Protocol of the intercomparison at ARPA, Aosta, Italy on September 2017 with the travelling reference spectroradiometer QASUME from PMOD/WRC

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The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer AAO operated by the Sezione Agenti Fisici - Radiazione Ultravioletta Solare, Agenzia Regionale per la Protezione dell'Ambiente (ARPA) and the travel reference spectroradiometer QASUME. The measurement site is located at Valle d'Aosta; Latitude 45.74 N, Longitude 7.34 E and altitude 569 m.a.s.l.
The horizon of the measurement site is free down to at least 80° solar zenith angle (SZA). Measurements between 5:30 UT and 19:00 UT have been analysed.

QASUME was installed at ARPA Aosta 25th September 2017. The spectroradiometer was installed next to AAO with the entrance optic of QASUME within 1 m of AAO. The spectroradiometer in use at ARPA Aosta is a Bentham DTMc300 double monochromator. The intercomparison between QASUME and the ARPA spectroradiometer lasted four days, from the morning of September 26 to noon of September 29.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Two lamps (T68523 and T61252) 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 %. The internal temperature of QASUME was 27.33±0.19 °C and the diffuser head was heated to a temperature of 29.32±0.45 °C.
The wavelength shifts relative to an extraterrestrial spectrum as retrieved from the MATSHIC analysis were between ±50 pm in the spectral range 290 to 500 nm.

Protocol:

The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 to 500 nm, every 0.25 nm, and 1.5 seconds between each wavelength increment. On 28th September the schedule was changed to scan every 15 minutes from 290 to 400 nm, every 0.25 nm.

DOY	Date	DAY	Weather	Comment (times are in UT)
268	25. Sep	Monday	Overcasted Sky	Installed at 14:00
269	26. Sep	Tuesday	Mix of Sun & Clouds	7:27 calibration using T68523
270	27. Sep	Wednesday	Mix of Sun & Clouds	10:20 Testing ARPA Calibrator I=6.2999 A 15:05 calibration using T68523
271	28. Sep	Thursday	Clear Sky with some Clouds at noon	6:22 calibration of AAO using T68253 6:39 calibration using T68523 6:58 calibration using T61252 7:18 calibration using T68522 7:30 change scan: 290:0.25:400, 1/4h
272	29. Sep	Friday	Mix of Sun & Clouds	6:24 calibration using T68523 End of Campaign: 11:00

Results:

In total 90 synchronised simultaneous spectra from QASUME and AAO are available from the measurement period. Measurements between 5:30 and 19:00 UT have been analysed (SZA smaller than 90°).

Remarks:

1. The ratios between AAO and QASUME have on average an offset of -4 %.
2. The diurnal variation of the AAO to QASUME ratio is around 3 %.
3. For all solar scans the wavelength shifts of the AAO are between ±40 pm.

Additional Measurements

1. The current of the AAO calibration system was checked using the PMOD calibration unit. The current is 6.2999 A.
2. The AAO system was calibrated on 28th September with the PMOD calibration system using T68523. The irradiance file from 2016 was used to calculate the responsivity of AAO. No difference to the calibration using the ARPA KS-Lamps was found.

Qasume Comments

1. The Bentham ADC of Qasume malfunctions when the main power is below 235 V. Due to the better temperature stabilisation of the Head and Box more current is drawn through the long power cable from the UPC to the Qasume Box and thus a larger voltage drop of this cable occurs. This leads to incorrect dark current readings just before the solar scans. This effect causes lower calculated UVB values of Qasume.
2. High frequency solar scans without pause in between reduce the relaxing period for the PMT of Qasume. Thus, for ¼ hour scans the dark current increases much more during the day than for ½ hour scans. This second effect leads also to lower calculated UVB values of Qasume.
3. After the ARPA-Aosta campaign Qasume was installed at PMOD/WRC next to QasumeII. The comparison and analysis of the data show that
    a. Effect 1 and 2 can be reproduced at PMOD/WRC
    b. The mean ratio of QasumeII to Qasume is around unit with a diurnal variability of around 2 %.
4. The 250W transfer lamps of the WCCUV where checked after the campaign in Davos using KS020, KS025, KS028, T61251, T68522 and T68523 using Qasume and QasumeII. The responsivities derived from these lamp calibrations are within ±0.5 %.
5. Finally, the irradiance scale of these lamps was checked by a transfer of the scale using a 1000W primary lamp to T68523 using Qasume: The difference of the irradiance derived during the irradiance scale realisation in January 2017 and October 2017 is below 0.2%.

Conclusion

From the Qasume system tests and lamp verifications test one must conclude that the difference between AAO and Qasume are mostly due to lower calculated UV signals of AAO. The Qasume effects 1 and 2 (described above) may lead to a higher diurnal variability and noise of the ratio AAO to Qasume – especially in the UVB spectrum.

The reason for the 4% offset of the ratio AAO to Qasume is substantially different to the AAO performance found in 2015. All successive procedures and equipment leading to the AAO UV irradiances have been check. Most important is that the Lamp calibrations carried are out without deviation to previous test.

There are several indications for instabilities of the AAO spectroradiometer:

1.) Increasing sensitivity during a solar scan (spectral shape of the ratio AAO to Qasume) which is pronounced for the long scans from 290 to 500 nm and less visible for the scans from 290 to 400nm
2.) Increasing of the ratio AAO to Qasume during a day. This is only present for the long scans on the more diffuse days and to a much smaller degree on the short scans during the clear sky day 271.
3.) Large diurnal decrease of the ratio of 5% on the last day of the campaign which contrasts with the previous measurement days.

The reason for the instability may be due to a bad performance of the AAO PMT.

The PMT of AAO is currently supplied with around 400 V.
For comparison:
The Qasume PMT runs with 728 V and the IBK PMT (Innsbruck) with 608 V.

Final General Remark:

The traceability chain of AAO is currently broken, because the KS lamp calibration cannot be performed anymore for the AAO system. An upgrade of the calibration procedure using 1000W FEL type lamp is recommended.

Comments from the local operator

1. during the absolute calibration of broadband (BB) radiometers by ARPA in summer 2017, all BB instruments showed a general decrease (Fig. 1), which, in the view of the QASUME audit, is now attributable to a decrease in the reference responsivity (AAO). The broadband 2017 intercomparison at PMOD also proved that the irradiance scale of ARPA is some percents too low;

Fig. 1: Variations of absolute calibration factors of ARPA broadband radiometers (the AAO Bentham spectroradiometer was used as reference).

2. it would be useful to know since when the Bentham had started drifting or had changed, in order to correct the measurements in the series or remove them from further analyses. To this purpose, we tried to compare AAO to the other colocated instruments. However, in the period between the second to last (2016) and the last (2017) BB calibration, no systematic trend or sudden change was detectable in the BB/AAO ratio (high noise), Fig. 2;

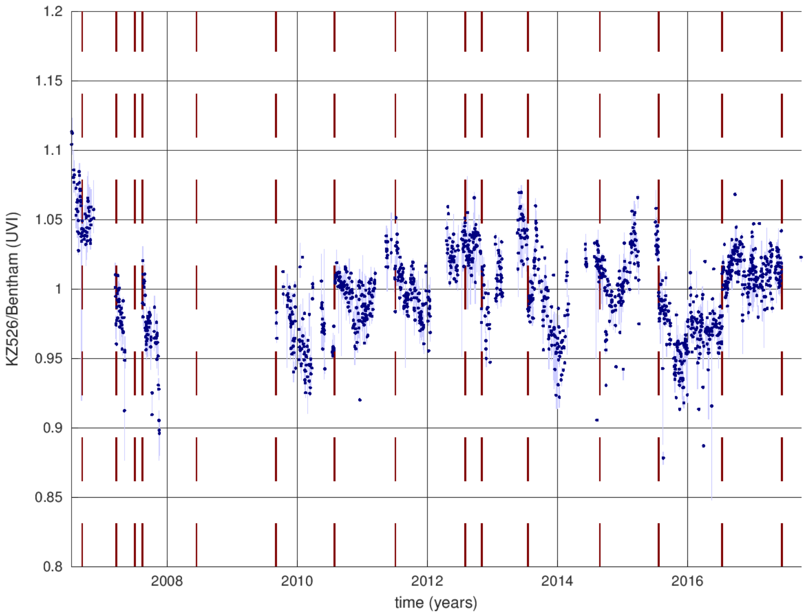


Fig. 2: BB/AAO ratio during clear-sky days. The vertical lines represent the calibration periods, when BB was aligned to AAO.

3. the AAO/Brewer ratio doesn't show any appreciable decrease in the time interval since last QASUME audit in 2015 (high noise, partly due to different measurement schedules and scan durations). Conversely, a slight increase of the ratio (likely due to a recent calibration of the Brewer by IOS) can be identified in 2017, which however goes in the wrong direction compared to the recent findings with QASUME, Fig. 3;

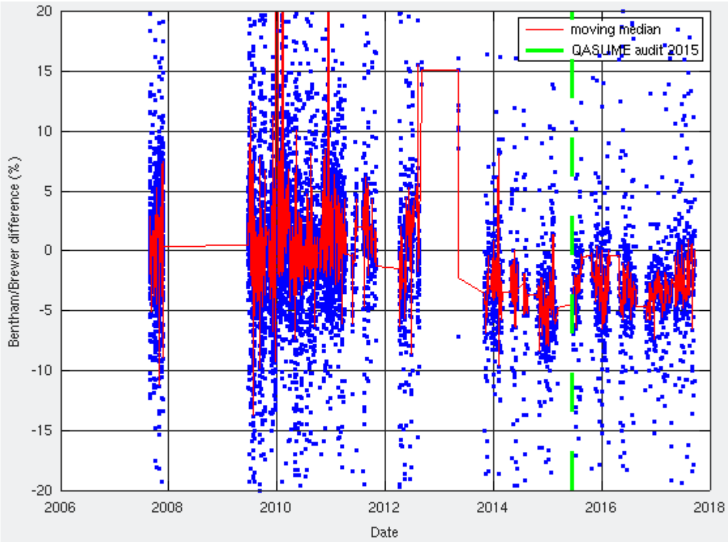


Fig. 3: Ratio AAO/Brewer. The -4% offset since the end of 2013 is due to the transition from AAO to Brewer #17 (IOS) as a reference for UV.

4. the comparison of AAO to the model (clear-sky days only) is also very noisy and doesn't allow any detection of a change in AAO responsivity (not shown). Interestingly, the comparison for some clear-sky days in 2017 seems to confirm the slight daily increase of AAO responsivity during the day (Fig. 4) revealed during the intercomparison. The measurement/model spectral ratio, however, is completely flat (Fig. 5), differently from the QASUME audit results;

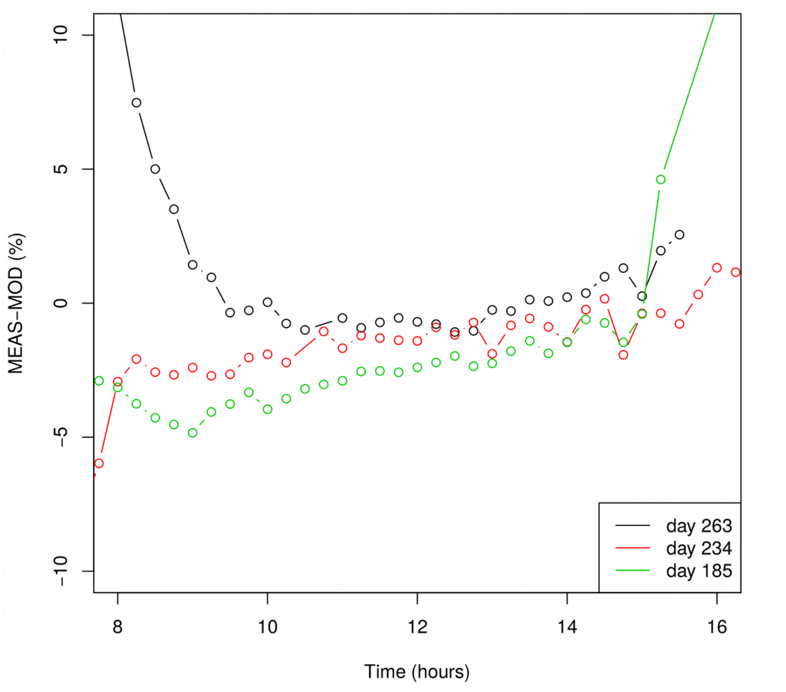


Fig. 4: Relative difference between measurements and model for three completely clear-sky days. Large deviations at the beginning/end of the day are expected due to the local horizon.

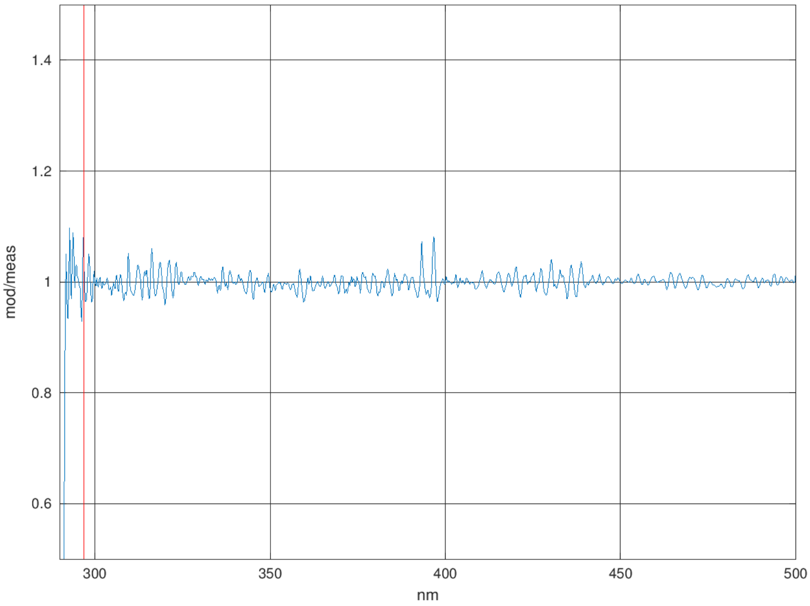
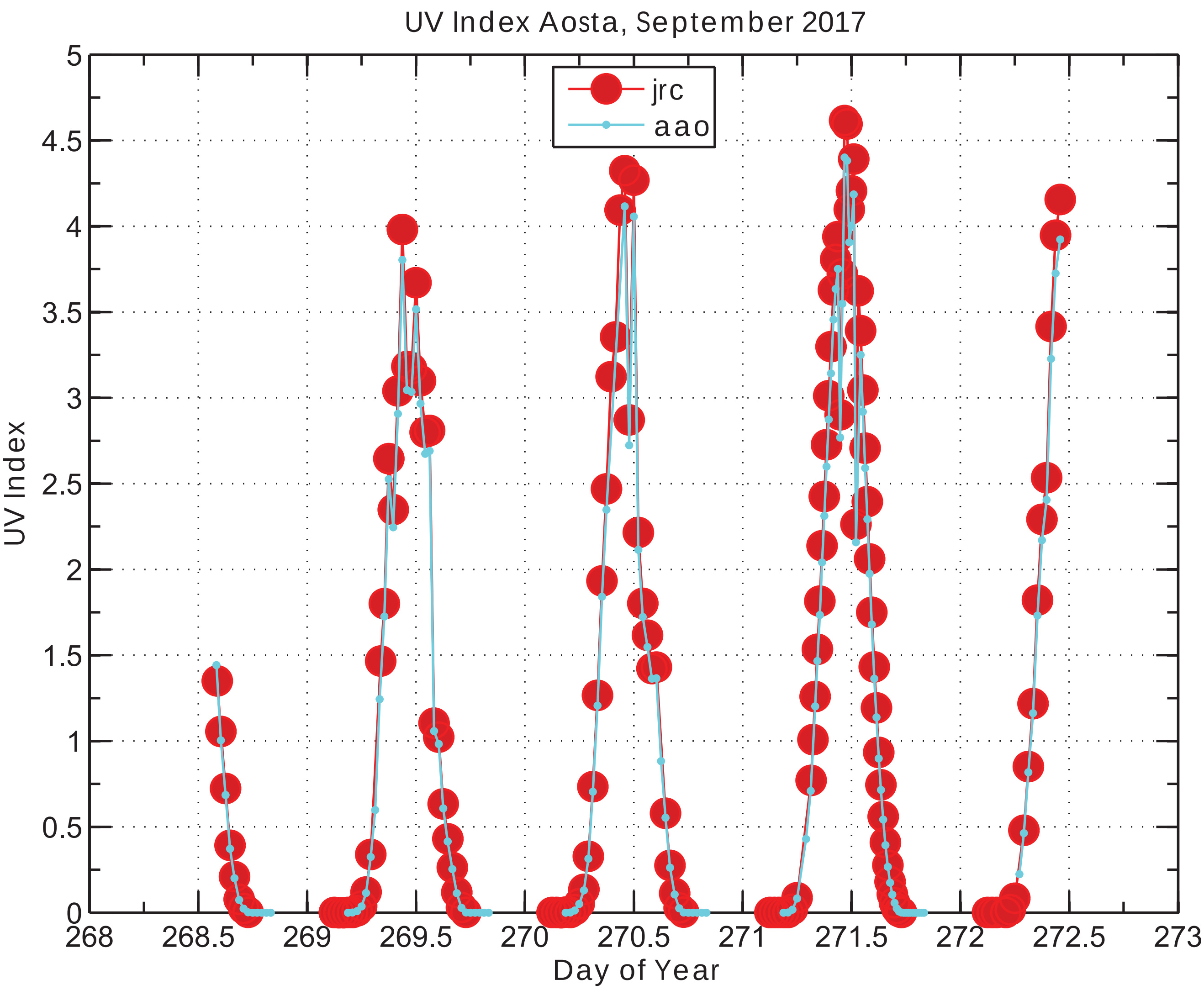


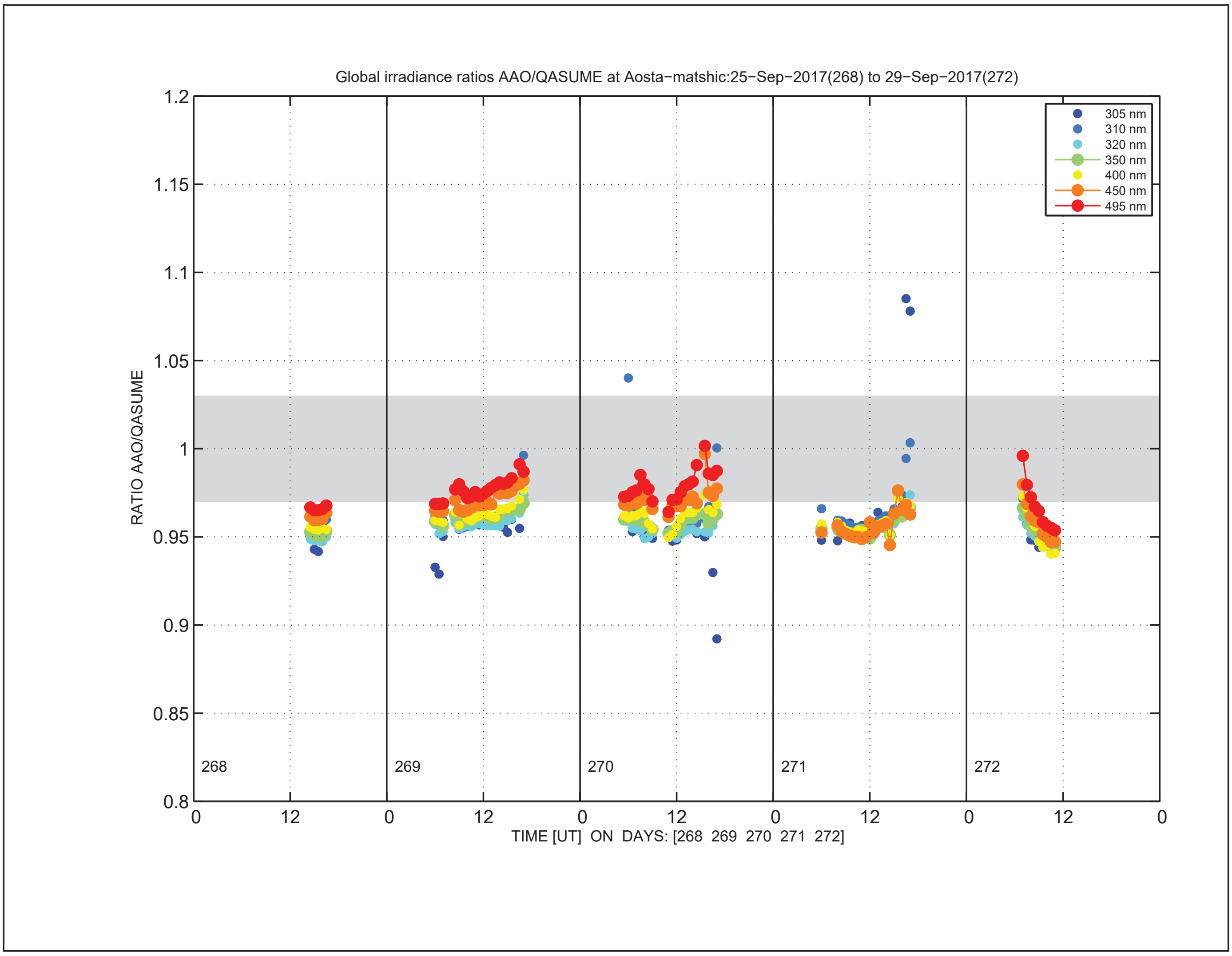
Fig. 5: Spectral ratio model/AAO.

6. In the past months, sudden shifts of the spectral scale were observed. Misalignments between the two monochromators in AAO were clearly visible, sometimes, in the ratio between two subsequent calibrations (about one month interval) as spectral oscillations (amplitude +/- 1% and period of 40-50 nm). However, the issue was solved before the audit by realigning the monochromators using a QHT lamp.

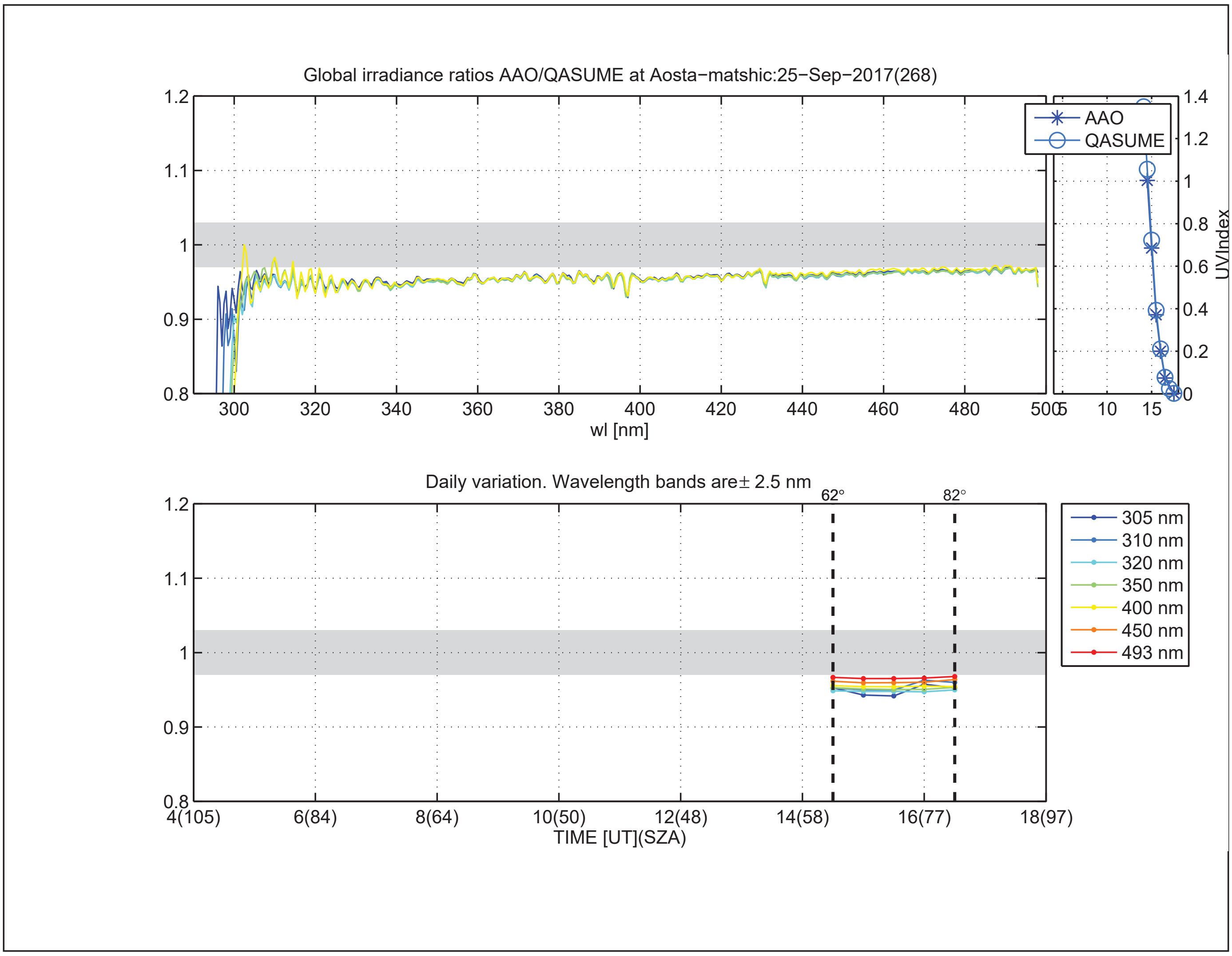
In conclusion, neither the reason of the deviations between QASUME and AAO or the length of the series affected by the issue is perfectly understood at the moment. The development of an optical laboratory for calibrations using 1000W lamps will be of help to resume the traceability chain, however maintenance of the instrument and further comparison must be scheduled for the future.



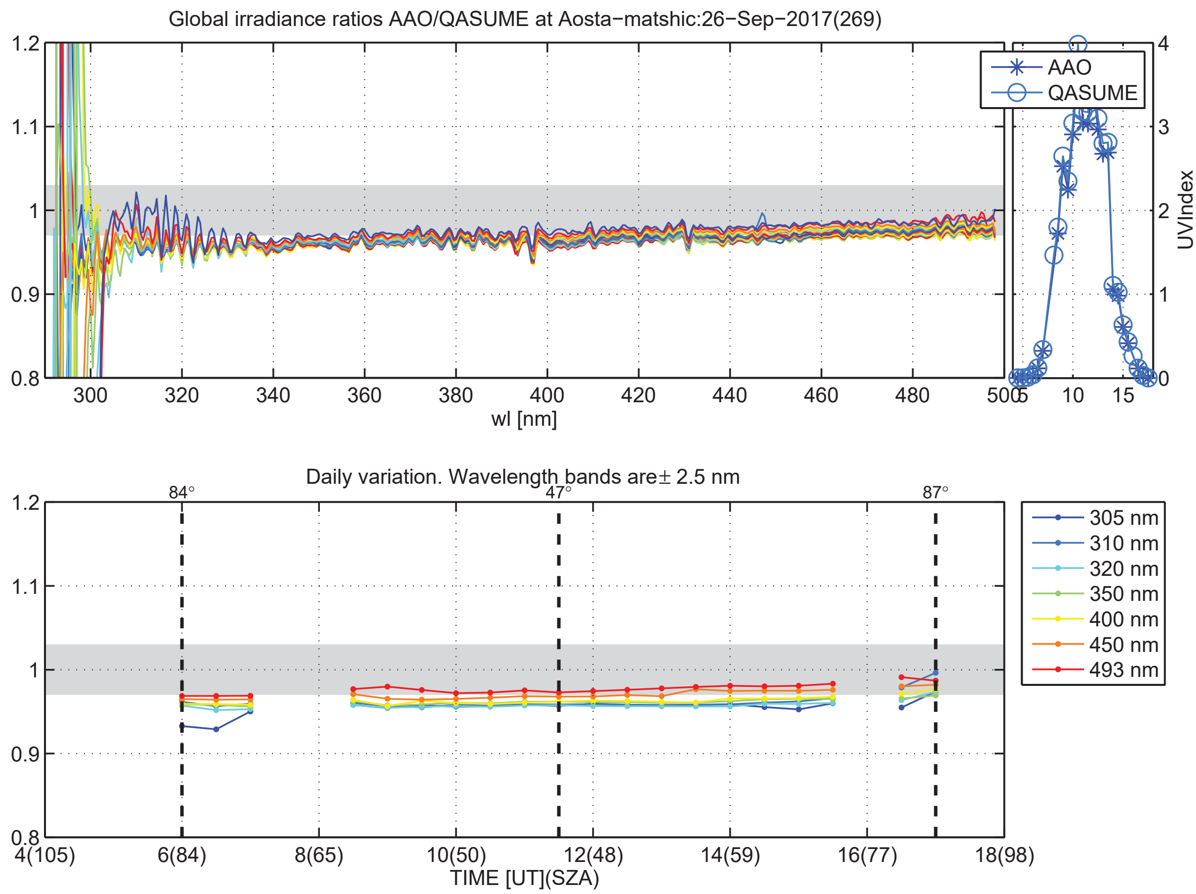
UV Index Aosta, September 2017
jrc
aao
UV Index
Day of Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
268
268.5
269
269.5
270
270.5
271
271.5
272
272.5
273

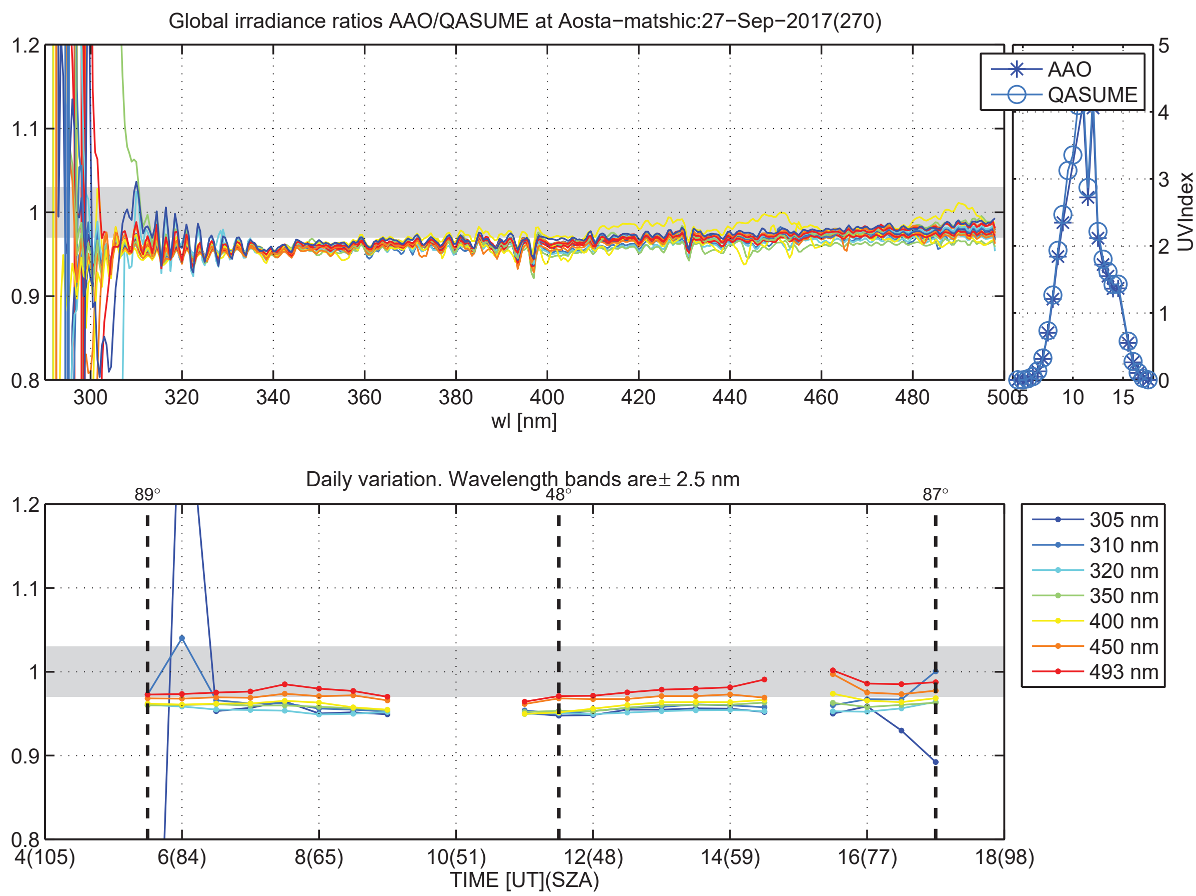


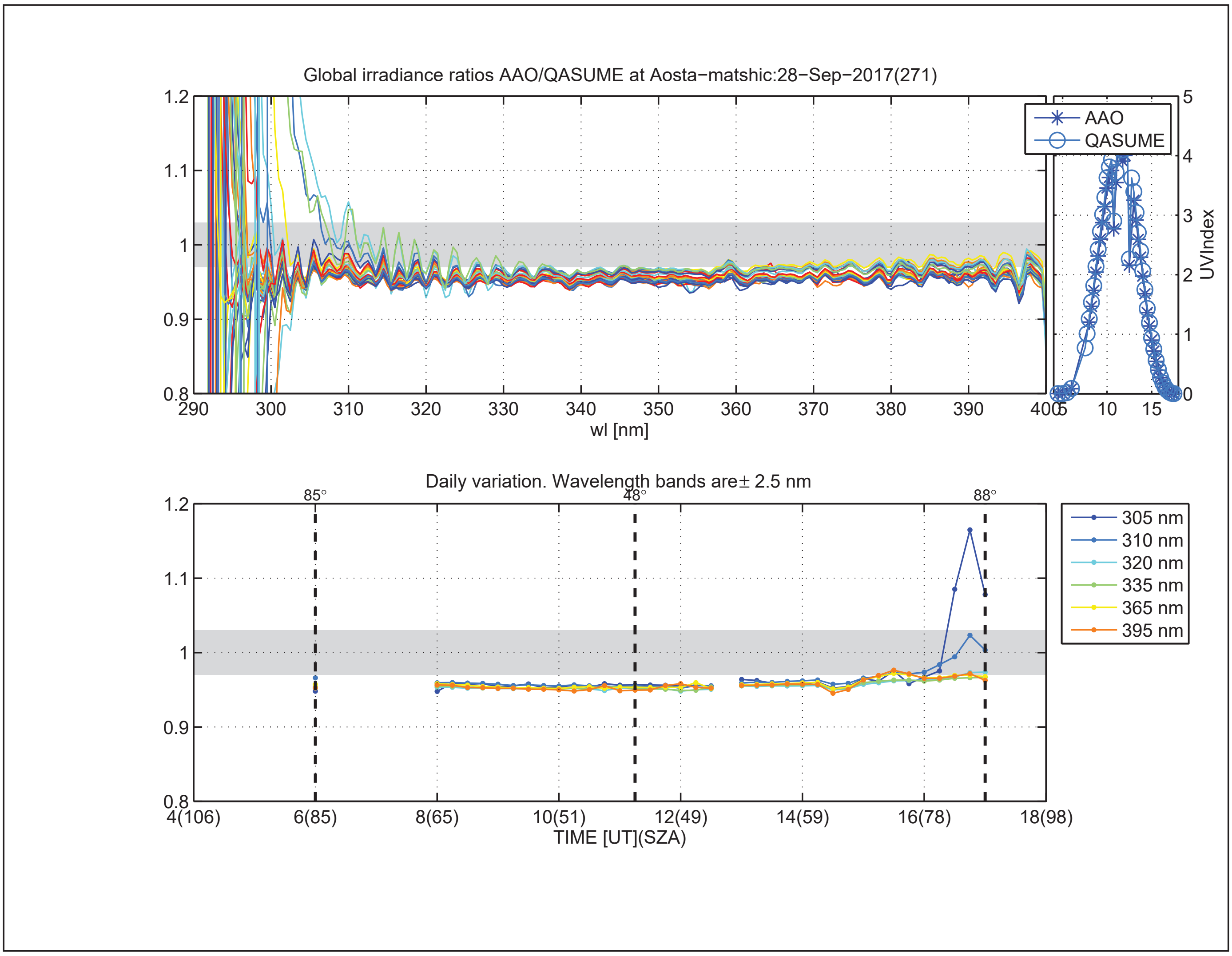
Global irradiance ratios AAO/QASUME at Aosta−matshic:25−Sep−2017(268) to 29−Sep−2017(272)
RATIO AAO/QASUME
TIME [UT] ON DAYS: [268 269 270 271 272]
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
268
269
270
271
272

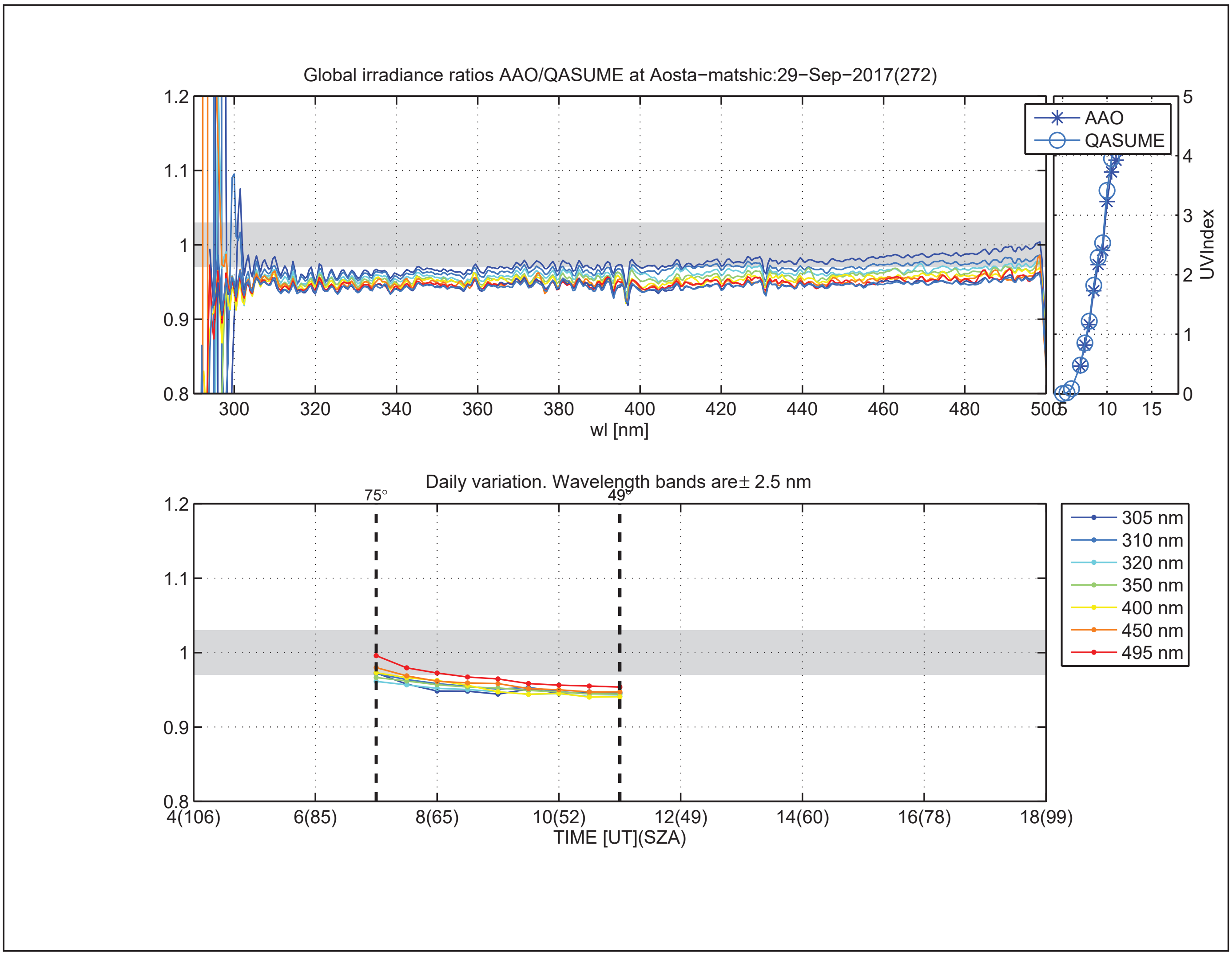


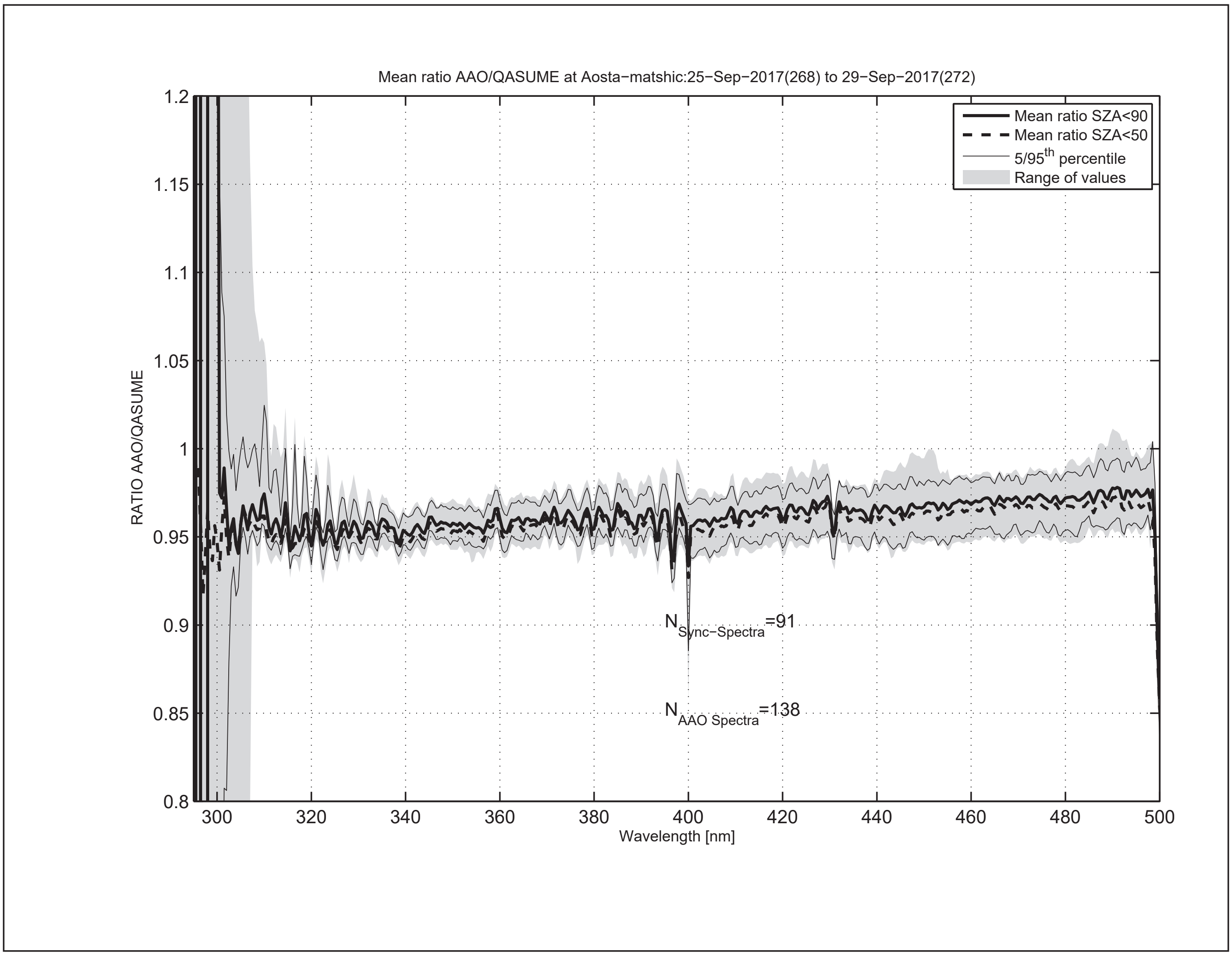
Global irradiance ratios AAO/QASUME at Aosta−matshic:25−Sep−2017(268)
wl [nm]
AAO
QASUME
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
62°
82°
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
493 nm
TIME [UT](SZA)

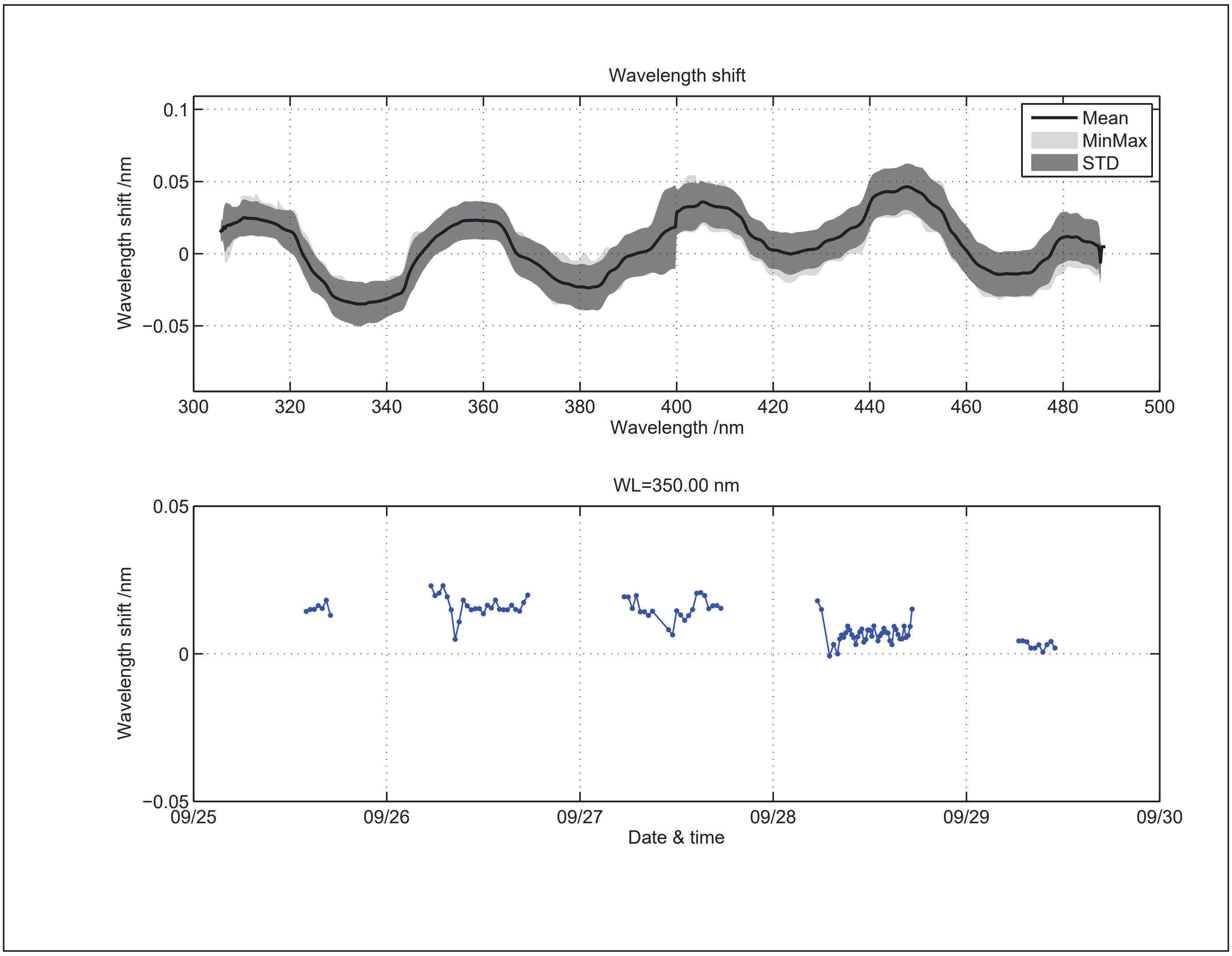

Global irradiance ratios AAO/QASUME at Aosta−matshic:26−Sep−2017(269)
1.2
1.1
1
0.9
0.8
300
320
340
360
380
400
420
440
460
480
500
wl [nm]
AAO
QASUME
5
10
15
0
1
2
3
4
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
84°
47°
87°
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
493 nm
4(105)
6(84)
8(65)
10(50)
12(48)
14(59)
16(77)
18(98)
TIME [UT](SZA)

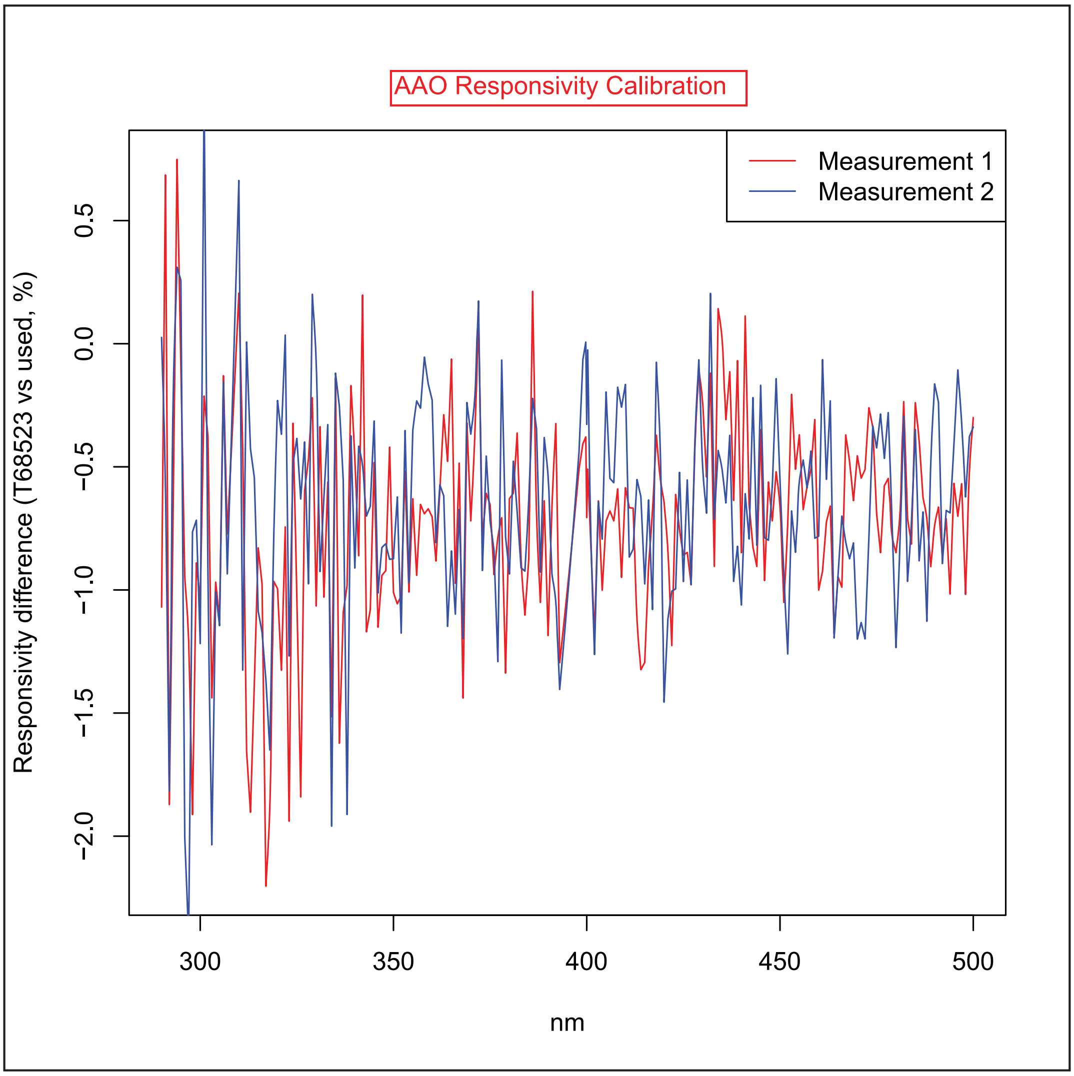

Global irradiance ratios AAO/QASUME at Aosta−matshic:27−Sep−2017(270)
1.2
1.1
1
0.9
0.8
300
320
340
360
380
400
420
440
460
480
500
wl [nm]
AAO
QASUME
5
10
15
0
1
2
3
4
5
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
89°
48°
87°
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
493 nm
4(105)
6(84)
8(65)
10(51)
12(48)
14(59)
16(77)
18(98)
TIME [UT](SZA)


Global irradiance ratios AAO/QASUME at Aosta−matshic:28−Sep−2017(271)
AAO
QASUME
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
85°
48°
88°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
4(106)
6(85)
8(65)
10(51)
12(49)
14(59)
16(78)
18(98)
TIME [UT](SZA)

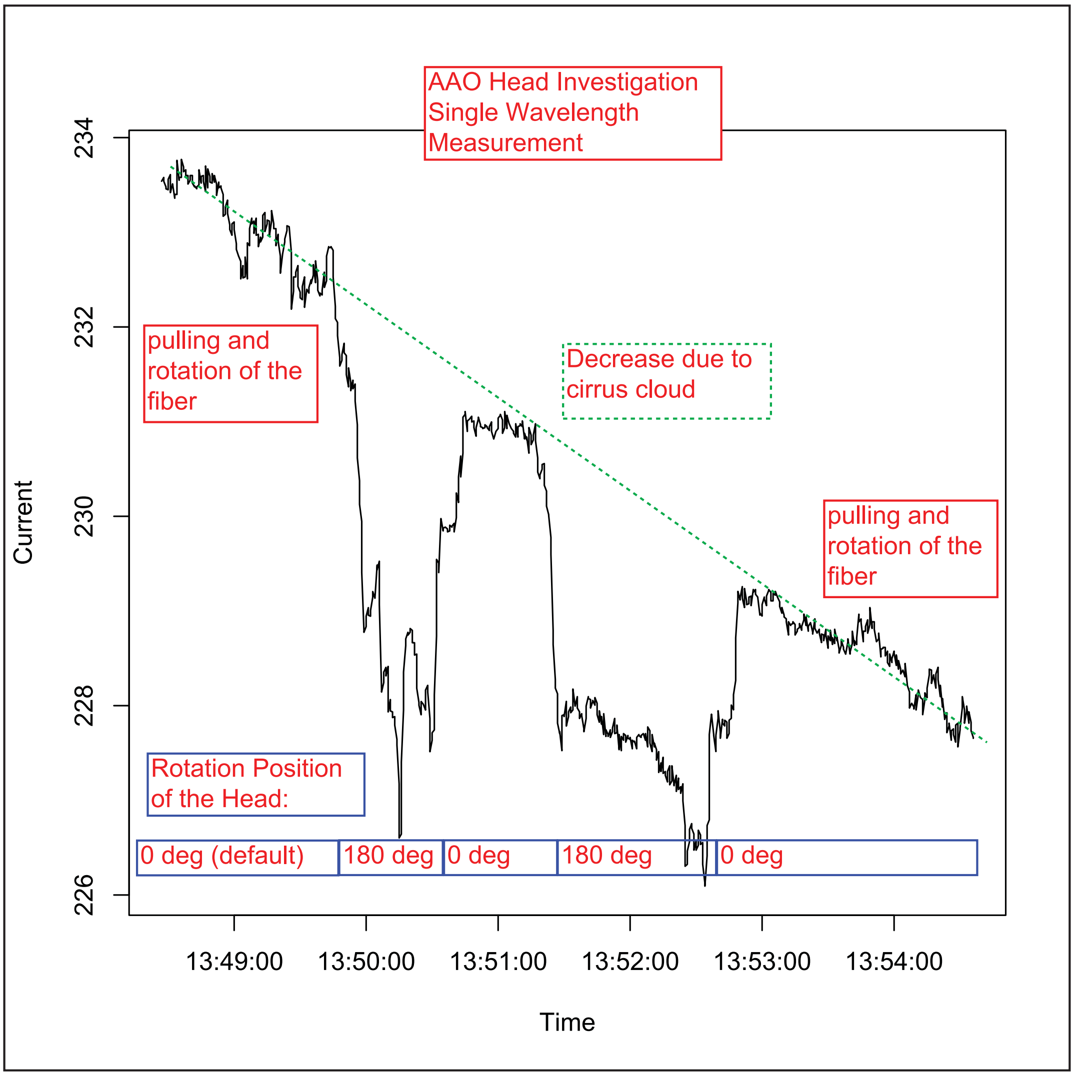

Global irradiance ratios AAO/QASUME at Aosta−matshic:29−Sep−2017(272)
AAO
QASUME
wl [nm]
UVIndex
Daily variation. Wavelength bands are± 2.5 nm
75°
49°
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
4(106)
6(85)
8(65)
10(52)
12(49)
14(60)
16(78)
18(99)
TIME [UT](SZA)


Mean ratio AAO/QASUME at Aosta−matshic:25−Sep−2017(268) to 29−Sep−2017(272)
Mean ratio SZA<90
Mean ratio SZA<50
5/95th percentile
Range of values
RATIO AAO/QASUME
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
N Sync−Spectra =91
N AAO Spectra =138
300
320
340
360
380
400
420
440
460
480
500
Wavelength [nm]

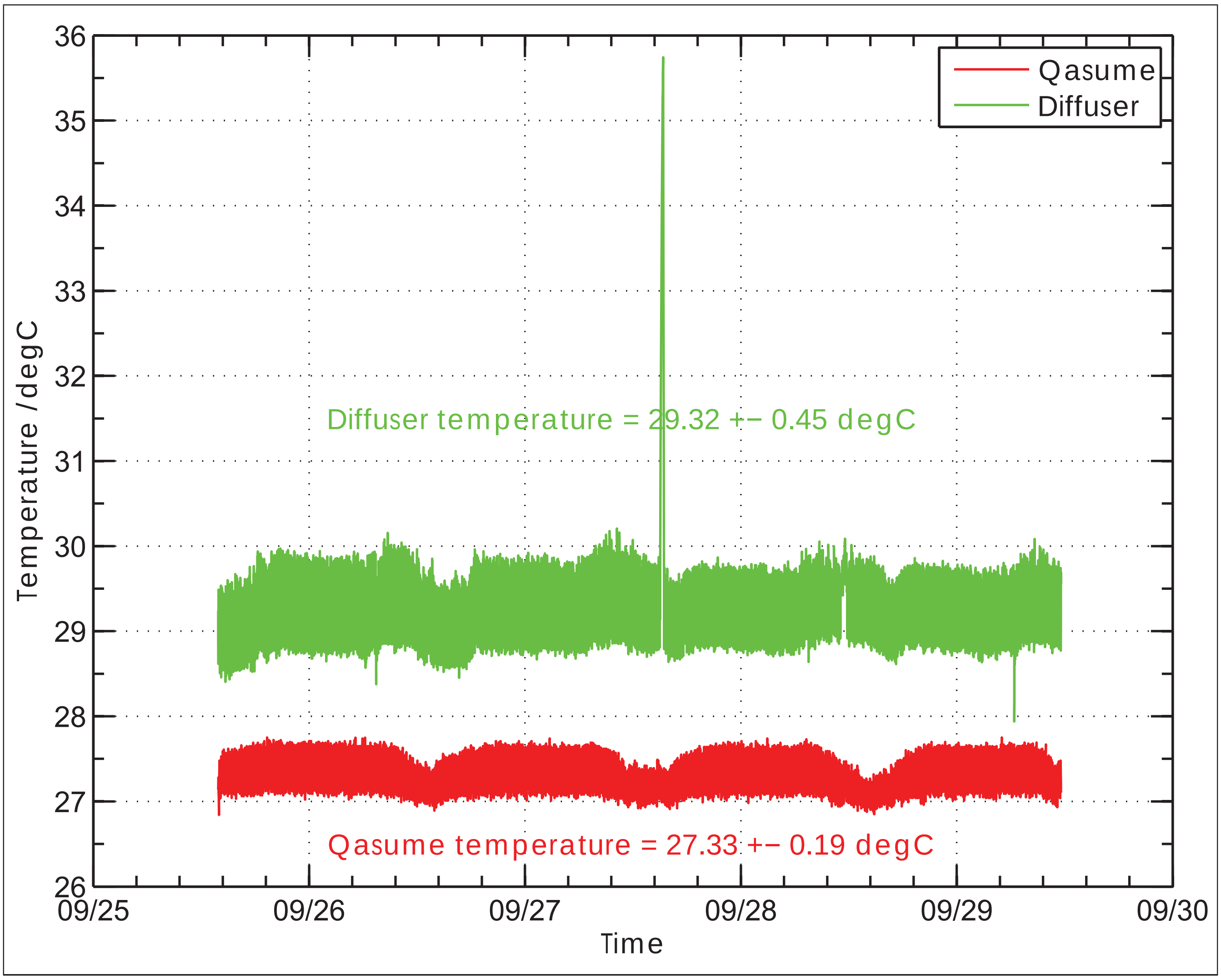

Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
0.1
0.05
0
−0.05
300
320
340
360
380
400
420
440
460
480
500
Wavelength /nm
WL=350.00 nm
0.05
0
−0.05
09/25
09/26
09/27
09/28
09/29
09/30
Date & time



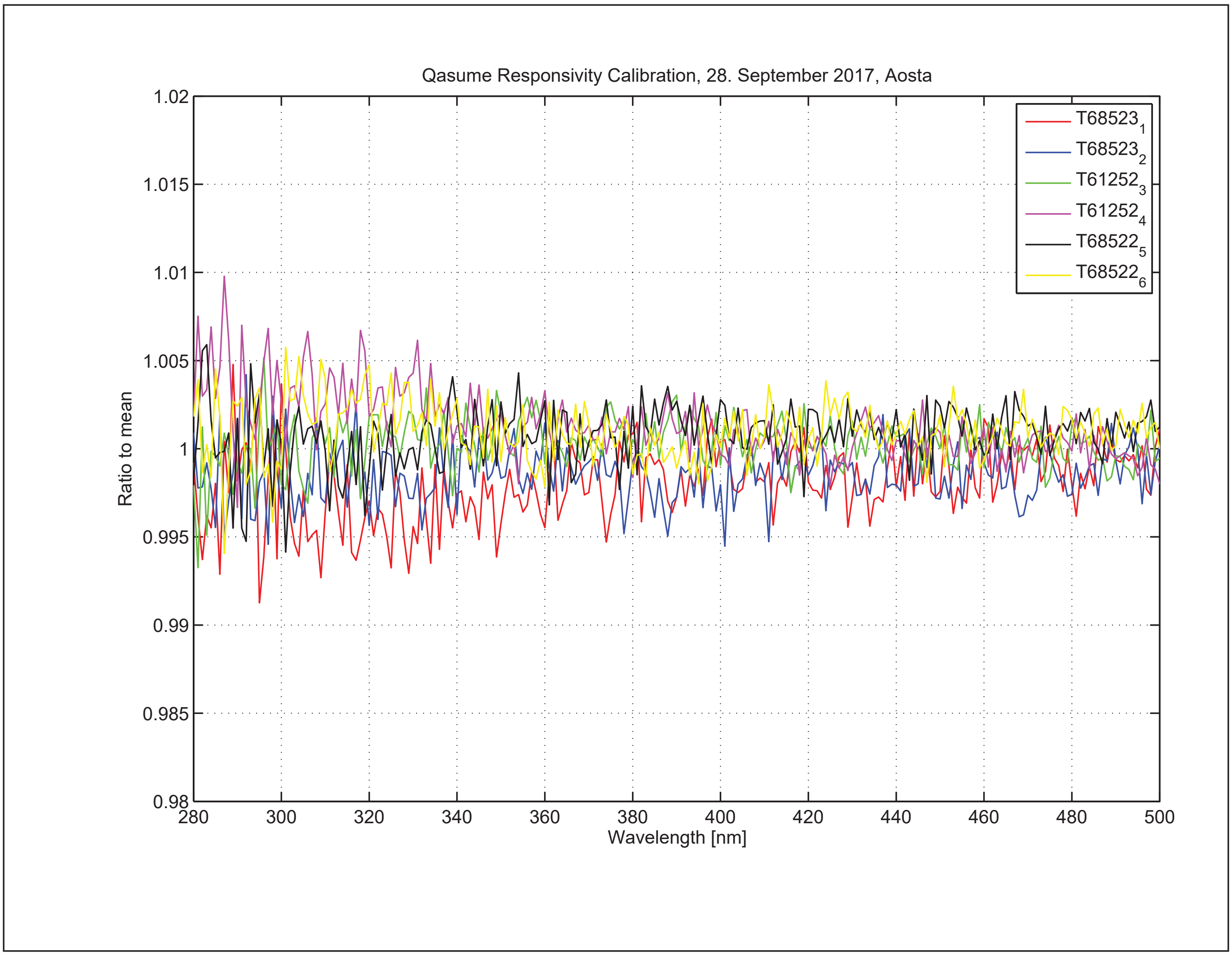
AAO Responsivity Calibration
Measurement 1
Measurement 2
Responsivity difference (T68523 vs used, %)
0.5
0.0
−0.5
−1.0
−1.5
−2.0
300
350
400
450
500
nm



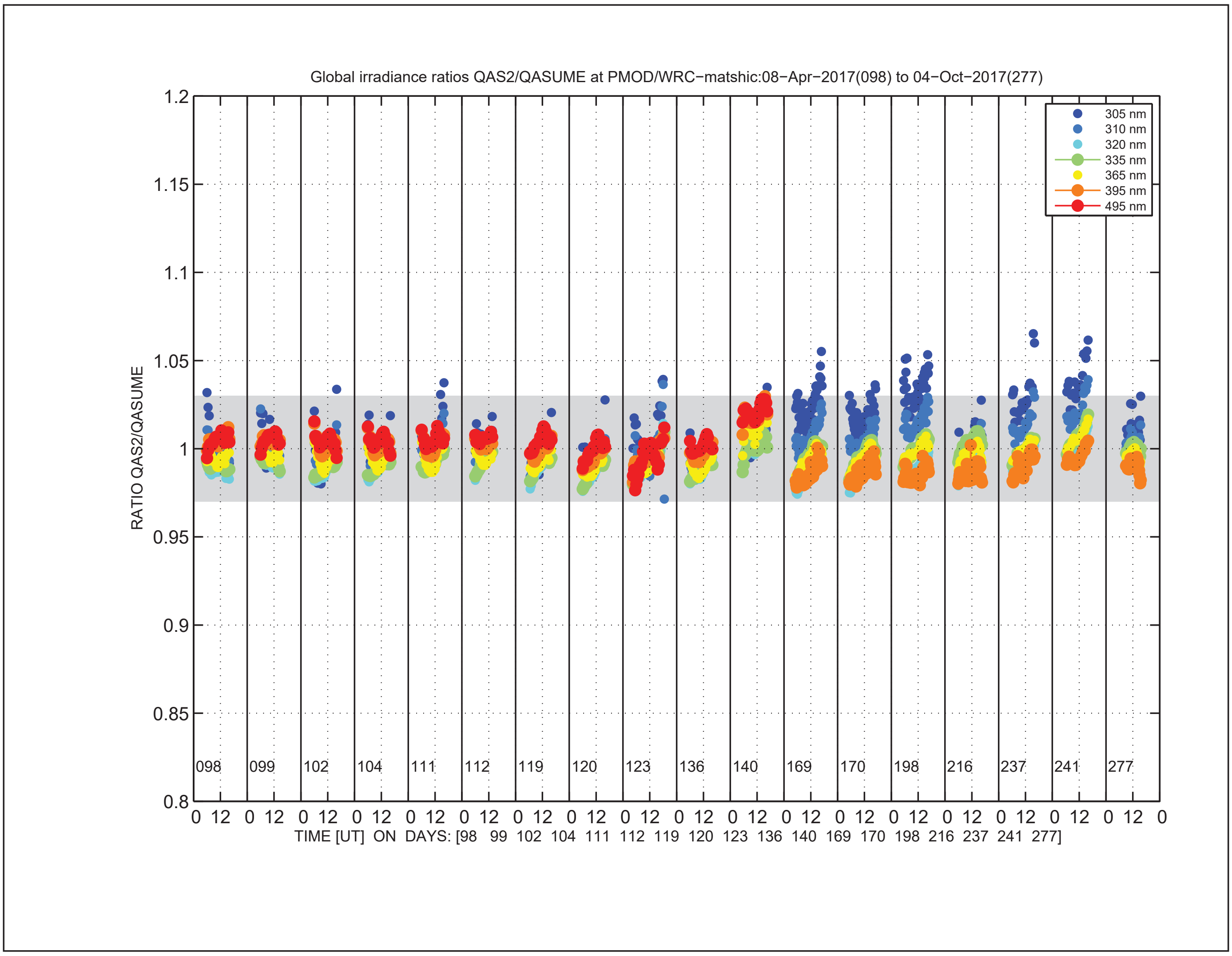
AAO Head Investigation
Single Wavelength
Measurement
pulling and
rotation of the
fiber
Decrease due to
cirrus cloud
pulling and
rotation of the
fiber
Rotation Position
of the Head:
0 deg (default)
180 deg
0 deg
180 deg
0 deg
Current
234
232
230
228
226
13:49:00
13:50:00
13:51:00
13:52:00
13:53:00
13:54:00
Time

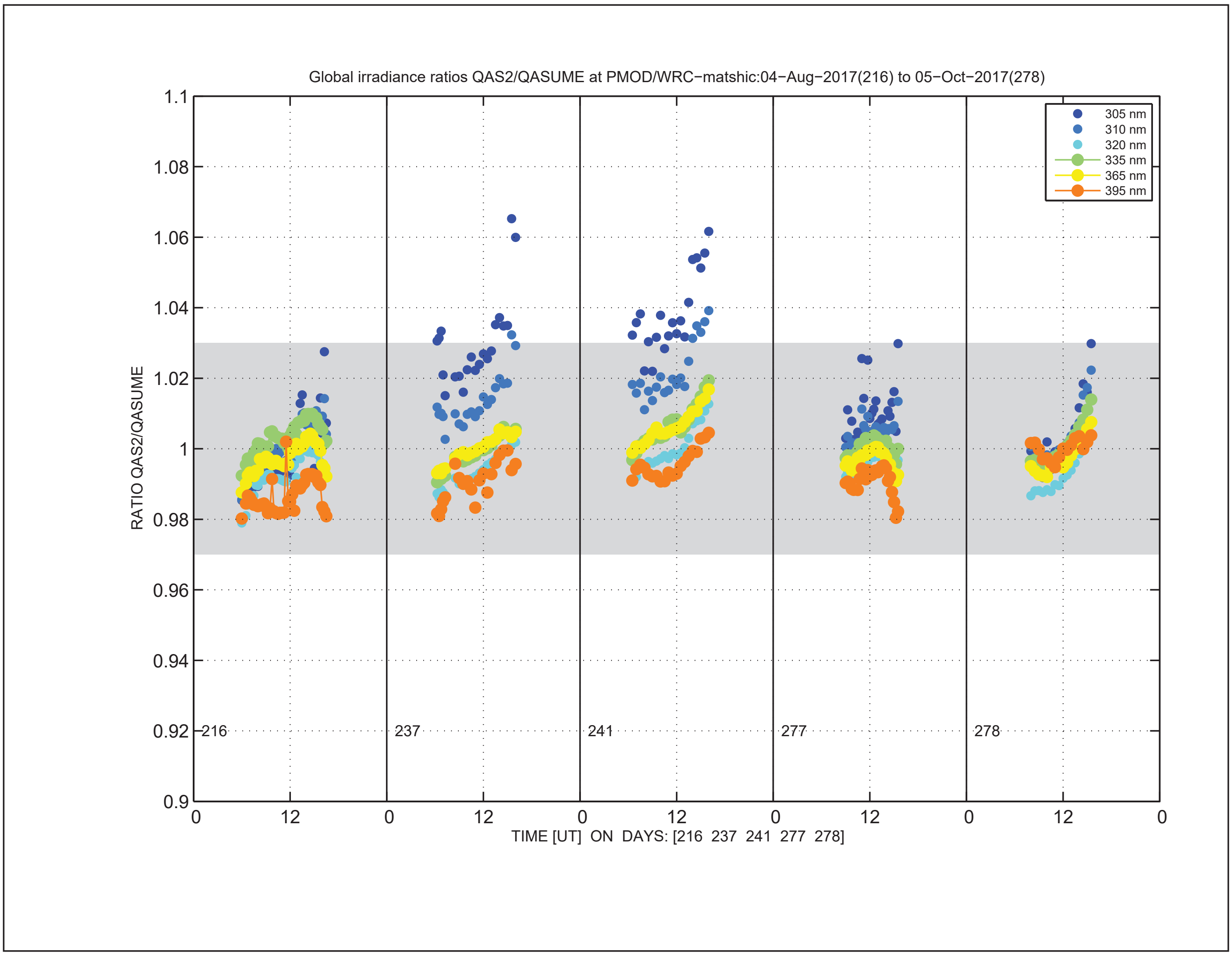


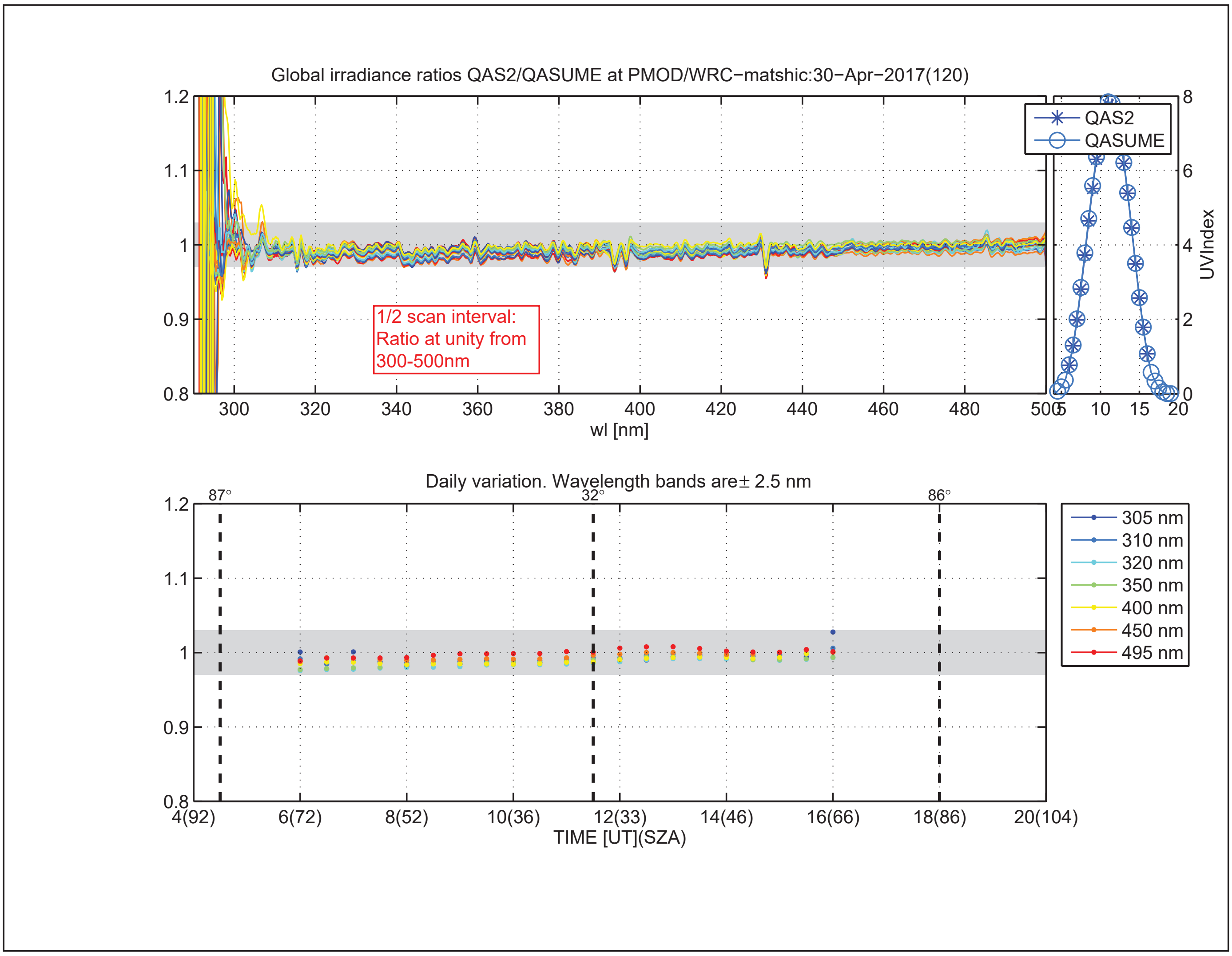
Qasume
Diffuser
Diffuser temperature = 29.32 +− 0.45 degC
Qasume temperature = 27.33 +− 0.19 degC
Temperature /degC
Time
09/25
09/26
09/27
09/28
09/29
09/30

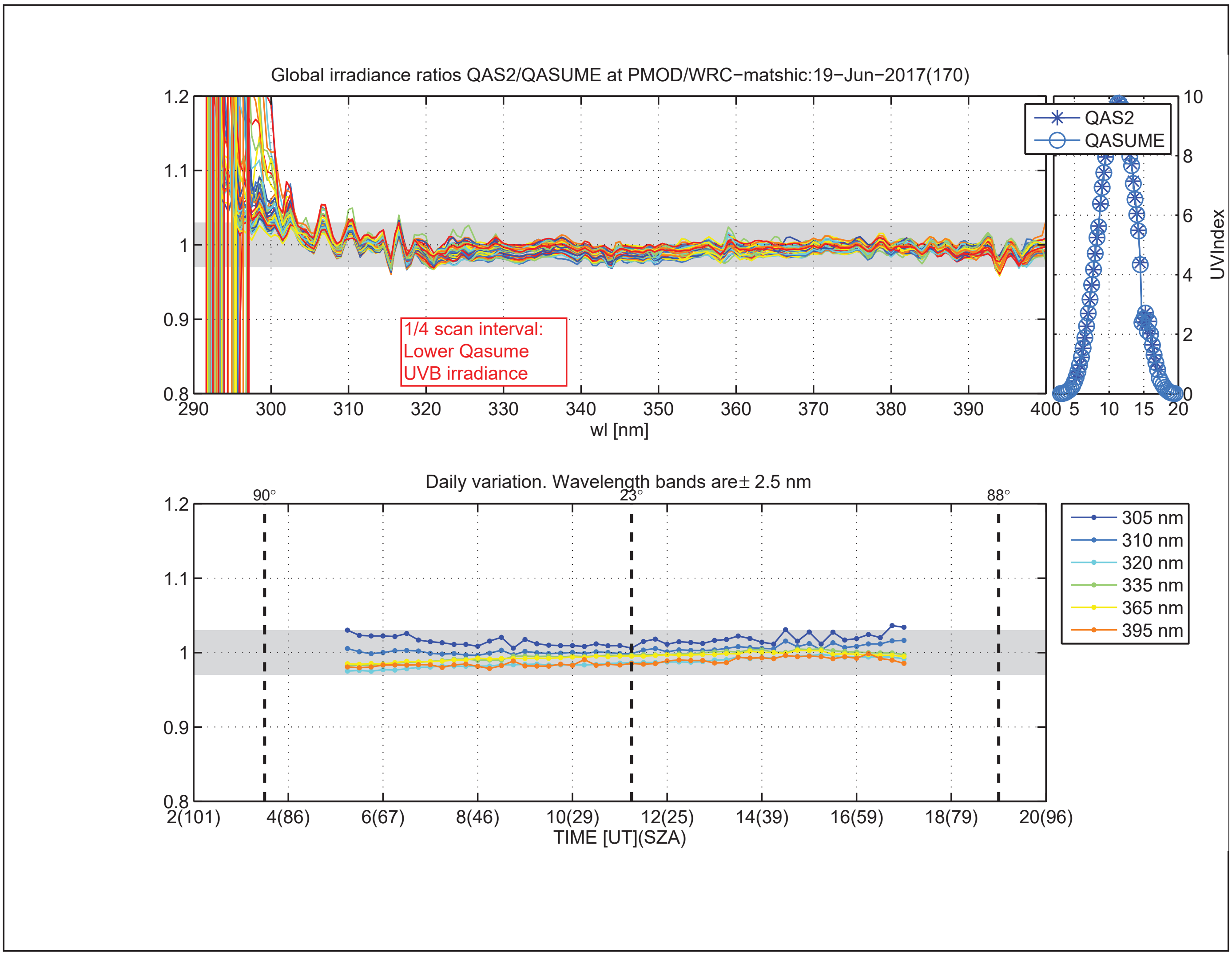


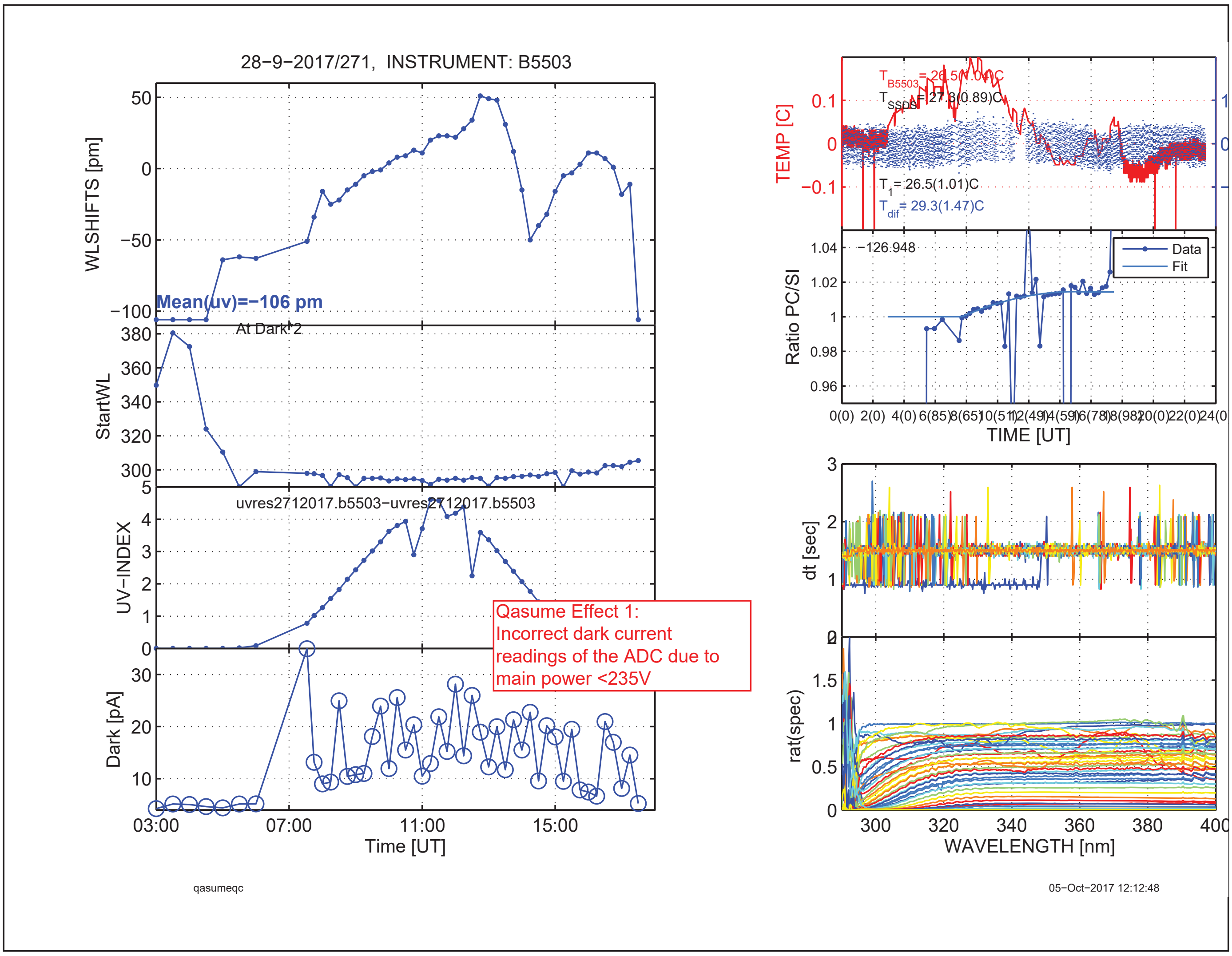
Qasume Responsivity Calibration, 28. September 2017, Aosta
T68523 1
T68523 2
T61252 3
T61252 4
T68522 5
T68522 6
Ratio to mean
Wavelength [nm]


Global irradiance ratios QAS2/QASUME at PMOD/WRC−matshic:08−Apr−2017(098) to 04−Oct−2017(277)
RATIO QAS2/QASUME
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
495 nm
098 099 102 104 111 112 119 120 123 136 140 169 170 198 216 237 241 277
TIME [UT] ON DAYS: [98 99 102 104 111 112 119 120 123 136 140 169 170 198 216 237 241 277]

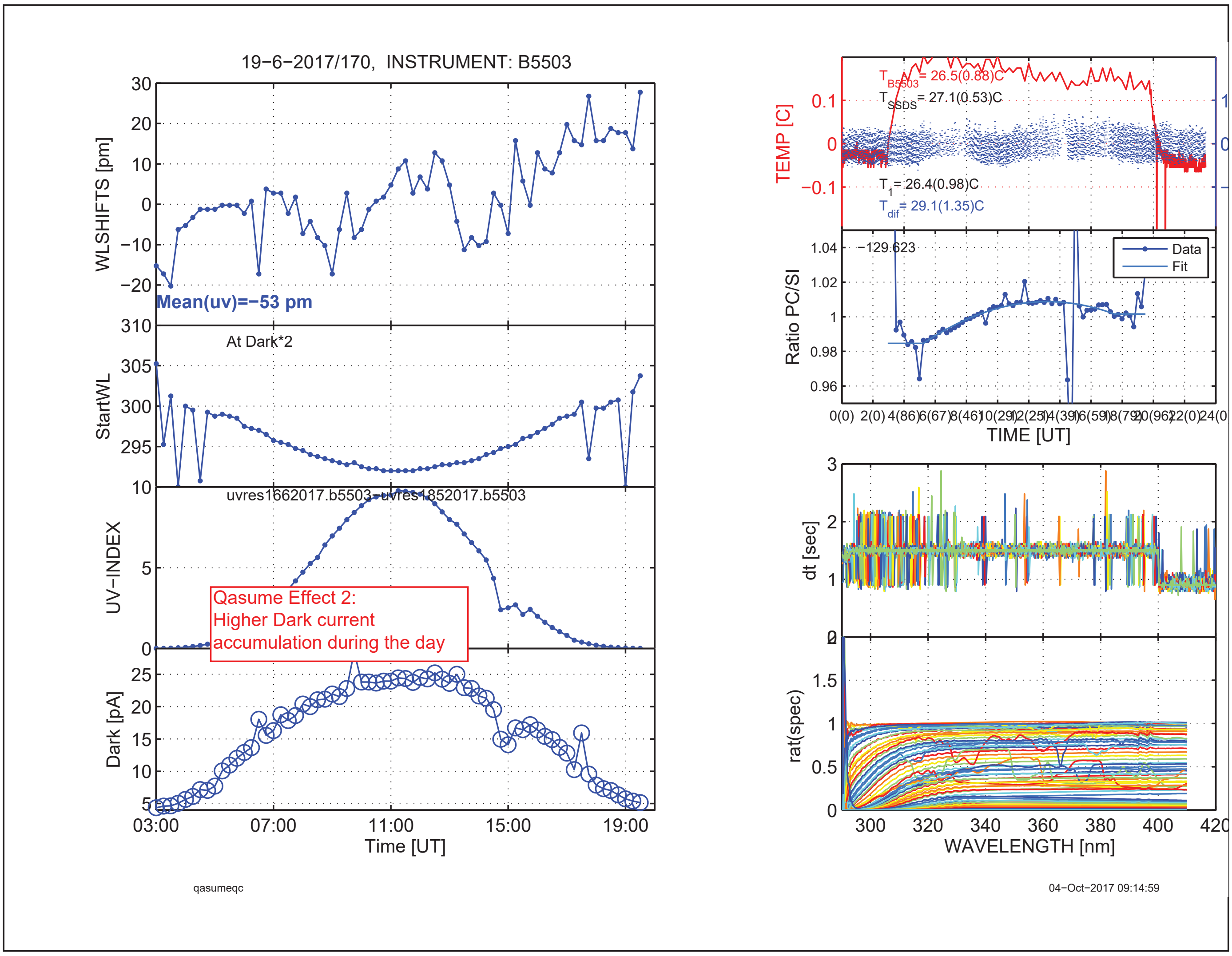

Global irradiance ratios QAS2/QASUME at PMOD/WRC−matshic:04−Aug−2017(216) to 05−Oct−2017(278)
RATIO QAS2/QASUME
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
216 237 241 277 278
TIME [UT] ON DAYS: [216 237 241 277 278]


Global irradiance ratios QAS2/QASUME at PMOD/WRC−matshic:30−Apr−2017(120)
QAS2
QASUME
UVIndex
1/2 scan interval:
Ratio at unity from
300-500nm
wl [nm]
Daily variation. Wavelength bands are± 2.5 nm
87°
32°
86°
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
TIME [UT](SZA)

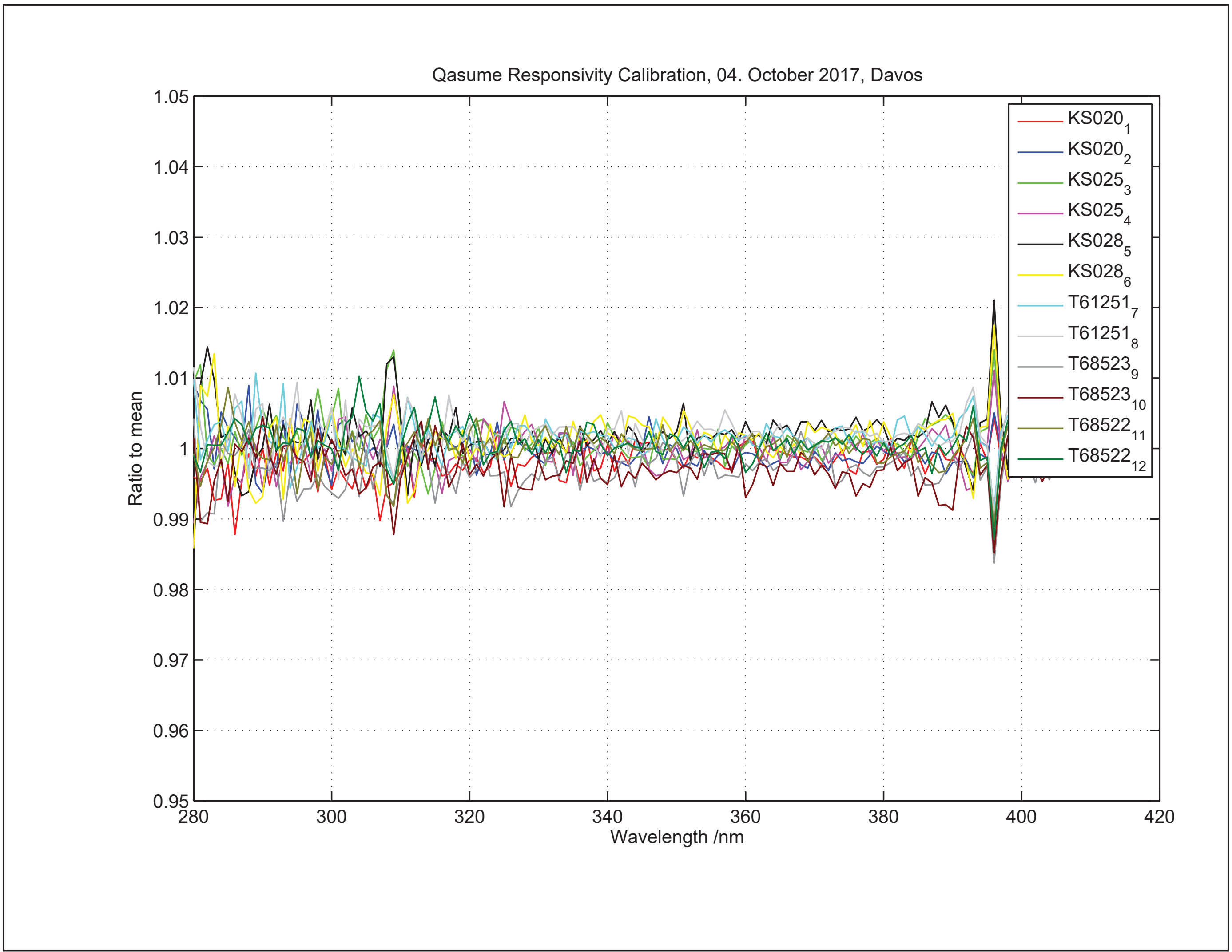

Global irradiance ratios QAS2/QASUME at PMOD/WRC−matshic:19−Jun−2017(170)
QAS2
QASUME
UVIndex
1/4 scan interval:
Lower Qasume
UVB irradiance
wl [nm]
Daily variation. Wavelength bands are± 2.5 nm
90°
23°
88°
305 nm
310 nm
320 nm
335 nm
365 nm
395 nm
TIME [UT](SZA)



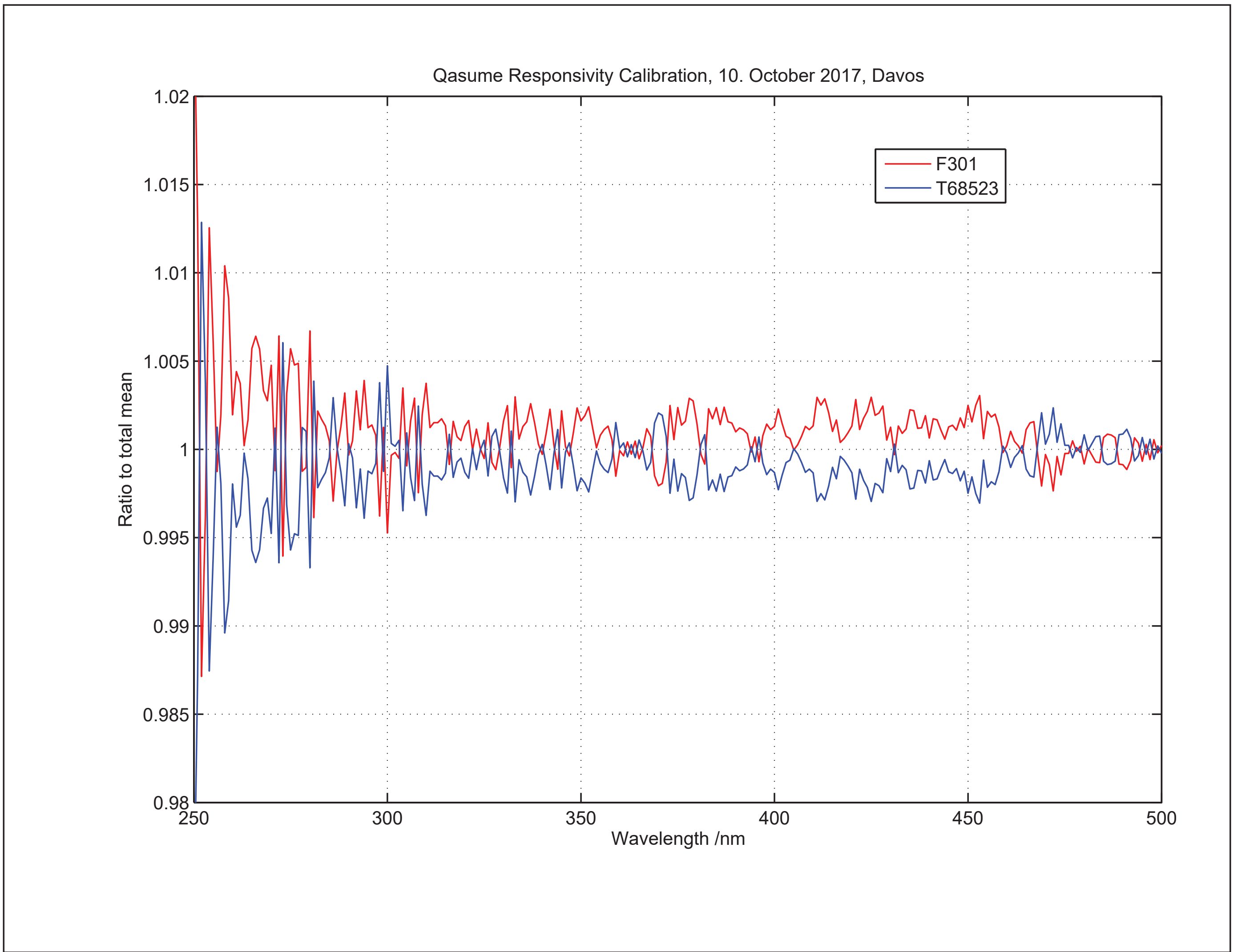
28−9−2017/271, INSTRUMENT: B5503
WLSHIFTS [pm]
Mean(uv)=−106 pm
StartWL
At Dark*2
UV−INDEX
uvres2712017.b5503−uvres2712017.b5503
Dark [pA]
Time [UT]
Qasume Effect 1:
Incorrect dark current
readings of the ADC due to
main power <235V
TEMP [C]
T1 = 26.5(1.01)C
Tdif = 29.3(1.47)C
Ratio PC/SI
−126.948
Data
Fit
TIME [UT]
dt [sec]
rat(spec)
WAVELENGTH [nm]
qasumeqc
05−Oct−2017 12:12:48



19−6−2017/170, INSTRUMENT: B5503
WLSHIFTS [pm]
Mean(uv)=−53 pm
StartWL
At Dark*2
UV−INDEX
uvres1662017.b5503−uvres1852017.b5503
Qasume Effect 2:
Higher Dark current
accumulation during the day
Dark [pA]
Time [UT]
TEMP [C]
TB5503 = 26.5(0.88)C
TSSDS = 27.1(0.53)C
T1 = 26.4(0.98)C
Tdif = 29.1(1.35)C
Ratio PC/SI
−129.623
Data
Fit
TIME [UT]
dt [sec]
rat(spec)
WAVELENGTH [nm]
qasumeqc
04−Oct−2017 09:14:59



Qasume Responsivity Calibration, 04. October 2017, Davos
Ratio to mean
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
KS020₁
KS020₂
KS025₃
KS025₄
KS028₅
KS028₆
T61251₇
T61251₈
T68523₉
T68523₁₀
T68522₁₁
T68522₁₂



Qasume Responsivity Calibration, 10. October 2017, Davos
Ratio to total mean
Wavelength /nm
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
250
300
350
400
450
500
F301
T68523


Qasume
AAO