Protocol of the intercomparison at FMI, Jokioinen, Finland on June 14 to 19, 2014 with the travelling reference spectroradiometer QASUME from PMOD/WRC

Report prepared by Gregor Hülsen

Operator: Gregor Hülsen

The purpose of the visit was the comparison of global solar irradiance measurements between the Brewer spectrophotometer operated by FMI and the travel reference spectroradiometer QASUME. The spectroradiometer from NRPA, Oslo, Norway also participated in this campaign. One NILU-UV 6-channel instruments also run side-by-side the QASUME spectroradiometer throughout the campaign. The measurement site is located at Jokioinen; Latitude 60.81 N, Longitude 23.50 E and altitude 110 m.a.s.l.
The horizon of the measurement site is free down to at least 85° solar zenith angle (SZA). Measurements between 1:00 UT and 20:00 UT have been analysed.

QASUME was installed on the measurement platform of FMI-Jokioinen in the morning of June 14, 2014. The spectroradiometer was installed next to the Brewer spectrophotometer "FIJ" and the NRPA spectroradiometer "NRP" and with the entrance optic of QASUME within 2 m to the other instruments. The Brewer Spectrometer is a double monochromator MkIII #107. The spectroradiometer in use at NRPA is a Bentham DM150 double monochromator system. The input optics is a Bentham D6 with a custom mode heading system. The GUV instrument was the travelling reference instrument for the Norwegian UV monitoring network (GUV-9273). The intercomparison between QASUME and the spectroradiometers lasted five days, from noon of June 14th to the afternoon of June 19th.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Three lamps (T68523, T685240 and T61252) 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 23.8±0.3 °C and the diffuser head was heated to a temperature of 28 °C.
The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm analysis were between ±50 pm in the spectral range 290 to 400 nm.

Protocol:

The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 to 400 nm, every 0.5 nm, and 3.0 seconds between each wavelength increment. Qasume recorded the spectra in 15 min intervals with 0.25 nm increments, the NRP spectroradiometer also every 15 min with 0.5 nm increments from 290 to 410 nm.

DOY	Date	DAY	Weather	Comment (times are in UT)
165	14. Jun	Saturday	Clear sky in the afternoon	Installed at 9:00 14:13 calibration T68523
166	15. Jun	Sunday	Clear sky in the morning and afternoon Arround noon: Cu+Ci	12:45+15:15 calibration (T68523)
167	16. Jun	Monday	Clear sky with few Cirrus	9:14 calibration (T68523)
168	17. Jun	Tuesday	Clear sky	14:43,15:12,15:47 calibration T68523,T685240,T61252
169	18. Jun	Wednesday	Clear sky with few Cirrus	15:47 calibration (T68523) 16:12 Qasume OFF 16:30 Qasume ON (Labor)
170	19. Jun	Thurday	Dark Room	6:10 calibration (T68523) 8:00 calibration (D01-FMI) 12-17: ARF measuremnt FIJ End of Campaign: 17:00

Results:

In total 131/187 synchronised simultaneous spectra from QASUME and FIJ/NRP are available from the measurement period. Measurements between 1:00 and 20:00 UT have been analysed (SZA smaller than 90°).

Spectra affected by rain are excluded from the analysis. In addition most of the spectra recorded on 17th June [168] are rejected because of fast moving clouds.

Remarks:

I. FIJ:

1. The ratios between FIJ and QASUME have on average an offset of -1 %.
2. The diurnal variation of the FIJ to QASUME ratio is less than 4 % on overcasted days and above 8% on the sunny days.
3. For all solar scans the wavelength shifts of the FIJ is between ±50 pm in the spectral range 290 to 365 nm.
4. The irradiance scale derived from the FMI DXW 1kW transfer standard agree within ±1 % to the WCCUV irradiance scale. This is consistent with the comparison of the standard lamps in 2009
5. Diurnal variability on clear sky days in previous intercomparisons (see figures at the end of the protocol):
    a. 10th July, 2002: <2 %
    b. 29th May, 2003: <5 %
    c. 16th June, 2009: <5 % (strong indication for cosine error)
    d. May 2010: No clear sky days
6. The large diurnal variability can be contributed either to the considerable large temperature correction or the cosine correction applied to the data of FIJ.
7. The angular response measurement (ARF) will be processed by FMI.

II. NRP:

1. The ratios between NRP and QASUME have on average an offset of less than 1 %.
2. The diurnal variation of the NRP to QASUME ratio is less than 2 %.
3. For all solar scans the wavelength shifts of the FIJ is between ±40 pm in the spectral range 290 to 400 nm.

III. Multifilter Radiometer GUV 9273:

The erythemal weighted irradiances, expressed as UV indices of the multifilter radiometer GUV 9273 were compared to the UV indices calculated from the solar UV spectra of QASUME.

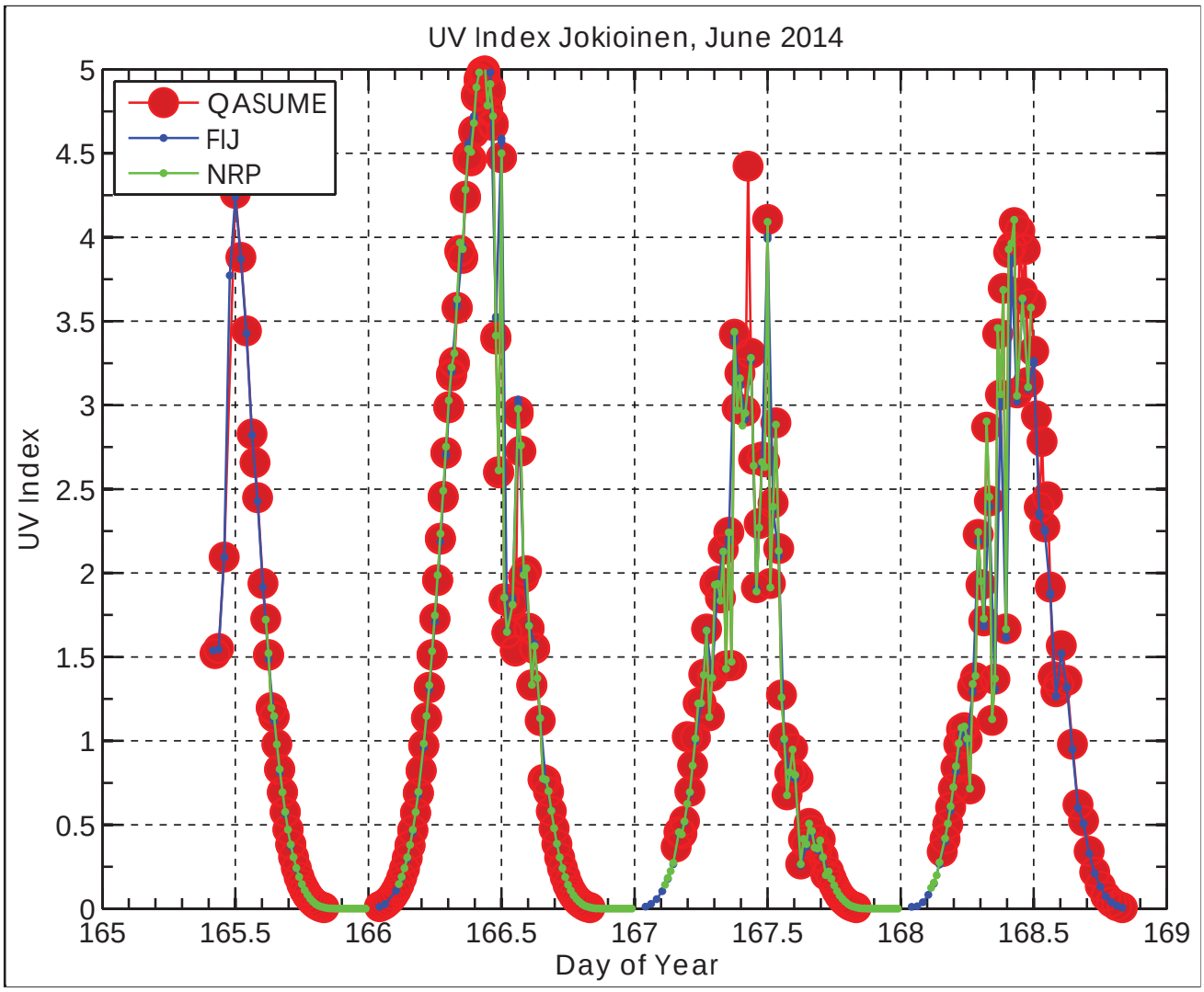
The agreement between GUV9273 and QASUME is good, with an average ratio of 0.98 and a standard deviation of less than 5%.

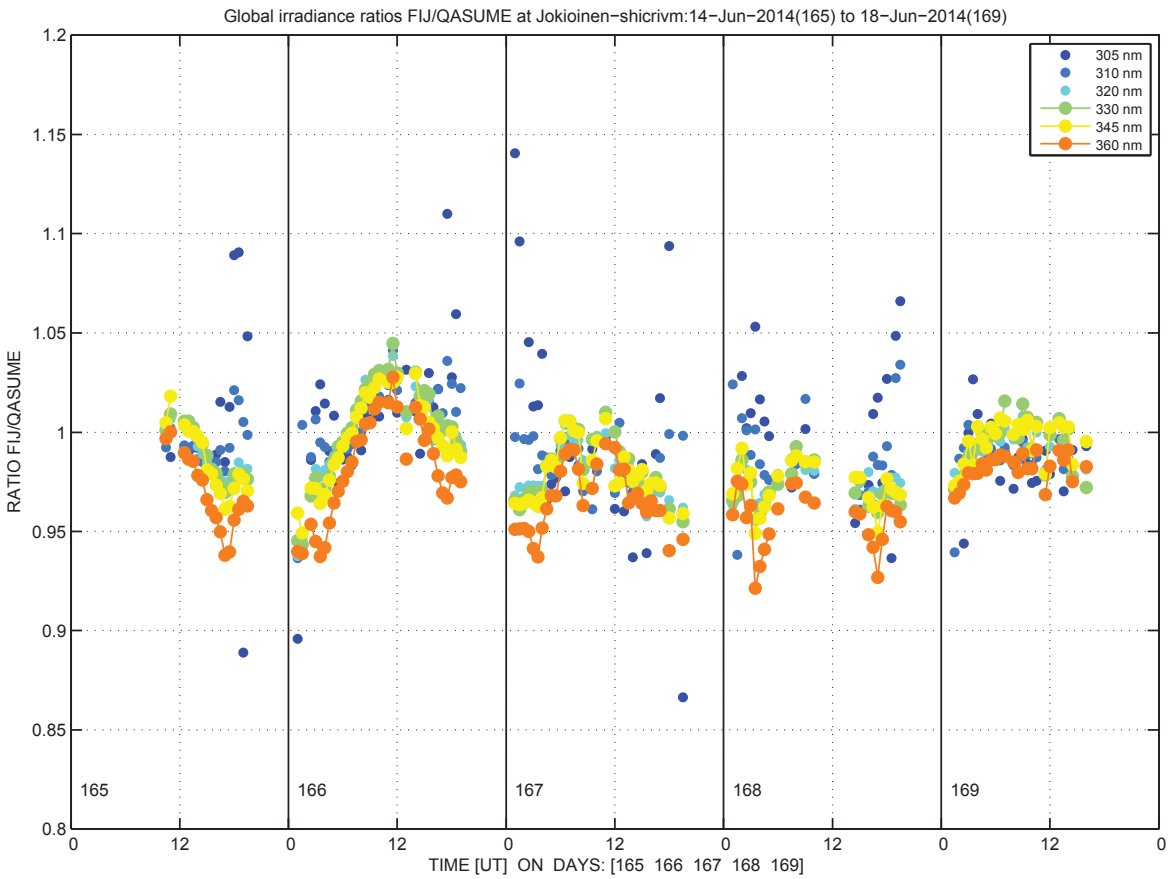
Recommendation (FIJ):
The correction applied to the data of FMI should be investigated. Especially the temperature and cosine correction are like to cause the large diurnal visibilities.

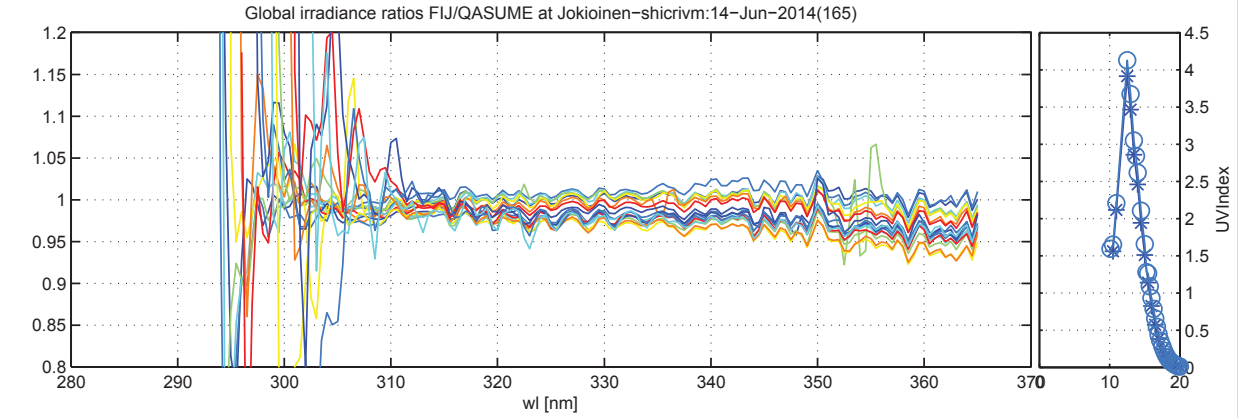
FMI Operator: Tapani Kosala
NRPA Operator: Bjorn Jonsen

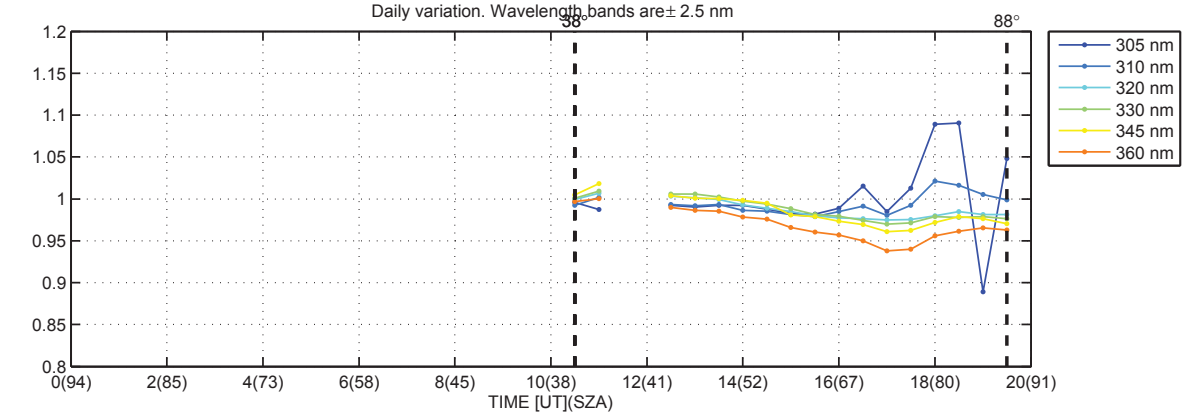
Comments from the operator:

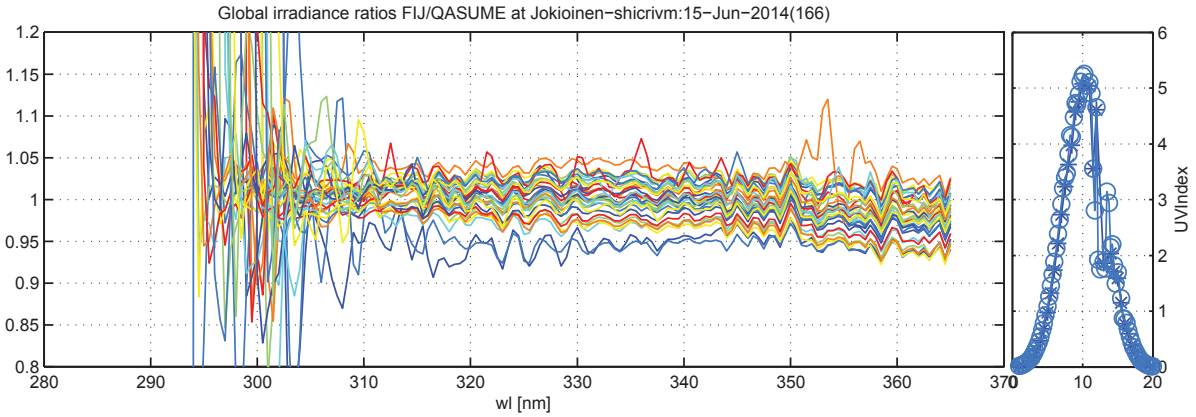
NRPA:
Irradiance calibrations are traceable to a set of three 1000 W lamps, calibrated by PMO-WRC in 2008.
Daily measurements with portable calibration lamps showed that the instrument was stable within 1 % for the campaign period.
Spikes in the global irradiance ratios are due to delays in the synchronization scheme caused by automatic ND-filter changes.
The optical head is temperature stabilized to 29 ± 3 degree Celsius.

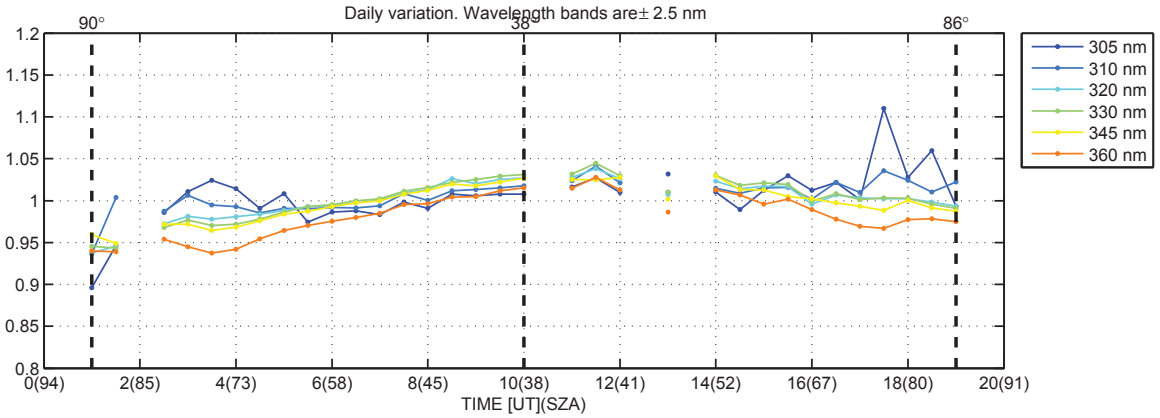

UV Index Jokioinen, June 2014
QASUME
FIJ
NRP
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
165
165.5
166
166.5
167
167.5
168
168.5
169

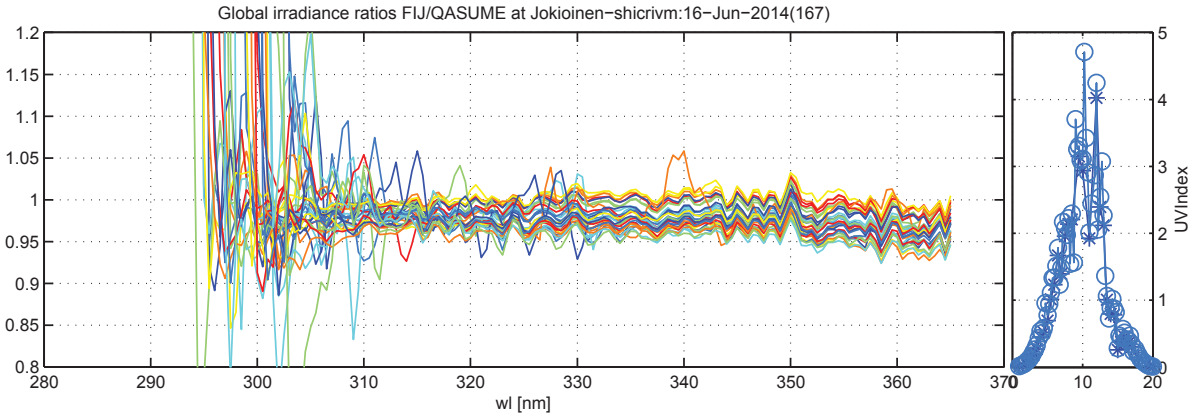

Global irradiance ratios FIJ/QASUME at Jokioinen−shicrivm:14−Jun−2014(165) to 18−Jun−2014(169)
RATIO FIJ/QASUME
TIME [UT] ON DAYS: [165 166 167 168 169]
165
166
167
168
169
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm

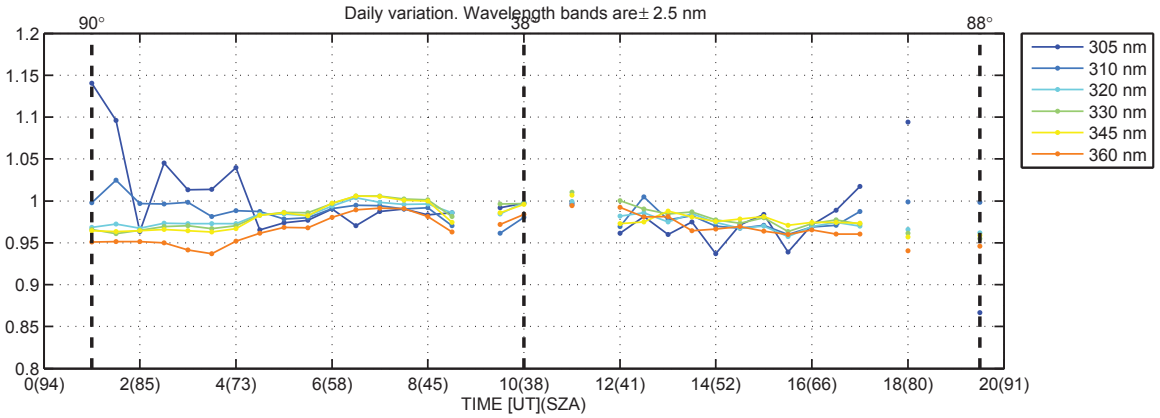

Global irradiance ratios FIJ/QASUME at Jokioinen−shicrivm:14−Jun−2014(165)
wl [nm]
UVIndex

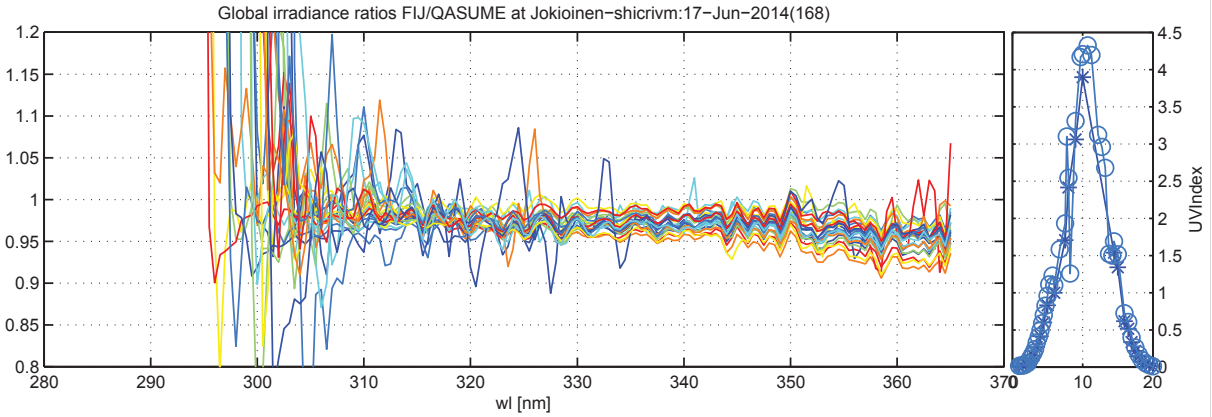

Daily variation. Wavelength bands are± 2.5 nm
88°
88°
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm

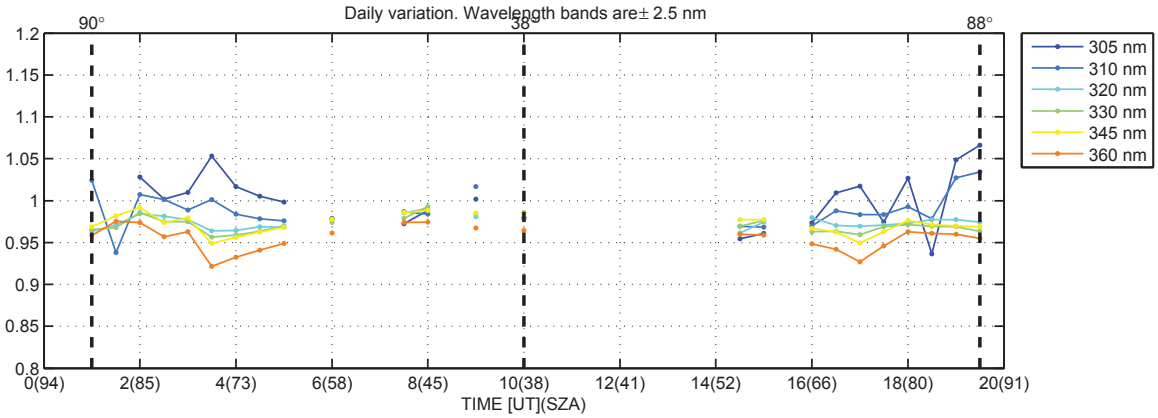

Global irradiance ratios FIJ/QASUME at Jokioinen−shicrivm:15−Jun−2014(166)
wl [nm]
UVIndex

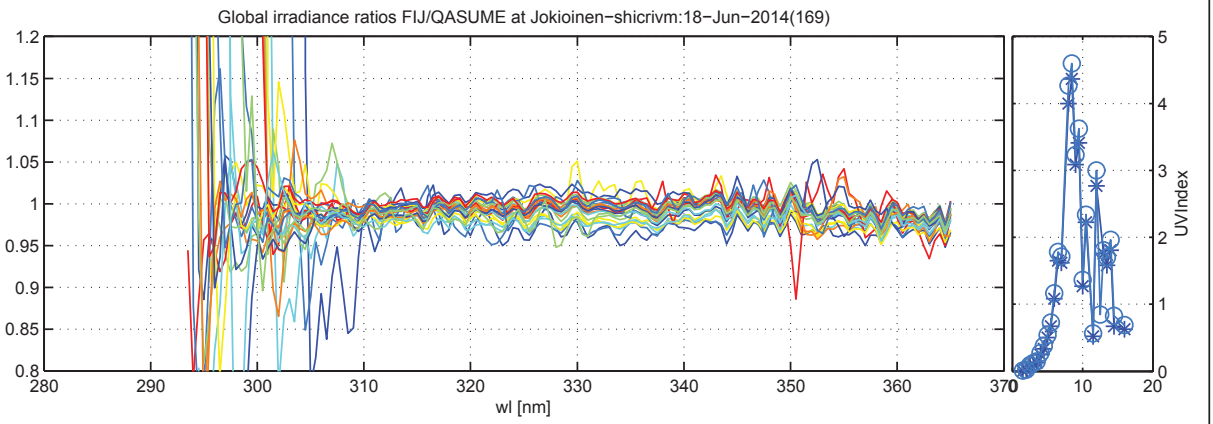

Daily variation. Wavelength bands are± 2.5 nm
90°
38°
86°
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
TIME [UT](SZA)

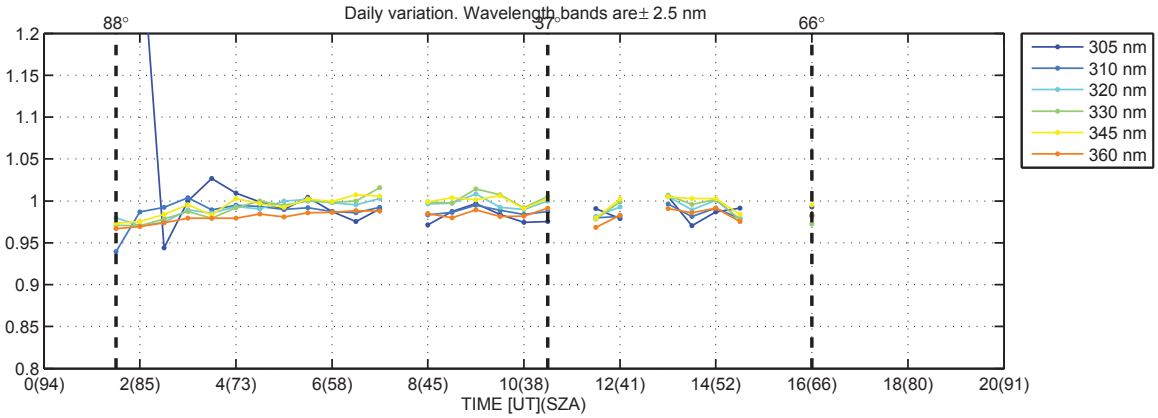

Global irradiance ratios FIJ/QASUME at Jokioinen−shicrivm:16−Jun−2014(167)
wl [nm]
UVIndex

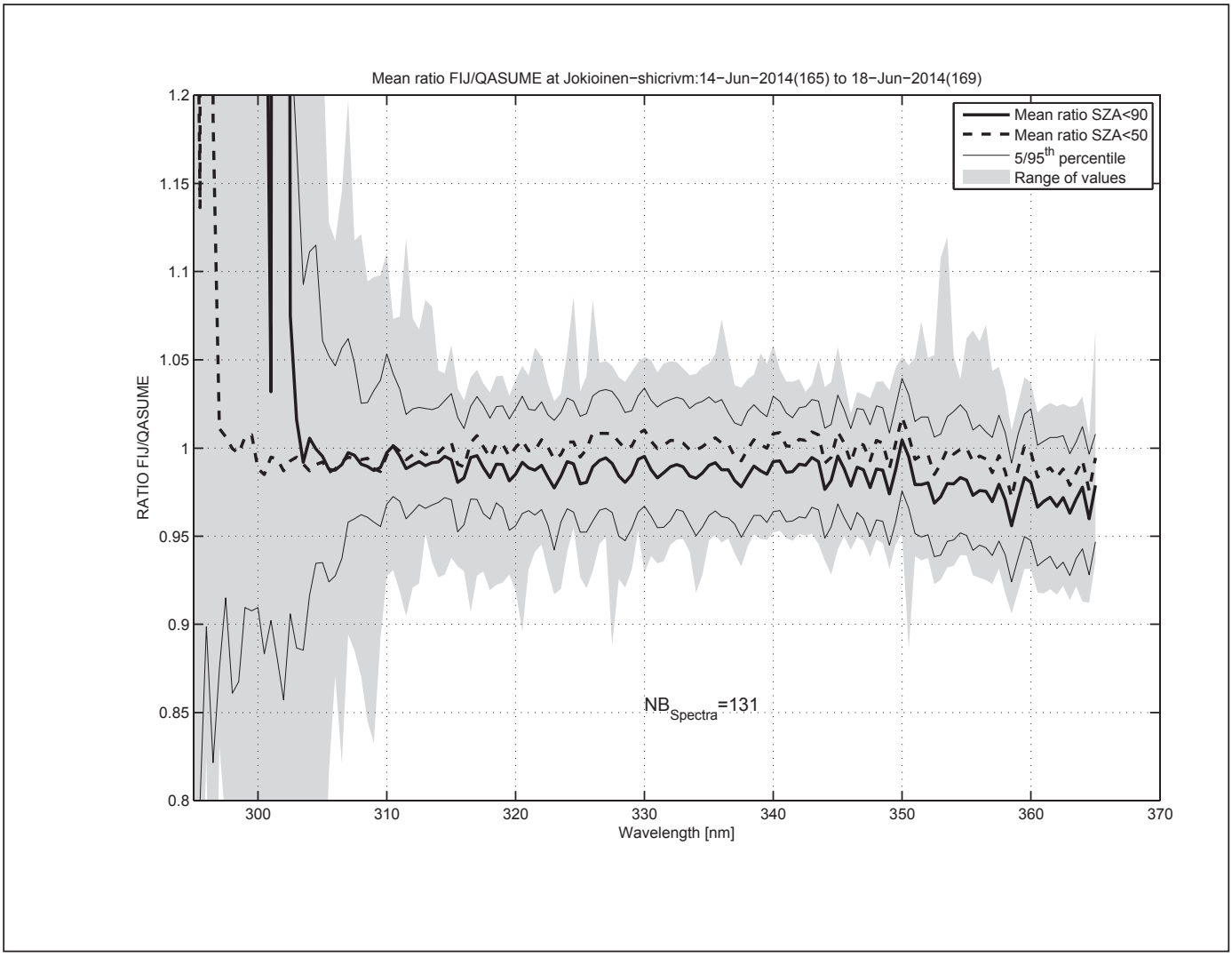

Daily variation. Wavelength bands are± 2.5 nm
90°
38°
88°
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
TIME [UT](SZA)

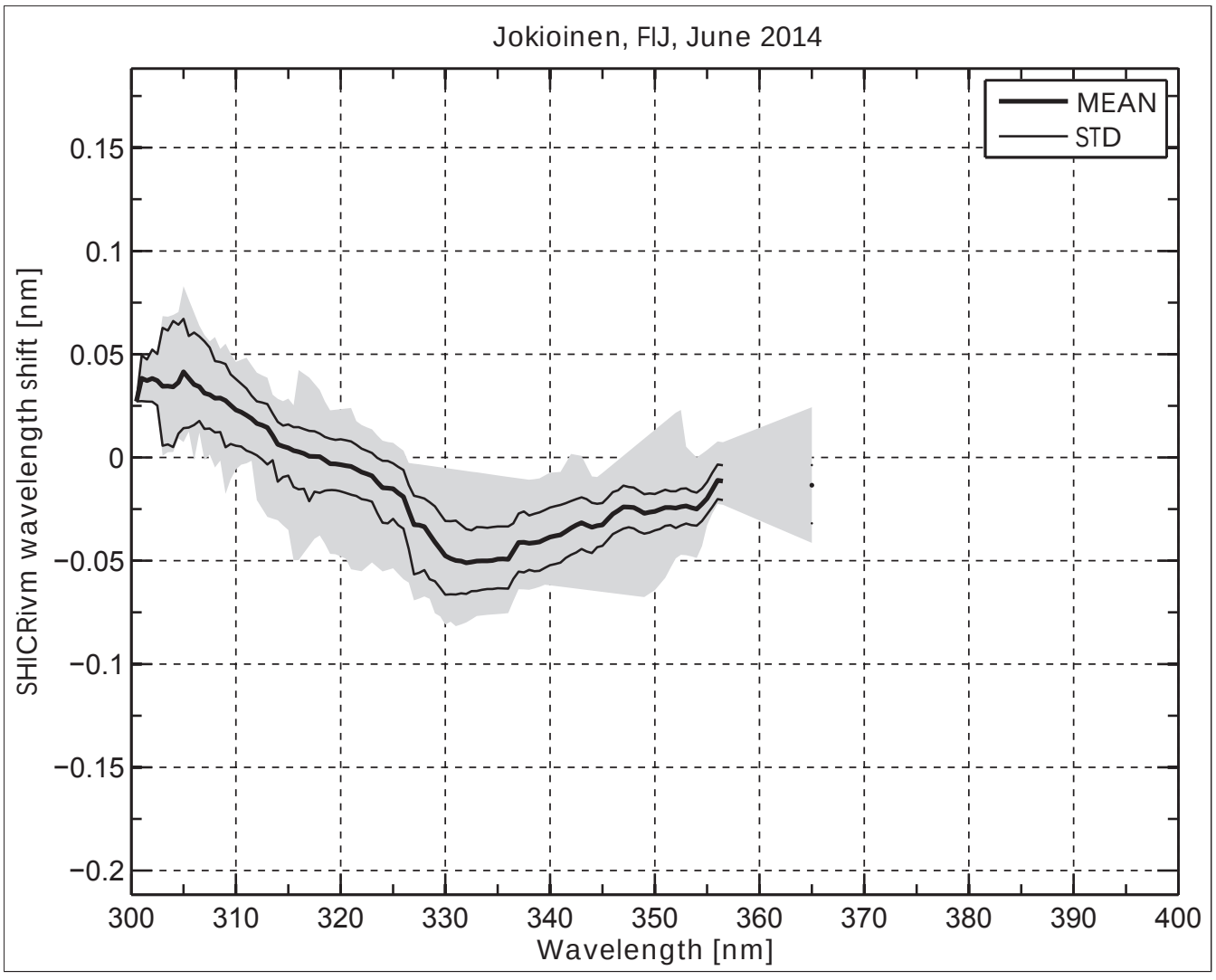

Global irradiance ratios FIJ/QASUME at Jokioinen−shicrivm:17−Jun−2014(168)
wl [nm]
UVIndex

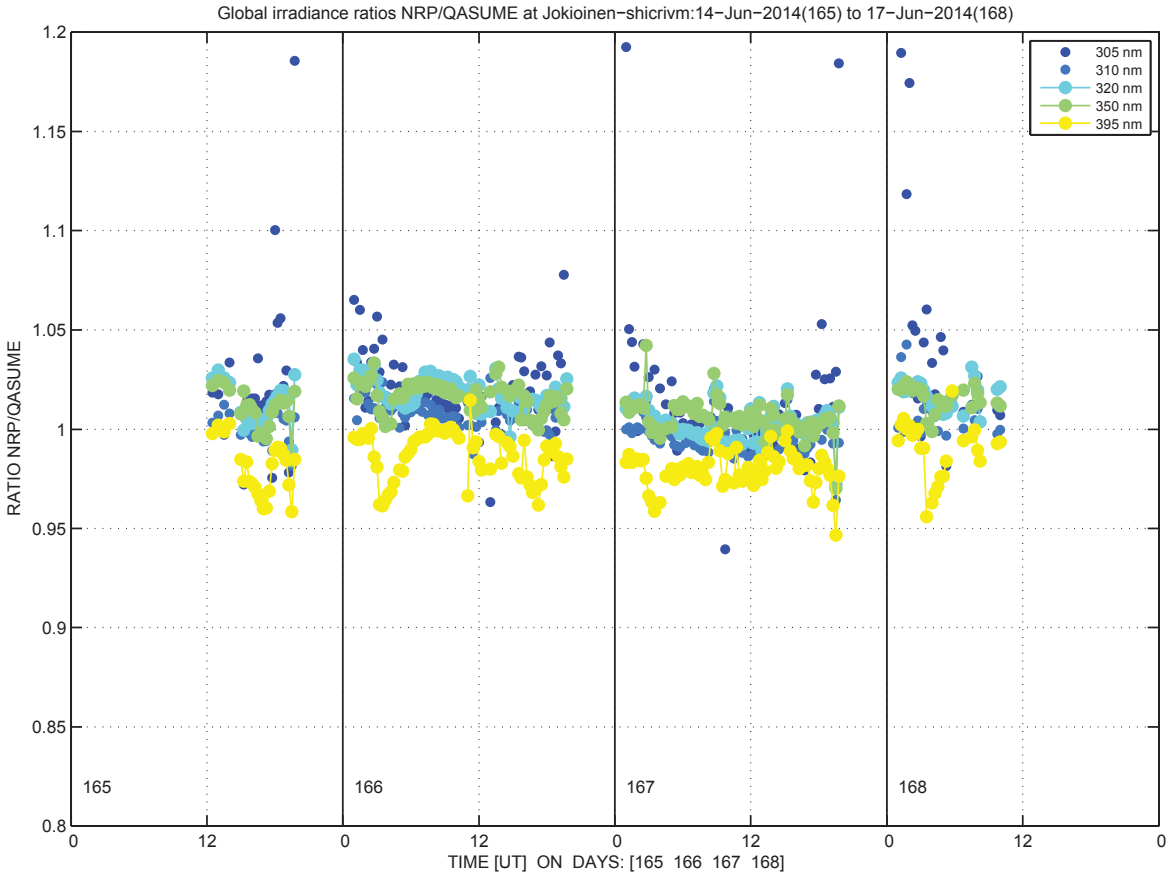

Daily variation. Wavelength bands are± 2.5 nm
90°
38°
88°
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm

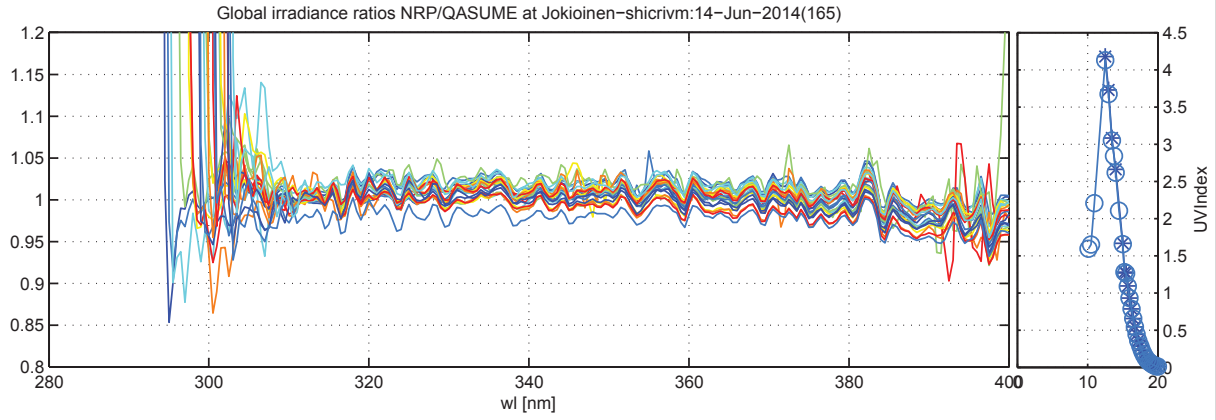

Global irradiance ratios FIJ/QASUME at Jokioinen−shicrivm:18−Jun−2014(169)
wl [nm]
UVIndex

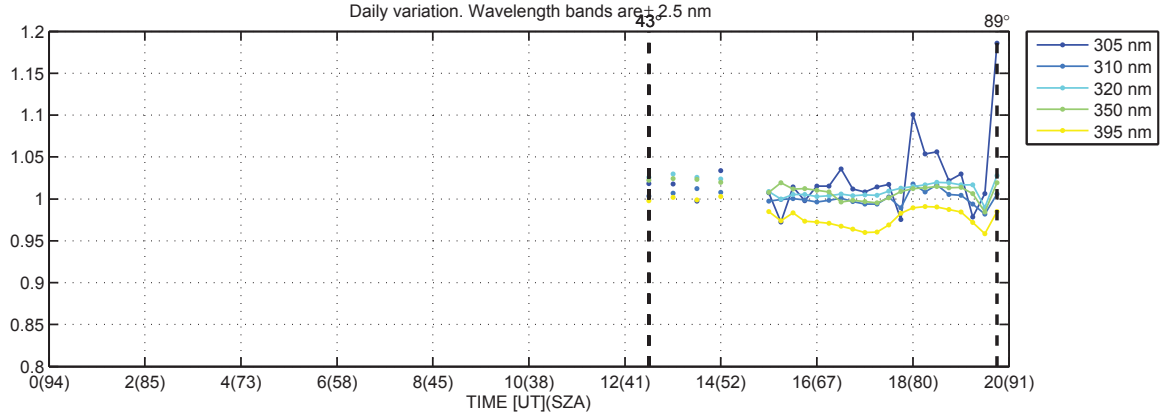

Daily variation. Wavelength bands are± 2.5 nm
88°
37°
66°
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm

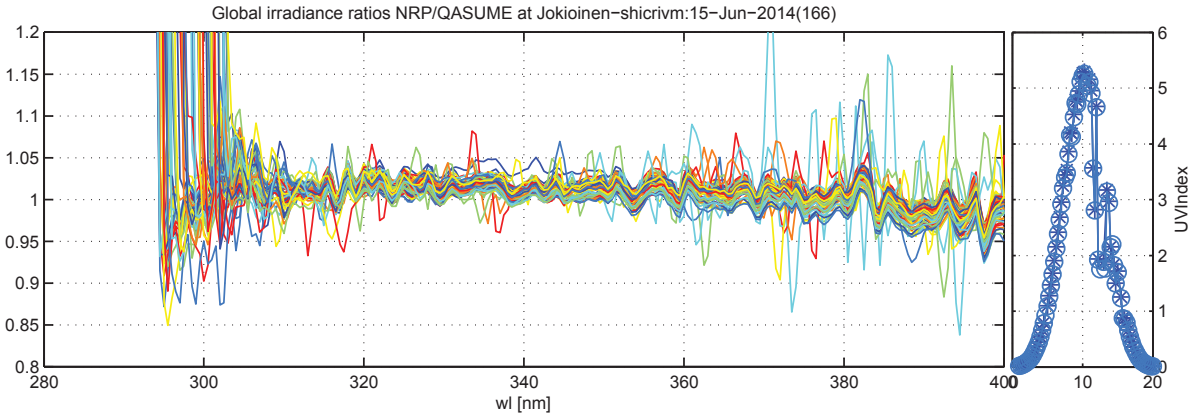

Mean ratio FIJ/QASUME at Jokioinen−shicrivm:14−Jun−2014(165) to 18−Jun−2014(169)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO FIJ/QASUME
NBSpectra=131
Wavelength [nm]

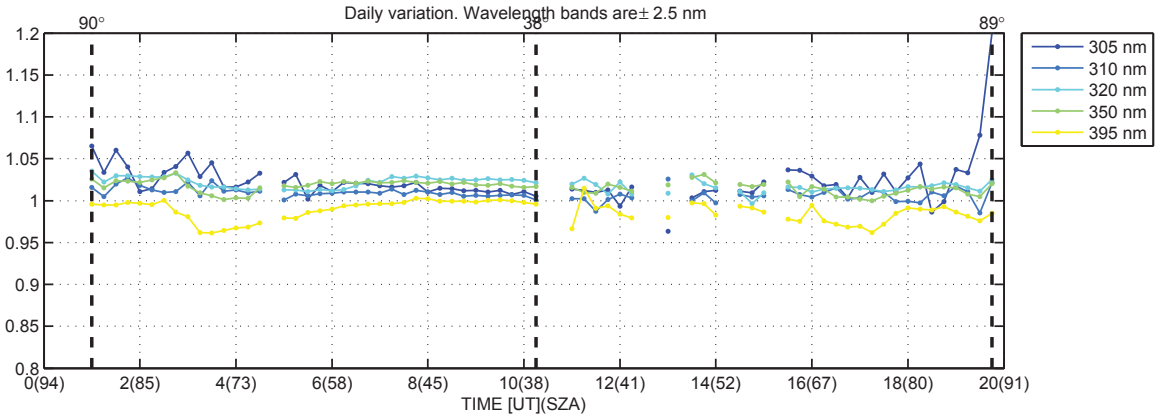

Jokioinen, FIJ, June 2014
MEAN
STD
SHICRivm wavelength shift [nm]
Wavelength [nm]

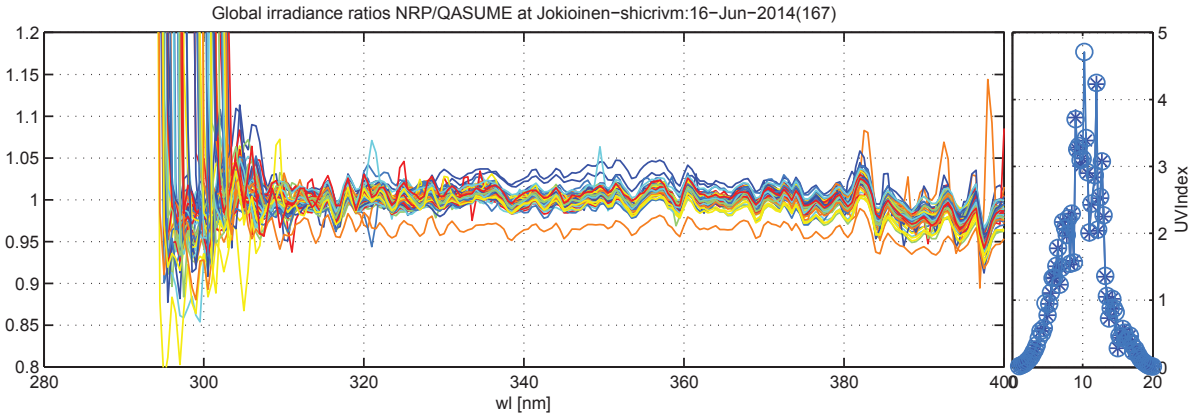

Global irradiance ratios NRP/QASUME at Jokioinen−shicrivm:14−Jun−2014(165) to 17−Jun−2014(168)
RATIO NRP/QASUME
TIME [UT] ON DAYS: [165 166 167 168]
305 nm
310 nm
320 nm
350 nm
395 nm
165
166
167
168

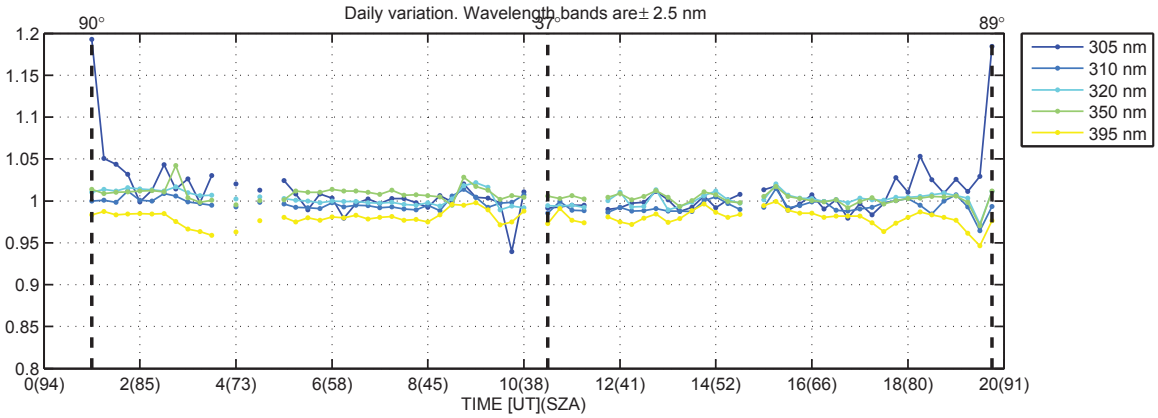

Global irradiance ratios NRP/QASUME at Jokioinen−shicrivm:14−Jun−2014(165)
wl [nm]
UVIndex

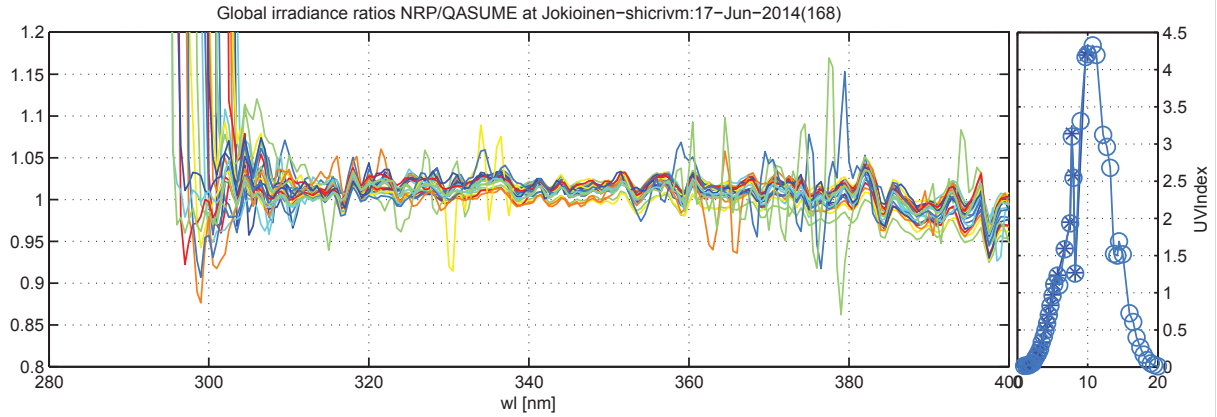

Daily variation. Wavelength bands are ± 2.5 nm
43°
89°
TIME [UT](SZA)
305 nm
310 nm
320 nm
350 nm
395 nm

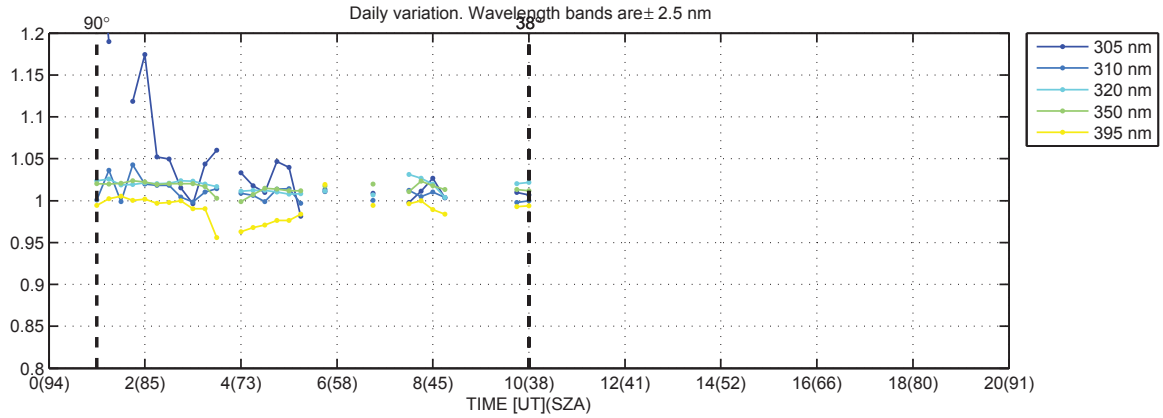

Global irradiance ratios NRP/QASUME at Jokioinen−shicrivm:15−Jun−2014(166)
wl [nm]
UVIndex

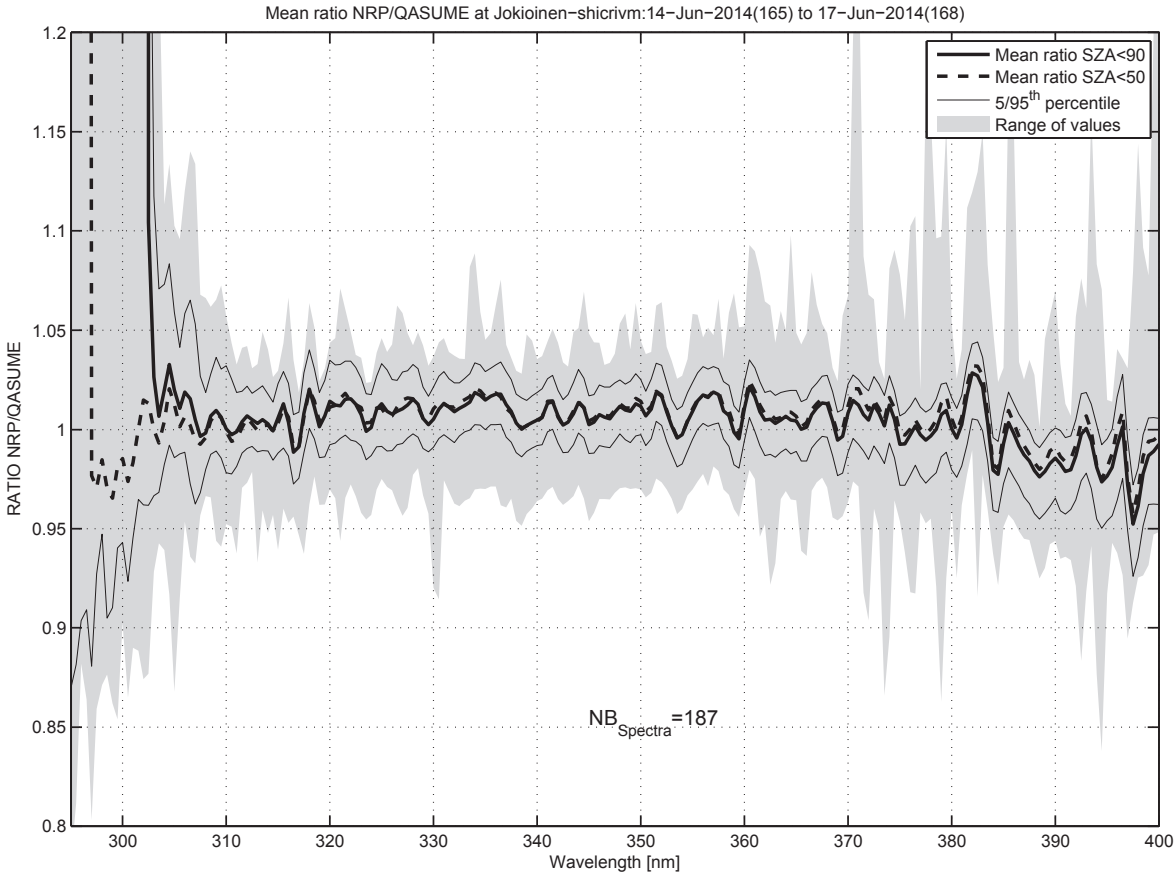

Daily variation. Wavelength bands are± 2.5 nm
90°
38°
89°
305 nm
310 nm
320 nm
350 nm
395 nm
0(94) 2(85) 4(73) 6(58) 8(45) 10(38) 12(41) 14(52) 16(67) 18(80) 20(91)
TIME [UT](SZA)

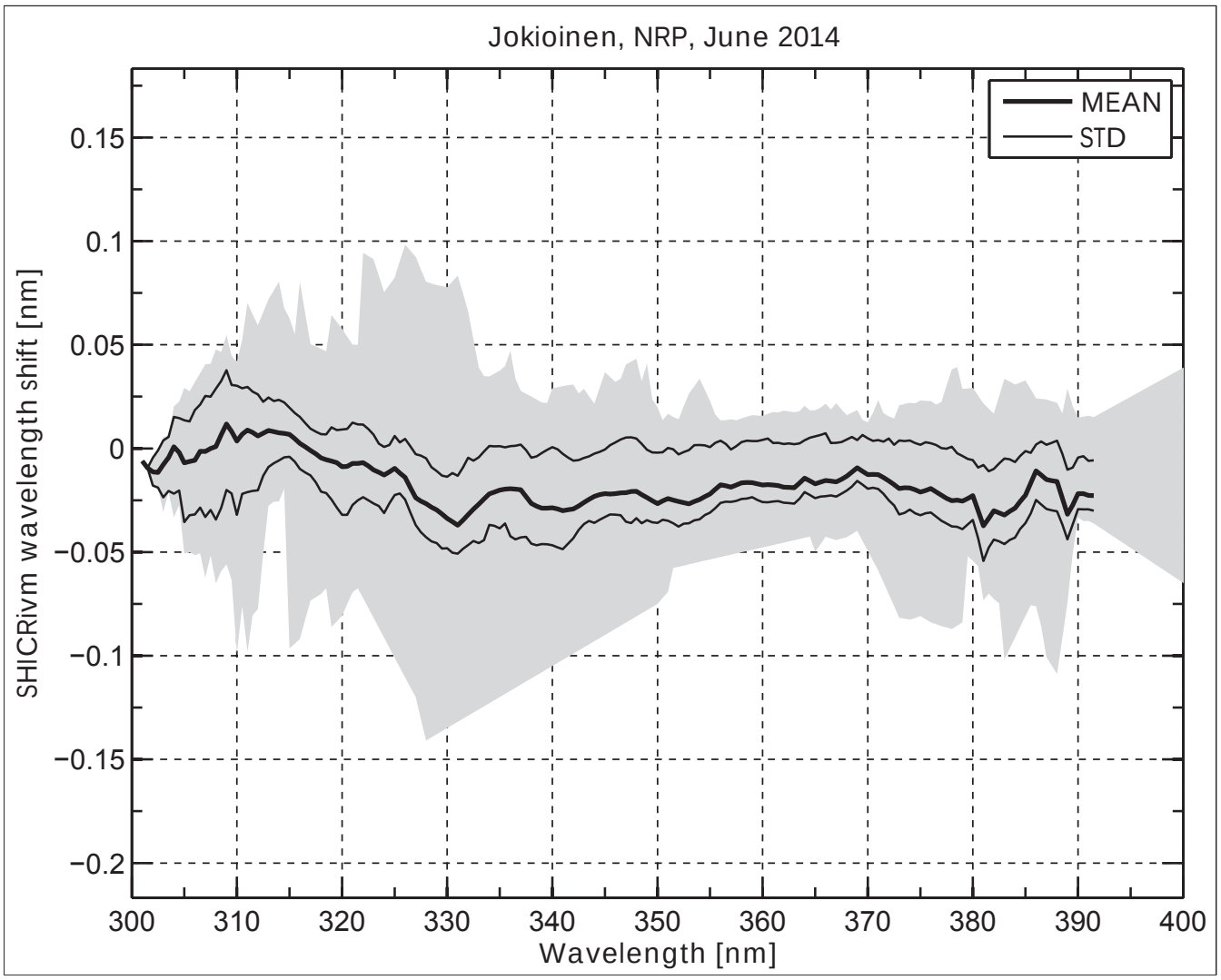

Global irradiance ratios NRP/QASUME at Jokioinen−shicrivm:16−Jun−2014(167)
wl [nm]
UVIndex

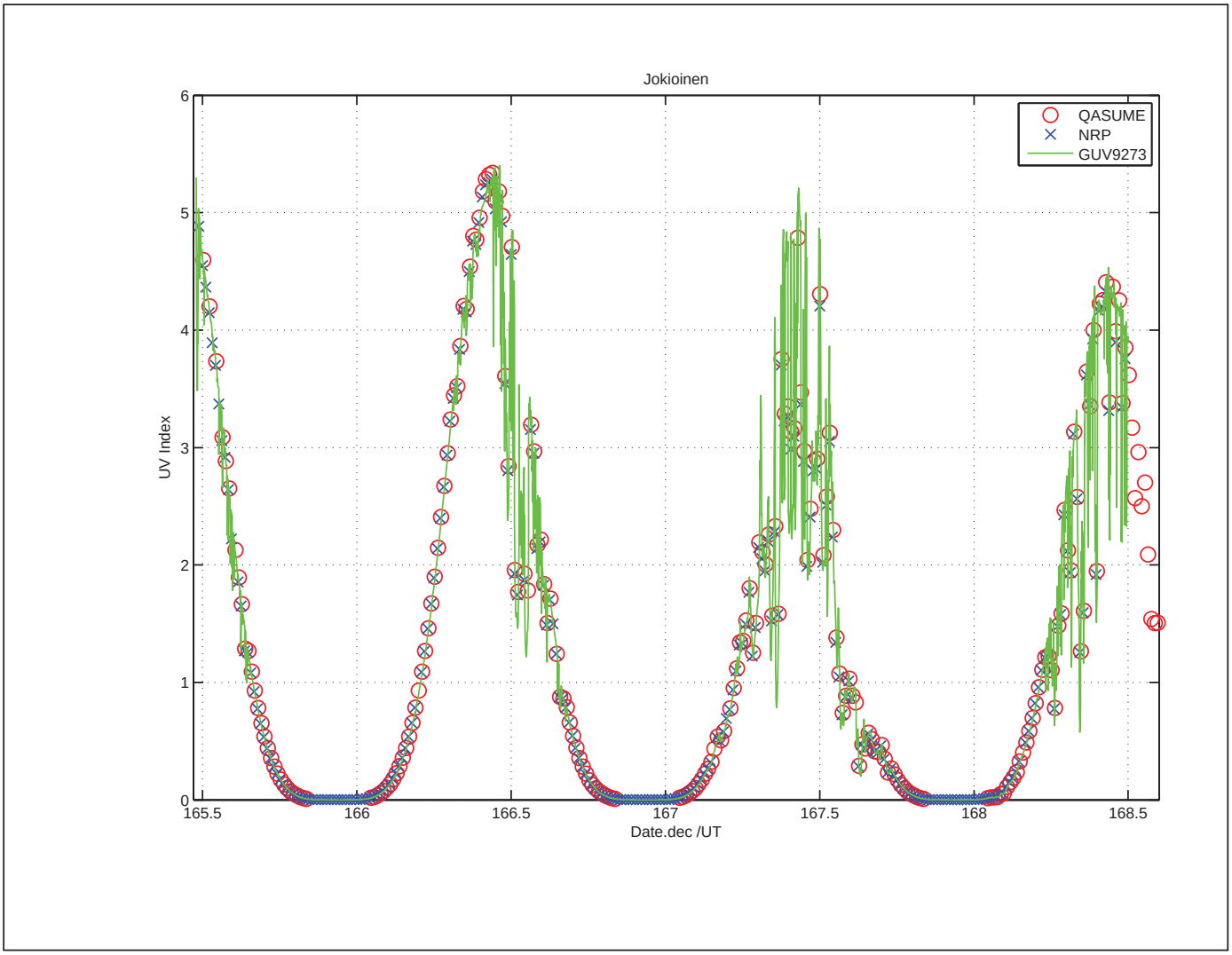

Daily variation. Wavelength bands are± 2.5 nm
90°
37°
89°
305 nm
310 nm
320 nm
350 nm
395 nm
0(94) 2(85) 4(73) 6(58) 8(45) 10(38) 12(41) 14(52) 16(66) 18(80) 20(91)
TIME [UT](SZA)

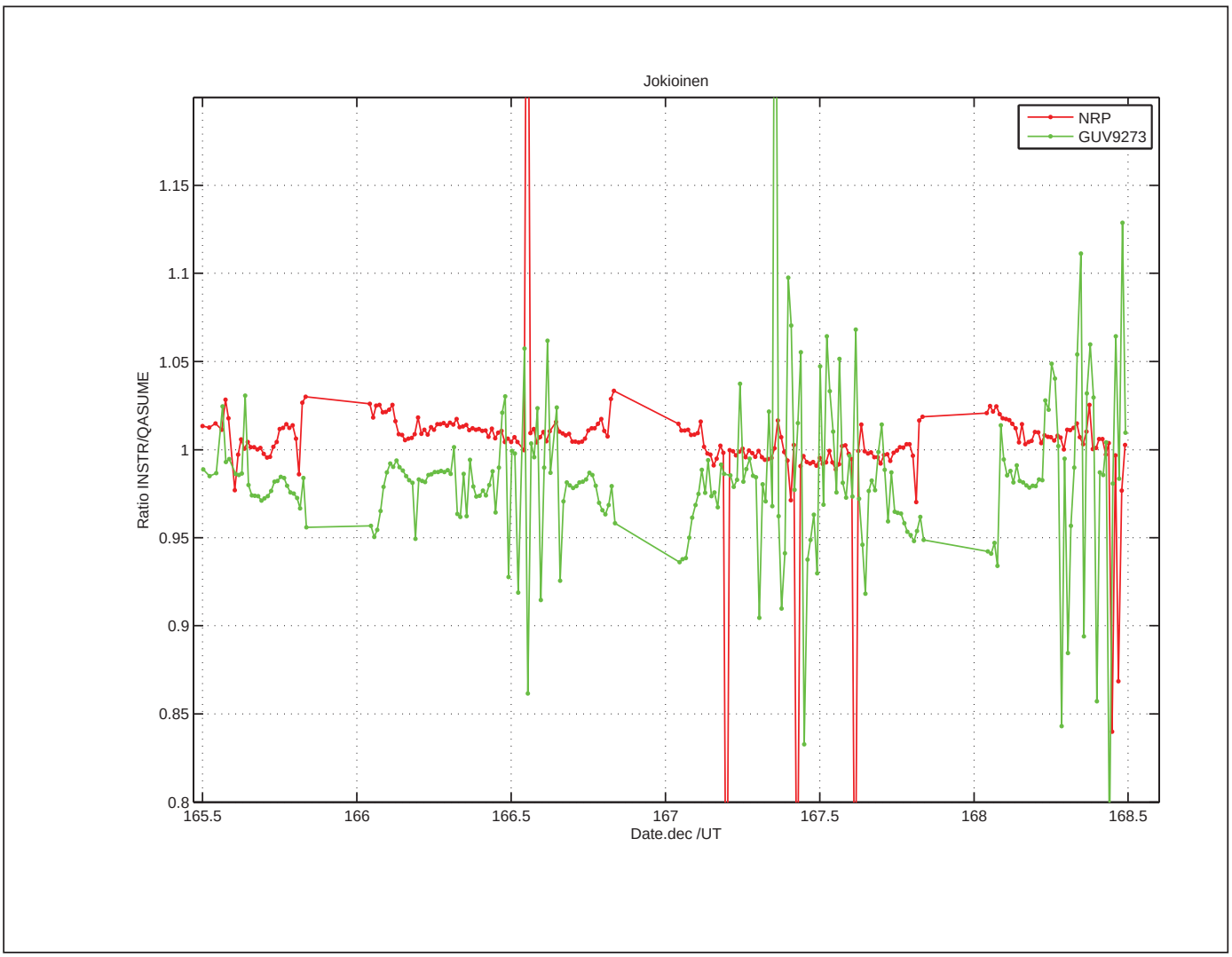

Global irradiance ratios NRP/QASUME at Jokioinen−shicrivm:17−Jun−2014(168)
wl [nm]
UVIndex

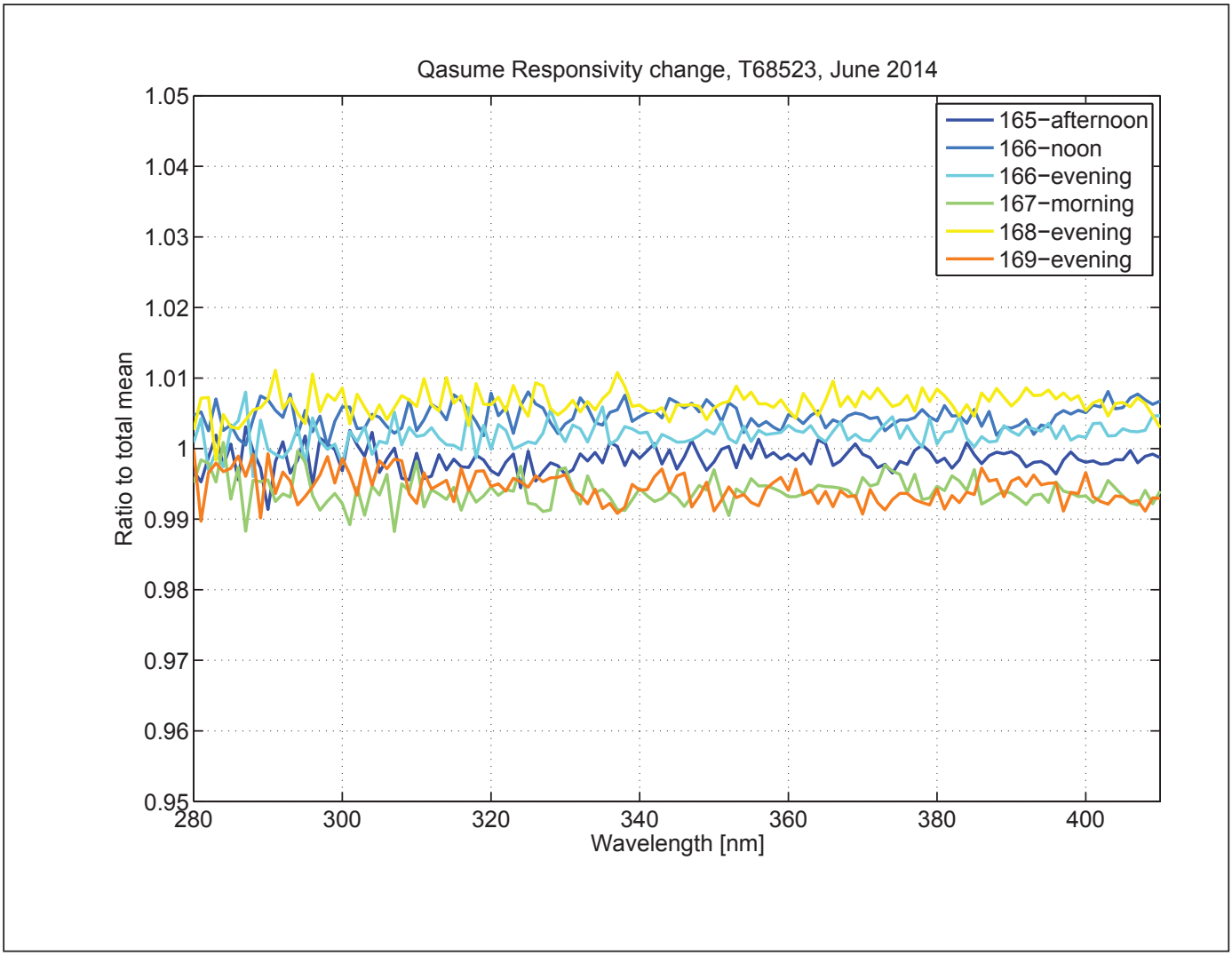

Daily variation. Wavelength bands are± 2.5 nm
90°
38°
305 nm
310 nm
320 nm
350 nm
395 nm
TIME [UT](SZA)

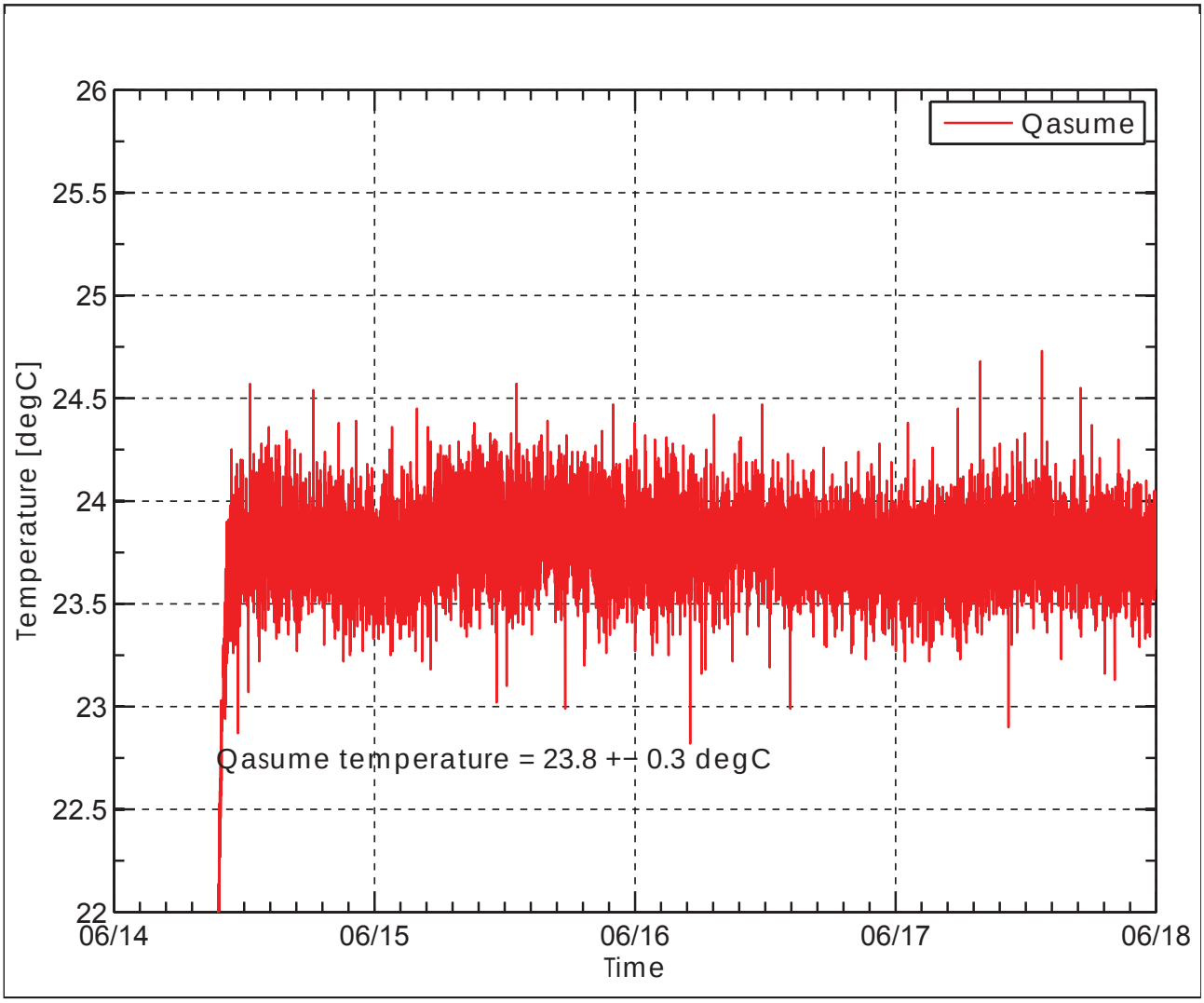

Mean ratio NRP/QASUME at Jokioinen−shicrivm:14−Jun−2014(165) to 17−Jun−2014(168)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO NRP/QASUME
NBSpectra=187
Wavelength [nm]

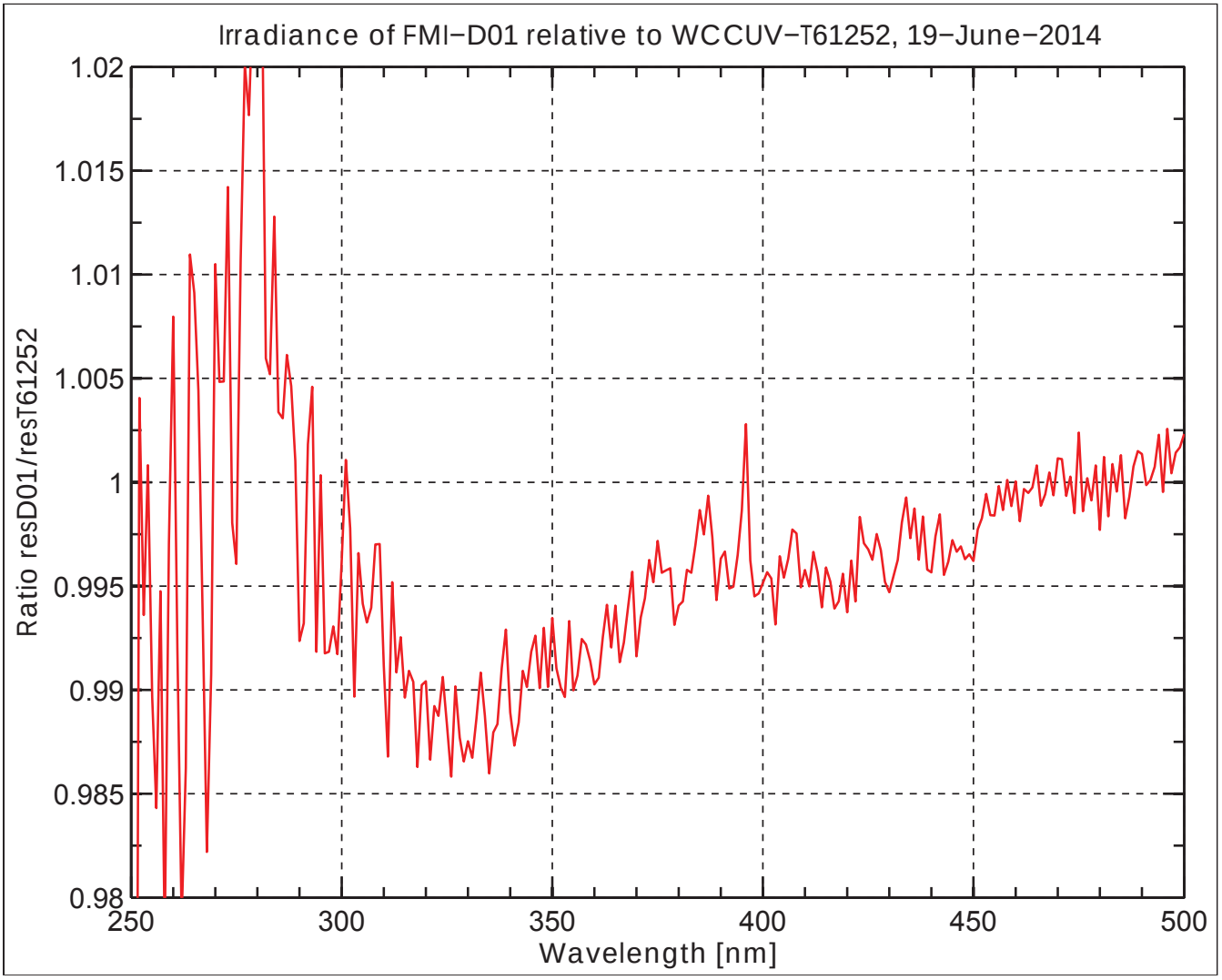

Jokioinen, NRP, June 2014
MEAN
STD
SHICRivm wavelength shift [nm]
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
300
310
320
330
340
350
360
370
380
390
400
Wavelength [nm]

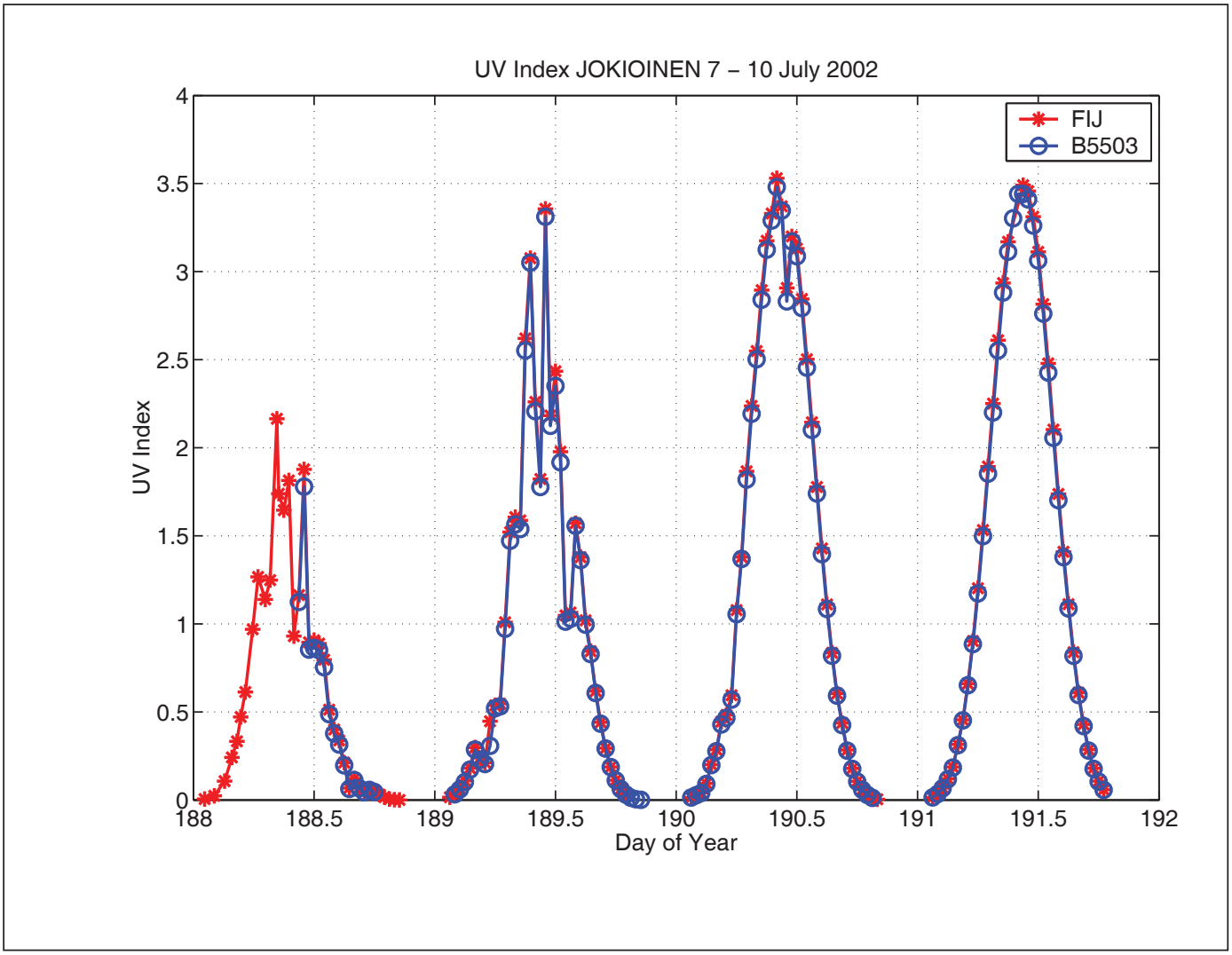

Jokioinen
QASUME
NRP
GUV9273
UV Index
Date.dec /UT
0
1
2
3
4
5
6
165.5
166
166.5
167
167.5
168
168.5

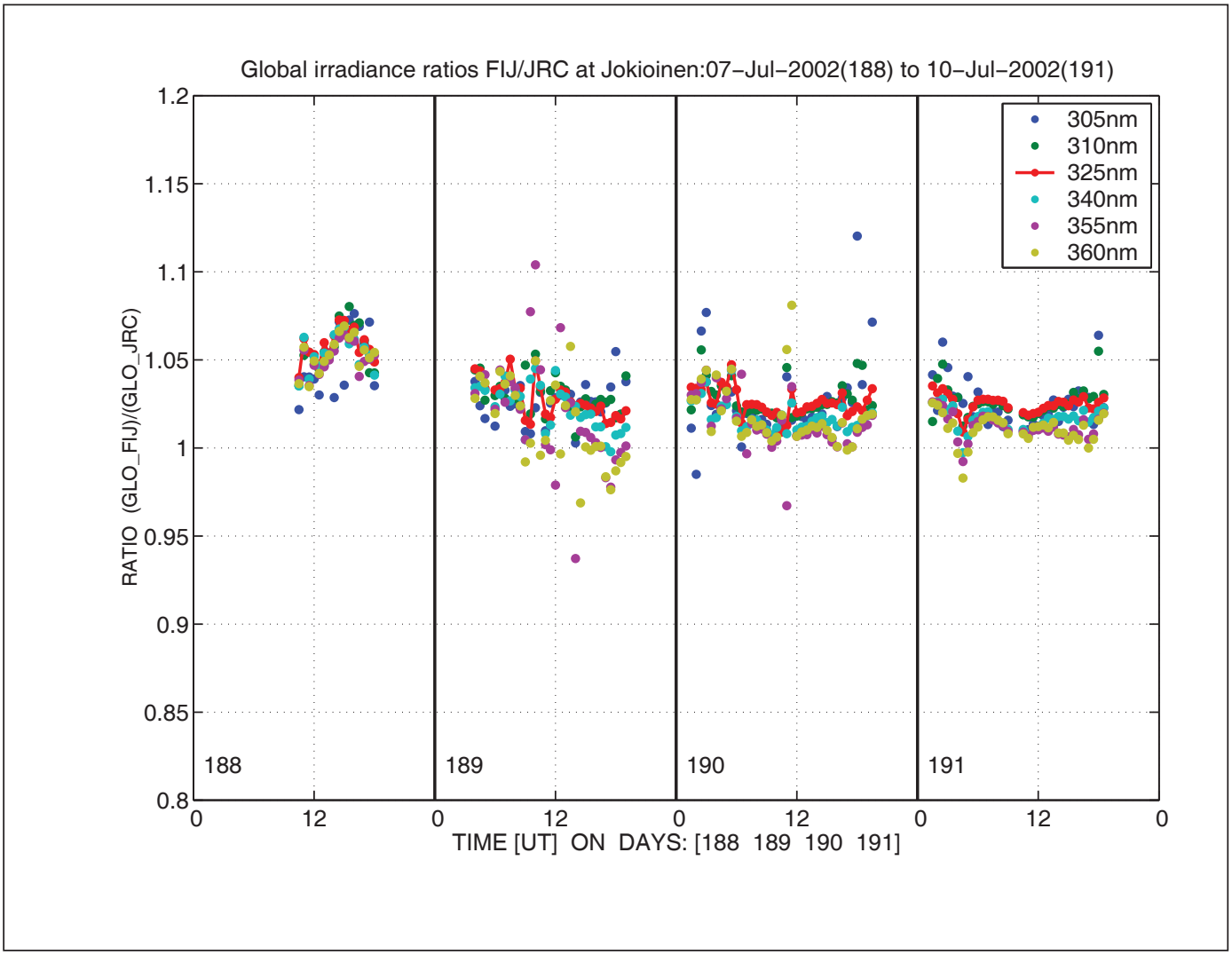

Jokioinen
NRP
GUV9273
Ratio INSTR/QASUME
Date.dec /UT
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
165.5
166
166.5
167
167.5
168
168.5

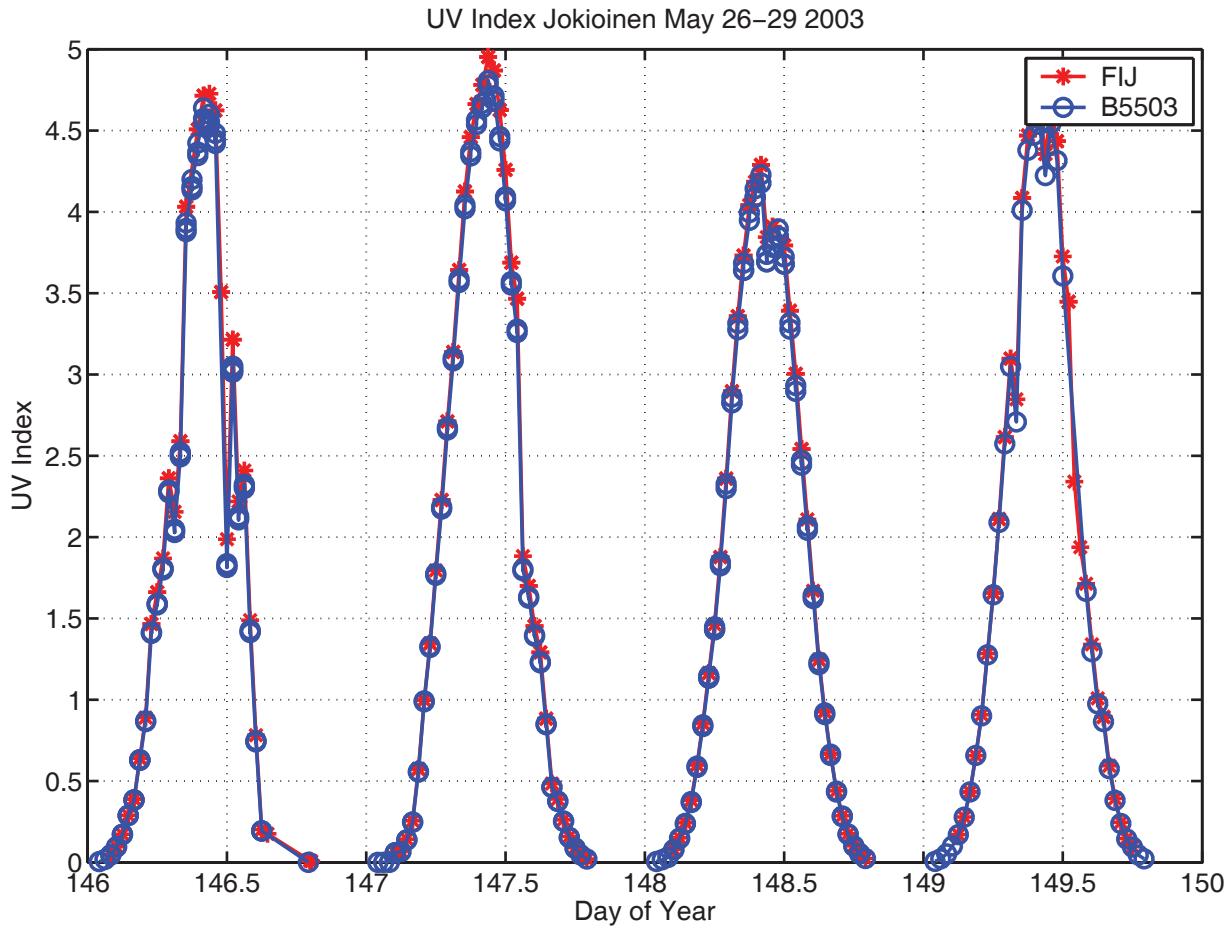

Qasume Responsivity change, T68523, June 2014
165−afternoon
166−noon
166−evening
167−morning
168−evening
169−evening
Ratio to total mean
Wavelength [nm]
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
280
300
320
340
360
380
400

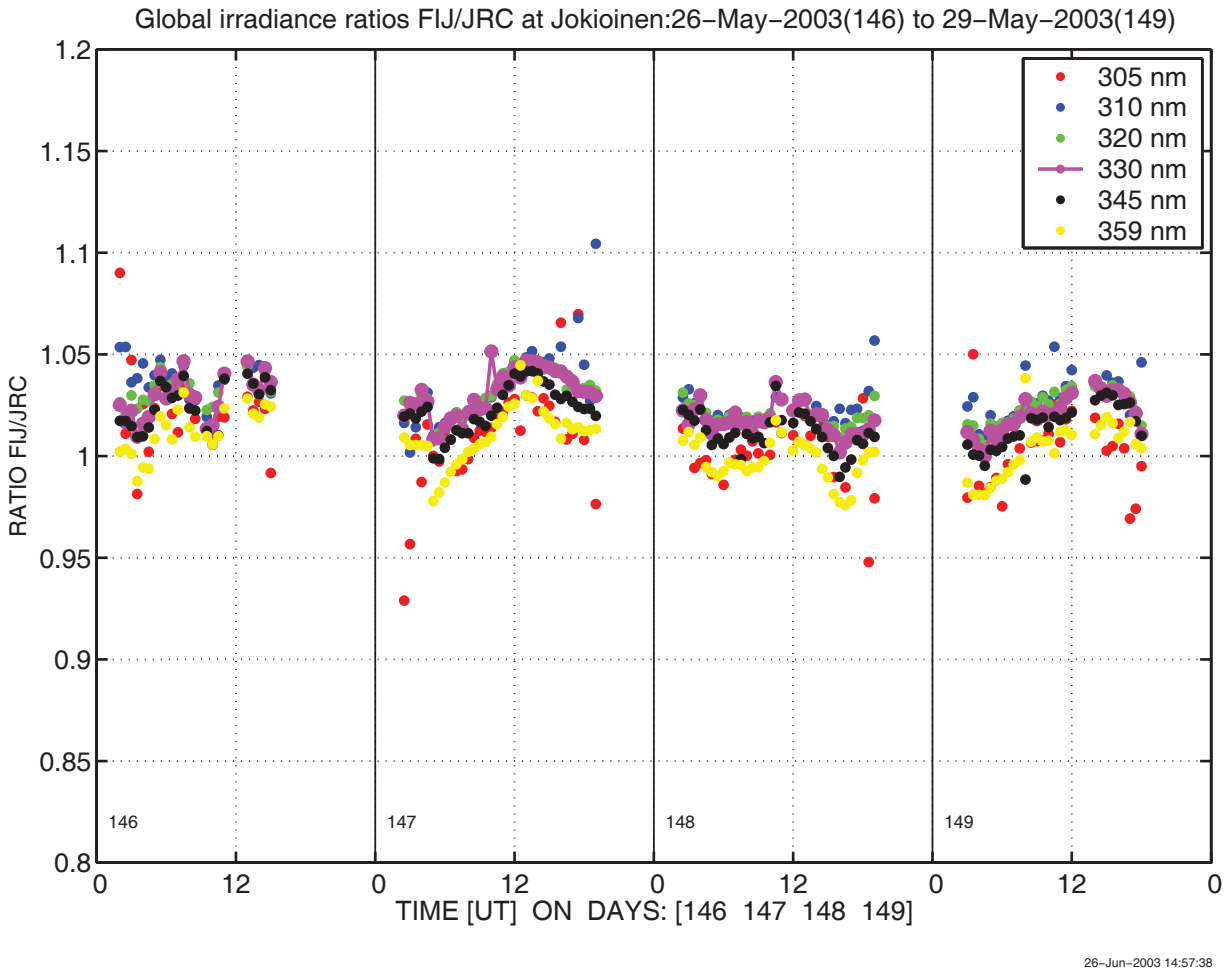

Qasume
Temperature [degC]
Time
Qasume temperature = 23.8 +− 0.3 degC
26
25.5
25
24.5
24
23.5
23
22.5
22
06/14
06/15
06/16
06/17
06/18

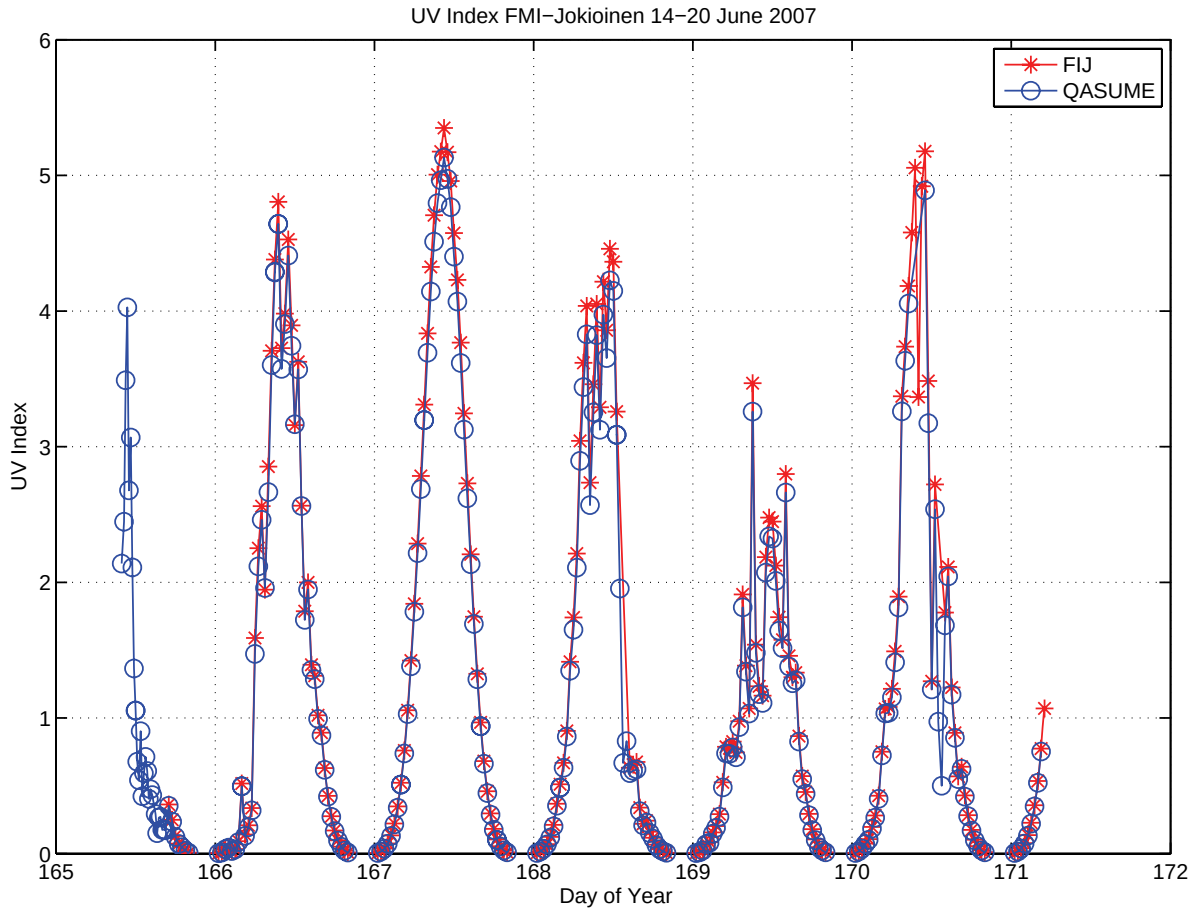

Irradiance of FMI−D01 relative to WCCUV−T61252, 19−June−2014
Ratio resD01/resT61252
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
250
300
350
400
450
500
Wavelength [nm]

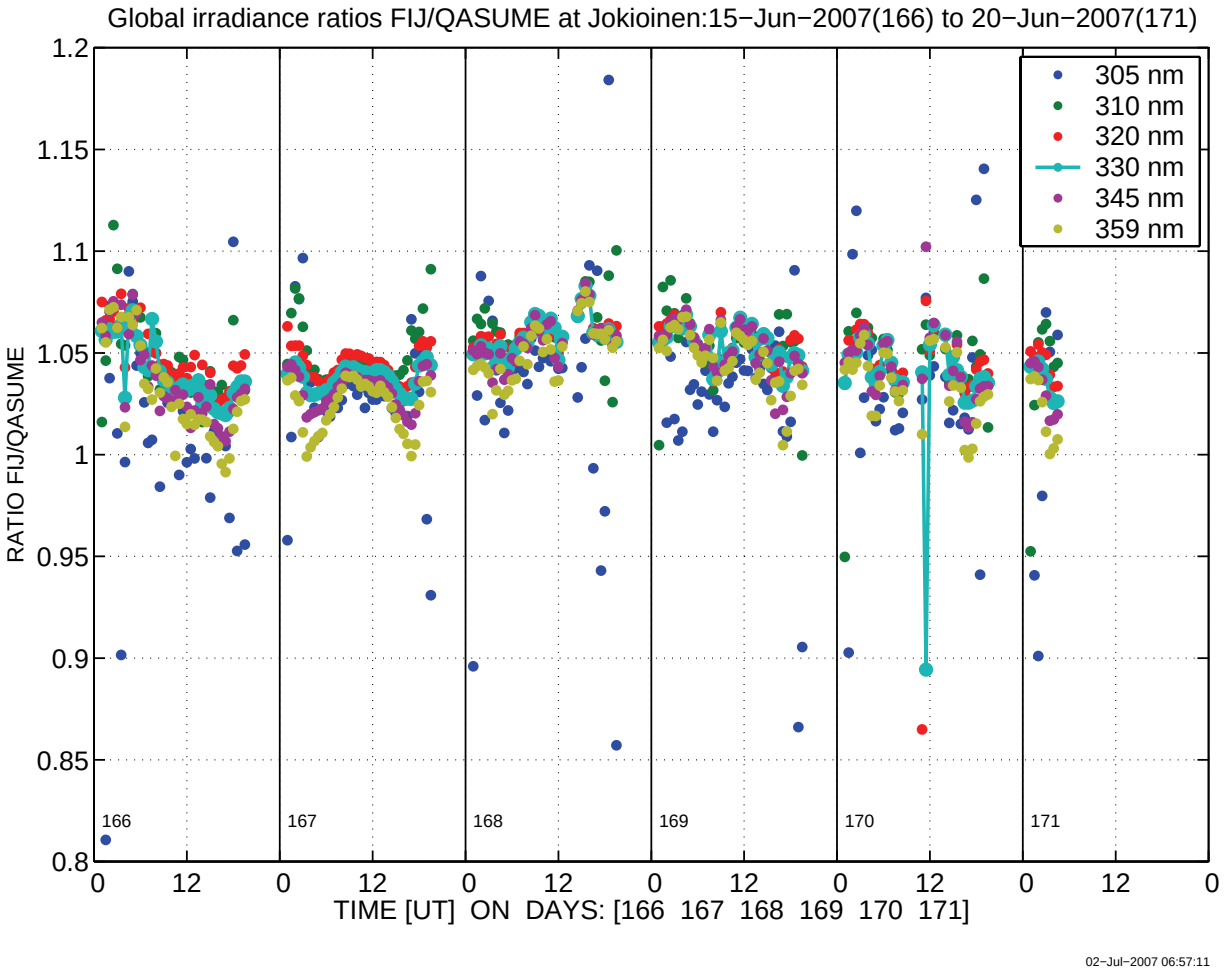

UV Index JOKIOINEN 7 – 10 July 2002
FIJ
B5503
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
188
188.5
189
189.5
190
190.5
191
191.5
192

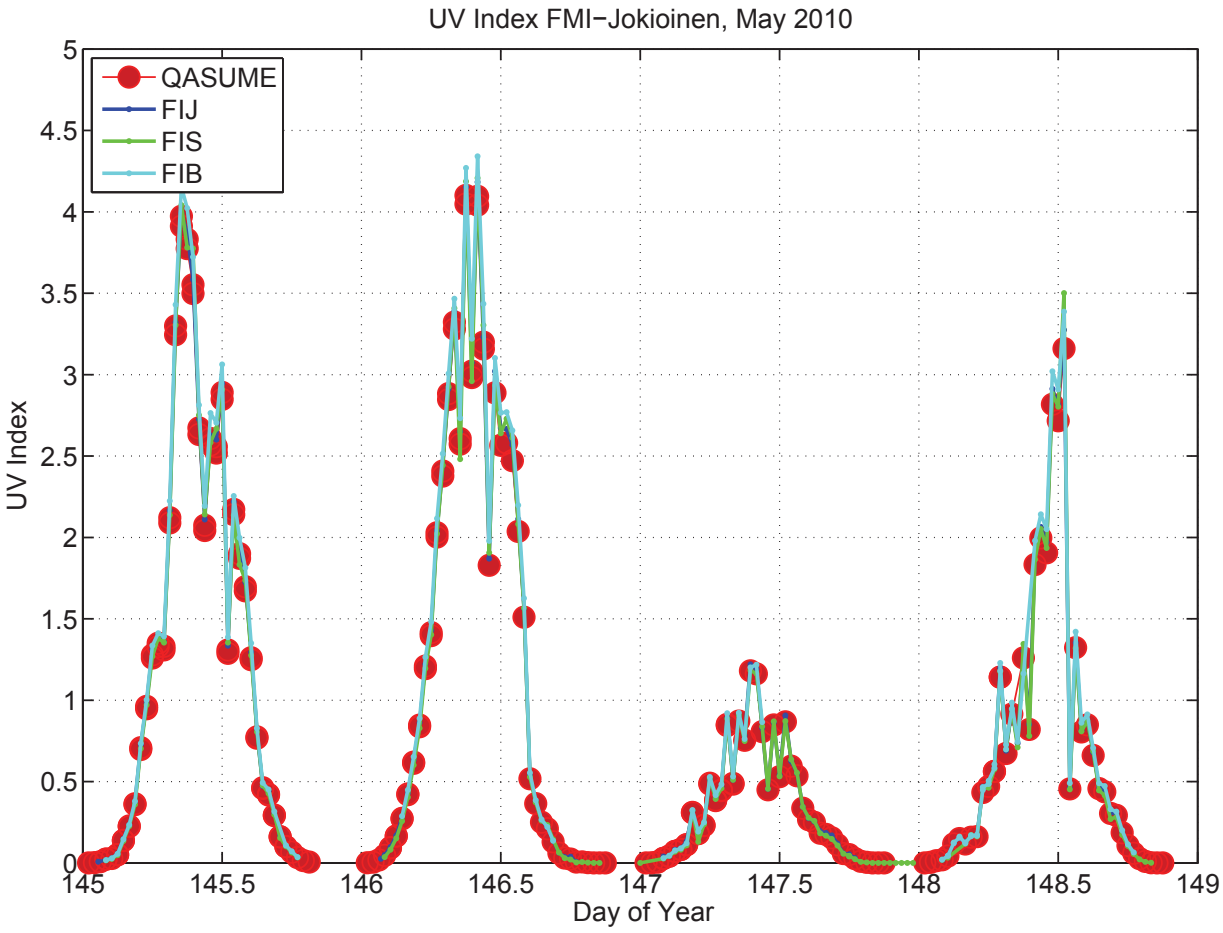

Global irradiance ratios FIJ/JRC at Jokioinen:07–Jul–2002(188) to 10–Jul–2002(191)
305nm
310nm
325nm
340nm
355nm
360nm
RATIO (GLO_FIJ)/(GLO_JRC)
TIME [UT] ON DAYS: [188 189 190 191]
188
189
190
191
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
0
12

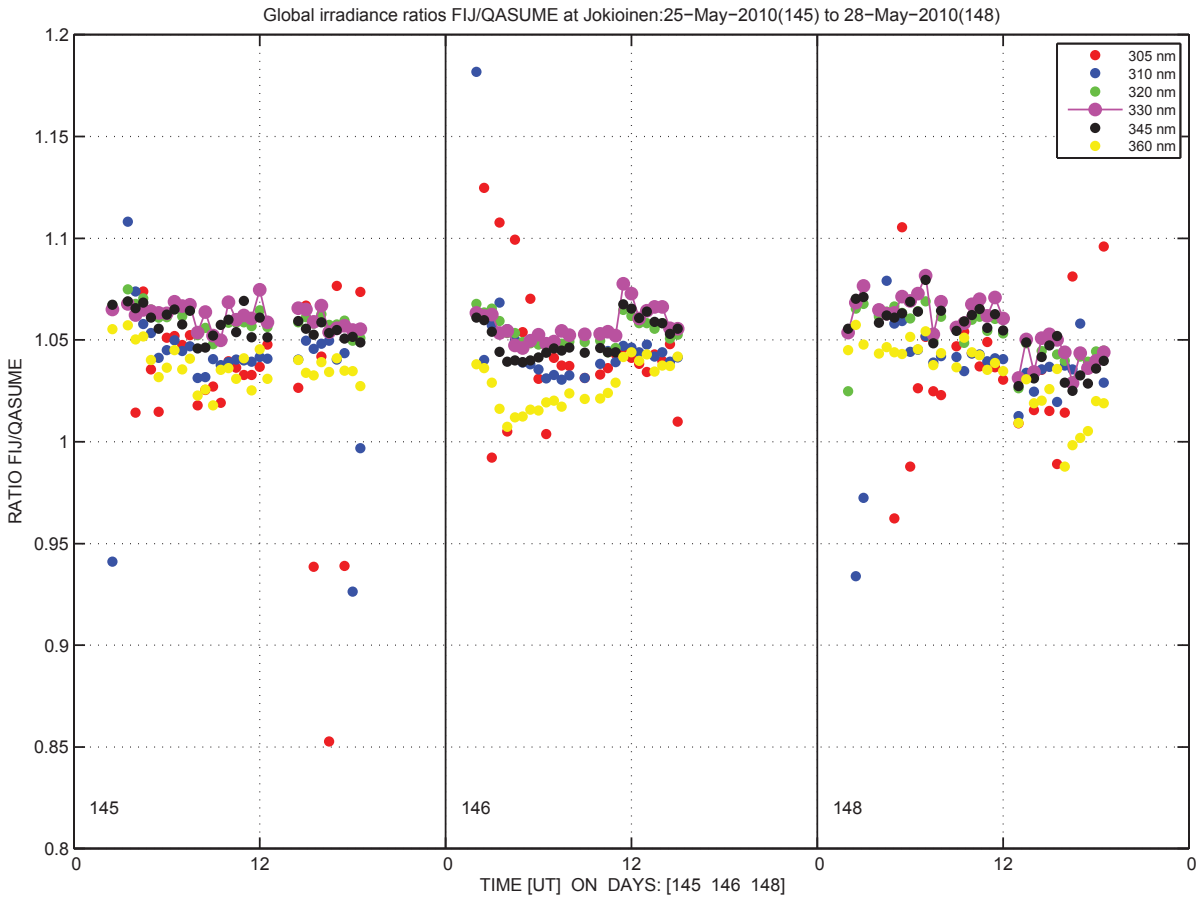

UV Index Jokioinen May 26–29 2003
FIJ
B5503
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
146
146.5
147
147.5
148
148.5
149
149.5
150

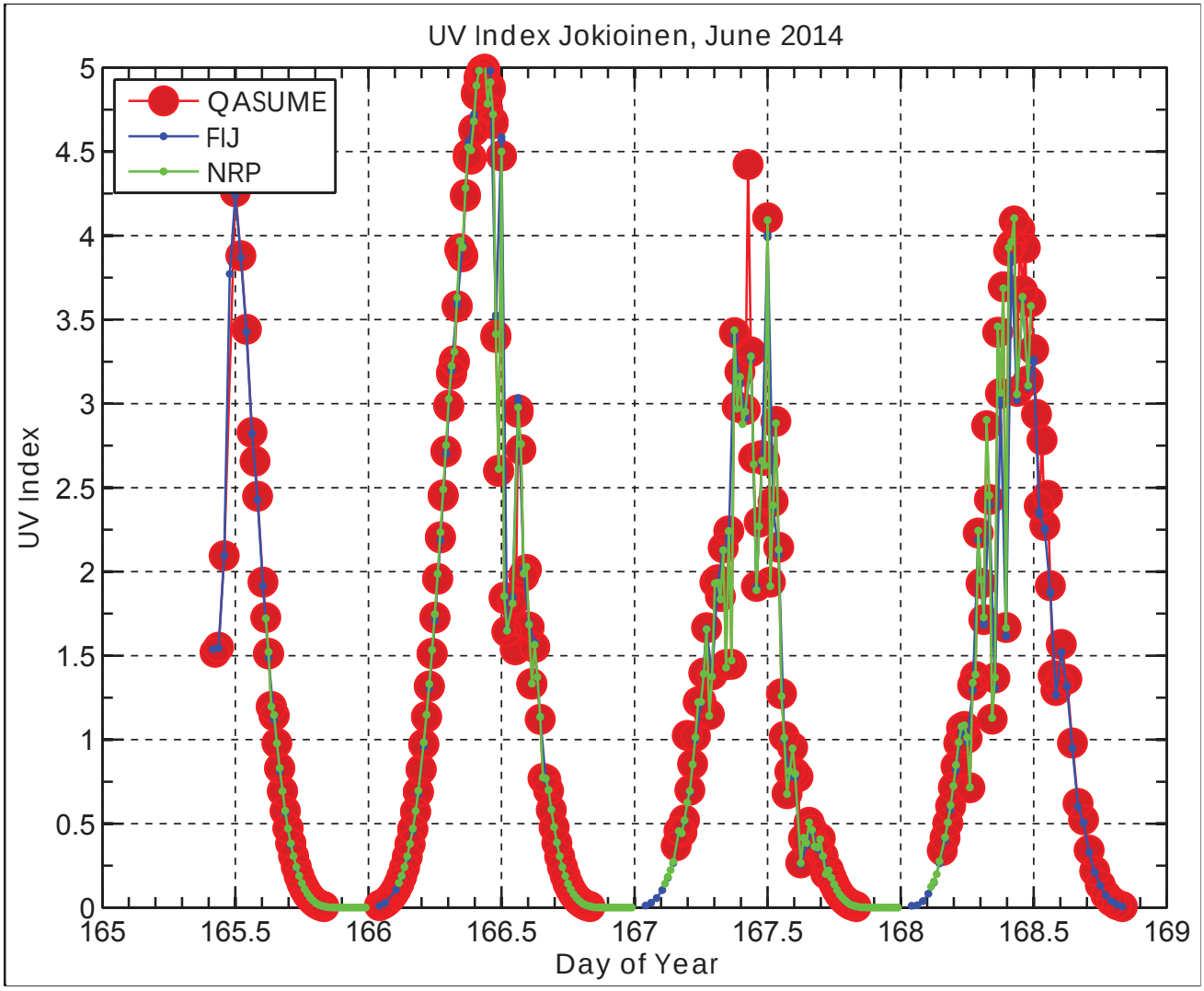

Global irradiance ratios FIJ/JRC at Jokioinen:26–May–2003(146) to 29–May–2003(149)
305 nm
310 nm
320 nm
330 nm
345 nm
359 nm
RATIO FIJ/JRC
TIME [UT] ON DAYS: [146 147 148 149]
146
147
148
149
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
0
12
26–Jun–2003 14:57:38

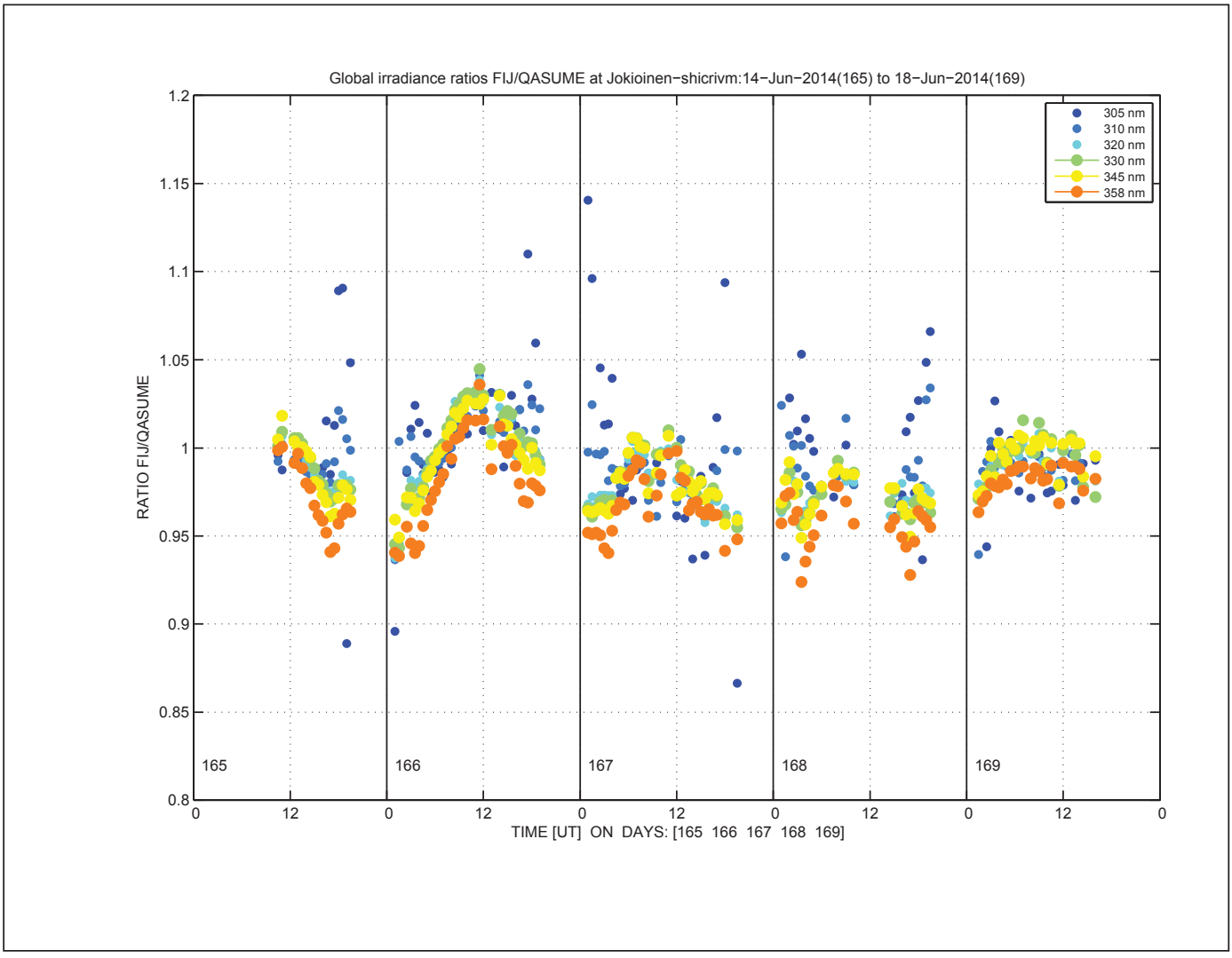

UV Index FMI−Jokioinen 14−20 June 2007
FIJ
QASUME
UV Index
Day of Year
0
1
2
3
4
5
6
165
166
167
168
169
170
171
172

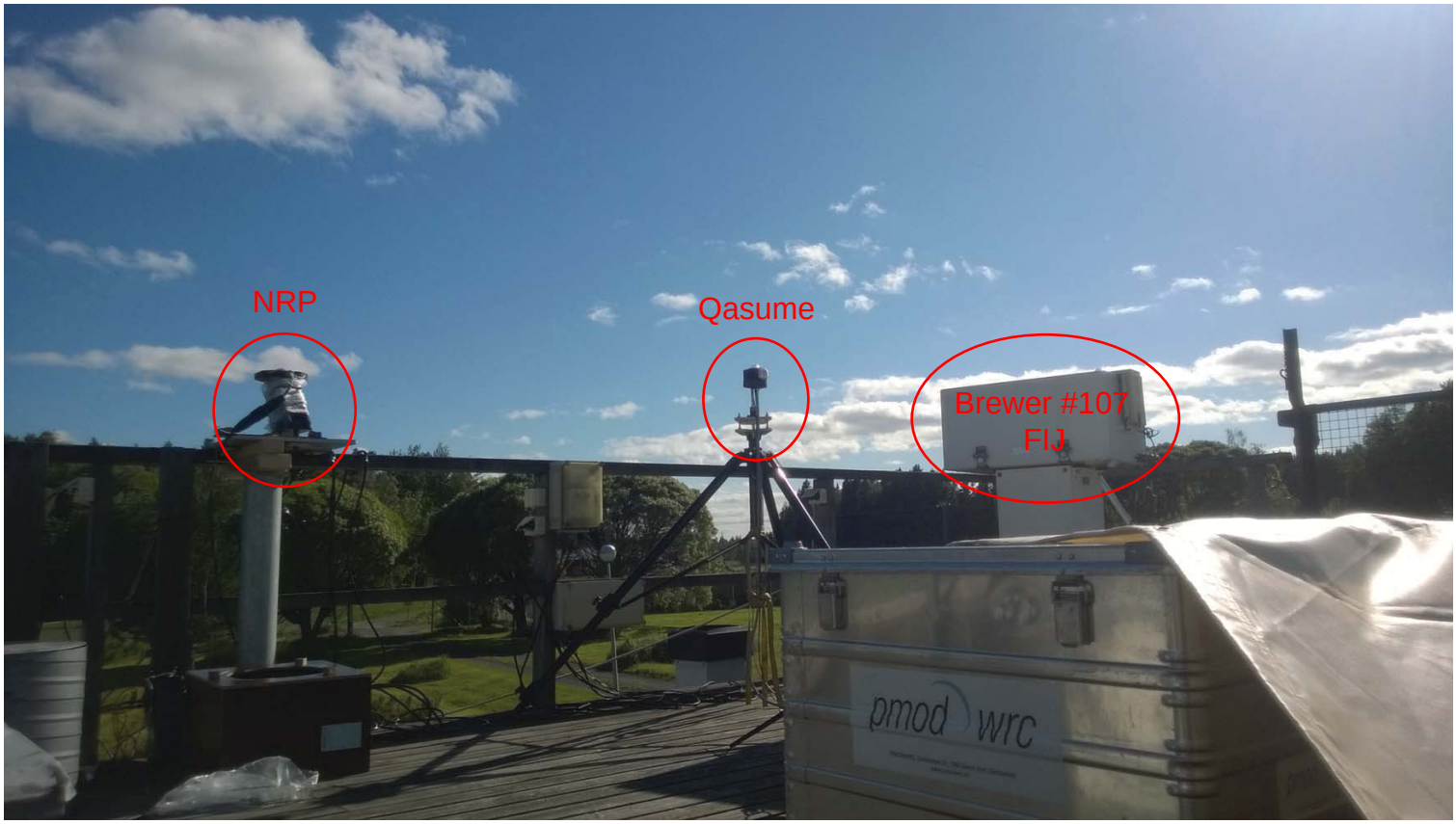

Global irradiance ratios FIJ/QASUME at Jokioinen:15−Jun−2007(166) to 20−Jun−2007(171)
305 nm
310 nm
320 nm
330 nm
345 nm
359 nm
RATIO FIJ/QASUME
TIME [UT] ON DAYS: [166 167 168 169 170 171]
166
167
168
169
170
171
02−Jul−2007 06:57:11

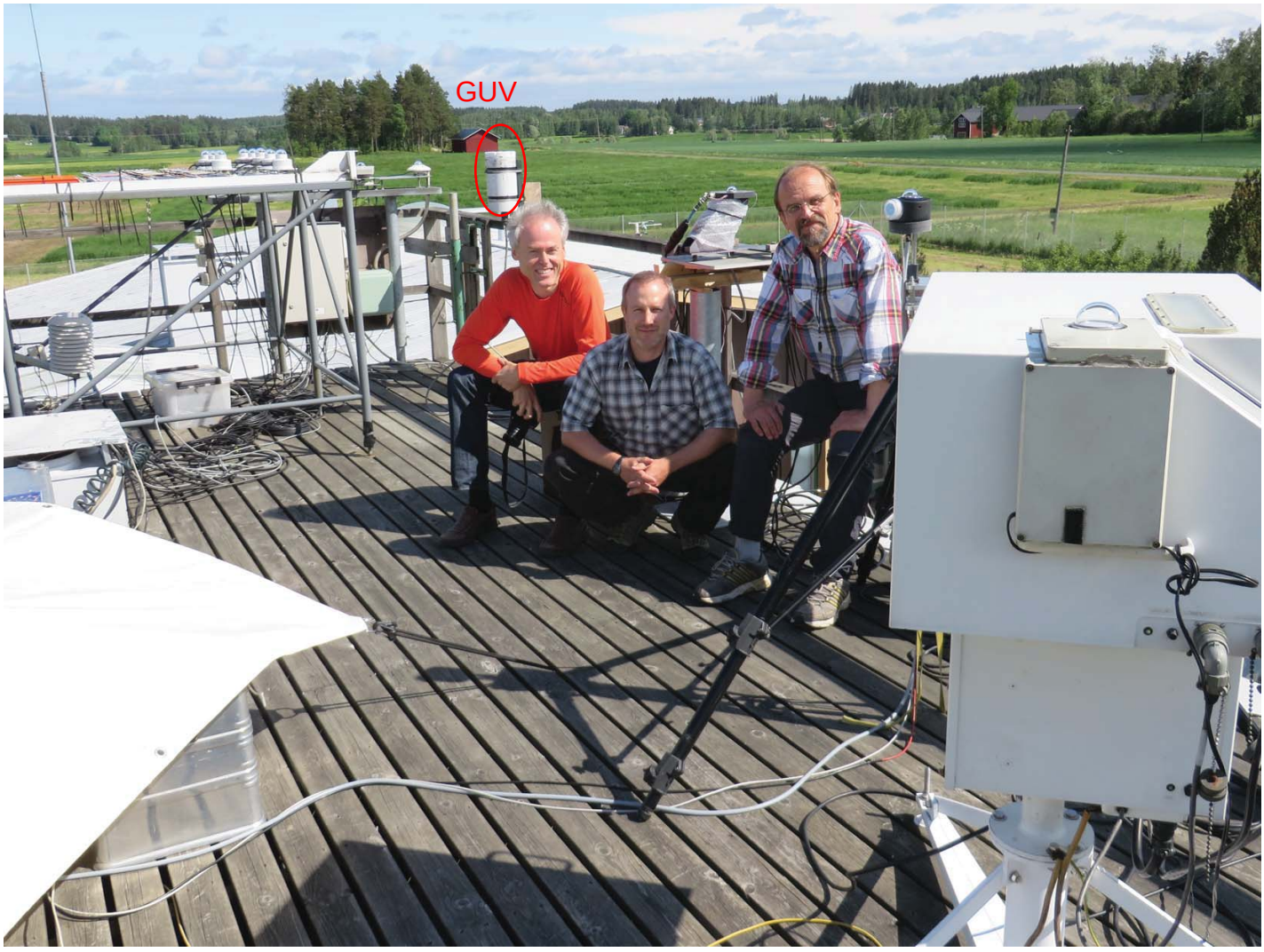

UV Index FMI−Jokioinen, May 2010
QASUME
FIJ
FIS
FIB
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
145
145.5
146
146.5
147
147.5
148
148.5
149


Global irradiance ratios FIJ/QASUME at Jokioinen:25−May−2010(145) to 28−May−2010(148)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
RATIO FIJ/QASUME
TIME [UT] ON DAYS: [145 146 148]
145
146
148
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
0
12


UV Index Jokioinen, June 2014
QASUME
FIJ
NRP
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
165
165.5
166
166.5
167
167.5
168
168.5
169


Global irradiance ratios FIJ/QASUME at Jokioinen-shicrivm:14-Jun-2014(165) to 18-Jun-2014(169)
305 nm
310 nm
320 nm
330 nm
345 nm
358 nm
RATIO FIJ/QASUME
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
165
166
167
168
169
0
12
TIME [UT] ON DAYS: [165 166 167 168 169]


NRP
Qasume
Brewer #107
FIJ
pmod wrc


GUV