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INTENSITY OF ULTRAVIOLET AND TOTAL SOLAR RADIATION IN ŁÓDŹ

Abstract: The paper presents the analysis of measurements of UV (290-400 nm) and total solar radiation (303-2800 nm) values in Łódź in the period 1997-1999. The daily values of UV and total radiation are highly correlated with a general linear relation. The UV daily values constituted on average 4.2% of total daily radiation. The high values of ratio Iuv/It (≥7%) occurred in cloudy days while the total irradiance decreased with increasing cloudiness. This shows that the clouds absorb more in near infra-red than UV region of the solar spectrum.

Key words: ultraviolet solar radiation, total solar radiation, Łódź, Poland.

1. Introduction

The measurements and the study of solar ultraviolet radiation have received considerable attention because of the significant biological and environmental effects e.g. skin and eyes diseases, pigmentation, photodecomposition, damage of crops, ecosystems and materials etc. For a long time just UVB (290-320 nm) was thought to be responsible for the negative effects. Nowadays the recording of broad band UV radiation (UVA+UVB, 290-400 nm) get more popular because of experimental and epidemiological evidences of biological effects of UVA (320-400 nm). Most of the stations recording the broad band UV radiation in Europe have been established recently and a very few results have been published. The data series of UV radiation have been analysed for Spain (Valencia: Martinez-Lozano, Casanovas 1994; Martinez-Lozano et al. 1996, 1999), for Germany (Potsdam: Feister, Grasnick 1992), for Slovakia (Bratislava: Zavodska, Reichrt 1985), and for a high altitude station in Switzerland (Ambach et al. 1991).

The recording of UV radiation in Poland has been entirely associated with UVB range (290-320 nm). The measurements have been made with Robertson-Berger radiometer, in relative units at the stations: Central Geophisical Observatory at Belsk

since 1975 and Łeba, Legionowo and Kasprowy Wierch since 1993. The measurements of broad band UV radiation were initiated only in 1997 in Łódź and in Warsaw. Preliminary analyses of the first seven-month data series of UV in Łódź were published in 1998 (Podstawczyńska, Fortuniak 1998).

2. Data and Methods

Concurrent registration of UV (290-400 nm) has been made with CUV3 Kipp&Zonen radiometer and total solar radiation (305-2800 nm) has been measured with CM11 pyranometer in the city centre of Łódź, on the roof of Institute of Physical Geography (51°45'N, 19°26'E, 220 m a.s.l.). The measurements were recorded continuously and every 10-min. averages were collected in Data Logger 21X in irradiance (radiation flux) units (Wm^{-2}).

The study was focused on the 10-min. averages of total and UV irradiance (Wm^{-2}) and the daily values of UV and total (direct and diffuse) radiation (radiation sums for the day in $MJm^{-2}day^{-1}$ and month in $MJm^{-2}month^{-1}$). The ratio of UV radiation to total radiation has been computed. The ratio Iuv/It of 10-min. irradiance have been calculated for the part of the day between 10 a.m. and 2 p.m. (local time) to exclude errors of measurement occurred during low sun elevation. The linear regression, statistical characteristics and relationship between cloudiness, cloud types and radiation was calculated.

3. Results

3.1. The annual course of the daily values of UV radiation (Iuv), total radiation (It) and the ratio Iuv/It (in %)

The annual variation of UV and total radiation depend on many factors, the most important are elevation of the sun and atmospheric condition (contents of ozone, transparency of air - degree of cloudiness, aerosols, dust particles). The daily mean values of UV and total radiation in analysed period (Fig. 1a) varied from 0.03 $MJm^{-2}d^{-1}$ (Iuv), 0.6 $MJm^{-2}d^{-1}$ (It) to 1.06 MJm^{-2} d^{-1} (Iuv), 26.6 $MJm^{-2}d^{-1}$(It). The maximum daily values of It reached nearly 30 $MJm^{-2}d^{-1}$ and Iuv over 1 $MJm^{-2}d^{-1}$ (Fig. 1b, Tab. 1). The maximum absolute daily value of Iuv and It occurred in July of 1999 (Iuv=1.2 $MJm^{-2}d^{-1}$, It=29.6 $MJm^{-2}d^{-1}$) and the minimum absolute daily value of Iuv and It occurred in December in 1997 (Iuv=0.02 MJm^{-2} d^{-1}, It=0.29 $MJm^{-2}d^{-1}$) (Tab. 1).

The annual course of the UV and total daily radiation are similar. The general linear relation y=ax+b was fitted to the daily values of Iuv and It. The results showed the clear linear relation between both quantities (Fig. 2). Computed values of coefficient of determination amount 0.99, the independent term b amounts nearly zero, therefore the relation is almost y=ax and the inconsiderable values of errors of regression coefficients show a satisfactory accuracy and can be used to estimate the UV values, being given the total radiation values (Tab. 2). The similar results of the regression coefficients were obtained by other authors (e.g.: Martinez-Lozano, Casanovas 1994; Martinez-Lozano et al. 1999; Al-Aruri 1990; Zavodska, Reichrt 1995).

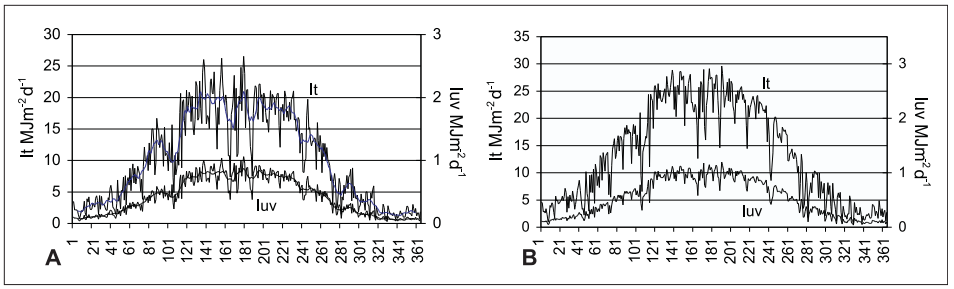

Fig. 1. The annual course of the daily value of UV (Iuv) and total radiation (It), $MJm^{-2}day^{-1}$ in Łódź in 1997-1999 [a] and the annual course of the maximum daily values of UV and total radiation [b] in Łódź in 1997-1999. Bold line –11-element moving average.

Tab.1. The daily and the annual values of UV (Iuv) and total radiation (It) in Łódź in 1997-1999.

MJ m^{-2}	1997		1998		1999	
	It	Iuv	It	Iuv	It	Iuv
Daily mean	10.2	0.4	10.3	0.43	10.5	0.44
Min daily	0.3	0.02	0.5	0.03	0.3	0.02
Max daily	28.1	1.1	29.0	1.2	29.6	1.2
Annual	3733.7	147.8	3613.8	150.4	3832.9	159.7

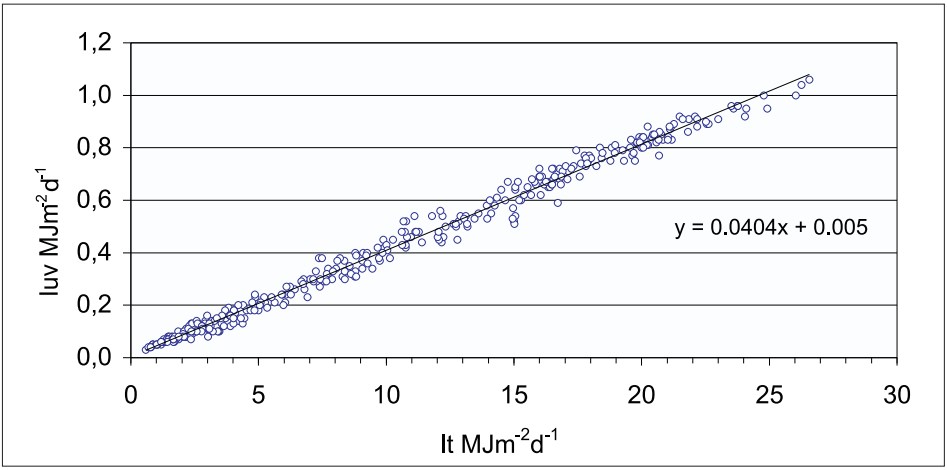

Fig. 2. The scatter plot and the regression line of UV daily radiation ($MJm^{-2}day^{-1}$) against total daily radiation ($MJm^{-2}day^{-1}$) in Łódź in 1997-1999.

Tab.2 The linear regression of : A - daily values of radiation Iuv, It ; B - 10-min values of irradiance Iuv, It in the days with ratio Iuv/It ≥7%; C - 10-min values of irradiance Iuv, It in the days with ratio Iuv/It ≤2%. The regression coefficients (a,b), the error of estimation the coefficients (Sig a,Sig b), the coefficient of determination (r^2).

	a	b	Sig a	Sig b	r^2
A	0.0404	0.005	0.0002	0.002	0.99
B	0.076	0.0799	0.0004	0.03	0.98
C	0.0194	0.209	0.0005	0.14	0.97

The annual variation of the ratio (in %) of UV daily mean values of radiation to total daily mean values of radiation is presented in Figure 3a. The percentage of Iuv/It varied from 2.6% to 5.9%. Over the year the UV daily radiation constituted 4.2% of total daily radiation. The high values and the variability of ratio Iuv/It from day to day can be seen in winter months: January, February, November and December. Other authors also find the higher ratio Iuv/It in winter (e.g. Feister, Grasnick 1992; Martinez-Lozano et al. 1999).The monthly standard deviations of daily ratio Iuv/It reached 0.6-0.7% in winter months (Fig. 3b) and decreased in spring and summer, in May the standard deviation amounts 0.13%. It had been found that higher frequency of cloud occurrence in winter can be the reason for high values and variability of the ratio Iuv/It.

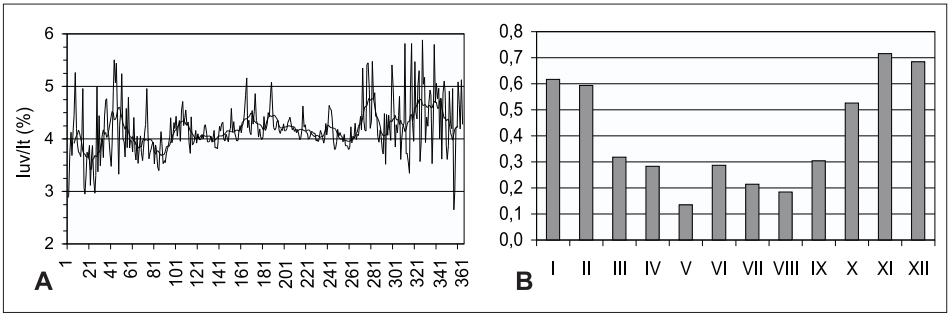

Fig. 3. The annual variation of the ratio of UV daily radiation to total daily radiation (Iuv/It, %) [a] and the monthly standard deviation of the ratio Iuv/It [b] in Łódź in 1997-1999.

3.2. The daily mean course of UV and total irradiance (Wm^{-2}) from January to June and from July to December. The monthly totals of Iuv and It radiation ($MJm^{-1}month^{-1}$)

The daily course of UV and total irradiance change in the year due to changing elevation of the sun and lenght of the day. The daily courses of UV and total irradiance are very similar in particular months (Fig. 4 a,b,c,d). The maximum monthly totals of Iuv and It occurred in May (Fig. 4a, c; Tab 3), Iuv=24.3 $MJm^{-2}month^{-1}$, It=602.2

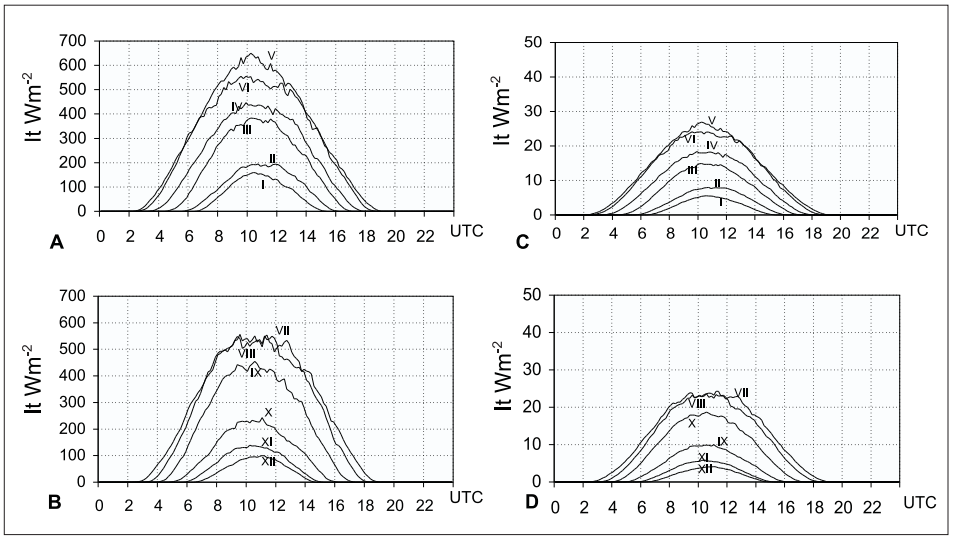

Fig. 4. The daily mean course of UV and total irradiance from January to June [a,c] and from July to December [b,d] in Łódź in 1997-1999. UTC - Coordinated Universal Time (Greenwich Mean Time, Universal Time).

Tab.3 The monthly mean values of UV (Iuv) and total radiation (It) in Łódź in 1997-1999.

MJm^{-2}	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Iuv	2.9	4.7	11.1	15.3	24.3	23.4	23.9	20.6	14.3	6.7	3.2	2.1
It	82.8	115.1	293.6	378.1	602.2	555.5	559.8	518.5	353.4	157.5	77.2	49.3

$MJm^{-2}month^{-1}$. December is the month with the lowest totals of Iuv and It (Fig. 4b,d; Tab 3), Iuv=2.1 $MJm^{-2}month^{-1}$, It=49.3 $MJm^{-2}month^{-1}$.

3.3. Relationship between cloudiness, types of clouds and the ratio of irradiance to total irradiance (10 a.m - 2 p.m.). The dependence between the ratio Iuv/It and total irradiance

The cloudiness in the days with high (≥7%) and low (≤2%) values of ratio Iuv/It between 10 a.m. and 2 p.m. was compared. It was found that the ratio Iuv/It increased in cloudy days. The days with 7-8 degree of cloud cover constituted 78% of the days with high values of ratio Iuv/It (Fig. 5a). The cloudless days never occurred in the group of days with high ratio values. Opposite situation is shown in Fig. 5b, the clear days (0-1 degree of cloud cover) constituted 76% of the days with low ratio Iuv/It values i.e. ≤2%. It can be concluded that the cloudiness reduces the total solar irradiance proportionally more than the UV irradiance due to absorption by water

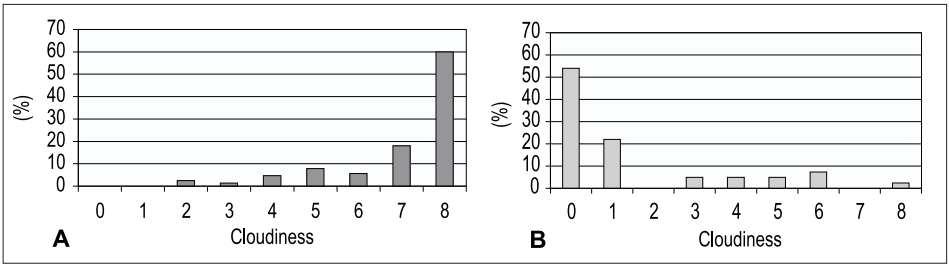

Fig. 5. The cloudiness in the days with high (≥7%) [a] and low (≤2%) [b] values of ratio of UV irradiance to total irradiance in Łódź in 1997-1999.

vapour stronger in near infra-red than in the shorter wave lengths. This conclusions were also obtained by other authors (e.g. Elhadidy et al. 1990; Khogali, Al.-Bar 1992; Zavodska, Reichrt 1985; Martinez-Lozano, Casanovas 1994; Martinez-Lozano et al. 1999).

The analysis of the types of clouds in the days with high and low ratios Iuv/It indicated that almost all days with high values of Iuv/It were associated with low clouds occurrence (the most frequently: Cb, Sc, Cu, St). In the days with low ratio Iuv/It high clouds dominated (Ci) but Cb, Cu, Sc, Ac also occurred.

The relation between ratio Iuv/It and total 10-min irradiance is presented in Fig. 6. The UV 10-min. irradiance constituted 4.6% of total 10-min irradiance (between 10 a.m. and 2 p.m.) on average in 3-year analysed period. The scatter plot shows that the points of nearly average ratio concentrated at high values of total irradiance (over 700 Wm^{-2}). The ratio values increase as the total irradiance decreases on cloudy days because the clouds reduce the total irradiance more than UV irradiance.

4. Conclusions

The analysis of 3-year data series of 10-min. irradiance and the daily UV and total radiation shows the following results:

– The maximum monthly sums of UV and total radiation (Wm^{-2}) occurred in May, the minimum in December.
– The daily values of UV radiation are proportional to total radiation with very high correlation.
– The ratio of UV daily radiation to total daily radiation varied from 2.6% to 5.9%. The maximum absolute values of ratio Iuv/It and the maximum variability of ratios from day to day occurred in winter.
– The high values of ratio Iuv/It (≥7%) occurred in cloudy days mostly in winter, the low values of ratio Iuv/It (≤2%) were observed in clear days in winter.

The ratio Iuv/It values increase as the total irradiance decreases on cloudy days, due to absorption by water vapour stronger in near infra-red than in the ultraviolet spectrum.

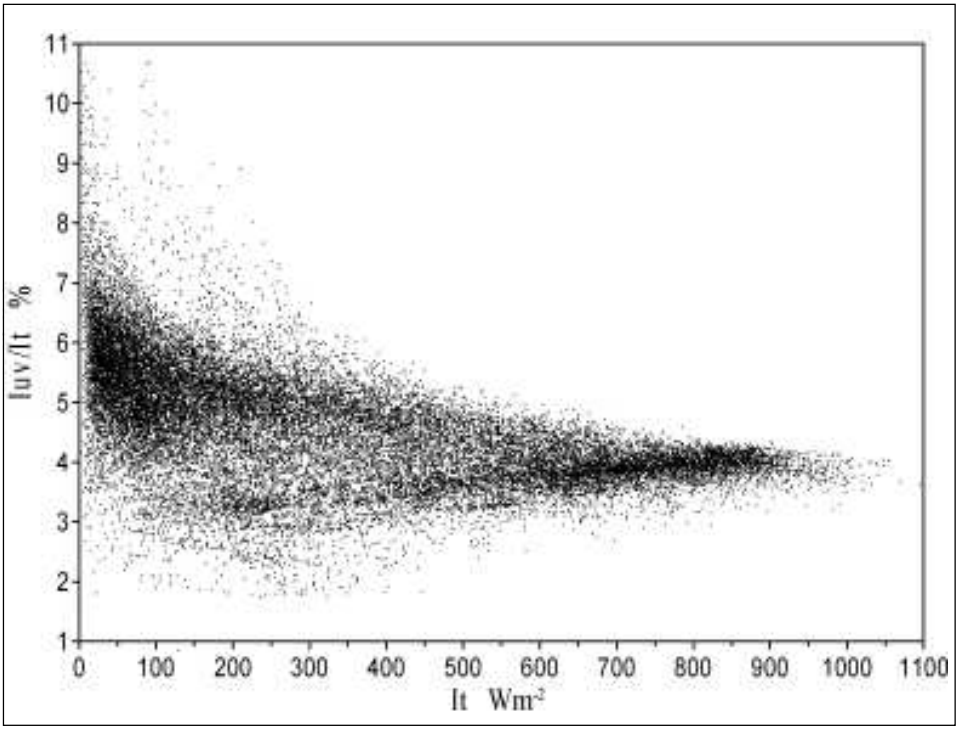

Fig. 6. The scatter plot of the ratio Iuv/It (in %) against total irradiance (Wm^{-2}) in Łódź in 1997-1999.

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