

Protocol of the solar UV intercomparison at INTA, El Arenosillo, Spain from May 26 to June 4, 2015 with the travelling reference spectroradiometer QASUME from PMOD/WRC

Report prepared by Julian Gröbner

Operator: Julian Gröbner (QASUME)

The purpose of the visit was the comparison of spectral global solar irradiance measurements between the 21 spectrophotometers participating at the 10th Regional Brewer Calibration Center – Europe (RBCC-E) Campaign (see Figure 1 and Table 1) and the travel reference spectroradiometer QASUME. The measurement site is located at El Arenosillo; Latitude 37.10 N, Longitude 6.73 W and altitude 50 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 19:00 UT have been analysed.

QASUME arrived at INTA in the morning of May 26, 2015. The spectroradiometer was installed in line to the Brewer spectrophotometers with the entrance optic of QASUME between 2 and 20 m away from the other instruments. The measurement campaign lasted nine days, from morning of May 27 to the afternoon of June 4; the core comparison days were June 2-4.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Two lamps (T68522, 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 intercomparison period. The internal temperature of QASUME was 27.9 ± 0.1 °C. The diffuser head was heated to a temperature of 33.8 ± 1.6 °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.

Table 1: Participating Brewer spectrophotometers; 10 single and 11 double monochromators.

Nr	Country	Brewer	Participants	email
1	Greece	5	Alkis Bais	abais@auth.gr
2	Canada	17	Kenneth Clark Lamb	ken@io3.ca
3	Spain	185	Alberto Redondas	aredondasm@aemet.es
4	Spain	150	J. MI Vilaplana	vilaplanagjm@inta.es
5	Argentina	201	BOULKELIA Lamine	m_mimouni_dz@yahoo.fr
6	Spain	70	Juan R. Moreta	jmoretag@aemet.es
7	Spain	186	J.M. San Atanasio	jsana@aemet.es
8	Spain	117	Francisco Escribá	fescribap@aemet.es
9	Spain	151	Francisco García	fgarciag@aemet.es
10	Spain	166.	Jose Maria San Atanasio	jsana@aemet.es
11	Spain	33	Jose Montero Cadalso	jmonteroc@aemet.es
11	UK	172	John Rimmer	john.s.rimmer@manchester.ac.uk,
12	UK	75	Peter Kelly	peter.kelly@manchester.ac.uk,
13	UK	126	John Rimmer	john.s.rimmer@manchester.ac.uk
14	Switzerland	163(ISQ)	Julian Gröbner	julian.groebner@pmodwrc.ch,
15	Netherlands	158	Oleksii Marianenko	
16	Netherlands	230	Keith M. Wilson	
17	Denmark	202	Paul Eriksen	pe@dm.dk
19	Denmark	228	Niss Jepsen	nje@dm.dk
20	Finland	214	Tomi Karppinen	Tomi.Karppinen@fmi.fi
21	Russia	44	Vadim Shirotov	v.shirotov@gmail.com

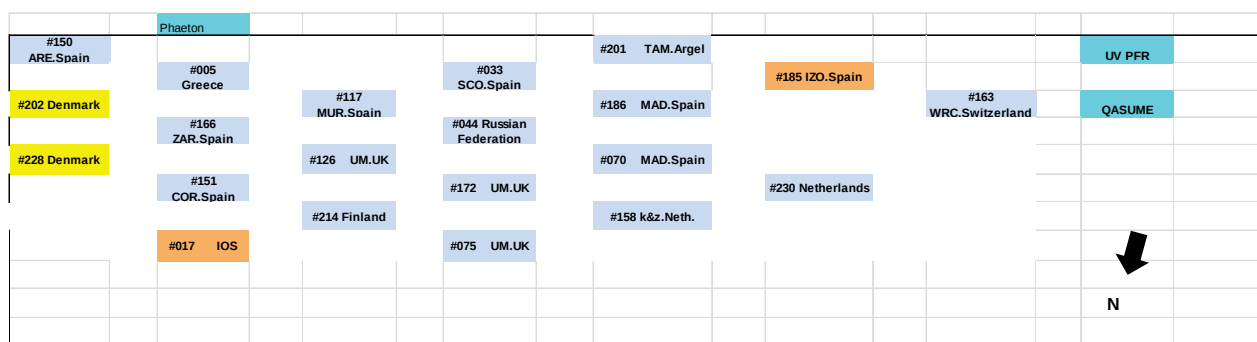


Figure 1: Roof setup at INTA

Protocol:

The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 to 400 nm, every 0.5 nm, and 3 seconds between each wavelength increment. The official UV days were scheduled from 2 to 4 June.

DOY	Date	DAY	Weather	Comment (time in UT)
145	25 May	Monday	Clear Sky	Installed at 16:17
146	26 May	Tuesday	Clear Sky, cirrus	Calibrated: 15-15:40 using T68523, T68522
147	27 May	Wednesday	Clear Sky, cirrus, light	Calibrated:11:00 using T68523
148	28 May	Thursday	Clear Sky, cirrus	
149	29 May	Friday	Clear Sky , Ci, Cu	
150	30 May	Saturday	Overcast until 10:00 , then Clear Sky	Calibrated: 12:50 using T68523
151	31 May	Sunday	Clear Sky	
152	1 June	Monday	Clear sky	Calibrated at 10:36 using T68523
153	2 June	Tuesday	Clear Sky	Calibrated at 8:36 using T68523 Calibrated at 10:34 using T68523
154	3 June	Wednesday	Clear sky	Calibrated: 17:37 using T68523
155	4 June	Thursday	Clear Sky	Calibrated at 16:12-17:00 using T68522 and T68523 17:00 end of Campaign

Results:

Up to 116 synchronised simultaneous spectra from QASUME and the Brewer spectrophotometers are available from the measurement period. Measurements between 6:00 and 19:00 UT have been analysed (SZA smaller than 90°) using the matSHIC tool developed within the EMRP project SolarUV. The program is open source and can be obtained on request.

Remarks:

- The UV scans were processed individually by all operators using reference standards traceable to different metrological institutes. Figure 2 shows a comparison of several reference standards used during the campaign. Lamp S1219 belongs to INTA and was used to calibrate Brewer #150. The observed offset of 3% was investigated after the campaign (personal communication J.M. Vilaplana), confirming the results and indicating that the lamp has become unstable. The remaining lamps are traceable to NIST, PTB, MIKES and PMOD/WRC and are within $\pm 1\%$.

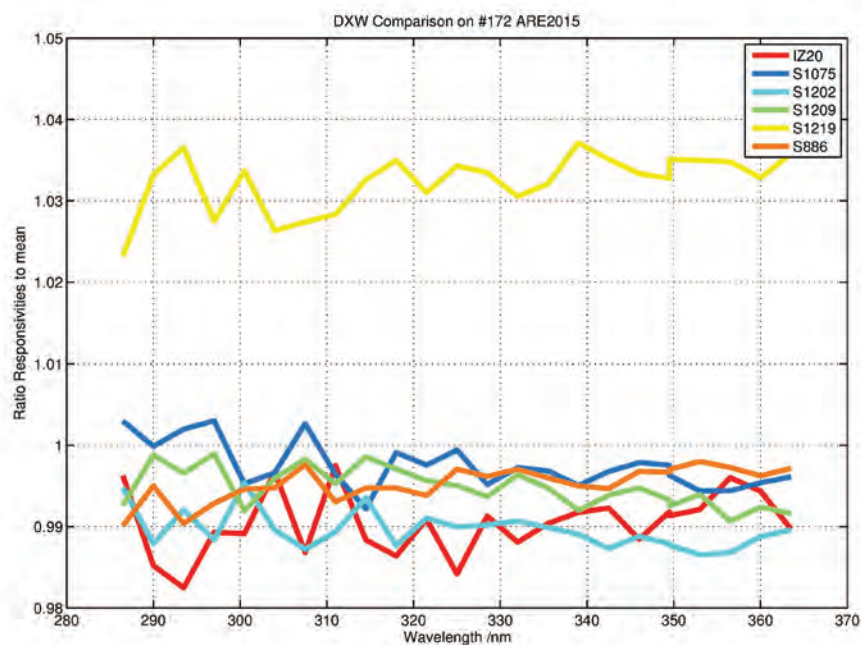


Figure 2 Standard lamp comparisons using Brewer#172 and the lamp setup system from Kipp&Zonen. The reason for the offset of S1219 is not yet understood.

- Brewer #158 and #228 did not submit any solar UV data during this campaign.
- Brewer #163 (ISQ) has a custom-diffuser (**Gröbner**, J., Improved entrance optic for global irradiance measurements with a Brewer spectrophotometer, Applied Optics, 42, 3516- 3521, 2003.) and is operated by PMOD/WRC. A temperature correction of $-0.15\%/K$ is applied to the data.

- Figure 3 shows the average ratios of all measurements of the whole period relative to QASUME using the calibrations from the instrument operators. The spread of the measurements is more than 20% with the majority of the instruments under-estimating the solar UV irradiance. The observed differences should in principle not be due to calibration differences between the instruments, since the reference standards agree to within 1% as shown in Figure 2. However the source of the calibrations is not always traceable. In addition, additional effects, such as angular response errors or temperature corrections also affect the measurements.

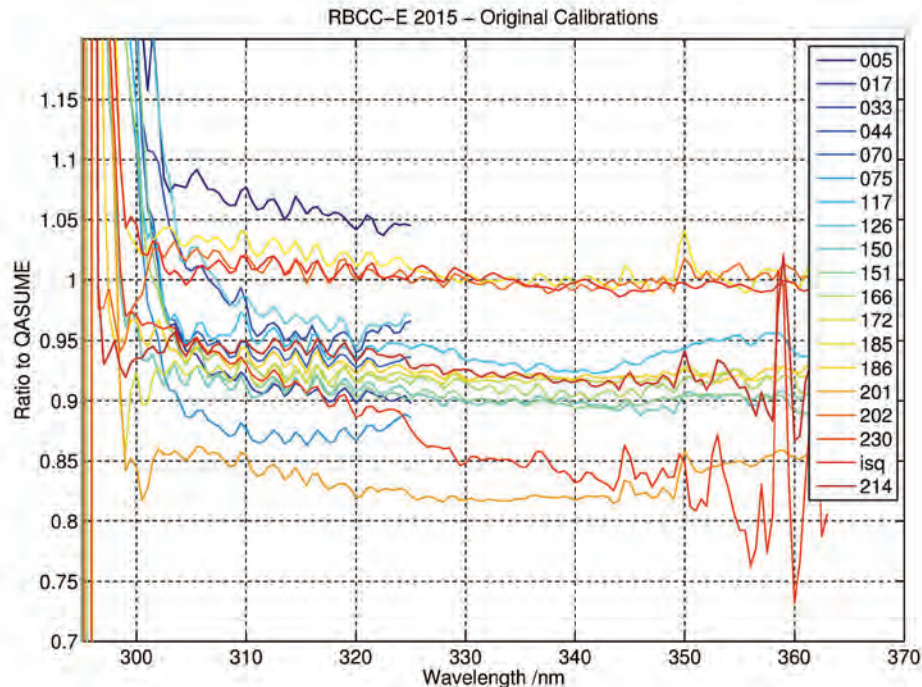


Figure 3 Average ratios from the whole campaign to QASUME using the calibrations from the instrument operators.

- Only 5 out of 18 Brewer spectrophotometers are within $\pm 5\%$ of the QASUME reference, while 6 Brewers are outside of the 10% band.
- Most instruments have significant diurnal variations due to uncorrected temperature and angular response problems. The individual measurements are shown in the following pages. Note that the grey-shaded area in the figure represents the uncertainty of the QASUME spectroradiometer at 95% confidence level.
- The UV data of most instruments was reprocessed using a common calibration based on the SL1075 lamp, using the equipment provided by Kipp&Zonen, and performed by the operators of Kipp&Zonen. The results are summarised in Figure 4.

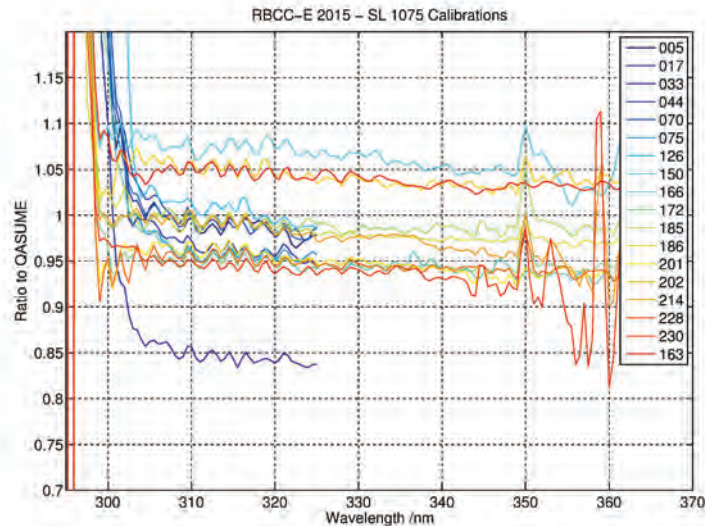


Figure 4 Average ratios from the whole campaign to QASUME using a common calibration based on SL1075.

- Comparing the calibrations between the ones from the instrument operator and the one based on SL1075 shows that they vary by up to 20%:

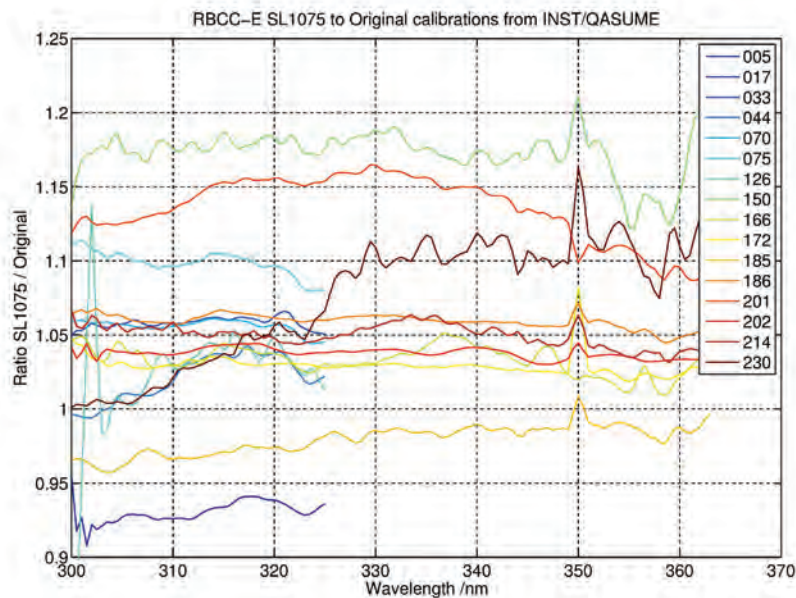
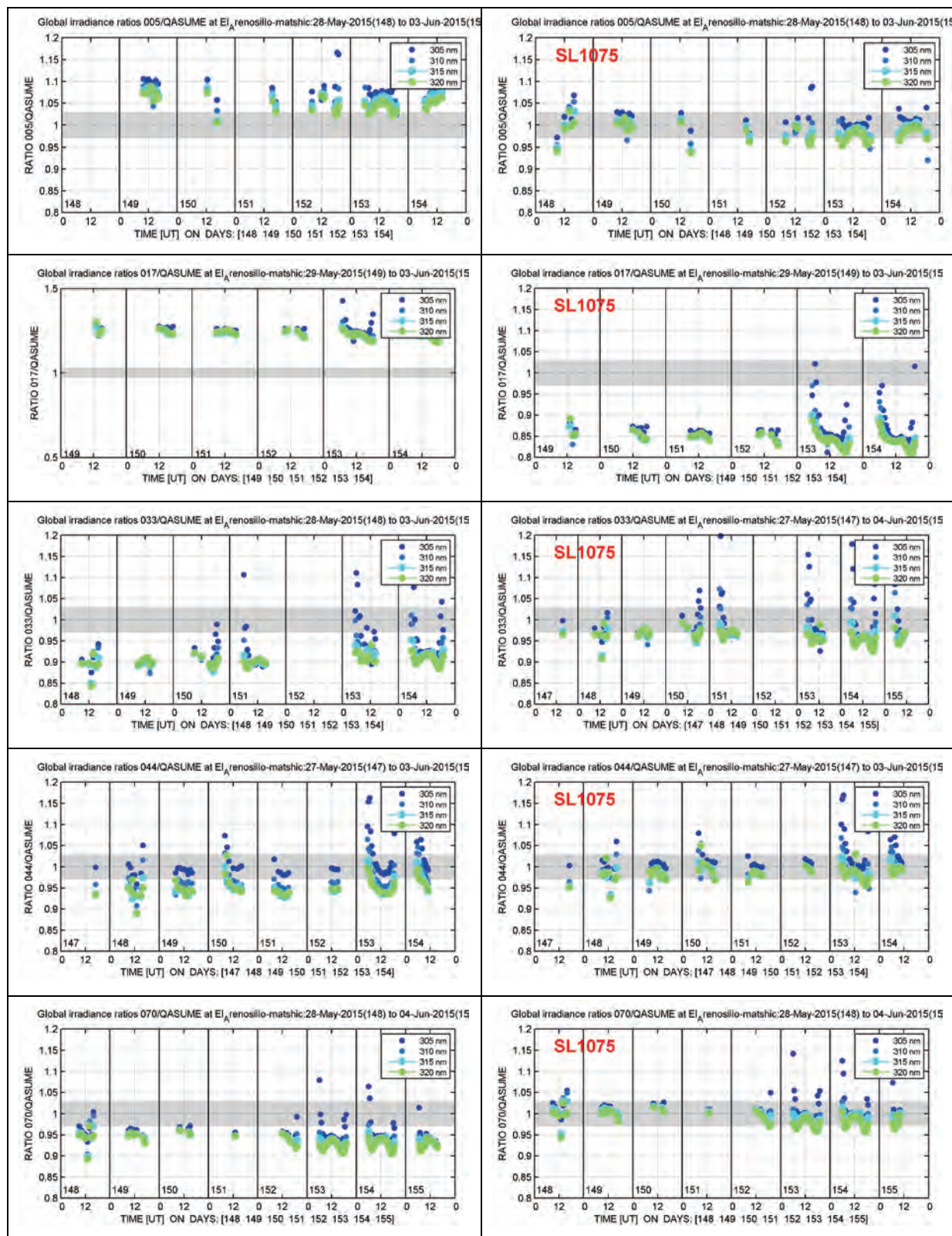
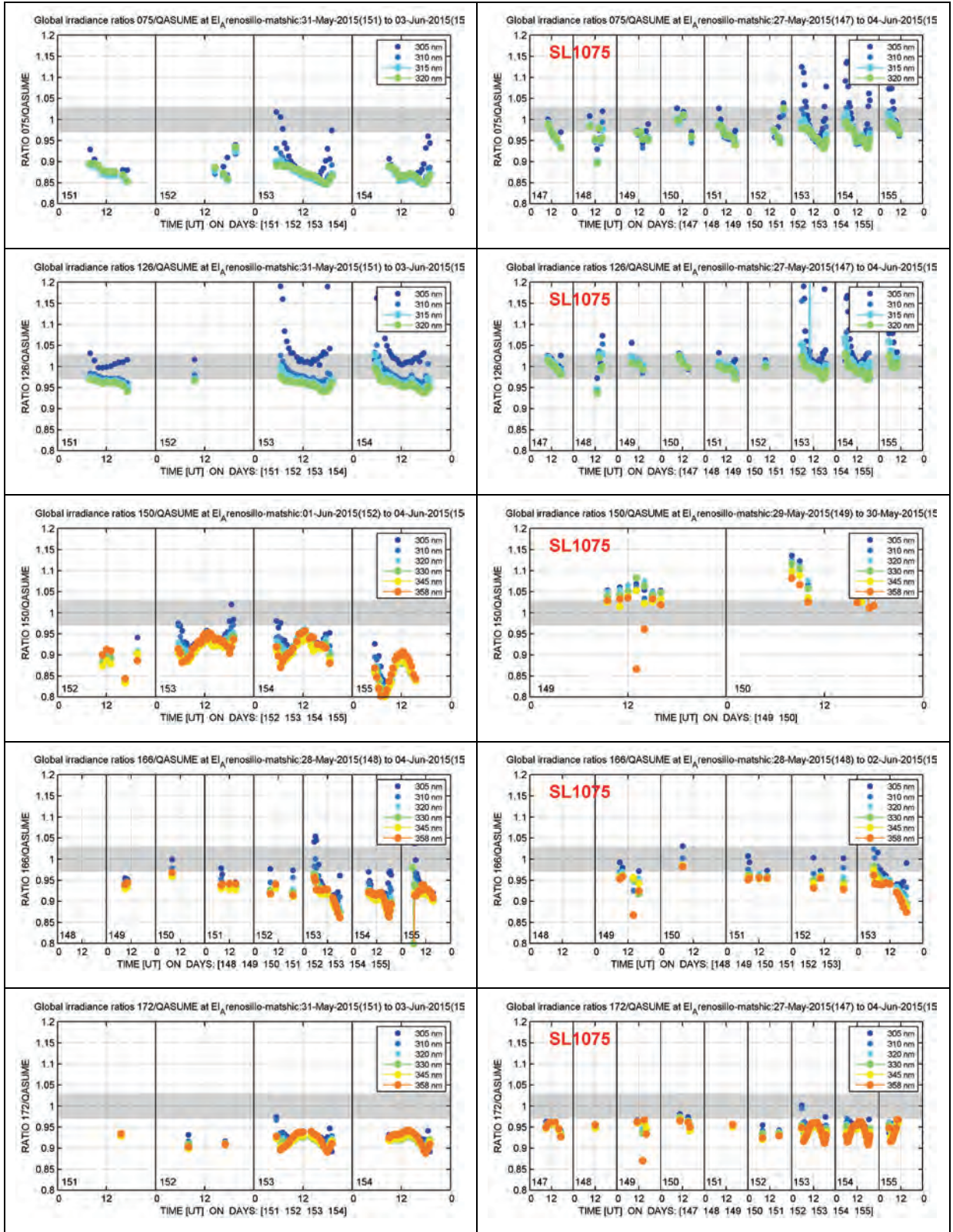


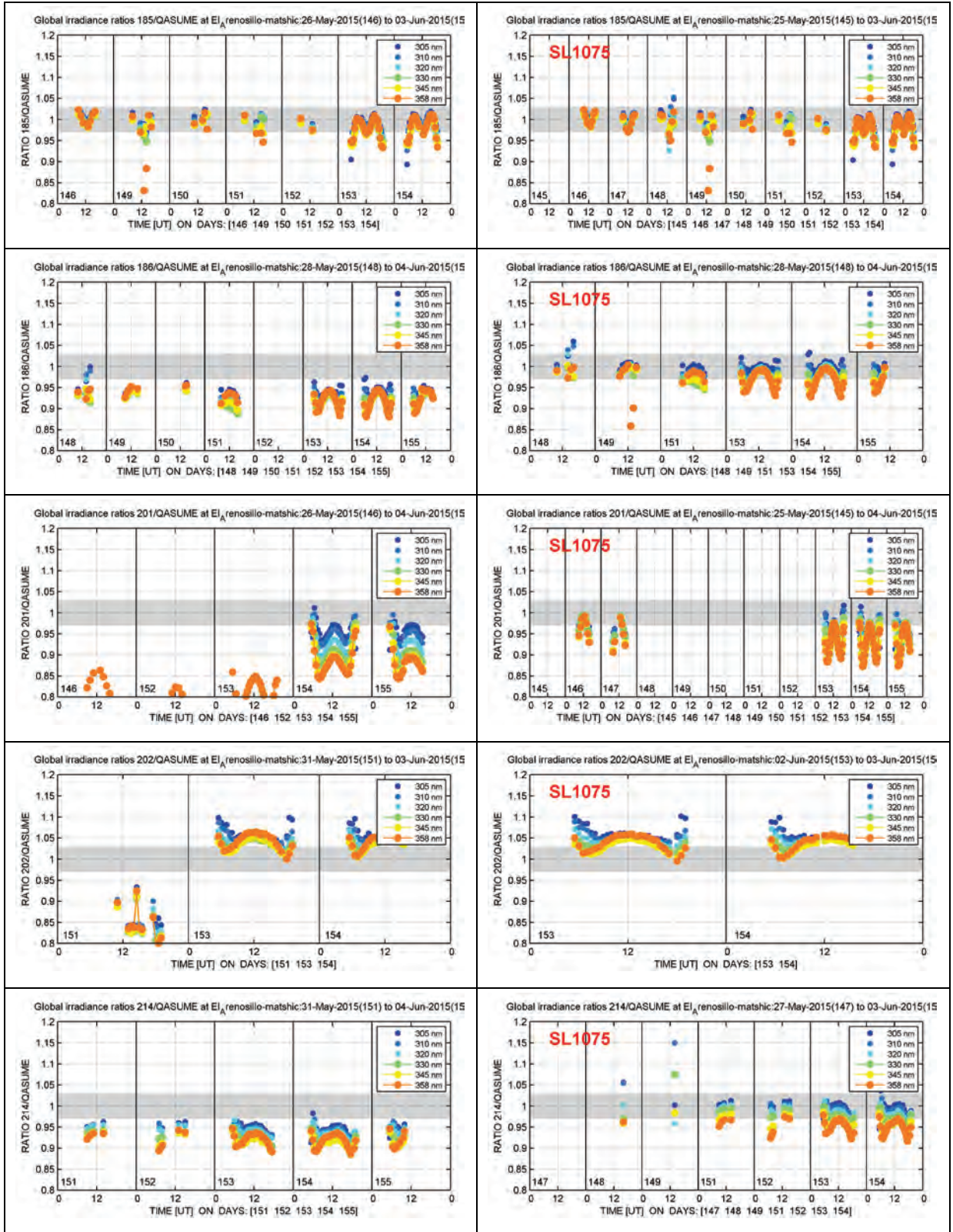
Figure 5 Difference between the calibration of the instrument operator and the common calibration based on SL1075.

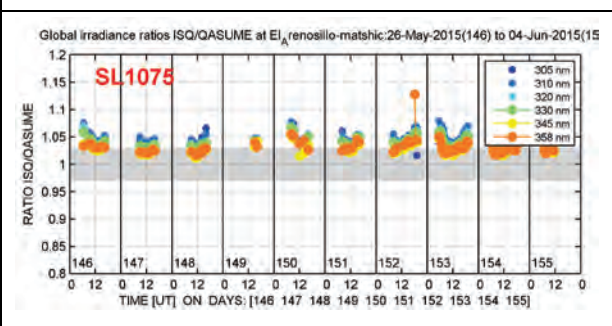
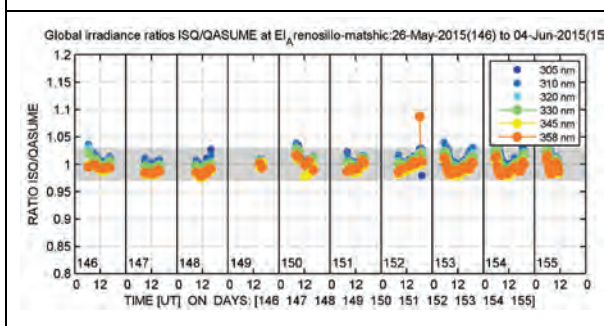
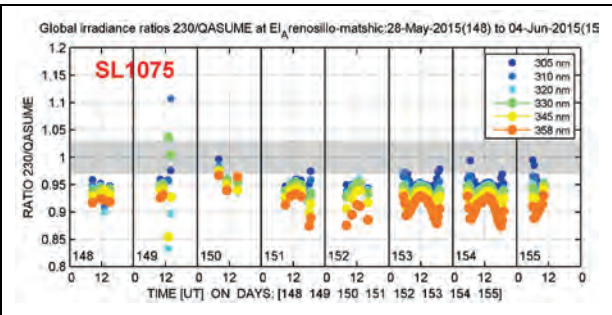
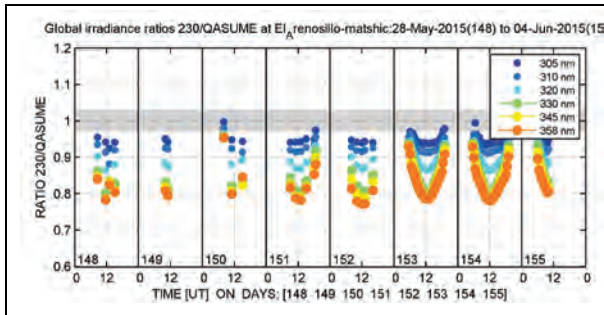
- The comparison of solar UV spectra based on the two calibrations are shown in the following figures for individual instruments, with respect to QASUME. As can be seen in the figures, for many Brewers the common calibration performed during the campaign, and based on SL1075, produces better results than the operator based calibration:

Summary of available solar irradiance measurements between each Brewer and QASUME. On the left is shown the data using the owner calibration (data submitted by the instrument operator), while the right side is based on the same raw UV data but using the calibration performed during the campaign using a secondary transfer standard (SL1075)



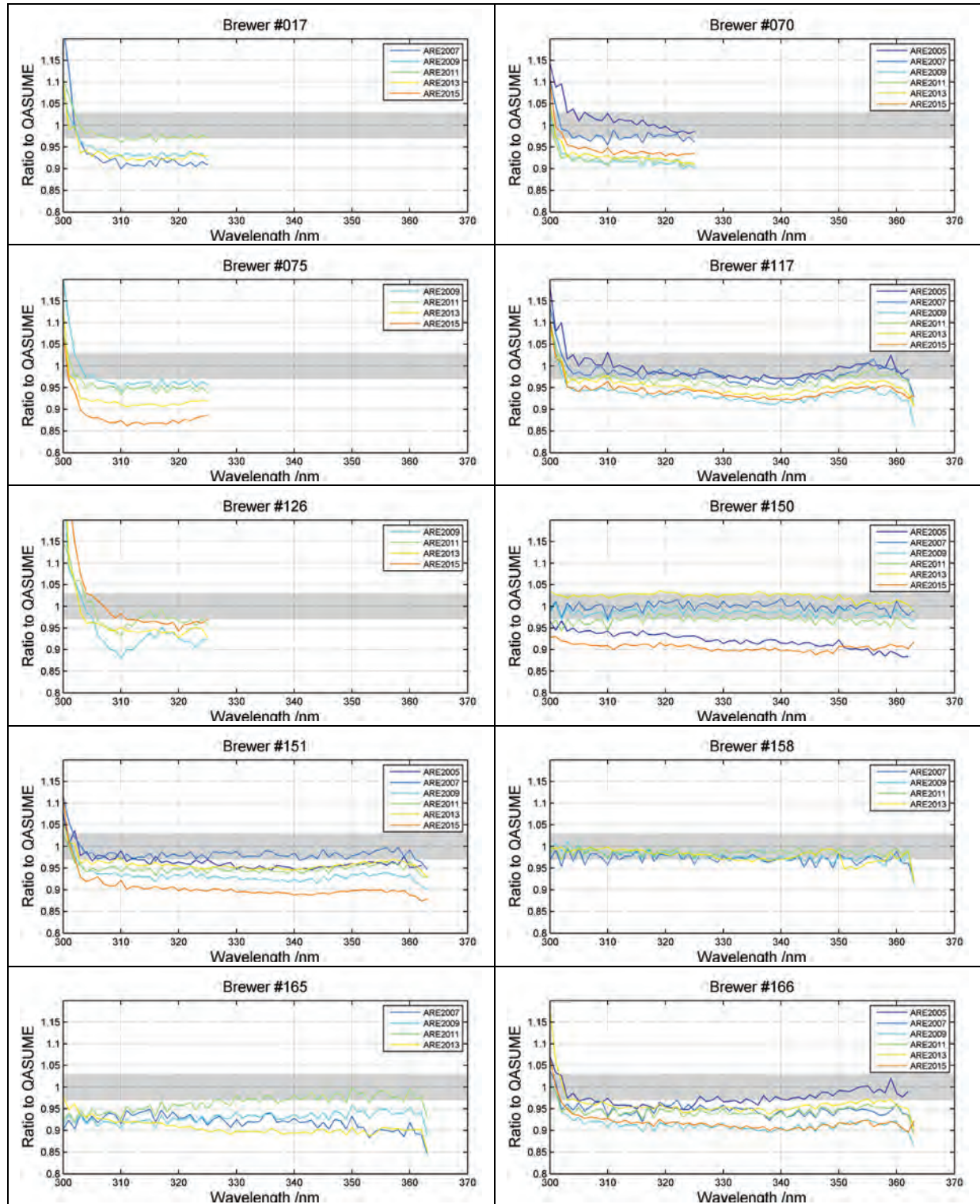


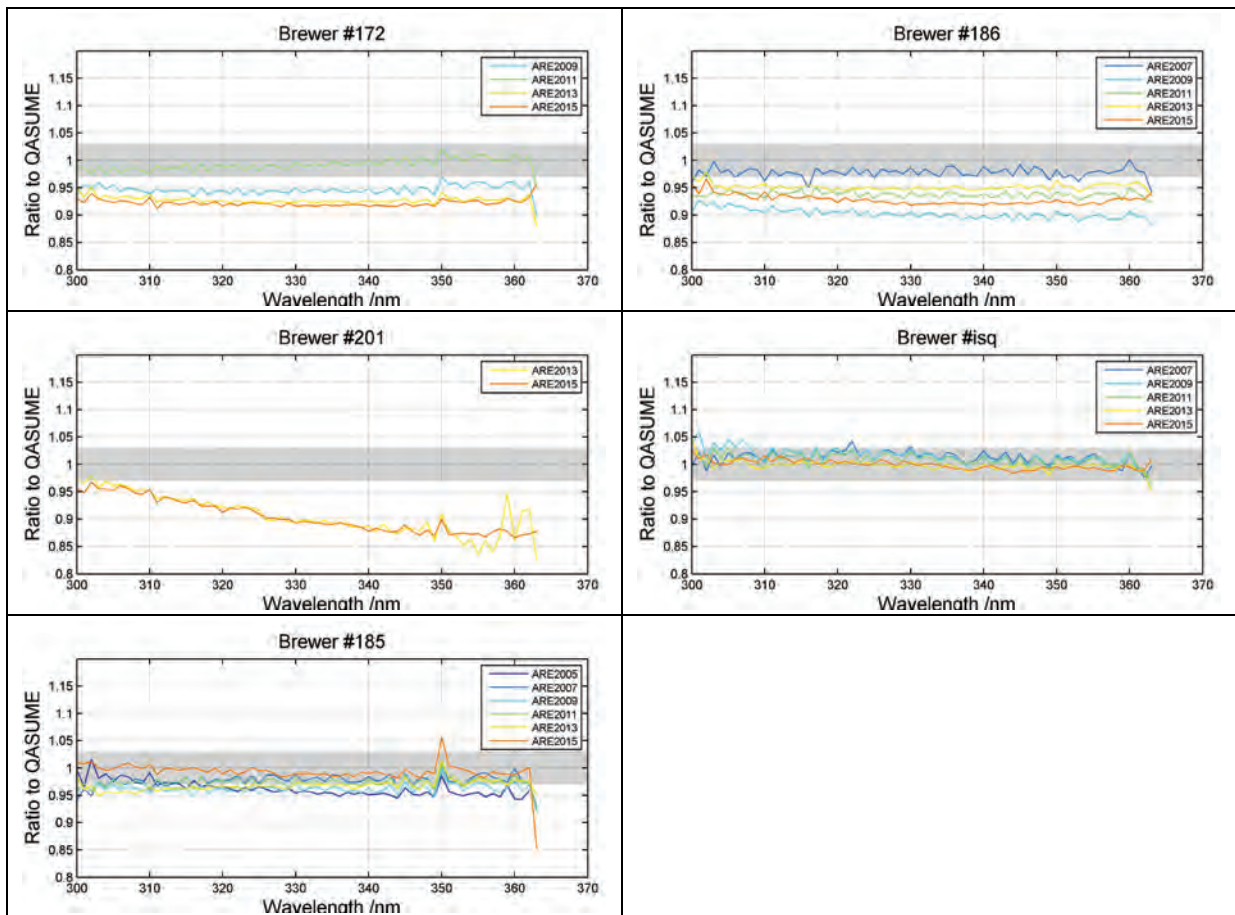




History:

The following figures show an overview of all comparisons between Brewers and QASUME during RBCC-E campaigns since 2005.





Conclusion:

- The current uncertainty of daily average solar UV measurements of the EUBREWNET network is at least $\pm 10\%$, with an overall bias towards under-estimating solar UV irradiance by about 5% to 10%.
- Individual solar UV spectra from the participating Brewer spectrophotometers range between -20% to +10% over the whole day.
- The calibration based on a common reference lamp used during the campaign improves the overall results, even though individual brewers still show large differences to QASUME.
- The comparison of the measurements to previous years show that the observed differences to QASUME vary by 10% to 15% between successive campaigns, generally underestimating the solar UV irradiance by 5% to 10%. This is an indication that the current long-term UV datasets from these Brewers have an uncertainty of 10% and a bias towards under-estimating solar UV irradiance.
- The wavelength shifts determined with respect to a high resolution reference spectrum using matSHIC are for most Brewers within ± 50 pm with a very low variability. Nevertheless, some Brewers exhibit discrepancies of up to 0.2 nm at wavelengths longer than about 340 nm. These deviations most likely result from the use of a quadratic dispersion function, which is generally not adequate in describing the micrometer to wavelength relationship for wavelength ranges between 280 and 360 nm.

Suggestions:

- The largest source of uncertainty is still the absolute calibration of the Brewer spectroradiometers, as performed by the instrument operators. A common calibration performed during the campaign improves considerably the results, but unexplained discrepancies (e.g. Br #163 original versus SL1075 calibration) indicate that there remain inconsistencies which need to be resolved.
- Another important source of uncertainty for solar UV measurements is currently the angular response of Brewer spectrophotometers, which is partly responsible for the under-estimation of solar UV radiation, as well as the pronounced diurnal pattern observed with all Brewers equipped with the standard diffuser.

Acknowledgments:

- The lamp comparisons shown in Figure 2 and the calibrations of all Brewers with SL1075 were done by Oleksii Marianenko and Pavel Babal.
- The UV data based on SL1075 was calculated by Alberto Redondas and Sergio Leon.

General UV Processing for Lamp 1075 (Alberto Redondas)

- UV response file is calculated using QL measurements of lamp 1075. For extended brewers the full resolution response file is obtained using piecewise cubic Hermite Interpolation polynomials independently for the two slits.

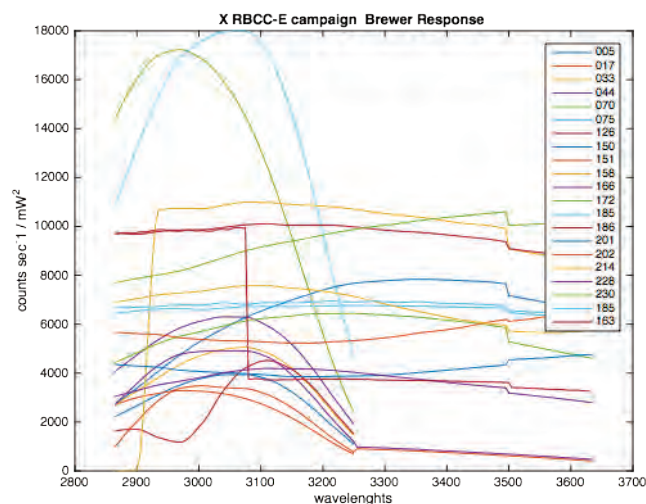


Figure 6 Spectral response of Brewers based on lamp 1075.

Comments from operators

Brewer 185. The solar UV data was revised after the campaign, and a new dataset submitted. The response of 185 looks stable since 2014 with, monthly 200W lamps are performed and shows deviations lower than 1% , thus we maintain the response of 185 the same as November 2014 (**UV33514.185**).

An exception was the calibration performed just before the campaign, the agreement between the lamps were bad. The new reference lamp NIST provided by PMOD/WRC were 5% off but agree with the current response whereas old reference 857 and 957 agree to each other and with the last calibration performed 10 days ago. The response **UV13515** used on the data delivery during the campaign was calculated removing the measurement of the lamps 120.

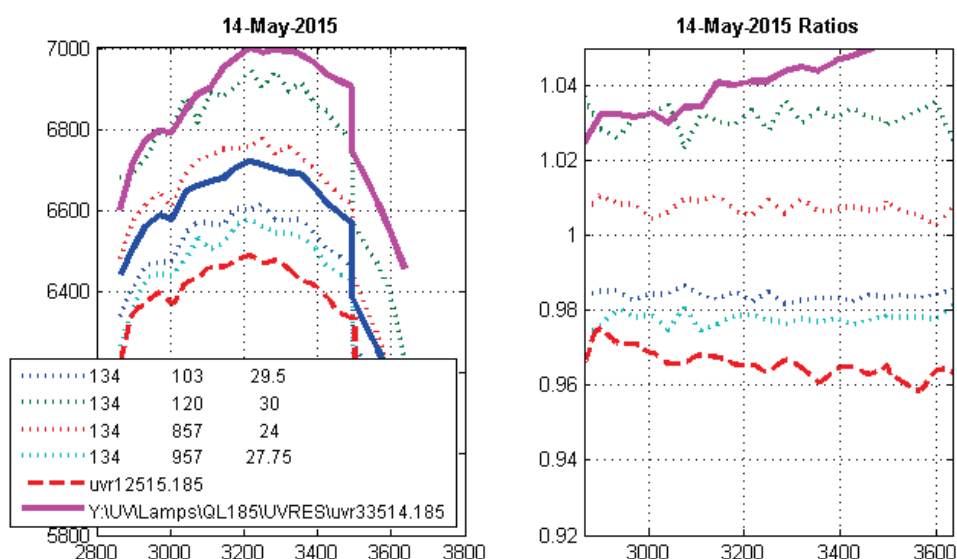
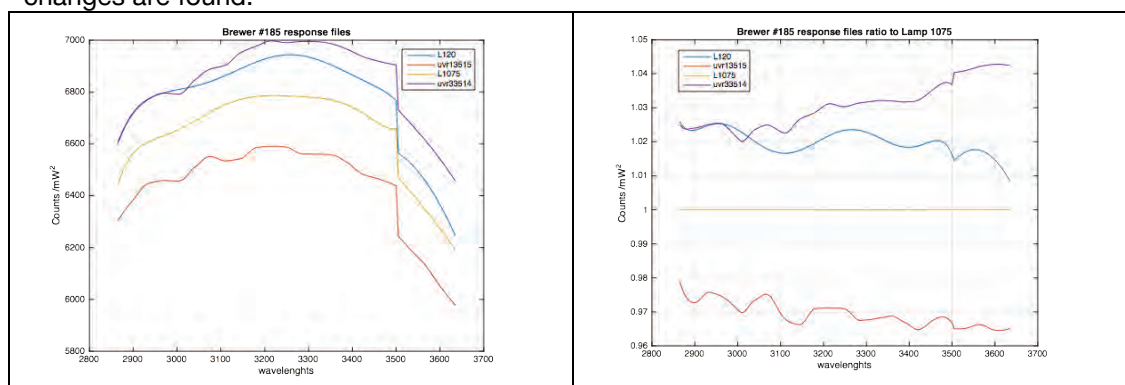


Figure Calibration performed at Izaña with the 1000W lamps

At huelva the lamp 120 were compared with the other references lamps and shows a quite good agreement so we decide to use the calibration performed with this lamp for the comparison with quasume. But by error the data were analyzed with UVR13515.185 with the exception of the last days who were calculated with the lamp L120.

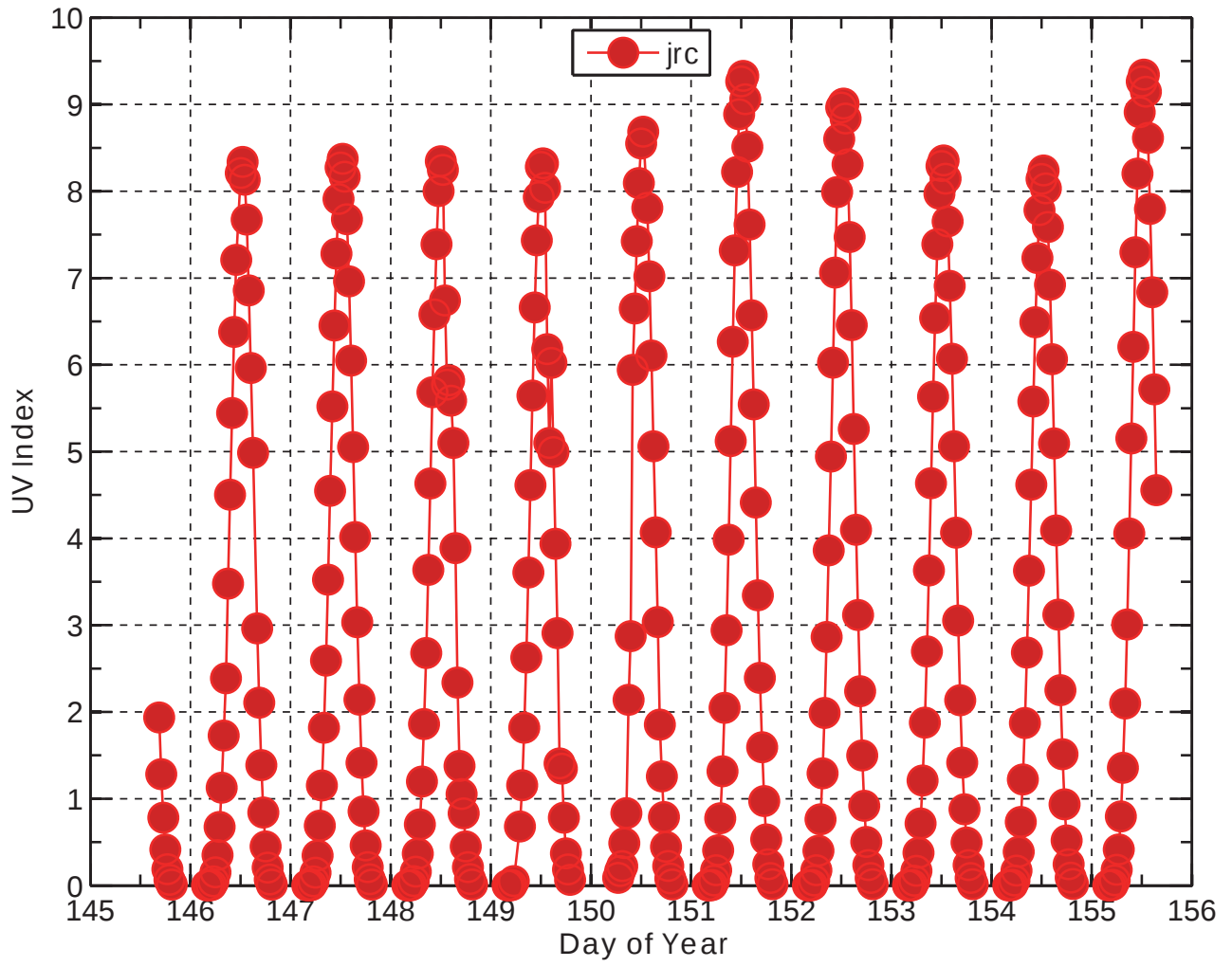
The revised data is processed with this response with all the days and not only the last days, the response is very similar 2% to the one obtained with the lamp 1075 and no significant changes are found.



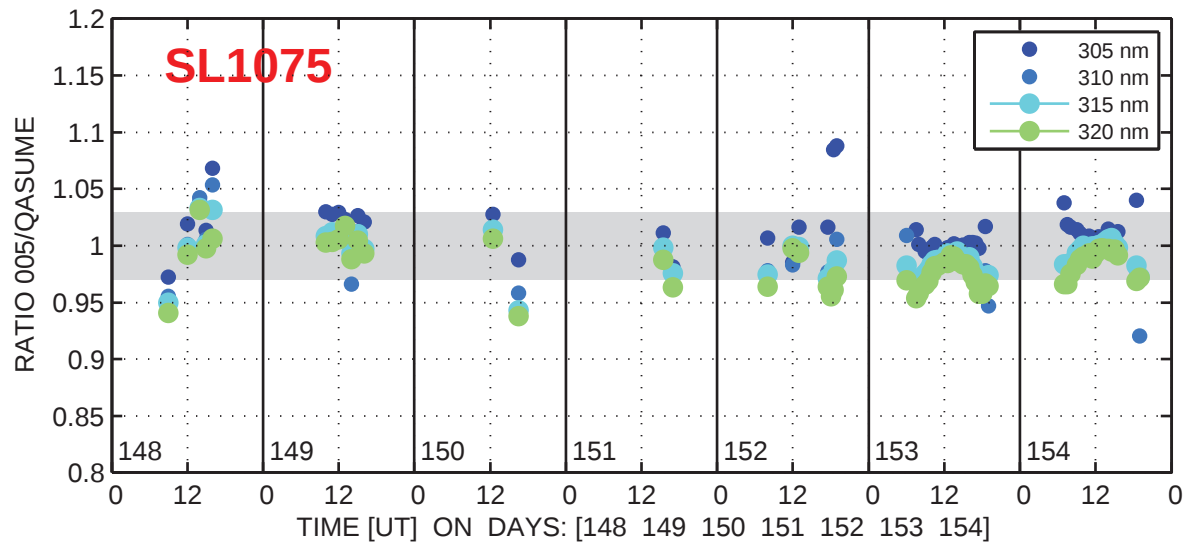
Appendix

Detailed results for all Brewer spectrophotometers with respect to the reference spectroradiometer QASUME

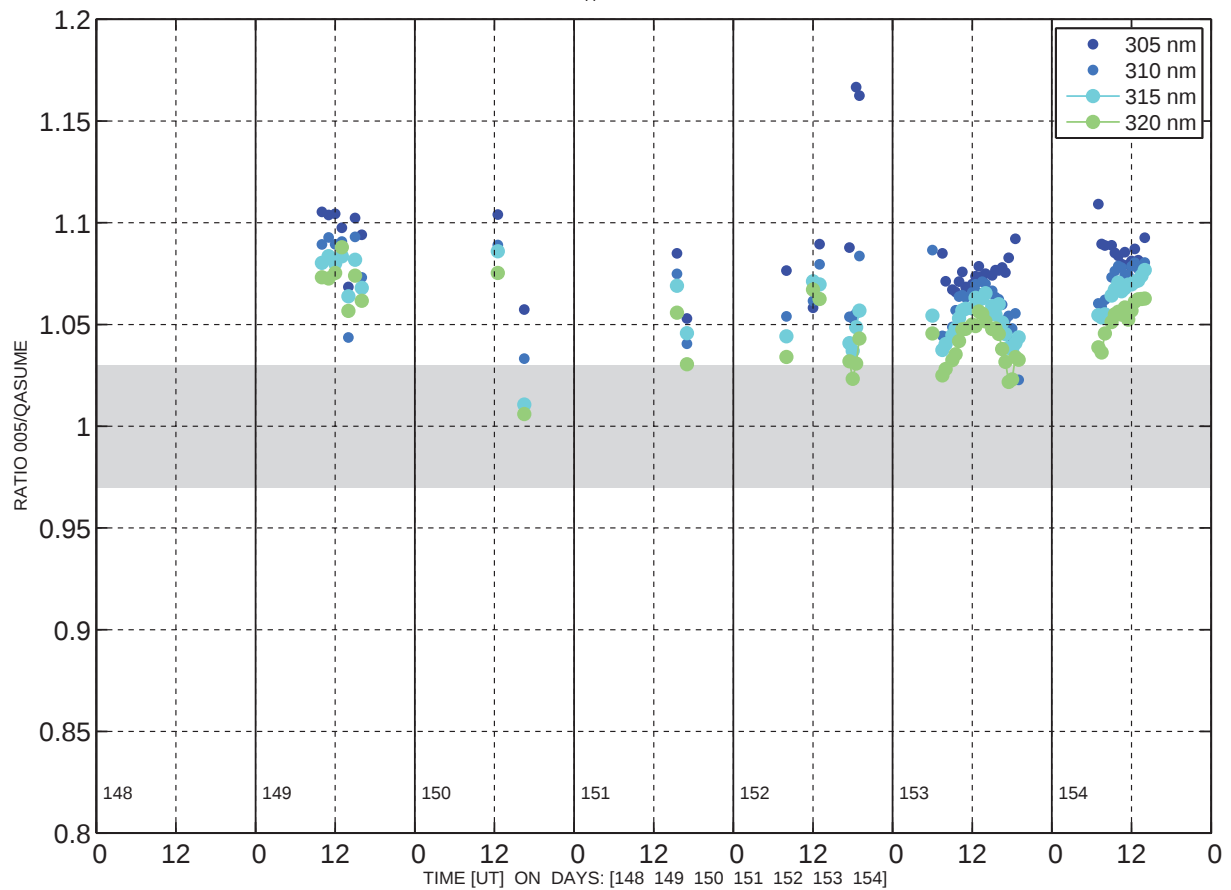
UV Index INTA, June 2015



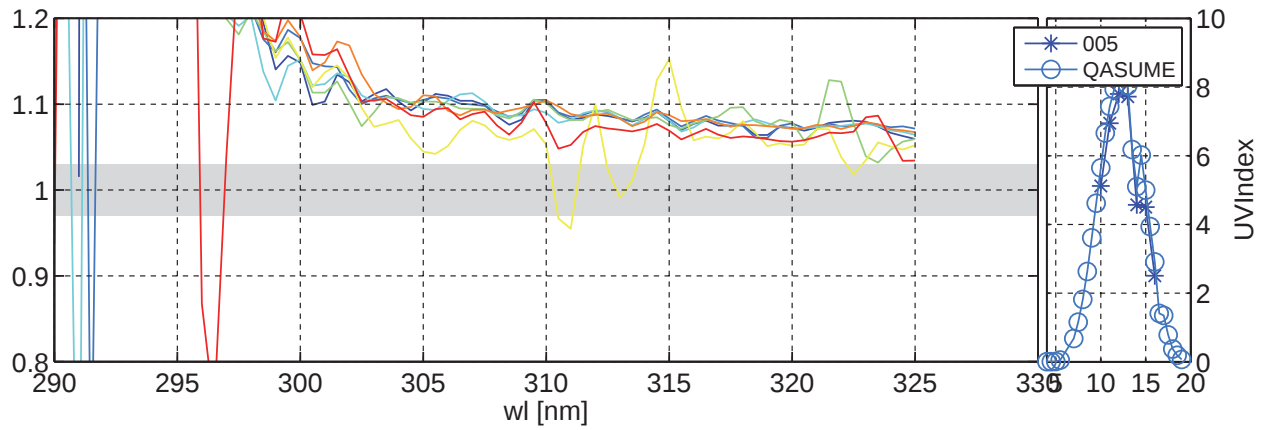
Global irradiance ratios 005/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 03-Jun-2015(154)



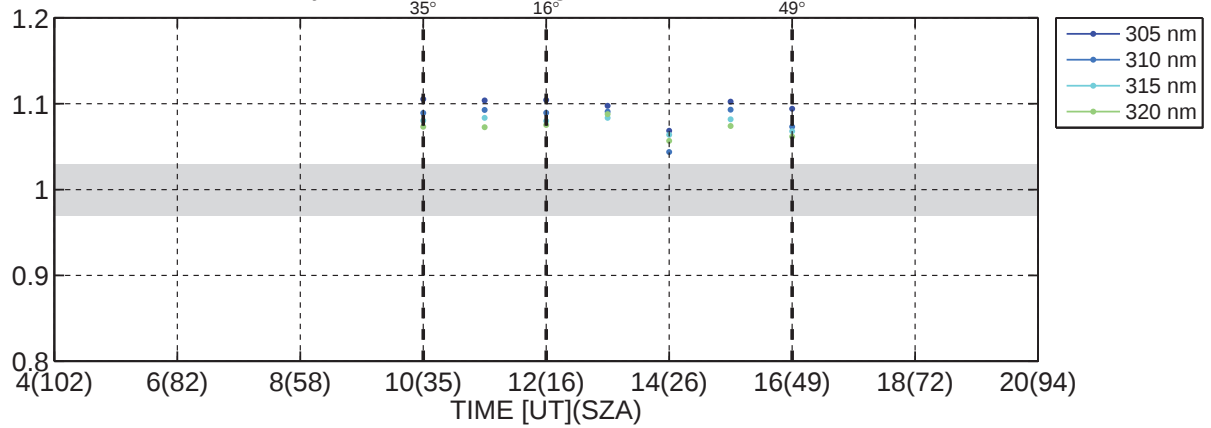
Global irradiance ratios 005/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 03-Jun-2015(154)



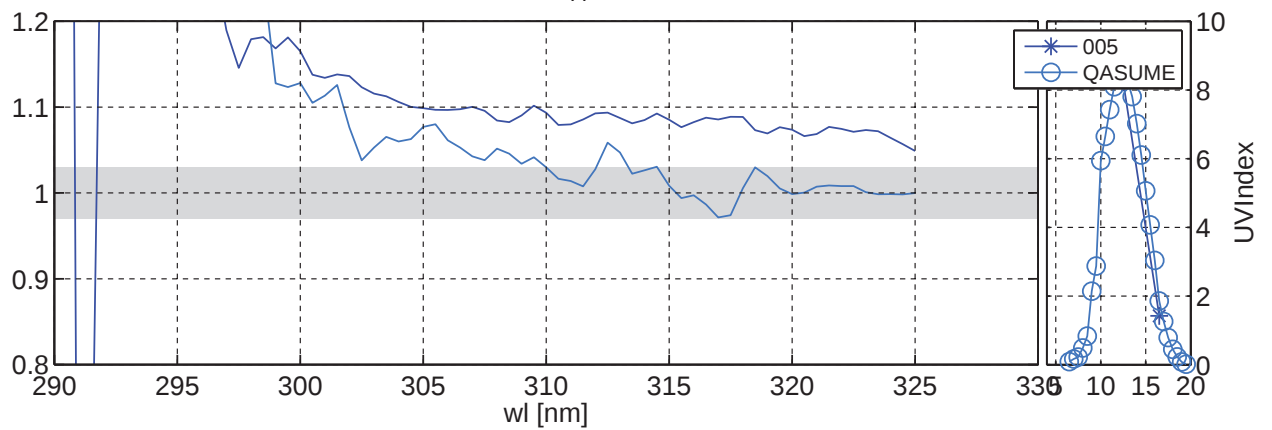
Global irradiance ratios 005/QASUME at El_A renosillo-matshic:29-May-2015(149)



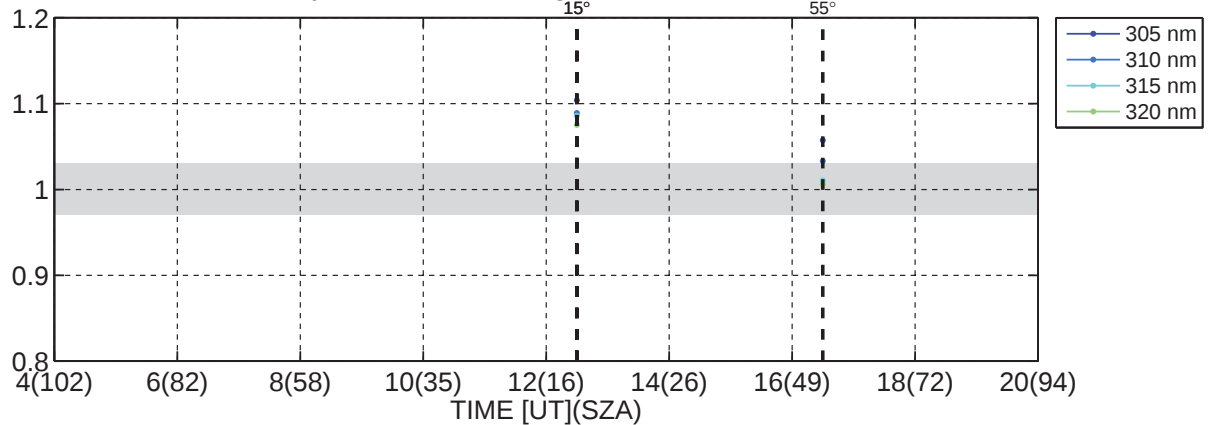
Daily variation. Wavelength bands are ± 2.5 nm



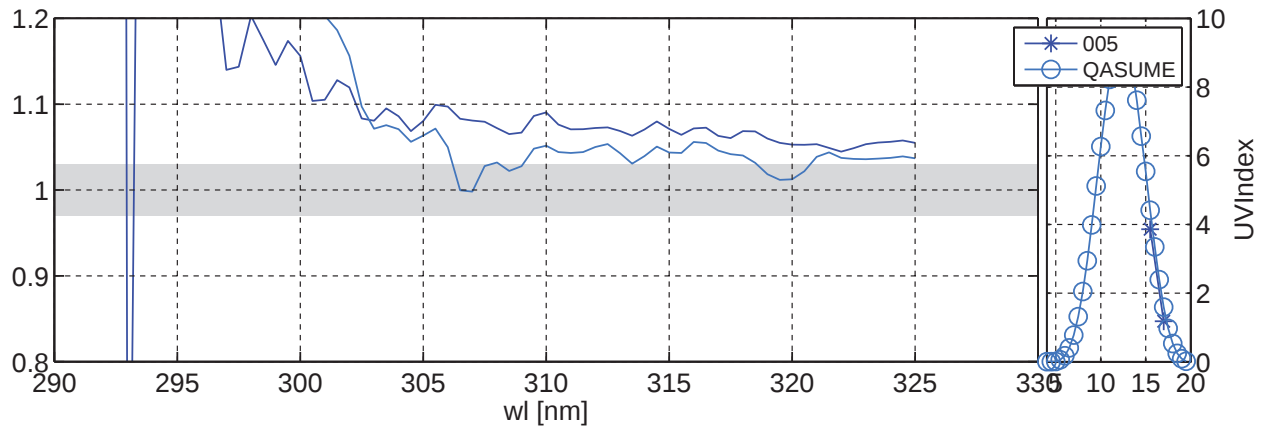
Global irradiance ratios 005/QASUME at El_A renosillo-matshic:30-May-2015(150)



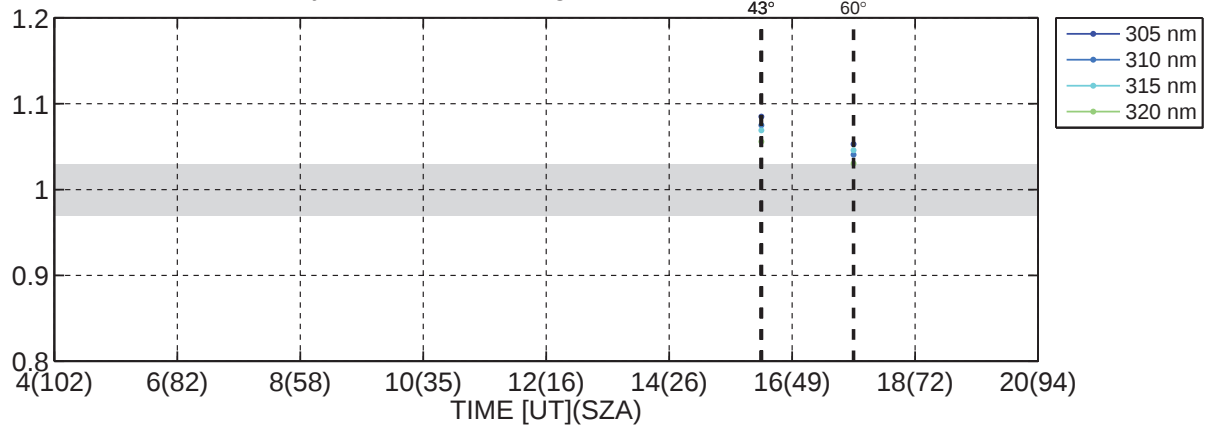
Daily variation. Wavelength bands are ± 2.5 nm



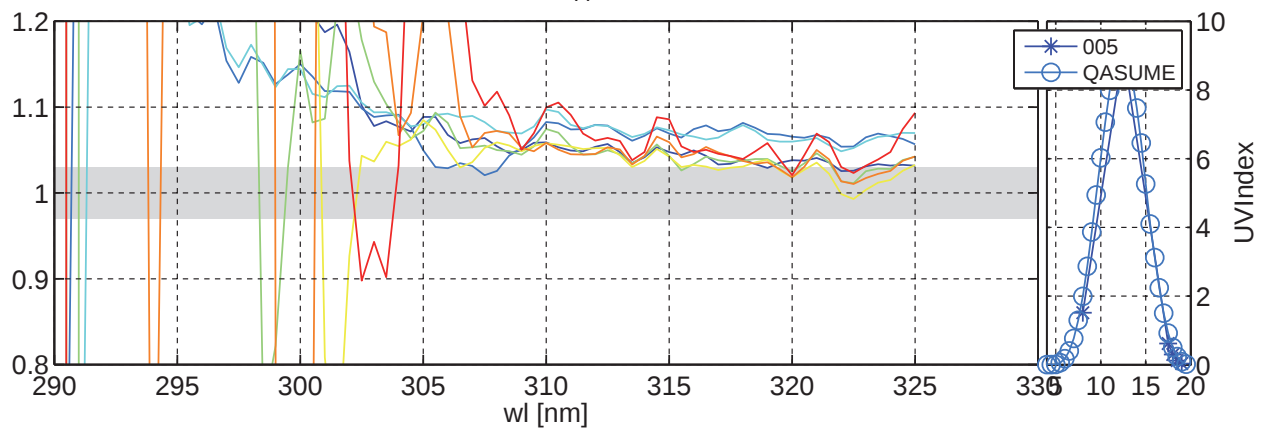
Global irradiance ratios 005/QASUME at El_Arenosillo-matshic:31-May-2015(151)



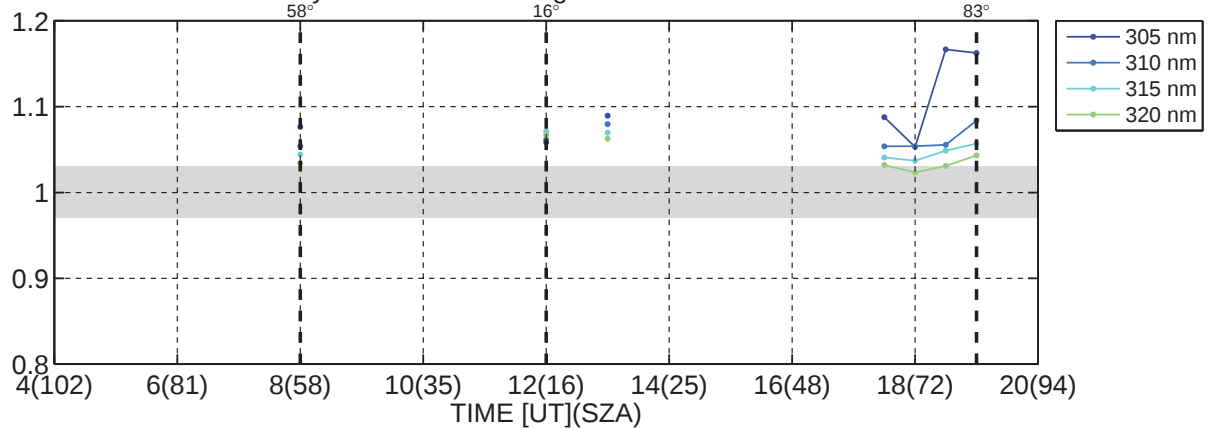
Daily variation. Wavelength bands are ± 2.5 nm



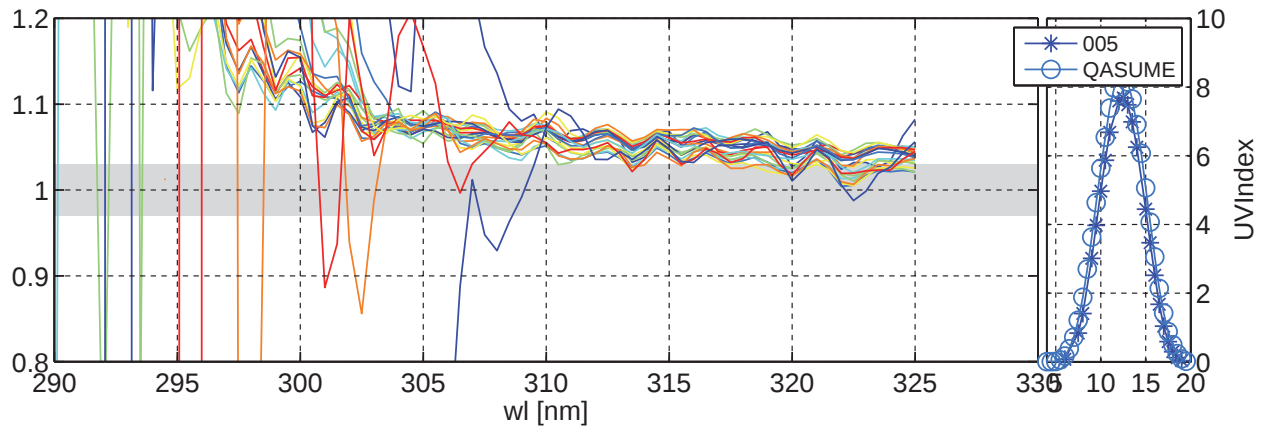
Global irradiance ratios 005/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



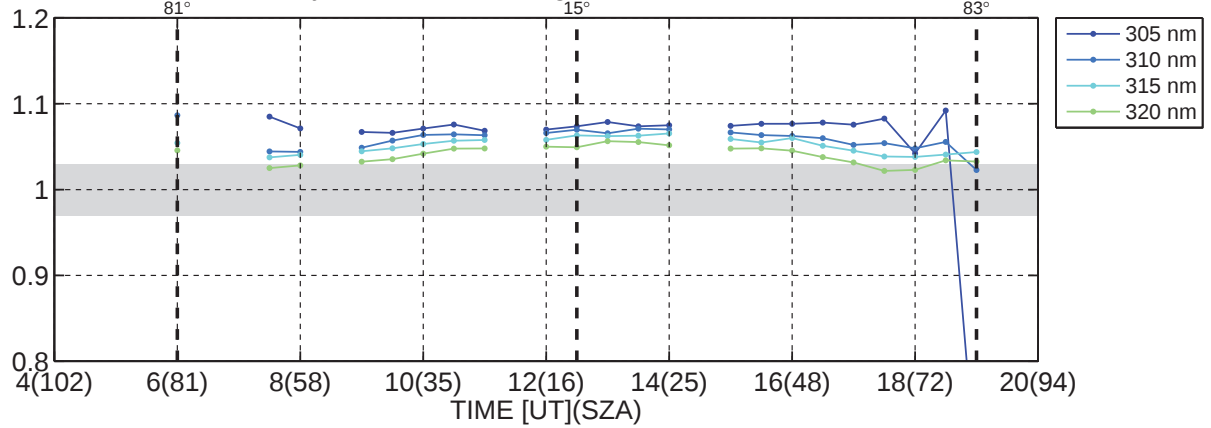
Daily variation. Wavelength bands are ± 2.5 nm



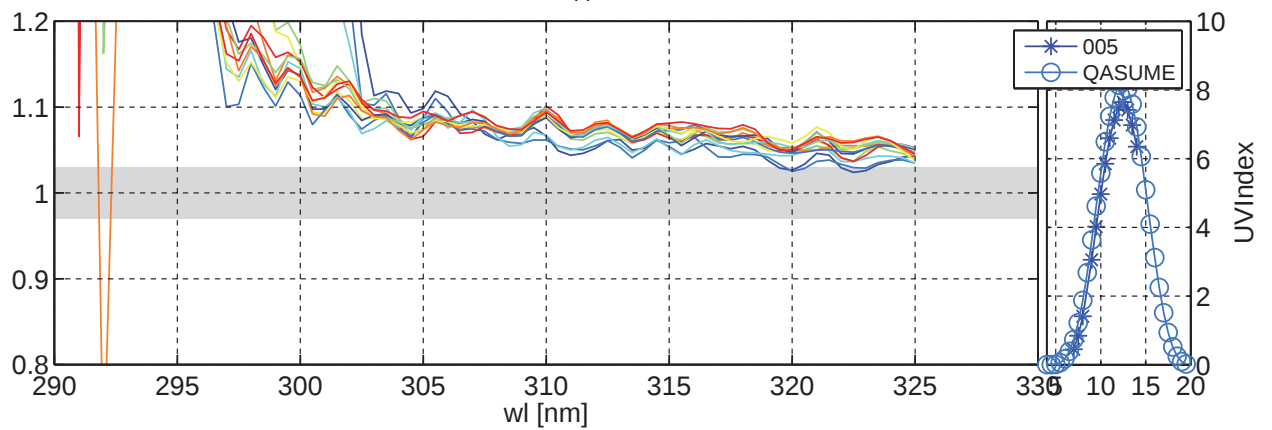
Global irradiance ratios 005/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



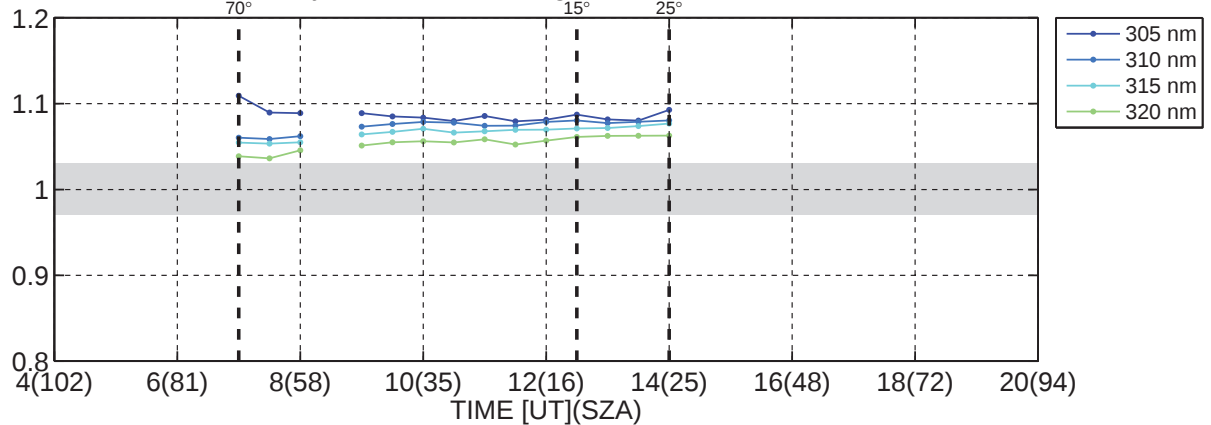
Daily variation. Wavelength bands are ± 2.5 nm

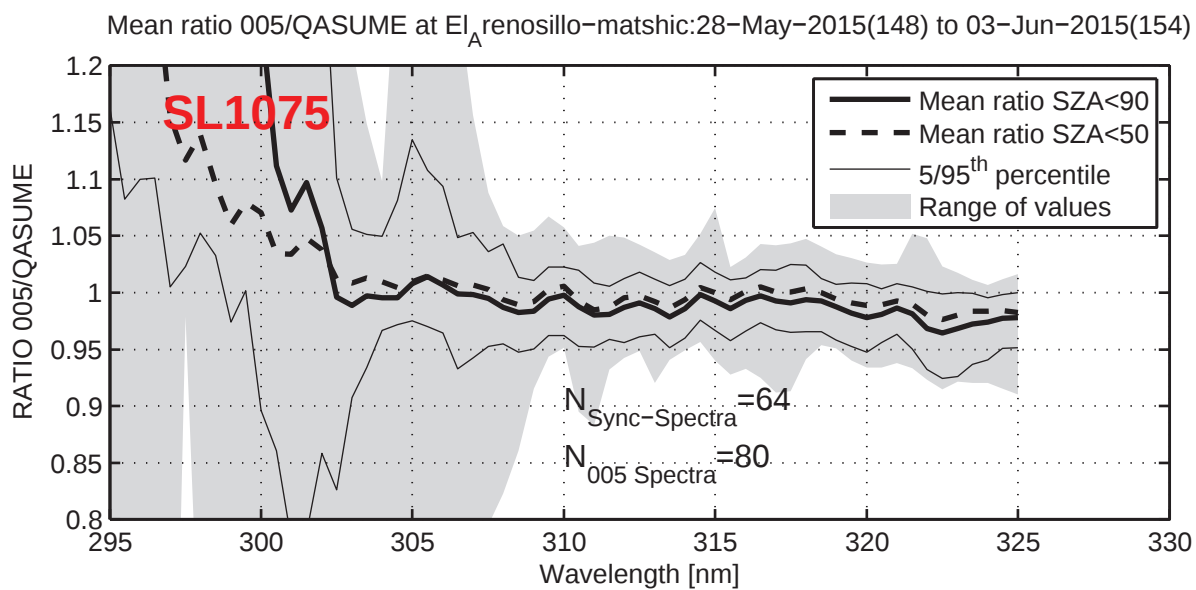
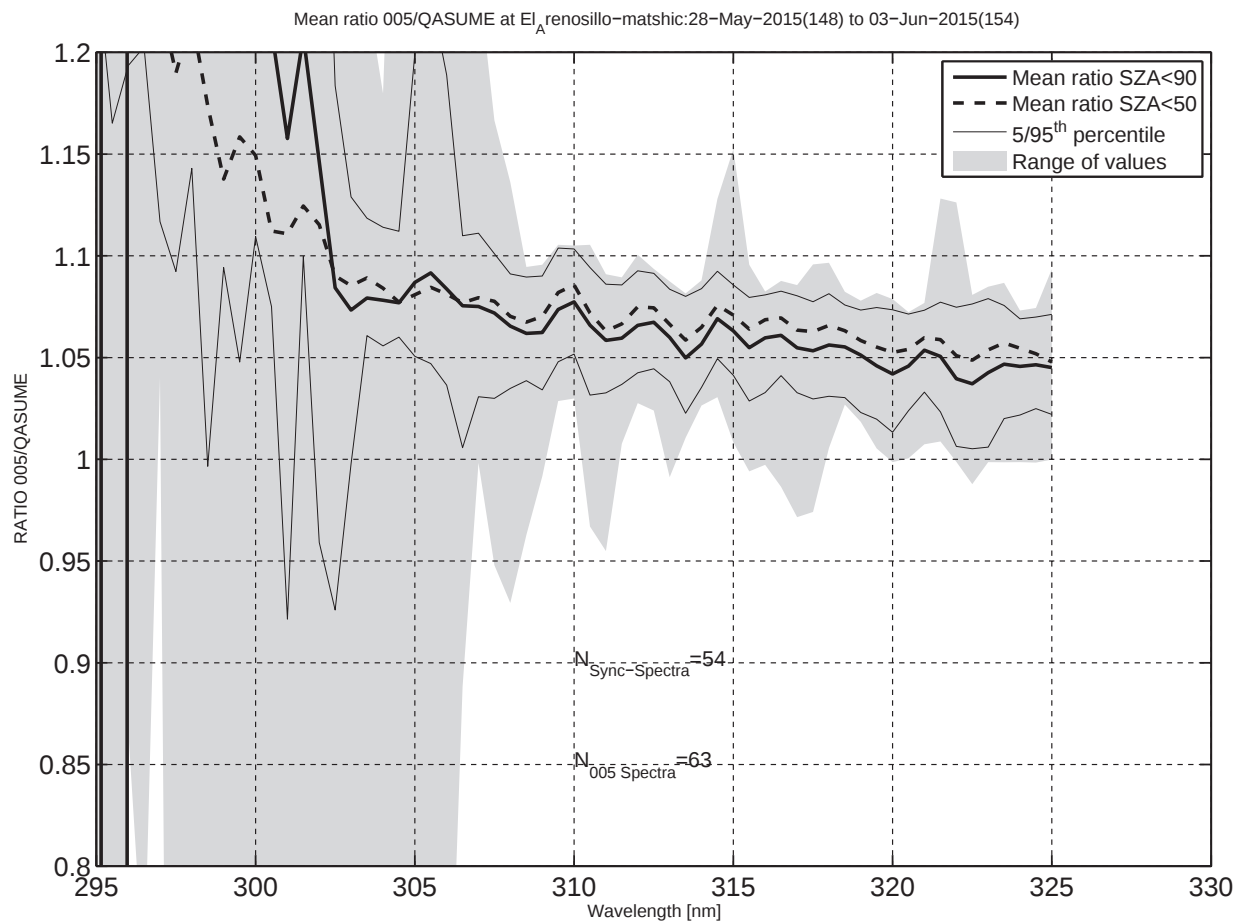


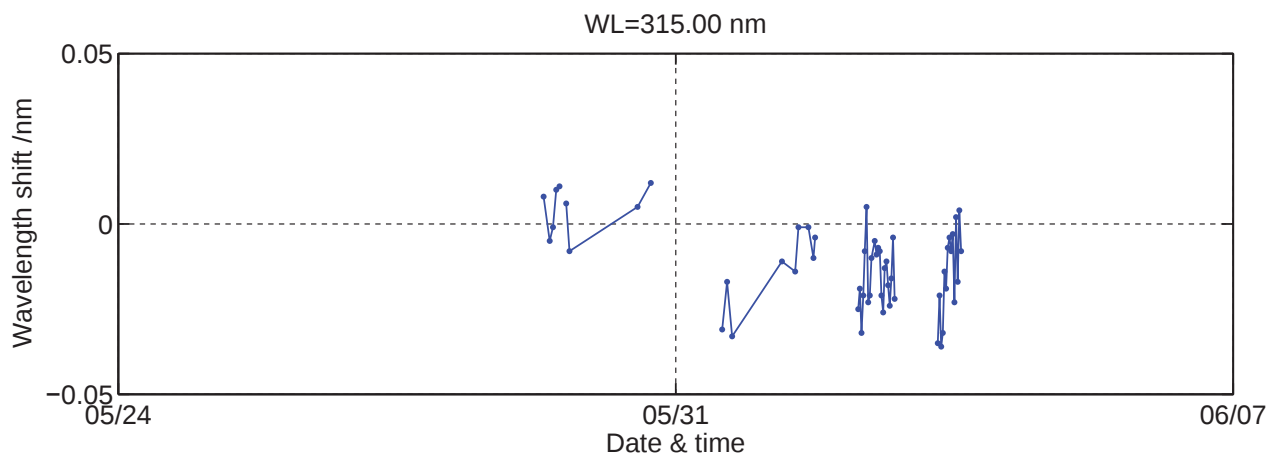
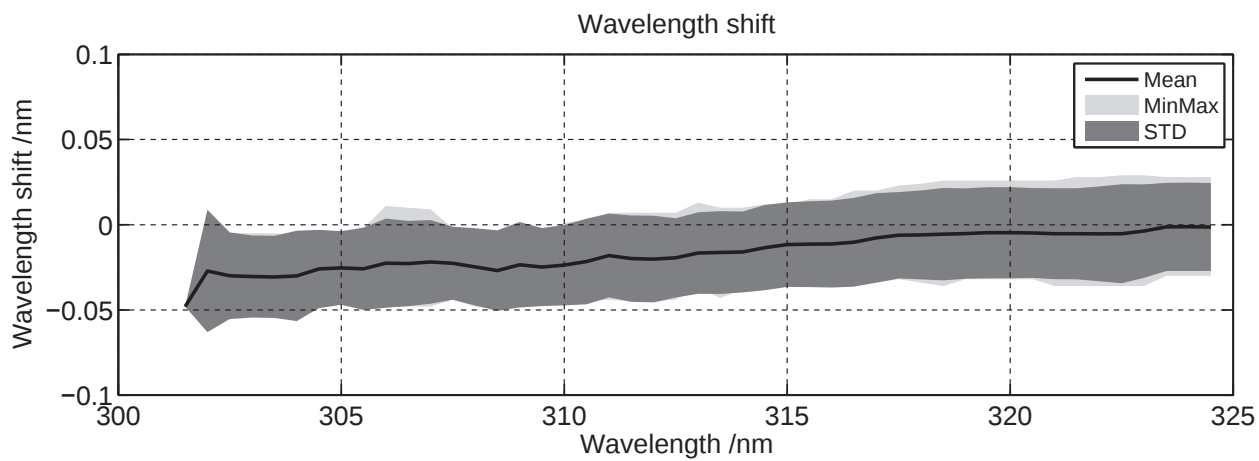
Global irradiance ratios 005/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)

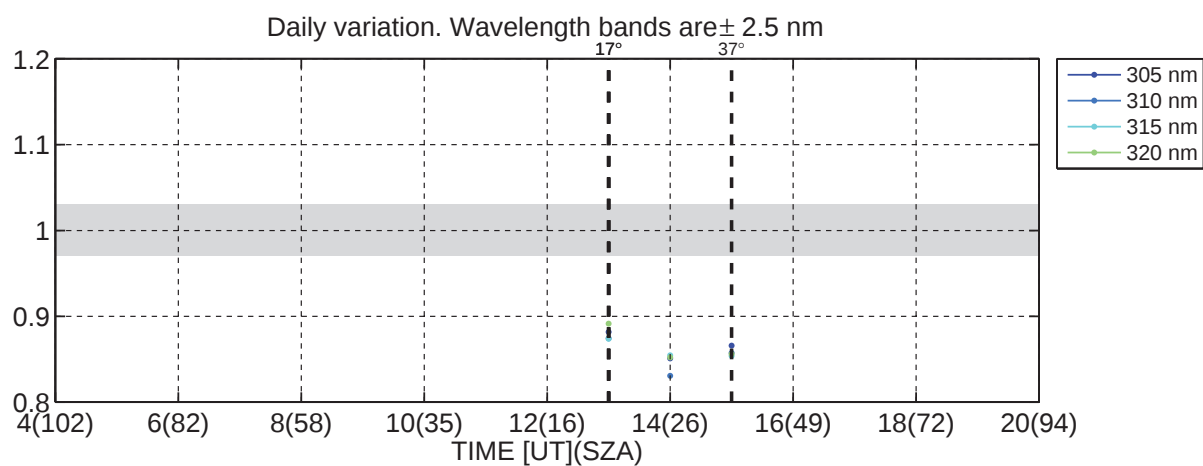
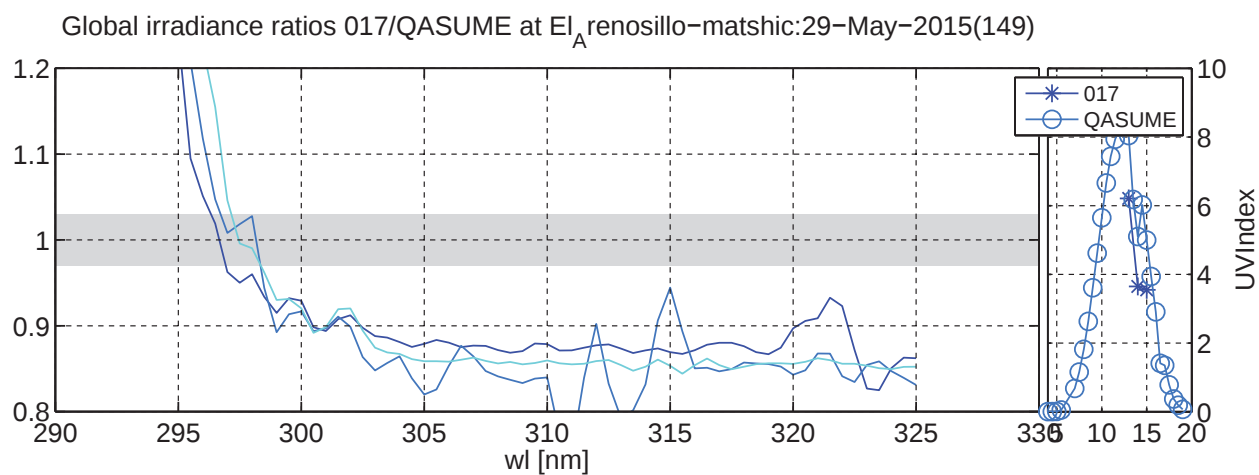
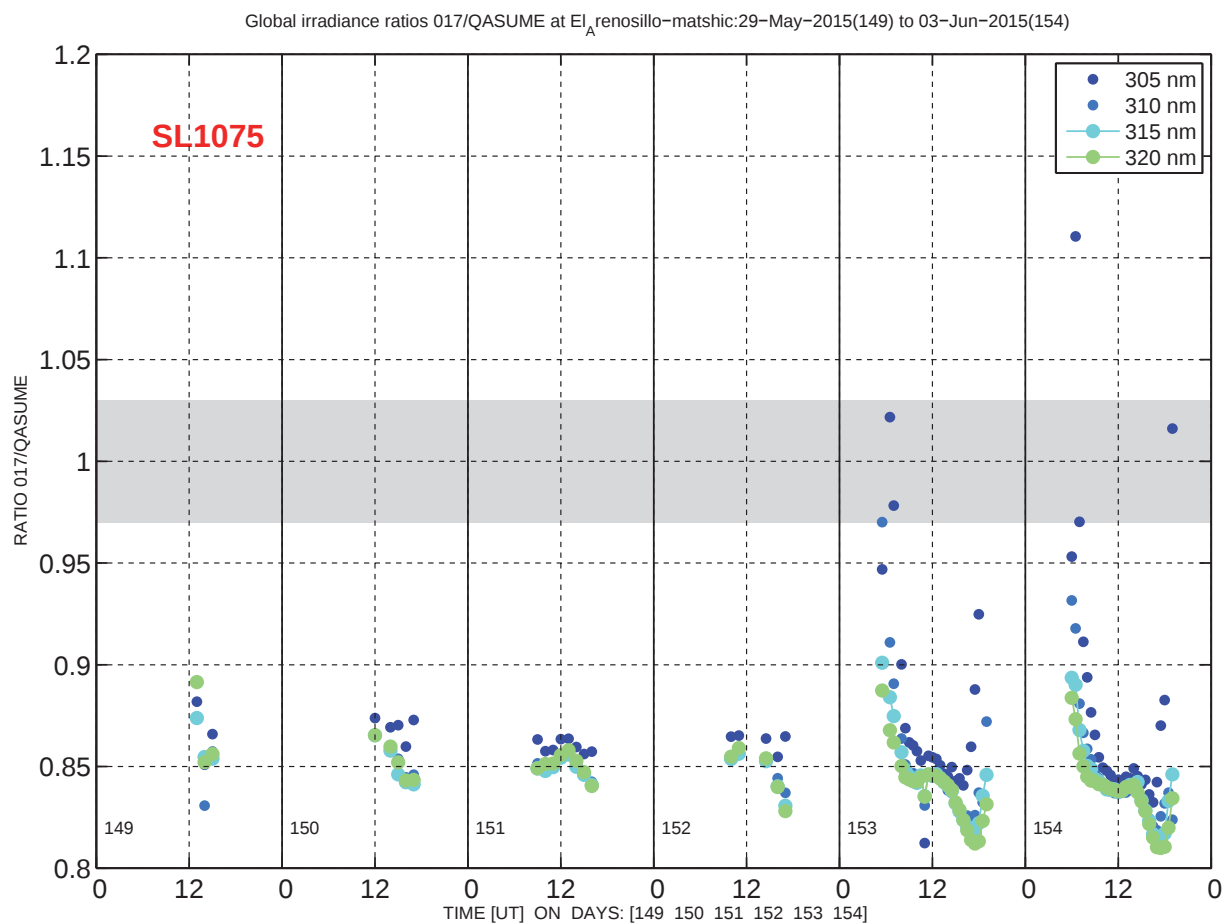


Daily variation. Wavelength bands are ± 2.5 nm

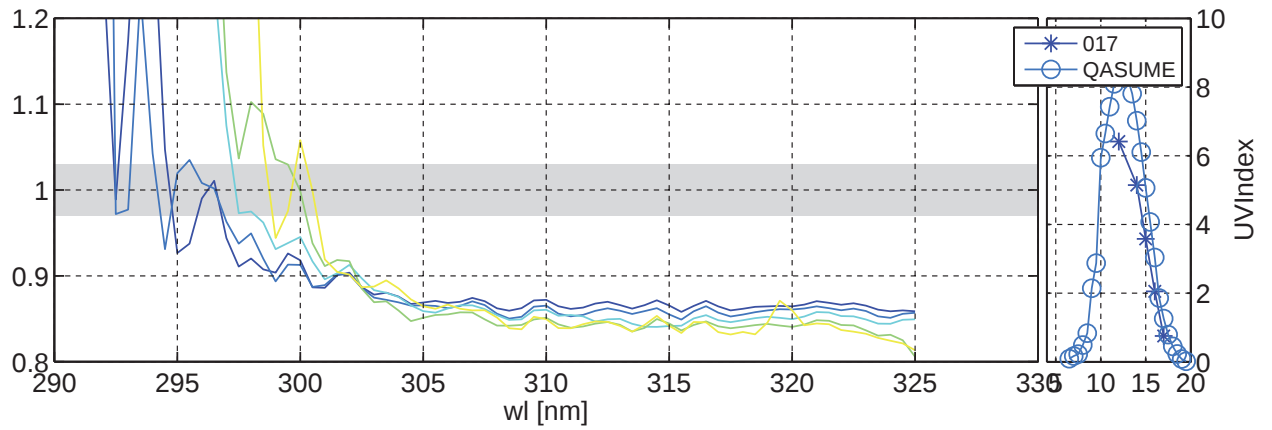




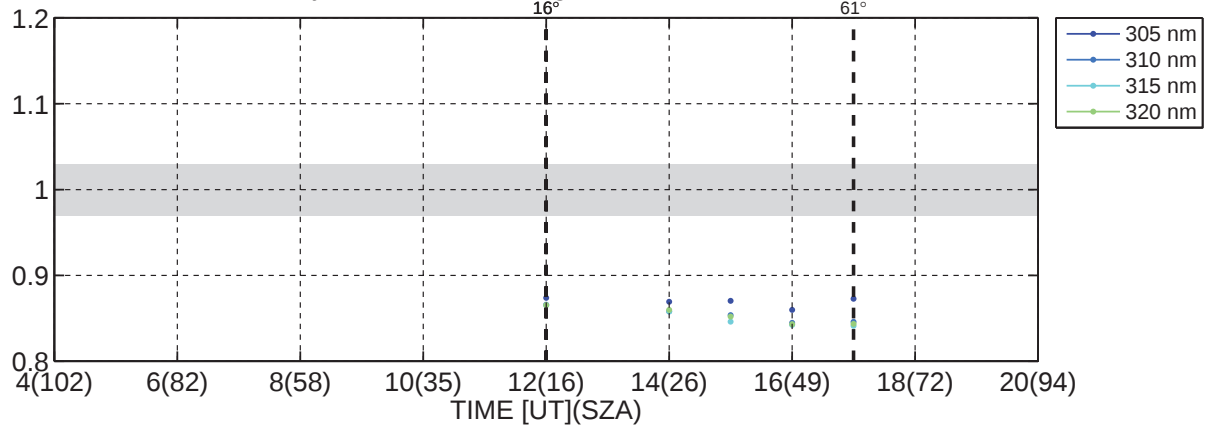




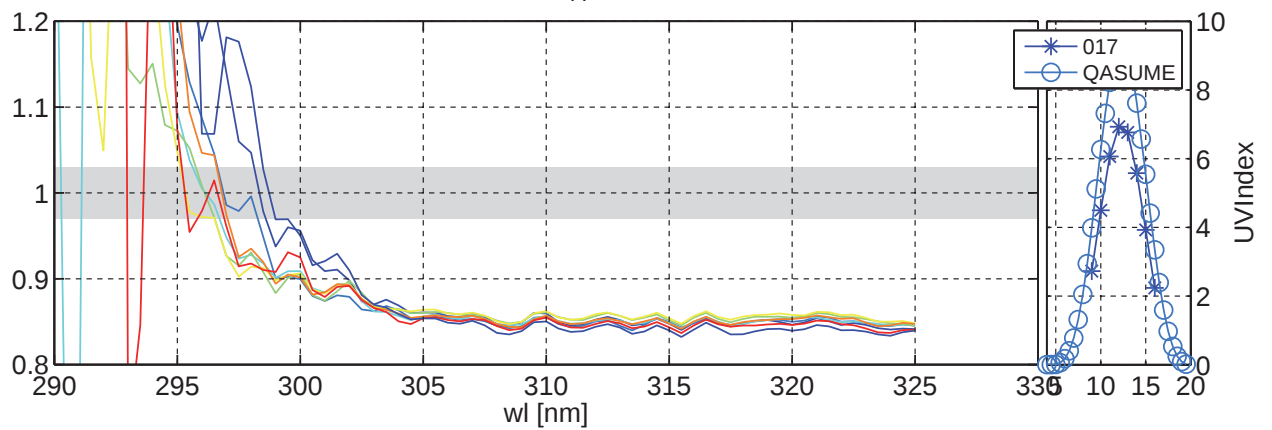
Global irradiance ratios 017/QASUME at El_A renosillo-matshic:30-May-2015(150)



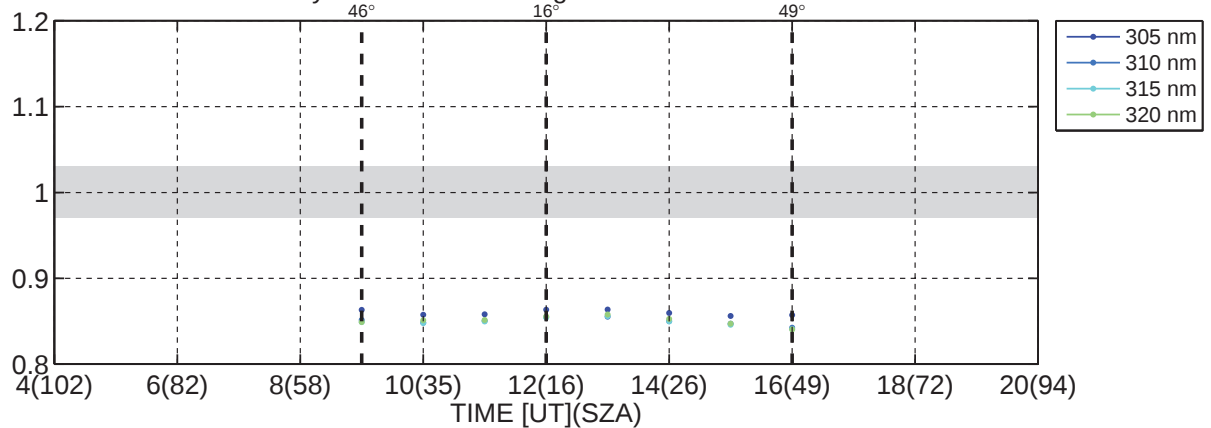
Daily variation. Wavelength bands are ± 2.5 nm



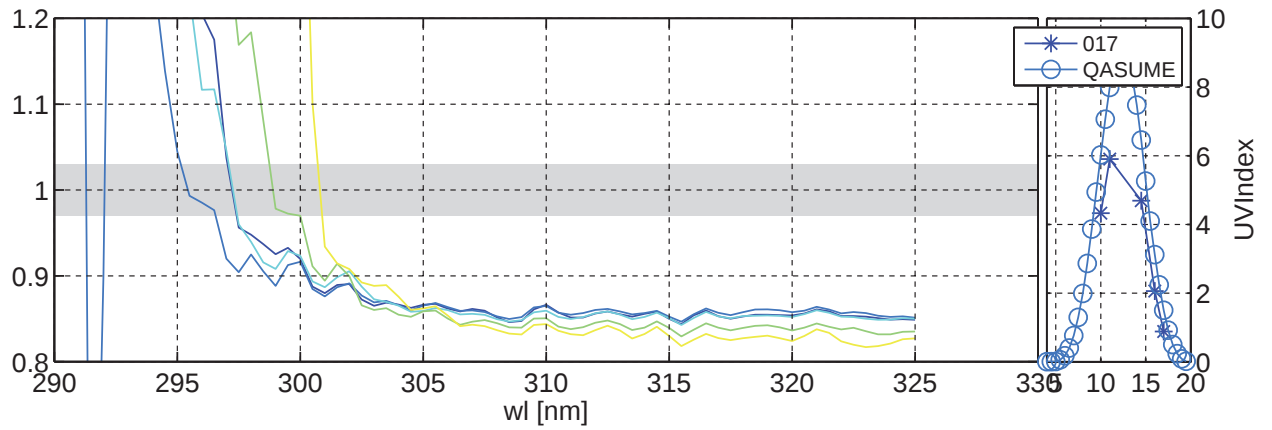
Global irradiance ratios 017/QASUME at El_A renosillo-matshic:31-May-2015(151)



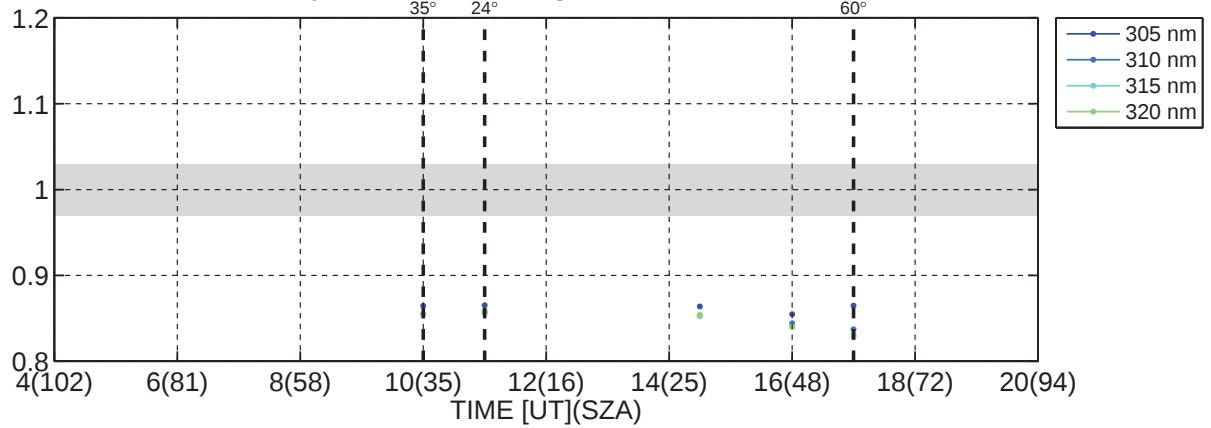
Daily variation. Wavelength bands are ± 2.5 nm



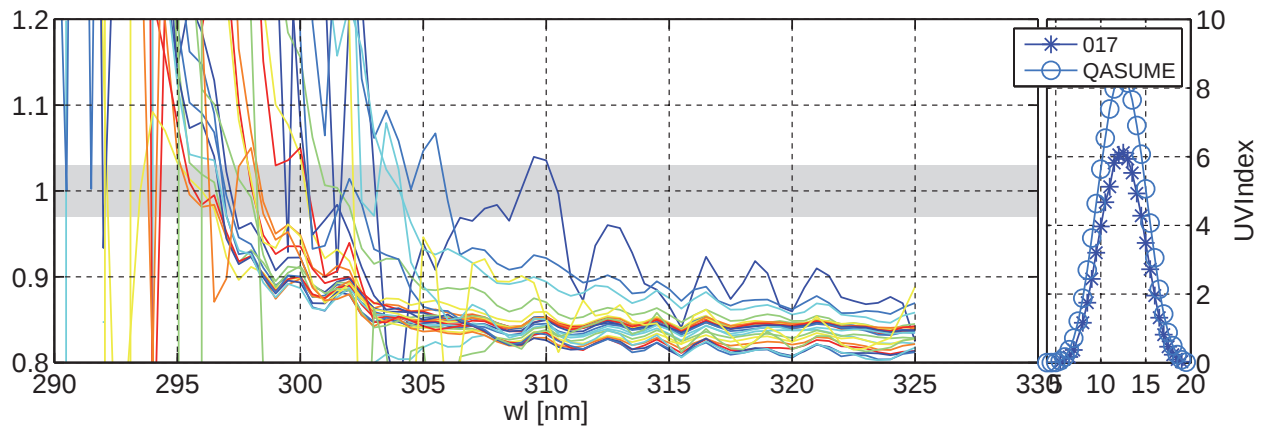
Global irradiance ratios 017/QASUME at El_A renosillo-matshic:01-Jun-2015(152)



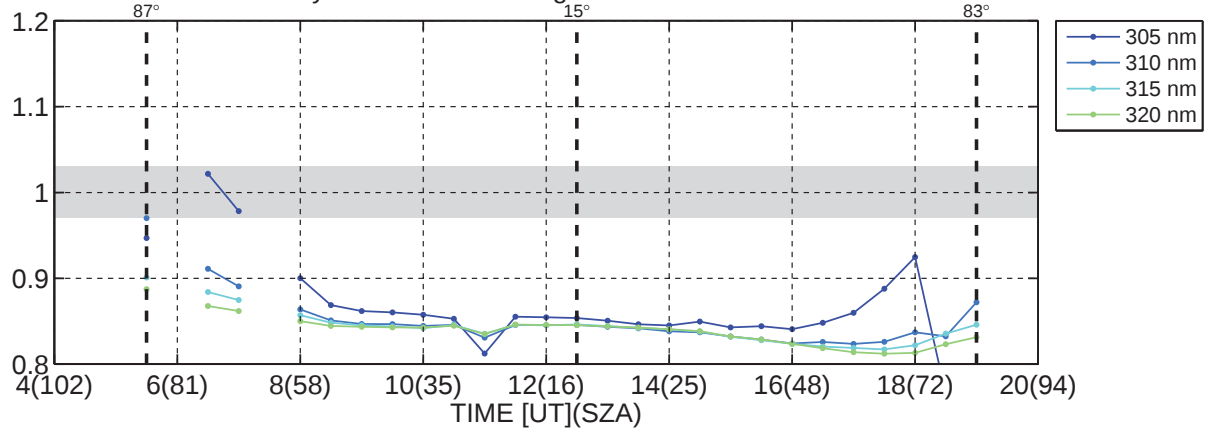
Daily variation. Wavelength bands are ± 2.5 nm



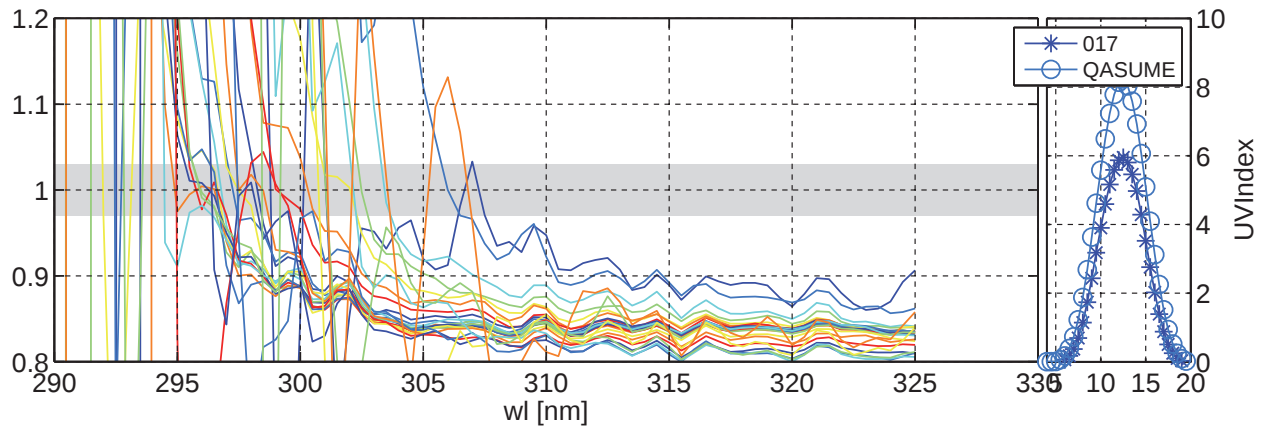
Global irradiance ratios 017/QASUME at El_A renosillo-matshic:02-Jun-2015(153)



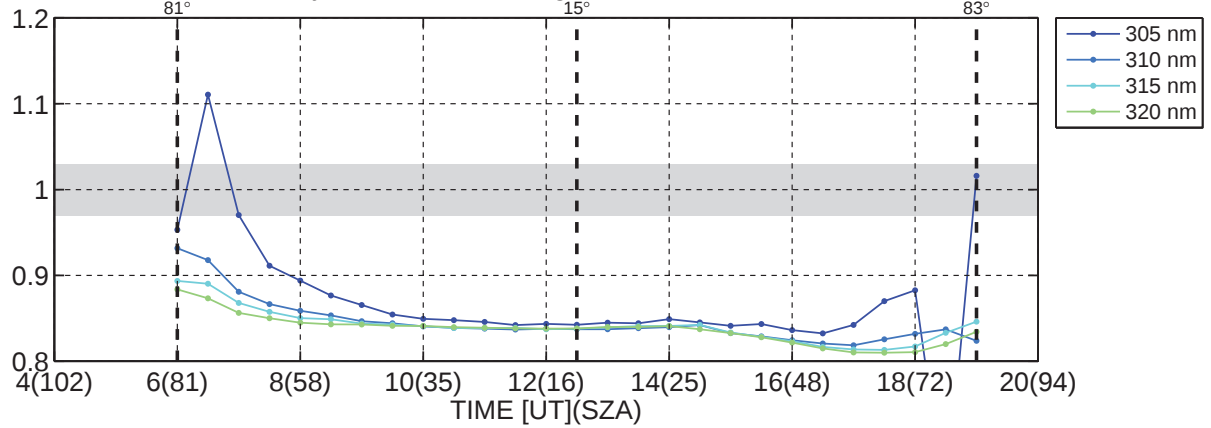
Daily variation. Wavelength bands are ± 2.5 nm



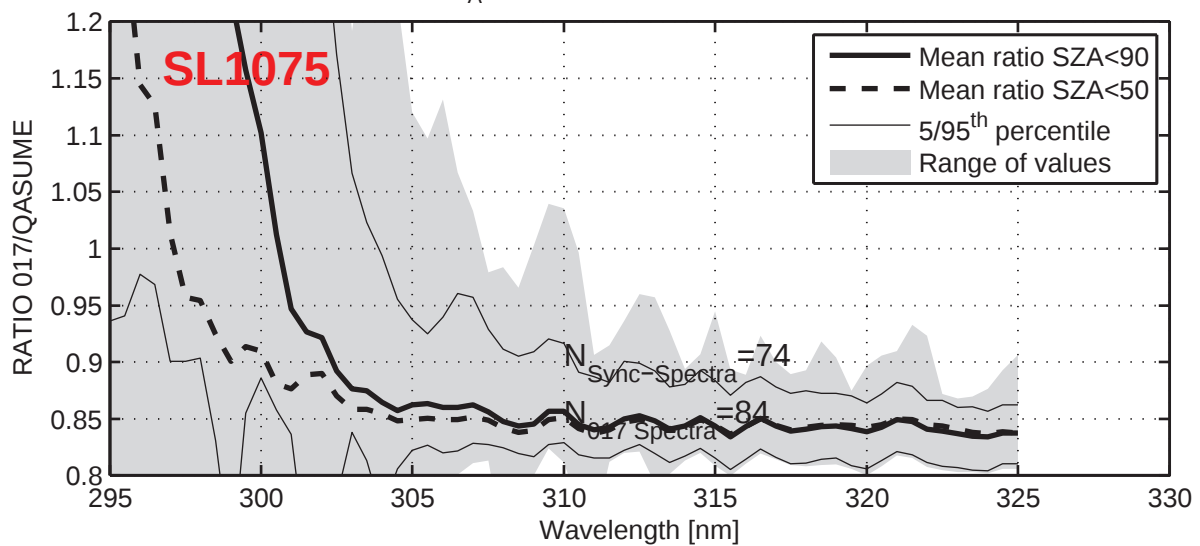
Global irradiance ratios 017/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)

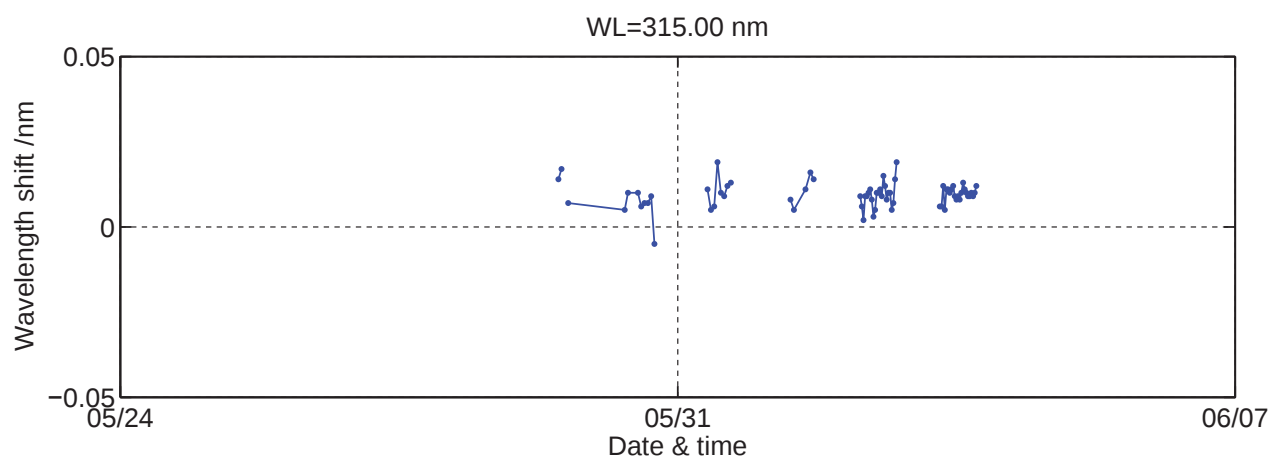
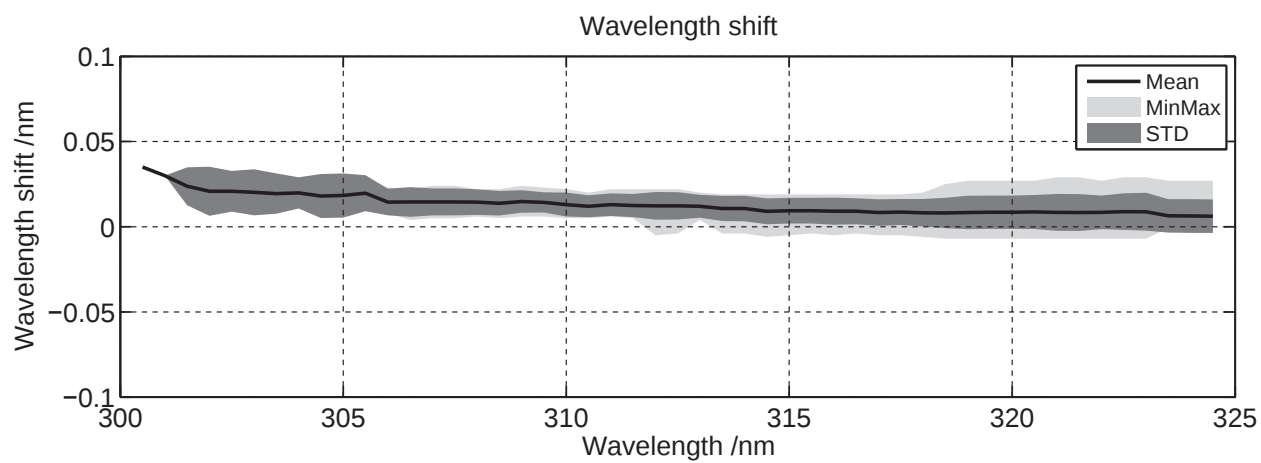


Daily variation. Wavelength bands are ± 2.5 nm

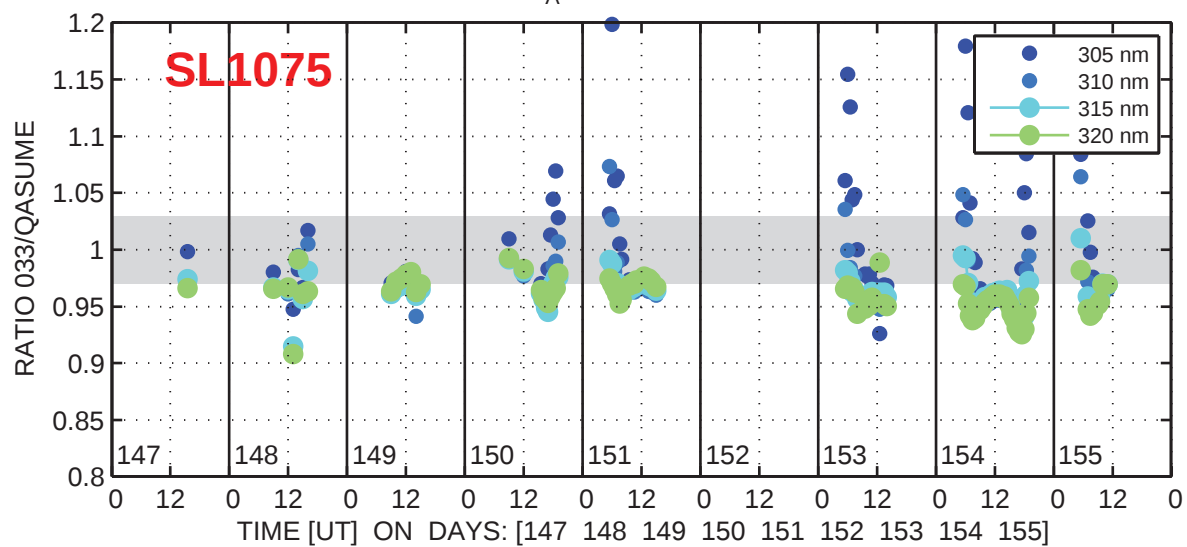


Mean ratio 017/QASUME at El_Arenosillo-matshic:29-May-2015(149) to 03-Jun-2015(154)

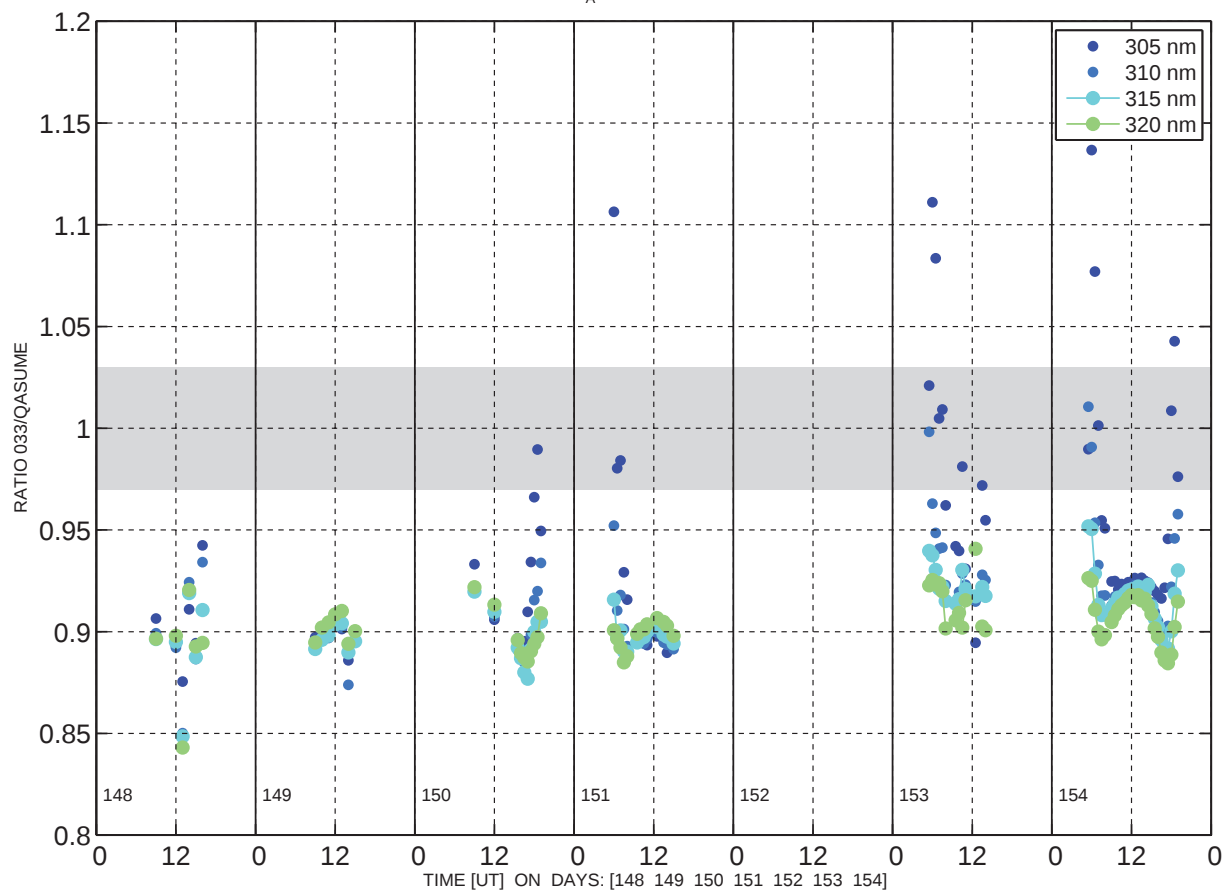




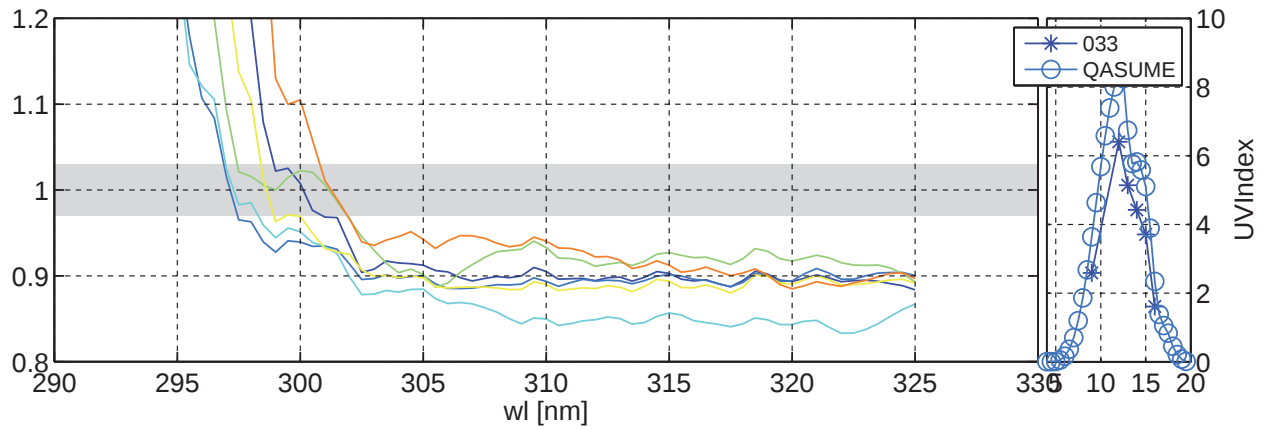
Global irradiance ratios 033/QASUME at El Arenosillo-matshic:27-May-2015(147) to 04-Jun-2015(155)



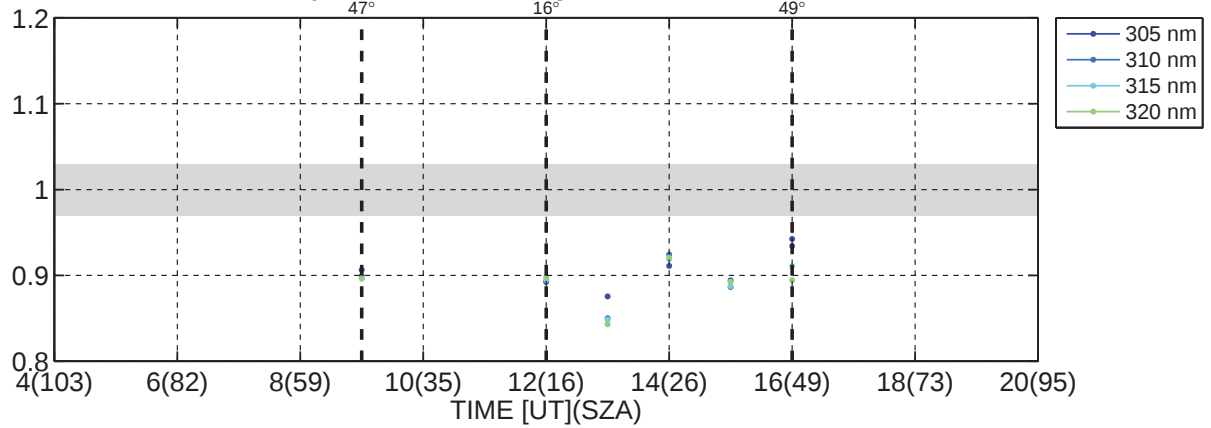
Global irradiance ratios 033/QASUME at El Arenosillo-matshic:28-May-2015(148) to 03-Jun-2015(154)



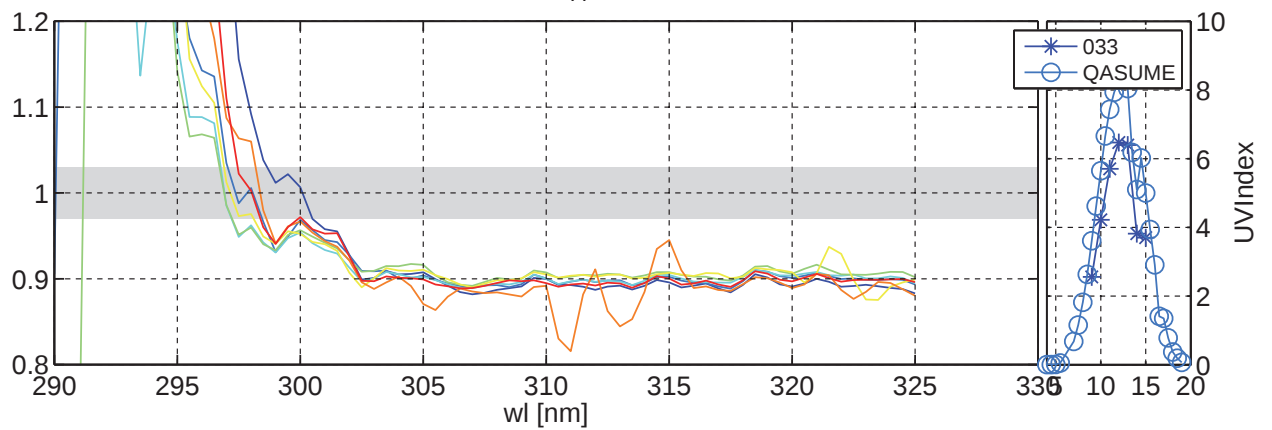
Global irradiance ratios 033/QASUME at El_A renosillo-matshic:28-May-2015(148)



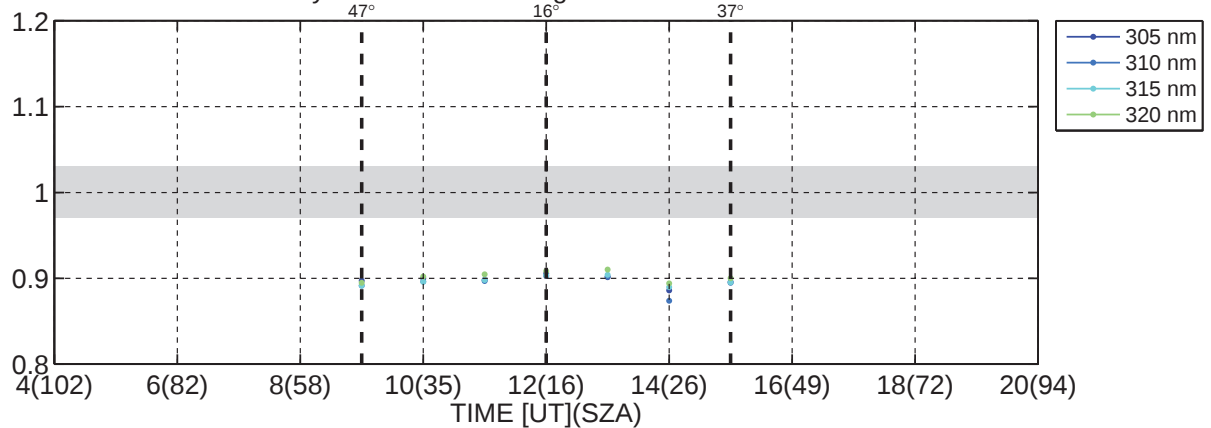
Daily variation. Wavelength bands are ± 2.5 nm



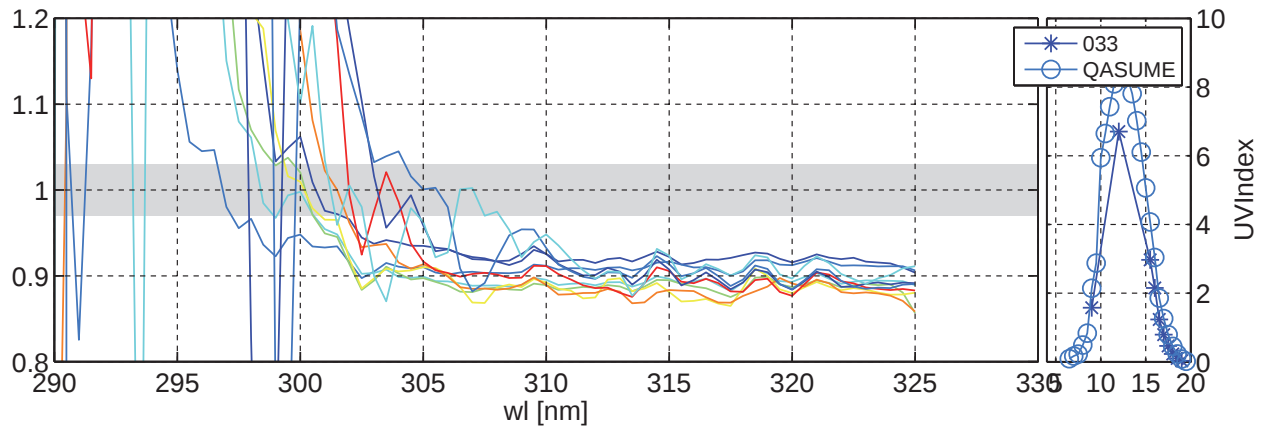
Global irradiance ratios 033/QASUME at El_A renosillo-matshic:29-May-2015(149)



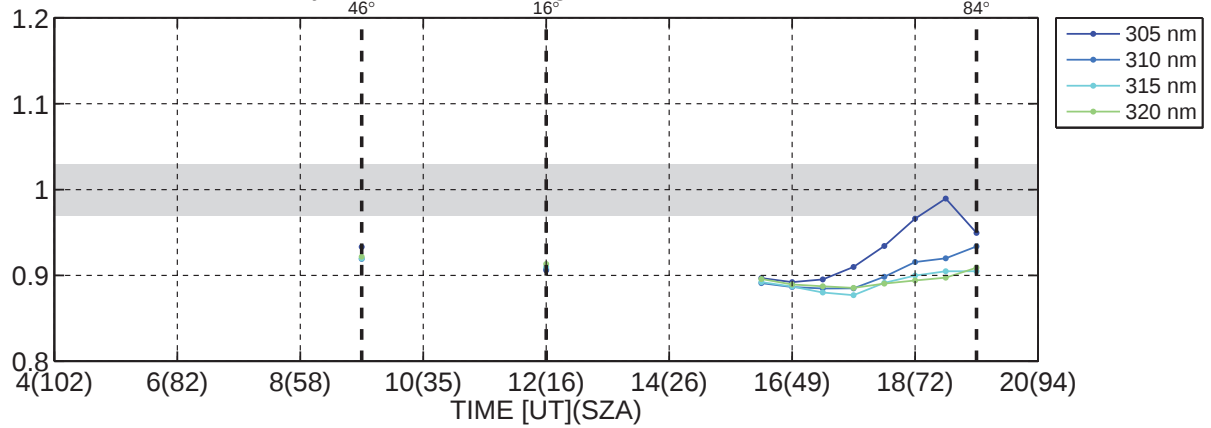
Daily variation. Wavelength bands are ± 2.5 nm



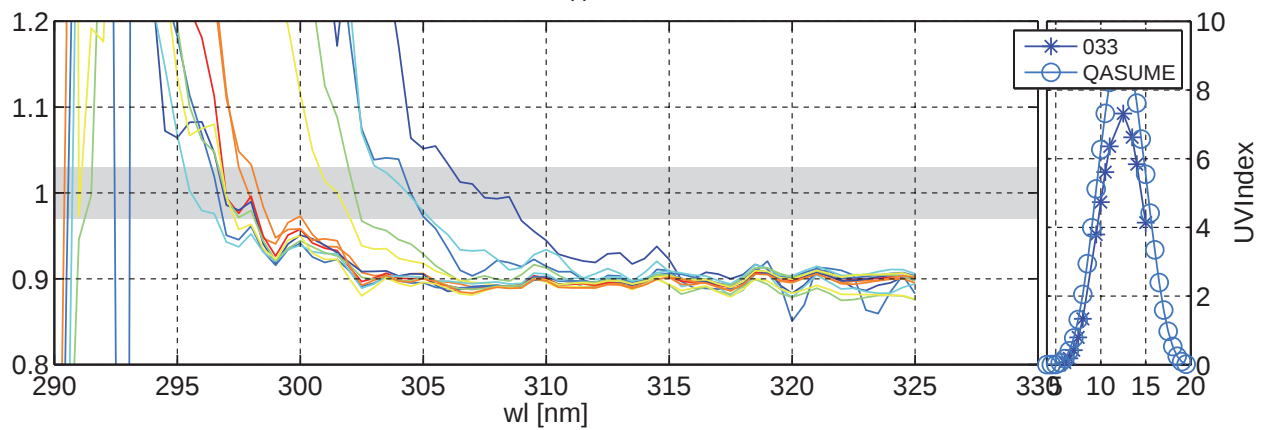
Global irradiance ratios 033/QASUME at El_A renosillo-matshic:30-May-2015(150)



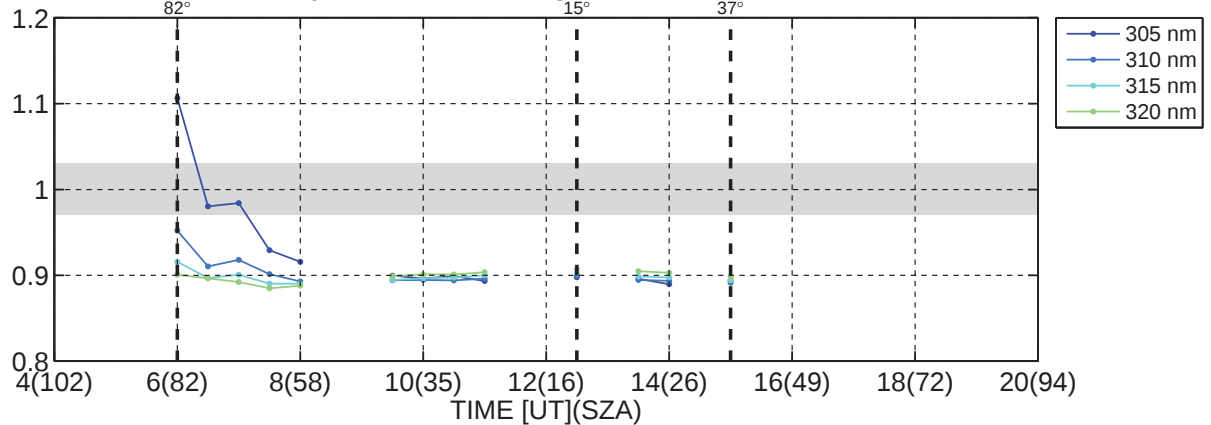
Daily variation. Wavelength bands are ± 2.5 nm



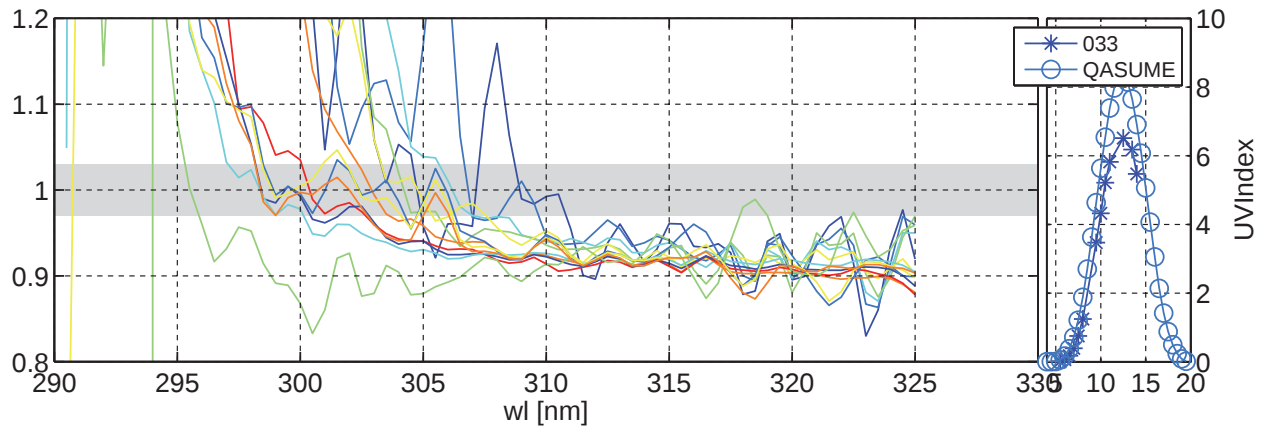
Global irradiance ratios 033/QASUME at El_A renosillo-matshic:31-May-2015(151)



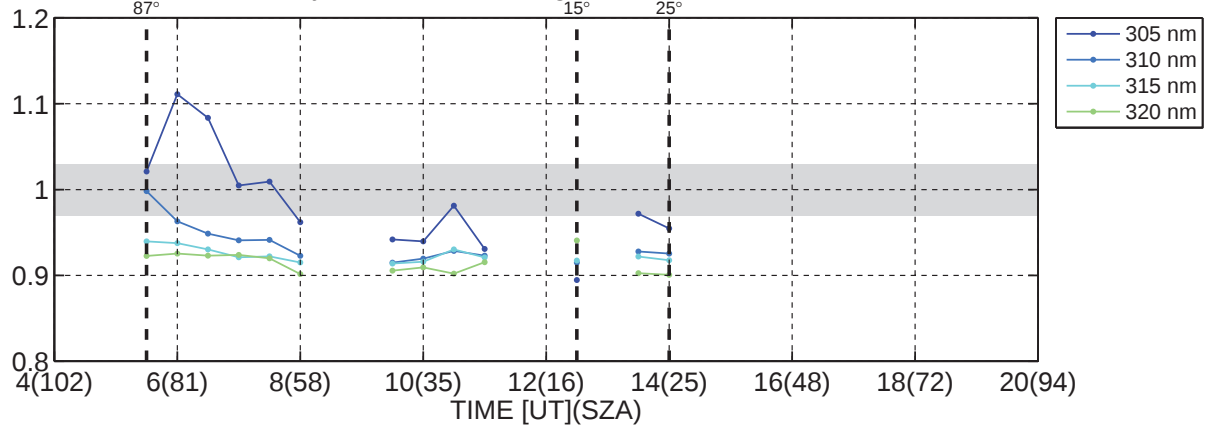
Daily variation. Wavelength bands are ± 2.5 nm



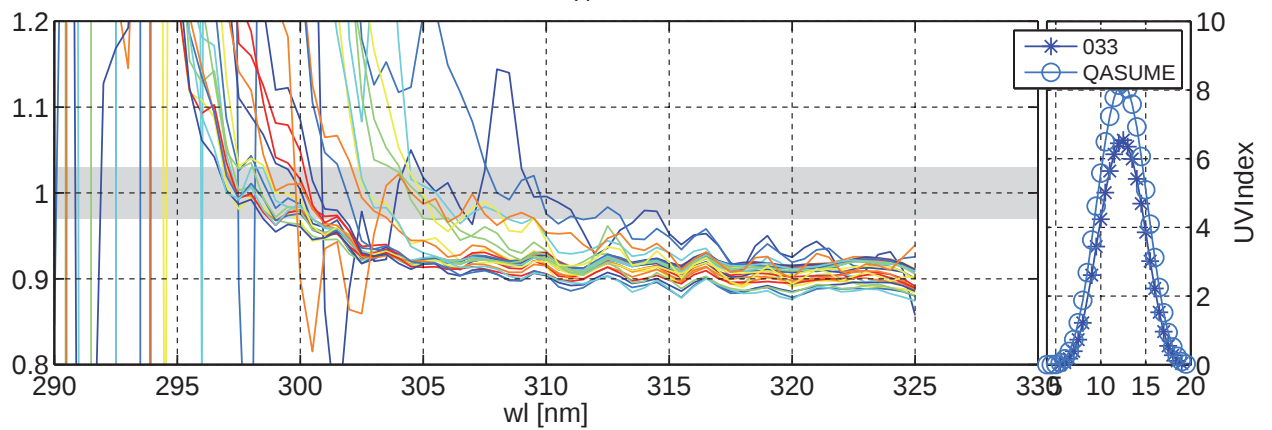
Global irradiance ratios 033/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



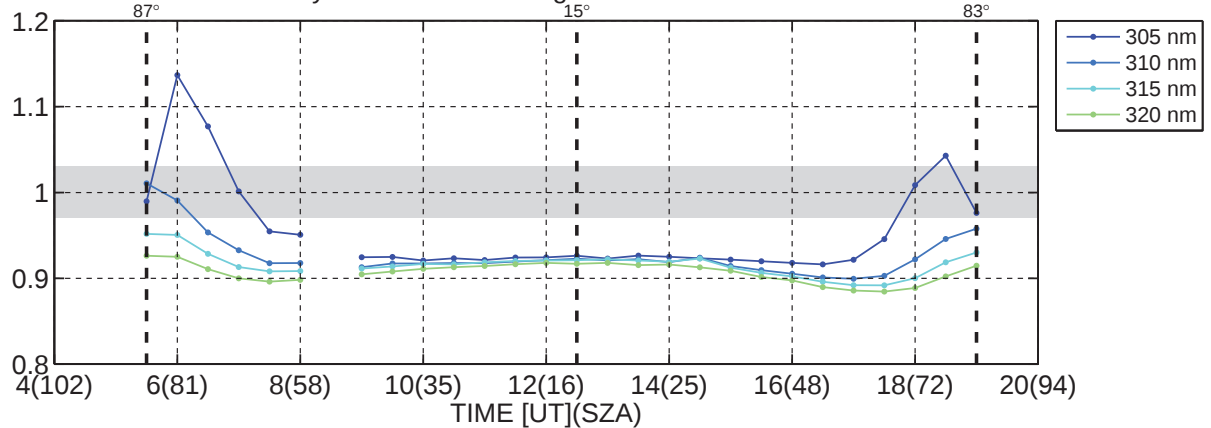
Daily variation. Wavelength bands are ± 2.5 nm

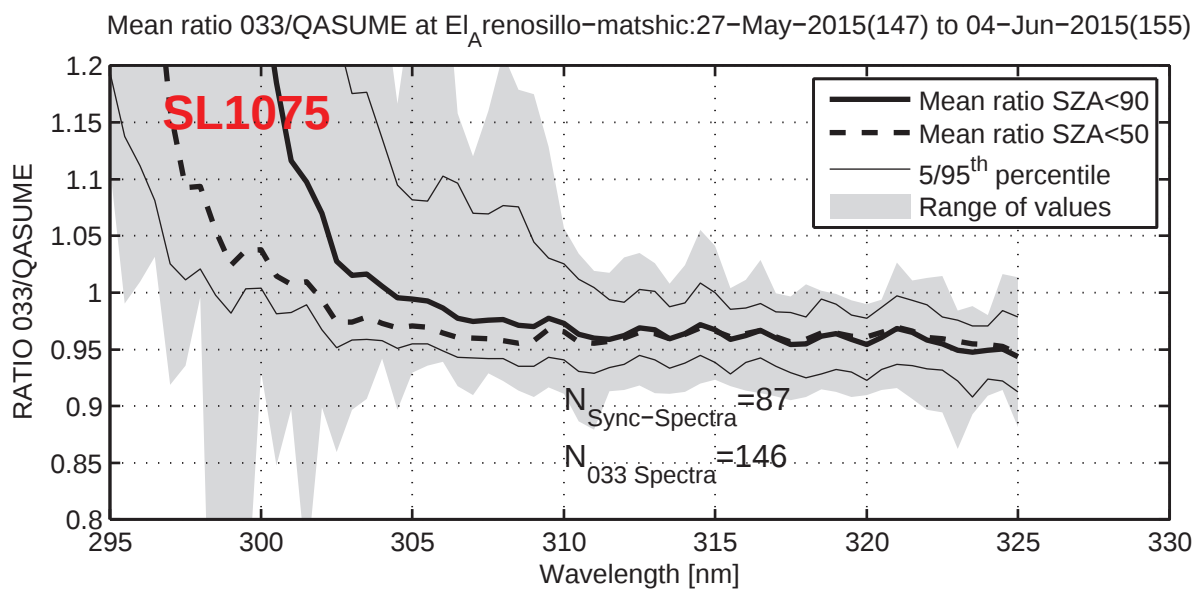
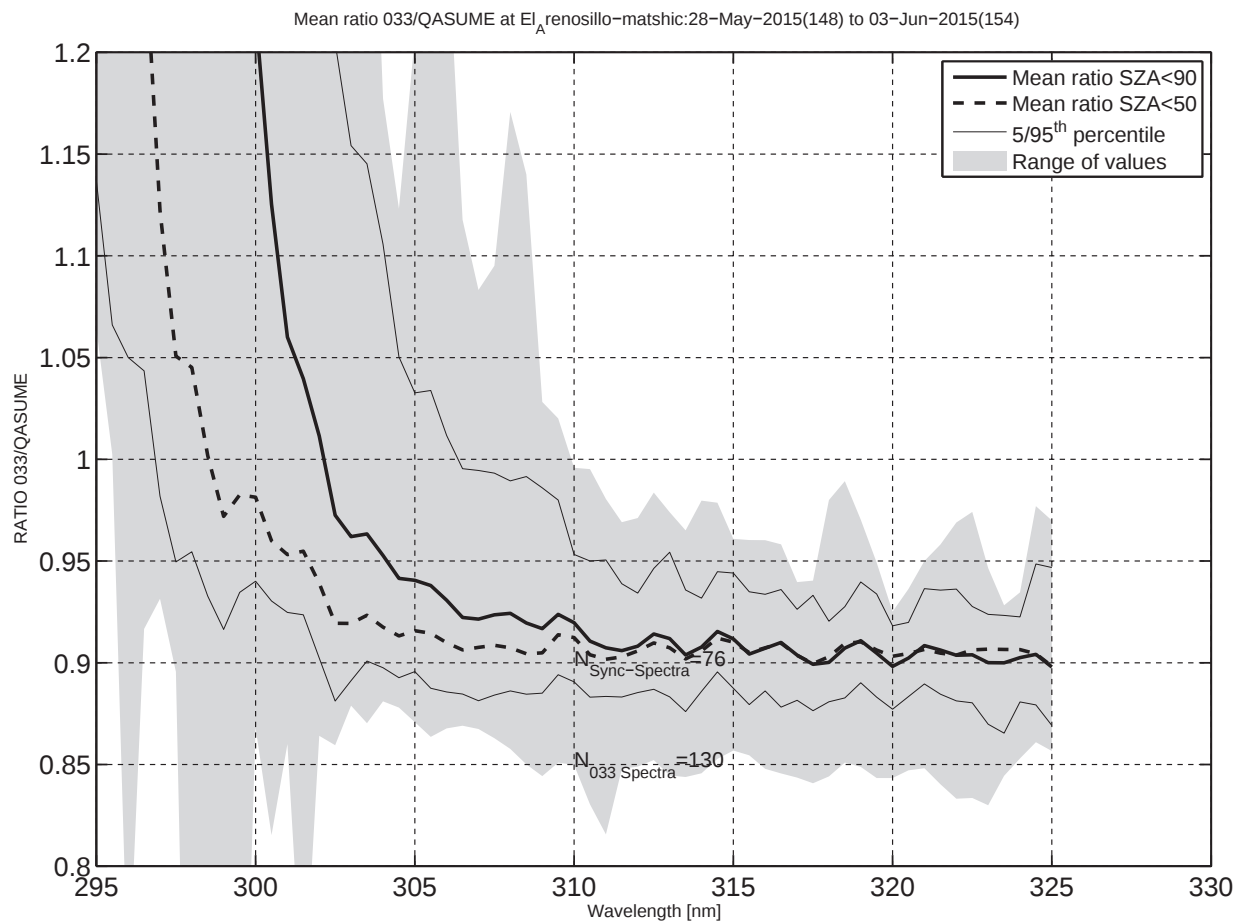


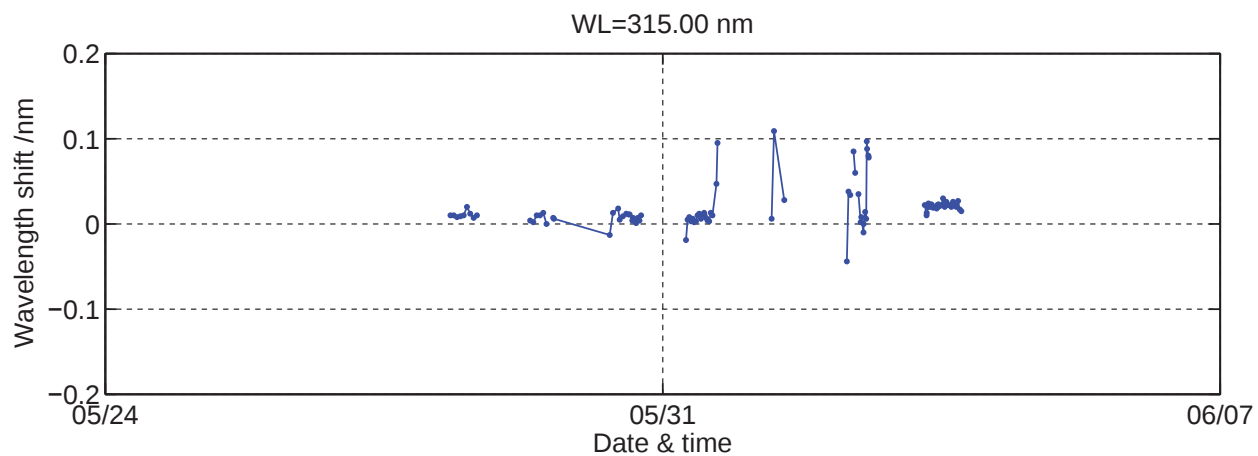
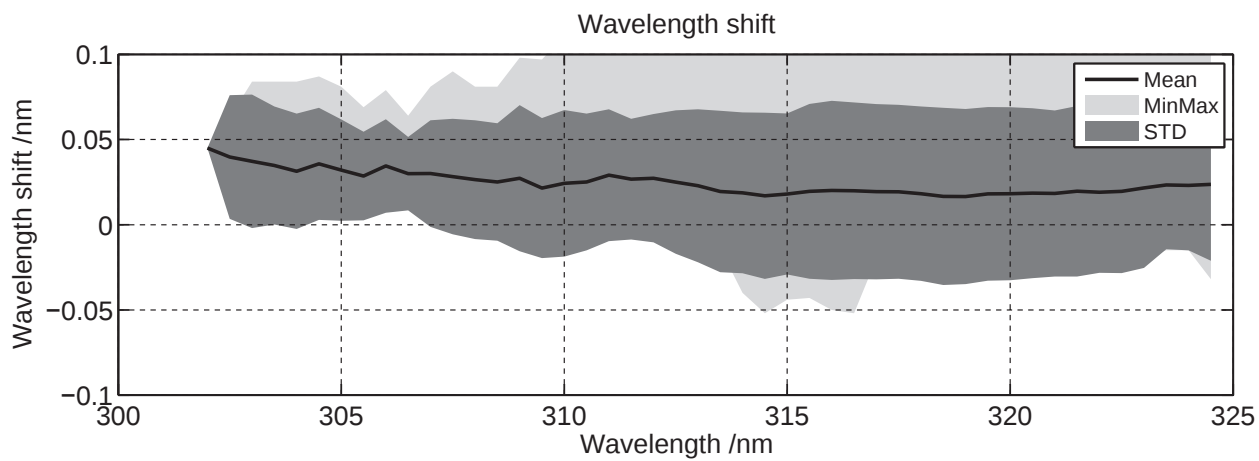
Global irradiance ratios 033/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



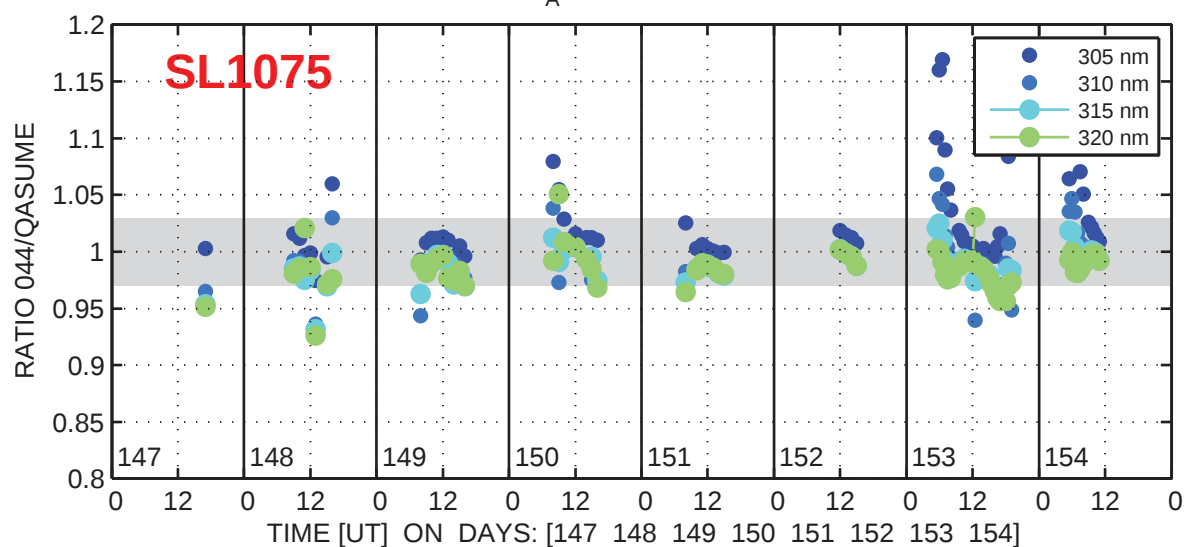
Daily variation. Wavelength bands are ± 2.5 nm



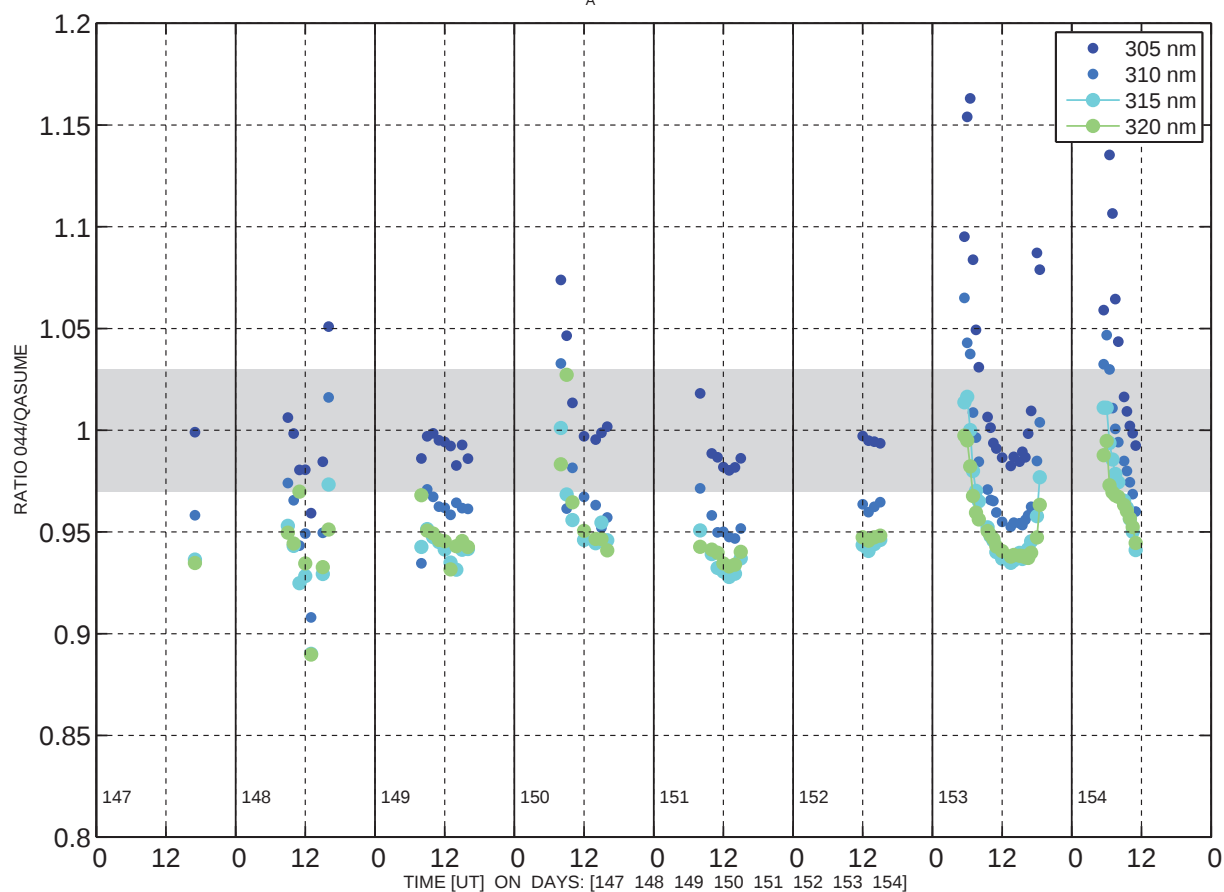




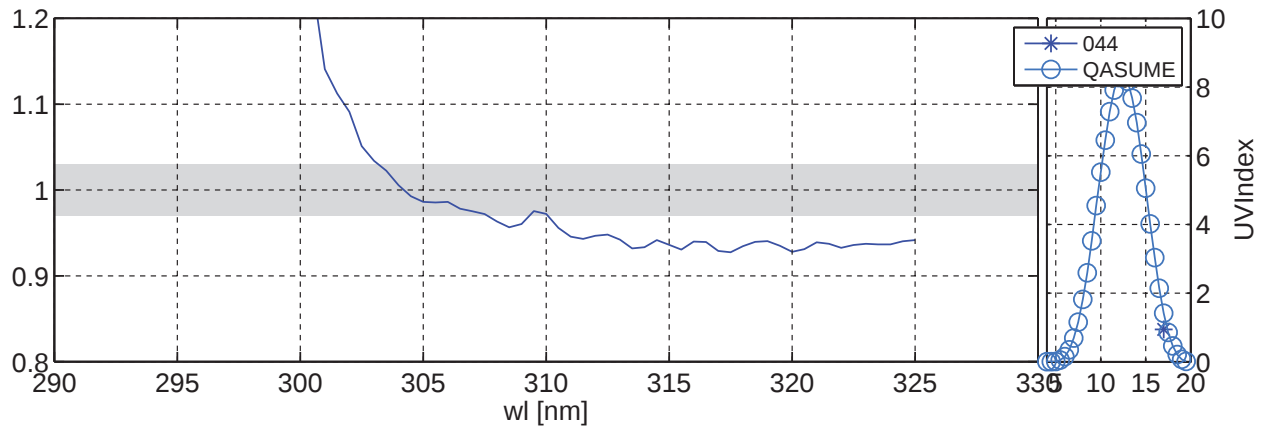
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 03-Jun-2015(154)



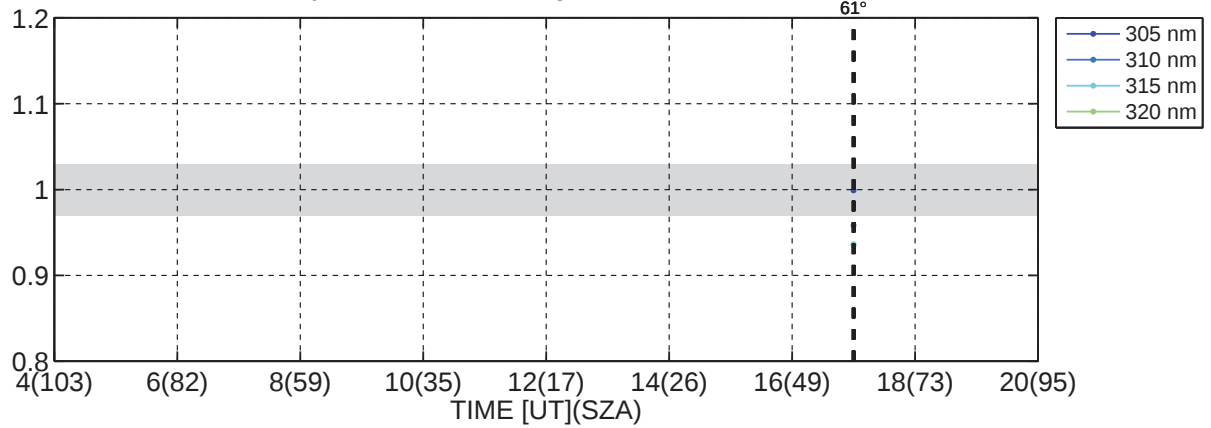
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 03-Jun-2015(154)



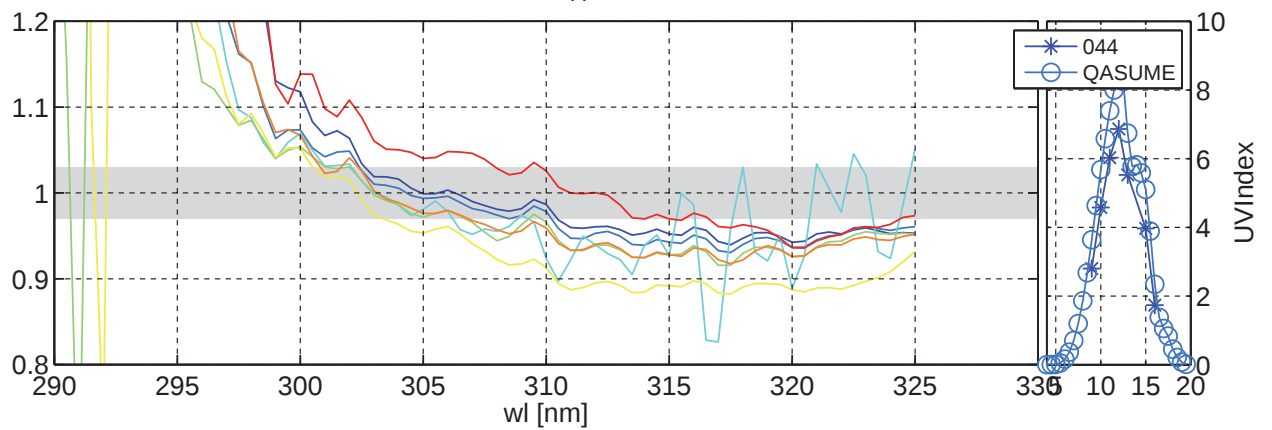
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:27-May-2015(147)



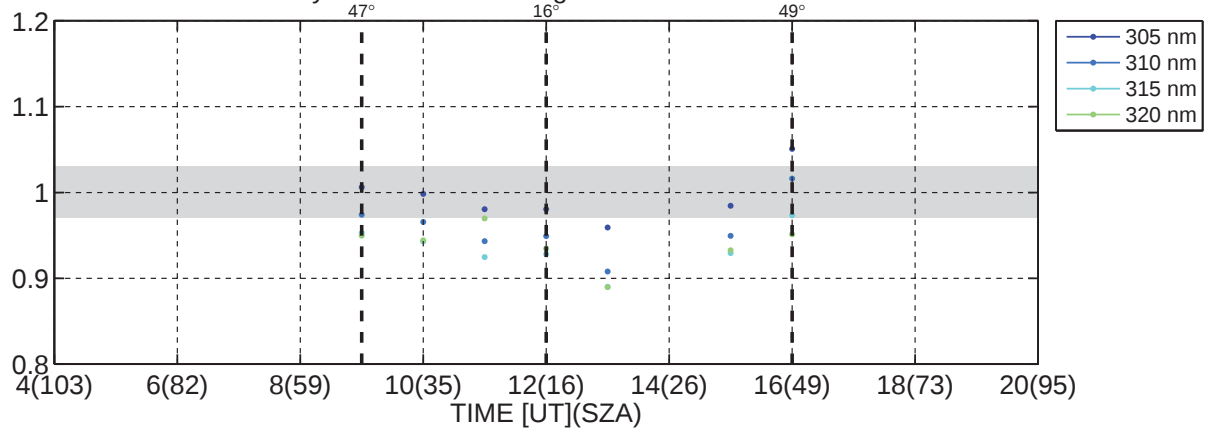
Daily variation. Wavelength bands are ± 2.5 nm



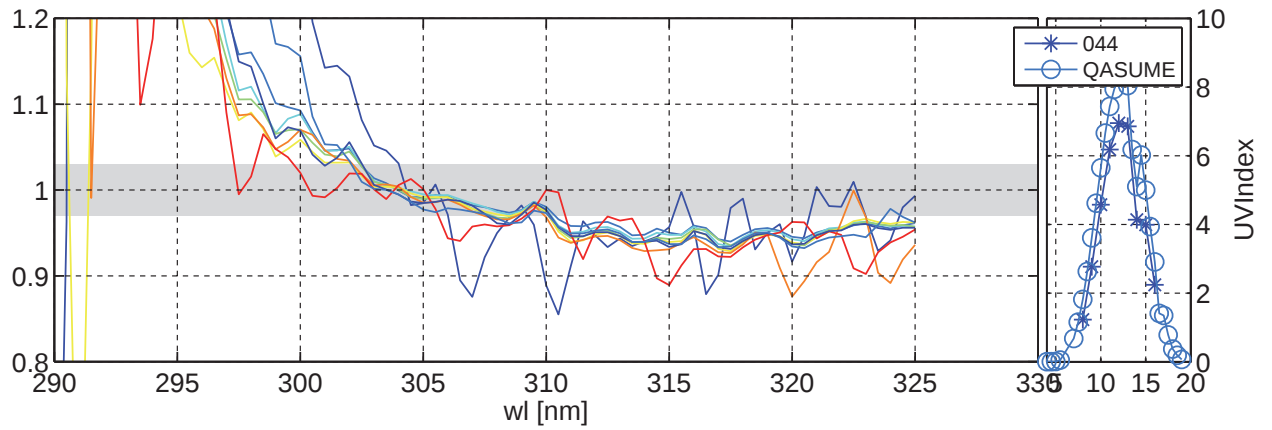
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:28-May-2015(148)



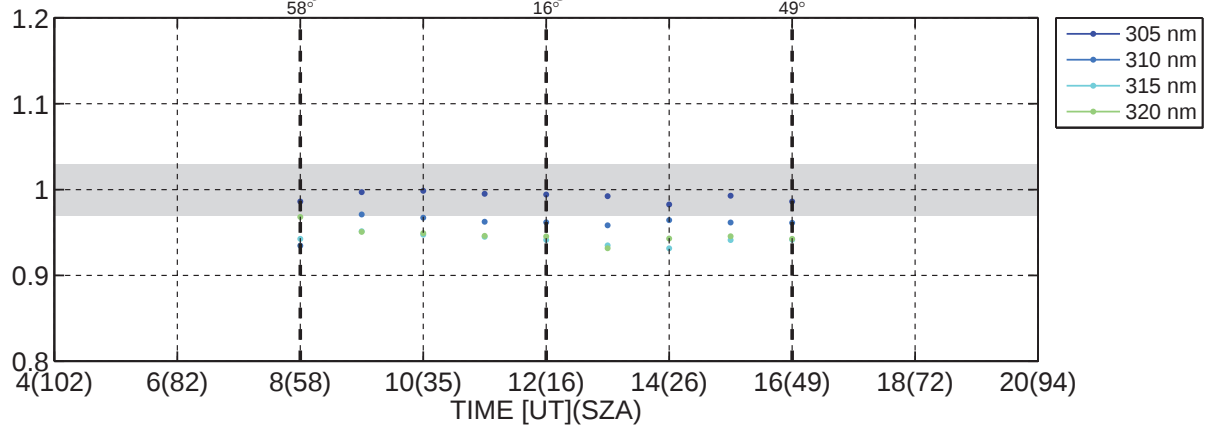
Daily variation. Wavelength bands are ± 2.5 nm



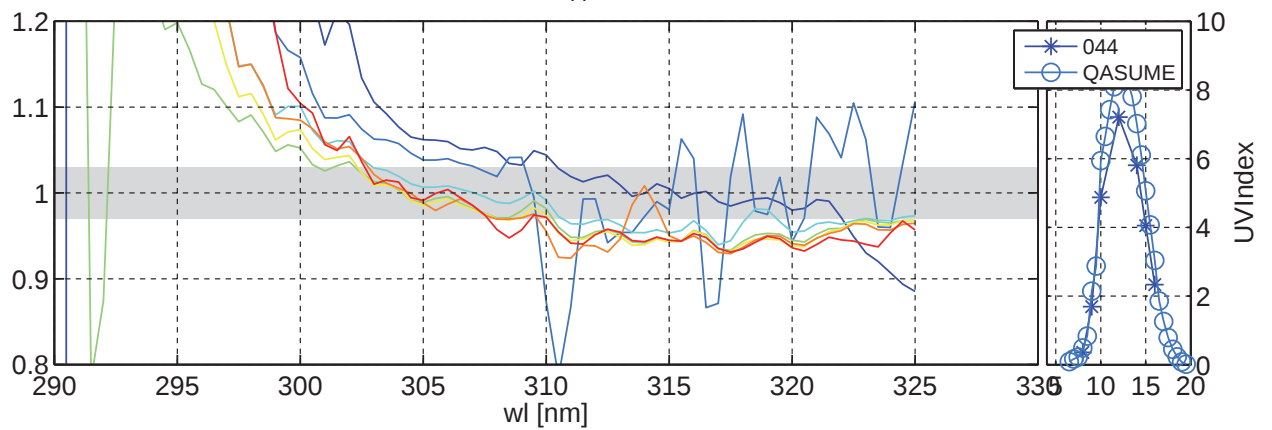
Global irradiance ratios 044/QASUME at El_A renosillo-matshic:29-May-2015(149)



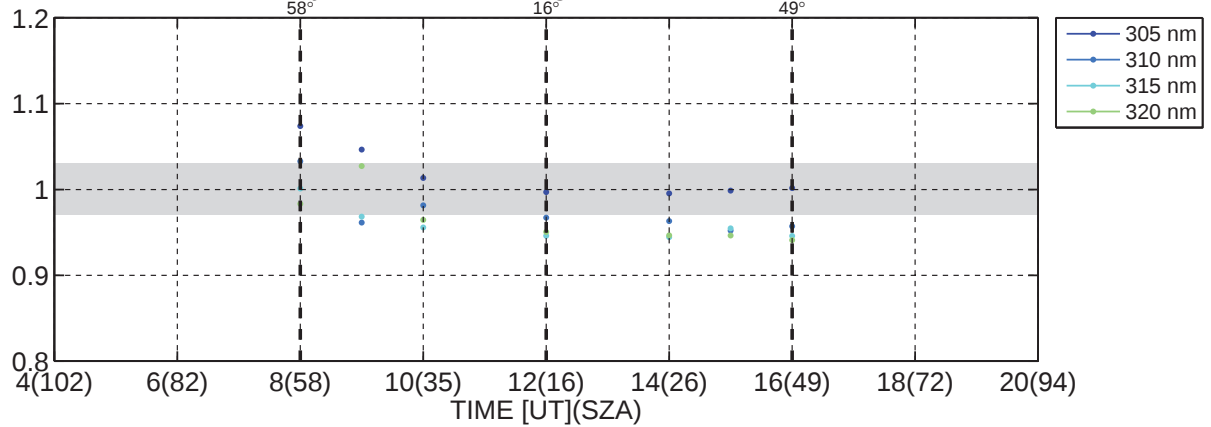
Daily variation. Wavelength bands are ± 2.5 nm



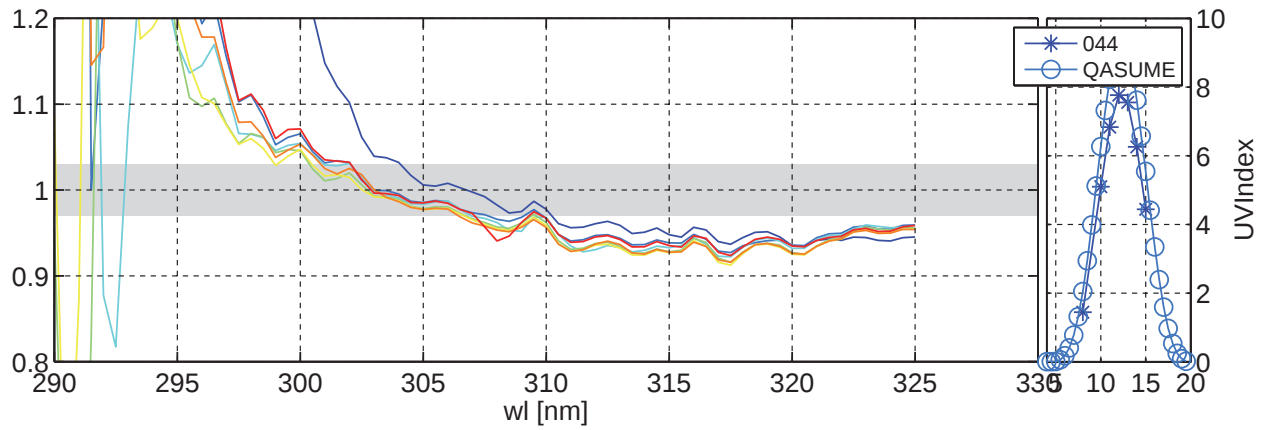
Global irradiance ratios 044/QASUME at El_A renosillo-matshic:30-May-2015(150)



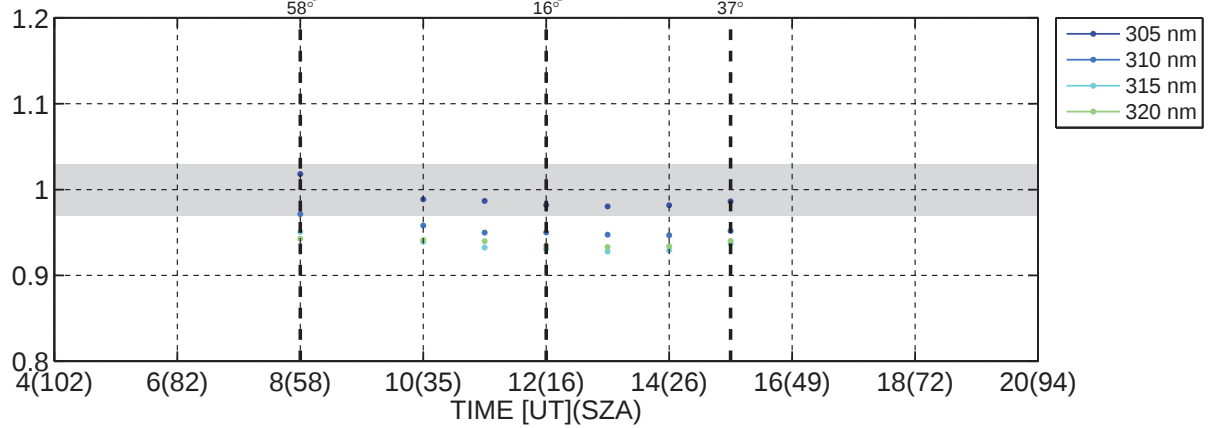
Daily variation. Wavelength bands are ± 2.5 nm



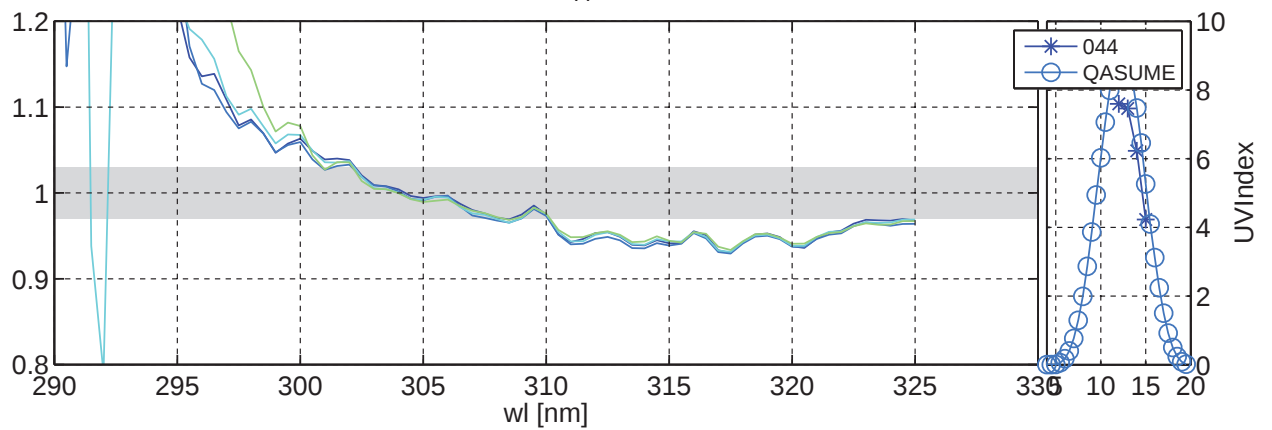
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:31-May-2015(151)



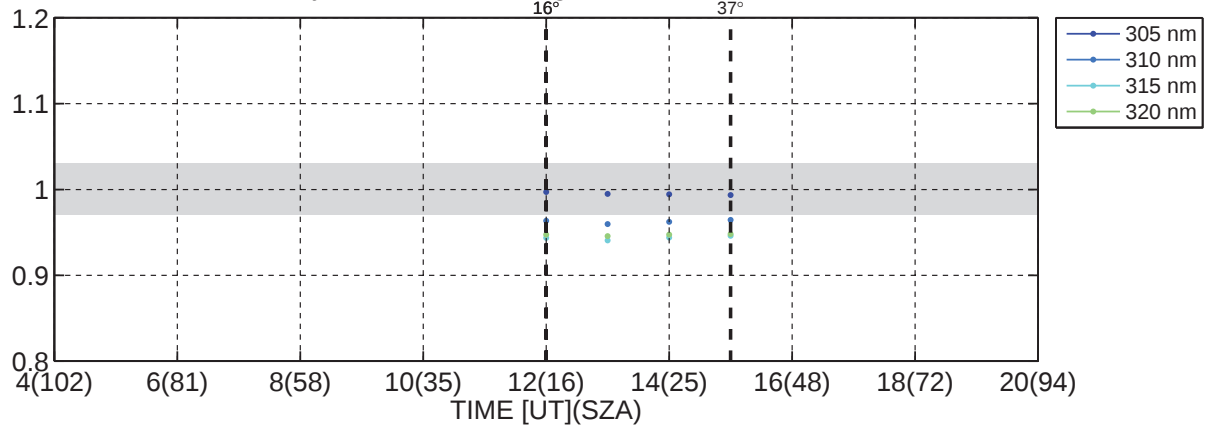
Daily variation. Wavelength bands are ± 2.5 nm



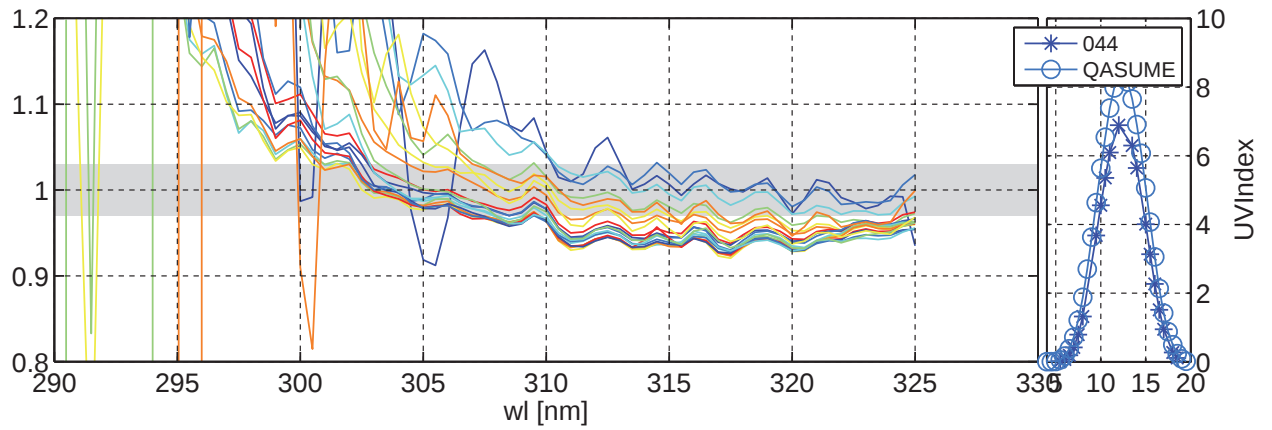
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



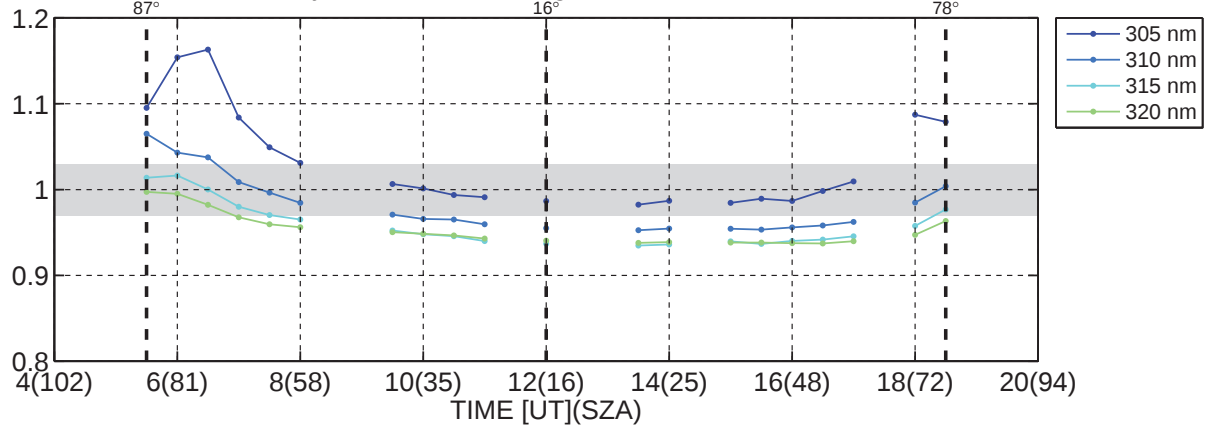
Daily variation. Wavelength bands are ± 2.5 nm



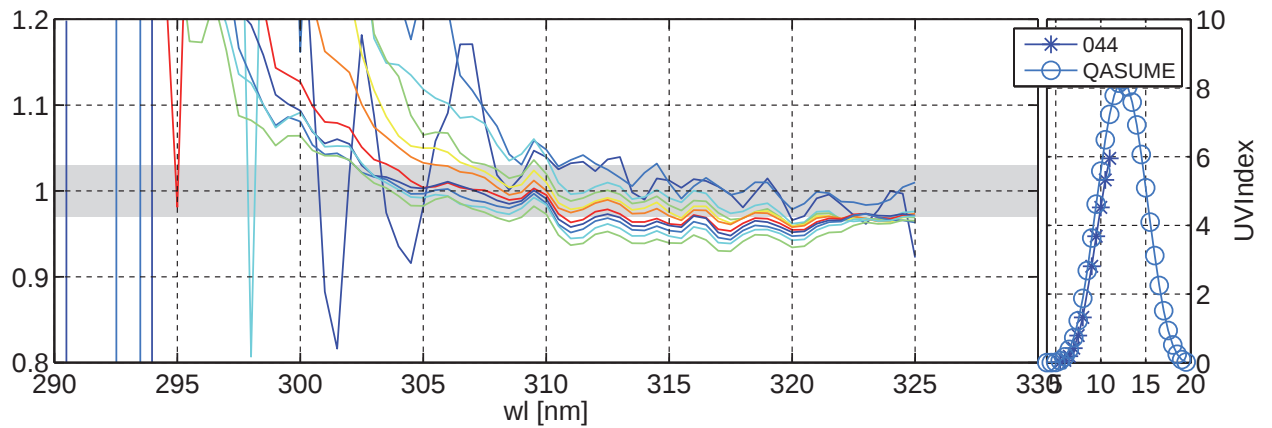
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



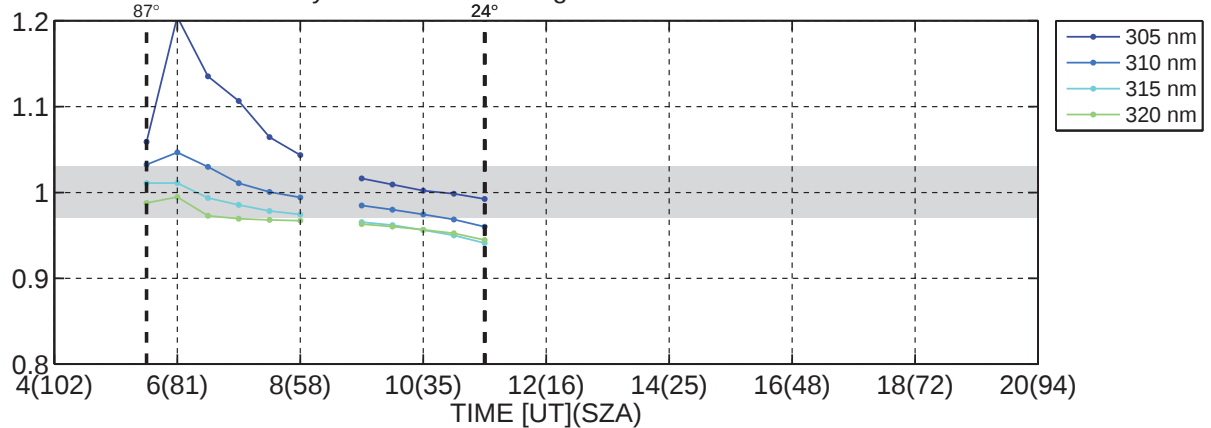
Daily variation. Wavelength bands are ± 2.5 nm

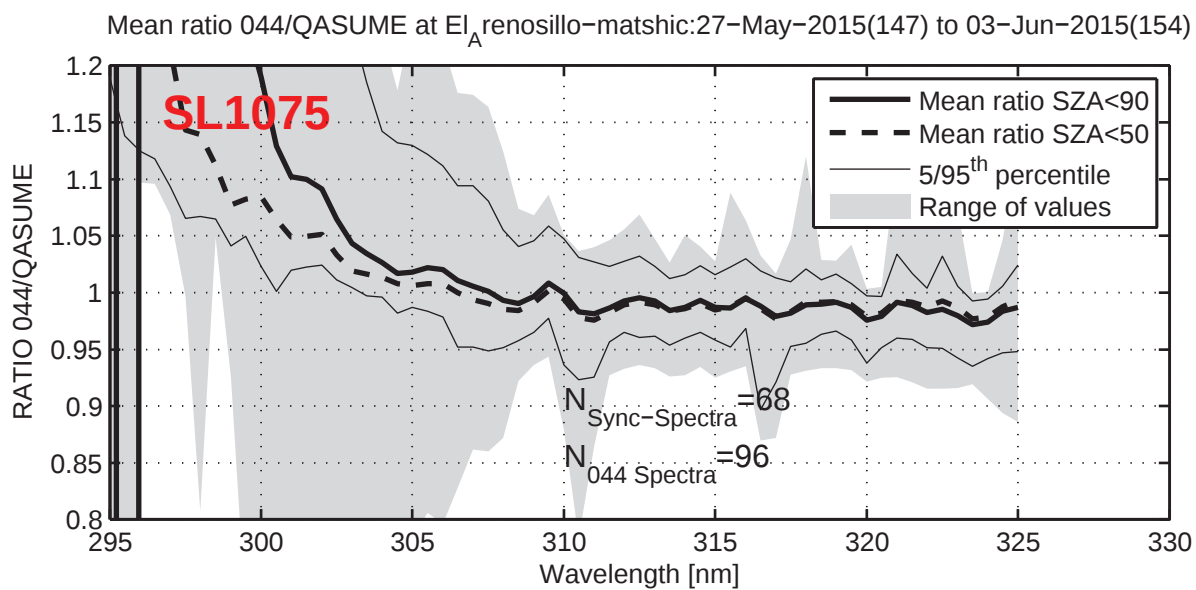
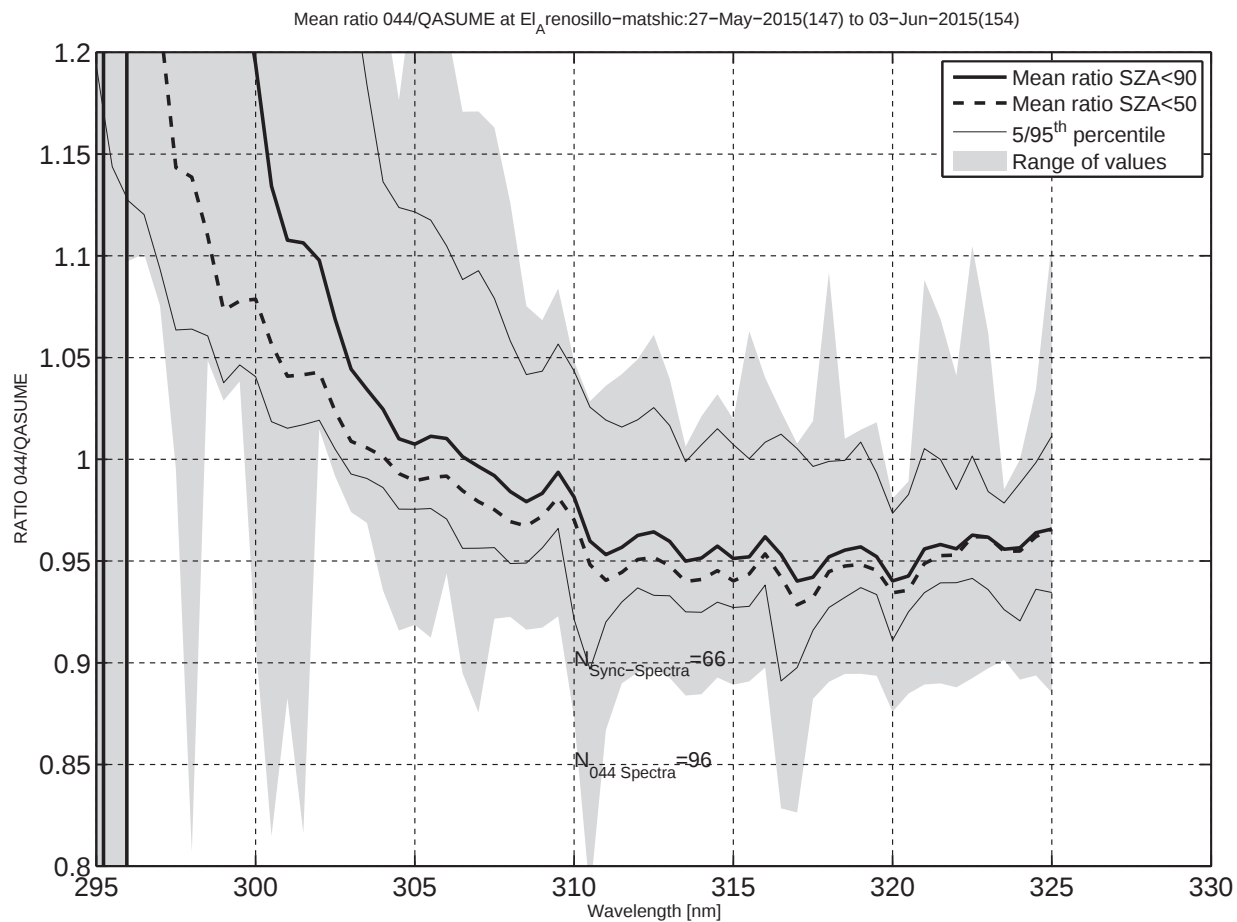


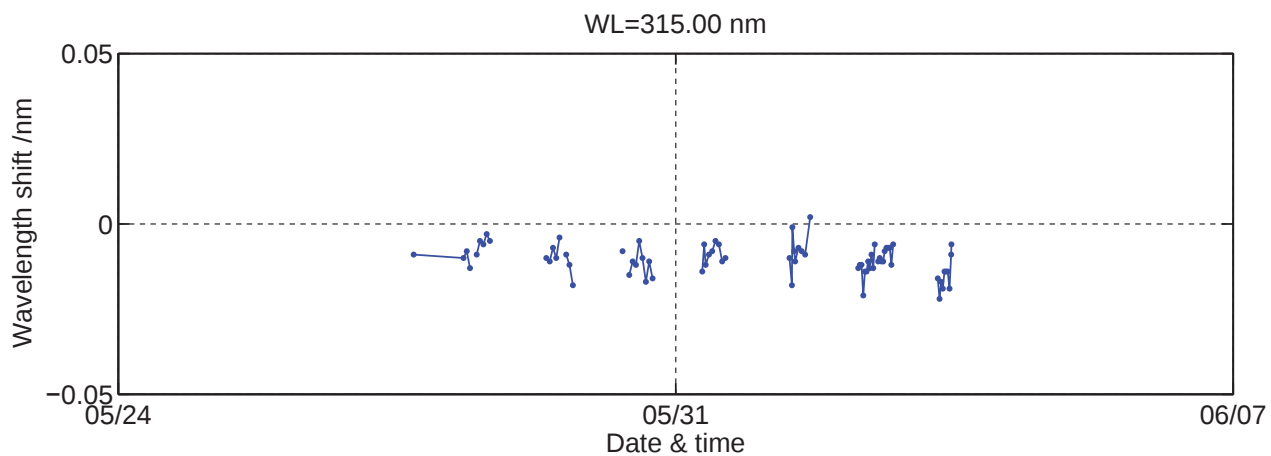
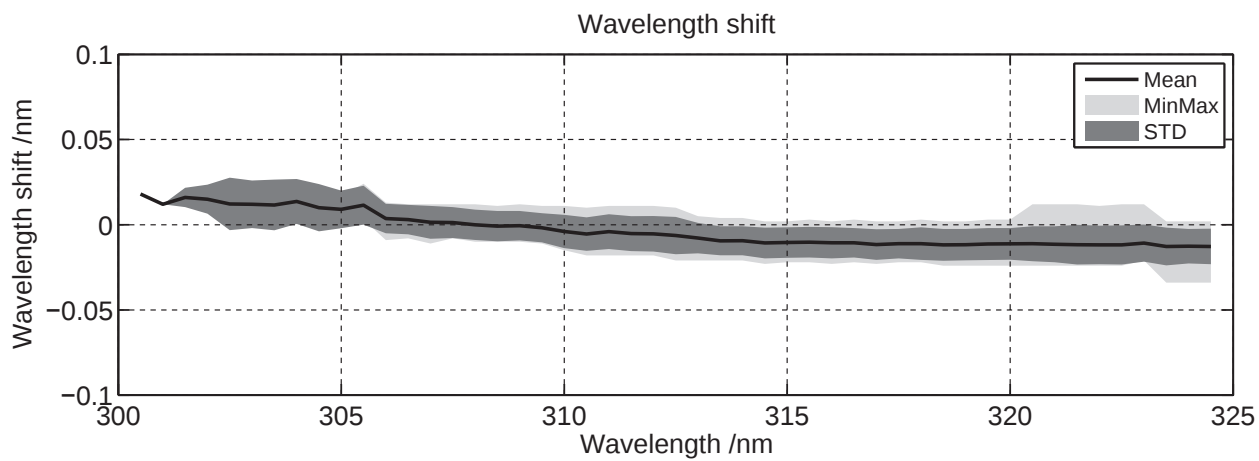
Global irradiance ratios 044/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



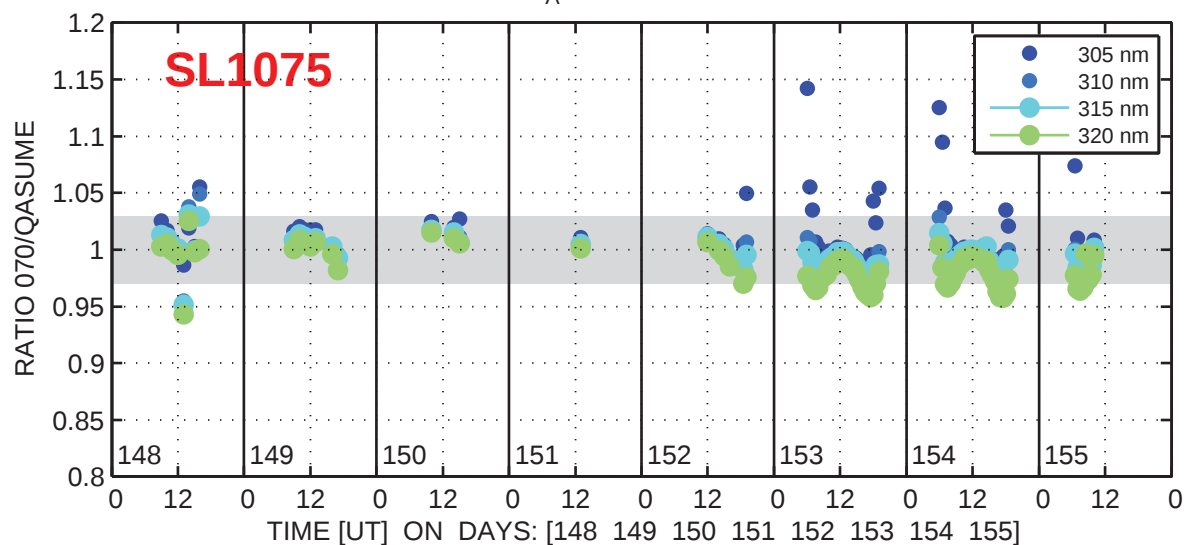
Daily variation. Wavelength bands are ± 2.5 nm



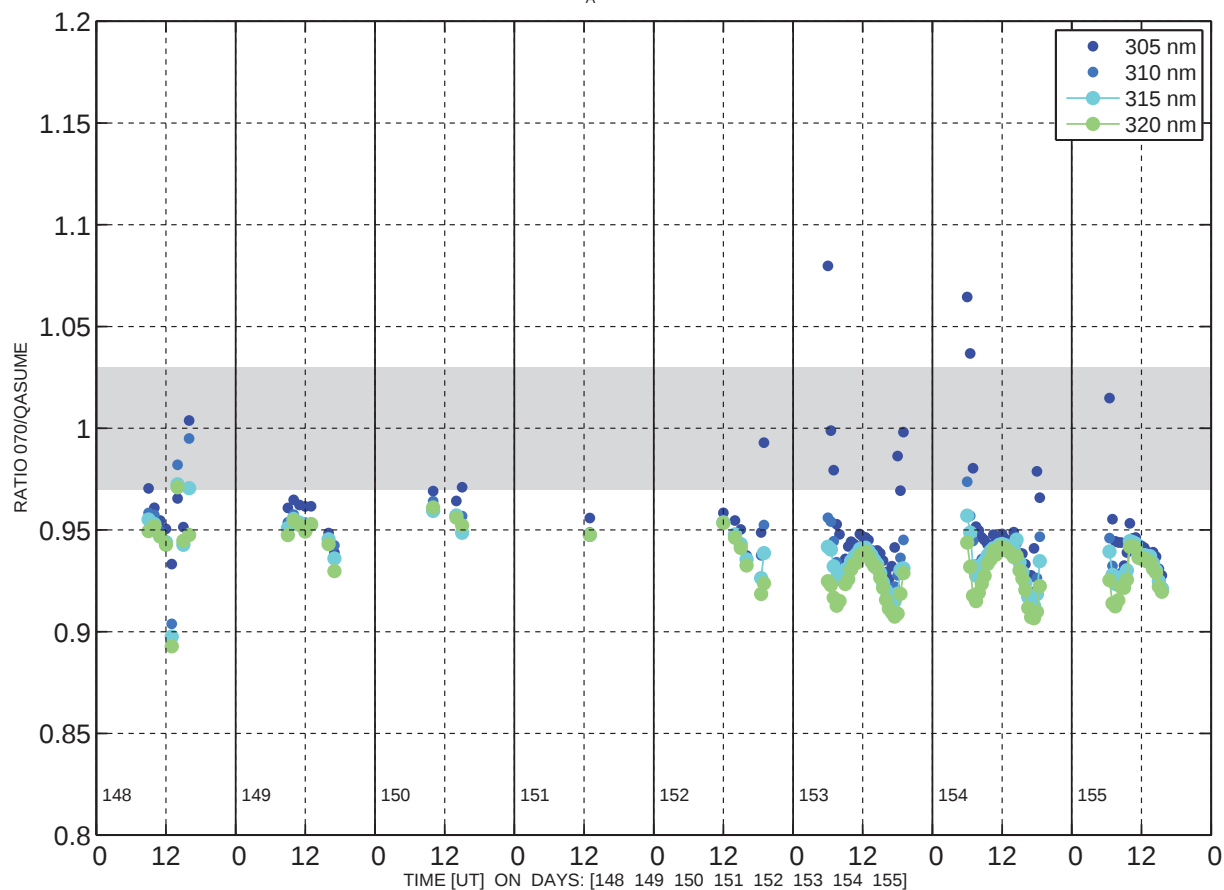




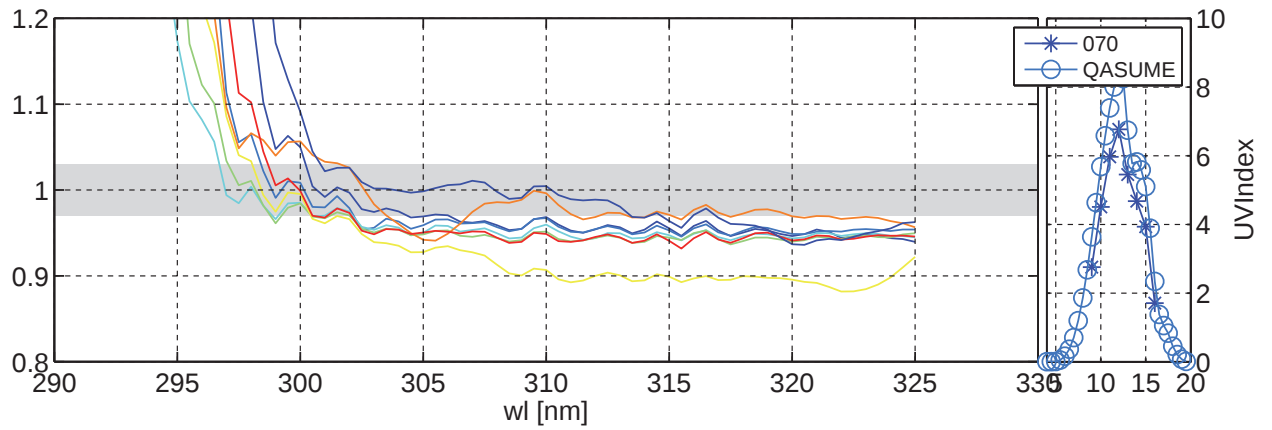
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



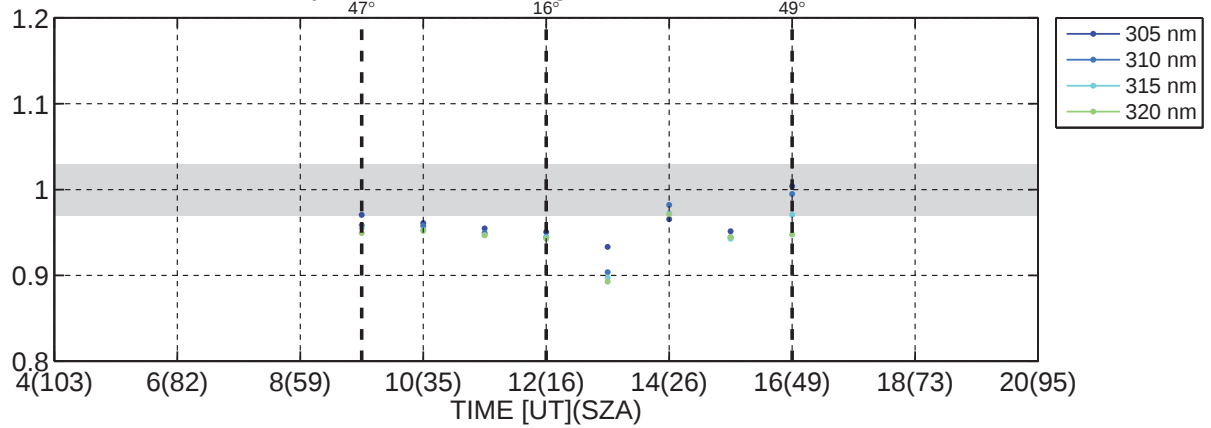
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



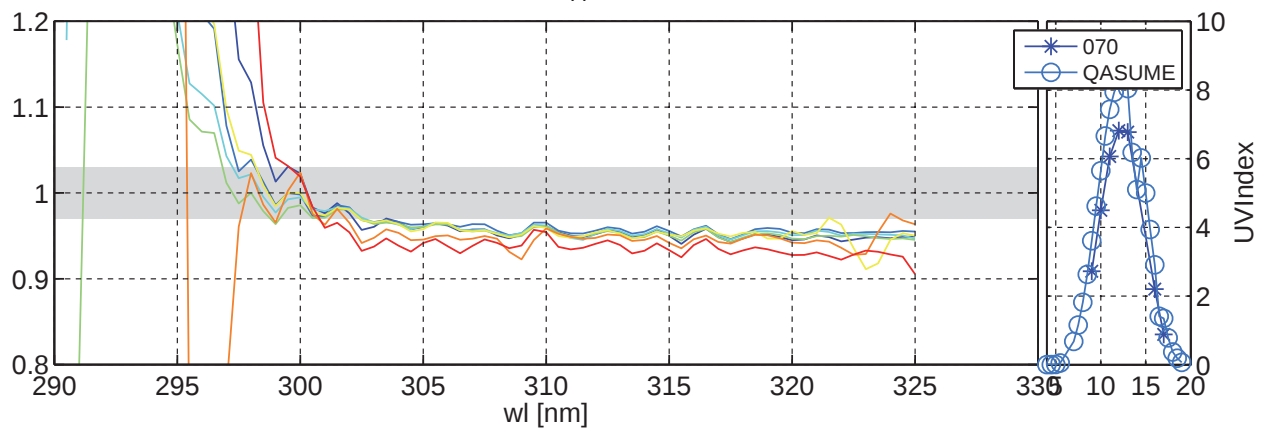
Global irradiance ratios 070/QASUME at El_A renosillo-matshic:28-May-2015(148)



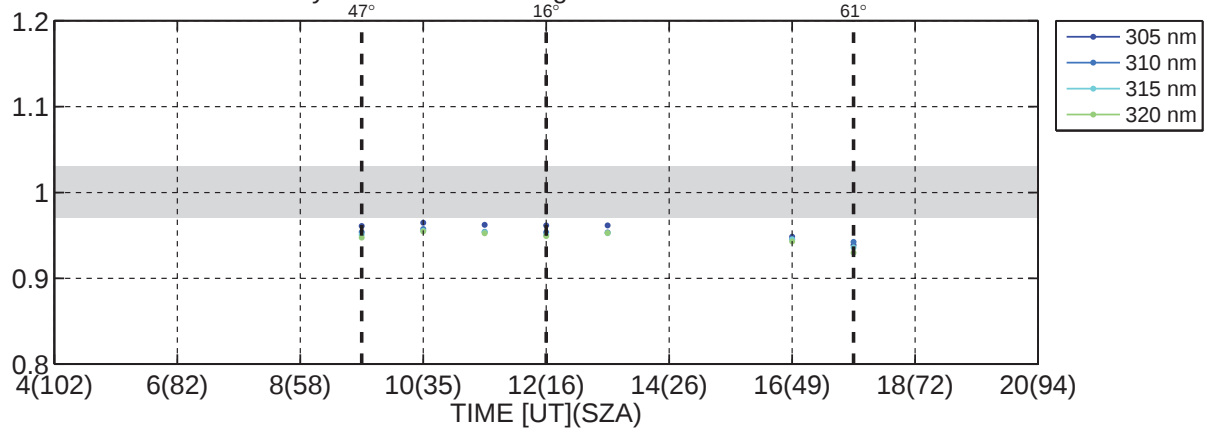
Daily variation. Wavelength bands are ± 2.5 nm



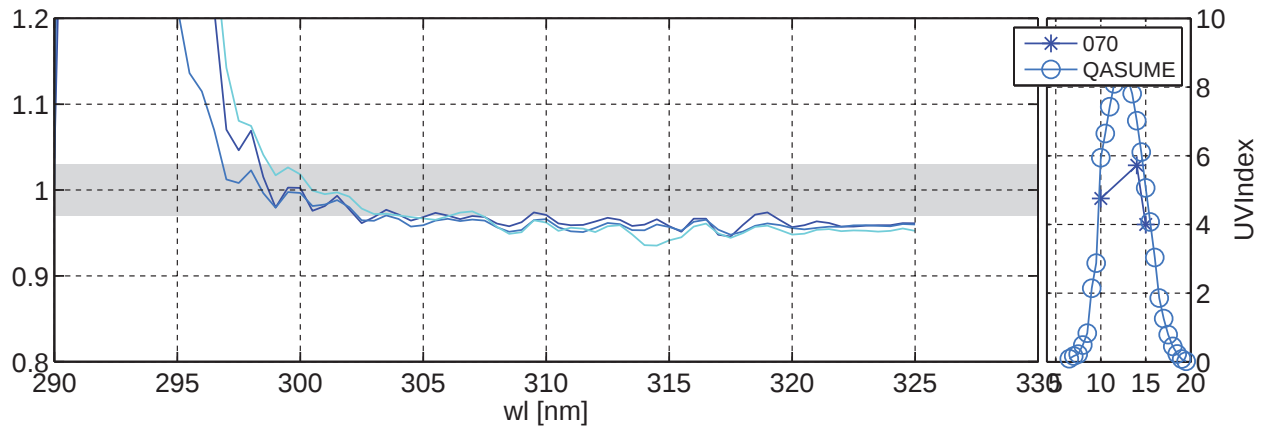
Global irradiance ratios 070/QASUME at El_A renosillo-matshic:29-May-2015(149)



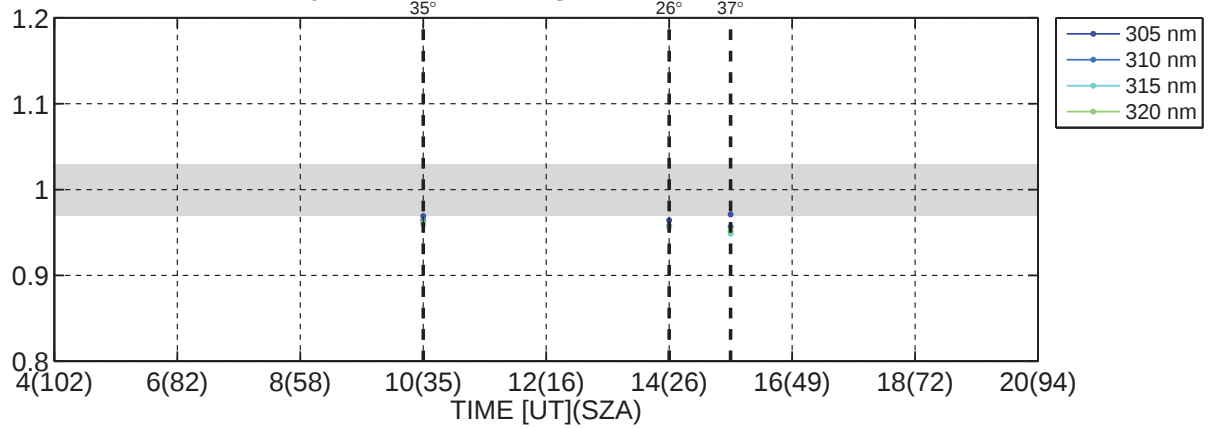
Daily variation. Wavelength bands are ± 2.5 nm



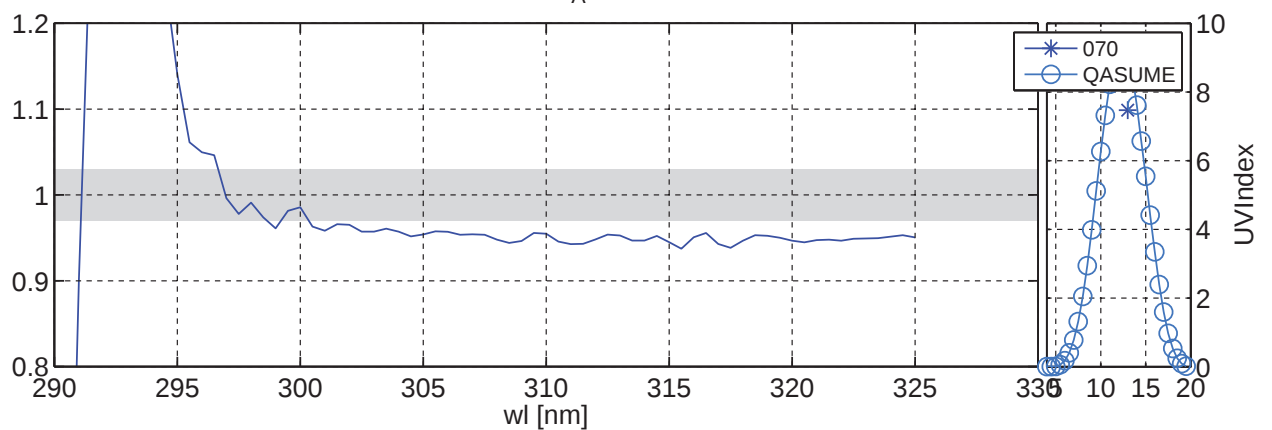
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:30-May-2015(150)



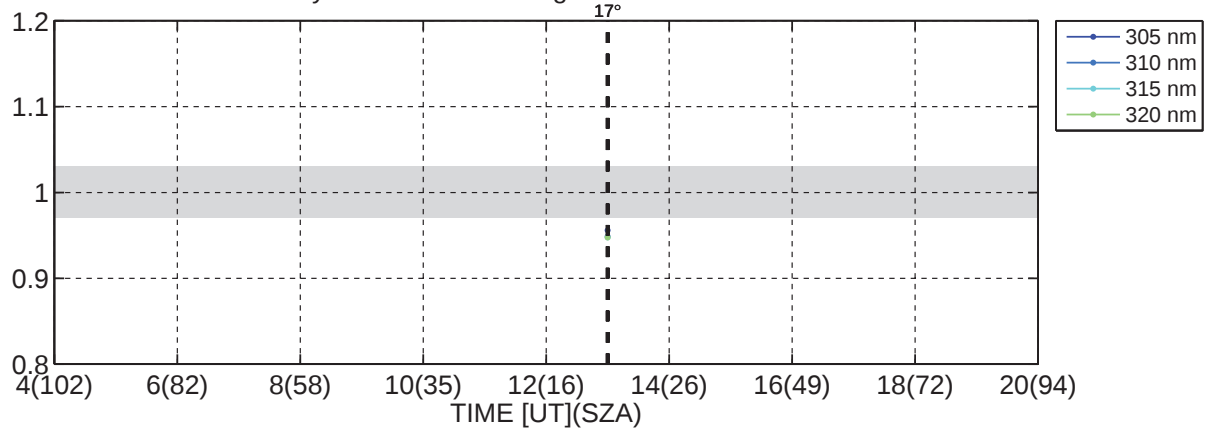
Daily variation. Wavelength bands are ± 2.5 nm



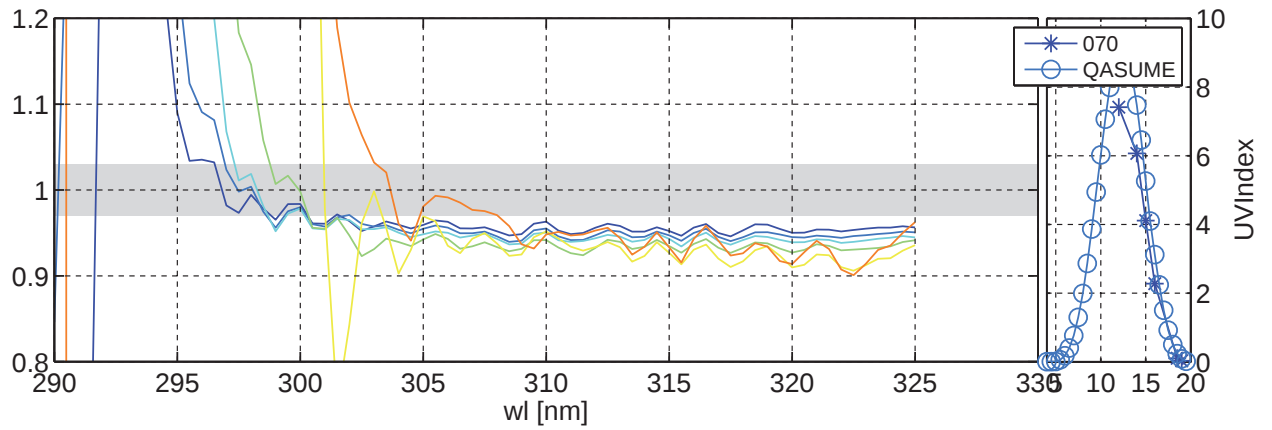
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:31-May-2015(151)



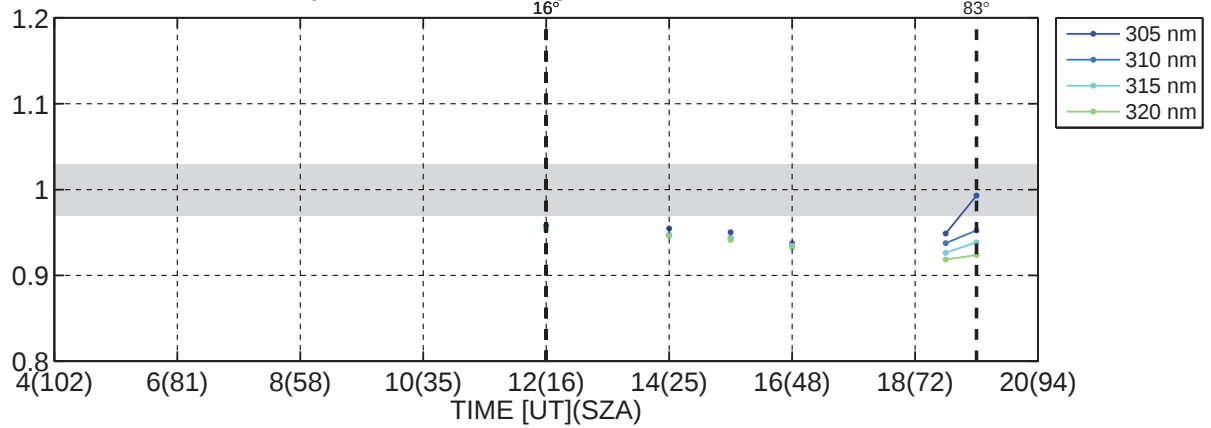
Daily variation. Wavelength bands are ± 2.5 nm



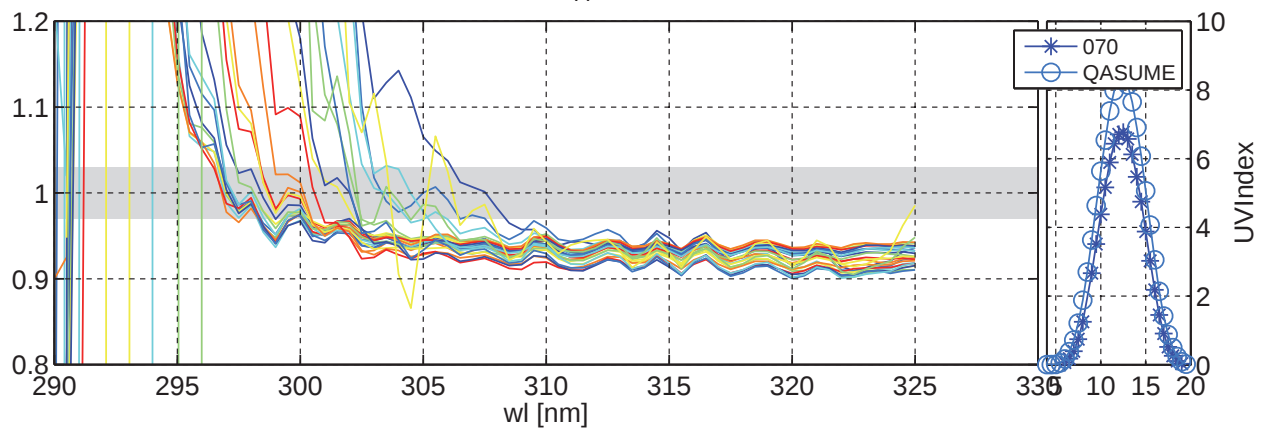
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



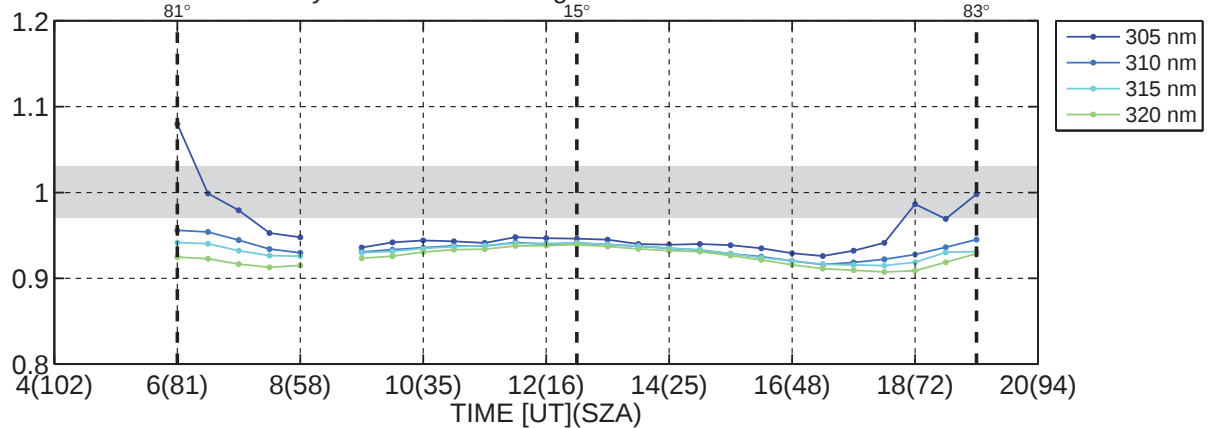
Daily variation. Wavelength bands are ± 2.5 nm



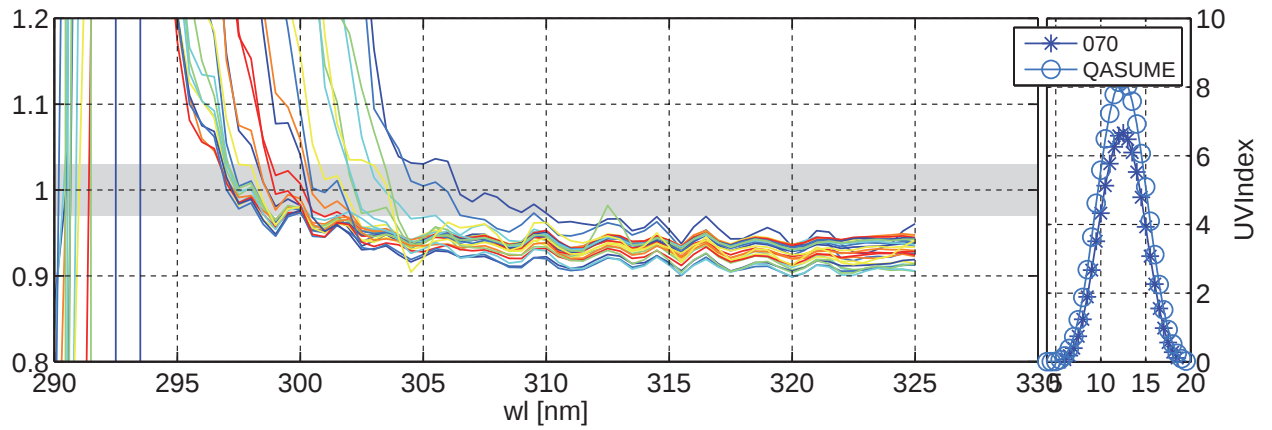
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



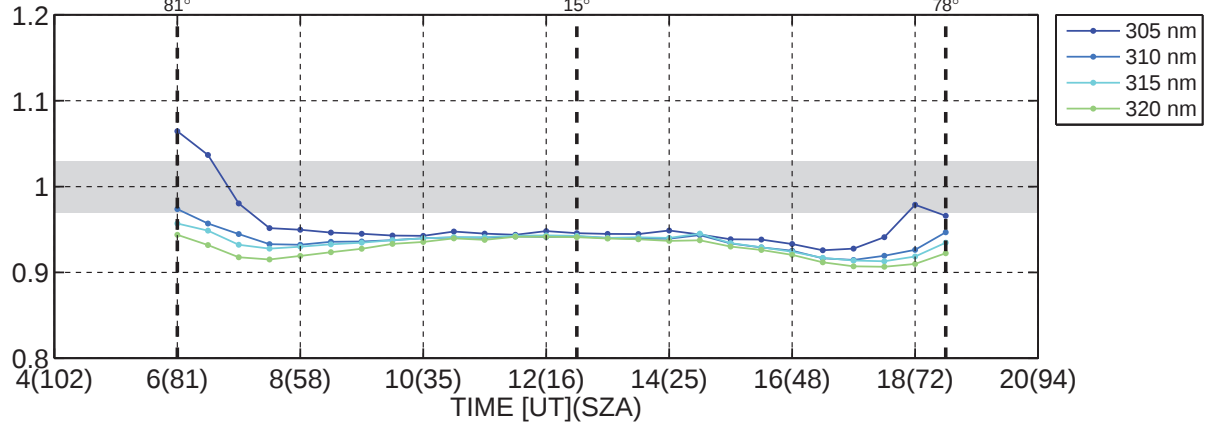
Daily variation. Wavelength bands are ± 2.5 nm



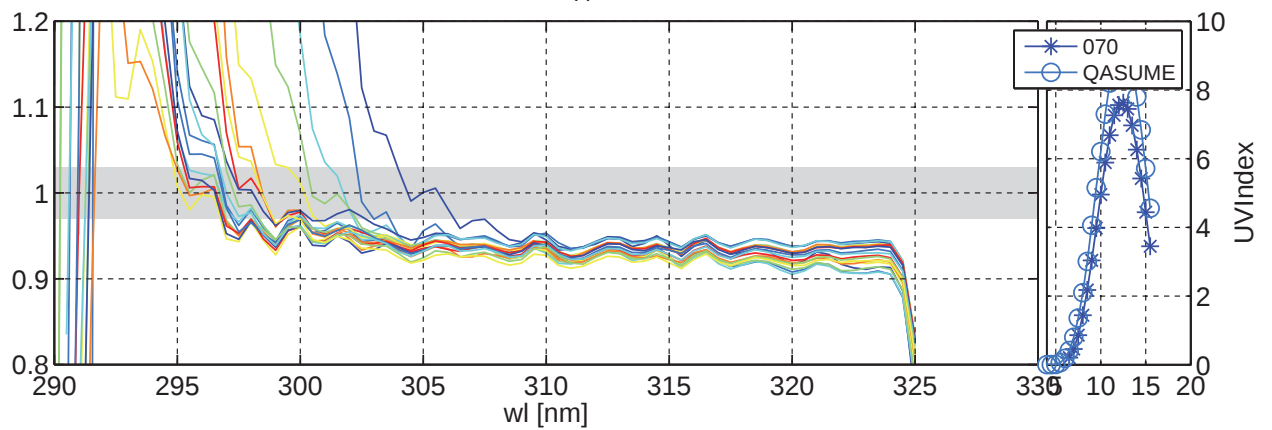
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



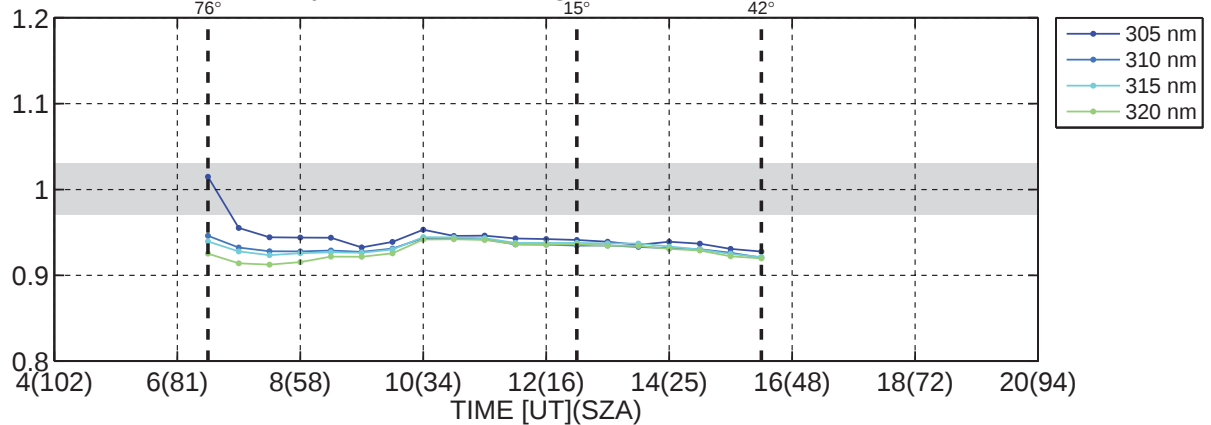
Daily variation. Wavelength bands are ± 2.5 nm

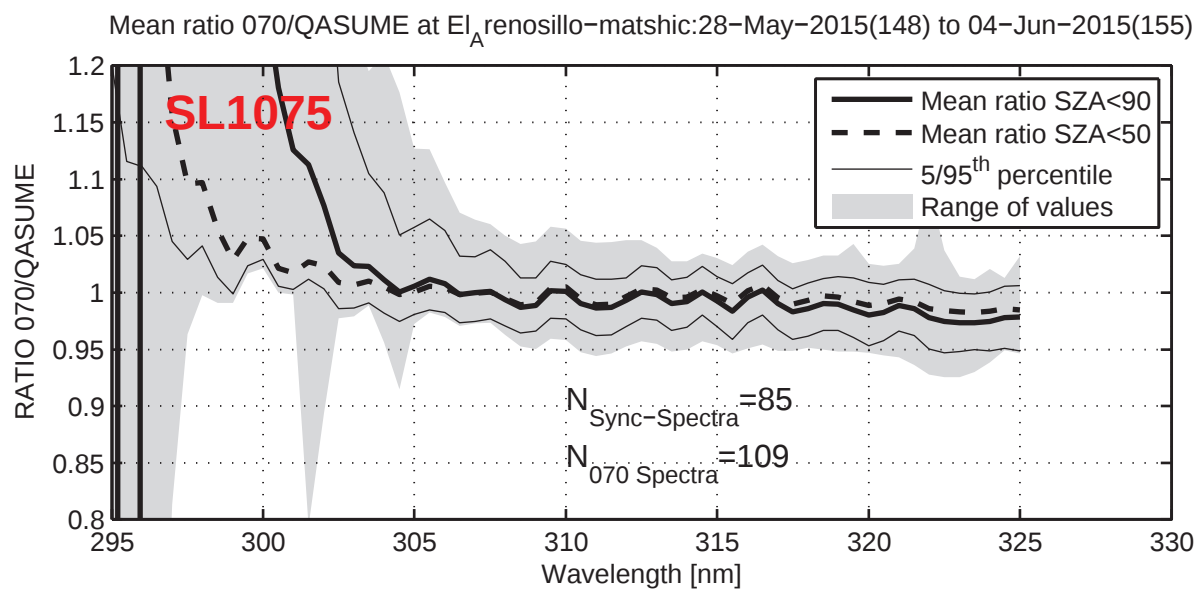
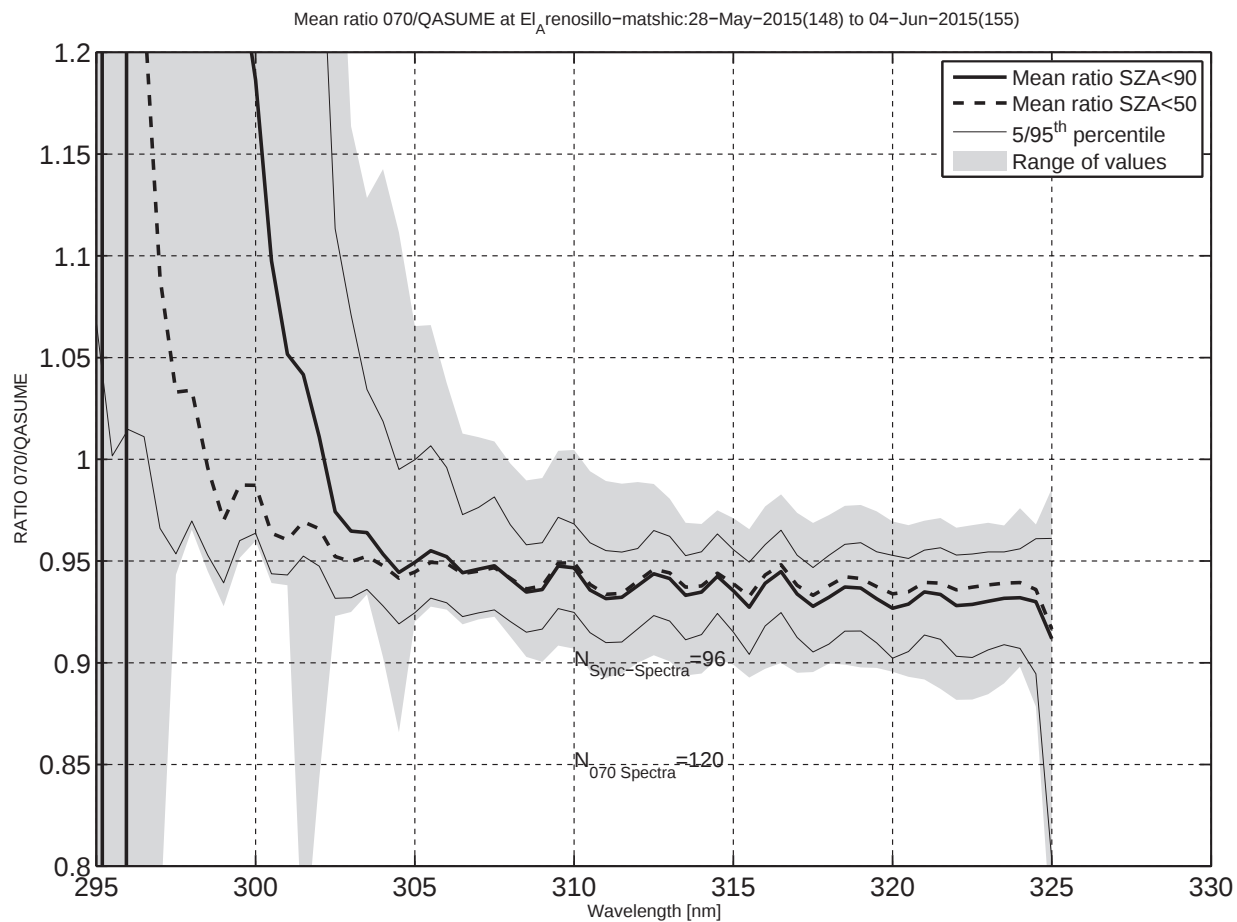


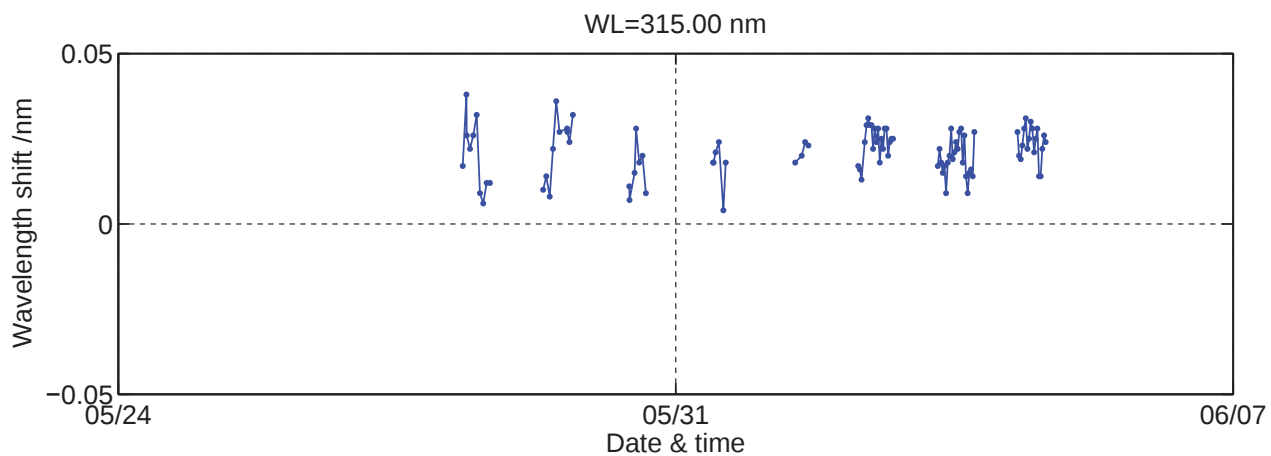
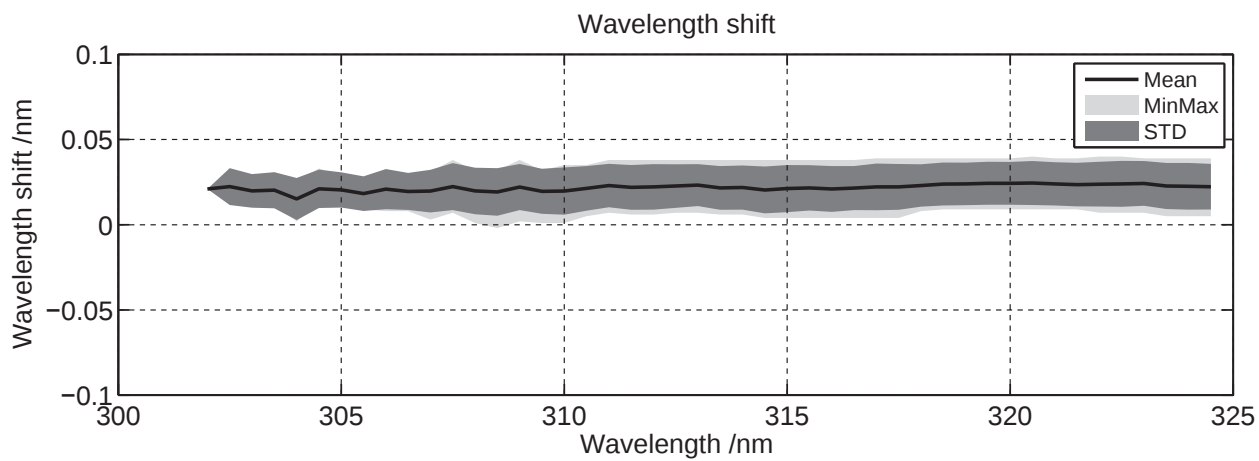
Global irradiance ratios 070/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)

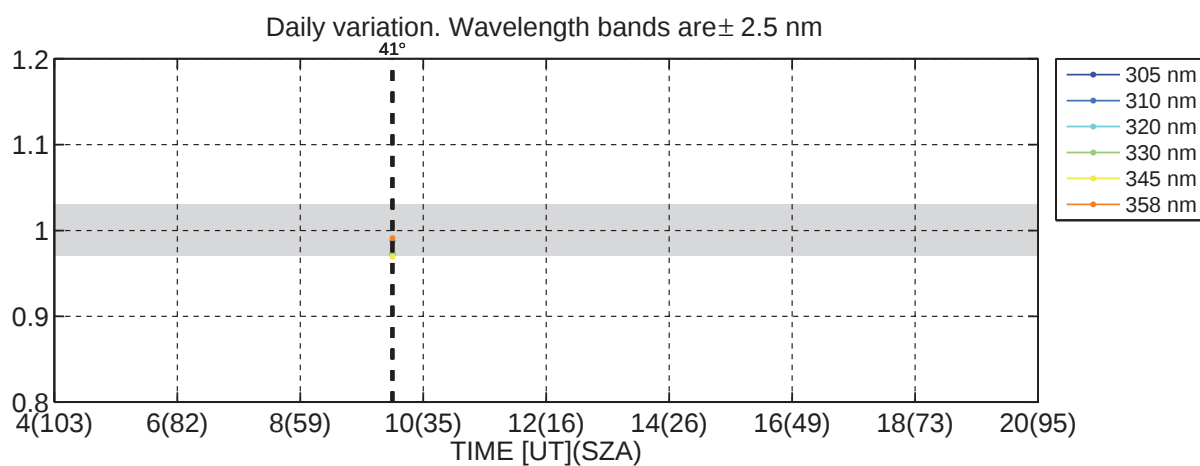
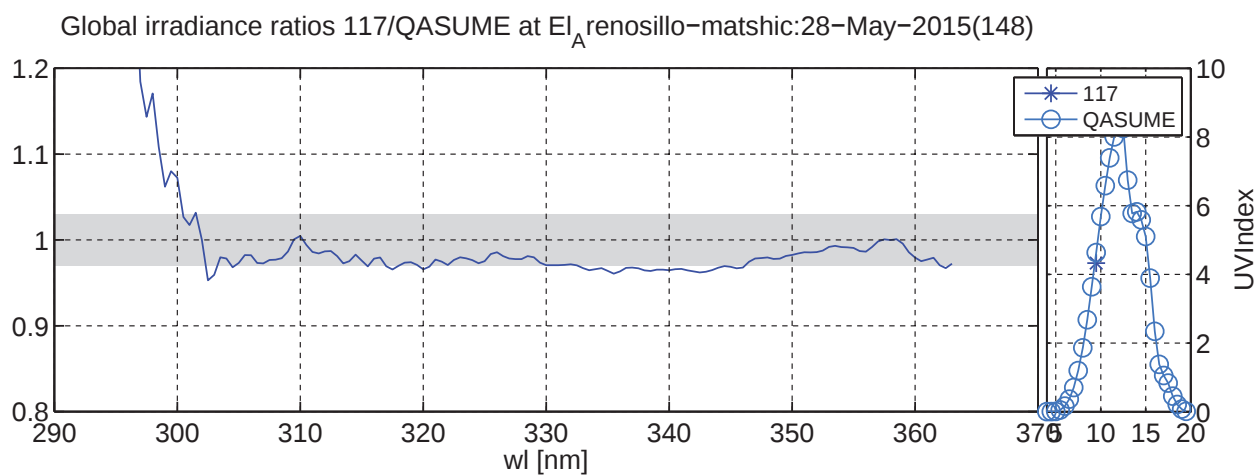
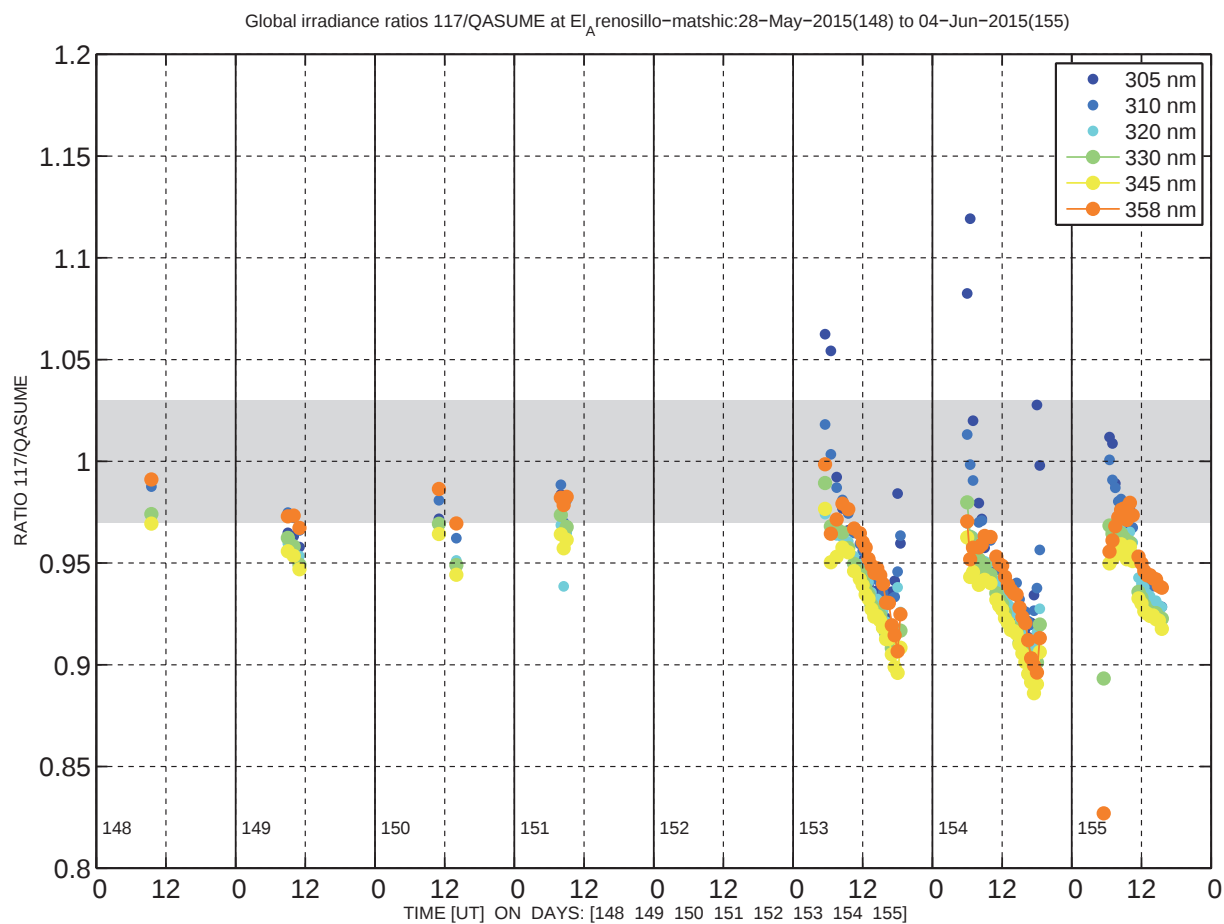


Daily variation. Wavelength bands are ± 2.5 nm

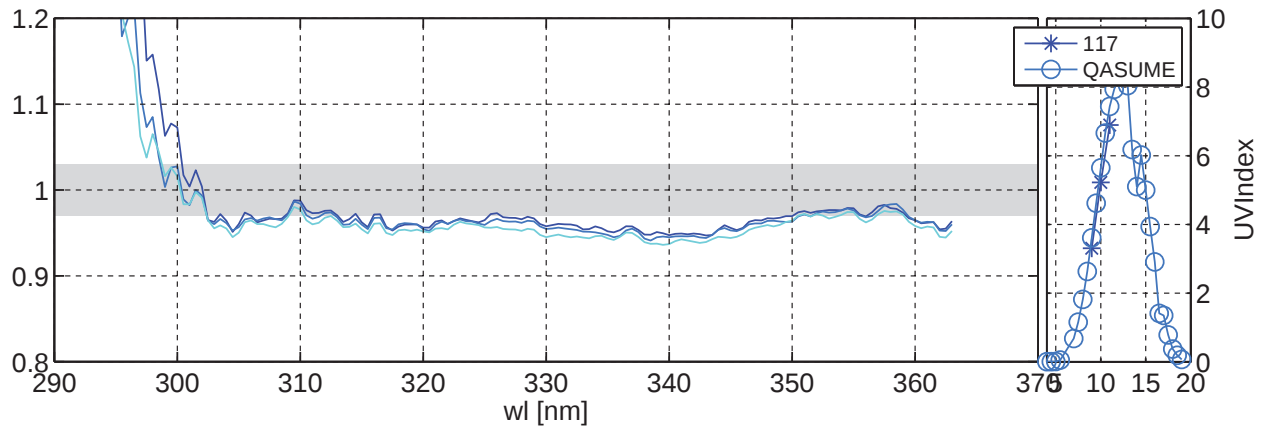




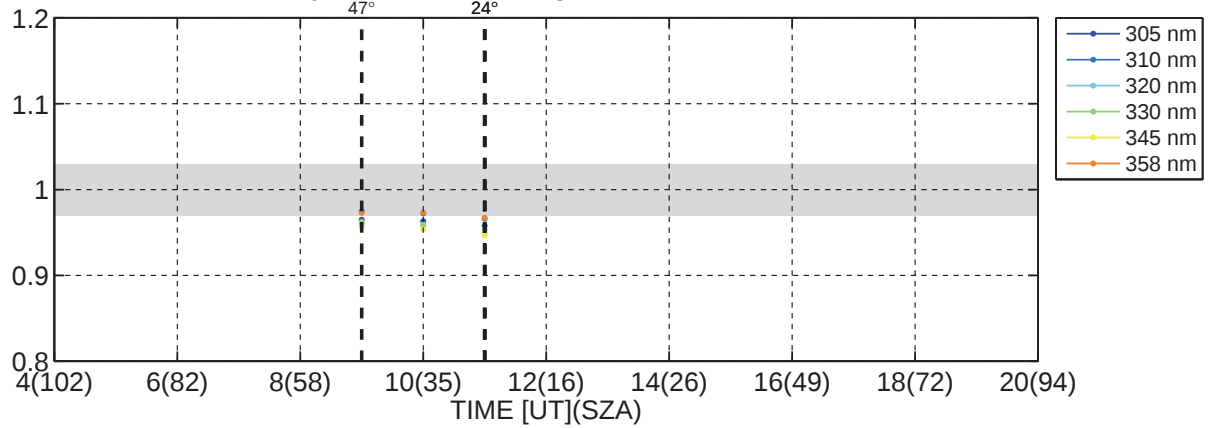




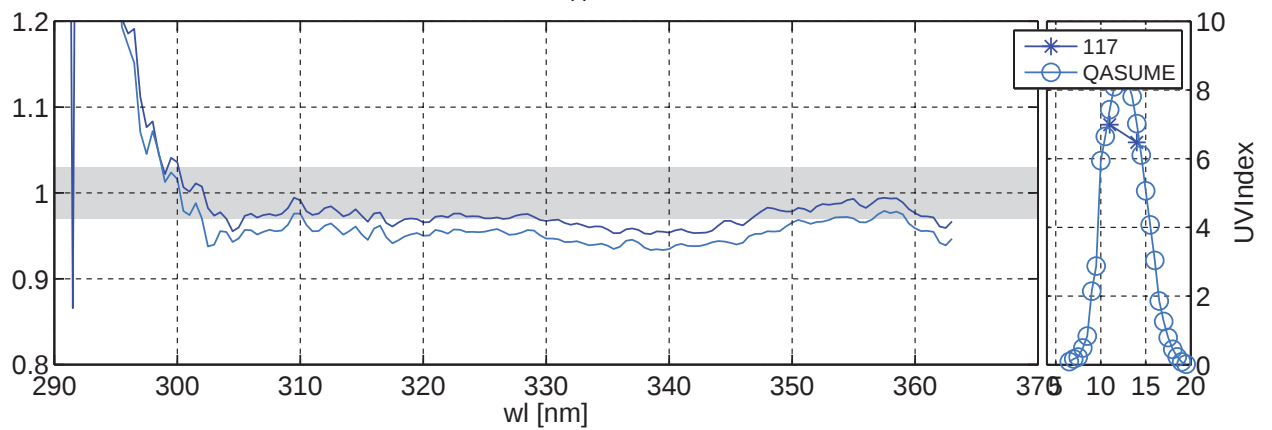
Global irradiance ratios 117/QASUME at El_Arenosillo-matshic:29-May-2015(149)



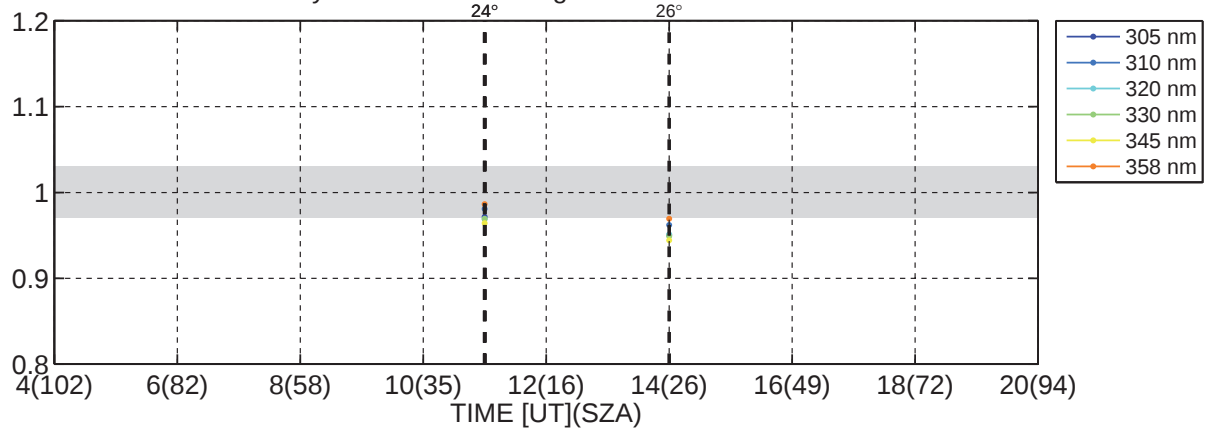
Daily variation. Wavelength bands are ± 2.5 nm



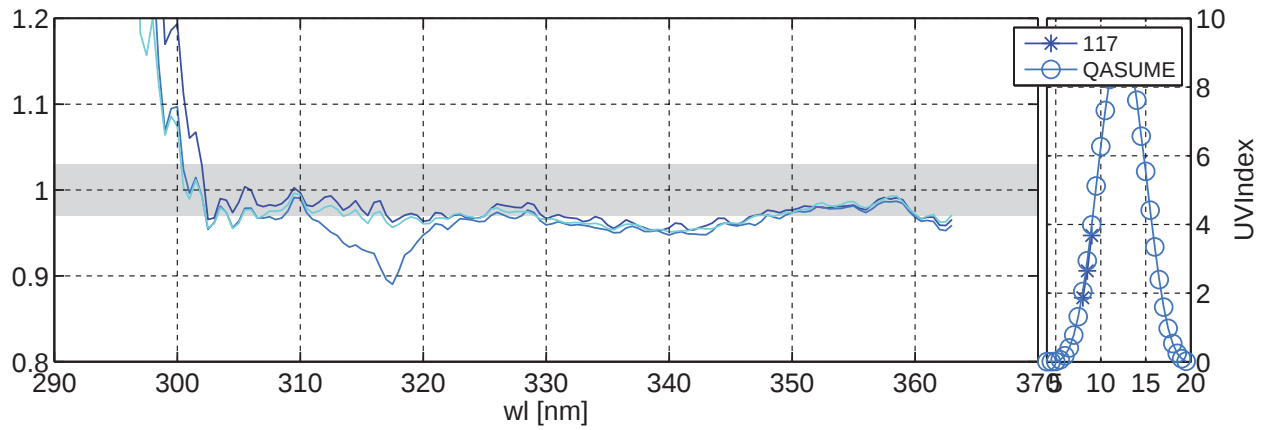
Global irradiance ratios 117/QASUME at El_Arenosillo-matshic:30-May-2015(150)



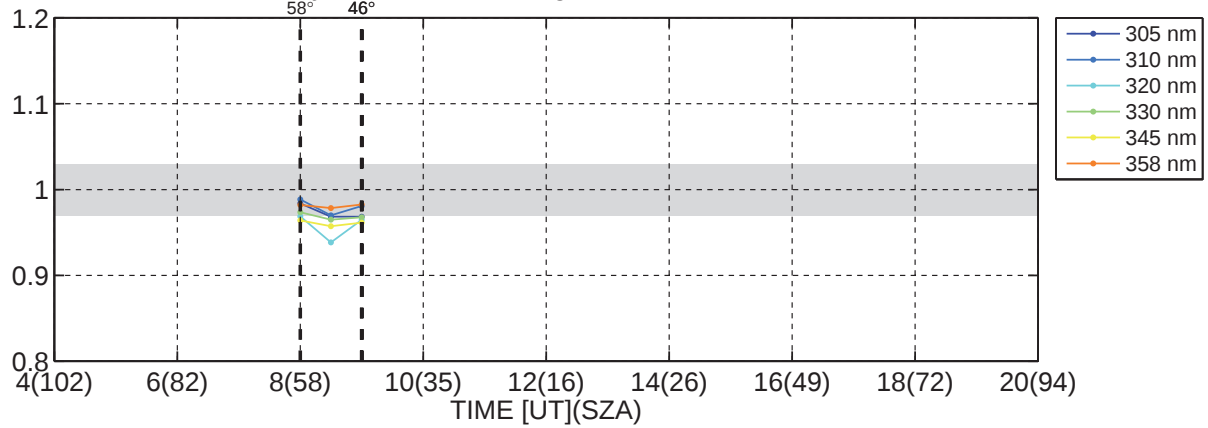
Daily variation. Wavelength bands are ± 2.5 nm



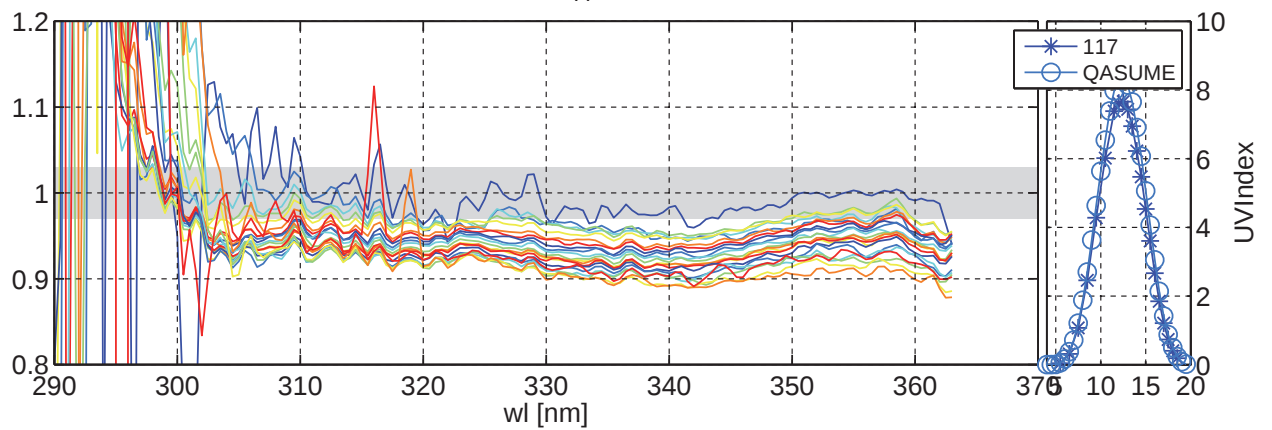
Global irradiance ratios 117/QASUME at El_Arenosillo-matshic:31-May-2015(151)



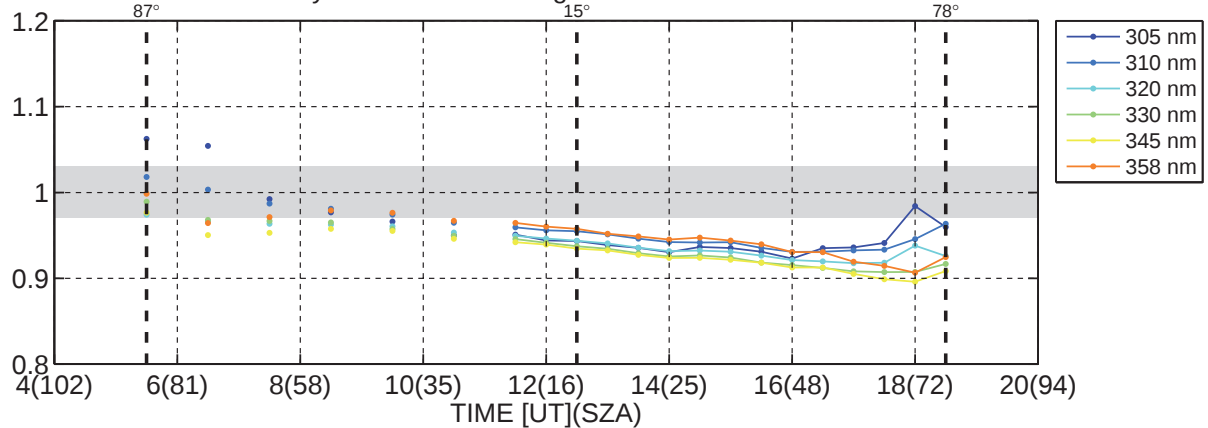
Daily variation. Wavelength bands are ± 2.5 nm



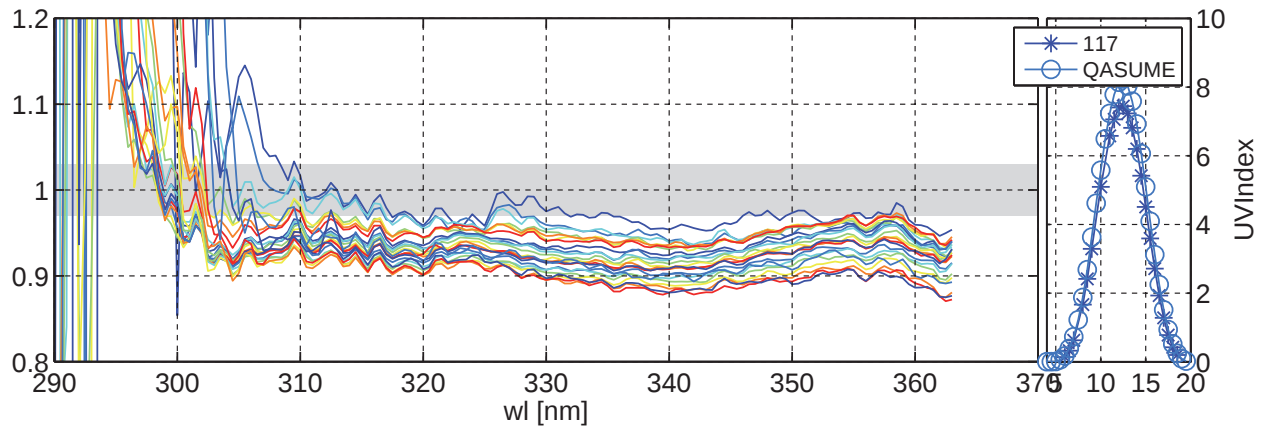
Global irradiance ratios 117/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



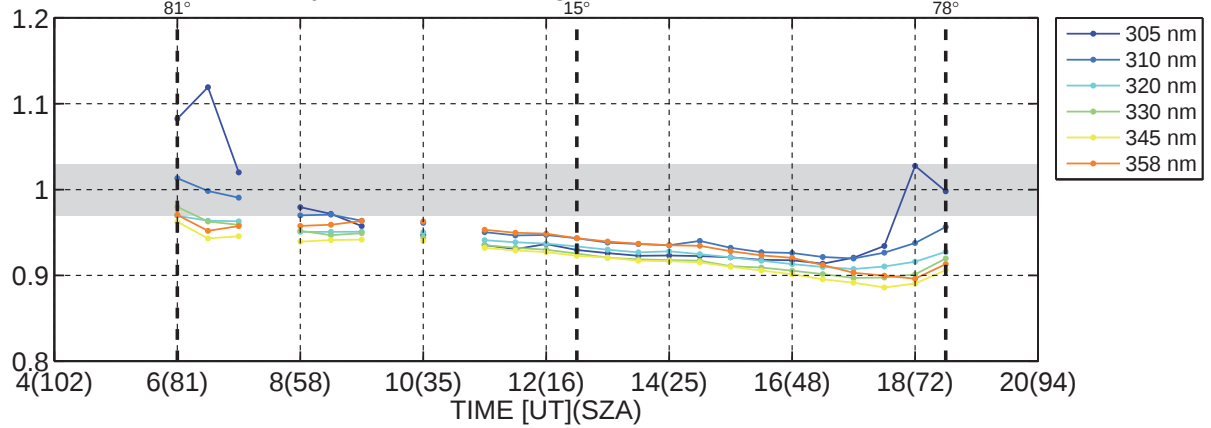
Daily variation. Wavelength bands are ± 2.5 nm



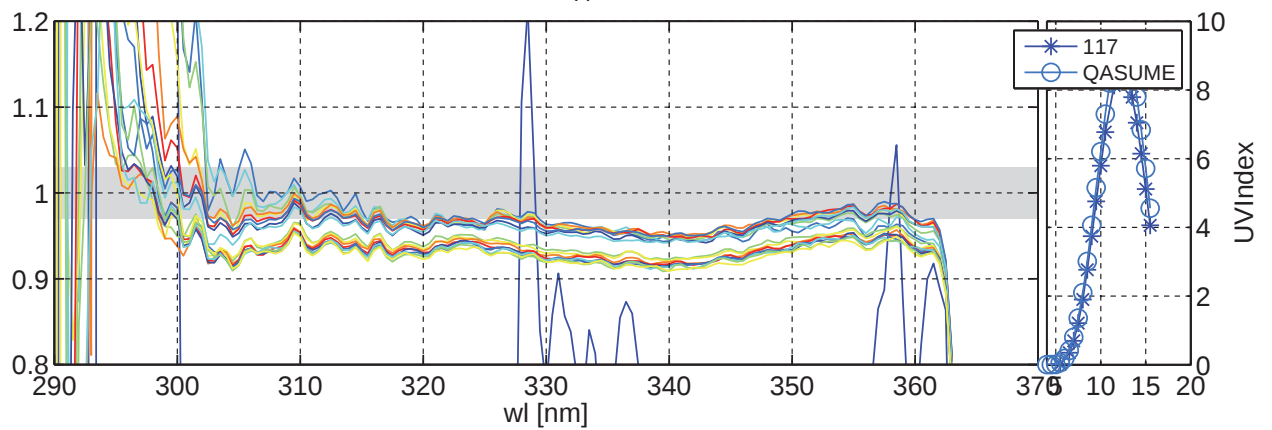
Global irradiance ratios 117/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



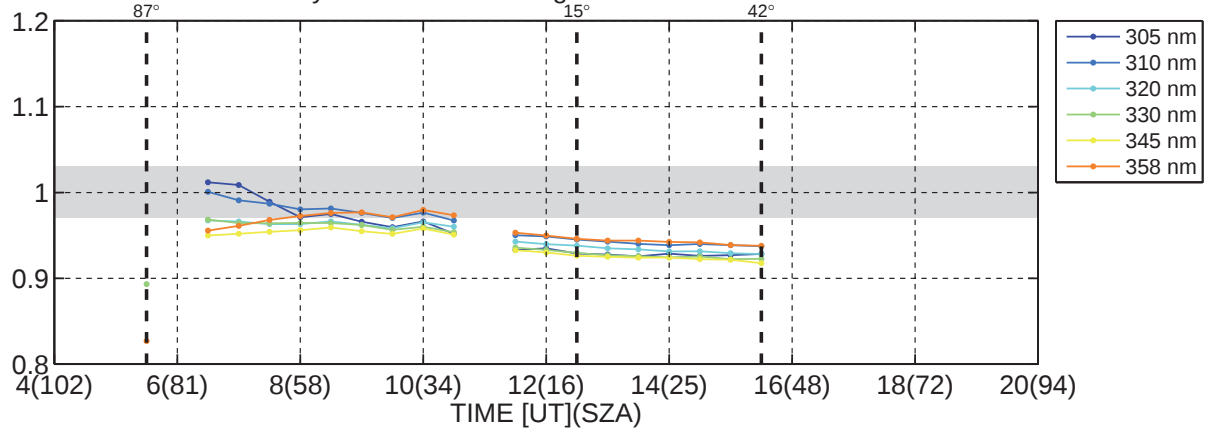
Daily variation. Wavelength bands are ± 2.5 nm



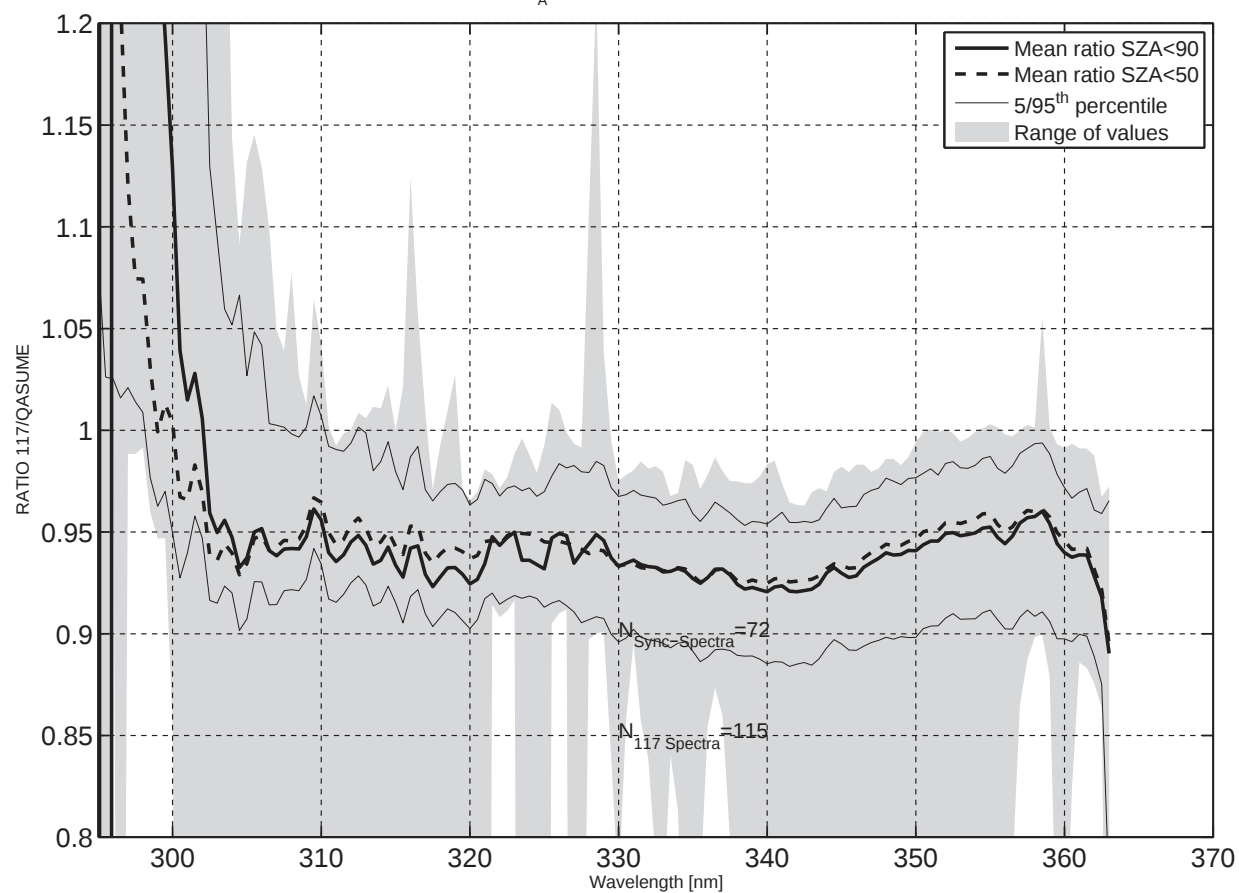
Global irradiance ratios 117/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



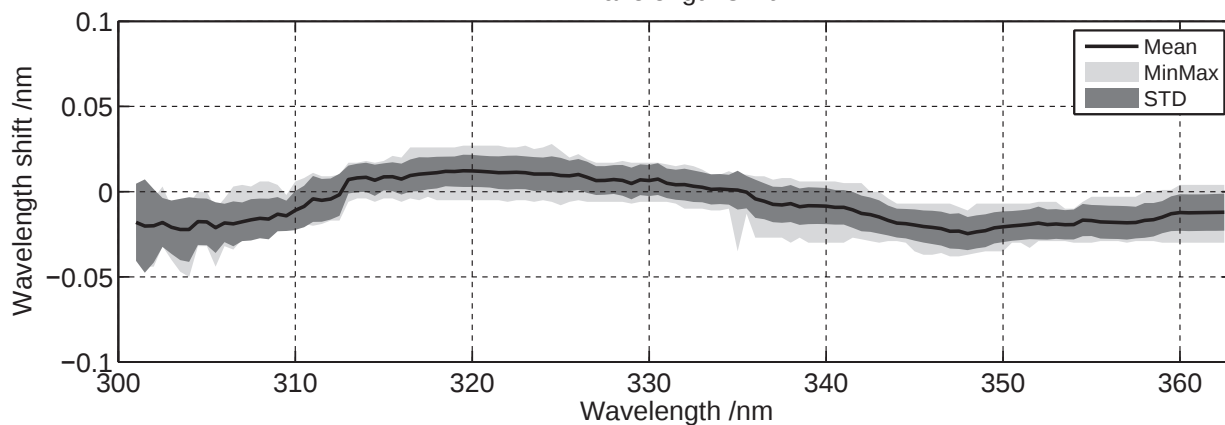
Daily variation. Wavelength bands are ± 2.5 nm



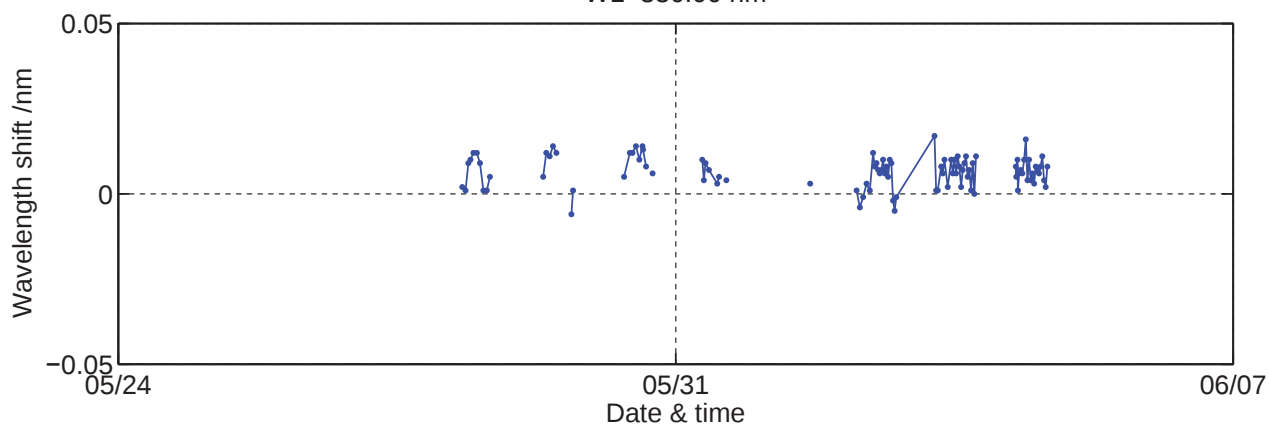
Mean ratio 117/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



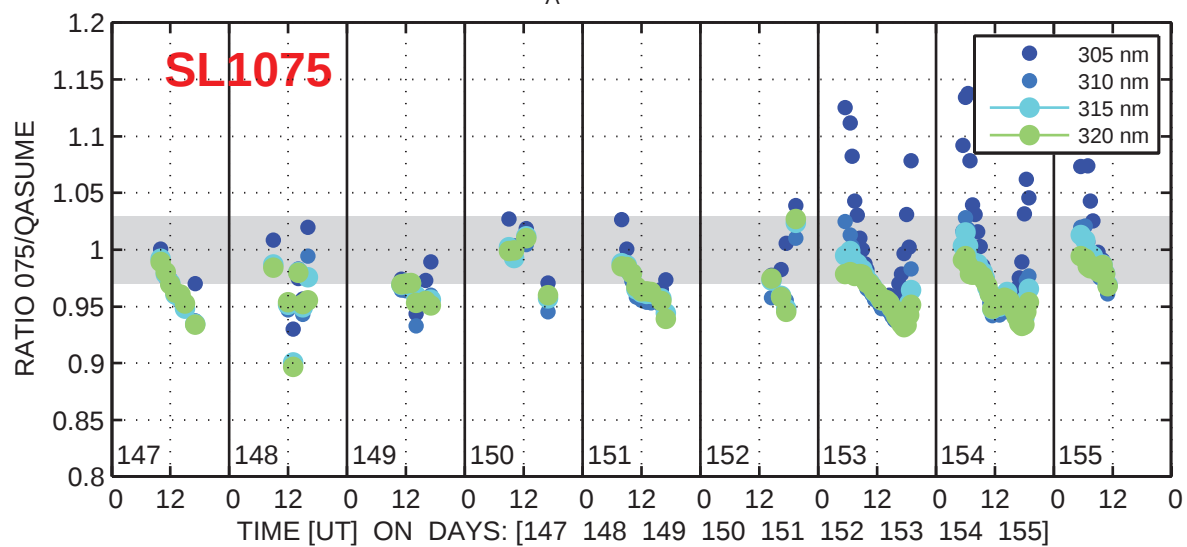
Wavelength shift



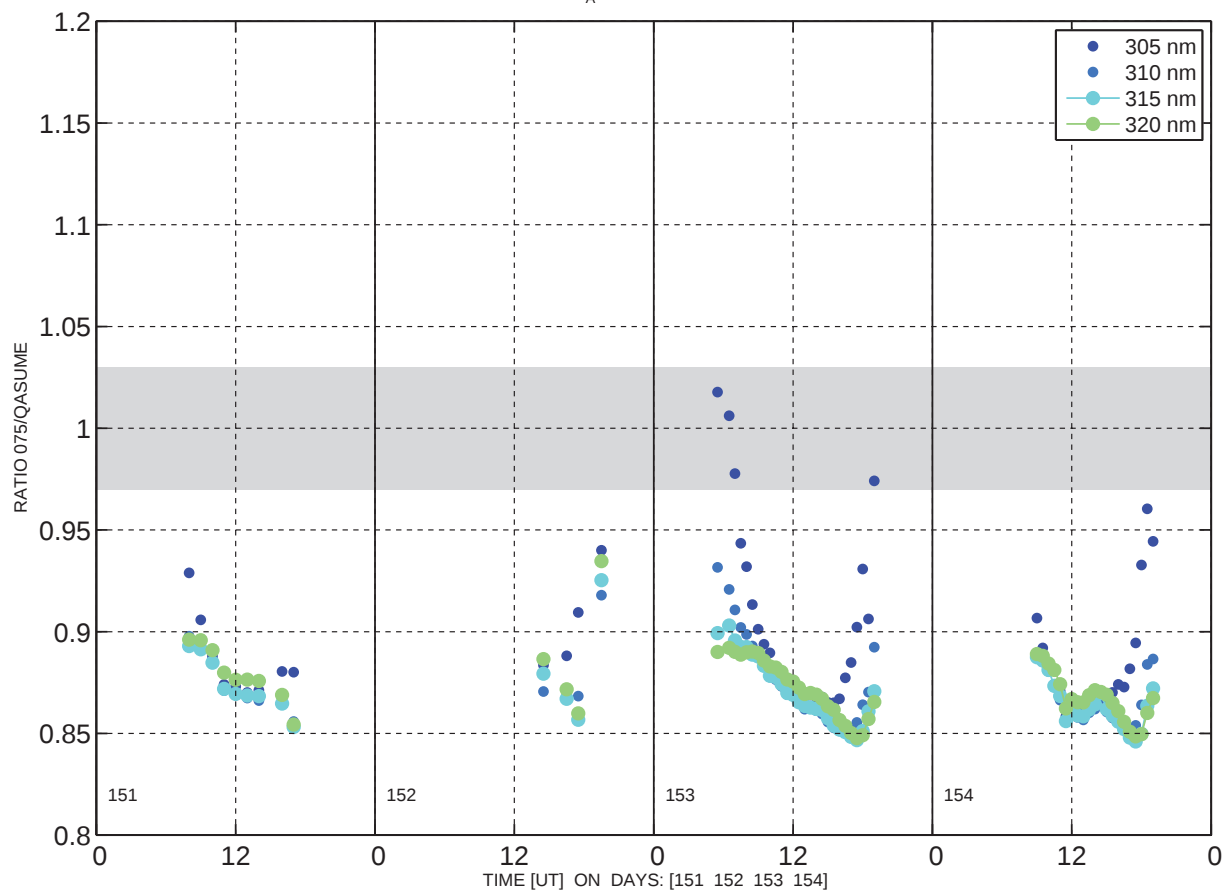
WL=330.00 nm



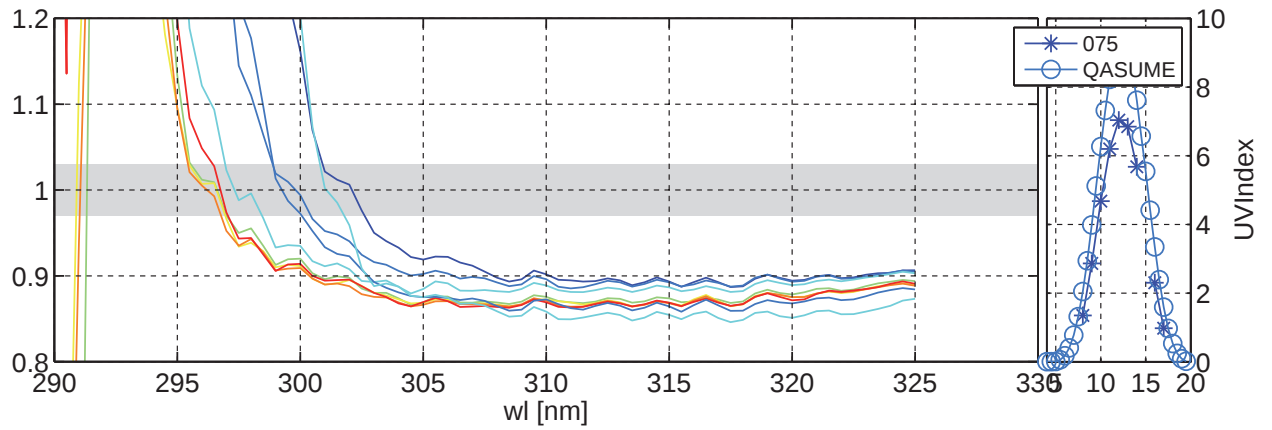
Global irradiance ratios 075/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 04-Jun-2015(155)



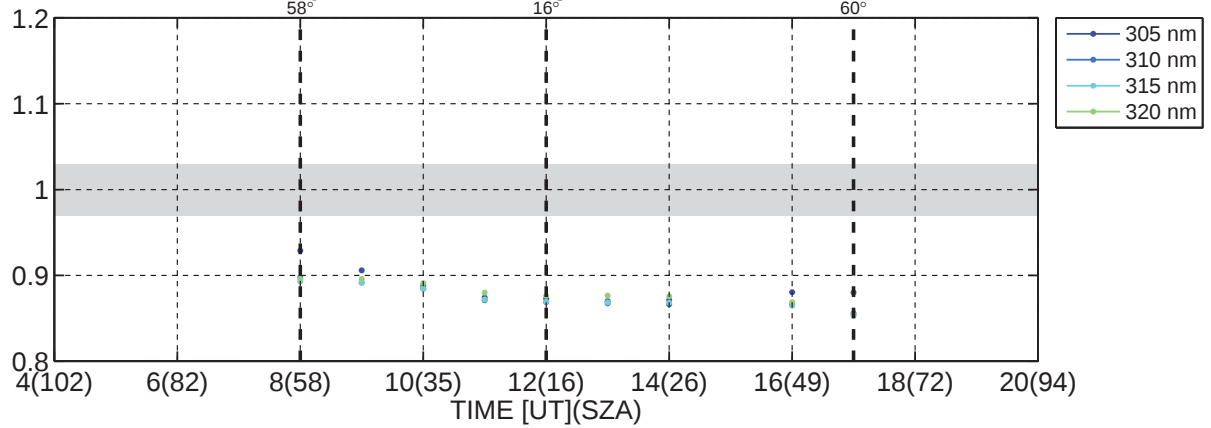
Global irradiance ratios 075/QASUME at El_Arenosillo-matshic:31-May-2015(151) to 03-Jun-2015(154)



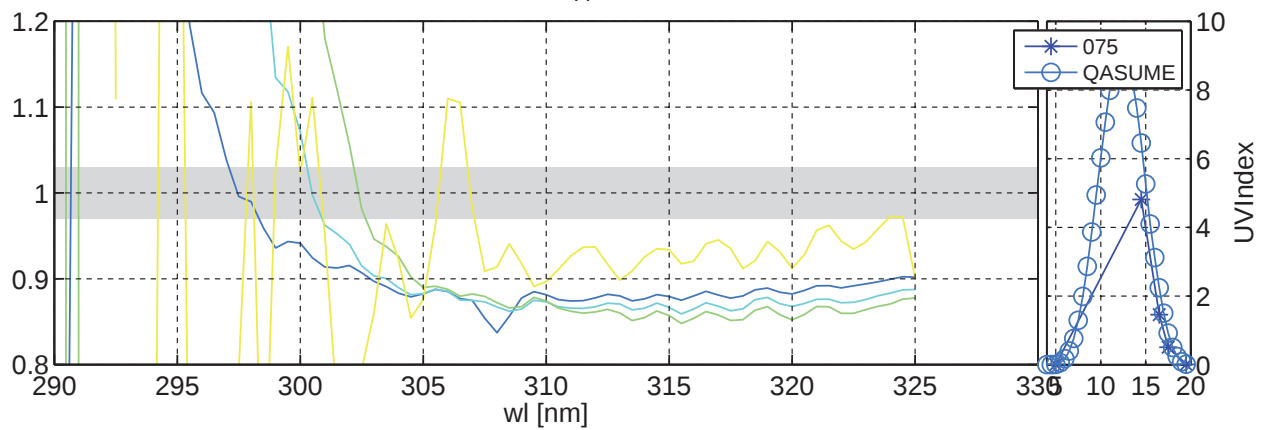
Global irradiance ratios 075/QASUME at El_Arenosillo-matshic:31-May-2015(151)



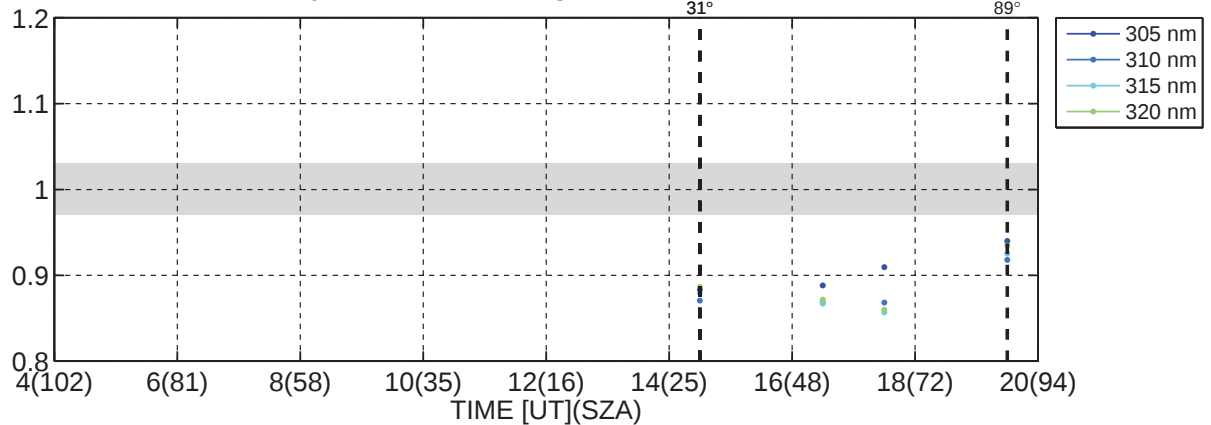
Daily variation. Wavelength bands are ± 2.5 nm



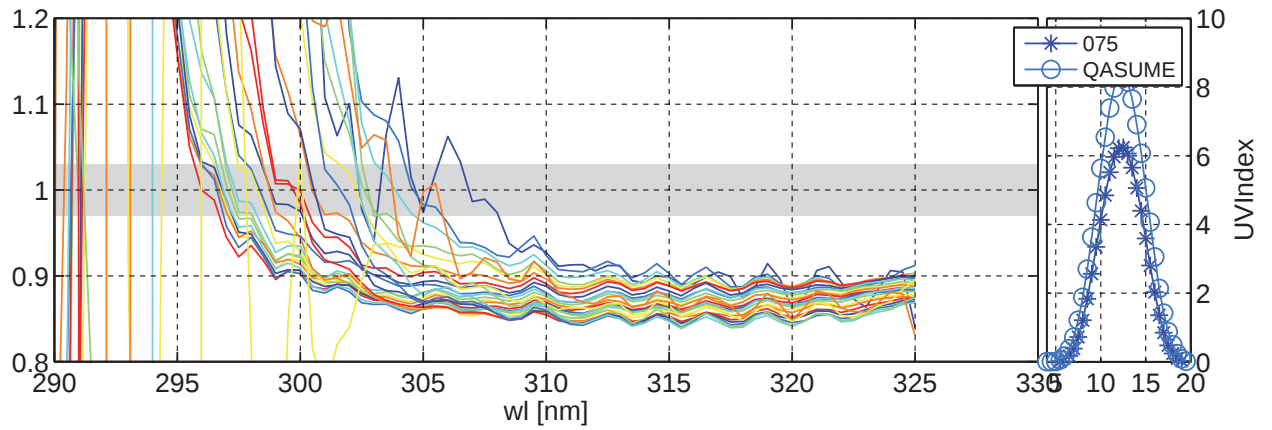
Global irradiance ratios 075/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



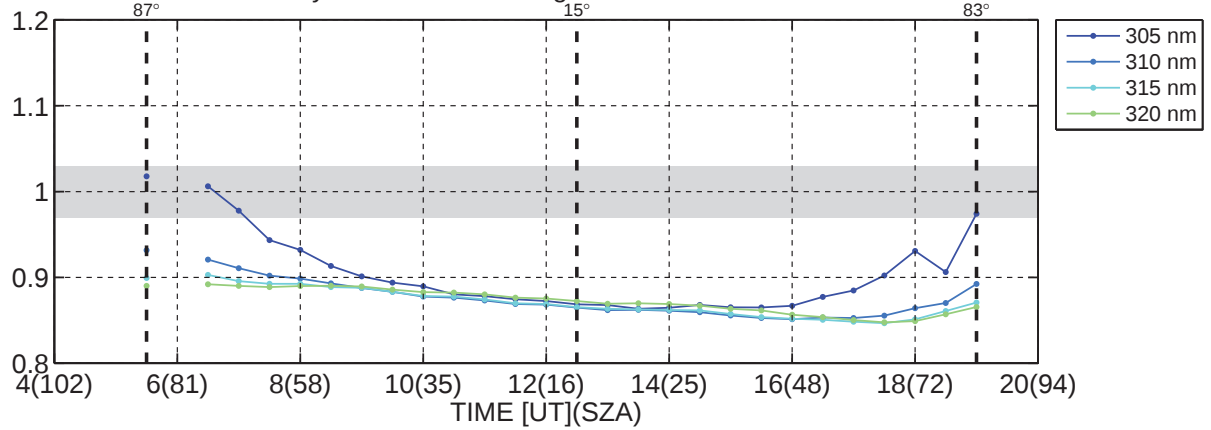
Daily variation. Wavelength bands are ± 2.5 nm



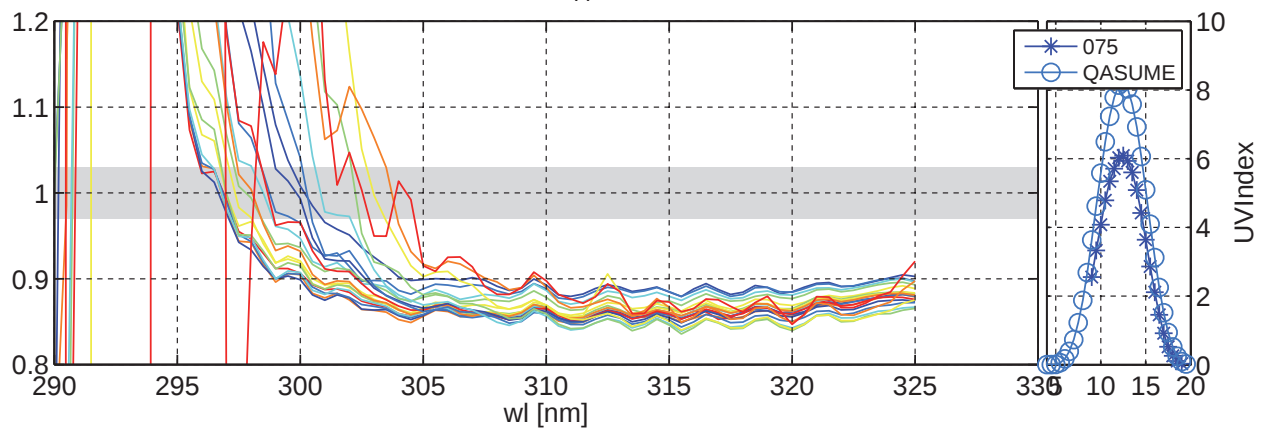
Global irradiance ratios 075/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



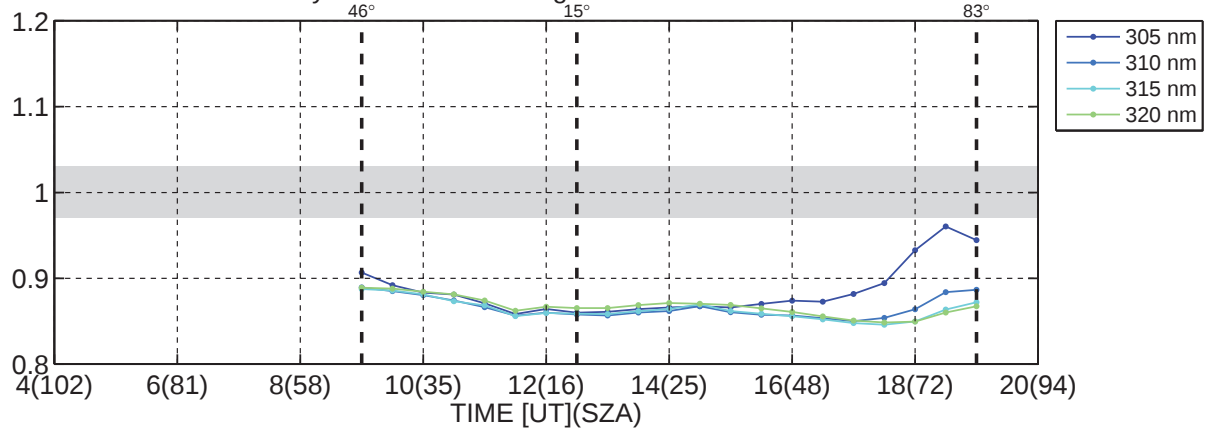
Daily variation. Wavelength bands are ± 2.5 nm



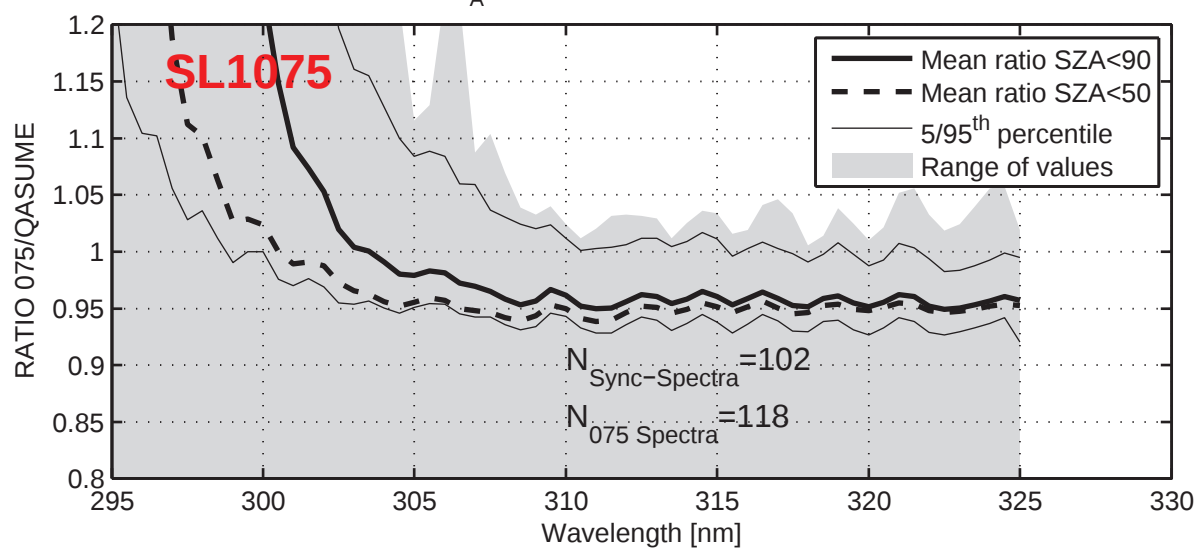
Global irradiance ratios 075/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



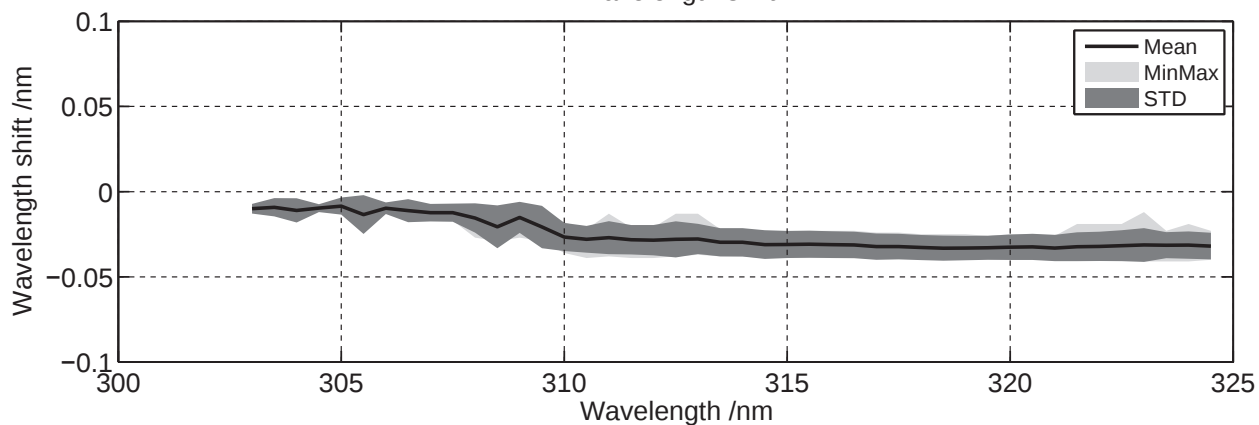
Daily variation. Wavelength bands are ± 2.5 nm



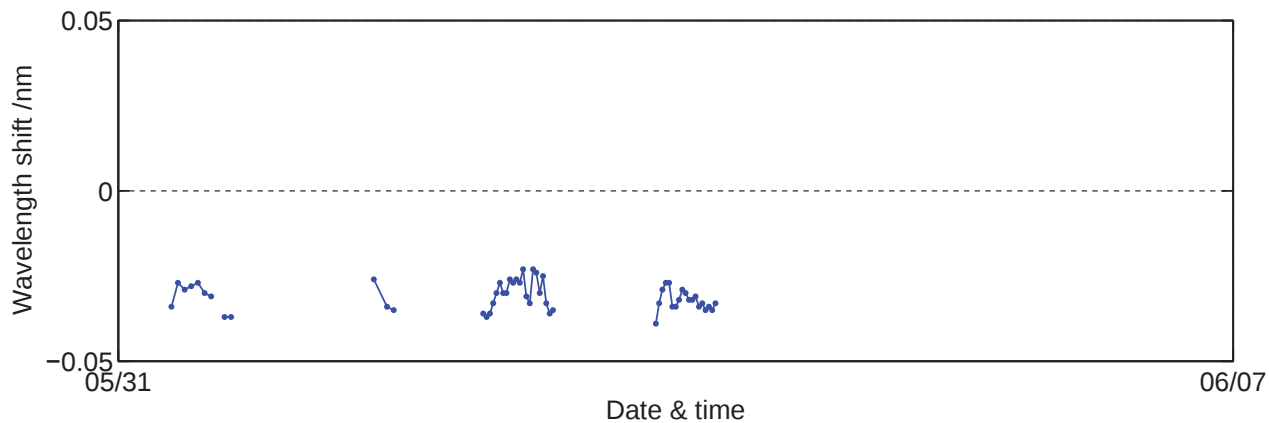
Mean ratio 075/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 04-Jun-2015(155)



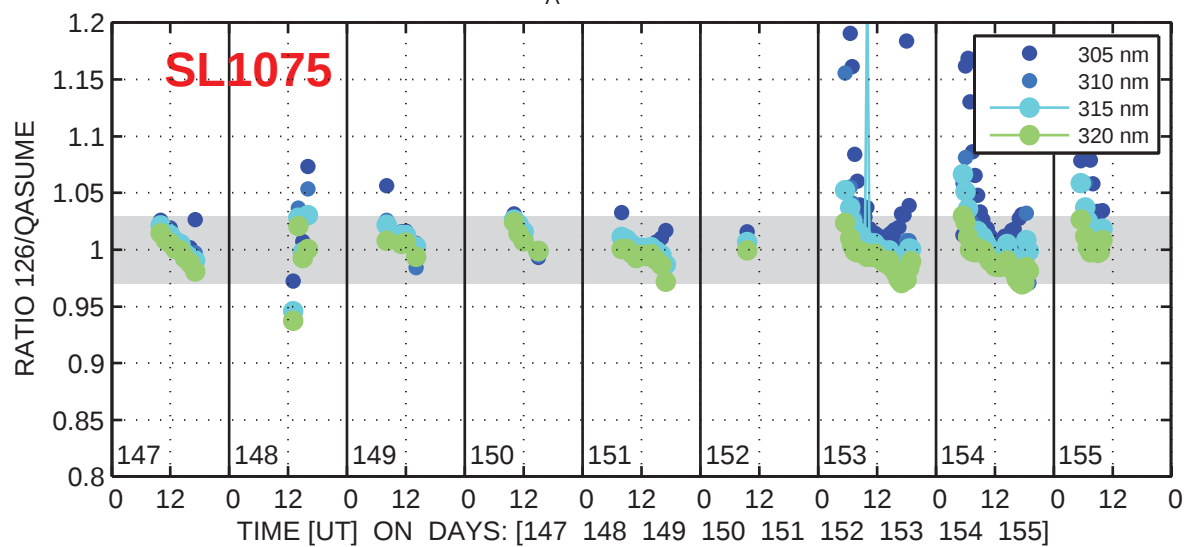
Wavelength shift



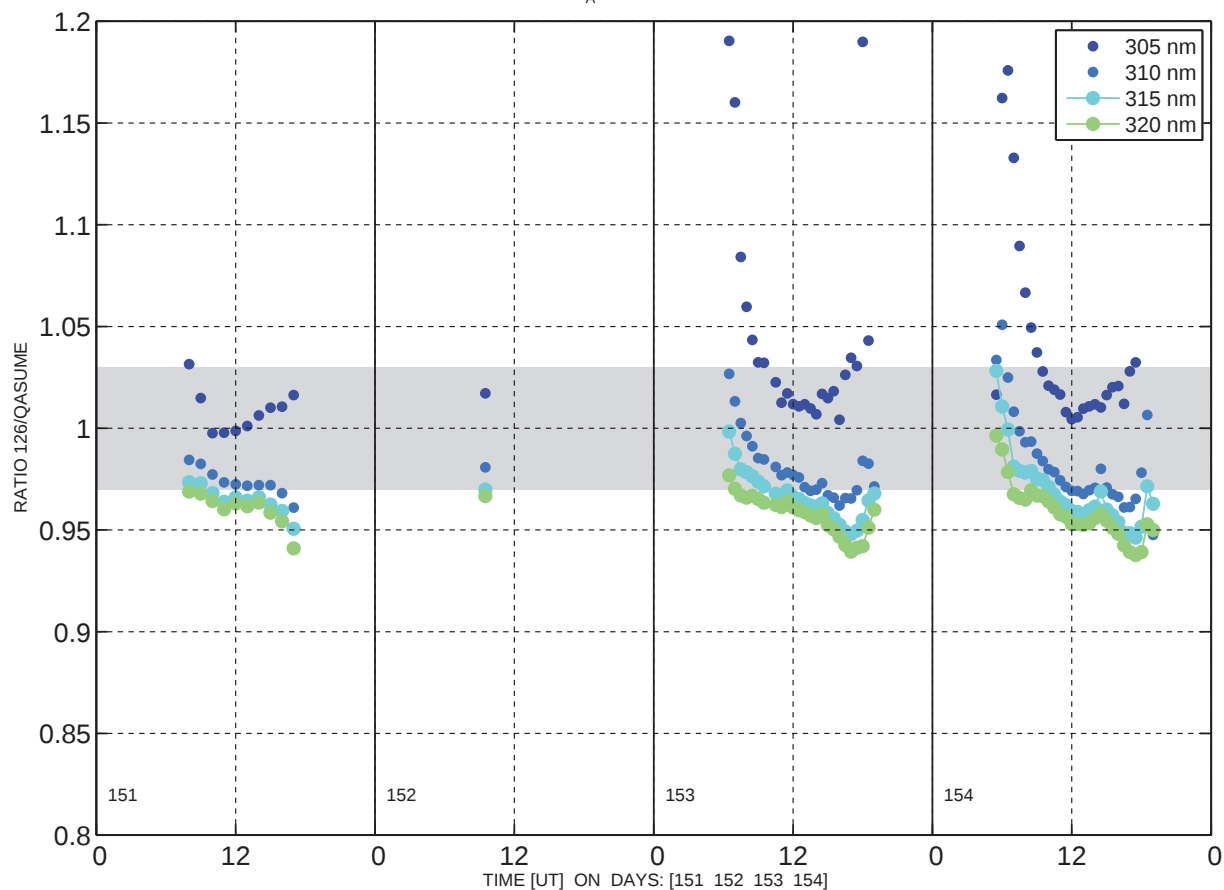
WL=315.00 nm



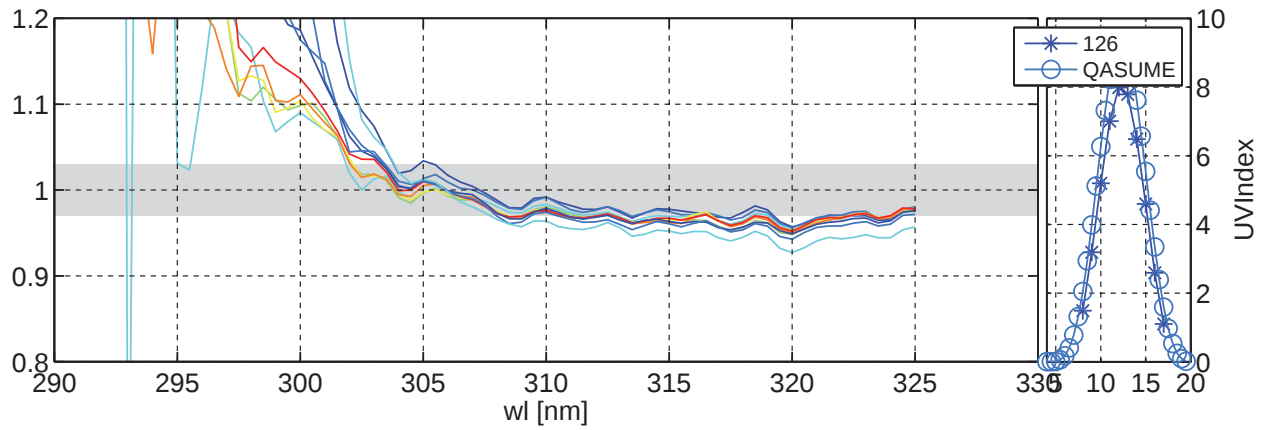
Global irradiance ratios 126/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 04-Jun-2015(155)



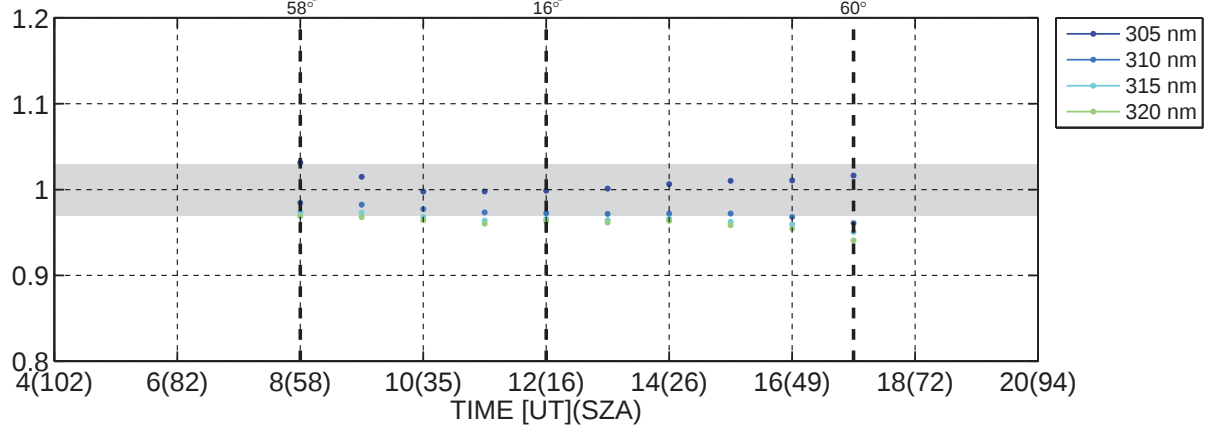
Global irradiance ratios 126/QASUME at El_Arenosillo-matshic:31-May-2015(151) to 03-Jun-2015(154)



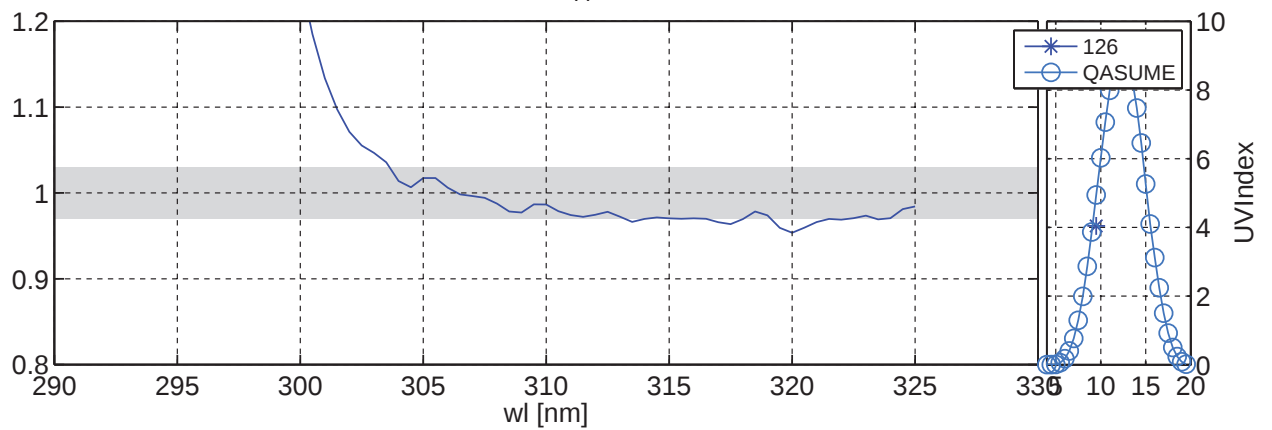
Global irradiance ratios 126/QASUME at El_Arenosillo-matshic:31-May-2015(151)



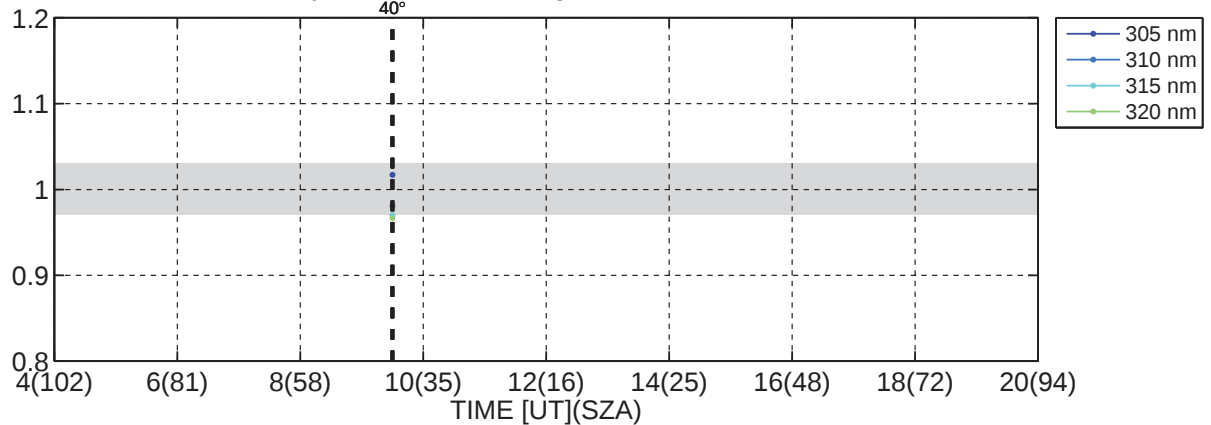
Daily variation. Wavelength bands are ± 2.5 nm



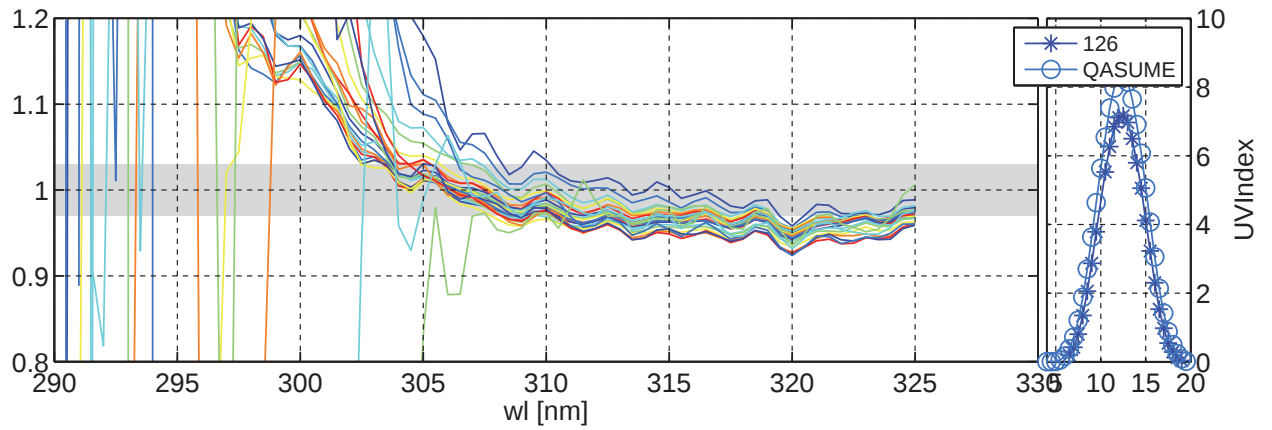
Global irradiance ratios 126/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



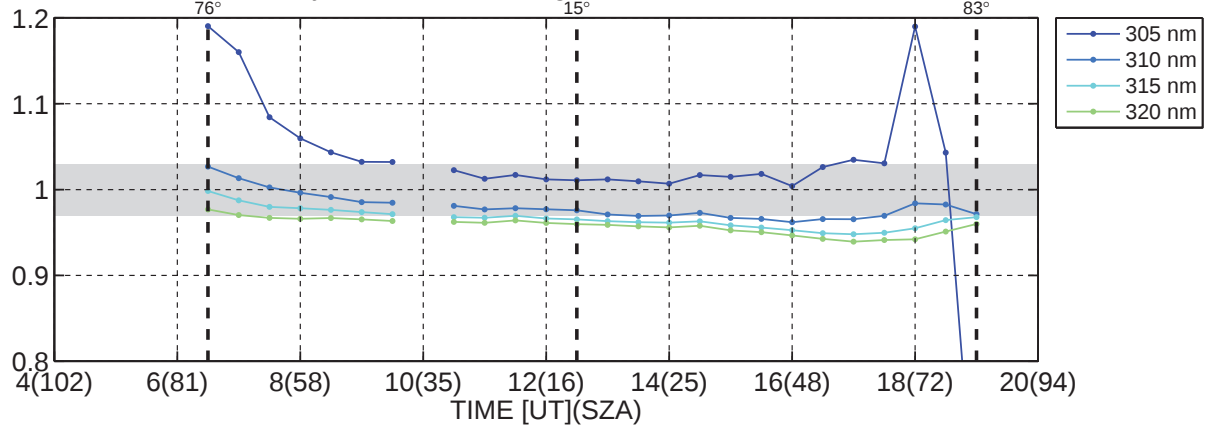
Daily variation. Wavelength bands are ± 2.5 nm



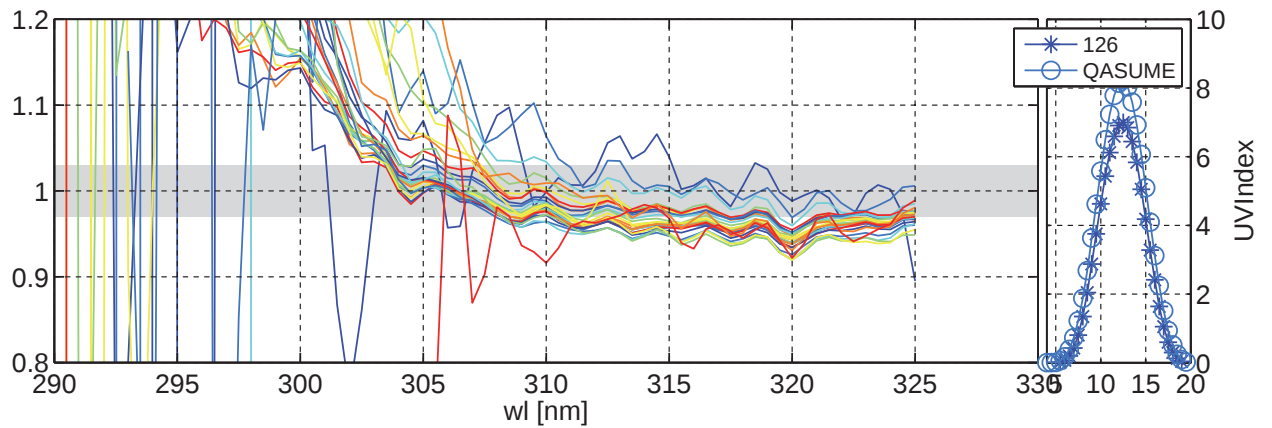
Global irradiance ratios 126/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



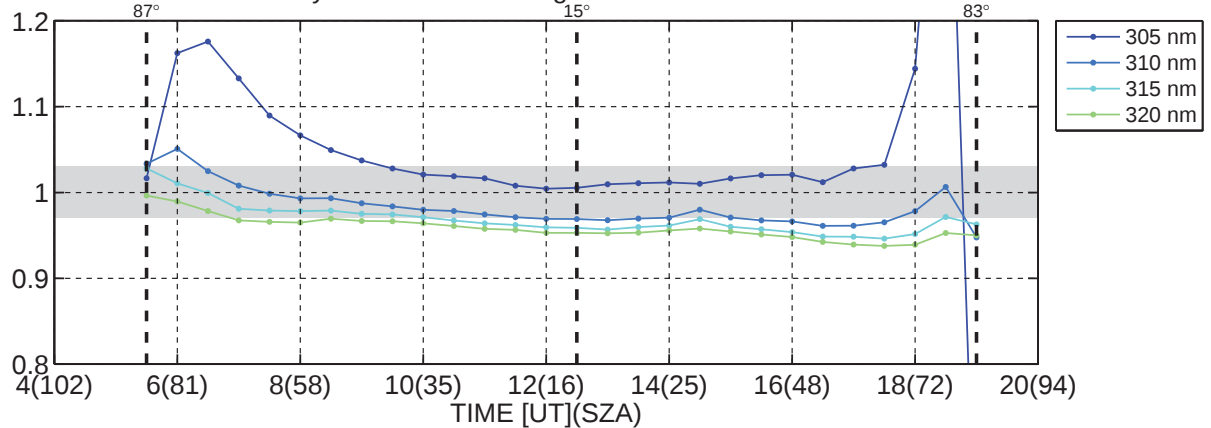
Daily variation. Wavelength bands are ± 2.5 nm

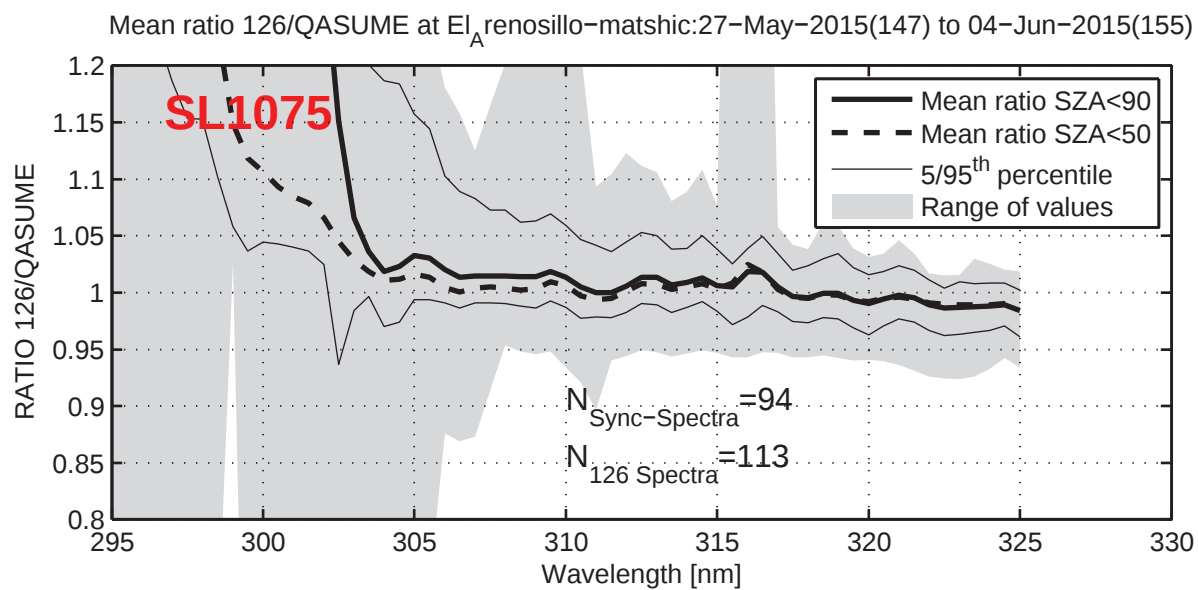
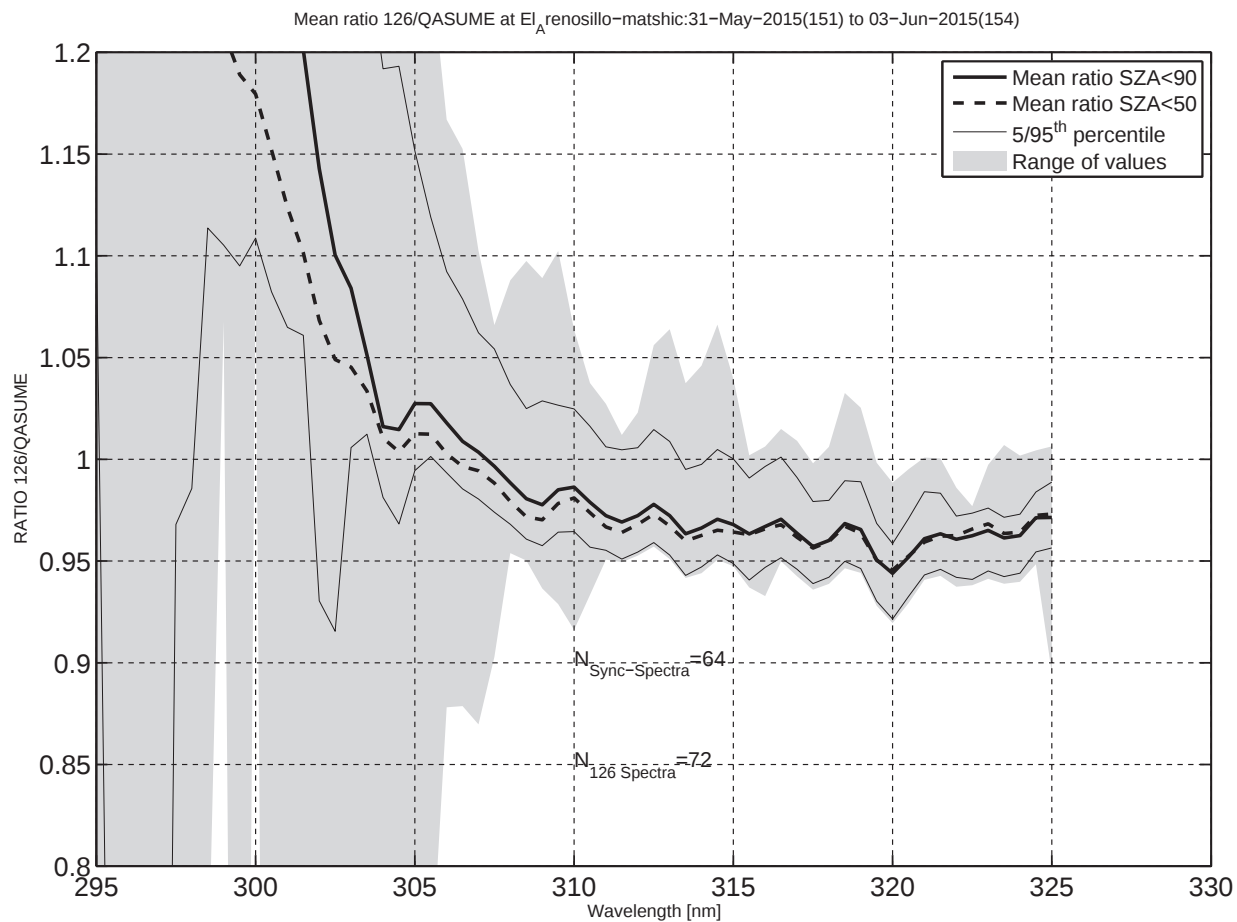


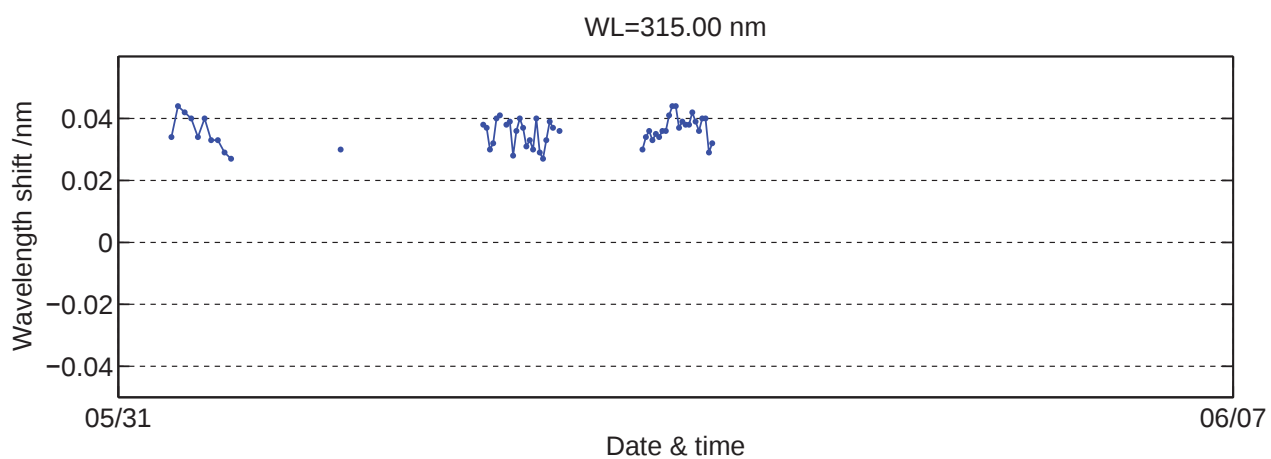
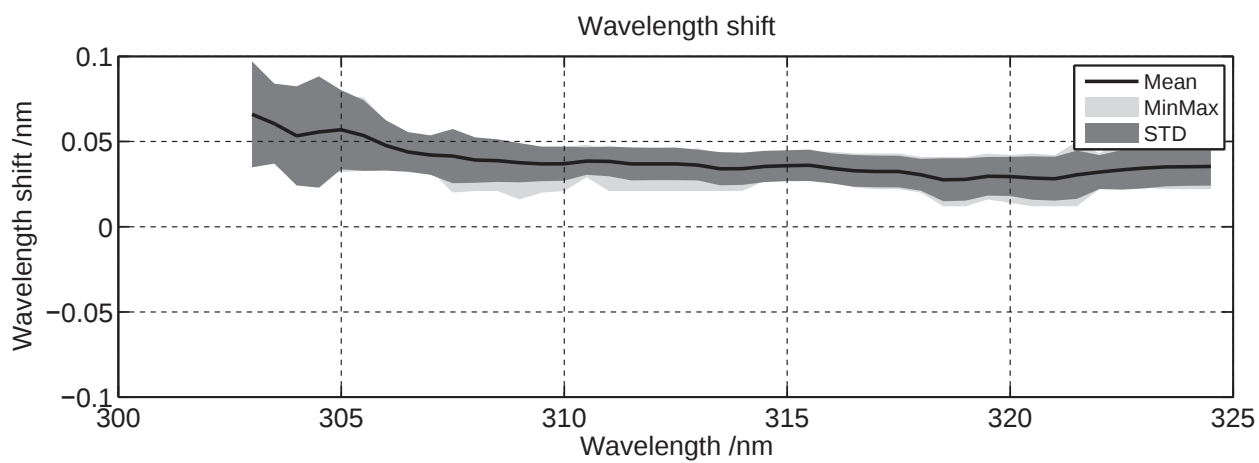
Global irradiance ratios 126/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



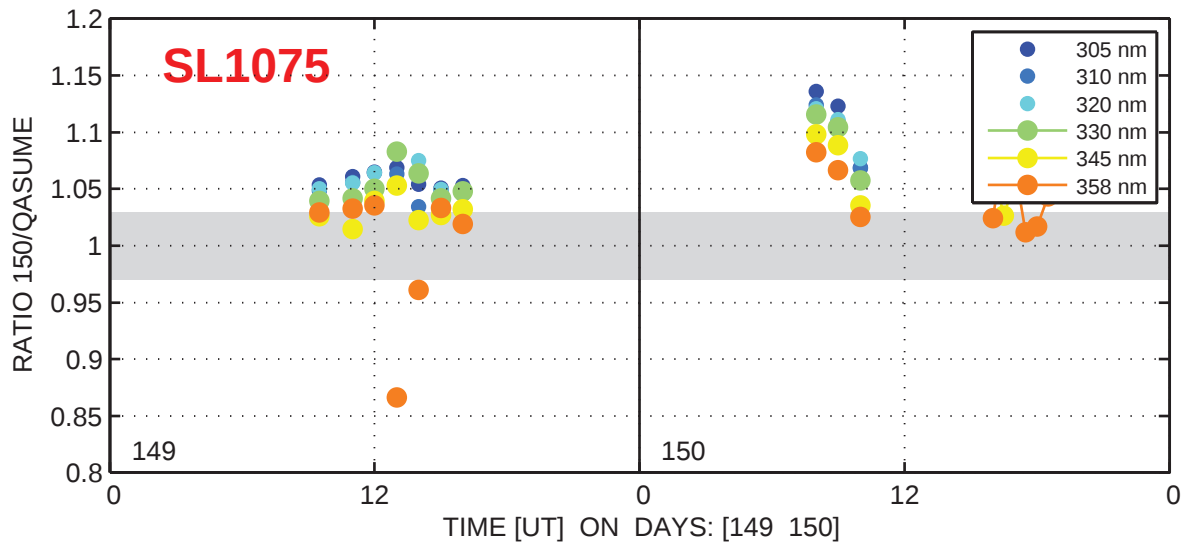
Daily variation. Wavelength bands are ± 2.5 nm



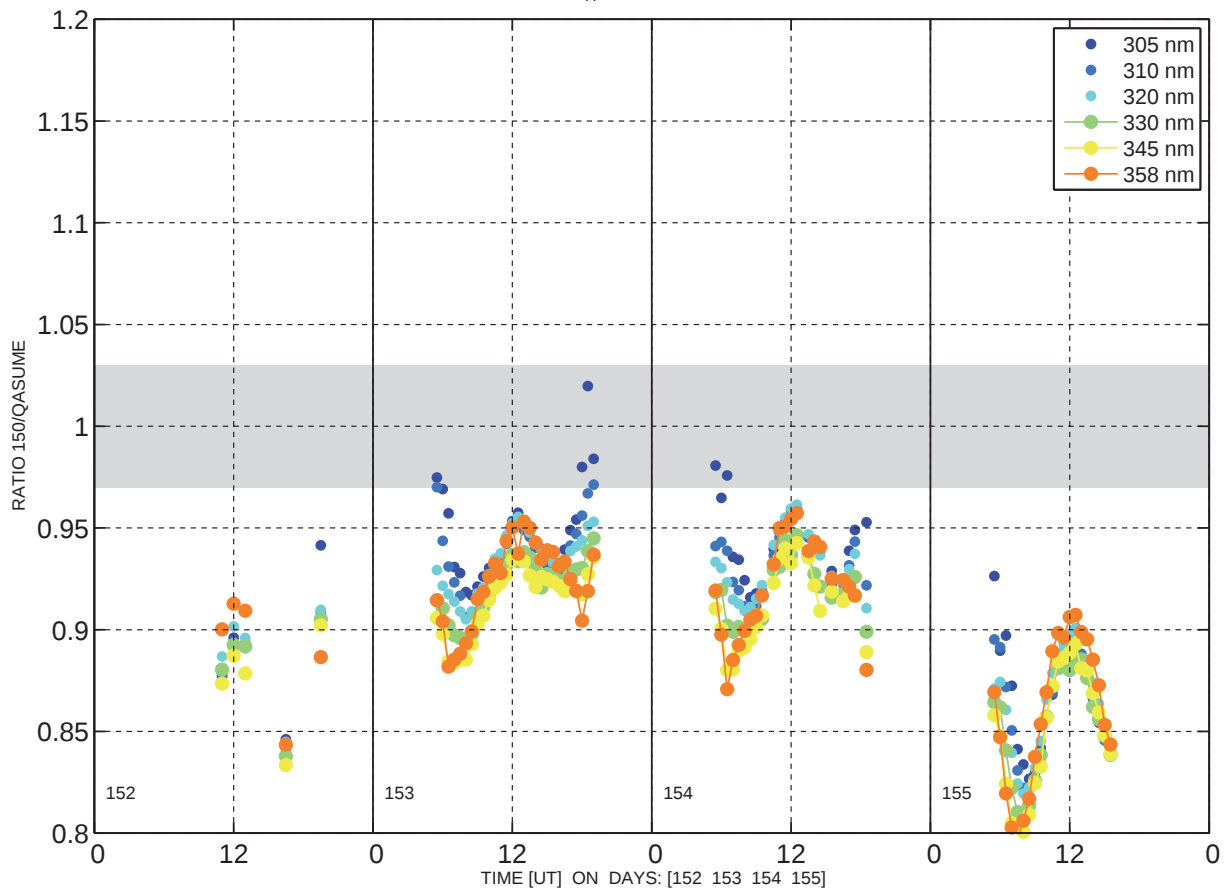




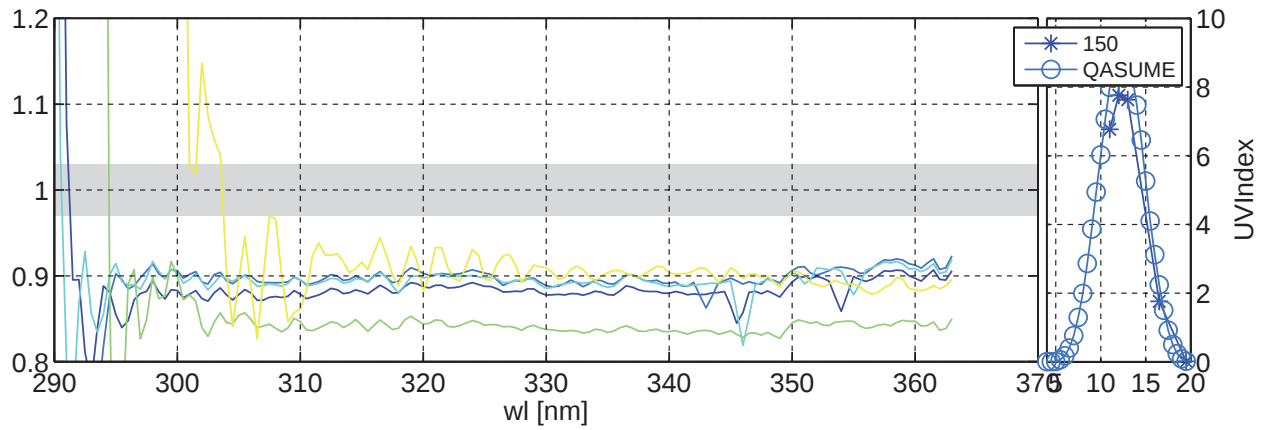
Global irradiance ratios 150/QASUME at El_Arenosillo-matshic:29-May-2015(149) to 30-May-2015



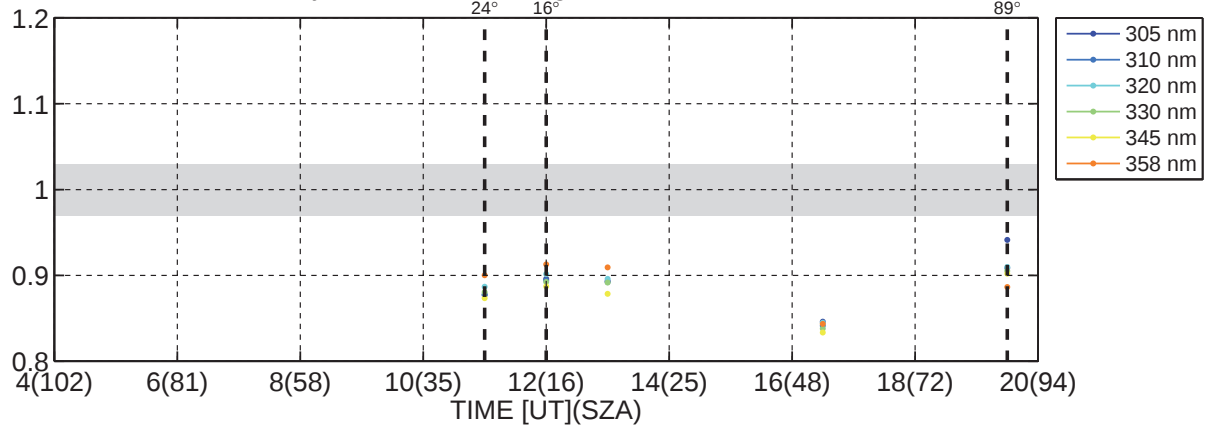
Global irradiance ratios 150/QASUME at El_Arenosillo-matshic:01-Jun-2015(152) to 04-Jun-2015(155)



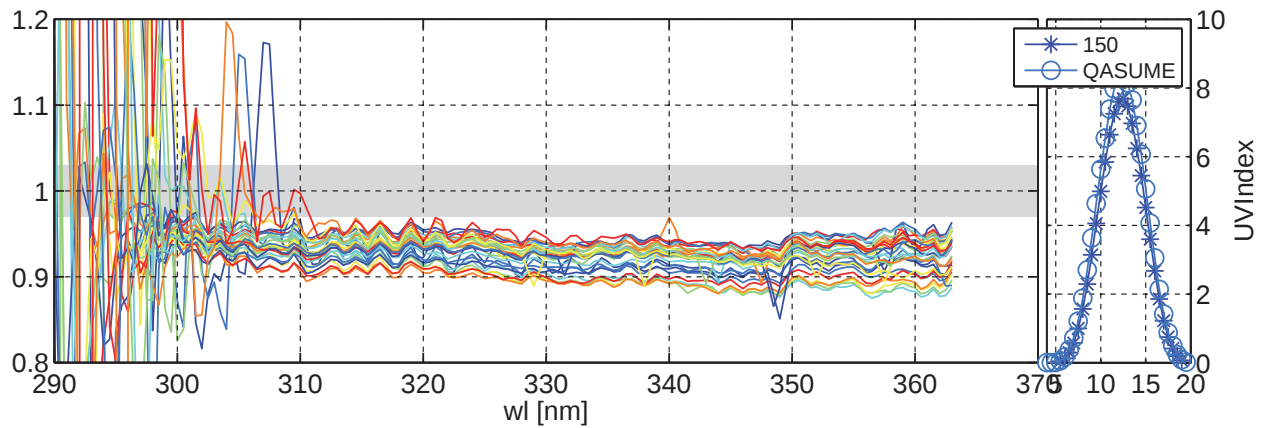
Global irradiance ratios 150/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



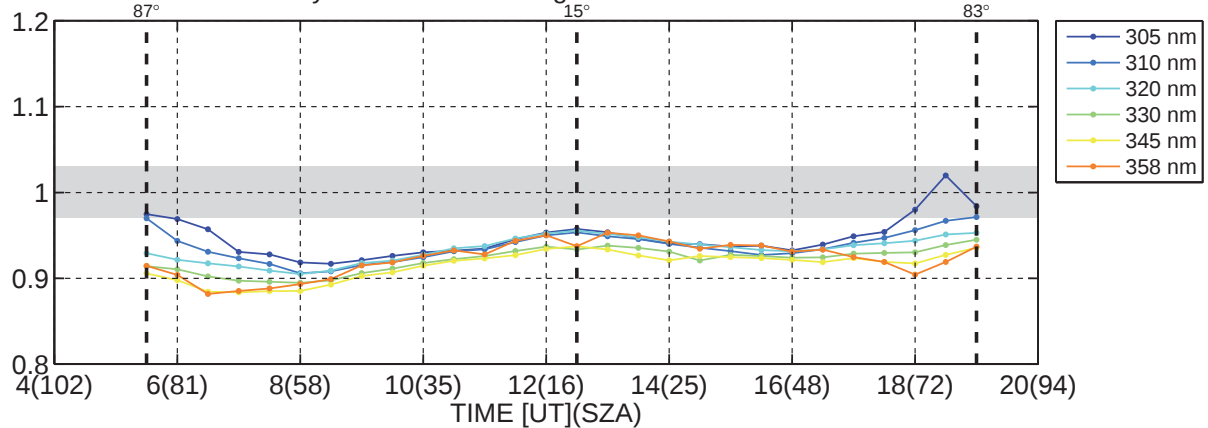
Daily variation. Wavelength bands are ± 2.5 nm



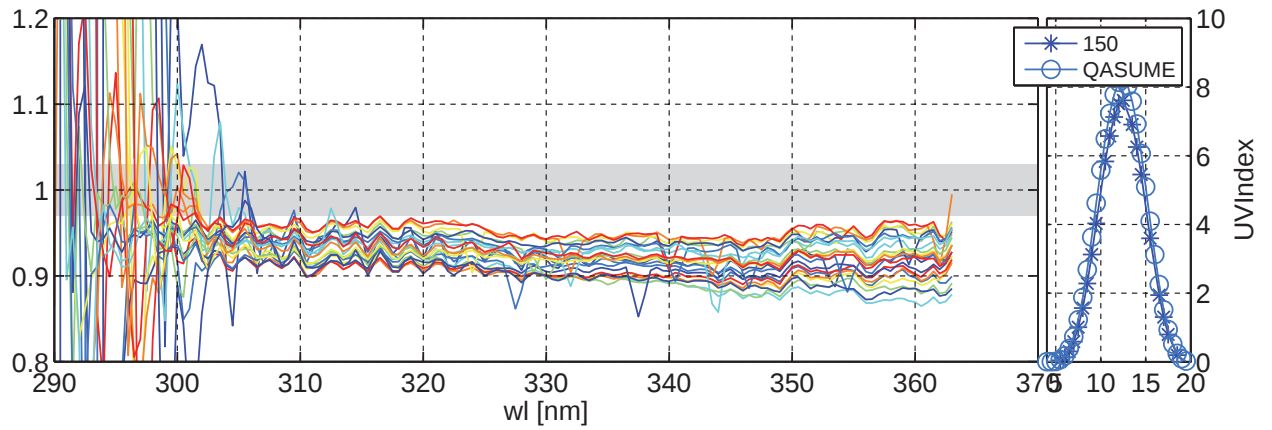
Global irradiance ratios 150/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



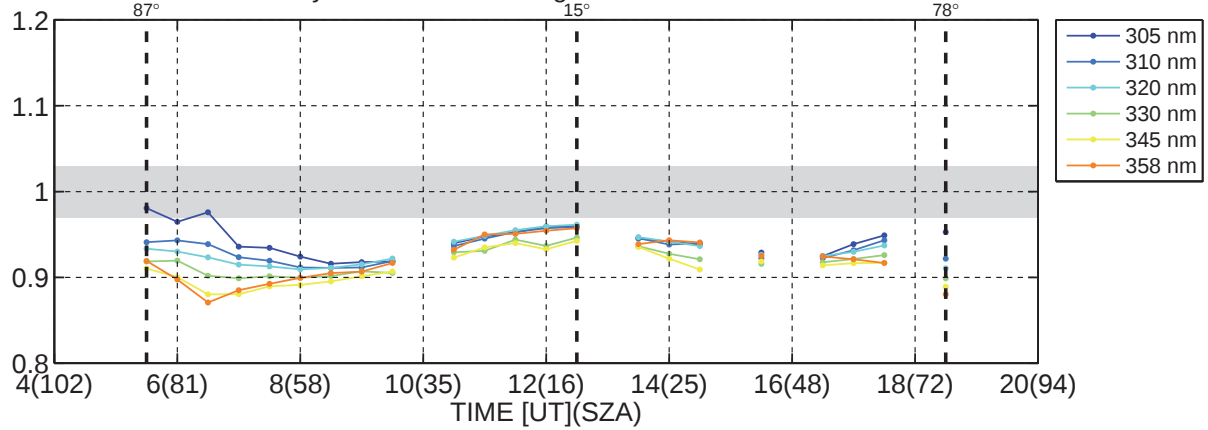
Daily variation. Wavelength bands are ± 2.5 nm



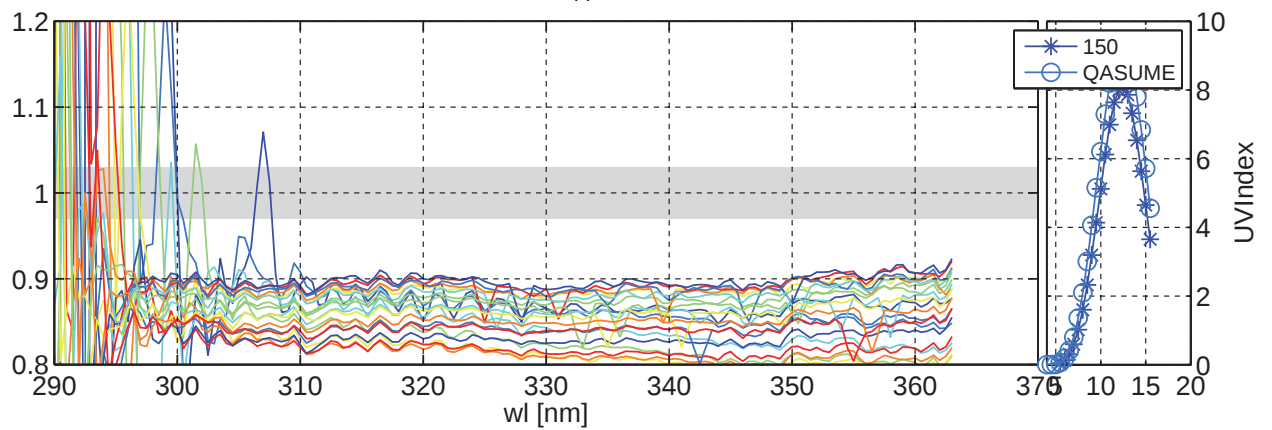
Global irradiance ratios 150/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



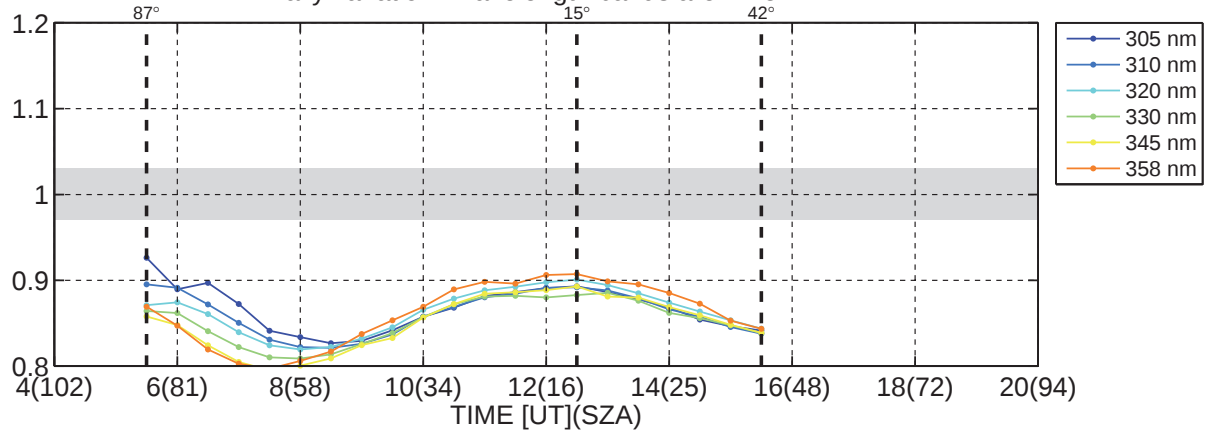
Daily variation. Wavelength bands are ± 2.5 nm



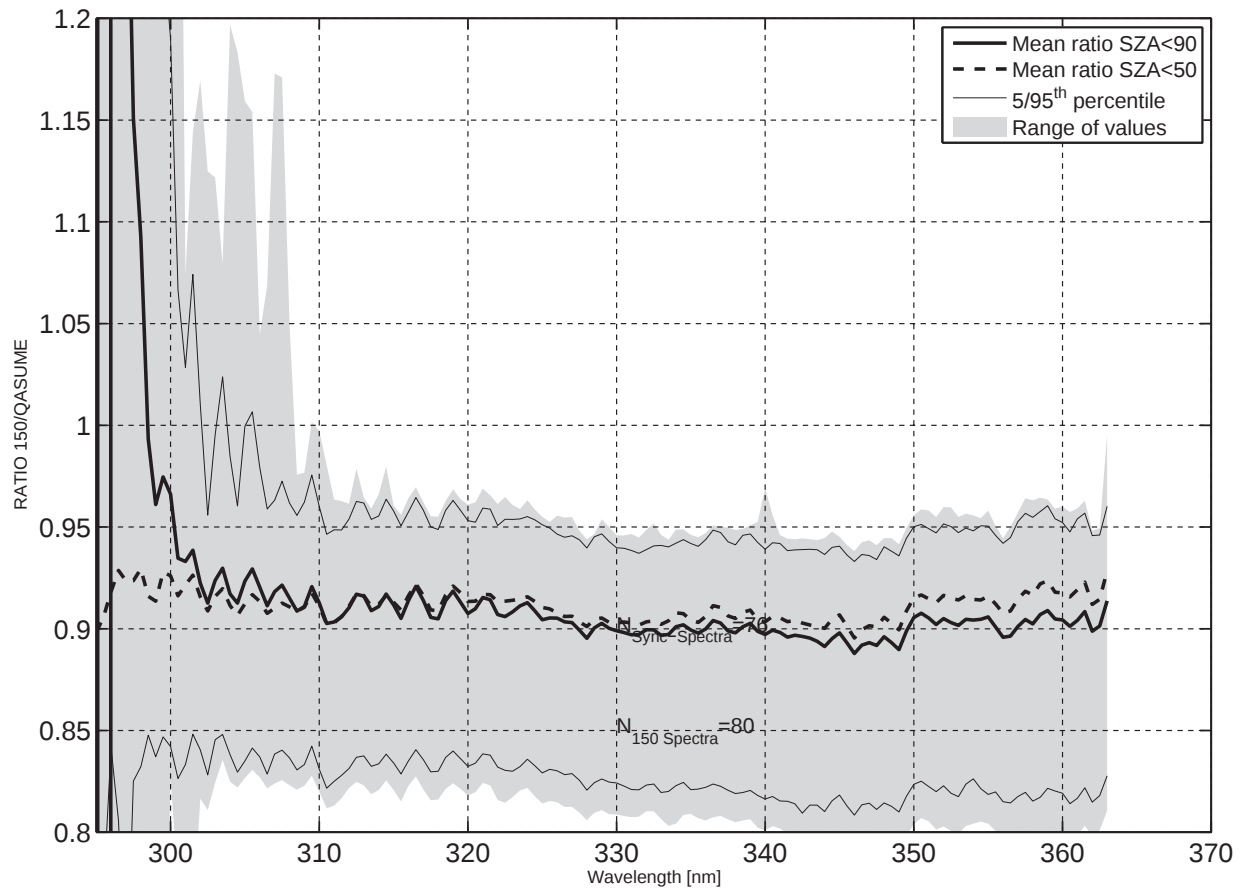
Global irradiance ratios 150/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



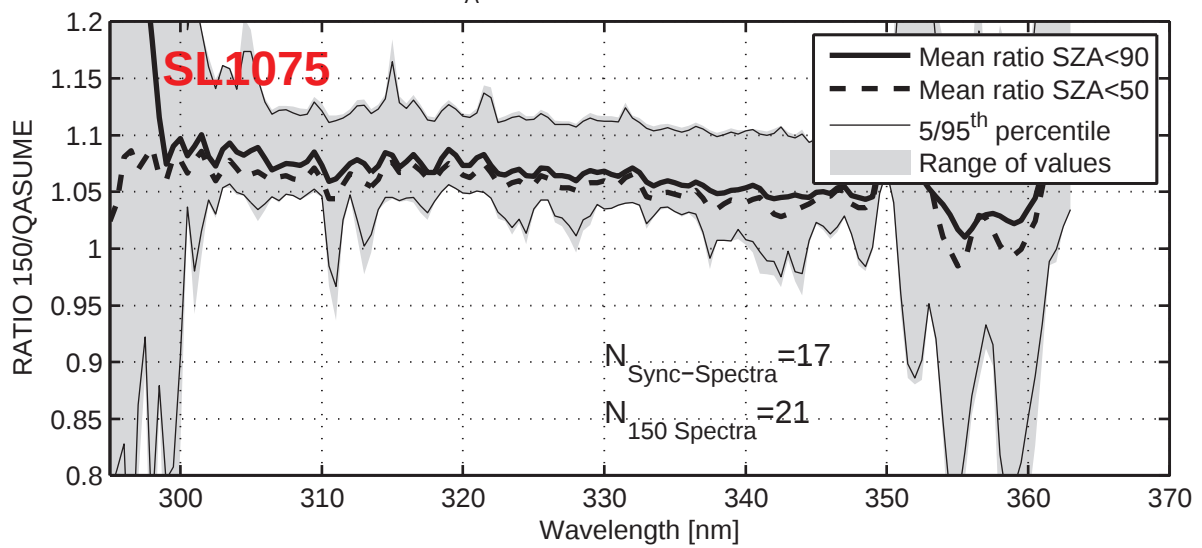
Daily variation. Wavelength bands are ± 2.5 nm

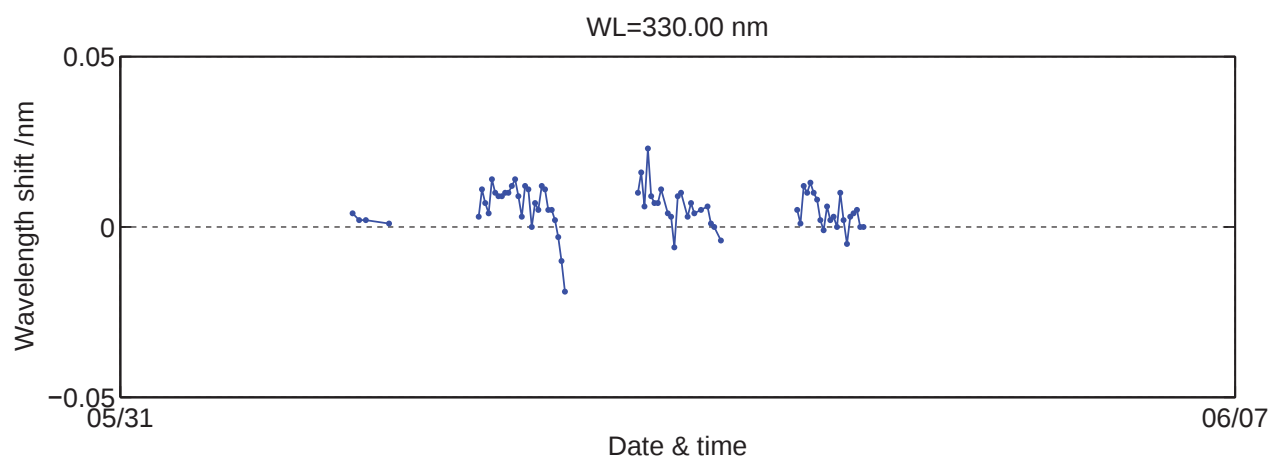
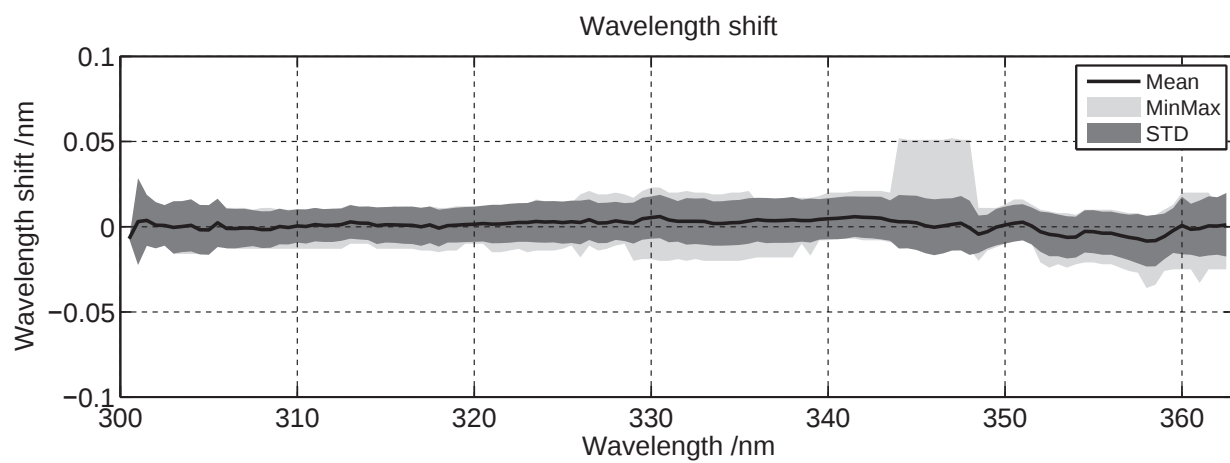


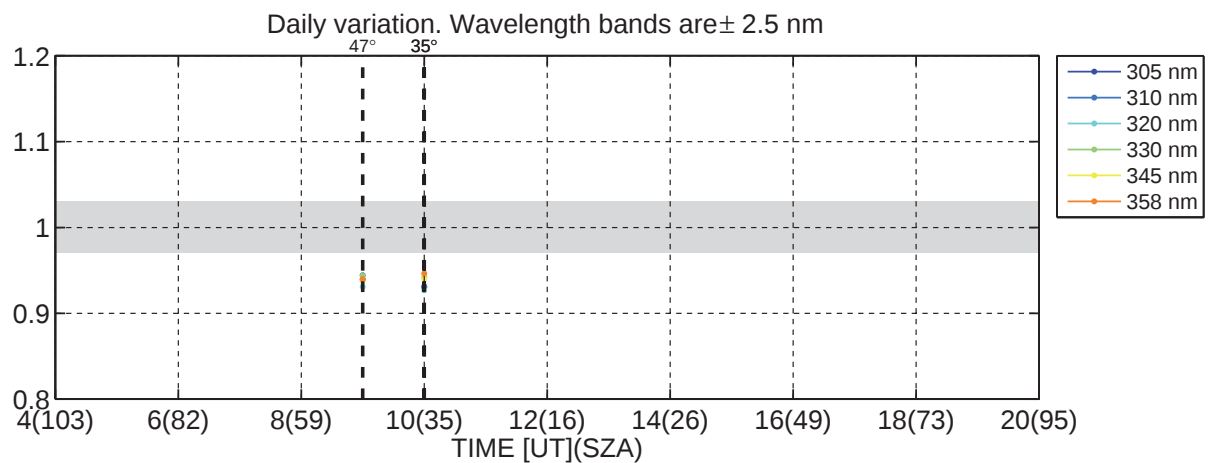
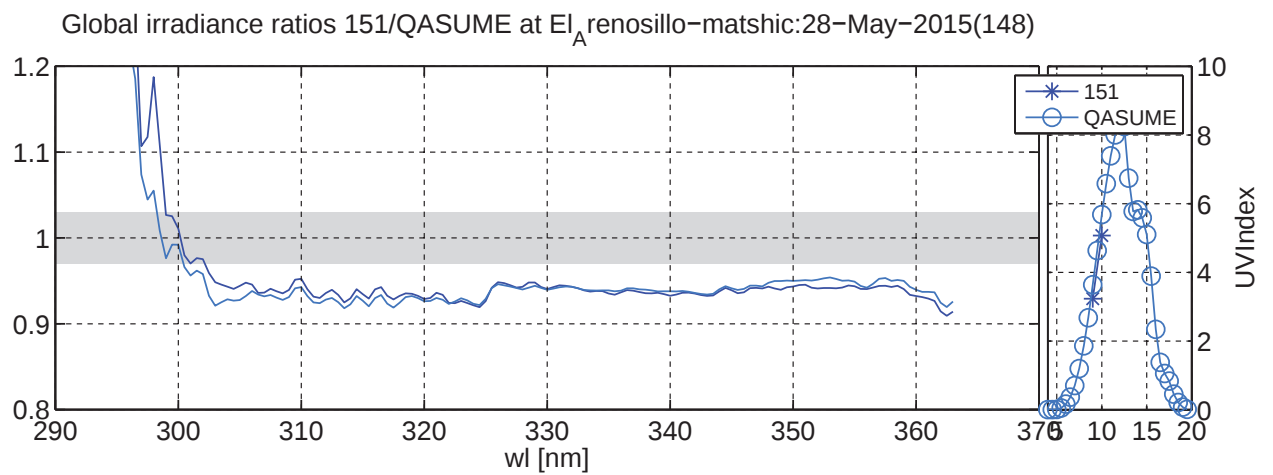
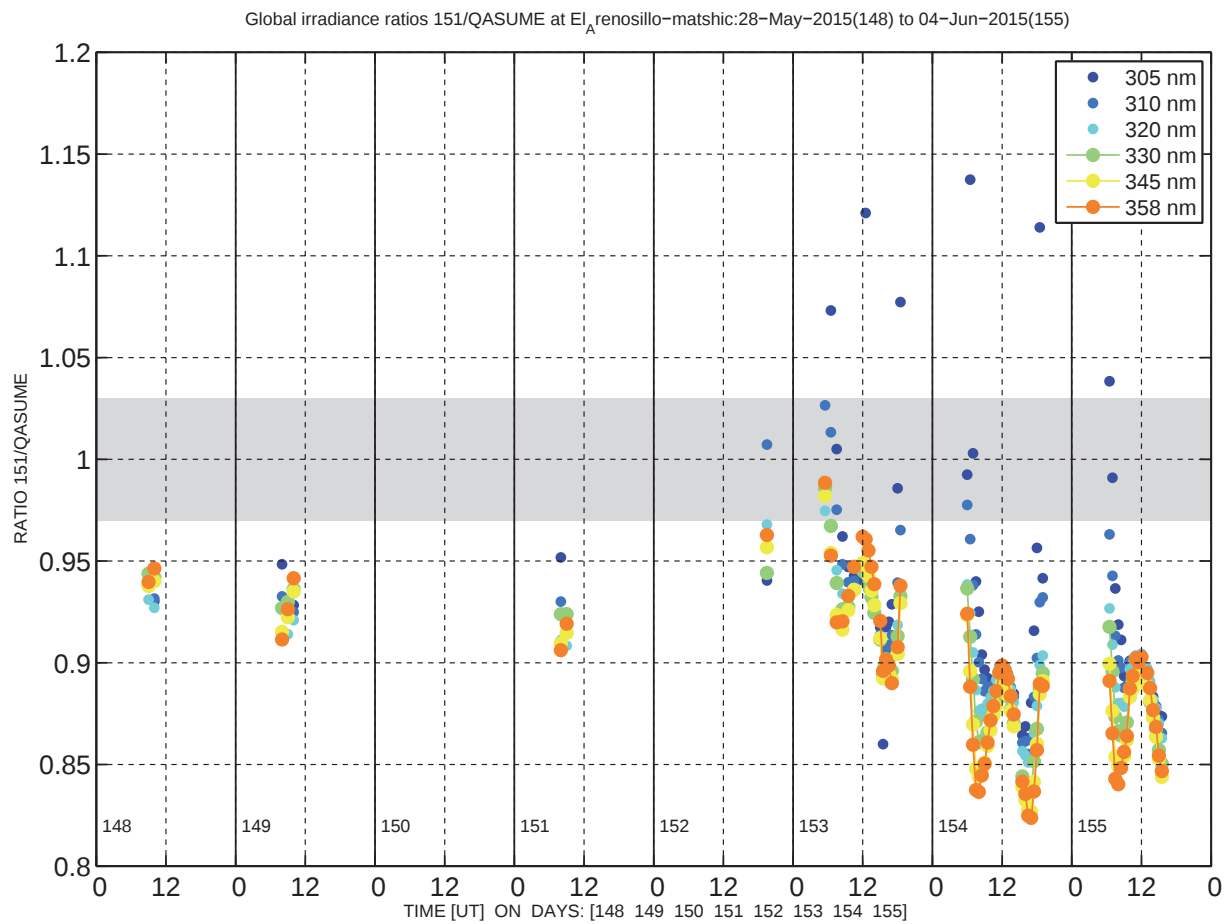
Mean ratio 150/QASUME at El_Arenosillo-matshic:01-Jun-2015(152) to 04-Jun-2015(155)



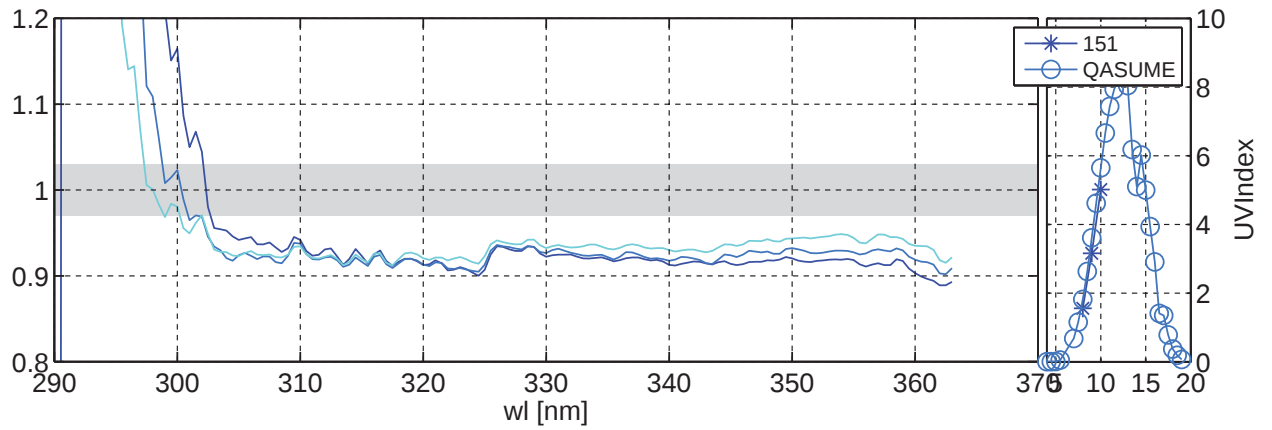
Mean ratio 150/QASUME at El_Arenosillo-matshic:29-May-2015(149) to 30-May-2015(150)



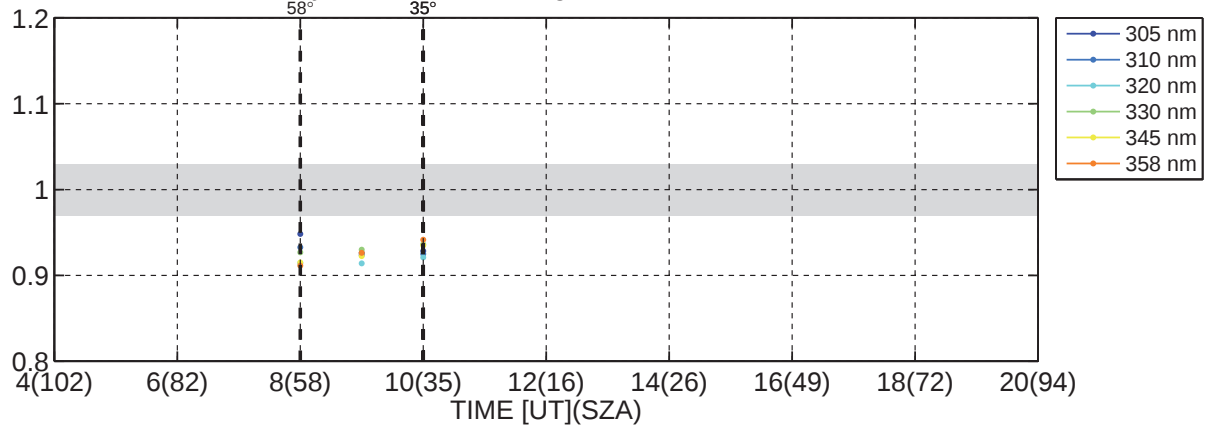




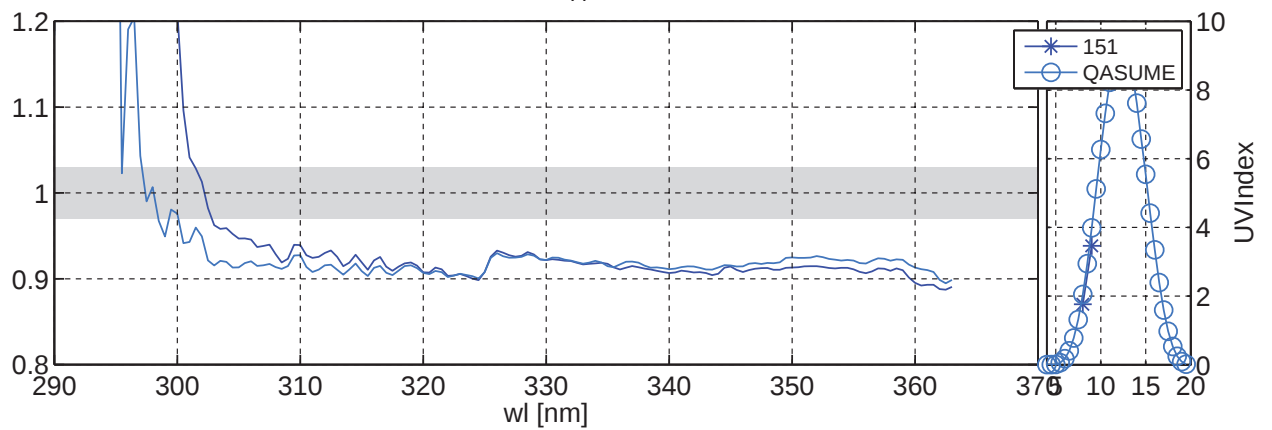
Global irradiance ratios 151/QASUME at El_A renosillo-matshic:29-May-2015(149)



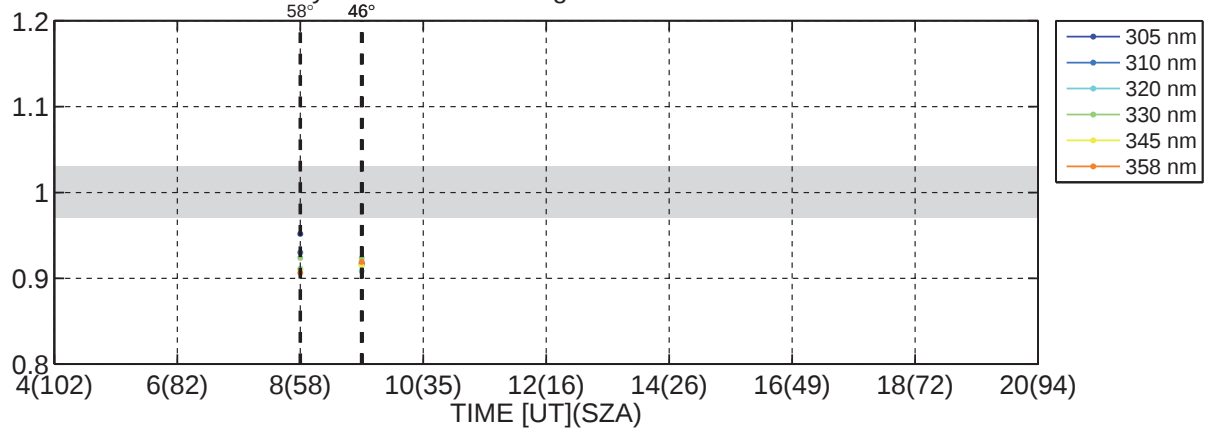
Daily variation. Wavelength bands are ± 2.5 nm



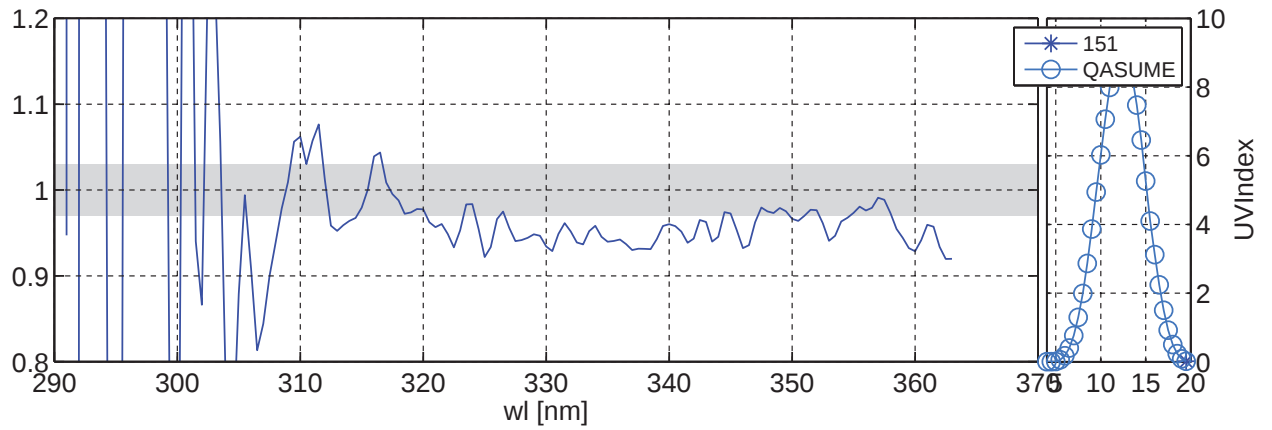
Global irradiance ratios 151/QASUME at El_A renosillo-matshic:31-May-2015(151)



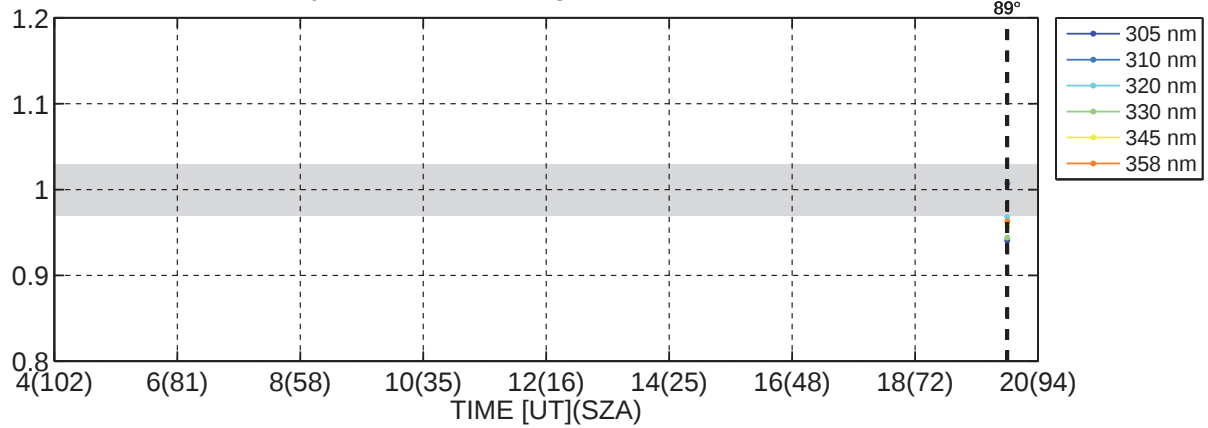
Daily variation. Wavelength bands are ± 2.5 nm



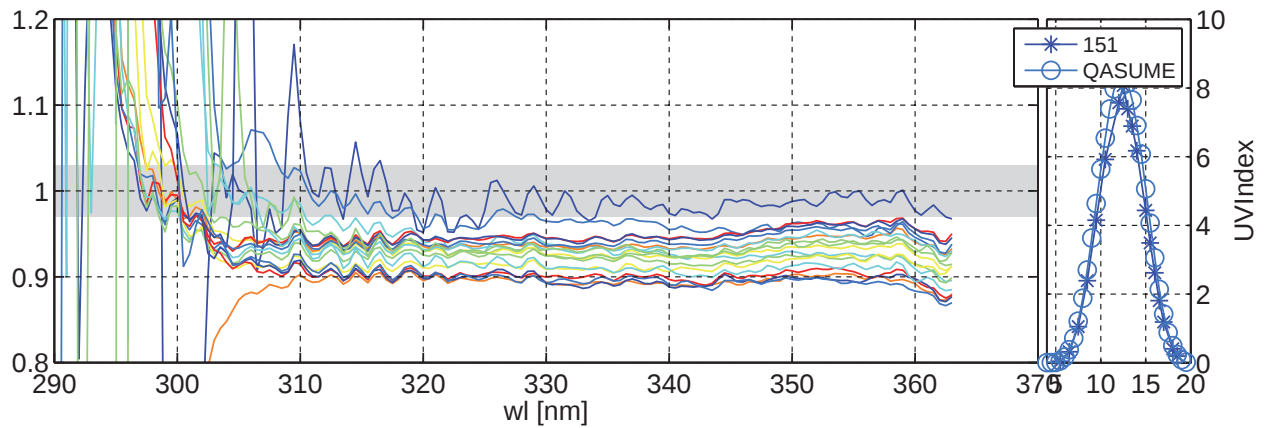
Global irradiance ratios 151/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



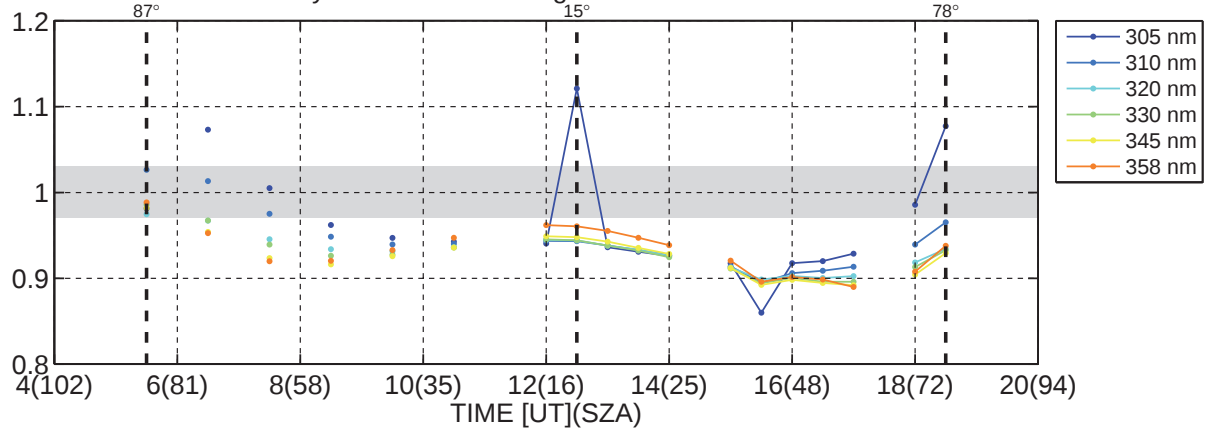
Daily variation. Wavelength bands are ± 2.5 nm



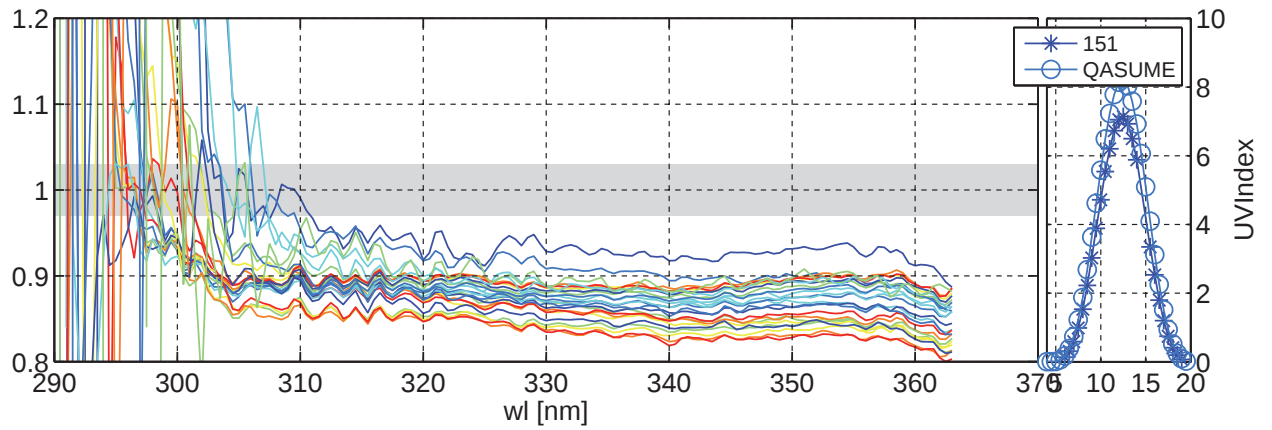
Global irradiance ratios 151/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



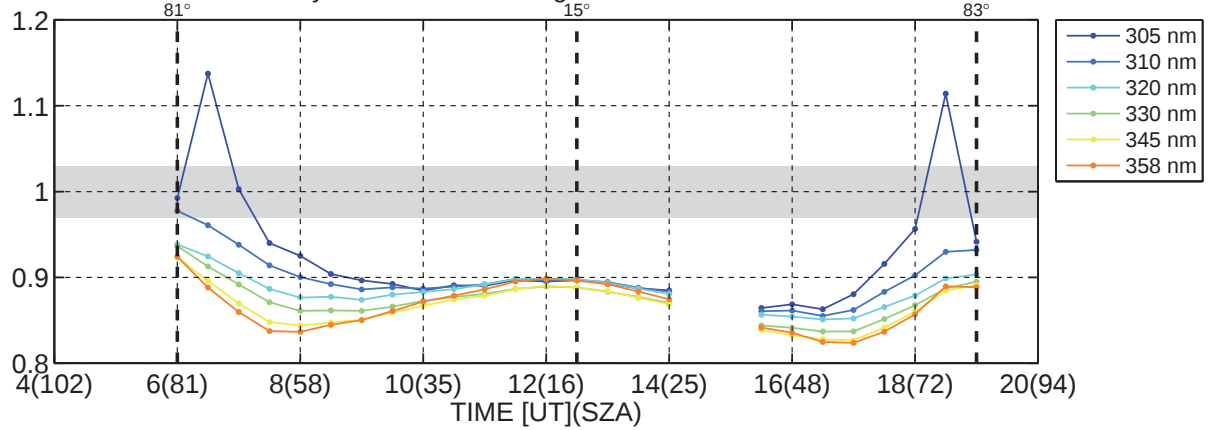
Daily variation. Wavelength bands are ± 2.5 nm



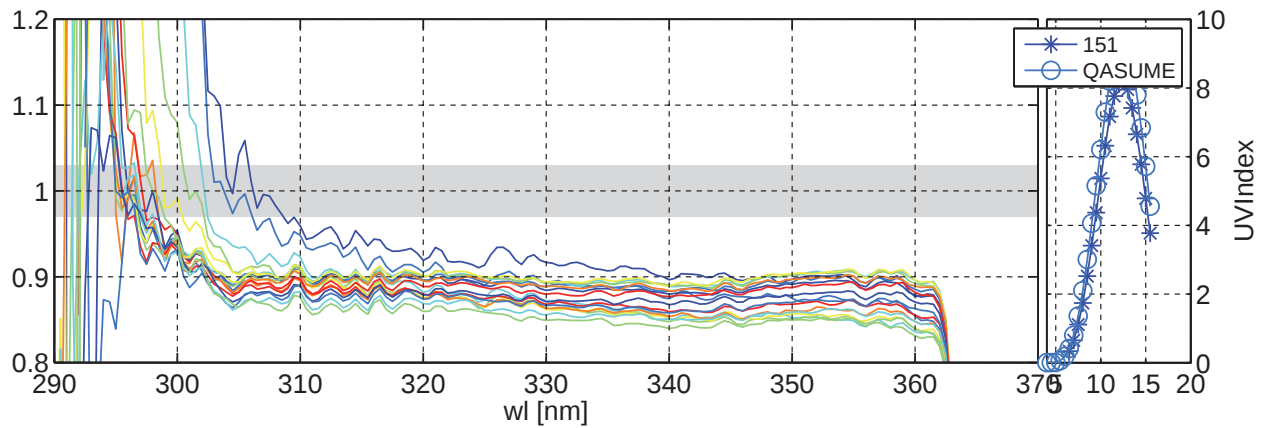
Global irradiance ratios 151/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



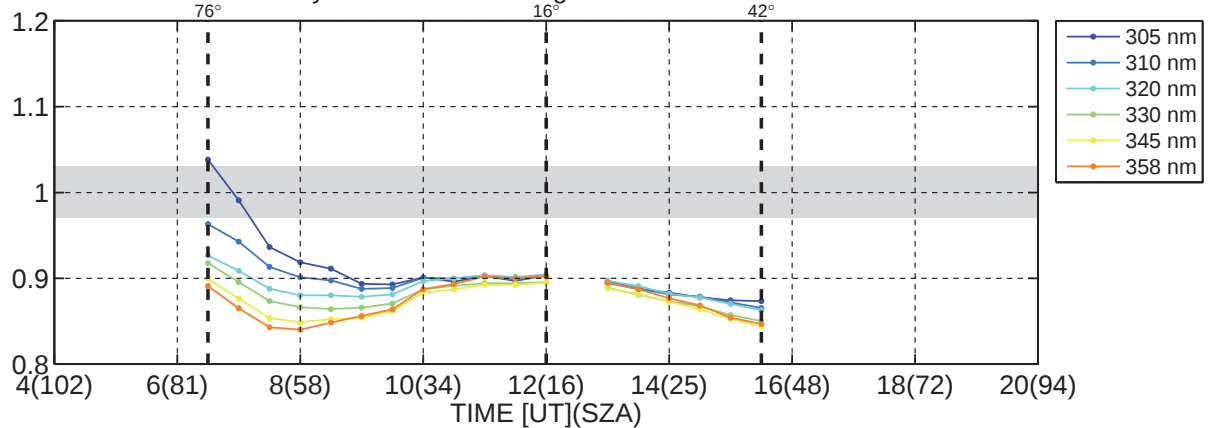
Daily variation. Wavelength bands are ± 2.5 nm



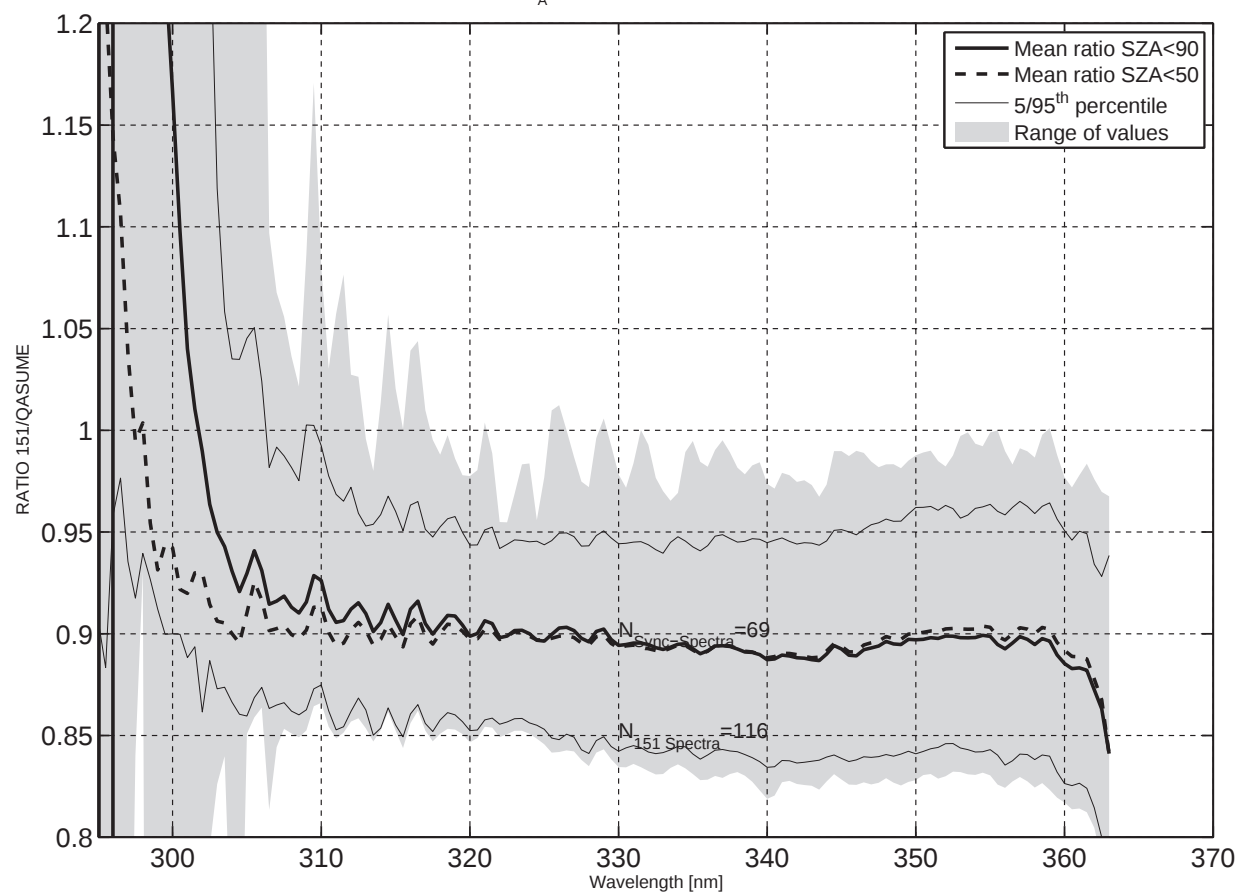
Global irradiance ratios 151/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



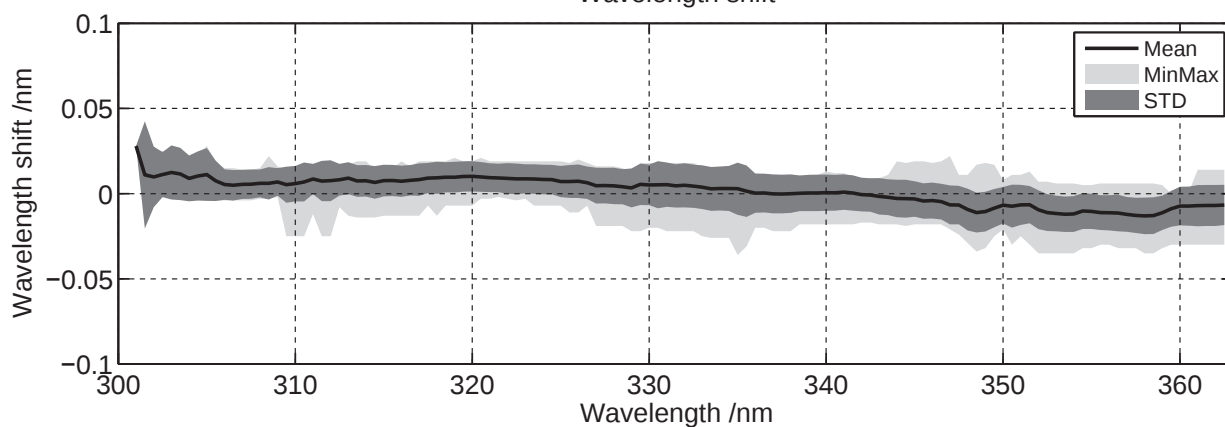
Daily variation. Wavelength bands are ± 2.5 nm



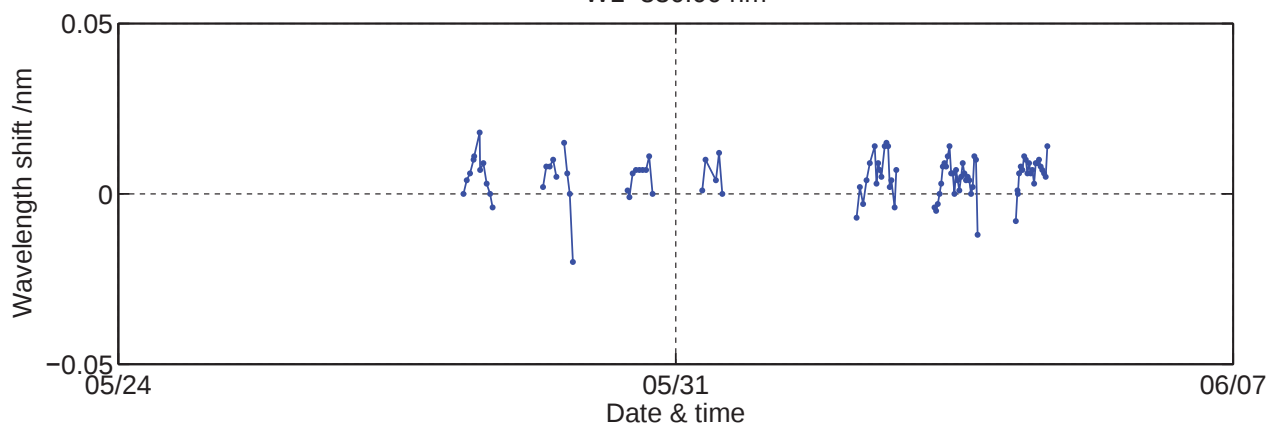
Mean ratio 151/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



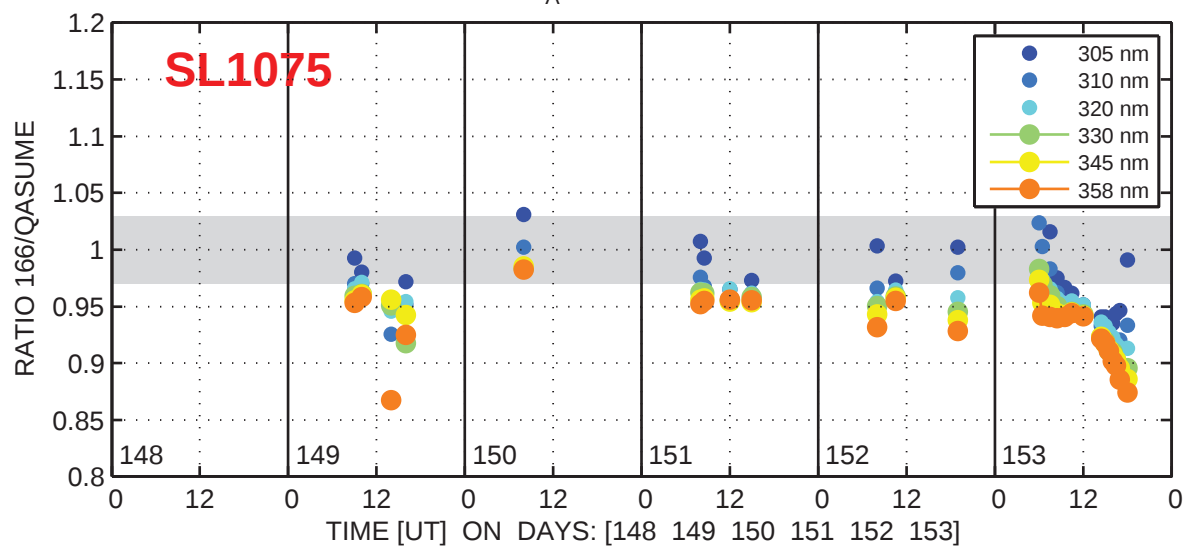
Wavelength shift



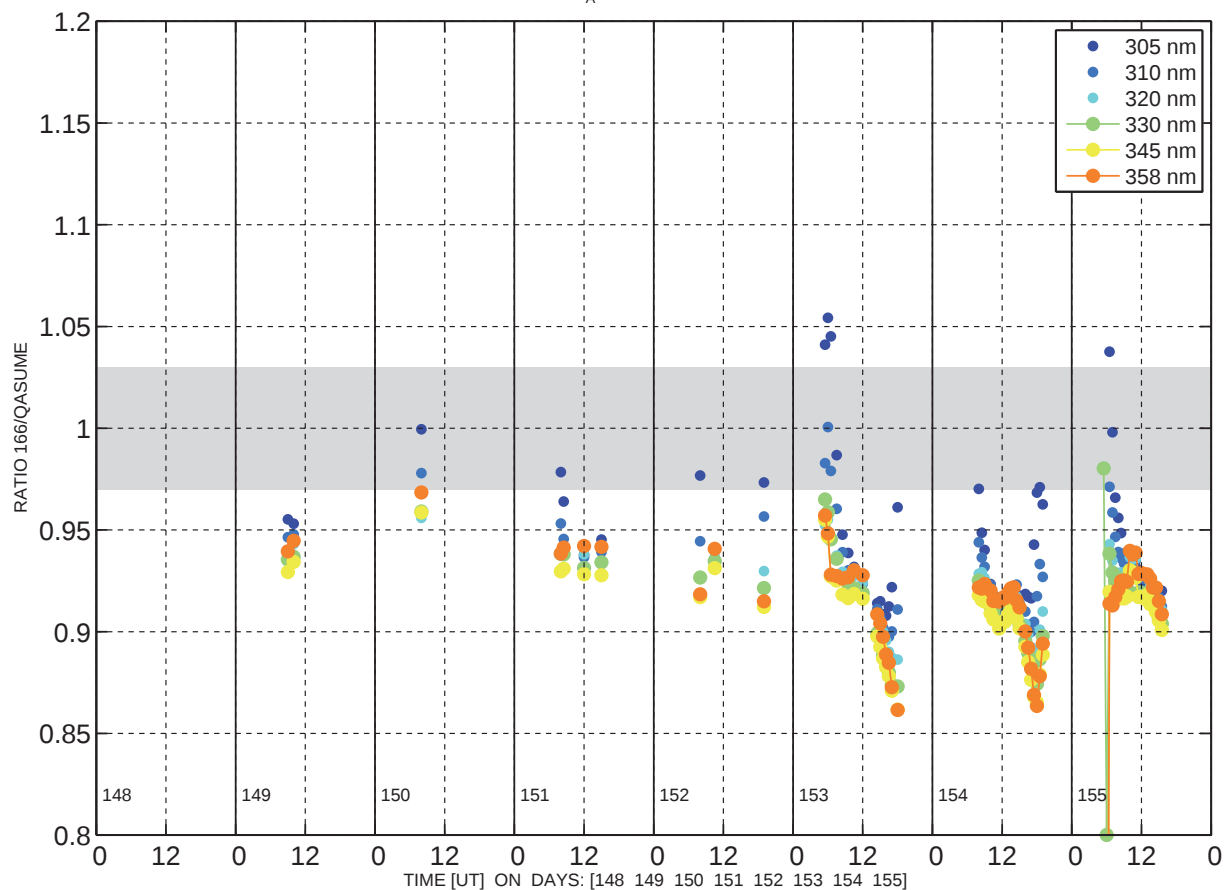
WL=330.00 nm



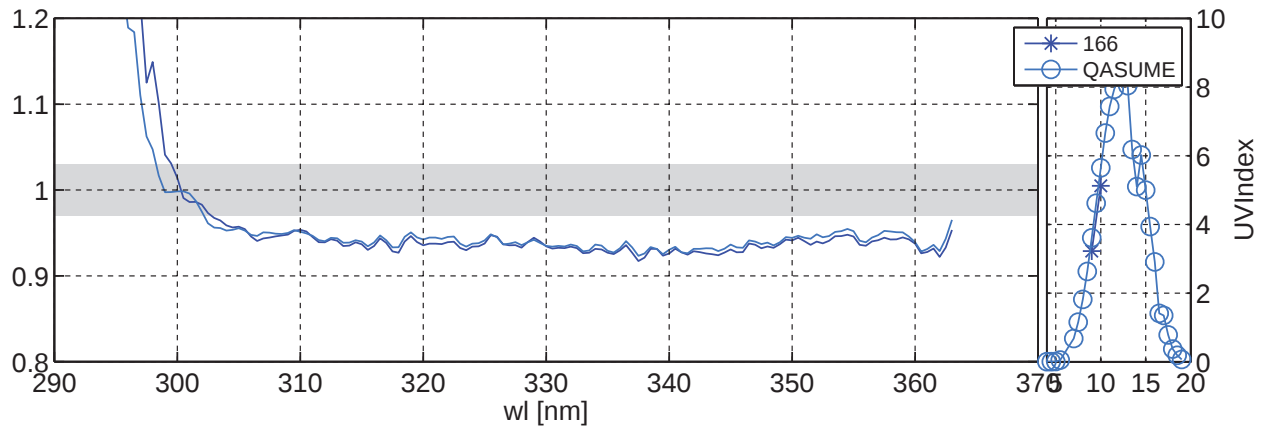
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 02-Jun-2015(153)



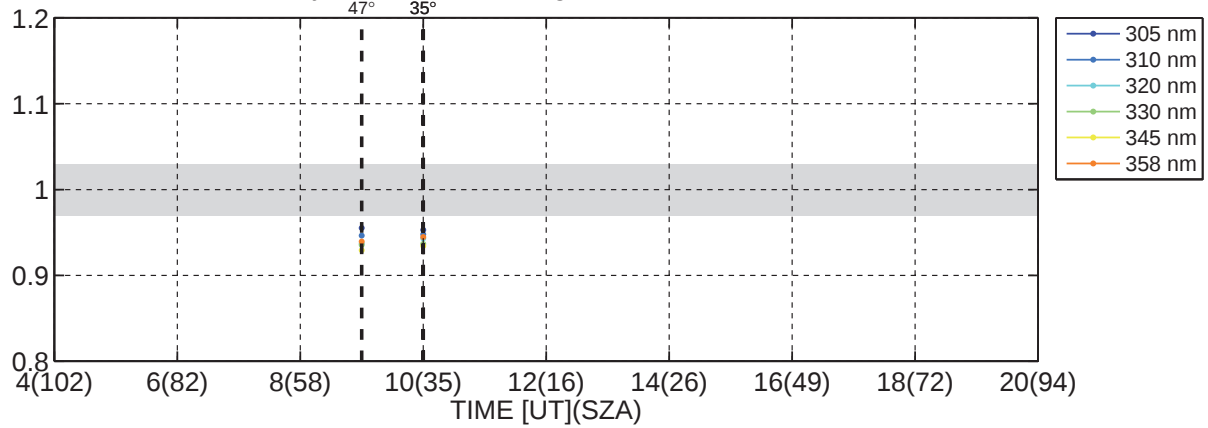
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



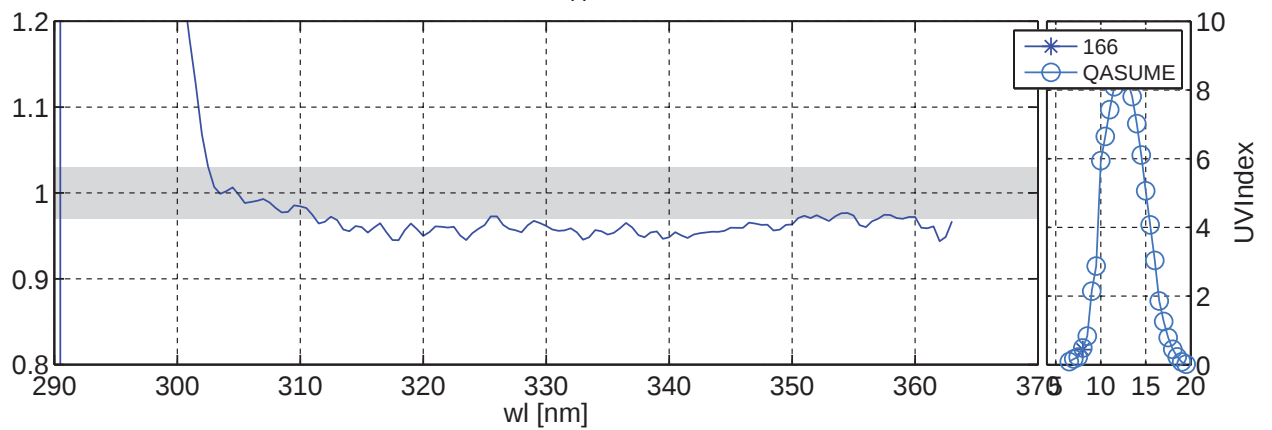
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:29-May-2015(149)



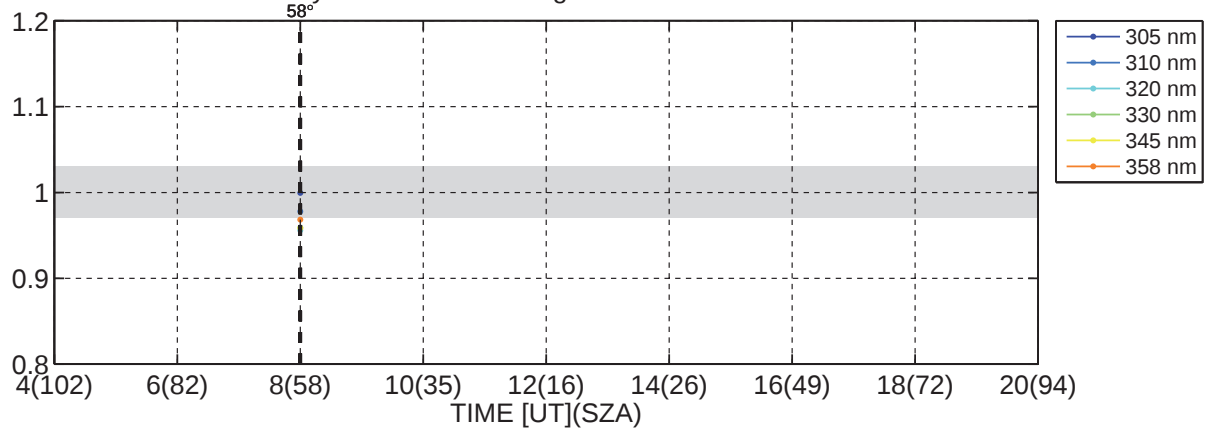
Daily variation. Wavelength bands are ± 2.5 nm



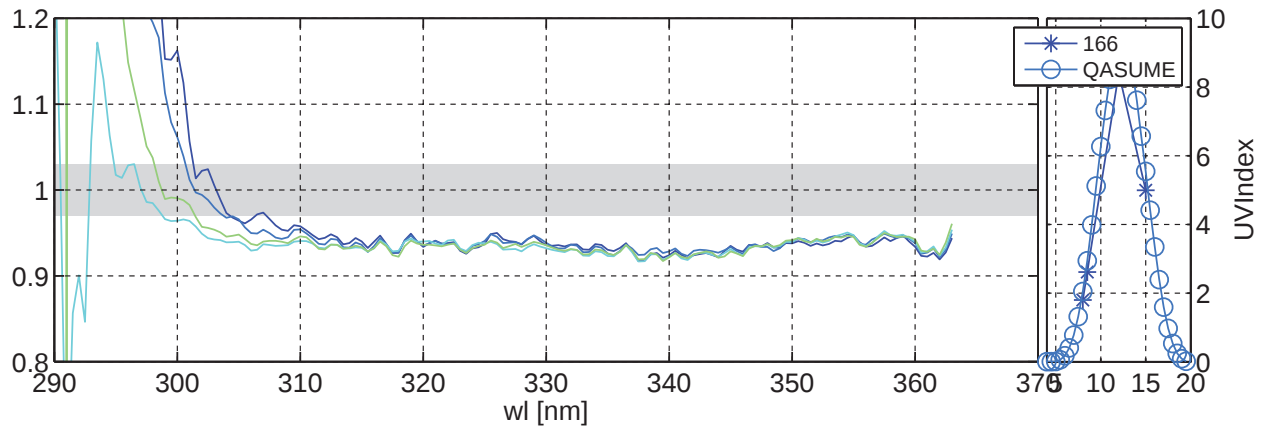
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:30-May-2015(150)



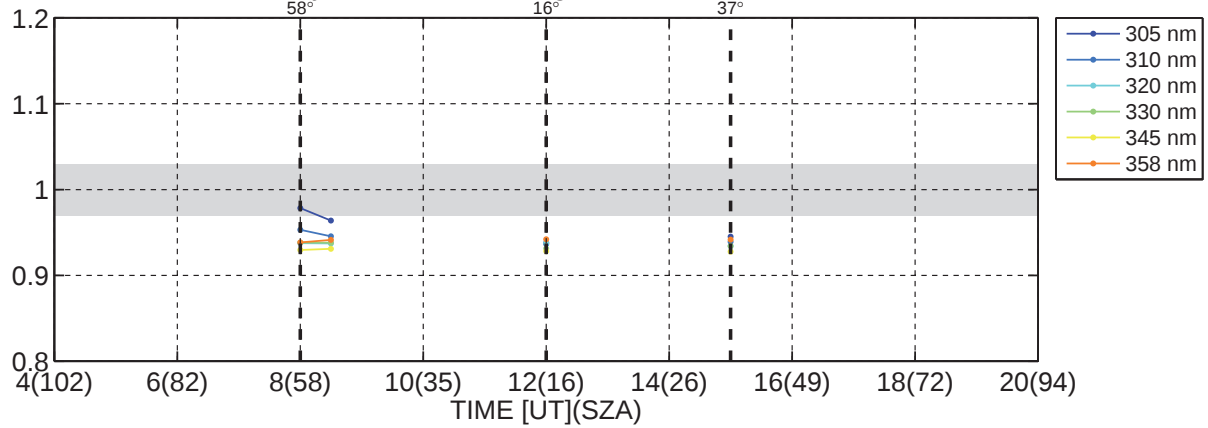
Daily variation. Wavelength bands are ± 2.5 nm



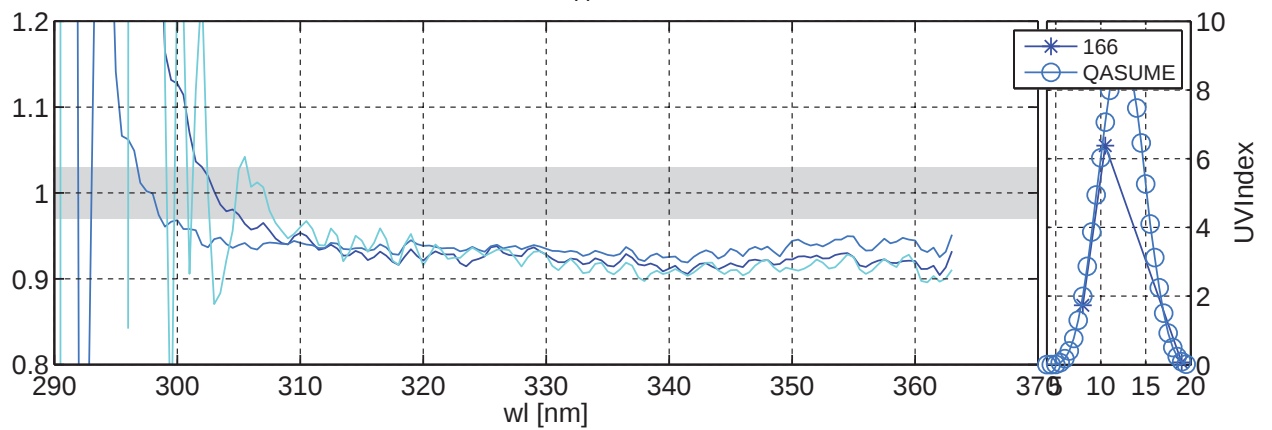
Global irradiance ratios 166/QASUME at El_A renosillo-matshic:31-May-2015(151)



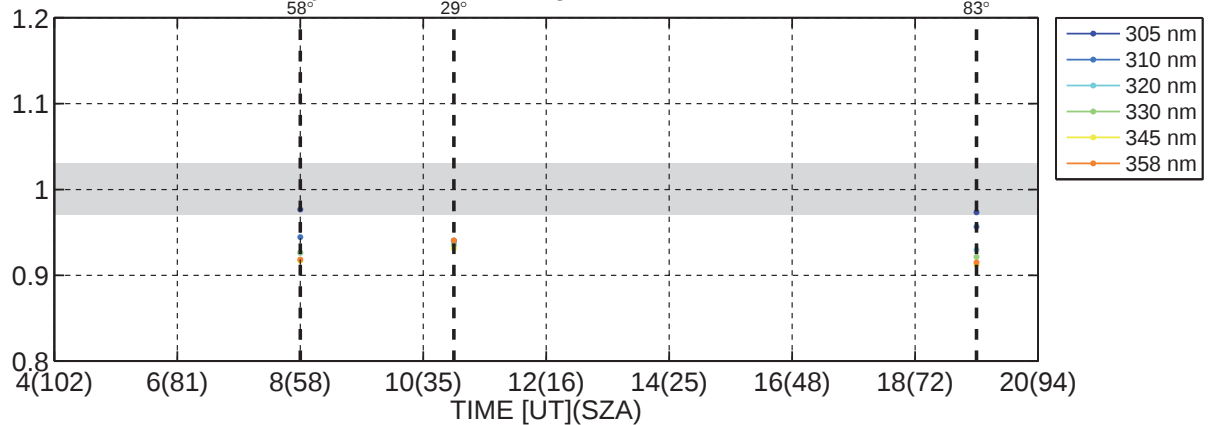
Daily variation. Wavelength bands are ± 2.5 nm



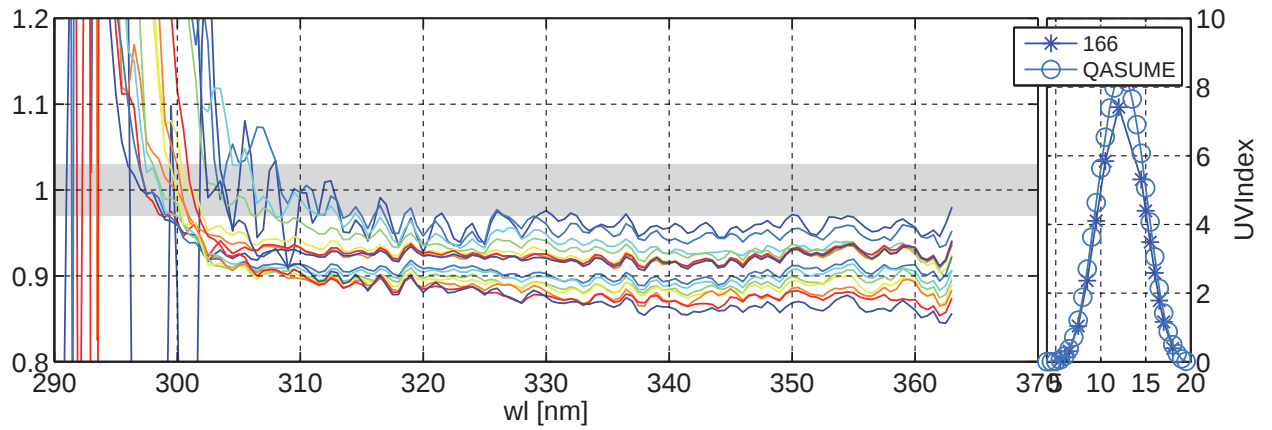
Global irradiance ratios 166/QASUME at El_A renosillo-matshic:01-Jun-2015(152)



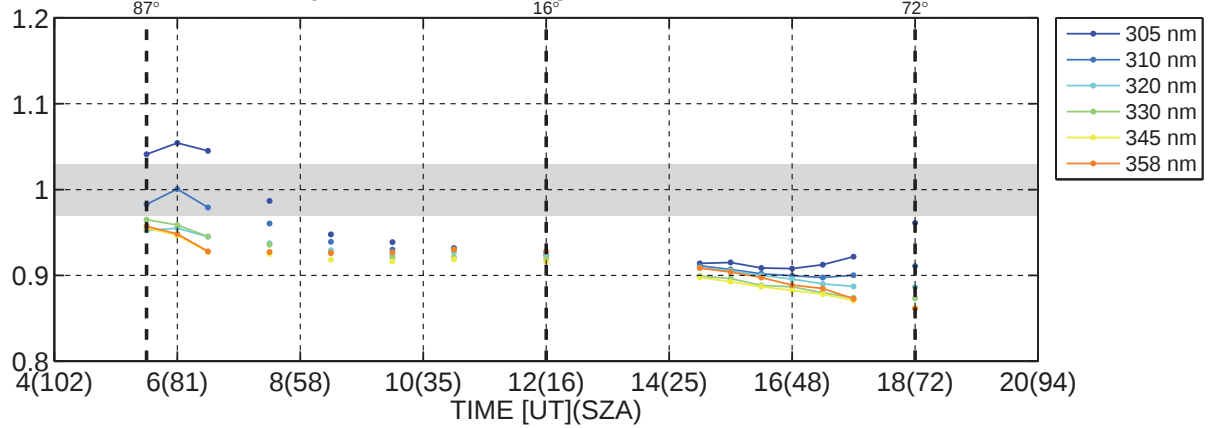
Daily variation. Wavelength bands are ± 2.5 nm



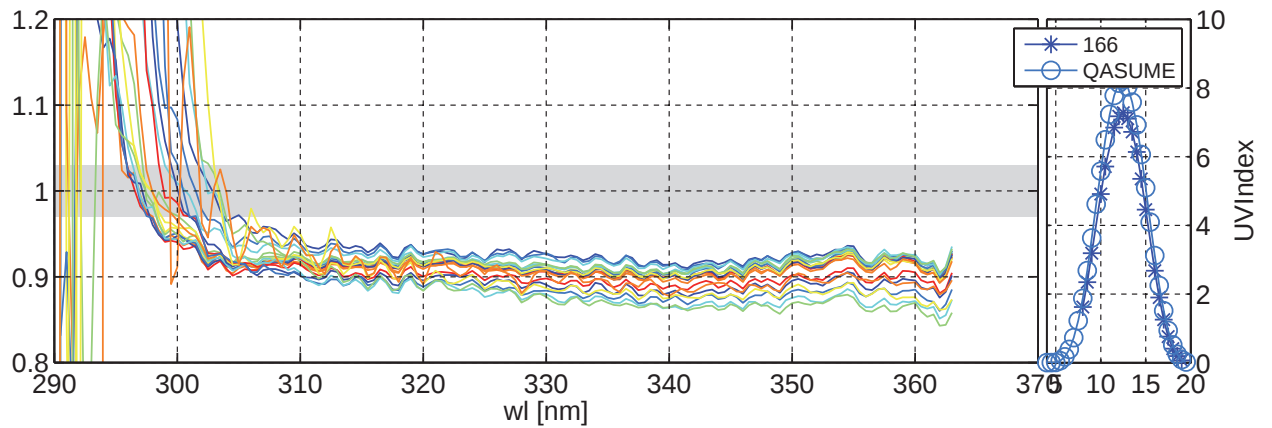
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



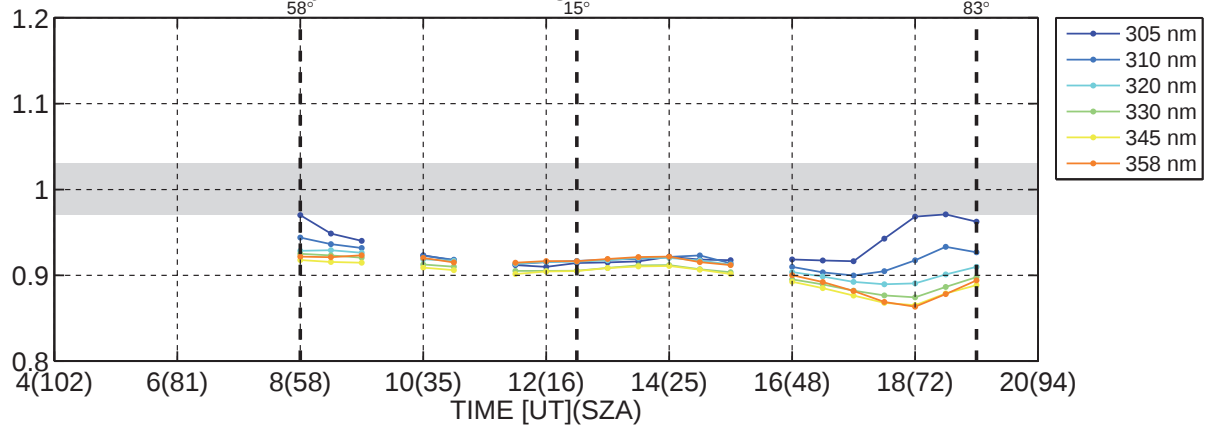
Daily variation. Wavelength bands are ± 2.5 nm



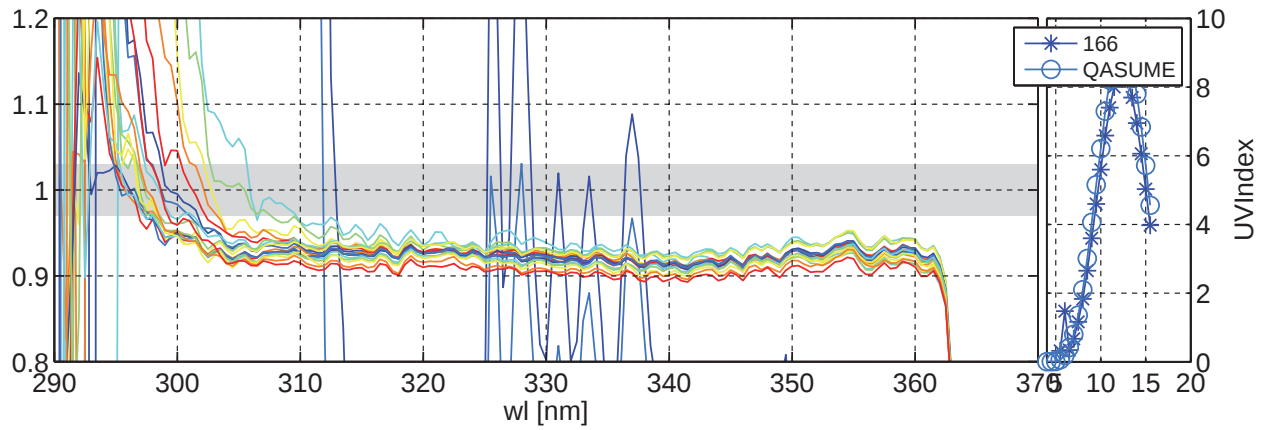
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



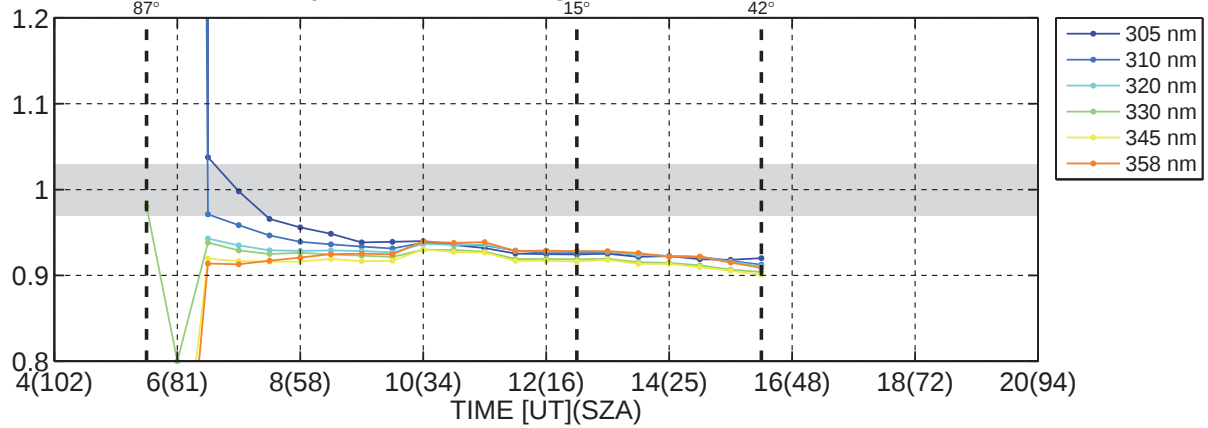
Daily variation. Wavelength bands are ± 2.5 nm



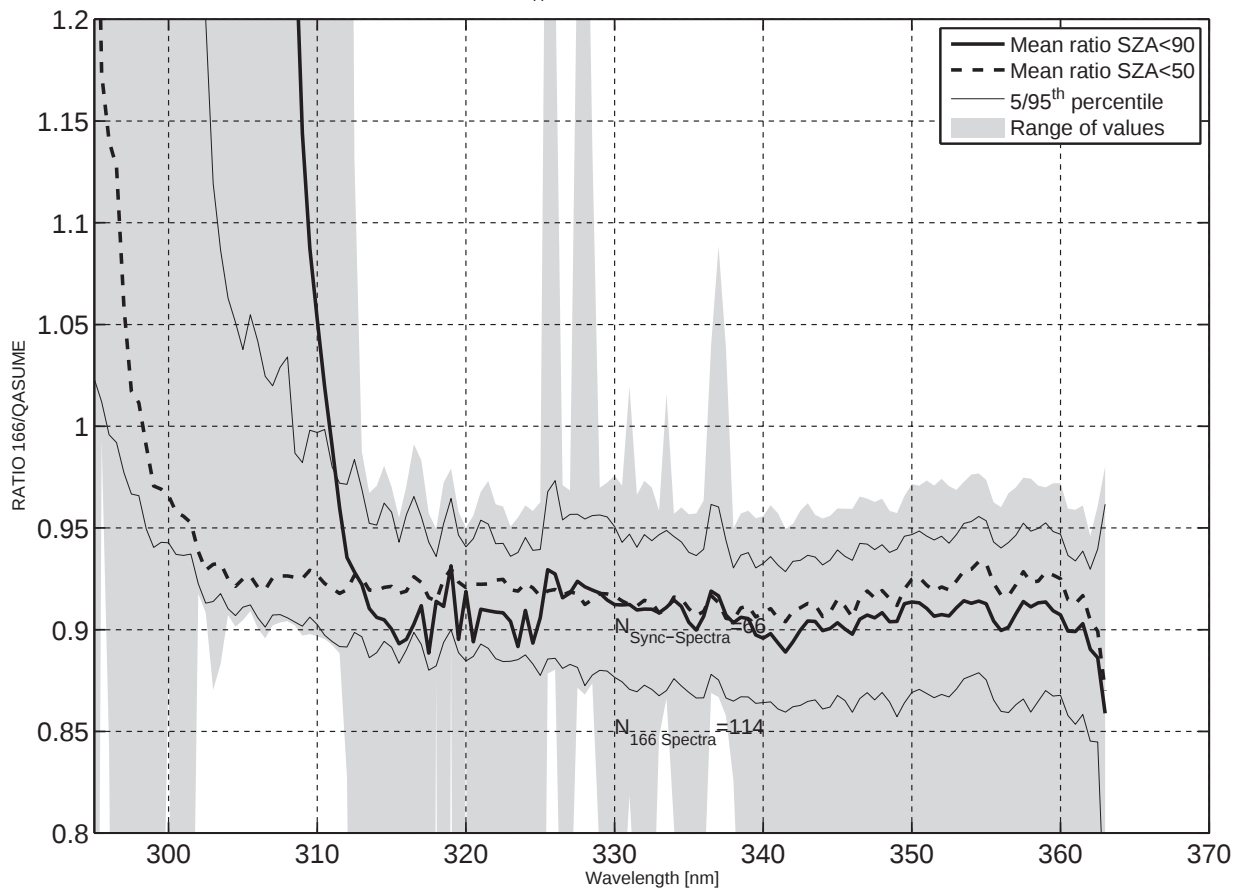
Global irradiance ratios 166/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



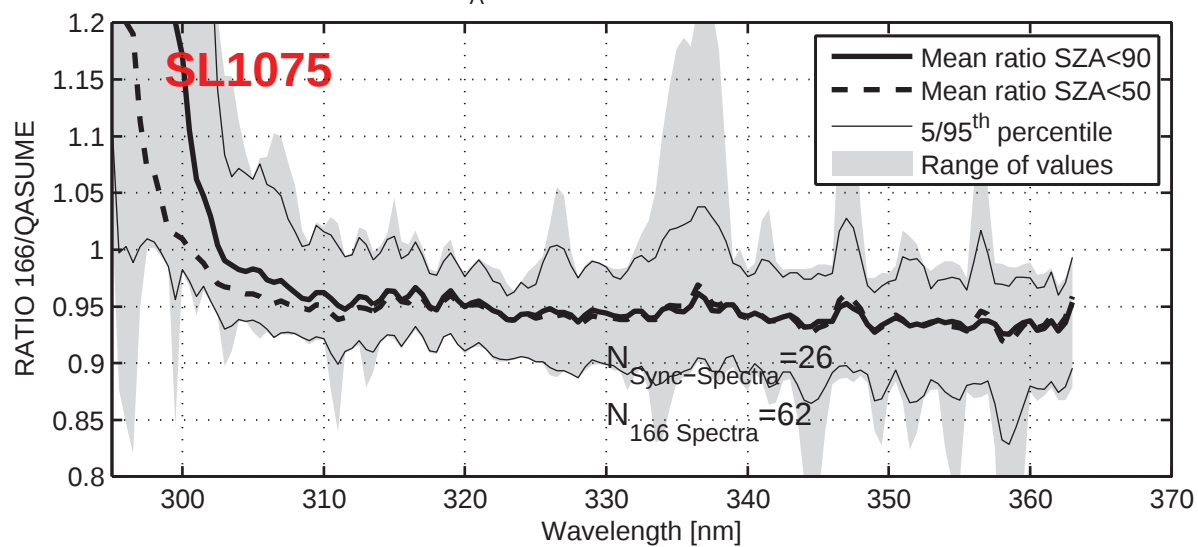
Daily variation. Wavelength bands are ± 2.5 nm



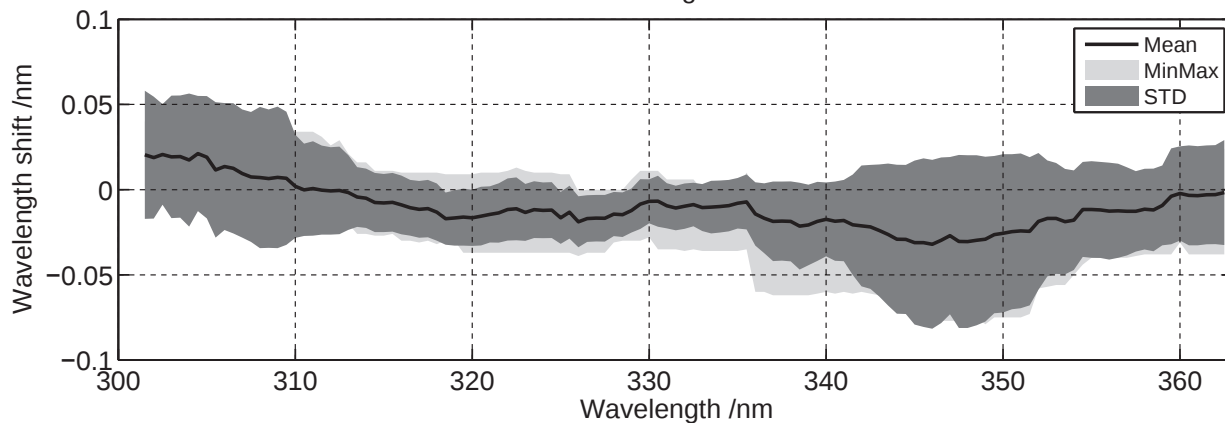
Mean ratio 166/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



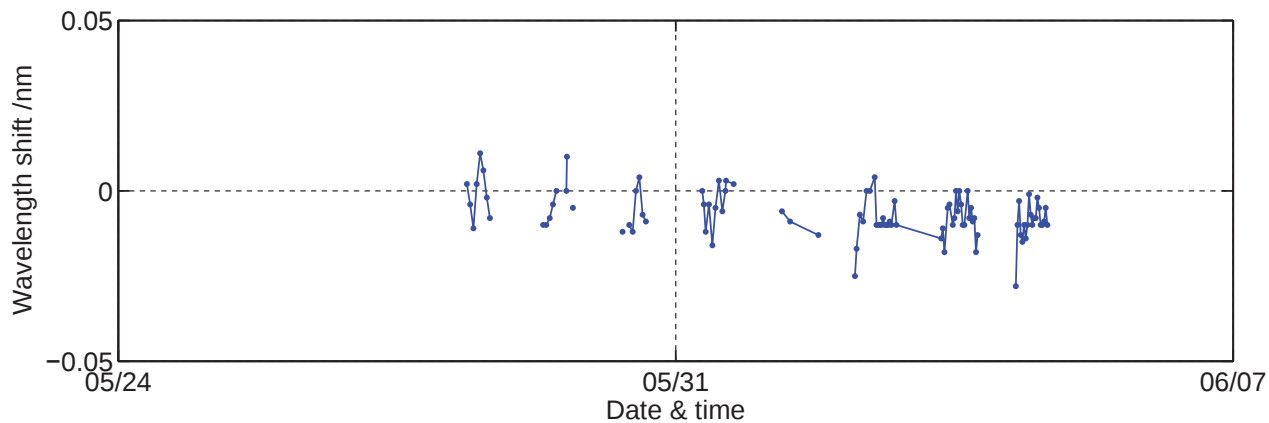
Mean ratio 166/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 02-Jun-2015(153)



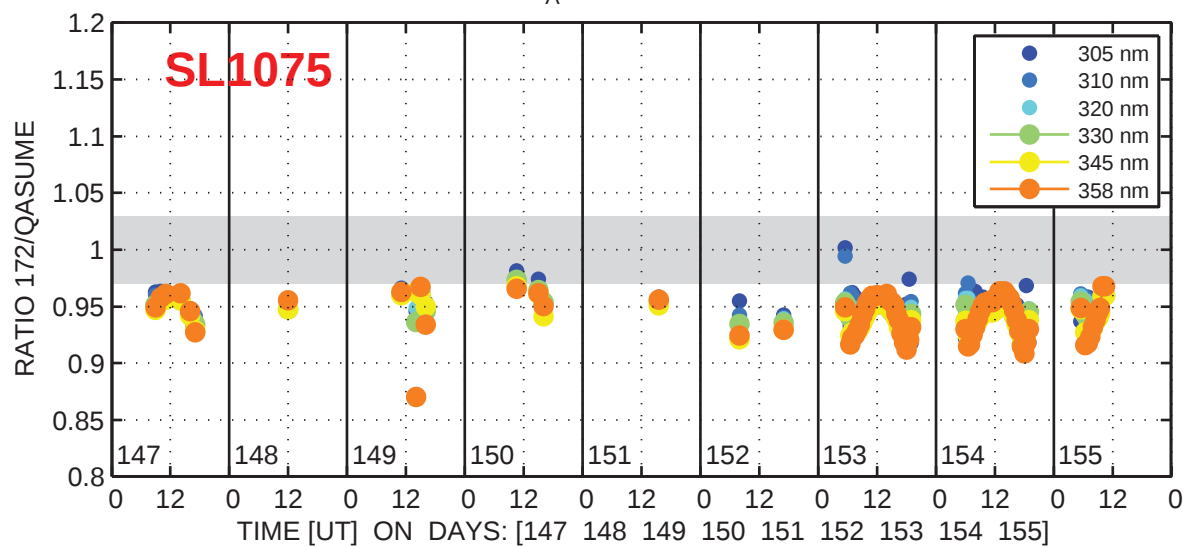
Wavelength shift



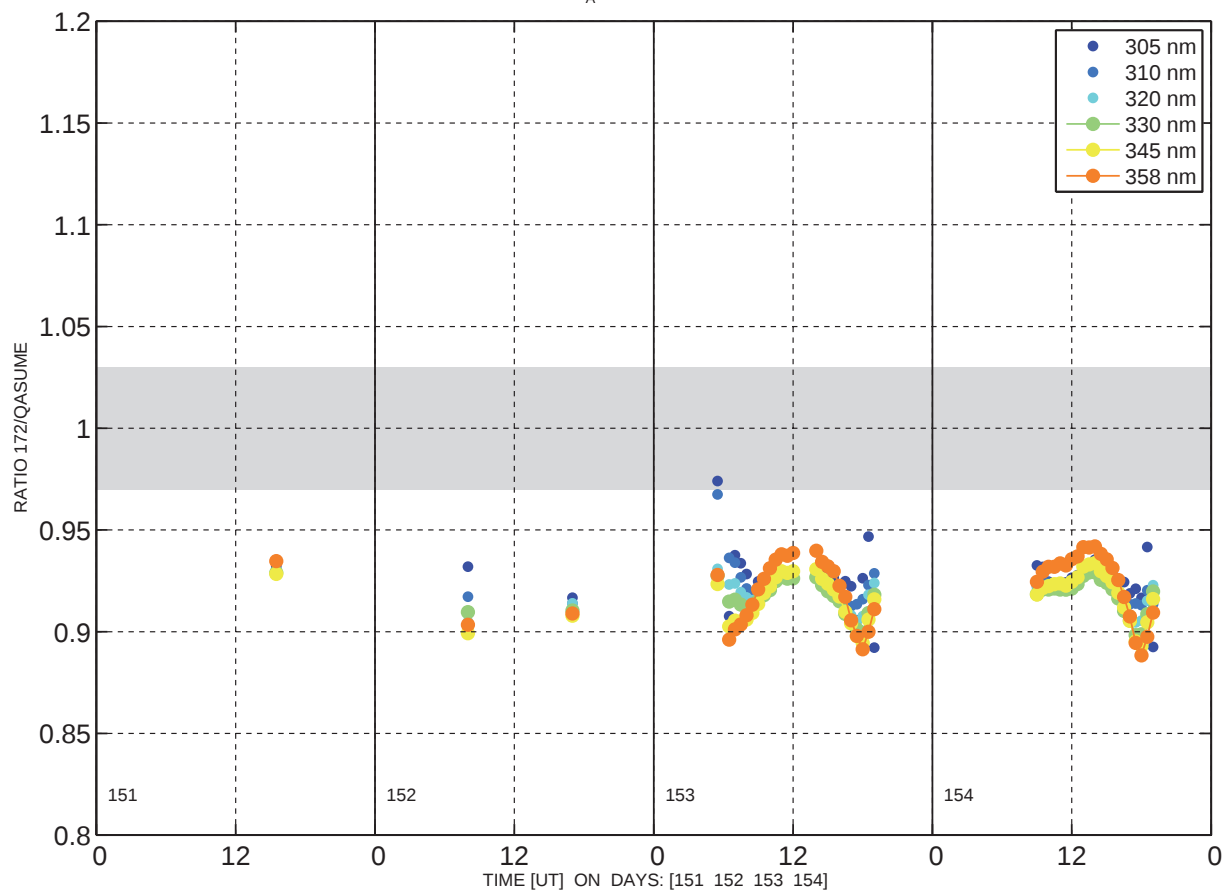
WL=330.00 nm



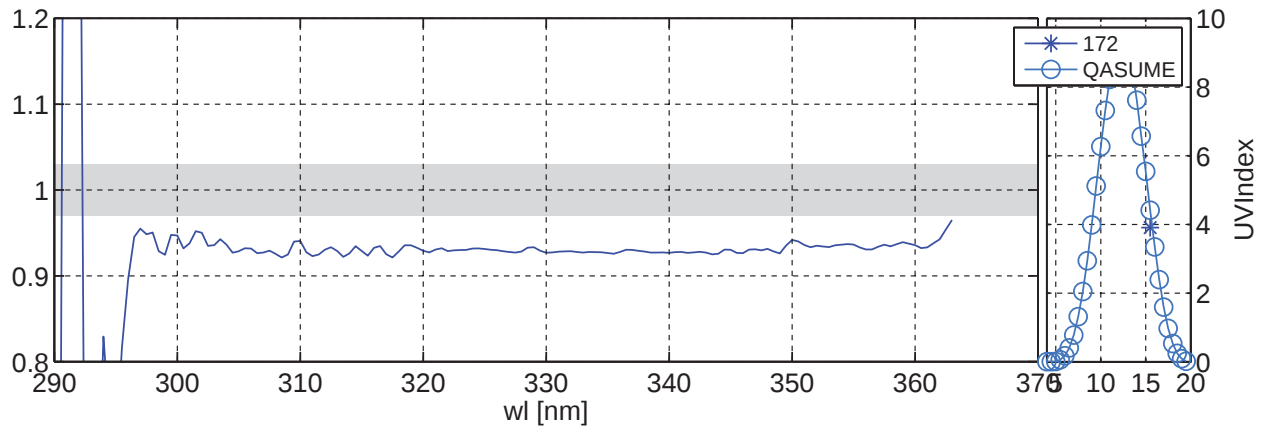
Global irradiance ratios 172/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 04-Jun-2015(155)



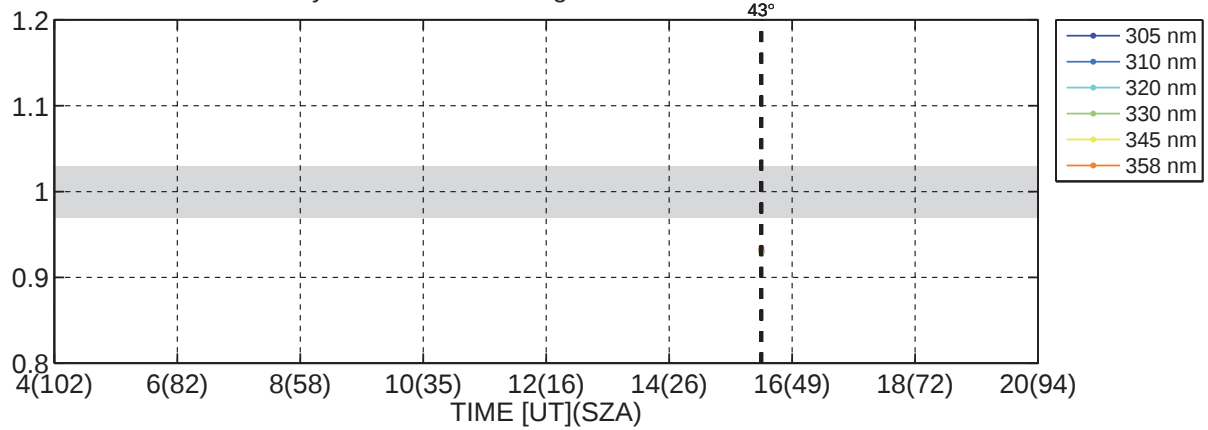
Global irradiance ratios 172/QASUME at El_Arenosillo-matshic:31-May-2015(151) to 03-Jun-2015(154)



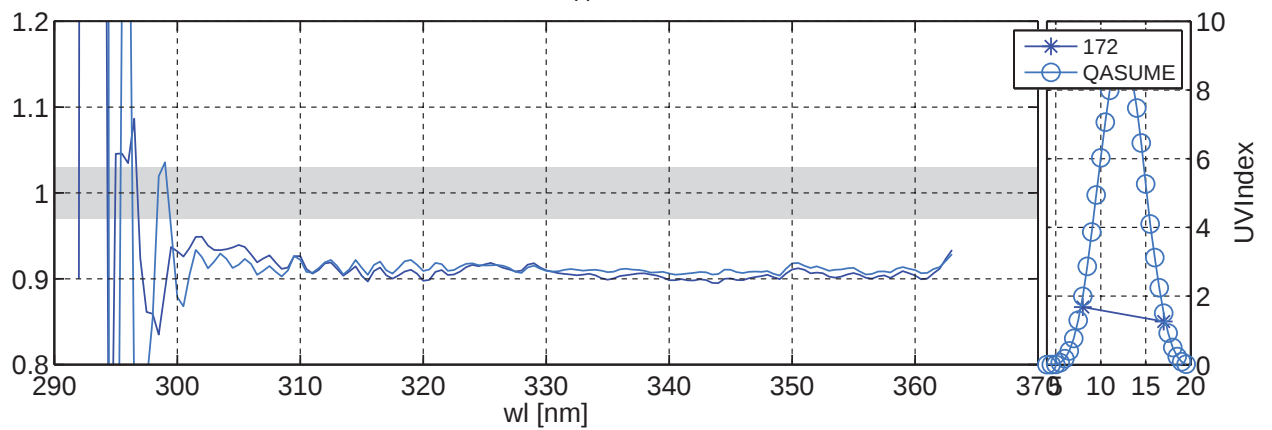
Global irradiance ratios 172/QASUME at El_Arenosillo-matshic:31-May-2015(151)



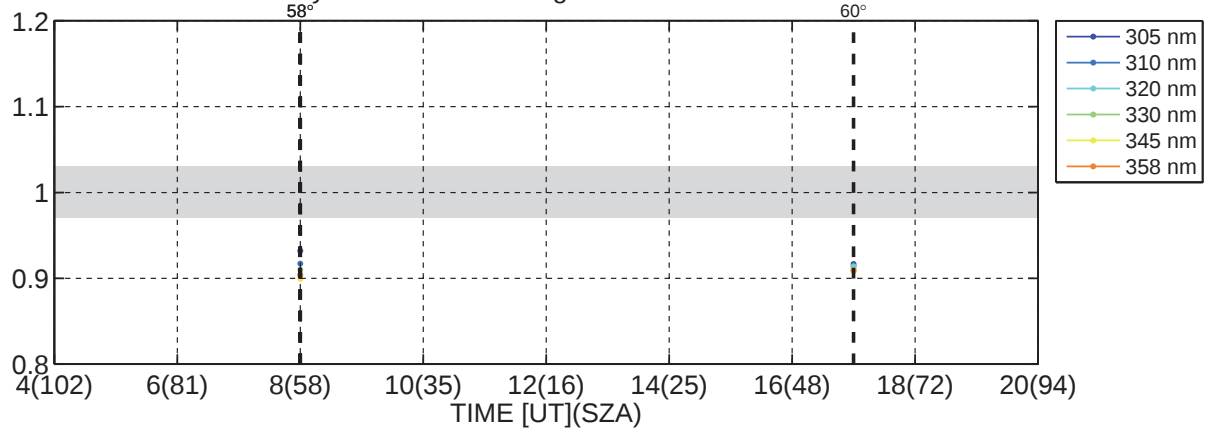
Daily variation. Wavelength bands are ± 2.5 nm



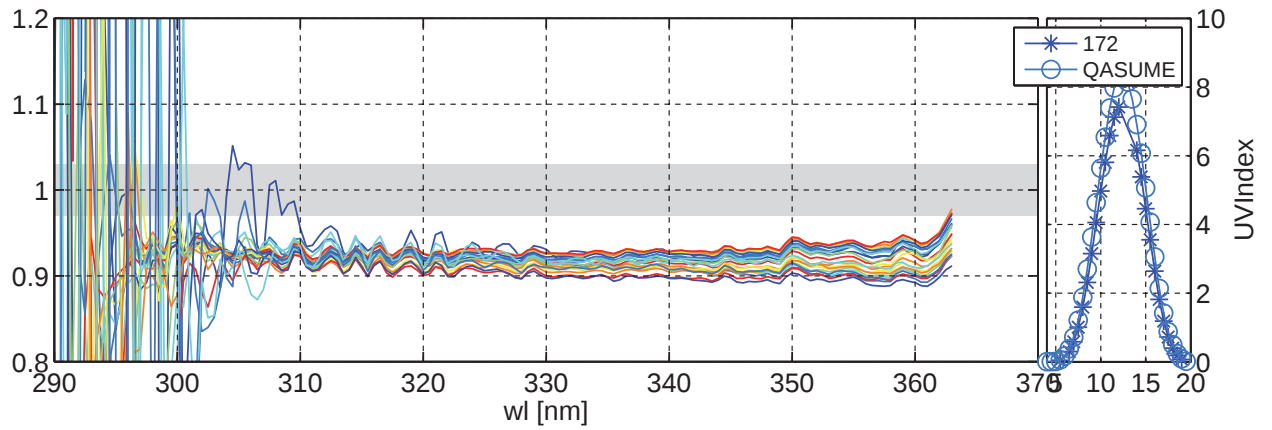
Global irradiance ratios 172/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



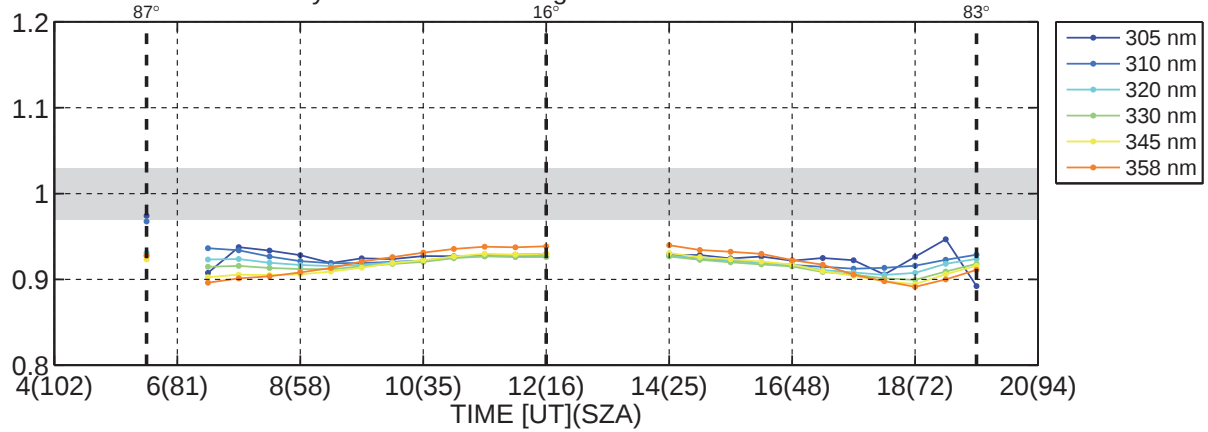
Daily variation. Wavelength bands are ± 2.5 nm



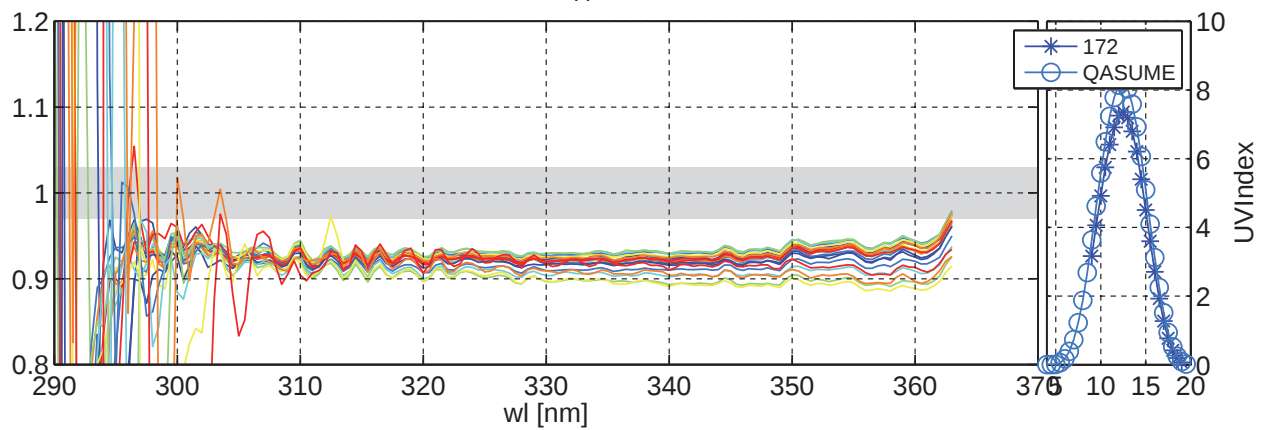
Global irradiance ratios 172/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



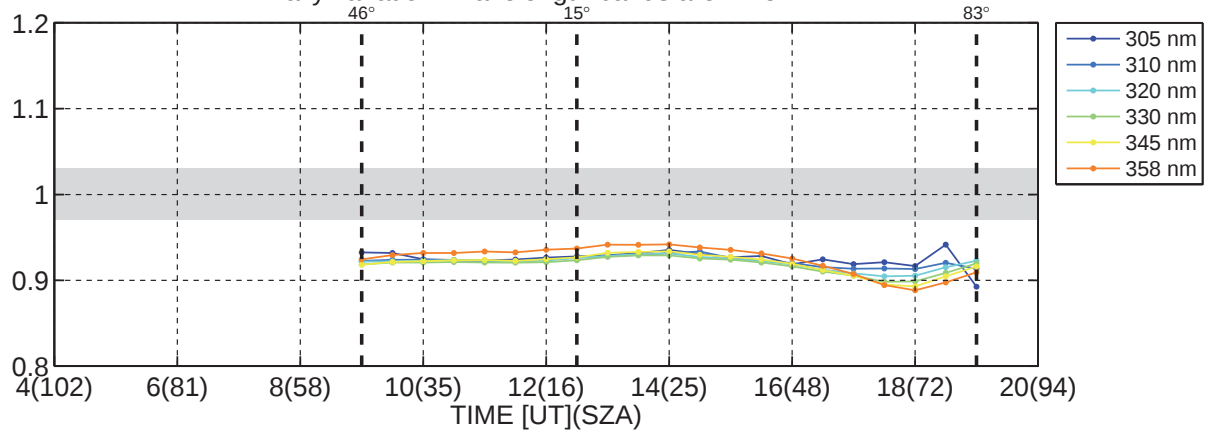
Daily variation. Wavelength bands are ± 2.5 nm

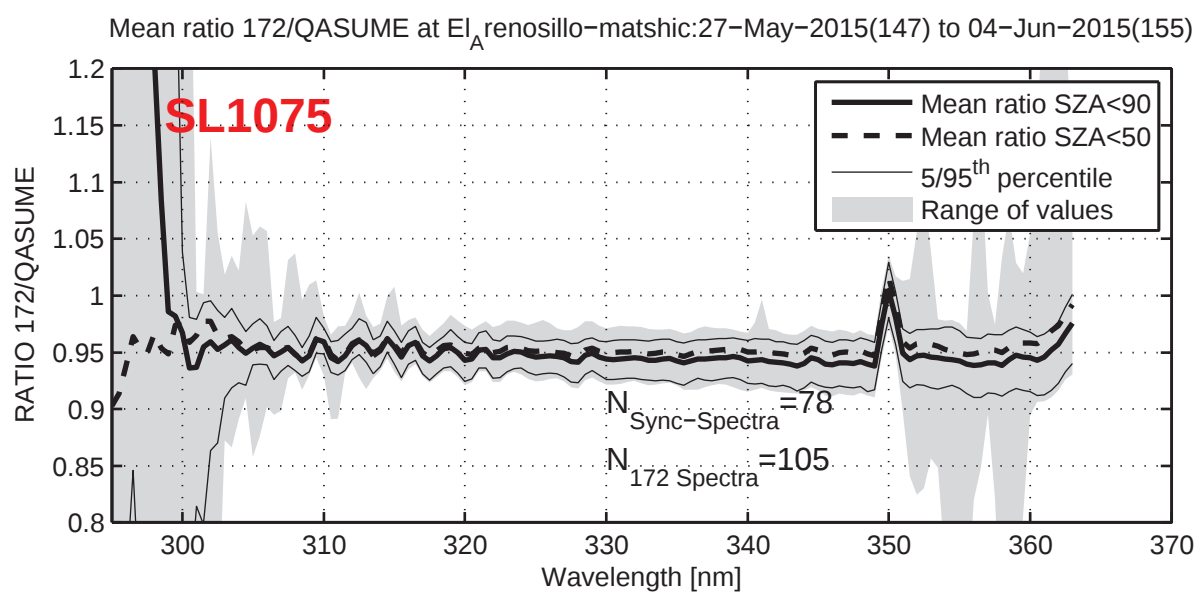
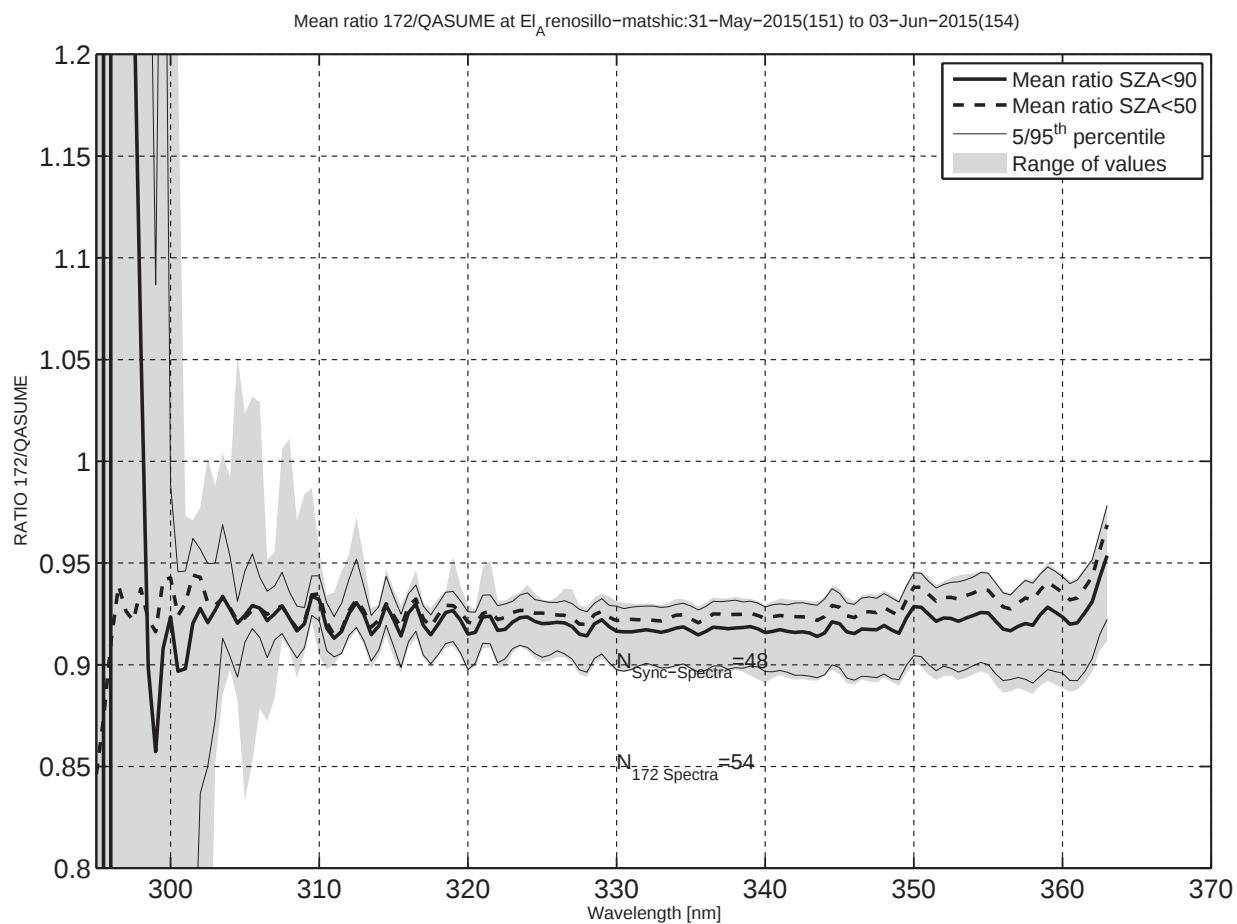


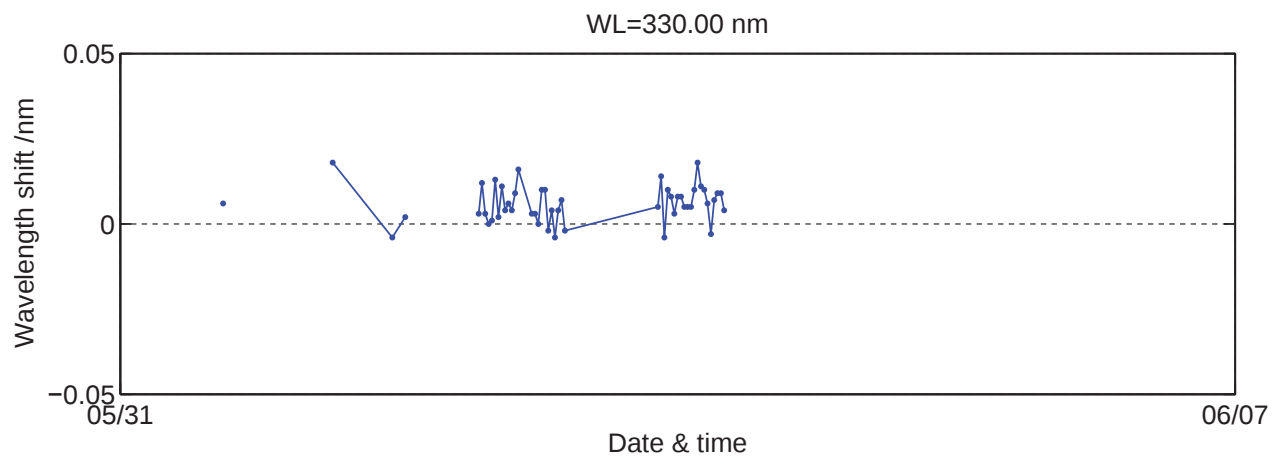
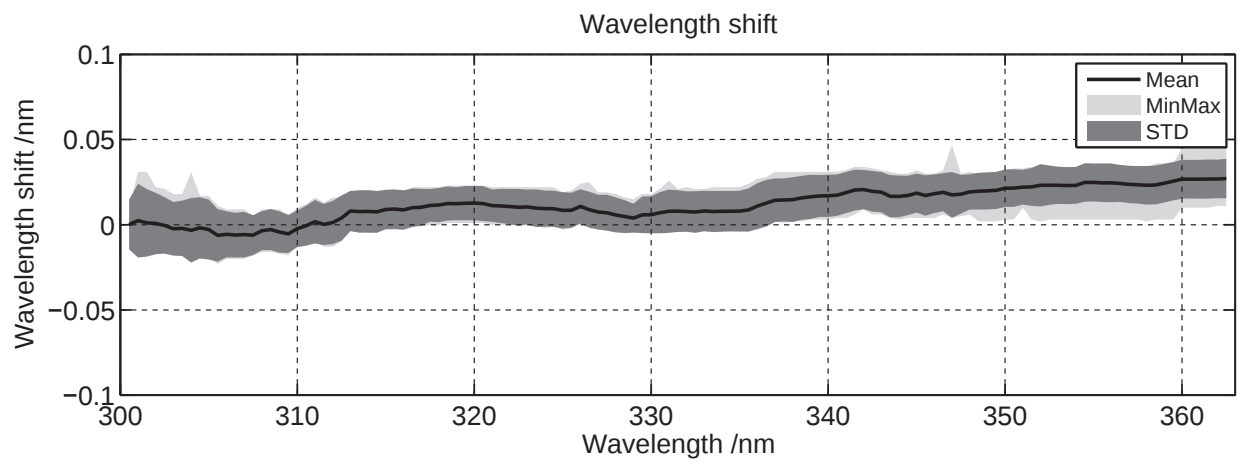
Global irradiance ratios 172/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



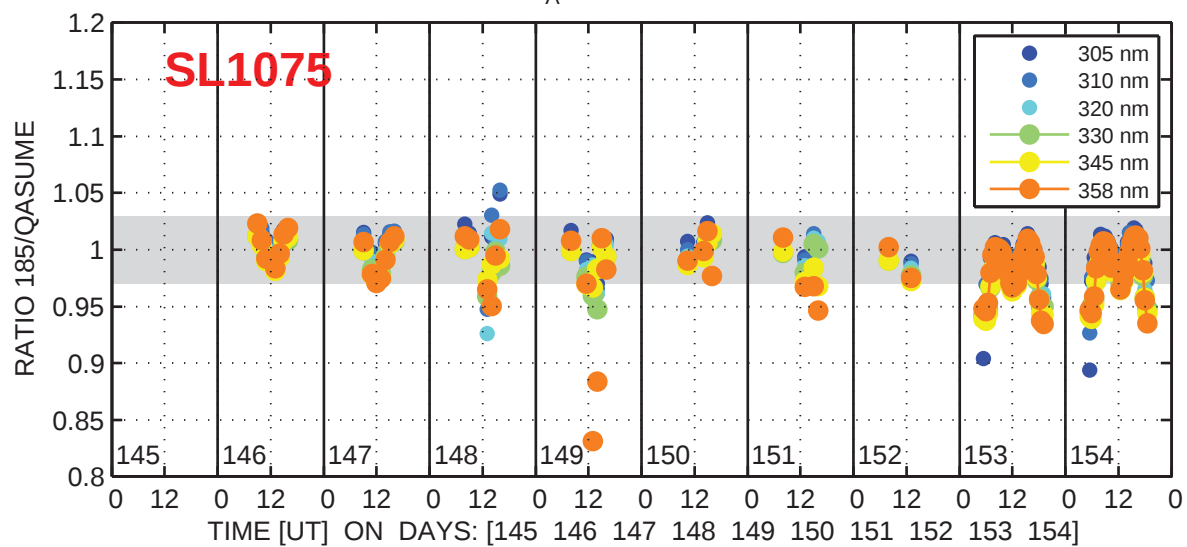
Daily variation. Wavelength bands are ± 2.5 nm



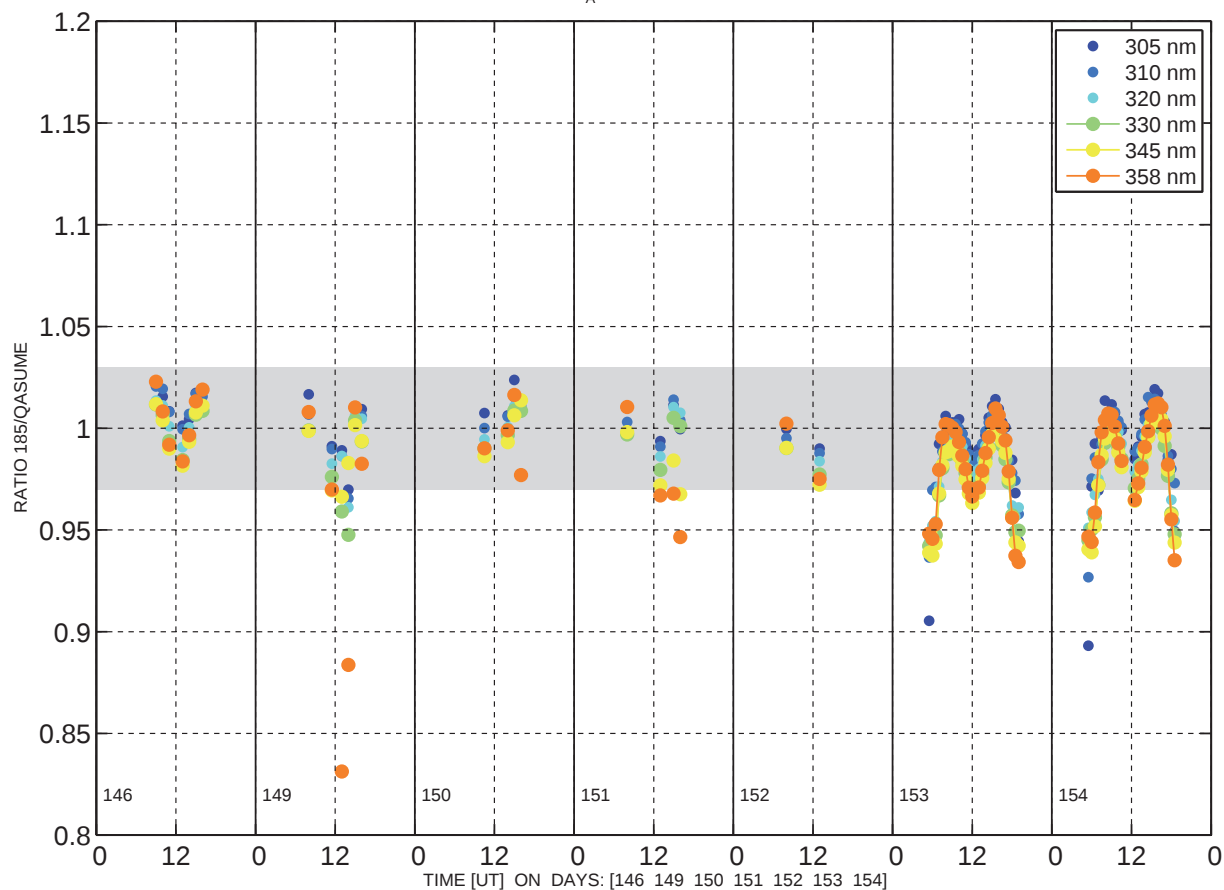




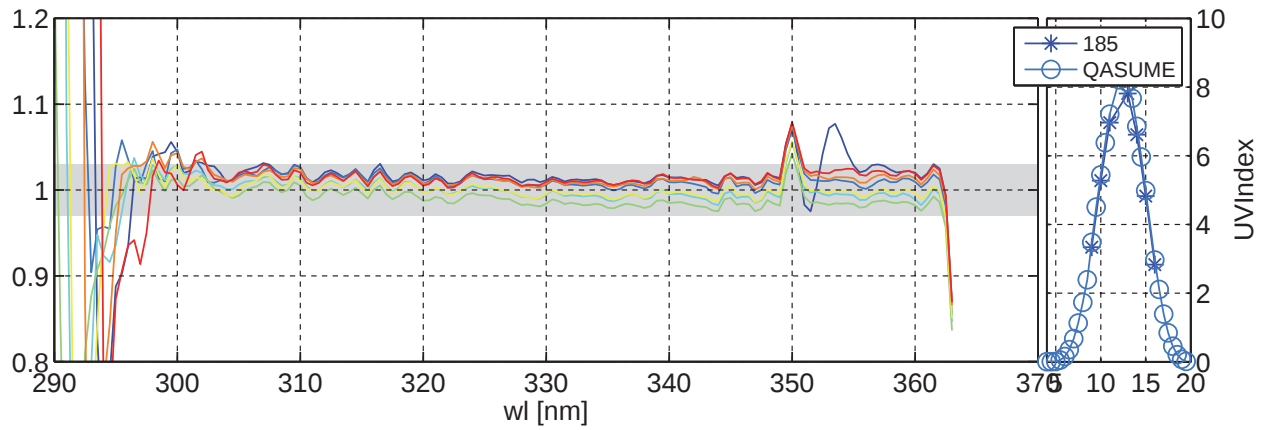
Global irradiance ratios 185/QASUME at El_Arenosillo-matshic:25-May-2015(145) to 03-Jun-2015(154)



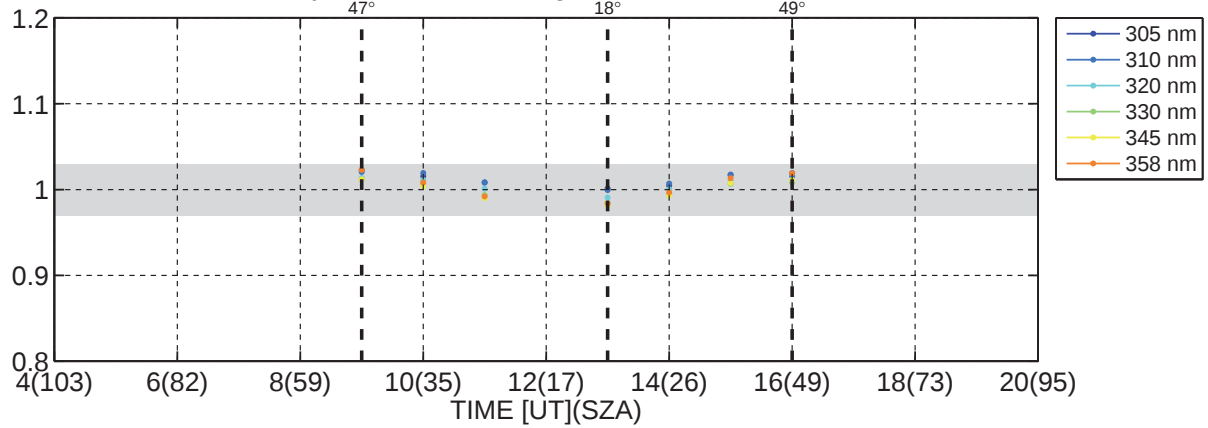
Global irradiance ratios 185/QASUME at El_Arenosillo-matshic:26-May-2015(146) to 03-Jun-2015(154)



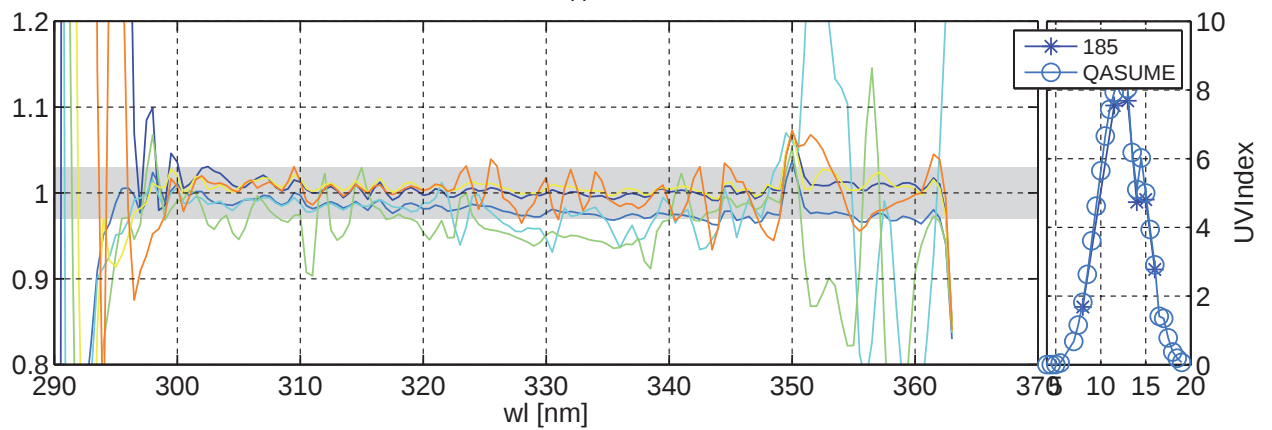
Global irradiance ratios 185/QASUME at El_A renosillo-matshic:26-May-2015(146)



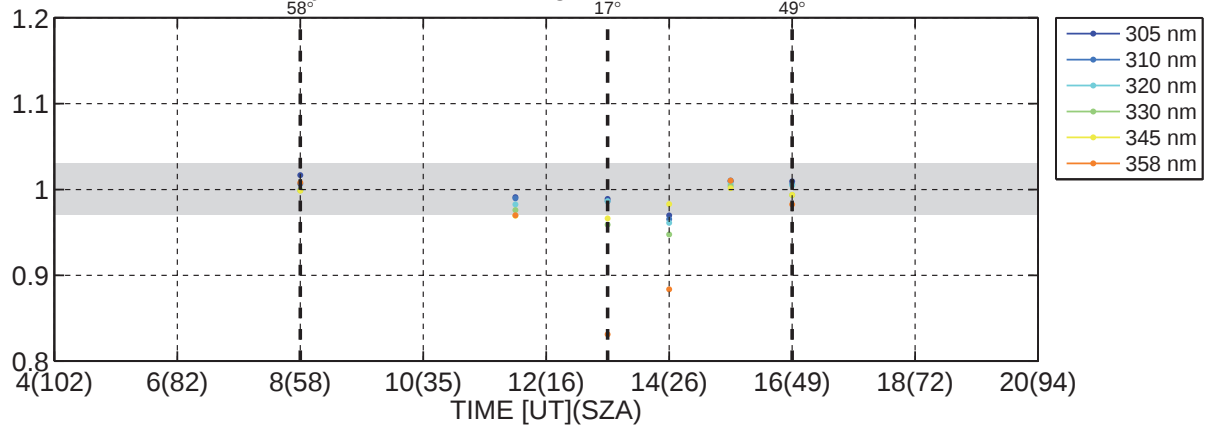
Daily variation. Wavelength bands are ± 2.5 nm



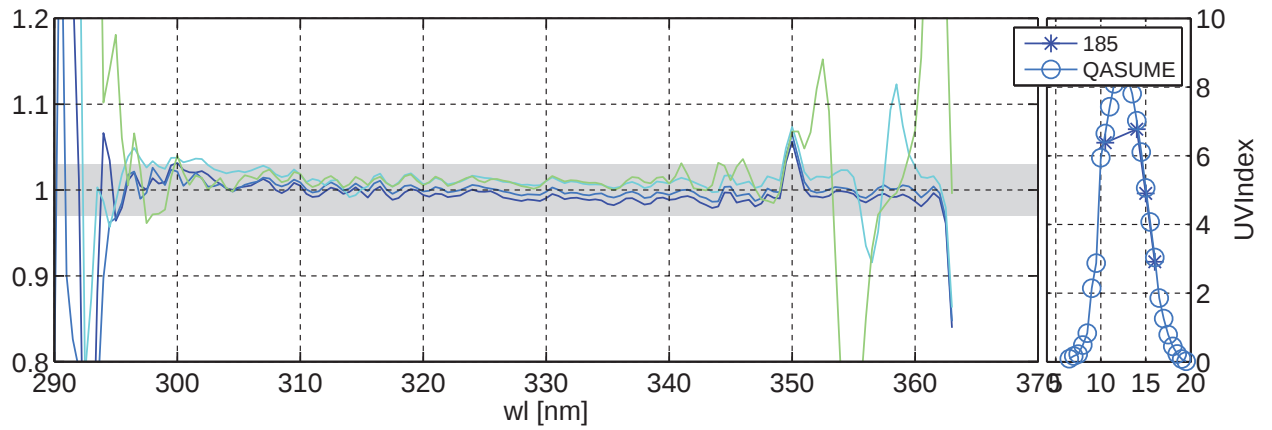
Global irradiance ratios 185/QASUME at El_A renosillo-matshic:29-May-2015(149)



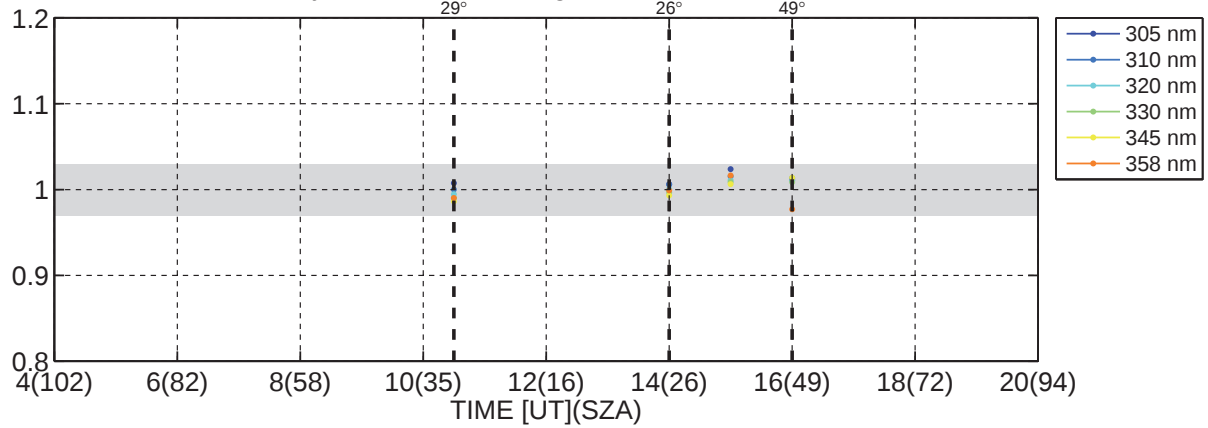
Daily variation. Wavelength bands are ± 2.5 nm



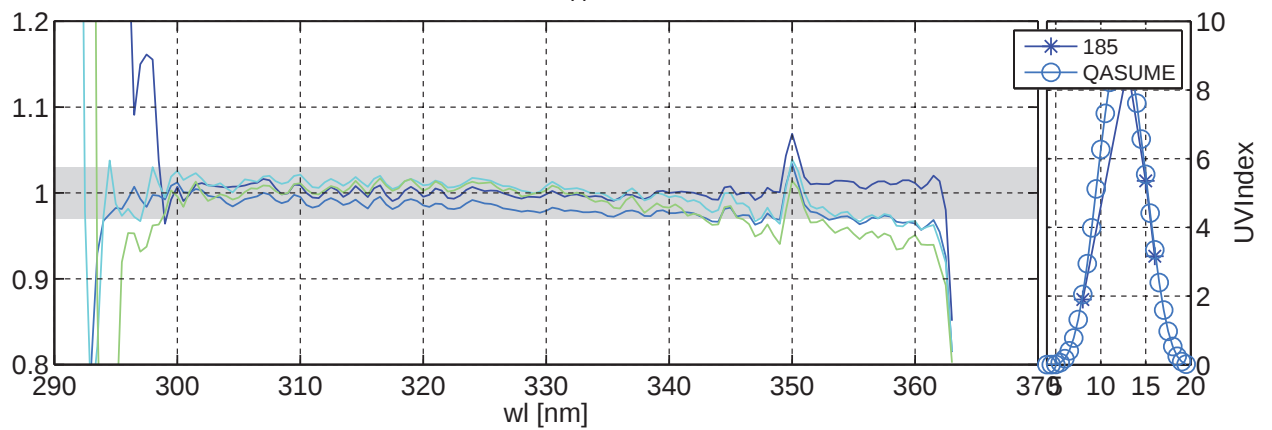
Global irradiance ratios 185/QASUME at El_A renosillo-matshic:30-May-2015(150)



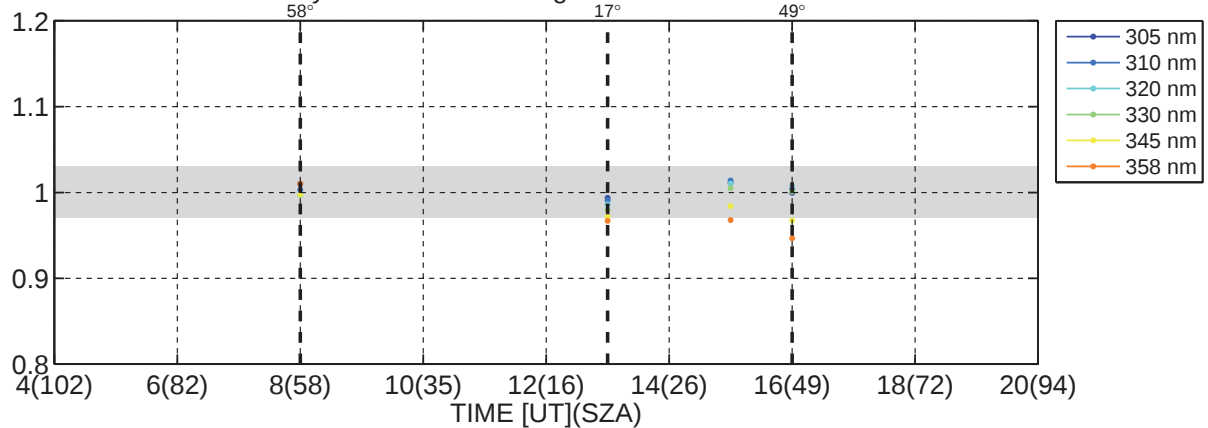
Daily variation. Wavelength bands are ± 2.5 nm



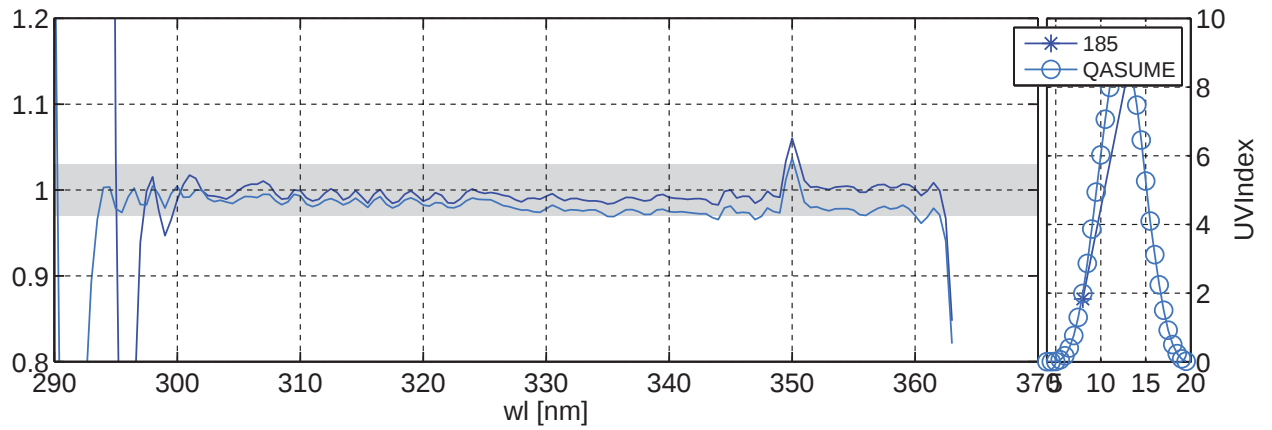
Global irradiance ratios 185/QASUME at El_A renosillo-matshic:31-May-2015(151)



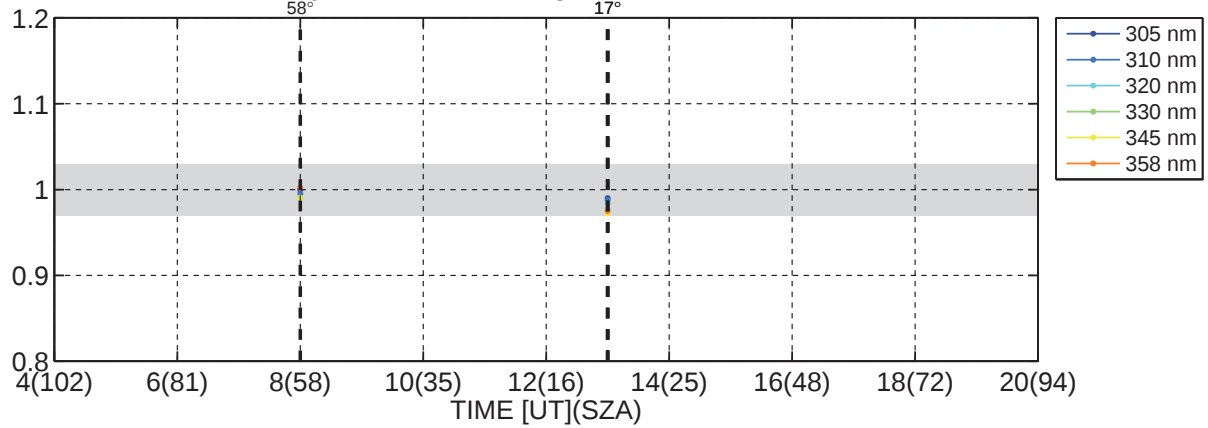
Daily variation. Wavelength bands are ± 2.5 nm



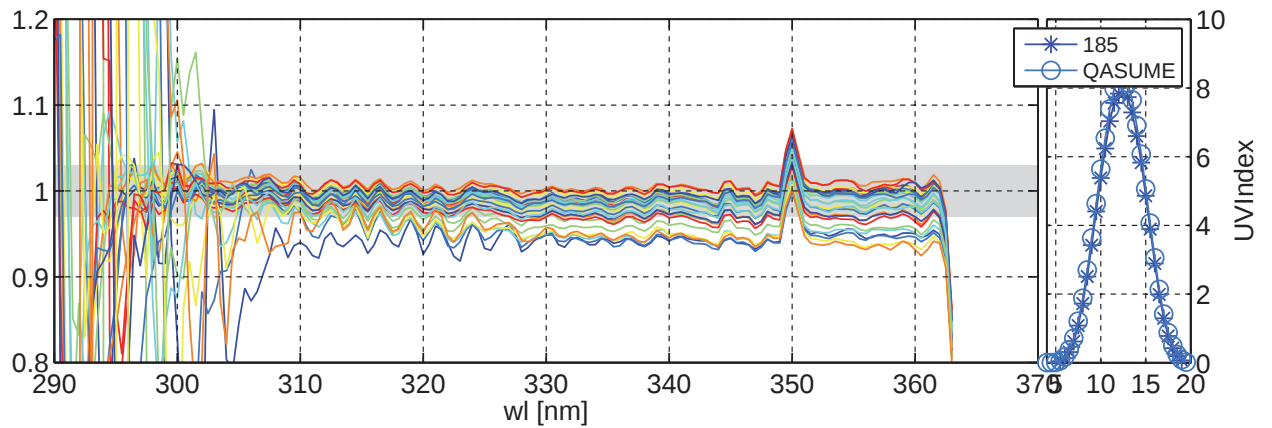
Global irradiance ratios 185/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



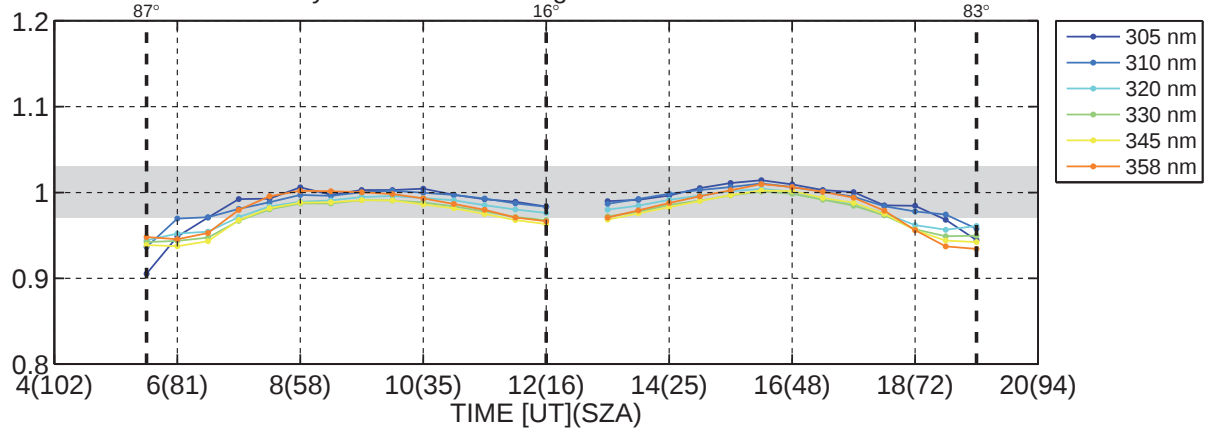
Daily variation. Wavelength bands are ± 2.5 nm



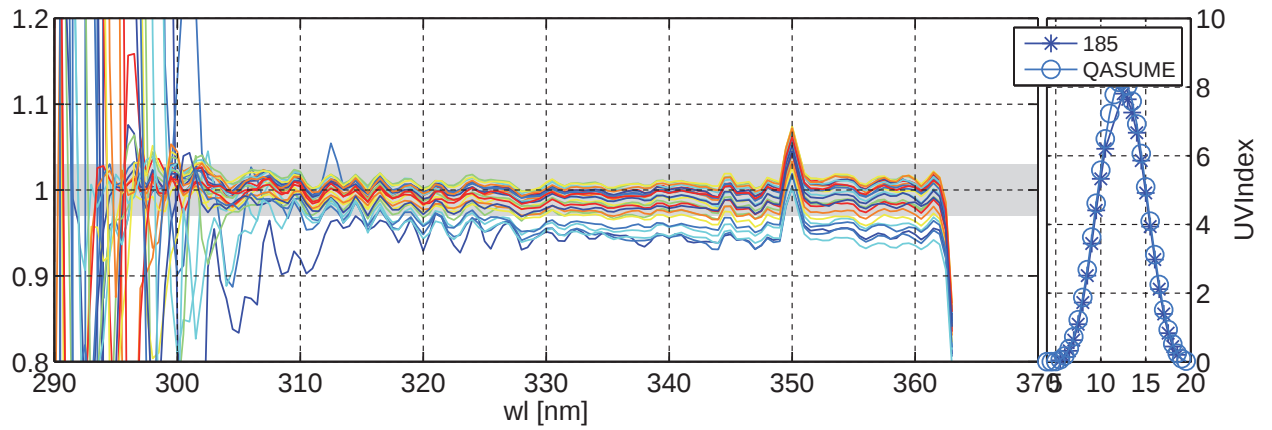
Global irradiance ratios 185/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



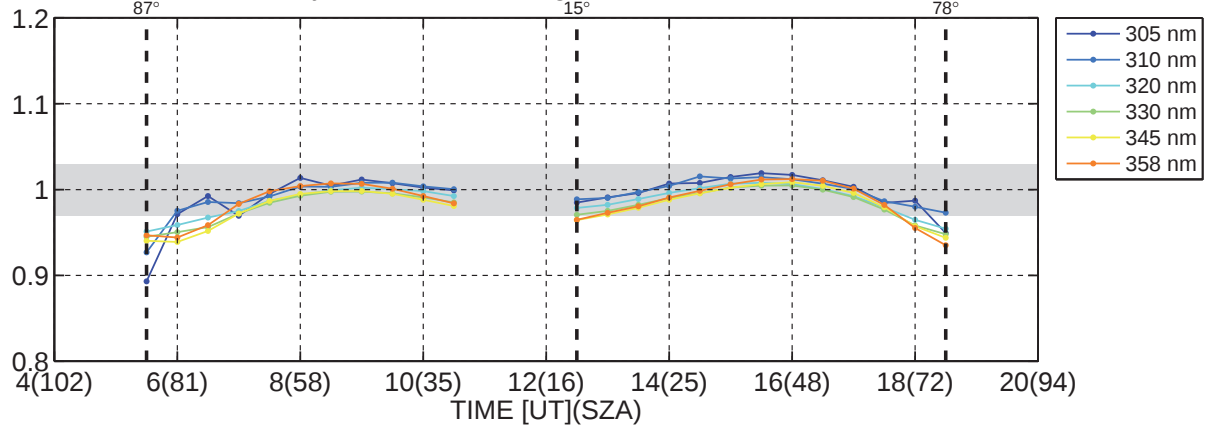
Daily variation. Wavelength bands are ± 2.5 nm



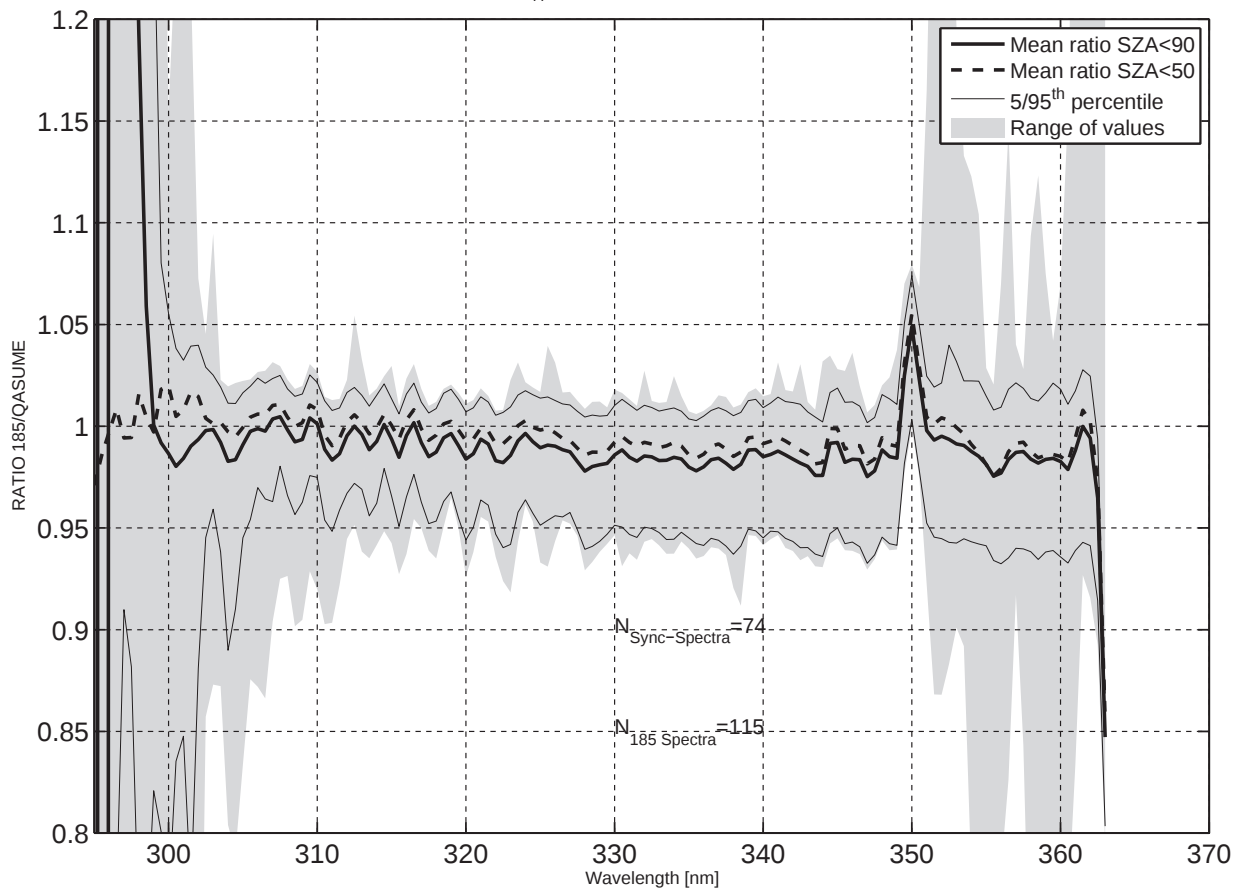
Global irradiance ratios 185/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)

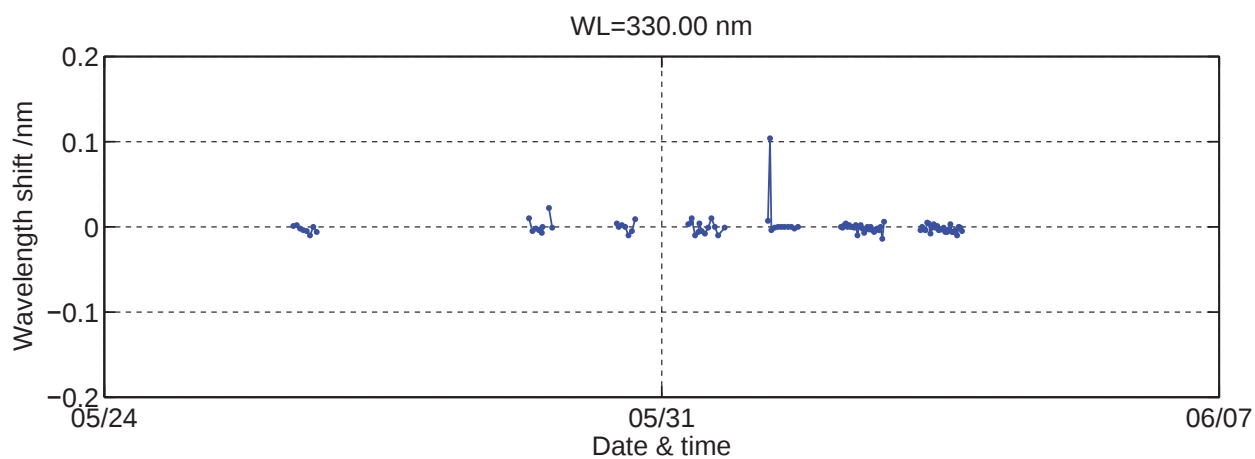
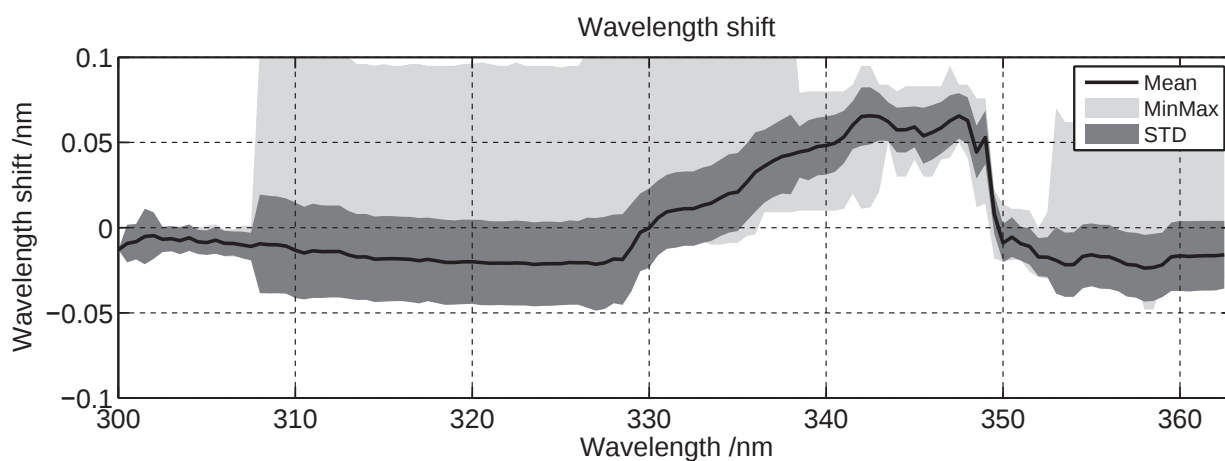
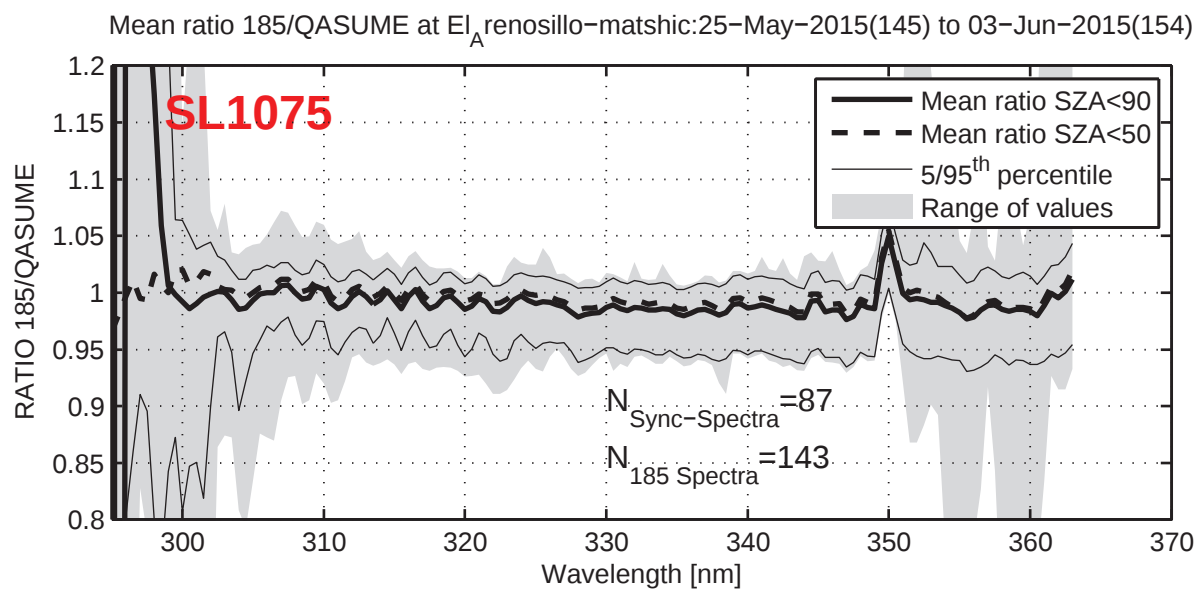


Daily variation. Wavelength bands are ± 2.5 nm

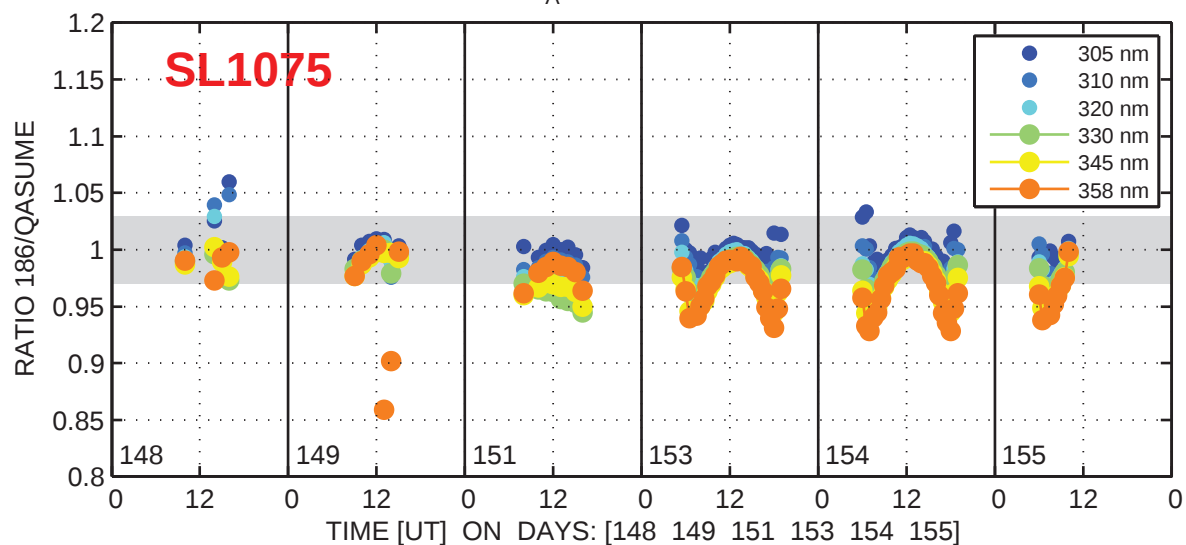


Mean ratio 185/QASUME at El_Arenosillo-matshic:26-May-2015(146) to 03-Jun-2015(154)

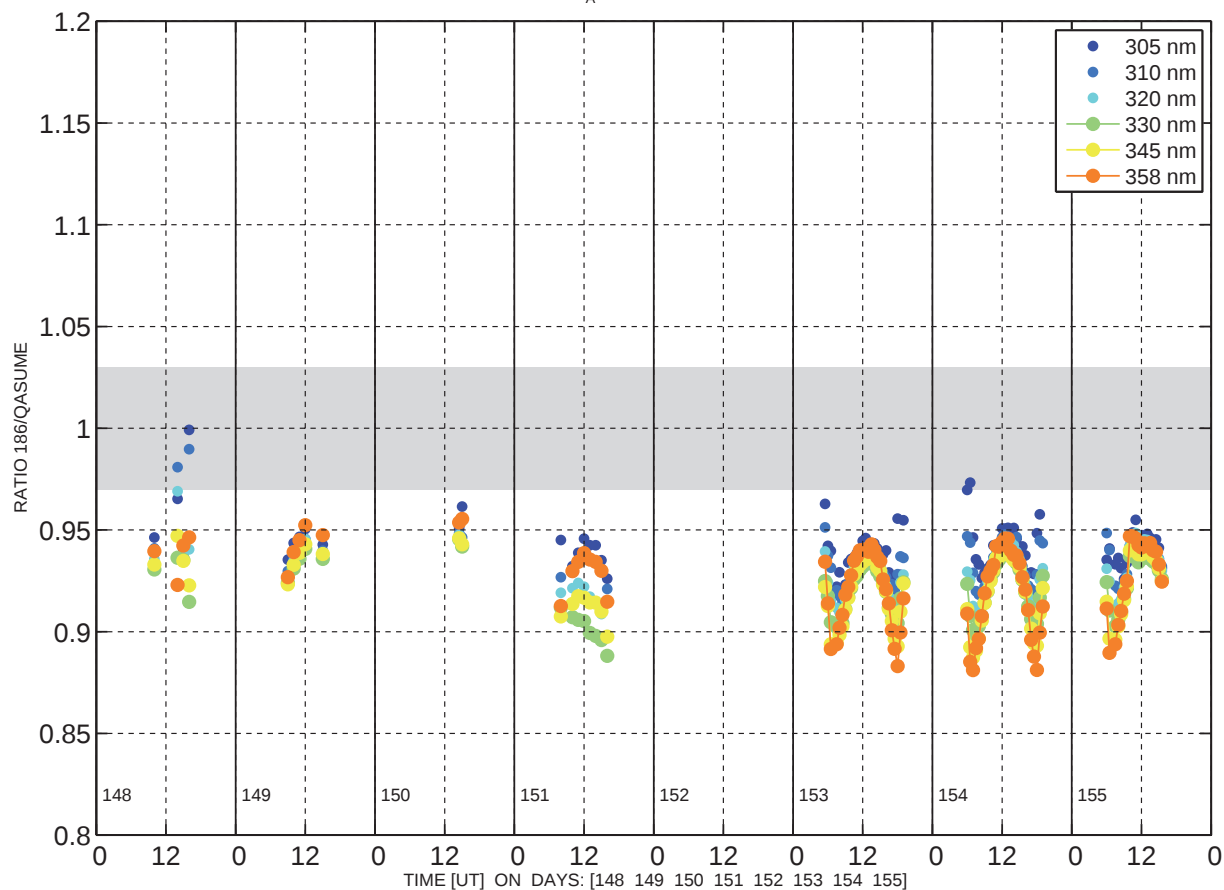




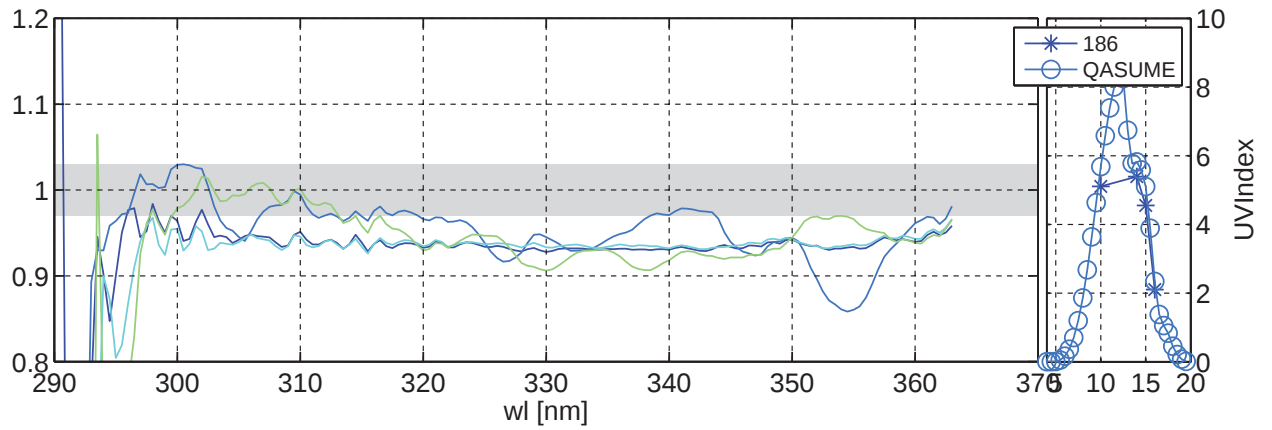
Global irradiance ratios 186/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



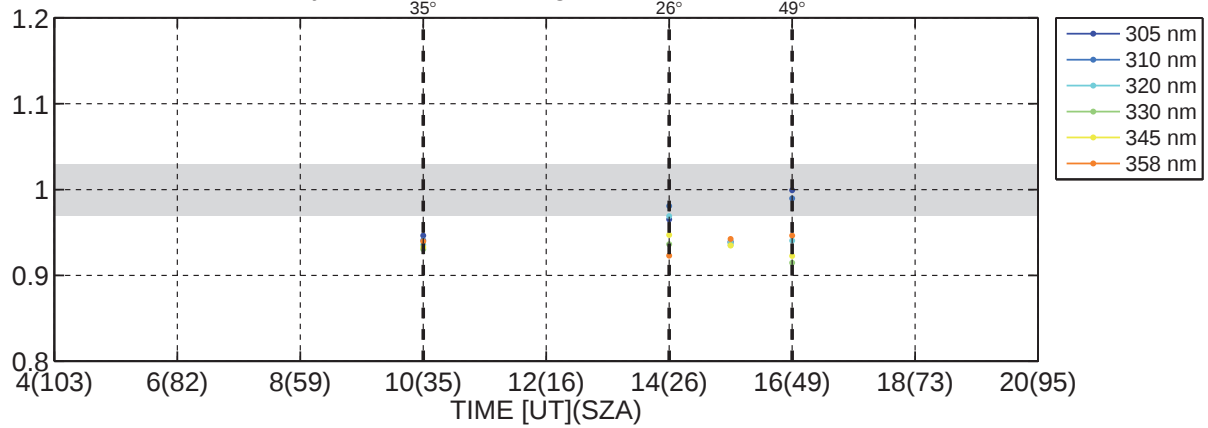
Global irradiance ratios 186/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



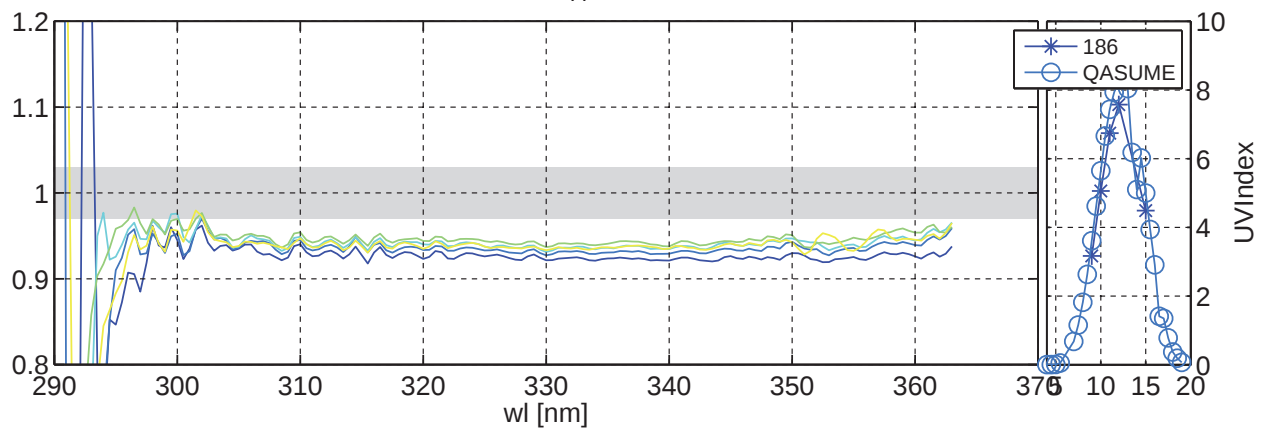
Global irradiance ratios 186/QASUME at El_A renosillo-matshic:28-May-2015(148)



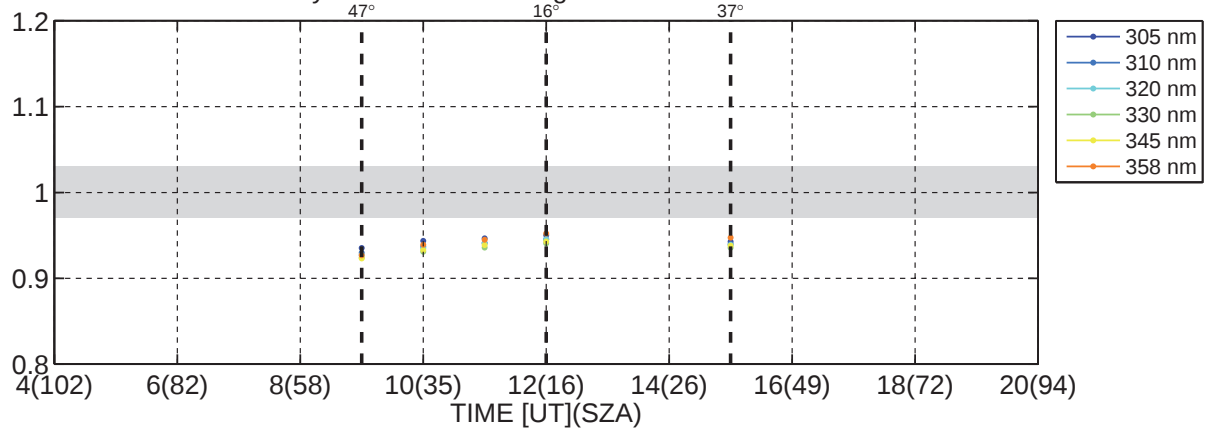
Daily variation. Wavelength bands are ± 2.5 nm



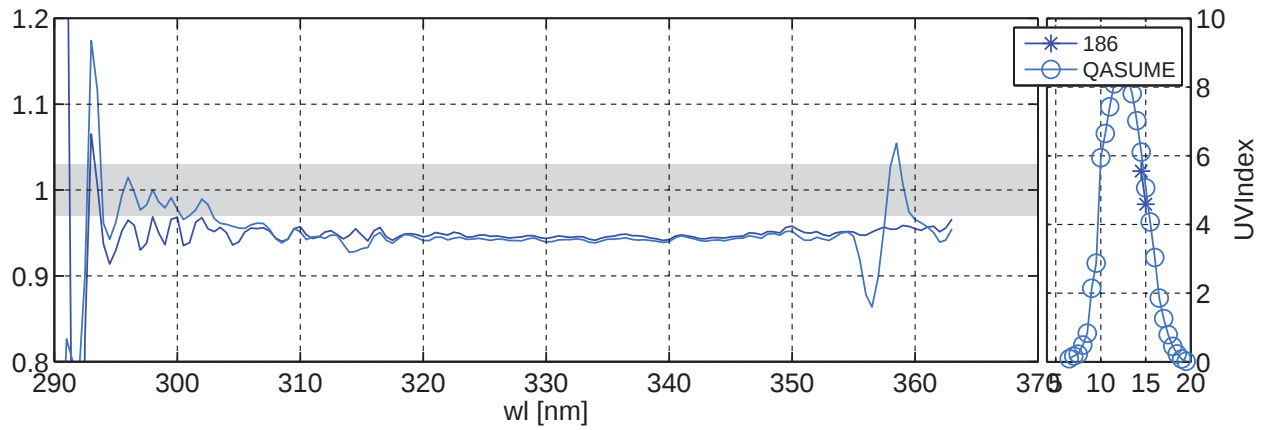
Global irradiance ratios 186/QASUME at El_A renosillo-matshic:29-May-2015(149)



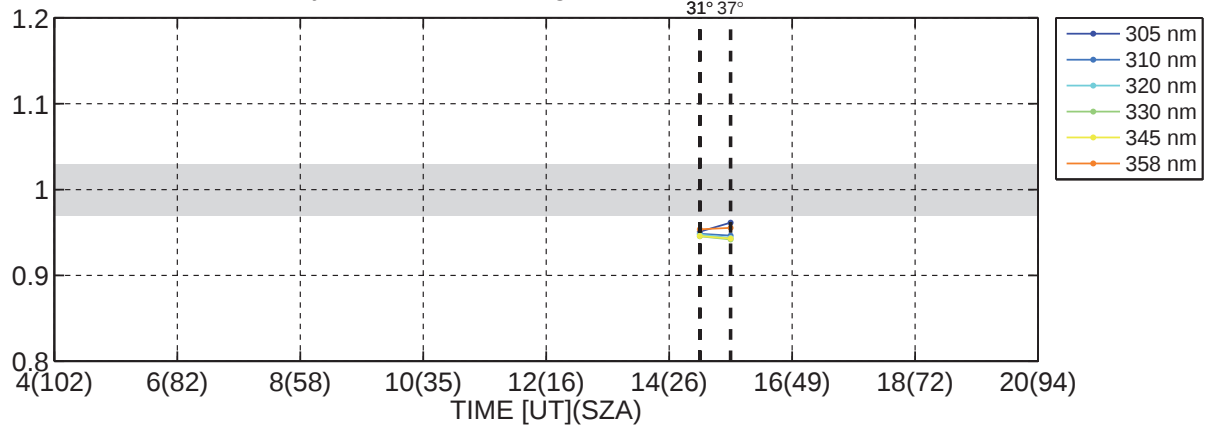
Daily variation. Wavelength bands are ± 2.5 nm



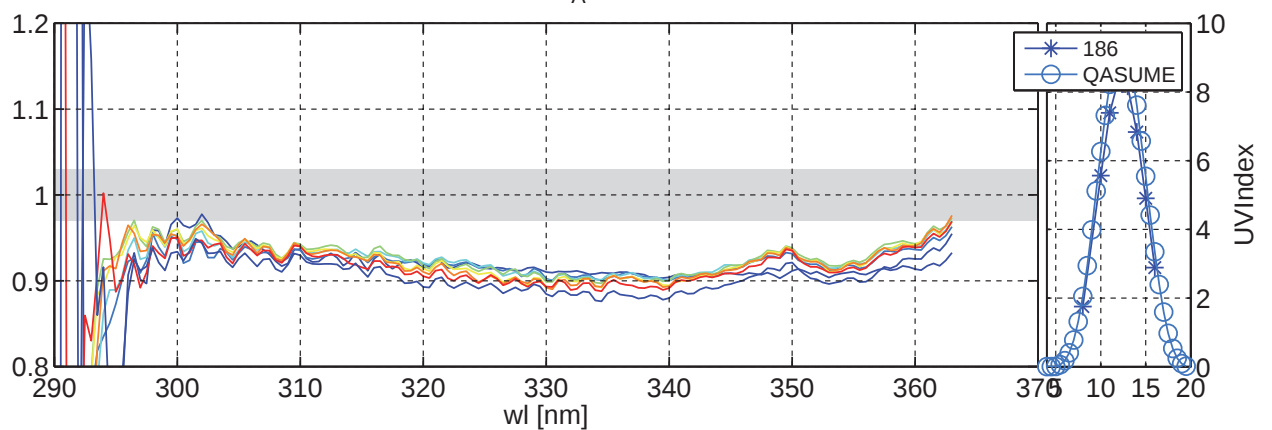
Global irradiance ratios 186/QASUME at El_A renosillo-matshic:30-May-2015(150)



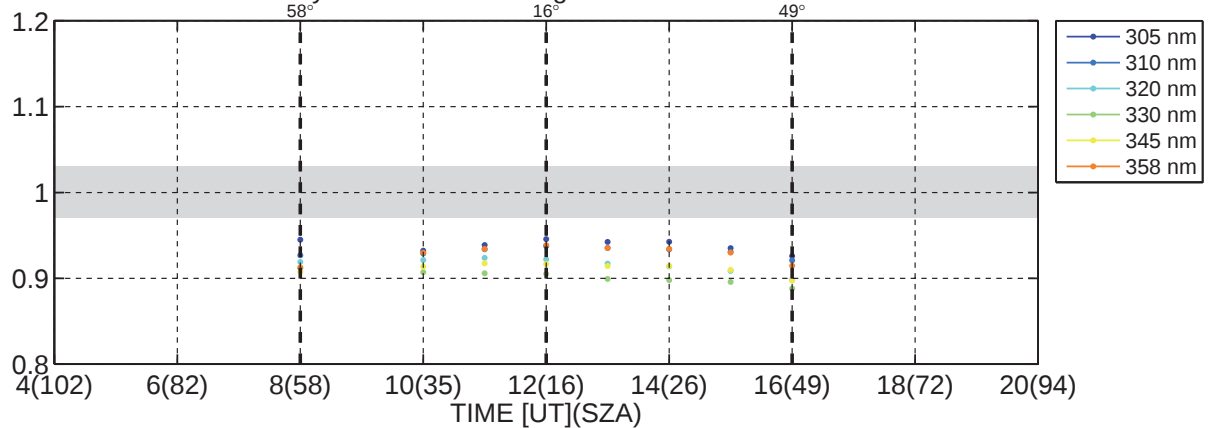
Daily variation. Wavelength bands are ± 2.5 nm



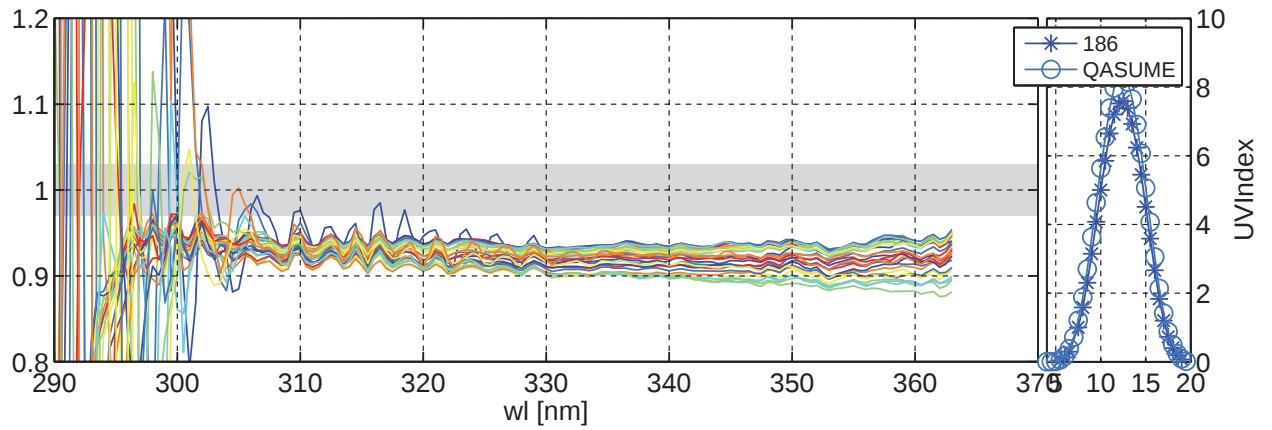
Global irradiance ratios 186/QASUME at El_A renosillo-matshic:31-May-2015(151)



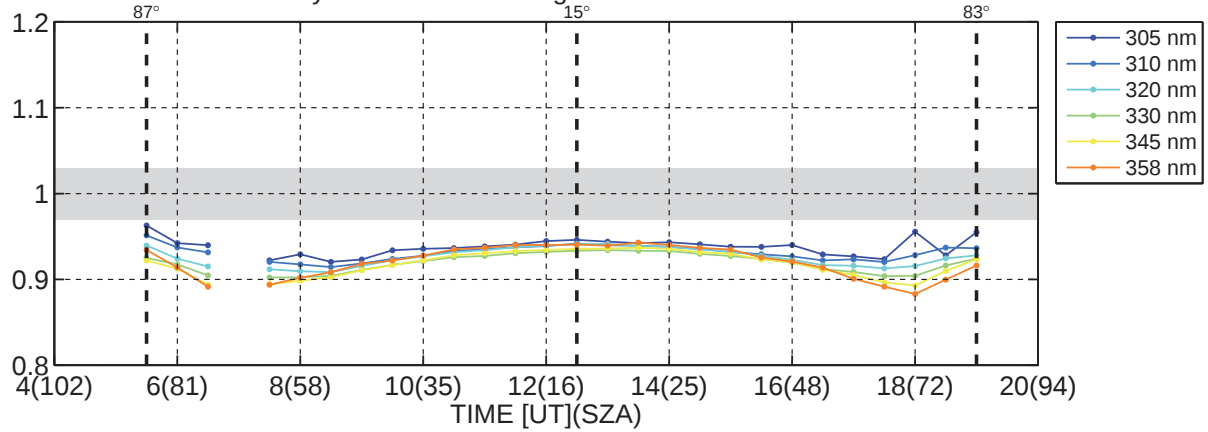
Daily variation. Wavelength bands are ± 2.5 nm



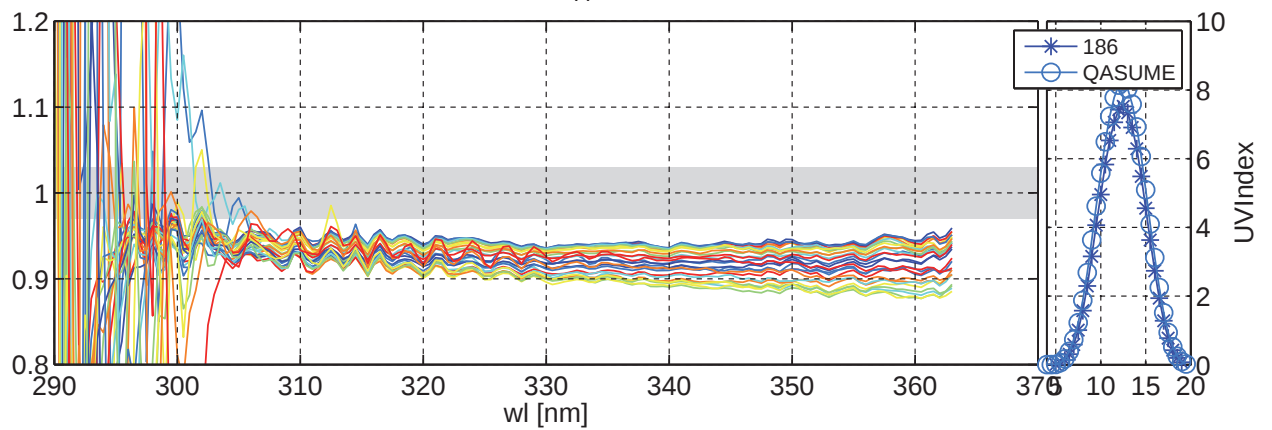
Global irradiance ratios 186/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



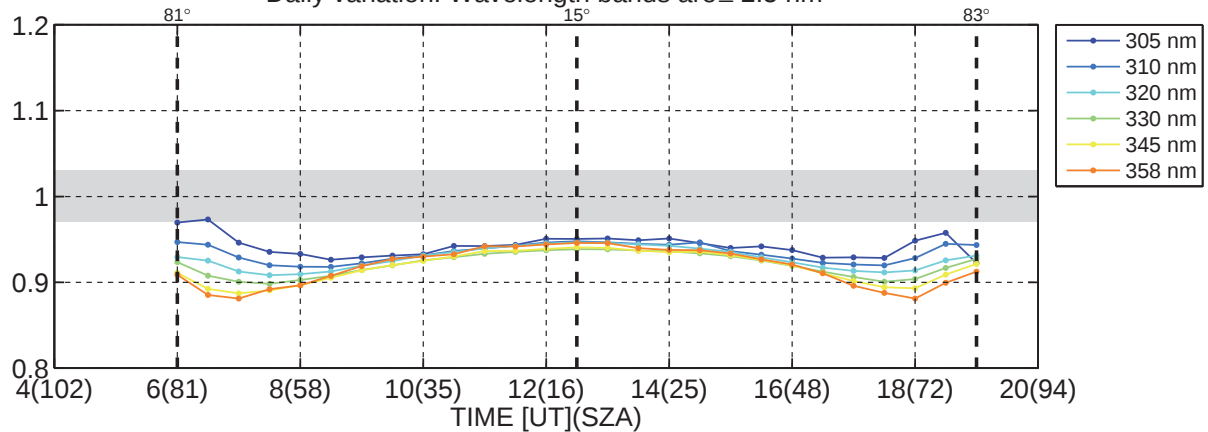
Daily variation. Wavelength bands are ± 2.5 nm



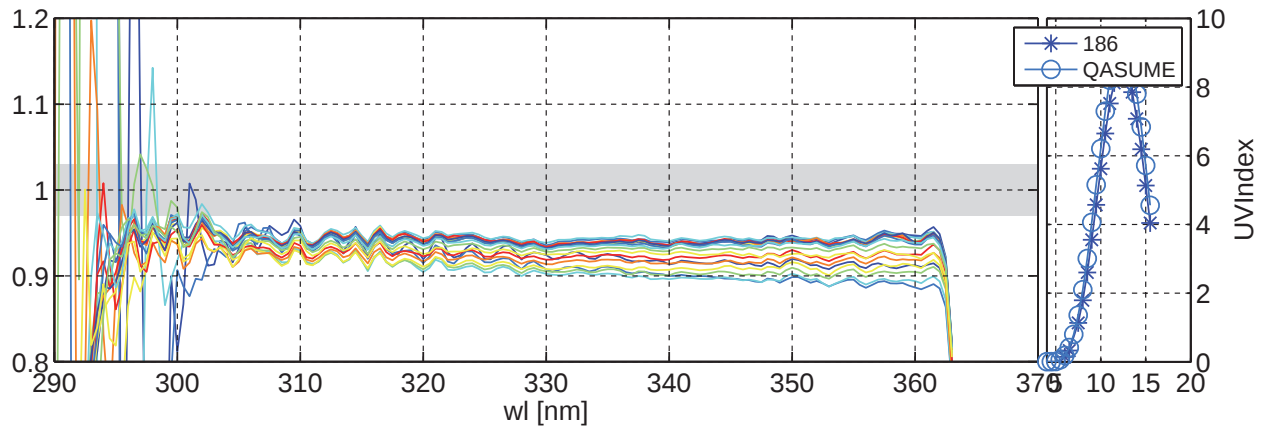
Global irradiance ratios 186/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



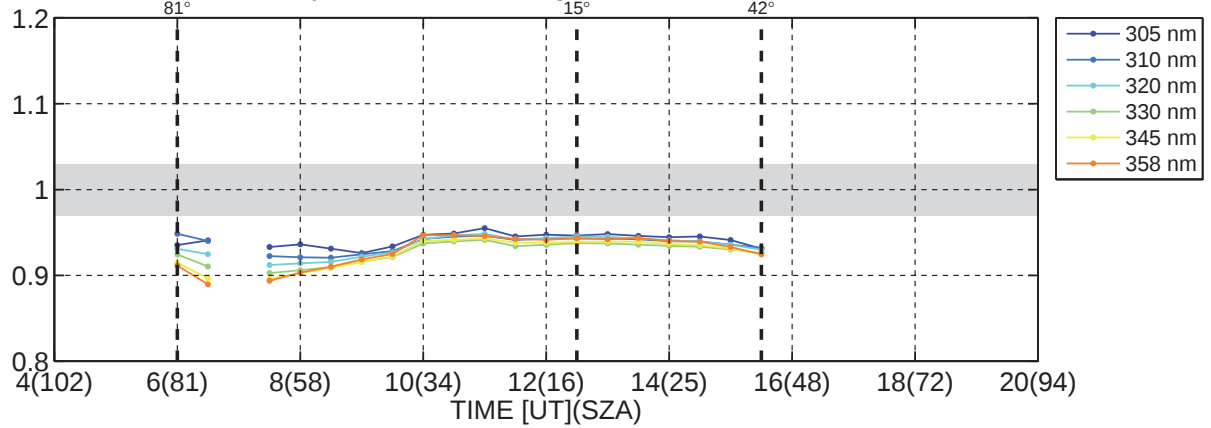
Daily variation. Wavelength bands are ± 2.5 nm



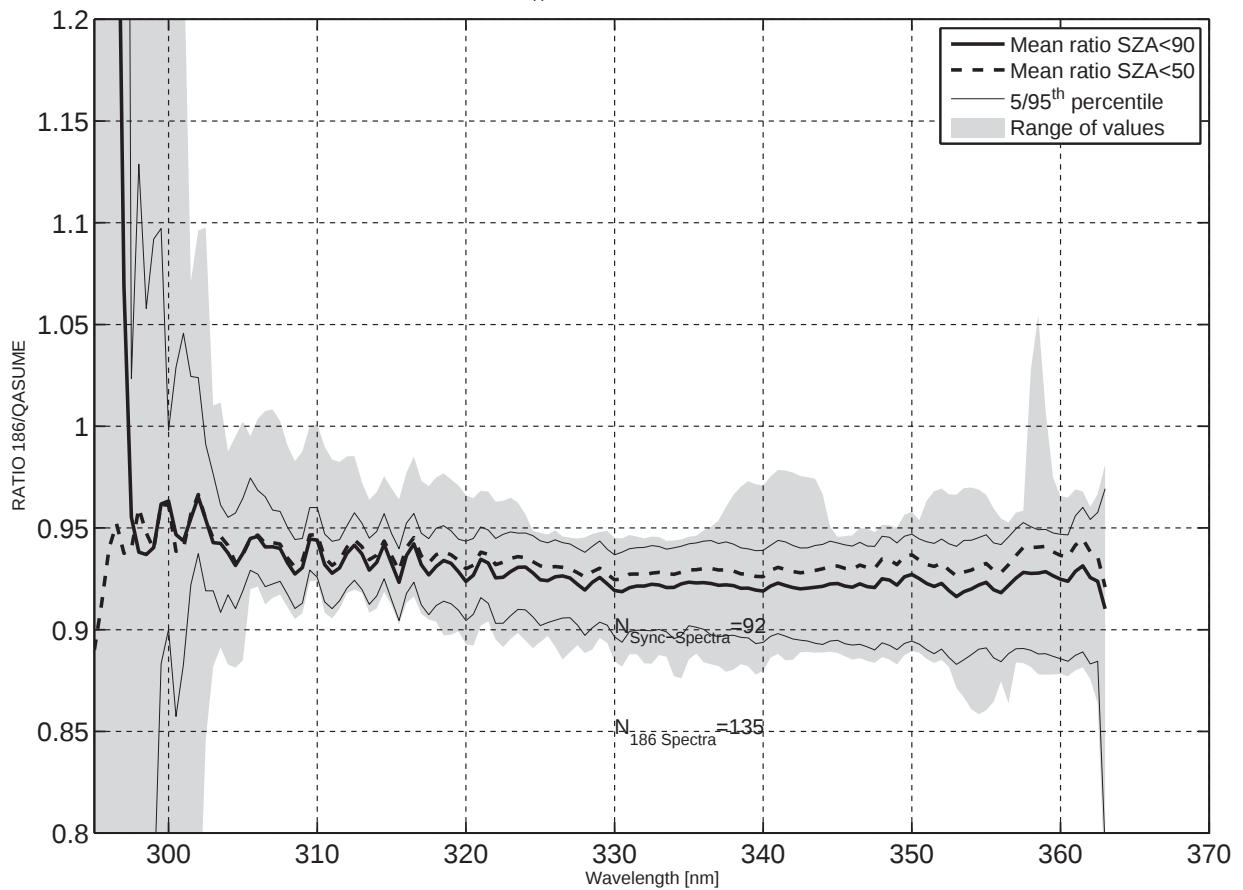
Global irradiance ratios 186/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



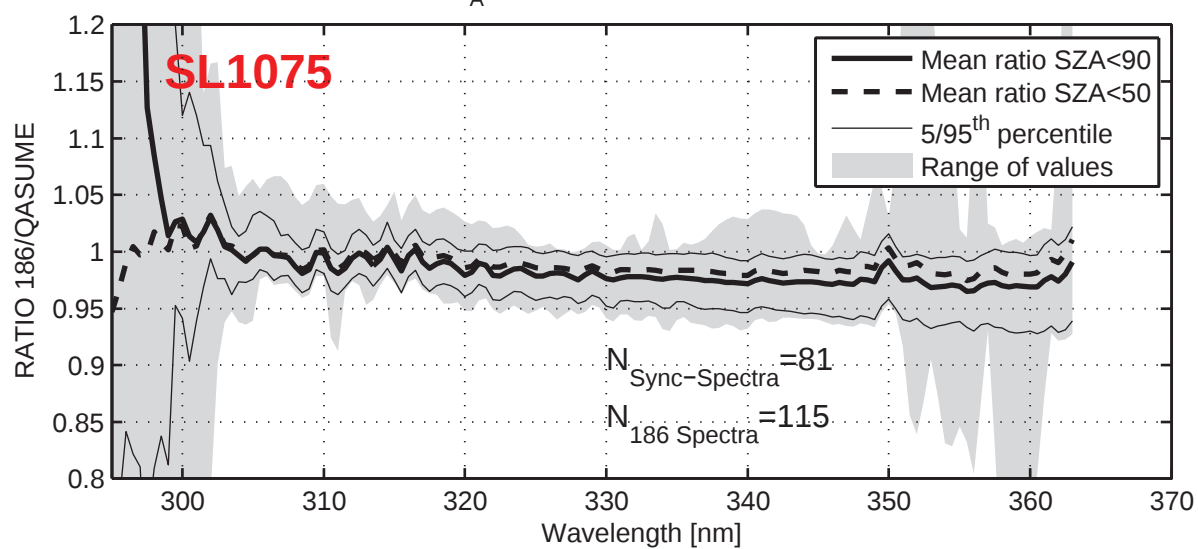
Daily variation. Wavelength bands are ± 2.5 nm



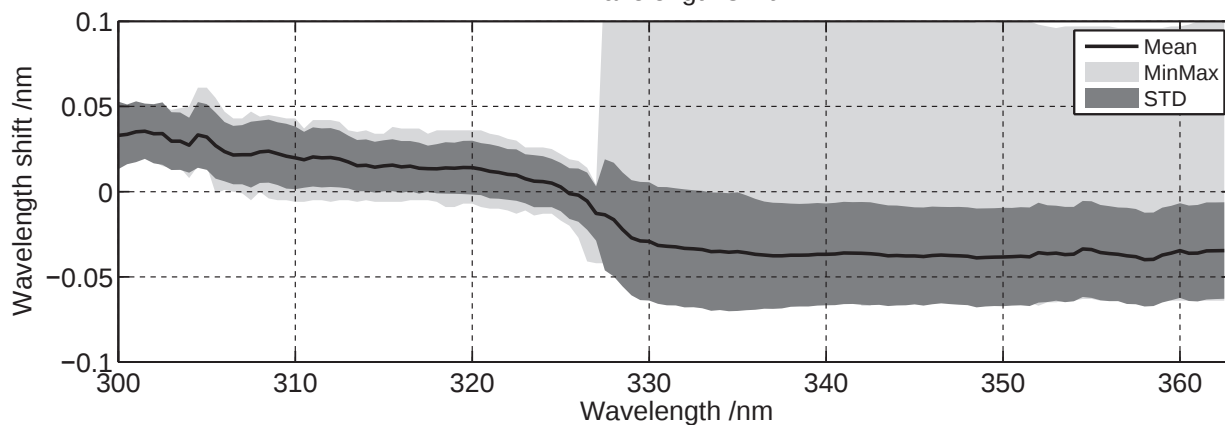
Mean ratio 186/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



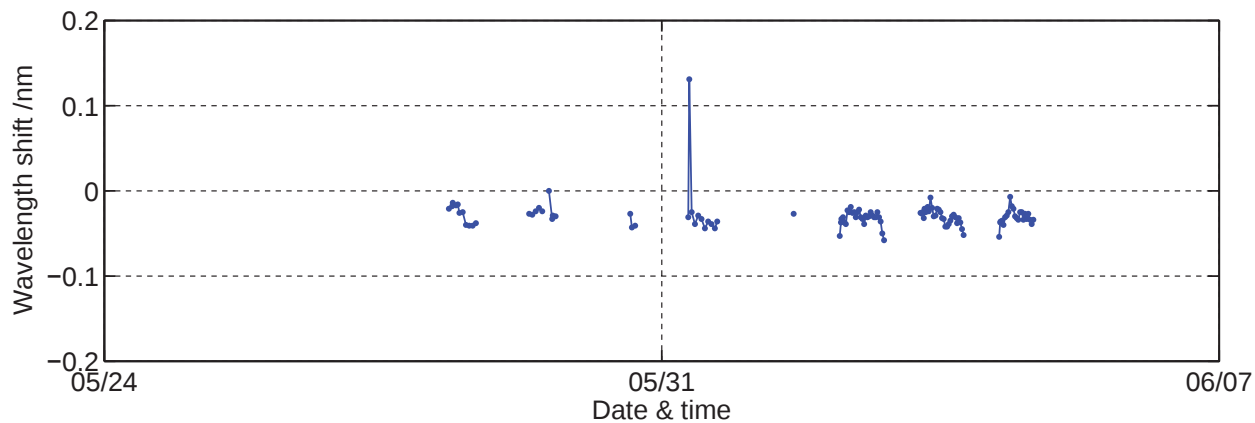
Mean ratio 186/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



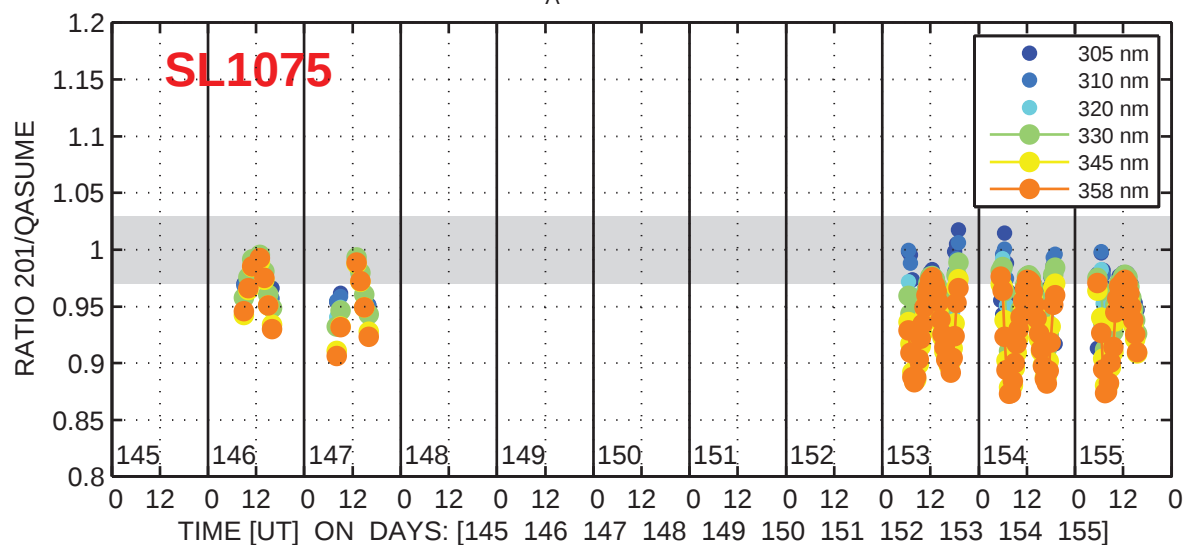
Wavelength shift



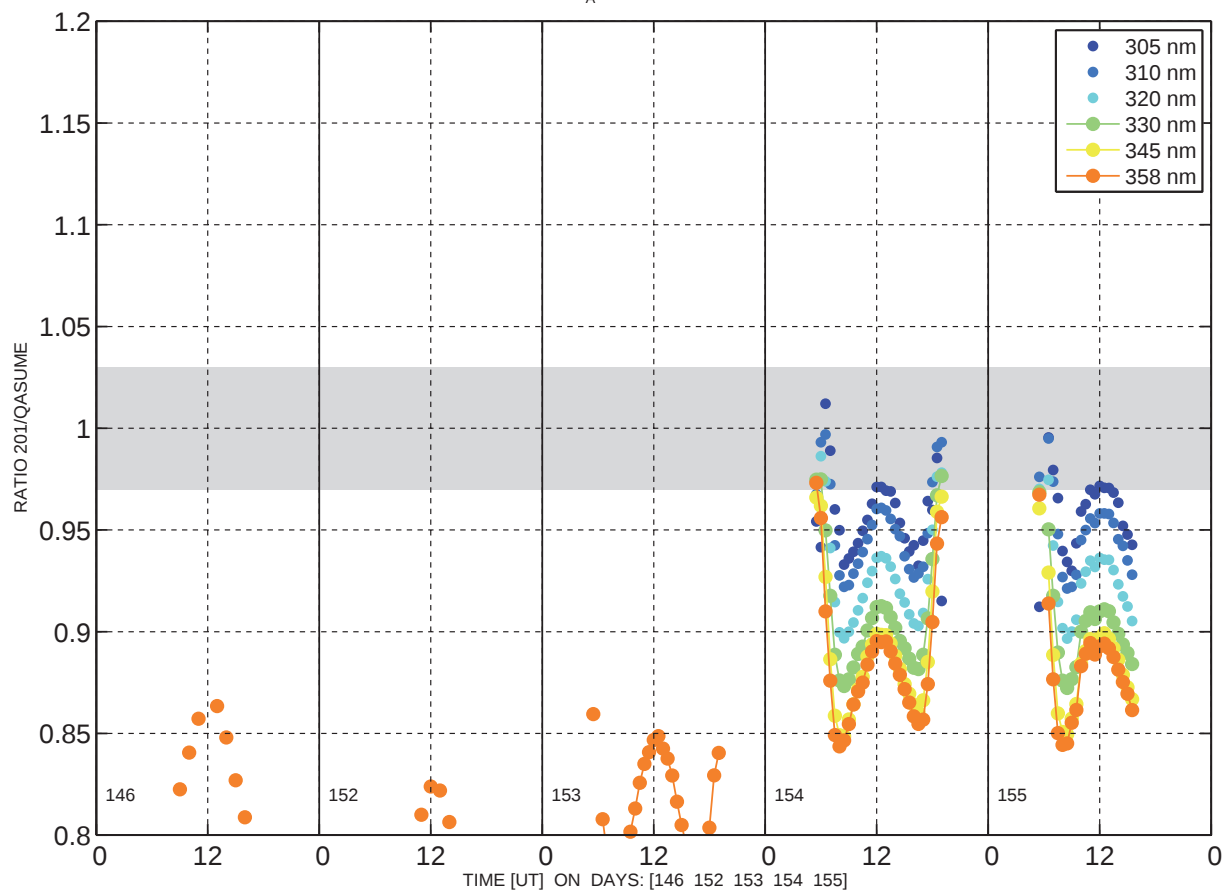
WL=330.00 nm



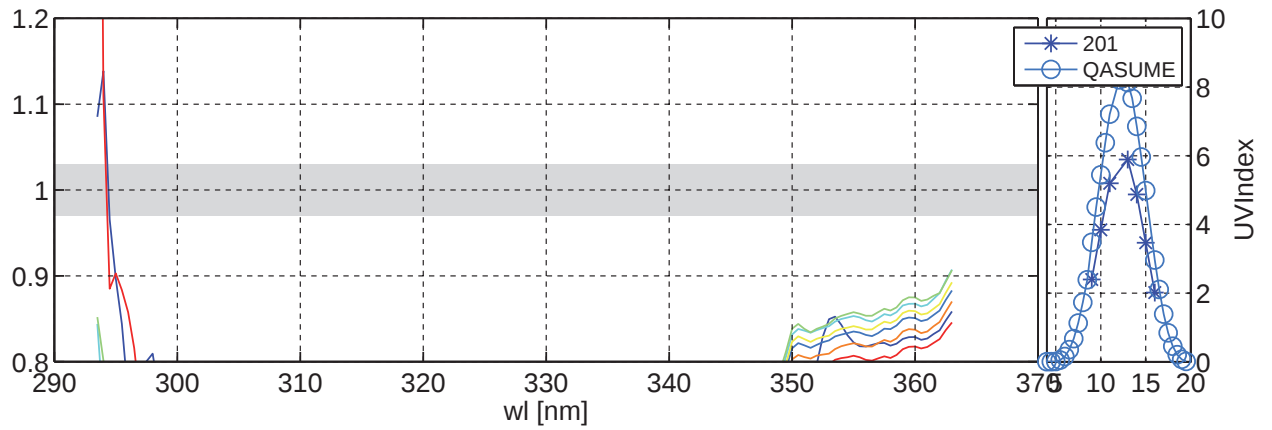
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:25-May-2015(145) to 04-Jun-2015(155)



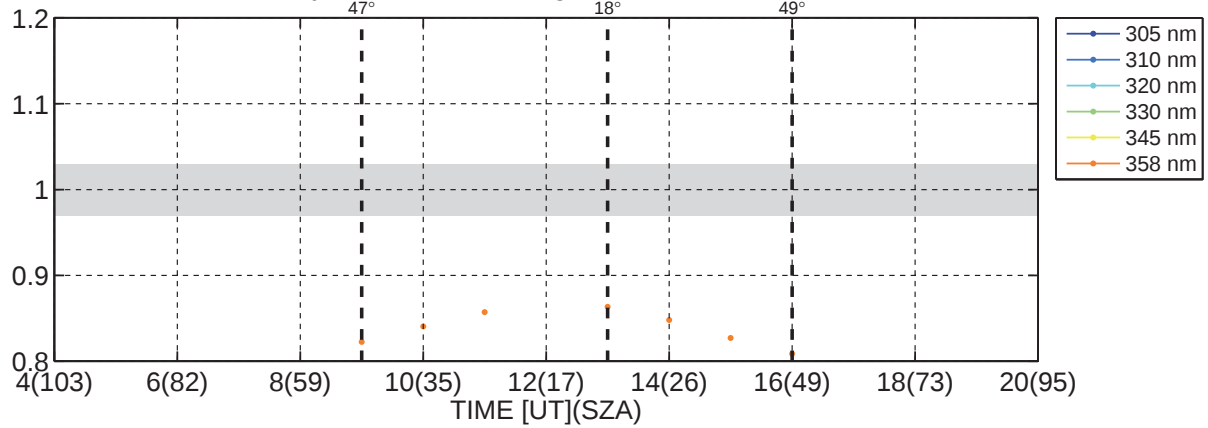
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:26-May-2015(146) to 04-Jun-2015(155)



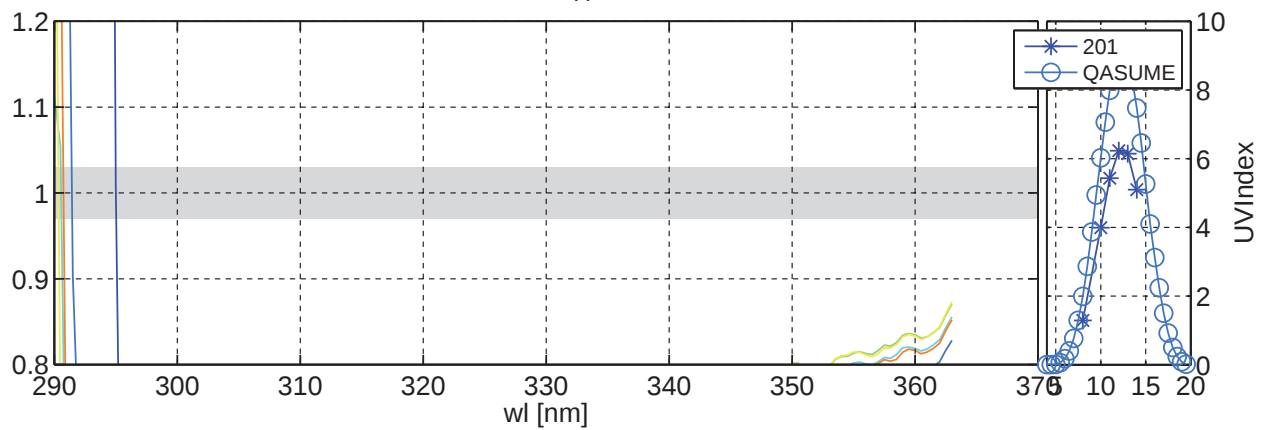
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:26-May-2015(146)



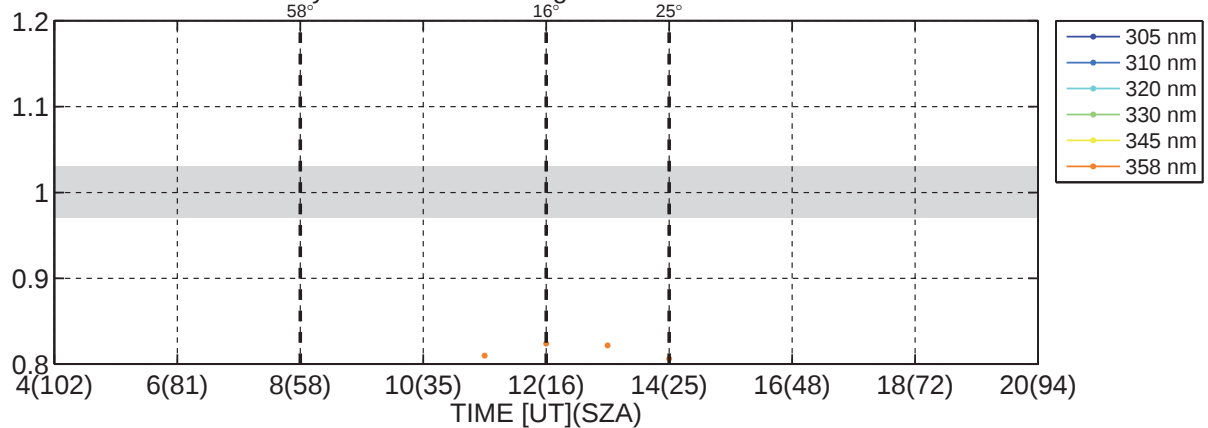
Daily variation. Wavelength bands are ± 2.5 nm



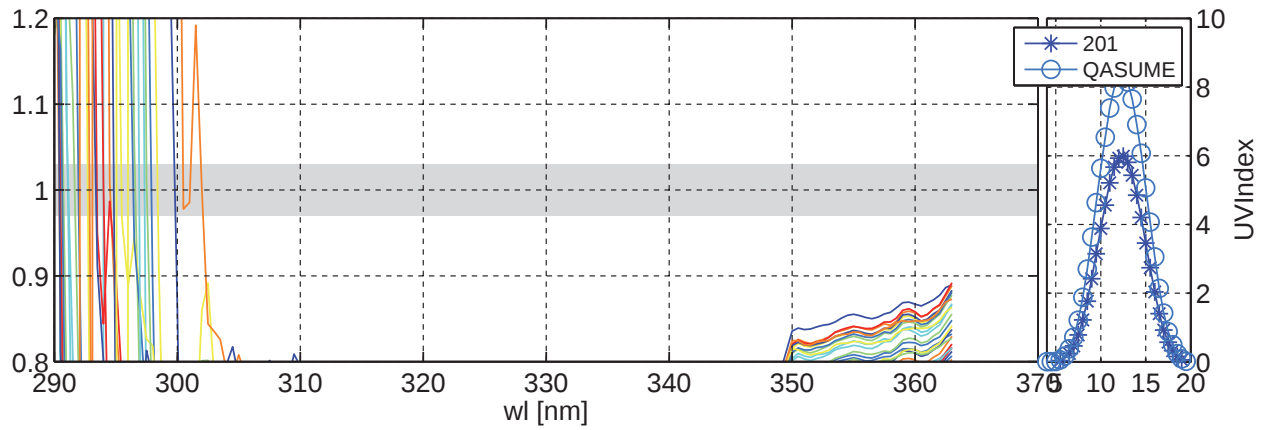
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



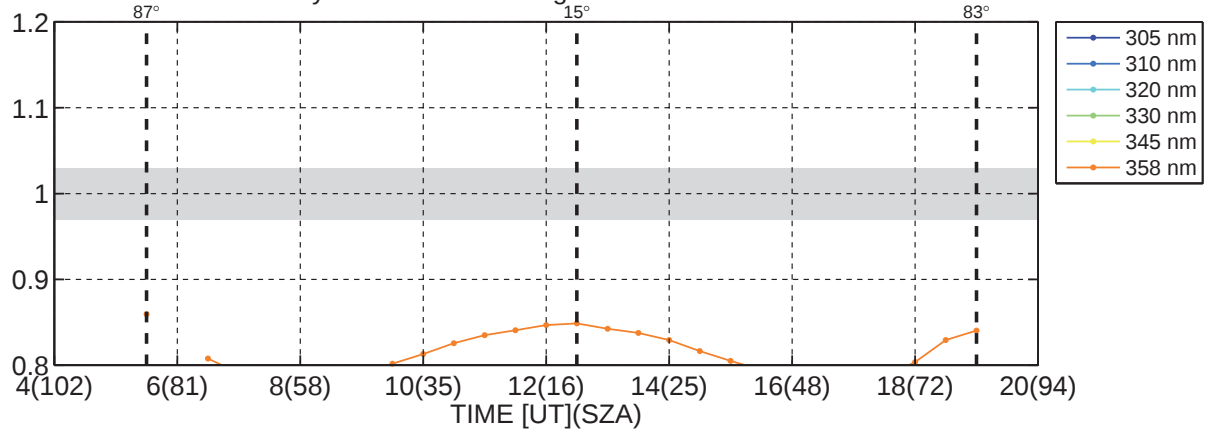
Daily variation. Wavelength bands are ± 2.5 nm



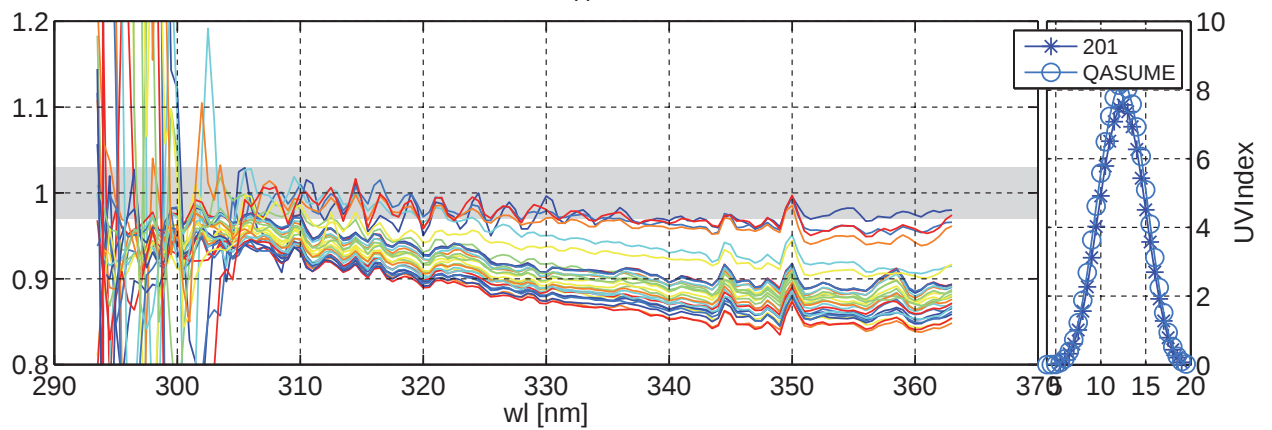
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



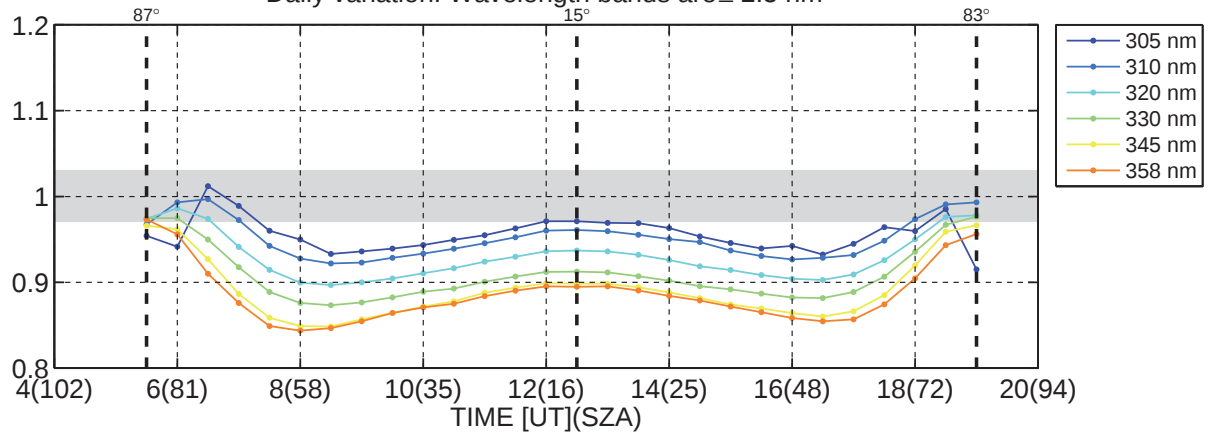
Daily variation. Wavelength bands are ± 2.5 nm



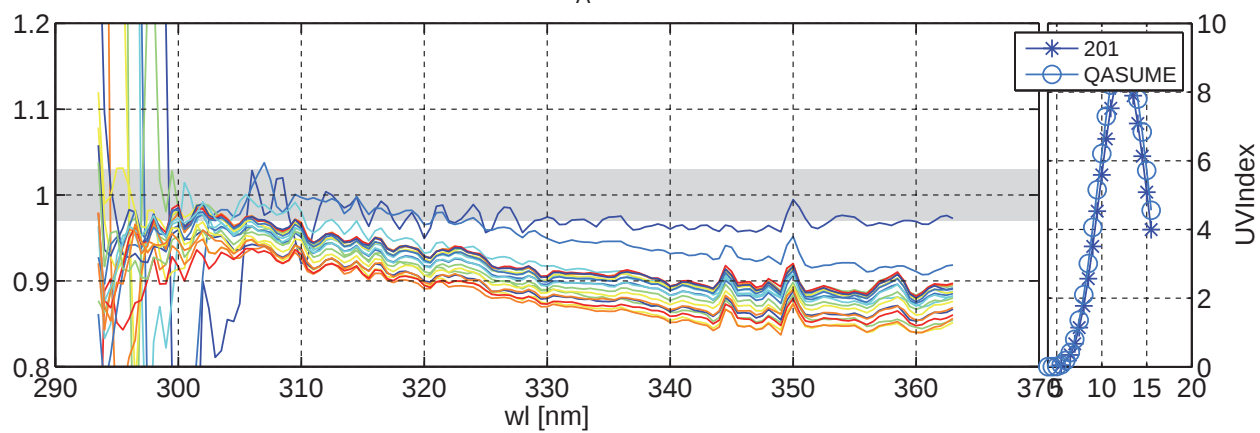
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



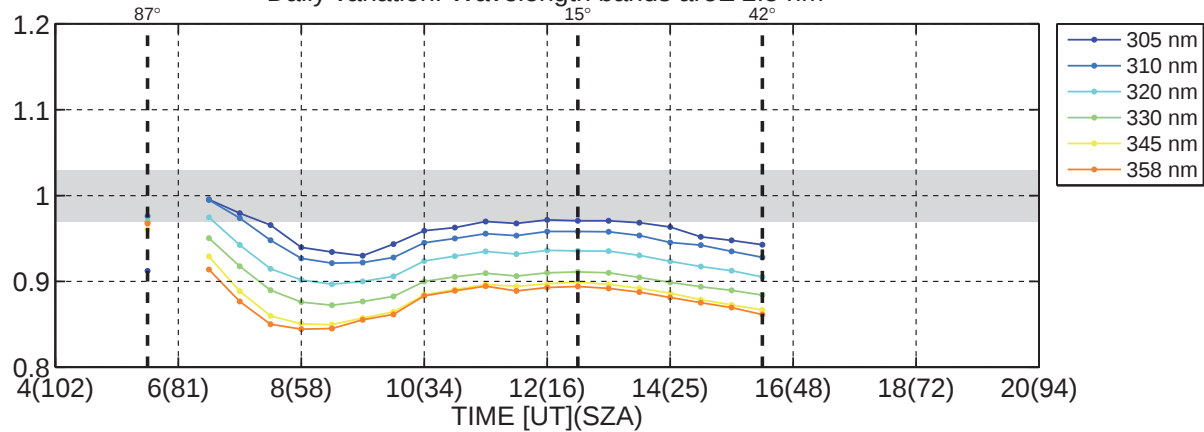
Daily variation. Wavelength bands are ± 2.5 nm

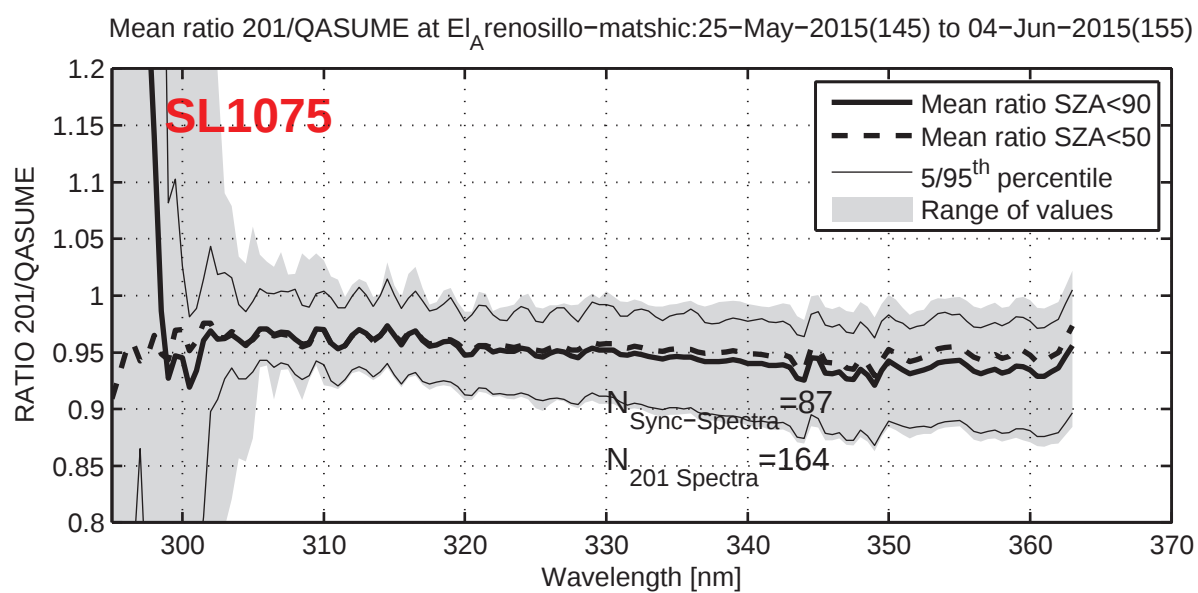
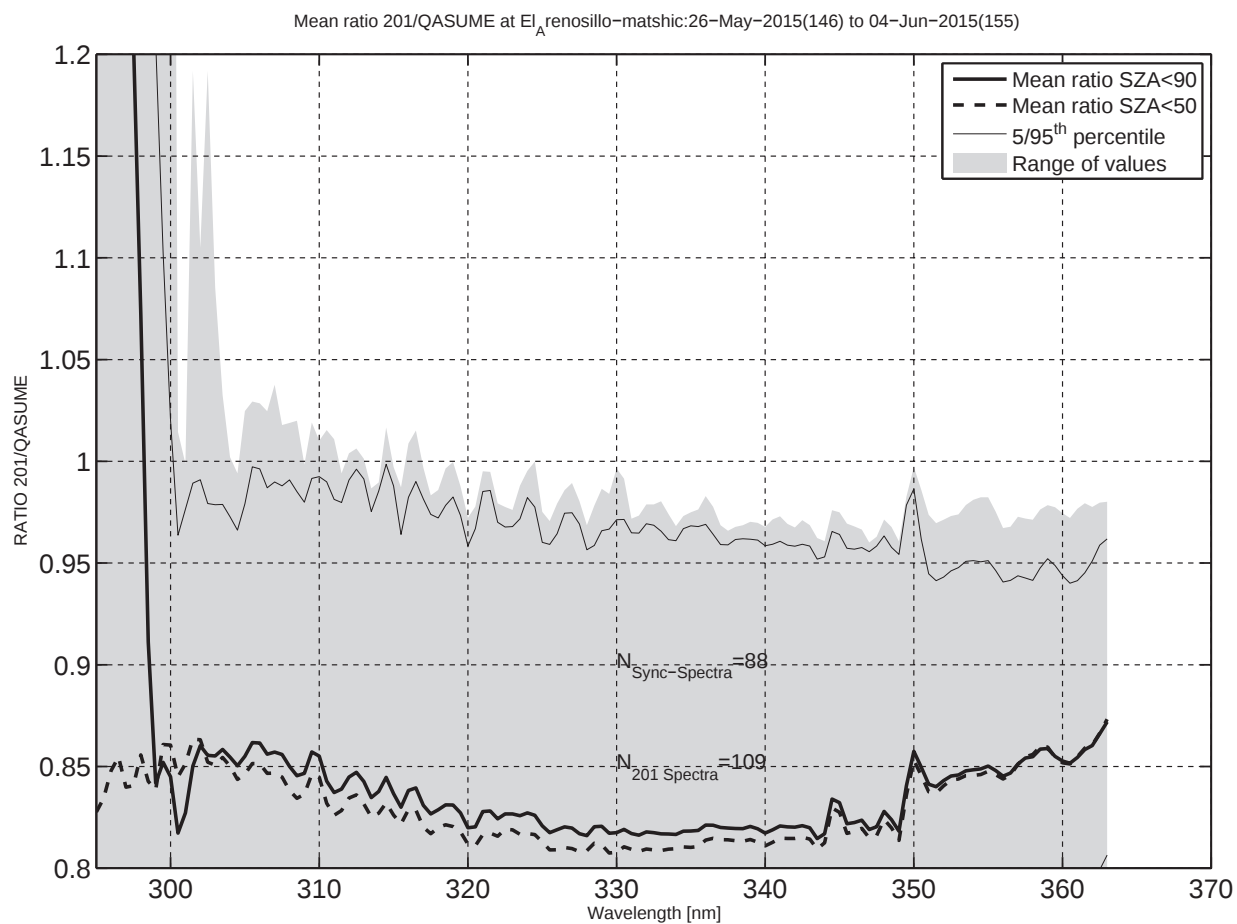


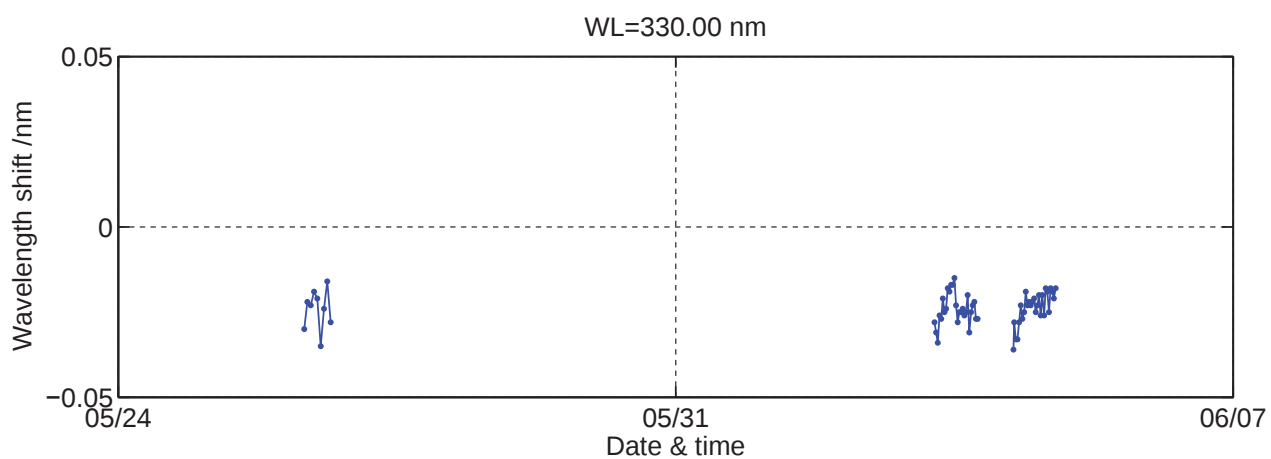
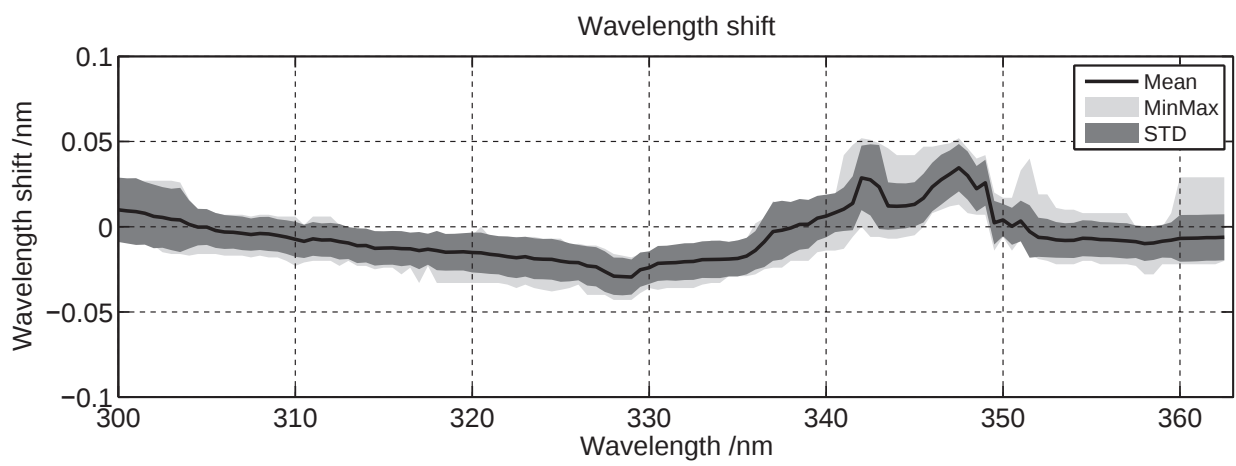
Global irradiance ratios 201/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



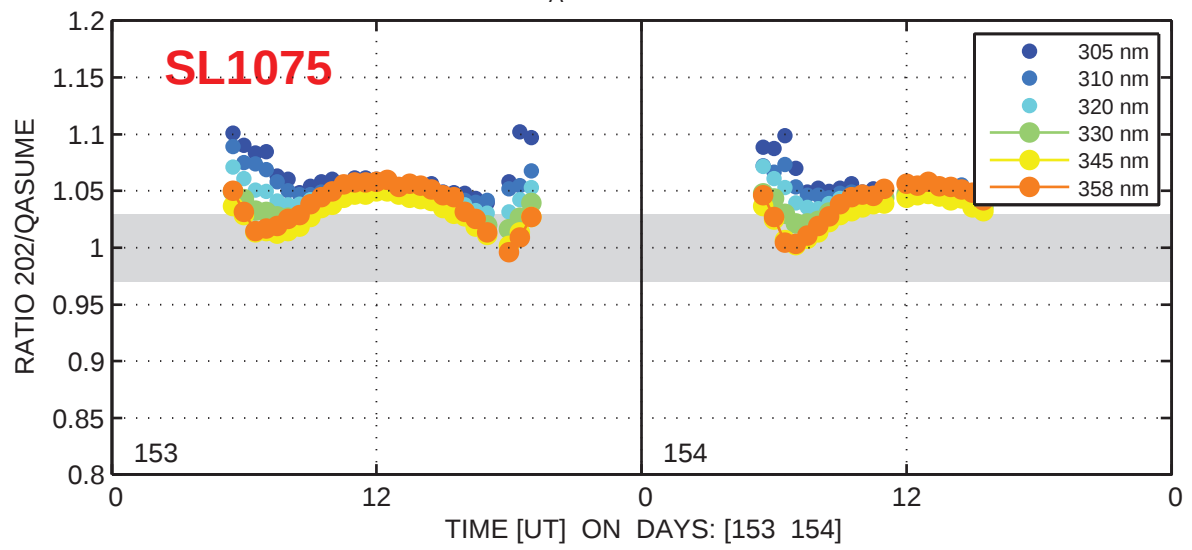
Daily variation. Wavelength bands are ± 2.5 nm



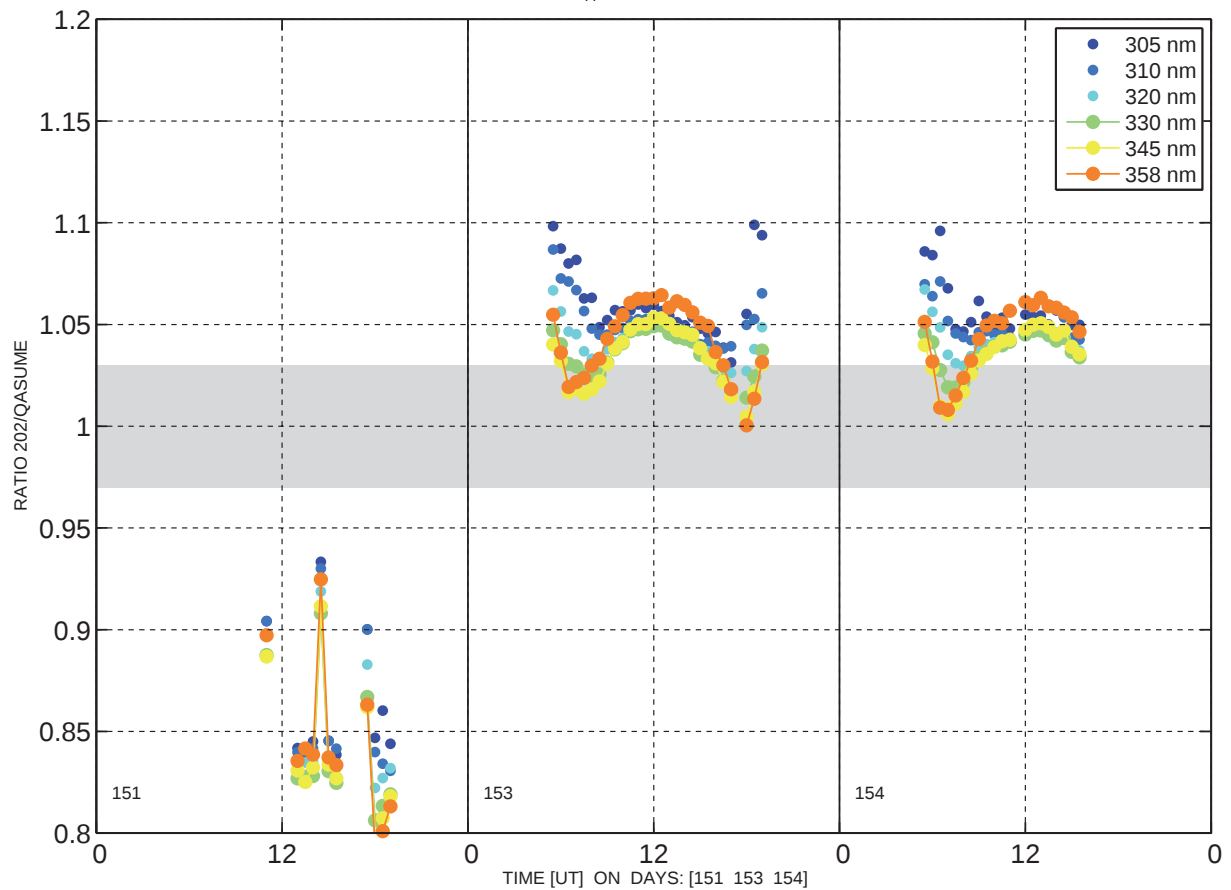




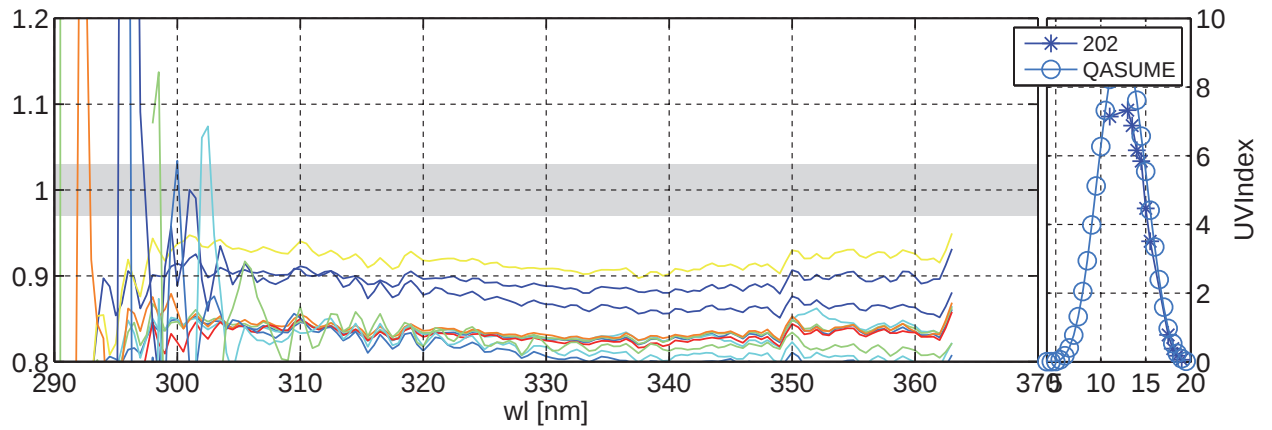
Global irradiance ratios 202/QASUME at El_Arenosillo-matshic:02-Jun-2015(153) to 03-Jun-2015(



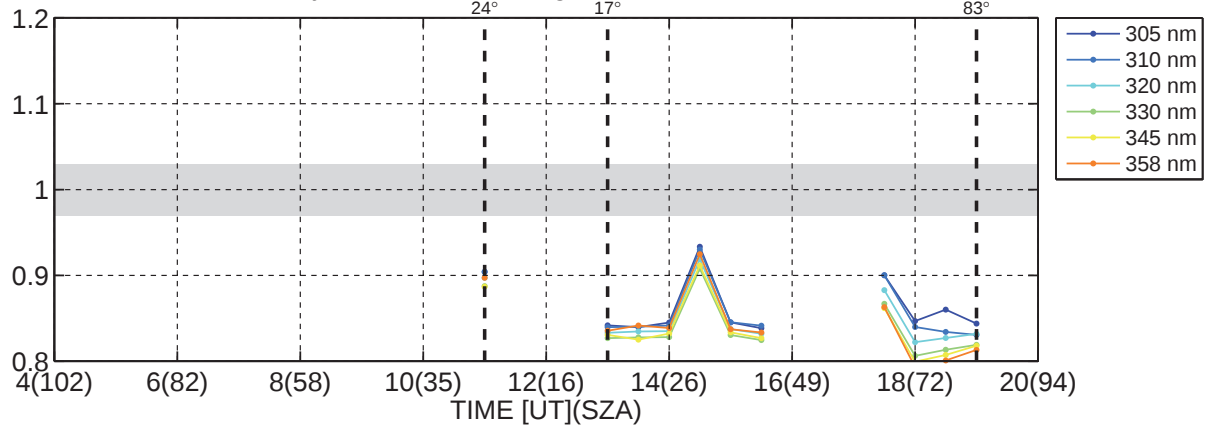
Global irradiance ratios 202/QASUME at El_Arenosillo-matshic:31-May-2015(151) to 03-Jun-2015(154)



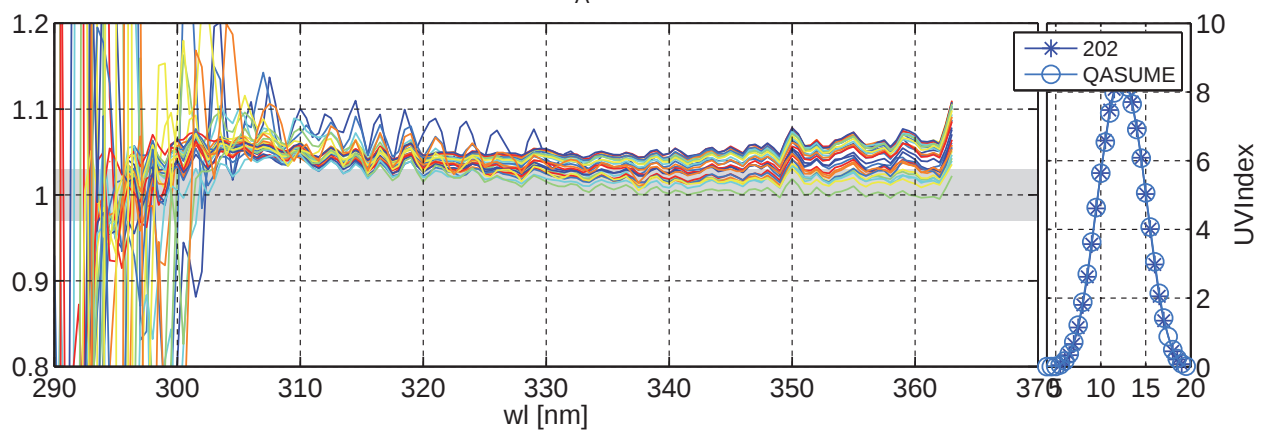
Global irradiance ratios 202/QASUME at El_Arenosillo-matshic:31-May-2015(151)



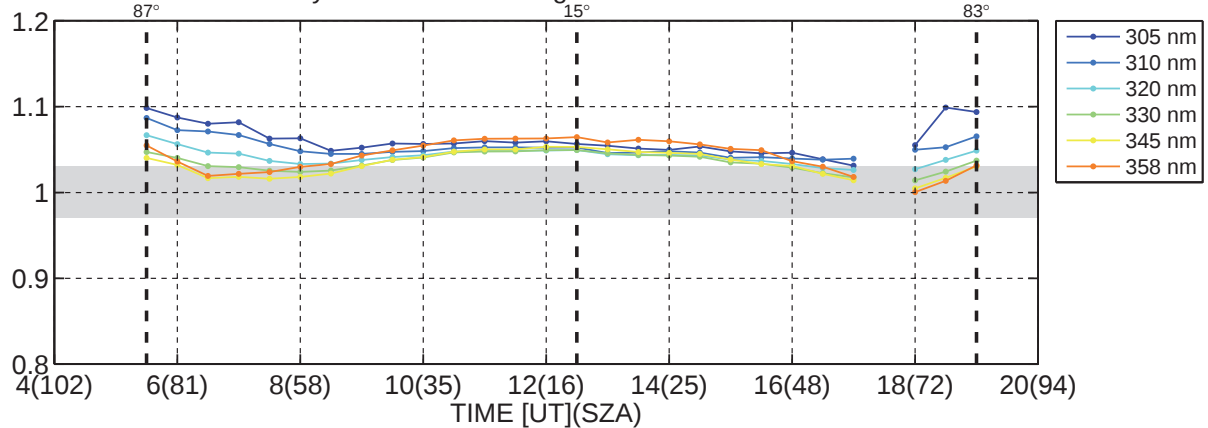
Daily variation. Wavelength bands are ± 2.5 nm



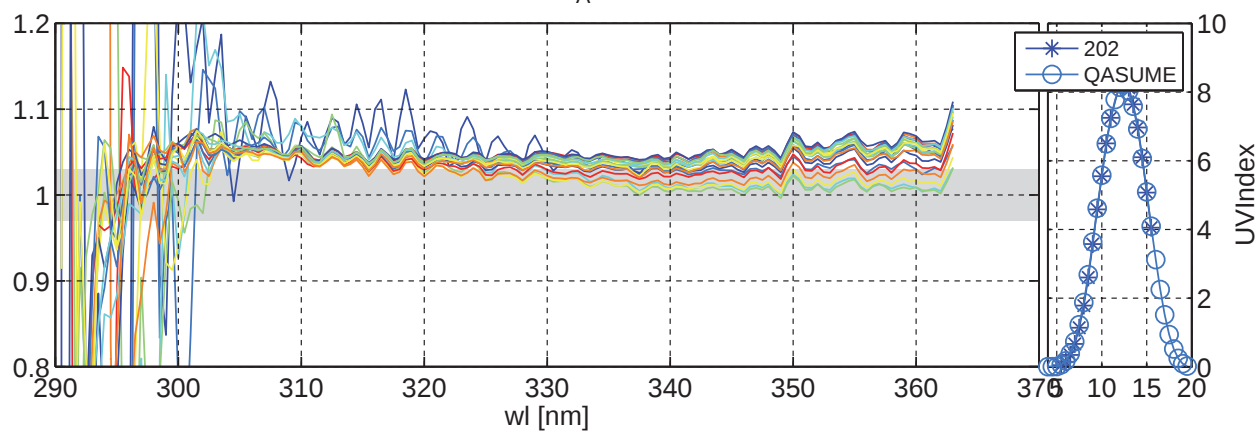
Global irradiance ratios 202/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



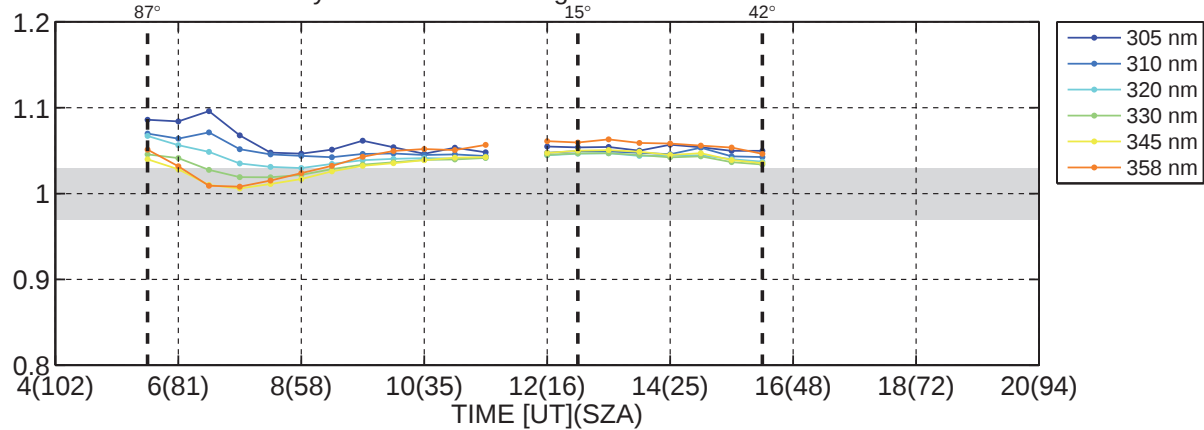
Daily variation. Wavelength bands are ± 2.5 nm

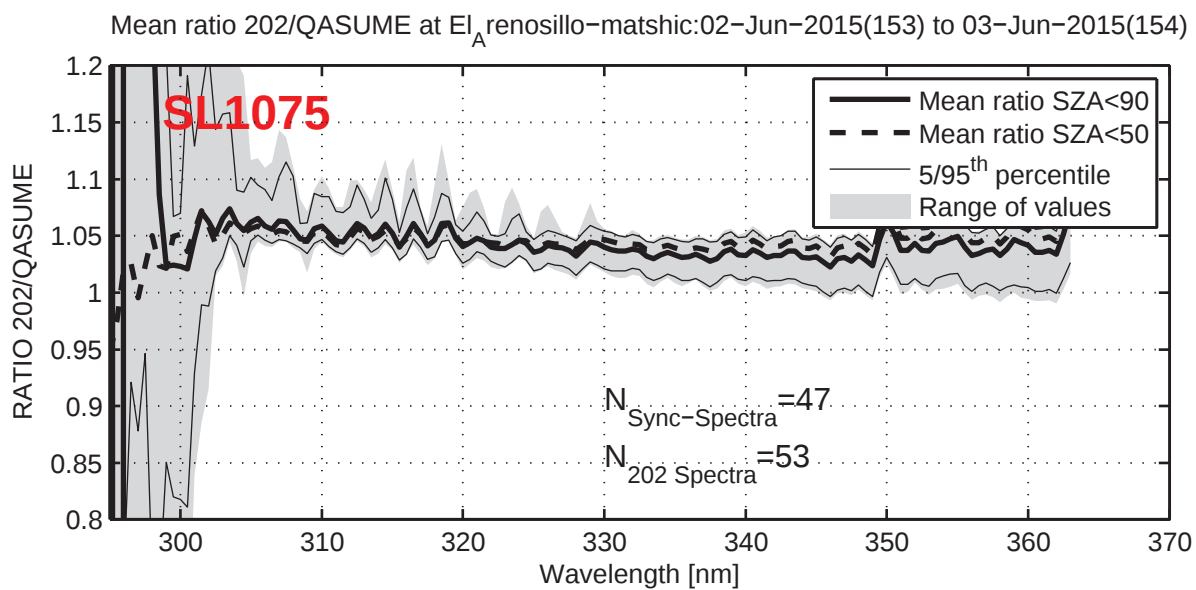
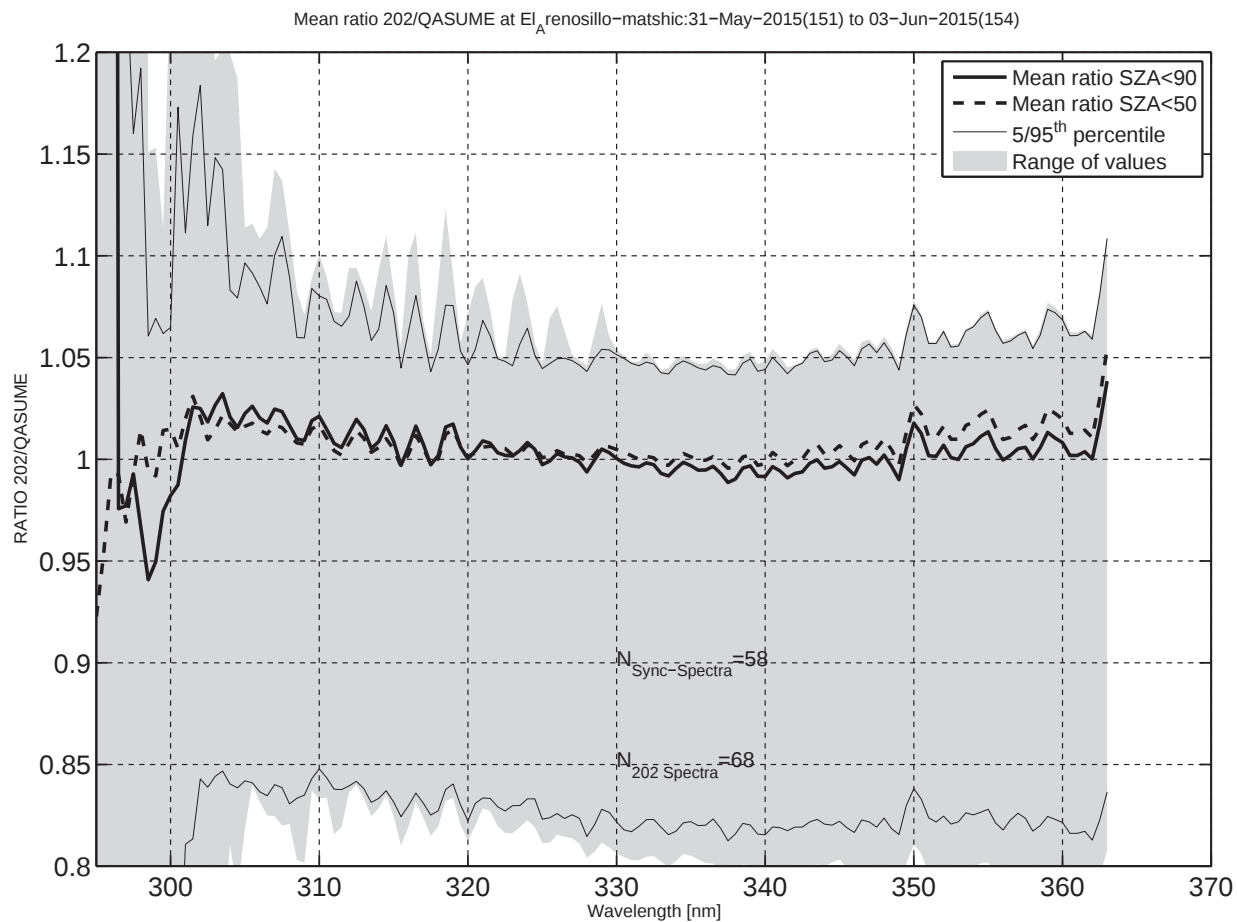


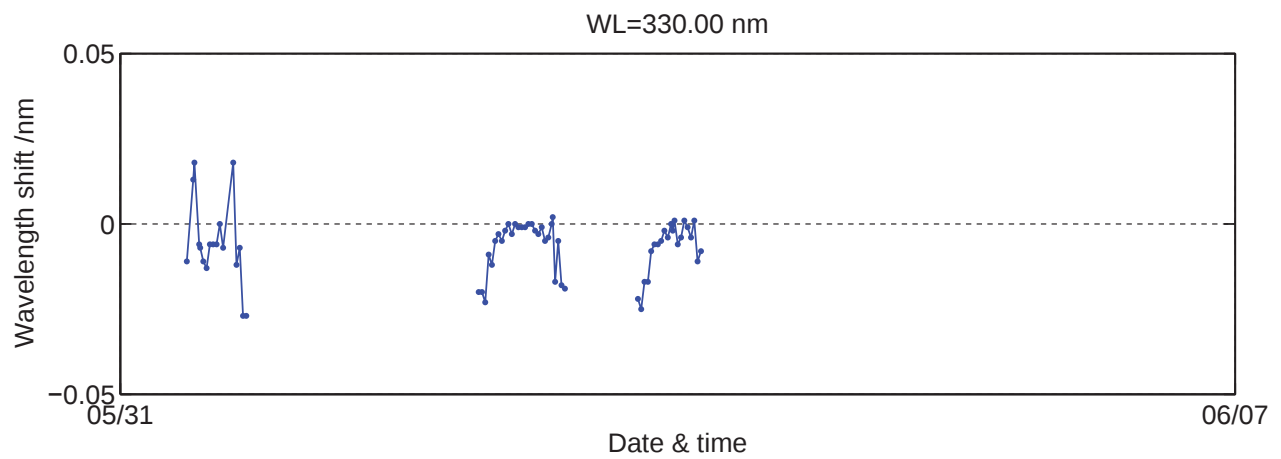
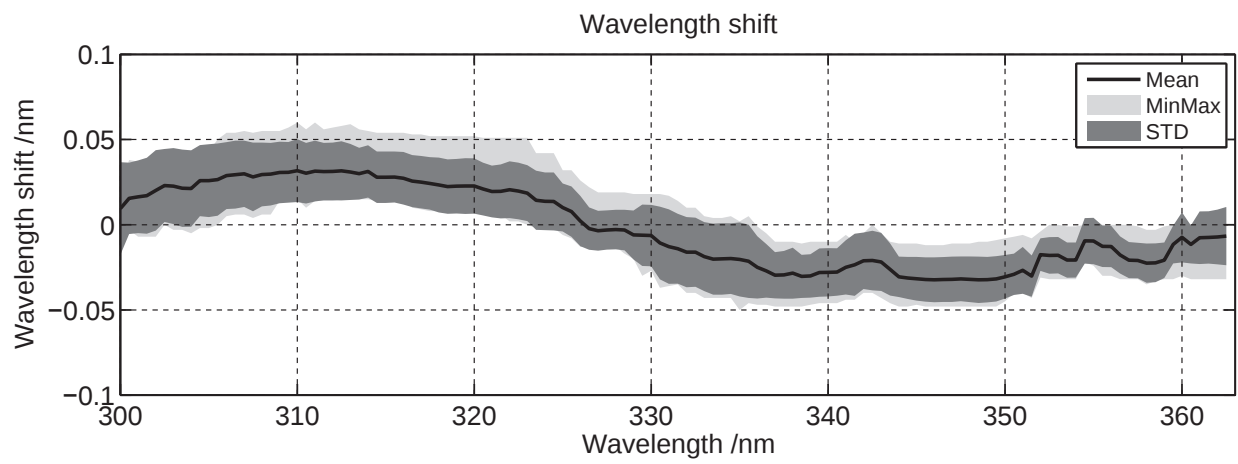
Global irradiance ratios 202/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



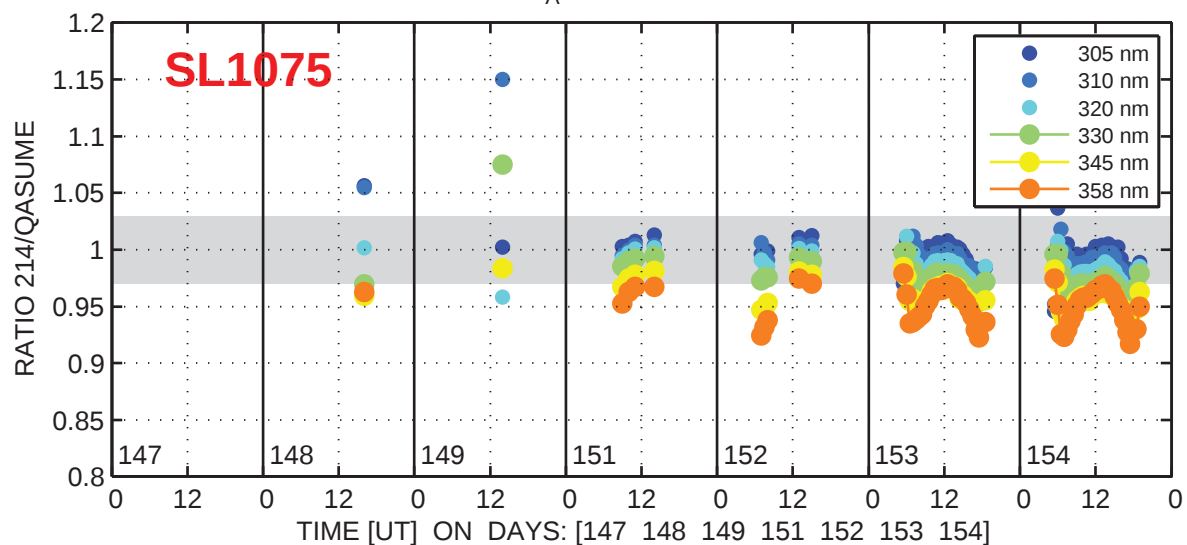
Daily variation. Wavelength bands are ± 2.5 nm



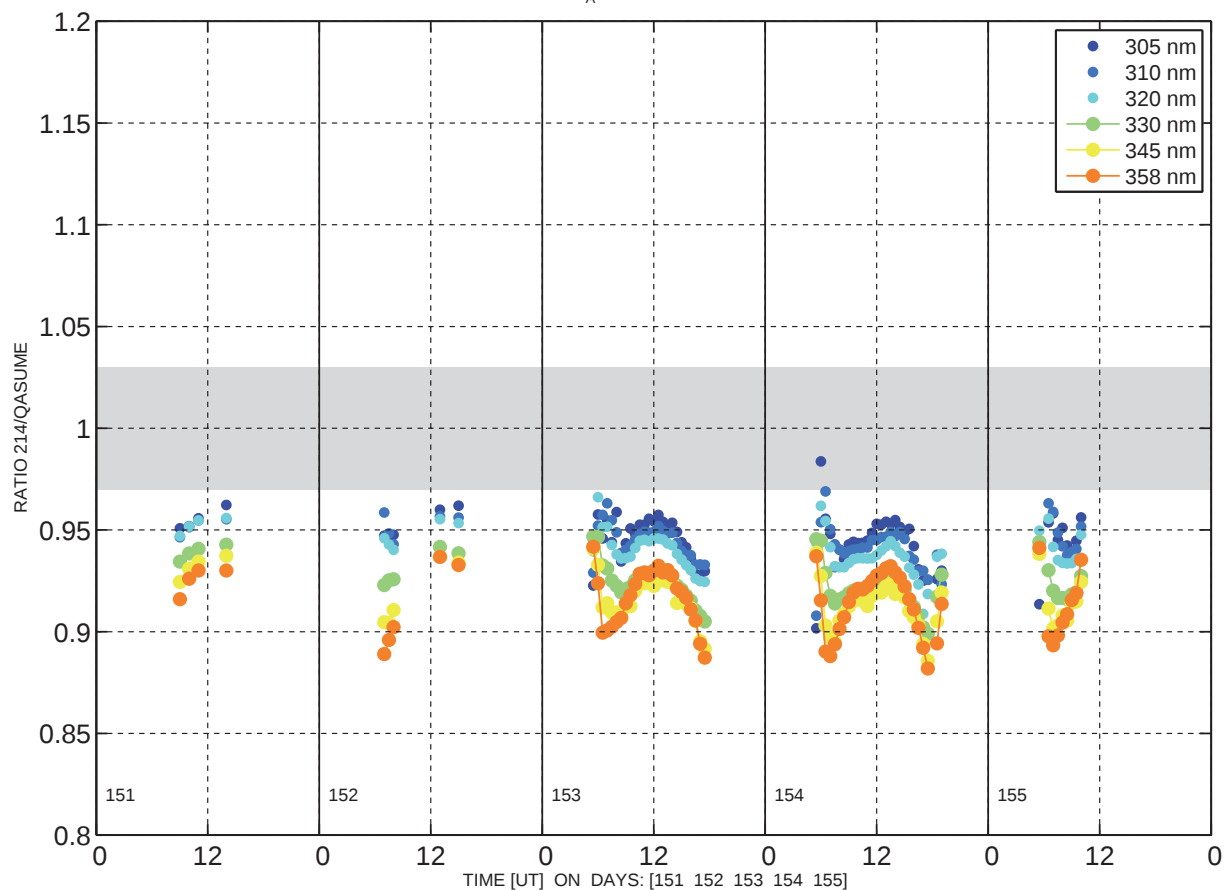




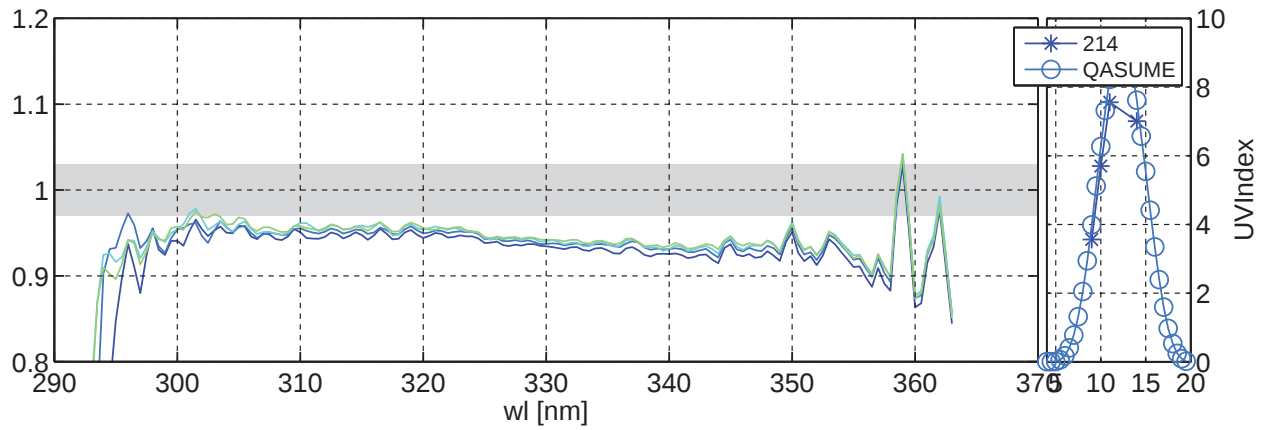
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:27-May-2015(147) to 03-Jun-2015(154)



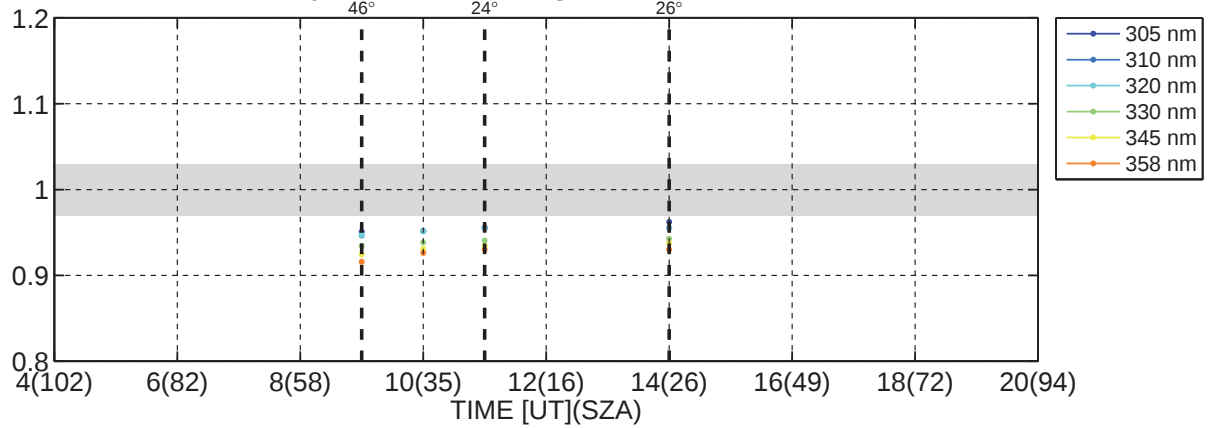
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:31-May-2015(151) to 04-Jun-2015(155)



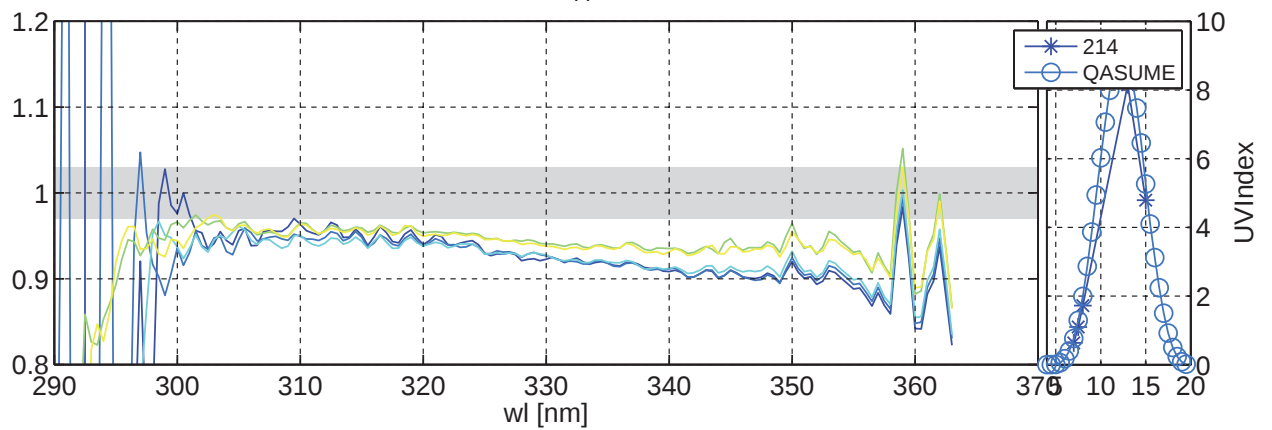
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:31-May-2015(151)



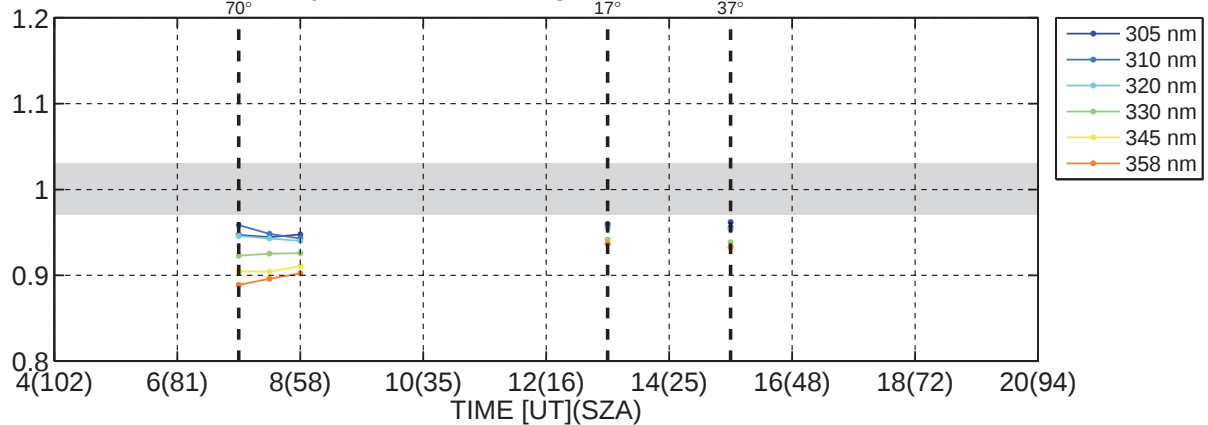
Daily variation. Wavelength bands are ± 2.5 nm



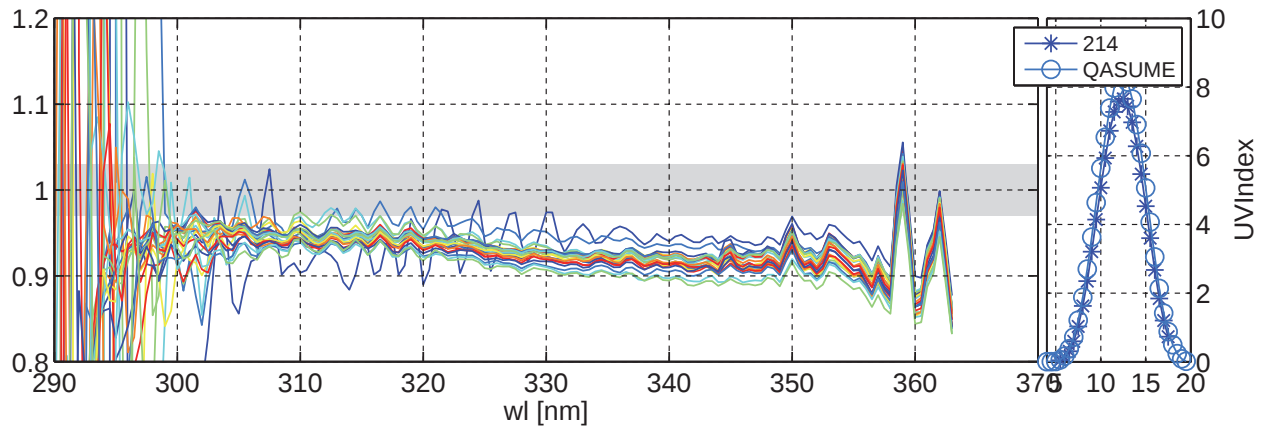
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



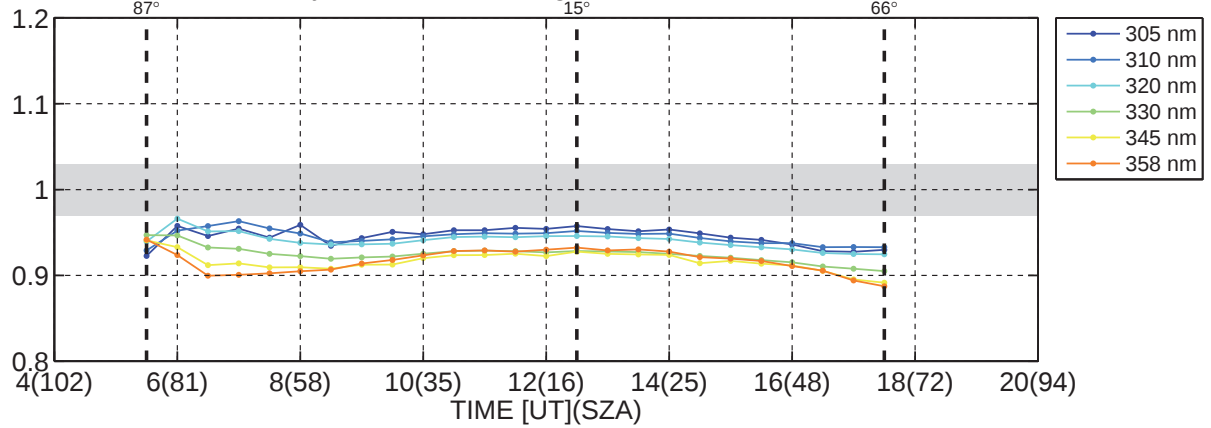
Daily variation. Wavelength bands are ± 2.5 nm



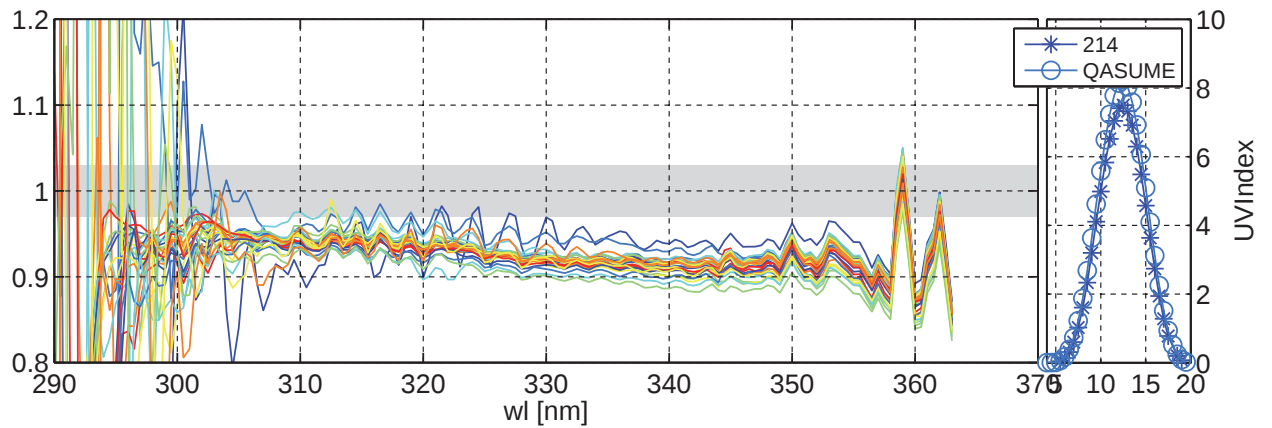
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



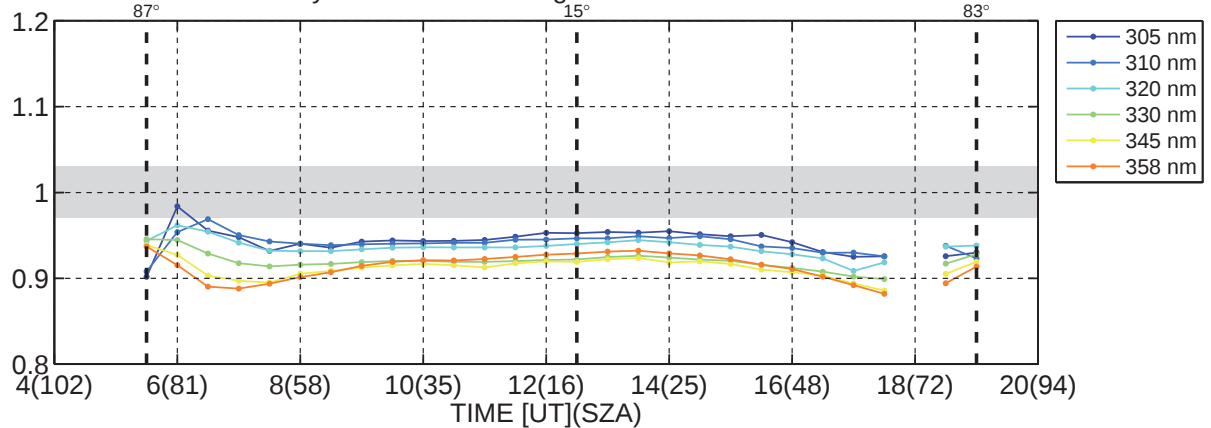
Daily variation. Wavelength bands are ± 2.5 nm



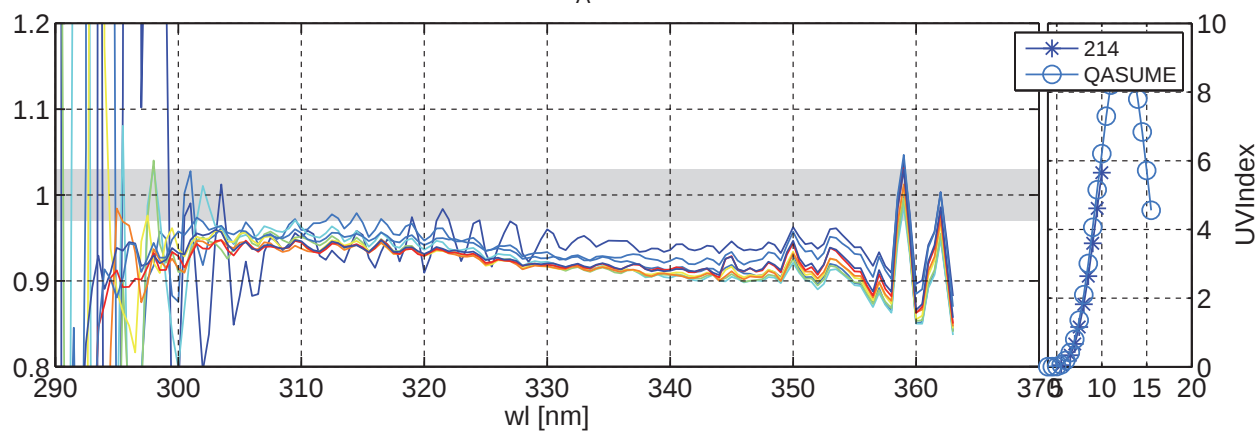
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



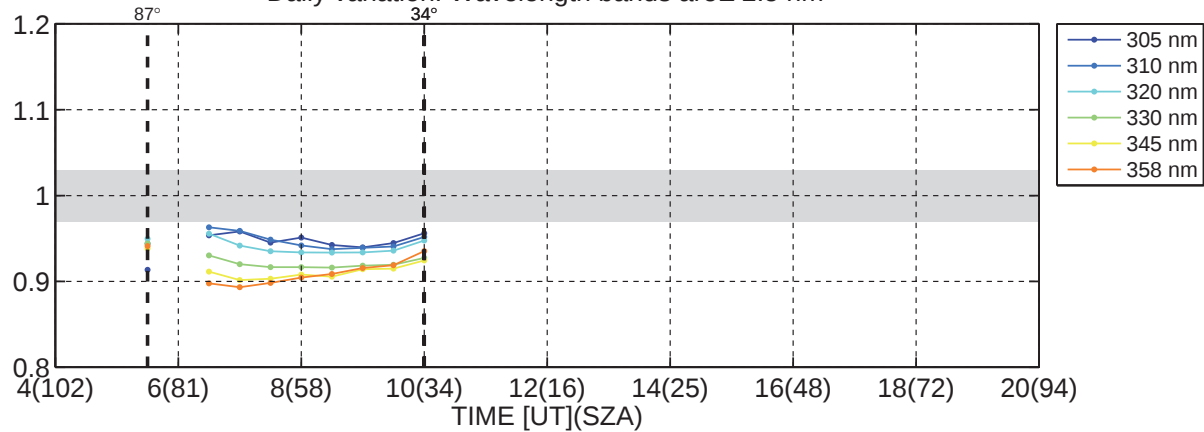
Daily variation. Wavelength bands are ± 2.5 nm

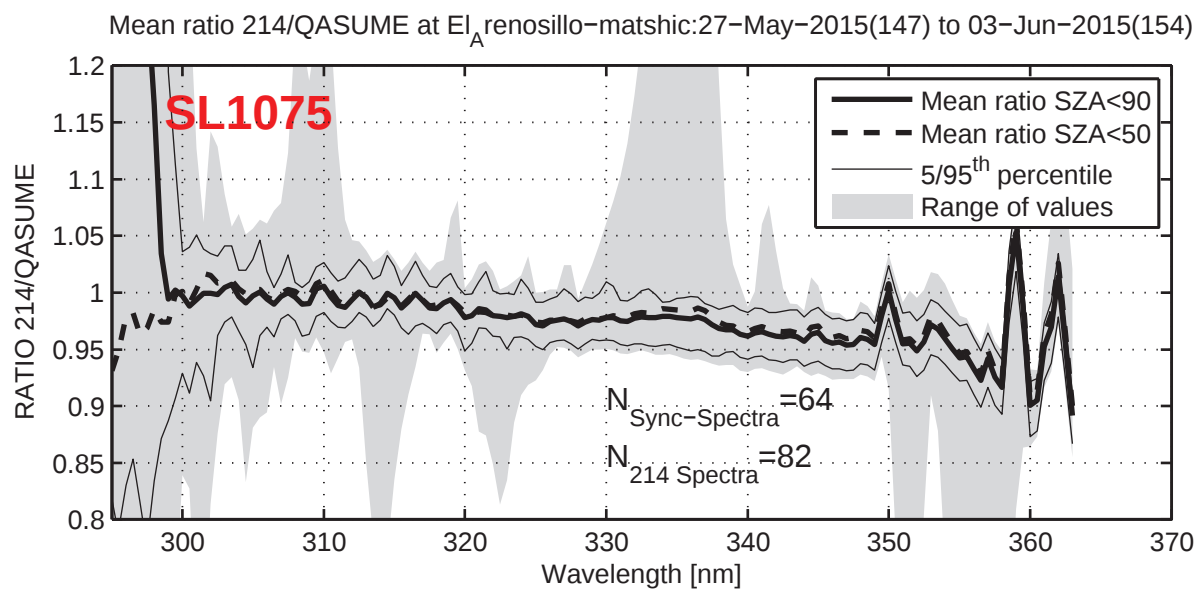
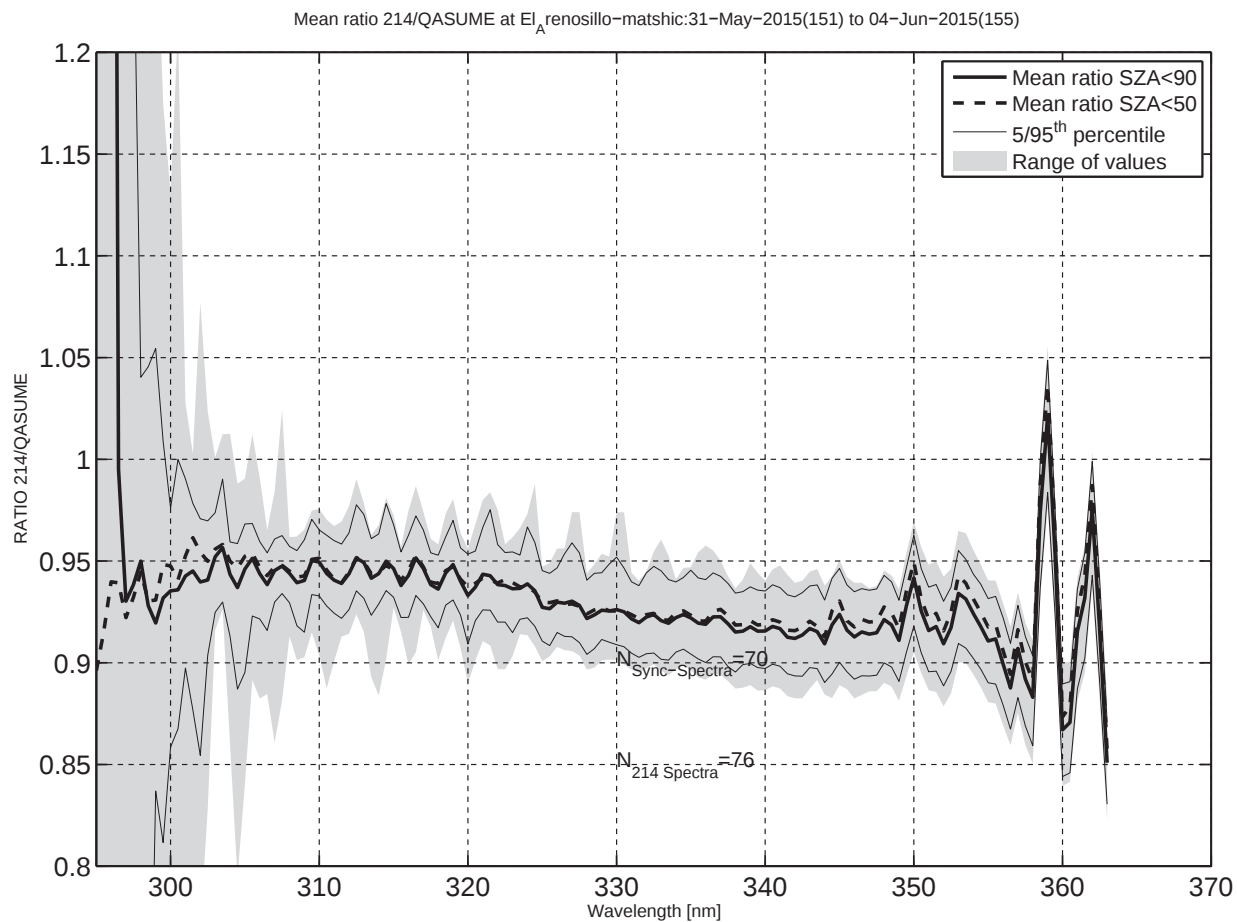


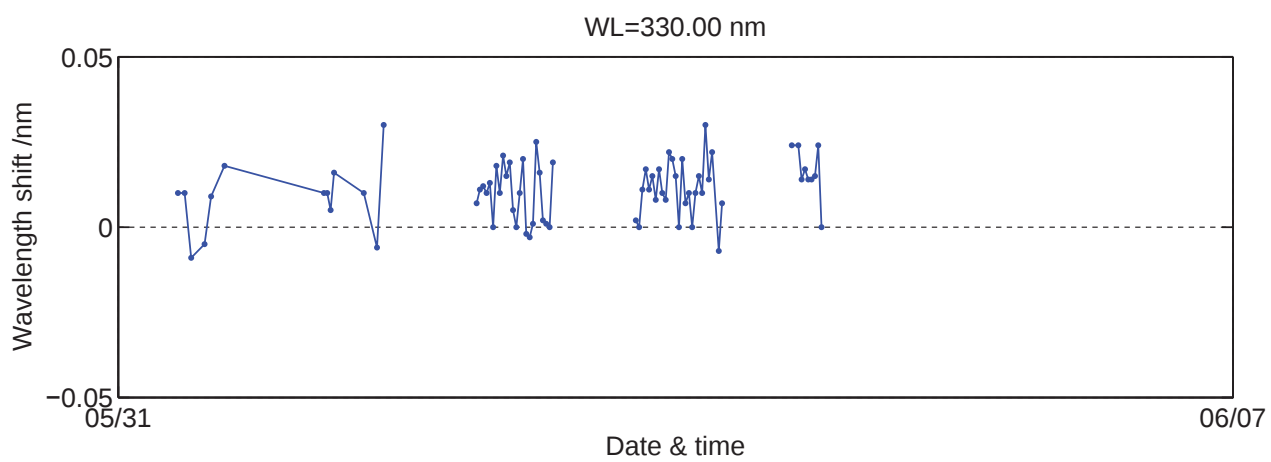
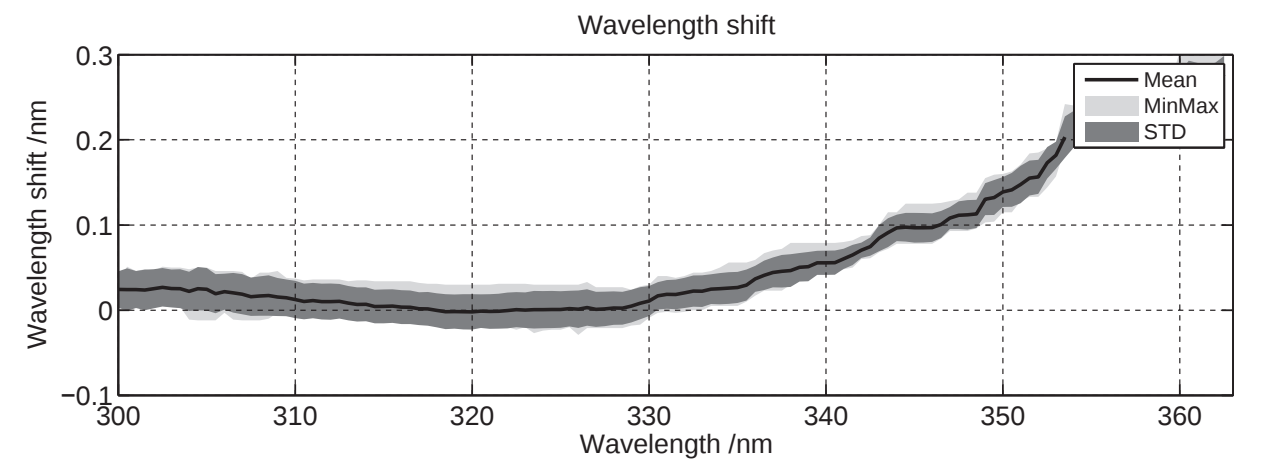
Global irradiance ratios 214/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



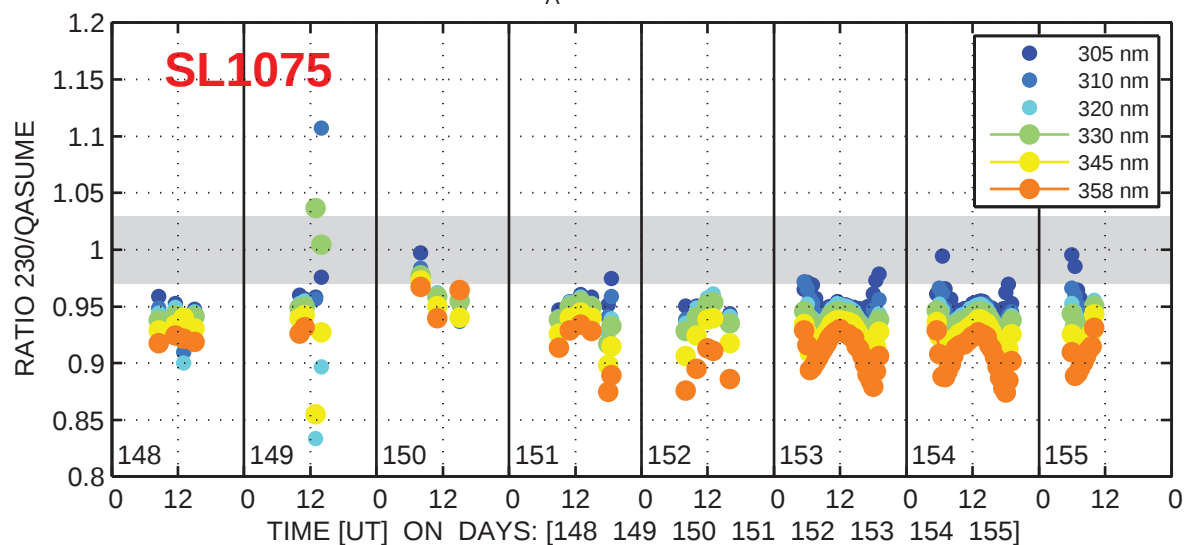
Daily variation. Wavelength bands are ± 2.5 nm



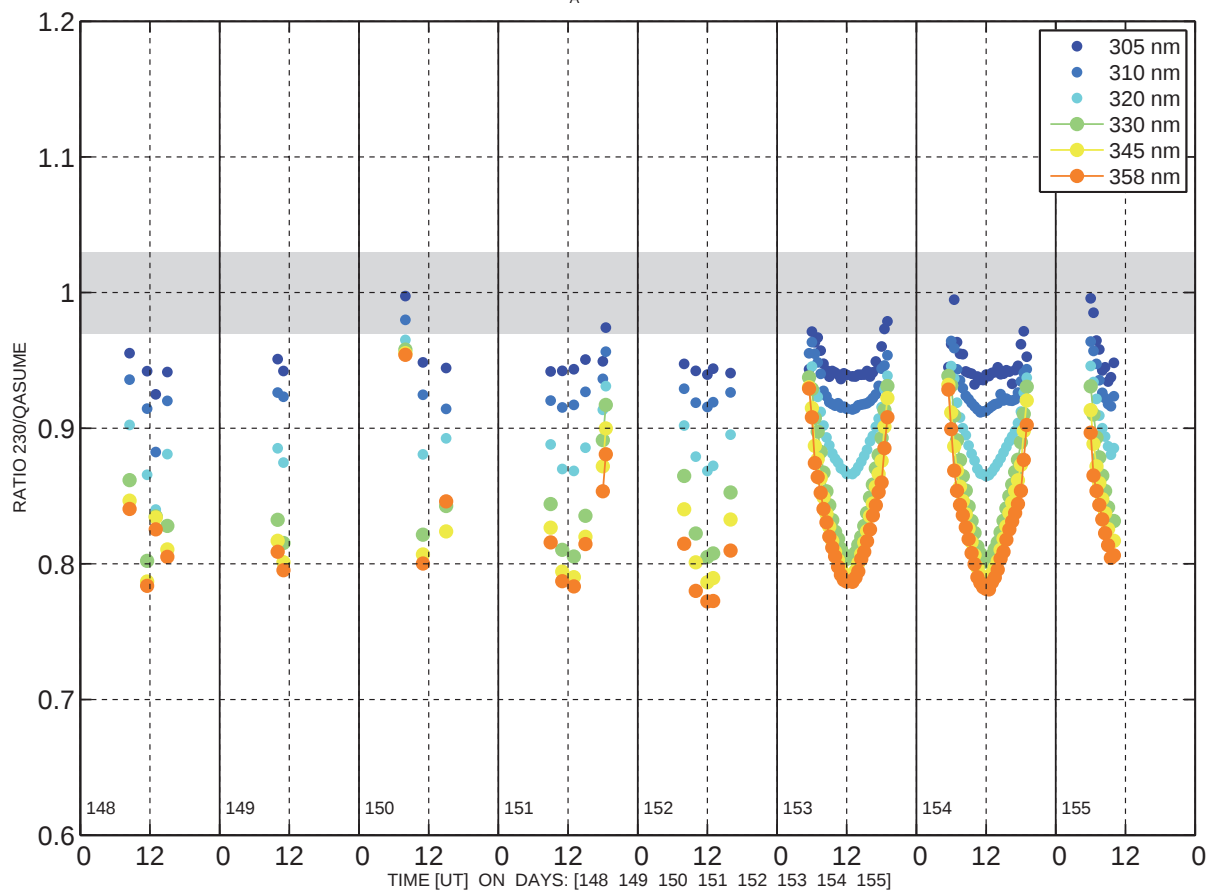




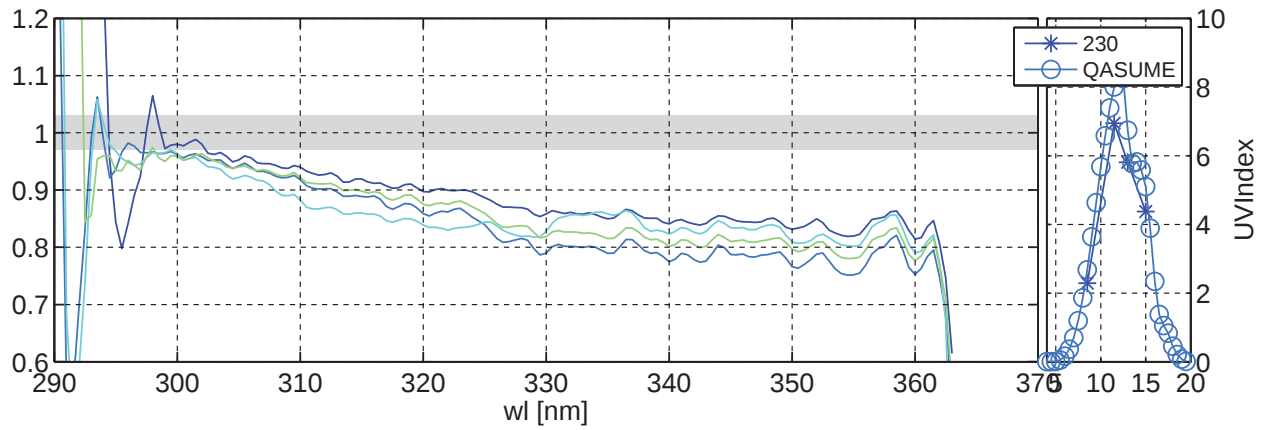
Global irradiance ratios 230/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



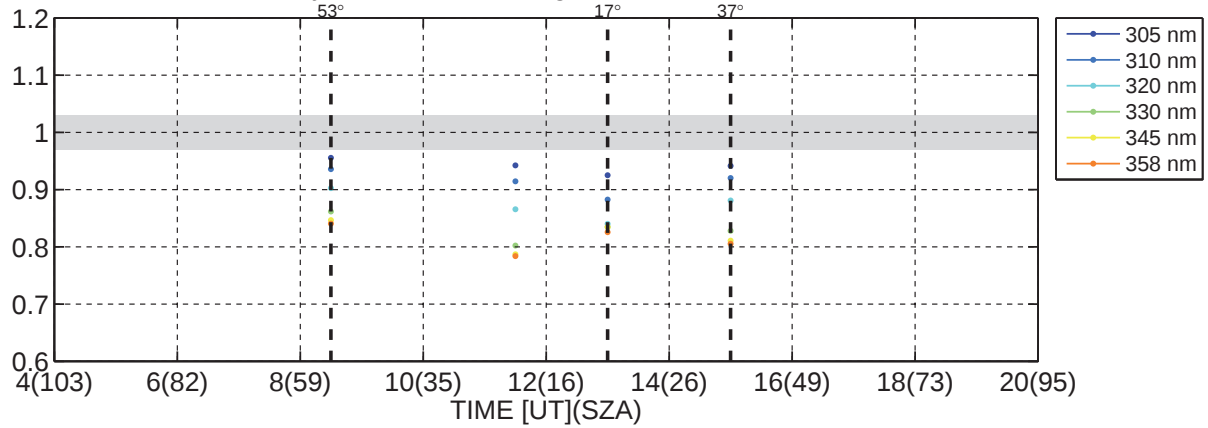
Global irradiance ratios 230/QASUME at El_Arenosillo-matshic:28-May-2015(148) to 04-Jun-2015(155)



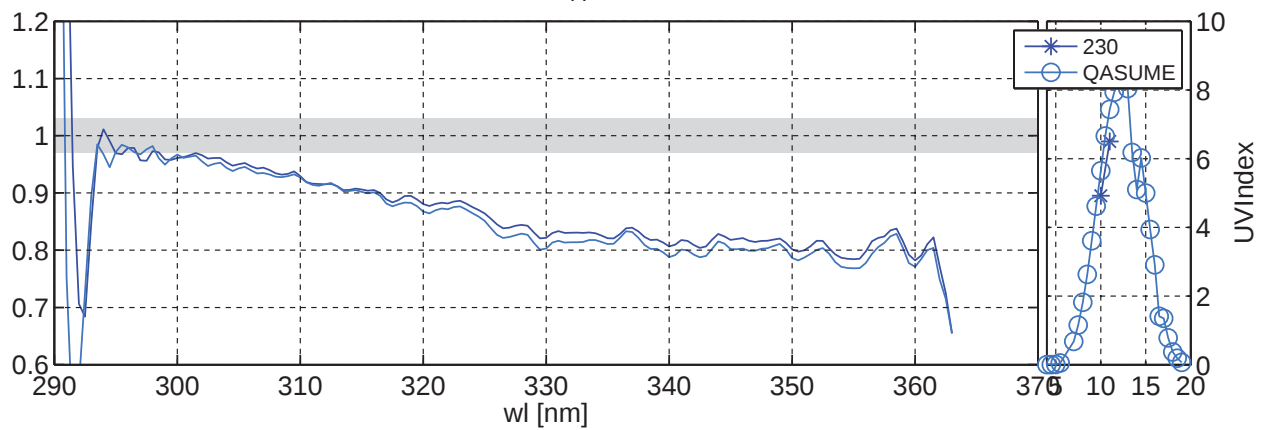
Global irradiance ratios 230/QASUME at El_A renosillo-matshic:28-May-2015(148)



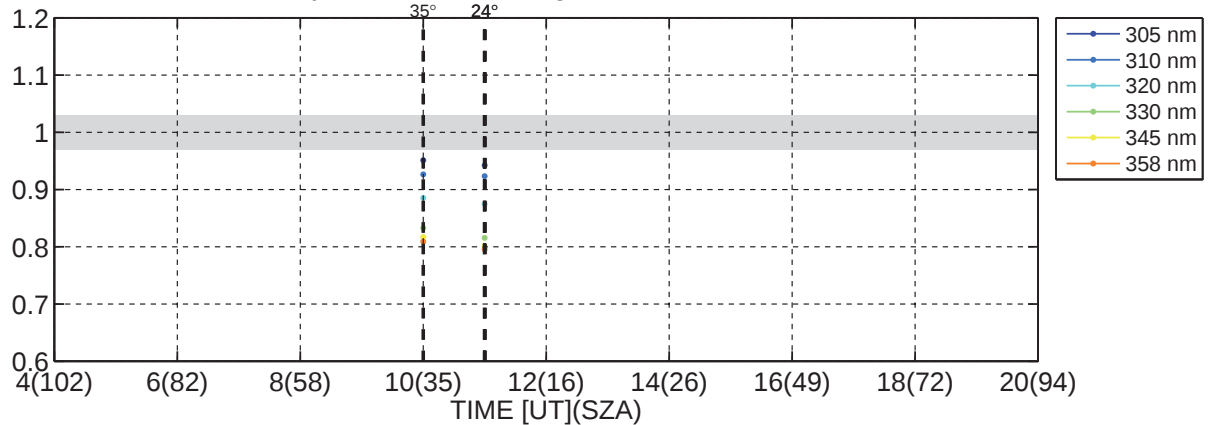
Daily variation. Wavelength bands are ± 2.5 nm



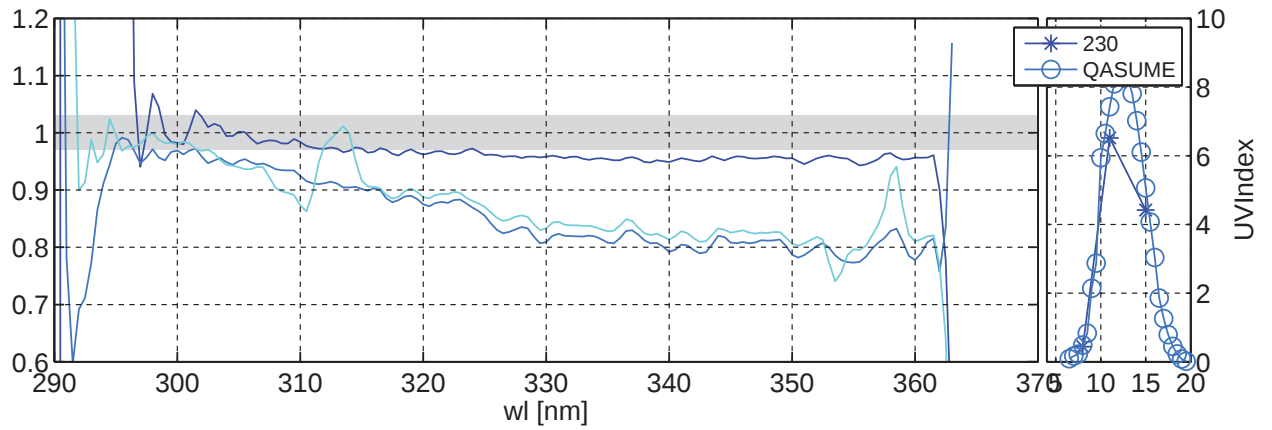
Global irradiance ratios 230/QASUME at El_A renosillo-matshic:29-May-2015(149)



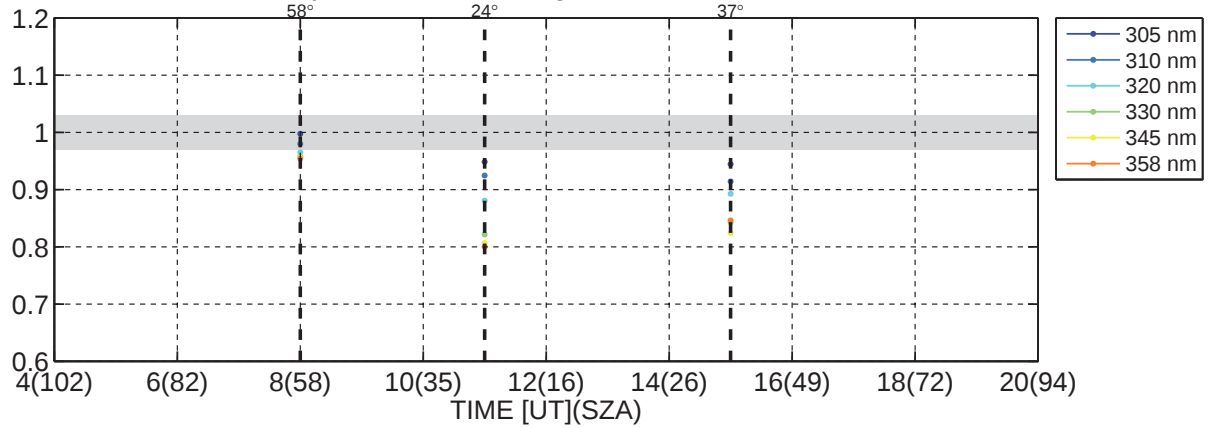
Daily variation. Wavelength bands are ± 2.5 nm



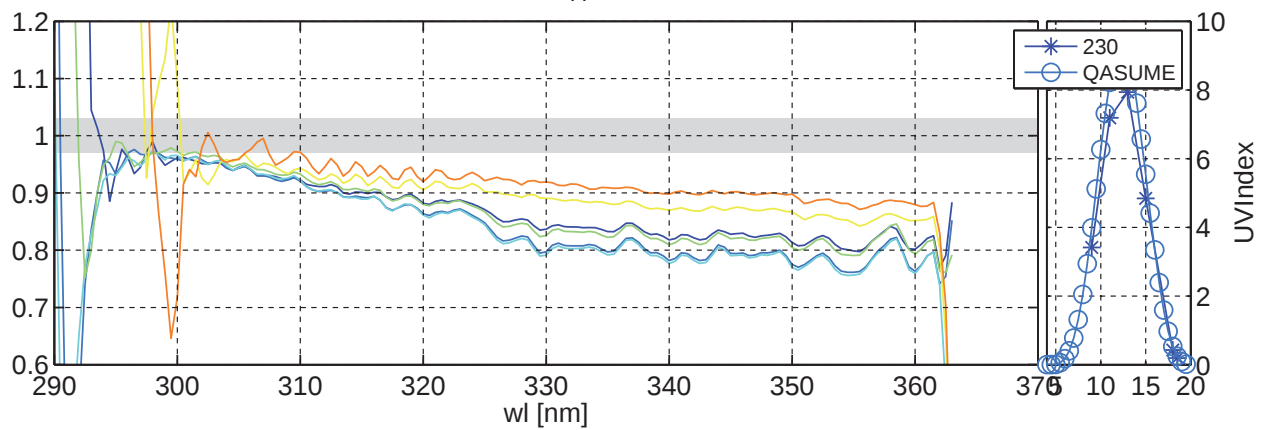
Global irradiance ratios 230/QASUME at El_A renosillo-matshic:30-May-2015(150)



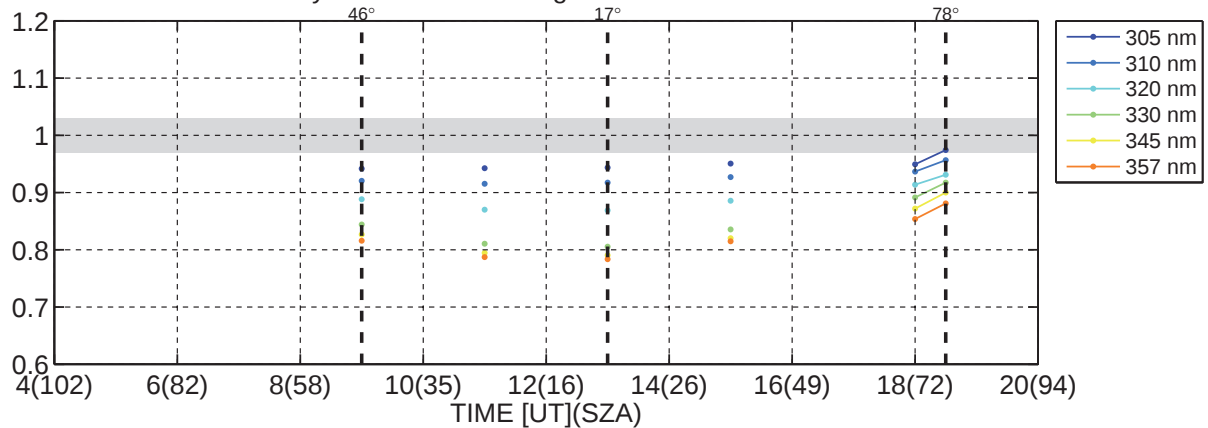
Daily variation. Wavelength bands are ± 2.5 nm



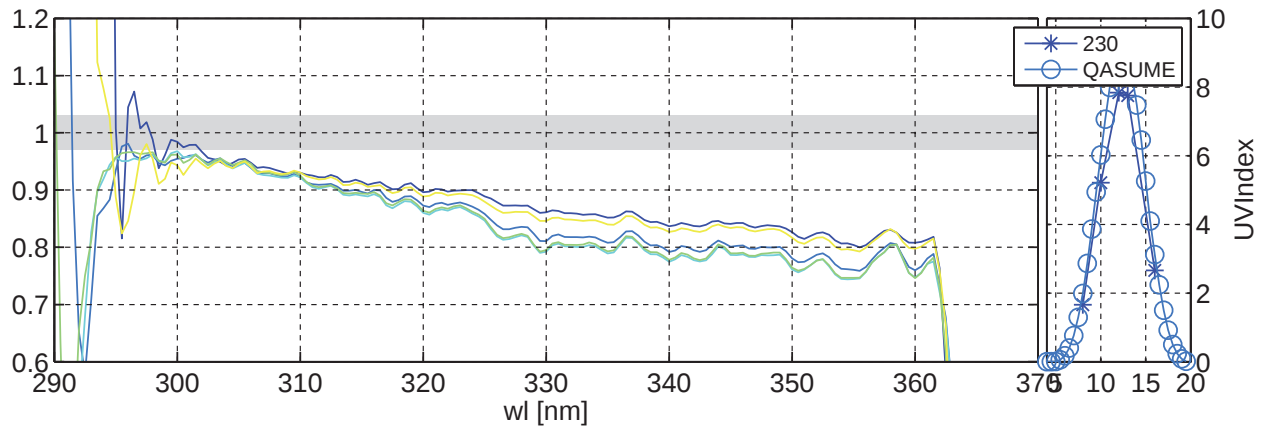
Global irradiance ratios 230/QASUME at El_A renosillo-matshic:31-May-2015(151)



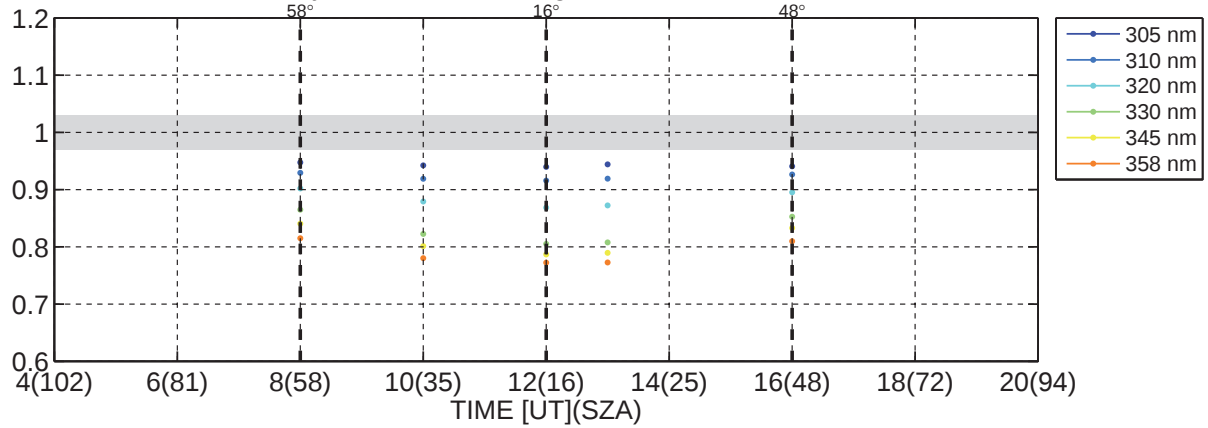
Daily variation. Wavelength bands are ± 2.5 nm



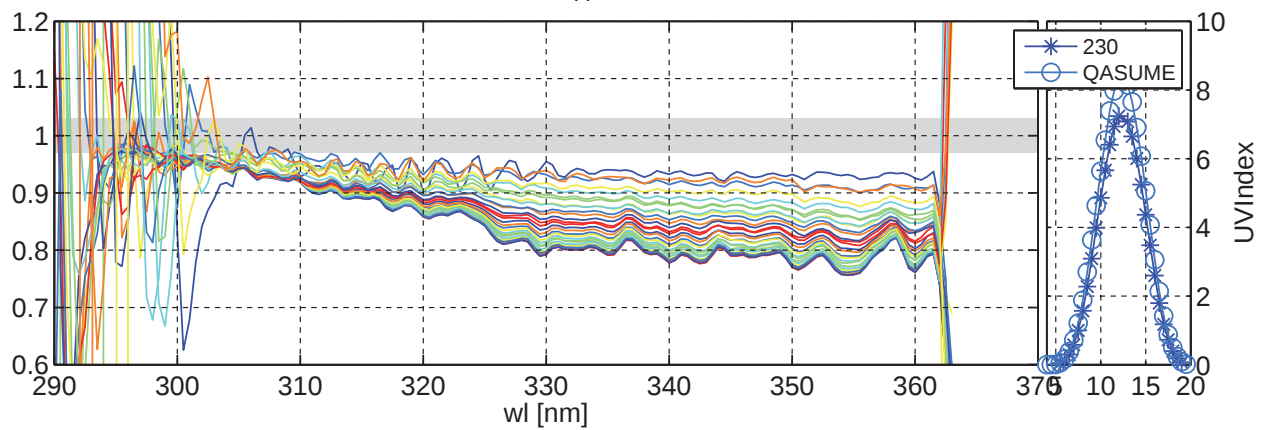
Global irradiance ratios 230/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



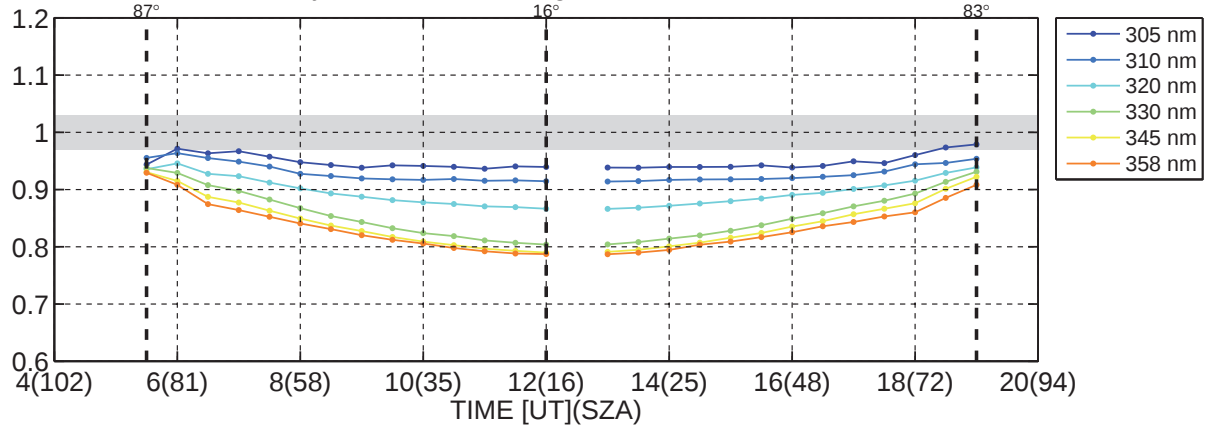
Daily variation. Wavelength bands are ± 2.5 nm



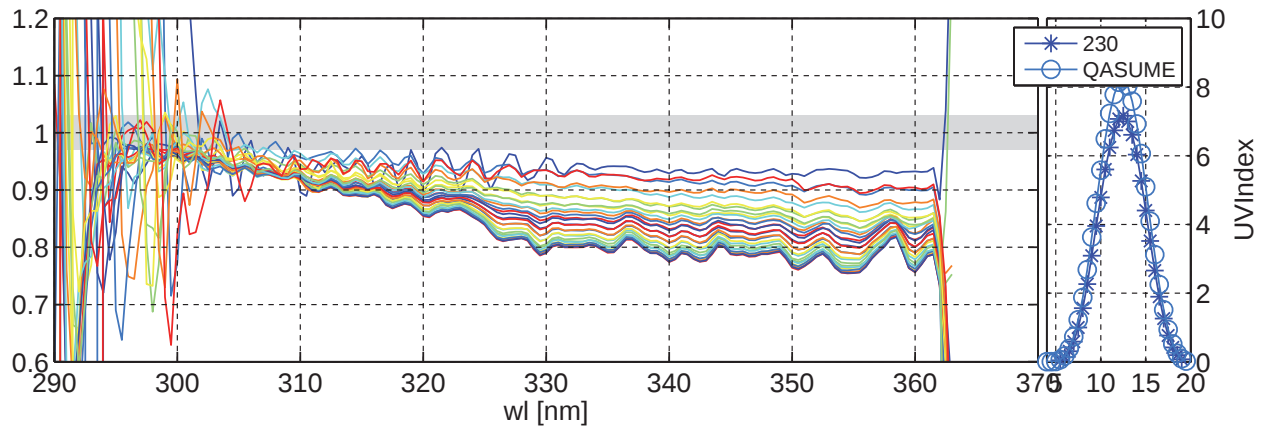
Global irradiance ratios 230/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



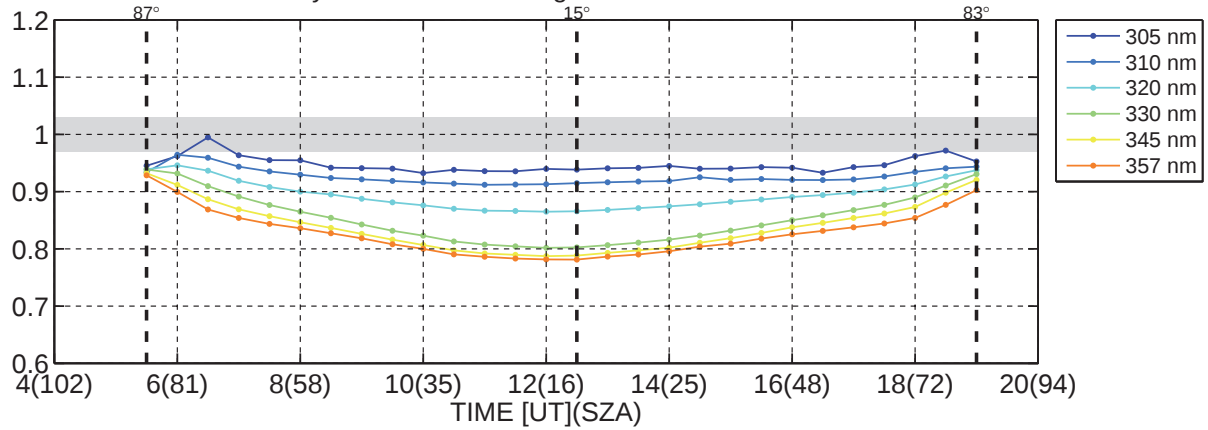
Daily variation. Wavelength bands are ± 2.5 nm



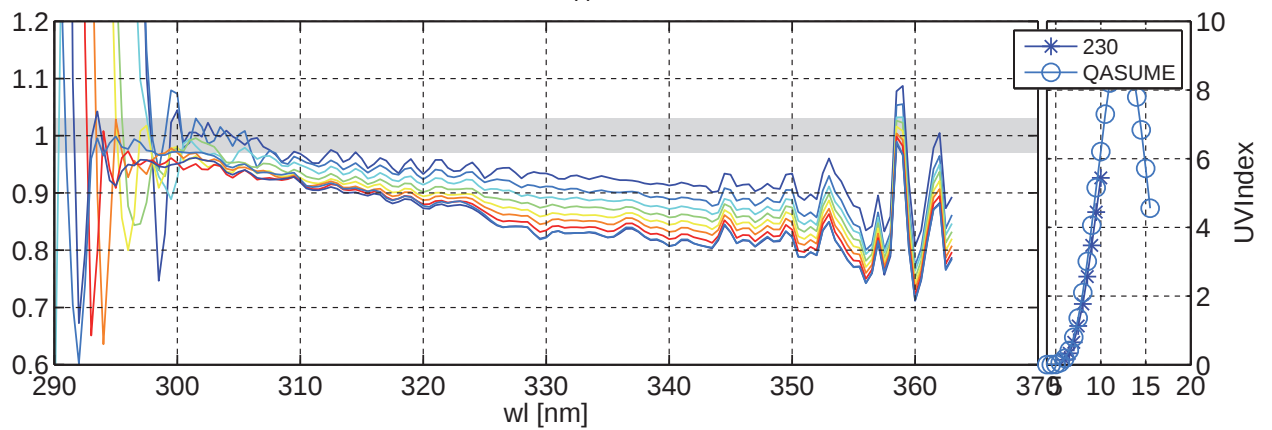
Global irradiance ratios 230/QASUME at El_A renosillo-matshic:03-Jun-2015(154)



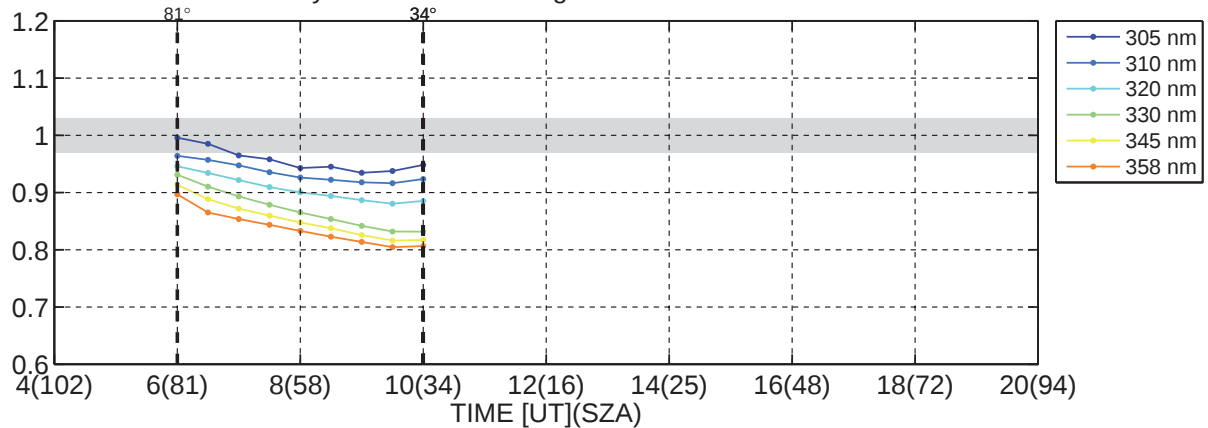
Daily variation. Wavelength bands are ± 2.5 nm

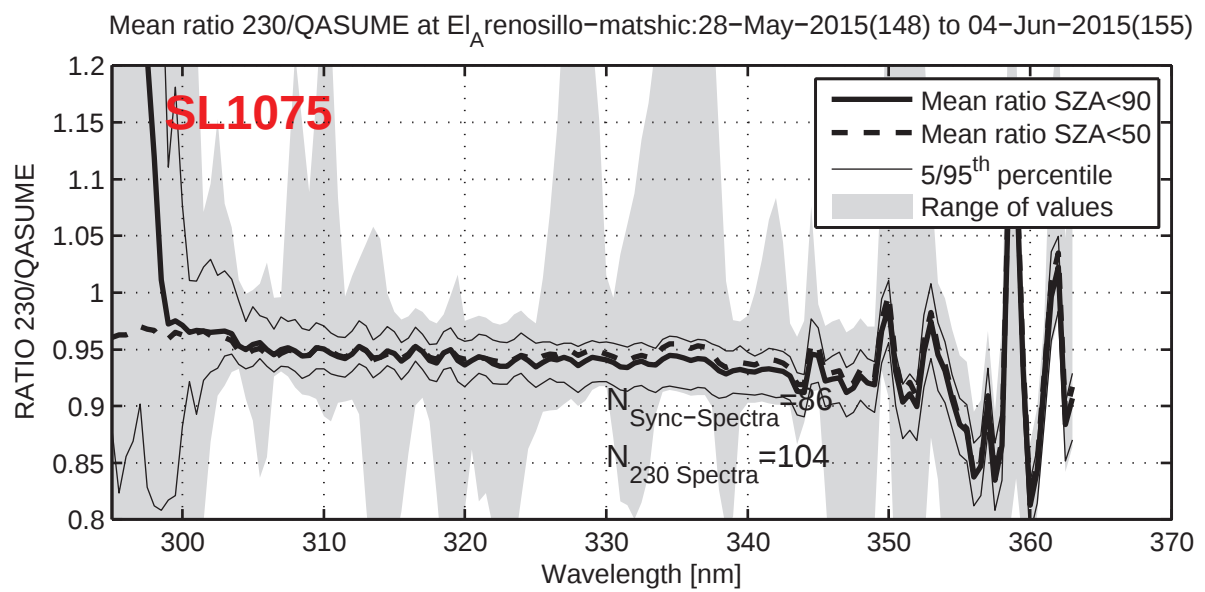
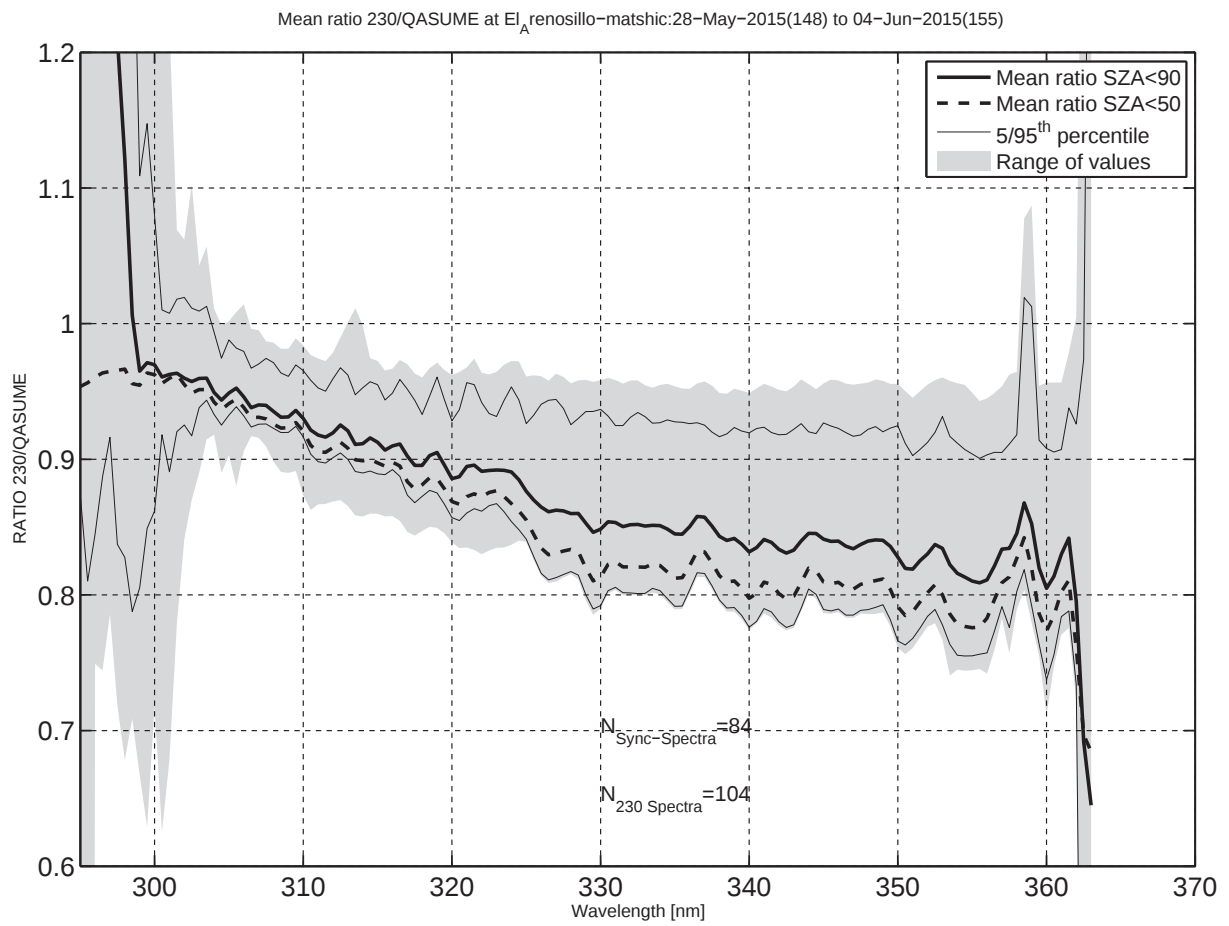


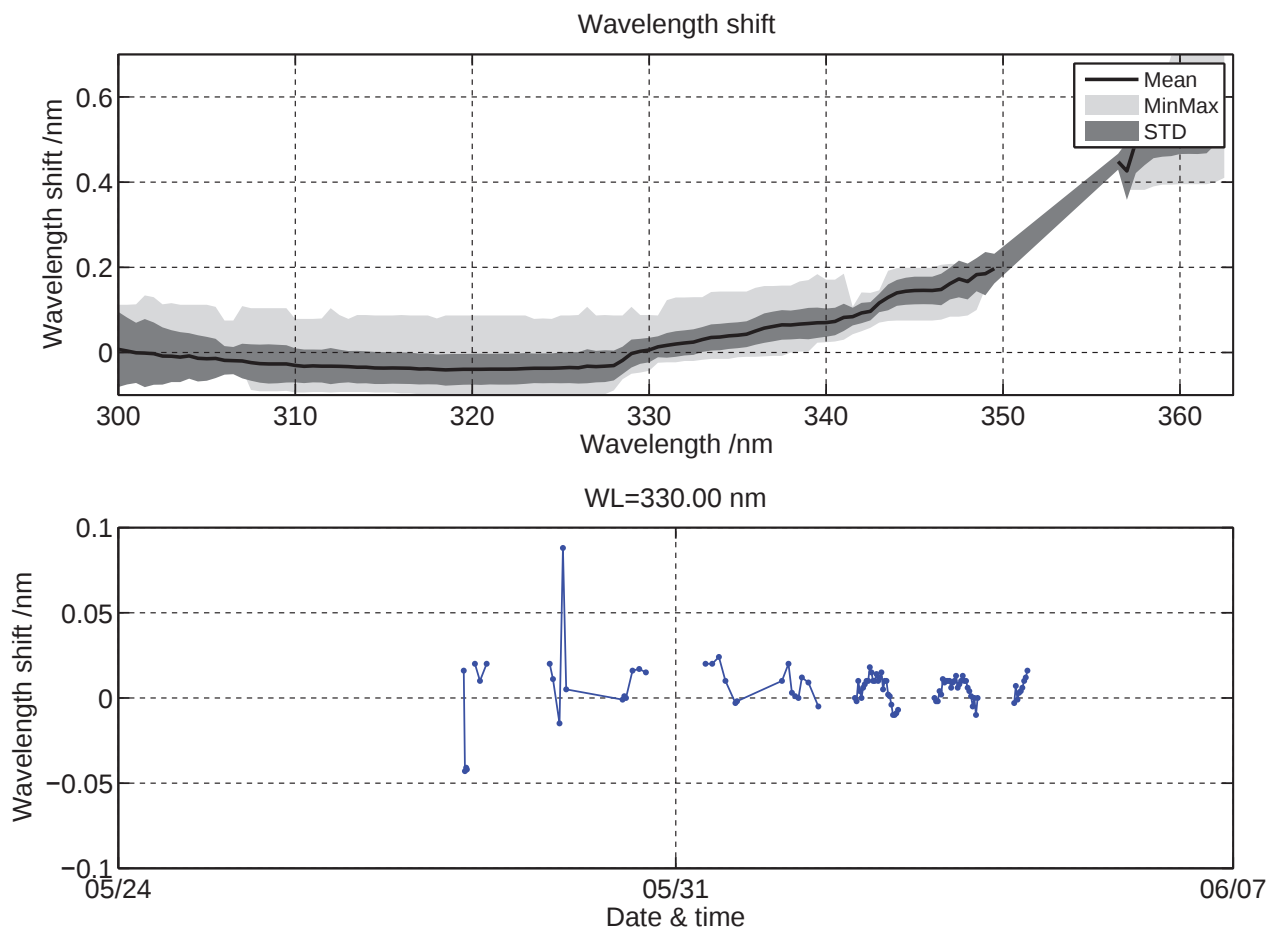
Global irradiance ratios 230/QASUME at El_A renosillo-matshic:04-Jun-2015(155)

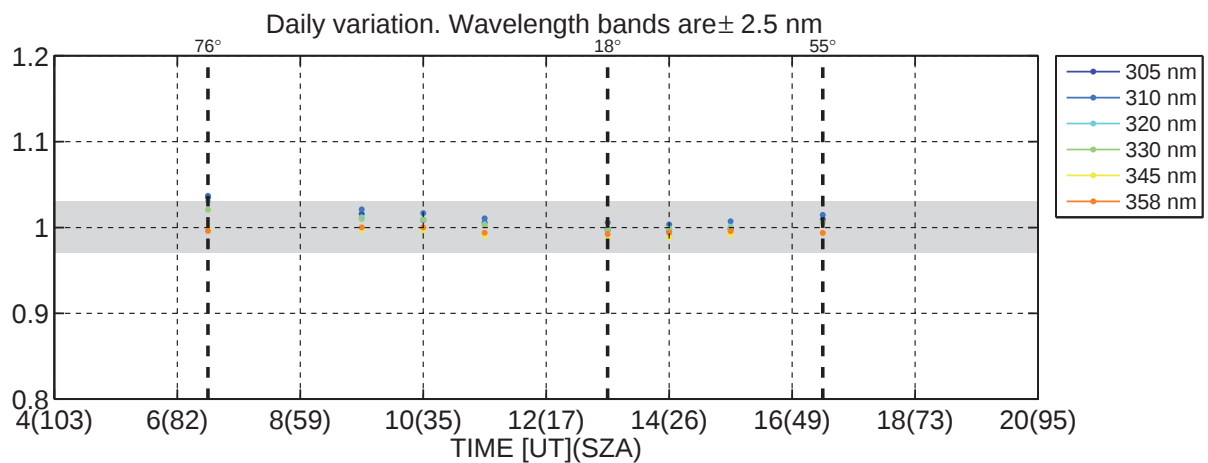
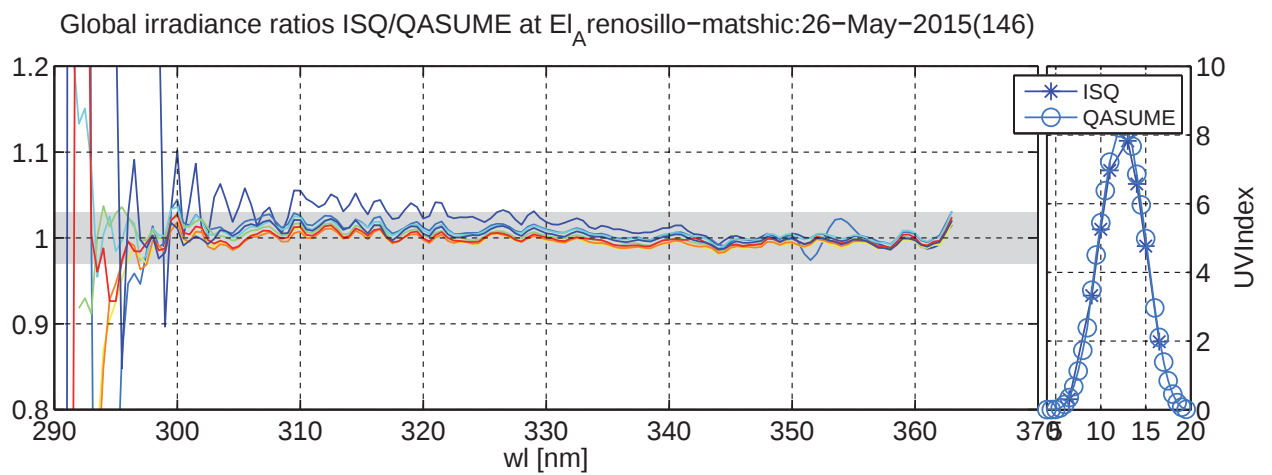
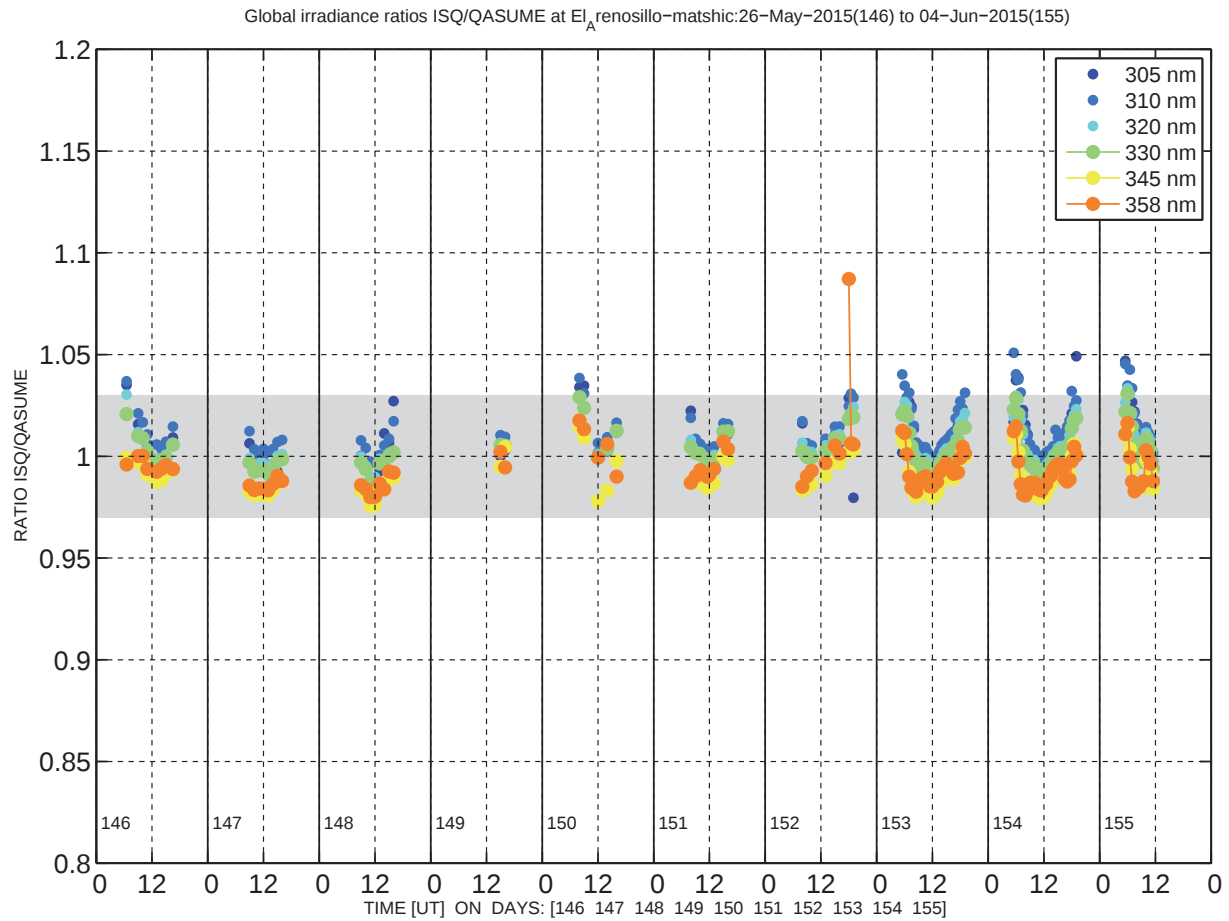


Daily variation. Wavelength bands are ± 2.5 nm

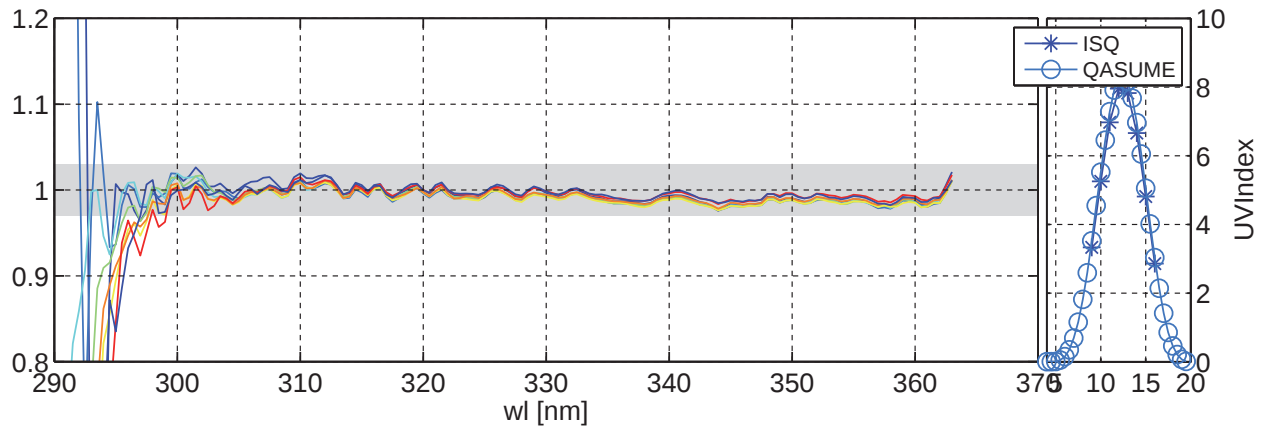




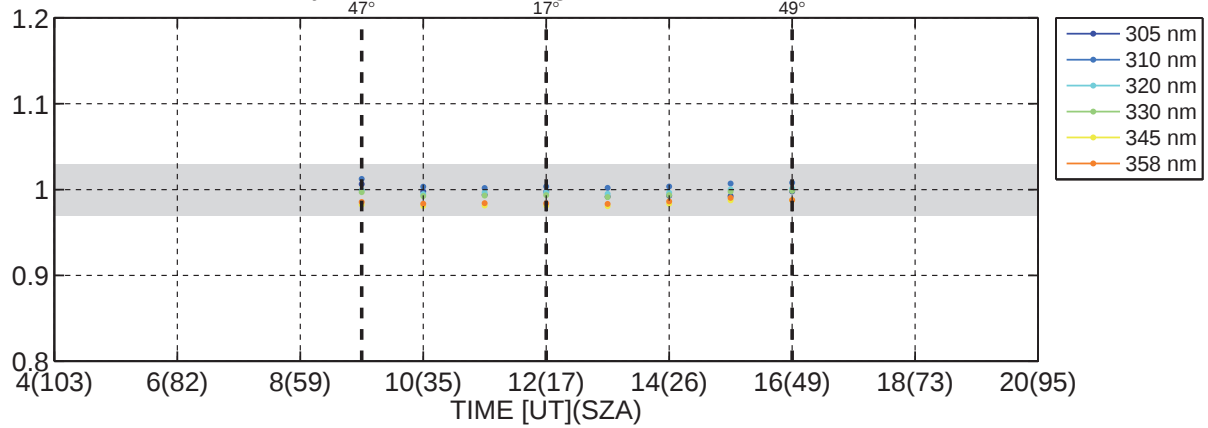




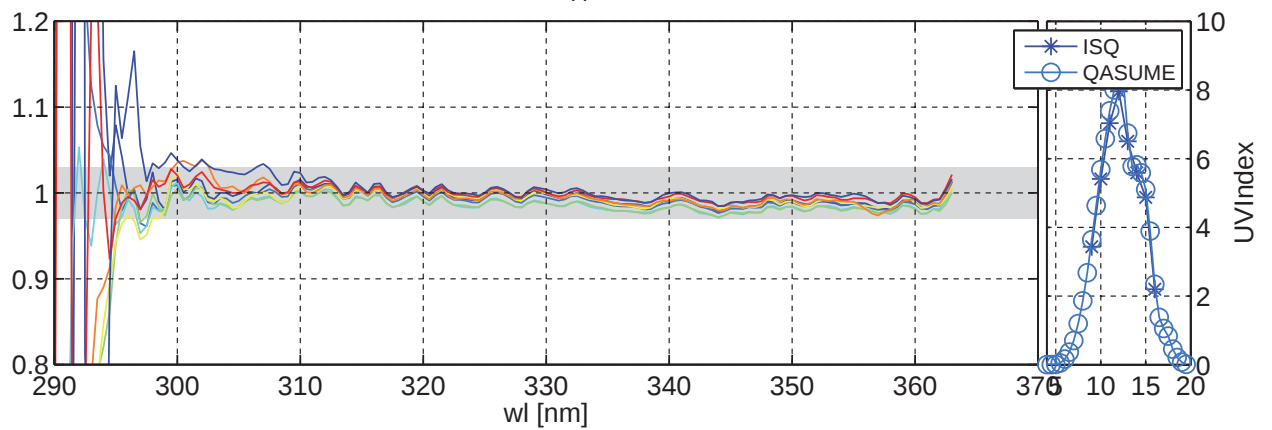
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:27-May-2015(147)



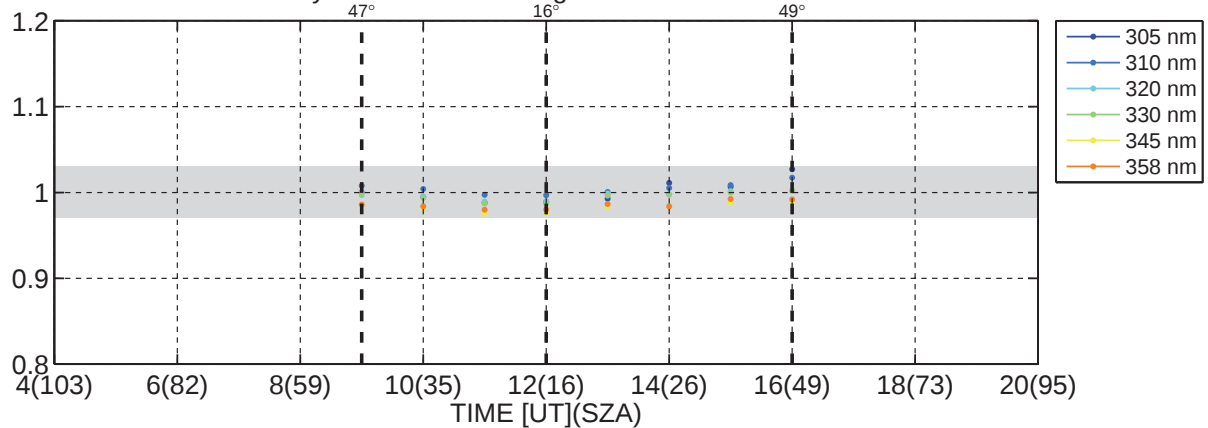
Daily variation. Wavelength bands are ± 2.5 nm



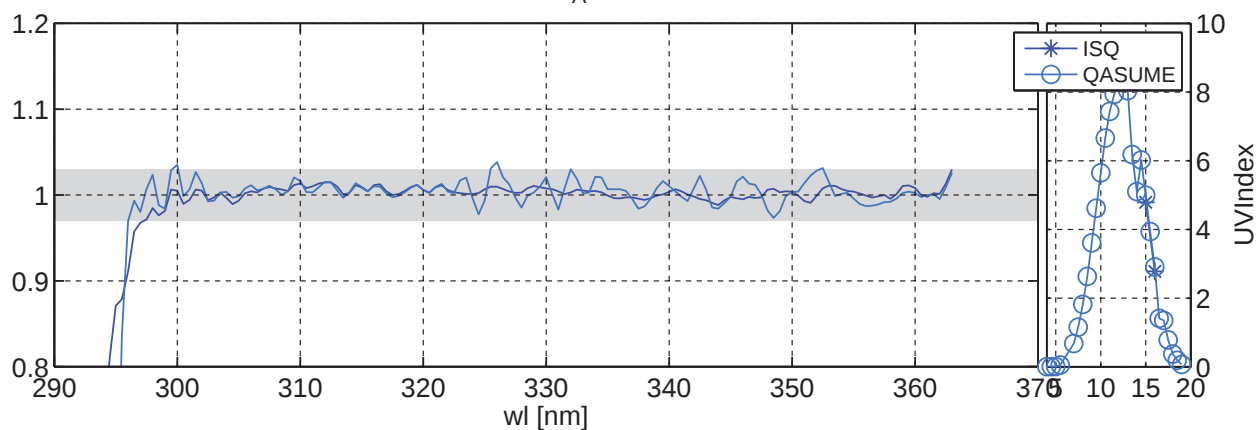
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:28-May-2015(148)



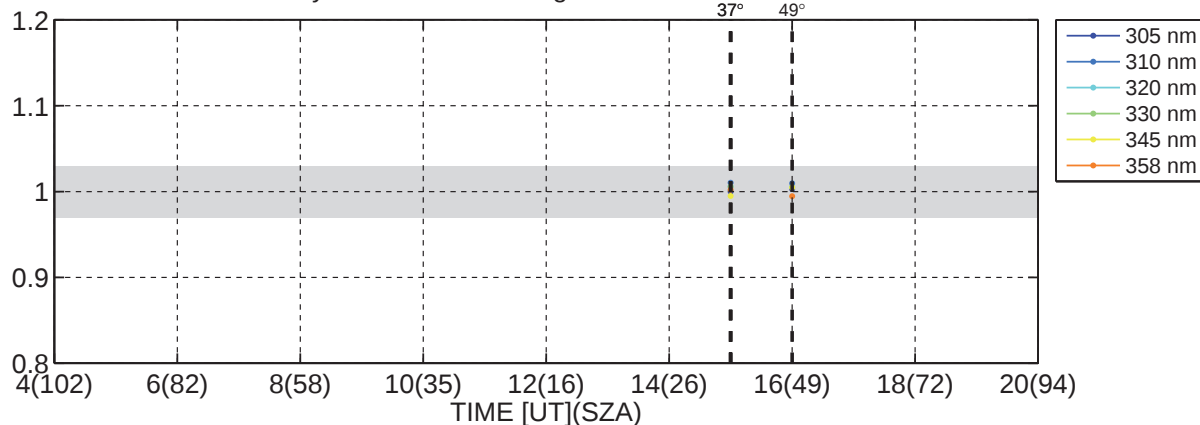
Daily variation. Wavelength bands are ± 2.5 nm



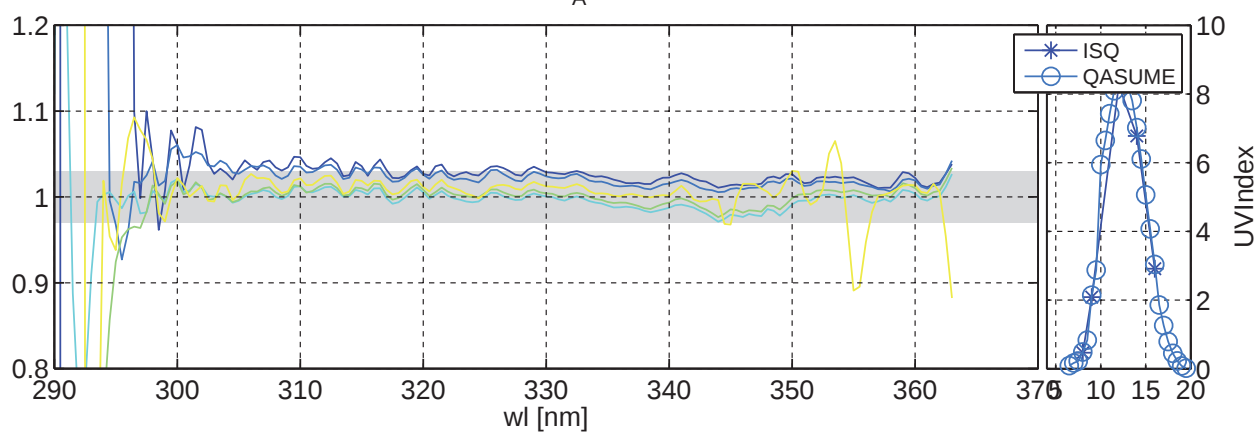
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:29-May-2015(149)



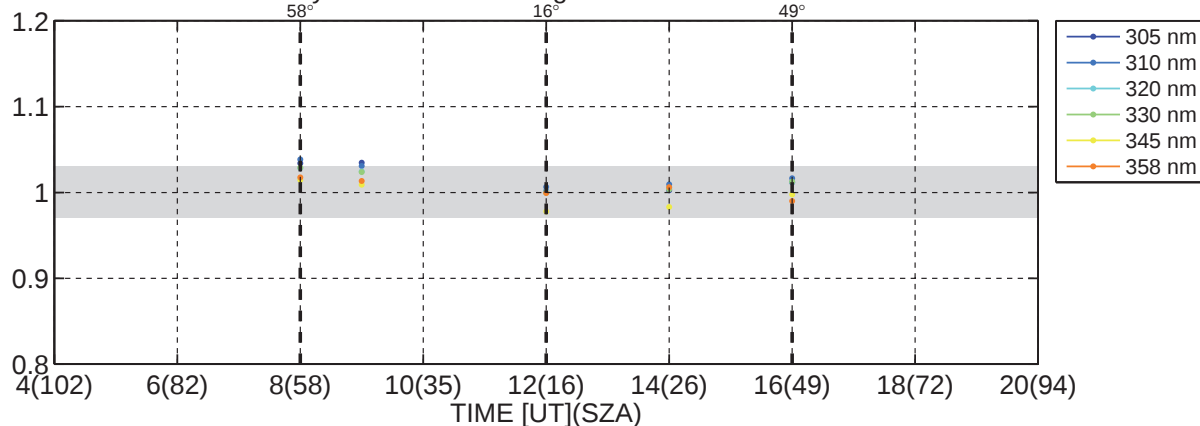
Daily variation. Wavelength bands are ± 2.5 nm



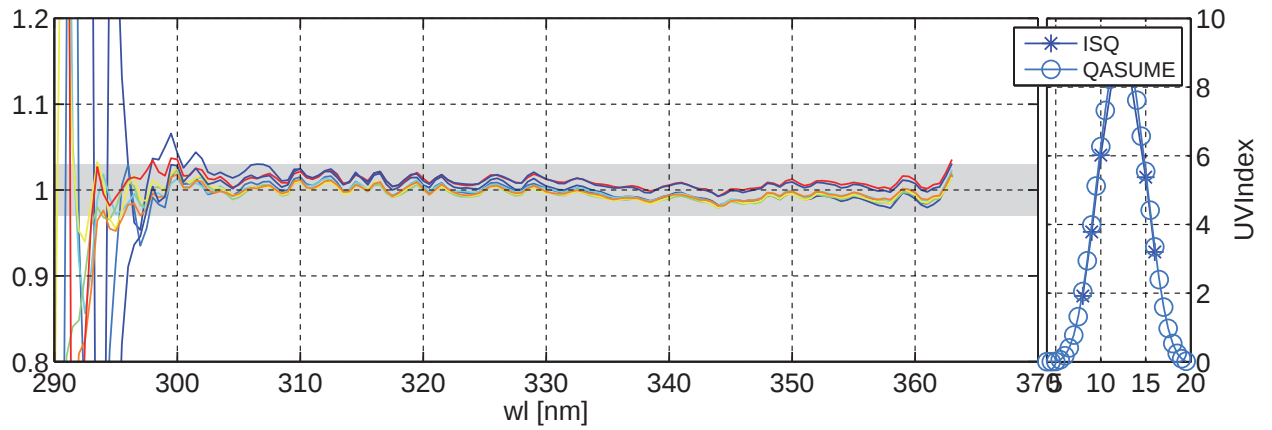
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:30-May-2015(150)



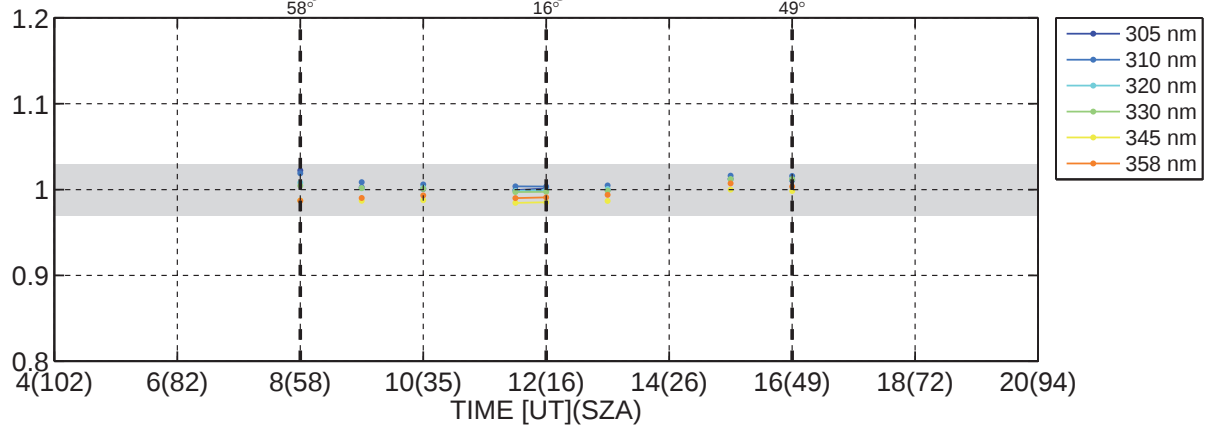
Daily variation. Wavelength bands are ± 2.5 nm



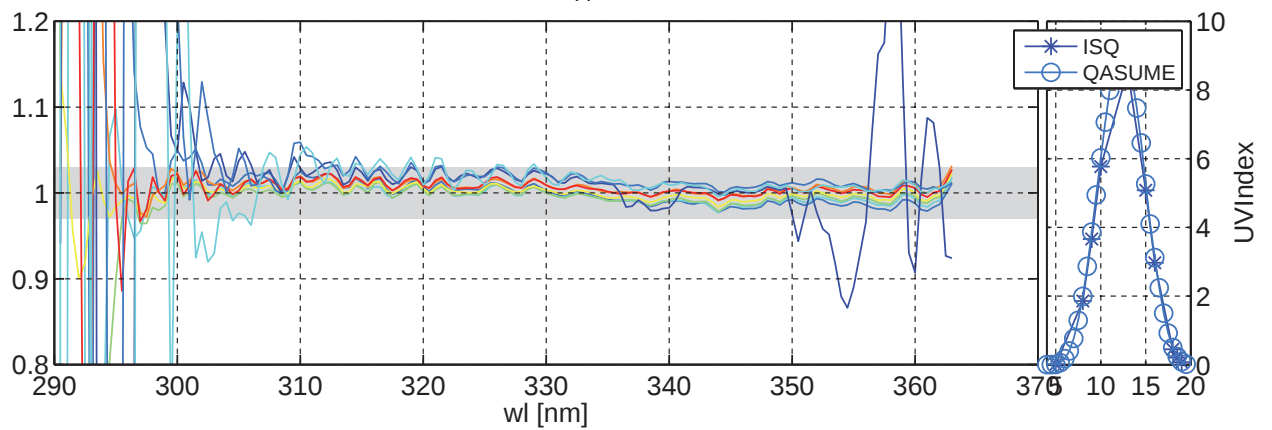
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:31-May-2015(151)



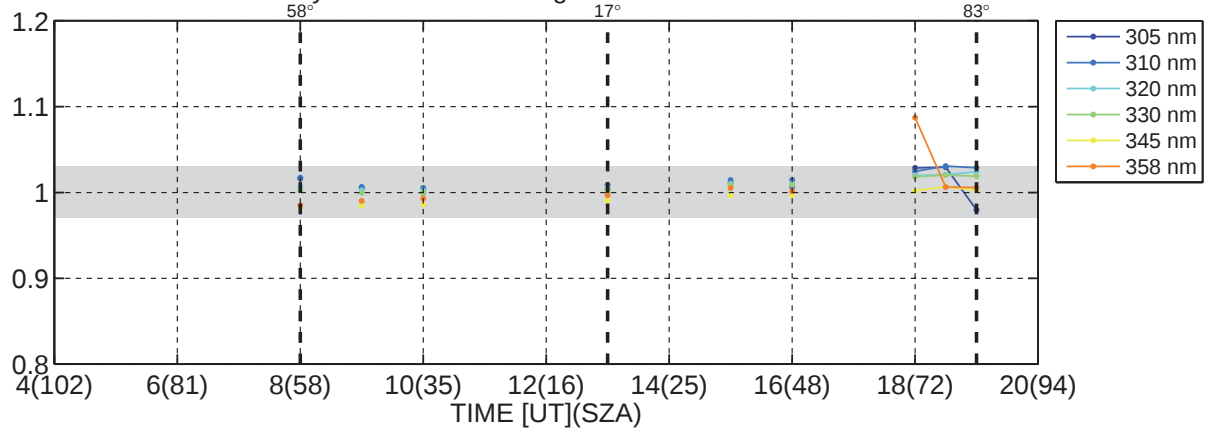
Daily variation. Wavelength bands are ± 2.5 nm



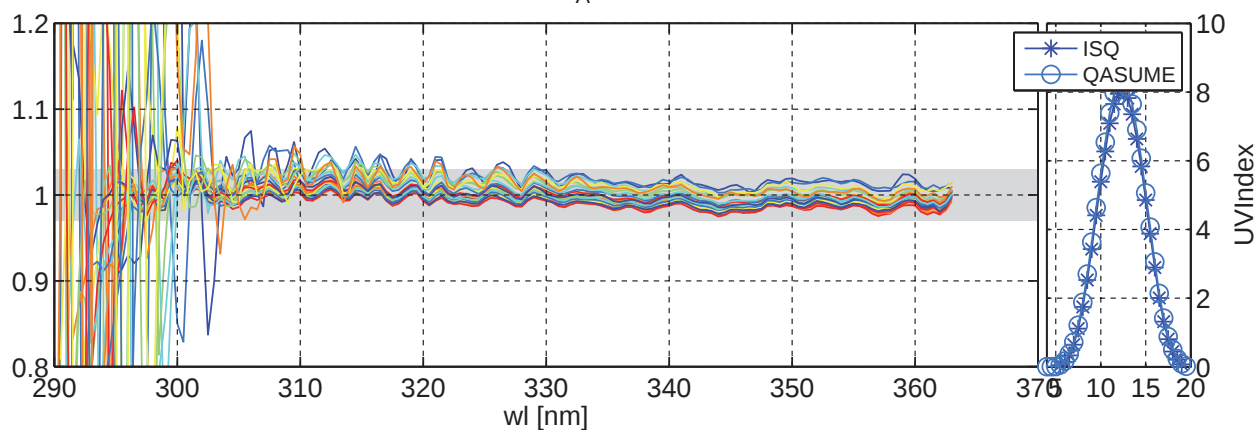
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:01-Jun-2015(152)



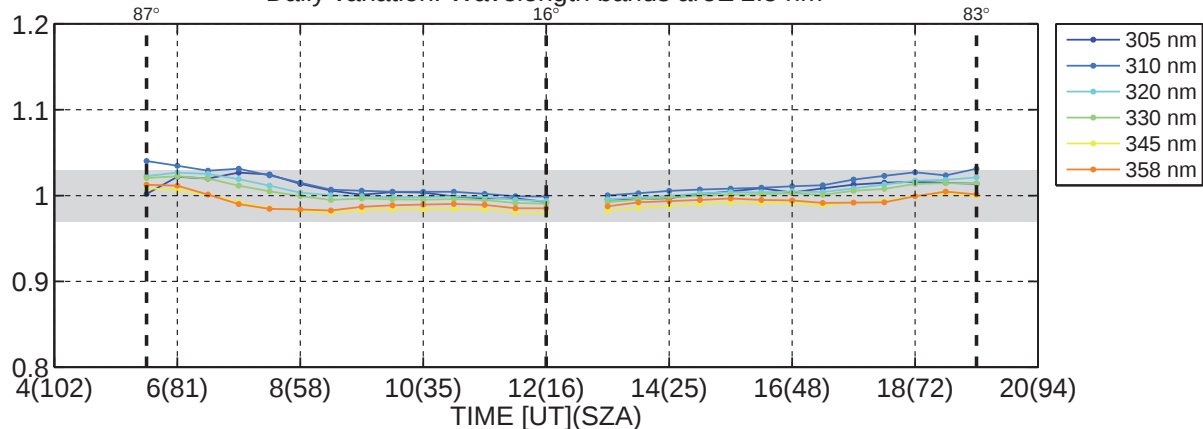
Daily variation. Wavelength bands are ± 2.5 nm



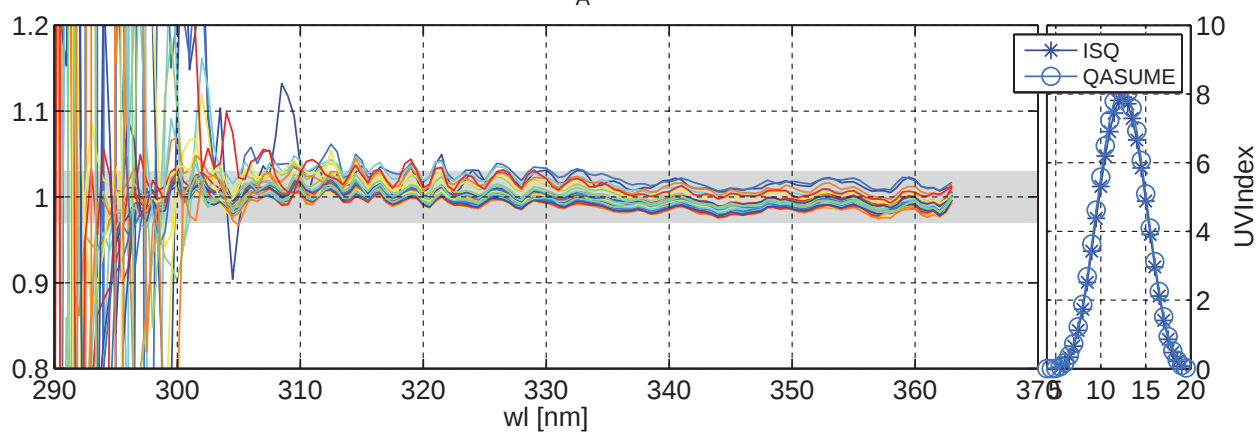
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:02-Jun-2015(153)



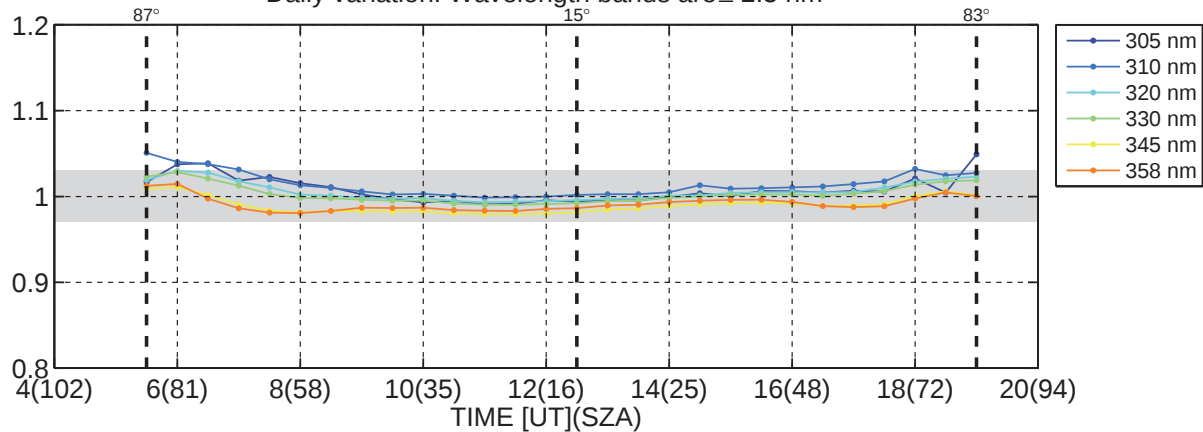
Daily variation. Wavelength bands are ± 2.5 nm



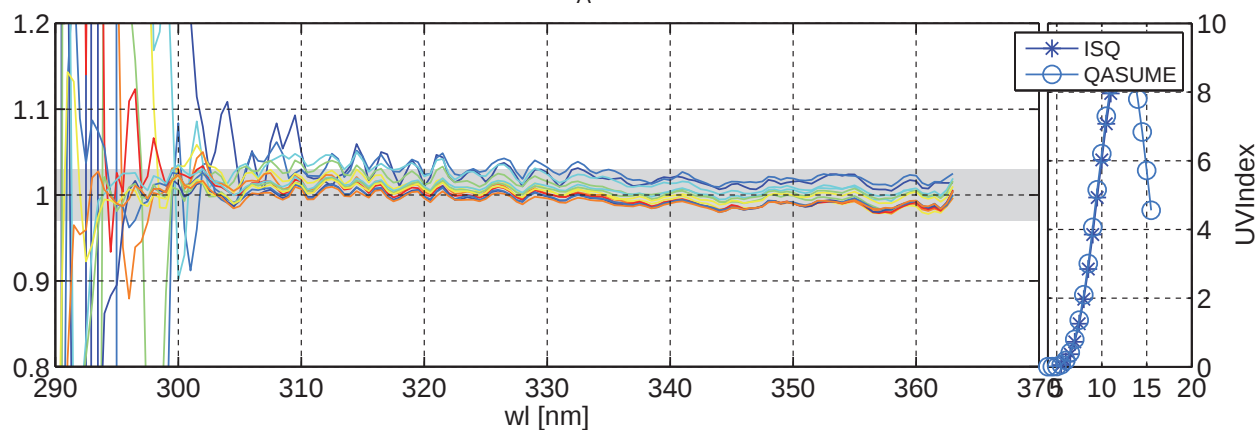
Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:03-Jun-2015(154)



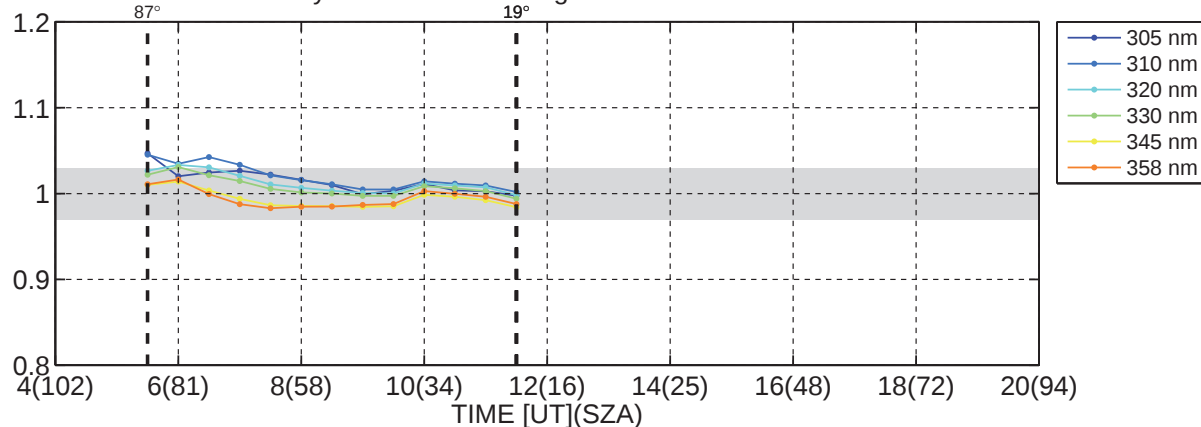
Daily variation. Wavelength bands are ± 2.5 nm



Global irradiance ratios ISQ/QASUME at El_Arenosillo-matshic:04-Jun-2015(155)



Daily variation. Wavelength bands are ± 2.5 nm



Mean ratio ISQ/QASUME at El_Arenosillo-matshic:26-May-2015(146) to 04-Jun-2015(155)

