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Development and evaluation of an extensive calibration procedure for UV filter radiometers

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Abstract

As a consequence of stratospheric ozone depletion and due to the current uncertainties in the Earth's climate, ultraviolet radiation observations are becoming increasingly important and nowadays form a part of many radiation monitoring networks. UV irradiance is commonly measured either with spectrophotometers or with filter instruments. While the most accurate UV radiation measurements are obtained from high-resolution UV spectrophotometers, e.g. routine observations for public health assessment are performed with wide-band UV filter radiometers (UV-A, UV-B, and Erythemal weighting) as they are simple to maintain.

Due to the physical limitations of filter materials and detectors, the spectral response functions of wide-band UV radiometers are not identical to theoretical spectral sensitivities. Such a spectral mismatch introduces discrepancies between measured and real UV radiative quantities. If the spectral mismatch of the radiometers and the calibration measurement conditions are accounted for in the calibration procedure the measurement accuracy is considerably increased. By using modelled UV spectra the improved measurement accuracy can be expanded to other measurement conditions that were not encountered during calibration, including variations in ozone column density and optical depth.

1. Introduction

The UV-S-X-X ultraviolet radiometers are calibrated using the sun as a calibration source. UV-S-X-X instrument properties and the limited ability to generate a realistic solar UV spectrum with artificial light sources require to derive the calibration factor from atmospheric UV irradiance measurements [1].

The calibration factor of the UV-S-X-X radiometers is obtained from synchronized and collocated UV measurements performed with the UV-S-X-X instruments and the Brewer MKIII No. 182 UV spectrophotometer at Delft, The Netherlands. As the UV-S-X-X radiometer calibration factor depends to a certain extend on solar zenith angle and total Ozone column density the UV-S-X-X radiometer is (strictly spoken) valid for a particular atmospheric measurement condition only. To extend the number of measurement conditions at which the UV-S-X-X radiometer can be used accurately several conversion factors for commonly encountered measurement conditions are determined. The conversion factors, obtained from modelled UV spectral irradiances, allow to account for changes in solar zenith angles and total Ozone column densities.

2. Instrumentation

Several instrument properties have to be known precisely to enable the accurate determination of the calibration factor. For the Brewer MKIII spectrophotometer the most important parameters to be included in the calibration procedure are cosine response function, spectral accuracy, and absolute irradiance accuracy. The critical parameters of the UV-S-X-X radiometers are spectral response function and offset voltage of the electronics.

The corrections for the Brewer spectrophotometer are either performed using discrete ordinate radiative transfer models (cosine response function error correction) or using built-in calibration procedures (e.g. Hg-lamp calibration to check the spectral accuracy). The uncertainty of the Brewer absolute spectral irradiance measurements is estimated to be about 5 to 7% in the UV-B and 4 to 5% in the UV-A.

For the determination of the spectral response function of the UV-S-X-X radiometers an ORIEL MS257 Monochromator is used with a 1000W Xe lamp. The cosine response function of the UV-S-X-X radiometer is not explicitly included in the calibration procedure. However, the measurement uncertainty of the UV-S-X-X radiometers due to the cosine response function error is estimated to be small.

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3. Calibration Procedure

In the present section a description of the calibration procedure is given for the UV-S-E-X instrument with the CIE 1987 [2] Erythemal weighting function only. However, the method is valid for any kind of weighting function, e.g. the UV-A or UV-B weighting function, which is simply a box-function with relative response equal to 1 in the UV-A or UV-B spectral region, respectively, and 0 elsewhere.

Ideally a UV-S-E-X radiometer measures with a spectral sensitivity equal to the (theoretical) Erythemal weighting function (CIE-1987). However, physical limitations of optical materials do not allow to reproduce the theoretical weighting functions exactly. Hence, the non-ideal spectral weighting function of the radiometer introduces differences between the exact irradiance (weighted with the theoretical CIE-1987 function) and the real (radiometer) irradiance. These differences between theoretical Erythema weighted and real UV irradiances are mainly due to varying solar zenith angles and varying ozone column densities, as these variations have a substantial effect on the shape of the UV-B spectrum. As a consequence, the instrument output will have to be adjusted to the measurement conditions by using a conversion factor. The parameters that have to be known for the adjustment are the daily mean total Ozone column density and the solar zenith angle. Daily mean total Ozone column densities are available for any location on the globe from TOMS satellite data. A good approximation of the solar zenith angle can be calculated straightforward using Julian Day, latitude and longitude of the measurement location, and GMT (Greenwich Mean Time).

The procedure for the adjustment of the instrument output to any measurement condition consists of two steps.

First, a 'radiometric' calibration factor, ρ, of the UV-S-X-X radiometers has to be determined using synchronized and collocated UV-S-X-X radiometer measurements and Brewer spectrophotometer measurements. The definition of the 'radiometric' calibration factor reads $\rho=U/E_{UVS}$, where U is the UV-S-X-X radiometer output in Volts and E_{UVS} is the UV-S-X-X spectral response function weighted irradiance in W/m^2, calculated with Brewer spectrophotometer measurements.

Second, the conversion factor, γ, has to be calculated using modelled UV spectral irradiances. The definition of the conversion factor reads $\gamma=T_{UVS}/T_{CIE}$, where T_{UVS} and T_{CIE} denote the UV-S-X-X spectral response function weighted irradiance and the CIE-1987 weighted irradiance, respectively, both calculated with modelled spectral irradiances [3]. The conversion factor is determined using solar zenith angles between 0^o to 90^o in steps of 5^o, and mean total Ozone column densities ranging from 200DU to 500DU in steps of 10DU (DU: Dobson units).

To obtain the 'true' Erythema weighted UV irradiance from UV-S-X-X radiometer measurements the radiometer output has to be multiplied with the factor $\chi=1/(\rho \bullet \gamma)$. Hence, the factor χ adjusts the UV-S-X-X radiometer output to the measurement conditions. A detailed discussion of measurement results obtained with UV-S-X-X radiometer that are calibrated according to the present calibration procedure will be given in the poster presentation or can be obtained from the author.

References

[1] WMO/GAW Report No. 120: WMO – UMAP Workshop on Broad-Band UV Radiometers, Garmisch-Partenkirchen, Germany, 1996. WMO TD – No. 894.

[2] McKinley, A.F. and B.L. Diffey, 1987: A reference action spectrum for ultraviolet induced erythema in human skin. *CIE J.*, 6, 17-22.

[3] Madronich, S. The TUV software package, ftp: acd.ucar.edu/user.