

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.

PART II, ANNEX A

WMO/GAW International Comparison of Dobson Spectrophotometers

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PART II, ANNEX B

WMO/GAW International Comparison of Dobson Spectrophotometers

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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:

1. 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.
2. 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.
3. 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.
4. 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.

5. 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:

1. 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.
2. 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.
3. 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.
4. A set of Q-tables for Marcapomacocha will be provided to the operator for use at the station.
5. 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:-1.5 d_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:

1. This instrument repeated the excellent results in other intercomparisons.
2. 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.

1. Wedge Calibration on November 26, 1999. Inspection of the optics showed a "smear" on mirror M1
2. Mirror cleaned and reset.
3. Discharge Lamps were performed. A new Q-setting table was created, very similar to the original.
4. 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 mu range 1.15 to 3.2 was -1.3% in total ozone, at high mu.

Recommendations and comments:

1. The Mirror M1 had a "smear" on the surface. This was cleaned with ether. The position was reset after installation.
2. The instrument response on the A wavelength shows that it is mu dependent. Cleaning the smeared mirror did not eliminate the problem. The mirror should be replaced when possible.
3. 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.
4. 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.
5. 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.
6. 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:

1. 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.
2. 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:

1. 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.
2. 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 .
3. 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:

1. 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.
2. 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.
3. The instrument does not have a connection to the earth (ground) and should have the connection made to reduce noise in the measurement.
4. 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.
5. 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.

1. The electronics were replaced with the 1999 version of the USA electronics.
2. Replaced Low voltage power supply (+/-15VDC) in High voltage section.
3. Replaced cork washer on Q1
4. 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.
5. 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:

6. The existing data set from this instrument does not need reprocessing, based on this analysis.
7. The N-tables and reference standard lamps dated December 07, 1999 are to be used to process all data taken after that date.
8. 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.
9. 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.

10. The electronics were replaced with the 1999 version of the USA electronics.
11. Attempted to repair of shutter drive problem with motor speed.
12. Wedge Calibration performed, but not used.
13. 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 mu 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 mu range 1.15 to 3.2 was +0.5% in total ozone

Recommendations and comments:

14. Existing data is correct by this analysis.
15. An intercomparison on December 04, 1999 repeated the results of the November 27, 1999 within about 0.6%.
16. The lamp test record at the intercomparison was inconsistent, but the changes were verified by the intercomparisons.
17. 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:-0.4 d_Nc:+0.1. d_Nd:+-1.0 d_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.

18. 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.
19. An attempt was made to improve the stability of the shutter drive system, with minor success.
20. 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.
21. 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.
22. The lamp 134A failed during the intercomparison, and a new lamp introduced.
23. 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:

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