Protocol of the intercomparison at ARPA, Aosta, Italy in June-July 2025 with the travelling reference spectroradiometer QASUME from PMOD/WRC

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Local Operator: Henri Diémoz and Annachiara Bellini

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 5:00 UT and 17:20 UT have been analysed.

QASUME was installed at ARPA Aosta 30 June 2025. 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 5 days, from the afternoon of June 30 to the morning of July 4, 2025.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Four lamps (T68523, T61251, T153061 and T153062) were used to obtain a 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 31.5±0.4 °C and the diffuser head was heated to a temperature of 29.2±1.2 °C.
The wavelength shifts relative to the QASUMEFTS (Gröbner et al., 2017) 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 second between each wavelength increment.

DOY	Date	DAY	Weather	Comment (times are in UT)
181	30-Jun	Monday	Mostly diffuse sky	Installed at 7:15 13:27 calibration T153062
182	01-Jul	Tuesday	Clear sky in the morning 14:00 Cumulus Cloud passing Diffuse sky after 16:00	13:26 Calibration T153061 14:24 Calibration T61251
183	02-Jul	Wednesday	Diffuse sky 11-14:30 thinner cloud layer with partially direct sun	09:45 Calibration T153061 09:45 Calibration Check AAO 10:05 Calibration T68523 10:36 Calibration T61251
184	03-Jul	Thursday	Mix of sun and clouds No direct sun from 12-16:40	09:25 Calibration T68523 09:45 Calibration T153062 15:59 AAO Head: Rotation by +180°
185	04-Jul	Friday	Clear sky in the morning Cumulus clouds after 8:30	08:25 AAO Head: Rotation by -180° 09:25 Calibration T153062 10:00 QASUME OFF

Results:

In total 114 synchronised simultaneous solar spectra from QASUME and AAO are available from the measurement period. Measurements between 5:00 UT and 17:20 UT have been analysed (SZA smaller than 80°).

The spectra from AAO were corrected for wavelength shift and convolved with a 1 nm triangular slit function before being submitted for the calibration.

Conclusions:

1. The spectral ratios between AAO and QASUME are on average at unity with a diurnal variability of less than ±3%.
2. During the scan with direct solar irradiance in the morning a small cosine error effect is revealed through the comparison to QASUME. This can also be seen in the change from direct to total diffuse irradiance at 14:00 UT on day 182. A clear-sky cosine correction to the AAO data was attempted, but it didn't improve the comparison.
3. The rotation test of the AAO input optic from 16:00 (183) to 8:25 (184) didn't reveal any azimuthal asymmetry of the input optic.

Summary:

The audit showed that the UV measurements performed at ARPA-Aosta with the AAO spectroradiometer are within the combined expanded uncertainty:

$$U_{comp} = \mathrm{sqrt}(U_{qas}^2 + U_{AAO}^2)$$

With U_{qas} = 1.74% and U_{qas} = 7.34% (λ<310 nm) (Hülsen et al., 2016). U_{AAO} was estimated to be 4%.

Comparison to previous QASUME site visits

The stability of AAO was assessed by comparing QASUME visits performed since 2006. As seen in figure 1, the campaign average ratio to QASUME has been stable to ±2%, except for the comparison performed in 2017 (the issue was explained in detail by Fountoulakis et al., 2020, ESSD and AAO the spectra were post-corrected accordingly.

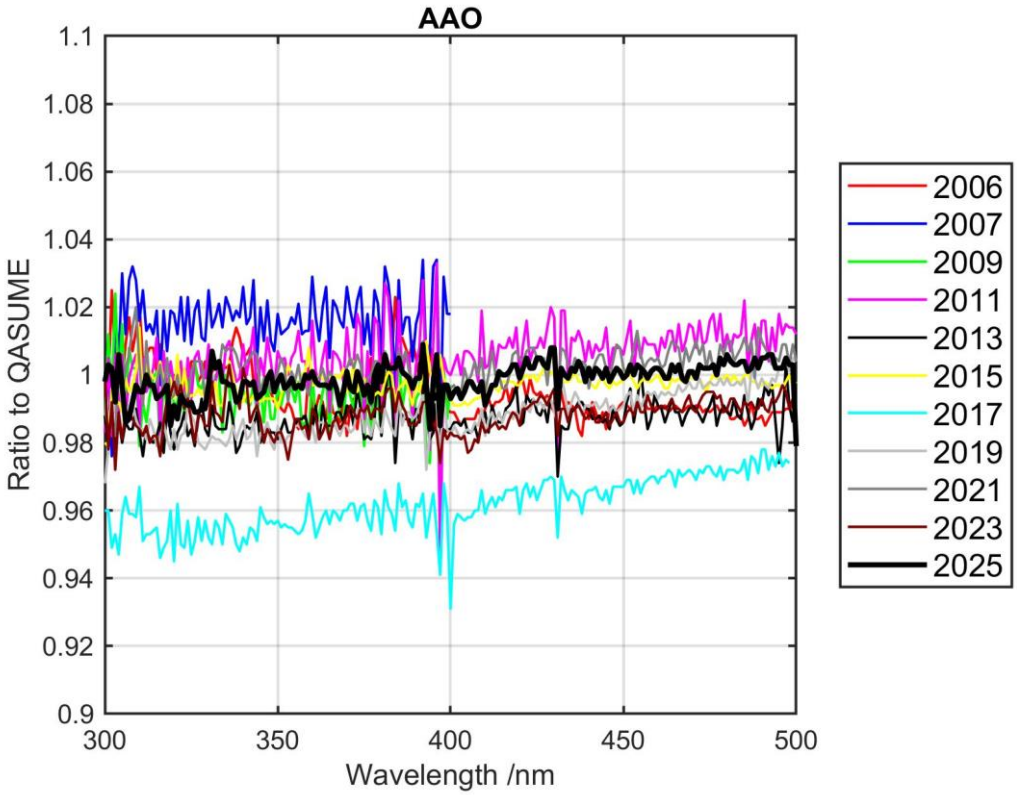


Figure 1 solar spectral ratios of AAO to QASUME averaged over each QASUME site visit.

References:

Fountoulakis, I., Diémoz, H., Siani, A. M., Hülsen, G., and **Gröbner, J**.: Monitoring of solar spectral ultraviolet irradiance in Aosta, Italy, Earth Syst. Sci. Data, 12, 2787–2810, https://doi.org/10.5194/essd-12-2787-2020, 2020.

J. Gröbner, I. Kröger, L. Egli, G. Hülsen, S. Riechelmann, and P. Sperfeld, “The high-resolution extraterrestrial solar spectrum (QASUMEFTS) determined from ground-based solar irradiance measurements", Atmos. Meas. Tech., 10, 3375-3383, 2017

G. Hülsen, J. Gröbner, S. Nevas, P. Sperfeld, L. Egli, G. Porrovecchio, and M. Smid, “Traceability of solar UV measurements using the Qasume reference spectroradiometer", Appl. Opt. 55, 7265-7275, 2016.

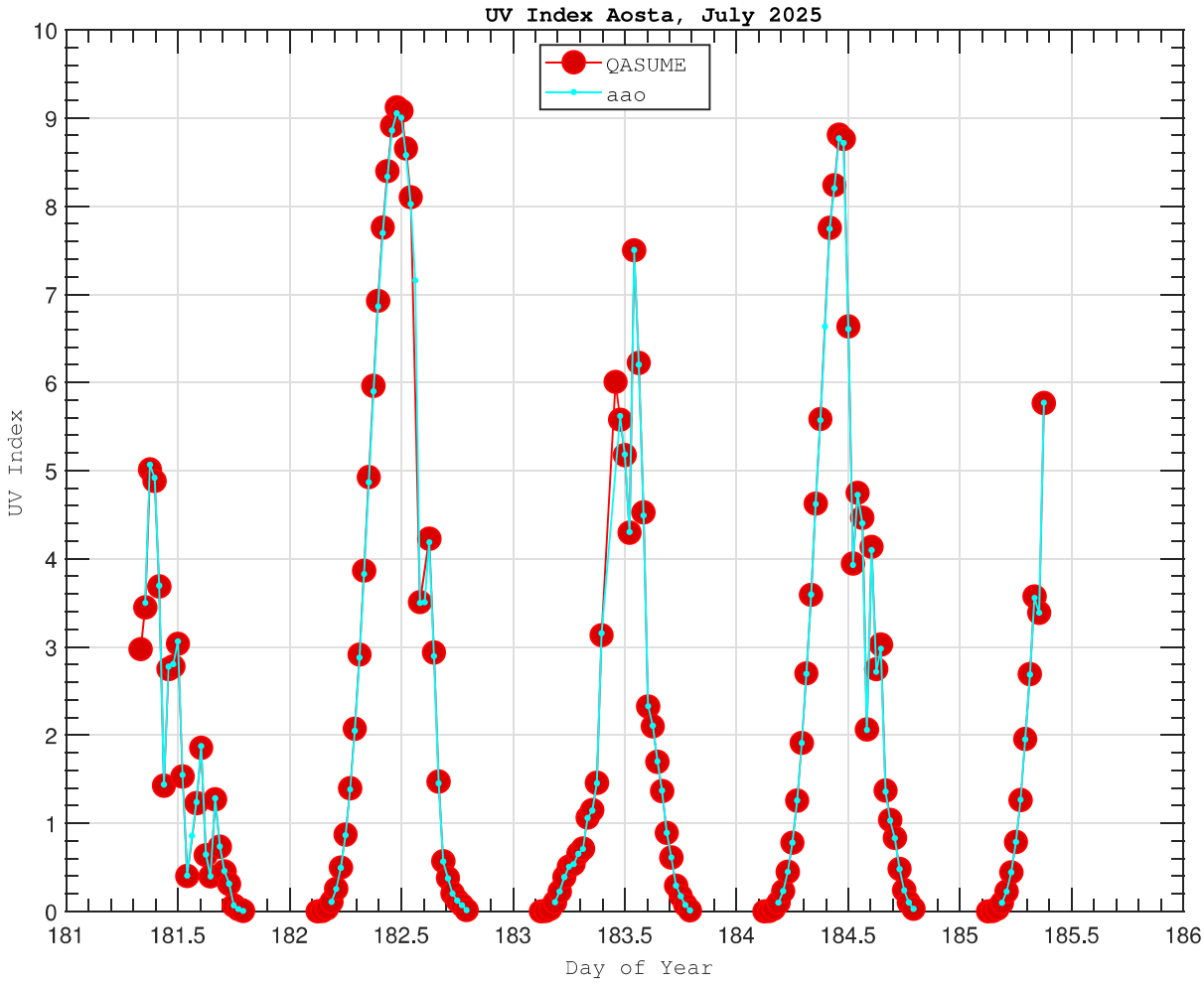
Comments from the operator:

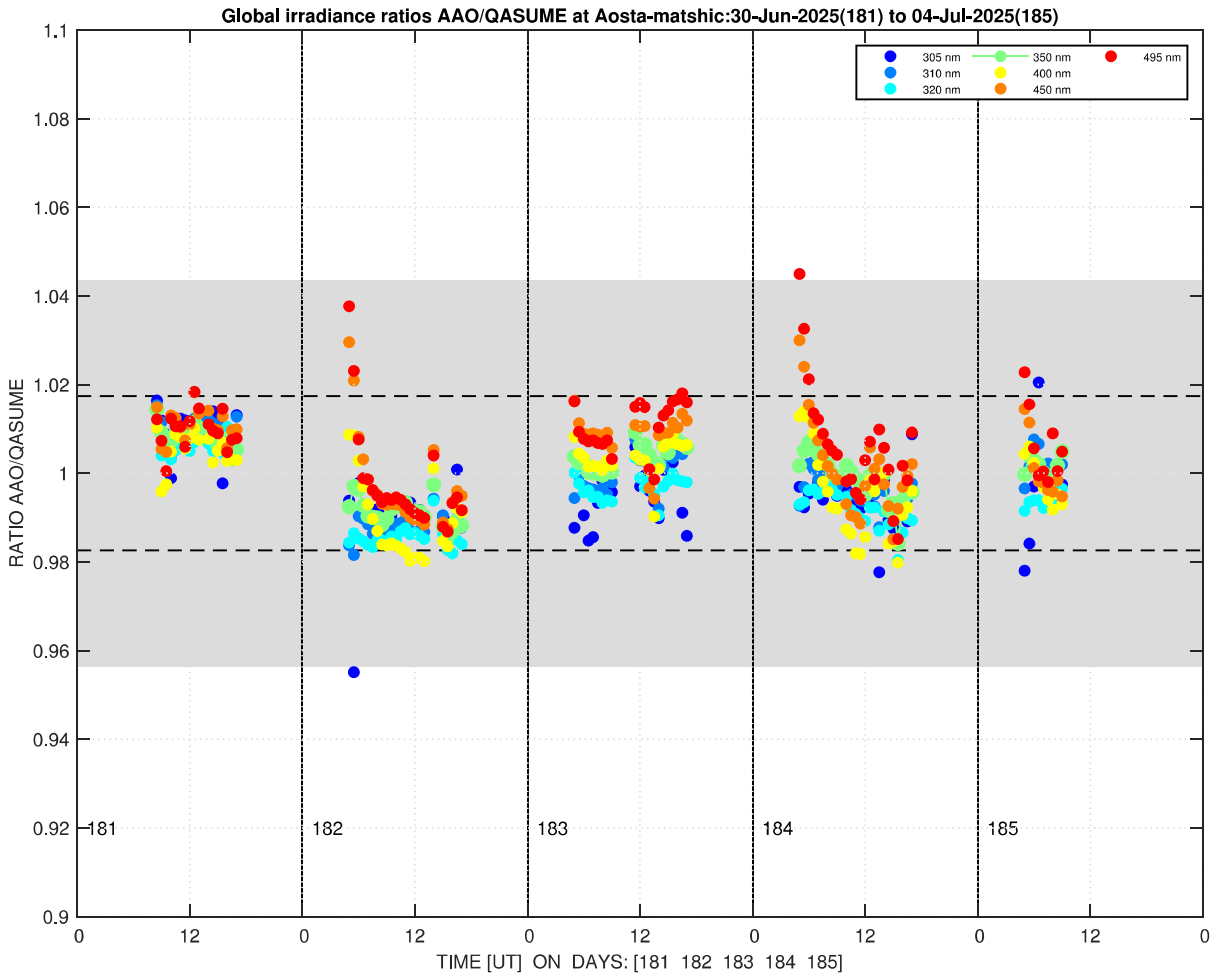
The irradiance of the final submitted spectra was multiplied by a correction factor of 1/0.991 (where 0.991 is the average diffuse angular error over the four planes).

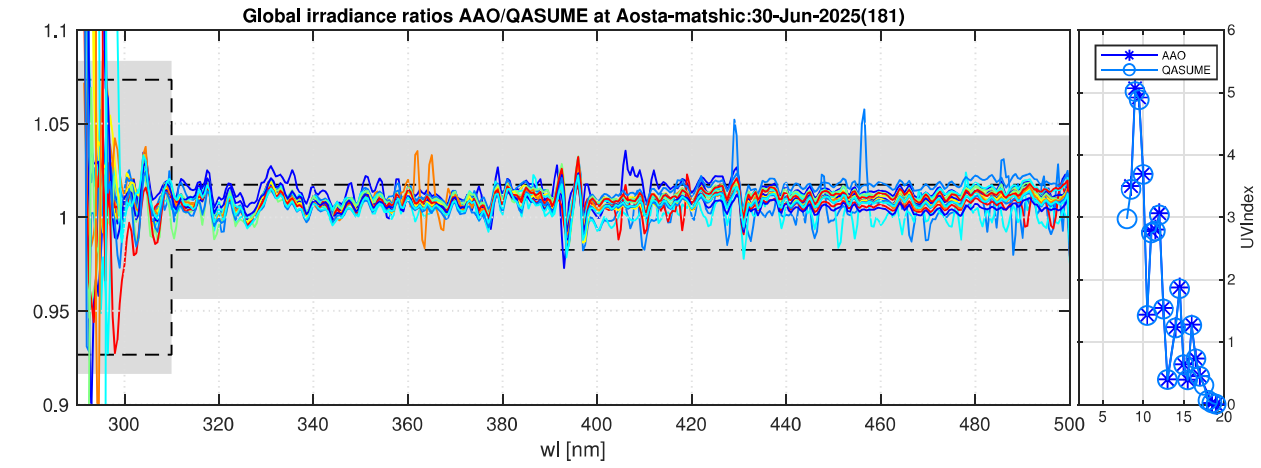
The stability of the AAO instrument during the audit was assessed on July 2 using two 200W lamps recently calibrated against 1000W lamps traceable to PMOD standards. The difference between responses obtained with the two lamps was 0.26%. Comparison with the previous calibration (June 27, 2025) showed -0.36%, confirming instrument stability. The AAO response was updated at 11:30 UT.

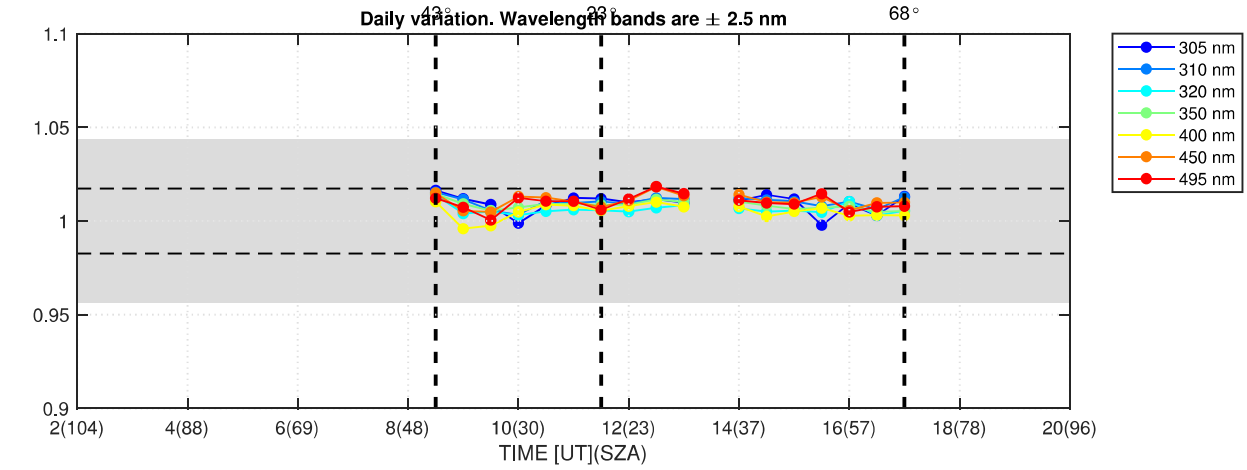
Appendix

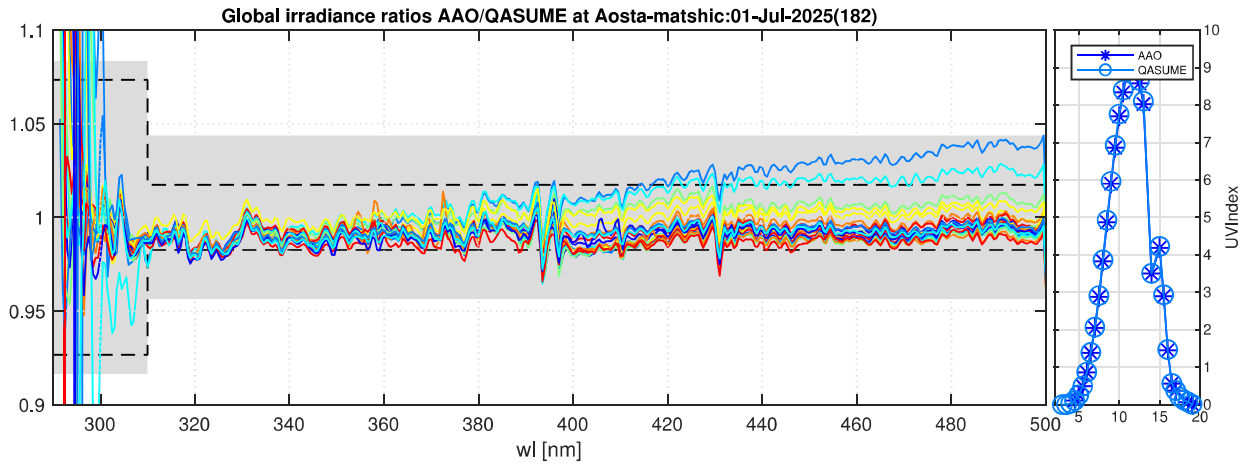
Detailed results for all local spectrophotometers with respect to the reference spectroradiometer QASUME

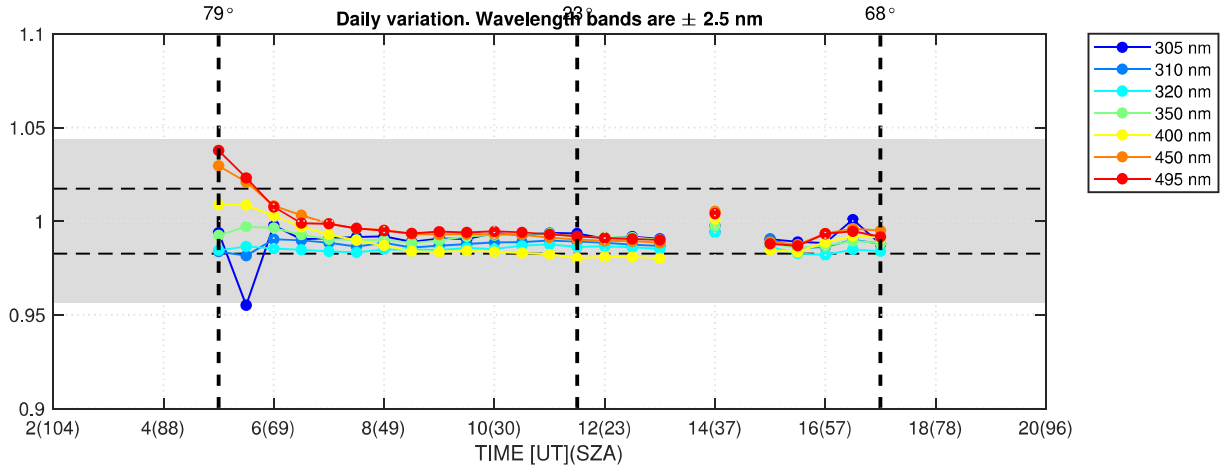

UV Index Aosta, July 2025
QASUME
aao
UV Index
Day of Year
0
1
2
3
4
5
6
7
8
9
10
181
181.5
182
182.5
183
183.5
184
184.5
185
185.5
186

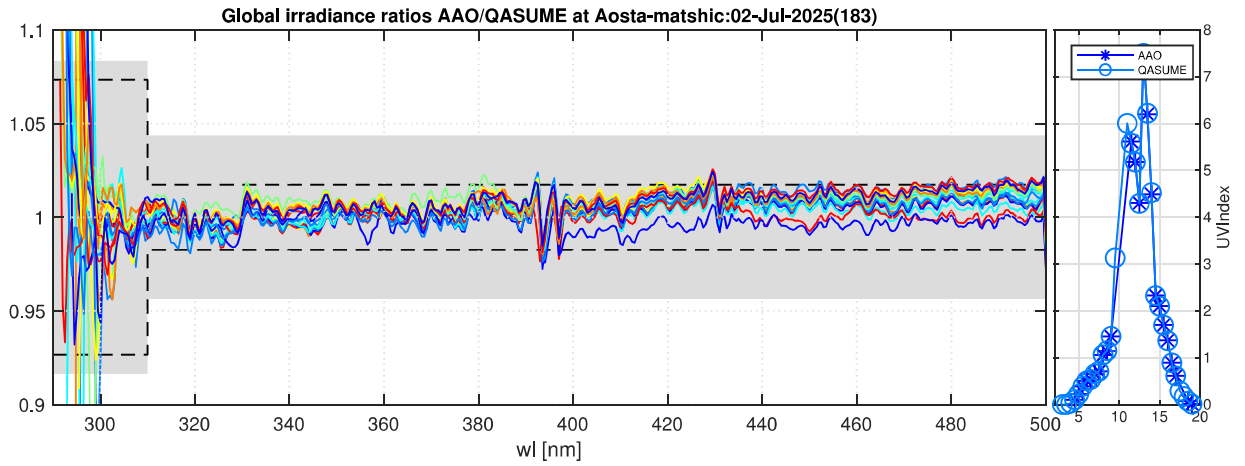

Global irradiance ratios AAO/QASUME at Aosta-matshic:30-Jun-2025(181) to 04-Jul-2025(185)
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
RATIO AAO/QASUME
181
182
183
184
185
TIME [UT] ON DAYS: [181 182 183 184 185]

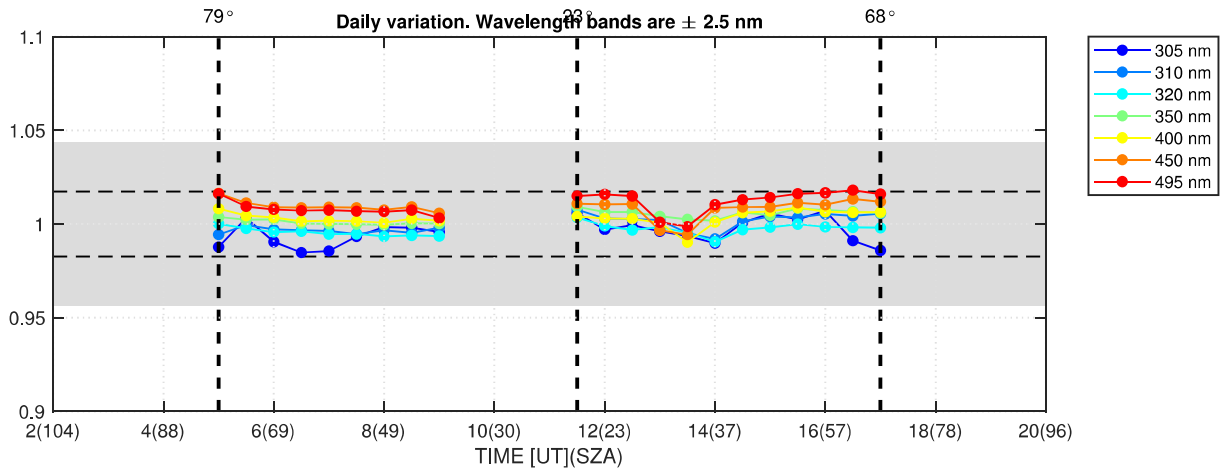

Global irradiance ratios AAO/QASUME at Aosta-matshic:30-Jun-2025(181)
AAO
QASUME
UVIndex
wl [nm]

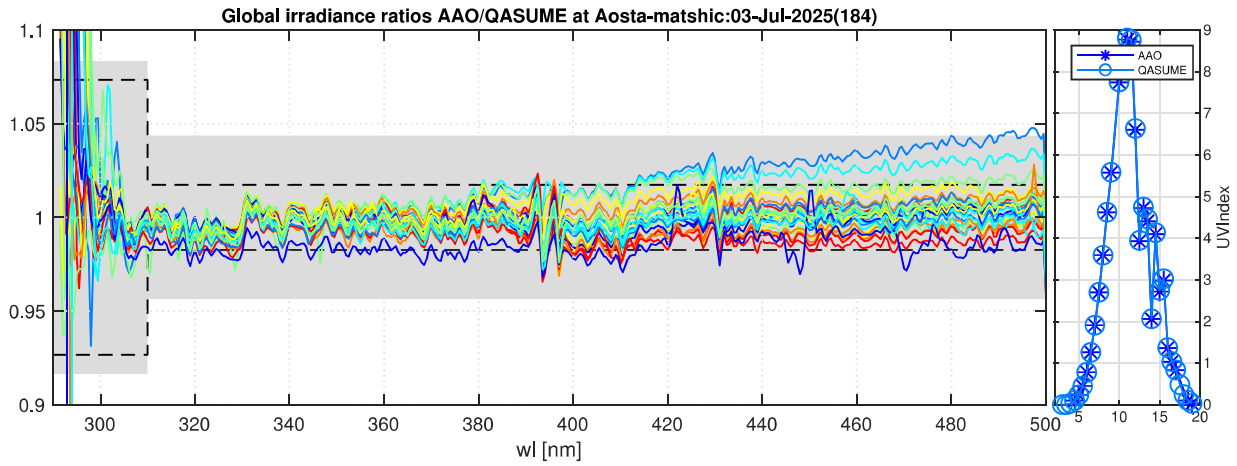

Daily variation. Wavelength bands are ± 2.5 nm
43°
23°
68°
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
TIME [UT](SZA)

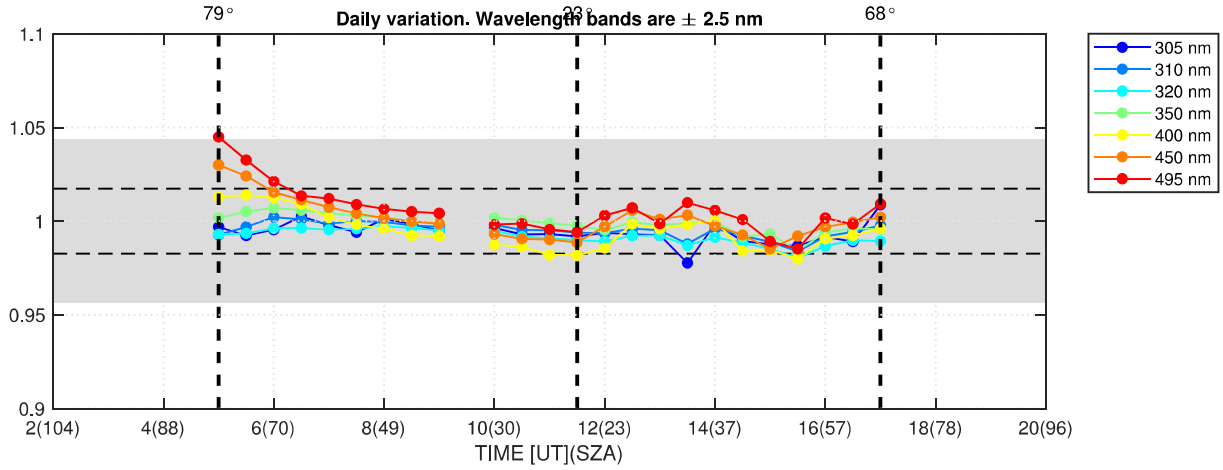

Global irradiance ratios AAO/QASUME at Aosta-matshic:01-Jul-2025(182)
AAO
QASUME
UVIndex
wl [nm]

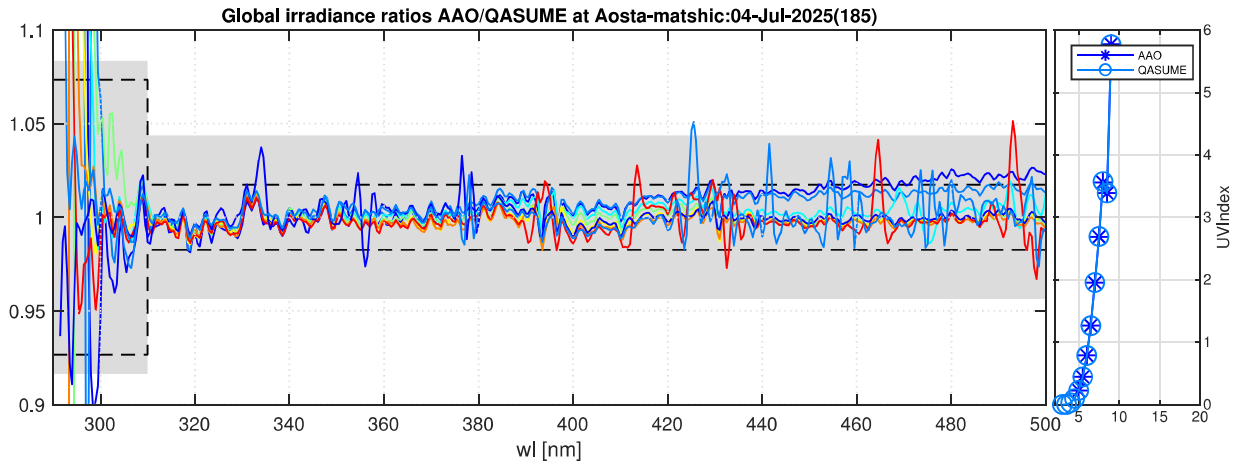

79°
68°
Daily variation. Wavelength bands are ± 2.5 nm
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
TIME [UT](SZA)

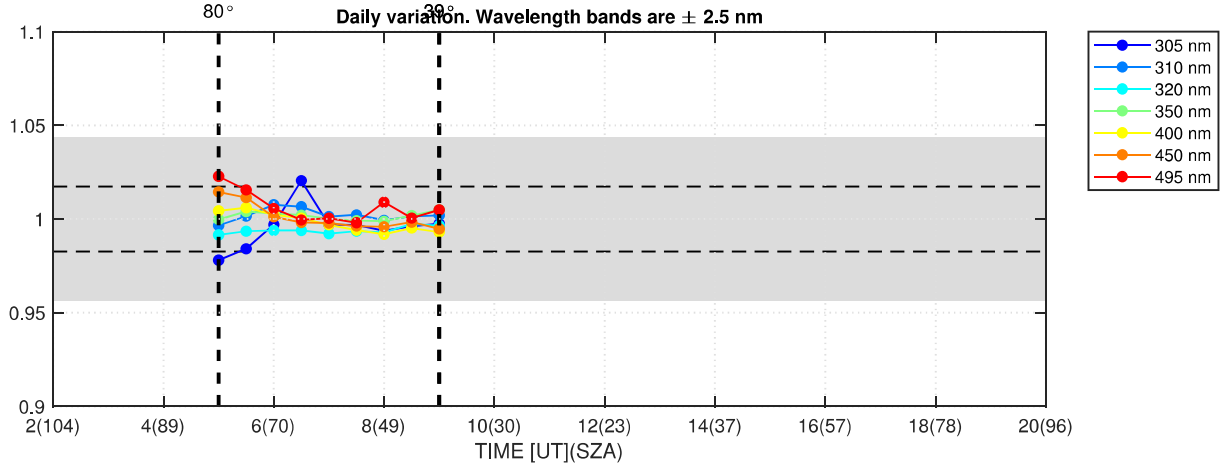

Global irradiance ratios AAO/QASUME at Aosta-matshic:02-Jul-2025(183)
AAO
QASUME
UVIndex
wl [nm]

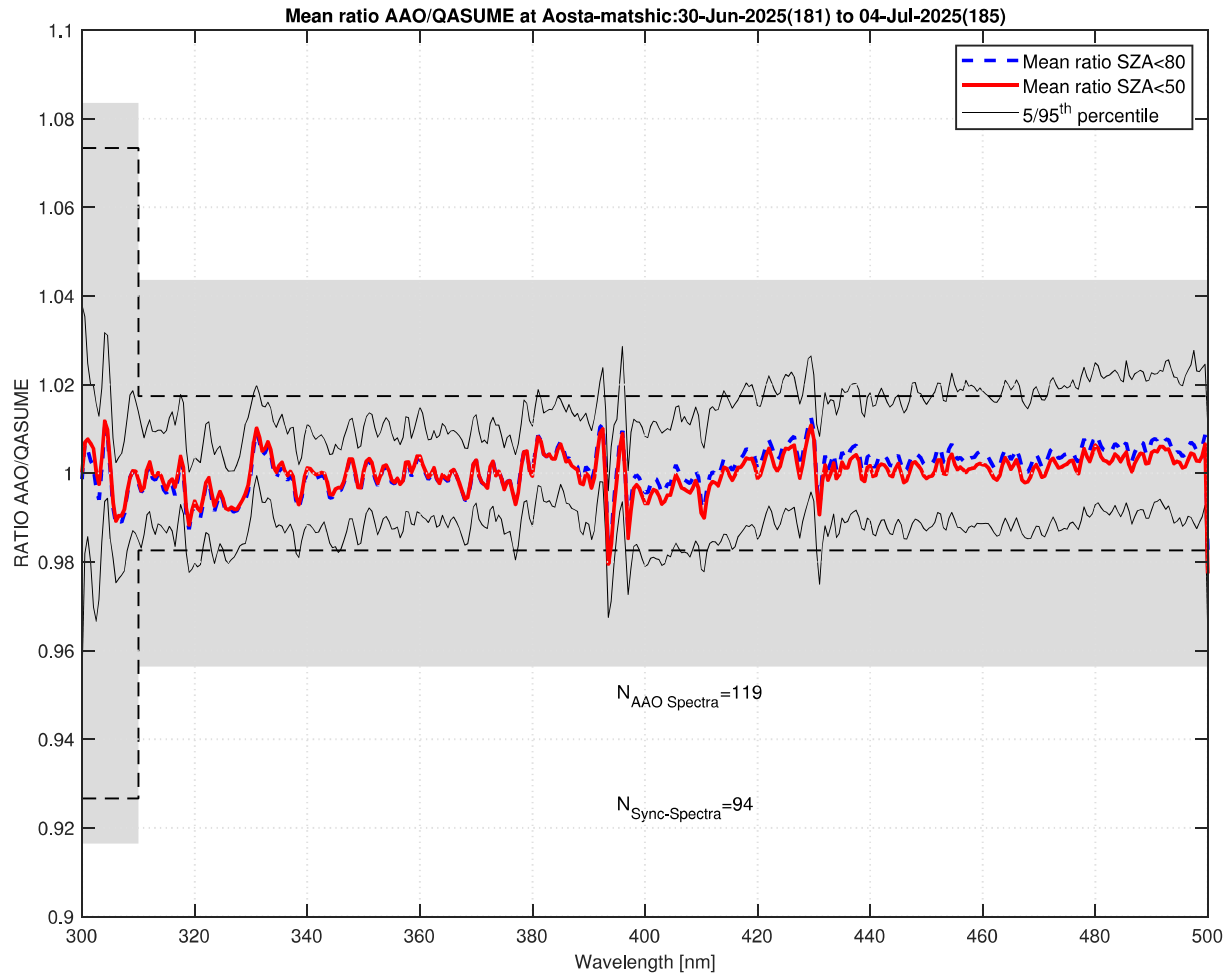

79°
68°
Daily variation. Wavelength bands are ± 2.5 nm
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
TIME [UT](SZA)

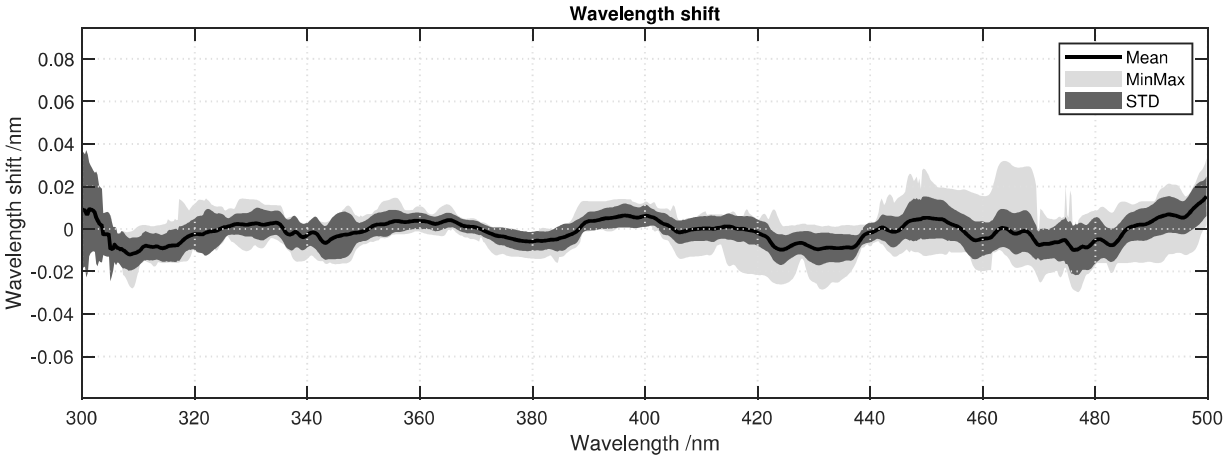

Global irradiance ratios AAO/QASUME at Aosta-matshic:03-Jul-2025(184)
AAO
QASUME
UVIndex
wl [nm]

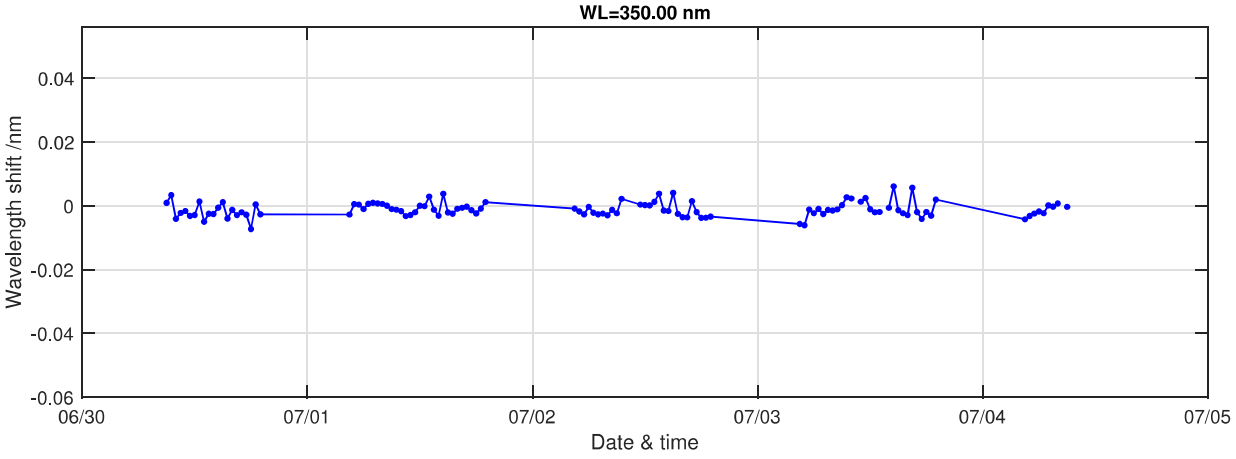

79°
68°
Daily variation. Wavelength bands are ± 2.5 nm
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
TIME [UT](SZA)

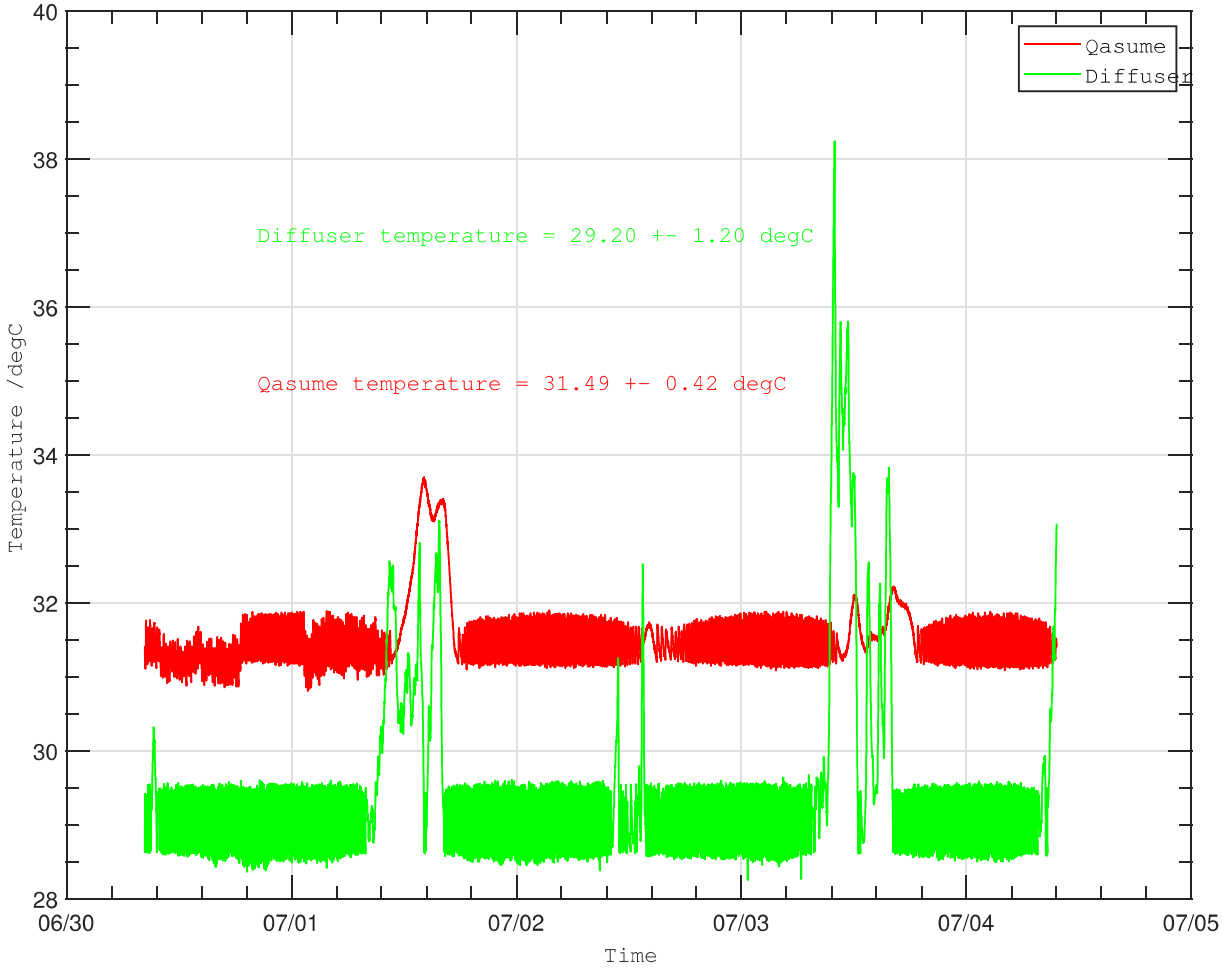

Global irradiance ratios AAO/QASUME at Aosta-matshic:04-Jul-2025(185)
AAO
QASUME
UVIndex
wl [nm]

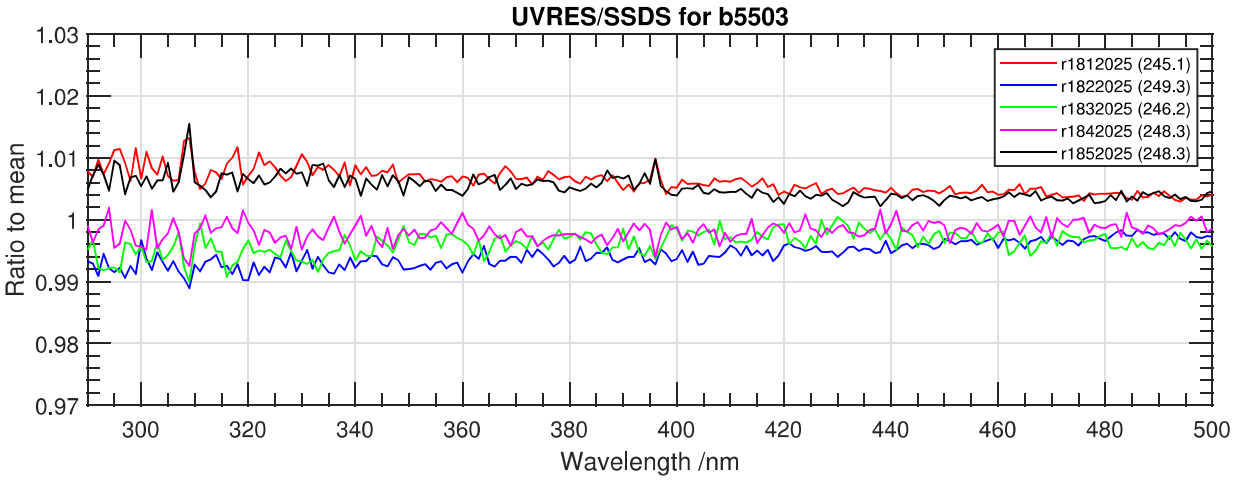

80°
Daily variation. Wavelength bands are ± 2.5 nm
305 nm
310 nm
320 nm
350 nm
400 nm
450 nm
495 nm
TIME [UT](SZA)

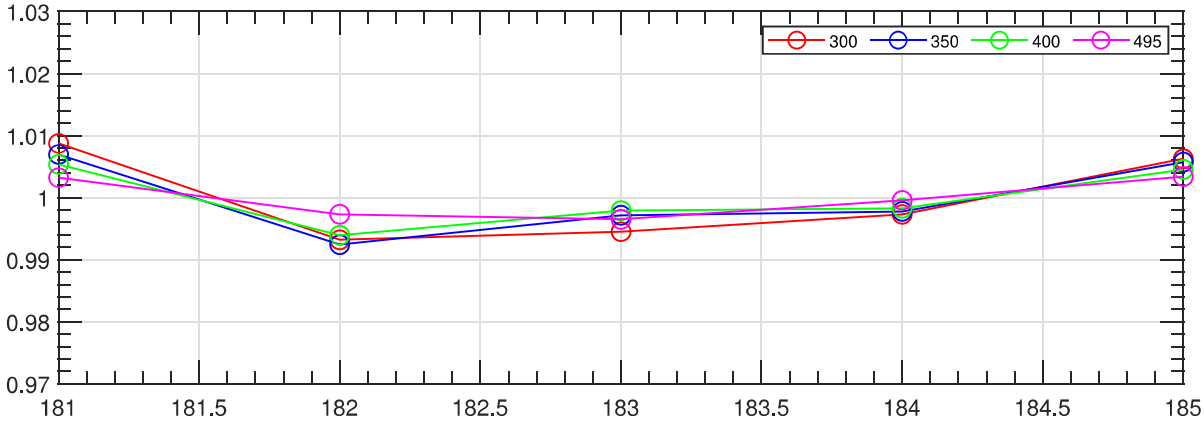

Mean ratio AAO/QASUME at Aosta-matshic:30-Jun-2025(181) to 04-Jul-2025(185)
Mean ratio SZA<80
Mean ratio SZA<50
5/95th percentile
RATIO AAO/QASUME
Wavelength [nm]
N AAO Spectra=119
N Sync-Spectra=94


Wavelength shift
Mean
MinMax
STD
Wavelength shift /nm
Wavelength /nm


WL=350.00 nm
Wavelength shift /nm
Date & time


Qasume
Diffuser
Diffuser temperature = 29.20 +- 1.20 degC
Qasume temperature = 31.49 +- 0.42 degC
Temperature /degC
Time
40
38
36
34
32
30
28
06/30
07/01
07/02
07/03
07/04
07/05


UVRES/SSDS for b5503
r1812025 (245.1)
r1822025 (249.3)
r1832025 (246.2)
r1842025 (248.3)
r1852025 (248.3)
Ratio to mean
Wavelength /nm
1.03
1.02
1.01
1
0.99
0.98
0.97
300
320
340
360
380
400
420
440
460
480
500


300
350
400
495
1.03
1.02
1.01
1
0.99
0.98
0.97
181
181.5
182
182.5
183
183.5
184
184.5
185


AAO
Qasume