AEROSOL EXTINCTION OF OPTICAL RADIATION IN THE ATMOSPHERE OF ARID ZONE

Yu.A. Pkhalagov, V.N. Uzhegov, and N.N. Shchelkanov

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
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We discuss the results of measurements of spectral aerosol extinction coefficients $\alpha(\lambda)$ *in the wavelength range from* 0.44 *to* 11.5 μm. *These measurements were performed in hazes of arid zone of Kazakhstan in the period 1984–1988. Statistical characteristics of* $\alpha(\lambda)$ *and meteorological parameters of the atmosphere are presented for three seasons (spring, summer, and fall). Seasonal variability of the* $\alpha(\lambda)$ *spectra is revealed and physical interpretation of this phenomenon is given.*

The studies of optical characteristics of the ground atmosphere (in particular, the spectral coefficients of aerosol extinction) in different regions of the Earth are of great importance for developing the regional empirical models of the atmosphere, which most adequately reflect the main peculiarities of one or another climatic (geographical) zone. The analysis of papers concerned with optical characteristics of the atmosphere in the basic climatic zones of the Earth (ocean, coastal zones of seas and oceans, midlatitudes of continents, and arid zones) indicates the atmosphere of regions with arid moistening conditions (evaporation is far beyond annual precipitation[1]) to be the least known at present.

At the same time the desert regions are of particular optical interest since they, occupying a substantial portion of dry land (15–20 mln km^2), must play an important role in the Earth's radiation balance. This is accounted for by the fact that a weather with few clouds, which is typical for these regions during warm seasons, is favourable for intense deflux of thermal radiation to space at night.

Taking into account what has been said above the Institute of Atmospheric Optics of Siberian Branch of the Russian Academy of Sciences started the experimental studies of spectral transmittance of the ground layer of the atmosphere of subarid zone in Kazakhstan (western part of Lake Balkhash) in 1984. This region represents a typical rocky semi–desert according to its climatic characteristics and type of underlying surface. Since there are no sources of industrial aerosol discharges in this region, we may assume, in the absence of dust storms, that the measurements were carried out under background aerosol concentration conditions. All of the optical investigations were accompanied by meteorological observations. In some cases microphysical measurements of aerosol were also made using an optical counter AZ–5. The goal of our work was to determine the peculiarities of aerosol extinction in the visible and IR spectral ranges in arid zone hazes for different seasons.

The spectral transmittance of the atmosphere (T_λ) was measured in the wavelength range λ = 0.44–11.5 μm (in 13 spectral intervals) using a fully automated transmissometer.[2,3] The interference (λ = 0.44–2.2 μm) and combined (λ > 3 μm) light filters centred at λ_i = 0.44, 0.48, 0.55, 0.69, 0.87, 1.06, 1.22, 1.60, 2.17, 3.97, 9.2, 10.6, and 11.5 μm were used to separate out the required wavelength. The filter half–width was about 10 nm in the visible spectral range, 15–20 μm at λ = 0.8–2.2 μm, and 0.15–0.30 μm at λ = 3.9–11.5 μm. The measurements were made along the 4 625 m ground path. The standard deviation of T_λ measurements (for T < 0.8) did not exceed 3 % in the wavelength range of 0.44–1.06 μm and 5 % at λ > 1.06 μm.

The measurements were carried out only in warm seasons from April to October. Two spring (1985 and 1987), three summer (1984, 1986, and 1987), and three fall (1986, 1987, and 1988) sets of 24–hour measurements at one–hour intervals were made. As a result we obtained more than one thousand of averaged transmission spectra of the atmosphere. The averaging was made over 3–4 results obtained during a 30–minute set of measurements. For final statistical processing we chose 589 transmission spectra measured under the most stable conditions corresponding to atmospheric hazes of spring (230), summer (167), and fall (192 cases).

The first results were published in Ref. 4 where we treated the peculiarities of spectral structure of aerosol optical radiation extinction coefficients in spring hazes based only on the 1985 data array. In the given paper we present the results of statistical analysis of the entire data array obtained during 1984–1988.

METEOROLOGICAL CONDITIONS OF MEASUREMENTS

The mean values of temperature ($\overline{t}$), relative air humidity ($\overline{R}$), partial pressure of water vapor ($\overline{e}$), wind velocity ($\overline{v}$), and radiation extinction coefficient at λ = 0.55 μm ($\overline{\varepsilon}_{0.55}$) related to the aforementioned data array for three seasons are listed in Table I. Here too the standard deviations of these parameters (σ_x) are given.

As seen from Table I the meteorological parameters of the arid zone atmosphere during spring and fall are close to each other. This is true for air temperature, absolute and relative humidity as well as wind velocity. At the same time the coefficients $\overline{\varepsilon}_{0.55}$ for these two seasons differ substantially. They are 0.101 for spring and 0.071 km^{-1} for fall. A low level of extinction coefficients $\varepsilon(0.55)$ in arid zone hazes are noteworthy here. It should be noted for comparison that in hazes of European part of Russia the mean coefficients $\varepsilon(0.55)$ in warm seasons are 0.25 in Voeikovo,[5] 0.31 in Zvenigorod,[6] 0.36 in Kazan',[7] and 0.19 km^{-1} in coastal region of the Black Sea.[8] This

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peculiarity indicates a low content of aerosol in the ground layer of the arid zone atmosphere in warm seasons. The results in Table I also testify to the fact that variations in air temperature and coefficients ε(0.55) during summer decrease more markedly than those in spring and fall, while variations in relative humidity of air somewhat increase. It enables us to assume that in summer in arid zone the variability of optical properties of the ground atmosphere is determined not by relative humidity of air but other physical mechanisms such as aerosol removal from the underlying surface due to turbulent diffusion.

Listed in Table II are the data on distribution of number of measurements over ranges of meteorological parameters e, R, t and the extinction coefficient ε(0.55) which characterize statistical information support of optical measurements under different meteorological conditions occurring in the region under study.

TABLE I. Mean values and standard deviation of meteorological parameters of the atmosphere (t, e, R, and v) and the aerosol extinction coefficients ($\varepsilon_{0.55}$) for the data array obtained in arid zone during the period from 1984 to 1988.

Measured parameter	Spring	Summer	Fall
$\overline{t}$,°C	6.2	26.75	4.16
σ_t	4.34	4.04	3.86
$\overline{e}$, mb	6.91	15.87	6.06
σ_e	2.29	4.54	1.47
$\overline{R}$, %	72.1	45.4	72.9
σ_R	18.0	12.9	14.2
$\overline{\varepsilon}_{0.55}$, km^{-1}	0.101	0.068	0.071
$\sigma_{\varepsilon\,(0.55)}$	0.047	0.024	0.035
$\overline{v}$, m/s	3.90	3.63	4.12
σ_v	1.86	1.49	2.19
Number of measurements	230	167	192

TABLE II. Measurement number distribution over the ranges of meteorological parameters e, R, t, and the extinction coefficient .

Meteorological parameter	Number of measurements			Meteorological parameter	Number of measurements		
e, mb	spring	summer	fall	t,°C	spring	summer	fall
< 2	–	–	2	< – 4	–	–	8
2–4	6	–	6	– 4–0	6	–	12
4–6	105	–	45	0–4	90	–	78
6–8	65	6	72	4–8	63	–	67
8–10	28	10	17	8–12	48	–	27
10–12	19	16	–	12–16	19	–	–
12–14	3	12	–	16–20	2	10	–
14–16	4	17	–	20–24	2	35	–
16–18	–	15	–	24–28	–	58	–
18–20	–	26	–	28–32	–	42	–
20–22	–	15	–	32–36	–	22	–
22–24	–	12	–				
24–26	–	19	–				
26–28	–	9	–				
> 28	–	10	–				
R, %				ε(0.55), km^{-1}			
< 20	–	2	–	< 0.03	5	13	32
20–30	8	29	–	0.03–0.06	38	62	55
30–40	8	32	2	0.06–0.09	64	56	51
40–50	16	37	13	0.09–0.12	50	31	29
50–60	20	46	20	0.12–0.15	26	3	15
60–70	45	19	50	0.15–0.18	22	2	6
70–80	48	2	43	0.18–0.21	18	–	3
80–90	39	–	37	> 0.21	7	–	–
90–100	45	–	27				

Table III represents the coefficients of mutual correlation between meteorological parameters of the atmosphere in each of the data arrays, which are needed for analyzing the correlations between the aerosol extinction coefficients and the meteorological parameters. Here too in the last column there are levels of significant correlation which are related to a number of measurements in each of the seasons (see Table I). It is seen that for all of the three seasons there is a significant positive correlation between R and e as well as between e and t. The correlation between R and t is negative and significant in all cases. It should be noted that in the summer data array the correlation coefficients ρ_{Re} and ρ_{et} differ strongly from those for spring and fall data arrays.

TABLE III. Coefficients of correlation between meteorological parameters in the atmosphere of arid zone.

Seasons	ρ_{Re}	ρ_{Rt}	ρ_{et}	ρ_{sign}
spring	0.50	–0.40	0.56	0.15
summer	0.67	–0.39	0.39	0.17
fall	0.43	–0.36	0.65	0.15

To obtain the data array for aerosol extinction coefficients $\alpha(\lambda)$ we first determined the coefficients of total extinction $\varepsilon(\lambda)$ from the given values of spectral transmittance of the atmosphere $T(\lambda)$ using the Bouguer formula. Then aerosol components were separated out from the general extinction coefficients in the IR wavelength range using the data arrays of the parameters $\varepsilon(0.55)$ and e and the method of successive separation of components.[9] Then, based on the obtained data arrays of the coefficients $\alpha(\lambda)$, we formed individual subarrays for three seasons. And using these subarrays we calculated the mean values of $\alpha(\lambda)$, their rms, and the coefficients of autocorrelation between $\alpha(\lambda_i)$ and $\alpha(\lambda_j)$ over the entire wavelength range and the coefficients of mutual correlation between $\alpha(\lambda_i)$ and meteorological parameters of the atmosphere.

SPECTRAL STRUCTURE OF THE AEROSOL EXTINCTION COEFFICIENTS

The mean values of the spectral coefficients of aerosol extinction $\alpha(\lambda)$ and their rms $\sigma_{a(k)}$ in arid zone hazes for three seasons are listed in Table IV. The analysis of these data indicates that very small values of the aerosol extinction coefficients over the entire wavelength range are realized in desert hazes in warm seasons. Even in spring when the largest values α in the visible spectral range are observed, the meteorological visible range S_m averages 39 km. In summer and fall the mean values of S_m are 57 and 55 km, respectively. The physical essence of this phenomenon can be as follows: in a warm seasons in the arid zone the aerosol of the atmospheric ground layer is removed into higher layers and distributed over a very large volume due to a well–developed convection and turbulent diffusion.[10] Moreover, in summer a low relative humidity of air results in intense drying of aerosol, which also increases the atmospheric transmission.

TABLE IV. Mean values and standard deviation of the aerosol extinction coefficients $\bar{\alpha}_\lambda$ (km^{-1}) in the atmosphere of arid zone.

λ, μm	Spring		Summer		Fall	
	$\bar{\alpha}_\lambda$	σ_α	$\bar{\alpha}_\lambda$	σ_α	$\bar{\alpha}_\lambda$	σ_α
0.44	0.111	0.058	0.057	0.025	0.072	0.043
0.48	0.103	0.054	0.058	0.025	0.064	0.038
0.55	0.089	0.047	0.056	0.024	0.059	0.035
0.69	0.065	0.034	0.054	0.023	0.049	0.029
0.87	0.047	0.024	0.055	0.024	0.042	0.025
1.06	0.042	0.022	0.052	0.022	0.043	0.025
1.22	0.036	0.018	0.056	0.024	0.043	0.025
1.60	0.031	0.016	0.054	0.023	0.040	0.024
2.17	0.026	0.013	0.061	0.026	0.042	0.025
3.97	0.026	0.013	0.069	0.030	0.044	0.026
9.20	0.032	0.015	0.073	0.031	0.053	0.031
10.6	0.030	0.015	0.062	0.026	0.049	0.029
11.5	0.039	0.019	0.071	0.030	0.054	0.032

The specific forms of averaged spectral dependences of aerosol extinction coefficients related to spring (curve *1*), fall (curve *2*), and summer (curve *3*) arid zone hazes are depicted in Fig. 1. It is seen that the spectral structure of the coefficients α has seasonal peculiarities. Thus, the spectral dependence $\alpha(\lambda)$ for spring hazes is characterized by a pronounced maximum in the visible spectral range and a minimum level of the aerosol extinction coefficients in the 2–12 μm wavelength range. For fall hazes, the maximum in a short–wave spectral range is less pronounced, and the level of the coefficients $\bar{\alpha}(\lambda)$ in the IR range is somewhat higher. As to summer hazes, the spectral behavior of the coefficients $\bar{\alpha}(\lambda)$ here is of quasineutral character with the tendency for an increase as it moves to the IR wavelength range, which is not typical for haze. It should be noted that a similar spectral dependence of the coefficients α in a subarid zone in summer was also revealed in Ref. 11 based on the data of microphysical studies.

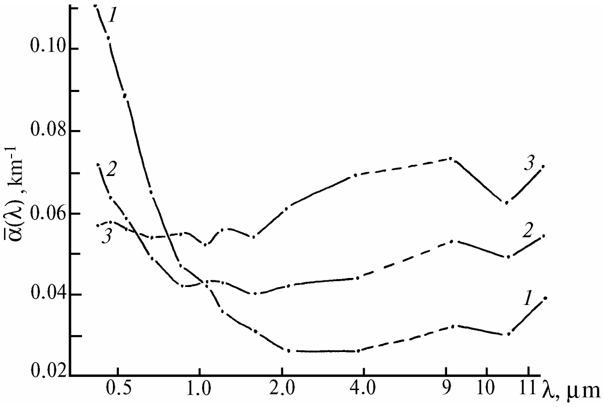

FIG. 1. Averaged spectral dependences of the aerosol extinction coefficients for arid zone hazes in spring (1), fall (2), and summer (3).

The seasonal transformation of spectral structure $\bar{\alpha}(\lambda)$ can be qualitatively accounted for by the following fact. In spring (April) in the measurement region after melting of a thin snow cover and frequent rain the soil is strongly moistened, saline lands are supplied with water, and different vegetation begin to grow intensively. This, in the presence of sunny weather, stimulates the formation of fine aerosol of photochemical origin in the ground layer of the atmosphere. In this case a great heat loss for evaporating the soil moisture reduces the power of convective flows substantially. Due to this fact the formed photochemical aerosol remains in the ground layer. Moreover, weak convection and a humid surface of the ground bound the removal of the coarse ground aerosol appreciably.

As a consequence it turns out that in spring in the arid zone atmosphere a fine aerosol prevails, and a spectral structure of the coefficients $\bar{\alpha}(\lambda)$ has the form similar to the dependence $\bar{\alpha}(\lambda)$ for the haze at midlatitudes of Russia (see, e.g., Refs. 6 and 7). The analysis of statistical relation between the coefficients $\alpha(\lambda)$ and the relative humidity of air made in Ref. 4 allows the conclusion to be drawn on hydroscopicity of submicron aerosol in spring hazes of arid zone. Conceivably, not only photochemical aerosol but also salt particles from irrigated saline lands which are supplied to the atmosphere through a bubble mechanism just as the case in the sea, might contribute to concentration of small particles. Possible participation of saline lands in formation of desert aerosol was discussed in Ref. 12.

In summer in the arid zone, because of the lack of rains, the area of green vegetation reduces substantially and the saline lands fully dry up that results in the decrease of fine aerosol concentration. Moreover, the intense heating of soil facilitates the formation of powerful convective flows of air and turbulent diffusion, that produces a stronger removal of fine aerosol into higher layers of the atmosphere. In the ground layer the concentration of larger particles arriving from the ground surface, which are not removed to larger altitudes due to their size, simultaneously increases. As a result, it is these particles that form a spectral structure of the aerosol extinction coefficients in the ground haze of arid zone in summer which is of quasineutral character over the entire wavelength range (see Fig. 1, curve *3*).

In fall the convection and turbulent diffusion become weaker with the decreased soil heating that leads to smaller fine–aerosol removal from the ground layer than that in summer. At the same time, the supply of coarse ground aerosol to the atmosphere decreases, since in this season in the measurement region it often rains and the soil is often humid. Due to simultaneous manifestation of these factors the spectral structure of the coefficients α in fall in the arid zone, in contrast to that in summer, is formed by both small and large particles.

The form of the short–wave interval in the averaged spectrum of the coefficients in fall is largely related to spring haze, and that of the long–wave interval is largely related to summer one thus occupying an intermediate position between them (see Fig. 1, curve *2*).

RESULTS OF CORRELATION ANALYSIS

As was mentioned above, the normalized coefficients of autocorrelation between $\alpha(\lambda_i)$ and $\alpha(\lambda_j)$ over the entire wavelength range as well as the coefficients of mutual correlation between $\alpha(\lambda_i)$ and meteorological parameters of the atmosphere were calculated based on the available data arrays of the coefficients $\alpha(\lambda)$ for three seasons of the year. It should be noted that the correlations between the aerosol extinction coefficients in different spectral intervals are of particular scientific interest, since it makes it possible to draw conclusion on the presence or absence of genetic community of different–size particles, existence of general factors of their variability, and so on. Moreover, such data are needed for developing the empirical models of the reconstruction of the coefficients $\alpha(\lambda_i)$ based on a small number of measured input parameters. The calculational results of the correlations are listed in Tables V–VII.

TABLE V. Coefficients of auto– $\rho_{\alpha(\lambda_i)\alpha(\lambda_j)}$, *mutual* $\rho_{\alpha_\lambda e}$ *and* $\rho_{\alpha_\lambda R}$, *and conventional* $\rho_{\alpha_\lambda R/e}$ *and* $\rho_{\alpha_\lambda e/R}$ *correlations for spring haze of arid zone.*

λ_i, μm	0.44	0.55	0.69	0.87	1.06	1.60	2.17	3.97	9.20	10.6	11.5
					Autocorrelation coefficients						
0.44	1.0										
0.55	0.99	1.0									
0.69	0.97	0.98	1.0								
0.87	0.89	0.91	0.95	1.0							
1.06	0.83	0.84	0.90	0.97	1.0						
1.60	0.56	0.57	0.65	0.79	0.87	1.0					
2.17	0.38	0.42	0.48	0.64	0.71	0.89	1.0				
3.97	0.24	0.28	0.34	0.49	0.59	0.83	0.90	1.0			
9.20	0.34	0.39	0.44	0.54	0.59	0.73	0.73	0.78	1.0		
10.6	0.28	0.34	0.38	0.50	0.54	0.70	0.72	0.81	0.93	1.0	
11.5	0.23	0.28	0.32	0.42	0.46	0.54	0.56	0.61	0.90	0.90	1.0
					Mutual–correlation coefficients						
$\rho_{\alpha_\lambda e}$	–0.16	–0.19	–0.18	–0.16	–0.09	–0.03	–0.11	–0.10	–0.16	–0.20	–0.20
$\rho_{\alpha_\lambda R}$	0.37	0.38	0.33	0.23	0.22	0.07	–0.06	–0.08	–0.01	–0.01	–0.02
					Conventional–correlation coefficients						
$\rho_{\alpha_\lambda R/e}$	0.52	0.56	0.49	0.36	0.31	0.10	–0.06	–0.03	–0.08	–0.11	–0.09
$\rho_{\alpha_\lambda e/R}$	0.03	0.00	–0.02	–0.05	0.02	0.06	–0.09	–0.07	–0.18	–0.19	–0.19

The analysis of the autocorrelation coefficients $\rho_{\alpha(\lambda_i)\alpha(\lambda_j)}$ for a spring haze (Table V) reveals that during this period the correlation between the coefficients $\alpha(\lambda)$ in the visible and IR spectral ranges at $\lambda = 1.6$ μm and, particularly, at 2.17 μm decreases rapidly. This is indicative of the fact that the fine and coarse aerosols in the arid zone are of different nature. In the foregoing section we showed that the fine aerosol is hygroscopic and might be of photochemical and salt nature. As to coarse particles, they might be of soil origin and weakly interact with atmospheric moisture.

In summer and especially in fall, in contrast to spring, a relatively high correlation between the aerosol extinction coefficients in the visible and IR ranges is realized (see Tables VI and VII). This unambiguously indicates the existence of the general factor of variability of the coefficients $\alpha(\lambda)$ over the entire range λ. The most probable factor here is a coarse aerosol of ground origin whose variations in concentration due to removal and sedimentation are adequately reflected on the extinction coefficients both in the visible and IR spectral ranges. Under weak winds (in the absence of dust storms) the basic physical mechanisms of coarse aerosol removal are convection and turbulent diffusion, whose intensity in the arid zone, from the estimates,[10] is by more than an order of magnitude larger than that in the regions covered with forest.

In addition to these general conclusions the analysis of Tables V–VII enables us to point out the following moments. Under spring conditions when small particles constitute a significant portion in atmospheric aerosol there is a substantial maximum in the correlation between the coefficients $\alpha(\lambda)$ in the visible spectral range and in the range $\lambda = 9.2$ μm. Since in this wavelength range we observe a strong absorption band of sulphates, it is possible to assume that the fine aerosol of the arid zone in spring has a portion of sulphate particles in its composition.

In contrast, in the summer correlation matrix at $\lambda = 9.2$ μm there is a pronounced gap in the correlation between all of the wavelengths. This extremely interesting fact can not be easily interpreted. We may assume that very small aerosol particles, which do not in fact scatter electromagnetic waves even in the range $\lambda = 0.44$ μm, absorb at this wavelength. Moreover, a substantial decrease in correlation between the coefficients $\alpha(0.44)$ and $\alpha(\lambda_i)$ over the entire IR spectral range is note worthy, because this is unexpected for quasineutral spectral behaviour of the mean values of $\alpha(\lambda)$. The comparison between the levels of the autocorrelation coefficients $\rho_{\alpha(0.44)\alpha(\lambda_i)}$ and the corresponding level $\rho_{\alpha(0.55)\alpha(\lambda_i)}$ reveals a stepwise growth of correlation in the last case. The analysis of these facts enables one to uniquely conclude that in the range $\lambda = 0.44$ μm in summer there is some factor of extinction, whose variations are not related to variations in the concentration of coarse aerosol which, forms a quasineutral character of spectral structure of the coefficients $\alpha(\lambda)$ in this season. It is natural to assume that this factor is scattering of short–wave radiation by sufficiently small particles whose action weakens substantially even at $\lambda = 0.55$ μm, it is not practically observed in the averaged spectral dependence $\alpha(\lambda)$. Nevertheless, such particles strongly affect the character of autocorrelation between the aerosol extinction coefficients. This is indicative of high sensitivity of autocorrelation matrix to presence of even small number of aerosol particles in the atmosphere.

TABLE VI. Coefficients of auto– $\rho_{\alpha(\lambda_j)\alpha(\lambda_i)}$, mutual $\rho_{\alpha_\lambda e}$ and $\rho_{\alpha_\lambda R}$, and conventional $\rho_{\alpha_\lambda R/e}$ and $\rho_{\alpha_\lambda e/R}$ correlations for summer haze of arid zone.

λ_i, μm	0.44	0.55	0.69	0.87	1.06	1.60	2.17	3.97	9.20	10.6	11.5
					Autocorrelation coefficients						
0.44	1.0										
0.55	0.91	1.0									
0.69	0.86	0.94	1.0								
0.87	0.84	0.91	0.95	1.0							
1.06	0.78	0.87	0.91	0.93	1.0						
1.60	0.70	0.80	0.84	0.87	0.95	1.0					
2.17	0.58	0.71	0.77	0.82	0.89	0.92	1.0				
3.97	0.51	0.66	0.71	0.77	0.83	0.91	0.94	1.0			
9.20	0.43	0.60	0.67	0.67	0.73	0.79	0.81	0.80	1.0		
10.6	0.53	0.65	0.71	0.76	0.81	0.85	0.87	0.84	0.86	1.0	
11.5	0.48	0.61	0.68	0.73	0.78	0.83	0.89	0.86	0.86	0.97	1.0
					Mutual–correlation coefficients						
$\rho_{\alpha_\lambda e}$	0.35	0.29	0.29	0.30	0.30	0.21	0.24	0.15	0.11	0.21	0.19
$\rho_{\alpha_\lambda R}$	0.16	0.19	0.21	0.21	0.16	0.15	0.23	0.23	0.19	0.26	0.26
					Conventional–correlation coefficients						
$\rho_{\alpha_\lambda R/e}$	–0.13	–0.02	–0.01	0.01	–0.07	0.01	0.08	0.16	0.16	0.16	0.17
$\rho_{\alpha_\lambda e/R}$	0.24	0.22	0.21	0.22	0.26	0.15	0.12	0.0	–0.02	0.05	0.02

TABLE VII. Coefficients of auto– $\rho_{\alpha(\lambda_j)\alpha(\lambda_i)}$, mutual $\rho_{\alpha_\lambda e}$ and $\rho_{\alpha_\lambda R}$, and conventional $\rho_{\alpha_\lambda R/e}$ and $\rho_{\alpha_\lambda e/R}$ correlations for fall haze of arid zone.

λ_i, μm	0.44	0.55	0.69	0.87	1.06	1.60	2.17	3.97	9.20	10.6	11.5
					Autocorrelation coefficients						
0.44	1.0										
0.55	0.98	1.0									
0.69	0.92	0.96	1.0								
0.87	0.80	0.86	0.95	1.0							
1.06	0.80	0.86	0.93	0.95	1.0						
1.60	0.68	0.74	0.85	0.90	0.96	1.0					
2.17	0.64	0.71	0.82	0.87	0.93	0.98	1.0				
3.97	0.59	0.67	0.78	0.84	0.91	0.97	0.98	1.0			
9.20	0.57	0.63	0.73	0.78	0.86	0.90	0.92	0.92	1.0		
10.6	0.63	0.70	0.79	0.84	0.92	0.95	0.95	0.96	0.97	1.0	
11.5	0.57	0.63	0.71	0.75	0.83	0.87	0.88	0.87	0.98	0.95	1.0
					Mutual–correlation coefficients						
$\rho_{\alpha_\lambda e}$	0.32	0.31	0.33	0.31	0.35	0.34	0.34	0.35	0.39	0.38	0.40
$\rho_{\alpha_\lambda R}$	0.45	0.46	0.40	0.30	0.31	0.24	0.20	0.21	0.14	0.25	0.17
					Conventional–correlation coefficients						
$\rho_{\alpha_\lambda R/e}$	0.35	0.37	0.29	0.18	0.17	0.10	0.05	0.05	–0.05	0.08	–0.02
$\rho_{\alpha_\lambda e/R}$	0.16	0.15	0.19	0.21	0.25	0.27	0.29	0.29	0.37	0.31	0.37

In fall haze, as well as in spring one, the coefficients $\rho_{\alpha(0.44)\alpha(\lambda_i)}$ substantially decrease after $\lambda = 1.06$ μm, but their level remains much higher that may be accounted for by increased content of coarse particles. Moreover, while the spring maximum of correlation between aerosol extinction in the visible and IR radiation (in the region of the 8–12 μm window) falls on the wavelength of 9.2 μm, the fall one is displaced to the region $\lambda = 10.6$ μm. Physical interpretation of this displacement remains to be made. The autocorrelation matrix for fall haze as a whole turns out to be close to a summer one (except for $\rho_{\alpha(0.44)\alpha(\lambda_i)}$). Somewhat larger correlation coefficients for fall than those for summer can be explained by the fact, that in fall we observe the evaluated relative humidity of air which is a complementary factor resulting in synchronous variations of $\alpha(\lambda)$ in different spectral intervals.

Let us consider correlations between the aerosol extinction coefficients and the relative humidity of air and partial pressure of water vapor, which are listed in Tables V–VII. These tables present both total coefficients of mutual correlation $\rho_{\alpha(\lambda)R}$ and $\rho_{\alpha(\lambda)e}$ and individual ones $\rho_{\alpha(\lambda)R/e}$ and $\rho_{\alpha(\lambda)e/R}$, i.e., the coefficients of correlation between two parameters with the third fixed.[13] In this case the individual coefficients of correlation must be considered, since in the aforementioned arrays there is a sufficiently close relationship between the partial pressure of water vapor and relative humidity of air (see Table III) which results in appearance of indirect relations between $\alpha(\lambda)$ and R or $\alpha(\lambda)$ and e. Therefore, all of the conclusions on correlations between the aerosol extinction coefficients and meteorological parameters will be made based on the analysis of only individual (conventional) coefficients of correlation.

For spring haze (Table V) we observed a pronounced relation between the aerosol extinction coefficients $\alpha(\lambda)$ in the short–wave region ($\lambda < 1.06$ μm) and the relative humidity of air. In the spectral range $\lambda > 1.06$ μm the correlation coefficients become lower than the level of significance. Such relation between $\alpha(\lambda)$ and R supports the aforementioned assumption on hygroscopicity of fine aerosol in the arid zone in spring. The table also reveals that in the spring haze there is in fact no relation between $\alpha(\lambda)$ and e over the entire wavelength range.

In summer (see Table VI) the relation between $\alpha(\lambda)$ and R and e changes very sharply. The correlation between $\alpha(\lambda)$ and R over the entire wavelength range is almost absent, but a significant correlation between $\alpha(\lambda)$ and e appears in a short–wave spectral interval ($\lambda < 1.06$ μm). This can be accounted for by the fact that in summer a synchronous removal of fine aerosol and water vapor occurs due to powerful convective flows.[14,15] It should be noted, however, that this relation is too weak and is indicative of only some tendency but not regularity inherent in the summer haze of arid zone.

In fall (see Table VII) the correlation between $\alpha(\lambda)$ and R turns out to be similar to that in spring as could be expected. At the same time the relation between $\alpha(\lambda)$ and e which, as one might expect, is similar to that in summer, differs strongly from it. In this case in the visible spectral interval the correlation coefficients are at the level of significance (0.15–0.16) and then slowly increase with the wavelength increase, and in the range $\lambda = 9.2$ μm they attain 0.37. We failed to provide physical interpretation of such spectral dependence of the correlation coefficients. It is possible to assume that an indirect relation between $\alpha(\lambda)$ and e is manifested here in air temperature due to relatively high correlation between e and t which is 0.65 in the fall data array (see Table VII). It should be noted that ρ_{et} in the summer data array is only 0.39, and this indirect relation is not manifested here. The physical interpretation of the relation between $\alpha(\lambda)$ and air temperature in this case is sufficiently simple and caused by removal of coarse aerosol from the ground surface due to convective flows, whose power is proportional to heating of the underlying surface.

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