REGIONAL BREWER CALIBRATION CENTER EUROPE RBCCE

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Brewer UK#172 Calibration Report

Arenosillo, Huelva (Spain), June 17th – June 28th, 2019

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1 Calibration Summary

The Fourteenth Intercomparison Campaign of the Regional Brewer Calibration Center Europe (RBCC-E) was held from June 17th to the 28th, 2019, at the *El Arenosillo* Atmospheric Sounding Station of the *Instituto Nacional de Técnica Aeroespacial* (INTA), Spain.

Brewer UK#172 participated in the campaign in the period from June 17th to 28th, although few measurements were taken the last day before the instrument was packed. The campaign days of Brewer UK#172 correspond to Julian days 168 – 178.

For the evaluation of the initial status, we used **136** simultaneous direct sun (DS) ozone measurements from days **170** to **172**. For final calibration purposes, we used **362** simultaneous DS ozone measurements taken from day **173** to **178**.

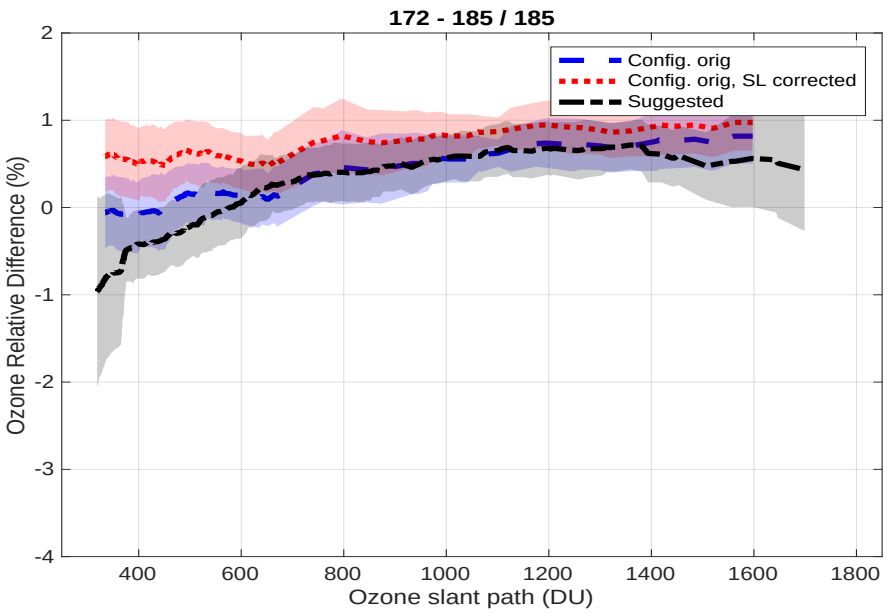


Figure 1 – Mean DS ozone column percentage difference between Brewer UK#172 and Brewer IZO#185, plotted as a function of the ozone slant path. Results for the current (issued in the previous calibration campaign) configuration are show in blue; the red dotted line corresponds to the same configuration, but with the standard lamp correction applied; the black line corresponds to results obtained with the updated configuration proposed in the current campaign. The shadow areas represent the standard deviation of the mean. The plot corresponds to the final days of the campaign.

As shown in Fig. 1, the current ICF (ICF15117.172, blue dashed line) produces ozone values with an average difference of around 0.5% with respect to the reference instrument. This is a rather small difference, and highlights the stability of Brewer UK#172. This is confirmed by the stability of the R6 standard lamp measurements, see Fig. 2. The SL correction (Fig. 1, red dotted line) is thus not necessary and does not improve the comparison with Brewer IZO#185.

All the other parameters analyzed (run/stop tests, Hg lamp intensity, CZ & CI files, dead time,...)

show results inside the tolerance limits only Dead time (DT) shows a small difference between the current and campaign values of around 1 ns, with its value changing from $3{\cdot}10^{-8}$ to $2.9{\cdot}10^{-8}$.

We have not applied any correction to filters, but filter #4 shows no-linearity issues.

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

We do not suggest changing the Ozone Absorption Coefficient, retaining its current value of 0.341.

1.1 Recommendations and Remarks

1. The R6 standard lamp test results from Brewer UK#172 have been very stable during the last 2 years. The old R6 reference value was 444 and, although the difference is almost within the acceptable error of ±5, it could be updated to **437**.
2. We suggest a new R5 reference value of **697**.
3. We suggest updating the DT to $\mathbf{2.9{\cdot}10^{-8}}$ seconds, which is one units less than the value proposed in the last intercomparison.
4. The neutral density filters show significative correction for filter #4.
5. Due the small change , we don't suggest to change configuration, but if the DT value is update we suggest updating also the ETC value from 1700 to **1703**.
6. Despite the stability of the instrument and the good agreement with the reference, the instrument shows an slope on the comparison to the reference, underestimating at low air masses and overestimate at high airmass , this suggest a change on the ozone absorption coefficient of two steps not confirmed during wavelength calibration.

1.2 External links

Configuration File

`http://rbcce.aemet.es/svn/campaigns/are2019/bfiles/172/ICF17818.172`

Calibration Report

`https://docs.google.com/spreadsheets/d/1WBzxK6bPrkD6mKIzkG8BbhlQgx0zLpsvvSmhllwDCiw/edit#gid=401824256`

Calibration Reports Detailed

Historic and instrumental

`http://rbcce.aemet.es/svn/campaigns/are2019/latex/172/html/cal_report_172a1.html`

Temperature & Filter

`http://rbcce.aemet.es/svn/campaigns/are2019/latex/172/html/cal_report_172a2.html`

Wavelength

`http://rbcce.aemet.es/svn/campaigns/are2019/latex/172/html/cal_report_172b.html`

ETC transfer

`http://rbcce.aemet.es/svn/campaigns/aro2019/latex/172/html/cal_report_172c.html`

2 Instrument History: Analysis of Average files

2.1 Standard Lamp Test

As shown in Figure 2 and 3, the standard lamp test performance is quite stable since August 2017, with mean values around **437** and **700** for R6 and R5, respectively. The current R6 value is only 7 units less that the reference value given in the previous intercomparison campaign. A small change in R5 can be associated with a variation of the lamp's intensity as shown in Fig. 4. Finally, small seasonal variations can be identified.

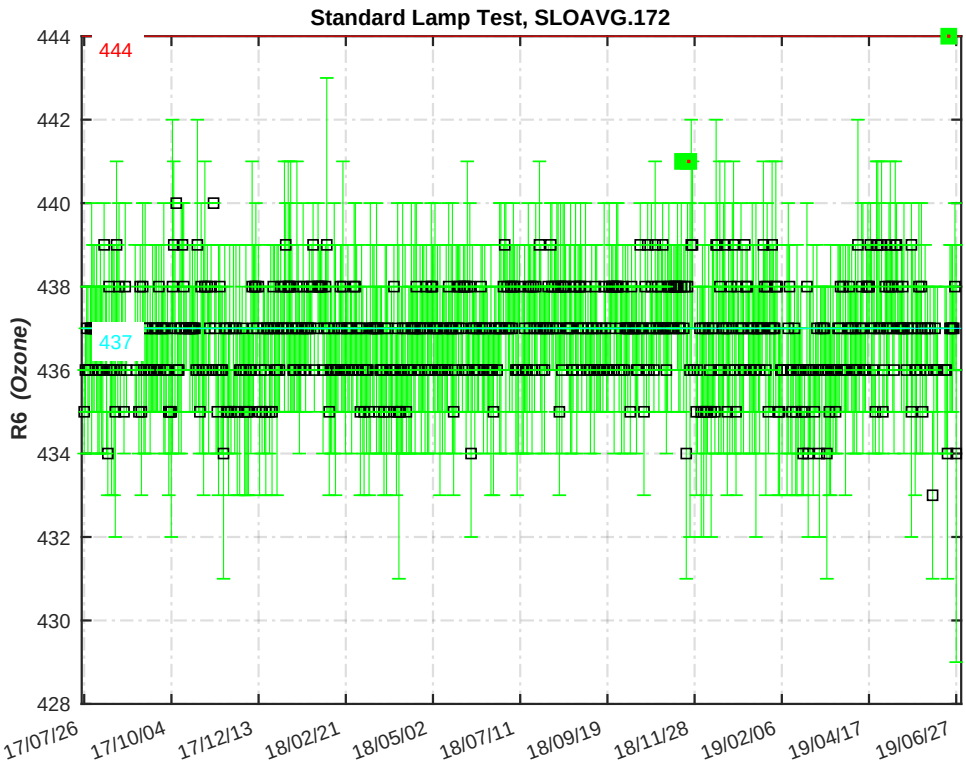


Figure 2 – Standard Lamp test R6 (Ozone) ratios. Horizontal lines are labeled with the original and final reference values (red and blue lines, respectively)

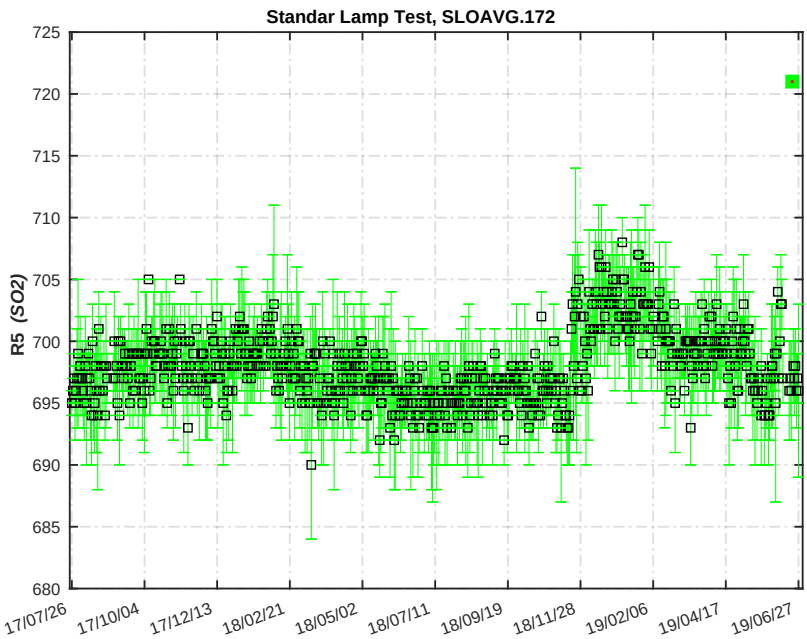


Figure 3 – Standard Lamp test R5 (SO_2) ratios

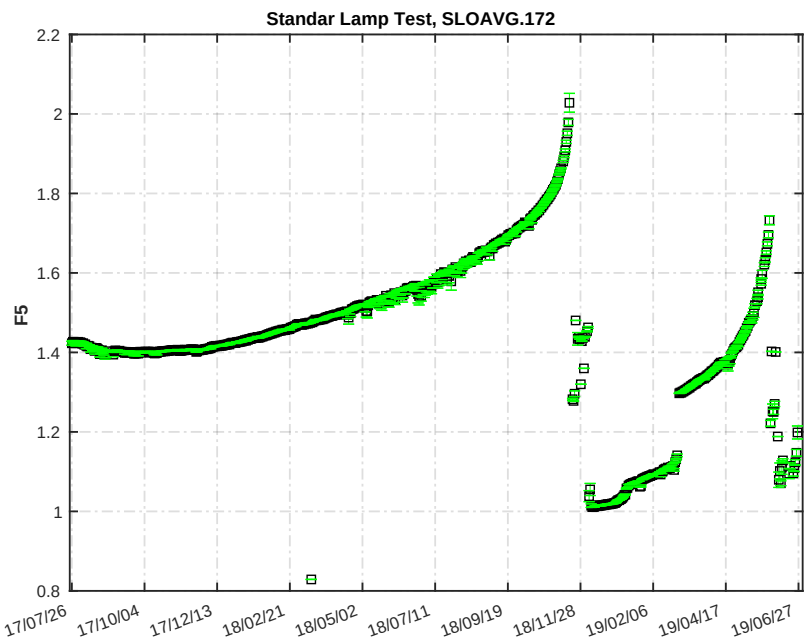


Figure 4 – SL intensity for slit five.

2.2 Run Stop and Dead Time

Run stops test values are within the test tolerance limits, see Fig. 5.

As shown in Fig. 6, the current DT reference value of $\mathbf{3{\cdot}10^{-8}}$ seconds is slightly larger than the value recorded during the calibration period, $\mathbf{2.9{\cdot}10^{-8}}$s. Therefore, this new value has been used in the new ICF.

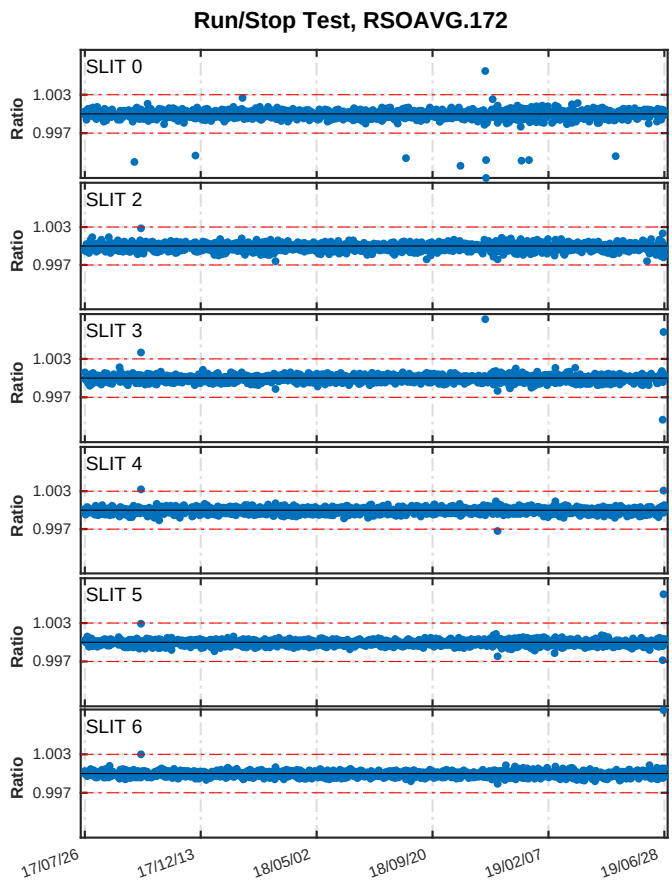


Figure 5 – Run/stop test

2.3 Analog Test

Fig. 7 shows that the high voltage has remained almost constant around at 1171 over the last two years. Furthermore, analog test values are within the test tolerance range.

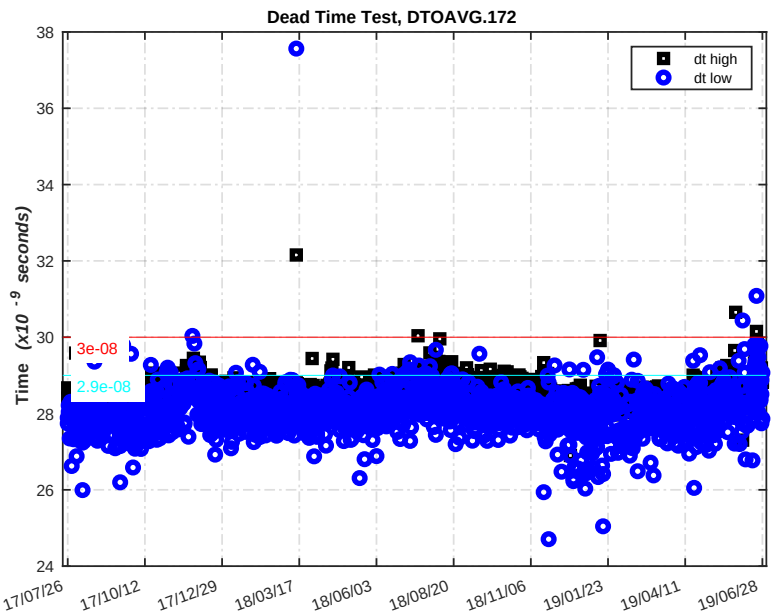


Figure 6 – Dead Time test. Horizontal lines are labelled with the current (red) and final (blue) values.

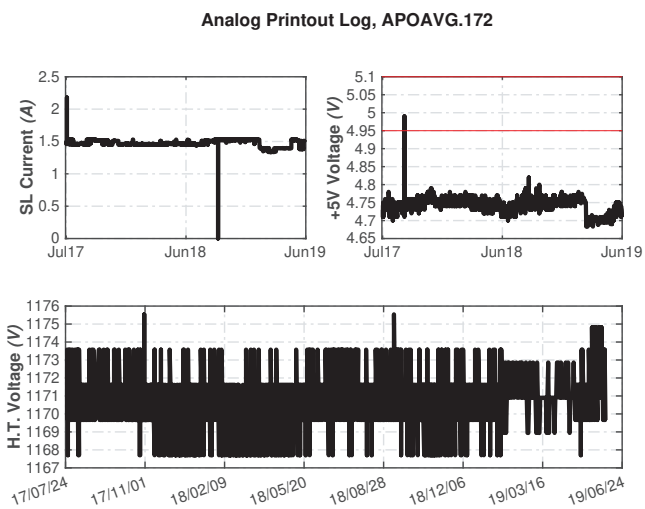


Figure 7 – Analog voltages and intensity.

2.4 Mercury Lamp Test

No noticeable internal mercury lamp intensity events have been observed during the campaign.

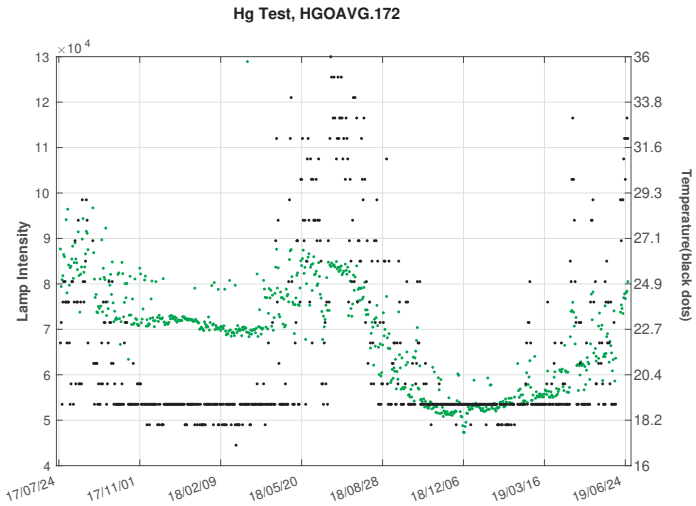
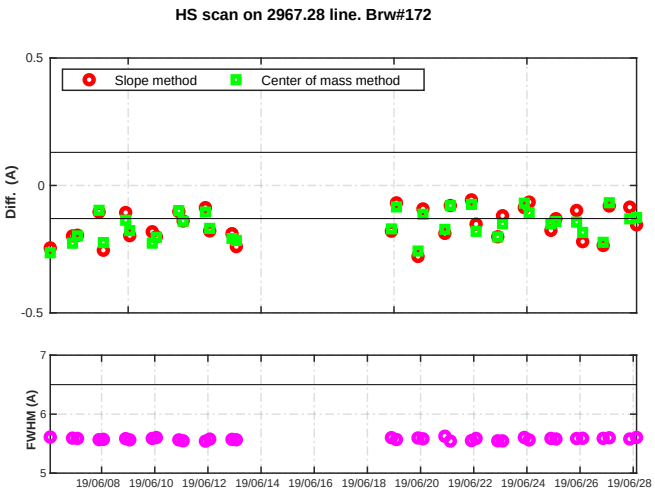


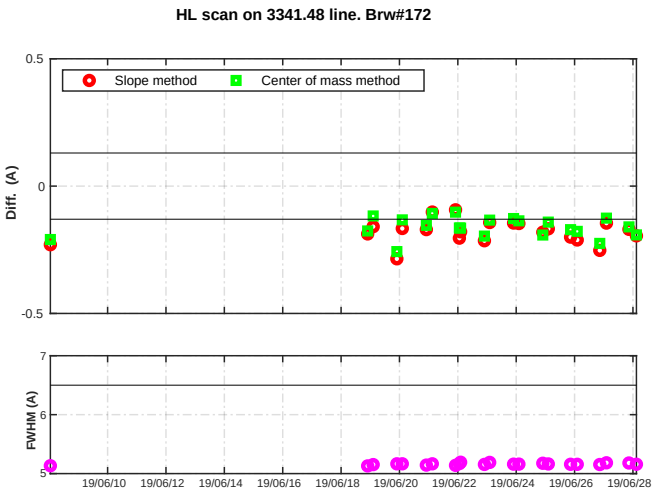
Figure 8 – Mercury lamp intensity (green squares) and Brewer temperature registered (black dots). Both parameters refer to maximum values for each day.

2.5 CZ scan on mercury lamp

In order to check both the wavelength settings and the slit function width, we analyzed the scans performed on the 296.728 nm, and 334.148 nm mercury lines, see Fig. 9. As a reference, the calculated scan peak, in wavelength units, should be within 0.013 nm from the nominal value, whereas the calculated slit function width should be no more than 0.65 nm. Analysis of the CZ scans performed on Brewer UK#172 during the campaign show reasonable results, with the peak of the calculated scans close, although slightly below, the accepted tolerance range. Regarding the slit function width, results are good, with a FWHM lower than 6.5 Å.



(a) *CZ scan on 296.728 nm*



(b) *CZ scan on 334.148 nm*

Figure 9 – CZ scan on Hg lines. The upper panels show differences with respect to the reference line (solid lines represent the limit ±0.013 nm) as computed by the slopes (red circles) and center of mass (green squares) methods. Lower panels show the Full Width at Half Maximum value for each scan performed (solid lines represent the 0.65 nm limit

2.6 CI scan on internal *SL*

CI scans of the standard lamp recorded at different times can be compared to investigate whether the instrument has changed its spectral sensitivity. We shown in Fig. 10 percentage ratios of the Brewer **UK#172** CI scans performed during the campaign relative to the scan CI17217.172. As it can be observed, the lamp intensity has varied respect to the reference spectrum around 5%. Similar variation have been observed in the daily R6 and R5 values. This behavior is normal for a SL lamp.

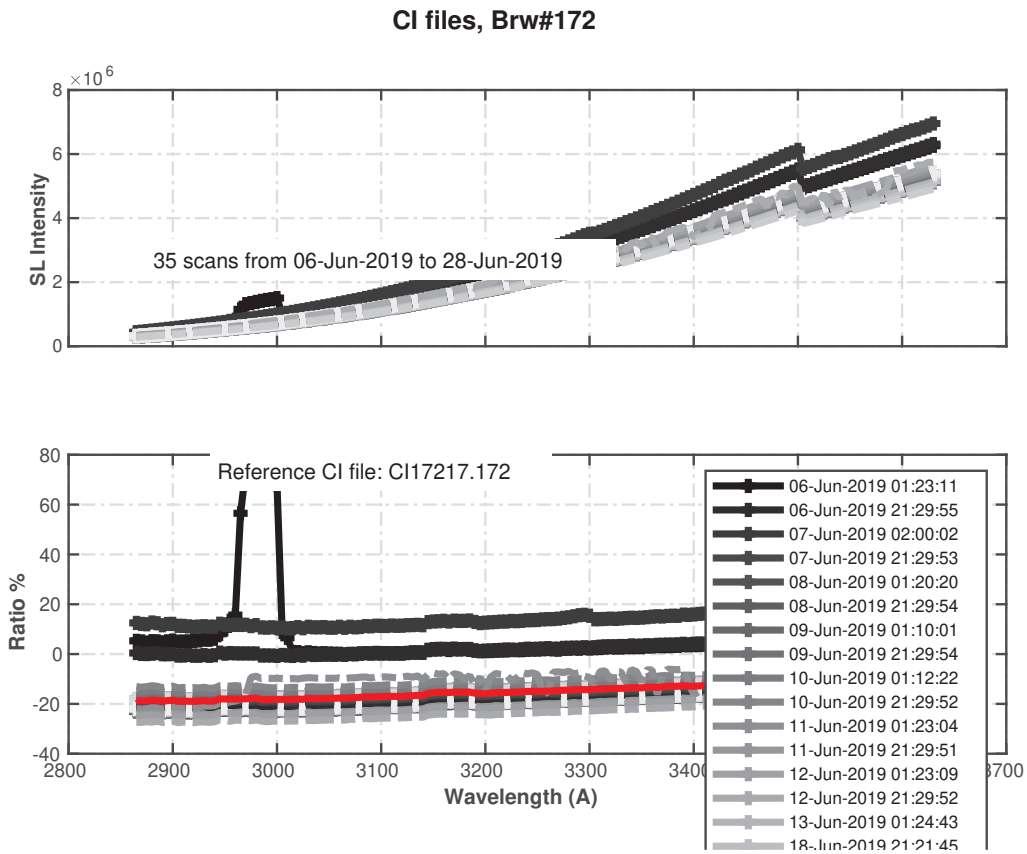


Figure 10 – CI scan of Standard Lamp performed during the campaign days. Scans processed (upper panel) and relative differences with respect to a selected reference scan (lower panel). Red line represents the mean of all relative differences

3 Absolute Temperature Coefficients

Temperature coefficients are determined using the standard lamp test. For every slit, the raw counts corrected for zero temperature coefficients are used in a linear regression against temperature with the slopes representing the instrument's temperature coefficients. From this we obtain the corrected *R6* and *R5* ratios to analyze the new temperature coefficients' performance.

As shown in Fig. 11 (temperature range from **19° C** to **32° C**, the current coefficients do an excellent job at reducing the temperature dependence, performing even better that the coefficients calculated using the data from the present campaign. The values of the coefficients are summarized in Table 1.

We have also extended our analysis using the data recorded since the previous campaign. As shown in Figs. 12 and 13, the current and new coefficients have a similar performance, the current coefficients being slightly better. For this reason, in the final ICF we have used the current coefficients.

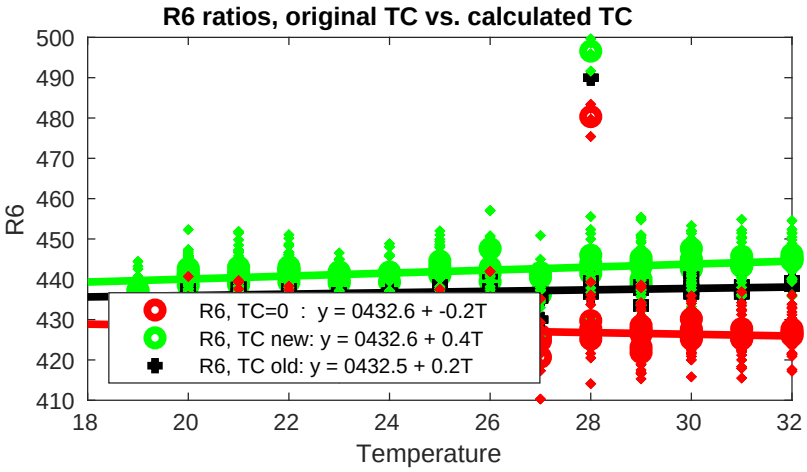


Figure 11 – Temperature coefficients performance. Red circles represent standard lamp R6 ratio calculated from raw counts without temperature correction (temperature coefficients null). Black crosses and green circles represent standard lamp R6 ratio corrected with original temperature coefficients and corrected with calculated temperature coefficients respectively. The values plotted correspond with the measurements obtained during the campaign

Table 1 – Temperature Coefficients. Calculated coefficients are normalized to slit#2

	slit#2	**slit#3**	**slit#4**	**slit#5**	**slit#6**
Current	6.2369	5.8351	5.7129	5.4500	5.0893
Calculated	0.0000	0.4000	0.3000	0.3000	-0.1000
Final	6.2369	5.8351	5.7129	5.4500	5.0893

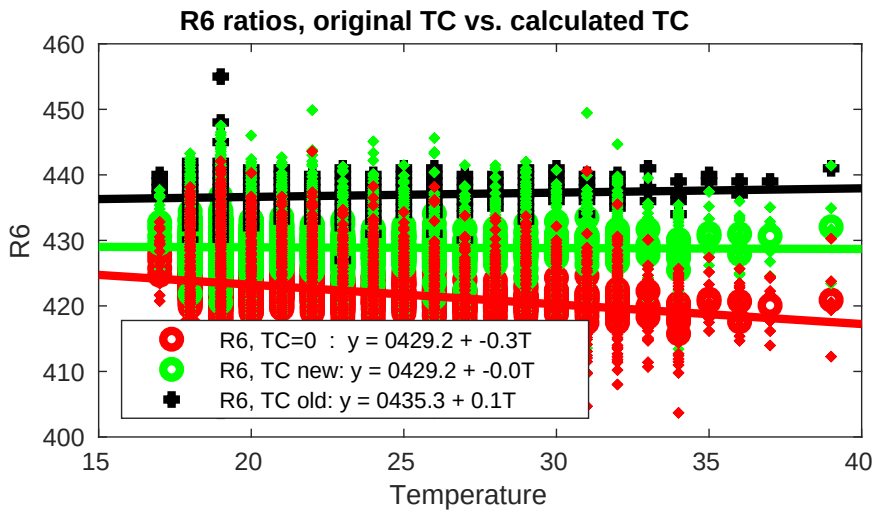


Figure 12 – Same as Fig. 11 but for the whole period between calibration campaigns.

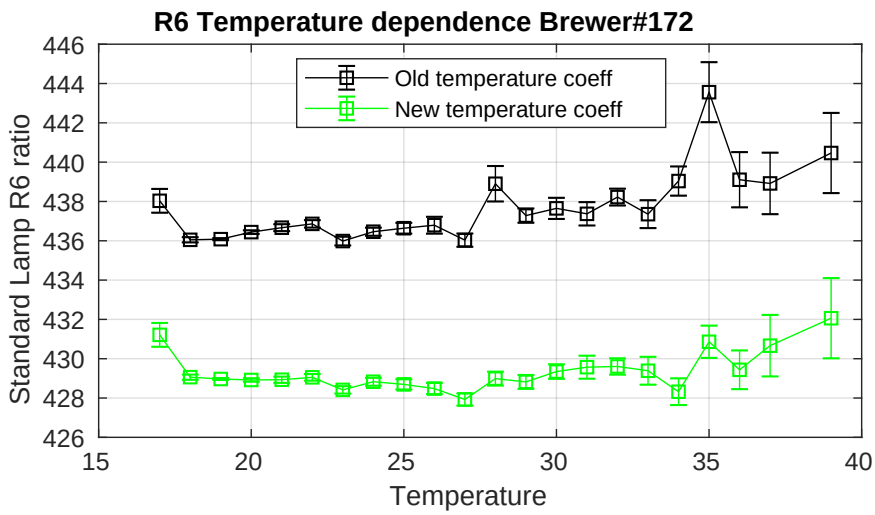


Figure 13 – Standard lamp R6 (MS9) ratio as a function of temperature. We plotted R6 ratio recalculated with the original (black) and the new (green) temperature coefficients

4 Attenuation Filter Characterization

4.1 Attenuation Filter Correction

The filter's spectral dependence affects the ozone calculation because the Brewer software assumes that their attenuation is wavelength-neutral. We can estimate the correction factor needed for this non-linearity by multiplying the attenuation of every filter and every wavelength by the ozone weighting coefficients.

During the calibration period, a total of **123** FI tests were analyzed to calculate the attenuation for every filter and slit. Fig. 14 shows the results of these tests, and Table 2 shows the calculated ETC corrections for each filter.

Compared to the current ETC filter corrections, suggested at the previous calibration campaign, the corrections calculated at the present campaign are lower. This is specially the case for Filter #3, which has a correction of -15 in the current configuration. For this filter, the correction obtained from the data of the present campaign (see Table 2) is within the ±5 error, so the correction could be even set to 0. Despite this, the current ETC corrections perform well, and we don't suggest changing them.

Table 2 – ETC correction due to Filter non-linearity. Median value, mean values and, 95% confidence intervals are calculated using bootstrap technique

	filter#1	**filter#2**	**filter#3**	**filter#4**	**filter#5**
ETC Filt. Corr. (median)	-3	-6	-5	-17	1
ETC Filt. Corr. (mean)	-2.5	-7.5	-4.5	-12.3	1.6
ETC Filt. Corr. (mean 95% CI)	[-5.7 0.8]	[-11.4 -3.7]	[-7.9 -1.1]	[-18.7 -5.9]	[-8.5 11.5]

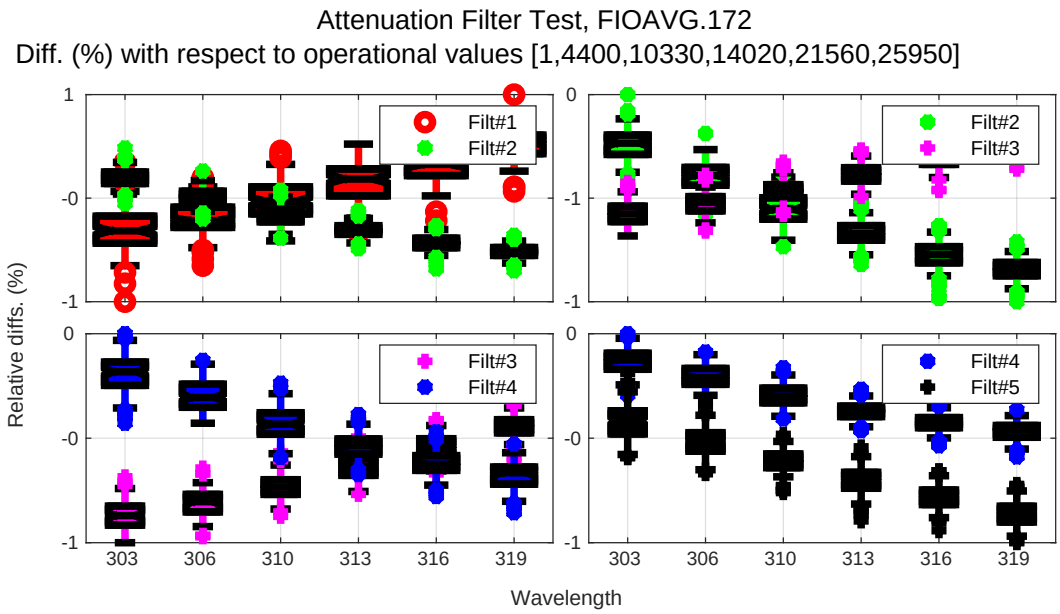


Figure 14 – Notched box-plot for the calculated attenuation relative differences of neutral density filters with respect to operational values. We show for each subplot relative differences corresponding to correlative filters (color box-plots). Solid lines and boxes mark the median, upper and lower quartiles. The point whose distance from the upper or lower quartile is 1 times larger than the interquartile range is defined as outlier.

5 Wavelength Calibration

5.1 Cal-Step determination

The sun scan routine takes DS ozone measurements by moving the micrometer about 15 steps below and above the ozone reference position (wavelength *Calibration step-number*). A Hg test is required before and after the measurement to assure the correct wavelength setting during the *sun scan* test. Ozone *versus* step number ideally shows a parabolic shape with a maximum at the ozone reference position. With this choice, small wavelength shifts ($\approx \pm$ 2 steps) do not affect the ozone value. This optimal micrometer position is a near-linear function of the ozone slant path at the time of the scan, see Fig. 15

During the campaign, sun-scan (SC) tests covering a ozone slant path range from 400 to 1200 DU were collected, see Fig. 16)). The calculated Cal-Step Number (CSN) was 1 step lower than the value in the current configuration: **285** *vs.* **286**. SC tests performed at the station before the campaign provide a CSN of **287**. Taking all this into account, we suggest keeping the current CSN, **286**.

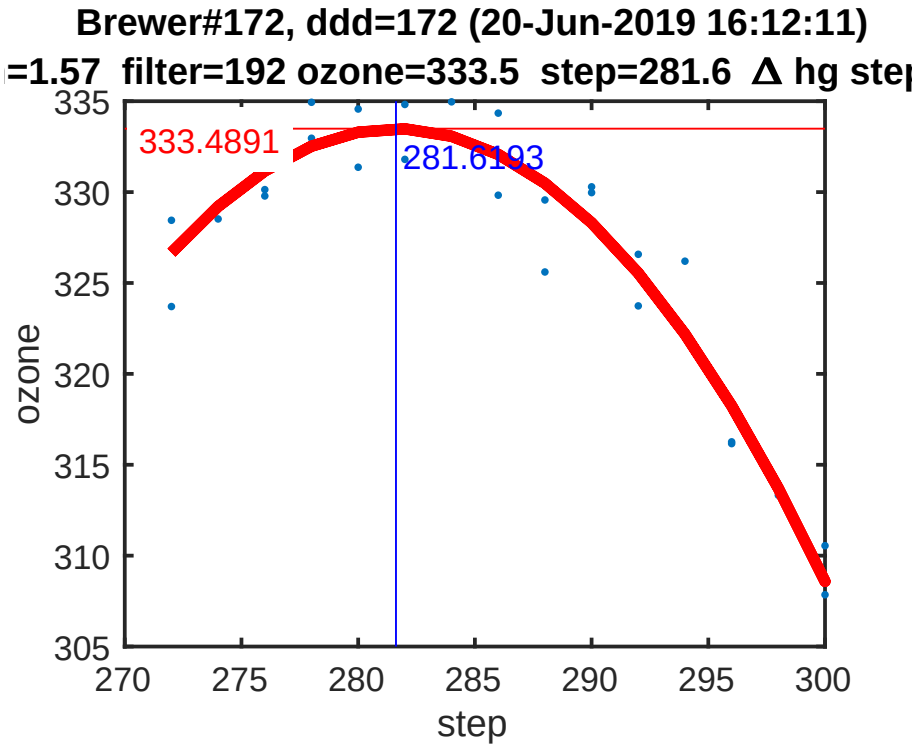


Figure 15 – Ozone measurements moving the micrometer 15 step around the operational CSN defined in the initial configuration

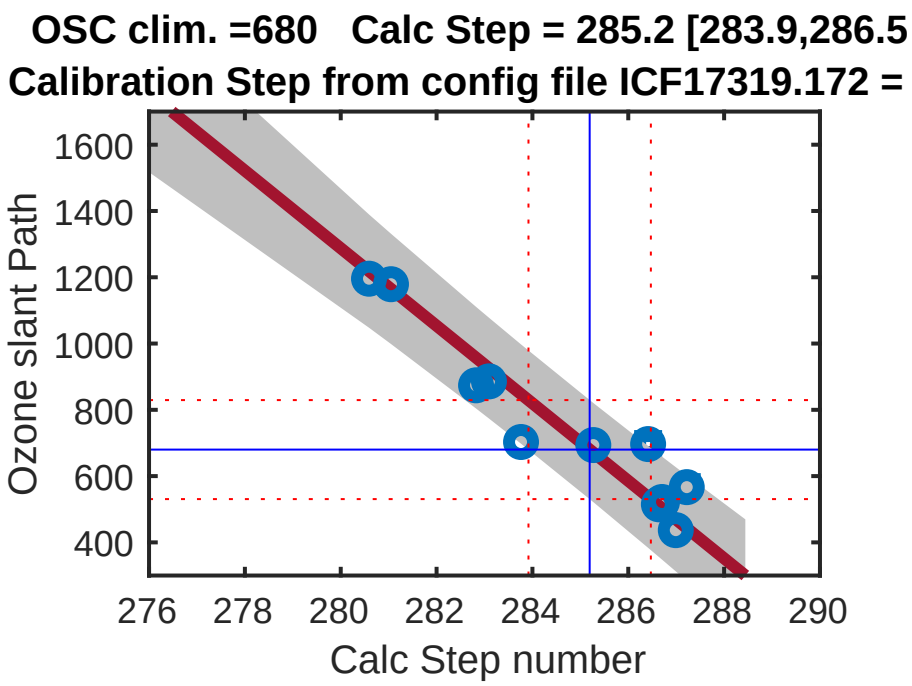


Figure 16 – Ozone Slant Path *vs* Calc – Step number. Vertical solid line marks the calculated *Cal Step Number* for a climatological OSC equal to **680** (horizontal solid line). Blue area represents a 95% confidence interval

5.2 Dispersion Test

We analyzed the dispersion tests carried out in the previous and present calibration campaigns. For all of them, we processed data from Mercury and Cadmium spectral lamps, using quadratic functions to adjust the micrometer step number to wavelength positions. The results of this historical analysis are summarized in Table 3.

In particular, for the current campaign, Fig. 17 shows that the quadratic fitting was good for all the dispersion tests, with residuals being lower than 0.1 Å in all slits. For the dispersion tests performed using the UV dome and the internal Hg lamp, Table 4 provides individual wavelength resolution, ozone absorption coefficient, sulfur dioxide absorption coefficient, and Rayleigh absorption for the operational CSN and those at ±1 step.

An absorption coefficient equal to 0.3412is suggested in the final configuration.

Table 3 – Dispersion derived constants

	Calc-step	**O3abs coeff.**	**SO2abs coeff.**	**O3/SO2**
Current	286	0.3410	2.3500	1.1585
16-Jun-2013	286	0.3453	3.2066	1.1539
02-Jun-2015	286	0.3425	3.2190	1.1466
02-Jun-2017	286	0.3420	3.2256	1.1452
23-Jun-2019	286	0.3412	3.2053	1.1435
Final	286	0.3410	2.3500	1.1585

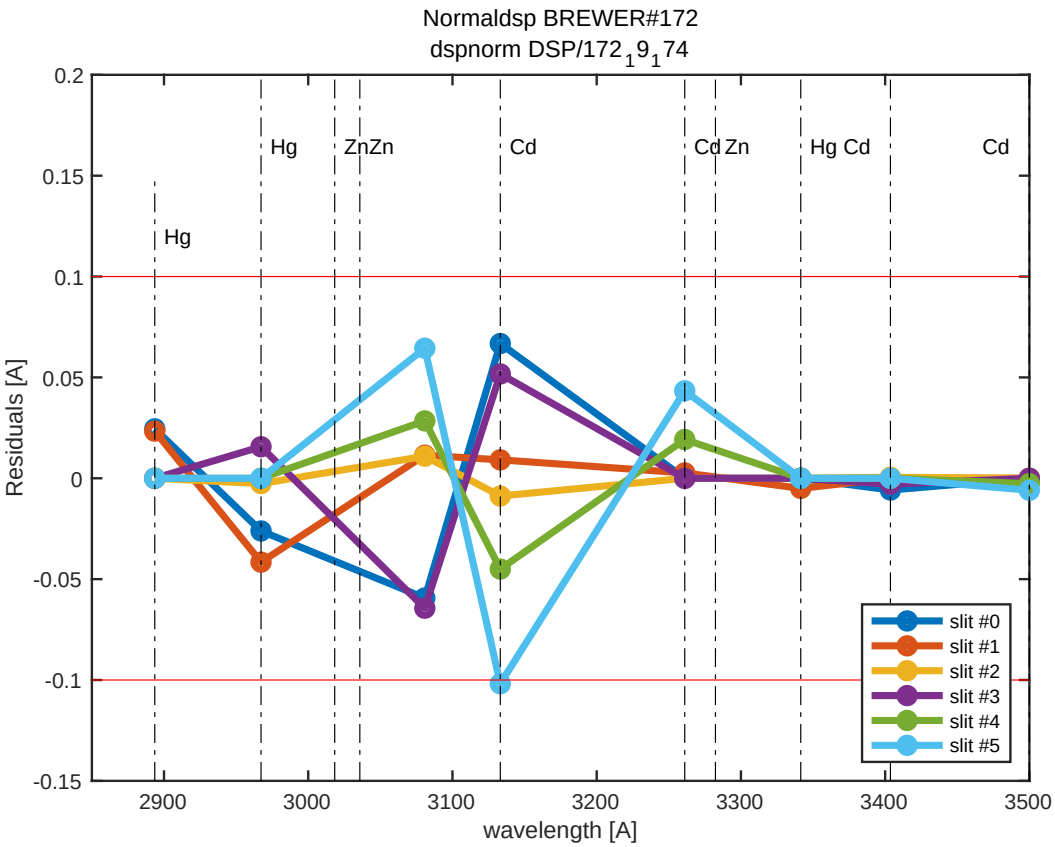


Figure 17 – 2019 Residuals of quadratic fit

Table 4 – 2019 Dispersion derived constants

step= 285	slit#0	slit#1	slit#2	slit#3	slit#4	slit#5
WL(A)	3031.91	3063.06	3100.43	3134.88	3167.89	3199.88
Res(A)	5.5014	5.4778	5.425	5.488	5.4343	5.3254
O3abs(1/cm)	2.5983	1.7794	1.0051	0.67736	0.37483	0.29482
Ray abs(1/cm)	0.50506	0.48319	0.45852	0.43718	0.41792	0.40027
SO2abs(1/cm)	3.4245	5.6707	2.3995	1.9213	1.0531	0.61551
step= 286	slit#0	slit#1	slit#2	slit#3	slit#4	slit#5
WL(A)	3031.98	3063.13	3100.5	3134.95	3167.96	3199.95
Res(A)	5.5013	5.4777	5.4249	5.4879	5.4342	5.3253
O3abs(1/cm)	2.5957	1.7778	1.0049	0.67708	0.37488	0.29434
Ray abs(1/cm)	0.50501	0.48314	0.45847	0.43714	0.41788	0.40023
SO2abs(1/cm)	3.4093	5.6912	2.4073	1.9096	1.0543	0.61325
step= 287	slit#0	slit#1	slit#2	slit#3	slit#4	slit#5
WL(A)	3032.06	3063.2	3100.57	3135.02	3168.03	3200.02
Res(A)	5.5013	5.4776	5.4248	5.4878	5.4341	5.3253
O3abs(1/cm)	2.5932	1.7761	1.0047	0.67675	0.37495	0.29387
Ray abs(1/cm)	0.50496	0.48309	0.45843	0.4371	0.41784	0.40019
SO2abs(1/cm)	3.3946	5.711	2.4155	1.8977	1.0556	0.611
step	O3abs	Rayabs	SO2abs	O3SO2Abs	Daumont	Bremen
285	0.34304	9.636	3.2174	1.1485	0.35377	0.34512
286	0.34201	9.6342	3.2256	1.1452	0.35283	0.34415
287	0.34096	9.6323	3.2329	1.1417	0.35185	0.34313

5.3 Umkehr

For the Umkehr calibration, only the lines shorter than 3400 Å were used. The Umkehr offset is calculated by forcing the wavelength of slit #4 at the ozone position to be the same as on slit #1 at the Umkehr setting. The Umkehr offset calculated is **1694** . Table 5 summarizes the dispersion test for umkehr: wavelength, resolution and ozone absorption coefficient.

Table 5 – 2019 Umkehr dispersion constants

step= 286	slit#0	slit#1	slit#2	slit#3	slit#4	slit#5
WL(A)	3032	3063	3101	3135	3168	3200
Res(A)	5.5631	5.4696	5.4163	5.5463	5.4702	5.3528
O3abs(1/cm)	2.6025	1.7791	1.0045	0.67539	0.3749	0.2944
Ray abs(1/cm)	0.50514	0.48318	0.4584	0.43699	0.41792	0.40024
step= 1691	slit#0	slit#1	slit#2	slit#3	slit#4	slit#5
WL(A)	3133	3164	3200	3233	3265	3296
Res(A)	5.4319	5.3516	5.2838	5.4119	5.339	5.2277
O3abs(1/cm)	0.67844	0.39767	0.29471	0.1229	0.062304	0.033359
Ray abs(1/cm)	0.43809	0.4204	0.40024	0.38282	0.36737	0.35285

6 ETC Transfer

Based on the Lambert-Beer law, the total ozone column in the Brewer algorithm can be expressed as:

$$X = \frac{F - ETC}{\alpha\mu} \tag{1}$$

where F are the measured double ratios corrected for Rayleigh effects, α is the ozone absorption coefficient, μ is the ozone air mass factor, and ETC is the extra-terrestrial constant. The F, α and ETC parameters are weighted functions at the operational wavelengths with weighting coefficients w:

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

$$ETC_i = F_i - X_i^{reference}\alpha\mu \tag{2}$$

For a good characterized instrument, the ETC determined values show a Gaussian distribution and the mean value is used as the instrument constant. One exception to this rule is the single monochromator Brewer models (MK-II and MK-IV) which are affected by stray light. In this case, the ETC distribution shows (see Fig.1) a tail at the lower ETC values for high Ozone Slant Column (OSC, the product of the total ozone content by the airmass). For this type of Brewer, only the stray-light free region is used to determine the ETC, generally from 300 to 900 DU OSC, depending on the instrument.

The stray light effect can be corrected if the calibration is performed against a double monochromator instrument, assuming that it can be characterized following a power law of the ozone slant column

$$F = F_o + k(X\mu)^s \tag{3}$$

where F are the true counts and F_o the measured ones.

$$ETC_i = ETC_o + k(X\mu)^s \tag{4}$$

where ETC_o is the ETC for the stray light free OSC region and k and s are retrieved from the reference comparison . These parameters, determined in several campaigns, have been found to be stable and independent of the ozone calibration.

As the counts (F) from the single brewer are affected by stray light, the ozone is calculated using an iterative process:

$$X_{i+1} = X_i + \frac{k(X_i\mu)^s}{\alpha\mu} \tag{5}$$

Only one iteration is needed for the conditions of the intercomparison, up to 1500 DU. For ozone slant path measurements in the 1500–2000 DU range, two iterations are enough to correct the ozone.

The ETC is obtained by comparison with the reference brewer **IZO#185** using near-simultaneous measurements during **6** days (two measurements are considered near-simultaneous if they are taken less than **3.5** minutes apart). Measurements with airmass difference greater than 3% were removed from the analysis.

6.1 Initial Calibration

For the evaluation of initial status of Brewer UK#172 we used the period from days **170** to **172** which correspond with **136** near-simultaneous direct sun ozone measurements. As shown in Fig. 18, the current calibration constants produce an ozone values slightly higher than the reference instrument (0.5%). When the ETC is corrected taking into account the difference between the SL and R6 reference (SL correction), the results do not improve.

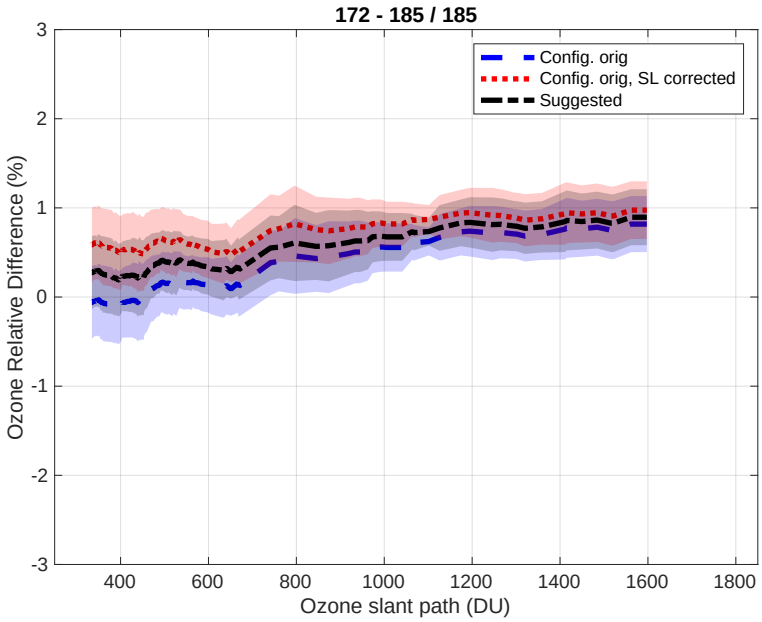


Figure 18 – Mean direct-sun ozone column percentage difference between Brewer UK#172 and Brewer IZO#185 as a function of ozone slant path.

6.2 Final Calibration

After the maintenance on day 172, a new ETC value was calculated (see Fig. 19). For the final calibration, we use **362** simultaneous direct sun measurements from days **173** to **178**. The new value (**1703**) is only three units higher than the current ETC value (**1700**) due the change e in DeadTime. The change is very small, therefore, we recommend to use the current configuration, together with the new proposed standard lamp reference ratios, **437** for R6. For reference we provide a new configuration with this new ETC taking into account the new suggested dead time, $\mathbf{2.9{\cdot}10^{-8}}$.

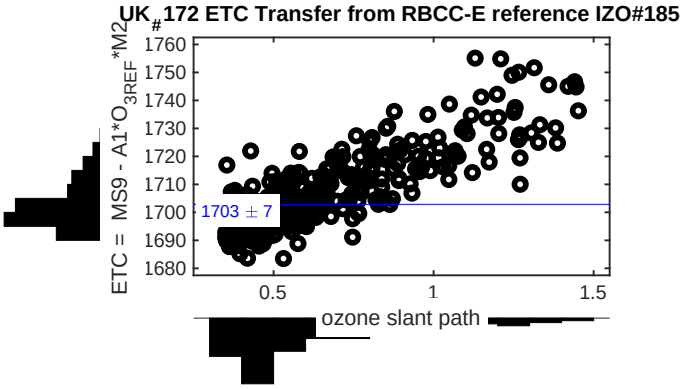


Figure 19 – Mean direct-sun ozone column percentage difference between Brewer UK#172 and Brewer IZO#185 as a function of ozone slant path.

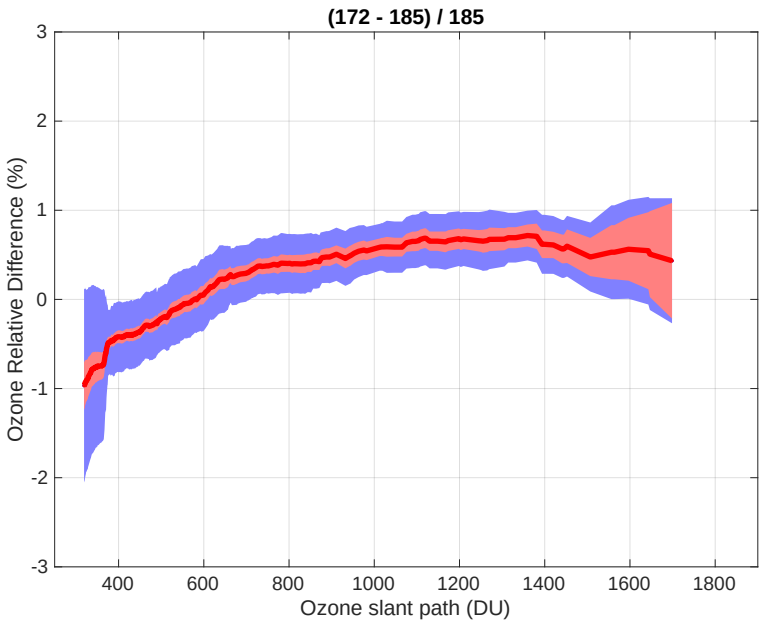
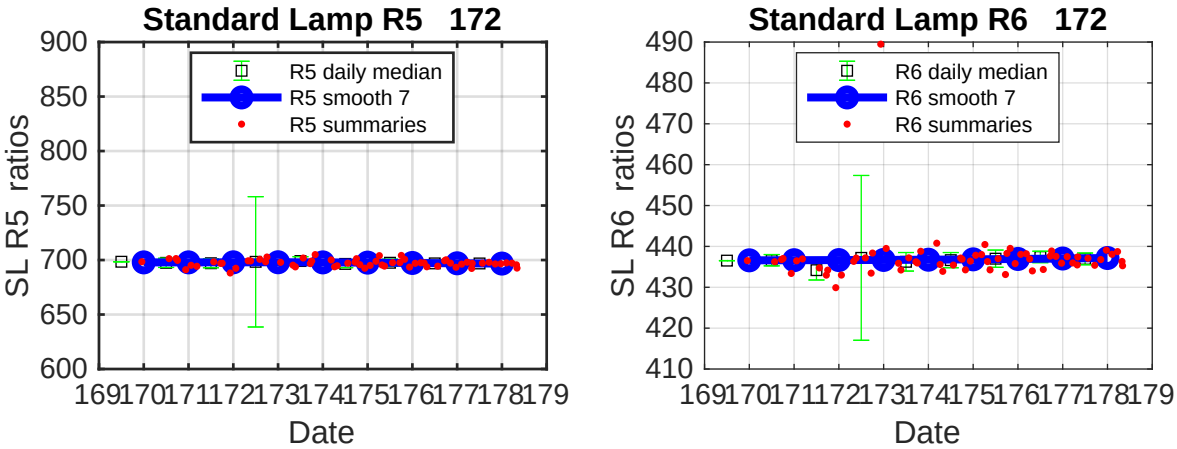


Figure 20 – Mean direct-sun ozone column percentage difference between Brewer UK#172 and Brewer IZO#185 as a function of ozone slant path.

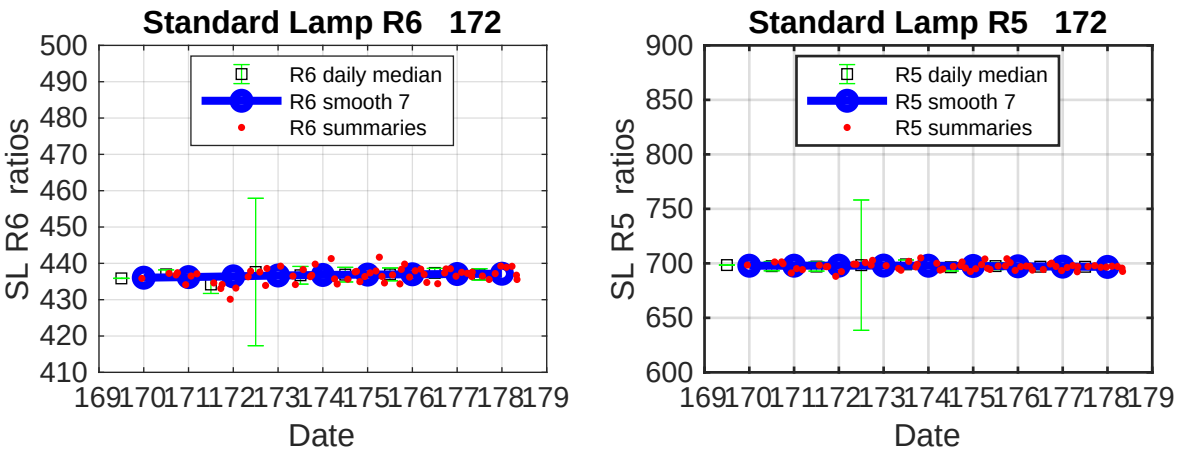
6.3 Standard Lamp Reference Values

The reference values of standard lamp ratios during the calibration period were **437** for R6 (Figure 21) and **697** for R5 (Figure 22).



(a) *Old instrumental constants* **(b)** *New instrumental constants*

Figure 21 – Standard Lamp O_3 R6 ratios: daily mean and standard deviation (squares), seven day running mean (circle) and individual tests (black dots). Reprocessed using old and new instrumental constants



(a) *Old instrumental constants* **(b)** *New instrumental constants*

Figure 22 – Standard Lamp SO_2 R5 ratios: daily mean and standard deviation (squares), seven day running mean (circle) and individual tests (black dots). Reprocessed using old and new instrumental constants

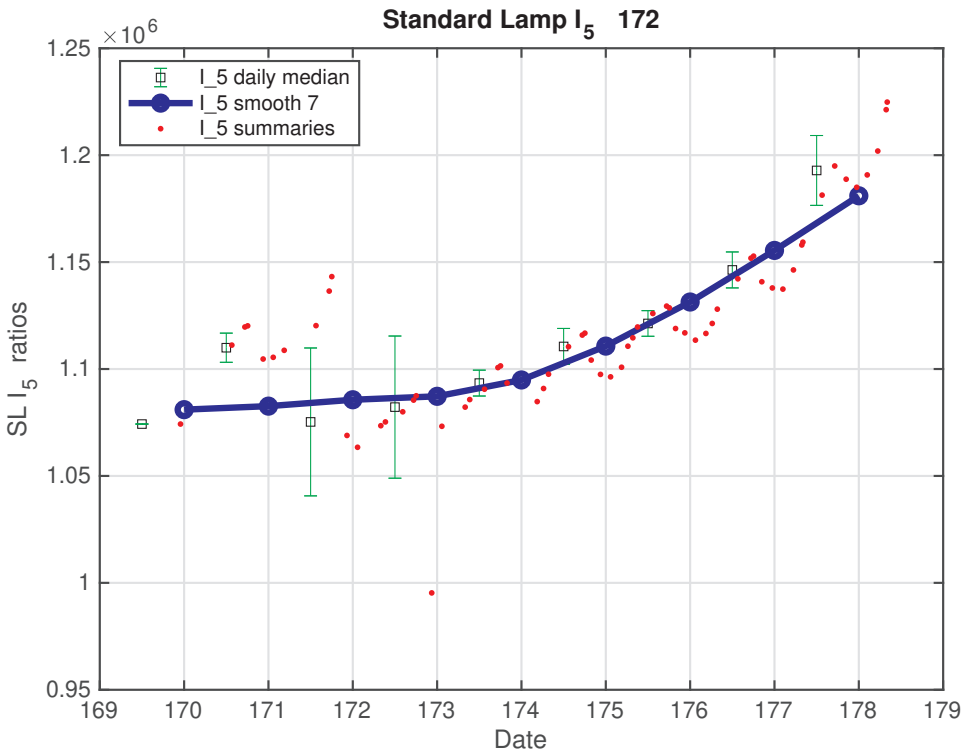


Figure 23 – Standard Lamp intensity: daily mean and standard deviation (squares), seven day running mean (circle) and individual tests (black dots)

7 Configuration

7.1 Instrument constant file

	Initial (ICF15117.172)	Final (ICF17819.172)
o3 Temp coef 1	6.2369	6.2369
o3 Temp coef 2	5.8351	5.8351
o3 Temp coef 3	5.7129	5.7129
o3 Temp coef 4	5.45	5.45
o3 Temp coef 5	5.0893	5.0893
Micrometer steps/deg	0	0
O3 on O3 Ratio	0.341	0.341
SO2 on SO2 Ratio	2.35	2.35
O3 on SO2 Ratio	1.1585	1.1585
ETC on O3 Ratio	1700	1703
ETC on SO2 Ratio	250	250
Dead time (sec)	3e-08	2.9e-08
WL cal step number	286	286
Slitmask motor delay	14	14
Umkehr Offset	1697	1697
ND filter 0	0	0
ND filter 1	4400	4400
ND filter 2	10330	10330
ND filter 3	14020	14020
ND filter 4	21560	21560
ND filter 5	25950	25950
Zenith steps/rev	2972	2972
Brewer Type	3	3
COM Port #	1	1
o3 Temp coef hg	0	0
n2 Temp coef hg	0	0
n2 Temp coef 1	0	0
n2 Temp coef 2	0	0
n2 Temp coef 3	0	0
n2 Temp coef 4	0	0
n2 Temp coef 5	0	0
O3 Mic #1 Offset	0	0
Mic #2 Offset	0	0
O3 FW #3 Offset	242	242
NO2 absn Coeff	-3	-3
NO2 ds etc	655	655
NO2 zs etc	630	630
NO2 Mic #1 Offset	2508	2508
NO2 FW #3 Offset	178	178
NO2/O3 Mode Change	2508	2508
Grating Slope	0.9986	0.9986
Grating Intercept	-3	-3
Micrometer Zero	2469	2469
Iris Open Steps	250	250
Buffer Delay (s)	0.2	0.2
NO2 FW#1 Pos	0	0
O3 FW#1 Pos	256	256
FW#2 Pos	0	0
uv FW#2 Pos	64	64
Zenith Offset	0	0
Zenith UVB Position	2224	2224

8 Daily Summary report

Table 7 – Ozone Summary Report. Mean daily ozone, grouped by ozone slant path ranges, with original and final configuration (with an asterisk)

Day	osc range	O3#185	O3std	N	O3#172	O3 std	%diff	(*)O3#172	O3 std	(*)%diff
170	700>osc>400	325	4.1	29	327	4.5	0.6	327	4.5	0.6
170	osc<400	326	2.5	38	328	2.8	0.7	328	2.8	0.7
171	osc>1500	329	8.9	3	333	7.7	1.2	333	7.7	1.2
171	1500>osc>1000	325	6.0	8	328	6.4	0.9	328	6.4	0.9
171	1000>osc>700	328	5.7	7	331	5.0	0.8	331	5.0	0.8
171	700>osc>400	334	3.8	32	336	3.3	0.7	336	3.3	0.7
171	osc<400	337	0.9	30	340	1.6	0.7	340	1.6	0.7
172	osc>1500	326	0.6	2	329	0.6	1.1	329	0.6	1.1
172	1500>osc>1000	334	3.1	8	337	2.8	0.8	337	2.8	0.8
172	1000>osc>700	332	0.0	1	335	0.0	1.0	335	0.0	1.0
172	700>osc>400	333	1.1	21	335	1.1	0.4	335	1.1	0.4
172	osc<400	340	1.4	17	341	1.5	0.4	341	1.5	0.4
173	osc>1500	320	3.4	2	324	0.5	1.3	323	0.4	1.1
173	1500>osc>1000	325	1.2	13	328	1.7	0.8	327	1.6	0.6
173	1000>osc>700	328	1.2	15	330	1.1	0.7	329	1.2	0.4
173	700>osc>400	329	3.0	43	330	2.7	0.4	328	2.5	-0.2
173	osc<400	332	1.0	7	334	0.6	0.4	331	0.5	-0.5
174	1500>osc>1000	318	4.6	12	321	4.6	0.9	320	4.5	0.7
174	1000>osc>700	321	3.7	18	324	3.4	0.8	322	3.3	0.4
174	700>osc>400	324	2.2	38	326	1.9	0.6	324	1.7	-0.1
174	osc<400	328	1.3	38	330	1.2	0.5	326	1.1	-0.4
175	osc>1500	309	0.3	3	309	1.6	0.1	309	1.6	-0.1
175	1500>osc>1000	307	1.3	12	310	0.9	1.0	310	1.0	0.8
175	1000>osc>700	308	1.1	14	311	1.3	0.9	310	1.4	0.5
175	700>osc>400	308	1.0	27	309	1.0	0.5	307	1.1	-0.2
175	osc<400	308	0.0	1	310	0.0	0.7	307	0.0	-0.4
176	osc>1500	308	1.4	4	309	0.7	0.4	309	0.7	0.2
176	1500>osc>1000	308	2.2	8	310	2.2	0.7	310	2.2	0.5
176	1000>osc>700	308	2.4	9	310	1.8	0.7	309	1.8	0.3
176	700>osc>400	309	1.6	27	310	1.6	0.4	308	1.6	-0.2
176	osc<400	312	1.5	23	310	4.2	-0.6	307	4.2	-1.5
177	1000>osc>700	312	5.8	8	314	6.5	0.6	313	6.6	0.2
177	700>osc>400	314	3.9	25	315	3.9	0.5	313	4.0	-0.1
177	osc<400	312	1.4	19	312	2.8	0.2	309	2.6	-0.8
178	1500>osc>1000	308	6.0	8	NaN	NaN	NaN	309	5.8	0.4
178	1000>osc>700	309	5.2	11	NaN	NaN	NaN	310	5.2	0.3
178	700>osc>400	314	3.4	20	NaN	NaN	NaN	314	3.4	0.0
178	osc<400	314	1.3	14	NaN	NaN	NaN	313	1.8	-0.5

9 Appendix: Summary Plots

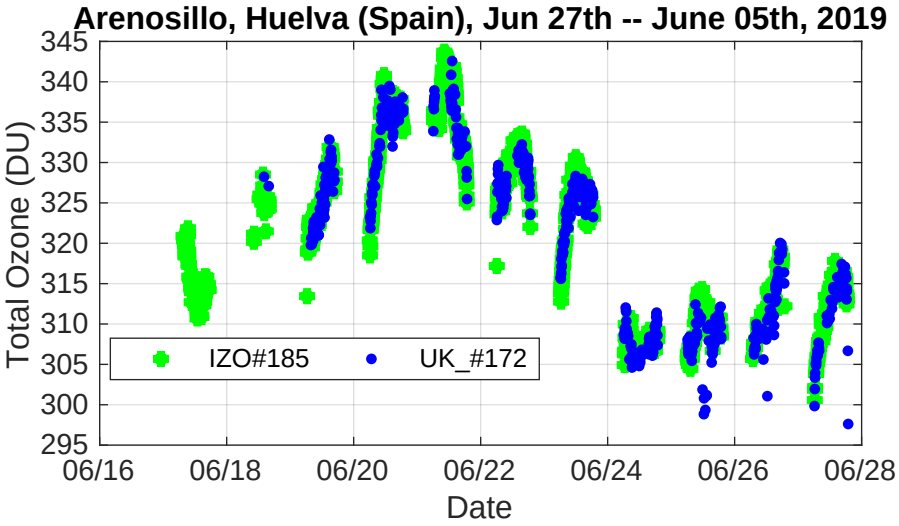
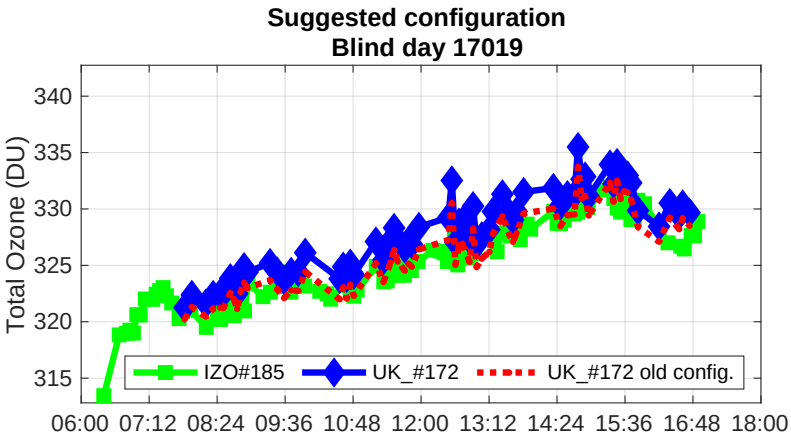
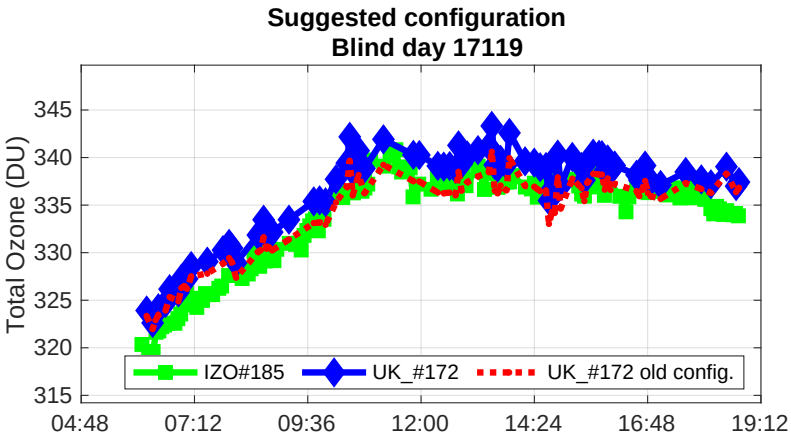
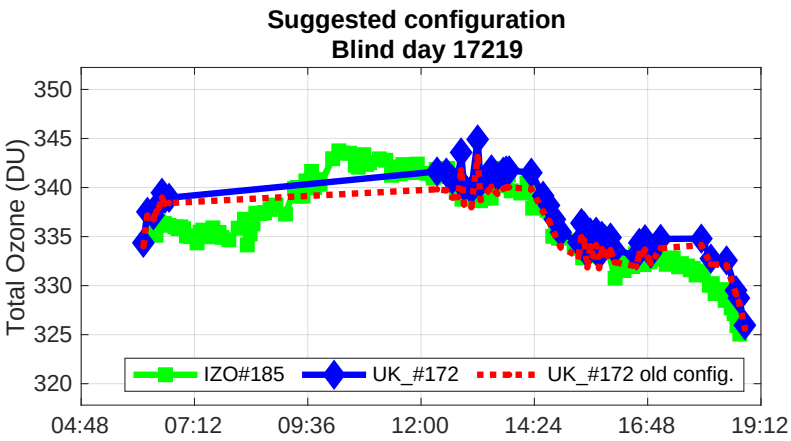
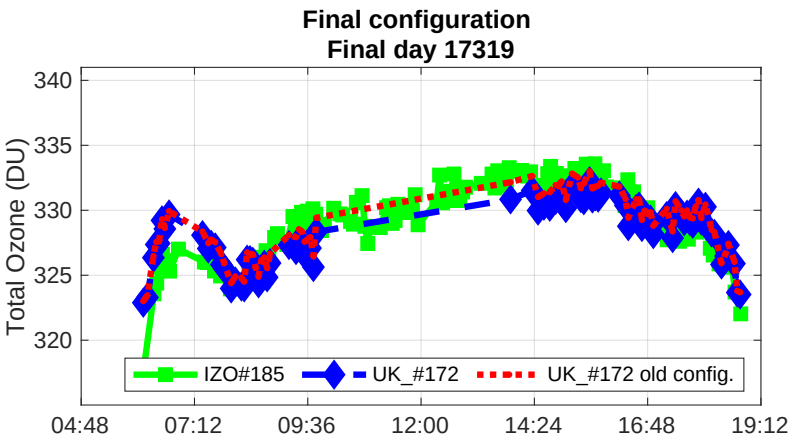


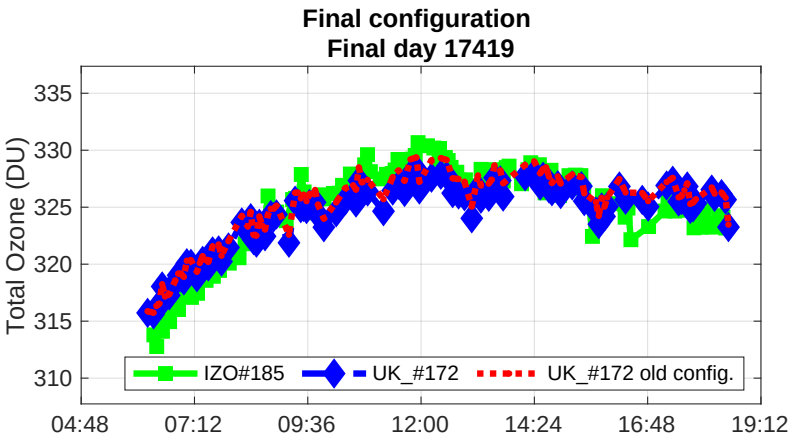
Figure 24 – Overview of the intercomparison. Brewer UK#172 data are evaluated using final constants (blue circles)

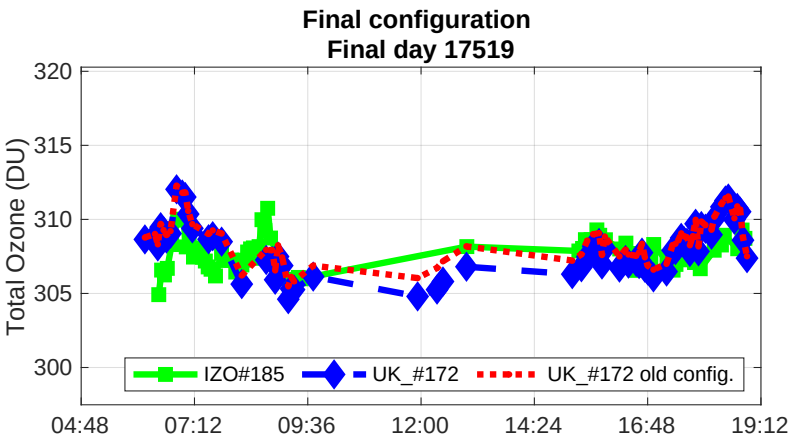


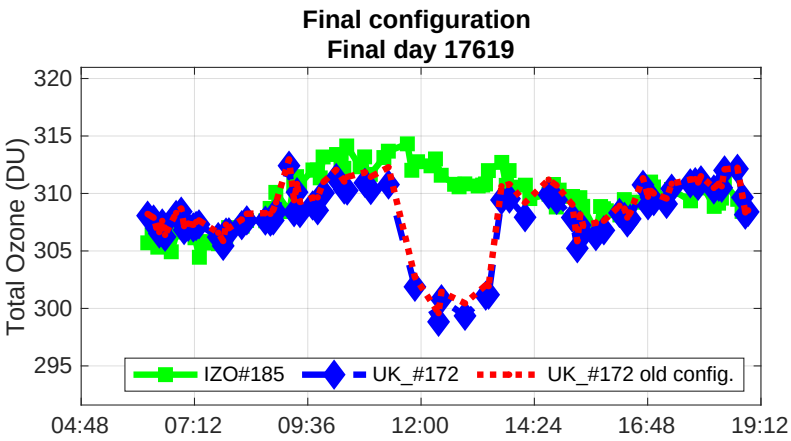

Suggested configuration
Blind day 17119
Total Ozone (DU)
345
340
335
330
325
320
315
04:48
07:12
09:36
12:00
14:24
16:48
19:12
IZO#185
UK_#172
UK_#172 old config.

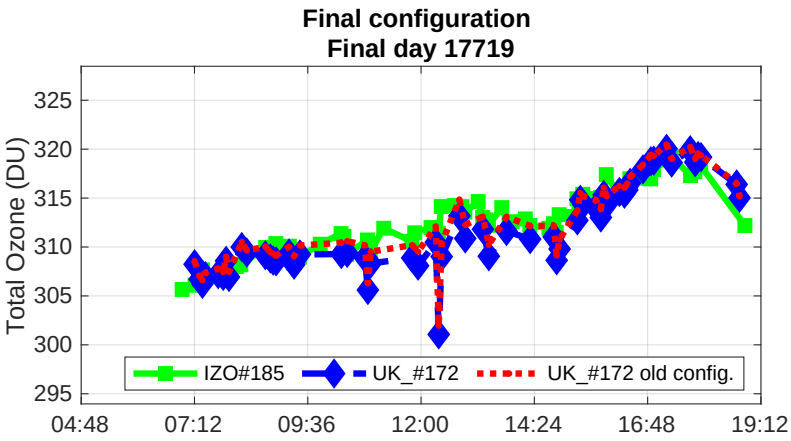

Suggested configuration
Blind day 17219
Total Ozone (DU)
350
345
340
335
330
325
320
04:48
07:12
09:36
12:00
14:24
16:48
19:12
IZO#185
UK_#172
UK_#172 old config.

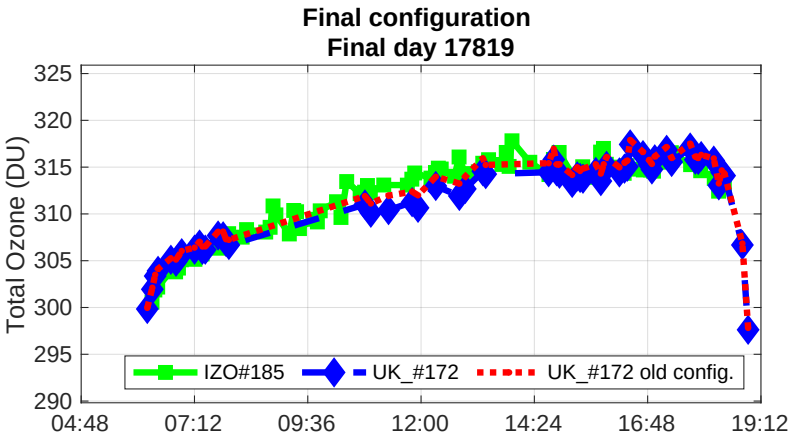

Final configuration
Final day 17319
Total Ozone (DU)
340
335
330
325
320
IZO#185
UK_#172
UK_#172 old config.
04:48
07:12
09:36
12:00
14:24
16:48
19:12

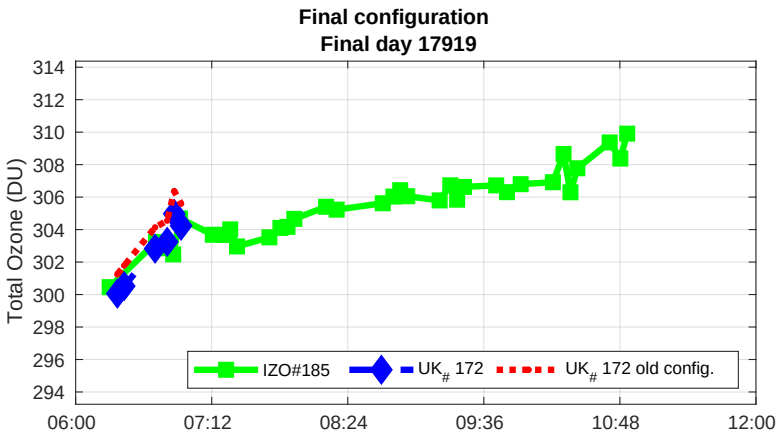

Final configuration
Final day 17419
Total Ozone (DU)
335
330
325
320
315
310
IZO#185
UK_#172
UK_#172 old config.
04:48
07:12
09:36
12:00
14:24
16:48
19:12


Final configuration
Final day 17519
Total Ozone (DU)
320
315
310
305
300
IZO#185
UK_#172
UK_#172 old config.
04:48
07:12
09:36
12:00
14:24
16:48
19:12


Final configuration
Final day 17619
Total Ozone (DU)
320
315
310
305
300
295
IZO#185
UK_#172
UK_#172 old config.
04:48
07:12
09:36
12:00
14:24
16:48
19:12


Final configuration
Final day 17719
Total Ozone (DU)
325
320
315
310
305
300
295
IZO#185
UK_#172
UK_#172 old config.
04:48
07:12
09:36
12:00
14:24
16:48
19:12


Final configuration
Final day 17819
Total Ozone (DU)
325
320
315
310
305
300
295
290
IZO#185
UK_#172
UK_#172 old config.
04:48
07:12
09:36
12:00
14:24
16:48
19:12


Final configuration
Final day 17919
Total Ozone (DU)
314
312
310
308
306
304
302
300
298
296
294
06:00
07:12
08:24
09:36
10:48
12:00
IZO#185
UK# 172
UK# 172 old config.