Protocol of the intercomparison at AEMET, Madrid, Spain on June 5 to June 10, 2015 with the travelling reference spectroradiometer QASUME from PMOD/WRC

Report prepared by Luca Egli

Operator: Luca Egli

The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer AEM and Brewer spectrophotometer 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 680 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 in the evening of June 5, 2015. The spectroradiometer was installed next to the AEM spectroradiometer and Brewer spectrophotometer with the entrance optic of QASUME within 2 m to the other instrument. The spectroradiometer in use at AEMET is a Bentham DM300 double monochromator system. The input optics is from CMS Schreder. The Brewer Spectrometer is a double monochromator MkIII with the ID 186. No comparison was carried out to the second Brewer #070. The intercomparison between QASUME and the AEMET spectroradiometers lasted four days, from afternoon of June 6 to the evening of June 9.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Three lamps (T68522, T68523 and T61253) 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 3 days of the intercomparison period (Day of year 157, 159, 160). Day 158 showed approx. 2% lower responsivity, which was stable during that day. To account for the responsivity change, the responsivity was calculated for each day separately and used for that specific day. The diurnal drift of the responsivity of around 2% was compensated with lamp calibrations in the morning and evening. The diurnal trend was also calculated and applied for each day separately. The internal temperature of QASUME was 28.01±0.07 °C and the diffuser head was heated to a temperature of 35.33±3.39 °C. The diffusor heating temporarily failed in the evening of the last day (160). However the temperature was above 21°C and a diffusor temperature compensation was applied. Note that single peaks of the diffusor temperature are due to the KS lamp calibrations.
The wavelength shifts relative to an extraterrestrial 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)
156	05. Jun	Friday	Clear sky with Cirrus	Installed at 16:15
157	06. Jun	Saturday	Clear sky with few Cirrus	6:04 calibration (T68523) 6:04 calibration (T68523) 22:13 F386 measured on roof
158	07. Jun	Sunday	Clear sky	6:32 calibration (T68523) 7:31 measuring KS072 12:32 calibration (T68523) 15:33 calibration (T68523)
159	08. Jun	Monday	Clear sky	6:32 calibration (T68523) 7:30 calibration (T61253) 15:32 calibration (T68523)
160	09. Jun	Tuesday	Overcast	7:32 calibration (T68523) 8:12 KS055 8:44 KS071 9:15 KS072 14:32 calibration (T68523) 15:02 calibration (T68522)
161	10. Jun	Wednesday	Overcast	End of Campaign: 5:00

Results:

In total 107 synchronised simultaneous spectra from QASUME and AEM, respectively 105 spectra from 186 are available from the measurement period. Measurements between 5:00 and 20:00 UT have been analysed (SZA smaller than 90°).

Remarks:

I. AEM:

1. Lamp calibrations:
    a. Saturday night, 6 June, the AEM system was calibrated using a 1000 W FEL lamp F386 (Gigahertz), which is certified by PMOD/WRC. The calibration was performed outdoor on the roof of AEMET. The measurement was verified using QASUME reference spectroradiometer showing that the setup allows reproducing the calibration within 1%.

    b. The Aemet 200 W transfer standards KS055, KS071, KS072 where also measured with QASUME, showing that all 3 lamps are within 1% uncertainty. The comparison with the PMOD/WRC portable transfer standard lamp showed that all 3 KS lamps show a bias from 0% for wavelength around 290 nm with an upward trend of about 2% with increasing wavelength (400 nm). This bias is still within the uncertainty of the certificate for the KS lamps.

    c. The sun spectra calibrated with KS072 showed a 1-2% lower irradiance compared to QASUME due to the higher responsivity when using KS lamps. This was expected due to the results of point b. The corresponding analysis is not shown in this report and was not used for the certificate.

    d. The final dataset of AEMET is based on the F386 FEL calibration.

2. The ratios between AEM and QASUME have on average an offset of -1 %.
3. The diurnal variation of the AEM to QASUME ratio is less than 3 %. The ratios AEM to QASUME show a dip in the morning and in the evening, as in the previous campaign in 2013. The reason is still unknown.
4. For all solar scans the wavelength shifts of the AEM show a shift of +100 to + 150 pm, which was stable during the comparison period.

I. Brewer #186:

1. Brewer #186 was compared relative to QASUME in May/June 2015 at El Arenosillo during the 10th RBCC-E. The Brewer was re-installed at AEMET Madrid in June.
2. The ratios between the AEM and QASUME is about 1% lower to the calibration carried out at the RBCC-E:
    a. The average offset is -7 %. At El Arenosillo the averaged offset was about -6%. This difference is acceptable.
    b. A re-calibration of the Brewer #186 with a 1000W lamp after the campaign at Aemet showed an averaged offset of -7%, indicating that the calibration of El Arenosillo is acceptable.
    c. The diurnal variation of the #186 to QASUME ratio is around 4 %.

3. The certificate will be given for the campaign at El Arenosillo.

4. For all solar scans the wavelength shifts of the Brewer #186 show a shift of less than +50pm to -50pm.

Recommendation:

The setup for the 1000W lamp calibration on the roof has been shown as applicable for lamp calibration/comparison at Aemet. The irradiance scale based on the F386 FEL can now be transferred to the two un-calibrated FEL lamps of AEMET using this setup.
It is recommended to make the transfer to the 2 other FEL lamps at least at 2 different nights to ensure the reproducibility.

In the same procedure, the small bias of the CMS KS transfer standards can be recalibrated using the F386 FEL with the setup on the roof.

Once the KS lamps have been re-calibrated, they can be used to monitor and also to calibrate the system.

Following procedure for long term stability monitoring is recommended.

a. Once a year: Calibration with the 1000W lamp (F386).
b. Every 2 weeks or every month: monitoring with 1 KS lamp.
c. Comparison of the responsivity of the KS calibrations from the previous measurement.
d. If the responsivity varies more than +/- 1% from the previous measurement: A calibration with a second lamp is recommended.
e. If the second lamp agrees with the first lamp within 1%, the responsivity of the system changed and the KS lamp can be used for a re-calibration of the sensitivity.
f. If the second lamp is more than +/-1% biased, a third lamp can be used to determine which lamp might have changed.
g. If a lamp has changed, the KS lamp should be re-calibrated with the 1000 W FEL lamp F386.

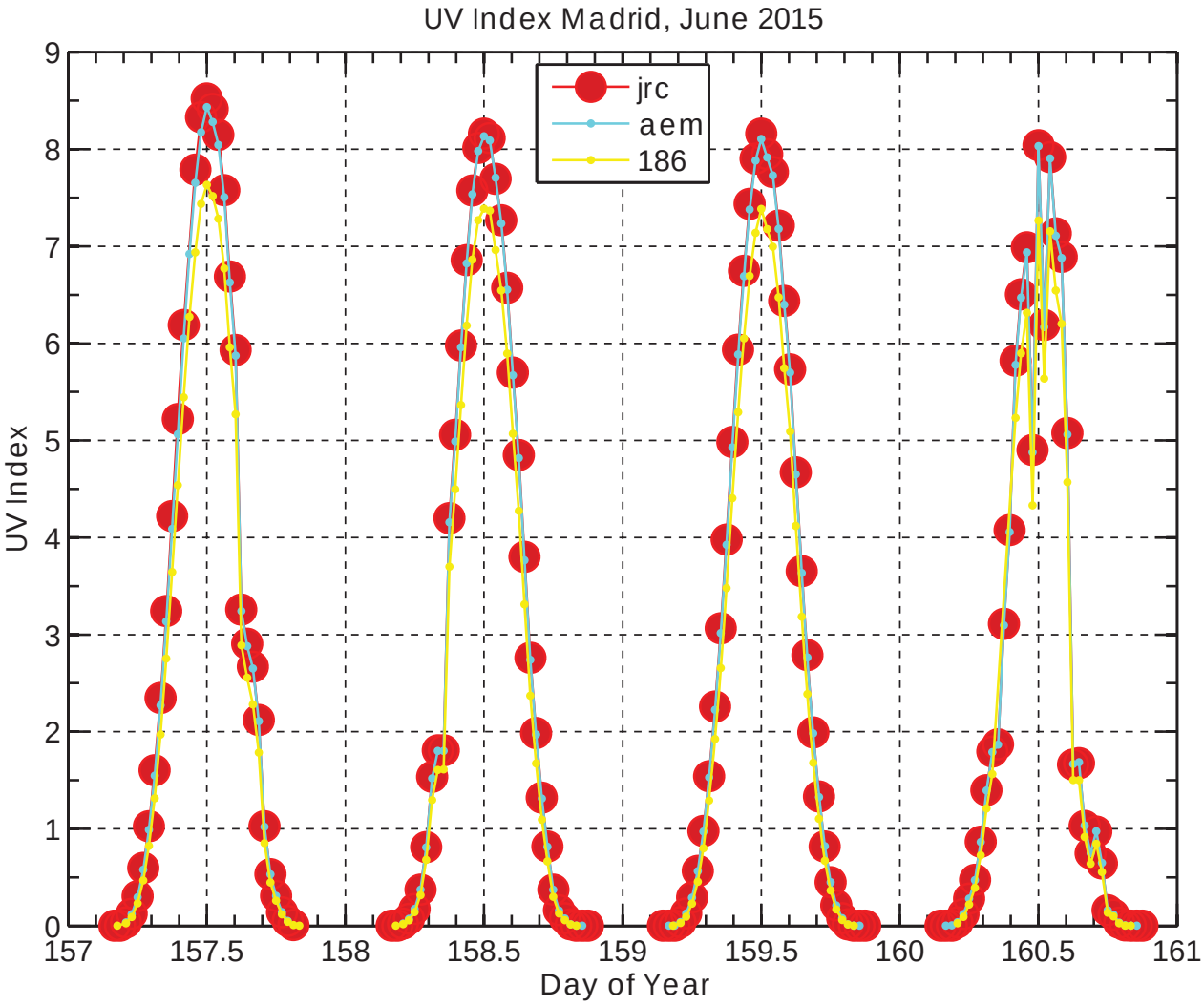
Between the KS lamp measurements the increase of the temperature of the input optic should minimized. This was successfully achieved during the comparison applying the recommendation of the previous report.

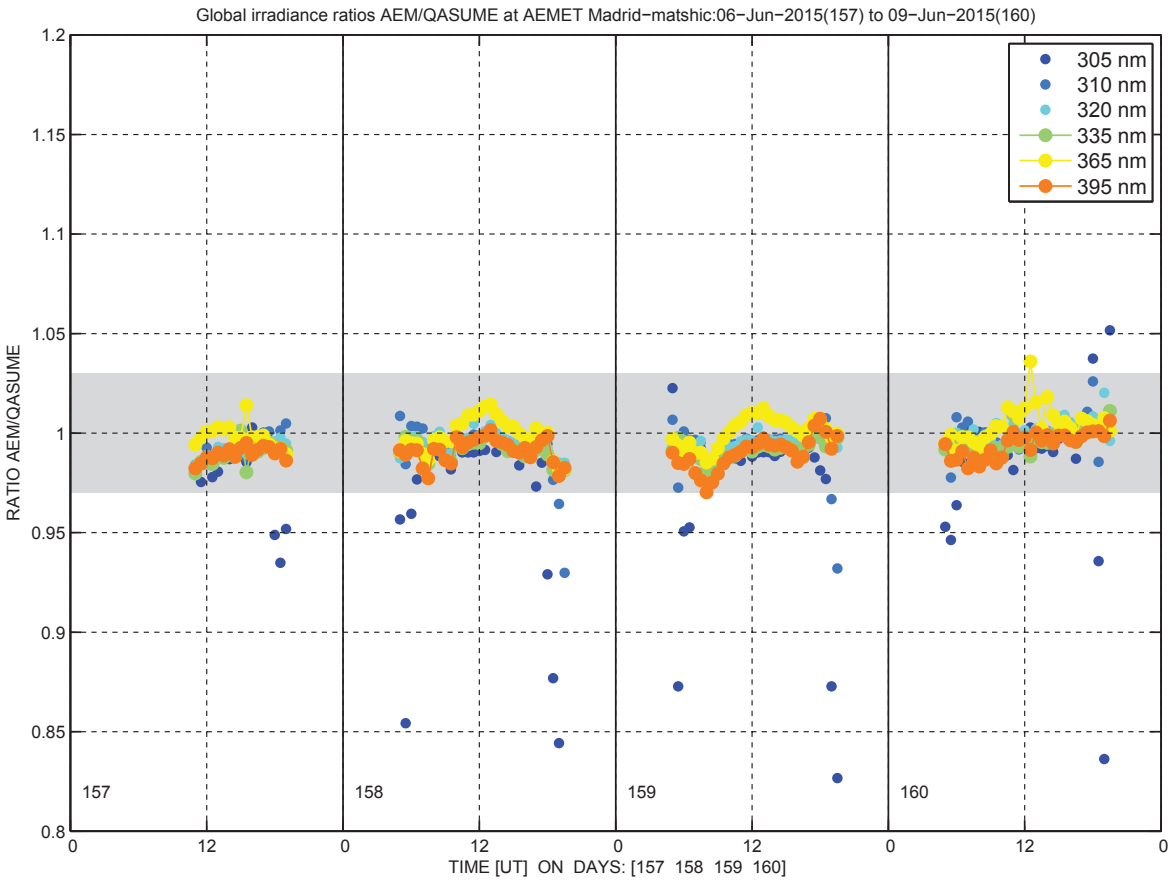
AEMET Operators:

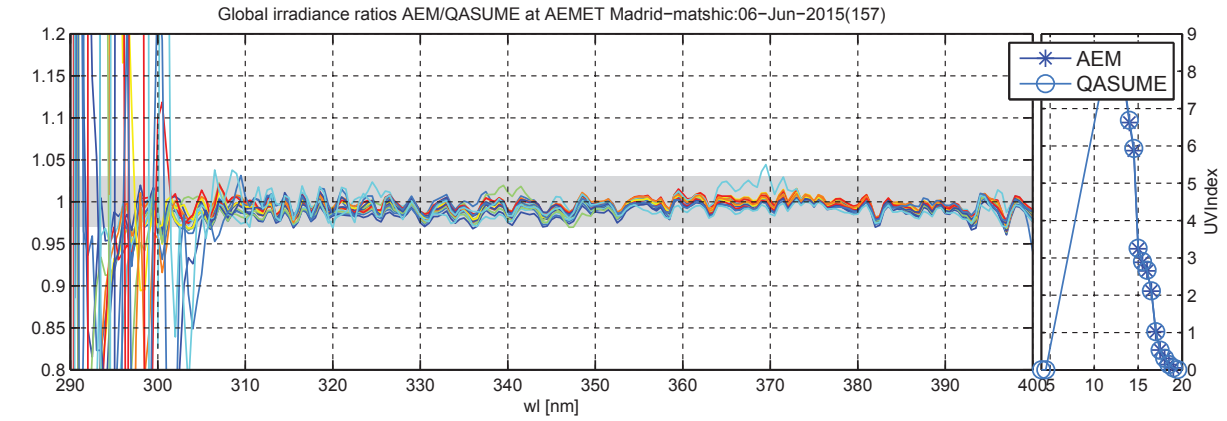
Ana Diaz
Juan Ramón Moreta
Irene Melero-Asensio
Dario Callau (AFC)

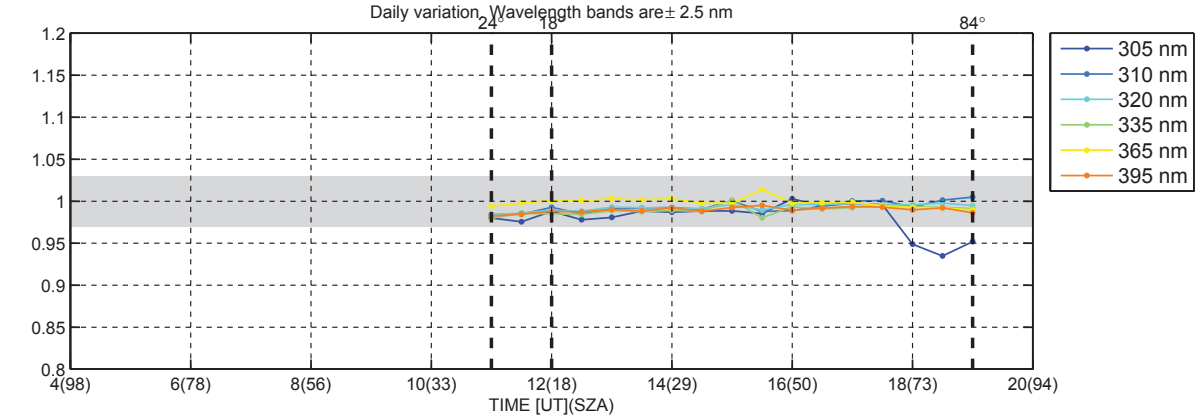
Comments by the Operator:

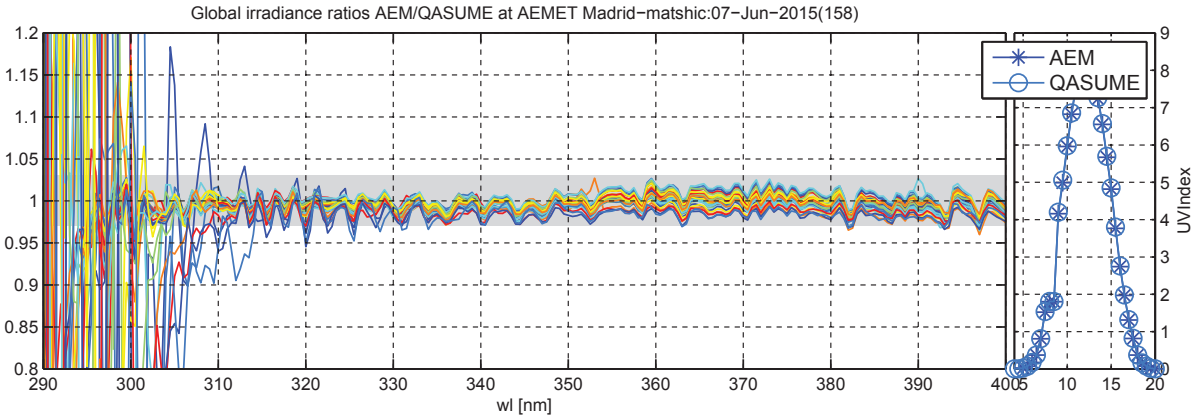
The local operators commented some minor issues of the preliminary report.

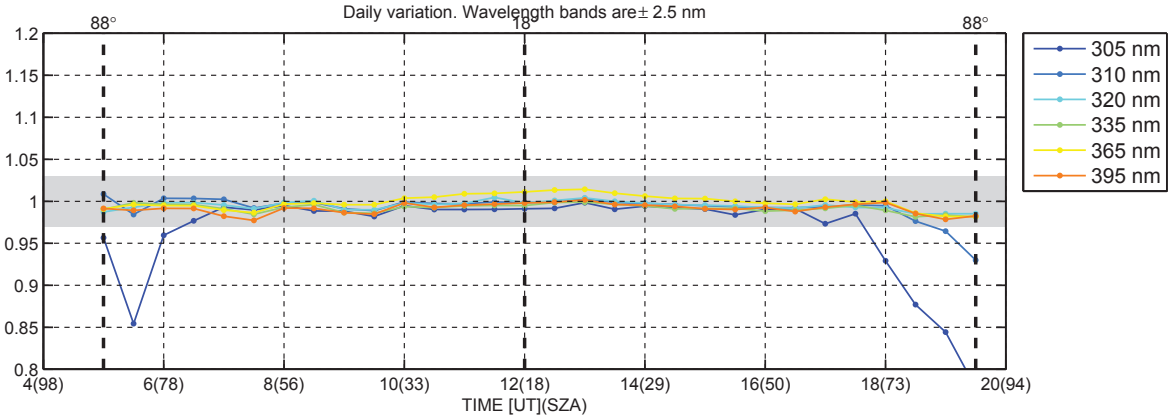

UV Index Madrid, June 2015
jrc
aem
186
UV Index
Day of Year
0
1
2
3
4
5
6
7
8
9
157
157.5
158
158.5
159
159.5
160
160.5
161

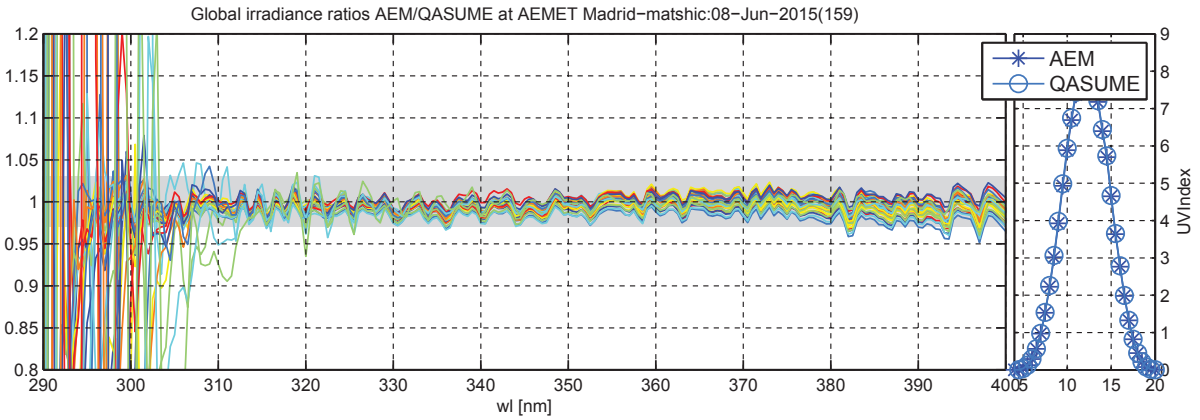

Global irradiance ratios AEM/QASUME at AEMET Madrid−matshic:06−Jun−2015(157) to 09−Jun−2015(160)
RATIO AEM/QASUME
TIME [UT] ON DAYS: [157 158 159 160]
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
157
158
159
160

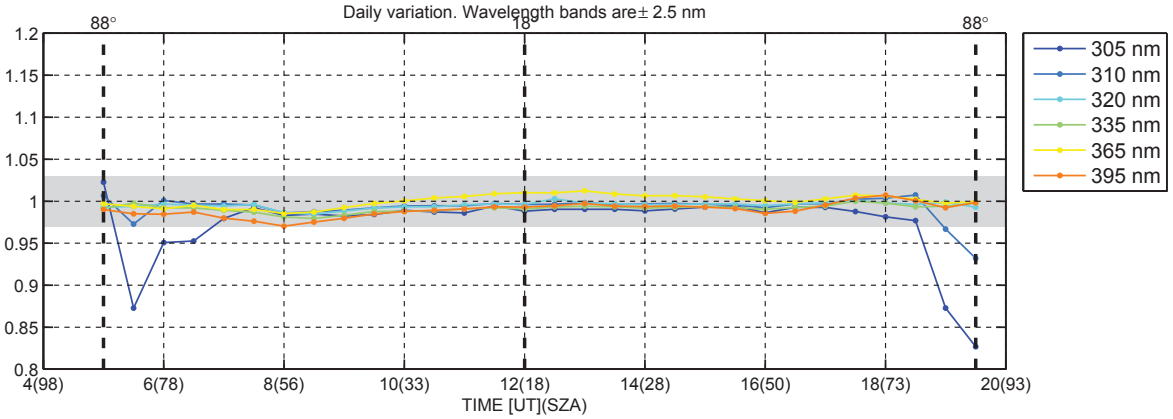

Global irradiance ratios AEM/QASUME at AEMET Madrid−matshic:06−Jun−2015(157)
AEM
QASUME
wl [nm]
UVIndex

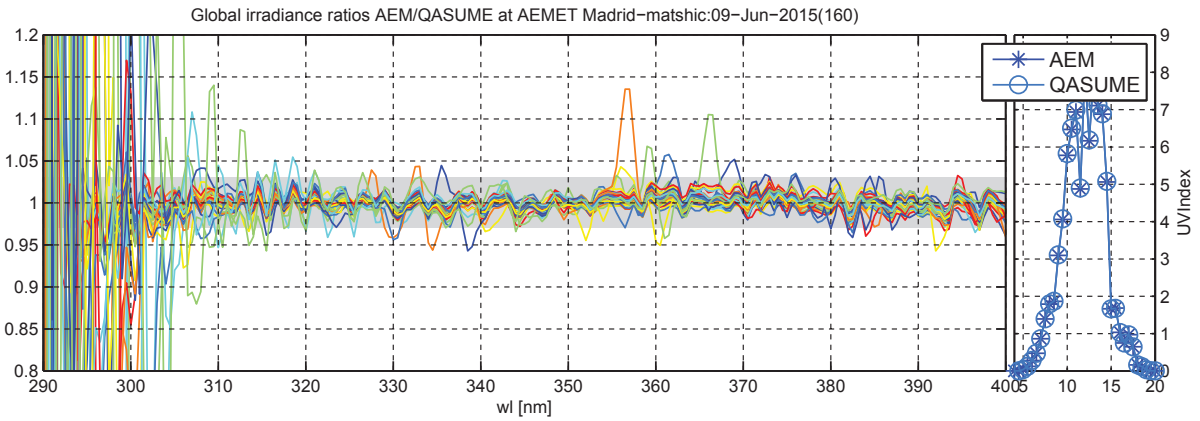

Daily variation, Wavelength bands are± 2.5 nm
24°
18°
84°
TIME [UT](SZA)
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm

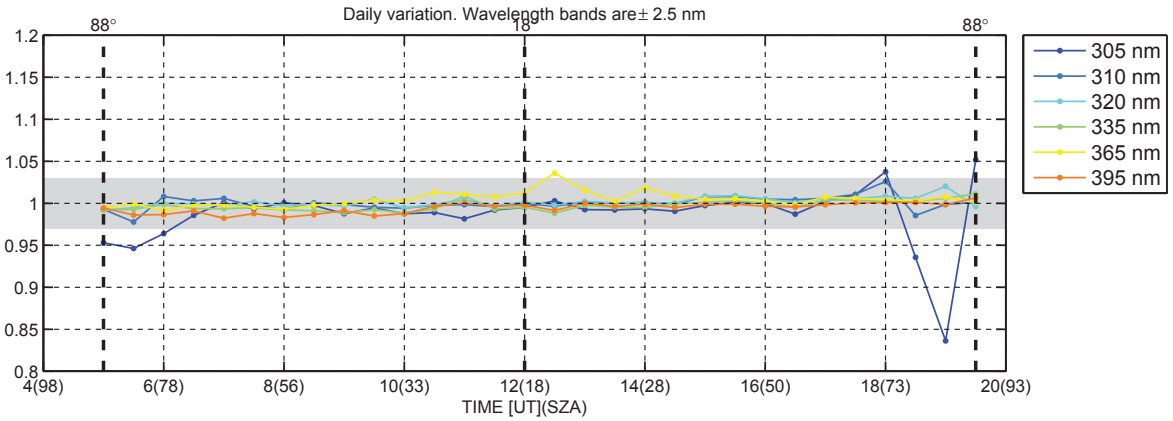

Global irradiance ratios AEM/QASUME at AEMET Madrid−matshic:07−Jun−2015(158)
AEM
QASUME
wl [nm]
UVIndex

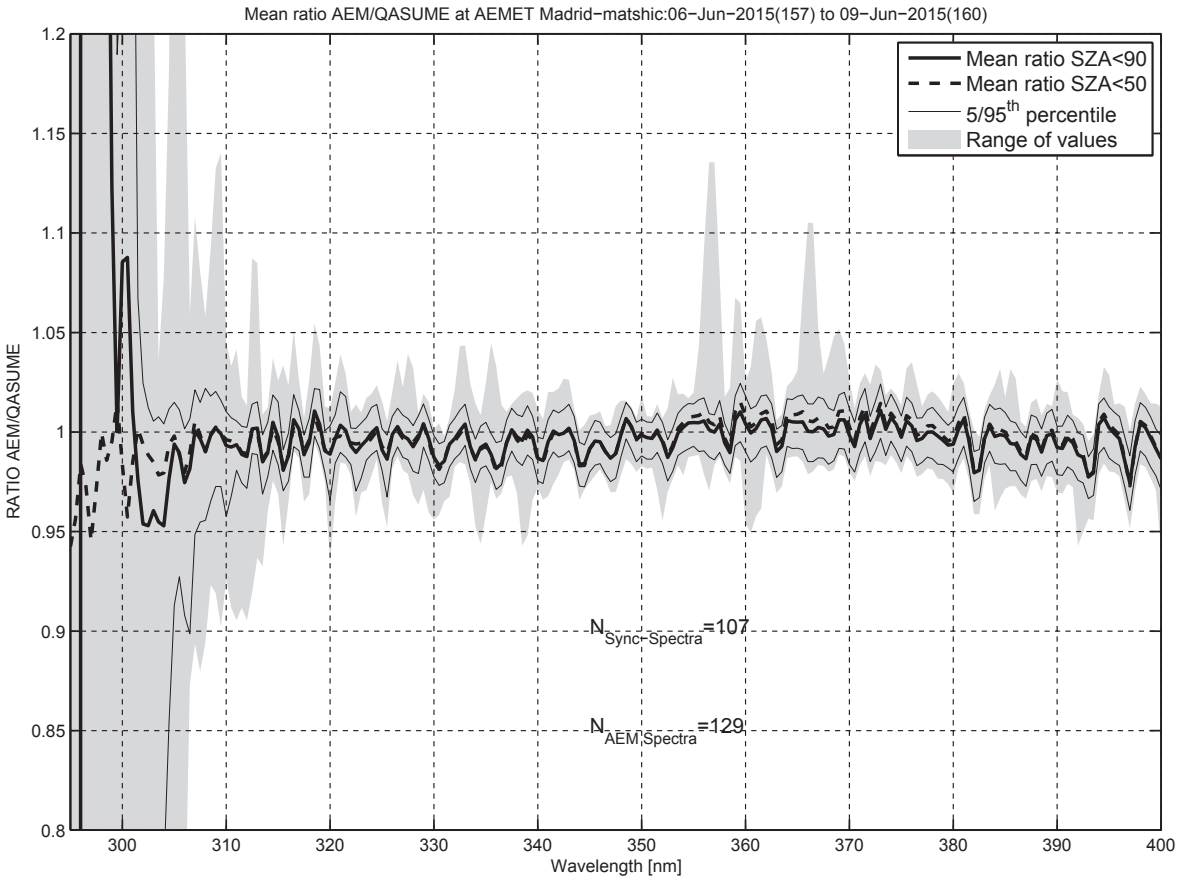

Daily variation. Wavelength bands are± 2.5 nm
88°
88°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)

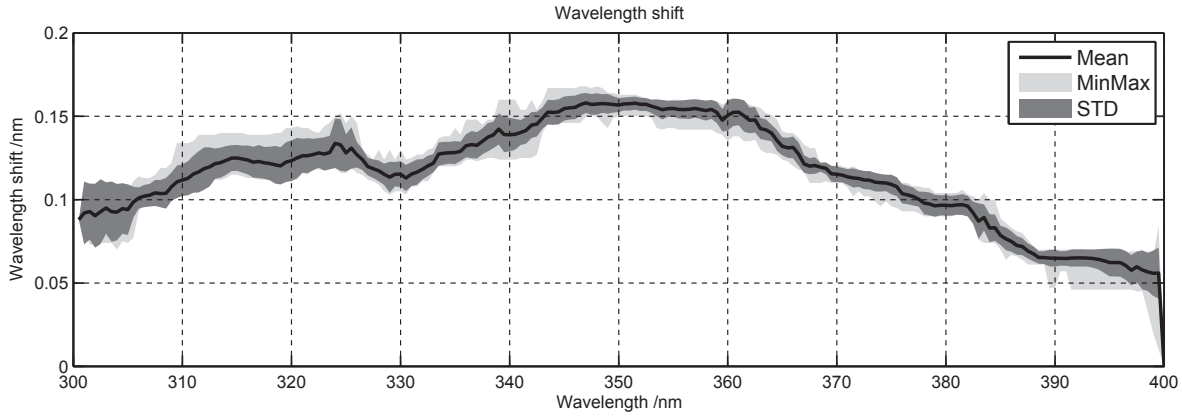

Global irradiance ratios AEM/QASUME at AEMET Madrid−matshic:08−Jun−2015(159)
AEM
QASUME
wl [nm]
UVIndex

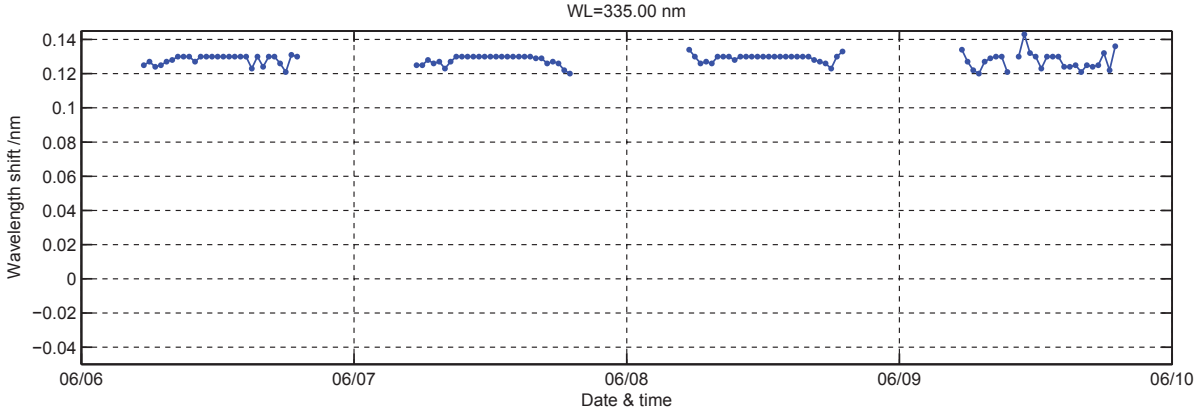

Daily variation. Wavelength bands are± 2.5 nm
88°
88°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)

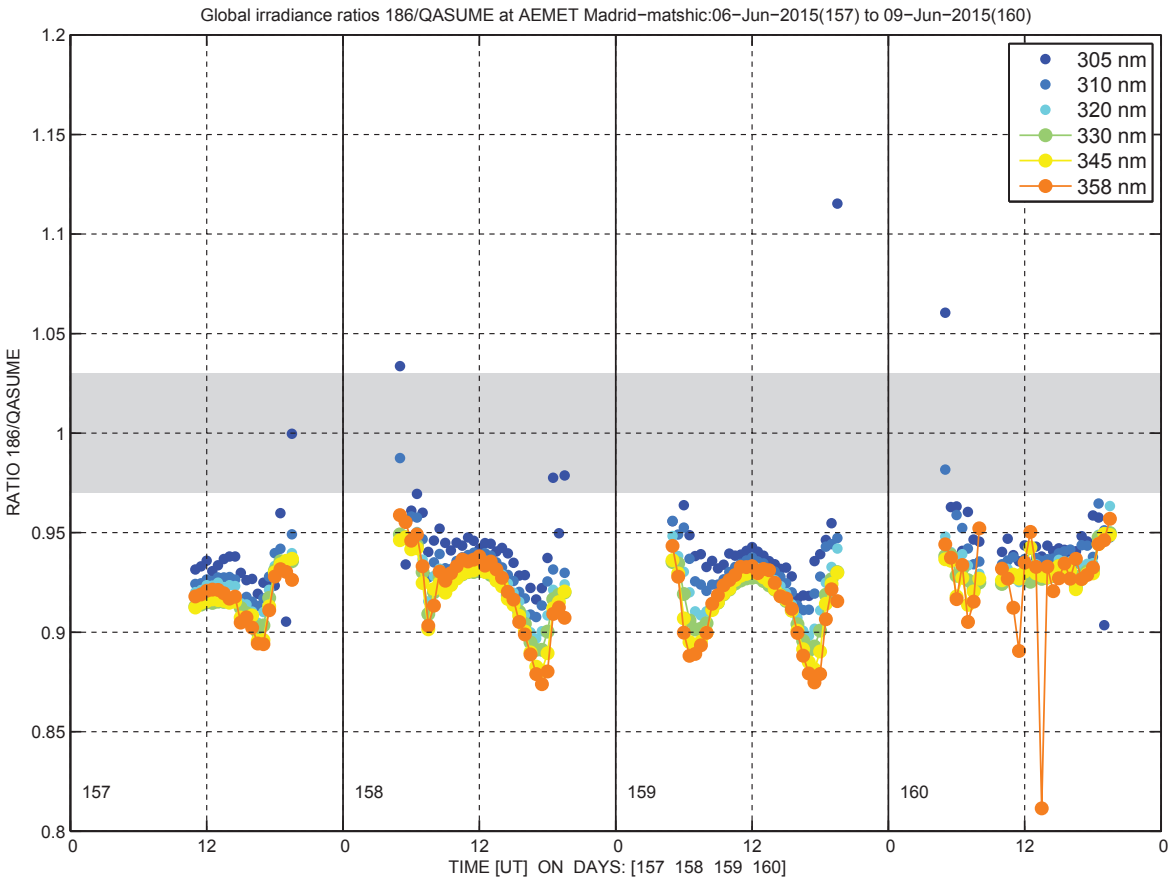

Global irradiance ratios AEM/QASUME at AEMET Madrid−matshic:09−Jun−2015(160)
AEM
QASUME
wl [nm]
UVIndex

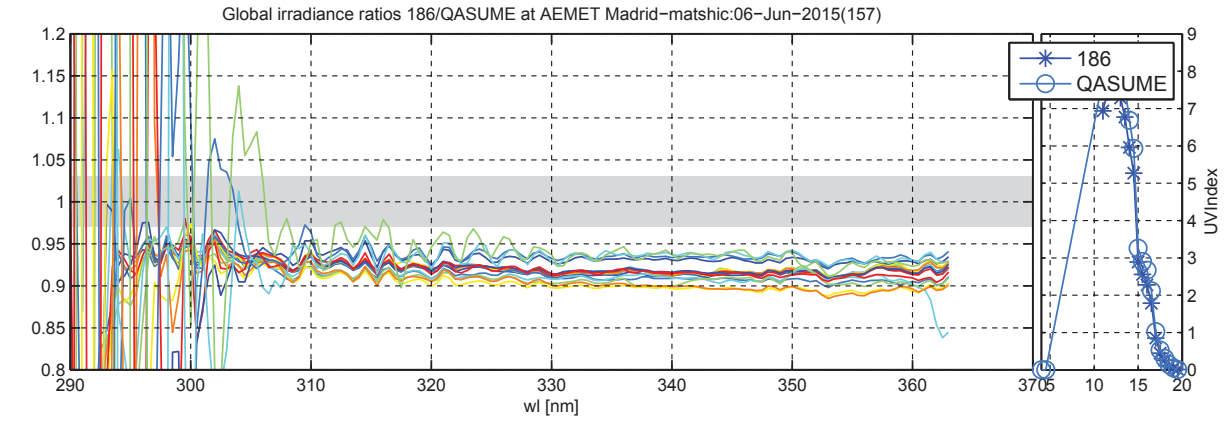

Daily variation. Wavelength bands are± 2.5 nm
88°
88°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)

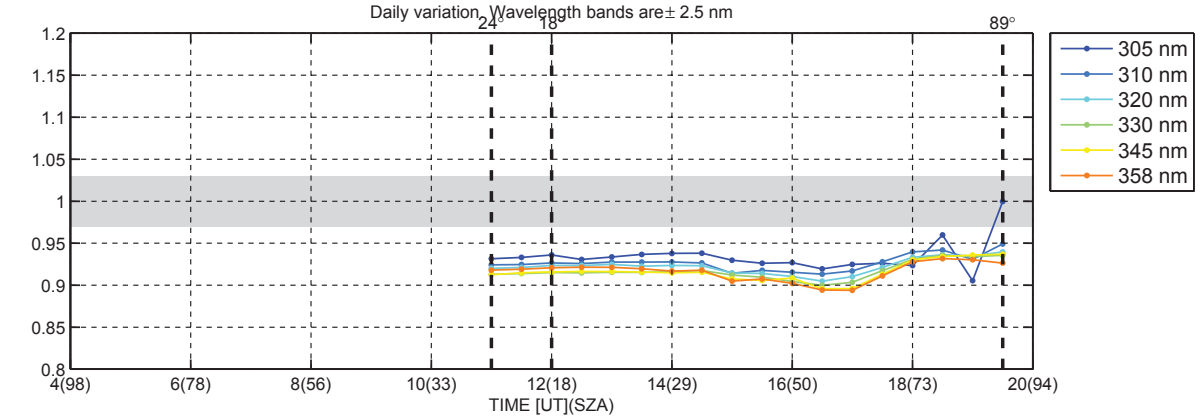

Mean ratio AEM/QASUME at AEMET Madrid−matshic:06−Jun−2015(157) to 09−Jun−2015(160)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO AEM/QASUME
N Sync−Spectra =107
N AEM Spectra =129
Wavelength [nm]

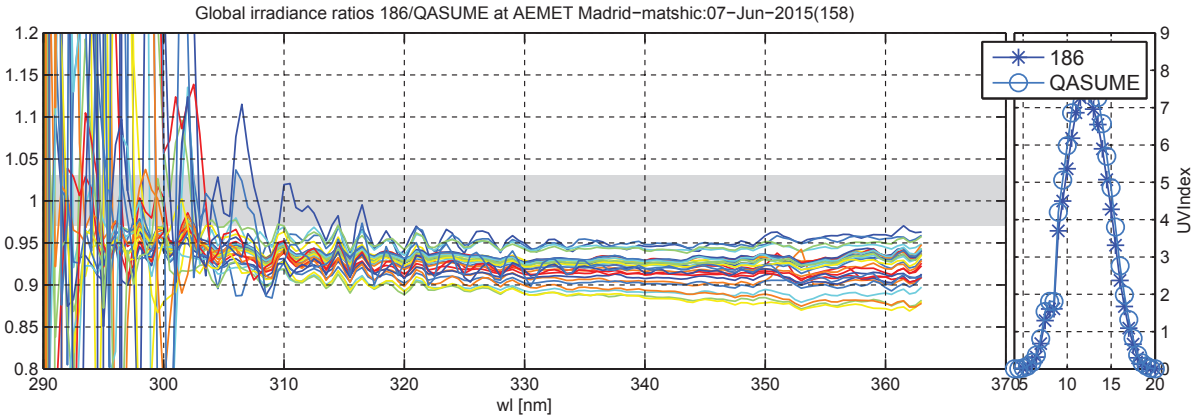

Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
Wavelength /nm
0.2
0.15
0.1
0.05
0
300
310
320
330
340
350
360
370
380
390
400

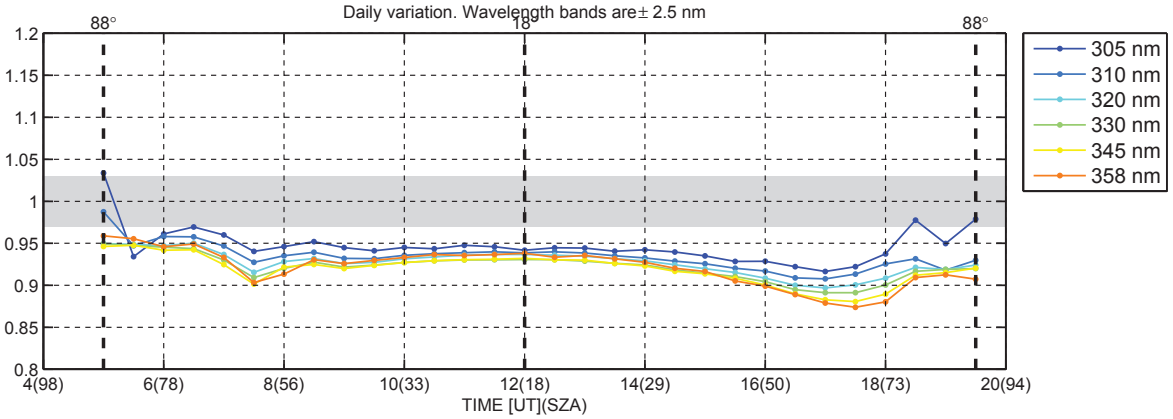

WL=335.00 nm
Wavelength shift /nm
Date & time
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
06/06
06/07
06/08
06/09
06/10

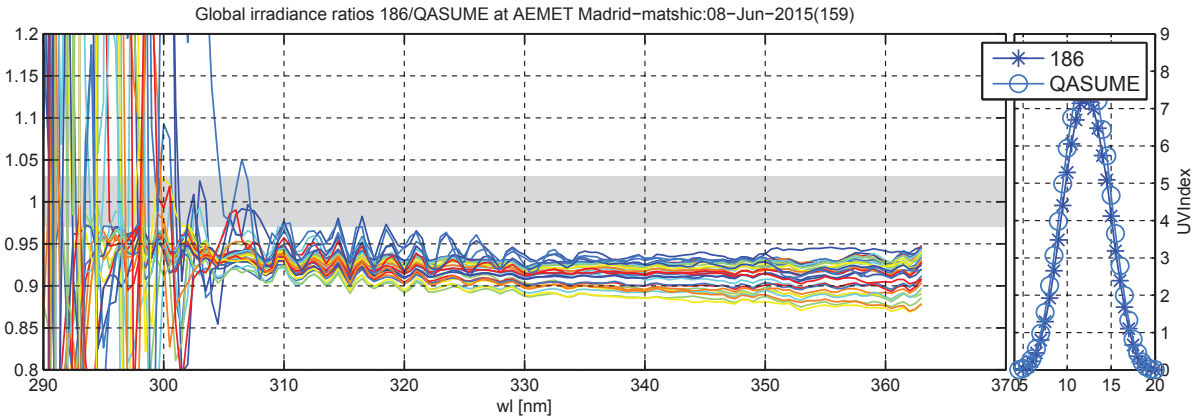

Global irradiance ratios 186/QASUME at AEMET Madrid−matshic:06−Jun−2015(157) to 09−Jun−2015(160)
RATIO 186/QASUME
TIME [UT] ON DAYS: [157 158 159 160]
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
157
158
159
160

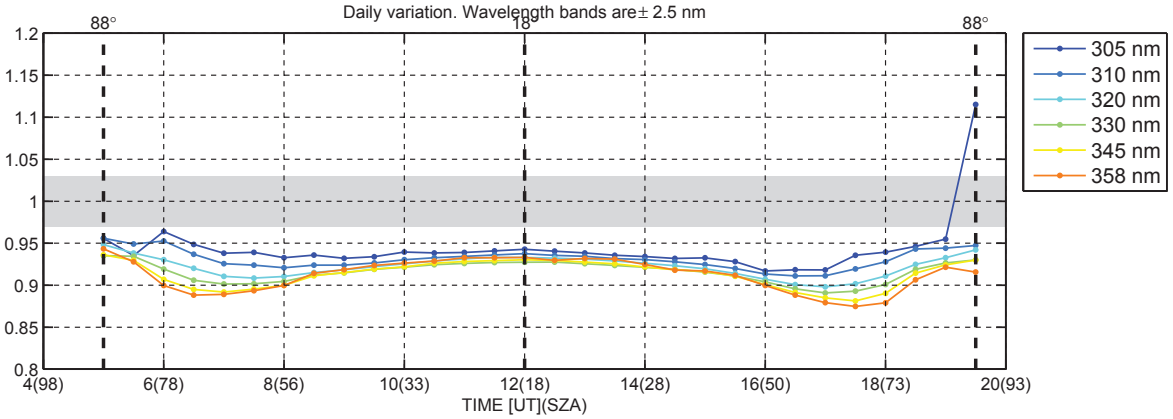

Global irradiance ratios 186/QASUME at AEMET Madrid−matshic:06−Jun−2015(157)
186
QASUME
wl [nm]
UVIndex

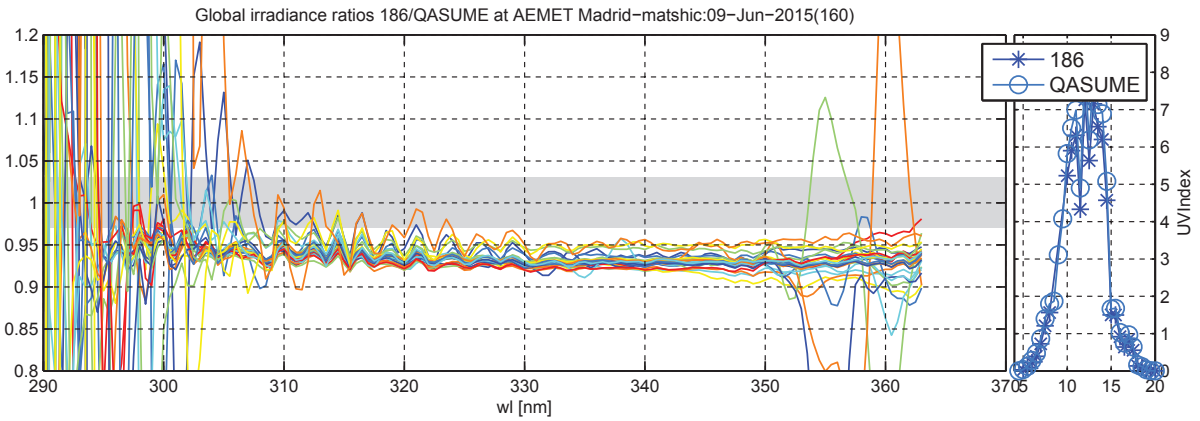

Daily variation, Wavelength bands are± 2.5 nm
24°
18°
89°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

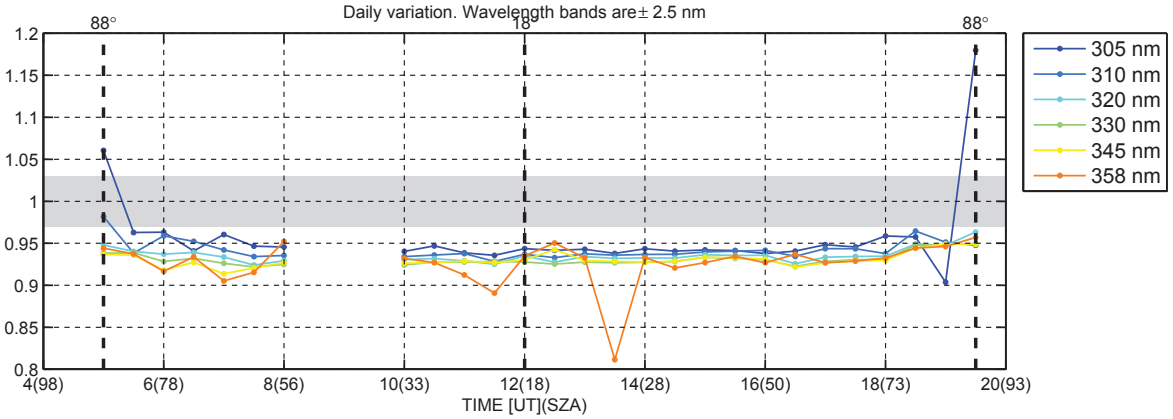

Global irradiance ratios 186/QASUME at AEMET Madrid−matshic:07−Jun−2015(158)
186
QASUME
UVIndex
wl [nm]

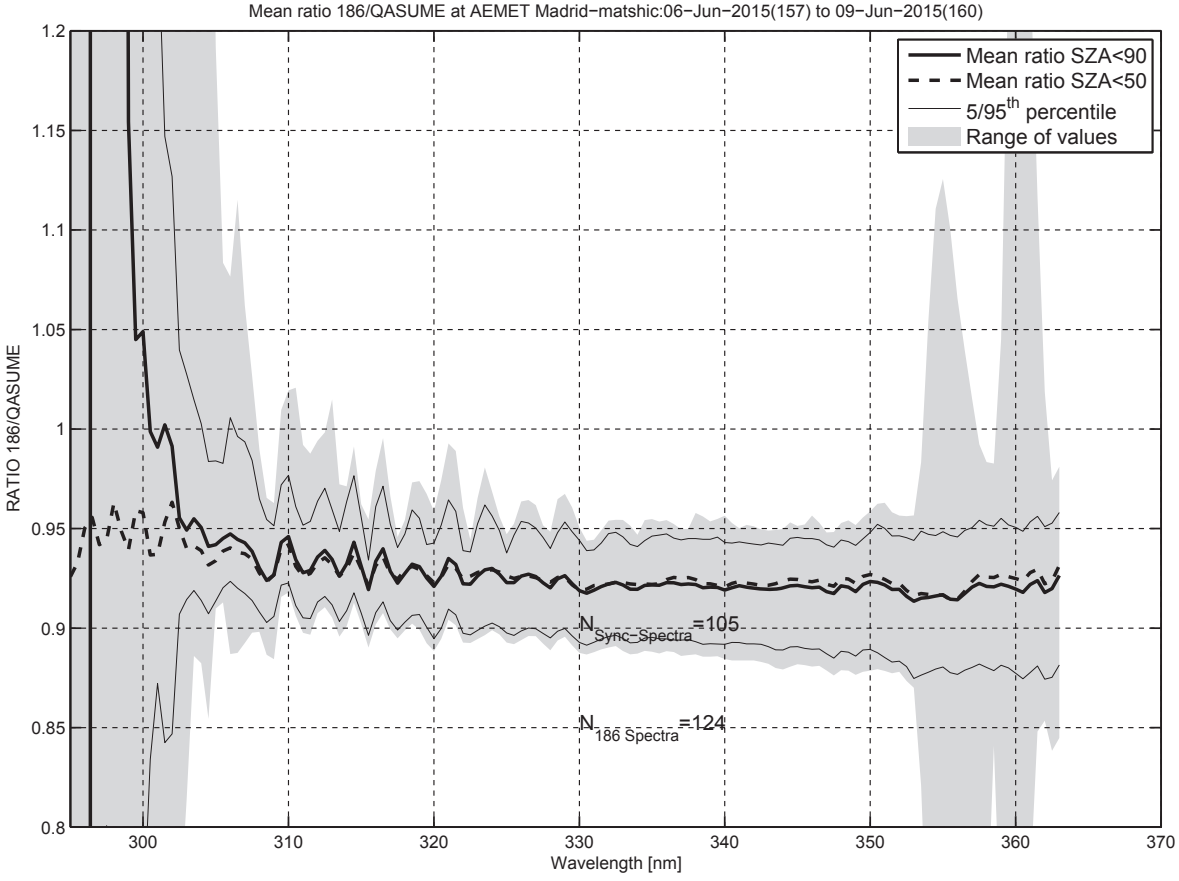

Daily variation. Wavelength bands are± 2.5 nm
88°
18°
88°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
4(98)
6(78)
8(56)
10(33)
12(18)
14(29)
16(50)
18(73)
20(94)
TIME [UT](SZA)

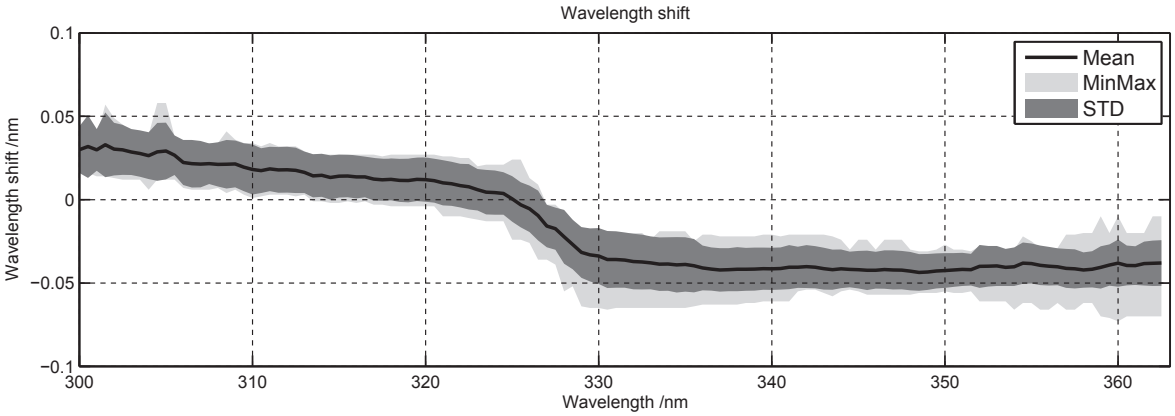

Global irradiance ratios 186/QASUME at AEMET Madrid−matshic:08−Jun−2015(159)
186
QASUME
UVIndex
wl [nm]

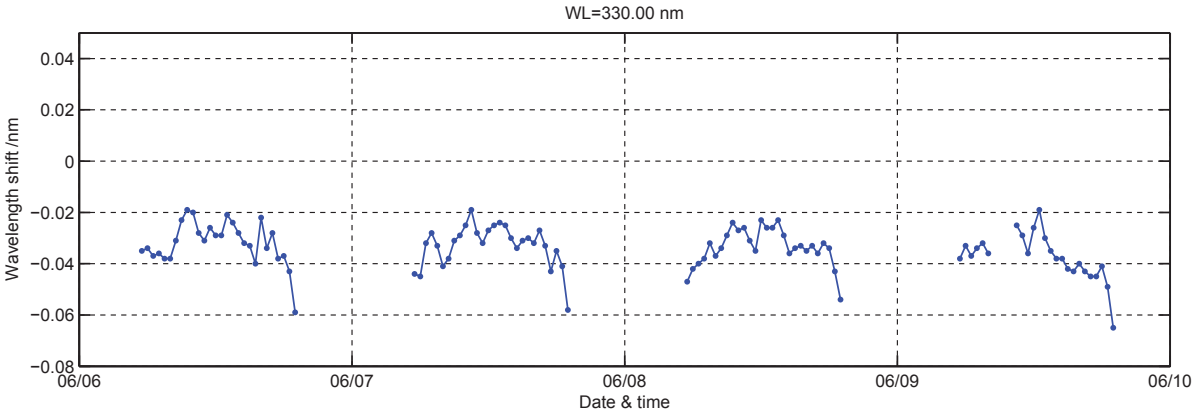

Daily variation. Wavelength bands are± 2.5 nm
88°
18°
88°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
4(98)
6(78)
8(56)
10(33)
12(18)
14(28)
16(50)
18(73)
20(93)
TIME [UT](SZA)

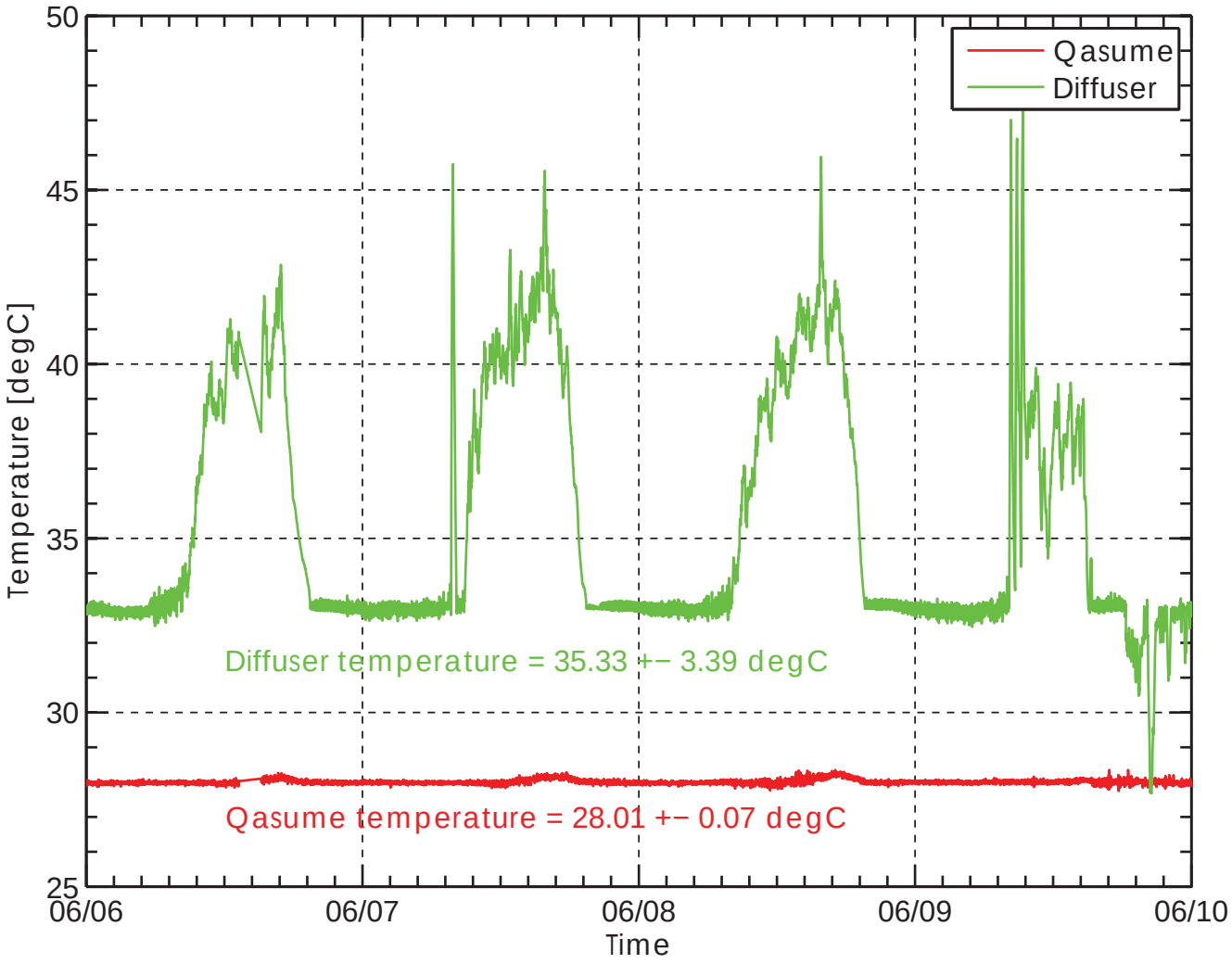

Global irradiance ratios 186/QASUME at AEMET Madrid−matshic:09−Jun−2015(160)
186
QASUME
wl [nm]
UVIndex

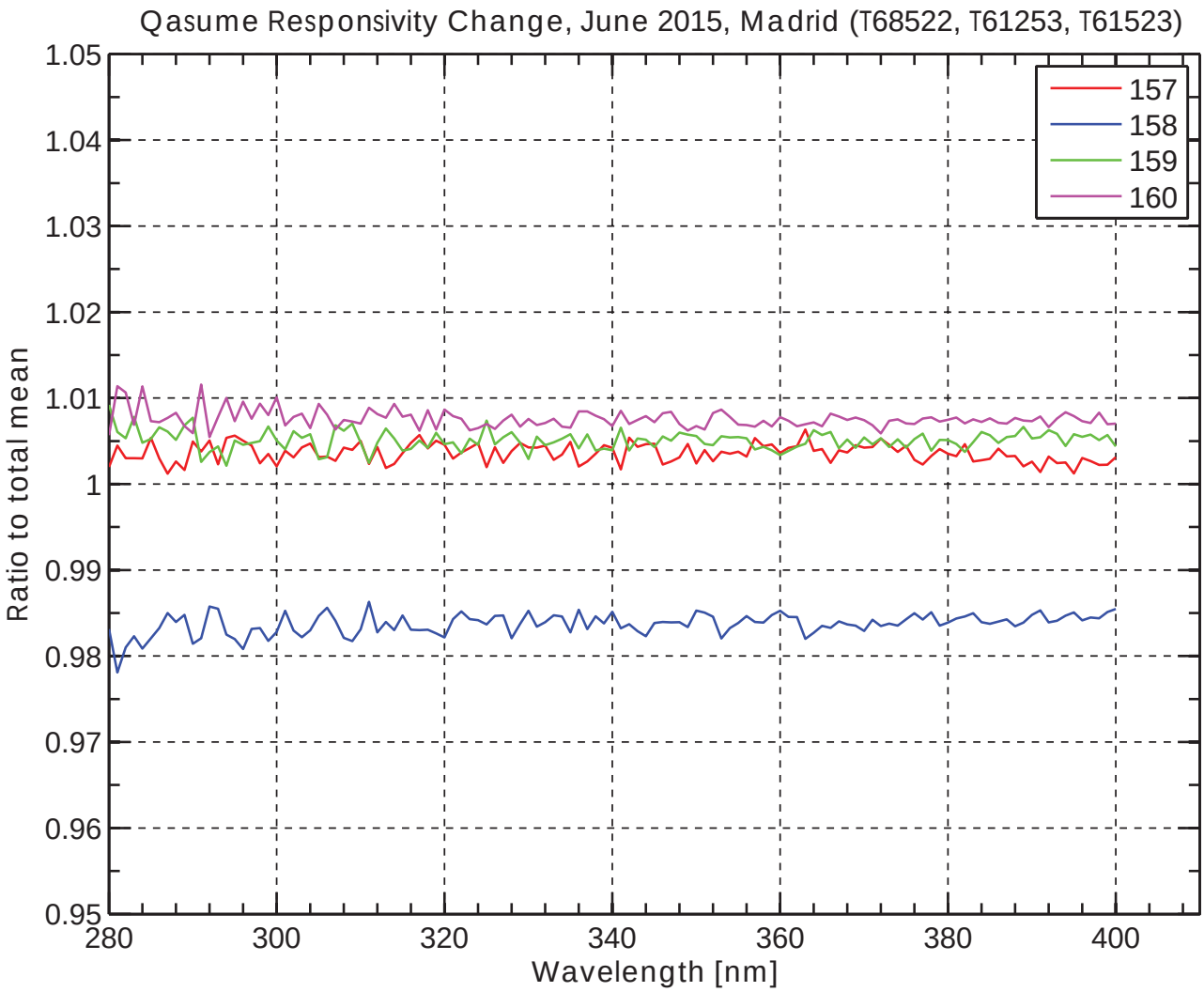

Daily variation. Wavelength bands are± 2.5 nm
88°
18°
88°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

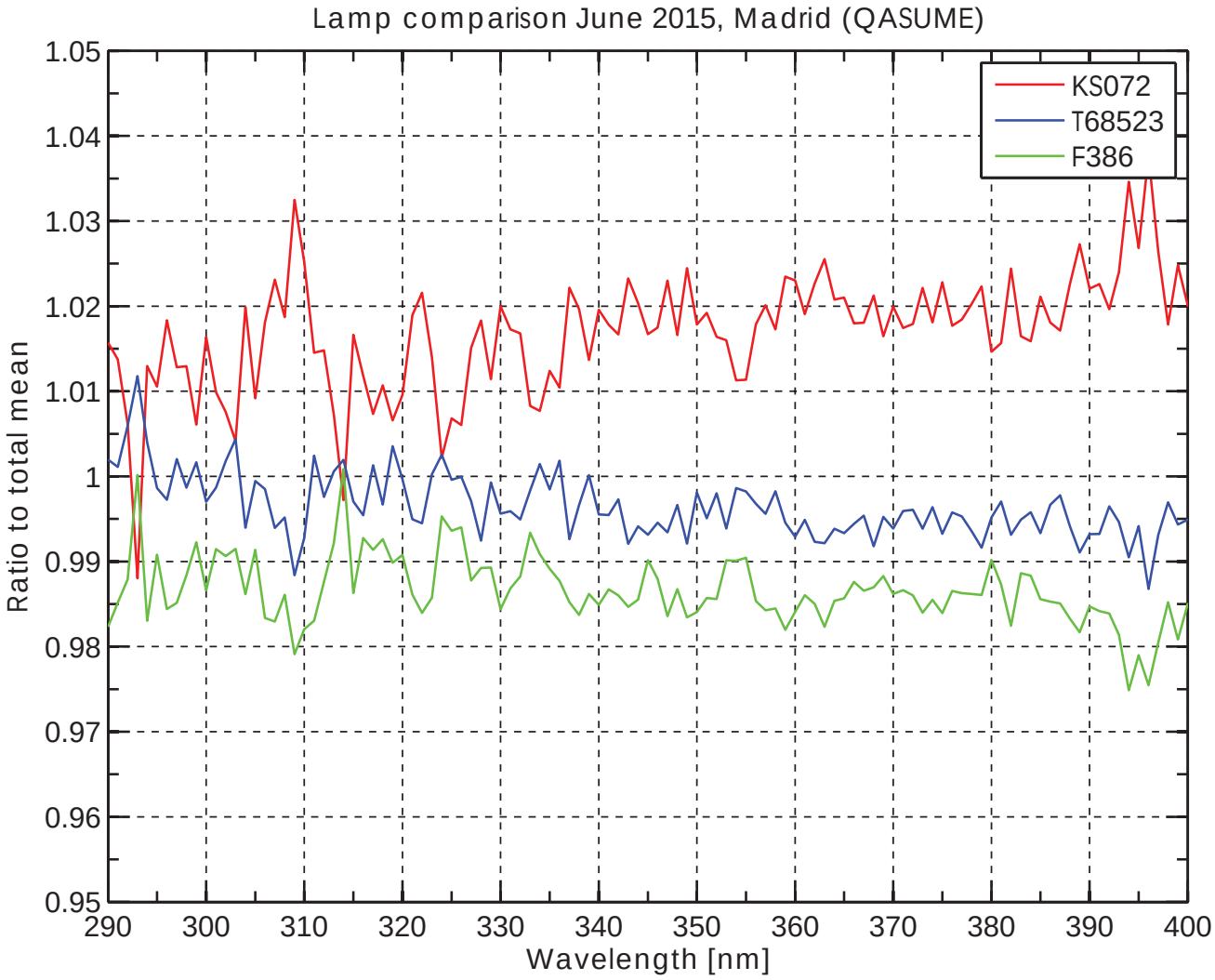

Mean ratio 186/QASUME at AEMET Madrid−matshic:06−Jun−2015(157) to 09−Jun−2015(160)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO 186/QASUME
N Sync−Spectra =105
N 186 Spectra =124
Wavelength [nm]

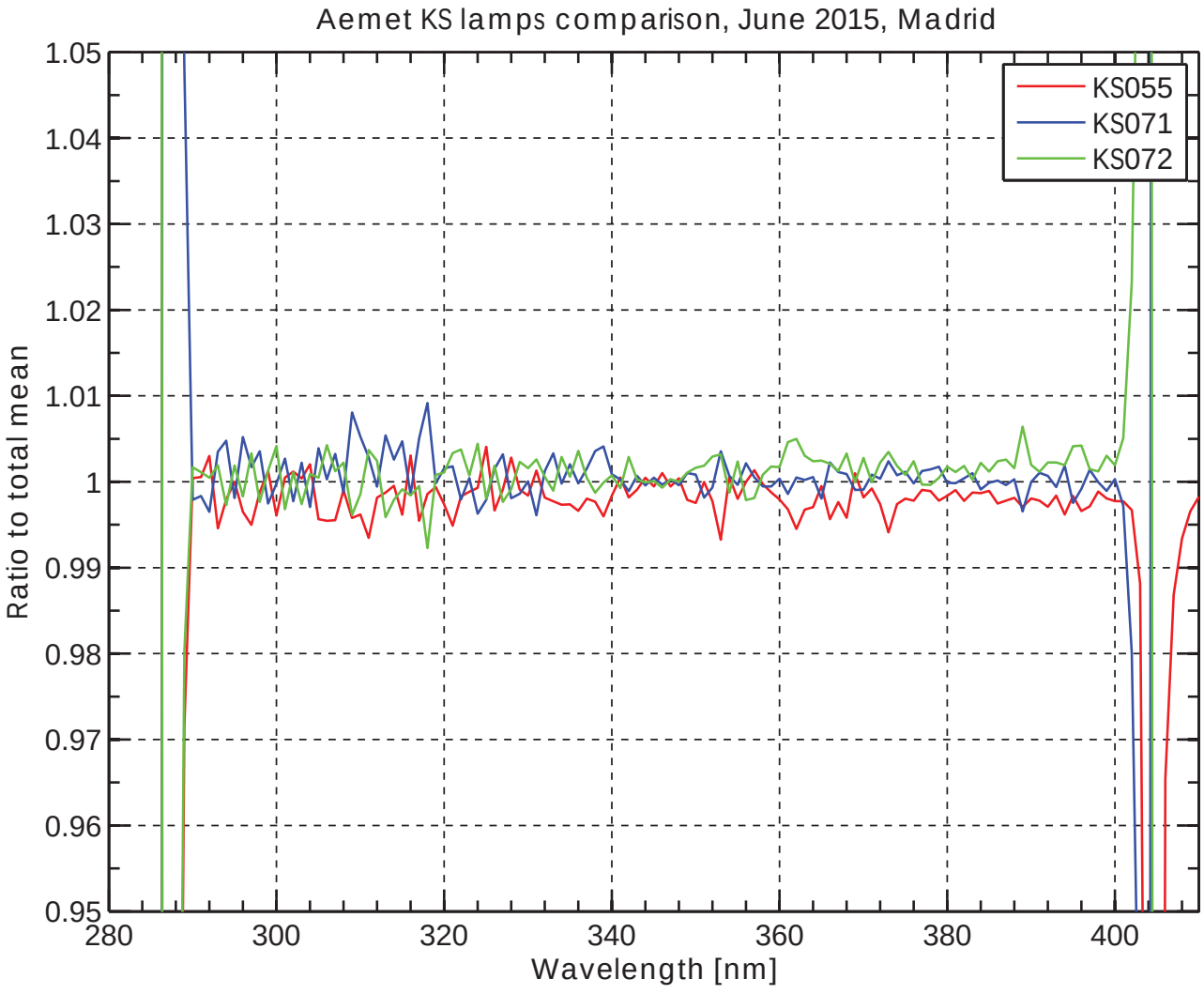

Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
Wavelength /nm
0.1
0.05
0
−0.05
−0.1
300
310
320
330
340
350
360

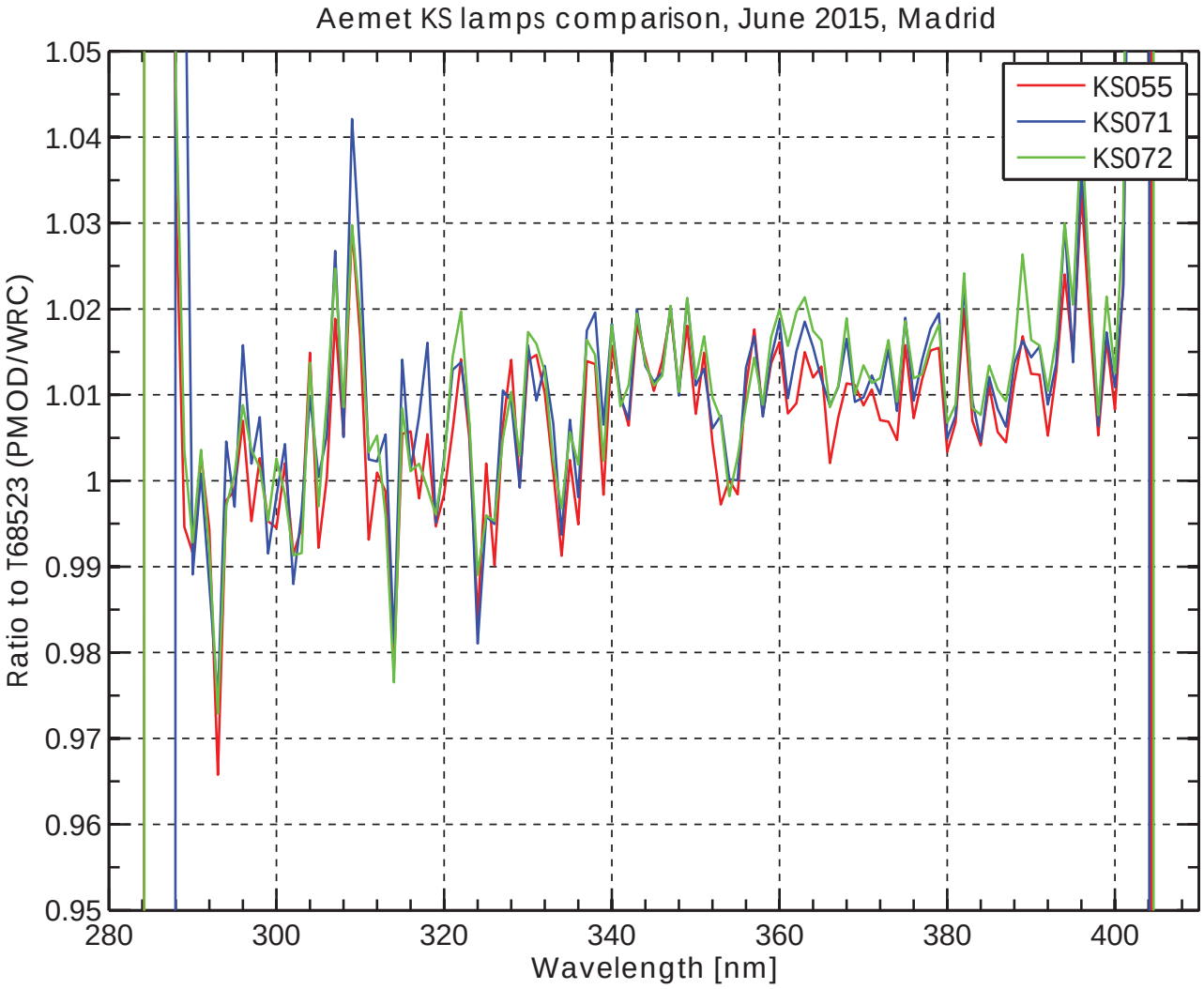

WL=330.00 nm
Wavelength shift /nm
Date & time
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
06/06
06/07
06/08
06/09
06/10


Qasume
Diffuser
Temperature [degC]
Diffuser temperature = 35.33 +− 3.39 degC
Qasume temperature = 28.01 +− 0.07 degC
Time
06/06
06/07
06/08
06/09
06/10


Qasume Responsivity Change, June 2015, Madrid (T68522, T61253, T61523)
157
158
159
160
Ratio to total mean
Wavelength [nm]


Lamp comparison June 2015, Madrid (QASUME)
KS072
T68523
F386
Ratio to total mean
Wavelength [nm]
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
290
300
310
320
330
340
350
360
370
380
390
400


Aemet KS lamps comparison, June 2015, Madrid
KS055
KS071
KS072
Ratio to total mean
Wavelength [nm]
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
280
300
320
340
360
380
400


Aemet KS lamps comparison, June 2015, Madrid
KS055
KS071
KS072
Ratio to T68523 (PMOD/WRC)
Wavelength [nm]
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
280
300
320
340
360
380
400


Brewer 186
QASUME
AEM