GAW Report No. 223

Eighth Intercomparison Campaign of the Regional Brewer Calibration Center for Europe (RBCC-E)

(El Arenosillo Atmospheric Sounding Station, Heulva, Spain, 10-20 June 2013)

World Meteorological Organization
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GLOBAL ATMOSPHERE WATCH

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Eighth Intercomparison Campaign of the Regional Brewer Calibration Center Europe (RBCC-E)

El Arenosillo Atmospheric Sounding Station, Huelva, Spain

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Prepared by

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1. SUMMARY

The eighth Regional Brewer Calibration Center for Europe (RBCC-E) intercomparison was held at El Arenosillo Atmospheric Sounding Station of the Instituto Nacional de Técnica Aeroespacial (INTA) during the period 10-20 June 2013. This campaign was organized in collaboration with the Area of Instrumentation and Atmospheric Research of INTA, with the support of the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) and a CEOS CALVAL project of the European Space Agency (ESA).

Figure 1. Group photo of the participants of the VIII RBCC-E campaign, Huelva 2013

A total number of 18 Brewer spectrophotometers from eight countries participated in the intercomparison. These campaigns, with a large number of participant instruments, provide an overview of the current state of ozone measurements being made by the European Brewer network. The instruments were compared with the RBCC-E standard Brewer#183 for ozone and with the European UV reference from the World Radiation Center (QASUME unit) for UV. For this report we used our own calibration constants obtained by Langley plots at IZO. Apart from the RBCC-E standards, two additional reference instruments were present at the campaign: the single-monochromator Brewer #017 (IOS, EC) and the double-monochromator Brewer #158 (K&Z).

Table 1. El Arenosillo 2013 intercomparison campaign: participating instruments

Institution	*Name*	*Instrument*	*Country*
RBCC-E AEMET	Alberto Redondas Juan José Rodríguez Virgilio Carreño	Brewer #183-MKIII Brewer #185-MKIII	Spain
IOS	Ken Lamb V. Savastiouk Martin Stanek	Brewer #017-MKII	Canada Czech Republic
Kipp&Zonen	David Godoy Keith M. Wilson	Brewer #158-MKIII	Netherland
INTA	Jose Manuel Vilaplana	Brewer #150-MKIII	Spain
AEMET	J.R. Moreta González Daniel Moreno J.M San Atanasio Angel Miguel Boned Francisco Escribá Francisco García	Brewer #070-MKIV Brewer #186-MKIII Brewer #166-MKIV Brewer #117-MKIV Brewer #151-MKIV	Spain
ONM	Ouchene Bouziane Ferroudj Mohammed Salah	Brewer #201-MKIII	Algeria
UKMO	John Rimmer Peter Kelly	Brewer #075-MKIV Brewer #126-MKII Brewer #172-MKIII	U.K.
DMN	Hamza Rachidi Mohammed Jamaleddine Abdelkarim Faquih	Brewer #051-MKII Brewer #165 - MKIII	Morocco
WRC	Luca Egli Christian Thomann	Brewer #163-MKIII QUASUME	Switzerland
KMA	JungMi Lee Young Suk You Yun Gon Lee	Brewer #095-MKII	Korea

This intercomparison campaign was scheduled into three main stages:

- Initial calibration to assess the current calibration of the instruments
- Servicing, adjustments and maintenance work
- Final calibration

We present in this brief report an overview of the main results obtained during the intercomparison, focusing on the following main topics: a short introduction to the calibration process, the RBCC-E reference status, initial status of the instruments during the first days of the intercomparison, which allow us to check the Brewer European network condition through analysis of a subsample representative of this network. Lastly, we will show the instruments' status after maintenance was done and after the final constants were calculated and applied to individual instruments.

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2. CALIBRATION PROCESS

The Brewer spectrometer detects spectral irradiance in six channels in the UV (303.2, 306.3, 310.1, 313.5, 316.8, and 320.1 nm) each covering a bandwidth of 0.5 nm (resolution power λ/1λ of around 600). The spectral analysis is achieved by a holographic grating in combination with a slit mask which selects the channel to be analysed by a photomultiplier.

Based on the Lambert Beer's law the Brewer algorithm can be expressed as

$$O_3 = F - ETC / a * m \qquad (1)$$

Where F is Rayleigh corrected the measured double ratios, α is the ozone absorption coefficient; m is the ozone air mass and ETC is the extra-terrestrial constant.

The ozone ratios are defined for the four operational wavelengths L=310,313,5,316.8,320.0 with weights w_i=(1,-0.5,-2.2,-1.7). Whereas all the instruments use the same weighing functions the wavelengths are slightly different

We can divide the calibration in three steps. Instrumental, wavelength and ETC transfer:

- The Instrumental calibration includes all the parameters that affect the measured counts (F): in particular Dead Time, Temperature coefficients and Filter attenuation.
- The wavelength calibration determines the ozone absorption coefficient, or differential absorption coefficient, this procedure called dispersion test obtain the particular wavelength for the instrument and the slit or instrumental function of the instrument
- Finally the ETC transfer is performed by comparison with the reference.

The calibration process can be considered as cycle changes in instrumental and/or wavelength calibration affect the final ETC changes in the wav

The calibration campaigns is scheduled into three main stages:

- Initial calibration to assess the current calibration of the instruments
- Servicing, adjustments and maintenance work
- Final calibration

The initial calibration is performed during the first days of the campaign; during this period modifications of the instrument are not allowed. After the determination of how the instrument is measuring the next days are dedicated to characterize the instrument and perform the necessary adjustments. At the end of the maintenance period the instrumental and wavelength calibration must be almost finished, and the instruments are ready for the ETC transfer or 'Final days'.

For each instrument we consider if during the maintenance the instrument change or not, if the instrument do not change the 'Blind Days ' and Final days periods are the same. The duration of these periods are not fixed and depends on the adjustments or fix required by the instrument, this finally determines the number of simultaneous measurements used on the calibration.

The transfer of the calibration scale (namely ETC) is done by side-by-side operation with the standard instrument. Once we have collected enough near-simultaneous direct sun ozone measurements we calculate the new extraterrestrial constant after imposing the condition that the measured ozone will be the same for simultaneous measurements which in terms of Equation 1 leads to the following:

$$ETC = O_3(reference) * a * m - F \tag{2}$$

For a good characterized instrument the ETC values shows a Gaussian distribution and the mean value is used as instrument constant. One exception to this rule is the single monochromator Brewer models (MK-II, and MK-IV) who are affected by stray light, and the distribution shows a tail to the lower ETC. For this Brewer only stray-light free region is used to determine the ETC, generally from 600 DU to 900 DU OSC, depending of the instrument. During this campaign we test a methodology to correct the stray light based on the comparison of the reference. The calibration is performed assuming that the stray light can be characterized following a power law of the ozone slant column (O3*m) thus

$$ETC = ETC_0 + K * (O_3 * m)^s \tag{3}$$

Where ETCo is the ETC for the stray light free osc region and A and B are retrieved from the reference comparison. As the counts (F) from the single Brewer are affected by straylight, the ozone is calculated using an iterative process:

$$O_3^{i+1} = O_3^i + K(O_3^i * m)^s \tag{4}$$

Only one iteration is needed for the conditions of the intercomparison (up to 1500 DU) for further ozone slant path measurements 1500 DU – 2000 DU two iterations are enough to correct the ozone.

---

3. CHARACTERIZATION AND CALIBRATION OF THE RBCC-E REFERENCE INSTRUMENT

The Regional Brewer Calibration Center for Europe (RBCC-E) was established at the Izaña Atmospheric Research Centre in 2003. Since that moment the RBCC-E transferred the calibration constants from the world reference triad located in Toronto (Canada) and managed by the EC-MSC (Environmental Canada-Meteorological Service of Canada). The members of the RBCC-E triad are linked to the world Brewer reference triad by yearly calibrations using the travelling standard Brewer#017. In 2011, the WMO SAG Ozone authorized the RBCC-E to transfer its own calibration based on Langley plots carried out at the Izaña Atmospheric Observatory (IZO), since no direct cross-link to the Toronto triad was available with the exception of the participation of the #017 at the RBCC-E campaigns.

The RBCC-E Brewer triad comprises three double monochromator instruments: the absolute standard Brewer#157, the experimental unit Brewer#183 and the travelling standard Brewer#185. At the recent Arenosillo 2013 campaign we took with us both 183 and 185 serial number units.

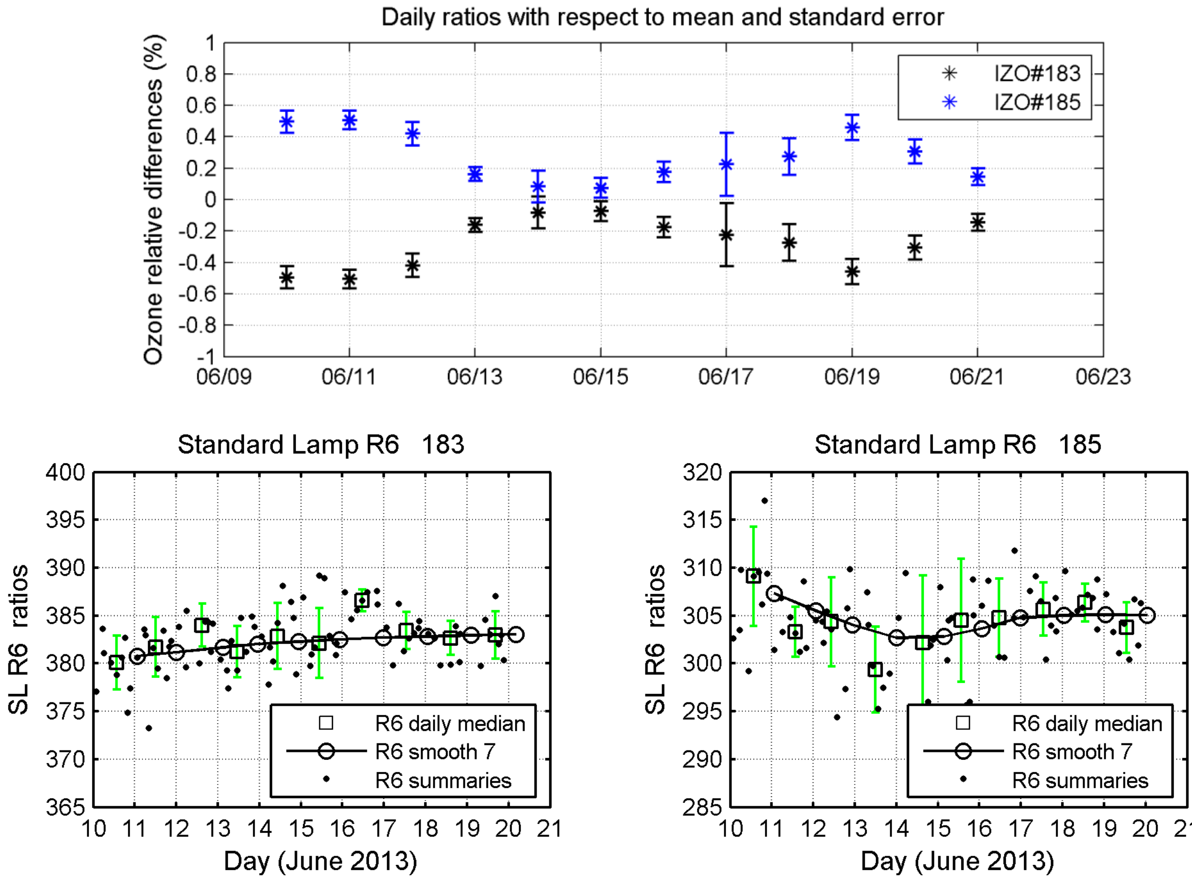


Figure 2. Deviations of ozone values of RBCC-E triad units Brewe#183 and Brewer#185 from the mean of both instruments (top) and standard lamp R6 ratio during the El Arenosillo 2013 intercomparison campaign (bottom)

The behaviour of the Brewer #185 during the campaign were not stable showing deviation of the order or 0.5% respect to Brewer #183 (see Figure 2, top) and also confirmed with some other brewer's present at the campaign (not shown). We was related significant temperature dependence on Brewer#185 not properly corrected (Figure 3) and several instrumental issues affecting the instrument's performance since the last servicing, including neutral density filters attenuation change and issues with the micrometer performance. For that reason we used in this report the Brewer #183 as a reference standard.

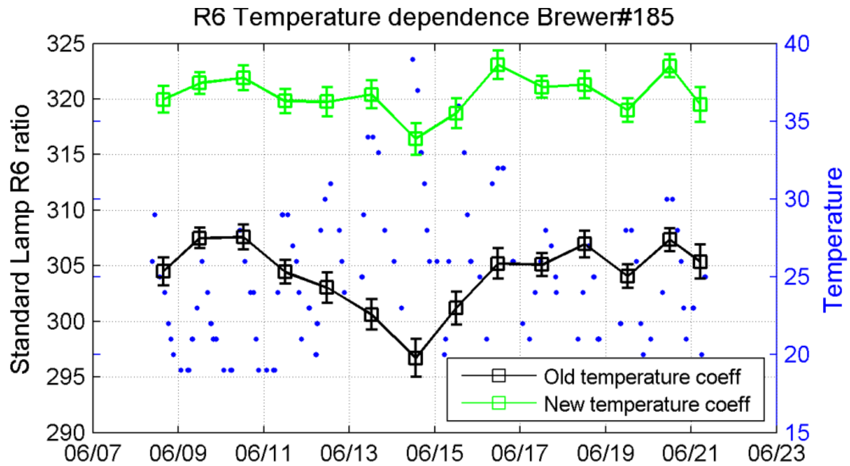


Figure 3. Standard lamp R6 (MS9) ratio as a function of temperature. We plotted R6 ratio recalculated with the original (black) and the new (green) temperature coefficients.

The stability of the travelling standard is checked before and after the campaign by comparison with all the members of the triad, and, if possible, by performing Langley plots. We show in Figure 4 weekly means for the ozone relative differences of each triad member with respect to the triad mean during the year of 2013. All the RBCC-E triad members agreed with each other within +/-0.5%.

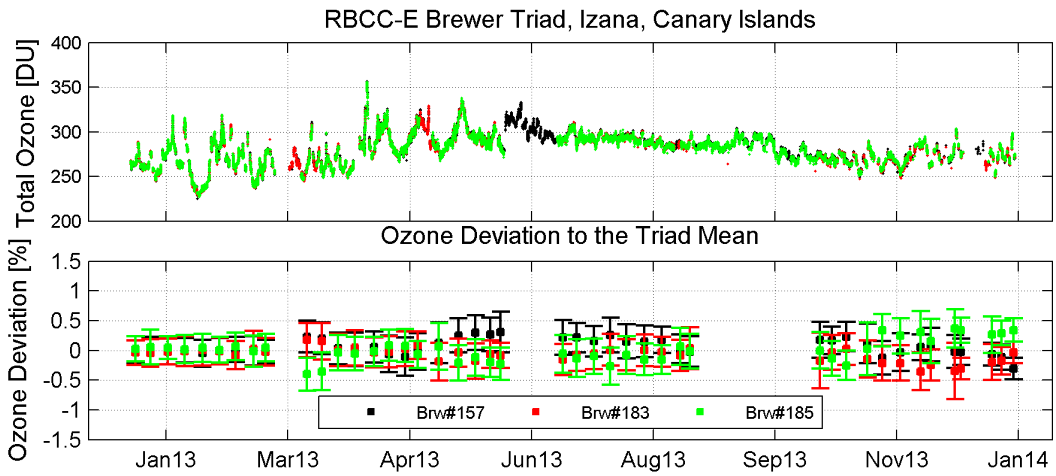


Figure 4. Deviations of ozone values of individual RBCC-E triad Brewers from the mean of the three instruments. Each point on the graph represents a weekly average.

The results obtained from analysis of Langley plots performed at IZO before and after the campaign confirmed the calibration constant transferred during the intercomparison (see Figure 5 and Table 2). We also summarize in Table 3 instrumental parameters as well as specific ozone calibration constants of the reference.

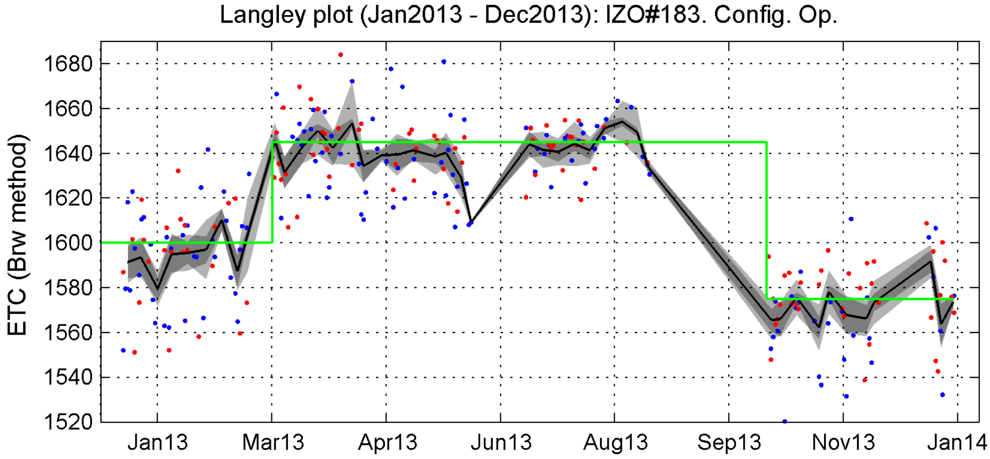


Figure 5. Langley ETC calculation at IZO during the year of 2013. Blue (red) dots correspond to Langley results derived from AM (PM) data sets. Red (blue) circles correspond to Langley results after some filters were applied to AM (PM) raw data. The black solid line represents weekly means of both AM and PM filtered Langley results, with standard deviation (light grey shadow) and standard error of the mean (dark grey shadow). The green solid line indicates the operational ETC constant.

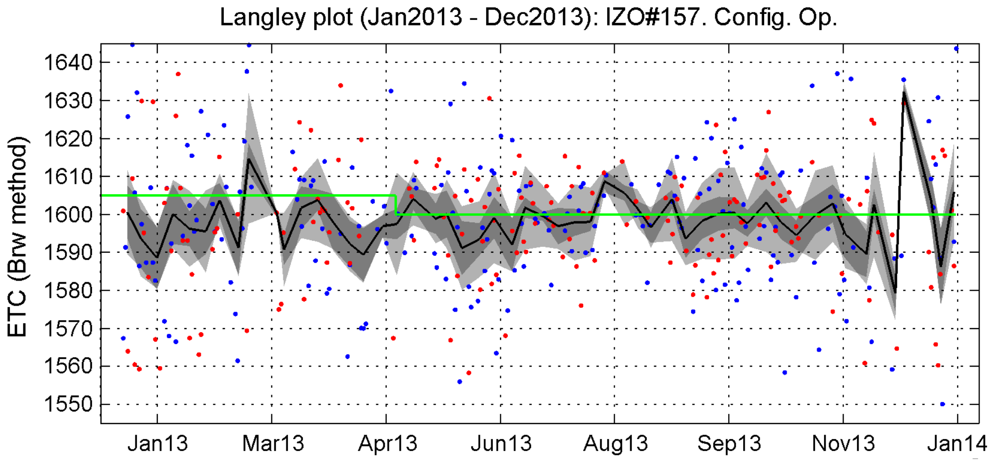
Table 2. Langley weekly mean extraterrestrial constant and corresponding standard error for the Brewer #183 obtained by two different methods: OLS ordinary Least Square and the Dobson regression 1/m.

Weekly average	*ETC*	*SEM*	*ETC corr. (Dobson)*	*SEM*	*N*
09-May-2013	1638	5	-7	5	8
16-May-2013	1642	7	-0	6	7
23-May-2013	1629	9	-13	4	10
28-May-2013	1624	9	-18	8	5
28-Jun-2013	1642	4	-7	4	10
04-Jul-2013	1641	4	-6	4	13
11-Jul-2013	1644	2	-2	3	13
15-Jul-2013	1644	3	-0	3	4

Table 3. Travelling Standard Checklist

Traveling Standard checklist: Brewer#183	*Description*	*Passed ?* Y	N	*Value*	*Comments*
Calibration data					
Reference of the traveling (Triad, RBCC-E,....)					Langley method plus regular triad intercomparisons
Is traveling standard calibrated?		Y			
%difference before travel				-0.1 +/- 0.24	Days 135-153
%difference after travel				-0.1 +/- 0.24	Days 176-196
Instrument operation:					
HP/HG	Hp/Hg tests repeatable to within 0.2 steps	Y			
SH	SH shutter delay is correct			NaN	
RS	Run/Stop test within +/- 0.003 from unity for illuminated slits and between 0.5 and 2 for the dark count	Y			
DT	Dead time is between 28 ns and 45 ns for multiple-board Brewers and between 16 ns and 25 ns for single-board Brewers	Y		22/23	$DT_{\_ref}$=23
SL R6	SL ratio R6 is within 5 units from calibration	Y		382 / 384	$R6_{\_ref}$=383
SL R5	SL ratio R5 is within 10 units from calibration	Y		664 / 675	$R5_{\_ref}$=665
Ozone constants					
Ozone absorption coefficient				0.3435	Dispersion test
Ozone extraterrestrial constant				1645	Langley derived

The ETC constant derived from Langley during the week previous to the campaign shows a value 10 units lower than operational values of the three instruments. We don't use this value during the intercomparison since it is unlikely that the three instruments change their calibrations during the same period of time (Figure 6). This conclusion is reinforced as the instruments recovered their operational values after this event. We are investigating if this value is due to the high aerosol content or changes in the solar emission.



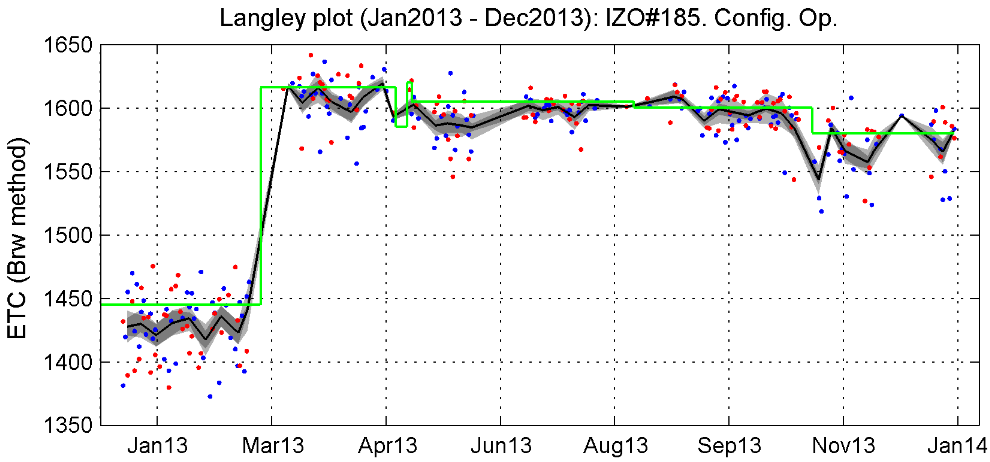


Figure 6. Langley ETC calculation at IZO during the 2013 year. Blue (red) dots correspond to Langley results derived from AM (PM) data sets. Red (blue) circles correspond to Langley results after some filters were applied to AM (PM) raw data. The black solid line represents weekly means of both AM and PM filtered Langley results, with standard deviation (light grey shadow) and standard error of the mean (dark grey shadow). The green solid line indicates the operational ETC constant.

Finally, we show in Figure 7 near-simultaneous ozone relative differences of RBCC-E triad members with respect to the mean of the three instruments for a period of 20 days before (May 13 – June 2, 2013) and after (June 25 – July 15, 2013) the El Arenosillo 2013 campaign. No change is observed in responses of Brewer #157 and Brewer #183, with a slight change in ETC constant in the case of Brewer #185. In any case, the instrument deviations are within 0.3% for both periods (Table 4).

	#157	#183	#185	Nobs
Before	0.3 +/- 0.33	-0.1 +/- 0.20	0.2 +/- 0.30	670
After	0.2 +/- 0.32	0.0 +/- 0.29	-0.1 +/- 0.30	538

Table 4. Percentage difference between the triad instruments before and after the campaign

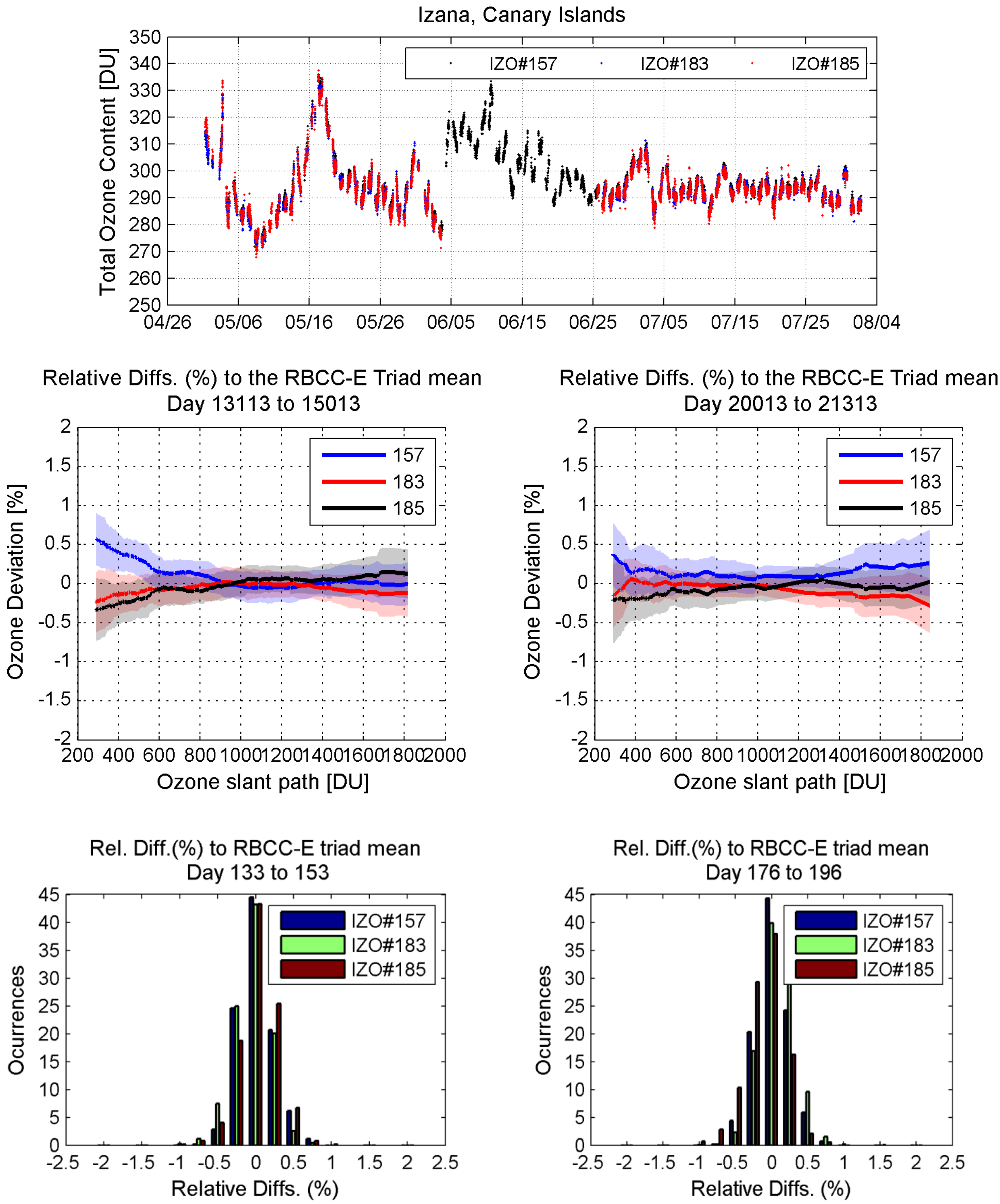


Figure 7. Near-simultaneous ozone ratios of RBCC-E standard Brewers (serial no. #157, #183 and #185) to the mean of all instruments are shown before (left) and after (right) the El Arenosillo 2013 intercomparison

4. THE INTERCOMPARISON CONDITIONS

We collected during the campaign ~850 direct sun ozone measurements with the reference instrument, most of them (~85%) within the 300-600 DU ozone slant path range. The lower number of near-simultaneous ozone measurements was around 400. Total ozone content values at El Arenosillo station during the intercomparison ranged between 310 to 400 DU. This campaign was characterized by high internal temperatures, above 40ºC for some of the participant instruments.

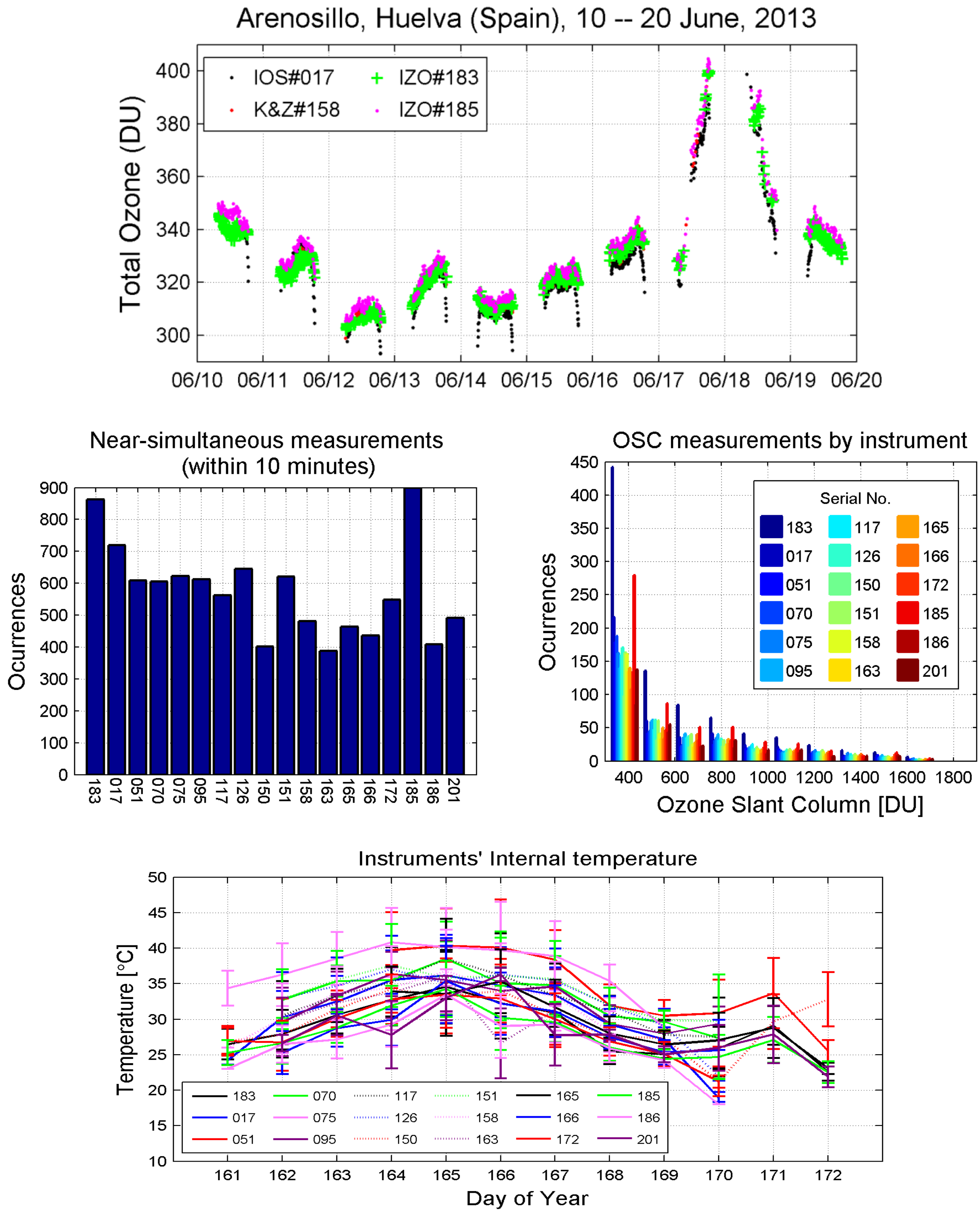


Figure 8. Summary of the instrument statistics of the intercomparison conditions

5. STANDARD INSTRUMENTS INTERCOMPARISON

The following reference instruments, routinely used for ozone transfer calibration, were present at the campaign: single-monochromator Brewer #017 (IOS, EC) and double-monochromator Brewer #158 (K&Z).

The agreement between IOS#017 and IZO#183 is excellent during the first day of the campaign (day of year 161), but the difference goes up to -3% during the campaign course if we don't apply the SL correction. The Brewer #017 standard lamp R6 ratio decreased around 30 units during the intercomparison days, but if we apply the SL correction (Figure 9) we would achieve an overall improvement of Brewer's comparison, but then it resulted in ozone deviations around -1% for OSC lower than 800 DU, on average.

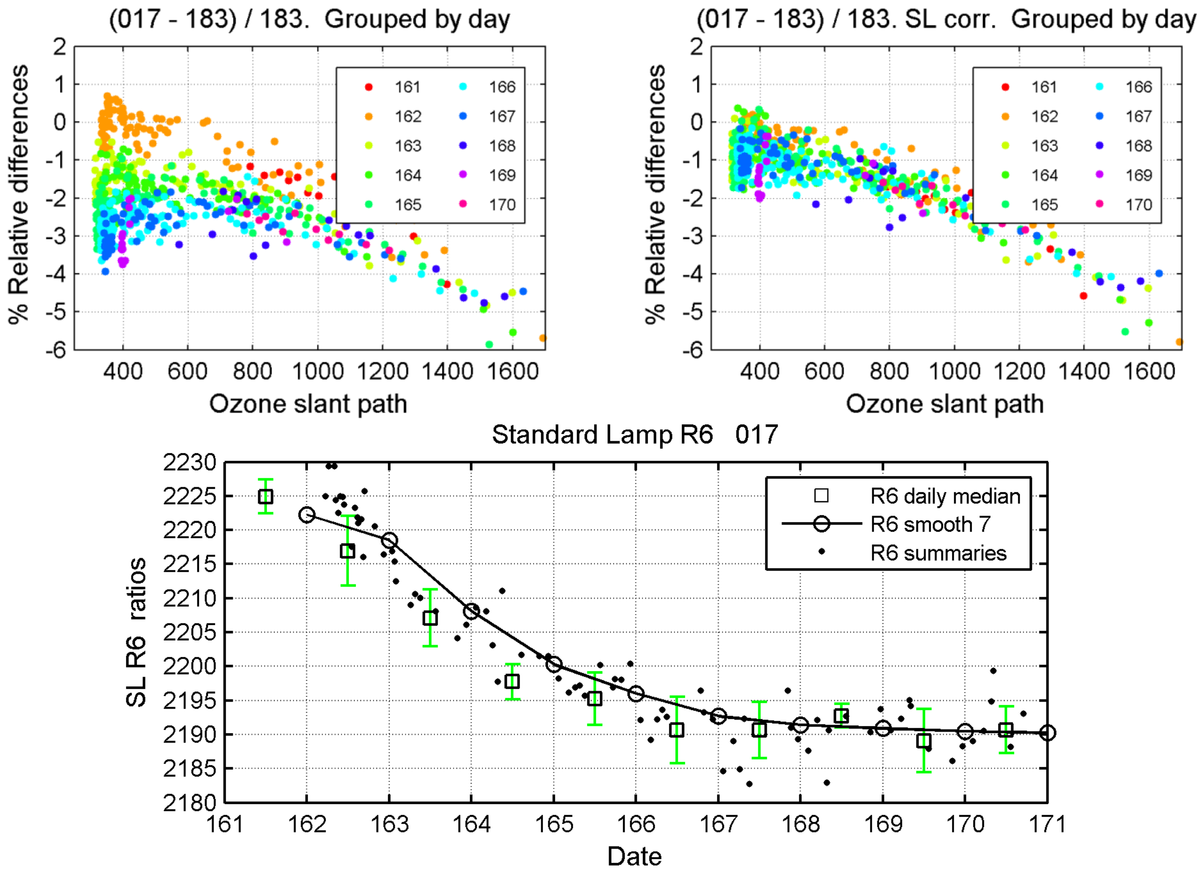


Figure 9. Near-simultaneous direct sun ozone column percentage differences between travelling standard Brewer IOS#017 and RBCC-E reference Brewer#183 grouped by Julian day as a function of ozone slant path (top) and standard lampR6 ratio series (bottom) during the intercomparison days. We show Brewer#017 ozone data with (top, right) and without (top, left) SL correction The Brewer#017 standard lamp R6 ratio decreased around 30 units during the intercomparison days. This change in R6 ratio seems to be related to changes in the instrument's response.

The Brewer#158 standard lamp R6 ratio was quite stable during the campaign days (within the accepted tolerance range +/-5 units).

The initial calibration constants (no SL corrected) resulted in ozone deviations of the order of +1%, on average. The comparison with reference Brewer#183 improved after applying the SL correction to the extraterrestrial constant. Even in this case, ozone measurements obtained from Brewer#158 were of the order of 0.5-1% higher as compared to Brewer#183 ozone data (see Figure 10).

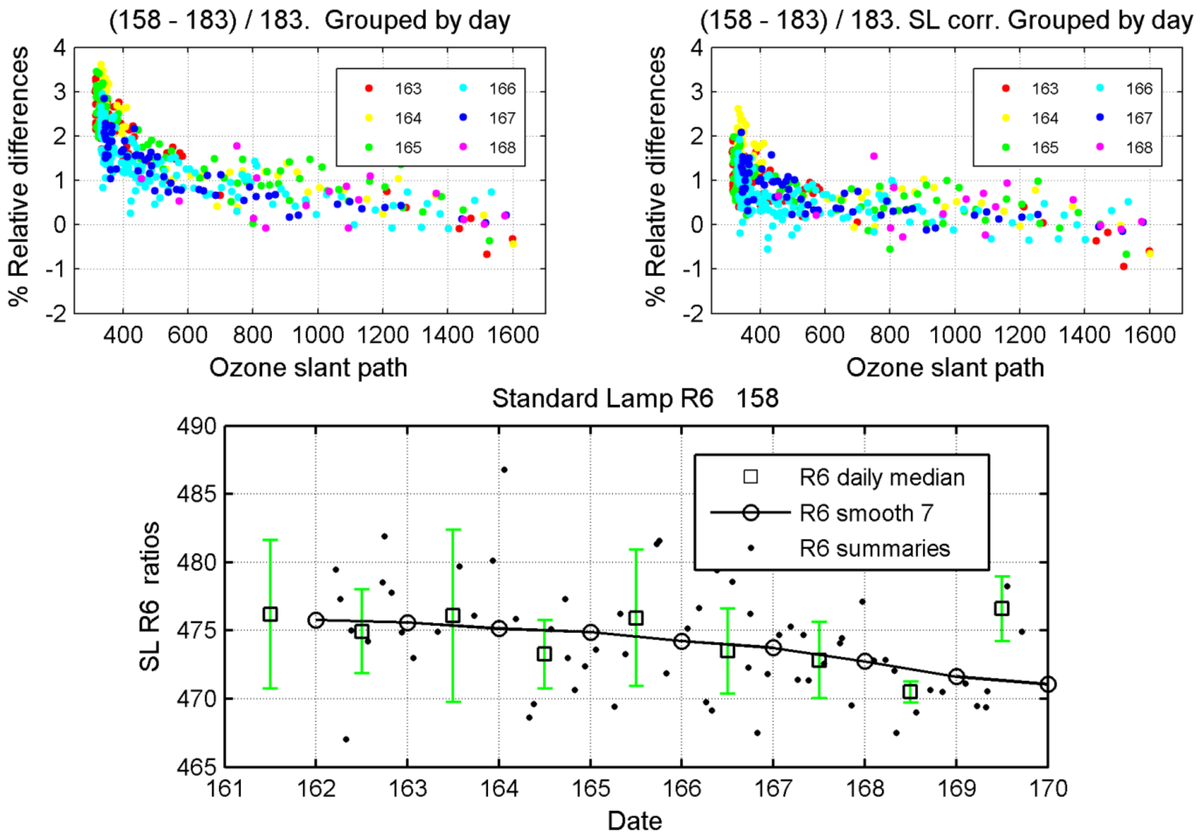


Figure 10. Near-simultaneous direct sun ozone column percentage differences between travelling standard Brewer K&Z#158 and RBCC-E reference Brewer IZO#183 grouped by Julian day as a function of ozone slant path (top) and standard lampR6 ratio series (bottom) during the intercomparison days. We show Brewer#158 ozone data with (top, right) and without (top, left) SL correction.

In summary, we observed ozone deviations or the order of +/-1% between standard instruments, which are routinely used for ozone transfer calibration worldwide. It's important to regularly calibrate these travelling instruments against a reference before and after the travel to minimize the calibration errors when transfer the calibration.

6. BLIND DAYS

The blind comparison gives us an idea of the initial status of the instrument, i.e. how well the instrument performed using the original calibration constants (those operational at the instrument's station).

The Standard Lamp (SL) test is used to track the spectral response of the instrument and therefore the ozone calibration. The ozone is corrected assuming that changes in R6 are related to changes in the ETC constant. In this case the ETC constant is corrected by the observed change in the standard lamp R6 ratio as $ETC_{new} = ETC_{old} - (SL_{ref} - SL_{measured})$. This procedure constitutes the so-called Standard Lamp Correction.

Only 8 out of 18 instruments agreed (on average) within +/-10 units (on the order of ~1% in ozone) with the corresponding R6 reference value.

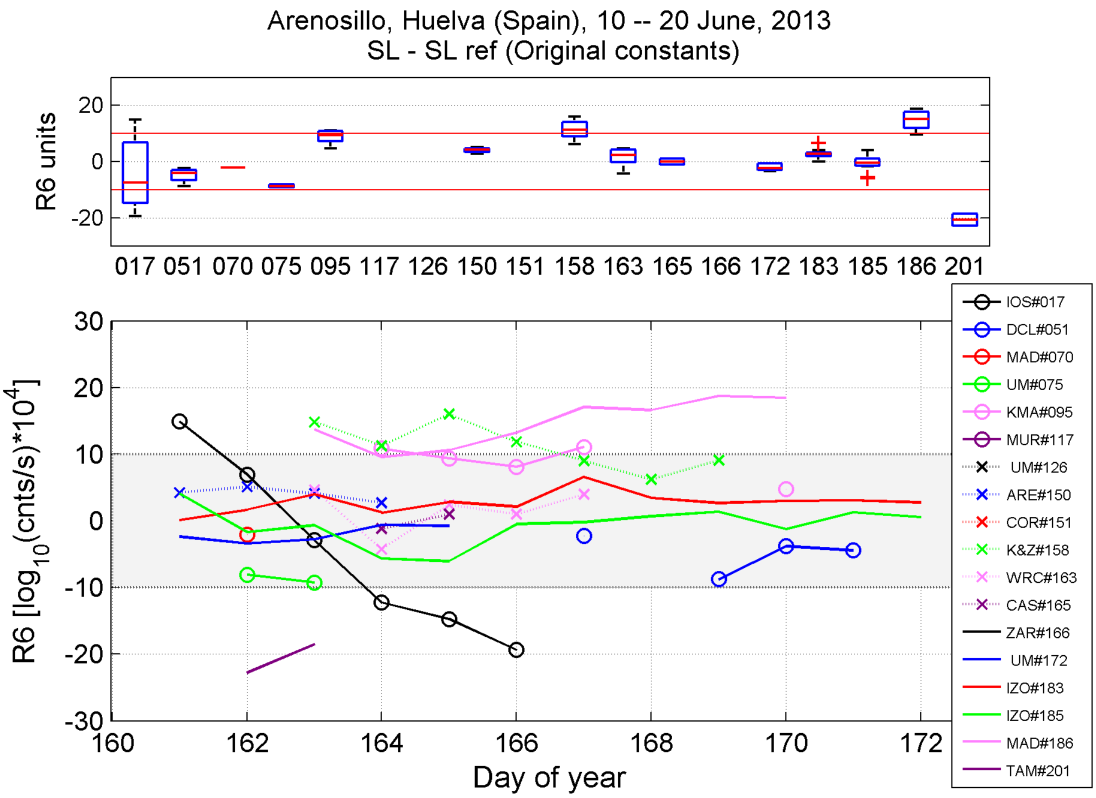


Figure 11. Standard lamp R6 difference to R6 reference value from last calibration during the blind days, before the maintenance. Data is grouped by Brewer serial number (above) and as a function of time (below). Variations of the order of +/- 10 units (~1% in ozone) are considered normal. Larger changes would require further analysis of the instrument performance.

The comparison with a reference standard instrument is the only tool to assess whether the SL R6 ratio change is related or unrelated with changes in the instrument's response.

The blind-days comparison shows rather poor results for the comparison with the reference Brewer#183, with ozone deviations within +/-1% for only 8 out of 18 instruments. In most cases, the SL correction did not improve the comparison.

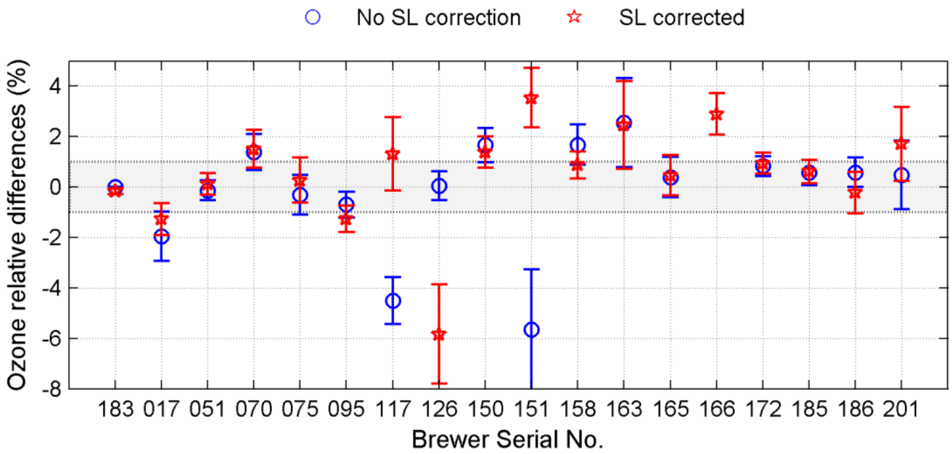
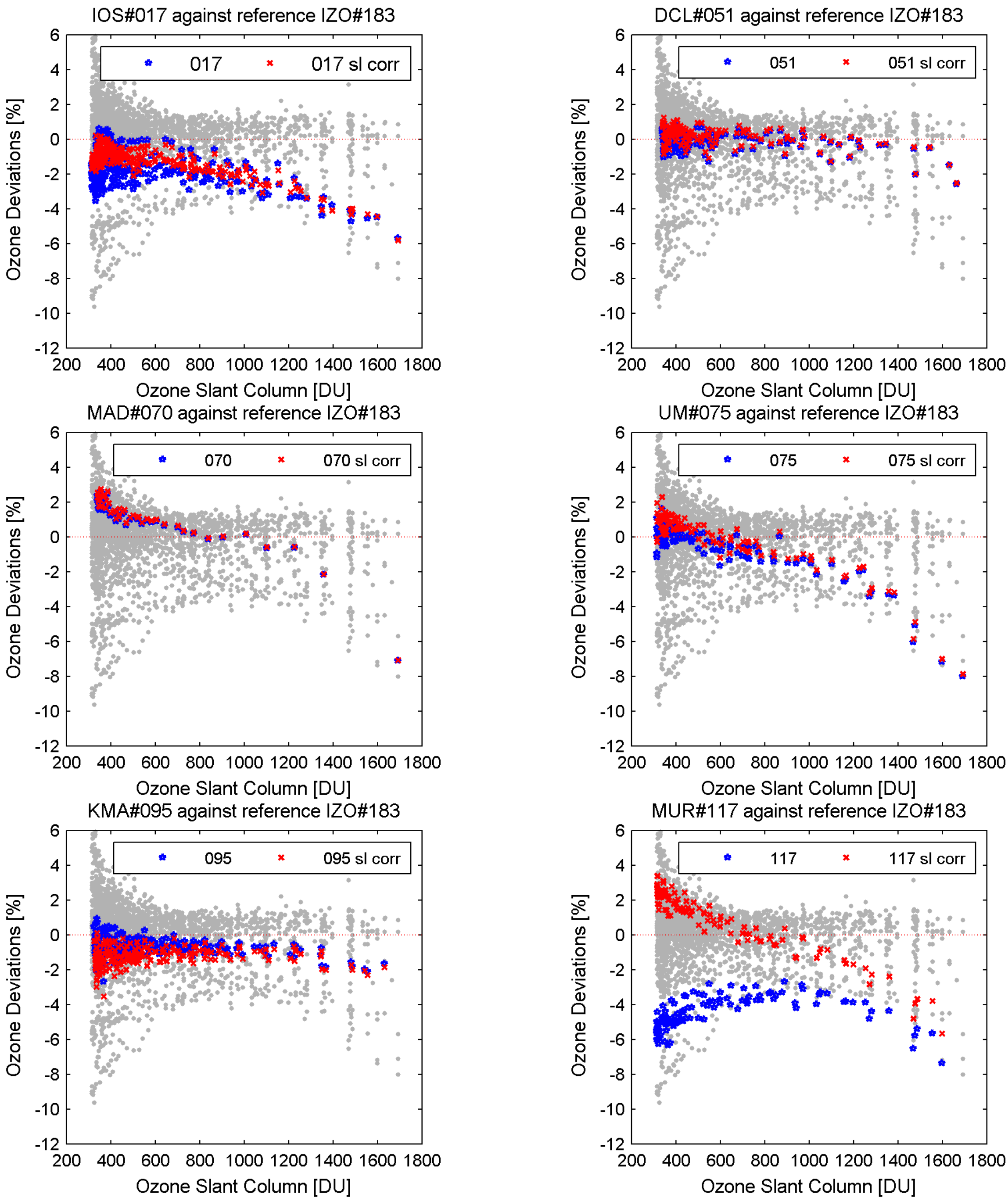
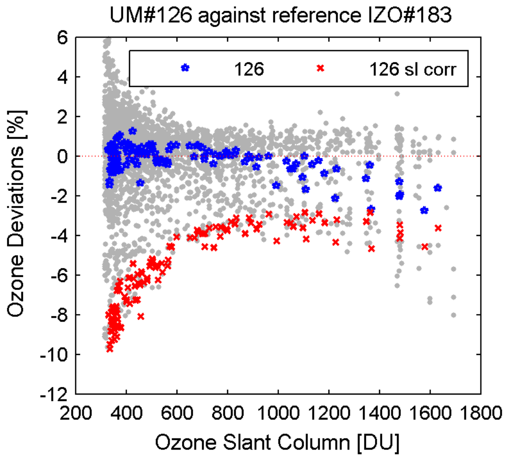


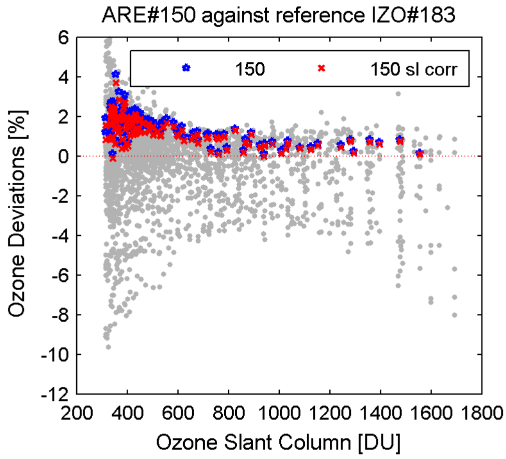
Figure 12. Blind-days ozone relative differences (percentage) of El Arenosillo 2013 participant instruments to RBCC-E travelling standard #183. Ozone measurements collected during the blind period (before the maintenance) are reprocessed using the original calibration constants, with (red plots) and without (blue plots) SL correction. Ozone deviations in bottom figure represent only the ozone slant column range not affected by the stray light rejection (OSC< 900 DU). The error bars represent the standard deviation of the mean.

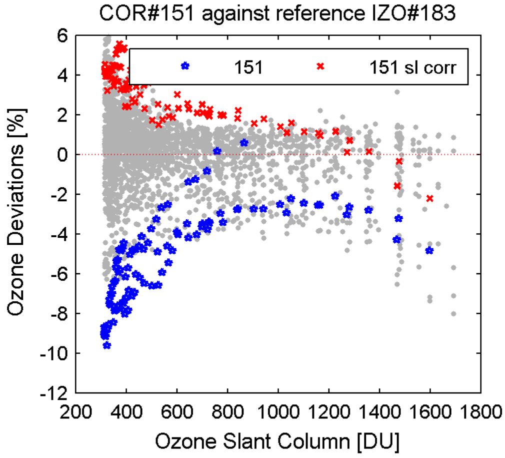
Table 5. Deviations of ozone values of Arosa 2014 participating instruments to the RBCC-E travelling standard IZO#183 for ozone slant path below 900 DU, with and without applying the SL correction. Blind days.

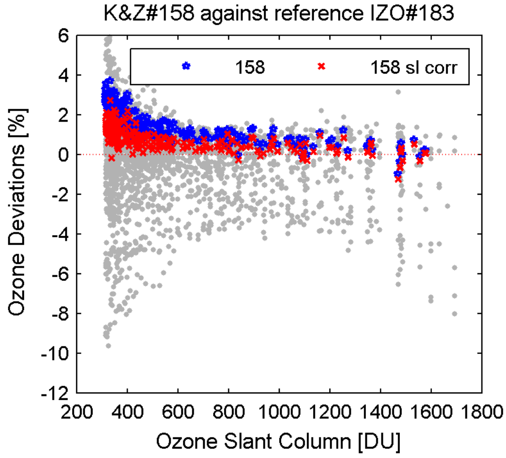
	No SL corr.	*SL corr.*	*The best*
IOS#017	-1.7+/-0.95	-1.0+/-0.45	-1.0+/-0.45
DCL#051	-0.0+/-0.45	0.3+/-0.47	0.0+/-0.45
MAD#070	1.5+/-0.56	1.7+/-0.58	1.5+/-0.56
UM#075	-0.1+/-0.57	0.5+/-0.64	-0.1+/-0.57
KMA#095	-0.6+/-0.57	-1.3+/-0.59	-0.6+/-0.57
MUR#117	-4.7+/-0.84	1.8+/-0.79	1.8+/-0.79
UM#126	-0.2+/-0.74	-5.8+/-2.02	-0.2+/-0.74
ARE#150	1.8+/-0.62	1.5+/-0.59	1.5+/-0.59
COR#151	-5.1+/-2.29	3.1+/-1.53	3.1+/-1.53
K&Z#158	1.5+/-0.87	0.8+/-0.59	0.8+/-0.59
WRC#163	2.1+/-1.81	2.1+/-1.80	2.1+/-1.80
CAS#165	0.7+/-0.75	0.7+/-0.73	0.7+/-0.75
ZAR#166	45.5+/-14.35	2.1+/-1.29	2.1+/-1.29
UM#172	0.7+/-0.36	0.8+/-0.37	0.7+/-0.36
MAD#186	0.7+/-0.52	-0.1+/-0.77	-0.1+/-0.77
TAM#201	-0.1+/-1.69	1.0+/-1.95	-0.1+/-1.69

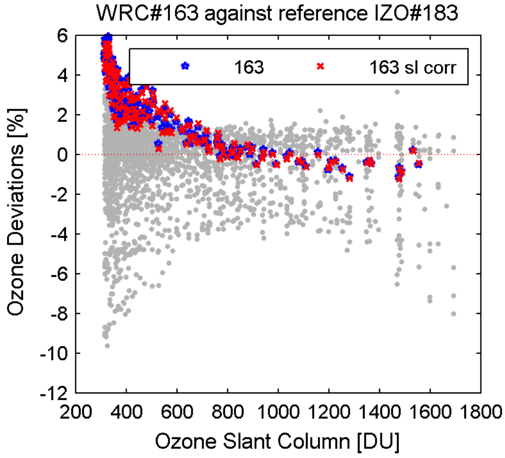

IOS#017 against reference IZO#183
017
017 sl corr
DCL#051 against reference IZO#183
051
051 sl corr
MAD#070 against reference IZO#183
070
070 sl corr
UM#075 against reference IZO#183
075
075 sl corr
KMA#095 against reference IZO#183
095
095 sl corr
MUR#117 against reference IZO#183
117
117 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]
6
4
2
0
-2
-4
-6
-8
-10
-12
200
400
600
800
1000
1200
1400
1600
1800

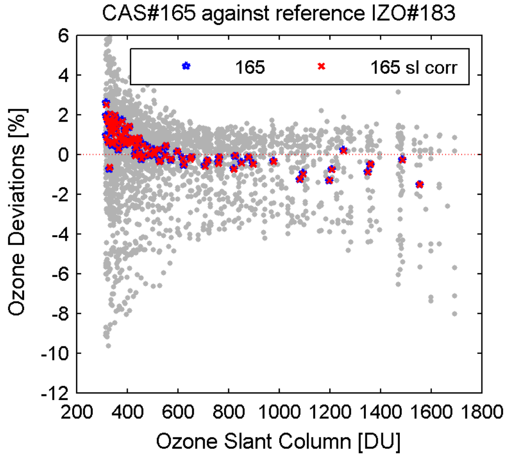

UM#126 against reference IZO#183
126
126 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]

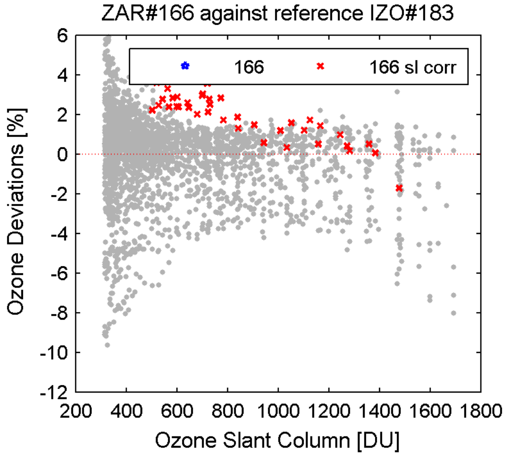

ARE#150 against reference IZO#183
150
150 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]

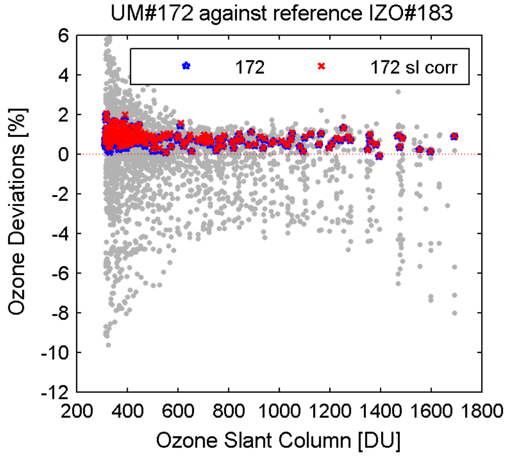

COR#151 against reference IZO#183
151
151 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]


K&Z#158 against reference IZO#183
158
158 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]


WRC#163 against reference IZO#183
163
163 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]


CAS#165 against reference IZO#183
165
165 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]


ZAR#166 against reference IZO#183
166
166 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]


UM#172 against reference IZO#183
172
172 sl corr
Ozone Deviations [%]
Ozone Slant Column [DU]

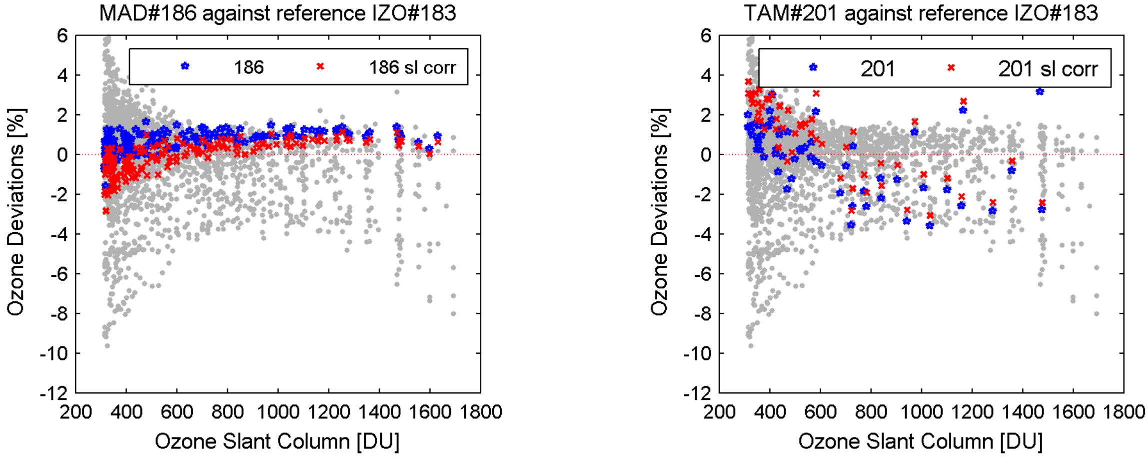


Figure 13. Blind-days ozone relative differences (percentage) of Arenosillo 2013 participant instruments to RBCC-E travelling standard Brewer#183. Ozone measurements collected during the blind period (before the maintenance) were reprocessed using the original calibration constants, with (red stars) and without (blue stars) standard lamp correction. Grey dots mean ozone deviations for all participating instruments.

7. FINAL DAYS

We used ozone data after the maintenance (final-days) to perform the ozone final calibration for all the participating instruments. The standard lamp R6 value recorded during the final days is normally adopted as the new SL reference value. It is also expected that this parameter will not vary more than 5 units during the same period (see Figure 14).

All the participant instruments were calibrated using the one parameter ETC transfer method (ozone absorption coefficients were derived from the wavelength calibration). The two parameters calibration method is also used as a quality indicator.

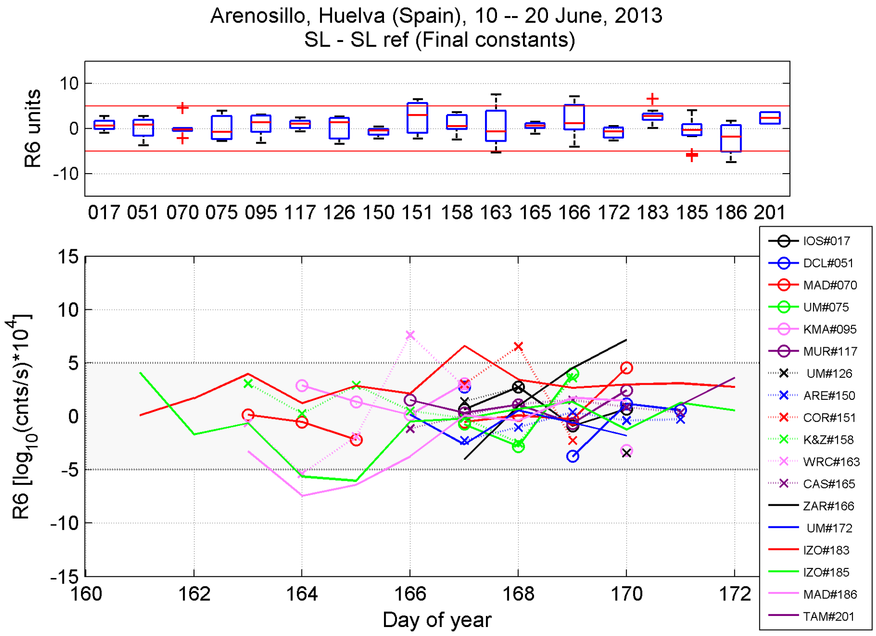


Figure 14. Standard lamp R6 ratio to R6 reference value from last calibration differences during the final days grouped by Brewer serial number (above) and as a function of time (below). The shaded area represents the tolerance range +/- 5 R6 units.

Overall, we found a good agreement with the reference instrument Brewer#183. Ozone deviations are found to be of the order of +/-0.5% for ozone slant path region less affected by the stray light rejection (OSC<900 DU). We used original constants for standard instruments IOS#017 and IZO#185.

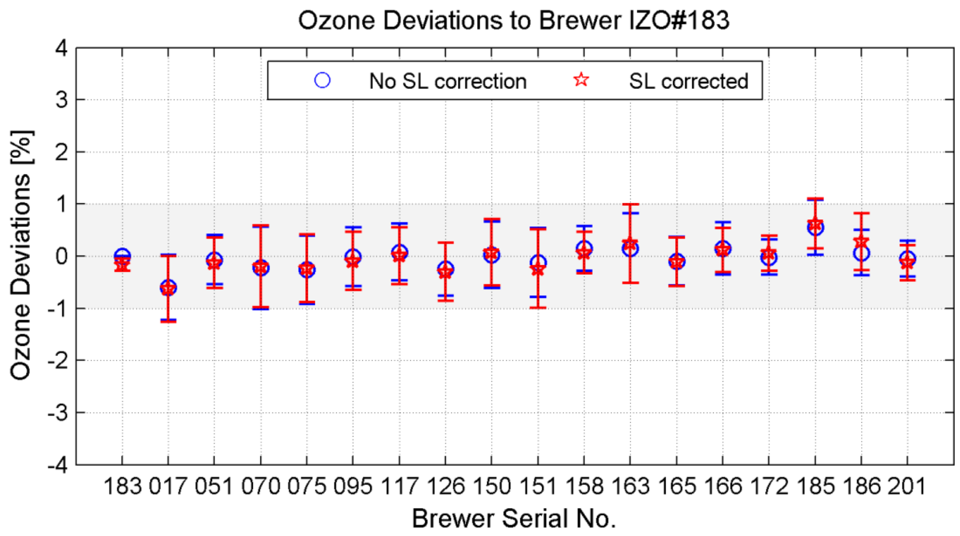
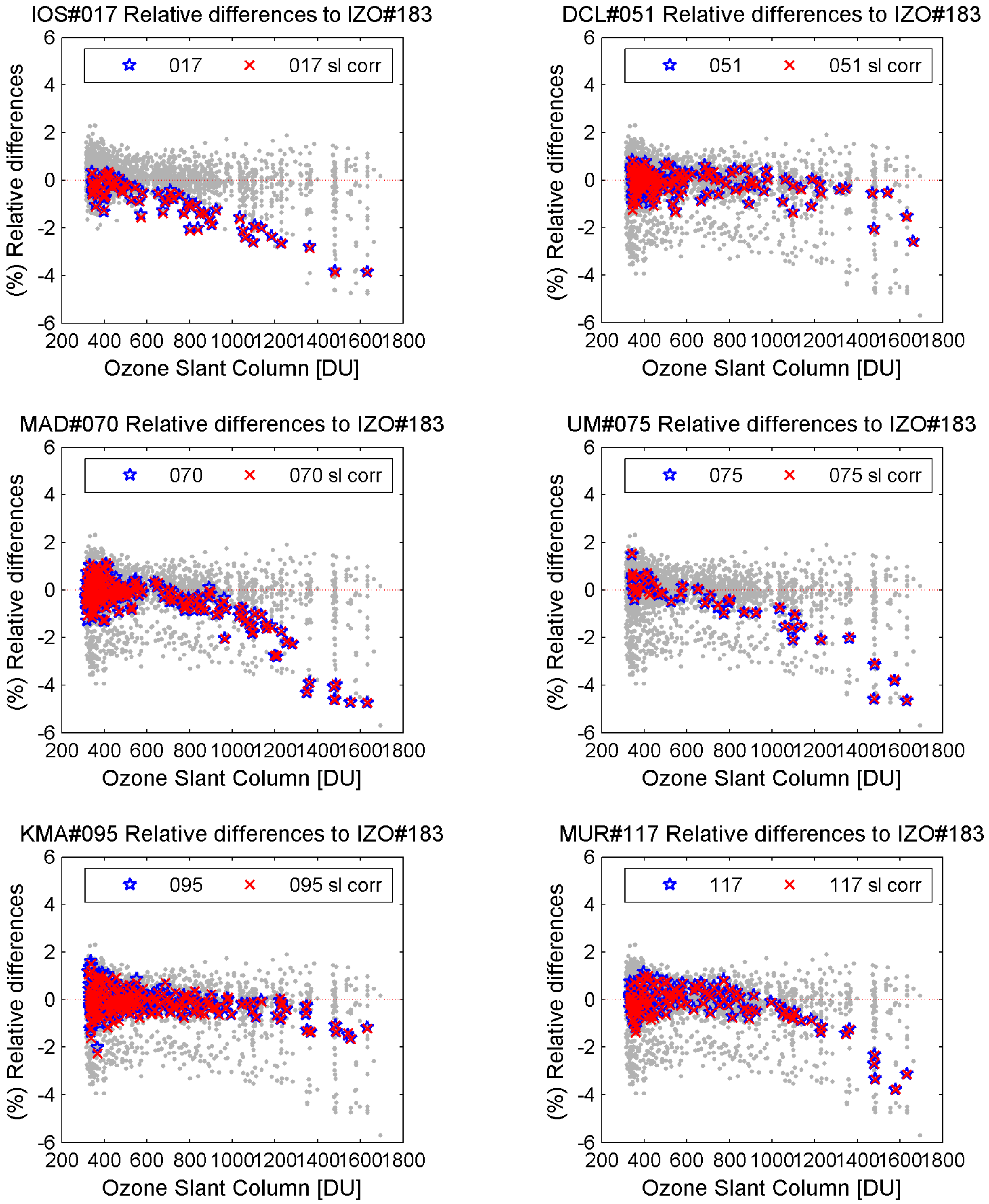
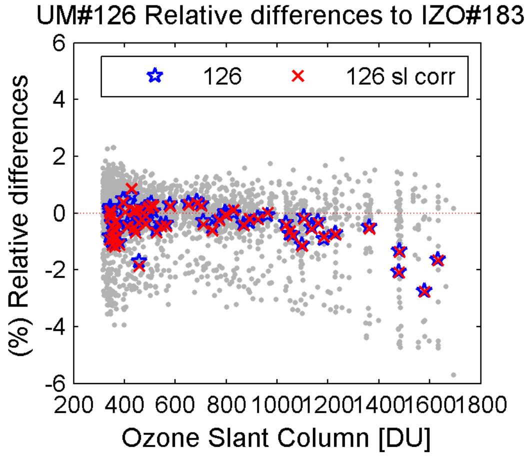


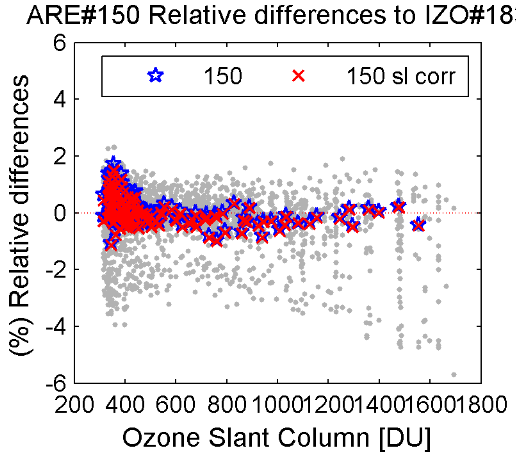
Figure 15. Final-days ozone relative differences (percentage) of El Arenosillo 2013 participant instruments to RBCC-E travelling standard #183. Ozone measurements collected during the final period (after the maintenance) are reprocessed using the final calibration constants, with (red plots) and without (blue plots) SL correction. The error bars represent the standard deviation of the mean. Ozone deviations in bottom figure represent only the ozone slant column range not affected by the stray light rejection (OSC< 900 DU). The error bars represent the standard deviation of the mean.

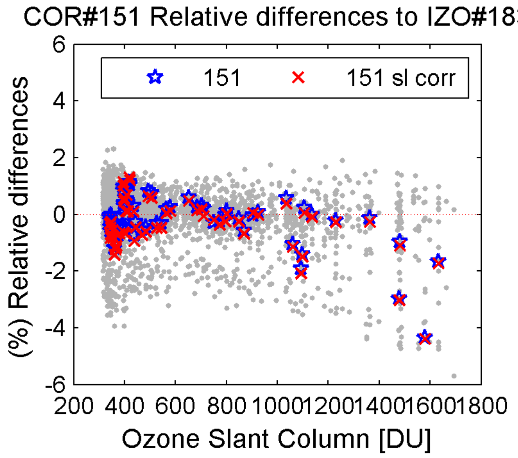
Table 6. Deviations of ozone values of Arosa 2014 participating instruments to the RBCC-E travelling standard IZO#183 for ozone slant path below 900 DU, with and without applying the SL correction. Final days.

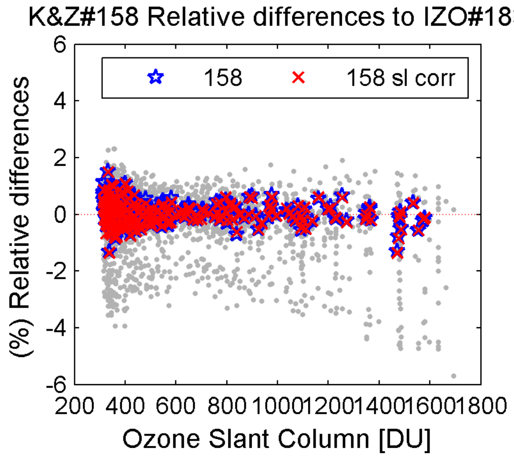
	No SL corr.	*SL corr.*
IOS#017	-0.4+/-0.44	-0.4+/-0.44
DCL#051	-0.0+/-0.45	-0.1+/-0.46
MAD#070	-0.0+/-0.53	-0.0+/-0.51
UM#075	0.1+/-0.42	0.1+/-0.43
KMA#095	0.0+/-0.57	-0.1+/-0.57
MUR#117	0.1+/-0.51	-0.0+/-0.52
UM#126	-0.2+/-0.50	-0.3+/-0.54
ARE#150	0.2+/-0.52	0.1+/-0.49
COR#151	-0.0+/-0.60	-0.2+/-0.72
K&Z#158	0.1+/-0.45	0.0+/-0.42
WRC#163	0.2+/-0.69	0.3+/-0.75
CAS#165	-0.1+/-0.45	-0.1+/-0.46
ZAR#166	0.2+/-0.52	0.1+/-0.48
UM#172	-0.1+/-0.37	0.0+/-0.36
MAD#186	0.1+/-0.49	0.3+/-0.58
TAM#201	0.0+/-0.32	-0.0+/-0.32

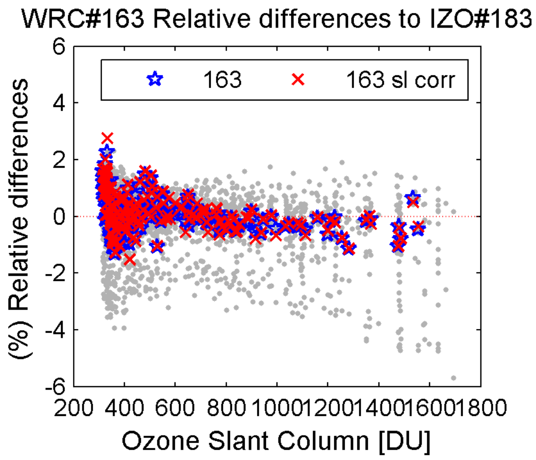

IOS#017 Relative differences to IZO#183
017
017 sl corr
DCL#051 Relative differences to IZO#183
051
051 sl corr
MAD#070 Relative differences to IZO#183
070
070 sl corr
UM#075 Relative differences to IZO#183
075
075 sl corr
KMA#095 Relative differences to IZO#183
095
095 sl corr
MUR#117 Relative differences to IZO#183
117
117 sl corr
(%) Relative differences
Ozone Slant Column [DU]

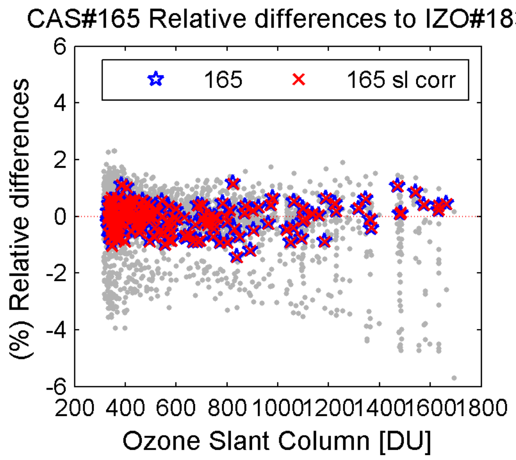

UM#126 Relative differences to IZO#183
126
126 sl corr
(%) Relative differences
Ozone Slant Column [DU]


ARE#150 Relative differences to IZO#183
150
150 sl corr
(%) Relative differences
Ozone Slant Column [DU]


COR#151 Relative differences to IZO#183
151
151 sl corr
(%) Relative differences
Ozone Slant Column [DU]


K&Z#158 Relative differences to IZO#183
158
158 sl corr
(%) Relative differences
Ozone Slant Column [DU]


WRC#163 Relative differences to IZO#183
163
163 sl corr
(%) Relative differences
Ozone Slant Column [DU]


CAS#165 Relative differences to IZO#183
165
165 sl corr
(%) Relative differences
Ozone Slant Column [DU]

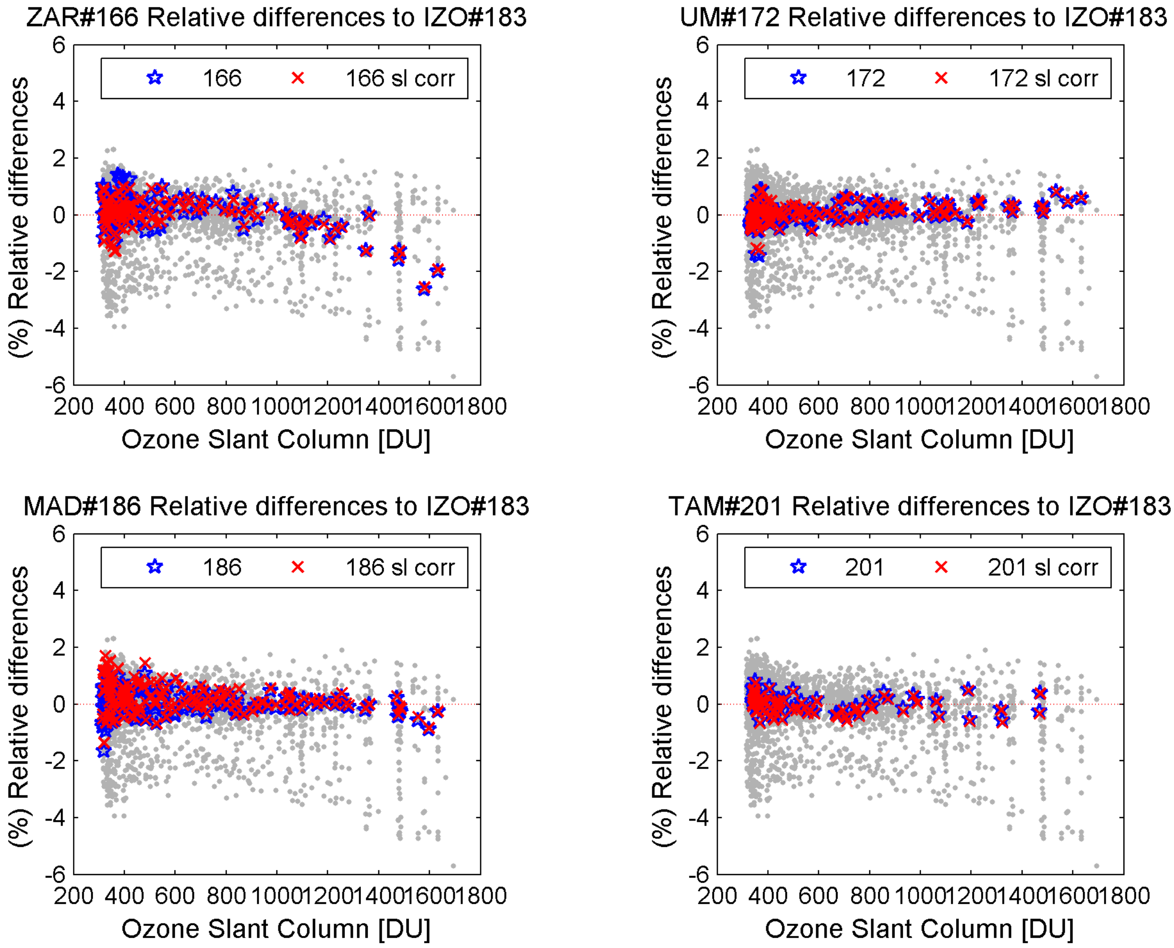


Figure 16. Final-days ozone relative differences (percentage) of Arosa 2014 participant instruments to RBCC-E travelling standard Brewer#185. Ozone measurements collected during the final period (after the maintenance) were reprocessed using the proposed calibration constants, with (red stars) and without (blue stars) standard lamp correction. Grey dots mean ozone deviations for all participating instruments.

8. OZONE BREWER REPORTS

8.1 Instrument: IOS#017, Station: (Toronto, Travelling instrument)

Brewer IOS#017 participated in the campaign during the period 10-20 June 2013. The instrument's performance was found to be quite unstable during the intercomparison days. Days 16th to 19th June were used for final calibration purposes (192 near-simultaneous direct sun measurements).

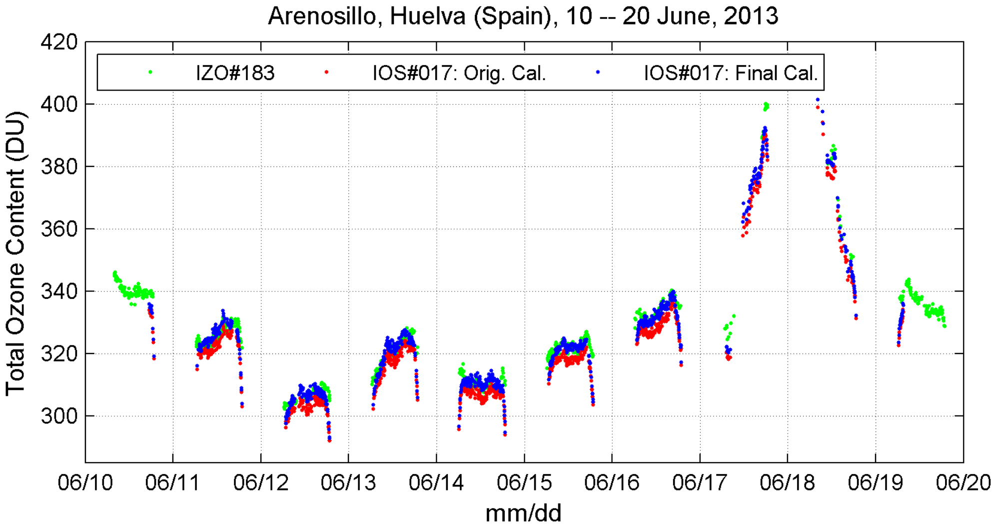


Figure 17. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf16213.017 and reference value 2210 for the standard lamp R6 ratio.

Historical analysis

The standard lamp (SL) test results from IOS#017 have been very unstable during the last 2 years. R6 ratios stabilized around values 2190 during the campaign days. This is the new reference value proposed. All the other parameters analysed (Dead Time, Run/Stop test, Hg lamp intensity, CZ and CI scans) were inside tolerance limits.

Initial comparison

The instrument's performance was unstable during the first days of the campaign. Correcting for the SL change improved the comparison with the reference instrument IZO#183, but with ozone deviations below -1% for ozone slant path values lower than 700 DU (see Figure 9 and Figure 19).

Final calibration

We achieved a very good agreement against the RBCC-E traveling standard using the final calibration constants, with ozone deviations within the 1% range up to ozone slant path 700 DU. The ozone data from 26th March 2013 should be reprocessed using these new constants (ETC=3375, R6=2190). We advise to check carefully the effect of standard lamp correction before that date.

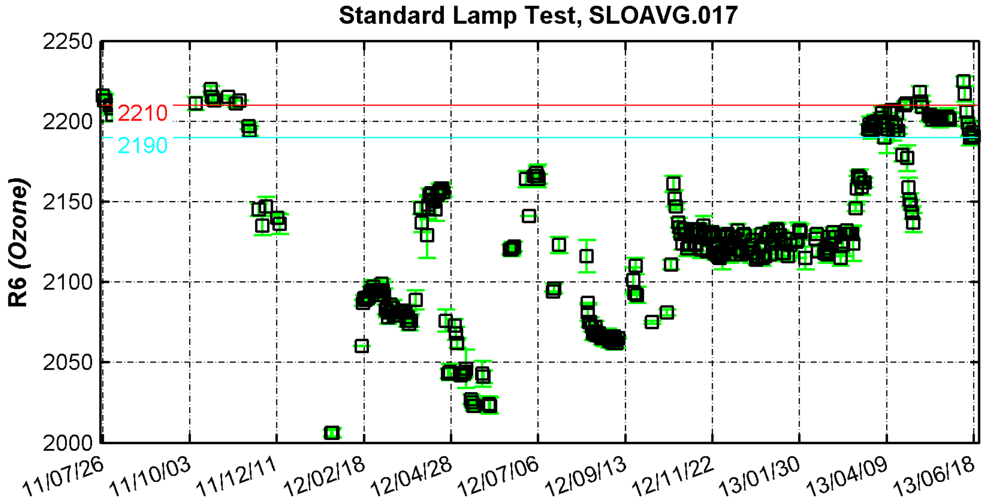


Figure 18. Standard Lamp test R6 (Ozone) ratio

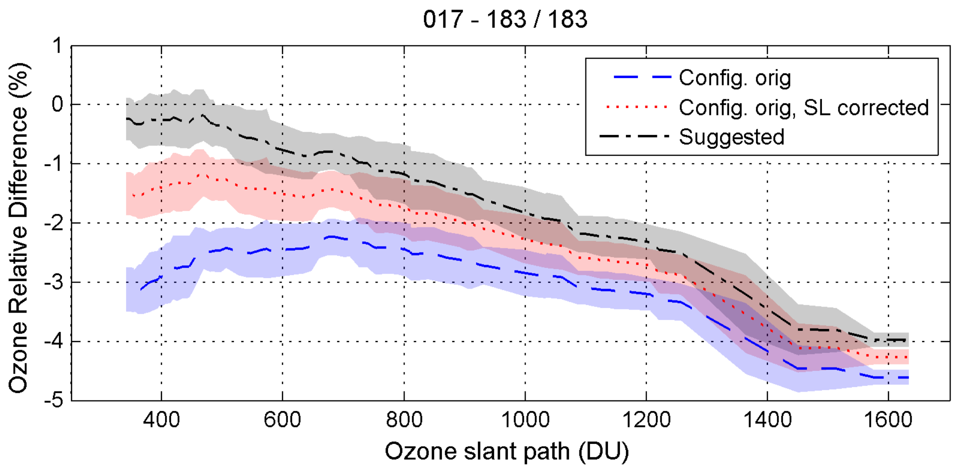


Figure 19. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

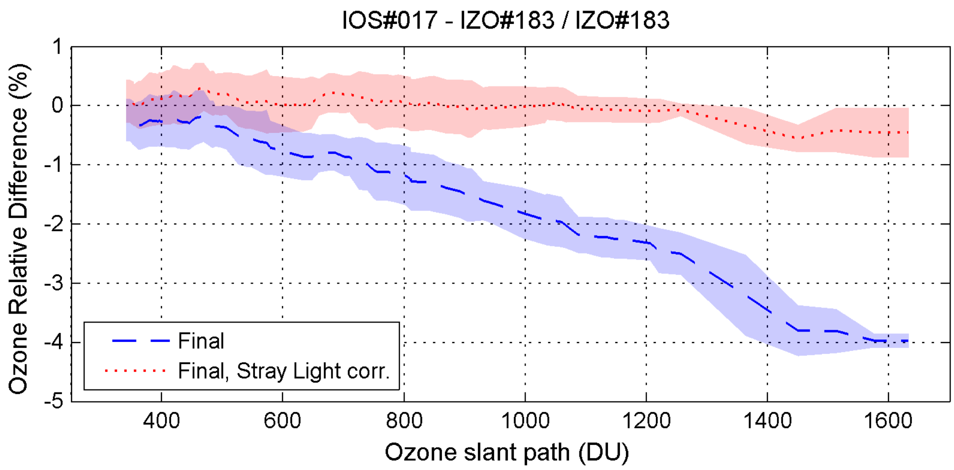


Figure 20. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight

This single Brewer shows large stray light rejection, leading to total ozone being underestimated up to around 1% at ozone slant path 700 DU. This is greatly improved after the stray light correction is applied (see Figure 20, red dotted line).

Calibration constants summary: IOS#017

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	3410	3375	3375
SL R6 reference value	2210	2190	2190
change SL R6 ratio /ETC		>10 / >10	<5 / <5
DT Constant (ns)	30	30	30
Temp. Coeffs.		No change	No change
Cal Step Number	862		862
Ozone Abs. Coeff.	0.3380		0.3380
Stray Light factors (F0 / k / s)		3379/ -64.2/ 2.72	3379/ -64.2/ 2.72
Calibration File recommended		Icf16713.017 SL corrected	Icf16713.017

Recommendations and comments

- The standard lamp test results from Brewer IOS#017 have been very unstable during the last 2 years. The SL correction should work fine from natural day 08513. However, we advise to check carefully the effect of standard lamp correction before that date. All the other diagnostics analysed (DT, RS, AP records, CZ scans ...) were normal.

- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters.

- No sun scans, nor dispersion test were available for this instrument. We kept the original Cal Step number and ozone absorption coefficient in the final configuration file (862 and 0.3380, respectively).

- The instrument's performance was very unstable during the first days of the campaign. Ozone retrievals, SL corrected, were notably improved, but ozone deviations to the reference instrument were then lower than 1%. Ozone deviations were within the 1\% range (for ozone slant path values lower than ~700\,DU) after the final calibration constants were applied (SL corrected).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_017.pdf

8.2 Instrument: DCL#051, Station: Casablanca, Morocco

Brewer DCL#051 participated in the campaign from 12 to 21 June 2013. Ozone data collected before the maintenance was not feasible for calibration purposes (wrong location setup). We do not provide any evaluation for the instrument’s initial status. Spherical mirror and diffraction grating were adjusted as part of the maintenance work. Days June 16 to 20, after the maintenance was done, were used for final calibration purposes (225 near-simultaneous direct sun measurements).

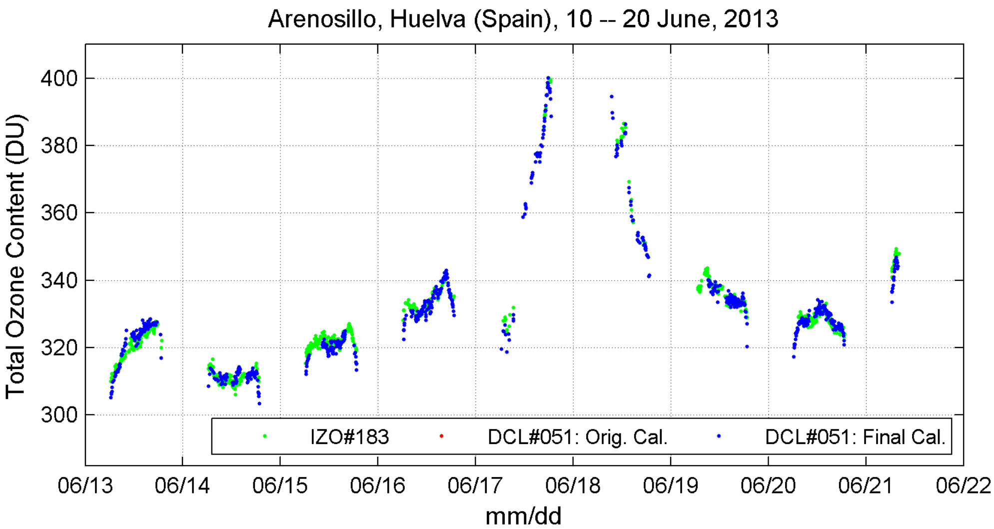


Figure 21. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf18711.051 and standard lamp R6 ratio reference value 1890. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), using the RBCC-E travelling standard Brewer IZO#185 as the reference instrument.

Historical analysis

This instrument was inoperative during the last two years. No historical data was available, except for some data collected in summer and early autumn 2012. A significant change in SL ratios is observed in September 2012 due to unknown reasons.

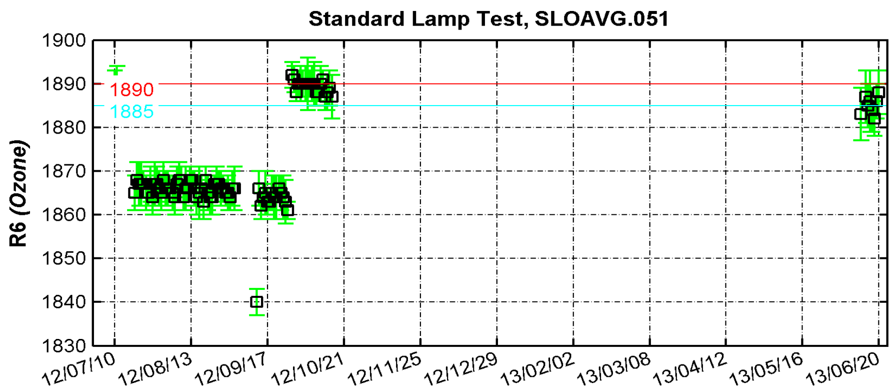


Figure 22. Standard Lamp test R6 (Ozone) ratio

Initial comparison

DCL#051 shows a good agreement with the reference instrument, with ozone deviations within 1% for ozone slant path lower than 800 DU.

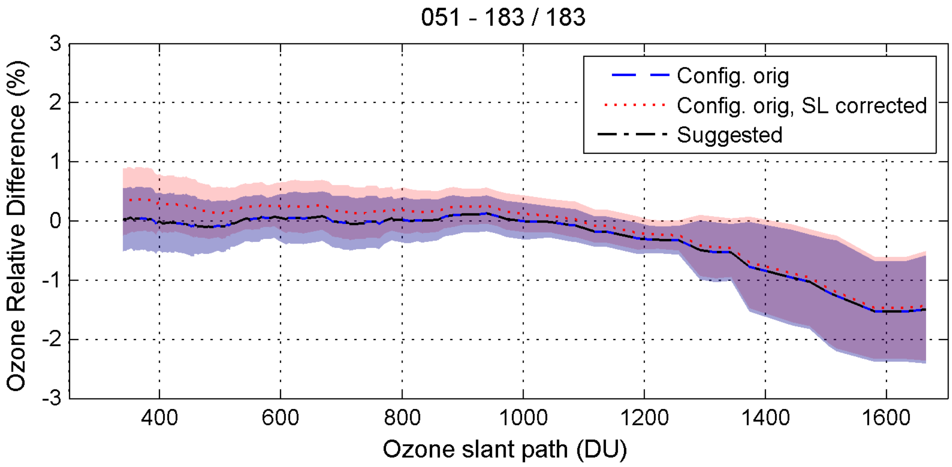


Figure 23. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

The original and the calculated extraterrestrial constants agreed each other within 5 units. With the exception of the SL R6 ratio reference value, all the other ozone calibration constants have been kept the same. We achieved a very good agreement against the RBCC-E traveling standard using this calibration set, with ozone deviations lower than 0.5% up to ozone slant path of 1200 DU.

Straylight

This single Brewer shows not much stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1400 DU. This is greatly improved after the stray light correction is applied (see Figure 24, red dotted line).

Recommendations and comments

- No historical data was available for this instrument, except for some data collected in summer and early autumn 2012. The instrument's performance looked fine after the maintenance work was done, as deduced from the analysis of all important parameters (Dead Time and Run/Stop test, Hg lamp intensity, CZ \& CI files). A new reference value is proposed for the SL R6 ratio (1885).

- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters.

- The original and the calculated extraterrestrial constants agreed each other within 5 units. Correcting for the standard lamp ratio change made the comparison with reference instrument slightly worse.

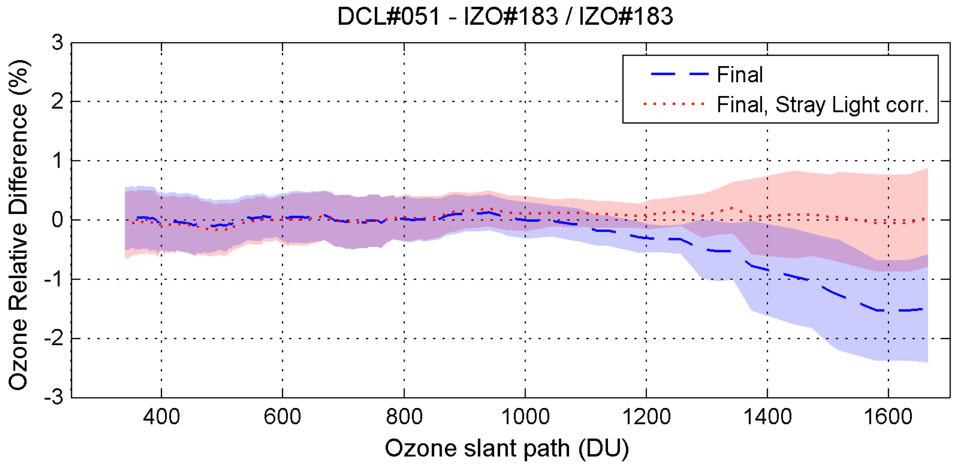


Figure 24. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Calibration constants summary: DCL#051

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	3085		3085
SL R6 reference value	1890		1885
change SL R6 ratio /ETC			<5 / <5
DT Constant (ns)	34		34
Temp. Coeffs.			No change
Cal Step Number	159		159
Ozone Abs. Coeff.	0.3413		0.3413
Stray Light factors (F0 / k / s)			3085 / -5.27 / 6.55
Calibration File recommended	Icf18711.051		Icf16513.051

- We recommend using the proposed configuration file together with the new reference value for the SL R6 ratio, 1885. We advise as well to check the effect of the SL correction in case you wanted to re-evaluate ozone data collected in summer 2012.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_051.pdf

8.3 Instrument: MAD#070, Station: Madrid, Spain

Brewer MAD#070 participated in the campaign from 11 to 19 June 2013. Filter Wheel #3 setting and communications problems occurring on reset were fixed as part of the maintenance work. For the evaluation of initial calibration we used the ozone data collected during natural day 162 (92 near-simultaneous direct sun ozone measurements). Days from 12 to 19 June were used for final calibration (343 near-simultaneous direct sun ozone measurements).

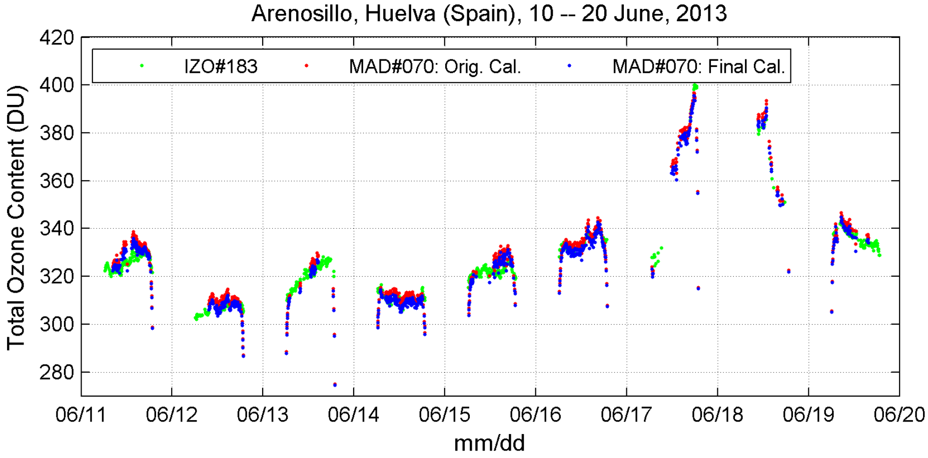


Figure 25. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf19111.070 and reference value 1700 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

Historical analysis

The historical SL records show two periods since the last intercomparison (El Arenosillo 2011): from July 2011 to November 2012 the original constants SL corrected should work fine. We provided a new set of constants to be applied from December 2012.

The calculated Dead Time constant is about 7 units lower than the operational one. We did not update this constant in the final configuration file (H.V. voltage should be updated, instead). All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were within the normal limits.

Initial comparison

The original calibration constants performance was not good, with ozone deviations above 1% for low ozone slant path values (OSC<600 DU, see Figure 27). We recommend using a new set of constants (icf33612.070 and R6=1698) to be applied from December 2012.

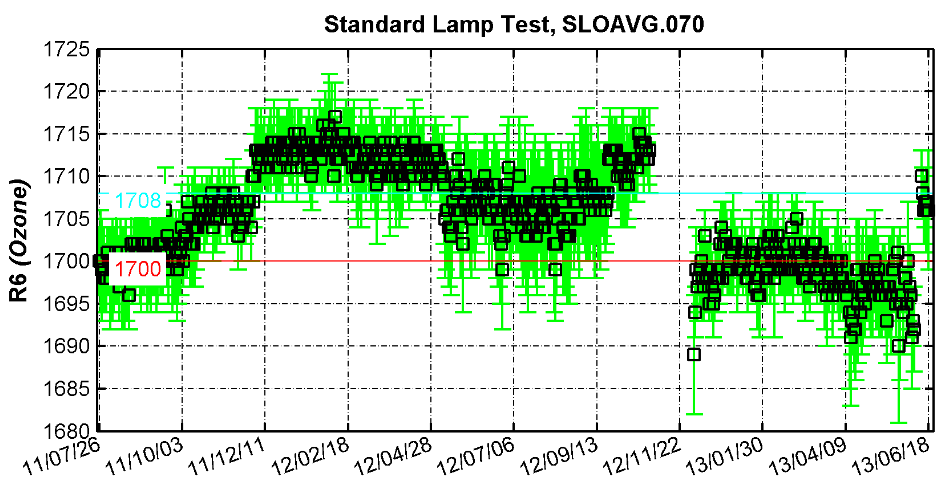


Figure 26. Standard Lamp test R6 (Ozone) ratio

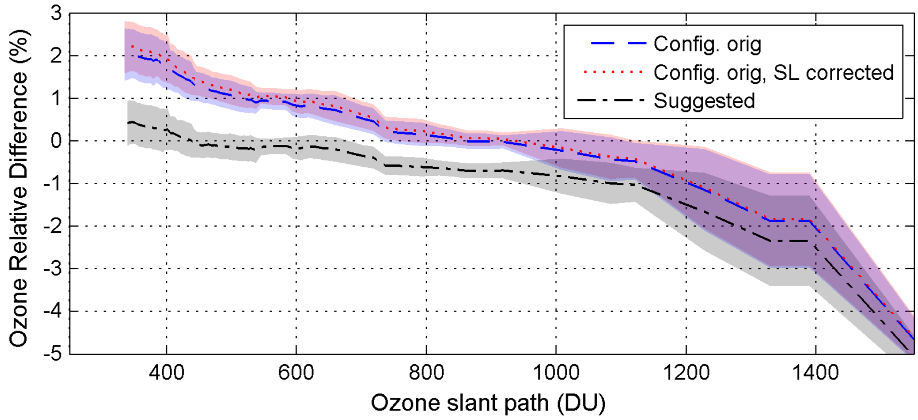


Figure 27. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

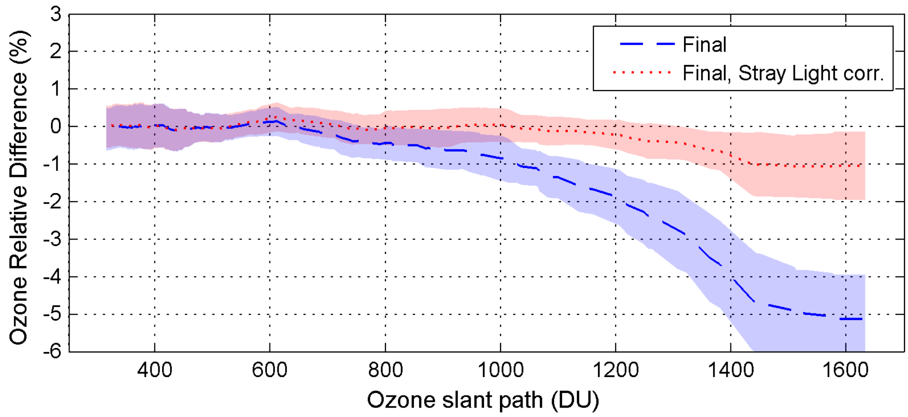


Figure 28. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight

This single Brewer shows a moderate stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1000 DU. This is greatly improved after the stray light correction is applied (see Figure 28, red dotted line).

Calibration constants summary: MAD#070

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	2960	2980	2970
SL R6 reference value	1700	1698	1708
change SL R6 ratio / ETC		<10 / 20	<10 / 10
DT Constant (ns)	41	41	41
Temp. Coeffs.		No change	No change
Cal Step Number	162	162	162
Ozone Abs. Coeff.	0.3365	0.3365	0.3365
Stray Light factors (F0 / k / s)			2971 / -32.0 / 5.06
Calibration File recommended	Icf19111.070	icf33612.070	icf16113.070

Recommendations and comments

- We detected some sun-tracking failures affecting the normal operation of the instrument. We discarded ozone data collected on natural days 164 and 166 from the analysis.

- The calculated DT constant was about 7 units lower than the operational one. However, we believe that the change in DT is not real (the comparison with the reference IZO#183 turned worse with the updated constant).

- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters.

- The original calibration constants SL corrected should work fine from July 2011 to November 2012. Then, a change in instrument's response is observed in December 2012, coinciding with the transport to Zaragoza station. We provided a new set of constants to be applied during this second period.

- We achieved a very good agreement with the RBCC-E traveling standard IZO#183 using the proposed final calibration set, with ozone deviations lower than 0.5% up to ozone slant path of 1200 DU.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_070.pdf

8.4 Instrument: UM#075, Station: Reading, United Kingdom

Brewer UM#075 participated in the campaign from 10 to 18 June 2013. We used ozone data collected on natural days 162 to 163, before the maintenance work, to evaluate the original constants (154 near-simultaneous direct sun ozone measurements), whereas ozone data collected on natural days 167 to 169 were used for final calibration (53 near-simultaneous direct sun measurements).

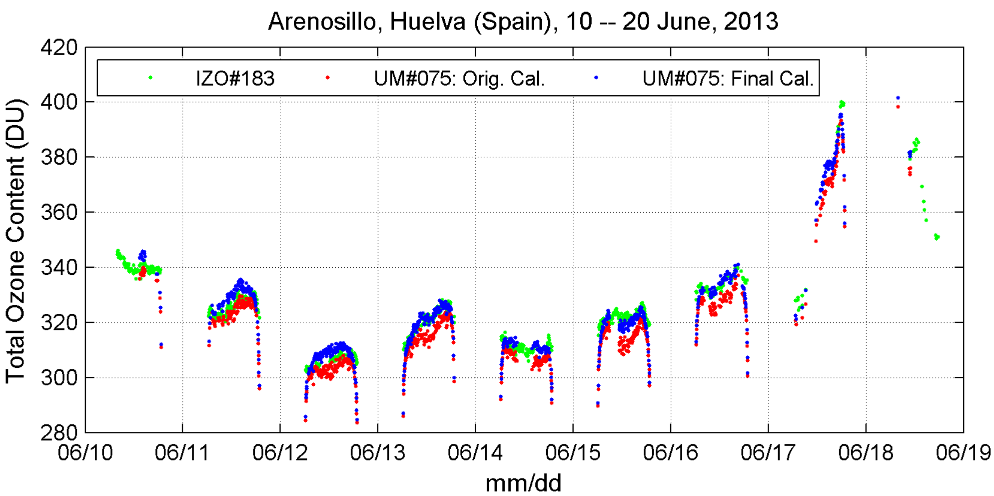


Figure 29. Brewer Intercomparison El Arenosillo 2013

Original calibration
The instrument operates with the configuration file icf00512.075 and reference value 1820 for the SL R6 ratio. The corresponding calibration constants are different to those provided during the last El Arenosillo intercomparison (icf19211.075).

Historical analysis
The SL tests have been very stable since the last intercomparison campaign (El Arenosillo 2011), except for two noticeable events: in December 2011 we observed an abrupt change in SL ratios, and at late March 2013 SL ratios started decreasing (see Figure 30). We used an updated Dead Time constant to evaluate both the initial and the final periods. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were normal.

Initial comparison
The calibration constants provided during the last (El Arenosillo 2011) campaign should work until December 2011. As well, we provide in this report a set of calibration constants (icf33611.075}, R6=1815) valid from December 2011. Note that, as concerns to neutral density filters (ND) performance, we have applied correction factor -8 and -15 on ETC for ND#3 and ND#4, respectively. These are the same correction factors used during the last intercomparison campaign.

Final calibration
Calibration constants included in the configuration file icf16813.075, together with the updated R6 ratio reference value 1810, are the proposed final constants. We used the same Dead Time constant and corrections on ETC for ND filters #3 and #4 for both the blind and the final periods. We achieved a very good agreement with the RBCC-E traveling standard IZO#183 using this calibration set, with ozone deviations lower than 0.5% up to ozone slant path around 800 DU (see Figure 32, blue dashed line).

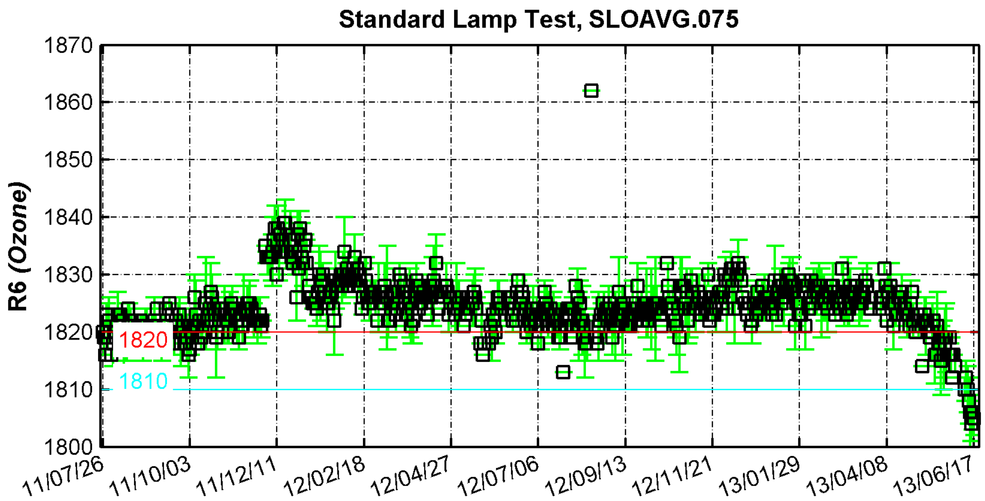


Figure 30. Standard Lamp test R6 (Ozone) ratio

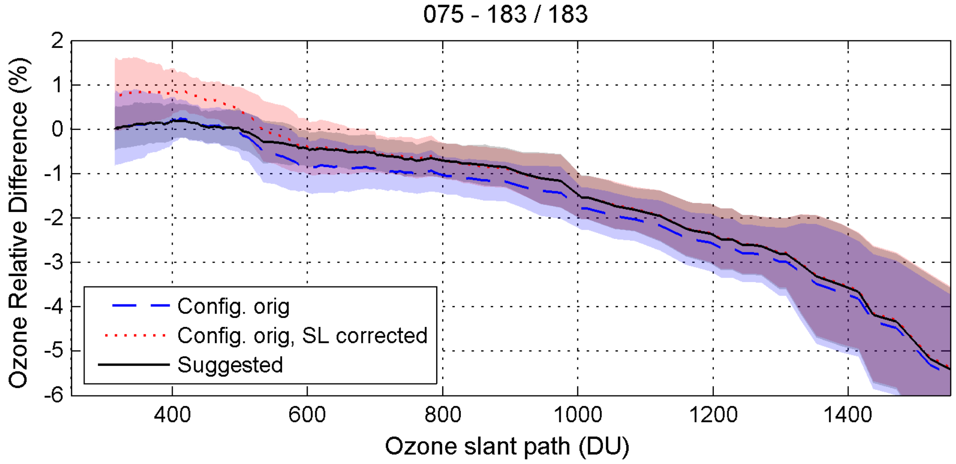


Figure 31. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight

This single Brewer shows a moderate stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 900 DU. This is greatly improved after the stray light correction is applied (see Figure 32, red dotted line).

Recommendations and comments

- The SL performance has been very stable since the last intercomparison campaign except for two events in December 2011 and in late March 2013. The calibration constants provided after El Arenosillo 2011 campaign should work until December 2011.

- We provide two sets of calibration constants: the first one (icf33611.075, R6=1815) would be valid from December 2011 until June 2013. The second one (icf16813.075, R6=1810) should be applicable from the campaign date onwards.

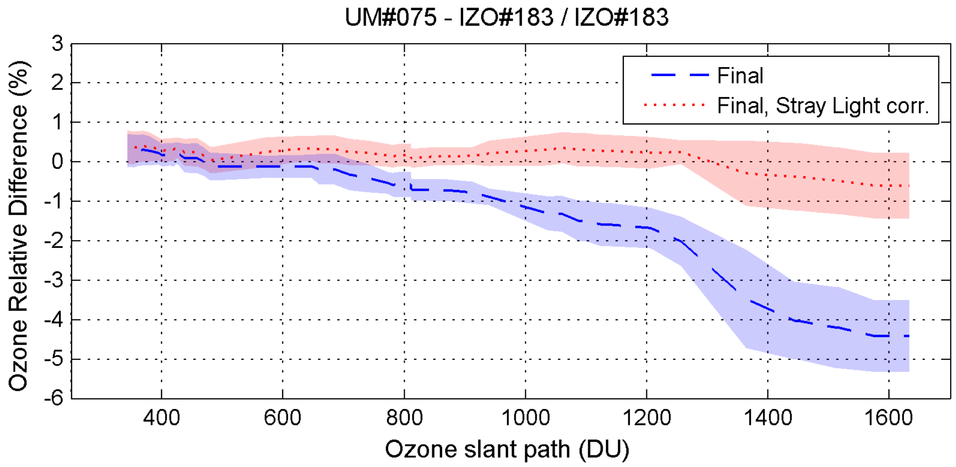


Figure 32. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation

Calibration constants summary: UM#075

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	3040	3035	3021
SL R6 reference value	1820	1815	1810
change SL R6 ratio /ETC			
DT Constant (ns)	34	35	35
Temp. Coeffs.		No change	No change
Cal Step Number	293	293	291
Ozone Abs. Coeff.	0.3398	0.3398	0.3398
Stray Light factors (F0 / k / s)			3024 / -48.7 / 3.74
Calibration File recommended	icf00512.075	Icf33611.075	Icf16813.075

- We used an updated Dead Time constant for both configuration files. As well, it is recommended to apply the same correction factors -8 and -15 for ND filters #3 and #4 during both periods. These are the same correction factors used during the last intercomparison campaign

- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters.

- The original calibration constants SL corrected should work fine from July 2011 to November 2012. Then, a change in instrument's response is observed in December 2012, coinciding with the transport to Zaragoza station. We provided a new set of constants to be applied during this second period.

- We achieved a very good agreement with the RBCC-E traveling standard IZO#183 using the proposed final calibration set, with ozone deviations within 1% up to ozone slant path around 800 DU.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_075.pdf

8.5 Instrument: KMA#095, Station: Pohang, Korea

Brewer KMA#095 participated in the campaign from 10 to 20 June 2013. The instrument was inoperative since the last maintenance work done by the private company K&Z (January 2013), so we do not provided any evaluation for the initial status of the instrument. The instrument performance is found to be quite stable during the intercomparison days. Accordingly, days 13 to 19 June were used for final calibration purposes (307 near-simultaneous direct sun measurements).

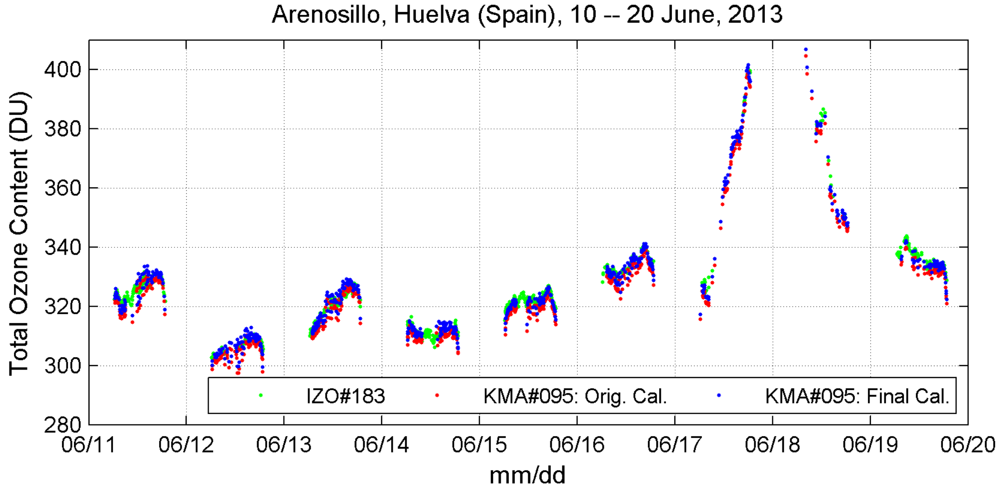


Figure 33. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf29309.095 and reference value 1745 for the SL R6 ratio.

Historical analysis

No historical data was available for this instrument. The performance of the instrument during the campaign was good. A new value 1753 is proposed for the SL R6 ratio.

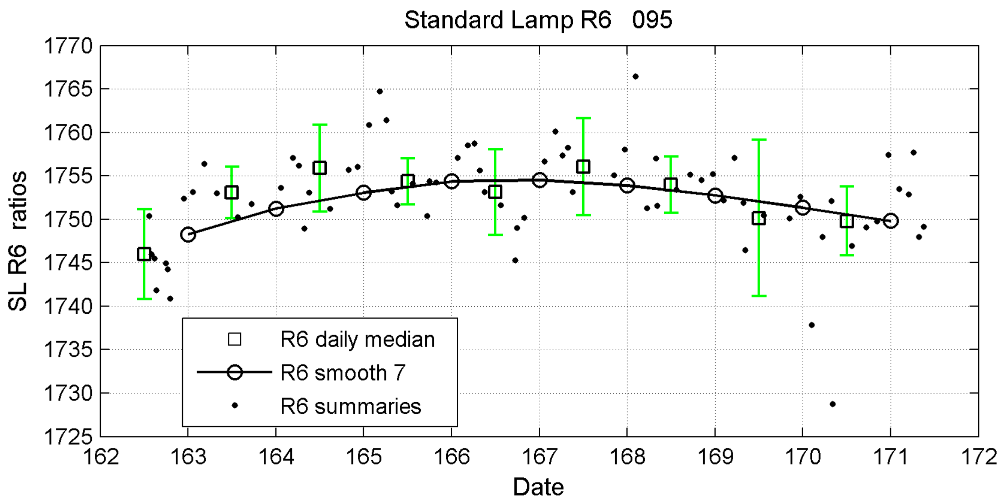


Figure 34. Standard Lamp test R6 (Ozone) ratio

Initial comparison

The original constants provided are found to be not good enough, underestimating ozone around -0.5\% on average as compared to reference instrument IZO#183. Correcting for the SL ratio change made the comparison even worse (see Figure 35, red dotted line).

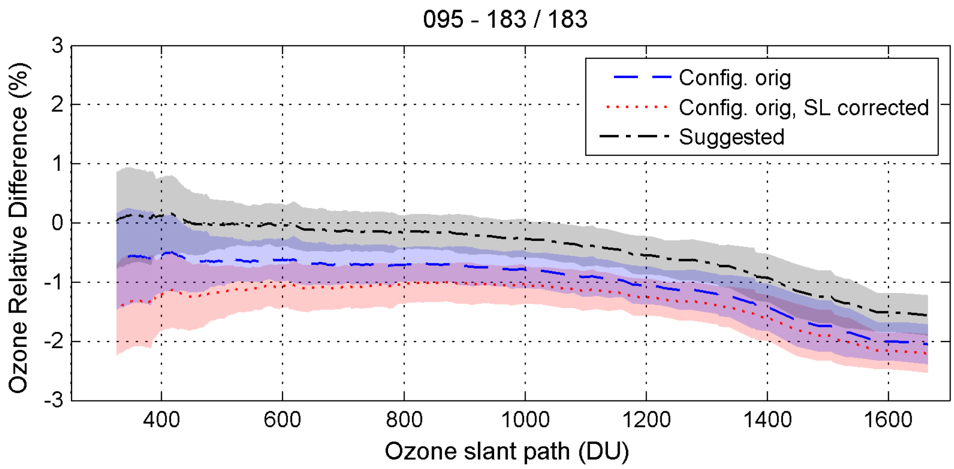


Figure 35. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

The Extraterrestrial constant calculation resulted in a value around 2957, quite similar to the original one 2960. We achieved a very good agreement with the RBCC-E traveling standard IZO#183 using this calibration set, with ozone deviations lower than 0.5% up to ozone slant path around 1200 DU (see Figure 35, blue dashed line). We recommend using this new ETC constant, together with the updated ozone absorption coefficient (0.3415) and the new SL R6 reference value (1753).

Straylight

This single Brewer shows not much stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1300 DU. This is greatly improved after the stray light correction is applied (see Figure 36, red dotted line).

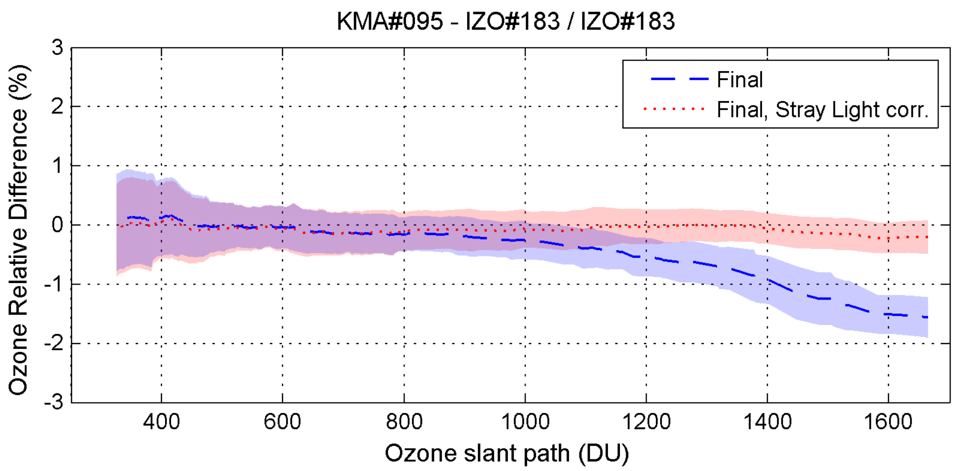


Figure 36. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation

Calibration constants summary: KMA#095

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	2960		2957
SL R6 reference value	1745		1753
change SL R6 ratio / ETC			<10 / <5
DT Constant (ns)	38		38
Temp. Coeffs.			No change
Cal Step Number	293		297
Ozone Abs. Coeff.	0.3430		0.3415
Stray Light factors (F0 / k / s)			2957 / -7.62 / 5.46
Calibration File recommended	Icf29309.095		Icf16313.095

Recommendations and comments

- No historical data was available for this instrument. The instrument's performance was good during the intercomparison days.
- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters. On the contrary, both the Cal-Step number and the ozone absorption coefficient were updated to new values 297 and 0.3415, respectively.
- We achieved a very good agreement with the RBCC-E traveling standard IZO#183 using the proposed final calibration constants, with ozone deviations within 1% up to ozone slant path around 1300 DU.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_095.pdf

8.6 Instrument: MUR#117, Station: Murcia, Spain

Brewer MUR#117 was present at the campaign from 11 to 19 June 2013. Though maintenance work did not significantly affect the instrument's response, we used days 11 to 14 June to evaluate the original constants (146 near-simultaneous direct sun ozone measurements), whereas days from 15 to 19 June were used for final evaluation purpose (382 near-simultaneous direct sun ozone measurements).

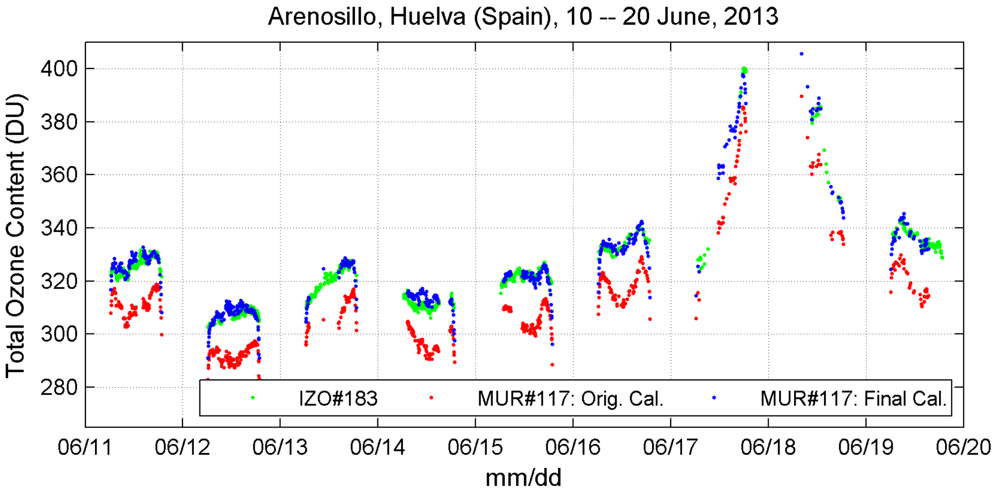


Figure 37. Brewer Intercomparison El Arenosillo 2013

Original calibration
The instrument operates with the configuration file icf18611.117 and reference value 1670 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

Historical analysis
The SL results have been very unstable since the last intercomparison campaign (El Arenosillo 2011). The most noticeable event is related to a drastic change in SL ratios in December 2011, due to unknown reasons (see Figure 38). All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were normal, except for the measured Dead Time constant, about 3 units lower than the operational value.

Initial comparison
The calibration constant provided during the last intercomparison (El Arenosillo 2011, icf18611.117) should be valid until December 2011. We suggest to use the configuration file icf33711.117, together with the SL reference R6 ratio 1580, to re-evaluate the period from December 2011 to June 2013, including natural days 162 through 165 (blind days of the current intercomparison).

Final calibration
A new Extraterrestrial constant has been calculated using updated Dead Time constant and ozone absorption coefficient (instrument's configuration file icf16613.117). We achieved a very good agreement with the reference instrument IZO#183 after using this calibration set, with ozone deviations within 0.5% up to ozone slant path 1000 DU (see Figure 40, blue dashed line).

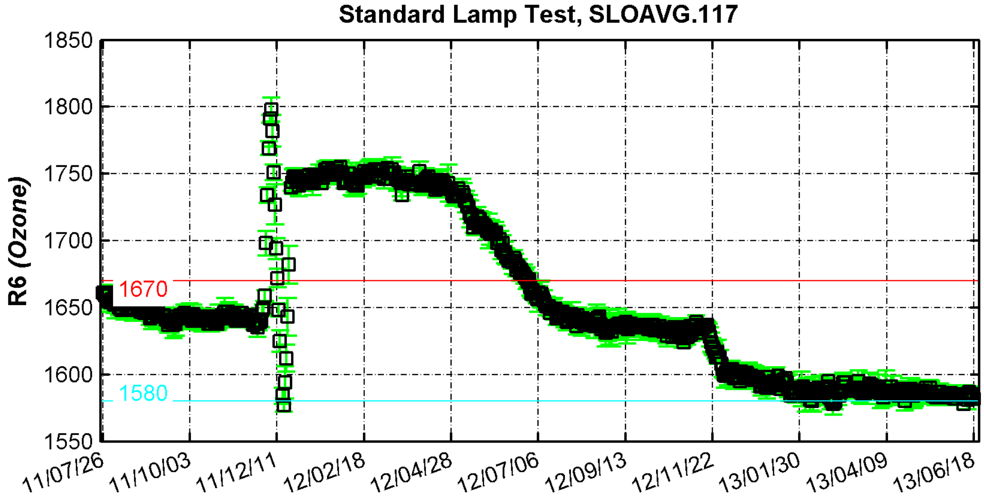


Figure 38. Standard Lamp test R6 (Ozone) ratio

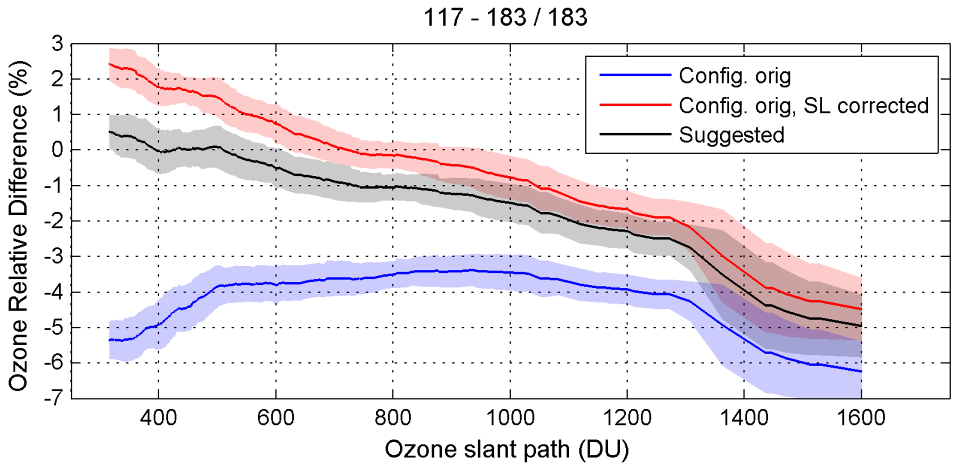


Figure 39. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation

Straylight

This single Brewer shows a moderate stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1200 DU. This is greatly improved after the stray light correction is applied (see Figure 40, red dotted line).

Recommendations and comments

- Analysis of SL test results during the last 2 years revealed the existence of two distinct periods separated by a marked change in SL ratios in December 2011.
- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters.

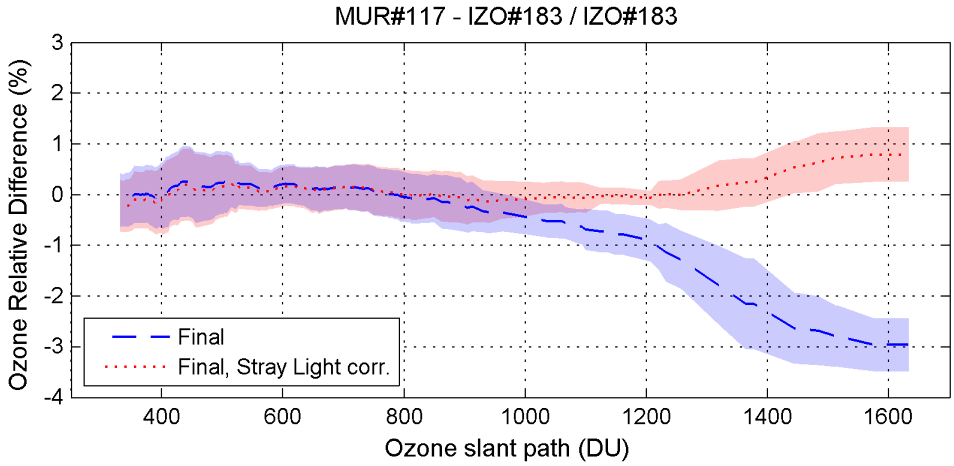


Figure 40. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation

Calibration constants summary: MUR#117

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	2865	2800	2805
SL R6 reference value	1670	1580	1580
change SL R6 ratio / ETC		90 / 65	<5 / <5
DT Constant (ns)	27	27	24
Temp. Coeffs.		No change	No change
Cal Step Number	286	286	286
Ozone Abs. Coeff.	0.3394	0.3394	0.3342
Stray Light factors (F0 / k / s)			2807 / -12.6 / 7.21
Calibration File recommended	icf18611.117	Icf33711.117	icf16613.117

- A re-evaluation of the past ozone observations is advised. The calibration constants provided during the last campaign (icf18611.117) should work until December 2011, while we propose a new set of calibration constants for the period from this date onwards (icf33711.117, R6=1580).

- The operational ozone absorption coefficient was significantly different as compared with the calculated one. A new value was adopted in final configuration. We have also updated the Dead Time constant. We suggest using this new set of calibration constants (icf16613.117), together with the new R6 reference value, 1580.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_117.pdf

8.7 Instrument: UM#126, Station: Manchester, United Kingdom

Brewer UM#126 was present at the campaign from 10 to 19 June 2013. The instrument has been working indoors since the last intercomparison campaign (El Arenosillo 2011). Major maintenance was provided during the current campaign. Among others, mirrors and gratings were slightly re-seated and HT voltage was raised to a new value (1460 V). Neutral density filter ND#3 was also replaced. We do not provide any evaluation for the instrument's initial status. We used ozone data collected from 15 to 19 June for final calibration purposes (125 near-simultaneous direct sun measurements).

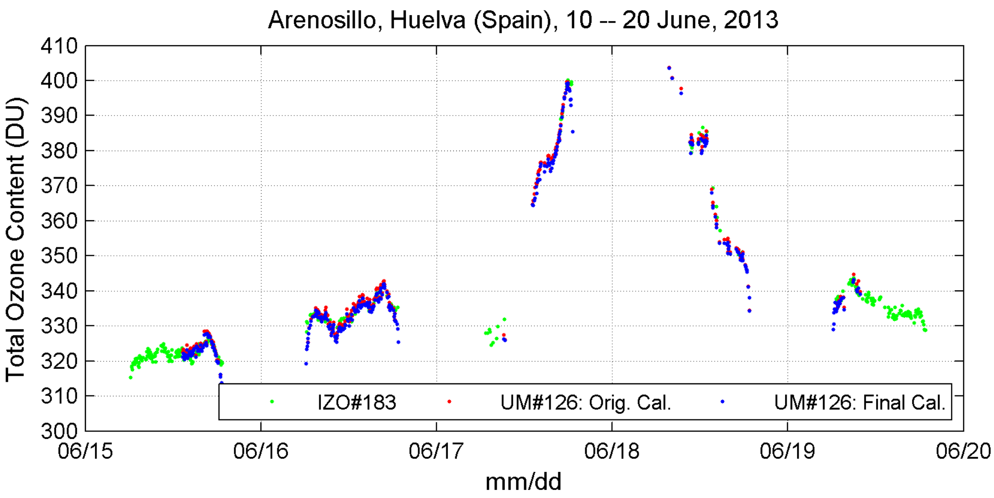


Figure 41. Brewer Intercomparison El Arenosillo 2013

Original calibration
The instrument was operating indoors during the last 2 years.

Historical analysis
We limit the analysis to data collected during the campaign days. The instrument’s performance was unstable during the campaign, but it improved significantly after maintenance was performed (see e.g. the SL R6 ratio, ***Figure***). A new value 2100 is proposed for the SL R6 ratio reference value. The Dead Time constant should be updated to the new value 35 ns.

Initial comparison
We do not provide any evaluation for the instrument's initial status.

Final calibration
For the extraterrestrial constant transfer we updated the Dead Time constant, resulting in a new ETC of 2750. We achieved a quite good agreement with the reference instrument IZO#183 using these new constants (icf16613.126, R6=2100), see Figure 43, blue dashed line.

Straylight
This single Brewer shows not much stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1300 DU. This is greatly improved after the stray light correction is applied (see Figure 43, red dotted line).

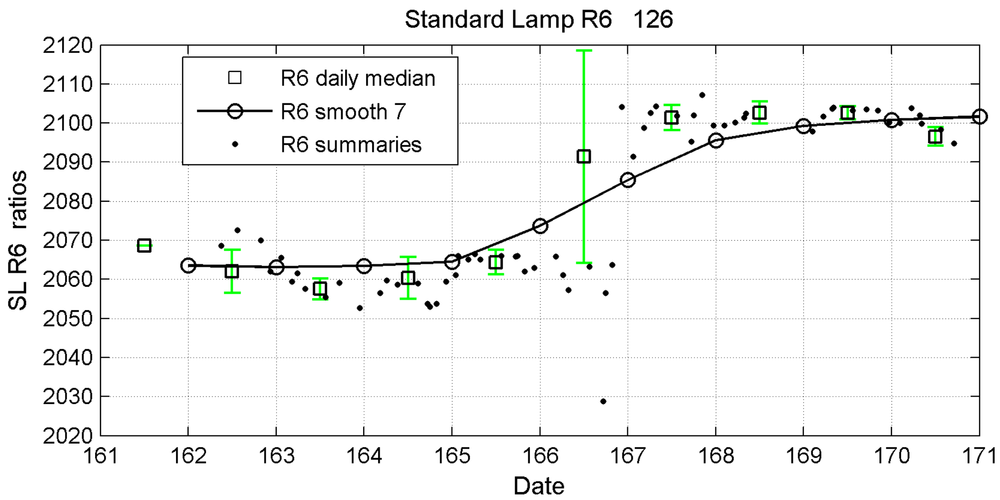


Figure 42. Standard Lamp test R6 (Ozone) ratio

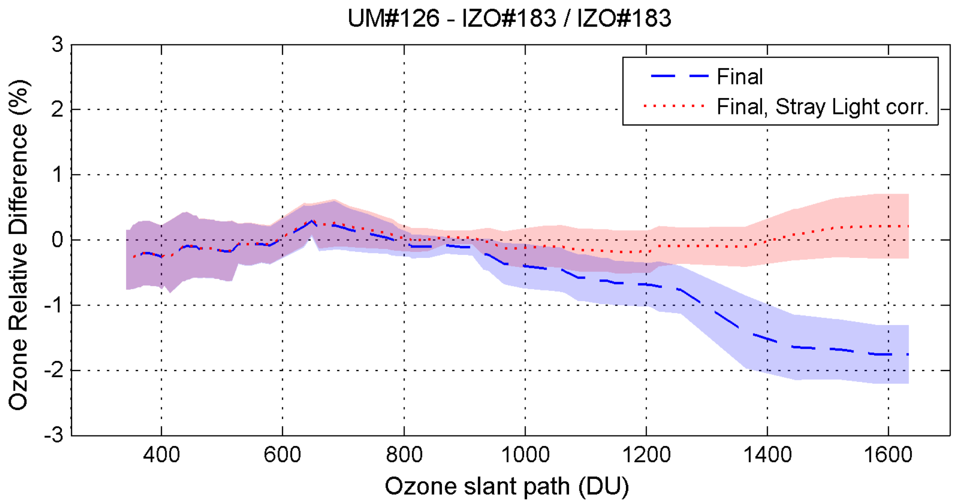


Figure 43. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation

Calibration constants summary: UM#126

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant			2750
SL R6 reference value			2100
change SL R6 ratio / ETC			
DT Constant (ns)			35
Temp. Coeffs.			No Change
Cal Step Number			290
Ozone Abs. Coeff.			0.3435
Stray Light factors (F0 / k / s)			3250 / -9.08 / 6.18
Calibration File recommended			Icf16613.126

Recommendations and comments

- Brewer UM#126 has been working indoors during the last 2 years. In addition, major maintenance was provided during the current campaign. We do not provide any evaluation for the instrument's initial status.
- The SL R6 ratios stabilized during the campaign to a new value 2100. We have used a new Dead Time constant, improving performance of attenuation filter ND #3. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were normal.
- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We did not apply any correction factor to neutral density filters.
- We recommend using the new configuration file icf16613.126 together with the new proposed standard lamp reference R6 ratio, 2100.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_126.pdf

8.8 Instrument: ARE#150, Station: El Arenosillo, Spain

Brewer ARE#150 operates normally at El Arenosillo station. Major maintenance was provided during the current campaign: zenith blocker was repaired and overall zenith alignment was improved. A new UV diffuser was installed and HT voltage was raised to a new value 1480 V. Neutral density filter ND#4 and internal halogen and mercury lamps were also replaced. We used ozone data collected from 10 to 13 June for instrument's initial status evaluation, whereas ozone data collected from 15 to 19 June were used for final calibration purposes (37 near-simultaneous direct sun measurements).

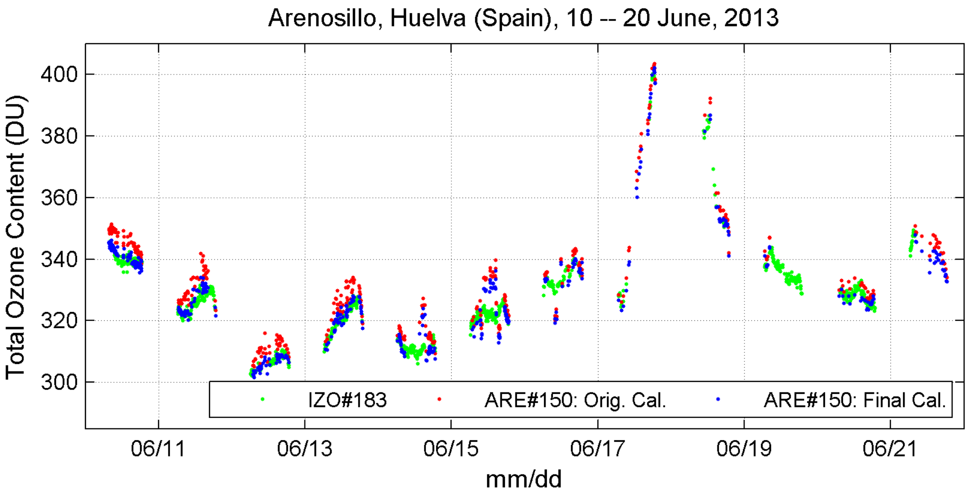


Figure 44. Brewer Intercomparison El Arenosillo 2013

Original calibration
The instrument operates with the configuration file icf18811.150 and reference value 312 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison

campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

Historical analysis
The SL results have been very stable since the last intercomparison campaign and in good agreement with the provided R6 reference value (see Figure 45). It is worth noting in any case a different period starting in November 2012, noisier and apparently not related to changes in F5. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were normal, except for the measured Dead Time constant, about 4 units lower than the operational value. It agreed with the operational value after the photomultiplier voltage was updated.

Initial comparison
The original constants provided performed bad, with ozone deviations larger than 1%, on average. Correcting for the SL ratio change had little effect on ozone measurement, as expected for this instrument (see Figure 46, red dotted line). We suggest using icf16113.150 to re-evaluate past ozone data. We believe this new constants should work from November 2012, but it is advised to confirm this assumption (e.g. comparing with satellite overpass). Note that we are using updated temperature coefficients (those proposed by the RBCC-E during the last intercomparison). Apart from this, a correction factor -15 is being applied to ND#4.

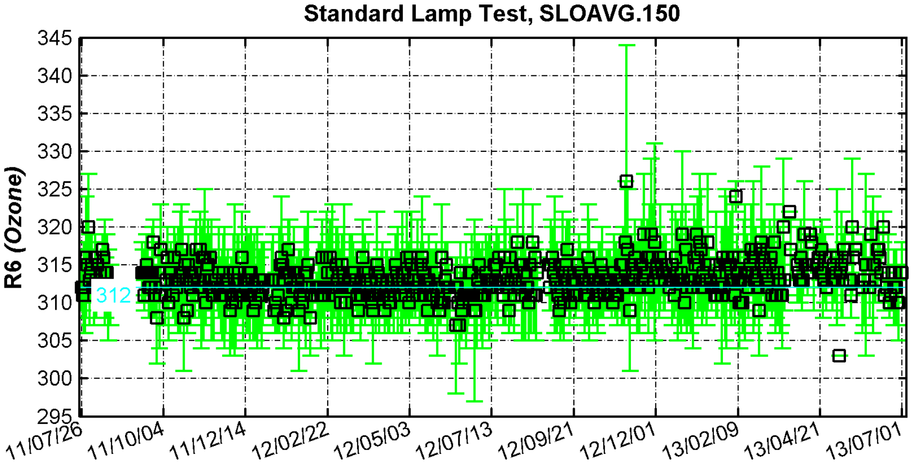


Figure 45. Standard Lamp test R6 (Ozone) ratio

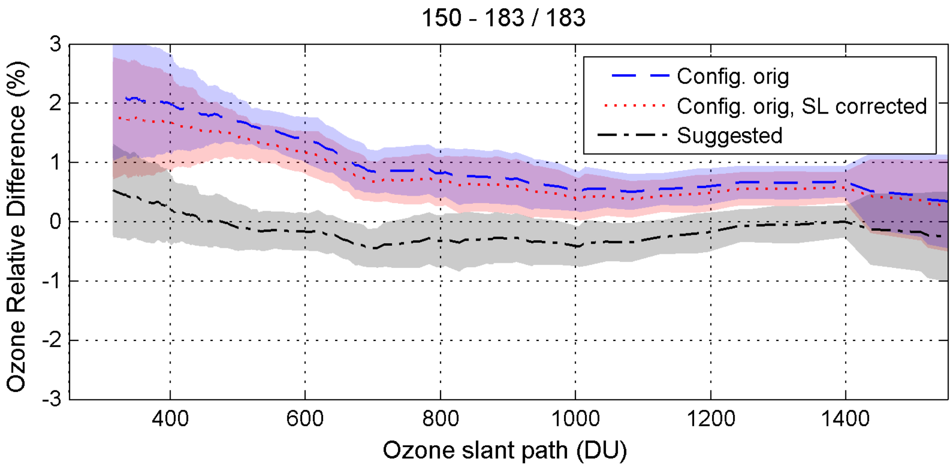


Figure 46. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration
For the extraterrestrial constant transfer we used the same temperature coefficients and correction factor to ND#4 as for evaluation of the instrument's initial status. We achieved a quite good agreement with the reference instrument IZO#183 using these new constants (icf16713.150, R6=312), see Figure 47, black dashed line.

Straylight
Double monochromator.

Recommendations and comments

- The SL results have been very stable since the last intercomparison campaign and in good agreement with the provided R6 reference value, but with a noisier period starting in November 2012. The measured Dead Time constant was about 4 units lower than the operational value. It agreed with the operational value after the photomultiplier voltage was updated.

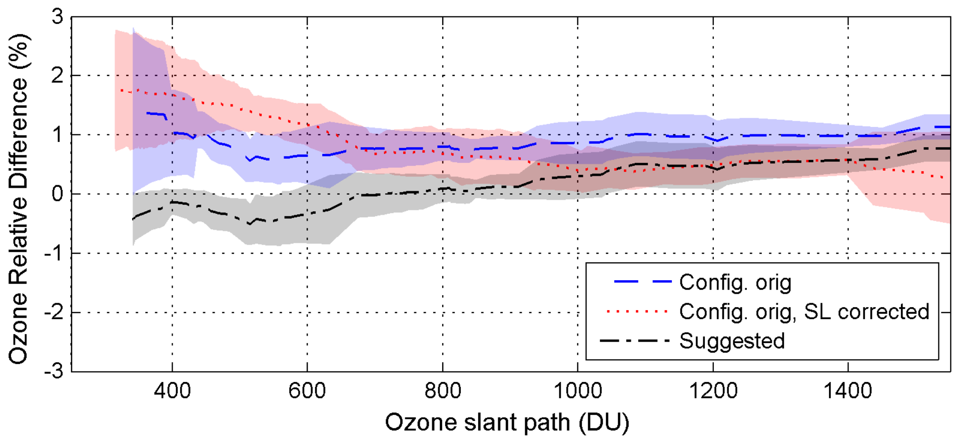


Figure 47. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Calibration Constants Summary: ARE#150

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	1565	1595	1585
SL R6 reference value	312	312	312
change SL R6 ratio / ETC		<5 / 30	<5 / 20
DT Constant (ns)	32	32	32
Temp. Coeffs.		Change	Change
Cal Step Number	1034	1034	1031
Ozone Abs. Coeff.	0.3405	0.3405	0.3405
Stray Light factors (F0 / k / s)			
Calibration File recommended	icf18811.150	icf16113.150	icf16713.150

Recommendations and comments

- The SL results have been very stable since the last intercomparison campaign and in good agreement with the provided R6 reference value, but with a noisier period starting in November 2012. The measured Dead Time constant was about 4 units lower than the operational value. It agreed with the operational value after the photomultiplier voltage was updated.
- We recommend using a different temperature coefficients set to the operational one. These coefficients are the same as the ones recommended during the El Arenosillo 2011 campaign.
- We did apply a correction factor -15 to the attenuation filter ND#4 for evaluation of the instrument's initial status, the same correction factor suggested at the last campaign. This filter was replaced as part of the maintenance. Unfortunately, too few ozone measurements collected with it were available, so it is difficult to be sure about the convenience of applying the same correction factor. This issue will be analysed during the next intercomparison (El Arenosillo 2015).
- A re-evaluation of the past ozone observations is recommended: the calibration constants provided during the last campaign (icf18811.150) should work until November 2012, while we propose a new set of calibration constants for the period from this date onwards (icf16113.15, R6=312). However, it is strongly advised to confirm this assumption.
- New calibration constants were provided to be applied from 15 June 2013 (icf16713.150, R6=312).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_150.pdf

8.9 Instrument: COR#151, Station: La Coruña, Spain

Brewer COR#151 was present at the campaign from 11 to 19 June 2013. The reasons for the observed large variability in ozone for this instrument are unknown, but problems with correct positioning of the FW#3 could contribute. We used days 11 and 12 June for evaluation of the original calibration constants (101 near-simultaneous direct sun ozone measurements), before the instrument's response changed. Days from 13 to 19 June were used for final calibration purposes (159 near-simultaneous direct sun ozone measurements).

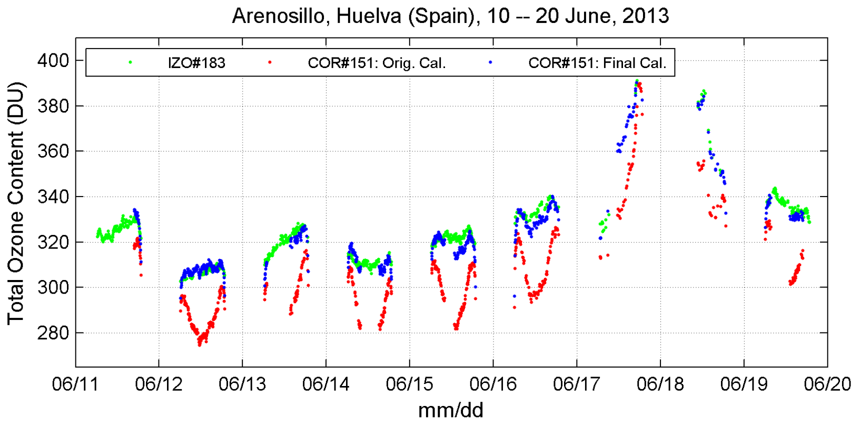


Figure 48. Brewer Intercomparison El Arenosillo 2013

Original calibration
The instrument operates with the configuration file icf19011.151 and reference value 1925 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

Historical analysis
The analysis of SL ratios revealed two periods with distinct standard lamp ratios during the last two years (see Figure 49): from July 2011 to March 2012 and then from March 2012 until just before the current campaign. We provided new calibration constants to re-evaluate ozone measurements during the last period. The SL R6 ratio stabilized during the campaign days to the new reference value 1805. Note that these values correspond to updated temperature coefficients. All the other parameters analysed were normal.

Initial comparison
Ozone deviations to the reference instrument IZO#183, based on the original constants, were around -3% on average. They turned to be around 2% after correcting for SL change. We suggest using the configuration file icf06812.151, together with the reference value for the SL R6 ratio 1795, to re-evaluate the period from March 2012 onwards. This would include natural days 16213 through 16313 (blind days of the current intercomparison). We recommend also applying during this period a correction factor -15 to attenuation filter ND#3. On the other hand, the original calibration constants (icf19011.151, R6=1925) should be valid until March 2012.

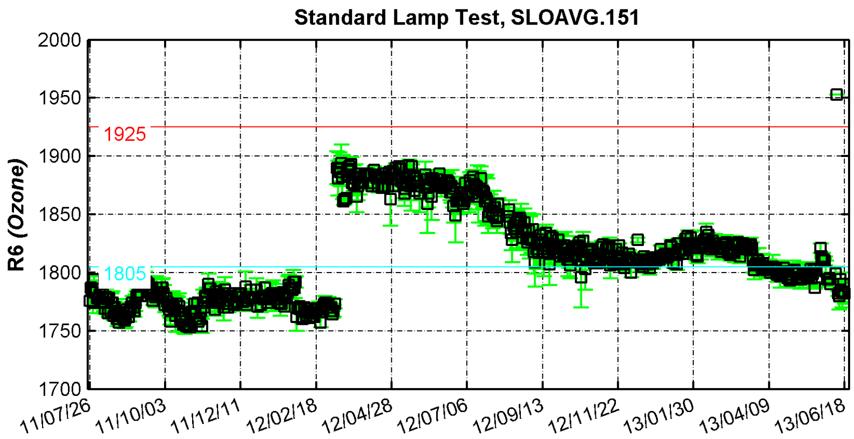


Figure 49. Standard Lamp test R6 (Ozone) ratio

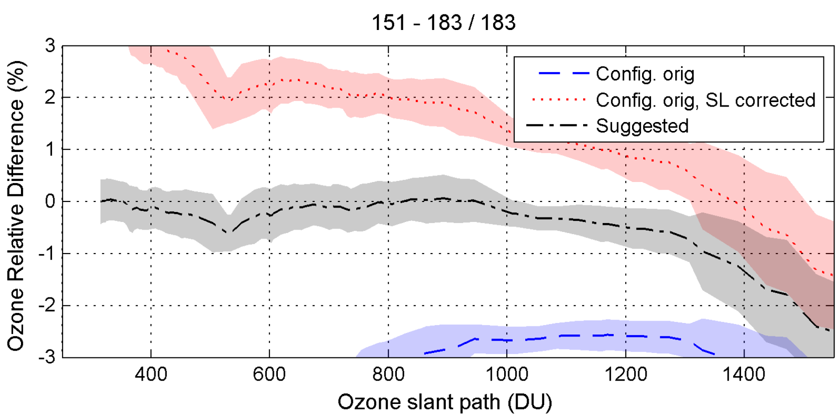


Figure 50. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

New temperature coefficients have been used in final configuration file. We also applied a correction factor -15 to attenuation filter ND#3. We achieved a quite good agreement with the reference instrument IZO#183 using these new constants (icf16513.151, R6=1805), see Figure 51, blue dashed line.

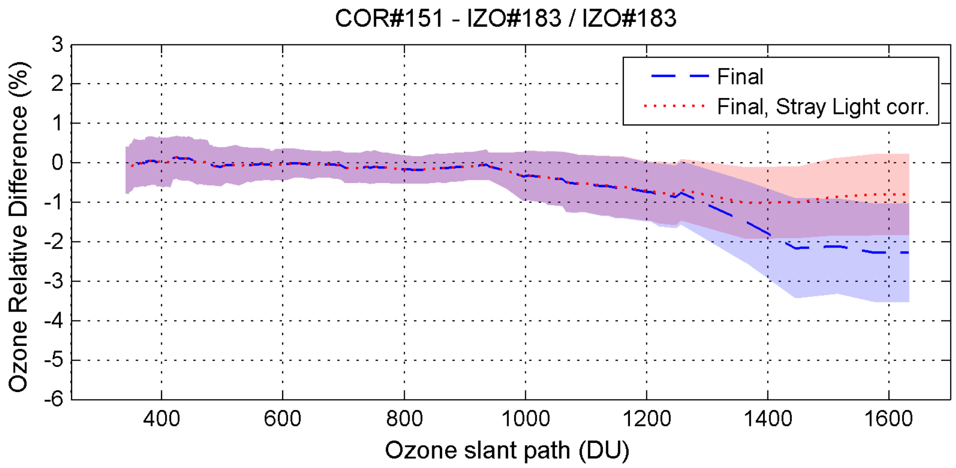


Figure 51. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight

This single Brewer (MKIV type) shows not much stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1400 DU. This is improved after the stray light correction is applied (see Figure 51, red dotted line).

Calibration constants Summary: COR#151

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	3055	2970	2978
SL R6 reference value	1925	1795	1805
change SL R6 ratio /ETC		-130 / -85	<5 / -5
DT Constant (ns)	31	31	31
Temp. Coeffs.		No change	Change
Cal Step Number	288	288	288
Ozone Abs. Coeff.	0.3417	0.3417	0.3417
Stray Light factors (F0 / k / s)			2977/-0.062 /17,71
Calibration File recommended	Icf19011.151	Icf06812.151	Icf16513.151

Recommendations and comments

- The SL results have been unstable since the last intercomparison campaign. We detected during these last two years two periods with distinct standard lamp ratios: from July 2011 to March 2012 and from March 2012 until just before the current intercomparison. The SL R6 ratio stabilized during the campaign days to the new adopted references value 1805.

- We did apply a correction factor -15 to the attenuation filter ND#3 for evaluation of the instrument's initial status (icf06812.151), the same correction factor suggested at the final configuration file (icf16513.151). We improved in this way the overall performance of the instrument for low ozone slant path.

- A re-evaluation of the past ozone observations are recommended: the calibration constants provided during the last campaign (icf19011.151) should work until March 2012. We propose a new set of calibration constants for the period from this date onwards (icf06812.151, R6=1795), together with a correction factor -15 to be applied to attenuation filter ND#3.

- New calibration constants were provided to be applied from 14 June 2013 (icf16513.151, R6=1805). Note that temperature coefficients have been updated in final configuration file.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_151.pdf

8.10 Instrument: K&Z#158, Station: Delft, The Netherlands

Brewer K&Z#158 was present at the campaign from 11 to 18 June 2013. Some refurbishment was carried out recently (year 2013), and calibration constants other than those provided during the last intercomparison (Arosa 2012) were needed. No maintenance was done to this instrument during the intercomparison. We used the same ozone data set to evaluate the initial status as well as for final calibration purposes (380 near-simultaneous direct sun ozone measurements).

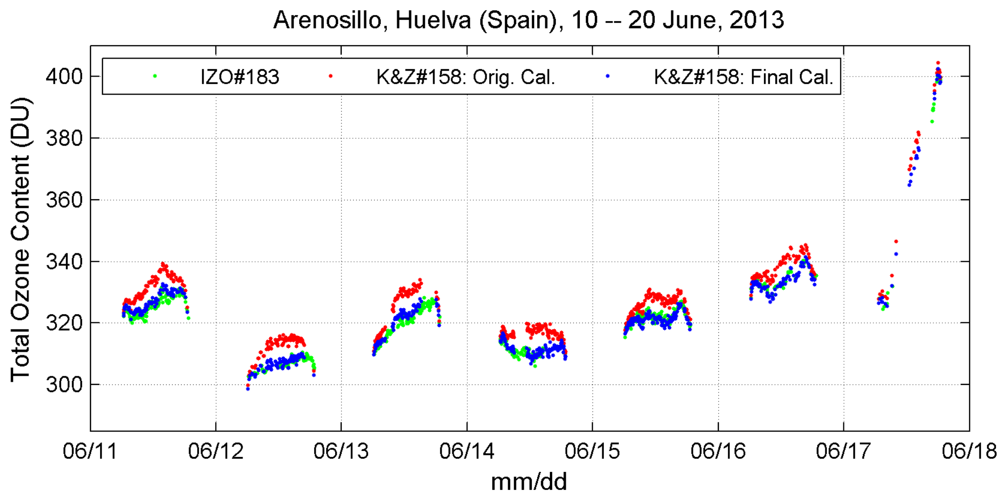


Figure 52. Brewer Intercomparison El Arenosillo 2013

Original calibration
The instrument operates with configuration file icf06013.158 and reference value 476 for the SL R6 ratio. It is worth noting that these are the same constants since year 2010 (icf11010.158)

Historical analysis
Several temperature coefficients have been used during the last year. Thus, SLOAVG records are not reliable for tracking changes in the instrument's response. We reprocessed all SL tests performed during the last year using the same temperature coefficients (those proposed during the

Arosa 2012 campaign). The result is show in Figure 53. All the other parameters analysed were normal, except for the Dead Time, decreasing around 4 units in January 2013. We kept the original value in final configuration.

Initial comparison

We used the same ozone data set to evaluate the initial status as well as for final calibration purposes (see below).

Final calibration

The original calibration constants performed badly, with ozone deviations above 1%, on average. The comparison with the reference instrument IZO#183 improved after the calibration constant was corrected for the SL changes (see Figure 54). A new Extraterrestrial constant has been calculated using updated temperature coefficients (instrument's final configuration file icf16313.158, R6=473). We achieved a very good agreement with the reference instrument IZO#183 after using these calibration constants, with ozone deviations within 0.5% (see Figure 54, black dashed line). The same calibration constant, SL corrected, should be valid to re-evaluate ozone past data, but it is strongly advised to confirm this.

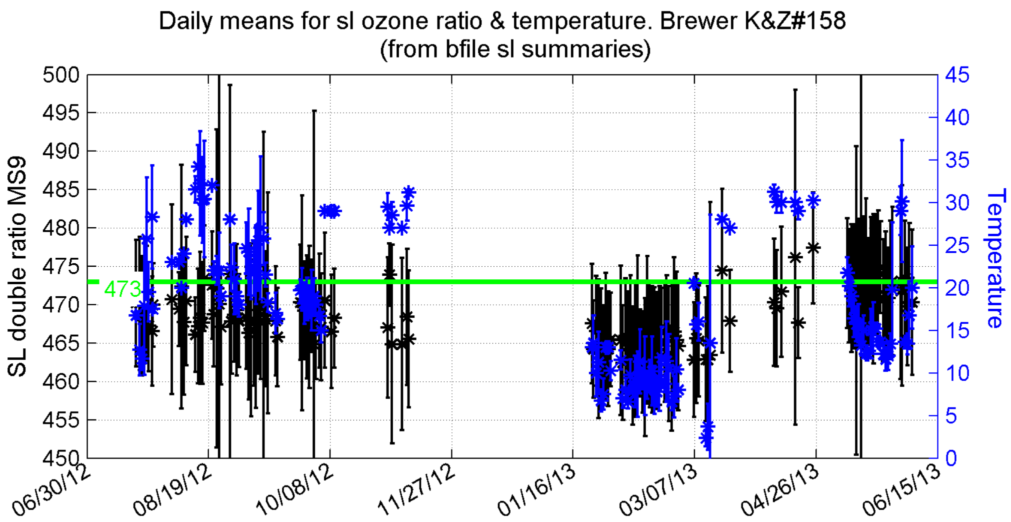


Figure 53. Standard Lamp test R6 (Ozone) ratio and Temperature

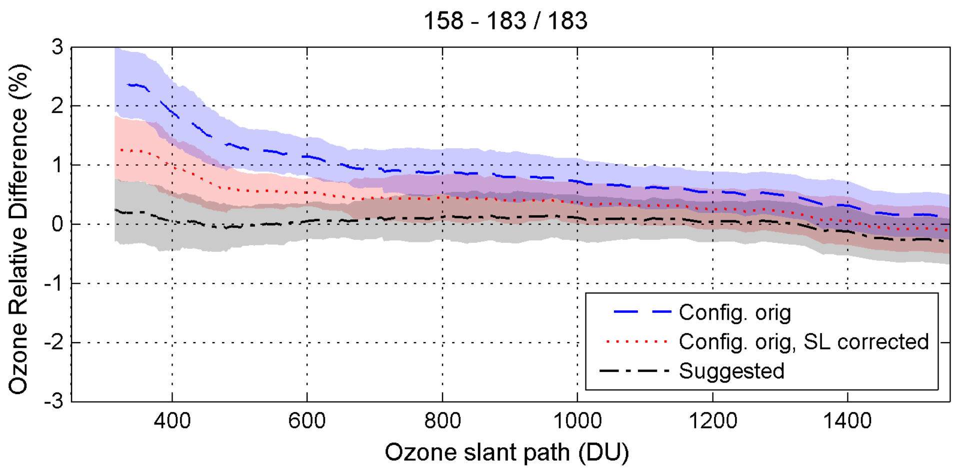


Figure 54. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight
Double monochromator.

Recommendations and comments

- SLOAVG records are not reliable for tracking changes in the instrument's response during the last year, due to different temperature coefficients used in this period.

- The Dead Time constant decreased around 4 units in January 2013. We kept the original value in final configuration.

- We have updated the operational temperature coefficients in final configuration file (those proposed at the last intercomparison, Arosa 2012). A new value 473 is proposed for the SL R6 ratio reference value. We did not apply any correction factor to neutral density filters.

Calibration constants Summary: K&Z#158

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	476	473	473
SL R6 reference value	1738	1745	1745
change SL R6 ratio /ETC		-5 / <5	<5 / <5
DT Constant (ns)	22	22	22
Temp. Coeffs.		Change	Change
Cal Step Number	284	284	284
Ozone Abs. Coeff.	0.3435	0.3435	0.3435
Stray Light factors (F0 / k / s)			
Calibration File recommended	Icf06013.158	Icf16313.158	Icf16313.158

- We kept the original Cal Step number and ozone absorption coefficient in the final configuration file (284 and 0.3435, respectively).

- A re-evaluation is recommended for the past ozone observations: the calibration constants provided during the current intercomparison (icf16313.158, R6=473) should work until at least April 2013. We can't say too much about which calibration constants should be applied from July 2012 to April 2013: it is recommended to check both the Arosa 2014 (icf19812.158, R6=468) and the El Arenosillo 2013 (icf16313.158, R6=473) proposals. Careful inspection of the most important events related to the instrument's response during this period would help.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_158.pdf

8.11 Instrument: WRC#163, Station: Davos, Switzerland

Brewer WRC#163 was present at the campaign from 12 to 17 June 2013. No maintenance was done to this instrument during the intercomparison. Accordingly, we used the same ozone data set to evaluate the initial status as well as for final calibration purposes (239 near-simultaneous direct sun ozone measurements).

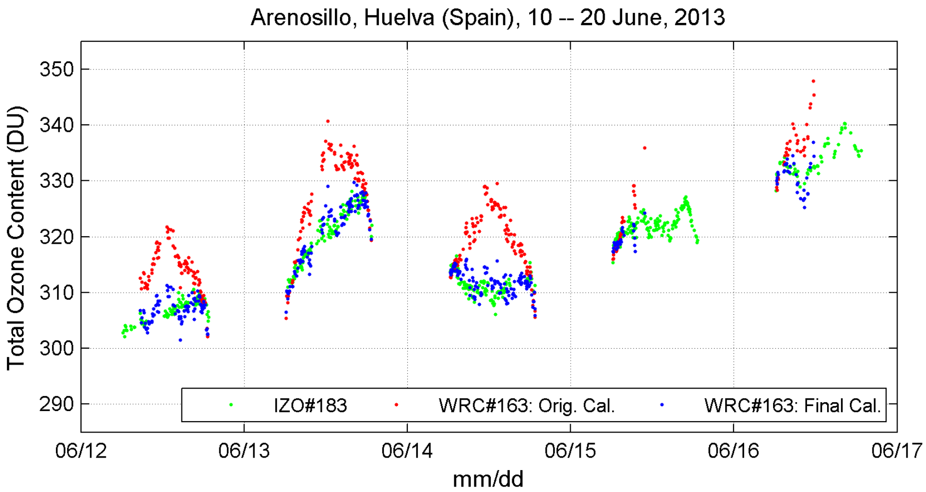


Figure 55. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf20412.163 and reference value 240 for the SL R6 ratio. These calibration constants were different to those provided after the last RBCC-E intercomparison campaign (Arosa, July 2012, icf19812.163, R6=178).

Historical analysis

The SL R6 ratios have been rather stable during the last year, with the exception of two events: on the one hand, from July 2012 to October 2012 with R6 increasing around 25 units, and, on the other hand, just during the current intercomparison, with some significant increase in R6 ratio (see Figure 56). This last 15 units increasing in R6 is related to wrong operational temperature coefficients (see also Figure 57).

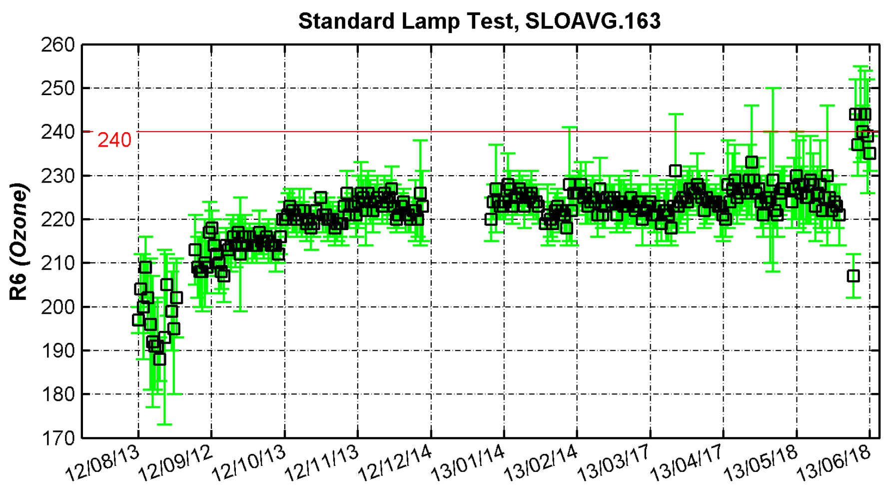


Figure 56. Standard Lamp test R6 (Ozone) ratio

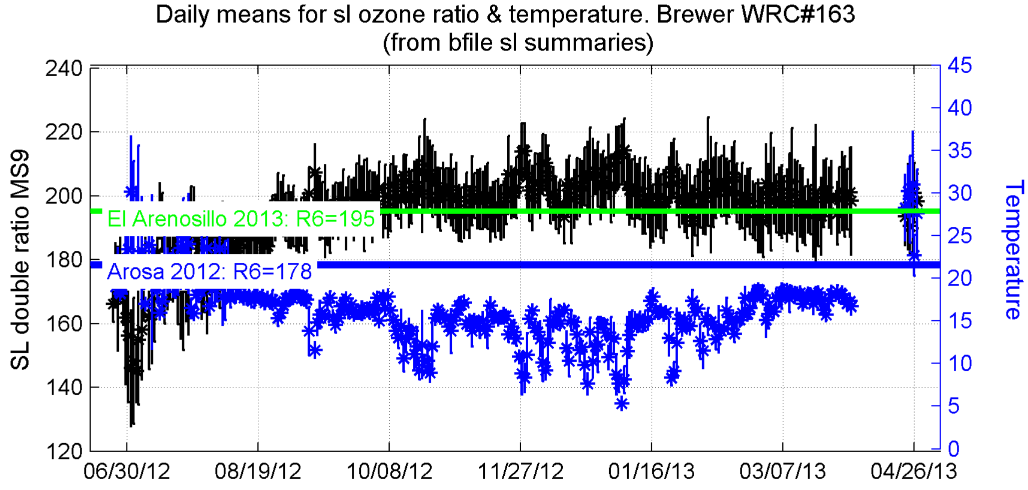


Figure 57. Daily mean of Standard Lamp using previous constants

Initial comparison

Ozone deviations to the reference instrument IZO#183, using the original calibration constants, were larger than around 2% for ozone slant path below 600 DU, on average. Correcting for the SL change did not improve the comparison. We suggest using the calibration constants provided during the last RBCC-E intercomparison campaign (Arosa 2012, icf19812.163, R6=178) to re-evaluate historical ozone data during the period from July 2012 to June 2013. Note that for this to be valid, you should correct your calibration constant for the SL change. We show in Figure 57, black dashed line, and the comparison against reference Brewer IZO #183 after applying these constants.

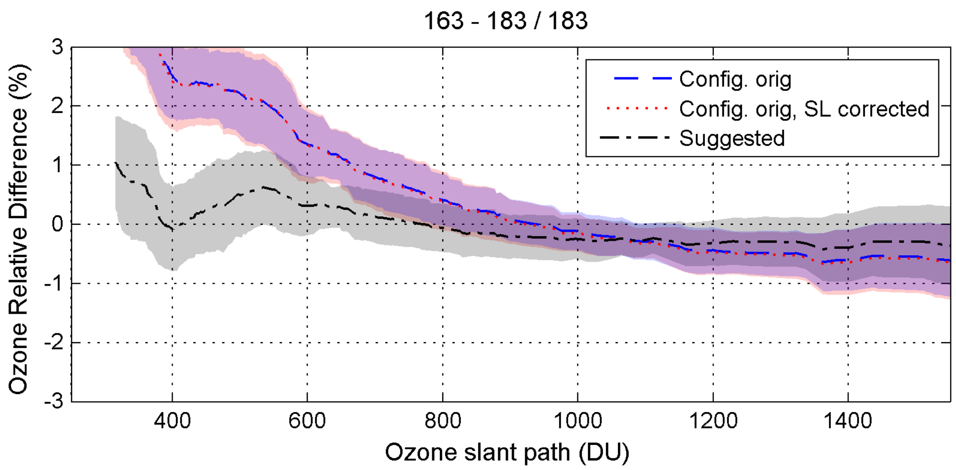


Figure 58. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

The Extraterrestrial constant has been calculated using the same temperature and ozone absorption coefficients as stated in the instrument's final configuration file icf19812.163. The resulting ETC was 1445, which is the same as the corresponding ETC (1426) SL corrected. We suggest using new calibration constants icf17013.163 and R6=195 to be applied from June 2013 (see Figure 54, black dashed line).

Straylight
Double monochromator.

Calibration constants Summary: WRC#163

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	1450	1426	1445
SL R6 reference value	240	178	195
change SL R6 ratio /ETC		<15 / <15	<5 / <5
DT Constant (ns)	32	32	32
Temp. Coeffs.		Change	Change
Cal Step Number	1024	1024	1024
Ozone Abs. Coeff.	0.3412	0.3380	0.3380
Stray Light factors (F0 / k / s)			
Calibration File recommended	Icf20412.163	Icf219812.163	Icf17013.163

Recommendations and comments

- The SL R6 ratios have been rather stable during the last year, but in disagreement with the provided R6 reference value (240).
- We observed too noisy Dead Time and Run/Stop measurements. However, this should be related just to low internal SL intensity and not affecting to the instrument's performance.
- We have updated the temperature coefficients in the final configuration file, the same as the one proposed during the last intercomparison campaign (Arosa 2012). No correction factors are needed to be applied to neutral density filters.
- Analysis of sun scans performed during the campaign days confirmed the operational calibration step number. As concerns the ozone absorption coefficient, we suggest using the same as the one proposed during the last campaign (0.3380 instead of 0.3415).
- A re-evaluation is recommended for the historical ozone observations: instrument's configuration file icf19812.163 should be valid from July 2012, together with the reference value R6=178. Note that these are the same calibration constants as the one proposed during the last RBCC-E intercomparison (Arosa 2012).
- New calibration constants are provided to be applied from 19 June 2013 (icf17013.163, R6=195).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_163.pdf

8.12 Instrument: CAS#165, Station: Casablanca, Morocco

Brewer CAS#165 participated in the campaign from 12 to 21 June 2013. The photomultiplier feeding voltage was increased to a new value 1535 V on day 14th June. We used days 12 to 14 June for evaluation of the initial calibration (146 near-simultaneous direct sun ozone measurements). Days 15 to 20 were used for final calibration purposes (272 near-simultaneous direct sun measurements).

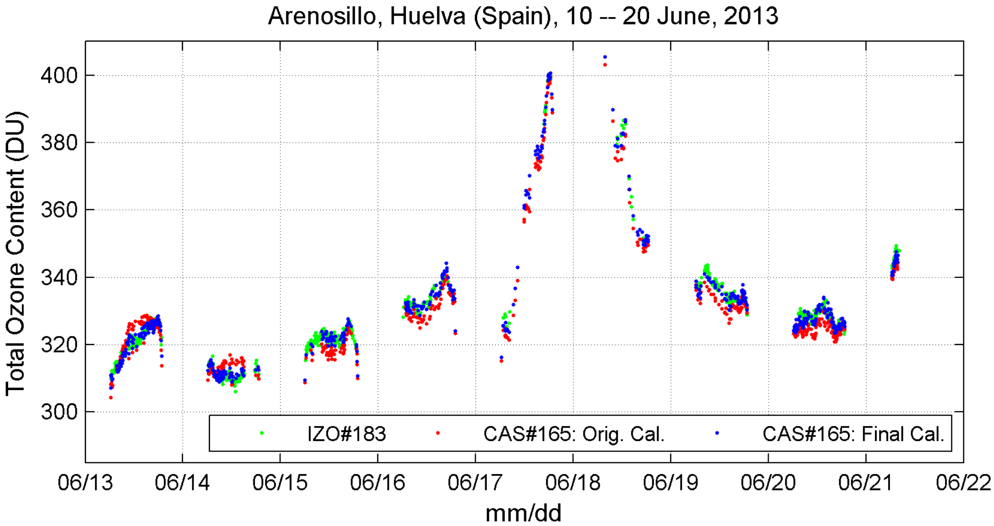


Figure 59. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf19511.165 and reference value 307 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), using the RBCC-E travelling standard Brewer IZO#185 as the reference instrument.

Historical analysis

The SL results have been very stable since the last intercomparison campaign and in good agreement with the provided R6 reference value (see Figure 60). The SL R6 ratio stabilized around 301 units, which is the new reference value proposed. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were ok, except for the Dead Time constant: a change of 23 units (from 11 ns to 34 ns) was observed after the high voltage update on natural day 165. We kept the original value in final configuration.

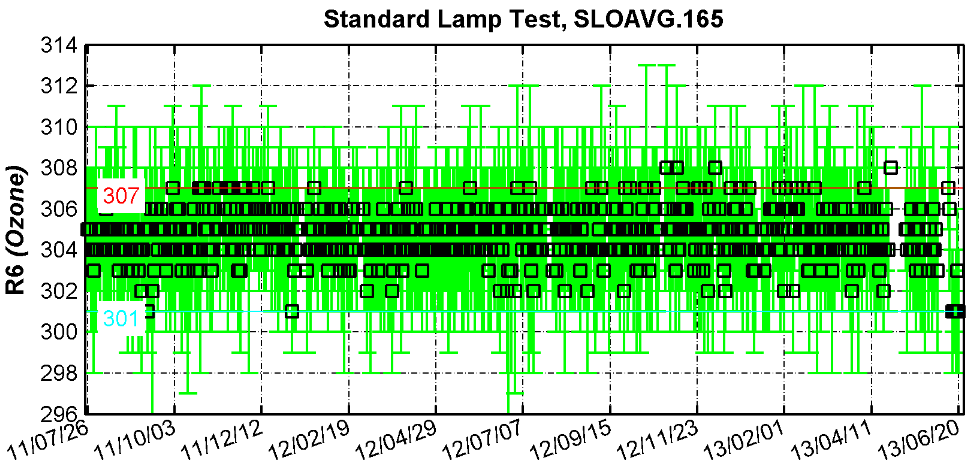


Figure 60. Standard Lamp test R6 (Ozone) ratio

Initial comparison

The original calibration constants performed badly: ozone deviations higher / lower than around 1% was observed for shorter / longer ozone slant path ranges, respectively (see Figure 61). Correcting for the SL ratio change did not improve the results. We recommend using new calibration constants (icf24212.165, R6=307) to re-evaluate historical ozone data. We also suggest applying a correction factor -18 to attenuation filter ND#4 (the same correction factor was deduced during the last campaign, El Arenosillo 2011). We believe that these new constants should be valid at least since August 2012.

Final calibration

The comparison with the reference instrument IZO#183 improved after the maintenance was performed on this instrument. Now it is not needed any correction factor to be applied to ND#4 filter. We achieved a good agreement with the reference instrument using the new calibration constants (icf16613.165, R6=301), with ozone deviations within 0.5% (see Figure 62, red solid line).

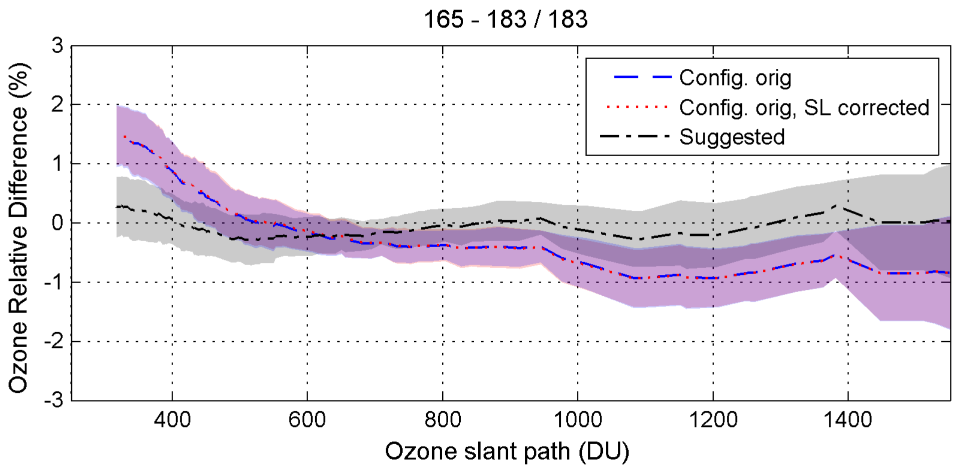


Figure 61. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

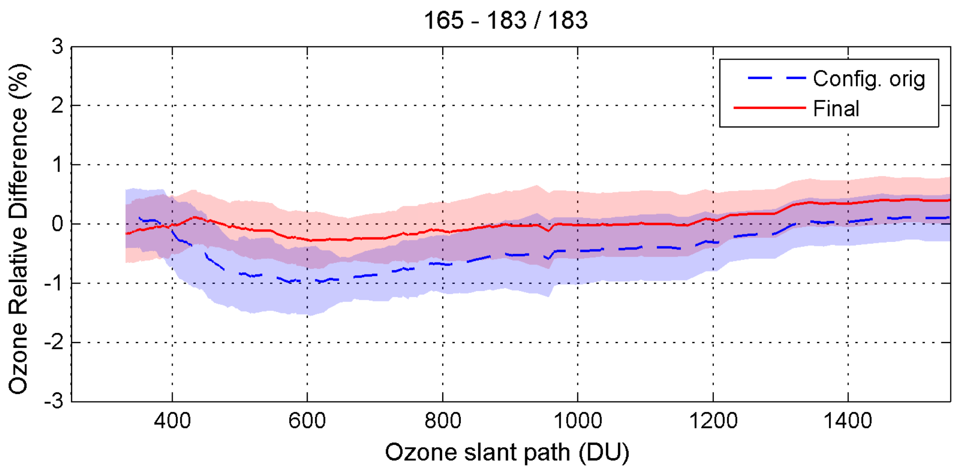


Figure 62. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight
Double monochromator

Calibration constants Summary: CAS#165

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	1560	1591	1545
SL R6 reference value	307	307	301
change SL R6 ratio /ETC		<5 / 30	<5 / 15
DT Constant (ns)	28	28	28
Temp. Coeffs.		No Change	No Change
Cal Step Number	1025	1025	1025
Ozone Abs. Coeff.	0.3446	0.3395	0.3446
Stray Light factors (F0 / k / s)			
Calibration File recommended	Icf19511.165	Icf24212.165	Icf16613.165

Recommendations and comments

- The lamp test results from Brewer CAS#165 have been very stable during the last 2 years. The standard lamp R6 ratio stabilized around 301, the new reference value proposed. The Dead Time constant was 17 units lower than the original value. It increased to around 32 ns after the photomultiplier feeding voltage was updated. We kept the original value in final configuration.

- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We suggest applying a correction factor -18 to ND#4 filter. No correction is needed after the maintenance was performed.

- We kept the original Cal Step number and ozone absorption coefficient in the final configuration file.

- A re-evaluation is recommended for the past ozone observations: configuration file icf24212.165 should be valid from August 2012, together with reference value R6=307 and correction factor -18 to be applied to attenuation filter ND#4.

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_165.pdf

8.13 Instrument: ZAR#166, Station: Zaragoza, Spain

Brewer ZAR#166 was present at the campaign from 11 to 19 June 2013. UV ($NiSO_4$) filter was replaced on day 13 June, resulting in a big change in the instrument's response (see Figure 63, red plot). Ozone data collected during the period from 10 to 13 June was used to evaluate the initial status of the instrument (46 near-simultaneous direct sun ozone measurements). Days 14 to 19 June were used for final calibration purposes (227 near-simultaneous direct sun ozone measurements).

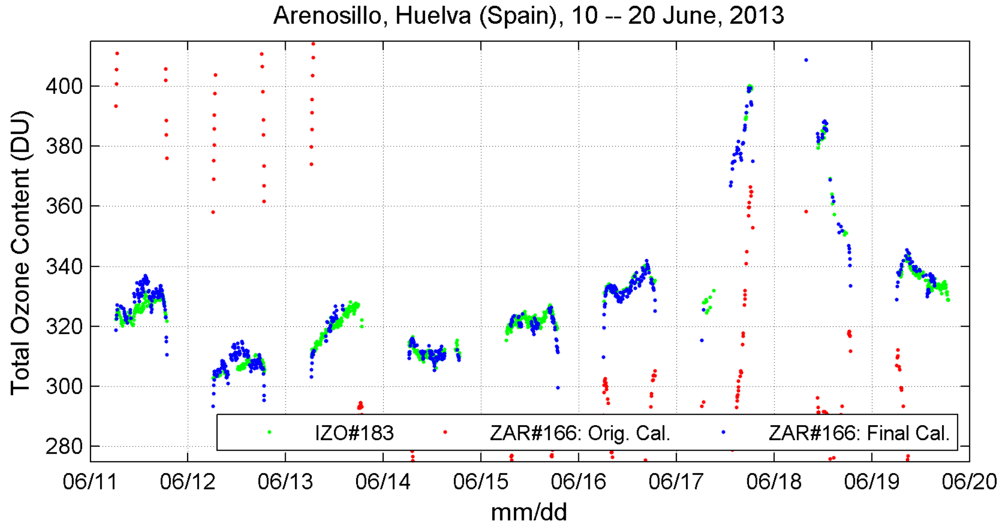


Figure 63. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf18811.166 and reference value 2260 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

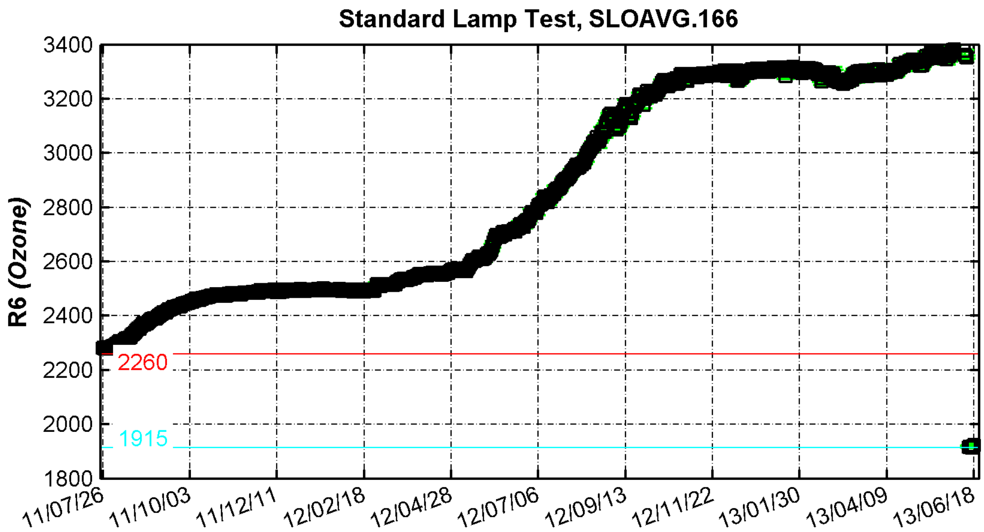


Figure 64. Standard Lamp test R6 (Ozone) ratio

Historical analysis

Standard lamp ratios were very unstable during the last two years. Two main periods are determined based on F5 records: from July 2011 to around May 2012 and from September 2012 to just before the current campaign (June 2013). SL R6 ratio stabilized during the campaign days to the new reference value proposed, 1915. The measured Dead Time constant was around 4 units lower than the operational value. We used an updated DT constant (31 ns) in final configuration file, the same value as the one suggested at El Arenosillo 2011 campaign.

Initial comparison

The original constants provided performed badly, with ozone deviations larger than 50%. Correcting for the SL ratio change improved the comparison, but not enough (see Figure 65, red dotted line). The calibration constants, SL corrected, provided during the last intercomparison campaign (icf18811.166, R6=2260) should be valid until February 2012. We suggest using the new calibration constants icf16113.166 and R6=3365 to re-evaluate ozone data from February 2012 (see Figure 65, black dashed line).

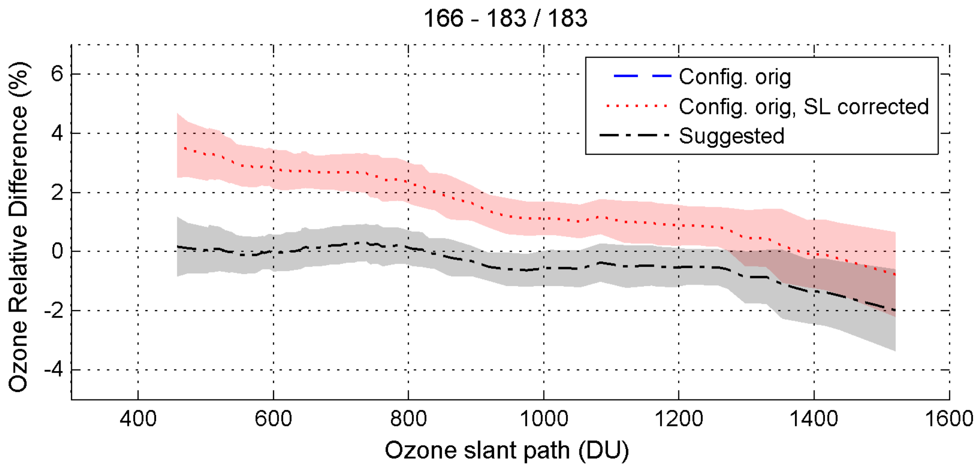


Figure 65. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

We achieved a good agreement with the reference instrument IZO#183 using the new calibration constants (icf16513.166, R6=3130), with ozone deviations within 0.5% (see Figure 66, red solid line) for ozone slant path values lower than around 1200 DU.

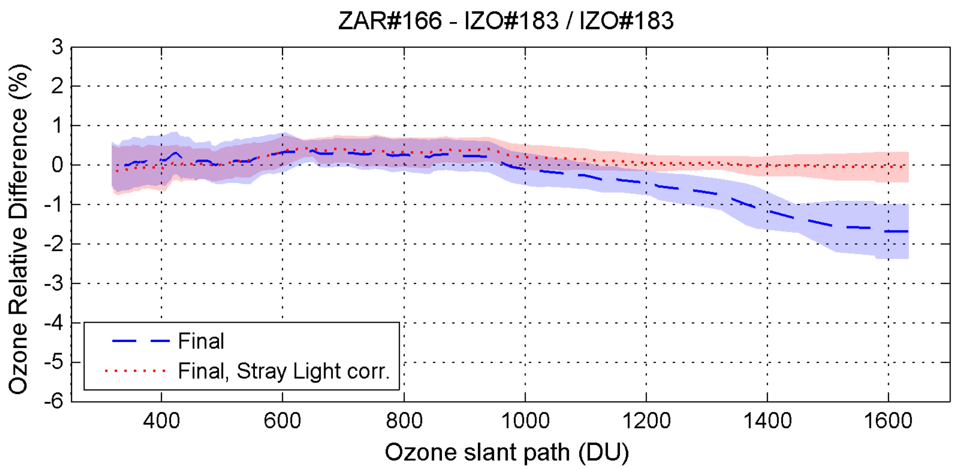


Figure 66. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight

This single Brewer shows not much stray light rejection, leading to ozone being underestimated by around 1% at ozone slant path 1300 DU. This is greatly improved after the stray light correction is applied (see Figure 66, red dotted line).

Calibration constants Summary: ZAR#166

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	3470	4625	3130
SL R6 reference value	2260	3365	1915
change SL R6 ratio /ETC		1105 / 1155	<5 / <5
DT Constant (ns)	33	31	31
Temp. Coeffs.		No Change	No Change
Cal Step Number	283	283	283
Ozone Abs. Coeff.	0.3432	0.3410	0.3410
Stray Light factors (F0 / k / s)			3137 / -9.49 / 5.34
Calibration File recommended	Icf18811.166	Icf16113.166	Icf16513.166

Recommendations and comments

- The SL ratios have been very unstable during the last two years, due to unknown reasons. R6 ratio stabilized during the campaign days, after the maintenance was performed, to the new reference value proposed, 1915. The measured Dead Time constant was about 4 units lower than the operational value. We used the same value as the one proposed during the last intercomparison campaign both for initial as well as for final evaluation purposes.

- We maintain the original temperature coefficients in final configuration file. No correction factors to be applied to attenuation filters are needed.

- Analysis of sun scans performed after the campaign (natural days 185 to 188) confirmed the current calibration step setting. As concerns the ozone absorption coefficient, we suggest using the same value as the one that was given at the last intercomparison campaign.

- A re-evaluation of the past ozone observations is recommended: the calibration constants, SL corrected, provided during the last campaign should work until February 2012. We propose a new set of calibration constants for the period from this date onwards (icf16113.166, R6=3365).

- A large change in the instrument's response is observed after $NiSO_4$ filter replacement. New calibration constants were provided to be applied from 14 June 2013 (icf16513.150, R6=1915).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_166.pdf

8.14 Instrument: UM#172, Station: Manchester, United Kingdom

Brewer UM#172 was present at the campaign from 10 to 19 June 2013. Ozone data collected from 10 to 14 June, before the zenith prism alignment, was used to evaluate the original constants (blind days, 233 near-simultaneous direct sun ozone measurements), whereas days 15 to 19 June (final days, 108 near-simultaneous direct sun measurements) were used for final calibration purposes.

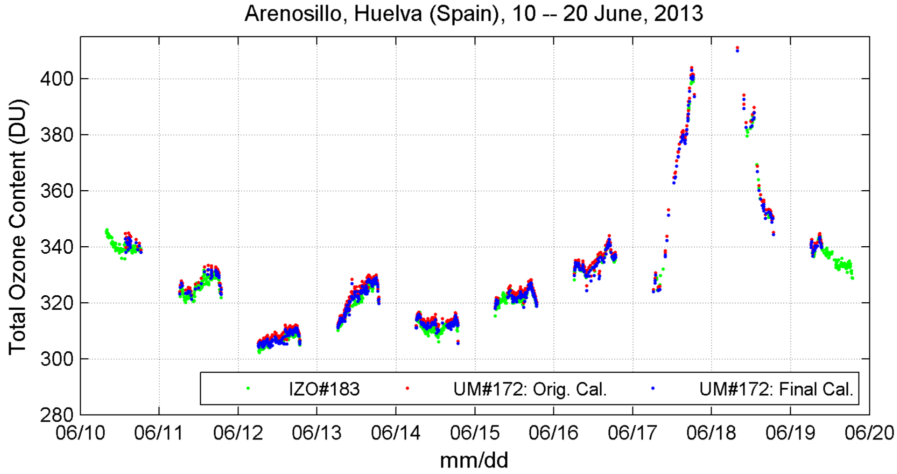


Figure 67. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf18611.172 and reference value 444 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

Historical analysis

The standard lamp performance has been very stable since the 2011 intercomparison campaign, with R6 mean value around 442 (see Figure 68). We did not change the R6 reference value during the current intercomparison. All the other parameters analysed (Dead Time constant, Run/Stop test, Hg lamp intensity, CZ & CI files) were normal.

Initial comparison

The original calibration constants produced ozone deviations more than 0.5% higher as compared to reference instrument IZO#183. Correcting for the standard lamp ratio change did not improve the comparison. We found that agreed the calculated ETC 1705 (note that we used also here the same ozone absorption coefficient, 0.3428). We recommend using the calibration constants provided by the RBCC-E team during the last intercomparison (El Arenosillo 2011, icf18711.172, R6=440) to re-evaluate ozone data from July 2011 to natural day 16513 (see Figure 69, dashed black line).

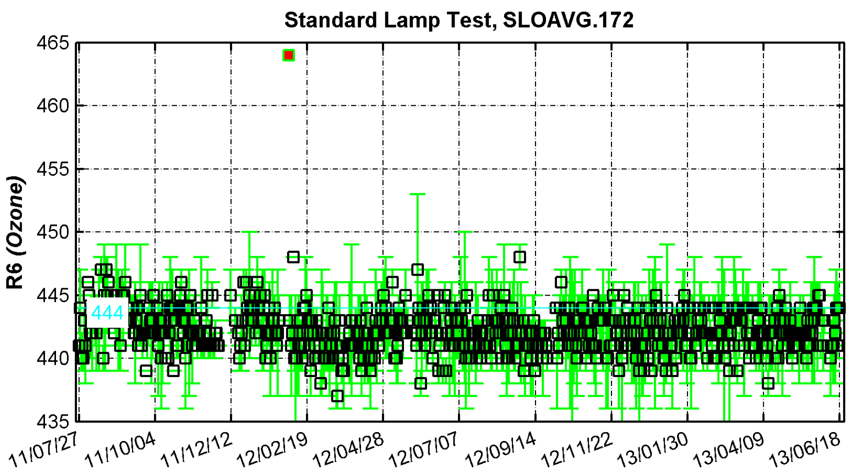


Figure 68. Standard Lamp test R6 (Ozone) ratio

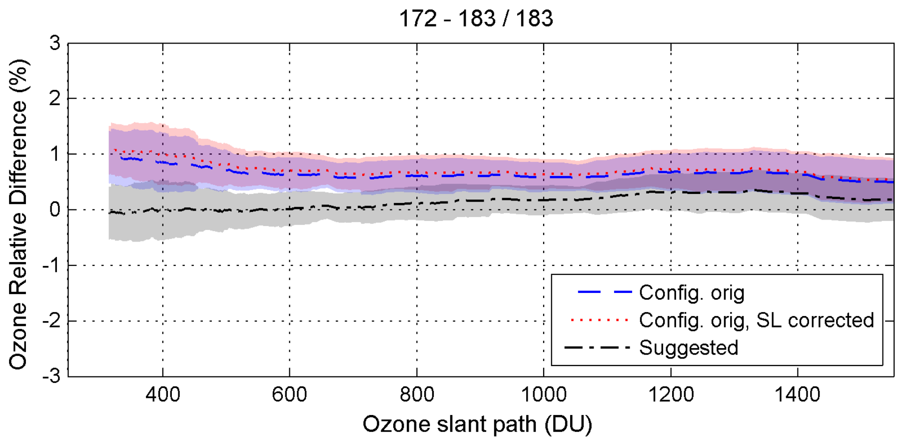


Figure 69. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

We achieved a good agreement with the reference instrument IZO#183 using the proposed calibration constants (icf16613.172, R6=444), with ozone deviations within 0.5% (see Figure 70, black solid line).

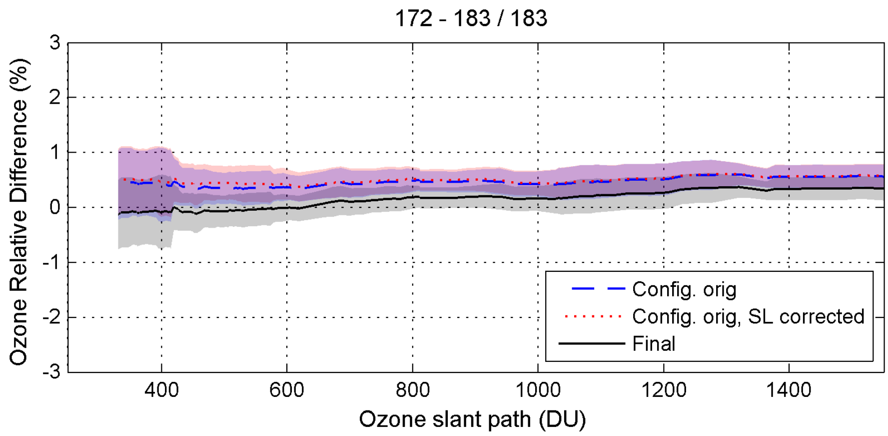


Figure 70. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Calibration constants Summary: UM#172

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	1695	1705	1700
SL R6 reference value	444	440	444
change SL R6 ratio /ETC		<5 / 10	<5 / <5
DT Constant (ns)	30	30	30
Temp. Coeffs.		No Change	No Change
Cal Step Number	286	286	286
Ozone Abs. Coeff.	0.3424	0.3428	0.3428
Stray Light factors (F0 / k / s)			
Calibration File recommended	Icf18611.172	Icf18711.172	Icf16613.172

Recommendations and comments

- The SL ratios have been very stable during the last two years and in good agreement with the provided R6 reference value.
- We did not detect any appreciable temperature dependence in the ozone or the standard lamp observations, which indicates the correct choice of the temperature coefficients. We have not applied any correction factor to neutral density filters.
- We used the same ozone absorption coefficient as the one we provided during the last intercomparison campaign.
- A re-evaluation of the past ozone observations are recommended: the calibration constants provided during the last campaign should work until just the beginning of the current intercomparison.
- New calibration constants were provided to be applied from 15 June 2013 (icf16613.172, R6=444).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_172.pdf

8.15 Instrument: MAD#186, Station: Madrid, Spain

Brewer MAD#186 was present at the campaign from 11 to 19 June 2013. We did not detect any change in the instrument's performance before and after the maintenance, so we used the same ozone data set to evaluate the initial status of the instrument as well as for final calibration purposes (183 near-simultaneous direct sun measurements).

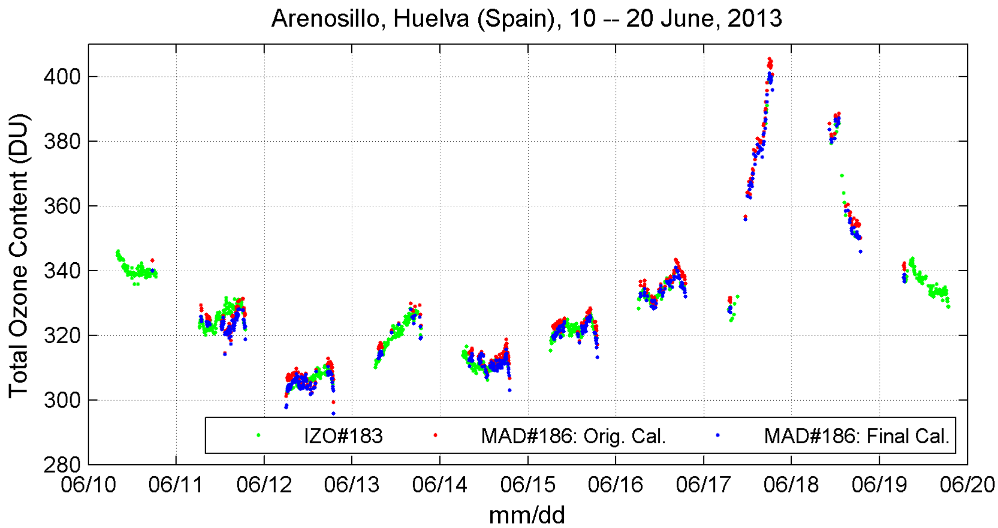


Figure 71. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf19511.186 and reference value 288 for the SL R6 ratio. These calibration constants were obtained after the last RBCC-E intercomparison campaign (July 2011), but using the travelling standard IOS#017 as the reference instrument (calibration constants provided by the private company IOS).

Historical analysis

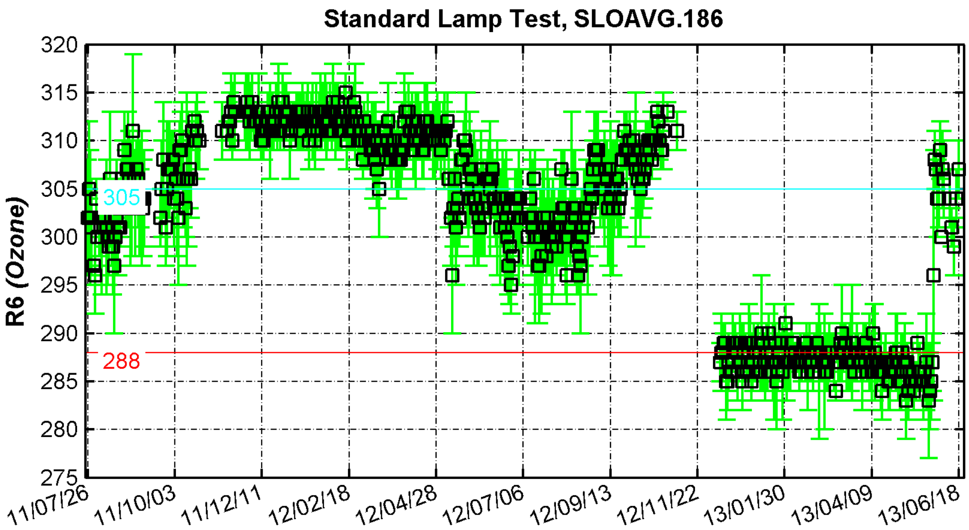


Figure 72. Standard Lamp test R6 (Ozone) ratio

Analysis of SLOAVG files during the last 2 years reveals two periods showing rather different averaged SL ratios: from July 2011 to November 2012, with averaged R6 ratio around 305 and from December 2012 to June 2013, just before the current campaign, with averaged R6 ratio around 288. The new R6 reference value adopted was 305. All the other parameters analysed (Dead Time constant, Run/Stop test, Hg lamp intensity, CZ & CI files) were normal.

Initial comparison

We used the same ozone data set to evaluate the initial status of the instrument as well as for final calibration purposes. The original calibration constants produced total ozone values of the order of 1% higher than those of the reference instrument IZO#183 at large ozone slant paths (see Figure 73). Correcting for the SL change did not improve the comparison. We recommend using the original constants SL corrected to re-evaluate ozone past data from July 2011 to November 2012 (provided you use 305 as the R6 reference value).

Final calibration

A new set of calibration constants (icf16113.186, R6=305) is provided to evaluate ozone data since December 2012 (see Figure 73, black solid line). We used the 2-parameter ETC transfer method to transfer the ETC in the case of Brewer MAD#186.

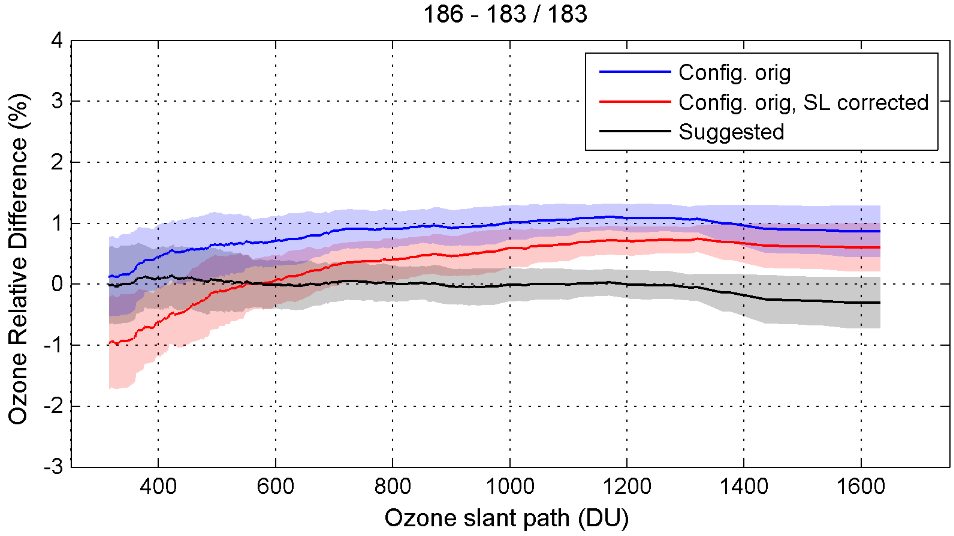


Figure 73. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Straylight

Double monochromator.

Calibration constants Summary: MAD#186

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	1545	1530	1530
SL R6 reference value	288	305	305
change SL R6 ratio /ETC		15 / 15	<5 / <5
DT Constant (ns)	26	26	26
Temp. Coeffs.		No Change	No Change
Cal Step Number	283	283	283
Ozone Abs. Coeff.	0.3425	0.3475	0.3475
Stray Light factors (F0 / k / s)			
Calibration File recommended	Icf19511.186	Icf16113.186	Icf16113.186

Recommendations and comments

- The R6 reference value provided (R6=288) did not match the value proposed during the last intercomparison (305). You should take this into account in order to re-evaluate historical ozone data.
- We maintain the original temperature coefficients in final configuration file. No correction factors to be applied to attenuation filters are needed.
- We have updated the ozone absorption coefficient to a new value 0.3475 in final configuration file. It has been calculated from the 2-parameters ETC transfer method. The wavelength calibration is not correct for this instrument, but it will work reasonably well.

- A re-evaluation of the past ozone observations based in the historical SL data is recommended: on the one hand, the original calibration constants SL corrected should work fine during the period from July 2011 through November 2012 provided you use 305 as the R6 reference value. On the other hand, and from December 2012, the new calibration constants provided during the current intercomparison are also valid constants (icf16113.186, R6=305).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_186.pdf

8.16 Instrument: TAM#201, Station: Tamanrasset, Algeria

Brewer TAM#201 was present at the campaign from 10 to 21 June 2013. Large ozone variability was observed for this instrument during the campaign days (see Figure 76). Possible reasons for this behaviour would be time synchronization issues as well as maintenance been carried out. Among others, the zenith drive was changed and the photomultiplier voltage feeding was raised to a new value 1166 V. Internal halogen and mercury lamps were also replaced, and grating constants were updated. Unfortunately, no valid ozone data was available for evaluation of the original calibration constants. Ozone data collected from 20 to 21 June were used for final calibration purposes (121 near-simultaneous direct sun measurements).

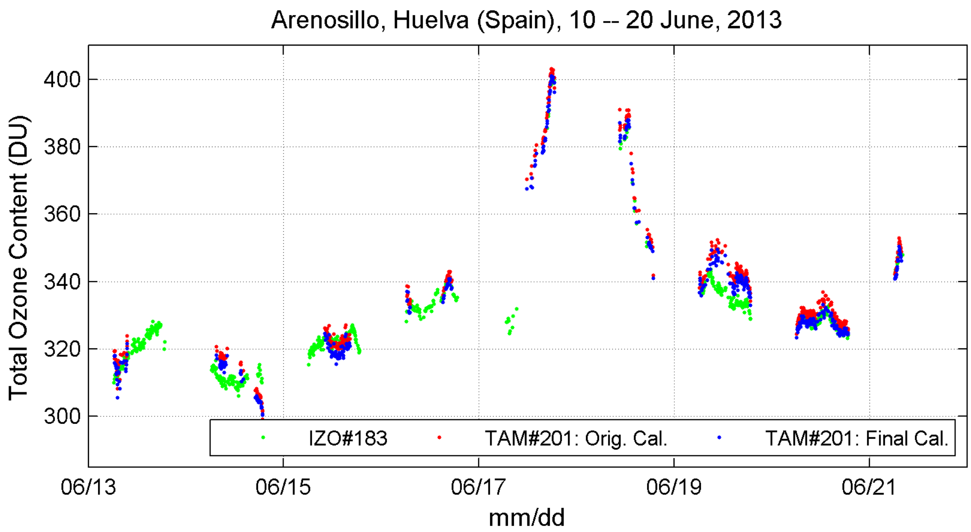


Figure 74. Brewer Intercomparison El Arenosillo 2013

Original calibration

The instrument operates with the configuration file icf29311.201 and reference value 328 for the SL R6 ratio.

Historical analysis

We analysed the period from October 2011, when the instrument was first installed at the Tamanrasset station. The SL R6 ratios show two distinct periods: from October 2011 to June 2012 (R6=315) and from June 2012 to just before the current campaign (R6=305). SL R6 ratio stabilized during the campaign days to the new reference value proposed, 325. The anomalous Dead Time constant observed (10 ns) recovered normal values (28 ns) after the photomultiplier voltage feeding was updated to a new value 1166V on 13 June. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) were normal.

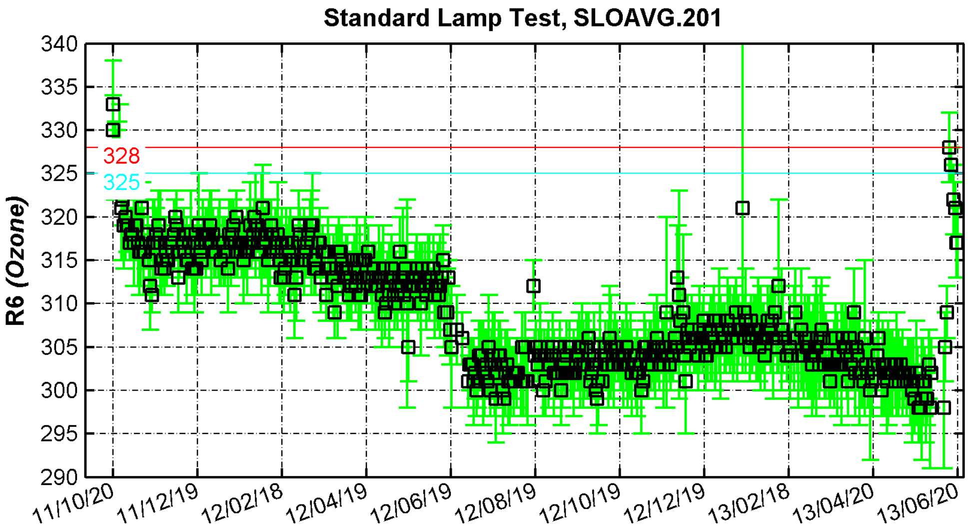


Figure 75. Standard Lamp test R6 (Ozone) ratio

Initial comparison

No valid ozone data was available for evaluation of the original calibration constants. We do not provide any evaluation for the instrument's initial status.

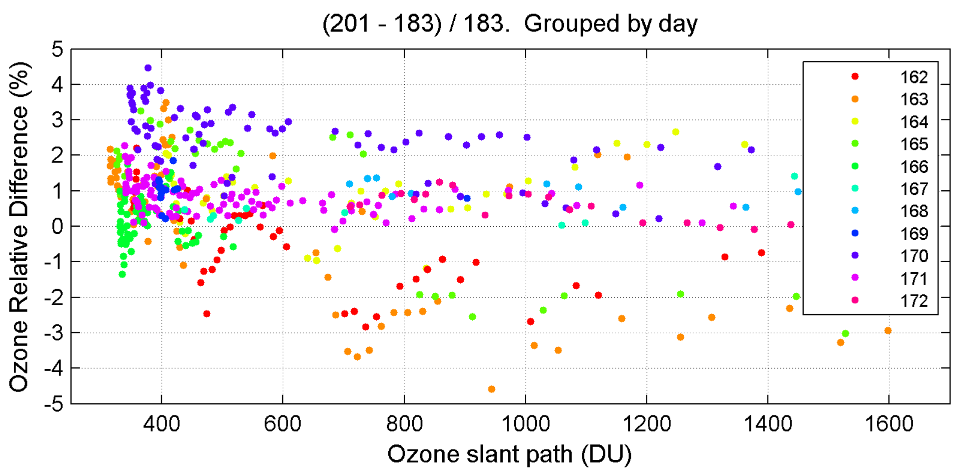


Figure 76. Ozone deviation to the reference instrument as a function of ozone slant path. The shadow areas represent standard deviation.

Final calibration

We used ozone data collected during days 20 to 21 June, after the maintenance was done and time synchronization issues were fixed, for final calibration purposes. We achieved a good agreement with the reference instrument using the new calibration constants (icf16813.201, R6=325), with ozone deviations within 0.5% (see Figure 77).

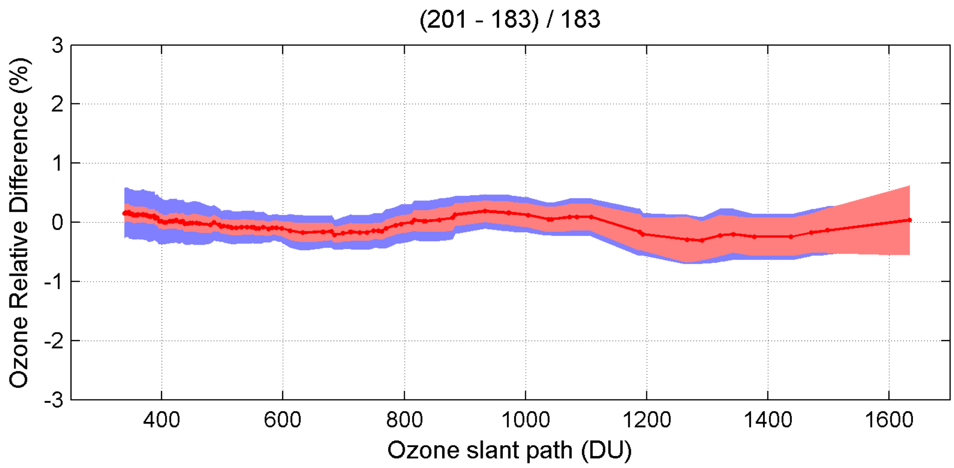


Figure 77. Ozone deviation to the reference instrument as a function of ozone slant path.
The blue and red shadow areas represent the standard deviation and the standard error of the mean, respectively.

Straylight
Double monochromator.

Calibration constants Summary: TAM#201

	Last Cal.	*Initial (blind)*	*Final*
O3 ETC constant	1525		1552
SL R6 reference value	328		325
change SL R6 ratio /ETC		<20 / NaN	<5 / <5
DT Constant (ns)	22		28
Temp. Coeffs.			Change
Cal Step Number	285		285
Ozone Abs. Coeff.	0.3465		0.3465
Stray Light factors (F0 / k / s)			
Calibration File recommended	icf29311.201		Icf16813.201

Recommendations and comments

- We note two main periods in the SL R6 ratios during the last two years, characterized with mean values of 315 (October 2011 to June 2012) and 305 (June 2012 to June 2013).

- Anomalously low Dead Time constant (around 10 ns) has been measured since November 2011, more than 11 units lower than the operational value (22 ns). As a consequence of this, the overall instrument's performance resulted significantly affected. In particular, it affected to neutral density filter's performance. The DT constant recovered normal values, around 28 ns, after the photomultiplier voltage feeding was raised to a new value 1166 V.

- We have updated the temperature coefficients in the final configuration file. No correction factors are needed to be applied to neutral density filters.

- Analysis of sun scans performed during the campaign days confirmed the operational calibration step number. As concerns the ozone absorption coefficient, no change is suggested.

- Grating constants as well as dispersion relation were updated (new file dcf16813.201), improving the wavelength accuracy of this instrument.

- We could not provide an evaluation of the initial status for Brewer TAM#201. However, the original calibration constant corrected by the SL change could improve the overall instrument's performance. We suggest confirming this through comparison of Brewer ozone data with satellite overpass.

- New calibration constants were provided to be applied from 17 June 2013 (icf16813.201, R6=325).

Calibration report

http://www.iberonesia.net/archives/reports/Are2013/CALIBRATION_201.pdf

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LIST OF RECENT GLOBAL ATMOSPHERE WATCH REPORTS*

149. Comparison of Total Ozone Measurements of Dobson and Brewer Spectrophotometers and Recommended Transfer Functions (prepared by J. Staehelin, J. Kerr, R. Evans and K. Vanicek) (WMO TD No. 1147).

150. Updated Guidelines for Atmospheric Trace Gas Data Management (Prepared by Ken Maserie and Pieter Tans (WMO TD No. 1149).

151. Report of the First CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Geneva, Switzerland, 18-19 March 2003) (WMO TD No. 1181).

152. Current Activities of the Global Atmosphere Watch Programme (as presented at the 14th World Meteorological Congress, May 2003). (WMO TD No. 1168).

153. WMO/GAW Aerosol Measurement Procedures: Guidelines and Recommendations. (WMO TD No. 1178).

154. WMO/IMEP-15 Trace Elements in Water Laboratory Intercomparison. (WMO TD No. 1195).

155. 1st International Expert Meeting on Sources and Measurements of Natural Radionuclides Applied to Climate and Air Quality Studies (Gif sur Yvette, France, 3-5 June 2003) (WMO TD No. 1201).

156. Addendum for the Period 2005-2007 to the Strategy for the Implementation of the Global Atmosphere Watch Programme (2001-2007), GAW Report No. 142 (WMO TD No. 1209).

157. JOSIE-1998 Performance of EEC Ozone Sondes of SPC-6A and ENSCI-Z Type (Prepared by Herman G.J. Smit and Wolfgang Straeter) (WMO TD No. 1218).

158. JOSIE-2000 Jülich Ozone Sonde Intercomparison Experiment 2000. The 2000 WMO international intercomparison of operating procedures for ECC-ozone sondes at the environmental simulation facility at Jülich (Prepared by Herman G.J. Smit and Wolfgang Straeter) (WMO TD No. 1225).

159. IGOS-IGACO Report - September 2004 (WMO TD No. 1235), 68 pp, September 2004.

160. Manual for the GAW Precipitation Chemistry Programme (Guidelines, Data Quality Objectives and Standard Operating Procedures) (WMO TD No. 1251), 186 pp, November 2004.

161 12th WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurement Techniques (Toronto, Canada, 15-18 September 2003), 274 pp, May 2005.

162. WMO/GAW Experts Workshop on a Global Surface-Based Network for Long Term Observations of Column Aerosol Optical Properties, Davos, Switzerland, 8-10 March 2004 (edited by U. Baltensperger, L. Barrie and C. Wehrli) (WMO TD No. 1287), 153 pp, November 2005.

163. World Meteorological Organization Activities in Support of the Vienna Convention on Protection of the Ozone Layer (WMO No. 974), 4 pp, September 2005.

164. Instruments to Measure Solar Ultraviolet Radiation: Part 2: Broadband Instruments Measuring Erythemally Weighted Solar Irradiance (WMO TD No. 1289), 55 pp, July 2008, electronic version 2006.

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* *(A full list is available at http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html)*

165. Report of the CAS Working Group on Environmental Pollution and Atmospheric Chemistry and the GAW 2005 Workshop, 14-18 March 2005, Geneva, Switzerland (WMO TD No. 1302), 189 pp, March 2005.

166. Joint WMO-GAW/ACCENT Workshop on The Global Tropospheric Carbon Monoxide Observations System, Quality Assurance and Applications (EMPA, Dübendorf, Switzerland, 24 – 26 October 2005) (edited by J. Klausen) (WMO TD No. 1335), 36 pp, September 2006.

167. The German Contribution to the WMO Global Atmosphere Watch Programme upon the 225th Anniversary of GAW Hohenpeissenberg Observatory (edited by L.A. Barrie, W. Fricke and R. Schleyer (WMO TD No. 1336), 124 pp, December 2006.

168. 13th WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurement Techniques (Boulder, Colorado, USA, 19-22 September 2005) (edited by J.B. Miller) (WMO TD No. 1359), 40 pp, December 2006.

169. Chemical Data Assimilation for the Observation of the Earth's Atmosphere – ACCENT/WMO Expert Workshop in support of IGACO (edited by L.A. Barrie, J.P. Burrows, P. Monks and P. Borrell) (WMO TD No. 1360), 196 pp, December 2006.

170. WMO/GAW Expert Workshop on the Quality and Applications of European GAW Measurements (Tutzing, Germany, 2-5 November 2004) (WMO TD No. 1367).

171. A WMO/GAW Expert Workshop on Global Long-Term Measurements of Volatile Organic Compounds (VOCs) (Geneva, Switzerland, 30 January – 1 February 2006) (WMO TD No. 1373), 36 pp, February 2007.

172. WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008 – 2015 (WMO TD No. 1384), 108 pp, August 2008.

173. Report of the CAS Joint Scientific Steering Committee on Environmental Pollution and Atmospheric Chemistry (Geneva, Switzerland, 11-12 April 2007) (WMO TD No.1410), 33 pp, June 2008.

174. World Data Centre for Greenhouse Gases Data Submission and Dissemination Guide (WMO TD No. 1416), 50 pp, January 2008.

175. The Ninth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Delft, Netherlands, 31-May – 3 June 2005) (WMO TD No. 1419), 69 pp, March 2008.

176. The Tenth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Northwich, United Kingdom, 4-8 June 2007) (WMO TD No. 1420), 61 pp, March 2008.

177. Joint Report of COST Action 728 and GURME – Overview of Existing Integrated (off-line and on-line) Mesoscale Meteorological and Chemical Transport Modelling in Europe (ISBN 978-1-905313-56-3) (WMO TD No. 1427), 106 pp, May 2008.

178. Plan for the implementation of the GAW Aerosol Lidar Observation Network GALION, (Hamburg, Germany, 27 - 29 March 2007) (WMO TD No. 1443), 52 pp, November 2008.

179. Intercomparison of Global UV Index from Multiband Radiometers: Harmonization of Global UVI and Spectral Irradiance (WMO TD No. 1454), 61 pp, March 2009.

180. Towards a Better Knowledge of Umkehr Measurements: A Detailed Study of Data from Thirteen Dobson Intercomparisons (WMO TD No. 1456), 50 pp, December 2008.

181. Joint Report of COST Action 728 and GURME – Overview of Tools and Methods for Meteorological and Air Pollution Mesoscale Model Evaluation and User Training (WMO TD No. 1457), 121 pp, November 2008.

182. IGACO-Ozone and UV Radiation Implementation Plan (WMO TD No. 1465), 49 pp, April 2009.

183. Operations Handbook – Ozone Observations with a Dobson Spectrophotometer (WMO TD No. 1469), 91 pp, March 2009.

184. Technical Report of Global Analysis Method for Major Greenhouse Gases by the World Data Center for Greenhouse Gases (WMO TD No. 1473), 29 pp, June 2009.

185. Guidelines for the Measurement of Methane and Nitrous Oxide and their Quality Assurance (WMO TD No. 1478), 49 pp, September 2009.

186. 14th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (Helsinki, Finland, 10-13 September 2007) (WMO TD No. 1487), 31 pp, April 2009.

187. Joint Report of COST Action 728 and GURME – Review of the Capabilities of Meteorological and Chemistry-Transport Models for Describing and Predicting Air Pollution Episodes (ISBN 978-1-905313-77-8) (WMO TD No. 1502), 69 pp, December 2009, electronic version -July 2009.

188. Revision of the World Data Centre for Greenhouse Gases Data Submission and Dissemination Guide (WMO TD No.1507), 55 pp, November 2009.

189. Report of the MACC/GAW Session on the Near-Real-Time Delivery of the GAW Observations of Reactive Gases, Garmisch-Partenkirchen, Germany, 6-8 October 2009, (WMO TD No. 1527), 31 pp. August 2010.

190. Instruments to Measure Solar Ultraviolet Radiation Part 3: Multi-channel filter instruments (lead author: G. Seckmeyer) (WMO TD No. 1537), 55 pp. November 2010.

191. Instruments to Measure Solar Ultraviolet Radiation Part 4: Array Spectroradiometers (lead author: G. Seckmeyer) (WMO TD No. 1538), 43 pp. November 2010.

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193. Guidelines for Reporting Total Ozone Data in Near Real Time (WMO TD No. 1552), 19 pp, April 2011 *(electronic version only).*

194. 15th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (Jena, Germany, 7-10 September 2009) (WMO TD No. 1553). 330 pp, April 2011.

195. WMO/GAW Expert Workshop on Global Long-term Measurements of Nitrogen Oxides and Recommendations for GAW Nitrogen Oxides Network (Hohenpeissenberg, Germany, 8-9 October 2009) (WMO TD No. 1570), 45 pp, February 2011.

196. Report of the Second Session of the CAS JSC OPAG-EPAC and GAW 2009 Workshop (Geneva, Switzerland, 5-8 May 2009), (WMO TD No. 1577).

197. Addendum for the Period 2012 – 2015 to the WMO Global Atmosphere Watch (GAW) Strategic Plan 2008 – 2015, 57 pp, May 2011.

198. Data Quality Objectives (DQO) for Solar Ultraviolet Radiation Measurements (Part I). Addendum to WMO/GAW Report No. 146 - Quality Assurance in Monitoring Solar Ultraviolet Radiation: State of the Art (*electronic version only*).

199. Second Tropospheric Ozone Workshop. Tropospheric Ozone Changes: observations, state of understanding and model performances (Météo France, Toulouse, France, 11-14 April 2011), 226 pp, September 2011.

200. WMO/GAW Standard Operating Procedures for In-Situ Measurements of Aerosol Mass Concentration, Light Scattering and Light Absorption (Edited by John A. Ogren), 134 pp, October 2011.

201. Quality Assurance and Quality Control for Ozonesonde Measurements in GAW (Prepared by Herman Smit and ASOPOS Panel), 95 pp. October 2014

202. Workshop on Modelling and Observing the Impacts of Dust Transport/Deposition on Marine Productivity (Sliema, Malta, 7-9 March 2011), 50 pp, November 2011.

203. The Atmospheric Input of Chemicals to the Ocean. Rep. Stud. GESAMP No. 84/GAW Report No. 203. 69 pp. (ISSN: 1020-4873).

204. Standard Operating Procedures (SOPs) for Air Sampling in Stainless Steel Canisters for Non-Methane Hydrocarbons Analysis (Prepared by Rainer Steinbrecher and Elisabeth Weiß), 25 pp. September 2012.

205. WMO/IGAC Impacts of Megacities on Air Pollution and Climate, 309 pp. September 2012 (ISBN: 978-0-9882867-0-2).

206. 16th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (GGMT-2011), Wellington, New Zealand, 25-28 October 2011, 67 pp, October 2012.

207. Recommendations for a Composite Surface-Based Aerosol Network, Emmetten, Switzerland, 28-29 April 2009, 66 pp. November 2012.

208. WMO GURME Workshop on Urban Meteorological Observation Design, (Shanghai, China, 11-14 December 2011).

209. Guidelines for Continuous Measurements of Ozone in the Troposphere (Prepared by Ian E. Galbally and Martin G. Schultz), 80 pp, February 2013 (WMO-No. 1110, ISBN: 978-92-63-11110-4).

210. Report of the Third Session of the CAS Joint Scientific Committee of the Open Programme Area Group on Environmental Polllution and Atmospheric Chemistry (JSC OPAG-EPAC), (Geneva, Switzerland, 27-29 April 2011) (*electronic version only*).

211. Rationalizing Nomenclature for UV Doses and Effects on Humans (CIE209:2014/GAW Report No. 211) (ISBN: 978-3-902842-35-0).

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213. 17th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (GGMT-2013), (Beijing, China, 10 - 13 June 2013), 168 pp. July 2014.

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215. Report of the First Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC), (Geneva, Switzerland, 10-12 June 2014), 32 pp. December 2014.

216. Seventh Intercomparison Campaign of the Regional Brewer Calibration Center Europe (RBCC-E), Lichtklimatisches Observatorium, Arosa, Switzerland, 16-27 July 2012, 106 pp. March 2015.

217. System of Air Quality Forecasting And Research (SAFAR – India), 60 pp. June 2015.

218. Absorption Cross-Sections of Ozone (ACSO), Status Report as of December 2015, 46 pp. December 2015.

219. Izaña Atmospheric Research Center, Activity Report 2012-2014,157 pp. June 2015.

220. Report of the Second Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC), Geneva, Switzerland, 18-20 February 2015, 54 pp. June 2015.

221. Report for the First Meeting of the WMO GAW Task Team on Observational Requirements and Satellite Measurements (TT-ObsReq) as regards Atmospheric Composition and Related Physical Parameters, Geneva, Switzerland, 10-13 November 2014, 22 pp. July 2015.

222. Analytical Methods for Atmospheric SF6 Using GC-μECD, World Calibration Centre for SF6 Technical Note No. 1. 47 pp. September 2015.