Protocol of the intercomparison of the Fourier transform spectroradiometer PFS of the PTB with the travelling reference spectroradiometer QASUME from PMOD/WRC at PTB Berlin, Germany, on March 31 to April 4, 2014

Report prepared by Gregor Hülsen and Peter Meindl

Operator of QASUME: Gregor Hülsen
Operators of PFS: Peter Meindl and Martin Wähmer

The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer PFS operated by PTB Berlin and the travel reference spectroradiometer QASUME. The measurement site is located at Berlin; Latitude 52.52 N, Longitude 13.32 E and altitude 59 m.a.s.l. The horizon of the measurement site is free down to at least 85° solar zenith angle (SZA). Measurements between 4:45 UT and 17:30 UT have been analysed.

QASUME was installed on the roof of the PTB building "Siemensbau" in the afternoon of March 31, 2014. The spectroradiometer was installed next to the PFS spectroradiometer with the entrance optic of QASUME within 0.5 m to the other instrument. The spectroradiometer in use at PTB is a Fourier transform spectroradiometer (FTS) prototype. The input optics is a J1002 from CMS Schreder – identical to the QASUME optic. The intercomparison between QASUME and the PFS spectroradiometer lasted four days, from morning of April 1st to the afternoon of April 4th.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Three lamps (T61253, T68522 and T685240) 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 (24.3±0.1) °C and the diffuser head was heated to a temperature 31.7 °C. Due to a malfunction of the diffusor head temperature sensor the head temperature could not be monitored during the afternoon of April 1st.
The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the SHICRivm analysis were between ±50 pm in the spectral range 290 to 400 nm.

The Fourier transform spectroradiometer PFS was also calibrated several times during the intercomparison period using the QASUME portable calibration system. Further calibrations have been performed in advance against a high-temperature black body radiator and against a secondary irradiance standard of PTB which is traceable to the national irradiance standard of PTB. The diffuser head temperature was heated to 28,0 °C. However, this temperature was not monitored. The temperature of the FTS housing was stabilized to 25 °C.

Protocol:

The measurement protocol was to measure solar irradiance spectra from 290 nm to 400 nm. QASUME measured one spectrum every 15 minutes, in steps of 0.25 nm and 1.5 seconds between each wavelength increment. The FTS recorded continuously interferograms where each interferogram was measured in about 0.6 sec. In order to limit the amount of data, 32 interferograms recorded in 19 seconds have been averaged and saved consecutively. A further averaging of the recorded interferograms have been performed during the postprocessing of the data depending on the atmospheric conditions The spectral resolution of the FTS was set to 10 cm^{-1}. A Blackman-Harris-4-Term apodization was applied to the measured interferograms to reduce the signal leakage into side lobes. The resolution after applying this apodization is about 20 cm^{-1}. A Hamamatsu photosensor module H10723-210 in combination with different spectral filters has been applied during the measurements.

DOY	Date	DAY	Weather	Comment (times are in UT)
90	31. Mrz	Monday	Mix of Sun & Clouds	Installed at 12 UT First Scans at 13:45 16 UT: FTS calibration (T61253) FTS Filter: UG5
91	01. Apr	Tuesday	Mix of Sun & Clouds, Haze	9:13 calibration (T68522) 16:30: FTS calibration (T61253) FTS Filter: UG5 16:45: FTS calibration (T61253) FTS Filter: UG11 9:30-15:30: No head temp. Control
92	02. Apr	Wednesday	Mix of Sun & Clouds, Haze	16:44 calibration (T685240) 17:30 FTS Fliter UG5
93	03. Apr	Thursday	Clear sky with few Cirrus Mix of S&C in the afternoon	6:59 calibration (T685240) 7:15 calibration (T61253)
94	04. Apr	Friday	Mix of sun & clouds	13:45+14:03 calibration T61253+T68522 End of Campaign: 15:00

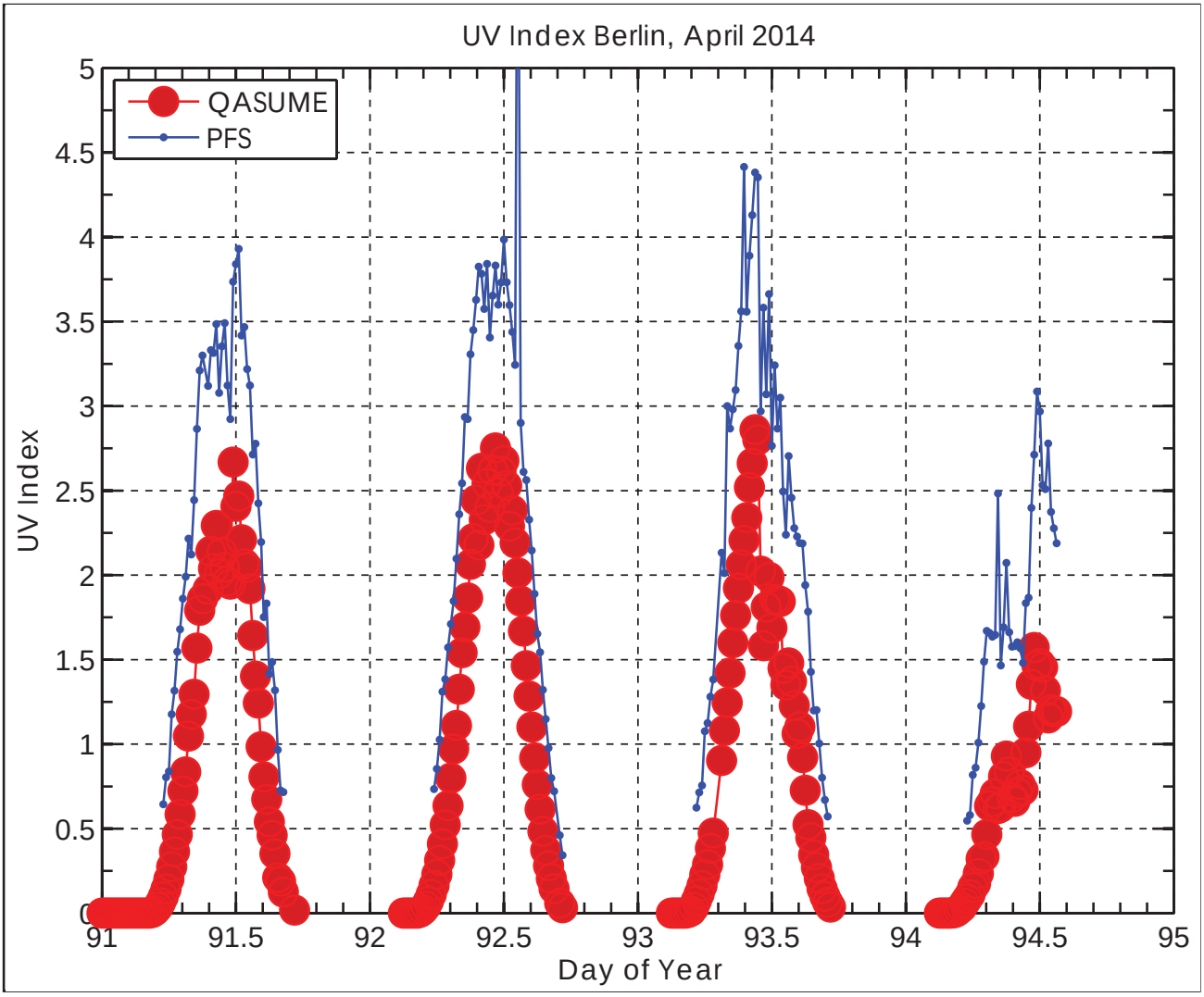
Results:

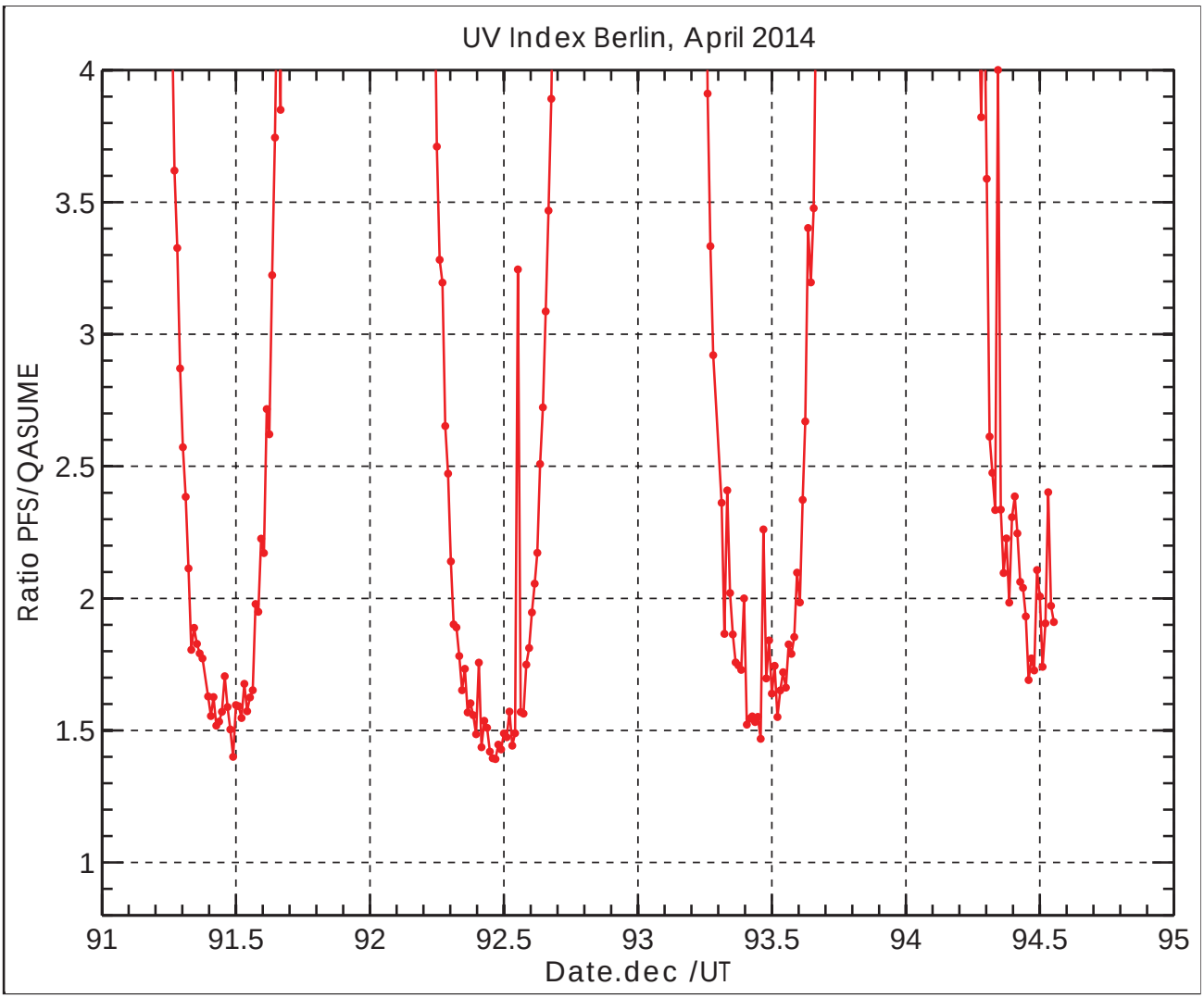
In total 159 spectra from QASUME and 8005 PFS interferograms are available from the measurement period. Measurements between 4:45 and 17:30 UT have been analysed (SZA smaller than 90°).

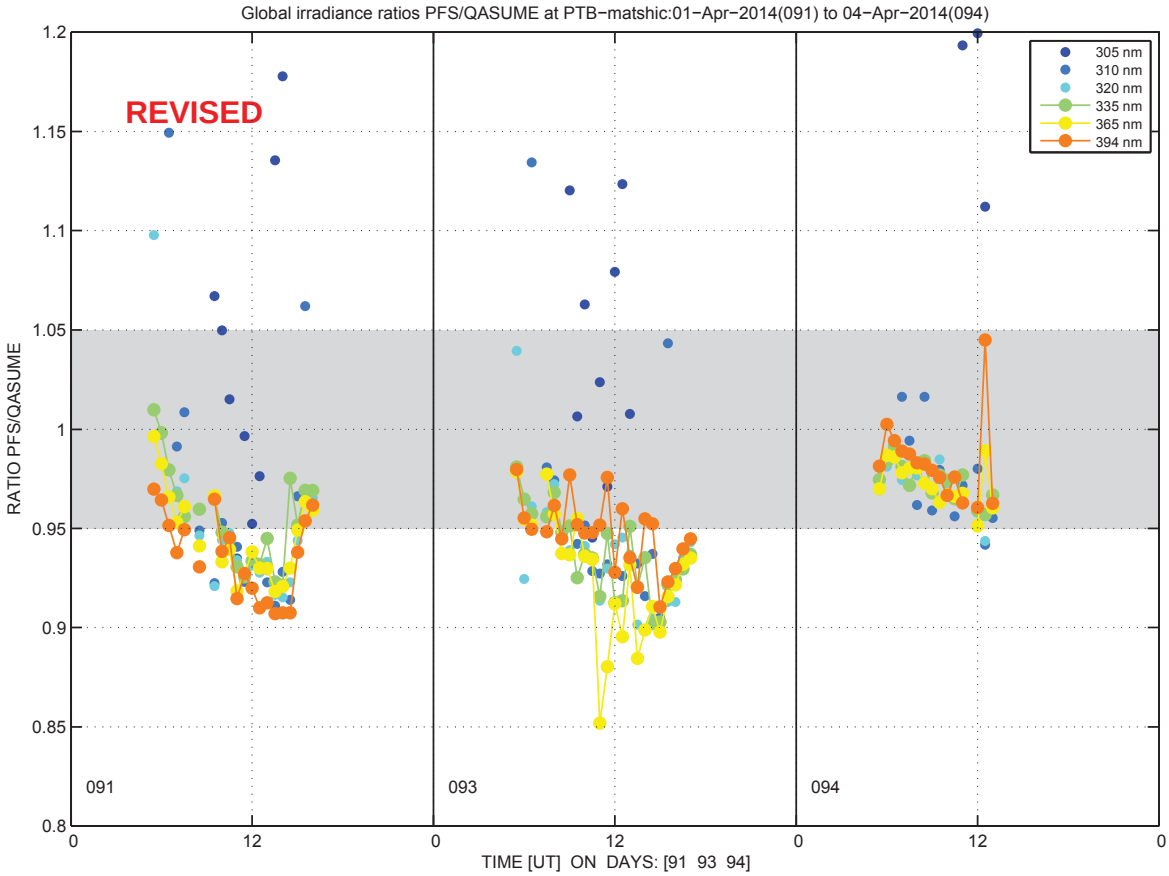
Remarks:

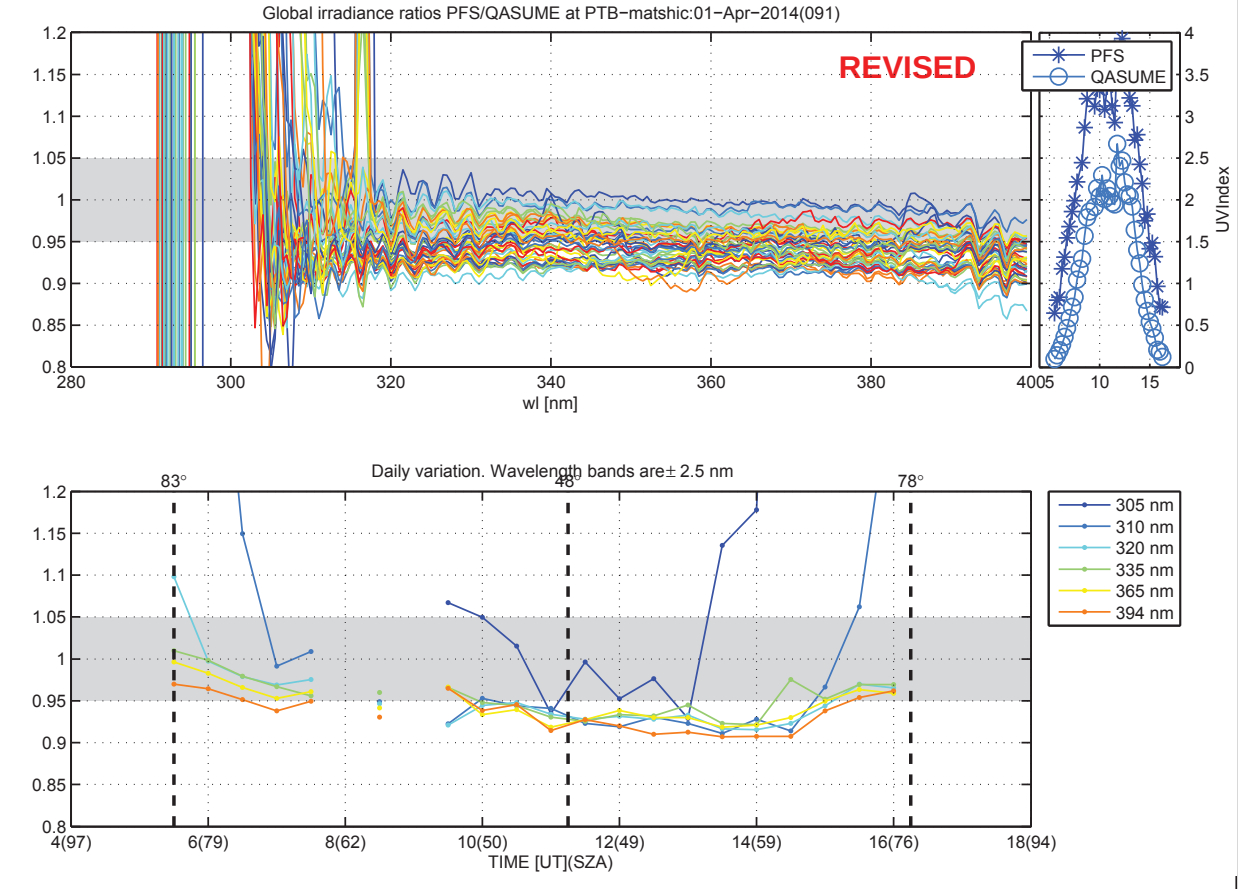
1. The interferograms of the FTS where processed as explained above.
2. The resulting spectra are further processed using the "matshic.m" algorithm. Finally the spectra of the FTS recorded during on QASUME scan where extracted using "griddata.m" to enable a comparison of the two datasets.
3. Standard Lamp calibrations:
    a. The PFS spectroradiometer was calibrated by the PTB using a 250 W transfer standard KSL003 and a HTBB3200pg (High Temperature Blackbody) in the laboratory of the PTB before the intercomparison.
    b. Monday evening, 1st April, the PFS system was calibrated using the T61253 250 W transfer standard from PMOD/WRC in the FTS configuration 1 (UG5 filter). This measurement was repeated 24h later (2nd April evening). The calibration was also performed in the FTS configuration 2 (UG11-UV filter).
    c. The difference of the PTB and the PMOD-Lamp calibrations are around 3%
    d. The finial dataset of PTB is based on the T61253 calibration.

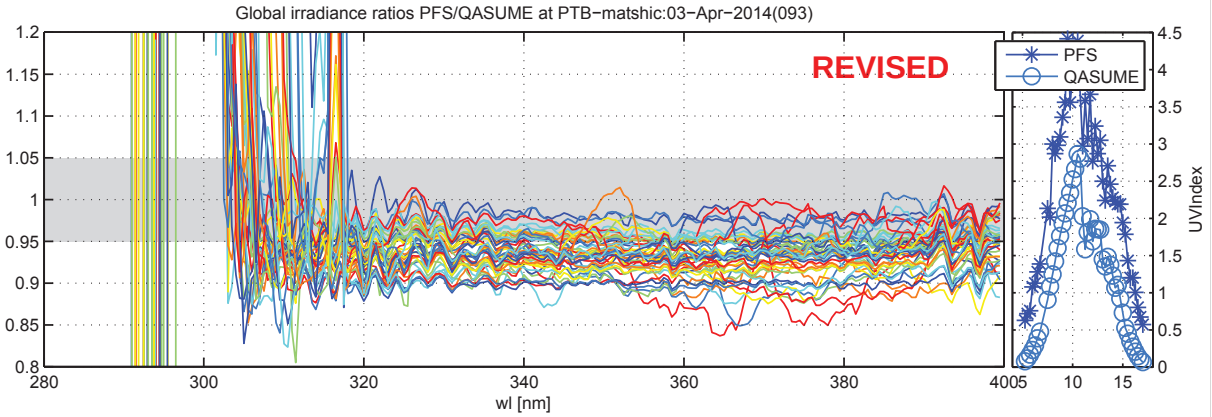
4. Two spectral filter configurations inside the FTS where tested during the campaign:
    a. 1st, 3rd and 4th April: UG5 filter
    b. 2nd April: UG11 filter
5. The ratios between PFS and QASUME have on average an offset of -5 %.
6. The diurnal variation of the PFS to QASUME ratio is 8 %. The ratios PFS to QASUME decrease constantly from the morning to the afternoon and rise again until the evening. The reason can to some degree be addressed to the different input optic of the two devices (Azimuth Error, Temperature / Humidity Sensitivity of the Teflon Sensor, Cosine Error).
7. For all solar scans the wavelength shifts of the PFS are 0 pm.
8. The original dataset has been revised:
    a. Off-axis-light correction
    b. Vacuum-Air Wavelength conversion
    c. New PFS responsivity. Adjusted for artefacts from the HeNe-laser line at 316.5 nm. Vacuum-Air Wavelength conversion.
9. Differences using the UG5 and UG11 filter:
    a. UG5 Dataset: A prominent peak around 316.5 nm for low irradiance levels (SZA<60 deg) – see figures. This is an artefact caused by the internal HeNe laser of the PFS.
    b. UG11 Dataset (only DOY 93): The peak at 316.5 nm is not visible. However, the ratios become noisy for wavelengths >390 nm.

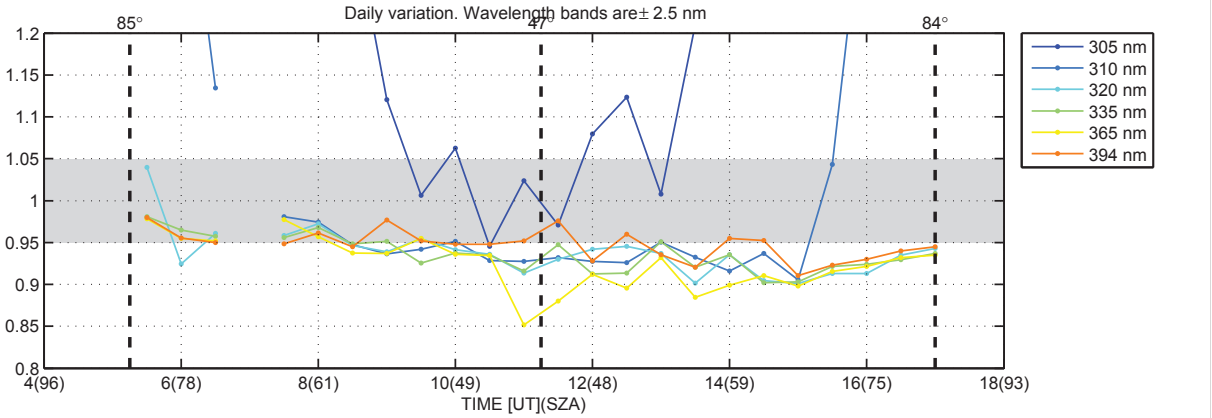

UV Index Berlin, April 2014
QASUME
PFS
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
91
91.5
92
92.5
93
93.5
94
94.5
95

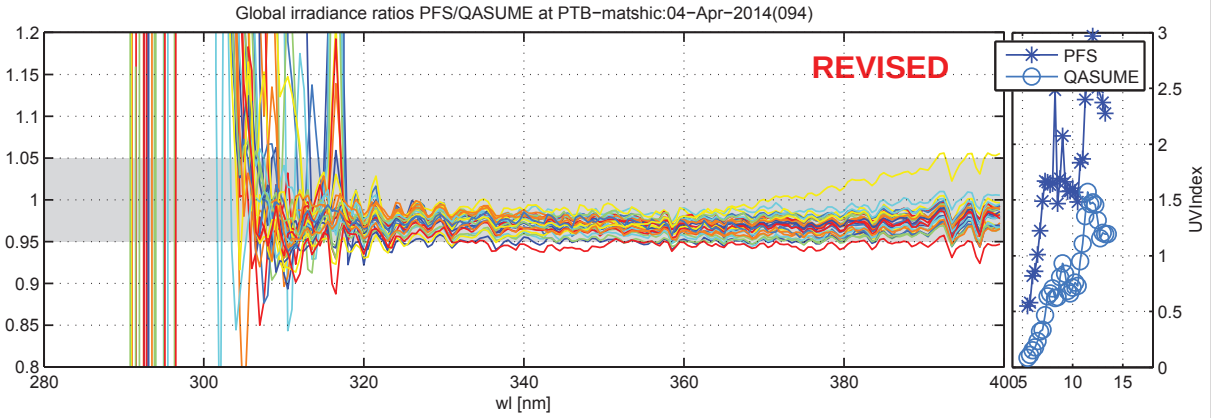

UV Index Berlin, April 2014
Ratio PFS/QASUME
Date.dec /UT
1
1.5
2
2.5
3
3.5
4
91
91.5
92
92.5
93
93.5
94
94.5
95

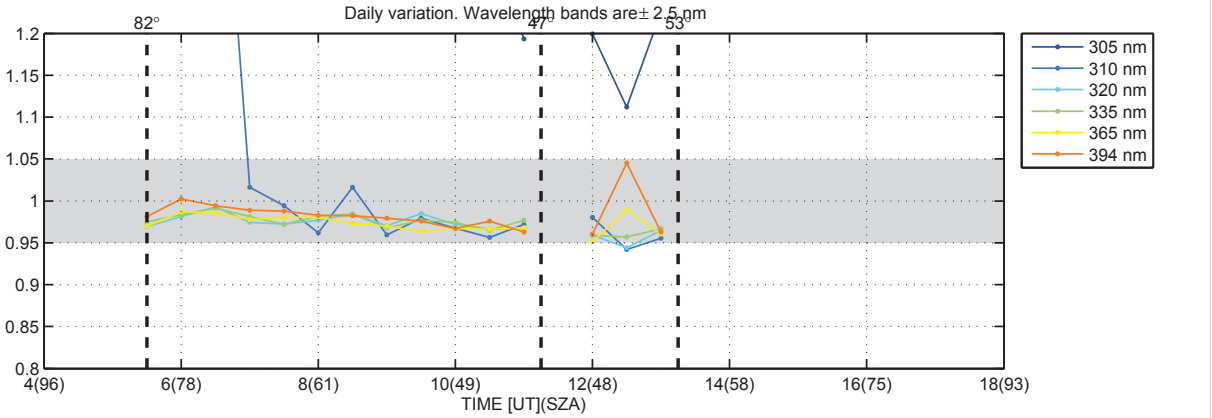

Global irradiance ratios PFS/QASUME at PTB−matshic:01−Apr−2014(091) to 04−Apr−2014(094)
REVISED
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
RATIO PFS/QASUME
091
093
094
TIME [UT] ON DAYS: [91 93 94]

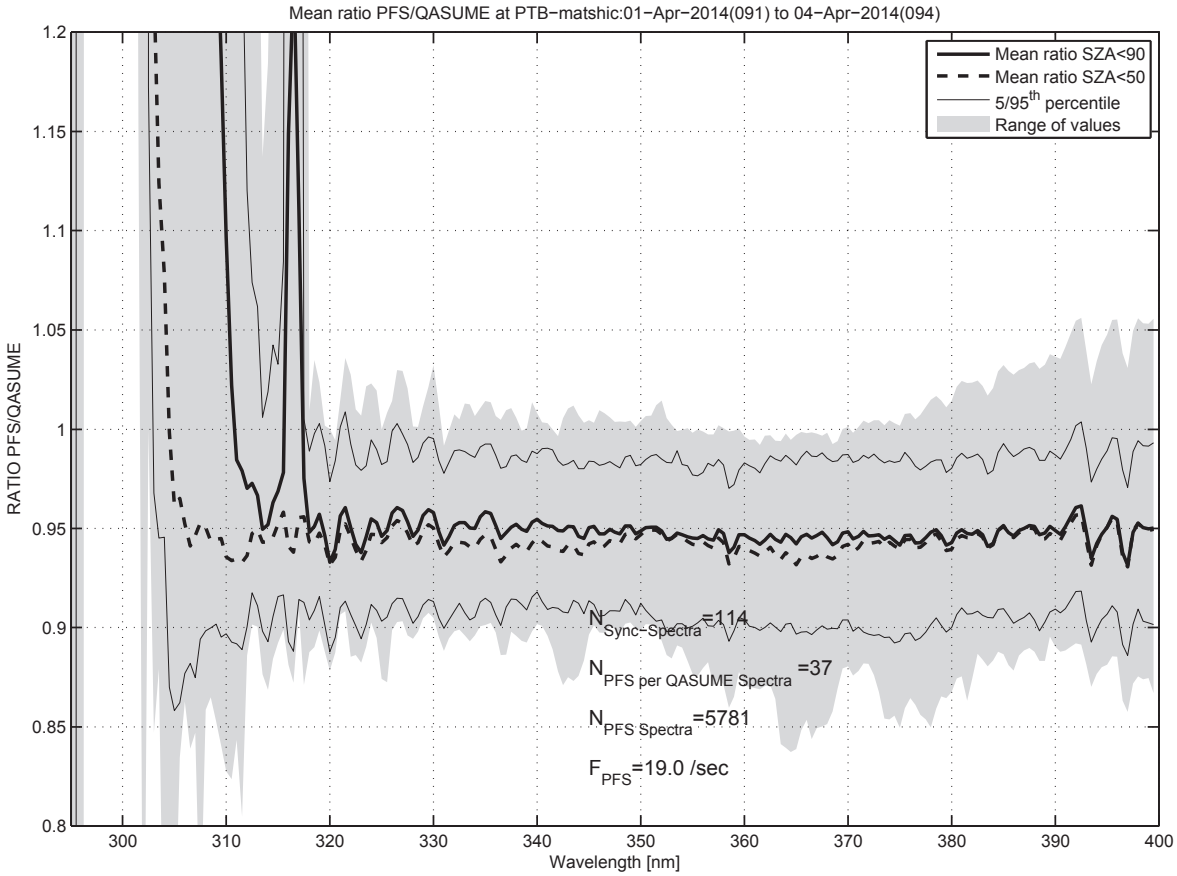

Global irradiance ratios PFS/QASUME at PTB−matshic:01−Apr−2014(091)
REVISED
PFS
QASUME
UVIndex
wl [nm]
Daily variation. Wavelength bands are± 2.5 nm
83°
48°
78°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
4(97)
6(79)
8(62)
10(50)
12(49)
14(59)
16(76)
18(94)
TIME [UT](SZA)

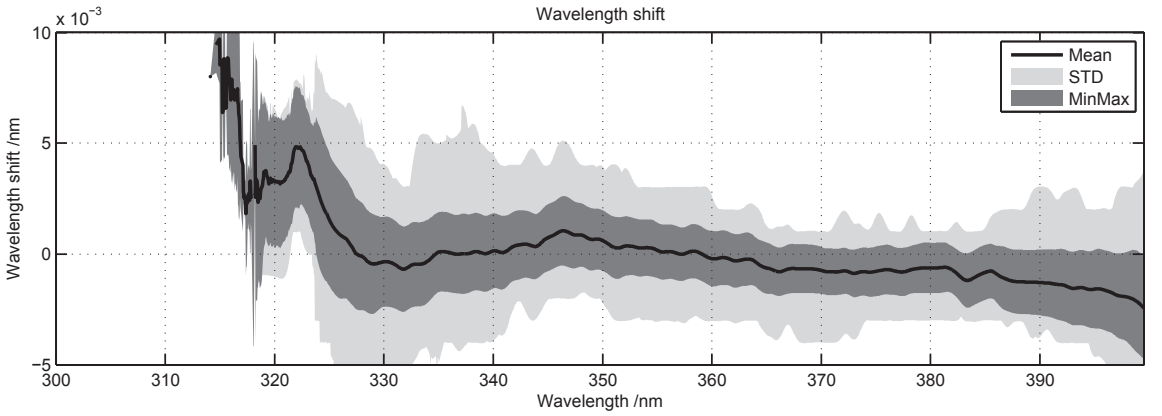

Global irradiance ratios PFS/QASUME at PTB−matshic:03−Apr−2014(093)
REVISED
PFS
QASUME
UVIndex
wl [nm]

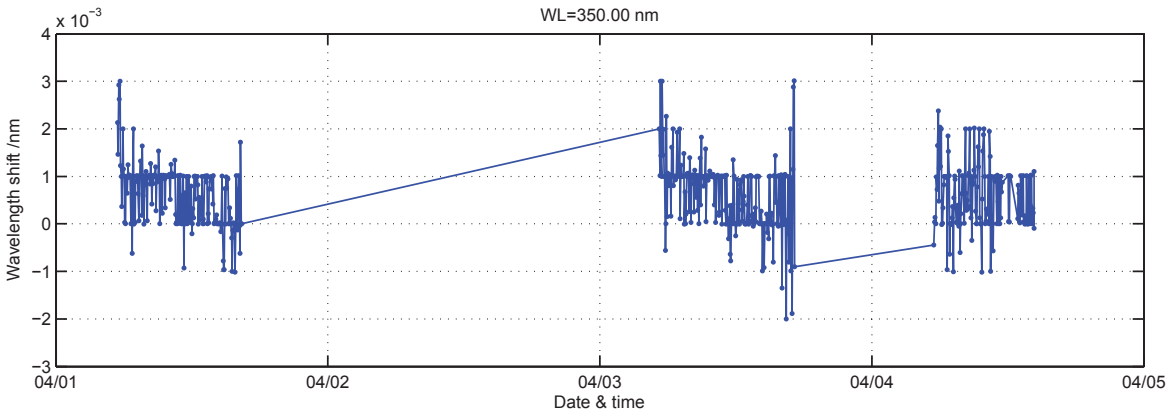

Daily variation. Wavelength bands are± 2.5 nm
85°
47°
84°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
TIME [UT](SZA)

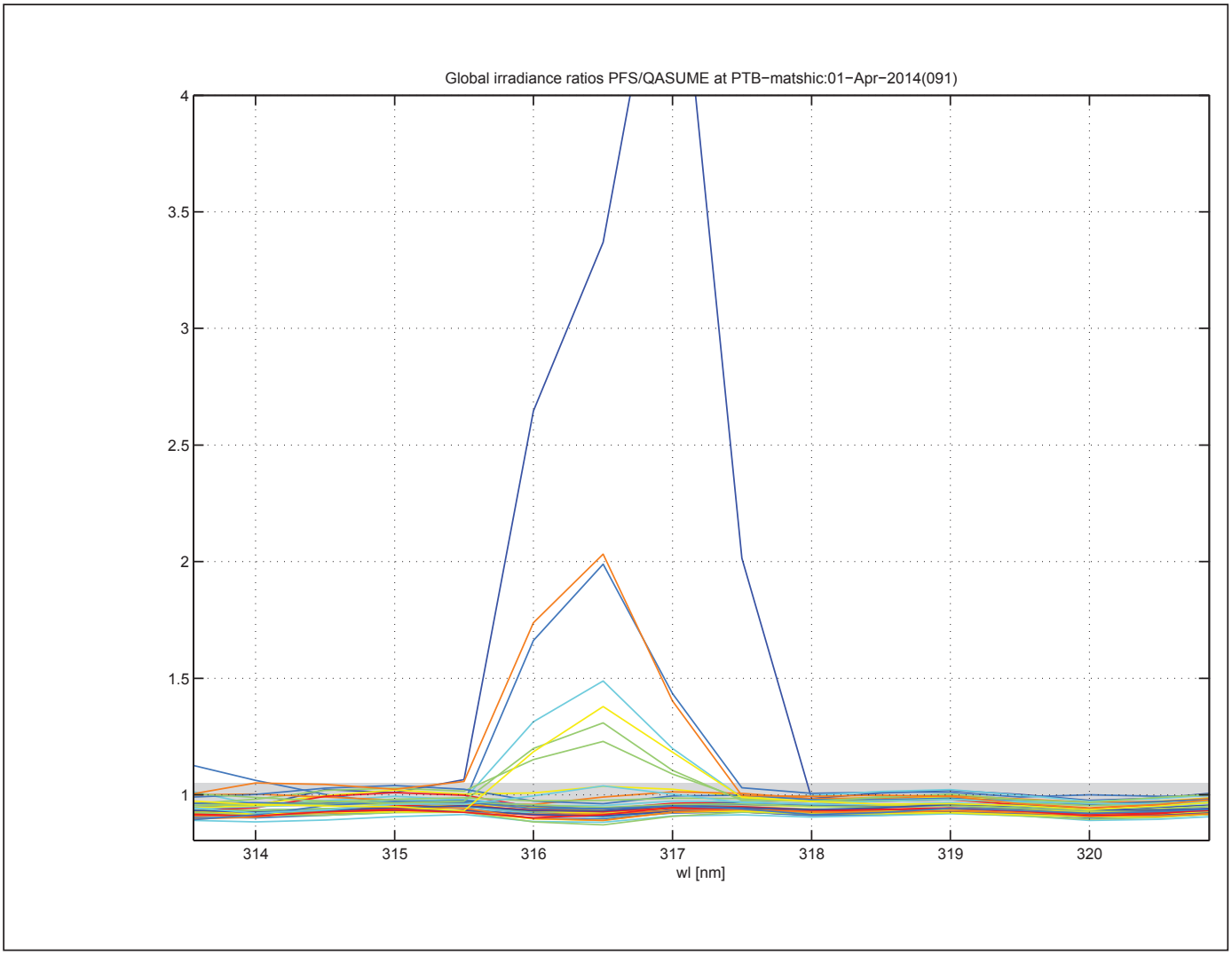

Global irradiance ratios PFS/QASUME at PTB−matshic:04−Apr−2014(094)
REVISED
PFS
QASUME
UVIndex
wl [nm]

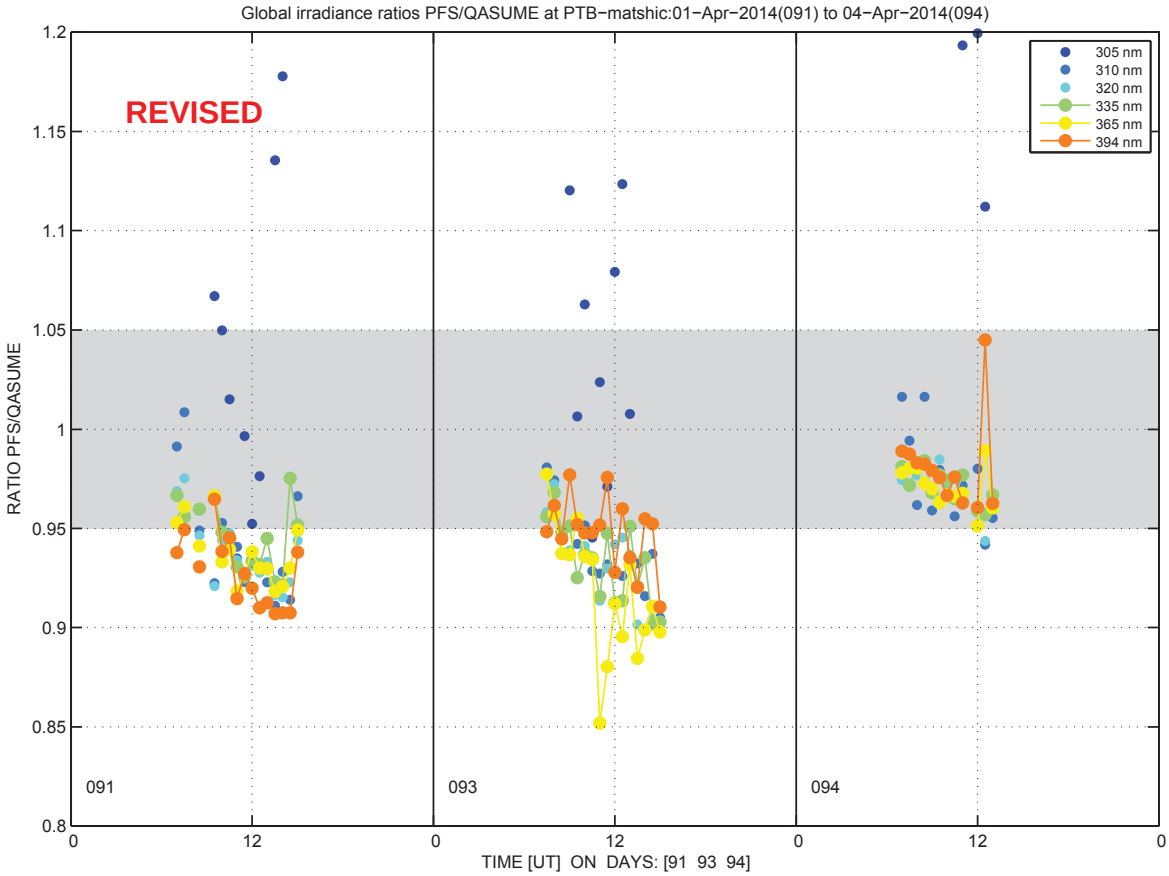

Daily variation. Wavelength bands are± 2.5 nm
82°
47°
53°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
TIME [UT](SZA)

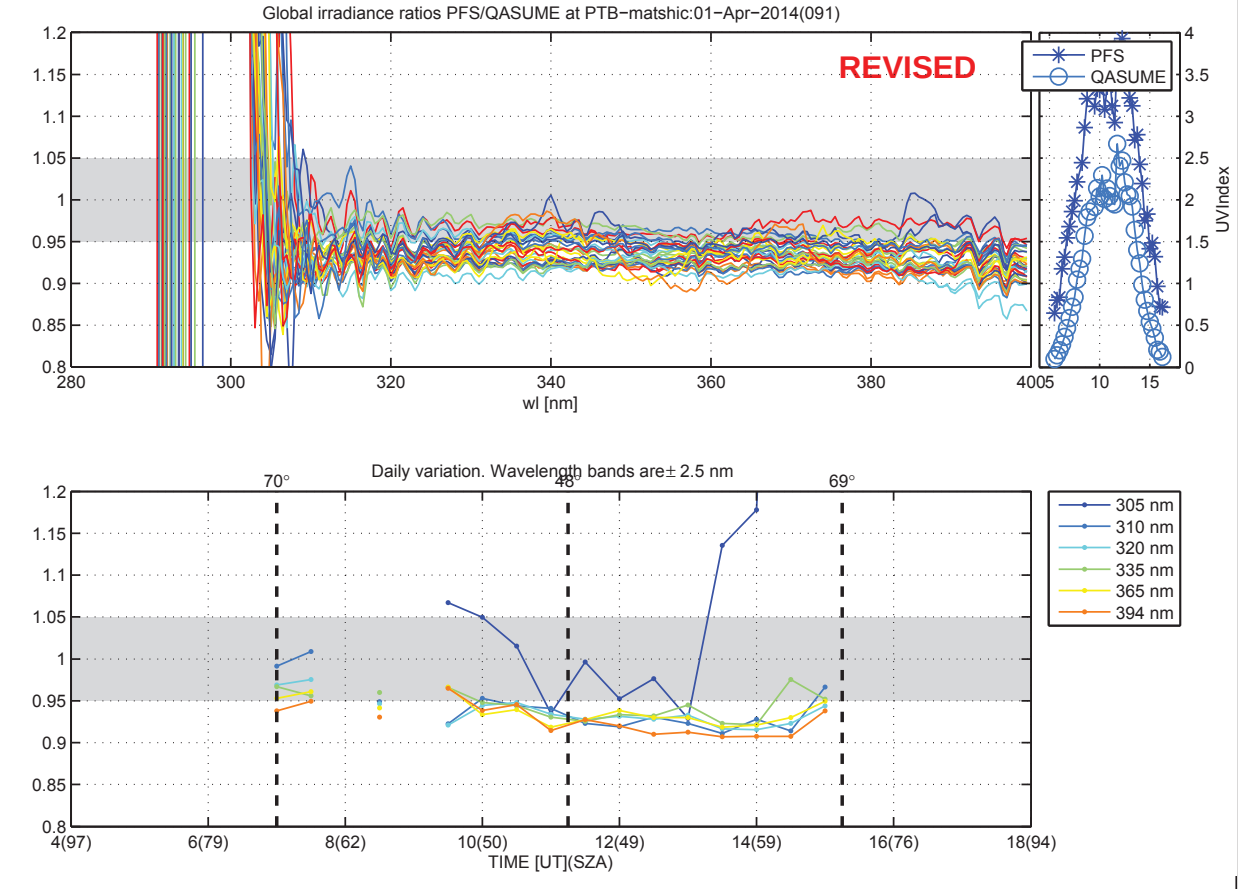

Mean ratio PFS/QASUME at PTB−matshic:01−Apr−2014(091) to 04−Apr−2014(094)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO PFS/QASUME
Wavelength [nm]
N Sync−Spectra =114
N PFS per QASUME Spectra =37
N PFS Spectra =5781
F PFS=19.0 /sec

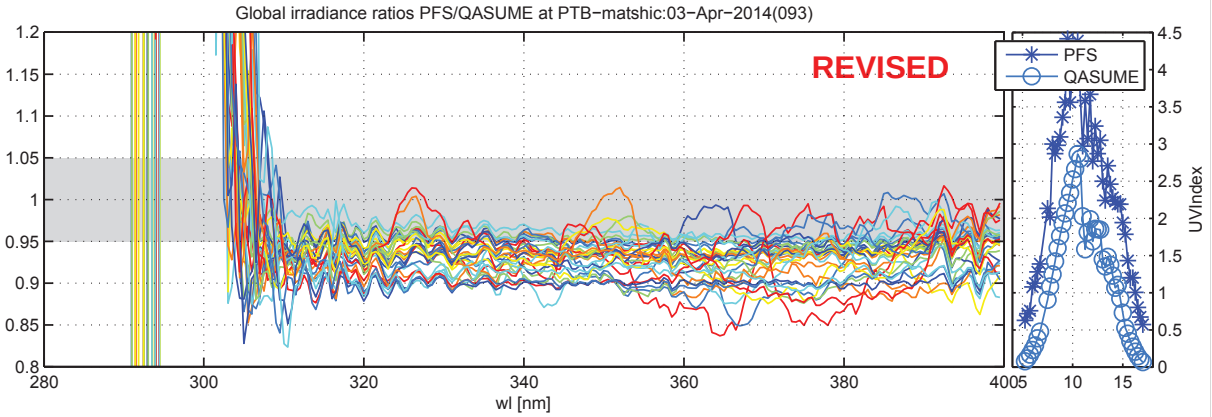

Wavelength shift
x 10−3
Mean
STD
MinMax
Wavelength shift /nm
Wavelength /nm

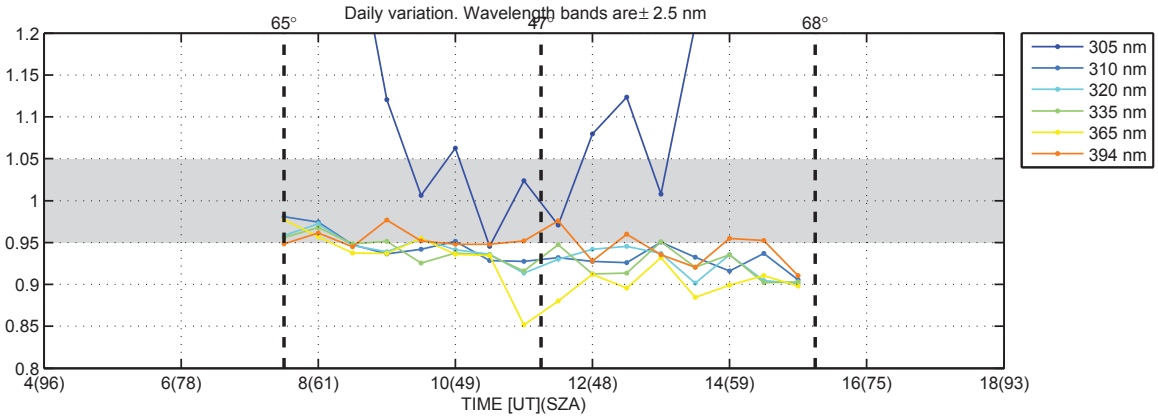

WL=350.00 nm
x 10−3
Wavelength shift /nm
04/01
04/02
04/03
04/04
04/05
Date & time

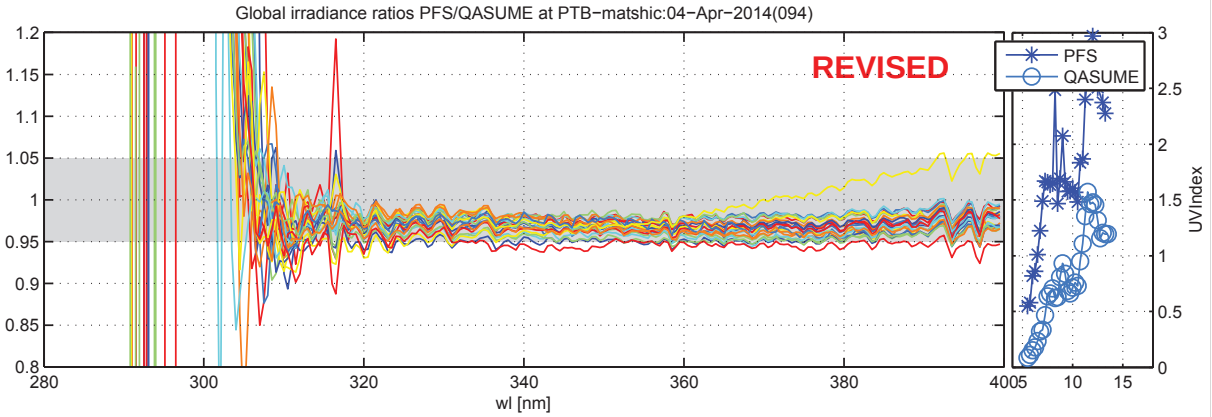

Global irradiance ratios PFS/QASUME at PTB−matshic:01−Apr−2014(091)
4
3.5
3
2.5
2
1.5
1
314
315
316
317
318
319
320
wl [nm]

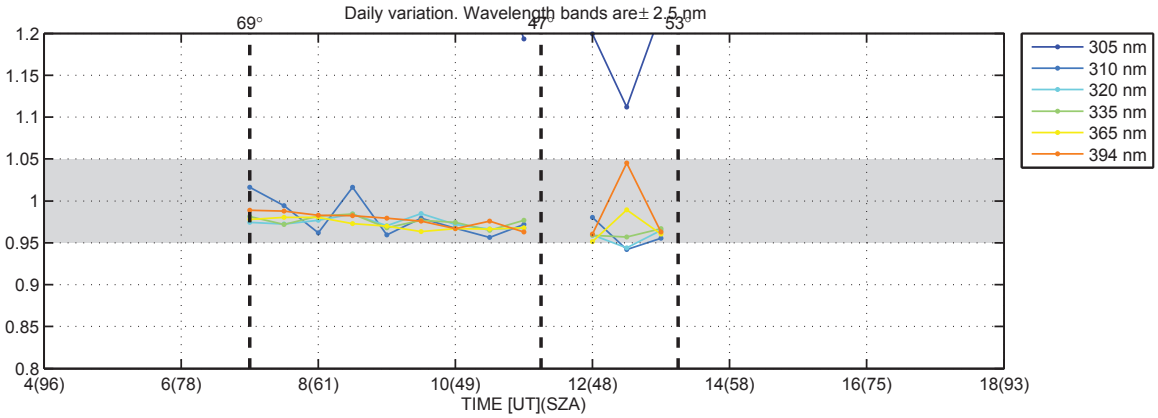

Global irradiance ratios PFS/QASUME at PTB−matshic:01−Apr−2014(091) to 04−Apr−2014(094)
REVISED
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
RATIO PFS/QASUME
091
093
094
TIME [UT] ON DAYS: [91 93 94]

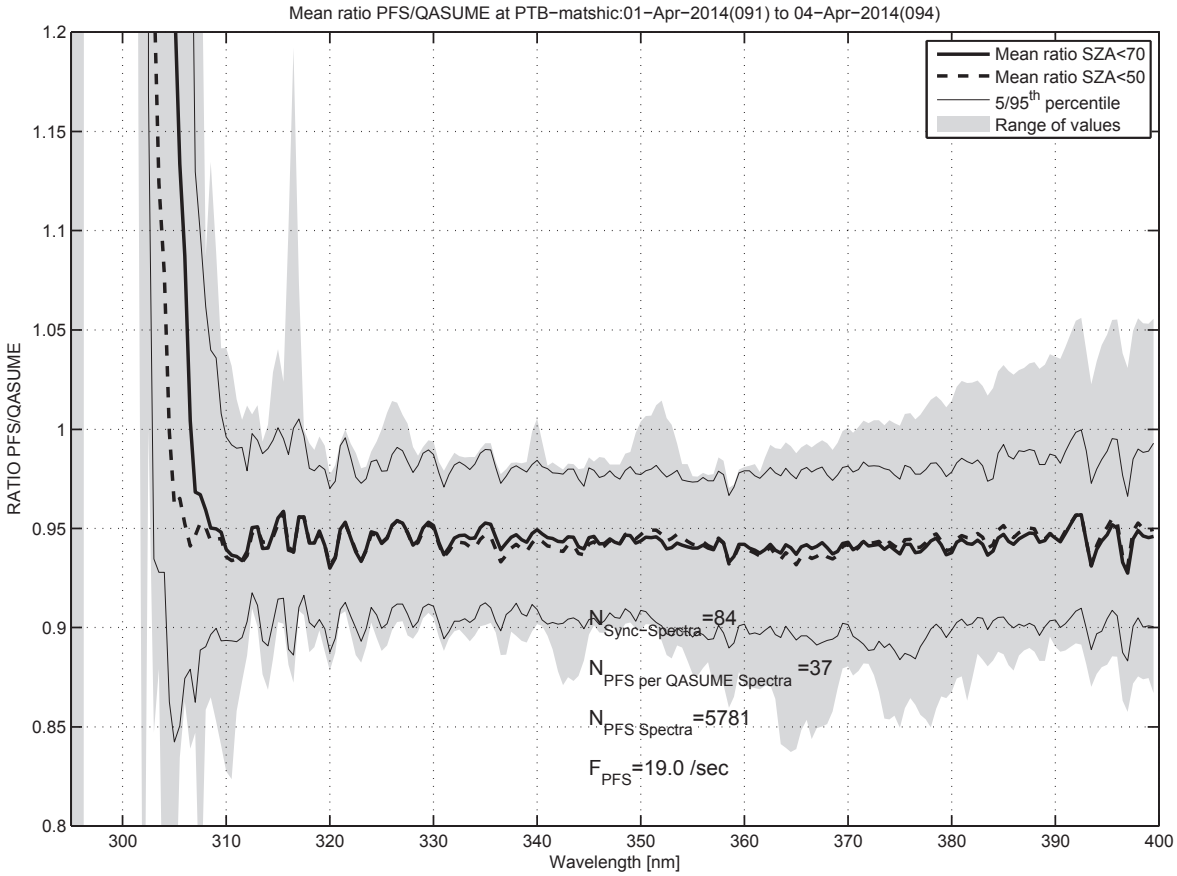

Global irradiance ratios PFS/QASUME at PTB−matshic:01−Apr−2014(091)
REVISED
PFS
QASUME
UVIndex
wl [nm]
Daily variation. Wavelength bands are± 2.5 nm
70°
48°
69°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
4(97)
6(79)
8(62)
10(50)
12(49)
14(59)
16(76)
18(94)
TIME [UT](SZA)

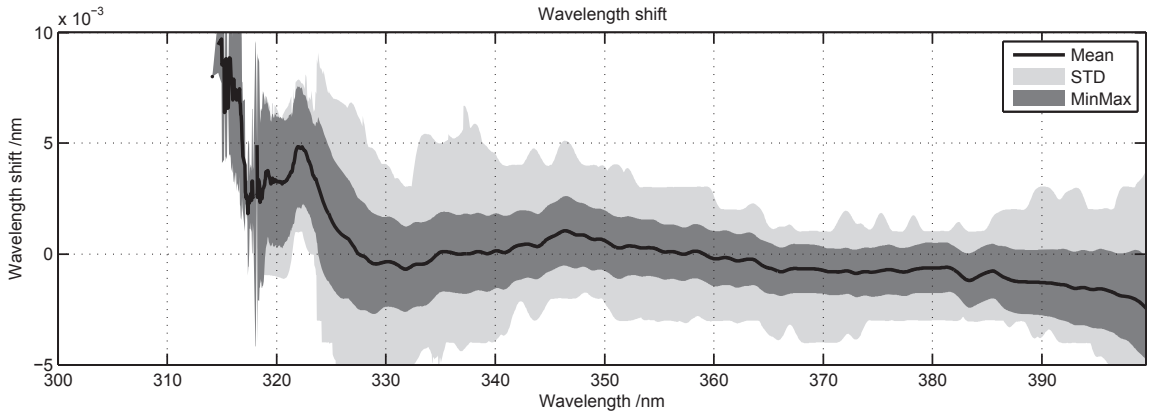

Global irradiance ratios PFS/QASUME at PTB−matshic:03−Apr−2014(093)
REVISED
PFS
QASUME
UVIndex
wl [nm]

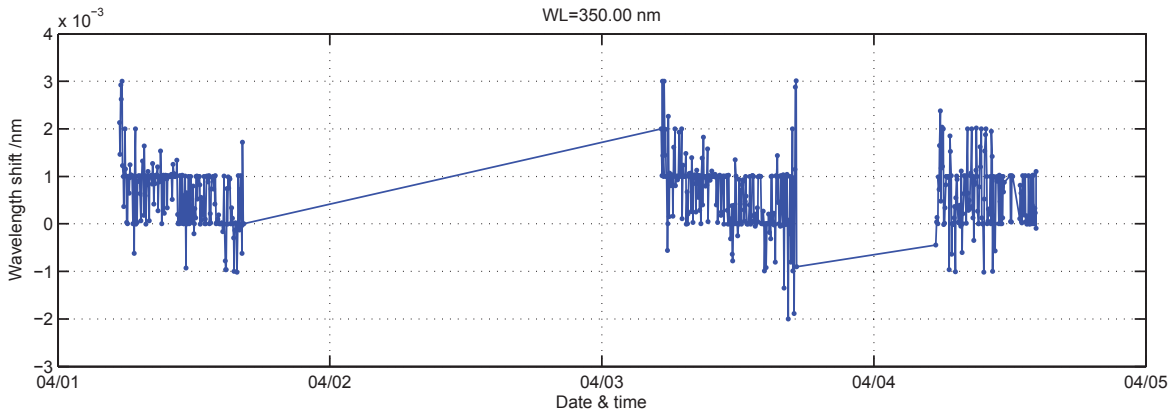

Daily variation. Wavelength bands are± 2.5 nm
65°
47°
68°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
TIME [UT](SZA)

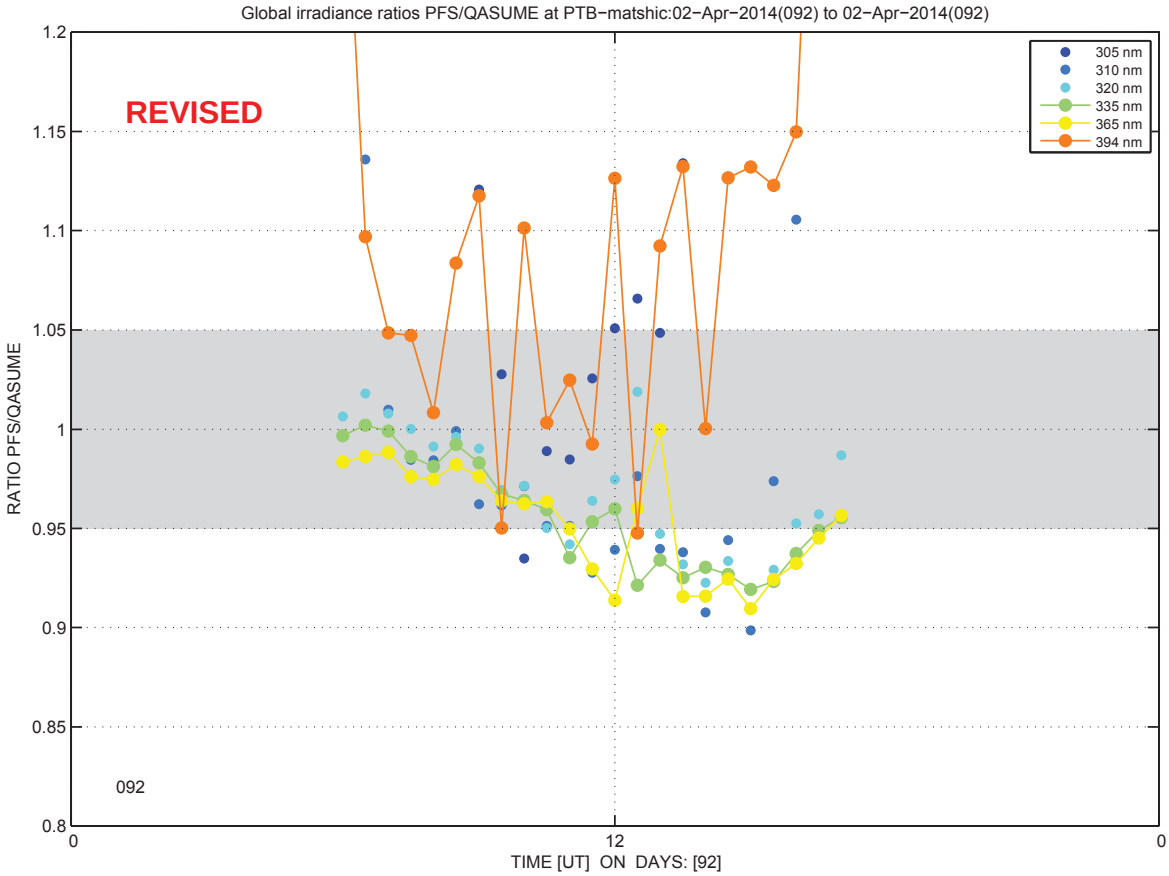

Global irradiance ratios PFS/QASUME at PTB−matshic:04−Apr−2014(094)
REVISED
PFS
QASUME
UVIndex
wl [nm]

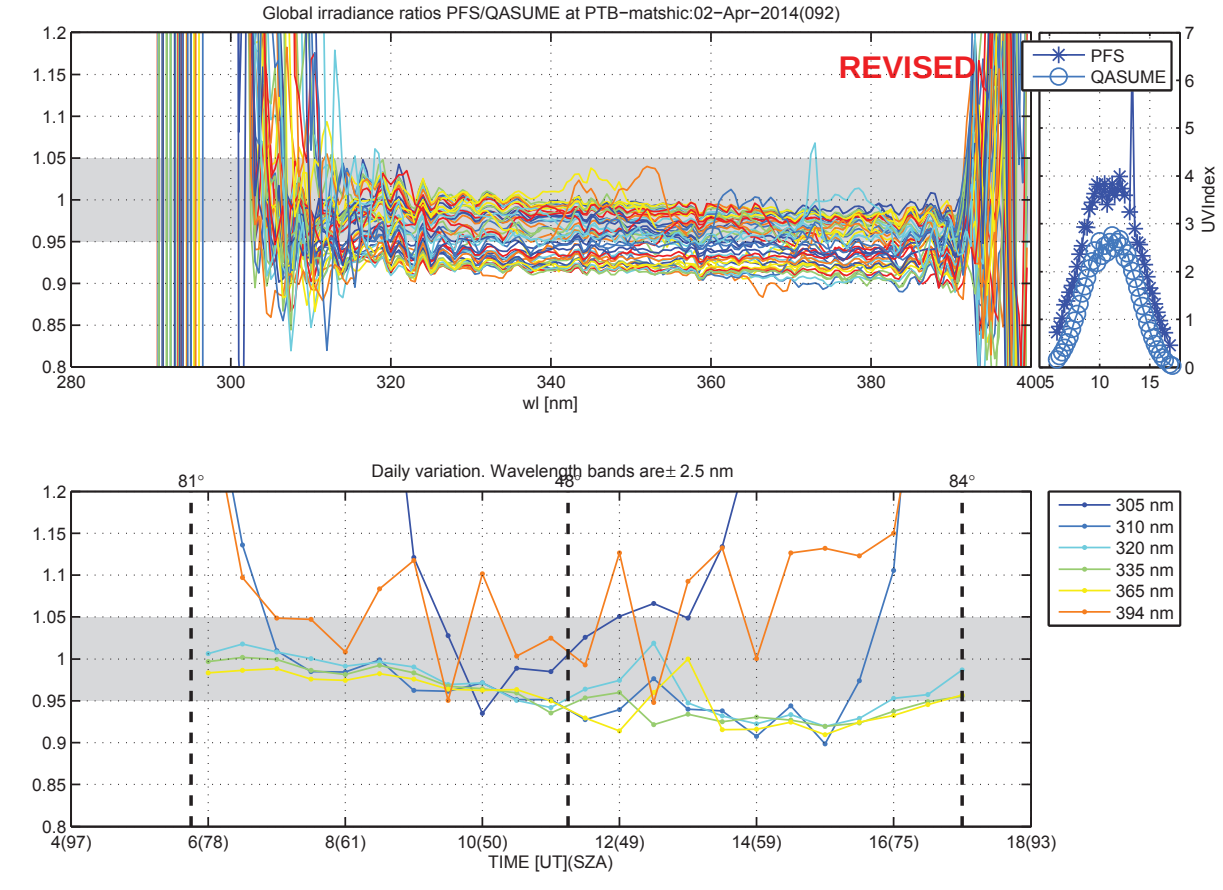

Daily variation. Wavelength bands are± 2.5 nm
69°
47°
53°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
TIME [UT](SZA)

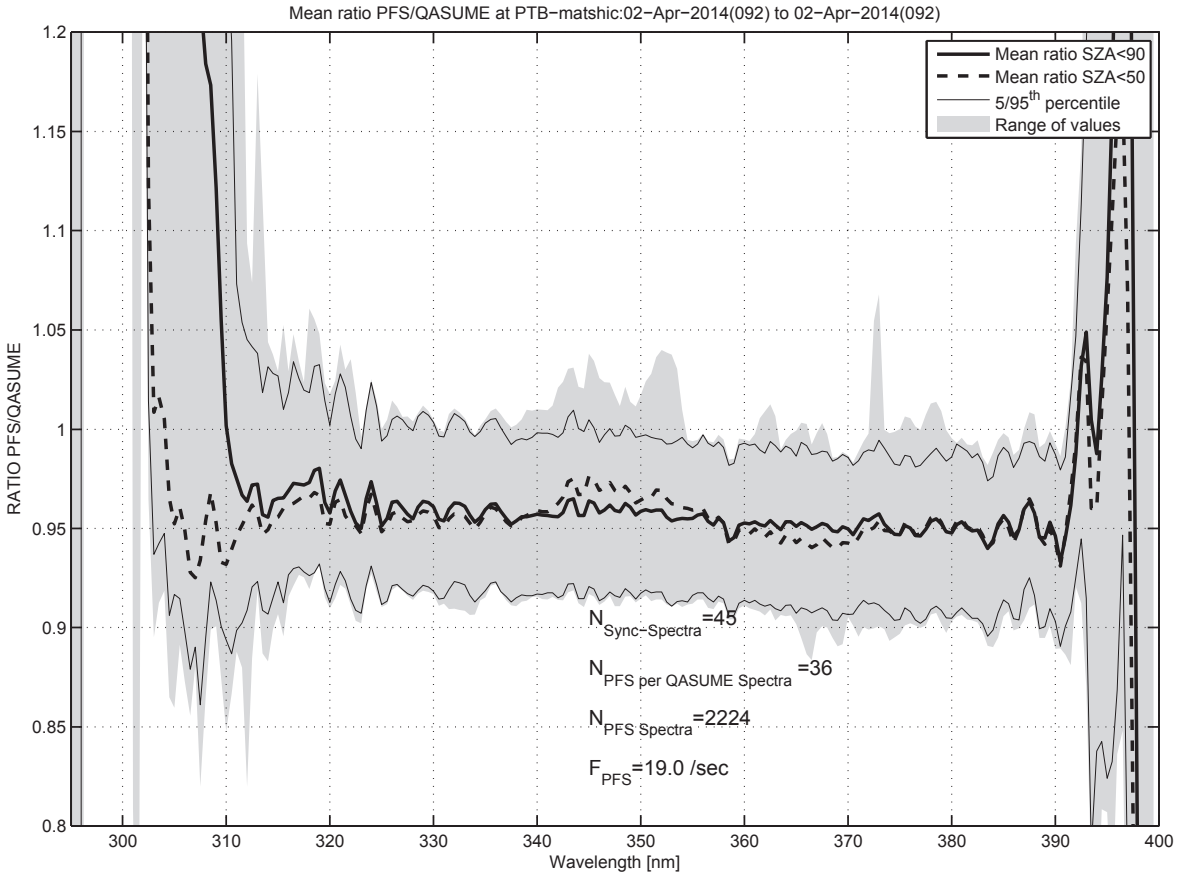

Mean ratio PFS/QASUME at PTB−matshic:01−Apr−2014(091) to 04−Apr−2014(094)
Mean ratio SZA<70
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO PFS/QASUME
Wavelength [nm]
N Sync−Spectra =84
N PFS per QASUME Spectra =37
N PFS Spectra =5781
F PFS=19.0 /sec

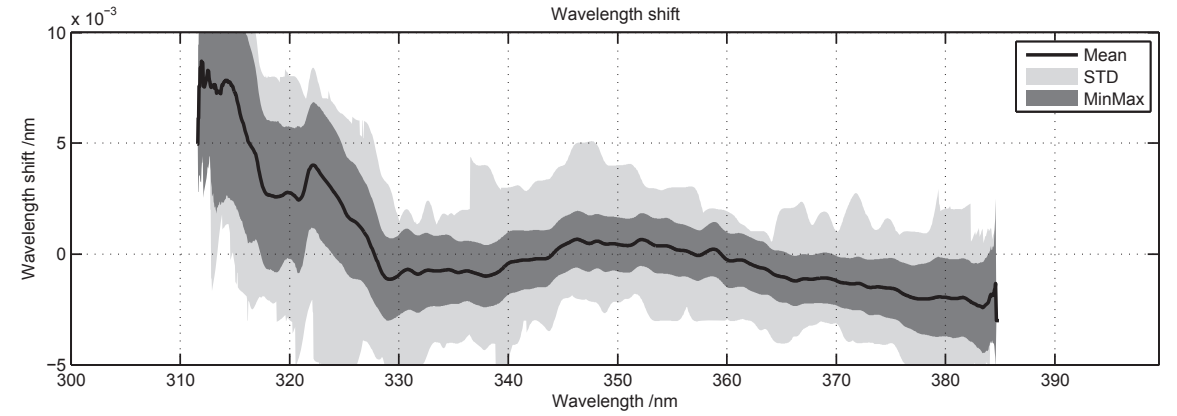

Wavelength shift
x 10−3
Mean
STD
MinMax
Wavelength shift /nm
Wavelength /nm

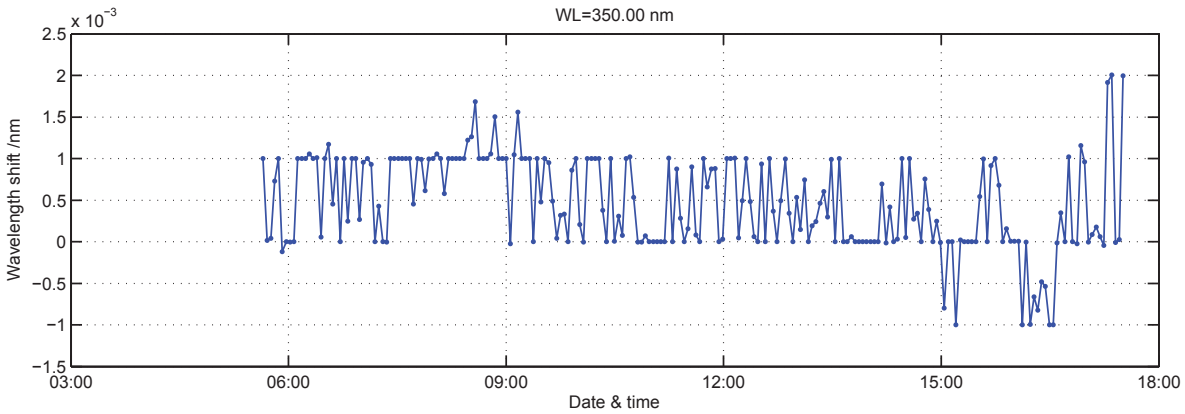

WL=350.00 nm
x 10−3
Wavelength shift /nm
04/01
04/02
04/03
04/04
04/05
Date & time

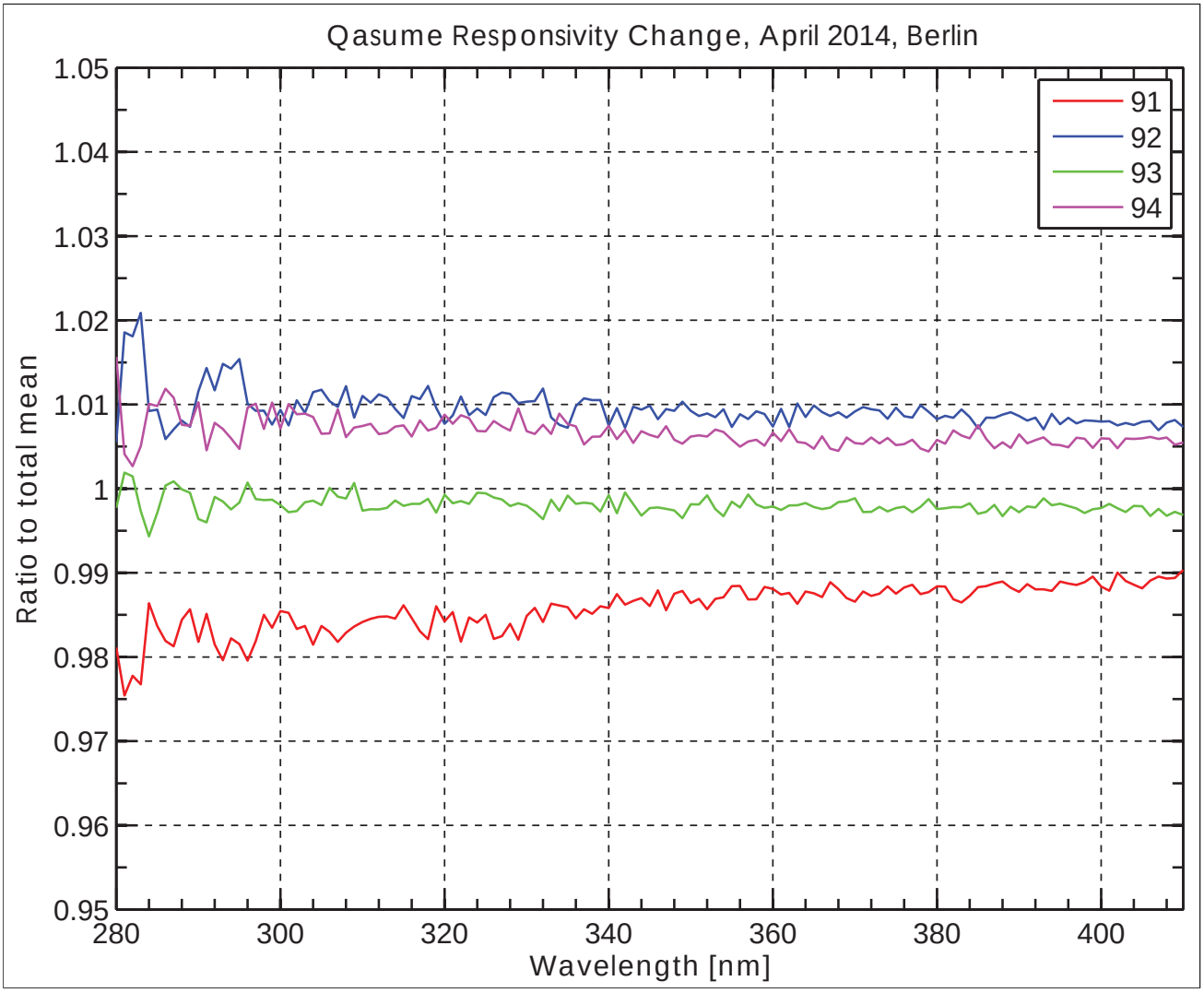

Global irradiance ratios PFS/QASUME at PTB−matshic:02−Apr−2014(092) to 02−Apr−2014(092)
REVISED
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
RATIO PFS/QASUME
092
TIME [UT] ON DAYS: [92]

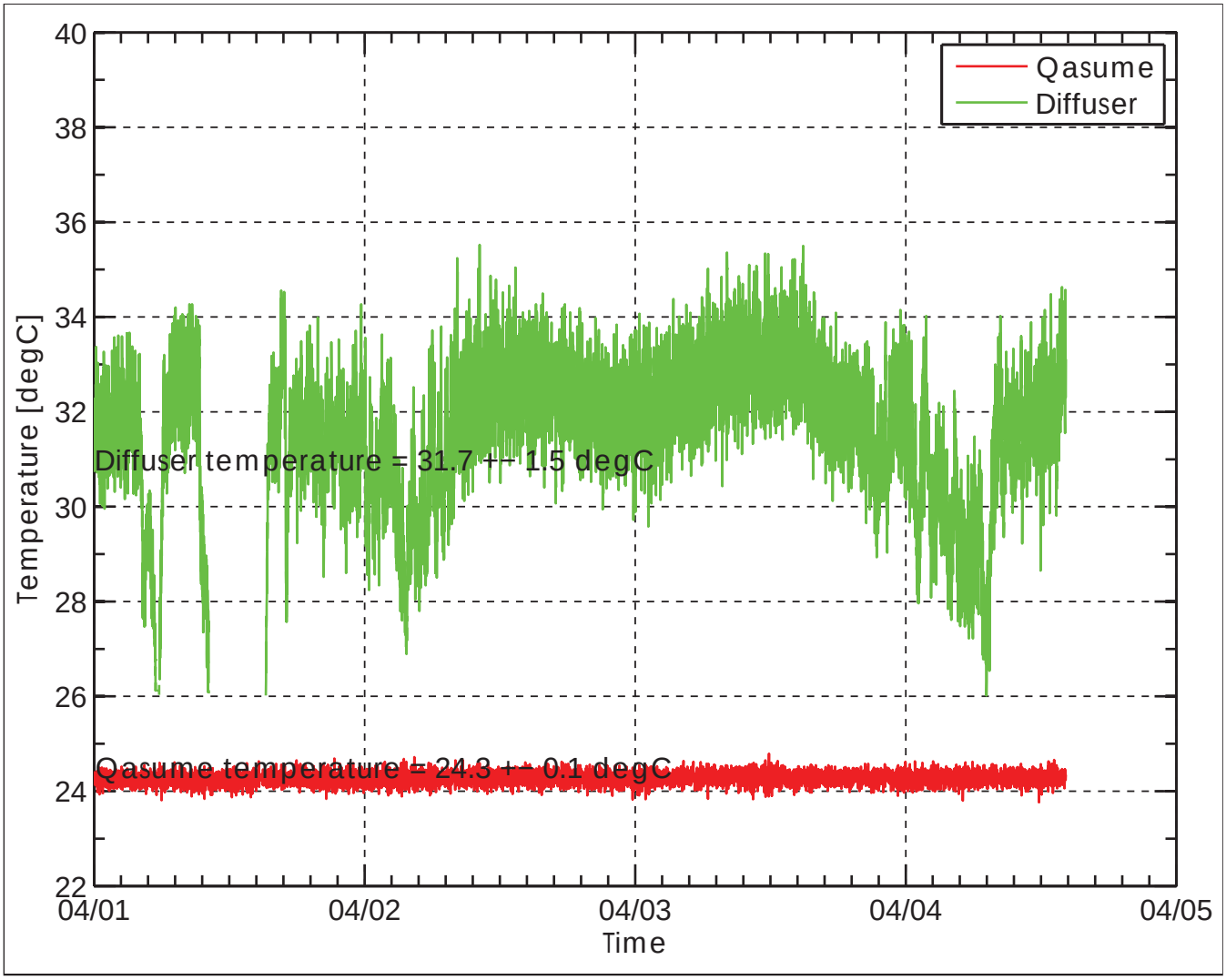

Global irradiance ratios PFS/QASUME at PTB−matshic:02−Apr−2014(092)
REVISED
PFS
QASUME
UVIndex
wl [nm]
Daily variation. Wavelength bands are± 2.5 nm
81°
48°
84°
305 nm
310 nm
320 nm
335 nm
365 nm
394 nm
TIME [UT](SZA)


Mean ratio PFS/QASUME at PTB−matshic:02−Apr−2014(092) to 02−Apr−2014(092)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO PFS/QASUME
Wavelength [nm]
N Sync−Spectra =45
N PFS per QASUME Spectra =36
N PFS Spectra =2224
F PFS=19.0 /sec

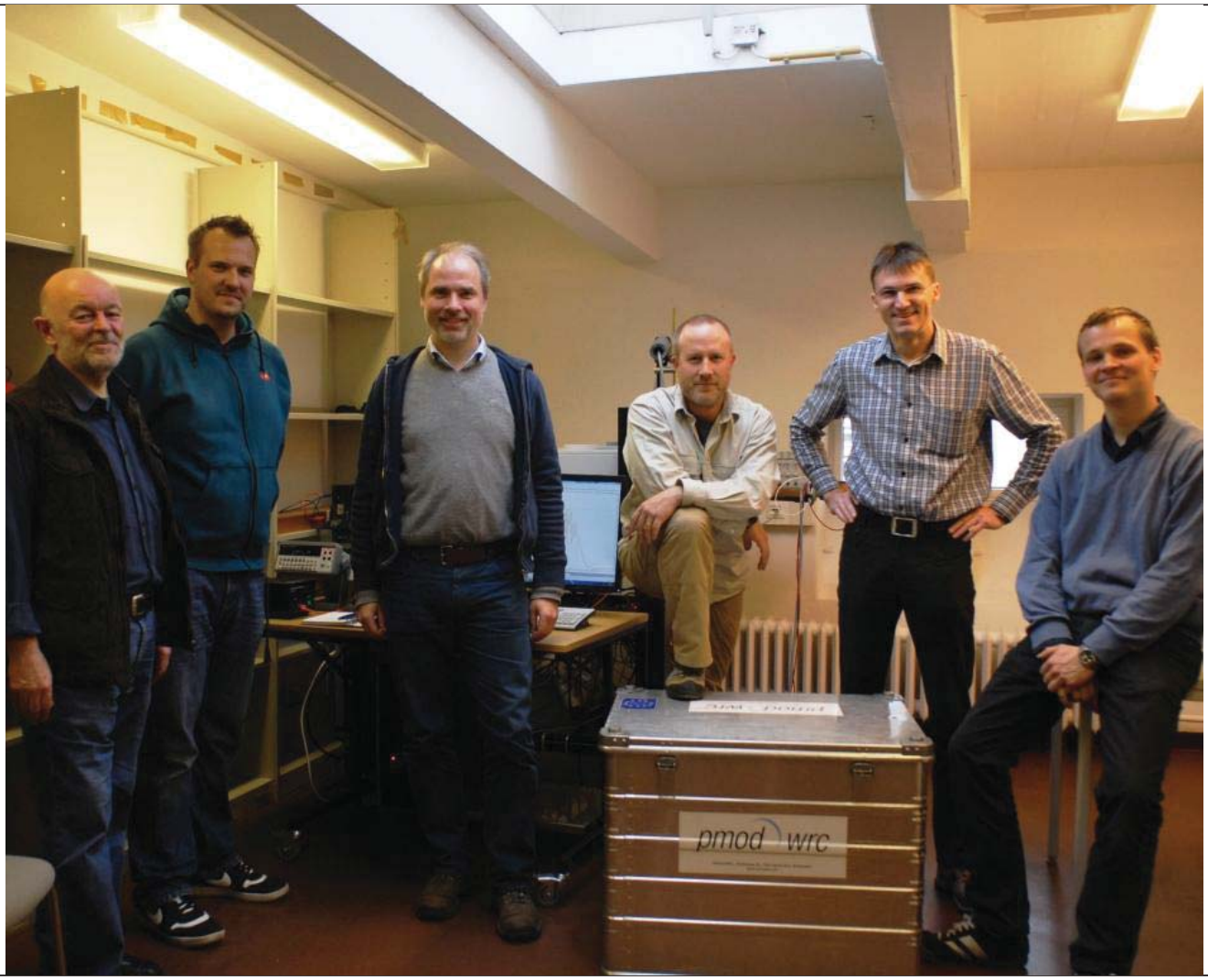

Wavelength shift
x 10−3
Mean
STD
MinMax
Wavelength shift /nm
Wavelength /nm


WL=350.00 nm
x 10−3
Wavelength shift /nm
Date & time


Qasume Responsivity Change, April 2014, Berlin
Ratio to total mean
Wavelength [nm]
91
92
93
94
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


Temperature [degC]
Time
Qasume
Diffuser
Diffuser temperature = 31.7 +- 1.5 degC
Qasume temperature = 24.3 +- 0.1 degC
40
38
36
34
32
30
28
26
24
22
04/01
04/02
04/03
04/04
04/05


Qasume
PFS


pmod wrc