Aerosol Extinction of 0.44 to 12 M Radiation by Atmospheric Hazes (Continent, Coastal and Arid Zones)

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The atmospheric haze is known to enhance the earth's albedo, and this must be accounted for in radiation calculations. Since the optical properties of atmospheric aerosol making up the haze have regional distinctions and may vary widely under the impact of many factors, most suited for such calculations are empirical regional haze models built upon the statistical experimental data.

In the context of this problem, the many-year program was conducted in the Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences (SB RAS), to study the optical properties of hazes of sea coastal zone, arid zone, and continental forest region in the wavelength range of 0.44 to 12 µm on extended near-water and near-ground paths. The appropriate measurements were performed on the Black Sea coast (coastal zone), in the region of Balkhash Lake (arid zone), and near Tomsk (continental forest zone). For these different climatic zones, we have acquired statistically extensive data arrays of spectral aerosol extinction coefficient $\alpha(\lambda)$ and atmospheric meteoparameters. The molecular absorption by water vapor and atmospheric gases was accounted for by using a specially developed statistical technique (Pkhalagov and Uzhegov 1988). Below we briefly discuss the main results from these studies separately for every location.

Coastal Haze

The main feature of the atmosphere of coastal zone stems from the presence of two powerful sources of aerosol (sea and land), which is transported by the breeze air circulation and causes the substantial variations in the haze optical properties. The spectral atmospheric transmission measurements were made in the warm seasons only, using instrumentation detailed in Pkhalagov et al. (1992). Total data array included over 800 spectra of aerosol extinction coefficient $\alpha(\lambda)$, and simultaneous measurements of relative humidity of air RH, partial pressure of water vapor e, air temperature t, as well as the speed and direction of wind. Most general characterization of meteorological conditions at the time of measurements being discussed is given in Table 1, listing the mean values of atmospheric meteoparameters and their rms deviations (RMSDs).The results of the studies are the mean values of the coefficients $\alpha(\lambda)$ for maritime hazes of coastal zone, the autocorrelation coefficients between $\alpha(\lambda_i)$ and $\alpha(\lambda_j)$ as well as coefficients of correlation between variations in $\alpha(\lambda)$ and atmospheric meteoparameters.

Table 1. Characterization of meteorological conditions.

Measured parameters	Mean	RMSD
RH,%	68.29	12.65
e, mb	16.48	3.88
t,°C	20.40	3.77
V, m/s	3.2	2.5
Wind from sea,%	50	--
$\alpha(0.55)$, km^{-1}	0.186	0.112

The mean spectral structure of coefficients $\alpha(\lambda)$ in hazes of coastal zone is illustrated in Figure 1 (curve 1). Noteworthy is the high level of aerosol extinction in the 8 to 12-µm range, with value of about 0.1 km^{-1} at the mean visibility of 8-12 km. As compared to the corresponding data for continental hazes, the same level in the of 8 to 12-µm range takes place for the visibility of 11-12 km (curves 2 and 3) and lower (curve 4). Obviously, such a high level of in the infrared in hazes of coastal zone is due to the increased concentration of coarsely-dispersed salt aerosol generated by the sea surface.

Depending on the meteorological conditions, the mean spectrum of coefficients $\alpha(\lambda)$ may substantially transform. Most abruptly, the spectrum of $\alpha(\lambda)$ changes with varying relative humidity of air, that is clearly seen in Figure 2.

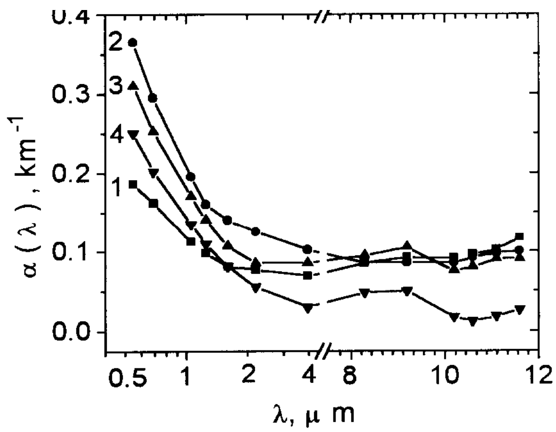

Figure 1. The spectral behavior of averaged aerosol extinction coefficients α(λ), obtained for maritime haze on Black Sea coast (curve 1) and continental haze near Kazan (2,), in Moscow suburb (3), and Saint Petersburg suburb (4).

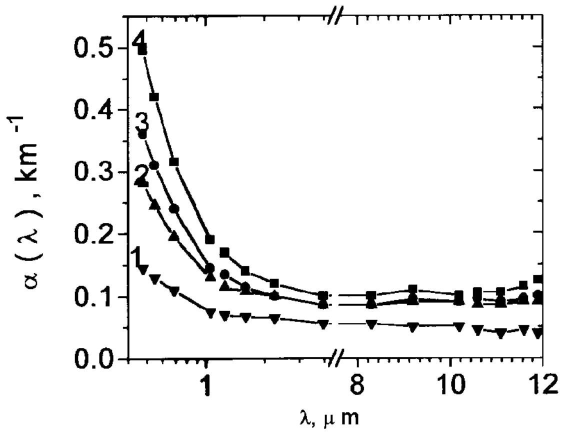

Figure 2. The α(λ) spectrum transformation with varying relative humidity of air: (1) RH=60%, (2) 76%, (3) 84%, (4) 93% for maritime coastal haze.

Continental Forest Region

In this section we analyze results from two cycles of diurnal measurements of spectral aerosol extinction coefficients during June-July 1992. The first, three-day cycle of diurnal measurements was from 25 to 15 June on a 1-km long path in the east suburb of Tomsk. The second, reduced cycle of diurnal measurements was taken from 17 to 23 July 70 km southwest of Tomsk under the near-background conditions. The 1.2-km long path (with reflection) passed over the grassland along the coastline of Ob river. This time, measurements spanned 0.44-1.06-μm range only. A total of 212 averaged realizations of spectrum of aerosol extinction coefficient α(λ) were obtained during first measurement cycle, and 62 realizations during second cycle. It can be assumed that the first cycle measurements pertain to urban haze, while the second cycle to rural haze. The mean values of temperature, relative air humidity, partial pressure of water vapor, and radiation extinction coefficient at λ = 0.55 μm related to the aforementioned data array for two masses are listed in Table 2.

Table 2. Measurements for urban and rural haze.

Measured Parameter	Urban Haze	Rural Haze
$\bar{t}$, °C	10.8	19.8
σ_t	5.33	3.97
$\bar{e}$, mb	7.68	18.7
σ_e	3.01	2.49
$\overline{R}$H,%	58.2	81.9
σ_R	20.0	13.8
$\bar{\varepsilon}_{0.55}$, km^{-1}	0.168	0.217
σ_ε(0.55)	0.086	0.139

Here too the standard deviations of these parameters (σ_x) are given. The spectral structure of mean values of the coefficients α(λ) for these two types of hazes is shown in Figure 3. From inspection of Figure 3 it follows that the urban haze (curve 1) exhibits essentially flat spectral dependence of coefficients α(λ). Taking conventionally the α = 0.125 km^{-1} level (at l = 1.25 μm) as a contribution to the extinction due to coarsely-dispersed fraction of particles, we see that the finely-dispersed aerosol around λ = 0.44 μm contributes only 0.07 km^{-1}. This means that at the time of measurement the urban haze was characterized by deficit of finely-dispersed aerosol. Since for the period of this measurement cycle the region was dominated by clean Arctic masses, it is likely that major contributors to the attenuation of optical radiation were moderately- to coarsely-dispersed aerosols of local and, possibly, anthropogenic origin. At the same time, the very high level of α(λ) coefficients in the IR range, in excess of 0.1 km $^{-1}$, is believed to owe lot to the scattering of optical radiation by particles of biological origin (primarily, by down from poplar, aspen, etc.) which were visually observed on the measurement path at that time.

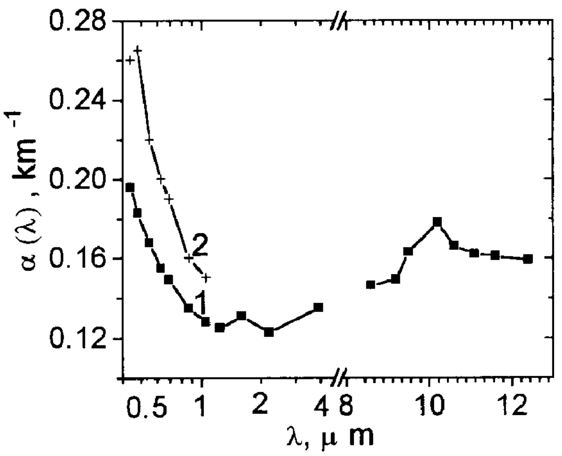

Figure 3. The spectral structure of aerosol extinction coefficients for urban (1) and rural (2) hazes.

Rural haze (curve 2), under the conditions of elevated air temperature and relative humidity, acts to enhance aerosol extinction coefficient a between 0.44- and 1.06-µm wave-lengths, and leads to pronounced spectral dependence of α(λ) relative to urban haze. Characteristic of rural haze is the fairly close correlation between variations of α(λ) across the entire wavelength range (0.44 to 1.06 µm) and those of the relative air humidity (with correlation coefficients of 0.5-0.6). That may be an indication of the dominating role of submicron fraction of particles in determining the spectral dependence of α(λ) in this wavelength range.

Arid Zone

Optical properties of the atmosphere in the regions with arid moistening conditions have not been sufficiently studied to date. 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 favorable for intense deflux of thermal radiation to space at night. In this paper we discuss the results of measurements of spectral aerosol extinction coefficients α(λ) 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. The measurements were made along the 4 625 m ground path. For 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 mean values of temperature, relative air humidity, partial pressure of water vapor, wind velocity, and radiation extinction coefficient at λ = 0.55 µm related to the aforementioned data array for three seasons are listed in Table 3. Here too the standard deviations of these parameters (σ_χ) are given. 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 Figure 4.

Table 3. Measurements for three seasons.

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

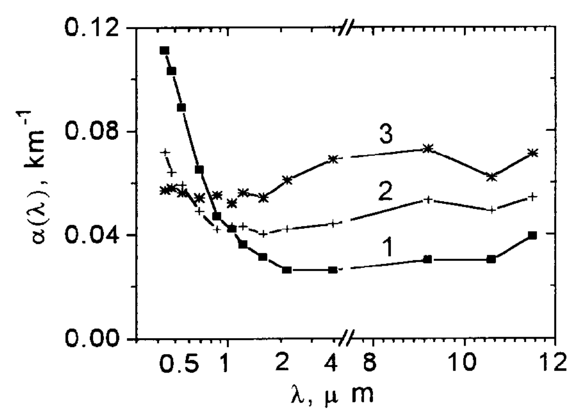

Figure 4. Averaged spectral dependences of the aerosol extinction coefficients for arid zone hazes in spring (1), fall (2), and summer (3).

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 $\alpha(\lambda)$ in the IR range is somewhat higher. As to summer hazes, the spectral behavior of the coefficients $\alpha(\lambda)$ 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.

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. 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.

References

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