

# Protocol of the intercomparison at FMI, Sodankylä, Finland on May 29 to June 2, 2023 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 two Brewer spectrophotometer, FIS and FIA operated by the Finnish Meteorological Institute (FMI) and the travel reference spectroradiometer QASUME. The measurement site is located at Sodankylä; Latitude 67.37 N, Longitude 26.63 E and altitude 179 m.a.s.l. The horizon of the measurement site is free down to at least 80° solar zenith angle (SZA). Measurements between 1:00 UT and 23:00 UT have been analysed.

QASUME was installed on the measurement platform of FMI-Sodankylä in the evening of May 28, 2023. The spectroradiometer was installed next between the Brewer spectrophotometer "FIS" and "FIA" with the entrance optic of QASUME within 2 m to the other instruments. The Brewer Spectrometer FIS is a single monochromator (Brewer MkII #037) and the FIA Brewer spectroradiometer is a double monochromator (Brewer MkIII #214). The intercomparison between QASUME and the Brewer Spectrometers lasted 5 days, from the morning of May 28 to the afternoon of June 2<sup>nd</sup>.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Three lamps (T61251, 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 wavelength shifts relative to the QASUMEFTS (Gröbner et al., 2017) spectrum as retrieved from the matSHIC analysis were between  $\pm 50$  pm in the spectral range 290 to 400 nm.

**Protocol:**

The measurement protocol was to measure one solar irradiance spectrum every 30 minutes from 290 nm to 363 nm, every 0.5 nm, and 3.0 seconds between each wavelength increment. QASUME recorded the spectra in 30 min intervals with 0.25 nm increments from 290 nm to 400 nm.

DOY	Date	DAY	Weather	Comment (times are in UT)
148	28-May	Sunday	Mix of sun and clouds (Cu)	Installed at 18:45 19:00 start UV measurements
149	29-May	Monday	Mix of sun and clouds (Cu) Some rainshowers	10:44 Calibration T68522
150	30-May	Tuesday	Clear sky in the morning Increasing number of clouds during the day	07:12 Calibration T68522 07:45 Calibration T61251
151	31-May	Wednesday	Mostly overcast sky Occasional rain showers	15:12 Calibration T68522
152	01-Jun	Thursday	Clear sky in the morning Mix of sun & clouds and rainshowers	04:12 Calibration T68522 04:44 Calibration T68523
153	02-Jun	Friday	Mix of sun & clouds Some rainshowers	12:10 Calibration T68523 12:41 Calibration T68522 14:00 QASUME OFF

**Results:**

In total 153 (FIS) and 162 (FIA) synchronised simultaneous spectra from QASUME and FIS/FIA are available from the measurement period. Measurements between 2:00 and 22:00 UT have been analysed (SZA smaller than 90°).

**Remarks:**

FMI delivered two datasets for the FIS and two for the FIA Brewer. They differ by the way of processing the data. They were labelled as follows:

FIA1: FMI standard processing without temperature correction but cosine correction (Lakkala et al. 2008, Lakkala et al. 2018).

FIA2: same as FIA1, but temperature correction from Fountoulakis et al. (2017).

FIS1: FMI standard processing with FMI linear temp correction and cosine correction (Lakkala et al. 2008, Lakkala et al. 2018).

FIS2: same as FIS1 but temperature correction from Fountoulakis et al. 2017 with updated (25.9.2018) temperature correction coefficients.

In the appendix the comparison of the two different datasets is shown. The differences are below 0.5 % for FIA and 1.5 % for FIS.

The dataset used for the calibration report are FIA1 and FIS1.

**Conclusions:****A) FIA:**

1. The average spectral ratio between FIA and QASUME has a slight spectral trend, from 1.03 at 305 nm decreasing to 0.98 at 363 nm.
2. The temporal variation of the spectra between FIA and QASUME was very stable, with variations less than 2% during the whole campaign.
3. The wavelength shifts of FIA relative to the high spectral resolution solar spectrum are between  $\pm 50$  pm in the spectral range 290 to 365 nm.
4. The signal to noise ratio at short wavelengths smaller than about 305 nm rises at solar zenith angles larger than about 70°.

**B) FIS:**

1. The average spectral ratio between FIS and QASUME is 1.00 increasing for wavelength smaller than 305 nm.
2. The temporal variation of the spectra between FIS and QASUME was very stable, with variations less than 2% during the whole campaign.
3. The wavelength shifts of FIS relative to the high spectral resolution solar spectrum are between 0 and +50 pm in the spectral range 290 to 325 nm.
4. The signal to noise ratio at short wavelengths smaller than about 305 nm rises at solar zenith angles larger than about 70°.

**Comparison to previous QASUME site visits**

The long-term stability of FIA and FIS was assessed by comparing QASUME site visits performed since 2002.

As seen in figure 1 the campaign average ratio of FIA to QASUME are similar within  $\pm 4\%$  since 2018. The measurement in 2014 were lower than QASUME with  $-5\%$ .

Figure 2 shows that the campaign average ratio of FIS to QASUME has been stable to within  $\pm 1\%$  since 2018. Measurements before 2014 were slightly higher than QASUME above  $+4\%$  except 2010 with  $+2\%$ .

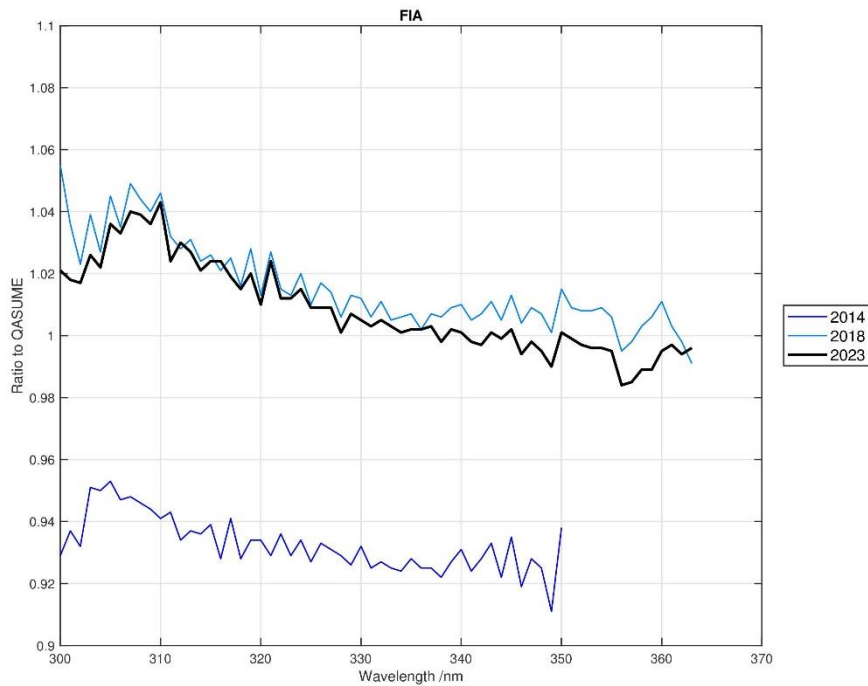


Figure 1 solar spectral ratios of FIA to QASUME averaged over each QASUME site visit

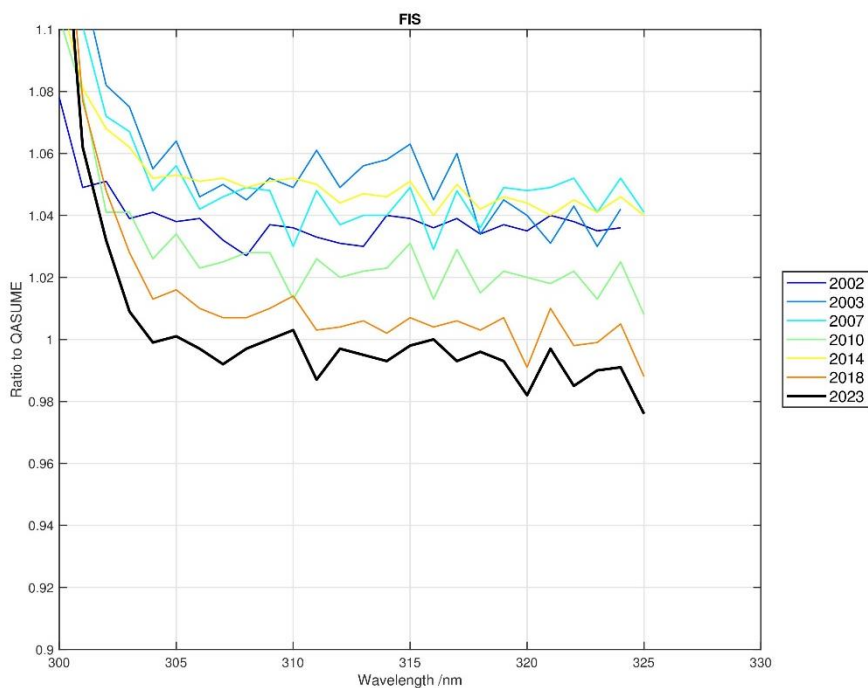


Figure 2 solar spectral ratios of FIS to QASUME averaged over each QASUME site visit.

## **Comments from the operator:**

For days with rain showers, it's possible that not all rainy scans were excluded from the FIS and FIA data.

## **References:**

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## **Appendix**

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

