Protocol of the intercomparison at AEMET, Madrid, Spain on June 29th June to 1th July, 2019 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 spectroradiometer 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 28, 2019. The spectroradiometer was installed next to the AEM spectroradiometer and Brewer spectroradiometer 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 spectroradiometer is a double monochromator MkIII with the ID 186. The intercomparison between QASUME and the AEMET spectroradiometers lasted three days, from morning of June 29 to the afternoon of July 1, 2019.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Two lamps (T61252 and T68523) 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 3 days of the intercomparison period (Day of year 180-182). To account for the responsivity change, the responsivity was calculated for each day separately and used for that specific day. The internal temperature of QASUME was 29.21±0.43 °C and the diffuser head was heated to a temperature of 34.78±4.98 °C.
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)
179	28. Jun	Friday	Clear sky	Installed at 15:30
180	29. Jun	Saturday	Clear sky	08:03 calibration (T68523) 08:35 Calibration (T61252)
181	30. Jun	Sunday	Clear sky with few Cirrus	06:04 calibration (T68523)
182	01. Jul	Monday	Clear sky with Cirrus	06:01 calibration (T68523) 16:21 Calibration (T68523) End of Campaign: 18:15

Results:

In total 77 synchronised simultaneous spectra from QASUME and AEM, respectively 66 spectra from Brewer #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. The ratios between AEM and QASUME have on average an offset of about -1 %.
2. The diurnal variation of the AEM to QASUME ratio is less than 3 %.
3. For all solar scans the wavelength shifts of the AEM show a shift of +70 pm to +210 pm, which was stable during the comparison period.

II. Brewer #186:

1. The dataset of Brewer #186 is based on responsivity measured at El Arenosillo.
2. For all solar scans the wavelength shifts of the Brewer #186 show a shift of less than +50pm to -50pm.
3. The ratios between Brewer #186 and QASUME have on average an offset of -6 % to -4% for non-cosine-corrected data.
4. The diurnal variation of the #186 to QASUME ratio is around 6 % for non-cosine-corrected data.
5. To exemplarily demonstrate the potential of improving the UV data of the Brewer spectroradiometer, PMOD/WRC applied a cosine correction based on Lakkala et al. 2018, after the campaign.
6. **For cosine corrected data:** The ratios between Brewer #186 and QASUME have on average an offset of -2 % to +1%.
7. **For cosine corrected data:** The diurnal variation of the #186 to QASUME ratio is around 3% for cosine-corrected data.

Recommendation:

Since the Bentham data is used to monitor the UVB index of the broadband radiometer at AEMET, the spectral UV data from the Bentham has to be corrected for the large wavelength shift of up to 0.21 nm. Please note that due to the sharp decrease of UV in the UVB part, a wavelength shift has a significant impact on the calculated UV Index.

The analysis clearly shows, that the cosine corrections according to Lakkala et al, 2018, substantially improves the UV data from the Brewer spectroradiometer. Due to the applied correction, the spectral UV data is within the uncertainty band of the QASUME reference instrument, resulting in excellent data for research and atmospheric monitoring with this Brewer. It is therefore strongly recommended to apply a cosine correction on this instrument.

Remarks by the AEMET Operators:

I. AEM:

The Bentham spectroradiometer has been adjusted by the manufacturer several times, before beginning the UVB broadband calibration campaigns, in order to correct the wavelength shift that increases slightly. In this occasion the adjustment hasn't been performed to avoid a new 1000 W lamp calibration needed after each adjustment, and the spectra will be corrected through the software ShicRivm, and the effect of the wavelength shift on the Global Calibration Factor of the Broadband radiometers will be evaluated.

II. Brewer #186:

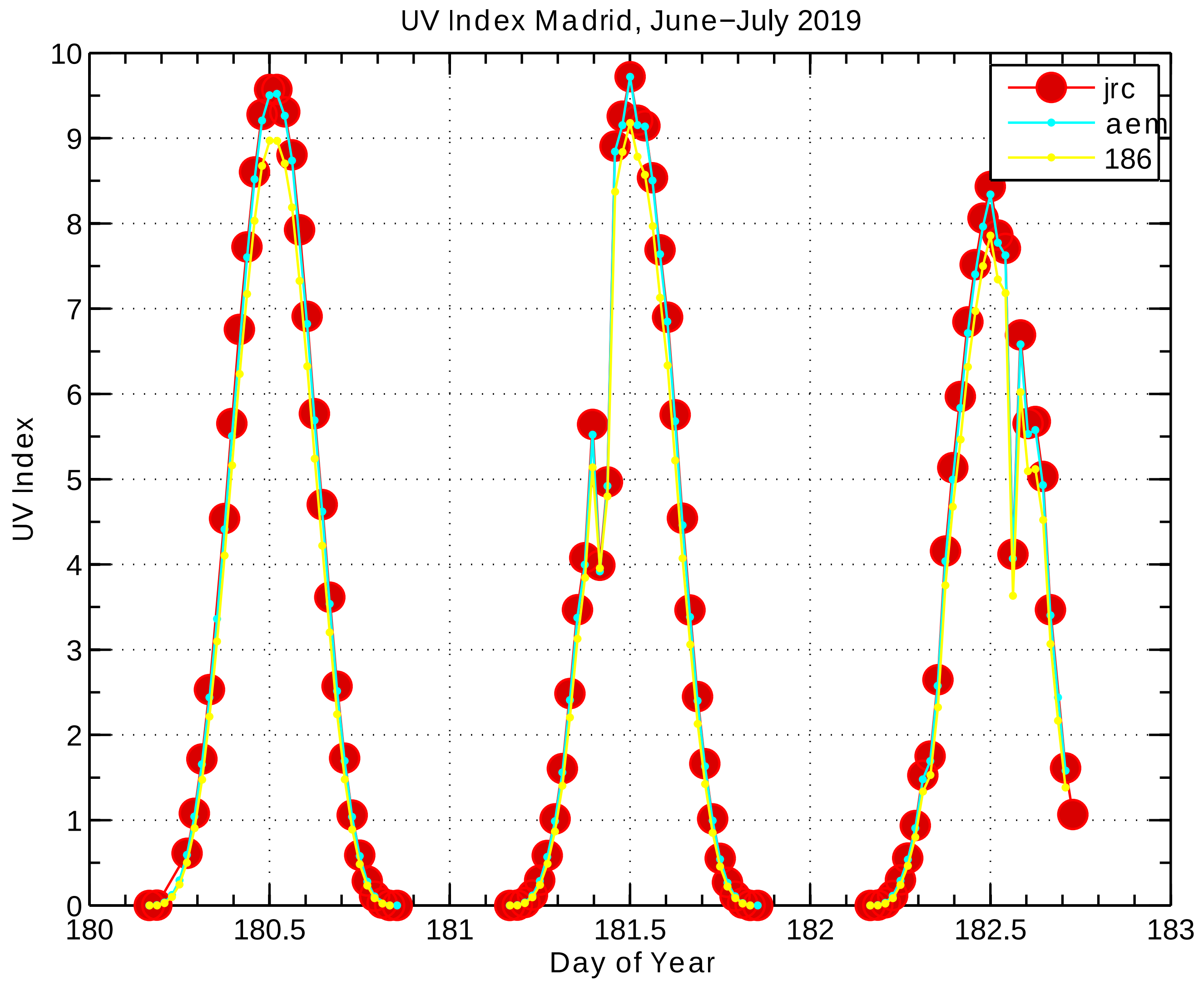
The results of the RBCC-E campaign (El Arenosillo, 2017) already showed that the application of the cosine correction improves the data of the #186. We will work to implement the cosine correction for the process of the spectra, a complex task because the cosine correction depends on the zenith solar angle and the wavelength.

AEMET Operators:

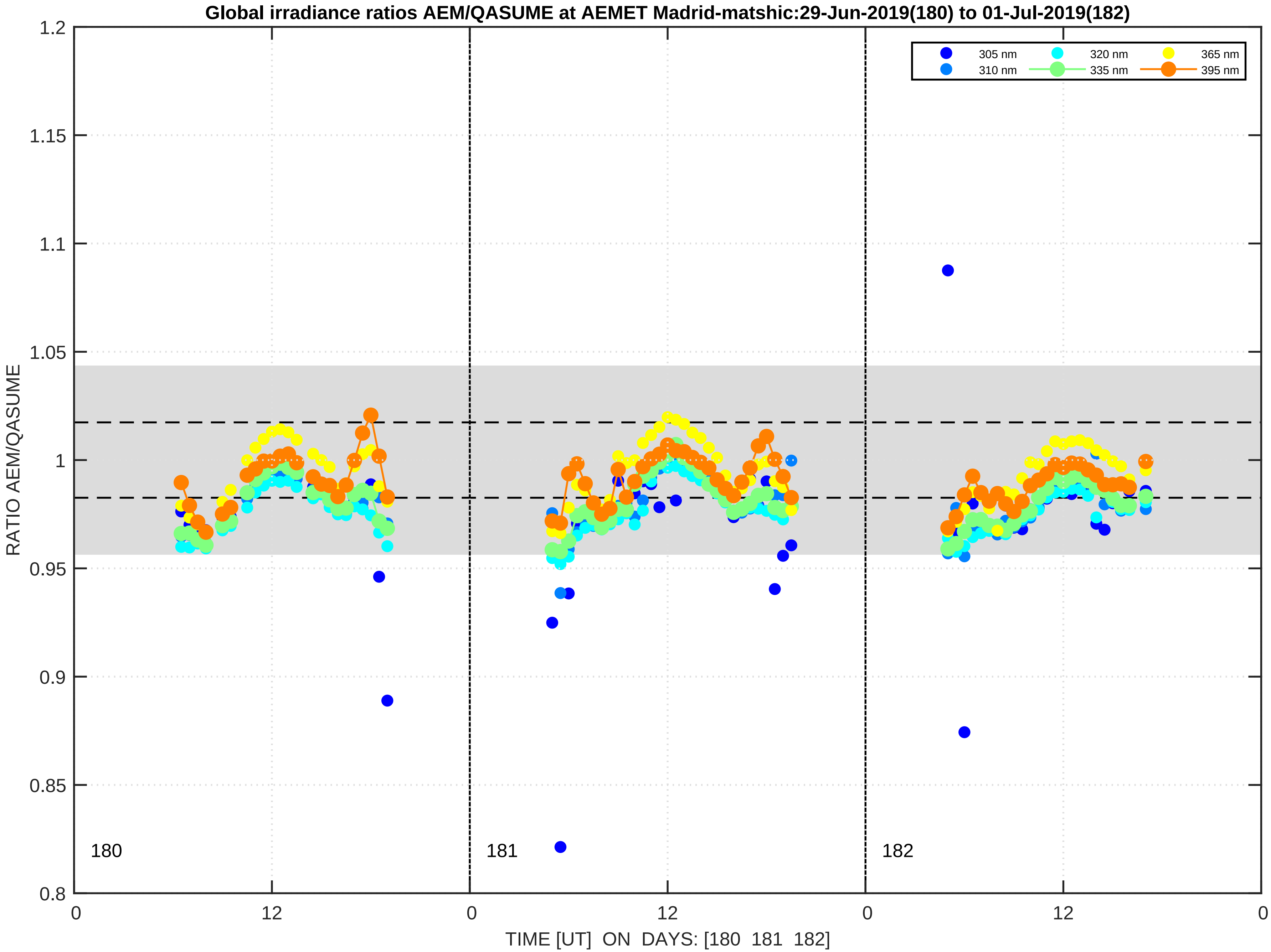
José María San Atanasio
Ana Diaz
Irene Melero
Dario Callau (AFC)

Reference:

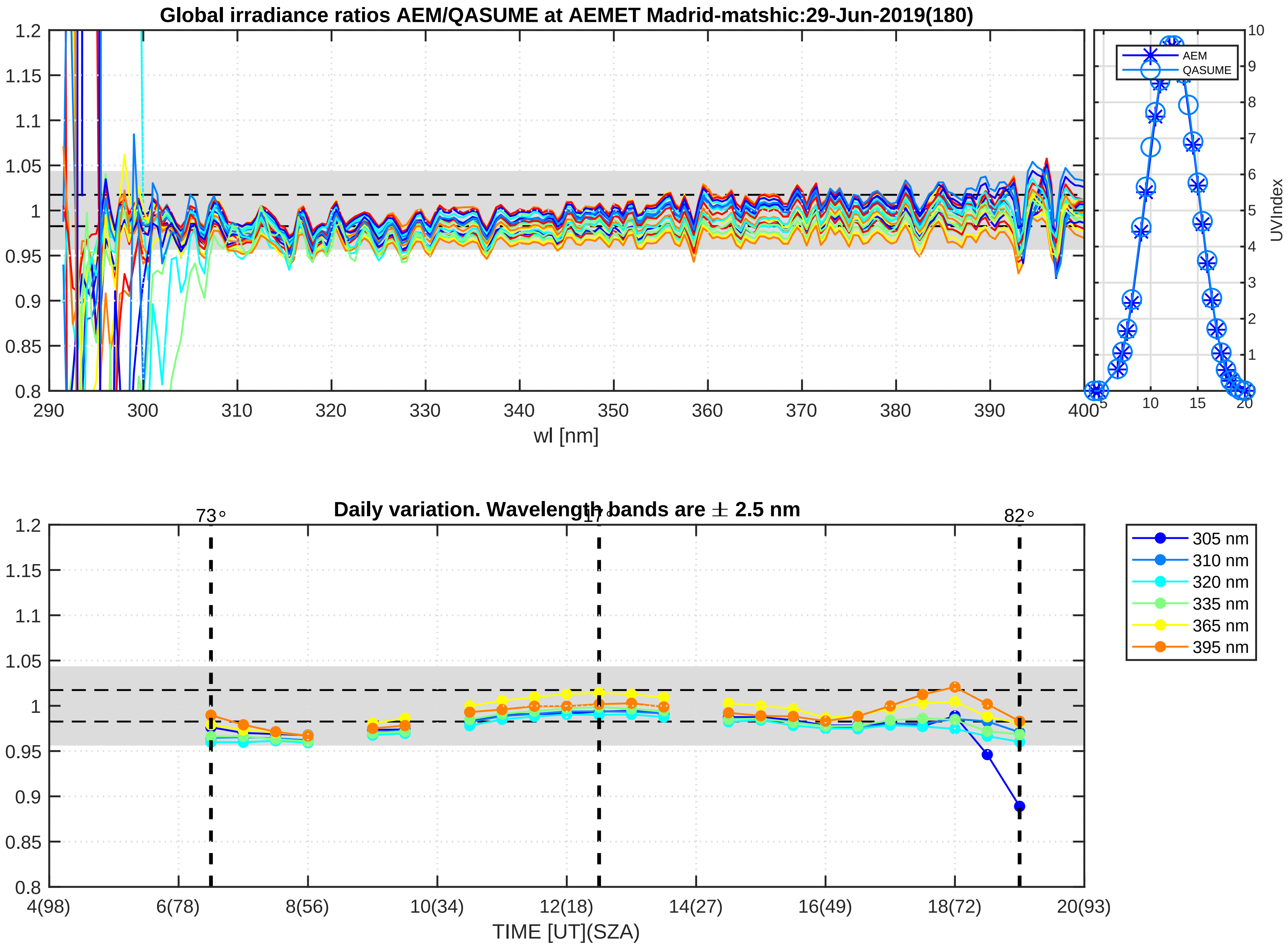
[1] Kaisa Lakkala, Antti Arola, Julian Gröbner, Sergio Fabian León-Luis, Alberto Redondas, Stelios Kazadzis, Tomi Karppinen, Juha Matti Karhu, Luca Egli, Anu Heikkilä, Tapani Koskela, Antonio Serrano and José Manuel Vilaplana, 2018: Performance of the FMI cosine error correction method for the Brewer spectral UV measurements, *Atmos Meas.Tech.,11,5167-5180,2018*



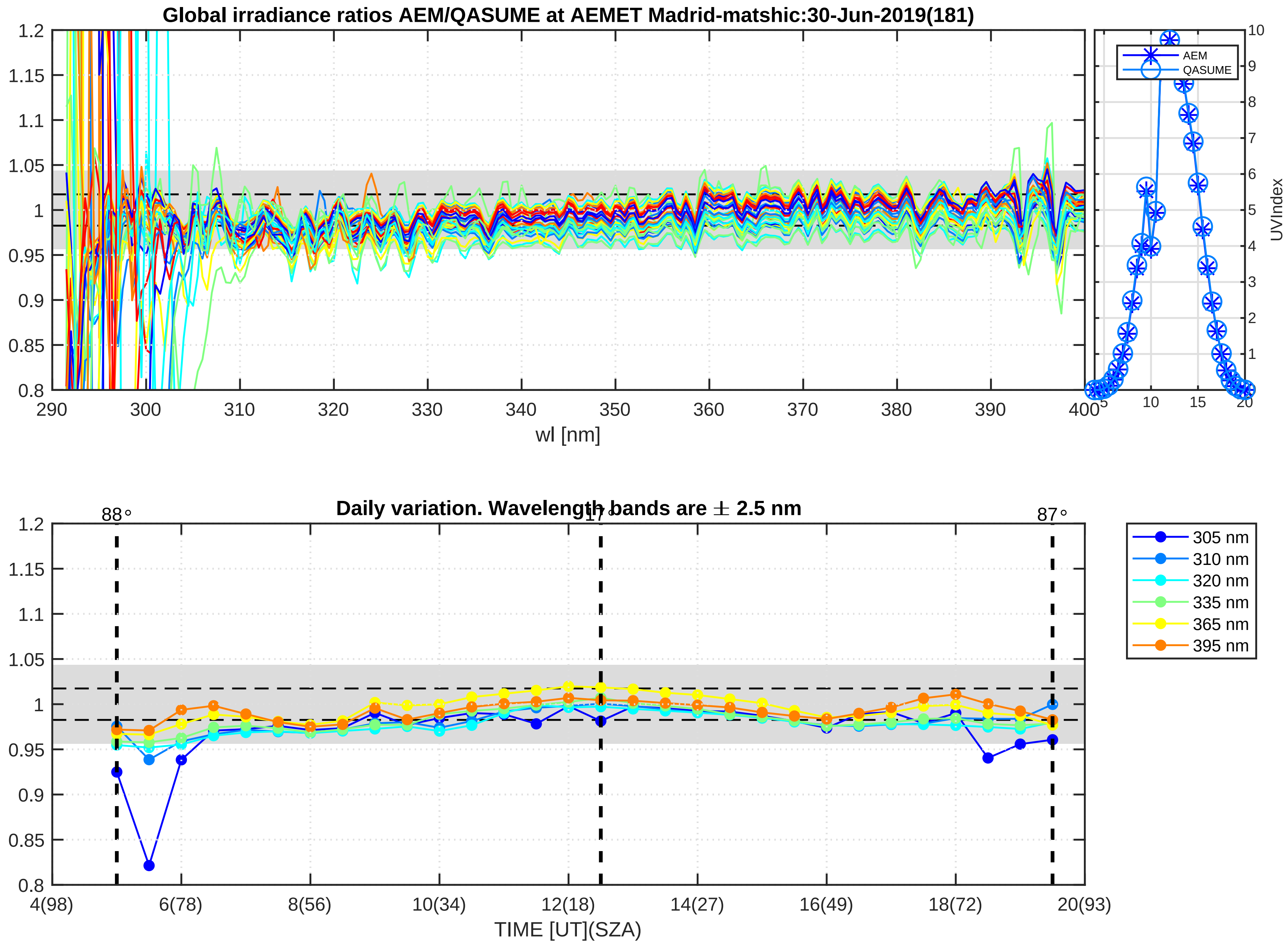
UV Index Madrid, June−July 2019
UV Index
Day of Year
jrc
aem
186
0
1
2
3
4
5
6
7
8
9
10
180
180.5
181
181.5
182
182.5
183



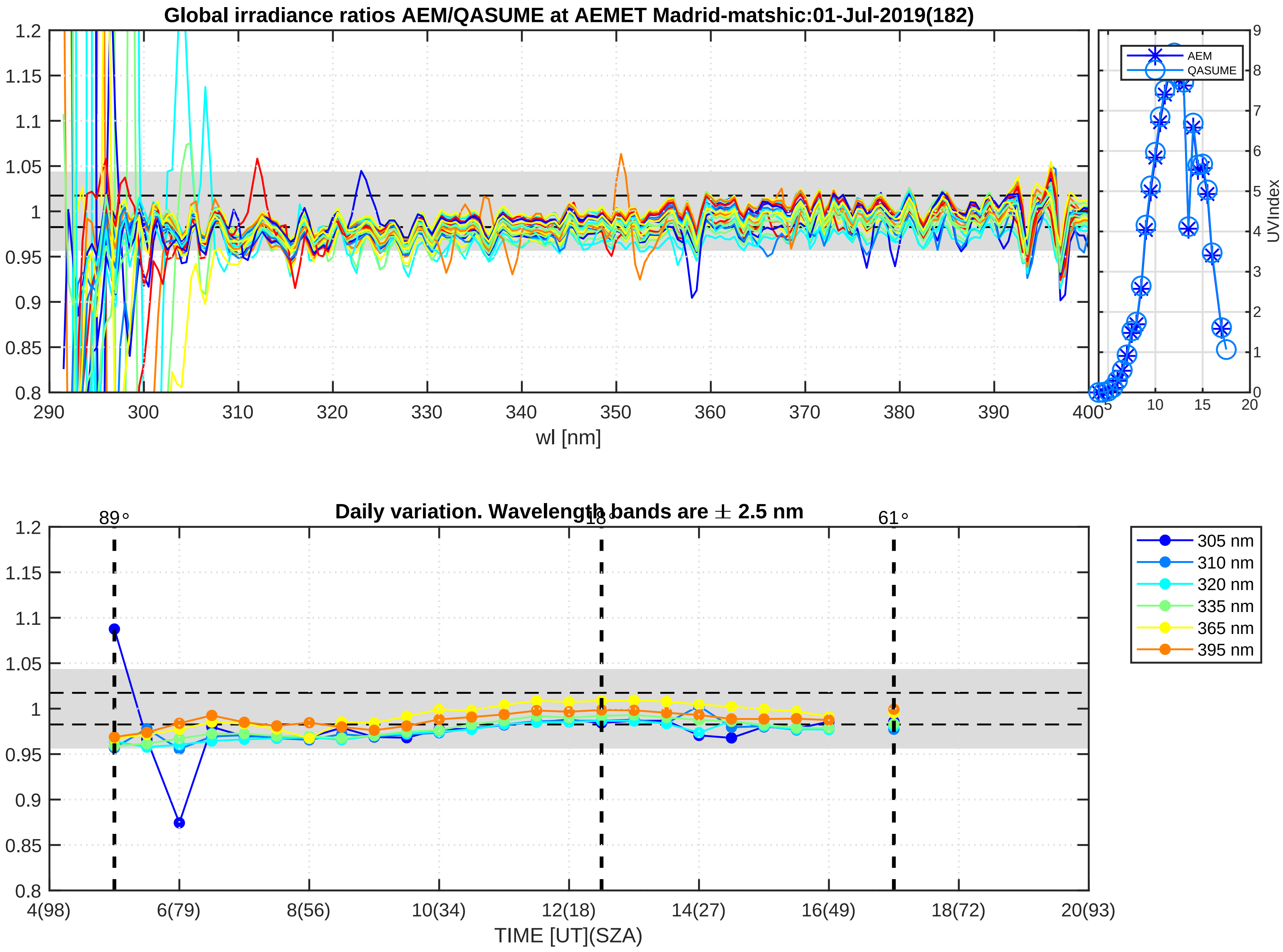
Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:29-Jun-2019(180) to 01-Jul-2019(182)
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
RATIO AEM/QASUME
180
181
182
0
12
0
12
0
12
0
TIME [UT] ON DAYS: [180 181 182]



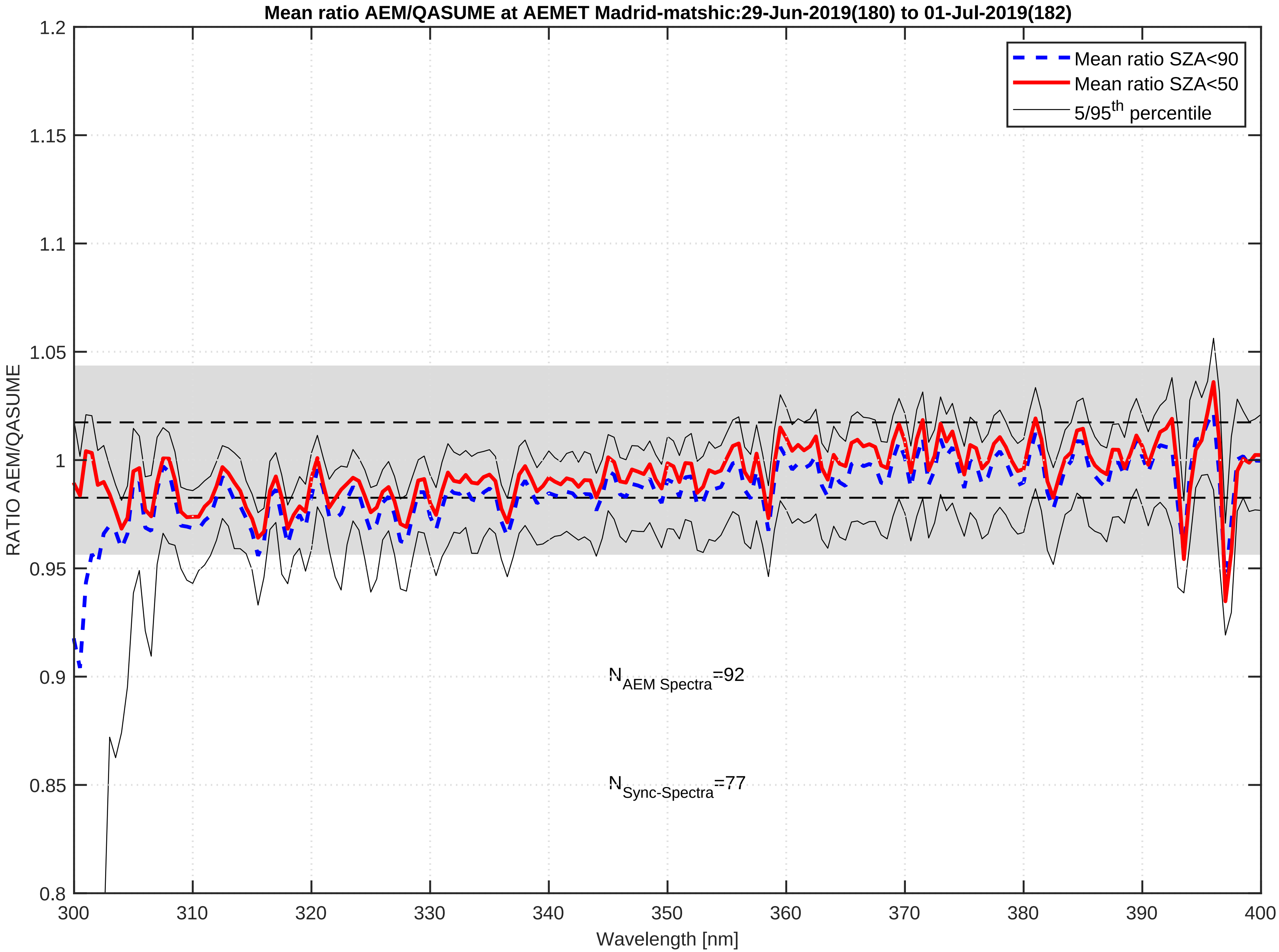
Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:29-Jun-2019(180)
wl [nm]
AEM
QASUME
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
73°
17°
82°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)



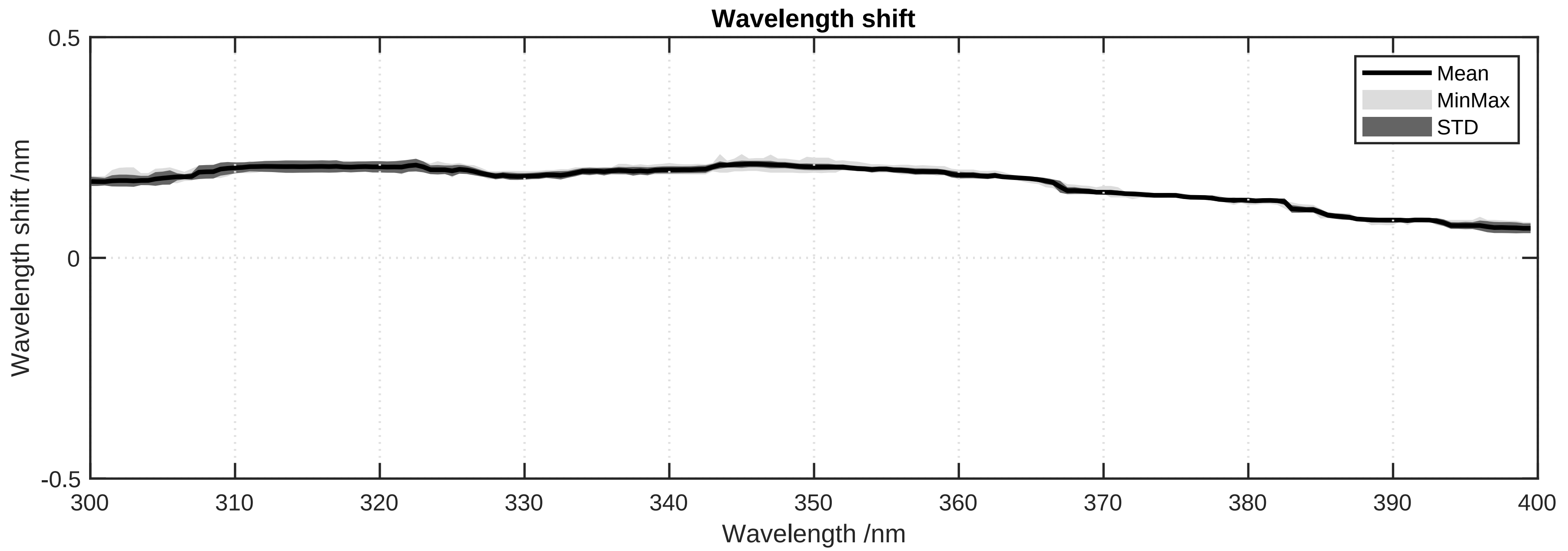
Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:30-Jun-2019(181)
wl [nm]
AEM
QASUME
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
88°
17°
87°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)

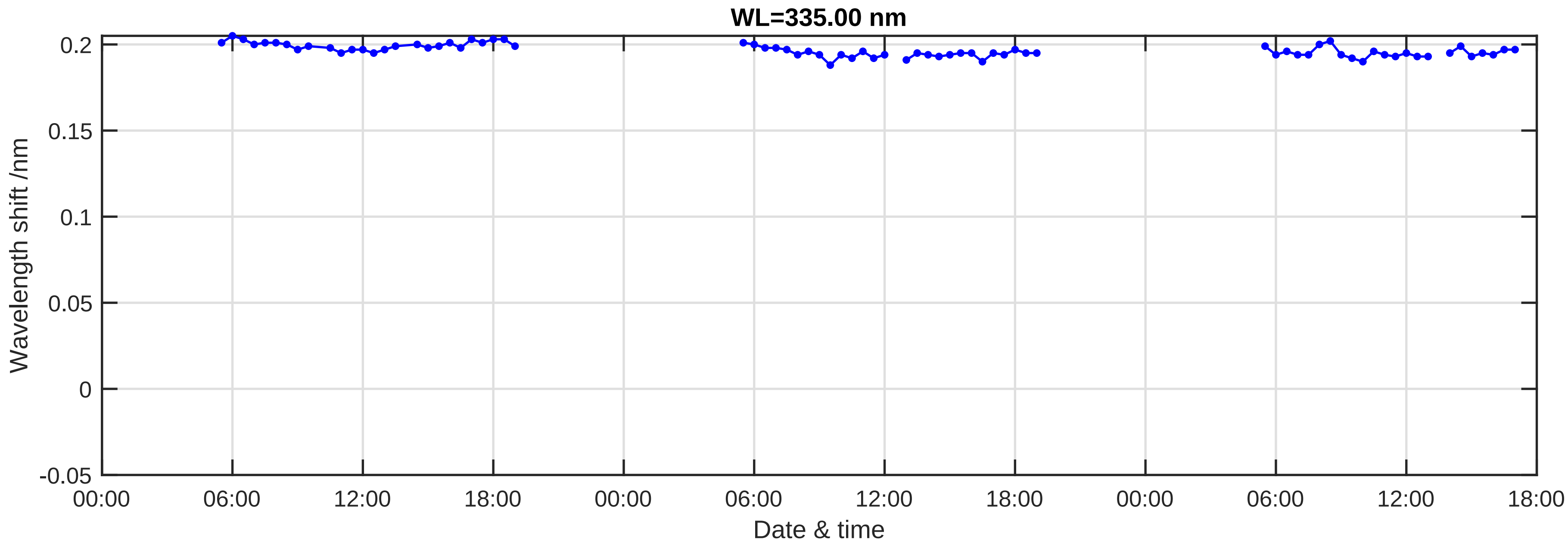


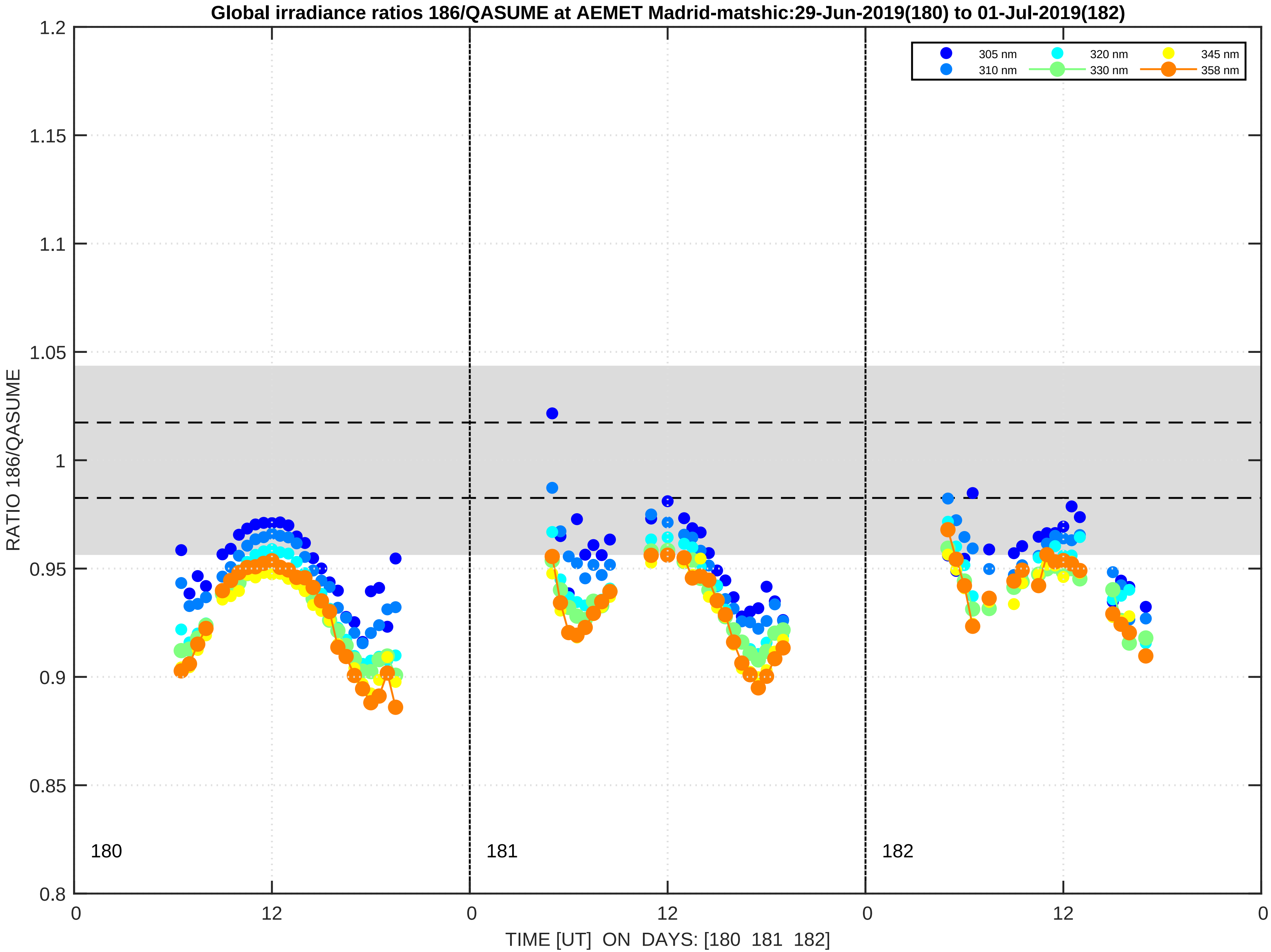
Global irradiance ratios AEM/QASUME at AEMET Madrid-matshic:01-Jul-2019(182)
wl [nm]
AEM
QASUME
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
89°
18°
61°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)
4(98)
6(79)
8(56)
10(34)
12(18)
14(27)
16(49)
18(72)
20(93)

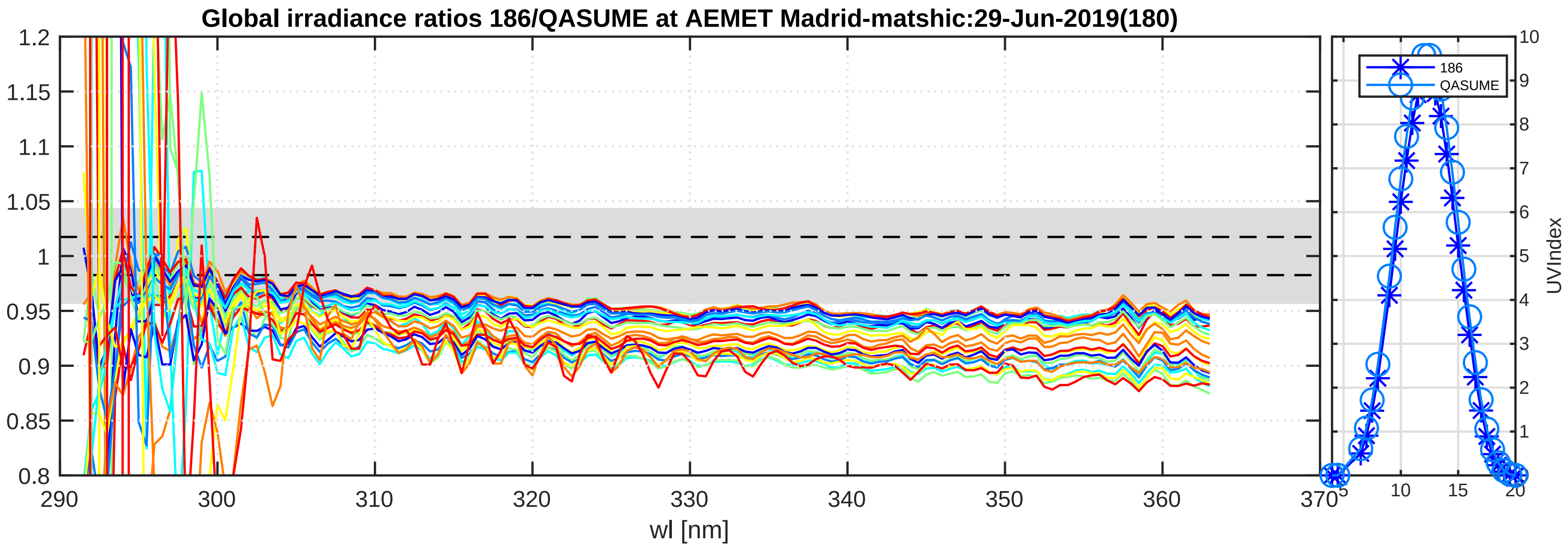


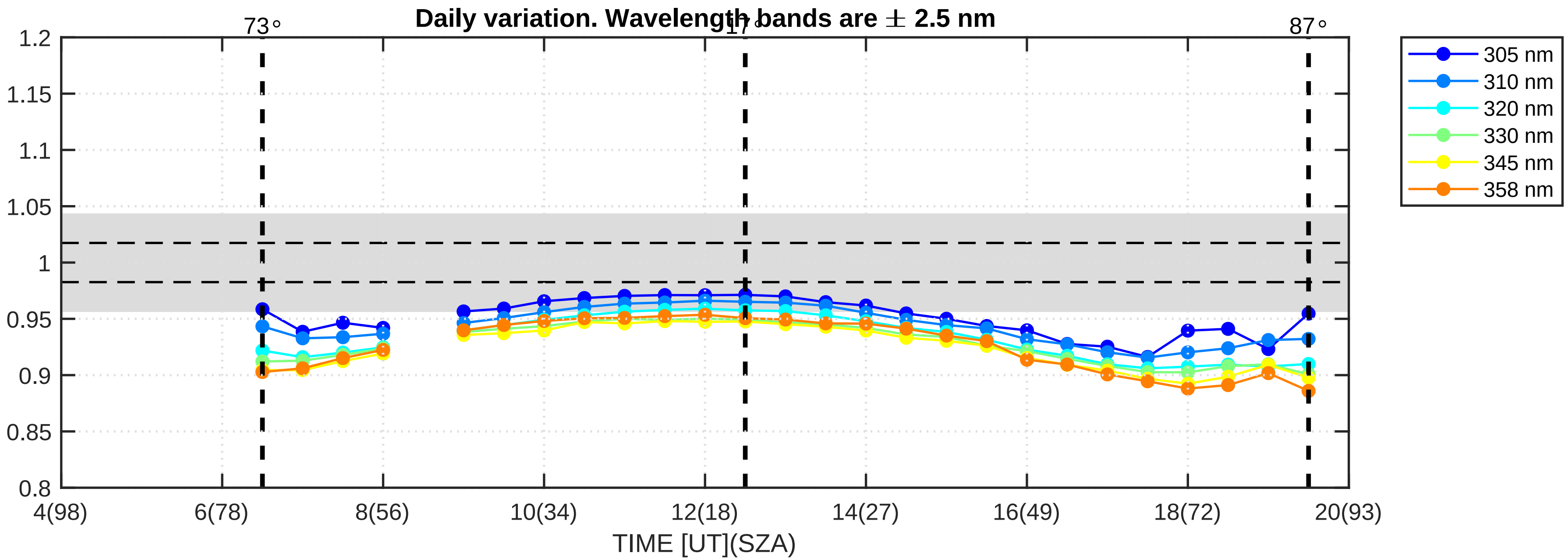
Mean ratio AEM/QASUME at AEMET Madrid-matshic:29-Jun-2019(180) to 01-Jul-2019(182)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
RATIO AEM/QASUME
Wavelength [nm]
N AEM Spectra=92
N Sync-Spectra=77
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
310
320
330
340
350
360
370
380
390
400

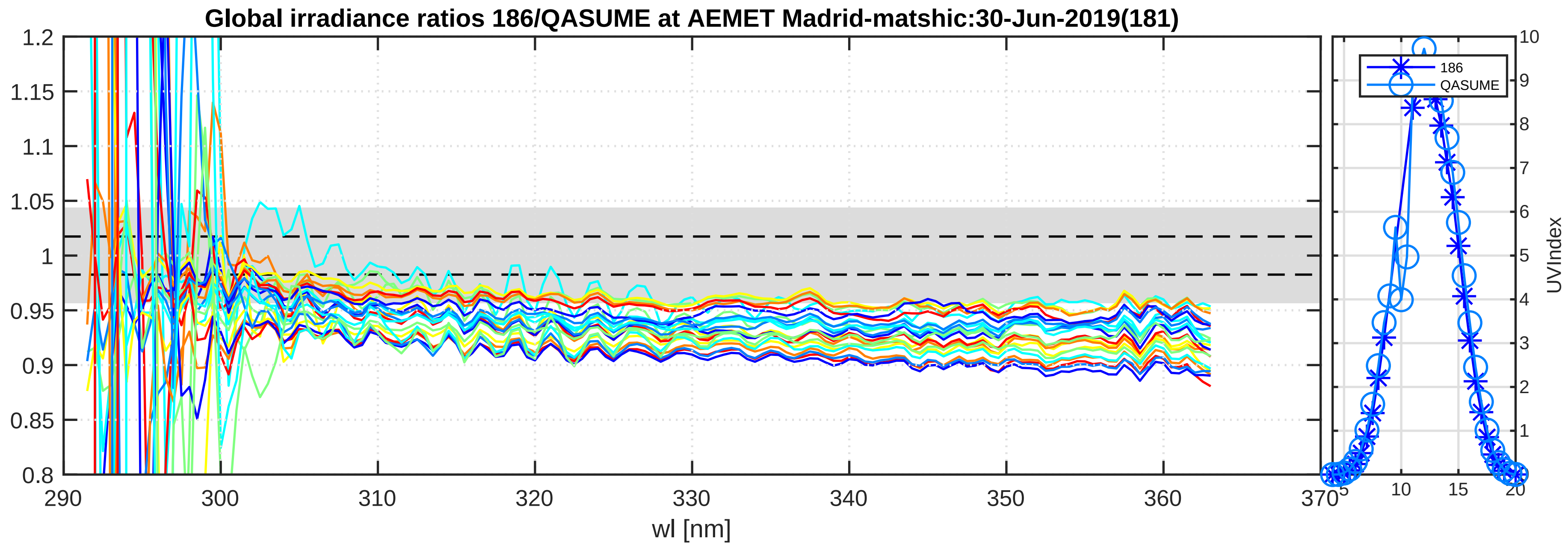

Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
Wavelength /nm
0.5
0
-0.5
300
310
320
330
340
350
360
370
380
390
400


WL=335.00 nm
Wavelength shift /nm
Date & time
0.2
0.15
0.1
0.05
0
-0.05
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00

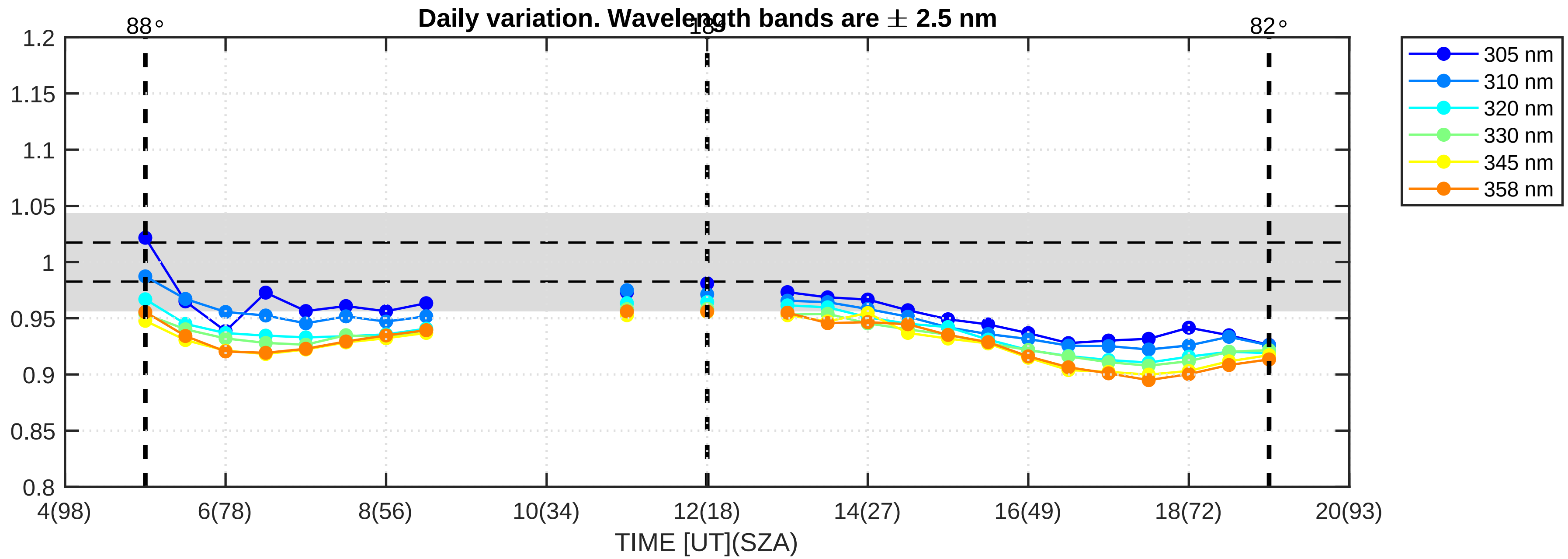

Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:29-Jun-2019(180) to 01-Jul-2019(182)
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
RATIO 186/QASUME
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
180
181
182
0
12
0
12
0
12
0
TIME [UT] ON DAYS: [180 181 182]


Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:29-Jun-2019(180)
wl [nm]
186
QASUME
UVIndex

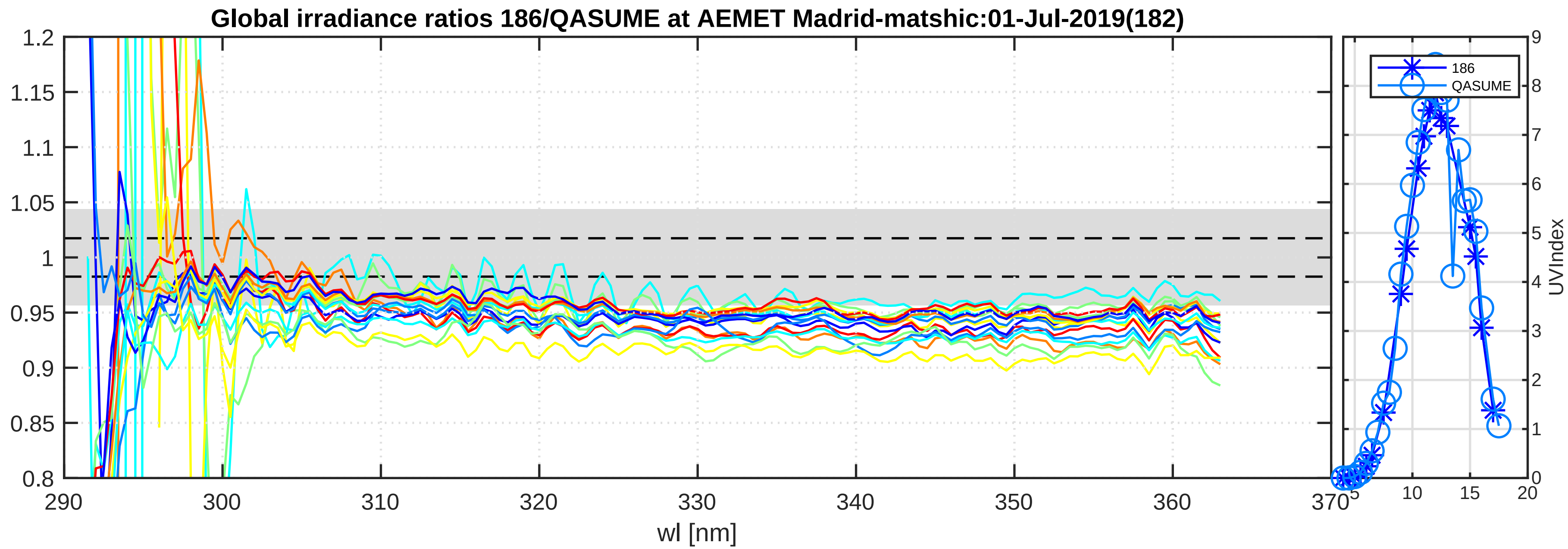

Daily variation. Wavelength bands are ± 2.5 nm
73°
17°
87°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

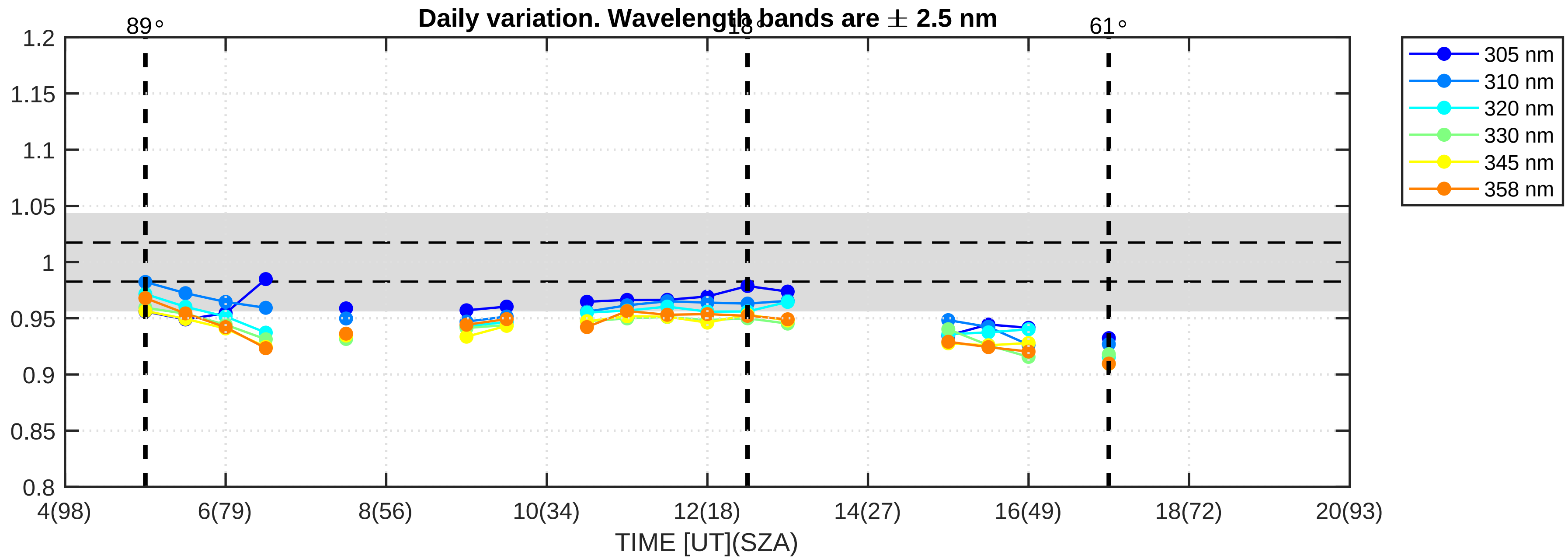


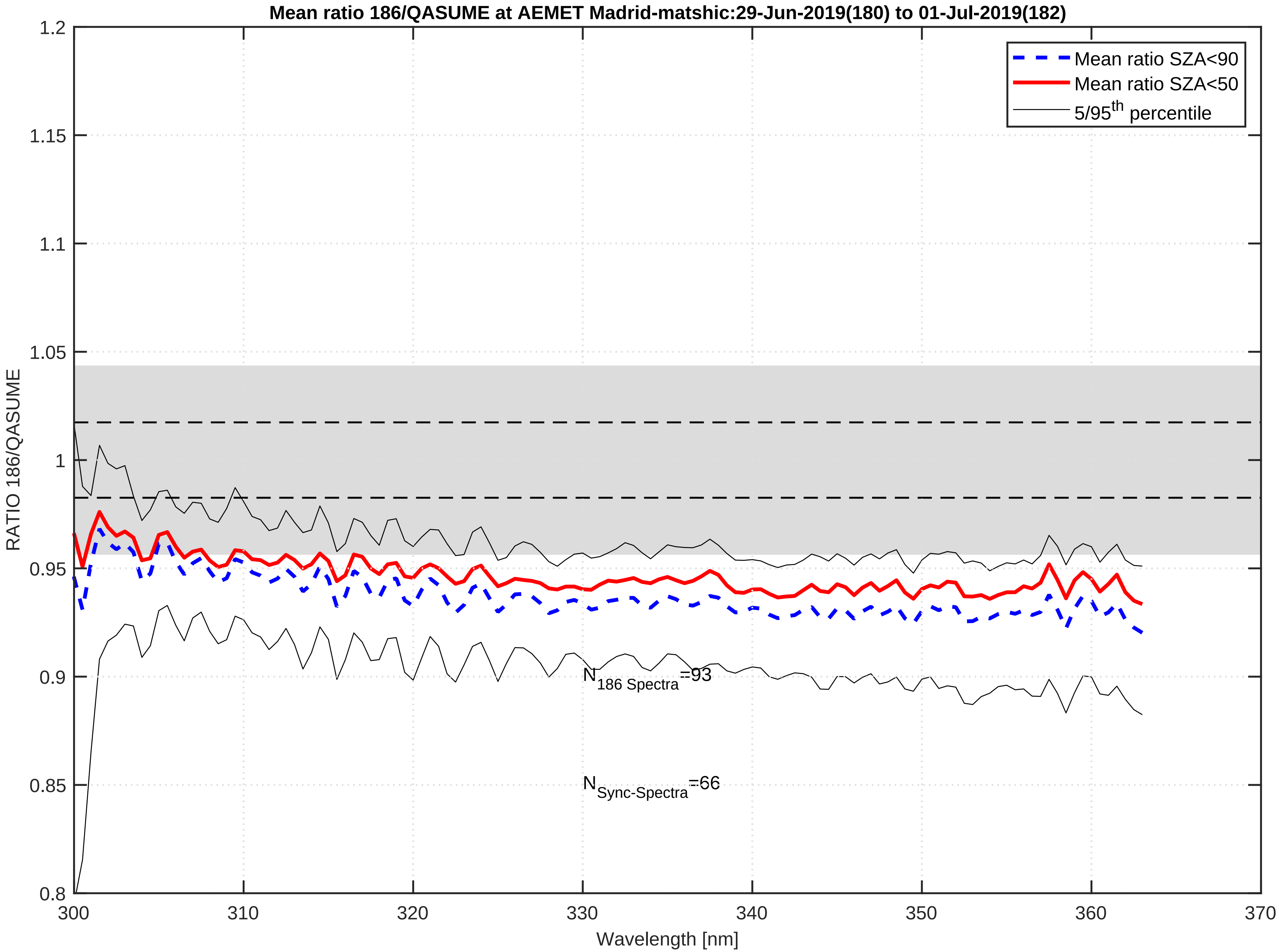
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:30-Jun-2019(181)
wl [nm]
186
QASUME
UVIndex

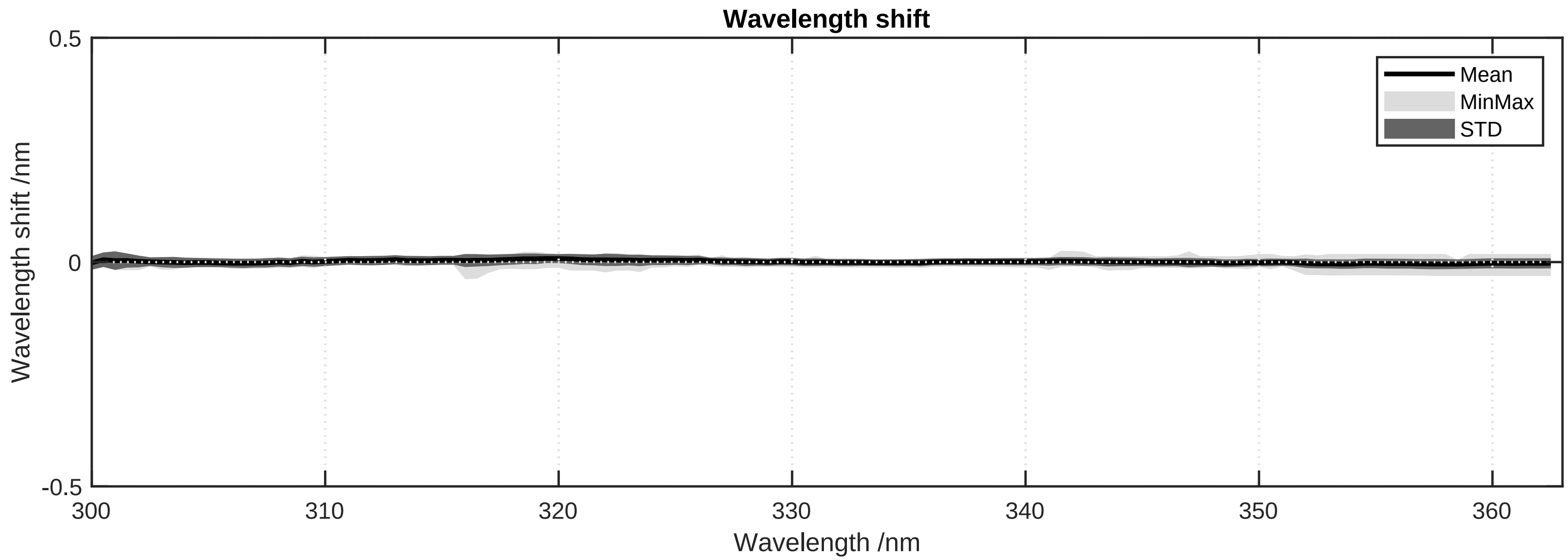


Daily variation. Wavelength bands are ± 2.5 nm
88°
18°
82°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)

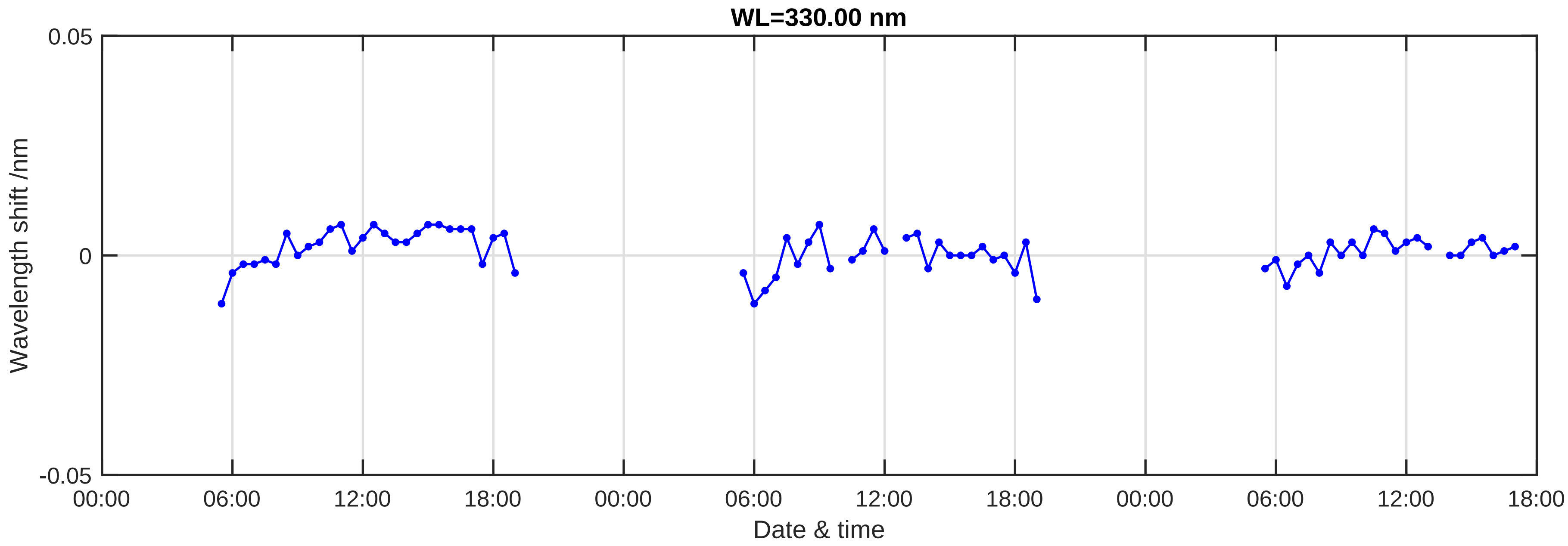

Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:01-Jul-2019(182)
wl [nm]
UVIndex
186
QASUME


Daily variation. Wavelength bands are ± 2.5 nm
89°
18°
61°
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm

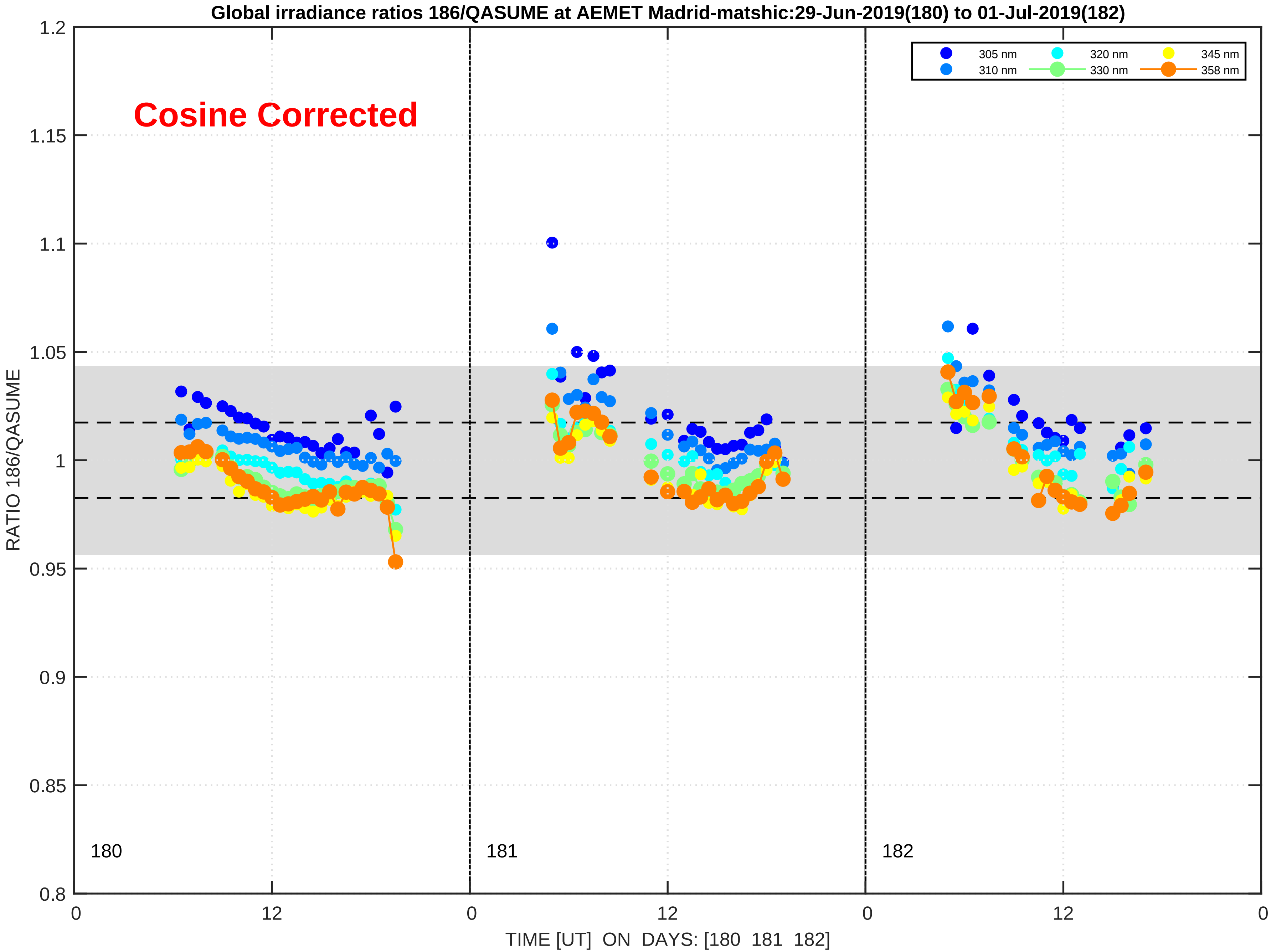

Mean ratio 186/QASUME at AEMET Madrid-matshic:29-Jun-2019(180) to 01-Jul-2019(182)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
RATIO 186/QASUME
Wavelength [nm]
N186 Spectra=93
NSync-Spectra=66
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
310
320
330
340
350
360
370



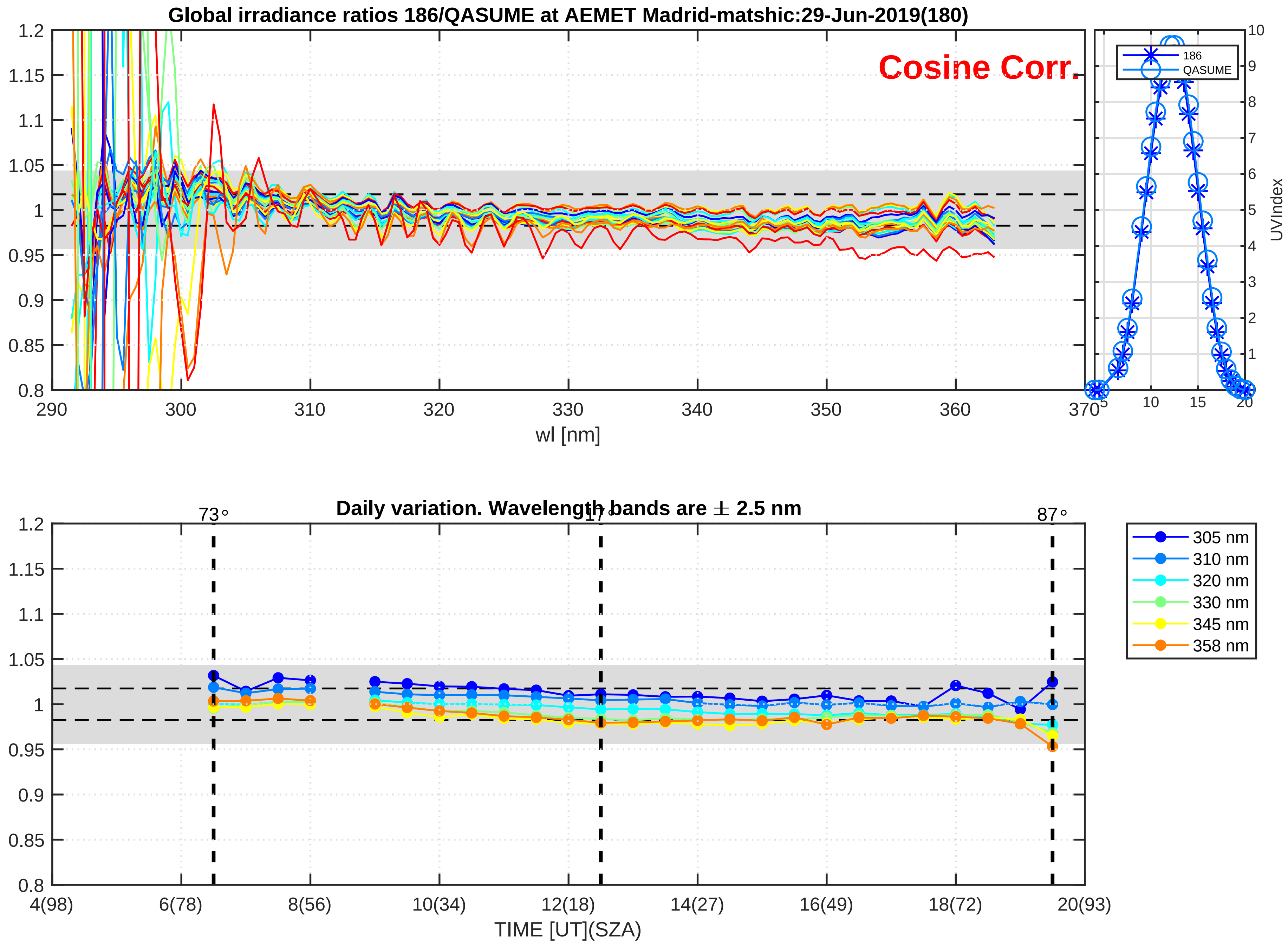
Wavelength shift
Mean
MinMax
STD
0.5
0
-0.5
300
310
320
330
340
350
360
Wavelength /nm
Wavelength shift /nm



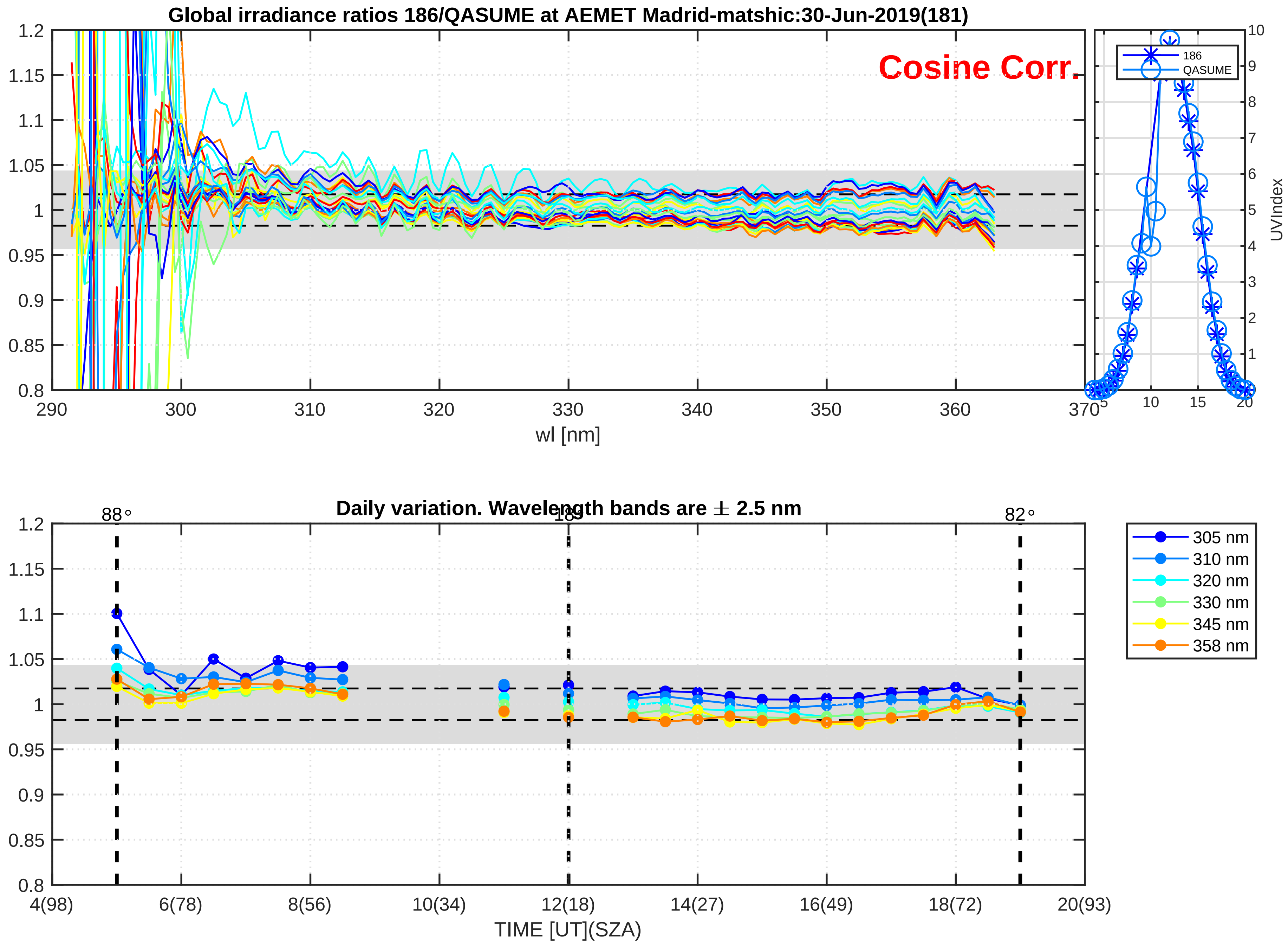
WL=330.00 nm
0.05
0
-0.05
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
Date & time
Wavelength shift /nm



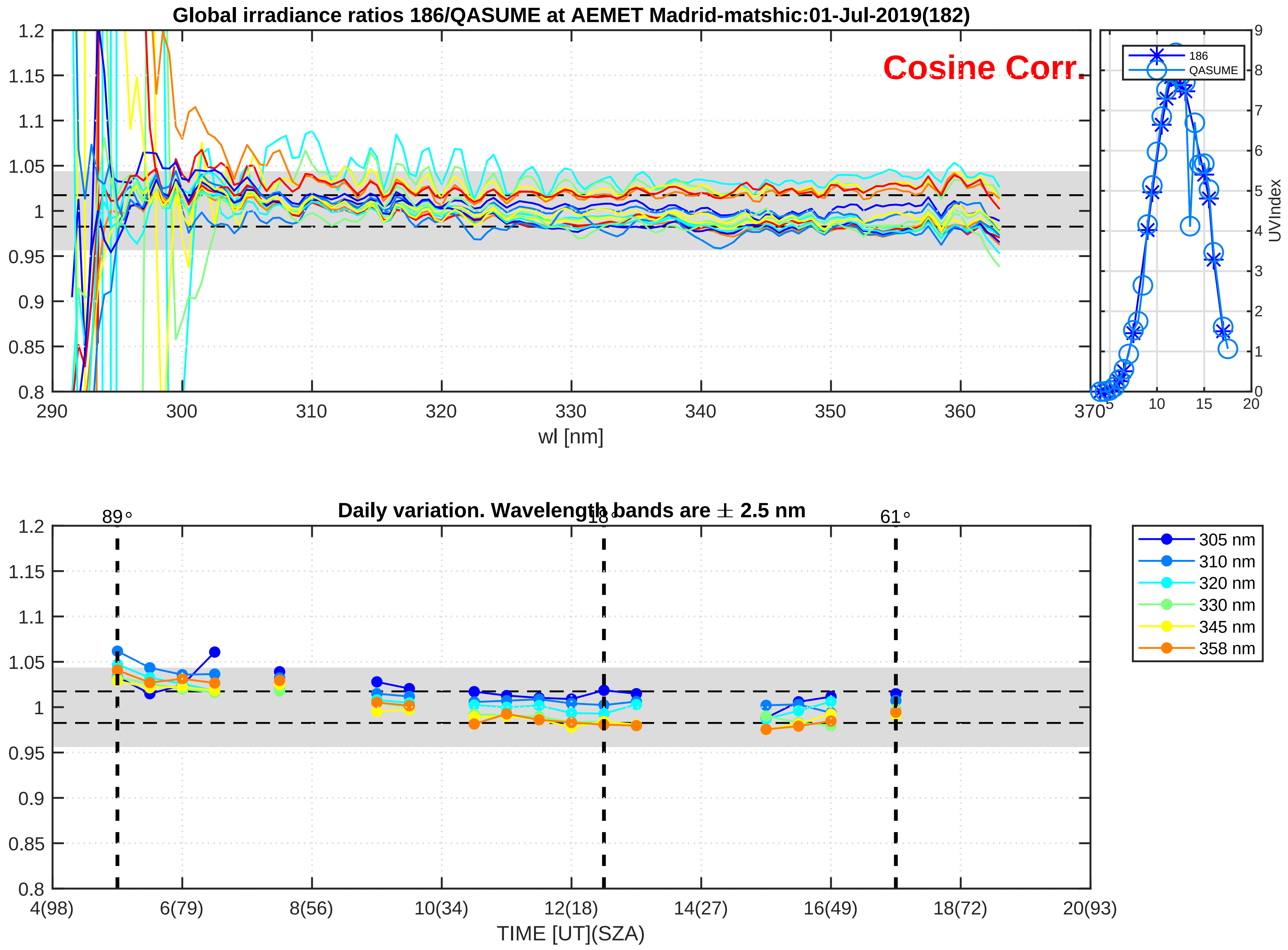
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:29-Jun-2019(180) to 01-Jul-2019(182)
Cosine Corrected
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
RATIO 186/QASUME
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
180
181
182
0
12
0
12
0
12
0
TIME [UT] ON DAYS: [180 181 182]



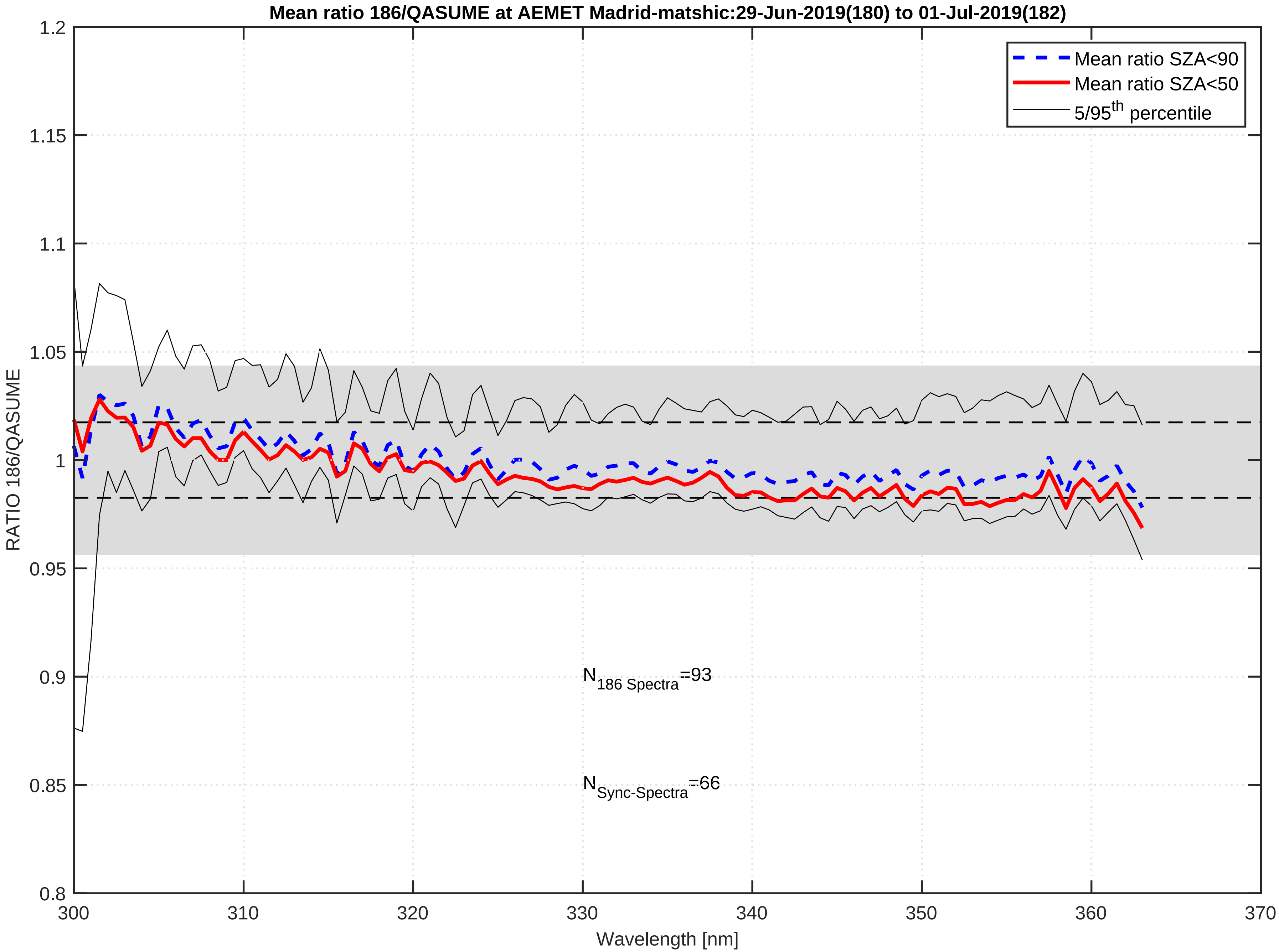
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:29-Jun-2019(180)
Cosine Corr.
wl [nm]
186
QASUME
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
73°
17°
87°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)
4(98)
6(78)
8(56)
10(34)
12(18)
14(27)
16(49)
18(72)
20(93)



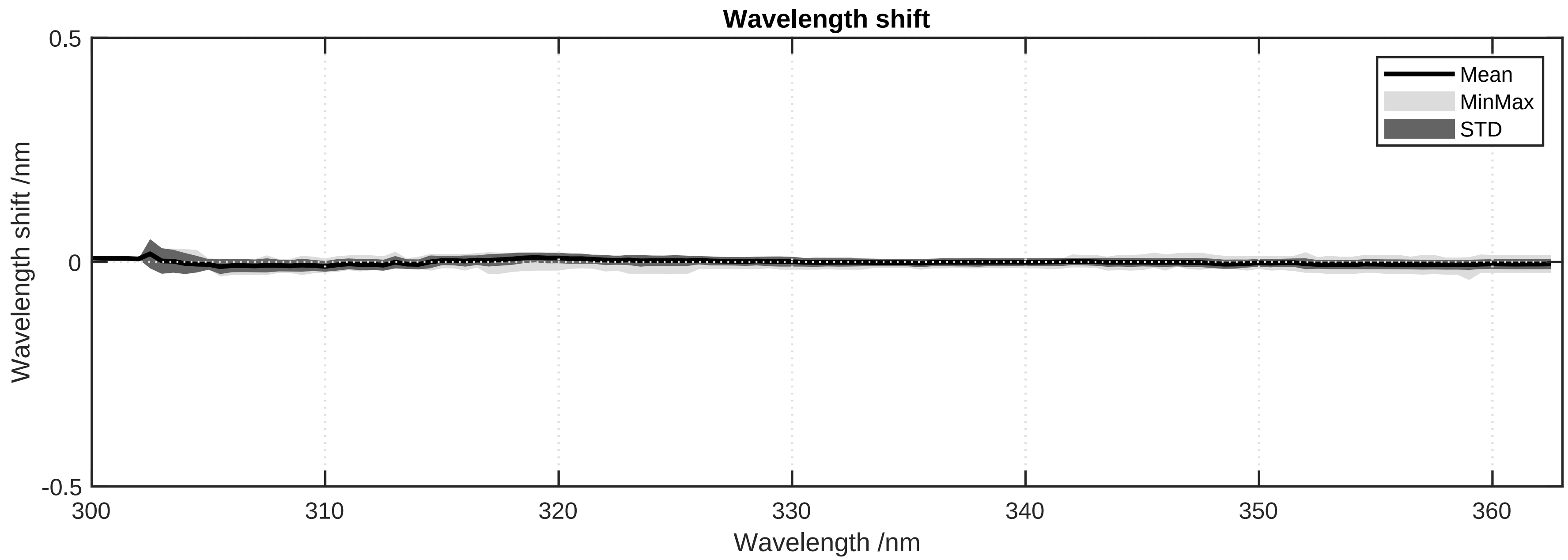
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:30-Jun-2019(181)
Cosine Corr.
186
QASUME
UVIndex
wl [nm]
Daily variation. Wavelength bands are ± 2.5 nm
88°
18°
82°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)
4(98)
6(78)
8(56)
10(34)
12(18)
14(27)
16(49)
18(72)
20(93)



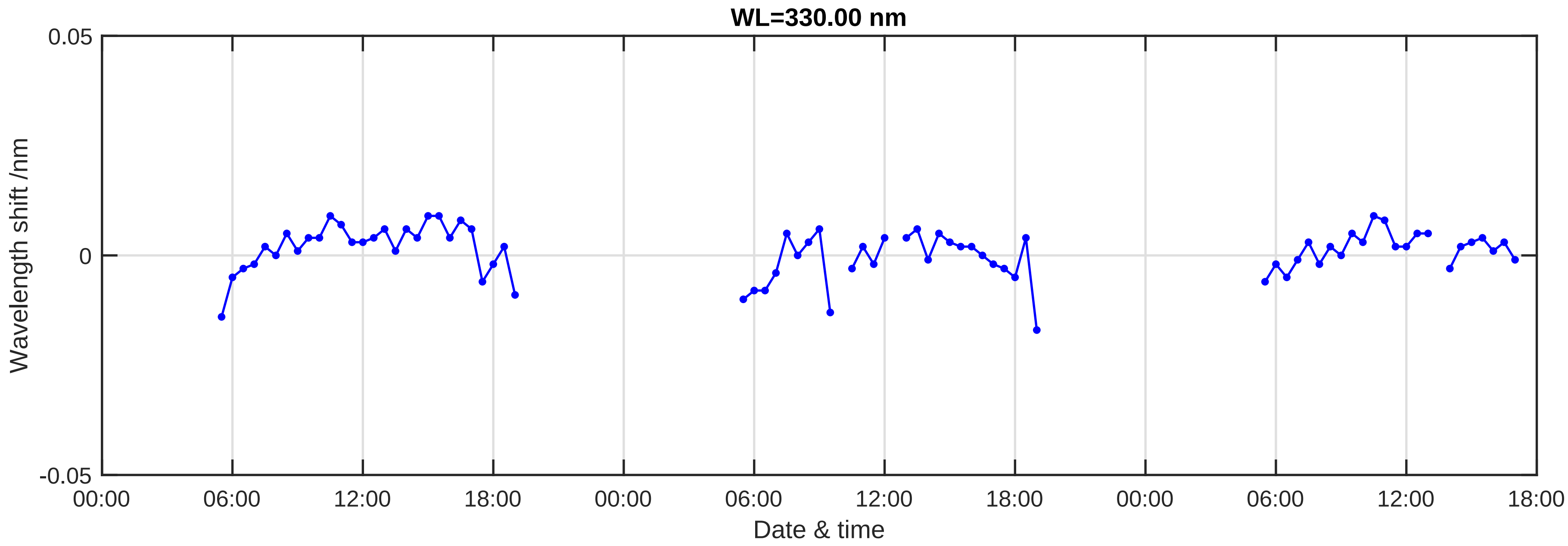
Global irradiance ratios 186/QASUME at AEMET Madrid-matshic:01-Jul-2019(182)
Cosine Corr.
wl [nm]
186
QASUME
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
89°
18°
61°
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
TIME [UT](SZA)



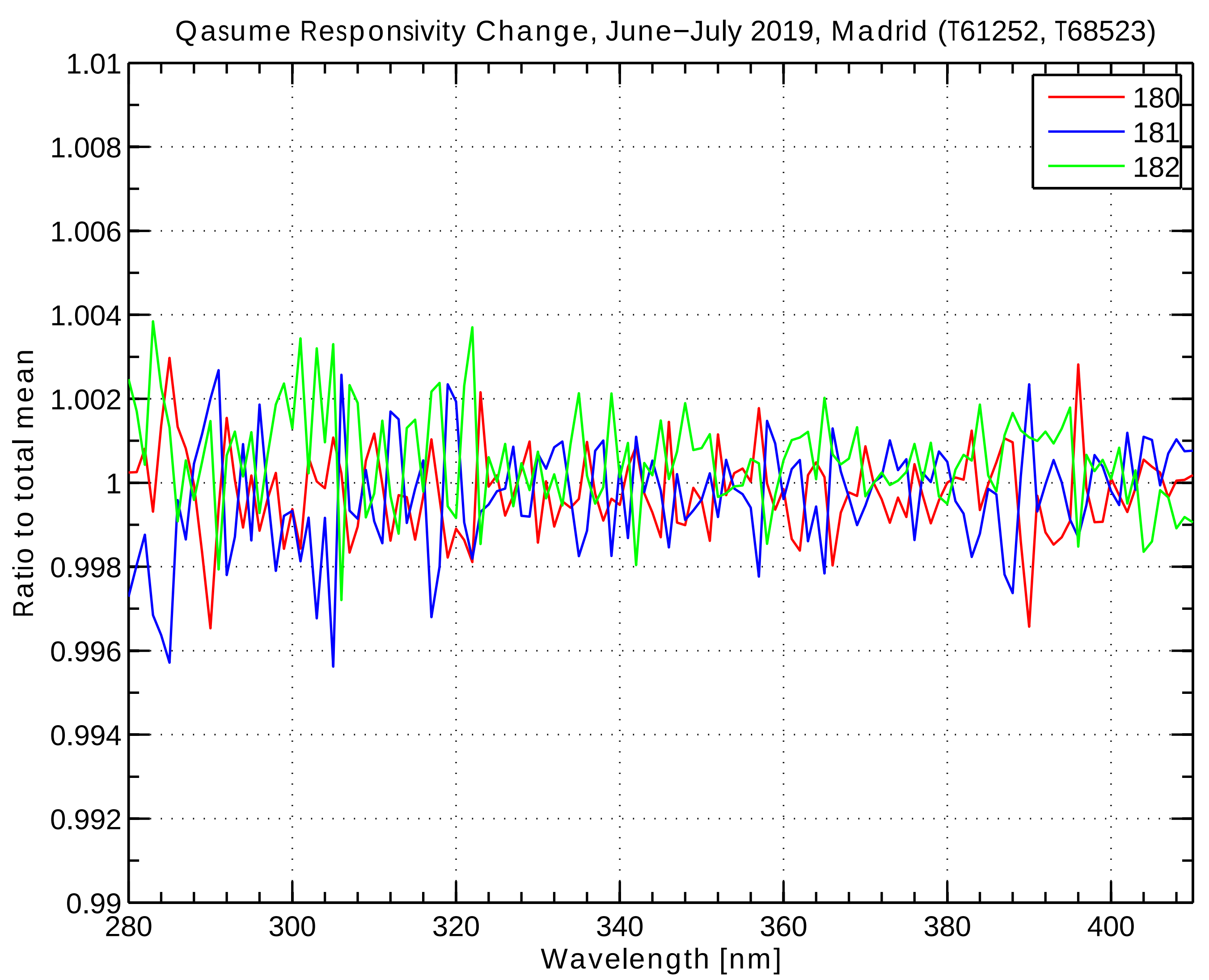
Mean ratio 186/QASUME at AEMET Madrid-matshic:29-Jun-2019(180) to 01-Jul-2019(182)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
RATIO 186/QASUME
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
310
320
330
340
350
360
370
Wavelength [nm]
N186 Spectra=93
NSync-Spectra=66

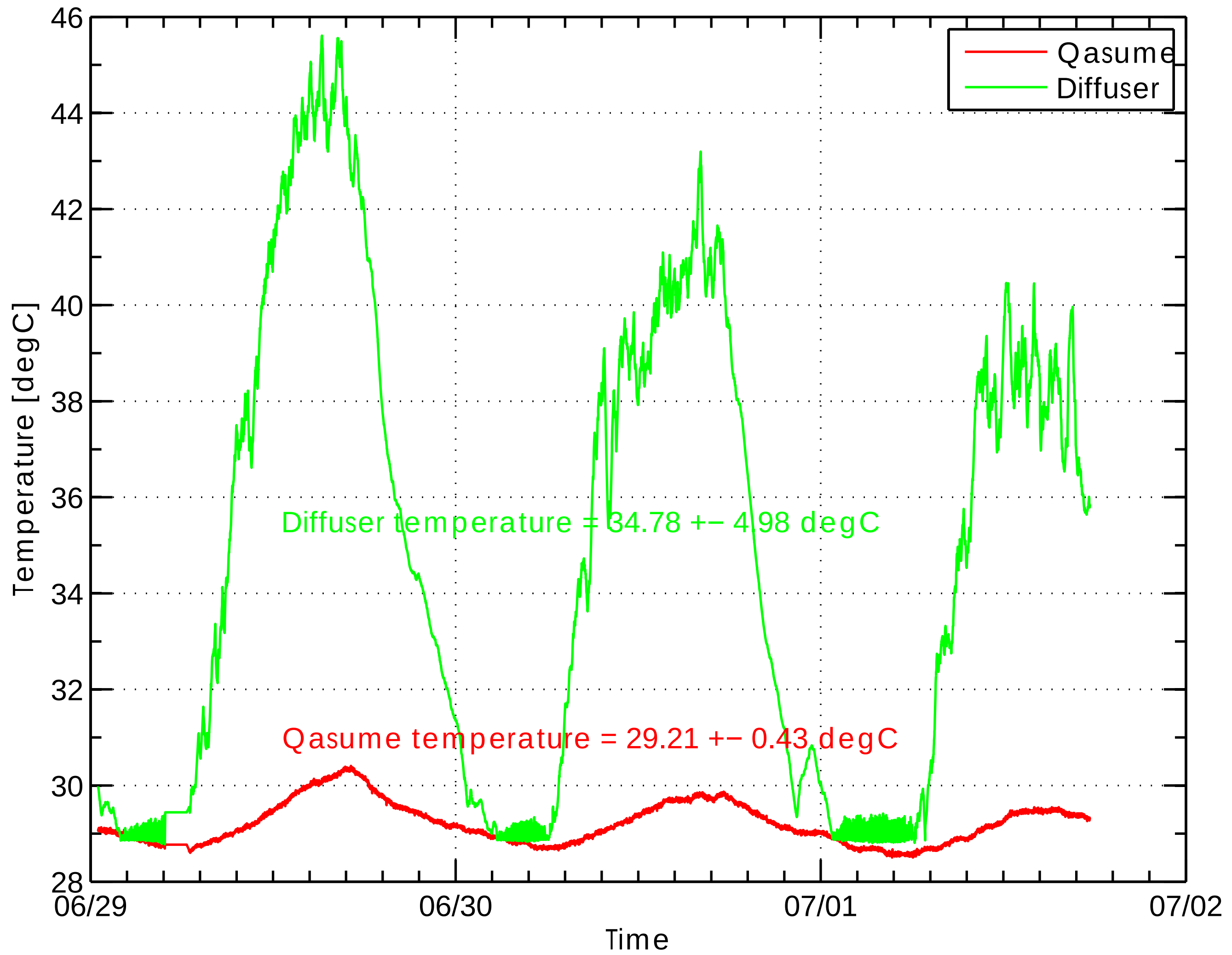


Wavelength shift
Mean
MinMax
STD
0.5
0
-0.5
300
310
320
330
340
350
360
Wavelength /nm
Wavelength shift /nm



WL=330.00 nm
0.05
0
-0.05
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
Date & time
Wavelength shift /nm


Qasume Responsivity Change, June−July 2019, Madrid (T61252, T68523)
180
181
182
Ratio to total mean
1.01
1.008
1.006
1.004
1.002
1
0.998
0.996
0.994
0.992
0.99
280
300
320
340
360
380
400
Wavelength [nm]



46
44
42
40
38
36
34
32
30
28
Temperature [degC]
06/29
06/30
07/01
07/02
Time
Qasume
Diffuser
Diffuser temperature = 34.78 +− 4.98 degC
Qasume temperature = 29.21 +− 0.43 degC


AEM
Brewer 186
QASUME