Balloon and surface UV radiation measurements with the NILU-CUBE instrument

A. Kylling, T. Danielsen, A. Webb, M. Blumthaler, and J. Schreder
Norwegian Institute for Air Research, Kjeller, Norway. E-mail: arve.kylling@nilu.no

Abstract

The NILU-CUBE is a multichannel medium bandwidth filter radiometer designed to be flown as part of balloon payloads. It may also readily be operated on the ground. Below the instrument and its characteristics are presented together with measurements from a twilight stratospheric balloon flight from Gap-Tallard, France, from two hot-air balloon flights over East-Anglia, England, and from surface measurements in Nea Michaniona, Greece. All measurements are compared with model simulations.

The NILU-CUBE instrument

The NILU-CUBE, Figure 1, measures the irradiance on the six faces of a cube. On each face the radiation is measured at 312 nm and 340 nm with a bandwidth of approximately 10 nm at full width half maximum. The weight of the instrument including a separate data logging unit is 4 kg. Data are logged every 3 second. The calibration factors k_i for each channel are determined by comparing measurements $E(\lambda)$ from a well characterized and high-quality spectroradiometer with simultaneous measurements of the current C_i from the filter instrument

$$k_i = \frac{C_i}{\int_0^\infty R_i(\lambda) E(\lambda) d\lambda}.$$

The relative spectral response, $R_i(\lambda)$, of the NILU-CUBE was measured in the laboratory using a 1000 W Xe-lamp, a light-intensity controller and a calibrated reference radiometer. Further details of the calibration procedure for moderate bandwidth filter instruments are provided by Dahlback [1996].

Figure 1: The NILU-CUBE in flight position without styrofoam protection.

Stratospheric balloon flights

Rather few measurements are available of the UV radiation field from the Earth's surface up into the stratosphere. Considering the importance of UV radiation for photochemistry, this is surprising. Measurements are needed both for model validation and for understanding the processes that affect the radiation. Figure 2 show measurements and model simulations from a stratospheric balloon flight that originated in Gap-Tallard, France, on 30 June, 2000. The measurements were made for very large solar zenith angles which are a challenge for radiative transfer models. Still the multistream model [Stamnes et al. 1988], utilizing pseudo-spherical geometry [Dahlback and Stamnes 1991], reproduces the measurements within ± 10 % (± 20 %) for solar zenith angles smaller than 93° (90°) for the 340 (312) nm channel.

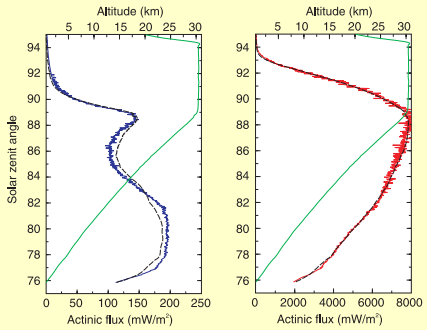

Figure 2: The measured total signal from all heads as a function of solar zenith angle for 312 nm (blue line) and 340 nm (red line). The black lines are model simulations. The green line is the altitude of the instrument. An ozone layer signature is clearly present in the 312 nm signal.

Tropospheric balloon flights

The NILU-CUBE may be suspended from manned hot air balloons to study how the radiation field varies in the lower troposphere. Two hot air ballon flights were carried out in September 2002 over East-Anglia, UK, as part of the INSPECTRO project. Due to safety reasons the flights took place just before sunset, implying solar zenith angles between 73° and 83°. A fairly homogeneous cloud layer was present above the balloon during both flights. The measured effective albedo along with model simulations are shown in Figure3.

Surface measurements

For studies of UV radiation the most common quantity to measure is the irradiance on a horizontal surface. This is also the basis for the UV index. However, for many situations it is of interest to know the radiation field on surfaces with a different orientation. The NILU-CUBE may readily be used for such purposes. During the ADMIRA campaign the NILU-CUBE was located about 3 m above a roof on a seashore building. The measured irradiances are shown in Figure 4.

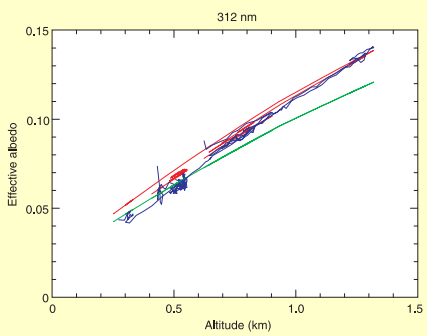

Figure 3: The measured albedo (= upwelling/ downwelling irradiances) as a function of altitude (blue lines). The green and red lines are model simulations with and without a cloud layer respectively.

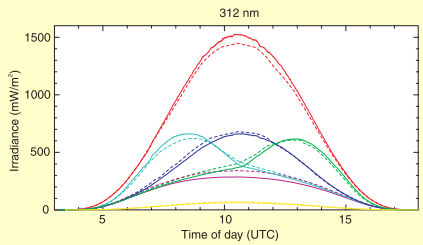

Figure 4: The irradiances from the various heads as function of time for 5 Aug. 2000 during the ADMIRA campaign, Nea Michaniona, Greece, (Webb et al.[2002]). The downwelling irradiance is shown in red, the upwelling in yellow. The magenta, blue, green and purple colored lines represent the vertical east, south, west and north irradiances respectively. The measurements are shown as solid lines while the dashed lines represent model simulations.

Further development

A new version of the NILU-CUBE is currently under development. It will have improved cosine response, a built in data logger including a GPS unit and temperature and pressure sensors. In addition orientation sensors will be included. Finally, each head will measure the irradiance in six different channels in the UV, visible and NIR. The radiative transfer model is available from www.libradtran.org.

Acknowledgments

The measurement campaigns were in part supported by the EC-funded ADMIRA, INSPECTRO and HIBISCUS projects. In addition support from the COZUV project funded by the Norwegian Research Council is acknowledged.

References

Dahlback, A. (1996) Measurements of biologically effective UV doses, total ozone abundances, and cloud effects with multichannel, moderate bandwidth filter instruments. *Appl. Opt.*, 35, 6514-6521.

Dahlback, A. and Stamnes, K. (1991) A new spherical model for computing the radiation field available for photolysis and heating at twilight. *Planet. Space Sci.*, 39, 671-683.

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

Webb, A.R., Bais, A.F., Blumthaler, M., Gobbi, G.-P., Kylling, A., Schmitt, R., Thiel, S., Barnaba, F., Danielsen, T., Junkermann, W., Kazantzidis, A., Kelly, P., Kift, R., Liberti, G.L., Misslbeck, M., Schallhart, B., Schreder, J. and Topaloglou,C. (2002) Measuring spectral actinic flux and irradiance: Experimental results from the ADMIRA (Actinic Flux Determination from Measurements of Irradiance) project. *J. Atm. Ocean Technol.*, 19 (7), 1049-1062.