Protocol of the intercomparison at the Agencia Estatal de Meteorologia (AEMET) in Madrid, Spain on September 01 to 04, 2009 with the travelling reference spectroradiometer QASUME[1] from PMOD/WRC

Report prepared by Julian Gröbner

Operator: Julian Gröbner

The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer operated by the AEMET and the travel reference spectroradiometer QASUME. The measurement site is located on the roof of the Headquarters of AEMET in Madrid; Latitude 40.45 N, Longitude 3.72 W and altitude 680 m.a.s.l..
The horizon of the measurement site is free down to at least 85° solar zenith angle (SZA). Measurements between 6:00 UT and 18:40 UT were analysed.

QASUME arrived at the AEMET in the afternoon of September 01, 2009. The spectroradiometer was installed on the roof of the measurement platform close to the spectroradiometer of AEMET. The spectroradiometer in use at AEMET is a Bentham DM300 double monochromator system with custom made input selector to select between three input optics: Two integrating spheres to measure diffuse or global irradiance and a direct irradiance optic. The intercomparison between QASUME and the local spectroradiometer lasted three days, from the morning of September 02 to the evening of September 04.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. One lamp (T68523) was 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 ±0.5 % during the intercomparison period. The internal temperature of QASUME was 27.7±0.1 °C. The diffuser head was heated to a temperature of 31.5±3 °C.
The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm 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 20 minutes from 290 to 400 nm, every 0.25 nm, and 1.5 seconds between each wavelength increment. On September 2, measurements between 5:45 UT and 17:00 were measured with a period of 15 minutes.

September 01 (244) Tuesday:

QASUME was installed on the measurement site at 13:30 UT. Synchronisation tests were initiated at 14:00 UT. Weather conditions were mostly Cirrus clouds with a few Cumulus clouds around 15 UT.

The slit width of the AEMET Bentham was set to a fixed width of 0.74 mm. The corresponding slit function with a Full Width at Half Maximum (FWHM) of about 0.6 nm of the AEMET Bentham was determined using an external Mercury discharge lamp with the emission line at 296.728 nm.

September 02 (245) Wednesday:

Synchronised measurements are available from 5:45 to 18:40 UT. Weather conditions were cirrus clouds and some cumulus clouds in the afternoon. At 14:00 AEMET Bentham was set to a new slit width of 1.48 mm, about 1.0 nm FWHM, to increase the signal during lamp calibrations. Measurements started again at 15:30 UT.

QASUME was calibrated at 9:43 UT.

September 03 (246) Thursday:

Synchronised scans are available from 5:45 to 18:40 UT. Weather conditions were clear skies with cirrus clouds. From 8:00 to 9:20 UT the input optic selector of AEMET Bentham was set to a fixed position (global) to reduce the observed scan to scan variability (during solar as well as lamp scans). At 10:40 UT the solar tracker of AEMET was stopped and rotated to point towards South-West. At 13:00 UT the tracker was rotated by -90°. At 14:40 UT the integrating sphere of the diffuse port was used for the global irradiance measurements by removing the shading ball mechanism.

QASUME was calibrated at 6:51 UT.

September 04 (247) Friday:

Synchronised measurements are available from 6:00 to 15:00 UT. Weather conditions were clear skies. At 13:00 the AEMET integrating sphere was rotated by 180° so that the optical fiber entry point of the integrating sphere faced north. At the same time, the tracker was turned on again to track the sun.

End of the campaign: after the 15:00 UT scan.

Results:

In total 105 synchronised spectra from QASUME and AEM are available from the measurement period. The spectra were convolved to a common slit width of 1 nm using the SHICRivm algorithm and wavelength shifts to the reference spectrum used by SHICRivm were determined and corrected. Measurements between 5:45 and 18:40 UT have been analysed (SZA smaller than 90°).

- The wavelength scale of the AEMET Bentham is shifted towards shorter wavelengths by 0.7 to 0.9 nm over the wavelength range 290 to 400 nm. AEMET measured the mercury emission line 296.728 nm at a wavelength of 295.92 nm, i.e. 0.81 nm less than the nominal wavelength.
- The signal to noise ratio of the AEMET Bentham during lamp calibrations was very low using a slit width of 0.74 mm. It was therefore increased to 1.48 mm after the first day. This low signal to noise ratio is due to the use of an integrating sphere as global input optic.
- The ratio between AEMET and QASUME until 13:30 UT on September 2 is between 0 and 0.2. After increasing the width of the slit function and recalibrating the instrument, the average ratio became 0.8 with a variability of ±10%.
- To reduce the variability of ±10% observed in the afternoon of September 2 and the morning of September 3, it was decided to set the input selector of the AEMET Bentham to a fixed position for global irradiance measurements. This considerably reduced the observed random scan to scan variability.
- The large variability of 30% observed between 9:20 UT and 13:00 UT on September 3 could be traced to a pronounced azimuth dependent angular response of the integrating sphere used for global irradiance measurements. Therefore it was decided to use the second integrating sphere on the diffuse input port and turn off the tracker. A new calibration was performed, and measurements with this new input optic started at 14:40 UT.
- The measurements after 14:40 UT on September 3 showed a stable ratio to QASUME of about 0.95, i.e. 5% lower than QASUME. A wavelength dependent change in the ratios could be seen at SZA of about 70° which is probably due to a departure of the AEMET angular response from the nominal cosine response.
- The AEMET measurements on September 4 show a “double peak” feature with a maximal deviation of about 25% relative to the QASUME measurements. This feature could be traced to an insufficient suppression of the forward scattering peak of the integrating sphere since the minimum of the double peak coincides with the alignment of the solar azimuth with the fiber optic entrance hole of the integrating sphere.

Conclusions:

- The current design and operation of the spectroradiometer do not allow reliable measurements of spectral solar UV irradiance and need to be modified.

Suggestions:

The following suggestions are aimed at improving the quality of spectral solar UV irradiance measurements at AEMET:

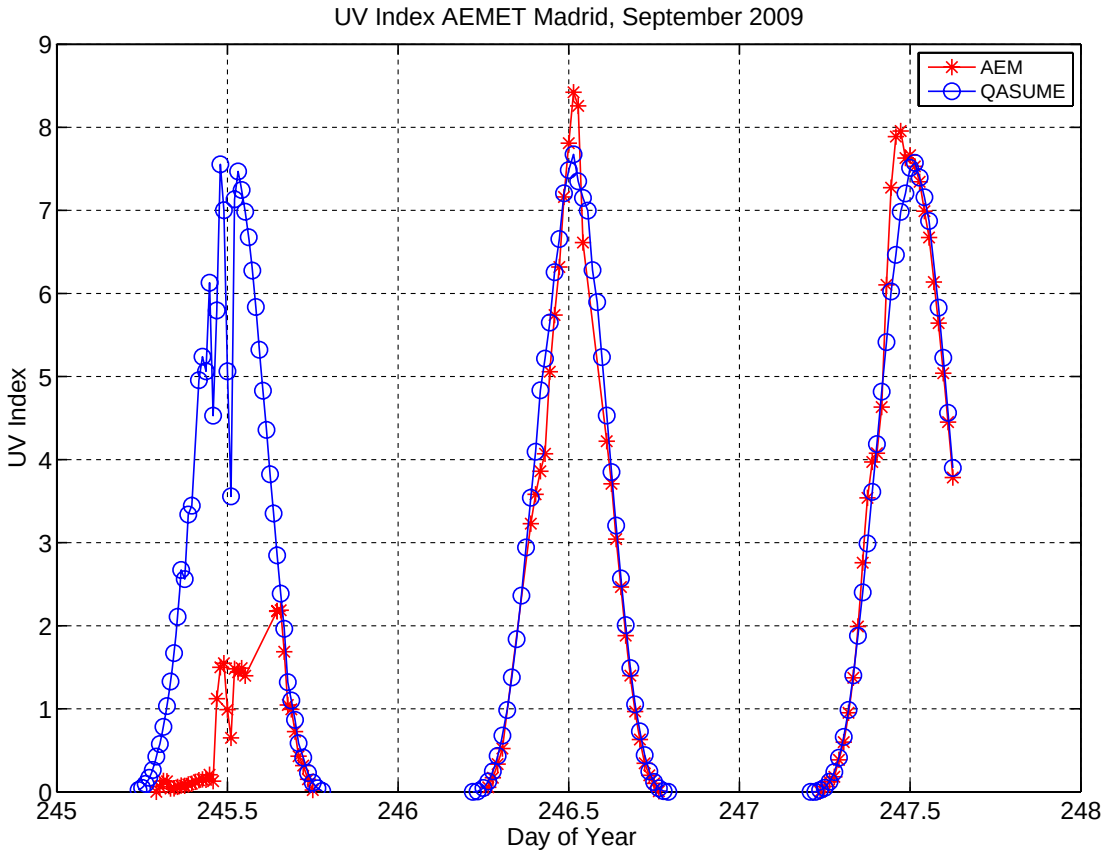
1) The integrating spheres used in the present system show significant azimuthal dependencies and reduce considerably the sensitivity of the system which does not allow to perform lamp calibrations with sufficient signal to noise levels. It is suggested to exchange the integrating sphere with a diffuser having better directional response characteristics and higher throughput.
2) The wavelength scale of the spectroradiometer is shifted to shorter wavelengths by 0.7 to 0.9 nm and requires a new calibration. This should be performed by measuring spectral discharge lamps and determining a new dispersion relation for the relationship between wavelength and motor steps.
3) The input selector introduces scan to scan variabilities of ±10% and needs to be improved. The operation in a permanently fixed position as during the second part of the campaign could remove this variability.
4) The absolute irradiance calibration should be based on a set of at least three irradiance reference lamps directly traceable to the irradiance references held at national metrological institutes.
5) The slit width of the spectroradiometer should be set to a fixed position with a full width at half maximum of equal or less than 1 nm for solar ultraviolet radiation measurements.

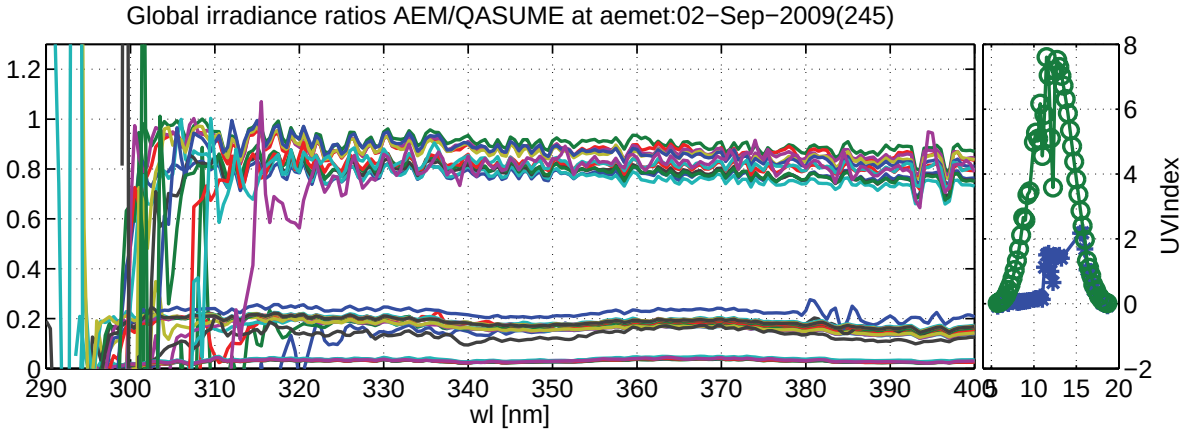
COMMENTS OF THE LOCAL OPERATOR

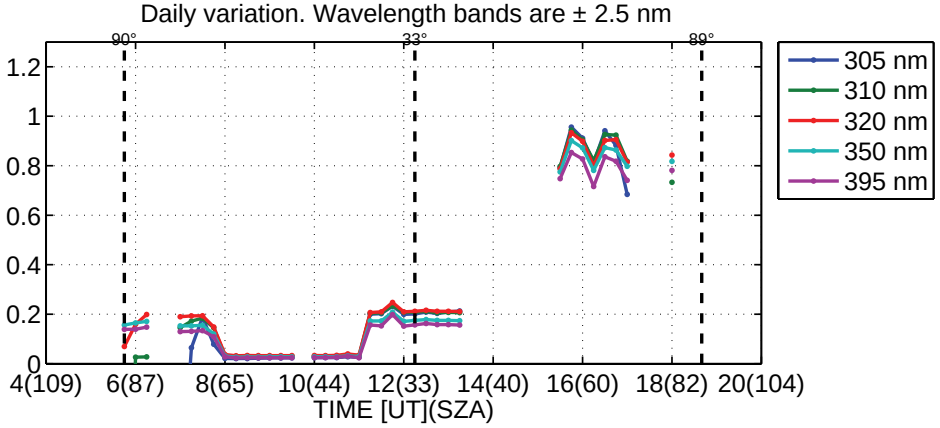
The Bentham DTM300 double monochromator was acquired by AEMET in 2004 so as to produce measurements of global, difuse and direct irradiance in the whole range of solar spectra.

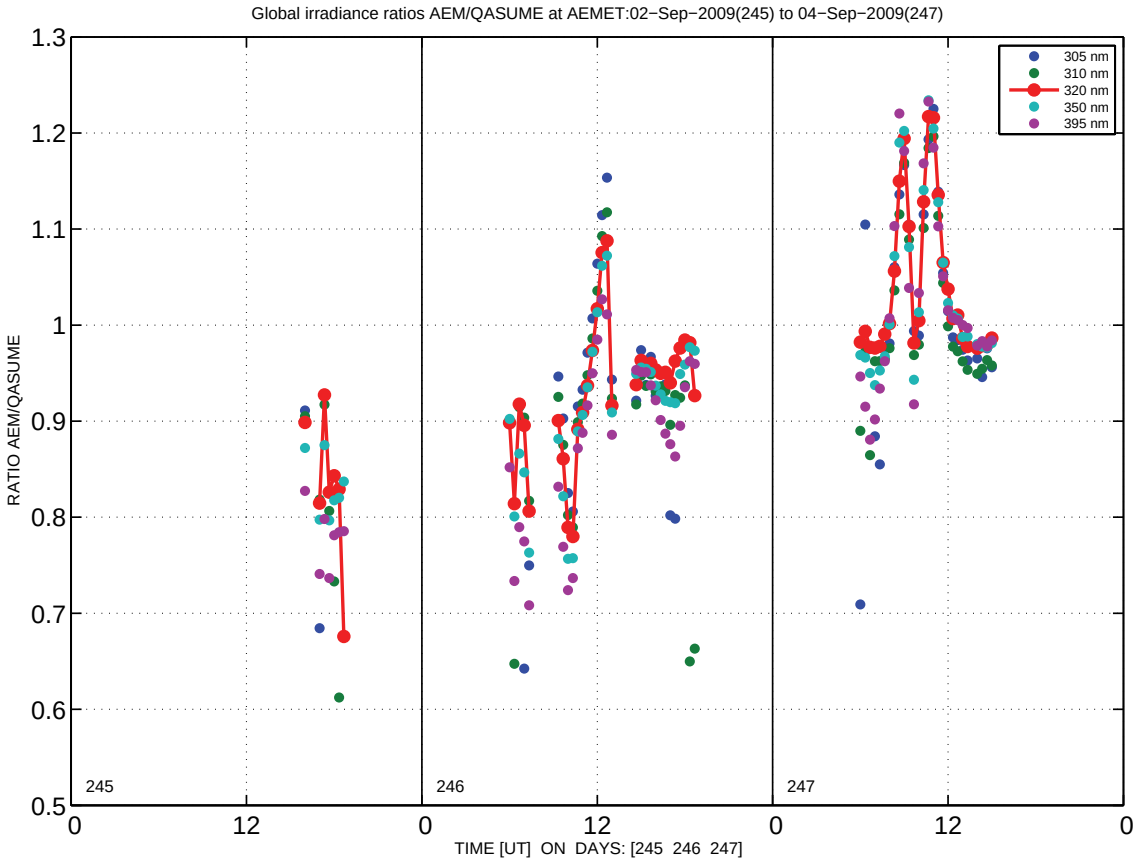
Due to the complexity of the instrument it has taken a lot of time to resolve different system problems and put it in operation.

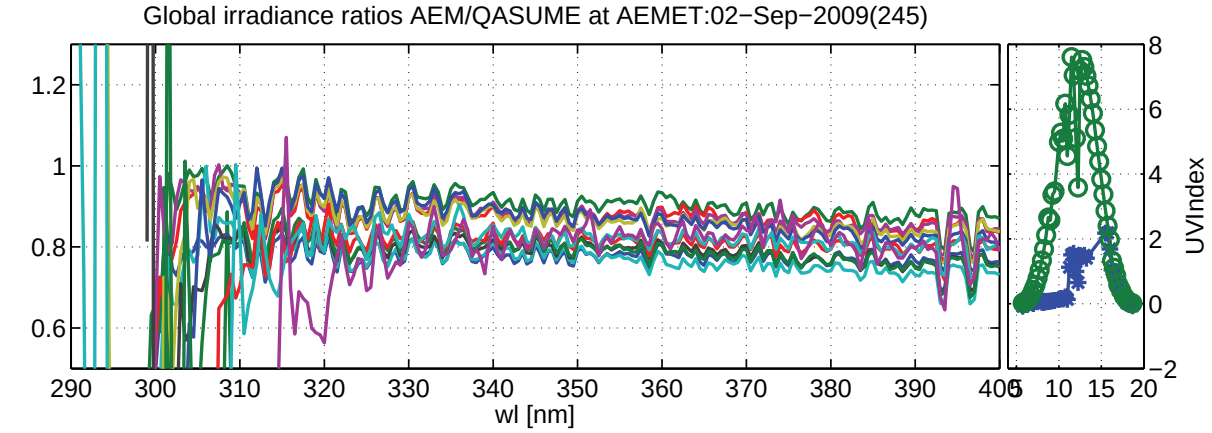
Once successful, AEMET asked for the visit of QASUME to explore the possibility of using DTM300 as a standard for the UV calibration. This visit has demonstrated that some aspects of the instrument design need to be improved for this purpose.

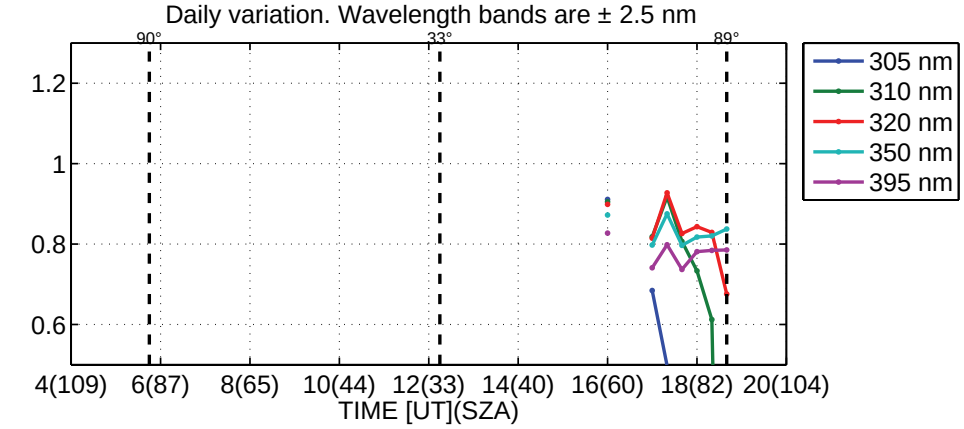

UV Index AEMET Madrid, September 2009
AEM
QASUME
UV Index
Day of Year
0
1
2
3
4
5
6
7
8
9
245
245.5
246
246.5
247
247.5
248

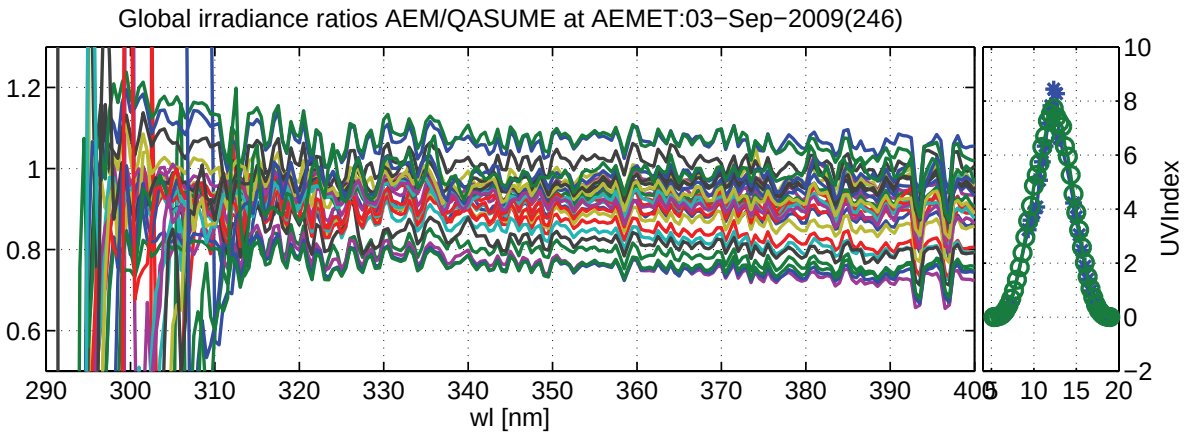

Global irradiance ratios AEM/QASUME at aemet:02−Sep−2009(245)
wl [nm]
UVIndex
0
0.2
0.4
0.6
0.8
1
1.2
290
300
310
320
330
340
350
360
370
380
390
405
−2
0
2
4
6
8
5
10
15
20

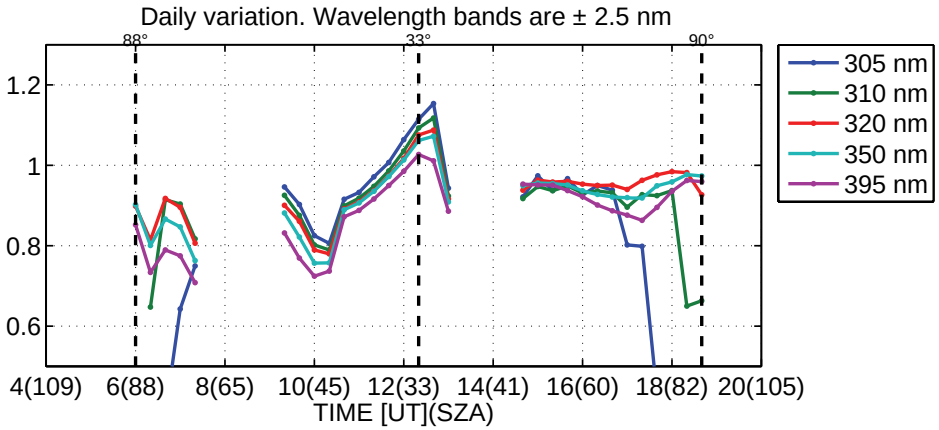

Daily variation. Wavelength bands are ± 2.5 nm
90°
33°
89°
305 nm
310 nm
320 nm
350 nm
395 nm
0
0.2
0.4
0.6
0.8
1
1.2
4(109)
6(87)
8(65)
10(44)
12(33)
14(40)
16(60)
18(82)
20(104)
TIME [UT](SZA)

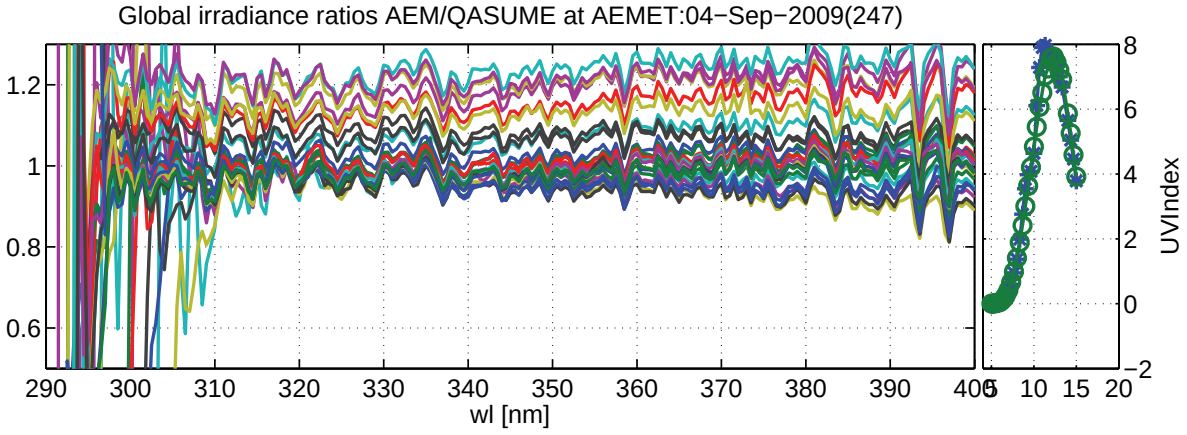

Global irradiance ratios AEM/QASUME at AEMET:02−Sep−2009(245) to 04−Sep−2009(247)
RATIO AEM/QASUME
TIME [UT] ON DAYS: [245 246 247]
305 nm
310 nm
320 nm
350 nm
395 nm
245
246
247

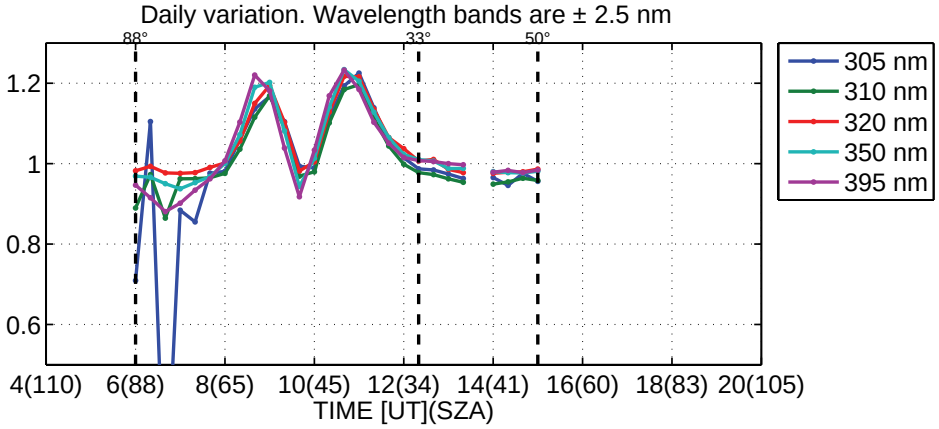

Global irradiance ratios AEM/QASUME at AEMET:02−Sep−2009(245)
wl [nm]
UVIndex

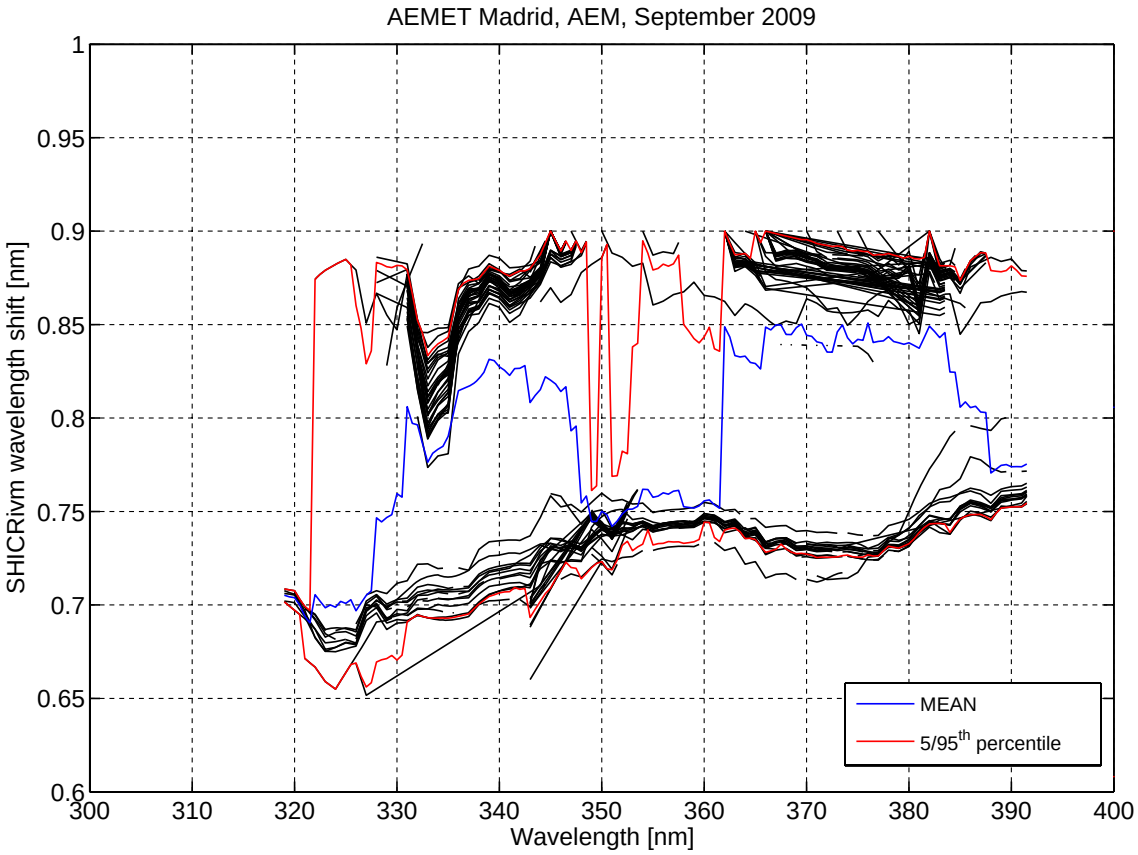

Daily variation. Wavelength bands are ± 2.5 nm
90°
33°
89°
TIME [UT](SZA)
305 nm
310 nm
320 nm
350 nm
395 nm

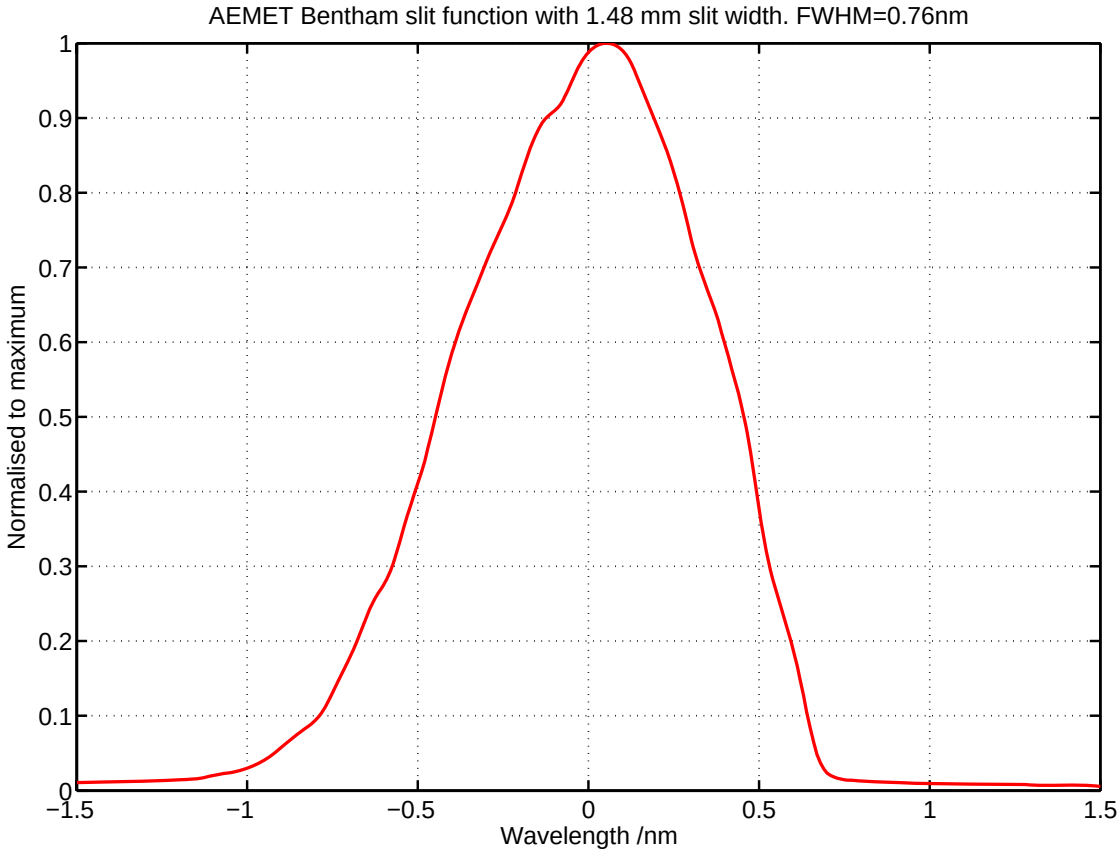

Global irradiance ratios AEM/QASUME at AEMET:03−Sep−2009(246)
wl [nm]
UVIndex

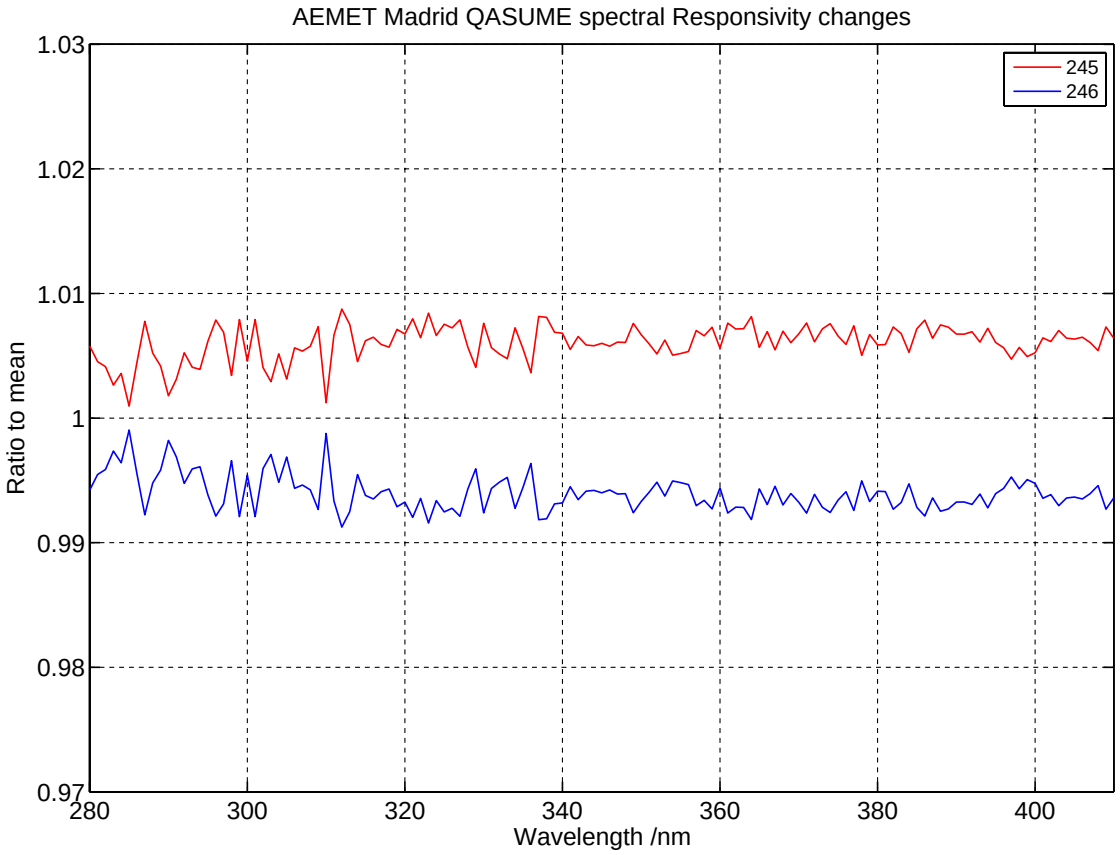

Daily variation. Wavelength bands are ± 2.5 nm
88°
33°
90°
305 nm
310 nm
320 nm
350 nm
395 nm
4(109) 6(88) 8(65) 10(45) 12(33) 14(41) 16(60) 18(82) 20(105)
TIME [UT](SZA)


Global irradiance ratios AEM/QASUME at AEMET:04−Sep−2009(247)
wl [nm]
UVIndex


Daily variation. Wavelength bands are ± 2.5 nm
88°
33°
50°
305 nm
310 nm
320 nm
350 nm
395 nm
4(110) 6(88) 8(65) 10(45) 12(34) 14(41) 16(60) 18(83) 20(105)
TIME [UT](SZA)


AEMET Madrid, AEM, September 2009
SHICRivm wavelength shift [nm]
Wavelength [nm]
MEAN
5/95th percentile


AEMET Bentham slit function with 1.48 mm slit width. FWHM=0.76nm
Normalised to maximum
Wavelength /nm


AEMET Madrid QASUME spectral Responsivity changes
245
246
Ratio to mean
1.03
1.02
1.01
1
0.99
0.98
0.97
280
300
320
340
360
380
400
Wavelength /nm


QASUME
AEMET Bentham
Diffuse
Global
BREWER