Aerosol optical depth in the European Brewer Network: Reply to Anonymous Referee #1, RC1, 20 Nov 2017

Javier López-Solano[1,2,3], Alberto Redondas[1,3], Thomas Carlund[4,5], Juan J. Rodriguez-Franco[1,3], Henri Diémoz[6], Sergio F. León-Luis[1,3], Bentorey Hernández-Cruz[2,3], Carmen Guirado-Fuentes[7,1], Natalia Kouremeti[4], Julian Gröbner[4], Stelios Kazadzis[4], Virgilio Carreño[1,3], Alberto Berjón[2,3], Daniel Santana-Díaz[2,3], Manuel Rodríguez-Valido[2,3], Veerle De Bock[8], Juan R. Moreta[9], John Rimmer[10], Andrew R. D. Smedley[10], Lamine Boulkelia[11], Nis Jepsen[12], Paul Eriksen[12], Alkiviadis F. Bais[13], Vadim Shirotov[14], José M. Vilaplana[15], Keith M. Wilson[16], and Tomi Karppinen[17]

[1]Izaña Atmospheric Research Center, Agencia Estatal de Meteorología, Tenerife, Spain
[2]Departamento de Ingeniería Industrial, Universidad de La Laguna, Tenerife, Spain
[3]Regional Brewer Calibration Center for Europe, Izaña Atmospheric Research Center, Tenerife, Spain
[4]Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center, Davos, Switzerland
[5]Swedish Meteorological and Hydrological Institute, Norrköping, Sweden
[6]Regional Agency for Environmental Protection of the Aosta Valley (ARPA), Saint-Christophe, Italy
[7]Atmospheric Optics Group, University of Valladolid, Valladolid, Spain
[8]Royal Meteorological Institute of Belgium, Brussels, Belgium
[9]Agencia Estatal de Meteorología, Madrid, Spain
[10]Centre for Atmospheric Science, University of Manchester, Manchester, United Kingdom
[11]National Meteorological Office, Algeria
[12]Danish Meteorological Institute, Copenhagen, Denmark
[13]Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[14]Scientific and Production Association "Typhoon", Obninsk, Russia
[15]National Institute for Aerospace Technology - INTA, Atmospheric Observatory "El Arenosillo", Huelva, Spain
[16]Kipp & Zonen, Delft, The Netherlands
[17]Finnish Meteorological Institute, Sodankyla, Finland

Correspondence to: A. Redondas (aredondasm@aemet.es)

We thank the referee for their detailed comments on our manuscript. Below we include in italics a copy of their review and address their questions and suggestions.

Review of "Aerosol optical depth in the European Brewer Network" by López Solano et al.'

5   *The manuscript by López Solano et al is the result of a big collaborative work. It describes the algorithm and the processes used in EUBREWNET to retrieve AOD from the Brewer network, provides a quantitative estimation of the uncertainties, and lists a number of possible actions which could further improve the quality of the specific product. My main comment is that, although the manuscript is well structured and concise, linguistic corrections are necessary prior to its publication to ACP.*

In the following, there is a list of more specific suggestions minor comments.

10   *Abstract*

P1, L1-2: Add "," after the words "networks" and "time"

This sentence has been rewritten as follows:

"Aerosols play an important role in key atmospheric processes and feature high spatial and temporal variabilities. This has motivated scientific interest in the development of networks capable of measuring aerosol properties over large geographical areas in near real time."

P1, L4: According to the Eubrewnet webpage, the Eubrewnet network includes more than 50 instruments deployed not only in Europe, but from Patagonia, Argentina and Tasmania, Australia to Kangerlussuaq, Greenland. Why only 30 instruments are referred? Do you refer only to the currently calibrated instruments? Please be more specific.

This sentence has been rewritten as follows:

"In this work we present and discuss results of an aerosol optical depth (AOD) algorithm applied to instruments of the European Brewer Network. This network is comprised by close to 50 Brewer spectrophotometers, mostly located in Europe and adjacent areas, although instruments operating at e.g. South America and Australia are also members. Although we only show results for instruments calibrated by the Regional Brewer Calibration Center for Europe, the implementation of the AOD algorithm described is intended to be used by the whole network."

Furthermore, we have added a new paragraph (no. 5) to the Introduction:

"It should be noted that the RBCC-E provides calibration data for approximately half the Brewer spectrophometers integrated in EUBREWNET, and this paper is focused on these instruments. However, the present implementation of the AOD algorithm is intended to run directly on EUBREWNET's dataserver using any measurements and calibration data available. This would allow to extend the applicability of the present implementation of the AOD algorithm, with minor modifications as needed, to the whole EUBREWNET network, because any other calibration data could be used besides that supplied by the RBCC-E. This includes calibrations transferred from other Brewer reference spectrophotometers, such as the one operated by International Ozone Services (Toronto, Canada, http://www.io3.ca/). Furthermore, preliminary work on the feasibility of using an Ultraviolet Precision Filter Radiometer (UVPFR) from the Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center (Davos, Switzerland, https://www.pmodwrc.ch/) to calibrate Brewer instruments has also been carried out (Carlund et al., 2017)."

P1, L9: Replace "aerosols" with "AOD".
Done.

Introduction
Some information regarding the importance of measuring the AOD in the UV, and especially in the UV-B region (where Brewers perform measurements), should be also added in the introduction. This would give the reader a better sense of the importance of this product. E.g., the interaction of aerosols with UV radiation, especially at lower wavelengths, is usually stronger and more complicated compared to the interaction between aerosols and the radiation at visible wavelengths, and yet not fully understood (Bais et al., 2015: Ozone depletion and climate change: impacts on UV radiation). Thus, measurements

of the aerosol optical properties in the UV can improve the understanding of these interactions and help obtaining more information regarding the physical and chemical properties of aerosols. Furthermore, over several mid-latitude stations aerosols have found to be the main driver of the long-term changes of both, the (very important for the human health) UV and visible radiation.

We have added the following text at the end of the second paragraph of the Introduction:

"Although Brewer spectrophotometers can be used to retrieve AOD at longer wavelengths, in their standard operational mode most instruments can only produce data in the 300–320 nm range. This is nevertheless an important wavelength range to study, because the optical properties of aerosols in the UV-B are rather different from those in the visible and are yet not well known (see Bais et al. (2015) and references therein). It is also worth noting that the shortest wavelength provided by the AOD product of the Aerosol Robotic Network (AERONET, https://aeronet.gsfc.nasa.gov/), one of the most used sources for ground-based aerosol data, is 340 nm, which makes Brewer AOD data in the 300–320 nm range a useful complement."

P2, L1: Use "such as" instead of "like"

Done.

P2, L4 – 6: Use "introduce large uncertainties" instead of "add a large uncertainty".

Done.

P2, L18: Again, I think that Brewers in Eubrewnet are more.

We have modified paragraph 3 in the Introduction as follows:

"[...] instruments integrated in EUBREWNET (COST Action ES1207, "a European Brewer Network", Rimmer et al. (2018), http://www.eubrewnet.org/cost1207), which is comprised by close to 50 Brewer spectrophotometers. Most of these Brewer instruments operate in Europe and adjacent areas, although some located farther away, for example in South America and Australia, have also joined the network."

Furthermore, we have added a new paragraph (5) to the Introduction, as already mentioned above.

P2, L28: "Further ... information". The specific sentence is not very clear. Please rephrase.

The sentence has been modified as follows:

"The multiple research programs carried out at IZO (Cuevas et al., 2015) provide additional information that may help to carry out calibrations, such as e.g. forecasts of adverse weather conditions."

P3, L1: Replace "first give details" with "present the results of"

Done.

P3, L2: I think that "estimate" would be more accurate than "derive"

Yes, we agree, change done.

P3, L3: replace "in these Brewer instruments in" with "from these Brewer instruments for"
Done.

5

Method
P3, L9: Use "Methodology" instead of "method"
Done.

10 *P3, L13: Delete "used ... spectrophotometer"*
Done.

P3, L17: Use "performs" instead of "makes". Also, replace the phrase "and, through a well defined process, produces a TOC value" with "which, through a well defined process, are used to calculate TOC"
15 Done.

P3, L19: Replace the phrase "but ... work" with "the most relevant parts of which to the present study are highlighted in the following"
The whole sentence has been modified as follows:
20 "In the rest of this section we highlight the most relevant details for the present work of the instrument and the measurement process, see Kerr (2010) for further information."

P3, L20: Use "measures" instead of "detects"
Done.

25

P5, L8: Use "In addition to" instead of "Besides"
Done.

P5, L9: Use "we apply those" instead of "we also apply the ones"
30 Done.

P5, L10: Use "for" instead of "of"
Done.

35 *P5, L14 – 16: This sentence is not clear, please rephrase*

The text has been modified as follows:

"X_o: measured TOC in atm-cm. We currently use the real-time ozone level 1.5 product available at EUBREWNET's data server. However, instead of the Rayleigh coefficients supplied by default for all Brewer spectrophotometers, we use specific coefficients for each instrument determined during the RBCC-E calibration. These coefficients are calculated within the prescription of (Nicolet, 1984) and this modification in the Rayleigh contribution lowers the ozone value by approx. 0.003 cm, in agreement with the value reported by Kiedron and Stierle (2009)."

P6, L15: Re-write Eq. (6) so that all terms are in the same line.

Done.

P6, L27: I suppose that you add this last criterion (AOD st. dev. <0.02) to filter out the measurements performed under cloudy conditions (since these measurements are only partially filtered out by applying the TOC filters). Please add some more information.

We have added the following sentence at the end of this paragraph:

"Together with the criterion on the standard deviation of the ozone data described above, this ensures that measurements affected by clouds are removed."

P8, L7: I think that using the word "reliable" would be more accurate than using the word "correct".

Yes, that's right, word changed.

P9, L7: Replace "For the uncertainty" with "For the estimation of the AOD uncertainty due to the corresponding uncertainty in".

Done.

P9, L28: Use "dataset" instead of "data"

Done.

P9, L29: Use "from" instead of "for"

Done.

P9, L30: Add "which is" after "provided,"

Done.

P9, L31: Use "which is" instead of "this being"

Done.

P10, L6: Do you mean the corrections which are currently applied or the corrections which should be applied to reduce the effect of large FWHM? Please clarify.

The text has been modified as follows:

"Both Langley calibrations and AOD retrievals are affected by the finite FWHMs. Corrections which were used to reduce this influence, together with more detailed information about the UVPFR, are described by Carlund et al. (2017)."

Results

P11, L7: Do you mean the difference between the results for different filters?

Yes, that's right. The sentence has been changed to

"The difference between the results for different filters is $\sim 1\%$ at most"

P11, L8: I think that what you mean here is that the filter correction removes the greatest part of the effect of the different attenuation by different ND filters. Please re-write this sentence and make clear what you mean.

The sentence has been changed to

"[...] the filter correction applied to the data [...] removes most of the effect produced by the different attenuation of the different filters."

P11, L13: Use "by" instead of "due to"

Done.

P11, L15: Use "considered to be" instead of "taken as"

Done.

P11, L16: Delete "For comparison"

Done.

P12, L10: Use "for Brewers" instead "of Brewers"

Done.

P12, L11: Use "consider to be equal to" instead of "approximate by"

Done.

P13, L10: Delete "ones"

Done.

P13, L11: Use "toward" instead of "in"

Done.

5

Figure 3: The format of the date used at x-axis labels is a bit confusing. Using a format like mon-yy or at least something like "/" between DOY and year would be better.

We have added a slash between the DOY and the year.

10   *P13, L20: "with the lowest" instead of "the lowest"*

This part of the text has been rewritten as follows:

"As shown by the AOD series, there is clear correlation between the data of both instruments, with correlation coefficients above 0.90. The lowest correlation corresponds to the Reading/Chilboton data, which also shows the largest spread of Brewer-Cimel differences, in part due to the separation between the Brewer and Cimel sites, and in part due to sporadic data from the

15   Cimel sunphotometer."

P13, L26: Delete "it should ... Sect. 3.1" and add "(see Sect. 3.1)" at the end of the sentence.

The sentence has been changed to

"Regarding Brewer #070, in Sect. 3.1 it was found [...]"

20

P13, L28: Use "possible reasons" instead of "a possible reason"

Done.

P14, L13: Use "using" instead of "by"

25   Done.

Table 2: It seems to me that in this table you provide the 1-sigma instead of the 2-sigma standard deviation. Please double check.

Yes, in the tables we provide the standard deviation without any multiplicative factor because this is the most usual way of

30   presenting the data. Note that we always indicate in the text whether the $2sigma$ uncertainty has been used in the calculation of uncertainties. Regardless, to make it completely clear, the headers of Tables 1 and 2 now read

"[...] standard deviation (1σ) of differences"

Discussion

35   *P16, L2: "generally" instead of "overall"*

Done.

Conclusions

P17, L9: Replace "AOD results" with something like "the results of the AOD retrieval from Brewers participating in Eubrewnet".

The sentence has been changed to

"In this work we have presented results of the AOD retrieval for selected instruments participating in EUBREWNET"

P17, L16: Add "with" before "the corresponding"

Done.

P17, L21: Again, this area is possibly larger.

The sentence has been changed to

"The European Brewer Network can thus provide reliable aerosol data across Europe and adjacent areas (plus some more distant locations in e.g. South America and Australia) [...]"

References

Bais, A. F., McKenzie, R. L., Bernhard, G., Aucamp, P. J., Ilyas, M., Madronich, S., and Tourpali, K.: Ozone depletion and climate change: impacts on UV radiation, Photochemical & Photobiological Sciences: Official Journal of the European Photochemistry Association and the European Society for Photobiology, 14, 19–52, https://doi.org/10.1039/c4pp90032d, 2015.

5 Carlund, T., Kouremeti, N., Kazadzis, S., and Gröbner, J.: Aerosol optical depth determination in the UV using a four-channel precision filter radiometer, Atmos. Meas. Tech., 10, 905–923, https://doi.org/10.5194/amt-10-905-2017, http://www.atmos-meas-tech.net/10/905/2017/, 2017.

Cuevas, E., Milford, C., Bustos, J. J., del Campo-Hernández, R., García, O. E., García, R. D., Gómez-Peláez, A. J., Ramos, R., Redondas, A., Reyes, E., Rodríguez, S., Romero-Campos, P. M., Schneider, M., Belmonte, J., Gil-Ojeda, M., Almansa, F., Alonso-Pérez, S., Barreto,

10 A., González-Morales, Y., Guirado-Fuentes, C., López-Solano, C., Afonso, S., Bayo, C., Berjón, A., Bethencourt, J., Camino, C., Carreño, V., Castro, N. J., Cruz, A. M., Damas, M., De Ory-Ajamil, F., García, M. I., Fernández-de Mesa, C. M., González, Y., Hernández, C., Hernández, Y., Hernández, M. A., Hernández-Cruz, B., Jover, M., Kühl, S. O., López-Fernández, R., López-Solano, J., Peris, A., Rodriguez-Franco, J. J., Sálamo, C., Sepúlveda, E., and Sierra, M.: Izaña Atmospheric Research Center Activity Report 2012-2014, no. 219 in GAW Report, State Meteorological Agency (AEMET), Madrid, Spain, and World Meteorological Organization, Geneva, Switzer-

15 land, http://www.wmo.int/pages/prog/arep/gaw/documents/Final_GAW_Report_No_219.pdf, 2015.

Kerr, J. B.: The Brewer Spectrophotometer, in: UV Radiation in Global Climate Change, pp. 160–191, Springer, 2010.

Kiedron, P. and Stierle, S.: Rayleigh optical depths used by Brewer, Tech. rep., NOAA-EPA Brewer Spectrophotometer UV and Ozone Network, http://www.esrl.noaa.gov/gmd/grad/neubrew/docs/RayleighInBrewer.pdf, 2009.

Nicolet, M.: On the molecular scattering in the terrestrial atmosphere : An empirical formula for its calculation in the homosphere, Planet.

20 Space Sci., 32, 1467–1468, https://doi.org/10.1016/0032-0633(84)90089-8, 1984.

Rimmer, J. S., Redondas, A., and Karppinen, T.: EuBrewNet – A European Brewer network (COST Action ES1207), an overview, Atmos. Chem. Phys. Discuss., 2018, 1–14, https://doi.org/10.5194/acp-2017-1207, https://www.atmos-chem-phys-discuss.net/acp-2017-1207/, 2018.