A New multichannel, moderate bandwidth filter instrument for UV and visible irradiance measurements: characteristics and performance

B. A. K. Høiskar[1], A. Kylling[1], K. Edvardsen[1], A. Dahlback[2], M. Blumthaler[3], T. Danielsen[1] and R. Haugen[1]

[1] Norwegian Institute for Air Research, Norway. [2] Department of Physics, University of Oslo, Norway. [3] Institute for Medical Physics, Austria.

Introduction

To monitor UV radiation in all weather conditions requires accurate and robust instrumentation. NILU has developed an accurate, reliable and robust filter instrument for measuring irradiances at ultraviolet (UV) and visible wavelengths. The NILU-UV instrument has been thoroughly tested through comparisons with well calibrated spectral radiometers over extended time periods with significant variations in ozone and cloud cover. The objective of this work is to present the instrument and to derive UV doses, total ozone abundances and cloud effects from the NILU-UV instrument, and compare the results with similar results from a double monochromator Bentham spectroradiometer and a Brewer ozone spectrophotometer.

The instrument

The NILU-UV has six channels; five in the UV region with center wavelengths at 304, 311, 318, 336 and 378nm and a bandpass of approximately 10nm. A sixth channel covers the photosynthetic active radiation (PAR, 400-700nm). The spectral responses of the five UV-channels are shown below.

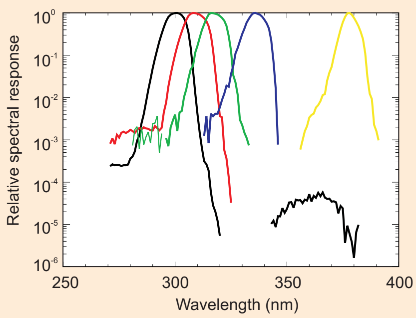

Figure 1: The relative spectral response of the five UV channels.

The NILU-UV is a self-contained unit, with a built-in data logger. The data logger has capacity to store up to 3 weeks of one-minute averages. Data may be retrieved directly from the NILU-UV using a built-in RS-232 port and a PC. Remote data retrieval is also possible via a modem and public telephone lines.

Calibration

The calibration procedure has been described in detail by Dahlback (1996). If $R_i'(\lambda)$ is the relative spectral responsivity of channel i, the absolute responsivity $R_i(\lambda)$ is related to $R_i'(\lambda)$ by

$$R_i(\lambda) = k_i \cdot R'_i(\lambda)$$

The channel dependant calibration factor k_i is determined by

$$V_i = \int_0^\infty k_i \cdot R_i(\lambda) \cdot F(\lambda) \cdot d\lambda$$

V_i : output from channel i
$F(\lambda)$: the spectral irradiance measured by a co-located spectroradiometer.

Only one single spectrum from the spectroradiometer is needed to calibrate all channels. Here a spectrum measured by the Bentham DM300 spectroradiometer located at the Norwegian Radiation Protection Authority (NRPA) at Oslo, Norway, was used.

Various biological effective UV dose rates, D, are derived using N of the channels of the filter radiometer

$$D = \left(\sum_{i=1}^{N} a_i \cdot V_i\right) \cdot \varepsilon(z,\Omega)$$

a_i : coefficients that depend on the chosen biological action spectrum.
$e(z,\Omega)$: error function, normally close to unity
z, Ω : solar zenith angle, total ozone amount

Below CIE (McKinley and Diffey, 1987) weighted UV dose rates derived from the NILU-UV instrument are presented.

The total ozone abundance is determined by comparing a calculated and a measured irradiance ratio, N

$$N(z,\Omega) = \frac{V_i(z,\Omega)}{V_j(z,\Omega)}$$

i, j : two channels with different sensitivity to ozone absorption.

For a UV-A channel, j, that is weakly or unaffected by ozone absorption a cloud transmission factor (CLT) may be defined as

$$CLT = \frac{V_j^{meas}(z)}{V_j^{clear}(z)} \cdot 100\%$$

$V_j^{clear}(z)$: calculated clear-sky irradiance, no aerosols, zero surface albedo.
$V_j^{meas}(z)$: measured irradiance.

The UV radiation model used in this work is based on the discrete ordinate solution to the radiative transfer equation (Stamnes et al., 1988). It has been modified to include the curvature of the atmosphere (Dahlback and Stamnes, 1991).

Results

Total ozone

Total ozone columns measured with a NILU-UV instrument located at the Norwegian Institute for Air Research, Kjeller, Norway, has been compared with total ozone columns from the Brewer instrument no.042. located at the University of Oslo, Norway. The two instruments are separated by approximately 25 km. Figure 2 shows the total ozone measured by the two instruments during 2000 and the percentage deviation between the NILU-UV and the Brewer instrument. The atmospheric conditions during the measurement period were highly variable and the results are therefore representative for both cloudy and clear-sky conditions. The solar zenith angle varied between 37º and 80º during this period. The mean deviation is (-1.1 ± 2.5)%.

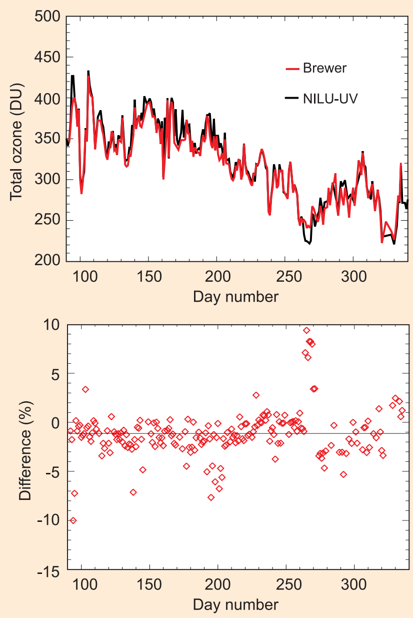

Figure 2: Upper panel: Total ozone measured by the NILU-UV and the Brewer instruments. Lower panel: Percentage deviation.

CIE weighted UV dose rates

In August 2000 a NILU-UV was co-located for seven days with a Bentham DM300 during the ADMIRA (Actinic flux determination from measurements of irradiance) campaign in Nea Michaniona, Greece. CIE-weighted doserates from the NILU-UV are compared with CIE doserates from the Bentham DM300 in the figure below. The mean deviation was (2.3 ± 1.6)%.

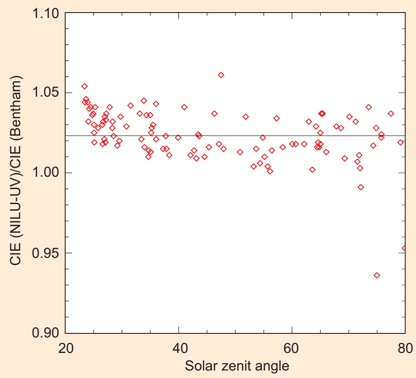

Figure 3: Ratios of CIE weighted UV dose rates: NILU-UV/Bentham.

Cloud effects

The cloud transmittance factor is shown below for a partly cloudy day together with the CIE doserate.

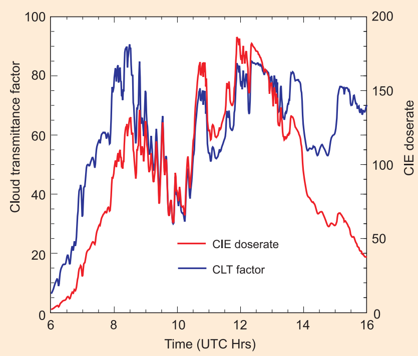

Figure 4: Cloud transmittance factor and CIE weighted UV doserates measured by the NILU-UV instrument in Oslo 1 May 2000.

References

Dahlback, A (1996) Measurements of biologically effective UV doses, total ozone abundances, and cloud effects with multichannel, moderate bandwidth filter instruments. Appl. Opt., Vol. 35, No 33: 6514-6521.

Stamnes, K, S.-C. Tsay, W. Wiscombe, and K. Jayaweera (1988) Numerically stable algorithm for discrete-ordinate method radiative transfer in multiple scattering and emitting layered media. Appl. Opt., 27: 2502-2509.

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