Protocol of the intercomparison at the Norwegian Radiation Protection Authority at Oslo (NRPA), Norway on June 10 to 13, 2003 with the travelling standard spectroradiometer B5503 from ECUV within the project QASUME

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The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer operated by NRPA (NRP) and the travel standard B5503. The measurement site is located at Oslo; Latitude 59.92 N, Longitude 10.75 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 Oslo in the morning of June 10, 2003. The spectroradiometer was installed on the roof at 2.5 m distance from the NRPA instrument. The spectroradiometer in use at NRPA is a Bentham DM-150 double monochromator. The intercomparison between B5503 and the spectroradiometer from NRPA lasted four days, from noon of June 10 to noon of June 13.

B5503 was calibrated several times during the intercomparison period using a 100 W portable calibration system. Three 100 W lamps (T38986, T57825, T57824) 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 6% during the intercomparison period. These variations were taken into account on a daily basis. Observed diurnal variations of the responsivity were 7% on June 12 and 4% on June 13 and were taken into account for the analysis. On June 10 and 11 only one set of lamp measurements was performed per day and therefore no information on possible diurnal variations of the responsivity of B5503 is available. The internal temperature of B5503 was 25.3±0.2 °C. The diffuser head was heated to a temperature of 27±7°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>June 10 (161):</u>

B5503 was installed on the measurement platform at 9:00 UT. Synchronised scans started at 11:30 UT and lasted until 19:00 UT. Weather conditions during the day were mostly overcast, but no rain.

B5503 calibrated from 15:10 to 16:20 UT and therefore missed the 15:30 scan.

June 11 (162):

Synchronised measurements are available from 8:00 UT to 19:00 UT with interruptions due to rain from 15:00 to 18:00 UT. Rain over night which lasted until 7:50 UT. The rest of the day was characterised by a complete cloud cover until 11:00 UT and a mix of sun and clouds in the afternoon until 15:00 UT. Measurements after 18:00 were again under fully overcast conditions.

B5503 calibrated from 14:10 to 14:50 UT and therefore missed the 14:30 scan.

June 12 (163):

Synchronised scans are available from 2:30 to 20:00 UT. Heavy rain over night but clear with only few clouds in the morning. The weather conditions during the day were nearly clear skies from 2:30 to 6:00 UT and a mix of sun and clouds until 15:00. Rain during the 15:30 , 17:00 and 17:30 scan.

Lamp measurements from B5503 at 6:38, 8:12, 8:40, 10:50, 11:20, 13:40, 14:15, 14:45, 15:15, 16:45, and 17:15.

June 13 (164):

Synchronised scans are available from 2:00 to 11:00 UT. B5503 calibrated and therefore missed the 5:00 and 5:30 UT scans. Rain over night. Weather conditions are a mix of sun and clouds during the measurement period.

Lamp measurements from B5503 from 4:40 to 5:50 UT, and at 6:15, 6:45, 7:15, 7:45, 8:15, 8:45, 9:15, 9:45, 11:15, and from 11:45 to 13:30 UT.

Results:

81 synchronised simultaneous spectra from B5503 and NRPA are available from the measurement period. The wavelength shifts of the submitted solar spectra of the NRPA spectroradiometer retrieved through the SHICRivm analysis were between –50 to +50 pm. The wavelength shifts varied by 70 pm in the UVB and above 400 nm. In the wavelength range 340 to 400 nm the wavelength shifts were more stable and varied by less than 30 pm over time.

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

- Global solar irradiances measured by NRPA were between 8% to 2% lower than those measured by B5503 for wavelengths between 300 and 450 nm.
- The spectral ratios between NRPA and B5503 are spectrally flat between 300 and 450 nm for all SZA below 85°. At SZA below about 40° the spectral ratios are flat and show little spectral variability down to 296 nm.

- The diurnal variability was 2%, 4%, 5%, and 2% on June 10 to 13 respectively. On June 12, the variability during the morning was 2% at wavelength below 350 nm and 4 to 5% at longer wavelengths, which might have been caused by a difference in directional responses of the two entrance optics; the effect was only visible on that day because of the clear sky conditions until 7:00 UT.

Conclusion:

NRPA measures global solar irradiance on average 5% lower than B5503. The variability between the two spectroradiometers seems to be independent of wavelength (except June 12) and was around 2% on June 10 and June 13 and 4 to 5% on June 11 and June 12.

In July 2003 NRPA received 3 1000 W DXW lamps from ECUV. These lamps have been used in previous lamp intercomparisons[1] and have been shown to be stable to ±1.2% over extended time periods and during transportation. The comparison between the NRPA and ECUV irradiance scale using these lamps as transfer standards show that the NRPA scale is about 1% lower than the ECUV scale.

[1] Gröbner, J., D. Rembges, A.F. Bais, M. Blumthaler, T. Cabot, W. Josefsson, T. Koskela, T.M. Thorseth, A.R. Webb, and U. Wester, Quality Assurance of reference standards from nine European solar-ultraviolet monitoring laboratories, *Applied Optics, 41*, 4278-4282, 2002.

Comments from the local operator:

I have gone through my calibrations and find that the -5% lower irradiance of our solar measurements may be composed of 2 parts:

One is the fact that the certified data for our 'primary lamps' (certified November 2002) applied for calibrations in December 2002 all have -2% to -3% lower irradiances than compared with the certificates from 1992 and 1996. The consistency between several of our lamps indicates that they have been stable in this period, and that the new lamp certificate probably introduces a new irradiance scale. The use of new lamp data from December 2002 onwards has implied a scale change for our time series of spectral solar measurements on the order of -2% to -3%..

The second part is due to different traceability to standards laboratories. We have traceability to NIST through the Swedish Testing and Research Institute (SP), whereas QASUME lamps are traceable to PTB. According to Liedquist at SP, their NIST lamps deviate by -1.8% from their cryogenic-based irradiance scale. They are currently running a lamp comparison towards HUT in Finland, which will be ready this autumn. HUT applies cryogenic-based irradiance scale, as well as does PTB, and from this I will know how my own lamp data are compared to HUT (probably also PTB) scales.

In theory, accounting for these facts, there should be smaller differences between the spectroradiometer at NRPA and QASUME.

Concerning the irradiance scale for the national UV-monitoring network, it is traceable to Nogic2000, and is not affected by the scale-change of the latest spectroradiometer calibrations.

Attached is also cosine-response data, azimuthally averaged for 350nm. There is no numeric cosine-corrections applied for the solar spectra. (angresp_nrpa.fla and b2875_angresp.txt).

The azimuthal variation at SZA 75 degree and 350nm varies from 0.994 to 1.022. I have oriented the head in a direction I believe would minimize the errors in daily UV-doses. From comparisons made on the rooftop, it appears that our Bentham head has an azimuthal variation in the cosine error by the order of -1% or -1.5% in the morning/forenoon and +1% or +1.5% in the afternoon/evening. Usually, by subtracting 30 to 60 seconds from the timescale of scans, the spectra on rising and setting sun can be overlaid.

Some more information:
The optical head is thermostatted by a block of metal, fed by 75W. The inside of the optical head is constantly flushed with a small amount of dry Nitrogen.

Comparing the graph showing the mean daily responsivity of the QASUME spectroradiometer for the period 10-13 June (6%), the response change of the NRPA spectroradiometer was within 0.4% for the whole period, but spectral ripples in the order of ±2%. Repeated lamp measurements, following solar scans on 12 and 13. June showed no significant diurnal change of the spectral response for this instrument. The lamps used were 150 W QTHs mounted in housings that could be fixed to the front optic. A 50-litre box, with a ventilation lid was put above the lamp housing to serve as windshield and fairly temperature stable compartment.

File: b2875_angresp_proc.txt

"The frontoptic has been assembled and optimised at NRPA, using"
"a quartz dome and a teflone part purchased through GigaHertz Optik"
"The set-up for optimisation and measurement of the cosine response"
"included a 1kW QTH lamp with a collimating lens afront, baffles between"
"source and target, and a rotation stage holding the front optic"
"For each modification of the front optic, 4 ortogonal scans were made"
"90 degree at each side, covering SZA 0 to 90 degree in 8 azimuthal directions"

file: angresp_nrpa.fla

```
#
# Information on the NRPA instrument's angular response function, Bentham s/no 2875
#
begin angular_response
begin table angular_response
angle_of_incidence(deg.dec)  relative_angular_response()
0      1.000
5      0.995
10     0.989
15     0.973
20     0.969
25     0.996
30     1.008
35     1.005
40     1.001
45     0.998
50     1.000
55     1.005
60     1.012
66     1.015
70     1.010
75     1.015
78     1.030
80     1.030
82     0.957
84     0.872
86     0.810
88     0.851
89     1.089
end table angular_response
end angular_response
```

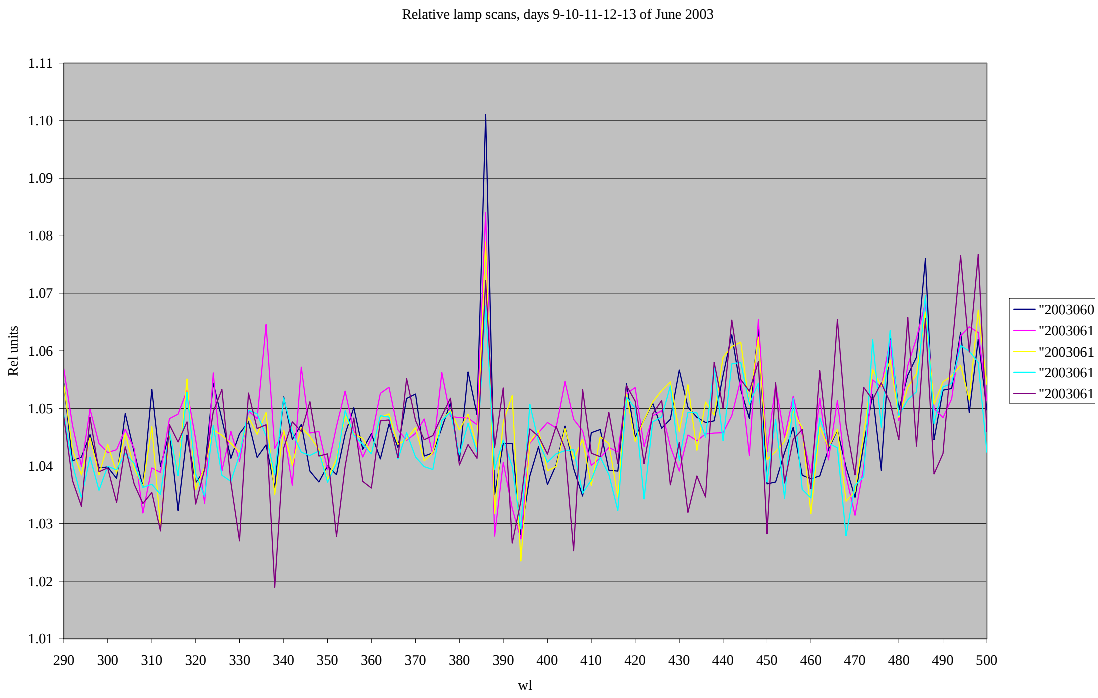
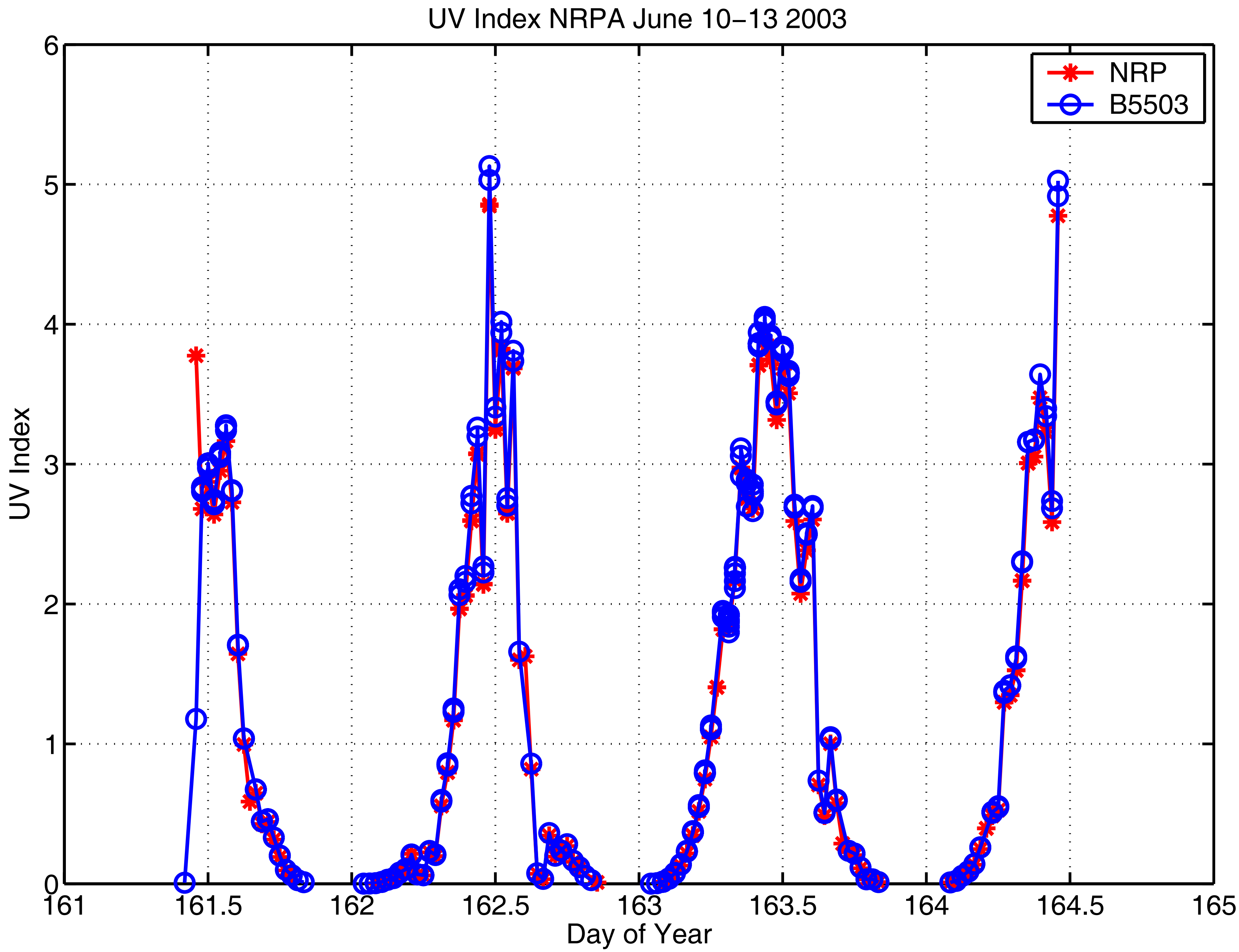
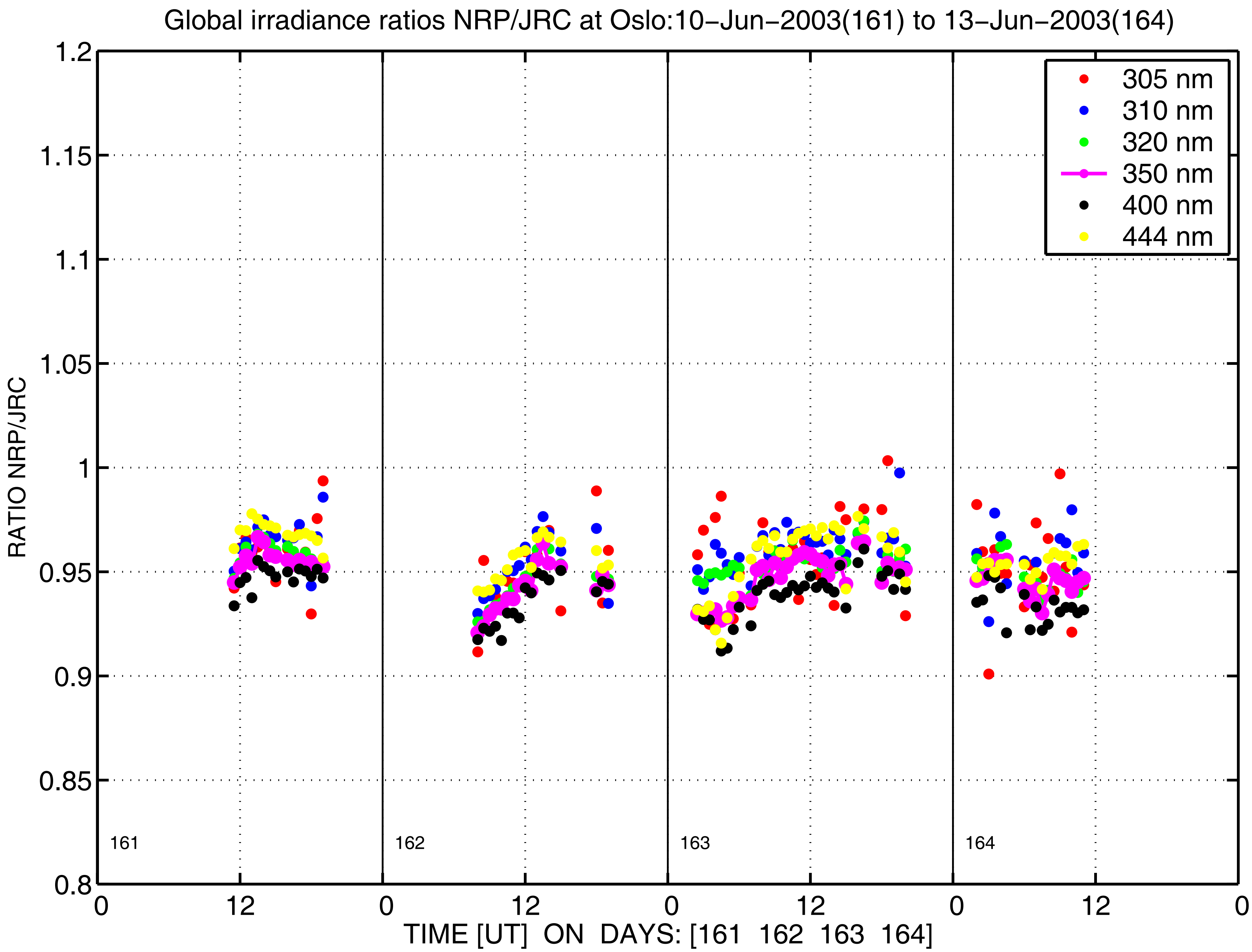


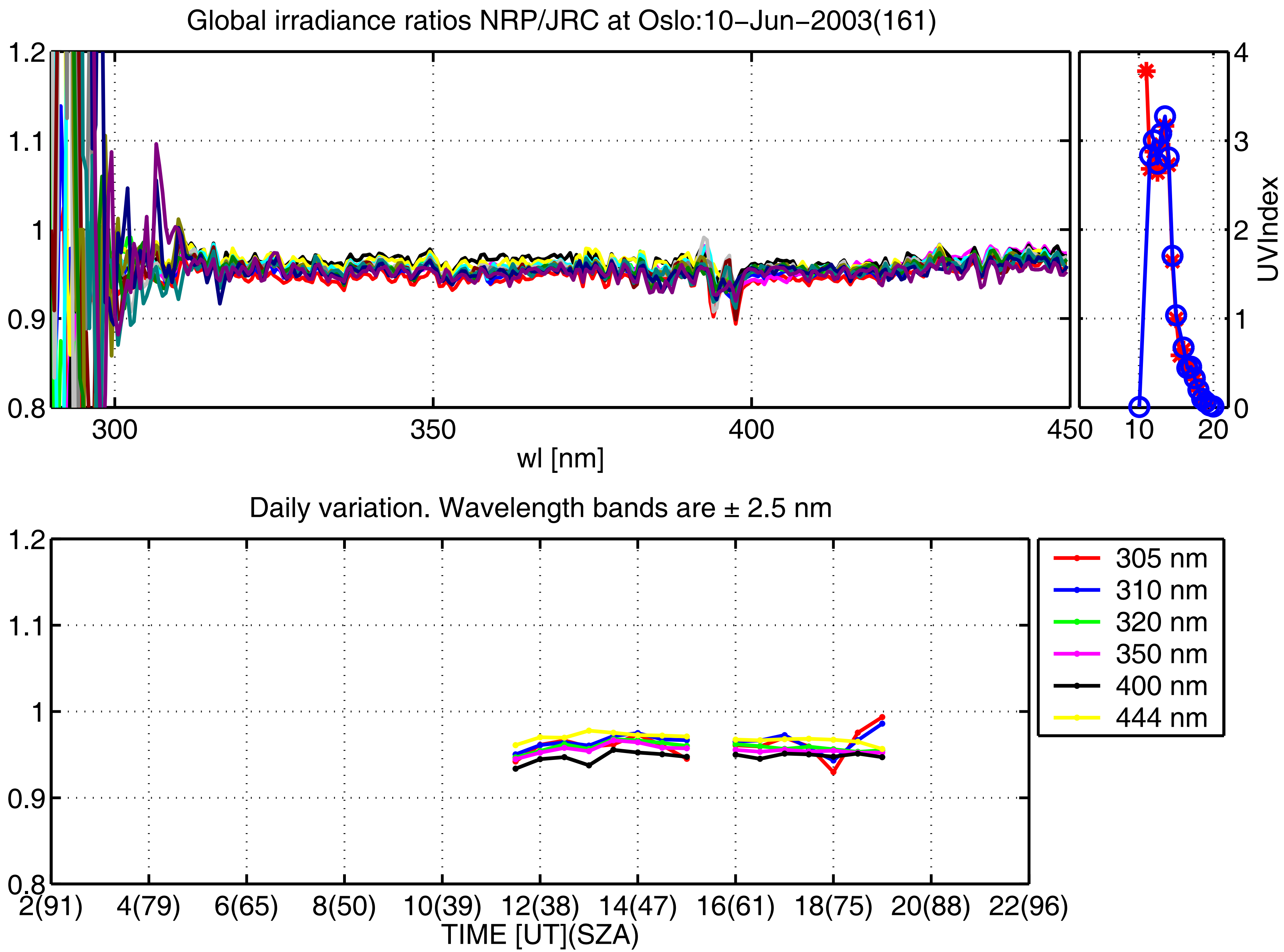
Figure 1 Lamp ratios of NRPA applied for the correction of solar spectra. These ratios have been obtained with the portable lamp, where each spectrum has been divided by the reference-spectrum measured in December 2002 after the primary calibration. The corrections of the solar measurements have been made with a polynomal fit to these lamp ratios. Any diurnal differences seen between the 2 spectroradiometers that are above 2 x 0.4% I would believe are due to differences in the cosine response of each instrument and diurnal variation in the response of the QASUME instrument.



UV Index NRPA June 10−13 2003
NRP
B5503
UV Index
Day of Year
0
1
2
3
4
5
6
161
161.5
162
162.5
163
163.5
164
164.5
165



30−Jul−2003 12:55:39



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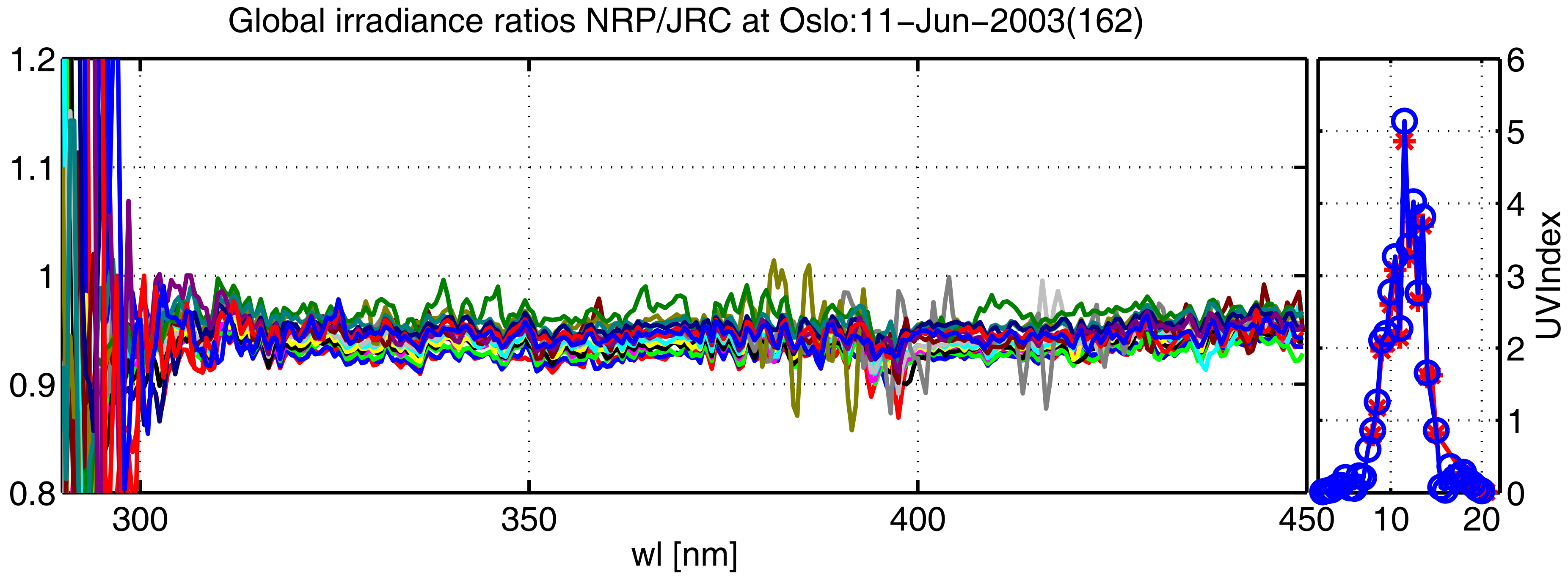

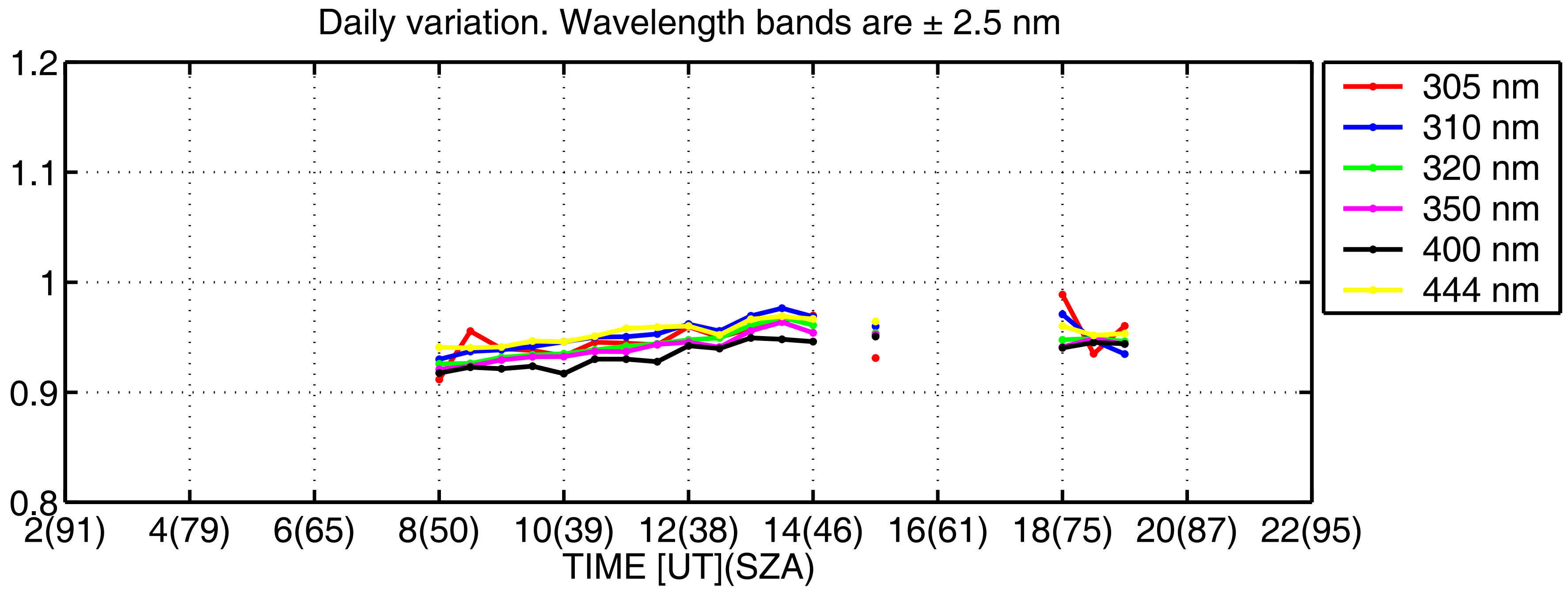

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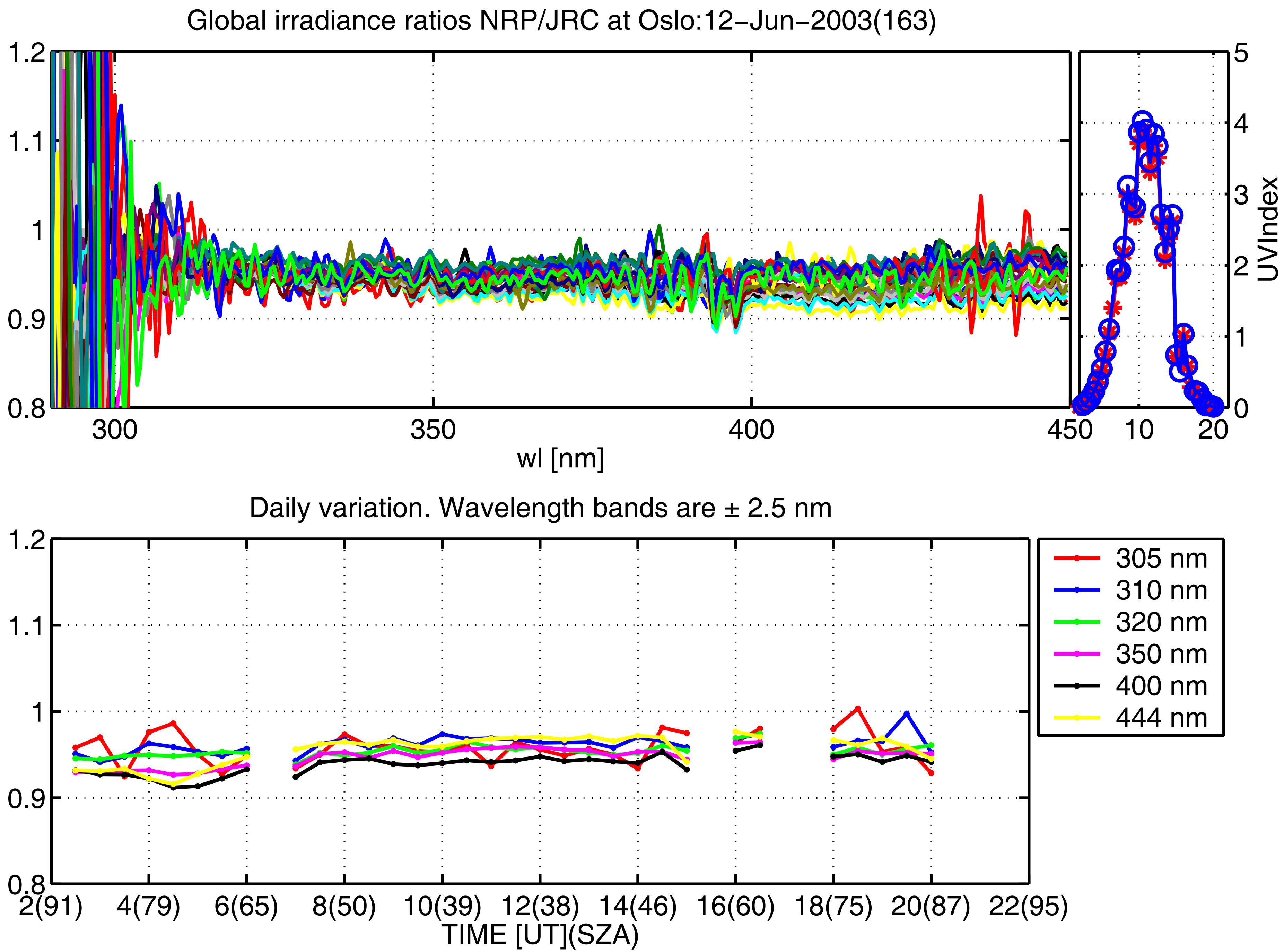

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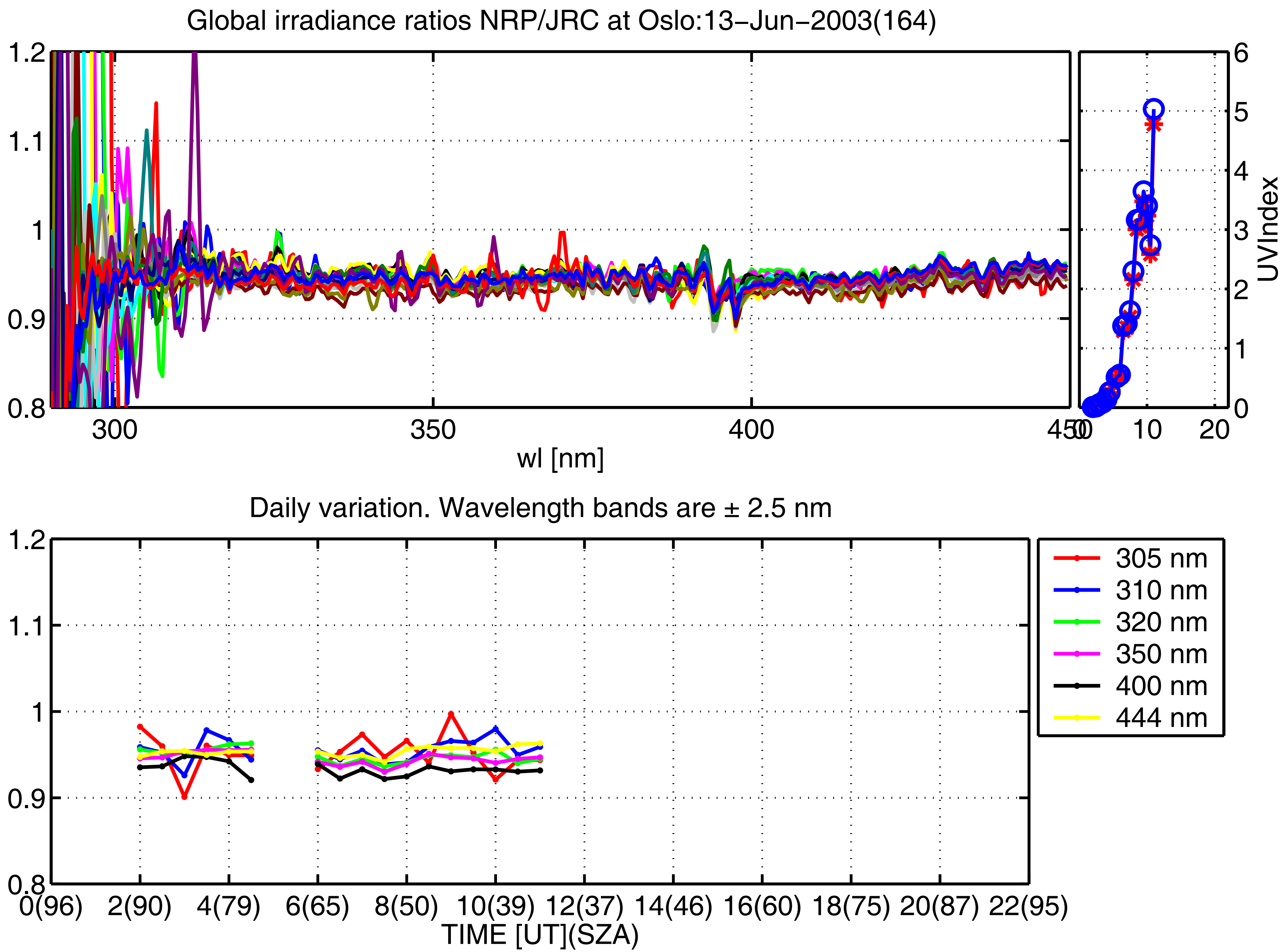

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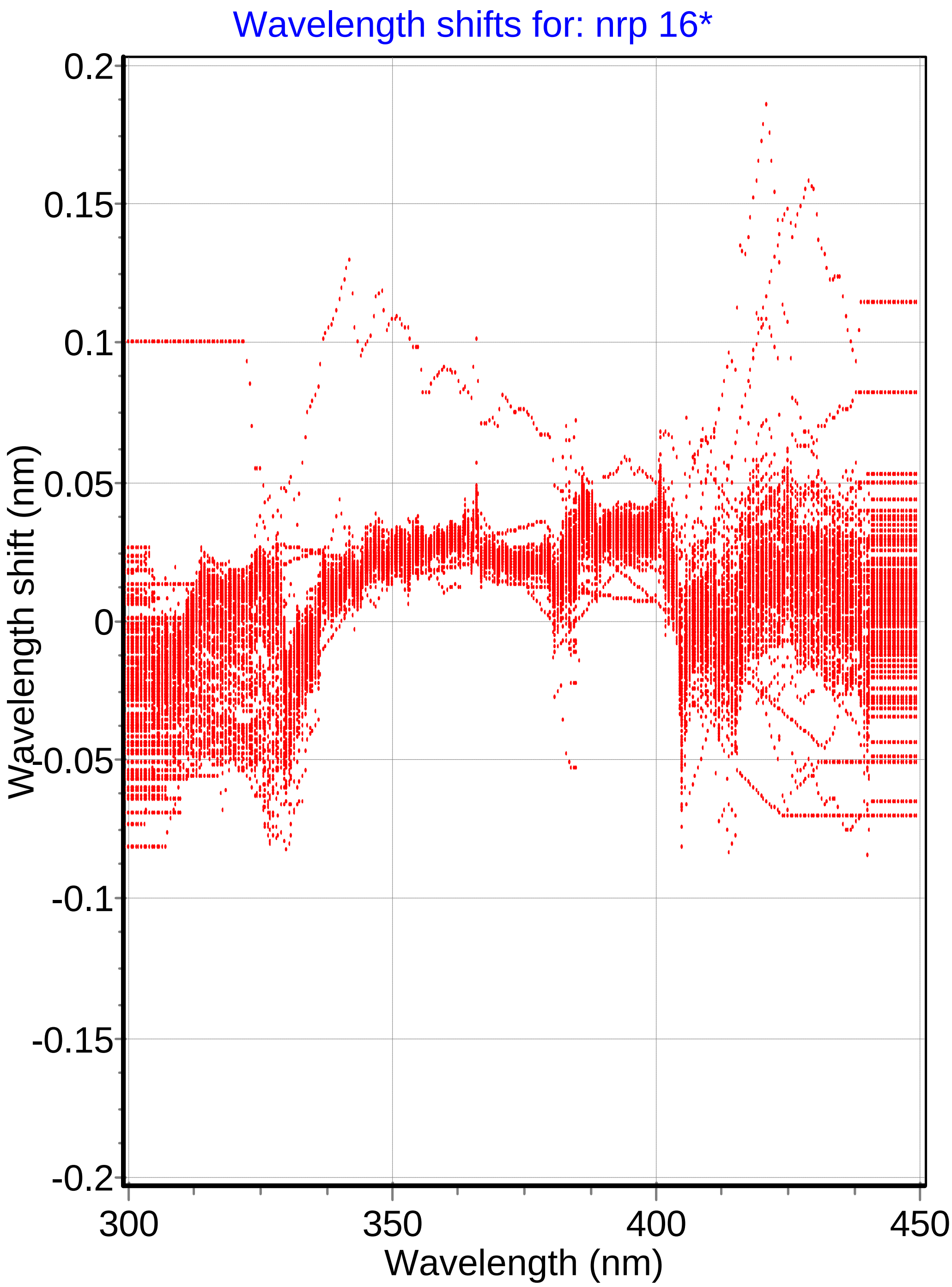
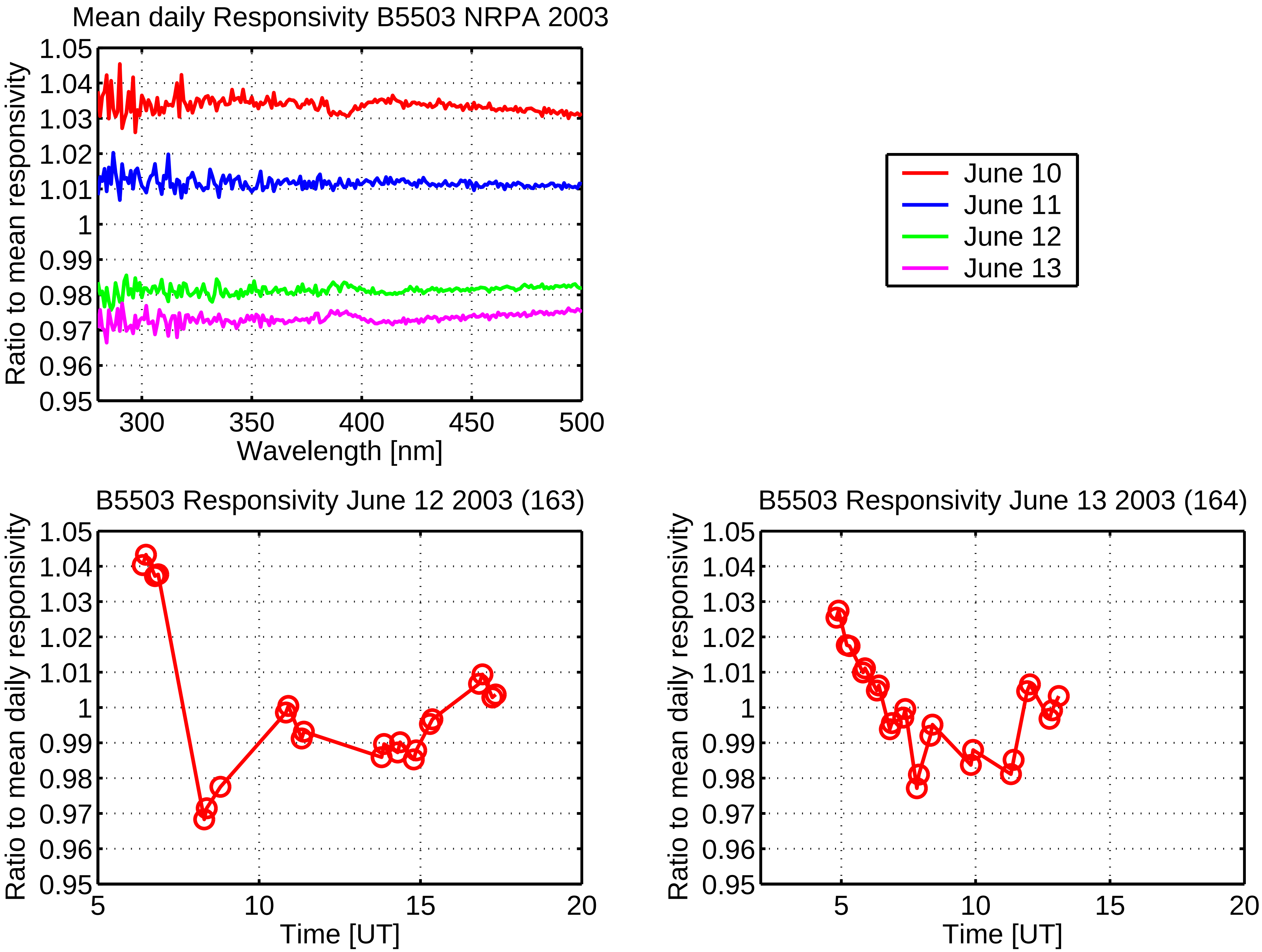

Wavelength shifts for: nrp 16*
Wavelength shift (nm)
Wavelength (nm)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
300
350
400
450


Mean daily Responsivity B5503 NRPA 2003
Ratio to mean responsivity
Wavelength [nm]
June 10
June 11
June 12
June 13
B5503 Responsivity June 12 2003 (163)
Ratio to mean daily responsivity
Time [UT]
B5503 Responsivity June 13 2003 (164)
Ratio to mean daily responsivity
Time [UT]