Protocol of the intercomparison at the Istituto di Biometeorologia del CNR (IBIMET), Italy on September 08 to 11, 2008 with the travelling reference spectroradiometer QASUME[2] from PMOD/WRC

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The purpose of the visit was the comparison of global solar irradiance measurements between the spectroradiometer operated by the IBIMET and the travel reference spectroradiometer QASUME. The measurement site is located at the Polo Scientifico Universitario di Sesto Fiorentino; Latitude 43.82 N, Longitude 11.20 E and altitude 55 m.a.s.l..
The horizon of the measurement site is free down to at least 85° solar zenith angle (SZA). Measurements between 5:20 UT and 16:40 UT have been analysed.

QASUME arrived at the IBIMET in the morning of September 08, 2008. The spectroradiometer was installed on the roof of the measurement platform close to the spectroradiometer of IBIMET. The spectroradiometer in use at IBIMET is a MACAM double monochromator type 9910-V.7 s/n 7467 (MAC). The intercomparison between QASUME and the local spectroradiometer lasted two days, from the morning of September 09 to the evening of September 10.

QASUME was calibrated several times during the intercomparison period using a portable calibration system. Two lamps (T61252, T68524) 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 31.1±0.1 °C. The diffuser head was heated to a temperature of 32.5±7 °C.
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.

[2] The QASUME spectroradiometer B5503 is made available by the Physical and Chemical Exposure Unit of the Joint Research Centre of the European Commission, Ispra, Italy through a collaboration agreement with PMOD/WRC.

Protocol:

The measurement protocol was to measure one solar irradiance spectrum every 20 minutes from 290 to 400 nm, every 0.25 nm, and 1.5 seconds between each wavelength increment. The local spectroradiometer was manually synchronised with QASUME to within 2 nm.

September 08 (252) Monday:

QASUME was installed on the measurement site at 11:00 UT. Synchronisation tests were initiated at 13:00 UT. Weather conditions were mostly Cirrus clouds with a few Cumulus clouds around 12 UT.

QASUME was calibrated at 15:53 UT.

September 09 (253) Tuesday:

Synchronised measurements are available from 5:20 to 16:40 UT. Weather conditions were clear skies with low turbidity during the whole day. Haze increased after 14:00 UT.

QASUME was calibrated at 8:33 and 16:13 UT.

September 10 (254) Wednesday:

Synchronised scans are available from 10:00 to 16:20 UT. Weather conditions were clear skies and very hazy. At 12:00 UT the input optic of the MACAM spectroradiometer was rotated by 90° counter-clockwise. MAC was calibrated at 13:00; the measurement at 13:40 UT used this calibration. A second calibration was performed at 14:00 UT using only the tungsten-halogen lamp for the whole wavelength interval. The measurement at 15:07 UT used this calibration. Measurements after 15:40 UT used again the original (2004) calibration used in the morning and on the previous day.

End of the campaign: after the 16:20 UT scan.

Results:

In total 48 synchronised spectra from QASUME and MAC are available from the measurement period. Measurements between 5:20 and 16:40 UT have been analysed (SZA smaller than 85°). The measurements of QASUME were convolved with a nominal triangular slit function of 1.9 nm to optimize the comparability between QASUME and MAC and to reduce the spectral structures in the ratios between the two instruments. The wavelength shift of MAC could only be determined at wavelengths above about 330 nm. The wavelength shift resulted to be of the order of 0.3 nm, relative to the QASUME spectroradiometer. This wavelength shift was not taken into account in the analysis. However it should be noted that a wavelength shift of 0.3 nm results in a change in irradiance of 16% at 300 nm.

- The average ratio between MAC and QASUME for the wavelength range 300 to 400 nm is 0.80. Therefore, MAC underestimates solar UV irradiances by 25%. However individual measurements underestimate solar irradiances by up to 40% (see measurements of 9 September between 14:40 to 16:00 UT).
- The ratio MAC to QASUME varied between 0.95 and 0.8 at 310 nm and between 0.8 and 0.72 at 390 nm. This variability is partly due to an angular response error (systematic variability in the morning and evening around 65° SZA), and possibly to a temperature dependence of MAC which was operated at ambient temperatures, which varied between approximately 18 °C and 33 °C.
- The calibrations performed on Wednesday, 10 September were able to account for the observed differences of 25% above approximately 330 nm. However between 300 and 330 nm the calibration overestimated subsequent solar irradiance measurements by up to 20%.

A NILU multifilter Radiometer #120 is routinely operating on the measurement platform. The erythemally weighted irradiances retrieved with this radiometer were 12% lower than those from the QASUME spectroradiometer.

Conclusions:

- The local spectroradiometer underestimated solar irradiances by up to 40%. An average underestimation of 25% was estimated from all measurements. Subsequent calibrations were not able to account for this discrepancy in the wavelength region below about 330 nm.
- The wavelength error is of the order of 0.3, which results in uncertainties of 16% at 300 nm.
- The instrument showed diurnal variabilities of up to 30%, which are due to a combination of angular response errors and a temperature dependence of the spectroradiometer which was operated at ambient temperature.

Based on the above findings, this spectroradiometer is currently not able to measure spectral solar UV irradiance with low enough uncertainties compatible with its intended use.

Suggestions:

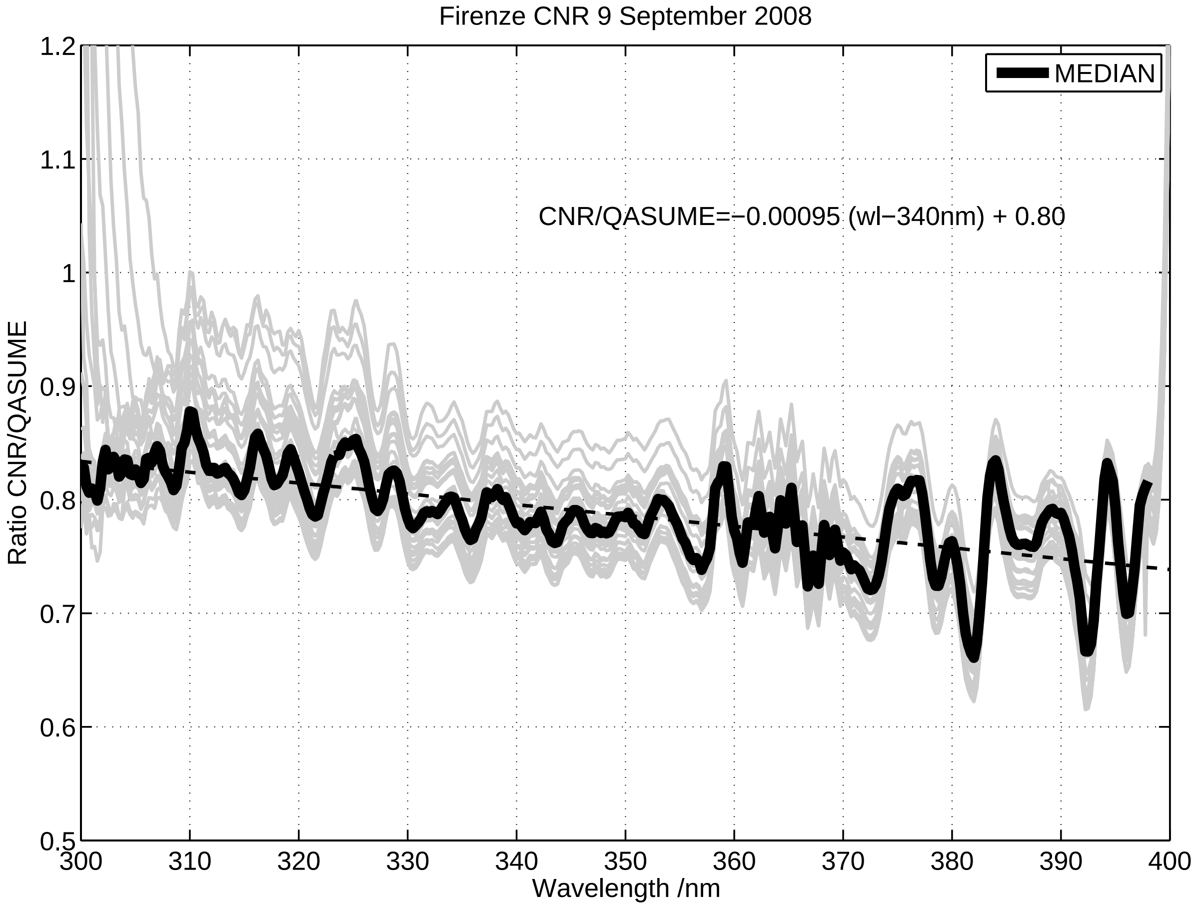
The WMO-GAW report Nr. 125, “Instruments to measure Solar Ultraviolet Radiation, Part 1: Spectral Instruments”, describes specifications for two types of instruments, S-1 and S-2, intended for activities in which IBIMET is also involved, such as specific process studies, determination of UV Index, Information of UV levels to the public. The recommended WMO specifications for these instruments are, among others: a wavelength uncertainty below ±0.1 nm, overall calibration uncertainty ±10%, bandwidth (spectral resolution) below 1 nm. The MACAM Spectroradiometer 9910-V7.0 used by IBIMET does currently not fulfil these WMO recommendations.

The following suggestions are aimed at improving the quality of spectral solar UV measurements at IBIMET:

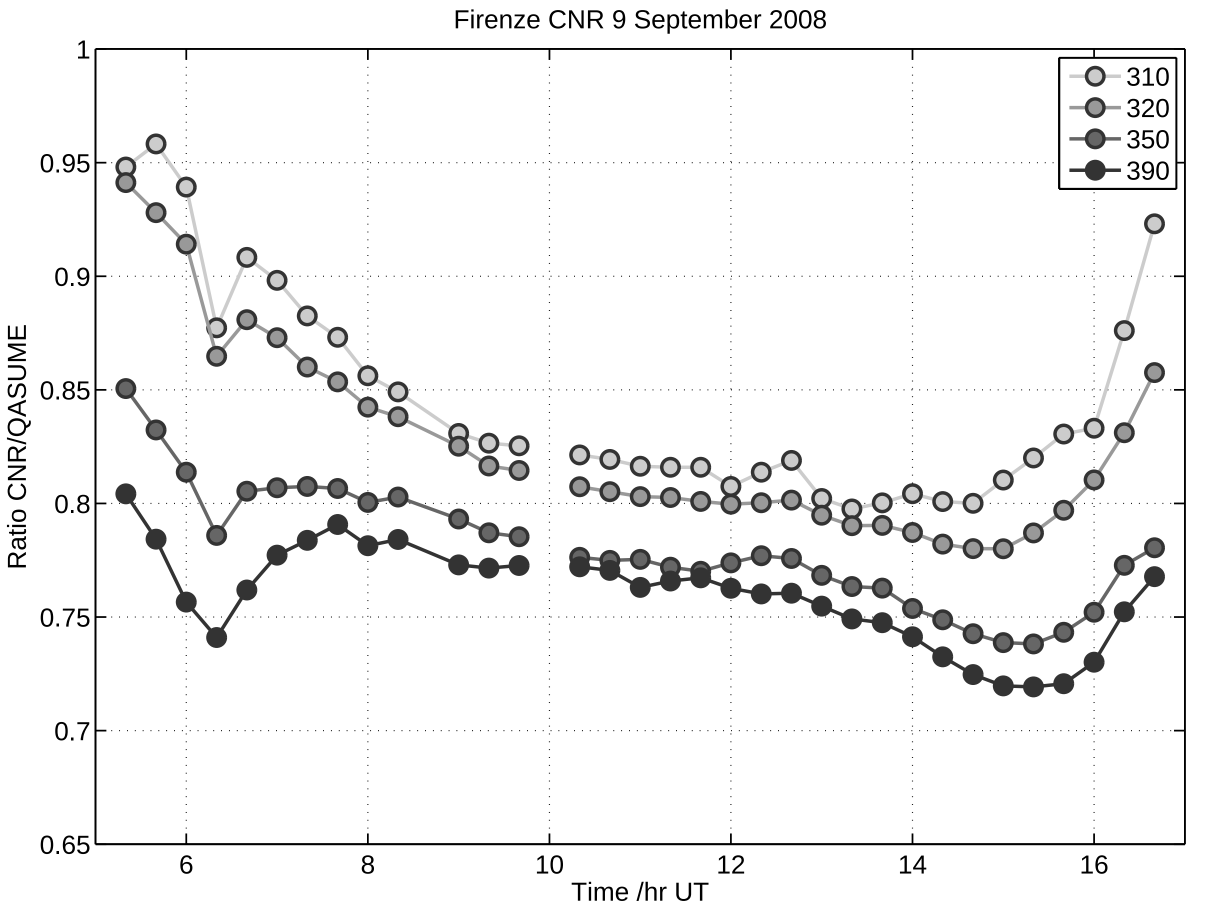
1) The manufacturer specifications of MACAM 9910-V7.0 do not fulfil the WMO recommendations for neither S-1 nor S-2 instruments; based on the instrument purchasing procedure at CNR and taking into account the instrument lifetime, a replacement of the MACAM spectroradiometer should be considered.
2) Spectroradiometer stability is obtained through regular calibrations based on reference standards (for example tungsten-halogen lamps) traceable to recognized reference laboratories. To discriminate between instrument and lamp variability the use of multiple reference lamps (at least three) is recommended.
3) A detailed characterisation of the instrument needs to be performed at least once, including angular response, slit function, temperature dependence, wavelength accuracy, spectral stray light.

References

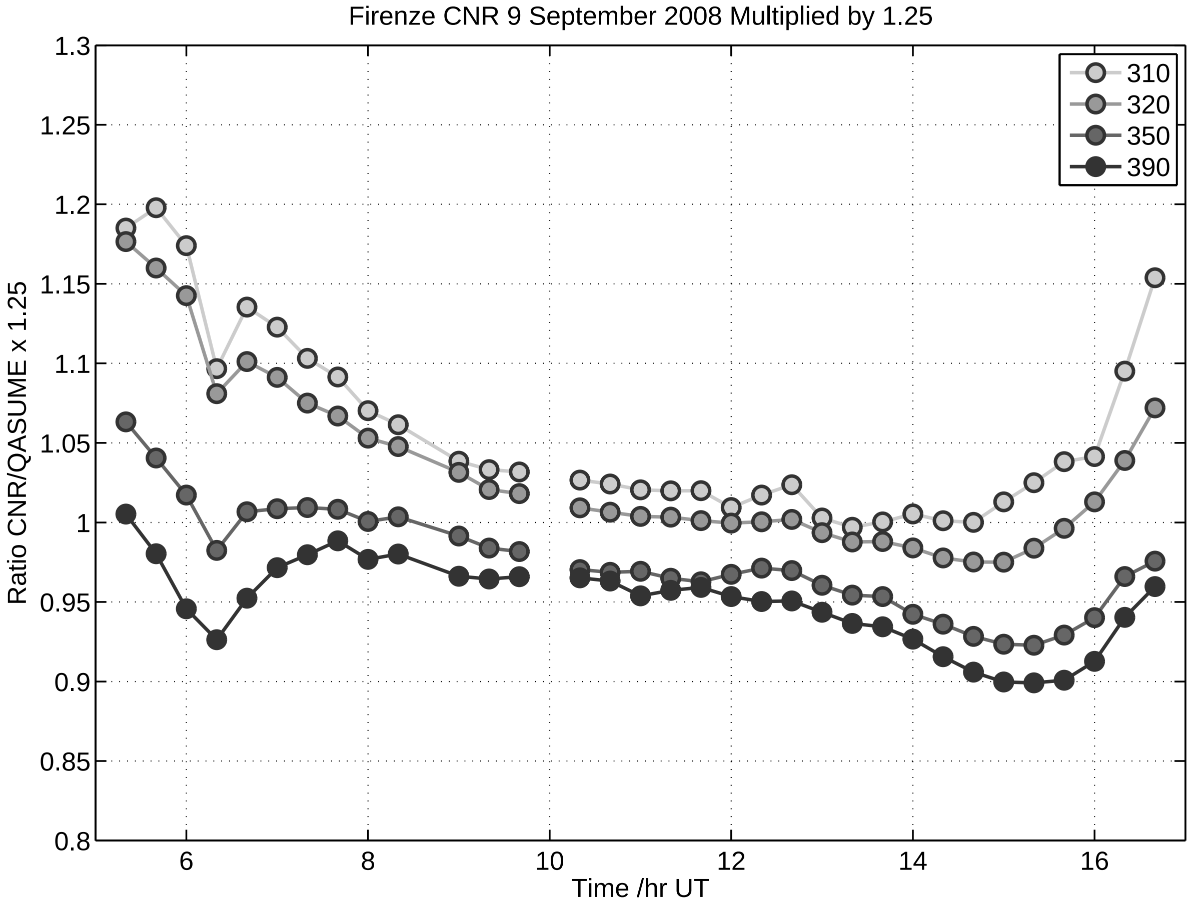
WMO, Instruments to measure solar Ultraviolet radiation, Part 1: Spectral instruments, Global Atmosphere Watch Report Nr. 125, WMO TD No. 1066,



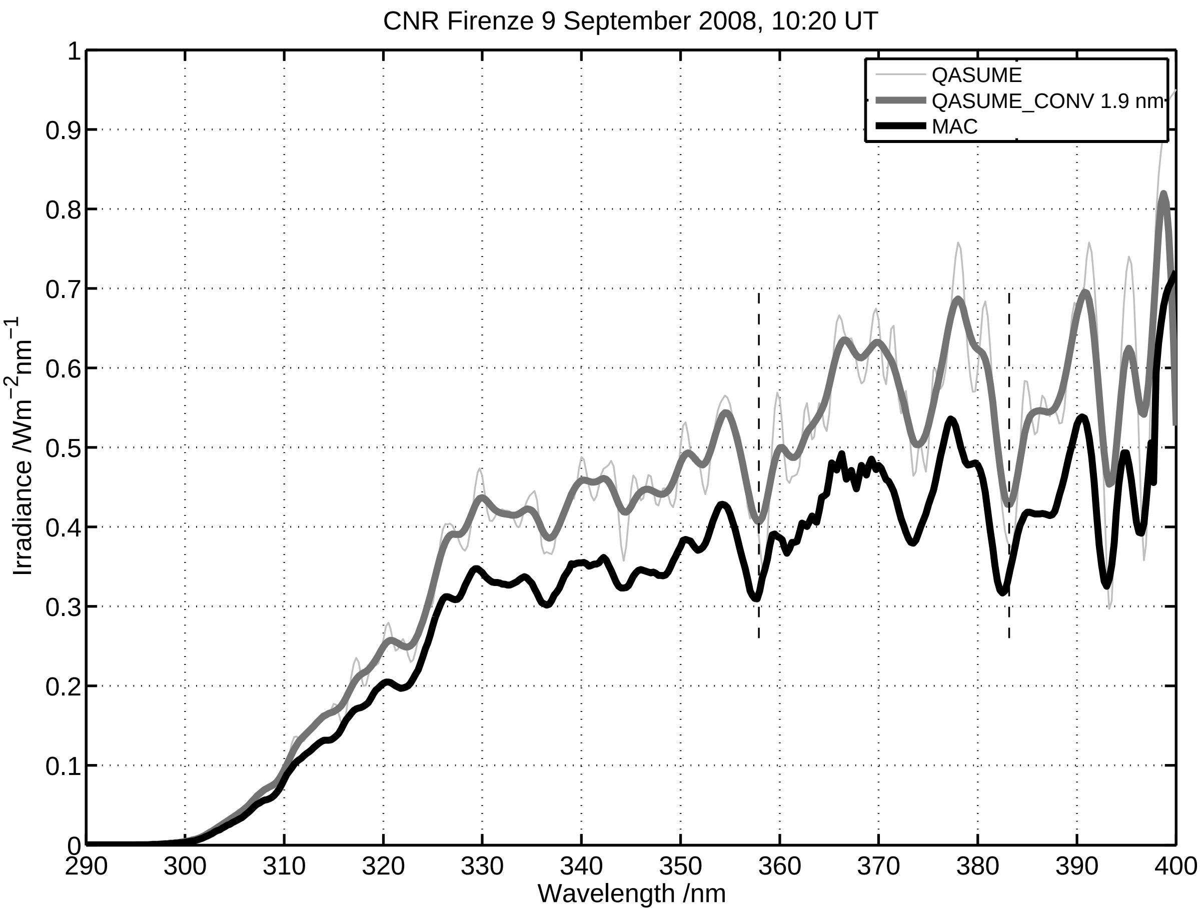
Firenze CNR 9 September 2008
MEDIAN
CNR/QASUME=−0.00095 (wl−340nm) + 0.80
Ratio CNR/QASUME
Wavelength /nm

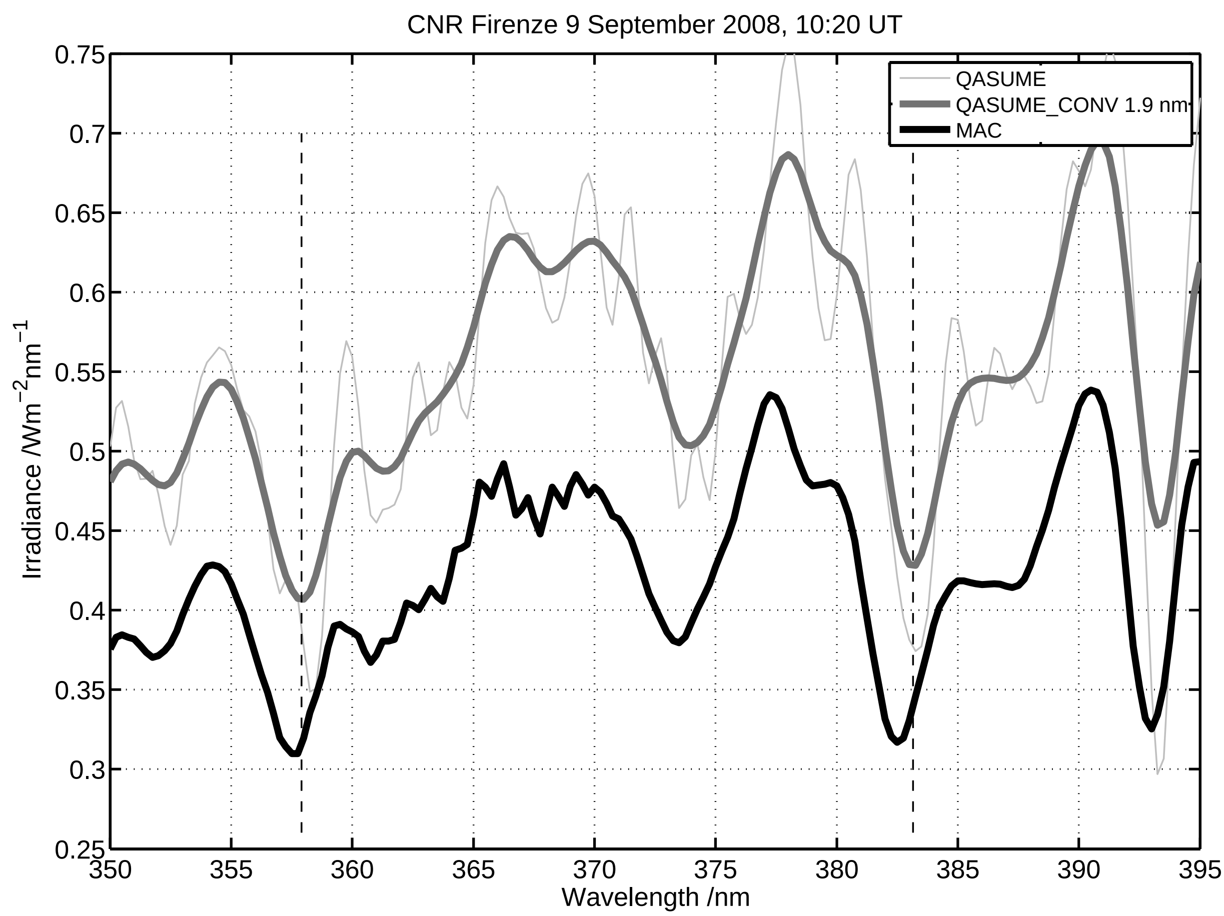


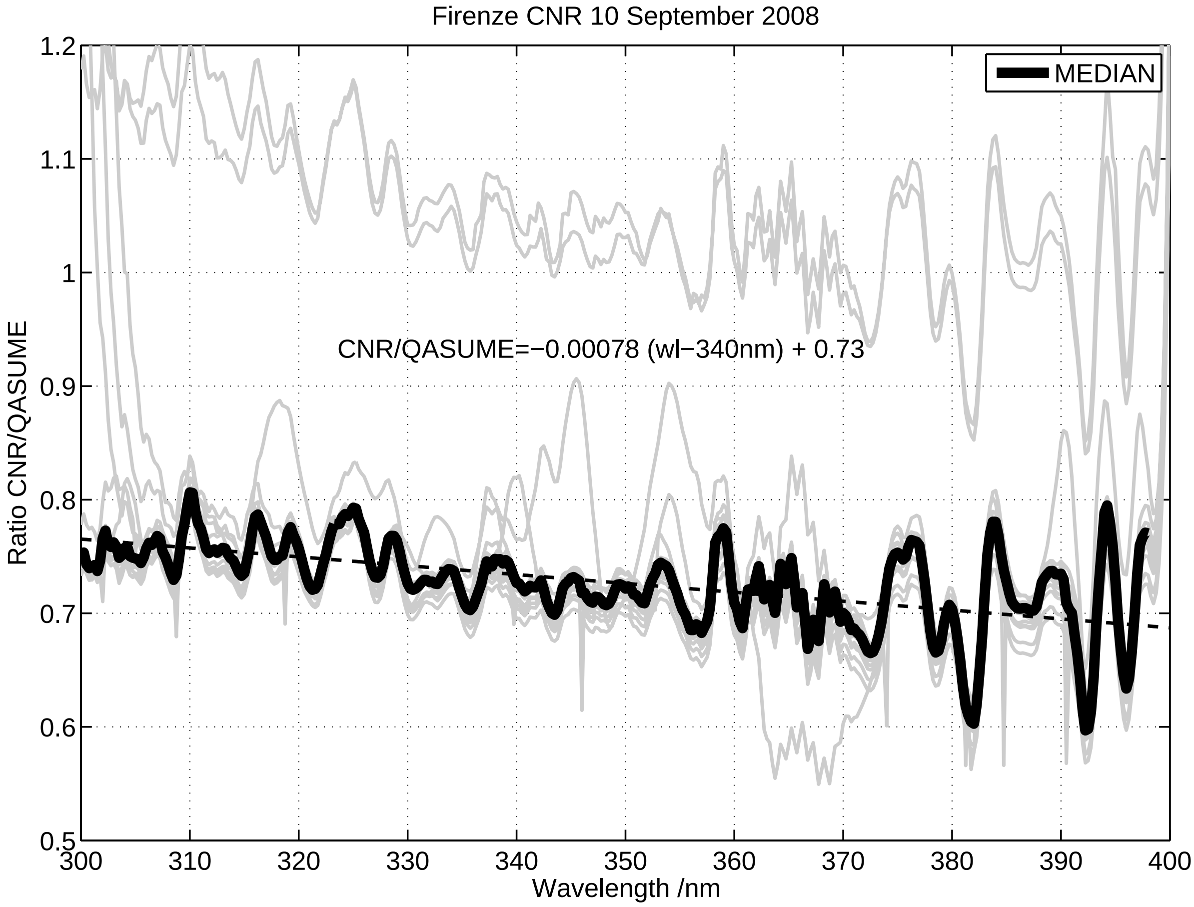
Firenze CNR 9 September 2008
310
320
350
390
Ratio CNR/QASUME
Time /hr UT

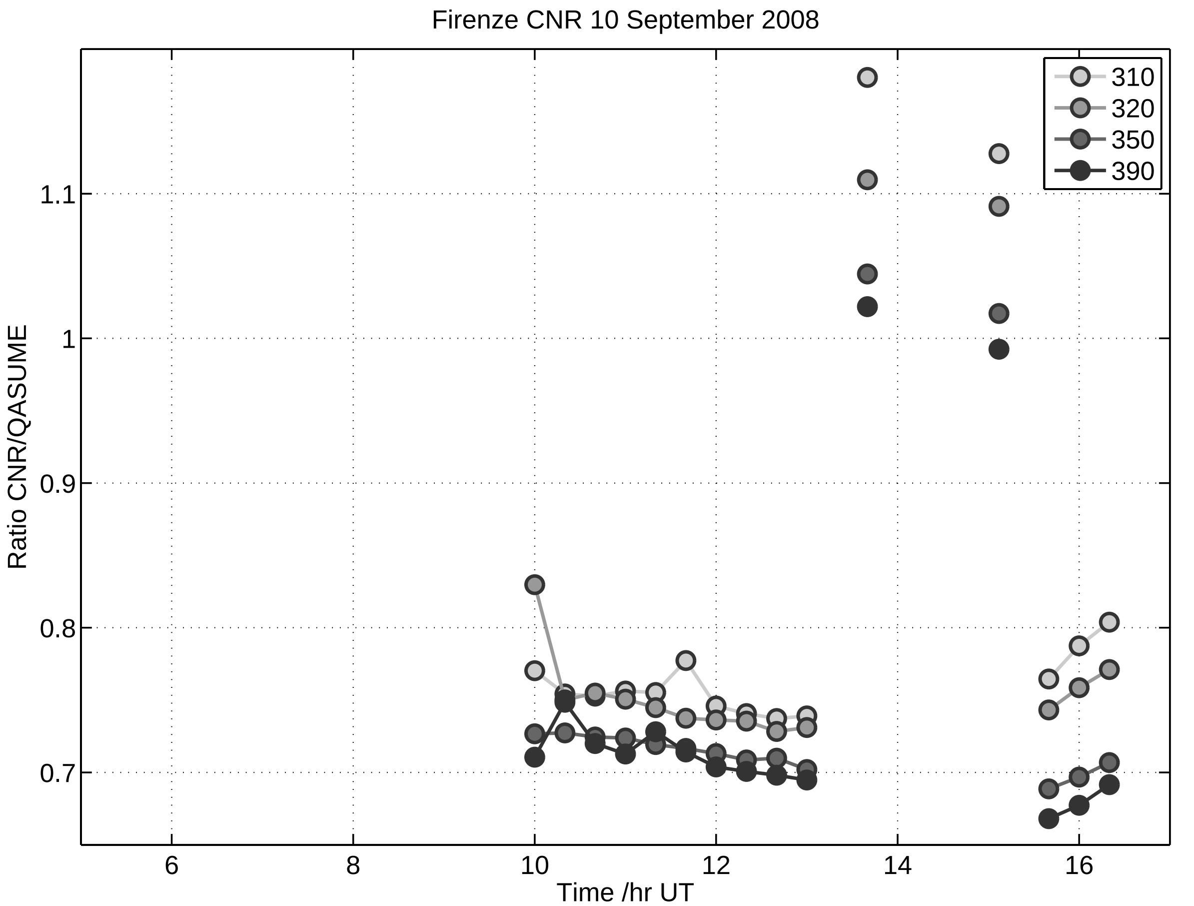


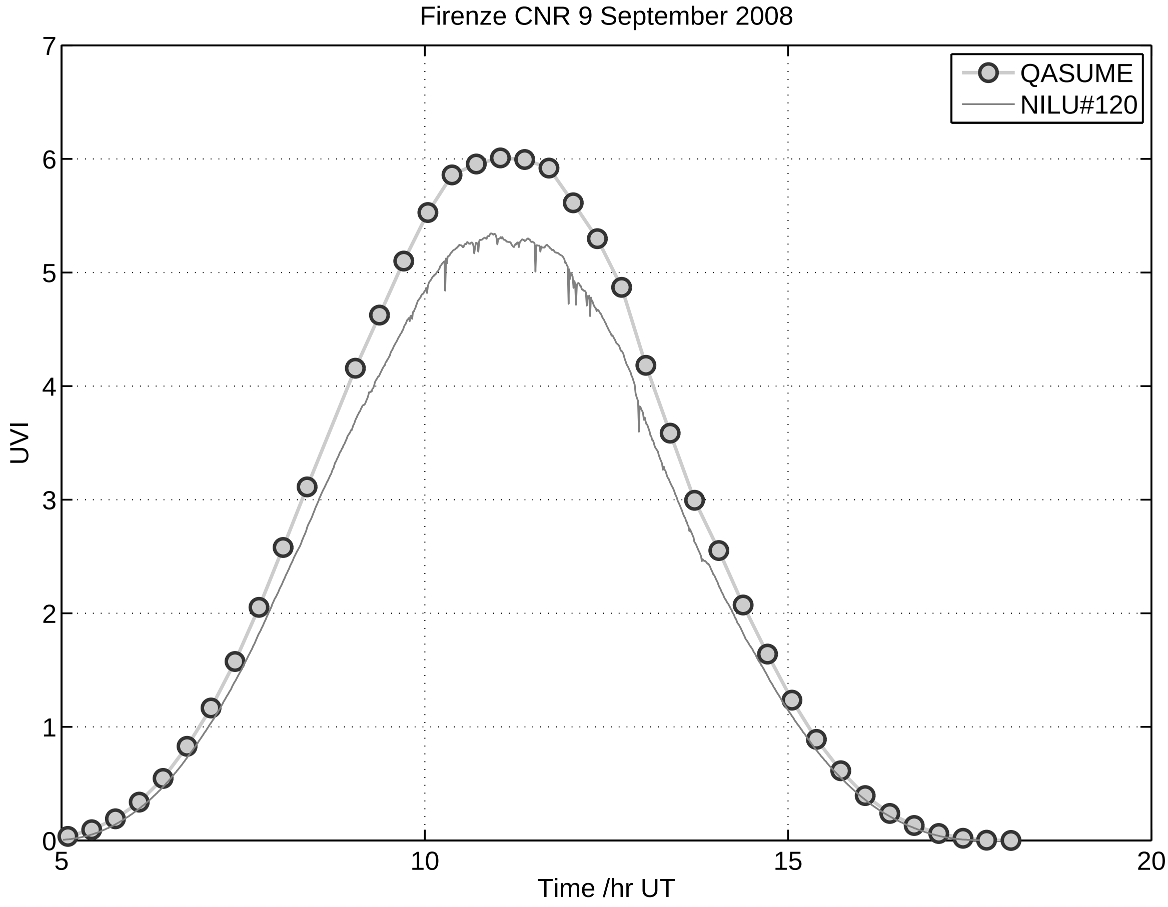
Firenze CNR 9 September 2008 Multiplied by 1.25
Ratio CNR/QASUME x 1.25
Time /hr UT
310
320
350
390
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
6
8
10
12
14
16

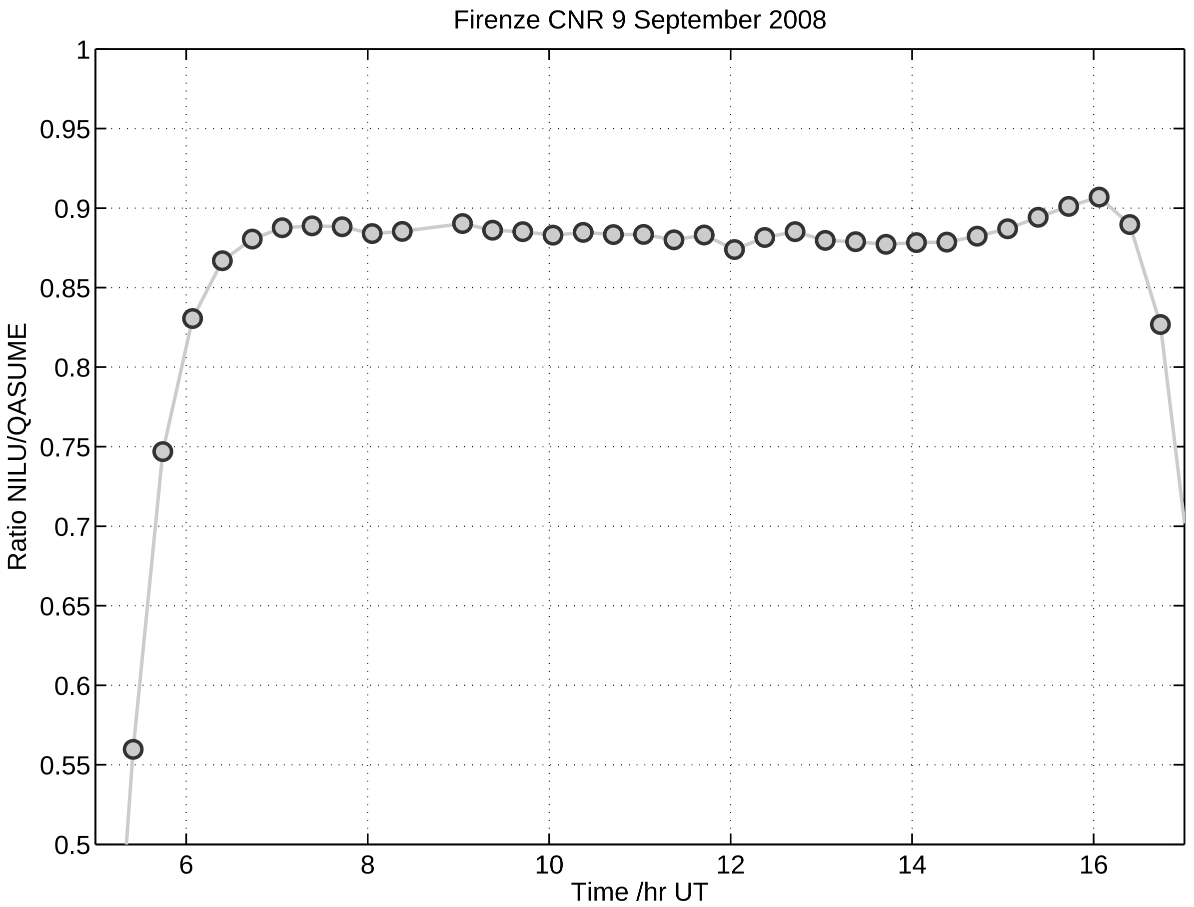

CNR Firenze 9 September 2008, 10:20 UT
QASUME
QASUME_CONV 1.9 nm
MAC
Irradiance /Wm^{-2}nm^{-1}
Wavelength /nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
290
300
310
320
330
340
350
360
370
380
390
400

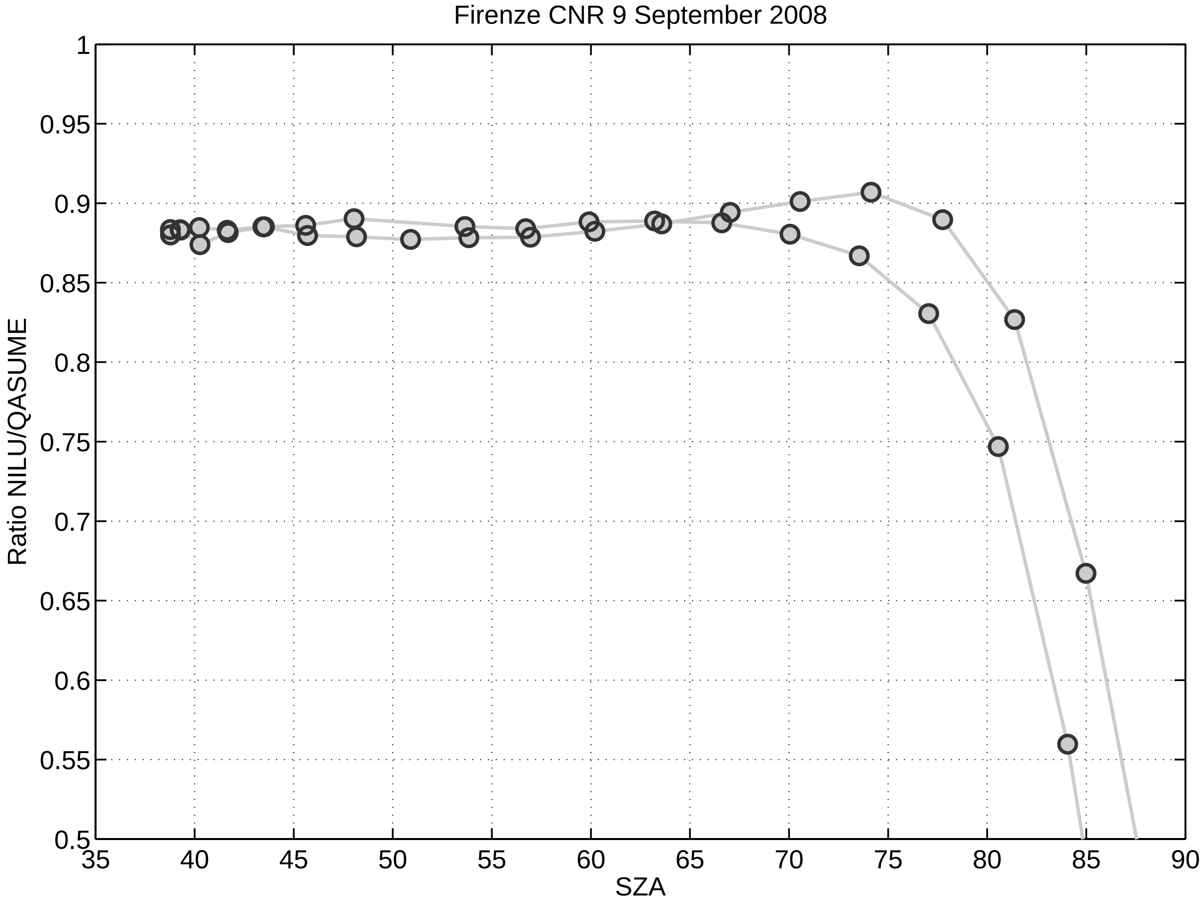

CNR Firenze 9 September 2008, 10:20 UT
QASUME
QASUME_CONV 1.9 nm
MAC
Irradiance /Wm^{-2}nm^{-1}
Wavelength /nm
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
350
355
360
365
370
375
380
385
390
395


Firenze CNR 10 September 2008
MEDIAN
CNR/QASUME=−0.00078 (wl−340nm) + 0.73
Ratio CNR/QASUME
Wavelength /nm
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
300
310
320
330
340
350
360
370
380
390
400


Firenze CNR 10 September 2008
310
320
350
390
Ratio CNR/QASUME
Time /hr UT
1.1
1
0.9
0.8
0.7
6
8
10
12
14
16


Firenze CNR 9 September 2008
QASUME
NILU#120
UVI
Time /hr UT
0
1
2
3
4
5
6
7
5
10
15
20


Firenze CNR 9 September 2008
Ratio NILU/QASUME
Time /hr UT
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
6
8
10
12
14
16


Firenze CNR 9 September 2008
Ratio NILU/QASUME
SZA
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
35
40
45
50
55
60
65
70
75
80
85
90


MAC
QASUME
NILU