STUDY OF THE UV SOLAR RADIATION AT THE EARTH'S SURFACE

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Received October 13, 1993

We have started regular measurements of the solar and sky ultraviolet radiation in Tomsk (56.5° N, 85°E). *In this paper we present the absolute values of the total radiant energy density as a function of the solar elevation angle. For cloudless and windless days, we have observed the "scissors effect" in the spectral range A that we explain by the influence of industrial emission and transport exhaust into the atmosphere.*

This paper is devoted to the study of the ultraviolet (UV) solar radiation reaching the earth's surface. As is known,[1] the radiation strongly affects the biological objects including people.

The effect of the UV radiation in the wavelength range from 200 to 400 nm on people is ambiguous. So it is common practice to divide this range into three parts: *A*, *B*, and *C*. The radiation of the part *B* (wavelength range 280–315 nm) has the most pronounced erythematous effect (congestion of the smallest skin capillaries and accompanying processes). In small dose, the radiation has a wholesome erythematous effect, but strong erythema is an inflammatory process. In addition to the erythematous effect, the radiation of the range *B* has therapeutic and antirachitic effects. The UV radiation of the part *A* (325–400 nm), adjacent to the range of visible radiation, has less pronounced biological effect, but also has erythematous and sunburn effects. The radiation of the part *C* (wavelengths shorter than 280 nm) has a strong bactericidal effect and generally has a negative effect on the living organism. Due to strong and versatile effect of the UV radiation on living organisms, people and animals must be irradiated by the UV light in strict doses.

The UV radiation affects many organic substances used by people, for example, polymers, plastics, dyes, and so on. It is also known[2] that the UV radiation plays an important role in photochemical processes occuring in the atmosphere, in particular, in smog formation.

At last, the UV radiation flux at the earth's surface is directly related with the total ozone content in the atmosphere.

From the above reasoning the necessity of continual observations of the UV solar radiation flux at the earth's surface is clear. Researchers of the Siberian Physical–Technical Institute at the Tomsk State University have started regular measurements of the UV radiation flux in the ranges *A*, *B*, and *C*.

For this purpose the UV filter spectrophotometer was developed and produced. Its receiving antenna was a quartz hemisphere convex upwards, which provided the reception of radiation contained in the 0.6π solid angle that corresponded to 90° apex angle of cone. The direct solar radiation enters an input of horizontally positioned device only when the solar elevation angle is larger than 45°.

The spectral module of the device contained three light filters matched to the wavelength ranges *A*, *B*, and *C* of the UV radiation. Specifications of the employed filters are given in Table I. The following designations are used here: λ_{max} is the wavelength of maximum transmission of the light filter; $\Delta\lambda_{0.5}$ and $\Delta\lambda_{0.1}$ are the transmission bandwidths of the light filter measured at half maximum and 0.1 of maximum, and T is the maximum transmission of the light filter.

TABLE I . Spectral parameters of the spectrophotometer.

UV range	λ_{max}, nm	$\Delta\lambda_{0.5}$, nm	$\Delta\lambda_{0.1}$, nm	T, %	C_k, %
A	353	63	80	27	3
B	281	24	60	25	10
C	260	22	50	30	25

The photomultiplier FÉU–170 with a Te–Rb photocathode was used as a photodetector. It was chosen by the following reasons. The UV radiation flux in the part *C* is a few orders of magnitude less than that in the part *A*. The Te–Rb photocathode has the maximum sensitivity in the wavelength range 200–220 nm. The parameter C_k in Table I shows the photocathod sensitivity at the given wavelength as a portion (in %) of its maximum sensitivity taken as 100%. The UV spectrophotometer had a digital display. The errors in measuring with the UV spectrophotometer are the sum of two components, namely, the random error in direct measuring with the photometer and the error in its calibrating.

To estimate the random error, we carried out 32 measurements of the sky radiation at intervals of 5 s under conditions of the stable (windless and cloudless) atmosphere. In this case the variance of the results was less than 0.5%. This value must be taken as the upper limit of the random measuring error. The errors in calibrating were so large that the obtained absolute values of the radiant energy density indicated only the order of magnitude.

The UV radiant flux in Tomsk were measured on the World Geophysical Dates (February 16–18, March 16–18, April 20–22, and May 18–20, 1993). The radiation was measured every hour (sometimes more often) for horizontal position of the device. Measurements for inclined position of the device were carried out for that days and hours when the Sun was not covered by clouds, to record the direct solar radiation or, conversely, to exclude it.

In Tomsk, the solar elevation angle is slightly larger than 45° only in May, June, and July. So almost all measurements carried out for inclined position of the device give the data on the scattered UV radiation, i.e., the UV radiation of the sky.

The temporal dependence of the UV radiation for windless cloudless days is described by a symmetrical bell–shaped curve. For windy days the "bell" was not smooth. The spread of points about the average value in windy but cloudless weather reached 3%. The spread of points in windy and cloudy weather was more than an order of magnitude greater and readings of the device change every minute. In separate moments the measurable radiation decreases almost tenfold.

Dips 30–70% in depth whose duration varied from 1 to 3 hours were observed in the smooth curves of daily variations of the UV radiant flux on separate days in some hours. They cannot be always explained by visible cloudiness. Such a dip was observed on February 18 between 8 and 11 h, Greenwich time. The most probable reasons of the observed dips are the variations in the aerosol component of the atmosphere.

For cloudy days, when all sky was uniformly white, the scattered UV radiant flux was greater than for sunny days. For example, for cloudy days on February 17 and 18 the "bell A" was approximately 20% higher in maximum than that for sunny day on February 16. This effect was less pronounced in the parts *B* and *C*.

In addition to measurements of the UV radiant flux, the solar elevation angle was calculated and the dependence of the UV radiant flux on the solar elevation angle was constructed. The absolute values of irradiance are given in Table II (average dayly and monthly values obtained at different solar elevation angles and expressed in $\mathrm{mW/nm \cdot m^2}$).

TABLE II. Spectral irradiance at the earth's surface vs. the solar elevation angle for different wavelengths.

Wavelength, nm	Solar elevation angle, deg			
	10	20	30	40
353 (*A*)	$6\cdot10^1$ (1)	$13\cdot10^1$ (1)	$23\cdot10^1$ (1)	$27\cdot10^1$ (1)
281 (*B*)	$6\cdot10^{-2}$ (10^{-3})	$16\cdot10^{-2}$ ($1.1\cdot10^{-3}$)	$35\cdot10^{-2}$ ($1.5\cdot10^{-3}$)	$52\cdot10^{-2}$ ($1.9\cdot10^{-3}$)
260 (*C*)	$9\cdot10^{-3}$ ($1.6\cdot10^{-4}$)	$26\cdot10^{-3}$ ($1.9\cdot10^{-4}$)	$52\cdot10^{-3}$ ($2.2\cdot10^{-4}$)	$69\cdot10^{-3}$ ($2.6\cdot10^{-4}$)

The relative values of the irradiance are given in the same table in parentheses, with the radiant energy density at a wavelength of 353 nm (part *A*) being taken as 1. These results are evidence of the fact that the contribution of the parts *B* and *C* of the UV radiation to the scattered radiation increases as the solar elevation angle increases.

High values of the radiant energy density in parts *B* and *C* (Table II) have engaged our attention. Even if the values in the part *A* have been underestimated by an order of magnitude, and the values in the part *C* have been overestimated by an order of magnitude, we obtain the ratio $E_C/E_A \approx 10^{-6}$, that is, very high value. This is due to the fact that the light filters we used for selecting the part *B* and *C* have very wide wings (see $\Delta\lambda_{0.1}$ in Table I). Actually the light filter *C* transmitted the radiation up to 310 nm, and the light filter *B* – up to 330 nm. Thus when recording the part *C*, we partially record the part *B*, and when recording the part *B*, we partially record the part *A*. So the results obtained for the parts *B* and *C* will be considered as essentially overestimated if we adopt the generally accepted selection of parts indicated at the beginning of this paper.

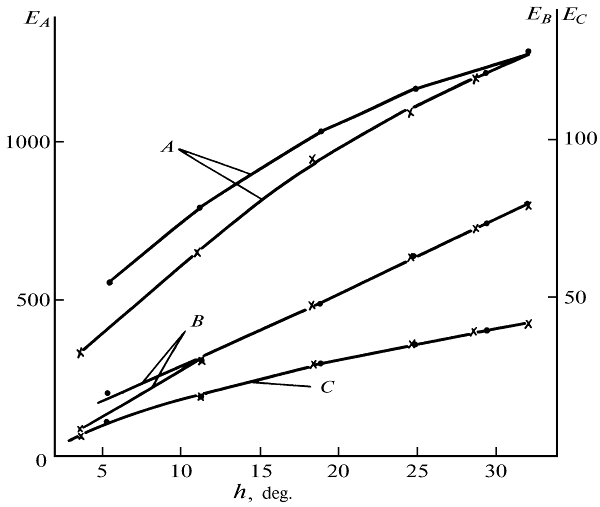

FIG. 1. Energy density of the UV irradiance as a function of the solar elevation angle for spectral ranges A, B, and C (March 16, 1993). Points are for sunrise, and crosses are for sunset.

The "scissors effect" was observed in the part *A* for windless cloudless days (February 16 and March 16). The effect is that the curve of the dependence of the radiant flux on the solar elevation angle, when the Sun sets, does not coincide with the corresponding curve, constructed when the Sun rises (Fig. 1), and the curve for sunset runs under the corresponding curve for sunrise. Possibly, it is connected with industrial and transport exhaust into the atmosphere that occur mainly in the daytime. We do not observe this effect in the parts *B* and *C*. For windy days (February 17 and 18, March 17 and 18, and all observation days in April and May) this effect, if it existed in the part *A*, was masked by fluctuations due to instability of the atmosphere.

Further we plan to monitor the UV radiation level in Tomsk regularly.

REFERENCES

1. V.A. Belinskii et al., *Ultraviolet Solar and Sky Radiation* (Moscow State University Publishing House, Moscow, 1968).
2. T.E. Graedel, React. and Process, 107–143 (1980).