

Spectral Ultraviolet Radiation Measurements and Correlation with Atmospheric Parameters

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Abstract

At KNMI an experimental infrastructure for ground based monitoring of ultraviolet radiation (UV) and ozone has been realized since the beginning of 1994. In this article the measuring instruments will be discussed, and some preliminary results from our data analysis are shown. Spectral UV-radiative transfer calculations have been compared with measurements, but those results are presented elsewhere [1].

1. Introduction

The amount of ultraviolet radiation (UV) reaching the Earth surface depends on parameters such as solar elevation, total column ozone and ozone profile, aerosol, clouds, ground albedo, etc. Since many of these parameters change when atmospheric conditions change, ground level UV also is highly variable. However, if long term ozone depletion occurs, a gradual increase of ground level UV may be observed. At this moment UV-measurements provide contradicting evidence for slightly decreasing and increasing UV-levels [2-5]. The 'long term' spectral UV-measurement series are still too short to provide definite answers on the issue of increasing/decreasing UV-levels.

Ultraviolet radiation measured at sea level spans a wavelength region from 290 to 400 nm. To obtain a single number representing the energy in a UV-spectrum, the dose rate dD/dt (mWm^{-2}) is introduced as the weighed wavelength integrated UV by [6]

$$\frac{dD}{dt} = \int_{100}^{400} I(\lambda)A(\lambda) d\lambda, \quad (1)$$

where λ is the wavelength in nm, $I(\lambda)$ is the spectral UV-irradiance in $mWm^{-2}nm^{-1}$. $A(\lambda)$ is the CIE-action spectrum (also called McKinlay-Diffey action spectrum [7]), which is a mathematical representation of the sensitivity of 'the human skin' to sunburn. The total dose, D , is obtained by integrating Eq.(1) over the time the exposure takes place. From hereon the dose rate will be called Damaging UV (DUV). DUV is used here to represent amounts of UV for all kinds of processes in which UVB is a dominant factor.

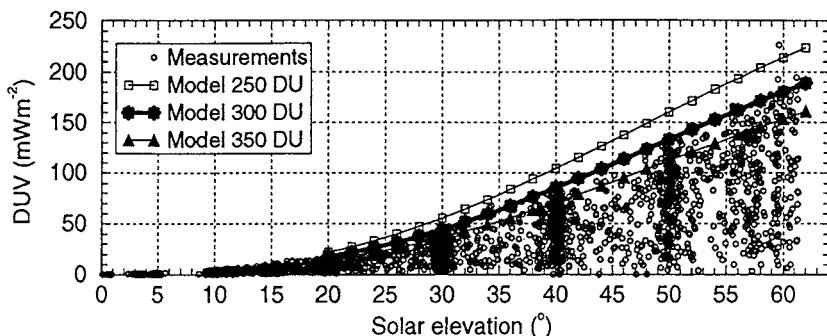


Figure 1. All DUV-measurements from January to September 1994, as a function solar elevation. The curve that agrees best with the maximum observed values is a model calculation using total column ozone of 300 DU.

2. Measurements and Calibrations

To study the correlation between ozone and UV, spectral measurements should be performed at least every 0.5 nm. In medical and biological sciences various action spectra are frequently used to describe effects of UV-radiation on different systems. This can also only be done if spectral UV-measurements are available. However, for monitoring purposes it is more convenient to have additional 'simple' instruments that require little maintenance, are (relatively) cheap, and easy to handle in the sense that they do not require highly educated operators. Therefore, both types of instruments are used at KNMI.

Measurements performed at KNMI concerning UV-research are:

Spectral UV Spectral UV-monitoring between 285 and 365 nm is performed with Brewer spectrophotometer #100. The optical part of the instrument consists of a scanning double monochromator.

Total column ozone measurements The same instrument is employed to measure total column ozone with an accuracy between 1 and 5%. There are at the moment over 100 Brewers spread over the globe for ozone measurements, which are collected by the World Meteorological Organisation (WMO).

Narrow band UV-measurements Four narrow band instruments are used to monitor UV-radiation at 306 nm (UVB, FWHM: 3 nm) and 367 nm (UVA, FWHM: 10 nm). For both the wavelengths we perform global measurements (irradiance passing through a horizontal plane) and direct sun measurements (flux in the direct solar beam). The instruments for the direct sun measurement are mounted on a solar tracker.

Additional radiation and meteorological measurements Broad band global, direct and diffuse solar radiation monitoring is performed at the same radiation measurement setup at the KNMI-rooftop as that for the UV-measurements. Cloud cover observations and all other meteorological parameters measured at KNMI, are used or available for UV-research.

Irradiance calibrations of (spectral) UV-measurement instruments are very difficult, especially in the UVB-region of the spectrum. Therefore, special requirements have to be met to do reliable and reproducible calibrations. Moreover, the scientific UV-community is still arguing

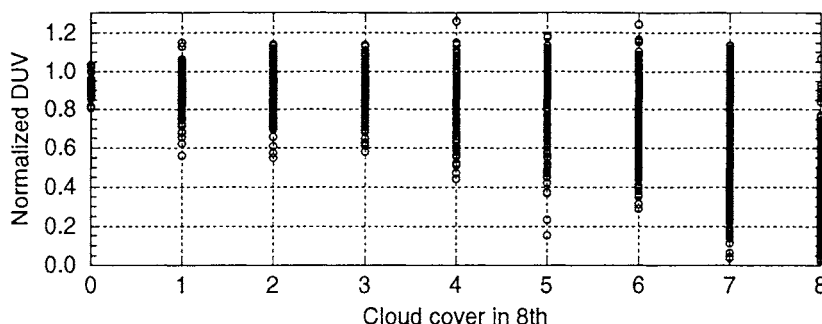


Figure 2. Normalized DUV as a function of cloud cover for the period January–September 1994.

about the best procedures, and at the KNMI-calibration laboratory we participate in this research. The main features of the lab, that was finished after the summer in 1994, are discussed elsewhere [1].

3. Results

In Fig. 1 all DUV measurements recorded in the period January–September 1994 are shown as a function of solar elevation. These measurements thus include all kinds of possible cloud cover conditions, i.e. from clear skies to completely overcast conditions. From this figure it can be seen that for a certain solar elevation almost every value for the DUV is possible within a certain maximum. In the same graph three curves are shown. These were computed employing an empirical model that uses total column ozone and solar elevation as input [8,9]. For the Netherlands the maximum value for the DUV can be approximated using this model with a total column ozone of 300 DU.

DUV measurements recorded at the KNMI with the Brewer during the first eight months of 1994, are depicted in Fig. 2 as a function of cloud cover. The measurements are normalized using maximum values for clear sky conditions that were obtained from the empirical model. Because both solar elevation and ozone are taken into account in this model, the normalized measurements are independent of these parameters.

From Fig. 2 it can be seen that for 0/8th cloud cover all ratios are within 0.8 and 1.1. The model does not take into account effects of aerosol, haze, ground albedo, UV-absorption by SO_2 , and all other parameters that may influence ground level UV-irradiance for clear sky conditions. The magnitude of the fluctuations in the normalized DUV thus demonstrates that variations in UV-irradiance up to 20% can be expected for a given solar elevation and total column ozone.

The highest values for the DUV do not occur for clear sky conditions, but for situations with 1/8th to 6/8th cloud cover. This effect is caused by reflections at the side of clouds. When (cumulus) clouds are located near the position of the Sun in the sky, a large amount of almost direct solar radiation can be reflected in the direction of the detector. The amount of observed global UV-radiation can then increase beyond values measured under clear sky conditions [10,11].

This increase in irradiance in the presence of cumulus clouds is also observed in measurements of the narrow band and the short wave (broad band) instruments. In Fig. 3, 10-minute averaged measurements of the global radiation and the UVA and UVB-global instruments are shown for 2 days in the summer of 1994. Between 11:00 UT and 14:00 UT on the partly cloudy day, cloud cover varied between 1/8th and 5/8th. This resulted in an increase of the global radiation of

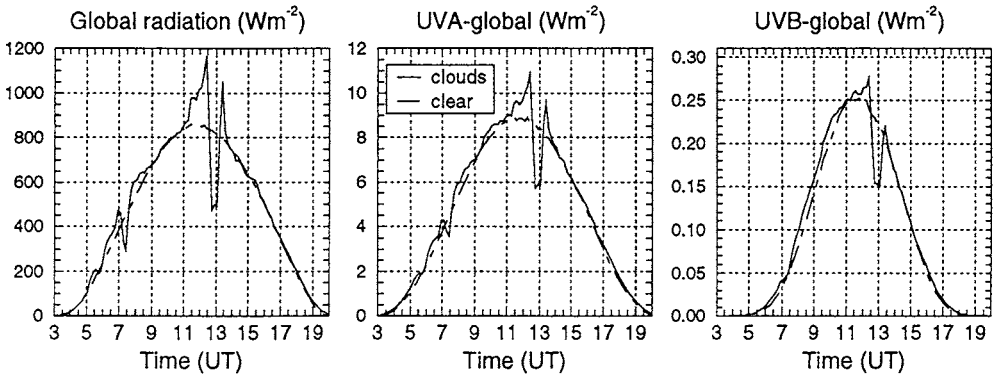


Figure 3. Broad band global radiation, UVA and UVB global radiation, for June 28, 1994 (solid line). The sharp increases in radiation relative to the clear sky measurements (July 12, 1994) are caused by reflection of solar radiation at the side of cumulus clouds.

38%, and approximately 15% for both the UVA and UVB global measurements, relative to the clear sky measurements.

4. Acknowledgements

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