Protocol of the intercomparison at Reading University, UK on July 7 to 10, 2003 with the travelling standard spectroradiometer B5503 from ECUV within the project QASUME

Report prepared by Julian Gröbner and Stelios Kazadzis

Operators: Stelios Kazadzis , Vasilis Amoiridis

The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer operated by the University of Reading (UKR) and the travel standard B5503. The measurement site is located at Reading; Latitude 51.44 N, Longitude 0.94 W and altitude 50 m.a.s.l..
The horizon of the measurement site is free down to about 85° solar zenith angle (SZA) in all directions.

B5503 arrived at Reading in the morning of July 7, 2003. The spectroradiometer was installed in a small hut at less than 1.5 m distance from the UKR instrument. The spectroradiometer in use at Reading University is a Bentham DM-150 double mono-chromator. The intercomparison between B5503 and the UKR spectroradiometer lasted three days, from the evening of July 7 to noon of July 10.

B5503 was calibrated several times during the intercomparison period using a 100 W portable calibration system. Five 100 W lamps (T38986, T57825, T57824, T53062, and T53063) were used to obtain an absolute spectral calibration traceable to the primary reference held at ECUV, which is traceable to PTB. The daily mean responsivity of the instrument based on these calibrations varied by 2% during the intercomparison period. These variations were taken into account on a daily basis. Observed diurnal variations of the responsivity were 2% on July 8 and 3% on July 9 and were taken into account for the analysis. The internal temperature of B5503 was 27.9±0.2 °C. The diffuser head was heated to a temperature of 30±5°C.
The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm analysis were between ± 50pm in the spectral range 310 to 400 nm.

Protocol:
The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 to 450 nm, every 0.5 nm, and 3 seconds between each wavelength increment.

<u>July 7 (188):</u>

B5503 was installed on the measurement site at 9:00 UT. Synchronised scans started at 18:30 UT and lasted until 20:00 UT. Weather conditions during the measurement period were mostly overcast without sunshine.

B5503 calibrated from 15:30 to 18:15 UT.

July 8 (189):

Synchronised measurements are available from 4:30 UT to 20:00 UT with some interruptions; JRC calibrated during the 5:30 UT scan, UKR was one minute late for the 10:30 UT scan, the 11:00 UT scan was disturbed by rain, and UKR missed the 13:30 UT scan due to quality control on the spectroradiometer. Weather conditions were fully overcast in the morning with some sunshine in the afternoon.

B5503 calibrated from 5:10 to 5:50 UT, at 12:17, 12:47, 17:18, and 17:45 UT.

July 9 (190):

Synchronised scans are available from 4:30 to 20:00 UT without interruptions. The weather conditions during the day were a mix of sun and clouds during the day.

Lamp measurements from B5503 at 4:45, 5:17, 8:48, 9:18, 11:47, 12:18, 14:18, 14:50, 15:19, 16:48, 17:18, 18:47, and 20:16 UT.

July 10 (191):

Synchronised scans are available from 5:30 to 13:30 UT. JRC calibrated from 10:00 to 11:20 UT and missed the scans during this period. Weather conditions were few scattered clouds before 10:00 and fast changing clouds conditions from 11:00 to 13:30 UT. The large short-term variability seen in the global irradiance ratios on this day are all from measurements after 11:00 UT.

Lamp measurements from B5503 from 10:00 to 11:20 UT.

Results:

79 synchronised simultaneous spectra from B5503 and UKR are available from the measurement period. The wavelength shifts of the submitted solar spectra of the UKR spectroradiometer retrieved through the SHICRivm analysis varied between 0.07 and at least -0.9 nm; This lower bound at –0.9 is a lower limit imposed by the SHICRivm software; the true wavelength shift might be larger. The spectral shape of the wavelength shifts has an amplitude of about 0.1 nm.

The intercomparison of the global irradiance measured by the two instruments can be summarized as follows:

- Global solar irradiances measured by UKR were between 8% lower to 3% higher than those measured by B5503 for wavelengths between 300 and 370 nm and between 400 to 450 nm. The extreme values apply to measurements at large solar zenith angles.
- The spectral ratios between UKR and B5503 show a dip between 380 and 400 nm which is correlated to the wavelength shifts of UKR. While the dip is absent when the wavelength shift is below 0.1 nm, it reaches a depth of 15% for wavelength shifts of –0.9 nm or more. Since the solar spectra of UKR have been wavelength shift corrected but not the spectral responsivity of UKR, this feature between 380 and 400 nm should be correlated to the gradient of the responsivity in this wavelength region. To test this assumption the measurement data

could be reanalysed by also shifting the responsivity of UKR by the same wavelength shift as the solar spectra.

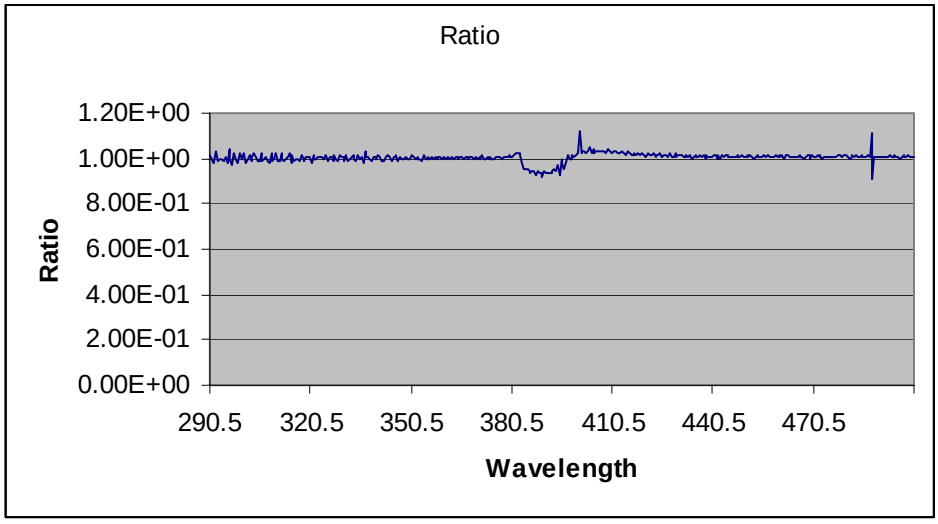
- The diurnal variability was 4% in the UVB and 7% at longer wavelengths on July 8 and 9 and 5% and 12% on July 10.

Conclusion:

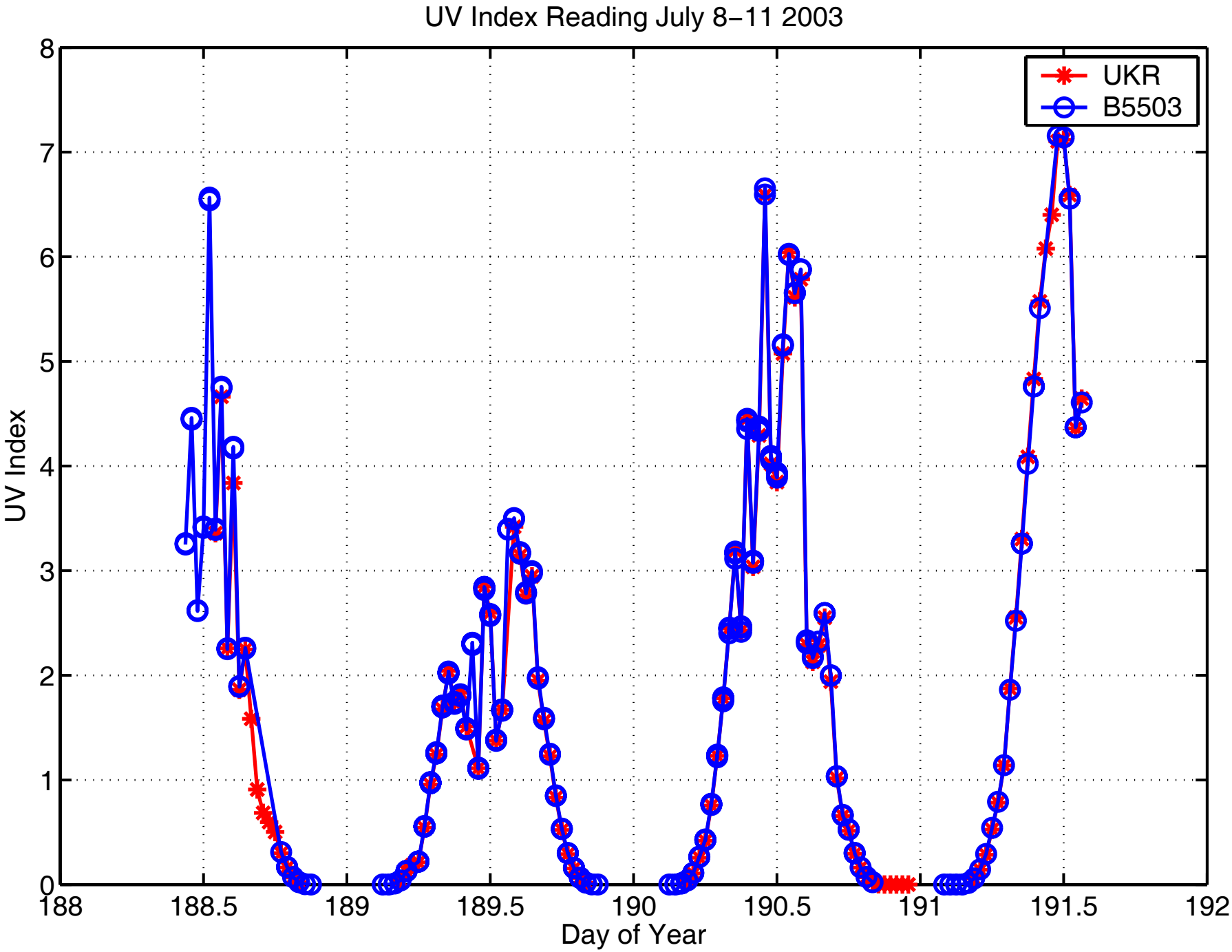
UKR measures global solar irradiance on average 2% lower than B5503. The variability between the two spectroradiometers is between 4 and 12%. A pronounced spectral feature of 15% amplitude can be occasionally observed in the wavelength region 380 to 400 nm. The wavelength shifts of UKR vary between 0.05 and more than –0.9 nm between successive solar spectra.

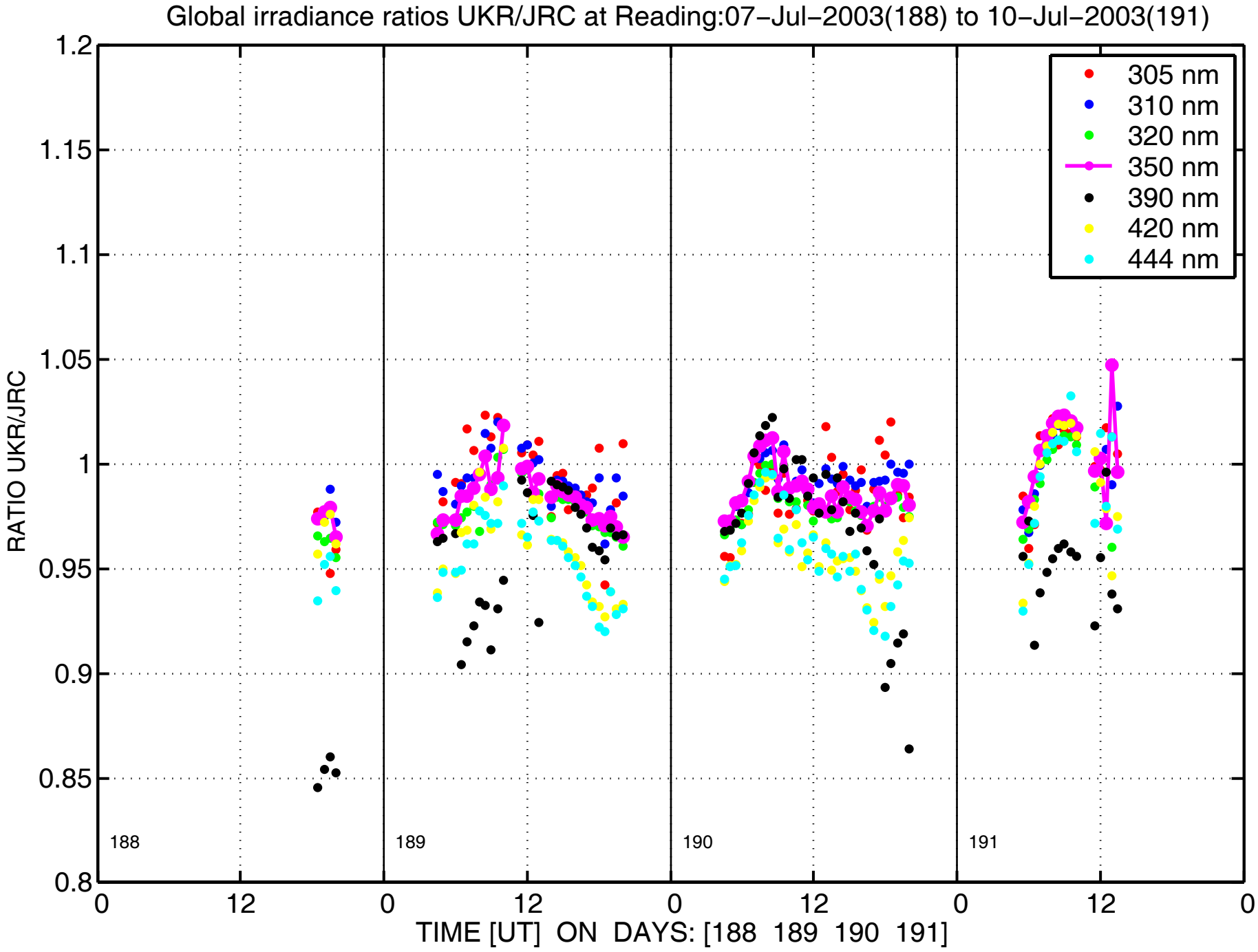
Comments from the local operator:
There is clearly a problem with the wavelength setting of this instrument: the setting slips in wavelength steps of ~0.5nm and does not recover even when parked at a reference point between scans. If the monitoring is interrupted and the programme restarted (or returned to a higher level / previous menu) then parking the monochromator restores the correct wavelength registration. It is apparent that the instrument is occasionally missing an instruction to step. We have been working with the manufacturer on this issue (it was known before the intercomparison) and the problem will shortly be corrected by upgrading the interface protocols.

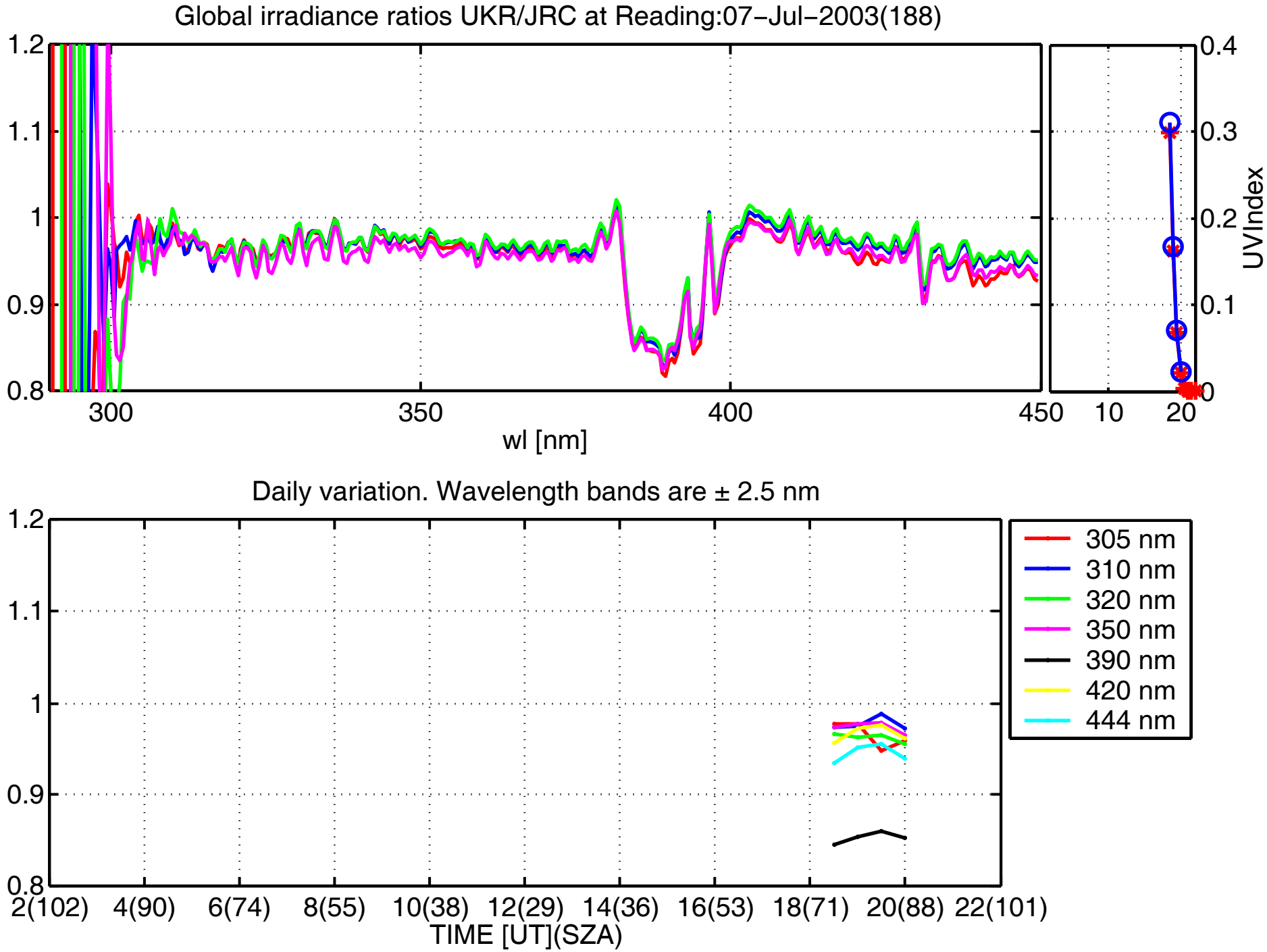
The wavelength shift is responsible for the dip in the ratio between 380 and 400nm. As suggested in the report, the system response changes very rapidly in this region causing an error in wavelength-but-not-response shifted data. The discrepancies between B5503 and UKR at 387nm (the pink lines in the data plots) clearly follow the time course of the 3 stage wavelength shifts seen in the wavelength shift plots. This has been tested by shifting an uncalibrated measured spectrum 0.5 nm and re-applying the calibration. The ratio between the shifted and unshifted versions is shown in the figure where the dip can clearly be seen.

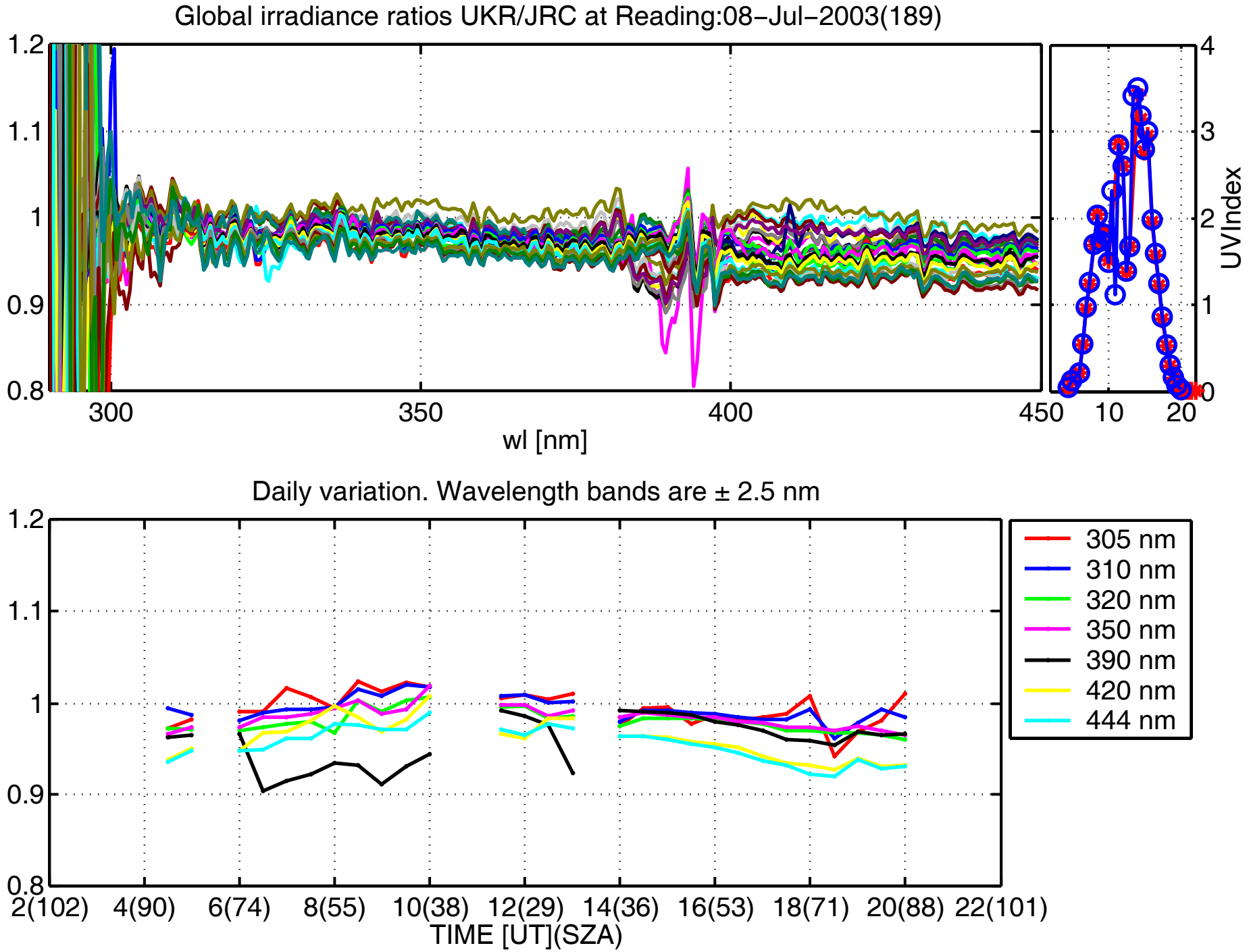


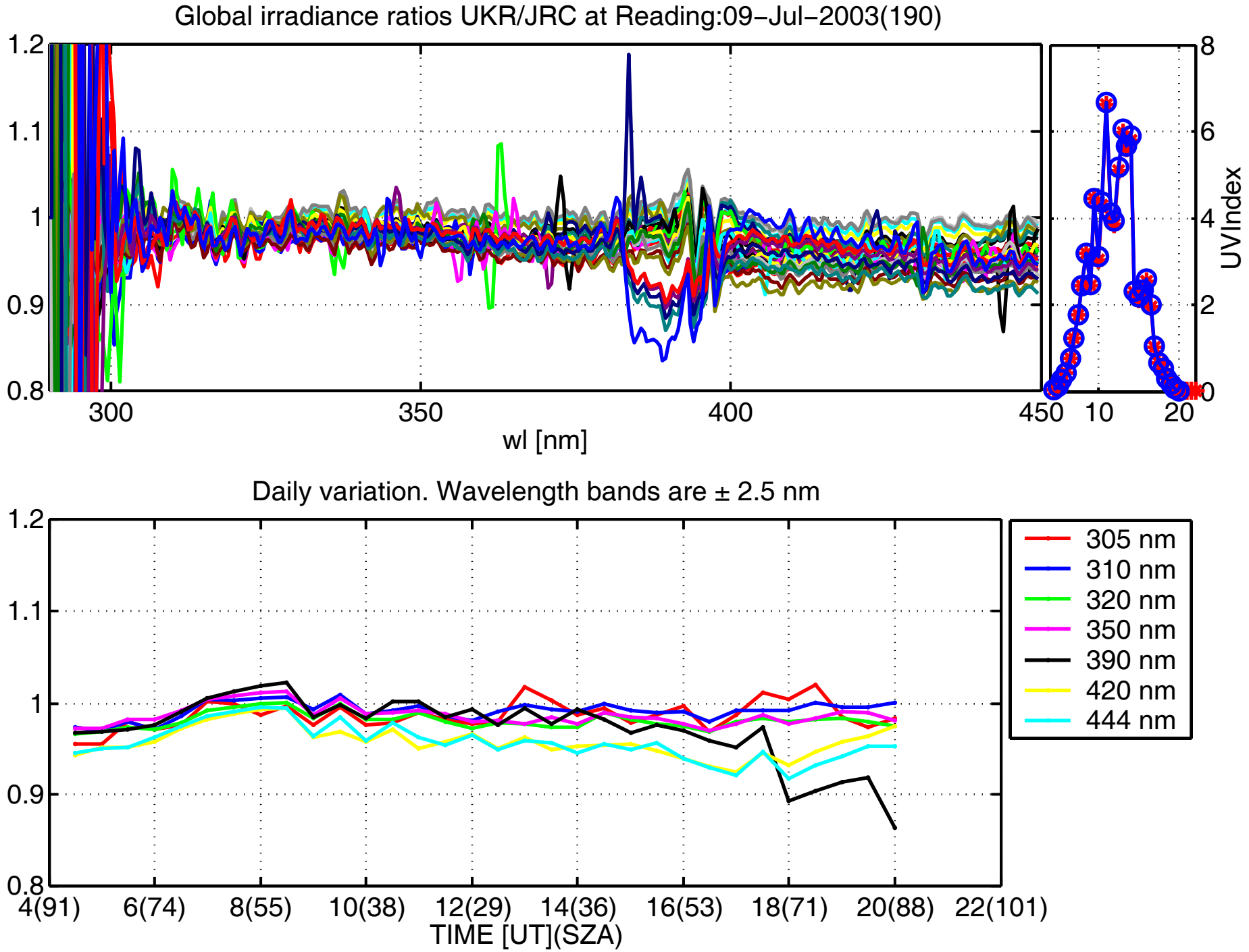
It would be possible to correct the data for this fault but that would give a false impression of the instrument performance during the intercomparison, and the results illustrate the value of the travelling instrument in identifying such issues. The overall performance of the instrument, at 2% different to B5503, was very pleasing.

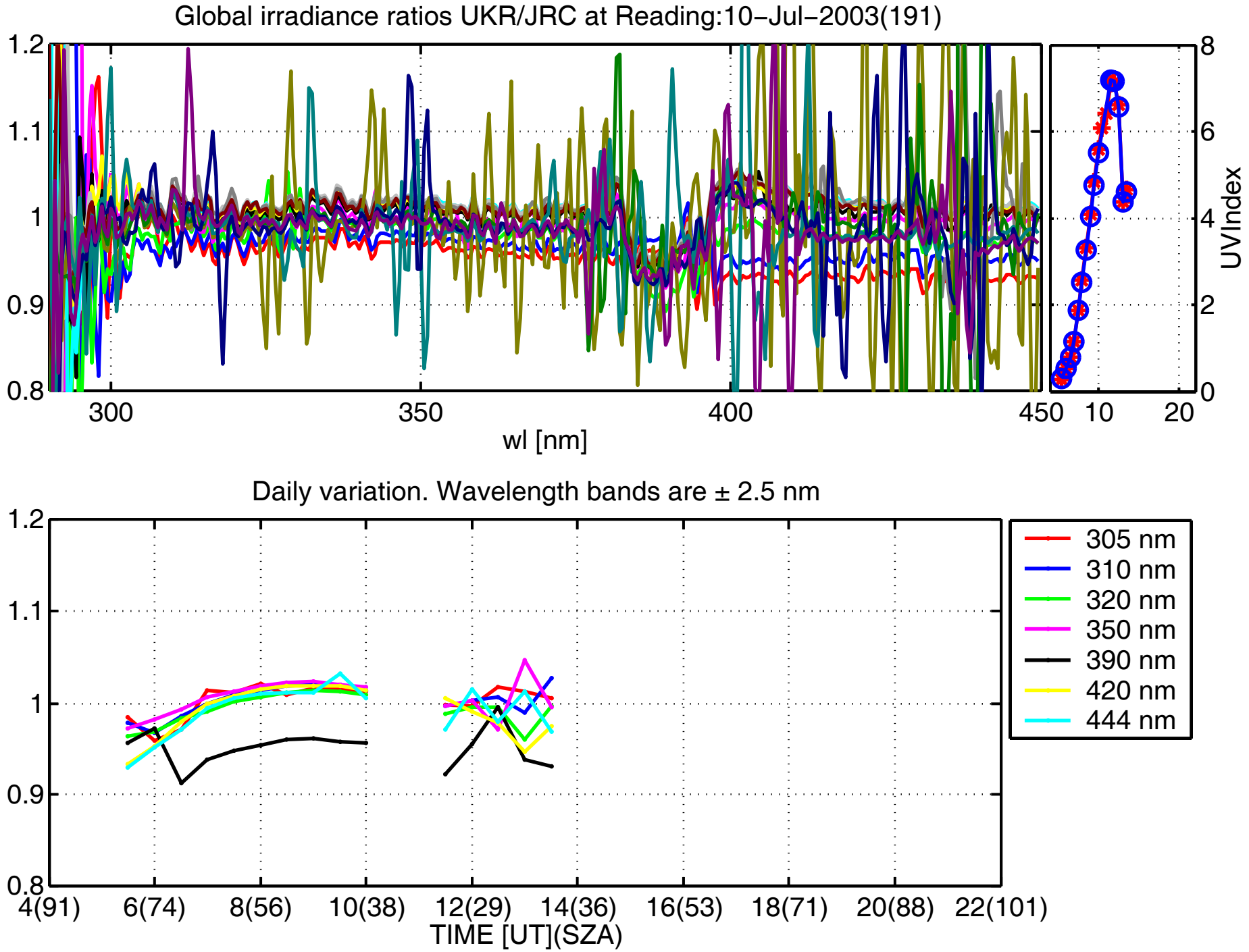

UV Index Reading July 8–11 2003
UKR
B5503
UV Index
Day of Year
0
1
2
3
4
5
6
7
8
188
188.5
189
189.5
190
190.5
191
191.5
192

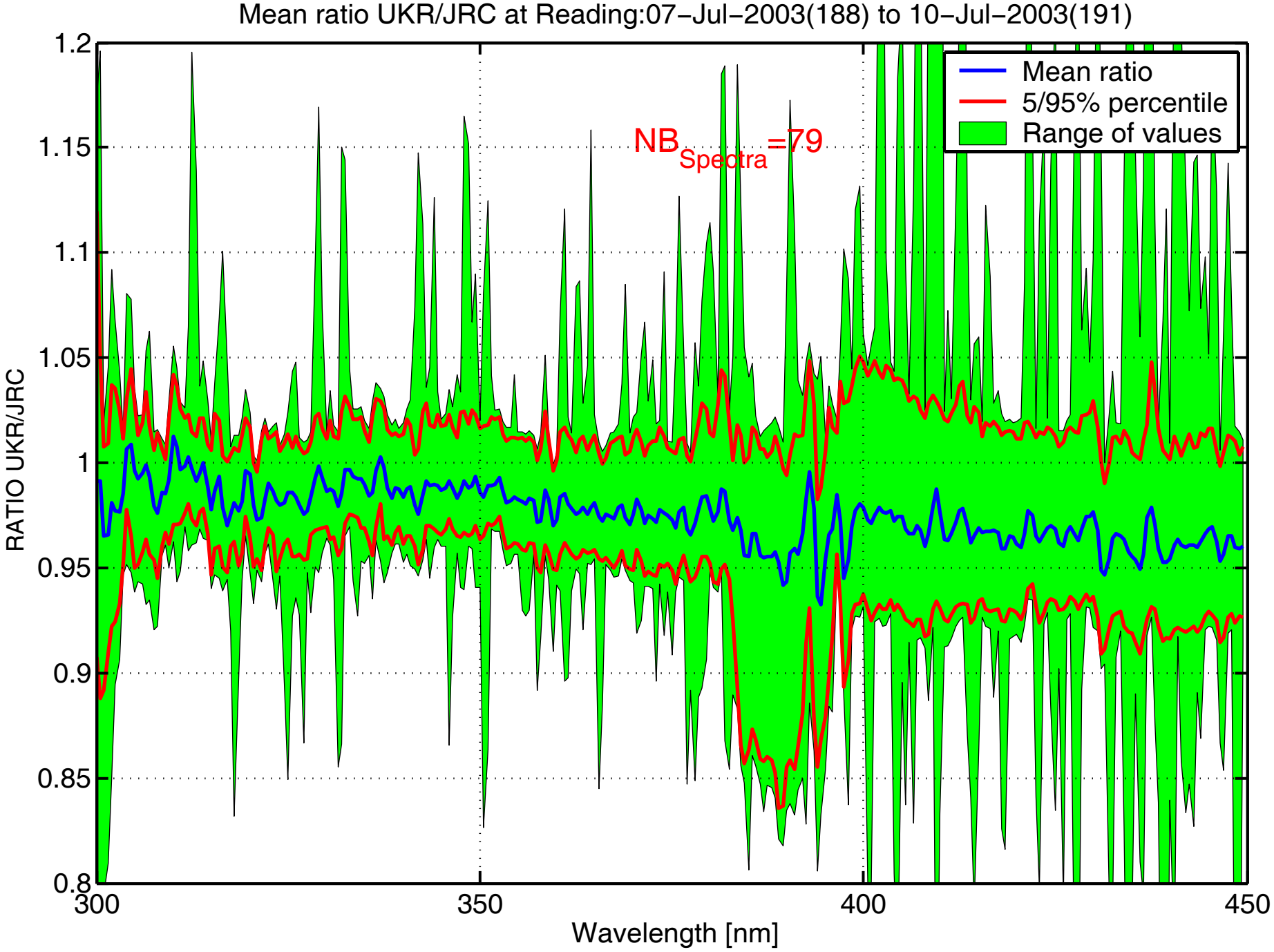

Global irradiance ratios UKR/JRC at Reading:07−Jul−2003(188) to 10−Jul−2003(191)
RATIO UKR/JRC
TIME [UT] ON DAYS: [188 189 190 191]
305 nm
310 nm
320 nm
350 nm
390 nm
420 nm
444 nm
188
189
190
191
22−Sep−2003 13:32:42

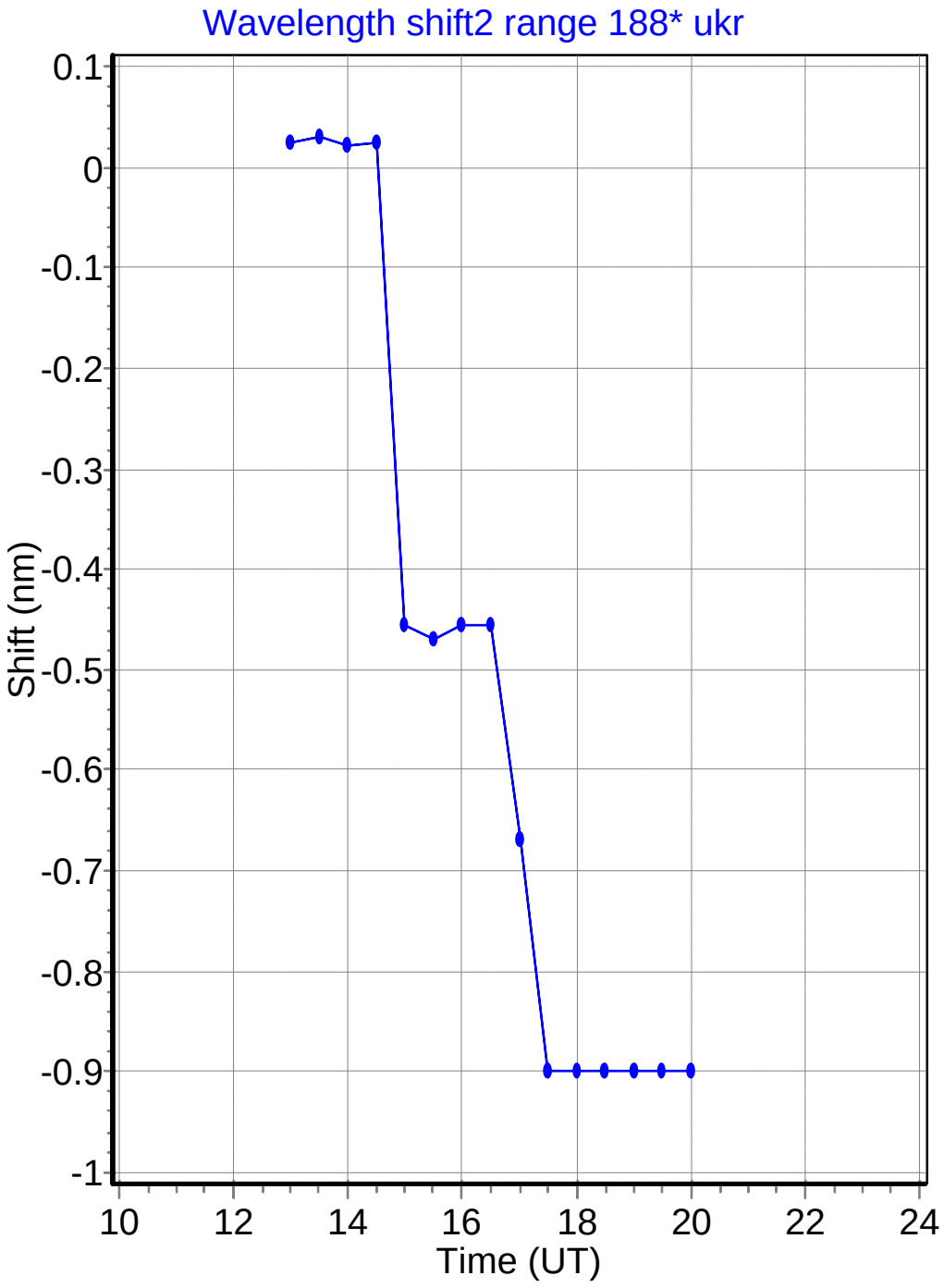

Global irradiance ratios UKR/JRC at Reading:07–Jul–2003(188)
1.2
1.1
1
0.9
0.8
300
350
400
450
wl [nm]
0.4
0.3
0.2
0.1
0
10
20
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
1.2
1.1
1
0.9
0.8
2(102)
4(90)
6(74)
8(55)
10(38)
12(29)
14(36)
16(53)
18(71)
20(88)
22(101)
TIME [UT](SZA)
305 nm
310 nm
320 nm
350 nm
390 nm
420 nm
444 nm
22–Sep–2003 13:32:42

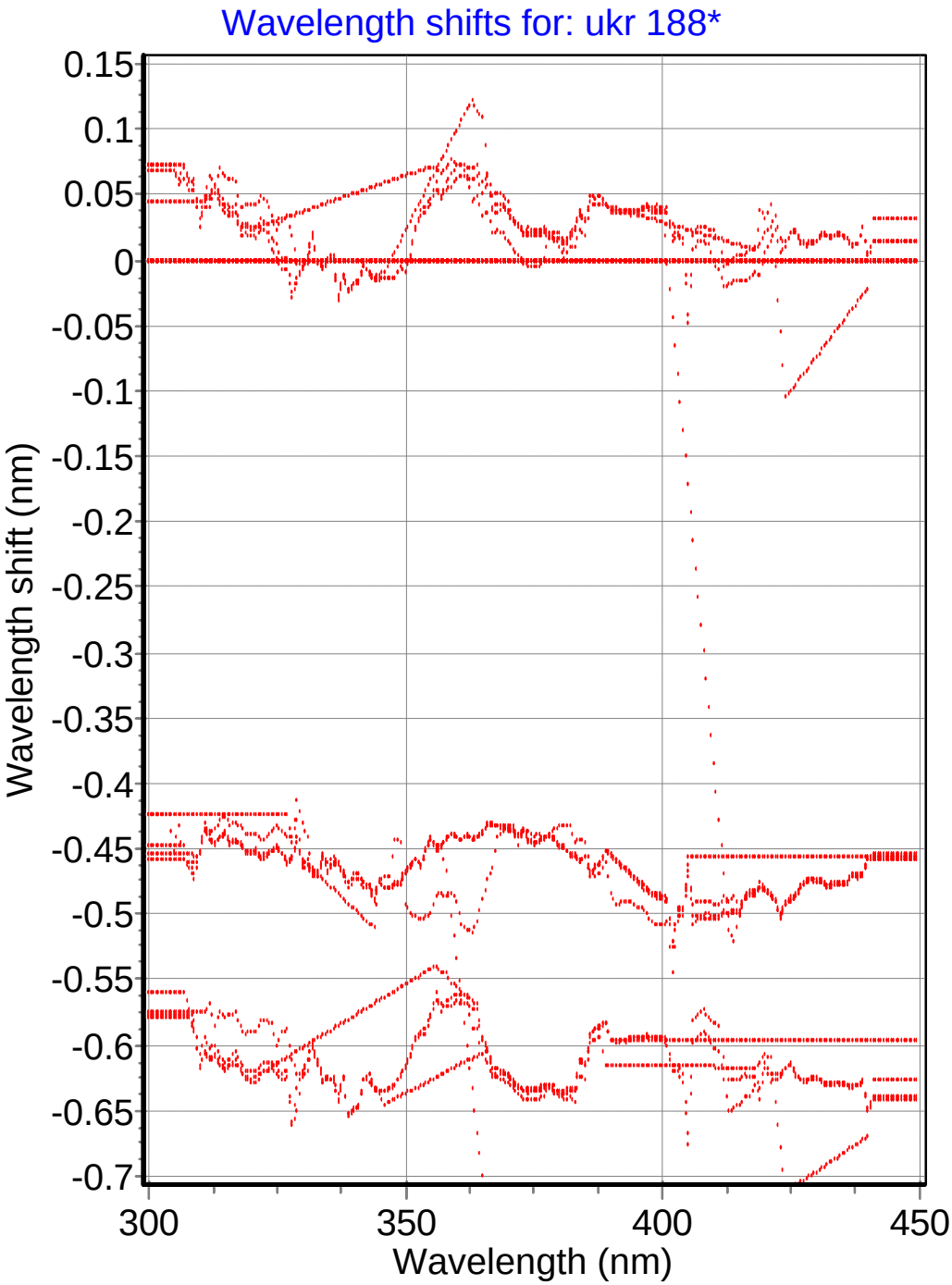

Global irradiance ratios UKR/JRC at Reading:08–Jul–2003(189)
1.2
1.1
1
0.9
0.8
300
350
400
450
wl [nm]
4
3
2
1
0
10
20
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
1.2
1.1
1
0.9
0.8
2(102)
4(90)
6(74)
8(55)
10(38)
12(29)
14(36)
16(53)
18(71)
20(88)
22(101)
TIME [UT](SZA)
305 nm
310 nm
320 nm
350 nm
390 nm
420 nm
444 nm
22–Sep–2003 13:32:42

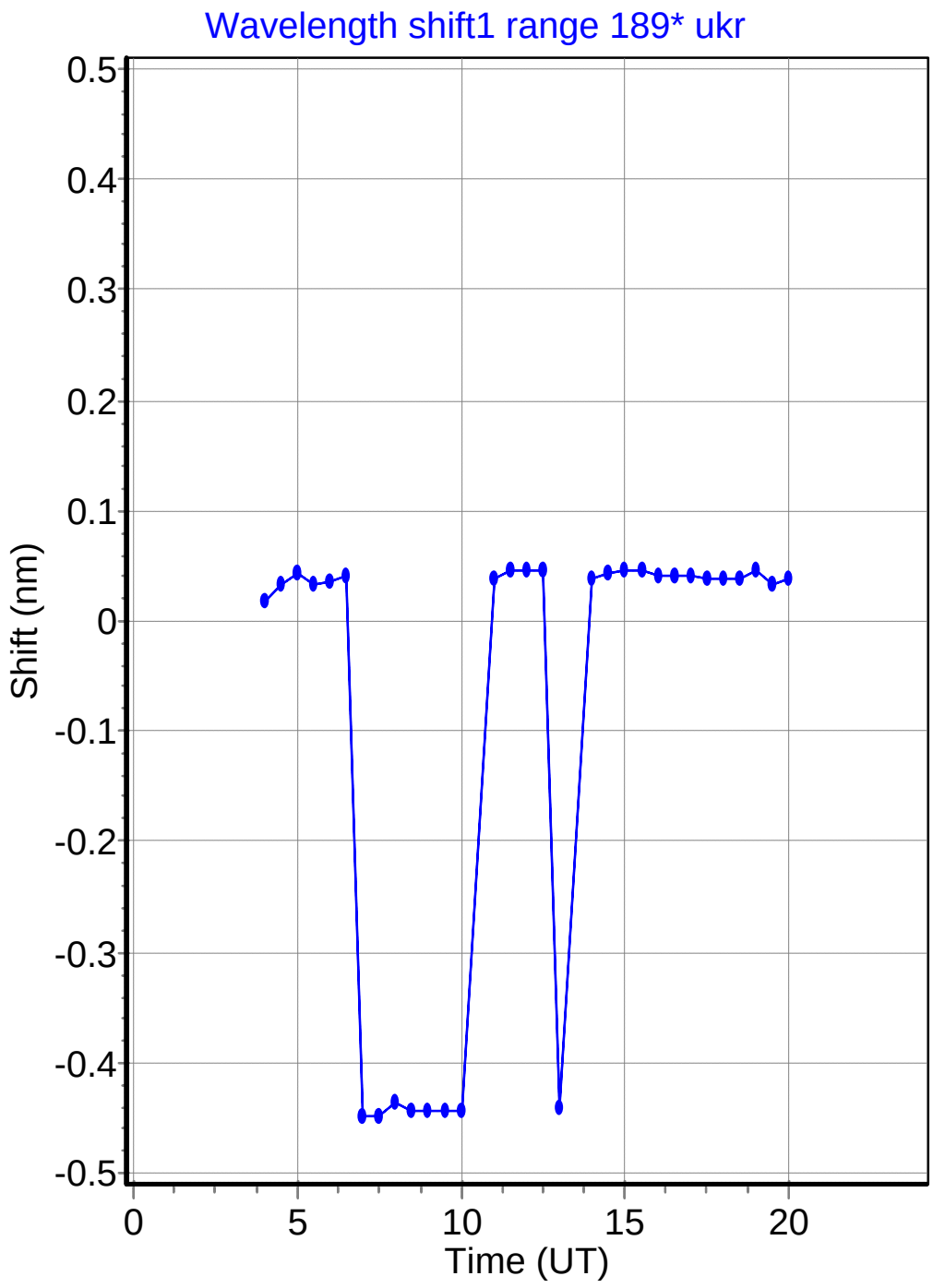

Global irradiance ratios UKR/JRC at Reading:09–Jul–2003(190)
1.2
1.1
1
0.9
0.8
300
350
400
450
wl [nm]
10
20
8
6
4
2
0
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
1.2
1.1
1
0.9
0.8
4(91)
6(74)
8(55)
10(38)
12(29)
14(36)
16(53)
18(71)
20(88)
22(101)
TIME [UT](SZA)
305 nm
310 nm
320 nm
350 nm
390 nm
420 nm
444 nm
22–Sep–2003 13:32:42

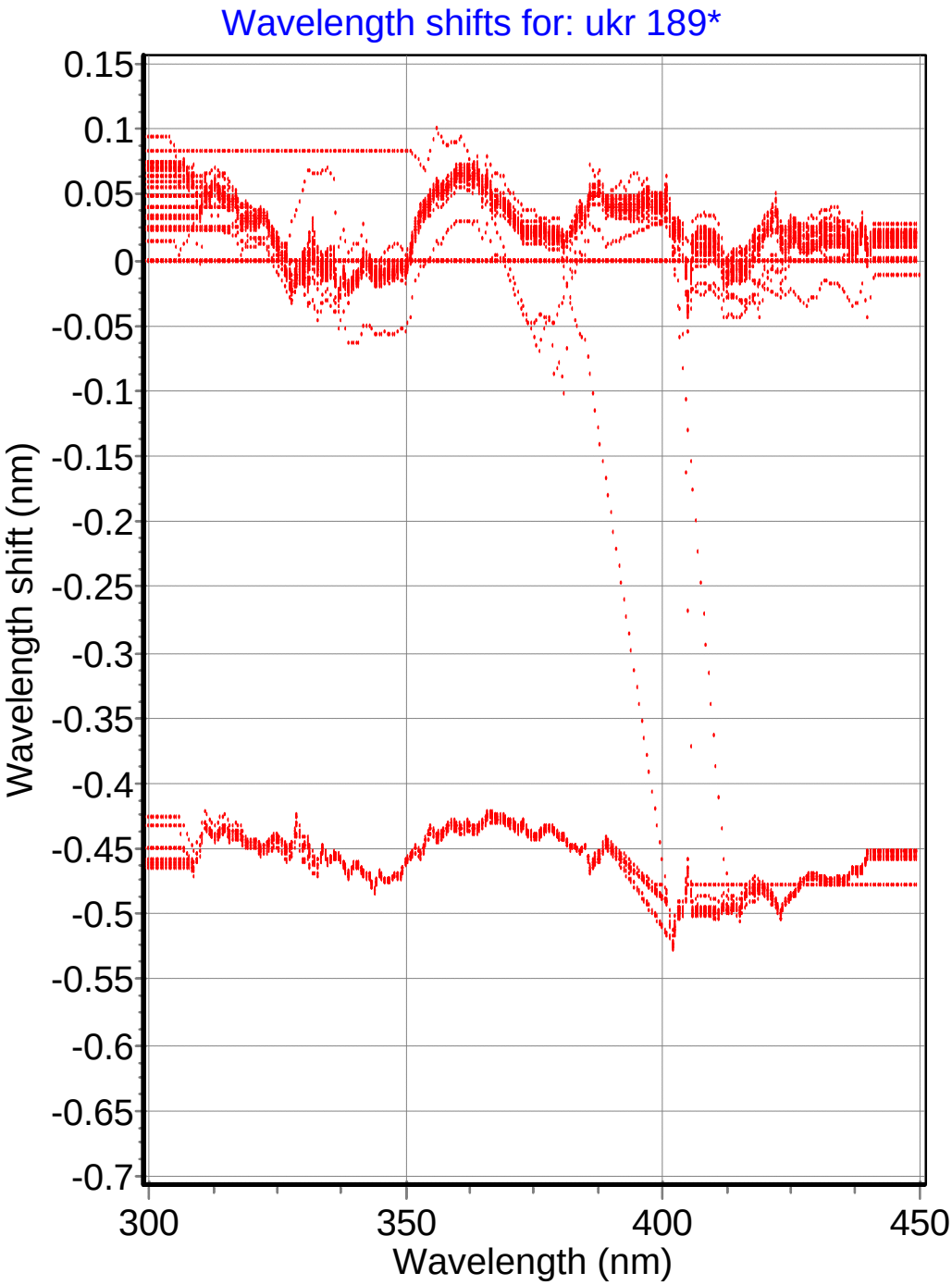

Global irradiance ratios UKR/JRC at Reading:10–Jul–2003(191)
1.2
1.1
1
0.9
0.8
300
350
400
450
wl [nm]
8
6
4
2
0
10
20
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
1.2
1.1
1
0.9
0.8
4(91)
6(74)
8(56)
10(38)
12(29)
14(36)
16(53)
18(71)
20(88)
22(101)
TIME [UT](SZA)
305 nm
310 nm
320 nm
350 nm
390 nm
420 nm
444 nm
22–Sep–2003 13:32:42

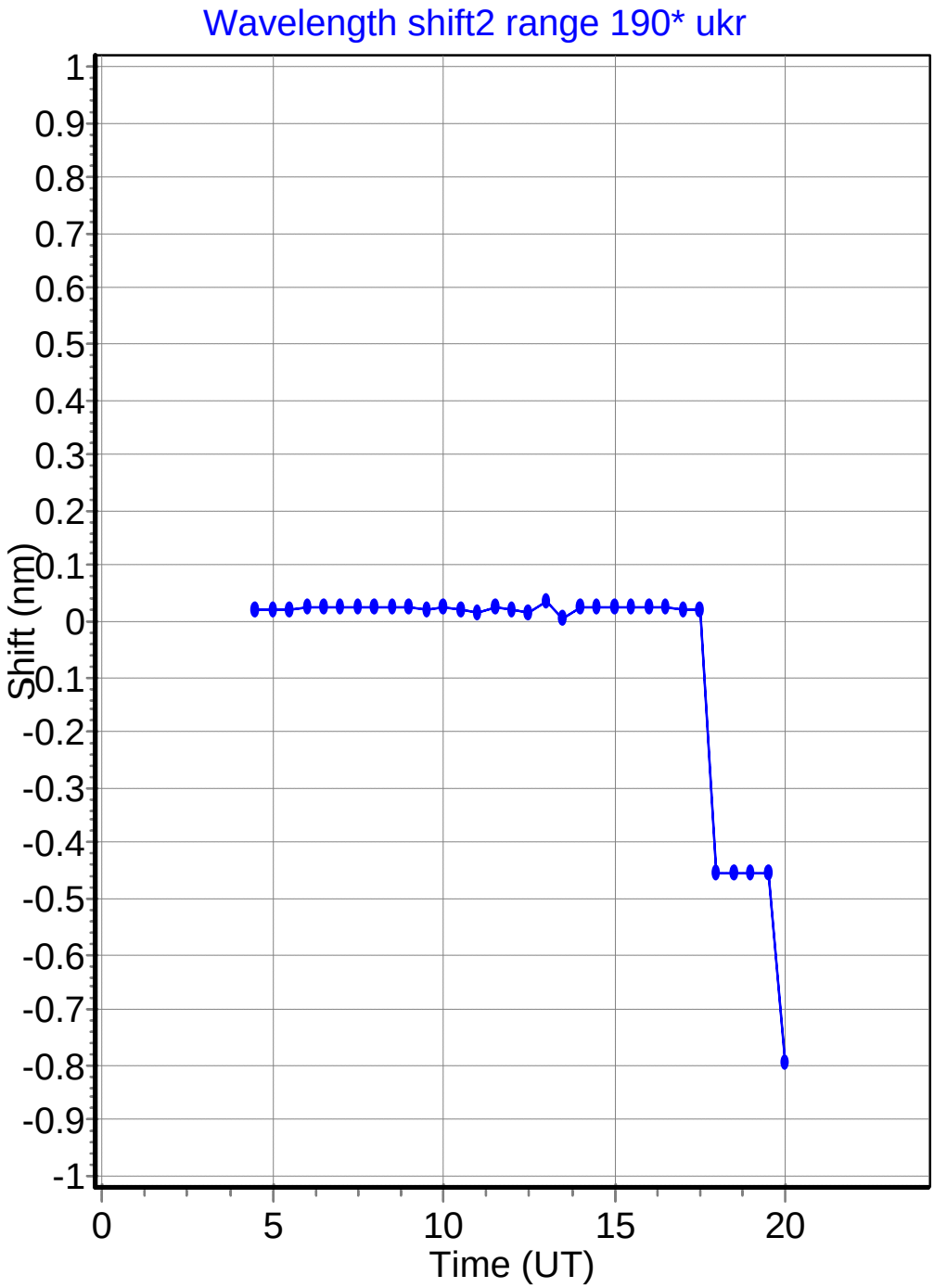

Mean ratio UKR/JRC at Reading:07−Jul−2003(188) to 10−Jul−2003(191)
Mean ratio
5/95% percentile
Range of values
NB Spectra =79
RATIO UKR/JRC
Wavelength [nm]
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
350
400
450

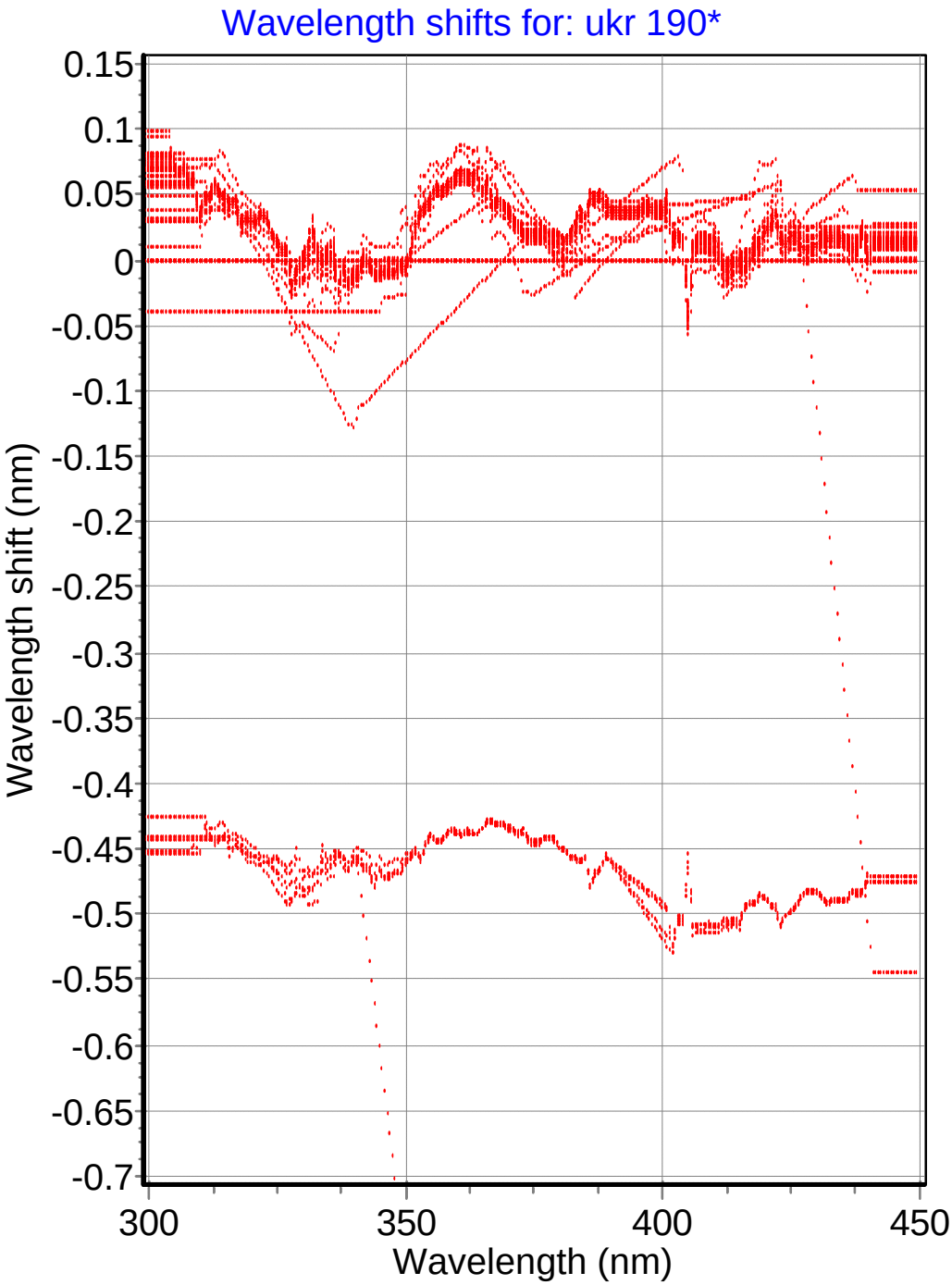

Wavelength shift2 range 188* ukr
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
Shift (nm)
10
12
14
16
18
20
22
24
Time (UT)

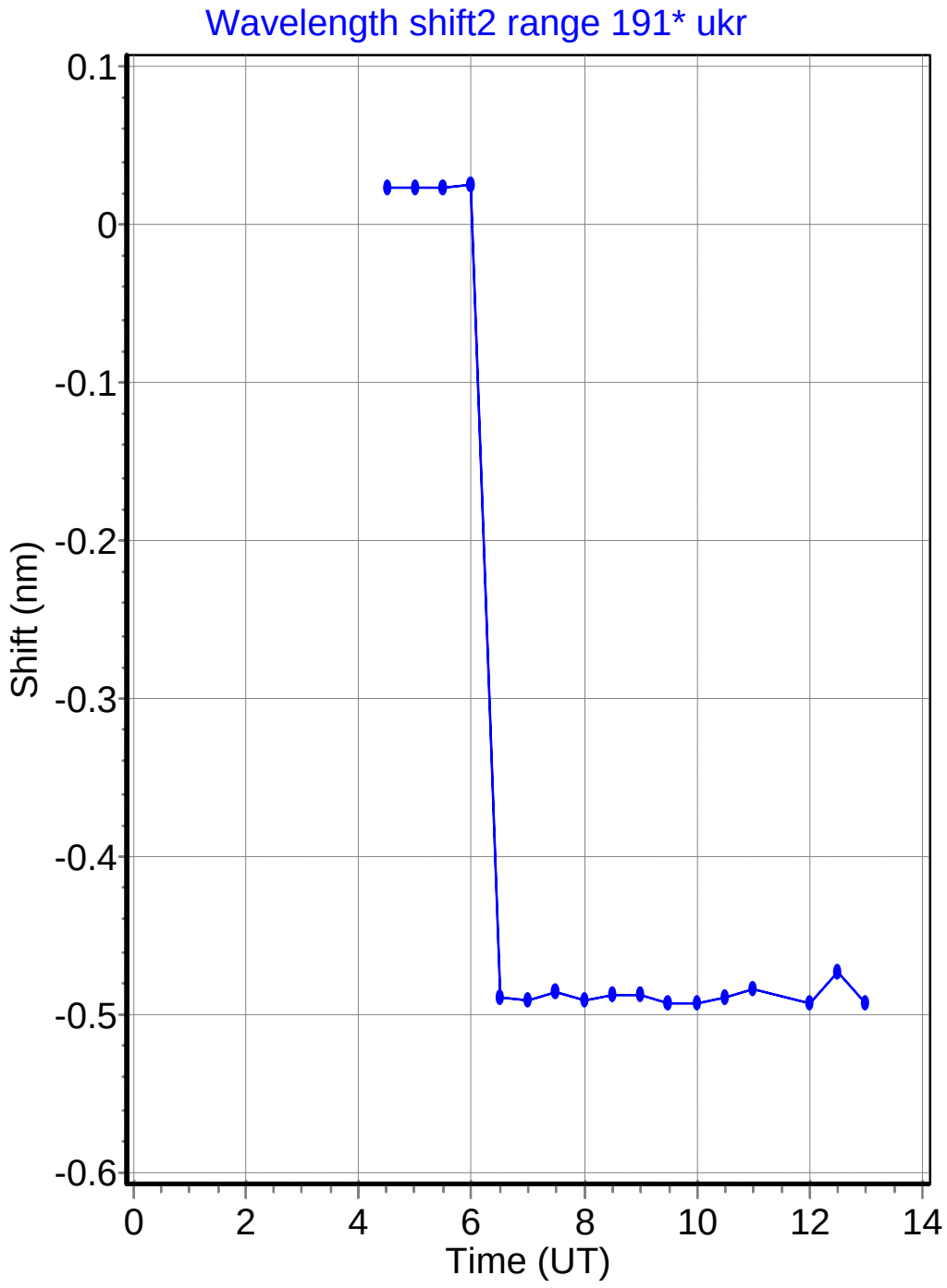

Wavelength shifts for: ukr 188*
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
Wavelength shift (nm)
300
350
400
450
Wavelength (nm)

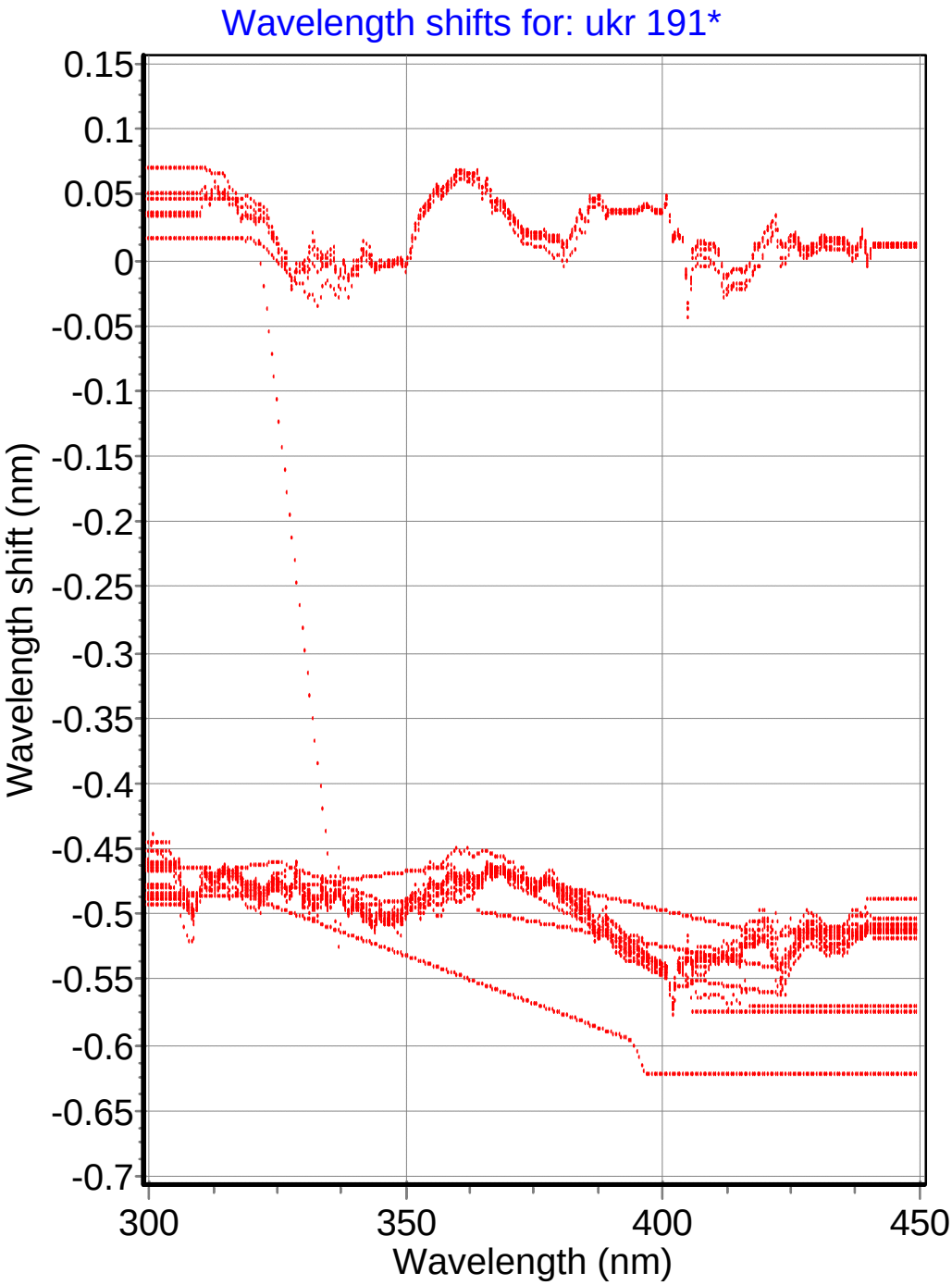

Wavelength shift1 range 189* ukr
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Shift (nm)
0
5
10
15
20
Time (UT)

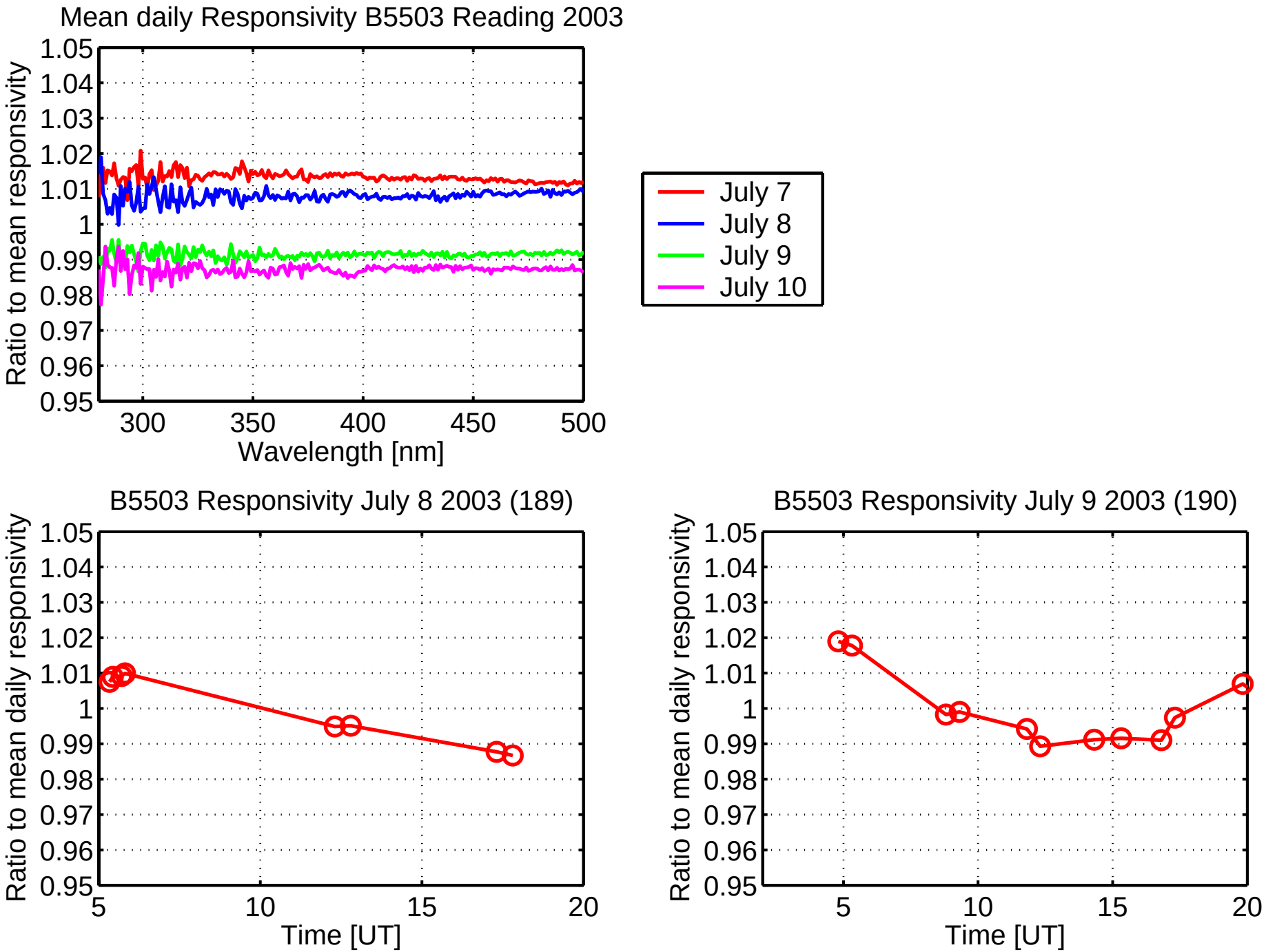

Wavelength shifts for: ukr 189*
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
Wavelength shift (nm)
300
350
400
450
Wavelength (nm)


Wavelength shift2 range 190* ukr
Shift (nm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
0
5
10
15
20
Time (UT)


Wavelength shifts for: ukr 190*
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
Wavelength shift (nm)
300
350
400
450
Wavelength (nm)


Wavelength shift2 range 191* ukr
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Shift (nm)
0
2
4
6
8
10
12
14
Time (UT)


Wavelength shifts for: ukr 191*
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
Wavelength shift (nm)
300
350
400
450
Wavelength (nm)


Mean daily Responsivity B5503 Reading 2003
Ratio to mean responsivity
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
300
350
400
450
500
Wavelength [nm]
July 7
July 8
July 9
July 10
B5503 Responsivity July 8 2003 (189)
Ratio to mean daily responsivity
5
10
15
20
Time [UT]
B5503 Responsivity July 9 2003 (190)
Ratio to mean daily responsivity
Time [UT]