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ASPECTS REGARDING THE CLIMATOLOGY OF THE GLOBAL ULTRAVIOLET SOLAR RADIATION IN ROMANIA

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Abstract. The solar ultraviolet radiation represents the spectral domain ranging from 280 to 400 nm. Despite its weak energetic contribution, its biological action is important. The ultraviolet solar radiation is measured in no more than one location in Romania, at Bucuresti (Bucharest) – Afumati. On the basis of a measurement data set (1994-2000) the paper analyses the daily and annual evolution, as mean values, of the total and erithermal ultraviolet, function of the astronomical factors specific to Bucharest latitude and to the ozone layer.

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Introduction

The ultraviolet radiation is that domain of the solar radiation spectrum, with wavelengths smaller than the visible. According to CIE (Comission Internationale de l'Eclairage) classification, the ultraviolet spectral domain is divided (conforming to Etude des gains…1969) in:

- ultraviolet radiation A (UV-A) 315-400 nm;
- ultraviolet radiation B (UV-B) 315-400 nm;
- ultraviolet radiation C (UV-C) 100-280 nm.

The ultraviolet solar radiation is just a small fraction of the incident solar energy. At the upper limit of the atmosphere, it does not exceed 9%, whereas at the level of the terrestrial surface it decreases to values smaller than 1%.

The transfer of the ultraviolet solar radiation through the atmosphere is mainly influenced by two factors:

-the height of the Sun above the horizon,

-the ozone layer.

The variation of the Sun's height above the horizon is the result of the Earth-Sun geometry variation, which modifies the length of the optical course traveled by the solar radiation through the atmosphere. The smaller the Sun's height values, the greatest the length of the optical course traveled through the atmosphere by the ultraviolet solar radiation and the smaller the values of the radiation, as a result of the intensifying radiation extinction; see table 1 (Etude des gains, 1969).

Tab. 1 - Relative percent of UV-A and UV-B from the total solar radiation

Spectral domain	**Upper limit of the atmosphere**	Section 1.01 Terrestrial surface level		
		90°	**30°**	**11,5°**
UV-B	1.46%	0.27	0.11	0.00
UV-A	7.06%	3.94	2.57	0.51

As can be noticed in table 1, this process is markedly spectrally selective.

The ozone absorbs the UVC domain totally, at the level of the stratosphere, limiting the UV spectrum around 280 nm. At the same time, ultraviolet B is much more sensible to the ozone layer concentration variations. Depletion by 10% of the total ozone amount may lead to an increase by 20% of the UV-B radiation intensity (Frimescu, 1991).

Although the intensity of the UV radiation is small, compared to the other domains of the solar radiation total spectrum, it exerts a particularly important biological action. Thus, it has a strong anti-bacteria action, it produces the synthesis of vitamin D, through exposing the human skin to the sun and it causes the sun tanning phenomenon (the erithem).

At the same time, the UV radiation in excess, from prolonged exposure to the sun, causes negative influences on the human health, mostly through favoring the occurrence of eye diseases (glaucoma) or skin cancers.

2. Ultraviolet solar radiation data

Taking into account the importance of knowledge about the ultraviolet solar radiation, an ***Eppley TUVR model radiometer***, manufactured in the U.S. was installed in 1994 at the Bucuresti (Bucharest) Afumati Atmospheric Physics Observatory (44° 30', lat.N, 26° 13`, long.E, h = 91m) to continuously record the global ultraviolet over the horizontal surface. The instrument is installed on the roof of the Observatory, approximately 12 m above ground.

The device uses as sensor a Weston photoelectrical cell, with a selenium layer. The spectral sensitivity of the photocell ranges within 295-385 nm, with a maximum of 335 nm. That interval roughly corresponds to the ultraviolet radiation reaching the terrestrial surface. The cell is covered with a Teflon diffusive disc, which has the role to reduce the light intensity that reaches the cell, augmenting its stability with the exposition time. The sensor is coupled to a Minicomp KE-type paper band recorder manufactured by Thies Clima Enterprise (Germany).

Recordings on the diagram are deciphered hourly in real solar time with a slider made by the manufacturer (Thies Clima), values being expressed as Wm^{-2}.

The real solar time (RST) is a local time defined by the hour angle w, formed by the meridian plane passing through the Sun and the meridian plane of the location. It might reach a difference against the legal time of about +14 minutes in February (11 – 13 February) and -16 minutes in November (3 – 4 November).

From the daily recording series, the reference period 1994 – 2000 was chosen for the computation of the hourly and monthly means. The observation material was grouped in mean values for all days and by clear sky (cloudiness 0-3 tens) and overcast days (cloudiness 8-10 tens) respectively.

During a limited interval (1996), a UVSB sensor for ultraviolet radiation B functioned in Bucharest at the automatic weather station operational here, equipped with a photo cell with spectral sensitivity ranging within 295-315 nm, manufactured by Kipp & Zonnen.

3. Experimental results, discussions

3.1. Global ultraviolet radiation (a+b)

The global, ultraviolet solar radiation, displays, in terms of mean values, a **diurnal course,** irrespective of the moment in the year and cloudiness, with an ascending phase in the former part of the day, till noon, when, as a rule, maximum values are reached. In the latter part of the day, the ultraviolet radiation displays a declining course. This course is imposed by the similar variation of the Sun in the sky, at Bucharest latitude.

Figure 1 displays the diurnal course of the global ultraviolet solar radiation in the months of the summer and winter solstice respectively, when the highest and smallest heights of the Sun are reached, i.e. in June and December.

For Bucharest latitude, the maximum values of the sun heights at noon time are 69° at the summer solstice and 23° at the winter solstice.

In these circumstances, the global ultraviolet radiation reaches in June, values over 30 Wm^{-2} at noon, and up to 2 Wm^{-2} at sunrise and sunset respectively.

In December, the values of the global ultraviolet radiation at noon are approximately five times smaller compared to those in June, not exceeding 7 Wm^{-2} and being smaller than 1 Wm^{-2} at the beginning and end of the day. This type of variation preserves for both clear and cloudy day. It is however worth mentioning that in the case of clear sky days, the highest mean values are recorded in July – the month with a higher frequency of clear sky compared to June.

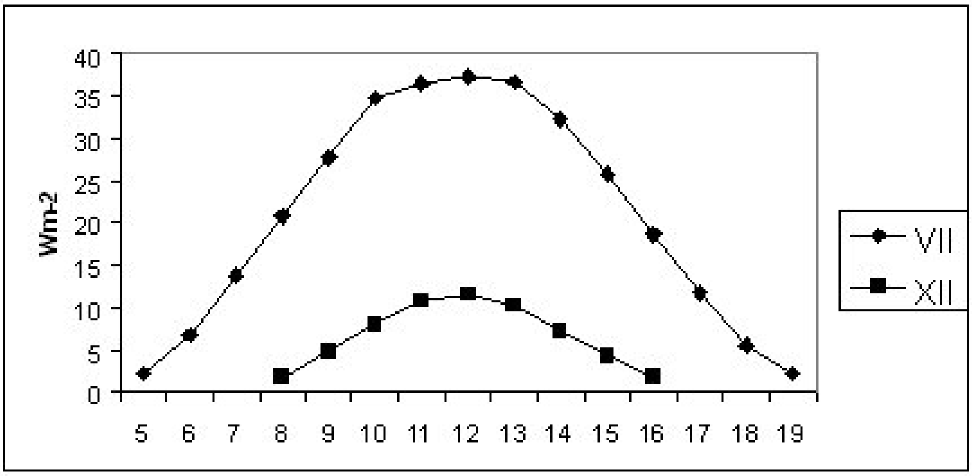

Fig. 1 - Bucharest – The solar global ultraviolet radiation over the horizontal surface, hourly values in characteristic months

In the case of clear days, the global ultraviolet solar radiation reaches values over 37 Wm^{-2} at noon and around 2 Wm^{-2} at the beginning and end of the day in July and from 11 Wm^{-2} to 2 Wm^{-2} in December (fig. 2).

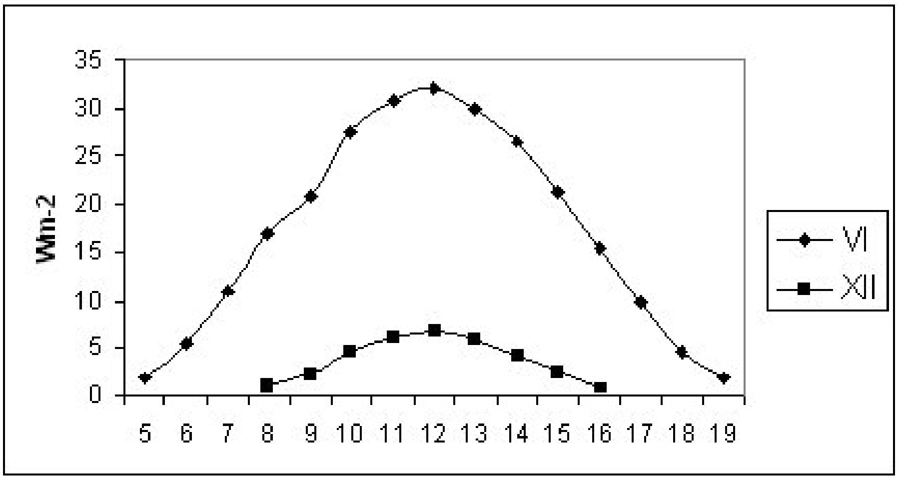

Fig. 2 - Bucharest – The solar global ultraviolet radiation over the horizontal surface, hourly values in characteristic months (clear sky)

The values of the global ultraviolet radiation in overcast days are smaller by about 40% on the average compared to those in clear sky days and they do not exceed at noon 15 Wm^{-2} in June and 5 Wm^{-2} in December (fig. 3).

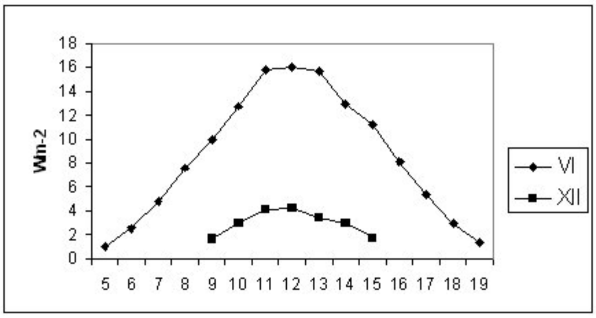

Fig. 3 - Bucharest – The solar global ultraviolet radiation over the horizontal surface, hourly values in characteristic months (overcast sky)

Annually, the values of the global ultraviolet solar radiation reach a maximum in June–July and a minimum in December, values in the other months being distributed in a relative symmetry against the annual maximum (fig. 4). In this case also, the variation of the ultraviolet solar radiation is first and foremost connected to the Earth-Sun geometry. It is remarkable, however, that the values in the former half of the year are higher than those in the latter half, mostly in the overcast sky case. The phenomenon can be explained through the higher frequency of stratiform cloudiness – a strongly absorbing environment to ultraviolet radiation.

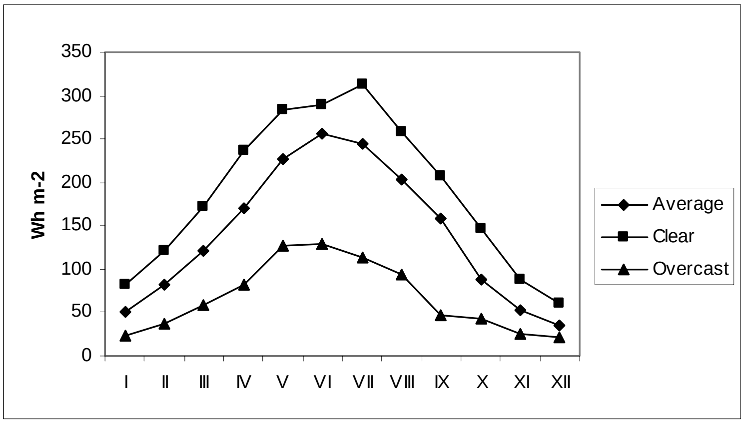

Fig. 4 - Bucharest – The solar global ultraviolet radiation over the horizontal surface, monthly average values

3.2 Global ultraviolet radiation - b

The global ultraviolet radiation B is the most important spectral component of the total global ultraviolet solar radiation, not so much through its energetic component but mostly through its biological effects, especially on the human skin. Penetrating the skin, the UVB radiation leads to the formation in the skin tissues of certain hormones (histamine) that cause irrigation with blood to increase in the superficial layers of the skin. Erithem (skin reddening) (Herovanu, M., 1939) thus occurs. Since it causes erithem, the global ultraviolet radiation B is also known as erithermal ultraviolet radiation. The erithermal action of the UVB radiation has a strong spectral selectivity (table 2).

A severe decrease of the erithermal effect is noticeable as the wave lengths increase in the UVB spectral domain (Frimescu, M., 1991).

Tab. 2 - Erithermal action of the UVB radiation on human skin (relative units)

Wave lengths nm	295	297	300	305	310	315
Erithermal action (relative units)	0.98	1.0	0.73	0.20	0.054	0.015

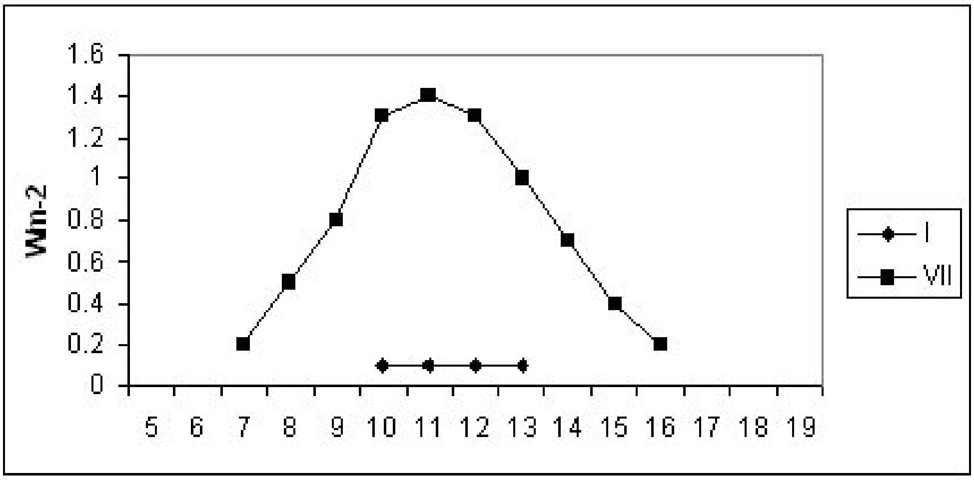

Fig. 5 - Bucharest – The solar global ultraviolet B radiation, hourly values, in 1996 year

As regards its value, the UVB spectral domain is very small compared to the total global ultraviolet radiation (A+B), 1.3 to 1.4 Wm^{-2} as mean values, at noon, in the summer months and below 1 Wm^{-2} at the same moment of the day in the winter months (fig. 5; Costin V., Copaciu V., 1996). This explains through the very large the UVB diffusive capacity, as short wave radiation on the cloud particles. As a rule, these hourly values have an extreme values character.

The UVB radiation is influenced in its diurnal and annual course by the variation of the Sun's height above the horizon and mostly by the ozone layer height.

Tab. 3 - Bucharest – intensity of erithermal ultraviolet solar radiation (mW er m^{-2}) in characteristic months

Hour		**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
VII	8,5	124,7	148,7	194,0	213,3	194,0	148,7	124,7	58,5
XII		3,8	16,2	16,2	27,2	16,2	16,2	3,8	

Having in view the strict dependence of the UVB against the ozone layer height, Blumhaler and Ambach computed the UVB radiance values they named erithermal ultraviolet radiation, function of the zenithal distance (the complement of the Sun height angle) and the ozone layer height (Blumthaler, M..; Ambach, W., 1989).

The values of the erithermal ultraviolet solar radiation for July and December, in Bucharest, computed with the help of the Blumhaler and Ambah nomograms for Bucharest are rendered in table 3. Given the very low intensity of this radiation, the authors used as a measure unit the erithermal miliwatt (mW er).

3.3 Methods to warn on the danger posed by the ultraviolet radiation – b. Uv index

Within normal limits the ultraviolet solar radiation B has a beneficial effect on the biological domain. An excessive amount of this radiation may induce unwanted effects, mostly on humans, since they lack sense organs apt to warn them on this danger.

Under the aegis of the World Meteorological Organization, a simple method has been worked out to warn the population on the danger of prolonged exposure to the action of ultraviolet radiation. This is the method of the UV index (WMO/TD-No. 625, 1994):

$$\text{UV Index} = F / 25$$

Where:

F = Erithermal ultraviolet solar radiation on horizontal surface in partially clear sky, function of the zenithal distance (z = 90° - h), expressed as mW er., and the total ozone column, expressed as Dobson units;

25 = Dose value for eritherm occurrence (mW er. m^{-2}), after the Canadian method WMO/TD-No. 625, 1994).

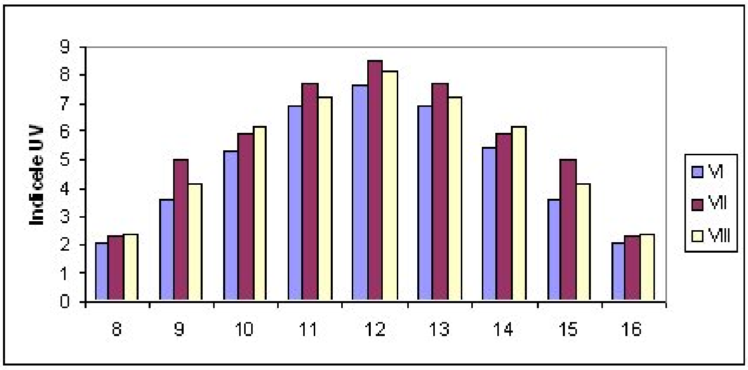

Fig. 6 - Bucharest – The hourly averages values of the UV index for the summer months

The index represents the possible number of ultraviolet radiation doses that produce the erithem in a certain time interval, usually one hour. It practically expresses the potential danger as regards prolonged exposure to the action of the ultraviolet solar radiation intensity.

The mean hourly values of the UV index, computed for Bucharest, also display a course resembling that of the ultraviolet solar radiation (fig. 6). It increases during the former part of the day, reaches a maximum at noon, further declining during the latter part of the day. The annual course shows a maximum in the summer months, when the ultraviolet intensity is the highest in the year.

Correlated with a time scale regarding the human skin exposure to the sun, the UV index can be a really useful indicator for informing the population (table 3).

Tab. 4 - Sun exposure according to the different values of the UV index

UV index	Intensity	Exposure time/hour
1 – 4	Light	1 hour
4.1 – 7	Moderate	30 minutes
7.1 – 9	Strong	20 minutes
Over 9	Extreme	15 minutes

For Bucharest latitude, it can be noticed that the possible danger posed by the exposure to the ultraviolet radiation action occurs only during the summer months, especially July. It should not be forgotten, however, that even during the summer months cloudiness can substantially reduce the value of the UV index.

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