Response to Anonymous Referee #1

Authors' response to Referee #1 comments on "Comparison of global UV irradiance measurements between a BTS CCD-array and a Brewer spectroradiometers".

The authors thank the Referee for the careful and constructive examination of the manuscript and reply to all comments below. The answer is structured as follows: the comments from Referee #1 are marked in red and the authors' response and changes in manuscript are written in black.

This is a very interesting paper on the performance of the BTS CCD-array spectroradiometer, compared with a Brewer spectroradiometer.

My major comments are related:

a. With the explenation of the differences / changes of this ratio with wavelength (mainly)

b. With a conclusion of the measurement uncertainty and accuracy of the Brewer instrument and through this comparison reporting on the uncertainty of the new BTS CCD array

Speciffic comments

Line 39 maybe also include an OMI related validation publication: Arola et al., A new approach to correct for absorbing aerosols in OMI UV DOI: 10.1029/2009GL041137

The reference (Arola et al., 2009) has been added to the manuscript.

Line 62 Probably a reference to the Qasume: Quality assurance of spectral ultraviolet measurements in Europe through the development of a transportable unit (QASUME) DOI: 10.1117/12.468641

The reference (Bais et al., 2003) has been added to the manuscript.

Line 115 probably a table mentioning the dates, names, ozone, temperature , cloud comments of the 3 periods could be useful

The following table has been added in the section "Methodology" to summarize the dates, names, ozone, temperature and number of cloudless spectra of each campaign.

Campaign	Date	Number of spectra	Temperature (°C)		Ozone (DU)	
			Range	Mean	Range	Mean
Spring 2020	26/05–16/06	350	12–28	20	290–333	313
Summer 2021	05/07–15/07	219	16–33	23	284–324	301
Autumn 2021	10/11–25/11	142	5–23	13	280–325	303

Line 137 : why have you put the limits for 70 degrees and the cloudless sky ?

The study is restricted to 70º in order to avoid possible issues related to the cosine error, whose contribution can be significant at large solar zenith angles.

Additionally, only cloudless sky conditions have been considered in order to obtain a reliable comparison BTS - Brewer. The Brewer takes 4.5 minutes to measure one spectrum and, therefore, stable conditions are required to obtain a scan that can be compared to the almost instantaneous spectrum measured by the BTS. These required stable conditions are only guaranteed under cloudless conditions.

The previous information has been added to the methodology section as follows:

"Only cloud-free conditions have been considered in order to reliably compare the almost instantaneous spectrum measured by the BTS to the slow-scanned spectrum of the Brewer. Furthermore, the comparison has also been limited to SZAs lower than 70° to avoid possible issues related to the cosine error, whose contribution can be significant at large SZAs."

Line 145: Kouremeti

The reference has been corrected so the author's name was properly written.

Table 1: Variability: is this 1 sigma ?

No, the variability was obtained calculating the difference between the 5th and 95th percentile of all scans. This information has been added to the manuscript, for greater clarity.

Section 4.1:

-Is there any idea for the low but obvious drop of the ratio going from 305 to the end of the spectrum (e.g. fig. 3) ?

Figure 1 shows that the spectral ratio behaves differently depending on the wavelength. In this way, it increases rapidly below 300 nm, while it decreases steadily for longer wavelengths. Consequently, as we move from 305 nm to the end of the spectrum the spectral ratio falls gradually. These differences may be partly due to stray light, calibration procedures and cosine response. This fact has been discussed in the text as follows:

"As expected, the spectral ratio slightly decreases as wavelength increases, displaying the same behavior shown in Figure 1. These differences may be partly due to remaining stray light, cosine response and the different calibration sources for the two instruments."

-Can you comment on the signal to noise ratio for low wavelengths and high solar zenith angles ?

Signal-to-noise ratio decreases as solar zenith angle rises, since the incident radiation traverses a larger path through the atmosphere, increasing its absorption and scattering. This effect is more pronounced for short wavelengths as the signal measured in this wavelength interval is especially low, according to the spectral distribution of the solar spectrum. This information has been added to the text as follows:

“Signal-to-noise ratio is especially low for short wavelengths according to the spectral distribution of the solar spectrum. This decrease is particularly strong for high SZAs since the radiation is attenuated as it traverses a larger path through the atmosphere”.

-Is the curvature of the ratios in figure 2 due to the instrument calibration principles/sources ? or is there any other reason involved?

The curvature could be due to several factors:

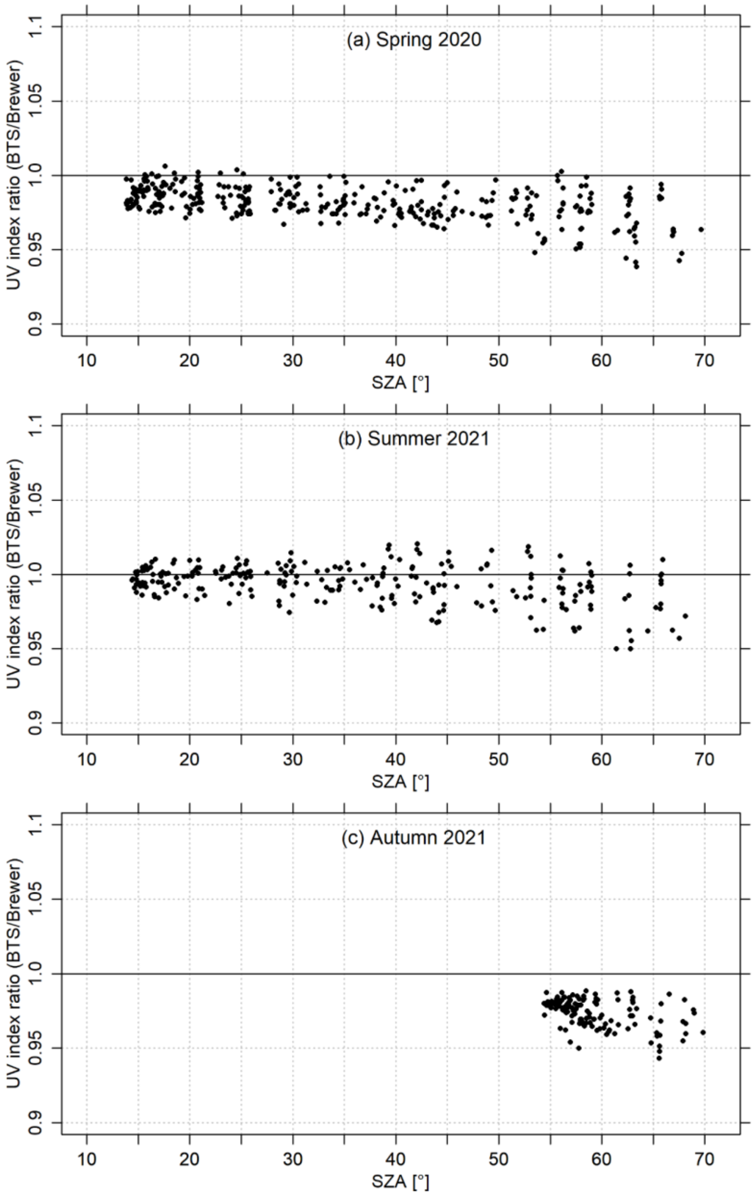
1. Calibration sources. The calibration procedure for the Brewer and the BTS are quite different. Brewer #150 is usually calibrated by comparison with the QASUME and 1000 W lamps, while the BTS is calibrated using 250W and 30 W lamps. Furthermore, the setup used to calibrate both instruments also differ, leading to distinct uncertainty sources.
2. Cosine error. Even if the two instruments have improved diffusers the contribution of their angular error cannot be completely neglected.
3. Stray light. Although the BTS has a filter wheel to automatically remove stray light, its spectra are still affected by it, especially at low wavelengths.
4. Ratio’s sensitivity. The ratio is very sensitive to small variations, further contributing to the curvature.

All the previous points have been included in the manuscript as follows:

“The curvature observed in Figure 2 could be produced due to several factors such as calibration sources, cosine error, stray light or the ratio’s sensitivity to small variations.

Figure 4c: ratios seem slightly lower than the other periods.

Figure 4 has been modified after incorporating the suggestions made by the Anonymous Referee #2. Now, the three charts have the same x-scale and it can be seen that the UV index ratios show the same behavior in the three campaigns. Therefore, ratios may have seemed slightly lower in Figure 4c because of the former x-scale used.



Could you provide an estimation of the Brewer accuracy and uncertainty on deriving UV Index and based on this work to report also on the accuracy and uncertainty of the new instrument ?

An uncertainty estimation of the CCD-array instrument would be very useful for this work.

Following the recommendation of the reviewer, we have attempted to estimate the BTS' uncertainty on deriving the UV Index. Assuming uncorrelated error sources as well as linear effects on the irradiance values, the BTS' uncertainty, regarding the UV index, is ±10%.

Nevertheless, this estimation is likely inaccurate since the irradiance measured by a spectrometer is obtained from prior information acquired during the absolute calibration. As a result, errors produced in these previous procedures affect the irradiance data in a nonlinear manner. Furthermore, when there are uncertainty contributions that have a similar effect on the whole spectral measurement, correlations with respect to wavelength may arise.

Therefore, the uncertainty analysis must take into consideration both the nonlinear effects and the possible correlations in the spectral data.

Additionally, to provide a reliable uncertainty estimation a very careful quantification of error sources is needed.

For the Brewer, the uncertainty sources are well-known but hard to assess: radiometric calibration, stray light, linearity, angular response, temperature dependence, wavelength shift and radiometric stability. Thus, the Brewer's uncertainty, regarding spectral UV irradiance, is yet to be accurately determined, even though the Brewers have supported the scientific community for more than 30 years. In fact, as far as we are aware, only the study of Garane et al. (2006) has attempted to estimate it. They, found that the expanded uncertainty of their double Brewer was $\pm$10% following the methodology set by Bernhard and Seckmeyer (1999).

As for the BTS, its global spectral irradiance uncertainty has not been studied either. Currently, only its direct irradiance uncertainty has been assessed. Vaskuri et al. (2018), using a Monte Carlo approach, found it to be $\pm$2.5%. However, this value does not completely quantify the BTS uncertainty, since it does not include the angular response, which is one of the most important uncertainty sources. Therefore, reliably estimating the uncertainty of the BTS spectra is a very complex task which is far beyond the scope of this paper.