Comments to:

The world Brewer reference triad – updated performance assessment and new double triad

Xiaoyi Zhao, Vitali Fioletov, Michael Brohart, Volodya Savastiouk, Ihab Abboud, Akira Ogyu, Jonathan Davies, Reno Sit, Sum Chi Lee, Alexander Cede, Martin Tiefengraber, Moritz Mülle, Debora Griffin, and Chris McLinden

https://doi.org/10.5194/amt-2020-324

Sergio Fabián León-Luis[1,2], Alberto Redondas[1,2], Virgilio Carreño[1,2], Javier López-Solano[3,2], Alberto Berjón[3,2], and Daniel Santana-Díaz[4,2]

[1]Izaña Atmospheric Research Center, Agencia Estatal de Meteorología AEMET, Tenerife , Spain
[2]Regional Brewer Calibration Center for Europe, Izaña Atmospheric Research Center, Tenerife, Spain
[3]Tragsatec, Madrid, Spain
[4]LuftBlick, Mutters, Austria

Correspondence: Alberto Redondas (aredondasm@aemet.es)

1 Comparison with the RBBC-E triad in León-Luis *et al.* (2018)

In the paper the authors claim that the comparison with the RBCC-E Triad presented in León-Luis *et al.* (2018) should not be carried out because the calculation is not consistent with the results of Model 1 in the present paper by Zhao et al. Note Model 1 was proposed in Fioletov *et al.* (2015).

In León-Luis *et al.* (2018), we calculate a quadratic polynomial fit for every Brewer as

$$O_3 = A + B \cdot (t - t_0) + C \cdot (t - t_0)^2 \tag{1}$$

obtaining for each instrument the corresponding values of A, B and C. Model 1 in Fioletov *et al.* (2015) however calculates common B and C values for all instruments.

We take the opportunity of the open discussion of this paper to update the calculations of the RBCC-E Triad to be consistent with Fioletov *et al.* (2015), and also to compare the results of both Eq. 1 and Model 1 from Fioletov *et al.* (2015).

Table 1 contains the 3-month standard deviation of the A_i coefficients obtained when the RBCC-E data are re-evaluated using Model 1, together with our previous published results. As can be observed, the values for each Brewer change slightly, depending on the method applied. However, the mean value of the Triad is similar, 0.23% versus 0.27%. This result confirms that there is very little difference between both methods when are applied to the RBCC-E Triad data.

This point can be better understood with an example. Fig. 1 demonstrates the total ozone column recorded on November 16th, 2016 (Fig. 4 in León-Luis *et al.* (2018)), where the data have been fitted used the two methods previously described. Table 2 contains the A, B and C coefficients calculated by both methods. As can be seen, regardless of the method used,

Table 1. RBCC-E and World Reference Triads: 3-month standard deviation. We include the values of the World Reference Triad from Zhao *et al.* (2020) for comparison.

RBCC-E			World Reference			
Brewer	σ_{3month}, Eq.1	σ_{3month}, Model 1	Brewer	σ_{3month}, Model 1	Brewer	σ_{3month}, Model 1
#157	0.20 [1]	0.19	#008	0.43 (0.40)	#145	0.44
#183	0.31	0.26	#014	0.36 (0.46)	#187	0.26
#185	0.29	0.23	#015	0.42 (0.39)	#191	0.33
Mean	0.27	0.23		0.40 (0.42)		0.34

Note: The standard deviations of Brewers 157 and 185 were interchanged in Table 5 of reference León-Luis *et al.* (2018)

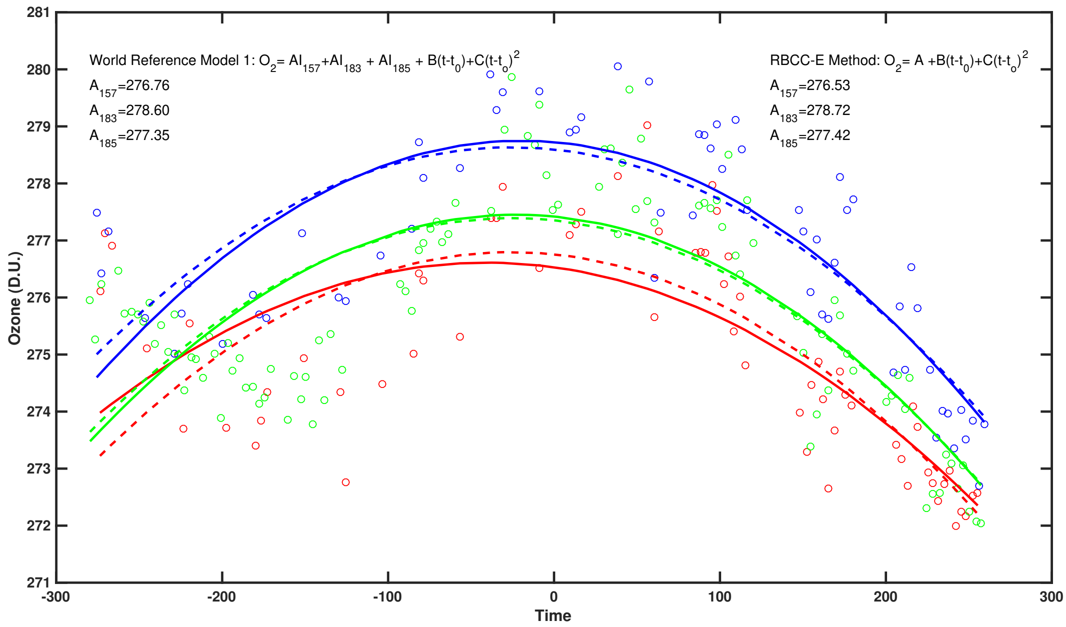

Figure 1. Ozone values measured on November 16th, 2016, marked with circles. Solid and dotted lines correspond to the 2^{nd} order polynomial fitted using Eq. 1 (RBCC-E method) and Model 1 from Fioletov *et al.* (2015) (World Reference Model method), the Time units are the minutes from solar noon. The A coefficients calculated with both methods are also shown.

the derived A coefficients are very similar. Therefore, the mean daily value of the RBCC-E Triad, the relative errors for each instrument, and the standard deviation, calculated from these coefficients, should not differ significantly. Furthermore, the B and C coefficients calculated by both methods are similar, which suggests that the adjusted functions will exhibit the same behavior as shown the Fig. 1. In conclusion, although both calculation methods are not the same, the results in the case of the RBCC-E Triad are very close. A similar result is achieved when no mathematical adjustment is used and the mean from the simultaneous measurements is calculated directly.

Table 2. Coefficients calculated with the two methods for the RBCC-E Triad data of November 16th, 2016

	A, B, and C coefficients
RBCC-E	$A_{157} = 276.53,\ B_{157} = -0.0040,\ C_{157} = -4.855e-5$
	$A_{183} = 278.72,\ B_{183} = -0.0025,\ C_{183} = -6.337e-5$
	$A_{185} = 277.42,\ B_{185} = -0.0028,\ C_{185} = -6.033e-5$
World Reference	$A_{157} = 276.76,\ A_{183} = 278.60,\ A_{185} = 277.35$
	$B = -0.0030,\ C = -5.8122e-5$

Table 3. Percentage difference of the mean of the three instruments, mean and its standard deviation and the percentage of observations 1% 0.5% and 0.25% of the five minutes simultaneous measurements and daily mean

	Brewer	Mean	σ	<1%	<0.5%	<0.25%
5 min	#157	-0.041	0.342	0.994	0.909	0.687
	#183	0.023	0.372	0.991	0.900	0.701
	#185	0.018	0.342	0.99	0.921	0.758
daily	#157	-0.002	0.245	0.999	0.979	0.816
	#183	-0.005	0.309	0.999	0.931	0.757
	#185	0.007	0.267	0.992	0.954	0.866

Table 3 shows the mean and standard deviation of the ratios for the 5 minutes simultaneous measurements and daily mean values and note that the standard deviations values in this table are fairly similar to those in Table 1, even though the periods used for the calculations are not the same (5 minutes, daily and 3 months).

Up to this point, we have shown that both methods produce a similar result. The difference between the standard deviation reported by both Brewer Triads could then be associated to others factors which have not been considered in these works, such as e.g. the intra-day ozone variability or the number of ozone (Direct Sun) measurements made per day at each station. These factors can affect the robustness of the mathematical fits and, hence, introduce small differences between the calculated A coefficients that are difficult to evaluate for two stations so far apart.

2 Additional comments

In this section we include some other comments to Zhao *et al.* (2020), but first we want to acknowledge the effort of the World Reference Triad to maintain all these instruments during decades with such a high precision. Once the precision of the Triads has been established the challenge is to quantify the uncertainty, especially that produced by the described instrumental issues and include them in the analysis.

1. We do not agree with the comment that the 0.5% level cannot be achieved due to limitations of the Brewer hardware. Some of the issues described, such as for example the filter non linearity, can be addressed, and indeed are accounted

for in the processing performed at Eubrewnet. Eubrewnet's processing also takes into account the issue described for Brewer #15 – the observations not compensated with mercury tests are automatically filtered out.

2. The cited Pandora manual has more than 150 pages, so it is difficult to find the ozone processing details. It could be better to refer to the ozone processing in the user guidelines avaliable at https://www.pandonia-global-network.org/wp-content/uploads/2020/01/LuftBlick_FRM4AQ_PGNUserGuidelines_RP_2019009_v1.pdf. Furthermore, if we understand it correctly, the data used in the present paper by Zhao et al. is not the operational one that is available to the public for download.

3. It looks that there is a trend on the Merra comparison from 2005 to 2015, with Brewer #015 going from +2% to -2%

4. **Appendix A**. The standard deviation of the ozone measurement is strongly affected by clouds and is also used as cloud mask to filter the AOD measurements affected by rapid moving clouds (López-Solano *et al.*, 2017). Some of the brewer are equipped with full sky cameras, are the observations reported in Zhao *et al.* (2020) also filtered by clouds ?

5. **Appendix A**. Figure A2 shows the dependence with the ozone air mass factor (AMF), as the stray-light is a function of AMF (Karppinen *et al.* (2015)) , but in the text the discussion is focused on the solar zenith angle and air mass

6. **Appendix A**. An statistical approach to estimate the single triad stray light Diemoz *et al.* (2015) or the determination of the empirical correction by comparison with the double one (Redondas *et al.*, 2018) could be performed to the dataset.

References

Diémoz, H., Redondas, A., Karppinen, T., Siani, A. M., Casale, G. R., Scarlatti, F., Eleftheratos, K., Stanek, M. and San Atanasio, J. M.: Statistics-based evaluation of the stray-light effect on ozone measurements in the framework of the European Brewer Network (EUBREWNET), [online] Available from: https://repositorio.aemet.es/handle/20.500.11765/11816 (Accessed 3 November 2020), 2015.

Fioletov, V. E., Kerr, J., McElroy, C., Wardle, D., Savastiouk, V., and Grajnar, T.: The Brewer reference triad, Geophys. Res. Lett., 32, L20805, https://doi.org/10.1029/2005GL024244, 2005.

Karppinen, T., Redondas, A., García, R. D., Lakkala, K., McElroy, C. T. and Kyrö, E.: Compensating for the Effects of Stray Light in Single-Monochromator Brewer Spectrophotometer Ozone Retrieval, Atmosphere-Ocean, 53(1), 66–73, doi:10.1080/07055900.2013.871499, 2015.

León-Luis, S. F., Redondas, A., Carreño, V., López-Solano, J., Berjón, A., Hernández-Cruz, B. and Santana-Díaz, D.: Internal consistency of the Regional Brewer Calibration Centre for Europe triad during the period 2005–2016, Atmospheric Measurement Techniques, 11(7), 4059–4072, doi:https://doi.org/10.5194/amt-11-4059-2018, 2018.

López-Solano, J., Redondas, A., Carlund, T., Rodriguez-Franco, J. J., Diémoz, H., León-Luis, S. F., Hernández-Cruz, B., Guirado-Fuentes, C., Kouremeti, N., Gröbner, J., Kazadzis, S., Carreño, V., Berjón, A., Santana-Díaz, D., Rodríguez-Valido, M., De Bock, V., Moreta, J. R., Rimmer, J., Smedley, A. R. D., Boulkelia, L., Jepsen, N., Eriksen, P., Bais, A. F., Shirotov, V., Vilaplana, J. M., Wilson, K. M. and Karppinen, T.: Aerosol optical depth in the European Brewer Network, Atmos. Chem. Phys., 18(6), 3885–3902, doi:10.5194/acp-18-3885-2018, 2018.

Redondas, A., Carreño, V., León-Luis, S. F., Hernández-Cruz, B., López-Solano, J., Rodriguez-Franco, J. J., Vilaplana, J. M., Gröbner, J., Rimmer, J., Bais, A. F., Savastiouk, V., Moreta, J. R., Boulkelia, L., Jepsen, N., Wilson, K. M., Shirotov, V. and Karppinen, T.: EUBREWNET RBCC-E Huelva 2015 Ozone Brewer Intercomparison, Atmospheric Chemistry and Physics, 18(13), 9441–9455, doi:https://doi.org/10.5194/acp-18-9441-2018, 2018.

Zhao, X. and Fioletov, V. and Brohart, M. and Savastiouk, V. and Abboud, I. and Ogyu, A. and Davies, J. and Sit, R. and Lee, S. C. and Cede, A. and Tiefengraber, M. and Müller, M. and Griffin, D. and McLinden, C.: The world Brewer reference triad – updated performance assessment and new double triad., Atmospheric Measurement Techniques Discussions, https://doi.org/10.5194/amt-2020-324.