Scientific Report for STSM 726-03:

Spectral UV measurements during the broadband intercomparison at PMOD

by

Mario Blumthaler,

Division for Biomedical Physics, Innsbruck Medical University

Within WG4 of the COST action 726 a campaign for characterisation, calibration and intercomparison of erythemal broadband radiometers was carried out at the PMOD during August 2006. This intercomparison contains characterisation of the detectors in the laboratory of PMOD as well as operation of the detectors outdoors for several days. For the absolute calibration of the detectors in front of the sun the comparison with high resolution spectral measurements is necessary. During this calibration the QASUME spectrometer of PMOD as well as the spectroradiometer of the research group in Innsbruck provided the absolute reference for the broadband detectors.

The spectroradiometer of the Division for Biomedical Physics, Innsbruck Medical University, is a Bentham DTM 300 double monochromator. The entrance optics for measurements of global irradiance is especially shaped to follow as closely as possible the cosine-law for the angular responsivity. It is connected with a 5 m quartz fibre to the entrance slit of the doublemonochromator. The full width at half maximum of the instrument is 0.95 nm. The doublemonochromator as well as the controlling electronic are housed in a closed box with a temperature stabilisation better than +-0.2°. The spectroradiometer is accompanied by 3 broadband detectors for total irradiance, UVA irradiance and erythemally weighted UV irradiance, which are used for continuous quality control of the spectroradiometer.

This instrumentation was transported by car from Innsbruck to the observatory in Davos on 07.08.2006 and set up in the loft. The quartz fibre with the global input optics and the broadband detectors were mounted on the roof, so that they had an almost undisturbed field of view, just aside the input optics of the spectroradiometer of PMOD. After one day of stabilisation of the spectroradiometer, an absolute calibration was carried out, using a portable lamp system with a calibrated 250 W halogen lamp and a computer controlled power supply.

In order to compare the sources of calibration between the 2 spectroradiometers, the Innsbruck spectroradiometer was also measuring the reference lamp of PMOD and the PMOD instrument was measuring the reference lamp of Innsbruck. The result of this comparison was very promising; the difference between the 2 reference lamps was less than 1% for the whole wavelength range from 280 nm to 500 nm. This is by far within the given uncertainty limits of the calibration certificates of the two lamps, which are 3% for both lamps, for 95% confidence interval.

Starting with 09.08.2006, spectral measurements of global irradiance were carried out every 15 minutes. The routine schedule started every day at 04:45 UTC in the morning (solar elevation about 3°) and the last scan in the evening started at 18:00 UTC (solar elevation about 3°). Each scan covered the wavelength range from 290 nm to 400 nm with a step size of 0.25 nm. In order to make the results of the 2 spectroradiometers comparable even during time periods with changing cloudiness, the scans were carried out in a synchronous way, where both instruments started at the same time and made one step in wavelength every 1.2 seconds. Thus both instruments measured exactly at the same time the same wavelengths.

Unfortunately the weather conditions during the intercomparison were not very good, on several days precipitation occurred and only one day was at least partly cloud free with visibility of the direct sun during the most time of the day. On this day (15.08.2006), the Innsbruck instrument carried out in addition to the global measurements also spectral measurements of the direct sun. This is done with a second fibre, connected to the second input slit of the spectrometer and on the other end connected to a small telescope with a field of view of about 1.5°. This telescope is mounted on a suntracker, so that it follows the sun during the day. The direct sun measurements could be carried out between 09:30 and 12:30 UTC, while afterwards thin clouds covered the sun. Each direct sun scan covered the wavelengths from 290 nm to 450 nm with steps of 0.5 nm, and due to a fast scanning mode it was possible to make these additional measurements in the 6 minutes break between two global scans, thus not disturbing the routine operation of global scans every 15 minutes. From the direct sun spectra the aerosol optical depth and its wavelength dependency could be derived, as well as the total ozone amount. On this day, the aerosol optical depth at 352 nm varied between 0.12 and 0.15 and the Angstrom exponent characterising the wavelength dependency was around 1.05. The total ozone content was around 345 DU. All this information is important to carry out model calculations for correction of instruments with a poor angular response ('cosine error'). On this day, also a check of the calibration of the global

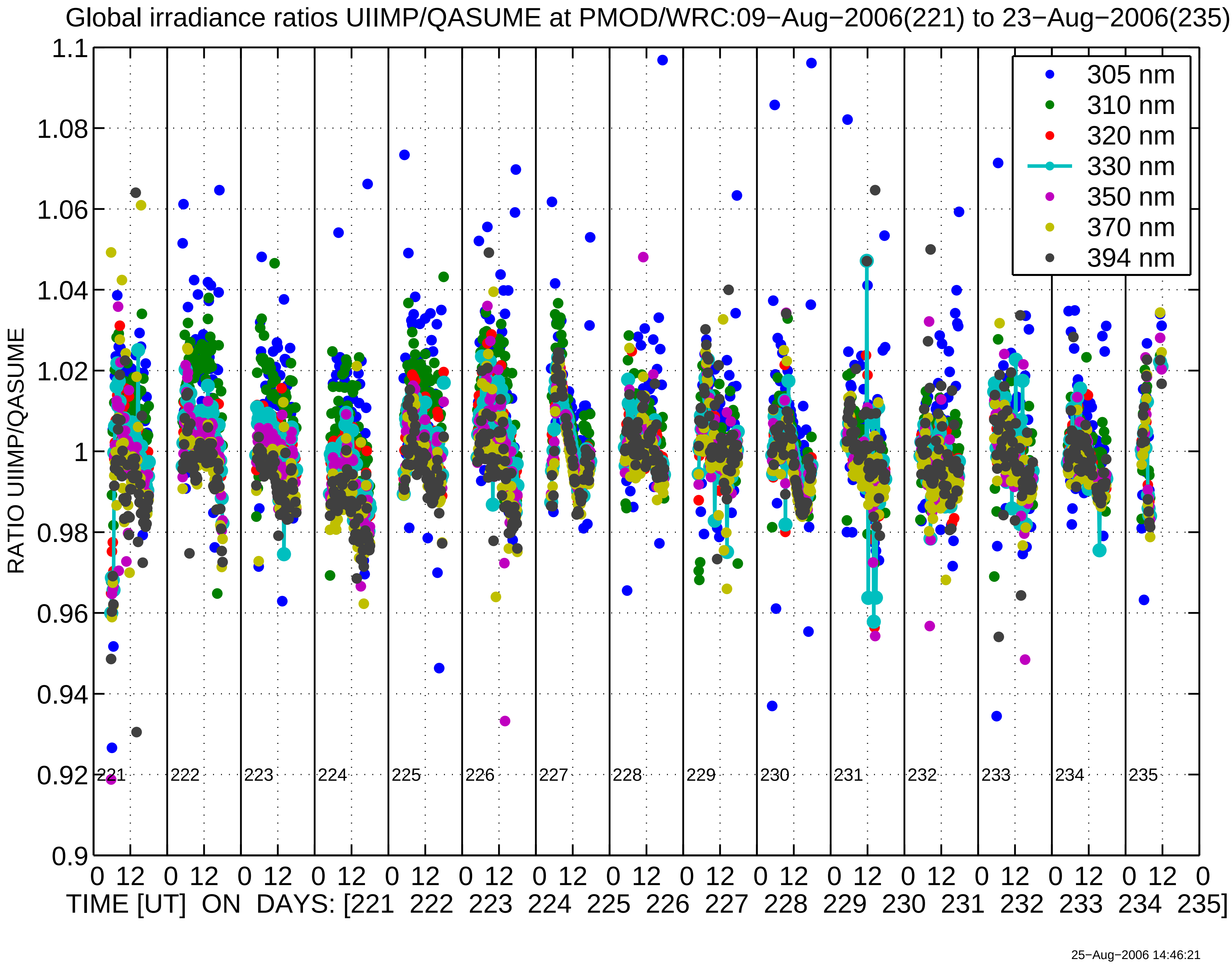
measurements with the reference lamp was carried out, as during the installation of the direct sun measurement setup some disturbance to the global input port occurred.
Due to the poor weather conditions the outdoor measurements were extended by almost one week. Therefore the last measurements with the spectroradiometer were carried out on 23.08.2006. Before the dismounting of the instrument a final check of the calibration with the reference lamp was carried out, showing no difference larger than 1% relative to the previous calibration. After this final check the whole setup was dismounted and transported back to Innsbruck by car.
In total 731 spectra of global solar irradiance were collected synchronously between the PMOD spectrometer and the Innsbruck spectrometer. Despite the poor and often very fast changing weather conditions, the data agree very well with an average ratio of 1.00 and 90% of the measurements show a deviation of less than +-2%. There is no spectral dependence in this ratio. This is a very good result, compared with previous spectroradiometer intercomparison campaigns, where an average agreement on the 5% level was a good result. In the appendix the graphs of the intercomparison of the two spectrometer systems are shown in the way as the QASUME instrument operated during its usual application as a travelling reference instrument.

In conclusion, the aim of this STSM was to assure the quality of the spectral measurements for the calibration of the broadband detectors and this aim could be completely achieved.

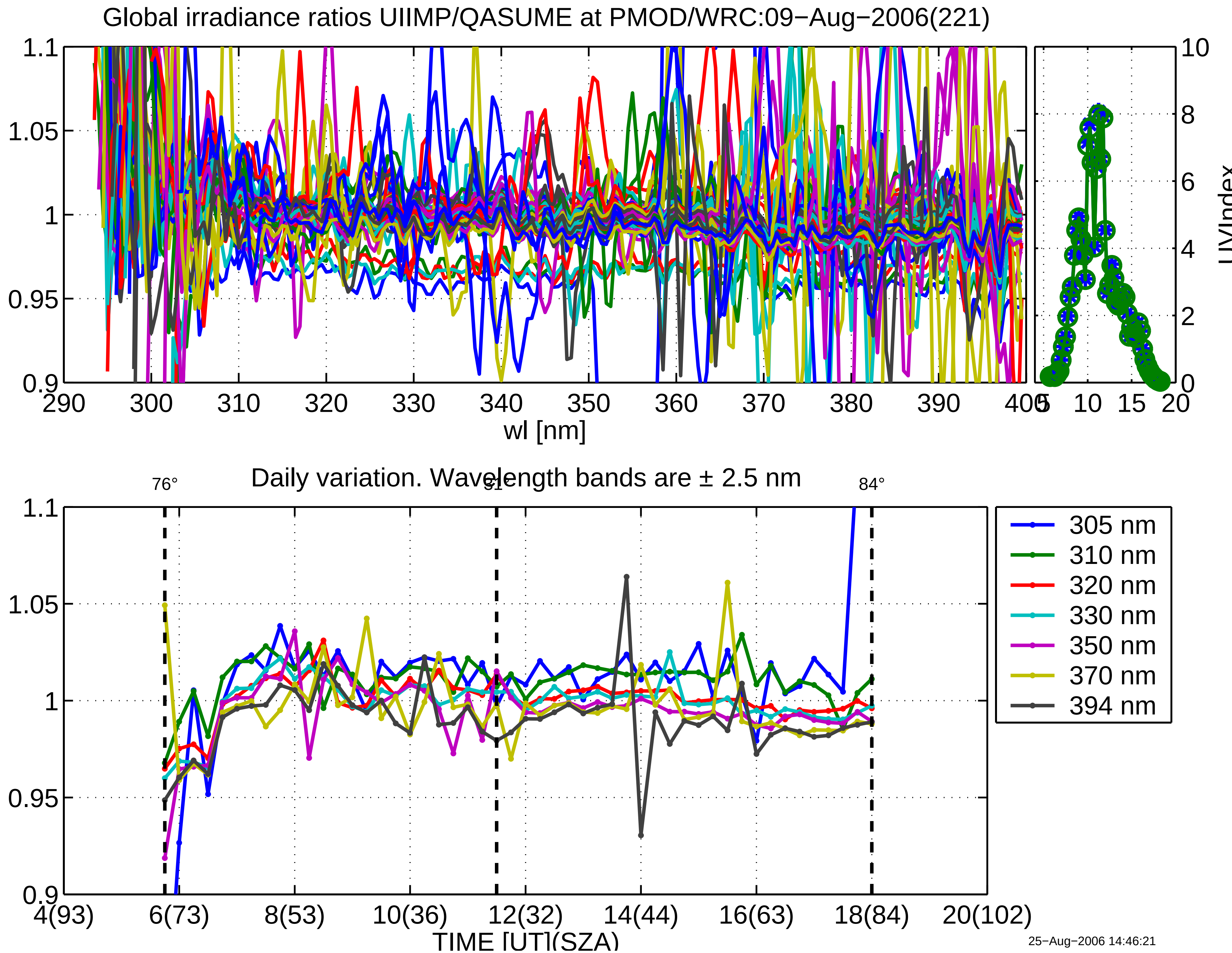
Innsbruck, 04.09.2006

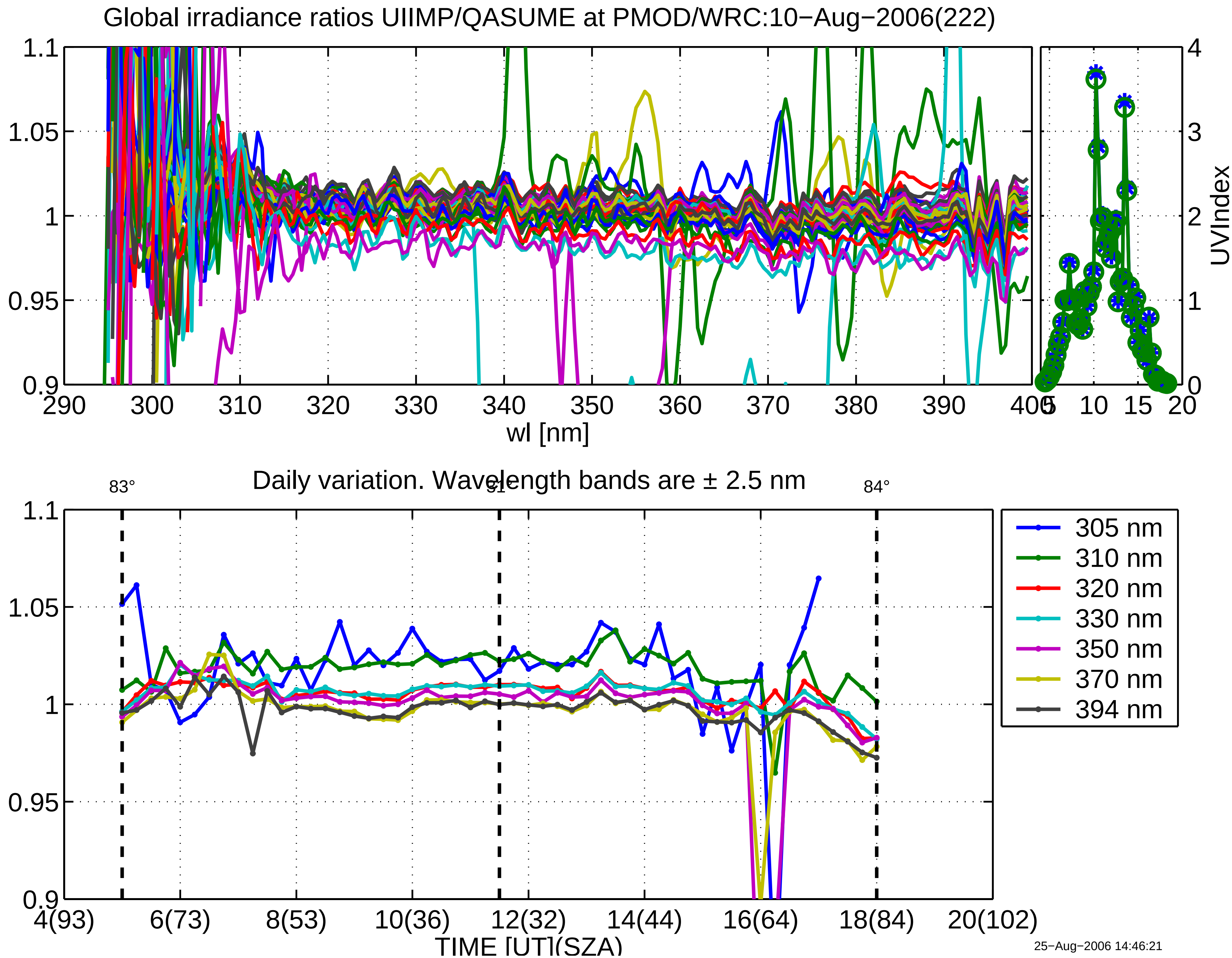
Blumthaler

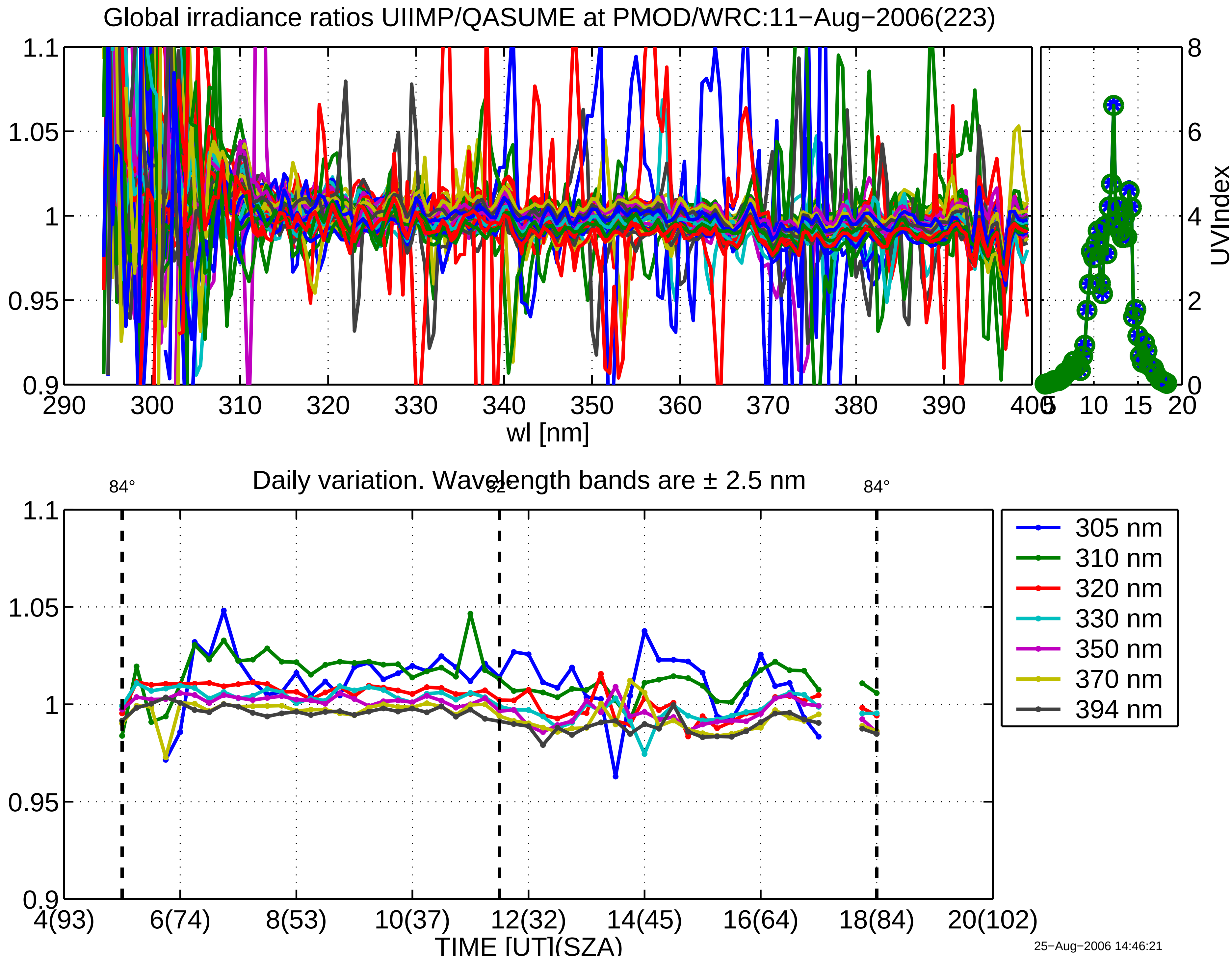
Mario Blumthaler



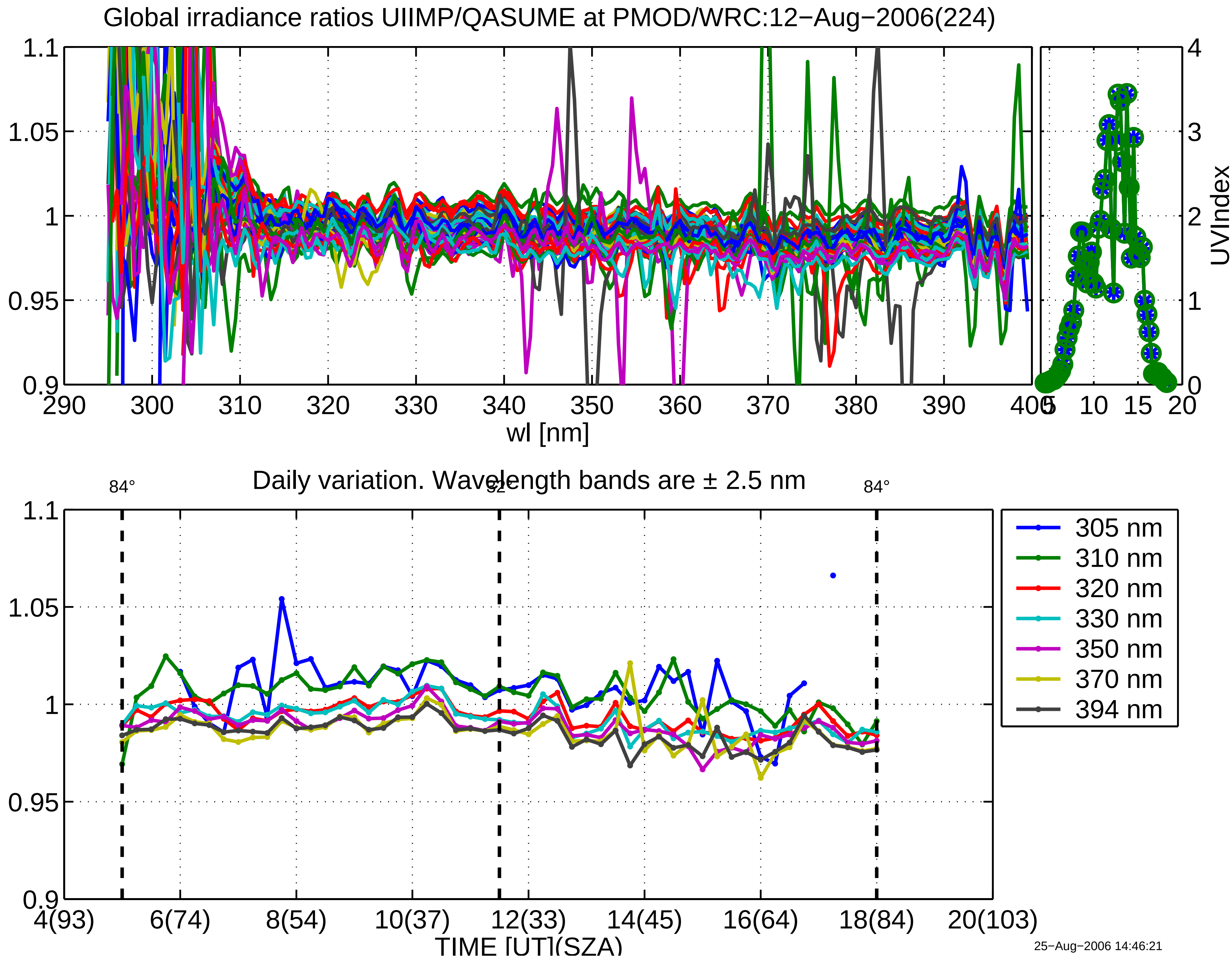
Global irradiance ratios UIIMP/QASUME at PMOD/WRC:09−Aug−2006(221) to 23−Aug−2006(235)
RATIO UIIMP/QASUME
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0
TIME [UT] ON DAYS: [221 222 223 224 225 226 227 228 229 230 231 232 233 234 235]
25−Aug−2006 14:46:21


Global irradiance ratios UIIMP/QASUME at PMOD/WRC:09−Aug−2006(221)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
10
8
6
4
2
0
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
76°
81°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(93)
6(73)
8(53)
10(36)
12(32)
14(44)
16(63)
18(84)
20(102)
TIME [UT](SZA)
25−Aug−2006 14:46:21

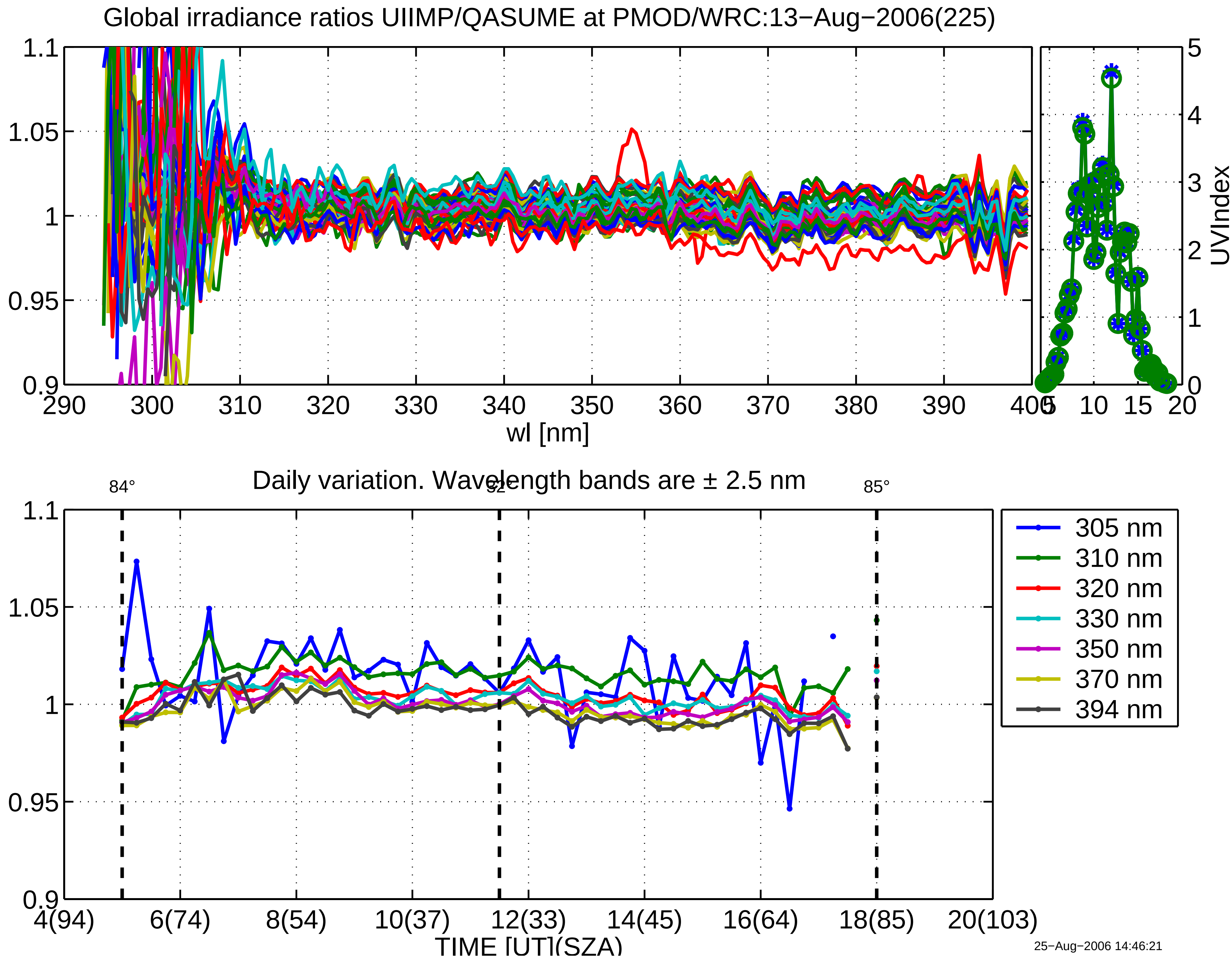

Global irradiance ratios UIIMP/QASUME at PMOD/WRC:10−Aug−2006(222)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
0
1
2
3
4
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
83°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(93)
6(73)
8(53)
10(36)
12(32)
14(44)
16(64)
18(84)
20(102)
TIME [UT](SZA)
25−Aug−2006 14:46:21

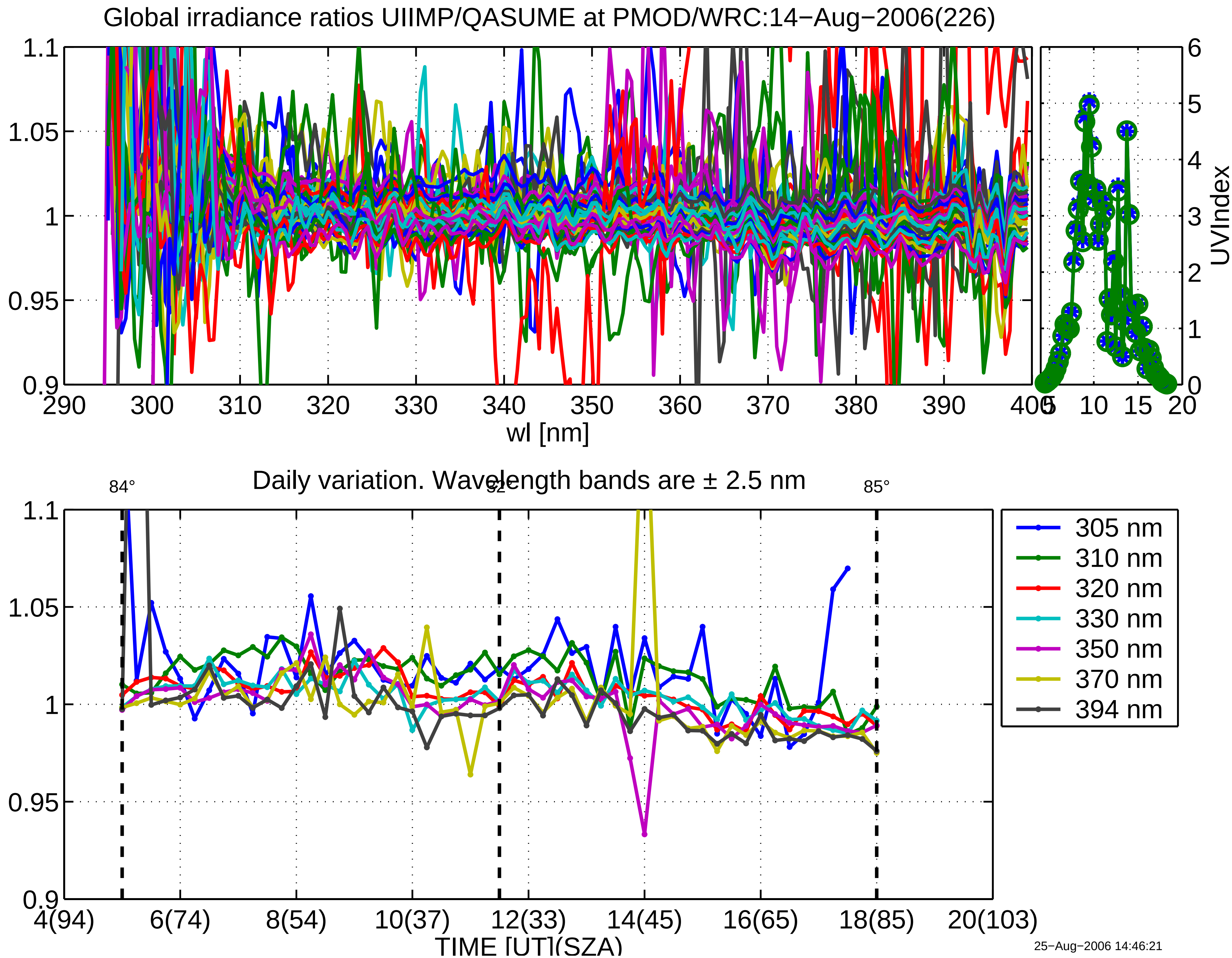


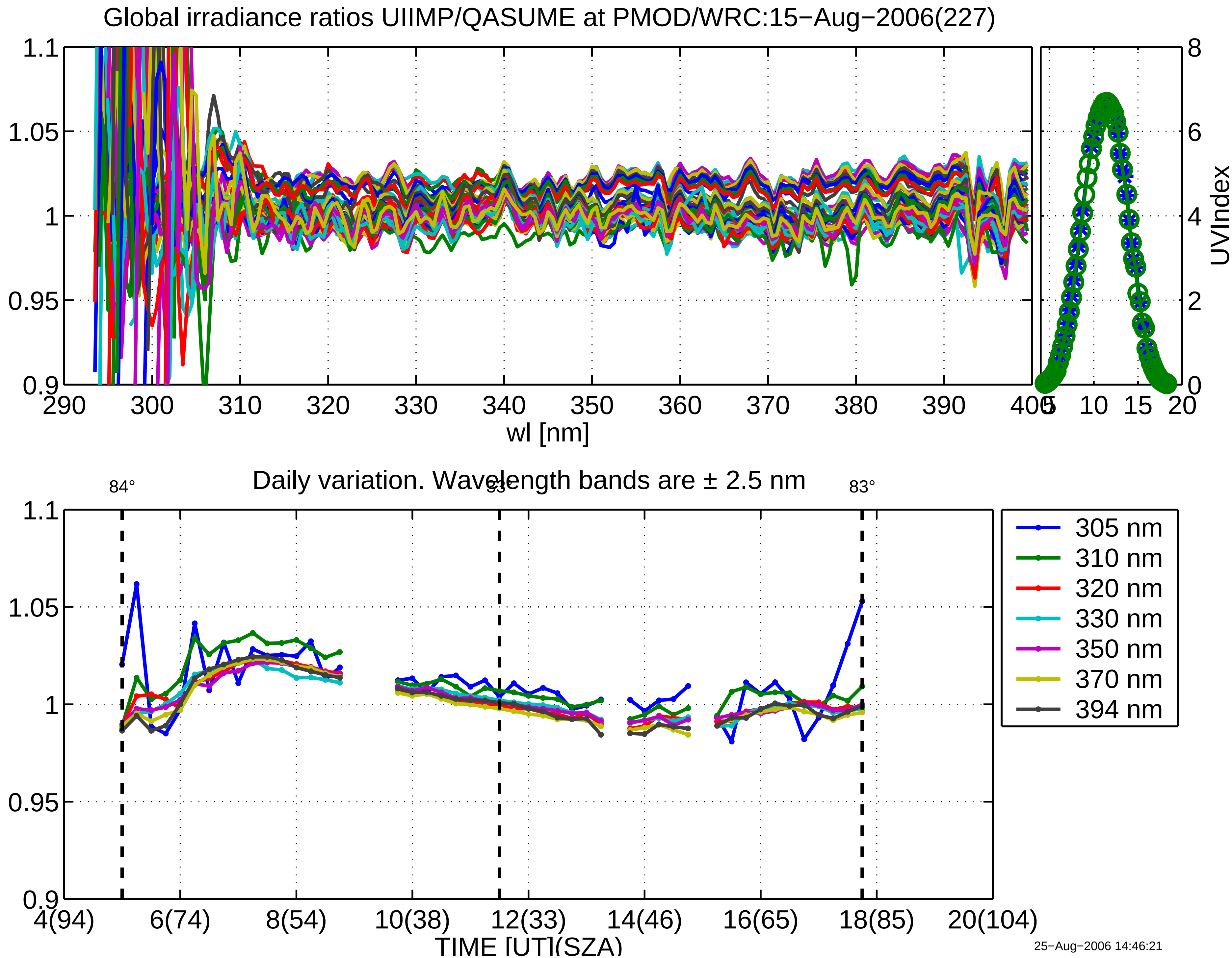
Global irradiance ratios UIIMP/QASUME at PMOD/WRC:11−Aug−2006(223)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
8
6
4
2
0
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
84°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(93)
6(74)
8(53)
10(37)
12(32)
14(45)
16(64)
18(84)
20(102)
TIME [UT](SZA)
25−Aug−2006 14:46:21



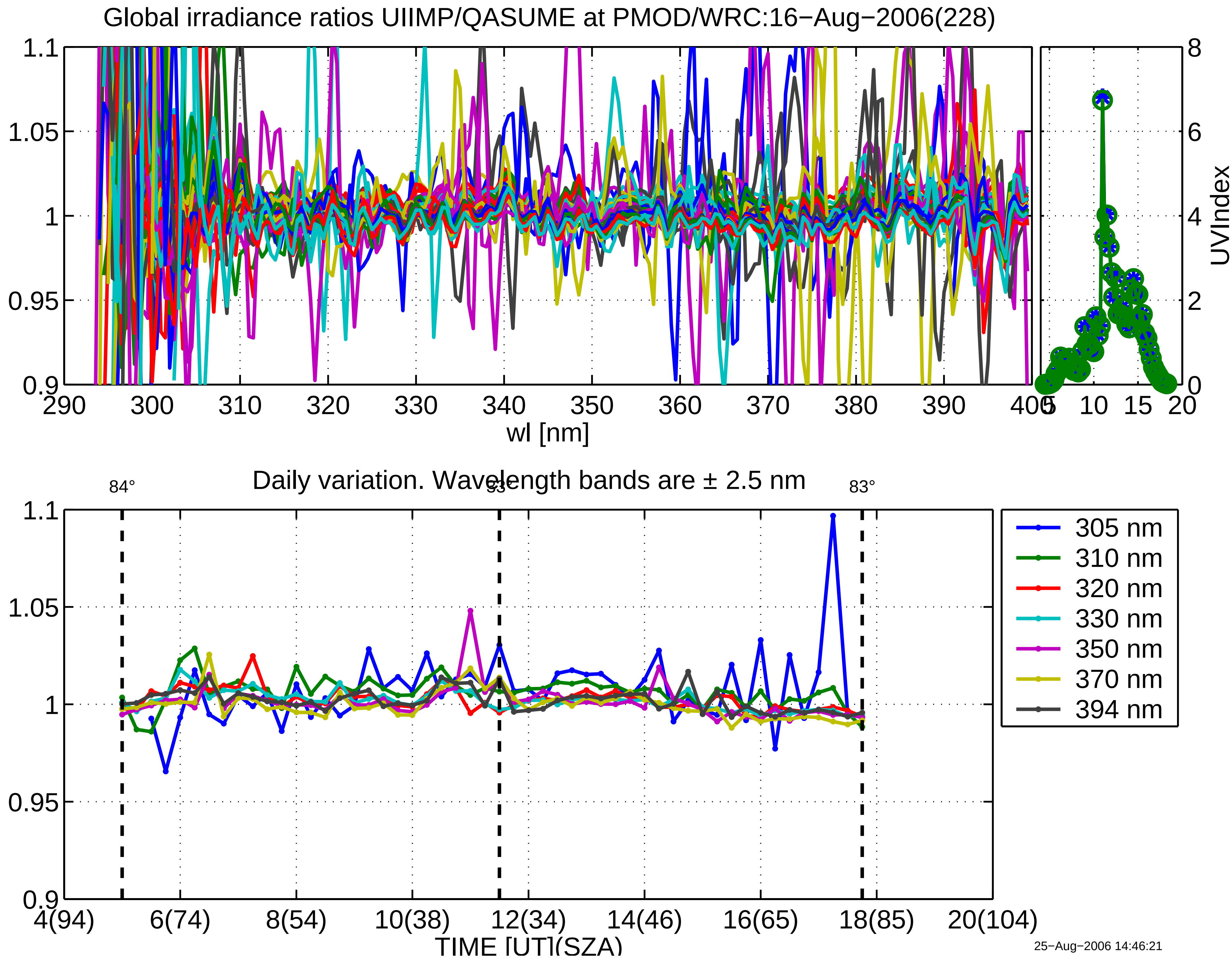
Global irradiance ratios UIIMP/QASUME at PMOD/WRC:12−Aug−2006(224)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
4
3
2
1
0
5
10
15
20
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
84°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(93)
6(74)
8(54)
10(37)
12(33)
14(45)
16(64)
18(84)
20(103)
TIME [UT](SZA)
25−Aug−2006 14:46:21


Global irradiance ratios UIIMP/QASUME at PMOD/WRC:13−Aug−2006(225)
wl [nm]
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
84°
82°
85°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
TIME [UT](SZA)
25−Aug−2006 14:46:21

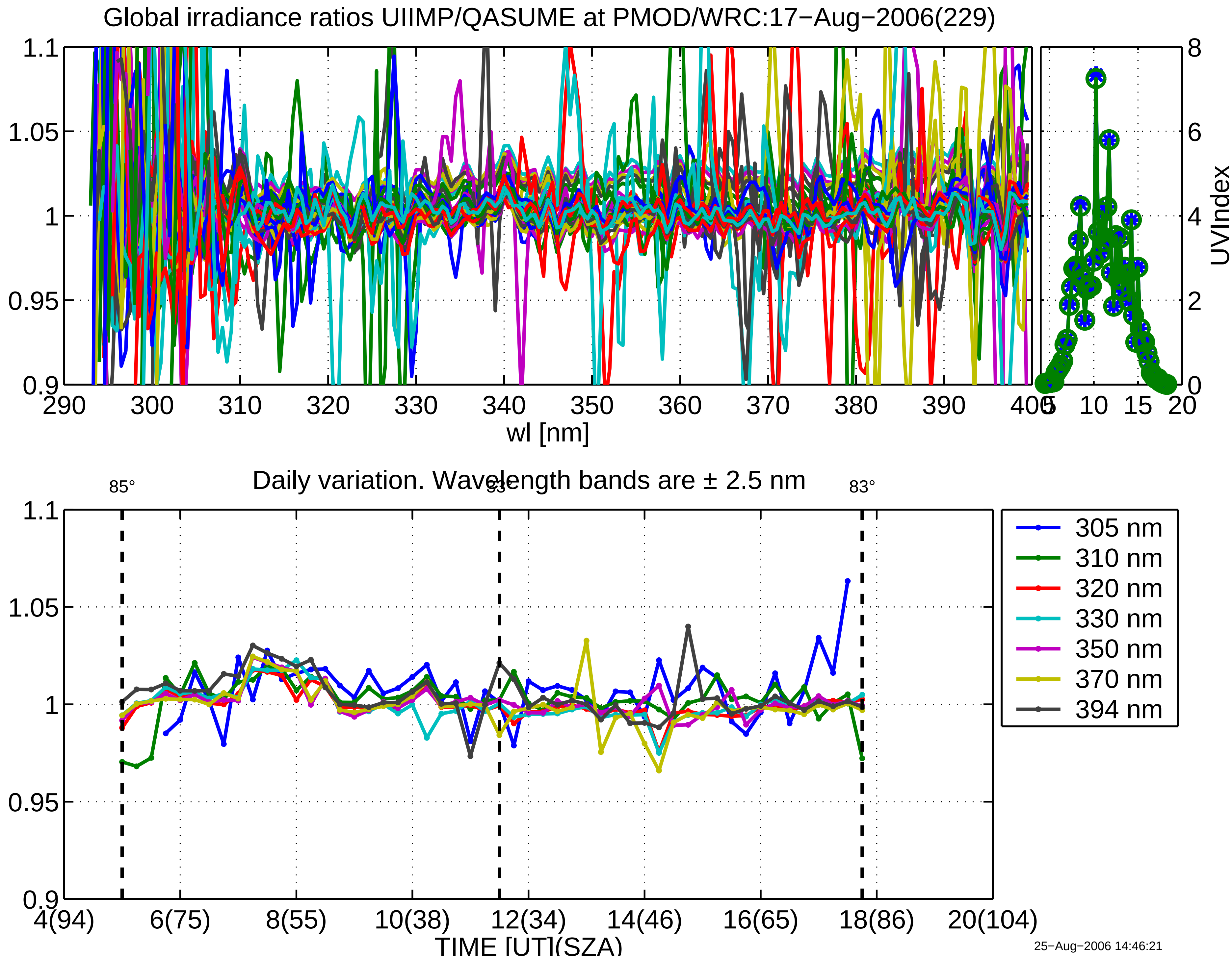

Global irradiance ratios UIIMP/QASUME at PMOD/WRC:14−Aug−2006(226)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
0
1
2
3
4
5
6
UVIndex
5
10
15
20
Daily variation. Wavelength bands are ± 2.5 nm
84°
82°
85°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(94)
6(74)
8(54)
10(37)
12(33)
14(45)
16(65)
18(85)
20(103)
TIME [UT](SZA)
25−Aug−2006 14:46:21

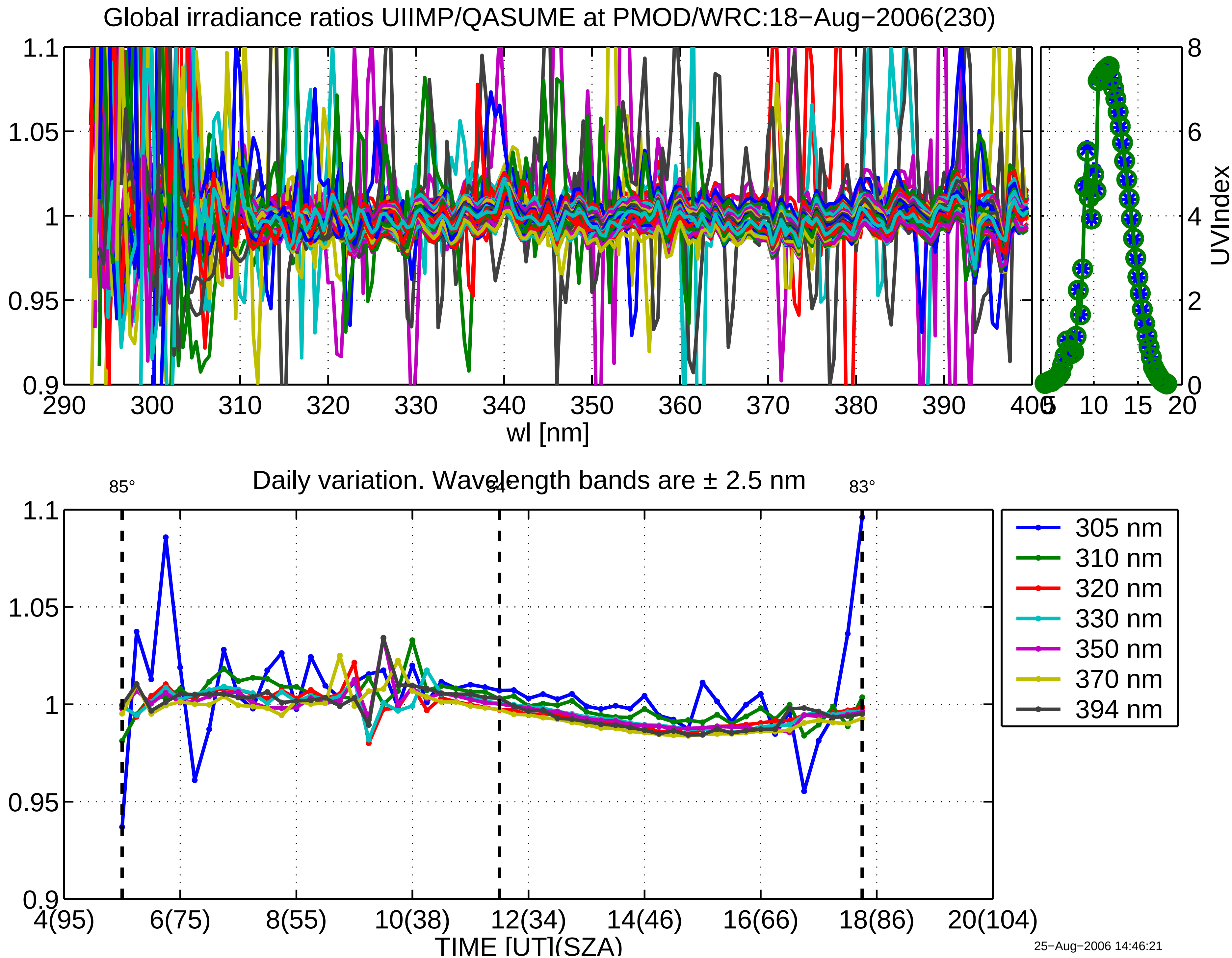


Global irradiance ratios UIIMP/QASUME at PMOD/WRC:15−Aug−2006(227)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
8
6
4
2
0
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
84°
33°
83°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(94)
6(74)
8(54)
10(38)
12(33)
14(46)
16(65)
18(85)
20(104)
TIME [UT](SZA)
25−Aug−2006 14:46:21

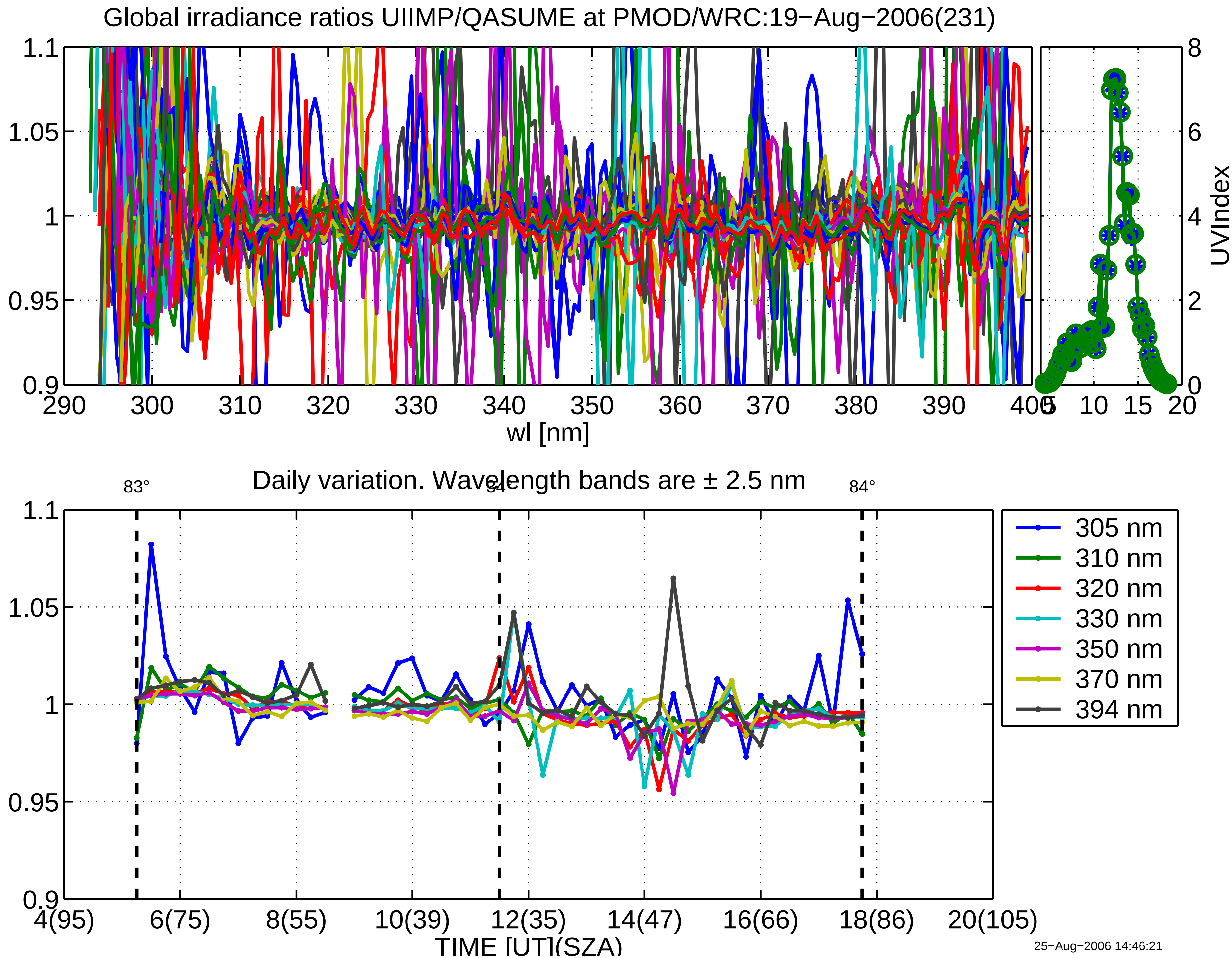


Global irradiance ratios UIIMP/QASUME at PMOD/WRC:16−Aug−2006(228)
wl [nm]
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
84°
83°
83°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
TIME [UT](SZA)
25−Aug−2006 14:46:21

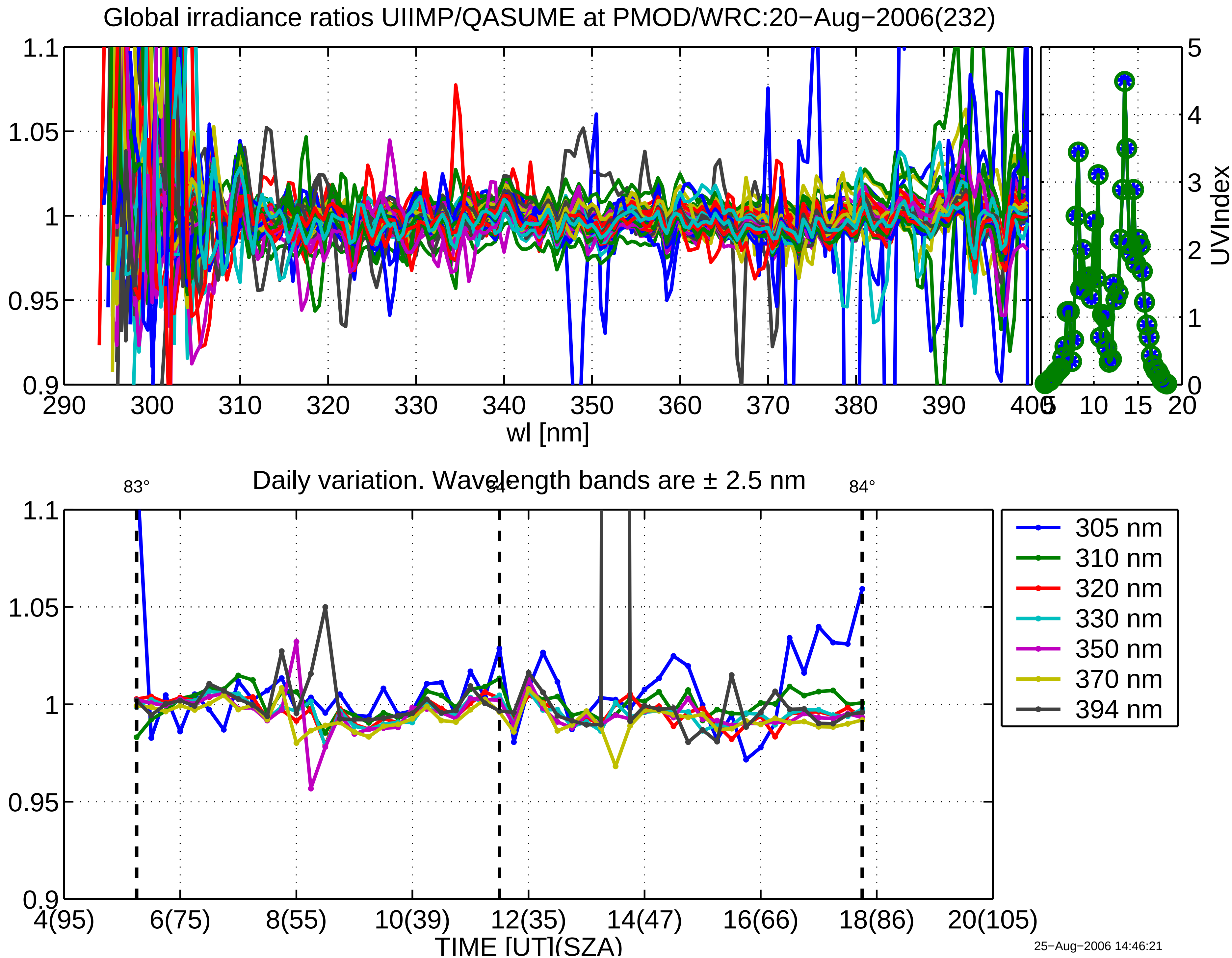

Global irradiance ratios UIIMP/QASUME at PMOD/WRC:17−Aug−2006(229)
wl [nm]
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
85°
33°
83°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
TIME [UT](SZA)
25−Aug−2006 14:46:21



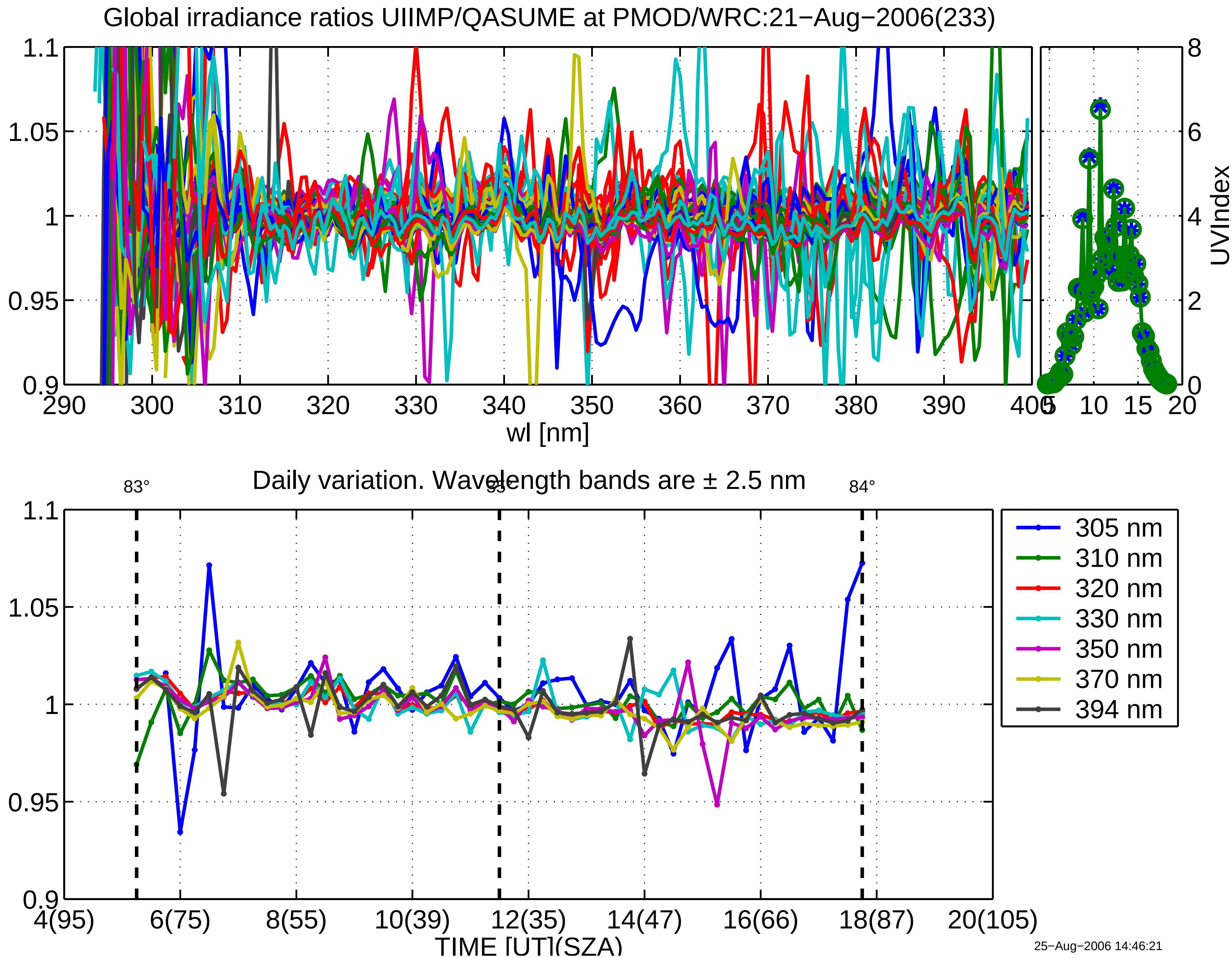
Global irradiance ratios UIIMP/QASUME at PMOD/WRC:18−Aug−2006(230)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
0
2
4
6
8
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
85°
34°
83°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(95)
6(75)
8(55)
10(38)
12(34)
14(46)
16(66)
18(86)
20(104)
TIME [UT](SZA)
25−Aug−2006 14:46:21

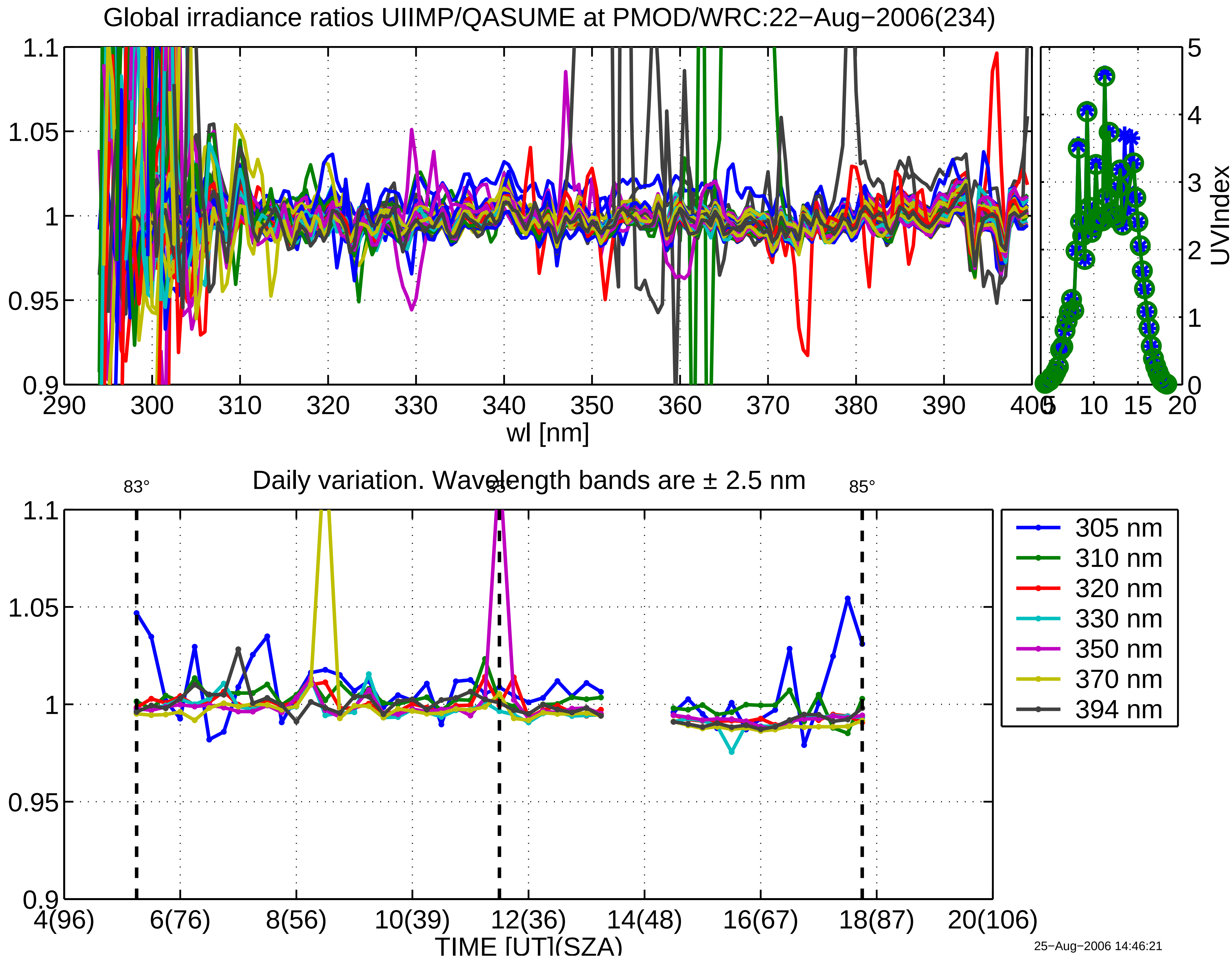


Global irradiance ratios UIIMP/QASUME at PMOD/WRC:19−Aug−2006(231)
1.1
1.05
1
0.95
0.9
290 300 310 320 330 340 350 360 370 380 390 400
wl [nm]
5 10 15 20
8 6 4 2 0
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
83°
84°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(95) 6(75) 8(55) 10(39) 12(35) 14(47) 16(66) 18(86) 20(105)
TIME [UT](SZA)
25−Aug−2006 14:46:21

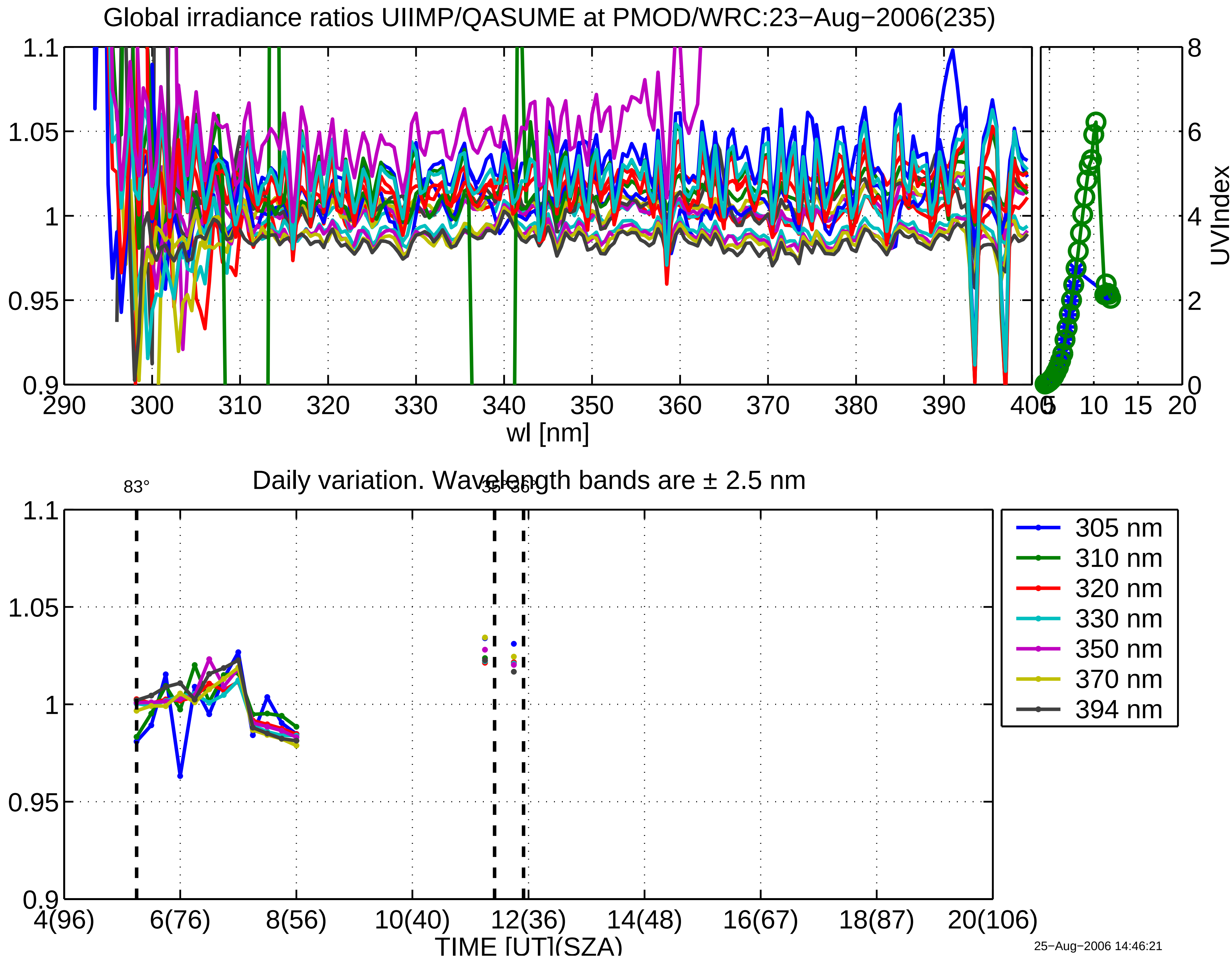


Global irradiance ratios UIIMP/QASUME at PMOD/WRC:20−Aug−2006(232)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
0
1
2
3
4
5
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
83°
84°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(95)
6(75)
8(55)
10(39)
12(35)
14(47)
16(66)
18(86)
20(105)
TIME [UT](SZA)
25−Aug−2006 14:46:21

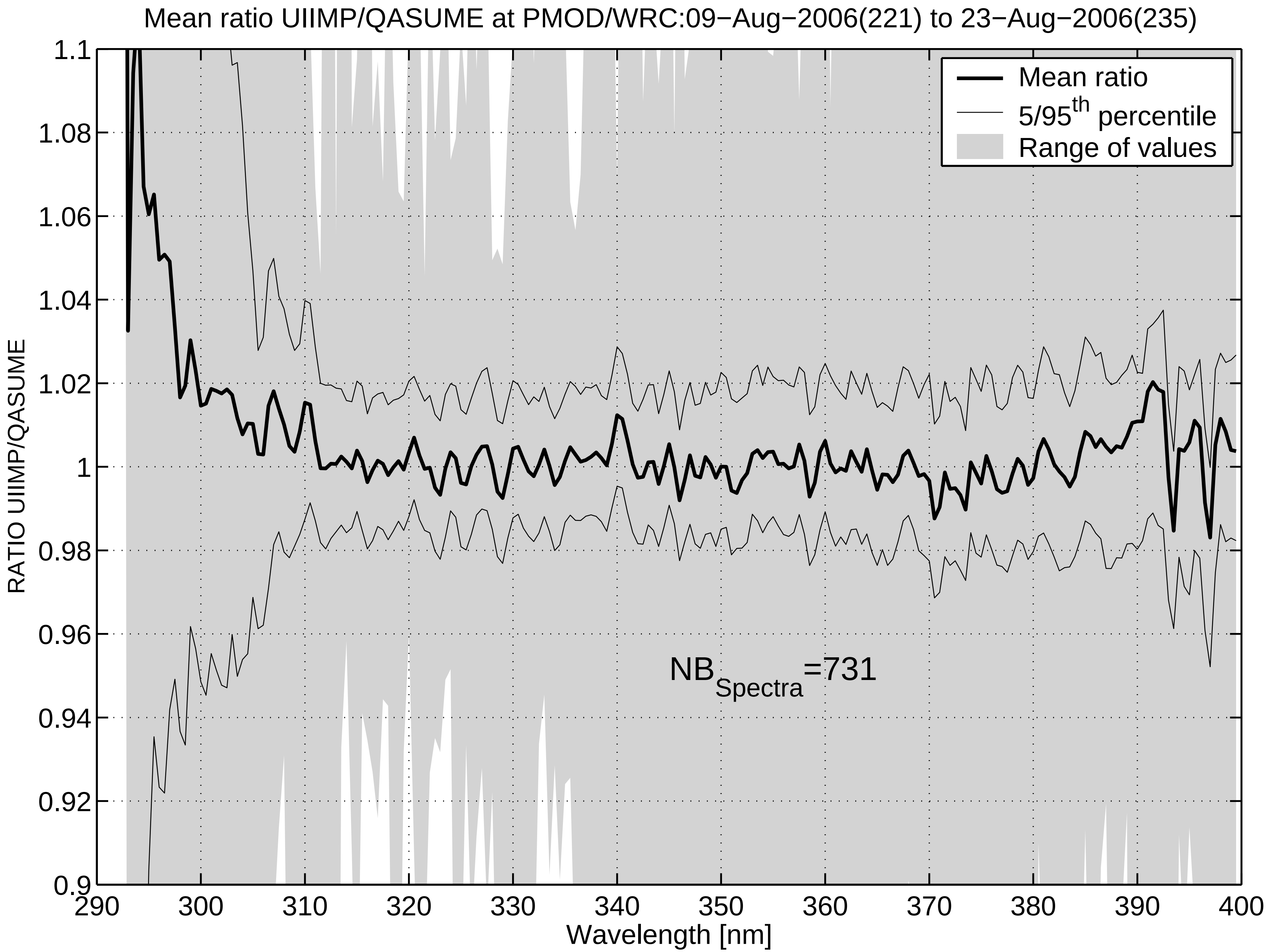

Global irradiance ratios UIIMP/QASUME at PMOD/WRC:21−Aug−2006(233)
wl [nm]
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
83°
83°
84°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
TIME [UT](SZA)
25−Aug−2006 14:46:21



Global irradiance ratios UIIMP/QASUME at PMOD/WRC:22−Aug−2006(234)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
0
1
2
3
4
5
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
83°
85°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(96)
6(76)
8(56)
10(39)
12(36)
14(48)
16(67)
18(87)
20(106)
TIME [UT](SZA)
25−Aug−2006 14:46:21



Global irradiance ratios UIIMP/QASUME at PMOD/WRC:23−Aug−2006(235)
1.1
1.05
1
0.95
0.9
290
300
310
320
330
340
350
360
370
380
390
400
wl [nm]
5
10
15
20
0
2
4
6
8
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
83°
35°
36°
305 nm
310 nm
320 nm
330 nm
350 nm
370 nm
394 nm
4(96)
6(76)
8(56)
10(40)
12(36)
14(48)
16(67)
18(87)
20(106)
TIME [UT](SZA)
25−Aug−2006 14:46:21



Mean ratio UIIMP/QASUME at PMOD/WRC:09−Aug−2006(221) to 23−Aug−2006(235)
RATIO UIIMP/QASUME
Wavelength [nm]
Mean ratio
5/95th percentile
Range of values
NBSpectra=731
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
1.08
1.1
290
300
310
320
330
340
350
360
370
380
390
400