QA/QC of Spectral Solar UV irradiance measurements

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Abstract. With a transportable spectroradiometer system routine quality assurance of spectrally resolved ultraviolet irradiance measurements were performed at 26 UV monitoring sites in Europe. 20 out of the 26 visited sites agreed to within 5% in the UVB and in the UVA range with the travelling unit. The results so far have shown the unique possibilities offered by such a travelling unit for providing on-site quality assurance of solar ultraviolet irradiance measurements.

Introduction

Solar UV irradiance is measured in Europe at more than 25 stations with spectroradiometers since several years. Most of the data are transferred to the European UV database for spectral UV irradiance, which is operated by the Finish Meteorological Institute and which was initiated within the EU-funded project EDUCE (European database for Ultraviolet radiation climatology and evaluation) from 2000 to 2003. In order to assure the quality of these data, several activities have been carried out at the measurement sites and at the data base. Routine quality control at the site is based on a careful schedule for frequent absolute calibration of the spectroradiometer by use of calibrated lamps. Furthermore, several different methods for quality control are in use by the local operators, mainly the regular comparison of weighted spectral data with collocated broadband detectors in the UVB and in the UVA wavelength range, and the comparison of measurements under clear sky conditions with results from radiative transfer model calculations. Guidelines for this quality control of UV monitoring are published by WMO (*Webb*, 2001).

A new report about the state of the art for quality assurance in monitoring solar ultraviolet radiation is published by WMO (*Webb*, 2003). Until recently, the standard method for quality assurance of spectral UV measurements was the direct intercomparison of the instruments. The spectroradiometers from different parts in Europe were gathered at one location and operated there for several days in an synchronous mode, so that the individual results could be intercompared, even when the weather conditions were changing during the scanning time (i.e. *Bais et al*., 2001).

A new approach for quality assurance at the site of the UV measurements was undertaken with a travelling spectroradiometer system, which has been developed and validated within the frame of the EU-founded project QASUME (Quality Assurance of Spectral Ultraviolet Measurements in Europe through the development of a transportable unit). The aim of the project is to establish a reliable unit which can be transported to any UV monitoring site in Europe to provide an assessment of the UV measurements performed by the local site instrument. This on-site quality assurance exercise should be viewed as an alternative to the intercomparisons performed previously. The advantages of the proposed approach are that local monitoring instruments do not need to be transported and are used in their natural environment during the intercomparison; furthermore, a site can be visited at regular intervals to check its stability over extended time periods. While this is a more realistic evaluation of a monitoring site, it places strict criteria on the performance and operation of the travelling instrument that must be proven to be stable at a level against which all other instruments will be judged.

Validation

The validation phase of the travelling unit (B5503) was scheduled for the first year of the project (2002), and consisted of an intercomparison with six qualified spectroradiometers followed by site visits to each of the home sites of these instruments. The summary of the results are shown in Figure 1. The absolute offset between five out of six instruments and the travelling unit are between –5 and

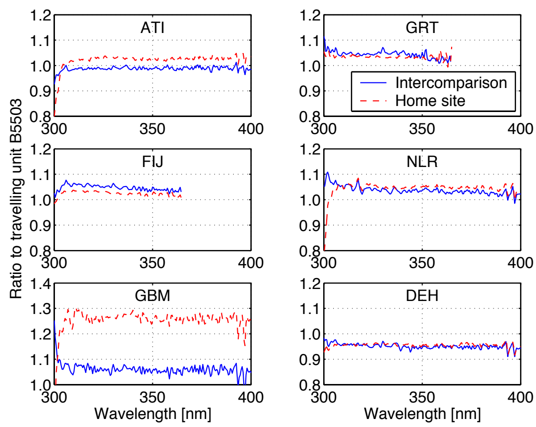

Figure 1 Mean spectral ratios between six spectroradiometers and the travelling unit B5503. The blue curves were measured during the joint intercomparison at JRC, the red (dashed) ones were obtained at the home sites of each instrument.

+5% and are in good agreement with the differences in the respective irradiance standards to which each instrument is referenced. The consistency between the intercomparison and the home site measurements is good, with four out of six site visits being within 2%. The deviations seen relative

Table 1: Summary of the quality assurance of spectral UV measurements. The ratio to the travelling unit B5503 was calculated from the mean of all simultaneously measured spectra in the wavelength range 305 to 315 nm (UVB) and above 315 nm (UVA-visible).

Site	No. of spectra / No. of days	Ratio to B5503 UVB / UVA-Vis.	Variability in % 5-95th percentile
Austria, Innsbruck	53 / 3	1.00 / 0.98	4
Austria, Wien	45 / 4	1.08 / 1.04	8
Belgium, Brussels, 1	51 / 3	1.05 / 1.03	5
Belgium, Brussels, 2	52 / 3	0.97 / 0.96	9
Belgium, Brussels, 3	52 / 3	0.95 / 0.94	7
Czech, Hradec Kralove	52 / 3	0.98 / 0.97	5
EU - JRC, Ispra	1094 / 54	1.01 / 0.99	4
Finland, Jokioinen	228 / 8	1.03 / 1.02	6
Finland, Sodankyl	67 / 3	1.05 / 1.03	4
France, Briancon	65 / 3	0.90 / 0.87	5
France, Lille	55 / 3	1.01 / 0.99	8
Germany, Hanover	13 / 3	0.96 / 0.96	8
Germany, Lindenberg	41 / 2	0.98 / 0.96	6
Germany, Neuherberg	59 / 5	1.05 / 1.01	10
Great Britain, Manchester	64 / 4	1.28 / 1.27	14
Great Britain, Reading	79 / 4	0.99 / 0.98	8
Greece, Thessaloniki	116 / 8	1.04 / 1.03	8
Italy, Lampedusa	59 / 4	1.05 / 1.04	8
Italy, Rome	53 / 3	0.98 / 0.95	5
Netherlands, Bilthoven	133 / 7	1.04 / 1.03	6
Norway, Oslo	82 / 4	0.96 / 0.95	4
Norway, Trondheim	75 / 4	0.98 / 0.99	9
Poland, Warsaw	69 / 4	0.99 / 0.97	8
Portugal, Lisbon	86 / 4	1.21 / 1.16	11
Spain, El Arenosillo	95 / 5	0.95 / 0.89	8
Sweden, Norrköping	107 / 5	1.03 / 1.03	10

to the GBM instrument are unresolved but are thought to be due to problems related with the local site instrument. Based on these measurements and on a comprehensive uncertainty estimate of all relevant parameters affecting the measurements, the conclusion is that the travelling unit is able to provide quality assurance of spectral ultraviolet measurements in the range 300 to 400 nm with an expanded uncertainty of 5%.

Results

Between May 2003 and September 2004, the travelling unit visited 19 further UV monitoring sites in Europe and performed routine quality assurance of each local site spectroradiometer. Each visit lasted between 3 and 5 days so as to gather simultaneous UV measurements between the local instrument and the travelling unit during at least two nonrainy days from morning to evening (solar zenith angle below 85°). The measurements were normalised to a common slit width of 1 nm using the publicly available SHICRivm software [*Slaper et al.,* 1995] and used successfully in previous intercomparisons. This procedure also allowed to determine the spectral wavelength shift of each local instrument.
Combined with the results from the validation round in 2002, a total of 26 UV monitoring sites were visited, of which two were visited twice. These quality assurance results are summarized in Table1. The results of each site visit are reported in individual reports which are available from the project WEB-page (http://lap.physics.auth.gr/qasume) and also as separately published documents (see *Gröbner et al.,* 2003a, b and 2004).
These results show that the majority of the instruments performed well during the intercomparison period with differences to the travelling unit of 5% or less. Even though the results from such a short intercomparison period cannot be extrapolated to the whole measurement series available at each site, it is hoped that these results are still representative for the overall performance of these site instruments.

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