Protocol of the intercomparison at AEMET, Madrid, Spain on June 9 to 13, 2025 with the travelling reference spectroradiometer QASUME from PMOD/WRC

Report prepared by Gregor Hülsen

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Local operator: Ana Diaz, Jose María San Atanasio and Patricia Fernández de Cos

The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer AEM and the Brewer 186 operated by AEMET Madrid and the travel reference spectroradiometer QASUME. The measurement site is located at Madrid; Latitude 40.45 N, Longitude 3.72 W and altitude 692 m.a.s.l.
The horizon of the measurement site is free down to at least 85° solar zenith angle (SZA). Measurements between 5:00 UT and 20:00 UT have been analysed.

QASUME was installed on the measurement platform of AEMET-Madrid at noon of 9 June 2025. The spectroradiometer was installed next to the AEM spectroradiometers with the entrance optic of QASUME within 3 m to the other instruments. The spectroradiometer in use at AEMET is a Bentham DM300 double monochromator system (AEM) with an input optics UV-J1002 from CMS-Schreder. The Brewer 186 is a MKIII double monochromator. The intercomparison between QASUME and AEM lasted five days, from the afternoon of June 9 to the afternoon of June 13, 2025.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Three lamps (T61251, T68523 and T153061) were used to obtain an absolute spectral irradiance calibration traceable to the primary reference held at PMOD/WRC, which is traceable to PTB. The daily mean responsivity of the instrument based on these calibrations varied by less than 1 % during the 5 days of the intercomparison period. To account for the responsivity change, the responsivity was calculated for each day separately and used for that specific day.
The wavelength shifts relative to the QASUMEFTS (Gröbner et al., 2017) spectrum as retrieved from the MatSHIC analysis were between ±50 pm in the spectral range 290 to 400 nm.

Protocol:

The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 to 400 nm, every 0.25 nm, and 1.5 seconds between each wavelength increment.

DOY	Date	DAY	Weather	Comment (times are in UT)
160	09-Jun	Monday	Mostly Clear sky, but hazy (dust)	Installed at 9:00 14:12 Calibration T68523
161	10-Jun	Tuesday	Clear sky in the morning Solid dust layer in the afternoon	08:12 Calibration T68523 08:42 Calibration T153061
162	11-Jun	Wednesday	Mostly overcasted sky Rain, thunderstorm and Hail at 14:00	08:42 Calibration T153061 09:12 Calibration T61251
163	12-Jun	Thursday	Clear Sky	08:43 Calibration T153061
164	13-Jun	Friday	Mostly Clear Sky Some clouds in the early morning	16:12 Calibration T153061 16:30 End of Campaign

Results:

In total 110 (82) quality controlled synchronised simultaneous spectra from QASUME and AEM (Brewer 186), are available from the measurement period. Measurements between 5:00 and 19:30 UT have been analysed (SZA smaller than 90°).

Conclusions:

AEM:

1. The average spectral ratio between AEM and QASUME has a slight spectral trend from 0% to +2%.
2. The mean spectral ratio is around unity.
3. The temporal variation of the spectra between AEM and QASUME indicate a small cosine error during the clear sky day, with variations around 3% during the campaign.
4. The wavelength shifts of AEM with respect to a high-resolution reference spectrum are constant during the intercomparison. However, there is a large offset of more than 0.4 nm between 300 nm and 400 nm. The wavelength shift is increasing during the years.

Brewer 186:

1. The average spectral ratio between Brewer 186 and QASUME has a slight spectral trend from +2% to 0%.
2. The mean spectral ratio is around unity.
3. The very small variation of the spectra between Brewer 186 and QASUME indicate that the cosine correction is working fine.
4. The wavelength shifts of Brewer 186 with respect to a high-resolution reference spectrum are constant during the intercomparison with a negletiable variability of ±20 pm between 300 nm and 368 nm.

Comparison to previous QASUME site visits:

The long-term stability of AEM was assessed by comparing QASUME site visits performed since 2011. As seen in figure 1 the campaign average ratio of AEM to QASUME are similar within ±2 % for the years 2013-2023. In 2011 AEM overestimated solar UV irradiance by more than 10%. The measurements in 2025 are again in good agreement.

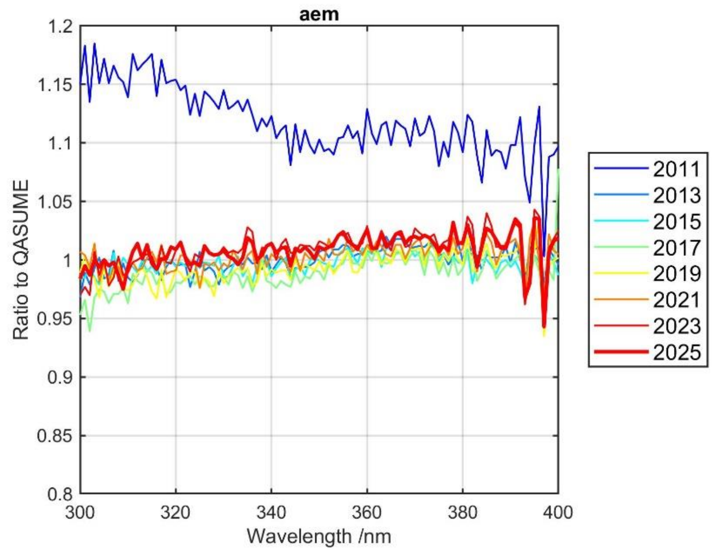


Figure 1: Solar spectral ratios of AEM to QASUME averaged over each QASUME site visit.

The long-term stability of Brewer 186 was assessed by comparing QASUME site visits performed since 2007. As seen in figure 2 the campaign average ratio of Brewer 186 to QASUME is varying between -10% and unity. This is mainly an effect of the use or neglection of the cosine correction.

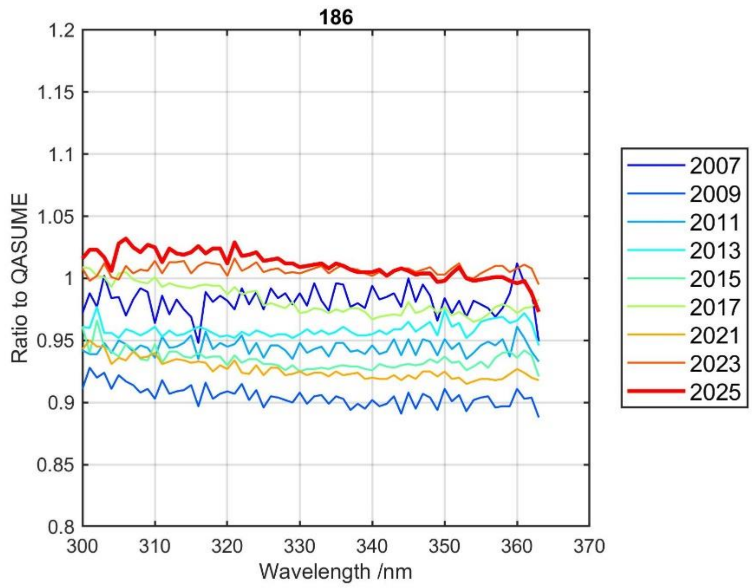


Figure 3: Solar spectral ratios of Brewer 186 to QASUME averaged over each QASUME site visit.

<u>Recommendation</u>:

Wavelength shift of AEM:

- The wavelength settings of AEM need to be updated to account for the spectral offsets observed during the intercomparison.

Cosine Error:

- Comparing the results of this year's campaign to the previous site visits show no increase of a possible cosine error.

Quality Control 1:

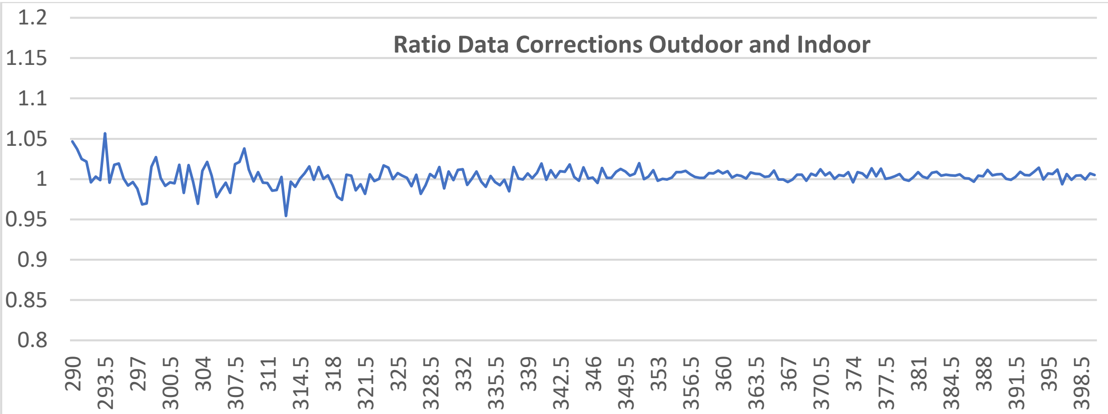
- It is recommended to develop standard operating procedures (SOP) for the yearly and monthly activities. The results should be summarized on a yearly basis in protocols.

Quality Control 2:

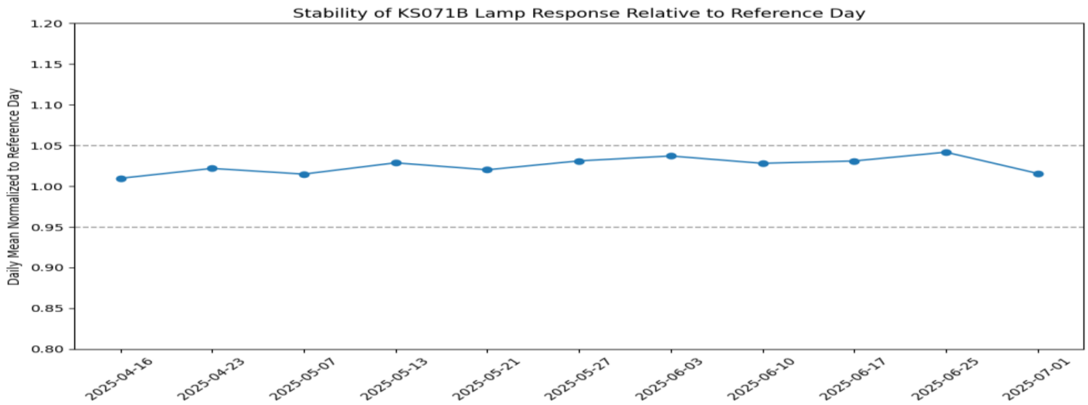
- It is strongly recommended that an internal intercomparison campaign is performed between AEM and the local Brewer 186. A minimum of two days throughout the year are sufficient to show any error in the calibration of either instrument. As both instruments are operated most of the time in parallel a routine to check the ratio AEM/186 all the time would be a powerful tool to have an independent monitor all year around.
- We recommend creating a figure for the ratio AEM/186 starting from the Qasume-Visit in 2021 until June 2025.

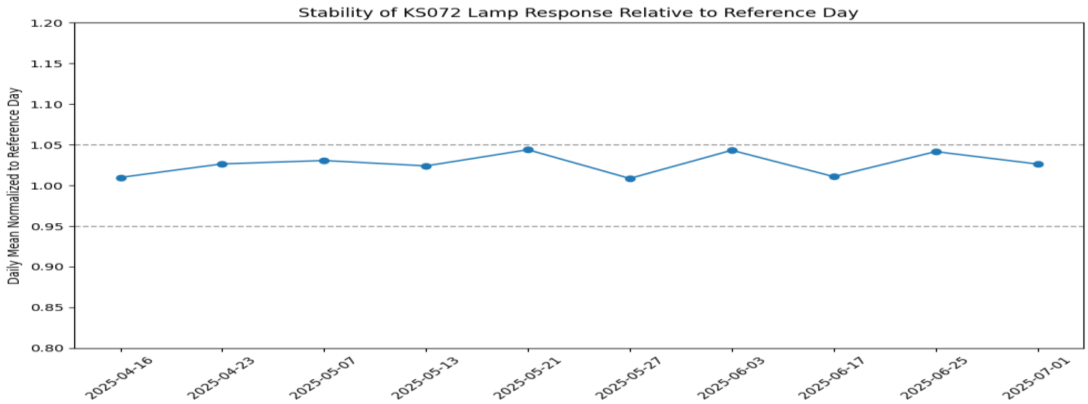
Comments of the Operator:

At AEMET, the operating procedure for ensuring the quality of the Bentham DTM300 (AEM) measurements consists in the following activities:
Every two years, the instrument is intercompared with the QASUME traveling reference (PMOD-WRC) at AEMET's installations.
Annually the spectroradiometer is calibrated using a 1000W lamp (FEL386, FEL407, FEL409 y FEL632) calibration system with properly referenced lamps to obtain the new correction file that will be applied for all spectra.
Recently, the 1000W lamp calibration setup —which had been carried out at night outdoors— has been changed to an indoor calibration system inside the BENTHAM cabin in order to avoid depending on external conditions. To validate the new setup, a comparison has been made between outdoor and indoor calibration, obtaining a mean value for the outdoor – indoor ratio of 1.0033 and a standard deviation of 0.0115.



Fortnightly, the responsivity of the instrument is monitored by calibrating it with a portable calibration system with 200W lamps (KS071B, KS072 y KS109B), which are referenced to the 1000W lamps used in the annual calibration. During the calibration campaign for the radiometers measuring global erythemal irradiance, this period becomes almost weekly.





In addition, efforts are being made to update the wavelength settings in the control software BenWin+ to correct the wavelength shift of the instrument. In the meanwhile, the software SHICRivm is applied to spectra to correct this offset.

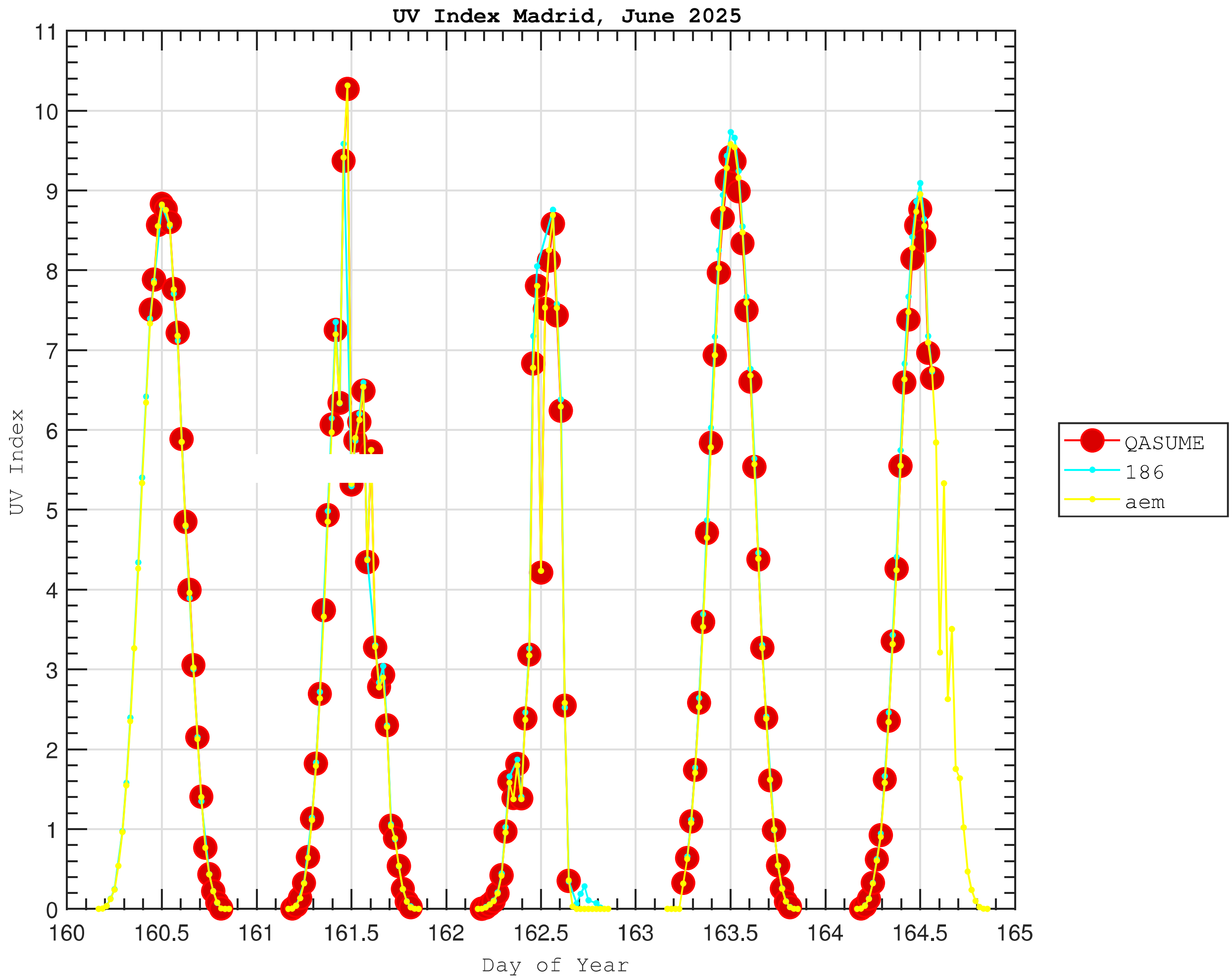
References:

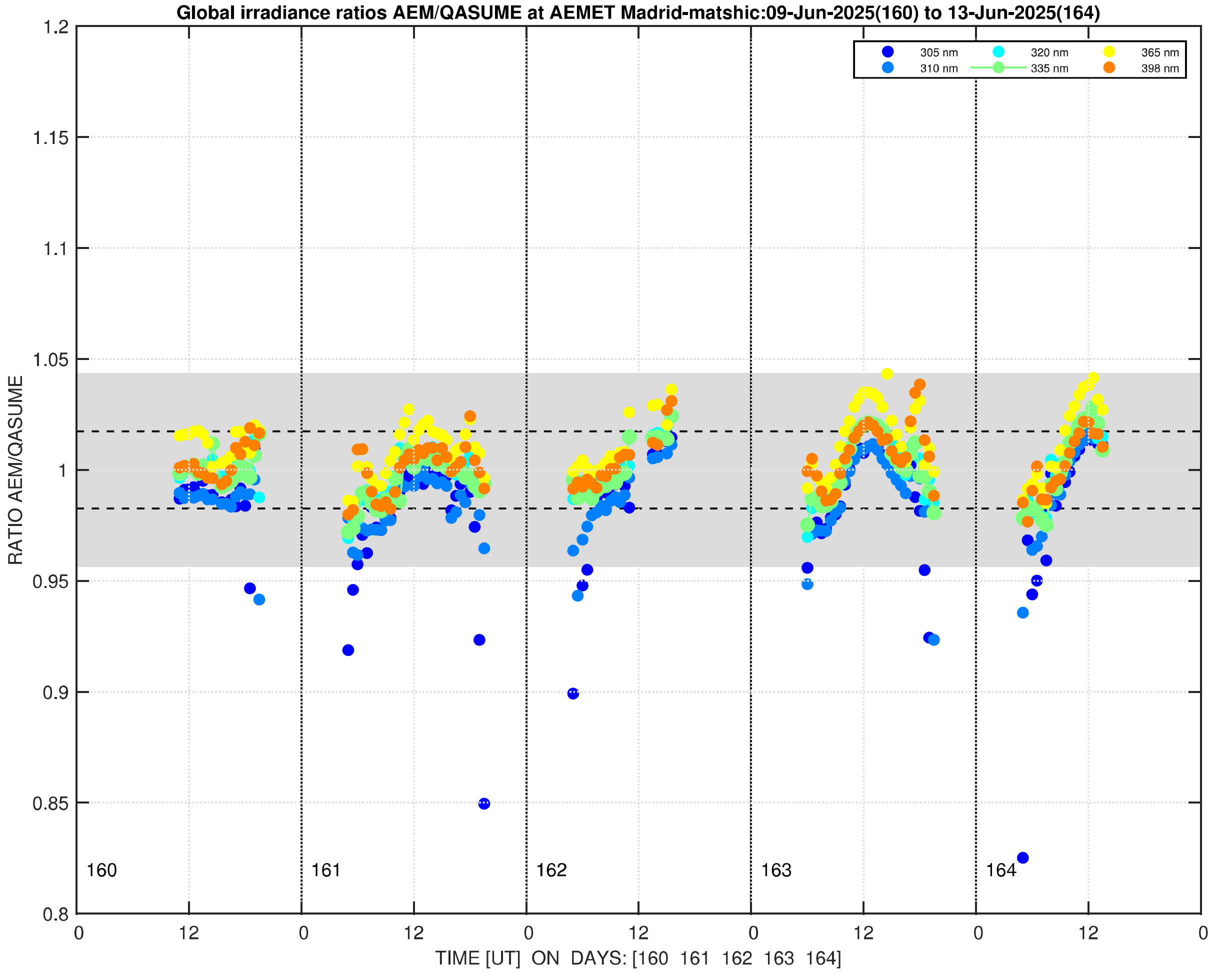
Gröbner, J., Kröger, I., Egli, L., Hülsen, G., Riechelmann, S., and Sperfeld, P.: The high-resolution extraterrestrial solar spectrum (QASUMEFTS) determined from ground-based solar irradiance measurements, Atmos. Meas. Tech., 10, 3375-3383, https://doi.org/10.5194/amt-10-3375-2017, 2017.

https://eubrewnet.aemet.es/dokuwiki/doku.php?id=codes:uvaccess#uv_corrections_flag

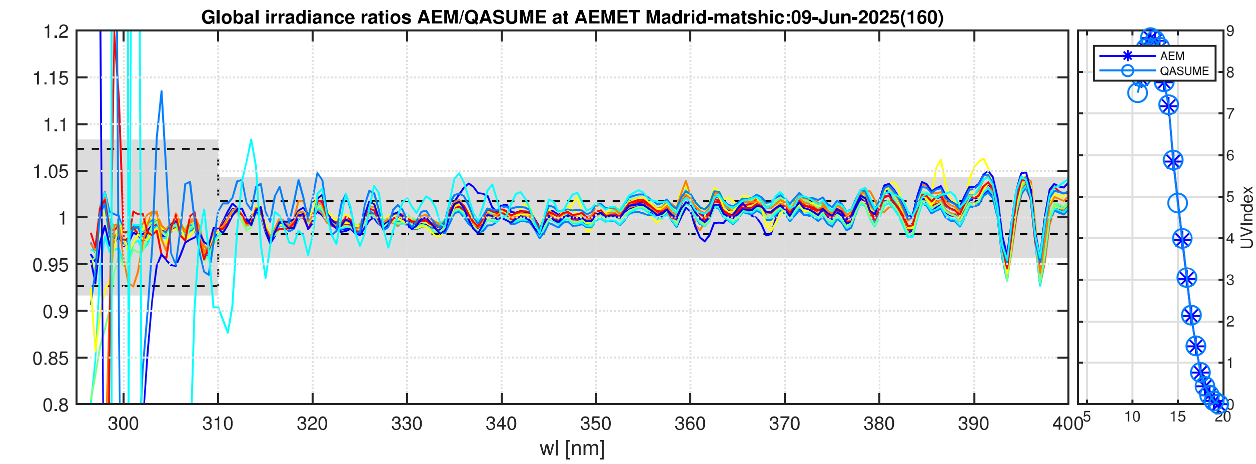
Appendix

Detailed results for the DTM 300 (AEM) spectroradiometer and Brewer 186 with respect to the reference spectroradiometer QASUME.

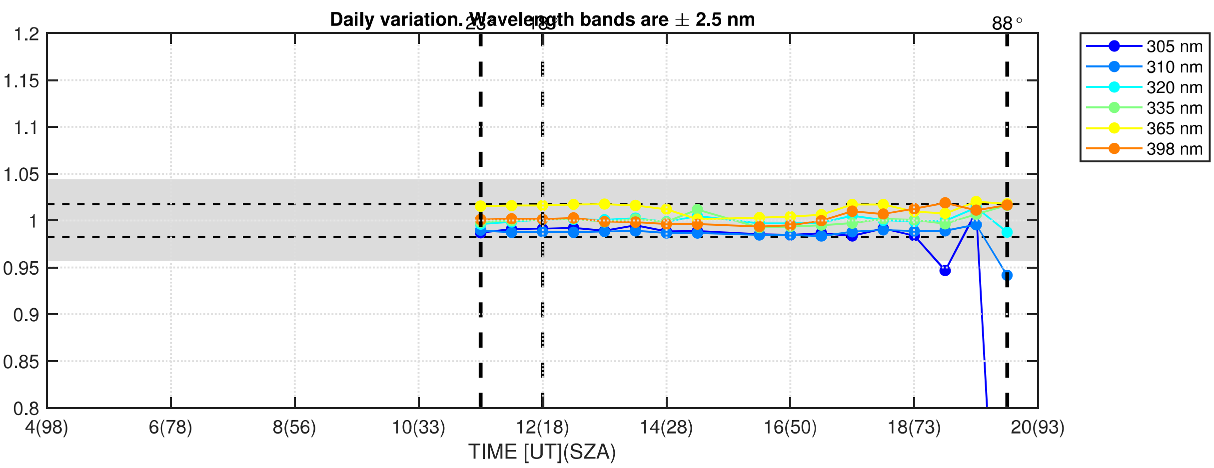

UV Index Madrid, June 2025
UV Index
Day of Year
QASUME
186
aem
0
1
2
3
4
5
6
7
8
9
10
11
160
160.5
161
161.5
162
162.5
163
163.5
164
164.5
165



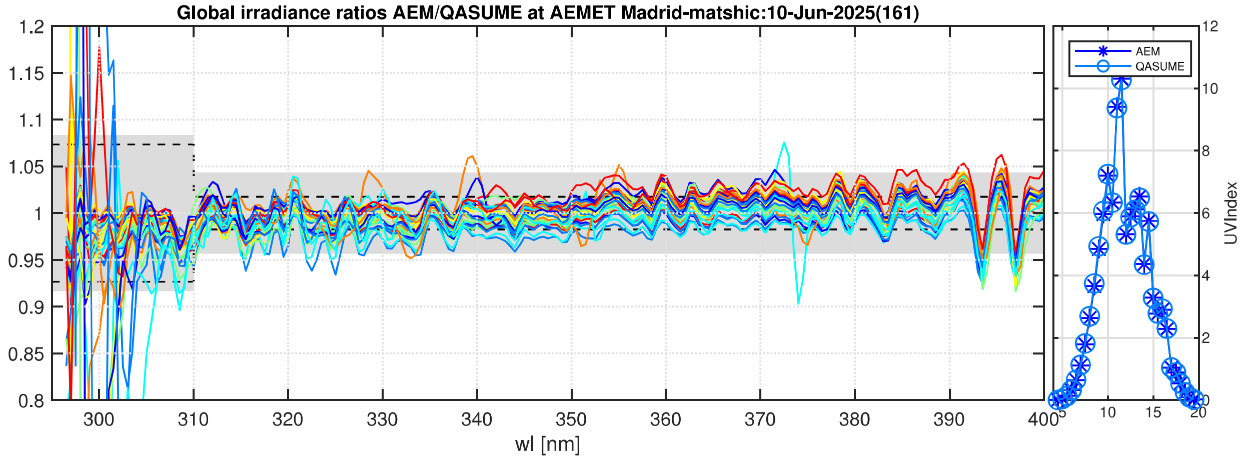
Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:09-Jun-2025(160) to 13-Jun-2025(164)
305 nm
310 nm
320 nm
335 nm
365 nm
398 nm
RATIO AEM/QASUME
160
161
162
163
164
TIME [UT] ON DAYS: [160 161 162 163 164]

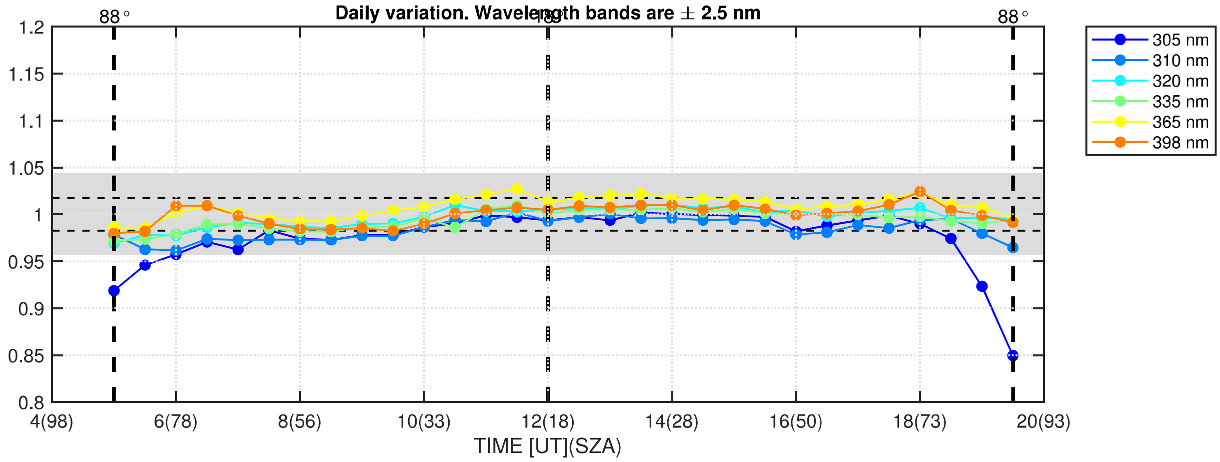


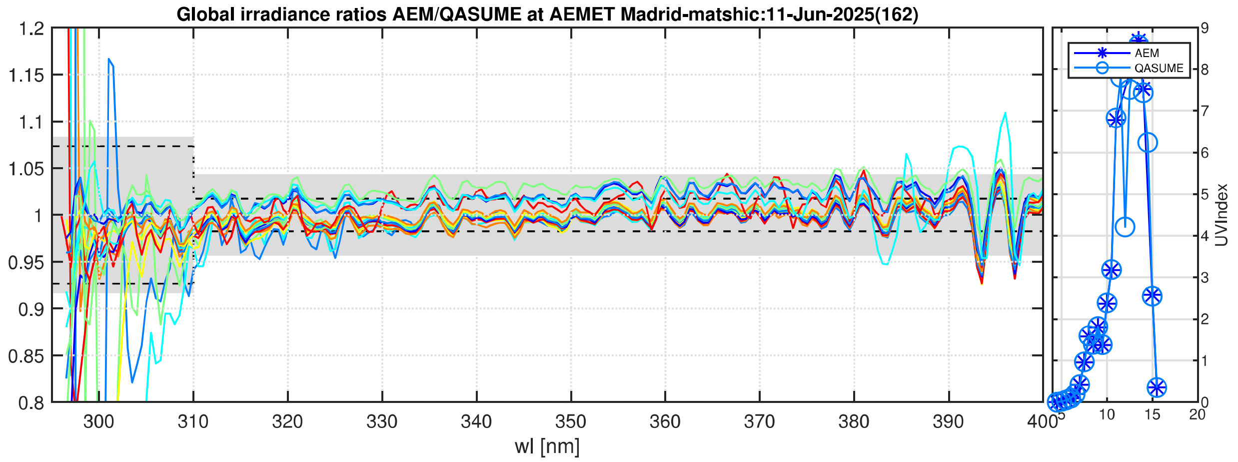
Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:09-Jun-2025(160)
wl [nm]
AEM
QASUME
UVIndex

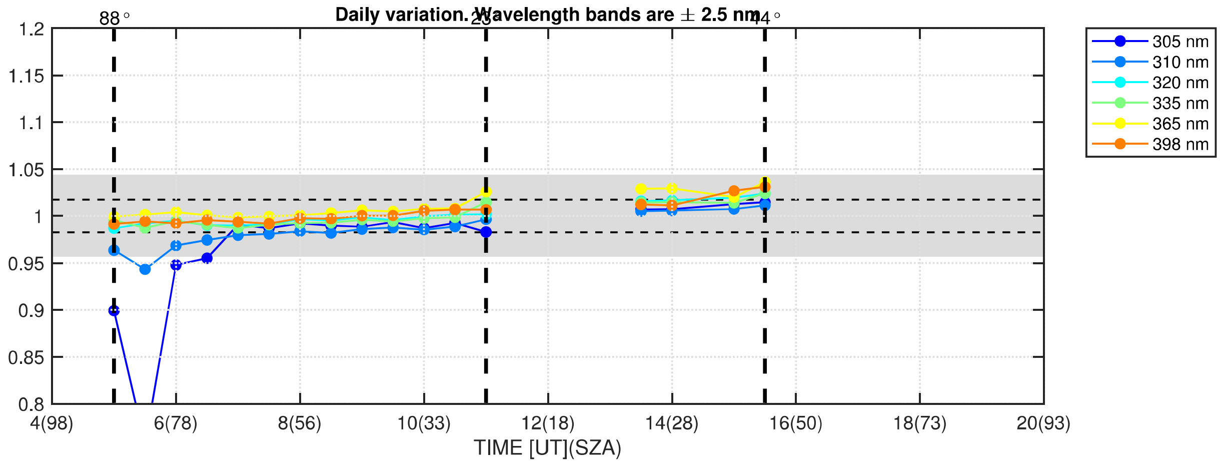


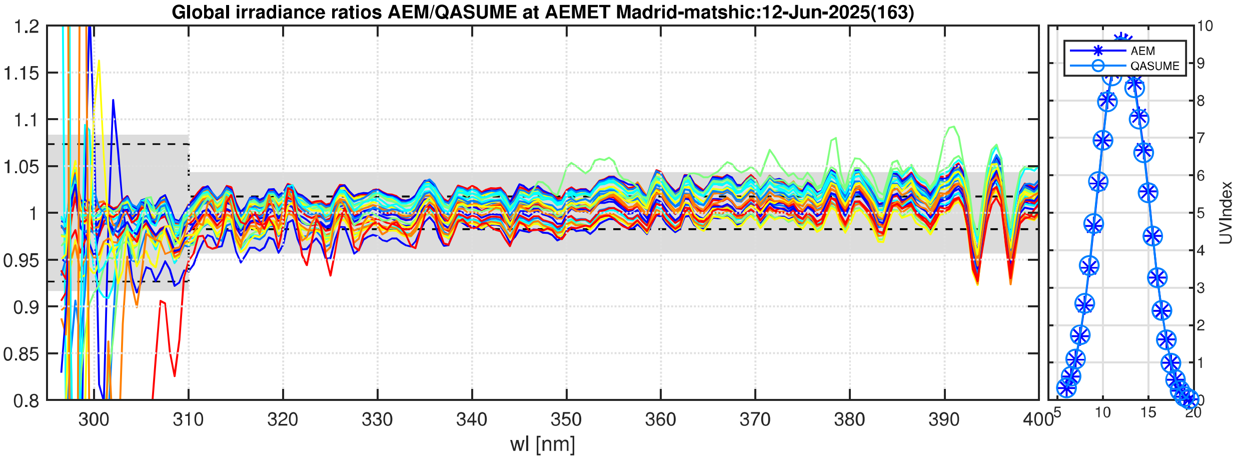
Daily variation. Wavelength bands are ± 2.5 nm
88°
305 nm
310 nm
320 nm
335 nm
365 nm
398 nm
TIME [UT](SZA)

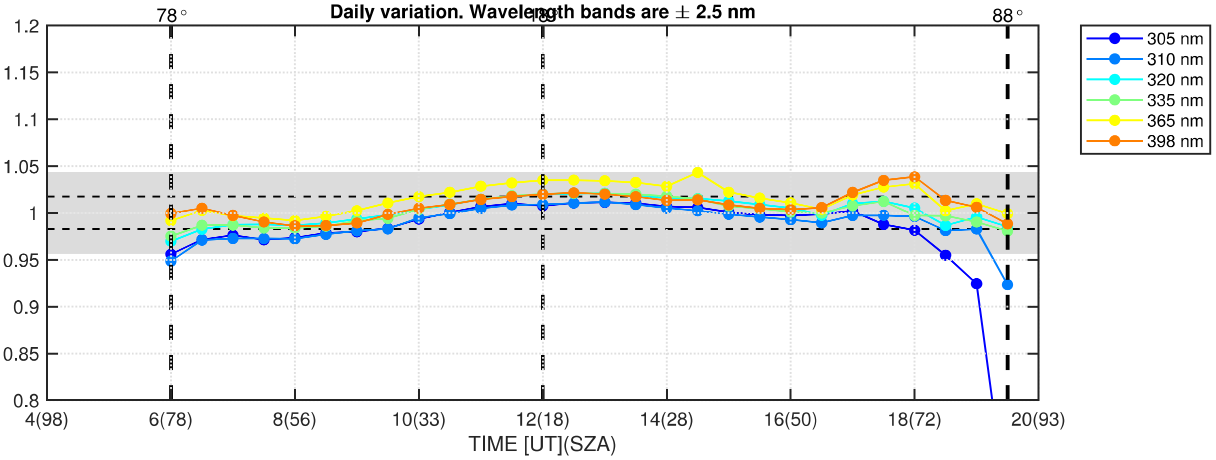

Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:10-Jun-2025(161)
wl [nm]
AEM
QASUME
UVIndex

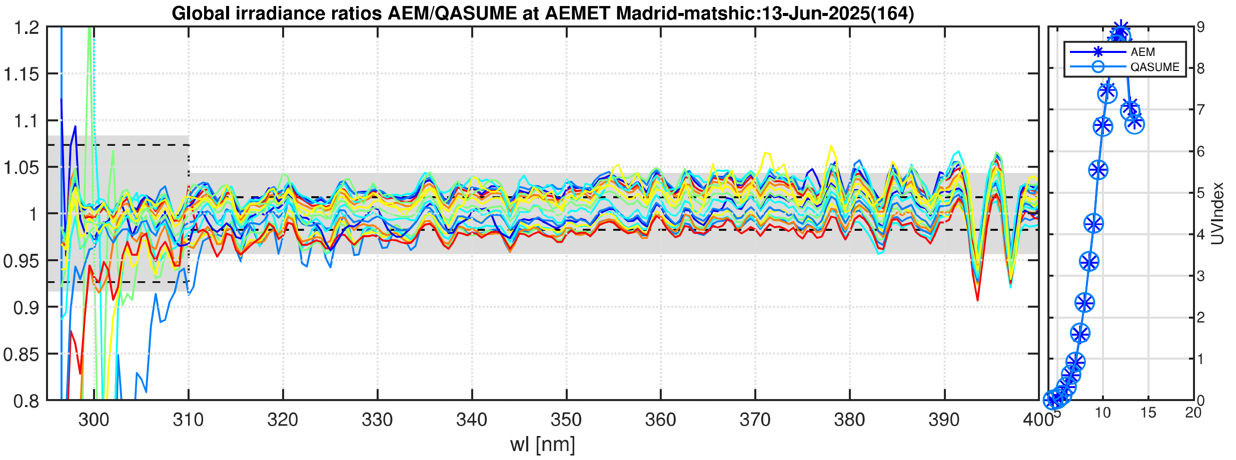

Daily variation. Wavelength bands are ± 2.5 nm
88°
88°
305 nm
310 nm
320 nm
335 nm
365 nm
398 nm
TIME [UT](SZA)

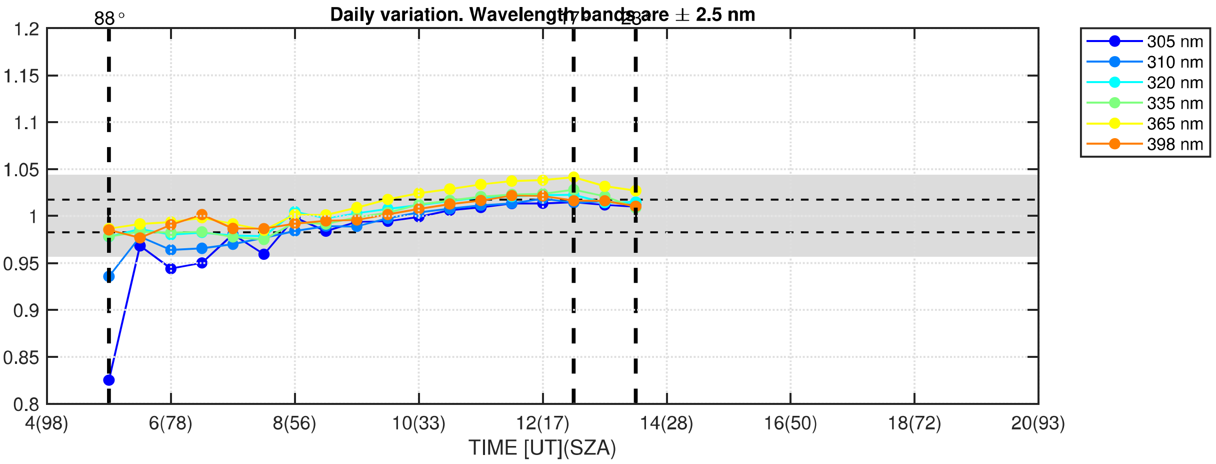

Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:11-Jun-2025(162)
wl [nm]
AEM
QASUME
UVIndex

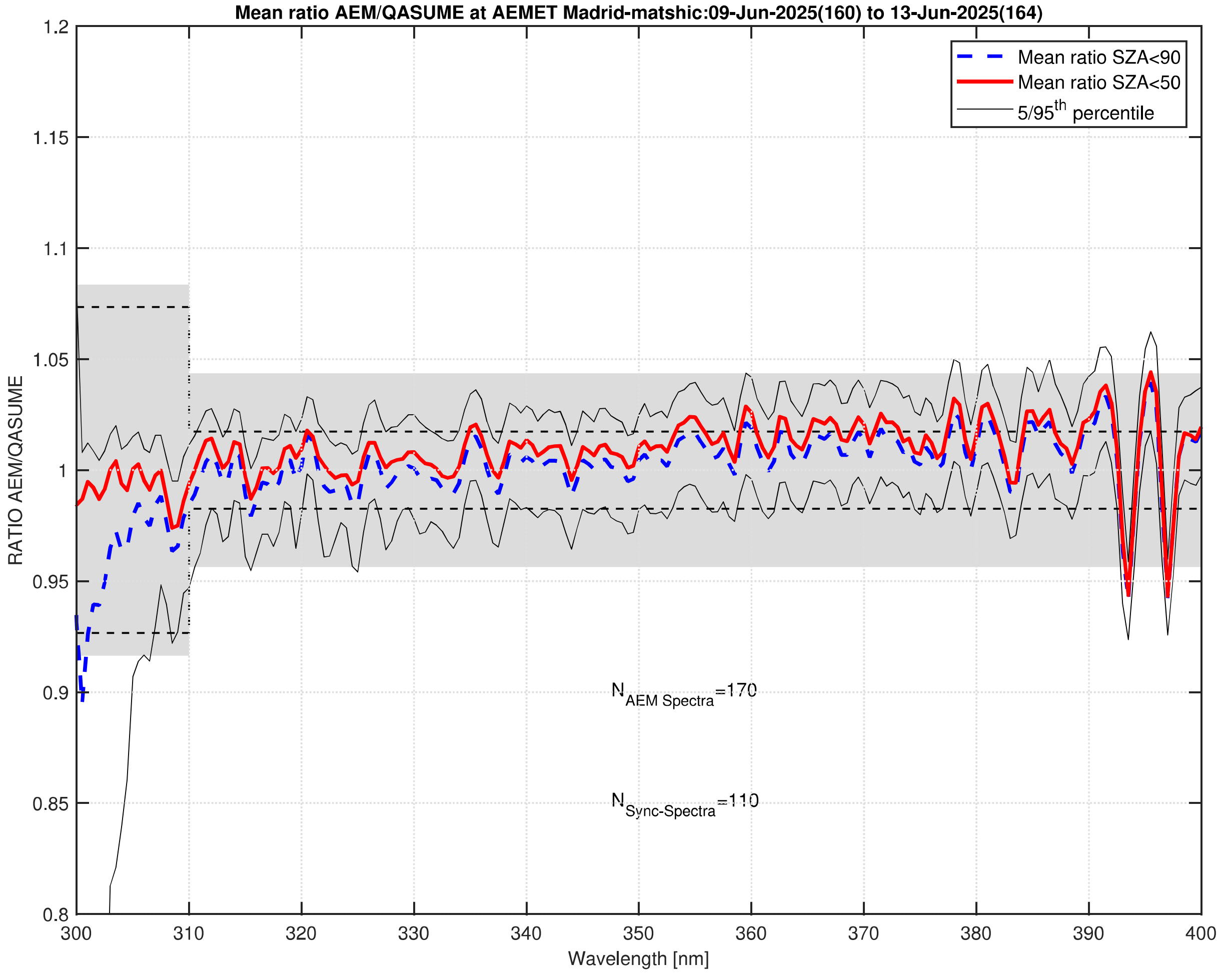

Daily variation. Wavelength bands are ± 2.5 nm
88°
305 nm
310 nm
320 nm
335 nm
365 nm
398 nm
TIME [UT](SZA)

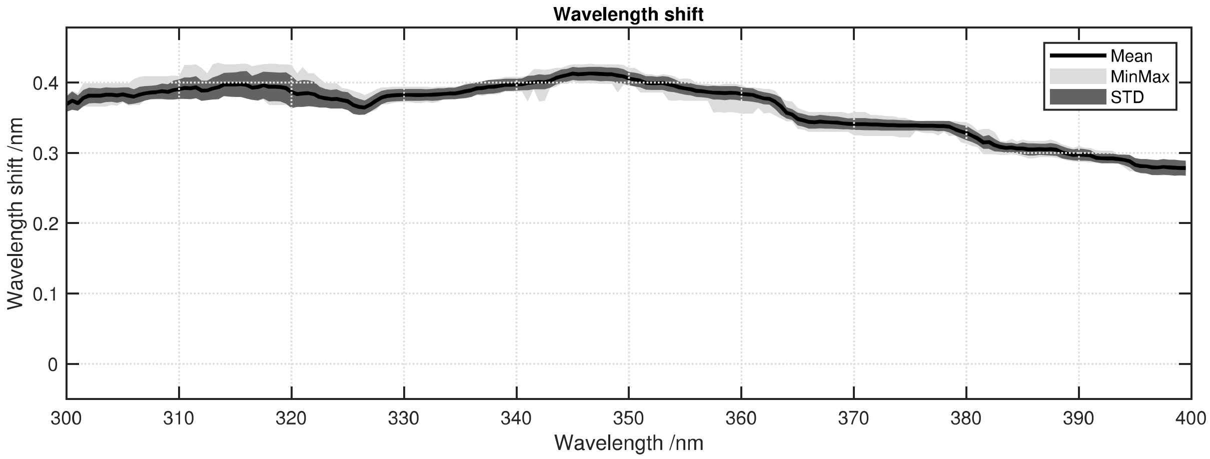

Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:12-Jun-2025(163)
wl [nm]
AEM
QASUME
UVIndex

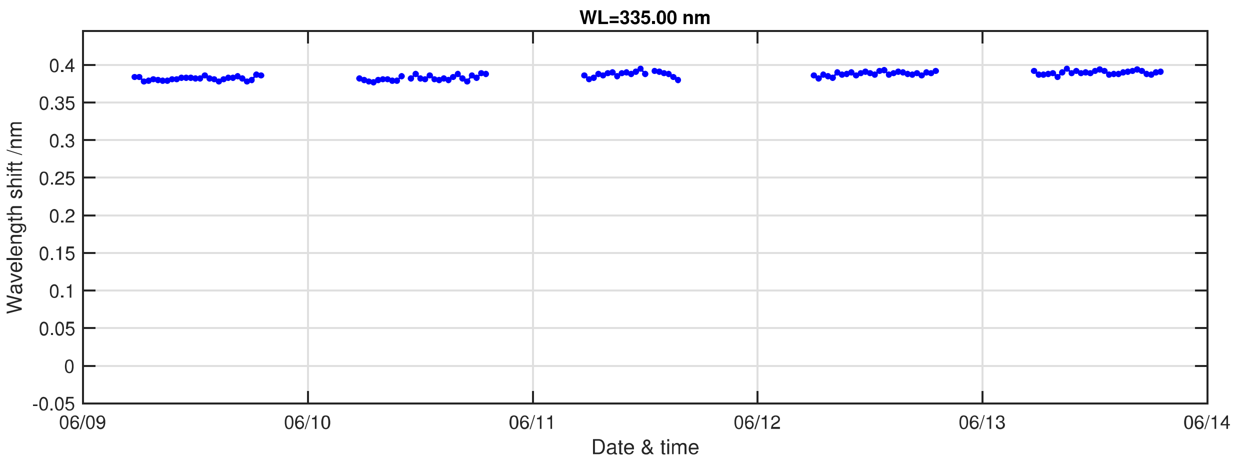

Daily variation. Wavelength bands are ± 2.5 nm
78°
88°
TIME [UT](SZA)
305 nm
310 nm
320 nm
335 nm
365 nm
398 nm

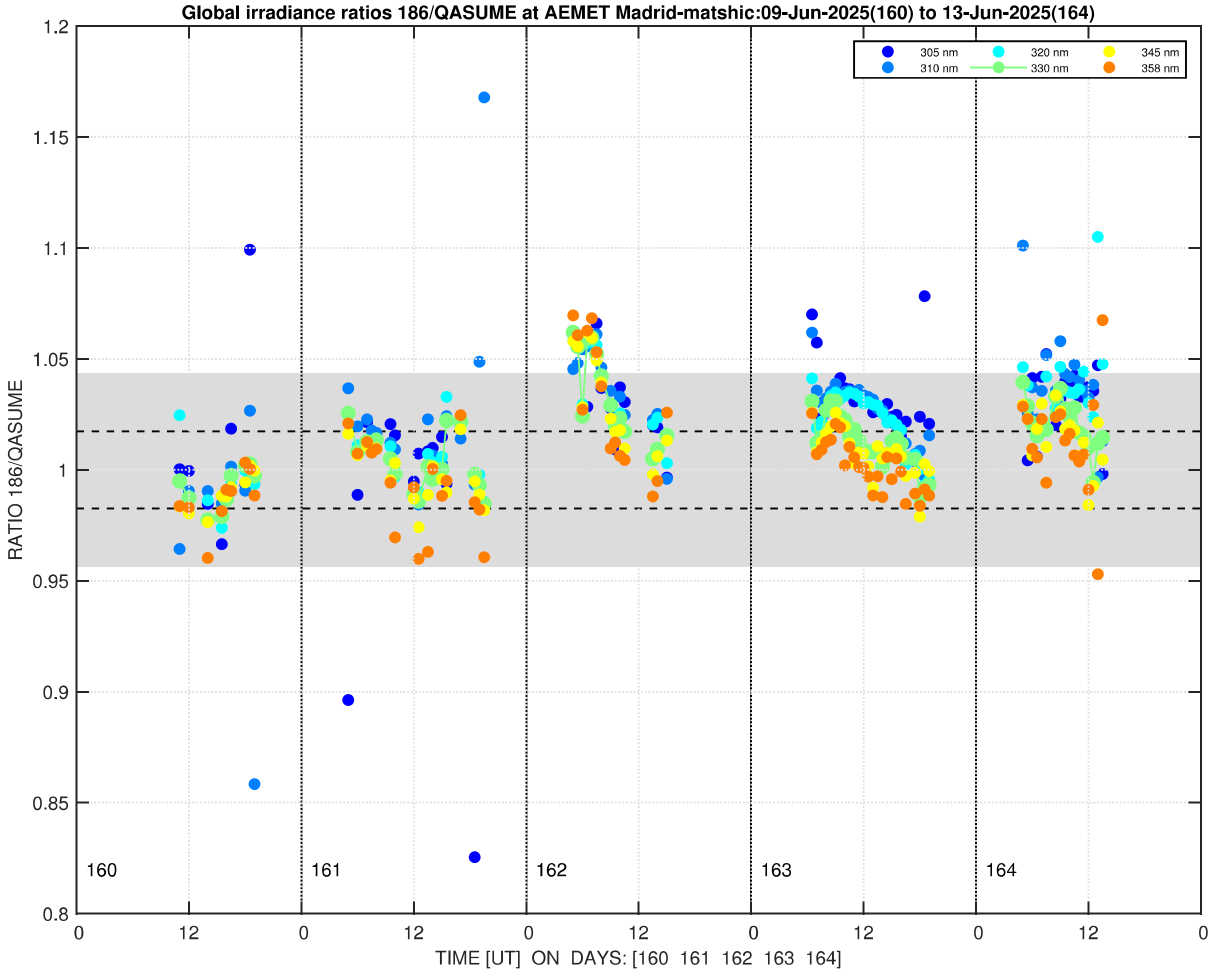

Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:13-Jun-2025(164)
wl [nm]
AEM
QASUME
UVIndex


Daily variation. Wavelength bands are ± 2.5 nm
88°
TIME [UT](SZA)
305 nm
310 nm
320 nm
335 nm
365 nm
398 nm

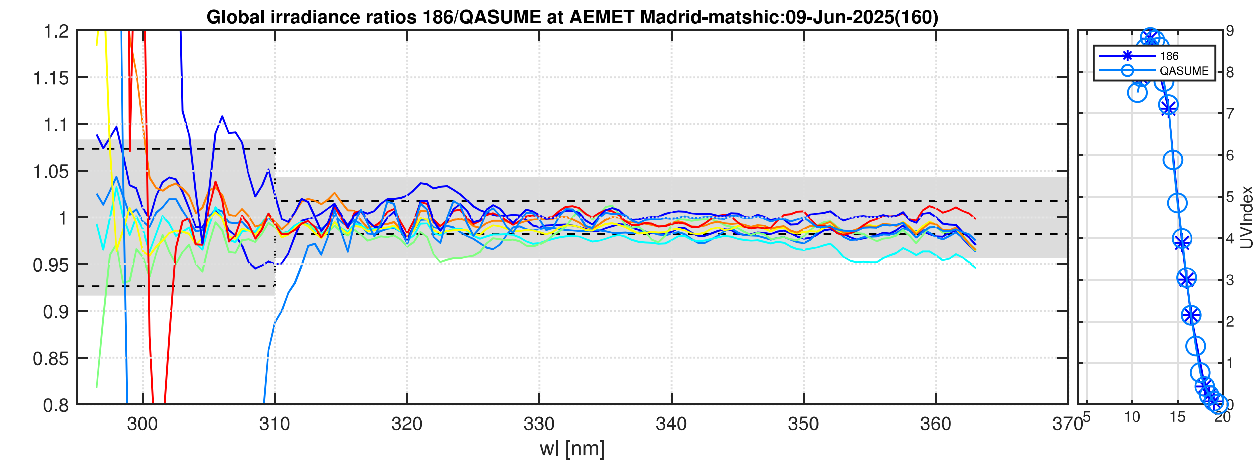

Mean ratio AEM/QASUME at AEMET Madrid-matshic:09-Jun-2025(160) to 13-Jun-2025(164)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
RATIO AEM/QASUME
N AEM Spectra=170
N Sync-Spectra=110
Wavelength [nm]


Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
Wavelength /nm

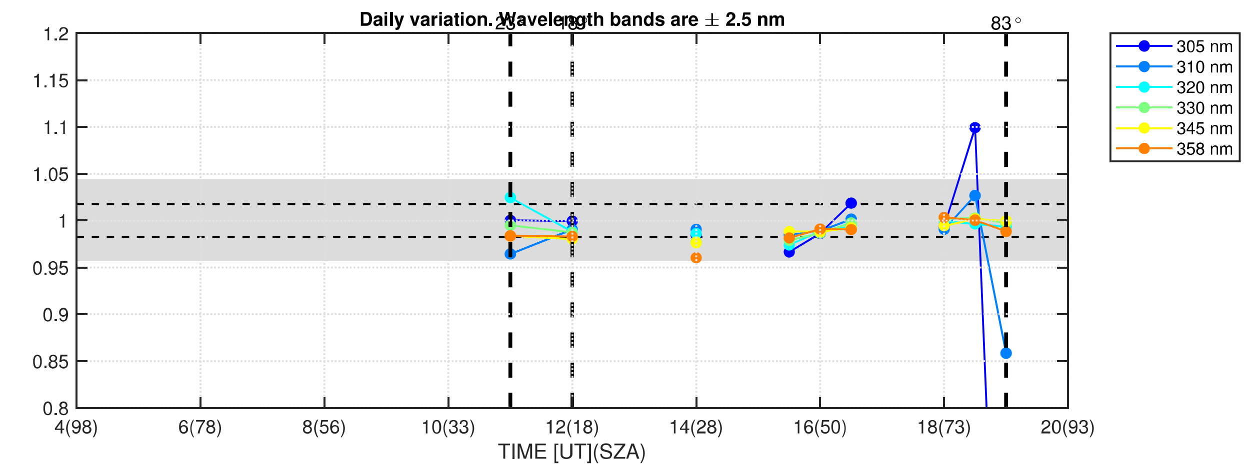

WL=335.00 nm
Wavelength shift /nm
Date & time



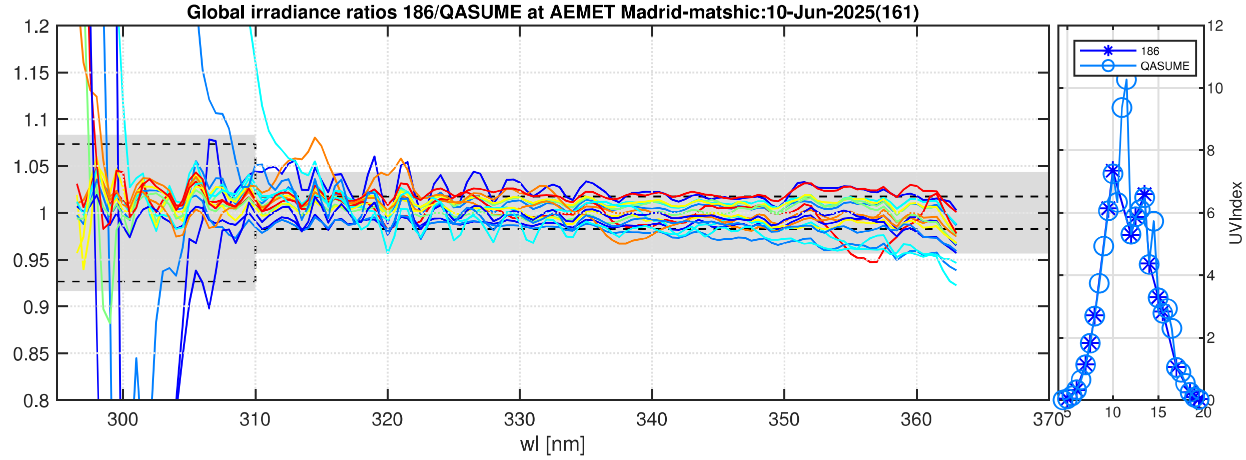
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:09-Jun-2025(160) to 13-Jun-2025(164)
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
RATIO 186/QASUME
160
161
162
163
164
TIME [UT] ON DAYS: [160 161 162 163 164]

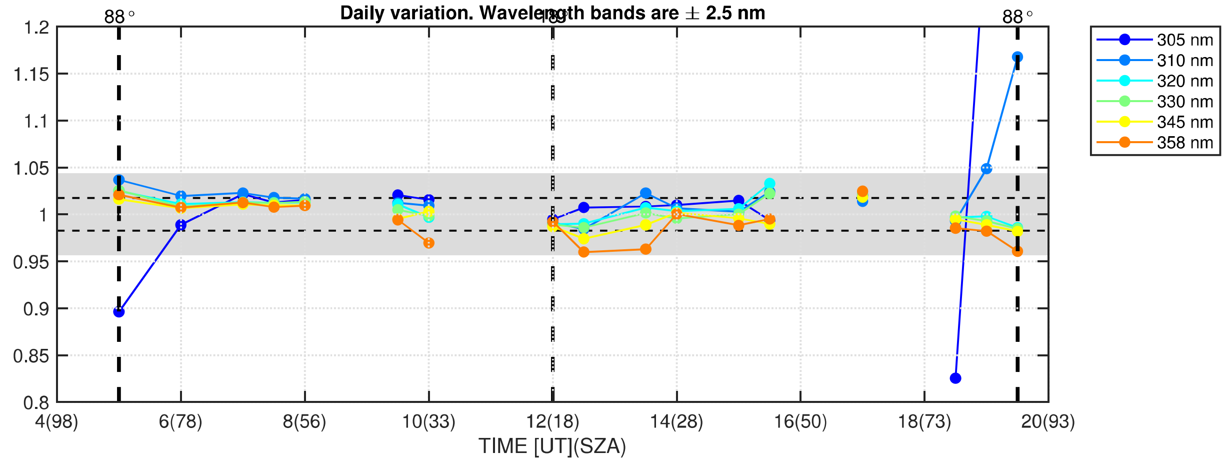


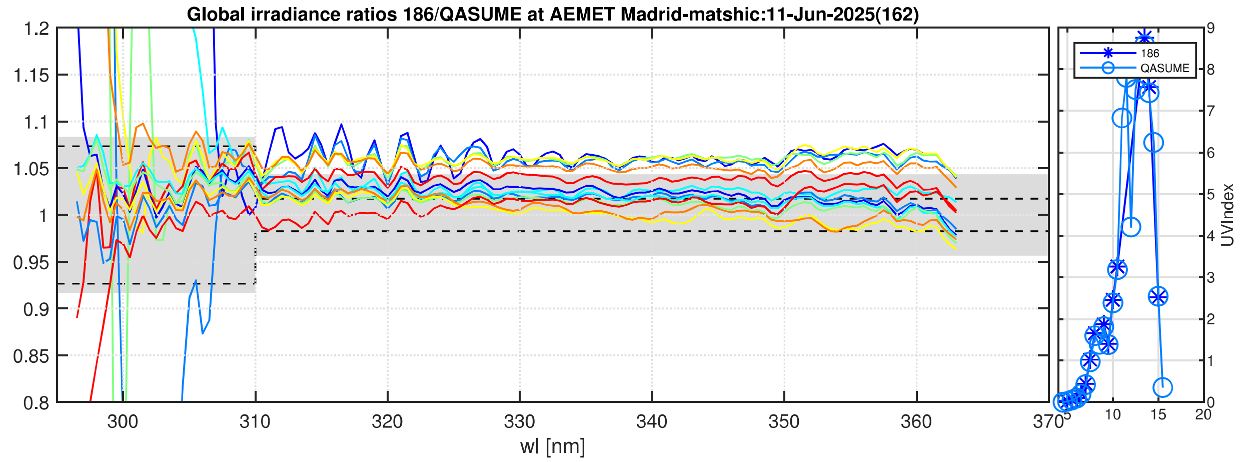
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:09-Jun-2025(160)
wl [nm]
186
QASUME
UVIndex

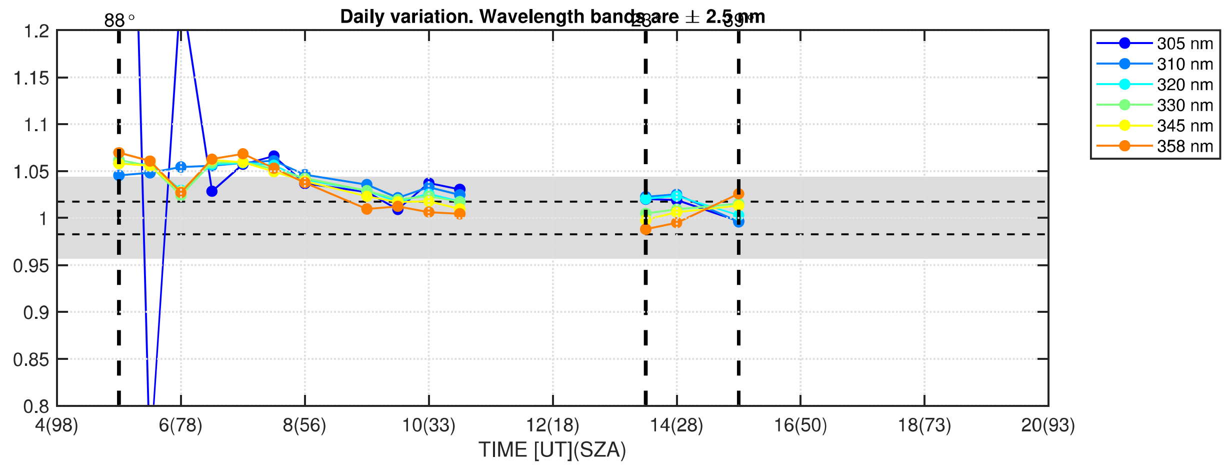


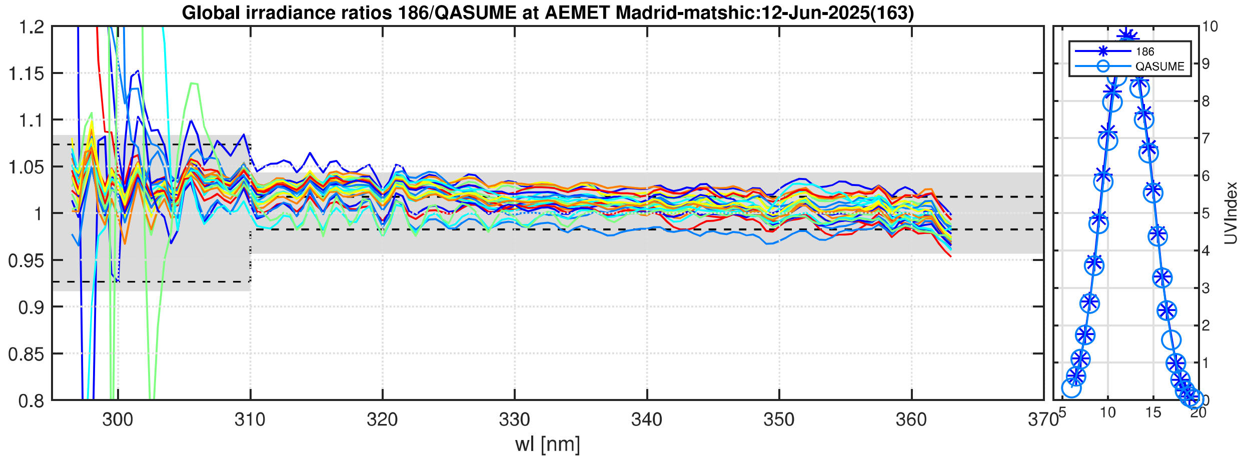
Daily variation. Wavelength bands are ± 2.5 nm
28°
18°
83°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

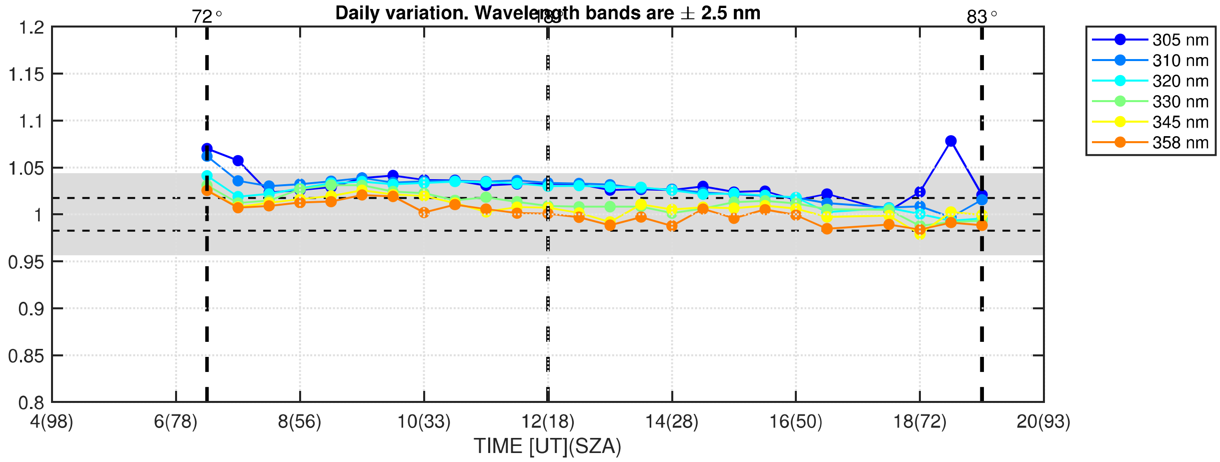

Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:10-Jun-2025(161)
wl [nm]
UVIndex
186
QASUME

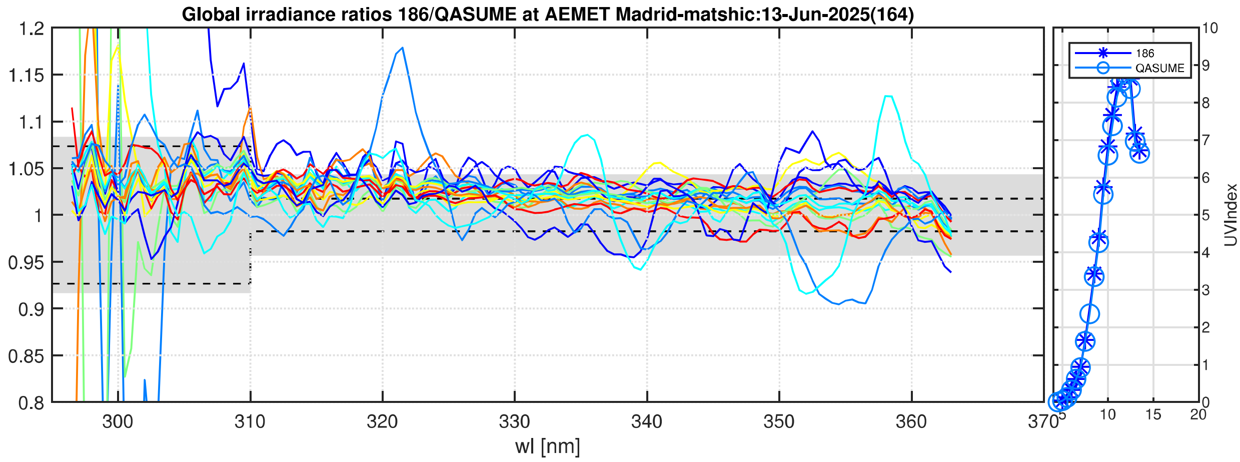

Daily variation. Wavelength bands are ± 2.5 nm
88°
88°
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm

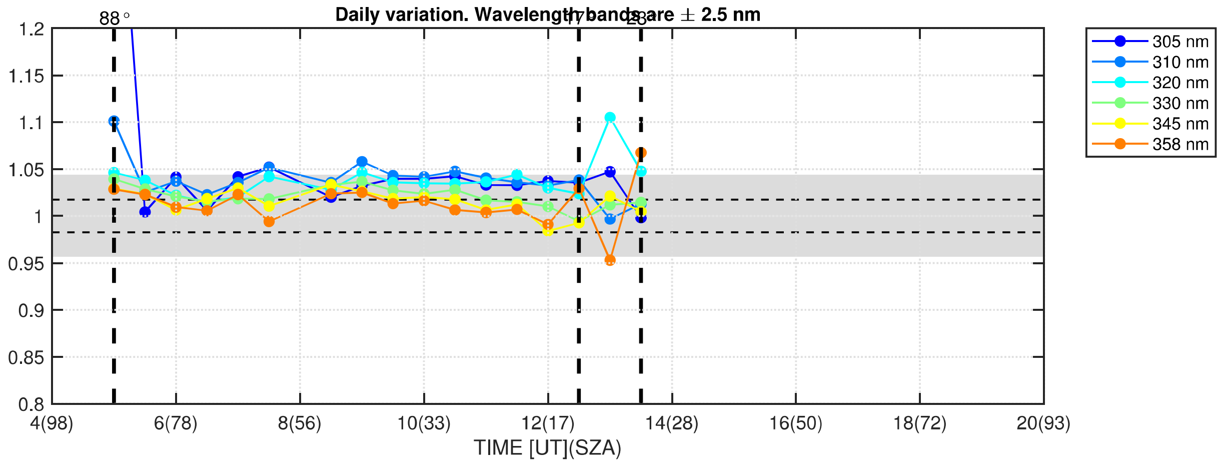

Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:11-Jun-2025(162)
wl [nm]
UVIndex
186
QASUME

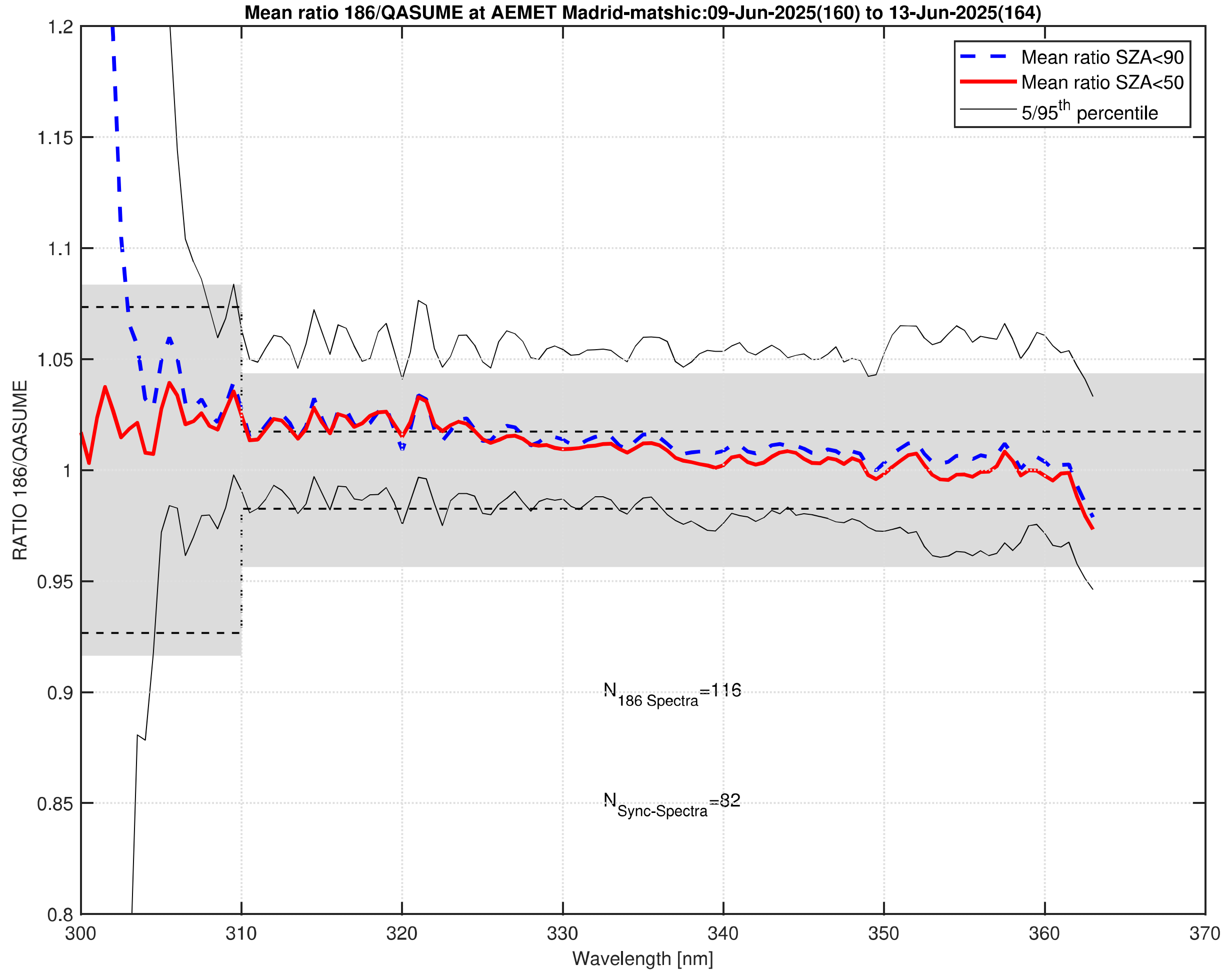

Daily variation. Wavelength bands are ± 2.5 nm
88°
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm

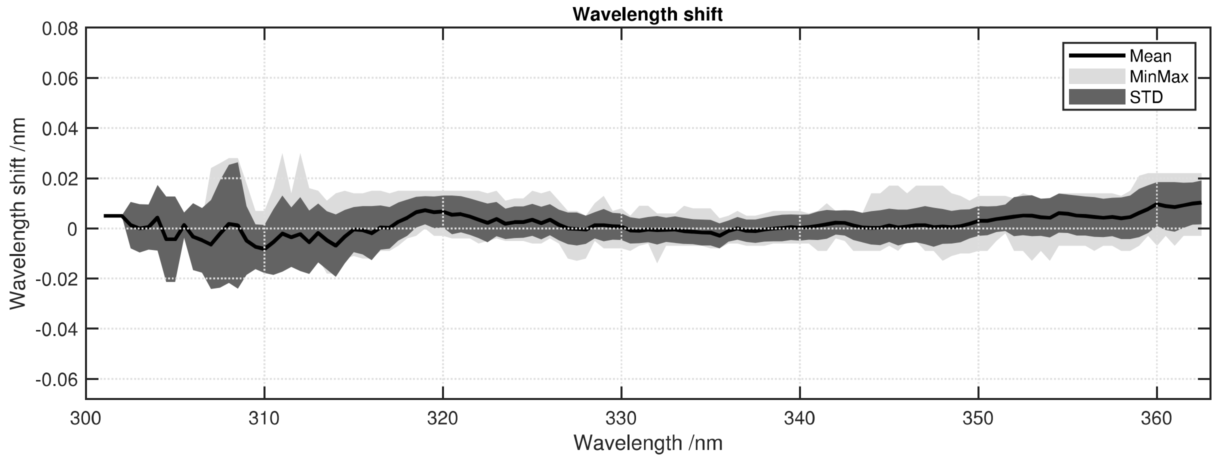

Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:12-Jun-2025(163)
wl [nm]
186
QASUME
UVIndex

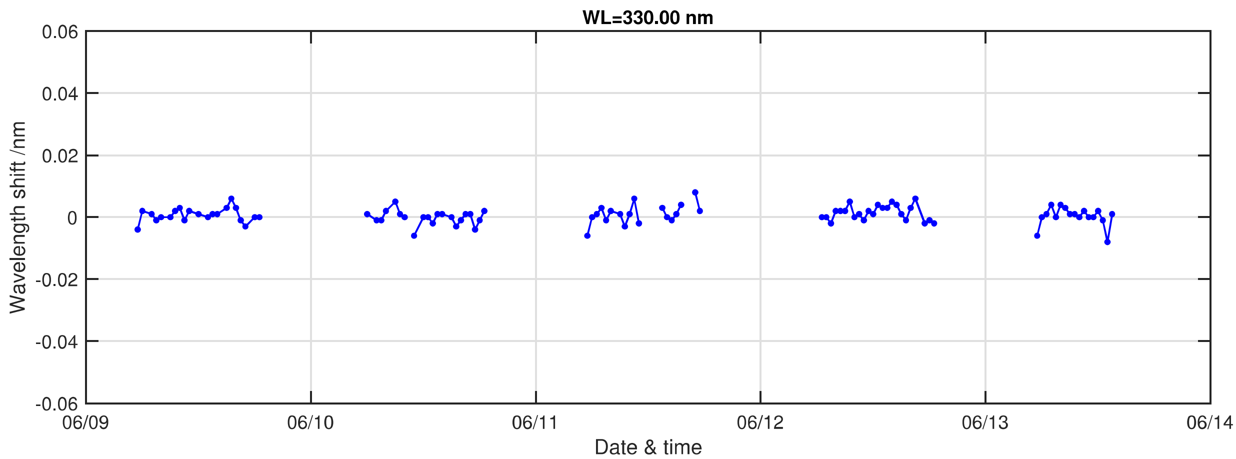

Daily variation. Wavelength bands are ± 2.5 nm
72°
83°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

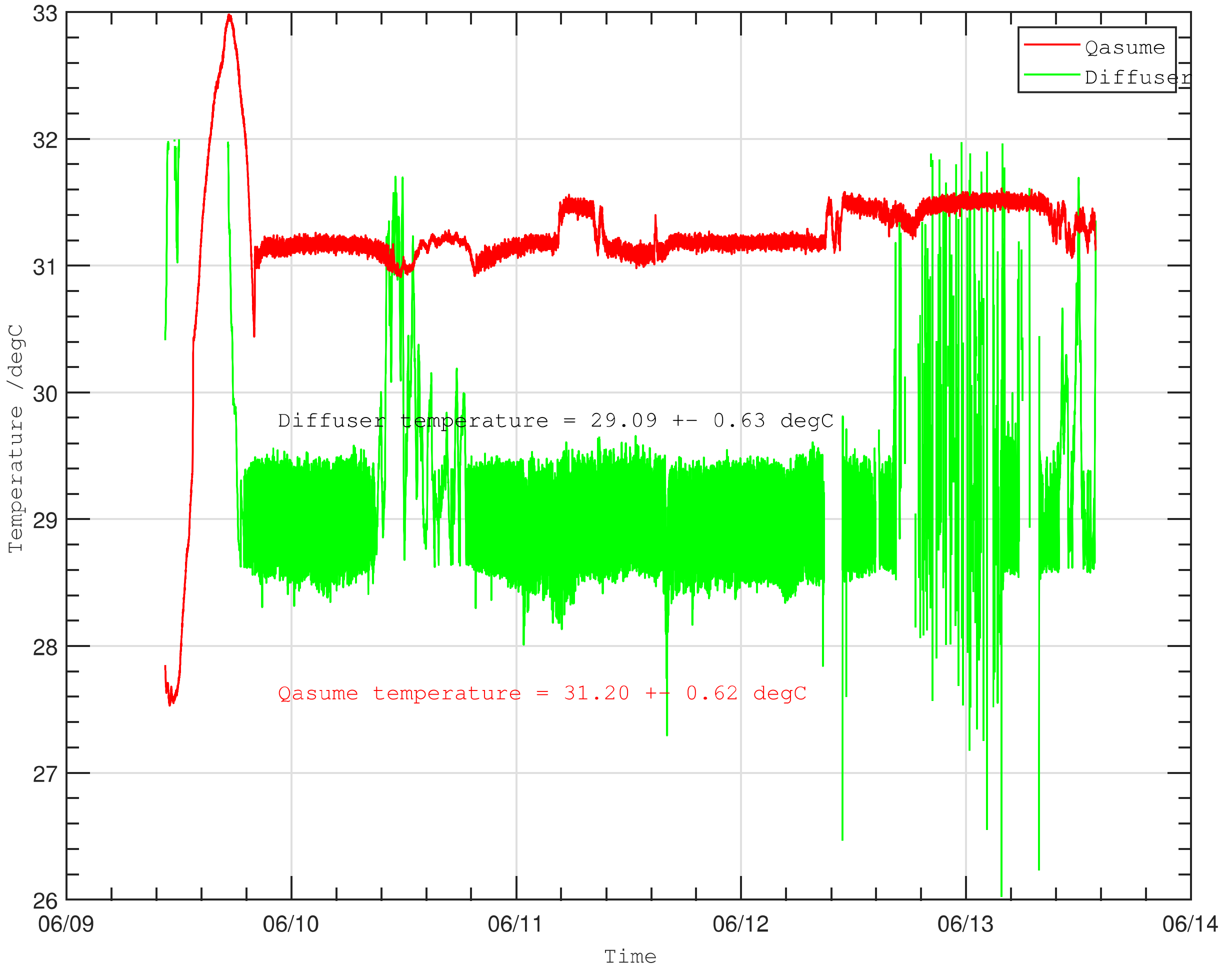

Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:13-Jun-2025(164)
wl [nm]
186
QASUME
UVIndex

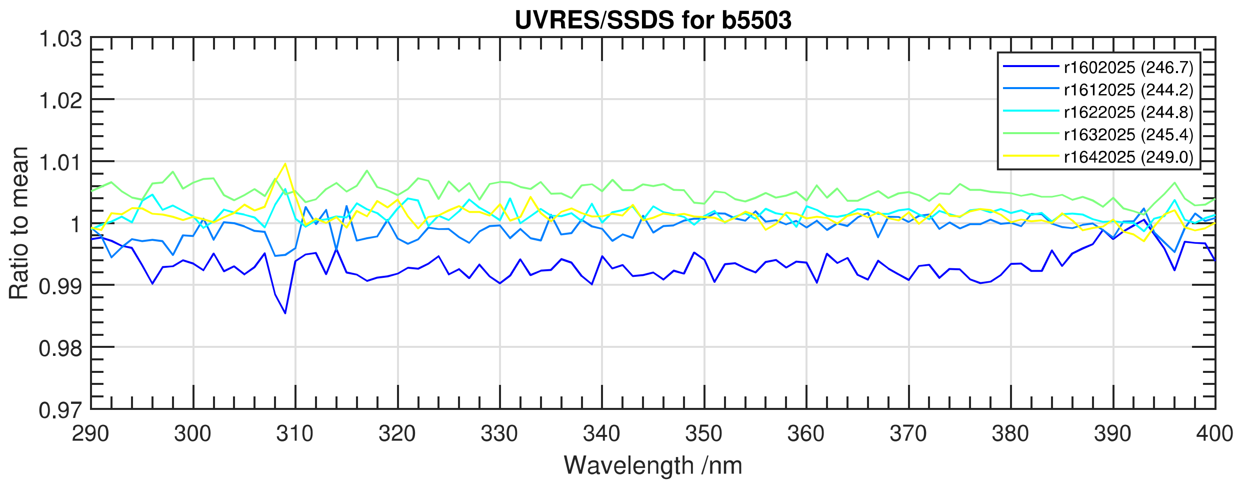

Daily variation. Wavelength bands are ± 2.5 nm
88°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

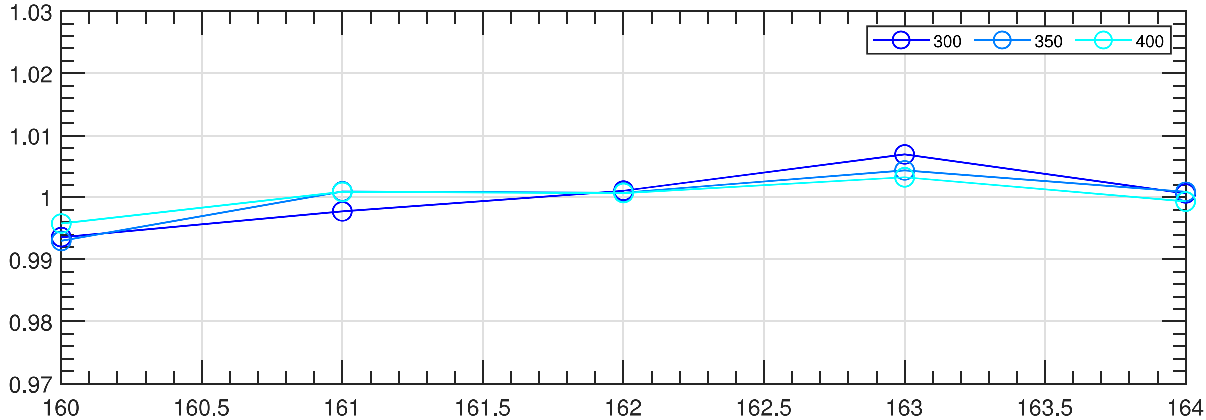

Mean ratio 186/QASUME at AEMET Madrid-matshic:09-Jun-2025(160) to 13-Jun-2025(164)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
RATIO 186/QASUME
N186 Spectra=116
NSync-Spectra=82
Wavelength [nm]


Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
Wavelength /nm


WL=330.00 nm
Wavelength shift /nm
Date & time


Qasume
Diffuser
Diffuser temperature = 29.09 +- 0.63 degC
Qasume temperature = 31.20 +- 0.62 degC
Temperature /degC
Time
06/09
06/10
06/11
06/12
06/13
06/14


UVRES/SSDS for b5503
r1602025 (246.7)
r1612025 (244.2)
r1622025 (244.8)
r1632025 (245.4)
r1642025 (249.0)
Ratio to mean
Wavelength /nm


300
350
400


AEM
Br 186
Qasume


SOUTH BEACH
JACK&JONES
BREWER