SMN/WMO/GAW
International Comparison of Dobson Spectrophotometers
Villa Ortuzar Observatory,
Argentina, 24.11 – 12.12.2003
Final Report

Prepared by R. Evans, Vcom O. Barturen

Buenos Aires, December 12, 2003

1. Purpose of the Intercomparison

The World Meteorological Organization (WMO) Secretariat and the Argentine Servicio Meteorológico Nacional (SMN) with close cooperation and assistance of the USA National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory (NOAA.CMDL) organized the Intercomparison (IC/BUA-03). 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 the Member stations. This action is a fulfillment of WMO/GAW/QC requirements for monitoring of atmospheric total ozone.

The main tasks were:

- The technical inspection and adjustment of the instruments, plus any needed repairs. Three instruments received new design shutter drives.
- Comparison of the Dobson spectrophotometers towards 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 program.

2. Accomplishment

The Intercomparison was held at the SMN's Villa Ortúzar Observatory, site of the Regional Dobson Calibration Center, in Buenos Aires.

The IC/BUA-03 was controlled by:

Vicecomodoro Carlos Villanueva, the Convener of the intercomparison.

Vcom. Osvaldo Barturen, operations director of the intercomparison.

Engineer Maximo Ginzburg, the technical director of the intercomparison. He was assisted by: Mr. Ricardo Sanchez, Mr. Osvaldo Blanco, and other observatory personnel.

Mr. Robert Evans, the scientific director of the intercomparison, who was assisted by Mr. Mark Clark.

Sixteen specialists from five countries and the WMO Secretariat participated at the Intercomparison – see Appendix A. The following national Dobson spectrophotometers were inspected, adjusted and compared at the IC/BUA-03:

Dobson No.	Country	Station
D065	USA	Boulder - World Secondary Standard Intr. (WSSI)
D067	Cuba	La Habana
D087	Peru	Marcapomacocha
D093	Brazil	Natal
D097	Argentina	Buenos Aires
D099	Argentina	Marambio, Antarctica
D114	Brazil	Cachoeira Paulista
D131	Argentina	Ushuaia
D133	Argentina	Comodoro Rivadavia
D134	Uruguay	Salto

The Intercomparison IC/BUA-03 was performed and all work was done 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 in the achievement of IC/BUA-03.

The main steps specified below were generally accepted for each Dobson spectrophotometer:

- Unpacking of the instrument and an inspection made after the transport to the Observatory.
- Inspection of the technical condition of the Dobson spectrophotometer and the daily monitoring by means of the 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-03.

The history of repairs and adjustments and the results obtained for individual instruments are summarized in Appendix B. This information is saved in detail in the files kept by operators, the Regional Dobson Calibration Center and by the scientific director of the IC.

The functioning of the IC was controlled mainly by instructions of the scientific and technical directors provided at the regular meetings of all participants. These instructions were specified at the meetings of the scientific and executive group.

With regards to the goal of sharing the knowledge of the operation of the Dobson instrument and the management of an observing program, the individual participants were required to perform the

necessary calibration procedures under the supervision of the scientific staff. As much as possible, the operator made repairs on their own instrument.

3. Other Activities

- Simultaneously, WMO and SMN held a regional intercomparison of UV-B instruments in the UV Center in Villa Ortuzar.
- coincident with the IC/BUA-03, the WMO and the SMN organized the UV-SAG meeting in Buenos Aires. Dr Liisa Jalkanen and the entire UV-SAG visited the Ortuzar Centre and shared in a workshop together with the Dobson IC and UV-B IC participants on November 26th.
- Dr. Mike Proffitt, scientific officer of the GAW department, WMO Secretariat, Geneva visited the IC/BUA-03 and discussed important issues related to the operation of the GAW total ozone monitoring program.

- Umkehr Measurements?

4. Conclusions

All participating instruments leave the intercomparison with a calibration that allows a precision of the DS observations less than 1% limit towards the WSSI spectrophotometer.

5. Recommendations

- The Scientific Director of the IC/BUA-03 acknowledges the excellent support and infrastructure provided to the intercomparison by SMN. The Villa Ortuzar Observatory facilities served well in the IC/BUA-03. The recommendation is for the intercomparison to be repeated in no more than four years in the future.

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Appendix A

List of Participants

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Appendix B

Individual Instrument Reports

Instrument D067
Havana, Cuba

Original Calibration Data:

G-tables from Boulder Colorado dated 02 April 2002.
Reference lamps:

Initial Calibration Results: **The instrument, originally from Jamaica, has been out of operation for a number of years. It was rebuilt in Boulder two years ago, and has no set of N-tables. It was brought to this intercomparison for the definition of calibration and training of the operator. No initial intercomparison was required.**

Work Performed.

- An external Drier was constructed for the instrument.

Final intercomparison: 03 December 2003

Highest Difference against the standard for ADDSGQP observations in Mu range 1.15 to 2.5 was –0.3% in total ozone. This instrument shows a Mu dependency at Mu>than 2.5

Recommendations and comments:

- Use the N-table and standard lamp values dated 03 December 2003 to process the data taken after that date.
- Two other earlier intercomparisons had similar results to the 03 December 2003 intercomparison.
- Restrict the direct sun observations using the AD pairs to Mu < 2.5.

Instrument 087
Marcapomacocha, Peru

Original Calibration Data:

N-tables from 07 December 1999 intercomparison with D065 in Buenos Aires.
Reference Standard Lamp values for lamps: 87Q2, 87Q3
Lamp tests **ARE** used regularly for data processing at home station.

Initial Calibration Results: 27 November 2003

Results after inclusion of standard lamp test results from 87Q2.

d_Na: +1.6 d_Nc: +1.6 d_Nd: +2.5 d_Nad: -1.0 (from complete analysis)

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:

- Minor repairs to Q-stops, Sun director
- Optical cleaning,
- Removed lens from Sun Director to aid in observations.

Final intercomparison: 03 December 2003 (using the 1999 calibration and including the lamp test results).

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was +2.3% in total ozone, at high sun. Agreement in the range 1.5-3.2 was +/-0.6%. This higher ozone at high sun was not always observed on other days, but was also noticed in 1999.

Recommendations and comments:

- Reprocess data since last intercomparison with a linear drift correction to account for the results of the initial intercomparison.
- The final intercomparison on 03 December 2003 had very similar results to the intercomparisons in 1999. The decision is made to continue using the 1999 calibration with new reference standard lamps add to the calibration
- An intercomparison on 01 December 2003 had results almost identical in N_ad difference as 27 November 2003. The lens was removed in this intercomparison.
- Users of the data from this station should be aware of the higher ozone values produced at high sun.
- The lens should not be replaced in the sun director.

Instrument D093
Natal, Brasil

Original Calibration Data:

N-tables from Izana 1995 intercomparison with dated 25 June 1994.
Reference lamps: 93Q2, 93Q3, 93Q5, 93Q6, and 93Q7

Initial Calibration Results: 01 December 2003

Adjustments based on the results of Standard Lamp tests included.

d_Na:-1.8 d_Nc:-1.0 d_Nd:-0.7 d_Nad:-1.1

The d_Nad value implies an average **+1.6% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed.

- The instrument electronics were repaired.
- The instrument optics were cleaned – some optical components had a "film" on the surfaces.
- A wedge calibration was performed.

Final intercomparison: 06 December 2003

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

Recommendations and comments:

- The initial calibration should be used to correct the data (linear drift correction) and the reprocessed data submitted to the World Ozone and UV Data Center. (Look at the ozonesonde vs Dobson record at Natal to determine a reprocessing method.)
- A new calibration is established using the intercomparison of 06 December and G-tables of 04 December 2003, and new reference lamps values defined.
- Use the N-table and standard lamp values dated 06 December 2003 to process the data taken after that date.
- The silica gel should be changed whenever the 75% of the gel has changed color.

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: 03 December 2003

Adjustments based on the results of Standard Lamp tests included

d_Na:=+1.3 d_Nc:0.0 d_Nd:-0.1 d_Na:1.5 (from analysis)

The d_Nad value implies an average **–2.0% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.
The application of the intercomparison results do not give a good matching – that is, the results of observations in the 1.15-1.5 range are 1% high and the results in the 2.5-3.2 range are 1% low compared to the standard.

Work Performed:

- Note that the results were repeated on two earlier other intercomparisons.
- A wedge calibration was performed on 05 December, and applied to the 03 December 2003 intercomparison, with very good results – indicating the wedge calibration had changed since 1999.
- The instrument was cleaned, and during the cleaning, it was discovered that the wedge still had glue between the surfaces, and the decision was made to convert the wedge to an air space wedge.
- The wedges were soaked in acetone for 24 hours before the glue loosened enough to allow separation the wedge and the quartz cover removed.
- One of the wedges has a vertical gradient, as well as a horizontal gradient.
- After the wedges were cleaned of residual glue, and replaced in the instrument (and a wedge calibration performed) a symmetry test showed that the apparent position of the slit S3 had changed. The removal of glue likely changed the light path through the wedge, and thus the apparent position with respect to S2. The S3 position now was 3 degrees high in Q than S1 (+/-0.5 is the expected difference.) This change is likely due to the change in light path through the wedges after the removal of the glue.
- The prism P1 was rotated clockwise to bring the difference to specification. After that both mirrors were adjusted to achieve right to left symmetry. (This was not the best solution – a more correct way to solve this would be to move the slit S3 to accommodate the change.)
- Another wedge calibration was then performed. The wedge density did change with the removal of the glue.
- An intercomparison was made with D065, with disappointing results.
- A discharge lamp series was made and the resulting Q-table was significantly different from the table used before the starting work on the instrument. (This change is like due to the change in the real dispersion when the prism was rotated).
- An intercomparison with D065 was attempted, and while the results indicated that the instrument was operation and producing good results, the span of Mu during the intercomparison was short.
- The final intercomparison was against D099, newly calibrated against D065. Instrument D133, also well calibrated with respect to D065, was operated at the same time as a "cross-check".

Final intercomparison: 17 December 2003

Highest Difference against the standard for ADDSGQP observations in Mu range 1.15 to 3.2 was +1% in total ozone.

Recommendations and comments:

- Based on the results with D099, which was calibrated against D097 in August 2001, D097 was likely in calibration at that time.
- The results of the initial intercomparison should be use to reprocess the existing data set – in the period August 2001 to December 2003, and to submit this new data set to the WOUDC. Consider using a linear drift correction
- The D097 Mu response is better than D099.

Instrument 99
Marambio, Antarctica, Argentina

Original Calibration Data:

N-tables from August 01, 2001 intercomparison in Buenos Aires against D097
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: 03 December 2003

Lamp tests results were included in the analysis.

d_Na:-0.8 d_Nc:-0.8 d_Nd:-0.4 d_Nad:-0.5 (from Analysis)

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.

- None

Final intercomparison: 03 December 2003

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was –0.9% in total ozone, at high mu.

Recommendations and comments:

- The results in two other intercomparisons were similar; one other had differences related to inexperienced operator.
- The new calibration is to bring D099 directly calibrated to D065.

Instrument D114
Cachoeira Paulista, Brazil

Original Calibration Data:

N-tables from 07 December 2003 intercomparison with D065.
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: 03 December 2003
Lamp test results included.

d_Na:-2.6 d_Nc: -1.3 d_Nd:+0.5 d_Nad:-3.1

The d_Nad value implies an average **~5% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Comments on Initial Intercomparison:

- The corrections determined by the intercomparison produce ozone values from the AD direct sun observations within 1% of the standard in the Mu range 1.15 to 3.2, but the matching on the individual wavelengths is poor.

Work Performed.

- Instrument optics were cleaned.
- The wedge slides are worn, and had become "sticky". The slides were lubricated with a high vacuum grease.
- Wedge Calibration was performed.

Final intercomparison: 06 December 2003

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

Recommendations and comments:

- The results of the initial intercomparison should be use to reprocess the existing data set – in the period December 1999 to December 2003, and to submit this new data set to the WOUDC. Consider using a linear drift correction.
- New N_tables and standard lamp reference values are defined from the 06 December 2003 intercomparison. These tables and reference values are to be used from this date forward to calculate ozone from the measurements of D114.
- Cobalt filter shows deterioration, as noted in 1999. 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.
- The drier for this instrument should be operation continuously – 24 hours per day. The silica gel should be changed whenever the 75% of the gel has changed color – humid conditions are related to the change in the cobalt.
- This instrument changed by a large amount since the last intercomparison. This may due to a deteriorating optical wedge or further deterioration of the cobalt filter. The replacement of the cobalt filter and wedge are not possible at this intercomparison meeting. If this instrument is to be used for further observations, a through rebuilding of the instrument should be done at the appropriate facility.
- This instrument should be allowed to become temperature stable before making observations, or lamp tests.

Instrument 131
Ushuaia, Argentina

Original Calibration Data:

N-tables from 07 December 1999 Buenos Aires 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:

(Adjustments based on the results of Standard Lamp tests included.)

d_Na:-0.8 d_Nc:-0.8 d_Nd:+0.5 d_Nad:-1.3

The d_Nad value implies an average **+1.8% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed.

- The shutter drive was replaced with a belt drive using an 115VAC motor, and transformer. Note this required a change in the motor start capacitor from 1.3 to 2.5 microfarad for the motor to operate at the correct speed.
- Optical were cleaned.

Final intercomparison: 03 December 2003

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:

- The initial calibration results are to use to reprocess the existing data set. Consider the use of a linear drift correction. The reprocessed data set must be submitted to the WOUVDC.
- The result of the second intercomparison, processed with the lamp test results, has very similar results to first.
- New N-tables and reference standard lamps are defined from the 03 December 2003 intercomparison.
- The new calibration is to be used for all data taken after 03 December 2003.
- This instrument has most of the screws painted with a varnish to keep the screws tight. There is a small stripe of this red varnish on the Prism P2, Mirror side. This does not seem to effect the measurements.

Instrument D133
Comodoro Rivadavia, Argentina

Original Calibration Data:

N-tables from 27 November 1999 (same as 12 April 1995).
Reference Standard Lamp Values for lamps 133A, 133B, 133Q3(Normally kept in Boulder)
Lamp tests results used in data processing at home station.

Initial Calibration Results: 03 December 2003

Adjustments based on the results of Standard Lamp tests included.

d_Na:+0.2 d_Nc:-0.4 d_Nd:+0.2 d_Nad:0.0

The d_Nad value implies an average **–0.0% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed.

- The instrument arrived with a non-operational friction shutter drive. The shutter drive was replaced with a belt drive using an 115VAC motor, and transformer. Note this required a change in the motor start capacitor from 1.3 to 2.5 microfarad for the motor to operate at the correct speed.
- Instrument was cleaned – optics and base. Some film (from the failing motor?) was noticeable on horizontal surfaces, but not on the optics.
- M2 was adjusted to bring symmetry in to specification.

Final intercomparison: none, as the instrument is in calibration.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was –0.9 % in total ozone.

Recommendations and comments:

- An intercomparison on 06 December 2003, after the optical cleaning and mirror adjustment, repeated the 03 December 2003 results with in 0.5%
- Existing data from this instrument does not need reprocessing.
- New standard lamp reference values for the new UQ bulbs will be added to this instrument's calibration.

Instrument D134
Salto. Uruguay

Original Calibration Data:

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

Initial Calibration Results: None, as the instrument has been out of operation for three years, and required several repairs to be come operational.

Work Performed.

- The instrument has been out of operation for since October 2000, due to the failure of the shutter drive. The shutter drive was replaced with a belt drive using an 115VAC motor, and transformer. Note this required a change in the motor start capacitor from 1.3 to 2.5 microfarad for the motor to operate at the correct speed.
- The prism P1 was discovered to be loose in its holder. Tightening the prism in the holder changed the optical symmetry, requiring re-alignment of mirrors and prism P2.
- The capacitor that couples the signal from the PMT anode to the amplifier was not mounted, and the wires to the capacitor were broken. This problem was repaired and the capacitor mounted to the back of the PMT circuit.
- The instrument's optics were cleaned. There is evidence that the instrument had been subject to high humidity, as the cobalt filter has deteriorated. Replacement of the cobalt filter is not normally attempted during field intercomparisons.
- The glue that holds the small prism before the Slit S1 has mitigated to the surfaces of the prism. The prism surfaces were cleaned with alcohol, to remove the glue, with an attempt to avoid damaging the glue.
- The lamp tests values have changed by a large amount since the last intercomparison, both in the absolute value and in the relationship between the A, C and D wavelengths.

Final intercomparison: 03 December 2003

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

Recommendations and comments:

- Use new N-tables, and Standard lamp reference values for all data taken after 03 December 2003
- The existing data cannot be evaluated considering the amount of repairs that have been made on the instrument and the deterioration in some optical parts. The existing data will remain unchanged. A note should be placed in the World Ozone data Center stating that calibration history was broken in October 2000, when data submission restarts.
- Verify that the lid nuts are tightened enough to have the right front part of the casing touching the spacer.
- The instruments should be protected from high heat and humidity.
- It is important for this instrument to have the calibration rechecked in four years.
- Lamp test results are more variable day to day than normal.