Research Infrastructure Quality Assurance

GAW Report No. 253

International Comparison of Dobson Spectrophotometers

Pretoria, Gauteng Province, South Africa
7–18 October 2019

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

GLOBAL ATMOSPHERE WATCH

Research Infrastructure Quality Assurance

GAW Report No. 253

International Comparison of Dobson Spectrophotometers

Pretoria, Gauteng Province, South Africa
7-18 October 2019

Prepared by U. Köhler, G.J.R. Coetzee, G. McConville

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: Publications@wmo.int

CONTENTS

Group photo of the participants of the IRENE2019 DIC in South Africa

BACKGROUND

The World Meteorological Organization (WMO) Secretariat's (Global Atmosphere Watch (GAW) programme) and the South African Weather Service (SAWS) with close cooperation and assistance of the National German Meteorological Service (DWD) Regional Dobson Calibration Centre (RDCC-E) at the Meteorological Observatory Hohenpeissenberg (MOHp) and the USA National Oceanic and Atmospheric Administration's Earth Systems Research Laboratory's Global Monitoring Division (NOAA/ESRL/GMD, World Dobson Calibration Centre WDCC) organized the DIC IRENE2019. IRENE2019 was a campaign to maintain the network of the Dobson ozone spectrophotometers operated in the southern African region, and to serve as an assurance of the quality of the total ozone datasets created at the regional stations. This action is a fulfilment of WMO/GAW/QC requirements for monitoring of atmospheric total ozone. The Dobson spectrophotometers of countries from the northern African region were already calibrated in advance during the WMO European DIC at INTA, El Arenosillo in September 2017 and an internal Egyptian campaign at Hurghada in September 2019 (Egyp2019).

The South African Weather Service, under the auspices of the World Meteorological Organization (WMO) hosted the 4th African Regional Dobson Spectrophotometer Intercomparison DIC IRENE2019 meeting from 7 to 18 October 2019, under the supervision of Mr Gerrie Coetzee. Mr Ulf Köhler took the position of technical director for the scientific soundness of the work undertaken.

Funding for this international event was provided from the UNEP Vienna Convention Trust Fund (VCTF) in support for WMO to assist countries in their efforts for monitoring and the protection of the Ozone Layer.

The participation of the German team (Mr U. Köhler and Mr M. Heinen) was completely funded by the DWD. NOAA funded Mr G. McConville's participation except for travel that came from the VCTF. South Africa funded their own participations of three Dobson's and participating resource staff.

PARTICIPATION AND PROCCEEDINGS

The technical and scientific aspects of the IRENE2019 event were supervised by Mr Ulf Köhler from the RDCC-E and by Mr Glen McConville from the WDCC, who supplied the reference standards D064 (Europe) and D065 (Travelling World Standard) and much appreciated technical equipment.

Eleven specialists from six countries participated at the DIC and are listed Appendix A. The Primary World Standard Dobson (D065) from NOAA and the Regional Standard Dobson (D064) were used as the references for the instruments noted below. Additionally Dr Siddharta Singh from the India Meteorological Department also participated with the Indian instrument D112. The planned calibration of the Shimadzu 5703 from Nigeria could not be performed, as the instrument arrived too late due to transportation/customs problems and also the participant could not obtain his visa in time. The participation of the instrument from the Seychelles (D057) was already cancelled in preparation of the campaign. Difficulties were also experienced as the two Botswana participants could only join the event on the last three days

of activities. The following national Dobson spectrophotometers were inspected, adjusted, and compared at the IRENE2019:

Dobson No.	*Country*	*Station*	*Purpose*
15	Botswana	Maun	regular calibration
18	Kenya	Nairobi	regular calibration
35	South Africa	Stellenbosch	regular calibration
64	Germany	Hohenpeissenberg	standard & calibration check with D065
65	USA	Boulder	standard
89	South Africa	Irene	regular calibration
112	India	New Delhi	calibration to resume operation
132	South Africa	Springbok	regular calibration

The main tasks of IRENE2019 were:

1) To evaluate each instrument calibration and the existing total ozone datasets.
2) Repair, clean and improve the instrument as needed.
3) Redefine a new calibration levels (where applicable) for the future measurements at the home station before returning the instruments in good operating order.

Besides the stated goals of Dobson intercomparison campaigns, such an event also provides a forum for sharing of information between observing programmes, and serves as a venue for training. These goals were successfully attained during this campaign. The experts from the calibration centres had enough time and good opportunities to train the less experienced participants. Educational video clips, how to do measurements and tests, are recommended for training purposes and can be watched under:
http://www.o3soft.eu/dobsonweb/instrument.html

As each instrument arrived, it and its accessories were inspected. At this stage no repairs, except those needed to make the instrument operate were made. The instrument was then operated in the condition as it would have been at the home station. Once a successful initial Intercomparison (IC) is made, those results then dictate whether significant optical, mechanical, or electronic repairs were needed. If needed, a final Intercomparison (FC) is performed to define a new calibration.

Other tasks included cleaning and/or repair/replacement of optical, electronic and mechanical parts followed by discharge lamp tests to create new Q-tables and an optical wedge calibration to define new R-G-tables, if needed. A series of lamp calibrations were also done on a daily basis.

The Regional Standard for Europe, D064 (DWD, Hohenpeissenberg, Germany), was compared with the World Standard D065 (NOAA, Boulder, USA) in order to check and confirm its calibration level. This event should be done every two to three years to guarantee the correct transfer of the calibration level of the World Standards D065 and D083 into the WMO RA VI Europe Dobson network.

FINAL RESULTS AND RECOMMENDATIONS

Technical Reports

The official technical report consisting of the detailed worked performed and assessment of each individual instrument is presented in Appendix B. All the participating instruments listed above are now well calibrated and in good operational condition. The revised IC Objectives were met satisfactorily under challenging circumstances. The calibration level of the regional Standard D064 was successfully confirmed.

General Recommendations

The Dobson/Shimadzu instruments and staff from Seychelles and Nigeria were not able to participate. These programmes should be assisted to be able to take part in other scheduled IC events, if the responsible institutes evince high interest in continuation of their ozone monitoring programme using Dobson/Shimadzu instruments. Contact has been established with the responsible persons on the Seychelles, how their programme can be resumed (with a repaired/refurbished Dobson or with a new instrument) with the support of UNEP and or WMO. It is also recommended that the Dobson and participant of Nigeria attend another future IC campaign if this can be accommodated.

One important finding of the campaign was the fact, that the regular WMO recommendation for calibration intervals of no longer than five to six years is absolutely justified. As the last regular DIC took place ten years ago in 2009, some of the instruments show significantly larger deviations than ±1% from the standard Dobsons. Furthermore it is helpful to use such campaigns for training purposes of the stations' Dobson staff, to improve the performance of the instruments and to avoid uncertain or even poor data quality because of not correct procedures of measurements and regular tests. The above mentioned video clips will surely support this goal.

The able assistance of Mr Glen McConville, Mr Ulf Köhler and Mr Michael Heinen in both the technical achievements of the intercomparison and the scientific assessment in this report is acknowledged, with appreciation.

Appendix A

SAWS/WMO/GAW – IRENE2019
International Comparison of Dobson Spectrophotometers (DIC)
Irene Technical Centre, Pretoria, Gauteng Province,
South Africa, 7-18 October 2019

List of Participants

Botswana
Mr Karabo Molefe
Botswana Meteorological Services,
P.O. Box 458 Maun, Meteorological Office Maun,
Maun airport
Tel.: +267 6860429 or 6800595
Email: krmolefe@gov.bw

Mrs Goitsemang Salethake
Botswana Meteorological Services
Plot 54216, Corner Maaloso/ Metsimotlhaba Rd, Gaborone Village
P.O. Box 10100, Gaborone
Tel.: +267 3612200
Fax: +267 3956282
Email: gsalethake@gov.bw

Germany
Mr Ulf Köhler
Deutscher Wetterdienst
Meteorological Observatory Hohenpeißenberg
Albin-Schwaiger- Weg, 10
82383 Hohenpeißenberg
Tel.: 0049 69 8062 9771
Email: Ulf.Koehler@dwd.de

Mr Michael Heinen
Deutscher Wetterdienst
Meteorological Observatory Hohenpeißenberg
Albin-Schwaiger- Weg, 10
82383 Hohenpeißenberg
Email: Michael.Heinen@dwd.de

India
Dr Siddhartha Singh
Email: siddhartha.singh74@imd.gov.in
India Meteorological Department
Ozone & Air Quality Unit
Environment Monitoring & Research Centre
New Delhi – 110003
Tel.: 0091 114 3824235

Kenya
Mrs Annet Nyaga
Kenya Meteorological Department
P. O. Box 30259,
00100 GPO Nairobi
Email: nyagaannet@gmail.com

South Africa
Mr Gerrie J R Coetzee
Email: gerrie.coetzee@weathersa.co.za
South African Weather Service
Eco Glades block 1b, Eco Park
Cnr Olievenhoutbosch and Ribbon Grass Streets
Centurion, 0157
Pretoria 001
Tel: +27 12 367 6048
Fax: +27 12 367 6189

Mr Daniel van der Spuy
South African Weather Service, C/O CCSIR,
11 Cilliers road
Stellenbosch
Email: Danie.vanderSpuy@weathersa.co.za

Mr Gerald Gerhardus Meyer
South African Weather Service
Springbok, 8240
Cell: 0636954879
Tel.: 02771 22961
Email: Gerald.Meyer@weathersa.co.za

Ms Tshidi Machinini
South African Weather Service
Eco Glades block 1b, Eco Park
Cnr Olievenhoutbosch and Ribbon Grass Streets
Centurion, 0157, Pretoria 001
Email Tshidi.Machinini@weathersa.co.za

USA
Mr Glen McConville
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Earth System Research Laboratory, Global Monitoring Division
Mail Code R/GMD-1
325 Broadway
Boulder, Colorado 80305
Telephone: 1 303 497 3989
Email: glen.mcconville@noaa.gov

Appendix B

SAWS/WMO/GAW – IRENE2019
International Comparison of Dobson Spectrophotometers (DIC)
Irene Technical Centre, Pretoria, Gauteng Province,
South Africa, 7-18 October 2019

Individual Instrument Reports

Intercomparison Results
Iren2019 from October 7 to 18, 2019 at Irene

Instrument D015
Botswana (Maun)

Initial calibration (18.10.2019):

	Date:	Comment:
G-Tables	8.3.94	after wedge-cal. on March. 8, 1994, location?
N-Tables	26.11.09	after FC on November 26, 2009 at Irene2009

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	-0.60	-0.90	-0.70	0.10	-0.20
from Comparison	1.40	-0.07	-0.24	1.64	0.17
Sum	0.80	-0.97	-0.94	1.74	-0.03

Comments: Initial = final calibration as only one intercomparison was possible
poor agreement in AD, data noisy, no reprocessing as not operational

Final Calibration (18.10.2019):

	Date:	Comment:
G-Tables	8.3.94	after wedge-cal. on March. 8, 1994, location?
N-Table (new)	18.10.19	after FC on October 18, 2019 at Irene2019

Corrections to:	A	C	D	AD	CD
old N-Table	0.80	-0.97	-0.94	1.74	-0.03

Comments: Initial = final calibration as only one intercomparison was possible
new R-N-table created, should be used for future observations

Reference Standard Lamp Data: Date: 18.10.19

for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
15Q1	20.30	10.68	20.50	15.79	20.10	17.61
15Q2	20.60	10.98	20.30	15.59	20.30	17.82

Q-Table: Check new Q-table from discharge lamp test October 17 after return by doing an HG-test and correct if necessary according the procedure described in Komhyr's old or Bob's new Dobson manual

Instrument D015
Botswana (Maun)

Original calibration data
N-tables from 26 November 2009 based on DSGQP-comparison with D083 on 26 November 2009 at Irene2009, G-tables from 8 March 1994, location unknown.
Reference Standard Lamp Values for lamps 15Q1 and 15Q2
(Lamp tests results used in data processing at home station)?

Introductory remarks
Instrument not operational in the past years. Arrival very late, thus only one intercomparison possible and no additional work could be done.

Initial calibration results
(Adjustments based on the results with Standard Lamp tests included)
18 October 2019:

d_Na: -1.40 d_Nc: -0.07 d_Nd: -0.24 d_Nad: 1.64 d_Ncd: 0.17

The d_Nad value implies an average **-2.3% error** in calculated ozone value, Mu=1.15 to 2.5, Total Ozone = 300 Dobson Units. Data noisy; no reprocessing necessary, as instrument not operational.

Optical, mechanical and electronical work performed

- Electric/Electronics: new US-type (original).
- Optical check: Q-plates, Ls and Ps dusty, Ms with scratches (M1) and cloudy (M2), wedge and cobalt filter O.K., prism sundirector dusty and head reversed and loose.
- Symmetry test: Not done.
- Measurement of slit widths and parallelism with microscope: Not done.
- Shutter motor: Toothbelt drive, 815 rpm.
- PMT vertical position test: Not done, Focus L1: Not done.
- Optics: Optics cleaned and loose sun director head fixed.
- Discharge lamp: Performed on 17 October 2019, new Q-table created.
- Wedge calibration: Not done.

Final intercomparison
18 October 2019

IC and FC on the same day, new R-N-tables created**; highest difference against the standard ADDSGQP observations of D064 in mu range 1.15 to 3.2 was 0.9 % in total ozone, moderate mue-dependency. CD-observations with large mue-dependence, but not used.**

Recommendations/comments

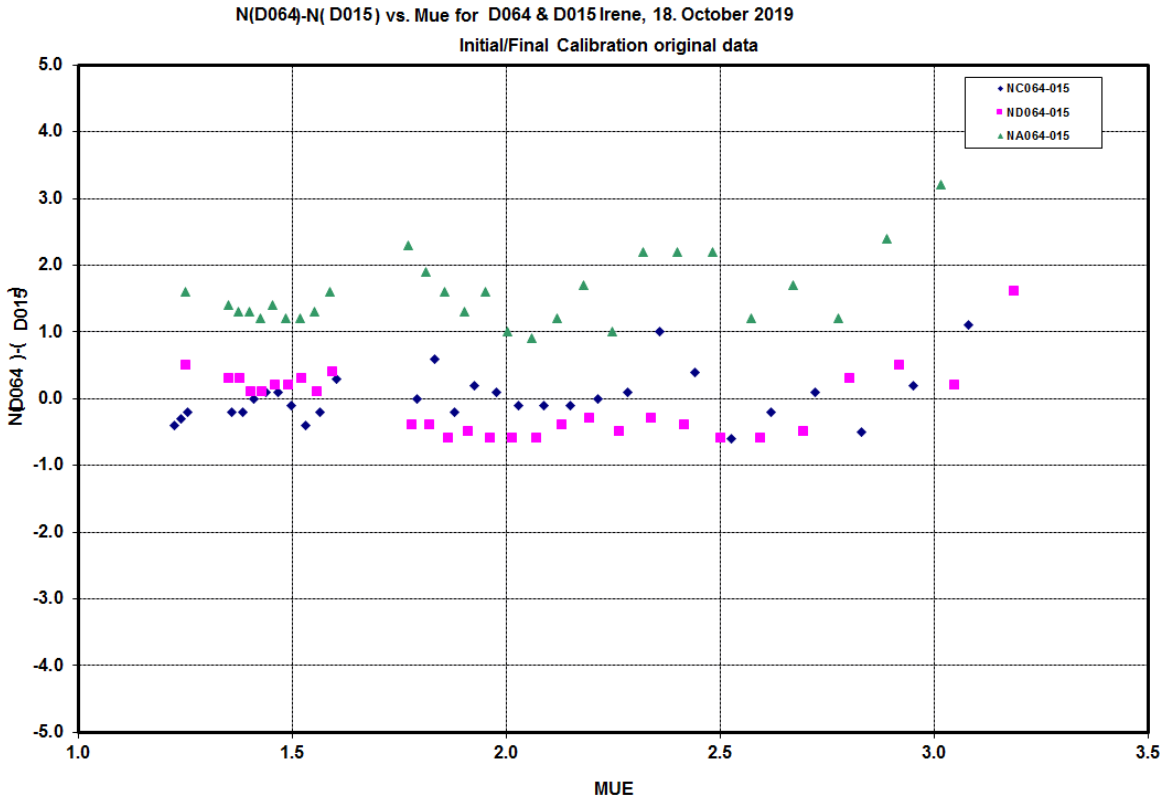
- The results of the initial/final calibration are not good, but no re-calculation necessary as instrument not operational. Final data can be used for:
- New calibration status with new R-N-tables defined based on old R-G/N-tables incl. determination of SL-reference values from corresponding tests (s. table with results).
- **Correction of the used-Q-tables at Irene derived from results of the Hg-Test immediately after return to station according the Dobson instructions.**

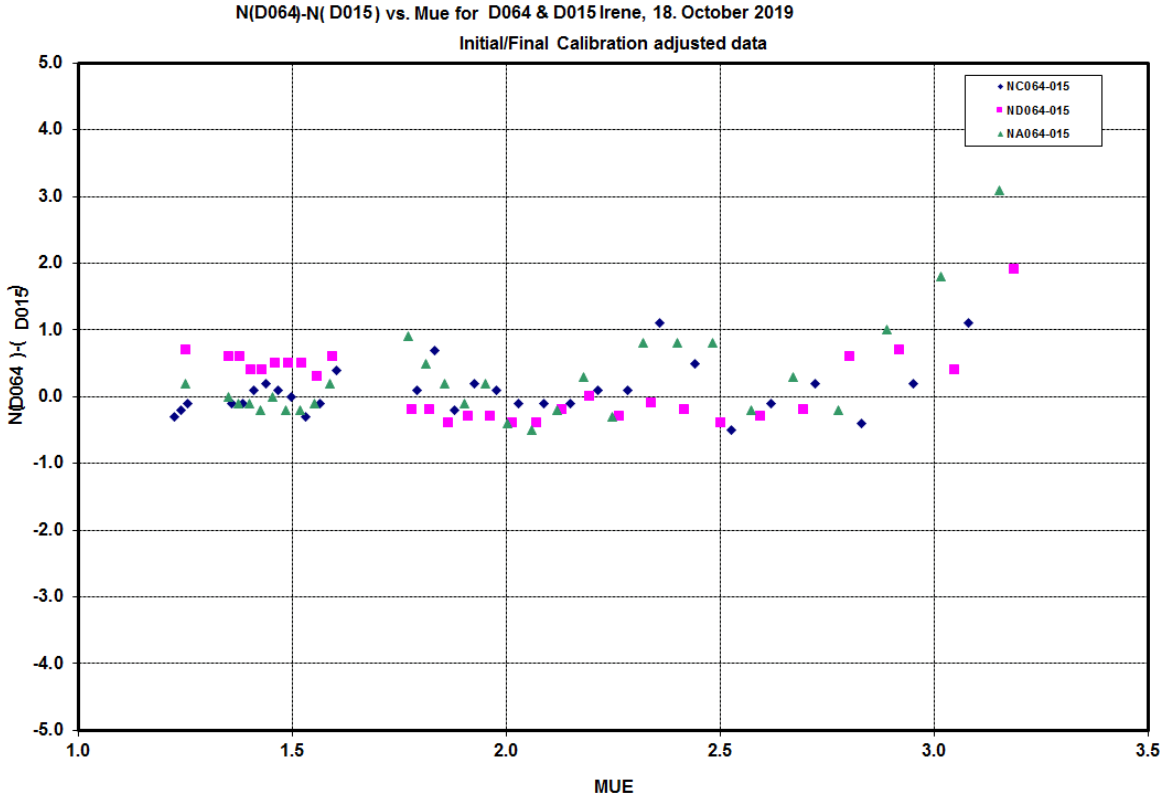
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.
- **New absorption coefficients will officially be introduced in the near future: reprocessing of all data necessary. Information will be given. Question of the future use of effective absorption coefficients (derived from optical characterization) not finally clarified.**

Hohenpeissenberg, 19.12.2019

Difference N_A-C-D to Reference Instrument D064

Initial/Final Calibration on 18 October 2019





Intercomparison Results
Iren2019 from October 7 to 18, 2019 at Irene

Instrument D018
Kenya (Nairobi)

Initial calibration (12.10.2019):

	Date:	Comment:
G-Tables	11.4.05	after wedge-cal. on April 11, 2005 at MOHp2005
N-Tables	14.4.05	after FC on April 14, 2005 with new R-G at

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	0.70	0.90	1.00	-0.30	-0.10
from Comparison	-0.32	-0.34	-1.02	0.70	0.68
Sum	0.38	0.56	-0.02	0.40	0.58

Comments: Good agreement in AD, larger differences in CD and single D
No data reprocessing necessary, as CD not used

Final Calibration (18.10.2019):

	Date:	Comment:
G-Tables	11.4.05	after wedge-cal. on April 11, 2005 at MOHp2005
N-Table (new)	18.10.19	after FC on Oct. 18, 2019 with old R-N at Irene2019

Corrections to:	A	C	D	AD	CD
old N-Table	0.70	0.90	0.30	0.40	0.60

Comments: Good agreement in AD and CD
New RN-tables created for future data processing

Reference Standard Lamp Data: Date: 18.10.19

for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
18V	61.20	13.50	62.50	17.45	62.90	19.00
18W	60.70	13.00	62.20	17.10	62.70	18.80

Q-Table: Checkoriginal Q-table in use at station
by doing an HG-test and correct if necessary according the procedure
described in Komhyr's old or Bob's new Dobson manual

Instrument D018
Kenya (Nairobi)

Original calibration data
N-tables from 14 April 2005 based on DSGQP-comparison with D064 on 14 April 2005, MOHp, G-tables from 11 April 2005.
Reference Standard Lamp Values for lamps 18V and 18W.
Lamp tests results used in data processing at home station.

Introductory remarks
The sometimes large deviations in the SL-tests were found not to be realistic. In these cases the SL-tests were probably made without ground quartz plate (GQP). Corresponding tests with and without GQP at Irene confirmed this assumption. **Thus check the "old" data: if corrections have been applied based on the wrong Sl-tests without GQP, these data have to be reprocessed**.

Initial calibration results
(Adjustments based on the results with Standard Lamp tests included)
12 October 2019:

d_Na: -0.32 d_Nc: -0.34 d_Nd: -1.02 d_Nad: 0.70 d_Ncd: 0.68

The d_Nad value implies an average **+1.00% error** in calculated ozone value, Mu=1.15 to 2.5, Total Ozone = 300 Dobson Units. Good agreement in AD, larger differences in CD and single D; no data reprocessing necessary, as CD not used.

Optical, mechanical and electronical work performed

- Electric/Electronics: New US type MOHp-modified.
- Optical check: Sun director, Q-plates, Lenses and Prismes slightly dusty, Mirrors, wedge plates and cobalt filter O.K.
- Symmetry test: Results acceptable.
- Measurement of slit widths and parallelism with microscope: Not done.
- Shutter motor: Belt drive, 865 rpm.
- PMT vertical position test: Not done, Focus L1: Not done.
- Optics: Dusty optics cleaned.
- Discharge lamp: Not done.
- Wedge calibration: Not done.

Final intercomparison
17 and 18 October 2019

Data of two final calibration processed, data of 17 October too noisy, therefore only 18 October used FC. **New R-N-tables created and should be used for future data processing; highest difference against the standard ADDSGQP observations of D064 in mu range 1.15 to 3.2 was -0.65 % in total ozone, small mue-dependency.**

Recommendations/comments

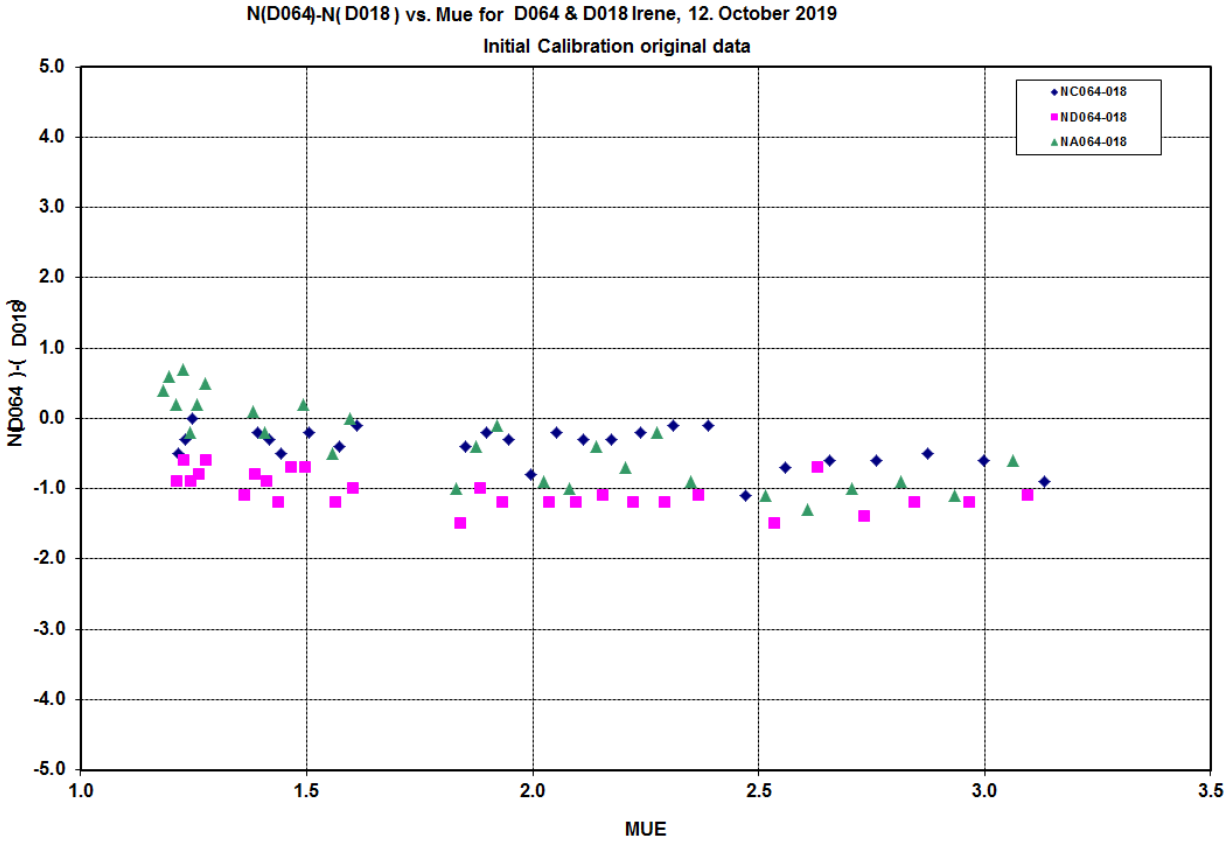
- The results of the initial calibration are good, therefore no re-calculation necessary (**only if wrong SL-corrections were applied**), especially as only AD used for data evaluation.

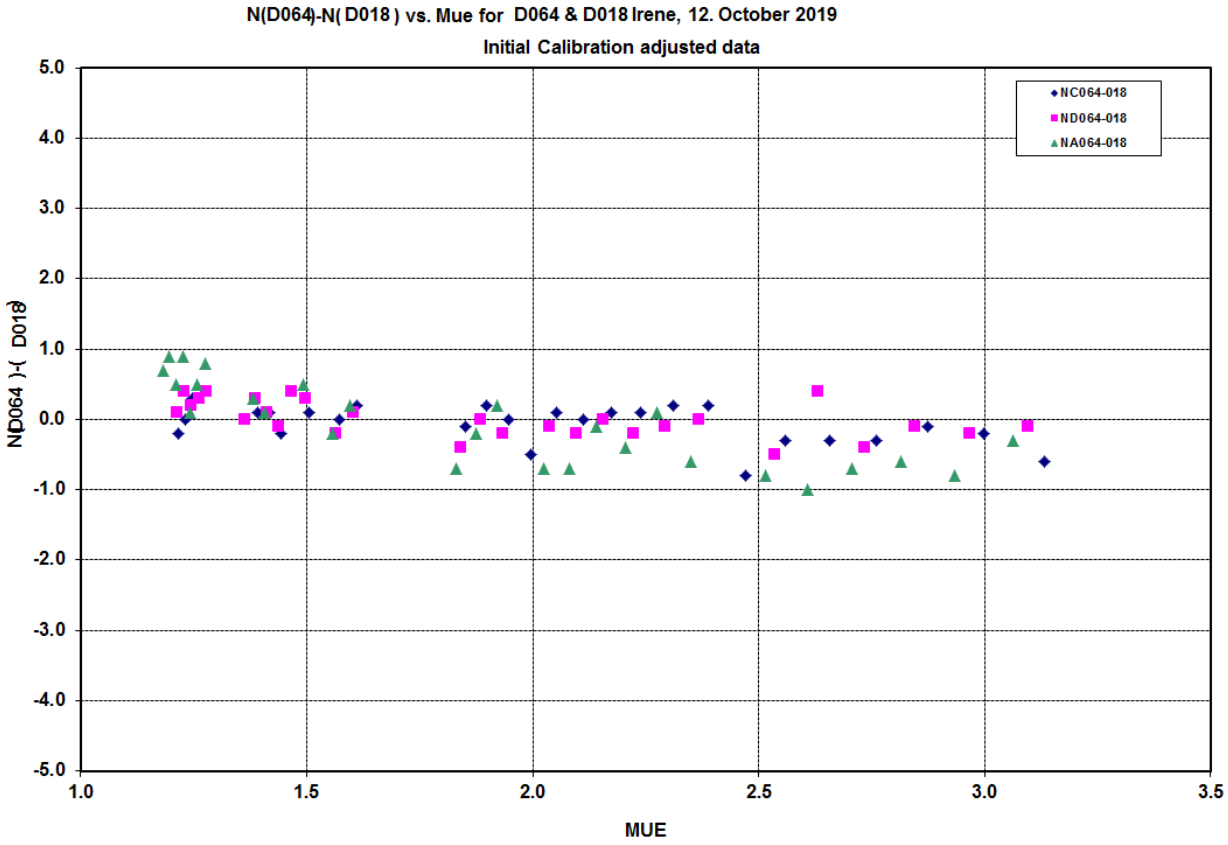
- New calibration status with new R-N-tables defined based on old R-N-tables incl. determination of SL-reference values from corresponding tests (s. table with results).
- **Correction of the used-Q-tables at Irene derived from results of the Hg-Test immediately after return to station according the Dobson instructions.**
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.
- **New absorption coefficients will officially be introduced in the near future: reprocessing of all data necessary. Information will be given. Question of the future use of effective absorption coefficients (derived from optical characterization) not finally clarified.**

Hohenpeissenberg, 20.12.2019

Difference N_A-C-D to Reference Instrument D064

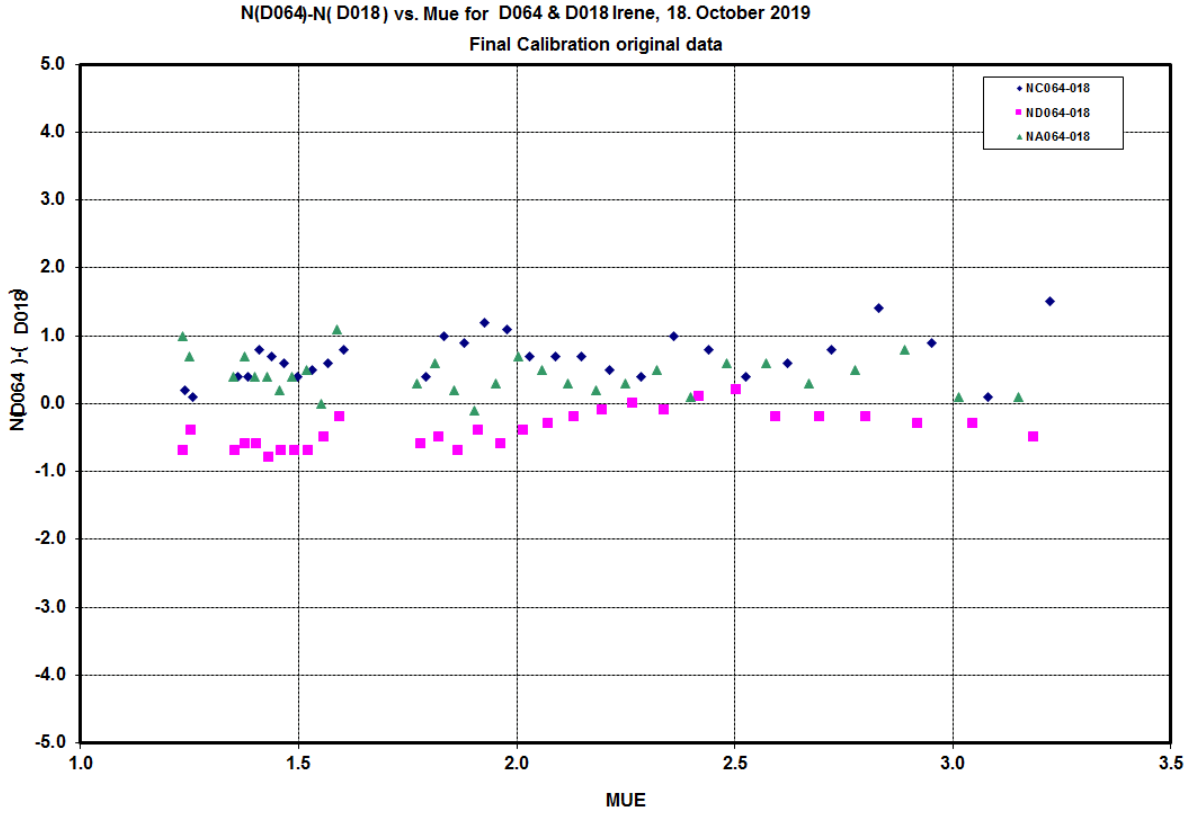
Initial Calibration on 12 October 2019

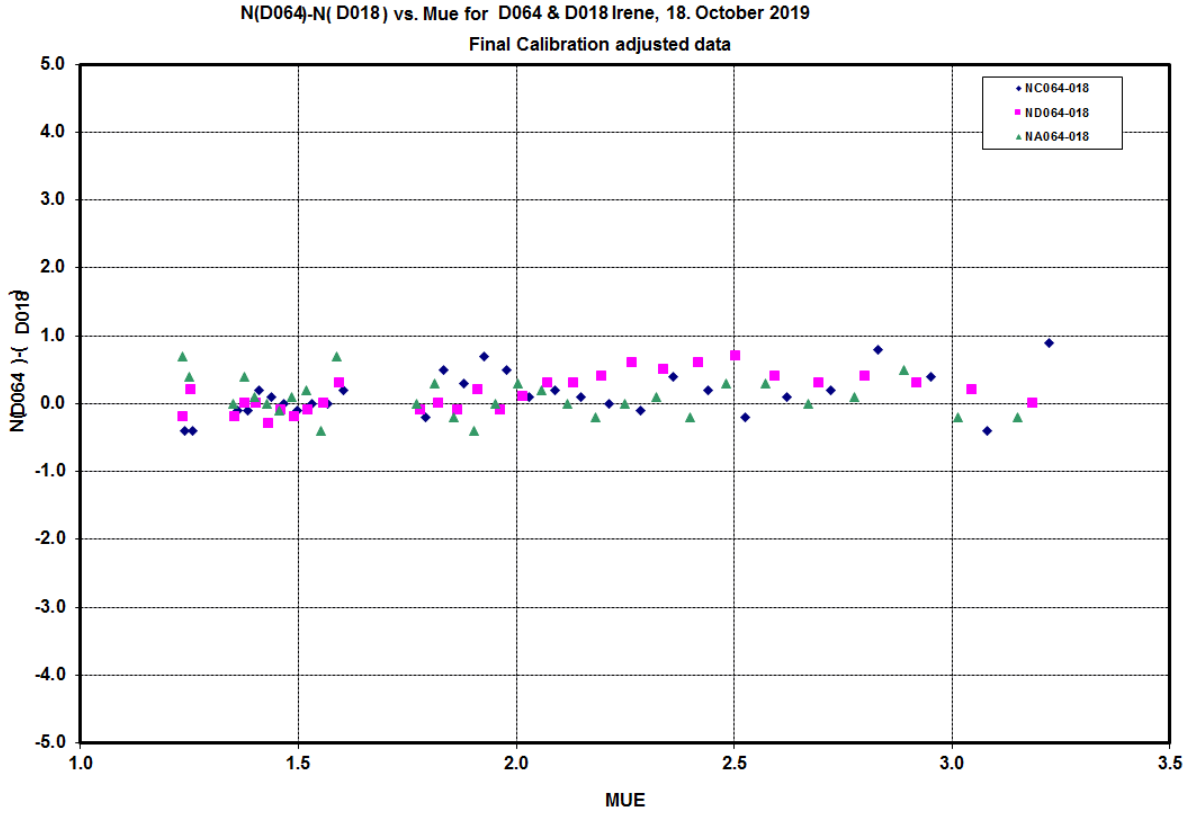




Difference N_A-C-D to Reference Instrument D064

Final Calibration on 18 October 2019





Intercomparison Results
Iren2019 from October 7 to 18, 2019 at Irene

Instrument D035
South Africa (Stellenbosch)

Initial calibration (09.10.2019):

	Date:	Comment:
G-Tables	15.7.04	after wedge-cal. on July. 15, 2004, at MOHp2004
N-Tables	27.10.09	after FC on Oct. 27, 2009, at Irene2009

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	0.20	0.50	0.40	-0.20	0.10
from Comparison	0.44	0.66	1.15	-0.71	-0.49
Sum	0.64	1.16	1.55	-0.91	-0.39

Comments: 1. IC on October 9, 2019, with old RN-tables: acceptable agreement in AD
Just within 1%-limit, no data reprocessing recommended
2. IC on October 12, 2019, not used as data too noisy

Final Calibration (18.10.2019):

	Date:	Comment:
G-Tables	15.7.04	after wedge-cal. on July. 15, 2004, at MOHp2004
N-Table (new)	18.10.19	after FC on Oct. 18, 2019, at Irene2019

Corrections to:	A	C	D	AD	CD
old N-Table	3.10	3.50	4.10	-1.00	-0.60

Comments: 2.FC on October18 with good result in AD at not too high sun,
Data should not be used at Mue-values < 1.4
New RN-tables created for future data processing

Reference Standard Lamp Data: Date: 18.10.19
for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
35Q2	33.07	9.08	36.30	14.06	39.43	15.78
35Q3	33.60	9.59	36.43	14.18	39.73	16.07

Q-Table: Check new Q-table created after discharge lamp test on 18.10. at station by doing an HG-test and correct if necessary according the procedure described in Komhyr's old or Bob's new Dobson manual

Instrument D035
South Africa (Stellenbosch)

Original calibration data
N-tables from 27 October 2009, based on DSGQP-comparison with D083 on 27 October 2009 at Irene, G-tables from 15 July 2004 at MOHp.
Reference Standard Lamp Values for lamps 35Q2 and 35Q3.
Lamp tests results used in data processing at home station.

Introductory remarks
Instrument operational at Stellenbosch. Second initial calibration on 12 October and first final calibration on 17 October were not used as data too noisy.

Initial calibration results
(Adjustments based on the results with Standard Lamp tests included)
9 October 2019:

d_Na: 0.44 d_Nc: 0.66 d_Nd: 1.15 d_Nad: -0.71 d_Ncd: -0.49

The d_Nad value implies an average **+1.0% error** in calculated ozone value, Mu=1.15 to 2.5, Total Ozone = 300 Dobson Units. Acceptable agreement with moderate mue-dependance in AD, no data reprocessing recommended.

Optical, mechanical and electronical work performed

- Electric/Electronics: New US type MOHp-modified.
- Optical check: Lenses, Q-plates and wedge dusty, all other optics O.K.
- Symmetry test: Done on 8 and 18 October with good results.
- Measurement of slit widths and parallelism with microscope: Not done.
- Shutter motor: Friction drive, speed with 750 rpm a little bit low.
- PMT vertical position test: Not done, Focus L1: Not done.
- Optics: Lenses, Q-plates and wedge cleaned.
- Further work: Function of wedge sled stiff, therefore greased.
- Discharge lamp: Done on 18 October, new Q-table created, which should be used back at station.
- Wedge calibration: Done in October with bad results because of fingerprints after first cleaning, cleaned again and C-wedge cal repeated, which shows no difference to wedge calibration in 2004.

Final intercomparison
17 and 18 October 2019

Data of two final calibration processed, data of October 17 too noisy, therefore only 18 October used as FC. **New R-N-tables created and should be used for future data processing; highest difference against the standard ADDSGQP observations of D064 in mu range 1.15 to 3.2 was 1.16 % in total ozone at high sun, thus data**

with mue < 1.4should not be used. Reason for too high ozone values at high sun (in contrast to 1.IC) not known.

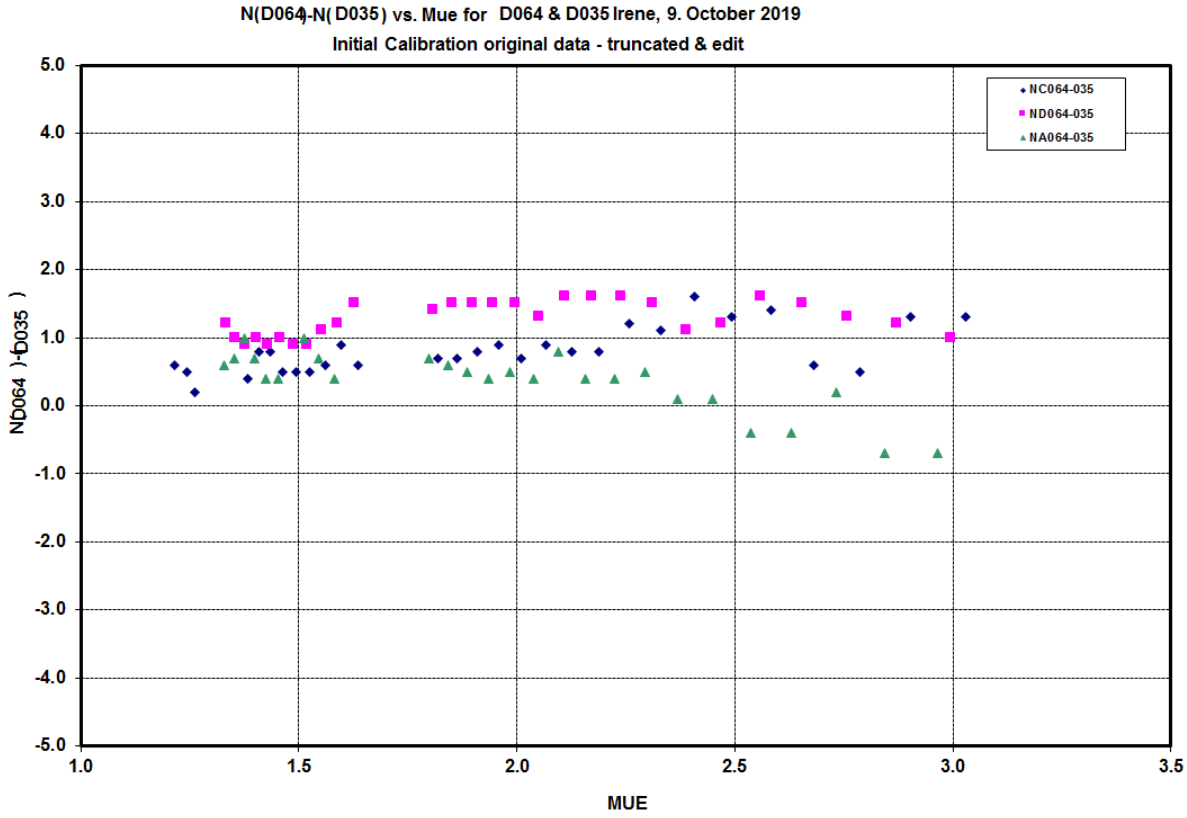
Recommendations/comments

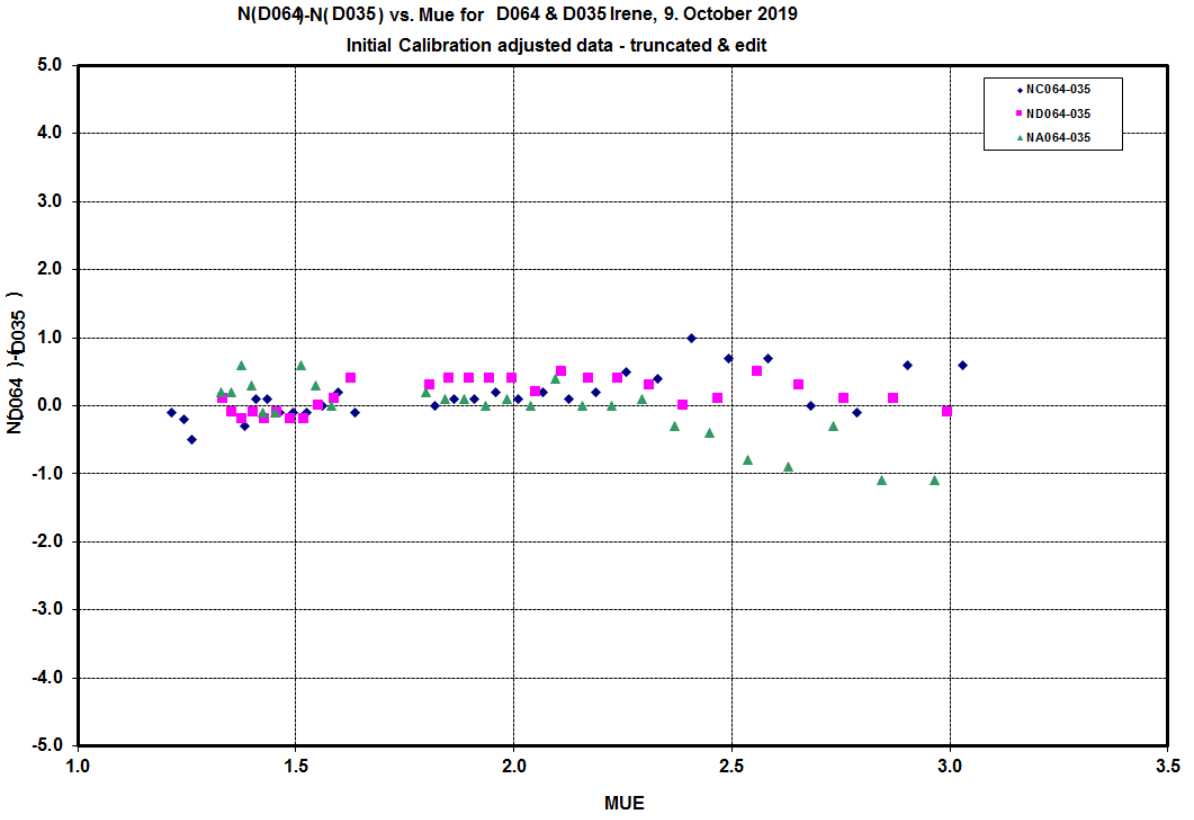
- The results of the initial calibration are satisfactory, therefore no re-calculation necessary, especially as only AD used for data evaluation.
- New calibration status with new R-N-tables defined based on old R-N-tables incl. determination of SL-reference values from corresponding tests (s. table with results), data at high sun (mue < 1.4) should not be used.
- **Correction of new Irene-Q-table (after discharge lamp test on 18 October 2019), from results of the Hg-Test immediately after return to station, if necessary.**
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.
- **New absorption coefficients will officially be introduced in the near future: reprocessing of all data necessary. Information will be given. Question of the future use of effective absorption coefficients (derived from optical characterization) not finally clarified.**

Hohenpeissenberg, 10.01.2020

Difference N_A-C-D to Reference Instrument D064

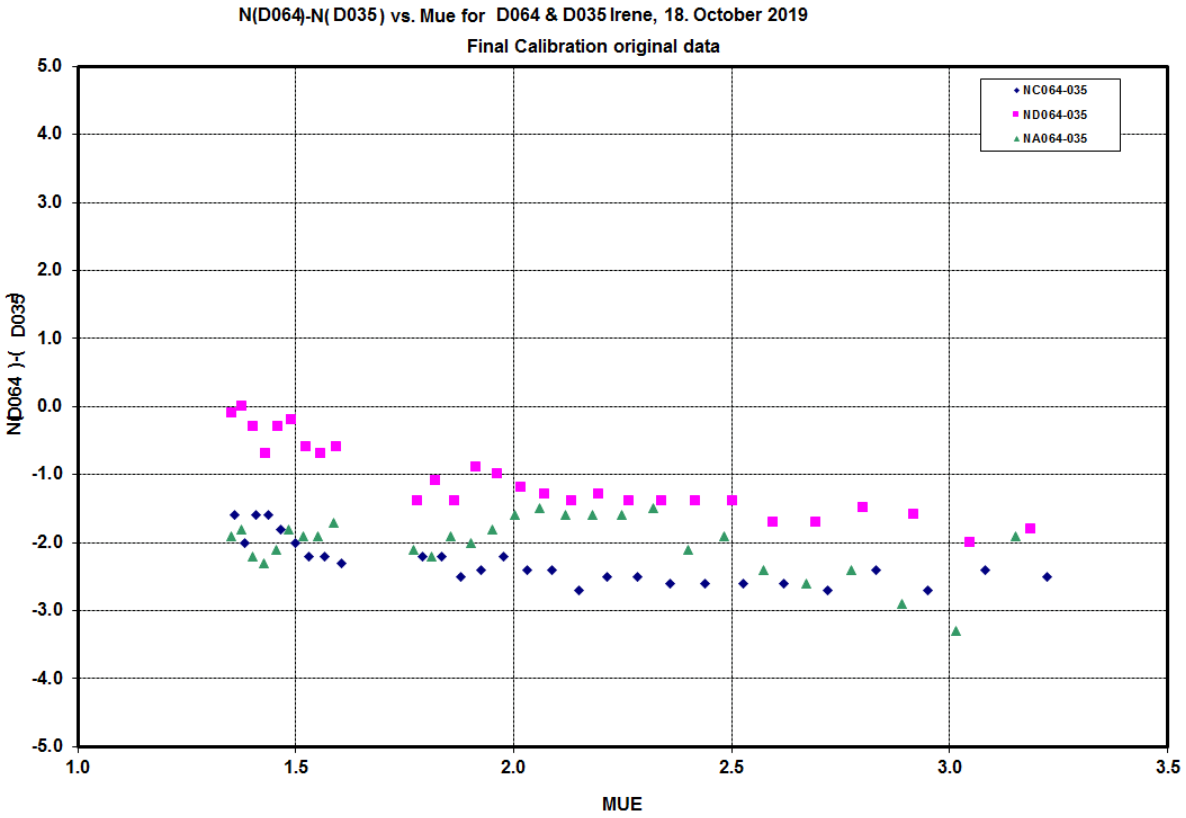
Initial Calibration on 9 October 2019

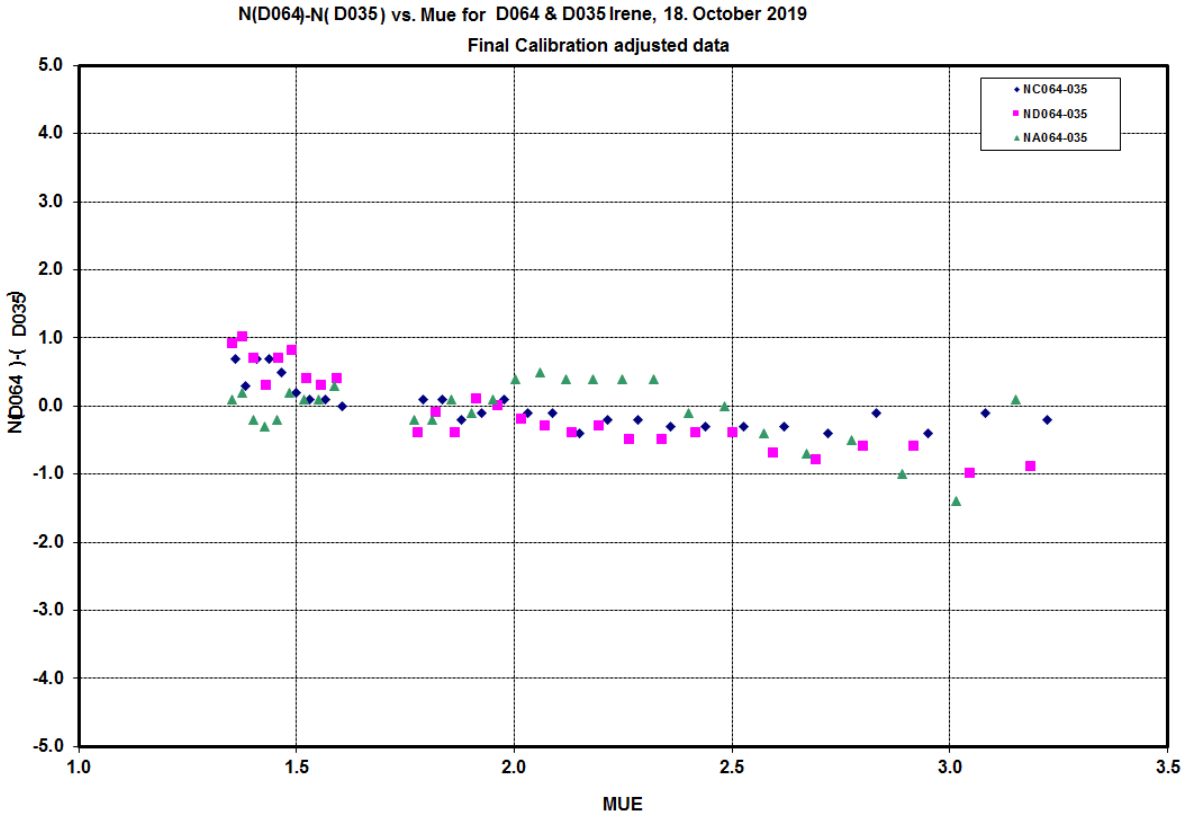




Difference N_A-C-D to Reference Instrument D064

Final Calibration on October 18, 2019





Intercomparison Results
Iren2019 from October 7 to 18, 2019 at Irene

Instrument D064
Germany (Hohenpeissenberg)

Initial calibration (09.10.2019):

	Date:	Comment:
G-Tables	4.6.02	after wedge cal. at Boulder on June 4, 2002
N-Tables	24.4.14	after FC with D065 on April 24, 2014 with old R-N at MOHp2014

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	-0,70	-0,70	-0,70	0,00	0,00
from Comparison	-0,09	-0,04	-0,11	0,02	0,07
Sum	-0,79	-0,74	-0,81	0,02	0,07

Comments: Very good agreement in AD and acceptable in CD with moderate mue-dependance
moderate mue-dependance because of larger mue-dep. in D065 C-data
no FC necessary, conparisons on October 12 and 17 do not provide better data

Final Calibration (09.10.2019):

	Date:	Comment:
G-Tables	4.6.02	after wedge cal. at Boulder on June 4, 2002
N-Table (new)	24.4.14	old R-N-table kept

Corrections to:	A	C	D	AD	CD
new G-Table				0,00	0,00

Comments: Final = Initial Calibration, as best results (smallest mue-dependance)
on October 9, 2019, intercomparisons on October 12 and 17
do not provide better data. Old R-N-tables and SL-references kept

Reference Standard Lamp Data: Date: - none -

for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
not necessary						

Q-Table: Q-table checked and adjusted (if necessary) when back at station
monthly check with HG-test and possibly necessary corrections
as described in Komhyr's old or Bob's new Dobson manual

Instrument D064
Germany (MOHp, European regional standard)

Original calibration data
N-tables from 24 April 2014, based on DSGQP-comparison with D065 on 24 April 2014 at MOHp2014, G-tables from 4 June 2002 at Boulder.
Reference Standard Lamp Values for lamps 64Q1, 64Q2 and 64Q3.
Lamp tests results used in data processing at home station.

Introductory remarks
D064 is European Regional Reference Dobson, normally calibrated relative against World Standards D065 or D083 or absolut after Langley Method at Izana.

Initial/final calibration results
(Adjustments based on the results with Standard Lamp tests included)
9 October 2019:

d_Na: -0.09 d_Nc: -0.04 d_Nd: -0.11 d_Nad: 0.02 d_Ncd: 0.07

The d_Nad value implies an average **0.00 % error** in calculated ozone value, Mu=1.3 to 2.5 (data truncated at Mu-values < 1.3), Total Ozone = 300 Dobson Units. No Mu-dependance in AD, moderate in CD due to Mu-dependance in D065 C-data.

Optical, mechanical and electronical work performed

- No more work done, only comparative measurements and regular lamp tests.

Final intercomparison
See under initial/final calibration results

IC and FC on the same day, as further comparisons on 12 and 17 October do not provide better data, old R-N-table and SL-references kept, **highest difference against the standard ADDSGQP observations of D065 in mue range 1.15 to 3.2 was 0.2 % in total ozone, small mue-dependency. CD-observations with moderate Mu-dependence, but normally not used and probably caused by D065 C-data.**

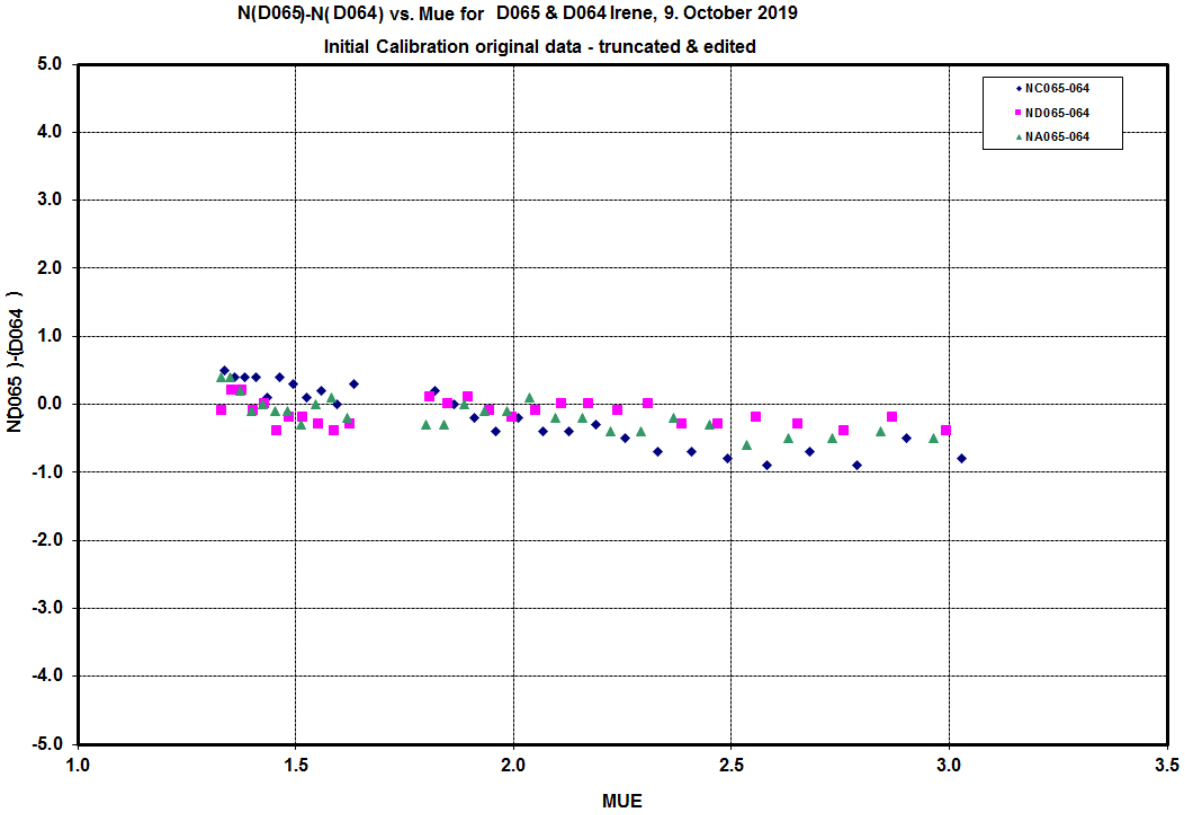
Recommendations/comments

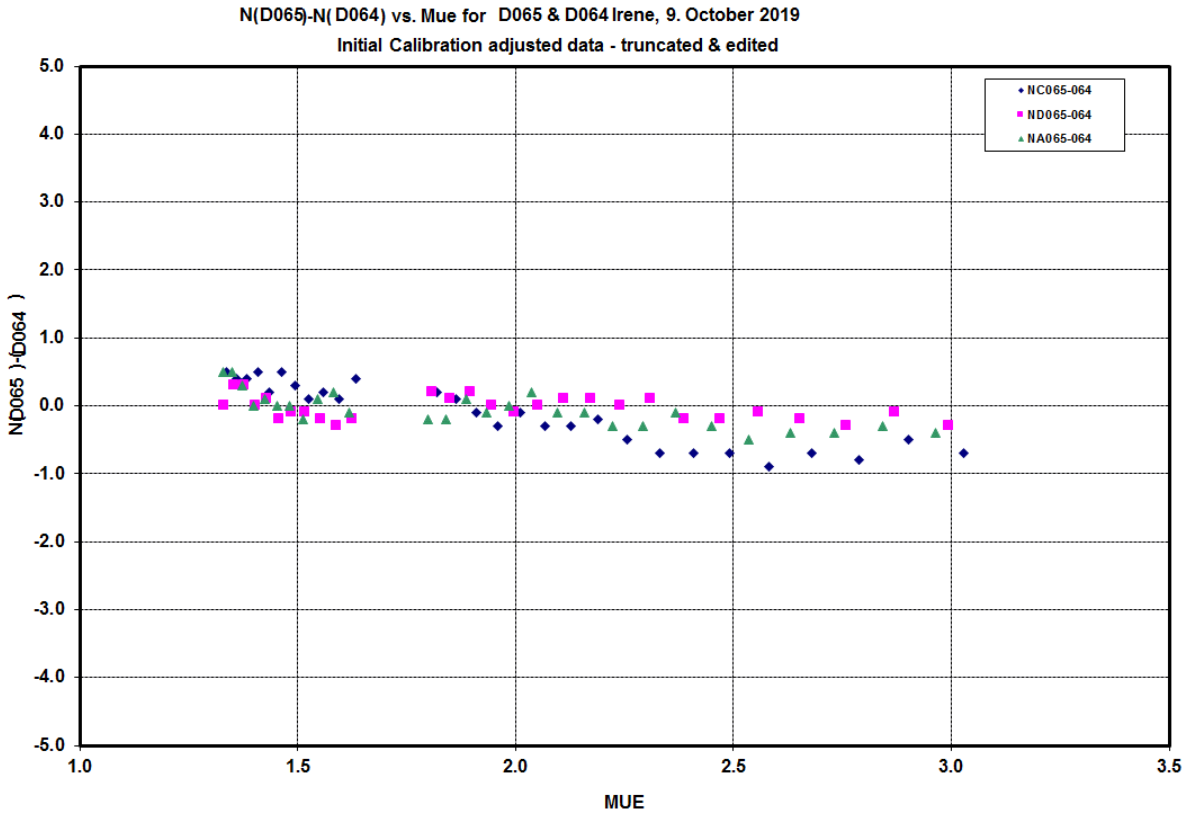
- The results of the initial calibration are very good in AD, therefore no re-calculation necessary, especially as only AD used for data evaluation.
- Old R-N-tables kept incl. old SL-reference values.
- Correction of new MOHp-Q-tables from results of the Hg-Test immediately after return to station.
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.

Hohenpeissenberg, 06.03.2020

Difference N_A-C-D to Reference Instrument D065

Initial/Final Calibration on October 9, 2019





Intercomparison Results
Irene2019 from October 7 to 18, 2019 at Irene

Instrument D089
South Africa (Irene)

Initial calibration (09.10.2019):

	Date:	Comment:
G-Tables	12.9.17	after wedge-cal. on Sept. 12, 2017 at ElAreno2017
N-Tables	13.9.17	after FC on Sept. 13, 2017 with new R-G at ElAreno2017

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	-1.60	-1.20	-1.40	-0.20	0.20
from Comparison	-2.51	-1.95	-1.98	-0.53	0.03
Sum	-4.11	-3.15	-3.38	-0.73	0.23

Comments: acceptable agreement in AD, data noisy, larger difference in mue-range 1.5-2
large difference in single A, C and D, no data reprocessing recommended

Final Calibration (17.10.2019):

	Date:	Comment:
G-Tables	13.10.19	new R-G-table after wedge calibration on 13.10.19
N-Table (new)	17.10.19	new R-N after 2. FC in 17.10.19 with new R-G

Corrections to:	A	C	D	AD	CD
new G-Table	-28.69	-20.72	-17.39	-11.30	-3.33

Comments: Results very good in AD and used to create new R-N-tables
for future data processing

Reference Standard Lamp Data:

Date: 17.10.19

for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
89Q6	38.80	11.49	35.80	16.23	34.80	18.18
89Q7	38.70	11.38	36.00	16.46	34.90	18.29
89Q9	38.90	11.61	36.00	16.46	34.90	18.29
64Q1	39.30	12.06	36.20	16.69	35.40	18.85

Q-Table: no new Q-table necessary, as D089 remains on station
monthly check with HG-test and possibly necessary corrections
as described in Komhyr's old or Bob's new Dobson manual

Instrument D089
South Africa (Irene)

Original calibration data
N-tables from 13 September 2017 based on DSGQP-comparison with D064 on 13 September 2017 at El Arenosillo, G-tables from 12 September 2017.
Reference Standard Lamp Values for lamps 89Q6, 89Q7 and 89Q9.
Lamp tests results used in data processing at home station.

Introductory remarks
Last calibration at El Arenosillo in 2017 was repeated and confirmed.

Initial calibration results
(Adjustments based on the results with Standard Lamp tests included)
9 October 2019:

d_Na: -2.51 d_Nc: -1.95 d_Nd: -1.98 d_Nad: -0.53 d_Ncd: 0.03

The d_Nad value implies an average **+0.7 % error** in calculated ozone value, Mu=1.15 to 2.5, Total Ozone = 300 Dobson Units. Measurements very noisy due to not optimal operation of the instrument, larger difference in mue-range 1.5 - 2.0 and in single A, C and D. As AD acceptable no data reprocessing recommended.

Optical, mechanical and electronical work performed

- Electric/Electronics: Old Komhyr-version, some noise problems, reason for the well-known problem of different readings (detected during SL-Test) at different setting of High Voltage found: shutter motor causes RFI on the electronics which results in an offset of the microamperemeter zero.
- Optical check: All optics (Ps, Ms, Ls, Q-plates, wedge dusty, surface of cobalt filter with film.
- Symmetry test: Done twice, Results satisfying in important values.
- Measurement of slit widths and parallelism with microscope: Not done.
- Shutter motor: Toothbelt driven, 815 rpm O.K.
- PMT vertical position test: and Focus L1: Not done.
- Optics: All optics cleaned, special cleaning of cobalt filter.
- Further work: Gasket replaced.
- Discharge lamp: Not done.
- Wedge calibration: Done on 12 October 2019, applied to create new R-G-tables for FC.

Final intercomparison
12 and 17 October 2019

Data of two final calibration processed with the new R-G-Tables to derive new R-N-tables, much less noise in the data than during the IC; **second FC used for future R-N-tables; highest difference against the standard ADDSGQP observations of D064 in mu range 1.15 to 3.2 was -0.7 % in total ozone, no significant mue-dependency. CD-results O.K. with mue-dependence, but not used.**

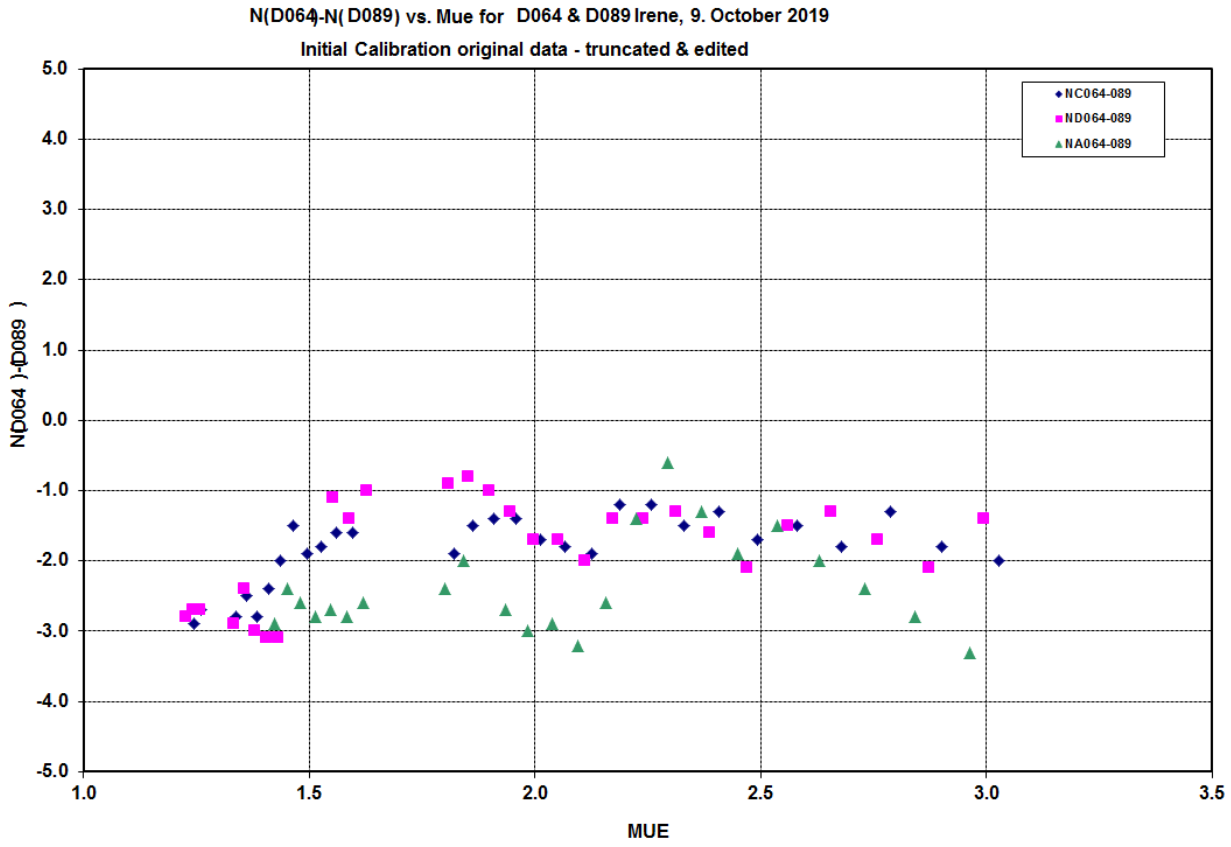
Recommendations/comments

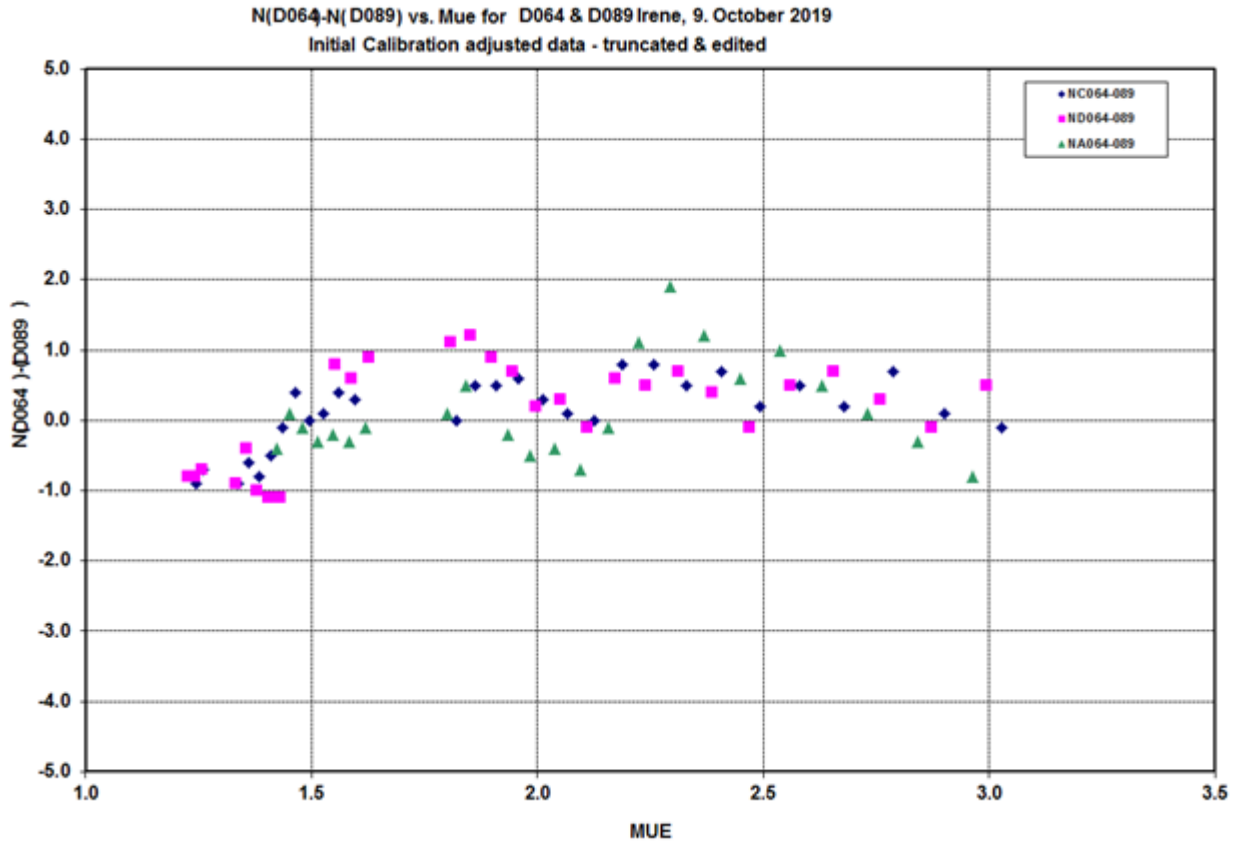
- The results of the initial calibration are satisfactory in AD, therefore no re-calculation necessary.
- New calibration status with new R-N-tables defined based on new R-G-tables incl. determination of SL-reference values from corresponding tests (s. table with results).
- **Correction of Q-tables from results of the Hg-Test not necessary.**
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.
- **Recommendation to avoid RFI-effect/zero-offset on SL-Test and measurements: Switch on shutter motor only with inlet window closed and correct offset of the microamperemeter if any.**
- **New absorption coefficients will officially be introduced in the near future: reprocessing of all data necessary. Information will be given. Question of the future use of effective absorption coefficients (derived from optical characterization) not finally clarified.**

Hohenpeissenberg, 28.11.2019

Difference N_A-C-D to Reference Instrument D064

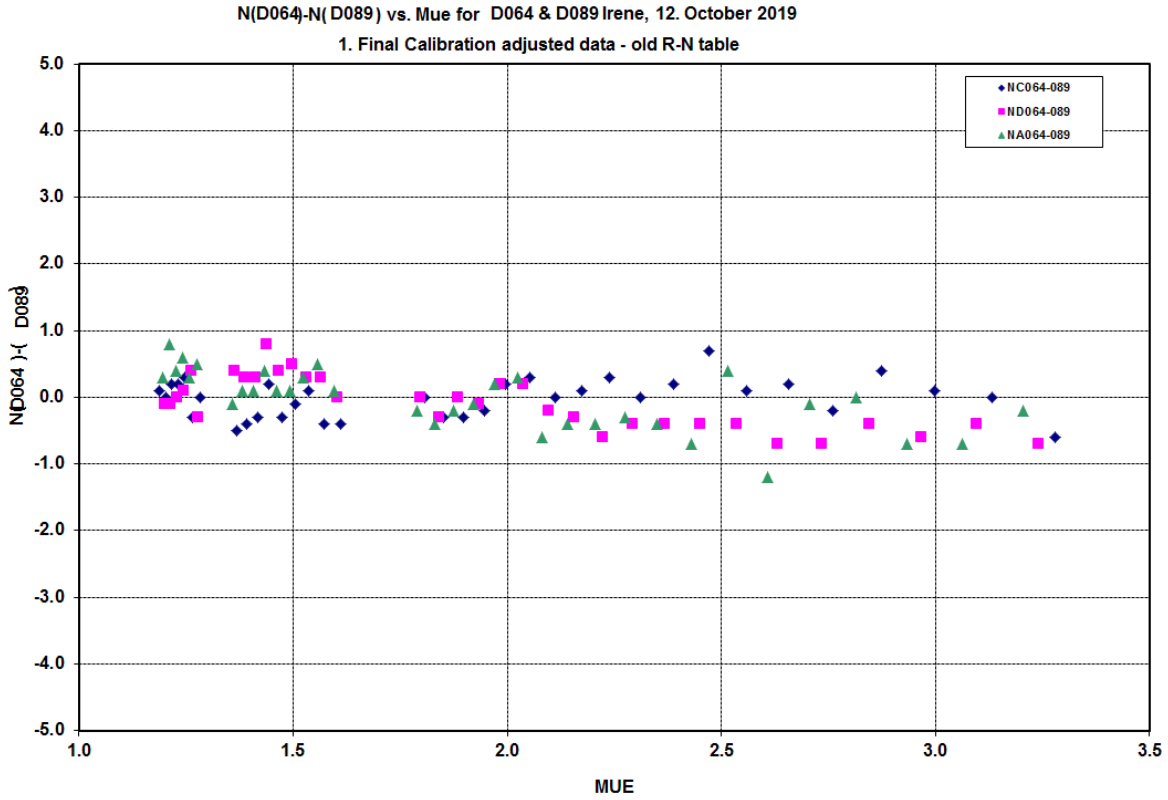
Initial Calibration on 9 October 2019

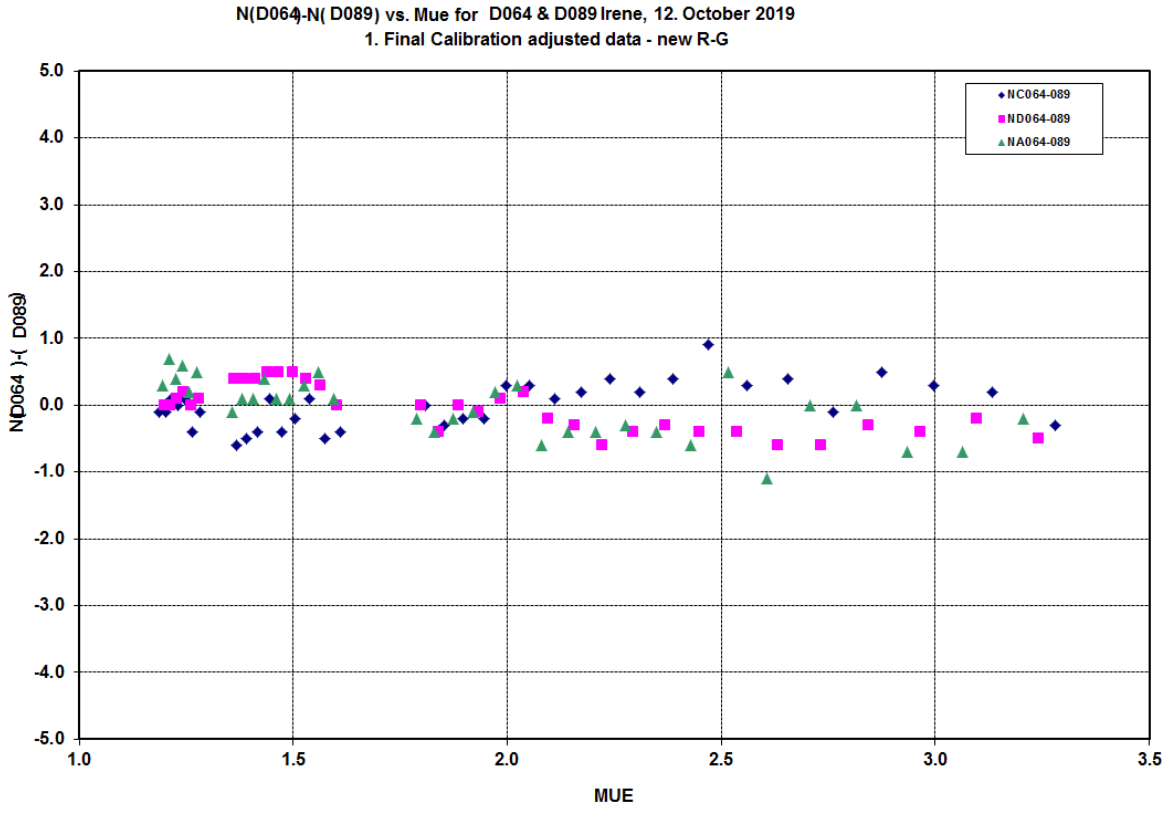


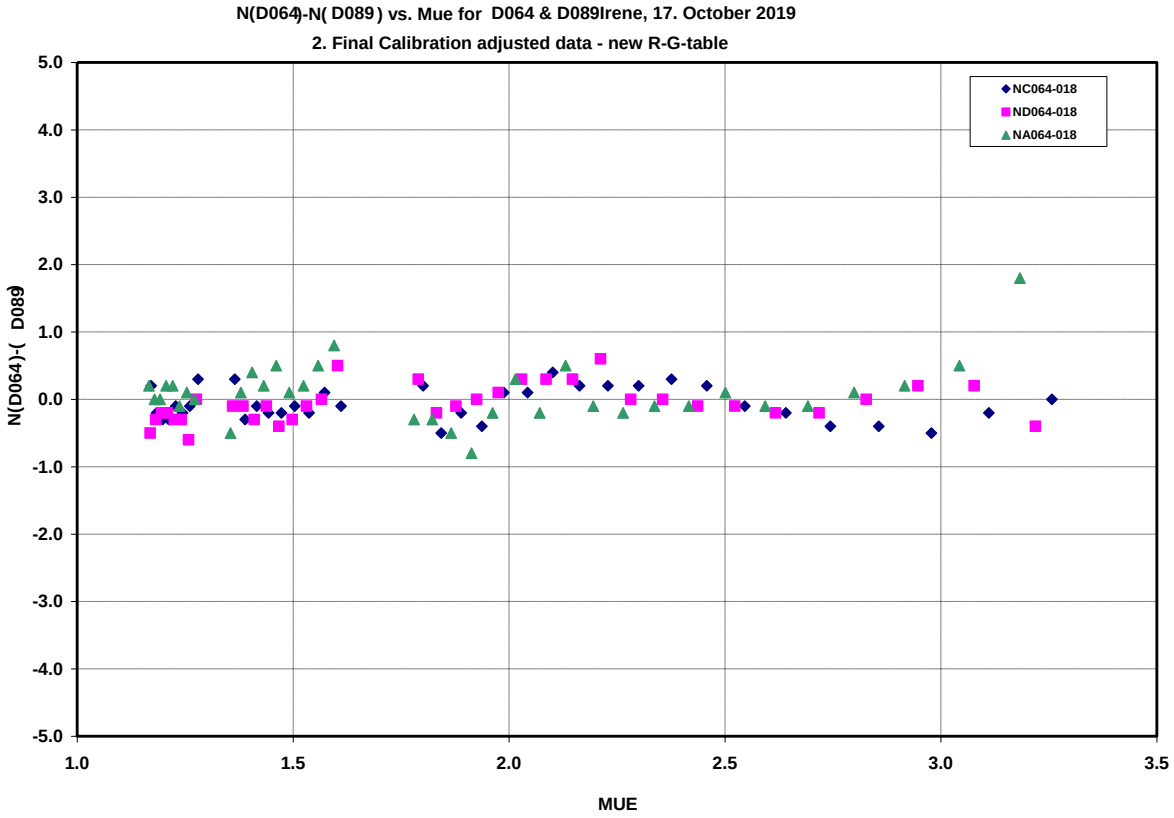


Difference N_A-C-D to Reference Instrument D064

1. & 2. Final Calibration on 12/17 October 2019
2. FC used for calibration and preparing of new R-N-table






N(D064)-N(D089) vs. Mue for D064 & D089Irene, 17. October 2019
2. Final Calibration adjusted data - new R-G-table
NC064-018
ND064-018
NA064-018
N(D064)-(D089)
MUE
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1.0
1.5
2.0
2.5
3.0
3.5

Intercomparison Results
Iren2019 from October 7 to 18, 2019 at Irene

Instrument D112
India (New Delhi)

Initial calibration (12.10.2019):

	Date:	Comment:
G-Tables	???	Origine not known
N-Tables	18.3.06	from FC on March 18, 2006 at Tsukuba

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	-3.10	-2.70	-2.50	-0.60	-0.20
from Comparison	1.37	1.57	2.38	-1.01	-0.81
Sum	-1.73	-1.13	-0.12	-1.61	-1.01

Comments: Agreement in AD out of limits, noisy data, large diff. especially in D
Reprocessing recommended after check of SL-test history
to determine doubtful periods

Final Calibration (17.10.2019):

	Date:	Comment:
G-Tables	16.10.19	from wedge cal. on October 16, 2019, at Irene
N-Table (new)	17.10.19	from IC on October 16, 2019 with new R-G

Corrections to:	A	C	D	AD	CD
new G-Table	-8.39	-5.54	-6.60	-1.79	1.06

Comments: Very good agreement in AD and single A, C and D
New R-N-tables derived from this IC using new R-G-table

Reference Standard Lamp Data: Date: 17.10.19

for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
112Q2	25.70	11.78	28.30	17.54	30.80	18.59
64Q1	25.70	11.78	28.40	17.64	30.80	18.59

Q-Table: Check new Q-table from discharge lamp test October 15 after return by doing an HG-test and correct if necessary according the procedure described in Komhyr's old or Bob's new Dobson manual

Instrument D112
India (New Delhi)

Original calibration data
N-tables from 18 March 2006 based on DSGQP-comparison with D116 on 18.3.2006, Tsukuba, origin of G-tables not known.
Reference Standard Lamp Values for lamps 112Q2.
Lamp tests results used in data processing at home station.

Introductory remarks
Instrument used as national standard. HG lamp not operational, therefore D064-equipment used.

Initial calibration results
(Adjustments based on the results with Standard Lamp tests included)
12 October 2019:

d_Na: 1.37 d_Nc: 1.57 d_Nd: 2.38 d_Nad: -1.01 d_Ncd: -0.81

The d_Nad value implies an average **+1.4% error** in calculated ozone value, Mu=1.15 to 2.5, Total Ozone = 300 Dobson Units. **AD-difference out of limits, large difference especially in D. Reprocessing recommended after check of SL-test history to determine doubtful periods.**

Optical, mechanical and electronical work performed

- Electric/Electronics: Japanese electronic type, shunt resistor of microamperemeter corroded.
- Optical check: All optics incl. wedge slightly dusty, film on surface of cobalt filter, mirrors with fingerprints and scratches.
- Symmetry test: Acceptable at the beginning, good after mirror replacement, optical alignment however very difficult.
- Measurement of slit widths and parallelism with microscope: Not done.
- Shutter motor: Problems with correct speed, very slow (250 rpm at the beginning of operation, 750 rpm after 10s), could be easily stopped with a finger. Repair or even replacement not possible at Irene; attempt with better lubrication.
- PMT vertical position test: Good after optical alignment after mirror replacement, Focus L1: Not.
- Optics: All optics cleaned, special cleaning of surface of cobalt filter, mirrors replaced.
- Further work: Shunt resistor and gasket replaced.
- Discharge lamp: Done twice, on 9 October before initial calibration and on 15 October after optical alignment, new Q-table created.
- Wedge calibration: Done on 16 October, manually data acquisition necessary, as encoder of wedge calibrator defective. New R-G-tables created.

Final intercomparison
17 October 2019

Data of final calibration processed with the new R-G-Tables to derive new R-N-tables as results better than with old R-N-tables, very good agreement in AD, small noise in the

data**; FC used for future R-N-tables; highest difference against the standard ADDSGQP observations of D064 in mu range 1.15 to 3.2 was -0.3 % in total ozone, no significant mue-dependency. CD-results O.K. with mue-dependence, but not used.**

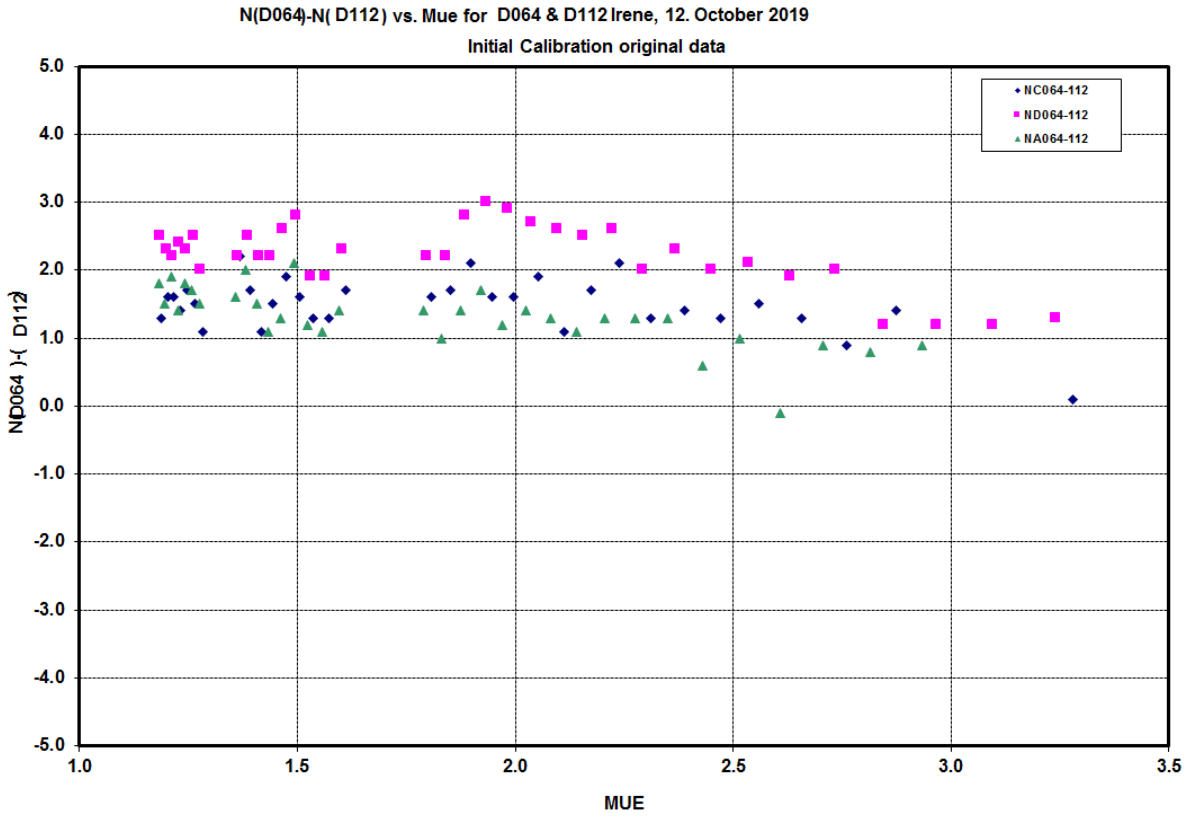
Recommendations/comments

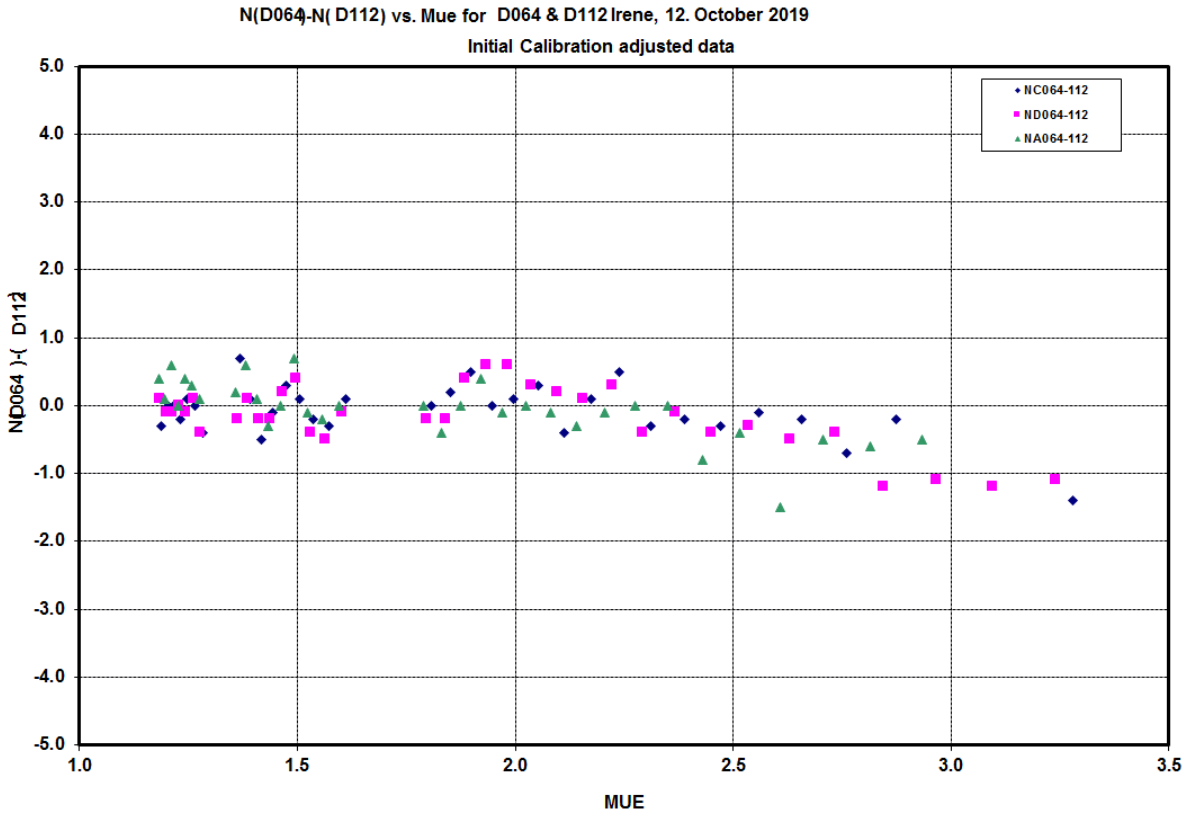
- The results of the initial calibration are out of 1%-limit, therefore re-calculation recommended after check of SL-test history to determine doubtful periods.
- New calibration status with new R-N-tables defined based on new R-G-tables incl. determination of SL-reference values from corresponding tests (s. table with results).
- **Correction of new Irene-Q-tables from results of the Hg-Test immediately after return to station.**
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.
- **New absorption coefficients will officially be introduced in the near future: reprocessing of all data necessary. Information will be given.**
- **Electronic and motor replacement recommended within the next years.**

Hohenpeissenberg, 27.12.2019

Difference N_A-C-D to Reference Instrument D064

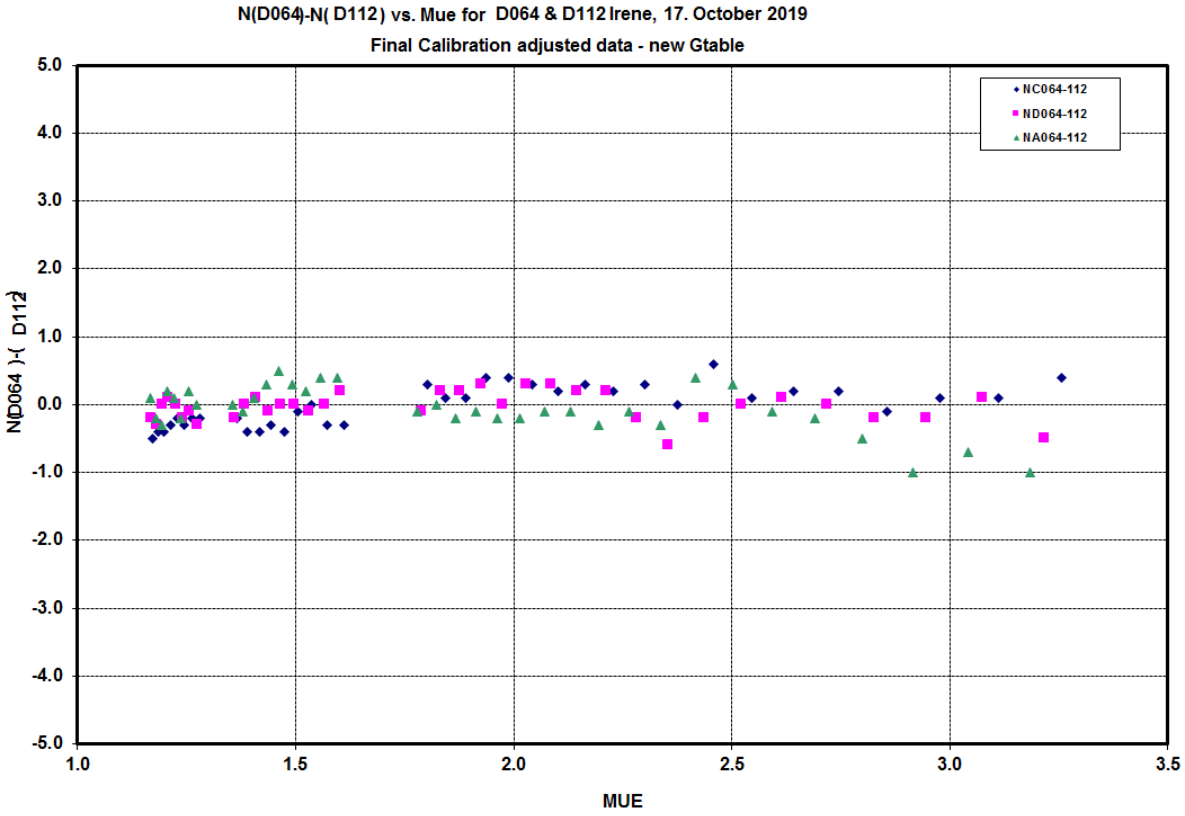
Initial Calibration on 12 October 2019

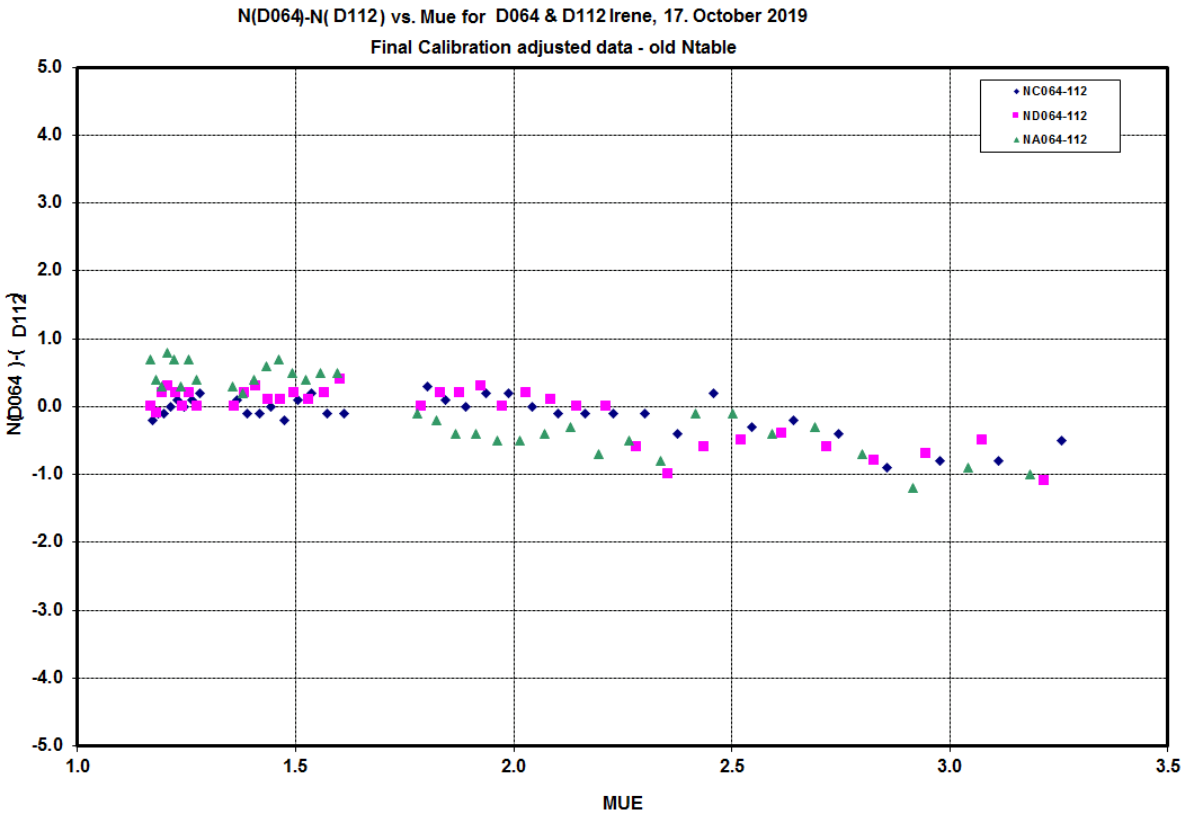




Difference N_A-C-D to Reference Instrument D064

Final Calibration on 17 October 2019





Intercomparison Results
Iren2019 from October 7 to 18, 2019 at Irene

Instrument D132
South Africa (Springbok)

Initial calibration (09.10.2019):

	Date:	Comment:
G-Tables	22.10.09	after wedge-cal. on Oct. 22, 2009 at Irene2009
N-Tables	27.10.09	after FC on Oct. 27, 2009 with new R-G at Irene2009

Corrections to N-Tables	A	C	D	AD	CD
from SL-Test	-3.90	-3.90	-3.50	-0.40	-0.40
from Comparison	-0.69	0.09	-0.50	-0.19	0.59
Sum	-4.59	-3.81	-4.00	-0.59	0.19

Comments: Good agreement in AD, noisy data in A, moderate mue-dependance
Used as results more consistent in single D than that of 2. IC on 12.10.
No data reprocessing recommended.

Final Calibration (17.10.2019):

	Date:	Comment:
G-Tables	22.10.09	after wedge-cal. on Oct. 22, 2009 at Irene2009
N-Table (new)	17.10.19	after FC on Oct. 17, 2019 with old R-N at Irene2019

Corrections to:	A	C	D	AD	CD
old N-Table incl. SL-test	-4.30	-3.50	-3.70	-0.60	0.20

Comments: Results very good in AD and good in single A, C and D
new R-N-tables derived and recommended for future data processing.

Reference Standard Lamp Data: Date: 17.10.19

for new R-N-table

Lamp No.	A		C		D	
	R	N	R	N	R	N
132A	39.10	12.69	39.90	17.93	40.00	19.43
132C	39.00	12.59	39.40	17.42	39.90	19.33
132D	39.20	12.79	39.80	17.83	40.00	19.43
132E	38.50	12.39	39.60	17.66	39.70	19.15

Q-Table:

Check original Q-table in use at station
by doing an HG-test and correct if necessary according the procedure
described in Komhyr's old or Bob's new Dobson manual

Instrument D132
South Africa (Springbok)

Original calibration data
N-tables from 27 October 2009 based on DSGQP-comparison with D064/D083
27 October 2009 at Irene, G-tables from 22 October 2009.
Reference Standard Lamp Values for lamps 132A, 132C, 132D and 132E.
Lamp tests results used in data processing at home station.

Introductory remarks
Two initial calibrations performed on 9 and 12 October 2019. Only IC on first day used, as results of second IC especially in D not consistent (reverse sign, data noisy and doubtful).

Initial calibration results
(Adjustments based on the results with Standard Lamp tests included)
9 October 2019:

d_Na: -0.69 d_Nc: 0.09 d_Nd: -0.50 d_Nad: -0.19 d_Ncd: 0.59

The d_Nad value implies an average **0.3 error** in calculated ozone value, Mu=1.15 to 2.5, Total Ozone = 300 Dobson Units. Good agreement in AD with moderate mue-dependance. No data reprocessing necessary using this first IC.

Optical, mechanical and electronical work performed

- Electric/Electronics: New US-type MOHp modified.
- Optical check: All optics slightly dusty, cobalt filter dirty, wedge O.K.
- Symmetry test: Done on 8 and 15 October, good results.
- Measurement of slit widths and parallelism with microscope: Not done.
- Shutter motor:
- PMT vertical position test: Not done, Focus L1: Not done.
- Optics: All optics incl. cobalt filter cleaned.
- Discharge lamp: Done on 11 October 2019, not used as no difference to original Q-table.
- Wedge calibration: Not done.

Final intercomparison
17 October 2019

Data of final calibration processed with old R-N-Tables to derive new R-N-tables, very good agreement in AD, small noise in the data**; FC used for future R-N-tables; highest difference against the standard ADDSGQP observations of D064 in mu range 1.15 to 3.2 was -0.5 % in total ozone, no significant mue-dependency. CD-results O.K. with mue-dependence, but not used.**

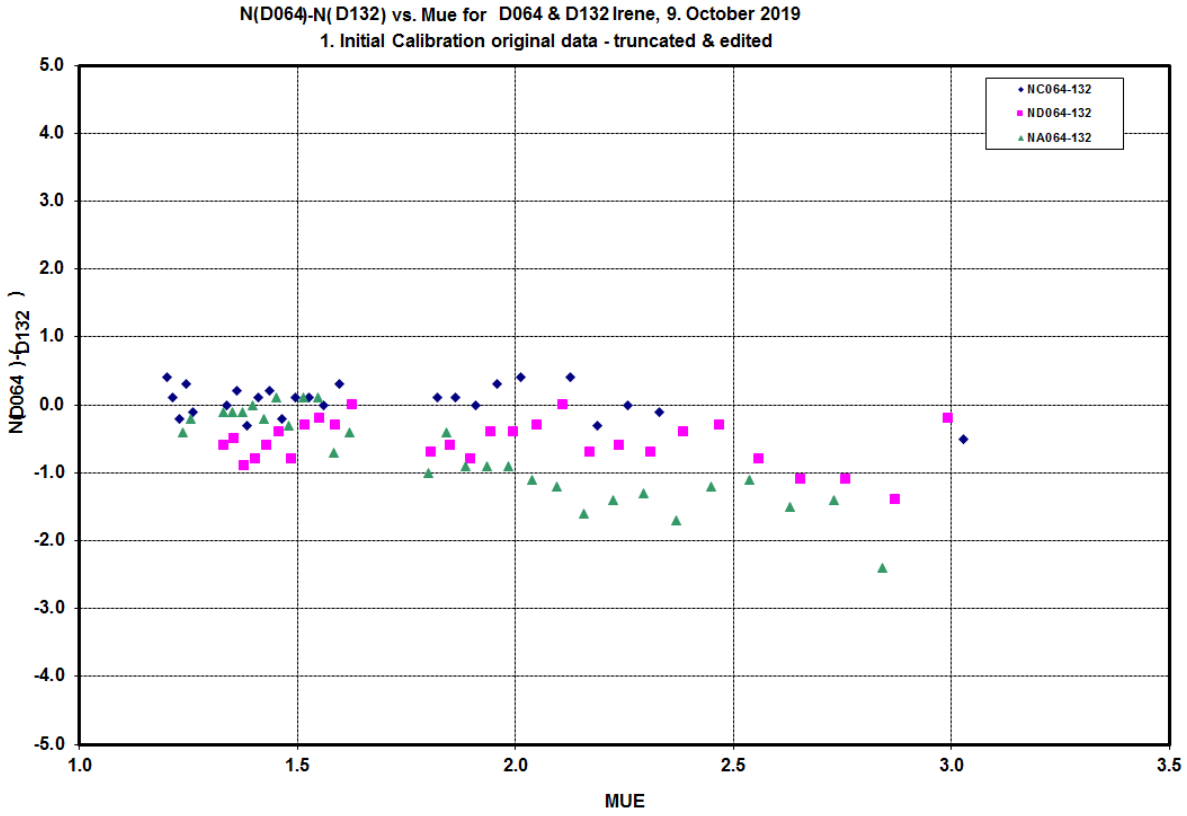
Recommendations/comments

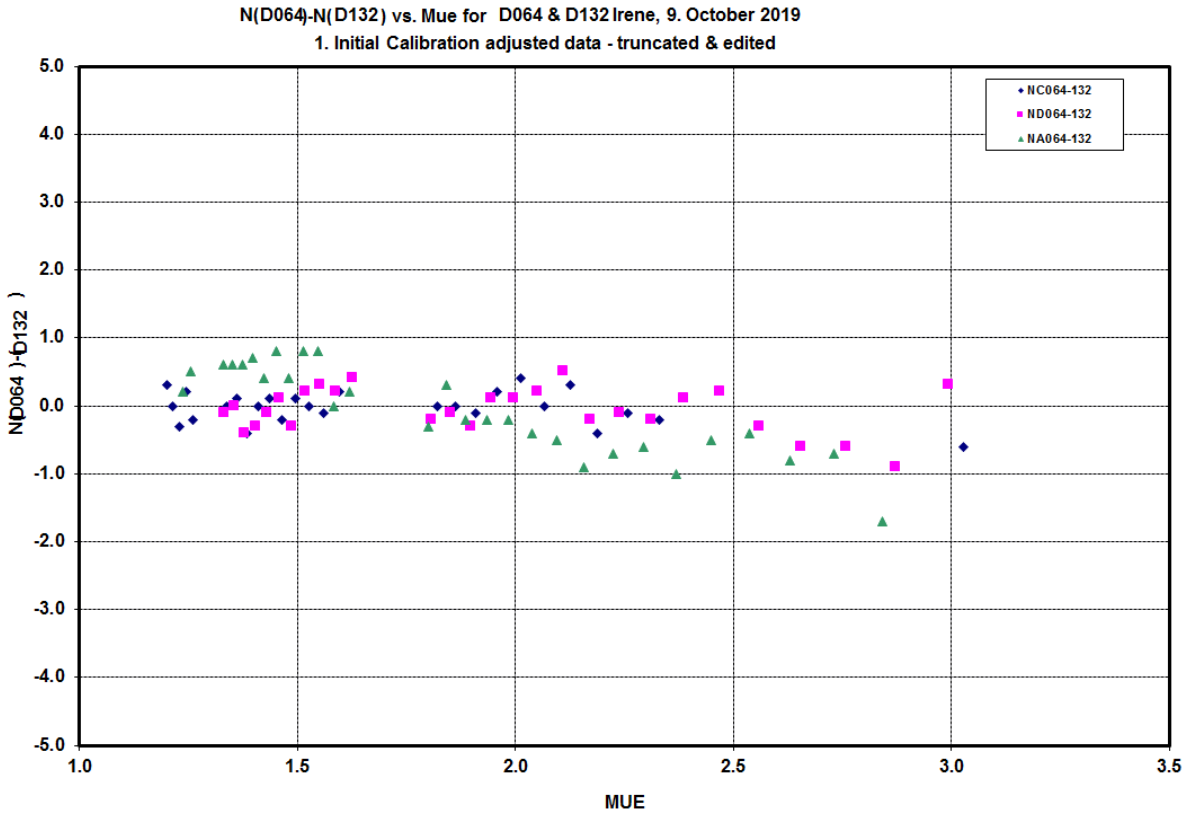
- The results of the initial calibration are good although data noisy and have to be edited, therefore no re-calculation necessary, especially as only AD used for data evaluation.
- New calibration status with new R-N-tables defined based on old R-N-tables incl. determination of SL-reference values from corresponding tests (s. table with results).
- **Correction of original-Q-tables at station from results of the Hg-Test immediately after return to station.**
- Regular test (monthly SL and HG, at least annual Symmetry Test) and cleaning of GQP/Sundirector.
- **New absorption coefficients will officially be introduced in the near future: reprocessing of all data necessary. Information will be given.**

Hohenpeissenberg, 30.12.2019

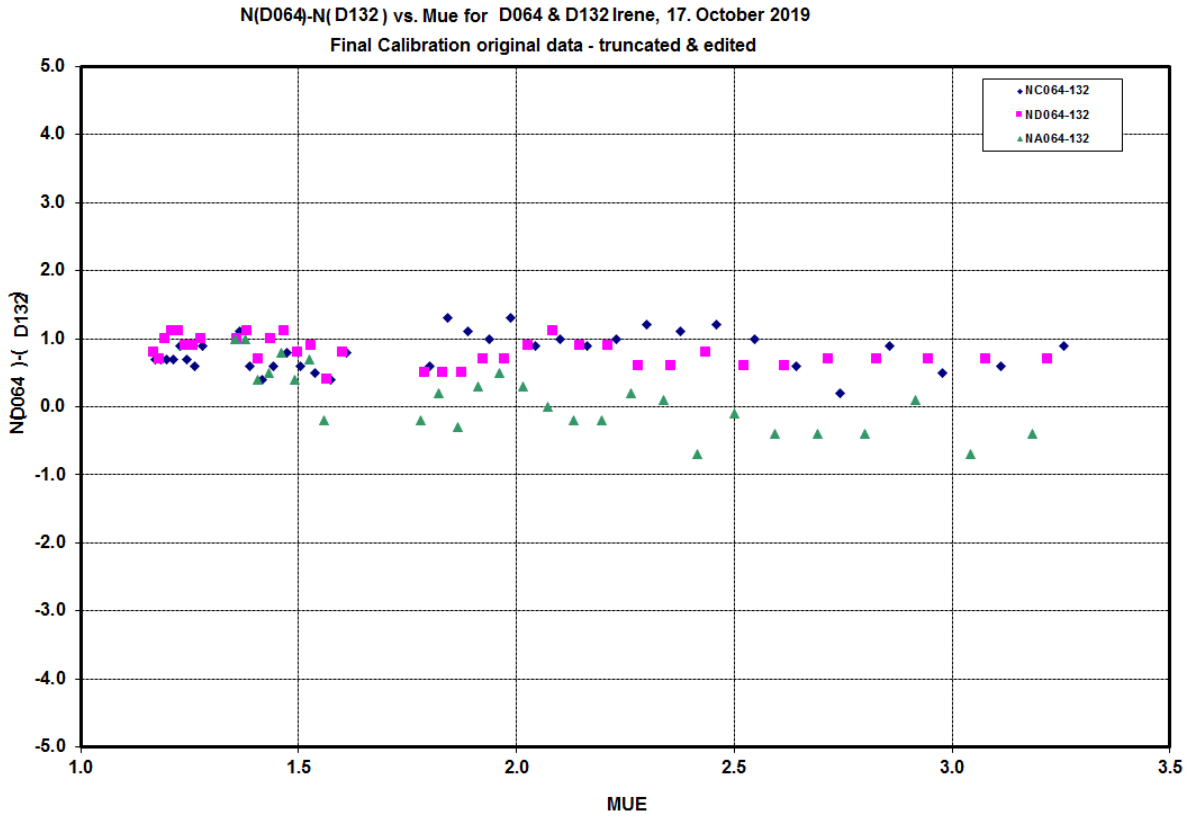
Difference N_A-C-D to Reference Instrument D064

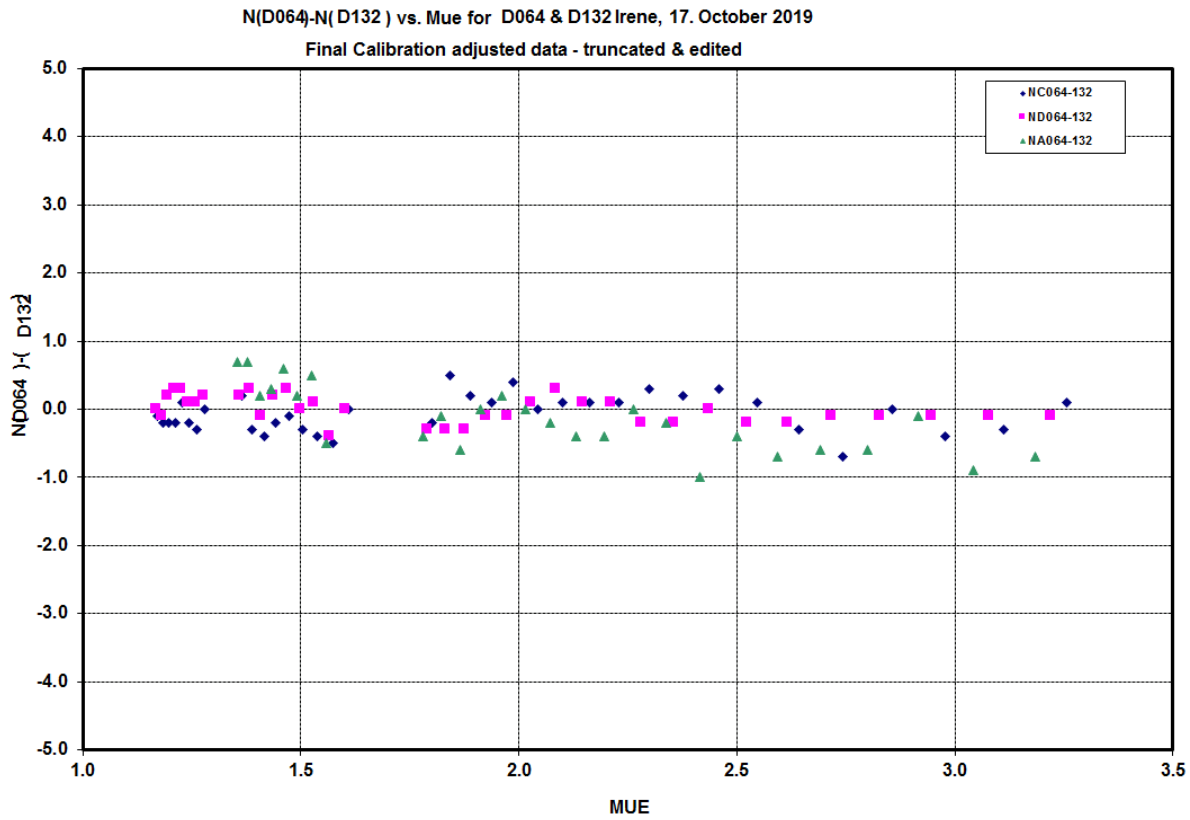
1.Initial Calibration on 9 October 2019





Difference N_A-C-D to Reference Instrument D064
Final Calibration on 17 October 2019





LIST OF RECENT GAW REPORTS*

252. Research Infrastructure Quality Assurance - System and Performance Audit of Surface Ozone, Carbon Monoxide, Methane, and Carbon Dioxide at the Global GAW Station Ushuaia, Argentina, November 2019, WCC-Empa Report No. 19/3.

251. Research Infrastructure Quality Assurance - System and Performance Audit of Surface Ozone, Carbon Monoxide, Methane, Carbon Dioxide and Nitrous Oxide at the Global GAW Station Izaña, Spain, May 2019, WCC-Empa Report No. 19/2.

250. Global Atmosphere Watch Expert Meeting Workshop on Measurement-Model Fusion for Global Total Atmospheric Deposition (MMF-GTAD), Geneva, Switzerland, 26-27 February 2019.

249. Report of the Fifth Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC), Geneva, Switzerland, 5-6 November 2018, 2020.

248. Twelfth Intercomparison Campaign of the Regional Brewer Calibration Center Europe, El Arenosillo Atmospheric Sounding Station, Huelva, Spain, 27 May–9 June 2017, 2019.

247. Izaña Atmospheric Research Center Activity Report 2017-2018, 2019.

246. Thirteenth Intercomparison Campaign of the Regional Brewer Calibration Center Europe (RBCC-E), Arosa Lichtklimatisches Observatorium, Switzerland, 30 July to 8 August 2018.

245. An Integrated Global Greenhouse Gas Information System (IG3IS) Science Implementation Plan, 2019.

244. Report of the 2017 Global Atmosphere Watch Symposium and Fourth Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC), Geneva, Switzerland, 10-13 April 2017, 2019.

243. Report of the Fifth Erythemal UV Radiometers Intercomparison, Buenos Aires, Argentina, 2019.

242. 19th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (GGMT-2017), Dübendorf, Switzerland, 27-31 August 2017, 2018.

241. SPARC/IOC/GAW Report on Long-term Ozone Trends and Uncertainties in the Stratosphere, SPARC Report No. 9, WCRP-2017/2018, GAW Report No. 241, 2018.

240. Report of the Second International UV Filter Radiometer Intercomparison UVC-II, Davos, Switzerland, 25 May-5 October 2017, 212 pp., 2018.

239. Calibration Methods of GC-μECD for Atmospheric SF6 Measurements, 26 pp., 2018.

238. The Magnitude and Impacts of Anthropogenic Atmospheric Nitrogen Inputs to the Ocean, Reports and Studies GESAMP No. 97, 47 pp., 2018

237. Final Report of the 44th Session of GESAMP, Geneva, Switzerland, 4-7 September 2017, Reports and Studies GESAMP No. 96, 115 pp., 2018.

236. Izaña Atmospheric Research Center: Activity Report 2015-2016, 178 pp., 2017.

235. Vegetation Fire and Smoke Pollution Warning and Advisory System (VFSP-WAS): Concept Node and Expert Recommendations, 45 pp., 2018.

A full list is available at:

http://library.wmo.int/opac/index.php?lvl=etagere_see&id=144#.WK2TTBiZNB

For more information, please contact:

World Meteorological Organization

Science and Innovation Department

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Tel.: +41 (0) 22 730 81 11 – Fax: +41 (0) 22 730 81 81

Email: GAW@wmo.int

Website: https://public.wmo.int/en/programmes/global-atmosphere-watch-programme

JN 20556