Protocol of the intercomparison at the Observatoire de Haute Provence (OHP), France on September 9 to 11, 2010 with the travelling reference spectroradiometer QASUME from PMOD/WRC

Report prepared by Julian Gröbner

Operator: Julian Gröbner

The purpose of the visit was the comparison of global solar irradiance measurements between the three spectroradiometers operated by the University Lille at OHP, and the travel reference spectroradiometer QASUME.

The instruments participating at the intercomparison at OHP were composed of two double monochromator Bentham DM300 Systems (OHP and LOA), and one double monochromator spectroradiometer system JY HD10 (FRL).

The measurement site is located at Observatoire de haute Provence; Latitude 43.935 N, Longitude 5.710 E and altitude 678 m.a.s.l. The horizon of the measurement site is free down to 85° solar zenith angle (SZA). Measurements between 6 UT and 17 UT were analysed.

QASUME was installed on the measurement platform in the afternoon of September 8, 2010. The spectroradiometer was installed next to the local spectroradiometers with the entrance optic of QASUME within 5 m of the other instruments. The intercomparison between QASUME and the local spectroradiometers lasted three days, from morning of September 9 to the evening of September 11.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Two lamps (T68522 and T68523) were used to obtain an absolute spectral irradiance calibration traceable to the primary reference held at PMOD/WRC, which is traceable to PTB. The daily mean responsivity of the instrument based on these calibrations varied by less than 1 % during the intercomparison period. The internal temperature of QASUME was 23.5±0.1 °C and the diffuser head was heated to a temperature of 27.8±1.5 °C.

Due to the clear sky conditions without noticeable turbidity nor clouds, a cosine correction was applied to the QASUME measurements. The size of the correction was between ±2% of the uncorrected measurements, with a diurnal variability of 1% at wavelengths shorter than 350 nm, and reaching 3% at 400 nm (see attached figure).

The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm analysis were between ±50 pm in the spectral range 290 to 440 nm.

Protocol:

The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 280 to 450 nm, every 0.5 nm, and 3 seconds between each wavelength increment.

DOY	Date	DAY	Weather	Comment
251	8-Sep	Wednesday	Clear Sky, very light Cirrus	Installed at 14:00 UT. Calibrated at 16:41 using T68523
252	9-Sep	Thursday	Clear Sky, some Cumulus during the day. (11:30 UT partly in front of sun)	Calibrated at 11:18 using T68523. Power failure at 16:14. HeCd Slit Function Measurement of LOA.
253	10-Sep	Friday	Clear Sky, few Cumulus	Calibrated at 11:18 using T68523. HeCd Slit Function Measurement of OHP and FRL.
254	11-Sep	Saturday	Morning with few Cirrus; After 9:30 UT clear Sky until Evening	Calibrated at 10:48 using T68522. OHP head in Darkroom to measure Angular Response.
255	12-Sep	Sunday		Campaign finished at 7:00 UT. The measurements of this day are not included in the following analysis.

Results:

1. In total 69, 64, and 60 synchronised simultaneous spectra from QASUME and LOA, FRL and OHP respectively, are available from the measurement period. Measurements between 6:00 and 17:00 UT were analysed (SZA smaller than 85°). All measurements are processed with the SHICRivm package to retrieve spectra with a nominal spectral resolution of 1 nm FWHM and a wavelength grid adjusted to a reference high resolution extraterrestrial spectrum.
2. The slit function of all three Spectroradiometers was measured with a HeCd Laser at 325 nm. The Full Width at Half maximum (FWHM), assuming a Gaussian shaped slit function, was 0.48 nm, 0.95, and 0.50 nm for LOA, FRL, and OHP respectively (see figures).
3. The angular response of the OHP entrance optic was measured in a provisional laboratory with the portable angular response facility (ARF) of PMOD/WRC in four planes at 310, 360, 410, 460, and 510 nm (see figure). The diffuse cosine error, determined from these measurements, is between 1.0 and 1.02, slightly increasing with wavelength.

Remarks:

The measurements of LOA, FRL, and OHP were processed by the Univ. of Lille after the measurement campaign and delivered by email. Several dataset versions were submitted, of which the latest version is discussed in this protocol. Details of this submitted revised dataset can be found in the attached “comments of the operator”.

Spectroradiometer OHP

1. The average wavelength offset between the reference extraterrestrial spectrum and the measured solar spectra varies spectrally between +0.07 nm at 420 nm to +0.0 nm at 440 nm. The wavelength stability (90% coverage) during the measurement period is better than ±20 pm over the whole wavelength interval. The average wavelength offset is 0.03 nm.
2. On average, OHP irradiance measurements are lower than those from QASUME by about 15% at 300 nm to 6% at 450 nm.
3. The measurements on 11 September (DOY 254) are about 5% higher than the measurements on the two previous days.
4. On 9 September (DOY 252), the ratios between OHP and QASUME show a diurnal variability of 10% at 445 nm, decreasing to 5% at 305 nm. The diurnal variability is significantly decreased to 5% or less at all wavelengths on the two following days. The significantly different diurnal variation between the first and subsequent days can be explained by an improved levelling of the entrance optic by the OHP operator.

Spectroradiometer LOA

1. The average wavelength offset between the reference extraterrestrial spectrum and the measured solar spectra varies spectrally between -0.04 nm at 300 nm to +0.02 nm at 350 nm. The wavelength stability (90% coverage) during the measurement period is better than ±20 pm over the whole wavelength interval. The average wavelength offset is 0.0 nm.
2. On average, LOA irradiance measurements are lower than those from QASUME by about 15% at 300 nm to 6% at 430 nm. The overall day to day variability relative to QASUME is less than ±1%, indicating a very stable System. As mentioned in the remarks of the local operator, the LOA and OHP systems are traceable to the same reference standards which therefore explains the similar differences relative to QASUME.
3. The diurnal variability is very similar on all three measurement days. The amplitude of the diurnal variability is 5% at 444 nm, to 2% at 305 nm, indicating that this diurnal variability is probably due to differences in the respective angular responses of the OHP and QASUME entrance optics.

Spectroradiometer FRL

1. The average wavelength offset between the reference extraterrestrial spectrum and the measured solar spectra varies spectrally between -0.06 nm at 420 nm to +0.02 nm at 350 nm. The wavelength stability on the first two days of the intercomparison, 9 and 10 September), is of the order of ±20 pm. On 11 September 2010, the wavelength shift below about 340 nm shows a significant drift during the whole day, from -0.04 nm in the morning to -0.16 nm in the late afternoon. The wavelength shifts could not be determined in this short wavelength range for several spectra on this day due to a spectral artefact at 321 nm.
2. On average, FRL irradiance measurements are 5% to 15% higher than QASUME at 305 nm, decreasing to -5% at 450 nm. The increasing irradiances at short wavelengths could be due to stray light contamination within the FRL monochromator. The measurements at wavelengths shorter than 305 nm show increased variability (noise).
3. The diurnal variability on 9 September (DOY 252) was 3% or less at all wavelengths. On subsequent days, the overall diurnal variability increased significantly, showing a variability of 10% to 15% on 11 September (DOY 254).
4. On 11 September a significant drop in intensity is observed between 320 and 322 nm which also affects the wavelength shift retrieval procedure (see comment 1 above).

   The attached comments of the local site operator on the next pages provide additional information on the observed performance of the three spectroradiometers.

Comments on the intercomparison campaign between three LOA spectroradiometers and QASUME instrument held at OHP (September 9-11, 2010)

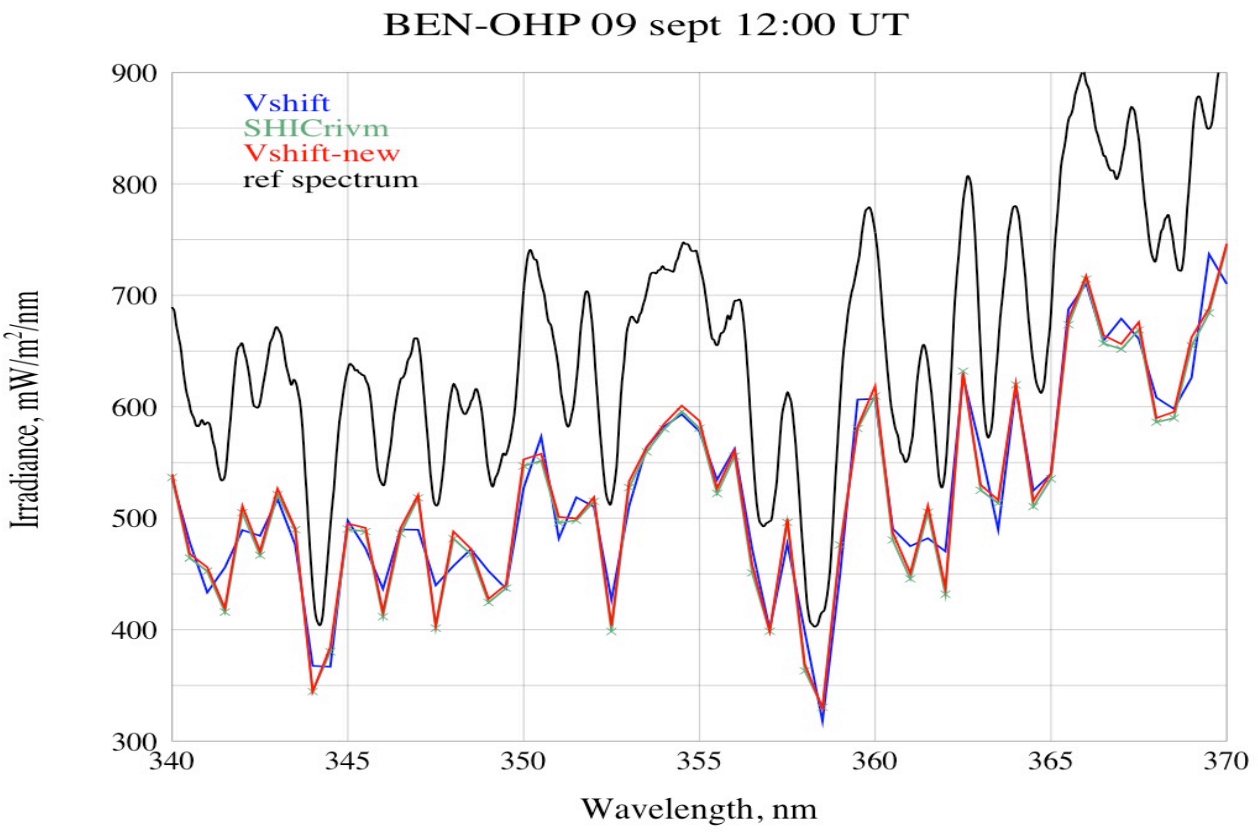
General comments

Two of the three spectroradiometers are new instruments (Bentham DM300). One is installed at OHP (called in the following OHP instrument). The second one (called LOA) is planned to replace an old instrument, Jobin-Yvon HD10 (called FRL), which is still operational at Villeneuve d'Ascq (VDA). The two new instruments were never intercompared.

During the campaign the LOA and FRL instruments were located on the roof of the OHP station and, since the days were very sunny, their thermal regulations encountered some problems.

Remarks

To correct the spectra from wavelength misalignment, the measurements have been processed with a software (called Vshift) developed at LOA for the FRL instrument. Few years ago the results of the Vshift software for the FRL instrument have been satisfactorily compared to the results of the SHICrivm software (Houet, 2003, Gröbner et al., 2006). For the QASUME 2010 campaign we also processed few spectra of each instrument with SHICrivm, and the Vshift processing was found generally satisfying except below about 320 nm and above 420 nm.
First, the spectra processed with Vshift were submitted to J. Gröbner who compared them to QASUME spectra. J. Gröbner pointed out that the shapes of few features in the spectra of the two Bentham instruments were not sharp enough compared to QASUME spectra. J. Gröbner suggested that the interpolation technique used in Vshift was not satisfying for instruments whose FWHM is close to the wavelength step (0.5 nm). We have therefore worked on that issue and improved our software. The following figure compares for the OHP instrument, 9 September at 12:00 UT, the spectra processed with the old Vshift (blue), with SHICrivm (green), with our new Vshift (red), and also the extraterrestrial spectrum convolved with the instrument slit function (black). It shows that the green and the red spectra are now very close and exhibit features much similar to the extraterrestrial spectrum than the blue one.



We have then submitted the spectra processed with the new Vshift to J. Gröbner for a new comparison with QASUME.

As explained below, we have not changed the calibration files we had selected for the first comparison.

Specific comments

Spectroradiometer OHP

1- "The average wavelength offset … varies between 0.07 nm at 420 nm…":
We have not yet an explanation for the feature around 420 nm.

2- "On average, OHP irradiance measurements are lower than those from QASUME …":
Calibrations of OHP were performed with three 1000 W lamps on 12 September (F538, F540, F964). They were very close (within 4% below 300 nm, and 2% above). We chose the calibration with the lamp F964 that is the most recent and also because it has not travelled before the campaign (it is the lamp that remains on the OHP site). The difference with QASUME is probably due to calibration issue.

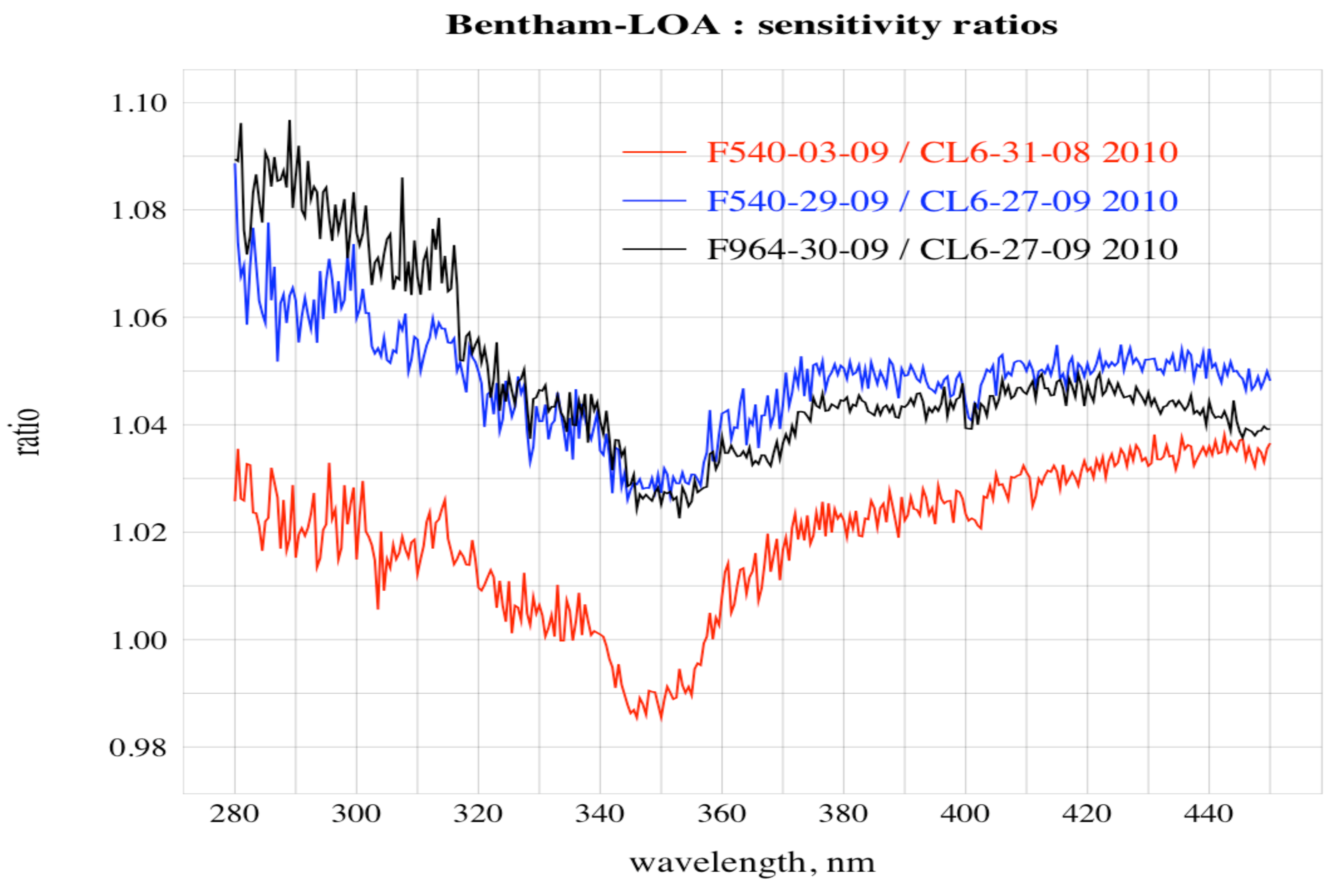
3- "The measurements (ratios) on 11 September are about 5% higher than the measurements (ratios) on the two previous days":
The measurements have been stopped on 10 September evening to allow the slit function measurement. To do that the optics has been removed from its support and, after slit function measurement it has been repositioned on its support. Maybe something has moved (the optical fibre?).

4- "On 9 September the ratios between OHP and QASUME show a diurnal variability of 10% at 444 nm…":
Indeed, on 9 September there was a problem with the levelling of the entrance optics: it was improved on 10 September at 5:25. After that, the spectra recorded are correct (6:00 spectrum included).

Spectroradiometer LOA

2- "On average, LOA irradiance measurements are lower than QASUME ones…":
There was no possibility to perform calibration in the dark room with the 1000 W lamps. Therefore, calibrations were performed on site with a CL6 (150 W) on 8 September (at 19.6ºC) and 11 September (at 23.2ºC).
Then, calibrations were performed after the campaign, in VDA, with the CL6 and the three 1000 W lamps. Comparisons between the calibrations in VDA have been carried out and show that the three 1000 W lamps give very close sensitivities. The CL6 (at 19.6ºC) gives a sensitivity different from the one obtained during QASUME on 8 September (same temperature, but after transportation and removing/repositioning the optic fibre) but close to the one obtained in VDA before the campaign.
Since the sensitivities of the CL6 and of the 1000W lamps are different, we decided to apply a correction factor (spectral ratio F964/CL6 obtained after the campaign, close to the F540/CL6 ratio) to the calibration of the CL6 performed on 11 September (not the one of 8 September because the instrument was often warm). We chose the F964 lamp as a reference for consistency with OHP calibration.
Note that this rescaling is not completely satisfying because before the campaign we had measured a different ratio F540/CL6. The following figure compares few ratios obtained before the campaign with one 1000 W lamp (red) and after with two 1000 W lamps (blue and black).

If we chose to rescale the calibration with the ratio F540/CL6 obtained before the campaign that will give a better agreement with QASUME.



Moreover, due to thermal regulation problem, the temperature was varying all day long and therefore was different for each spectrum. As stated above, the calibration with the CL6 provided only two choices for the temperature, introducing error in the calibration processing of the raw measurements.
During routine measurements carried out in VDA the thermal regulation works well and of course the instrument doesn't travel and we don't remove/reposition the optic fibre before performing calibration.

3- "The amplitude of the diurnal variability is…, indicating that this diurnal variability is probably due to differences in the respective angular responses of the LOA and QASUME entrance optics…":
The angular response is accounted for in the processing, so maybe the correction that includes the ratio direct/global (that depends on the atmospheric conditions) is not adequate. Note that we use the same mean correction for all wavelengths.

Spectroradiometer FRL

In the routine measurements performed in VDA we have defined two spectral regions with different photomultiplier (PM) voltage HV: 280-320 nm with HV = 900 V and 280-450 nm with HV = 700 V (that is with a common wavelength range).
To simplify the synchronised measurements, on 9 and 10 September the spectrum acquisition was performed with one spectral region (280-450 nm), with HV = 700 V.
Nevertheless, to check the quality of the measurements performed with HV = 900 V, on 11 September, after 6:18, two spectral regions were defined: 280-320 nm with HV = 900 V and 320.5-450 nm with HV = 700 V. The two regions had no common range because of the required synchronisation of the measurements of all instruments.
In that conditions, one can observe in the raw data files of 11 September that there is a gap at 320.5 nm (signal very weak, we don't know why, maybe a problem with the PM). So in the first figure for FRL, the first green point on 11 September is correct (at 6:00) while the remaining green data are wrong (since there is an average made over 320 +/- 2.5 nm).

No calibration was possible on site during the campaign, so calibrations have been performed in VDA before travelling to the campaign (with one lamp) and after coming back (with the three lamps). The calibrations with the three lamps gave very close calibrations, but showed 10% difference with the calibration performed before the campaign. We choose the calibration obtained with the F964 lamp (for consistency with the calibrations of the two other instruments).

1- “The wavelength stability during the measurement period increases from about +/-0.2 nm to 0.15 nm at wavelengths shorter than about 340 nm”:
We are currently searching for an explanation for this bad correction of the shift.

2- “On average, FRL irradiance measurements are 5% to 15% higher than QASUME …”:
As told previously, the calibration was not performed on site so that the instrument has travelled after the first calibration and has travelled one more time before the calibrations with the three lamps. It is hard to say when the instrument has changed. The comparison with QASUME indicates that the change likely occurred during the second trip.

If we replace the calibration obtained after the campaign by the one obtained before, the ratios will be improved for wavelength larger than about 350 nm (about 5%), not below 320 nm.

3- “The diurnal variability on 9 September …. On subsequent days the overall diurnal variability increased significantly…”:
As told in the general comments, the FRL instrument was located on the roof of the station. The 10 and 11 September were very sunny days, and in the afternoon the thermal regulation was not working well so the temperature increased inside the box of the instrument. The PM could have encountered some problems.
Note that on 11 September the curve for the band around 320 nm (in green) is very close to the curves for larger wavelengths, while on the two previous days it is almost in the middle between the 310 nm and the other bands. This is because of the spectrum acquisition performed with two spectral regions as mentioned previously. Therefore, the 320 nm curve must not be considered on that day.

As for the LOA instrument, due to thermal regulation problem, the temperature was varying all day long and therefore was different for each spectrum. There is no doubt that the calibration performed after the campaign at the usual working temperature introduced error in the calibration process.
During routine measurements carried out in VDA the thermal regulation works well and of course the instrument doesn’t travel before performing calibration.

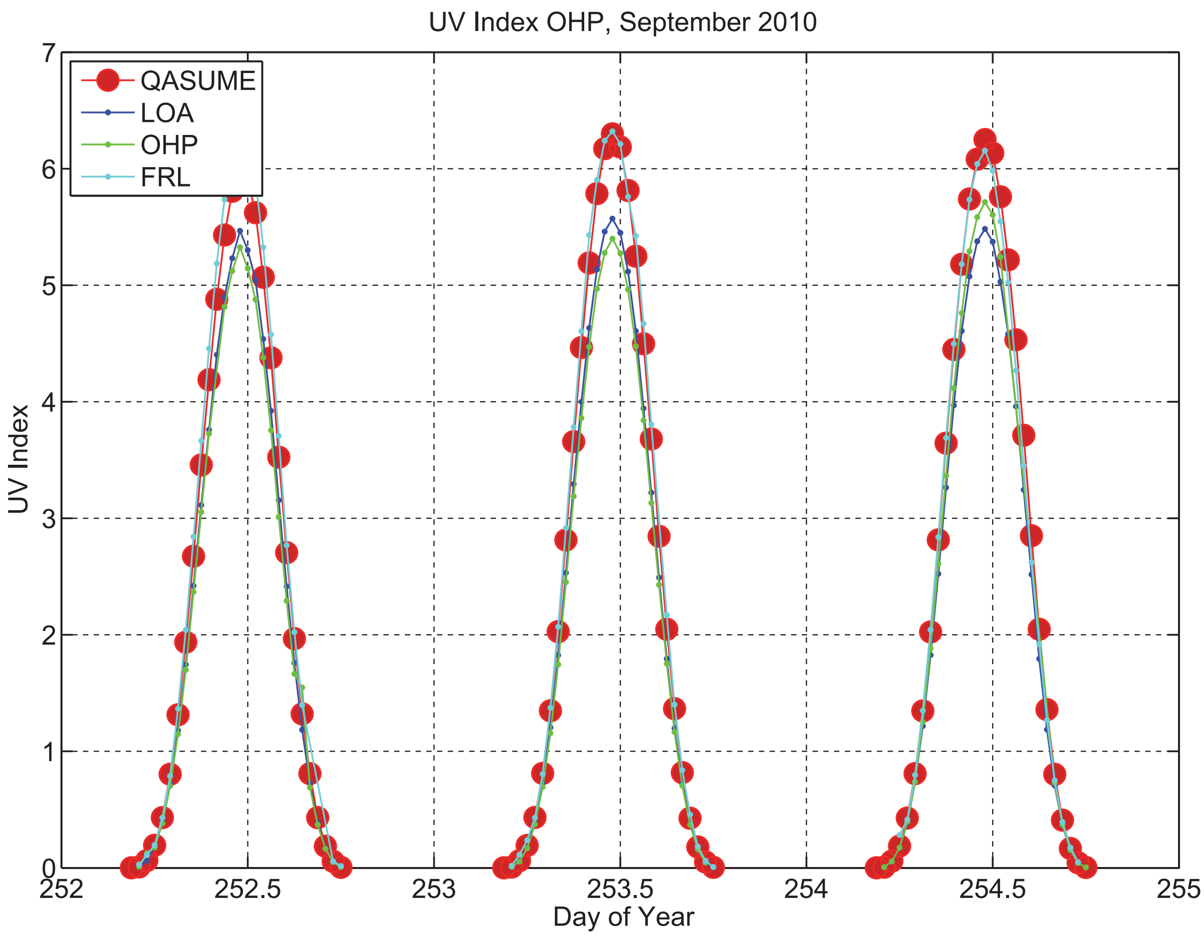
Conclusion

For the three instruments, the differences with QASUME seem to be linked to calibration issues. We did not change yet the calibrations because we intend to carry out new calibrations of the three 1000 W lamps at PMOD/WRC. We will reprocess the data after that if needed.

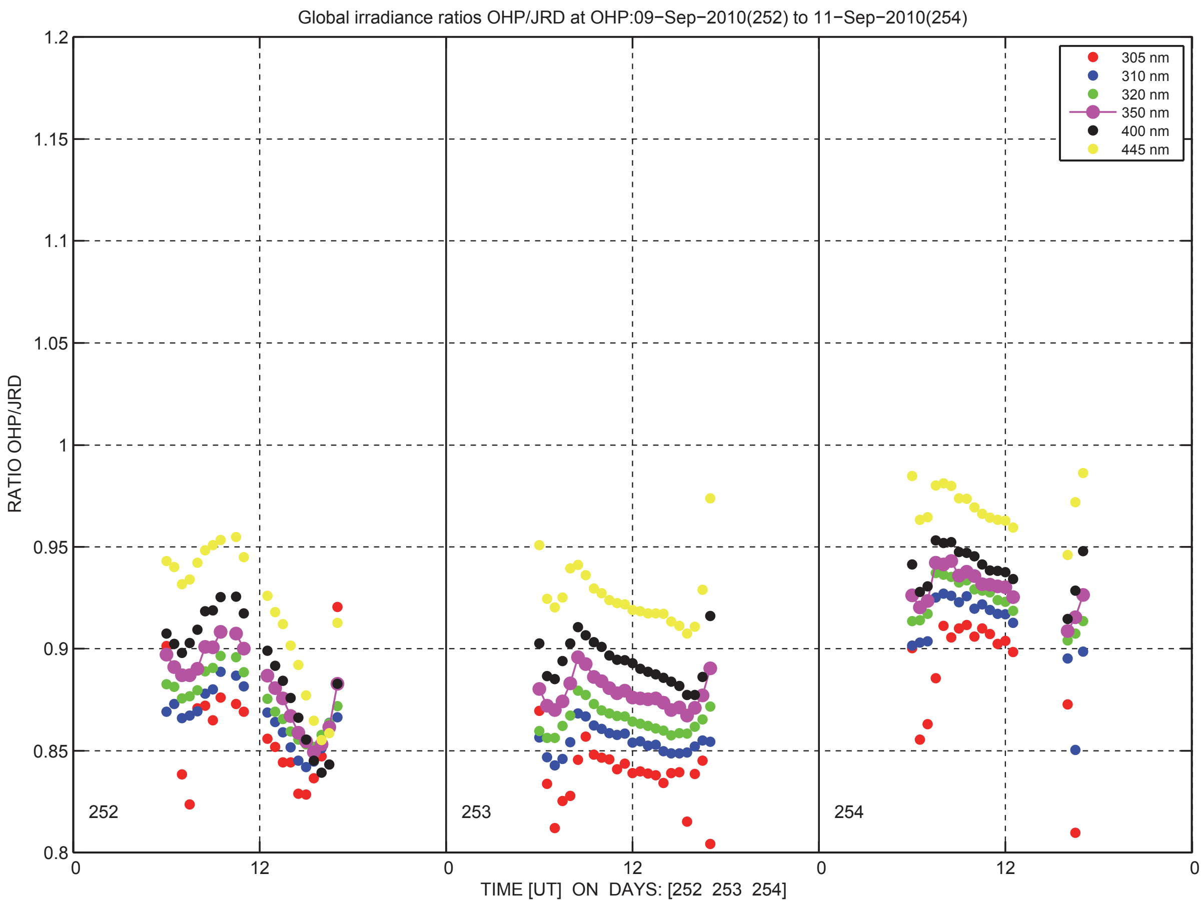
References

Houët, M. : Spectroradiométrie du rayonnement Solaire UV au sol: Améliorations apportées à l’instrumentation et au traitement des mesures. Analyse pour l’évaluation du contenu atmosphérique en ozone et en aérosols, Ph.D. thesis, Univ. of Lille, France, 2003.

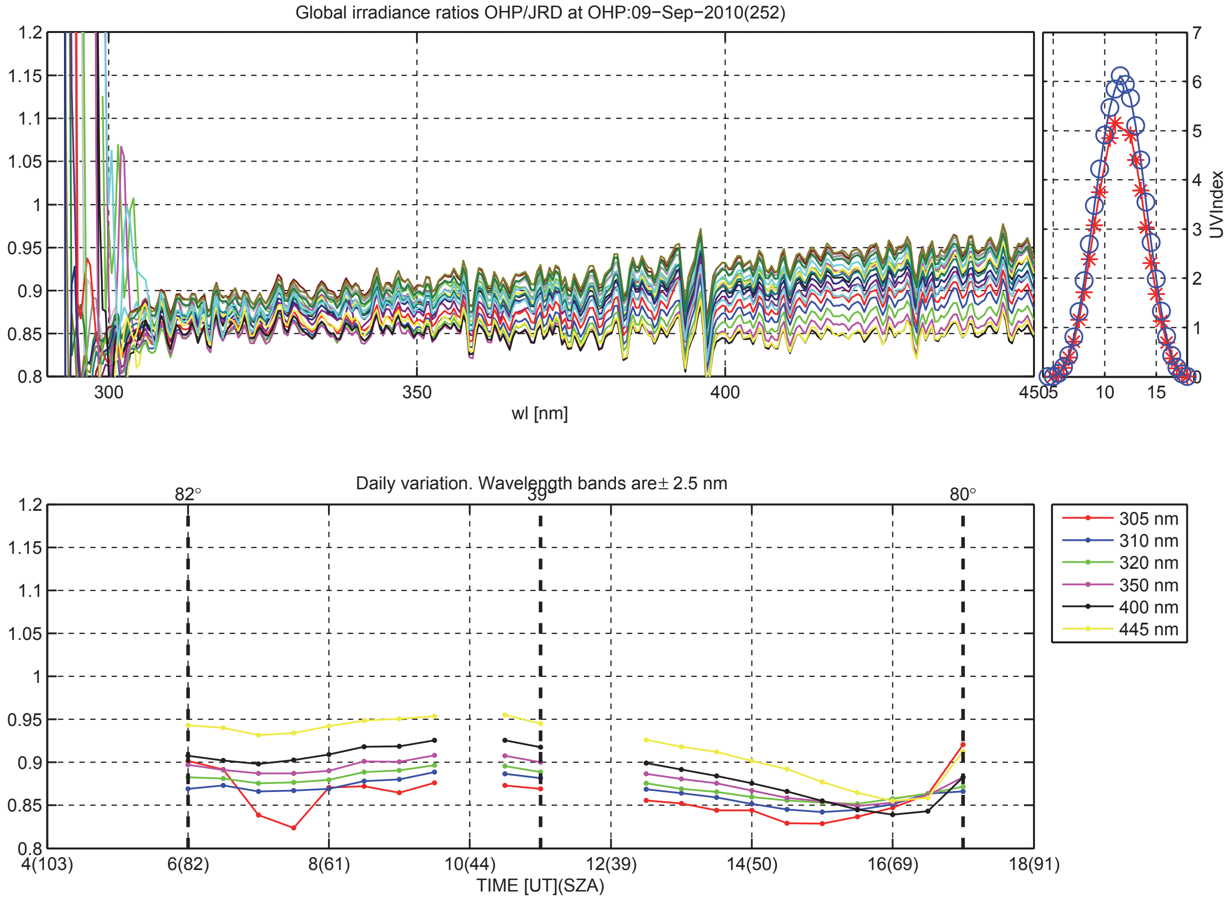
Gröbner, J., Blumthaler, M., Kazadzis, S., Bais, A., Webb, A., Schreder, J., Seckmeyer, G., and Rembges, D.: Quality assurance of spectral solar UV measurements : results from 25 UV monitoring sites in Europe 2002 to 2004. Metrologia, 43(S66-S71), doi :10.1088/0026 − 1394/43/2/S14, 2006.

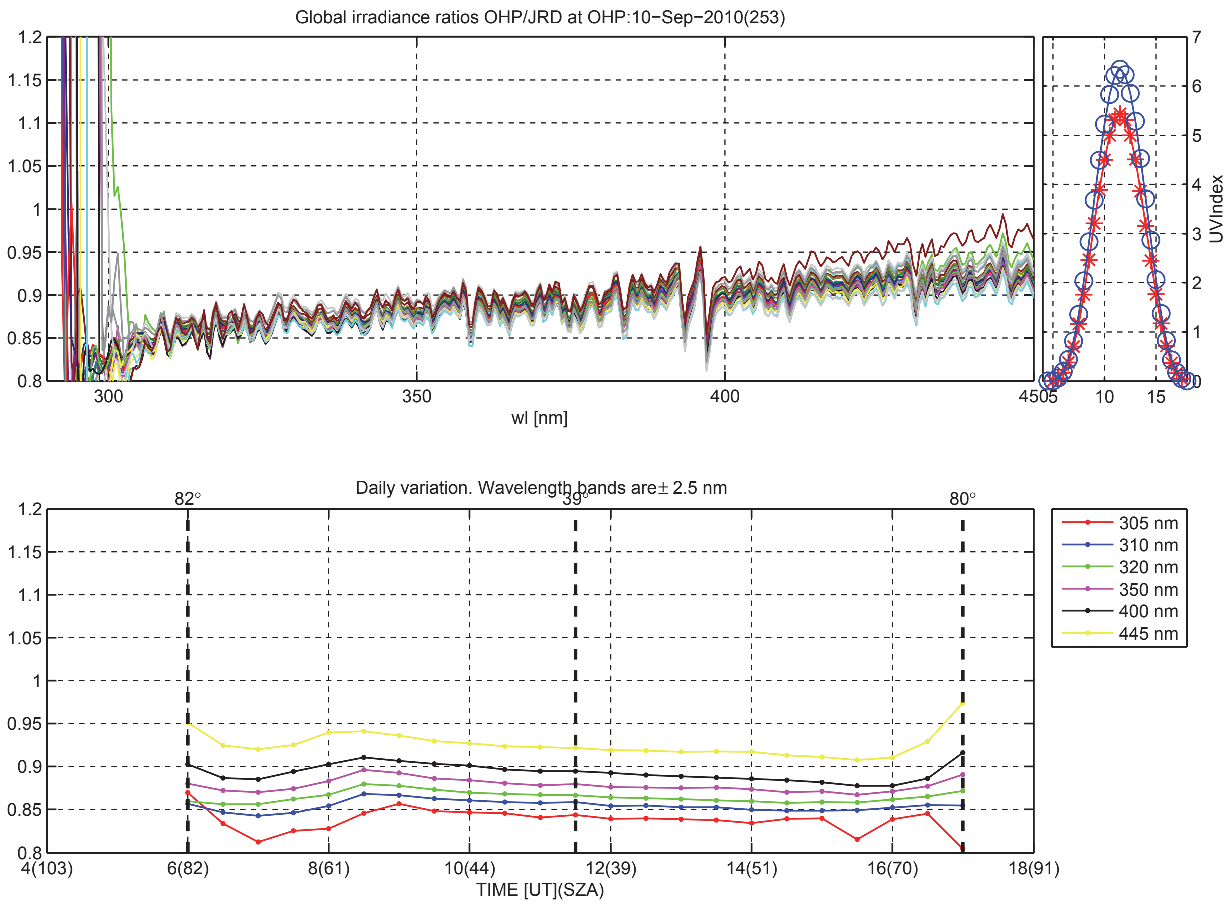


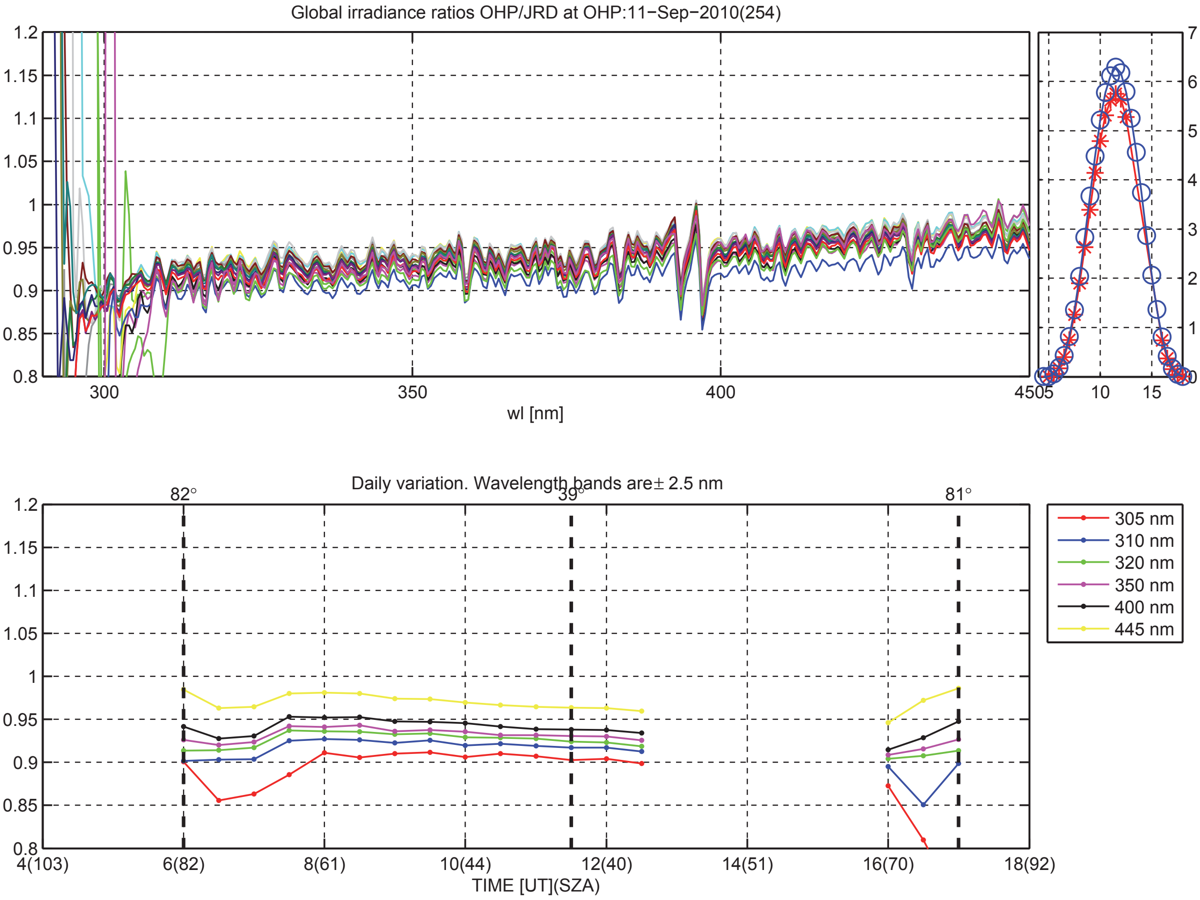
UV Index OHP, September 2010
QASUME
LOA
OHP
FRL
UV Index
Day of Year
252
252.5
253
253.5
254
254.5
255
0
1
2
3
4
5
6
7

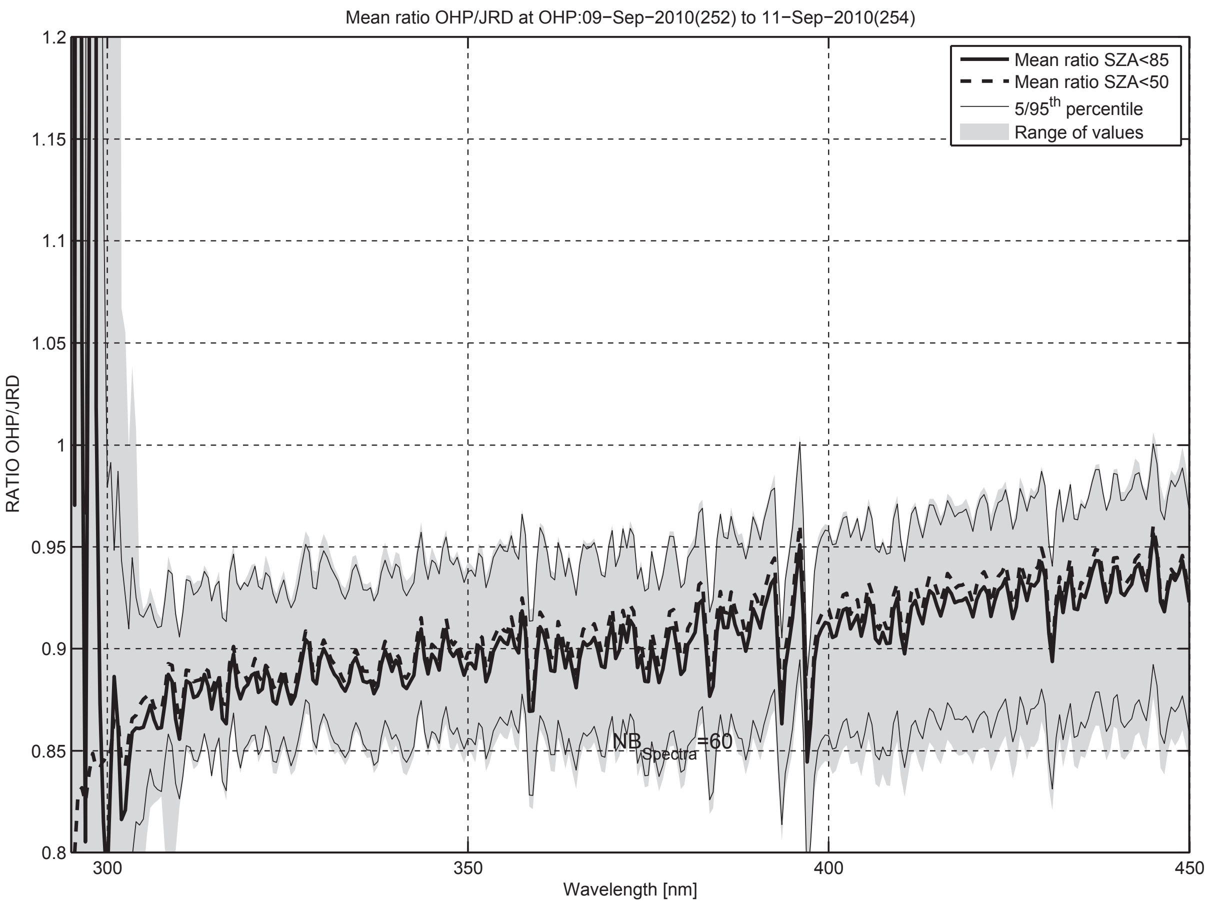


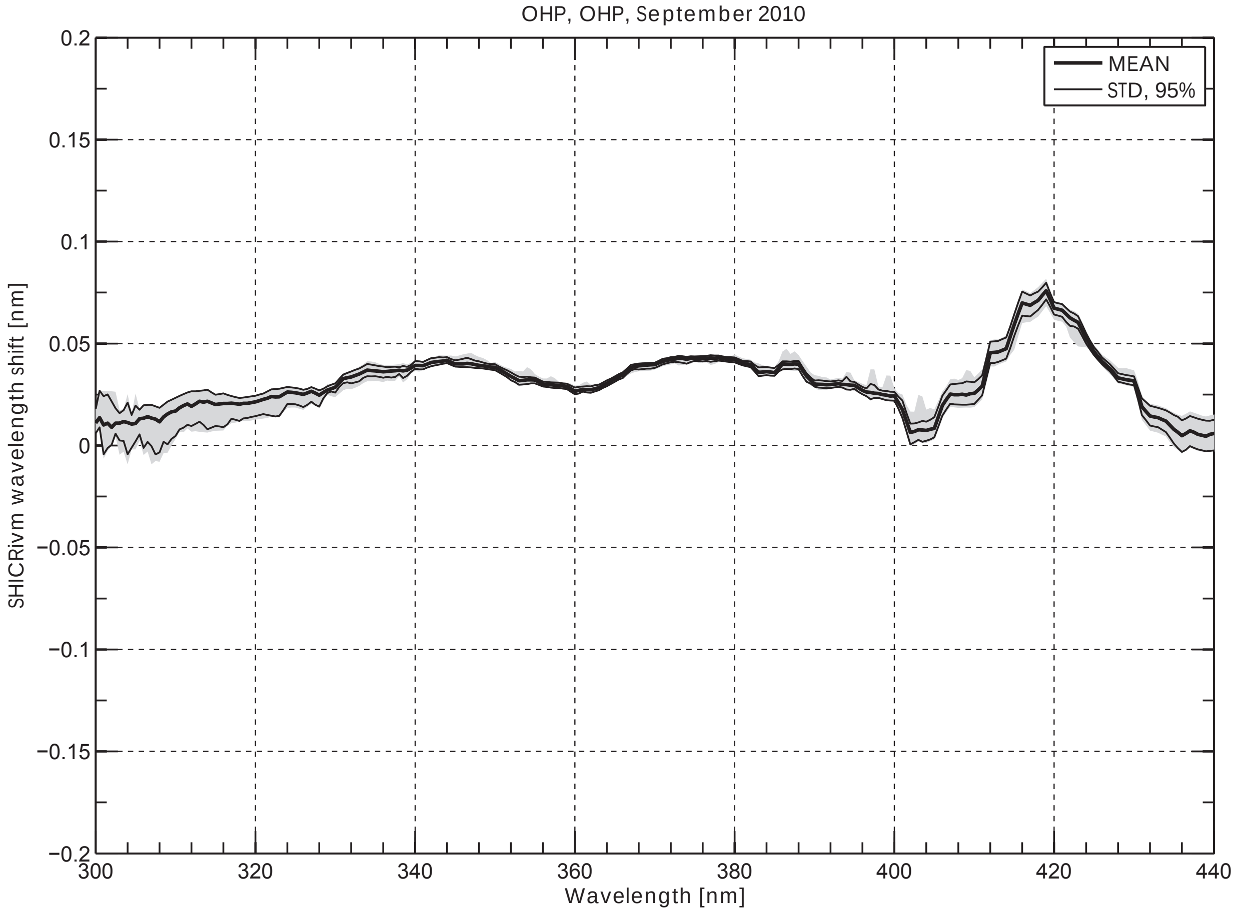
Global irradiance ratios OHP/JRD at OHP:09−Sep−2010(252) to 11−Sep−2010(254)
305 nm
310 nm
320 nm
350 nm
400 nm
445 nm
RATIO OHP/JRD
TIME [UT] ON DAYS: [252 253 254]
252
253
254
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
0
12
0
12
0
12
0


Global irradiance ratios OHP/JRD at OHP:09−Sep−2010(252)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
80°
305 nm
310 nm
320 nm
350 nm
400 nm
445 nm
TIME [UT](SZA)
4(103)
6(82)
8(61)
10(44)
12(39)
14(50)
16(69)
18(91)

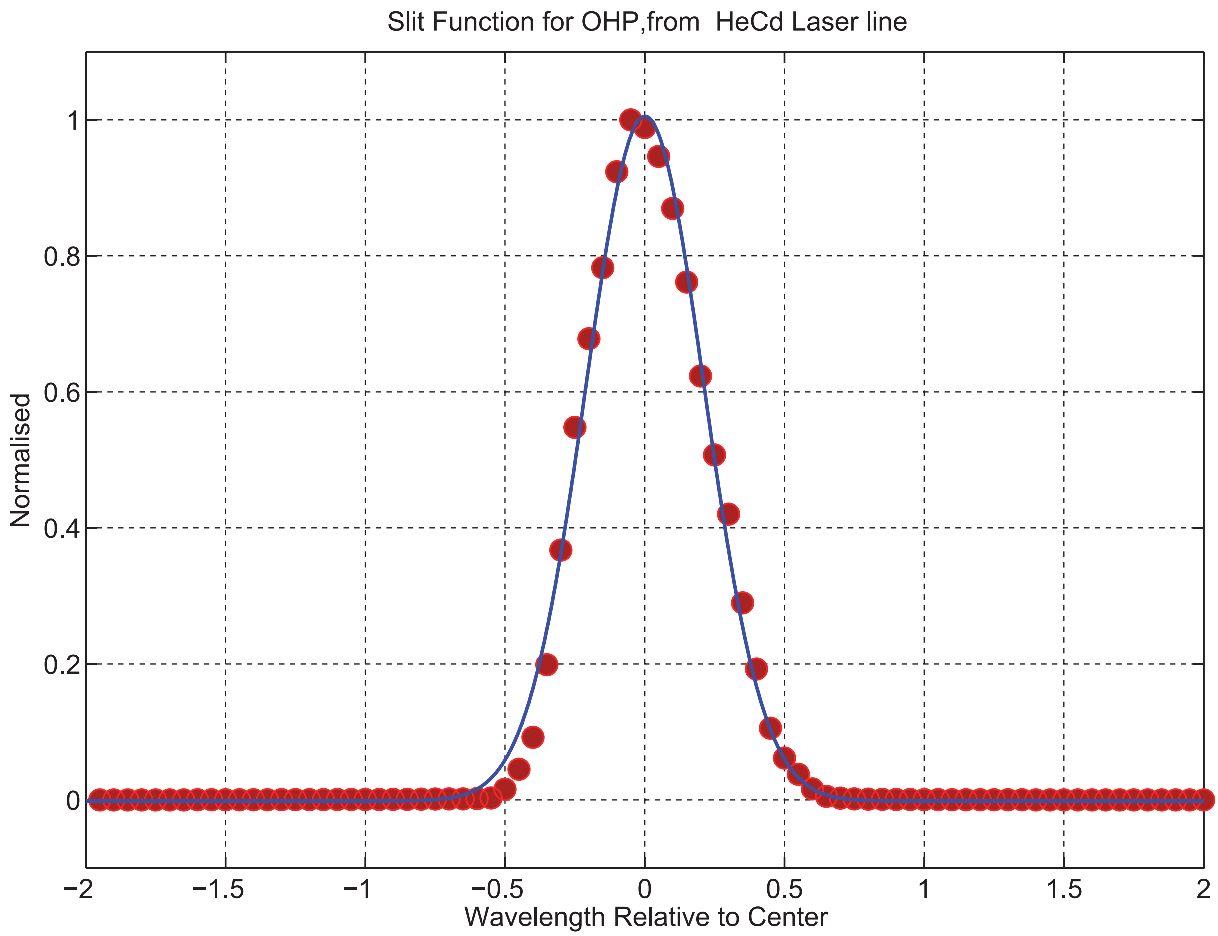

Global irradiance ratios OHP/JRD at OHP:10−Sep−2010(253)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
80°
305 nm
310 nm
320 nm
350 nm
400 nm
445 nm
TIME [UT](SZA)
4(103)
6(82)
8(61)
10(44)
12(39)
14(51)
16(70)
18(91)


Global irradiance ratios OHP/JRD at OHP:11−Sep−2010(254)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
81°
305 nm
310 nm
320 nm
350 nm
400 nm
445 nm
TIME [UT](SZA)
4(103)
6(82)
8(61)
10(44)
12(40)
14(51)
16(70)
18(92)

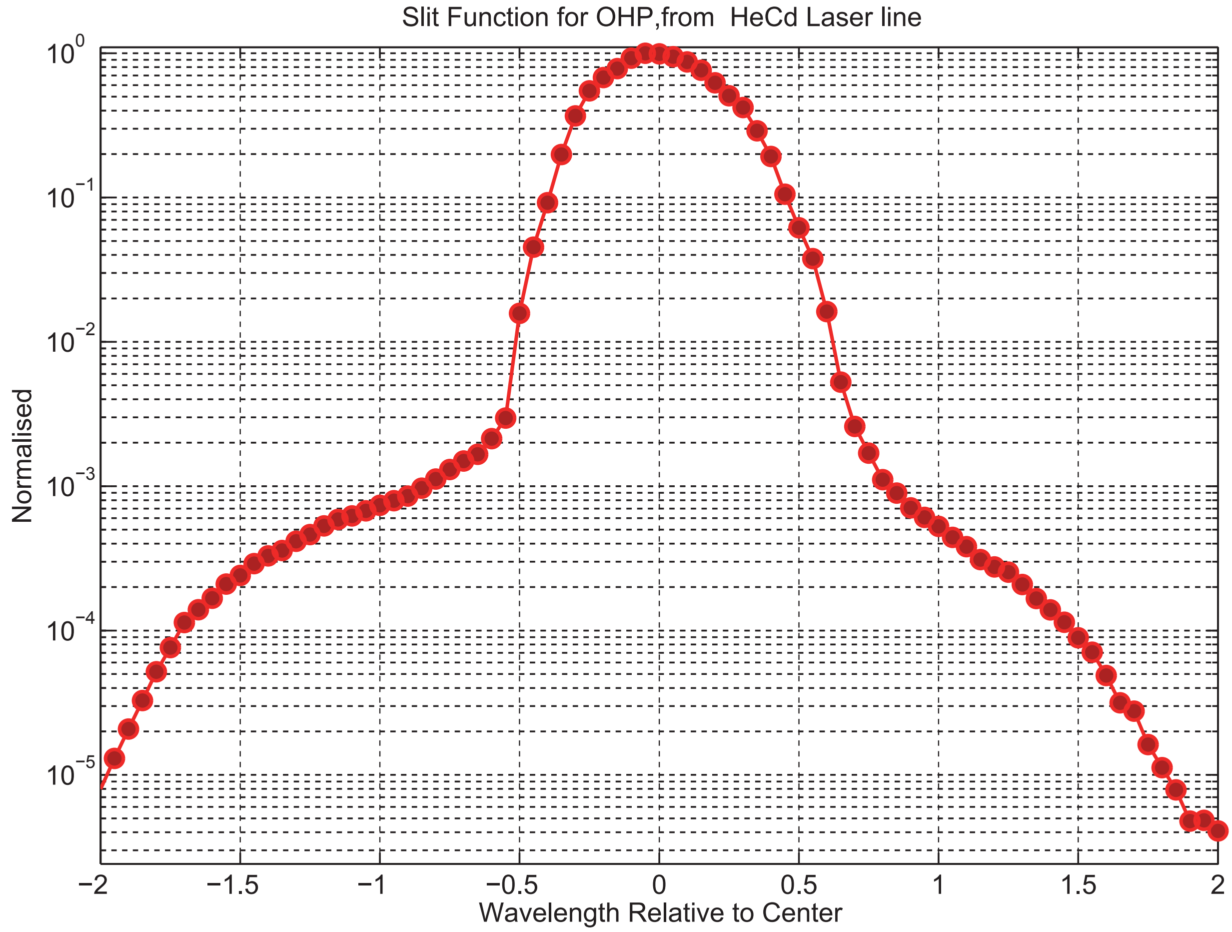

Mean ratio OHP/JRD at OHP:09−Sep−2010(252) to 11−Sep−2010(254)
Mean ratio SZA<85
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO OHP/JRD
NB Spectra =60
Wavelength [nm]

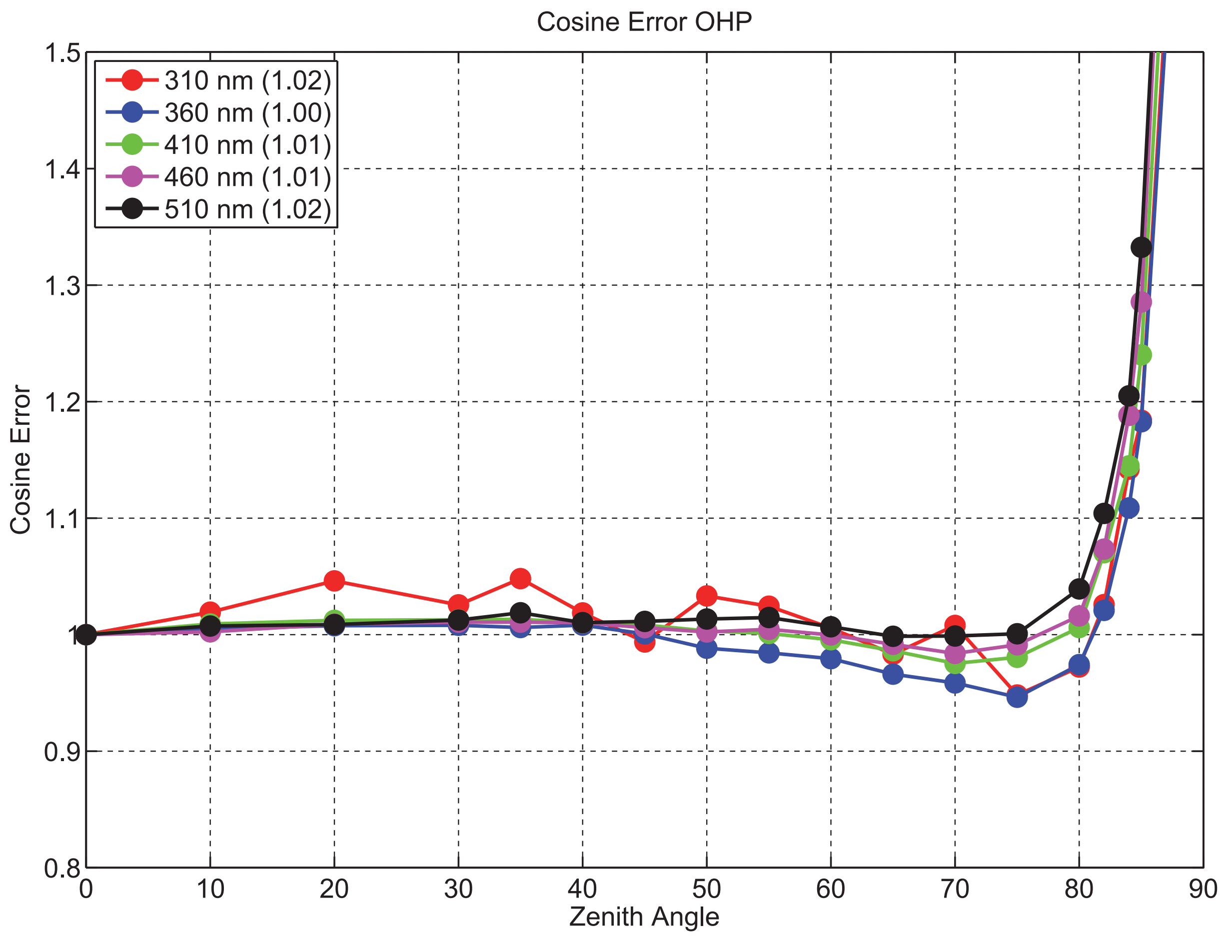


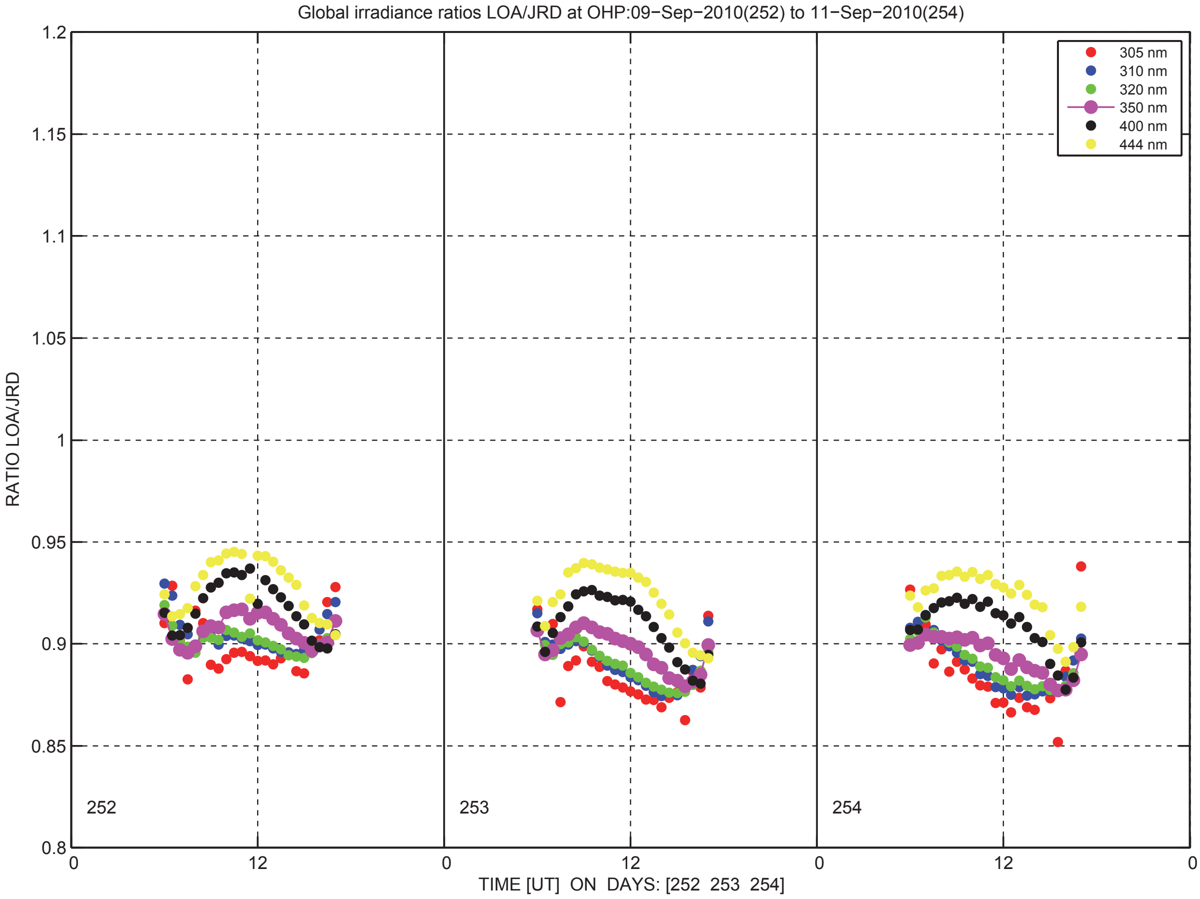
OHP, OHP, September 2010
MEAN
STD, 95%
SHICRivm wavelength shift [nm]
Wavelength [nm]
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
300
320
340
360
380
400
420
440

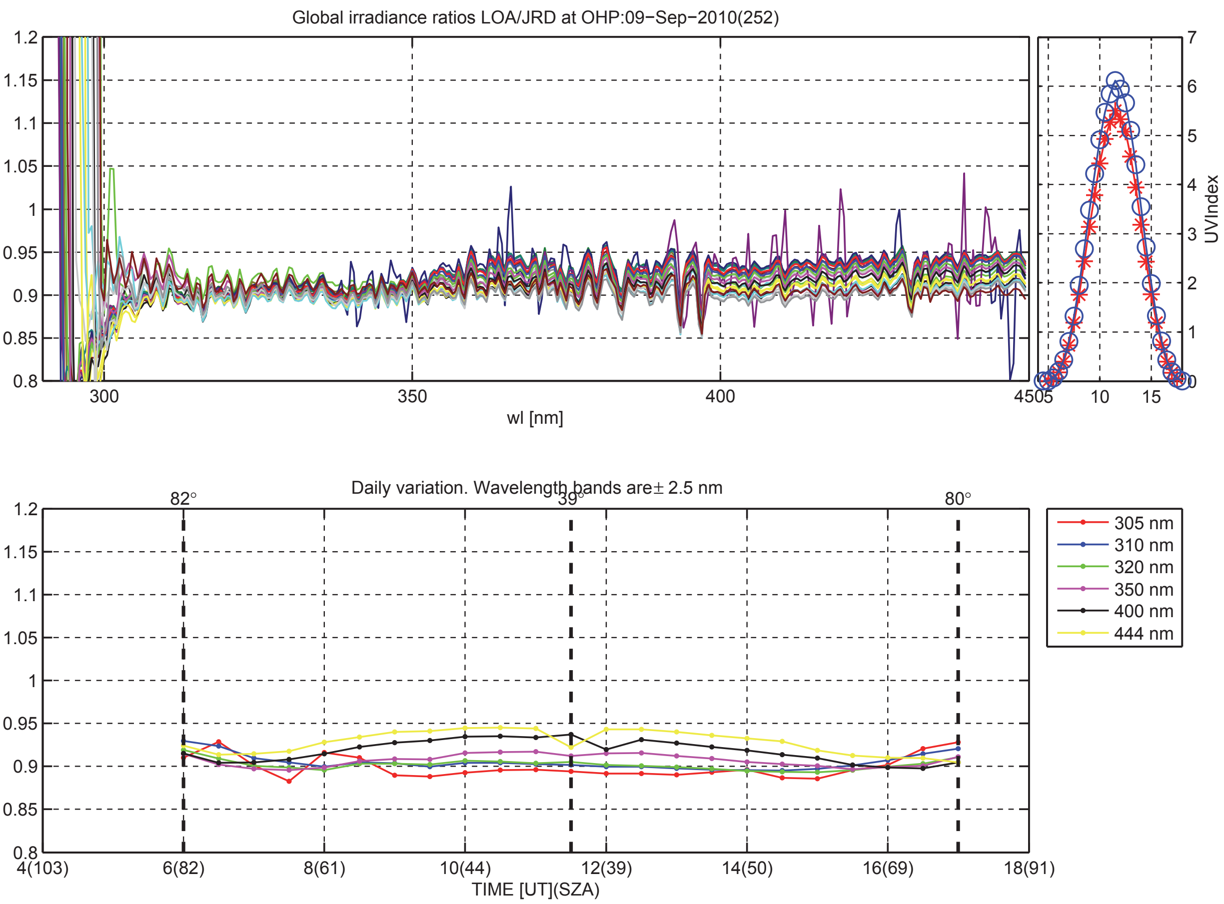


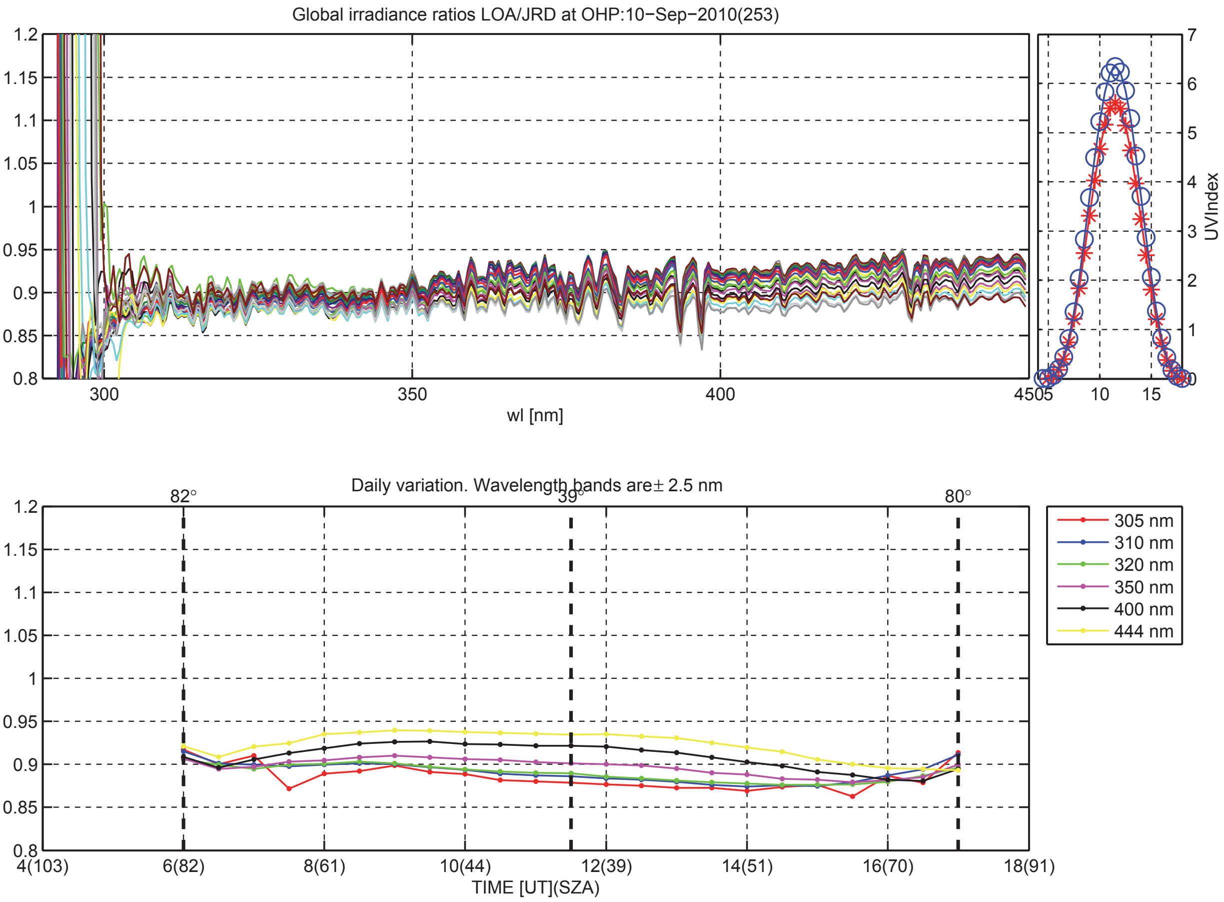
Slit Function for OHP,from HeCd Laser line
Normalised
Wavelength Relative to Center
1
0.8
0.6
0.4
0.2
0
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2


Slit Function for OHP,from HeCd Laser line
Normalised
Wavelength Relative to Center


Cosine Error OHP
310 nm (1.02)
360 nm (1.00)
410 nm (1.01)
460 nm (1.01)
510 nm (1.02)
Cosine Error
Zenith Angle


Global irradiance ratios LOA/JRD at OHP:09−Sep−2010(252) to 11−Sep−2010(254)
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
RATIO LOA/JRD
252
253
254
TIME [UT] ON DAYS: [252 253 254]


Global irradiance ratios LOA/JRD at OHP:09−Sep−2010(252)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
80°
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
TIME [UT](SZA)


Global irradiance ratios LOA/JRD at OHP:10−Sep−2010(253)
wl [nm]
UVIndex
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80°
305 nm
310 nm
320 nm
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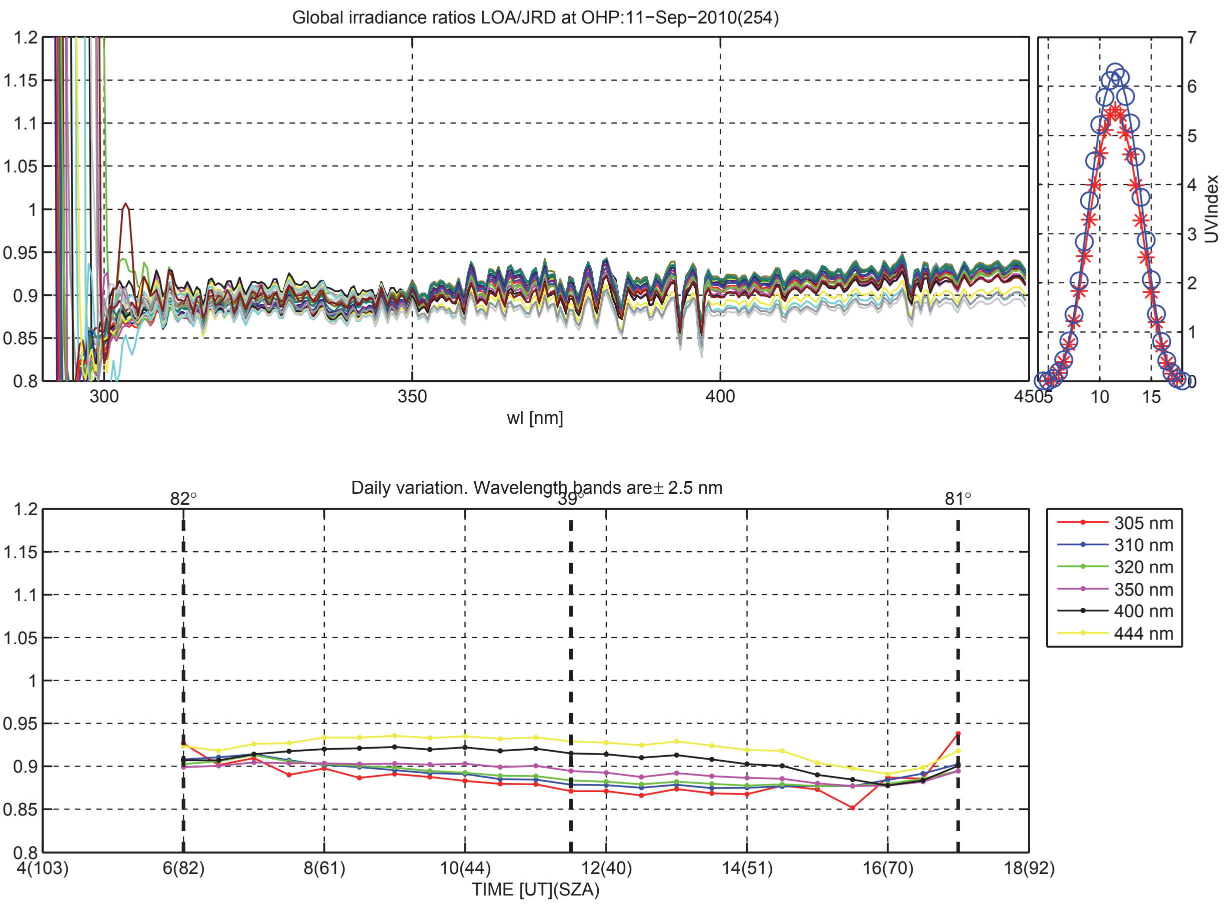
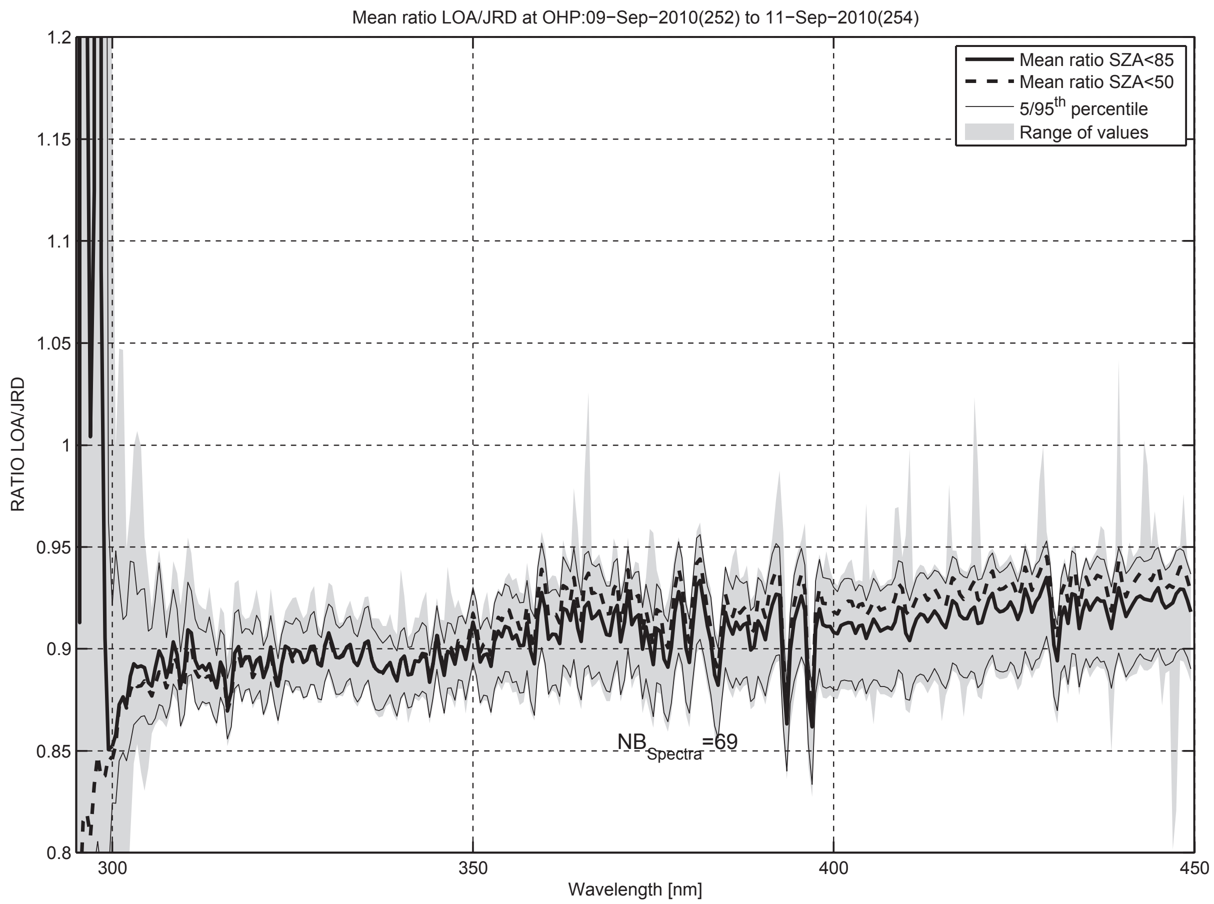
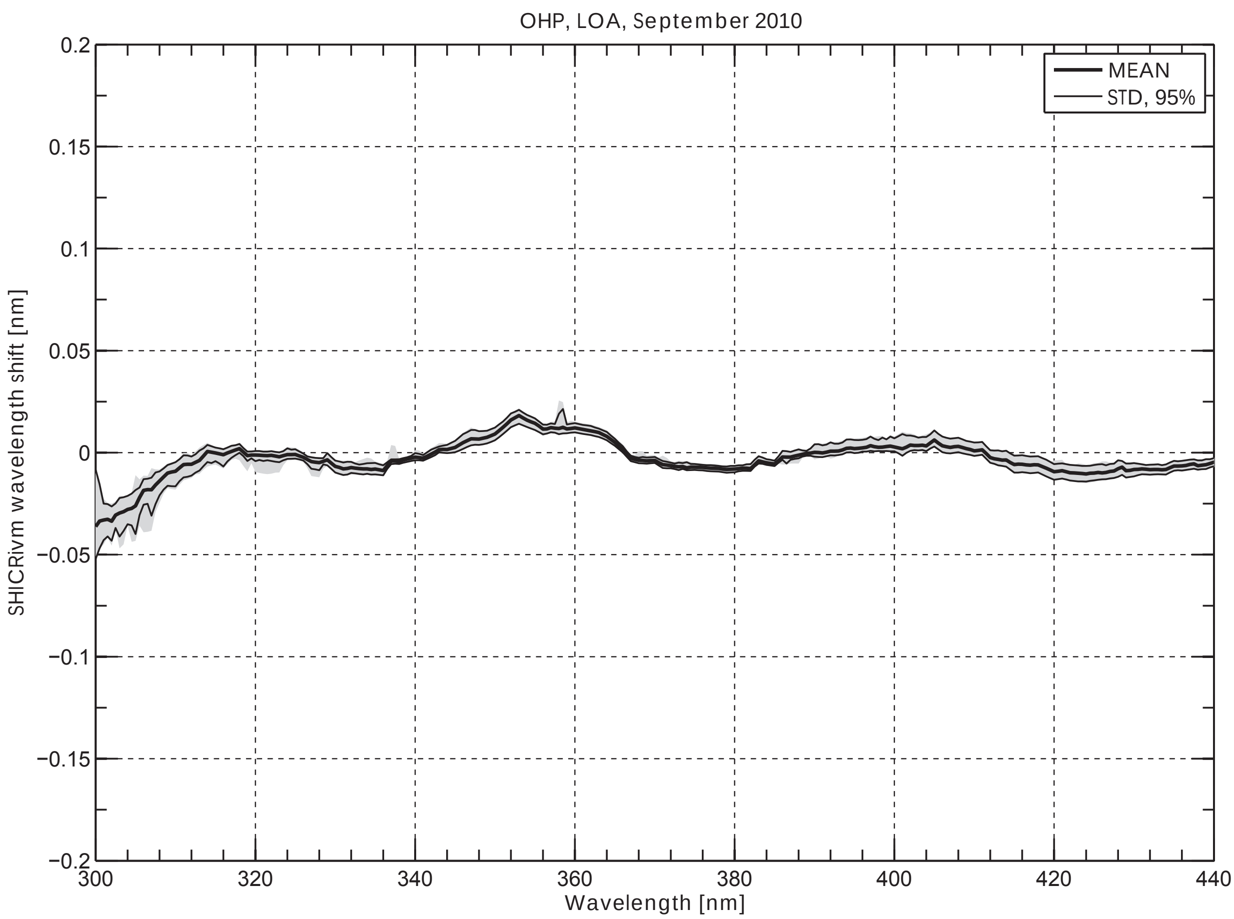
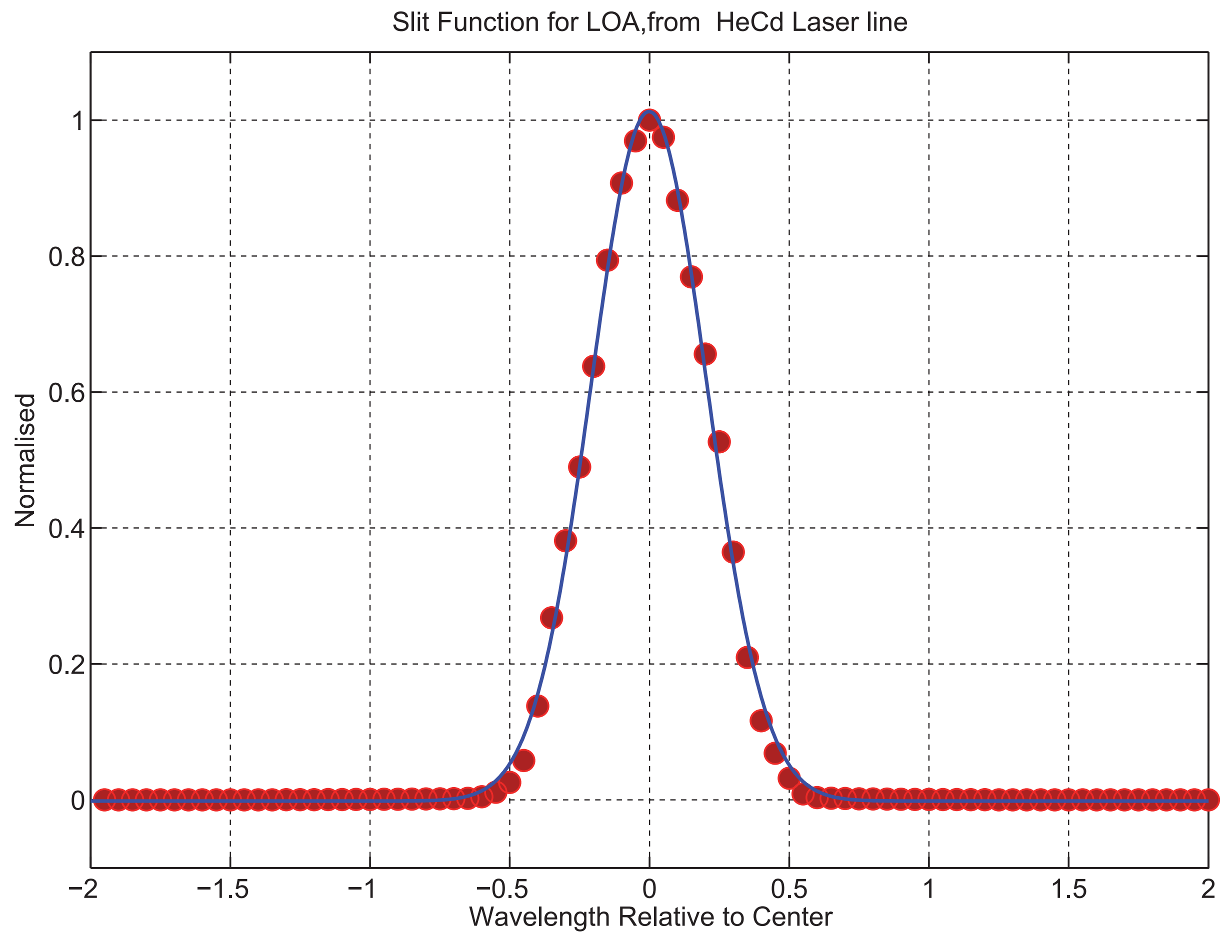
400 nm
444 nm
TIME [UT](SZA)

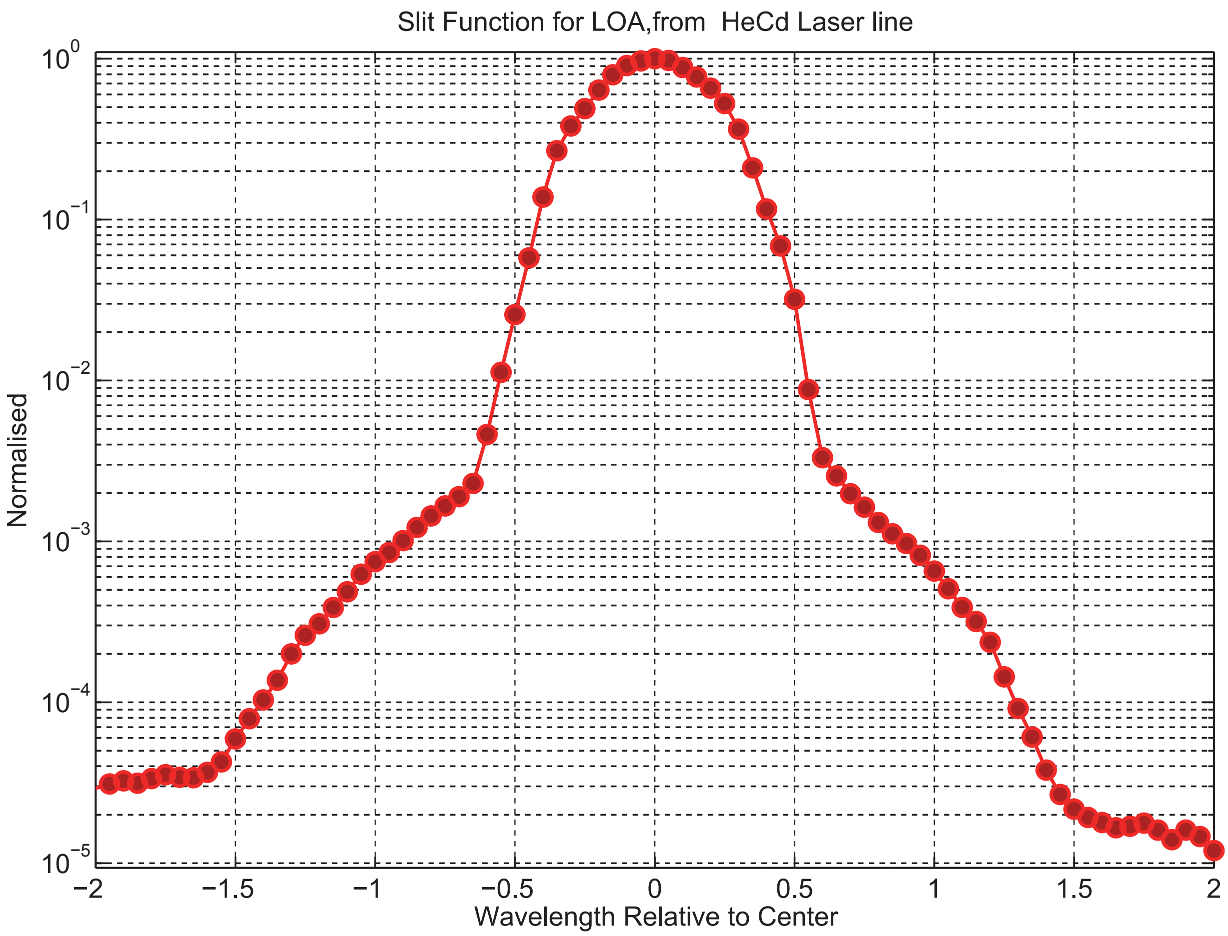

Global irradiance ratios LOA/JRD at OHP:11−Sep−2010(254)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
81°
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
TIME [UT](SZA)


Mean ratio LOA/JRD at OHP:09−Sep−2010(252) to 11−Sep−2010(254)
Mean ratio SZA<85
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO LOA/JRD
NB Spectra =69
Wavelength [nm]
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
350
400
450

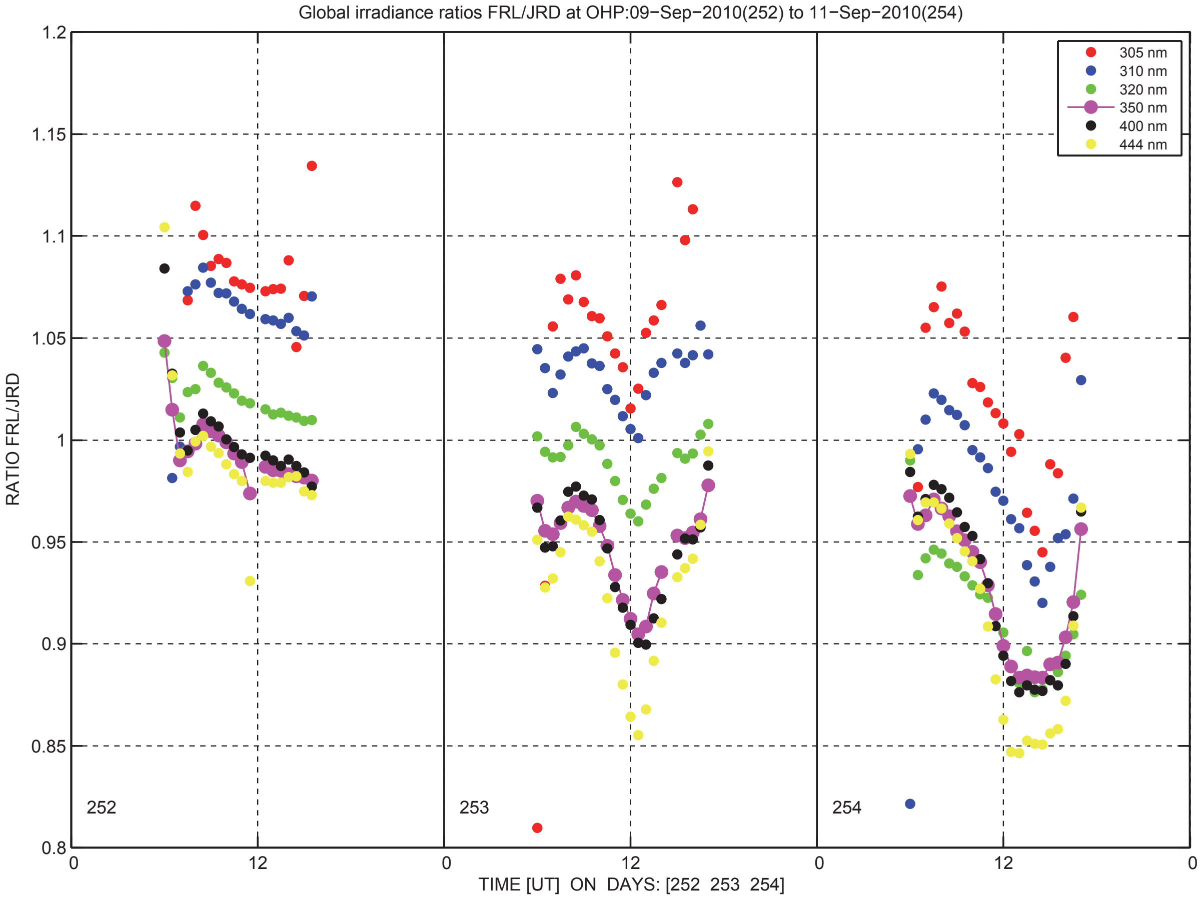

OHP, LOA, September 2010
MEAN
STD, 95%
SHICRivm wavelength shift [nm]
Wavelength [nm]
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
300
320
340
360
380
400
420
440

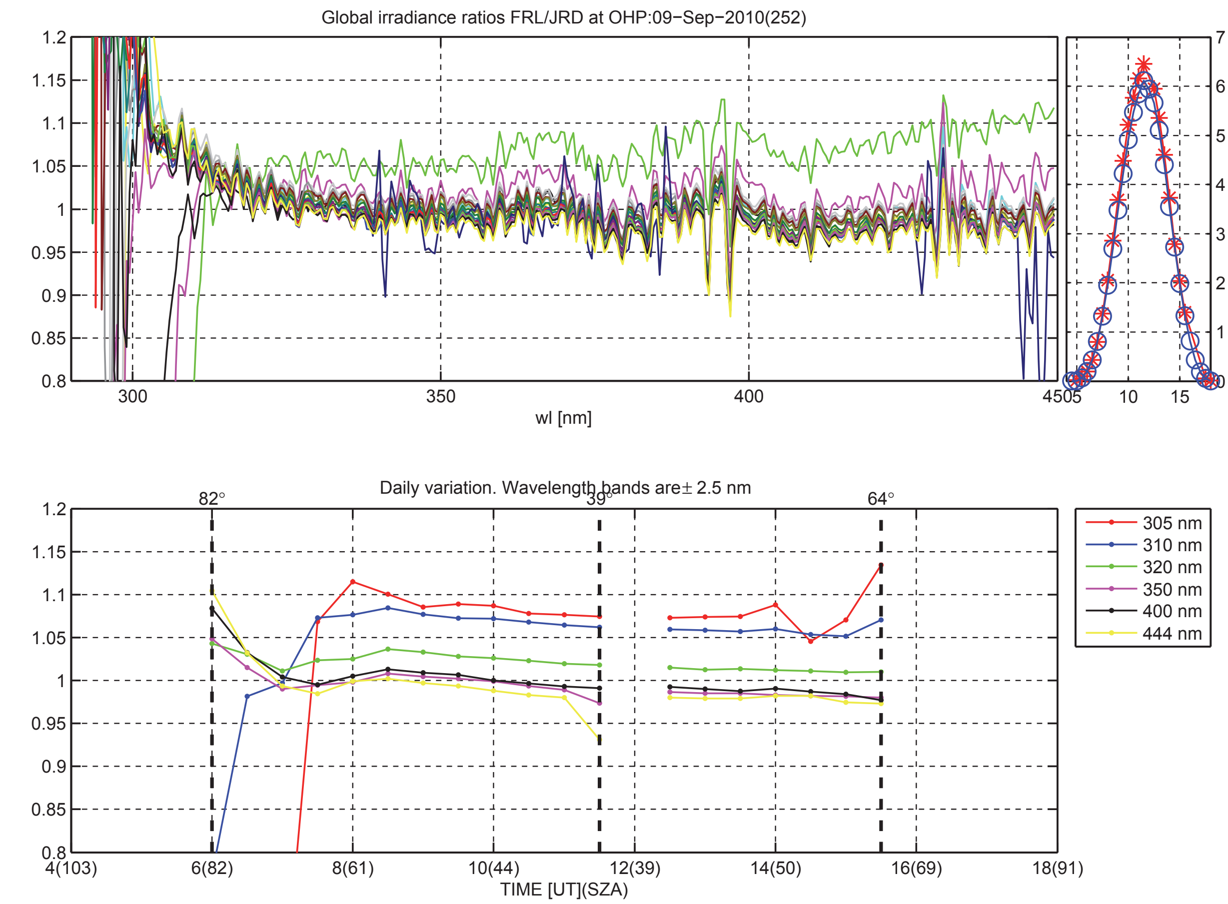


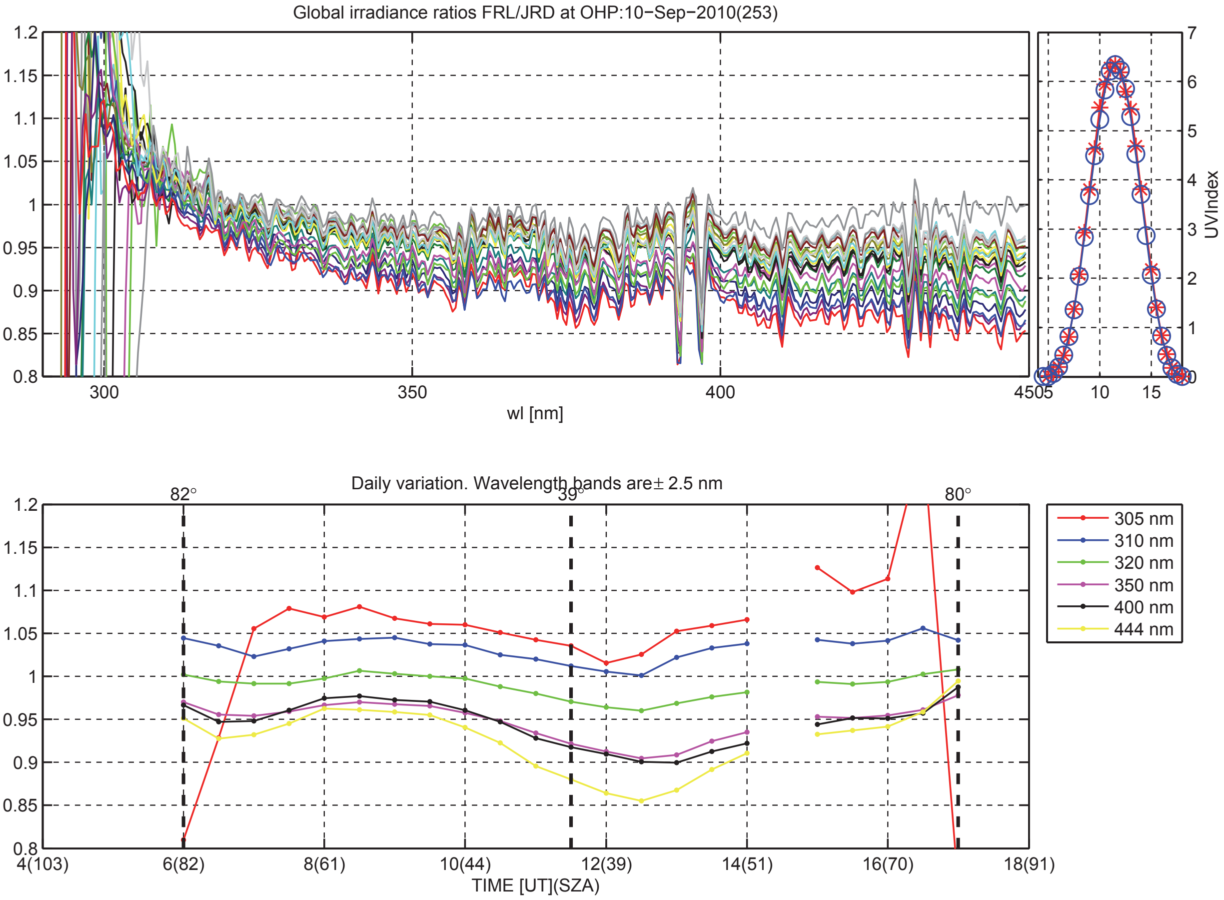
Slit Function for LOA,from HeCd Laser line
Normalised
Wavelength Relative to Center
1
0.8
0.6
0.4
0.2
0
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2

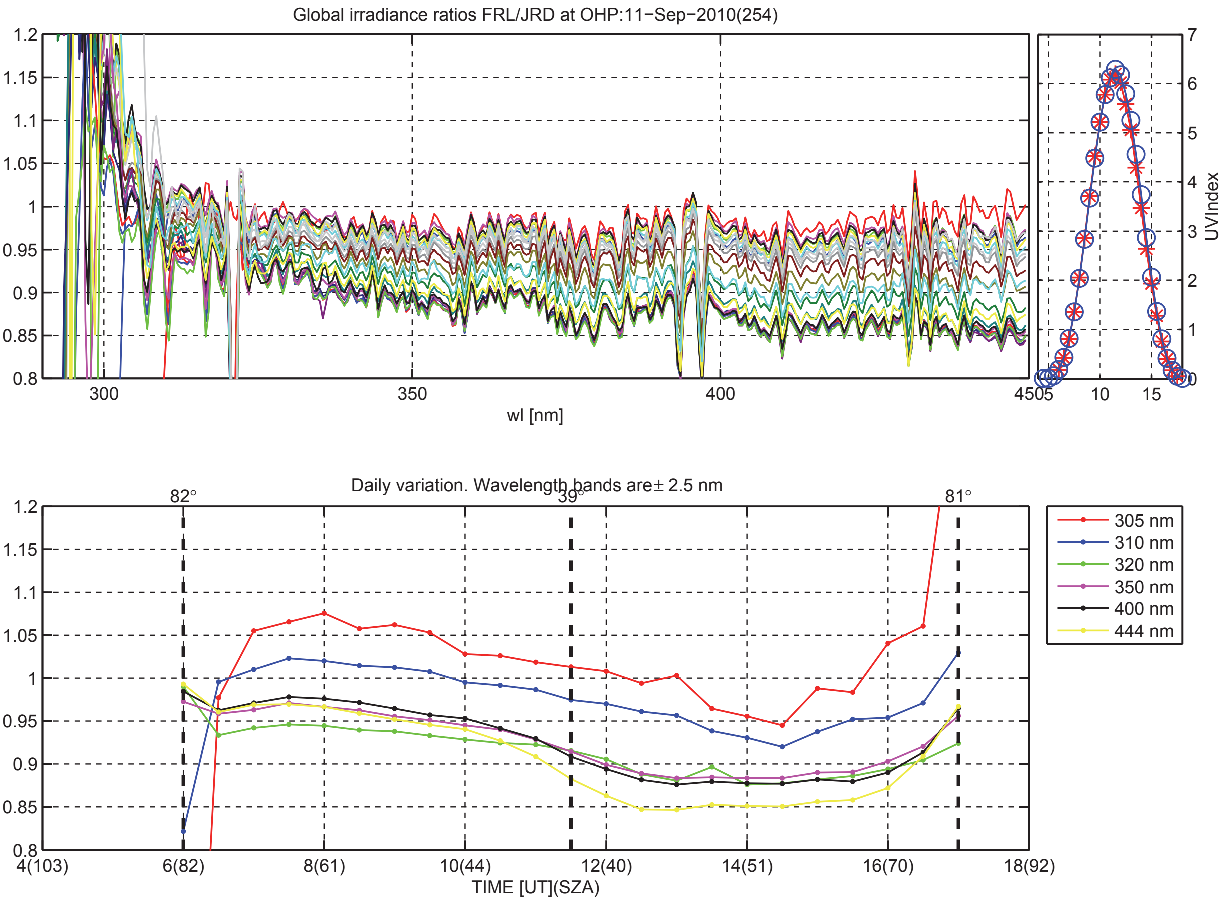


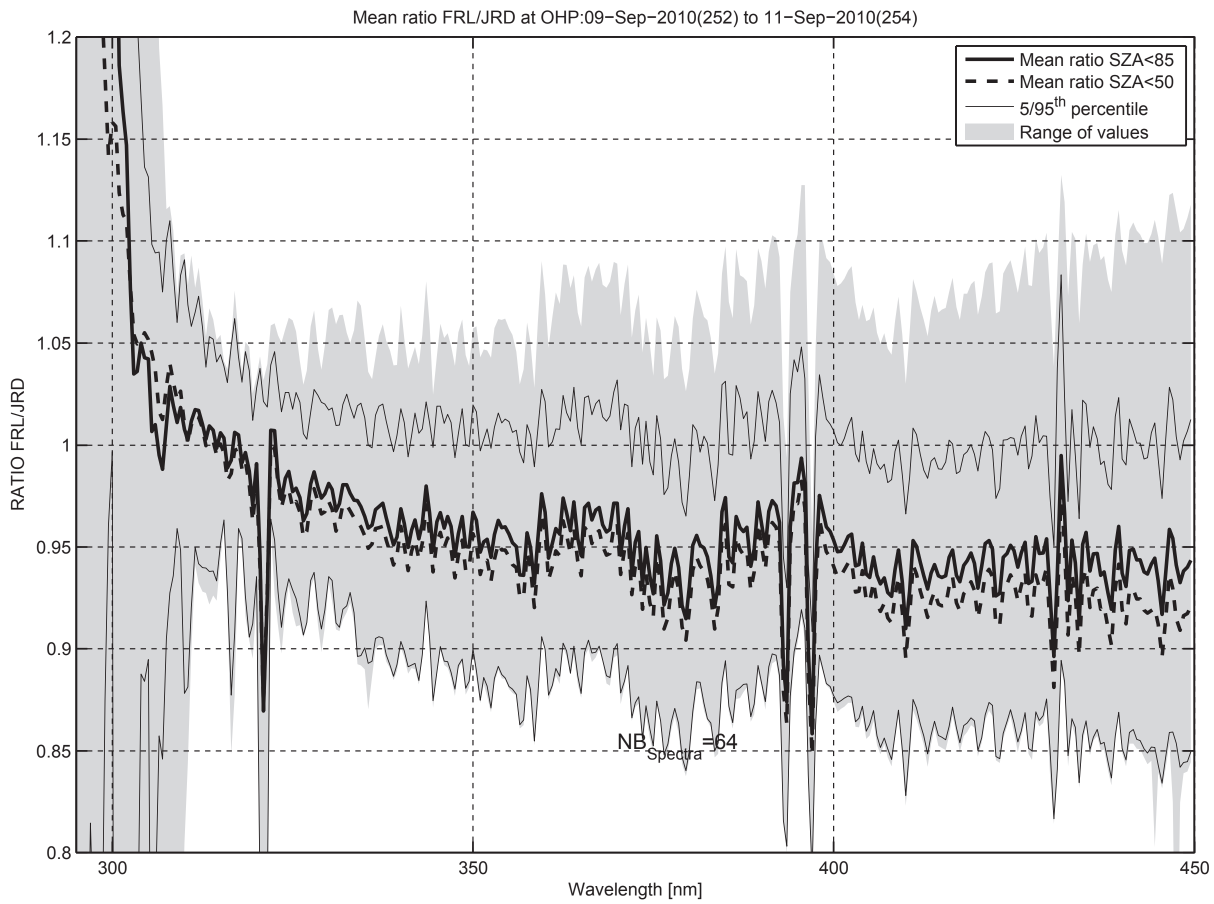
Slit Function for LOA,from HeCd Laser line
Normalised
Wavelength Relative to Center
10^0
10^−1
10^−2
10^−3
10^−4
10^−5
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2

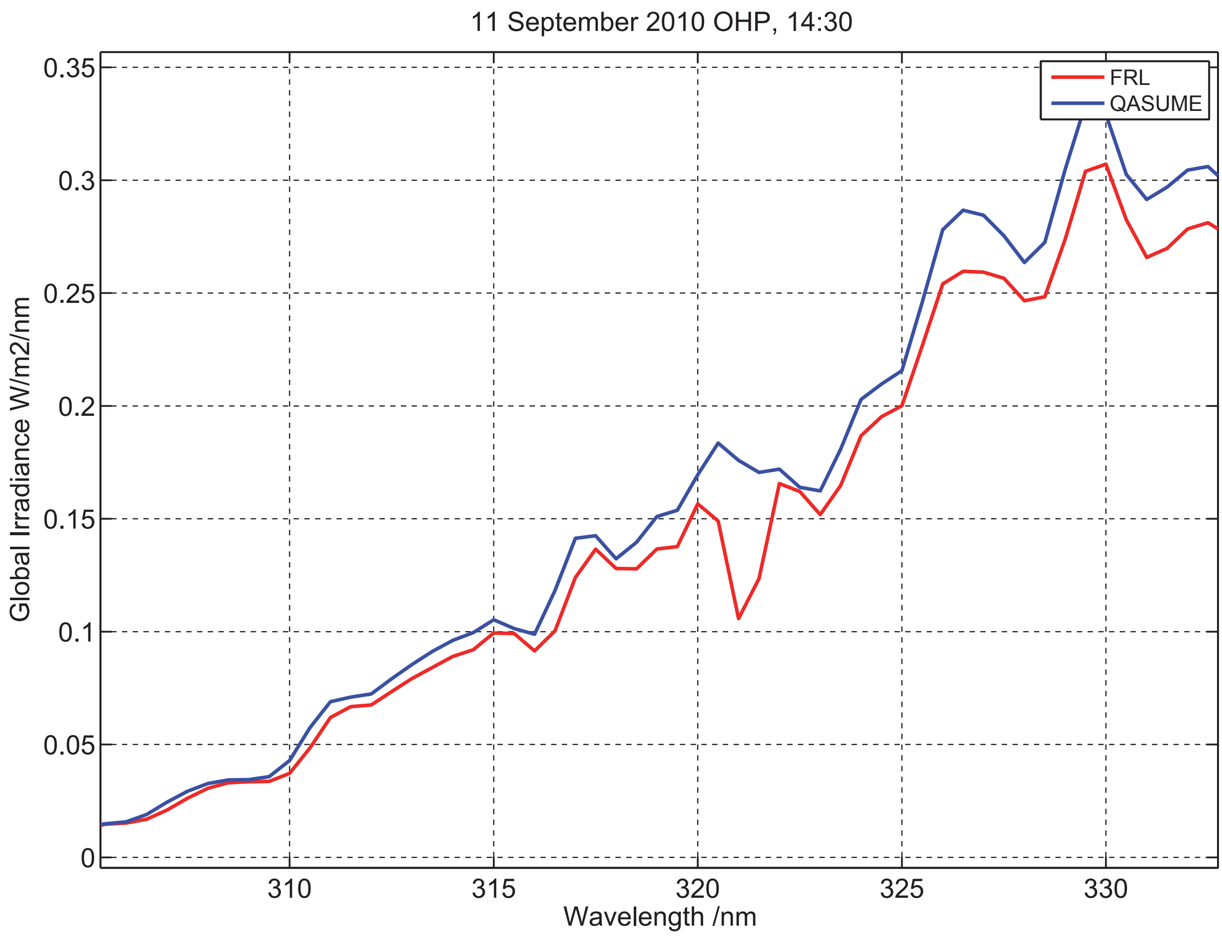

Global irradiance ratios FRL/JRD at OHP:09−Sep−2010(252) to 11−Sep−2010(254)
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
RATIO FRL/JRD
252
253
254
TIME [UT] ON DAYS: [252 253 254]

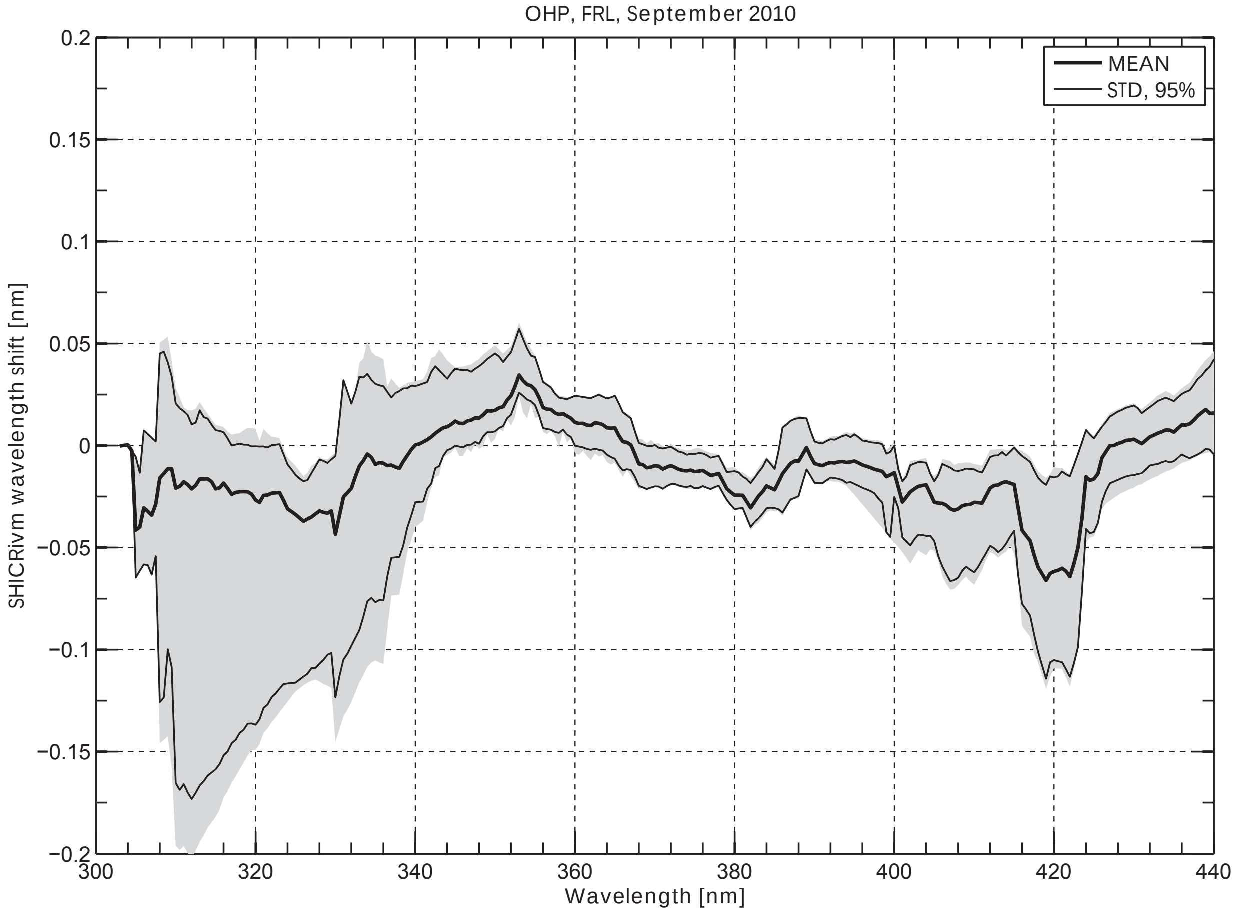

Global irradiance ratios FRL/JRD at OHP:09−Sep−2010(252)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
64°
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
TIME [UT](SZA)


Global irradiance ratios FRL/JRD at OHP:10−Sep−2010(253)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
80°
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
TIME [UT](SZA)
4(103)
6(82)
8(61)
10(44)
12(39)
14(51)
16(70)
18(91)

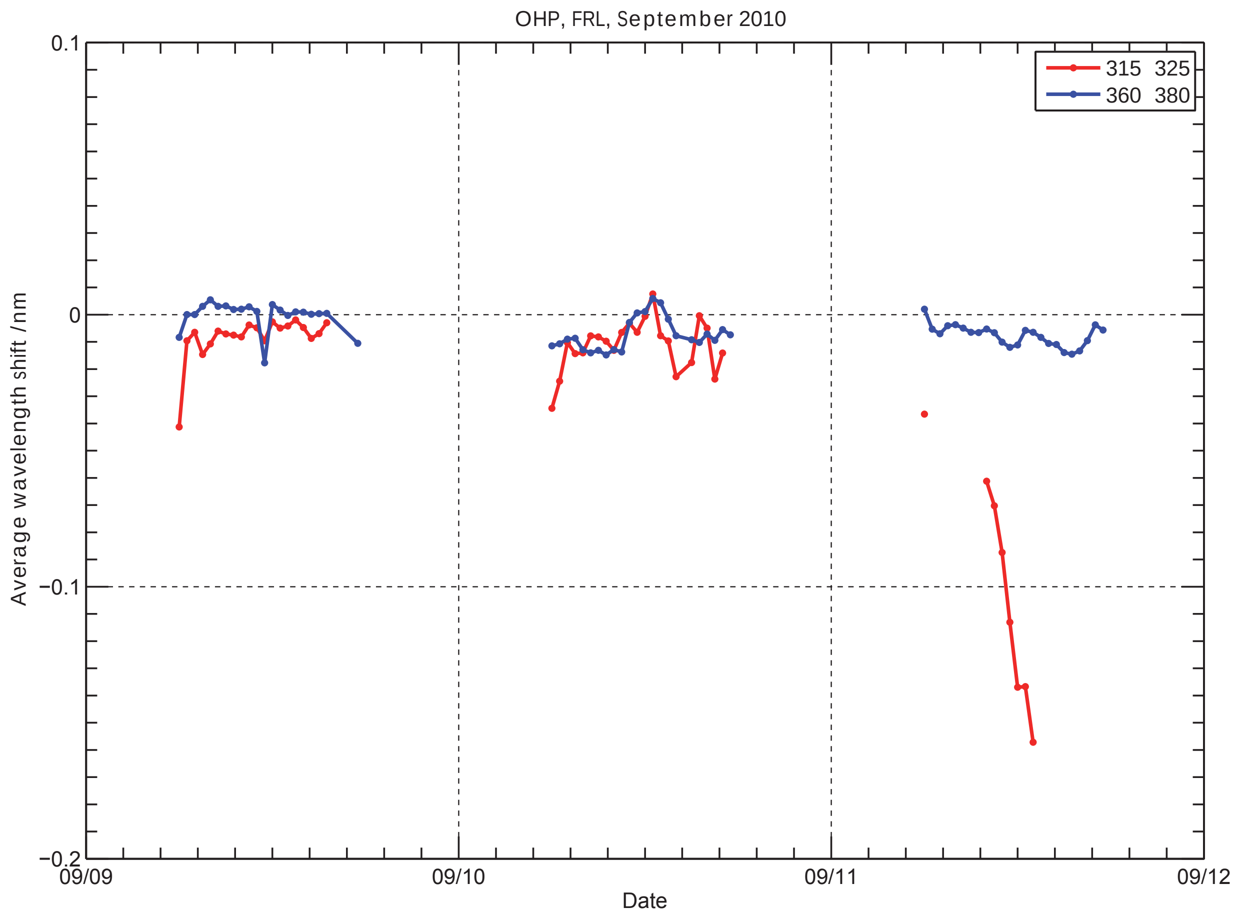

Global irradiance ratios FRL/JRD at OHP:11−Sep−2010(254)
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
82°
39°
81°
305 nm
310 nm
320 nm
350 nm
400 nm
444 nm
TIME [UT](SZA)
4(103)
6(82)
8(61)
10(44)
12(40)
14(51)
16(70)
18(92)


Mean ratio FRL/JRD at OHP:09−Sep−2010(252) to 11−Sep−2010(254)
Mean ratio SZA<85
Mean ratio SZA<50
5/95th percentile
Range of values
NB Spectra =64
RATIO FRL/JRD
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
300
350
400
450
Wavelength [nm]

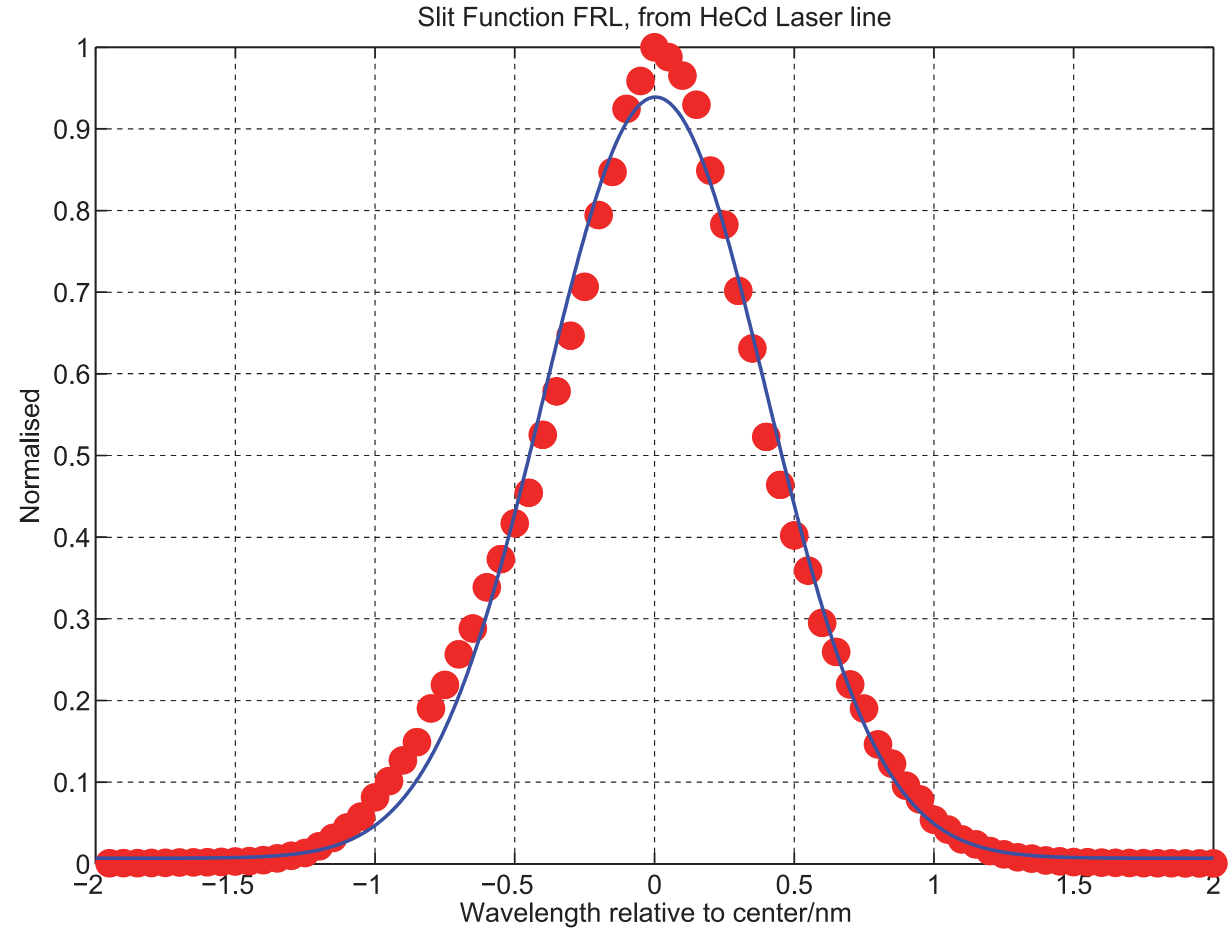

11 September 2010 OHP, 14:30
FRL
QASUME
Global Irradiance W/m2/nm
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
310
315
320
325
330
Wavelength /nm



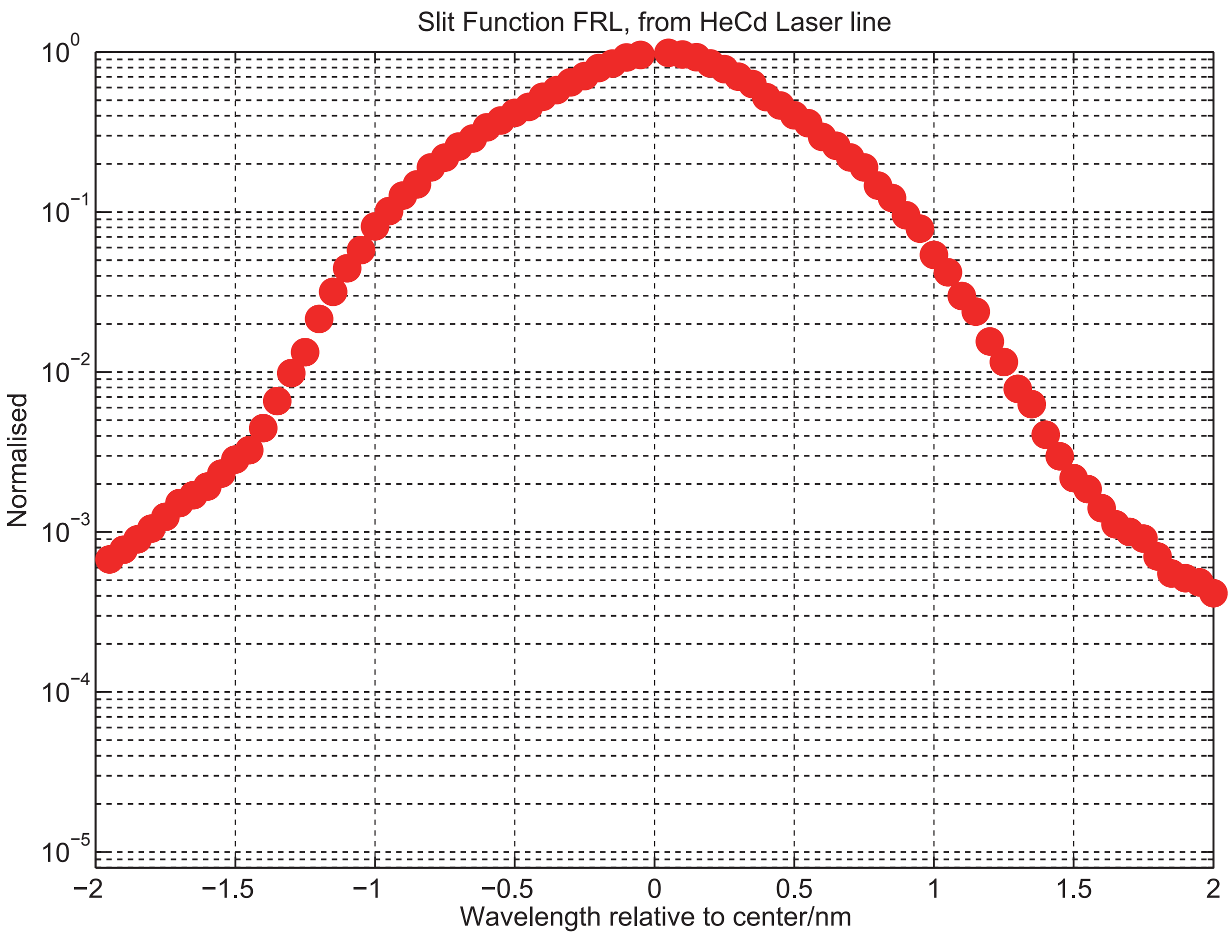
OHP, FRL, September 2010
MEAN
STD, 95%
SHICRivm wavelength shift [nm]
Wavelength [nm]
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
300
320
340
360
380
400
420
440



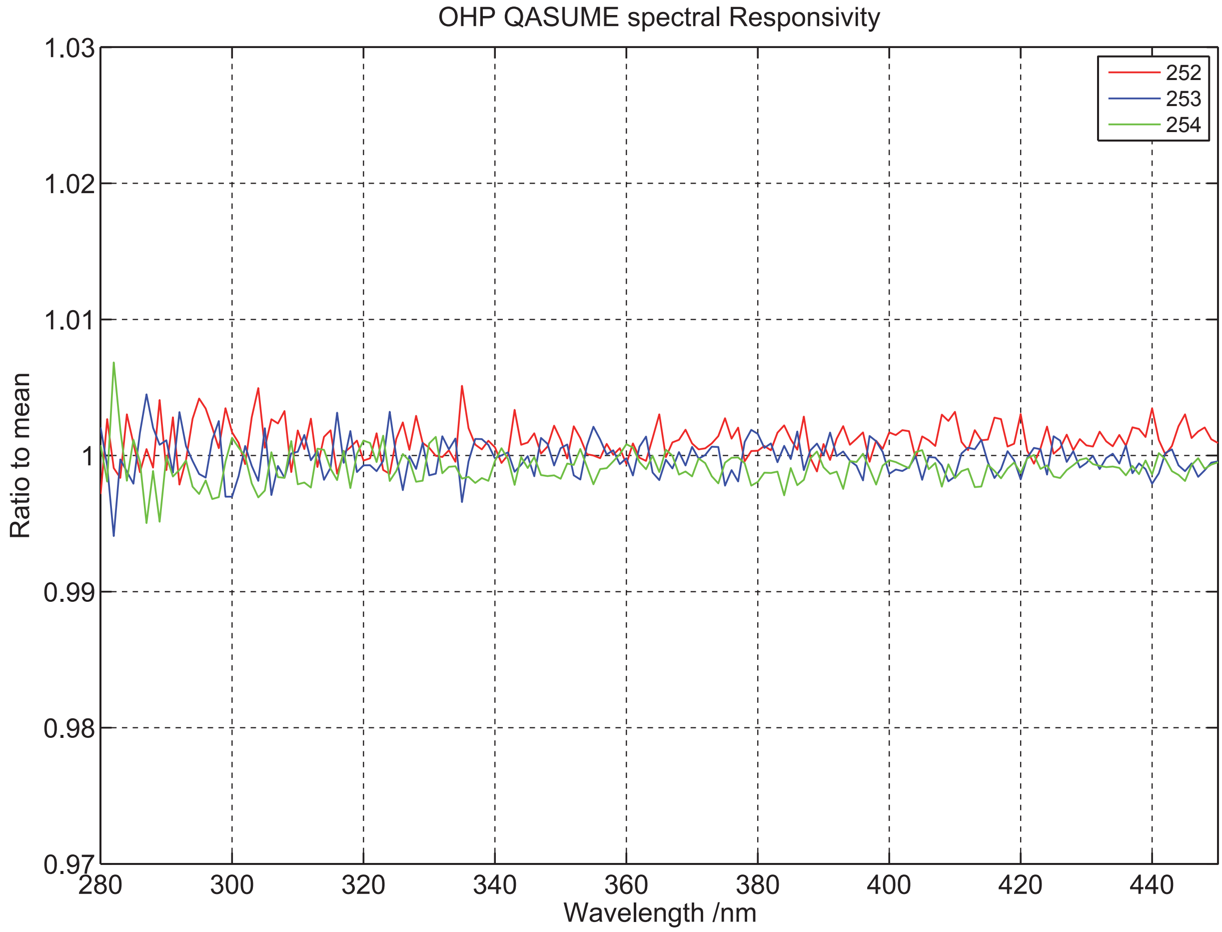
OHP, FRL, September 2010
315 325
360 380
Average wavelength shift /nm
Date
0.1
0
−0.1
−0.2
09/09
09/10
09/11
09/12



Slit Function FRL, from HeCd Laser line
Normalised
Wavelength relative to center/nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2



Slit Function FRL, from HeCd Laser line
Normalised
Wavelength relative to center/nm
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2


OHP QASUME spectral Responsivity
1.03
1.02
1.01
1
0.99
0.98
0.97
Ratio to mean
280
300
320
340
360
380
400
420
440
Wavelength /nm
252
253
254