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FOREIGN TECHNOLOGY DIVISION

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SCATTERING OF LIGHT IN THE EARTH'S ATMOSPHERE
(SELECTED ARTICLES)

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EDITED TRANSLATION

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SCATTERING LIGHT IN THE EARTH'S ATMOSPHERE (SELECTED ARTICLES)

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	sinh^{-1}
cos	cos	ch	cosh	arc ch	cosh^{-1}
tg	tan	th	tanh	arc th	tanh^{-1}
ctg	cot	cth	coth	arc cth	coth^{-1}
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

SOME RESULTS FROM AN INVESTIGATION OF SPECTRAL ATTENUATION OF IR-RADIATION BY THE SURFACE ATMOSPHERE

V. L. Filippov, S. O. Mirumyants, L. M. Artem'yeva

At the present time a large number of works are known which deal with the investigation of aerosol attenuation of visible light, but data of similar measurements in the IR-range of the spectrum which are suitable for the solution of practical problems are lacking. The use of computers opens wide possibilities for the direct calculation of the spectral coefficients of aerosol attenuation $\alpha(\lambda)$ on the basis of Mie theory relationships, but only if the microphysical parameters of the particles which are responsible for the fogging of the atmosphere are known.

Unfortunately, information concerning microstructure, although numerous, works [1,2] for example, are not reliable for use in calculations which characterize specific meteorological conditions [3]. These circumstances indicate that one of the effective methods for studying the optical properties of aerosols at the present time is their direct and systematic measurement. Statistical processing of the results of such measurements makes it possible to obtain data on the connection between coefficients $\alpha(\lambda)$ and the meteorological parameters of the environment and on the possibility of prediction of aerosol attenuation.

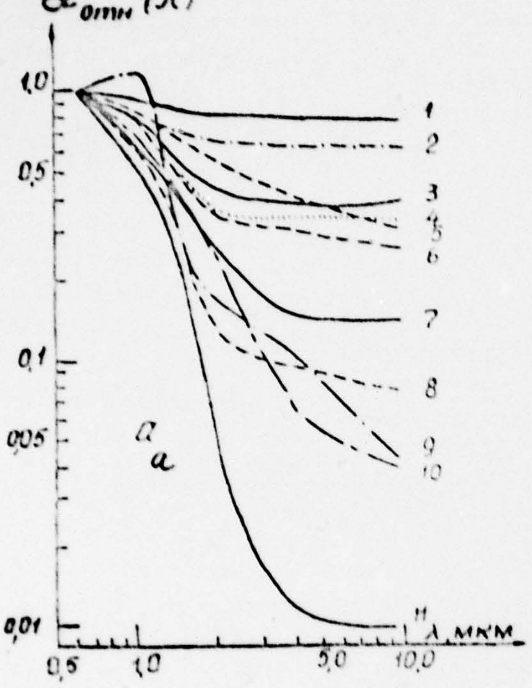

Figure (a)

The curves which are shown in Figure (a) are the result of investigations [4-7] of aerosol attenuation in the "atmospheric windows" (OP) in the area of λ=10-0.59 μm. They characterize the spectral dependences of α(λ), averaged on many realizations of spectra, which were recorded in 11 types of aerosol situations selected by us. In this article we will not dwell in detail on the characteristics of situations of each type, we will note only that the probability of realization of spectral curves 1-11 in the corresponding meteorological conditions was substantiated by statistical analysis of experimental material (more than 1500 spectra), and the correlation coefficients obtained, connecting the change of optical density of fogs for two wavelengths of the investigated area of the spectrum, just as in [5], turned out to be high. Curves 4 and 10 in the drawing depict the course of the spectral dependence of α(λ), typical for light hazes, when the pressure of water vapors in the atmosphere was greater than 4 and less than 10 levels of their saturation relative to ice. Curves 1, 2 and 3 are characteristic for situations of light haze with fine sparse snow, drizzle (rain with snow) and light rain respectively. Under conditions of foggy haze [3] in the spring and in the fall the spectral dependence of the $\alpha(\lambda)$ coefficients was similar to spectrum 5. An extremely finely-dispersed composition of aerosol was observed in summer hazes of a radiation origin (curve 11). However, the form of the curves $\alpha(\lambda)$ for hazes which were preserved for 24 hours and longer testified to the redistribution in the spectrum of the dimensions of the particles to the side of an increase in the concentration of the large fraction. Curve 8 corresponds to the persistant summer hazes, curve 7 - to spring-fall situations, in which the duration of existence of hazes in them increases significantly [9].

A form of dependence of type 6 in the drawing was noted under conditions of spring and fall following light rain precipitation. Finally, the spectral dependence of aerosol attenuation (curve 9) was recorded for several autumn days. Without drawing on the corresponding microphysical measurements it was not possible to identify the reason for the appearance of a similar optical situation.

Also interesting is the experimental study under natural conditions of the attenuation of IR-radiation in areas of the spectrum which coincide with the position of the absorption bands of liquid water - 2.9. 6.3 and 10-14 μm [7]. For obtaining similar information the spectra of transmittance (SP) — $T_{\text{атм}}(\lambda)$ were described in a light haze directly by wavelength for a time of 4-5 min. On the basis of measurements of transmittance of an aerosol in OP — $T_{\text{аэр}}(\lambda)$ and SP of clear atmosphere — $T_{\text{мол}}(\lambda)$ (with the same absolute and relative humidity on the path) the optical densities were found

$$\sigma_{\text{ж.в.}}(\lambda) = \ln\left[T_{\text{атм}}(\lambda)/T_{\text{аэр}}(\lambda)T_{\text{мол}}(\lambda)\right]. \qquad (1)$$

One of the spectra $\sigma_{ж.в.}(\lambda)$ for the conditions $\sigma_{0.59}=1$ and $\lambda=2-14$ µm is shown in drawing (b) by solid line 1 (dots denote the areas in which $T_{мол} < 5\%$ and the curve was extrapolated). Here the broken line shows the spectrum $\sigma_{ж.в.}(\lambda)$ based on the data of work [8]. Selection of this spectrum is analogous to expression (1), i.e., the spectra of the coefficients of aerosol attenuation which were presented in [8] were considered conditionally in the form of the sum of two curves - the OP envelope and that corresponding to attenuation in the area of absorption bands of liquid water. Attention is called to the significant difference in the results which are being compared. This makes it possible to assume the validity of the report that the atmosphere contains minute water particles with dimensions $\leqslant 0.1$ µm, which absorb IR-radiation in the same manner as water vapor. The results of the change in $\sigma_{ж.в.}(\lambda)$ were obtained in measurements when the temperature of the environment $t \geqslant 0^{\circ}C$. Curve 3 on the drawing (b) characterizes the preliminary data on the spectral coefficients of $\sigma_{ж.в.}(\lambda)$ in the area $\lambda=2-4$ µm for conditions $t \simeq -20^{\circ}C$.

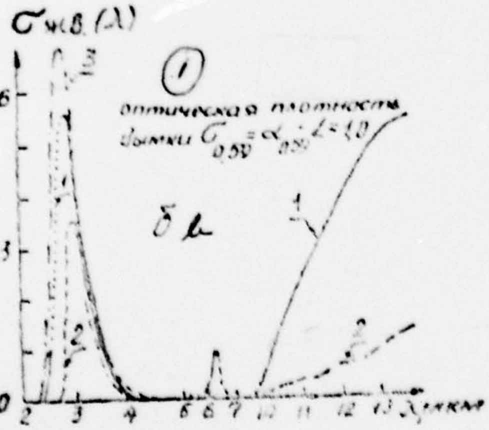

Figure (b)

Key: (1) Optical density of haze.

In conclusion it is necessary to note that when considering the applicability of the results of the investigations which were discussed for the probable calculation of attenuation of IR-radiation in other geographical points (the authors made their measurements in the vicinity of Moscow) it is very important to have available data similar to that expounded in work [9]. Actually, when analyzing the many years of measurements of meteorological ranges of visibility S_M in different regions of the USSR [9], compared with other meteorological parameters, it is possible to isolate the probable zones in which one should expect uniform optical properties for an aerosol.

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SUMMARY

In spite of the variations of the spectral behaviour of IR radiation attenuation coefficients $\alpha(\lambda)$ in haze, a possibility of the statistically based prediction of them and extreme approximity of the calculation results $\alpha(\lambda)$ according to the Mie theory in terms of available representations on the microstructure aerosol characteristics is noted.

STATISTICAL STRUCTURE OF AEROSOL TRANSMITTANCE IN THE CASE OF A CONSTANT MASS

K. S. Shifrin, G. L. Shubova

In an analysis of materials of observations, made with the help of filters, of direct solar radiation in Karadag during the period 1936-1949 and in Vladivostok during the period 1938-1947, we discovered that the transmittance of the atmosphere in the spectral sector of around 0.577 μm has a great daily variation [1]. Since in the spectral interval under study attenuation is caused mainly by the aerosol, this means that in a vertical column of the atmosphere a noticeable daily variation is observed in the content of the atmospheric aerosol. In order to eliminate the daily variation of transmittance, we will investigate the values of aerosol transmittance of the atmosphere at a constant mass and consider the statistical structure of this variable. This will make it possible for us to isolate in a pure form the characteristic types of atmospheric turbidity, caused by different states of the atmosphere above the observation point.

Statistical Structure of Transmittance

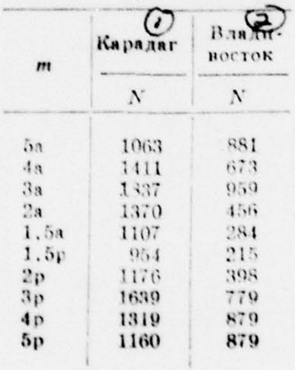
Table 1 shows the number of cases of observations which we used for constructing the curves for Karadag and Vladivostok for the entire period of observations. In the table m - mass of the atmosphere, at which the observations were made, N - number of cases of observations.

For a given m (individually by each point) the values of the function

$$f(\tau) = \frac{\Delta N}{N \Delta \tau}$$

are calculated and its graphs are constructed.

Table 1



m	① Карадаг	② Владивосток
	N	N
5a	1063	881
4a	1411	673
3a	1337	959
2a	1370	456
1.5a	1107	284
1.5p	954	215
2p	1176	398
3p	1639	779
4p	1319	879
5p	1160	879

Key: (1) Karadag; (2) Vladivostok.

In contrast to works [2, 3], where the curves of distribution were constructed for the intervals $\Delta\tau = 0.02$, in this article $\Delta\tau$ is accepted equal to 0.04. This is done for increasing the statistical guarantee of the curves of distribution, since the number of cases of observations which belong to a given mass, needless to say, is considerably less than their total number.

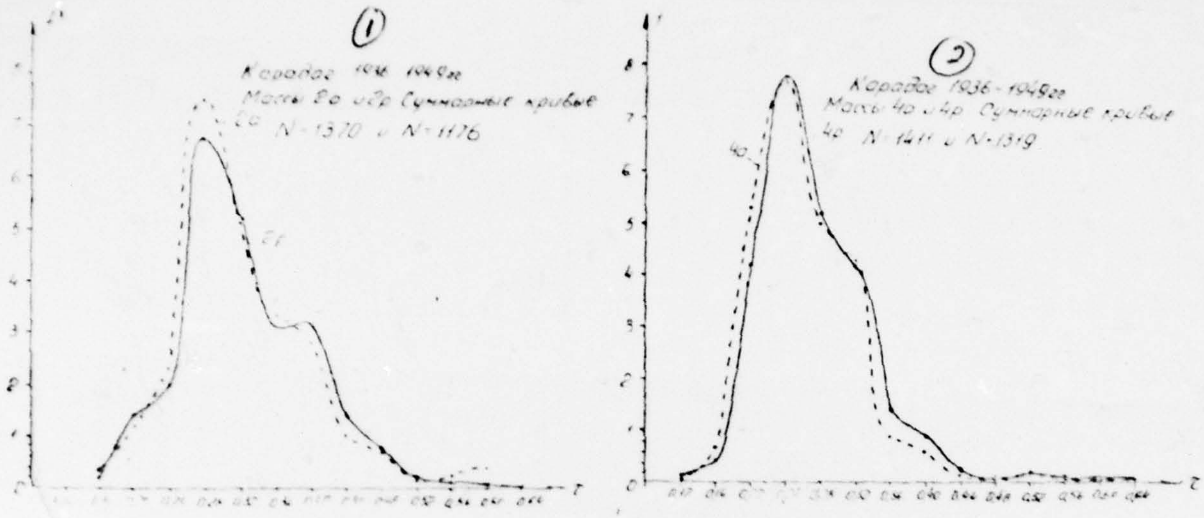


Figure 1. Curves of distribution f(τ) in the case of a constant mass of atmosphere for Karadag.

Key: (1) Karadag 1936-1949. Masses 2a and 2p. Total curves N=1370 and N=1176; (2) Karadag 1936-1949. Masses 4a and 4p. Total curves N=1411 and N=1319.

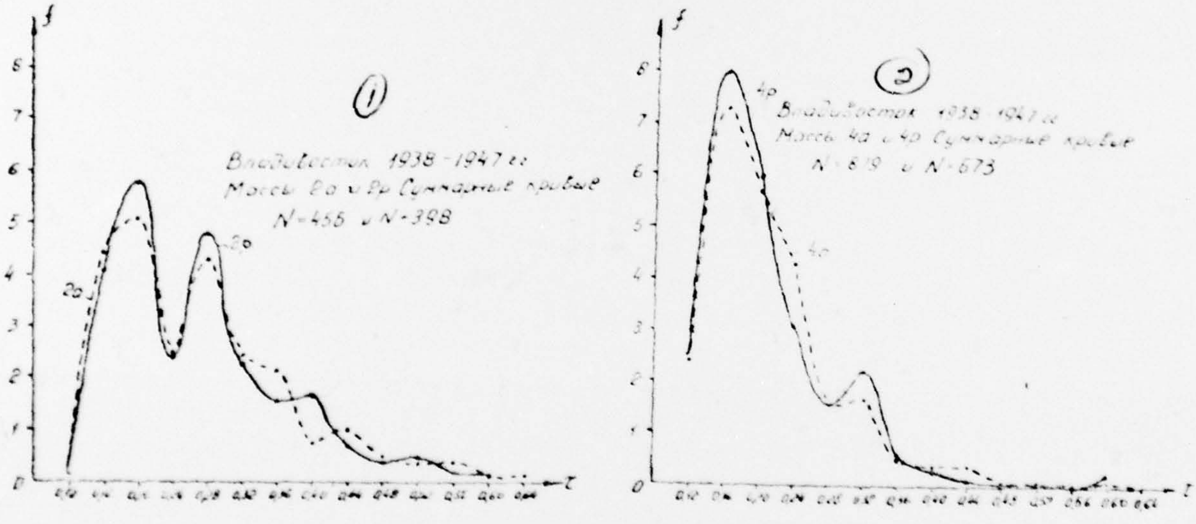


Figure 2. Curves of distribution f(τ) in the case of a constant mass of atmosphere for Vladivostok.

Key: (1) Vladivostok 1938-1947. Masses 2a and 2p. Total curves N=455 and N=398; (2) Vladivostok 1938-1947. Masses 4a and 4p. Total curves N=879 and N=673.

The results for different m turned out to be similar. Figure 1 gives the curves f(τ) for four cases of observations at Karadag, and in Figure 2 - the analogous curves for Vladivostok. It is necessary to turn attention to the following circumstances.

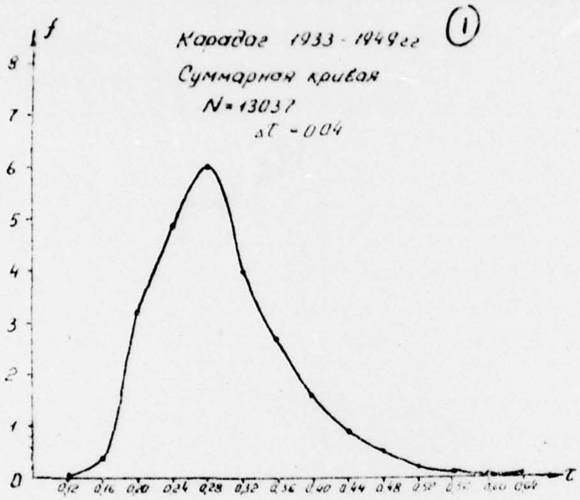


Figure 3. Curve of distribution f(τ) for the complete set of observations for Karadag.

Key: (1) Karadag 1933-1949. Total curve N=13037. Δτ=0.04.

The curves of distribution for the same mass before noon and after noon have the same structure. For an example, let us consider the curves of distribution for Karadag. The positions of the maximums and minimums on curves 2a and 2p coincide. A similar picture is noted for other m, in particular for m=4a and 4p. The values of function f(τ) in symmetric (in respect to noon) points here are also approximately the same. However, the afternoon values of turbidity, as a rule, were higher than those before noon. The same picture is observed on the curves for Vladivostok.

Figures 3 and 4 show the graphs of the function f(τ) correspondingly for Karadag and Vladivostok, constructed for the entire set of values (not separated by masses) with the same spacing as the curves in Figures 1 and 2.

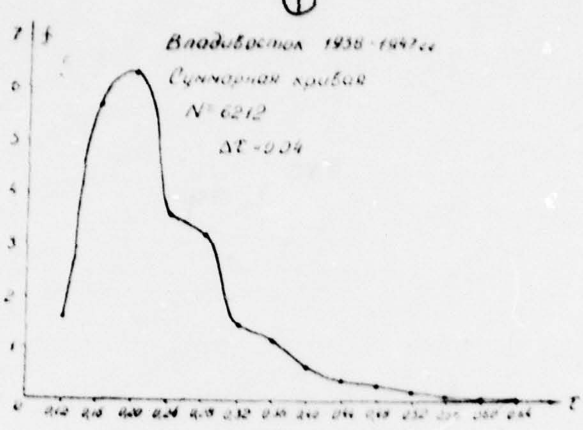


Figure 4. Curve of distribution f(τ) for the complete set of observations for Vladivostok.

Key: (1) Vladivostok 1938-1947. Total curve N=6212. Δτ=0.04.

The curves in Figures 3 and 4 differ noticeably from the analogous curves, constructed with a spacing Δτ=0.02 [2, 3]. With an increase in the spacing of the average important details disappear, minimums are smoothed out or disappear, etc. In comparing the curves, depicted in Figures 1 and 3 and correspondingly in Figures 3 and 4, we see that the curves of distribution, referred to a specific mass, differ noticeably from the total curves.

Without a doubt the curves of distribution at a constant mass are a superposition of no less than two single-model curves. In particular this is clearly evident on the curves for Vladivostok (Figure 2). Standing out clearly here are the conditions of the atmosphere with maximums at τ=0.20 and 0.28 with a mass of 2 and conditions with a maximum at τ=0.16 and 0.32 with a mass of 4. It is interesting that for masses m=1.5 a, p for Vladivostok (we did not depict these curves) the main maximum lies at τ=0.24. If this result is confirmed, then it is possible that this means that in Vladivostok two types of daily variations of aerosol turbidity are observed. In the case of the first type a maximum is noted around noon, and the second - a minimum. These possible types are indicated in Table 2, where the positions of the maximums on curves f(τ) are depicted.

Table 2

m	5а	4а	3а	2а	1,5а	1,5р	2р	3р	4р	5р
(1) 1-й тип	0,16	0,16	0,20	0,20	0,24	0,24	0,20	0,20	0,16	0,16
(2) 2-й тип	—	0,32	0,28	0,28	0,24	0,24	0,28	0,28	0,32	—

Key: (1) 1st type; (2) 2nd type.

On the total curves of distribution conditions with different turbidity with a spacing of $\Delta\tau=0.04$ are not noted. The curves are smooth and single-model. On the curve in Figure 4 (for Vladivostok) without a doubt there is a type of condition with increased turbidity concentrated around $\tau=0.28$. This means that even in the common set (with a large averaged spacing) the conditions with a high degree of turbidity are singled out noticeably on the common curve of distribution.

Seasonal Variability of Transmittance

Data on the curves of distribution f( ), calculated at a constant mass and complete, contain valuable information on the types of optical weather or on the types of circulation which is most prevalent over the observation point. For an illustration of this statement we will consider initially the question of the seasonal variability of transmittance over Vladivostok and Karadag.

According to the data from [7], for Vladivostok, where a monsoon climate prevails, a considerable seasonal variability in the types of circulation is characteristic. In the winter (from December through February) clear days are observed there and the winds are predominantly north and northwest. The recurrence of these wind directions is 82%. The recurrence of south and southeast winds, opposite to the main direction of the winter monsoon, comprises all told 1-11%. In the summer (July - August) the direction of the monsoon winds is mainly south and southeast and their recurrence is 71%. The recurrence of north and northwest winds is 9-17%.

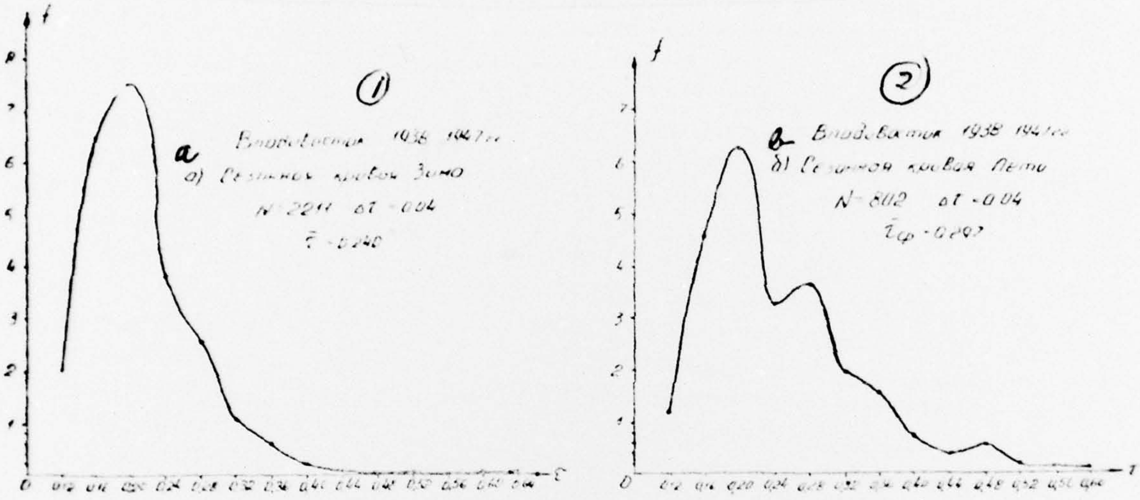


Figure 5. Average seasonal values of the curve of distribution $f(\tau)$ for Vladivostok. a - winter, b - summer.

Key: (1) Vladivostok 1938-1947. Seasonal curve. Winter. N=2211, $\Delta\tau=0.04$, ?=0.240; (2) Vladivostok 1938-1947. Seasonal curve. Summer. N=802, $\Delta\tau=0.04, \tau_{cp}$=0297

According to the data in [8], in Karadag such a clear division of recurrence of wind direction by seasons is not observed.

The difference in the types of circulation is manifested distinctly on the curves $f(\tau)$. In Figure 5 the curves $f(\tau)$ are compared for winter and summer in the case of Vladivostok. Since it is cloudy in Vladivostok in the summer, then for obtaining a statistically controlled curve we had to examine the weighted mean values of all the masses. It is natural that for the comparison we used the analogous data for winter, although there were not sufficient winter observations. It is evident from Figure 5 that the winter curves differ sharply from summer. In the winter observations primarily clear days with high transmittance are encountered. In summer the curve of distribution is wide, there are many conditions with low transmittance.

We add that the analogous seasonal curves for values f(τ) with a constant mass doubtlessly confirm what was stated. We will not depict these curves due to their low frequency.

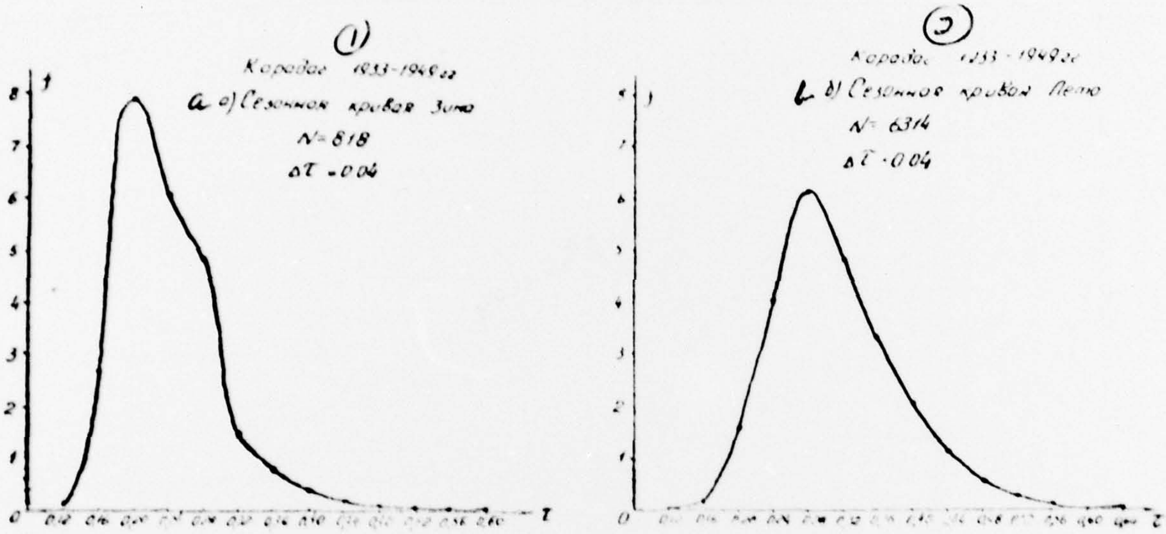


Figure 6. Average seasonal values of the curve of distribution f(τ) for Karadag. a - winter, b - summer.

Key: (1) Karadag 1933-1949. Seasonal curve. Winter. N=818, Δτ=0.04; (2) Karadag 1933-1949. Seasonal curve. Summer. N=6314, Δτ=0.04.

In Figure 6 the analogous curves are given for Karadag. Curves f(τ) in both cases turn out to be more similar, since there are no significant differences in the seasonal types of circulation here. However, nowhere are these curves identical. The winter curve is narrower. This indicates the high degree of homogeneity of the cloudless atmosphere over Karadag in the winter. In the summer the dispersion of conditions is considerably greater, which testifies to the great variety of conditions of the atmosphere over Karadag in the summer.

The connection between turbidity and the type of circulation was investigated by a number of authors [4, 5, 6] on the basis of an analysis of data on the total factor of turbidity. This factor is influenced both by absorption in the bands of gases (water vapor and CO_2) and by attenuation on the aerosol. Our analysis is based on the study of variability only of the aerosol portion of turbidity. Without a doubt it is not excluded that water vapor has a specific value here, since it can influence the swelling or drying of the aerosol particles. However, it still doesn't exert a direct action. Therefore it is very important to investigate the statistical structure of the aerosol factor.

Based on the data of daily variability of transmittance as related to a constant mass it is possible to present the rearrangement of an atmospheric aerosol as the result of the action of two mechanisms. The first - a macroscale process - is connected with the establishment over the observation point of an atmospheric condition with a specific type of circulation. The second - a local process - determines the daily variability within a given type of transmittance. It is characteristic for each point and is connected with intermediate-scale or local phenomena, typical for the particular observations point. The real variability of transmittance of the atmosphere is the result of the superposition of both processes.

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SUMMARY

The direct Solar radiation filter measurements in Karadag (1936—1949 years) and Vladivostok (1938—1947 years) are analysed. It is found that the aerosol quantity variations in vertical direction during a day have place. The statistical structure of aerosol transparence for these places has been found.

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