Protocol of the intercomparison at the Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden, May, 18-23, 2003 with the travelling standard spectroradiometer B5503 from ECUV within the project QASUME

Report prepared by Julian Gröbner

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The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer operated by SMHI (SEN) and the travel standard B5503. The measurement site is located at Norrköping; Latitude 58.58 N, Longitude 16.15 E 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 SMHI in the evening of May 18, 2003. The spectroradiometer was installed on the solar radiation measurement platform of SMHI at about 10 meters from the ground. The spectroradiometer in use at SMHI is a Brewer #128 double monochromator. The intercomparison between B5503 and the spectroradiometer from SMHI lasted five days, from the morning of May 19 to the morning of May 23.
A spectroradiometer Optronics 742 from the Swedish Radiation Protection Authority (SSI) was present during the intercomparison and participated in the synchronised measurement schedule.

B5503 was calibrated several times during the intercomparison period using a 100 W portable calibration system. Three 100 W lamps (T53063, T38986, T57825) were used to obtain an absolute spectral calibration traceable to the primary reference held at ECUV, which is traceable to PTB. The responsivity of the instrument based on these calibrations varied by 3.5% during the intercomparison period. These variations were taken into account on a daily basis. Observed diurnal variations of the responsivity were 2% or less and have only been taken into account on May 21 (141).
The internal temperature of B5503 was 25.6±0.2 °C. The diffuser head was heated to a temperature of 25±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 (see appended graphs).

Protocol:
The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 to 365 nm, every 0.5 nm, and 4 seconds between each wavelength increment.

<u>May 18 (138):</u>
Arrival and setup of the instrument in the late afternoon. The instrument was turned on and temperature stabilised since 9 UT prior to arriving at Norrköping. After installation on the measurement platform it was left to stabilise over night.

May 19 (139):

First 100 W calibration from 5:40 to 7:15 UT using lamps T38986, T57825, and T53063. Start synchronised scans at 7:30 UT. Last synchronised scan at 19:30 UT. SEN missed a scan at 14:30 UT. Weather conditions during the day were mostly overcast but with periods of sunshine and scattered clouds. No rain.

May 20 (140):

Start synchronised scans at 3:00 UT (SZA >=85°). Sun clear of clouds till 4:00 UT. Then low-level clouds bring overcast conditions without sunshine. After 8:00 UT fast moving clouds for the rest of the day. Rain starts at 14:34 UT and lasts to the end of the day. SEN misses scans at 8:00 and 8:30 UT. B5503 calibrates from 9:45 to 10:25 UT (misses 10:00 UT scan).

May 21 (141):

Start synchronised scans at 3:00 UT. Sun clear of clouds till 5:35 UT. Then low level clouds bring overcast conditions and fast moving clouds. Rain from 9:00 to 10:00 UT. Restart measurements at 10:00 UT; fast moving clouds. 11:30, 12:30, 13:00, 14:00 and 15:30 UT scans aborted due to rain. After 16:00 UT conditions good with sun clear of clouds. 100 W Calibration at 13:00 till 13:30 UT.

May 22 (142):

Start synchronised scans at 3:00 UT. Sun free of clouds till 4:30 when low-level clouds move in front of the sun. Overcast conditions and fast moving clouds for the rest of the day. Rain during 12:00 UT scan.

May 23 (143):

Start synchronised measurements at 3:00 UT. Good conditions till 5:30 UT when clouds move in. End of the campaign after the 5:30 UT scan. Final 100 W Calibration using two lamps, T63063 and T57825.

Results:

106 synchronised simultaneous spectra from B5503 and SMHI are available from the measurement period. The time reference used by SMHI and B5503 differed by up to 3 seconds during the measurement period. Some of the scatter seen in the measurement ratios is due to the combination of the not perfect time synchronisation and the rapidly changing cloud cover.

The wavelength shifts of the submitted solar spectra of the SMHI spectroradiometer retrieved through the SHICRivm analysis were constant to within 20 pm. The absolute wavelength shift relative to the extraterrestrial spectrum used by the SHICRivm software is less than ±50 pm for all spectra.

The irradiance scale of SMHI is 3% higher than the one of B5503 based on the results from a previous lamp intercomparison (Gröbner et al, Applied Optics 41(21) 4278-4282, 2002).

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

- Global irradiances measured by SMHI were between 4% lower to 10% higher than those measured by B5503 on the five days. The average difference during the measurement period is +3%.

- A diurnal variation with amplitude about 6% at 345 nm can be seen on most days, with the maximum coincident with solar noon. This diurnal variation is most pronounced at long wavelengths and decreases for shorter wavelengths. The mornings and evenings of May 21 and 22 were nearly cloud free while the rest of day was perturbed by low-lying fast moving clouds. On these cloud free episodes the measurements at 310 nm show nearly no diurnal variation while those at 345 nm vary by about 4 to 5% (particularly evident on the morning of May 21 (day of year 141)). This behaviour can be partly explained by the directional response of the SMHI instrument, which deviates from an ideal cosine response by about 6% (diffuse cosine error).
- Measurement ratios between the SMHI instrument and B5503 which are unperturbed by clouds are spectrally flat to within about 5% between 300 and 350 nm with very little spectral structure. At high SZA (>85°) measurements start deviating for wavelengths shorter than 305 nm while at mid day measurements agree down-to 300 nm. Some “spikes” in the irradiance measured by SEN occurred at several individual wavelengths which the processing software corrected as best as possible. These corrected values showed uncertainties of about 15% when compared to B5503.
- The observed decrease of 2-3% after 15:30 UT in the measurement ratios SEN/B5503 is unexplained. This feature is more significant at longer wavelengths and coincident with it is a change in cloud cover with the sun totally covered by thick clouds. This might indicate an effect due to the difference in directional responses between SEN and B5503.

Comments from the local operator:

QASUME Comparison at Norrköping, Sweden, May 19-23, 2003.

Weine Josefsson
SMHI (Swedish Meteorological and Hydrological Institute)

All data recorded during the comparison is available upon request, no restrictions. Questions regarding the measurements and the data can be forwarded to W. Josefsson (e-mail weine.josefsson@smhi.se).

Summary

The comparison between Brewer #128 and the JRC travel standard was done on the special solar radiation platform on the roof of building 11 at SMHI, Norrköping, Sweden. The surroundings within a few km consist of lower buildings, gardens and roads. The sky as seen from the instruments are almost free from obstructions. The Swedish Radiation Protection Authority (SSI) also attended the comparison with their spectroradiometer Optronics 742. From the platform measurements of solar radiation quantities are done, e.g. direct solar irradiance, diffuse solar irradiance and global irradiance.

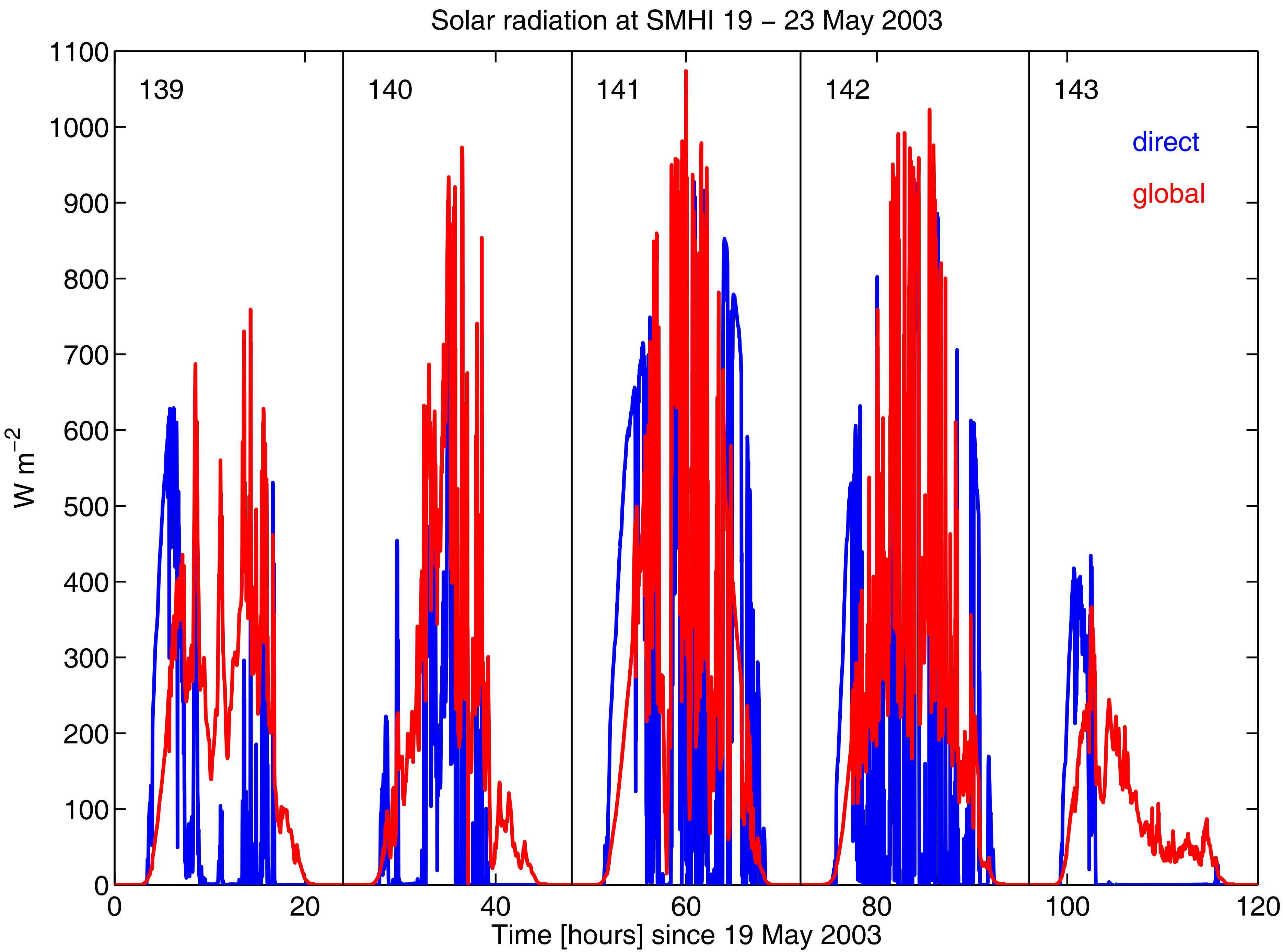
Before the comparison the Brewer #128 instrument was calibrated on the 28th of April 2003, day of the year 118. It was brought into the dark room at SMHI on the evening of 27th of April for acclimatising during night. Next day a calibration was done using a vertical set-up and a DXW 1000 W lamp denoted SMHI#3 (three runs). Before the instrument was put outdoors again another calibration was done on the 29th of April using a 1000 W Osram lamp denoted SP-6 (two runs).

The calibration based on the lamp SMHI#3 was used during the comparison. This response file is called XR11803.128.

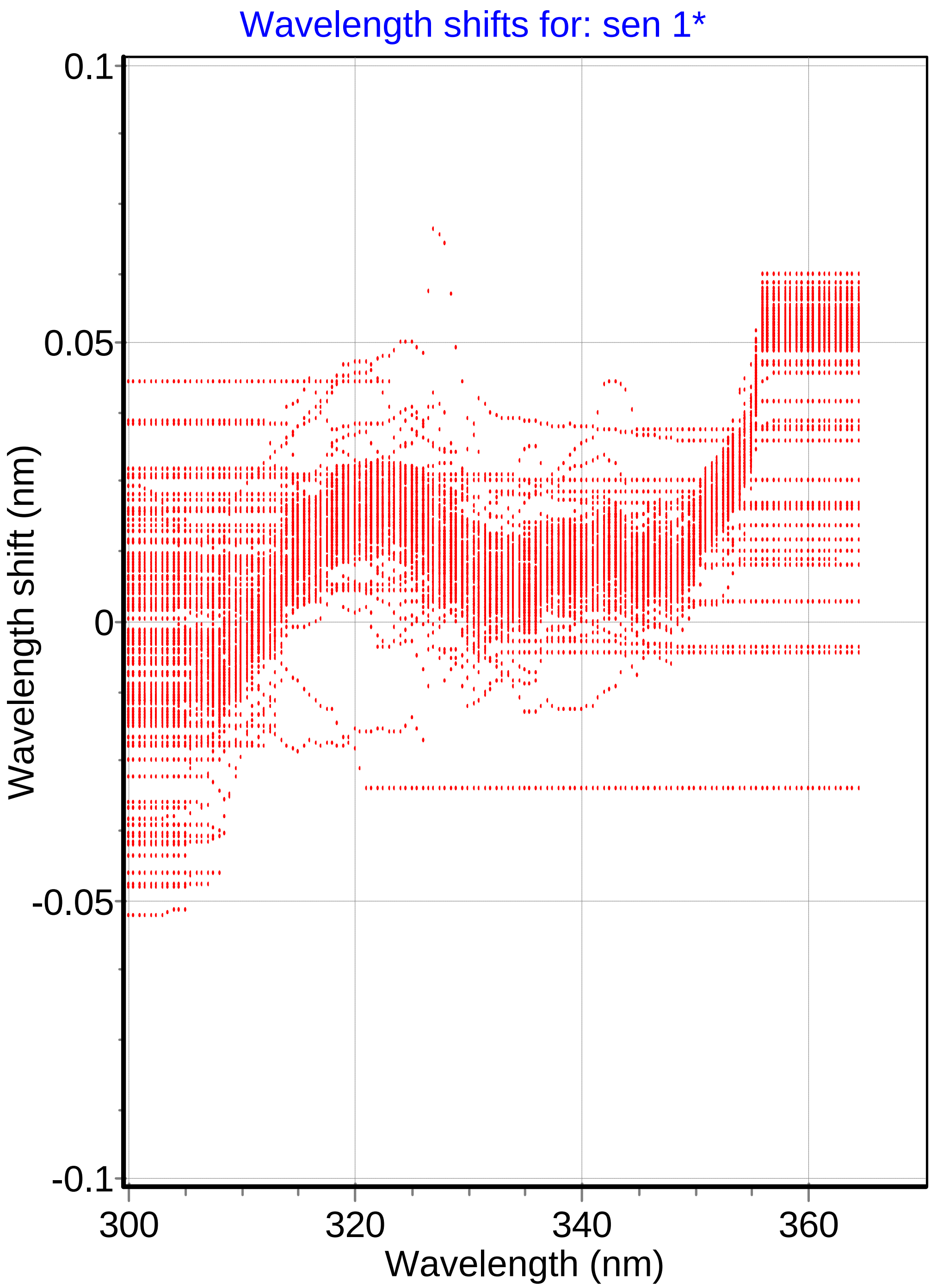
During the comparison time synchronised spectra were collected using the Brewer UA-routine. Brewer #128 measurements started at 290 nm and ended at 365 nm. They were made in steps of 0.5 nm with a time increment of 4 seconds. One should note that the Brewer changes slit at 350 nm. Therefore, the synchronisation is lost after that wavelength and the Brewer measurements will be delayed compared to the reference instrument. Another special feature with the Brewer #128 is its high and increasing responsivity in the UV-A while the responsivity in the UV-B decreases strongly towards shorter wavelengths. The high responsivity in the UV-A may cause saturation of the photomultiplier. Therefore, neutral density (ND) filters are inserted during the spectral scan when necessary.

The raw spectra from the Brewer UV-files were processed using the program Rd_u_nd.bas, which includes a part that takes the ND-filters into account, and the spectral response file XR11803.128. The output file from this program was then checked for spikes (if found replaced) and converted to a QASUME-format using the program Spi_cor.bas.

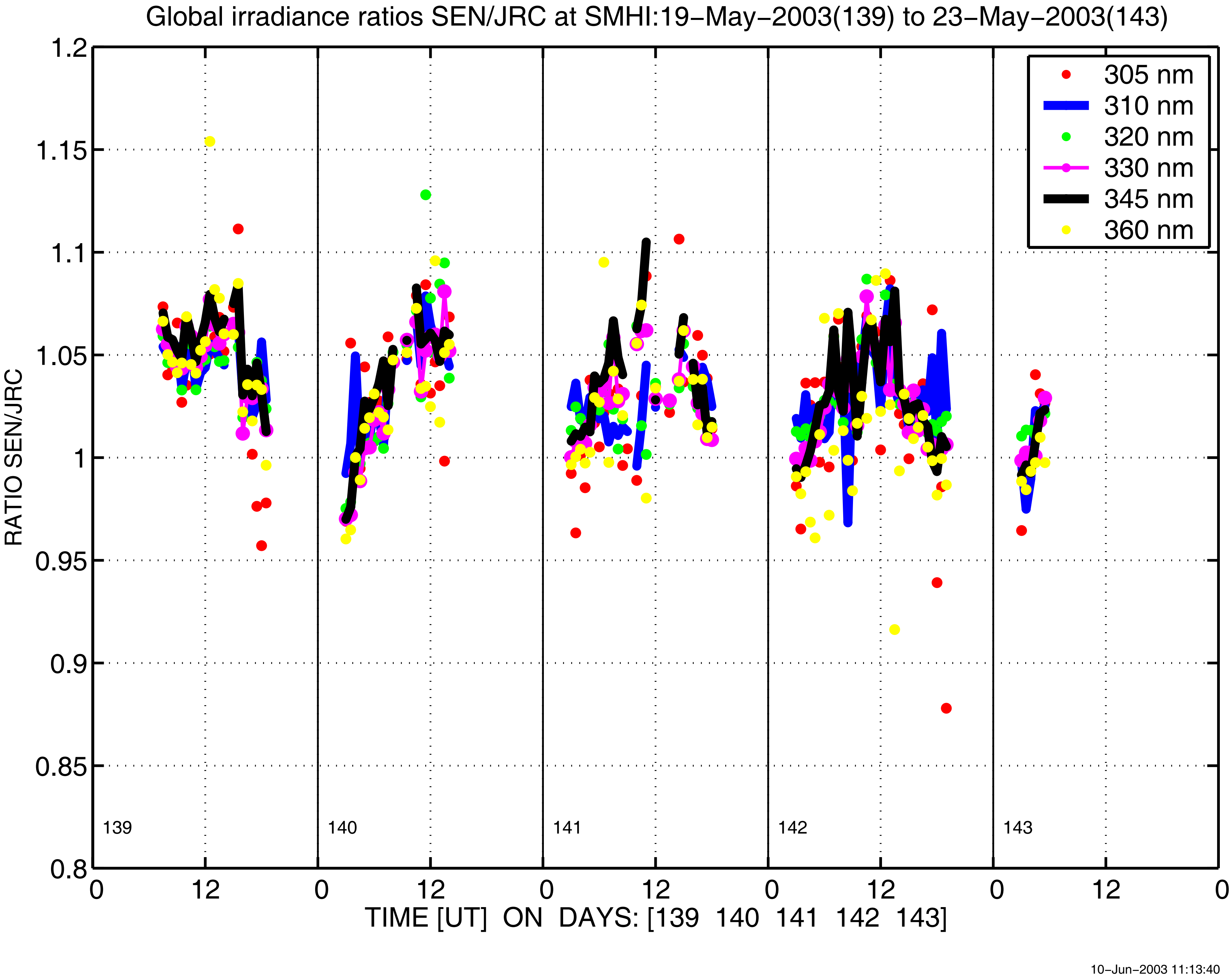
For Brewer #128 a constant factor 1.05 is applied for cosine correction. This is done in the Rd_u_nd.bas program. The same factor has been applied during previous campaigns although some theoretical calculations for clear skies, applying the measured cosine response, gives a slightly lower value on average (maybe 1.035). The use of a constant cosine correction value will also (during clear sky conditions) give a false daily variation. It is estimated to be some 3 % for longer wavelengths and about half that value for the shorter wavelengths measured by the Brewer.

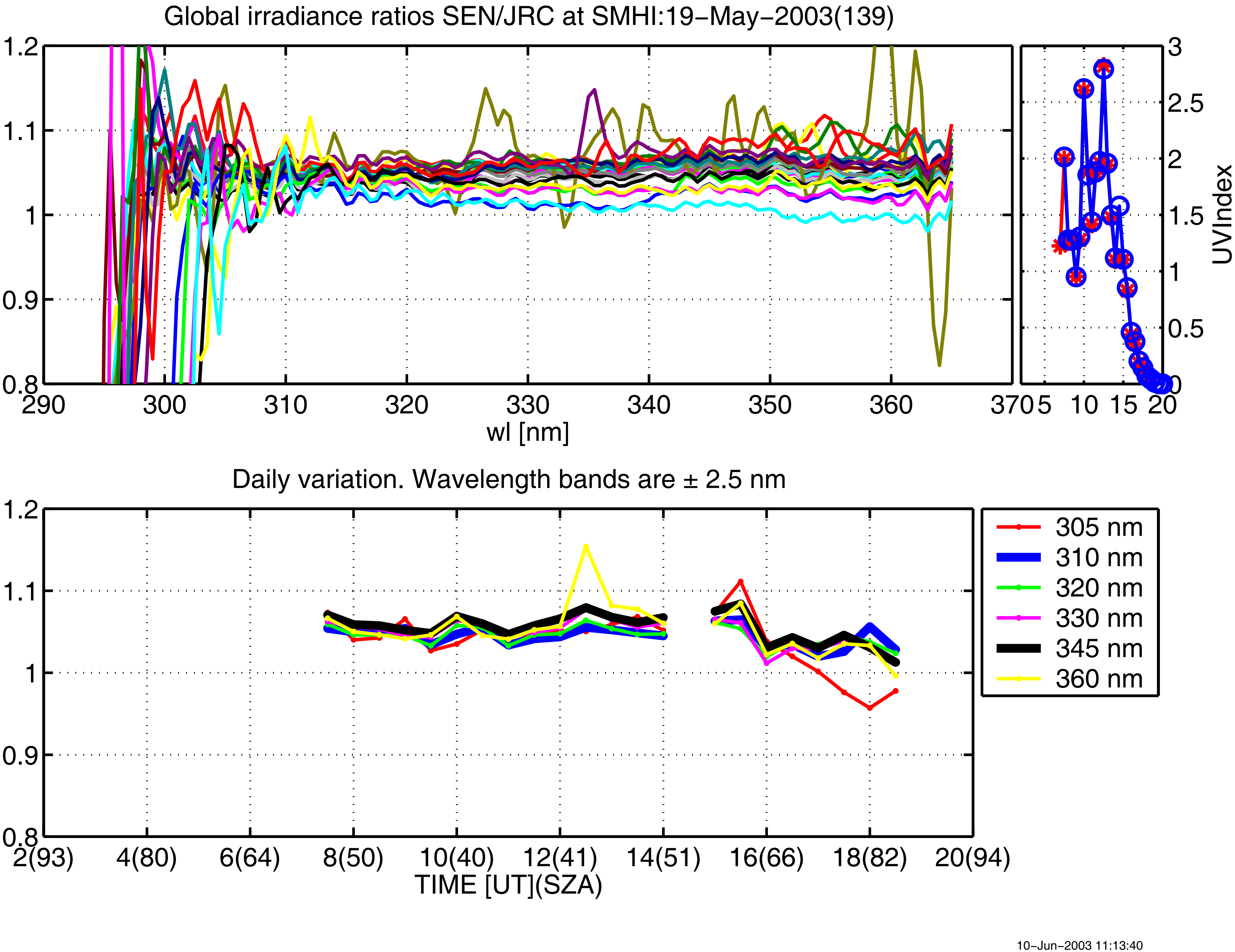


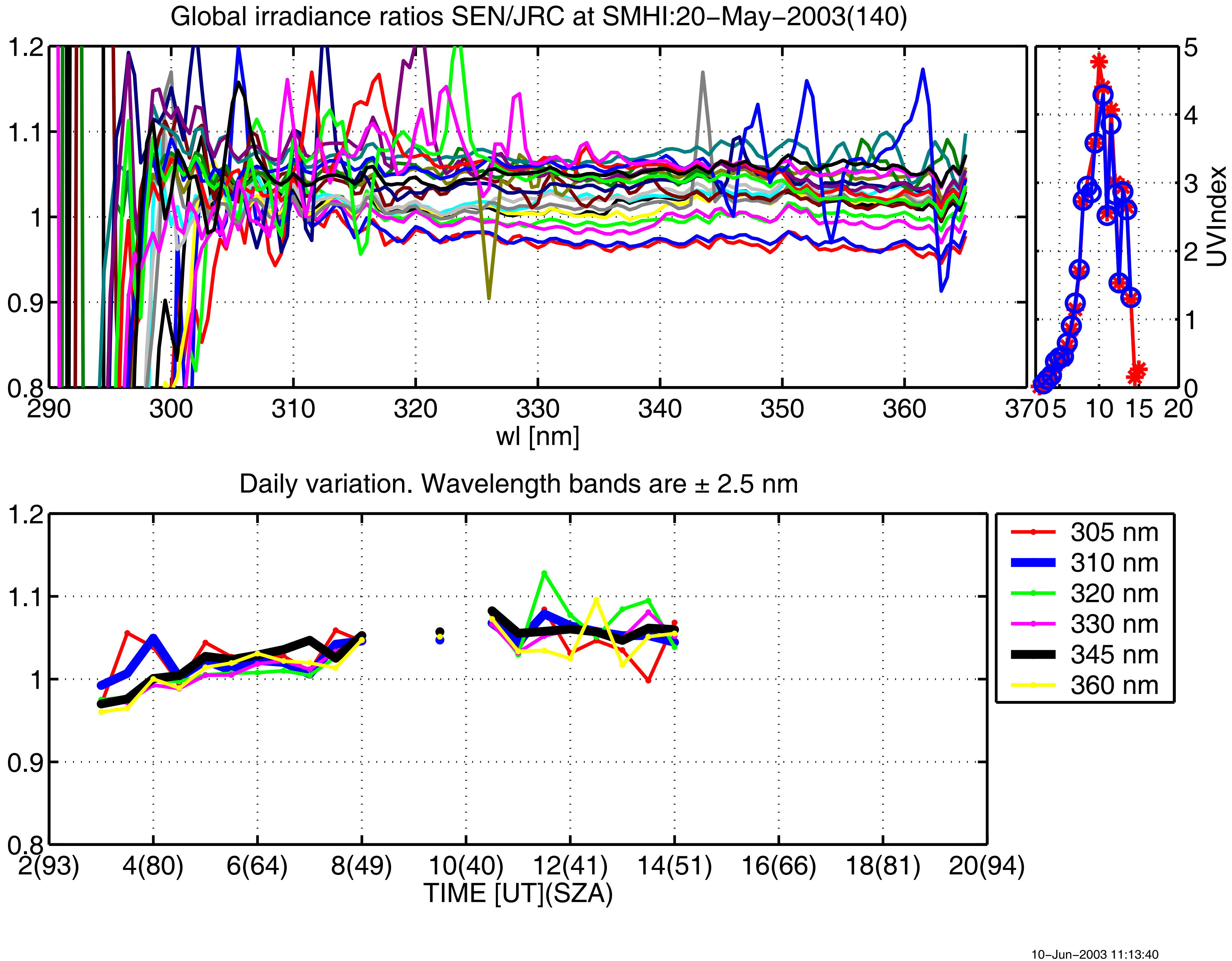
Solar radiation at SMHI 19 – 23 May 2003
139
140
141
142
143
direct
global
W m−2
0
100
200
300
400
500
600
700
800
900
1000
1100
0
20
40
60
80
100
120
Time [hours] since 19 May 2003



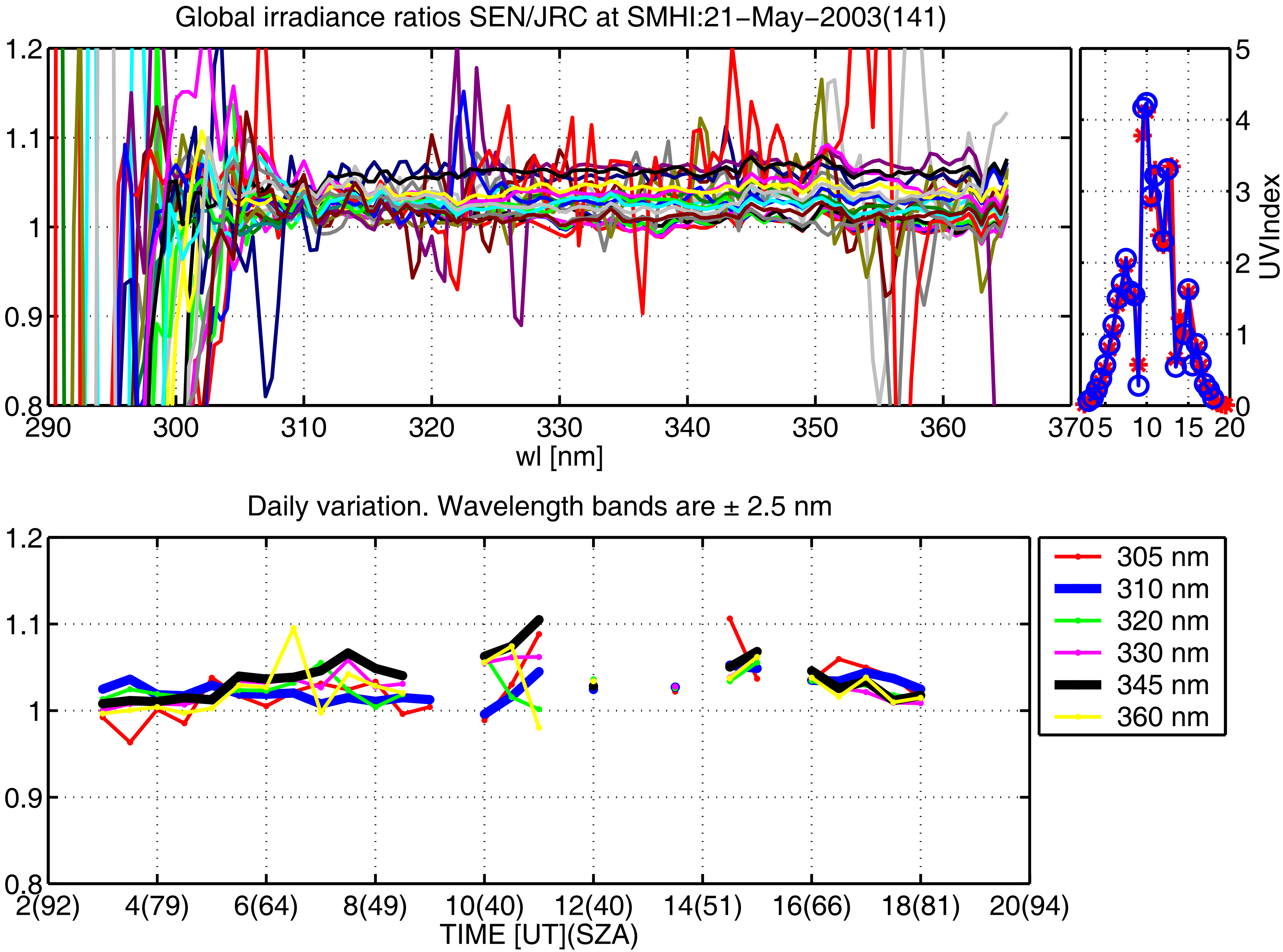
Wavelength shifts for: sen 1*
0.1
0.05
0
-0.05
-0.1
Wavelength shift (nm)
300
320
340
360
Wavelength (nm)


Global irradiance ratios SEN/JRC at SMHI:19−May−2003(139) to 23−May−2003(143)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
RATIO SEN/JRC
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
139
140
141
142
143
0
12
TIME [UT] ON DAYS: [139 140 141 142 143]
10−Jun−2003 11:13:40

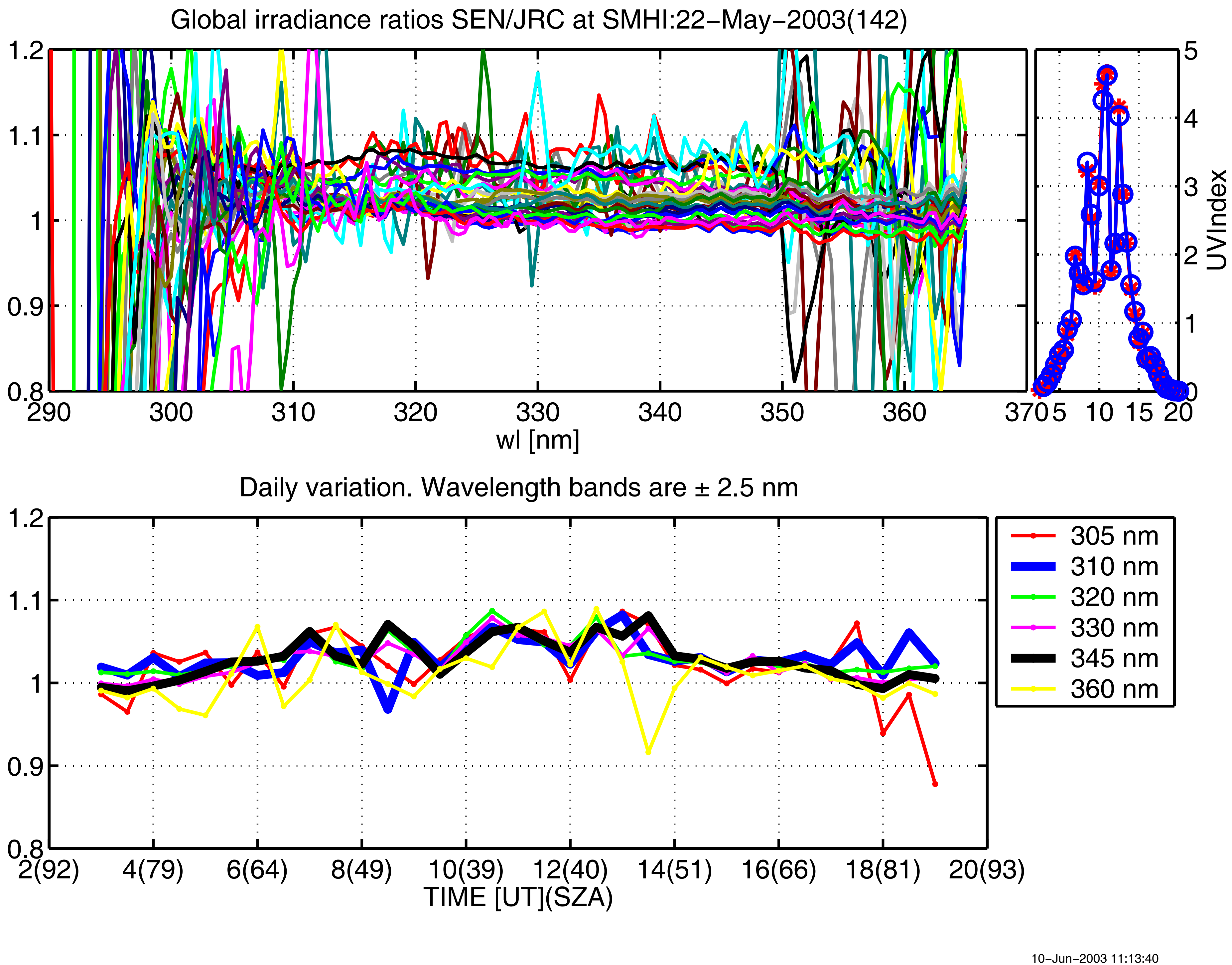

Global irradiance ratios SEN/JRC at SMHI:19−May−2003(139)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
5
10
15
20
3
2.5
2
1.5
1
0.5
0
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
2(93)
4(80)
6(64)
8(50)
10(40)
12(41)
14(51)
16(66)
18(82)
20(94)
TIME [UT](SZA)
10−Jun−2003 11:13:40

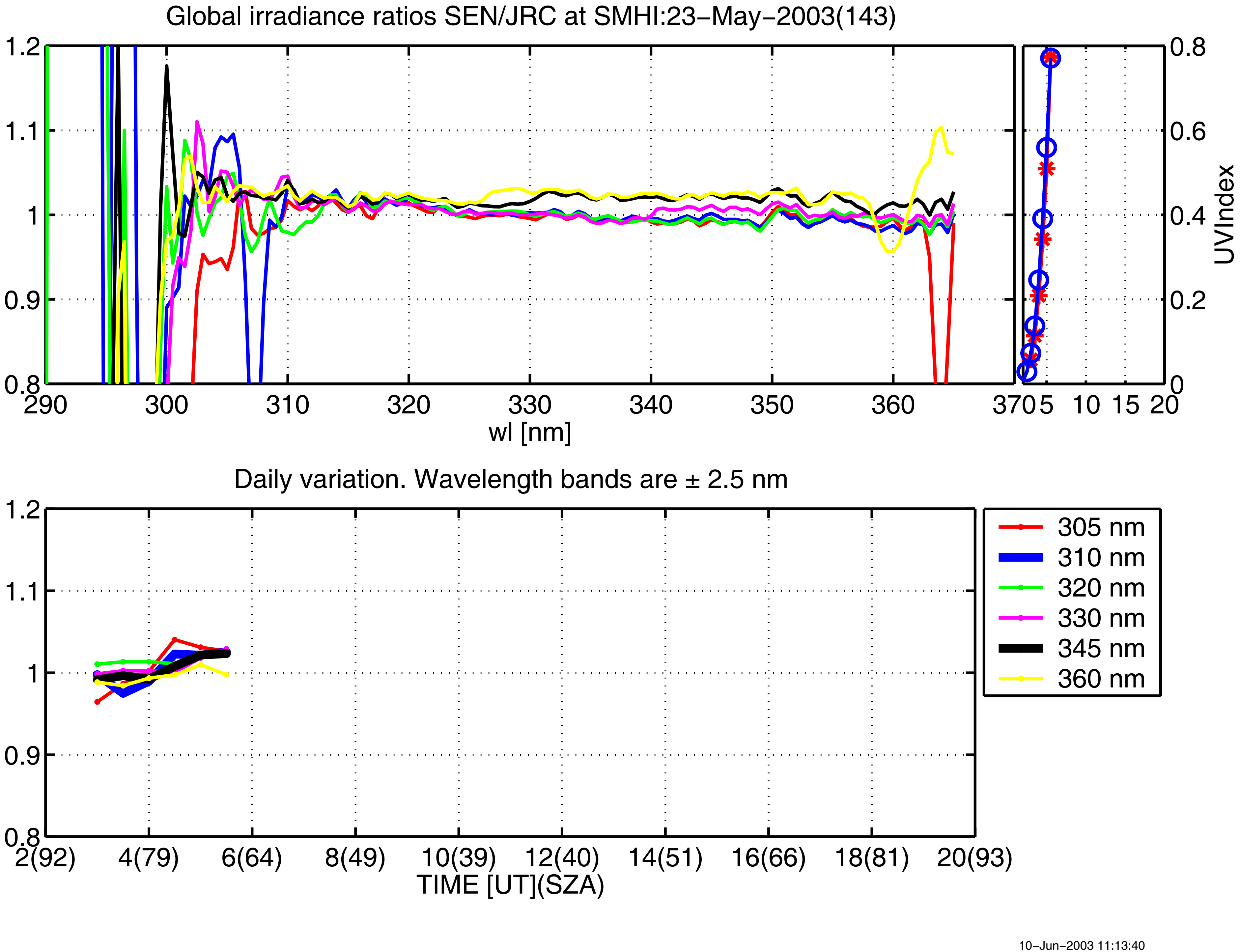


Global irradiance ratios SEN/JRC at SMHI:20−May−2003(140)
wl [nm]
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
10−Jun−2003 11:13:40



10−Jun−2003 11:13:40


Global irradiance ratios SEN/JRC at SMHI:22−May−2003(142)
wl [nm]
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
TIME [UT](SZA)
10−Jun−2003 11:13:40



Global irradiance ratios SEN/JRC at SMHI:23−May−2003(143)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
360
370
wl [nm]
0.8
0.6
0.4
0.2
0
5
10
15
20
UVIndex
Daily variation. Wavelength bands are ± 2.5 nm
1.2
1.1
1
0.9
0.8
2(92)
4(79)
6(64)
8(49)
10(39)
12(40)
14(51)
16(66)
18(81)
20(93)
TIME [UT](SZA)
305 nm
310 nm
320 nm
330 nm
345 nm
360 nm
10−Jun−2003 11:13:40


B5503
SEN
SSI