations, and sharing knowledge concerning the management of an ozone-observing programme.

2. ORGANIZATION

The Intercomparison was held at the SMN's Villa Ortuzar Observatory in Buenos Aires. The infrastructure for the comparison was prepared and preliminary comparison of some of the instruments was conducted prior to the formal comparison.

The IC/BUA-99 was arranged by:

Vice-commander Carlos Villanueva, the Convener of the intercomparison.

Mr Eduardo Piacentini, the operations director of the intercomparison, who was assisted by Engineer Maximo Ginzburg, the Technical Director of the intercomparison, Mr Ricardo Sanchez, Mr Oswaldo Blanco, and other observatory personnel.

Mr Robert Evans, the Scientific Director of the intercomparison, who was assisted by Mr Michael O'Neill.

Twenty five specialists from five countries and the WMO Secretariat participated at the Intercomparison – see Part II, Annex A. The following national Dobson spectrophotometers were inspected, adjusted and compared.

<u>Dobson No.</u>	<u>Country</u>	<u>Station</u>
D065	USA	Boulder - World Secondary Standard Intr.(WSSI)
D087	Peru	Marcapomacocha

D097	Argentina	Buenos Aires
D099	Argentina	Marambio, Antarctica
D114	Brazil	Cachoeira Paulista
D131	Argentina	Ushuaia
D133	Argentina	Comodoro Rivadavia
D134	Uruguay	Salto

Brewer No. 162 and Automated Filter Ozonometer No. 03-95 made measurements on several days.

The Intercomparison IC/BUA-99 was conducted and all activity arranged in daily schedules according to the weather conditions and with respect to the technical state of the individual instruments. The technical support of SMN and special facilities from NOAA, Boulder, CO, USA were used during IC/BUA-99.

The main steps specified below were applied to each Dobson spectrophotometer:

- Unpacking the instrument and an inspection following transport to the Observatory.
- Inspection of the technical condition of the Dobson spectrophotometer and its functioning by means of daily standard lamp (SL) and mercury (HG) lamp tests.
- Initial comparison against the WSSI to determine the existing calibration level.
- Definition of the technical adjustments and special tests required (wedge calibrations, discharge lamp tests, cleaning and adjustment of the optics etc.).
- Final comparisons against the WSSI.
- Assessment of the results, determination of new calibration constants (Reference R-N tables, Q-table and Reference Standard Lamp Readings).
- Interview by the Scientific Director with the operator in charge on the results of his instrument intercomparison and other calibrations. At this point, copies of documentation related to the spectrophotometer calibration were given to the operators.
- Packing of the instrument and other technical facilities for transport to home station.
- Preparing the Final Report of the IC/BUA-99.

The history of repairs and adjustments and the results obtained for individual instruments are summarized in Part II, Annex B. This information has been saved in detail by operators and by the Scientific Director of the intercomparison.

The success of the IC/BUA-99 was accomplished mainly through the instructions provided by the Scientific and Technical Directors at the regular meetings of all participants. These instructions were determined at the meetings of the scientific and executive group.

With regard to the goal of sharing knowledge on the operation of the Dobson instruments and the management of an observing programme, the individual participants were required to perform the necessary calibration procedures under the supervision of the scientific staff. For example, the instruments own operator undertook all wedge calibrations. The operator, under the supervision of the scientific staff also made electronic and other repairs.

3. OTHER ACTIVITIES

- The participants of the IC/BUA-99 took part in the Workshop on Ozone and Solar Ultraviolet Radiation from 6 – 8 December 1999 and presented several contributions related to monitoring total ozone and function of the global ozone monitoring network.
- Dr Mike Proffitt, scientific officer, WMO Secretariat, Geneva visited the IC/BUA-99 and discussed important issues related to the operation of the GAW total ozone monitoring programme.
- Dr Gordon Labow and Dr Richard Stolarski from the USA National Air and Space Administration visited the intercomparison in an effort to understand and reduce the differences between ground-based and satellite measurements.
- Special Umkehr observations on the zenith sky were made by all participating instruments on 6 December (morning) and 9 December (evening) to create a reliable data set for verification of the technologies used for processing these observations. Specialists from NASA interested in Umkehr ozone vertical profiles data were present during the 9 December observations at the Villa Ortuzar Observatory.

4. CONCLUSIONS

All participating instruments left the intercomparison properly calibrated with a precision of the DS observations less than 1% limit with the WSSI spectrophotometer.

The results of the Dobson IC/BUA-99 confirmed the technical stability of the calibration level of the Dobson spectrophotometers operated in the South American Region. A majority of the instruments that participated at IC/BUA-99 arrived with the calibration offset less than 1%. Nevertheless, systematic attention must continue with respect to the maintenance of the instruments at all stations.

Because of good weather conditions and no significant technical problems with the Dobson instruments the IC/BUA-99 was completed on schedule.

5. RECOMMENDATIONS

- The Scientific Director of the IC/BUA-99 acknowledged the excellent support and infrastructure provided to the intercomparison by SMN. The Villa Ortuzar Observatory facilities served well in the IC/BUA-99. It was recommended that the intercomparison be repeated in another four years.
- An important part of an intercomparison with a large number of participants is the sharing of instrument operations and observing programme experiences. The addition of participants who are users of the data enabled effective communication between the data producers and users. The participants recommended that WMO continue to organize regular meetings of the monitoring community and data users.

**WMO/GAW International Comparison of Dobson Spectrophotometers
(Buenos Aires, Argentina, 29 Nov. – 12 December 1999)**

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**WMO/GAW International Comparison of Dobson Spectrophotometers
(Buenos Aires, Argentina, 29 Nov. – 12 Dec. 1999)**

Individual Instrument Reports

Instrument 087

Marcapomacocha, Peru

Original Calibration Data:

N-tables from June 22, 1994 intercomparison with D065 in Izana, Tenerife, Spain.

Reference Standard Lamp values for lamps: 87Q2

Lamp tests **NOT** used regularly for data processing at home station.

Initial Calibration Results: December 07, 1999

Three intercomparisons were made with this instrument. There were problems with the Q-levers and stops that made the setting of the wavelength difficult. All three intercomparisons showed that the instrument results were within 1% of the standard, but were more noisy than normal. The December 07, 1999 intercomparison was made after all repairs were made.

d_Na:+0.5 d_Nc:+0.3 d_Nd:+1.0 d_Nad:-0.5

The d_Nad value implies an average **+0.7% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- The instrument was not operational when it arrived in Buenos Aires. Some of the electronic problems are believed to be caused by AC power fluctuations at the home station, which is a remote site at 4530 meters MSL. The station has a solar power source, and a 12VDC to 220VAC inverter was purchased for use at the home station.
- This instrument was originally an automated instrument, and the Q-levers were remade with very low friction bearing. The Q-stops were removed. The setting of the wavelength manually was difficult. Spacer washers of the low friction material were removed and replaced with higher friction material, and Q-stops repaired.
- Wedge Calibration was performed as a verification – the R vs Delta R curve was the same as that obtained in 1994 at Izana. The wedge calibration was not used.
- The symmetry tests on the instrument showed a mismatch between the right and left sides of the instrument of over 2 degrees. Investigation with 90-degree angle test determined that the Q2 lever was set incorrectly. The Q2 lever was reset to the proper values.
- A discharge lamp test was performed, which produced a table very similar to the original Q-table.

Final intercomparison: The June 22, 1994 calibration will remain, but will be dated the December 07, 1999 as proof of attendance of this instrument at this intercomparison. New Reference standard lamps values are also defined for this date.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was +1.3 in total ozone, at high sun. This higher ozone at high sun was not always observed on other days.

Recommendations and comments:

- This instrument has been operated as a cooperative project in the past at Huancayo Observatory. It is the property of the USA government, on loan to the Peruvian Government.
- The existing data set of observations from this instrument consists primarily of values taken earlier this year. The data should be reprocessed with the June 22, 1994 N-tables, and submitted to the World Ozone and UV data center in Toronto, Canada. Lamp test corrections are not needed.
- Use the N-table dates December 07, 1999 and the results of the standard lamp tests to process the data taken after December 07, 1999. This data should be submitted to the World Ozone and UV data center.
- A set of Q-tables for Marcapomacocha will be provided to the operator for use at the station.
- The instrument was supplied with spare parts, a Standard lamp power supply, an insulating jacket, and special tools.

Instrument 97

Buenos Aires, Argentina

Original Calibration Data:

N-tables from June 07, 1998 intercomparison with D083 in Boulder, Colorado, USA.
Reference Standard Lamp Values for lamps: 97Q3, 97Q4, 97Q5, UQ1, and UQ2
Lamp tests results used in data processing at home station.

Initial Calibration Results: **November 29, 1999**

Adjustments based on the results of Standard Lamp tests included

d_Na:-1.5d_Nc:-.6 d_Nd:-1.5 d_Na:0.0

The d_Nad value implies an average **0% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed: None

Final intercomparison: Not applied, as the instrument is within calibration limits to D065

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was -0.5% in total ozone.

Recommendations and comments:

- This instrument repeated the excellent results in other intercomparisons.
- The calibration is 18 months old, and will not be changed.

Instrument 99

Marambio, Antarctica, Argentina

Original Calibration Data:

N-tables from August 31, 1992 intercomparison in Boulder, Colorado, USA.
Reference Standard Lamp Values for lamps: on 99Q2, 99Q3, and 99Q4.
Lamp test results are used for data processing at home station

Initial Calibration Results: November 27, 1999

Lamp tests results were included in the analysis.

d_Na:-1.8 d_Nc:+0.0 d_Nd-0.1: d_Nad:-1.7

The d_Nad value implies an average **+2.5% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- Wedge Calibration on November 26, 1999. Inspection of the optics showed a “smear” on mirror M1
- Mirror cleaned and reset.
- Discharge Lamps were performed. A new Q-setting table was created, very similar to the original.
- Symmetry tests after the resetting of the mirror are slightly out of tolerance on the right-left matching.

Final intercomparison: December 07, 1999

New calibration defined using the Wedge Calibration of November 26, 1999.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -1.3% in total ozone, at high μ .

Recommendations and comments:

- The Mirror M1 had a “smear” on the surface. This was cleaned with ether. The position was reset after installation.
- The instrument response on the A wavelength shows that it is μ dependent. Cleaning the smeared mirror did not eliminate the problem. The mirror should be replaced when possible.
- After cleaning the mirror, an intercomparison on December 04, 1999 showed a great improvement. The calibration level shifted back into the 1% matching with the standard.
- Concerning the existing data record: The CDDS observations matched the standard very well on the November 27, 1999 intercomparison. Inspection of the data record for a change in the relationship between the results on the AD vs CD wavelength pairs should be made to determine the approximate time that the mirror smear became a problem.
- The instrument seems insensitive and noisily. This could be related to a problem of instability in the PMT high voltage circuit, and should be investigated.
- The new N-tables and reference standard lamps should be used to process data taken after December 07, 1999.

Instrument D114 Cachoeira Paulista, Brazil

Original Calibration Data:

N-tables from Nov 24, 1980. No G-table Date given. An addition adjustment to the N-tables is used, based on an May 17, 1995 intercomparison with D093, which was calibrated against D065 at Izana, Spain June 1994.

Reference Standard Lamp Values for lamps 114Q1, 114Q5, and 114Q6. 114Q3 was brought from Boulder for this intercomparison.

Lamp test results are used for data processing at home station.

Initial Calibration Results: November 30, 1999

Lamp tests results were included in the analysis.

d_Na:-4.3 d_Nc:-5.0 d_Nd:-4.2 d_Nad:-0.1

The d_Nad value implies an average **+0.1% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Comments on Initial Intercomparison:

- This instrument is used for observations on AD wavelength pairs only, the total (1994 adjustment plus lamp change) lamp corrections for the C pair were estimated.
- Although the average difference in AD ozone is very small, the ozone calculated from observations at high sun ($\mu < 1.5$) increase sharply to 3-5% higher. At large μ , the ozone values are 1-3% low.

Work Performed:

- Discharge lamp series were performed. The Q-table derived from this series of measurements is same as the existing table, shifted by the difference in the mercury test.
- Wedge calibration performed, and the results applied the intercomparison of the Nov 30, 1999. The resultant N-tables produce a much-improved response in calculated ozone with μ .
- The symmetry tests on the instrument show that the instruments is slightly out of specification, but the results of the intercomparisons do not show any problem related to this.

Final intercomparison: December 07, 1999.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was +0.1% in total ozone.

Recommendations and comments:

- New N-tables and standard lamp reference values are defined from the December 07, 1999 intercomparison. These tables and reference values are to be used from this date forward to calculate ozone from the measurements of D114.
- An N-table, can be created from the November 30, 1999 intercomparison, and the lamp tests of the November 29, 1999. This calibration can be used to reprocess and re-evaluate the existing data record from this instrument. This process should be done after consultation with experts in the re-evaluation of Dobson Data records. This is a complex matter that requires some care so that the results are real. This instrument has had an almost twenty year gap between wedge calibrations, and the G-functions have changed. The effect of the ageing may or may not be linear, and the reprocessing must be done with this consideration.
- The instrument does not have a connection to the earth (ground) and should have the connection made to reduce noise in the measurement.
- There is some indication in the results that the instrument may still produce results too high at high sun and low ozone. The data record, and new data taken with the instrument should be inspected to see if this effect does occur. The G-function of the wedge is such that at low readings the density is low, and may contribute to this effect.
- Cobalt filter shows deterioration. No attempt was made to replace this filter, as it is common for this filter to be chosen at time of instrument construction to match the G-function of the wedge. The full correction of this problem is beyond the scope of this intercomparison.

Instrument 131 Ushuaia, Argentina

Original Calibration Data:

N-tables from June 22 1994, Izaña Intercomparison
Reference Standard Lamp Values for lamps I31Q1, 97Q6, used as 131Q3, UQ1
Lamp tests results used in data processing at home station.

Initial Calibration Results: November 27, 1999

Lamp tests results were included in the analysis.

d_Na:-0.7 d_Nc:-0.9 d_Nd:-0.9 d_Nad:+0.2

The d_Nad value implies an average **-0.3% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- The electronics were replaced with the 1999 version of the USA electronics.
- Replaced Low voltage power supply (+/-15VDC) in High voltage section.
- Replaced cork washer on Q1
- Performed Wedge Calibration, and applied the result to the November 27, 1999 intercomparison. The results were improved, especially at higher μ . There was a noticeable change since 1994 in the lower part of the curve.
- Symmetry test shows some mismatch in part that measures dispersion (S2Q1-S3Q1). There is no evidence in the intercomparison results that this is a problem.

Final intercomparison:

New N-tables and Reference Standard Lamp values defined.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was +0.2% in total ozone.

Recommendations and comments:

- The existing data set from this instrument does not need reprocessing, based on this analysis.
- The N-tables and reference standard lamps dated December 07, 1999 are to be used to process all data taken after that date.
- This instrument was had mechanical problems with the wedge, and has been repaired twice by the operator. The results of the first intercomparison show that the repairs were made correctly.
- The operator was given a new Standard lamp to be included with the instrument, after the intercomparison. The operator must define the reference values by comparison with the other standard lamps.

Instrument D133

Comodoro Rivadavia, Argentina

Original Calibration Data:

N-tables from April 12, 1995 Boulder, Colorado
Reference Standard Lamp Values for lamps 133A, 133B, 133Q3(Boulder)
Lamp tests results used in data processing at home station.

Initial Calibration Results: **November 27, 1999**

Adjustments based on the results of Standard Lamp tests included.

d_Na:-0.7 d_Nc:-1.2 d_Nd:-1.0 d_Nad:0.3

The d_Nad value implies an average **-0.5% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- The electronics were replaced with the 1999 version of the USA electronics.
- Attempted to repair of shutter drive problem with motor speed.
- Wedge Calibration performed, but not used.
- Symmetry test performed, and shows right to left small mismatch, but dispersion good. This was left unchanged.

Final intercomparison:

None, as the calibration will be left unchanged, but given the date on November 27, 1999 to document the verification of the calibration done here.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -1.5% in total ozone, at high sun. A second intercomparison had a highest difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was +0.5% in total ozone

Recommendations and comments:

- Existing data is correct by this analysis.
- An intercomparison on December 04, 1999 repeated the results of the November 27, 1999 within about 0.6%.
- The lamp test record at the intercomparison was inconsistent, but the changes were verified by the intercomparisons.
- The problem with shutter motor appears to be a design problem, and the solution is to change the drive to a tooth belt and pulley system, or some other more positive drive.

Instrument D134

Salto. Uruguay

Original Calibration Data:

N-tables from April 12, 1995 Intercomparison in Boulder
Reference Standard Lamp Values for lamps 134A, 134B, 134Q3, UQ1.
Lamp tests results used in data processing at home station.

Initial Calibration Results: November 30, 1999

Lamp test results were used in the processing the intercomparison.

d_Na:-0.4d_Nc:+0.1.d_Nd:+-1.0d_Nad:+0.6

The d_Nad value implies an average **-0.8% error** in calculated ozone value, $\mu=1$ to 3,
Total Ozone = 300 Dobson Units.

Work Performed.

- The instrument has been out of operation for since June 1999, and was intermittent before that. This was due to the failure in the amplifier electronics. The electronics were replaced with the 1999 version of the USA electronics.
- An attempt was made to improve the stability of the shutter drive system, with minor success.
- Wedge Calibration was performed, and when used in the processing of the November 30, 1999 intercomparison produced some improvement in the results over the N-table.
- The upper casing (lid) is warped and must have the nuts holding the case down tighten so that the lid touches the spacer on the right front. The mercury lamp test results were not very repeatable until this was done.
- The lamp 134A failed during the intercomparison, and a new lamp introduced.
- The symmetry test is slightly out of tolerance, but does not affect the intercomparison results.

Final intercomparison: December 07, 1999

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was -0.4% in total ozone.

Recommendations and comments:

- Use new N-tables, and Standard lamp reference values for all data taken after December 07, 1999.
- Existing data is correct by this analysis.
- Verify that the lid nuts are tightened enough to have the right front part of the casing touching the spacer.

PART III

WMO/GAW International Comparison of Dobson Spectrophotometers (Pretoria, South Africa, 18 March - 10 April 2000)

1. PURPOSE OF THE INTERCOMPARISON

The Intercomparison (SAWB2000IC) was organized by the World Meteorological Organization (WMO) Secretariat and the South Africa Weather Bureau (SAWB) in close cooperation and with the assistance of the USA National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL). In addition, the Czech Hydrometeorological Institute contributed a skilled person for training of operators in instrument and station management. It was a campaign to maintain the quality of the network of the Dobson ozone spectrophotometers operated in Africa. The Dobson Intercomparison also served as an assurance of the quality of the total ozone data sets created at WMO Member stations. This action is a fulfillment of WMO/GAW/QC requirements for monitoring atmospheric total ozone.

The main tasks were:

- The technical inspection and adjustment of the instruments. Three of the instruments received new amplifier electronics supplied by the WMO.
- Comparison of the Dobson spectrophotometers with the World Secondary Dobson Standard Instrument (WSSI) No. 65 from NOAA/CMDL's World Dobson Calibration Center (WDCC), Boulder, CO, USA, to determine the existing calibration level.
- Determination of new calibration constants for each Dobson spectrophotometer, as needed.
- To provide a forum for instruction for operating the Dobson spectrophotometers at home stations, and sharing knowledge concerning the management of an ozone-observing programme.

2. ORGANIZATION

The Intercomparison was held at the South African Bureau of Standards (SABS) facility in Groenkloof, Pretoria from 18 March to 10 April 2000, and was arranged by:

Dr Gerrie Coetzee, the Convener of the intercomparison, assisted by Mr Danie Esterhuysen

Mr Robert Evans, the Scientific Director of the intercomparison, assisted by Mr Michael O'Neill.

Twenty specialists from eight countries and the WMO Secretariat participated at the Intercomparison – see Part III, Annex A. The following national Dobson spectrophotometers were inspected, adjusted and compared at the SAWB2000IC:

<u>Dobson No.</u>	<u>Country</u>	<u>Station</u>
D011	Algeria	Tamanrasset
D015	Botswana	Maun, Botswana (Planned GAW Station)
D018	Kenya	Nairobi
D057	Seychelles	Victoria Airport (Rawinsonde station)
D065	USA	Boulder - World Secondary Standard Instrument. (WSSI)
D089	RSA	Irene
D132	RSA	Springbok

The Intercomparison was conducted and all activity arranged in daily schedules according to the weather conditions and with respect to the technical state of the individual instruments. The technical support of the SAWB, the SABS and special facilities from NOAA, Boulder, CO, USA were used during SAWB2000IC.

The main steps specified below were applied to each Dobson spectrophotometer:

- Unpacking the instrument, and an inspection following transport to the site.
- Inspection of the technical condition of the Dobson spectrophotometer and its functioning by means of daily standard lamp (SL) and mercury (HG) lamp tests.
- Initial comparison against the WSSI to determine the existing calibration level.
- Definition of the technical adjustments and special tests required (wedge calibrations, discharge lamp tests, cleaning and adjustment of the optics etc.).
- Final comparisons against the WSSI.
- Assessment of the results, determination of new calibration constants (Reference R-N tables, Q-table and Reference Standard Lamp Readings).
- Interview by the scientific director with the operator in charge on the results of his instrument intercomparison and other calibrations. At this point, copies of documentation related to the spectrophotometer calibration were given to the operators.
- Packing of the instrument and other technical facilities for transport to home station.
- Preparing the Final Report of the SAWB2000IC.

The history of repairs and adjustments and the results obtained for individual instruments are summarized in Part III, Annex B. This information has been saved in detail by operators and by the Scientific Director of the Intercomparison.

The success of the event was accomplished mainly through instructions provided by the Scientific and Technical Directors at the regular meetings of all participants.

With regard to the goal of sharing knowledge on the operation of the Dobson instrument and the management of an observing programme, the individual participants were required to perform the necessary calibration procedures under the supervision of the scientific staff. For example, the instruments own operator undertook all wedge calibrations. The operator, under the supervision of the scientific staff also made electronic and other repairs.

3. OTHER ACTIVITIES

- The participants of the SAWB2000IC took part in an Ozone Measurements Workshop and presented several contributions related to monitoring total ozone and functions of the global ozone monitoring network.
- Dr Mike Proffitt, scientific officer, WMO Secretariat, Geneva visited the SAWB2000IC and discussed important issues related to the operation of the GAW total ozone monitoring programme.

- Dr R. Stolarski and Dr Gordon Labow from the USA National Air and Space Administration visited the intercomparison in an effort to understand and reduce the differences between ground-based and satellite measurement.
- During the Intercomparison participants attended presentations by Mr Karel Vanicek from CHMI, Hradec Kralove. These were designed to increase theoretical knowledge on the Dobson instrument, improving its operation, and implementation of new tools for data processing and data management at home stations. The following topics were explained, discussed and practised at these presentations:
 - Theory of measurement of total ozone by means of UV solar radiation, specifically using the Dobson spectrophotometer.
 - Reason and physical background of Mercury tests and Standard lamp tests and their routine performance at stations.
 - Updating of Q-tables and N-tables at stations.
 - Description of the DOBSON-3.0 and DOBSTOOL software package.
 - A detailed description of rules for coding total ozone data reports in extCSV format - application for the Dobson stations
 - Recommended facilities at Dobson observatories for a maintenance of the instrument
 - Maintenance of the Dobson network under the GAW Project:
 - All participants received an updated software DOBSON version 3.0 and received instruction in its operation. Calibration histories of individual Dobson instruments were also investigated.

4. CONCLUSIONS

All participating instruments left the intercomparison properly calibrated with a precision of the DS observations less than 1% limit with the WSSI spectrophotometer.

5. RECOMMENDATIONS

- The Scientific Director of the SAWB2000IC acknowledged the excellent support and infrastructure provided to the intercomparison by SAWB and SABS. It was recommended that the intercomparison be repeated in another four years.
- An important part of an intercomparison with a large number of participants is the sharing of instrument operations and observing programme experiences. The addition of participants who are users of the data enabled effective communication between the data producers and users. The participants recommended that WMO continue to organize regular meetings of the monitoring community and data users.

6. ACKNOWLEDGEMENT

The South African Weather Bureau, in remembrance, acknowledged the magnanimous contribution from their esteemed colleague, Cal Archer, who had devoted the last ten years to efforts ensuring the re-establishment of the Weather Bureau's ozone research and monitoring programme. Cal Archer passed away on Friday, 17 March 2000, and unfortunately could not join the momentous occasion of participating in the First African Regional Dobson Intercomparison meeting, which undoubtedly would have been one of the most conspicuous highlights of his career.

Special appreciation was afforded to the South African Bureau of Standards, Groenkloof, Pretoria for providing the excellent facilities and infrastructure to conduct the Pretoria IC2000 Meeting and Workshop. Special thanks were given to Mr Marinus Lindhout, the facility maintenance and terrain manager for ensuring smooth logistical and technical assistance during the event.

**WMO/GAW International Comparison of Dobson Spectrophotometers
(Pretoria, South Africa, 18 March – 10 April 2000)**

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**WMO/GAW International Comparison of Dobson Spectrophotometers
(Pretoria, South Africa, 18 March – 10 April 2000)**

Individual Instrument Reports

Instrument: D011
Station: Tamanrasset, Algeria

Original Calibration Data:

N-tables from 22 July 1993, intercomparison in Boulder, Colorado, USA. Reference standard lamps 11Q1, 11Q2, 11Q3, UQ1 and UQ2 (Those three last lamps are held in Boulder.)

Initial Calibration Results:

24 March 2000 -- Adjustments based on the results of Standard Lamp tests included.

d_Na:-3.3d_Nc:-1.8 d_Nd:-1.6 d_Nad:-1.7

The d_Nad value implies an average **+2.4% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- New Electronics for the amplifier section was installed after the initial intercomparison.
- Instrument optics were inspected and found to be dusty, but otherwise in very good condition.
- The Mercury tests for verification of instrument alignment were performed, and in general were in specification, except for the S2Q2 to S3Q2 relationship (0.7 difference, versus expected 0.5). This small difference is not evident in the intercomparison results.

Final intercomparison:

New N-tables and reference standard lamp values will be defined from the results of the 24 March 2000 intercomparison. (Two other intercomparisons were performed, after the electronics were installed, with very similar results)

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -1% in total ozone, at high μ .

Recommendations and comments:

- The instrument's thermometer was broken before the first intercomparison, and used in the intercomparison. Results from the other intercomparisons, using a new thermometer, implied no problem with the first intercomparison.
- The standard lamp adjustments are quite large, (7.0, 5.7, 4.0), and do not correctly represent the instrument's calibration change. The instrument's data record should be recalculated, including both the lamp adjustments, and an additional correction of Nad Difference of -1.7 from start of observations to the present. The result ozone data set should then be compared to the satellite data set, as a verification of this reprocessing.
- An external drier unit should be constructed for and used with this instrument.
- A personal note: Mr. Bouziane Ouchene, the operator of this instrument was an indispensable part of this intercomparison. He took responsibility in assisting with the repair and rebuilding of other instruments participating in the intercomparison. This action is greatly appreciated by the directors of the intercomparison.

Instrument: D015
Station: Maun, Botswana (proposed)

Original Calibration Data:

G-tables from August 1994

Initial Calibration Results:

Not Applicable, as the instrument has no history of measurements

Work Performed:

- Electronics were replaced with latest USA type, and shutter drive was replaced with induction motor with toothed belt and pulley drive.
- The LHS mirror was found to be out of symmetry with the RHS by about 10 degrees of Q-setting. The mirror was adjusted to within a degree.

Final intercomparison:

09 April 2000

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was +1.7% in total ozone, at low mu.

Recommendations and comments:

- This instrument was originally used at Arosa, Switzerland since the 1930's, was rebuilt at least twice, the latest was in 1994. The instrument was compared against D065 in 1995, and this intercomparison repeats the Nad difference and Ncd differences to a tenth.
- The higher ozone values at low mu (high sun) were not evident at the intercomparison in 1995, which was done at a higher total ozone value.
- The N-values associated with the standard lamp values are unusually large.

Instrument D018

Station: University of Nairobi, Kenya

Original Calibration Data:

Ntables dates date 07 March 1995. Archie Asbridge in Nairobi produced the tables, and the ETC was determined by standard lamps. Reference standard lamps: 18V, 18W, 18Y, and 18Z, dated the same.

Initial Calibration Results:

24 March 2000

Adjustments based on the results of Standard Lamp tests included

d_Na:-2.6 d_Nc:-1.5 d_Nd:-2.5 d_Nad:-0.1

The d_Nad value implies an average **+0.2% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- A wedge calibration was performed on 28 March 2000. This wedge calibration was applied to the 24 April 2000 intercomparison without making a useful difference.
- The wedge and optics were cleaned, and another wedge calibration performed.

Final intercomparison:

03 April 2000 – Use this intercomparison, and the 1995 Ntable to define new tables, and new reference standard lamp values.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was -1.8% in total ozone, at low mu.

Recommendations and comments:

- Existing data set from 1995 appears to be correct as existing.
- The wedge calibration after the cleaning is not significantly difference from 1995-wedge calibration, and the 1995-wedge calibration will continue.
- When the instrument arrived there was an unexpected shift of approximated -0.6 in the Mercury test results. (Home station is about the altitude.) Investigation showed that the right hand mirror had likely moved slightly. Only the Q-setting table was changed.
- The instrument seems to have some instability in mercury lamp unit. The operators are advised to repair or replace the lamp.
- An insulating cover should be used on the instrument.
- An external drier unit should be constructed and used.
- The rhodium plate for slit S2 should removed, so that it will not be accidentally moved into the light path.
- The Q2 lever becomes loose in temperatures below 18DegreesC. The mechanism is of an ancient design, and it unclear how to correct this problem with out making the lever inoperative at high temperature. If repair at the station is needed, other experts should be consulted. (Note the reading, if the Q-plate is made to 90 degrees to the bottom of the lid.)
- The instrument does produce lower ozone values on the AD pair on high sun. The observing schedule at the station is for observation at $\mu=1.7$, and higher, so this is not a problem in the data set.

Instrument: D057
Station: Seychelles Rawinsonde

Original Calibration Data:

Ntables from 1988. One standard lamp 57Q7, with no references. Note that the instrument is used only on the AD pair. Observations are made on a limited basis – daily early morning or late afternoon. This is approximately mu range 2.0 to 1.5.

Initial Calibration Results:

31 March 2000

d_Na:+0.8 d_Nc:na d_Nd:+2.1 d_Na:-1.3

The d_Nad value implies an average **+2.0% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- The instrument's electronics were the of the UK "spinning lights" type. After the initial intercomparison, and a light cleaning of the optics (wedge was not cleaned, as it was not dirty.), The electronics were replaced with a combination of the Bertan high voltage supply, and the amplifier of the 1972 "Bob Grass" type. This combination can be supported by regional and international calibration centers.

Final intercomparison:

08 April 2000 – On a limited mu range

Highest Difference against the standard for ADDSGQP observations in mu range 1.5 to 2.5 was 0.2% in total ozone.

Recommendations and comments:

- The Power supply for the standard lamps is damaged, and an external meter at the main terminals inside the power supply must be used to read the voltage. The power supply should be repaired in a manner that the voltage can be read more easily.
- The mercury lamp power supply is highly corroded. A newer, safer mercury lamp and power supply should be obtained. (Bob Evans will supply from WMO stock.)
- The Standard lamp holder is highly corroded. Again a new holder should be obtained. (Bob Evans will supply from WMO Stock.)
- The initial intercomparison and the existing standard lamp should be used to process the existing data set. The 57Q7 bulb is given the reference values of **RA=20.1, RC=24.7, and RD=29.7**, based on lamp test on 31 March 2000.
- The station is supplied with two new bulbs: 57Q8 and 57Q9. The 57Q8 should be used for monthly tests, the 57Q9 should be used every 6 months with the 57Q8, and the 57Q7 should run yearly with the other two bulbs.
- The observation schedule used in the past at the station should be maintained.
- The final intercomparison was made with the operator learning how to use a different set of electronics, and just before the operator was to leave for the airport. There is more uncertainty in the results.
- A wedge calibration was performed, due to lack of time. This instrument should attend the next possible regional intercomparison to have the wedge calibrated.

Instrument: D089
Station: Irene, RSA

Original Calibration Data:

Ntables from 12 February 1997 intercomparison with D083 in Perth, Australia. Many Standard Lamps.

Initial Calibration Results:

24 March 2000

Adjustments based on the results of Standard Lamp tests included

d_Na:+0.7 d_Nc:-0.3 d_Nd:0.2 d_Nad:+0.5

The d_Nad value implies an average **0.8% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- Electronics were replaced with the newest NOAA type. The instrument had been modified with a Bertan type high voltage power supply with twin fine control potentiometers.
- Reference values of 89Q6, 89Q7, UQ1 and UQ2 were defined on the same level as the existing lamps.

Final intercomparison: None, as the instrument is within calibration of the standard.

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was -1.1% in total ozone.

Recommendations and comments:

- No change in the calibration, but the calibration date will be changed to 24 March 2000 so as to reflect the work done here.
- The instrument participated in two other intercomparisons (31 March and 08 April 2000, including one after the electronics were replaced. The results matched the initial intercomparison results within tenths of an N-value. All of the intercomparisons showed a match of less than one percent.
- This instrument can be considered a regional standard, and can be used to calibrate other instrument. As the instrument has shown a high μ dependence at high ozone, and high μ , the intercomparison period should be restricted to μ less than 2.5.

Instrument: D132
Station: Springbok, South Africa

Original Calibration Data:

11 February 1995 N-table by comparison with D089, and G-table performed during the same period. Many reference lamps. Note: Reference lamp values have been adjusted based on a 1997 intercomparison with D089 after the calibration was verified in Perth, Australia, against D083.

Initial Calibration Results:

An initial intercomparison was performed on 24 March 2000. The results were that the instrument was approximated 2 per cent too high on calculated ozone. A wedge calibration was performed, but during the set up for the wedge calibration, a loose "connection" between the R-dial and the wedge was discovered. An extremely small setscrew on the pulley at the bottom of the R-dial was loose. As this pulley was loose, the wedges could be moved independent of the R-dial. As one wedge would touch the end of the wedge bridge before the R-dial stop would stop the movement, it was apparent that the wedges had shifted. The setscrew was tightened, and wedge calibration performed. This calibration was applied to the intercomparison of the 24 March 2000, without improving the results. Another intercomparison was performed on 03 April 2000, with good results against the standard.

Because of this mechanical failure, the intercomparison of 24 March 2000 cannot be used to evaluate the calibration level of the instrument and level of the existing data set.

Work Performed:

- Tightened setscrew.
- The electronics were replaced with the latest USA type. During the replacement a cable carrying the digital signal from the photon-coupled interrupter to the electronics was routed close to the anode circuit of the photo-multiplier tube (PMT). When the instrument was turned on, an offset was evident in the output. An electronic filter was added to the amplifier circuit to eliminate the offset. After this, the instrument sensitivity was incorrect – the instrument output would "blank out", and take time to recover, if the signal was slightly too strong. An intercomparison was performed in this condition, but will not be used due to this problem, which was corrected after the intercomparison.
- No intercomparison was performed after the replacement of the electronics – four other instruments had a replacement of the electronics, without a change in calibration.

Final intercomparison:

03 April 2000. A new calibration will be created from the existing N-table and new Reference standard lamp values will be defined.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was –0.8% in total ozone.

Recommendations and comments:

- This instrument is one of four built in 1994. Other instruments in this series have had the problem with the setscrew also. This problem should be solved in a more permanent manner. (Suggest contacting Ing. Maximo Ginzburg, who has the other three instruments for a consistent repair for the series of instruments.)
- The other instruments have had problems with the shutter speed varying due to wearing of the pulleys in the friction drive system. Again, a solution should be found for all the series.

Instrument 5703
(Dobson Style Shimatzu Ozone Spectrophotometer)
Station: Lagos, Nigeria

Original Calibration Data:

Ntables from 22 July 1993 intercomparison with D065 in Boulder, Colorado. Reference Standard Lamps.

Initial	Calibration	Results:
(See Recommendations and Comments section.)		
31 March 2000		
Adjustments based on the results of Standard Lamp tests included		

d_Na:+2.3 d_Nc:-0.2 d_Nd:-0.7 d_Nad:+3.0

The d_Nad value implies an average **-4.4% error** in calculated ozone value, $\mu=1$ to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- The instrument arrived with a problem that made it almost impossible to get reliable results from the mercury lamp test. Investigation showed that the shutter motor speed had dropped to a value that made it very sensitive to AC line noise interference. As the motor drive system is a pulley drive with an induction motor, the output shaft speed is defined by the AC line frequency, and the shutter speed is then defined by the pulley drive ratio. Some time was spent in repairing this problem, including replacing the motor starting capacitor. The problem may be more in the bearings on the shutter drive shaft.
- The instrument was cleaned, and the mirror reset to match the LHS side. The Q-plates were checked with a 90-degree angle, and found to be correct. There was an obvious film on the wedges – almost like a spider web. (Note: The wedges are tilted in this instrument.)
- The instrument is different enough from a standard instrument, that a wedge calibration cannot be easily performed, unless a special mounting plate for the S4 bulb is made, and a connector from the R-dial to the encoder fabricated.
- The instrument has three rod for wavelength selection. Normal operation is with the center rod out, and the right and left rods at the “B” position. To perform the S3Q-test, the right rod is pulled out.
- Q-levers were tightened – note that this instrument has an adjustment for this purpose.
- High voltage power supply was replaced after the intercomparison.

Final intercomparison:

03 April 2000 (See Comments and Recommendation section.)

Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was **-0.3% in total ozone.**

Recommendations and comments:

- The Intercomparison on 31 March 2000 was performed on a limited range of μ . A second set of measurements was made in the afternoon of 01 April, 2000, on a lower sun through breaks in the cloud cover. The D_Nad was the same; implying that the difference was not due to wavelength errors. This large D_Nad at a low latitude station making observations on lower amounts of ozone, would create larger errors, and a marked μ dependence in the calculated ozone.

- The Intercomparison on 31 March 2000 was also performed with the RHS mirror out of place by about 3 degrees. The Q-table had been adjusted to account for this shift.
- After cleaning the wedge and resetting of the RHS mirror, an intercomparison was performed on 03 April 2000. If the results of standard lamp corrections from tests made after the cleaning are included, the result is that the instrument matches the standard within one percent – in all μ ranges and wavelengths. This implies that the wedge calibration is correct. Performance is very similar to the intercomparison with D065 in 1992.
- New Ntables and reference standard lamp values were defined from the 03 April 2000 intercomparison -- these are to be used for all future data reduction.
- External drier unit should be made and used.
- Body of instrument can be cleaned with cleaner wax for automobiles.
- The quilted cover should be used at all times, but a sheet over the instrument will help to keep dust out of the instrument.
- Reference values for Q5 and Q6(Q4new) for the period before the intercomparison are taken as the values from the tests of 31 March 2000.
- The Q4new was renamed Q6 after the intercomparison to avoid confusion.

DEFINITIONS

A, C and D Wavelength Pairs: The Dobson instrument measures the difference between the intensity of selected wavelengths in the range of 3000 to 3400 Ångstroms. Certain pairs were chosen to measure ozone. These are called the A, C and D pairs. There was a B, but it is rarely used due to interference by other atmospheric absorbers.

Intercomparison: Series of simultaneous measurements made by several Dobson instruments, one of which is a standard. Usually, the time period is chosen so the measurements are made over a wide range of Mu.

Standard Lamp Test: A measurement of the N-value of a specific Quartz-Halogen (normally) bulb for the standard wavelength pairs. These bulbs are usually specific to an instrument. The result is used as a measure of the drift of the instrument's specific ETC.

Q-setting Table: The table used to set the instrument's wavelength controls to a wavelength pair. The setting is dependent on instrument temperature. The controls are rotatable quartz plates, hence the name Q-setting.

Discharge lamp test series: A series of measurements on various spectral lines from discharge lamps to calibrate the instrument's wavelength controls.

Mercury Test: A test to determine the correctness of the Q-setting table with respect to a single spectral line of mercury. Normally performed routinely to verify the optical alignment of the primary (right hand side) optics to the slit S2.

Symmetry Test: A series of tests on two spectral lines of mercury to verify the spectral dispersion, and the right to left side alignment of the optics.

Wedge Calibration: The procedure used to determine the density of the optical wedge used in the instrument.

Mu(μ): Normalized optical path length through the atmosphere of radiation at the wavelengths used by the Dobson instrument. Calculated from the solar zenith angle, Mu ranges from 1.0 (sun overhead) to greater than 12.0 (sun on the horizon).

G-table: Table relating the position of the optical wedge, defined by degrees of arc on the R-dial, to relative attenuation. The Wedge Calibration defines g-tables for each A, C, and D wavelength pair.

N-table: A G-table converted by the addition of the instrument's extra-terrestrial constant (ETC) to all the entries. The ETC can be determined by lamps with a known N-value, direct intercomparison with a standard Dobson instrument, or by a Langley plot method.

Umkehr Measurement: A series of measurements made on the clear zenith sky as the sun rises or sets. The shape of the measurements when plotted against zenith angle is controlled by the ozone distribution with height. The series of measurements can be used to determine the ozone vertical profile.

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52. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1985. Volume I: Atmospheric Aerosol Optical Depth. September 1987

53. WMO Meeting of Experts on Strategy for the Monitoring of Suspended Particulate Matter in BAPMoN - Reports and papers presented at the meeting, Xiamen, China, 13-17 October 1986. October 1988
54. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1983, Volume II: Precipitation chemistry, continuous atmospheric carbon dioxide and suspended particulate matter (TD No. 283)
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111. Report of the WMO-BMBF Workshop on VOC Establishment of a "World Calibration/Instrument Intercomparison Facility for VOC" to Serve the WMO Global Atmosphere Watch (GAW) Programme (Garmisch-Partenkirchen, Germany, 17-21 December 1995) (TD No. 756)
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114. Report of the Fifth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the Second Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE^{Ed}, Garmisch-Partenkirchen, Germany, 15-19 July 1996 (TD No. 787)
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116. Expert Meeting on Chemistry of Aerosols, Clouds and Atmospheric Precipitation in the Former USSR (Sankt Peterburg, Russian Federation, 13-15 November 1995)
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119. Report on BoM/NOAA/WMO International Comparison of the Dobson Spectrophotometers (Perth Airport, Perth, Australia, 3-14 February 1997), (prepared by Robert Evans and James Easson) (TD No. 828)
120. WMO-UMAP Workshop on Broad-Band UV Radiometers (Garmisch-Partenkirchen, Germany, 22 to 23 April 1996) (TD No. 894)
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131. WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia (Singapore, 2 to 5 June 1998) (Gregory R. Carmichael). Two volumes
132. Report of the Ninth WMO Meeting of Experts on Carbon Dioxide Concentration and Related Tracer Measurement Techniques (Edited by Roger Francey), (Aspendale, Vic., Australia)
133. Workshop on Advanced Statistical Methods and their Application to Air Quality Data Sets (Helsinki, 14-18 September 1998) (TD No.956)
134. Guide on Sampling and Analysis Techniques for Chemical Constituents and Physical Properties in Air and Precipitation as Applied at Stations of the Global Atmosphere Watch. Carbon Dioxide
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)
136. WMO/EMEP/UNEP Workshop on Modelling of Atmospheric Transport and Deposition of Persistent Organic Pollutants and Heavy Metals (Geneva, Switzerland, 16-19 November 1999) (Volumes I and II) (TD No. 1008)
137. Report and Proceedings of the WMO RA II/RA V GAW Workshop on Urban Environment (Beijing, China, 1-4 November 1999) (WMO-TD. 1014) (Prepared by Greg Carmichael)
138. Reports on WMO International Comparisons of Dobson Spectrophotometers, Parts I – Arosa, Switzerland, 19-31 July 1999, Part II – Buenos Aires, Argentina (29 Nov. – 12 Dec. 1999 and Part III – Pretoria, South Africa (18 March – 10 April 2000).