Response to Anonymous Reviewer #2

Authors' response to Reviewer #2 comments on "Evaluation of the uncertainty of the spectral UV irradiance measured by double- and single-monochromator Brewer spectroradiometers".

The answer is structured as follows: (1) comments from Reviewer #2, (2) authors' response and (3) authors' change in the manuscript.

(1) General comments:

(1) The manuscript describes the evaluation of uncertainties of spectral UV irradiance measured by two types of Brewer spectroradiometers. The evaluation is done using measurements from an intercomparison campaign. I think the study and the results are very important for the scientific community, as they are among the first to use the MCM technique to account for the propagation of uncertainties of Brewers. The sensitivity test is used to distinguish the impact of each uncertainty component, which is also a very interesting result and can help the scientific community to improve the quality of measurements.

(2) The authors thank the Reviewer for their careful and constructive examination of the manuscript and reply to all their comments below.

(1) However, I think some issues need to be clarified before the manuscript can be published: There are already WMO-GAW guidelines for quality control (QC) and quality assurance (QA) of UV measurements, which are WMO-GAW Reports No. 146 (Webb et al., 2003, Quality assurance in monitoring Solar UV radiation: the state of the art) and No. 126 (Webb et al., 1998, Guidelines for site quality control of UV monitoring). I think you should discuss more in the Introduction how your study reflects the guidelines of these reports and refer to the "deductive" and "inductive" methods for QA introduced in Webb et al., 2003. You should also refer more closely to Webb et al., 1998. In addition, I think you should consider showing and discussing your uncertainty estimate and the results of the intercomparison campaign. You have the ideal setup of having the QASUME intercomparison results from the El Arenosillo campaign. Thus, you could compare the results of your "deductive" method with the results of the "inductive" method.

(2) The results of the intercomparison campaign (UV index, wavelength shift, daily global irradiance ratio, and its daily variation) are published in the report elaborated by PMOD/WRC (Hülsen, 2023). Therefore, it would be redundant to include them in this study. Nevertheless, the authors agree that it is interesting to include the uncertainty evaluation in the comparison to the QASUME. As a result, an uncertainty has been derived for the Brewer/QASUME ratio by combining the irradiance uncertainty of the QASUME (Hülsen et al., 2016) and each of the Brewers studied. Moreover, references to WMO-GAW reports No.146 and No. 126 have been added throughout the manuscript (especially in the introduction and methodology sections).

(3) Information regarding the QA methods proposed by Webb et al. (2003) has been added in the introduction section as: "On the other hand, QA can be performed using two methods (Webb et al., 2003). In the first one (inductive), the instrument's performance is assessed through intercomparison campaigns. As for the second (deductive) method, the user deduces the instrument's quality through a meticulous description of the calibration process as well as the instrumental characteristics, such as its linearity and angular response. For QA purposes, the general principles established by Webb et al. (1998) should be followed, expanded, and refined, so the user can report reliable uncertainties for any measurement, not limiting the analysis for a typical measurement at the station (Webb et al., 2003)". Moreover, the QA used in the RBCC-E

campaign has been described to reflect the guidelines of Webb et al. (2003). In this way, the following information has been added in line 60: “The QA performed for the instruments used in this work corresponds to the inductive method described by Webb et al., (2003). It is carried out during the campaigns performed by the Regional Brewer Calibration Center–Europe (RBCC-E) where Brewer spectrophotometers are compared to the European reference spectroradiometer, the QASUME unit (e.g. Gröbner et al., 2010; Lakkala et al., 2008). These intercomparison campaigns meet the main requirements laid out by Webb et al. (2003), i.e. transparency and objective comparison algorithms (see the campaign reports at the PMOD/WRC website, https://www.pmodwrc.ch/en/world-radiation-center-2/wcc-uv/qasume-site-audits/, the report of the 18th intercomparison campaign, Hülsen, 2023, and an overview of the EuBrewNet’s algorithms, López-Solano, 2024)”.

As for the QC guidelines, in line 82 (introduction), a comment has been added to reflect the work of Webb et al. (1998): “All the necessary uncertainty sources considered by Webb et al. (1998) have been included in the uncertainty evaluation presented in this work, plus some highly recommended and additional sources (such as stray light, alignment, or wavelength accuracy)”. Furthermore, this study has also been mentioned in the methodology section to reflect their findings regarding radiometric stability and the current of the reference lamp. In this way, in line 221 the following information has been added: “Based on the findings of Webb et al. (1994), the standard practice is to assume that a 1 % change in the current of the reference lamp leads to a 10 % change in the spectral irradiance measured by the instrument (e.g. Bernhard and Seckmeyer, 1999; Webb et al., 1998)”. Moreover, the results obtained in former Section 4.2.5 (distance alignment) have been compared with the ones determined by Webb et al. (1998): “According to Webb et al. (1998), if the nominal distance is d and its uncertainty u_{d}, the percentage uncertainty can be calculated using the inverse square law ($1/r^2$, where r is the distance between lamp and instrument) as $[(\mathrm{d} + u_{\mathrm{d}})^2 - \mathrm{d}^2] * 100 / \mathrm{d}^2$. Therefore, the previous results agree with the formula proposed by Webb et al. (1998)”. Additionally, the calibration guidelines established by Webb et al. (1998) have also been mentioned in the sensitivity analysis in line 473 as: “This agrees with the recommendations of Webb et al. (1998). They suggest calibrating the instruments using three reference lamps”.

Finally, a section regarding the uncertainty ratio between the QASUME and the instruments has been added to the Results section. A new figure and table have been added to the manuscript as follows:

“The corrections applied to the measured irradiance (described in Section 3.2) are recommended by numerous studies to improve the quality of the measurements (e.g. Fountoulakis et al., 2016b; Garane et al., 2006; Kerr, 2010; Lakkala et al., 2008, 2018). This was also verified during the 18th RBCC-E campaign, as the results show that including the cosine correction improves considerably the comparison to the QASUME (Hülsen, 2023). Although the campaign report shows the ratio of each participating Brewer to the QASUME (see Hülsen (2023)), it is interesting to represent the ratio of all studied Brewers together. In this way, Fig. 4 displays the global irradiance ratio to the QASUME obtained from dividing the irradiances shown in Fig. 1 to the irradiance recorded by the QASUME unit.

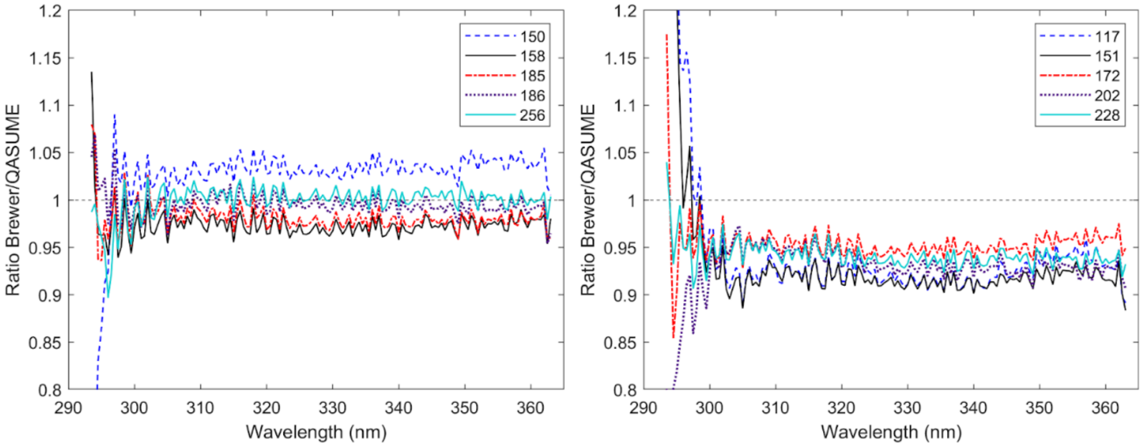

Figure 4. Global irradiance ratio to the QASUME recorded on 13 September at 14:00 UTC. (a) First group (double Brewers with cosine correction). (b) Second group (two single and three double Brewers with no cosine correction implemented).

Figure 4 shows the effectiveness of the cosine correction, since Brewers with such correction implemented (Fig. 4a) report irradiances more similar to the one measured by the QASUME. Nevertheless, the agreement between all Brewer spectrophotometers and the QASUME is within 10 % for wavelengths above 310 nm.

Furthermore, the irradiance uncertainty found for each Brewer in the previous section can be used to derive the uncertainty of their ratio to the QASUME. Table 3 summarises the combined standard uncertainty of the average Brewer/QASUME ratio measured on 13 September at three different wavelengths. These uncertainties were computed by combining the irradiance uncertainty of each Brewer and the one from the QASUME, provided by Hülsen et al. (2016).

Table 3. Number of simultaneous scans, mean ratio to the QASUME and its combined standard uncertainty (both absolute and relative) determined between 310 and 360 nm on 13 September.

Brewer ID	N	Ratio to the QASUME (310–360 nm)		
		Mean value	Combined standard uncertainty	Relative standard uncertainty (%)
#117	19	0.927	0.034	3.7
#150	20	1.035	0.035	3.4
#151	24	0.914	0.033	3.6
#158	17	0.972	0.036	3.7
#172	19	0.947	0.033	3.5
#185	18	0.978	0.030	3.1
#186	15	1.003	0.043	4.3
#202	19	0.928	0.033	3.6
#228	19	0.937	0.033	3.5
#256	19	1.003	0.037	3.7

Table 3 shows that only those Brewer spectrophotometers with a cosine correction implemented (#150, #158, #185, #186, and #256) include the ideal value of the ratio (unity) within their uncertainty interval. The remaining Brewers underestimate the UV irradiance and deviate from unity. This is likely caused by the cosine and temperature errors of the instruments, which couldn't be corrected (there was no available information regarding their characterisation). Therefore, to improve the performance of these uncorrected Brewers these two sources must be characterised and corrected".

(1) Another concern is the uncertainty associated with cosine correction. I don't understand why you get such higher uncertainties in measurements that are cosine corrected compared to those

that are not. Shouldn't it be the other way around? If the cosine correction is in the range of 5 to 10%, then the measurements missing that correction should be at least that far off and have higher uncertainties? And, as mentioned in the specific comments, please include the information of which part of the cosine correction (angular response characterization, dir/diff ratio determination...?) has the largest uncertainty. Maybe I missed something: please explain this more clearly.

(2) It is important to differentiate between an error and the uncertainty associated with its correction. If the spectral irradiance measured is not corrected for the instrument's cosine error, it will have a larger error (see the Figure 4 in the response to the previous comment). In fact, the comparison campaign showed that correcting the Brewer cosine error improved the global irradiance ratio to the QASUME (Hülsen, 2023). On the other hand, the calculation of the cosine correction factor has an uncertainty, which needs to be taken into account in the uncertainty analysis. Nevertheless, this uncertainty can only be determined if the cosine error is characterised. That is why the Brewers with no cosine correction have smaller uncertainties, because this uncertainty source could not be considered in their evaluation. As a result, the uncertainty evaluation of these Brewers is limited, as the cosine error is not included in the analysis.

Regarding the contributions to the cosine correction (angular characterisation, direct to global ratio, etc.), it wasn't considered in the original manuscript. To analyse the influence of every part of the cosine correction, the sensitivity analysis has been broadened to evaluate the uncertainty produced by these factors on their own.

(3) To clarify this issue, the definition of uncertainty and error used has been included in the methodology section as follows: "In the following, the term "error" will denote the imperfections in a measurement result, while the term "uncertainty" will be used to reflect the existing doubt regarding the value of the measured spectral UV irradiance". Furthermore, the limitation of the uncertainty evaluation of Brewers with no cosine correction has been addressed in the results section (line 363) by adding the following information "The uncertainty evaluation of the Brewer spectrophotometers in this second group is limited as it is missing one of the key uncertainty sources in solar radiometry, cosine correction. As a result, the uncertainties determined are likely an underestimation. Nevertheless, these estimations represent the uncertainty of the spectral irradiance reported by most of the participating Brewer spectrophotometers". Finally, the contributions of the cosine correction have been added in former Section 4.2.10 (sensitivity analysis of cosine correction) as "The uncertainties shown in Fig. 7 are mostly produced by the uncertainties of the of the diffuse (f_{d}) and direct (f_{r}) cosine errors. In fact, these factors account for more than 98 % of the total irradiance uncertainty caused by cosine correction. As for the direct to global irradiance ratio, its impact on the uncertainty budget is negligible as only cloud-free conditions have been considered in the analysis. This would likely change if overcast or mixed sky conditions were to be included in the uncertainty evaluation. Therefore, under cloud-free conditions, the main sources of uncertainty in the cosine correction are the errors committed in the angular characterisation and in the assumption of isotropic sky radiance to calculate the diffuse cosine error".

(1) Then comes the transfer of the irradiance scale from an accredited lab to the instrument itself (which is basically the spectral response determination). There are uncertainties in the transfer, which you've described well, but it's unclear how you've accounted for them in your analysis. I wonder if when you do the lamp calibration (transfer of the irradiance scale), you also have to

take into account the uncertainties in the Brewer irradiance measurements, don't you (in addition to the distance from the lamp: levelling, dead time, noise, etc....)?

(2) During the calibration, the Brewer spectroradiometer records the signal measured under the lamp four times. As the reviewer states, this signal is affected by several uncertainty sources such as dead time, noise, dark signal, and stray light (especially if the Brewer is a single-monochromator spectrometer). When determining the response of the instrument, the corrected signal (for dead time, dark signal, etc.) is used. This is not mentioned in Section 3.1.2, as it is focused on the sources of uncertainty produced during the calibration (distance alignment, uncertainty of the reference lamp, etc.), while the signal uncertainty sources are described earlier, in Section 3.1.1.

(3) To clarify this issue, the following information has been added to Section 3.1.2 at line 219: "Then, the signal under the lamp is recorded several times and corrected for dark counts, dead time, and stray light (see Section 3.1.1.). The responsivity of the instrument is derived by dividing the corrected signal by the irradiance of the reference lamp. However, this responsivity is also affected by other sources of uncertainty produced during the radiometric calibration such as the distance adjustment between the lamp and the diffuser, the radiometric stability, and the uncertainty of the spectral irradiance emitted by the reference lamp".

(1) And about stability, changes in response over time: I think you should discuss this as an additional source of uncertainty for long-term monitoring. Not for newly calibrated instruments. And add a time specification. That you assume for example a 1-3% drift in response per year. The drift is really instrument-dependent and depends on modifications/maintenance/upgrades of each instrument. As stated in Webb et al. 1998, "Each time the calibration is checked or changed, the data gathered between the two calibration times has an uncertainty which depends on the difference between the two calibrations, and it is these uncertainties which should be used for this calculation".

(2) The term "drift" was used to describe the uncertainty of the radiometric stability. It was determined by calculating the standard deviation of the differences between consecutive calibrations, as recommended by Bernhard and Seckmeyer (1999). Webb et al. (1998) recommend a similar approach. They characterise the stability by deriving the root mean square (rms) uncertainty over a significant period of time. Therefore, short- and long-term radiometric stability can be characterised as long as Brewer spectroradiometers are calibrated frequently enough to ensure a reliable standard deviation (or rms uncertainty). However, most of the Brewers used in this study are usually calibrated once a year (or even once every two years). Consequently, no short-term monitoring uncertainty could be derived and the radiometric stability was determined using all available calibration records. Moreover, this uncertainty depends on the instrument as well as on its modifications and maintenance. This further complicates the determination of the radiometric stability for each Brewer as most of them have been operating for several years and have undergone many modifications throughout this period. Therefore, to include this uncertainty source in the uncertainty evaluation, a 3 % uncertainty was assumed for most Brewers, in agreement with the findings of Garane et al. (2006) and Lakkala et al. (2008).

On the other hand, the newly calibrated instrument used in this study had been calibrated five times between its deployment and the RBCC-E campaign (1.5 years). During its first year in operation, the response of this Brewer decreased significantly, showing a deviation larger than 10 %. Then, it gradually stabilised. Therefore, assuming a 3 % uncertainty for this Brewer as well as the older ones, might not be such a large overestimation of its stability.

(3) To avoid confusion, the term "drift" has been replaced with "uncertainty". Furthermore, lines 236–238 have been modified to add the previous information as: "To characterise the radiometric stability of every Brewer, several studies recommend studying the difference between consecutive calibration factors over a significant period (e.g. a year) (Bernhard and Seckmeyer, 1999; Webb et al., 1998). These methods require that the instrument is calibrated frequently to derive reliable statistics". Furthermore, in line 244 a clarification regarding the assumption of a 3 % uncertainty for the newly calibrated Brewer has been added: "It should be noted that this value, derived from long-term monitoring, might not be a large overestimation for the newly calibrated Brewer (#256), as this instrument showed large instabilities during its first year of operation".

(1) Specific comments:

(1) line 157: Please specify in which section you describe which of the three uncertainty sources. Check that you make clear in text what do you mean by the three different uncertainty sources.

(2, 3) The sections for each of the uncertainty sources have been added to the manuscript. Furthermore, at the beginning of each section, the uncertainty sources have been listed and then described in detail. Moreover, following the suggestion made by Reviewer #1, the following table summarising the uncertainty sources considered has also been added to the text.

Table 2. Summary of the uncertainty sources considered for each Brewer under study. Red squares (–) represent the uncertainty sources not included in the evaluation, while green squares (×) indicate those uncertainty sources considered.

Uncertainty sources considered	Brewer ID									
	#117	#150	#151	#158	#172	#185	#186	#202	#228	#256
Noise	×	×	×	×	×	×	×	×	×	×
Dark signal	×	×	×	×	×	×	×	×	×	×
Stray light	×	–	×	–	–	–	–	–	–	–
Dead time	×	×	×	×	×	×	×	×	×	×
Distance adjustment	×	×	×	×	×	×	×	×	×	×
Uncertainty of the reference lamp	×	×	×	×	×	×	×	×	×	×
Radiometric stability	×	×	×	×	×	×	×	×	×	×
Wavelength shift	×	×	×	×	×	×	×	×	×	×
Temperature correction	–	×	–	–	–	–	–	–	–	–
Cosine correction	–	×	–	×	–	×	×	–	–	×

(1) lines 168-169: "However, deriving the uncertainty of this method for the Brewers under study is difficult, as it would use the information from only five wavelengths (from 290 to 292 nm)." -> I don't see your point. Uncertainty related to this approach could also be determined, e.g., compared to the QASUME. I think this sentence should be rethought.

(2) As stated by the referee, the comparison against the QASUME can be used to derive an uncertainty. At first, this approach was discarded as it would also consider, besides the stray light effects, the temperature and the cosine error of the instrument (single Brewers are not corrected for these two error sources). Nevertheless, the effect of these two sources is expected to be small below 292 nm. As a result, the uncertainty determined in this way is not a huge overestimation of the uncertainty produced by stray light correction. Furthermore, since the stray light was estimated during the RBCC-E campaign using the five-wavelength method, the uncertainty should be estimated using the suggested approach (comparison to the QASUME) instead of the one proposed by Savastiouk et al. (2023).

(3) Following the comments made by Reviewers #2 and #3, the methodology of Savastiouk et al. (2023) has been replaced with the one performed in the 18th RBCC-E intercomparison campaign. Therefore, the description in lines 168–184 has been changed to "The uncertainty of this method was estimated by comparing the corrected irradiance to the QASUME from 290 to 292 nm. This estimation also includes the effects of temperature and cosine errors since the single Brewers under study are not corrected for these two sources of error. Nevertheless, since the effect of these two sources is expected to be small below 292 nm, the uncertainty determined might be only a slight overestimation. Furthermore, the standard deviation from the measurements of the five wavelengths (from 290 to 292 nm) was also derived and combined with the uncertainty obtained from the QASUME comparison".

(1) line 229: "Brewer #150, on the other hand, has an additional source of uncertainty since the position of its diffuser's reference plane needs to be determined as well (González et al., 2023)"-> I don't understand the sentence, as the previous sentence describes as distance 500+-0.6mm, which is less than the "standard" one of 500+-1mm explained earlier.

(2) The indicated phrase can be confusing as it is comparing uncertainty and precision errors. The ruler used to adjust the distance has a precision of 1 mm, which translates to an uncertainty of 0.58 mm according to the GUM (Guide to the expression of Uncertainty in Measurement). This guide recommends that If the only available information are the lower x_- and upper x_+ limits of a variable x, the uncertainty should be calculated as:

$$u^2(x) = (x_+ - x_-)^2/12\,.$$

In our case, the lower and upper limits are 1 mm, which results in an uncertainty of 0.58 mm, according to the previous equation. However, Brewer #150 has an additional source of uncertainty as a result of the experimental determination of its diffuser plane, 0.15 mm (González et al., 2023). Combining both uncertainties (0.6 mm and 0.15 mm) leads to an uncertainty of 0.59 mm, slightly larger. As a result, the irradiance uncertainty produced by the distance adjustment is slightly larger for Brewer #150 (0.24 %) than for the other instruments (0.23 %).

(3) The previous information has been added to the text as follows: "According to the GUM, this precision error translates in an uncertainty of 0.58 mm (BIPM et al., 2008a)". As for the uncertainty of Brewer #150, it has been described as "Brewer #150, on the other hand, has an additional source of uncertainty since the position of its diffuser's reference plane needs to be determined as well (González et al., 2023), resulting in an uncertainty of 0.59 mm".

(1) line 230:"Regarding the uncertainties of the irradiances of the reference lamps, there is no need to determine them since all lamps used during the campaign had been previously calibrated in different standard laboratories." -> I suggest skipping this sentence or rephrasing it.

(2, 3) Following the reviewer's comment, the phrase has been deleted from the text.

(1) line 255: Please add a short sentence describing the idea of SHICRIVM wavelength shift detection.

(2, 3) Noted. The following information regarding SHICrivm has been added to the manuscript: "This software estimates the wavelength shift by comparing the structure of the spectrum measured by the ground-based instrument with the extraterrestrial spectrum. The latter is simulated using the SUSIM extraterrestrial spectrum (Slaper et al., 1995)".

(1) line 260: "Furthermore, there is a second contribution to the wavelength misalignment, the precision of the micrometre, i.e. the system setting the wavelengths measured by a Brewer spectroradiometer". -> yes, it contributes to the wavelength misalignment, but the impact is seen in the wavelength shift recorded by SHICRIVM. Please rephrase.

(2, 3) Following the reviewer's comment, line 260 has been rewritten as "the shifts determined by SHICrivm include the wavelength misalignment produced by the precision of the micrometre, i.e. the system setting the wavelengths measured by a Brewer spectrophotometer. This precision is approximately 8 pm (Gröbner et al., 1998)".

(1) Figure 6: I think you should also include the uncertainty related to stray light, even if the double monochromators are known to have less stray light than single ones.

(2) To our knowledge, no study of stray light in double Brewer exists. Savastiouk et al. (2020) tried to estimate it by looking at the sulphur dioxide retrievals at large ozone slant column densities. Their test suggests that the correction factor for stray light in MkIII Brewers is an order of magnitude lower than for single Brewers. Therefore, the level of stray light is very low and its contribution is likely lower than dark counts or noise at short wavelengths.

(1) Section 3.2 UV model -> Is it really a model? Couldn't the Chapter be called "UV processing algorithm"?

(2, 3) Following the reviewer's suggestion, the title of the chapter has been changed to "UV processing algorithm".

(1) line 465: What about the wavelength dependency of the distance-related uncertainty? The irradiance of the calibration lamp is wavelength-dependent, isn't it? So the effect of the distance measurement error is wavelength-dependent, too?

(2) The distance alignment and the irradiance of the reference lamp are two different uncertainty sources. In Line 465 only the effect of the distance adjustment is shown and no wavelength dependency is observed. On the other hand, if the uncertainty of the reference lamp is the only error source considered, it does lead to wavelength-dependent irradiance uncertainties, as described in Section 4.2.6. The distance alignment does not produce wavelength-dependent uncertainties as the distance between the lamp and the diffuser is sufficiently large and the lamp can be regarded as a point source. As a result, the UV irradiance decreases with distance following the inverse square law:

$$E'(\lambda) = E(\lambda)/\, d^2.$$

(3) The previous information has been added to the text as follows: "Furthermore, the uncertainty produced by the distance adjustment has no spectral dependency. Since the reference lamp can be regarded as a point source, the UV irradiance follows the inverse square. Therefore, a change in distance has the same effect on all wavelengths measured".

(1) Line 475 and 4.2.7. Radiometric stability: I think you should report the uncertainties at the moment of a fresh calibration. If I understand right, you assume some drift in the spectral responsivity of the Brewer, which is based on measurements over several years. The instruments drift at a different speed, and the spectral response is strongly dependent on instrumental modifications.

(2) To derive the uncertainty of the radiometric stability, it is recommended to study the difference between consecutive calibrations over a significant period (e.g. a year) (Webb et al., 1998; Bernhard and Seckmeyer, 1999). Although the Brewers are calibrated during the intercomparison campaign, this calibration file alone is not enough to derive a reliable uncertainty estimate. As a result, we checked the calibration records of all Brewers used in this study. Nevertheless, since the instruments are calibrated once every 1–2 years and they have undergone several modifications, it was impossible to calculate a reliable standard deviation or rms uncertainty, as recommended by Bernhard and Seckmeyer (1999) and Webb et al. (1998), respectively. Therefore, to include this source in the uncertainty analysis, an uncertainty was estimated from the literature (a 3 % uncertainty). To our knowledge, there are no studies that have reported radiometric uncertainties at the moment of a fresh calibration for Brewer spectrophotometers. In the sensitivity analysis, it was observed that radiometric stability caused irradiance uncertainties of 3 % (no other uncertainty sources were considered for this analysis). This was expected as the UV irradiance is inversely proportional to the responsivity (as shown in Eq. (8)), and a 3 % uncertainty was assumed for the latter.

(3) To clarify this issue, the methodology and the results sections have been modified. In this way, the calculation of the radiometric uncertainty in the methodology section has been written in greater detail, indicating the data period used and highlighting that the instrument modifications greatly affect the responsivity of the instrument. Besides the information shown in the response to the general comments, the following information has been added to the text: "For Brewer #150, the radiometric uncertainty was derived using the yearly calibration files from 2005 to 2023, while for Brewer #185 the uncertainty was calculated using the monthly calibration files recorded from 2021 to 2024. As mentioned earlier, no data from prior years could be used as the entrance optics of Brewers #150 and #185 were replaced in 2005 and 2021, respectively". On the other hand, lines 476–477 from Section 4.2.7 have been rewritten for greater clarity as: "For most Brewers, this uncertainty source leads to irradiance uncertainties of 3 %. This was expected, since the UV irradiance is inversely proportional to the responsivity (as shown in Eq. (8)), and a 3 % uncertainty in the responsivity was assumed for most Brewers, in agreement with the findings of Garane et al. (2006) and Lakkala et al. (2008) (see Section 3.1.2.). On the other hand, Brewers #150 and #185 had their instability characterised using their calibration records and reported irradiance uncertainties of up to 3.6 % and 2.5 %, respectively".

(1) Section 4.2.10 Cosine correction: What is the reason for the high uncertainty related to cosine correction? Is it due to the uncertainty in angular response characterization or the DIR/DIFF ratio or something else? Please include this information in the text.

(2) It is mostly produced by the errors committed in the angular response characterisation and the assumption that the sky radiance is isotropic (calculation of the diffuse cosine error). The DIR/GLO ratio has no impact in the uncertainty budget since only cloud-free conditions have been considered in this study. If cloudy conditions were to be included, this ratio would likely become a significant source of uncertainty.

(3) The previous information has been added to section 4.2.10 as follows: "The uncertainties shown in Fig. 7 are mostly produced by the uncertainties of the diffuse (fd) and direct (fr) cosine errors. In fact, these factors account for more than 98 % of the total irradiance uncertainty caused by cosine correction. As for the direct to global irradiance ratio, its impact on the uncertainty budget is negligible as only cloud-free conditions have been considered in the analysis. This would likely change if overcast or mixed sky conditions were to be included in the uncertainty

evaluation. Therefore, under cloud-free conditions, the main sources of uncertainty in the cosine correction are the errors committed in the angular characterisation and in the assumption of isotropic sky radiance to calculate the diffuse cosine error".

(1) line 520: But the Brewer ozone processing is not based on UV measurements you describe in this study. I don't see the point of this paragraph.

(2, 3) Following the reviewers' comments, the indicated paragraph has been deleted from the manuscript.

(1) line 534: Do you mean combined uncertainty?

(2, 3) Yes. Nevertheless, following the comment of Reviewer #3, this section has been summarised and the indicated line has been removed from the text.

(1) line 573: For global radiation?

(2, 3) Yes, for global UV radiation. The previous information has been added to the manuscript as follows: "More advanced developments, such as QASUMEII, have further improved accuracy, with a combined uncertainty for global UV measurements of 1.01 % between 310 and 400 nm and 3.67 % at 300 nm".

(1) line 582: I refer to my earlier comment that, at least for the Brewer, the ozone is not calculated using the UV irradiances which you describe in this manuscript.

(2, 3) Following the comments made by Reviewer #1 and #2, the paragraph regarding tropospheric ozone (former lines 582–586) has been removed from the manuscript.

(1) line 585: I don't see the connection between your work and the last sentence of this paragraph.

(2, 3) We agree with Reviewers #1 and #2 that tropospheric ozone is not calculated from Brewer UV measurements and that former lines 582–586 should be removed.