About "Effective" Height of the Aerosol Atmosphere in Visible and IR Wavelength Range

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Introduction

Aerosol component of the atmosphere is one of the important factors affecting the radiation budget of the space – atmosphere – underlying surface system in visible and infrared (IR) wavelength ranges. It is extremely important to take into account the contribution of this component into the extinction of solar radiation under cloudless sky conditions. Sometimes it is important to know not only the total value of the aerosol component of extinction, but also to have the possibility to estimate the "effective" height of the aerosol atmosphere in different spectral intervals, which qualitatively characterizes the height of the mixing layer for particles of different size. As is known, the "effective" height of the aerosol atmosphere $H_0(\lambda)$ is defined as follows.

$$H_0 (\lambda) = \tau (\lambda) / \alpha (\lambda), \qquad (1)$$

where $\tau(\lambda)$ is the optical thickness of the atmosphere at the wavelength (λ), $\alpha(\lambda)$ is the aerosol extinction coefficient in the near-ground layer. The parameters should be measured simultaneously. But as it is difficult to carry out synchronic measurements of the parameters $\tau(\lambda)$ and $\alpha(\lambda)$, investigations of the "effective" height of the aerosol atmosphere were performed occasionally and were limited by the wavelength range 0.44 to 1.06 µm (Sakerin 2002, Pkhalagov 2003).

The attempt is undertaken for the first time to determine the "effective" height of the aerosol atmosphere in the wavelength range $\Delta\lambda$ = 0.44 to 3.9 µm. A cycle of synchronic measurements of the parameters $\tau(\lambda)$ and $\alpha(\lambda)$ was carried out at the eastern vicinity of Tomsk since May 15 till July 7, 2002, by means of the instrumentation complexes (Pkhalagov 1992, Kabanov 2001). More than 160 spectral dependencies of $\tau(\lambda)$ and $\alpha(\lambda)$ were obtained during 33 days of measurements. The range of variations of the meteorological parameters of the atmosphere, such as air temperature (t), relative (RH) and absolute (a) humidity, specific pressure of water vapor (e), atmospheric pressure (P), wind velocity (v) and the "effective" height of water vapor (Hw), is presented in Table 1.

Results

All data obtained were statistically processed. Mean values of all measured parameters were obtained, and correlation coefficients between all of them were calculated. The correlation coefficients between $\alpha(\lambda)$, $\tau(\lambda)$ and $H_0(\lambda)$ at three wavelength are shown in Table 2.

Table 1. The range of variation of meteorological parameters of the atmosphere during the period of measurements.

Parameter, X	$\bar{X}$	Rms. error	X_{max}	X_{min}
t, °C	19.7	5.48	31.4	5.50
e, mbar	9.9	3.53	19.3	4.19
RH, %	43	15.8	92.0	18.0
a, g/m^3	7.3	2.56	14.2	3.25
Hw, km	1.96	0.39	3.08	1.16
P, mm Hg	743.8	4.62	753	734
v, m/sec	3.4	1.65	7.90	0.0

Let us note that high correlation between the measured parameters ($\rho_{\alpha\alpha} > 0.73$, $\rho\tau\tau > 0.52$) exists in the uniform data arrays, and only the correlation of the parameter H0(λ) at extreme wavelengths is less (ρHH >0.32).

Table 2. Correlation coefficients between some spectral values of the parameters α(λ), τ(λ), and H_0(λ).

	α (0.44)	α (0.56)	α (3.9)	τ(0.44)	τ(0.56)	τ(3.9)	H_0(0.44)	H_0(0.56)	H_0(3.9)
α (0.44)	1.0	0.945	0.736	0.607	0.548	0.490	-0.495	-0.478	0.011
α (0.56)		1.0	0.821	0.580	0.520	0.458	-0.459	-0.535	-0.061
α (3.9)			1.0	0.319	0.278	0.457	-0.489	-0.549	-0.171
τ(0.44)				1.0	0.971	0.516	0.236	0.203	0.348
τ(0.56)					1.0	0.558	0.246	0.263	0.440
τ(3.9)						1.0	-0.100	-0.042	0.753
H_0(0.44)							1.0	0.865	0.316
H_0(0.56)								1.0	0.410
H_0(3.9)									1.0

The correlation caused by the variability of the aerosol extinction in the near-ground layer and in the atmospheric column is of the greatest interest. It is seen in Table 2 that such correlation exists in the considered data array in the entire wavelength range $\rho\alpha\tau(0.44) = 0.61$, $\rho\alpha\tau(3.9) = 0.46$.

The average spectral dependencies of the measured parameters τ(λ) and α(λ) and the parameter H_0(λ) calculated by Eq. (1) are shown in Figure 1. Rms errors of these values are also shown here. The spectral structure of the "effective" height of the aerosol atmosphere (Figure 1c) is the most interesting. Maximum of H_0 in the visible wavelength range is well seen. It was already revealed earlier (Sakerin 2002), but unexpected increase of the values H_0(λ) is observed in the wavelength range 1.06 to 3.9 µm. According to general ideas, one should expect the decrease of H0(λ) as the wavelength increases, because the contribution of large particles increases, and their number density should be greater in the near-ground layer. Perhaps, the observed experimental fact is caused by the intensive turbulent emission of large particles to the above layers of the atmosphere in summer under conditions of high temperature and low relative humidity (see Table 1).

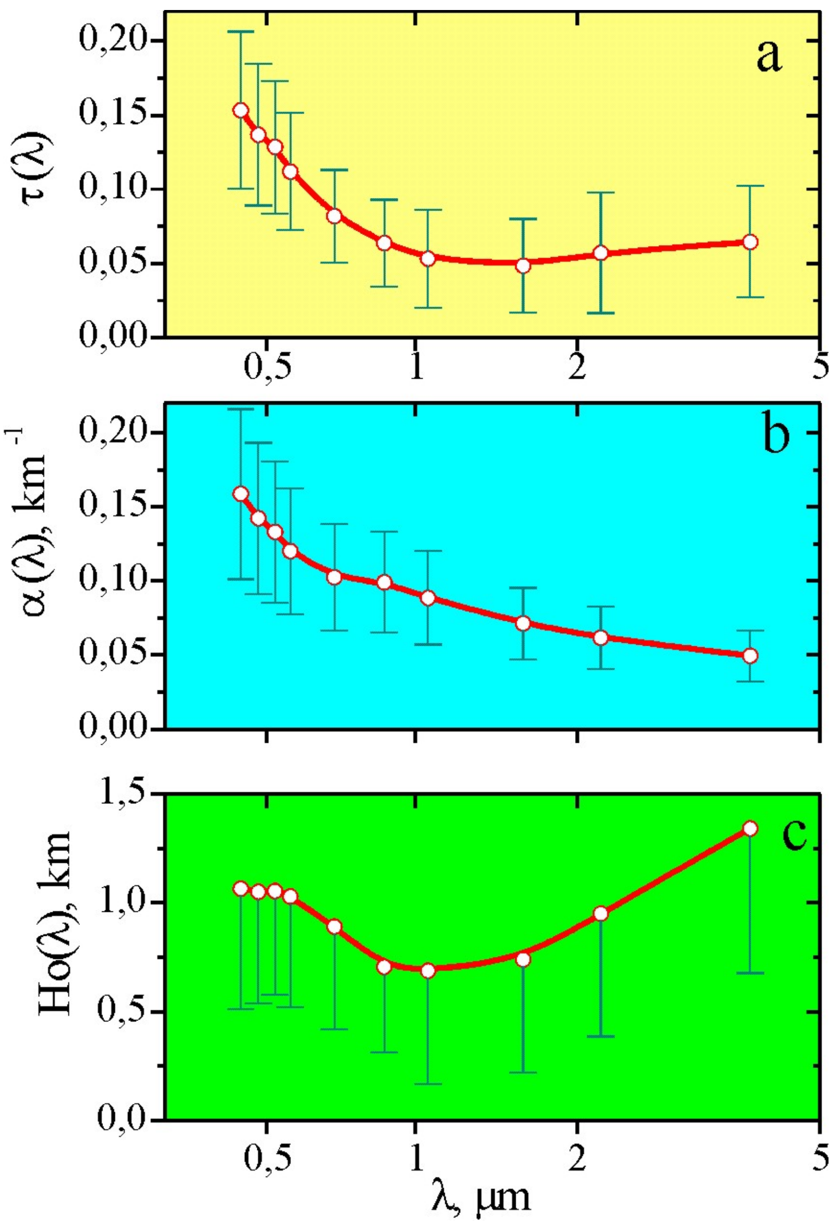

Figure 1. Mean spectral dependencies of the parameters τ(λ), α(λ) and H_0(λ) obtained since May 15 till July 2, 2002, near the city of Tomsk.

Aside from the mean spectral dependencies of the parameters τ(λ), α(λ) and H_0(λ), it is interesting to analyze their dynamics at different level of the atmospheric turbidity. To do this, the initial data array was divided into 4 subarrays depending on the range of variability of the parameters τ and α at the wavelength of λ = 0.56 μm.

The spectral dependencies of the aerosol optical thickness (AOT), aerosol extinction coefficients, and the height of the homogeneous aerosol atmosphere at four values of the parameter α(0.56 μm) are shown in Figure 2. The same dependencies at different values τ(0.56) are shown in Figure 3. It is seen

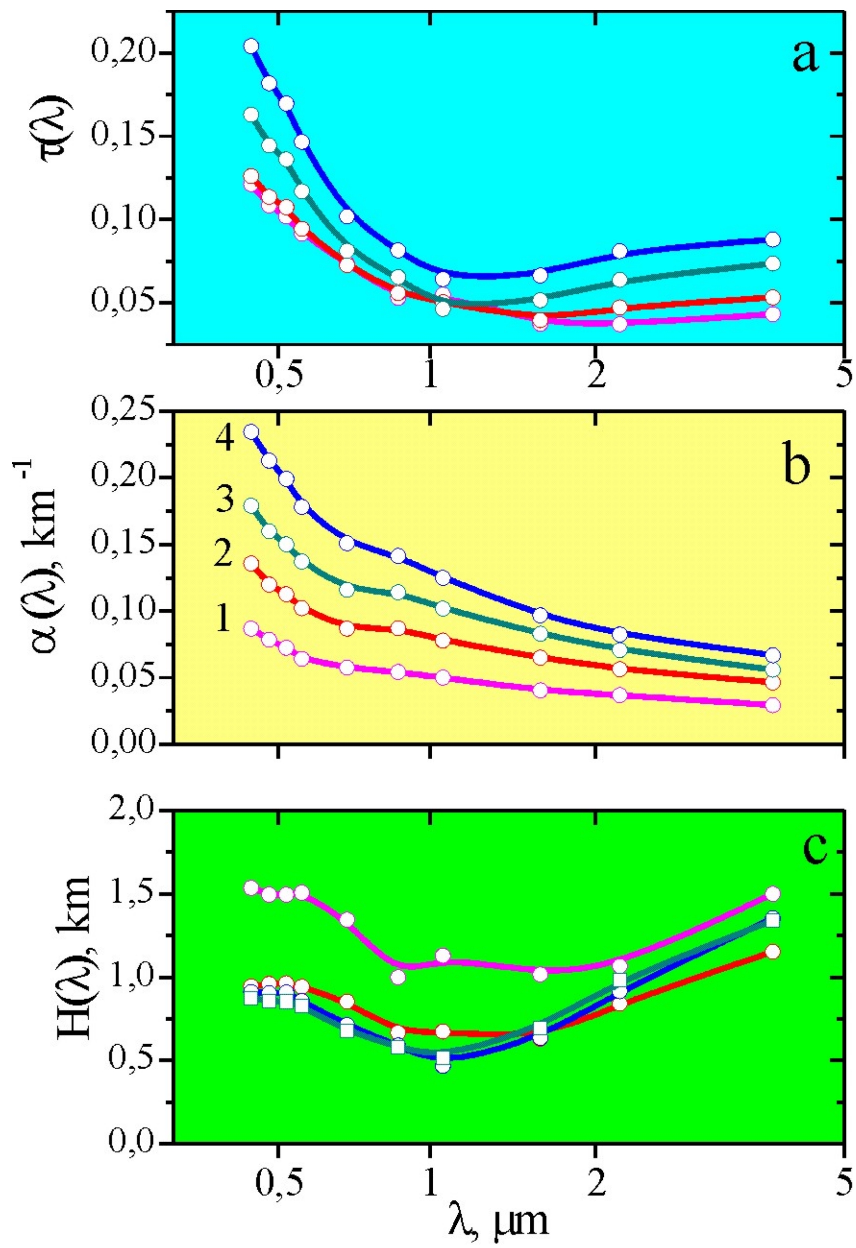

Figure 2. Transformation of the spectral dependencies of the aerosol extinction coefficient $\alpha(\lambda)$, AOT $\tau(\lambda)$ and the height of the homogeneous aerosol atmosphere H0(λ) depending on the turbidity of the near-ground air layer $\alpha(0.56)$=0.065; 0.10; 0.14, and 0.18 km^{-1} (curves 1–4).

in Figure 2 that the spectral dependencies $\alpha(\lambda)$ at all turbidities smoothly decreases as the wavelength increases (Figure 2b). At the same time, the dependence $\tau(\lambda)$ persistently decreases in the entire wavelength range only under the clearest conditions (Figure 2a, curve 1), then, as the turbidity increases, the more and more pronounced increase of t(λ) is observed in the wavelength range 1.6 to 3.9 μm. As for the manner of the spectral dependencies $H_0(\lambda)$ (Figure 2c), one can note that the maximum "effective" height of the aerosol atmosphere is realized only under the clearest conditions. As the turbidity of the near-ground layer increases, the value $H_0(\lambda)$ decreases in the entire wavelength interval, and especially in the shortwave range. Analysis of the data shown in Figure 3 shows that in this case, on the contrary, the lowest values of $H_0(\lambda)$ are realized at the smallest optical thickness, and the highest values are observed at strong turbidity of the atmospheric column. In general, the manner of the spectral dependence $H_0(\lambda)$ in Figure 2 does not change strongly in comparison with Figure 3.

To study the diurnal dynamics of the considered parameters, 14 cloudless days were isolated from the entire data array, during which synchronic continuous measurements were carried out. The spectral dependencies $\tau(\lambda)$, $\alpha(\lambda)$ and $H_0(\lambda)$ for this data subarray are shown in Figure 4. The data were obtained in the morning (curves 1), in the daytime (curves 2) and in the evening (curves 3). It is seen that the emission of large particles into the atmosphere from the underlying surface occurs during a day. As result, the value $\alpha(\lambda)$ increases from morning till evening with practically the same rate at all wavelengths (Figure 4b). The increase of the content of coarse aerosol in the atmosphere sine morning till evening is also seen in the spectral dependencies $\tau(\lambda)$ in the IR wavelength range (Figure 4a). However, the parameter $\tau(\lambda)$ in the visible wavelength range changes weakly during a day. On the background of the increase of the number density of coarse particles, it can be explained by only the corresponding decrease of the optical effect of small particles in the high layers of the atmosphere. It is difficult to conclude, what specific mechanism affects the number density or optical properties of small particles. Diurnal transformation of the height of the homogeneous atmosphere is shown in Figure 4. It is seen that the maximum "effective" height of the aerosol atmosphere in the shortwave range is observed in the morning and then slightly decreases. On the contrary, the minimum values of the parameter $H_0(\lambda)$ in the IR range are observed in the morning, and it noticeable increases in the daytime and in the evening. The diurnal dynamics of $H_0(\lambda)$ at the wavelength of 1.06 μm, which is most sensitive to the variability of intermediate fraction of particles, is the smallest.

Conclusions

1. Field data on the "effective" height of the homogeneous aerosol atmosphere in the wide wavelength range (0.44 to 3.9 μm) are obtained for the first time on the basis of simultaneous measurements of the spectral transmittance of the atmosphere on the long near-ground path and in the atmospheric column.

2. It is revealed that the spectral dependence of the "effective" height of the aerosol atmosphere has maximum in the visible wavelength range, minimum in the range $\lambda \sim 1$ μm and well pronounced increase in the range ~1.6 to 3.9 μm.

3. Diurnal dynamics of the spectral dependence of the "effective" height of the aerosol atmosphere is revealed. It is shown that the parameter $H_0(\lambda)$ in the visible wavelength range is maximum in the morning, and that in the range $\lambda \sim 3.9$ μm is maximum in the daytime and in the evening.

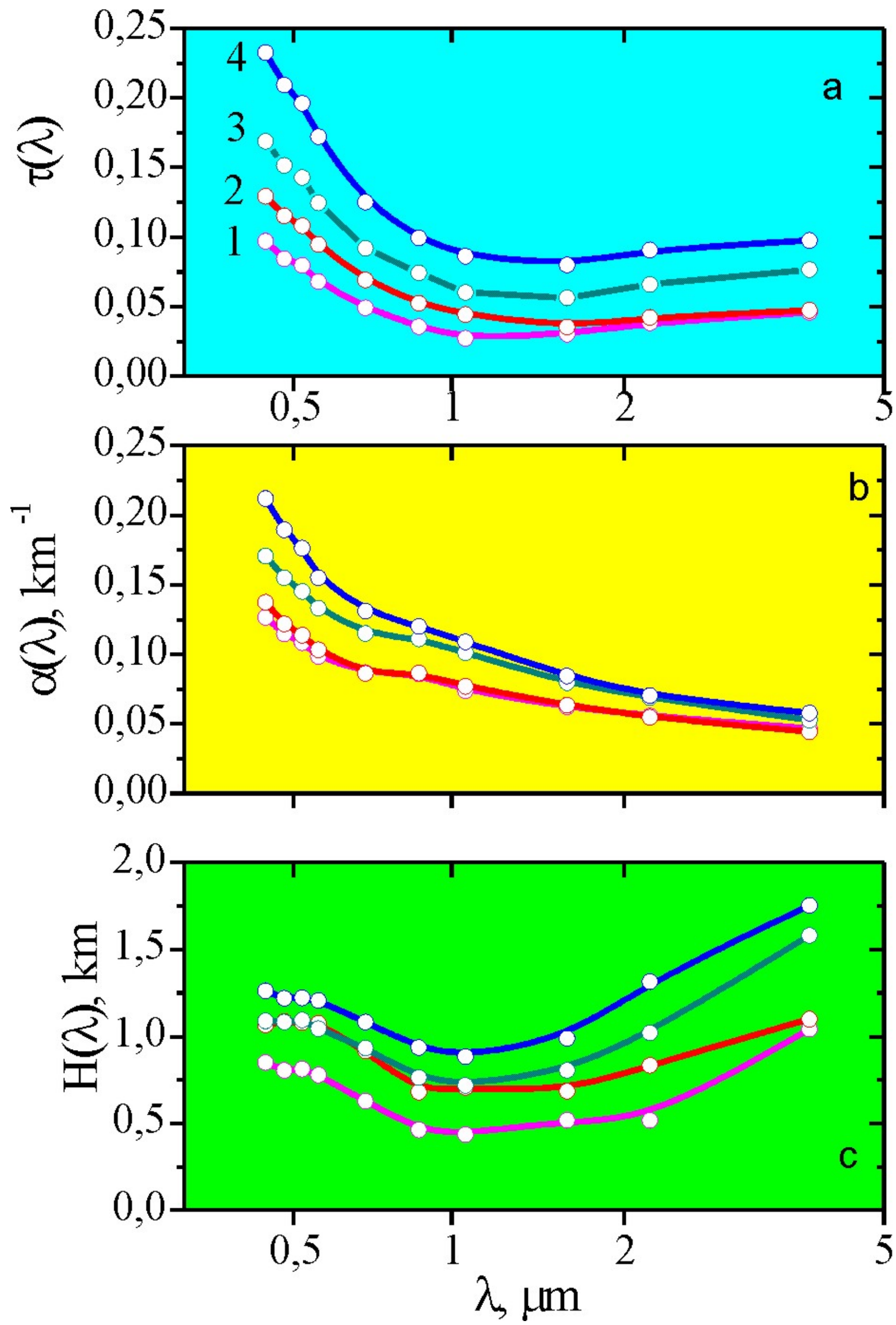

Figure 3. Transformation of the spectral dependencies of the aerosol extinction coefficient $\alpha(\lambda)$, AOT $\tau(\lambda)$ and the height of the homogeneous aerosol atmosphere $H_0(\lambda)$ depending on the turbidity of the atmospheric column $\tau(0.56)$= 0.07; 0.10; 0.14, and 0.17 (curves 1–4).

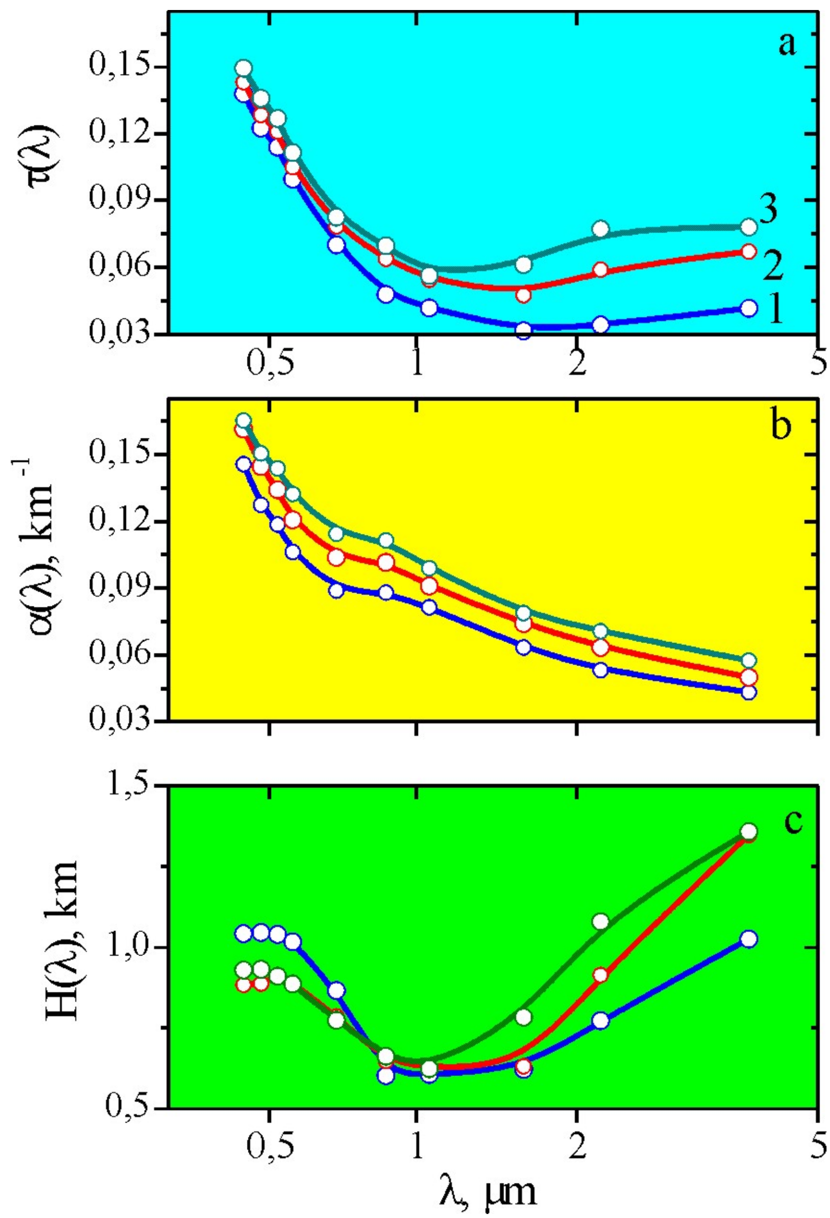

Figure 4. Spectral dependence of the 14-day average aerosol extinction coefficient $\alpha(\lambda)$, AOT $\tau(\lambda)$ and the height of the homogeneous aerosol atmosphere $H_0(\lambda)$ obtained in May and June 2002 in the morning (curves 1), in the daytime (2) and in the evening (3).

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