

Interactive comment on “Quality assurance of the Brewer UV measurements in Finland” by K. Lakkala et al.

K. Lakkala et al.

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Response to the Referee #1

We thank the Referee for her/his constructive comments and helpful suggestions. We have accordingly modified the manuscript, and the spelling in the manuscript has also been revised. As suggested by Referee #1, more discussion with respect to similar studies presented in other papers has been included in Sections 3.3, 4, 5.3 and 5.4. Please find here below the answers to Referee #1 comments. The authors's answers start with "A":

1. Title: I would suggest a slightly revised version: "Quality assurance of Brewer-derived spectral UV irradiance measurements in Finland", or something along this line.

A: The title has been revised. The current version is "Quality assurance of the Brewer

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spectral UV measurements in Finland".

2. Page 1418, line 12: This statement is not correct. Previous studies have discussed a lot the quality of spectral UV measurements with Brewer spectroradiometers. Some of these papers are cited already: Bais et al. 1996, 1998, 2001; Capellani and Kochler 2000.

A: Following the comment of the Referee, the statement has been removed, and the text of the manuscript revised. We would like to emphasis the complete data processing chain, not only part of the QC or QA. The following text has been added:" Previous papers about the complete data processing procedure of spectral UV measurements have been published for the SUV-type spectroradiometers of the National Science Foundation (NSF) network (Booth et al., 2001; Bernhard et al., 2004) and for two Brewer spectrophotometers of the Aristotle University of Greece in Thessaloniki (Garane et al., 2006)."

3. Recently a very similar paper has appeared (Garane et al. 2006, "Monitoring of UV spectral irradiance at Thessaloniki (1990-2005): Data re-evaluation and quality control." Annal. Geophys. 24(12), 3215-3228), dealing with 2 Brewer instruments operating at Thessaloniki. As the 2 cases have many similarities, it would be worth discussing how the results of the 2 papers compare (e.g. in temperature effects, long term sensitivity degradation, etc.)

A: We thank the Referee for drawing our attention to Garane et al. 2006. The two papers have studied the same features with different instruments and slightly different techniques, so the results are indeed interesting for comparison with each other. Discussions relating to this point have been added in Sections 3.3 Temperature dependence, 4 Long term spectral responsivity, 5.3 Temperature and 5.4. Cosine error.

A:Text added to Section 3.3:" Garane et al. (2006) presented a temperature characterization methodology that has a few differences compared to ours. They performed continuous scans with Brewers brought into and warming up in the laboratory, whereas

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in our measurements scans were taken after the Brewers had stabilized to a given temperature. The temperature correction factor for a double monochromator derived by Garane et al. (2006) exhibited no wavelength dependency, in contrast to our characterization measurements, in which wavelength dependencies for both the single and the double monochromator were detected. It is not yet known whether this difference is due to the differences in the measurement procedures or to inherent variations between the individual Brewer instruments discovered by, e.g., Weatherhead et al. (2001)."

A: Modified text in third paragraph of Section 3.3: "Each scan was made after the temperatures and gradients inside the instrument had fully stabilized."

A: Modified text in Section 5.3: "The procedure yields a time series of irradiance scans (in units of counts/cycle) normalized to the same reference (laboratory) temperature for which the response of the instrument has been derived (23 °C). The procedure differs from that presented by Garane et al. (2006) in the selection of the reference temperature. In our method, the reference is constant, whereas in the method presented by Garane et al. (2006), the reference is the temperature of the absolute calibration valid for the period."

A: Text added to Section 4: "Drifts of the same order of magnitude are also observed in Garane et al. 2006. They report a decrease in the spectral responsivity at 320 +- 5 nm of around 3% per year for both the single and double monochromator Brewer spectroradiometers of Thessaloniki. They suggest that the drift is due to an aging effect of the different optical components of the instrument, including the diffuser."

A: Text added to Section 5.4: "Garane et al., 2006 report mean cosine correction factors of 7 +- 1.5%(1 sigma) and 11+-2% (1 sigma) for the single and double monochromator Brewers of Thessaloniki, respectively."

4. Page 1419 Line 2: The UVB and UVA detectors were used for of the lamp stability in time or during the calibration only?

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A: They can only be used for monitoring the lamp stability during the calibration. The following sentence has been added to the manuscript, section 2.1: "These are used to monitor the stability of the lamp during an individual calibration event, but not to determine any long-term stability (Koskela, 1999)."

Koskela T.: On the stability of an irradiance calibration lamp, Extended Abstracts of the 2nd Workshop at PTB, Braunschweig 9-11 November 1998, the Thematic Network on UV Measurements, UVNEWS, Issue 2, ISSN 1456-2537, p.30-31, 1999. <http://metrology.hut.fi/uvnet/source/UVNEWS2.htm>

5. Page 1420, Line 15: Please define PFR or, better, provide a reference.

A: The following text has been added to the manuscript, section 2.3: "Both stations have carried out PFR-type (Precision Filter Radiometer) aerosol optical depth measurements since 2004 (Wehrl, 2000; Aaltonen et al. 2006)."

Aaltonen, V., Lihavainen, H., Kerminen, V.-M., Ginzburg, M., Kulmala, M., and Viisanen, Y., 2006. Three years of AOD measurements at three bipolar sites. In: Vehkamäki, H., Bergman, T., Julin, J., Salonen, M., and Kulmala, M. (Eds.), NOSA 2006 Aerosol symposium, combined with the X Finnish National Aerosol Symposium, Finnish-Czech Aerosol Symposium, and BACCI workshop, Helsinki 8.-10.11.2006. Report Series in Aerosol Science, No. 83, p. 17-20.

Wehrl, C. (2000) Calibrations of Filter Radiometers for Determination of Atmospheric Optical Depth, *Metrologia* 37, 419–422.

6. Page 1421, Line 19: A recent paper by Bais et al., 2005 Portable device for characterizing the angular response of UV spectroradiometers, *Appl. Opt.*, 44 (33), 7136-7143, shows among other instruments the angular response of the two Finnish Brewers. How these results are compared to the results presented here?

A: The angular response used for Brewer #107 was determined in 1996. The second characterization during a QASUME site visit in 2003, as reported in Bais et al. (2005),

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suggested changes of no more than 3% at $SZA < 80$ in the N-S plane. The measurement in 2003 was suspected to suffer from a minor instability of the light source that may have influenced the results, in particular in the E-W plane. Unfortunately, there has not yet been an opportunity to repeat the characterization using the QASUME equipment. For these reasons, the earlier characterization of 1996 has been kept in use to maintain the homogeneity of the data.

A: The following text has been added to Section 3.1. Angular response: "The angular response of Brewer #037 has been characterized in 1996, 2000 and in 2003, and Brewer #107 in 1996 and 2003 (Bais et al., 2005). The angular responses used in the actual data processing are those derived from the characterizations of 2000 and 1996 for the Brewers #037 and #107, respectively."

A: and section 5.4 Cosine error: "Bais et al., 2005 have described the cosine characterization of several spectroradiometers using a portable device for characterizing the angular responses. Among the instruments, the two Finnish Brewers were characterized as well. The results show angular response errors in the diffuse irradiance, assuming isotropic radiation, of $10.4 \pm 3\%$ (1 sigma) and $8.0 \pm 3.1\%$ (1 sigma) for the Brewer #037 and Brewer #107, respectively. The results are consistent with our results within the measurement uncertainties."

7. Page 1422, Line 11-18: I suggest to include here a short discussion on the differences between the slit function measurements of the Brewer MKIII, as well as on the differences between the 2 Brewers.

A: The following texts have been added to the manuscript, section 3.2: "In addition, the slit function of Brewer #107 was measured twice in 1997 immediately before and after the realignment of the monochromator, and once again in 2002. The repeated characterizations confirmed the stability of the slit function between the years 1996 and 1997, the expected change in 1997, and another period of stability thereafter."

A: "The two Brewers have symmetrical and nearly identical slit functions down to about

10⁻³ of the maximum of the signal. Below that level, the internal stray light in the Mk II Brewer at Sodankylä can be seen as persistent noise that is handled as described in Ch.5.2. In the Mk III instrument at Jokioinen, the stray light level is about two decades lower."

8. Page 1422, Line 19: How the wavelength calibration is made?

A: The following text has been added to the Section 3.2.: "The relation between the actual wavelength (L) during the scan of an irradiance spectrum and the position (M1) of the micrometer turning the grating in the first monochromator is given by the equation

$$L = d(1) + d(2) M(1) + d(3) M(1)^2,$$

where d1, d2, and d3 are the so-called dispersion coefficients. The determination of these coefficients is an essential part of each annual maintenance. This work utilizes the emission lines of spectral discharge lamps, usually those of mercury and cadmium. The correct positioning of the grating is physically checked on every UV scan using the 296.7-nm line of an internal mercury lamp."

9. Page 1423, Line 15: Were any measurements performed at temperatures below 15 C? In Finland the outside temperature can be much lower and the temperature of the dome and to a large extent of the diffuser below can reach much lower temperature from the stabilization temperature of 8C.

A: Yes, the temperature inside the Brewer can fall below 8 C, but is kept positive. No measurements could be performed at temperatures below 15 C during the temperature characterization, as we couldn't manage to cool the Brewers any further. For temperatures below 15 C, the correction procedure assumes the temperature dependence to be linear (equation 2). As explained in Section 5.3. each scan is normalized to the reference temperature by computing IO(λ) on the basis of equation 2.

A: The following text was added to Section 3.3: "Unfortunately, the available equipment did not allow cooling the system to any lower temperatures."

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 1415, 2008.

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