REPORT ON BoM/NOAA/WMO INTERNATIONAL COMPARISON OF THE DOBSON SPECTROPHOTOMETERS

(Perth Airport, Perth, Australia)
3-14 February 1997
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REPORT ON BoM/NOAA/WMO INTERNATIONAL COMPARISON OF THE DOBSON SPECTROPHOTOMETERS

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Prepared by Robert Evans and James Easson
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1. PURPOSE OF THE INTERCOMPARISON

The Perth intercomparison (PTH/IC) of Dobson instruments was sponsored by the Australian Bureau of Meteorology (BoM) and World Meteorological Organization (WMO), and assisted by the NOAA Climate Monitoring and Diagnostics Laboratory’s World Dobson Calibration Center. The PTH/IC consisted of the intercomparison of Dobson Instruments with the World Standard Dobson Instrument #83 of NOAA’s World Standard Dobson Spectrophotometer Number D083. Instruments and personnel from Australia, Singapore, South Africa, and New Zealand attended the Intercomparison. The long term quality controlled ozone data obtained within the framework of the WMO Global Atmospheric Watch (WMO/GAW) are essential to assessment of the state of the global ozone layer.

The main tasks were:

- The technical inspection and adjustment of the instruments.
- Comparison of the Dobson spectrophotometers with the World Standard Dobson Instrument No. 83, 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 of knowledge concerning the management of an ozone observing programme.

2. OPERATION

The Perth Intercomparison was held at the Perth Airport (PTH) facilities of the Australia Bureau of Meteorology in during 3-14 February 1997, under the management of the Ozone Monitoring Unit headed by Arthur Downey. Its operation was controlled by the scientific staff consisting of scientific director Robert Evans (NOAA/CIRES) ably assisted by Jim Easson (BoM), and Don Anderson (BoM).

The following Dobson spectrophotometers participated:

<table>
<thead>
<tr>
<th>No. of Dobson</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>D007</td>
<td>Singapore</td>
</tr>
<tr>
<td>D042</td>
<td>USA (Samoa)</td>
</tr>
<tr>
<td>D072</td>
<td>New Zealand (Lauder)</td>
</tr>
<tr>
<td>D081</td>
<td>Australia/USA (Perth Airport)</td>
</tr>
<tr>
<td>D089</td>
<td>South Africa (Irene)</td>
</tr>
<tr>
<td>D105</td>
<td>Australia (Melbourne/Regional Standard)</td>
</tr>
</tbody>
</table>

The Intercomparison (IC) was performed and all works were done in daily schedules according to the excellent weather conditions and with respect to the technical state of the individual instruments. The technical facilities of the Perth Airport and special facilities from NOAA, Boulder were used to complete the PTH/IC.

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

- unpacking of the instrument, its check after the transport and installation at the PTH/IC.
- Inspection of the technical condition of the spectrophotometer and its monitoring by means of the daily Standard and Mercury lamp tests.
- Initial comparison against the Regional Standard 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, refurbishing of the electronics etc.).

- Final comparison against the World Standard.
- Assessment of the results, determination of the 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 operator.
- Packing of the instrument and other technical facilities for transport to home station.

All repairs or adjustments which were done and the results obtained for individual instruments are described in Annex B, and briefly given in Table 1. This information are saved in detail in the files kept by operators and by the scientific director of the IC.

With regards to the goal of sharing the knowledge of the operation of the 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, all wedge calibrations and discharge lamp tests were performed at least partially by the instrument’s own operator.

3. CONCLUSIONS

The skies during the intercomparisons were uniformly very clear, with little visible evidence of haze, or smoke. (On one day, there was a fire in the area, but the wind direction kept the smoke from the intercomparison site.) The total ozone amount during the intercomparison was fairly low. The clear skies and low total ozone allow for some possible instrument problems not to be evident in the intercomparison data. The low ozone amount is representative of the conditions of the home stations of all the instruments except D072 (45 degrees south). This instrument’s calibration history does include intercomparisons at higher ozone.

All participating instruments leave the intercomparison with a proper calibration, and correct operating order. (See Annex B, Individual Instrument Results.)

Discussions of station operation and instrument maintenance were held amongst the participants. From these discussions, the scientific and technical directors make the following recommendations.

4. RECOMMENDATIONS

A recommendation is made to WMO to:

- Standardize the electronic circuits of the Dobson instrument with a simple, effective design using easily available components. To ensure the use of this design, WMO should provide the means of converting the various instrument to this circuit.
- To sponsor a revision of the Operational Handbook in light of the fifteen years of experience with the instruments since the last revision.
- To sponsor a station assessment programme, to evaluate station operation, and ensure data quality in the coming years.
- To better define the roles of the member countries in the various regions.

The directors of the 1997 PTH intercomparison urges that the three to four year schedule of Dobson Ozone Spectrophotometers intercomparison be continued.
Table 1: Review of the BOM/WMO/NOAA Intercomparison of Dobson Ozone Spectrophotometers, Perth Airport, Australia, O₃

<table>
<thead>
<tr>
<th>Instrument Number</th>
<th>Station</th>
<th>Original Calibration Date</th>
<th>Delta Nad</th>
<th>Implied Average Error in Ozone</th>
<th>Instrument refurbishing other than that common to all instruments</th>
<th>Final Maximum Difference from the Standard DO65</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Singapore</td>
<td>Sept, 1990 (Reference Lamps)</td>
<td>-0.7</td>
<td>+1.0%</td>
<td>Conversion to USA type electronics, Wedge repair, wedge calibration, New Q Table</td>
<td>+0.6%</td>
</tr>
<tr>
<td>42*</td>
<td>American Samoa</td>
<td>09 Sep 1991</td>
<td>0.0</td>
<td>+0.0%</td>
<td>New Q Table</td>
<td>-0.6%</td>
</tr>
<tr>
<td>72*</td>
<td>Lauder, New Zealand</td>
<td>22 Jul 1992</td>
<td>0.0</td>
<td>+0.0%</td>
<td></td>
<td>+0.4%</td>
</tr>
<tr>
<td>81*</td>
<td>Perth, Australia</td>
<td>02 Jul 1992</td>
<td>0.1</td>
<td>-0.2%</td>
<td></td>
<td>-0.6%</td>
</tr>
<tr>
<td>89</td>
<td>Irene, South Africa</td>
<td>May, 1993</td>
<td>0.2</td>
<td>-0.3%</td>
<td>Wedge Calibration</td>
<td>-0.4%</td>
</tr>
<tr>
<td>105*</td>
<td>Melbourne, Australia</td>
<td>29 Jul 1992</td>
<td>0.0</td>
<td>+0.0%</td>
<td></td>
<td>+0.5%</td>
</tr>
</tbody>
</table>

Notes:
* Instrument’s calibration level unchanged.
See Annex B for individual instrument discussion.
Delta Nad is the average N-value adjustment to the instruments N-tables to bring the instrument’s ADDS observations to the Standard’s.
Implied Average Error in Ozone is calculated from Delta Nad without regard to actual station data record.
Final Maximum Difference from Standard is the largest percentage difference in any mu range from 1.15 to 3.2, on the ADDSGQP type observation, using calibration tables defined during the intercomparison.
LIST OF PARTICIPANTS

PTH/IC Comparison of the Dobson Spectrophotometers
Perth Airport, Perth, Australia 3-14 February 1997

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ANNEX B

INDIVIDUAL INSTRUMENT REPORTS

PTh Intercomparison of the Dobson Spectrophotometers
Perth Airport, Perth, Australia 3-14 February 1997

D007
D042
D072
D081
D105
D089
Original Calibration Data:

Reference Standard Lamps 7Q1, 7Q2, 7Q3 and 7Q4
Examples of station lamp tests.

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
4 February 1996

d_Na: +0.21  d_Nc: +1.03  d_Nd: +0.93  d_Nad:-0.72

The d_Nad value implies an average +1.0% error in calculated ozone value, Mu = 1 to 3,
Total Ozone = 300 Dobson Units.

Comment: The instrument's electronics were of the `spinning' lights type. The instrument also
appears to have been constructed with parts from other instruments. The optical wedge assembly
was broken and repaired at some time in the past.

Work Performed:
- A steel strap was replaced on the wedge assembly after the intercomparison. The
  mechanical stops on the wedge assembly are not adequate to protect against over-extension
  of the straps, and an external stop was added.
- The electronics were removed and replaced with a more conventional design. This
  replacement required extensive time, and energy.
- Instrument optics were cleaned.
- Wedge Calibration was performed on 14 Feb. 1997.
- Discharge lamp test was performed, and a new Q-table was defined on 14 February 1997.
- Fitting for external drier were made and parts for the external drier were supplied.
- Revised observational instructions in light of the change in the electronics were provided to
  Singapore.
- Many small repairs were made to the mechanics of the instrument.

Final intercomparison: 15 February 1997 (with verification of d_Nd values morning of 16 February
1997 ). New N-tables and reference Standard Lamp values defined for this date.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 2.5
was +0.6% in total ozone.

Recommendations/Comments:
- Data taken before the 4 February 1997 Intercomparison should be reprocessed with the
  addition of the N-adjustments from the Intercomparison.
- A set of spare parts should be obtained by the station including spare belts, meters, and
  power supplies.
- A external silica gel drier should be fitted using parts supplier with the instrument. This drier
  should operate continuously.
- Continue and expand quasi-simultaneous direct sun and zenith observations to evaluate the
  zenith observation reduction method.
- The use of the Czech computer programme for is recommended reduction of the
  observations to ozone values, and for evaluation of zenith ozone values.
The Instrument's Q-levers and scales are of an old design, and are both difficult to read and adjust properly.

One pulley for the chopper drive is either warped, or worn. The toothed belt does not run smoothly. A replacement system and spares should be obtained by the operators.

Define the reference values for 7Q3 and 7Q4 are to be determined from test at station.

There is evidence that the instrument has either an improperly focused MI, or incorrectly set slit width of S2. No problem was noticeable in the intercomparison results. The intercomparison results may not be representative of the instrument's performance at much higher amounts of ozone.
Instrument D042

NOAA/CMDL Observatory, America Samoa

Original Calibration Data:

N-tables and reference standard lamp values from 9 September 1991 intercomparison with D083, Boulder Colorado.
5 September 1991 Q-tables
Instrument was checked against D083 in 1993 at MLO.
Standard Lamps 42Q1, 42Q2, and 42Q4

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
4 February 1997

\[ d_{Na}: +0.23 \quad d_{Nc}: +0.79 \quad d_{Nd}: +0.18 \quad d_{Nad}: 0.05 \]

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.
- Interior inspected and lightly cleaned, GQP cleaned. Optics in very good condition.
- Discharge lamps series was performed, and a new Q-table dated 05 February 1997 created.
- An intercomparison was performed on 10 February 1997; the results of which were similar to the 4 February 1997 results, but with a smaller \( d_{Nc} \) value.

Final intercomparison: Calibration unchanged, but the original calibration will be given a new date.

Highest Difference against the standard for ADDSGQP observations in \( mu \) range 1.15 to 2.5 was -0.6% in total ozone.

Recommendations/Comments:
- Analysis of the 04 February 1997 intercomparison showed a pattern in the C-wavelength results implying an incorrect wavelength setting. The results of the discharge lamps verified that the setting for the C-wavelength in the 05 September 1991 were incorrect by approximately 1.0 unit.
- Another intercomparison on the 11 February 1997, using the correct Q-table, verified that the existing calibration is correct.
- Existing Data set needs no reprocessing, as the station does not use CD direct sun measurements. Future CC" zenith observations will use the correct Q-setting for the C, and therefore the reduction procedure for future CC' observations should be reviewed.
- Instrument’s paint is deteriorating above the Q-levers.
- Lamp 42Q1 appears to be changing with respect to the other lamps, although the AD difference is the same. A new lamp, 42Q4 was created, and station personnel are advised to operate this bulb as to give it reference values.

*****
Instrument D072
Lauder, New Zealand

Original Calibration Data:
12 June 1989 Q-table.

Initial Calibration Results (Adjustments based on the results of standard lamp tests included.)
4 February 1997

\[
d_{Na}:-0.23 \quad d_{Nc}:+0.11 \quad d_{Nd}:-0.22 \quad d_{Nad}:-0.01
\]

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.
- Instrument interior was dusted, and optics lightly cleaned. There was a smudge on one end of an optical wedge.
- Photocoupled Interrupter for R-dial Zero position replaced.
- An intercomparison was performed on 10 February 1997, with verified the 04 February 1997 results.
- Symmetry test results show that the instrument is not aligned right to left side, but no problem is seen in intercomparison results.
- Discharge lamp test confirmed existing Q-table.

Final intercomparison: Calibration (N-tables and reference standard lamp values) remains unchanged, with a new Reference Date of 4 February 1997.

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

Recommendations/Comments.
- Existing data set from instrument is correct, based on the initial intercomparison.

*****
Instrument D081
Perth Airport, Perth, Australia

*Original Calibration Data:*

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
2 March 1996

\[
d_{Na}: +0.30 \quad d_{Nc}: +0.18 \quad d_{Nd}: +0.18 \quad d_{Nad}: +0.12
\]

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.*
Interior cleaned and optics dusted. Q-plates cleaned.

*Final intercomparison:* Original calibration left unchanged, but given 04 February 1997 date as a new reference date.

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

*Recommendations/Comments.*
- This instrument is automated, and intercomparisons were performed in the automated state.
- Two other intercomparisons were performed with similar results.
- The wedge drive has a small, 0.2 degree looseness. The lamp tests and observations have a 0.1-0.2 degree larger standard deviation, than other automated instruments.
- This instrument’s wedge was damaged once in it’s history. In 1992, wedge pulleys bearings were replaced. The R-dial still shows a small wobble.
Instrument D089
Irene, South Africa

Original Calibration Data:

N-tables and Reference Standard Lamp Values from Hradec Kralove, Czech Republic Intercomparison, May 1993, with D065.

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.) 4 February 1997.

d_{Na}: +0.29  d_{Nc}: +0.43  d_{Nd}: +0.04  d_{Nad}: +0.25

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.
- Ground Quartz Plate was cleaned, and a change was noted in the standard lamp test results.
- The instrument was opened after the initial intercomparison and cleaned. Wedge, and optics were cleaned.
- As the instrument's meter readings became electrically 'noisy', changes were made in the high voltage power supply circuit of the instrument. The original unregulated +/-15 volt power supply feeding the 0-1000 volt Bertan converter was found to be 'singing', and was replaced with a regulated +/- 15 modular power supply.
- Wedge Calibration was performed by Mr. Esterhuyse.
- An intercomparison was performed on 10 February 1997. The results were different from the initial intercomparison. One section of the intercomparison was performed with possible incorrect Q-setting on instrument D089.
- Discharge lamp tests were performed. The results of the tests verified the existing Q-table.
- A final intercomparison was performed on 12 February 1997. The results are similar, but more complete that those of the 10 February 1997 intercomparison.

Final intercomparison: 12 February 1997
New N-tables and Reference Standard Lamp values defined for instrument lamps plus UQ2 and UQ8.

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

Recommendations/Comments.
- Existing data set of observations from this instrument is acceptable as is.
- Use new N-tables and Standard Lamp Reference values for future observations.
- The high voltage power supply section is missing three components, and instructions were given for the addition of these parts at the home station.
- Total Observations performed at the home station should be made more careful, allowing approximately 30 seconds for each A and D reading and checking the sun spot between each reading.
- In past intercomparisons, this instrument has exhibited a large mu dependence on the A wavelength, and noticeable in the ADDS results for mu greater than 2.5. This mu dependence was not as noticeable in these series of intercomparisons, which were made a lower ozone than other intercomparisons.

*****
Instrument D105
Melbourne, Australia

Original Calibration Data:

Initial Calibration Results (Adjustments based on the results of Standard Lamp tests included.)
4 February 1997.

\[ d_{Na}: +0.20 \quad d_{Nc}: +0.70 \quad d_{Nd}: +0.23 \quad d_{Nad}: -0.04 \]

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.
- Instrument interior vacuumed and optics dusted.
- Wedge Calibration performed for record, not used.
- Intercomparison repeated on 12 February 1997, with results within 0.6% of 4 February 1997 results.

Final intercomparison: Calibration will remain the same, but referenced to 4 February 1997.

Highest Difference against the standard for ADDSGQP observations in \( mu \) range 1.15 to 2.5
was +0.5% in total ozone.

Recommendations/Comments.
- None.

*****
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(λ): 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. G-tables are defined for each A, C, and D wavelength pair by the Wedge Calibration.

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.

*****
ACKNOWLEDGEMENTS

The participants would like to acknowledge the excellent assistance from the staff of the BOM's WA Regional Engineering Centre, the Perth Airport Observers and particularly the contribution of Mr I. Boyd for retraining on the NOAA automated Dobson.

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11. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1982

12. Report on the Mount Kenya Baseline Station Feasibility Study edited by Dr. Russell C. Schnell


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73. Report of the Experts Meeting on Global Aerosol Data System (GADS), Hampton, Virginia, 11-12 September 1990


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76. The International Global Aerosol Programme (IGAP) Plan: Overview

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83. Report on the Global Precipitation Chemistry Programme of BAPMoN

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91. Extended Abstracts of Papers Presented at the WMO Region VI Conference on the Measurement and Modelling of Atmospheric Composition Changes Including Pollution Transport, Sofia, 4-8 October 1993


94. Report on the Measurements of Atmospheric Turbidity in BAPMoN


96. Global Atmospheric Background Monitoring for Selected Environmental Parameters WMO GAW Data for 1993, Volume I: Atmospheric Aerosol Optical Depth

97. Quality Assurance Project Plan (QAPP) for Continuous Ground Based Ozone Measurements


99. Status of the WMO Global Atmosphere Watch Programme as at 31 December 1993


101. Report of the WMO Workshop on the Measurement of Atmospheric Optical Depth and Turbidity, Silver Spring, USA, 6-10 December 1993, (edited by Bruce Hicks)


103. Report of the Meeting of Experts on the WMO World Data Centres, Toronto, Canada, 17-18 February 1995, (prepared by Edward Hare)

104. Report of the Fourth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the First Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE, Garmisch-Partenkirchen, Germany, 13-17 March 1995

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110. Report of the WMO-NOAA Expert Meeting on GAW Data Acquisition and Archiving (Asheville, NC, USA, 4-8 November 1995)


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