GAW Report No. 248

Twelfth Intercomparison Campaign of the Regional Brewer Calibration Center Europe

El Arenosillo Atmospheric Sounding Station, Huelva, Spain
29 May to 9 June 2017

WORLD METEOROLOGICAL ORGANIZATION

GLOBAL ATMOSPHERE WATCH

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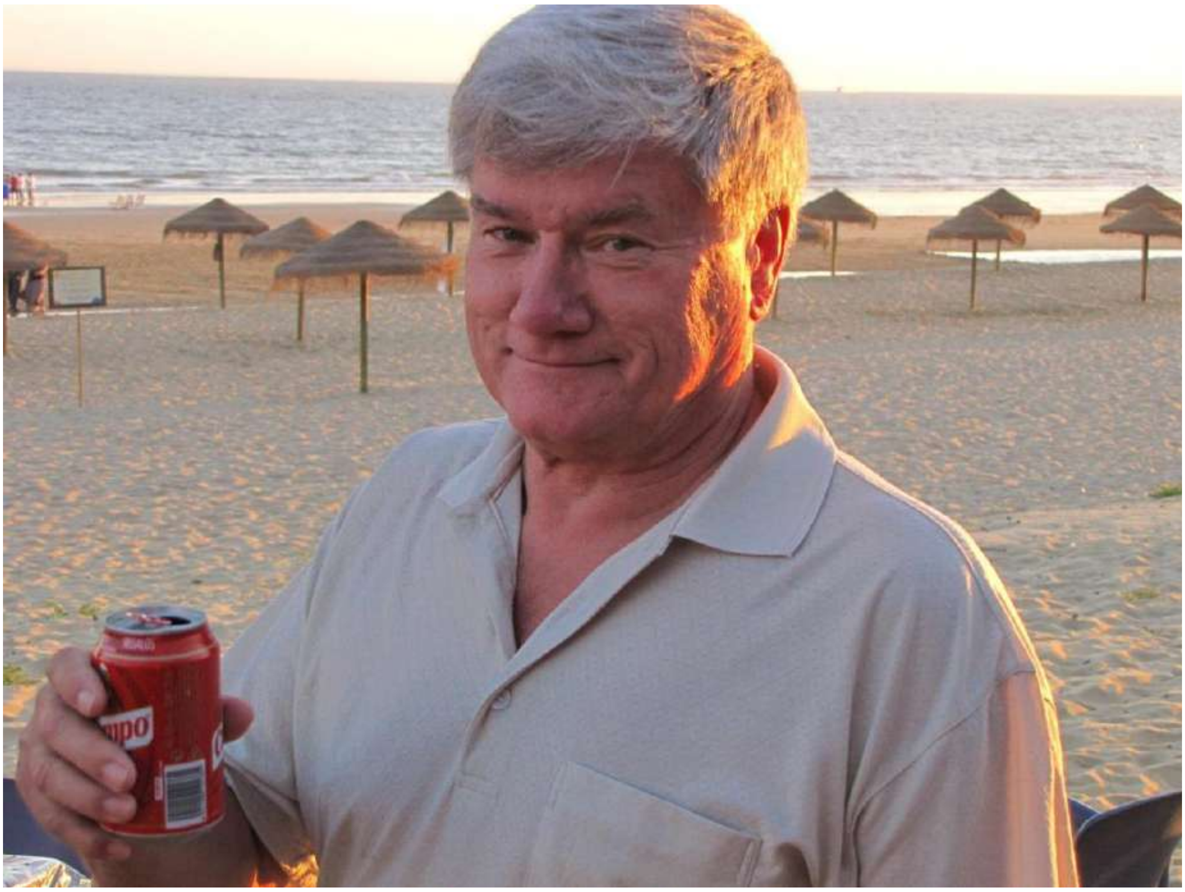
IN MEMORIAM

(7 February 1946-5 May 2017)

We would like to pay heartfelt tribute to our friend Ken Lamb, who passed away on 25 May 2017 just before the campaign started. Ken Lamb participated in many campaigns that we organized since our first in 1999. He accompanied us regularly in calibrations of our Brewers and collaborated with the RBCC-E since its establishment in 2003. He always helped us in the most difficult moments, and this Calibration Center would never have existed without his help, support and valuable input. We will always remember him. Ken Lamb was first and foremost a good person who will always be with us.



Ken Lamb at the farewell party during the 2013 campaign

1. INTRODUCTION

The twelfth European Brewer Intercomparison Campaign was organized by the Regional Brewer Calibration Center for Europe (RBCC-E) in collaboration with the "Area of Instrumentation and Atmospheric Research Area" of Instituto Nacional de Tecnica Aeroespacial (INTA), with the support of the Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO) and the EUBREWNET ES1207 COST Action. Alongside the campaign, the ATMOZ (Traceability of Atmospheric Total Ozone) project workshop took place at the station. In addition, this event was also used as a demonstration exercise of the calibration methodologies and error assessment developed by the project (Gröbner et al., 2018).

In this campaign, the RBCC-E transferred its own absolute ozone calibration obtained from the Langley method at the Izaña Observatory (IZO) to all other participating instruments. The calibration of the reference instrument (B#185) is discussed in Section 2. From the comparison with the reference instrument, all the participating Brewers were provided with a provisional calibration at the end of the campaign, which can be considered as final calibration constants for most of them. A detailed calibration report for each instrument is available online. Detailed historical data of the Brewers that have participated in previous campaigns are also included in the calibration report. This allows an easy recalculation of the past ozone data. In Section 3, the results from the comparison with the Regional standard are discussed for each instrument along with an individual summary of the findings and recommendations. A participant's list is presented in Table 1.

A total number of 20 Brewer spectrophotometers from nine countries took part in the intercomparison (see Table 1 and Appendix 3). Such intercomparison campaigns, with a large number of participating 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#185 for ozone and with the European reference standard from the World Radiation Center (WRC) QASUME unit for UV. The results for the UV campaign are available at the WRC website (Gröbner et al., 2017).

The following operations were performed by the RBCC-E during the intercomparison:

- Ozone calibration against the RBCC-E travelling reference (B#185).
- Compilation of the calibration histories of the instruments.
- Evaluation of the Level 2 Eubrewnet ozone data for the period between intercomparisons.

The initial Brewer comparison results (using the instruments' original calibration constants) indicate that the overall agreement is slightly lower than in the previous campaign; during this campaign 44% of the instruments present an ozone deviation lower than 1% with respect to the reference (see Figure 2), whereas the agreement in the previous campaign reached 50% of the instruments. On this campaign 72% of the instruments agree on the 2% range whereas in previous campaigns around 75% of the instruments reached this agreement (Redondas et al., 2018).

After the maintenance tasks, performed by International Ozone Services Inc. (IOS), using the new determined calibration constant and the stray light correction applied to single monochromator Brewers, the agreement with respect to the reference was very good: +/- 0.5% (Figure 3).

Figure 1. View of the Brewer spectrophotometers at El Arenosillo Atmospheric Sounding Station, Huelva, Spain

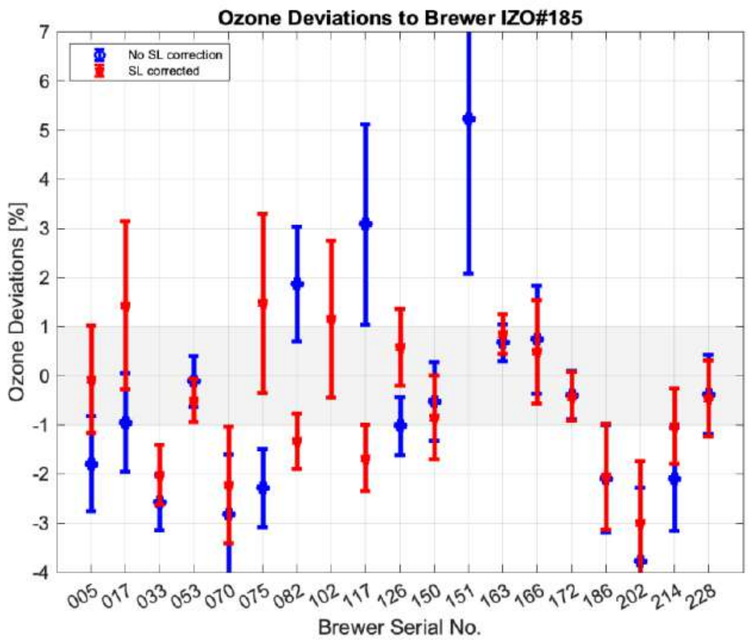


Figure 2. Ozone relative percentage differences of all Arenosillo 2017 participating instruments to RBCC-E travelling standard #185. Ozone measurements collected during the blind period are reprocessed using the original calibration constants, with (red) and without (blue) standard lamp correction. Error bars represent the standard deviation.

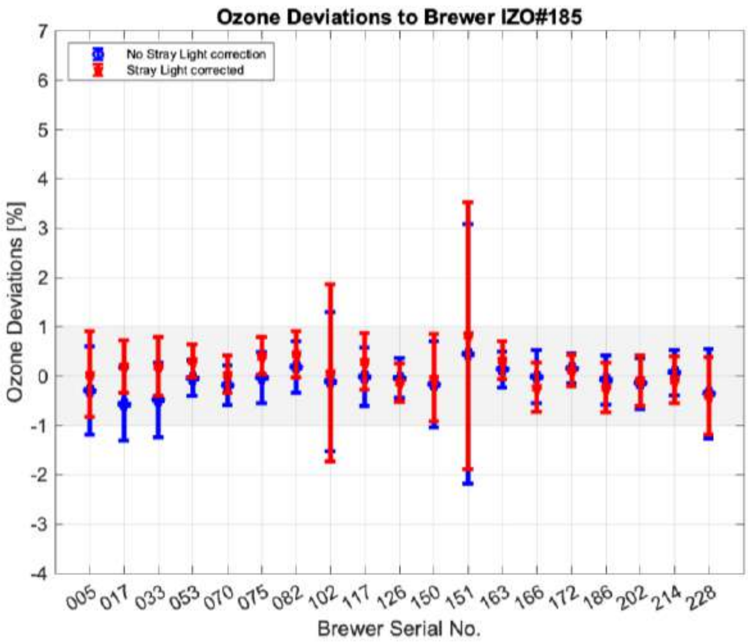


Figure 3. Ozone relative percentage differences of all El Arenosillo 2017 participating instruments to RBCC-E travelling standard #185. Ozone measurements collected during the final period are reprocessed using the updated calibration constants, with (red) and without (blue) stray light correction. Error bars represent the standard deviation.

Table 1. List of Participants

Institution	*PI*	*Brewer*	*Country*
TSK Thessaloniki University	Alkis Bais	#005	Greece
IOS International Ozone Service	Volodia Savastiouk	#017	Canada
SCO AEMET	Juan R. Moreta	#033	Spain
DNK Danish Meteorological Institute	Niss Jepsen	#053	Demark
MAD AEMET	Juan R. Moreta	#070	Spain
UM Manchester University	John Rimmer	#075	United Kingdom
DNK Danish Meteorological Institute	Niss Jepsen	#082	Demark
POR Instituto Português do Mar e da Atmosfera	Diamantino Henriques	#102	Portugal
MUR AEMET	Juan R. Moreta	#117	Spain
UM Manchester University	John Rimmer	#126	United Kingdom
INTA	J. M. Vilaplana	#150	Spain
COR AEMET	Juan R. Moreta	#151	Spain
WRC World Radiation Centre	Luca Egli	#163	Switzerland
ZAR AEMET	Juan R. Moreta	#166	Spain
UM Manchester University	John Rimmer	#172	United Kingdom
AEMET-IARC	Alberto Redondas	#185	Spain
AEMET	Juan R. Moreta	#186	Spain
DNK Danish Meteorological Institute	Paul Eriksen	#202	Denmark
Finnish Meteorological Institute	Tomi Karppinen	#214	Finland
DNK Danish Meteorological Institute	Paul Eriksen	#228	Denmark

2. CAMPAIGN GENERAL VIEW

2.1 Weather conditions and campaign schedule

The ozone calibration for Brewers requires clear skies. The weather conditions during the campaign at the El Arenosillo Sounding Station were excellent, with more than 800 direct sun observations of the reference instrument, allowing enough ozone measurements so as to perform a reliable calibration for all the instruments. The maintenance of the Brewer instruments was performed by IOS, and a summary of the maintenance works is provided in Appendix 1. The coordination of the measurement schedules, designed to maximize the ozone measurements during the campaign, worked properly, resulting in a large percentage of potential near-simultaneous ozone measurements by all the instruments. The conditions during the campaign are summarized in Figures 4, 5 and 6. Total ozone content during the campaign at El Arenosillo ranged between 320 and 355 DU. Most of the measurements (≈ 70%) were within the 350-600 DU ozone slant column (OSC) range. The internal instruments' temperature was approx. 30 +/- 10°C.

The activities carried out each day of the campaign are shown in Table 2. The first day was dedicated to the installation of the instrument. The next two days were dedicated to "blind" comparison. During blind days, any manipulation of the instrument that could produce a change on the initial calibration was avoided. After that, the service days started, when the routine measurement schedule could have been interrupted to perform any required maintenance tasks, and when standard characterization tests were performed (dispersion tests, lamp calibrations, and so forth). In this campaign, the instrument's repair and maintenance services were performed by IOS experts. Finally, the programmed UV measurements days are considered as final days for ozone calibration.

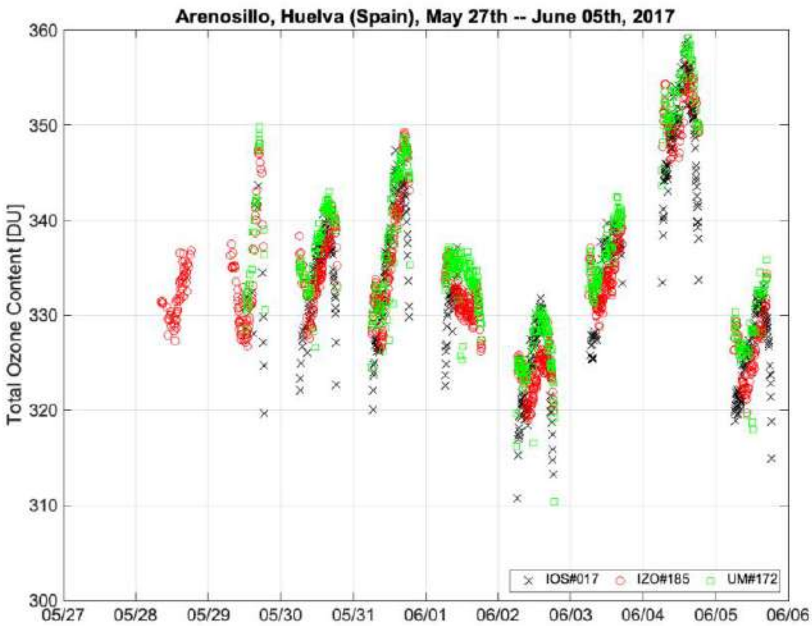


Figure 4. Total ozone observations of the reference instruments: RBCC-E travelling standard #185, IOS travelling #017 and the double monochromator #172.

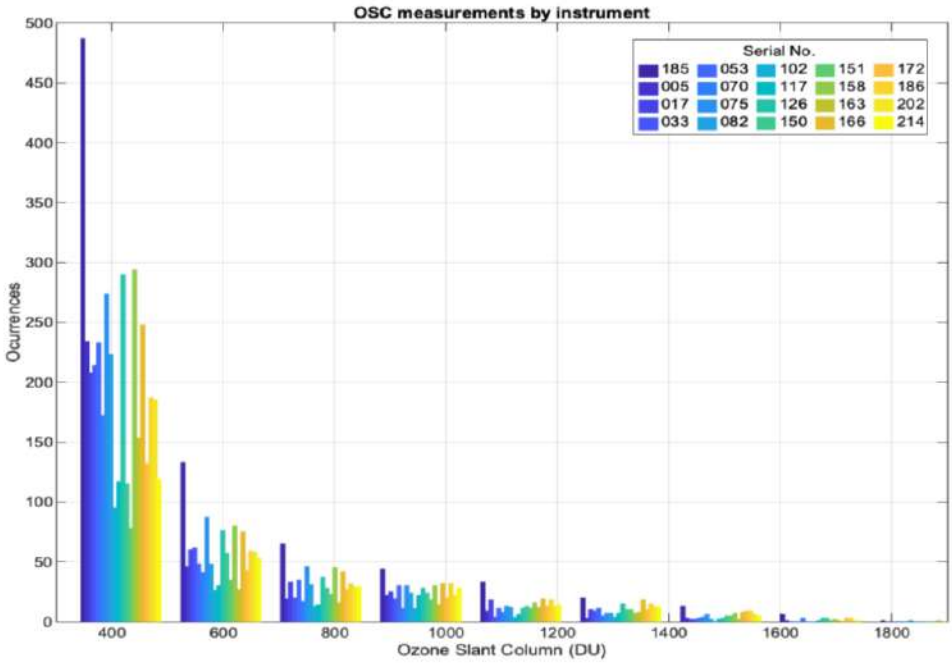


Figure 5. Statistics of the intercomparison conditions: frequency distribution of ozone slant column ranges

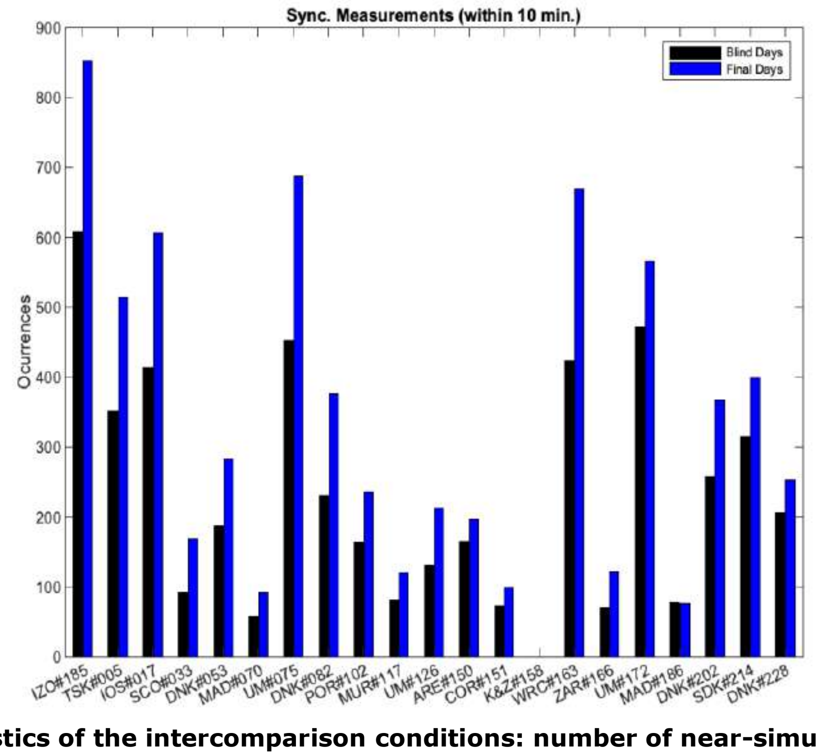


Figure 6. Statistics of the intercomparison conditions: number of near-simultaneous ozone measurements during blind (black) and final days (blue)

Table 2. Campaign schedule

Day	*Actions*	*Notes*
Monday 29 May	Installation	
Tuesday 30 May	O_3 Measurements	Blind days
Wednesday 31 May	O_3 Measurements	Blind days
Thursday 1 June	O_3 Measurements - O_3 Service	Maintenance
Friday 2 June	O_3 Measurements - O_3 Service	Maintenance
Saturday 3 June	O_3 Measurements - O_3 Service	Maintenance
Sunday 4 June	O_3/UV Measurements - O_3 Service	Maintenance
Monday 5 June	O_3/UV Measurements	Ozone final calibration
Tuesday 6 June	O_3/UV Measurements	Ozone final calibration UV comparison with QASUME
Wednesday 7 June	O_3/UV Measurements	Ozone final calibration UV comparison with QASUME
Thursday 8 June	O_3/UV Measurements	Ozone final calibration UV comparison with QASUME
Friday 9 June	Packing	

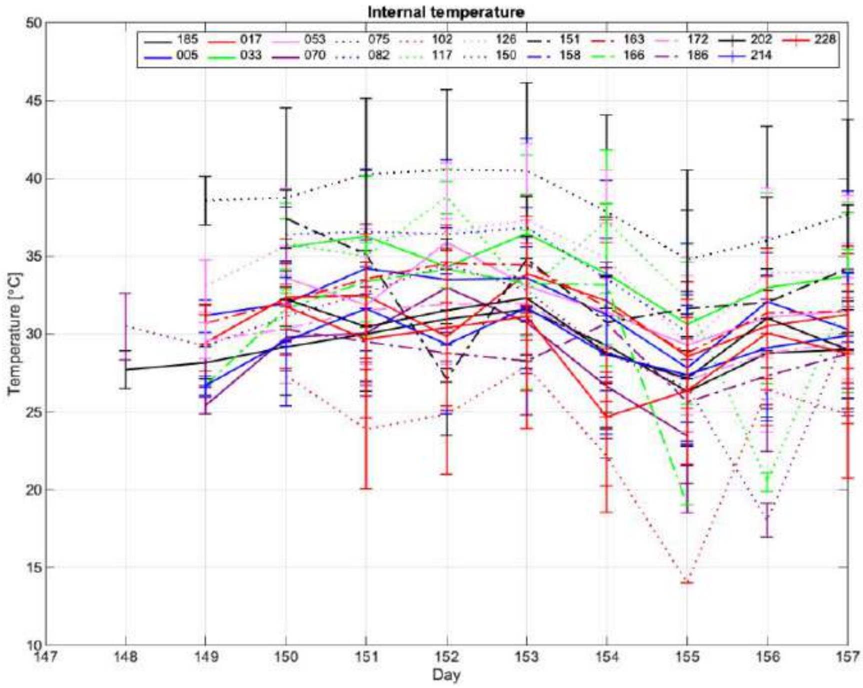


Figure 7. Statistics of the intercomparison conditions: internal temperature variability for all participating instruments

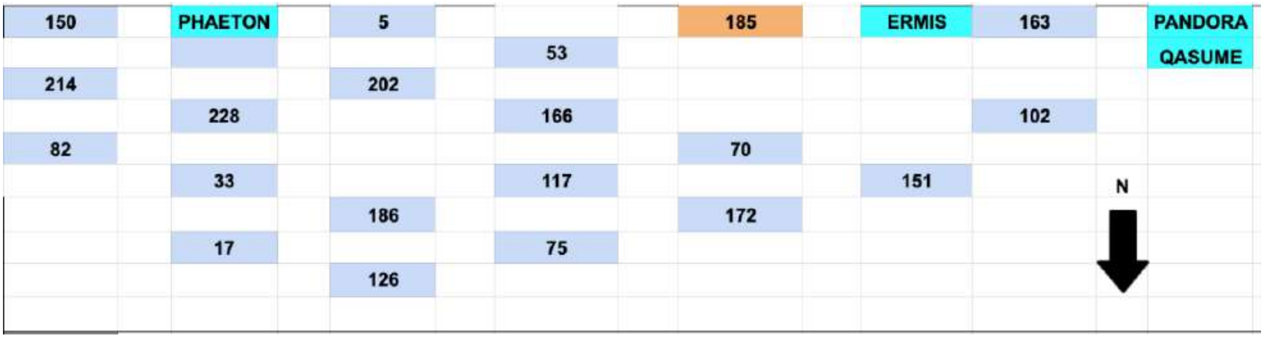


Figure 8. Schematics of the Brewers' locations at the terrace of El Arenosillo Station and the instrument participating at the ATMOZ comparison, ERMIS and QASUME managed by the World Radiation Center, PHAETON managed by Thessaloniki University and PANDORA managed by Izaña Atmospheric Research Centre.

2.2 RBCC-E Brewer spectrometer report

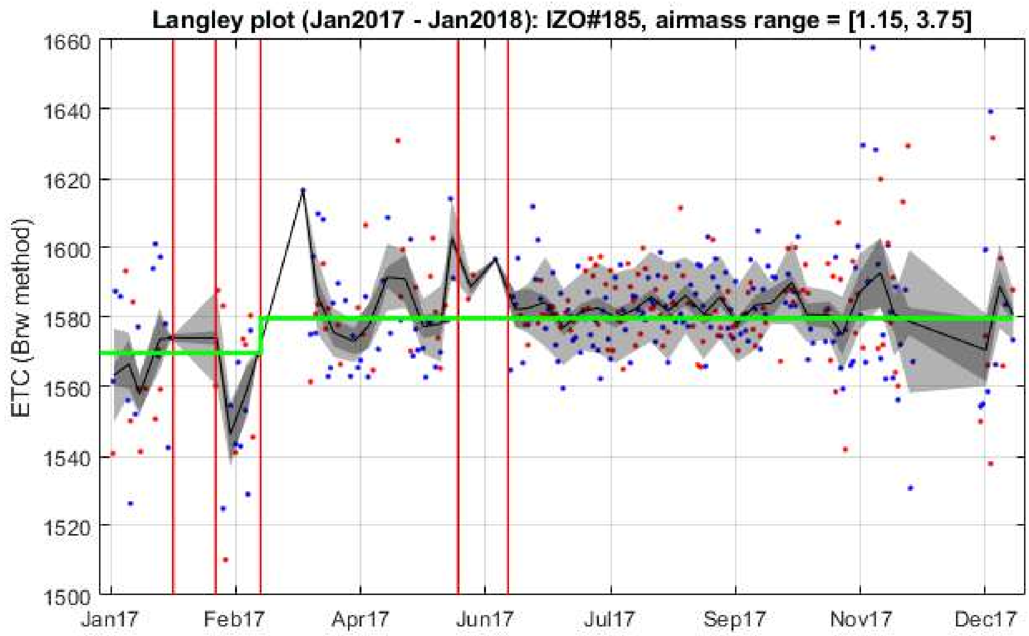
The RBCC-E was established at the Izaña Atmospheric Research Centre in 2003. It comprises three MkIII Brewer spectrophotometers: a Regional Primary Reference (Brewers#157), a Regional Secondary Reference (Brewers#183) and a Regional Travelling Standard (Brewers#185). The calibration of the RBCC-E triad against the World Brewer Triad (WBT) was established by a yearly comparison with the IOS travelling standard Brewer#017 and checked at the station by means of the Langley extrapolation method. In addition, during the RBCC-E Brewer intercomparison campaigns the travelling standard #185 is compared with other reference instruments when it is possible. These reference instruments are: IOS travelling reference #017, Brewer #145, operated by Environment and Climate Change Canada (ECCC), and Kipp & Zonen travelling reference #158. The first two instruments provide a direct link to the WBT. A report of the comparison between the references can be found in Redondas et al. 2018.

Since the beginning of 2012, due to the internal reorganization of the Spanish Meteorological Service (AEMET), the technical maintenance of the RBCC-E Brewer triad has been performed by Kipp & Zonen, Brewer manufacturer, and linking it to the WBT was achieved through comparisons directly in Toronto or by joint Langley campaigns at Mauna Loa or IZO stations. Such an intercomparison has not been possible since 2014, although the WMO scientific advisory group (WMO-SAG) authorized the RBCC-E in 2011 to transfer its own ozone absolute calibration. The methodology used to transfer ozone calibration is described in Redondas et al. (2003, 2018) and Ito et al. (2011). The current status and maintenance of the RBCC-E is discussed in Leon-Luis et al. (2018).

As a preliminary and subsequent task during all the calibration campaign, the reference instrument (Brewer#185) was analysed in detail. Its instrumental parameters – dead time, temperature dependence, as well as its ozone absorption coefficient were calculated from a dispersion test and were compared with the values recorded prior to the campaign.

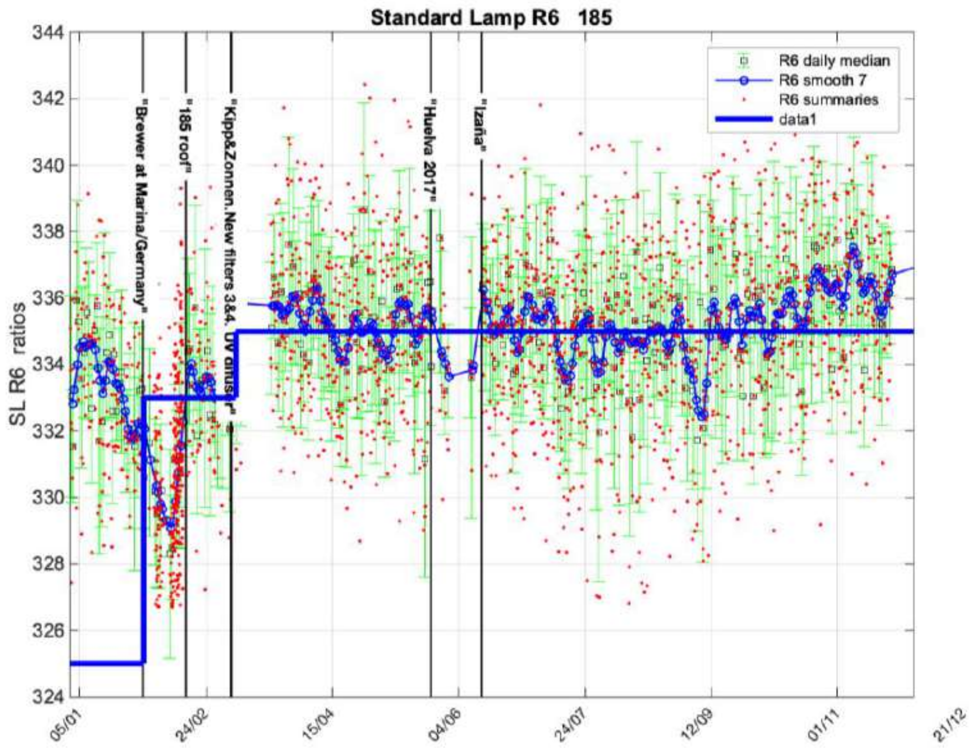
However, the Langley technique is the best procedure to detect if the calibration of the instrument has changed. In this respect, the extraterrestrial constant (ETC) obtained from this method must be constant as a guarantee of the instrument calibration. Figure 9 shows the Langley values calculated before and after the campaign from morning and afternoon observations made during this year. As can be observed, the values obtained are situated around 1580, which is used as ETC operative for this instrument. The stability of the

Brewer#185 since the maintenance of March 2017 can also be seen with the standard lamp measurements, shown in Figure 10.



Date	Brw	Brw Se	Dbs	Dbs Se	N	Comments
1/17/2017	1567.3	4.0	-2.1	3.9	25.0	Heater replaced
2/24/2017	1556.4	5.2	-13.5	5.2	18.0	Storm
4/23/2017	1582.2	1.9	2.6	2.0	62.0	Before Huelva, (Filter Replaced)
9/7/2017	1582.6	0.9	2.3	0.9	269.0	After Huelva 2017

Figure 9. Langley ETC calculation at IZO (Izaña Observatory) for Brewer #185 during 2017. The blue dots correspond to Langley results derived from morning (AM) observations and red dots correspond to afternoon (PM) observations. The black line represents the weekly means for both AM and PM Langley results, showing with dark and light grey shadows the standard error and the standard deviation from the mean, respectively. The vertical red lines indicate relevant events in the instrument's operation, see Table in the bottom panel.



Date	R6	std	R5	std_1	N	Comments
12/26/2016	333.4	1.4	489.4	2.1	29	Heater fix
1/30/2017	330.3	1.2	486.7	1.1	13	PTB (Germany)
2/16/2017	333.6	1.3	490.8	2.5	18	Storm
3/6/2017	335.3	1.2	494.1	2.2	68	Filter replacement
5/24/2017	334.5	1.4	494.8	3.6	7	Huelva 2017
6/13/2017	335.4	1.4	494.5	2.3	180	After Huelva 2017

Figure 10. Standard lamp ozone R6 ratios: daily mean and standard deviation (squares) and individual tests (black dots). The solid blue line represents the standard lamp R6 reference value used during the period of analysis. Vertical black lines mark the important events that concern the instrument's performance (see the table in bottom panel).

In addition, Table 3 shows the ETC values calculated from 1-point and 2-point methods when the Brewer#185 is calibrated from the other instruments that form part of the RBCC-E Triad (Brewer#157 and Brewer#183), which remain in the Izaña Atmospheric Observatory (IZO). The ETC and ozone coefficient and the operative values are compared with each other. Figure 11 shows the direct sun ozone measurements and relative differences of individual RBCC-E triad Brewers from the mean of the three instruments during the period from January 2017 to October 2019. Figure 12 shows in more detail the daily relative differences of the ozone observations between the three instruments before and after the Arenosillo campaign, which is of around 0.25% with respect to the mean. Finally, a summary with the main parameters of Brewer#185 is presented in Table 4.

Table 3. ETC values calculated from comparison between the RBCC-E instruments

Comparison RBCC-E instruments before the El Arenosillo Campaign						
Brewer Calibrated	Brewer Reference	$ETC_{Operative}$ (Langley)	O_3 Operative	ETC_{1P}	ETC_{2P}	O_3 2P
185	157	1580	0.341	1581	1568	0.344
185	183	1580	0.341	1574	1576	0.341
Comparison RBCC-E instruments after the El Arenosillo Campaign						
Brewer Calibrated	Brewer Reference	$ETC_{Operative}$ (Langley)	O_3 Operative	ETC_{1P}	ETC_{2P}	O_3 2P
185	183	1580	0.341	1583	1572	0.343
185	157	1580	0.341	1575	1580	0.340

Table 4. Reference checklist

Travelling Standard checklist: Brewer#185	*Step description*	*Passed?* Y	N	*Value*	*Comments*
Calibration data					
Reference of the travelling (Triad, RBCC-E,....)	RBCC-E reference #157, Absolute calibration (Langley)				
Is travelling standard calibrated?		Y			
% difference before travel				-0.2+/-0.3	620 obs
% difference after travel				-0.08+/- 0.3	966 obs

Instrument operation

HP/HG	Hp/Hg tests repeatable to within 0.2 steps	Y			
SH	SH shutter delay is correct				
RS	Run/Stop test within +/- 0.003 from unity for illuminated slits and between 0.5 and 2 for the dark count	Y			NAN
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		N	29	DT on cfg 33 ns
SL R6	SL ratio R6 is within 5 units from calibration	Y		217/216	
SL R5	SL ratio R5 is within 10 units from calibration	Y			

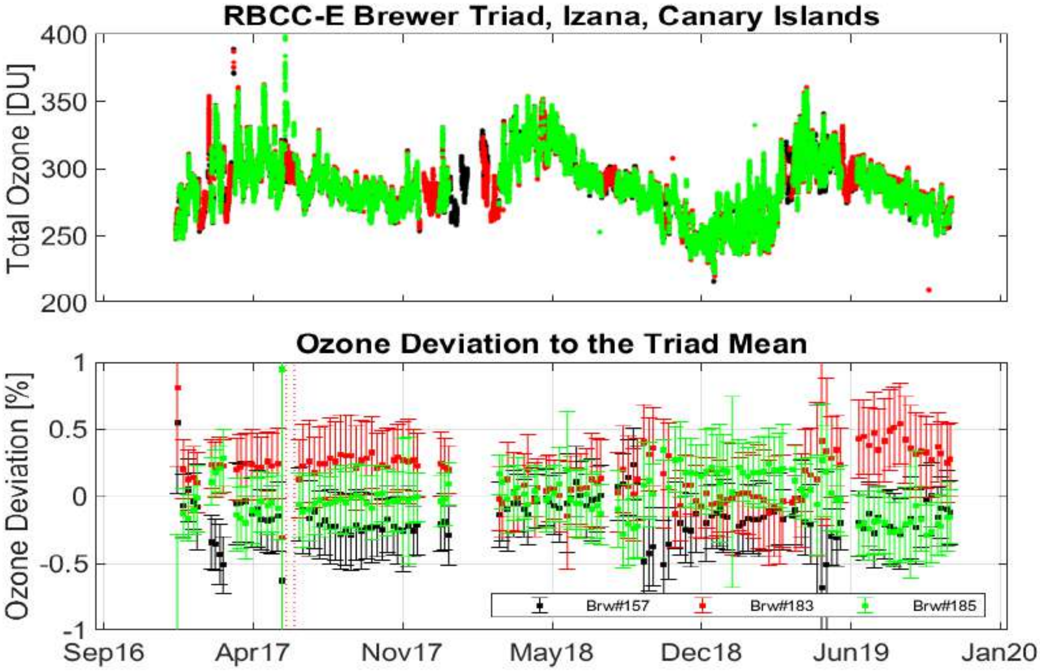


Figure 11. Near-simultaneous (within 5 minutes) direct sun ozone measurements (top) and deviations of ozone values of individual RBCC-E triad Brewers from the mean of the three instruments (bottom) during the period from January 2017 to October 2019. Each point on the graph represents a weekly average. Dot lines represent the Intercomparison campaign period, from 29th May (day of year 149) to 9th June (day of year 160) 2017.

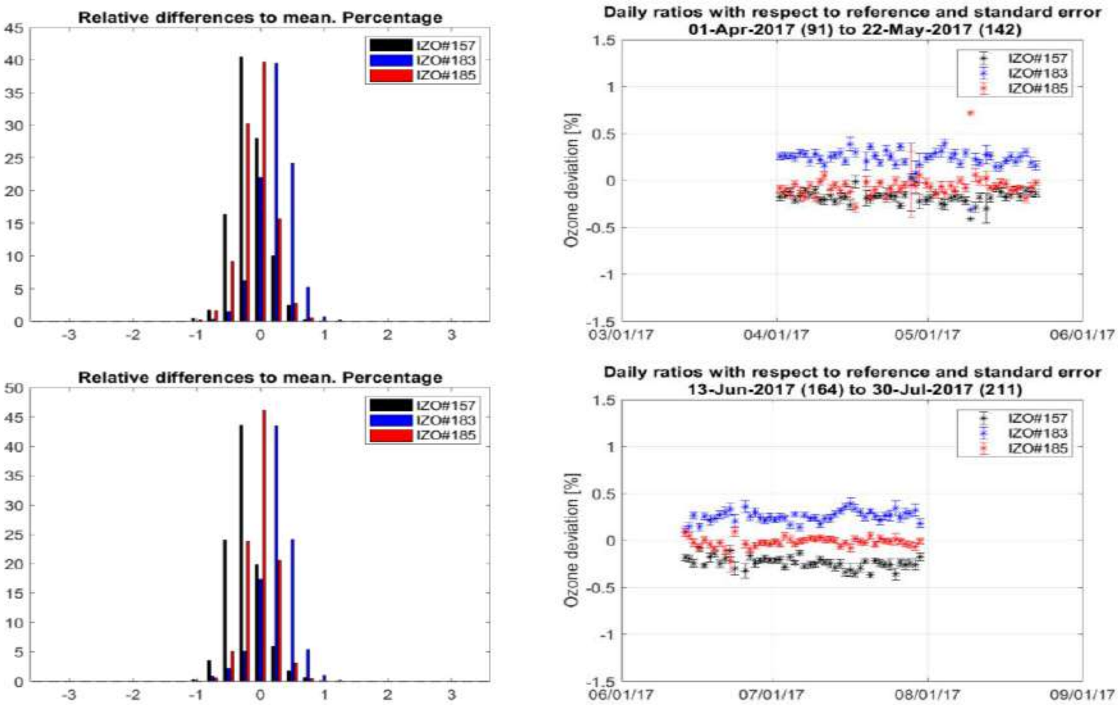


Figure 12. Deviations of near-simultaneous ozone measurements of RBCC-E standard Brewer (serial no. #157, #183 and #185) to the triad mean (left) and temporal evolution of daily mean deviation of near-simultaneous ozone measurements with the error bars representing the standard error (right). Data before (top) and after (bottom) the El Arenosillo 2017 intercomparison are presented.

2.3 Blind comparison

A blind comparison with the standard Brewer gives us an idea of the initial status of the instrument, such as how well the instrument performed using the original calibration constants (those operational at the instrument's station). Possible changes in the instrument response due to the travel can be detected through the analysis of internal tests performed before and after travelling.

The instruments are working during this period with their home calibration and the ozone is calculated using these calibration constants. The standard lamp (SL) test is an ozone measurement using the internal halogen lamp as a source. This test is performed routinely to track the spectral response of the instrument and therefore the ozone calibration. A reference value for the SL R6 ratio is provided as part of the calibration of the instrument. The ozone is routinely corrected assuming that deviations of the R6 value from the reference value are the same as the ones that change in the extraterrestrial constant (ETC). This is so-called standard lamp correction. Hence, it is reasonable to investigate if the observed R6 changes are related to similar changes in the calibration constant. If this was the case, then the ETC constant should be corrected by the same change in SL R6 ratio as $ETC_{new} = ETC_{old} - (SL_{ref} - SL_{measured})$.

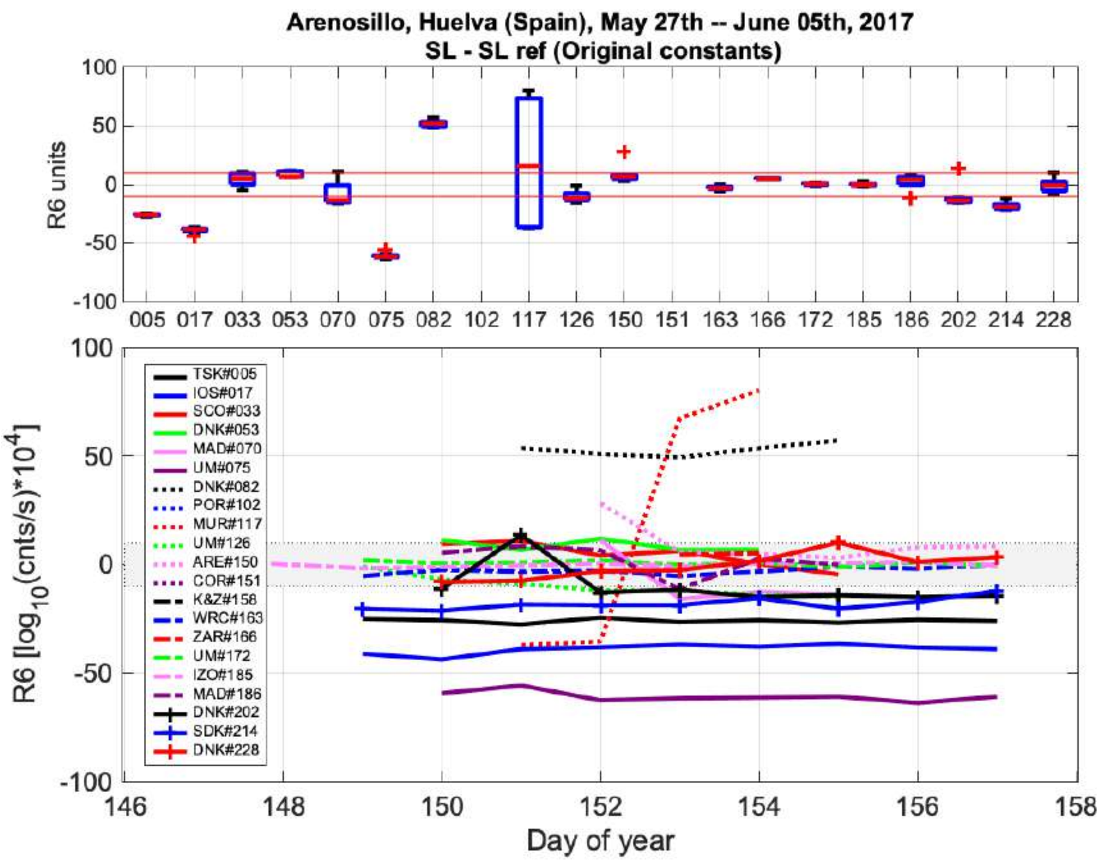


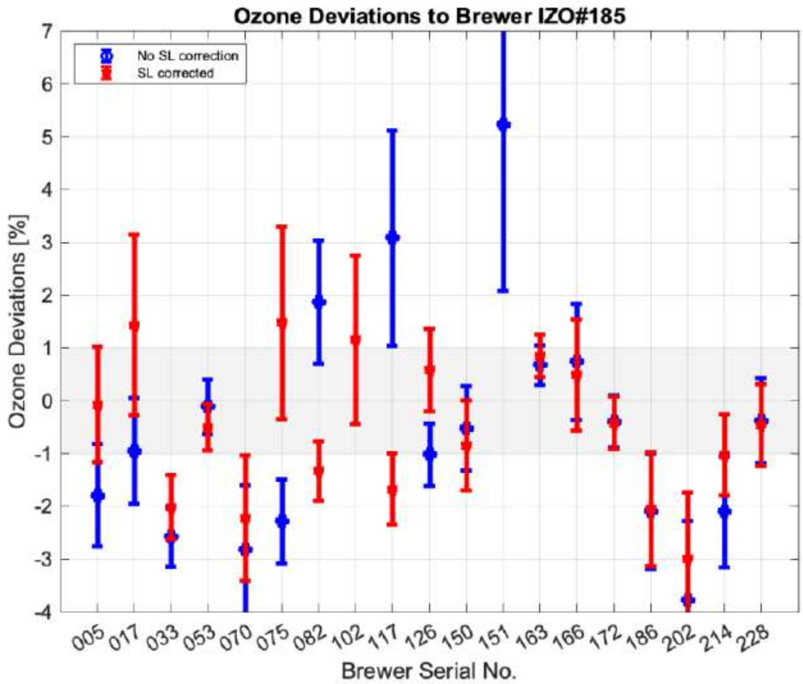
Figure 13. Standard lamp R6 difference to R6 reference value from the last calibration during the blind days, before maintenance. Variations within the ± 10 range (≈1% in ozone) are considered normal, whereas larger changes would require further analysis of the instrument performance.

Table 5. Standard lamp reference value from the last calibration, mean value during intercomparison blind days and its difference for all the participating instruments. The last column shows the associated percentage in ozone change if we apply the standard lamp correction (assuming the measurements at air mass 2).

	SL REF	*mean SL*	*Δ*	*ΔO3 (%)*
TSK_005	**1857**	**1831**	**26**	**3.9**
IOS_017	**2170**	**2131**	**39**	**5.7**
SCO_033	2329	2333	-4	-0.6
DNK_053	1845	1854	-9	-1.3
MAD_070	1703	1695	8	1.2
UM_075	**1769**	**1708**	**61**	**9.0**
DNK_082	**1615**	**1667**	**-52**	**-7.3**
POR_102	**2350**	**2763**	**-413**	**-60.0**
MUR_117	**1536**	**1555**	**-19**	**-2.8**
UM_126	2093	2083	10	1.5
ARE_150	322	332	-10	-1.5
COR_151	**1198**	**1393**	**-195**	**-28.5**
WRC_163	270	267	3	0.4
ZAR_166	1952	1957	-5	-0.7
UM_172	444	445	-1	-0.1
IZO_185	335	335	0	0.0
MAD_186	317	319	-2	-0.3
DNK_202	283	273	10	1.5
SDK_214	**234**	**216**	**18**	**2.6**
DNK_228	242	241	1	0.1

During the El Arenosillo 2017 intercomparison campaign 11 instruments agreed on average with the corresponding R6 reference value within ±10 units, which is about 1% ozone. The comparison with a standard instrument is the only way to assess whether the SL measurements properly track changes on the calibration constants or the change observed is just due to changes in the lamp's spectral emission. For example, in the case of Brewer #005, the SL correction improved the comparison, as can be seen in Figures 13 and 14. From this we deduced that changes in the SL ratios were related to changes in the instrument's response to light.

Results of the blind comparison with the standard instrument Brewer IZO#185 were slightly lower than normal, with ozone deviations greater than 1% for half of the instruments (see Figures 14 and 15). The travelling standard Brewer IOS#017, which is used to transfer the ozone calibration worldwide, shows a good agreement of 0.7%, but of around 2% when standard lamp correction is used. Due to the stray light rejection in single Brewers (single monochromator), a marked ozone slant column dependence in ozone measurements is observed for these instruments.



	No Standard Lamp Corr.	*Standard Lamp Corr.*		*No Standard Lamp Corr.*	*Standard Lamp Corr.*
TSK_005	-1.7+/-0.88	0.1+/-0.92	**ARE_150**	-0.6+/-0.86	-0.9+/-0.91
IOS_017	-0.7+/-0.62	1.9+/-1.18	**COR_151**	5.7+/-2.53	-33.5+/-8.42
SCO_033	-2.5+/-0.48	-2.0+/-0.48	**WRC_163**	0.7+/-0.37	0.9+/-0.39
DNK_053	-0.0+/-0.39	-0.4+/-0.34	**ZAR_166**	1.1+/-0.63	0.8+/-0.63
MAD_070	-2.7+/-1.04	-2.0+/-0.92	**UM_172**	-0.4+/-0.50	-0.5+/-0.51
UM_075	-2.1+/-0.42	1.9+/-1.23	**MAD_186**	-2.3+/-0.90	-2.2+/-0.89
DNK_082	2.1+/-0.85	-1.2+/-0.45	**DNK_202**	-4.2+/-1.10	-3.4+/-0.90
POR_102	30.0+/-7.63	1.5+/-1.22	**SDK_214**	-2.3+/-0.81	-1.2+/-0.62
MUR_117	3.7+/-1.24	-1.6+/-0.64	**DNK_228**	-0.4+/-0.83	-0.5+/-0.77
UM_126	-0.9+/-0.44	0.8+/-0.41			

Figure 14. Ozone relative percentage differences of all El Arenosillo 2017 participating instrument to RBCC-E travelling standard IZO#185. Ozone measurements collected during the blind period ar reprocessed using the original calibration constants, with (red plots) and without (blue plots) SL correction. Error bars represent the standard deviation. The table below the graph shows deviations of ozone values to the reference Brewer IZO#185 for ozone slant path below 900 DU, with and without applying the standard lamp correction.

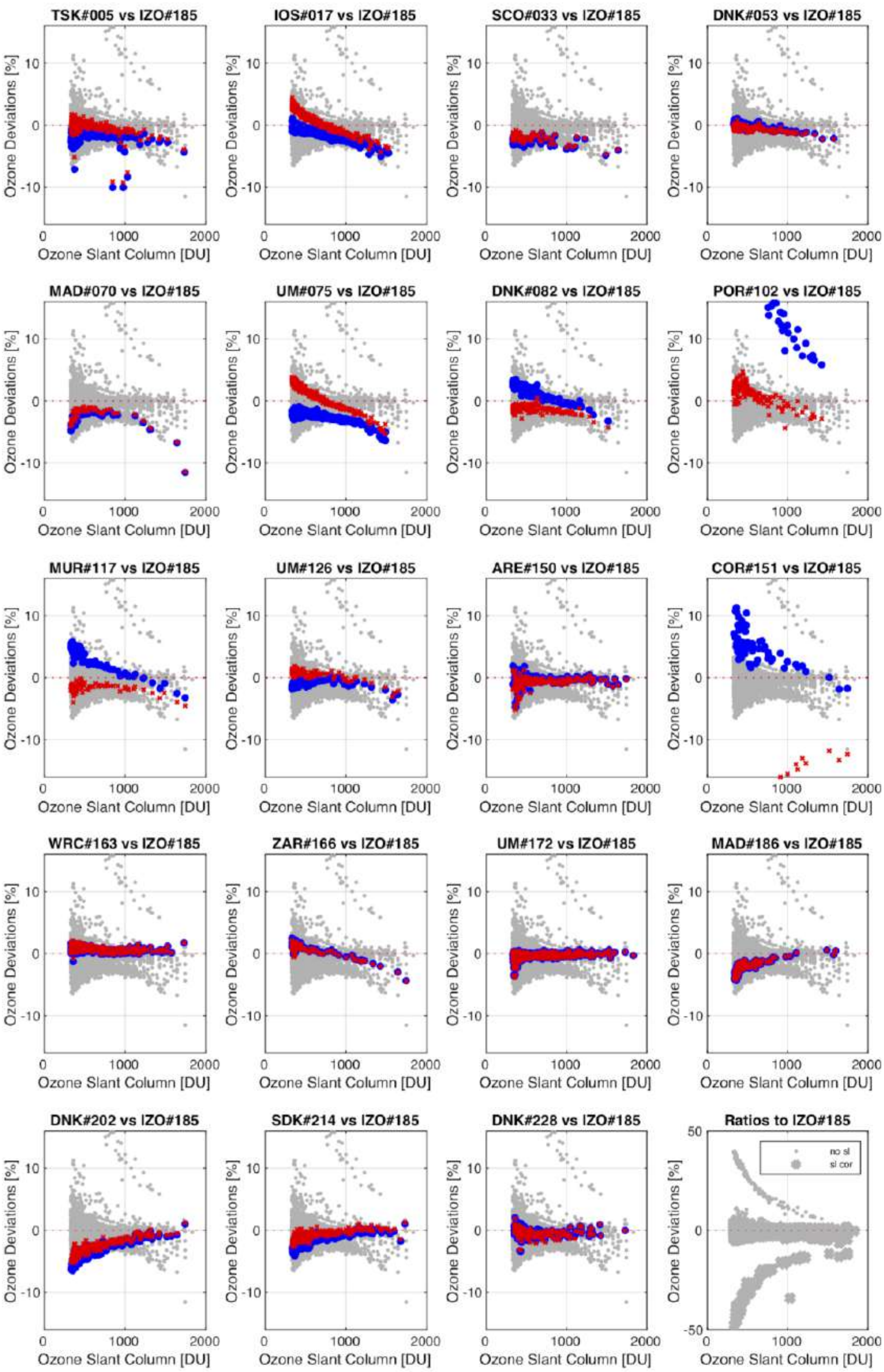


Figure 15. Blind-days ozone relative differences (%) of El Arenosillo 2017 participating instruments to RBCC-E travelling standard #185. Ozone measurements collected during the blind period (before maintenance) were reprocessed using the original calibration constants, with (red dots) and without (blue) lamp correction. Grey dots mean ozone deviations of all instruments.

2.4 Final calibration

We defined the final days as those available after the maintenance work was finished for each participating instrument. These days are used to calculate the final calibration constants, so we tried not to manipulate the instruments during this period. As well, the SL R6 value recorded during the final days is normally adopted as the new reference value. It is also expected that this parameter will not vary more than 5 units during the same period.

We show in Figure 16 the differences between the daily standard lamp R6 ratio and the proposed R6 reference value during the final days. As expected, the recorded SL values did not vary more than 5 units during this period, with the exception of Brewer POR#102. This instrument is analysed in more detail in Section 3.8.

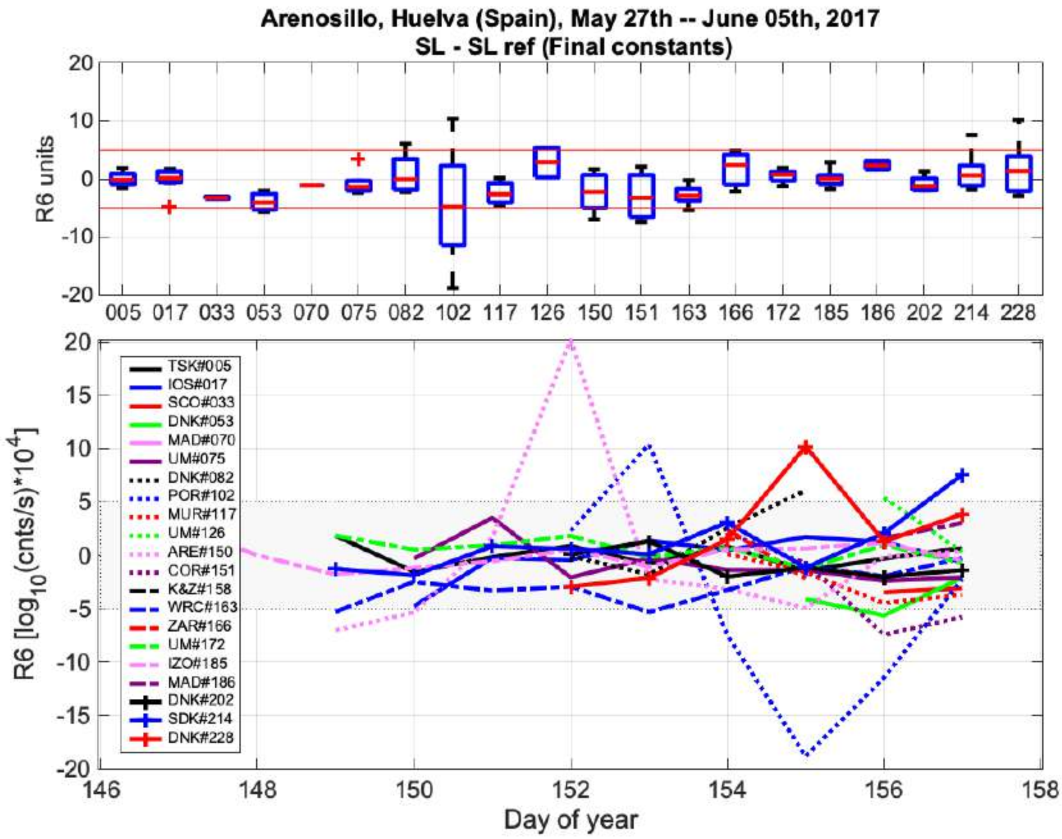
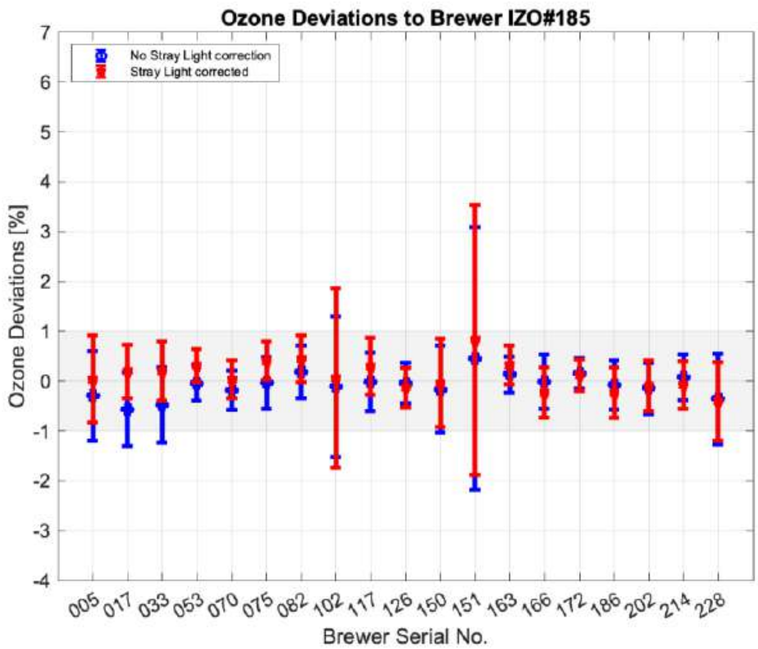


Figure 16. Standard lamp R6 ratio to R6 reference from the last calibration differences during the final days grouped by Brewer serial number (above) and as a function of time (below). The shadow area represents the tolerance range (±5 R6 units).

Deviations of ozone values for all the participating instruments to the RBCC-E travelling standard Brewer IZO#185 are shown in Figure 16. We have recalculated the ozone measurements using the final calibration constants, with and without the lamp correction. All Brewers were calibrated using the one parameter ETC transfer method, that is the ozone absorption coefficient was derived from the wavelength calibration (dispersion test) and only the ozone ETC constant was transferred from the reference instrument. The two parameters calibration method is also used as a quality indicator. For all the instruments both the one parameter and the two parameters ETC transfer methods agreed with each other within the limits of ±5 units for ETC constants and ±0.001 atm/cm for the ozone absorption coefficient (one micrometer step), which is a very good indication of the quality of the calibration provided.

We achieved good agreement with the reference instrument Brewer IZO#185 using the final calibration constants, within the range of ±0.5% (see Figure 17). Note that anomalous low total ozone deviations are frequent in the case of single monochromator Brewers, corresponding to high ozone slant values where stray light effect is large (see Figure 18).



Brewer	*No Stray Light corrected*		*Stray Light Corrected*		*Brewer*	*Stray Light corrected*		*Stray Light Corrected*	
	mean	std	mean	std		mean	std	mean	std
TSK#005	-0.5	1.1	0.0	0.9	ARE#150	0.0	0.8	0.0	0.8
IOS#017	-0.9	1.0	0.2	0.5	COR#151	0.2	3.5	0.4	3.4
SCO#033	-0.4	1.0	0.1	0.6	WRC#163	0.3	0.4	0.3	0.4
DNK#053	0.0	0.5	0.1	0.4	ZAR#166	-0.6	0.8	-0.3	0.5
MAD#070	-0.6	1.9	0.0	0.6	UM#172	0.1	0.3	0.1	0.3
UM#075	-0.2	0.8	0.4	0.4	MAD#186	-0.2	0.6	-0.2	0.6
DNK#082	0.0	0.8	0.4	0.5	DNK#202	0.0	0.5	0.0	0.5
POR#102	0.0	1.9	0.1	1.8	SDK#214	0.0	0.5	0.0	0.5
MUR#117	-0.2	0.9	0.2	0.5	DNK#228	0.0	0.8	0.0	0.8
UM#126	0.1	0.8	0.4	0.4					

Figure 17. Ozone relative percentage differences of all El Arenosillo 2017 participating instruments to RBCC-E travelling standard IZO#185. Ozone measurements collected during the final period are reprocessed using the proposed calibration constants, with (red plots) and without (blue plots) lamp correction. Error bars represent the standard deviation. The table below the graph shows deviations of ozone values to the reference Brewer IZO#185 for ozone slant path below 900 DU, with and without applying the lamp correction.

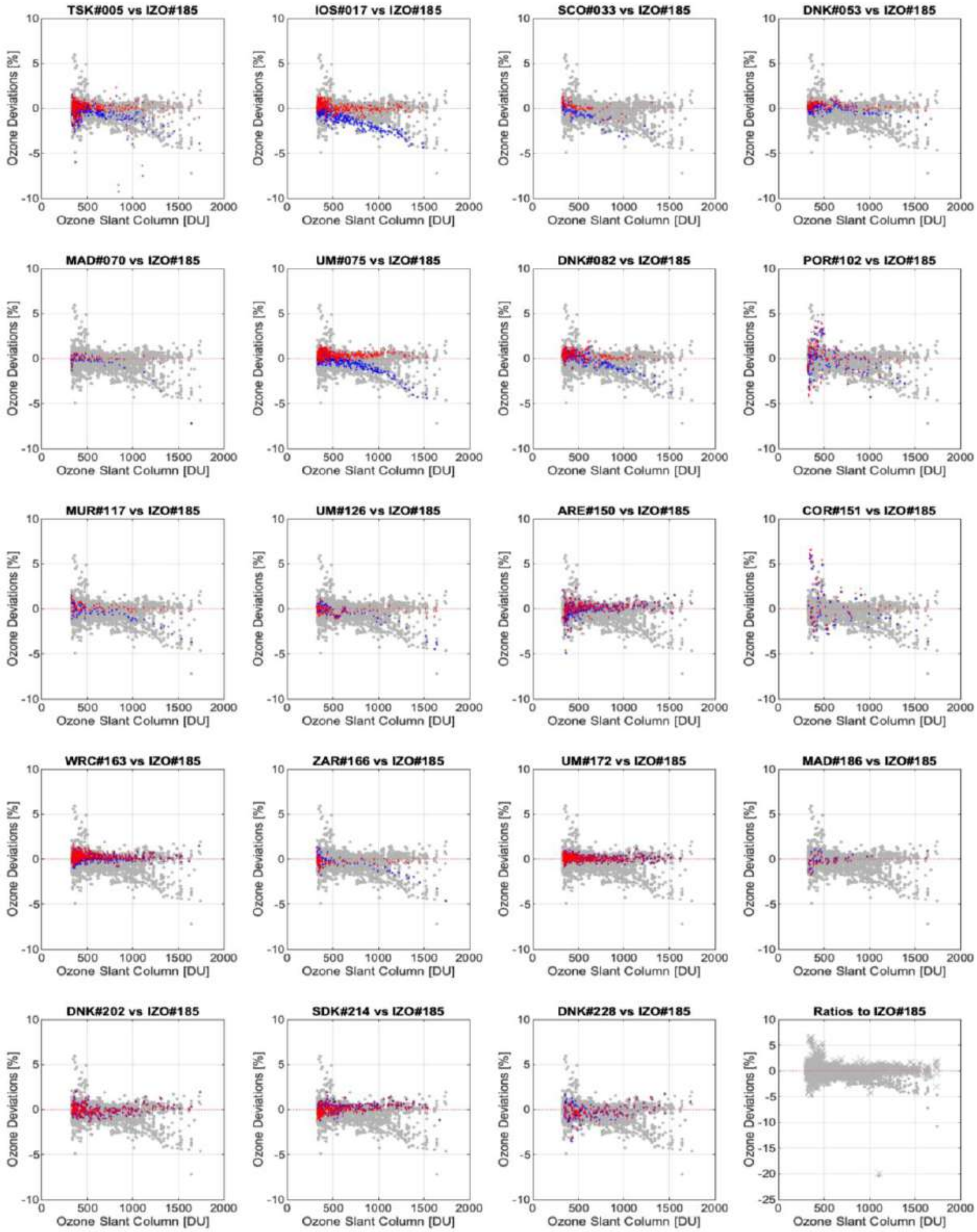


Figure 18. Final-days ozone relative differences (percentage) of El Arenosillo 2017 participating instruments to RBCC-E travelling standard Brewer #185. Ozone measurements collected during the final period (after the maintenance) were reprocessed using the proposed calibration constants, with (red stars) and without (blue stars) stray light correction. Grey dots mean ozone deviations for all participating instruments.

3. OZONE BREWER REPORTS

3.1 Brewer TSK#005, Station: Thessaloniki, Greece

Brewer TSK#005 participated in the campaign from 29 May to 7 June 2017 (Julian days 149 to 158). No maintenance work was conducted on this instrument, so for the evaluation of both the initial and final status we used 365 simultaneous direct sun ozone measurements from days 149 to 157, see Figure 19.

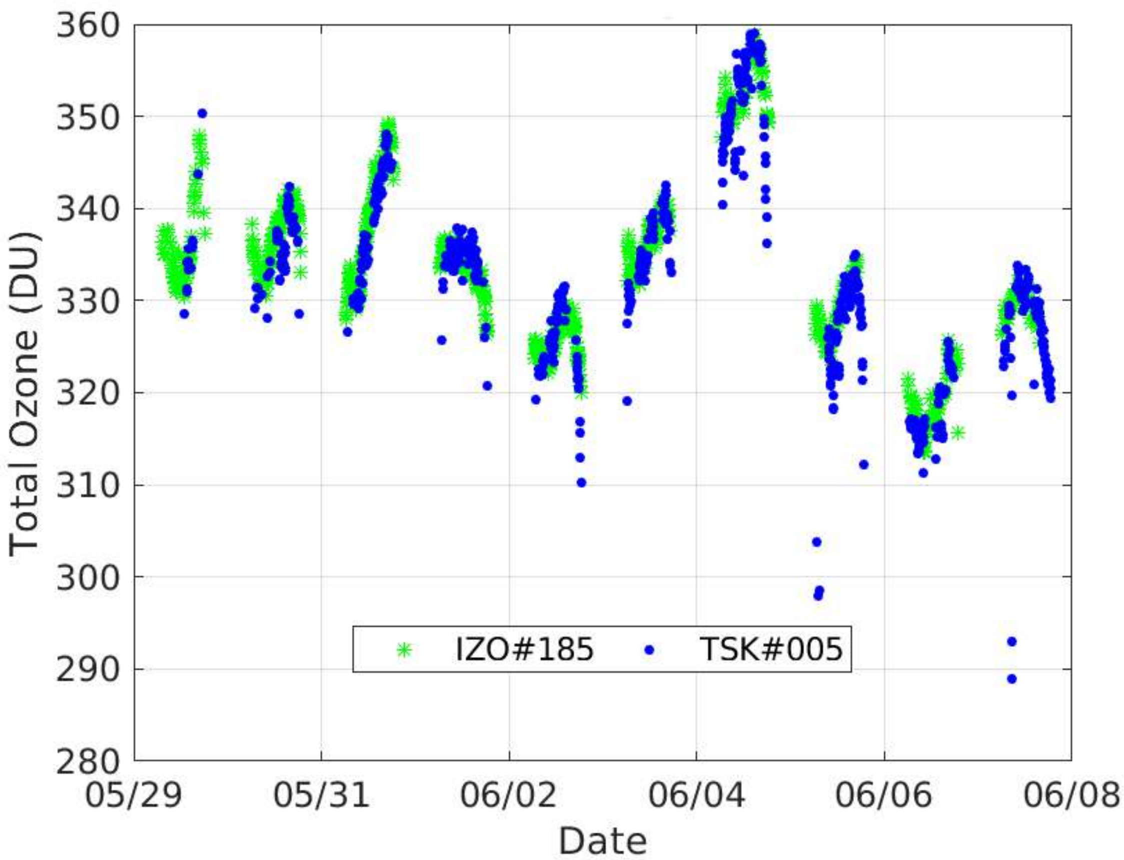


Figure 19. Brewer Intercomparison Arenosillo 2017 for B#005

Original calibration
The instrument operates with the configuration file ICF14815.005 and a reference value for the standard lamp R6 ratio 1857. These calibration constants were provided by RBCC-E in the previous intercomparison campaign.

Historical analysis
The lamp test results from Brewer TSK#005 present a significant jump in November 2015. But after this, it has been quite stable during the last 2 years. During the campaign days the standard lamp ratios stabilized around values 1838 and 3583 for R6 and R5, respectively (Figure 20). These values have been calculated taking into account the new temperature coefficients and dead time (DT) obtained in this campaign. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are good.

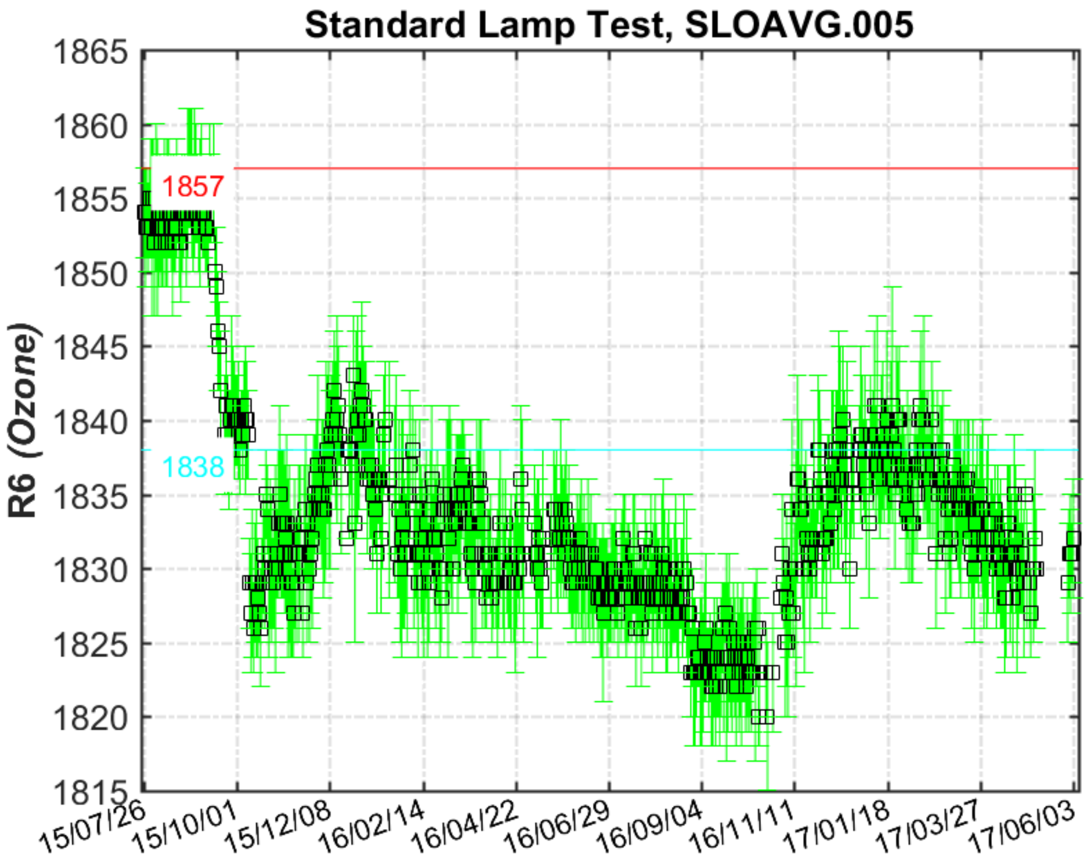


Figure 20. Standard lamp test R6 (Ozone) ratio for B#005

Initial comparison

For the evaluation of the initial status of Brewer TSK#005 we used the period from day 149 to 157, which corresponds to 365 near-simultaneous direct sun ozone measurements. As shown in Figure 21, the current calibration constants produce lower ozone values than the reference instrument (-1.5%). However, when the ETC is corrected by taking into account the difference between the standard lamp and R6 reference (lamp correction) the results get better, although not enough. During this campaign, a new DT and temperature coefficients were obtained hence, a new ETC had to be calculated for the final calibration.

Final calibration and stray light

Due to the difference with the reference Brewer, a new ETC value was calculated (see Figure 21). For the final calibration, we used 365 simultaneous direct sun measurements from days 149 to 157. The new value is approximately 10 units lower than the current ETC value (3040), and the R6 has changed by 19 units. Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1838 for R6. We updated the new calibration constants in the ICF provided. Of course, the new ETC has been calculated taking into account the new set of temperature coefficients and DT.

The instrument performed well after final calibration with error near zero for OSC<1000 and an underestimation of 2% at 1000 OSC, which is very good for a single Brewer. The empirical stray light model fits pretty well with coefficients k=-41.702, s=2.7464, and ETC=3031, which are in perfect agreement with the reference for the full range of OSC.

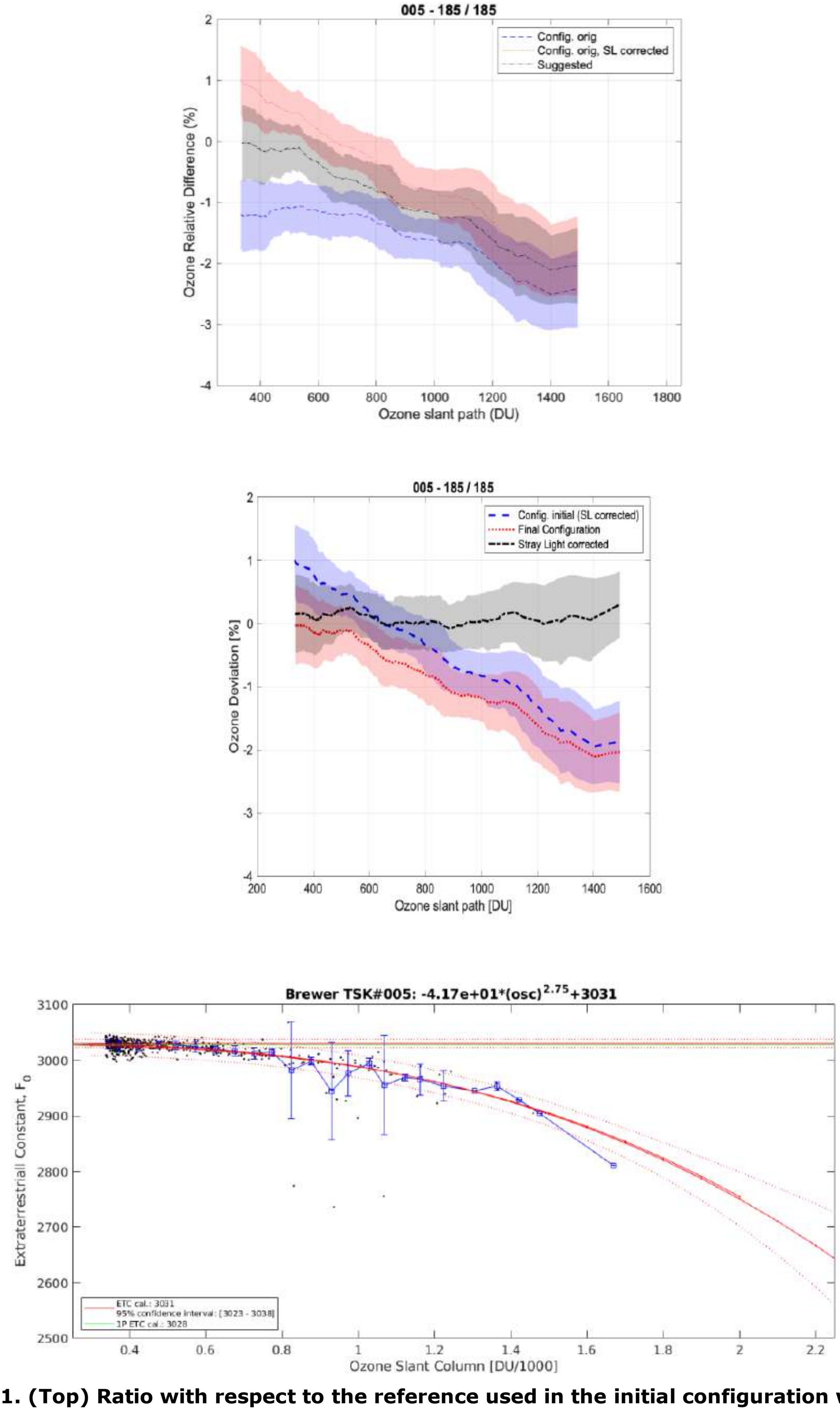


Figure 21. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#005.

Recommendations and comments

1. We recommended the application of the lamp correction in the period between the Huelva campaigns of 2015 and 2017.
2. New R6 and ETC have been calculated.
3. All the other diagnostics analysed (RS, AP records ...) were normal.
4. We suggest using a DT constant of $3.8 \cdot 10^{-8}$ seconds, which is two units less than proposed during the last intercomparison. Several studies suggest that a difference of around one nanosecond is admissible for a single Brewer.
5. We do not have enough data to reliably propose filter corrections.
6. We have adopted new temperature coefficients.
7. The Sun-scan tests were not conclusive enough to analyse the optical position of the CSN. Please check the SC routine and its format inside of B-files. We have not changed the current CSN.
8. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend its use.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/005/CALIBRATION_005.pdf

Table 6. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	3040	3030
SL R6 reference value	1857	1838
Change SL R6 ratio /ETC	<10	
DT constant (ns)	40ns	38ns
Temp. coefficients	old	[0, -0.64, -1.4, -2.06, -3.55]
Cal step number	159	159
Ozone abs. coeff.	0.33366	0.3336
Stray light factor Arenosillo 2017		3031-41.702*(OSC)^2.7464
Calibration file	ICF14815.005	ICF15117.005

3.2 Brewer IOS#017, Station: IOS, Canada

Brewer IOS#017 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of its initial status, we used 433 simultaneous direct sun ozone measurements from days 149 to 158. The observations made from day 150 were used for final calibration purposes (358 simultaneous measurements).

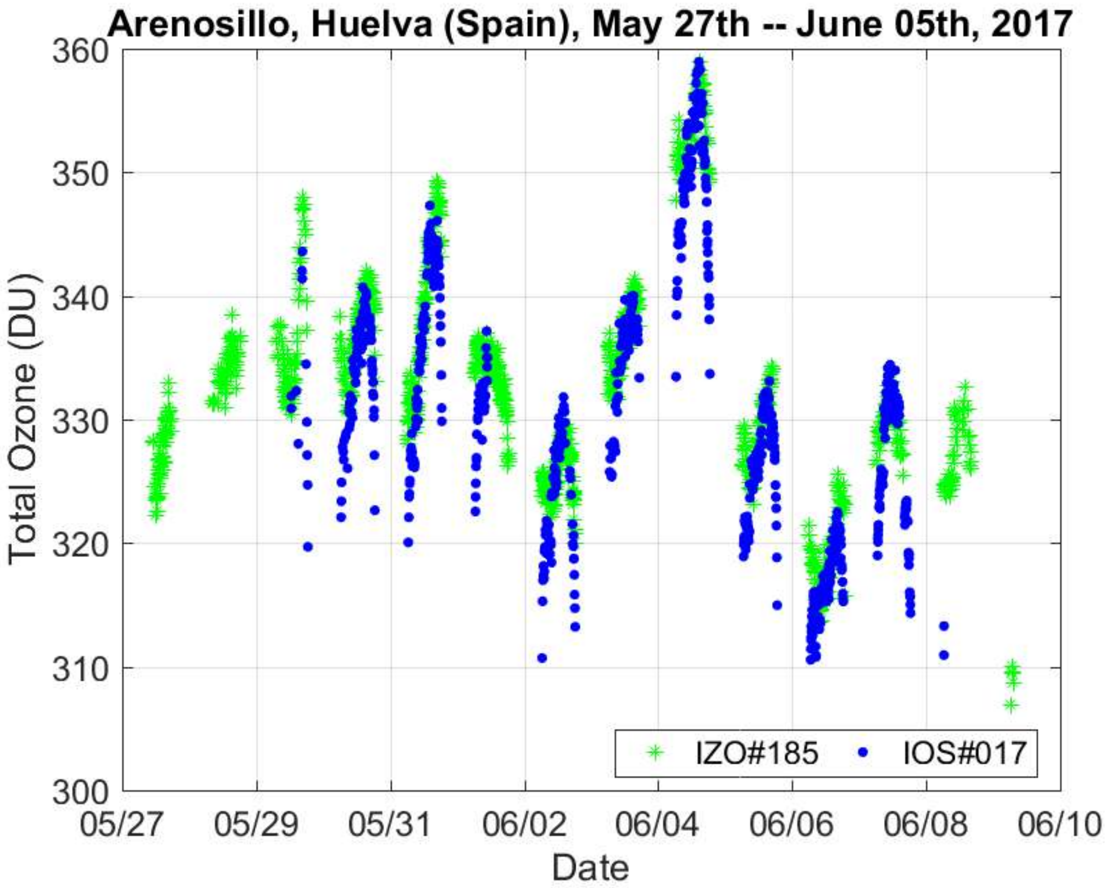


Figure 22. Brewer Intercomparison Arenosillo 2017 for B#017

Original calibration

The instrument operated with the configuration file icf12017.017 and reference value for the standard lamp R6 ratio 2125.

Historical analysis

The lamp test results from Brewer IOS#017 present several jumps because this instrument is a travelling reference (Figure 23). During the campaign days, the standard lamp ratios stabilized around values 2125 and 3795 for R6 and R5, respectively. These values have been calculated by taking into account the new dead time (DT) obtained in this campaign. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) present a proper behaviour. By contrast, the dead time shows an important difference between both original and recorded values, of around 6ns.

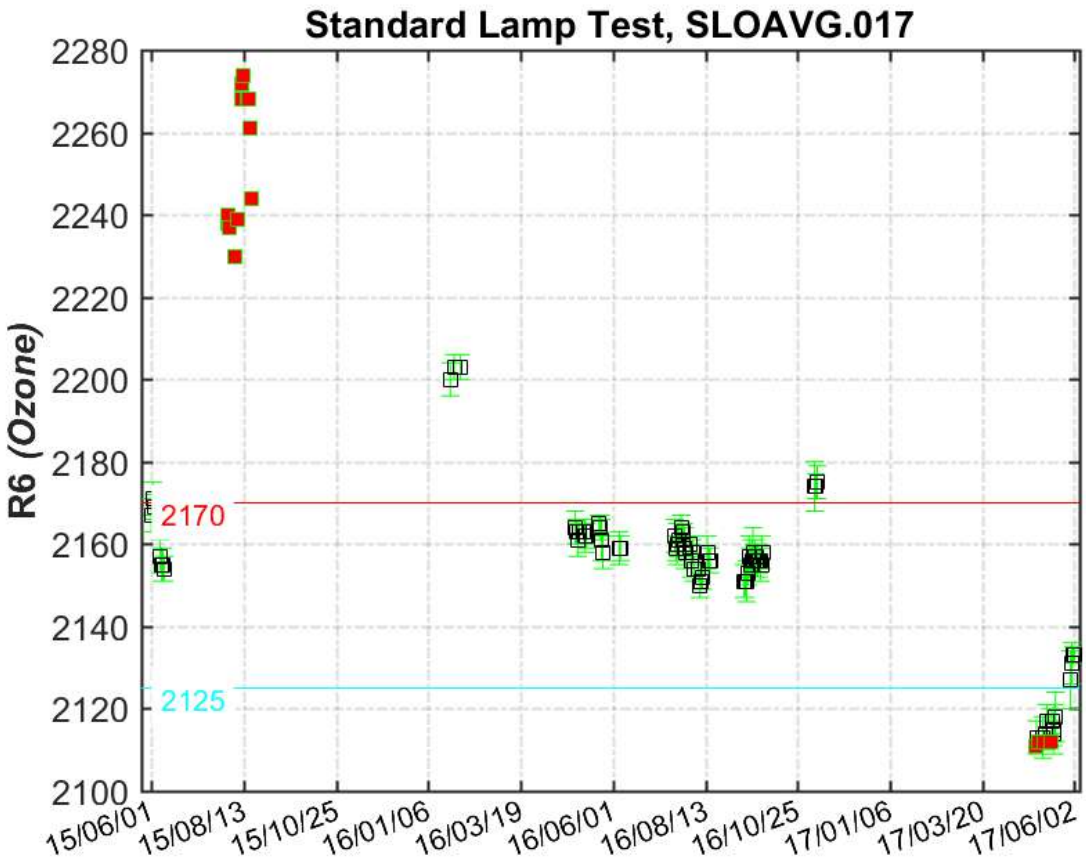


Figure 23. Standard lamp test R6 (Ozone) ratio for B#017

Initial comparison

For the evaluation of the initial status of Brewer IOS#017 we used the period from days 149 to 158, which corresponds to 433 near-simultaneous direct sun ozone measurements. As shown in Figure 24 the current calibration constants produce ozone values in good agreement with respect to the reference. However, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get worse.

Final calibration and stray light

Due to the new dead time and ozone absorption coefficient proposed, a new ETC value was calculated (see Figure 24). For the final calibration, we used 358 simultaneous direct sun measurements from days 150 to 158. The new value is 10 units lower than the current one (3310). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 2125 for R6. We updated the new calibration constants in the ICF provided.

The instrument performed well after the final calibration is applied with an error near zero for low OSC and an underestimation of 1% at 800 OSC, which is normal for a single Brewer. The empirical stray model fits pretty well with coefficients s=2.41, k=-76.0, and ETC=3300, which are in perfect agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

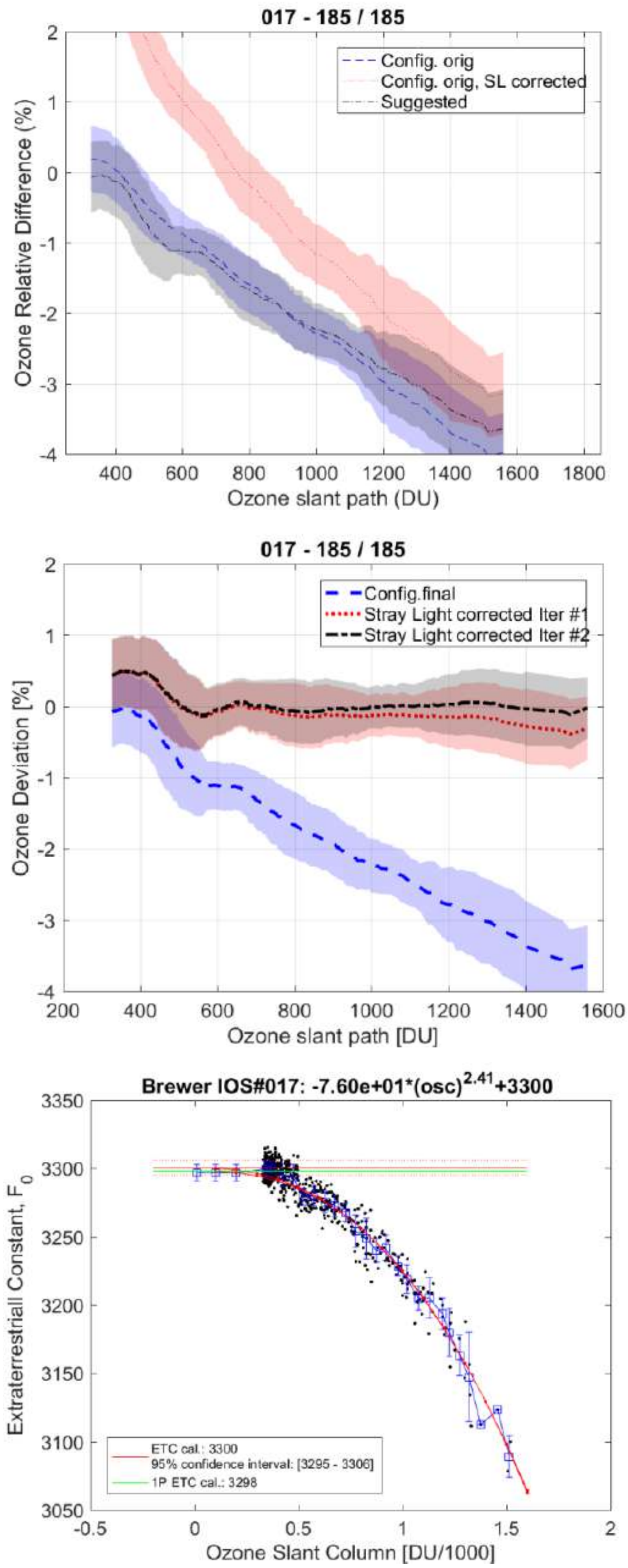


Figure 24. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#017.

Recommendations and comments

1. New ratio reference values were given in this campaign, R6= 2125 and R5=3795.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT which is really low.
3. We suggest using a DT constant of 30ns, which is six units lower than the current reference values. Several studies suggest that a difference of around one nanosecond is admissible for a single Brewer.
4. The current temperature coefficients were used in the proposed calibration.
5. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN.
6. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/017/CALIBRATION_017.pdf

Table 7. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	3310	3300
SL R6 reference value	2170	2125
Change SL R6 ratio/ETC	>10	
DT constant (ns)	36	30
Temp. coefficients	old	old
Cal step number	860	860
Ozone abs. coeff.	0.3416	0.341
Stray light factors Arenosillo 2017	3300-76*(OSC)^2.41	
Calibration file	icf12017.017 (IOS)	Icf15717.017 (RBCC-E)

3.3 Brewer SCO#033, Station: Santa Cruz de Tenerife, Spain

Brewer SCO#033 participated in the campaign from 29 May to 8 June 2017 (Julian days 149 to 159). Cal step was updated on day 155 to a new value of 914. For the evaluation of its initial status, we used 293 simultaneous direct sun ozone measurements from days 149 to 155, before the cal step change, whereas days 156 to 159 were used for final calibration purposes (159 simultaneous measurements, see Figure 25).

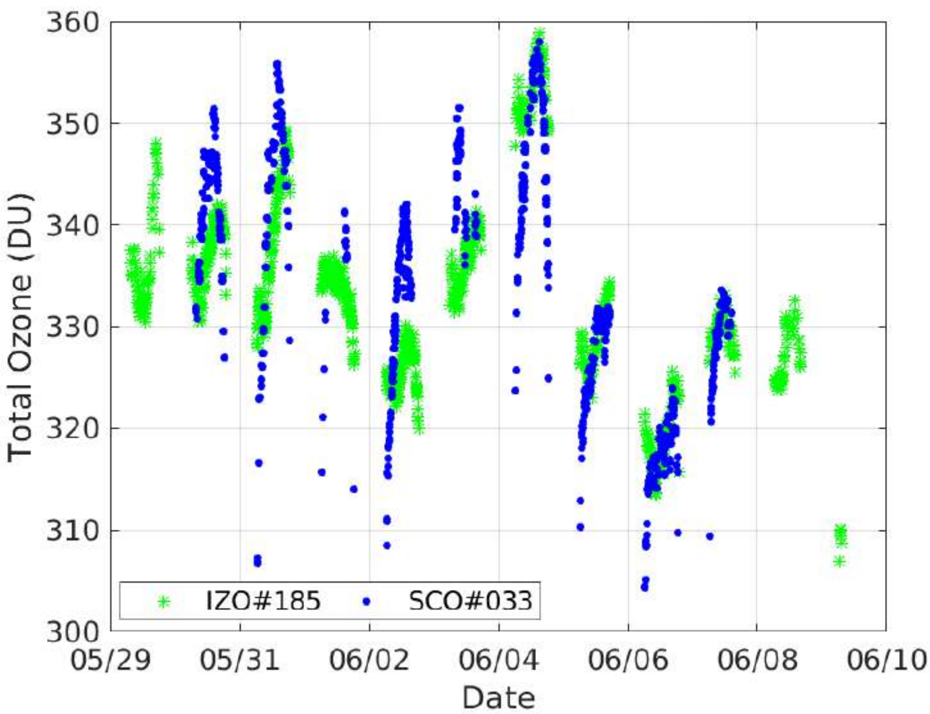


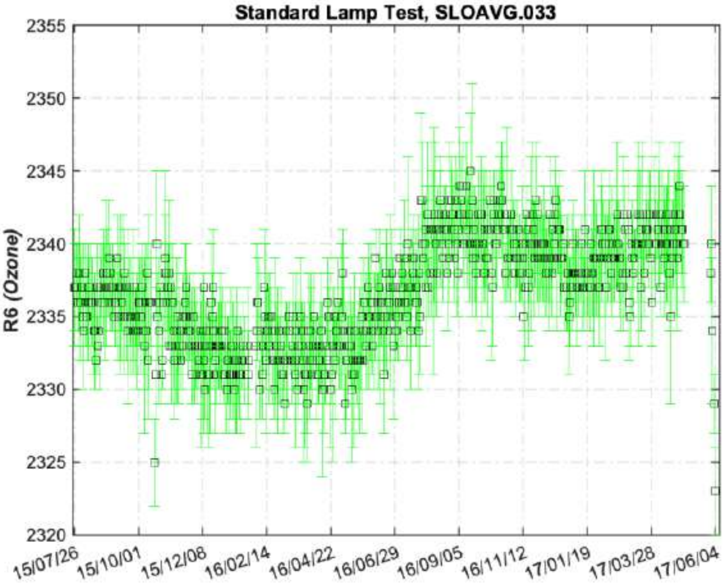
Figure 25. Brewer Intercomparison Arenosillo 2017 for B#033

Original calibration
As initial configuration, we have used the file ICF16913.033 and an R6 reference value of 2329.

Historical analysis
The lamp test results from Brewer SCO#033 have presented a stable but shows a seasonal behaviour with minimum in winter and maximum in summer until July 2016. During the campaign days, the standard lamp ratios stabilized around values 2325 and 4345 for R6 and R5 respectively (Figure 26). These values have been calculated taking into account the new dead time proposed.

All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are okay, except for DT value. Overall, this parameter shows a small drift downwards, and the DT low is rather noisy.

The Sun-scan (SC) tests performed during the campaign suggested that a change in the cal step number was needed (also confirmed by SC tests performed at the instrument's station before the campaign). It was updated to a new value of 914 on day 155. This change further required updating the ozone absorption coefficient to a new value of 0.339.



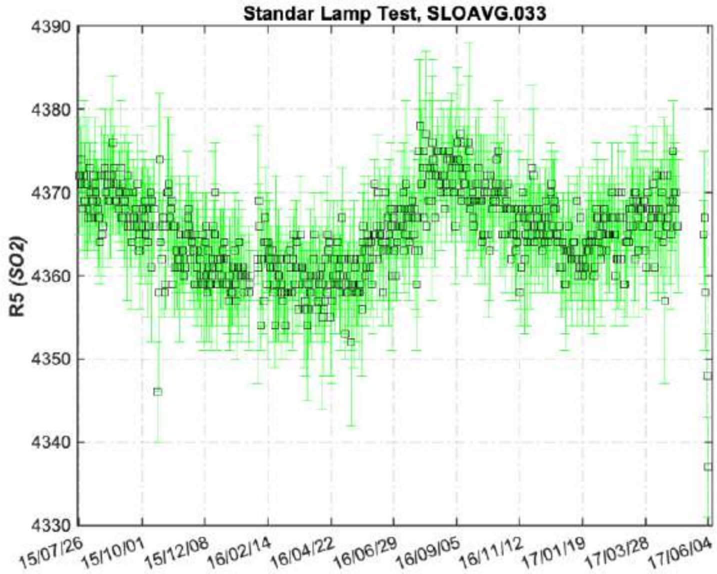


Figure 26. Standard lamp test R6 (Ozone) ratio upper panel and R5 for SO2 lower panel for B#033

Initial comparison

For the evaluation of the initial status of Brewer SCO#033, we used days 149 to 155, which correspond to 293 near-simultaneous direct sun ozone measurements. As shown in Figure 27, the current calibration constants produce ozone values lower than the reference instrument. Moreover, when the ETC is corrected by using the difference between the standard lamp and R6 reference (lamp correction), the results do not improve.

Final calibration and stray light

Due to the difference with the reference Brewer and the changes in the cal step, ozone absorption coefficient, and dead time, a new ETC value was calculated (see Figure 27). For the final calibration, we used 159 simultaneous direct sun measurements from days 156 to 159. The new value is 27 units lower than the current ETC value (3627). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 2325 for

R6. We have updated the calibration constants in the new ICF provided.

The final calibration performs well, with error near zero for low OSC. However, there is an underestimation of 3.5% at 1000 OSC due to the effect of the stray light in this MkII single Brewer. The empirical stray model fits with coefficients k=-89.7, s=2.49, and ETC=3604 produces a very good agreement with the reference Brewer for the full range of OSC. In order to correct the ozone, an iterative formula is used.

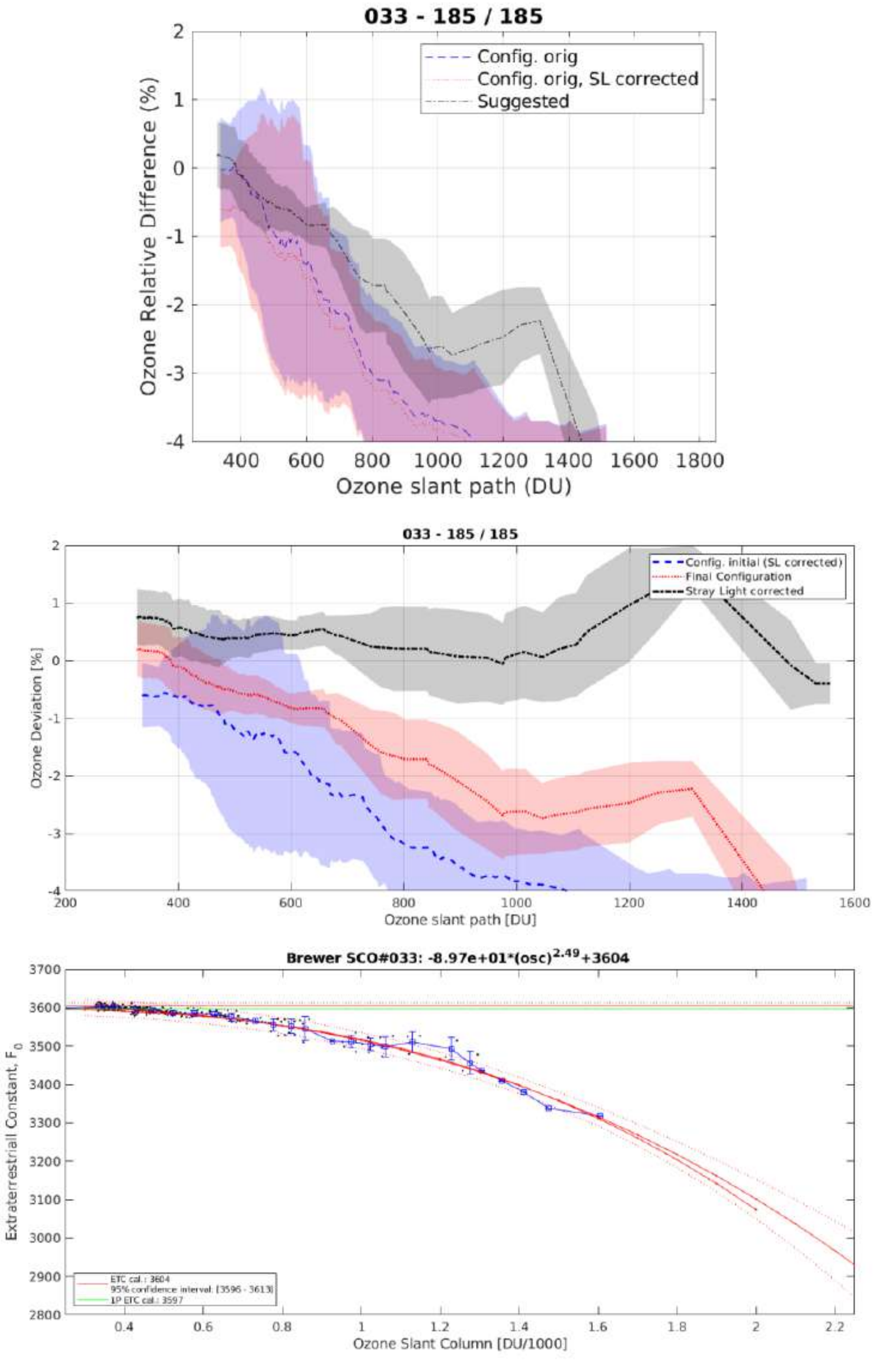


Figure 27. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#033.

Recommendations and comments

1. New reference values were given, R6=2325 and R5=4345.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT.
3. We suggest using a DT constant of $4 \cdot 10^{-8}$ seconds, which is five units greater than the configuration used for reference.
4. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN. A new cal step number was given in this calibration.
5. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/033/CALIBRATION_033.pdf

Table 8. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	3627	3600
SL R6 reference value	2329	2325
Change SL R6 ratio /ETC	>10	
DT constant (ns)	35	40
Temp. coefficients	[0, 0.0629, 0.0931, -0.7138, -2.0641]	no change
Cal step number	920	914
Ozone abs. coeff.	0.336	0.339
Stray light factors Arenosillo 2017		3604-89.7*(OSC)^2.49
Calibration file	ICF16913.033	ICF15617.033

3.4 Brewer DNK#053, Station: Denmark

Brewer DNK#053 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of the initial status, we used 443 simultaneous direct sun ozone measurements from days 150 to 154. Only days 155 to 158 were used for final calibration purposes (294 simultaneous measurements). This corresponds to the period after SL/HG replacements (Figure 28).

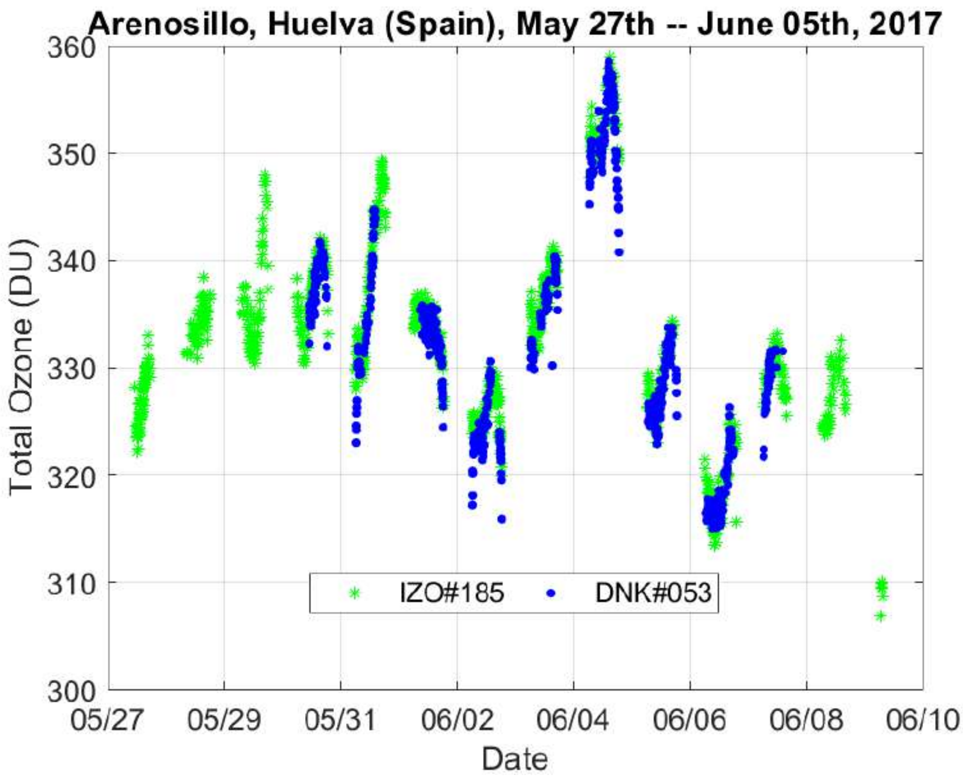


Figure 28. Brewer Intercomparison Arenosillo 2017 for B#053

Original calibration

The instrument operates with the configuration file icf15316.053 and reference value for the standard lamp R6 ratio 1845.

Historical analysis

The lamp test results from Brewer DNK#053 have presented a perfect behaviour during recent years. However, during the campaign both SL and HG lamps were replaced because they were old. During the campaign days, the standard lamp ratios stabilized around values 1850 and 3625 for R6 and R5 respectively (Figure 29). All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) present an excellent behaviour. The neutral density filters did not show nonlinearity in the attenuation spectral characteristics. We have not applied any corrections to filters.

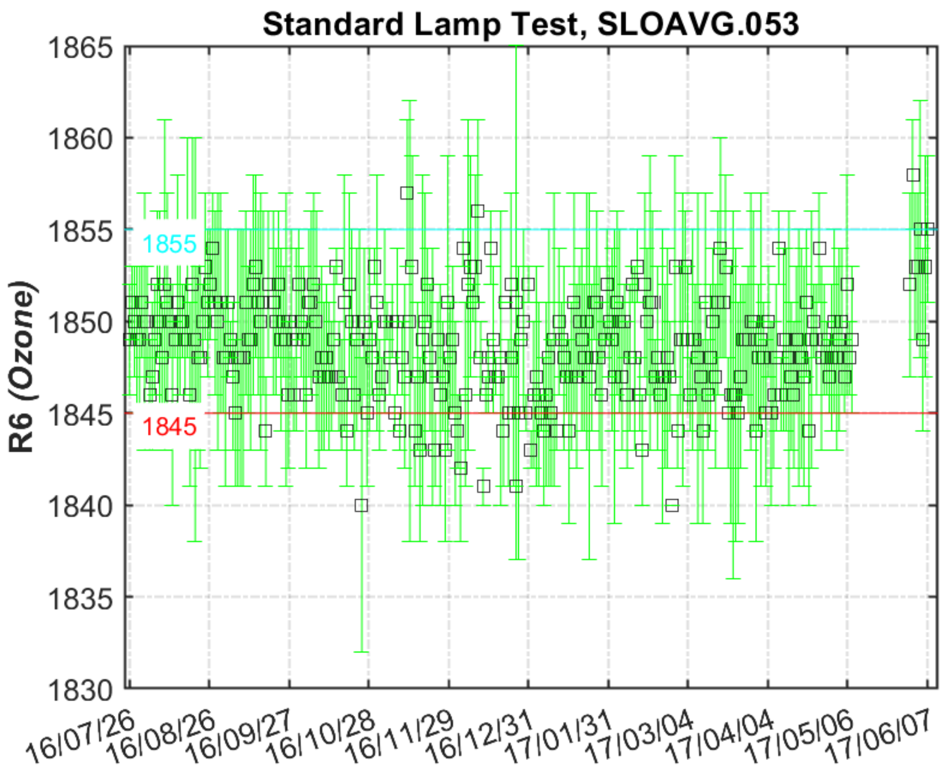


Figure 29. Standard lamp test R6 (Ozone) ratio for B#053

Initial comparison

For the evaluation of the initial status of Brewer DNK#053 we used the period from days 150 to 154, which corresponds to 443 near-simultaneous direct sun ozone measurements. As shown in Figure 30, the current calibration constants produce ozone values in good agreement with the reference. In fact, the lamp correction does not introduce an improvement because the R6 variation is below 5 units.

Final calibration and stray light

Despite the good agreement of the current ICF, in this calibration campaign we suggested to reduce the DT reference from 34 to 30 ns. Due to this, a new ETC value had to be calculated (see Figure 30). For the final calibration, we used 294 simultaneous direct sun measurements from days 155 to 158. The new value is approximately 5 units lower than the current ETC value (3050). Therefore, we recommend using this new ETC, together with the new proposed DT reference ratios. We updated the new calibration constants in the ICF provided. Of course, the new ETC has been calculated taking into account the new DT reference value. The final calibration performed well with error near zero for low OSC and an underestimation of 0.9% at 1000 OSC, which is very good for a single Brewer. The empirical stray model fits pretty well with coefficients s=2.43, k=-29.3, and ETC=3043, which are in perfect agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

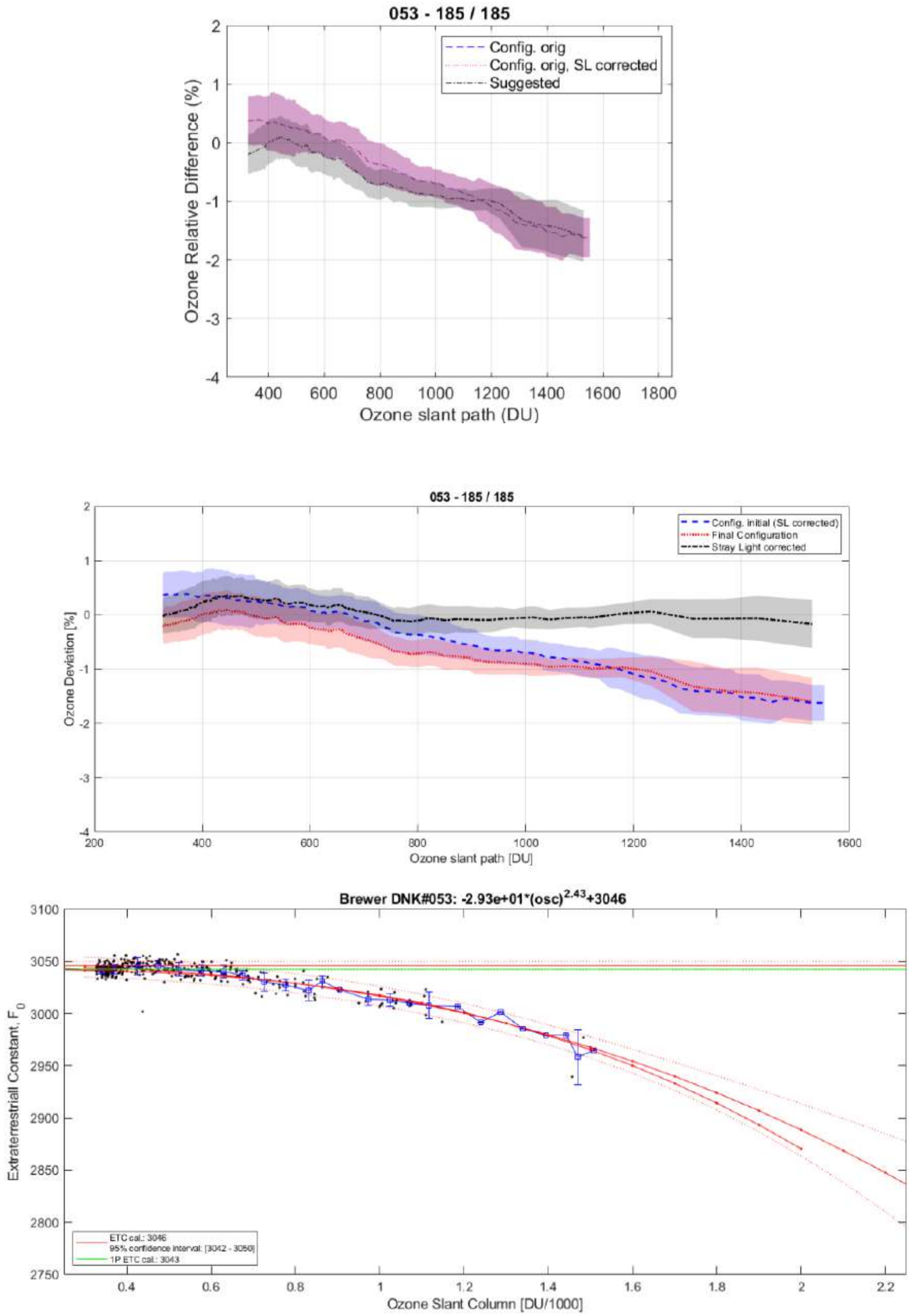


Figure 30. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#053.

Recommendations and comments

1. It was not necessary to correct with the lamp for the period before this calibration.
2. All the other diagnostics analysed (RS, AP records ...) were normal.
3. The DT has been changed to 30ns.
4. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
5. The current temperature coefficients work well.
6. The Sun-scan tests confirmed the CSN used.
7. Be careful with the file format. The structure of the files are different to the standard format which complicates the calibration. For example, we cannot open the CI files with our program.
8. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/053/CALIBRATION_053.pdf

Table 9. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	3050	3045
SL R6 reference value	1845	1850
Change SL R6 ratio/ETC	<10	
DT constant (ns)	34	30
Temp. coefficients	[0,-0.53,-1.06,-1.97,-3.53]	[0,-0.53,-1.06,-1.97,-3.53]
Cal step number	163	163
Ozone abs. coeff.	0.346	0.346
Stray light factors Arenosillo 2017	3046-29.3*(OSC)^2.43	
Calibration file	icf15616.053 (IOS)	Icf15517.053 (RBCC-E)

3.5 Brewer MAD#070, Station: Madrid, Spain

Brewer MAD#070 participated in the campaign during the period from 29 May to 7 June 2017 (Julian days 149-158). The Fore optics level and high voltage were changed in the first days of the intercomparison. For the evaluation of the initial status, we used 121 simultaneous direct sun ozone measurements from days 152 to 155, before maintenance tasks, whereas days 157 to 158 were used for final calibration purposes, see Figure 31.

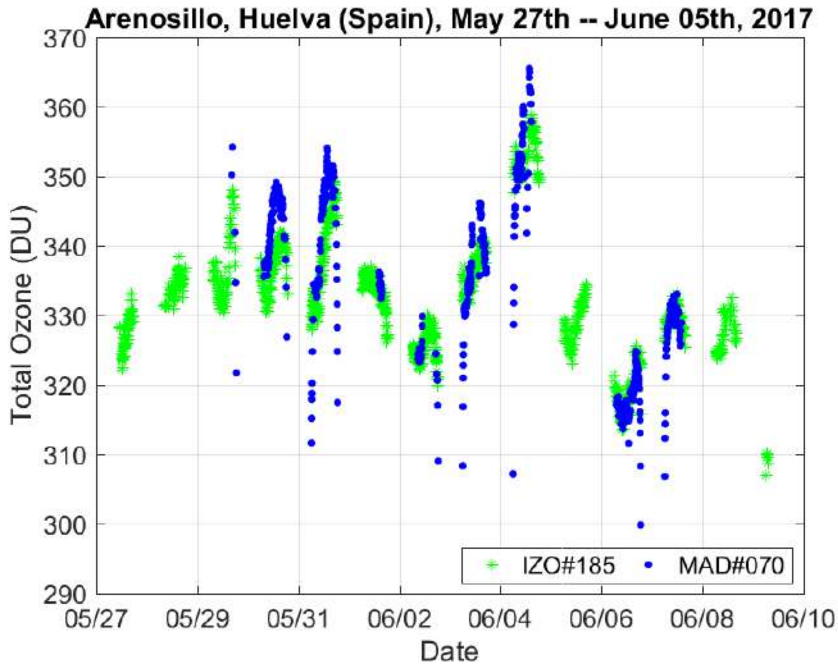


Figure 31. Brewer Intercomparison Arenosillo 2017 for B#070

Original calibration

The instrument operates with the configuration file icf15215.070 and reference value for the standard lamp R6 ratio 1703.

Historical analysis

As Figure 32 shows, the current ICF produces ozone values with a difference of around -2% (on average) with respect to the reference. Applying the lamp correction, the results improved slightly with a difference of around -1% (on average). The great dependence on the solar angle can be corrected easily using a recently developed method. However, it should be taken into account that the HV was changed on day 152 and, therefore, Figure 33 is only indicative of the state of the instrument.

The lamp test results from Brewer MAD#070 indicated a stable behaviour during the last two years, but a small seasonal dependence. During the campaign days, the standard lamp ratios stabilized around values 1707 and 3125 for R6 and R5 respectively (Figure 32). These values have been calculated taking into account the new temperature coefficients and dead time calculated in this campaign.

All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are okay, except for DT value. This parameter shows a great difference between both original and recorded values of about 5 units.

Concerning filters performance, we have applied a correction factor -10 to Filter#3.
The Sun-scan (SC) tests performed before and during the intercomparison are conclusive enough to analyse the optical position of the CSN. The value of the ozone absorption coefficient has been changed slightly with respect to the previous calibration.

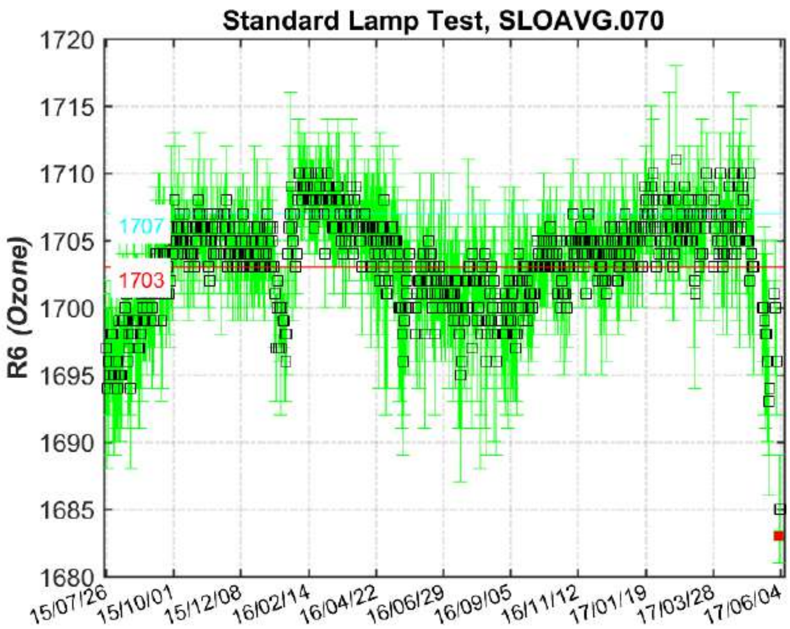


Figure 32. Standard lamp test R6 (Ozone) ratio for B#070

Initial comparison
For the evaluation of the initial status of Brewer MAD#070 we used the period from days 152 to 155 which correspond to 121 near-simultaneous direct sun ozone measurements. As shown in Figure 33, the current calibration constants produce ozone values lower than the reference instrument (-2%). However, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get better. It should be taken into account that the HV was changed on day 152 and, hence, this result is only indicative of the state of the instrument.

Final calibration and stray light
Due to the maintenance tasks, a new ETC value was calculated (see Figure 33). For the final calibration, we used 169 simultaneous direct sun measurements from days 156 to 157. The new value is 17 units lower than the current ETC value (2950). We recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1707 for R6. We updated the new calibration constants in the ICF provided. The new ETC has been calculated taking into account the new set of temperature coefficients and dead time.

The final calibration performed well, with error near zero for low OSC and an underestimation of 1% at 1000 OSC, which is very good for a single Brewer. The empirical stray model fits pretty well with coefficients s=4.55, k=-39.7, and ETC=2933, which are in perfect agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

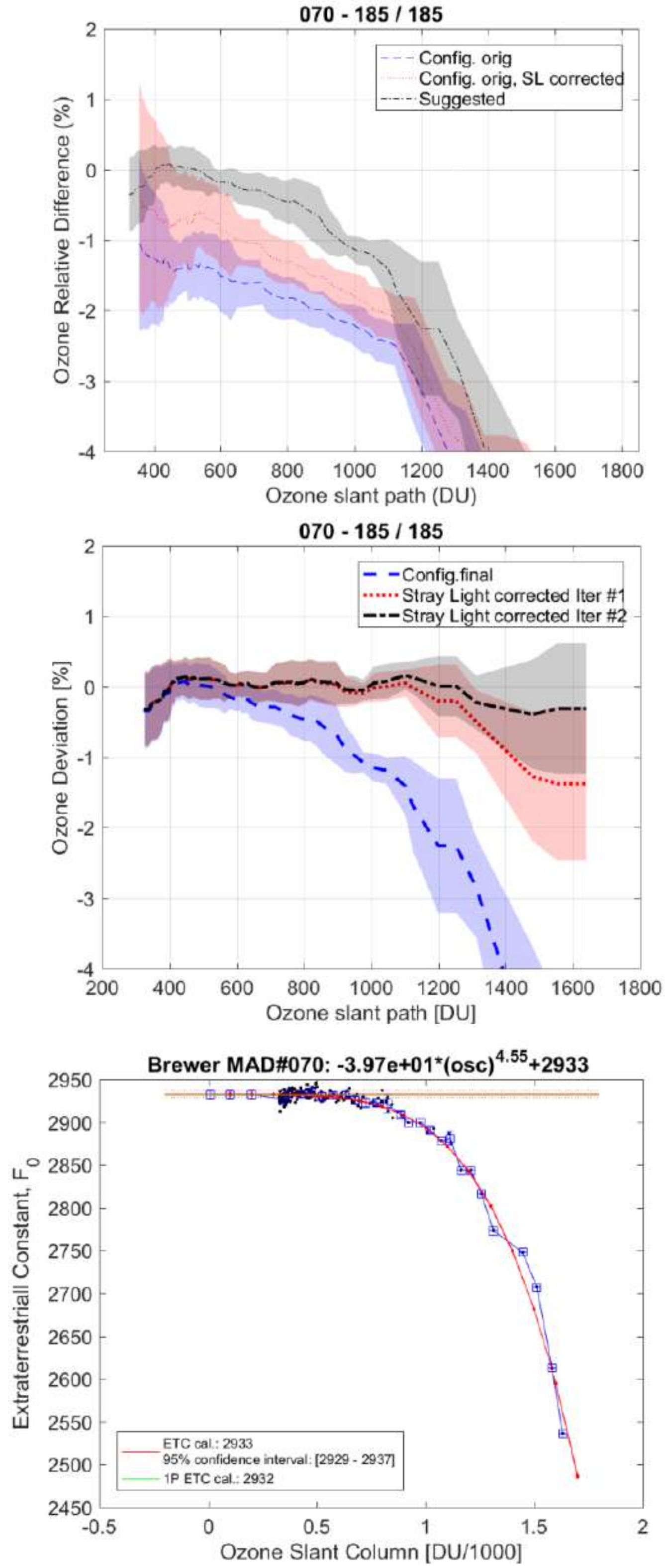


Figure 33. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#070.

Recommendations and comments

1. New reference values were given: R6=1707 and R5=3125.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT, which was really low with respect to the reference.
3. We suggest using a DT constant of 41 ns which was obtained after the high voltage was increased.
4. A correction factor of -10 to Filter#3 was applied.
5. We have adopted new temperature coefficients.
6. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN, the current CSN was not modified.
7. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/070/CALIBRATION_070.pdf

Table 10. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	2950	2933
SL R6 reference value	1703	1707
Change SL R6 ratio/ETC	>10	
DT constant (ns)	41ns	41ns
Temp. coefficients	old	[0,-0.79,-1.62,-3.19,-5.27]
Cal step number	162	162
Ozone abs. coeff.	0.3385	0.338
Stray light factor Arenosillo 2017	2933-39.7*(OSC)^4.55	
ETC filter corr.		[0, 0, 0, 10, 0, 0]
Calibration file	ICF15215.070	ICF15617.070

3.6 Brewer UM#075, Station: Manchester University, United Kingdom

Brewer UM#075 participated in the campaign from 29 May to 7 June 2017 (Julian days 149 to 158). For the evaluation of the initial status, we used 546 simultaneous direct sun ozone measurements from days 151 to 158. No maintenance work was carried out on this Brewer, so the same period was used for final calibration purposes, see Figure 34.

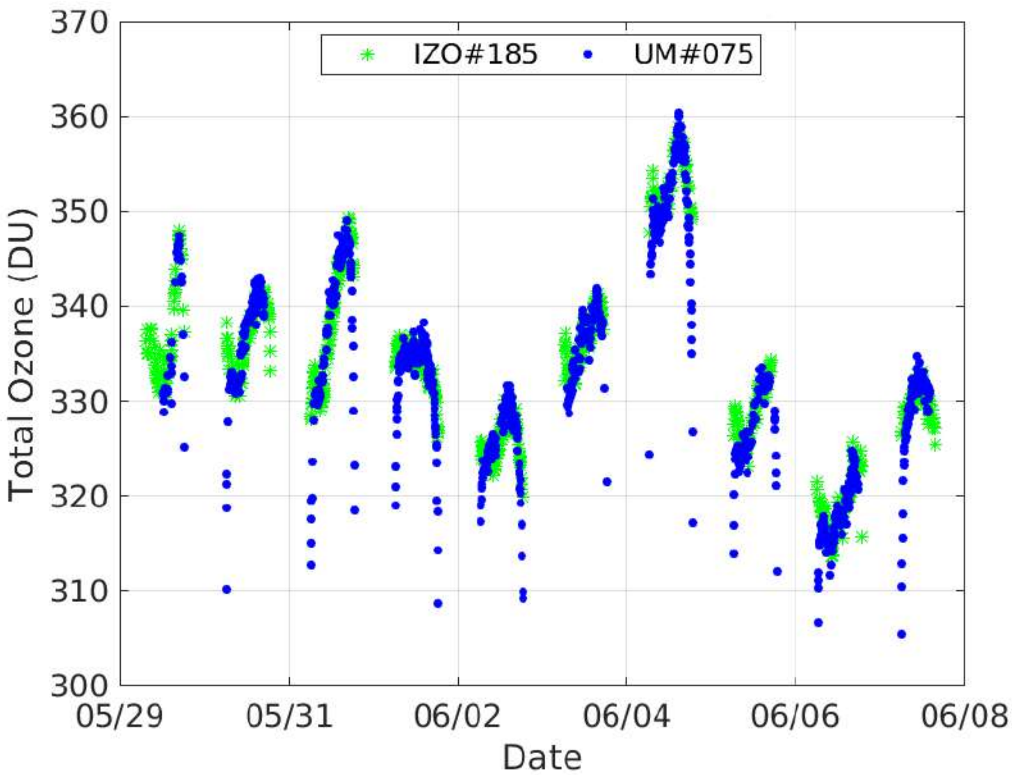


Figure 34. Brewer Intercomparison Arenosillo 2017 for B#075

Original calibration
The instrument operates with the configuration file ICF14615.075 and reference value for the standard lamp R6 ratio 1769.

Historical analysis
The lamp test results for Brewer UM#075 presented a change in September 2016. But after this, it has been quite stable. During the campaign days, the standard lamp ratios stabilized around values 1715 and 3300 for R6 and R5 respectively (Figure 35). These values have been calculated taking into account the new temperature coefficients calculated in this campaign. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are okay, except for DT value. This parameter shows a small difference between the original and campaign values of around 2 units, and we suggest updating its value to $3.2\cdot10^{-8}$.

Filters show significant non-linear effects, and we recommend corrections of 15 and 25 for filters 3 and 4, respectively.

As Figure 36 shows, the current ICF produces ozone values with a difference of around -1.5% with respect to the reference. This important difference could be associated with the change suffered by the Brewer since the previous campaign (Arenosillo 2015, see Figure 35). After applying the lamp correction, the results do not improve. The great dependence on the solar angle can be corrected easily using a recently developed method to correct for stray light effects on simple Brewers.

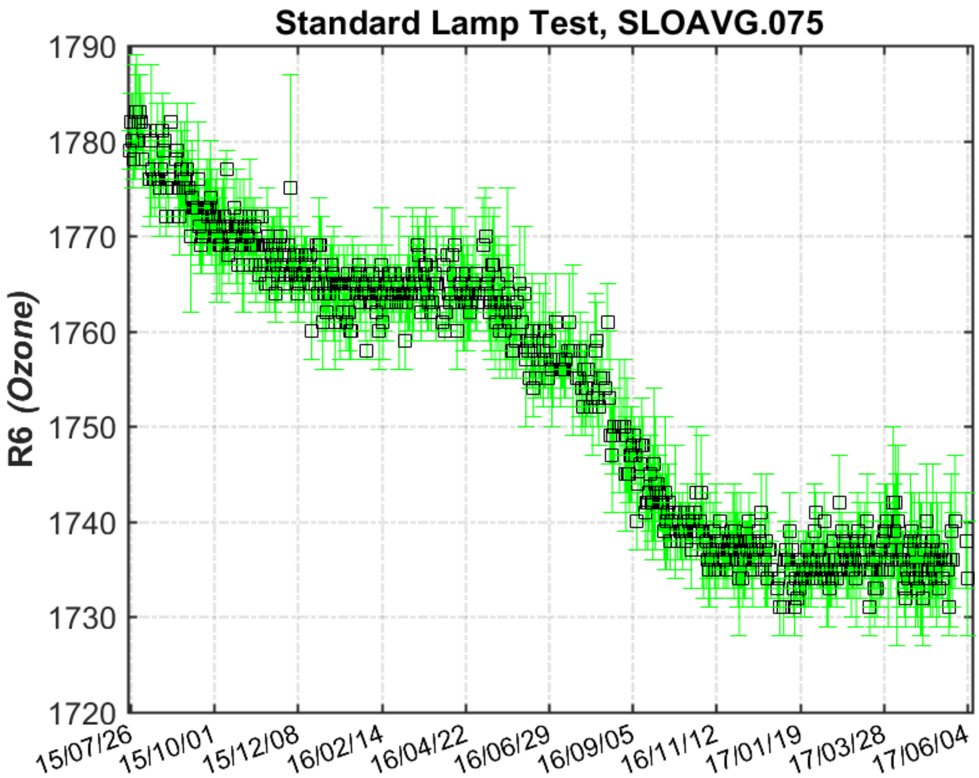


Figure 35. Standard lamp test R6 (Ozone) ratio for B#075

Initial comparison
For the evaluation of the initial status of Brewer UM#075 we used the period from days 151 to 158 which corresponds to 546 near-simultaneous direct sun ozone measurements. As shown in Figure 36, the current calibration constants produce ozone values lower than the reference instrument (-1.5%). In addition, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get worse.

Final calibration and stray light
Due to the difference with the reference Brewer, a new ETC value was calculated (see Figure 36). For the final calibration, we used 546 simultaneous direct sun measurements from days 151 to 158. The new value is approximately 30 units lower than the current ETC value (2955). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1715 for R6. We have updated the calibration constants in the new ICF provided. Of course, the new ETC has been calculated taking into account the new set of temperature coefficients and dead time.

The final calibration performed well, with error near zero for low OSC and an underestimation of 1.5% at 1000 OSC, which is very good for a single Brewer. The empirical stray model with coefficients k=-46.3, s=4.06, and ETC=2924 produces a very good agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

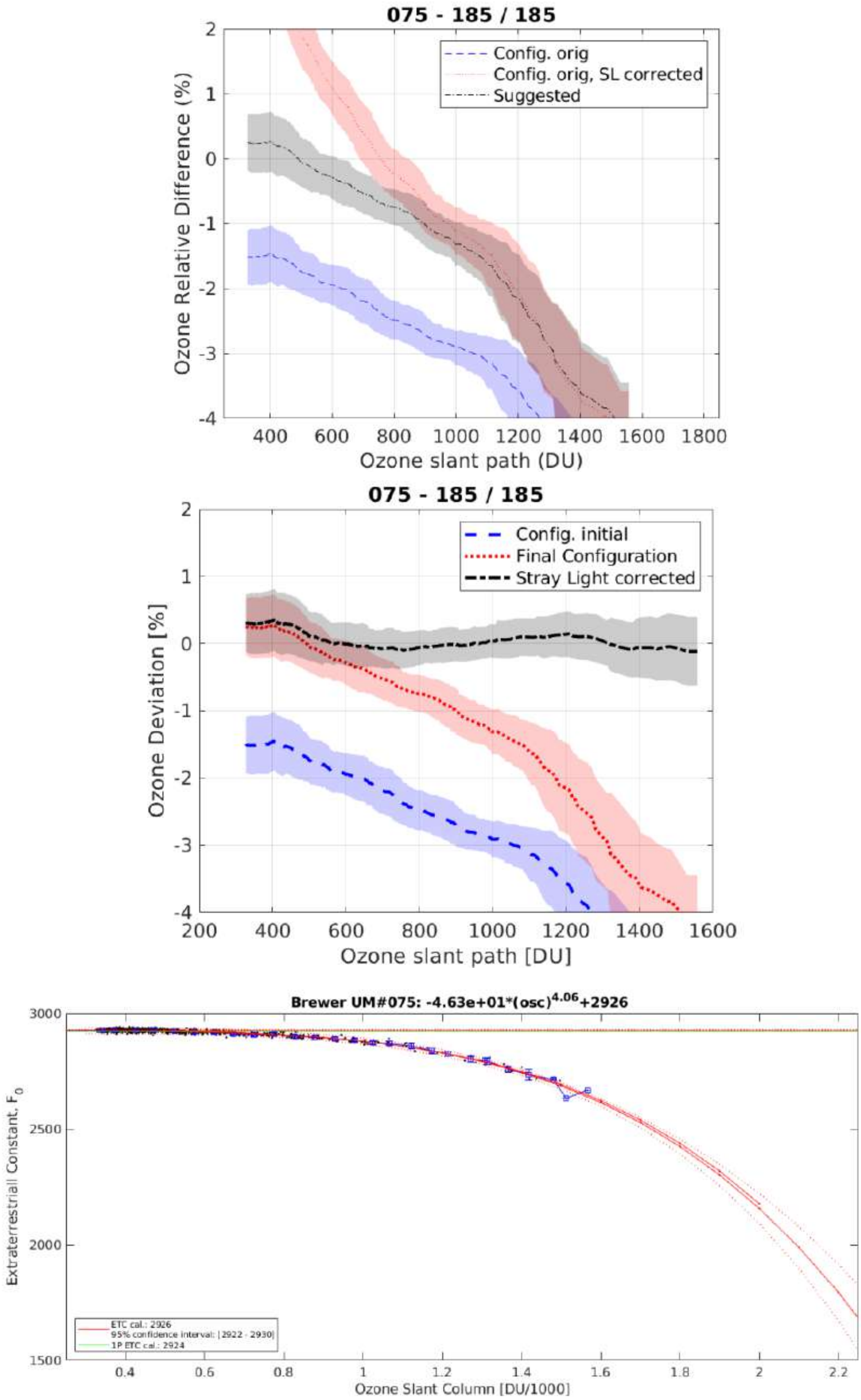


Figure 36. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#075.

Recommendations and comments

1. New R6 and R5 reference values were given with the new calibration.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT, which has been changed. We suggest using a DT constant of 32ns, which is two units less than proposed during the last intercomparison. Several studies suggest that a difference of around one nanosecond is admissible for single Brewers.
3. Filters showed significant non-linear effects, and we recommend corrections of 15 and 25 for filters 3 and 4, respectively.
4. We have adopted new temperature coefficients.
5. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/075/CALIBRATION_075.pdf

Table 11. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	2955	2920
SL R6 reference value	1769	1715
Change SL R6 ratio/ETC	>10	
DT constant (ns)	34ns	32ns
Temp. coefficients	old	[0, -0.18, -0.86, -2.02, -3.43]
Cal step number	291	291
Ozone abs. coeff.	0.3398	0.338
Stray light factor Arenosillo 2017		2924-46.3*(OSC)^4.06
ETC filter corr.		[0, 0, 0, 15, 25, 0]
Calibration file	ICF14615.075	ICF15017.075

3.7 Brewer DNK#082, Station: Denmark

Brewer DNK#082 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of the initial status, we used 461 simultaneous direct sun ozone measurements from days 151 to 158. Only days 152 to 158 were used for final calibration purposes with 496 simultaneous measurements (Figure 37).

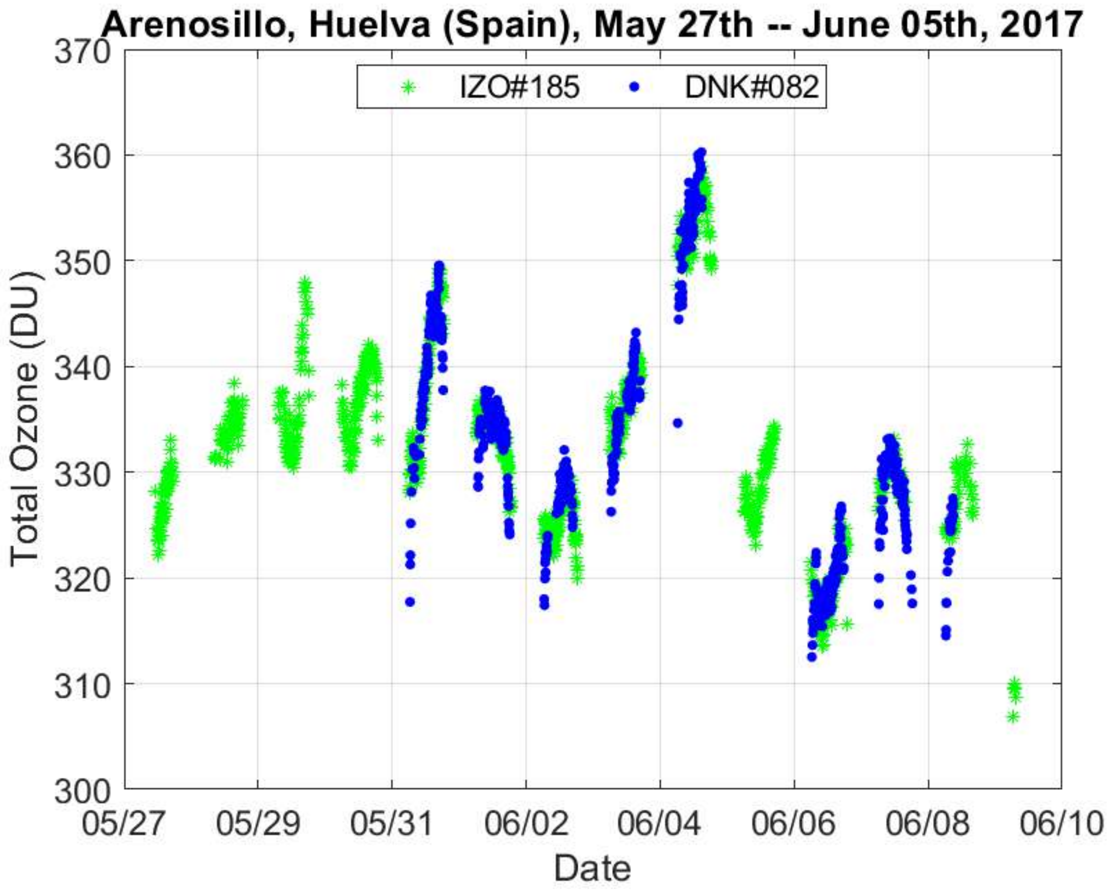


Figure 37. Brewer Intercomparison Arenosillo 2017 for B#082

As Figure 37 shows, the current ICF produces ozone values with a difference of around -0.5% (on average) with respect to the reference. However, a large dependence with respect to OSC can be observed, which suggests that the ETC must be recalibrated. After applying the lamp correction, the results improve slightly because the dependence on the solar angle decreases, but the error in average increases -1.5%. The great dependence on the solar angle can be corrected easily using a recently developed method to correct stray light effects on simple Brewers.

The lamp test results from Brewer DNK#082 presented an irregular behaviour in October 2016. However, we have indicated that the previous R6 reference was 1615, 50 units less than the current value. During the campaign days, the standard lamp ratios stabilized around values of 1666 and 3120 for R6 and R5 respectively (Figure 38). All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are stable.

The neutral density filters did not show nonlinearity in the attenuation spectral characteristics. We have not applied any corrections to filters.

Sun-scan (SC) tests performed before and during the intercomparison confirm that the current CSN is the optimal one.

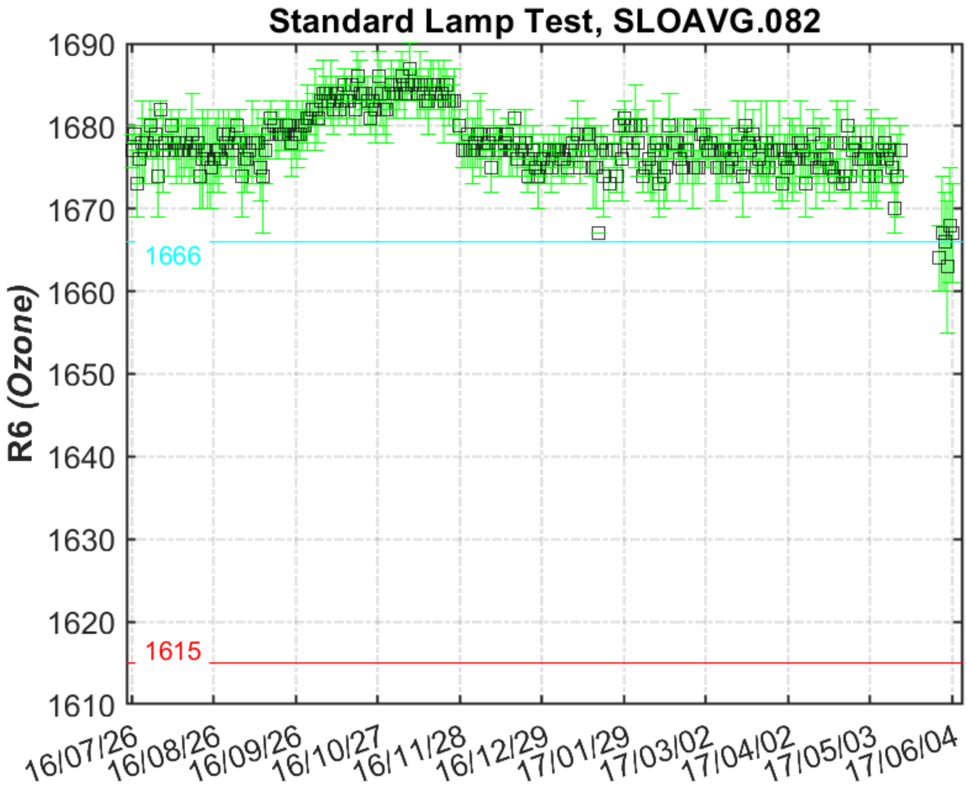


Figure 38. Standard lamp test R6 (Ozone) ratio for B#082

Initial comparison

For the evaluation of the initial status of Brewer DNK#082 we used the period from days 151 to 158, which correspond to 461 near-simultaneous direct sun ozone measurements. As shown in Figure 39, the current calibration constants produce ozone values higher than the reference instrument. However, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get better. In any case, this correction does get an optimal result what suggests that the ETC must be calculated.

Final calibration and stray light

Due to the difference with the reference Brewer, a new ETC value was calculated (see Figure 39). For the final calibration, we used 496 simultaneous direct sun measurements from days 152 to 158. The new value is approximately 35 units higher than the current ETC value (2765). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1666 for R6. We updated the new calibration constants in the ICF provided. Of course, the new ETC has been calculated taking into account the current set of temperature coefficients and dead time. The final calibration performed well with error near zero for low OSC and an underestimation of 1.2% at 1000 OSC which is good for a single Brewer. The empirical stray model fits pretty well with coefficients s=3.12, k=-46.7, ETC=2806, which are in perfect agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

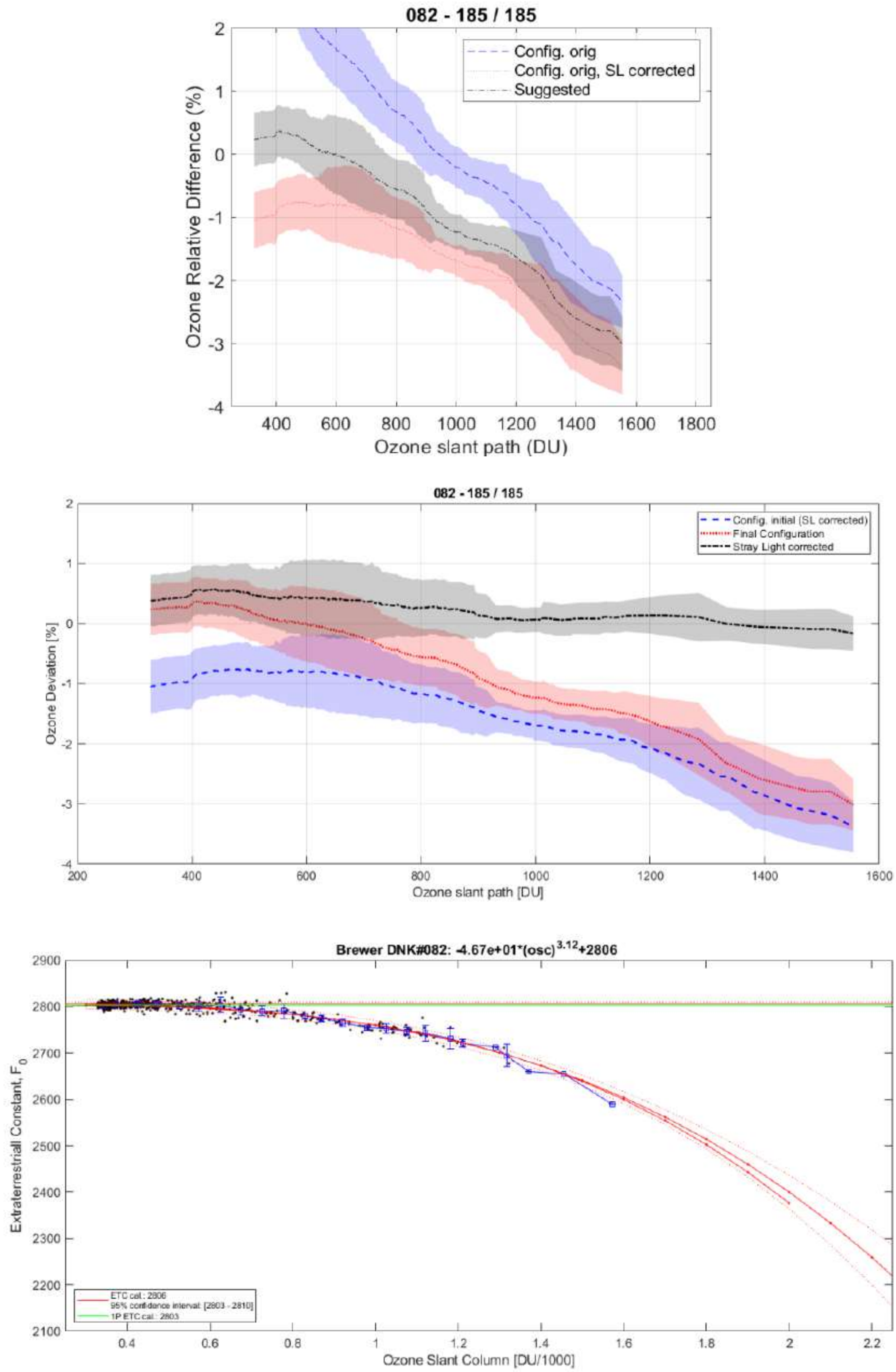


Figure 39. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#082.

Recommendations and comments

1. New R6 reference and ETC values have been calculated in this calibration campaign.
2. All the other diagnostics analysed (RS, AP records ...) were normal.
3. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
4. We have not adopted new temperature coefficients.
5. The Sun-scan tests confirmed that the CSN is the optimal one.
6. Be careful with the file format. The structure of the files is different to the standard format, which complicates the calibration. For example, we cannot open the CI files with our program.
7. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/082/CALIBRATION_082.pdf

Table 12. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	2765	2800
SL R6 reference value	1615	1666
Change SL R6 ratio/ETC	>10	
DT constant (ns)	40	40
Temp. coefficients	[0,0.61,0.92,1.19,0.77]	[0,0.61,0.92,1.19,0.77]
Cal step number	297	297
Ozone abs. coeff.	0.3545	0.3545
Stray light factor Arenosillo 2017	2806-47.7*(osc)^3.12	
Calibration file	icf15316.082	icf15017.082

3.8 Brewer POR#102, Station: Portugal

Brewer POR#102 participated in the campaign during the period from 30 May to 8 June 2017 (Julian days 150-159). For the evaluation of the initial status, we used 60 simultaneous direct sun ozone measurements from days 152 to 154. Only days 155 to 156 were used for final calibration purposes (102 simultaneous measurements, see Figure 40).

The last calibration was made in 2007 and, hence, it was considered as a new instrument in this campaign. Despite this, during the first days (150-154) it was not levelled and the measurements could not be used to calibrate it, especially being a single Brewer.

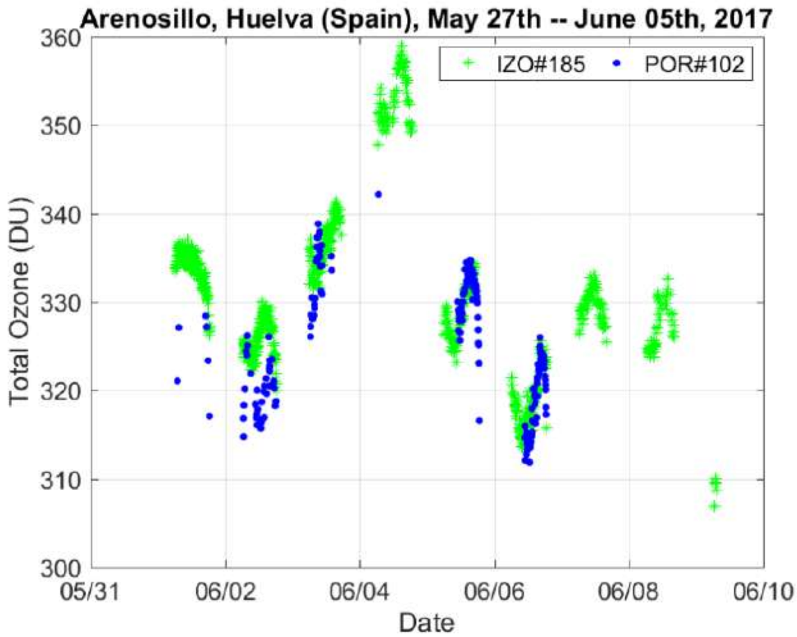


Figure 40. Brewer Intercomparison Arenosillo 2017 for B#102

Original calibration

The instrument operates with the configuration file icf25107.102 and reference value for the standard lamp R6 ratio 2350.

Historical analysis

As Figure 42 shows, the current ICF produces ozone values with a great difference with respect to the reference. In fact, the results improved significantly only applying the lamp correction. The great dependence on the solar angle indicates that a new ETC had to be calculated for this instrument.

The Sun-scan (SC) tests performed during the intercomparison are conclusive enough to analyse the optical position of the CSN. However, the value of the ozone absorption coefficient has changed with respect to the previous calibration.

The instrument has been inoperative since 2007. The values represented in the following figure were obtained during the campaign days with the initial configuration of the instrument.

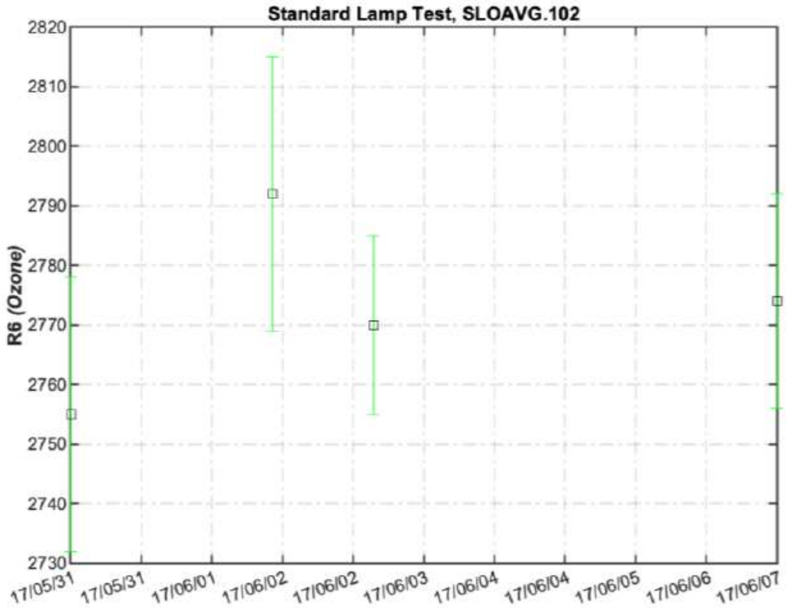


Figure 41. Standard lamp test R6 (Ozone) ratio for B#102

Initial comparison

For the evaluation of the initial status of Brewer POR#102 we used the period from days 152 to 155, which corresponds to 60 near-simultaneous direct sun ozone measurements. As shown in Figure 42, the current ICF produces ozone values with a great difference with respect to the reference. In fact, only applying the lamp correction the results improve significantly. The great dependence on the solar angle indicates that a new ETC must be calculated for this instrument.

Final calibration and stray light correction

Due to the difference with the reference Brewer, a new ETC value was calculated (see Figure 42). For the final calibration, we used 103 simultaneous direct sun measurements from days 156 to 157. The new value is 367 units greater than the current ETC value (3580). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 2718 for R6. We updated the new calibration constants in the ICF provided. The new ETC has been calculated taking into account the new set of temperature coefficients and dead time. The final calibration performed well with error near zero for low OSC and an underestimation of 1% at 1100 OSC, which is very good for a single Brewer. The empirical stray model fits pretty well with coefficients values: s=10.16, k=-62.5, ETC=3947, which are in perfect agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

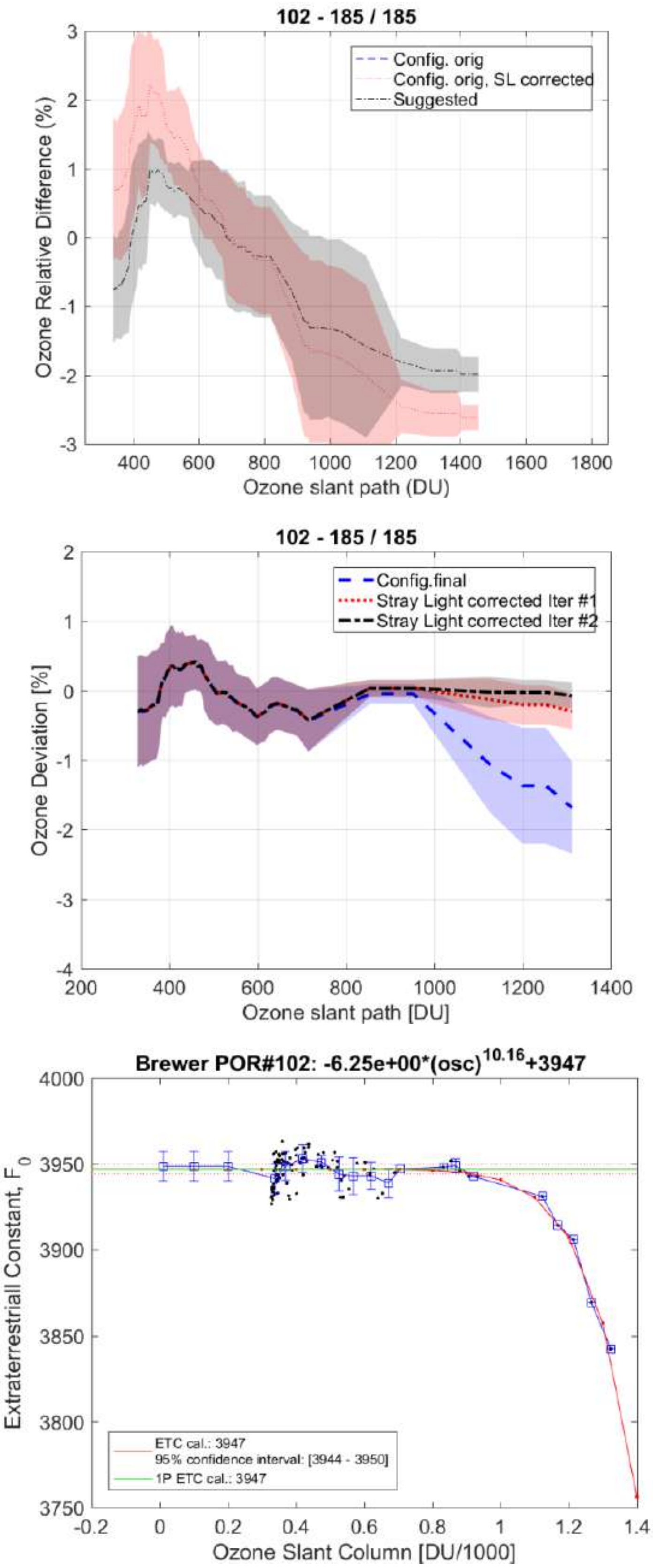


Figure 42. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#102.

Recommendations and comments

1. New reference ratios were given: R6=2718 and R5=5230.
2. It is necessary to check the standard and Hg lamps because they were replaced the last day of the campaign.
3. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT, which is really low.
4. We suggest using a DT constant of $3\cdot 10^{-8}$ seconds, which is six units lower than the current value (ICF25107.102).
5. We have not applied corrections to the filters. We recommend introducing the FI routine in your schedule more frequently.
6. We have adopted new temperature coefficients.
7. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN.
8. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/102/CALIBRATION_102.pdf

Table 13. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	3580	3947
SL R6 reference value	2350	2718
Change SL R6 ratio/ETC	>10	
DT constant (ns)	36ns	30ns
Temp. coefficients	old	new
Cal step number	295	295
Ozone abs. coeff.	0.3442	0.3451
Calibration file	icf25107.102	icf15517.102

3.9 Brewer MUR#117, Station: Murcia, Spain

Brewer MUR#117 participated in the campaign from 29 May to 7 June 2017 (Julian days 149 to 158). For the evaluation of the initial status, we used 122 simultaneous direct sun ozone measurements from days 151 to 154. Days 154 to 158 were used for final calibration purposes (100 simultaneous measurements, see Figure 43).

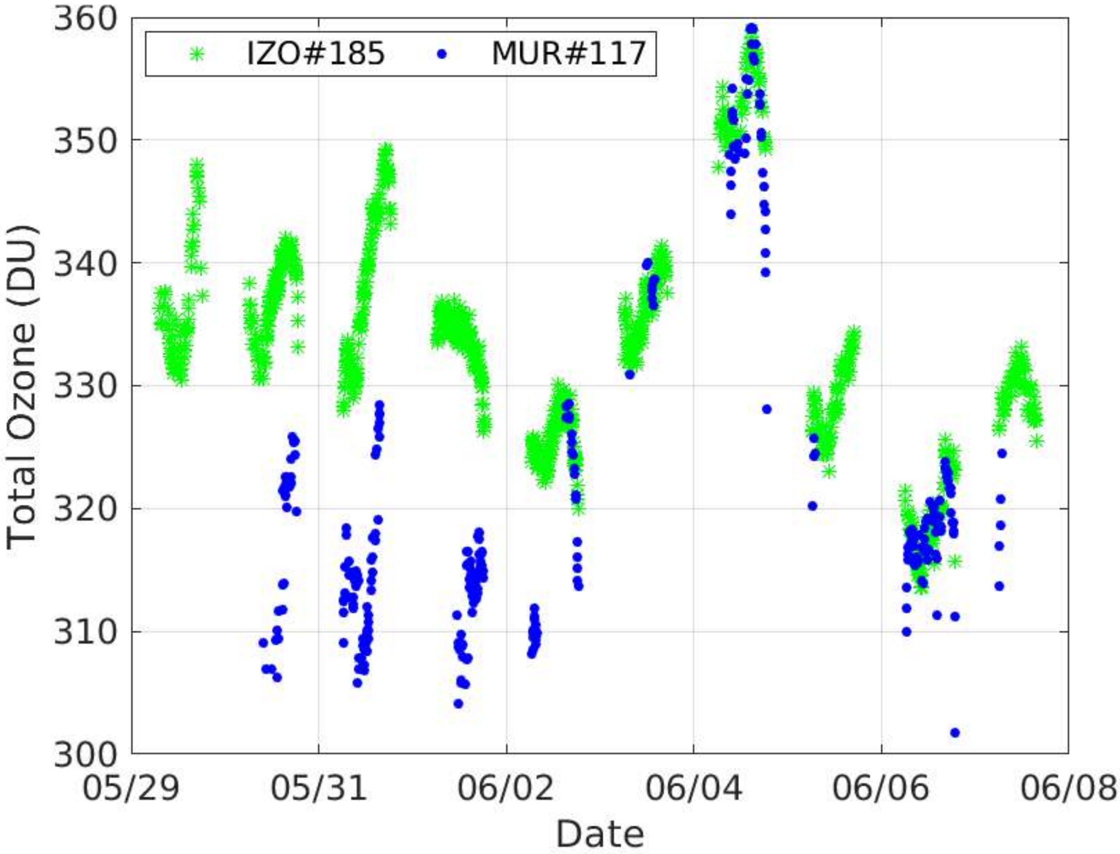


Figure 43. Brewer Intercomparison Arenosillo 2017 for B#117

Original calibration
The instrument operates with the configuration file icf14915.117, and 1536 as the reference value for the standard lamp R6 ratio.

Historical analysis
As Figure 45 shows, the current ICF produces ozone values with a difference of around -2% (on average) with respect to the reference. This decreasing tendency could be associated with the behaviour observed in the reference ratio during the last two years, see Figure 44. When the lamp correction is applied, the results improve (Figure 45). Moreover, the great dependence on the solar angle can be corrected using a recently-developed method to process data affected by stray light.

During the campaign days, after the maintenance tasks, the standard lamp ratios stabilized around values 1620 and 3000 for R6 and R5, respectively (Figure 44). These reference values were calculated from the new dead time proposed in this campaign. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) present a normal behaviour. After maintenance, the dead time was increased. The neutral density filters did not show nonlinearity in the spectral characteristics of the attenuation, so we have not applied any corrections to filters. The Sun-scan tests (SC) performed at the instrument station, before the campaign and during the first days of the intercomparison, confirm the current cal step value (286, within ±1 step error). We did not change the ozone absorption coefficient (0.338).

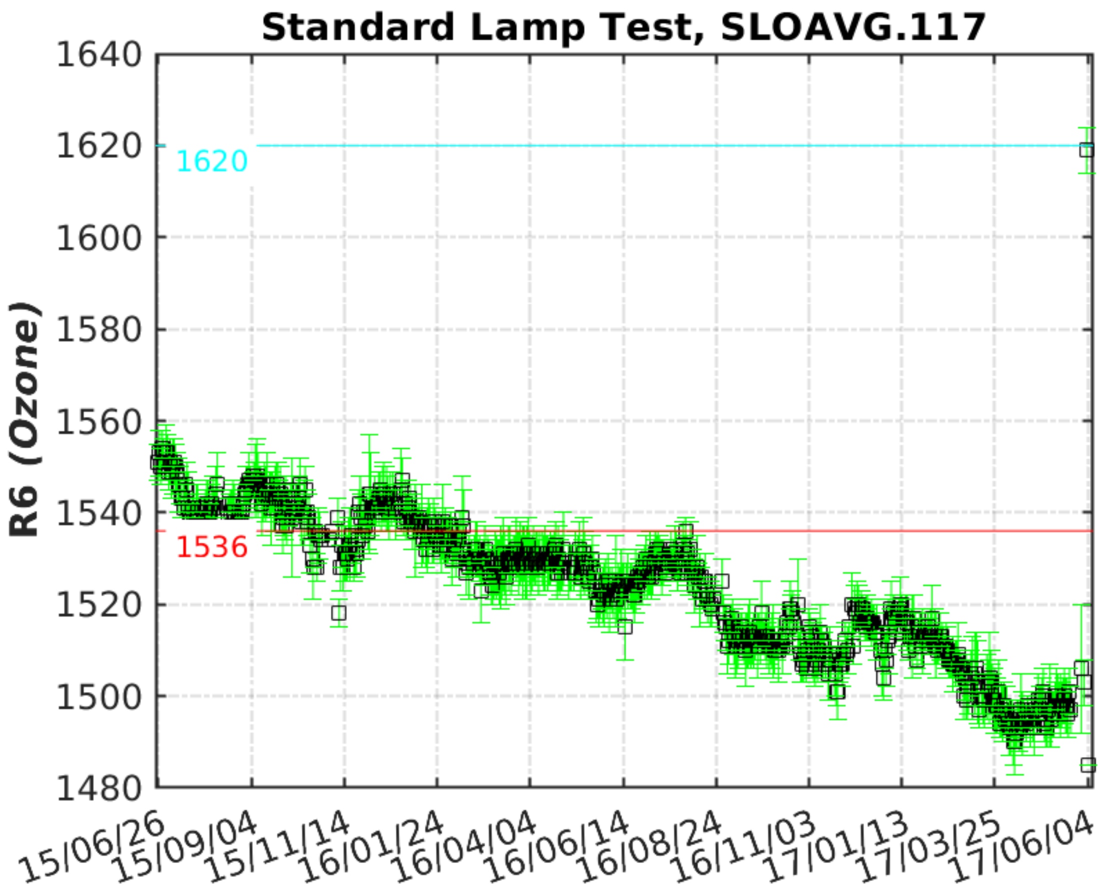


Figure 44. Standard lamp test R6 (Ozone) ratio for B#117

Initial comparison

For the evaluation of the initial status of Brewer MUR#117 we used the period from days 150 to 154, which correspond to 122 near-simultaneous direct sun ozone measurements. As shown in Figure 45, the current calibration constants produce ozone values lower than the reference instrument, with a difference of approx. -2%. When the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results improve.

Final calibration and stray light correction

Due to maintenance tasks, a new ETC value was calculated (see Figure 45). For the final calibration, we used 100 simultaneous direct sun measurements from days 154 to 158. The new value is 70 units higher than the current ETC value (2740). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1620 for R6. We updated these calibration constants in the new ICF provided. Note that the new ETC has been calculated taking into account the new dead time.

The final calibration performs well with error near zero for low OSC and an underestimation of 1% at 1000 OSC, which is very good for a single Brewer. The empirical stray-light model with coefficients k=-32.0, s=3.89, and ETC=2808, improves noticeably the agreement with the reference Brewer for the full range of OSC.

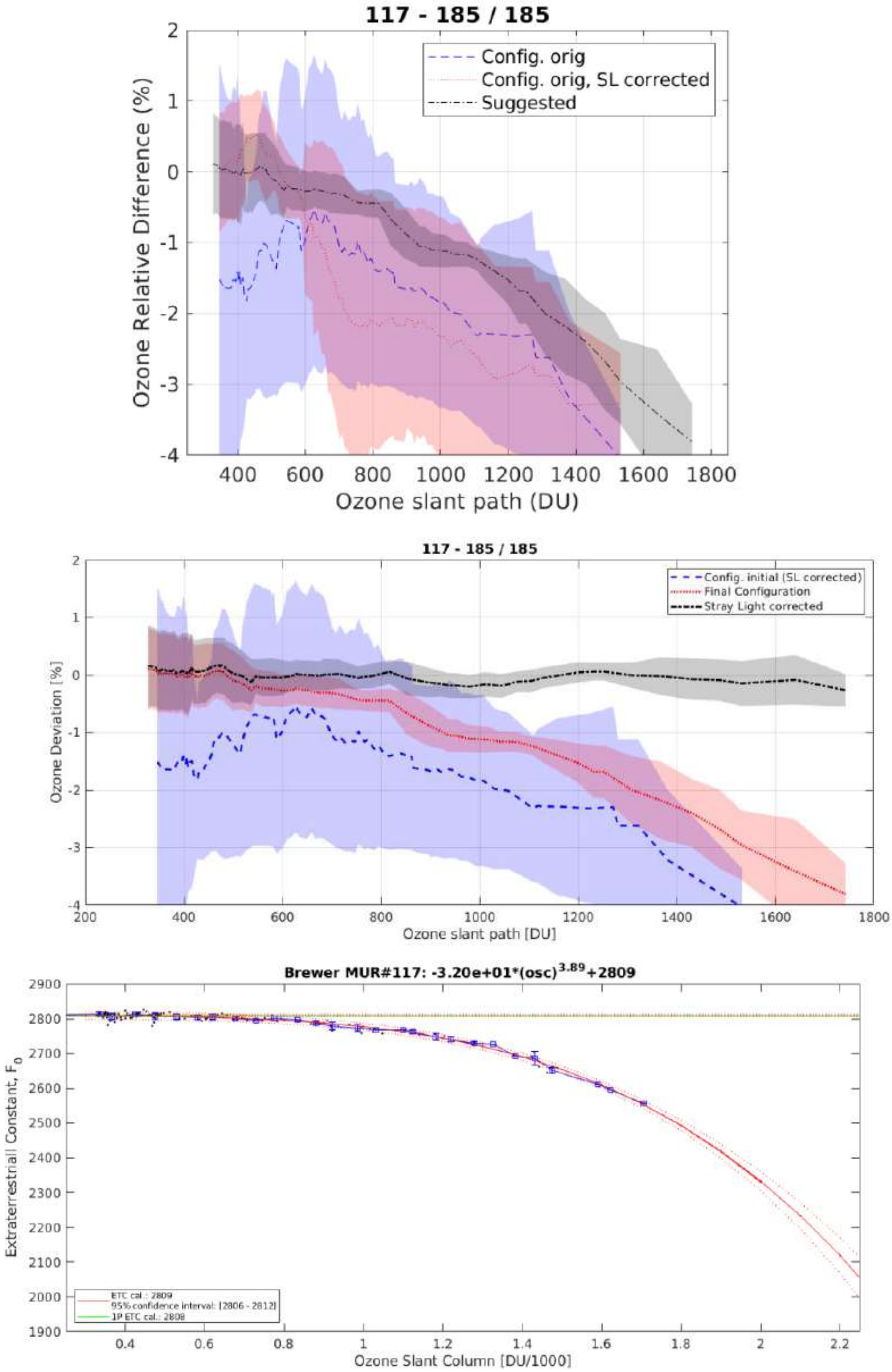


Figure 45. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#117.

Recommendations and comments

1. New reference ratios were given in this campaign: R6=1620, R5=3000.
2. All the other diagnostics analysed (RS, AP records ...) were normal.
3. After maintenance, DT increased.
4. The neutral density filters have a good behaviour and, hence, no correction factor is suggested.
5. We have not adopted new temperature coefficients.
6. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN.
7. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/117/CALIBRATION_117.pdf

Table 14. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	2740	2810
SL R6 reference value	1536	1620
Change SL R6 ratio/ETC	>10	
DT constant (ns)	23ns	27ns
Temp. coefficients	[0, 0.12475, 0.07659, -0.35919, -1.89282, -0.2]	no change
Cal step number	286	286
Ozone abs. coeff.	0.338	0.338
Stray light factor Arenosillo 2017		2808-32*(osc)^3.89
Calibration file	ICF14915.117	ICF15517.117

3.10 Brewer UM#126, Station: Manchester University, United Kingdom

Brewer UM#126 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of the initial status, we used 418 simultaneous direct sun ozone measurements from days 149 to 155. Because the CSN was changed on day 155, only days 156 to 158 were used for final calibration purposes with 267 simultaneous measurements (Figure 46).

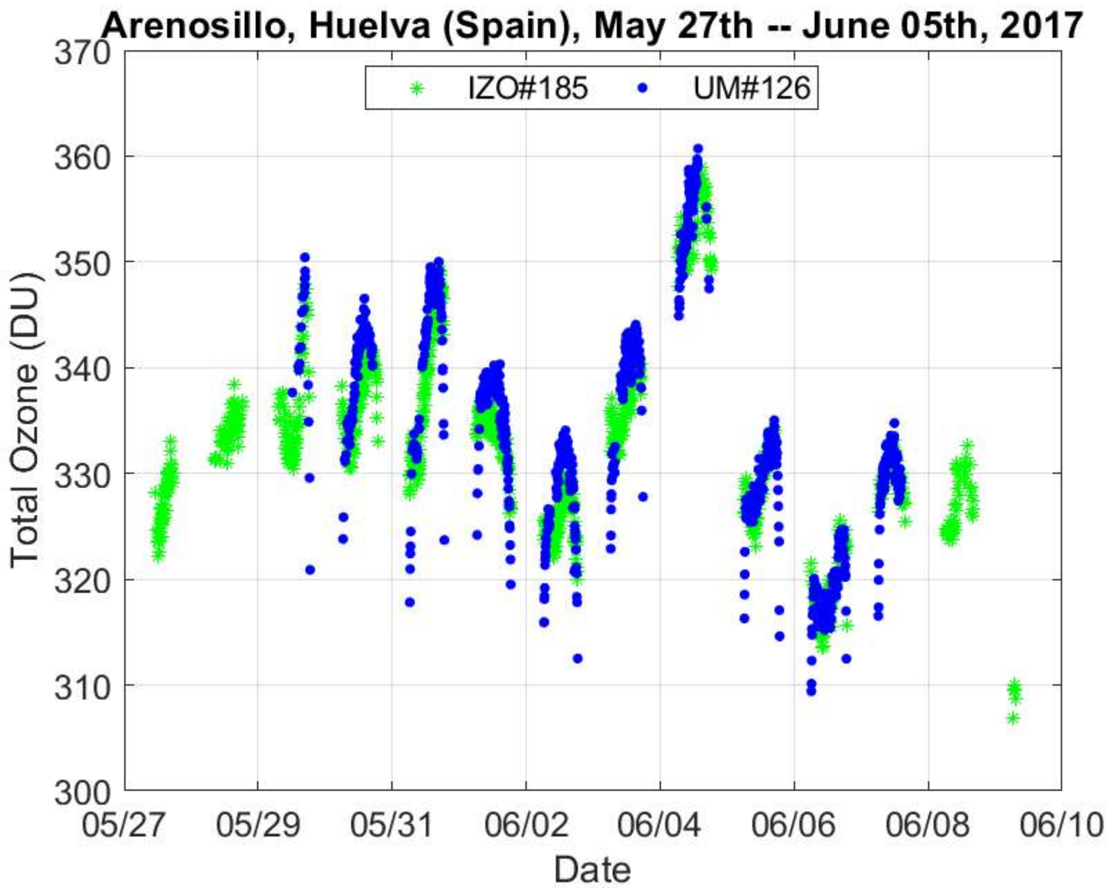


Figure 46. Brewer Intercomparison Arenosillo 2017 for B#126

As Figure 48 shows, the current ICF produces ozone values in good agreement with respect to the reference for low OSC and it shows the typical stray light dependence for high OSC. Because this Brewer has been inoperative since August 2016, we considered it as a new Brewer and, hence, the SL correction applied was zero. This explains why in this figure the "Config. orig." and "Config. orig. (SL correction)" lines are overlapped. The great dependence on the solar angle can be corrected easily using a recently developed method to correct stray light effects on simple Brewers.

During the campaign days, the standard lamp ratios stabilized around values 2070 and 4385 for R6 and R5 respectively (Figure 47). These values have been calculated taking into account the new CSN value. All the other parameters analysed (DT, Run/Stop test, Hg lamp intensity, CZ & CI files) are okay.

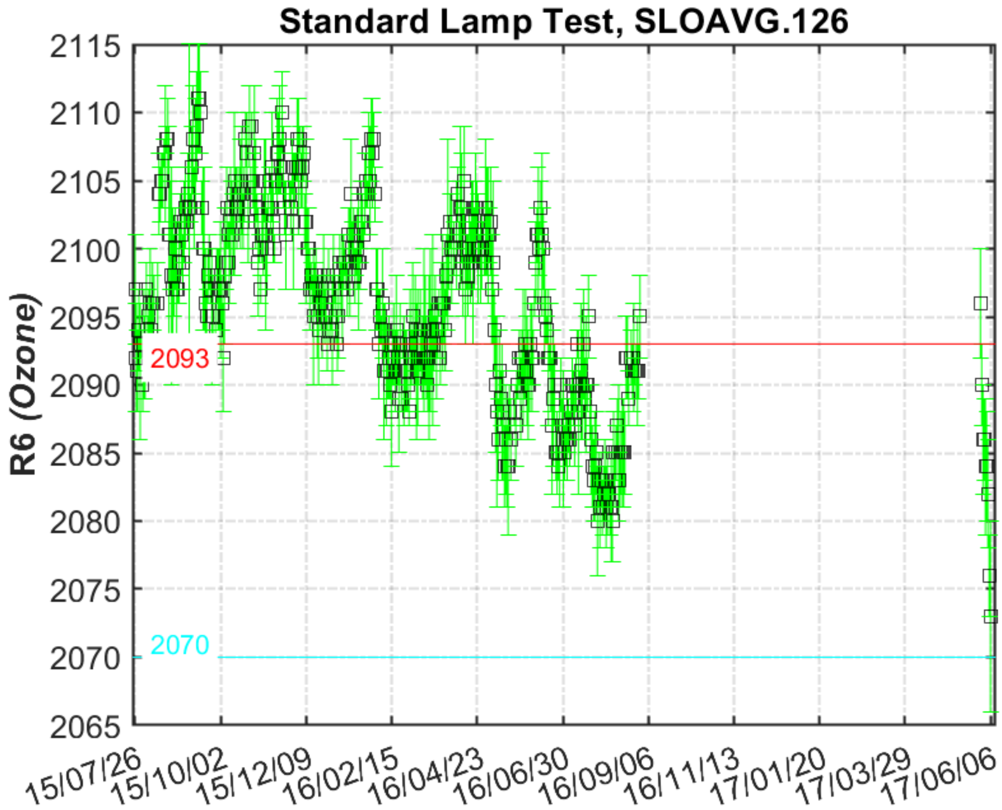


Figure 47. Standard lamp test R6 (Ozone) ratio for B#126

Initial comparison

For the evaluation of the initial status of Brewer UM#126 we used the period from days 149 to 155, which corresponds to 418 near-simultaneous direct sun ozone measurements. As shown in Figure 48, the current calibration constants produced ozone values in good agreement with low OSC. Because this Brewer has been inoperative since August 2016, we considered it as a new instrument and, hence, the SL correction applied was zero. This explains why in Figure 48 the “Config. orig.” and “Config. orig. (SL correction)” lines are overlapped.

Final calibration and stray light correction

The calibration process suggests that CSN must be changed. It is therefore necessary to calculate a new ETC value (see Figure 48). For the final calibration, we used 267 simultaneous direct sun measurements from days 156 to 158. We recommend using this new ETC, together with the new proposed standard lamp reference ratio, 2070 for R6. We updated the new calibration constants in the ICF provided. Of course, the new ETC has been calculated taking into account the current set of temperature coefficients and dead time. The final calibration performed well, with error near zero for low OSC and an underestimation of 0.5% at 1000 OSC, which is very good for a single Brewer. The empirical stray model fits pretty well with coefficients s=5.48, k=-12.8, and ETC=3229, which are in perfect agreement with the reference for the full range of OSC. In order to correct the ozone, an iterative formula is used.

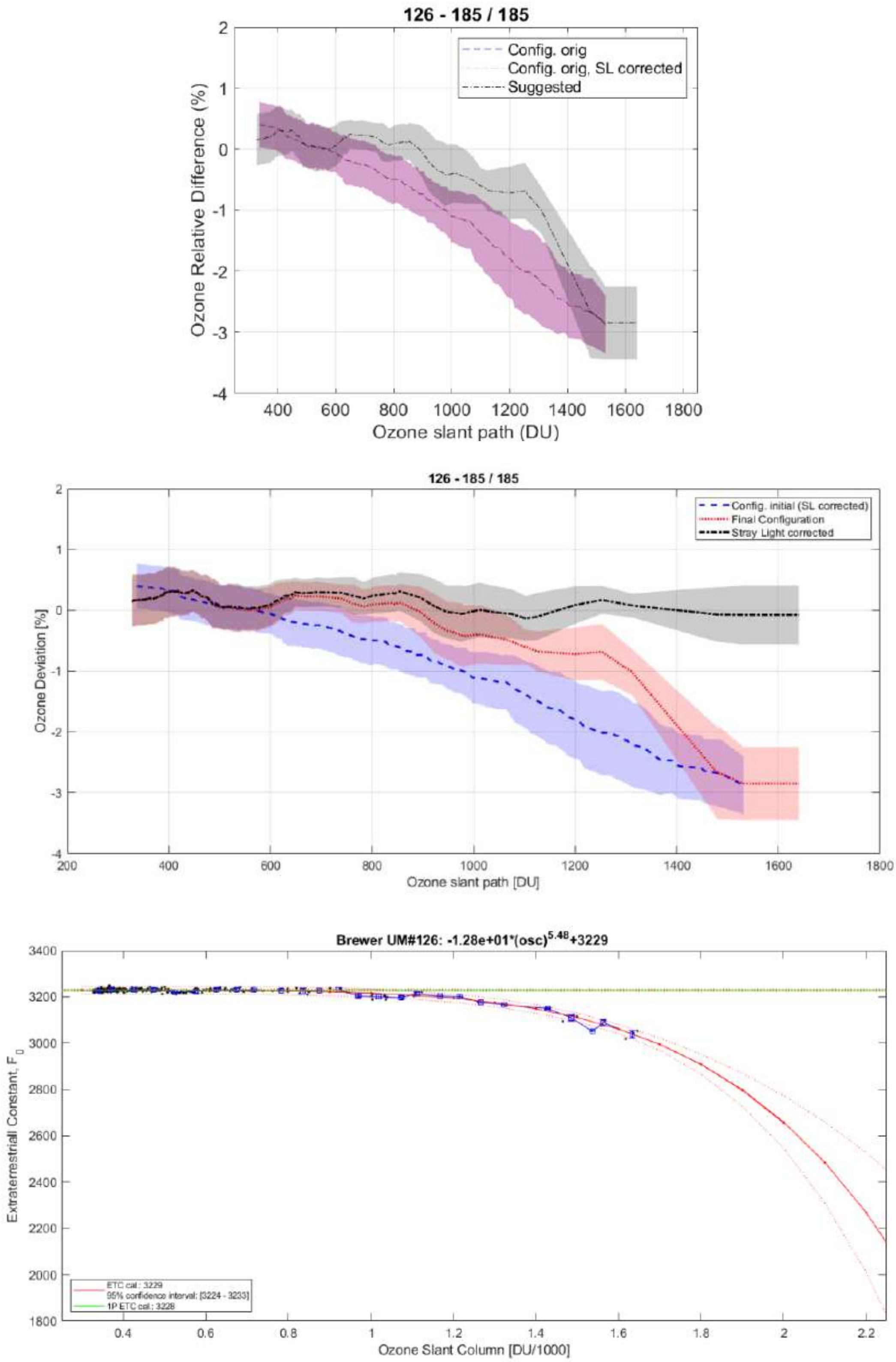


Figure 48. (Top) Ratio with respect to the reference used in the initial configuration with and without the lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#126.

Recommendations and comments

1. New R6 and ETC reference values were given in the new ICF.
2. All the other diagnostics analysed (DT, RS, AP records ...) were normal.
3. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
4. We have not adopted new temperature coefficients.
5. The Sun-scan tests suggested a new CSN=286.
6. The ozone absorption coefficient has been slightly modified to 0.341.
7. Check frequently the lamp intensity.
8. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/126/CALIBRATION_126.pdf

Table 15. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC Constant	3240	3225
SL R6 Reference Value	2093	2075
Change SL R6 ratio/ETC	<10	
DT Constant (ns)	34	36
Temp. Coefficients	[0,0.55,0.39,-0.19,-1.35]	[0,0.55,0.39,-0.19,-1.35]
Cal step number	290	286
Ozone Abs. Coeff.	0.34	0.341
Calibration file	icf15215.126	icf15517.126

3.11 Brewer ARE#150, Station: El Arenosillo, Spain

Brewer ARE#150 participated in the campaign during the period from 28 May to 8 June 2017 (Julian days 148-159). For the evaluation of the initial status, we used 70 simultaneous direct sun ozone measurements from days 148 to 151. Only days 153 to 159 were used for final calibration purposes with 213 simultaneous measurements (Figure 49).

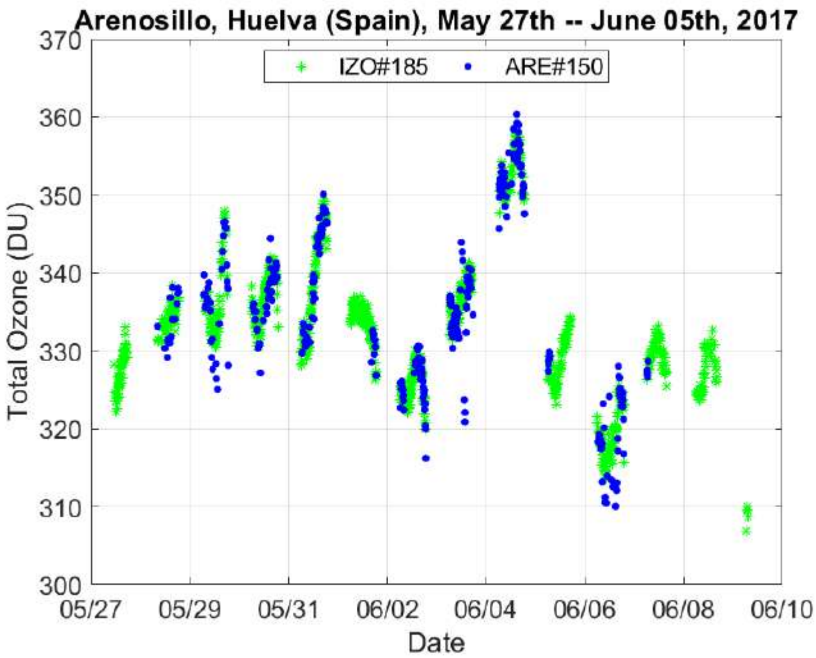


Figure 49. Brewer Intercomparison Arenosillo 2017 for B#150

As Figure 51 shows, the current ICF produces ozone values in good agreement with respect to the reference. However, differences with the reference for low ozone slant path are more dispersed than expected. The origin of this issue has been identified as a discrepancy in the differential ozone absorption coefficient (a.k.a. ozone-on-ozone ratio). This is in accordance with the dispersion tests carried out in recent years. We changed the ozone absorption coefficient from 0.344 to the new value 0.342.

The modification of the differential ozone absorption coefficient implies a change in the ETC, which is provided in the calibration certificate.

The lamp test results from Brewer ARE#150 present a stable behaviour with almost no seasonal dependence, which indicates a good behaviour of the Brewer during the last two years. From this result, SL correction is not needed. Furthermore, if the lamp correction is applied the results get slightly worse, as it can be seen in Figure 51.

The Sun-scan tests (SC) performed at the instrument station, before the campaign and during the first days of the intercomparison, confirm the current cal step value (1031 within ±1 step error). All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files, DT value) are okay. The neutral density filters did not show nonlinearity in the spectral characteristics of the attenuation, so we have not applied any corrections to filters.

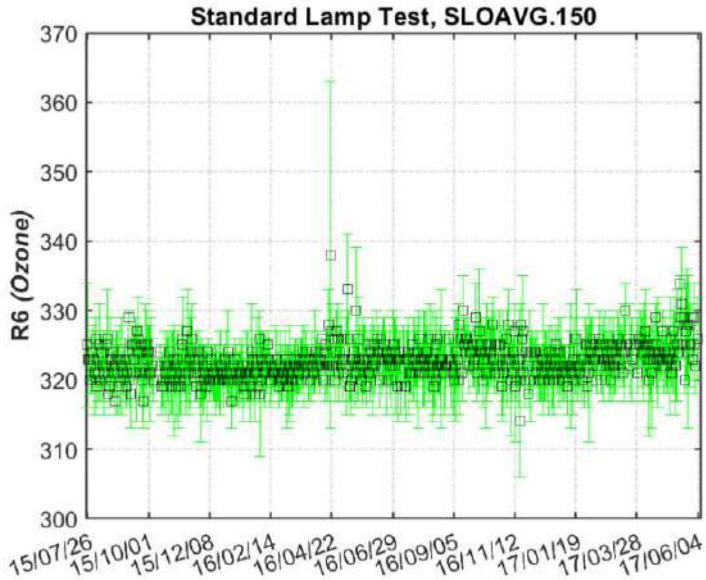


Figure 50. Standard lamp test R6 (Ozone) ratio for B#150

Initial comparison

For the evaluation of the initial status of Brewer ARE#150 we used the period from days 148 to 151, which corresponds to 70 near-simultaneous direct sun ozone measurements. As shown in Figure 51, the current calibration constants produce ozone values in good agreement with respect to the reference. In this case, when applying the lamp correction, the results do not improve significantly.

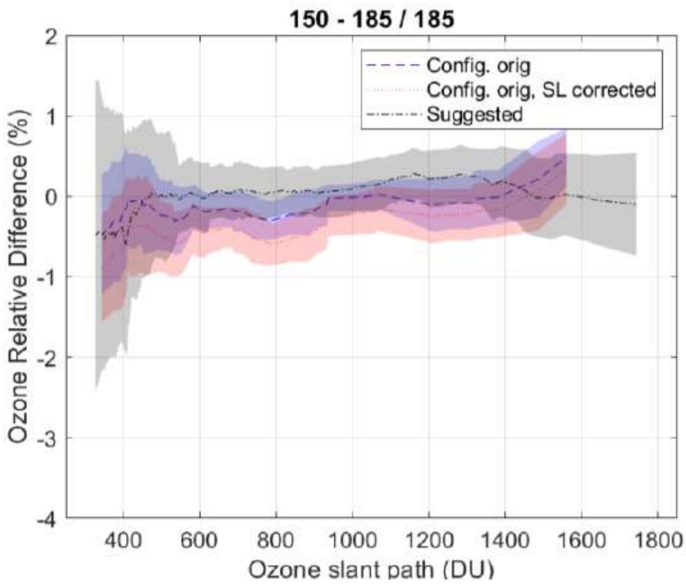


Figure 51. Ratio with respect to the reference using the initial configuration with and without the lamp correction, and the final configuration for B#150

Final calibration

Due to the modification of the differential ozone absorption coefficient, a new ETC value was calculated. For the final calibration, we used 213 simultaneous direct sun measurements from days 153 to 159. The new value is approximately 9 units higher than the current ETC value (1560). We recommend using this new ETC, together with the new proposed differential ozone absorption coefficient and the new proposed standard lamp reference ratio, 330 for R6. We updated the new calibration constants in the ICF provided.

Recommendations and comments

1. We recommend to change ozone absorption coefficient to 0.342.
2. Associated with the new ozone absorption coefficient, a new ETC=1569 has been calculated in this calibration campaign.
3. It was not necessary to correct with the lamp for the period before this calibration.
4. New reference ratios were given: R6=330 and R5=685.
5. The current temperature coefficients work correctly.
6. All the other diagnostics analysed (RS, AP records ...) were normal.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/150/CALIBRATION_150.pdf

Table 16. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	1560	1569
SL R6 reference value	322	330
Change SL R6 ratio /ETC	<10	
DT constant (ns)	32	32
Temp. coefficients	[0, 1.29, 1.94, 2.13, 2.00]	[0, 1.29, 1.94, 2.13, 2.00]
Cal step number	1031	1031
Ozone abs. coeff.	0.344	0.342
Calibration file	ICF14915.150	ICF15617.150

3.12 Brewer COR#151, Station: La Coruña, Spain

Brewer COR#151 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of the initial status, we used 51 simultaneous direct sun ozone measurements from days 151 to 153. The final calibrations were obtained from days 154 to 157 (77 simultaneous measurements).

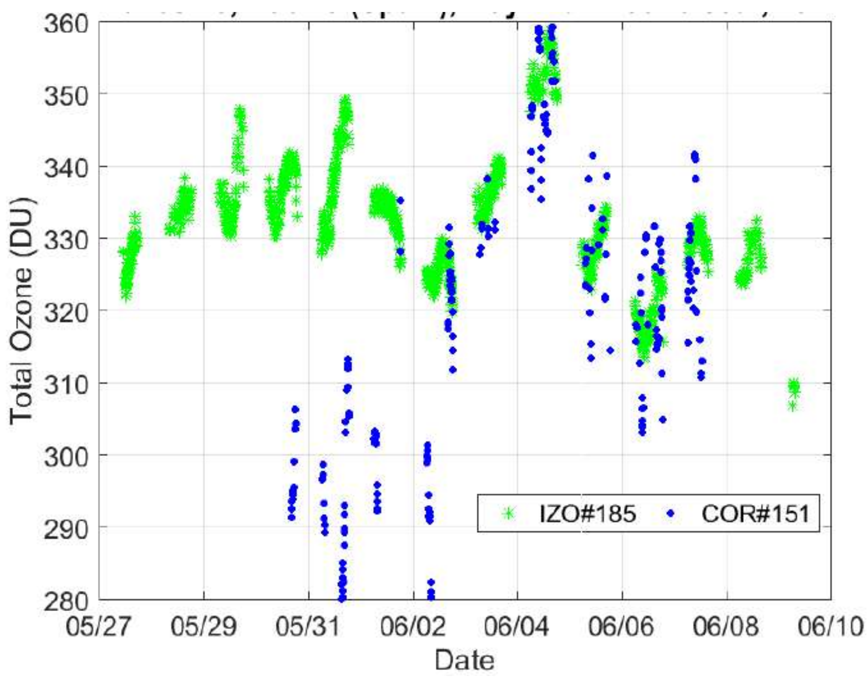


Figure 52. Brewer Intercomparison Arenosillo 2017 for B#151

As Figure 52 shows, the current ICF produces ozone values with an important difference with respect to the reference. Applying the lamp correction, the results did not improve. The great dependence on the solar angle can be corrected easily using a recently developed method to correct stray light effects on single Brewers.

The lamp test results from Brewer COR#151 presented an important jump in June 2016. But after this, it has been very stable during the last year (Figure 53). During the campaign days, the standard lamp ratios stabilized around values 1900 and 3500 for R6 and R5, respectively. These values have been calculated taking into account the new temperature coefficients and dead time calculated in this campaign.

All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are correct, except for the DT value. This parameter has increased its value, approx. 4 units ($3.5 \cdot 10^{-8}$), due to the voltage change in the photomultiplier.

The neutral density filters did not show nonlinearity in the attenuation spectral characteristics. We have not applied corrections to the filters.

Sun-scan (SC) tests performed before and during the intercomparison are conclusive enough to analyse the optical position of the CSN. The value of the ozone absorption coefficient has been slightly changed with respect to the previous calibration.

Initial comparison

For the evaluation of the initial status of Brewer COR#151 we used the period from days 151 to 153, which corresponds to 51 near-simultaneous direct sun ozone measurements. As shown in Figure 54, the current calibration constants produce ozone values lower than the reference instrument. Moreover, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get worse.

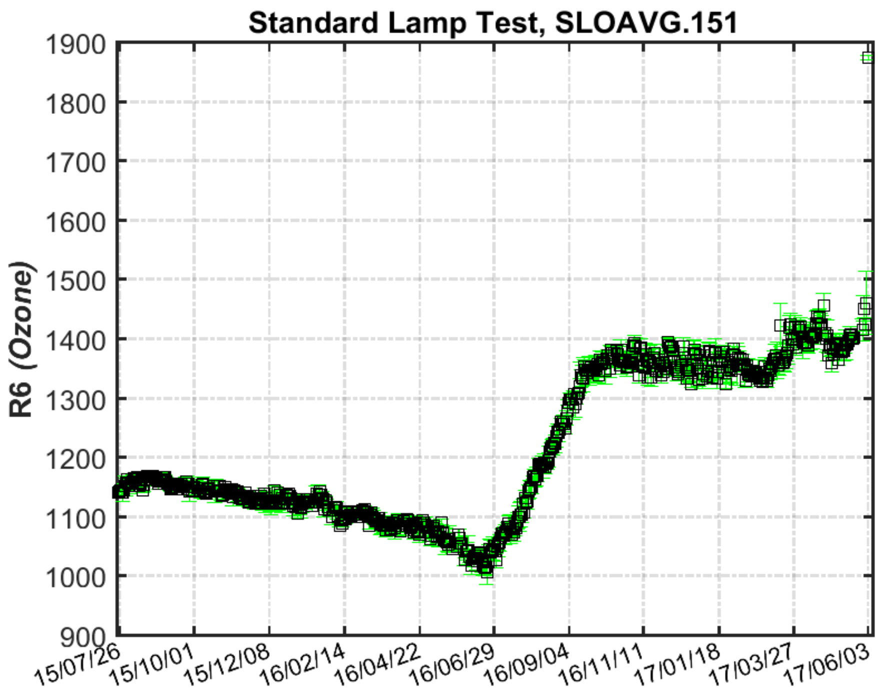


Figure 53. Standard lamp test R6 (Ozone) ratio for B#151

Final calibration

Due to the difference with the reference Brewer, a new ETC value was calculated, see Figure 54. For the final calibration, we used 77 simultaneous direct sun measurements from days 154 to 157. The new value is 55 units greater than the current ETC value (2945). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1900 for R6. We updated the new calibration constants in the ICF provided. The final ETC has been calculated taking into account the new set of temperature coefficients and dead time.

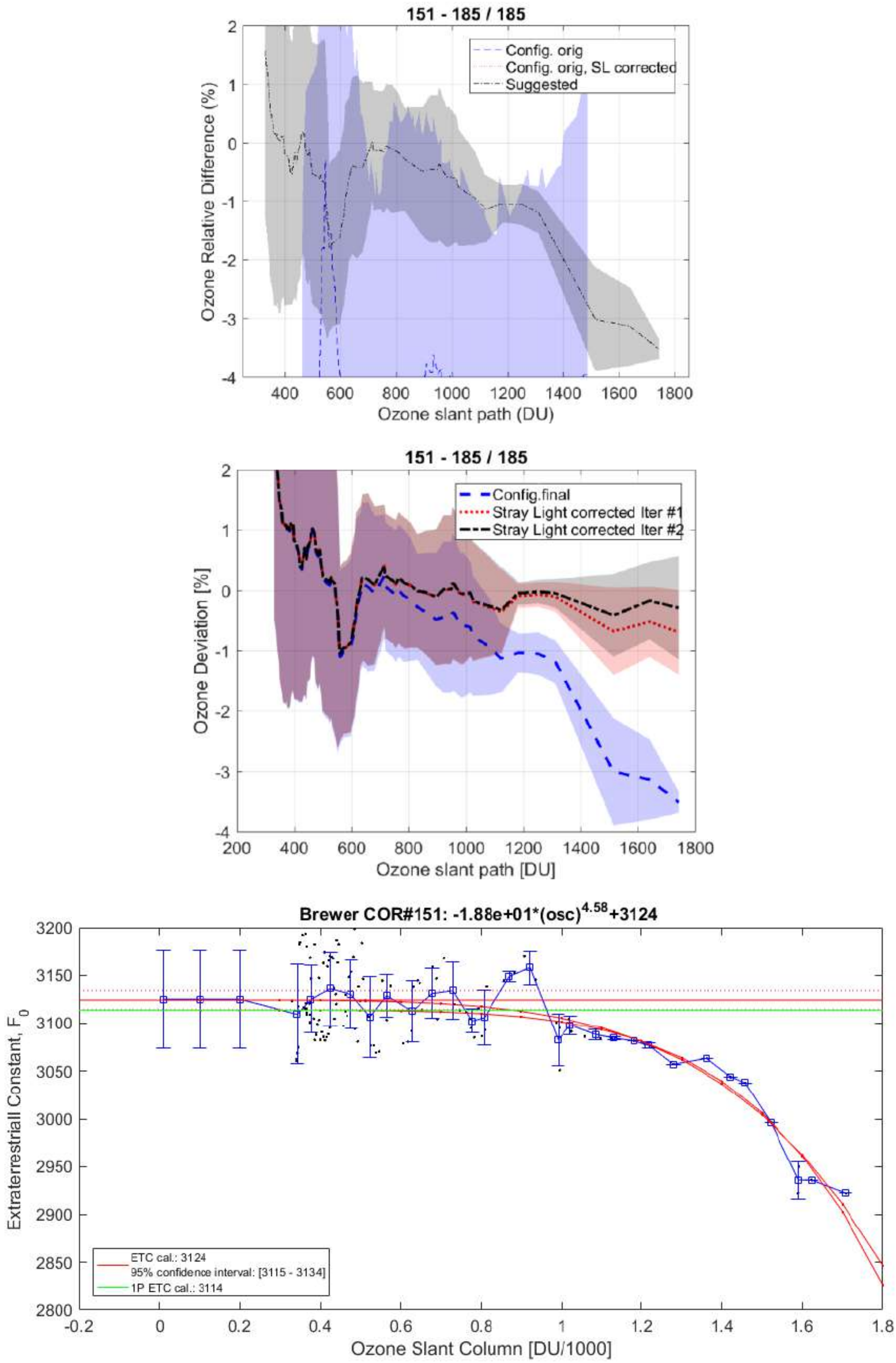


Figure 54. Ratio with respect to the reference using the initial configuration with and without the lamp correction, and the final configuration for B#151

Recommendations and comments

1. New reference values were given in this calibration: R6=1900 and R5=3500.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT.
3. This parameter has increased its value, in around 4 units ($3.5 \cdot 10^{-8}$), due to the voltage change in the photomultiplier.
4. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
5. We have adopted new temperature coefficients.
6. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN.
7. The value of the ozone absorption coefficient has been slightly changed with respect to the previous calibration.
8. The instrument performed very well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/151/CALIBRATION_151.pdf

Table 17. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	2945	3500
SL R6 reference value	1198	1900
Change SL R6 ratio /ETC	>10	---
DT constant (ns)	3.1e-08	3.5e-08
Temp. coefficients	[0, -1.228, -3.107, -4.097, -5.37]	[0, -0.96, -2.5, -4.343, -6.647]
Cal step number	288	288
Ozone abs. coeff.	0.3417	0.3416
Calibration file	ICF16913.151	ICF15317.151

3.13 Brewer WRC#163, Station: Davos, Switzerland

Brewer WRC#163 participated in the campaign during the period from 29 May to 7 June 2017 (Julian days 149-158). For the evaluation of the initial status, we used 739 simultaneous direct sun ozone measurements from days 149 to 158. The same period was used for final calibration purposes with 723 simultaneous measurements (Figure 55).

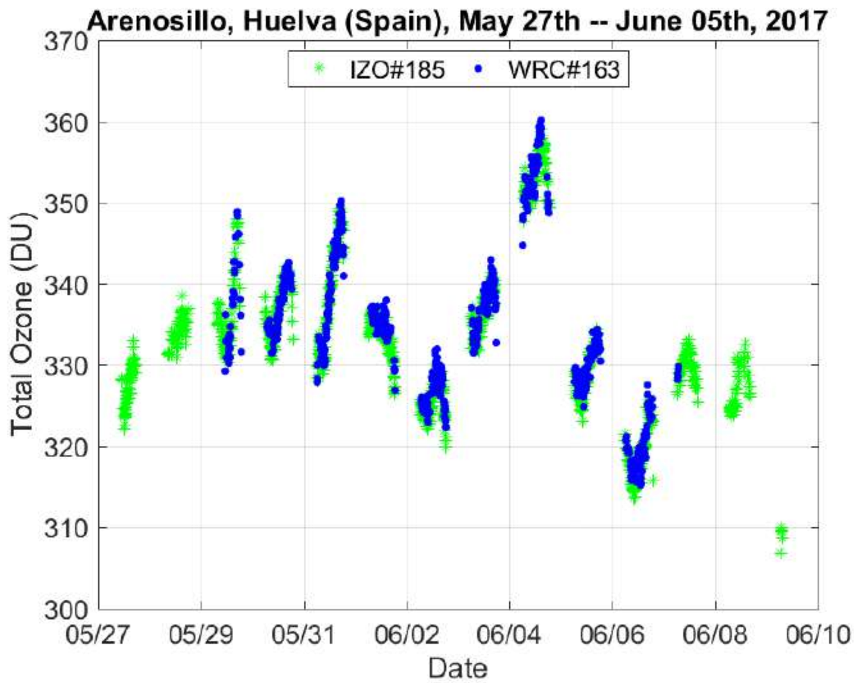


Figure 55. Brewer Intercomparison Arenosillo 2017 for B#163

Original calibration

The instrument operates with the configuration file icf17016.163 and reference value for the standard lamp R6 ratio 270.

Historical analysis

As Figure 57 shows, the current ICF produces ozone values with a difference of around +0.5% (on average) with respect to the reference. Applying the SL correction, the results do not present any significant improvement.

The lamp test results from Brewer WRC#163 presented a stable behaviour in the last year. During the campaign days, the standard lamp ratios stabilized around values 270 and 460 for R6 and R5 respectively (Figure 56).

All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files and DT) presented stable values. The neutral density filters did not show nonlinearity in the spectral characteristics of the attenuation. We have not applied any corrections to filters.

The Sun-scan (SC) tests performed before and during the intercomparison are conclusive enough to analyse the optical position of the CSN. However, the value of the ozone absorption coefficient has been changed with respect to the previous calibration.

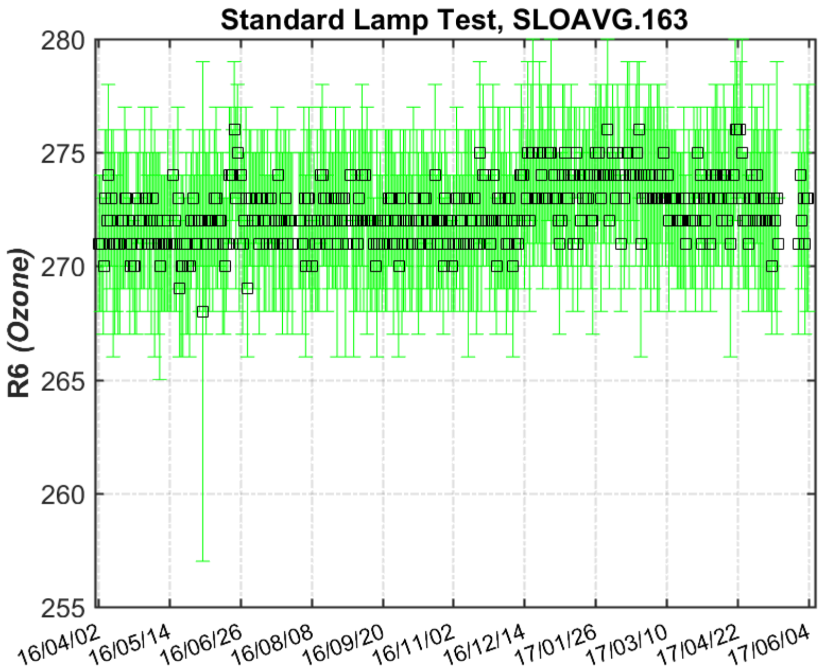


Figure 56. Standard lamp test R6 (Ozone) ratio for B#163

Initial comparison

For the evaluation of the initial status of Brewer WRC#163, we used the period from days 149 to 158, which correspond to 739 near-simultaneous direct sun ozone measurements. As shown in Figure 57, the current calibration constants produce ozone values greater than the reference instrument (+0.8%). Moreover, when the ETC is corrected taking into account the difference between the SL and R6 reference (SL correction), the results do not present any significant improvement.

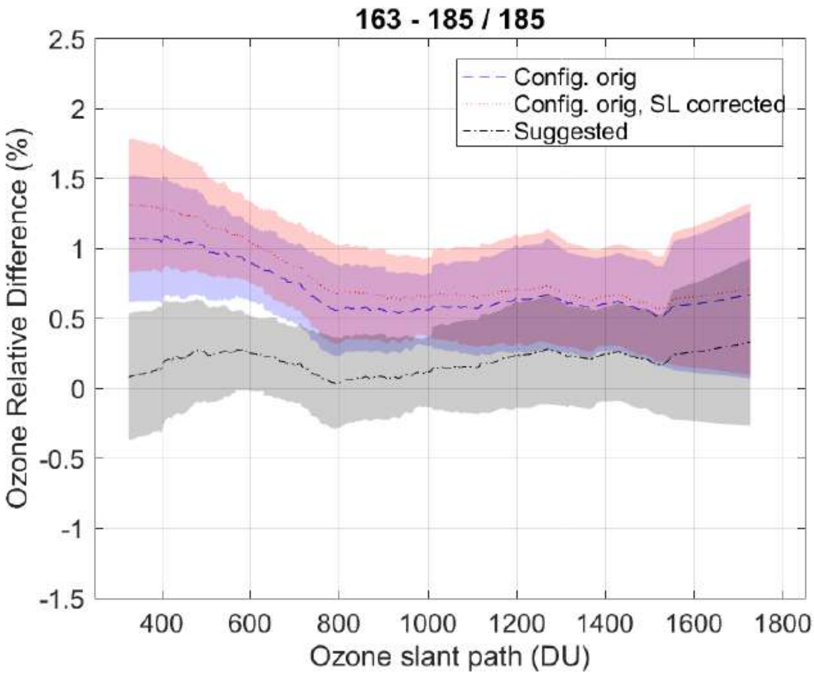


Figure 57. Ratio with respect to the reference used in the initial configuration with and without SL correction and final configuration for B#163

Final calibration

Due to the new ozone absorption coefficient proposed, a new ETC value was calculated. For the final calibration, we used 723 simultaneous direct sun measurements from days 149 to 158. The new value is 10 units greater than the current ETC value (1470). Therefore, we recommend using this, together with the current standard lamp reference ratio, 270 for R6.

Recommendations and comments

1. A new ETC reference value was given in the new ICF.
2. The ozone absorption coefficient has been slightly modified to 0.3405.
3. New reference values are given in this calibration: R6=270 and R5=466.
2. All the other diagnostics analysed (RS, AP records ...) were normal.
3. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
4. The current temperature coefficients are used in the new calibration.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/163/CALIBRATION_163.pdf

Table 18. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	1470	1480
SL R6 reference value	270	270
Change SL R6 ratio/ETC	<10	
DT constant (ns)	30	30
Temp. coefficients	[0,0.20,0.11,0.34,-0.56]	[0,0.20,0.11,0.34,-0.56]
Cal step number	1021	1021
Ozone abs. coeff.	0.34	0.3405
Calibration file	icf17016.163	icf15017.163

3.14 Brewer ZAR#166, Station: Zaragoza, Spain

Brewer COR#166 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of the initial status, we used 71 simultaneous direct sun ozone measurements from days 151 to 152. Only days 154 to 159 were used for final calibration purposes (123 simultaneous measurements) (Figure 58).

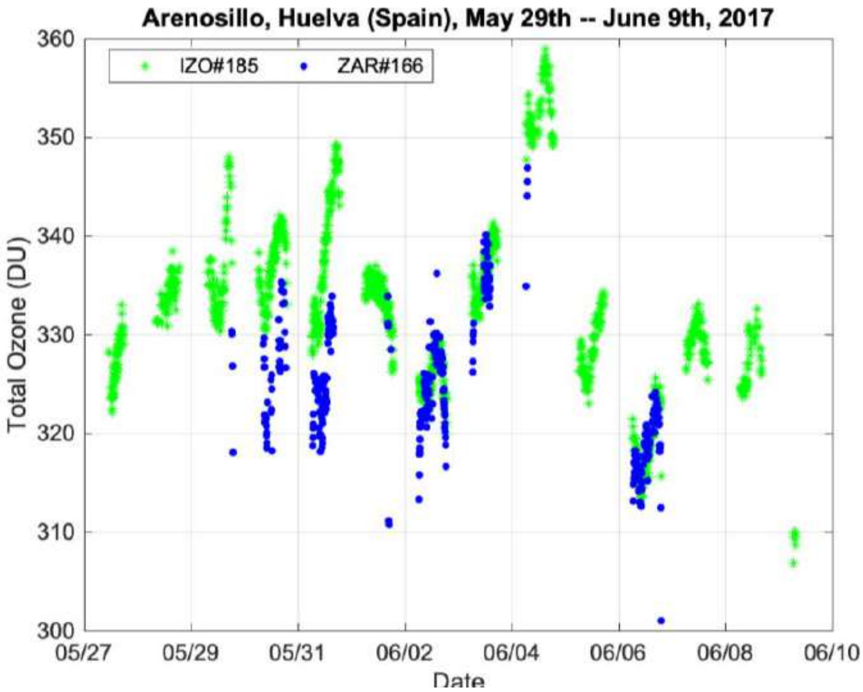


Figure 58. Brewer Intercomparison Arenosillo 2017 for B#166

As Figure 60 shows, the current ICF produces ozone values with a difference of around -2% (on average) with respect to the reference. After applying the SL correction, the results improve with a difference of around +1% (on average).

It is important to note that the instrument does not use the configuration provided in 2015 and uses a 2013 calibration file. In particular, the proposed temperature coefficients are not in use and the standard lamp ratio shows a clear seasonal dependence. During the campaign days, the standard lamp ratios were 1910 and 3660 for R6 and R5 respectively, after maintenance these values change to 1952 and 3733 (Figure 59). With the updated temperature coefficients the R6 value changes from 1940 before maintenance to 1980 after maintenance.

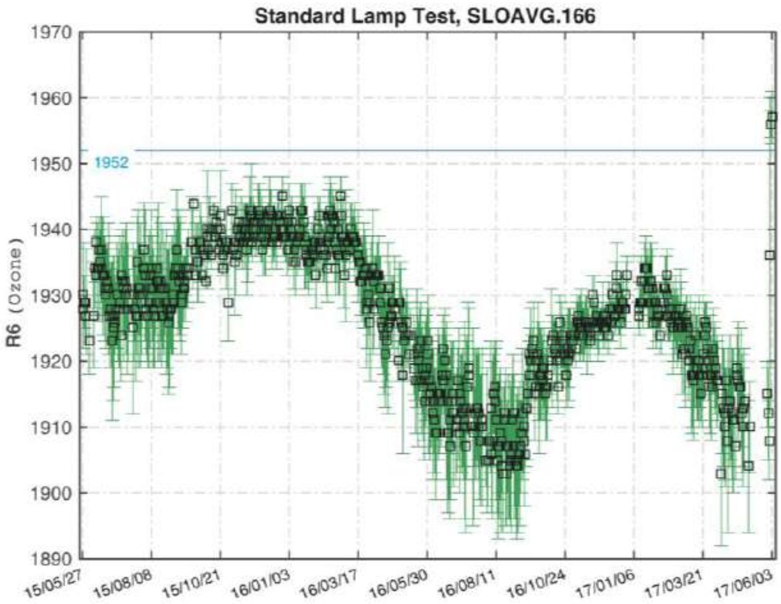


Figure 59. Standard lamp test R6 (Ozone) ratio for B#166

The instrumental test analysed (DT, test, Hg lamp intensity, CZ & CI files) are inside the tolerance range, except for the Run/Stop test at slits 5 and 6. The HL/HS test shows discrepancies bigger than 0.2A which suggests an incorrect dispersion relation.

The neutral density filters did not show nonlinearity in the attenuation spectral characteristics. We have not applied corrections to the filters.

The Sun-scan tests confirm the setting of the instrument, we have not updated the ozone absorption coefficient 0.3425, but using the mean of the three last calibrations we suggested a value of 0.3435.

Initial comparison

For the evaluation of the initial status of Brewer ZAR#166 we used the period from days 154 to 159, which corresponds to 71 near-simultaneous direct sun ozone measurements. As shown in Figure 60, the current calibration constants produce ozone values lower than the reference instrument (-2%). However, when the ETC is corrected taking into account the difference between the SL and R6 reference (SL correction), the results get better (+1%).

Final calibration

For the final calibration, we used 123 simultaneous direct sun measurements from days 153 to 155. Using the updated temperature coefficient, the new ETC is 50 units higher than the current ETC value (3135). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1980 for R6. We updated the new calibration constants in the ICF provided.

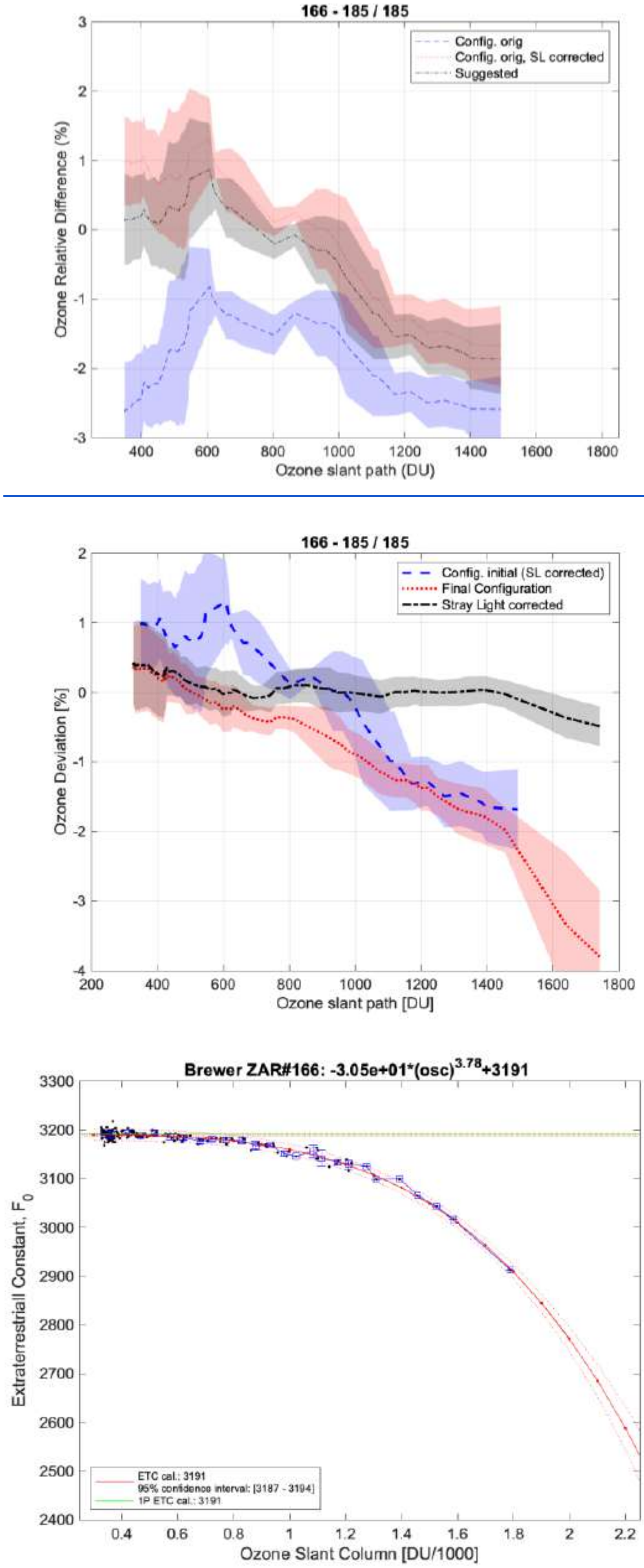


Figure 60. (Top) Ratio with respect to the reference used in the initial configuration with and without standard lamp correction. (Middle) Initial and final configuration with and without stray light correction. (Bottom) Stray light empirical model determination for B#166.

Recommendations and comments

1. We have updated the temperature coefficients, this correction can be applied backwards in time.
2. Run/Stop test showed anomalous results for slit 5 and 6. Slit assembly must be checked.
3. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
4. The Sun-scan tests confirmed the current setting but hg mercury line scan showed an offset outside the limits which suggested an update of the dispersion relation. We have not changed the ozone absorption coefficient.
5. The instrument performed well after the calibration constants were applied, with minimal ozone deviations when the stray light correction was used. We recommend the use of the stray light correction.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/166/CALIBRATION_166.pdf

Table 19. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	3135	3187
SL R6 reference value	1925(*)	1985
Change SL R6 ratio /ETC	>10	---
DT constant (ns)	3.3e-08	3.3e-08
Temp. coefficients	[19.4,19.11,19.40,18.42,17.04]	[0, 0.86, 1.39, 1.17, -0.32]
Cal step number	288	288
Ozone abs. coeff.	0.3425	0.3425
Calibration file	ICF16913.166	ICF15217.166

3.15 Brewer UM#172, Station: Manchester University, United Kingdom

Brewer UM#172 participated in the campaign from 29 May to 7 June 2017 (Julian days 149 to 158). We did not detect any change in the instrument during the campaign, so we used the same dataset to evaluate the initial status of the instrument as well as for final calibration purposes, with approx. 560 simultaneous direct sun ozone measurements taken from days 149 to 158, see Figure 61.

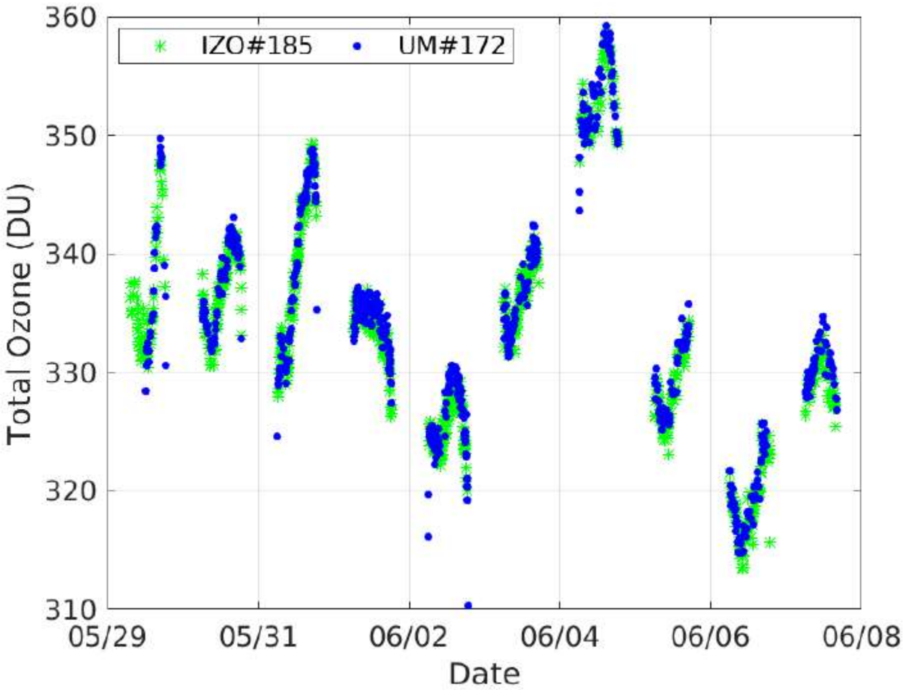


Figure 61. Brewer Intercomparison Arenosillo 2017 for B#172

The lamp test results from Brewer UM#172 presented a stable behaviour during the last 2 years. In this campaign, standard lamp ratios stabilized around values 444 and 710 for R6 and R5 respectively (Figure 3.15.2). However, the F5 lamp intensity presents an irregular behaviour. All the other parameters analysed (Run/Stop test, Hg lamp intensity, DT, CZ & CI files) present normal values.

Regarding the neutral density filters, filter #4 shows a non-linear behaviour which might require a correction of approx. -15. However, this correction is based on quite noisy data, and the analysis of 1 year of data shows that it is used by less than 3% of the measurements, so we do not recommend the application of the correction. In the ETC transfer, we have not used data with filter #4.

Finally, Sun-scan tests performed at the instrument's station, before the campaign, and during the first days of the intercomparison, confirm the current cal step value (286, within ±1 step error).

Initial comparison

For the evaluation of the initial status of Brewer UM#172 we used the days 149 to 158, which correspond to approx. 560 near-simultaneous direct sun ozone measurements. As shown in

Figure 63, the current calibration constants produce ozone values in good agreement with respect to the reference instrument. The lamp correction does not improve the results.

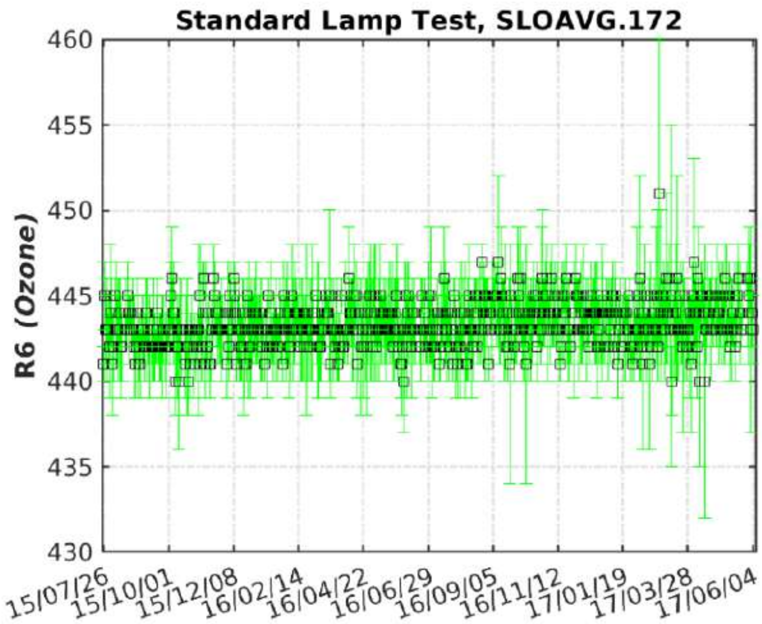


Figure 62. Standard lamp test R6 (Ozone) ratio for B#172

Final calibration

Despite the excellent results obtained with the current ICF, we performed a new transfer of the reference instrument's ETC, using simultaneous direct sun measurements from days 149 to 158. At the end of this process, we found that the new ETC was equal to the current one.

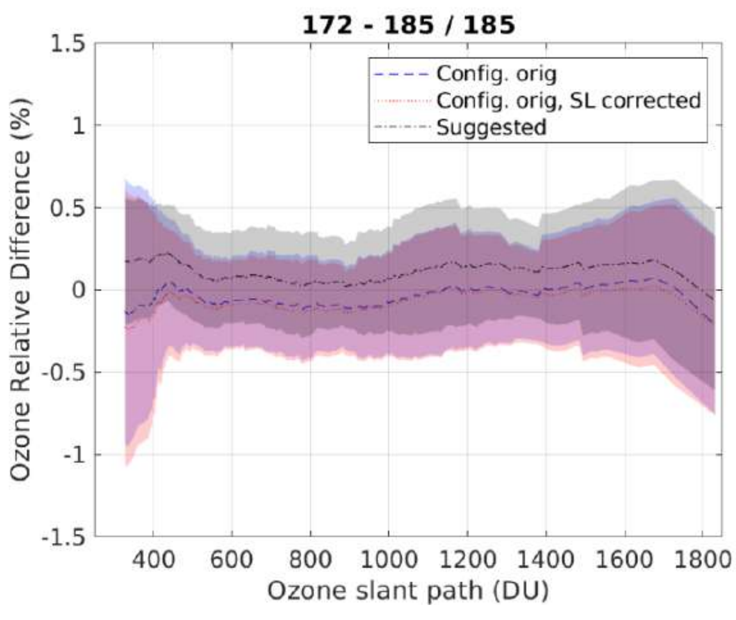


Figure 63. Ratio with respect to the reference used in the initial configuration with and without the lamp correction and final configuration for B#172

Recommendations and comments

1. As Figure 63 shows, the current ICF produced ozone values in excellent agreement with respect to the reference. The operator can continue using the current ICF. An alternative ICF is given in this calibration, with a very small change in the ozone absorption coefficient.
2. All the other diagnostics analysed (RS, AP records ...) were normal.
3. We recommend checking frequently the lamp intensity.
4. Sun-scan tests confirmed the current CSN.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/172/CALIBRATION_172.pdf

Table 20. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	1700	1700
SL R6 reference value	444	444
Change SL R6 ratio/ETC	0	
DT constant (ns)	3e-08	3e-08
Temp. coefficients	[6.2369, 5.8351, 5.7129, 5.45, 5.0893, 0]	no change
Cal step number	286	286
Ozone abs. coeff.	0.3415	0.341
Calibration file	ICF15115.172	ICF15117.172

3.16 Brewer MAD#186, Station: Madrid, Spain

Brewer MAD#186 participated in the campaign from 29 May to 7 June 2017 (Julian days 149 to 158). For the evaluation of the initial status, we used 192 simultaneous direct sun ozone measurements from days 150 to 155. Days 156 to 158 were used for final calibration purposes (132 simultaneous measurements, see Figure 64).

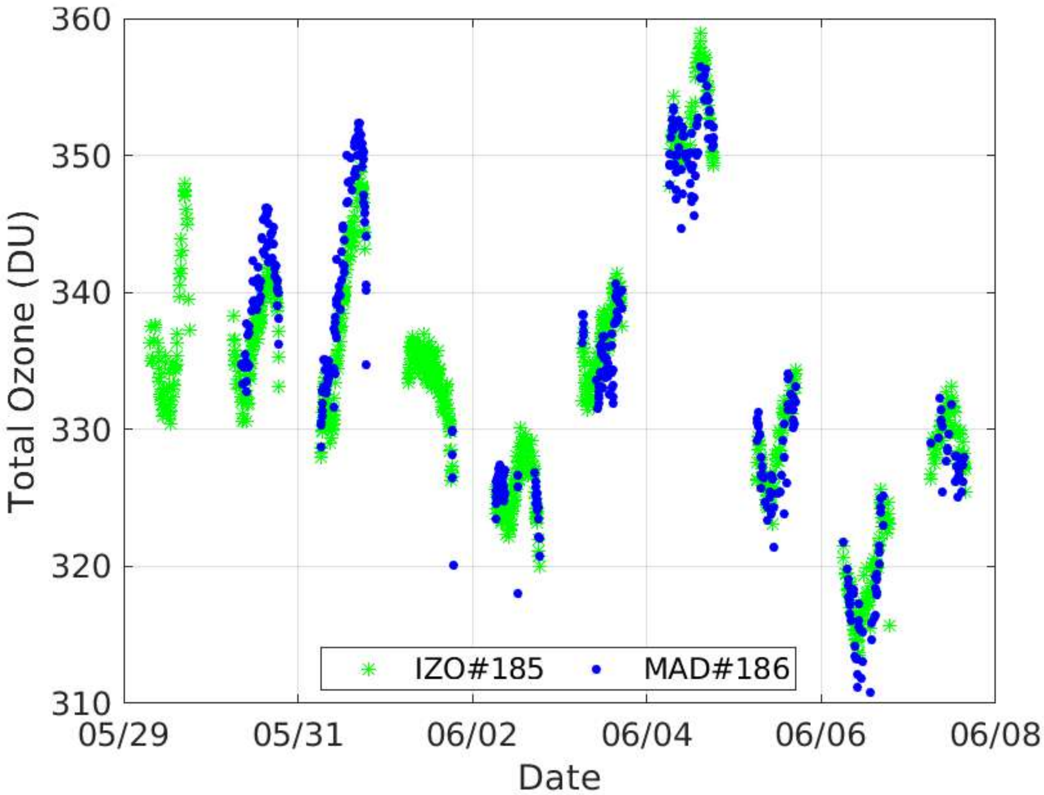


Figure 64. Brewer Intercomparison Arenosillo 2017 for B#186

The lamp test results from Brewer MAD#186 presented a noticeable jump in November 2015. But after this, it has been very stable during the last 2 years, with large seasonal variability (Figure 65). During the campaign days, the standard lamp ratios stabilized around values 316 and 530 for R6 and R5 respectively. These values have been calculated taking into account the new temperature coefficients calculated in this campaign (which, nevertheless, only produce rather small changes).

As Figure 66 shows, the current ICF produces ozone values with a difference of around -1.5% (on average) with respect to the reference. The application of the lamp correction does not result in a noticeable improvement of the results.

All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are okay, except for DT value. On day 153, during maintenance, the HT voltage was increased, and this resulted in a large change of the DT: from 26 to 31 ns.

Unfortunately, the Sun-scan (SC) tests performed before and during the intercomparison are not conclusive enough to analyse the optical position of the CSN. However, the value of the ozone absorption coefficient has not changed with respect to the previous calibration, which suggests that the brewer maintains the same CSN.

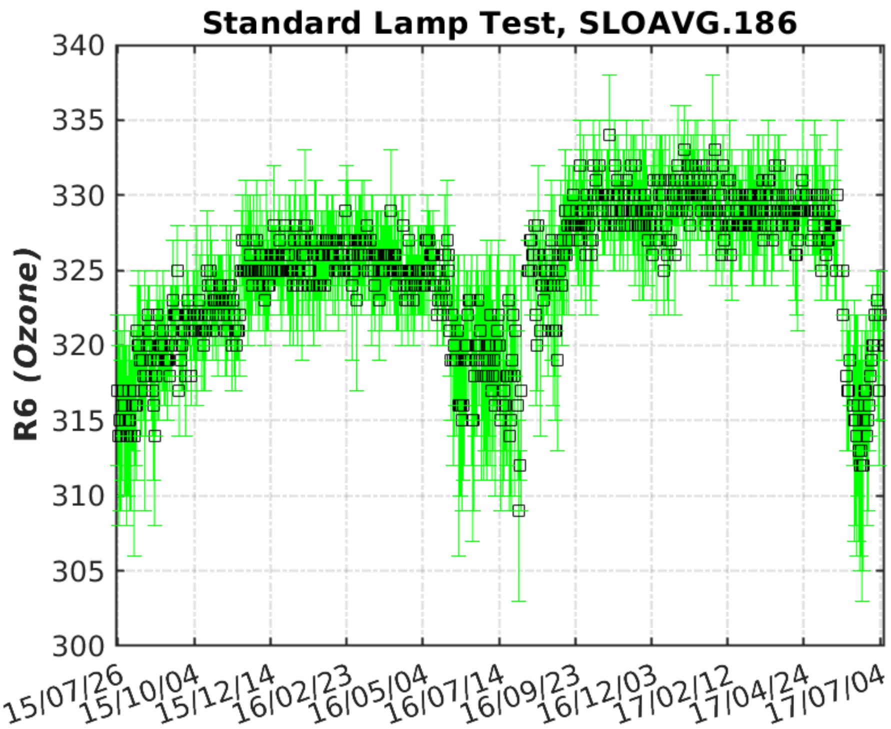


Figure 65. Standard lamp test R6 (Ozone) ratio for B#186

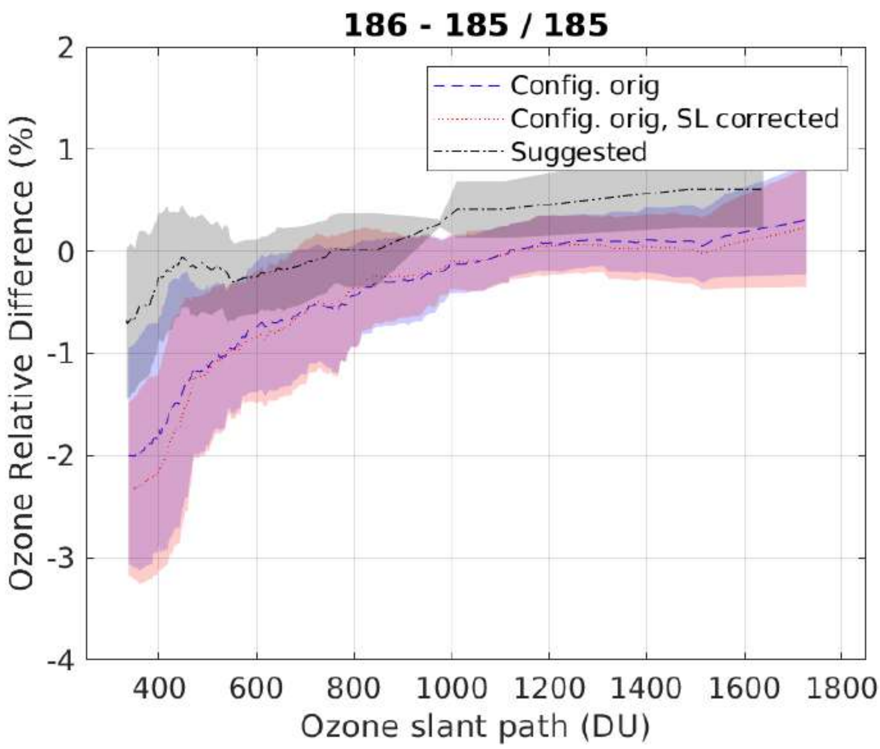


Figure 66. Ratio with respect to the reference using the initial configuration with and without the lamp correction, and the final configuration for B#186

Initial comparison

For the evaluation of the initial status of Brewer MAD#186 we used the period from days 149 to 155, which corresponds to 321 near-simultaneous direct sun ozone measurements. As shown in Figure 66, the current calibration constants produce ozone values lower than the reference instrument (-1.5%). When the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results do not improve.

Final calibration

Due to the difference with the reference Brewer, a new ETC value was calculated. For the final calibration, we used 132 simultaneous direct sun measurements from days 156 to 158. The new value is approximately 25 units lower than the current ETC value (1575). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratios, 316 for R6 and 530 for R5. We have updated the calibration constants in the new ICF provided. Of course, the new ETC has been calculated taking into account the new set of temperature coefficients and dead time.

Recommendations and comments

1. The standard lamp test results from Brewer #186 have been quite stable during the last 2 years, but they show a large seasonal dependence.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT low, which is very noisy.
3. We suggest using a DT constant of $3.1 \cdot 10^{-8}$ seconds, which is 5 units more than the value proposed during the last intercomparison. This large increase of the DT value is associated with the increase of the HT voltage during the maintenance in this campaign.
4. The neutral density filters have a good behaviour and no correction factors are suggested.
5. We have adopted new temperature coefficients, although the improvement might be rather small.
6. The Sun-scan tests were not conclusive enough to analyse the optical position of the CSN. We recommend performing more Sun-scan tests at the station. We have not changed the current CSN.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/186/CALIBRATION_186.pdf

Table 21. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	1575	1550
SL R6 reference value	317	316
Change SL R6 ratio/ETC	>10	
DT constant (ns)	26	31
Temp. coefficients	old	[0,0.06,-0.17,-0.34,-0.48]
Cal step number	283	283
Ozone abs. coeff.	0.3425	0.3425
Calibration file	ICF14915.186	ICF15317.186

3.17 Brewer DNK#202, Station: Denmark

Brewer DNK#202 participated in the campaign during the period from 30 May to 8 June 2017 (Julian days 150-159). For the evaluation of the initial status, we used 482 simultaneous direct sun ozone measurements from days 150 to 158. Only days 152 to 158 were used for final calibration purposes (414 simultaneous measurements).

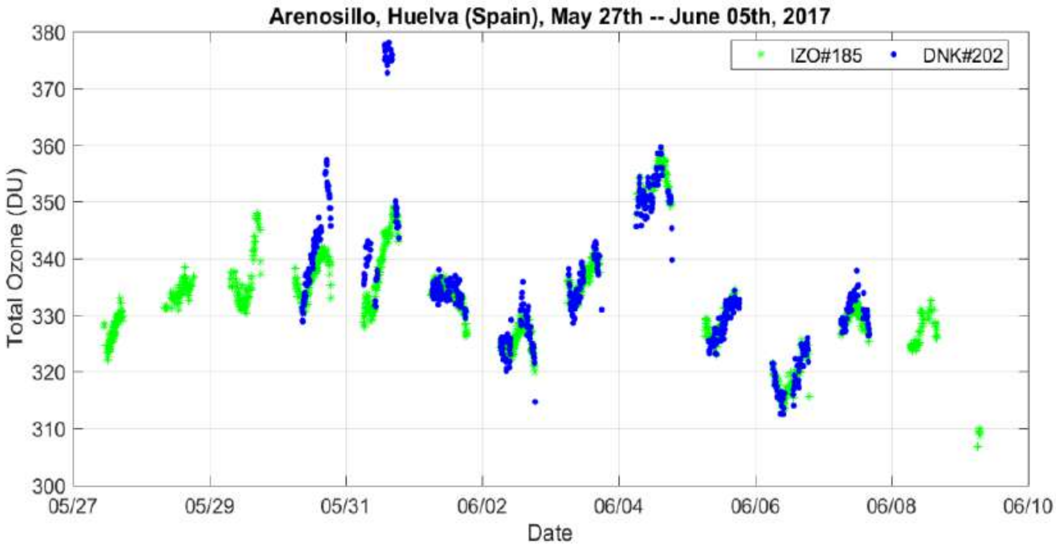


Figure 67. Brewer Intercomparison Arenosillo 2017 for B#202

As Figure 67 shows, the current ICF produces ozone values with a difference of around -2.5% (on average) with respect to the reference. This important difference could be associated with the change registered on the SL ratios in June 2016. However, when the SL correction is applied, the results improved only slightly with a difference of around -2.2% (on average).

During the campaign days, the standard lamp ratios were stabilized around values 270 and 560 for R6 and R5, respectively (see Figure 68). All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are within the expected behaviour.

The neutral density filters did not show nonlinearity in the attenuation spectral characteristics and, hence, we have not applied any corrections to the filters.

Finally, Sun-scan (SC) tests, performed before and during the intercomparison, suggest that the current CSN is not the optimal one, but in this campaign we have decided not to carry out this change.

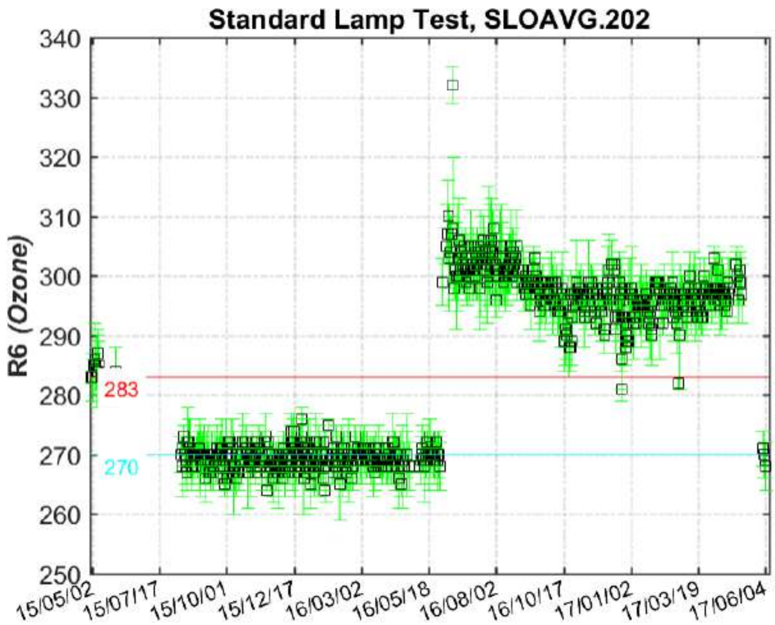


Figure 68. Standard lamp test R6 (Ozone) ratio for B#202

Initial comparison

For the evaluation of the initial status of Brewer DNK#202 we used the period from days 150 to 158 which corresponds to 482 near-simultaneous direct sun ozone measurements. As shown in Figure 69, the current calibration constants produce ozone values lower than the reference instrument (-2.5%).

However, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get better (-2.0%).

Final calibration

In this campaign a new absorption coefficient has been proposed, which implies that a new ETC must be calculated, see Figure 69. In the final calibration, we used 414 simultaneous direct sun measurements from days 152 to 158. The new value is 65 units lower than the current ETC value (1545). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 270 for R6.

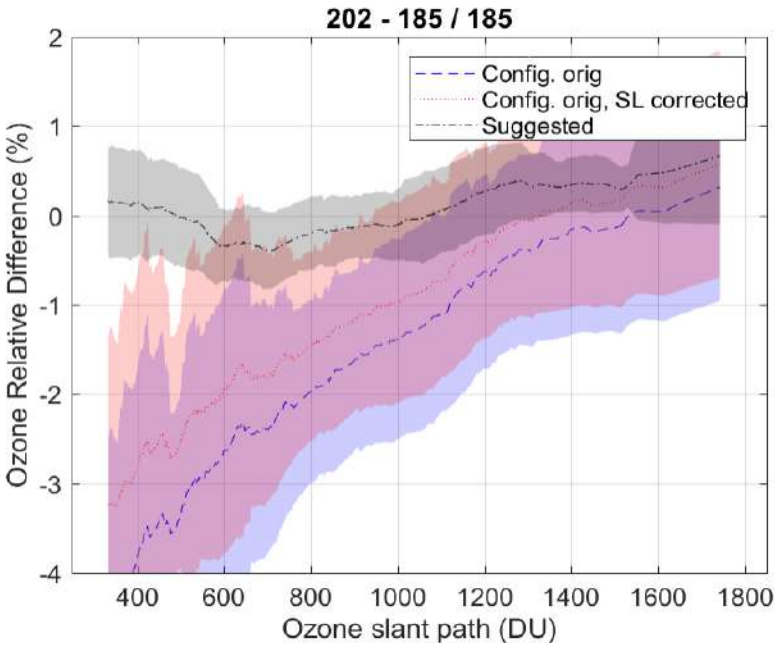


Figure 69. Ratio with respect to the reference using the initial configuration with and without SL correction, and the final configuration for B#202

Recommendations and comments

1. New reference values were given: R6=270 and R5=420.
2. We suggest using a DT constant of 2.5·10 −8 seconds.
3. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
4. We have not adopted new temperature coefficients.
5. Sun-scan (SC) tests performed before and during the intercomparison suggested that the current CSN is not the optimal but, in this campaign, we decided not to carry out this change.
6. New ozone absorption coefficient and ETC were given in the new calibration.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/202/CALIBRATION_202.pdf

Table 22. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	1545	1480
SL R6 reference value	283	270
Change SL R6 ratio /ETC	>10	
DT Constant (ns)	25	25
Temp. coefficients	[0,-0.546,-0.845,-0.992,-1.044]	[0,-0.546,-0.845,-0.992,-1.044]
Cal step number	286	286
Ozone abs. coeff.	0.3436	0.3444
Calibration file	ICF15215.202	ICF15017.202

3.18 Brewer SDK#214, Station: Finland

Brewer SDK#214 participated in the campaign during the period from 29 May to 7 June 2017 (Julian days 149-158). We did not detect any change in the instrument performance during the campaign, we used the same dataset to evaluate the initial status of the instrument as well as for final calibration purposes. For the evaluation of the initial status, we used 351 simultaneous direct sun ozone measurements from days 149 to 158. The final calibration was obtained using 404 simultaneous measurements.

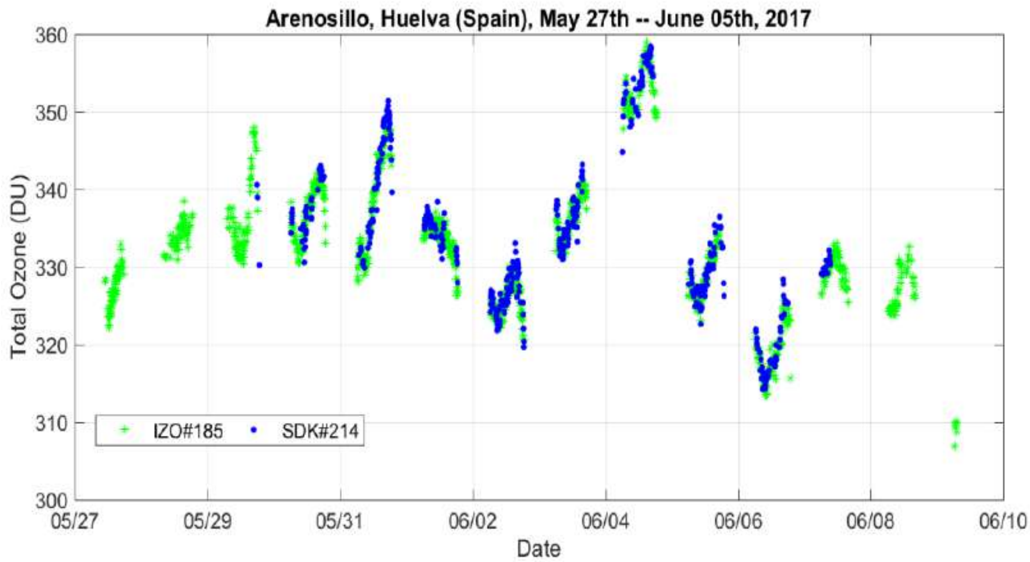


Figure 70. Brewer Intercomparison Arenosillo 2017 for B#214

As Figure 72 shows, the current ICF produces ozone values with a difference of around -1.5% (on average) with respect to the reference. This important difference could be associated with the maintenance carried out by Kipp&Zonen in 2016. After applying the lamp correction, the results improved slightly with a difference of around -0.5% (on average).

The lamp test results from Brewer SDK#214 have presented a stable behaviour from 2015, but due to the trip to Arenosillo there was a jump (Figure 71). During the campaign days, the standard lamp ratios stabilized around values 216 and 255 for R6 and R5, respectively. These values have been calculated taking into account the new dead time reference calculated in this campaign. All the other parameters analysed (Run/Stop test, Hg lamp intensity, CZ & CI files) are right, except for DT value. This parameter shows a small difference between both original and recorded values, of around 2 units ($2.9\cdot10^{-8}$).

Initial comparison
For the evaluation of the initial status of Brewer SDK#214 we used the period from days 149 to 158, which corresponds to 351 near-simultaneous direct sun ozone measurements. As shown in Figure 72, the current calibration constants produce ozone values lower than the reference instrument (-1.5%). However, when the ETC is corrected taking into account the difference between the standard lamp and R6 reference (lamp correction), the results get better.

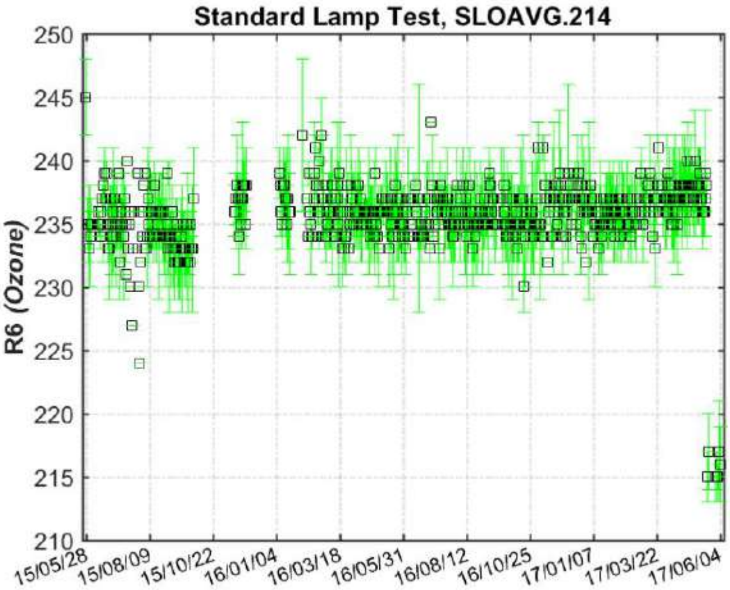


Figure 71. Standard lamp test R6 (Ozone) ratio for B#214

Final calibration

Because the difference with the reference Brewer cannot be corrected by the lamp correction, a new ETC value was calculated (see Figure 72). For the final calibration, we used 404 simultaneous direct sun measurements from days 149 to 158. The new value is approximately 30 units lower than the current ETC value (1455). Therefore, we recommend using this new ETC, together with the new proposed standard lamp reference ratio, 1832 for R6. We updated the new calibration constants in the ICF provided. Of course, the new ETC has been calculated taking into account the new dead time reference.

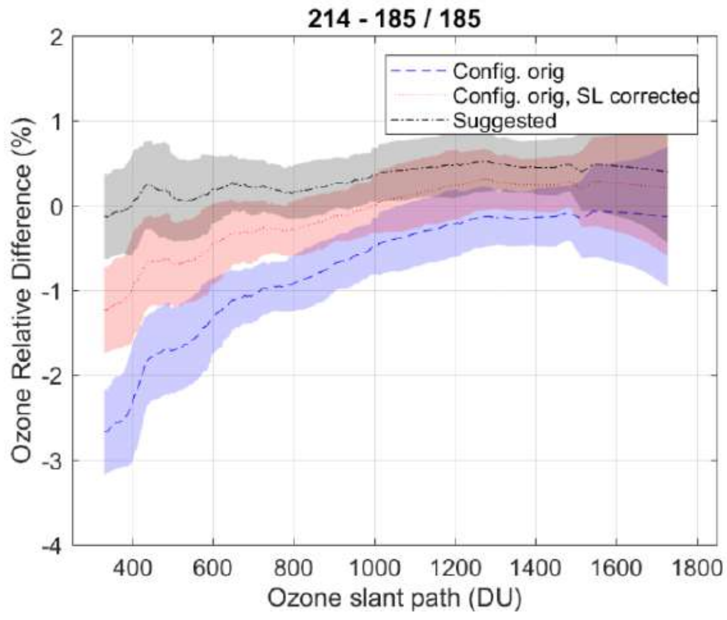


Figure 72. Ratio with respect to the reference used in the initial configuration with and without the lamp correction and final configuration for B#214

Recommendations and comments

1. New ratio references were given in this campaign: R6=215 and R5=255.
2. All the other diagnostics analysed (RS, AP records ...) were normal, except for the measurement of the DT.
3. We suggest using a DT constant of $2.9 \cdot 10^{-8}$ seconds, which is two units higher than proposed during the last intercomparison.
4. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
5. We have not adopted new temperature coefficients.
6. The Sun-scan tests suggest that the CSN must be changed to 287. However, a difference of one step is considered admissible.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/214/CALIBRATION_214.pdf

Table 23. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC constant	1455	1425
SL R6 reference value	234	216
Change SL R6 ratio/ETC	<10	
DT constant (ns)	27	29
Temp. coefficients	[0,0.082,0.126,0.078,0.025]	[0,0.082,0.126,0.078,0.025]
Cal step number	286	286
Ozone abs. coeff.	0.3458	0.3458
Calibration file	icf15015.214	icf15017.214

3.19 Brewer DNK#228, Station: Copenhagen, Denmark

Brewer DNK#228 participated in the campaign during the period from 29 May to 8 June 2017 (Julian days 149-159). For the evaluation of the initial status, we used 266 simultaneous direct sun ozone measurements from days 151 to 158. Only 152 to 155 were used for final calibration purposes with 176 simultaneous measurements (Figure 73). It is important to indicate that during the last days of the campaign (156-158) this instrument had an irregular behaviour. Therefore, these days were not used for the final calibration.

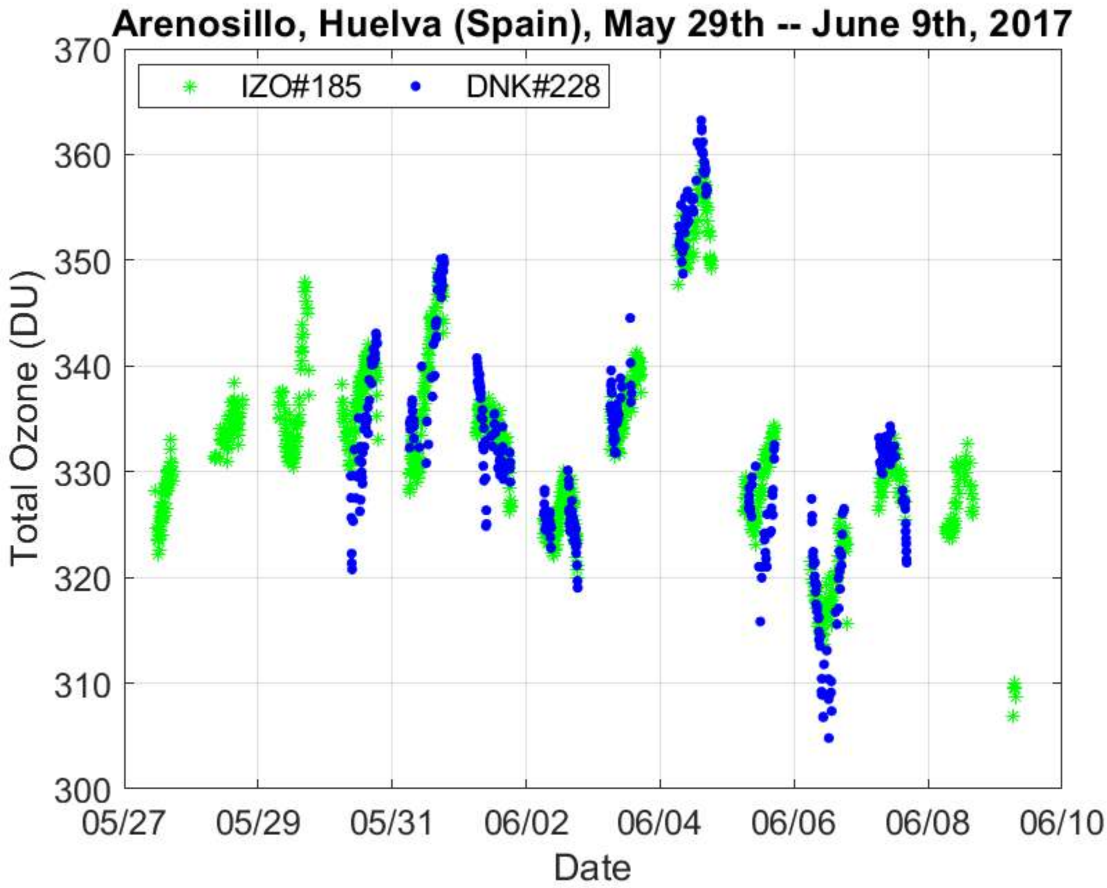


Figure 73. Brewer Intercomparison Arenosillo 2017 for B#228

Original calibration

The instrument operates with the configuration file ICF22416.228 and reference value for the standard lamp R6 ratio 242.

Historical analysis

The lamp test results from Brewer DNK#228 present several jumps during the last two years, possibly associated with the behaviour of the lamp intensity. During the campaign days, the standard lamp ratios stabilized around values 245 and 450 for R6 and R5, respectively (Figure 74). However, taking into account the new dead time calculated in this campaign, R6 and R5 take values of 203 and 400 respectively. These values are used as new references for the instrument. Run/Stop test shows that some slits present values outside the tolerance limits. Similar bad results are observed for CZ and CI measurements.

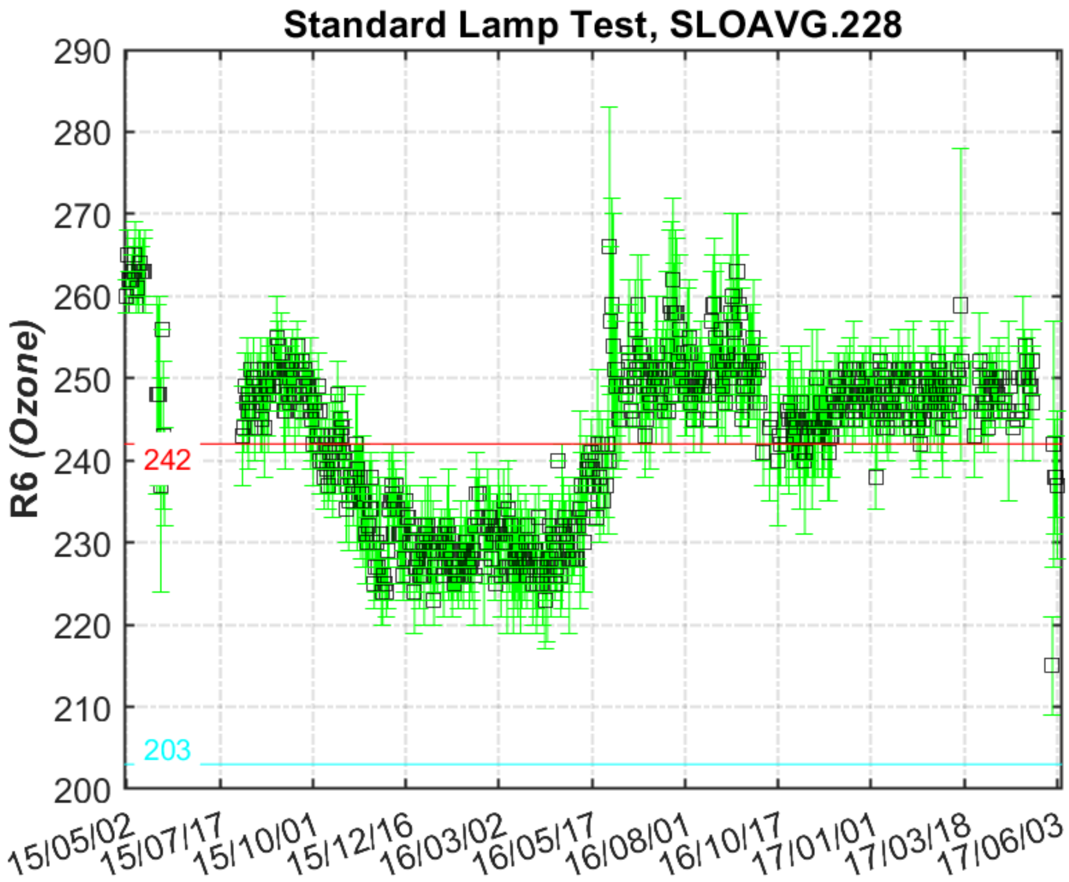


Figure 74. Standard lamp test R6 (Ozone) ratio for B#228

Initial comparison

For the evaluation of the initial status of Brewer DNK#228 we used the period from days 151 to 158, which correspond to 266 near-simultaneous direct sun ozone measurements. As shown in Figure 75, the current calibration constants produce ozone values in good agreement with respect to the reference. In this case, applying the lamp correction, the results do not improve significantly.

Final calibration

Due to the change in the dead time and the ozone absorption coefficient proposed, a new ETC value was calculated. For the final calibration, we used 172 simultaneous direct sun measurements from days 152 to 155. The new value is 20 units lower than the current value (1470). Therefore, we recommend using this, together with the new proposed standard lamp reference ratio, 203 for R6. We updated the new calibration constants in the ICF provided.

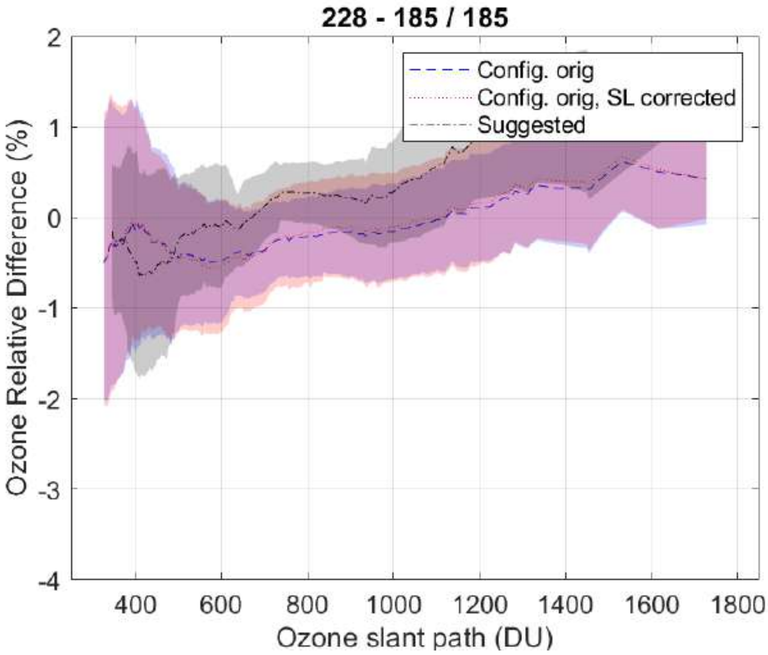


Figure 75. Ratio with respect to the reference using the initial configuration with and without SL correction, and the final configuration for B#228

Recommendations and comments

1. New reference values were given: R6=203 and R5=400.
2. We suggest using a DT constant of $3.8 \cdot 10^{-8}$ seconds, which is 12ns higher than proposed during the last intercomparison. This parameter must be checked frequently.
3. The neutral density filters have an excellent behaviour and, hence, no correction factor is suggested.
4. We have adopted new temperature coefficients.
5. The Sun-scan tests were conclusive enough to analyse the optical position of the CSN. However, the value obtained was not introduced in the final calibration because of the change in DT. CSN should be revised in the next calibration.

Calibration report

http://rbcce.aemet.es/svn/campaigns/are2017/latex/228/CALIBRATION_228.pdf

Table 24. Calibration constants summary

Parameters	*Initial Configuration*	*Final Configuration*
O_3 ETC Constant	1470	1450
SL R6 Reference Value	242	203
Change SL R6 ratio/ETC	<10	
DT Constant (ns)	26.5	38
Temp. Coefficients	[0.-0.90,-0.89,-1.02,-1.78]	[0, 0.01, 0.12, 0.24, 0.41]
Cal step number	1030	1030
Ozone Abs. Coeff.	0.3456	0.341
Calibration file	ICF22416.228	ICF15017.228

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

APPENDIX 1

Maintenance Table

149			27/5/2017	28/5/2017	29/5/2017	30/5/2017	31/5/2017	1/6/2017
JD			147	148	149	150	151	152
		Previous Events	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
WEATHER			Mainly cloudy. Mid clouds, going better in the evening	8/8 cloudy in the early morning, then 1/8 of spread Cu	Mainly covered in the early morning.some disperse low clouds the rest of the day. Increasing nubosity from noon	Only small cloud at high SZA. Clear from 8AM	Perfect, clear sky	Some low clouds, small but covering the sun. Completely clear from noon
5	Gre				Installed.		Can't read B files !!. Wrong format	
17	IOS				Installed.			
33	Esp				Installed.			DSP
53	Den				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	
70	Esp				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	Maintenance during the morning. DSP
75	Uk				Installed.	Time problem	Enought SC. Changed to O3 schedule. NI renamed and FI changed	
82	Den				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	
102	Por					Installed.	Brewer was blocked, bad orientation. Blocked Ni routine	Still trying to level it !!
117	Esp				Installed.		Enought SC. 9:05 changed to O3 schedule. NI renamed and FI changed	Reset in the early morning
126	Uk				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	
150	Esp							Maintenance during the morning. Moved to laboratory. DSP
151	Esp				Installed.	Some comunication problems	Enought SC. Changed to O3 schedule. NI renamed and FI changed	
163	Sui				Installed. Sitting correct.		Enought SC. 7:30 changed to O3 schedule. NI renamed and FI changed	7:10 Bad focusing, lost all the DS untill this hour. 11: 00 Stopped to Silica gel change. DSP
166	Esp				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	Maintenance during the morning. DSP
172	Uk				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	
185	IZO		Installed. Sitting correct.			Solved problem with time sync and Teamviewer. Enought SC. 19:00 changed to O3 schedule. NI renamed and FI changed		
186	Esp				Installed.	Lamp problem, not detected	Enought SC. 9:05 changed to O3 schedule. NI renamed and FI changed	Maintenance during the morning, started UV cal at 16:00. DSP. 1000W Lamps during the evening
202	Den				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	
214	Fin				Installed.		Brewer was blocked at 17:00 (Tuesday). The program was reseted at 6:30 and SC tests was introduced by menu (as Tenerife)	Enought SC. Changed to O3 schedule. NI renamed and FI changed .DSP
228	Den				Installed.		Enought SC. Changed to O3 schedule. NI renamed and FI changed	
PANDORA			Installed.					
PHANTOM					Installed.			
ERMIS					Installed.			

149		2/6/2017	3/6/2017	4/6/2017	5/6/2017	6/6/2017	7/6/2017	8/6/2017	9/6/2017
JD		153	154	155	156	157	158	159	160
		Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
WEATHER		Clear sky. Some Sahara dust in low levels	Very windy. Some clouds at very low angles	Windy again in the early morning and some cirrus. Clear from mid morning	Clear sky. No wind	Clear sky. No wind	Clear sky. Very little wind	Clear sky in the morning. Increasing clouds from noon	
5	Gre		1000W Lamp	Schedule to UV	Traker off during morning			Packing	
17	IOS			Schedule to UV			1000W Lamp	Packing	
33	Esp	Maintenance during the evening	Maintenance during the morning. Back to roof 7:00.	Schedule to UV			Packing		
53	Den	DSP	BAT in the morning. SL/HG replacement	Schedule to UV				Packing	
70	Esp	Maintenance during the morning.		Schedule to UV. Changed foreoptics leveling during the evening			Packing		
75	Uk	DSP	1000W Lamp	Schedule to UV				Packing	
82	Den	DSP. BAT, in the late evening	1000W Lamp	Schedule to UV				Packing	
102	Por	Still trying to level it !!		Schedule to UV. 1000w lamp	UV infinite cycle during the afternoon. No DS measurements		Didn't change schedule. 10 seconds delayed	Out of memory in NI	
117	Esp	Maintenance during the morning.	Changed software from 3.76b to 4.10. New DSP values in use from today				Packing		
126	Uk	DSP	1000W Lamp	Schedule to UV.18:14 Cal Step changed to 286				Packing	
150	Esp	1000W Lamps during the morning		Schedule to UV.			Stays at home		
151	Esp	HV was increased	1000W Lamp	50w lamps. Out of string space 18:45. Changed foreoptics leveling during the evening			Packing		
163	Sui			Schedule to UV			Packing		
166	Esp		Maintenance during the morning.	50w lamps.			Packing		
172	Uk	DSP	1000W Lamp	Schedule to UV				Packing	
185	IZO			Schedule to UV - Cosine Correction during midday			1000W Lamp	didn't have o3 schedule for today	
186	Esp	New ICF - icf15317.186		Schedule to UV	Filter #4 replaced	1000W Lamp. New UVR - uvr15717.186	Packing + 50w lamps		Packing
202	Den	DSP	1000W Lamp	Schedule to UV				Packing	
214	Fin		1000W Lamp	Schedule to UV			Packing		
228	Den	DSP	1000W Lamp	Schedule to UV	Micrometer clean/oil			Packing	
PANDORA					Packing				
PHANTOM								Packing	
ERMIS					Packing				

APPENDIX 2

Glossary

CI	Scan to the internal Standard Lamp
CSN	Cal step number
CZ	Custom Scan generally to the internal lamps
DSP	Dispersion File
DT	Dead Time
Hg	Internal Mercury Line
HL	Scan to the Internal Mercury Line of 295.nm
HS	Scan to the Internal Mercury Line of 345.nm
ICF	Instrument Constant File
OSC	Ozone Slant Column
R6	Ratio 6, Standard Lamp Ozone Ratio
R5	Ratio 5, Standard Lamp SO2 Ratio
SL	Standard Lamp
RS	Run Stop test
TC	Temperature Coefficients

APPENDIX 3

List of Participants

Country	*Brewer*	*Institutions*	*Participants*
Greece	5	Thessaloniki University	Alkis Bais
Greece		Thessaloniki University	Illias Fountitakis
Canada	17	IOS International Ozone Service	Vladimir Savastiouk
Canada		IOS International Ozone Service	Mike Brohart
Canada		York University	Tom McElroy
Spain	185	AEMET-IARC	Alberto Redondas
Spain		AEMET-IARC	Sergio León
Spain		AEMET-IARC	Virgilio Carreño
Spain		AEMET-IARC	Francisco Parra
Spain	150	INTA	J.M. Vilaplana
Spain		Universidad de Extremadura	Antonio Serrano
Spain		Universidad de Extremadura	Ana Álvarez Piedehierro
Spain		Universidad de Extremadura	Guadalupe Sánchez Hernández
Spain	33,186	AEMET	J.M. San Atanasio
Spain	70	AEMET	Juan R. Moreta
Spain	166	AEMET	Ana María Díaz
Spain	117	AEMET	Arcadio Blasco Loureiro
Spain	151	AEMET	Francisco García
UK	75,126,172	Manchester University	John Rimmer
Switzerland	163	World Radiation Centre	Julian Groebner
Switzerland		World Radiation Centre	Natalia Kournemeti
Switzerland		World Radiation Centre	Luca Egli
Denmark	202,228	Danish Meteorological Institute	Paul Eriksen
Denmark	53,82	Danish Meteorological Institute	Niss Jepsen
Finland	214	Finnish Meteorological Institute	Tomi Karprinen
Portugal	102	Instituto Português do Mar e da Atmosfera	Diamantino
Portugal		Instituto Português do Mar e da Atmosfera	Linda Moniz

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

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

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

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

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230. Airborne Dust: From R&D to Operational Forecast 2013-2015 Activity Report of the SDS-WAS Regional Center for Northern Africa, Middle East and Europe, 73 pp., 2016.

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225. WMO/UNEP Dobson Data Quality Workshop, Hradec Kralove, Czech Republic, 14-18 February 2011, 32 pp., April 2016.

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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, 79 pp., December 2015.

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

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.

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

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

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

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