

Protocol of the intercomparison at INTA, El Arenosillo, Spain
on June 10 to 19, 2013 with the travelling reference
spectroradiometer QASUME from PMOD/WRC

Report prepared by Luca Egli, Gregor Hülsen

Operator: Luca Egli, Christian Thomann

The purpose of the visit was the comparison of spectral global solar irradiance measurements between the 18 spectrophotometers participating in the 8th 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 June 10, 2013. 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 June 11 to the noon of June 19; the core comparison days were June 17-19.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Three lamps (T68522, T68523, and T685240) 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 26.3 ± 0.4 °C. At day 165 the temperature stabilization failed between 9:30 and 15:00 UTC. Excluding this period the mean temperature was 26.2 ± 0.1 °C. The diffuser head was heated to a temperature of 26.3 ± 4.2 °C. Due to a malfunction of the diffuser head stabilization the temperature of the head occasionally dropped below 23°C. These data (9 spectra) were excluded from the analysis for the certificate.

The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm analysis were between ± 50 pm in the spectral range 290 to 400 nm.

Table 1: Participating Brewer spectrophotometers; 9 single and 9 double monochromators.

Instrument ID	Institution	Operator	Country
#017-MKII	IOS	Ken Lamb	Canada
#051-MKIV	DMN	Abdelkarim Faquih	Morocco
#070-MKIV	AEMET MADRID	J.M. Santasasio	Spain
#075-MKIV	UKMO	John Rimmer	U.K.
#095-MKII	KMA	JungMi Lee	Korea
#117-MKIV	INM MURCIA	Jose Antonio Parodi	Spain
#126-MKII	UKMO	John Rimmer	U.K.
#150-MKIII	INTA HUELVA	Jose Manuel Vilaplana	Spain
#151-MKIV	AEMET CORUÑA	Francisco García	Spain
#158-MKIII	Kipp & Zonen	David Godoy	The Netherlands
#163-MKIII (ISQ)	PMOD/WRC	Luca Egli	Switzerland
#165-MKIII	DMN	Hamza Rachidi	Morocco
#166-MKIV	AEMET MADRID	J.M. Santasasio	Spain
#172-MKIII	UKMO	John Rimmer	U.K.
#183-MKIII (IZ2)	AEMED IZAÑA	Alberto Redondas	Spain
#185-MKIII (IZ3)	AEMED IZAÑA	Alberto Redondas	Spain
#186-MKIII	AEMED MADRID	Jose Montero	Spain
#201-MKIII	ONM	Ouchene Bouziane	Algeria

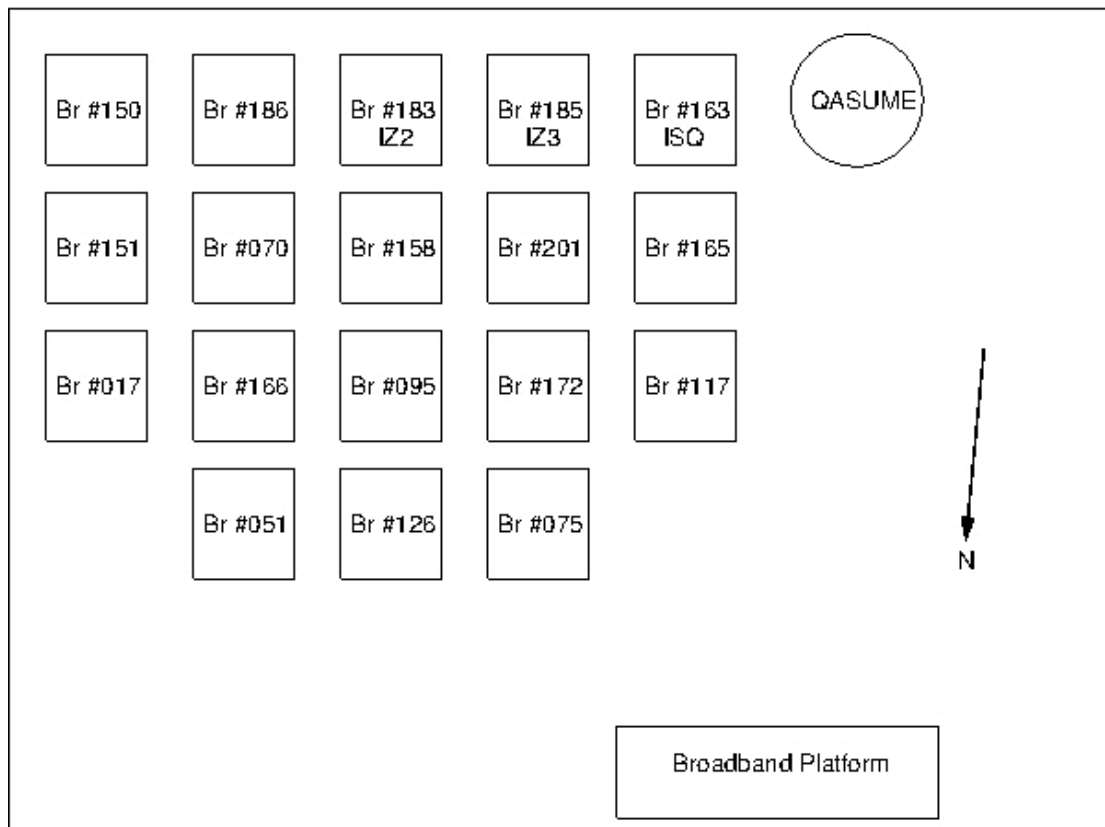


Figure 1: Roof setup at INTA

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.

DOY	Date	DAY	Weather	Comment (time in UT)
161	10-Jun	Monday	Clear Sky	Installed at 11:45
162	11-Jun	Tuesday	Clear Sky	Calibrated: 09:14 using T68523 Calibrated: 17:05 using T68522
163	12-Jun	Wednesday	Clear Sky	Calibrated: 7:12 using T68523 Calibrated: 7:35 using T68522 Calibrated: 11:15 using T685240 Calibrated: 15:35 using T68523
164	13-Jun	Thursday	Clear Sky	Calibrated: 7:13 using T68523 Calibrated: 11:13 using T68523 Calibrated: 11:43 using T685240 Calibrated: 15:43 using T68522 Calibrated: 16:12 using T68523
165	14-Jun	Friday	Clear Sky	Calibrated: 7:15 using T68523 Calibrated: 11:35 using T68523 Temperature stabilisation off between 9:30 - 15:00
166	15-Jun	Saturday	Clear Sky	Calibrated: 7:40 using T68523 Calibrated: 8:40 using T68522
167	16-Jun	Sunday	Clear Sky	UV Day Calibrated: 7:04 using T68522
168	17-Jun	Monday	Cloudy Sky	UV Day Calibrated: 10:43 using T68523 Calibrated: 12:13 using T685240
169	18-Jun	Tuesday	Cloudy Sky	UV Day Calibrated: 8:43 using T68523 Calibrated: 17:13 using T61251
170	19-Jun	Wednesday	Mostly Cloudy Sky	Calibrated: 7:15 using T68522 Calibrated: 7:43 using T68523
				End of Campaign 10:10

Results:

In total 26 to 51 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°).

Remarks:

1. QASUME arrived at the first day of the RBCC-E intercomparison, which was dedicated for the setup and training phase. The official “UV-days” were 16-18 July (days 167-169). However, synchronized UV scans are also available beginning from the 11th June.
2. Due to malfunctions of the QASUME temperature stabilization, the respective spectra were excluded for the analysis for the certificates.
3. Because of the different calibrations and measurements performed during the campaign, traffic on the roof could not be completely omitted. Therefore several scans are disturbed and excluded from the analysis.
4. The time synchronisation between QASUME and various Brewers was good using the same web-based clock for all instruments.

Brewer Temperature Dependence:

The standard Brewer global UV measurement procedure does not take into account the dependence of the Brewer spectral responsivity to ambient temperature. However several studies have shown, that Brewer spectrophotometers have a temperature dependence which can be as large as 0.9%/K and which depends on wavelength (Cappellani, F., and C. Kochler (2000), Temperature effects correction in a Brewer MKIV spectrophotometer for solar UV measurements, *J. Geophys. Res.*, 105(D4), 4829–4831; Weatherhead, E., et al. (2001), Temperature dependence of the Brewer ultraviolet data, *J. Geophys. Res.*, 106(D24), 34,121–34,129).

At El Arenosillo, due to the diurnal temperature variations, the temperature dependence of the Brewer spectrophotometers has a significant influence on the global UV measurements as can be seen in the respective ratios relative to the QASUME spectroradiometer (Table 2) which is temperature stabilised.

Recommendations:

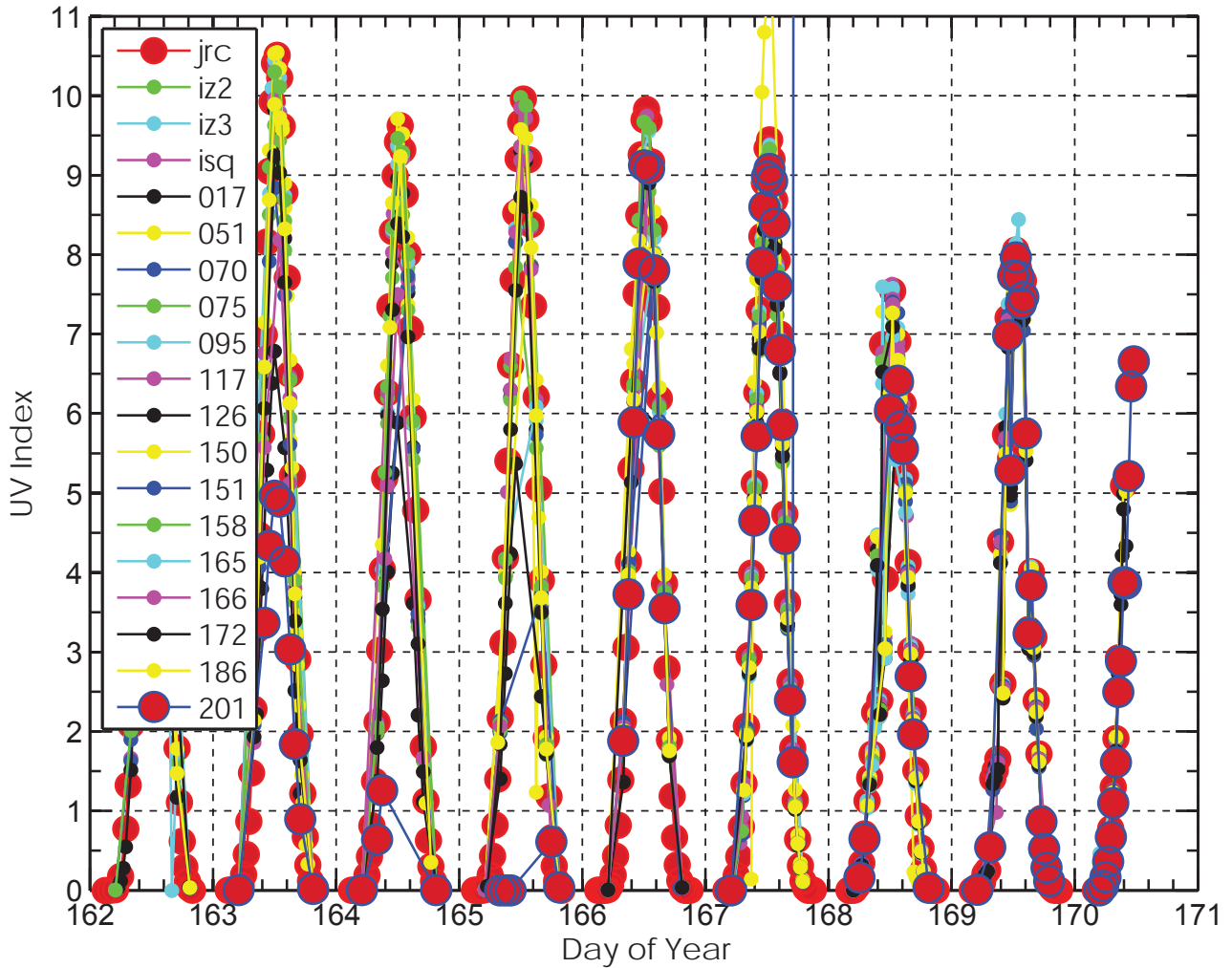
The variabilities observed between individual Brewer spectrophotometers relative to the QASUME spectroradiometer are due to ambient temperature variations on the one hand (see above paragraph), and to angular response errors which were not accounted for (See for example Gröbner, J., Improved entrance optic for global irradiance measurements with a Brewer spectrophotometer, *Applied Optics*, 42, 3516-3521, 2003). While a reliable correction of angular response errors requires the modification of the Brewer entrance optic, the temperature dependence can be corrected by applying a suitable spectral temperature correction to global UV measurements. The temperature dependence should therefore be determined individually for

every Brewer using a measurement procedure as described in the refereed literature (see references).

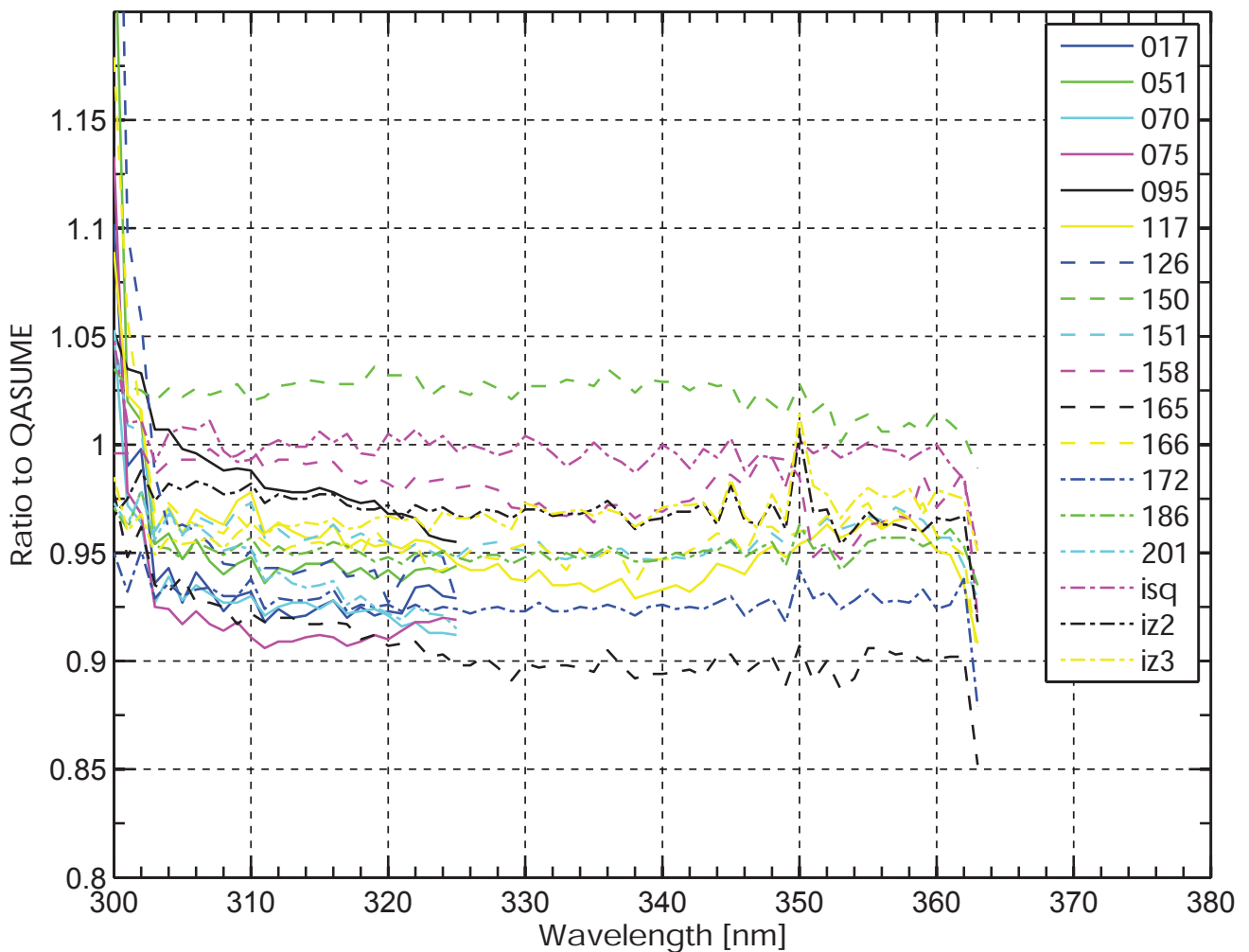
Table 2: Mean values of the ratio Brewer/QASUME (305 – 320/360 nm), the diurnal variability and the wavelength shifts.

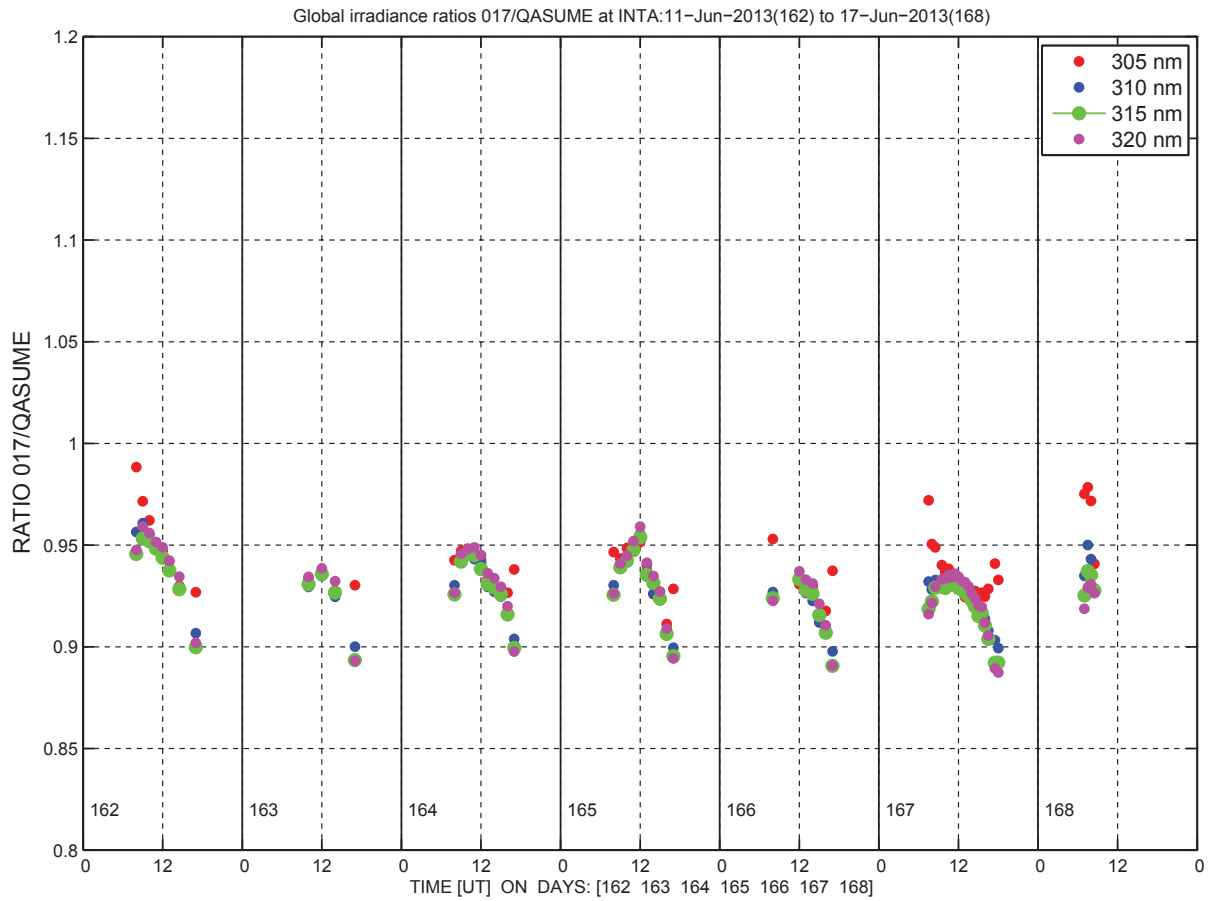
Instrument ID	Brewer to QASUME [%]	Diurnal variability [%]	Wavelength shift [pm]
#017	-7	±2	< ± 50
#051	-5	±2	< ± 50
#070	-7	±3	+20 .. +50
#075	-9	±2	-120 .. -100
#095	-2	±2	< ± 50
#117	-5	±5	< ± 50
#126	-4	±4	< ± 50
#150	2	±2	< ± 50
#151	-5	±4	< ± 50
#158	-2	±2	-70 .. -30
#163 (ISQ)	1	±1	< ± 50
#165	-4	±5	-100 .. -20
#166	-5	±4	-60 .. +60
#172	-7	±3	0 .. +70
#183 (IZ2)	-2	±3	< ± 50
#185 (IZ3)	-3	±3	-20 .. +80
#186	-5	±3	< ± 50
#201	-5	±2	+20 .. +50

UV Index Inta, June 2013

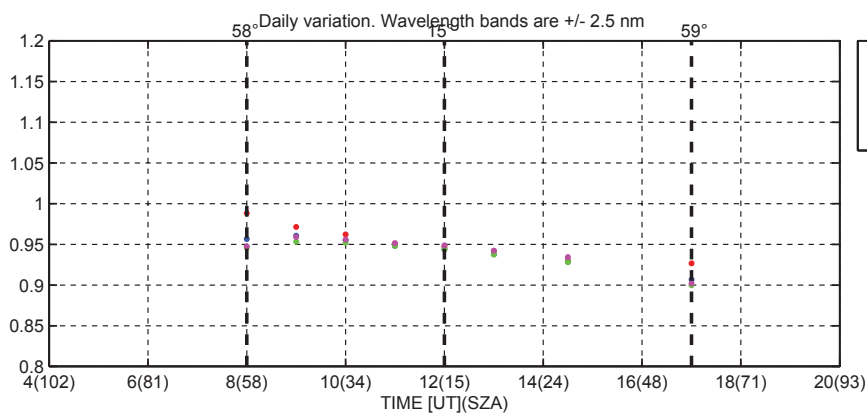
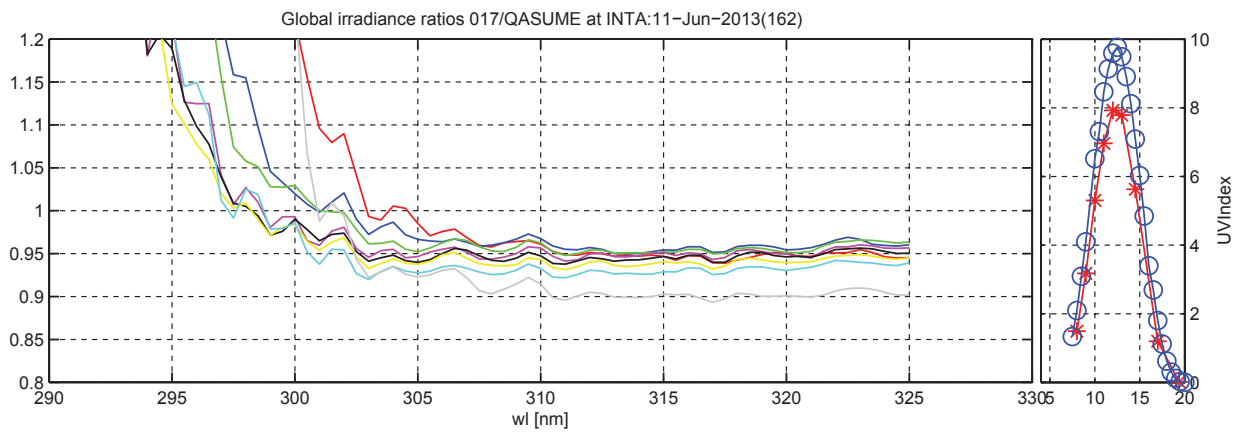


Mean ratios to QASUME for all Brewers at the 8th RBCC-E Campaign, INTA, July 2013

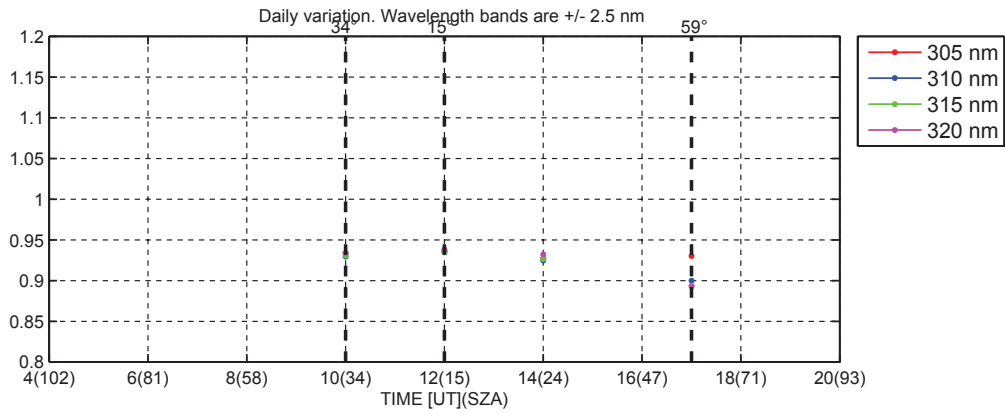
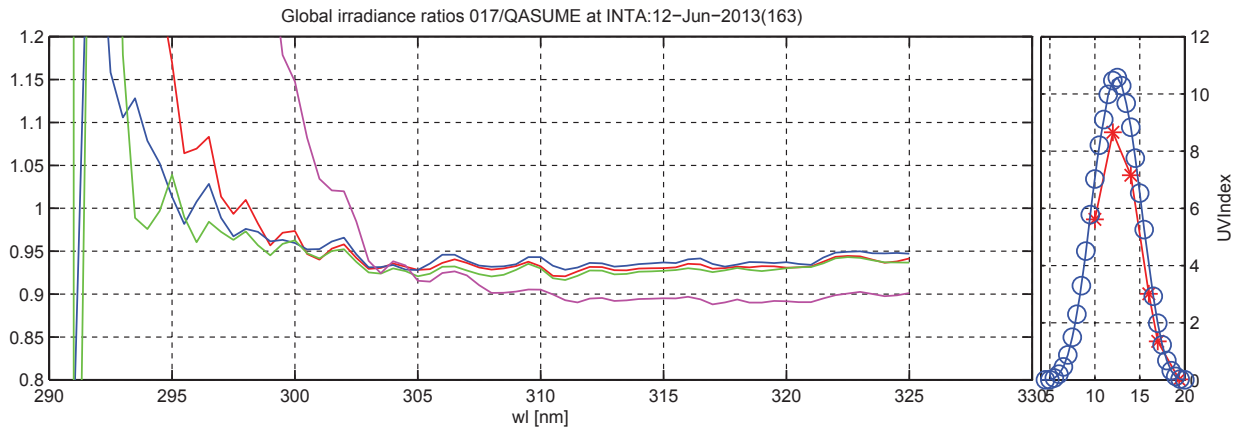




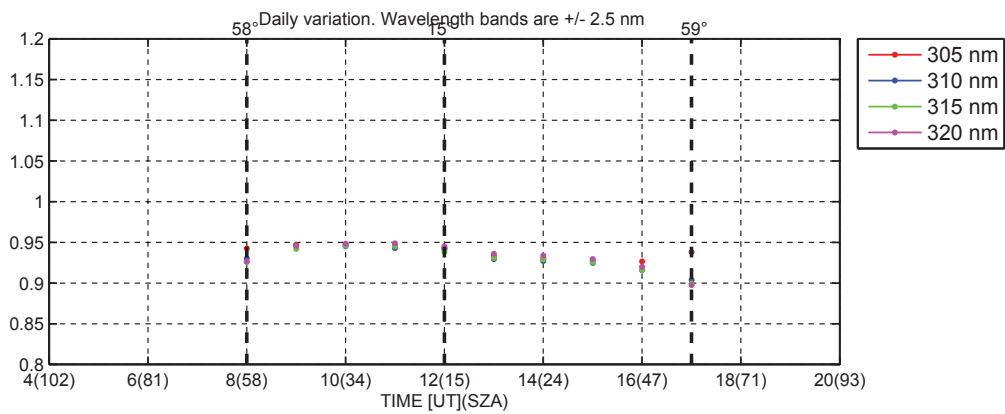
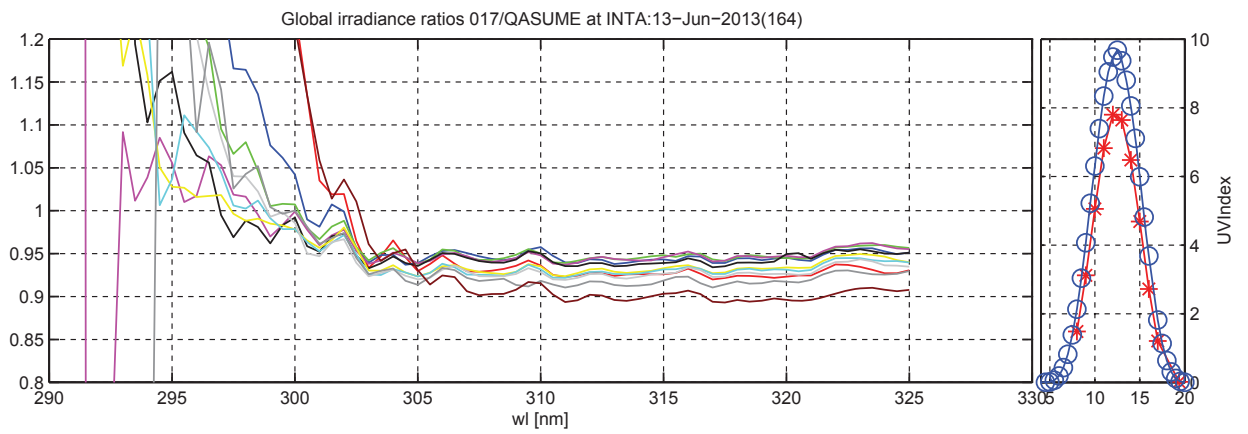
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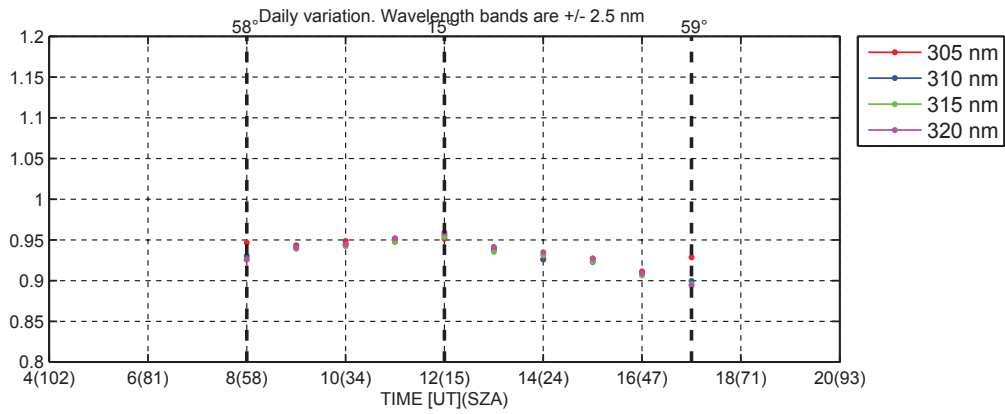
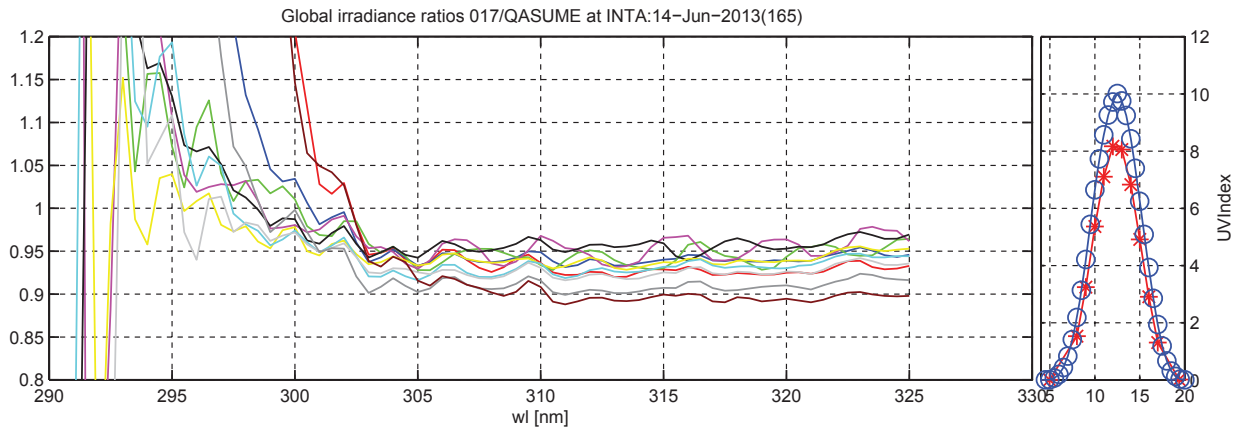
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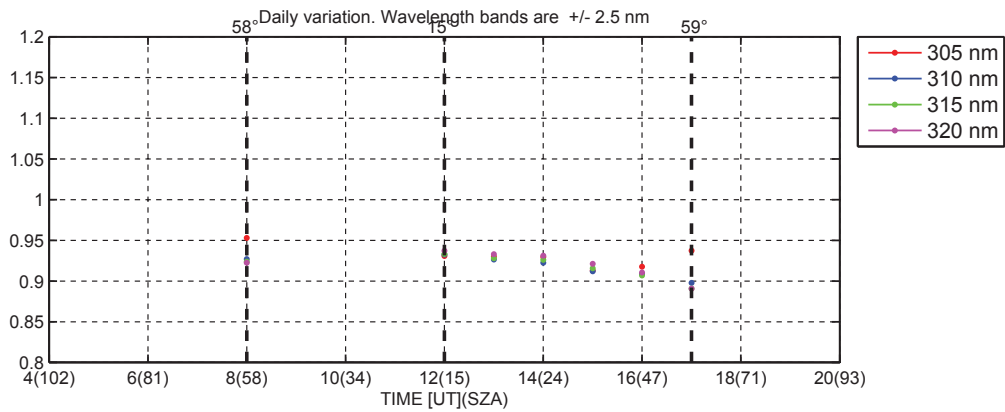
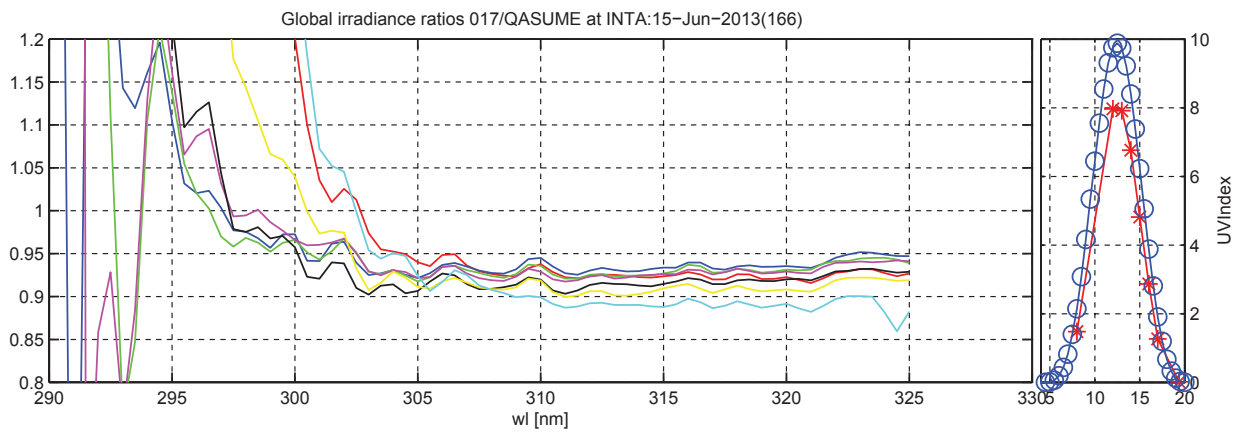
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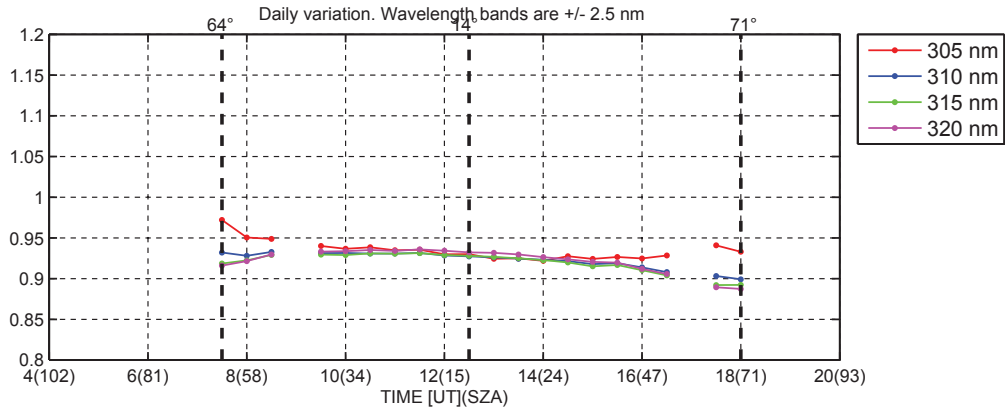
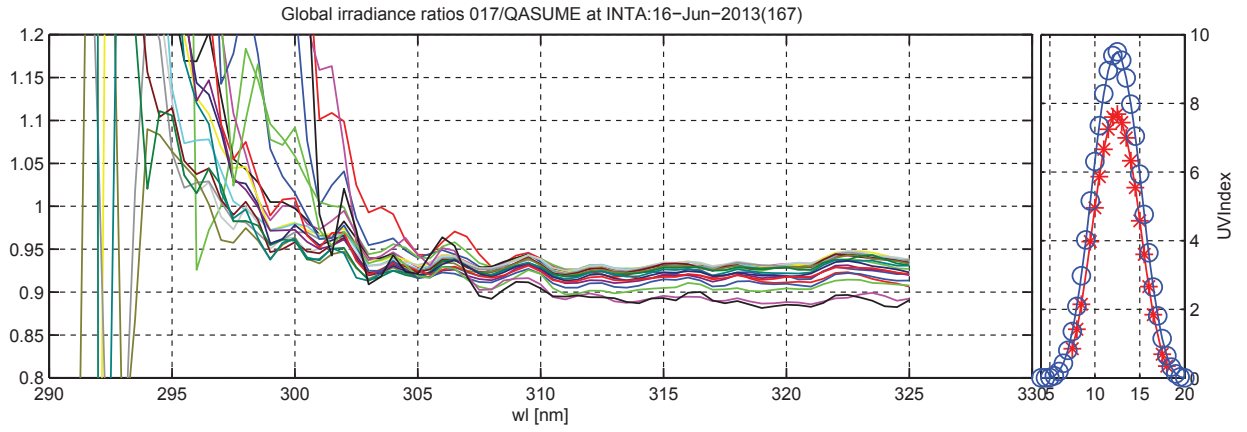
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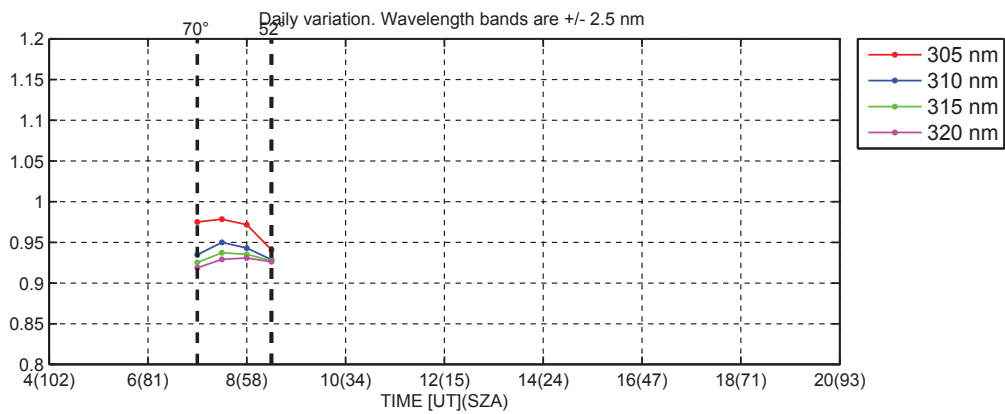
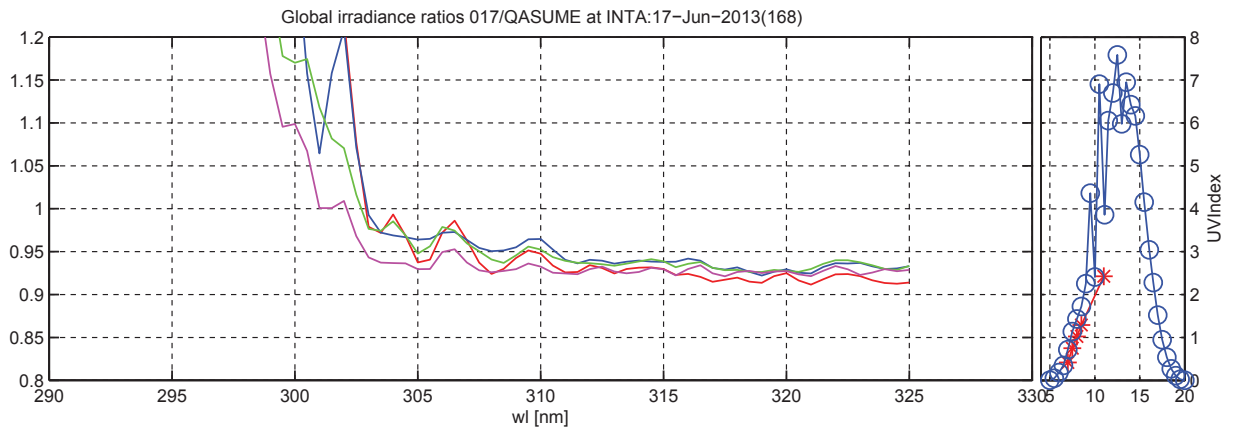
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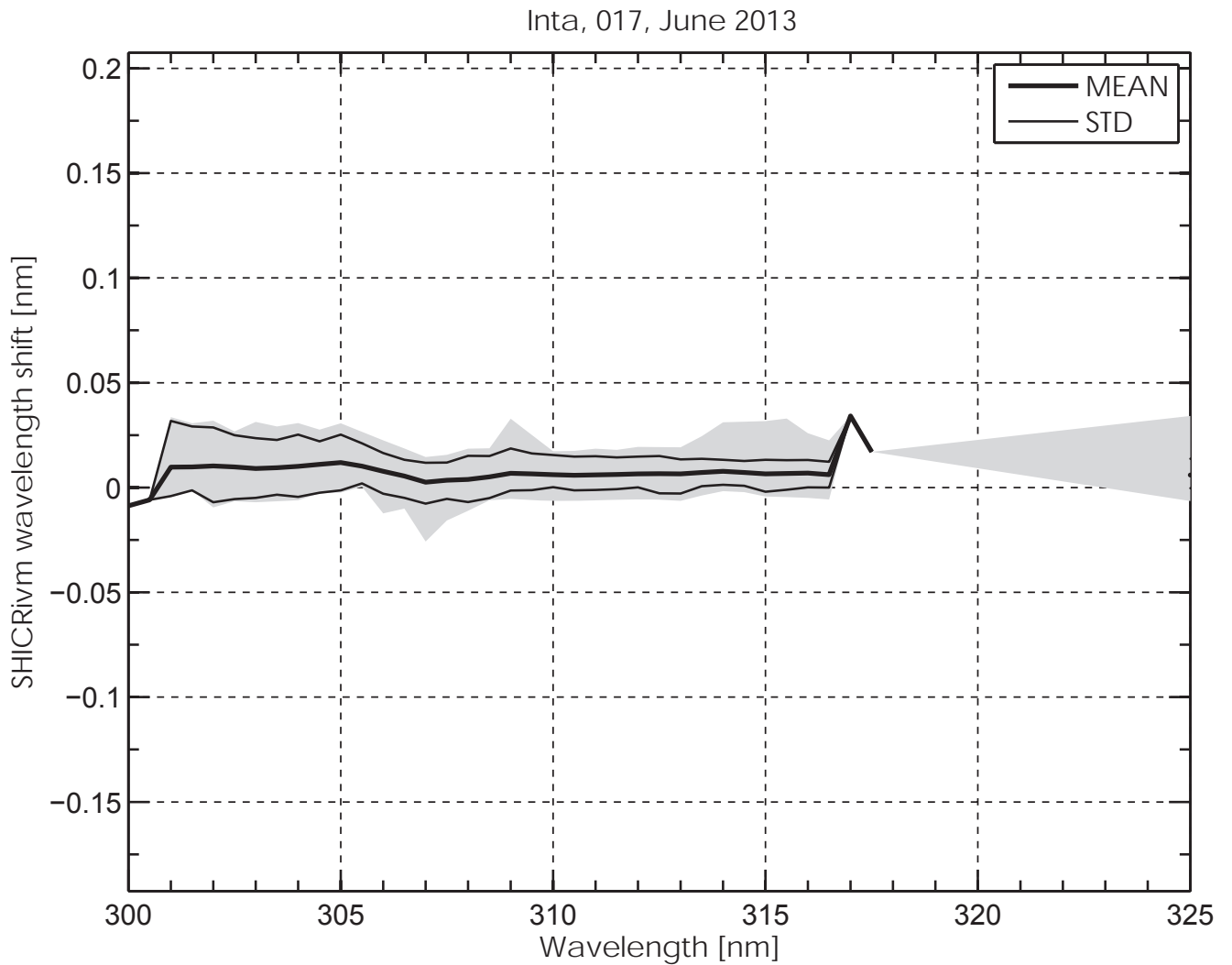
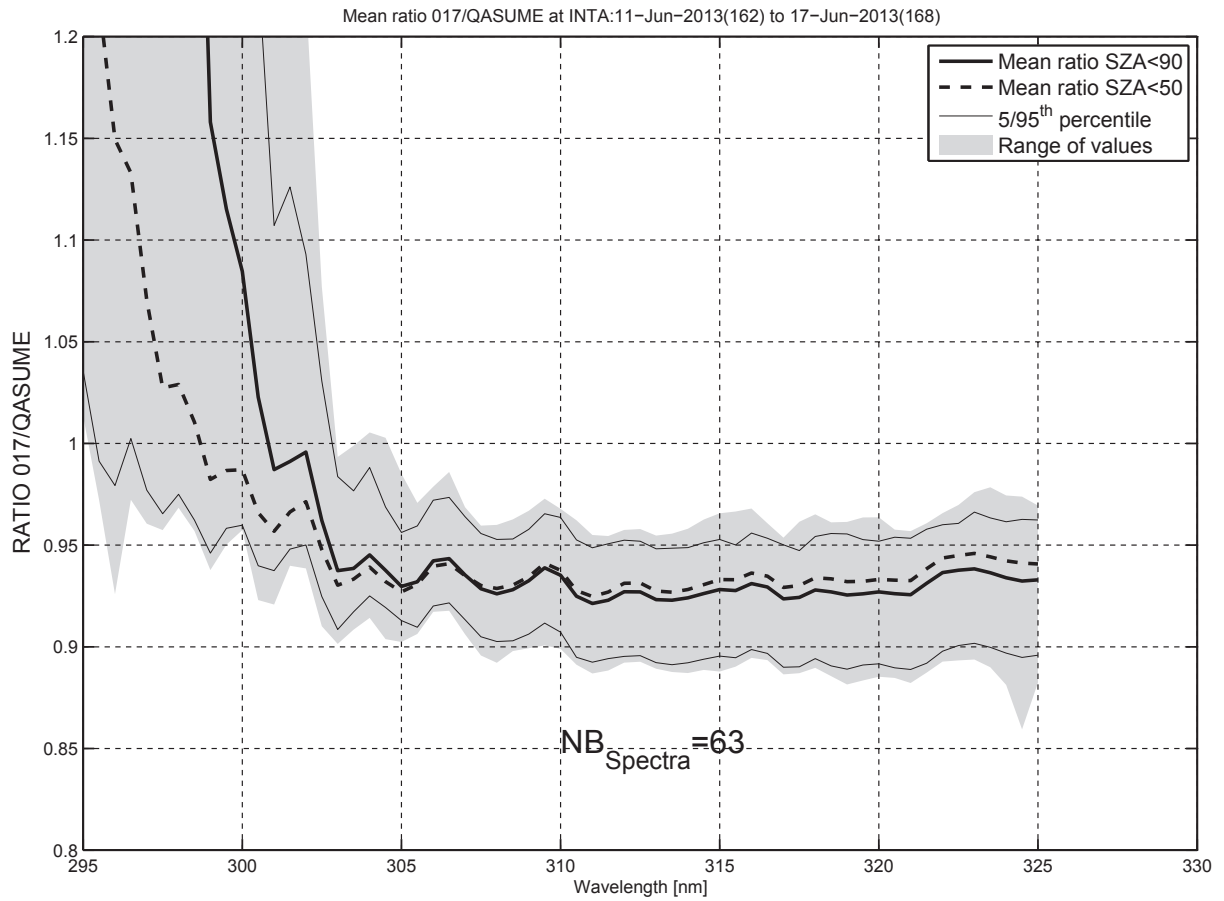
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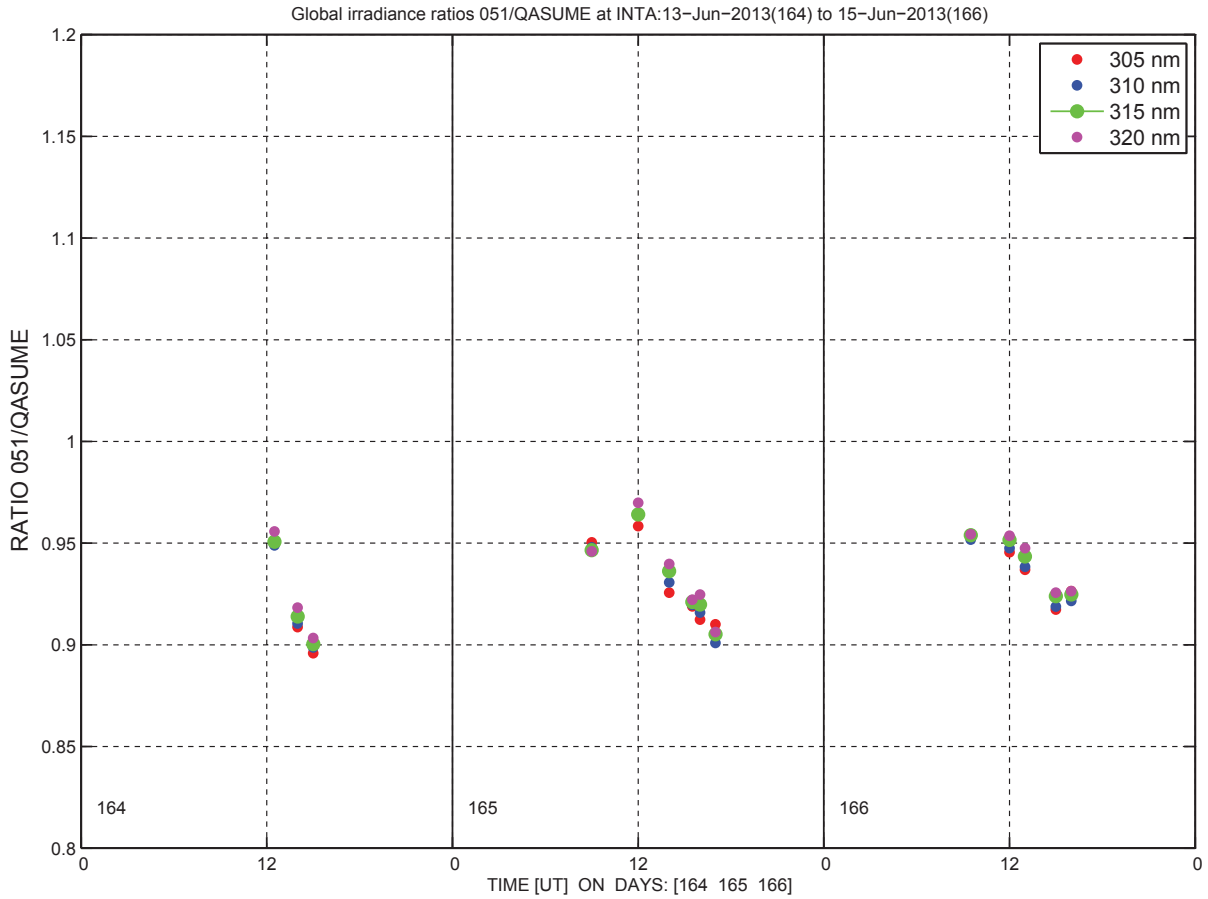


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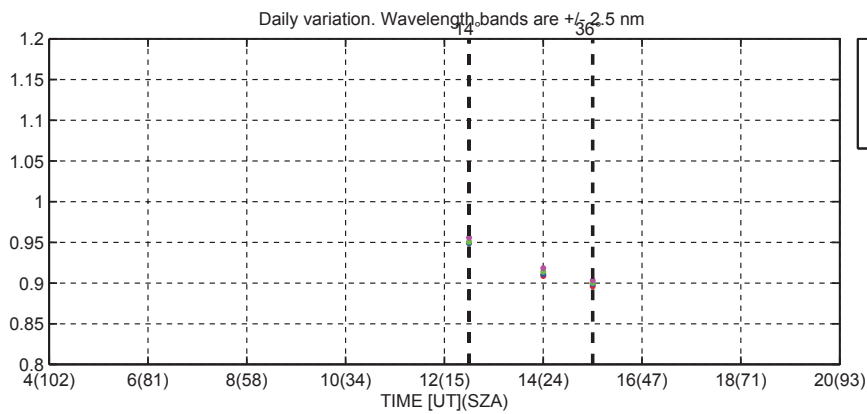
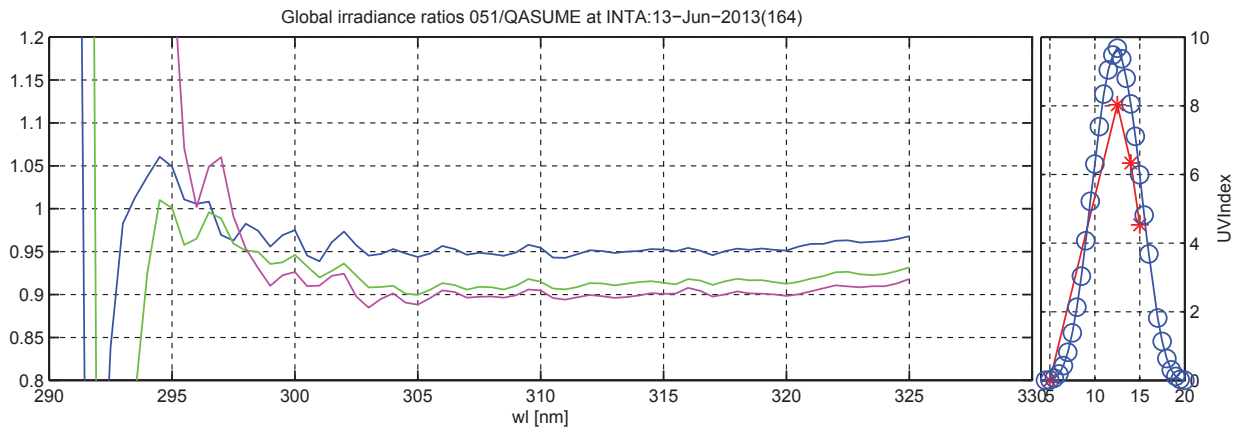


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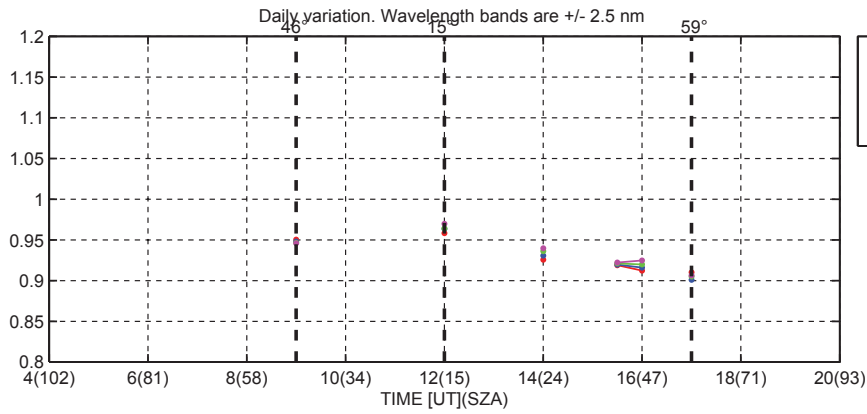
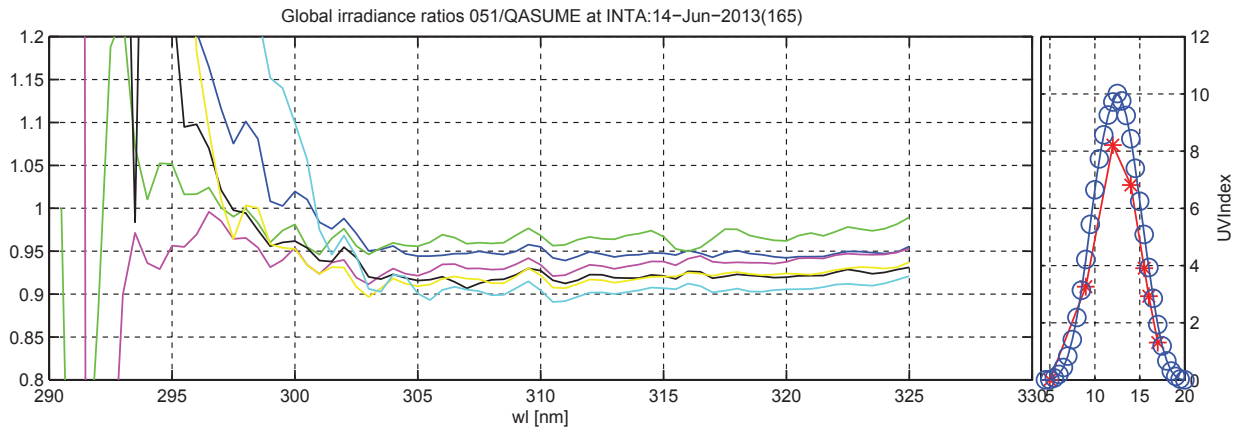




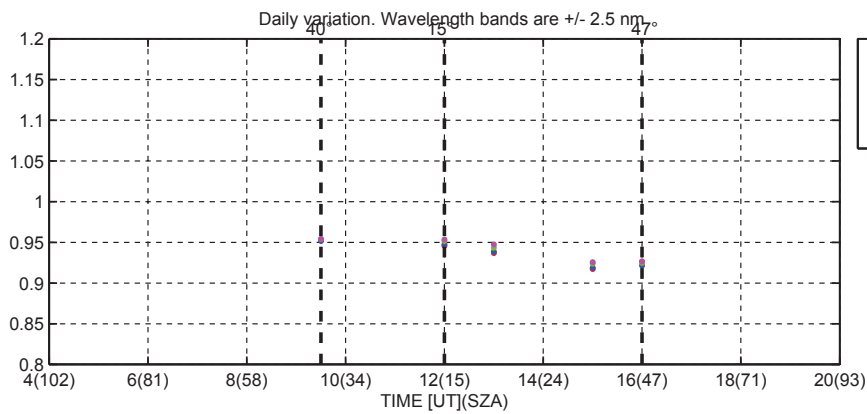
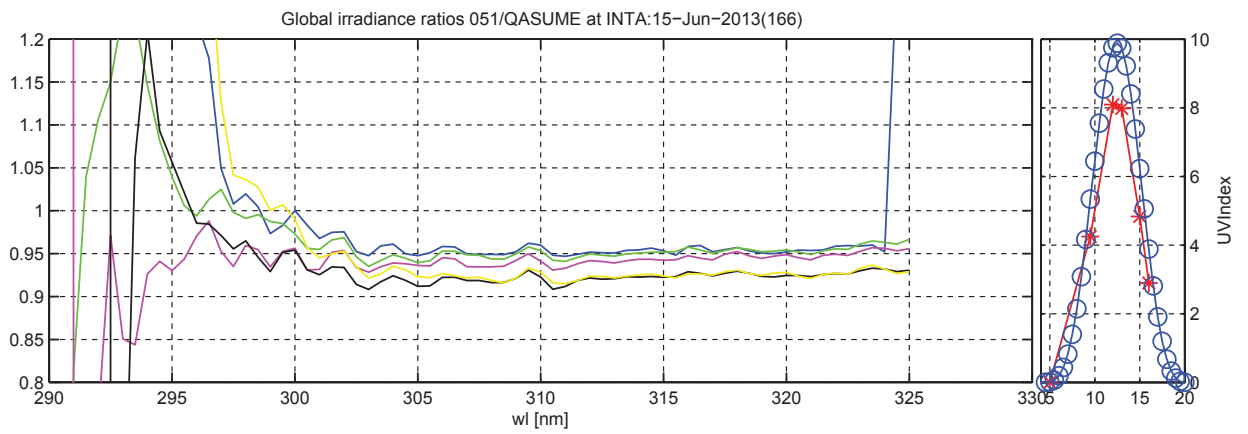
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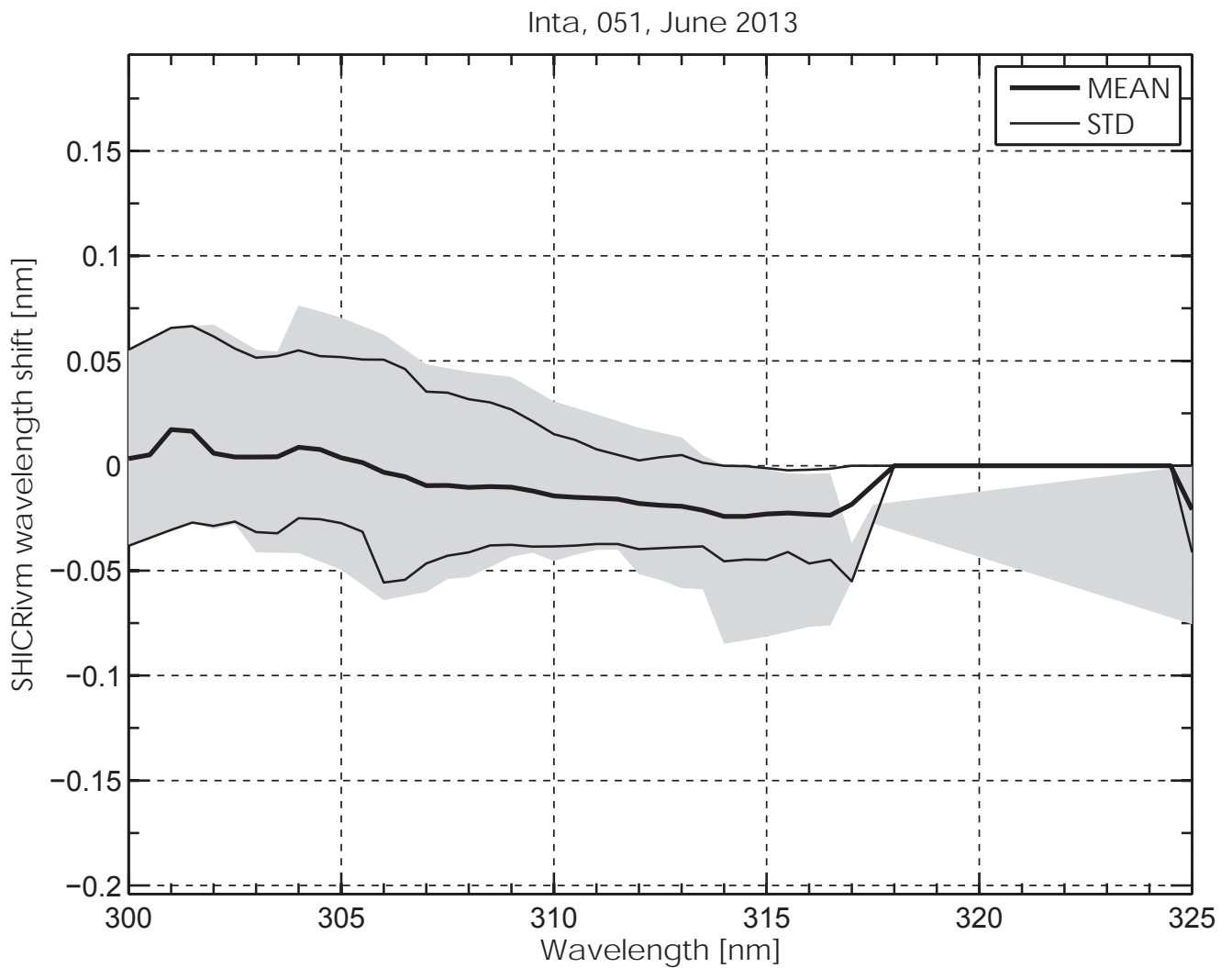
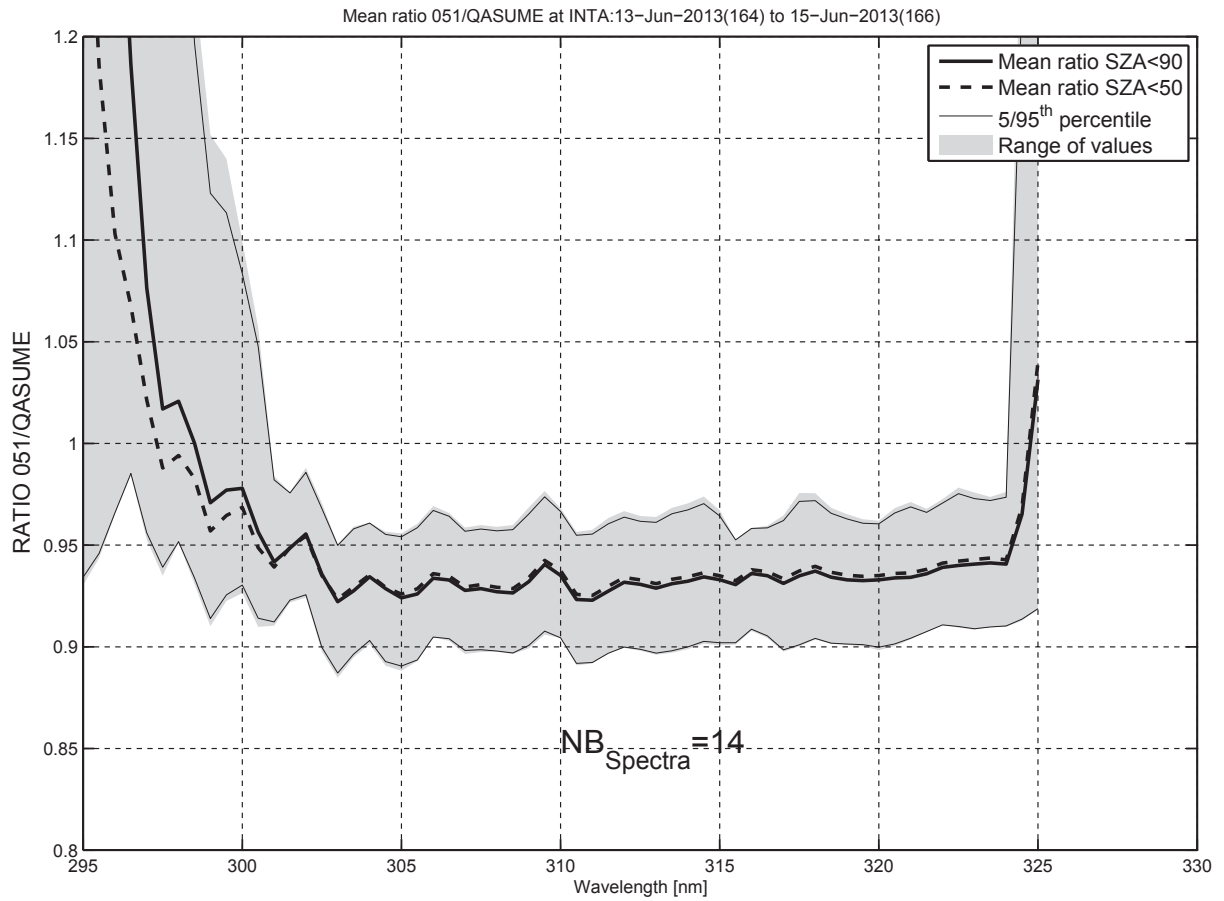
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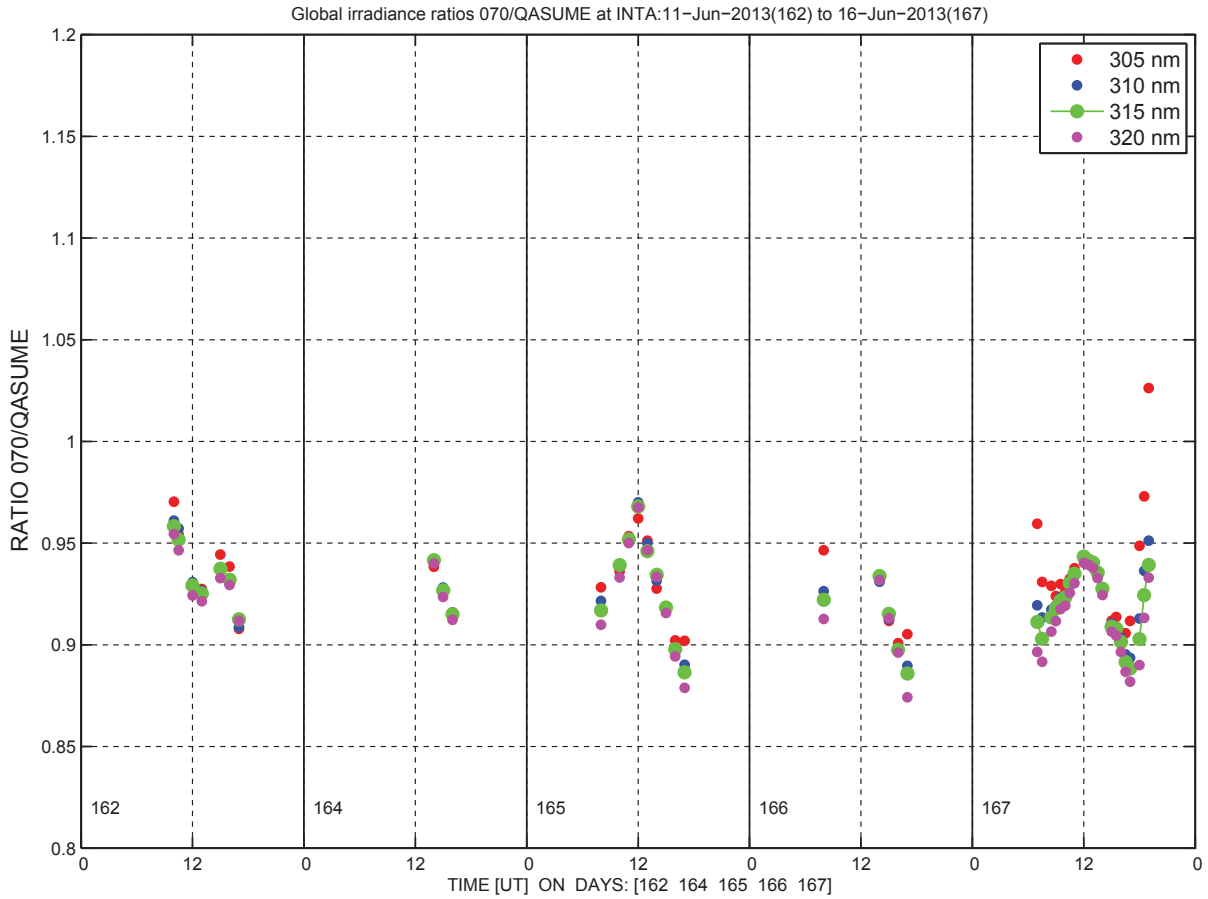


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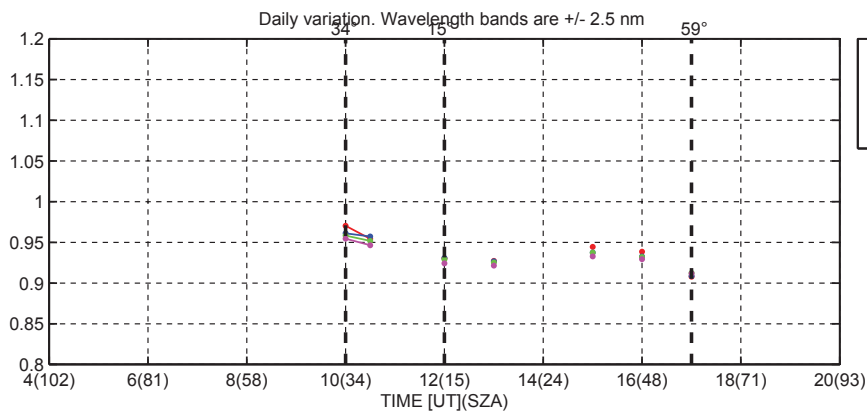
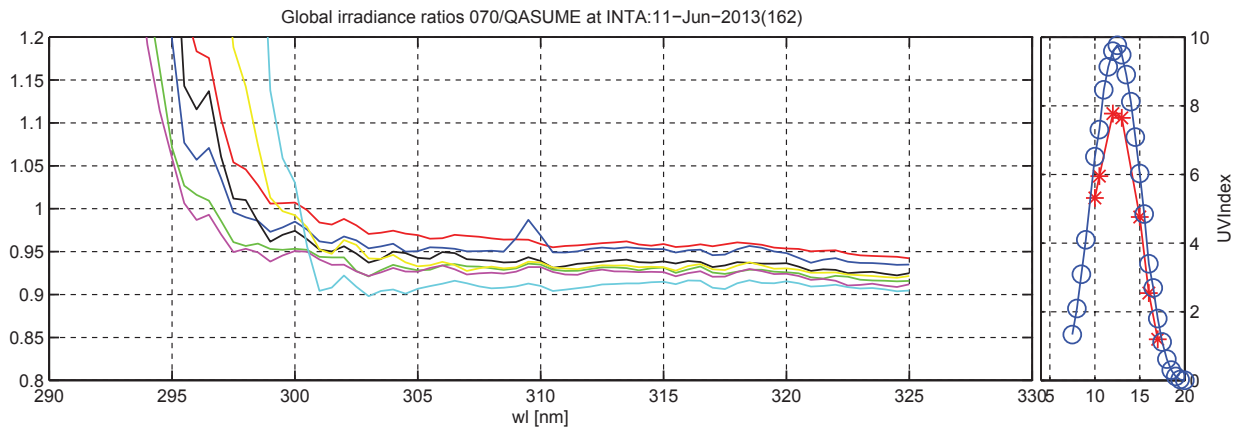


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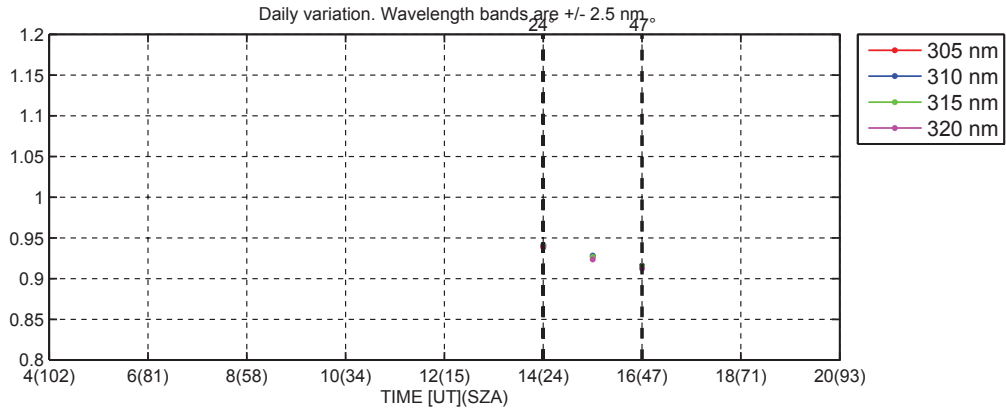
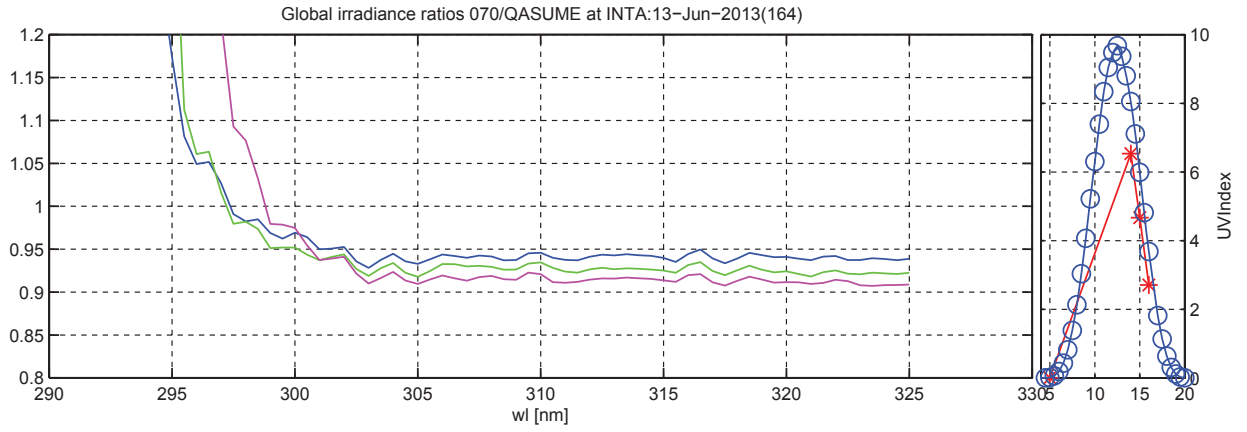




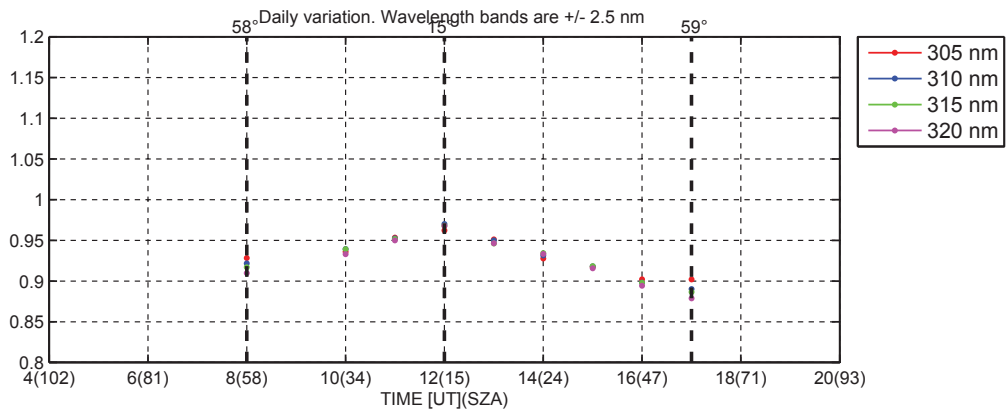
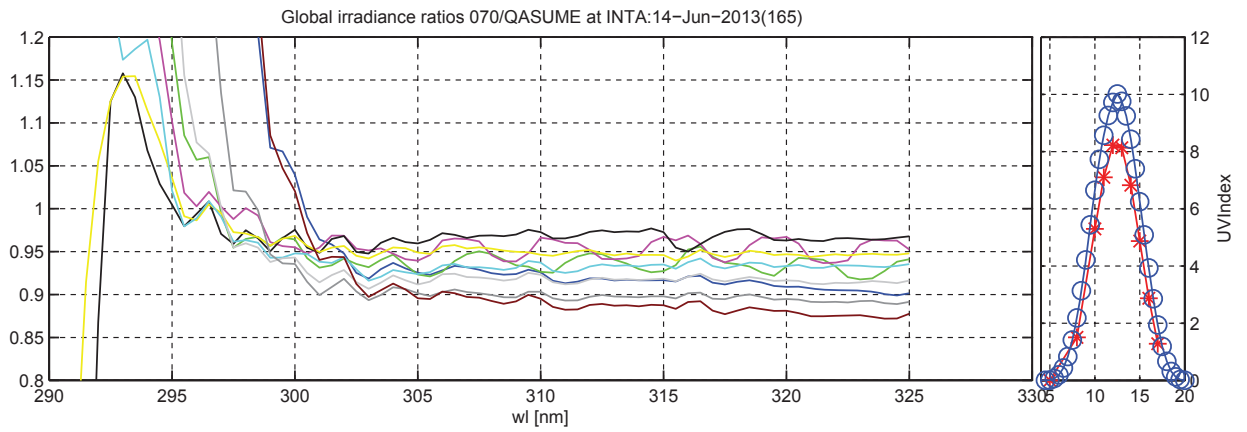
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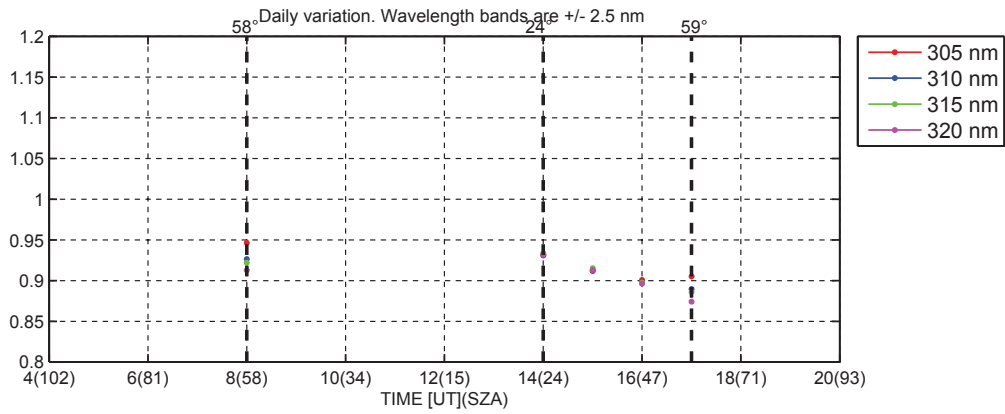
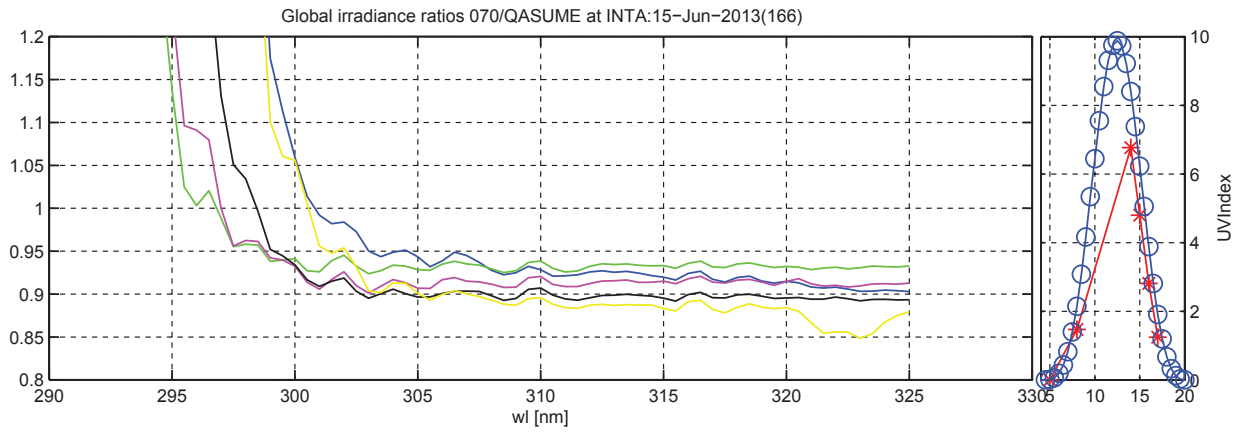
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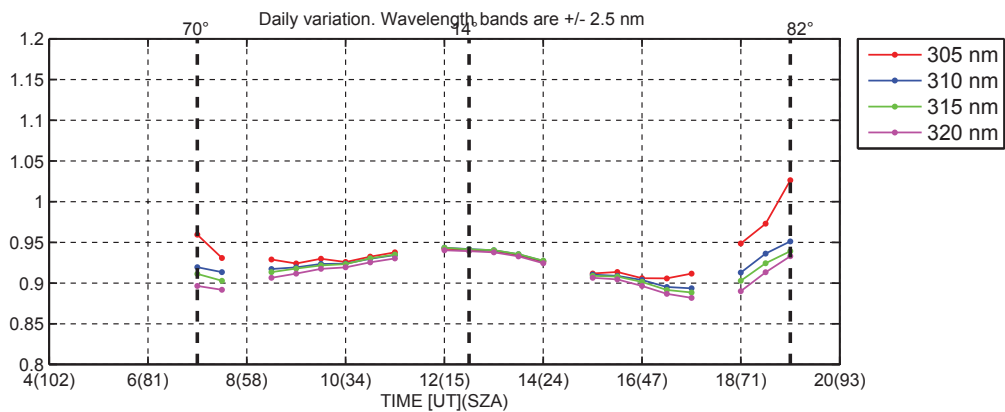
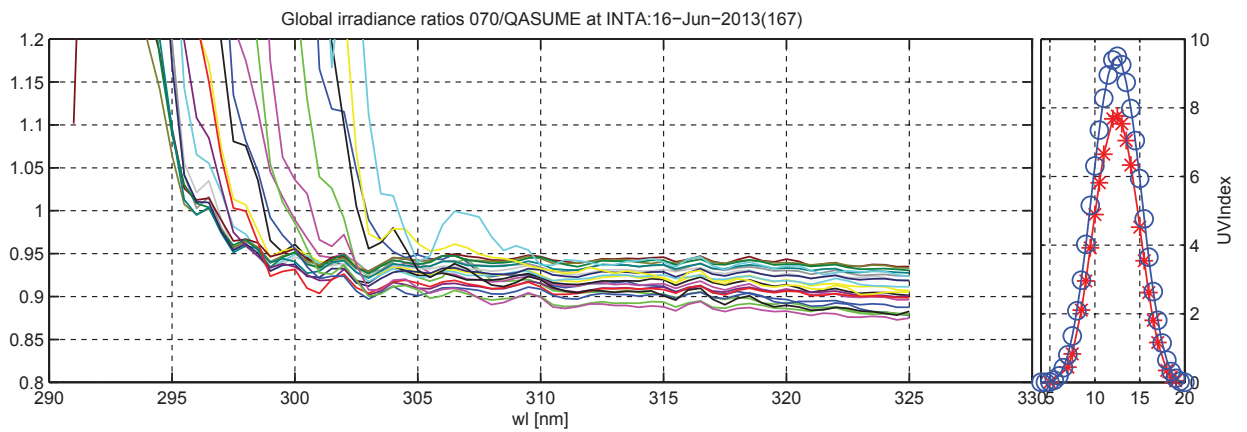
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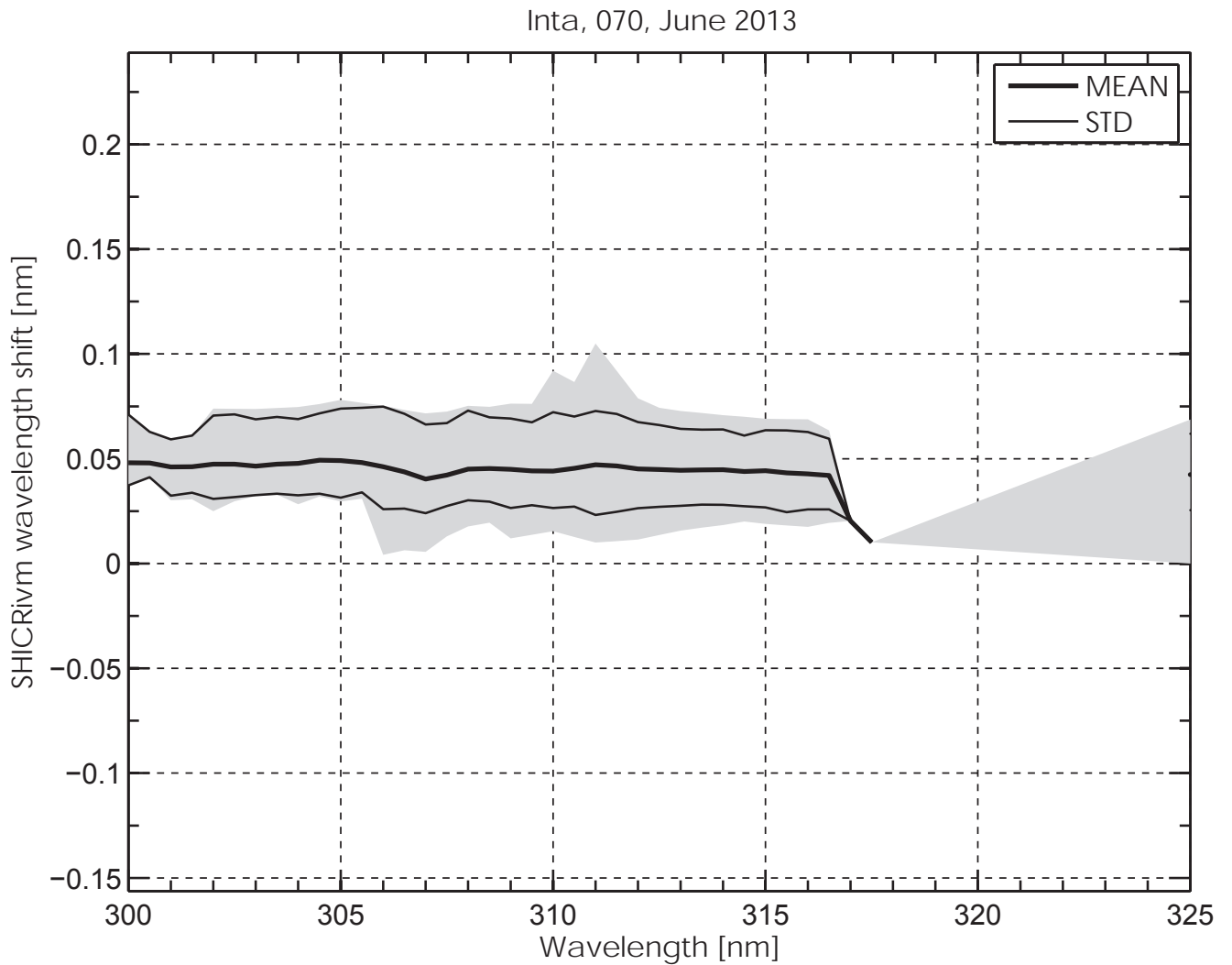
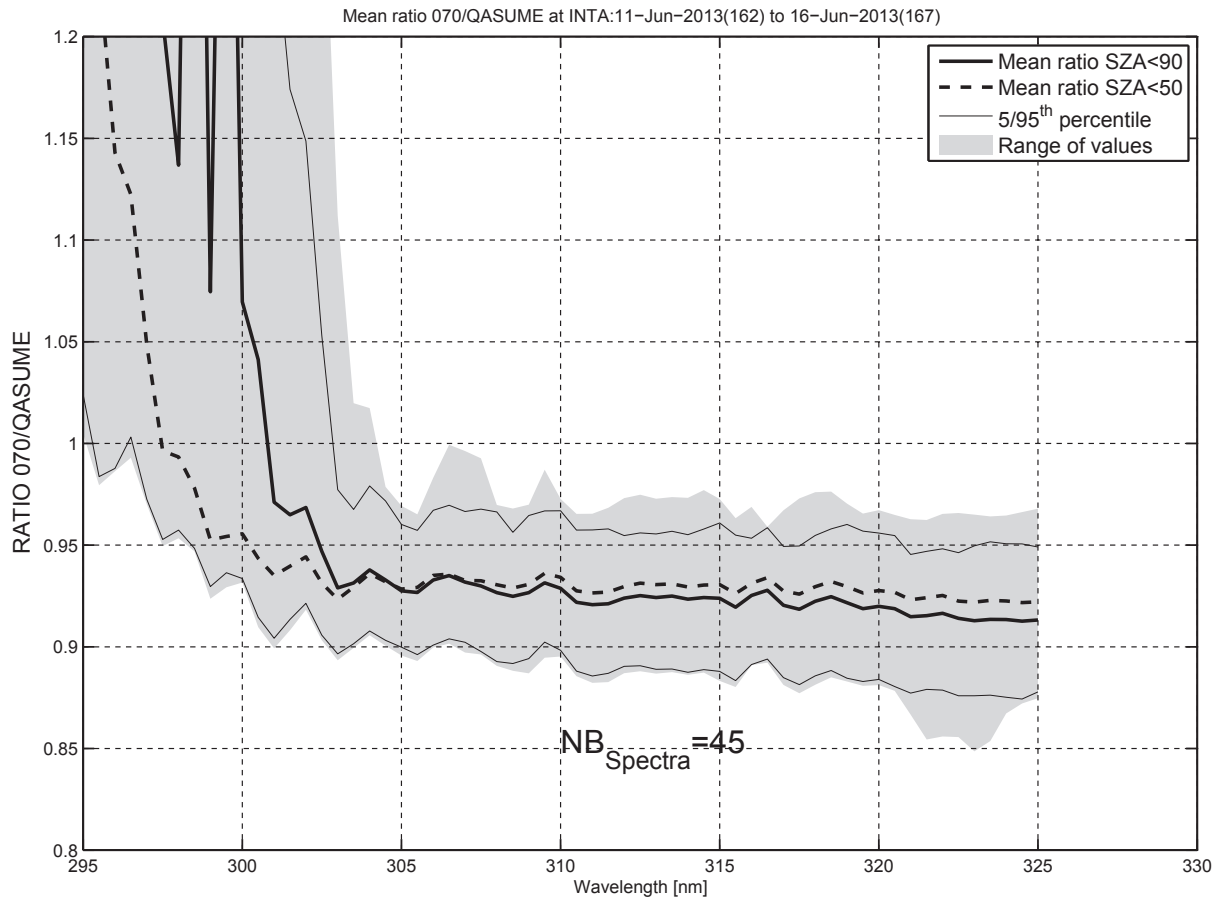
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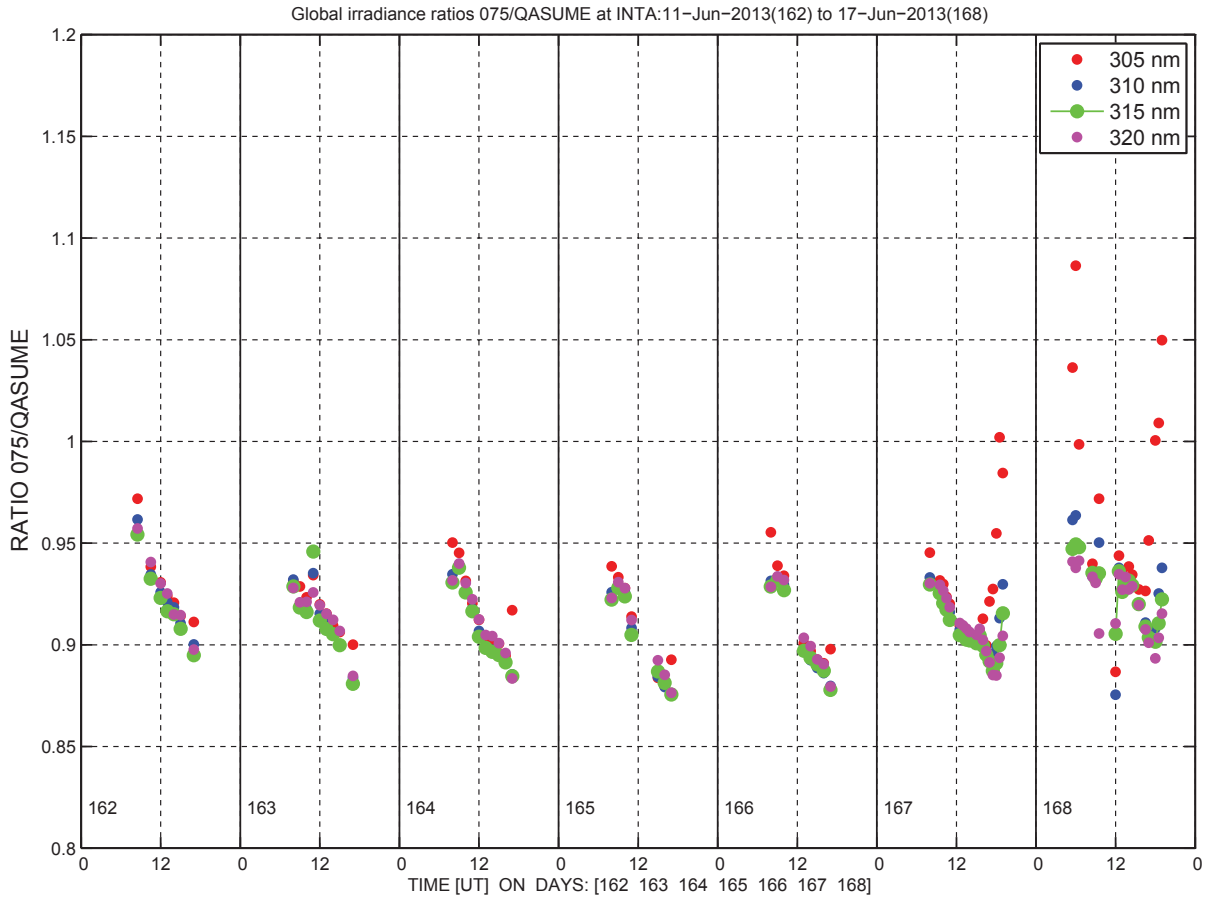


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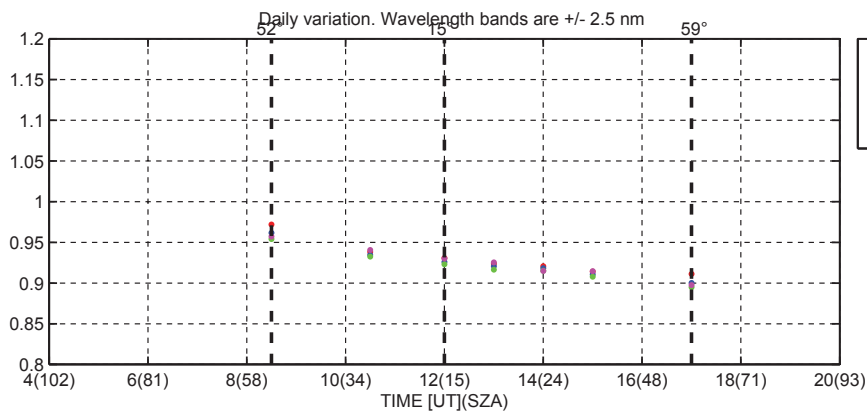
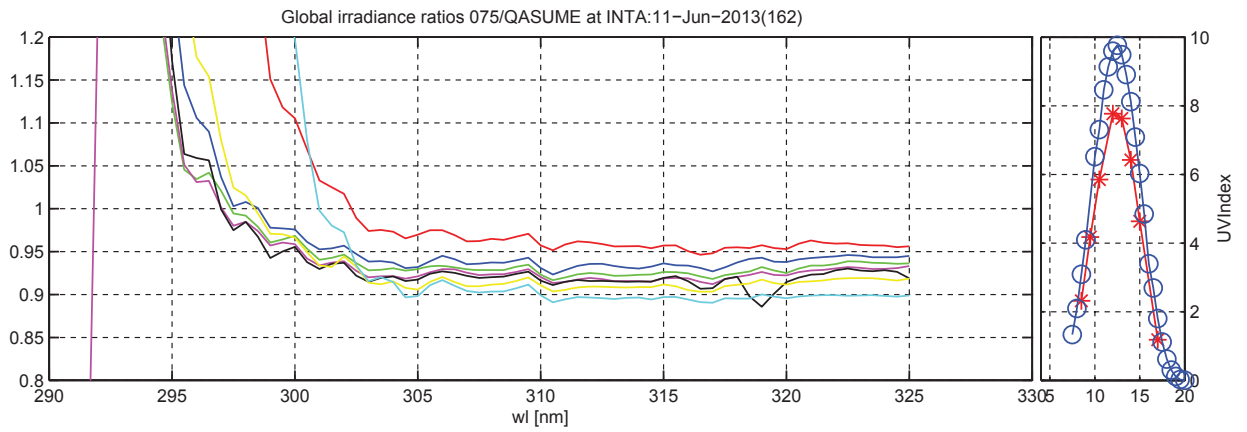


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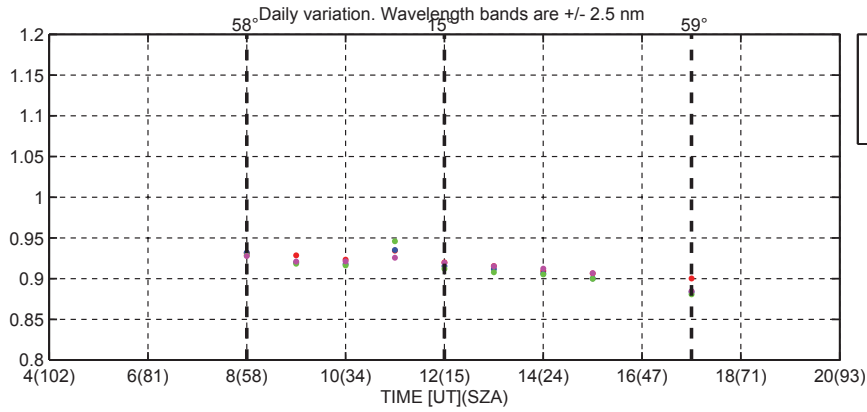
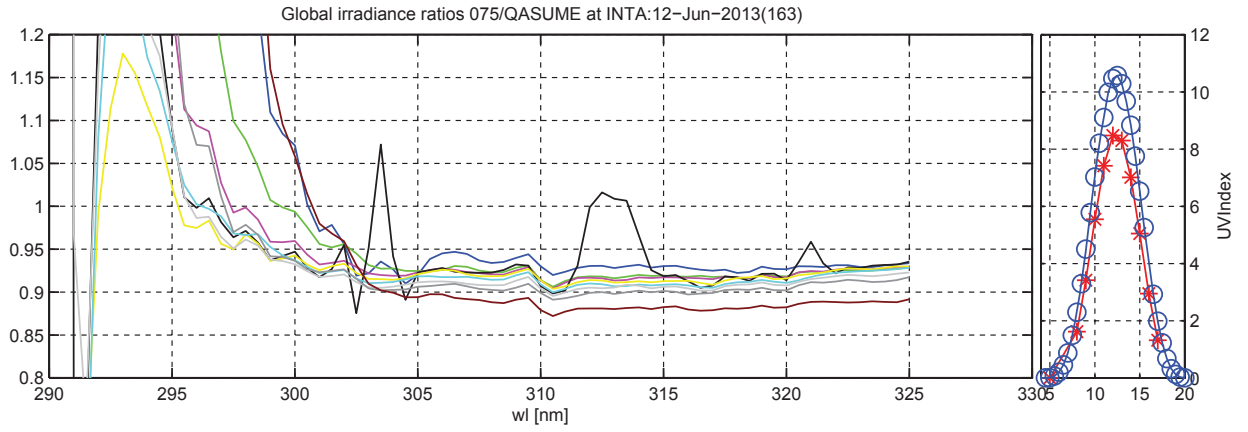




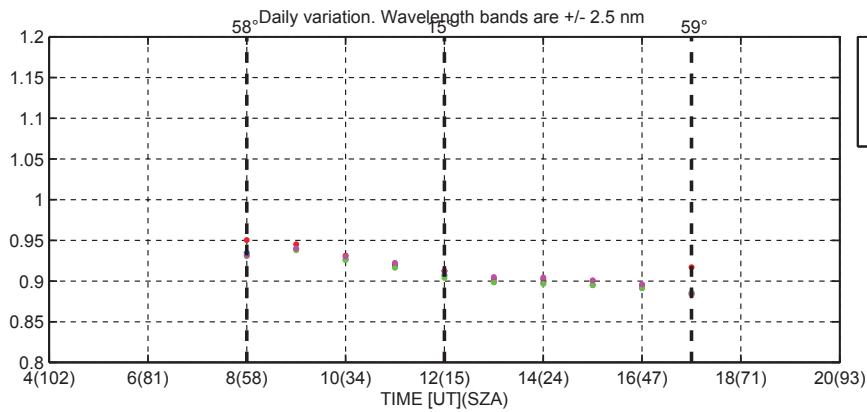
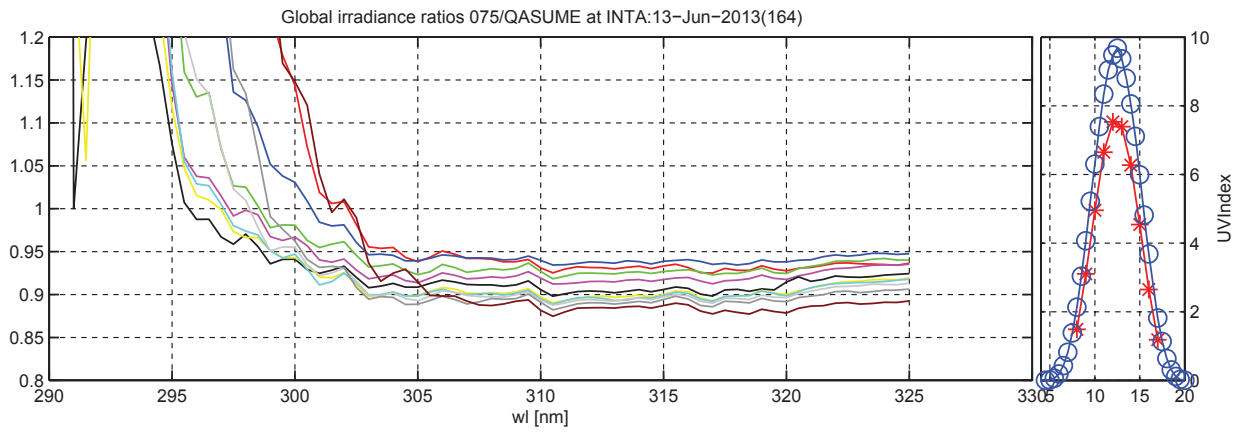
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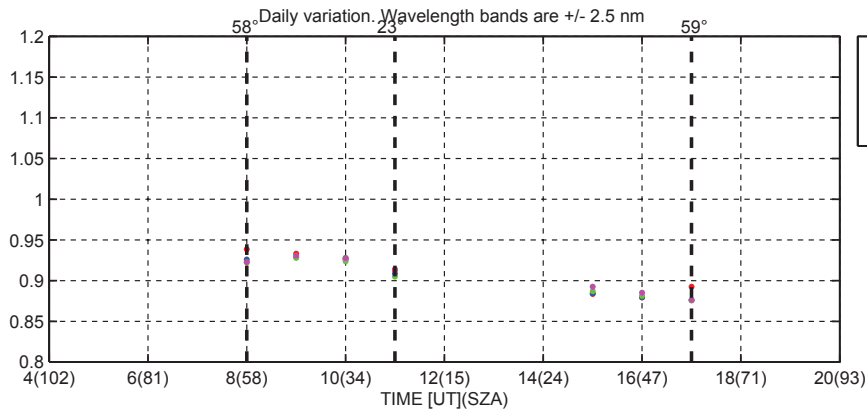
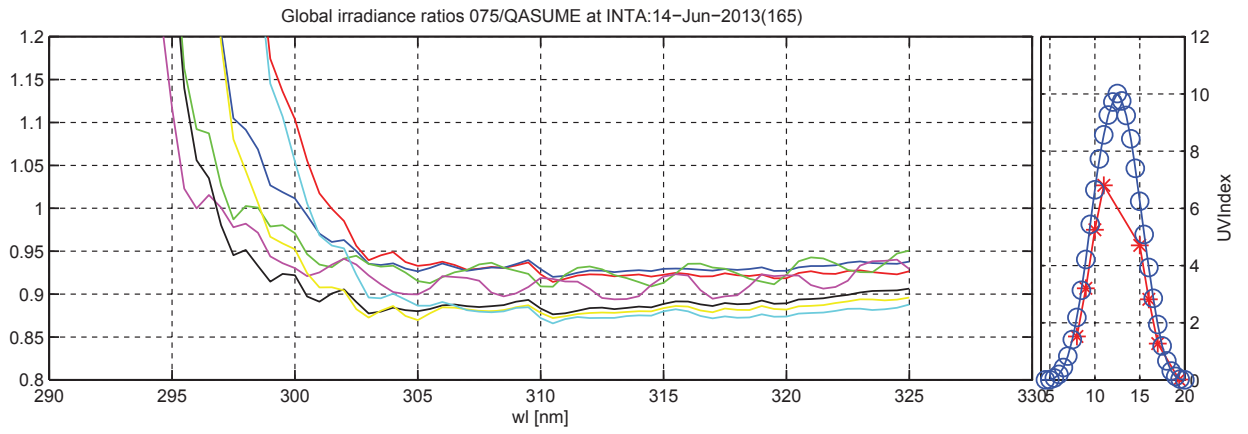
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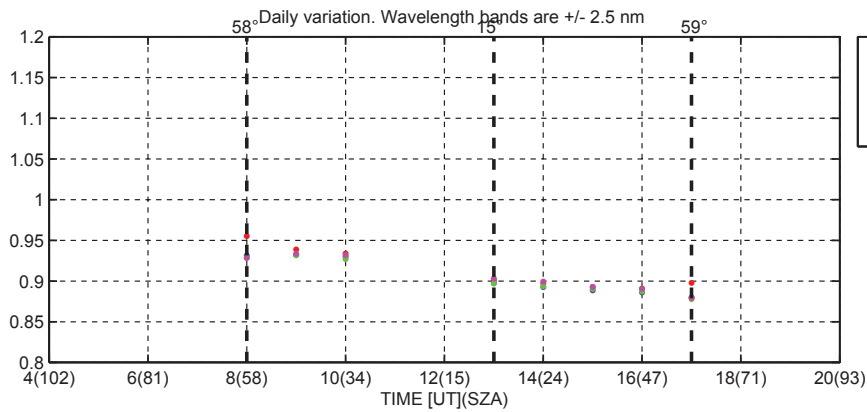
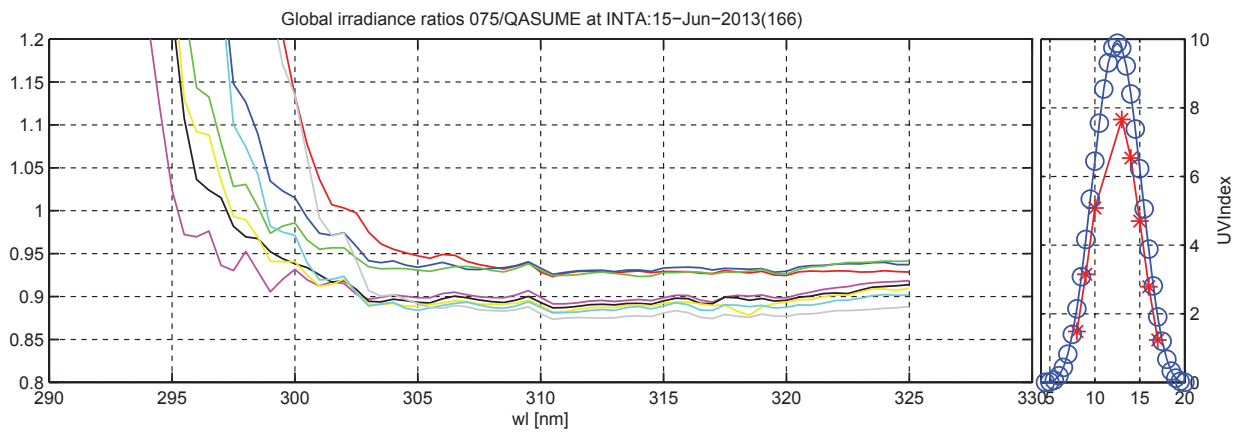
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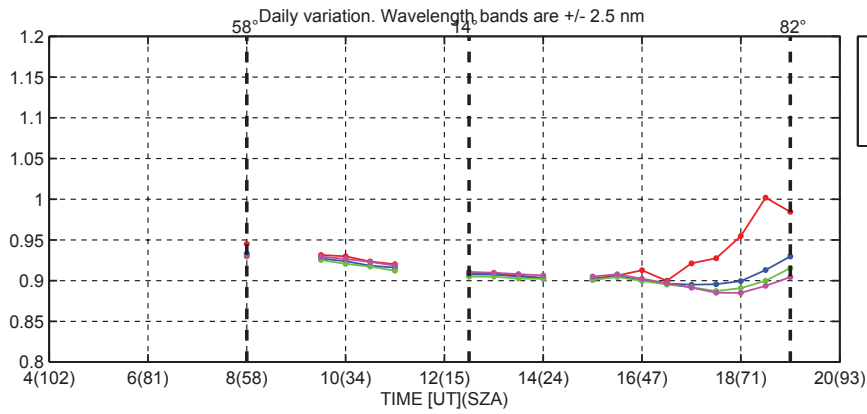
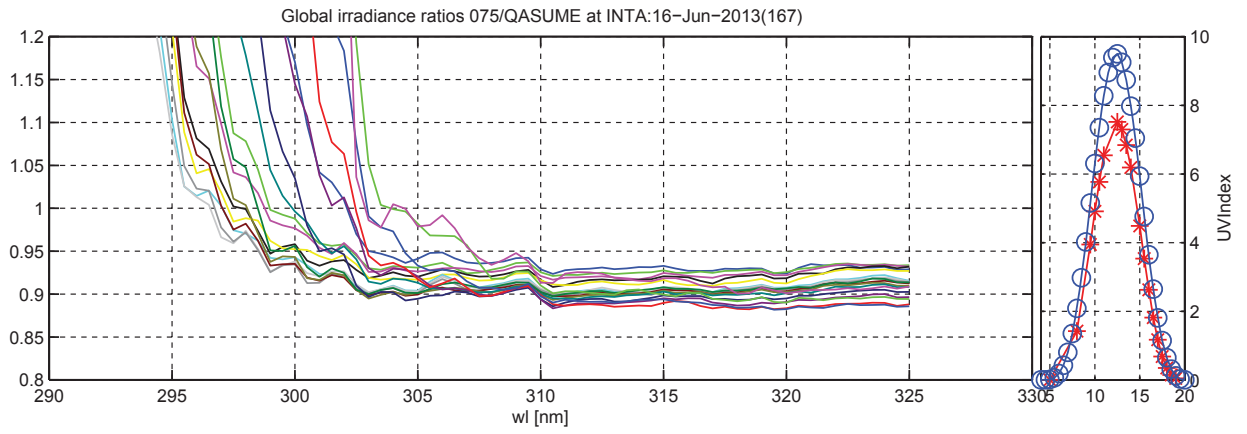
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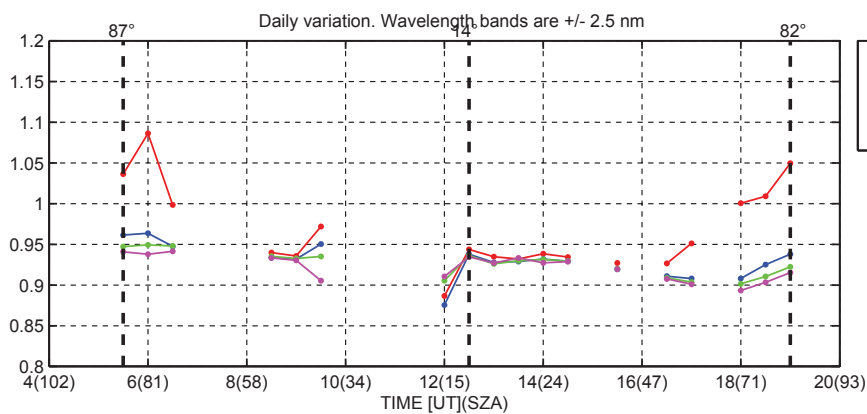
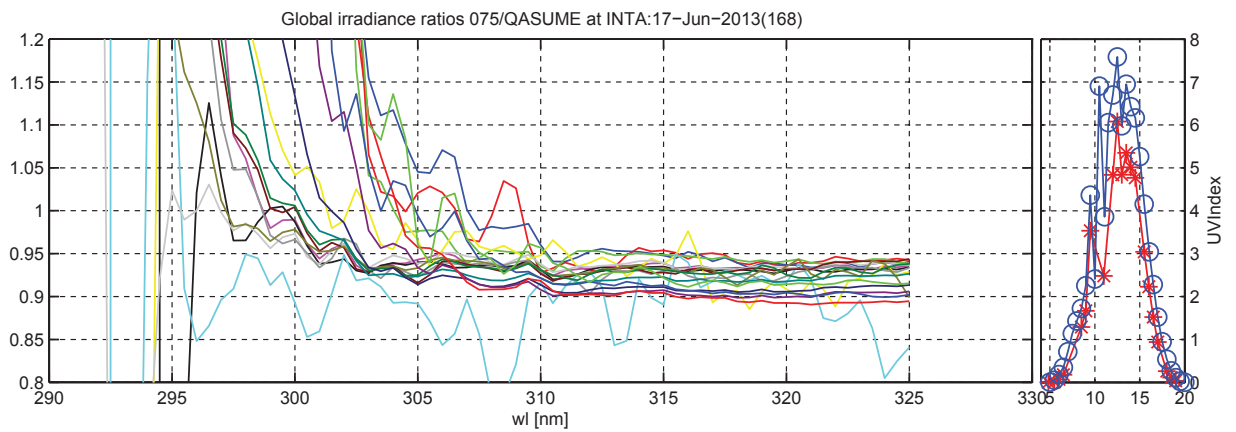
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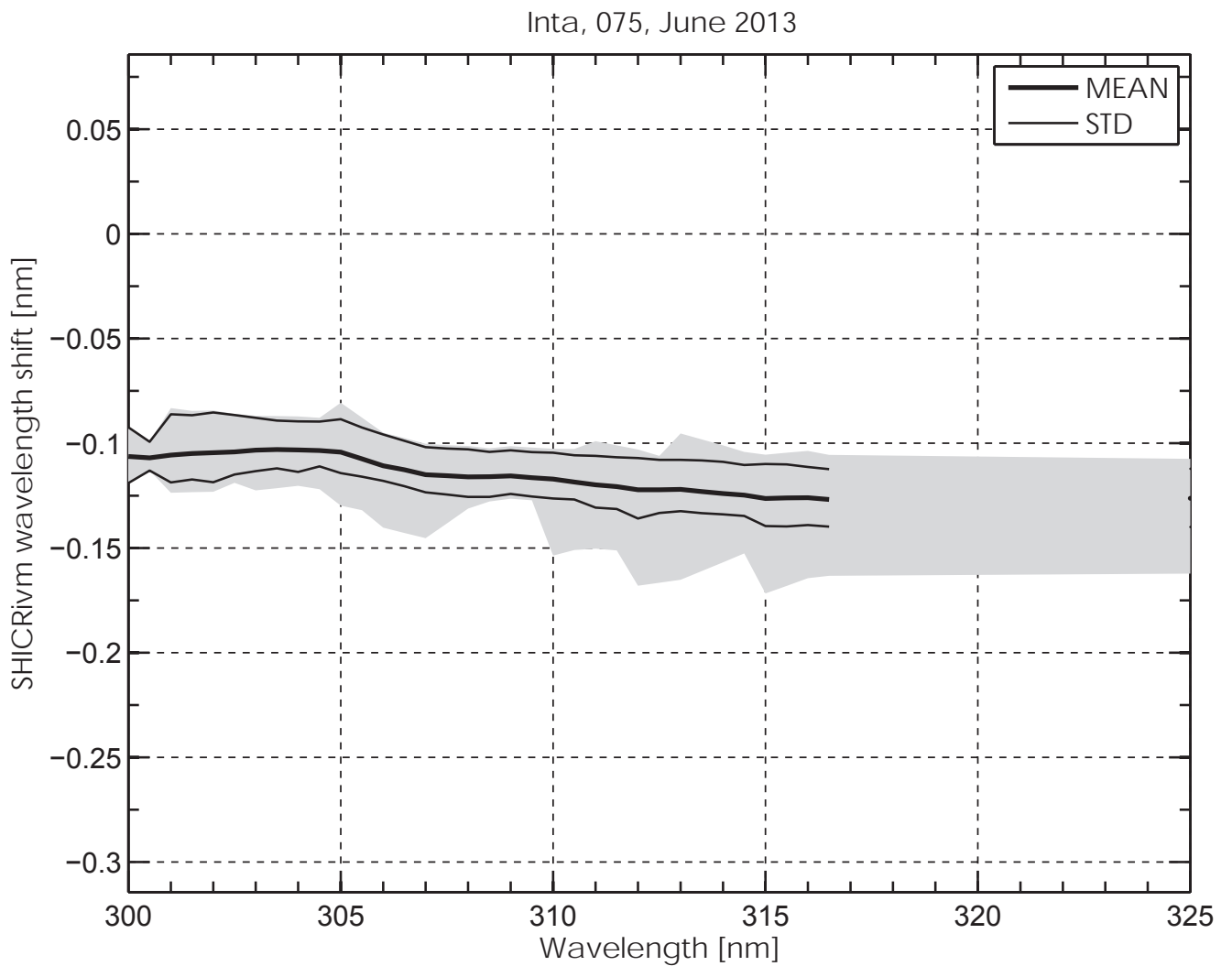
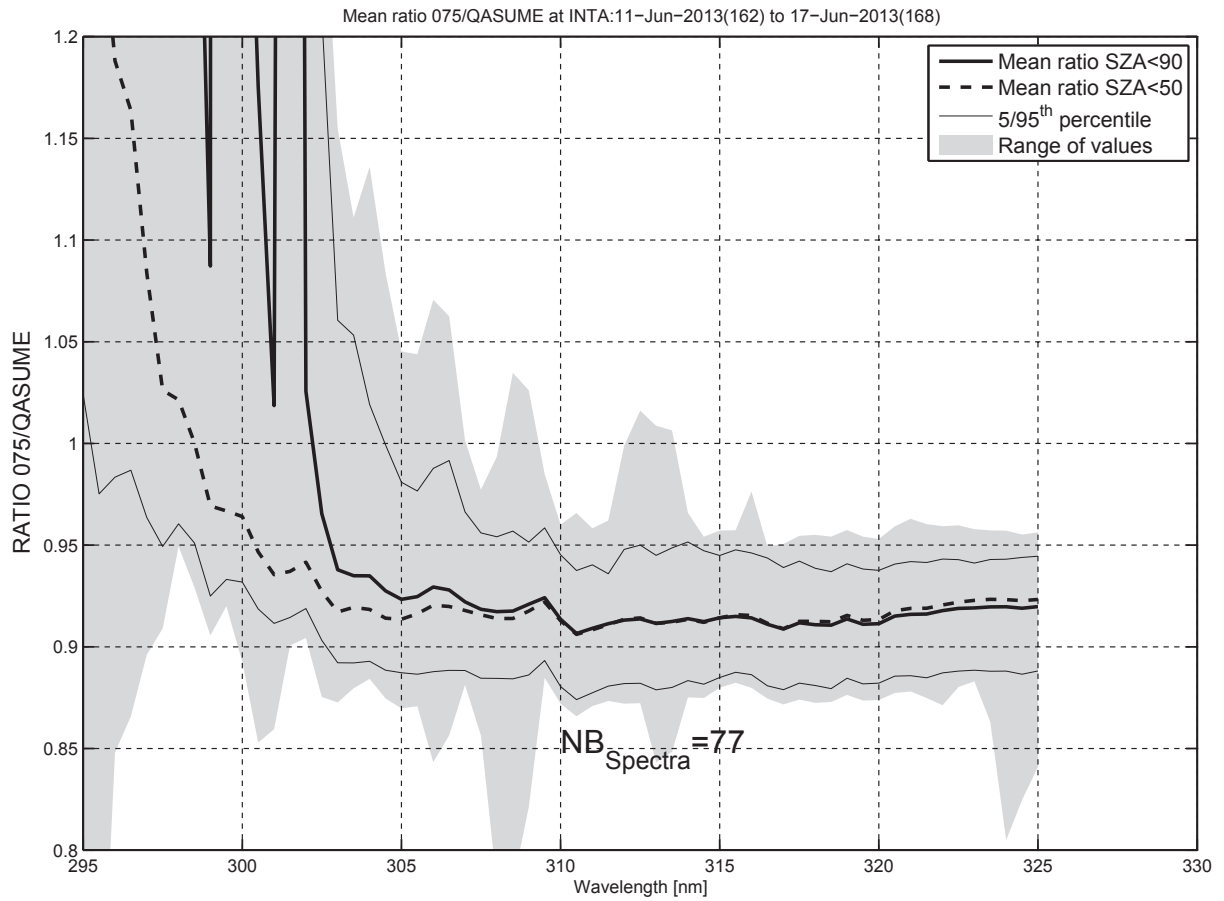
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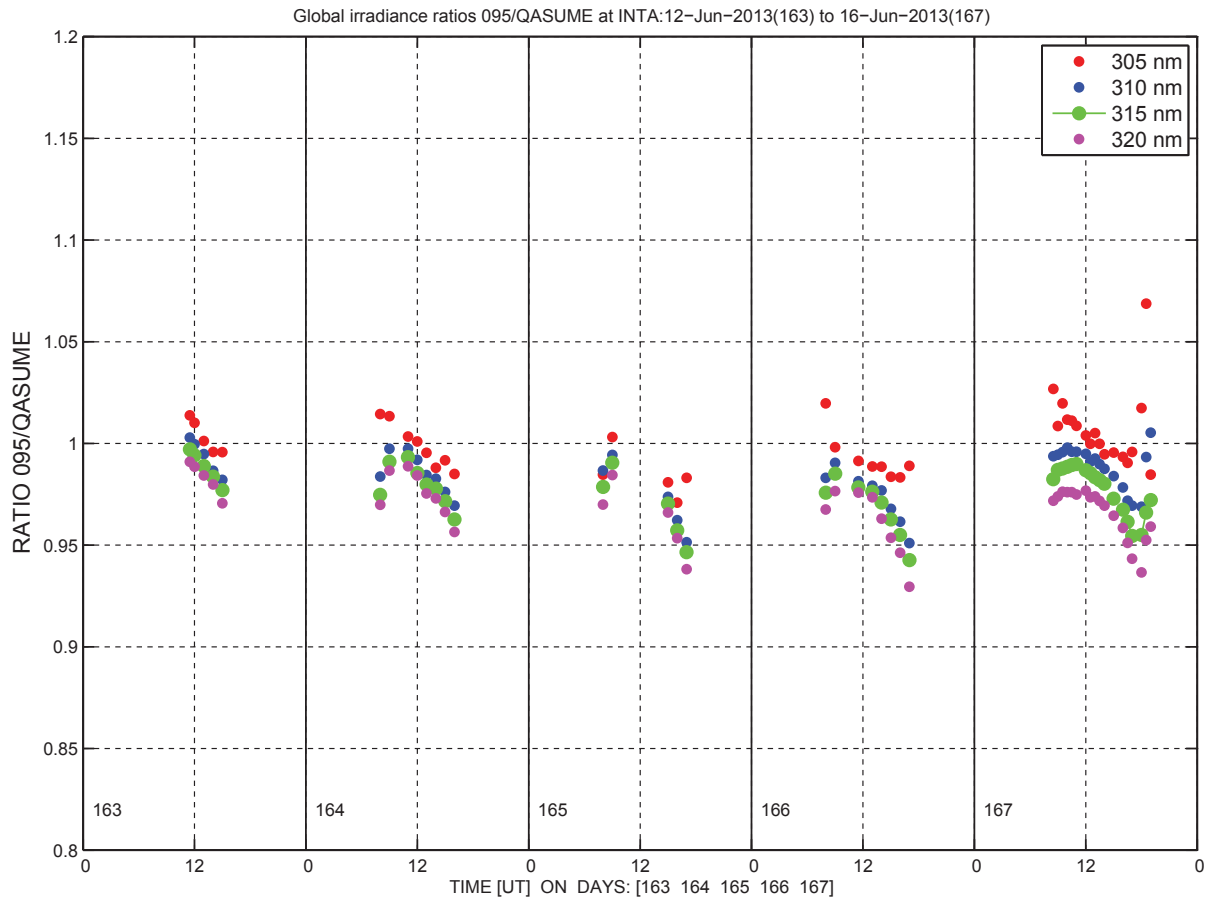


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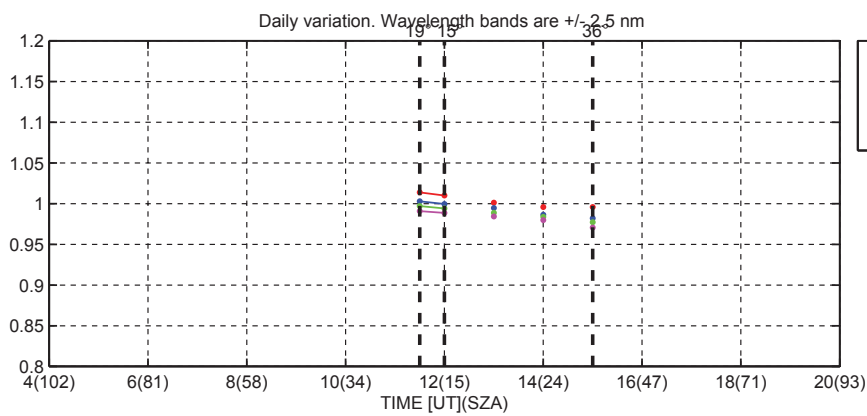
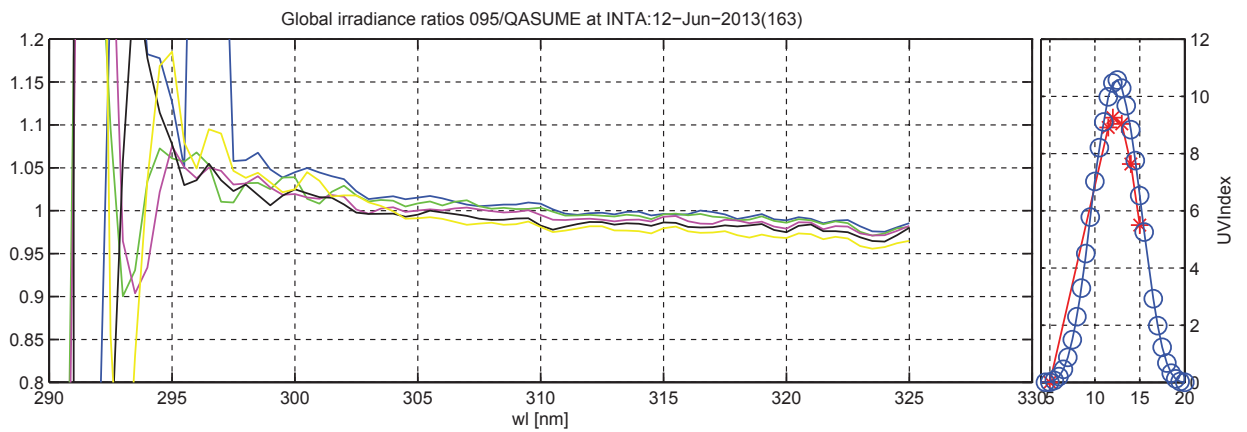


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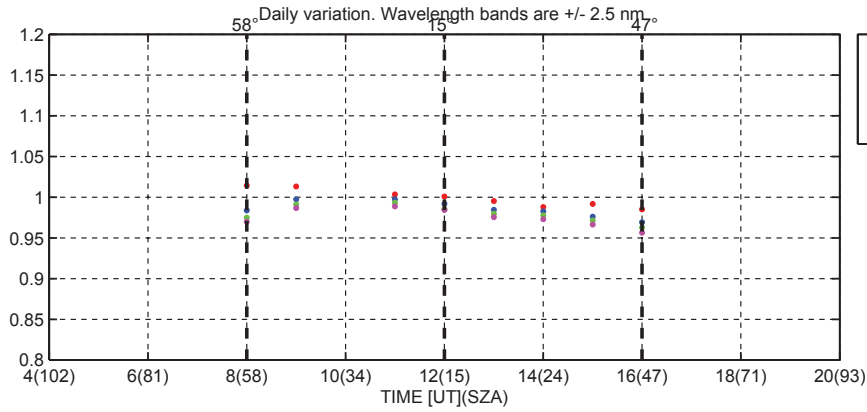
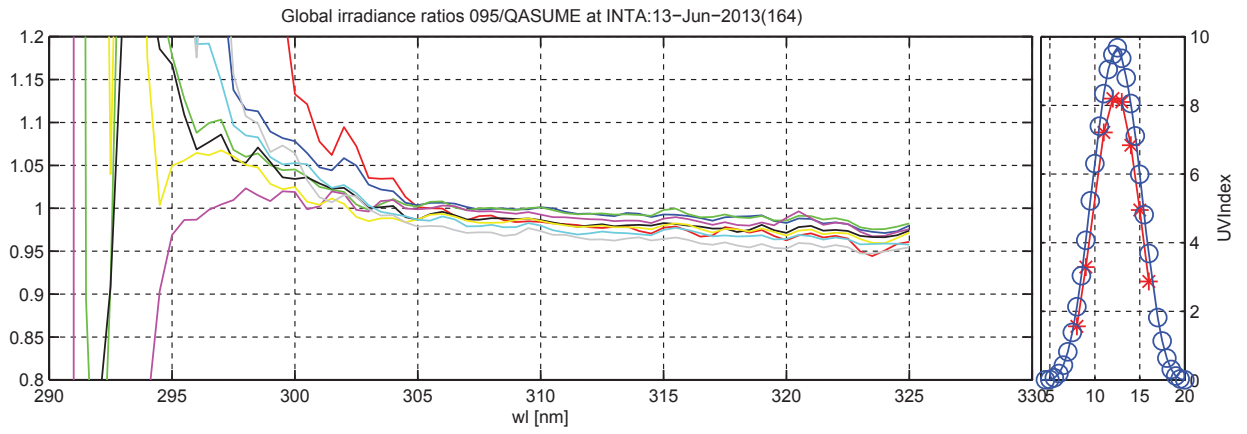




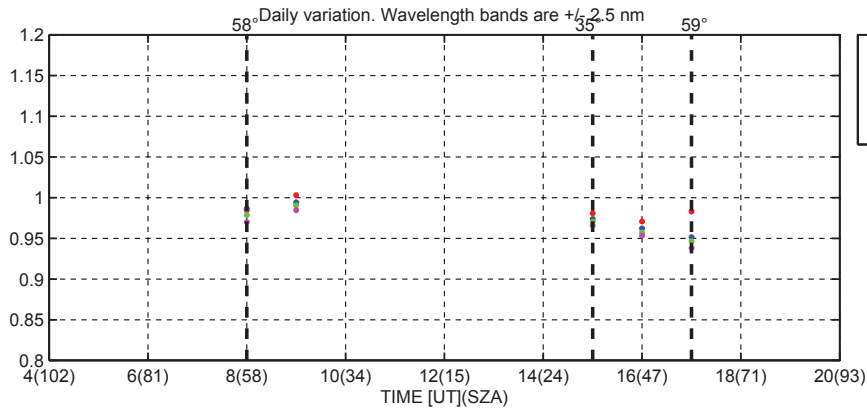
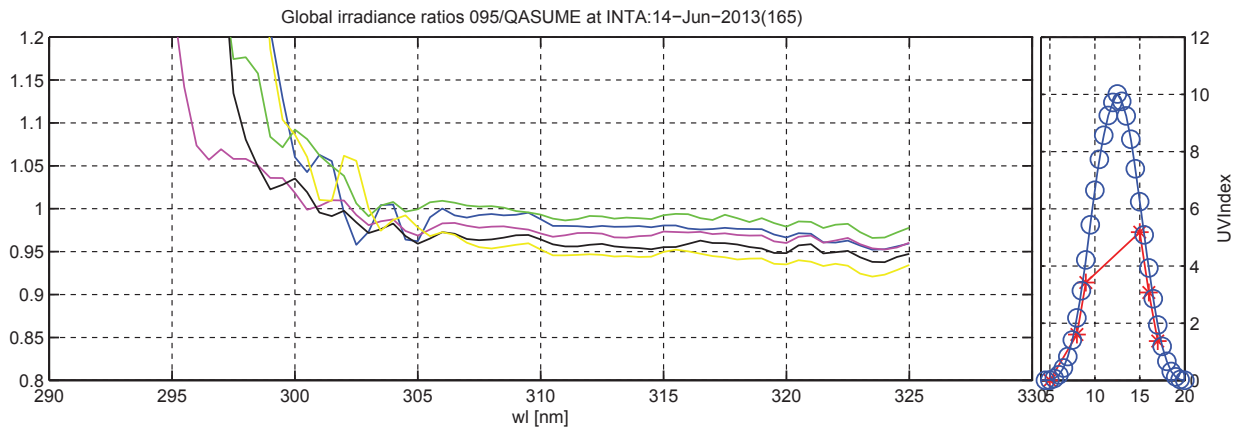
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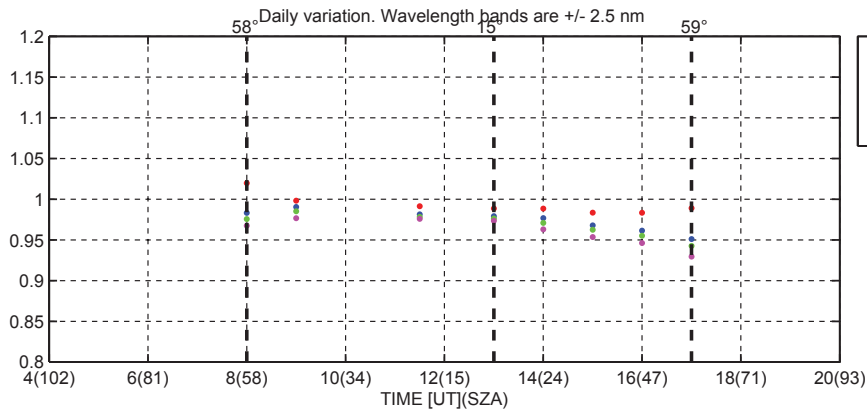
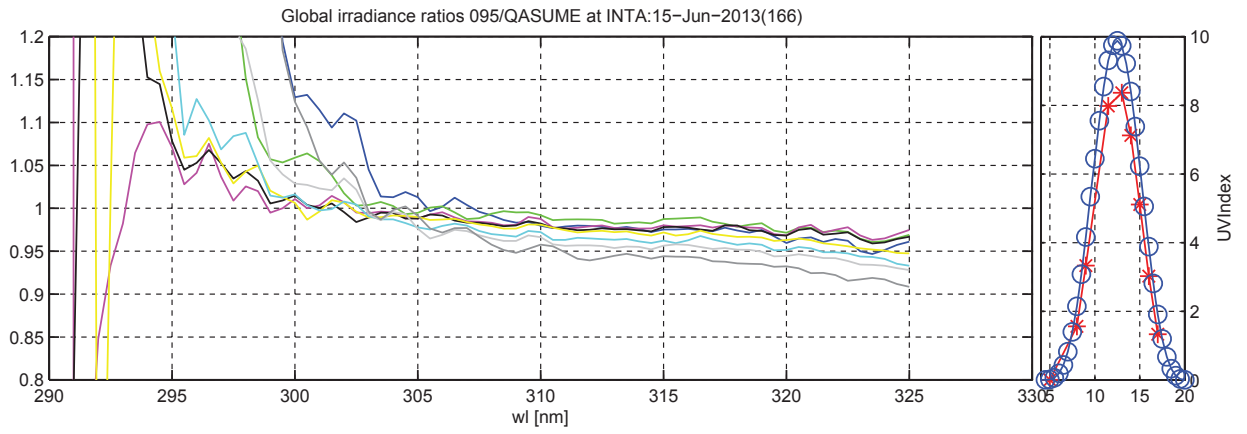
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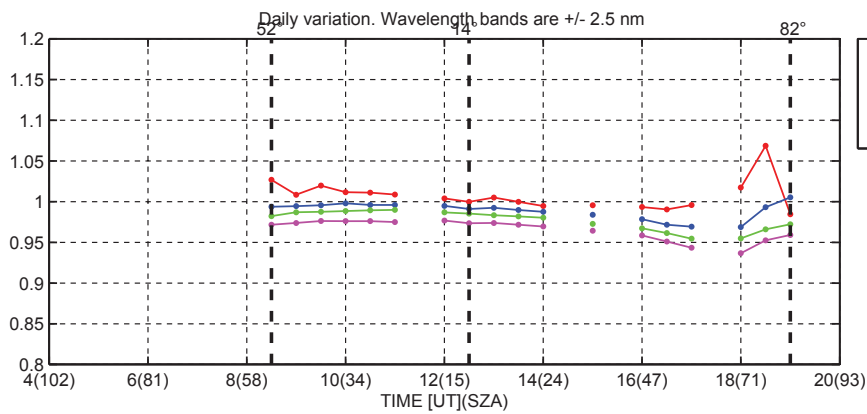
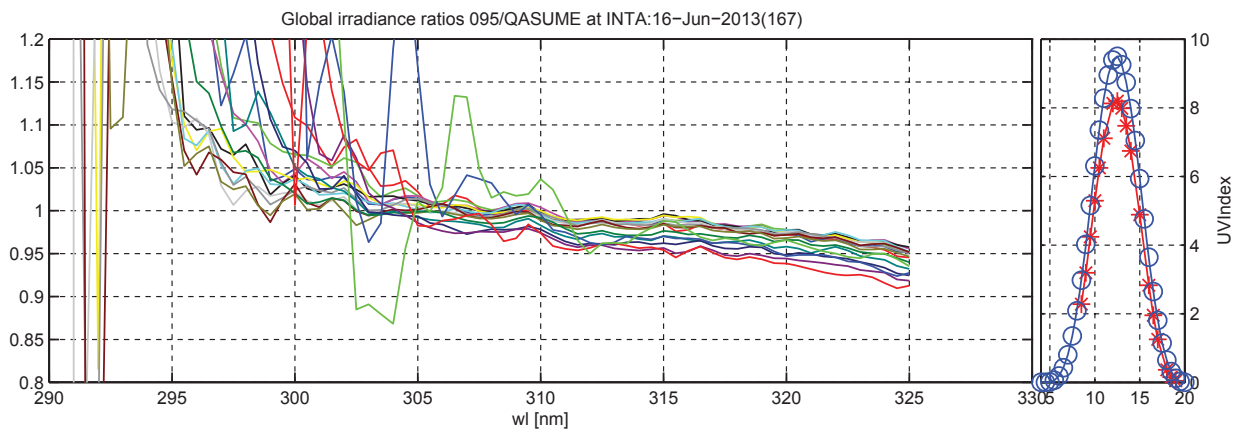
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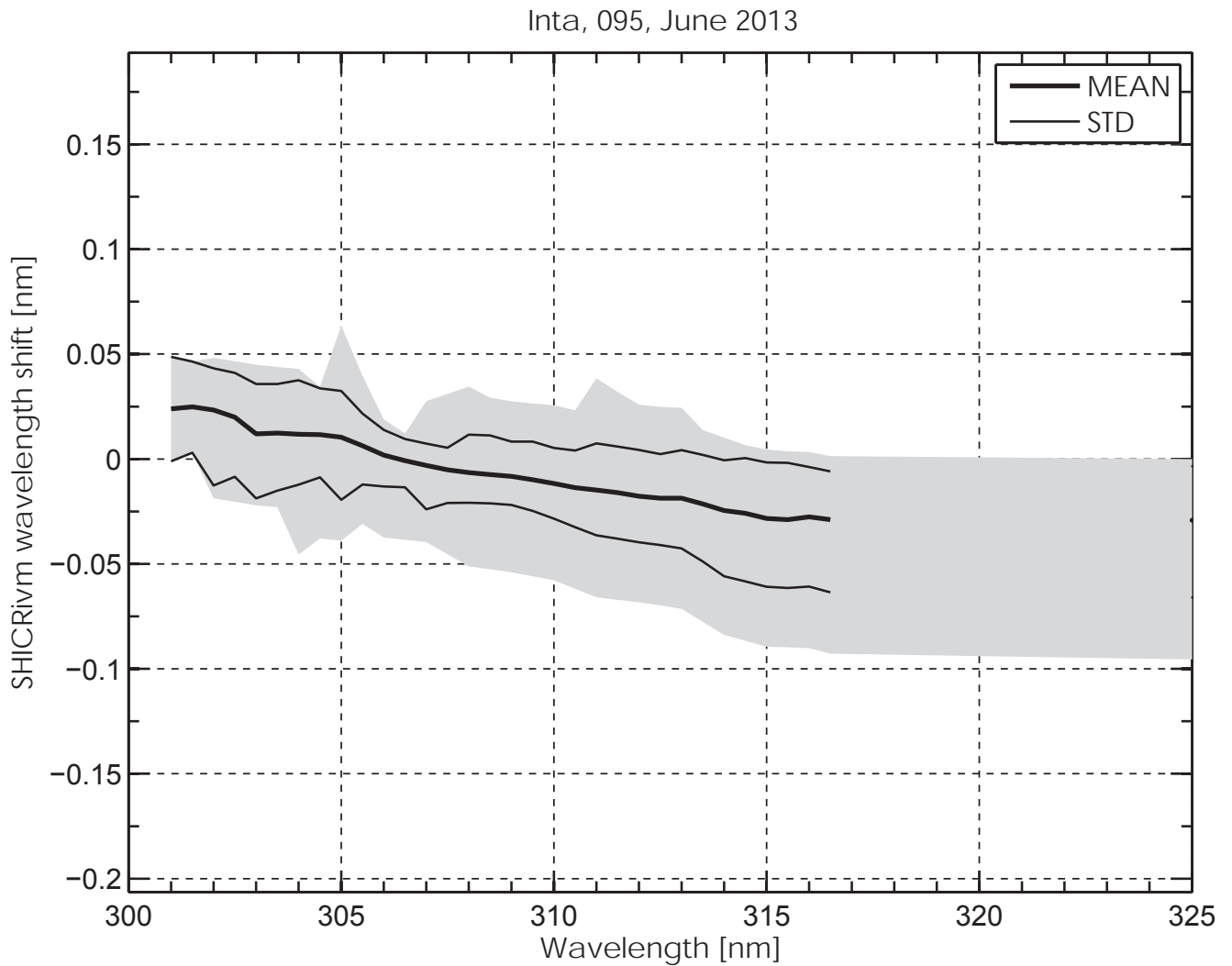
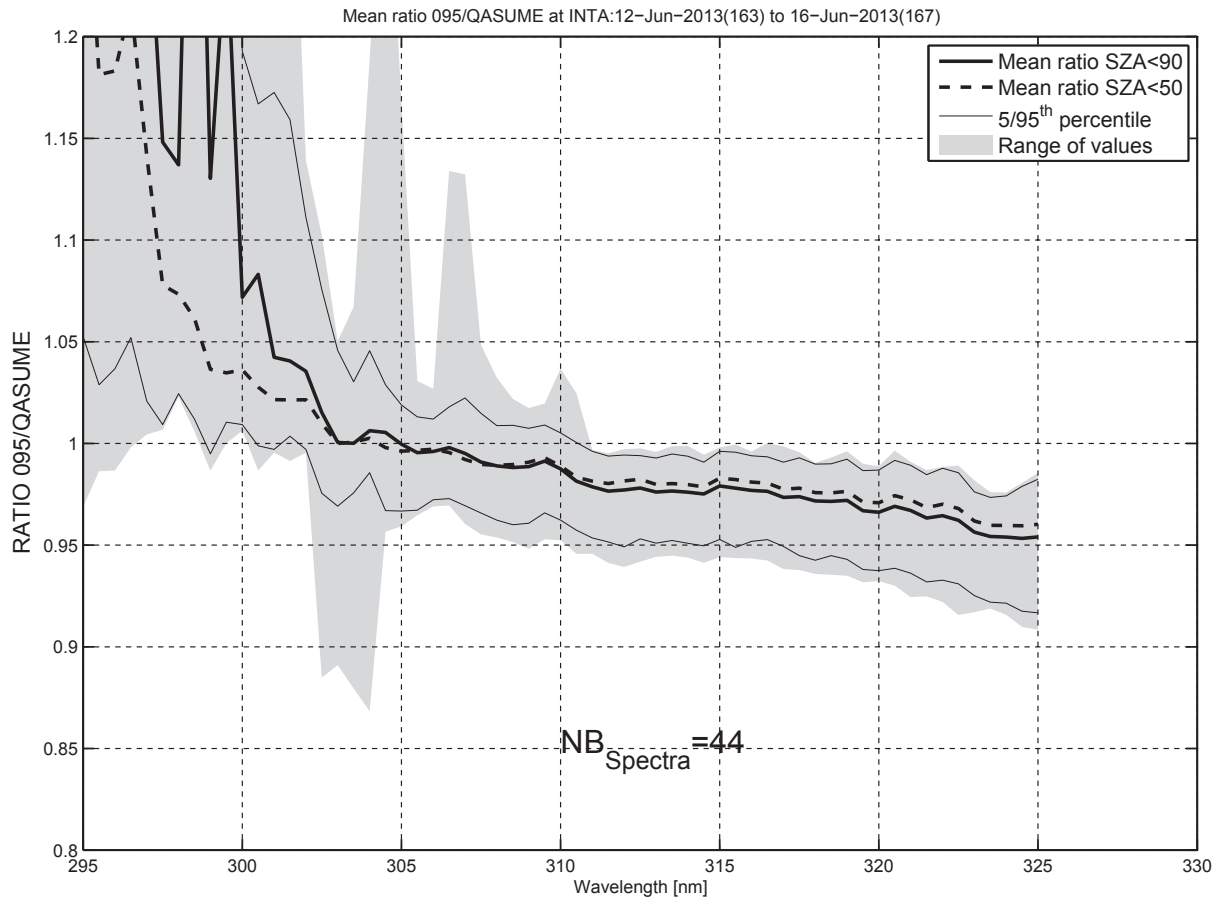
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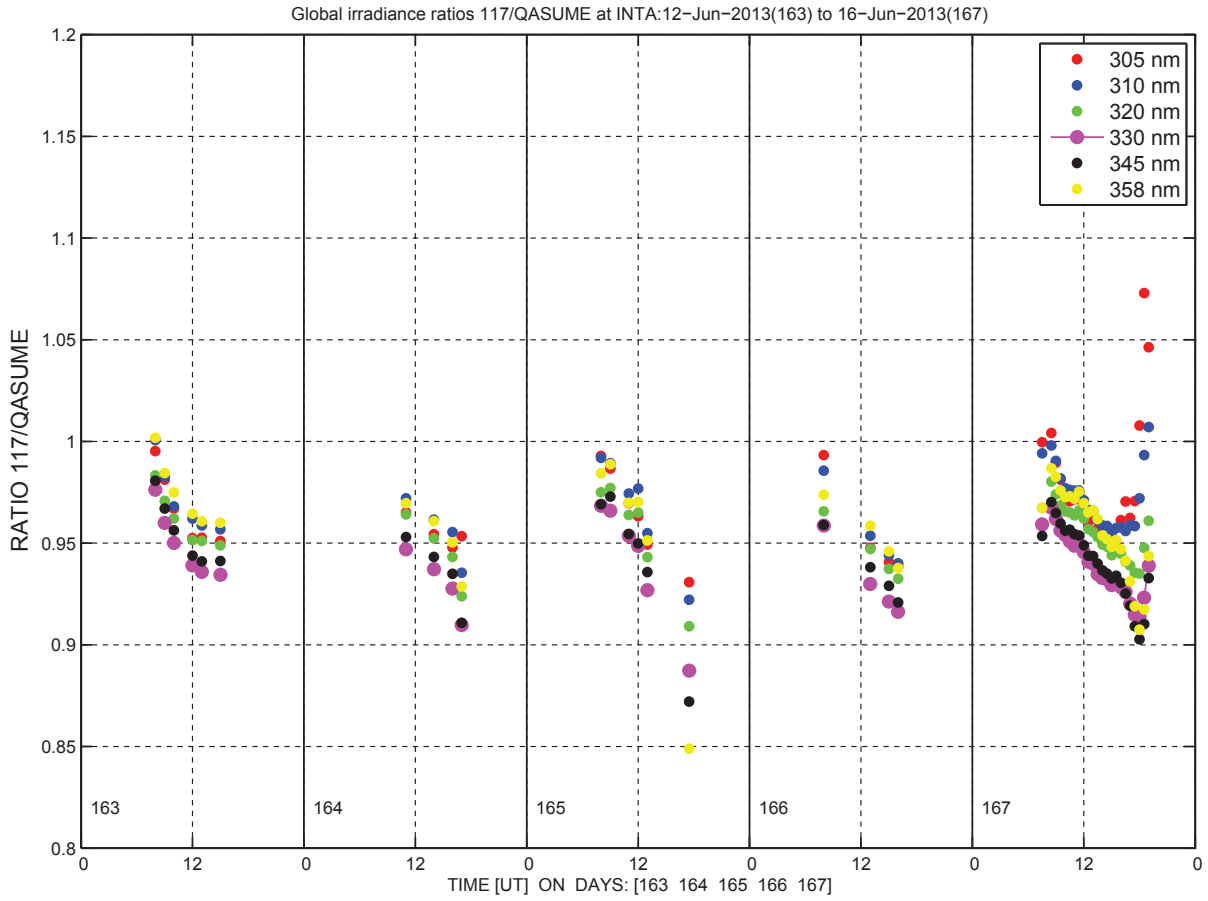


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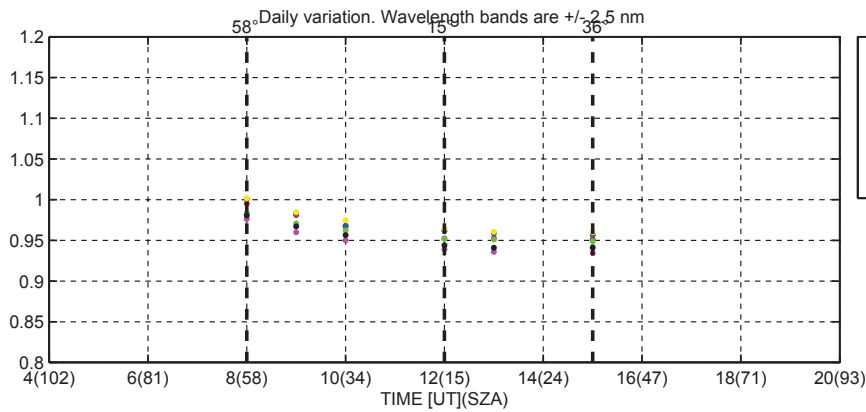
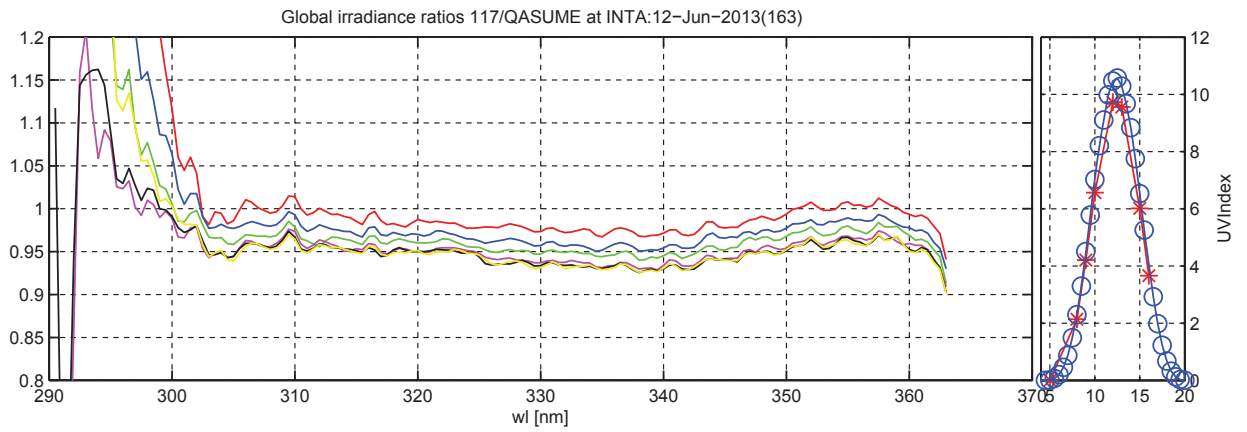


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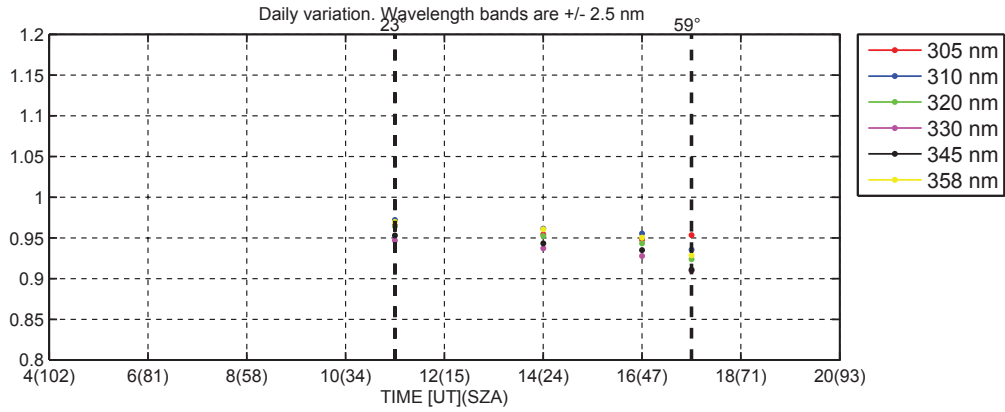
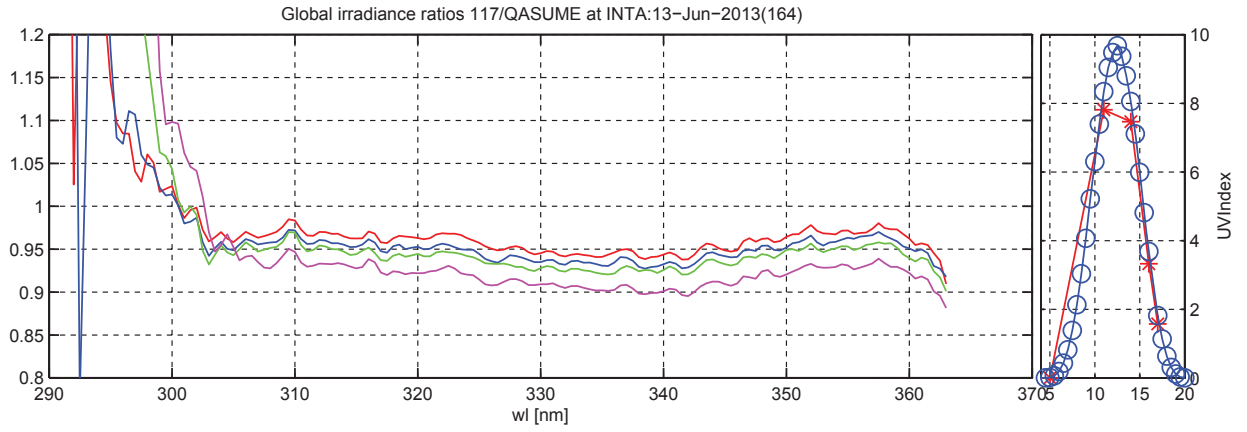




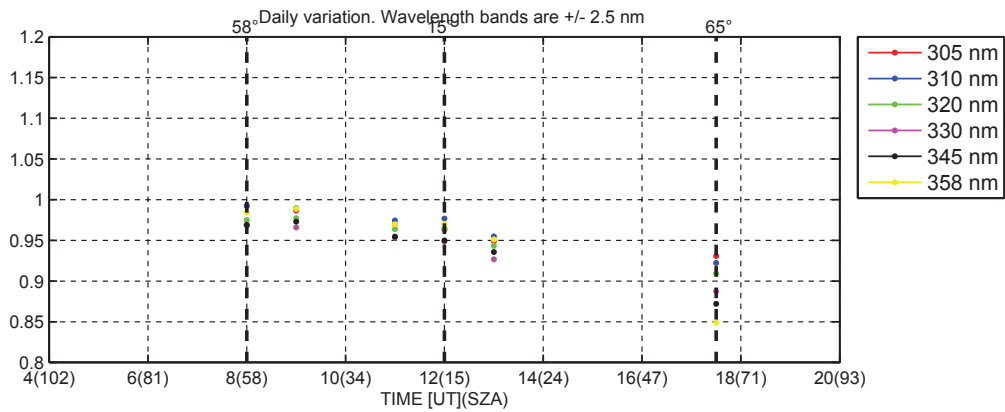
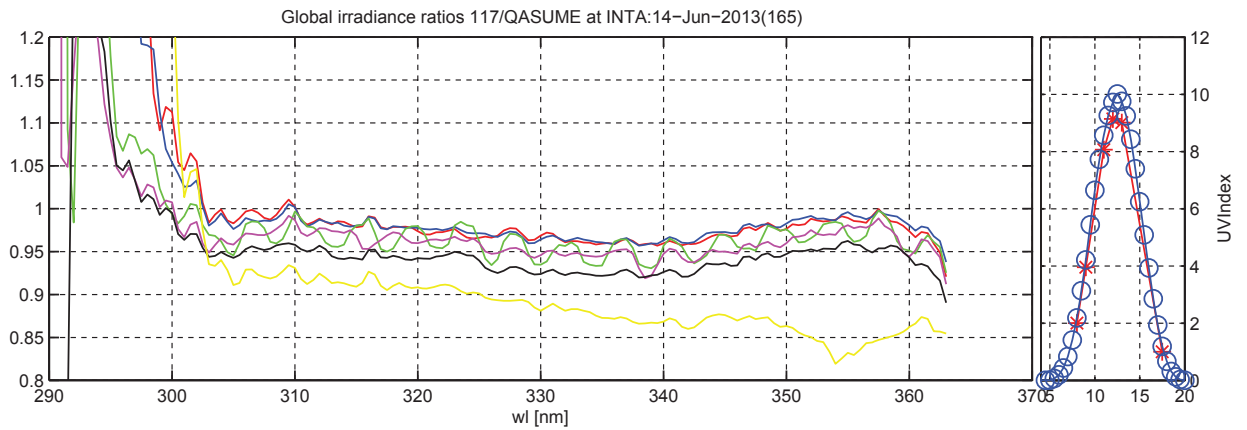
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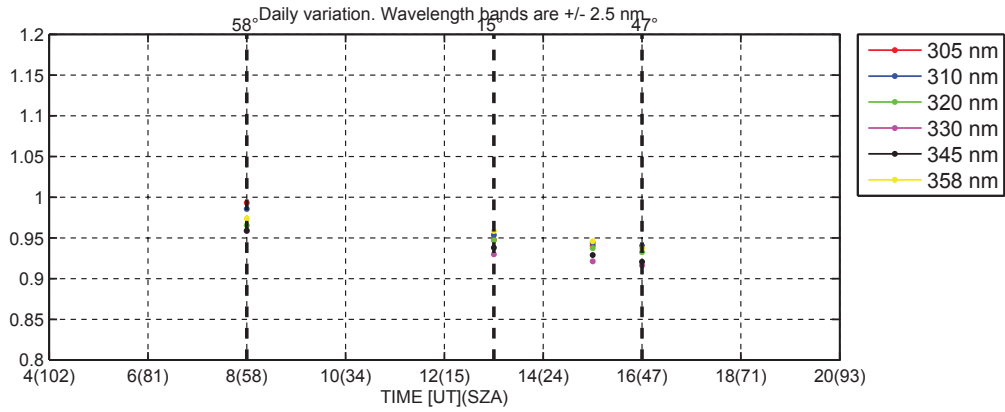
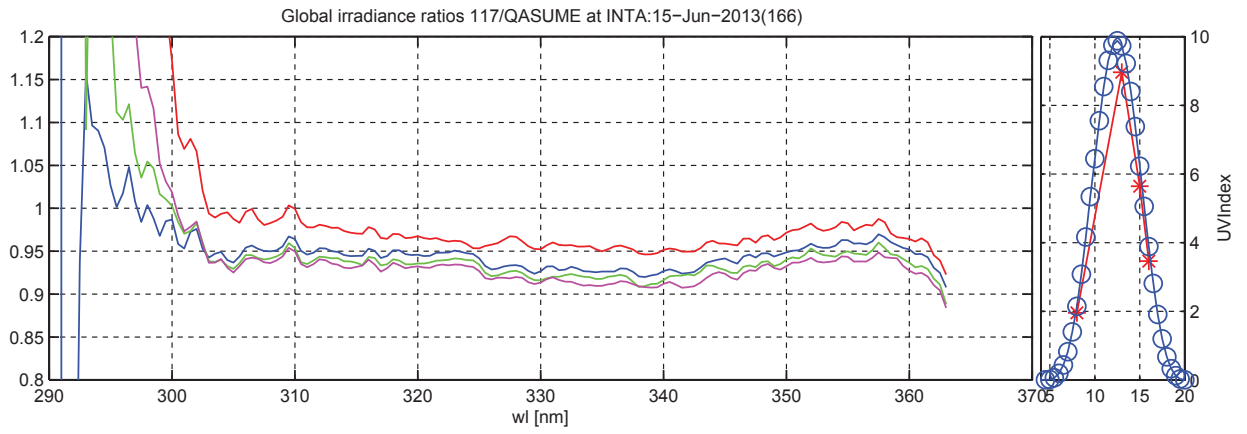
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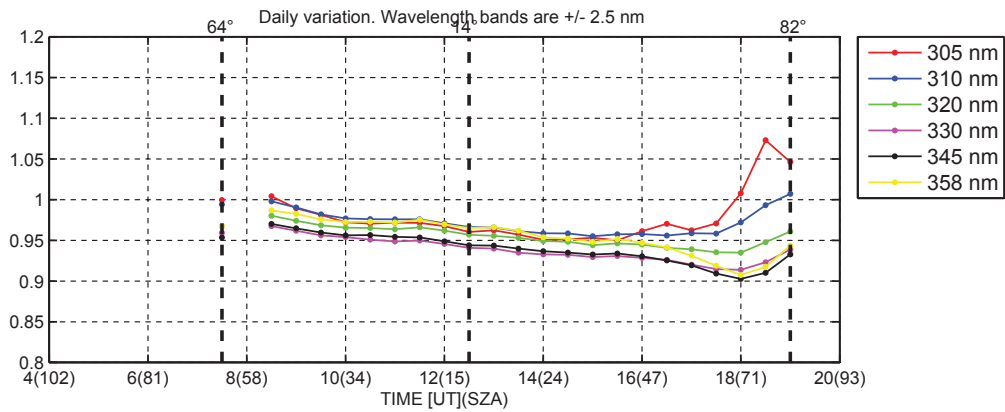
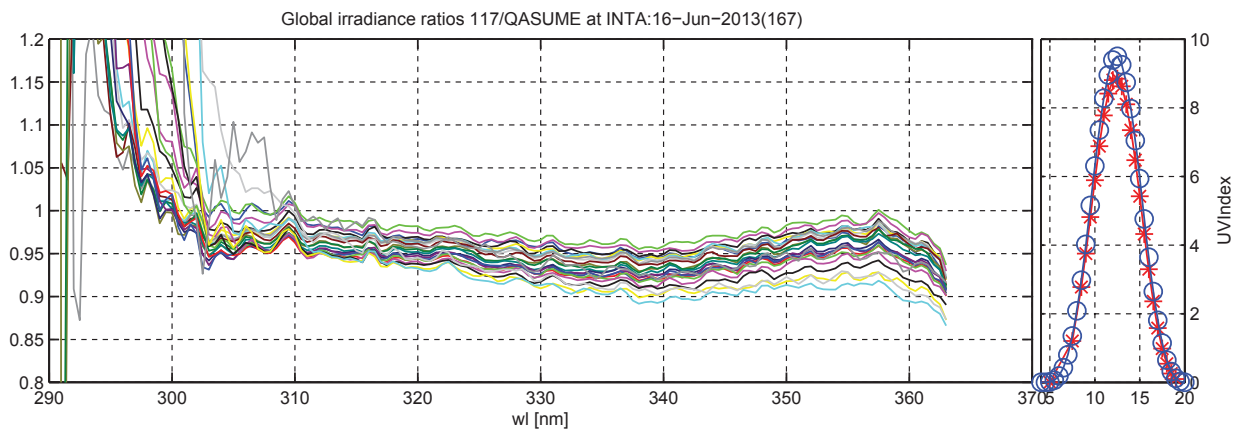
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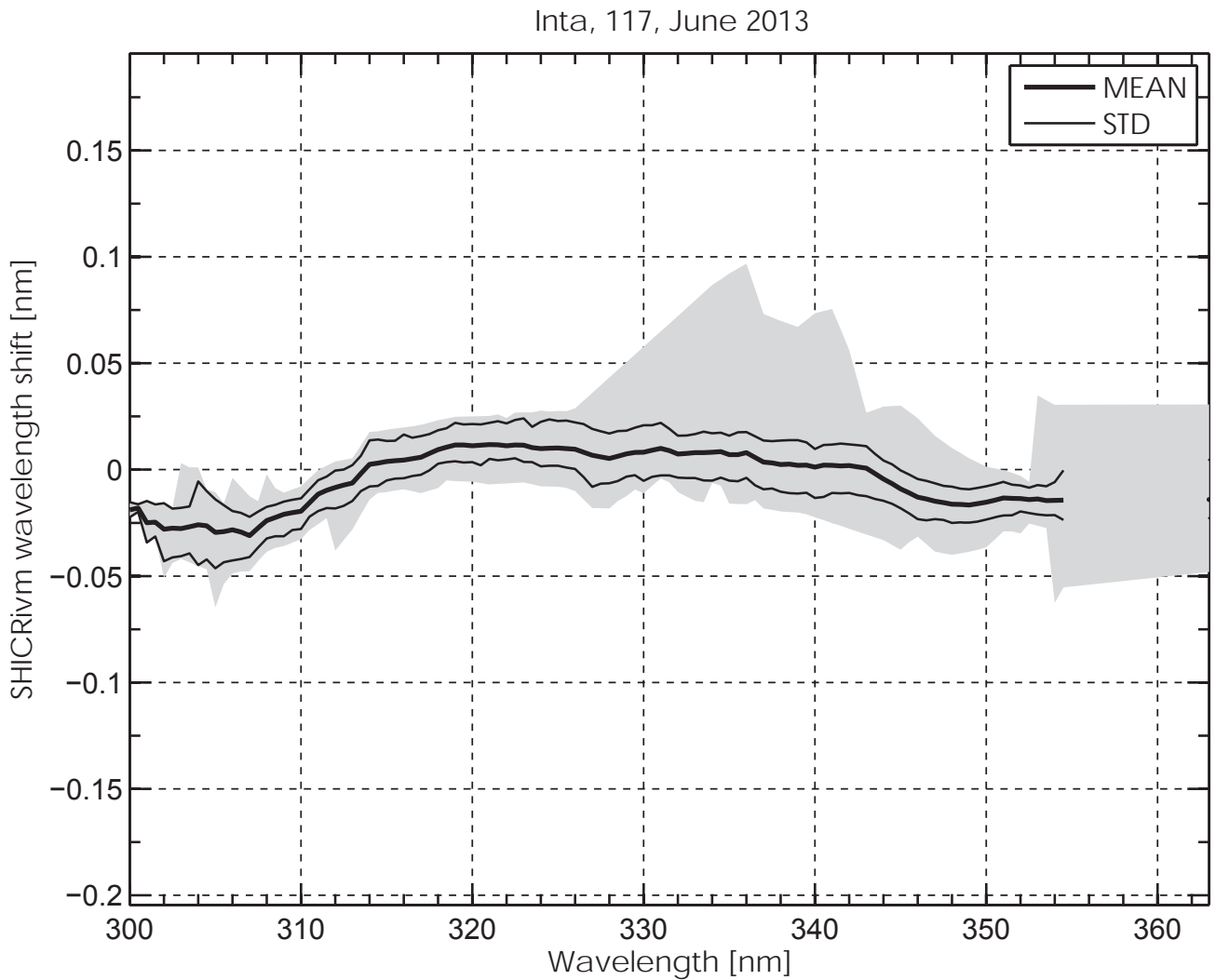
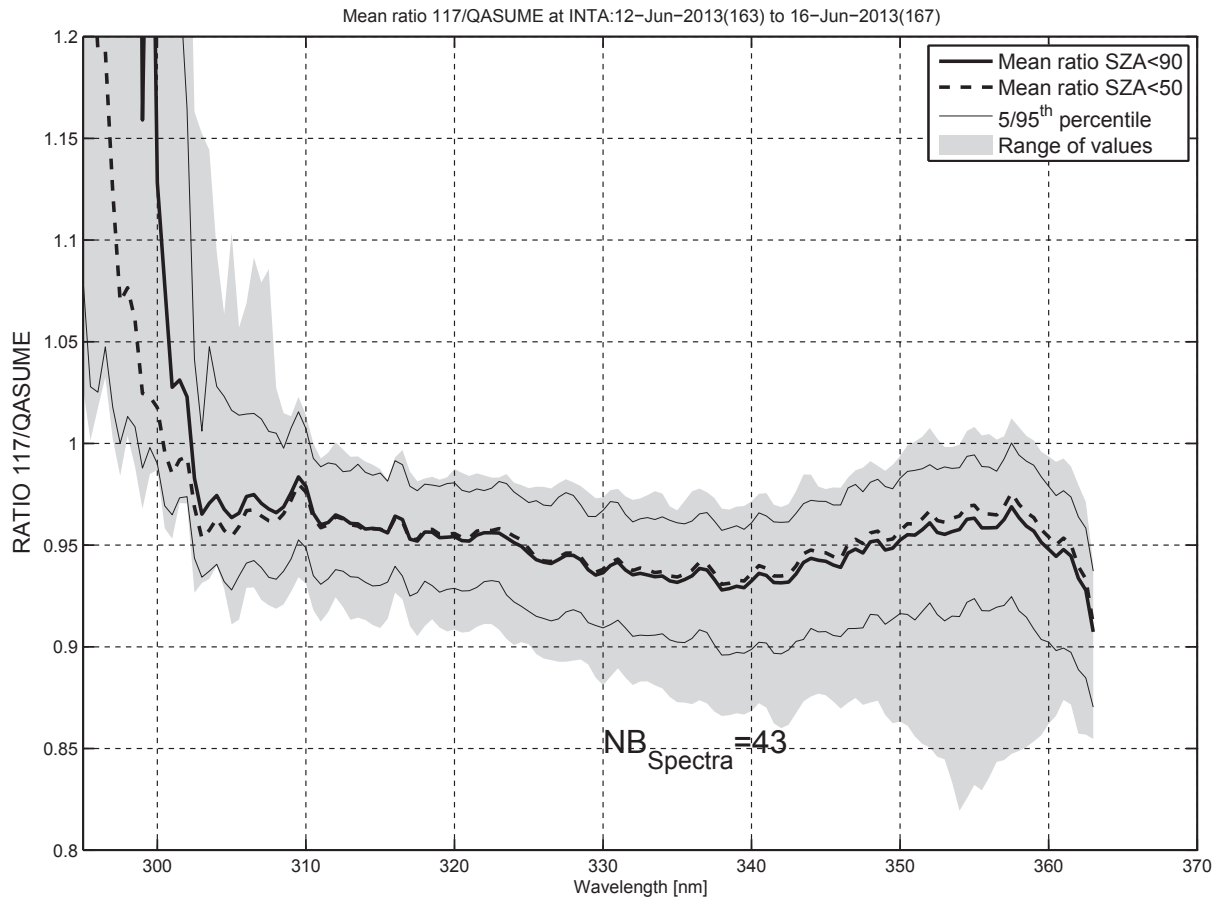
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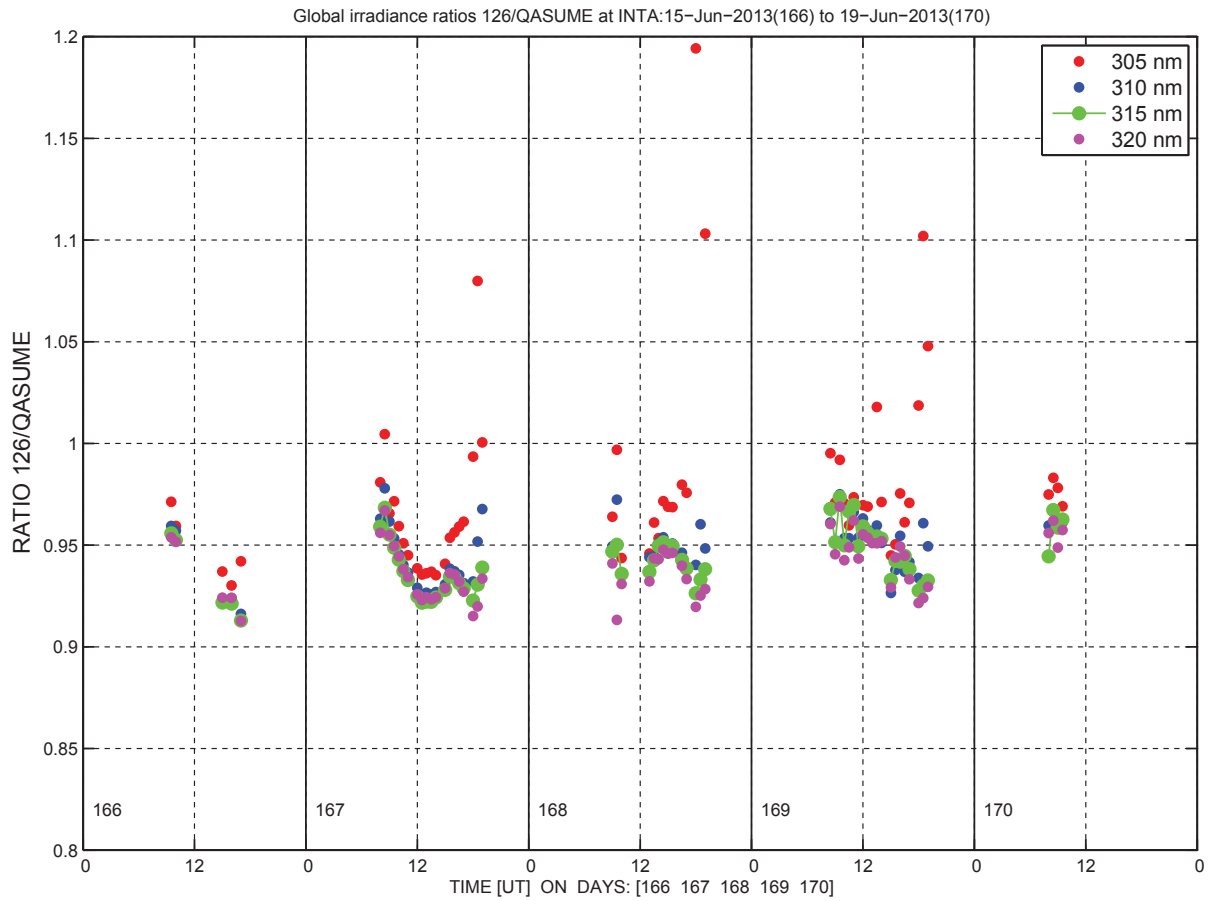


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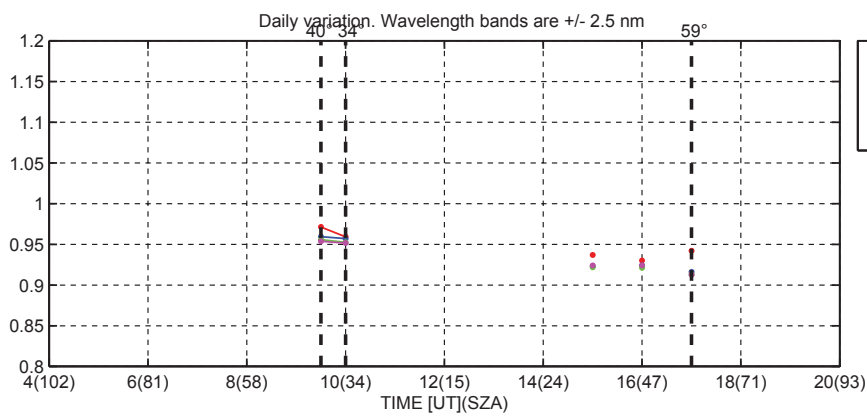
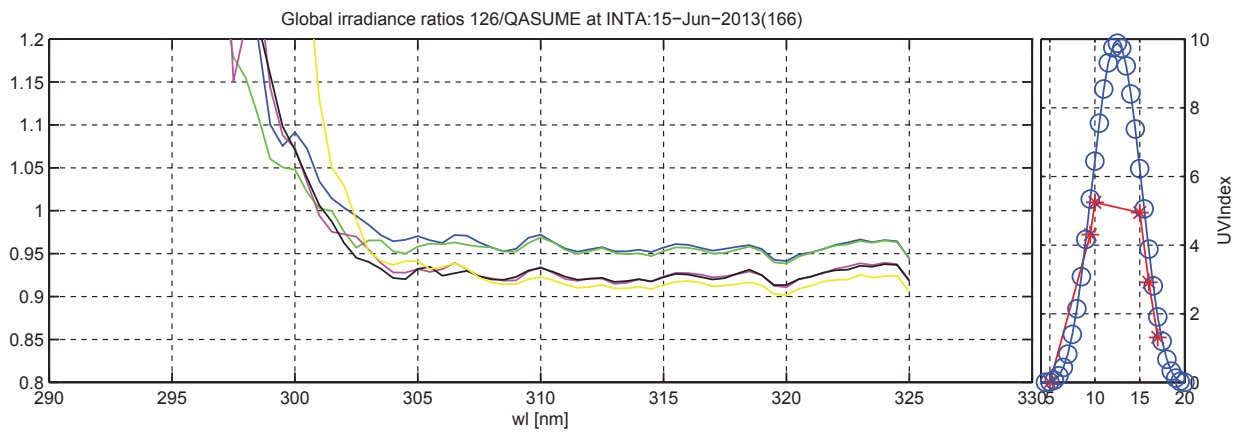


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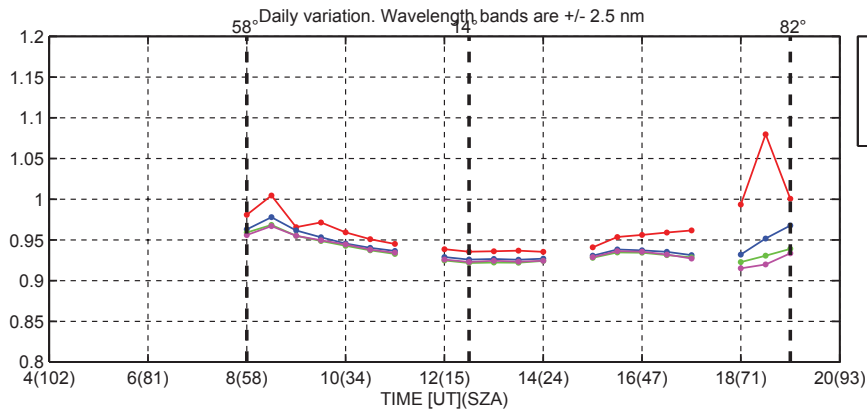
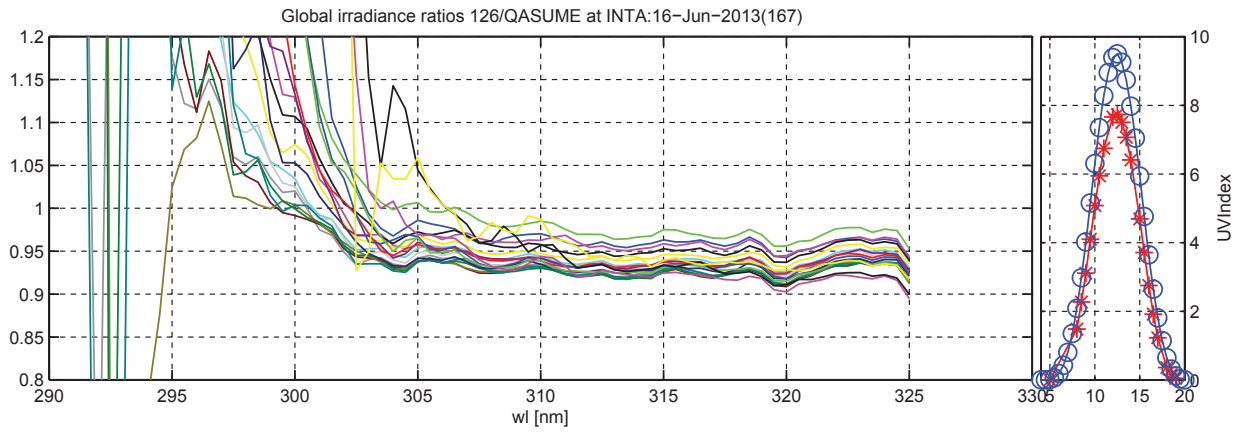




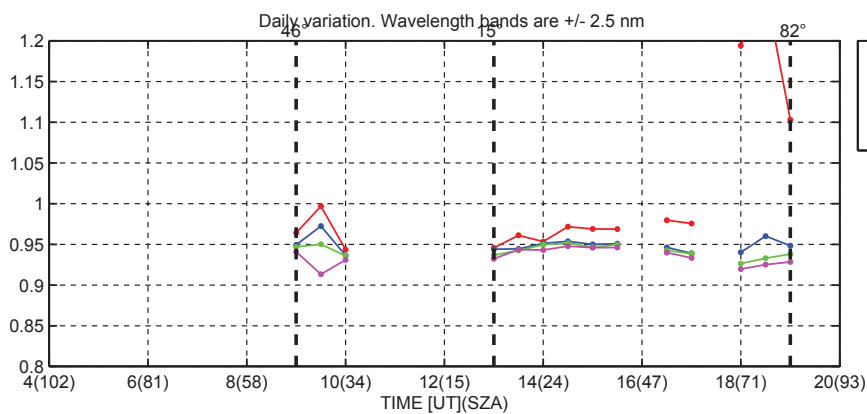
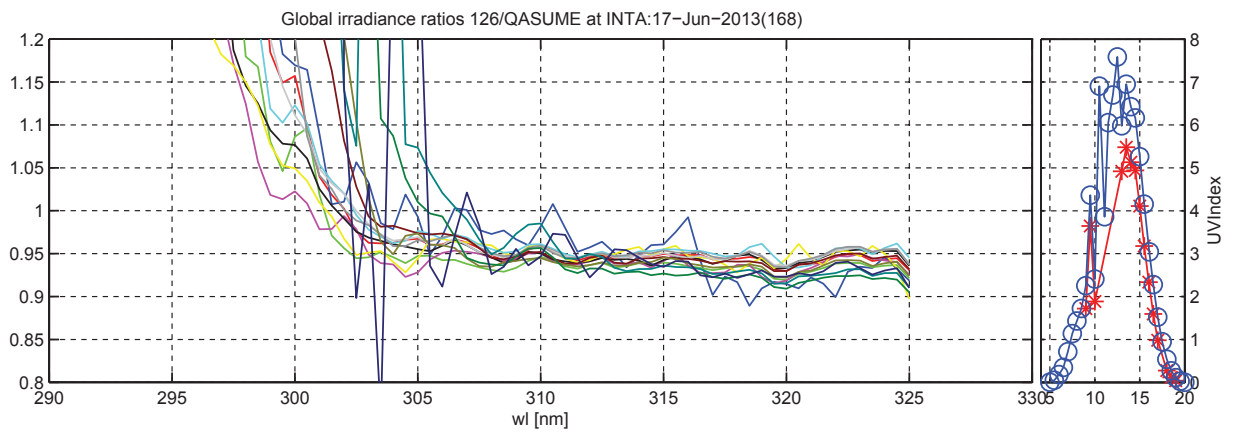
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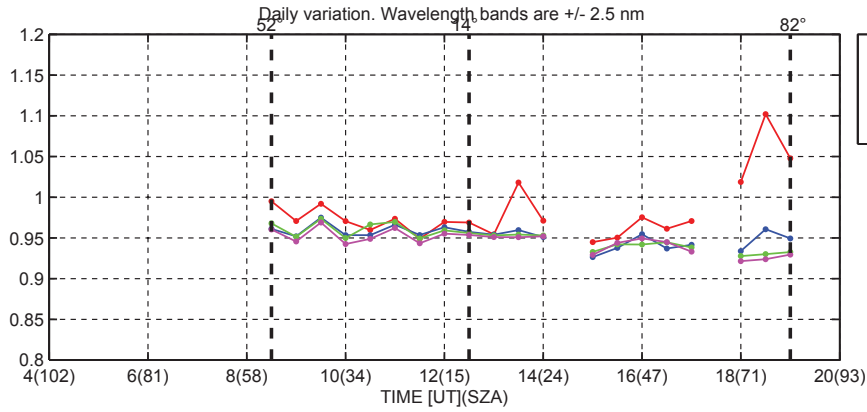
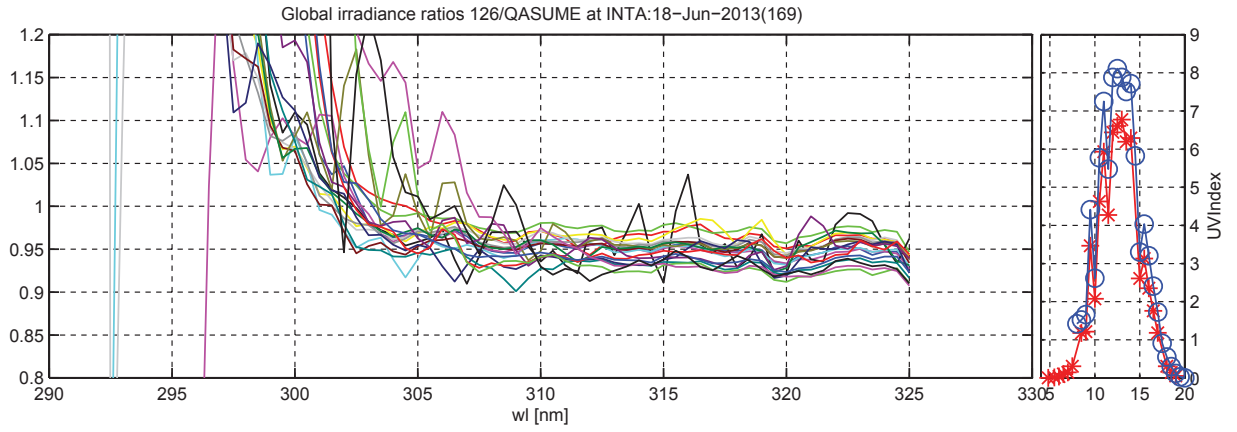
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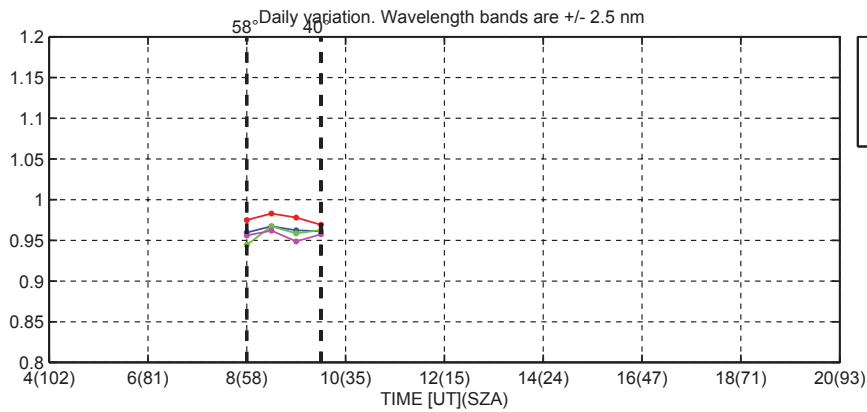
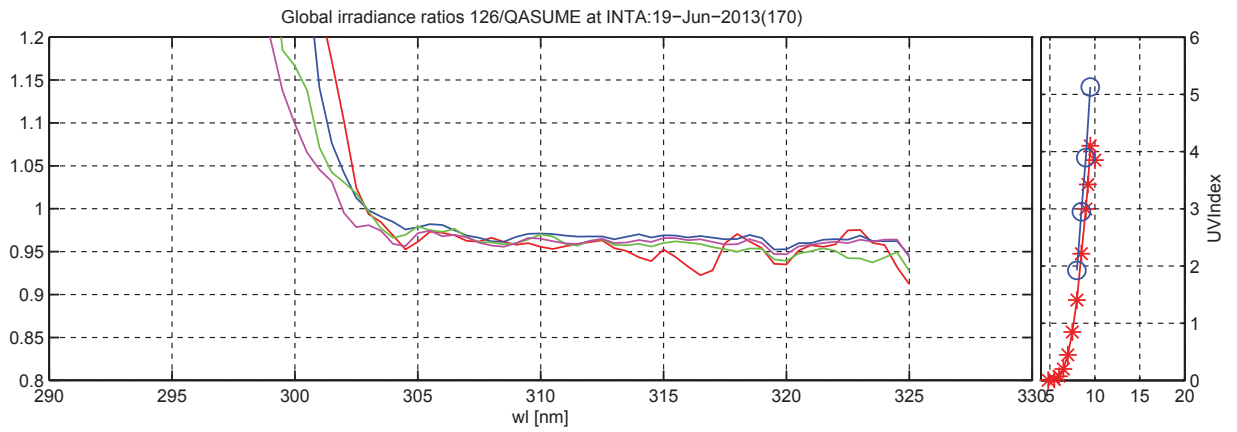
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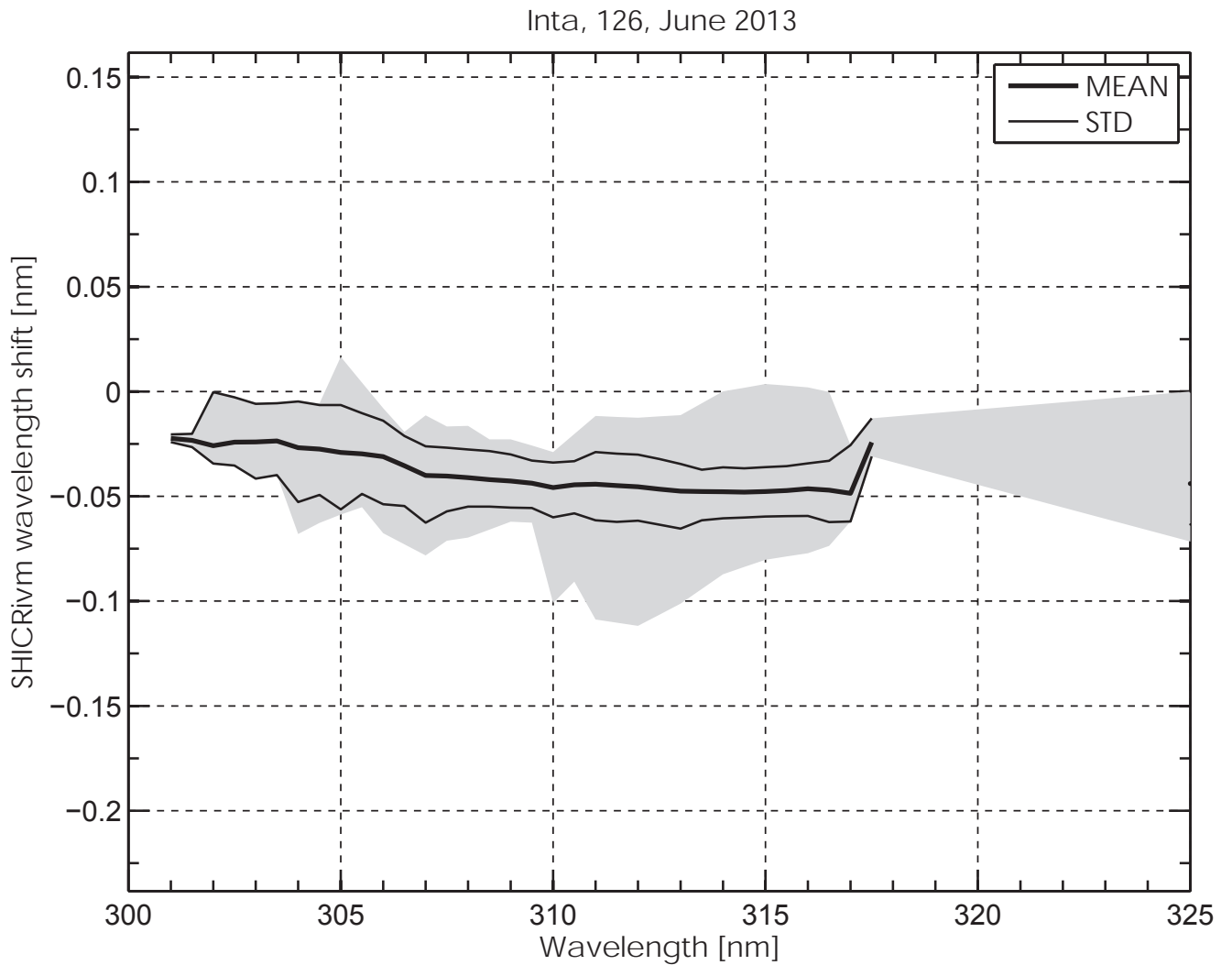
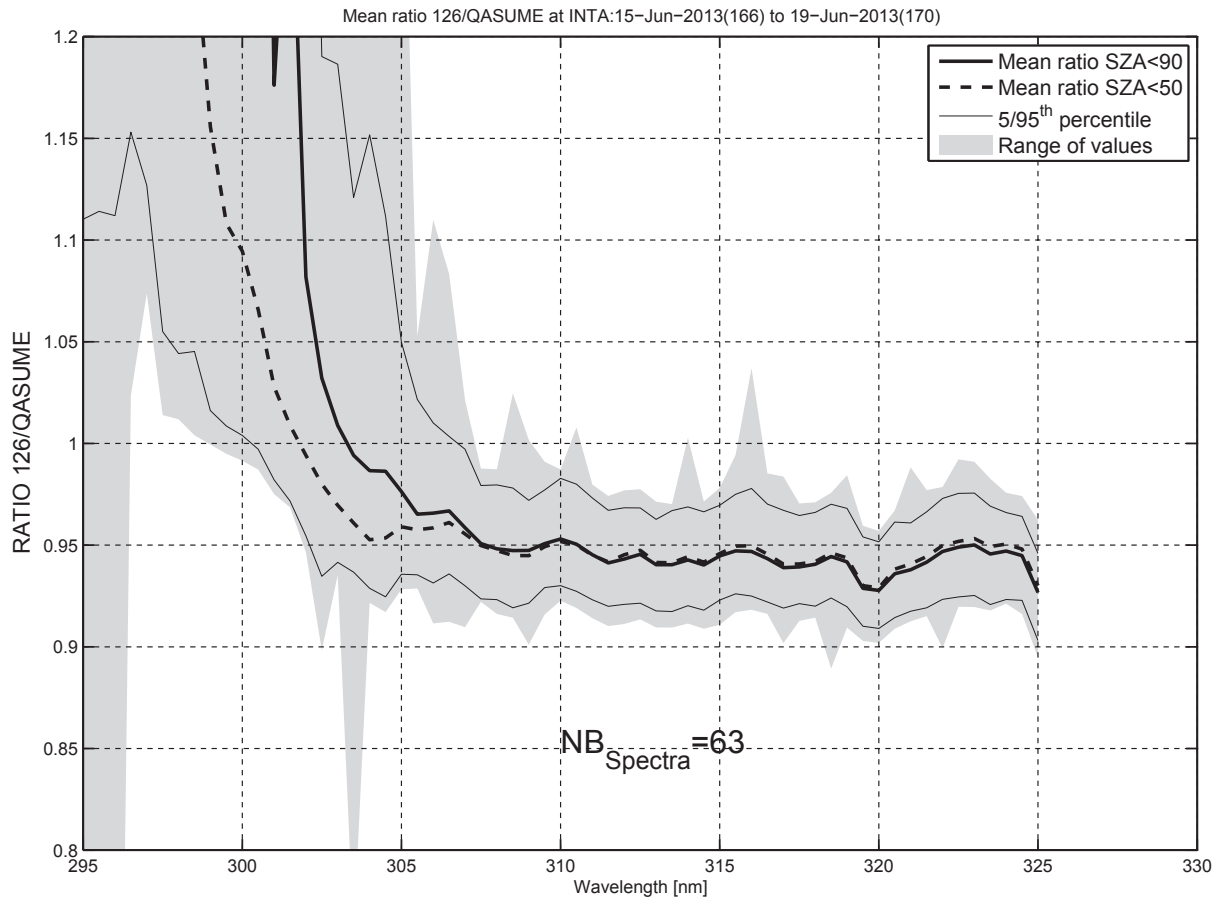
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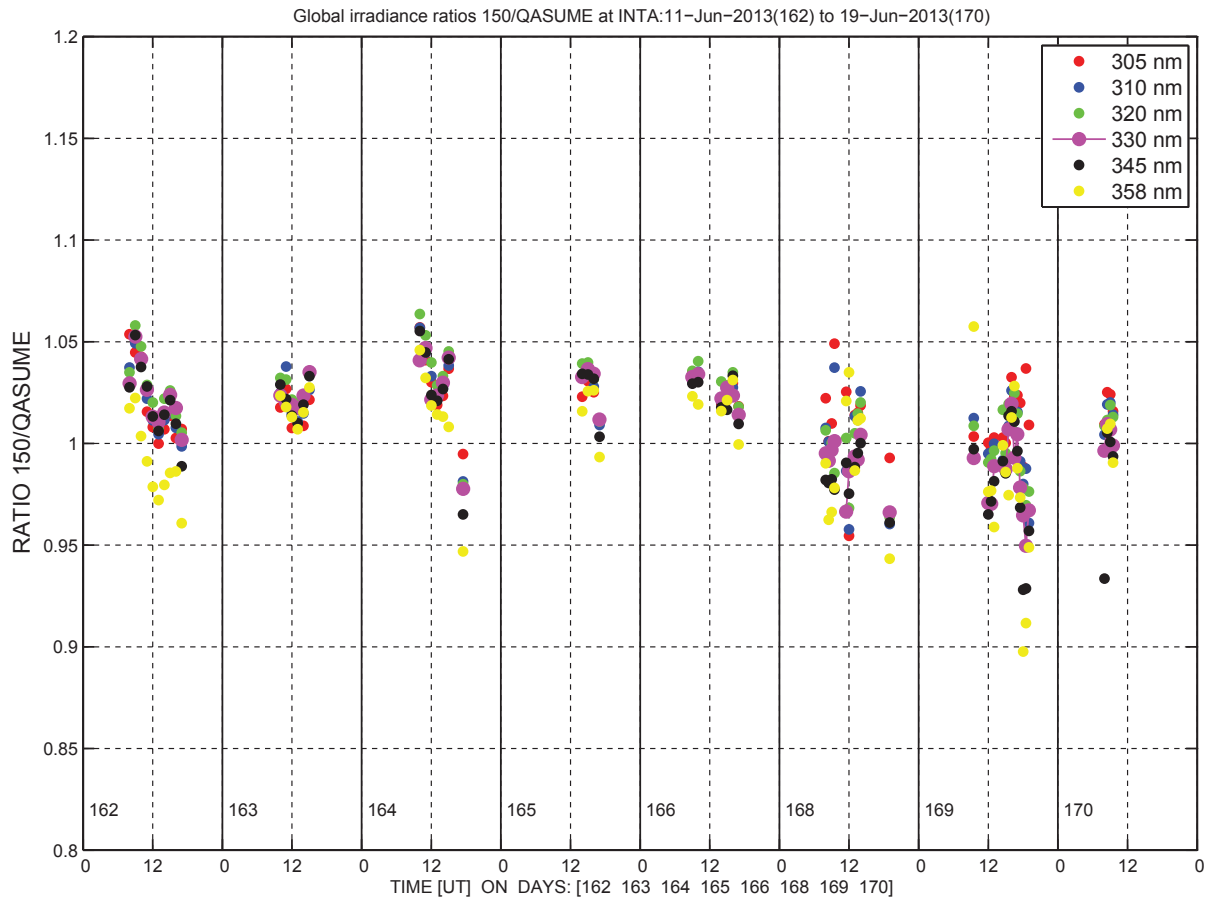


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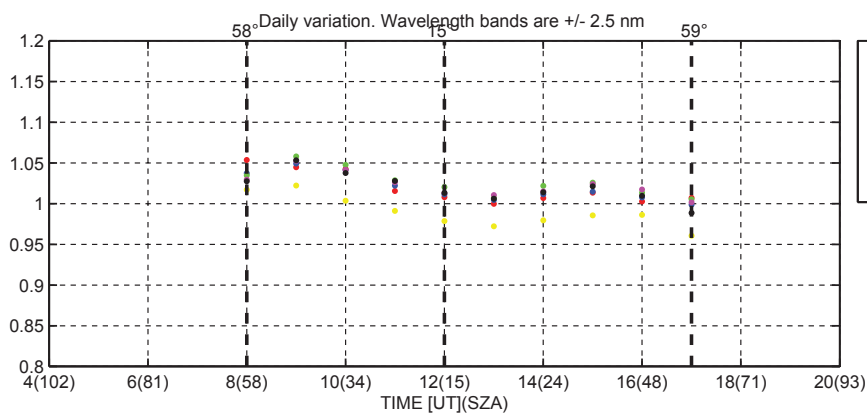
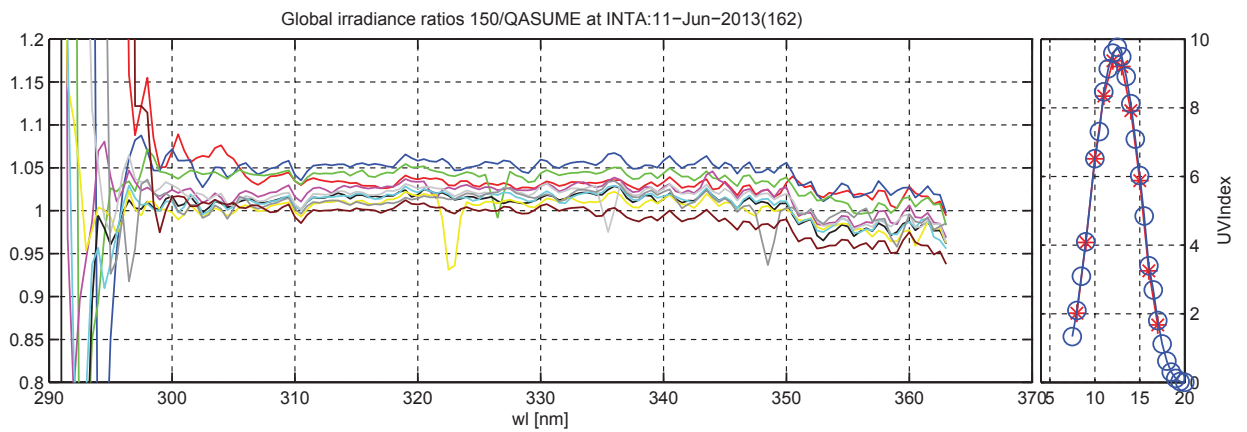


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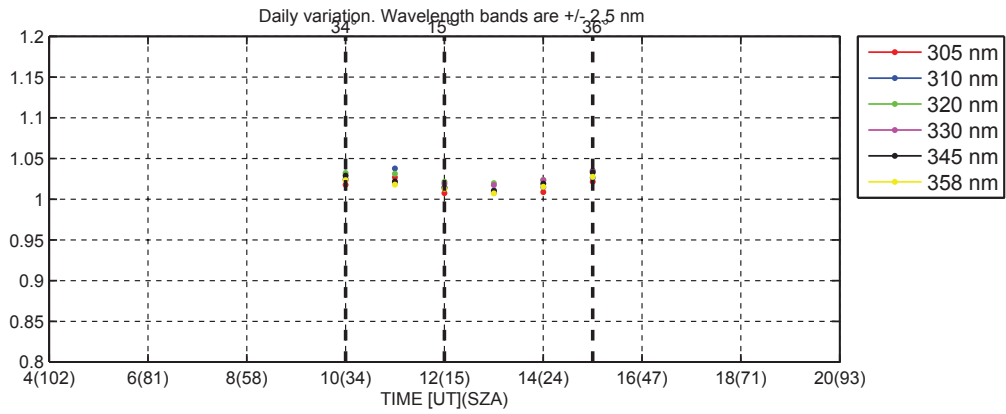
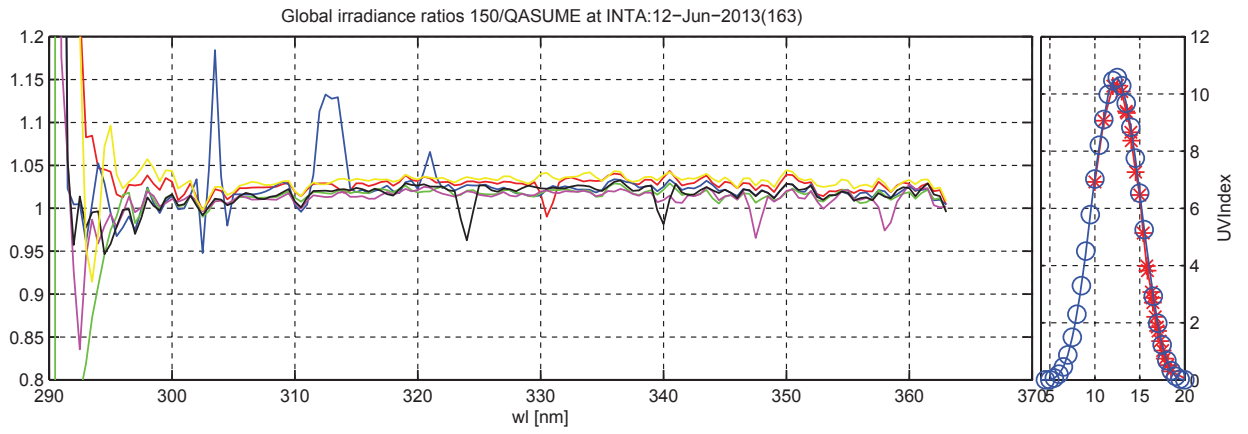




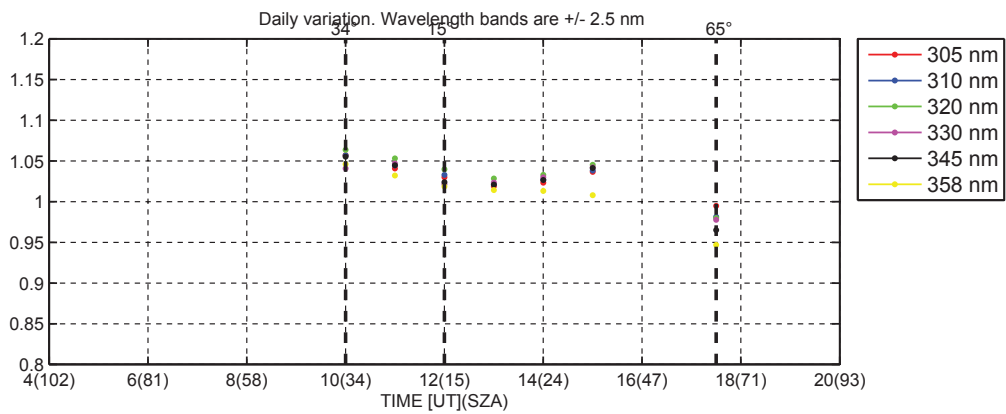
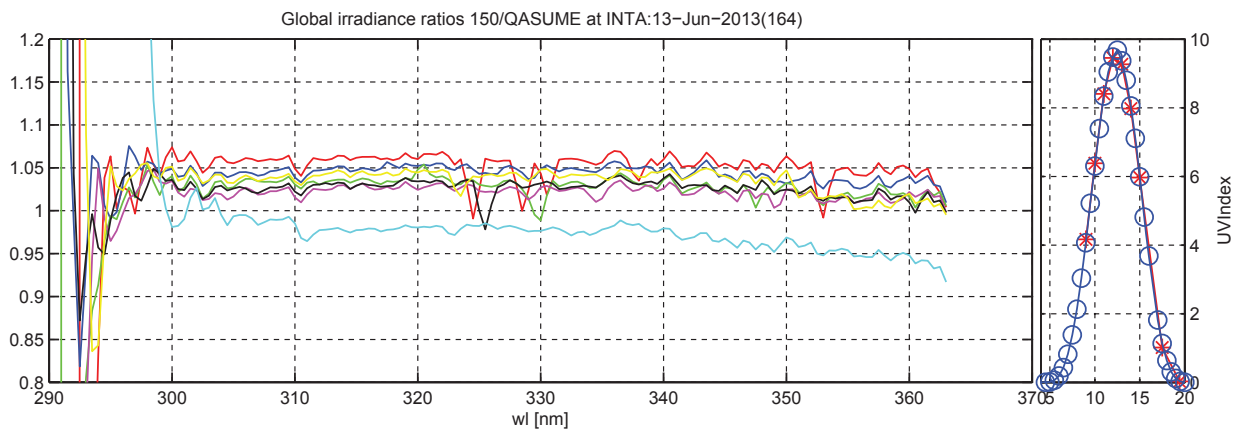
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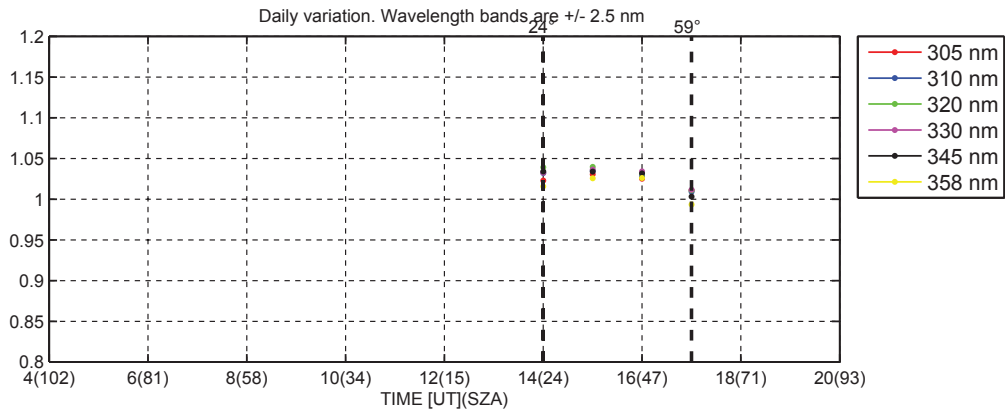
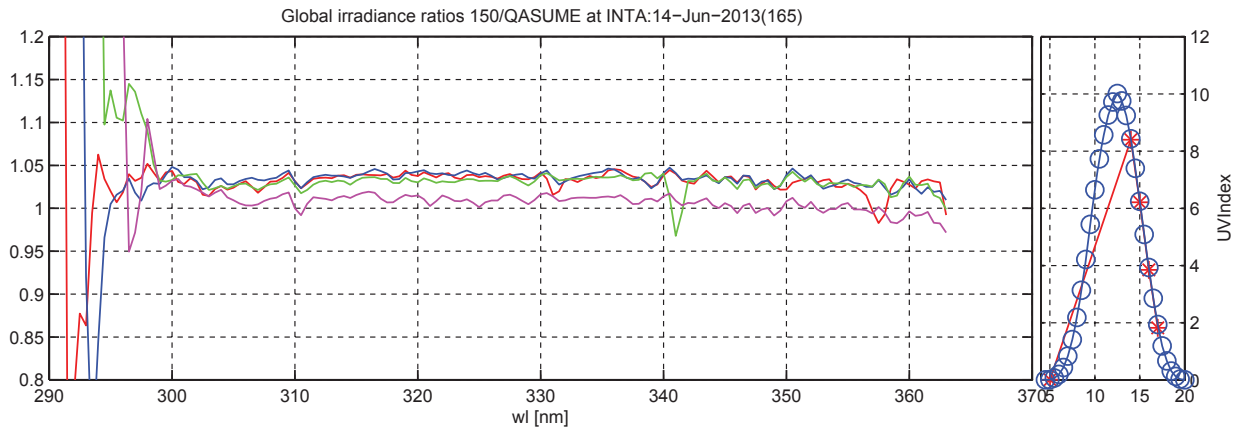
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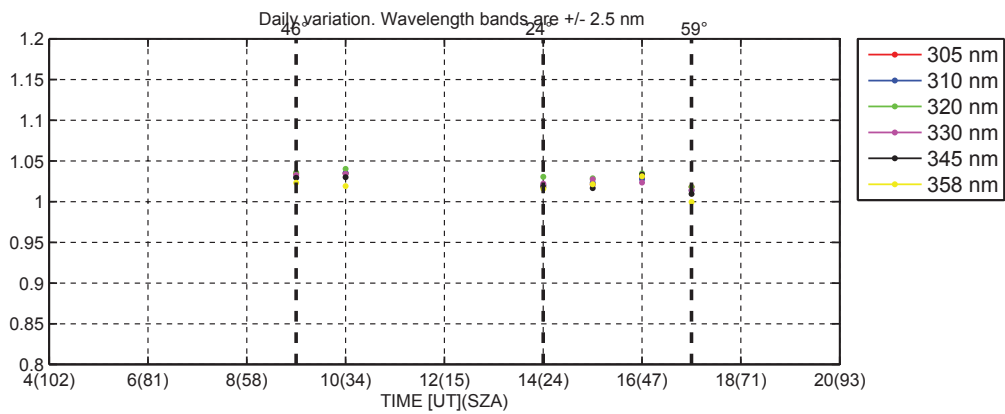
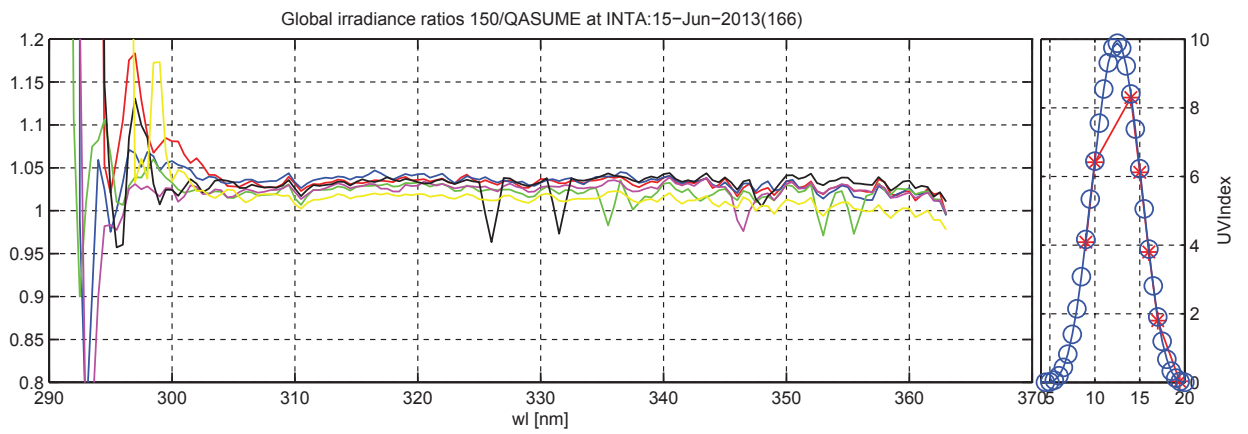
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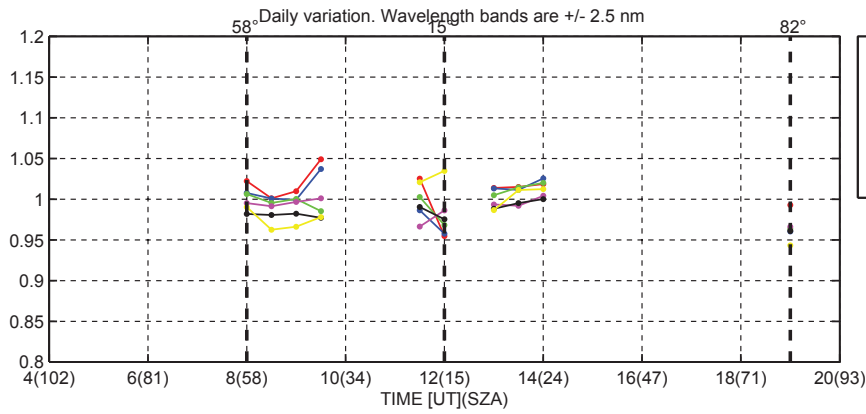
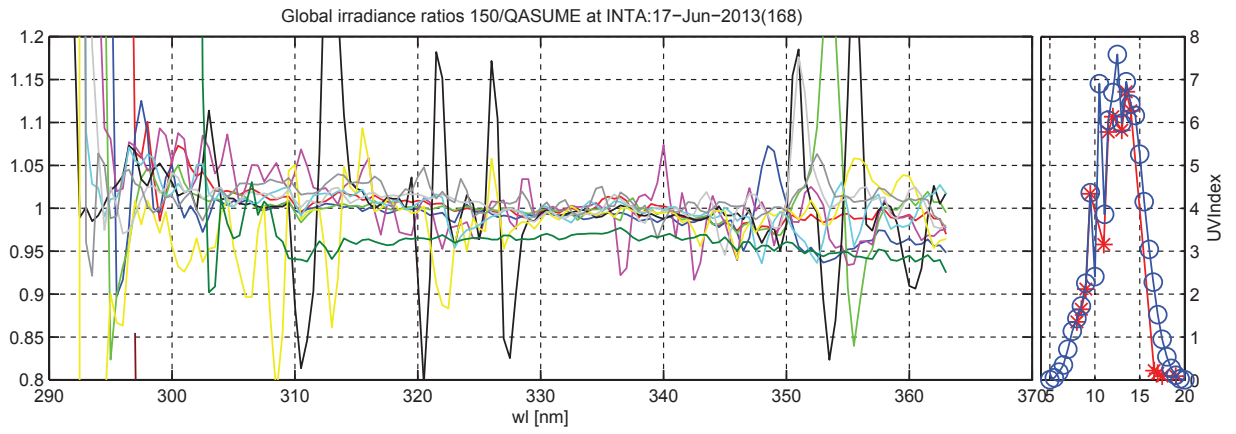
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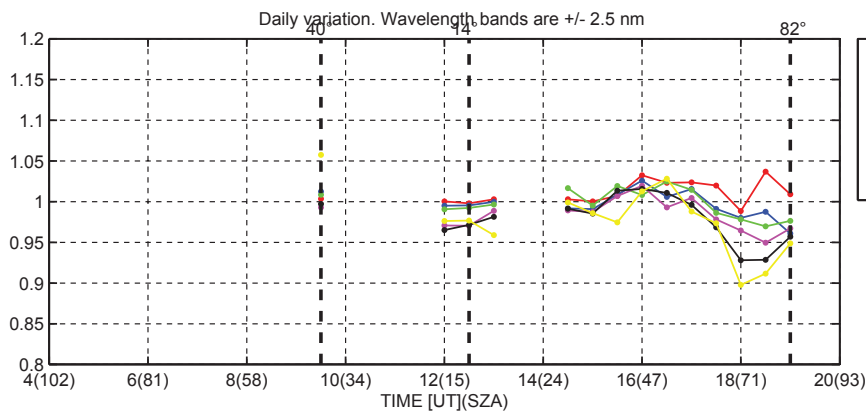
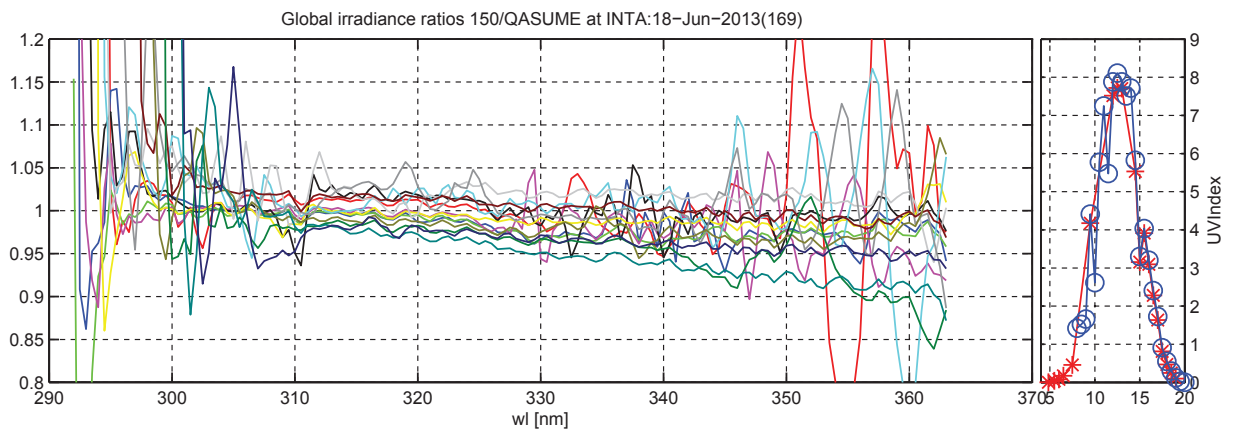
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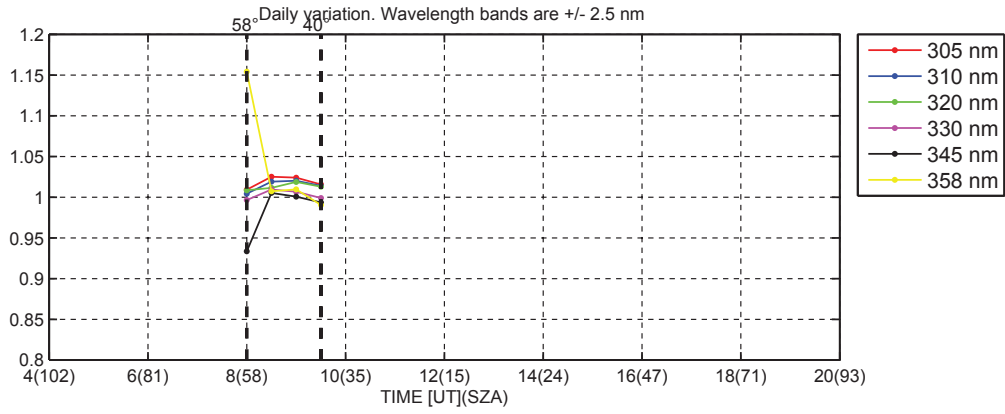
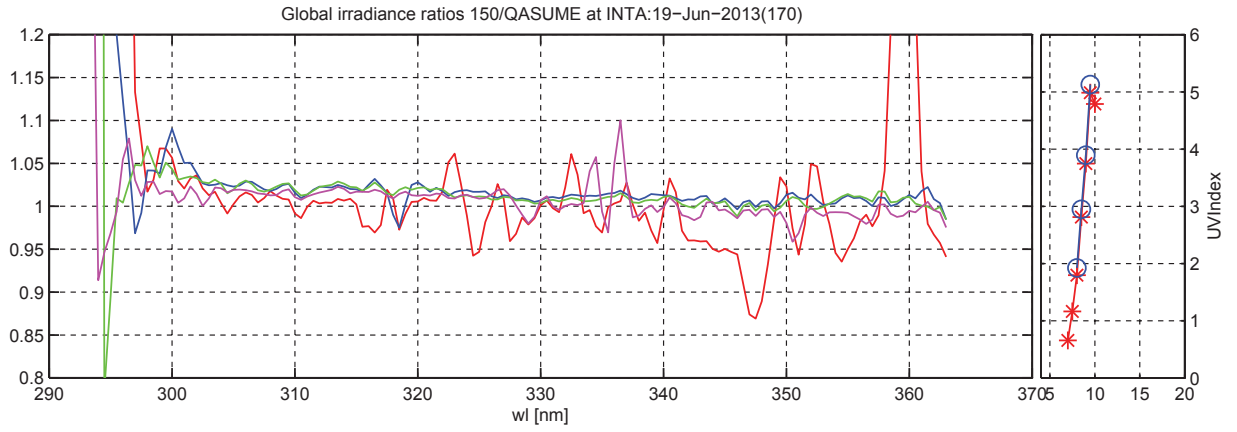
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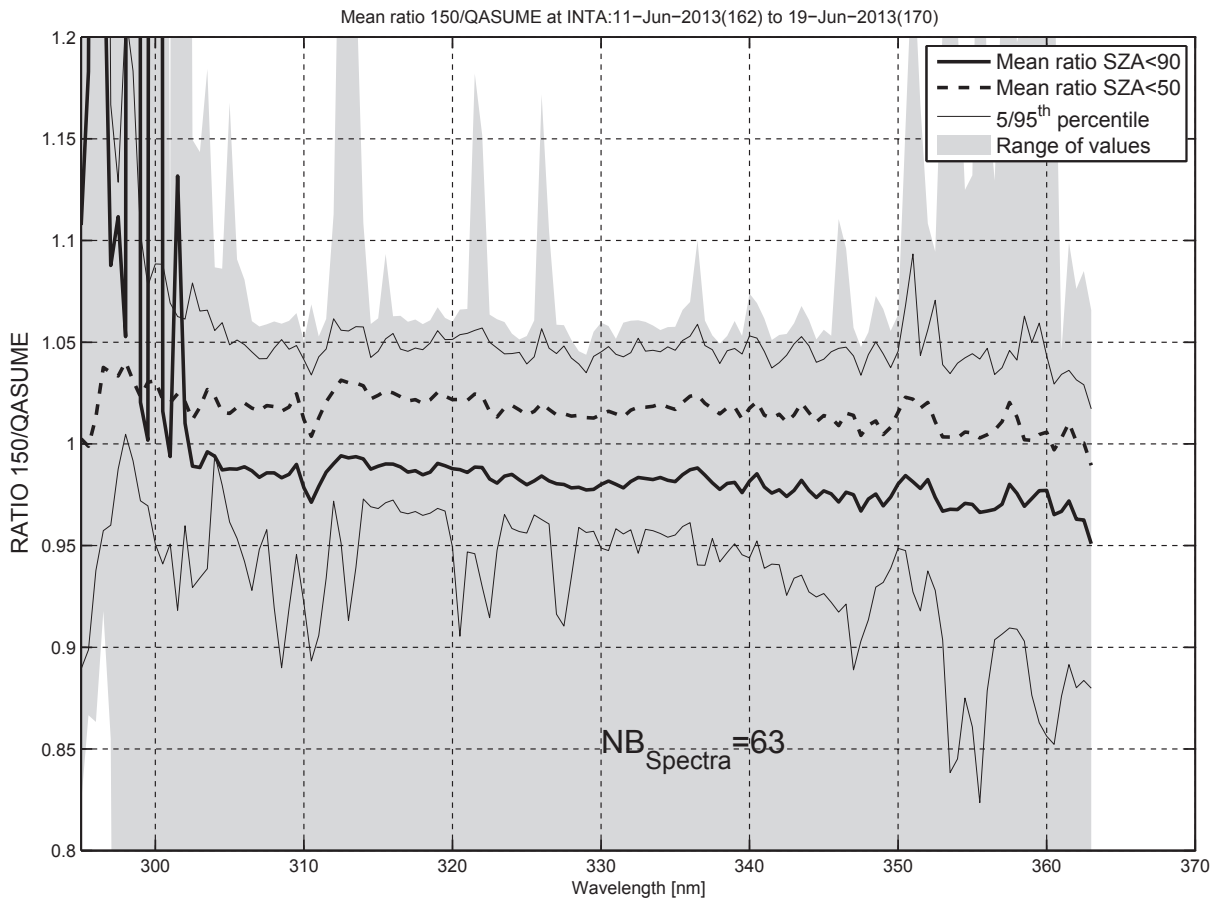
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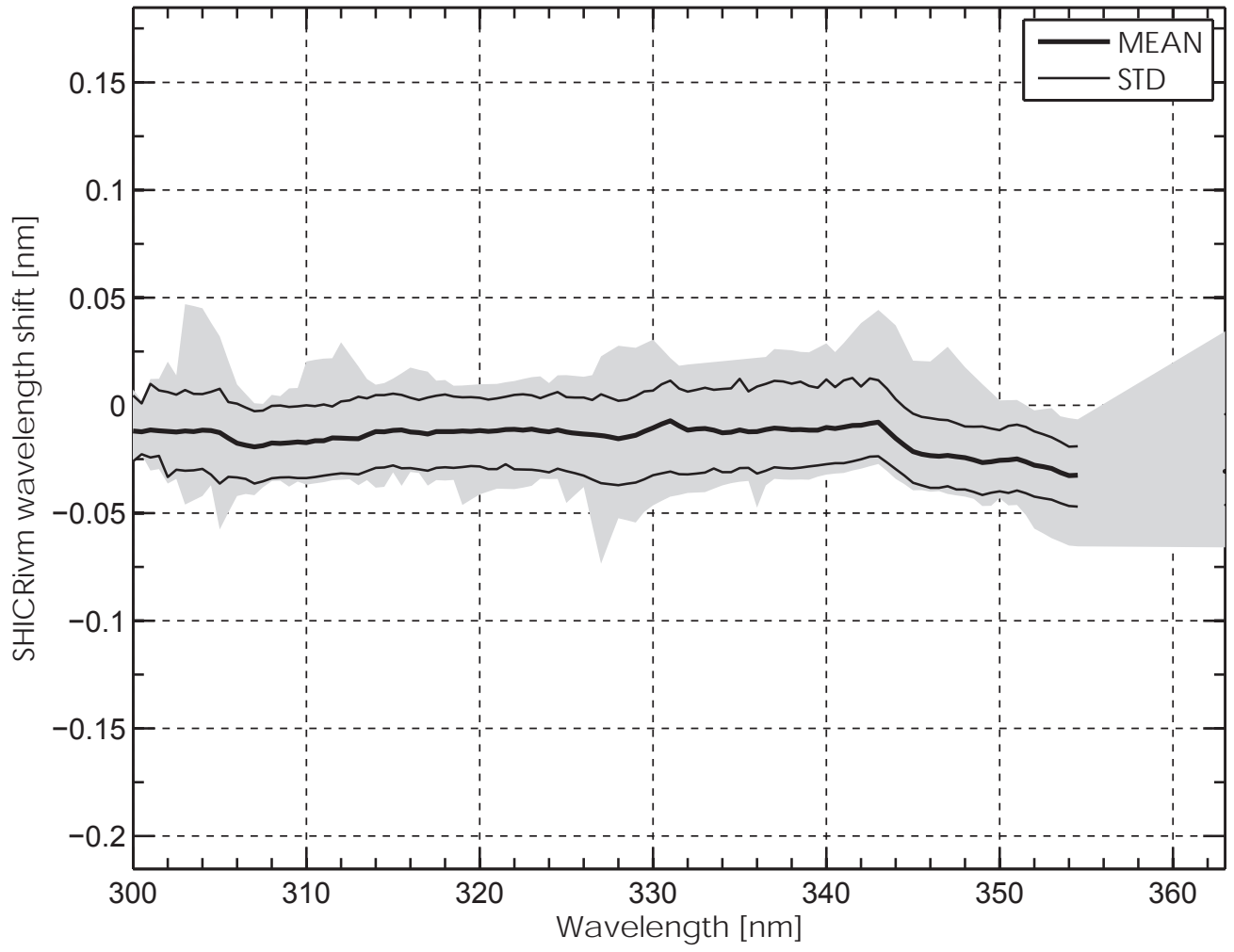
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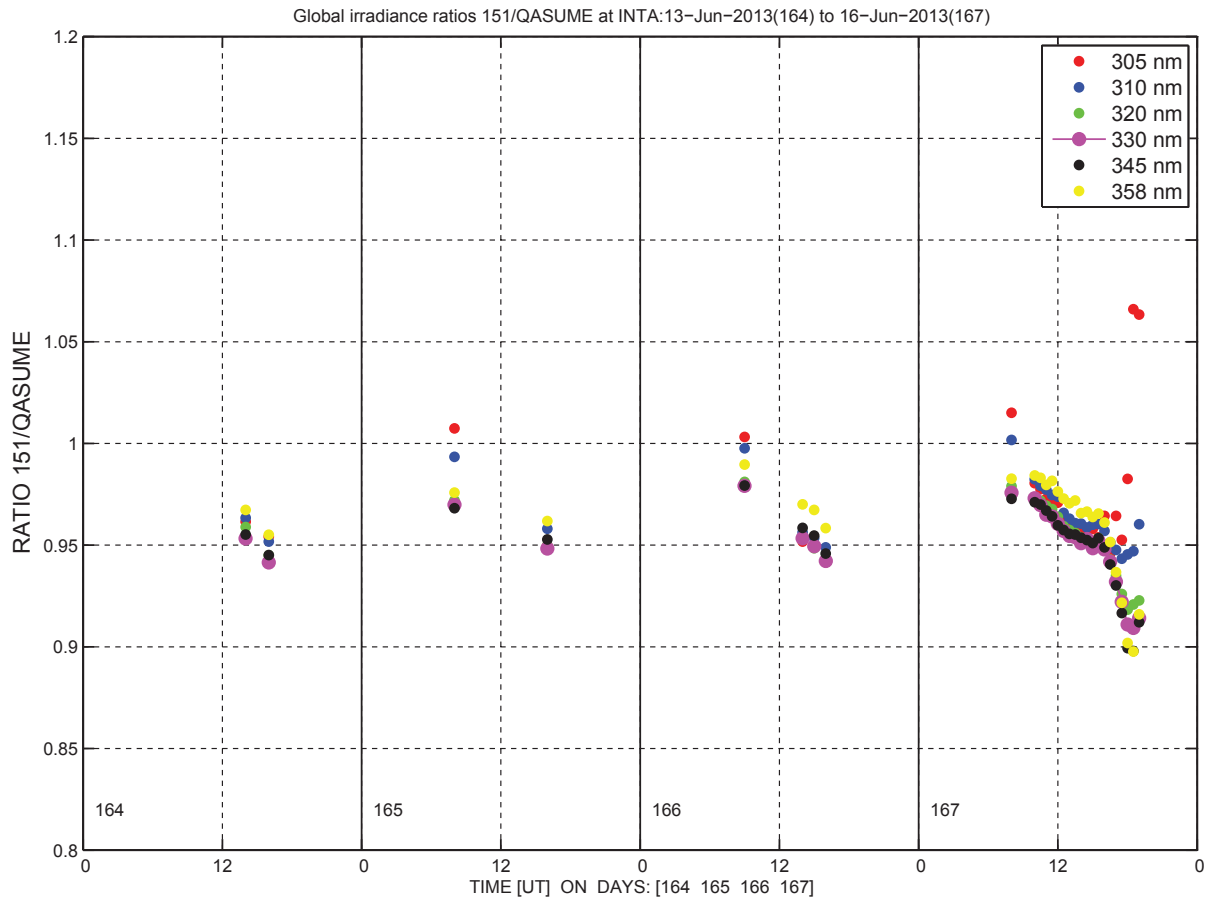


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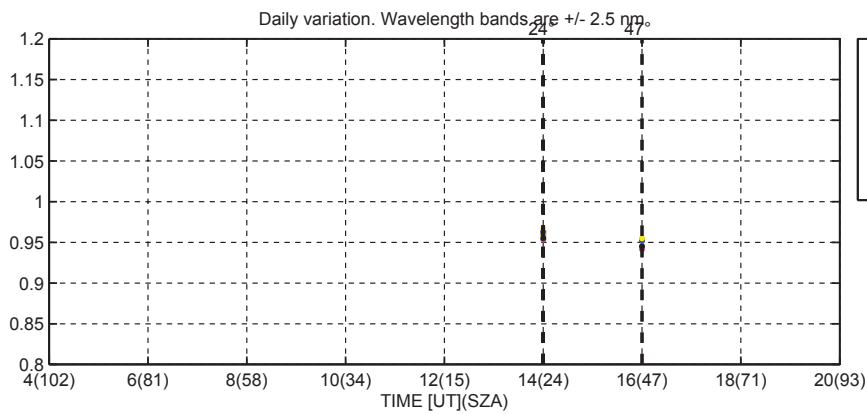
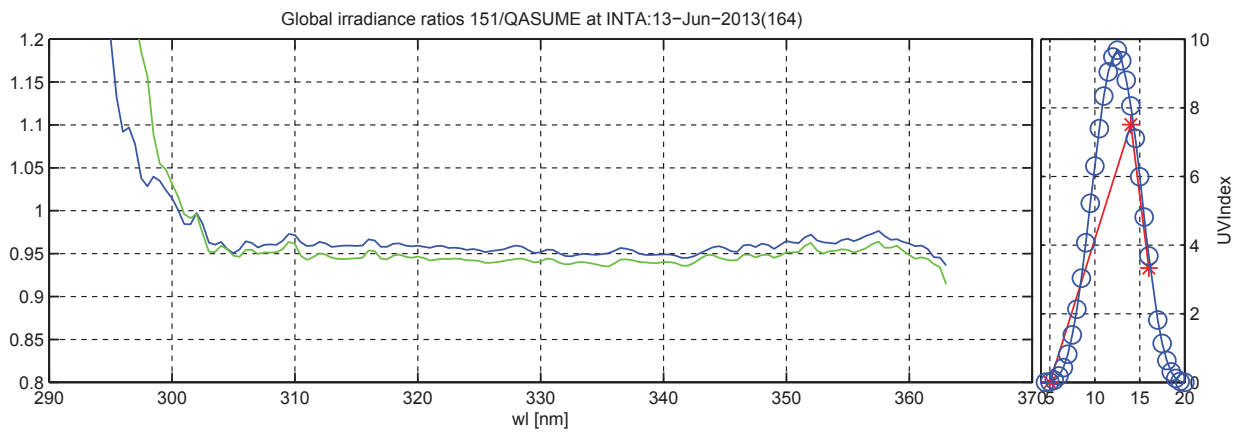


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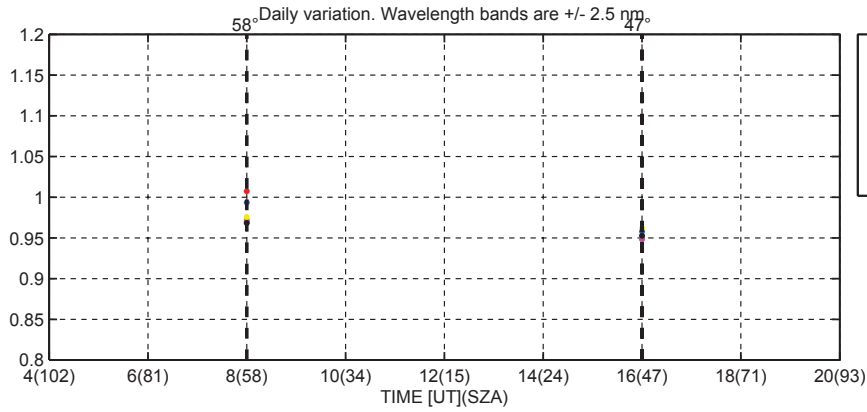
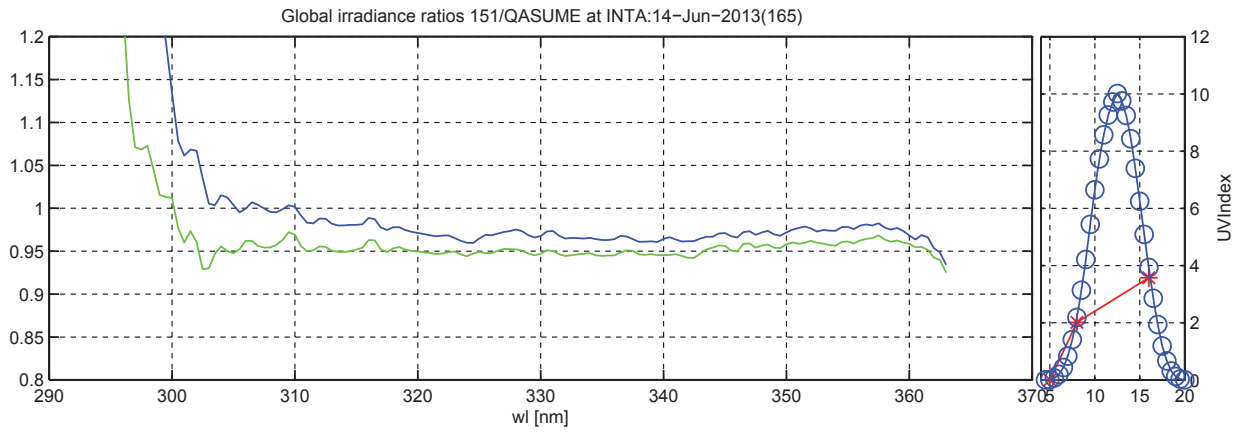




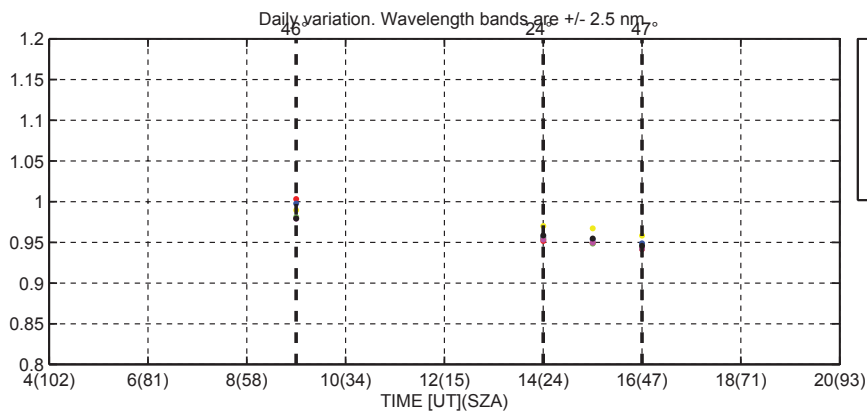
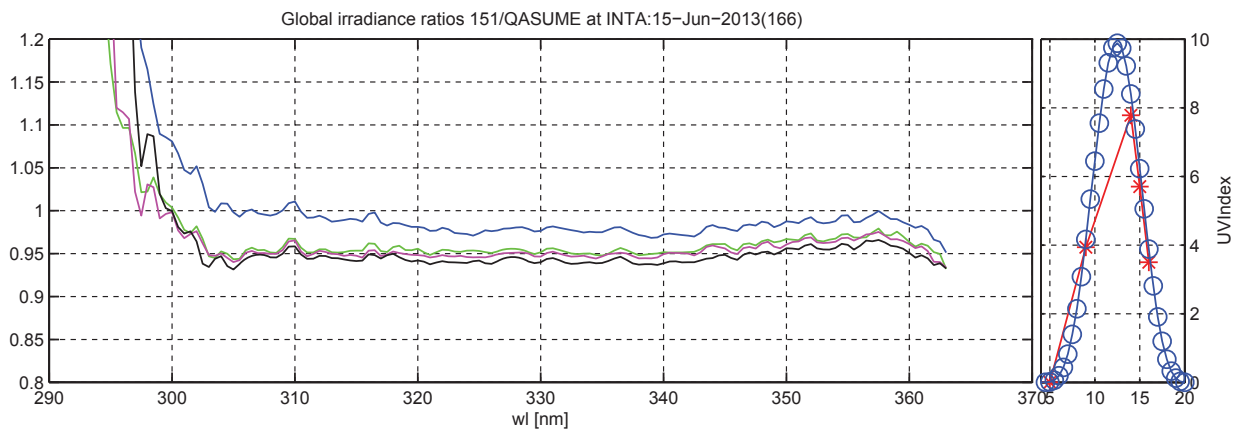
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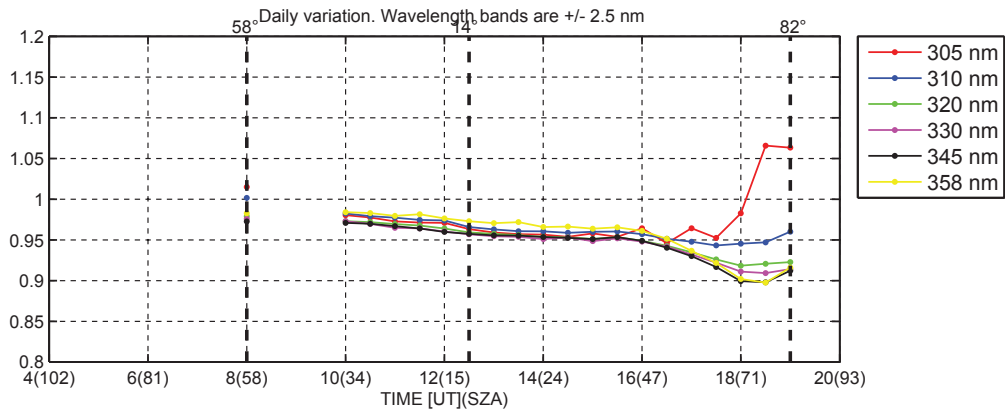
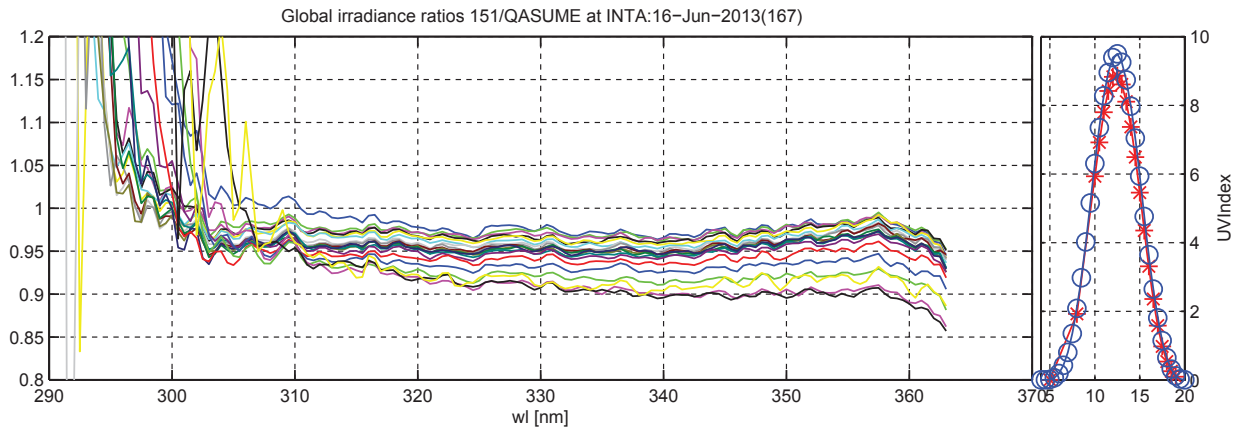
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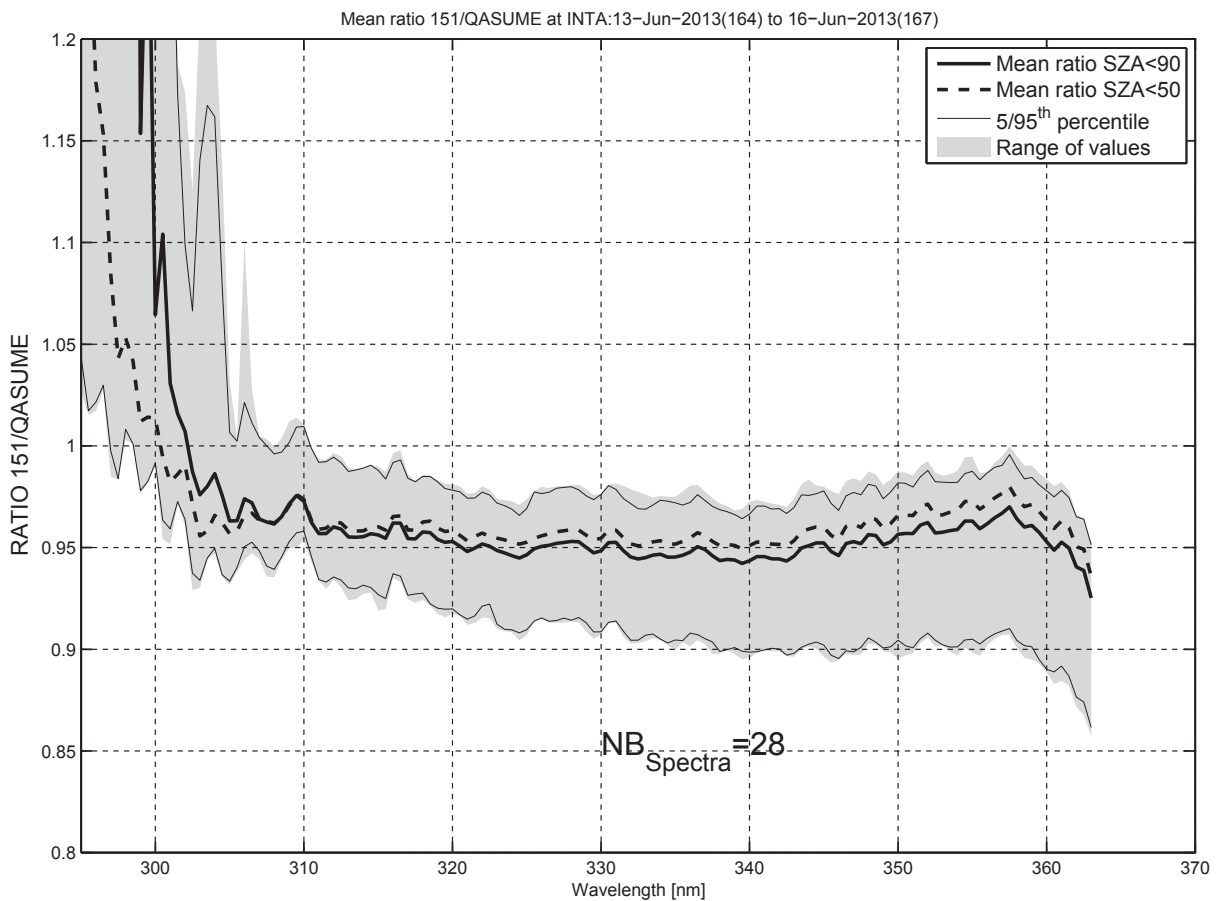
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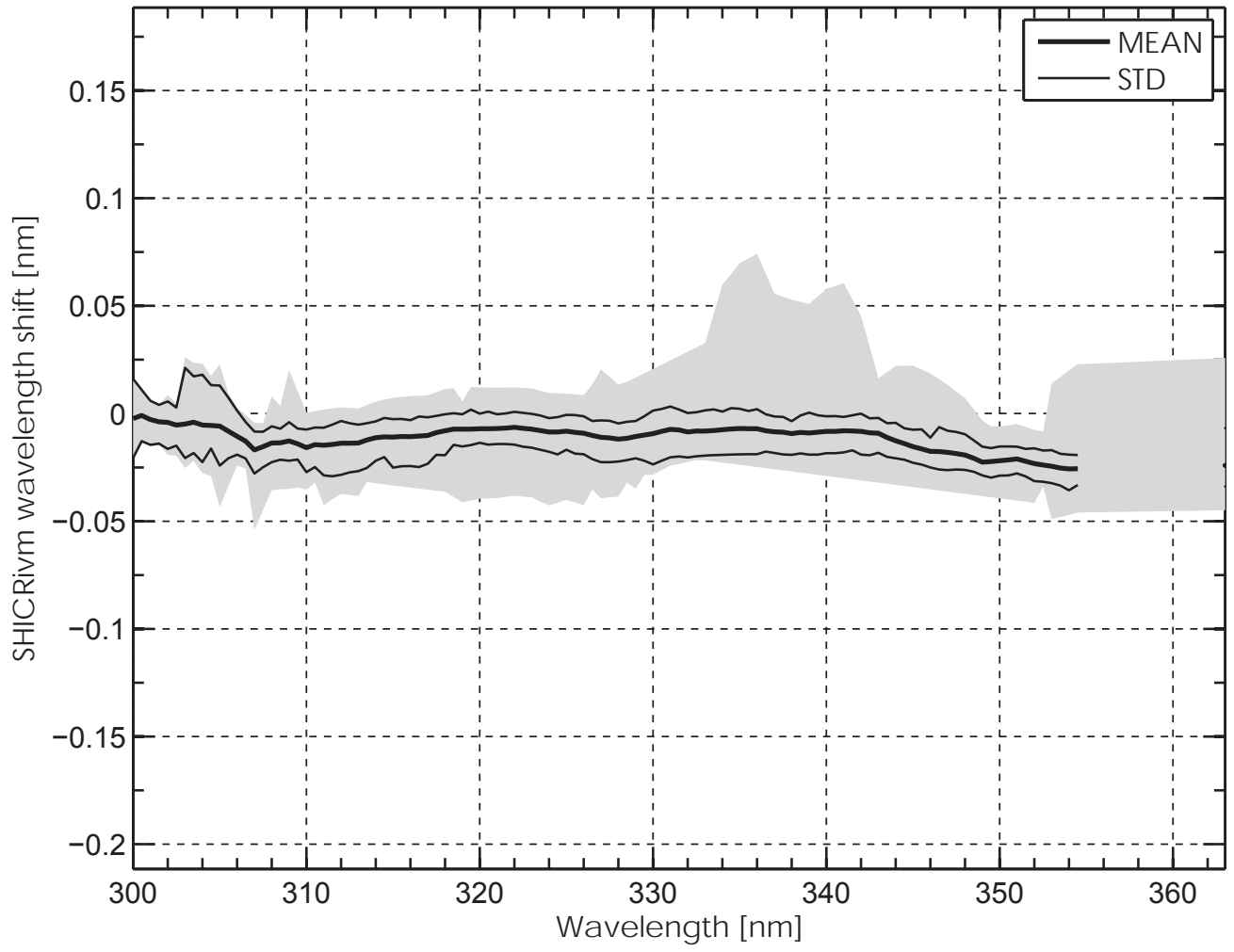


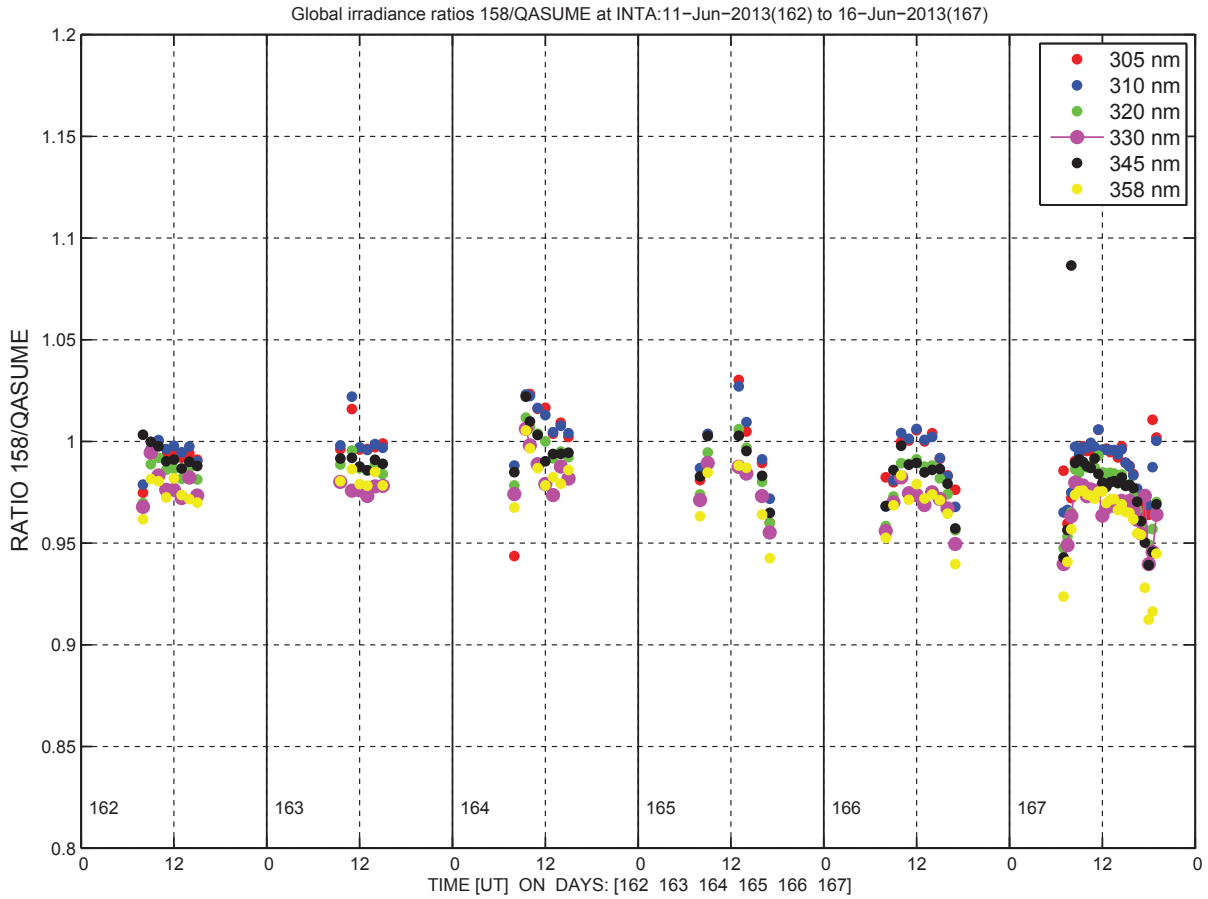
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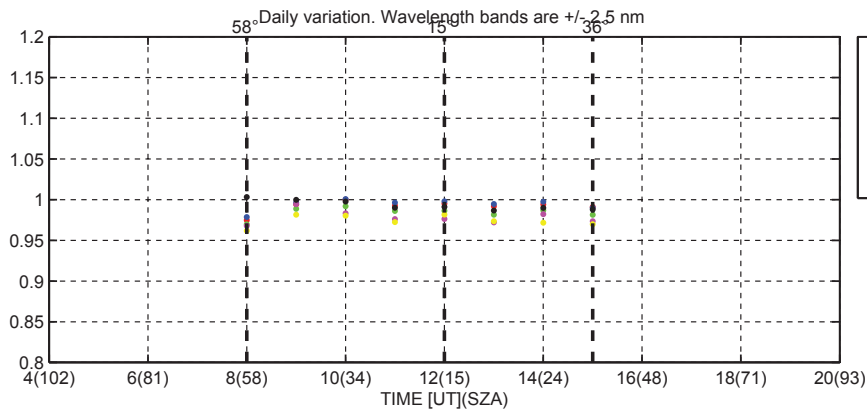
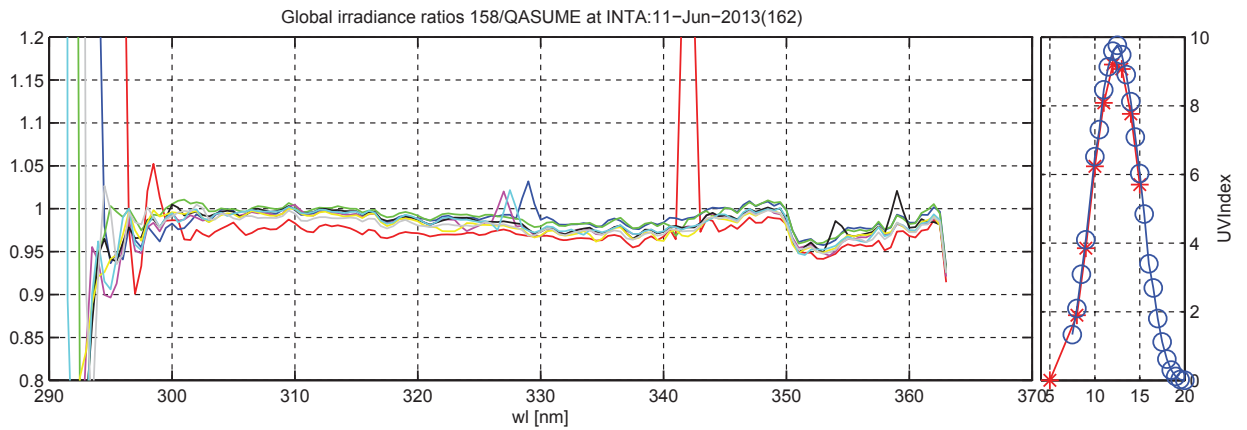
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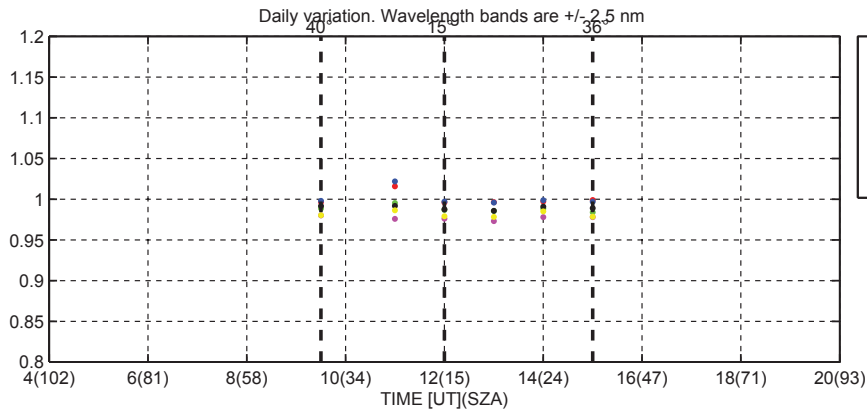
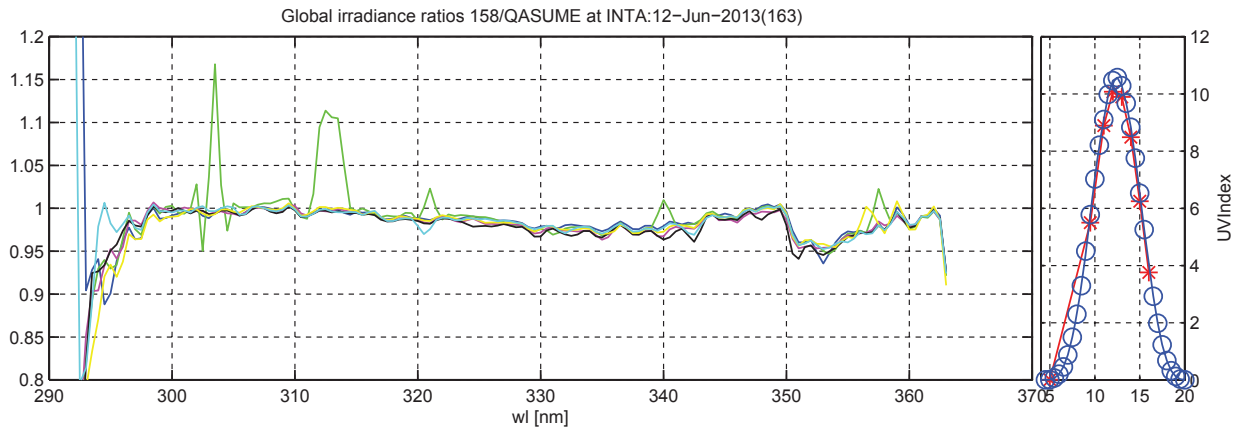




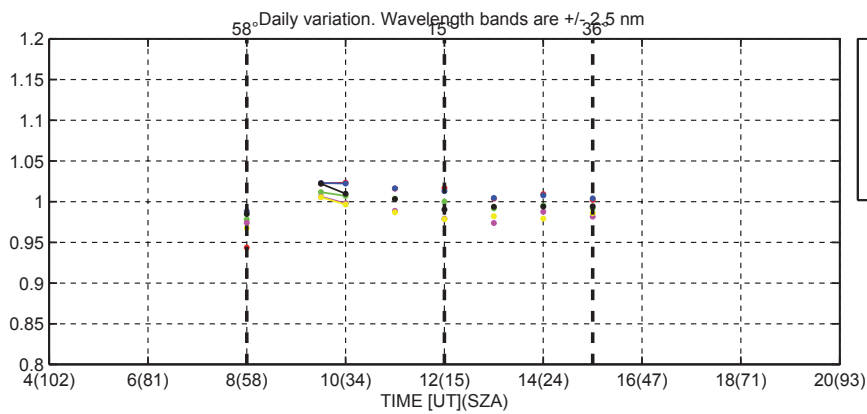
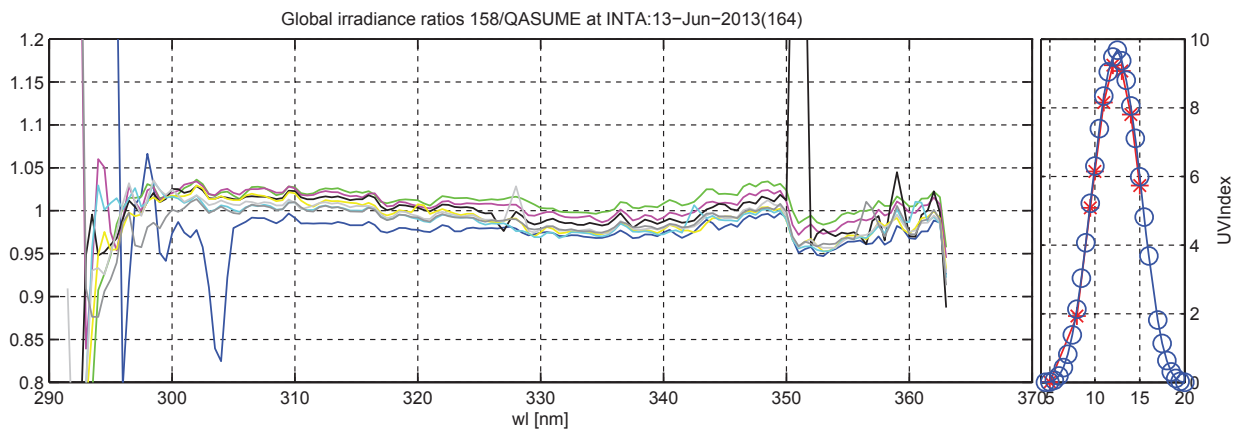
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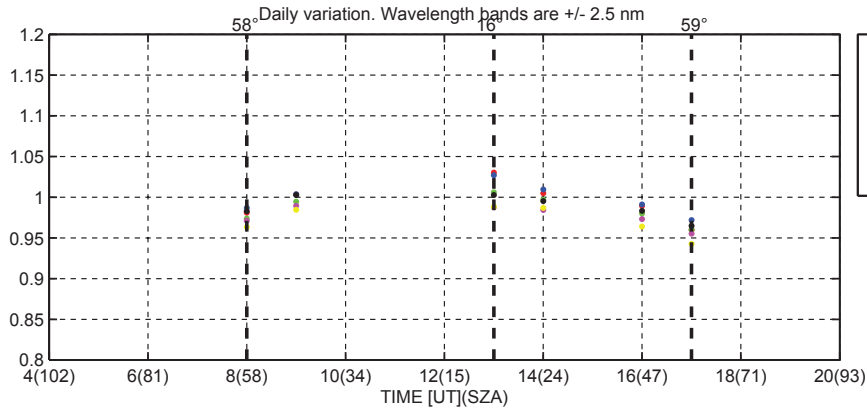
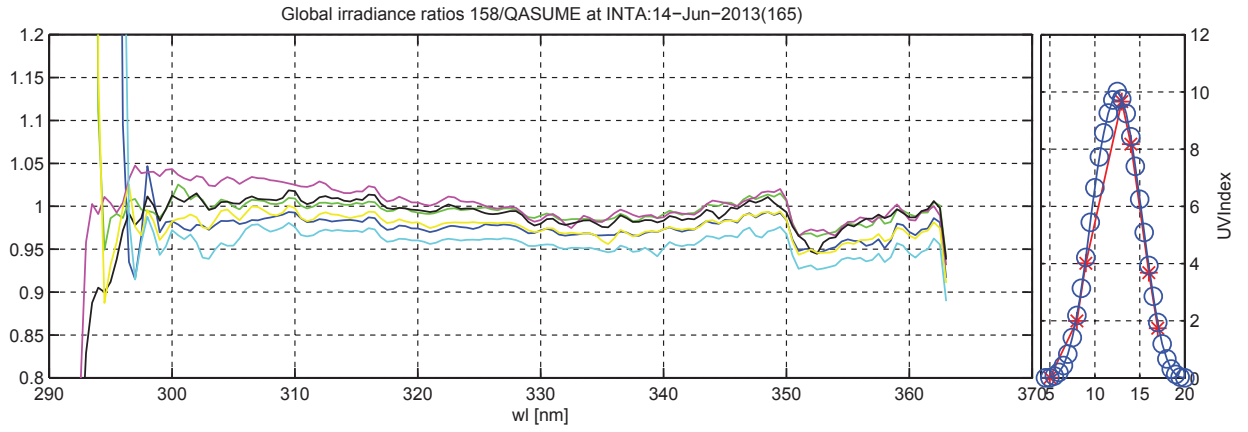
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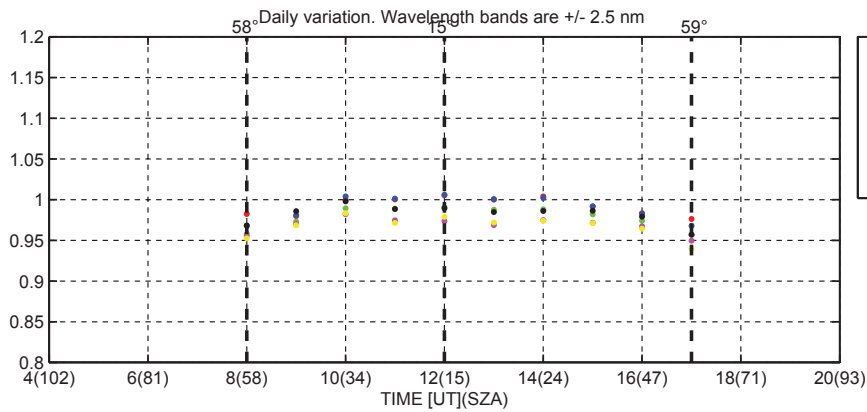
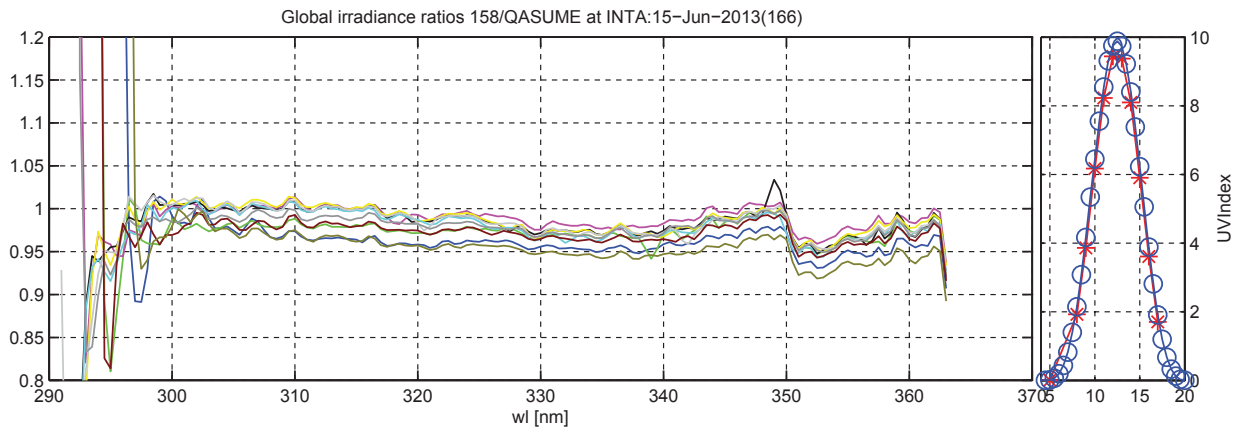
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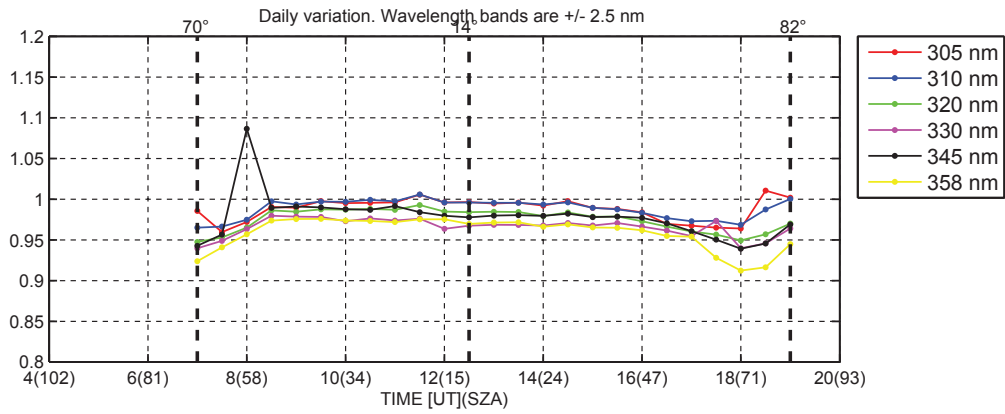
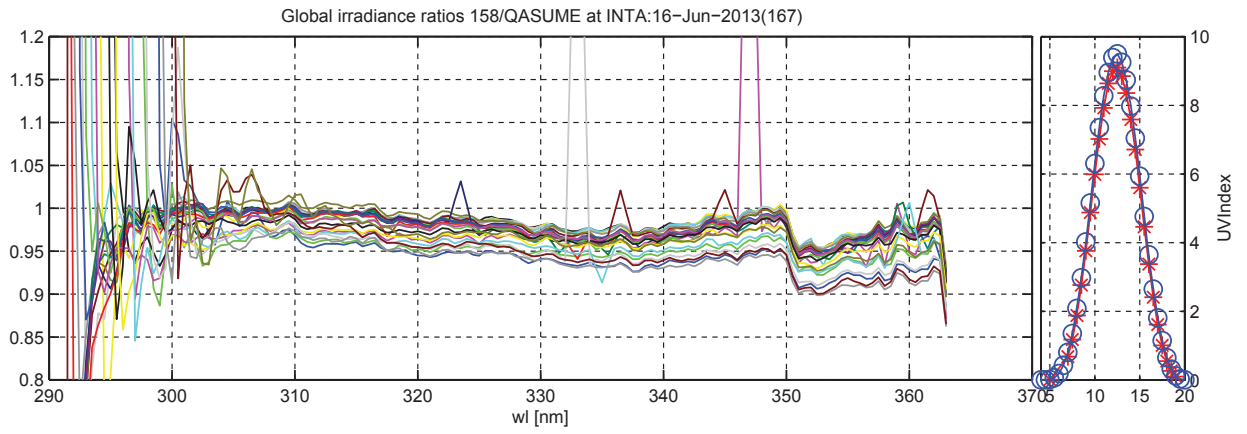
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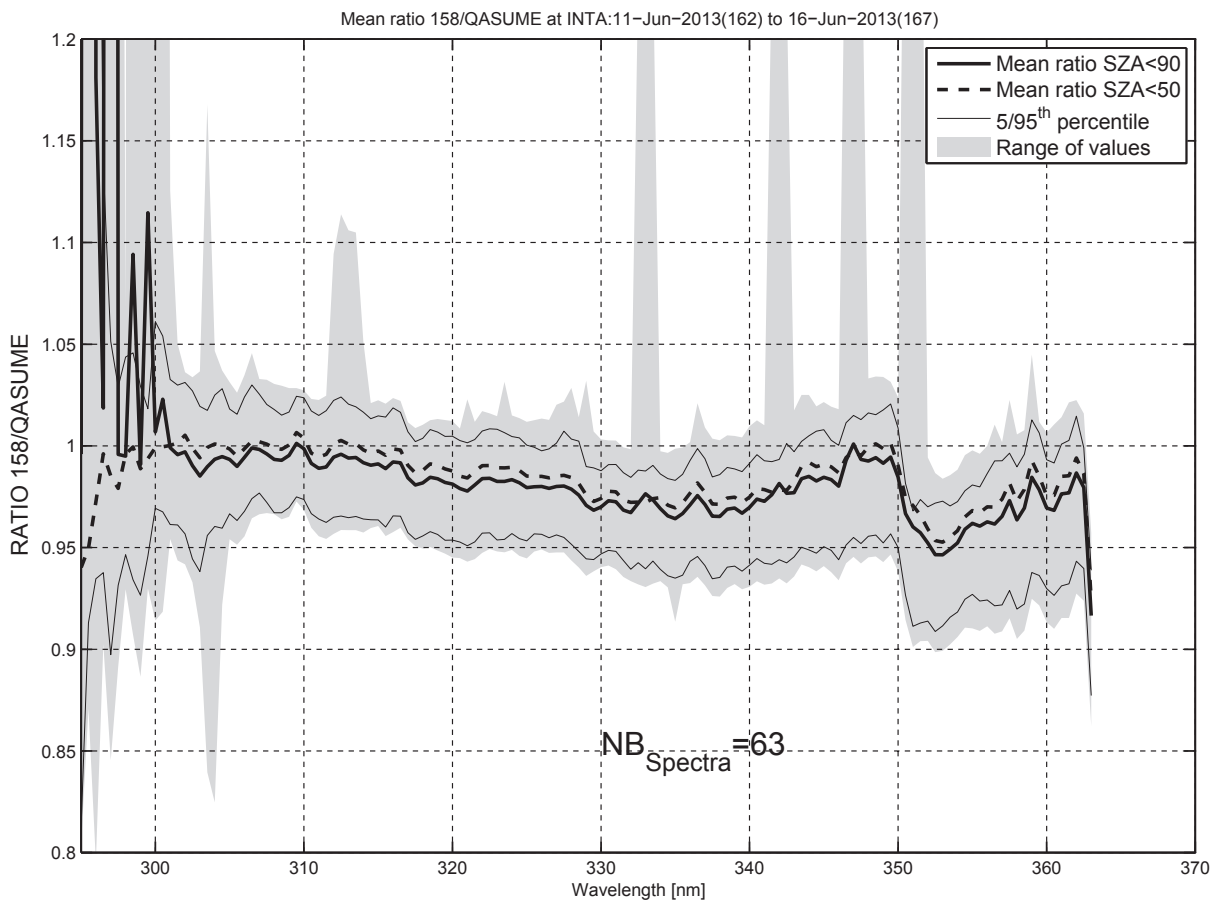
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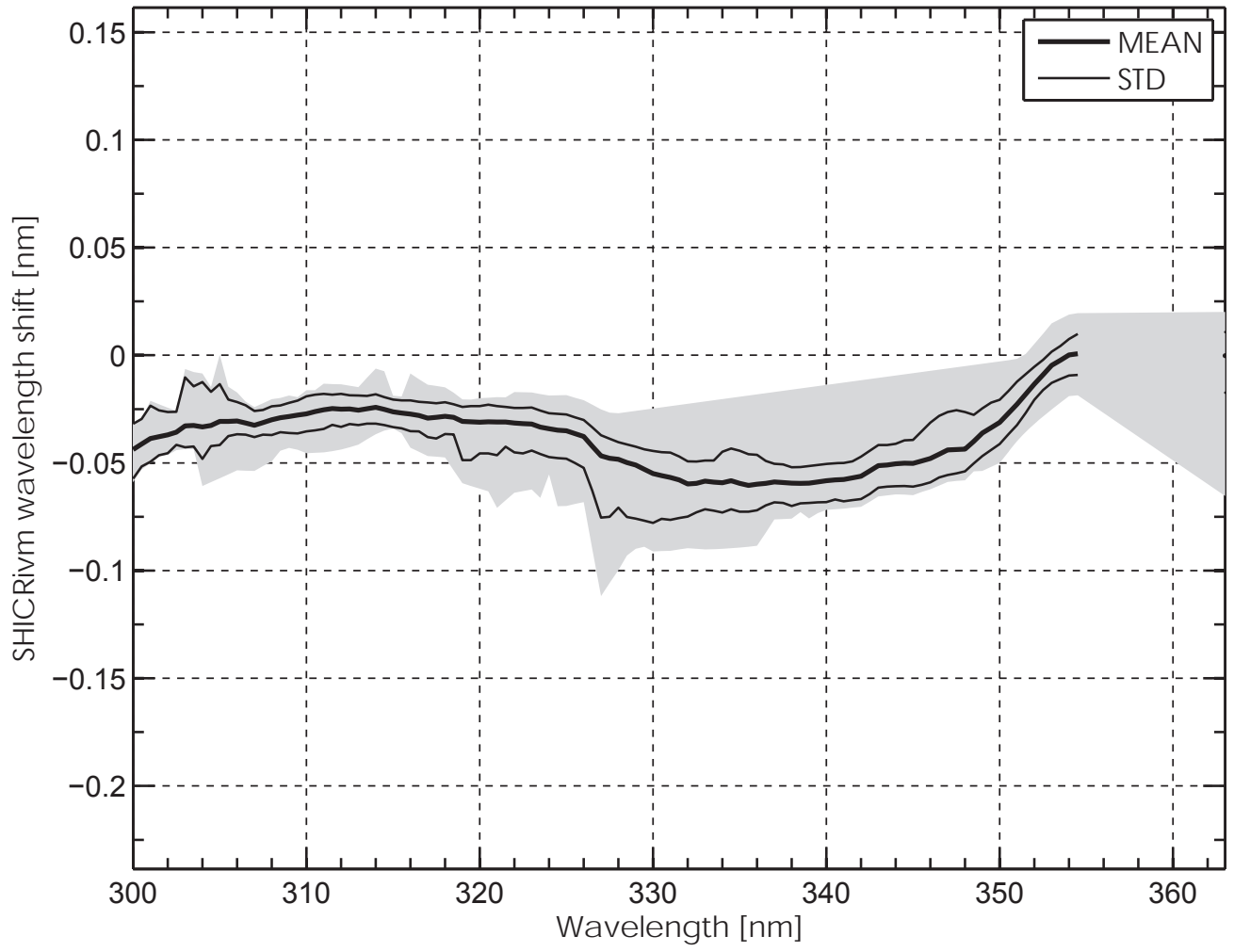


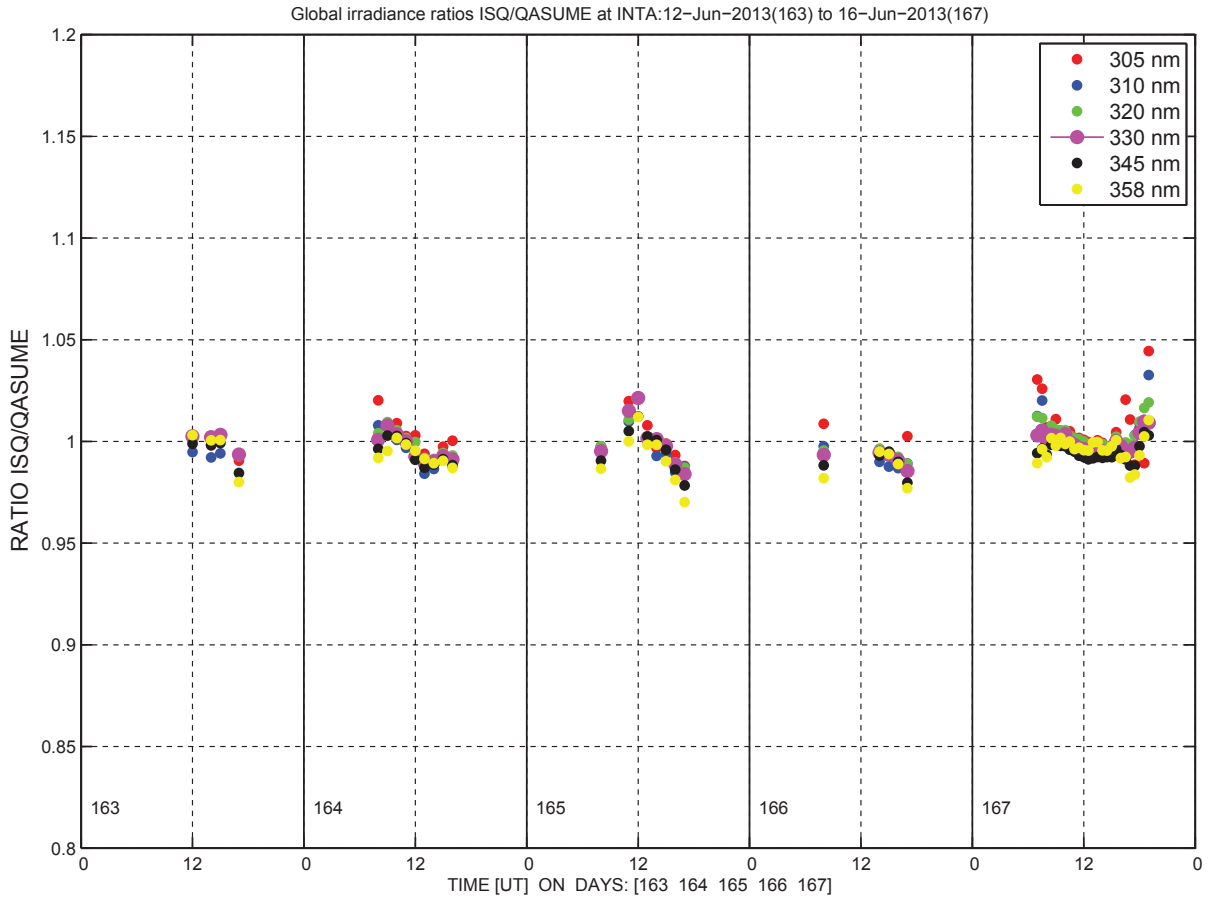
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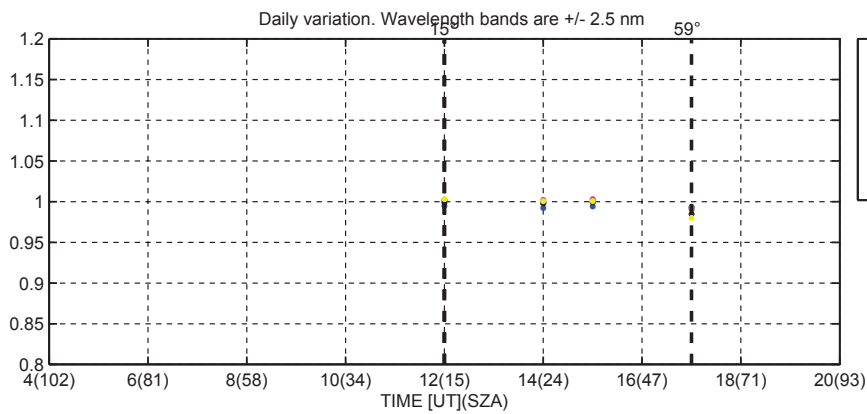
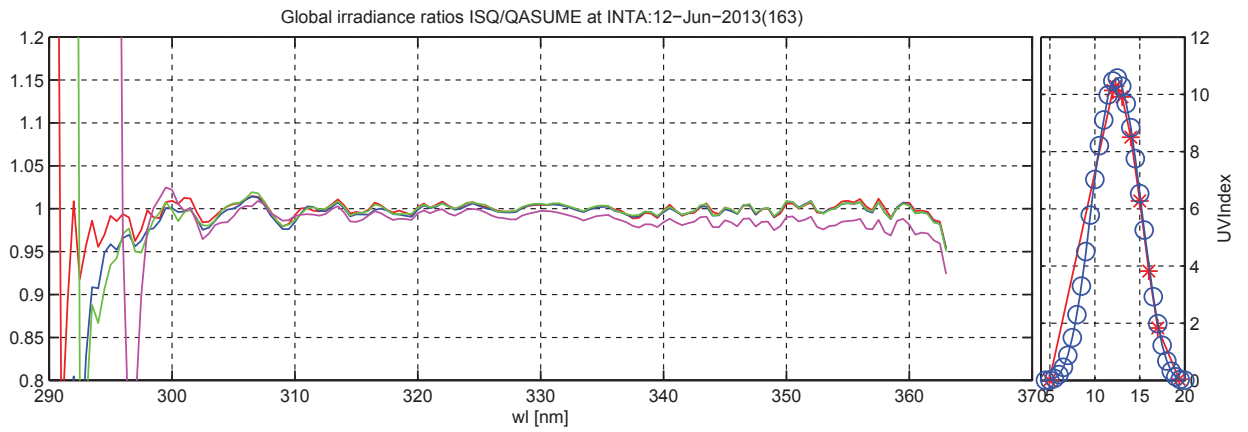
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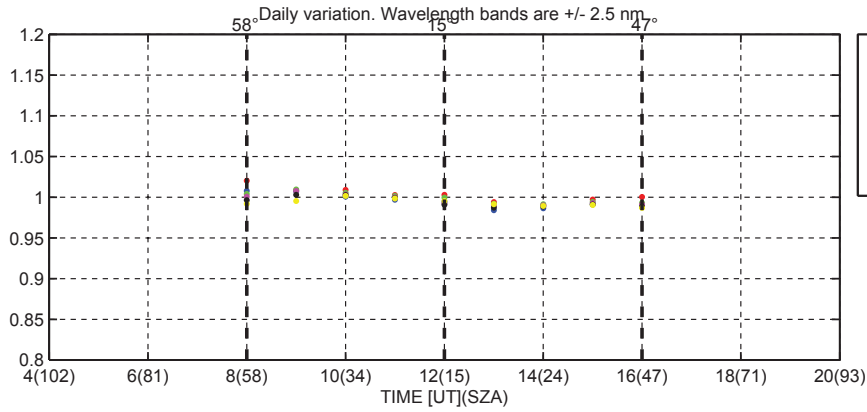
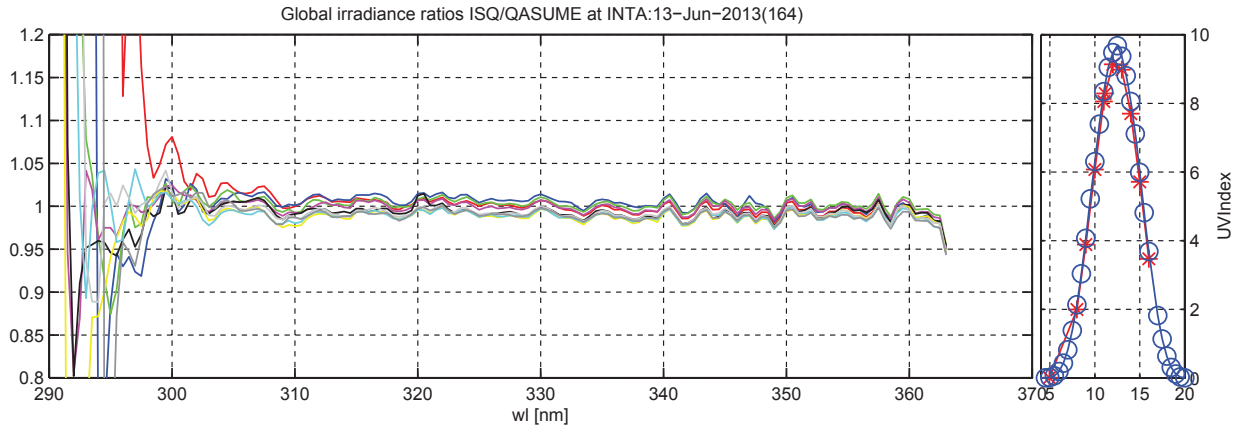




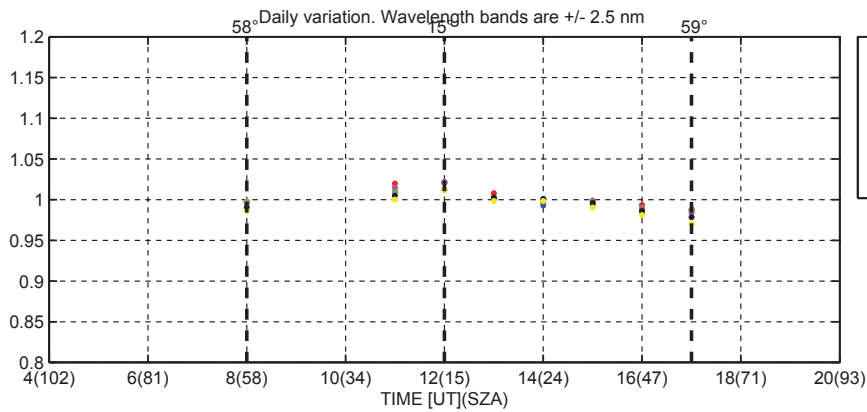
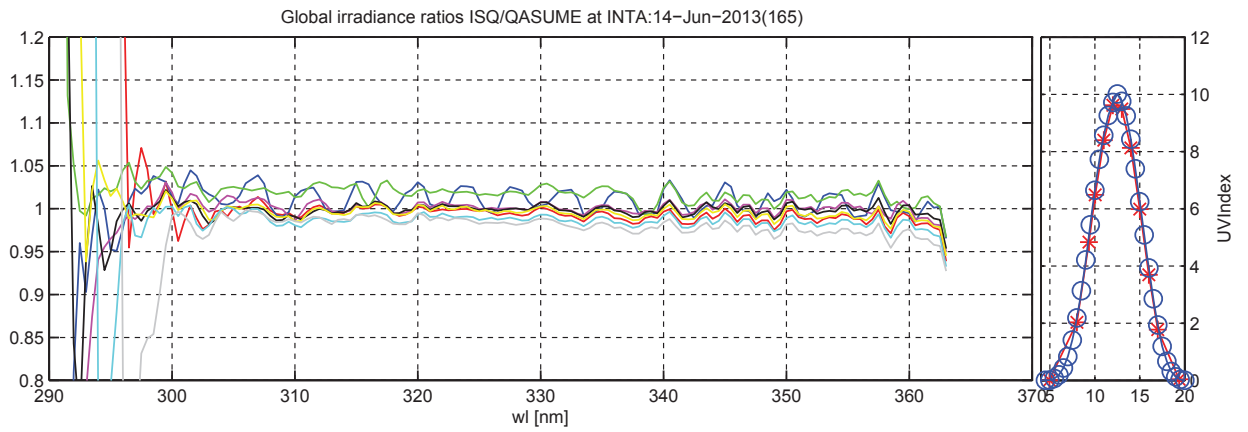
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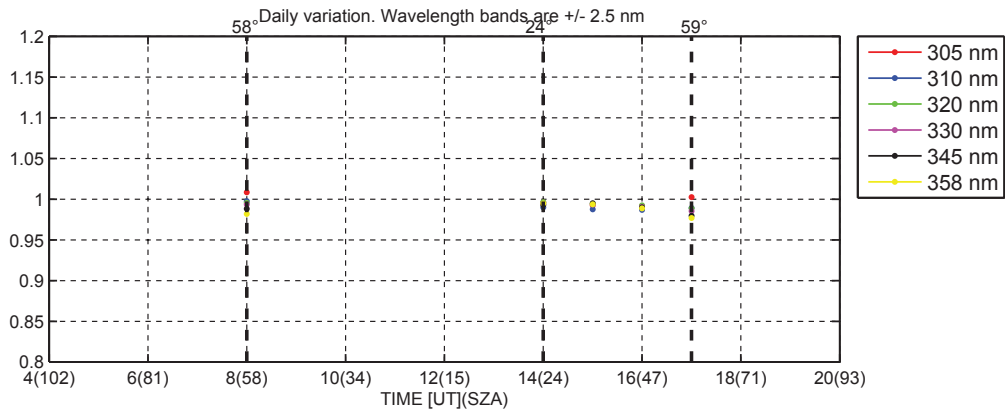
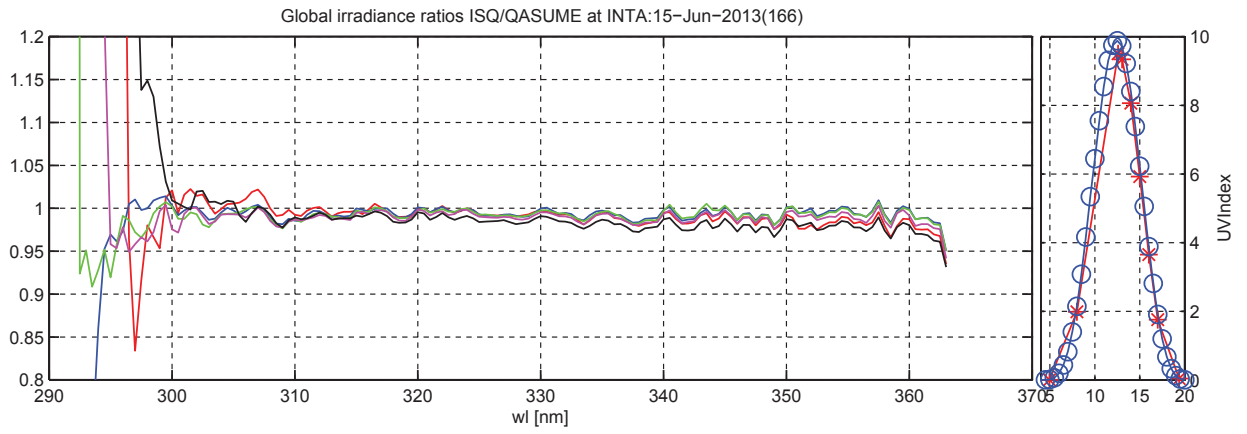
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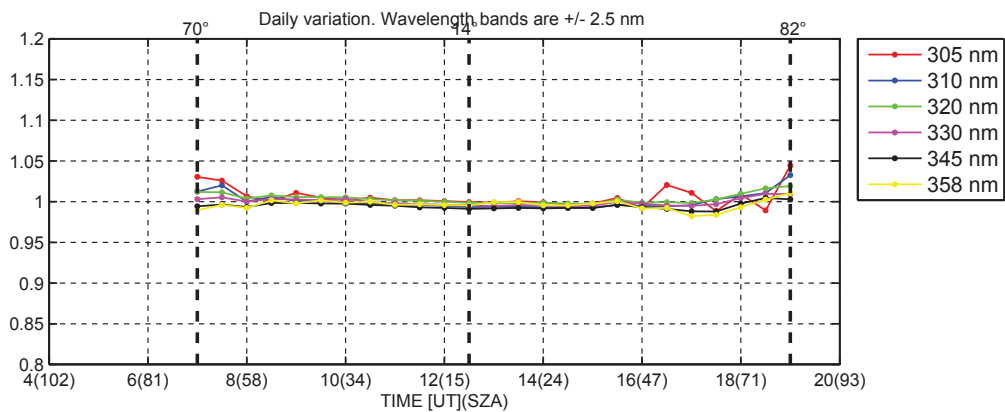
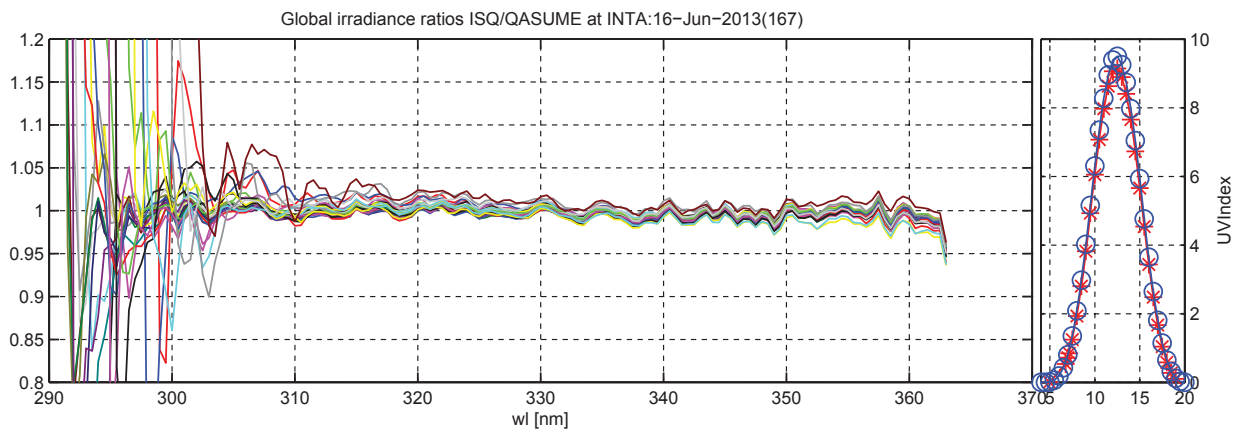
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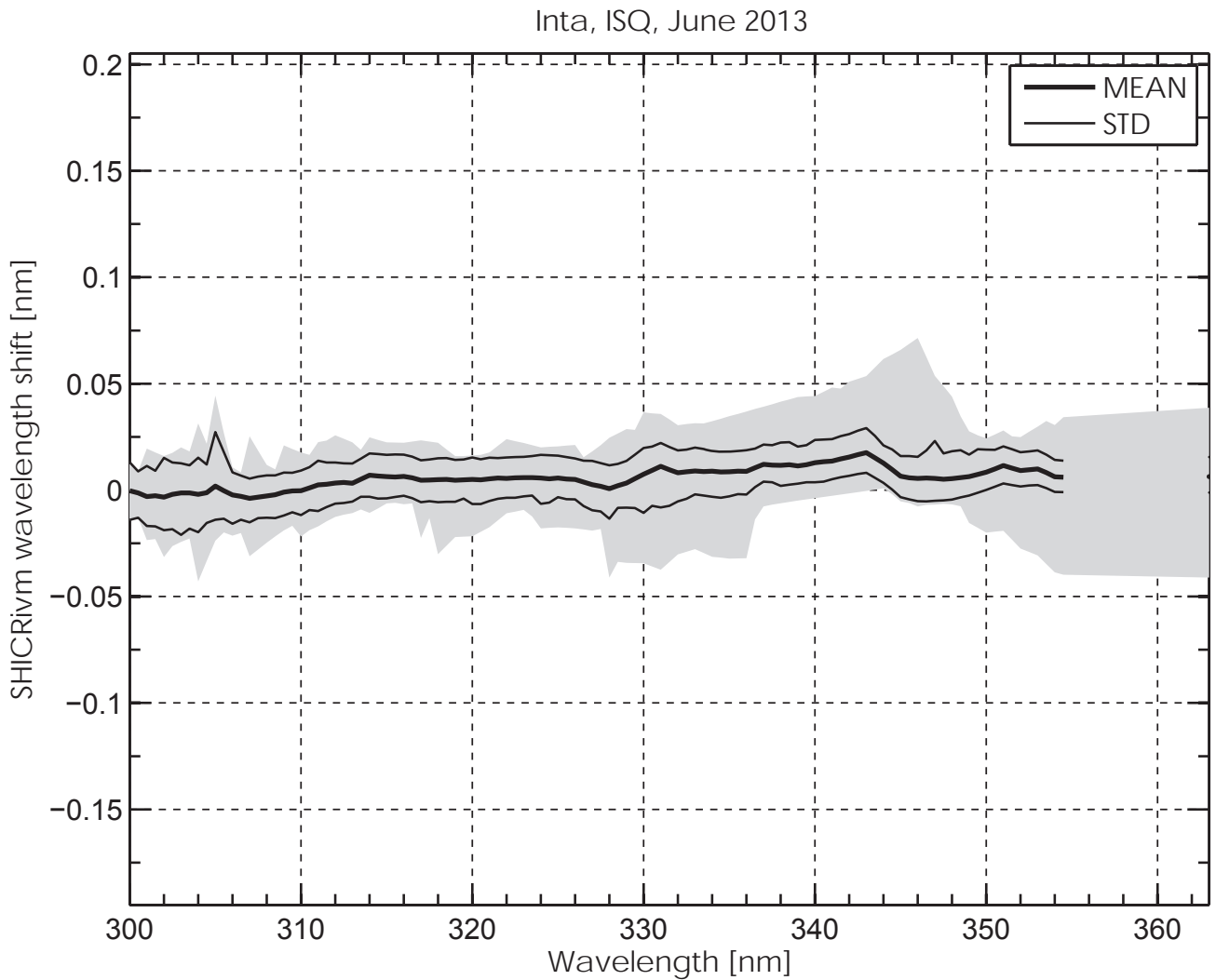
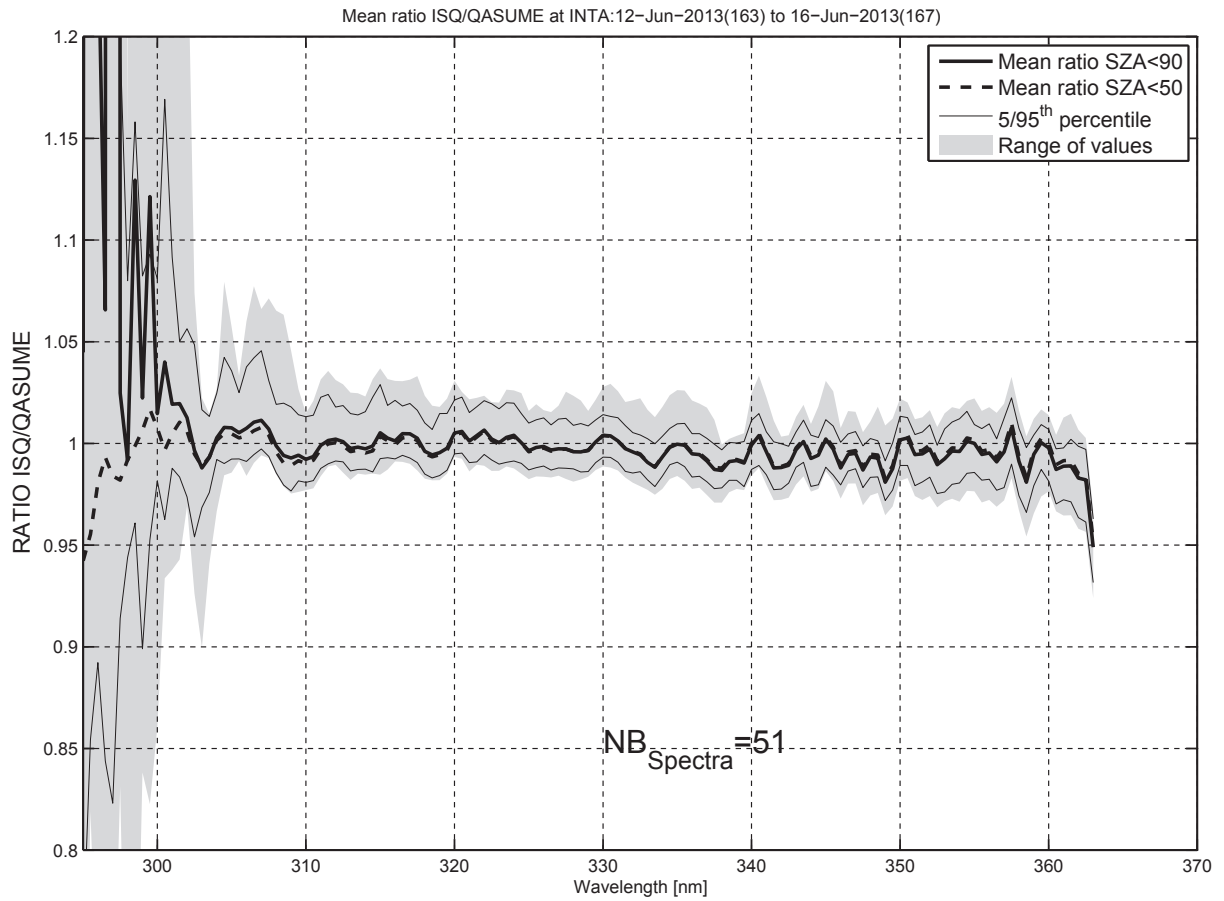
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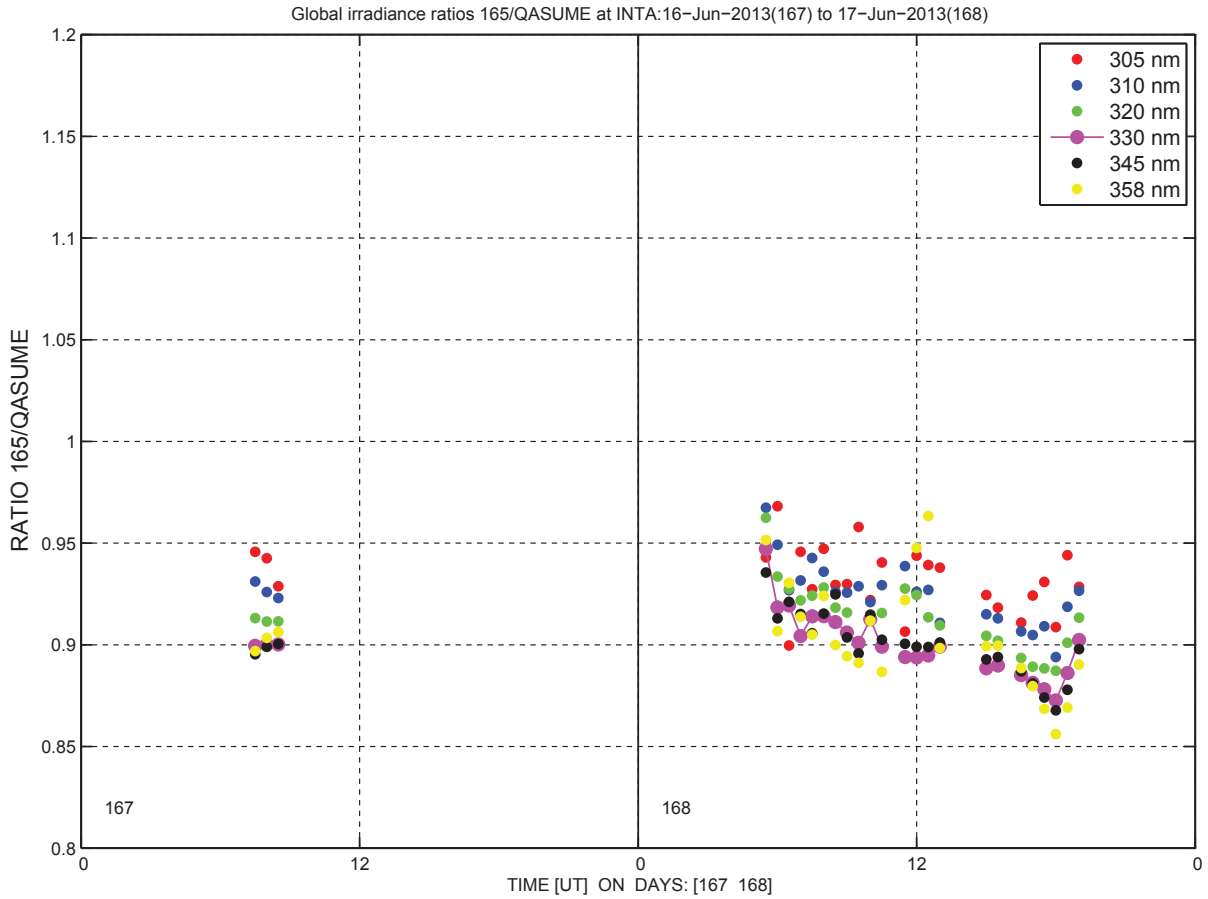


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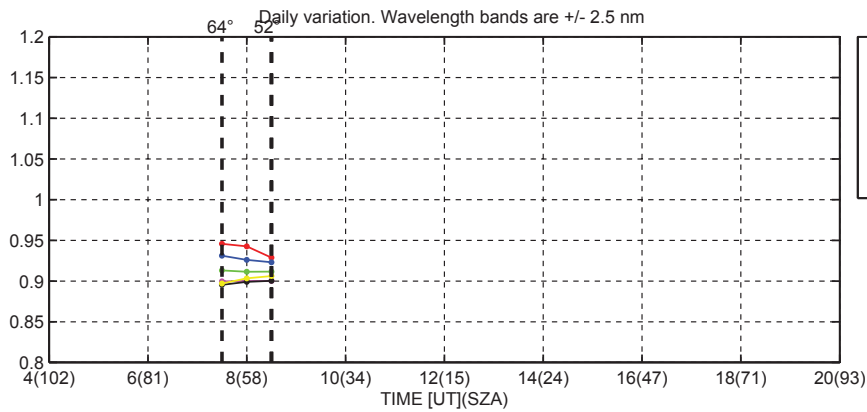
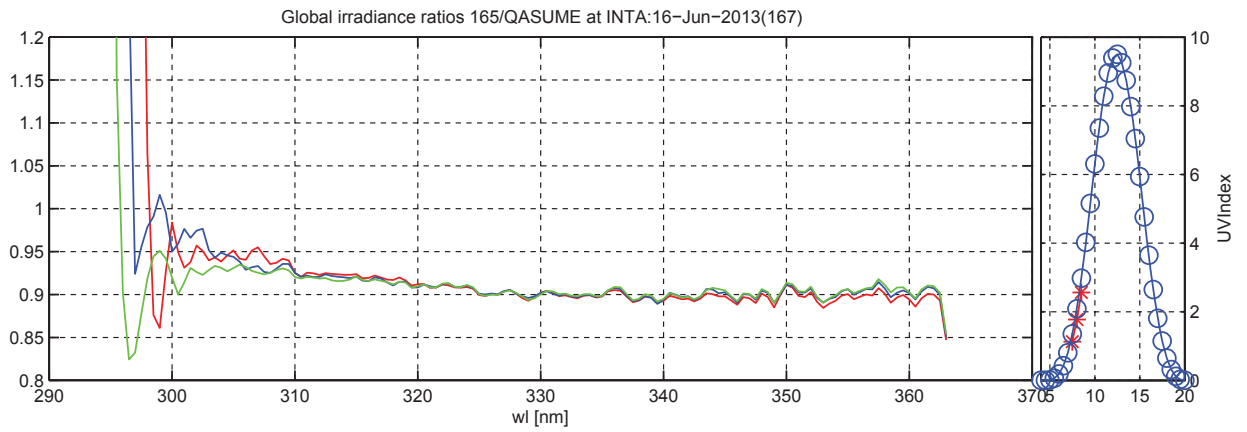


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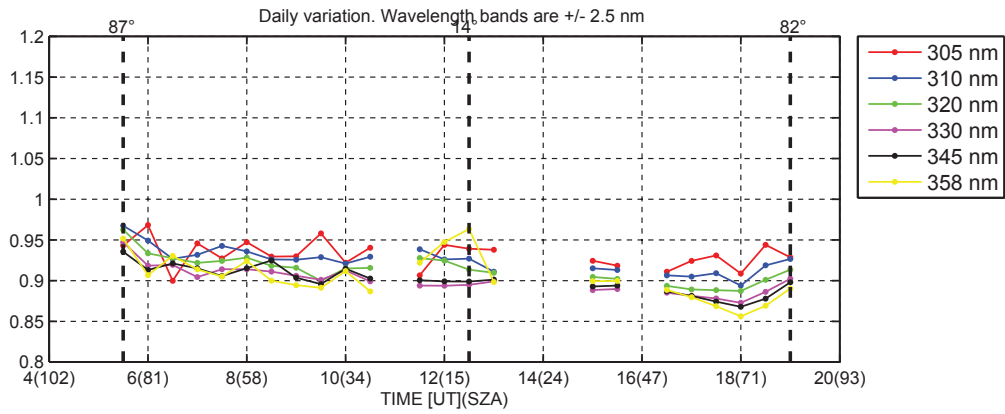
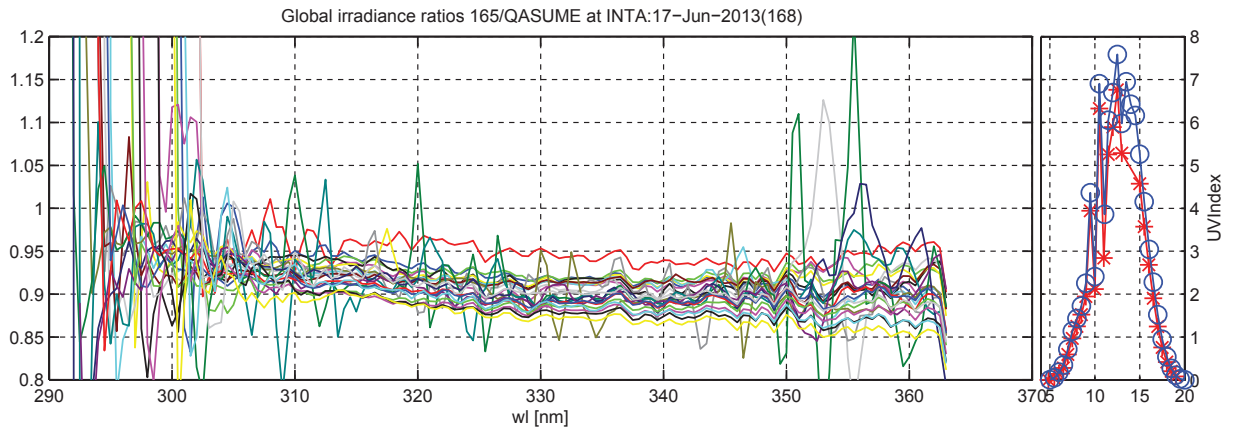




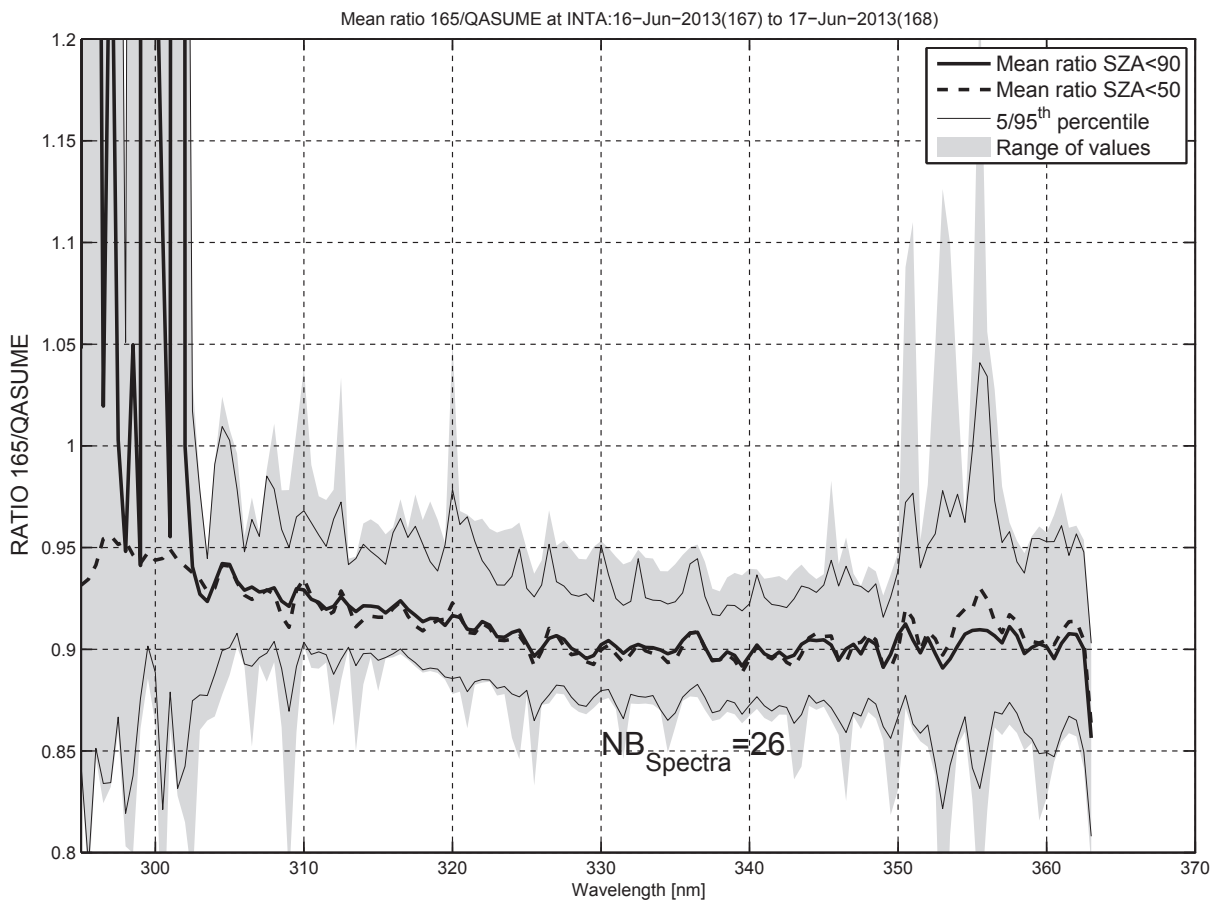
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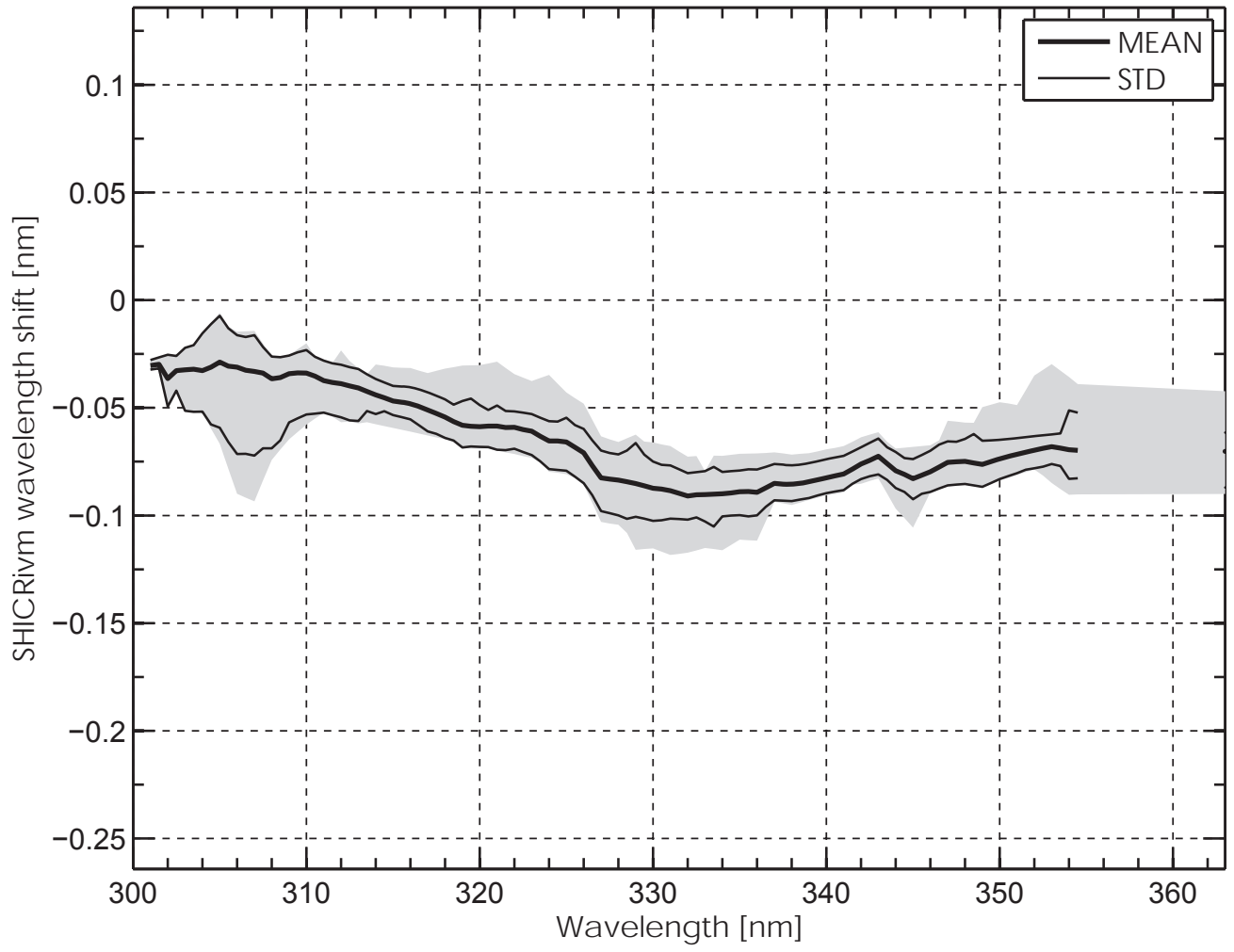
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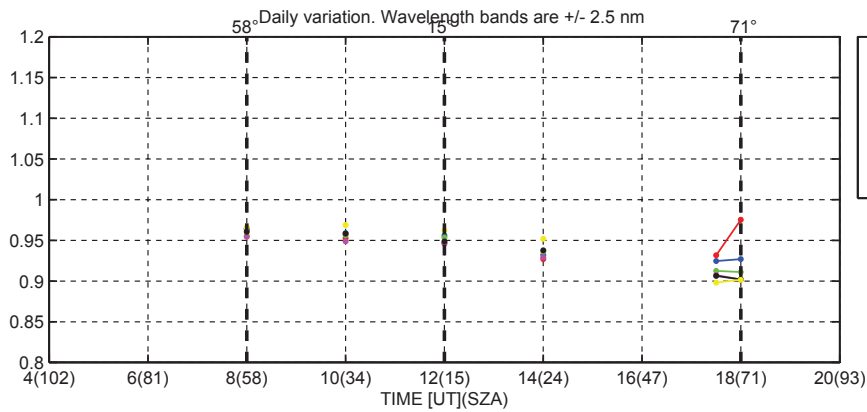
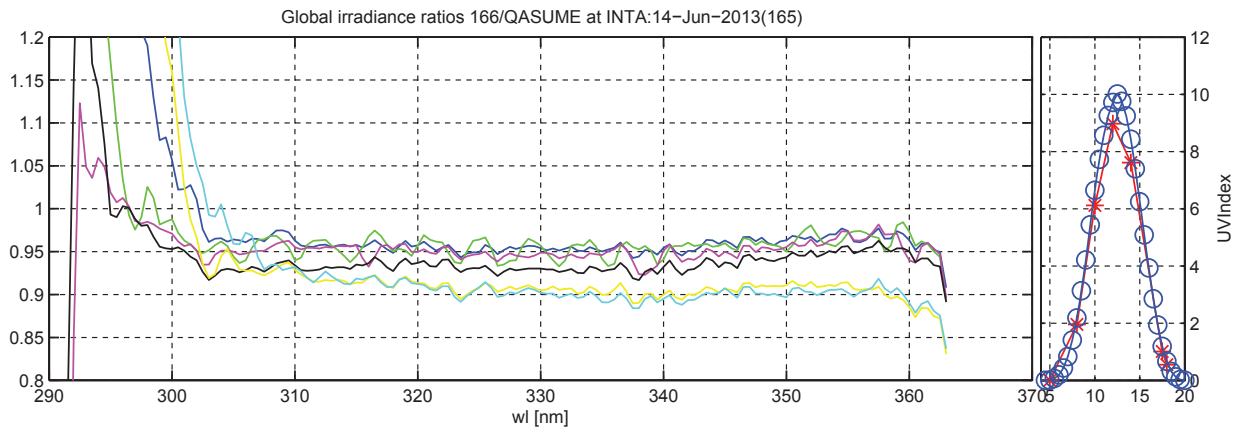
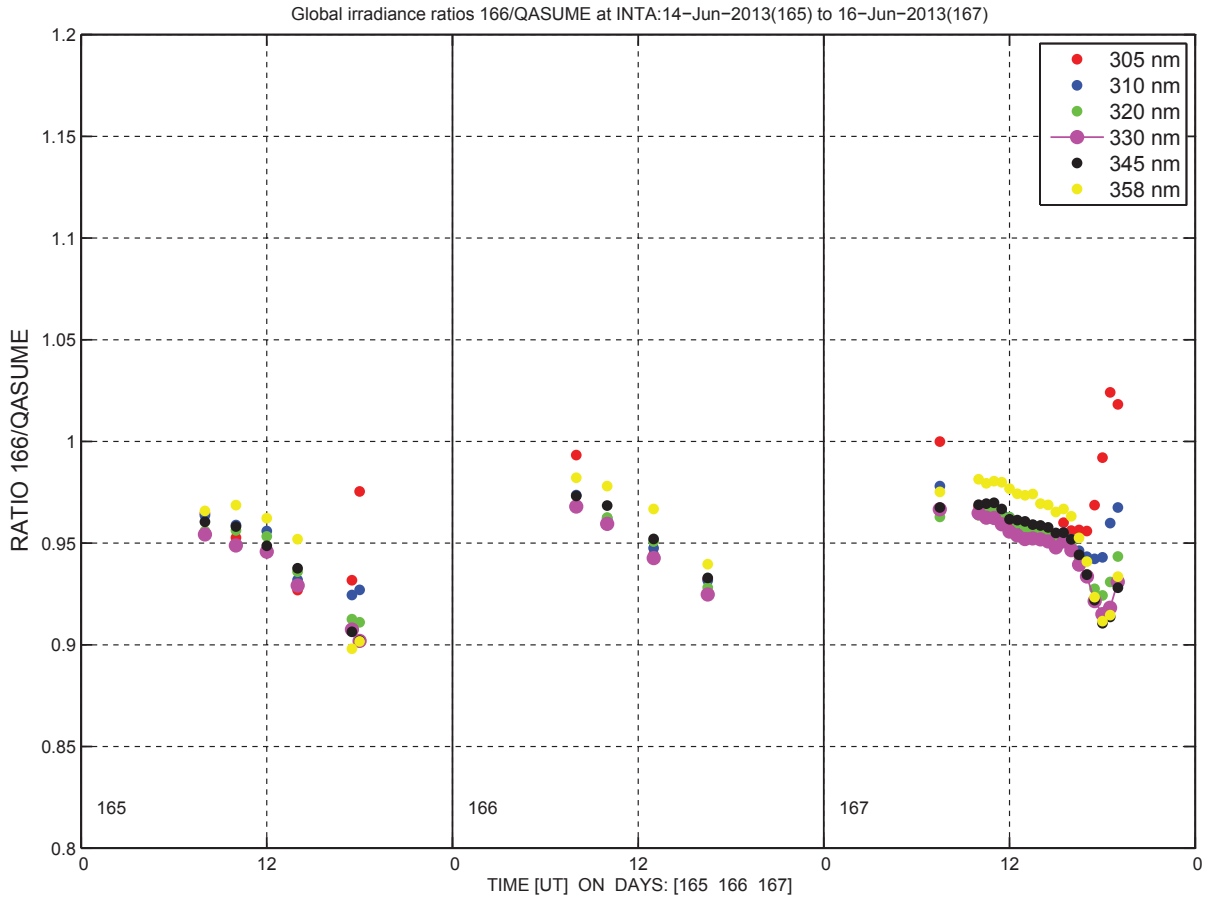


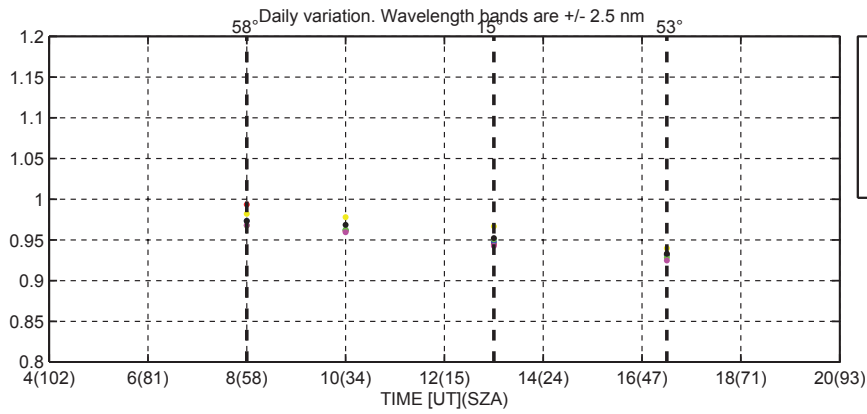
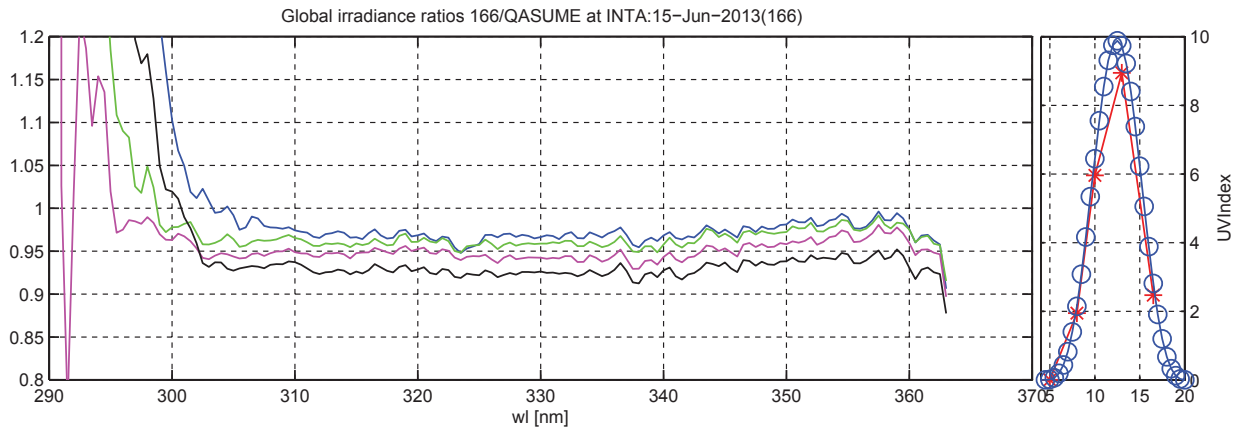
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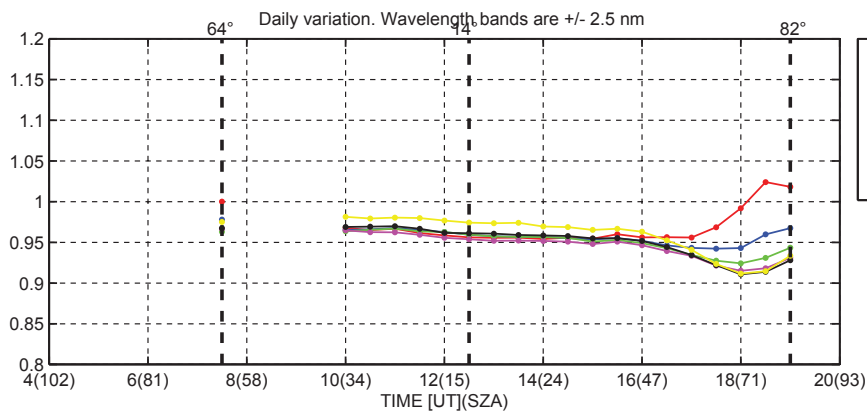
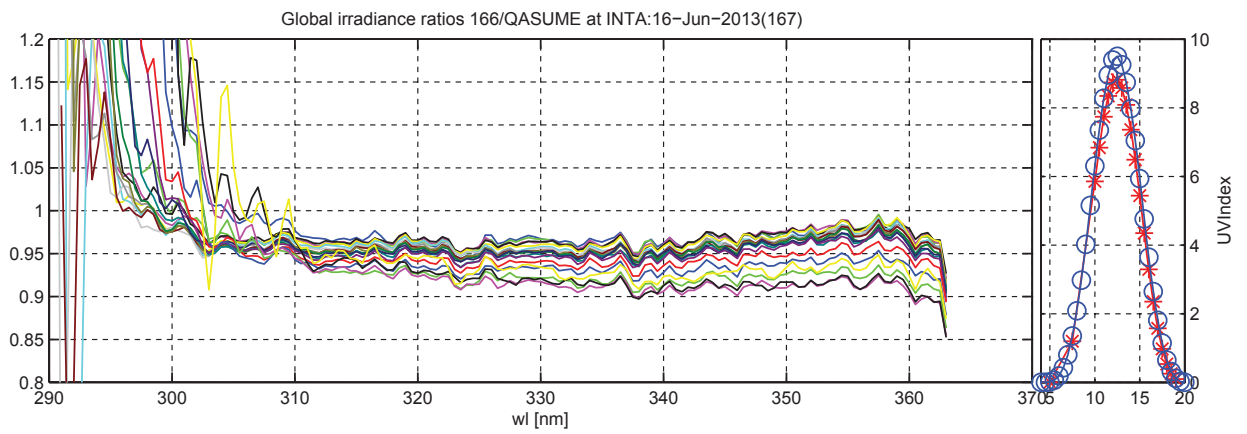
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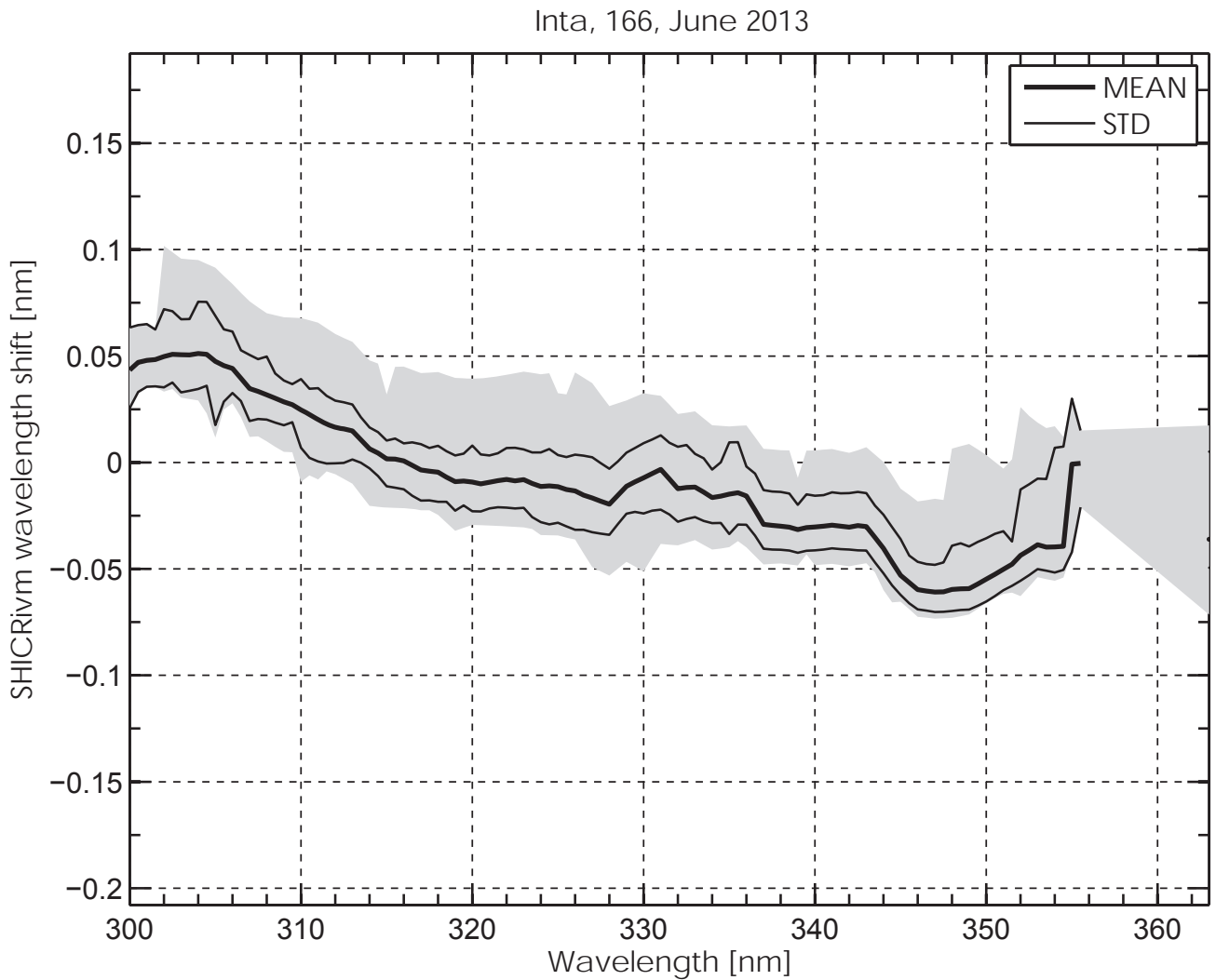
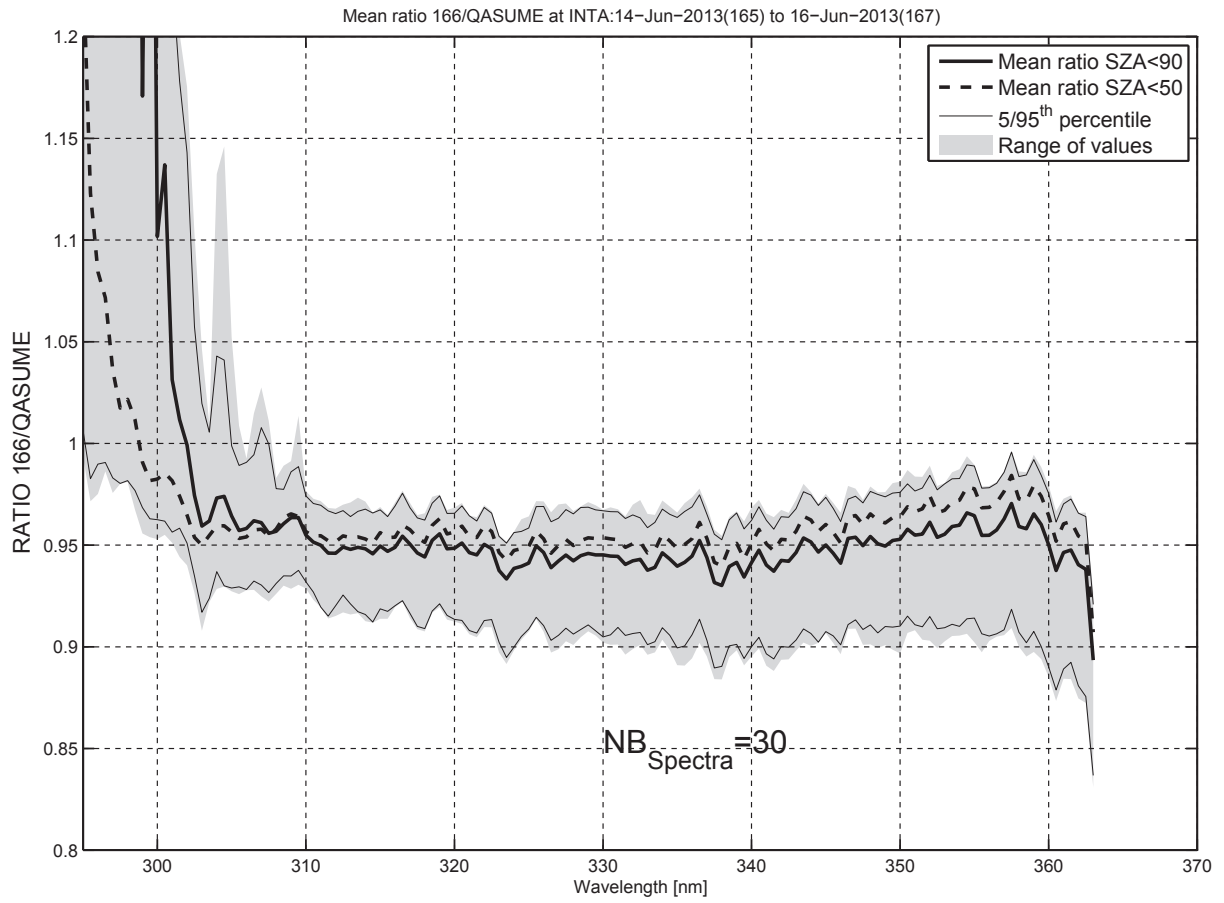


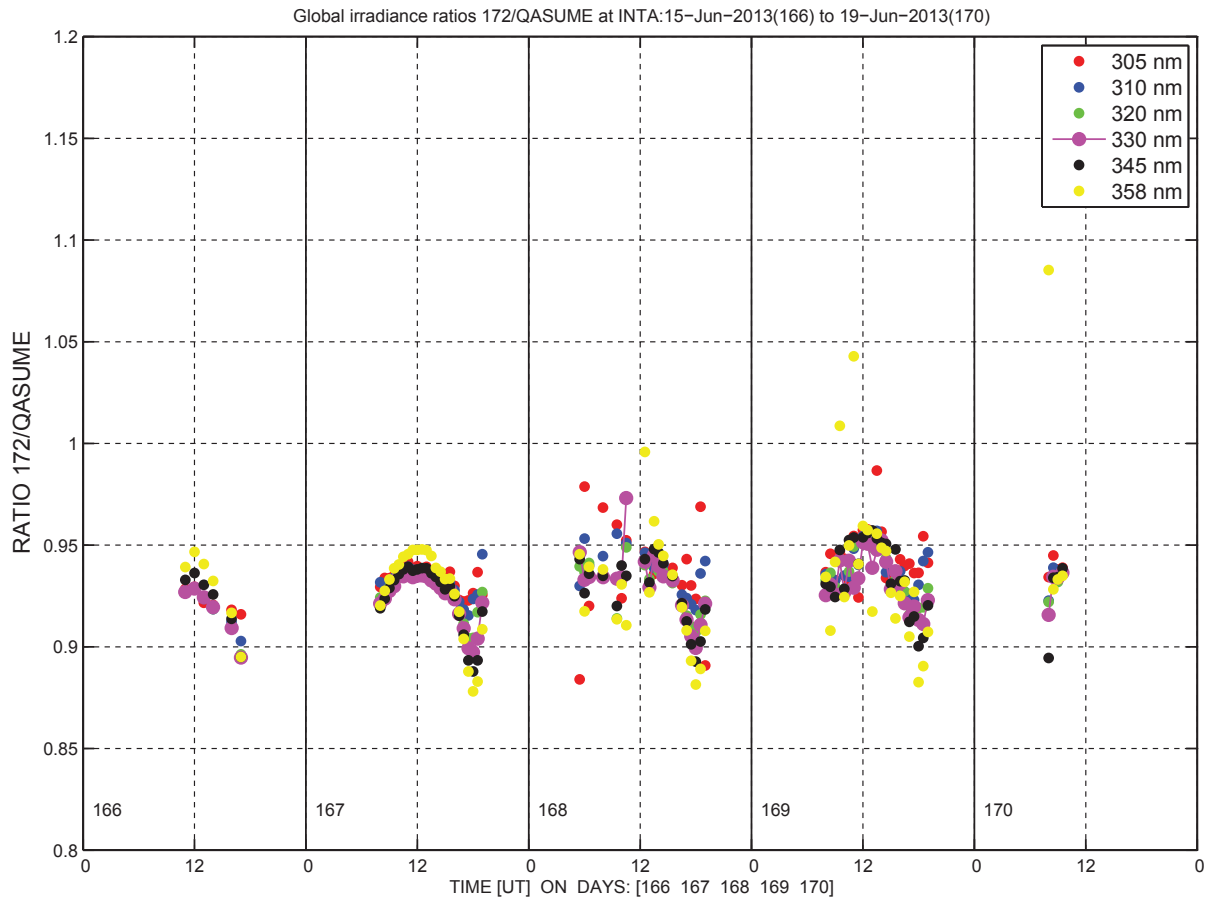


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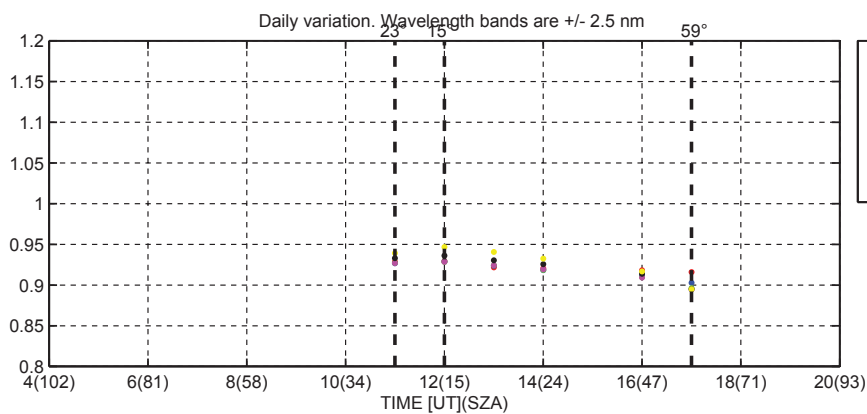
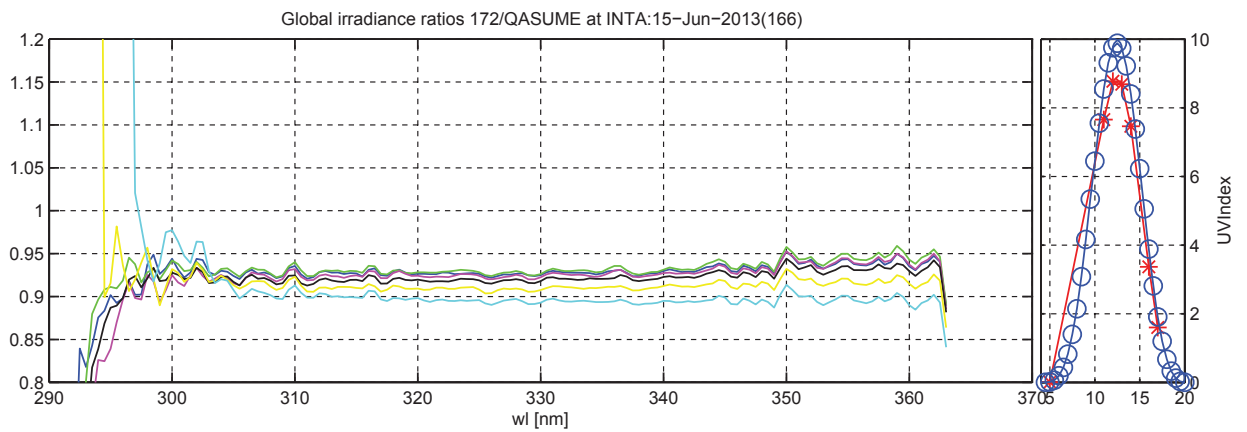


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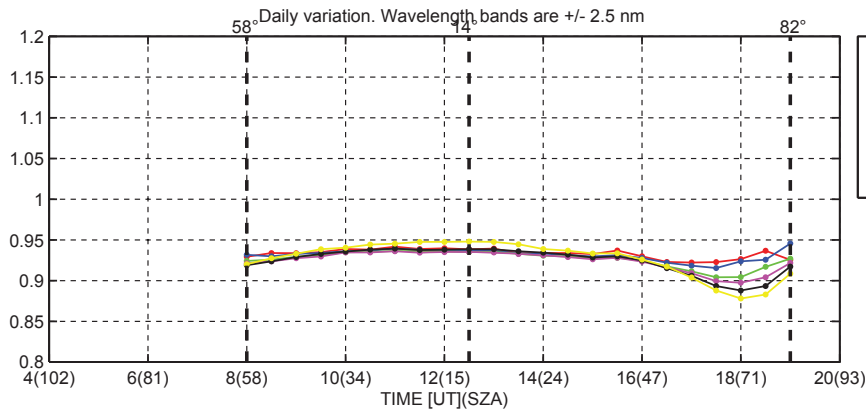
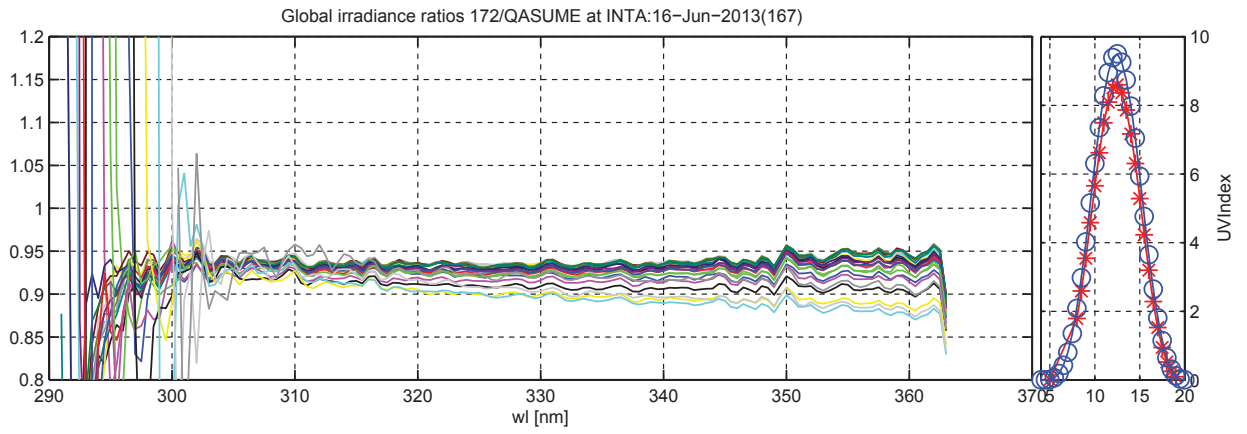




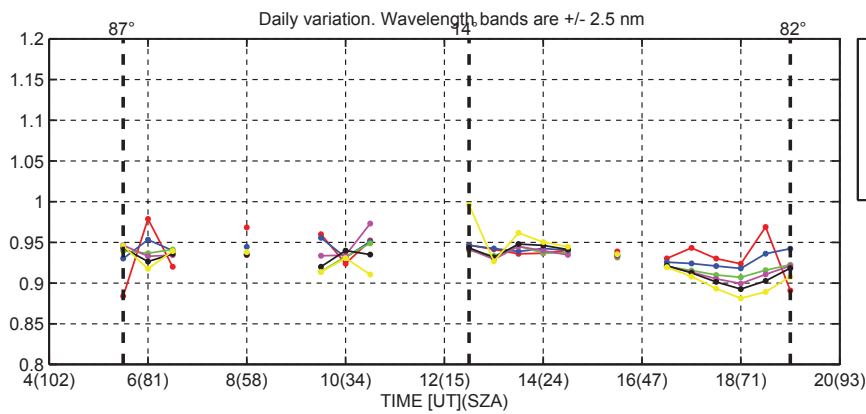
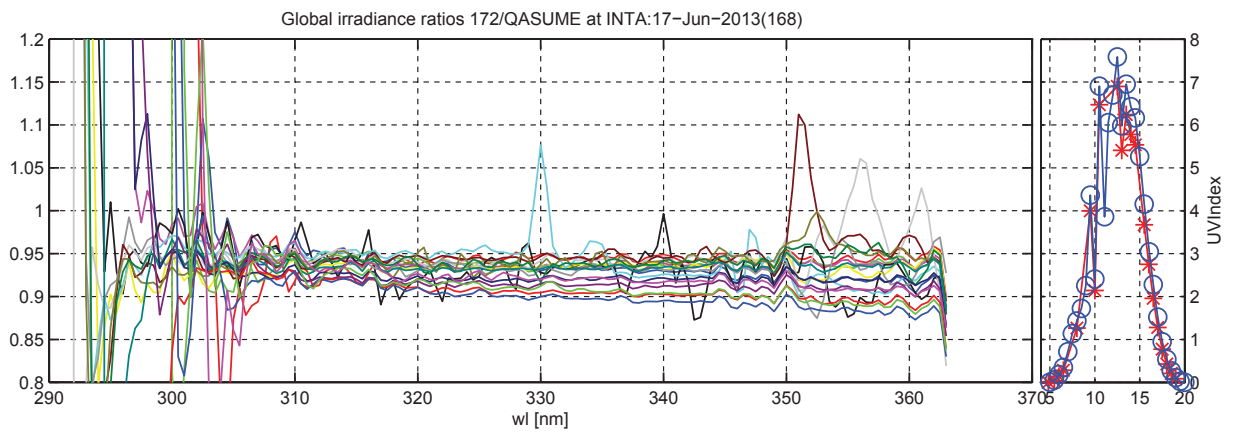
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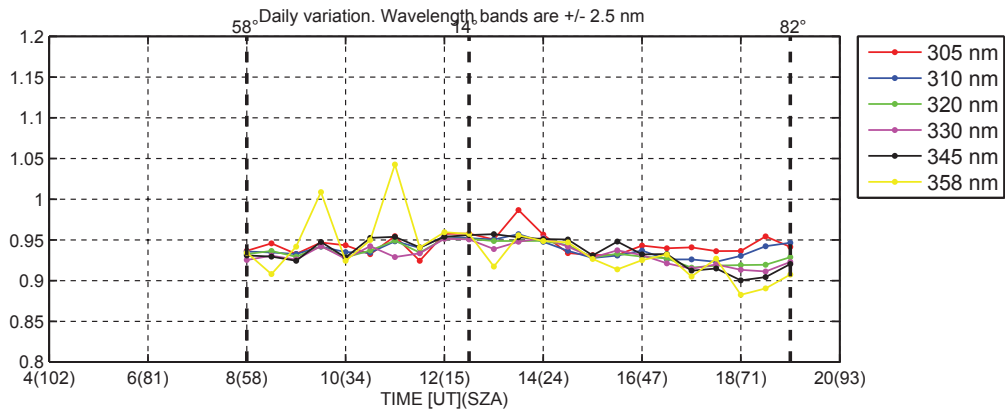
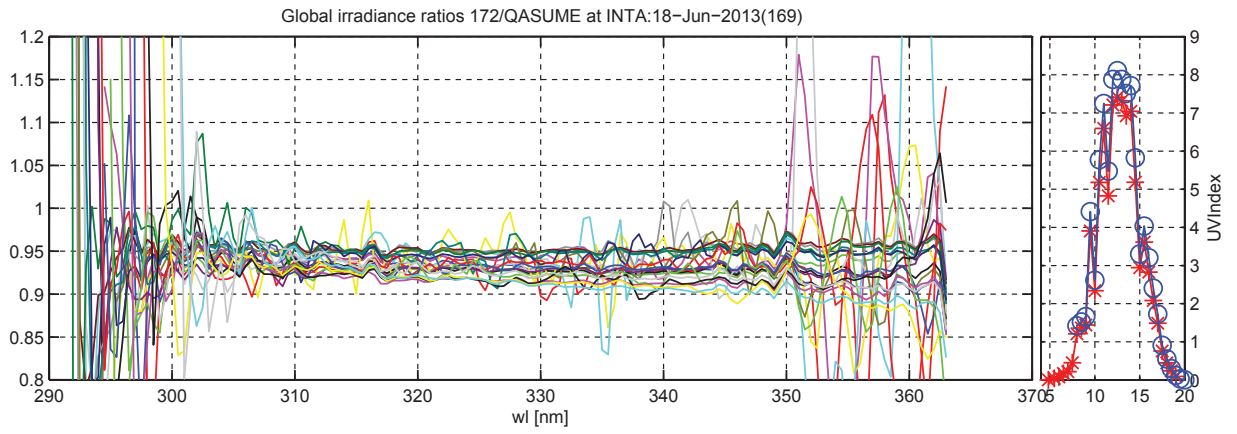
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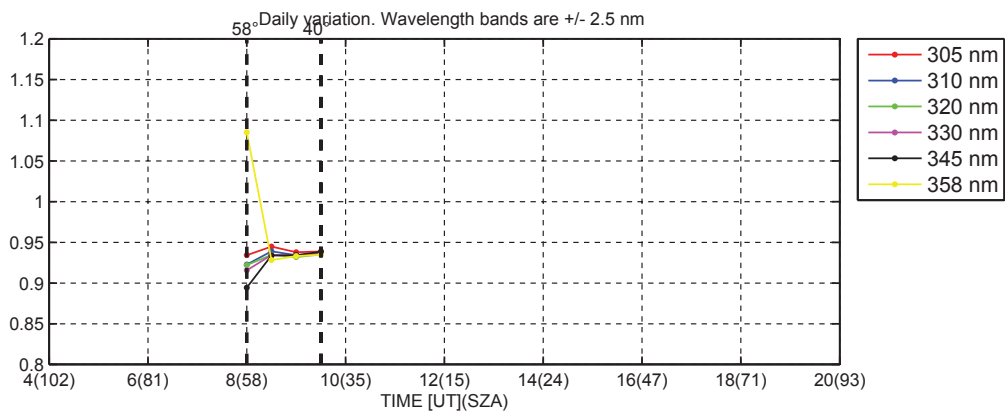
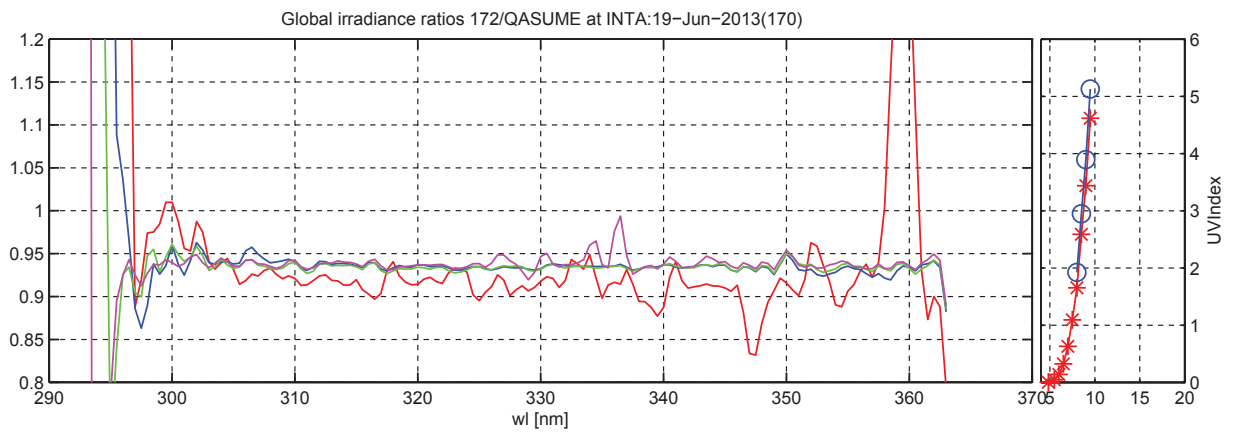
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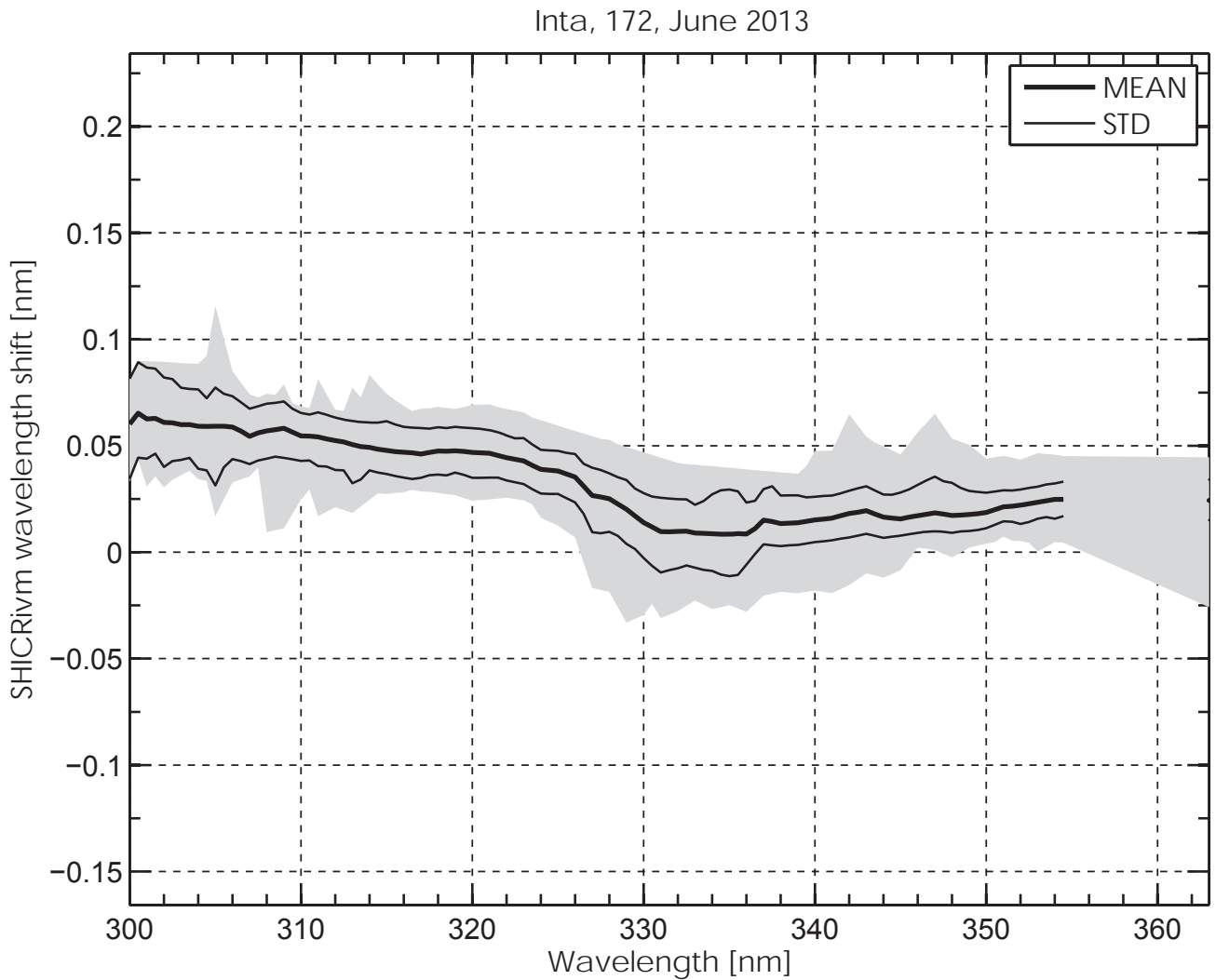
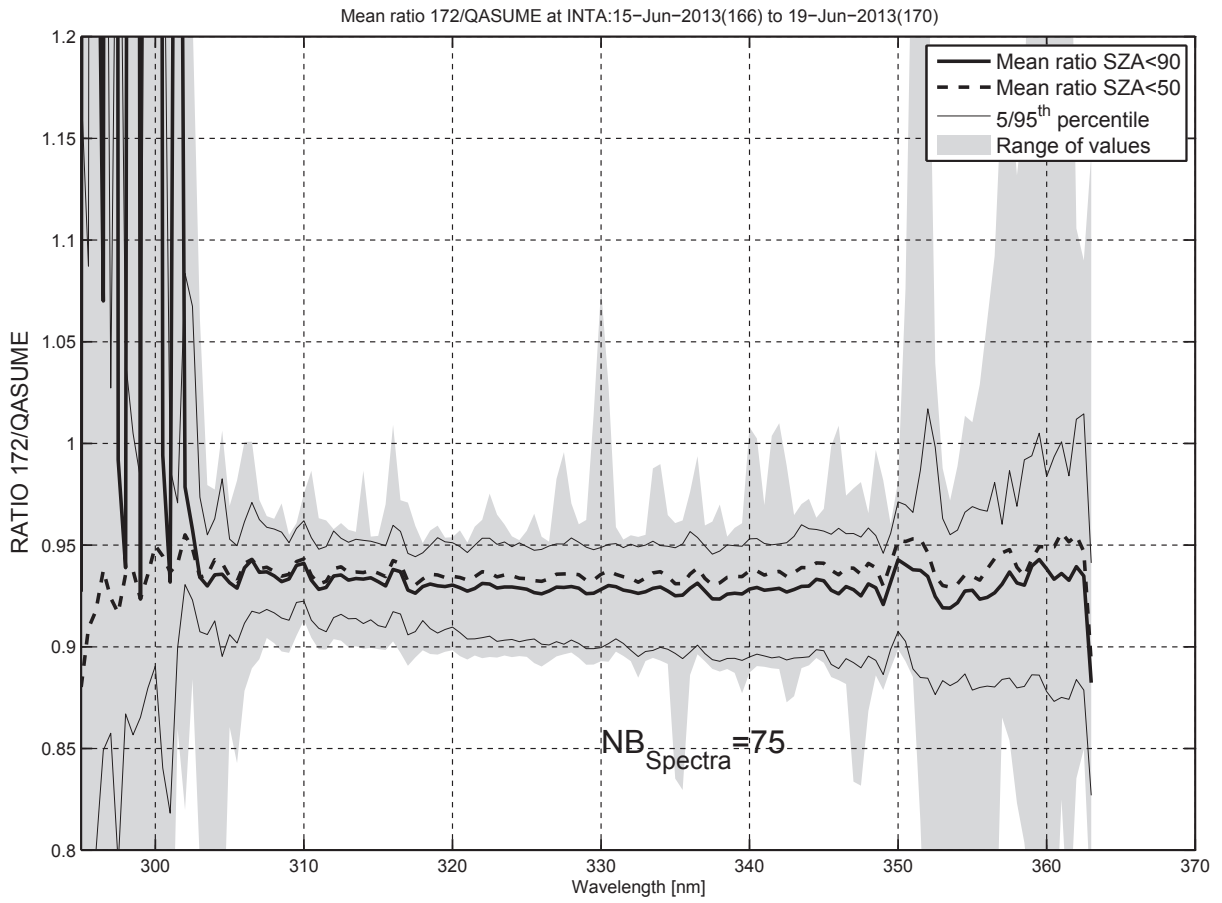
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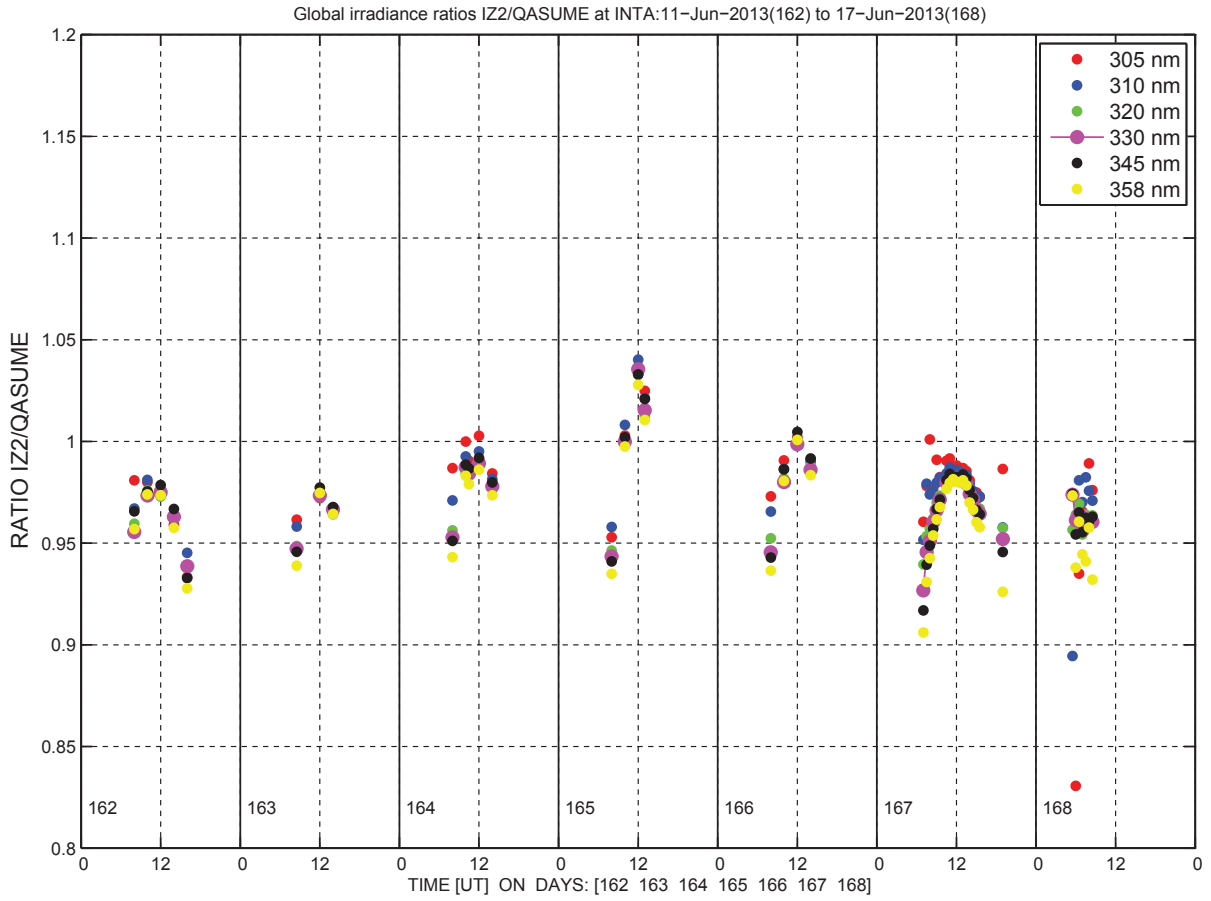


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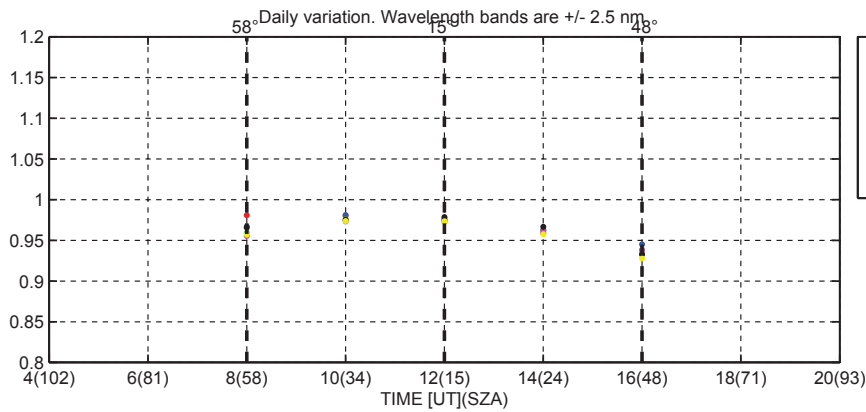
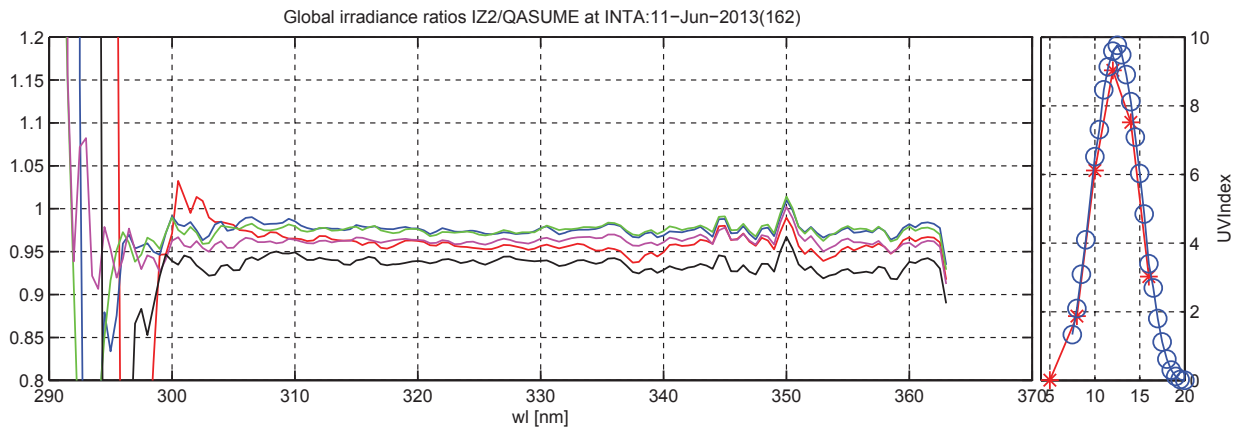


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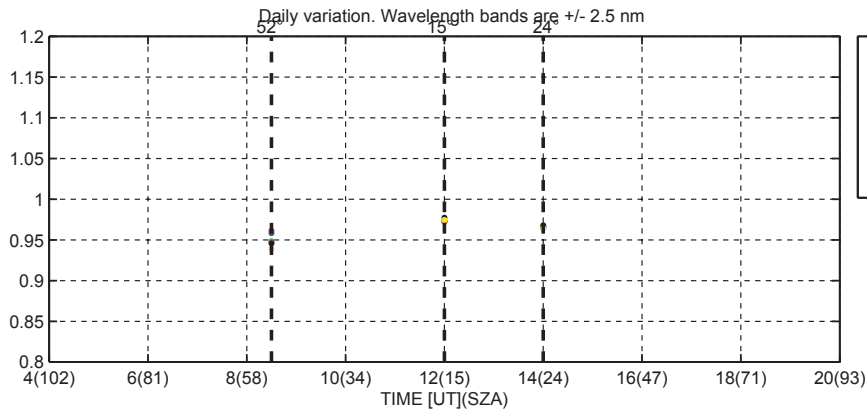
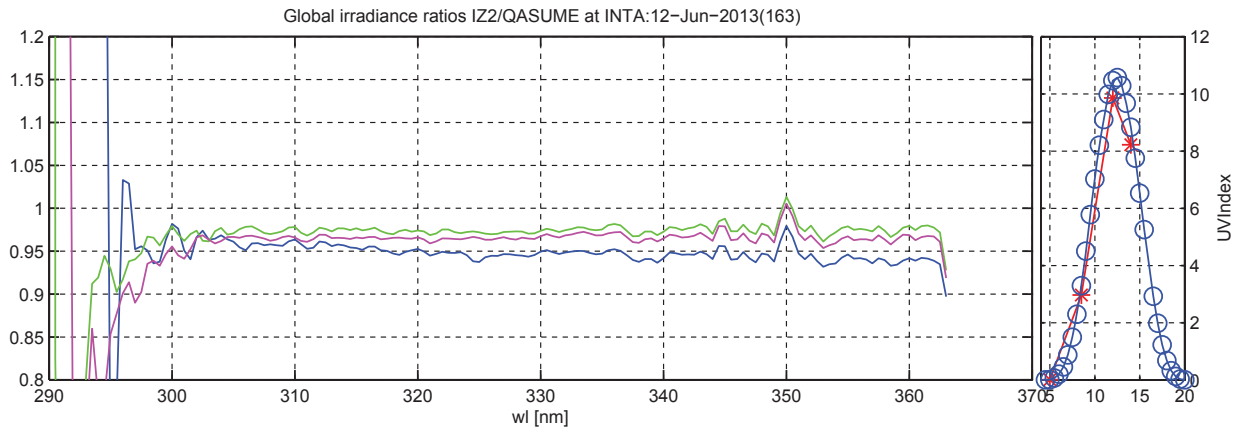




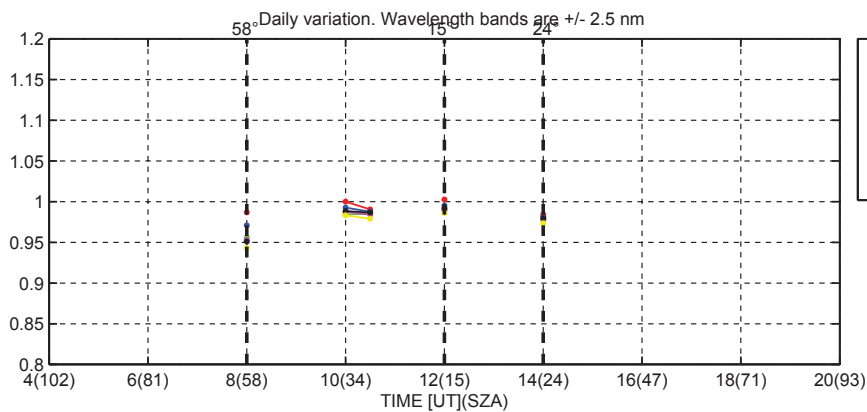
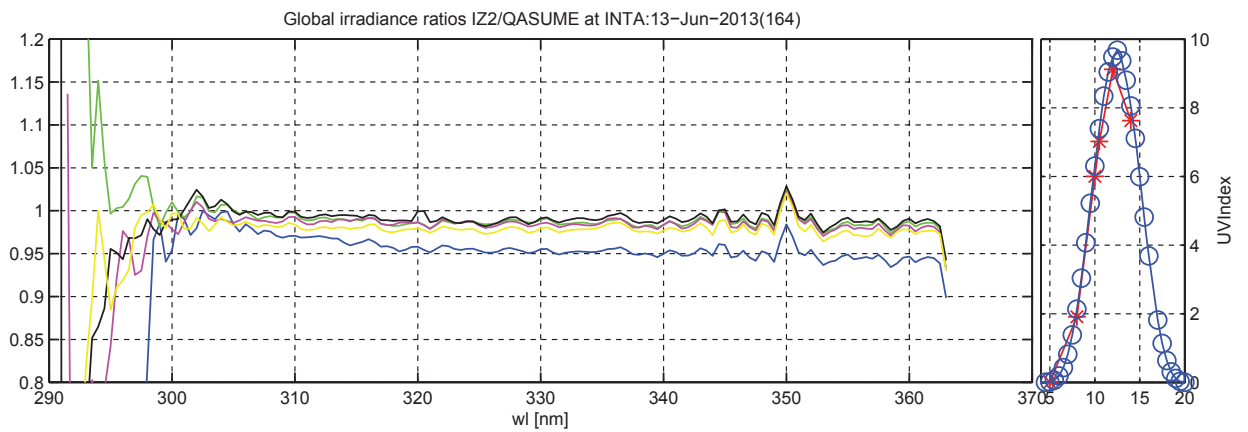
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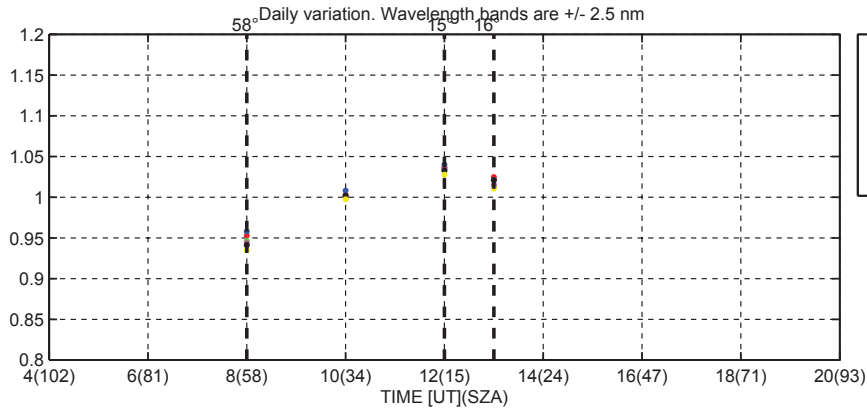
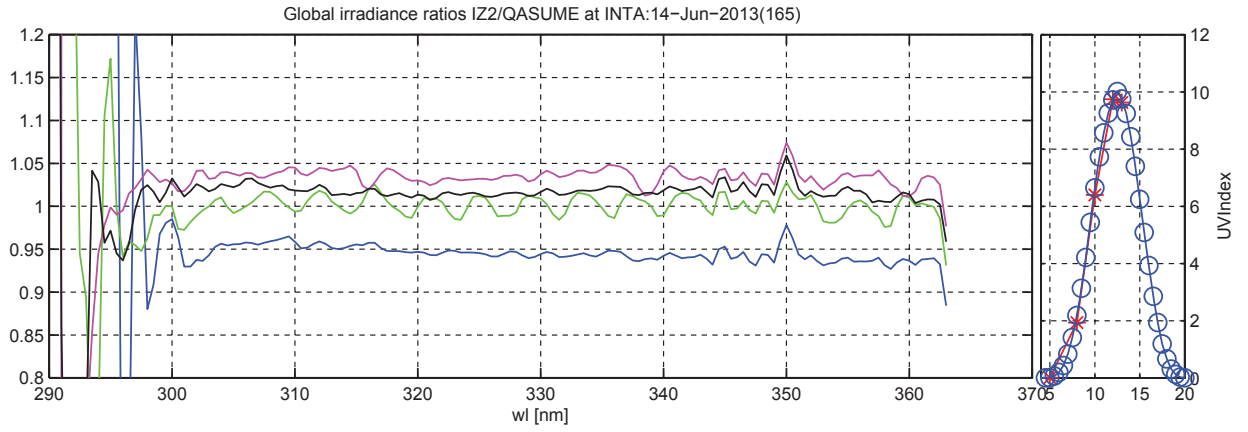
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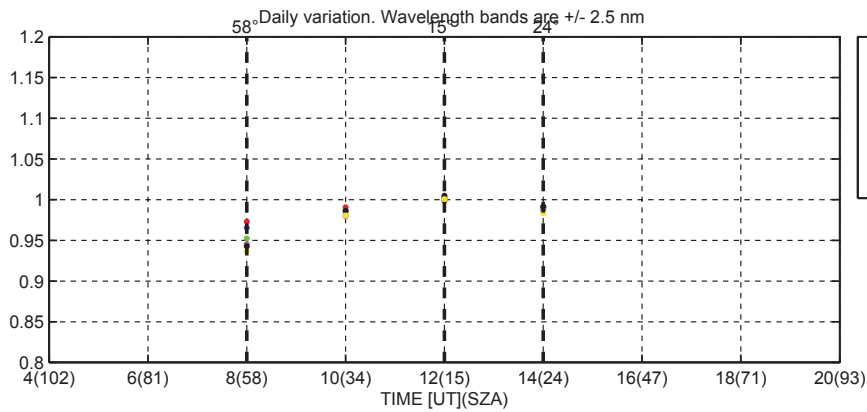
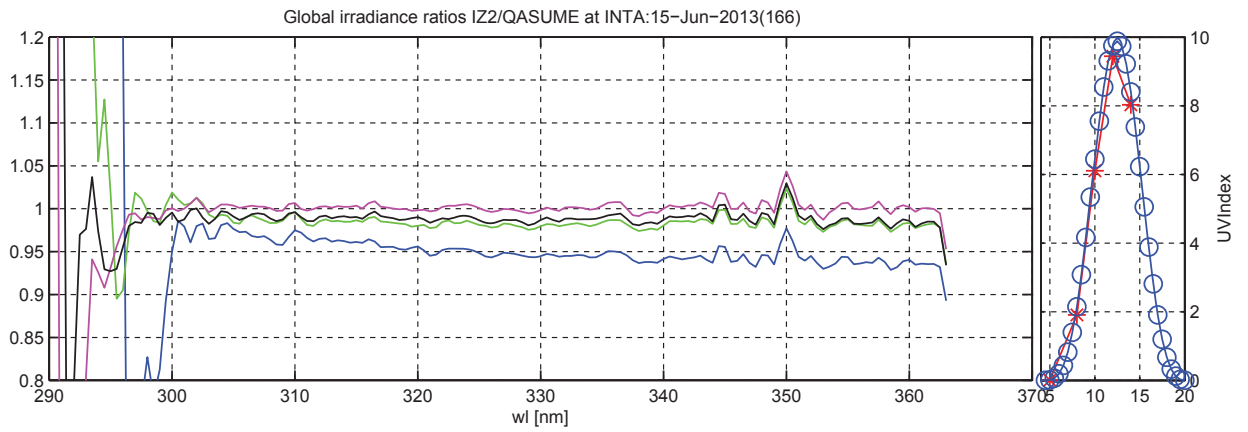
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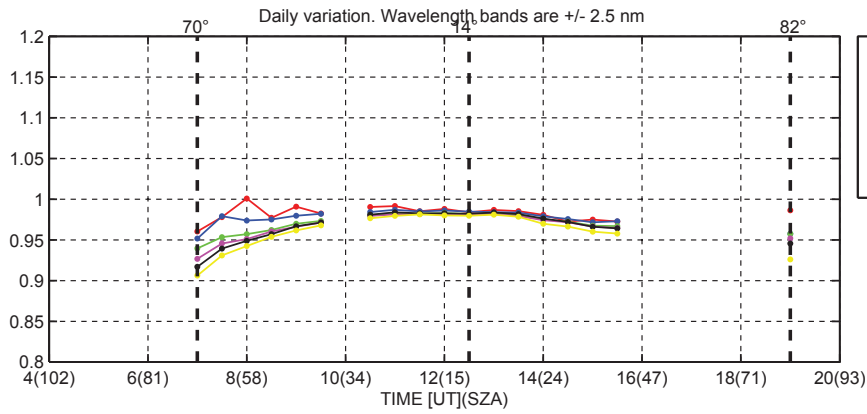
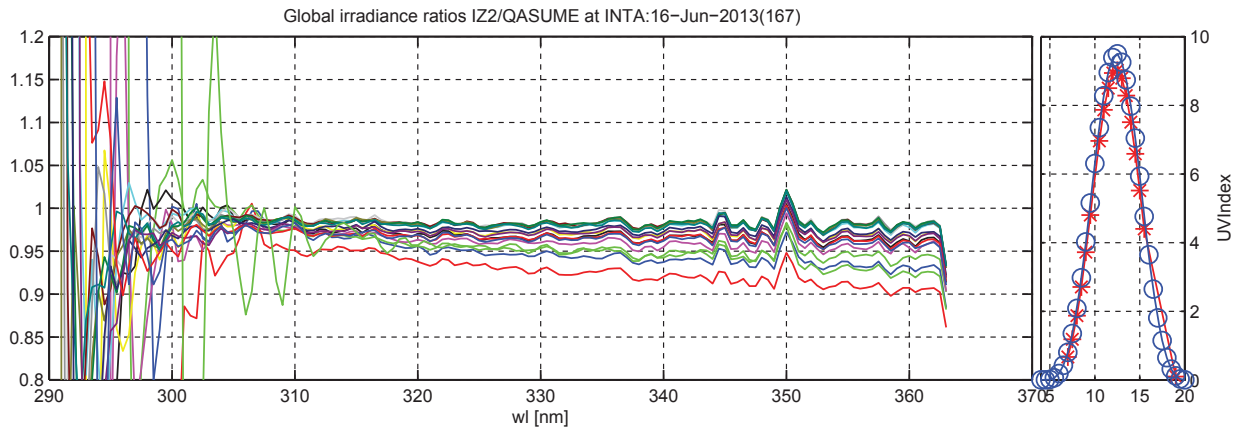
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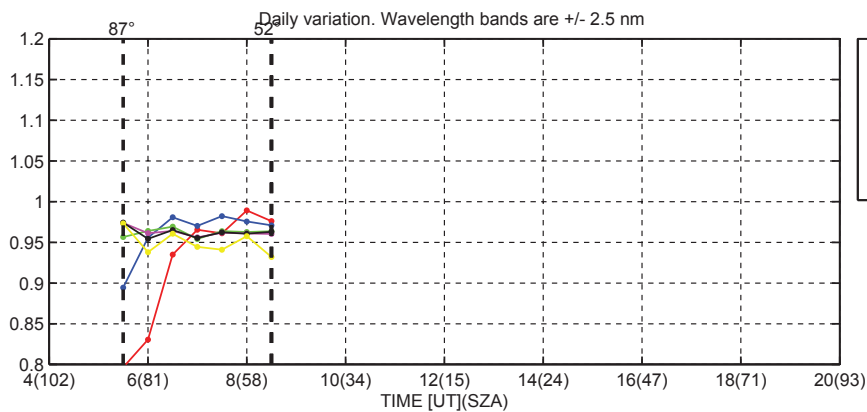
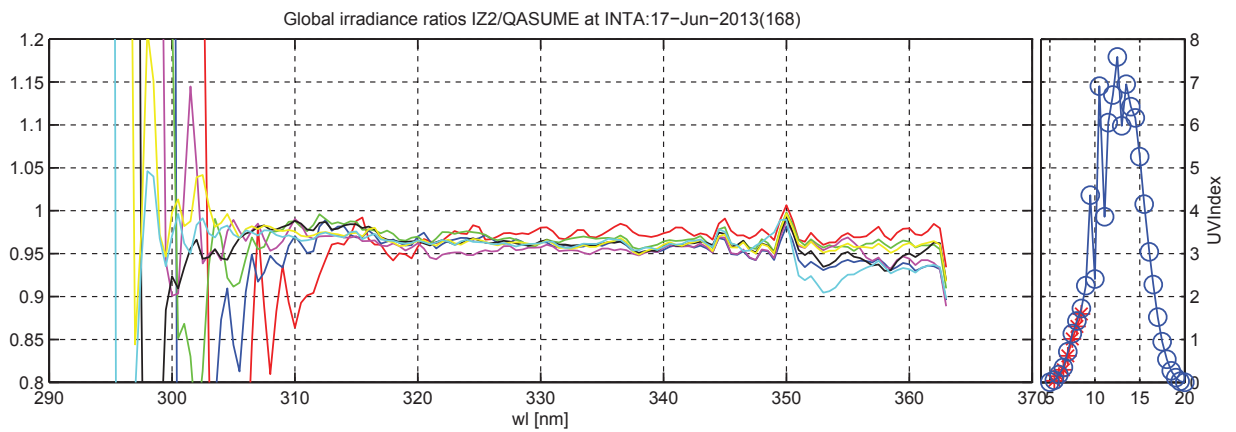
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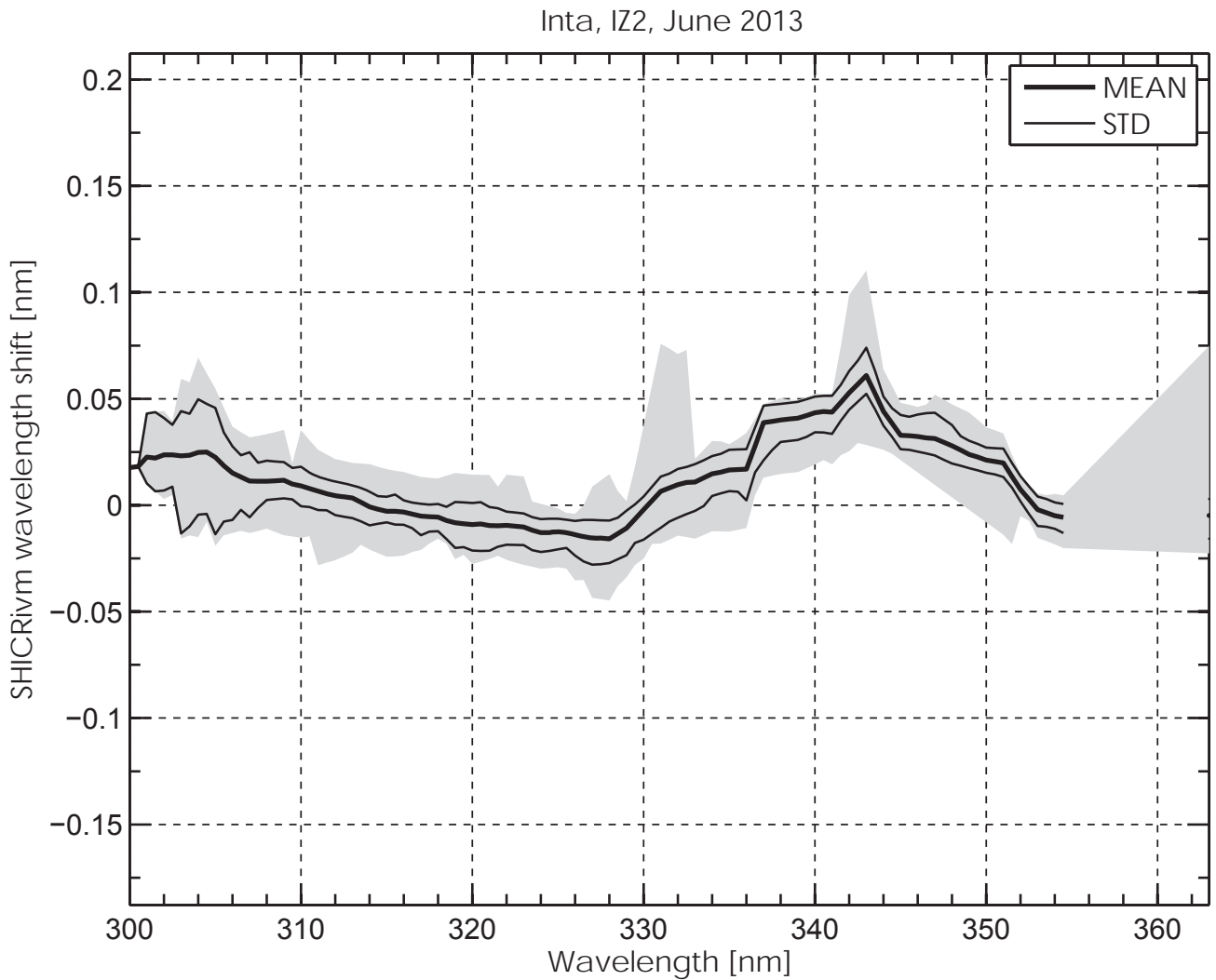
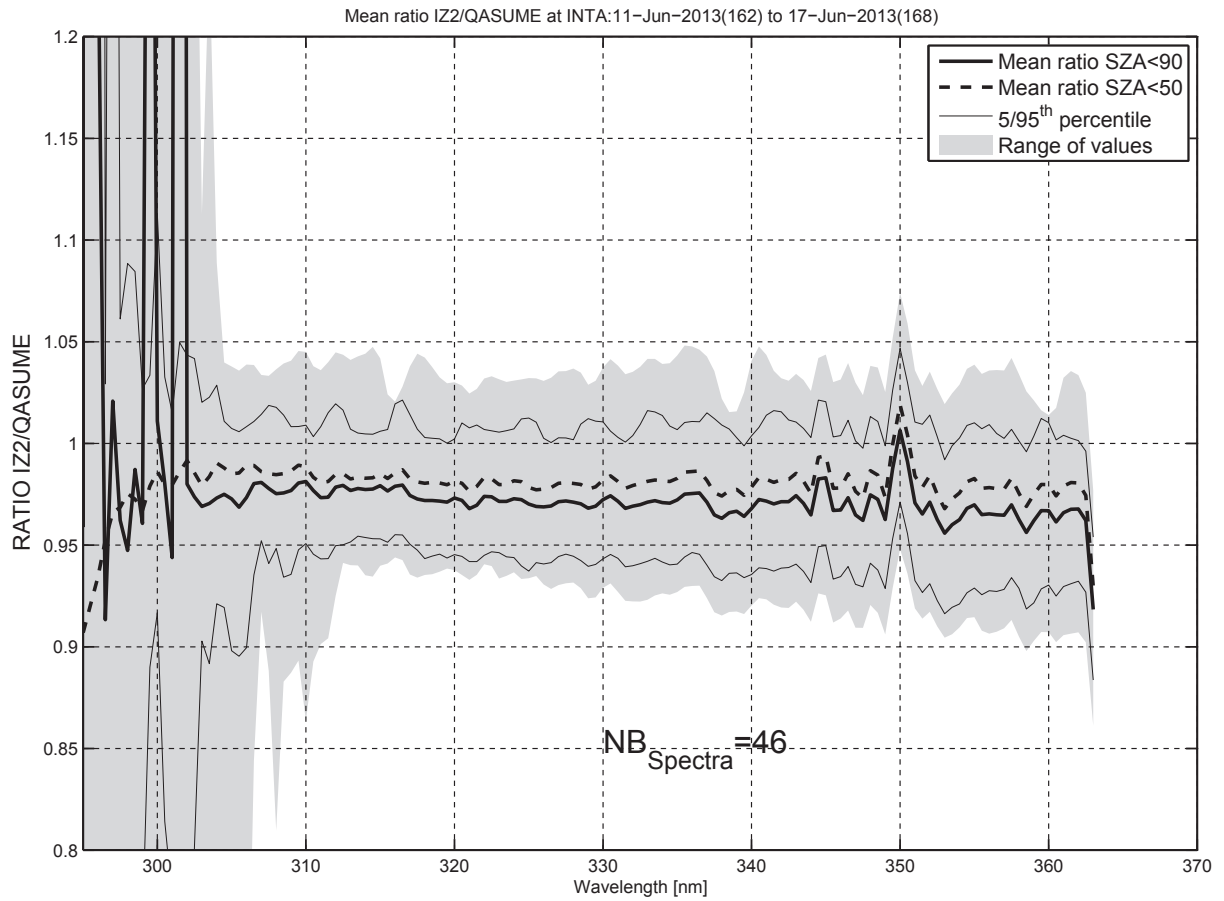
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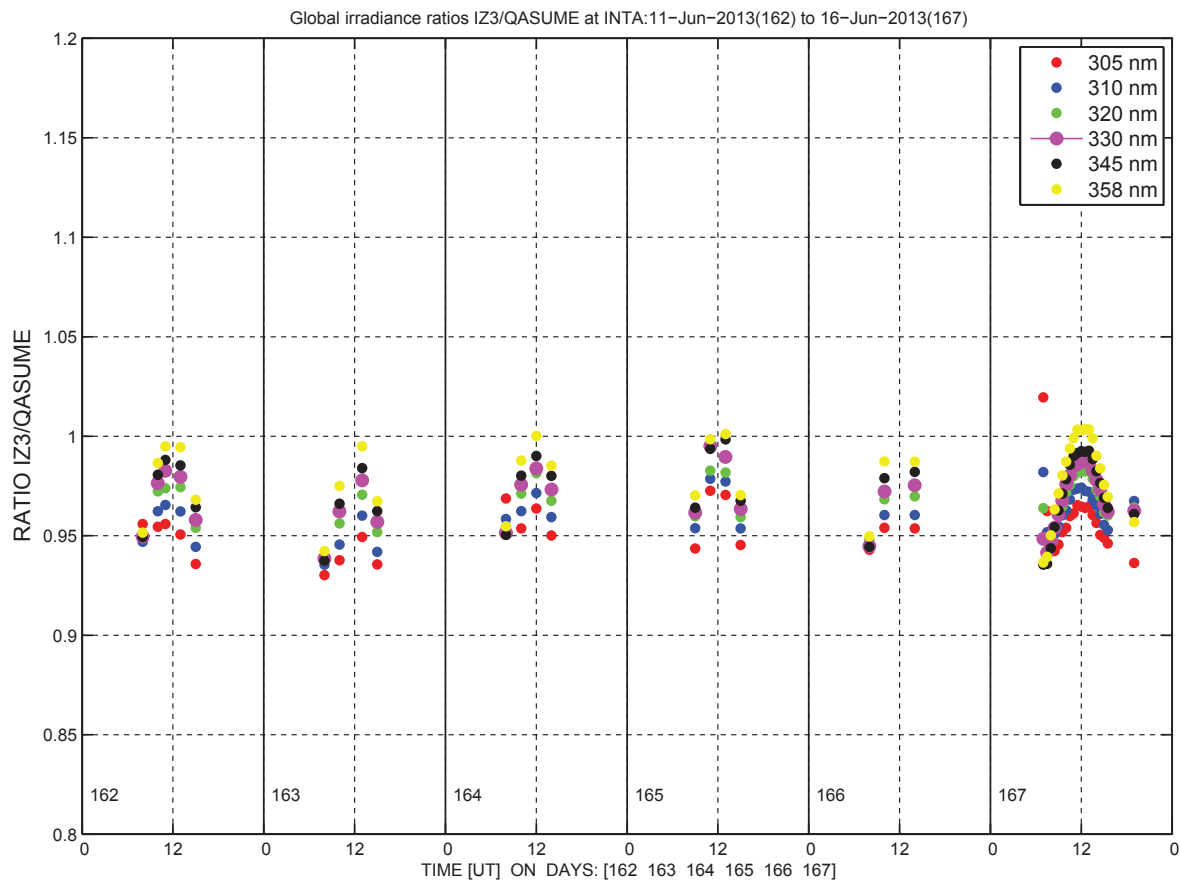


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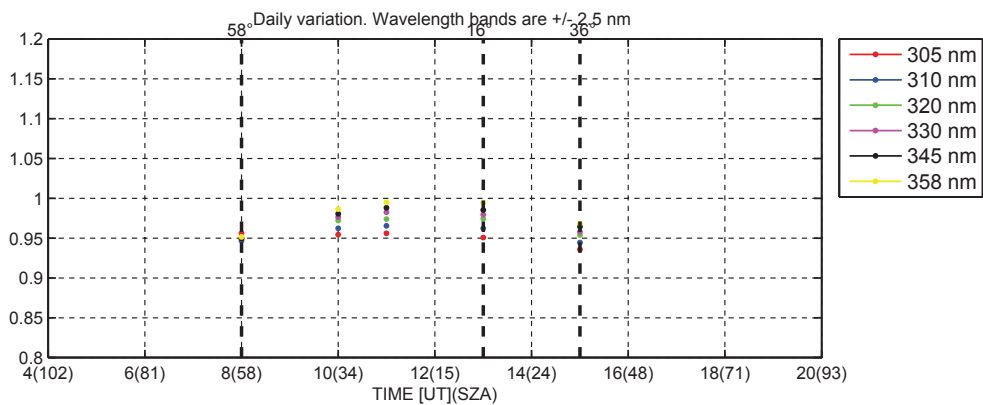
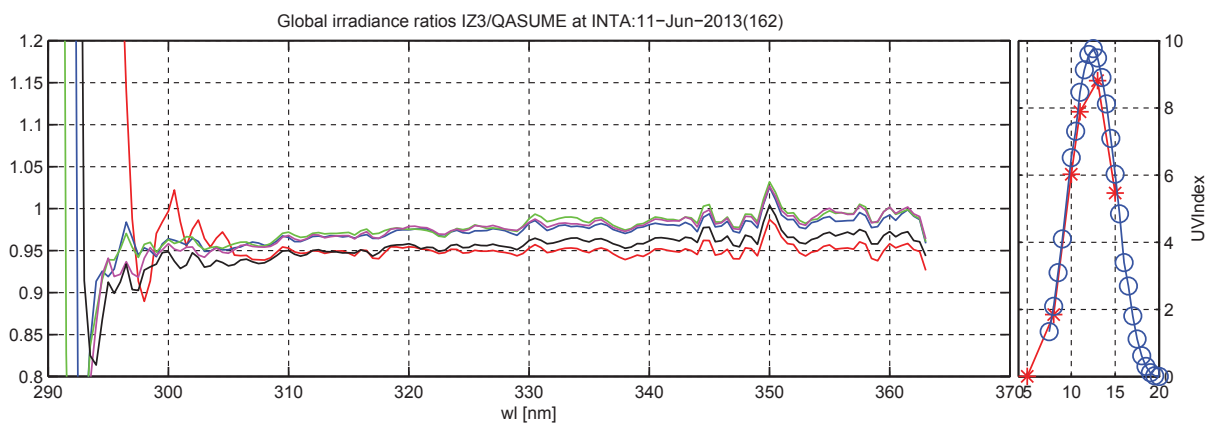


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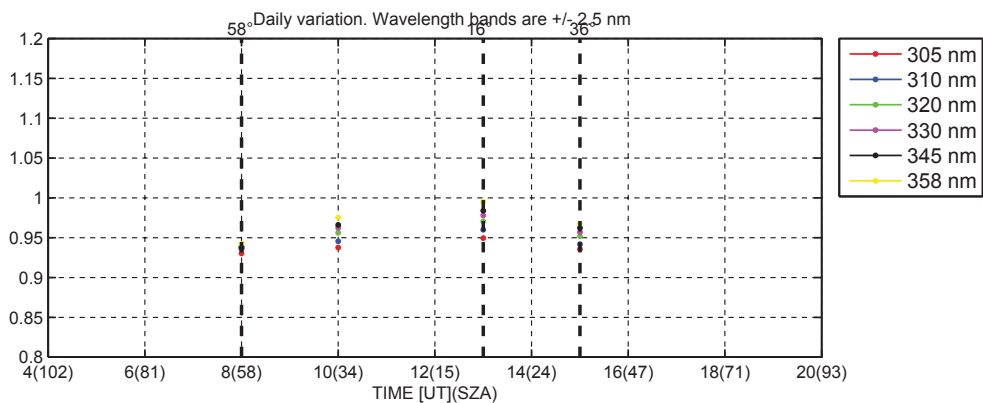
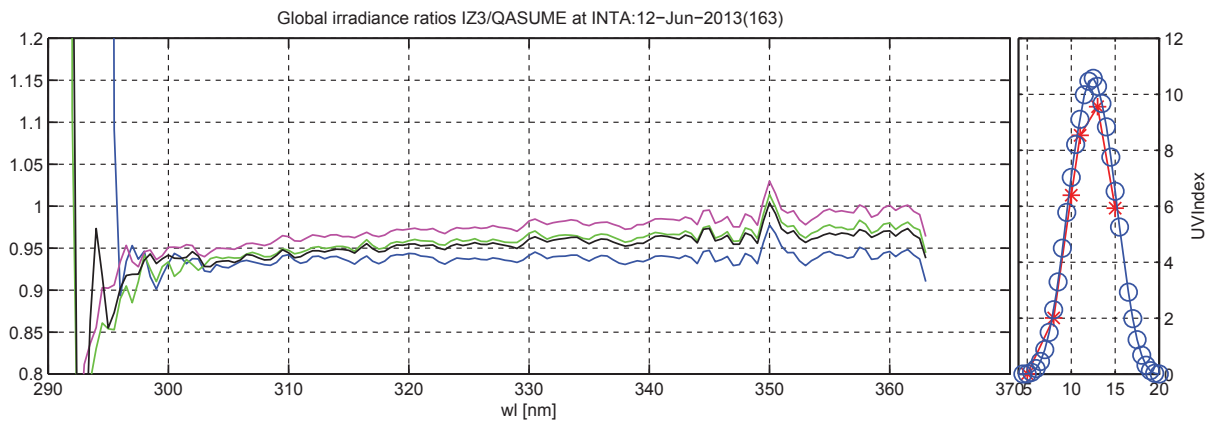




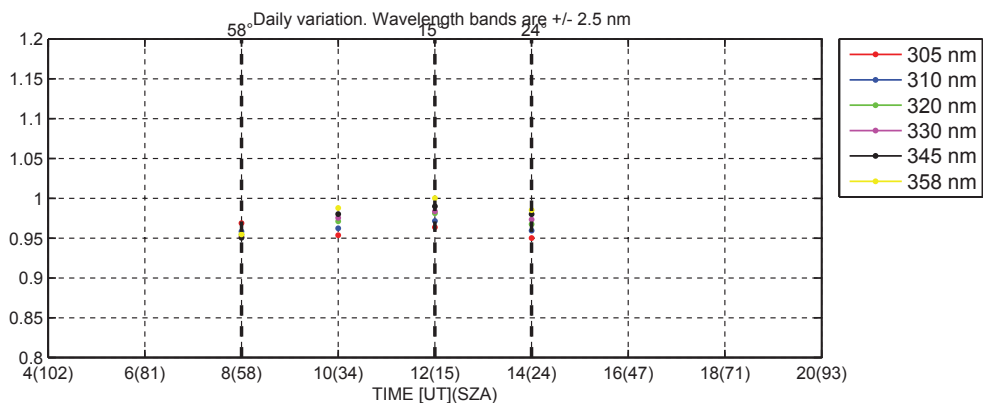
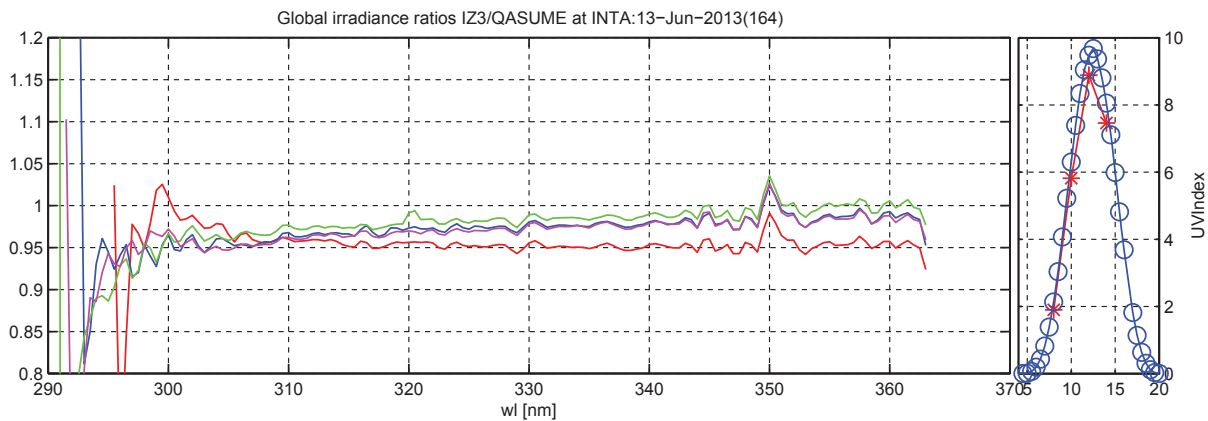
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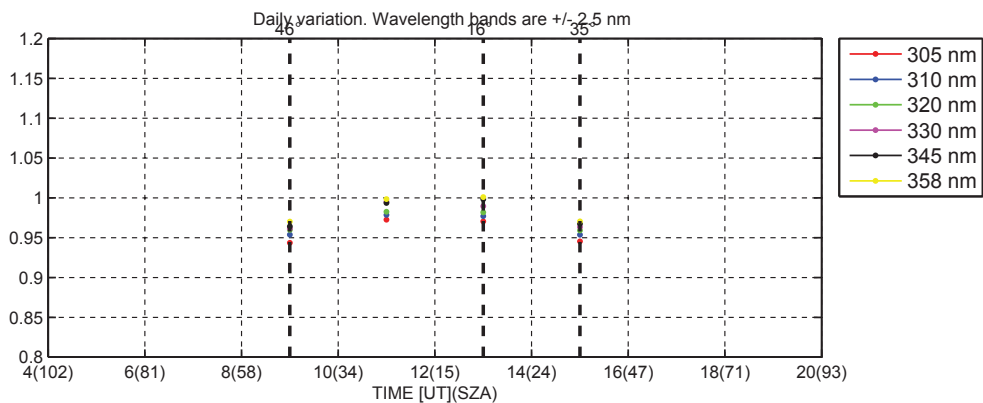
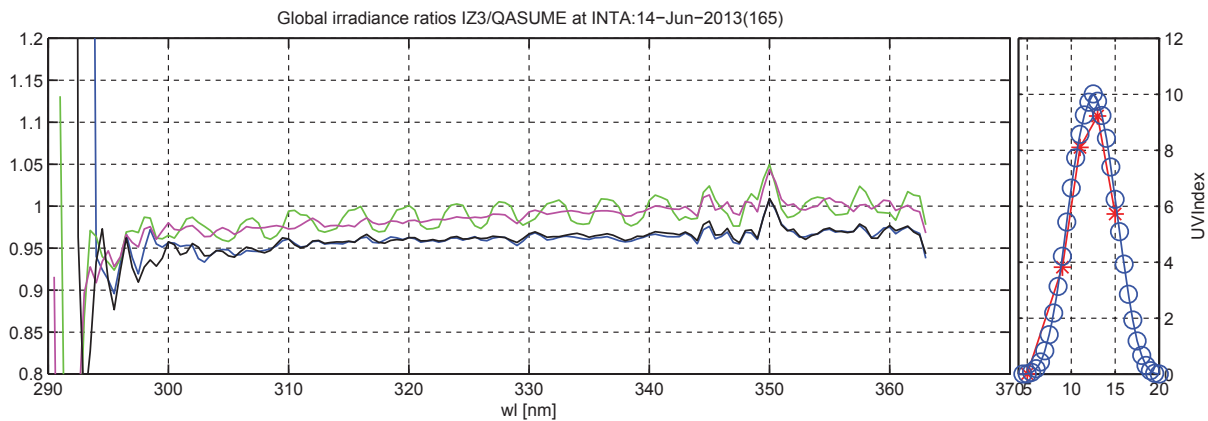
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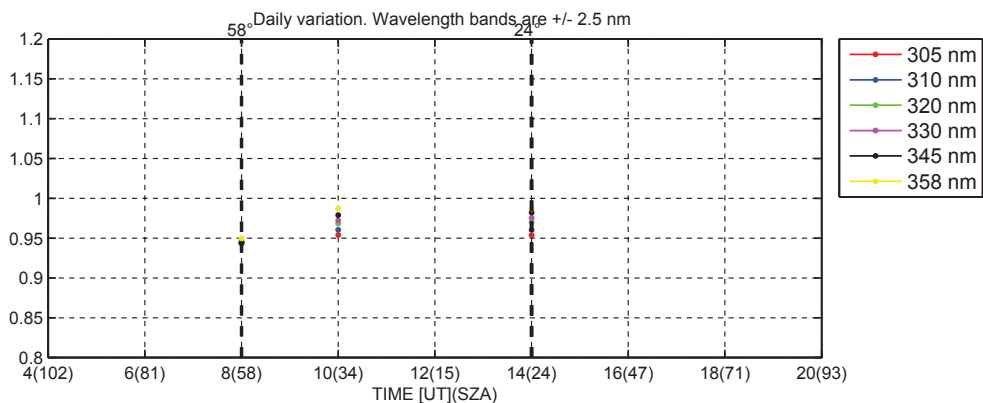
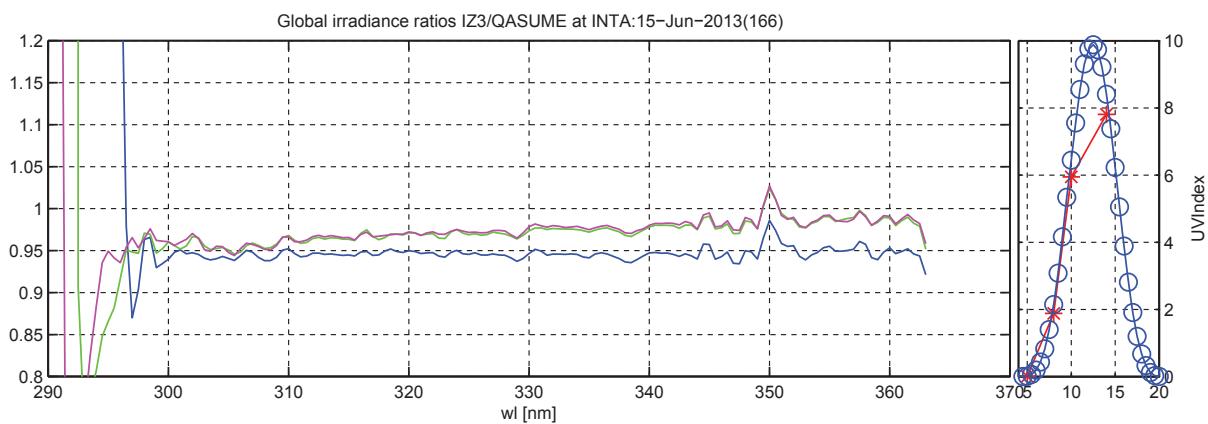
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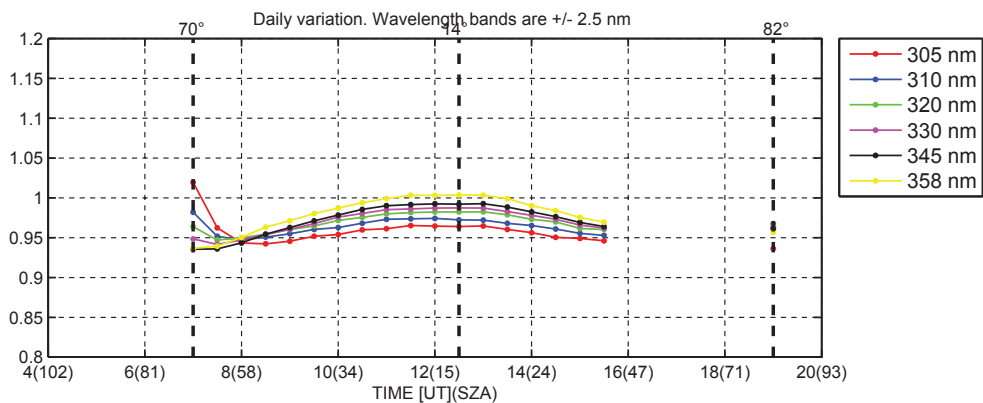
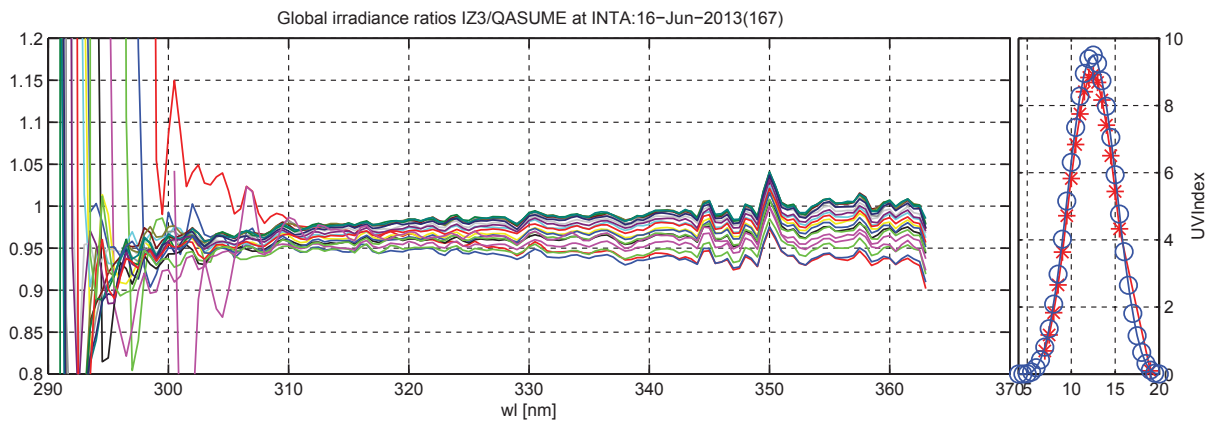
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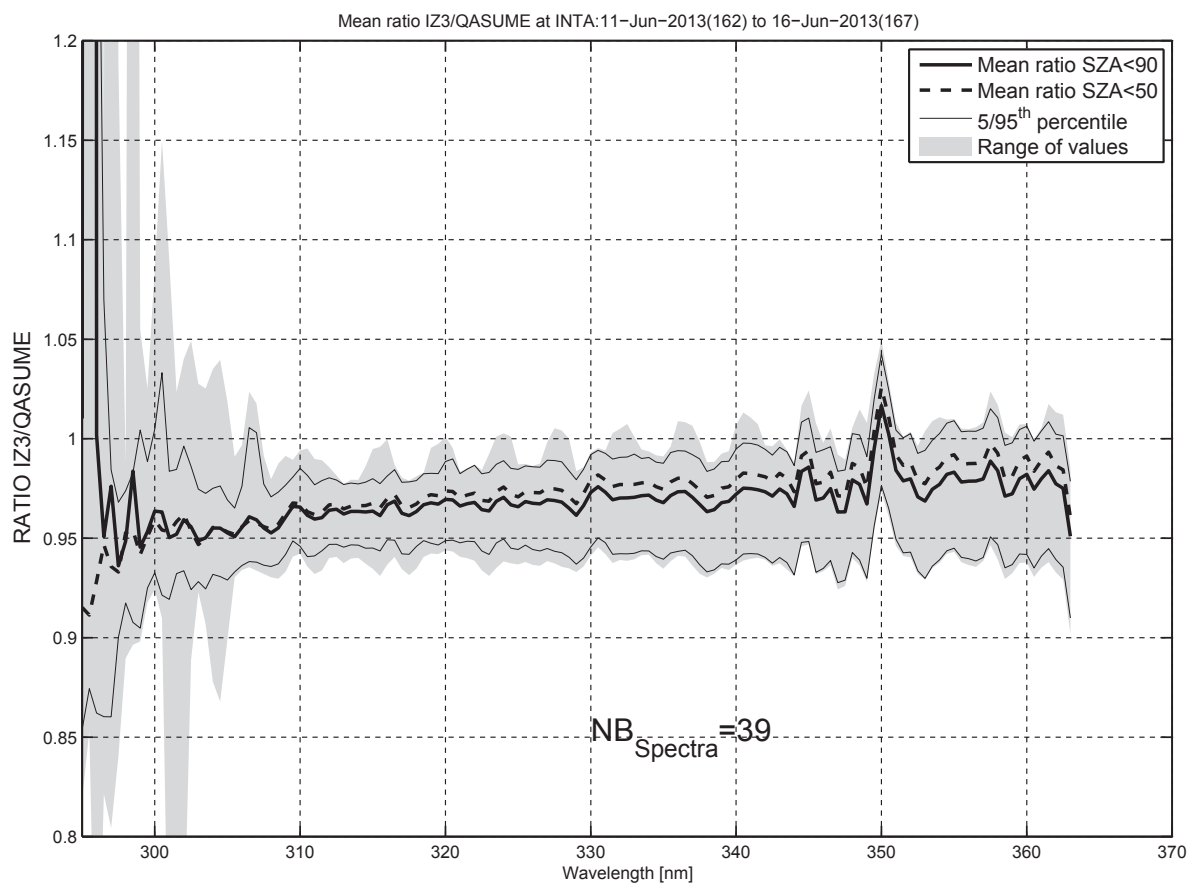
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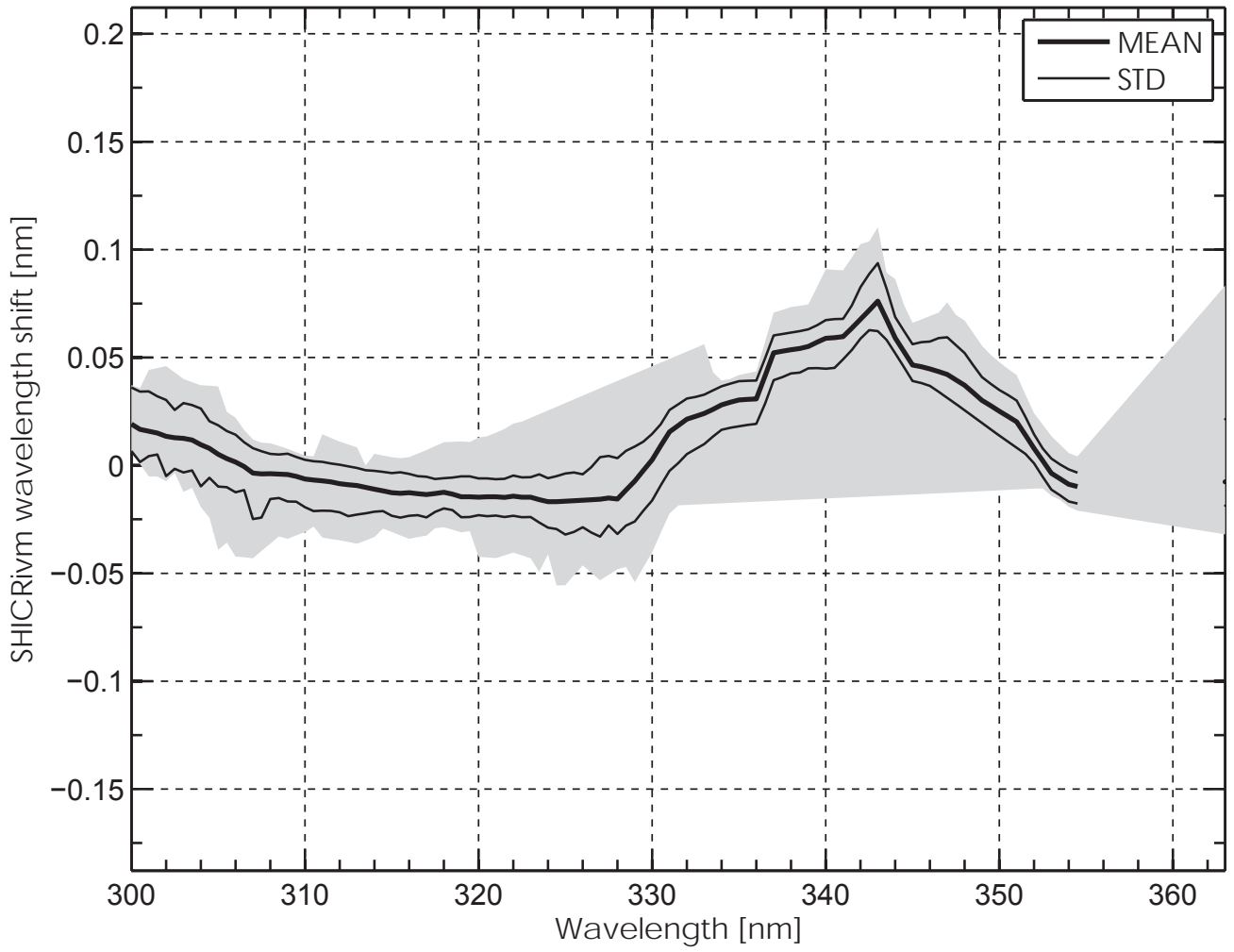


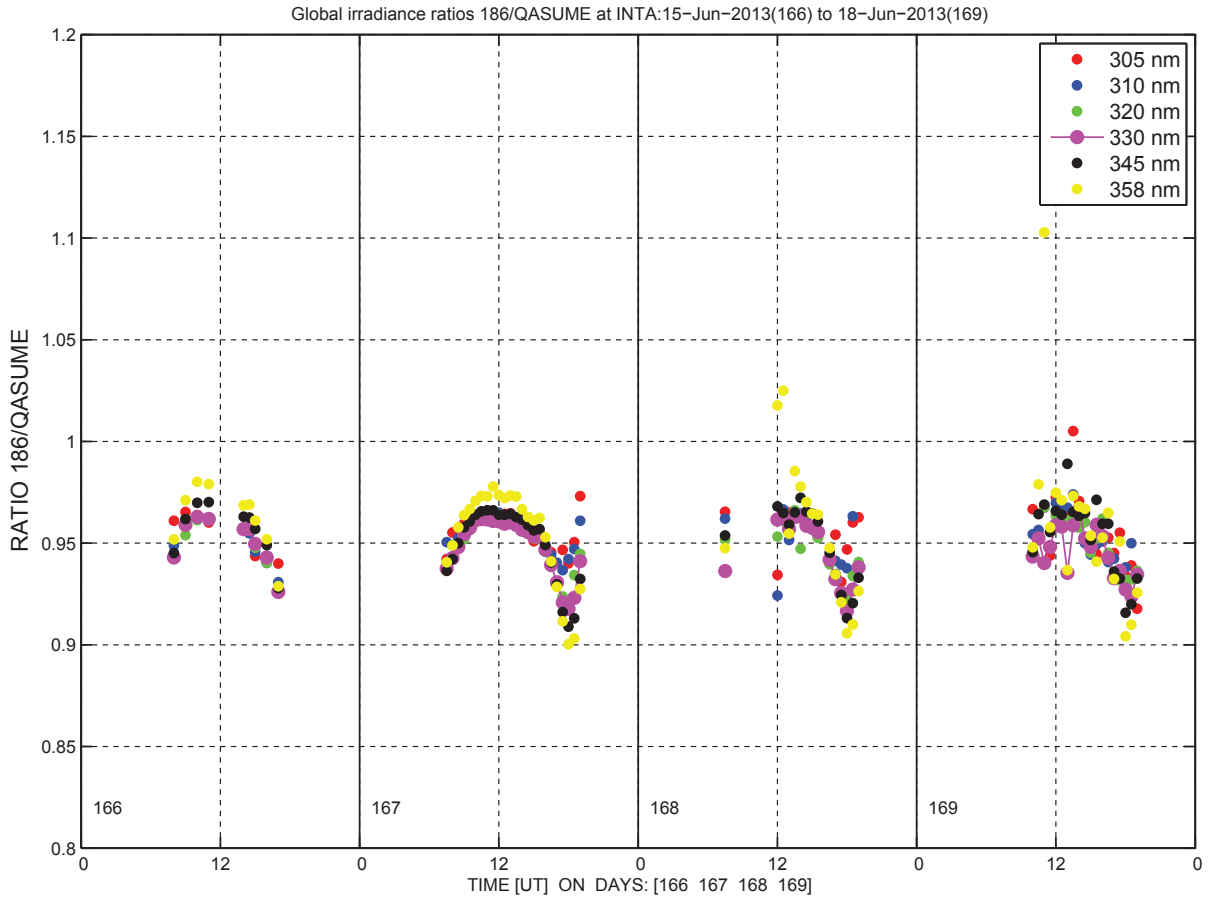
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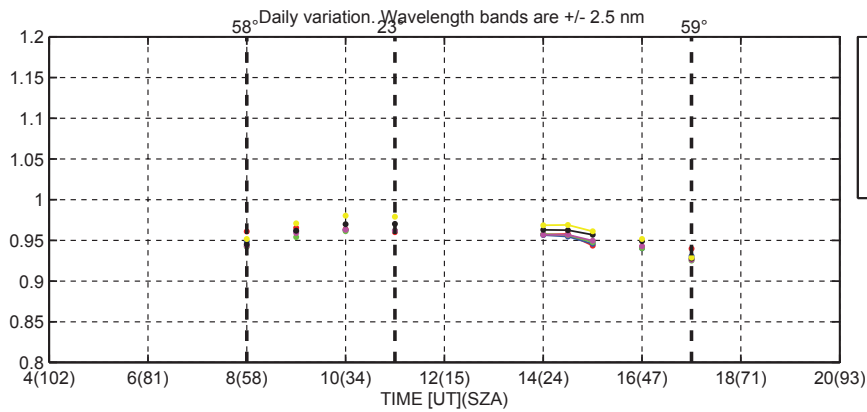
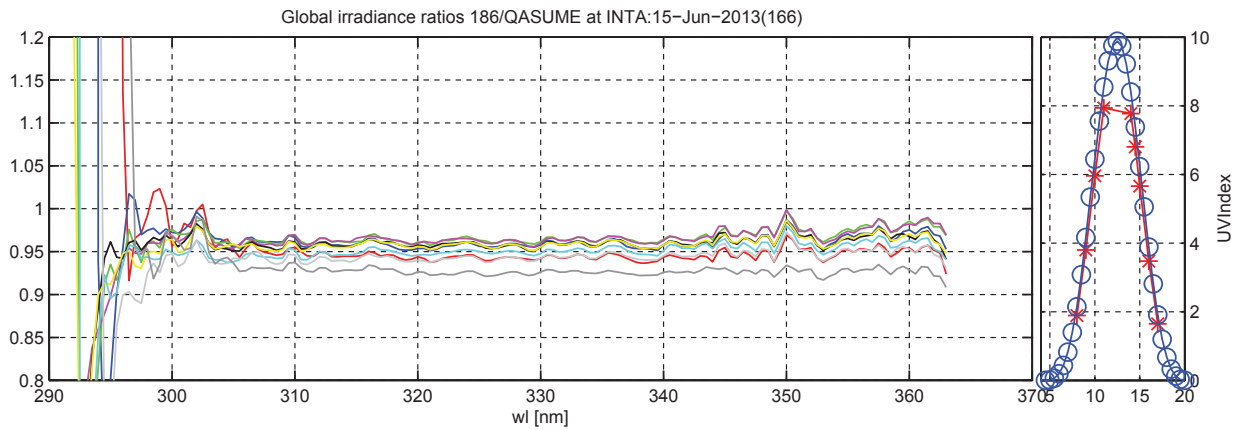
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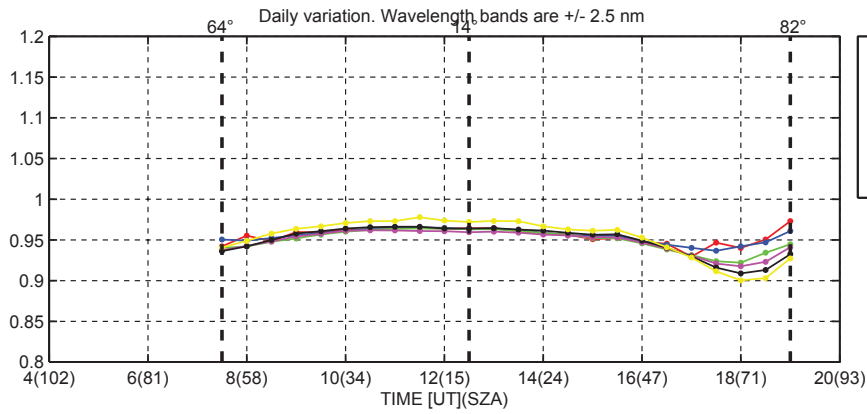
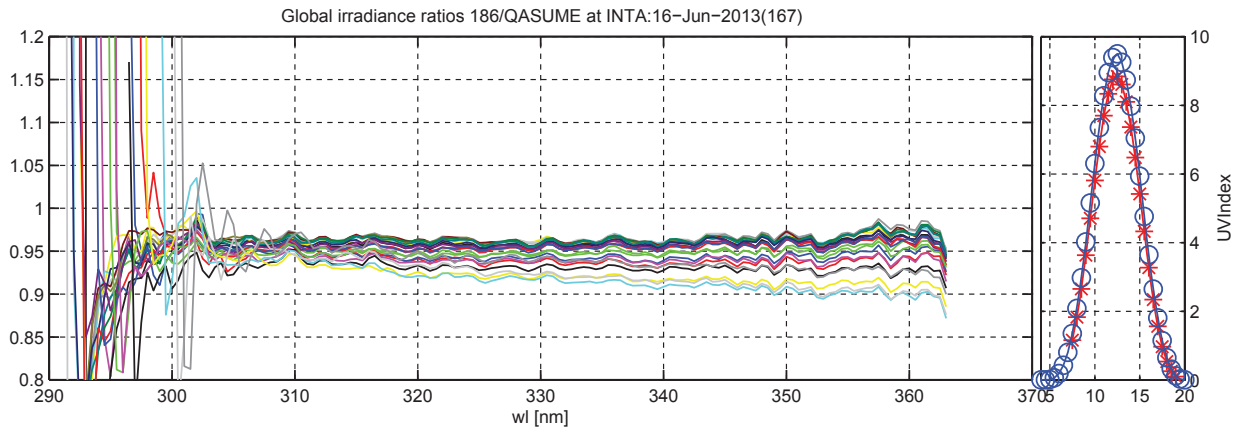




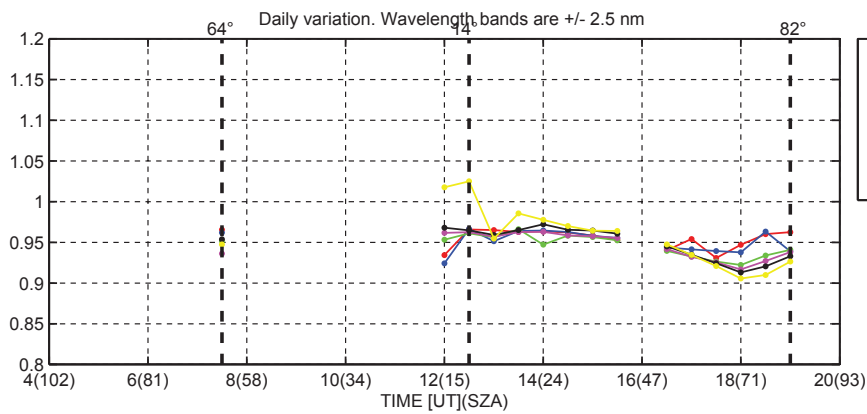
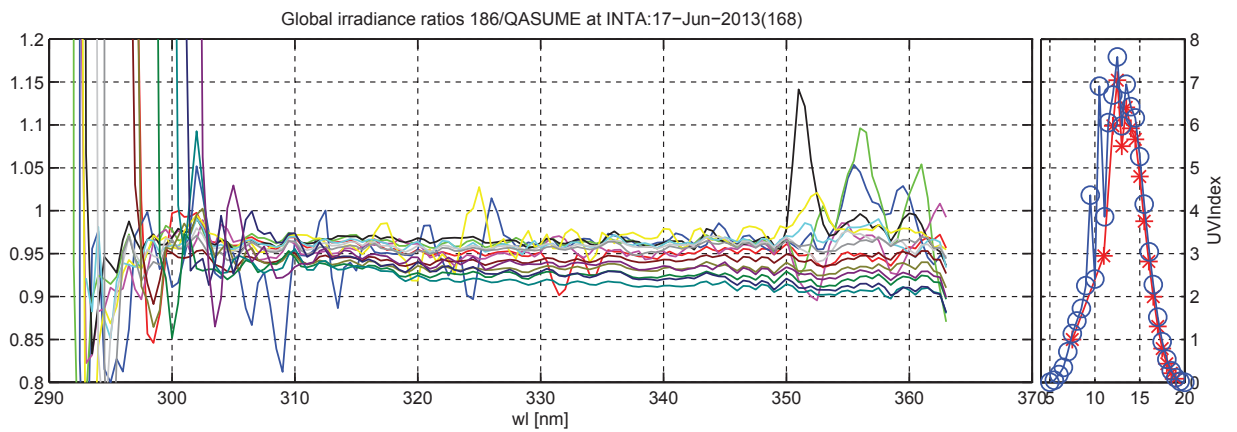
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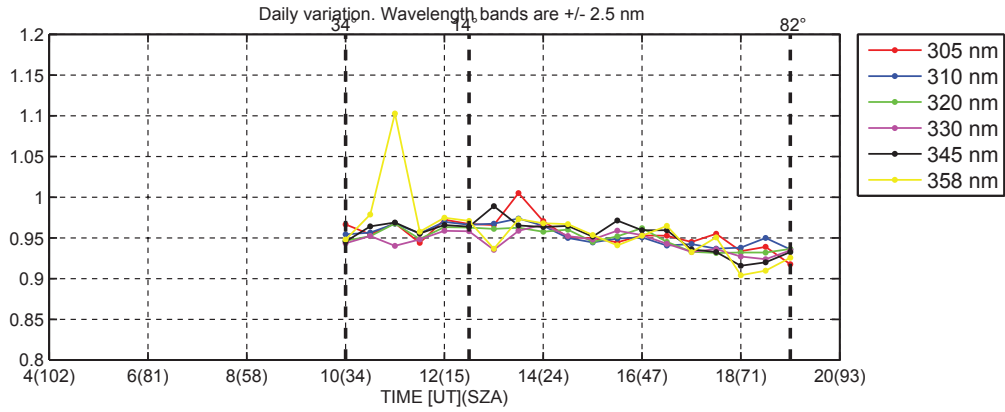
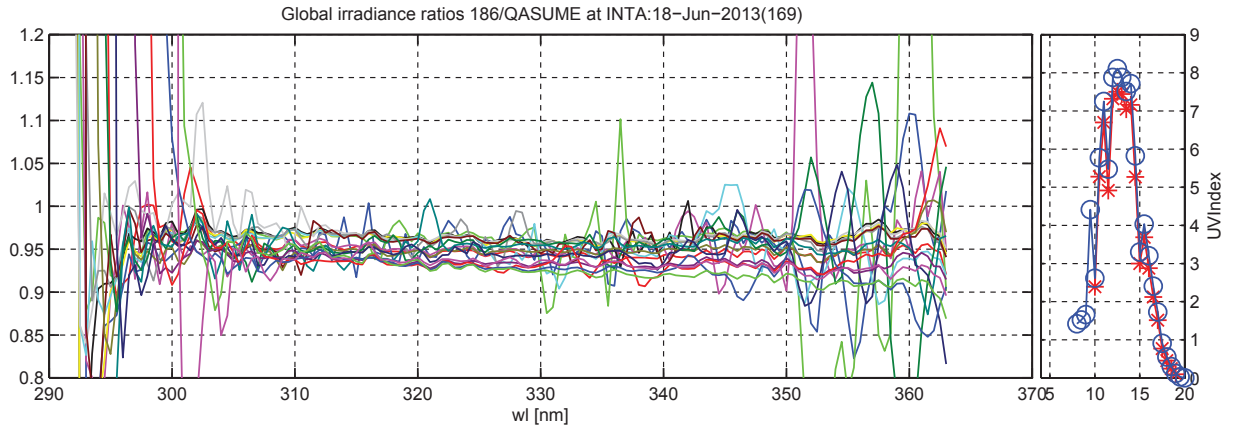
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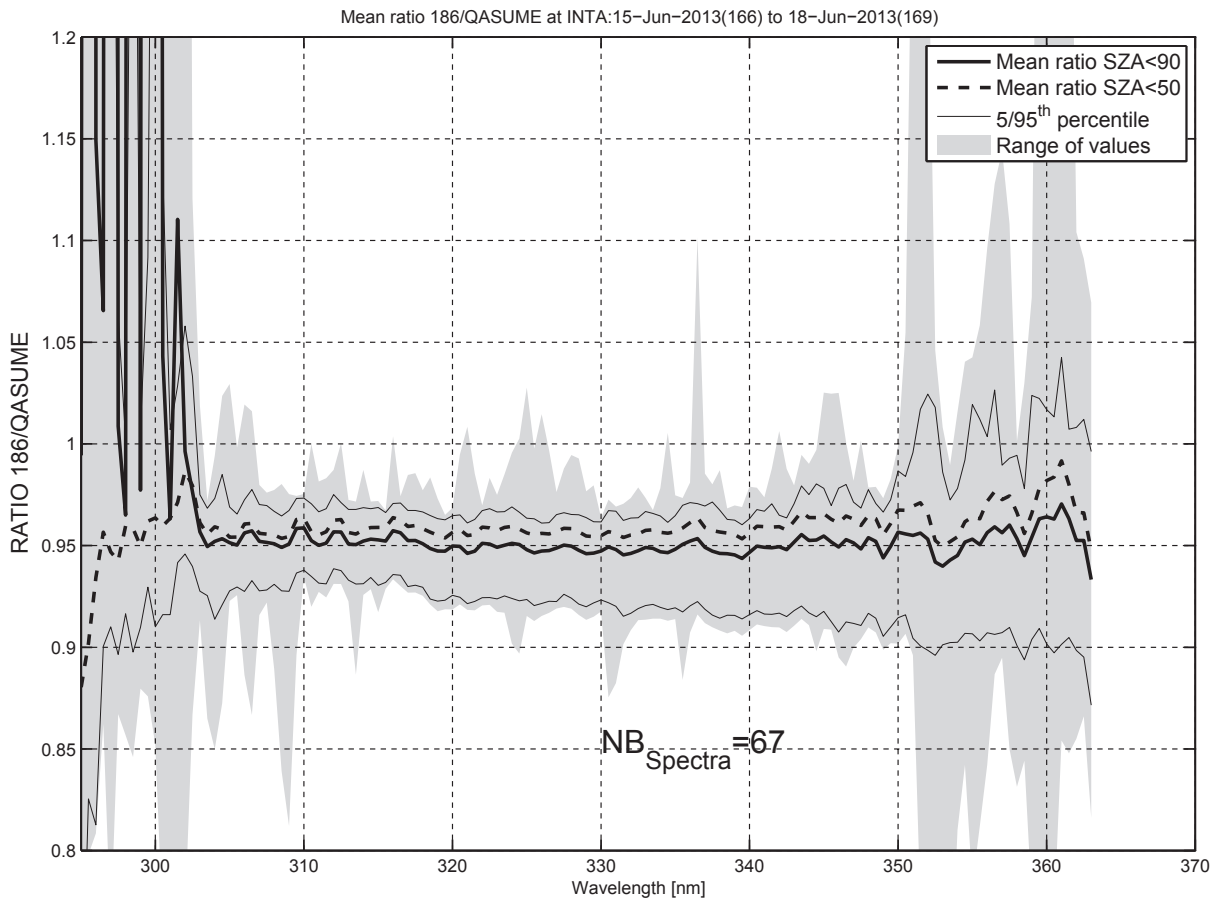
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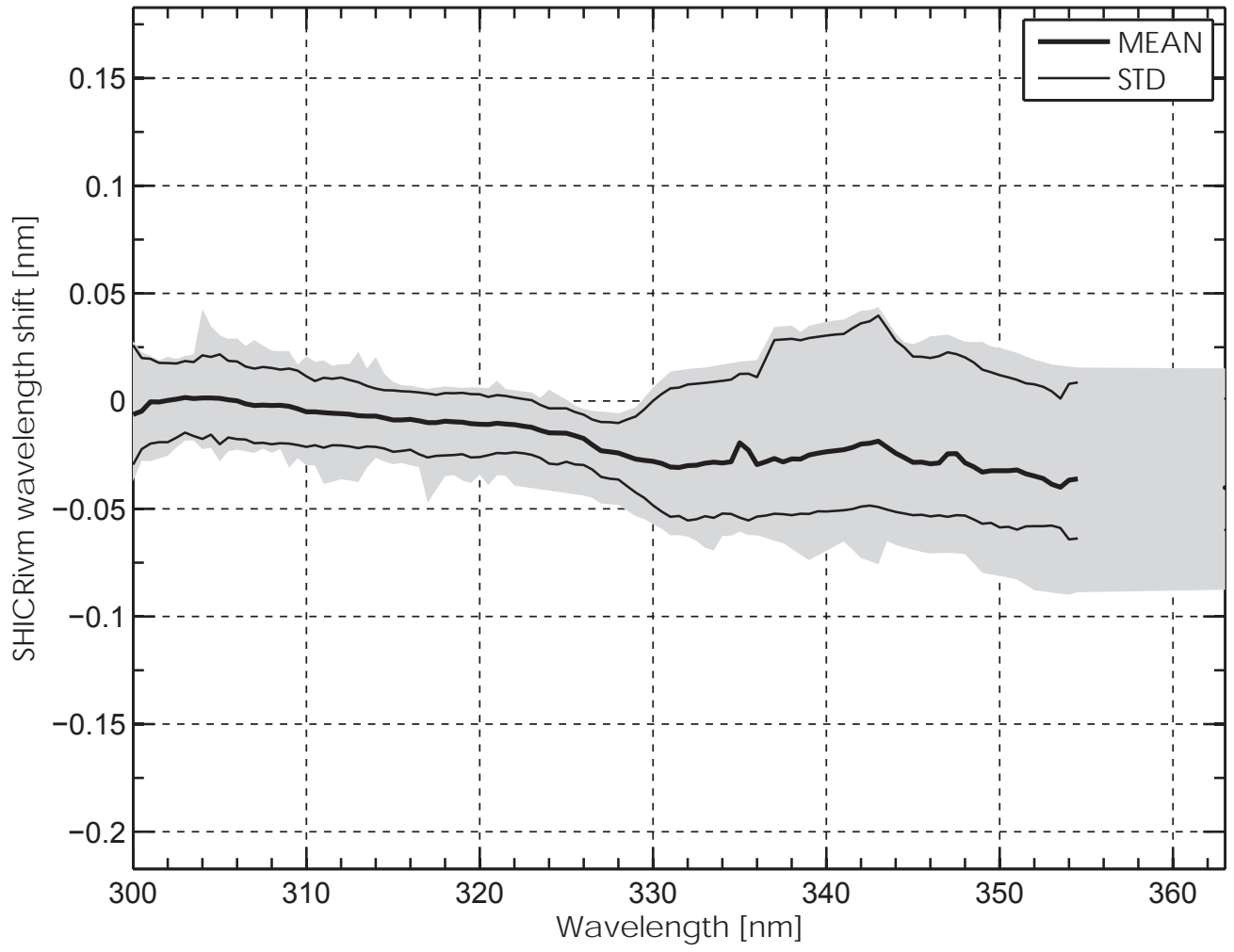


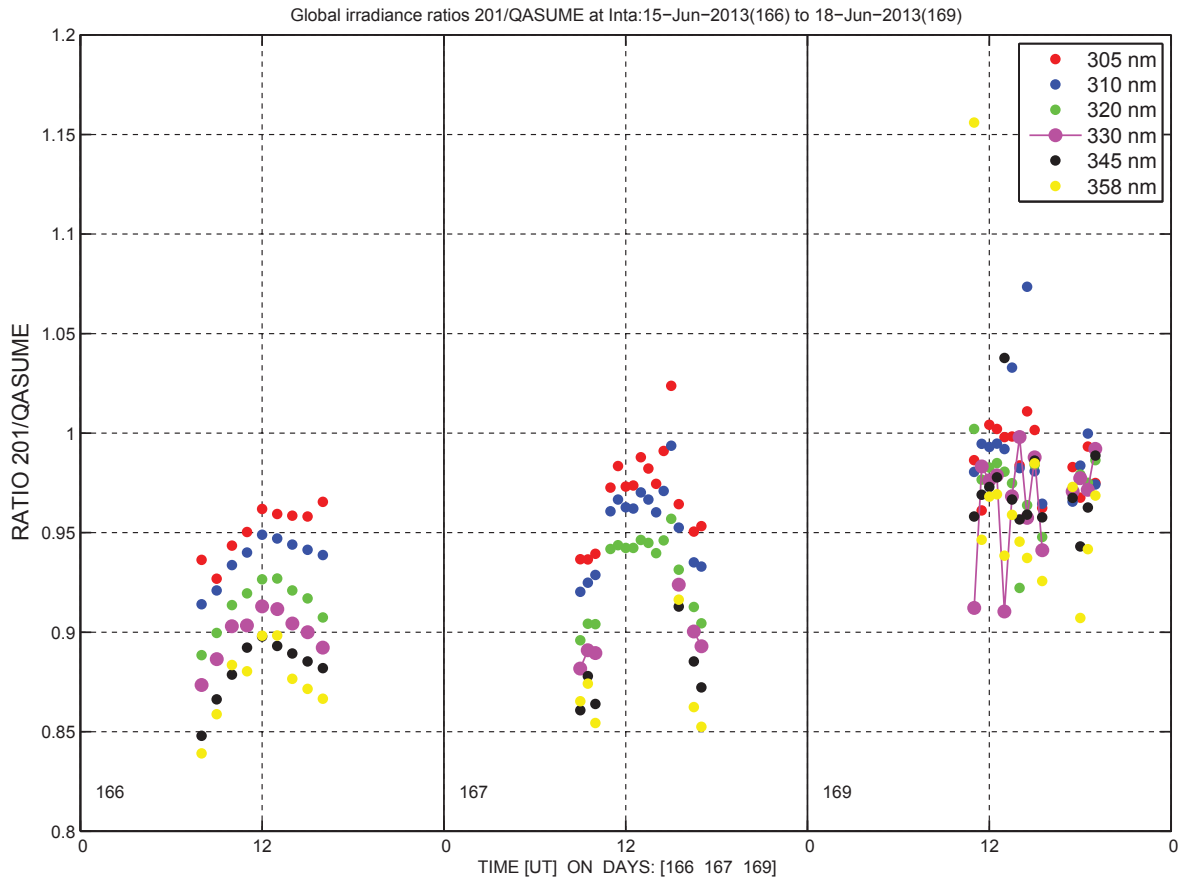
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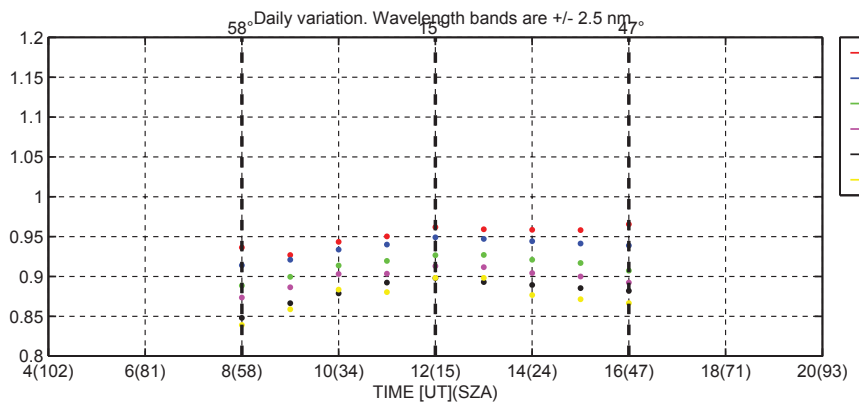
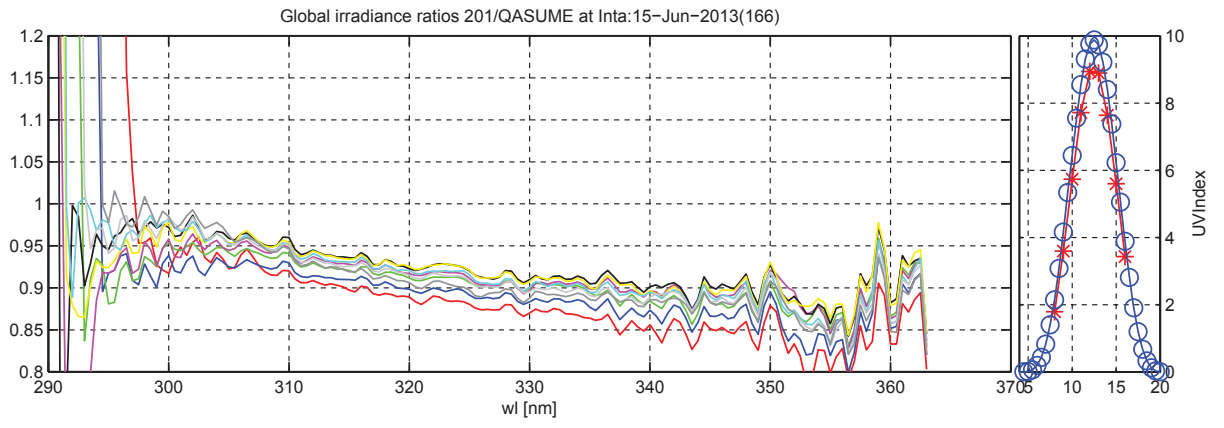
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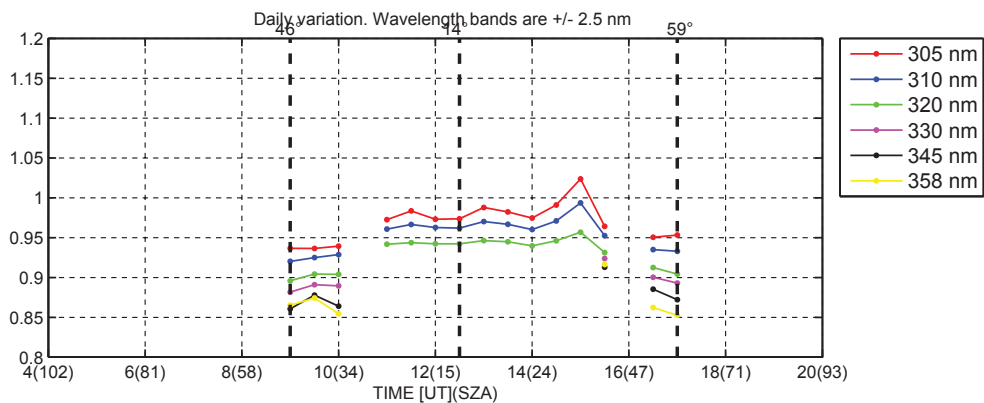
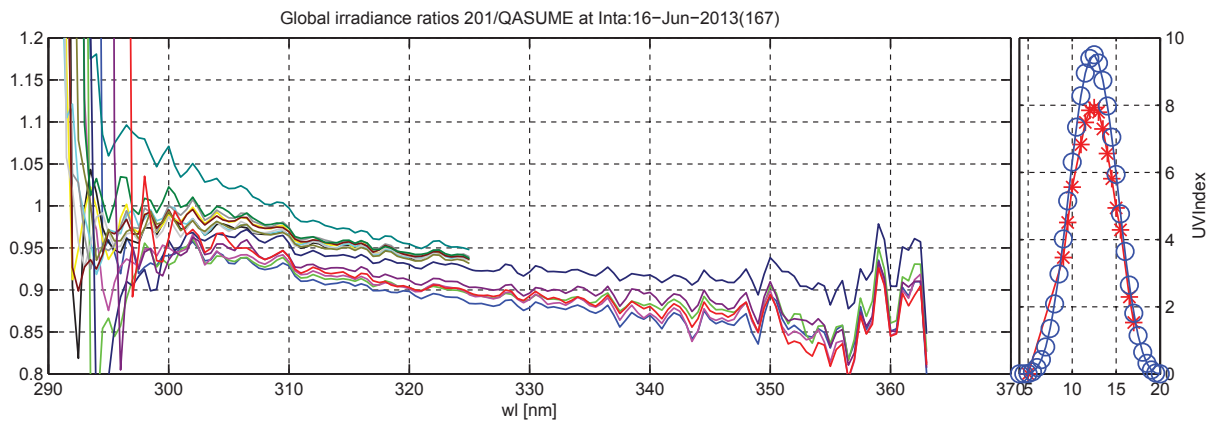




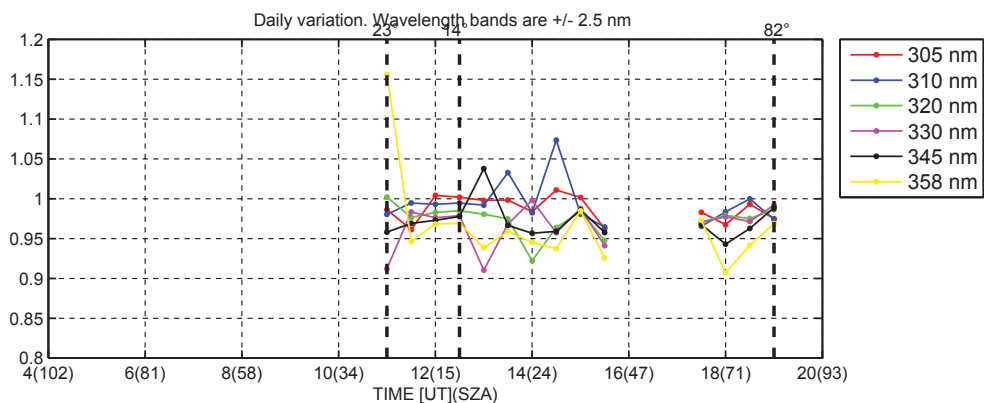
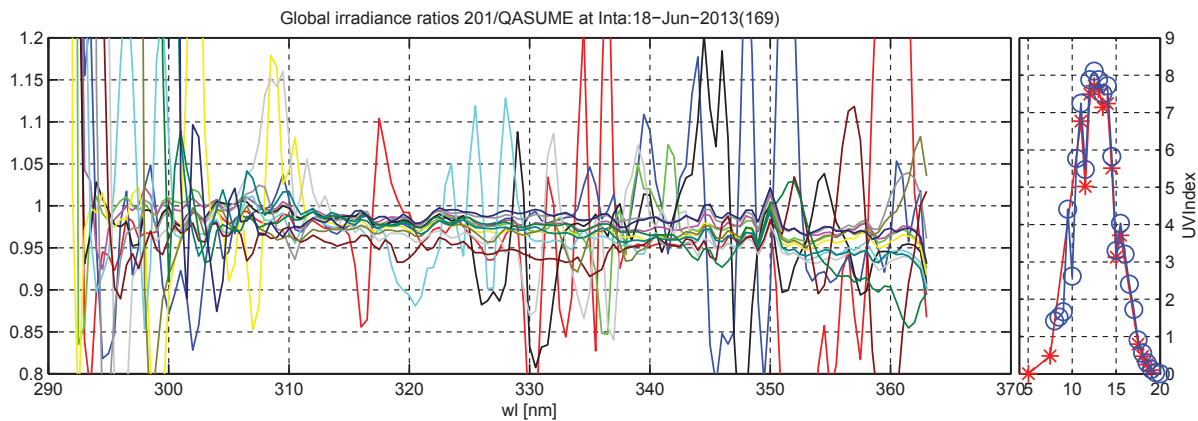
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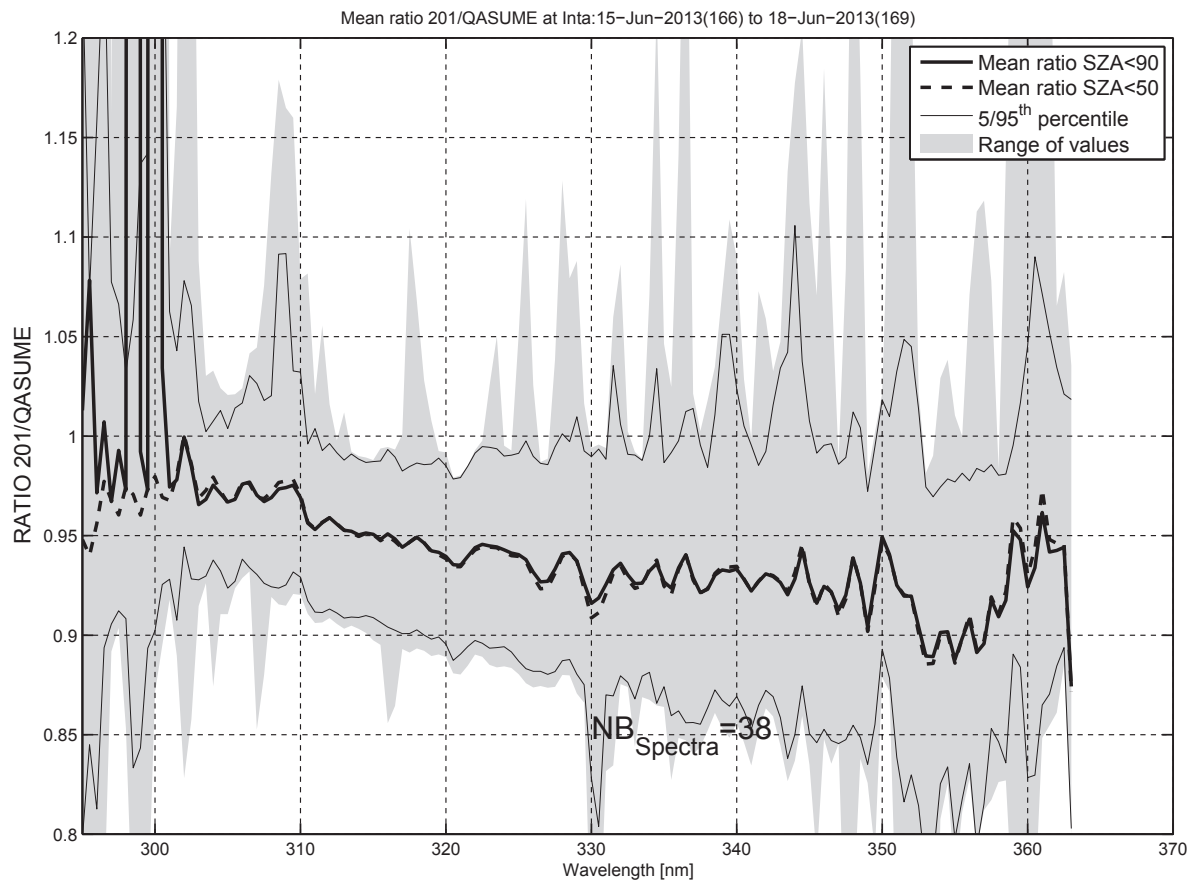
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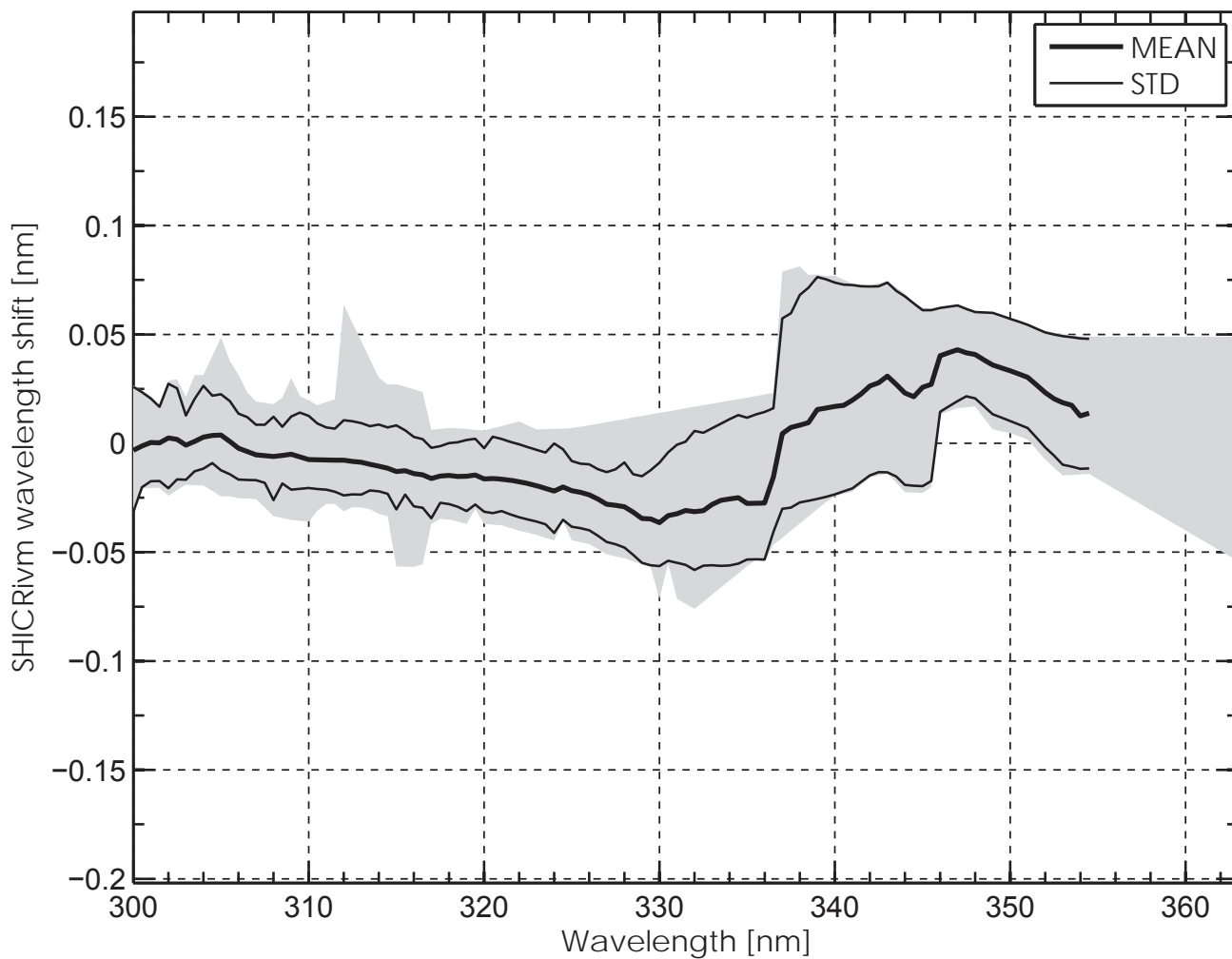
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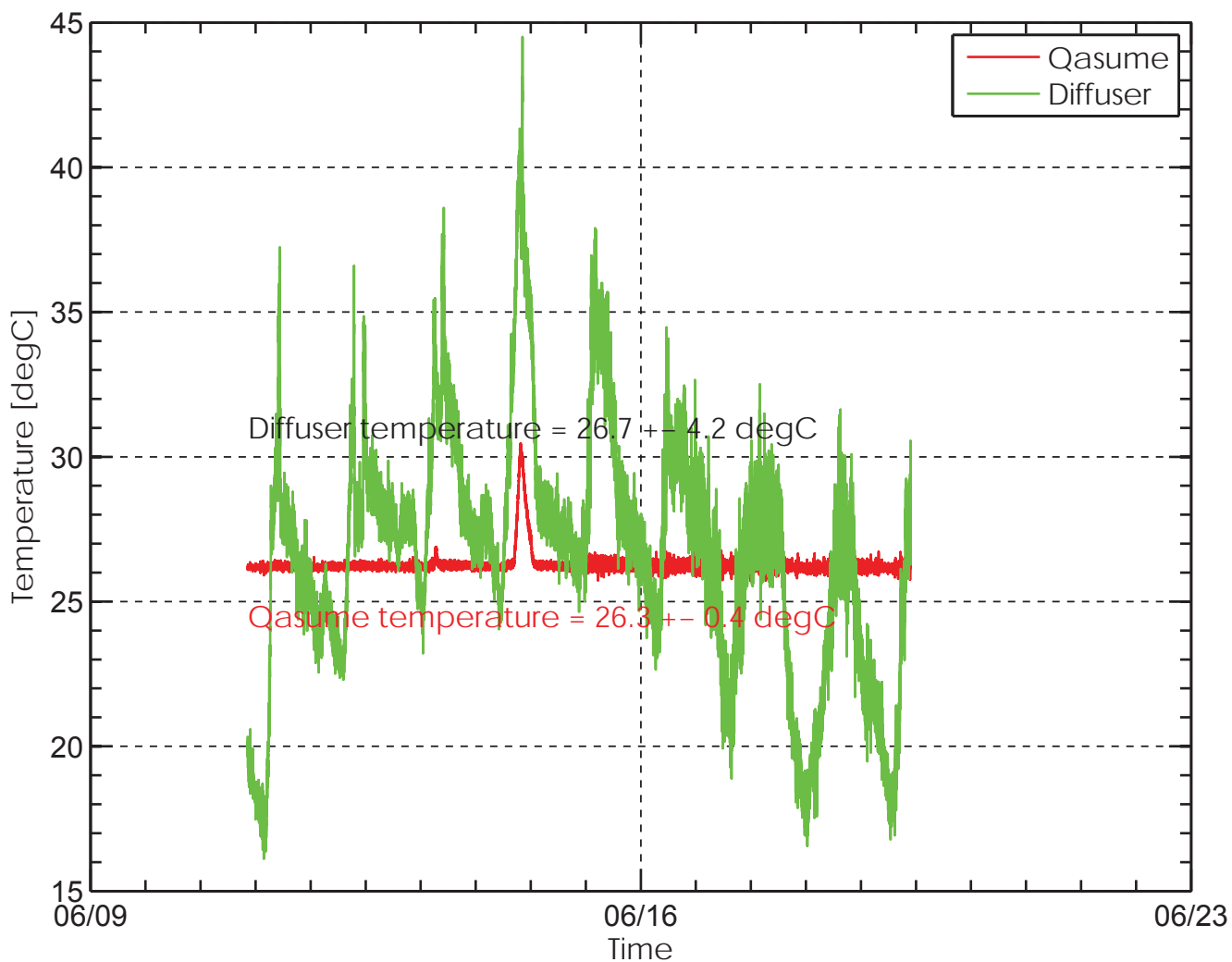


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Inta, 201, June 2013





Qasume Responsivity Change, June 2013, Inta (T68522, T65823)

