Protocol of the intercomparison at the Laboratory of Atmospheric Physics (LAP), Aristotle University of Thessaloniki, October 4-13, 2002 with the travelling reference spectrometer B5503 from ECUV within the project QASUME

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Operator: Stelios Kazadzis

The purpose of the visit was the comparison of global solar irradiance measurements between the spectrometer operated by LAP and B5503. The visit at LAP follows the previous intercomparison at the home site of B5503 at the JRC, Ispra, Italy. The measurement site is located on the roof of a building 20 meters above ground. Latitude is 40.634 N, Longitude 22.956 E and altitude is 60 m.a.s.l. The horizon of the measurement site is free to the South and to the West. There is a building blocking the east side by an angle of 80 degrees and the faciltites of the laboratory, which are situated at the north side of the instruments (see attached graph).

B5503 arrived at LAP in the evening of October 3, 2002. The instrument was installed about 1.5 m from the spectrometer of LAP. The intercomparison between B5503 and the spectrometer from LAP lasted eight days, from noon of October 4 to the afternoon of October 13.

B5503 was calibrated three times during the intercomparison period using a 100 W portable calibration system. Three 100 W lamps were used to obtain an absolute spectral calibration traceable to the primary reference (F330) held at ECUV and traceable to PTB. The first calibration on October 5 was held from 15:20 to 16:40 UT, the second on October 8 from 15:20 to 16:40 UT, and the last calibration on October 11 from 14:40 to 16:40 UT. The stability of the instrument during the intercomparison is ± 0.5%, based on the 100 W calibration data (see appended graph). The internal temperature of B5503 was 24.7 ± 0.1 °C during the whole period. No information is available on possible temperature gradients within the instrument. The diffuser used by B5503 has an azimuth dependency of about 5% at long wavelengths, which produces a spurious diurnal variation of the measured solar irradiance. In the following report, the position of the diffuser will be defined relative to the orientation of its levelling bulb which is fixed to the diffuser.
The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm analysis were between ± 50pm in the spectral range 310 to 500 nm (see appended graphs).

Protocol:
The measurement protocol was to measure one solar irradiance spectrum every 30 minutes between sunrise and sunset. The measured wavelength interval ranged from 290 to 500 nm, every 0.25 nm, and 1.5 seconds between each wavelength increment. The spectrometer of LAP, a double Brewer #086 measured from 290 to 365 nm, every 0.5 nm.

<u>October 3 (276):</u>

Arrival and setup of the instrument in the late afternoon. Left to stabilize over night. At 17:00, the temperature of B5503 was 21 °C.

<u>October 4 (277):</u>

LAP spectrometer is calibrated in the morning in the dark room. Synchronous measurements are available from 12:30 to 14:00 UT. The B5503 diffuser levelling bulb faces West.

<u>October 5 (278):</u>

Synchronous measurements are available from 5:30 to 15:00 UT. Atmospheric conditions were scattered cirrus clouds and haze for the whole day. The solar disc was free for most of the measurement period.

<u>October 6 (279):</u>

The B5503 diffuser was moved to within 0.5 m from the LAP spectrometer and rotated by 90° so that the levelling bulb faced North. The weather conditions were rainy with moderate to strong showers. This day was excluded from the intercomparison due to the unfavourable weather conditions.

<u>October 7 (280):</u>

The instruments were measuring unattended. Weather conditions consisted of rain in the morning and variable cloudiness for the rest of the day. This day was excluded from the intercomparison due to the above-mentioned reasons.

<u>October 8 (281):</u>

Synchronous measurements are available from 6:00 to 11:30 UT and from 13:30 to 15:30 UT. During the period 12:00 to 13:00 UT, measurements were interrupted due to the presence of a visiting group on the measurement platform. Weather conditions were 0-2 tenths cirrus clouds.

<u>October 9 (282):</u>

Synchronous measurements are available from 5:30 to 15:00 UT. At 12:20 the B5503 diffuser was rotated by 90° so that the levelling bulb faced East. Weather conditions were mostly clear with some haze in the afternoon.

<u>October 10 (283):</u>

Synchronous measurements are available from 5:30 to 15:30 UT. Weather conditions were broken clouds or overcast.

<u>October 11 (284):</u>

Synchronous measurements are available from 5:30 to 14:30 UT. Measurements between 6:30 and 7:00 UT as well as between 9:30 to 10:30 were disturbed by rain and removed from the analysis. B5503 missed the 11:00 and 11:30 scan. Weather conditions were overcast.

<u>October 12 (285):</u>

In the morning the LAP spectrometer was moved to the laboratory for the measurement of the HeCd Laser. Synchronous measurements are available from 11:30 to 15:30 UT. Weather conditions were broken clouds or overcast in the afternoon.

<u>October 13 (286):</u>

Synchronous measurements are available from 5:30 to 14:30 UT. The LAP spectrometer missed the measurements at 12:30 and 13:00. Weather conditions were variable clouds.

<u>Results:</u>

The wavelength shifts of the submitted solar spectra of the LAP spectrometer retrieved through the SHICRivm analysis were remarkably stable to within ±10 pm. The spectral shape of the wavelength shifts varied between 0 to –0.1 nm (see attached graphs).

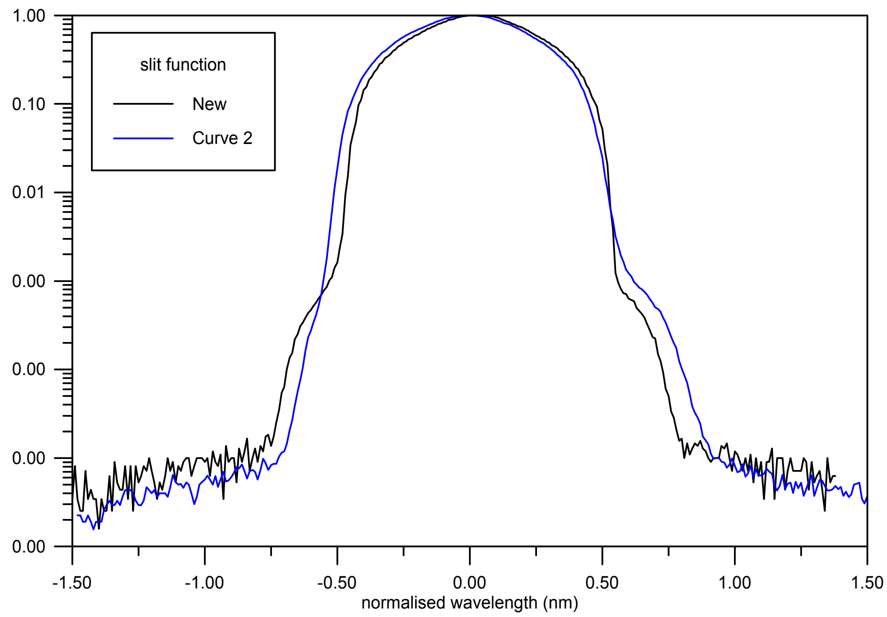
The intercomparison of the global irradiance measured by the two instruments can be summarized as follows:

- The overall ratio of global irradiances measured by LAP relative to B5503 is about 1.025±0.02%. The systematic decrease of the ratio after October 9 of about 2% coincides with the rotation of the B5503 diffuser and can therefore be probably attributed to a change of B5503.
- An obvious diurnal variation with amplitude 5% is clearly visible in the ratios between the two instruments. Probably it is largely a feature of B5503 due to the azimuthal dependency of its diffuser. This diurnal variation is more pronounced at longer wavelengths as well as for clear days with more direct irradiance, both of which would be a consequence of an azimuthal dependency of the diffuser.
- The spectral shape of the global irradiance ratios between LAP and B5503 are generally spectrally flat to within 2% between about 305 and 350 nm with very little structure. The ratio has a linear dependency on wavelength which is larger at longer wavelengths and which varies over the day. This dependency is dependent on the weather conditions, and on clear days (i.e. October 5 and October 9) the magnitude of this effect is about 5-10% at 350 nm and less than 2% at 305 nm. This is probably a feature of the azimuthal dependency of the B5503 diffuser as discussed previously. At shorter wavelengths the ratio is above the noise level for SZA smaller than about 70°. During variable cloud cover the ratios show more structure, which is caused by LAP not being totally synchronous at each wavelength (see comment by the local operator). Furthermore, at wavelengths longer than 350 nm, LAP is several seconds late and thus without synchronisation. Above 350 nm, a systematic feature of about 5% correlated to the shape of the solar spectrum can be seen in the ratios between LAP and B5503, which might point to a spectrally-dependent slit function of LAP.

<u>Comments from the local operator:</u>

The Brewer 086 is measuring the direct irradiance in-between (every 10 nm) the global irradiance scan. That leads to the fact that the instruments were not synchronised for the whole spectral scan. A typical example is that at 310 nm the instrument delays by an average (depending on solar zenith angle-rotation of the prism) of 10 seconds and it is catching up the synchronisation to 314 nm. This is repeated every 10 nm and also in the 351.5nm that the instrument is changing the internal slit of measurement. This fact can have an effect on the ratios in cases of fast moving clouds in front of the sun disk or other sudden changes of the radiation field. For the particular intercomparison taking into account the weather conditions it is suggested that only few measurement points could be affecter by this non ideal synchronisation. In parallel with the two instruments two single Brewers (no 001 and no 005) were measuring UV spectral irradiance in a synchronous mode. All measurements were started at the full and at the half hour and the step was 0.5 nm every 3 seconds.

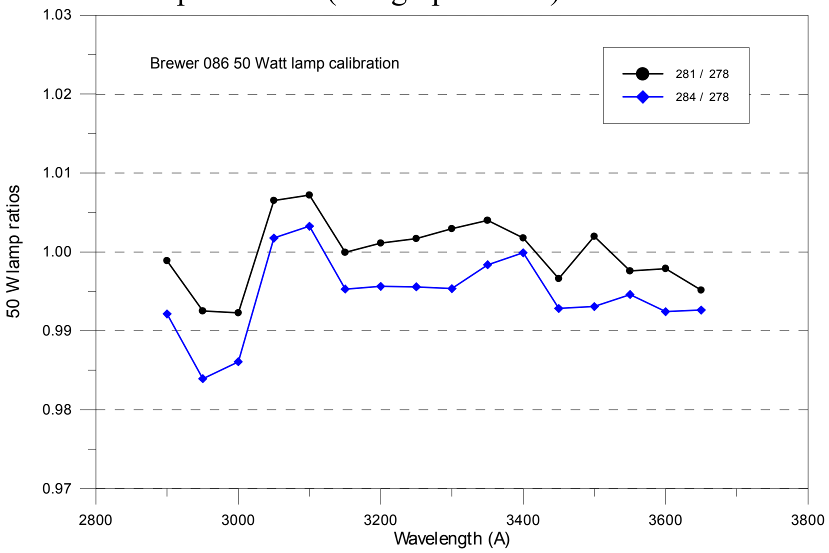
On October 12, the Brewer 086 instrument was moved in the dark room for the measurement of the slit function. Measurements were taken by using an external neutral density filter ND1.5 (30 times reduction). Three spectral scans were performed from 323 nm to 327 nm with the step of 0.01 nm. Each scan used the internal Brewer filters 0 (clear), 64 (reduction of the laser beam by 3 times) and 128 (reduction of the beam by 10 times). All three spectral scans gave similar results with better accuracy when using no internal filters.



Slit function of Brewer #86 using the HeCd Laser at 325 nm.

The spectral shape of the wavelength shift shows a spectral variation with the maximum deviation at 330-340 nm. The behaviour of the wavelength shift has changed since the last intercomparison at Ispra. This is due to the change of one of the two instrument's gratings. The wavelength calibration of the Brewer instrument was repeated two days before the start of this Qasume intercomparison. (See appended graphs)

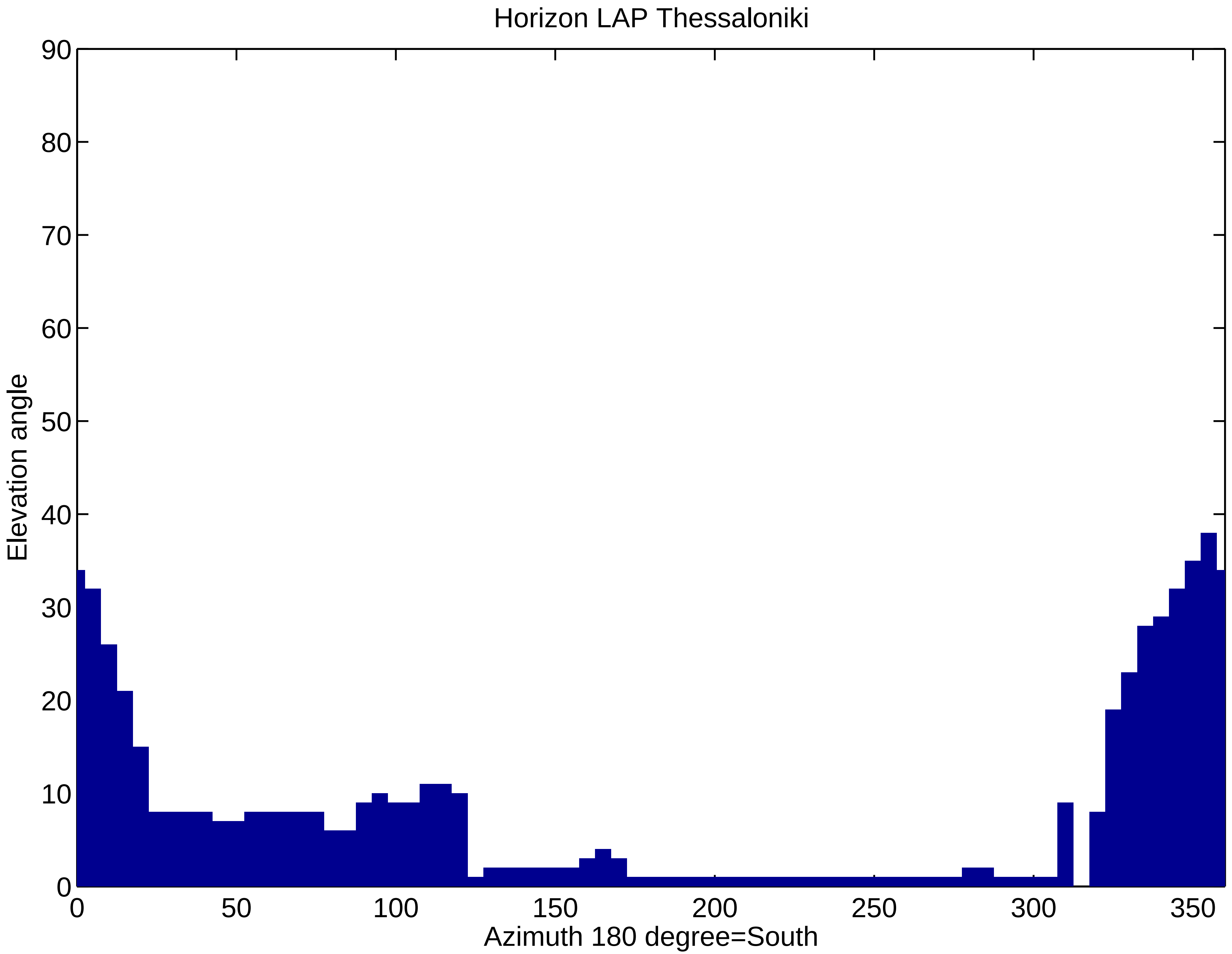
The Brewer instrument was stable to within 1.5% according to the 50 W lamp measurements that were performed. (See graph below)



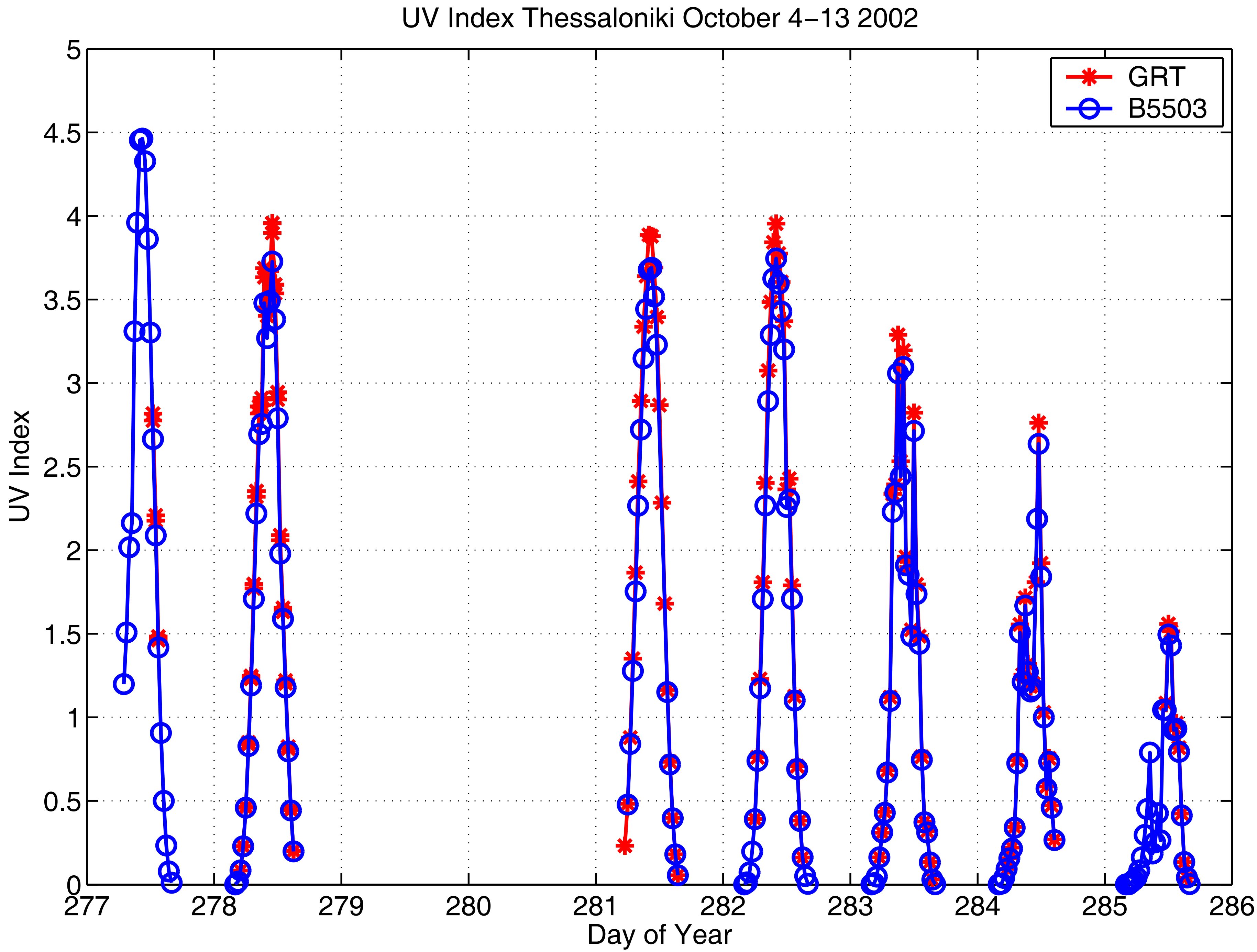
Ratio of the response functions of the Brewer instrument, calculated during the Qasume site-intercomparison

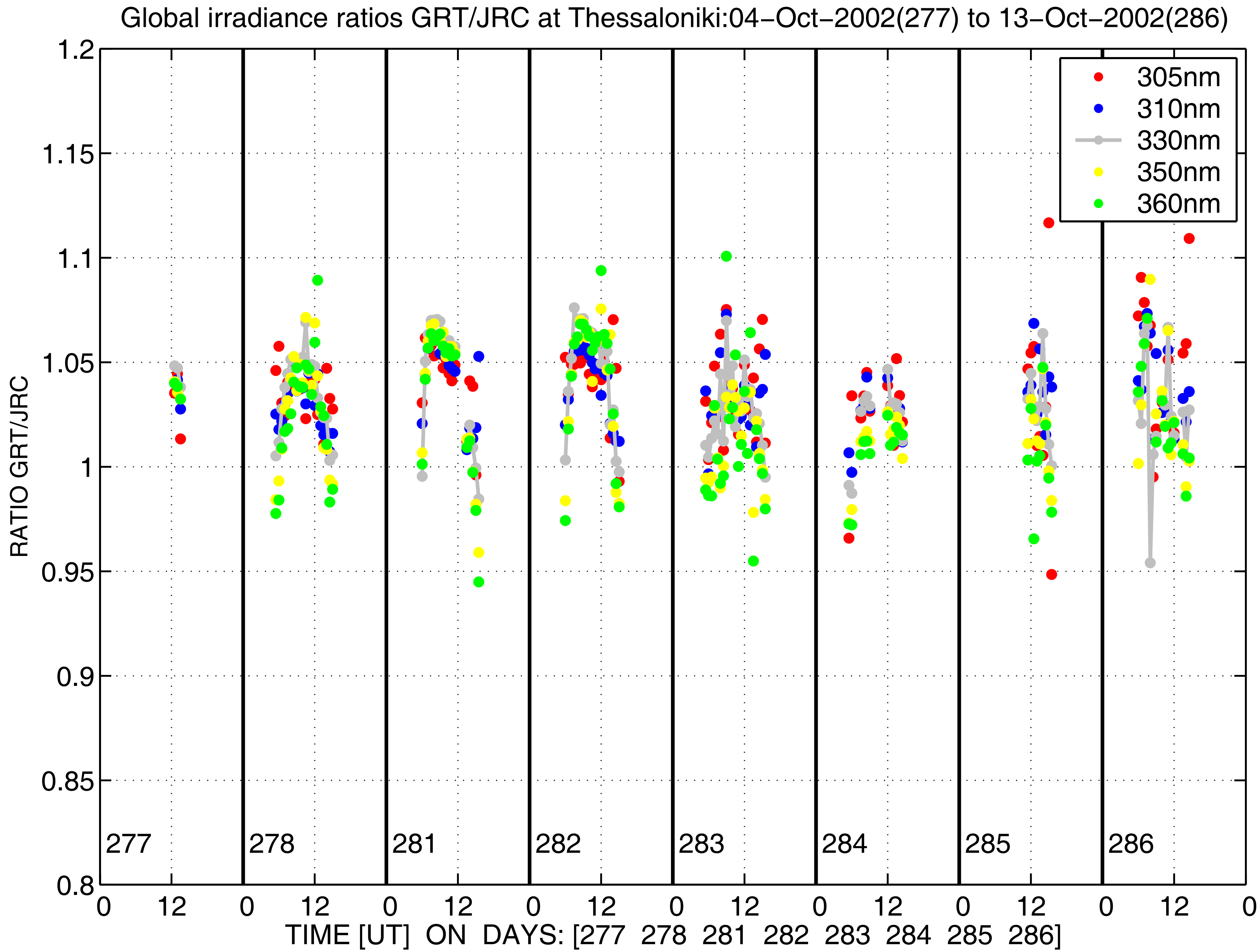
An investigation about possible effects of the cosine correction that is applied for the Brewer instrument showed that for the specific intercomparison, solar zenith angle range, the maximum deviation of the cosine correction factor is less than 1.5% (between local noon and sunrise-sunset measurements) for all wavelengths. A possible error in the cosine correction factor could only be attributed to a non-ideal measurement of the angular response of the instrument in the laboratory. This assumption is not in agreement with previous results of intercomparison campaigns that the instrument participated. Also, a 3-5% diurnal deviation in the cosine correction factor would mean an increase of more than 4% in the absolute level of the instrument's cosine corrected irradiance.

For measurements under scatter to overcast cloud conditions the ratio of the irradiances of the two instruments shows an absolute difference of 3% with a ± 3% scatter during the day, showing no particular solar zenith angle dependence (case of days 283-286).

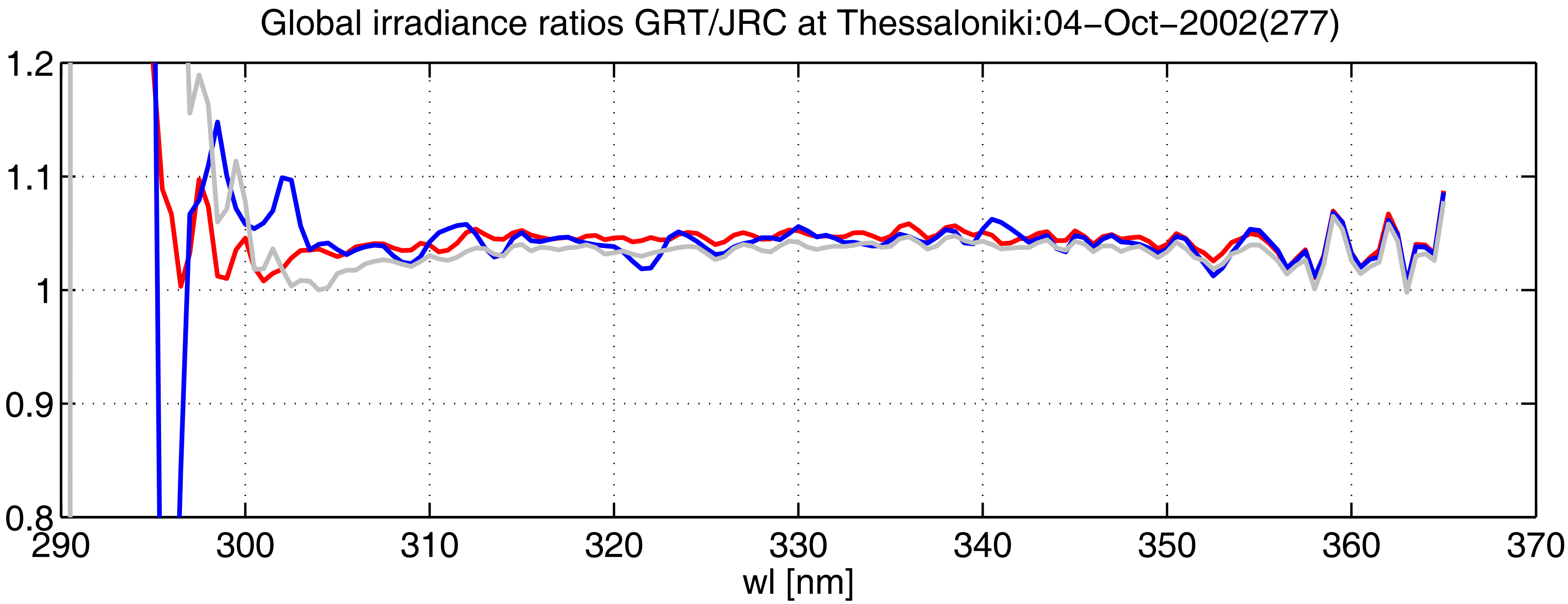


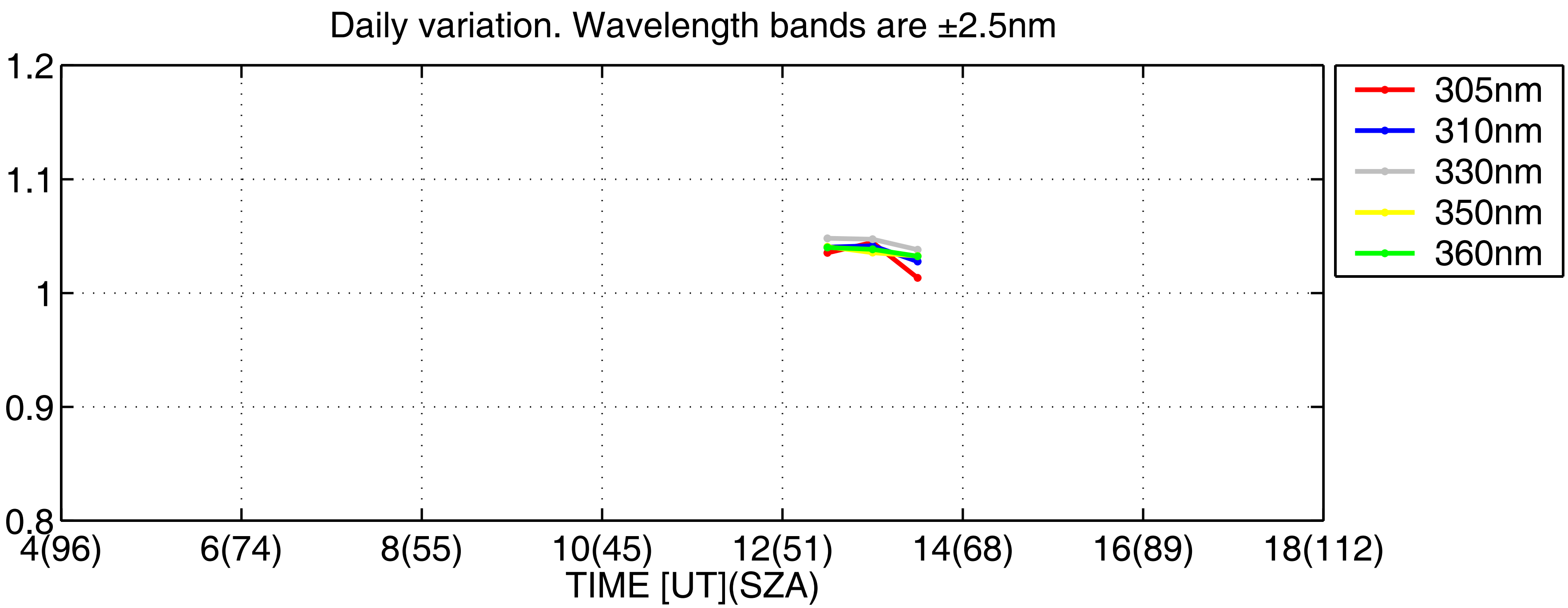
Horizon LAP Thessaloniki
Elevation angle
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
Azimuth 180 degree=South

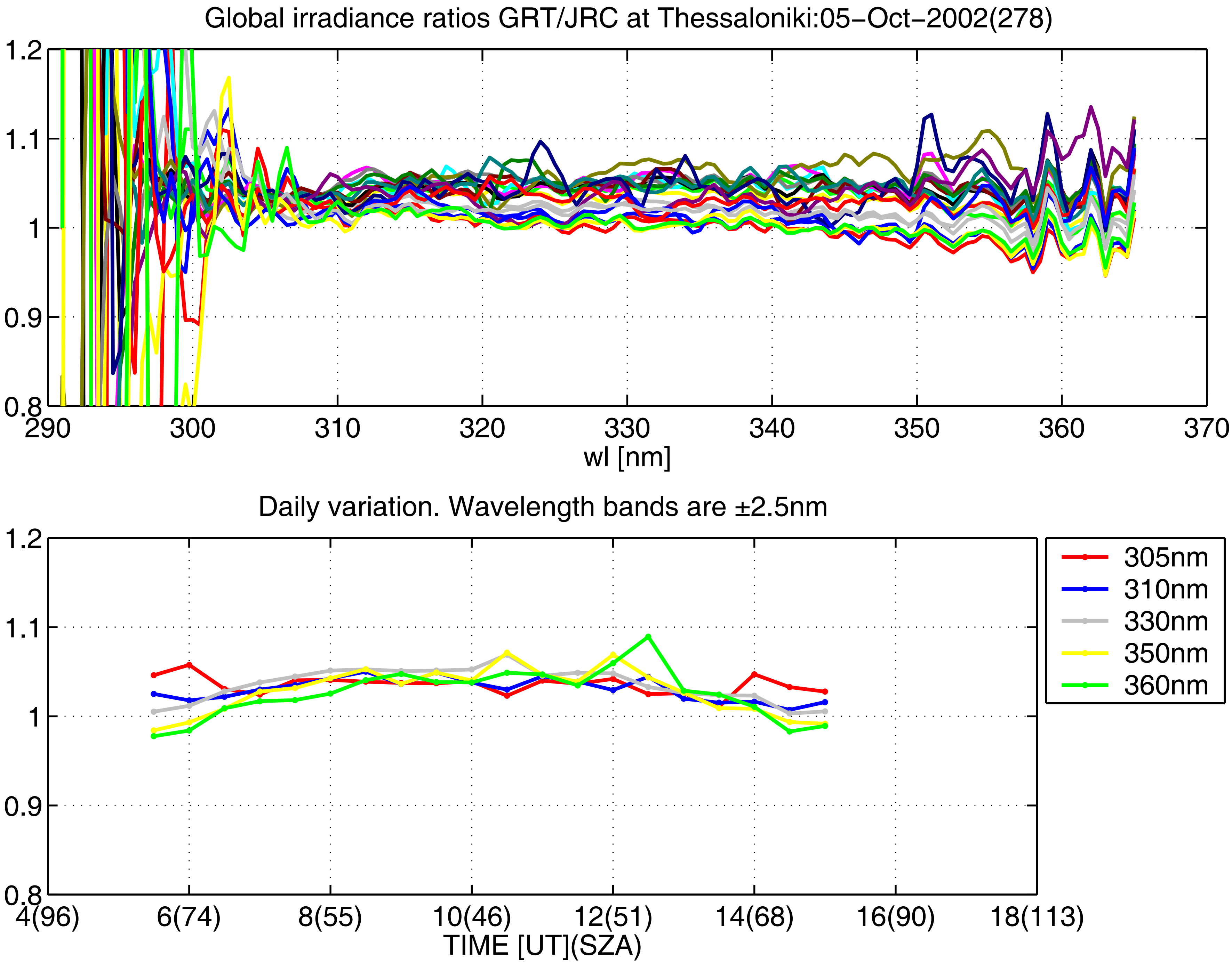

UV Index Thessaloniki October 4−13 2002
UV Index
Day of Year
GRT
B5503
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
277
278
279
280
281
282
283
284
285
286

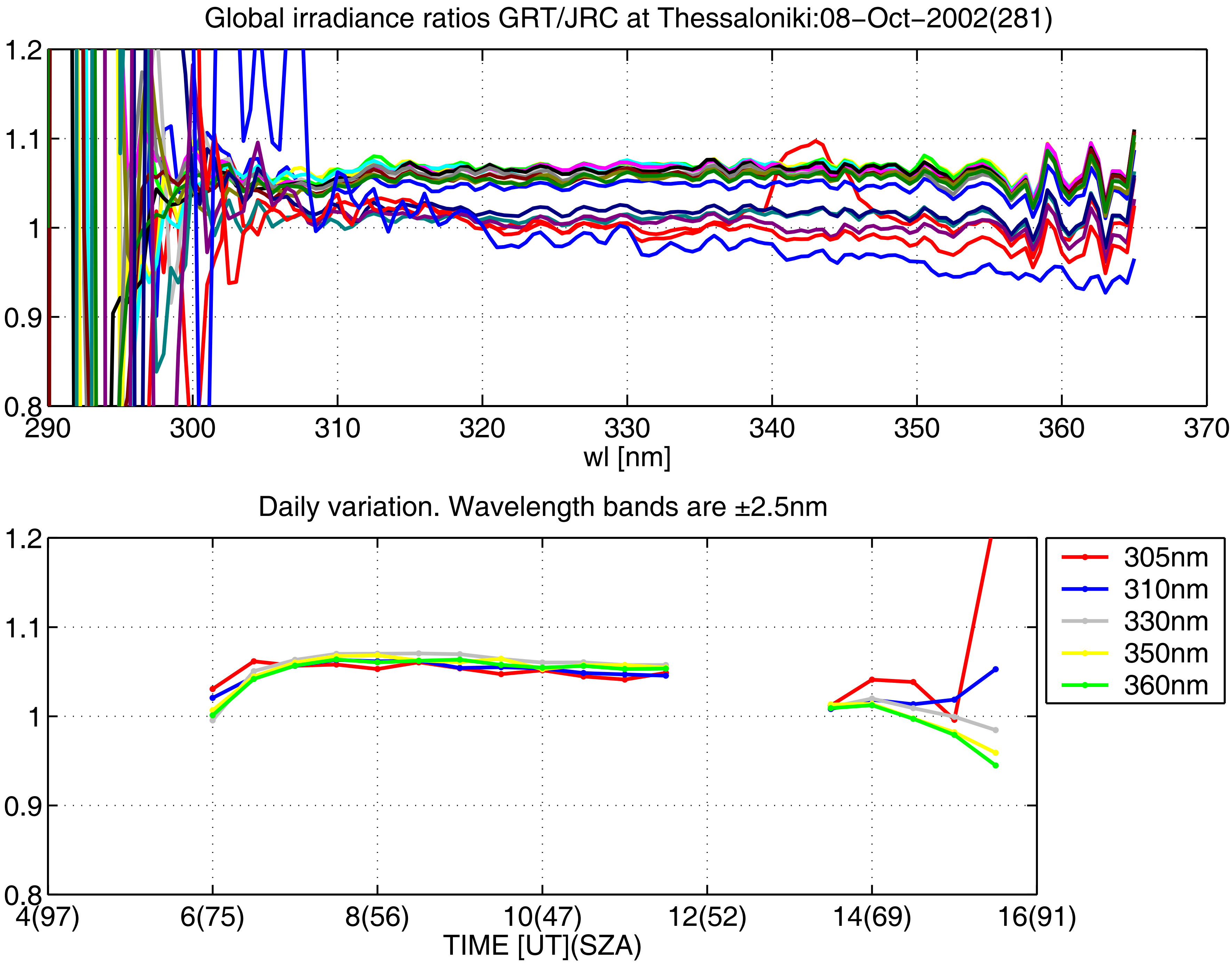


Global irradiance ratios GRT/JRC at Thessaloniki:04−Oct−2002(277) to 13−Oct−2002(286)
305nm
310nm
330nm
350nm
360nm
RATIO GRT/JRC
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
277
278
281
282
283
284
285
286
0 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12 0
TIME [UT] ON DAYS: [277 278 281 282 283 284 285 286]

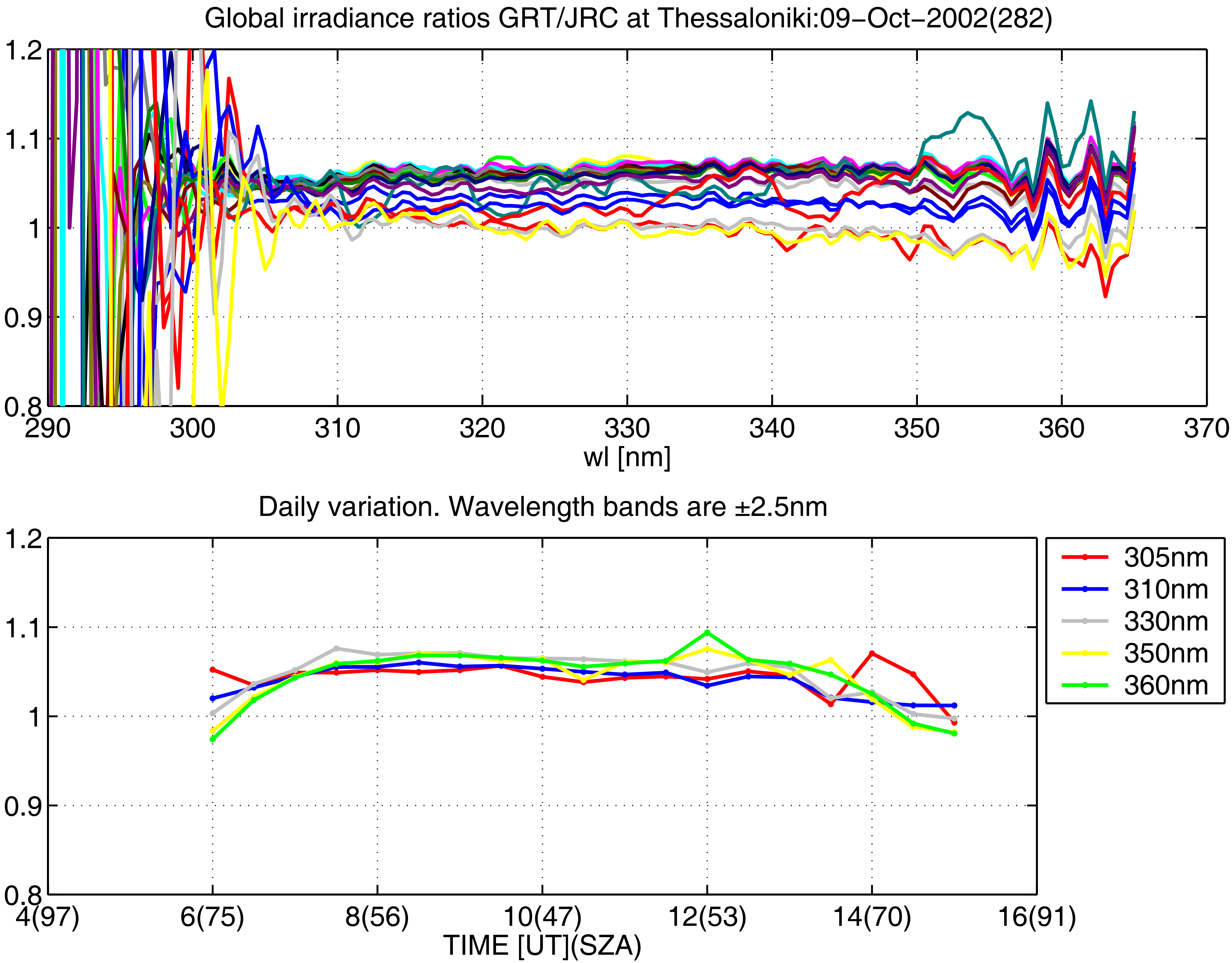

Global irradiance ratios GRT/JRC at Thessaloniki:04−Oct−2002(277)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]


Daily variation. Wavelength bands are ±2.5nm
1.2
1.1
1
0.9
0.8
4(96)
6(74)
8(55)
10(45)
12(51)
14(68)
16(89)
18(112)
TIME [UT](SZA)
305nm
310nm
330nm
350nm
360nm

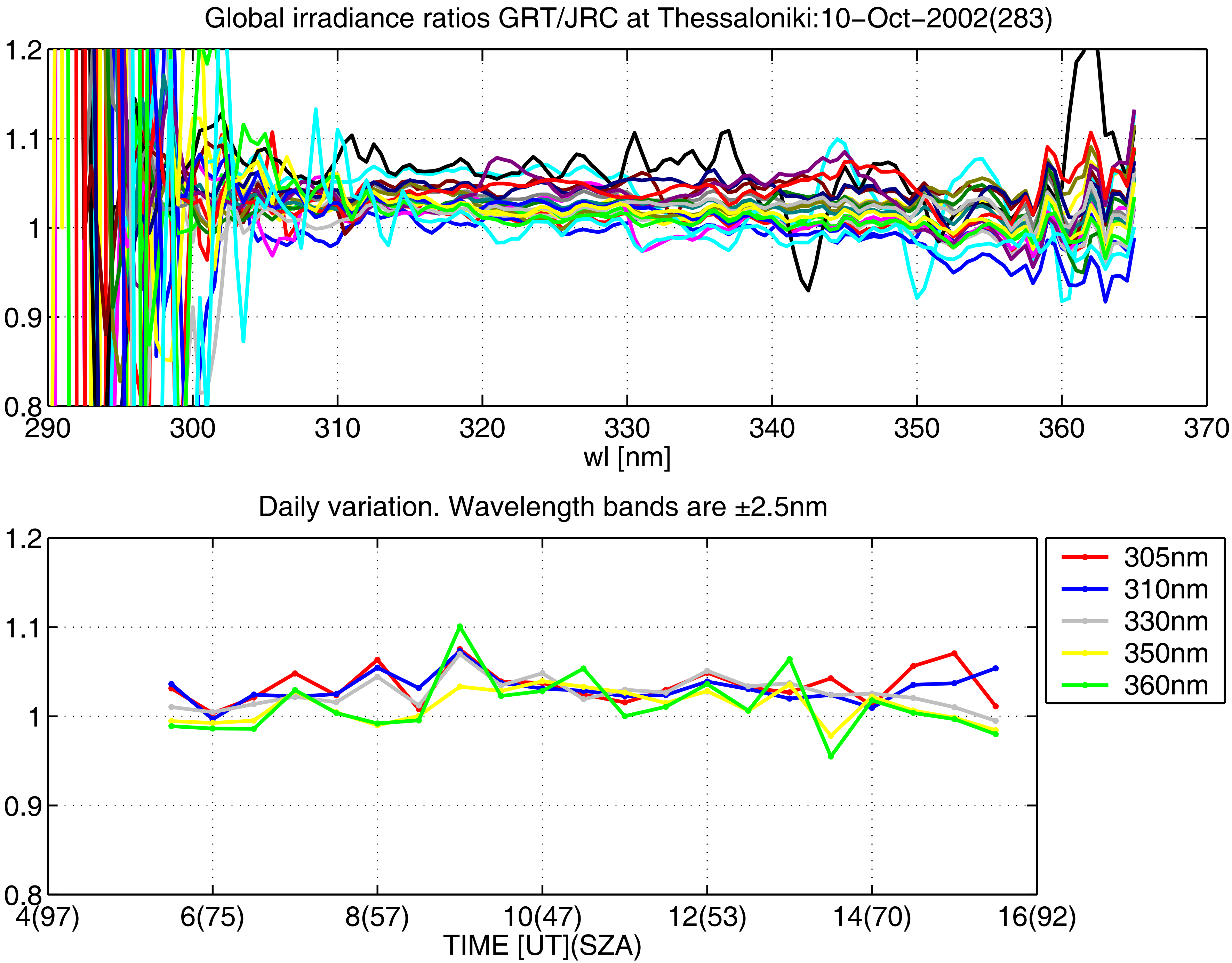

Global irradiance ratios GRT/JRC at Thessaloniki:05−Oct−2002(278)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
Daily variation. Wavelength bands are ±2.5nm
1.2
1.1
1
0.9
0.8
4(96)
6(74)
8(55)
10(46)
12(51)
14(68)
16(90)
18(113)
TIME [UT](SZA)
305nm
310nm
330nm
350nm
360nm

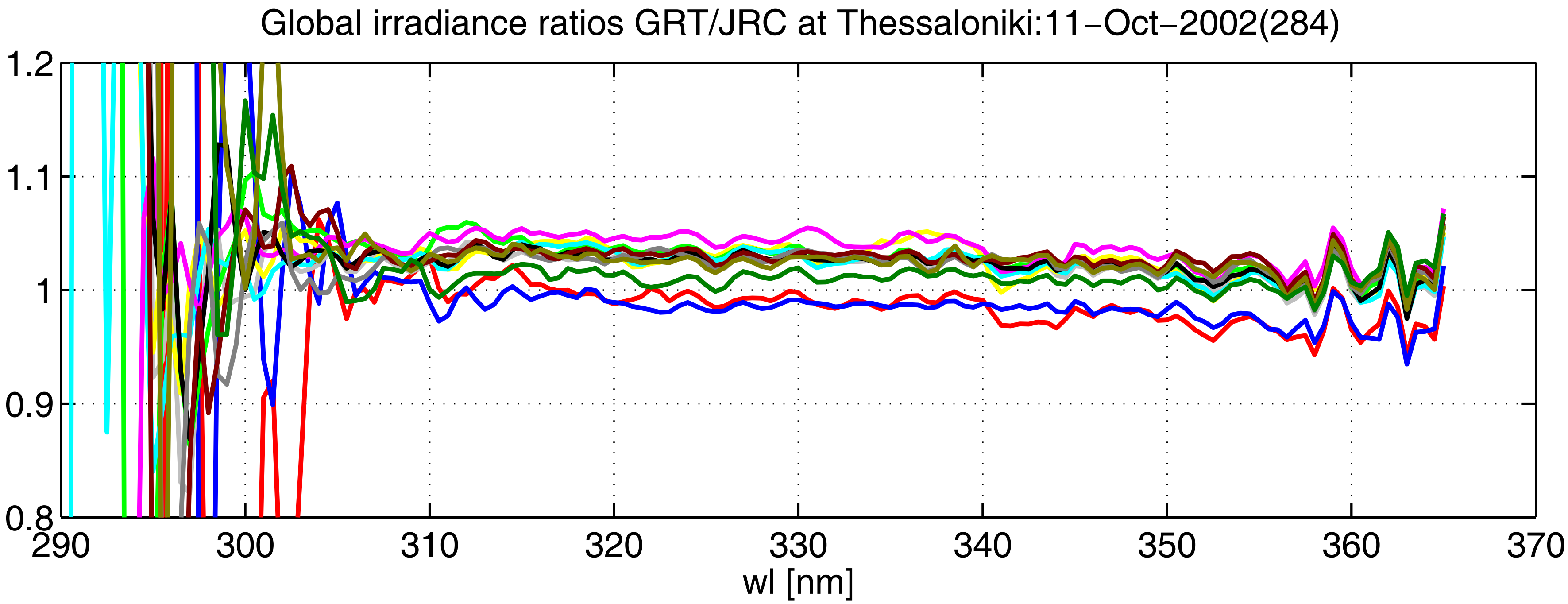


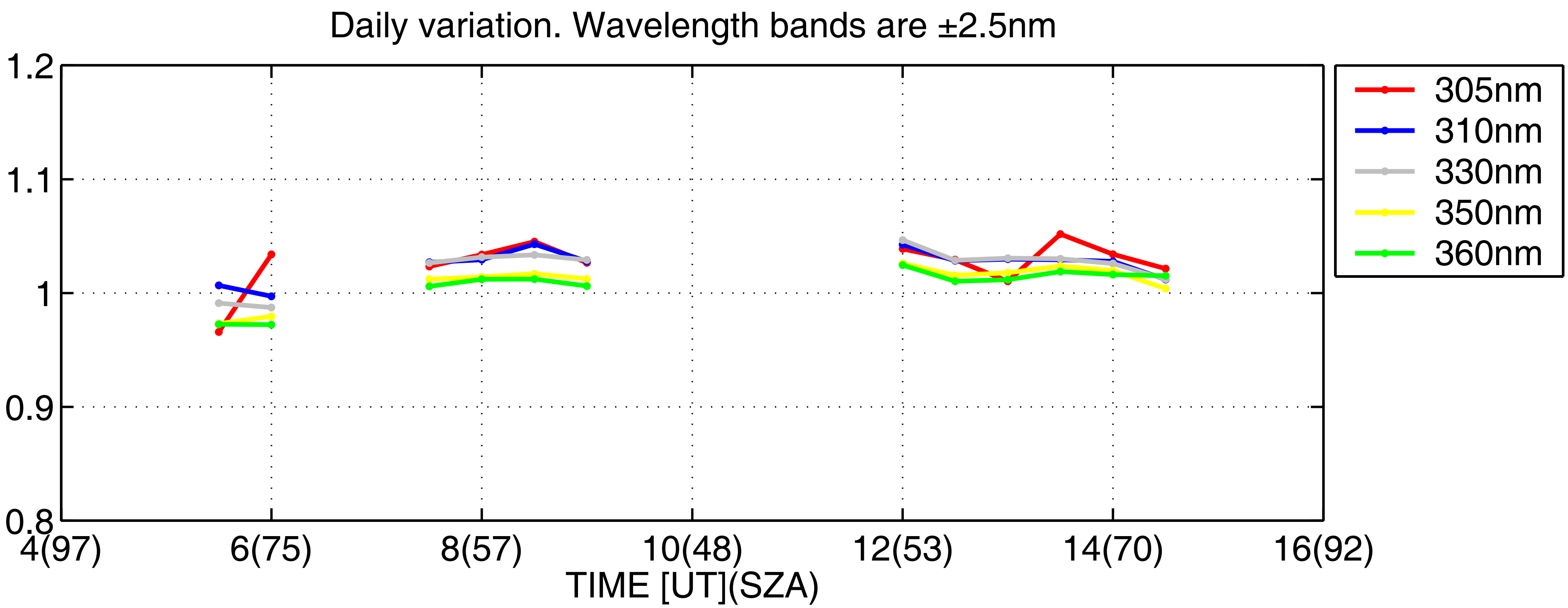
Global irradiance ratios GRT/JRC at Thessaloniki:08−Oct−2002(281)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
Daily variation. Wavelength bands are ±2.5nm
305nm
310nm
330nm
350nm
360nm
4(97)
6(75)
8(56)
10(47)
12(52)
14(69)
16(91)
TIME [UT](SZA)

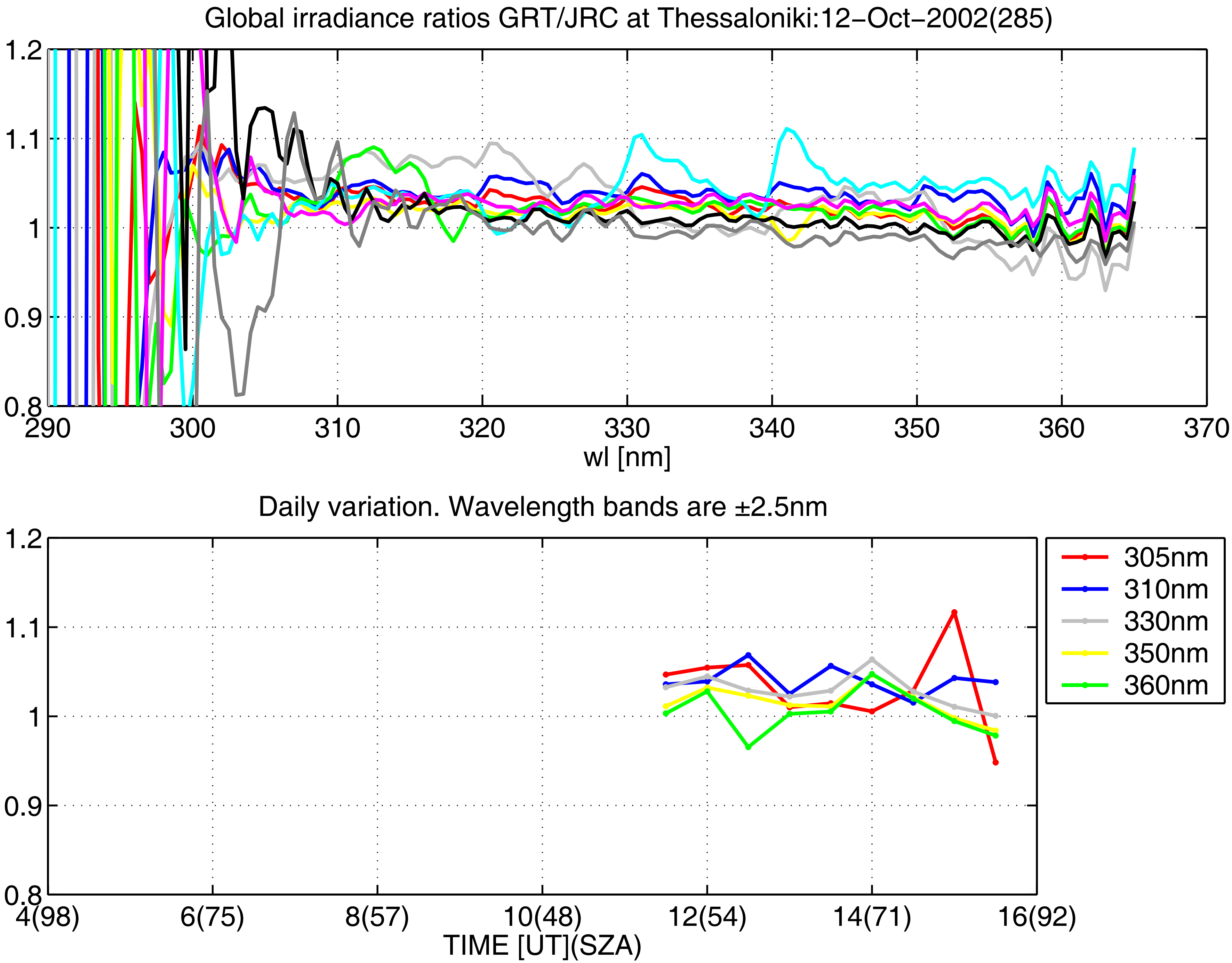


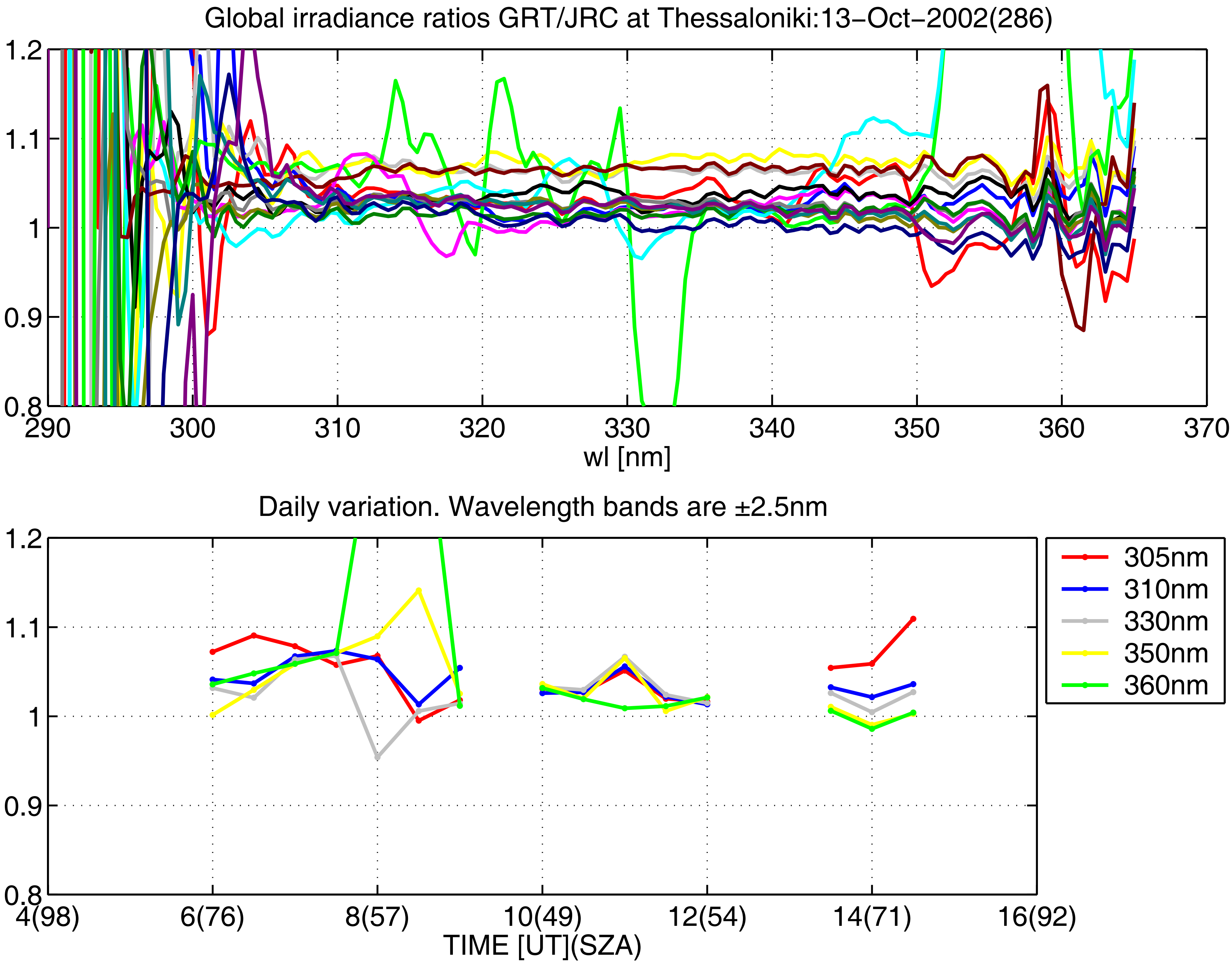
Global irradiance ratios GRT/JRC at Thessaloniki:09−Oct−2002(282)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
Daily variation. Wavelength bands are ±2.5nm
305nm
310nm
330nm
350nm
360nm
4(97)
6(75)
8(56)
10(47)
12(53)
14(70)
16(91)
TIME [UT](SZA)


Global irradiance ratios GRT/JRC at Thessaloniki:10−Oct−2002(283)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
Daily variation. Wavelength bands are ±2.5nm
305nm
310nm
330nm
350nm
360nm
4(97)
6(75)
8(57)
10(47)
12(53)
14(70)
16(92)
TIME [UT](SZA)

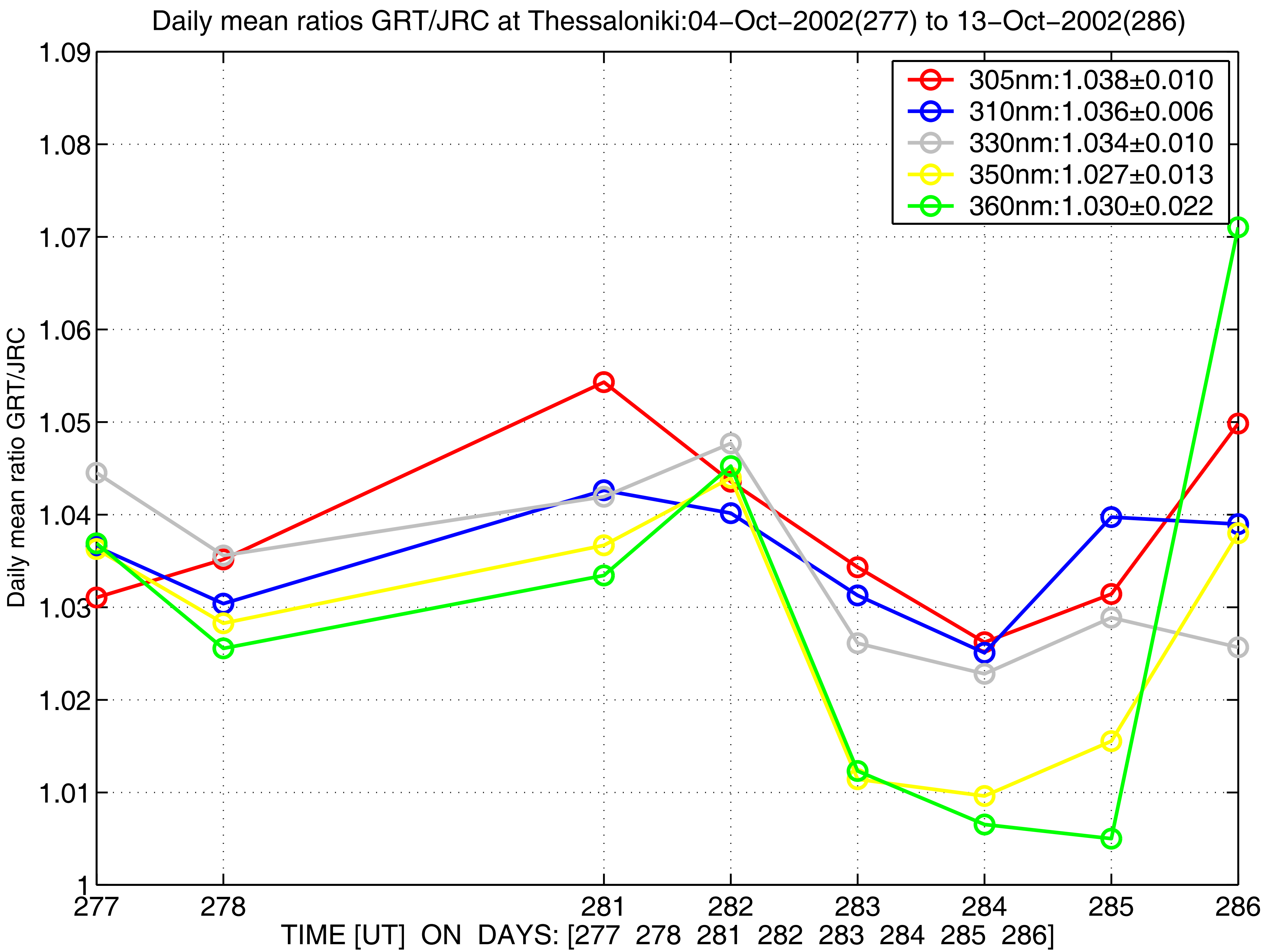

Global irradiance ratios GRT/JRC at Thessaloniki:11−Oct−2002(284)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]


Daily variation. Wavelength bands are ±2.5nm
1.2
1.1
1
0.9
0.8
4(97)
6(75)
8(57)
10(48)
12(53)
14(70)
16(92)
TIME [UT](SZA)
305nm
310nm
330nm
350nm
360nm

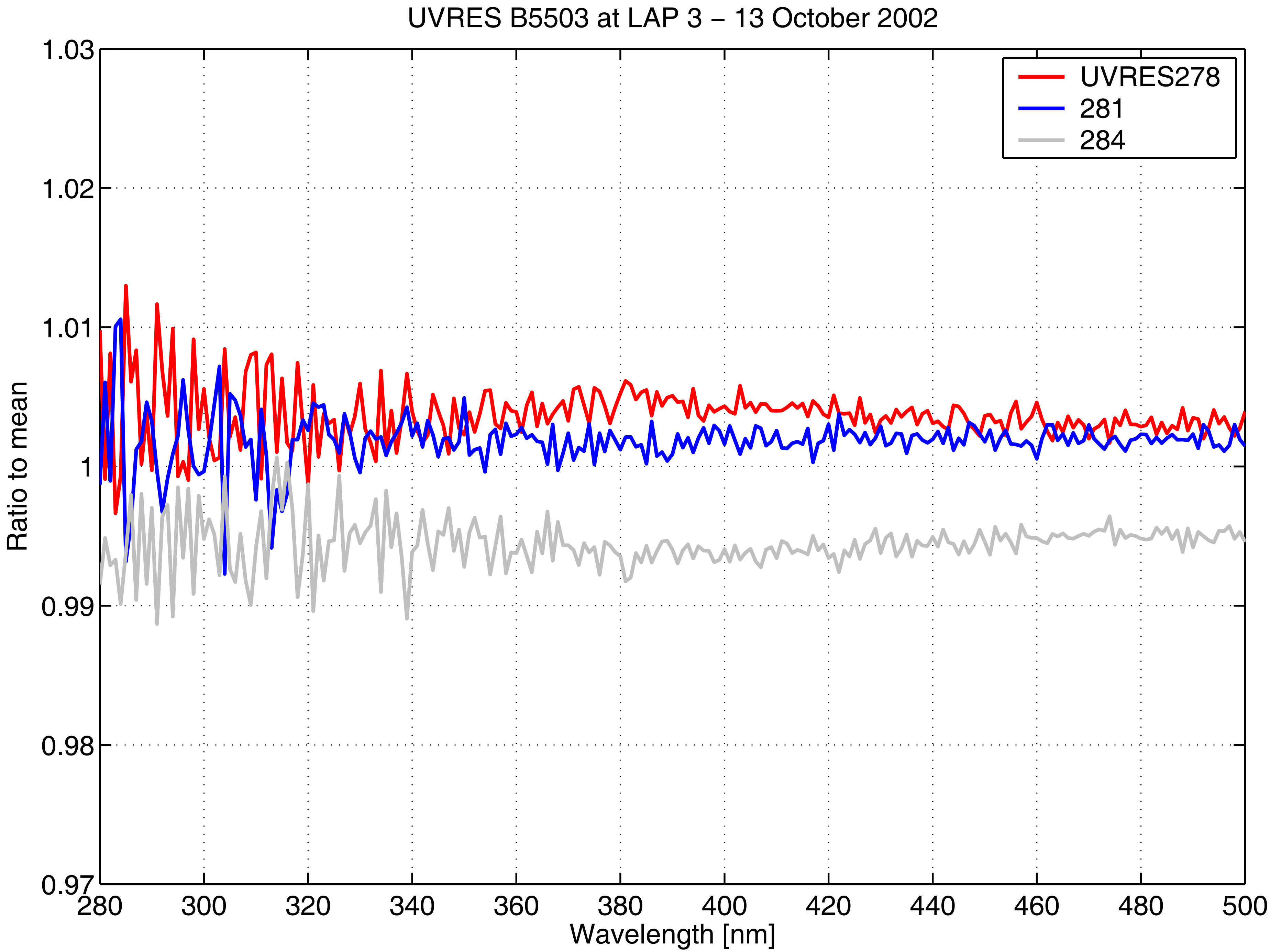

Global irradiance ratios GRT/JRC at Thessaloniki:12−Oct−2002(285)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
Daily variation. Wavelength bands are ±2.5nm
305nm
310nm
330nm
350nm
360nm
4(98)
6(75)
8(57)
10(48)
12(54)
14(71)
16(92)
TIME [UT](SZA)

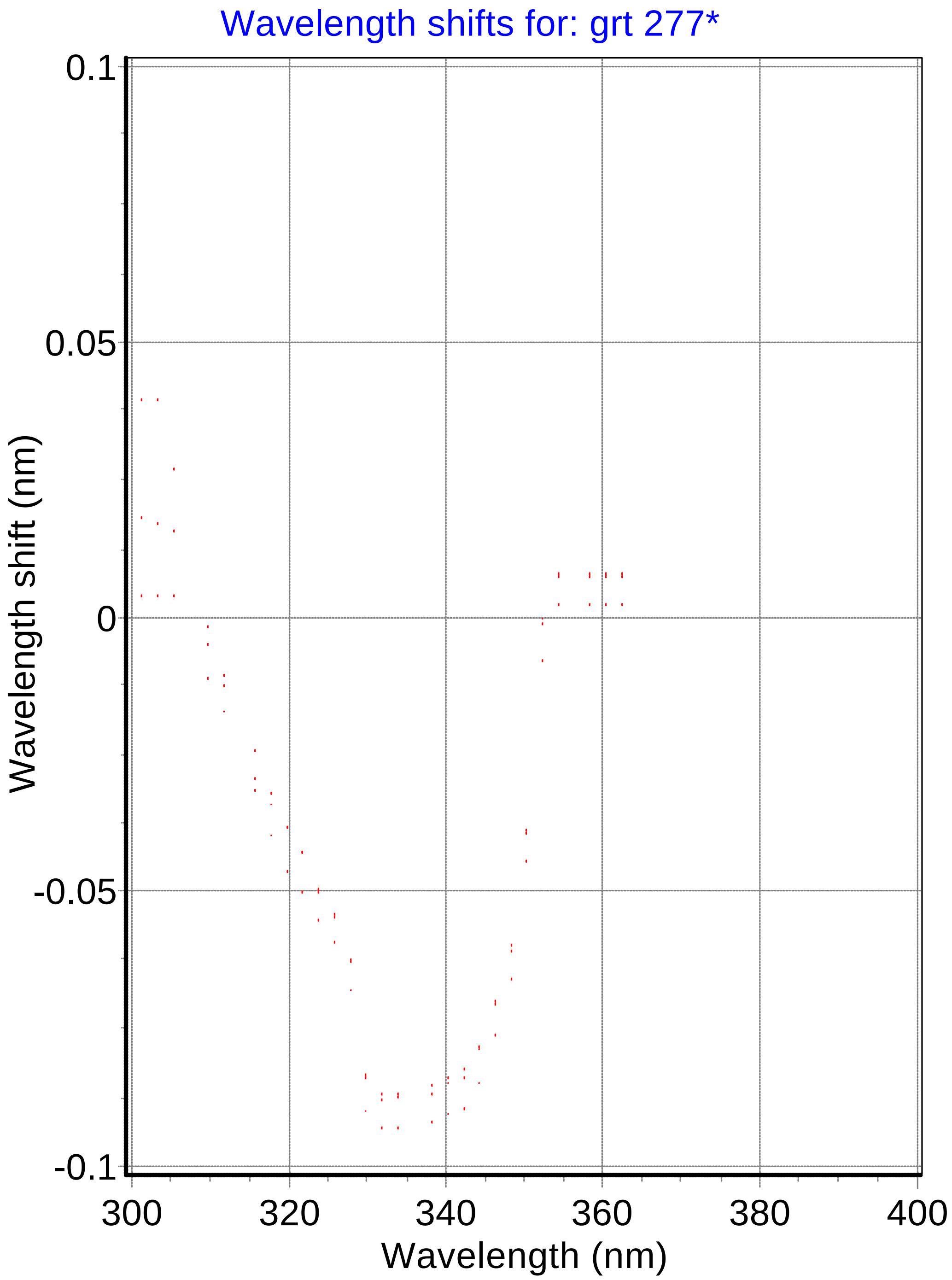


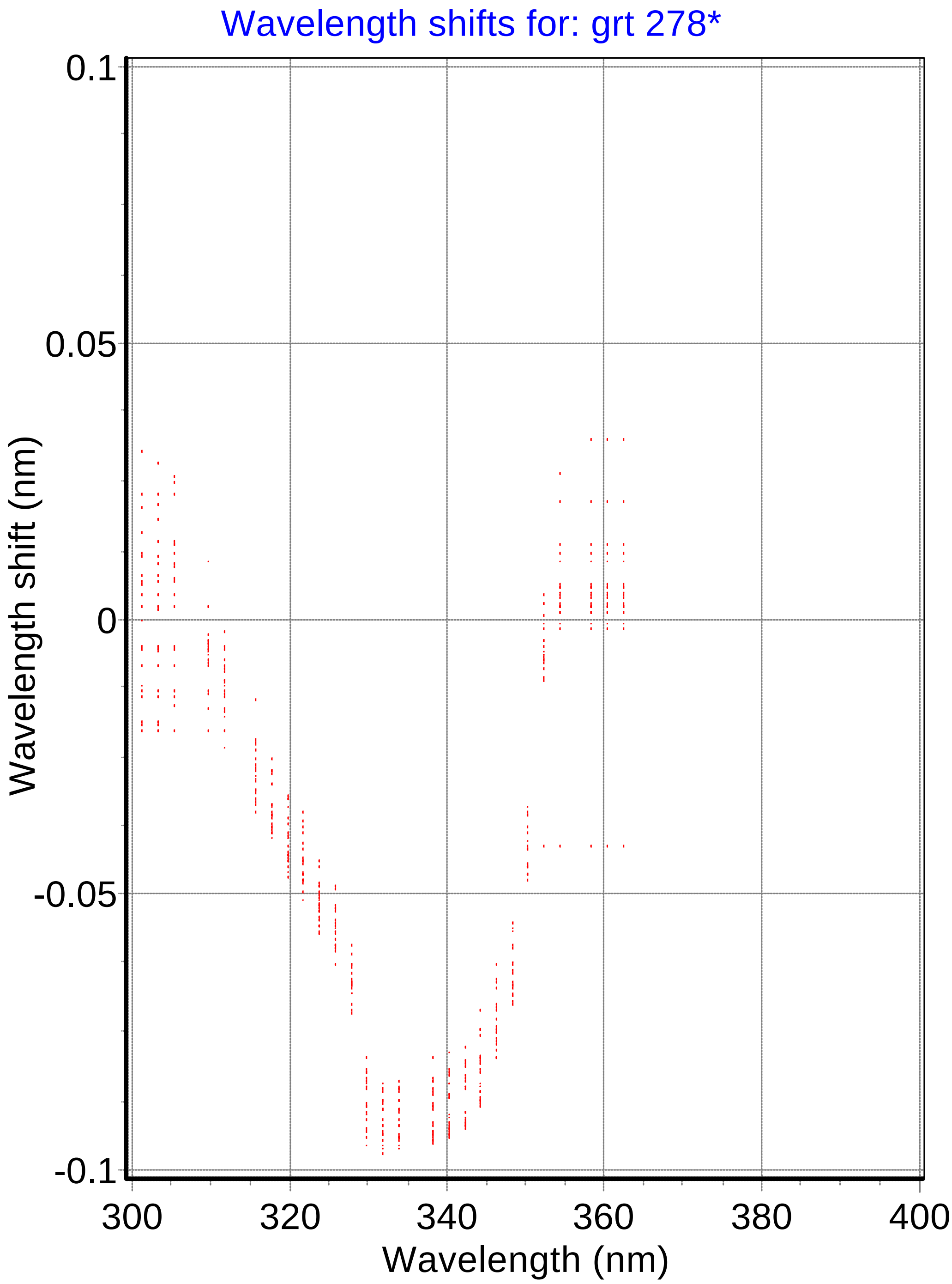
Global irradiance ratios GRT/JRC at Thessaloniki:13−Oct−2002(286)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
Daily variation. Wavelength bands are ±2.5nm
1.2
1.1
1
0.9
0.8
4(98)
6(76)
8(57)
10(49)
12(54)
14(71)
16(92)
TIME [UT](SZA)
305nm
310nm
330nm
350nm
360nm

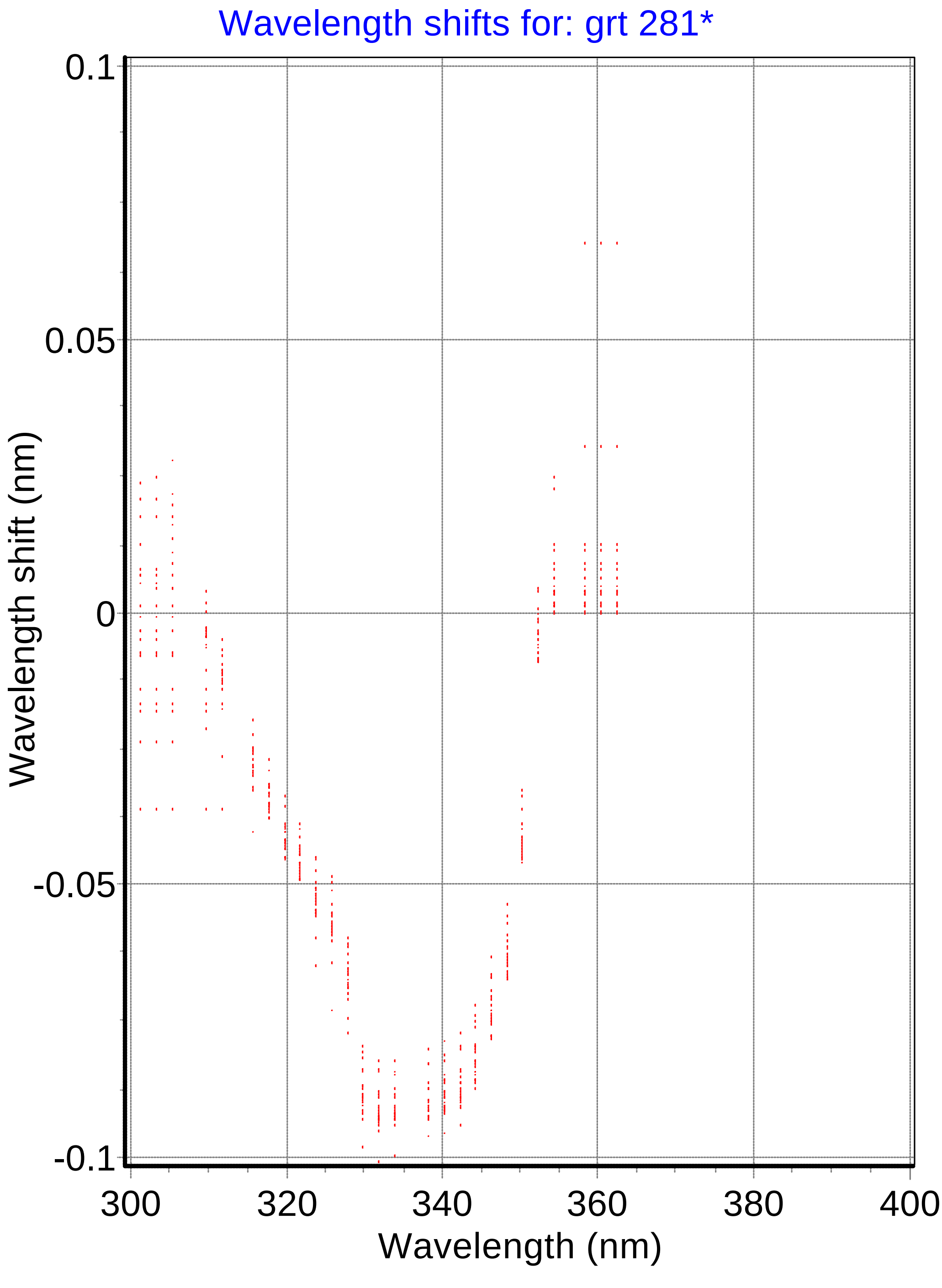


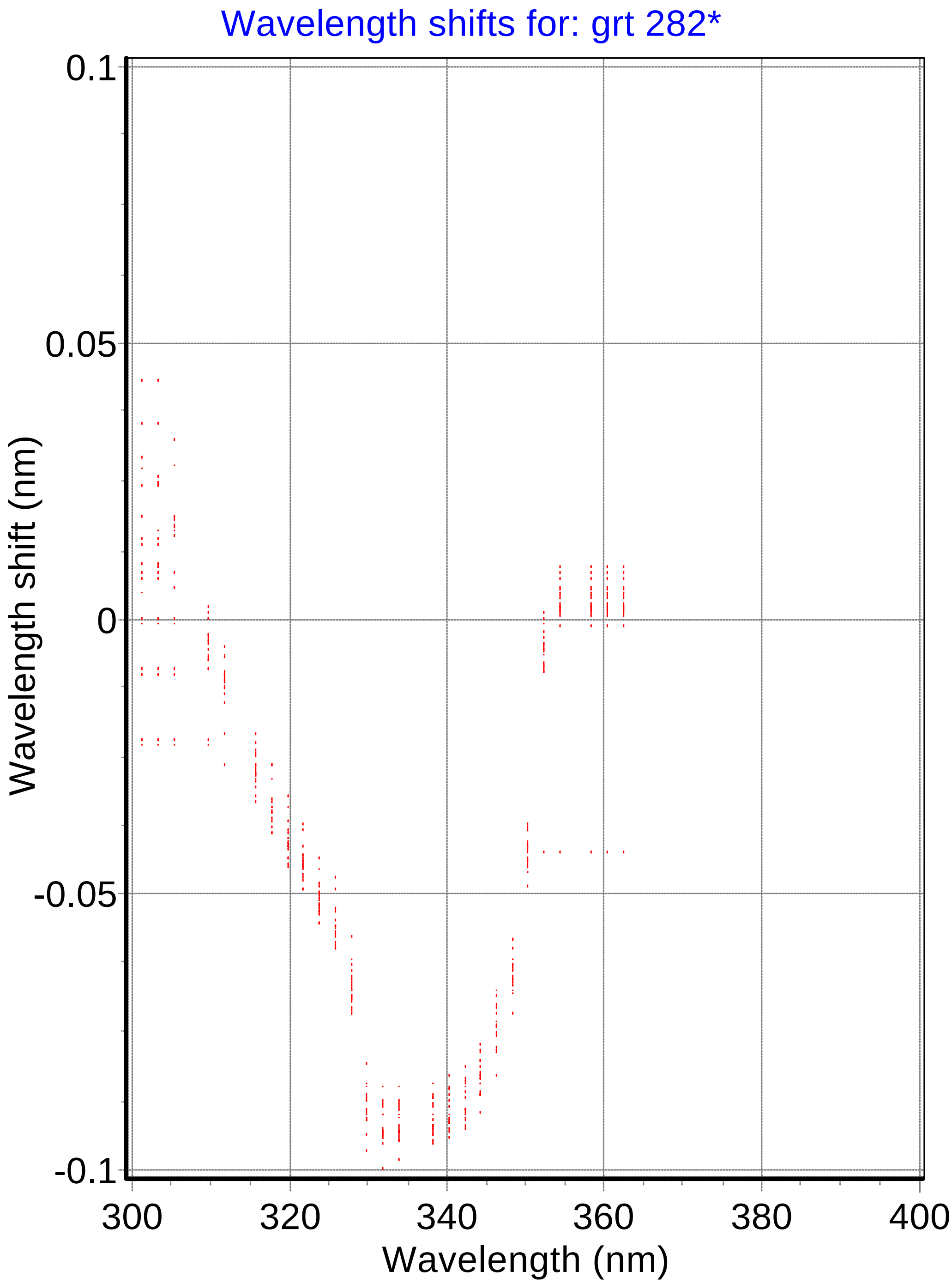
Daily mean ratios GRT/JRC at Thessaloniki:04−Oct−2002(277) to 13−Oct−2002(286)
305nm:1.038±0.010
310nm:1.036±0.006
330nm:1.034±0.010
350nm:1.027±0.013
360nm:1.030±0.022
Daily mean ratio GRT/JRC
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
277
278
281
282
283
284
285
286
TIME [UT] ON DAYS: [277 278 281 282 283 284 285 286]


UVRES B5503 at LAP 3 – 13 October 2002
Ratio to mean
1.03
1.02
1.01
1
0.99
0.98
0.97
280
300
320
340
360
380
400
420
440
460
480
500
Wavelength [nm]
UVRES278
281
284

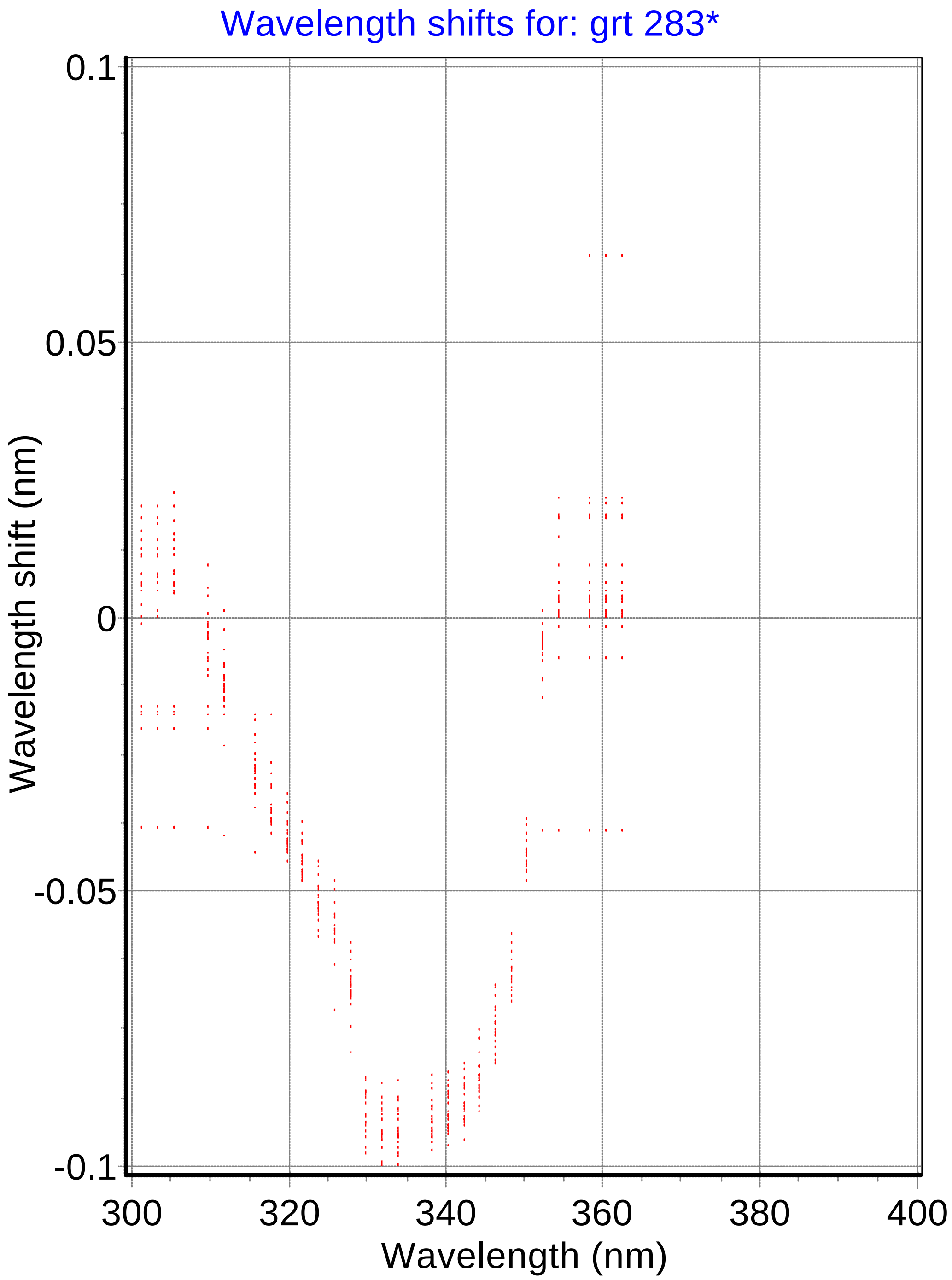

Wavelength shifts for: grt 277*
Wavelength shift (nm)
0.1
0.05
0
-0.05
-0.1
300
320
340
360
380
400
Wavelength (nm)


Wavelength shifts for: grt 278*
0.1
0.05
0
-0.05
-0.1
300
320
340
360
380
400
Wavelength (nm)
Wavelength shift (nm)

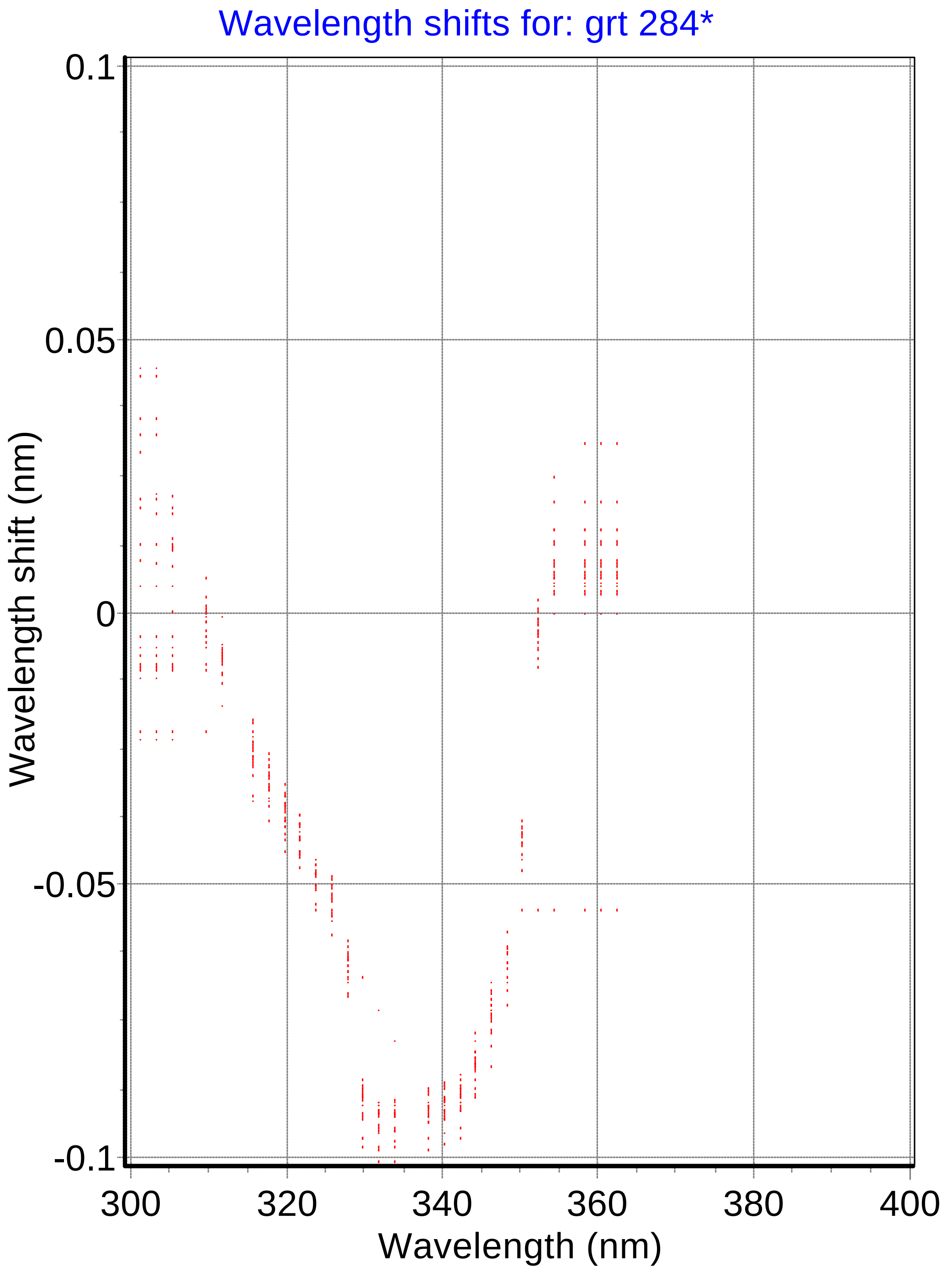

Wavelength shifts for: grt 281*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
380
400
Wavelength (nm)



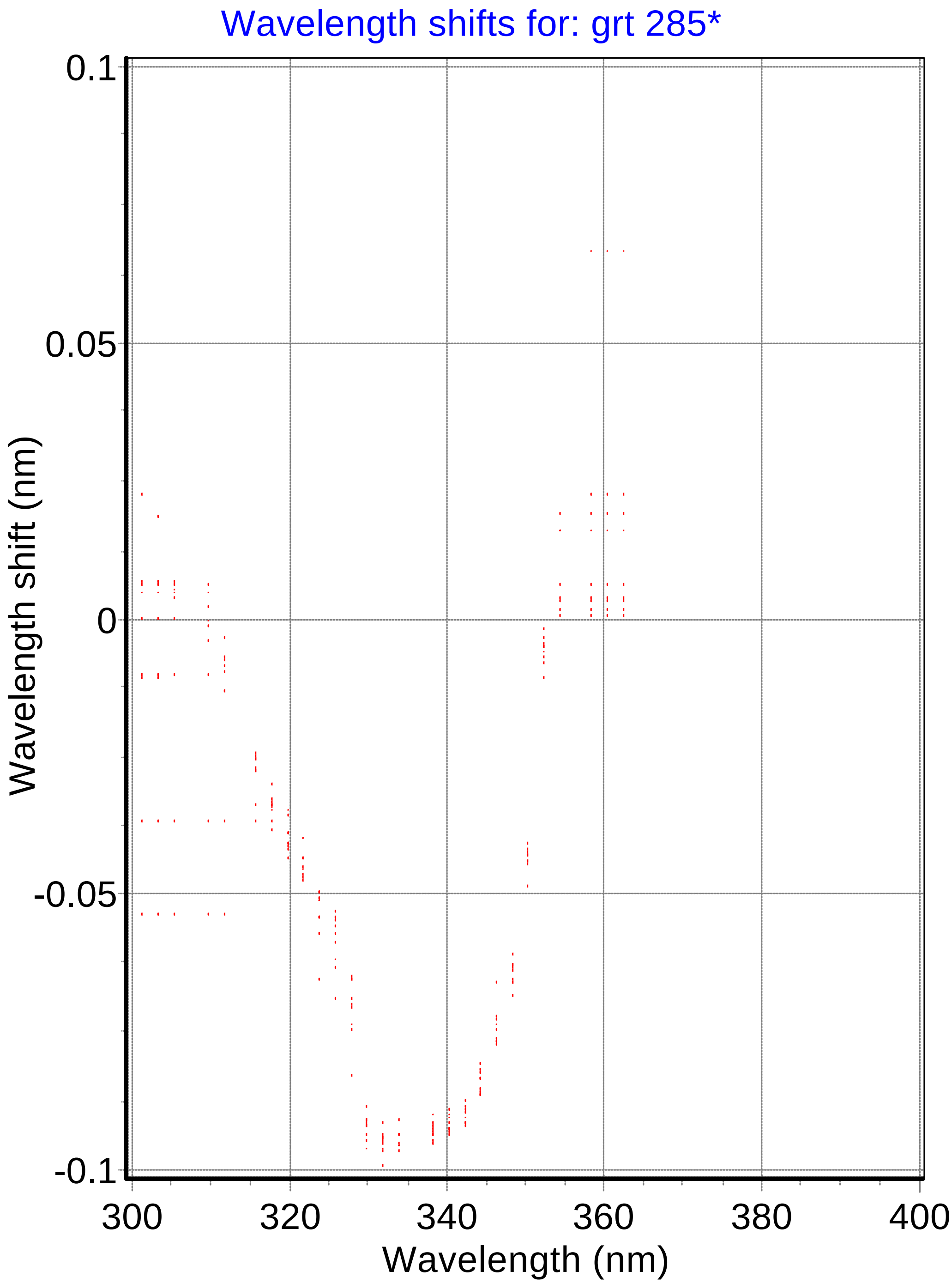
Wavelength shifts for: grt 282*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
380
400
Wavelength (nm)

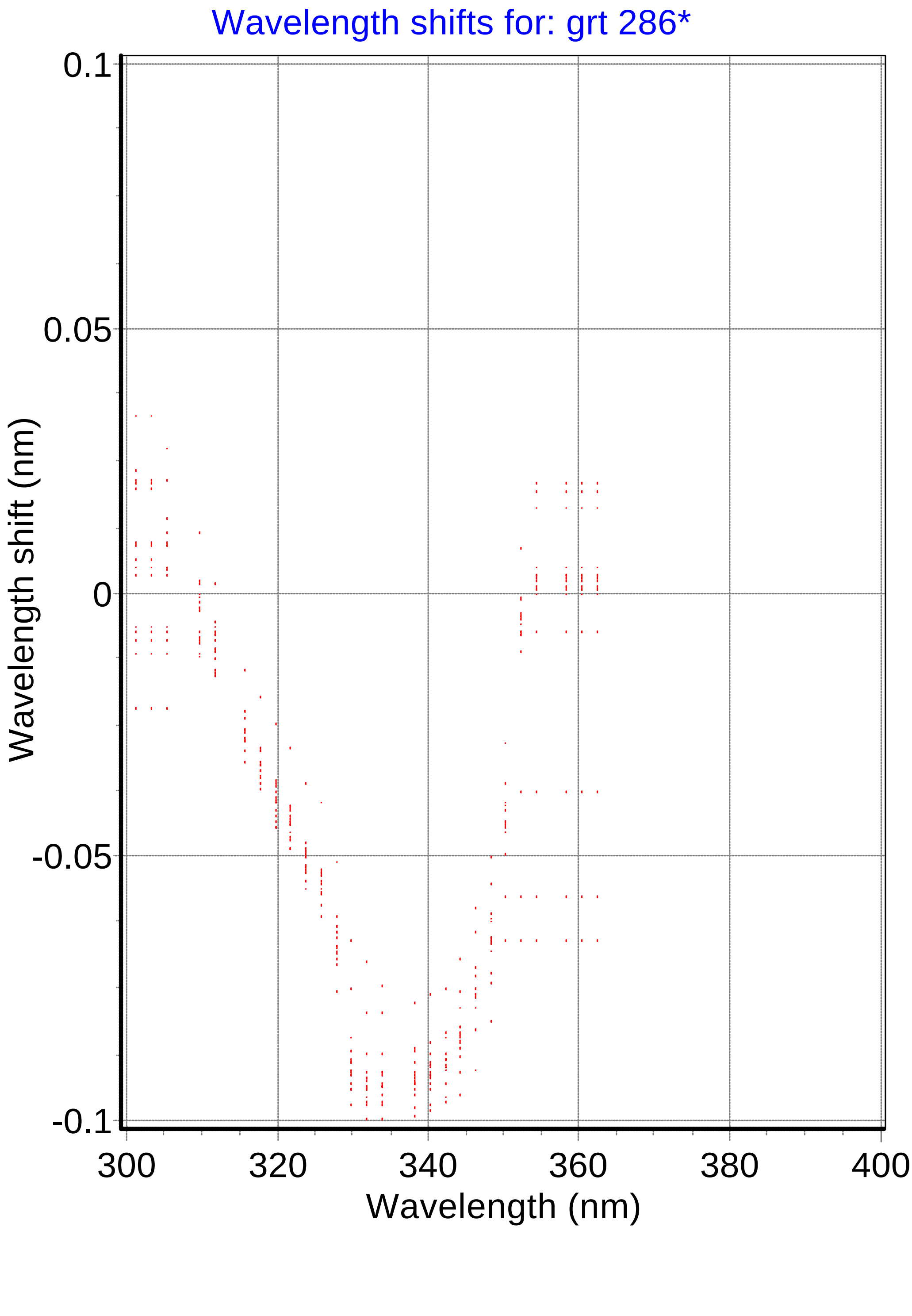


Wavelength shifts for: grt 283*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
380
400
Wavelength (nm)

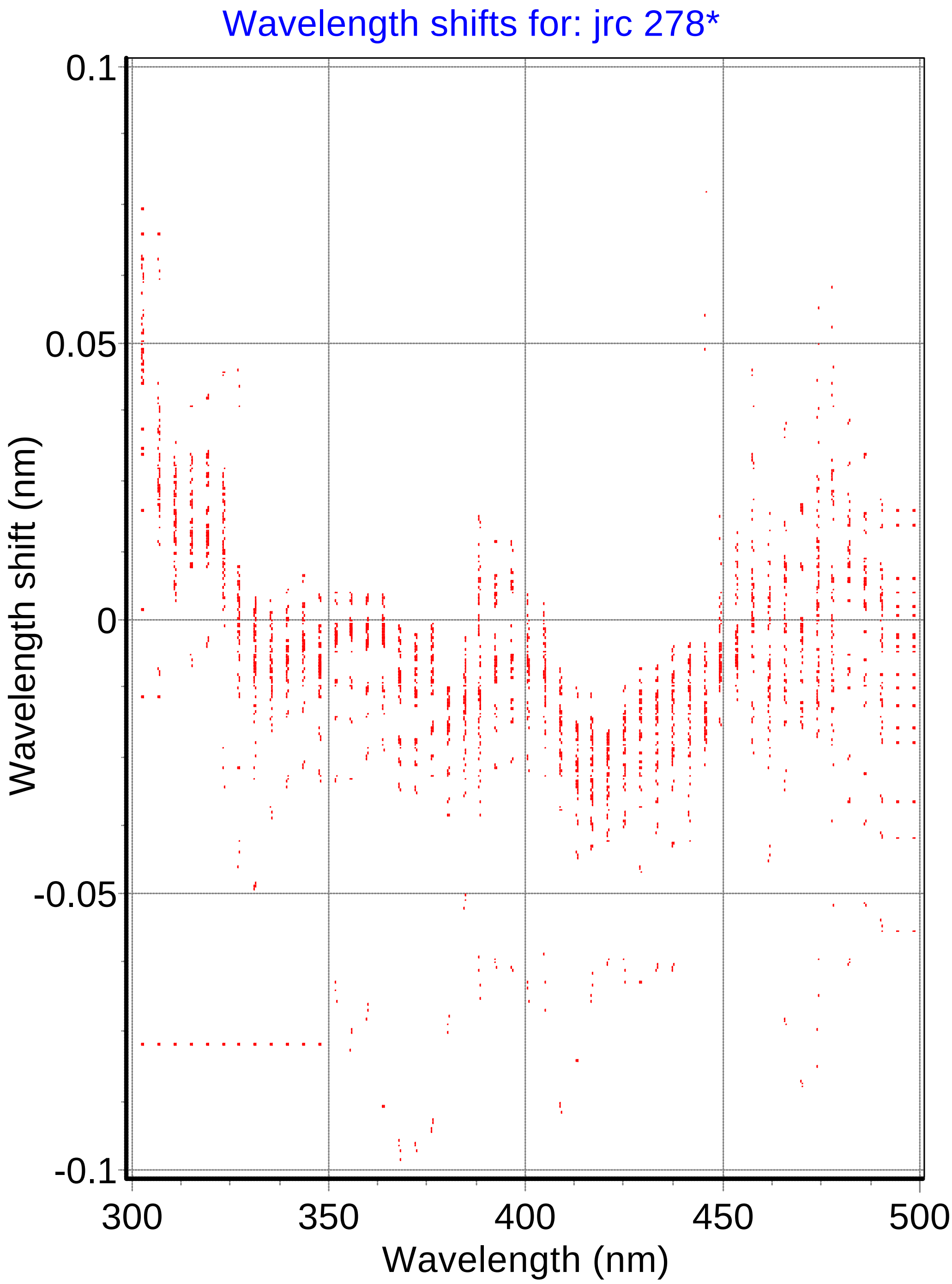


Wavelength shifts for: grt 284*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
380
400
Wavelength (nm)

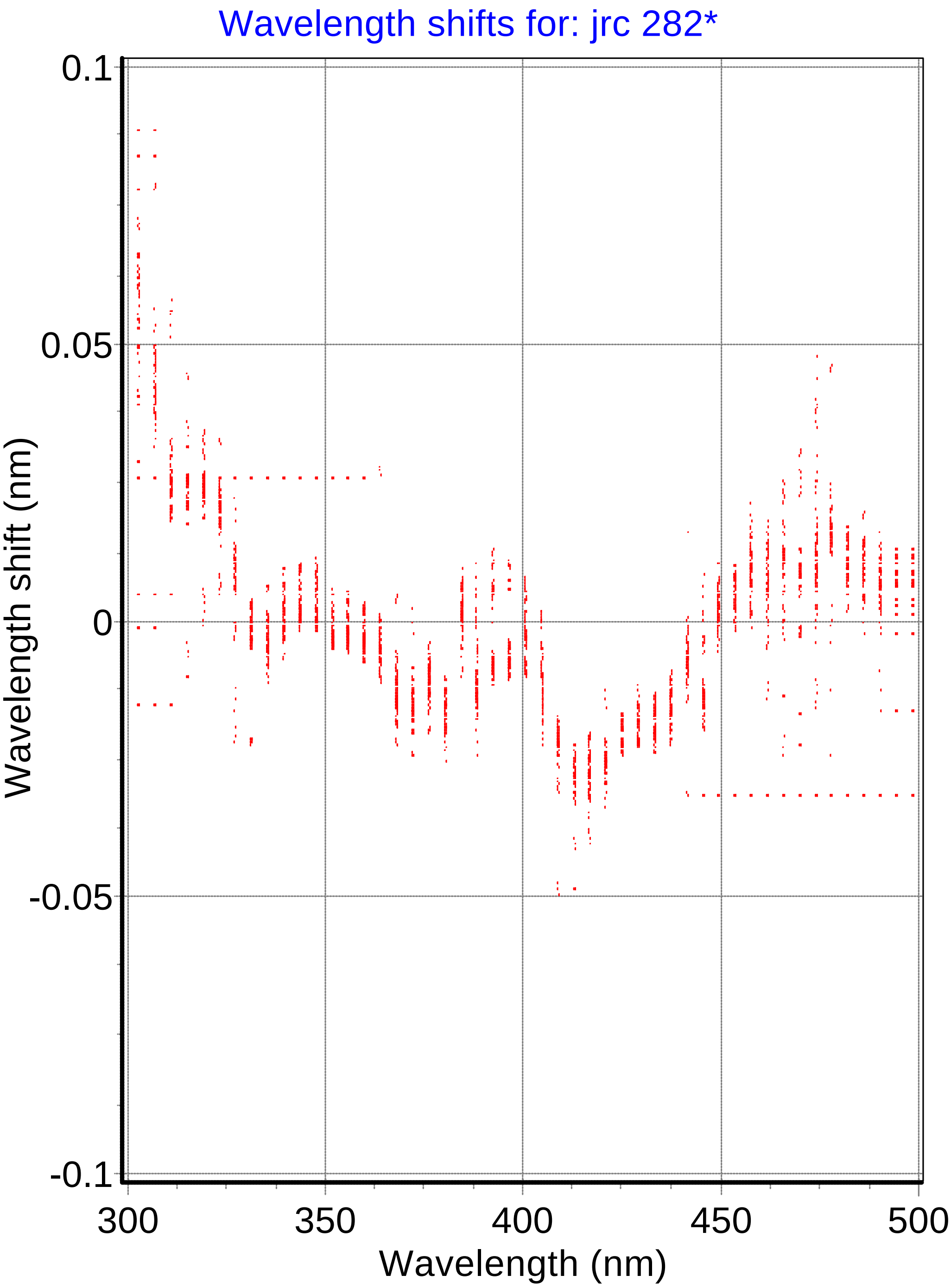

Wavelength shifts for: grt 285*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
380
400
Wavelength (nm)



Wavelength shifts for: grt 286*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
380
400
Wavelength (nm)



Wavelength shifts for: jrc 278*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
350
400
450
500
Wavelength (nm)



Wavelength shifts for: jrc 282*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
350
400
450
500
Wavelength (nm)

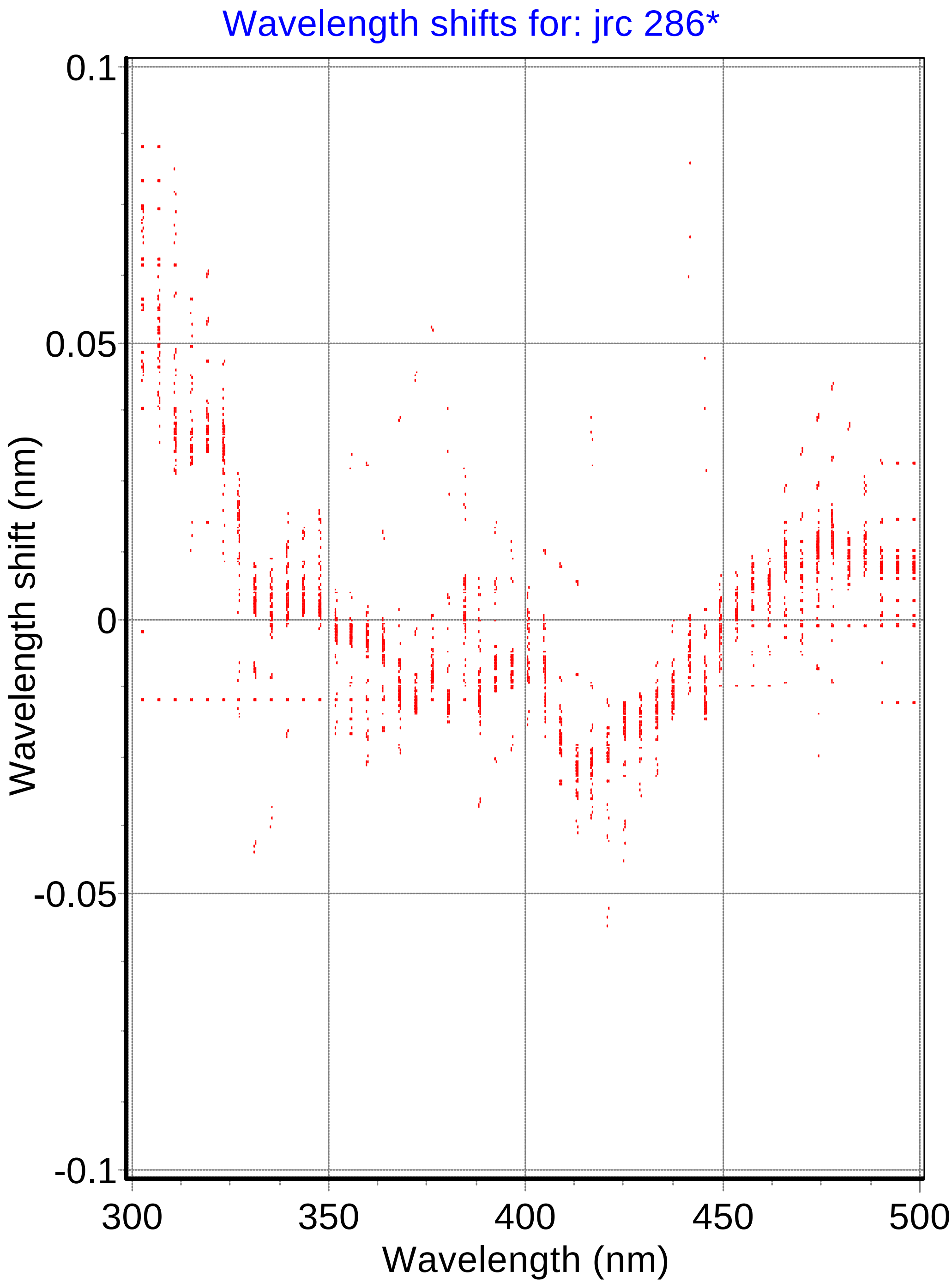

Wavelength shifts for: jrc 286*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
350
400
450
500
Wavelength (nm)

Figure 1 Measurement location at LAP, Thessaloniki October 5, 2002 at 11:30 AM. Looking South

Figure 2 Measurement location at LAP, Thessaloniki, October 5, 2002 at 11:30 AM. Looking East.

Figure 3 Measurement setup, LAP, Thessaloniki, October 5, 2002 at 7 PM. B5503 left, Brewer #086 at center background.