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Scientific note

Personal ultraviolet-B dosimetry at Koldewey-Station by using an electronic dosimeter ELUV-14

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Abstract: Personal exposure of ultraviolet-B irradiance (UV-B) was measured by small portable dosimeter (ELUV-14) at Koldewey-Station in Ny-Ålesund, from May 15 to August 15, 1999. While ten persons carried those dosimeters global irradiance was simultaneously measured by a UV-B spectral radiometer. The highest erythemal weighted global UV-B dose was 2200 J/m^2 recorded on June 8, 1999. The personal related maximum value was about 345 J/m^2 on May 25, 1999. This correponds to approximately 23% of the global dose recorded at the same day.

1. Introduction

Due to the ozone depletion during the last decades (*e.g*., WMO, 1995; Bojkov *et al*., 1990, 1995), increased concern has been given to the changes in the ultraviolet-B (UV-B) solar radiation reaching the earth surface (*e.g*., Booth and Mardonich, 1994; Karsten *et al*., 1999; Krzyscin, 2000; Seckmeyer *et al*., 1995; McKenzie *et al*., 1991). Since 1994 a personal dosimetry programme has been performed at Neumayer-Station (70°39′S; 08°15′W) to quantify the impacts of the UV-B radiation on human beings in Antarctica. During the summer season 1999, these studies were extended to Koldewey Station (78°56′N; 11°57′E) to quantify the range of personal related doses at Arctic latitudes for the first time.

Personal UV-B doses were measured with the dosimeter ELUV-14 (El Naggar *et al*., 1995) from May 15 to August 15, 1999. Ten persons carried dosimeters as badges during outdoor activities. Simultaneously, global UV-B irradiance was continuously measured by a UV-B spectral radiometer (Groß, 1998; Groß *et al*., 1998, 2001) and by a horizontally mounted dosimeter ELUV-14.

The obtained irradiance data were used to determine the global and the individual UV-B doses. Further evalution was focused on assessing a risk factor for Koldewey-Station by comparison of the measured irradiance to a reference. The reference here is set to be the maximum irradiance reaching the earth surface at sea level at a solar elevation of 90° measured at the Equator on June 8, 1998 (23°N; 17.75°W) using the same instrumentation.

2. Instrumentation and data processing

The UV-B spectral radiometer consists of a Bentham DM 150 double monochromator. A photon counting Micro-Channel Plate (MCP) is used as array detector. The MCP

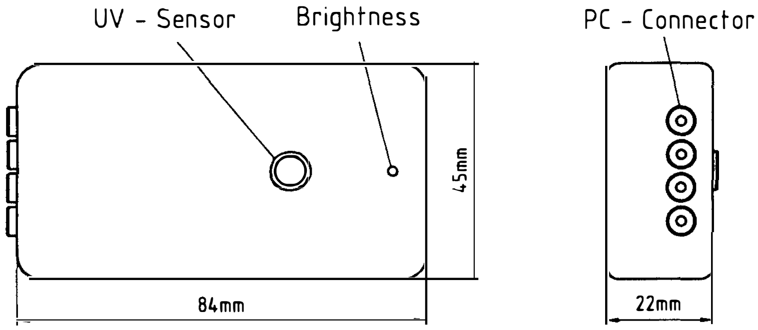

Fig. 1. A drawing of the ELUV-14 dosimeter illustrating size and position of sensors.

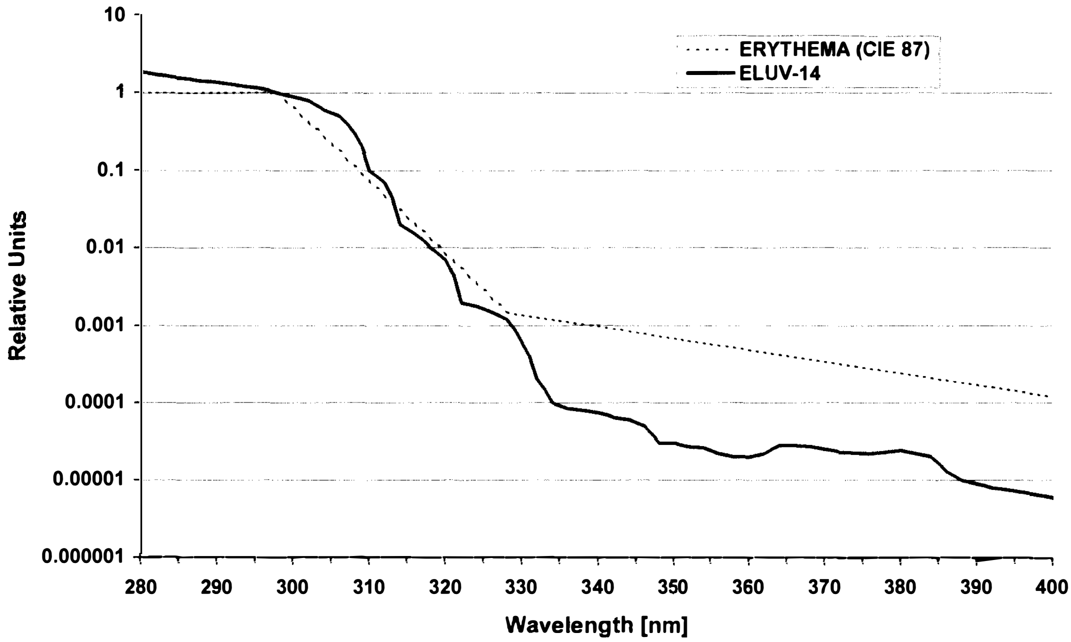

Fig. 2. Spectral sensitivity of the ELUV-14 dosimeter (solid line) and the standard erythemal spectra CIE 87 (dashed line).

consists of 32 channels. UV-B spectra are recorded in the wavelength range between 285 nm and 323 nm every 5 min. These irradiance data were used to calculate the unweighted, ELUV-14 and erythemal weighted global UV-B irradiances and doses. The ELUV-14 is a small robust waterproof 3-channel datalogger equipped with a special UV-B sensor, a Pt-100 temperature sensor, and a silicon photodiode as brightness sensor. It was designed as a personal outdoor dosimeter of size 82 × 45 × 22 mm and a weight of 95 g including the lithium battery (Fig. 1). The UV-B sensor had a relative spectral sensitivity similar to the standard erythemal spectrum (McKinlay *et al.*, 1987). In Fig. 2 the spectral sensitivities are compared to relative units for the ELUV-14 dosimeter and the standard spectral erythemal response. Because of the good coincidence in the spectral range between 280 nm and 330

Table 1. Technical data of the UV-B dosimeter ELUV-14.

UV-weighted irradiance:	The dosimeter provides an UV-B irradiance weighted by ELUV-14 response function in mW/m^2. The ratio between by ELUV-14 measured irradiance and the erythemal weighted irradiance, derived from high resolution spectra (integrated from 290 - 322 nm) varies between **1.2** and **1.6** and is mainly a function of solar elevation and ozone.
Spectral range:	240...380 nm
Sensor sensitivity (max. at 280 nm):	3 $\mu W/m^2$ (typ.)
Measuring range: (normal): (extended):	0 ~ 160 mW/m^2 (typ.) 0 ~ 3.1 W/m^2 (typ.)
Accuracy:	5%
Visible irradiance:	
Spectral range:	530...1020 nm
Sensor sensitivity (max. at 280 nm):	170 $\mu W/m^2$ (typ.)
Measuring range:	20 W/m^2 (typ.)
Temperature:	
Sensor:	PT-100
Range:	-55 °C...+50 °C
Resolution:	0.05 K
Accuracy:	0.5 K
Common parameters:	
Basic Sampling Rate (BSR):	programmable; 1..250 min, in 1 min steps for all input channels
Individual sampling rate:	1..250 min for each channel
Storage capacity:	512 KB
Autonomous operatio:	30 days (BSR = 1 min for all channels)
Battery:	Lithium, 2/3AA
Operation temperature:	- 40 °C .. +50 °C
Storage temperature:	-55 °C .. +70 °C
Size:	84*45*22 mm
Weight including battery	95 g
Housing:	PVC , waterproof
Data out:	ASCII, Microsoft EXCEL compatible
PC interface (with adaptor):	serial (RS-232)

nm, the ELUV-14 dosimeter can be used for erythemal weighted dosimetry.

The basic sampling rate is one minute and could be set up to 255 min. The storage capacity at a sampling rate of 1 min is about 30 days using a Flash Eprom Memory. System settings and data read out are controlled by a PC program running under MS Windows and using an RS-232 serial ASCII-spreadsheet data transfer. A special adaptor connects the dosimeter to the PC. Technical data of the ELUV-14 dosimeter are given in Table 1.

During the Arctic campaign, UV-B spectral radiometer and ELUV-14 data were permanently recorded.

The high resolution spectral radiometer data were used to derive weighted UV-B-irradiances by weighting the spectral data by the corresponding response function (ELUV-14, erythema) and integrating in the spectral range between 290 and 322 nm. Those

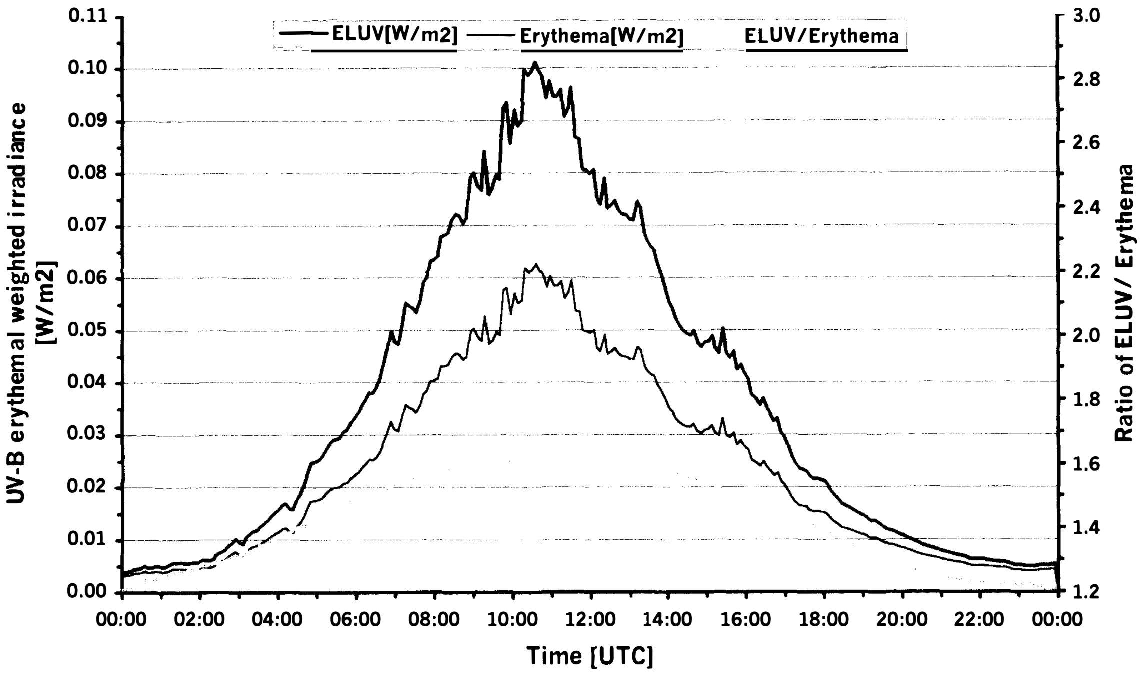

Fig. 3. Diurnal variation of ELUV-14 (bold line) and erythemal (thin line) weighted UV-B irradiances derived from spectral radiometer data recorded at Koldewey-Station on June 8, 1999. The ratio ELUV-14/Erythema (lower curve) is the transformation function between both weighted irradiances for this day.

weighted irradiances were used to calibrate the dosimeter.

The ELUV-14 weighted irradiance derived from spectrometer data in mW/m^2 was compared to the by ELUV-14 dosimeter directly measured irradiance at the same time and location. The ratio of those two irradiances yields the constant calibration factor of the dosimeter. The maximum relative error is about 5%.

Due to the fact that the spectral response of the dosimeter and that of the erythema are only similar but not equal (Fig. 2), a deviation between both weighted irradiances of the same day is expected. Comparison of both weighted irradiances derived from spectral data yields the transformation function between both weighted irradiances. This was calculated for each day. As an example, this comparison and the transformation function are shown in Fig. 3 for June 8, 1999. The ratio of the irradiances varies between 1.2 and 1.6 and is mainly a function of solar elevation and ozone.

The transformation of by ELUV-14 directly measured irradiance (ELUV-14 weighted) to the erythemal weighted irradiance was retrieved in post-processing according the derived transformation function of the same day.

The comparison shows that the small mobile ELUV-14 dosimeter is able to measure the erythemal weighted UV-B irradiances in good agreement with the spectral radiometer. Ozone data were obtained from the TOMS-data center (TOMS data, 1999) and used to study the impact of ozone column density on the erythemal weighted irradiance at Koldewey-Station.

Personal exposure of UV-B were recorded using 10 individual ELUV-14. The integrated UV-B irradiance, date, and time were recorded every minute. Daily erythemal weighted UV-B irradiance were retrieved by summing up the irradiance values after weighting by the corresponding transformation function.

3. Results and discussion

Figure 4 shows the record of unweighted and erythemal weighted daily global UV-B dose measured by the spectral radiometer at Koldewey-Station during the campaign. The large variability is mainly caused by the meteorological conditions, like cloud coverage, snow, and rain. In order to assess the impact of atmospheric ozone, the ratio between unweighted and erythemal weighted daily global UV-B dose was calculated and compared with the ozone column densities (DU) in Fig. 5. The ratio varies between 27 and 39 and is fairly well correlated to the corresponding daily ozone column densities. However, the original values of unweighted and weighted UV-B global doses are not correlated to ozone as can be seen by comparing Fig. 5 and Fig. 4. Only the ratio is significantly controlled by the variability of atmospheric ozone. This is explained by the effect of cloud coverage and snow as mentioned bevor.

Figure 4 shows that the maximum of daily UV-B dose was measured at Koldewey-Station on June 8, 1999. The diurnal variations of the erythemal weighted irradiances obtained by the spectral radiometer and by ELUV-14 for this case are shown in Fig. 3.

The maximum unweighted global UV-B irradiance was 1.6 W/m^2 and the corresponding maximum of erythemal weighted irradiance was 60 mW/m^2. The weighted UV-B dose for this day was 2200 J/m^2. The ozone column density was 312 DU.

In order to assess these doses recorded at Arctic latitudes, similar measurements performed at tropical latitudes are used as a reference. These data were obtained using the

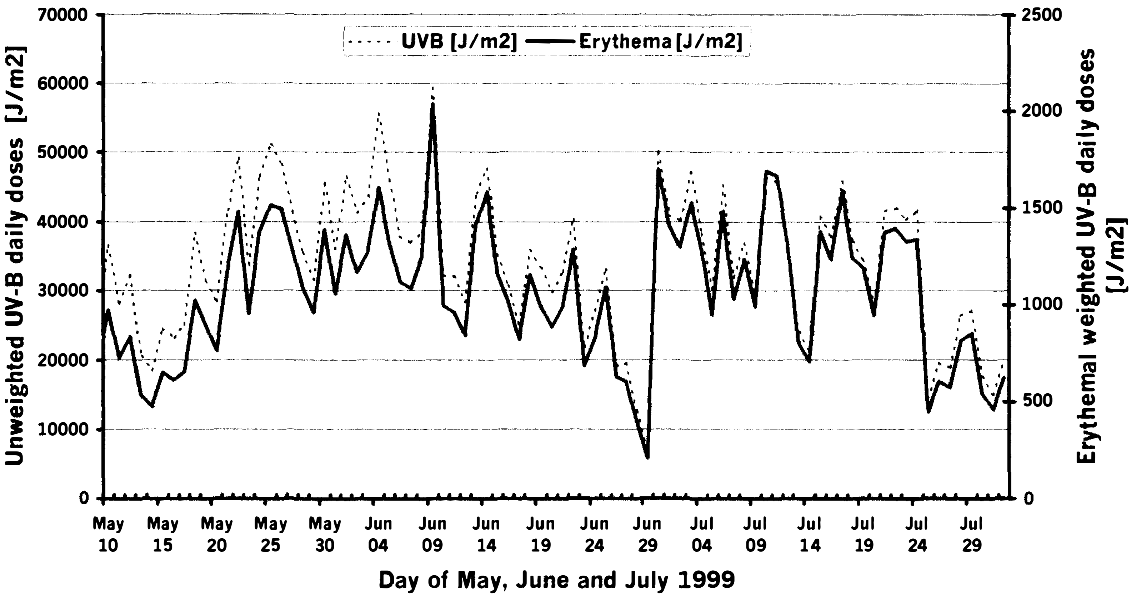

Fig. 4. Daily unweighted (dashed line) and erythemal weighted (solid line) global doses as recorded at Koldewey-Station from May to August, 1999.

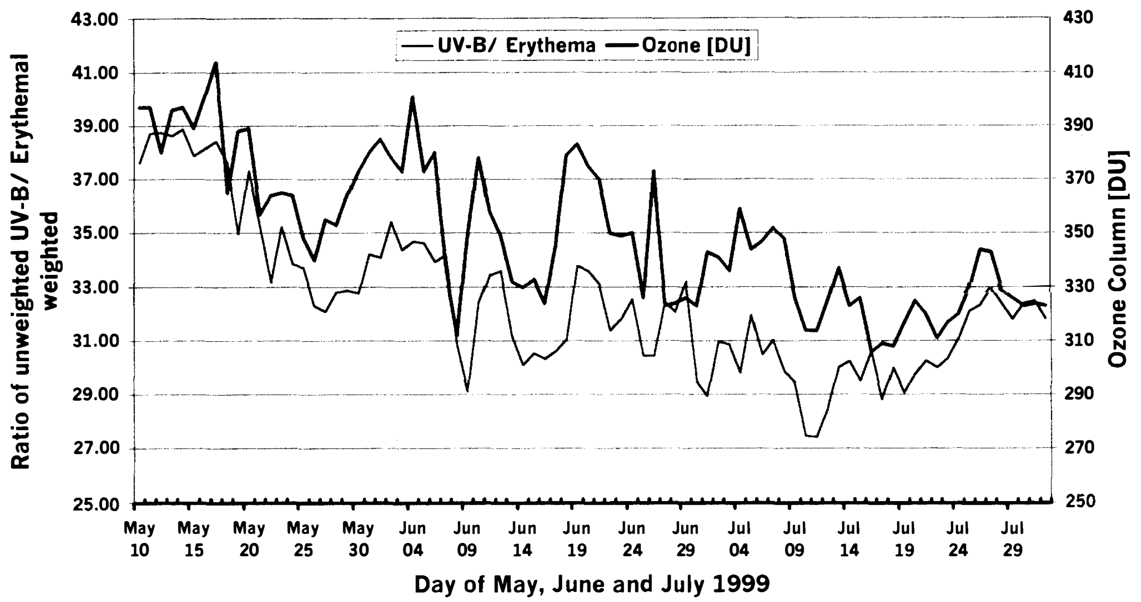

Fig. 5. *Ratio of daily unweighted to erythemal weighted global UV-B doses (thin line) and ozone column densities recorded at Koldewey-Station from May to August, 1999.*

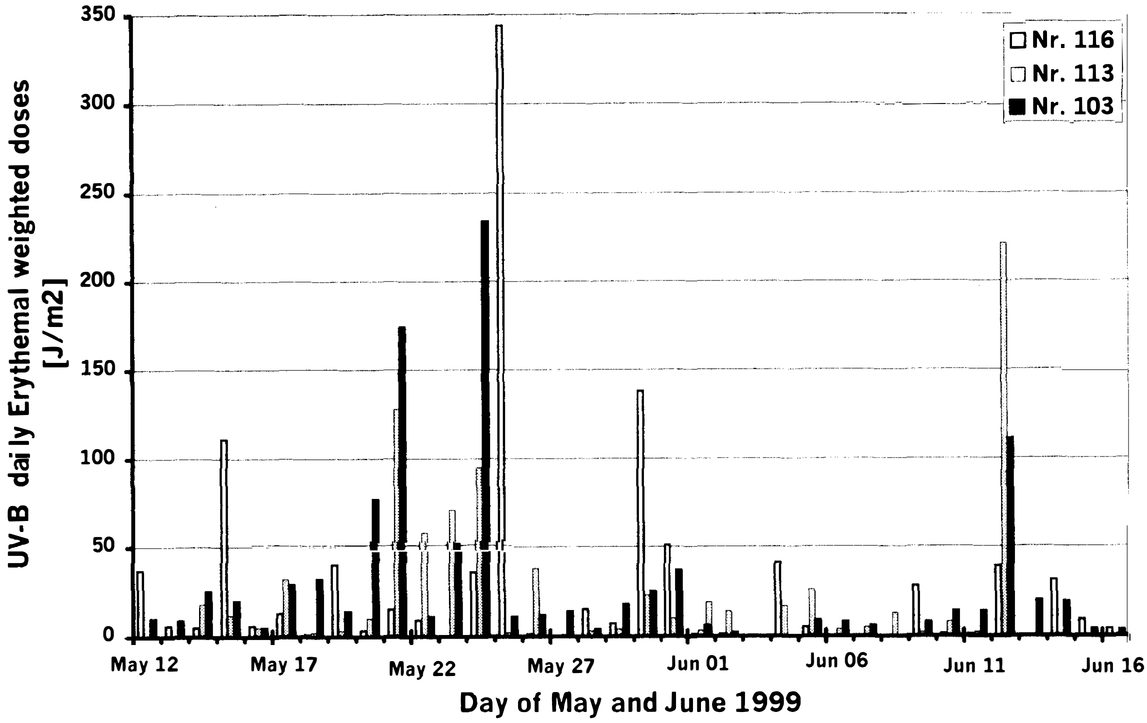

Fig. 6. *Personal UV-B doses obtained for three persons at Koldewey-Station from May to June, 1999.*

same instrumentation during voyages of the German research vessel "Polarstern" between Bremerhaven and Cape Town. Near the equator (23°N; 17.75°W) on June 8, 1998 the UV-B irradiance was 4.5 W/m^2 at a solar elevation of 90° and a comparable ozone column density of 310 DU. The corresponding erythemal weighted irradiance was 250 mW/m^2 and the erythemal daily weighted dose reached about 4500 J/m^2 for clear sky conditions. This comparison shows that at the Arctic Koldewey-Station, the maximum irradiance was only 22% of the corresponding equatorial value. However the corresponding daily dose reaches values up to 45%. This higher fraction of the daily dose might be due to longer lasting sunlit conditions during the polar day.

In Fig. 6 three examples for daily personal UV-B doses are shown. The inter-diurnal variability mainly depends on outdoor activities. Thus no correlation to the variation of global doses exists. The recorded maximum of personal dose was about 345 J/m^2 on May 24, 1999. This corresponds to only about 23% of the global dose of this day.

4. Conclusion

The ELUV-14 personal dosimeter provides reliable data of erythemal weighted UV-B doses. The relative values can be easily calibrated by comparison with spectral radiometer measurements.

At Koldewey-Station, the maximum erythemal weighted UV-B irradiance is only 22% of the equatorial values, but the daily doses might reach up to 45% because of the longer lasting polar day.

The maximum recorded personal dose was about 23% of the global dose for the same day.

Acknowledgments

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