Final Author comments

Authors' response to **Referee #1** comments on "Performance of the FMI cosine error correction method for the Brewer spectral UV measurements" by Kaisa Lakkala et al.

The authors thank the Referee for constructive comments and reply to all comments here below. The answer is structured as follow: (1) comments from Referee, (2) author's response, (3) author's changes in manuscript

(1) There are several grammar errors that could be easily corrected by a more careful reading of the document.

(2) The grammar of the manuscript has been checked.

(1) Specific Comments:

(1) 3, 2: The light scattered downwards by the diffuser is directed to the spectrometer by two prisms and not mirrors.

(2) The authors agree.
(3) The text has been changed to: "The light is directed from the diffuser towards the spectrometer using prisms."

(1) 3, 21: Differences in the slit functions among different instruments is mainly evident at the wings which are not easily seen in linear plots. I suggest plotting the slit functions of Figure 1 in logarithmic scale.

(2) The authors agree.
(3) The plot has been updated and logarithmic scale has been used in Figure 1.

(1) 4, 5: The reference spectroradiometer QASUME has a diffuser with a superior cosine response (very low cosine error) and this is one of the advantages of using this instrument in the current study. I suggest discussing in a couple of lines this feature of QASUME.
(2) The authors agree.
(3) The following sentences have been added to the manuscript:
"The global entrance optic of QASUME has a shaped Teflon diffuser with an angular response very close to the desired cosine response. The global irradiance measurements of QASUME are not corrected for the remaining cosine error, resulting in an average uncertainty of 1.2% in clear sky situations (Hülsen et al., 2016)."

(1) 6, 22: Cglob is also a function of θ, φ and λ, so it should be also mentioned.
(2) The authors agree.
(3) The following has been added to the manuscript:

“The amount of this correction factor depends on the distribution of sky radiance and is a function of solar zenith angle (θ), azimuth angle (φ) and wavelength (λ). “
In addition the equation 1 has been updated.

(1) 7, 7-8: The ratio F’dir/Fdir is the angular response (as it is correctly mentioned later in the text) and not the cosine error of direct component. Similarly, the ratio for the diffuse irradiance F’diff/Fdiff should be the cosine response of the diffuse component and not the cosine error.
(2) The authors agree.
(3) The text has been changed to
Page 7, line 7 “ 1) ….,i.e., angular response of the spectroradiometer”
line 8 “2) ….,i.e., cosine response of the diffuse component”

(1) 7, 15: Please mention that the integration is performed for the upper hemisphere, so the integral is over 2π.
(2) The authors agree.
(3) The text, page 7 line 16 has been changed to “, where the integration is performed for the upper hemisphere.”

(1) 7, 18-19: In this case, L is not constant but a function of wavelength only, so it should be L(λ), also in eq. (6).
(2) The authors agree.
(3) The text has been updated and is now:” as the exact distribution of sky radiance is not known during the measurements, isotropic diffuse radiation is assumed and L(θ, φ, λ)) becomes a function of wavelength L(λ).”
The equation 6 has been corrected.

(1) 8, 5-11: The assumption made in step (1), that all radiation is diffuse, results in an error in the calculated cosine correction factor. How this error is handled? If it is not taken into account, it should be at least quantified, using model simulations and added to the overall uncertainty.
(2) The error due to the assumption is not taken into account in the calculation of the correction factor. We made model calculations for conditions corresponding to measurements of the Huelva 2015 campaign. Under those conditions, the biggest error is made for mid days (SZA 15°). For clear skies, there is no problem, as the Irradiance is more than in the lookup table and cloud optical depth is set to zero. We calculated that the assumption made in step 1 that all radiation is diffuse leads to an overestimation of the global irradiance of up to 5% for SZA less than 20 degrees and cloudless skies. This has an impact on the calculated cloud optical depth and on the model retrieved direct to diffuse ratio. For cloudless conditions and for cloud optical depths >= 2 the effect on the cosine correction is in the order of 0 to 1.2% for all solar zenith angles and all Brewers. In the case of thin cirrus clouds (e.g. cloud optical depth =1) the relative error is 0 to 1.5%, where 1.5% is the under correction for the Brewer with the worse cosine response for SZA 15 º and for 320 nm. Results for the Brewers with the best cosine response presented in this study are in the order of 0-1% for the same conditions.

(3) The following text has been added to the Chapter Discussion: “Another error source was the first step of the correction procedure in which the irradiance was corrected assuming all radiation is diffuse. The assumption leads to an overestimation of the global irradiance of up to 5% for sza less than 20 degrees and cloudless skies. This has an impact on the calculated cloud optical depth and on the model

retrieved direct to diffuse ratio. For cloudless conditions and for cloud optical depths >= 2 the effect on the cosine correction is in the order of 0 to 1.2% for all solar zenith angles and all Brewers. In the case of thin cirrus clouds (e.g. cloud optical depth =1) the relative error is 0 to 1.5%, where 1.5% is the under correction for the Brewer with the worse cosine response for SZA 15 º and for 320 nm. Results for the Brewers with the best cosine response presented in this study are in the order of 0-1% for the same conditions. This under correction compensated completely or partially to the overcorrection of the same magnitude and under the same conditions (thin clouds, low szas) due to the bias between model calculations and measurements, discussed above. However, the study showed that possibility to see thin clouds, i.e. cirrus with cloud optical depth less than 1 (Giannakaki et al., 2007) was challenging."

(1) 8, 25-26: Up to this point irradiance was denoted by F. This should be kept consistent for the entire manuscript and not changed to I, as is done for eq. (11). The same stands for wavelength, which should continue denoted by the Greek λ, instead of l. (also in line 31)
(2) The authors agree.
(3) The text has been corrected following the comment of the Referee.

(1) 12, 22: Please avoid mixing fractions with percentages when discussion the cosine correction factors. Here you use 14% instead of 1.14 and 20% instead of 1.2.
(2) The authors agree.
(3) The percentages have been changed to fractions, when discussing the cosine correction factors.

(1) 15, Figure 7: Please increase the font size in figure labels and titles because it is very hard to read in its present format. Please do the same for Figures 8 and 9.
(2,3) The Figures 7-9 have been replotted using bigger fonts. Please not that to Figure 8, we added 2 plots of corresponding to results calculated using non cosine corrected measurements.

(1) 18, 6: Please revise to: "The mean differences between the Brewers and . . ..", to make sure that the reader realizes that the quoted 6% difference refers to the mean value.
(2) The authors agree.
(3) The text has been modified following the comment of the Referee and is now: "The mean differences between the Brewers and the QASUME were less than 6% for both Brewers, #037 and #107, depending on the wavelengths.

(1) It would be interesting to provide an estimate of the range of differences between the Brewer and QASUME encountered during the audits.
(2) Most of the measurements spectra (λ>310 nm for Brewer #037 and λ>305 nm for Brewer#107) were within ±2.5% from means showed in Fig. 19.
(3) The following sentence has been added to the text: "Most of the spectra (2σ) were within ±2.5% from the mean difference showed in Figure 19."

(1) Technical comments:

(1) 7, 16: replace L(θ) with L(θ, φ, λ)).
(2,3) replaced

(1) 8, 31: I would suggest using "smoothed" instead of "summarized".
(2,3) replaced

(1) 12, 16: Please replace “impact” with “contribution”
(2,3) replaced