EMA/WMO/GAW
International Comparison of Dobson Spectrophotometers
Region I (Africa)
Dahab, Egypt 23 February-12 March, 2004

Final Report

Prepared by the R. Evans, Darwish Ahmed

Dahab, Egypt March 2004

1. Purpose of the Intercomparison

The World Meteorological Organization (WMO) Secretariat and the Egyptian Meteorological Authority (EMA) in close cooperation and assistance of the USA National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory (NOAA.CMDL) organized the Intercomparison (DICE04). Further assistance was provided by the German Weather Service's European Dobson Regional Calibration Center (DWD-RDCC/E), and by the Czech Hydro-meteorological Institute's Solar and Ozone Observatory (SOO-HK). Funding was in part provided by the Trust Fund for Research and Systematic Observations under the Vienna Convention for the Protection of the Ozone Layer. It was a campaign to maintain the network of the Dobson ozone spectrophotometers operated in the Africa 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. One instrument was fully optically aligned.
- 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.
- To verify calibration of European Regional Standard Dobson D064.

2. Accomplishment

The Intercomparison was held at the EMA facilities in Dahab, South Sinai.

The DICE04 was controlled by:

Mr. Darwish Ahmed, the executive director of the intercomparison assisted by Dr. M. Arffa, Chairman of the Board of Directors of EMA.

Mr. Robert Evans, the scientific director of the intercomparison assisted by Mr. Michael O'Neill.

Mr. Ulf Koehler (DWD-RDCC), associate scientific director of the intercomparison.

Special technical assistance was provided by Mr. Bert Doemling (DWD-RDCC/E) and Mr. Martin Stanek (SOO)

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 DICE04:

Dobson No.	Country	Station
11	Algeria	Tamanrasset
15	Botswana	Maun
18	Kenya	Nairobi
57	Seychelles	Victoria Airport
59	Egypt	Hurghada
69	Egypt	Aswan
89	South Africa	Pretoria
96	Egypt	Cairo
Shimatzu 5703	Nigeria	Lagos

European Regional Standard D064 also participated for calibration verification.

The Intercomparison DICE04 was performed and all work was done in daily schedules defined to the weather conditions and with respect to the technical state of the individual instruments. The technical support of EMA and special facilities from NOAA, Boulder, CO, USA, European RDCC and the CHMI-SOO were used in the achievement of DICE04.

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 DICE04.

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 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.

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

- **Visitors:**
  Dr. Mike Proffitt, scientific officer of the GAW department, WMO Secretariat, Geneva visited the DICE04and discussed important issues related to the operation of the GAW total ozone monitoring program with the directors of the DICE04.
  Dr. Karel Vanicek, the Director of the SOO-HK and head of the Scientific Advisory Group on Ozone to the WMO visited the DICE04 for several days, interviewing the various operators and discussed issues of data archiving.
  Dr. Ahmed Adel Faris, Under Secretary of State for Stations and Instruments for the EMA
  Dr. Ahmed H. Ibrahiem, Director of Cairo Regional Meteorological Training Center of the EMA.
  Mr. Abdul, Cairo Regional Meteorological Training Center of the EMA.

- A measurement of the morning Umkehr curve was made on the 03 March 2003, as an aid to researchers into ozone profiles from this measurement.

4. Conclusions

All participating instruments but one, leave the intercomparison with a calibration that allows a precision of the DS observations less than 1% limit towards the WSSI spectrophotometer. D018 from Kenya arrived non-operational, and was not repairable during the DICE04.

5. Recommendations

- The Scientific Director of the DICE04 acknowledges the excellent support and infrastructure provided to the intercomparison by EMA. The recommendation is for the intercomparison to be repeated in another four years. Based on the experience gained in this intercomparison, October would be a more preferred time of the year.

- An important part of an intercomparison with a large number of participants is the sharing of instrument operations and observing program experiences. The addition of participants who are users of the data produced by the instruments enables communication between the data producers and users. Unfortunately, there were no data users at this intercomparison meeting. The participants recommend WMO to continue to organize regular meetings of the monitoring community and data users.

- The executive and scientific directors wish to express special appreciation to the respective governments of Germany and the Czech Republic for the assistance of personnel and special test equipment.

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Appendix A

List of Participants

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Appendix B

Individual Instrument Reports

Instrument: D011
Station: Tamanrasset, Algeria

Original Calibration Data:

N-tables from 2000 intercomparison with D065 at Pretoria, South Africa. Reference standard lamps 11Q1, 11Q2, 11Q3 (reserved in Boulder)

Repairs made at station: Photon-coupled interrupter was replaced, in 2002. Replaced power supply and corrected shutter motor speed.

Initial Calibration Results: 27 February 2004
Adjustments based on the results of Standard Lamp tests included.

d_Na:-0.6 d_Nc:-1.0 d_Nd:0.5 d_Nad:-0.1.1

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 sun director had been repaired on the station, and did not fit well on the instrument. This was repaired after the initial intercomparison.
- Inspection of the wedge revealed a spot in the region for the R-dial reading for many of the observations at the station.
- A wedge calibration was performed before the wedge was cleaned, and again after the wedge and instrument were cleaned. There were noticeable differences before and after cleaning.
- Discharge lamp series was performed, but the differences between the results and the existing table were small, and the existing table will continue to be used.
- Symmetry test after the wedge calibration and cleaning fail the S2Q2-S3Q2 test by a few tenths that seems to be temperature dependent. This instrument is one that was produced as single wavelength pair instrument, and then converted to multiple pairs. This instrument may have different temperature coefficients than later instruments.

Final intercomparison: 04 March 2004

New N-tables and reference standard lamp values will be defined from the results of the intercomparison.

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 measurements in the initial intercomparison are quite variable, and this variability likely is representative of measurements made at the station. The results of a short intercomparison on high sun on 26 February 2004 were similar to the 27 February results.
- The high sun measurements before correction were about 3% higher than the standard.
- Considering the variability in the initial calibration, and effects of editing on the results, the definition of a new calibration using the results of the wedge calibration are not recommended. The calibration results stated for the initial calibration are selected from editing to allow for reprocessing the existing data set in a more simple matter.
- The existing data from this instrument should be inspected for a shift in the high sun measurements on the direct sun to indicate when the spot appears. (Was there an episode when the instrument was exposed to rain?) Investigate the times when the instrument was opened for repairs.

- The data set from the point in time of the shift must be reprocessed using the results of the initial intercomparison and sent to the WOUDC.
- The data set of results prior to the 2000 Pretoria intercomparison is also to be reprocessed with the results of the initial intercomparison in the 2000 intercomparison.
- A new set of N-tables and reference standard lamp values will be produced from the 04 March 2004 intercomparison, and are to be used to process data after that date.
- The reserve lamp 11Q3 values will be determined on station after the instrument returns.

Instrument: D015
Station: Maun, Botswana

Original Calibration Data:

N-tables from 2000 intercomparison with D065 at Pretoria, South Africa. Reference standard lamps

Initial Calibration Results:

27 February 2004 – Adjustments based on the results of Standard Lamp tests included.

d_Na:-12.4 d_Nc:-12.4 d_Nd:-12.2 d_Nad:-0.1 (from analysis)

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

Work Performed:

- Minor repairs to instrument body and standard lamp power supply.

Final intercomparison: not used, as instrument is in calibration with the standard. New standard lamp reference values to include the new universal lamps kept in Boulder, Colorado, USA.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was -0.9% in total ozone, during measurements on high sun on 04 March 2004.

Recommendations and comments:

- The instrument has what appear to be access panels made of stainless steel in the top of the lid. The instrument has no insulated cover here – it should be operated with such a cover.
- An external drier should be derived for this instrument.
- Verify that the correct tables are used in Maun for calculation of ozone.
- Use the Q-table for Maun, not the one from Dahab.
- Second intercomparison repeated the results of the 27 February 2004 to within 0.5%
- Observers are well trained, and a pleasure to work with.

Instrument: D018
Station: University of Nairobi, Kenya

Original Calibration Data:

N-tables from 2000 intercomparison with D065 at Pretoria, South Africa. Reference standard lamps. Instrument failed in 2002, and station repairs were unsuccessful.

Initial Calibration Results:

None, -- Instrument is not operational

Work Performed:

- Two Technicians attempted to repair the instrument's wiring and electronics. No schematic was available, and some wiring changes appeared to have been made during the on-station repair. The attempts were successful in restoring the shutter motor, and the high voltage section. The amplifier section is not repairable here, as one capacitor had shorted and destroyed a voltage regulator. This voltage regulator is not easily available. The instrument is not repairable at the intercomparison

Final intercomparison: Not performed

Recommendations and comments:

- The instrument has a unique shutter and shutter drive, which makes the replacement of the electronics with the more modern type difficult. The effect of different shutter switching speed is unknown.
- The instrument should be sent to a facility where
    - A new shutter and drive can be constructed
    - A complete rewiring of the instrument can be done.
    - Optical alignment checked
    - Calibration re-established.
- Ulf Koehler of the European Regional Dobson Calibration Center at Hohenpeißenberg, Germany has agreed to accept the instrument for the repairs.
- This instrument needs to be operated with an insulating cover, and with an external drier.

Instrument: D057
Station: Seychelles

Original Calibration Data:

N-tables from 2000 intercomparison with D065 at Pretoria, South Africa. Reference standard lamps

Initial Calibration Results:

27 February 2004 -- Adjustments based on the results of Standard Lamp tests **not** included.

d_Na:+2.4 d_Nc:+2.1 d_Nd:3.8 d_Nad:-1.4

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:

- After the intercomparison, optical test indicated that the alignment of the instrument was very poor. Two experts in the optical alignment procedure considered it possible to correct the alignment, and this was done over several days.
- The bearing surface for the wedge slides was worn off, and metal was transferring from stationary to moving surfaces (galling). This was the reason for the past failure of the instrument. The wedge slides were reversed, to expose less worn bearing surface.
- Instrument has evidence of water damage.
- Wedge calibration was performed**,** and a new g-table was defined.
- Discharge lamp series was performed and a new Q-setting table was defined.

Final intercomparison: 08 March 2004

New N-tables and reference standard lamp values will be defined from the results of the intercomparison

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:

- Any data taken before the repair can not be evaluated with the results of the initial intercomparison.
- Any data taken after the repair should be processed with the results of the initial intercomparison included. If any of this data was submitted to the WOUDC, should be reprocessed and resubmitted.
- The final calibration was done on a difficult day – high winds, and cold temperature. The results are acceptable on the AD pair measurements, but the individual wavelength results were variable from Mu range to Mu range.
- The instrument is more sensitive to “dead” times if the Photomultiplier Tube. (PMT) voltage is set too high. The PMT circuit is different that normal, but common for British instruments. **Operators should be knowledgeable about the effect. The PMT voltage should be reduced before moving the Q-levers from the A to the D position, and increased after moving the Q-levers to from the D to the A position.**
- The PMT high voltage circuit is stable. A wedge calibration was performed, and this procedure is sensitive to the changes in the PMT voltage.
- The operator was not familiar with the instrument at first arrival, and learned quite quickly.

- More training is available for personnel at the home station. The program managers can request this training through the WMO channels.
- The international support of this training and participation in WMO sponsored intercomparisons and workshops are dependent on the station providing regular data to the WOUDC.

Instrument: D059
Station: Hurghada, Egypt

Original Calibration Data:

N-tables from 2000 intercomparison against D064 in Hohenpeißenberg, Germany. Reference standard lamps,

Initial Calibration Results: 27 February 2004-- Adjustments based on the results of Standard Lamp tests included.

d_Na:+0.1 d_Nc:-0.7 d_Nd:-1.2 d_Nad:+1.3

The d_Nad value implies an average **-1.9% error** in calculated ozone value, Mu=1 to 3, Total Ozone = 300 Dobson Units.

Work Performed:

- Optical Cleaning

Final intercomparison: 04 March 2004.

New N-tables and reference standard lamp values will be defined from the results of the intercomparison

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:

- The existing data set since the 2000 calibration should be reprocessed to account for the calibration change and the reprocessed data sent to the WOUDC. Investigate the data record to determine if there was a repair to the instrument that might explain the calibration shift. If there is not an apparent shift at some point in time, then use a time dependent drift correction to adjust the data.
- Use the 04 March 2004 N-tables and reference lamp values for data taken after that date.
- This instrument was originally used in Resolute, Canada and has a variation on the Canadian electronics. The high voltage section is external, and fairly large. The output of the electronics is somewhat noisier compared to other instruments. A skilled operator is required to get good results such as seen in the intercomparison. As these electronics are difficult to repair, it is recommended that the electronics be replaced. Until the electronics are replaced, local technicians perhaps can make some repairs to lower the noise.

Instrument: D064, European Regional Standard.
Station: Hohenpeißenberg, German

Original Calibration Data:

N-tables from 2002 intercomparison with World Standard Dobson D083 at in Boulder, Colorado. Reference standard lamps

Initial Calibration Results:

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

d_Na:+0.0 d_Nc:+0.5 d_Nd:-0.1 d_Nad:+0.1

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:

Final intercomparison: None as the instrument is in calibration with the standard.

New N-tables and reference standard lamp values will be defined from the results of the intercomparison.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was -.4% in total ozone.

Recommendations and comments:

- The difference in N-values on the C-pair measurements is not yet explained. The standard procedure is to define the calibration level on the AD-pair measurements. In general, the direct sun CD-pair measurement results differ from the AD results due to the approximations used in defining the equations used to reduce the measurements to total ozone values. In the mu range 2.4-3.0, measurements are made both with the AD- and CD-pair. This information is then used to define a multiplying factor for the CD-pair results to convert them to the AD-pair results.
- The C-pair results will be further evaluated after D065 is intercompared with D083 later in 2004.

Instrument: D069
Station: Aswan, Egypt

Original Calibration Data:

N-tables from 1999 intercomparison with D065 at Arosa, Switzerland. Reference standard lamps,

Initial Calibration Results:

27 February 2004 -- Adjustments based on the results of Standard Lamp tests included.

d_Na:-1.6 d_Nc:-1.3 d_Nd:-1.9 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:

- Optical Cleaning
- Repair of wedge steel bands
- Changed rubber seal
- Repair high voltage 12 position step switch.
- Wedge calibration on D wavelength.

Final intercomparison: 09 March 2004

New N-tables and reference standard lamp values will be defined from the results of the intercomparison

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

Recommendations and comments:

- Existing data from this instrument requires no reprocessing.
- The ozone values at high sun were lower by greater than 1%.
- After the repair of the steel band, this effect became greater.
- The “matching” on the single pair measurements was very good on the A and C pair, but not on the D. The wedge calibration was performed on the D wavelength and a special merged N-table was created. When this table was applied in the final calibration, the low values at high sun were removed.
- New N-tables and reference standard lamp values are defined from the 09 March 2004 intercomparison.
- The collar around the inlet window (part of the lid) is broken. As this collar supports the Ground Quartz Plate, this must be repaired by an expert familiar with brazing alloys.

Instrument: D089
Station: Irene, South Africa

Original Calibration Data:

N-tables from 2000 intercomparison with D065 at Pretoria, South Africa. Reference standard lamps

Initial Calibration Results: 27 February 2004

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

d_Na:-6.0 d_Nc:-6.6 d_Nd:-6.3d_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:

- Cleaned Optics, but not the wedge
- Wedge Calibration performed.

Final intercomparison: None, as the instrument is in calibration with the Standard

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

Recommendations and comments:

- The wedge calibration done on the instrument did not improve the results on the double pair measurements – in fact made the results slightly worse. The single pair measurements were improved. The calibration was not changed for two reasons. The double wavelength results were not improved, and the instrument is used for Umkehr measurements. The ozone profiles derived from the measurements are more sensitive to changes in the G-function used than total ozone measurements.
- The sign of the lamp corrections applied to the intercomparison processing was reversed. This does not affect the results of the intercomparison on the double pair measurements.
- It was a pleasure to work with the operators of this instrument.
- New reference lamps were added to the calibration information.

Instrument: D096
Station: Cairo, Egypt

Original Calibration Data:

N-tables from 2001 intercomparison with D064 at Hohenpeißenberg, Germany. Reference standard lamps

Initial Calibration Results: 27 February 2004 –

Adjustments based on the results of Standard Lamp tests included.

d_Na:+0.5 d_Nc:-0.1 d_Nd:-0.3 d_Nad:0.7 (From Analysis)

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

Work Performed:

- Optical cleaning

Final intercomparison: 04 March 2004

New N-tables and reference standard lamp values will be defined from the results of the intercomparison.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.2% in total ozone, at high mu.

Recommendations and comments:

- The existing data set should be reprocessed to account for this small calibration change, and the reprocessed data sent to the WOUDC.
- Use the new N-table and reference standard lamps for data taken after 04 March 2004.

Instrument: D570
Station: Lagos, Nigeria

Instrument is actually Shimatzu number 5703.

Original Calibration Data:

N-tables from 2000 intercomparison with D065 at Pretoria, South Africa. Reference standard lamps

Initial Calibration Results: 27 February 2004

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

d_Na:-0.3 d_Nc:-1.0 d_Nd:+0.1 d_Nad:-0.5, from analysis.

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:

- Before the initial intercomparison, the instrument received several electrical repairs. These repairs should not affect the intercomparison results.
- The instrument was inspected for optical symmetry and correctness
- Optics, other than the wedge were cleaned

Final intercomparison: None, as instrument is with calibration to the standard.

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:

- See instrument revaluation, Pretoria 2000, for comments.
- The mercury lamp holder does not fit the instrument well, and it was discovered that the results of the mercury lamp test are dependent on the orientation of the holder on the instrument. A new holder needs to be found, or fabricated.
- The bearings in the shutter motor were removed, cleaned and replace back in to the instrument. At some point, the bearing should be replaced.
- The instrument is different enough, that a wedge calibration would be difficult with existing calibration units – several special parts would have to be manufactured. At some future intercomparison meeting, the technical support should be prepared to make the parts required.
- The PMT voltage should be reduced before moving the Q-levers from the A to the D position, and increased after moving the Q-levers to from the D to the A position.
- Existing data archived in the WOUDC does not require reprocessing.
- Data taken at the station, but not yet processed and archived, should be as soon as possible.
- If training of station personnel is required, this training can be requested through the WMO.
- Support of this training and of intercomparison meeting such as the DICE 04 is dependent on the station archiving data in the WOUDC.