7.4 EUROPEAN UV BROAD BAND FILTER RADIOMETER REFERENCE SCALE

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Abstract

The pertinent lack of a standard calibration procedure for UV filter radiometers introduces unknown and potentially large uncertainties in their measurement products. Although most UV calibration facilities take into account many instrument properties that affect the measurement quality of UV filter radiometers, some instrument characteristics that are difficult to determine present substantial problems, which limit the measurement quality during long term use of the instruments. At the Joint Research Centre (JRC) of the European Commission a UV broad band filter radiometer reference group is under development which is intended to maintain an accurate UV irradiance scale for instruments used in UV filter radiometer networks throughout Europe. The reference group is intended to be composed of instruments from institutions who may benefit from a uniform and well maintained UV irradiance scale that will be traceable to the high class UV spectroradiometer standard established at the European Reference Centre for Ultraviolet Radiation Measurements (ECUV) at the JRC. From July 2003 on, several UV filter radiometers have been operating routinely next to the UV spectroradiometer standard. All UV filter radiometers together will form part of the reference group, which will be calibrated according to a common procedure. A subset of 3 units in a component summation measurement configuration has been used for a closure study that allows to define a measurement accuracy for UV filter radiometers. The presentation 7.4 gives an introduction to the proposed European UV broad band filter radiometer reference SCALE (EUVSCALE) project, shows first results obtained from the measurements at ECUV, and contains a short discussion of recommendations for UV filter radiometer measurements.

1 Objectives

The EUVSCALE project participates in the new COST-726 action "Long term changes and climatology of UV radiation over Europe". COST was founded in 1971. It is an intergovernmental framework for European *Co*-operation in the field of *S*cientific and *T*echnical research. The goal of COST is the co-ordination of nationally funded research on a European level. COST Actions cover basic and pre-competitive research as well as activities of public utility. The main objective of the COST-726 action in particular is to advance the understanding of UV radiation distribution under various meteorological conditions in Europe in order to determine UV radiation climatology and assess UV changes over Europe. The task of the EUVSCALE project is to establish a broad band UV radiometer reference group that will maintain an accurate UV irradiance scale for instruments used in Europe. To maintain the UV irradiance scale at the highest possible level highly accurate and stable reference spectroradiometers are needed, such as are available at the JRC. During scheduled intercomparison campaigns, the broad band instruments of the reference group will be installed at European UV radiation sites as a Quality Assurance exercise. These intercomparisons will allow to monitor and assess the homogeneity of the national broad band radiometer networks, based on a very short traceability chain.

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2 Calibration

2.1 Spectroradiometers

The main reference spectroradiometer in operation at ECUV is a modified double monochromator spectrophotometer Brewer #163. This instrument has been in operation at ECUV since July of 2001 and has been routinely measuring global and direct solar irradiance in the wavelength region 290nm to 363nm. Between 30 to 50 solar spectra are measured every day, depending on the season. The absolute calibration is traceable to the irradiance reference held at the Physikalisch-Technische Bundesanstalt (PTB) in Braunscheig, Germany. Brewer #163 is calibrated every two months in the laboratory using a set of secondary standards which are maintained and calibrated by ECUV. The global irradiance is measured with a modified entrance optic which was designed to minimize the uncertainties due to a non ideal directional response [1]. The expanded uncertainty (k=2) of solar global irradiance measurements with Brewer #163 is estimated to be less than 4% for solar zenith angles above 80 and for wavelengths between 300nm and 363nm.

The integrated erythemal dose is calculated from these solar spectra using the CIE-weighted action spectrum [4]. A small correction is necessary to compensate for the missing wavelength region from 363nm to 400nm. This correction is obtained from radiative transfer calculations and was validated by simultaneous measurements with a co-located spectroradiometer which measured up to 400nm. This correction varies between +1.5 and -1.5% as a function of solar zenith angle. It is multiplied by the solar irradiance measured at 363nm and added to the CIE-integrated solar spectrum measured by Brewer #163.

2.2 Broad band filter radiometers

The UV broad band reference radiometers are absolutely calibrated using the sun as a calibration source. Due to variations in broad band radiometer characteristics and the strong attenuation of atmospheric UV-B radiation the use of artificial light sources for broad band UV radiometer calibrations is not recommended [2]. The calibration is preferably performed under conditions in which direct solar irradiance is available during the entire spectral scanning period.

The radiometric sensitivity factor ρ is obtained from synchronized and collocated UV measurements performed with the broad band reference radiometers and Brewer #163. The definition of the radiometric sensitivity factor ρ reads [3]

$$\rho = \frac{U_{BBR}}{\int E_{Bre}(\lambda) S_{Rel}(\lambda)\, d\lambda} \tag{1}$$

where U_{BBR} is the broad band radiometer output signal in Volts, $E_{Bre}(\lambda)$ is the measured (and extended) Brewer spectrum in W/m^2nm^{-1}, and $S_{Rel}(\lambda)$ is the (relative) spectral response function (referred to as SRF) of the broad band radiometer. Ideally ρ does not vary during the course of a day as the measured broad band radiometer output signal (enumerator) should be similar to the collocated and synchronized SRF-weighted Brewer spectrum (denominator). The variability of ρ can therefore be used as an assessment of the SRF quality.

The SRF of the Erythemal weighting broad band radiometer is not exactly the same as the theoretical curve, defined by CIE in 1987 [4]. The difference between the instrument specific SRF and the CIE-1987 response function is called the spectral mismatch of the broad band radiometer. As a consequence, the broad band radiometer measurement will deviate from the true Erythemal weighted irradiance if only the radiometric sensitivity factor ρ is used as a calibration factor. To correct for the spectral mismatch error and to extend the number of measurement conditions at which the broad band radiometer can be used accurately, conversion factors for commonly encountered measurement conditions are calculated. The conversion factors, obtained from modelled UV spectral irradiances, allow to account for the effect of varying solar zenith angles (θ_0) and total ozone column density ($[O_3]$) changes on the broad band radiometer measurements. The conversion factor $\gamma(\theta_0, [O_3])$ is given by

$$\gamma(\theta_0, [O_3]) = \frac{\int E_{TUV}(\lambda) S_{Rel}(\lambda)\, d\lambda}{\int E_{TUV}(\lambda) S_{CIE}(\lambda)\, d\lambda} \tag{2}$$

where $E_{TUV}(\lambda)$ is the simulated UV spectrum obtained from a radiative transfer model (for example the TUV model [5]), and where $S_{CIE}(\lambda)$ is the CIE-1987 Erythemal weighting function [4]. Finally, the adjustment factor as a function of the solar zenith angle and the total ozone column density is obtained by

$$\sigma(\theta_0, [O_3]) = \frac{1}{\rho \cdot \gamma(\theta_0, [O_3])} \tag{3}$$

The calibration factor that has to be used for the broad band radiometer should be taken from the adjustment factor table for the conditions at measurement time.

3 Discussion and results

Preliminary results from the measurement campaign in the summer of 2003 at ECUV are available for the broad

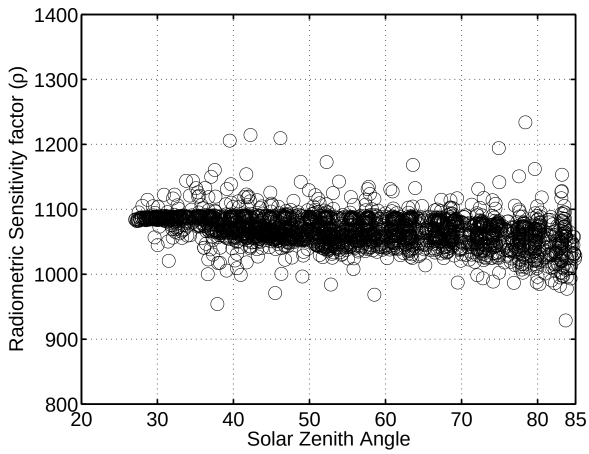

Fig. 1. Radiometric sensitivity factor ρ as a function of solar zenith angle θ_0. The circles represent all measurements made between July 29 and October 11 2003 at the Joint Research Centre (JRC) of the European Commission (Ispra, Italy).

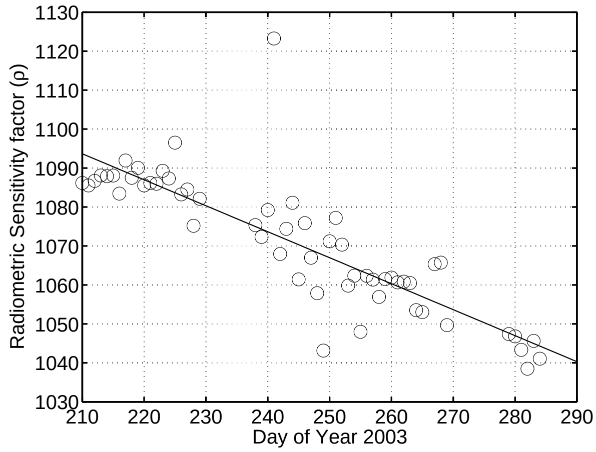

Fig. 2. Radiometer stability shown for ρ versus time for the whole measurement period. The radiometric sensitivity factor ρ is given for $60^\circ < \theta_0 < 65^\circ$.

band radiometer #020613. Figure 1 shows the radiometric sensitivity factor ρ as a function of the solar zenith angle θ_0 for all measurements between July 29 and October 11 2003. Several days are missing due to data acquisition problems and the routine calibration of Brewer #163. The ρ's shown in the figure vary by less than 10% over the range $25^\circ \leq \theta_0 \leq 85^\circ$ which is an indication that the SRF determined in the laboratory is correct. A detailed analysis of the daily variability of ρ also shows that the directional response of radiometer #020613 is very close to the desired cosine response since diurnal variations of the SRF are below 2% on any single day ($\theta_0 < 80^\circ$).

The stability of radiometer #020613 is shown in Figure 2 where ρ is given for $60^\circ < \theta_0 < 65^\circ$ versus time for the whole measurement period. The figure shows that the sensitivity of radiometer #020613 is decreasing over time. This decrease can be approximated quite well with a linear function with a rate of change of approximately -0.06% per day. Over the whole measurement period (74 days) the sensitivity decreased by 4.7%. The reason for this decrease is as yet unexplained and further measurements are needed to resolve these issues.

References

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