Results from a new multichannel, moderate bandwidth filter instrument for UV and visible irradiance measurements

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Introduction

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.

Why use multichannel broadband instruments?

- **Simpler and less expensive compared to high-wavelength-resolution spectroradiometers**
  - No moving parts, easy to calibrate, require little attention
  - Easy to maintain and operate in harsh environments
  - Increase geographic coverage
- **Provides reliable data on:**
  - biologically effective UV-dose rates
  - total ozone abundance during cloudy and clear sky conditions
  - Cloud effects/cloud transmission

The instrument

- **A 6-channels filter radiometer**
  - 5 channels that measure UV irradiance. Center wavelengths: 305 nm, 312 nm, 320 nm, 340 nm and 380 nm. Bandwidth: 10 nm FWHM
  - 1 channel that covers the photosynthetic active radiation (PAR, 400-700 nm)
- **Temperature controlled at 40°C**
- **Built in data logger with capacity to store 3 weeks of one-minute averages**

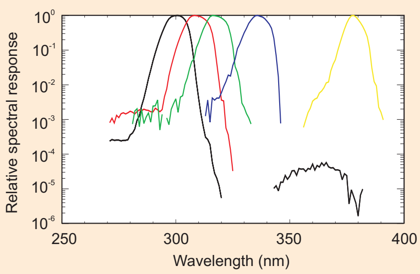

Figure 1: The spectral response of the five UV channels. The spectral response was measured at the Norwegian Radiation Protection Authority (NRPA).

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 dependent 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 data from N channels

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

a_i : coefficients that depend on the chosen biological action spectrum.

$\varepsilon(z,\Omega)$: error function, normally close to unity

z,Ω : solar zenith angle, total ozone amount

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 transmittance 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

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 Greece. CIE-weighted doserates from the NILU-UV are compared with CIE doserates from the Bentham in Figure 2. The mean deviation was (2.3 ± 1.6)%.

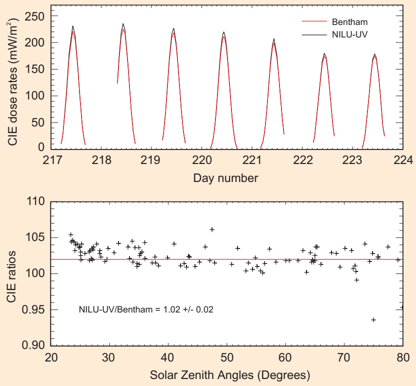

Figure 2: Upper panel: CIE-weighted dose rates from the NILU-UV and the Bentham DM300 as measured during the ADMIRA campaign in Greece. Lower panel: Ratios of CIE-weighted UV dose rates: NILU-UV/Bentham

Total ozone

Total ozone columns measured with a NILU-UV instrument located at the Norwegian Institute for Air Research, Kjeller, Norway, have 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 3 shows the total ozone measured by the two instruments during 2000 and 2001 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 37° and 75° during this period.

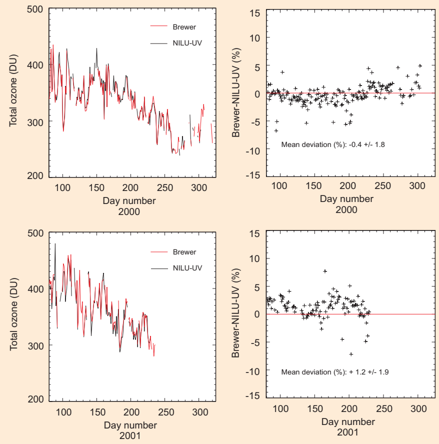

Figure 3: Left panels : Total ozone measured by the NILU-UV and the Brewer instruments in 2000 and 2001. Right panels: Percentage deviation

Cloud effects

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

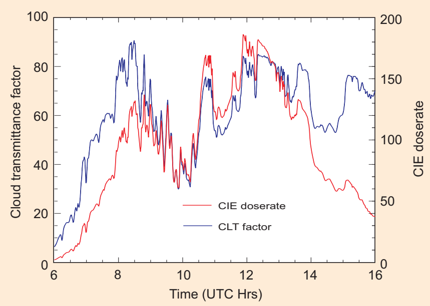

Figure 4: Cloud transmittance factor and CIE weighted UV doserates measured by the NILU-UV instrument in Oslo 1 May 2000.

References

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