Protocol of the intercomparison at the German Weather Service (DWD), Lindenberg, Germany, Jun, 07-09 2004 with the travelling standard spectroradiometer B5503 from ECUV within the project QASUME

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Operator: Josef Schreder

The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer operated by DWD (LGD) and B5503 within the project QASUME. The measurement site is located at Lindenberg; Latitude 52.209 N, Longitude 14.121 E and altitude 127 m.a.s.l..
The horizon of the measurement site is free in all directions.

B5503 arrived at Lindenberg in the morning of June 7, 2004. The spectroradiometer was installed on the measurement platform. The spectroradiometer used by DWD in this intercomparison is a Brewer #118 MKIII double monochromator. The intercomparison between B5503 and the local spectroradiometer lasted one and a half days, from the morning of June 8 to noon of June 9.

B5503 was calibrated several times during the intercomparison period using a portable calibration system. Three lamps were used to obtain an absolute spectral calibration traceable to the primary reference held at ECUV which is traceable to PTB: T53061 (100 W), T53062 (100W) and T61251 (250 W). The responsivity of the instrument based on these calibrations varied by less than 1% during the intercomparison. The internal temperature of B5503 was 24.4°C and varied by less than 0.4°C. The diffuser head was heated to a temperature of about 25±2°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 350 nm, every 0.5 nm, and 3 seconds between each wavelength increment.

<u>Jun 07 (159):</u>
Arrival and setup of the instrument in the late morning. After the instrument stabilised, measurements were initiated at 12:30 UT. Weather conditions were a mix of sun and clouds. Due to a timing discrepancy of 2 minutes of the local instrument (LGD), no synchronous measurements are available for this day.

<u>Jun 08 (160):</u>
Synchronised measurements are available from 4:30 to 18:30 UT. Weather conditions till 8:00 were slight overcast by cirrus clouds. Later middle-high

moving clouds. A discrepancy in the LGD measurement at 315 nm during the 18:00 UT scan is so far unexplained.
B5503 calibrated at 7:35 UT and at 8:05 UT.

Jun 09 (161):
Synchronised measurements are available from 4:00 to 9:30 UT. Weather conditions in the morning are sunny with cirrus clouds and later low lying rain clouds. At 9:30 UT a thunderstorm with heavy rain starts. End of the campaign.
B5503 calibrated at 7:35, 8:05, and 8:35 UT.

Results:
41 synchronised scans are available from the measurement period.
The wavelength shifts of the submitted solar spectra of the LGD spectroradiometer retrieved through the SHICRivm analysis varied by 70 pm.
The average wavelength shift relative to the extraterrestrial spectrum used by the SHICRivm software was between –40 pm at 310 nm to +0 pm above 320 nm. The following analysis uses wavelength-shift corrected spectra obtained with the SHICRivm software ver 3.075.
LGD submitted a revised data set after the end of the campaign. The revised data of spectral irradiance is lower than the original data set by a constant factor of 1.086. The revision consists in neglecting the non-standard cosine correction that was applied to the original data set (see comments of the local operator on the next page).

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

- Differences between the global irradiances measured by LGD and B5503 were between –8% to +2%. The average spectral ratio between LGD and B5503 varies nearly linearly from +4% at 300 nm to -5% at 350 nm.
- Measurement ratios between LGD and B5503 of June 8 (160) show a diurnal variation of 2 to 3%, while measurements in the morning of June 9 (161) show a marked variation with time and SZA which also depends on wavelength: at 344 nm the ratio changes by 7% between 6 UT (SZA 63°) and 8:30 UT (SZA 41°), while at 305 nm the variation is only 3%.

Conclusion:
LGD global solar irradiance measurements (uncorrected for cosine error) are on average 0-5% lower than those of B5503. Between 300 and 350 nm the spectral ratio of LGD to B5503 decreases by 9%. A marked diurnal variation is observed on the morning of June 8 (161) between a SZA of 85° to 41° which is probably due to the deviations of the directional response of LGD from the nominal cosine weighted response.

Comments from the local operator:

Comments to QASUME comparison between Brewer instrument #118 and Bentham DM150

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1. Calibration of Brewer instrument #118

Brewer instrument #118 was calibrated before the comparison with a DXW 1000 W lamp in the DWD radiation lab. The DXW lamp is part of a set of several DXW 1000 W Secondary Standard Lamps that have been calibrated by an OL754 spectroradiometer in the DWD lab. The set of DXW Secondary Standard Lamps was calibrated with an FEL 1000 W Primary Standard Lamp SN042 that was calibrated by the Physikalisch-Technische Bundesanstalt (PTB) in February 2004. Differences between this Primary Standard Lamp SN042 and the FEL 1000 W SL160 calibrated by the PTB and delivered in 2003 were determined in the DWD lab to be within ±1%, which is well within the stated absolute uncertainty of the PTB lamps of ±3% in the UV region. We mention that the conditions in the DWD calibration lab at Lindenberg were not ideal in March 2004 due to problems with the lab room's air condition that have not been solved by the time of writing these comments. We estimate an additional uncertainty introduced by the calibration of the Secondary Standard Lamps for the time of the calibration before the QASUME campaign to be within ±1.5%, with the result that the overall absolute uncertainty of the Secondary Standard Lamp should be within ±4%.

2. Corrections

Brewer UV spectral irradiance measurements are corrected for internal stray light and dark current. The method for cosine correction that used to be applied to Brewer #118 data measured at Potsdam by April 2003 (Feister et al. 1997) has not been used after moving the instrument to the Lindenberg site in May 2003, because the UV filter radiometers of the Grasnick type were replaced by another type of two-channel instruments at Lindenberg. As it turned out by first comparisons between integrals derived from spectroradiometric measurements, and measurements by those new UV filter radiometers, the calibration performed at the UV filter radiometers' manufacturer seems to have quite large errors and, therefore, measured data from those UV filter radiometers have not been applied to correct Brewer spectra for their cosine errors. We estimate that due to that neglected cosine correction, spectral irradiances measured by Brewer instrument #118 can be systematically low by about 1 ... 7%. The actual amount of that difference will depend on the ratio between direct and diffuse UV radiation, which in turn depends on wavelength, solar zenith angle and atmospheric conditions.

3. Weather conditions

Weather conditions during the time of the comparison between June 7 and June 9, 2004 (day 159 through 161) were not ideal for a comparison due to cloud cover and cloud optical depths that showed quite fast changes at times. Figure 1 (a – c) shows the direct to diffuse irradiance ratios derived from measurements of the pyrheliometer and pyranometer instruments that are operated at the BSRN site Lindenberg. There were sunny periods mainly during the morning hours, with clouds appearing and obstructing the sun at times. On June 9, the cloud optical depths became so high that between about 10 and 11 UTC sky brightness dropped to less than 5% of its clear sky value. The rain showers, which started at about 9:20 UTC, became heavy particularly between about 10 and 12 UTC, with precipitation intensities exceeding 1 mm per minute (Fig.2).

3. Model comparison

A few comparisons between Brewer spectra and model runs using the UVFastrt program by Ola Engelsen from NILU (http://nadir.nilu.no/~olaeng/fastrt/fastrt.html) were performed. A triangular slit function was used in the model runs. Due to the small number of cloudless conditions, comparisons between measured UV spectra and model calculations are shown for one case with cloudless sky, and for two other cases with stable (within the 6 minutes of the spectral scan) thin cloud conditions. The cases for model comparison were selected with the help of 6-minute averages as well maximum and minimum values of the direct to diffuse irradiance ratios within the 6 minutes of the spectral UV scans. The direct to diffuse irradiance ratios are shown in Fig. 3.
Variable model input parameters that were measured at the site are column ozone from Dobson spectrophotometer #71, aerosol optical depths from spectral photometer measurements by M. Weller, and cloud cover values from Whole Sky imager data. They are summarized in Table 1. Model calculations were calculated for cloudless conditions only, because global radiation and sky brightness measurements showed that the optical effect of the thin clouds that occurred during those periods should have been quite small for the UV region. Fig.4 shows the ratios between Brewer spectra and modeled spectral irradiance for the three selected cases. To account for the changing solar zenith angle within the time of period of 6 minutes needed to perform a spectral UV scan from 290 to 350 nm, the model calculations were carried out for both the start and end time of the spectral UV scan. It can be seen in the Figures 4 a – c that

- the overall shape of the measured Brewer spectrum is reproduced by the model
- there is a tendency of the measurements to be about 0% to 5 % lower than the modeled spectra for wavelengths longer than about 305 nm, and up to about 10% lower for wavelengths shorter than 305 nm
- model results seem to confirm the small systematic difference of too low irradiances measured by the Brewer, i.e. hardly any systematic differences at the shortest wavelengths around 300 nm, and about 5% at the longest wavelengths(350 nm).

We conclude that a significant portion of the systematic difference between the spectra of Brewer 118 and the Bentham instrument of about 0% ... -5% can be attributed to the cosine characteristics of the Brewer instrument.

References

Feister, U., R. Grewe and K. Gericke (1997), A method for correction of cosine errors in measurements of spectral UV irradiance, Solar Energy 60, No. 6, 313 -332

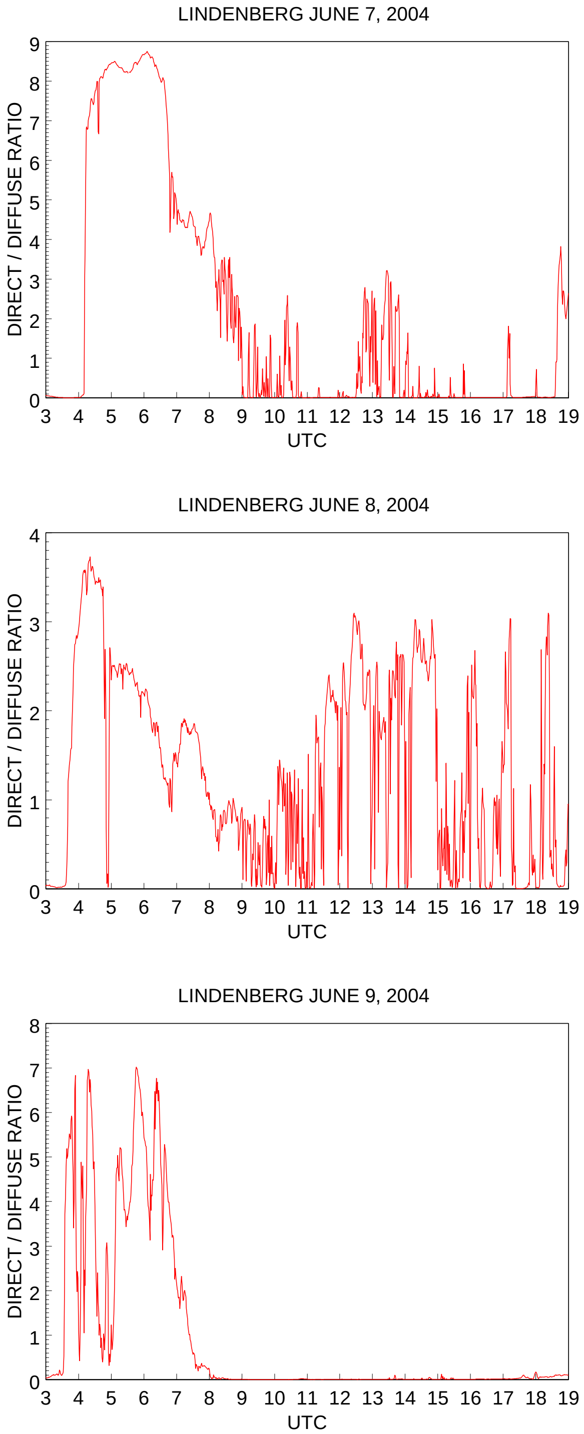


Fig.1 Direct to diffuse radiation ratios at Lindenberg on June 7, June 8, and June 9, 2004 (a – c)

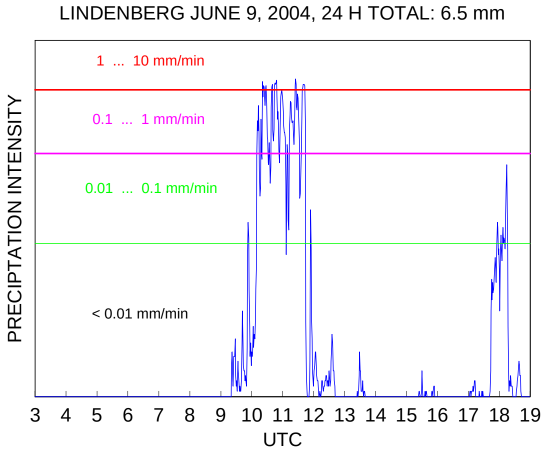


Fig. 2 Precipitation intensity at Lindenberg on June 9, 2004

Table 1 Input data to the model calculations: Total ozone values were taken from direct sun observations with Dobson spectrophotometer #71, and aerosol optical depth at 500 nm were derived from spectral photometer measurements at Lindenberg, cloud cover data from Whole Sky Imager measurements

DATE	START TIME (UTC)	STOP TIME UTC)	START SZA	STOP SZA	TOTAL OZONE (DU)	AOD AT 550 NM	CLOUD COVER WSI (Okta)	DAY
JUNE 7	06:00	06:06	63.473	62.554	334	0.13	0	159
JUNE 8	12:30	12:36	33.760	34.341	334	0.20	4 (thin)	160
JUNE 9	06:00	06:06	63.400	62.482	313	0.11	4 (thin)	161

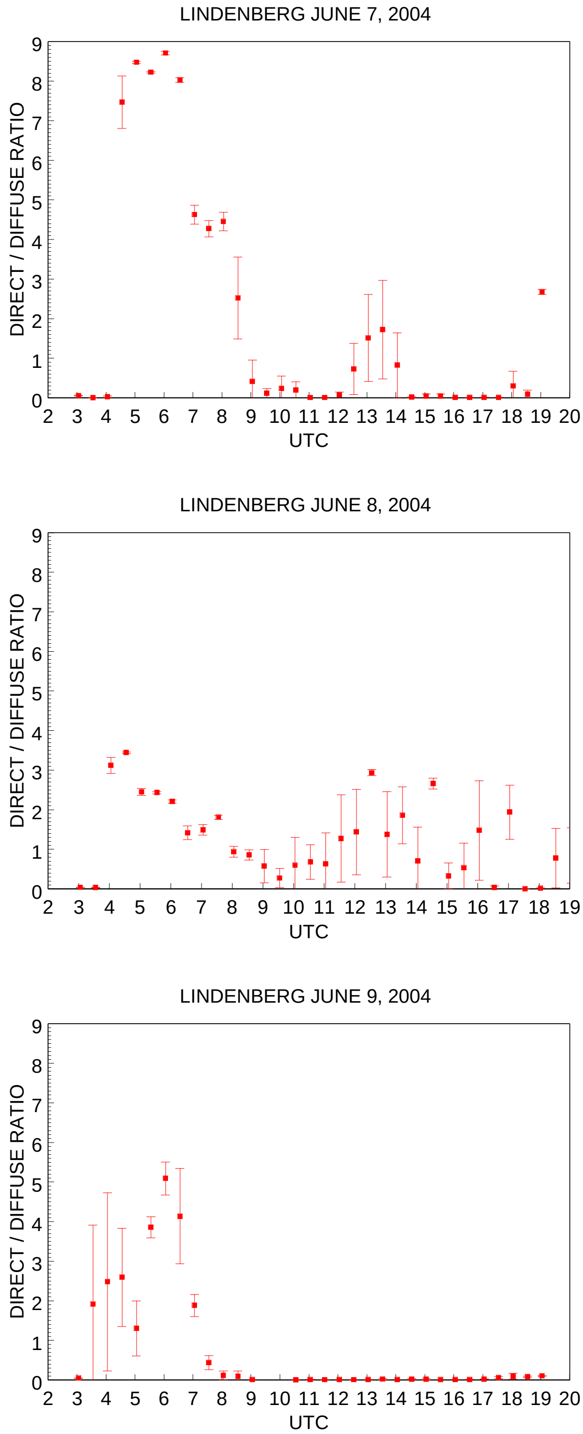


Fig. 3 Direct to diffuse radiation ratios averaged over 6 minutes at half-hourly time intervals at Lindenberg on June 7, June 8, and June 9, 2004 (a – c)

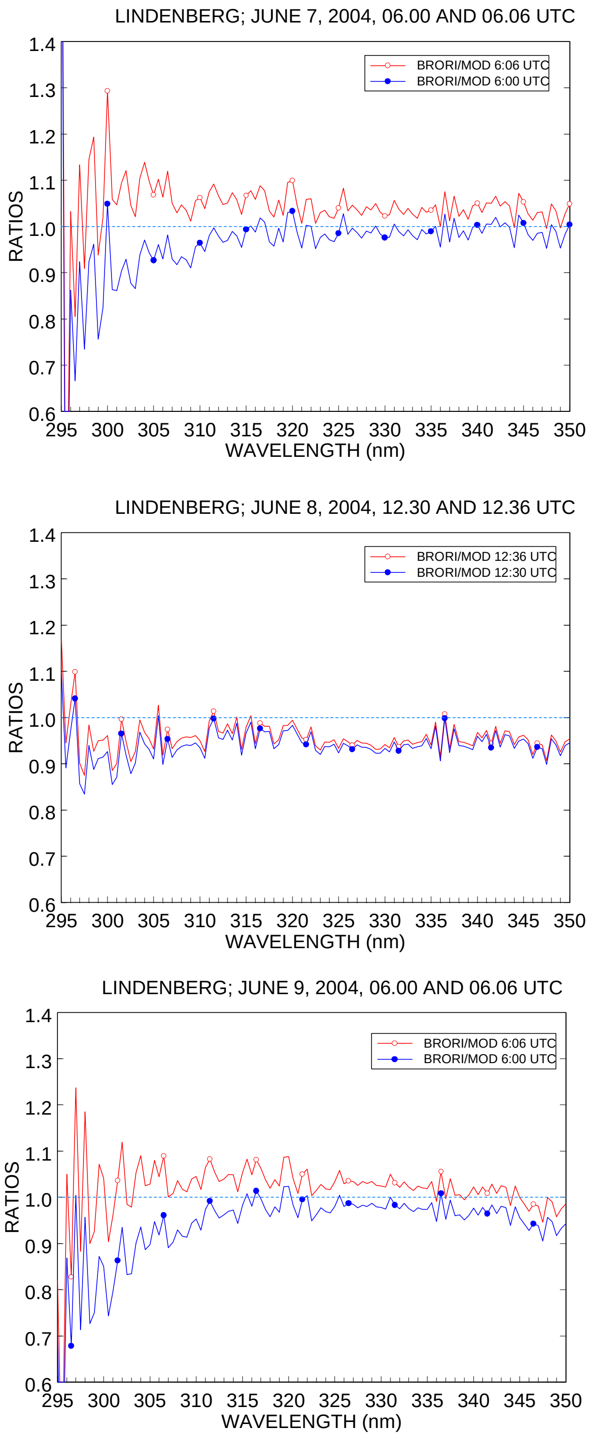
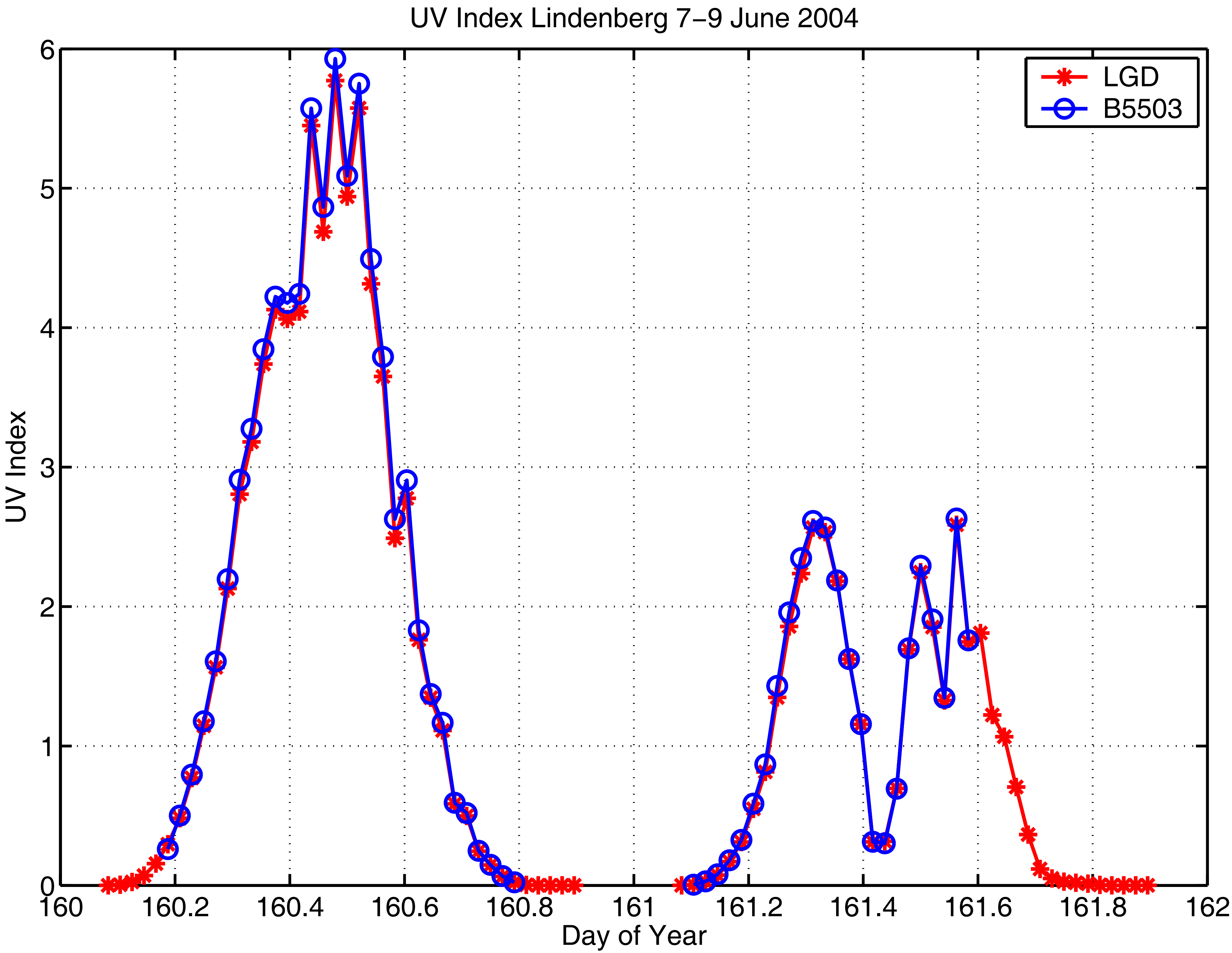
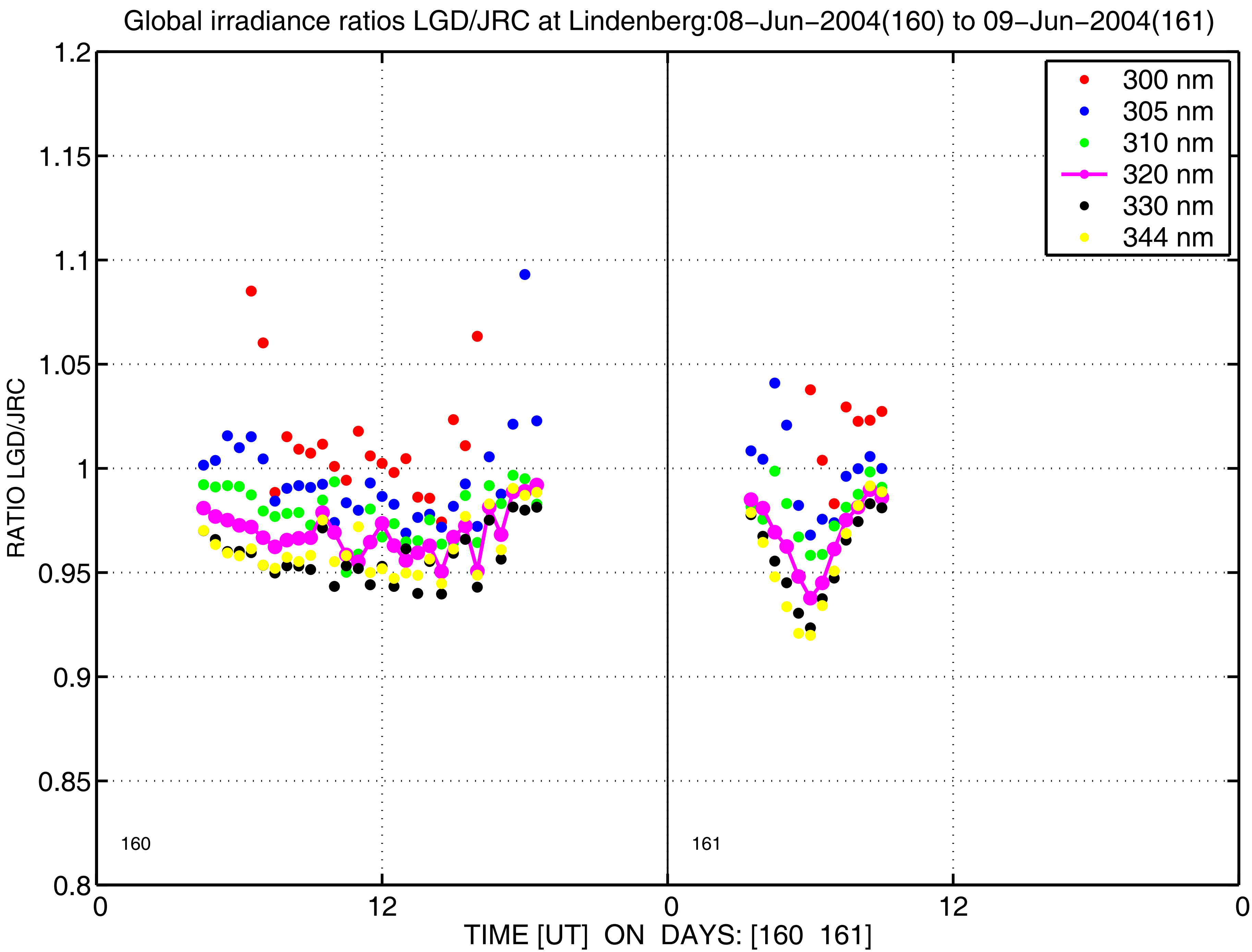


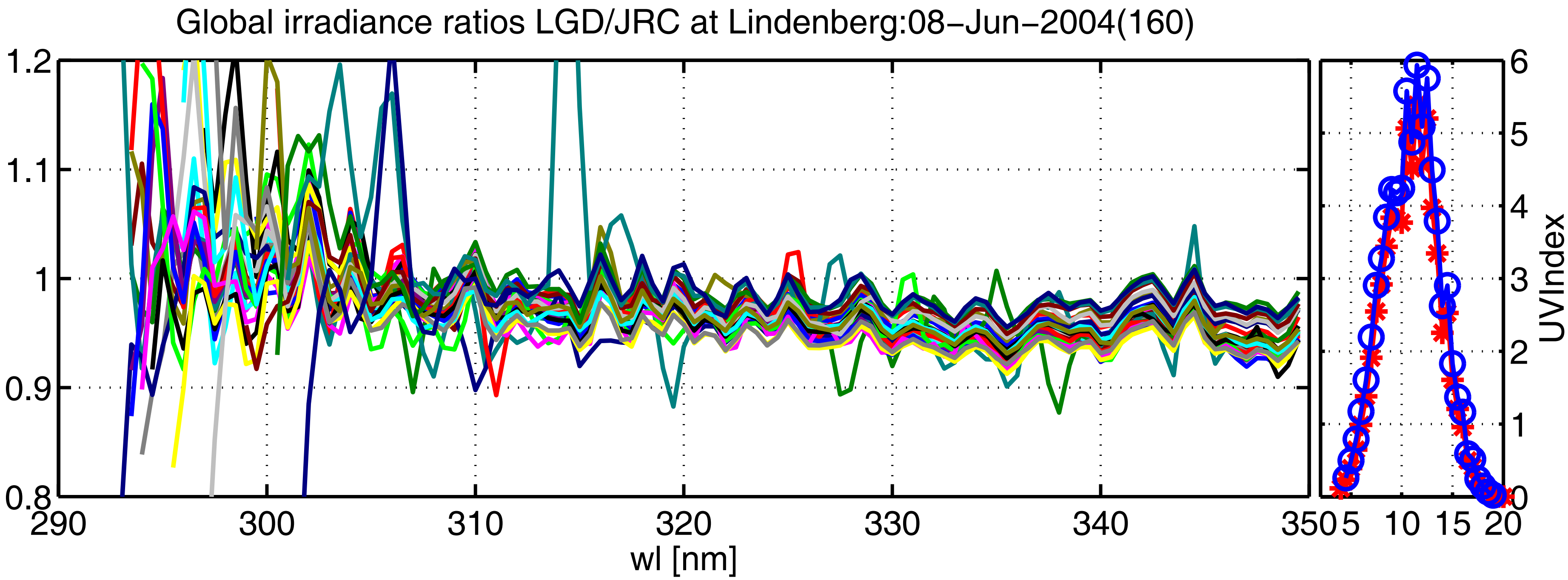
Fig. 4 Ratios between spectral irradiances measured by the Brewer instrument and modeled by the FastUV algorithm (see web page by Ola Engelsen nadir.nilu.no) with the measured input data as shown in Table 1

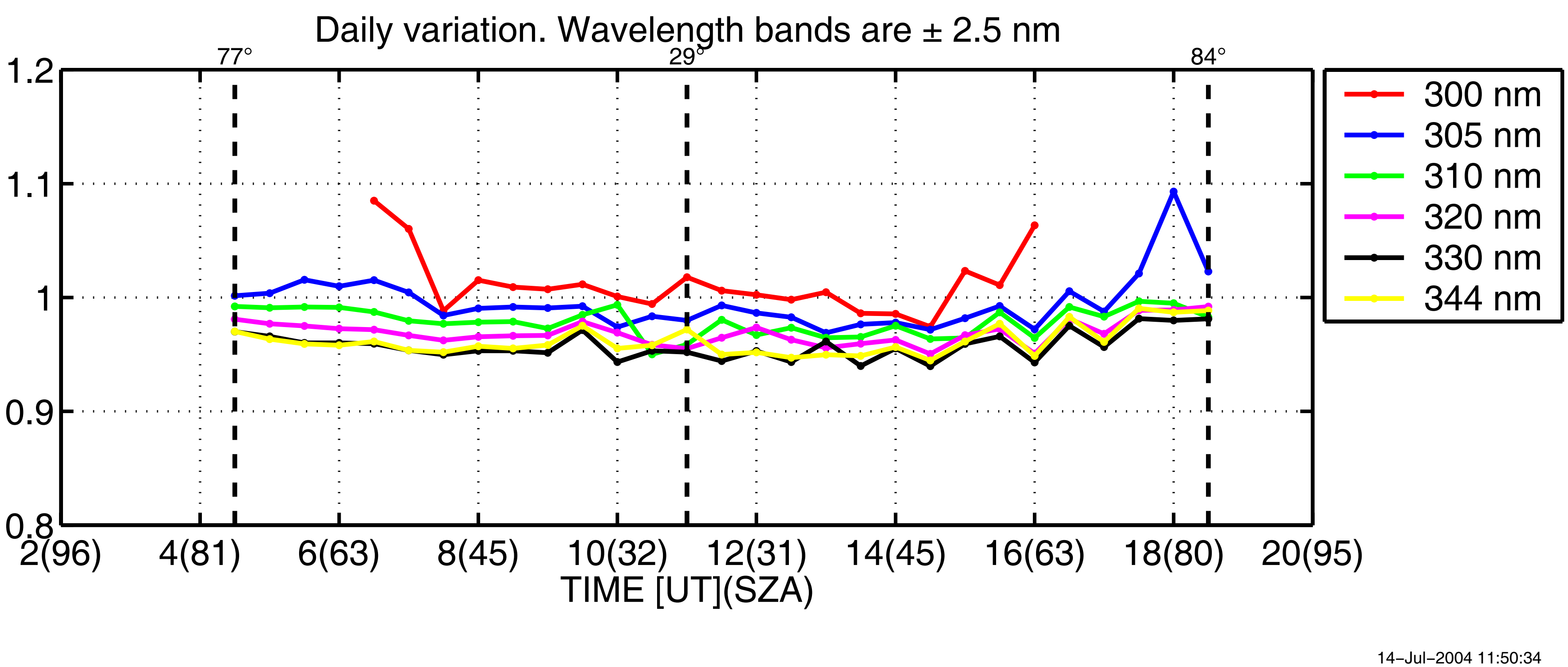


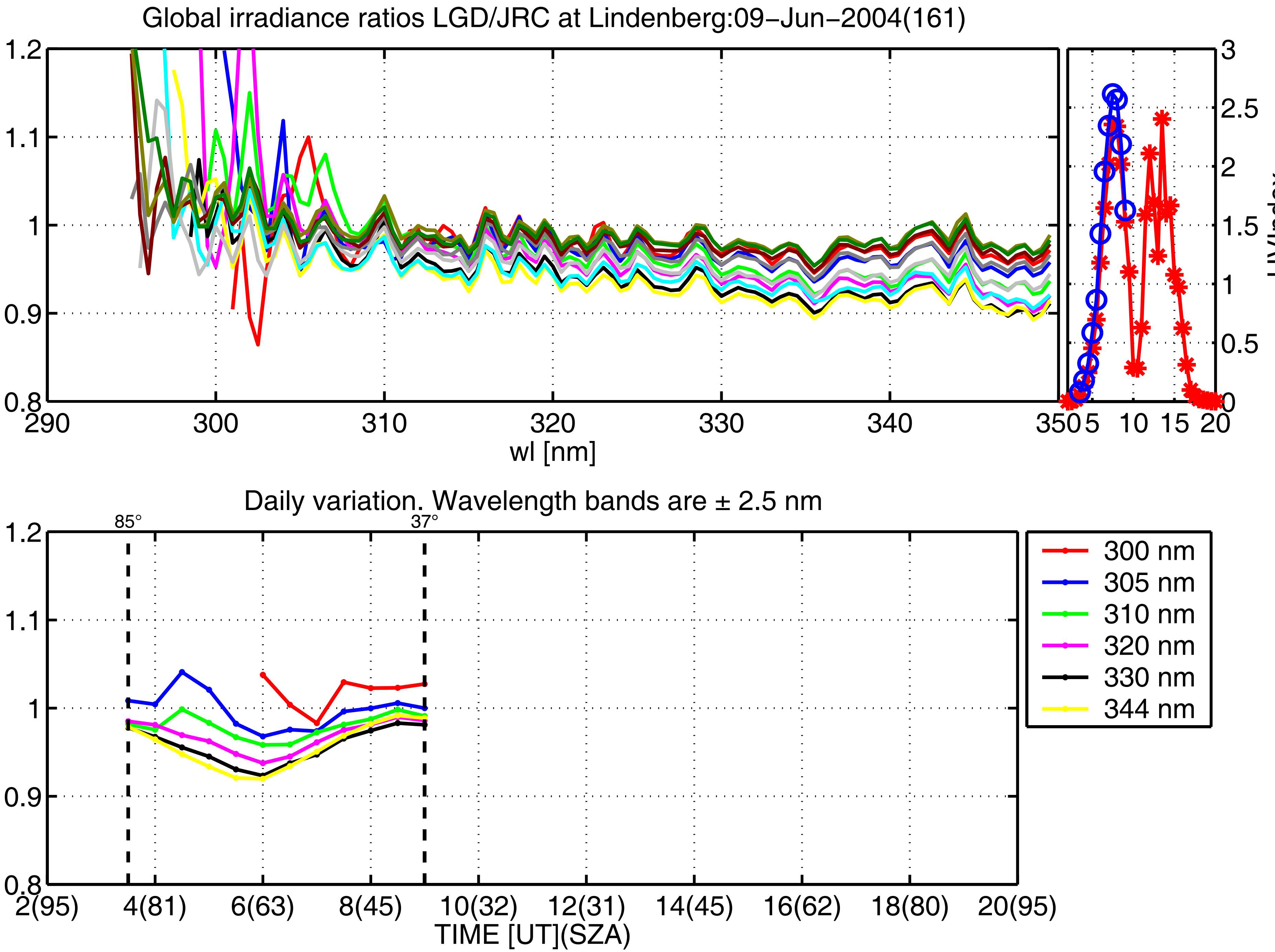
UV Index Lindenberg 7−9 June 2004
LGD
B5503
UV Index
Day of Year
0
1
2
3
4
5
6
160
160.2
160.4
160.6
160.8
161
161.2
161.4
161.6
161.8
162



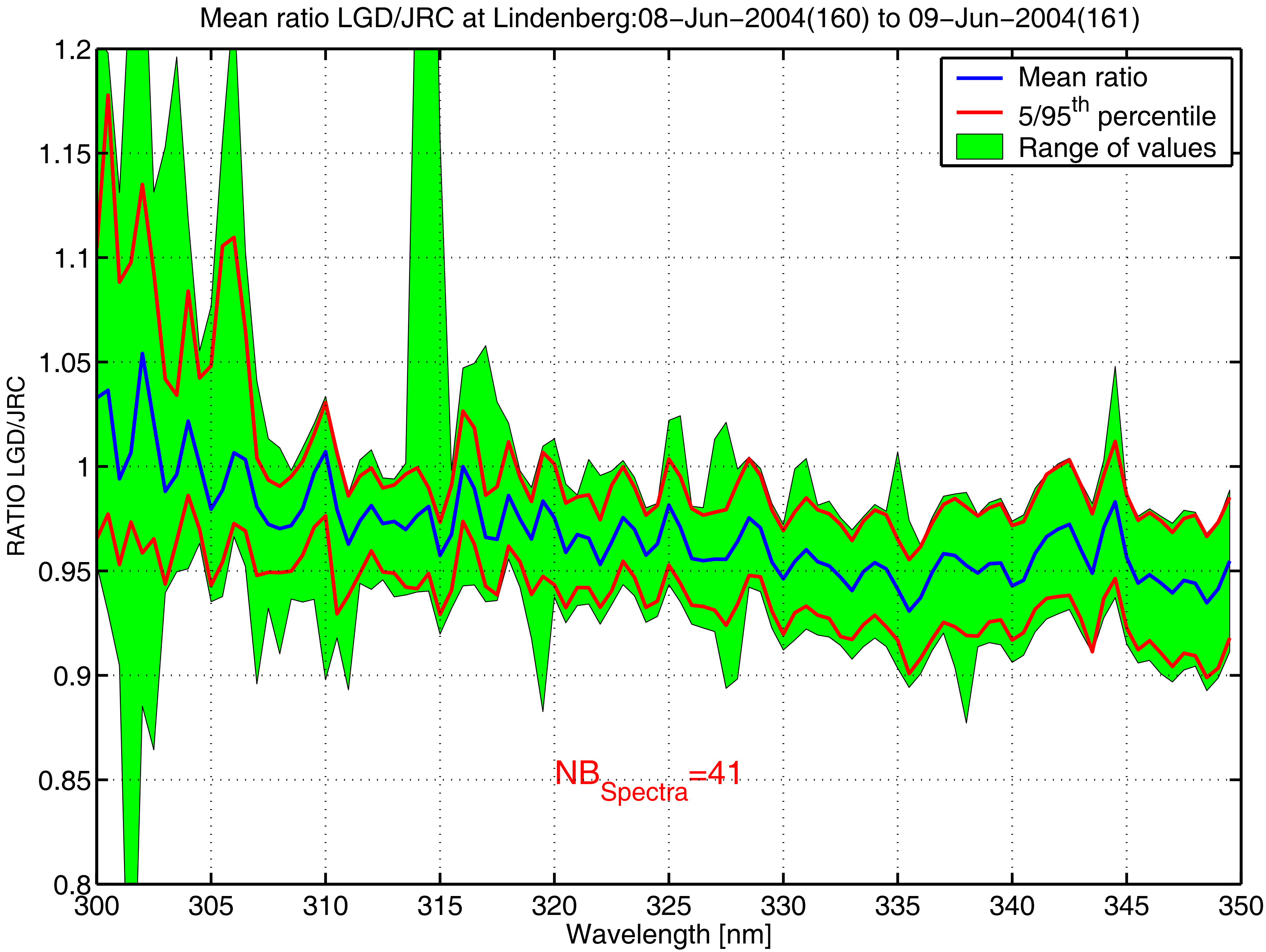
14−Jul−2004 11:50:34

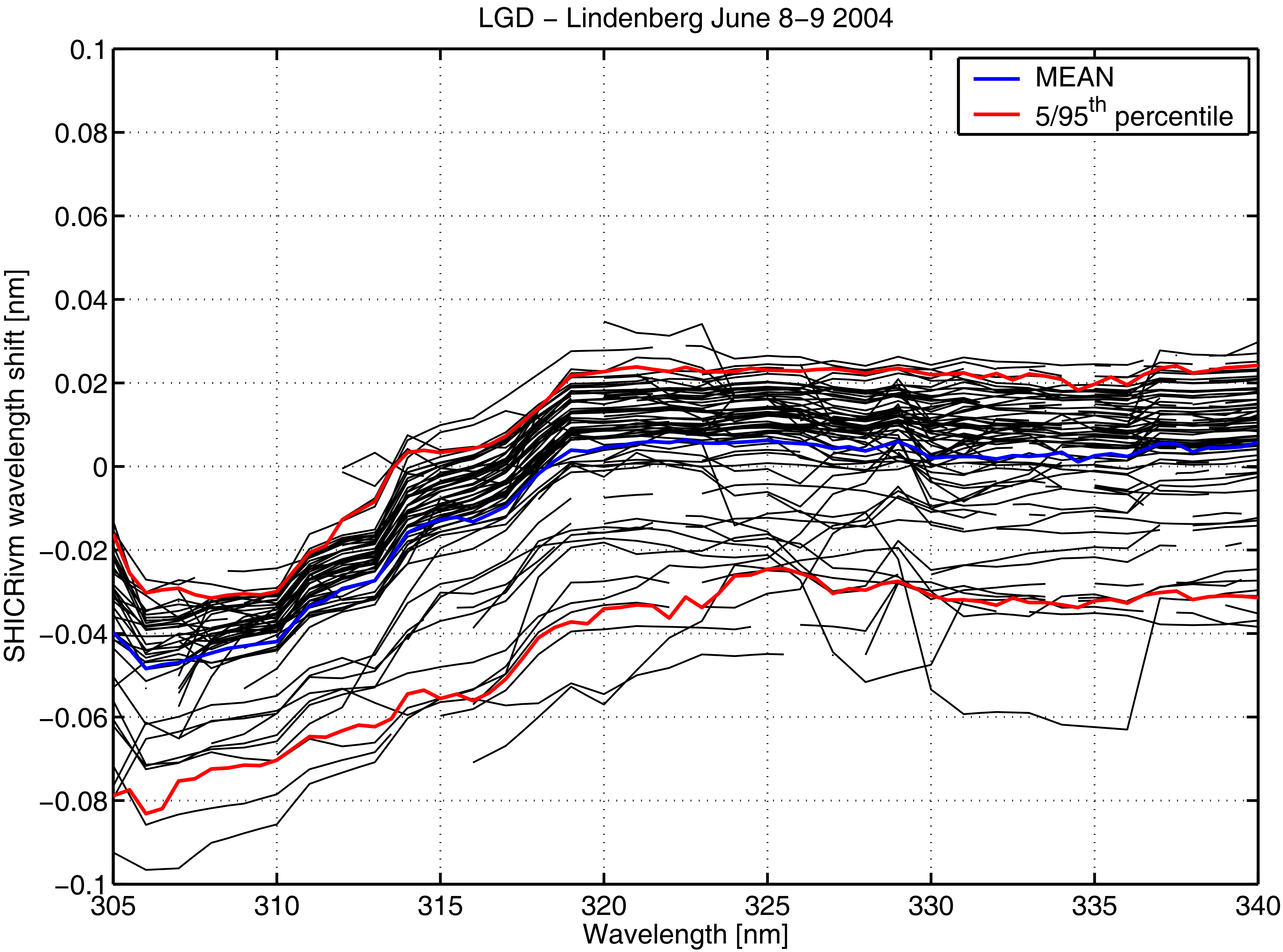

Global irradiance ratios LGD/JRC at Lindenberg:08−Jun−2004(160)
1.2
1.1
1
0.9
0.8
290
300
310
320
330
340
350
wl [nm]
5
10
15
20
0
1
2
3
4
5
6
UVIndex

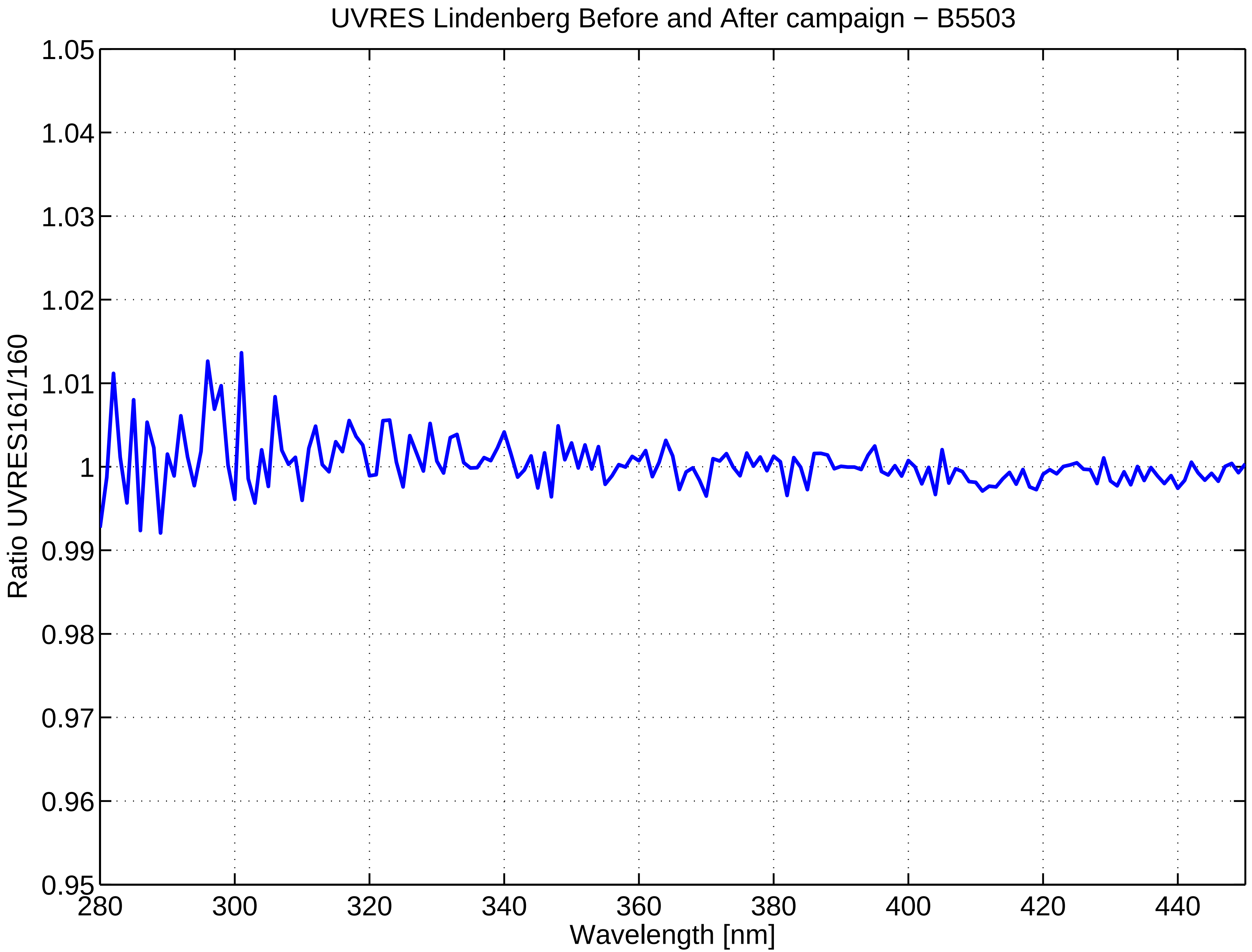

Daily variation. Wavelength bands are ± 2.5 nm
77°
29°
84°
1.2
1.1
1
0.9
0.8
2(96)
4(81)
6(63)
8(45)
10(32)
12(31)
14(45)
16(63)
18(80)
20(95)
TIME [UT](SZA)
300 nm
305 nm
310 nm
320 nm
330 nm
344 nm
14−Jul−2004 11:50:34

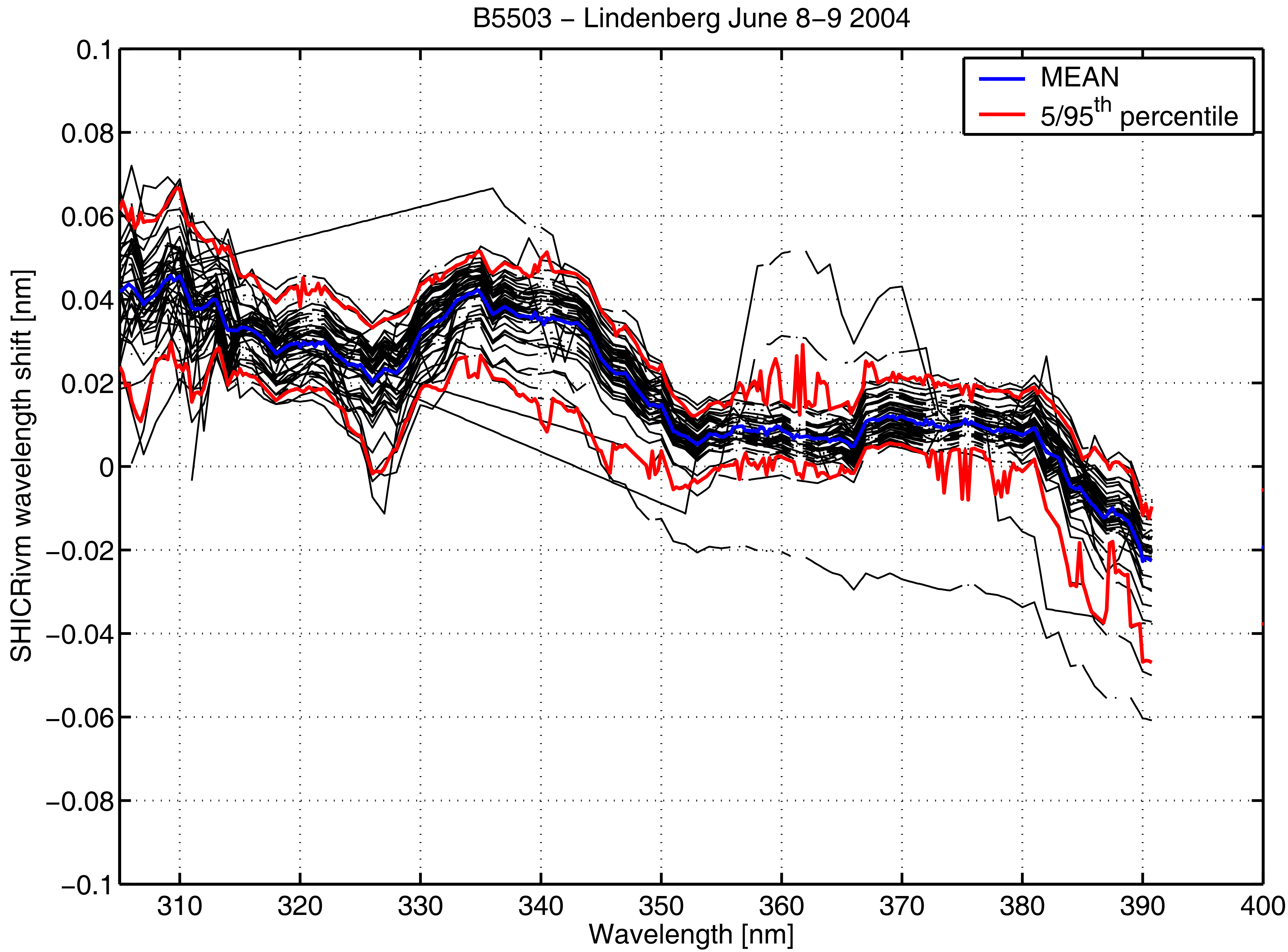


14−Jul−2004 11:50:34


Mean ratio LGD/JRC at Lindenberg:08−Jun−2004(160) to 09−Jun−2004(161)
Mean ratio
5/95th percentile
Range of values
RATIO LGD/JRC
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
305
310
315
320
325
330
335
340
345
350
Wavelength [nm]
NB Spectra =41


LGD – Lindenberg June 8–9 2004
MEAN
5/95th percentile
SHICRivm wavelength shift [nm]
Wavelength [nm]
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
305
310
315
320
325
330
335
340


UVRES Lindenberg Before and After campaign − B5503
Ratio UVRES161/160
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
420
440


B5503 – Lindenberg June 8–9 2004
MEAN
5/95th percentile
SHICRivm wavelength shift [nm]
Wavelength [nm]
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
310
320
330
340
350
360
370
380
390
400