Model estimates of the effective heights of the aerosol atmosphere according to data in the spectral region from 1.07 to 12 μm

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Experimental data on atmospheric transmittance along horizontal and slant paths in the spectral region from 0.44 to 1.06 μm are used to obtain model estimates of the effective atmospheric heights for the aerosol extinction coefficients and their components in the spectral region from 1.07 to 12 μm. The mean value of the effective atmospheric height for the aerosol extinction coefficient is shown to decrease from 1 km in the visible region to 0.2–0.3 km in the spectral region from 8 to 12 μm.

A closed optical scheme of the cloudless atmosphere was proposed in Ref. 1. This scheme assumes that the spectral value of the aerosol extinction coefficient exponentially decreases with increasing height:

$$\alpha(H,\lambda) = \alpha(0,\lambda)\exp[-H/H_0(\lambda)], \qquad (1)$$

where $\alpha(0, \lambda)$ is the aerosol extinction coefficient in the atmospheric surface layer at the wavelength λ; $H_0(\lambda)$ is the effective height of the atmosphere (or the height of the homogeneous atmosphere) for the aerosol extinction coefficient at this wavelength. The aerosol optical thickness of the entire atmosphere as a function of wavelength is

$$\tau(\lambda) = \int_0^\infty \alpha(H,\lambda)\mathrm{d}H = \alpha(0,\lambda)H_0(\lambda).$$

Represent the aerosol extinction coefficient and the aerosol optical thickness of the atmosphere as sums of the extinction components due to correspondingly submicron and coarsely disperse fraction of aerosol:

$$\alpha(0,\lambda) = \alpha_{\mathrm{sm}}(0,\lambda) + \alpha_{\mathrm{cd}}(0,\lambda)$$

and

$$\tau(\lambda) = \tau_{\mathrm{sm}}(\lambda) + \tau_{\mathrm{cd}}(\lambda),$$

where $\alpha_{\mathrm{sm}}(0,\lambda)$ and $\alpha_{\mathrm{cd}}(0,\lambda)$ are the aerosol extinction coefficients of the submicron and coarsely disperse fractions of aerosol in the atmospheric surface layer; $\tau_{\mathrm{sm}}(\lambda)$ and $\tau_{\mathrm{cd}}(\lambda)$ are the aerosol optical thickness of the submicron and coarse-disperse fractions. Then define the effective atmospheric heights for the aerosol extinction coefficients of the submicron and coarse fractions as

$$H_{\mathrm{sm}}(\lambda) = \tau_{\mathrm{sm}}(\lambda)/\alpha_{\mathrm{sm}}(0,\lambda)$$

and

$$H_{\mathrm{cd}}(\lambda) = \tau_{\mathrm{cd}}(\lambda)/\alpha_{\mathrm{cd}}(0,\lambda).$$

In Eq. (1) different optical states of the atmosphere are characterized by two parameters: $\alpha(0, \lambda)$ and $H_0(\lambda)$. The aerosol extinction coefficients in the atmospheric surface layer have been studied in a wide spectral region (0.4–12 μm) in a variety of geographical regions: central and northwestern parts of the European territory of Russia,[2–4] coastal zone of the Black Sea,[5] arid zone of Kazakhstan,[6] and Western Siberia.[7,8] The estimates of the effective atmospheric height for the aerosol extinction coefficient are available only in the visible and near-IR spectral regions (0.4–1.06 μm).[9–13] Already in Ref. 1 it was noted that the mean value of the effective atmospheric height for the aerosol extinction coefficient in the spectral region of 0.55 μm is about 1 km. In Ref. 12 it was shown that in the spectral region from 0.4 to 0.85 μm the effective height of the atmosphere for the scattering coefficient decreases with the increasing wavelength. Based on this, it was concluded[12] that the height of homogeneous atmosphere for the coarse-disperse aerosol is much lower than that for the submicron aerosol fraction. The effective heights for the aerosol extinction coefficients and their components in the 0.44–1.06 μm spectral region are presented in Ref. 13. However, no such results are available for longer waves. This paper presents the model estimates of the effective atmospheric height for the aerosol extinction coefficient and its components in the spectral region from 1.07 to 12 μm, where there are no experimental results.

The model calculations were based on the experimental data on the atmospheric transmittance along horizontal and slant paths in the spectral region from 0.44 to 1.06 μm from Ref. 13. For

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calculation of the effective atmospheric heights for the aerosol extinction coefficients and their components in the spectral region from 0.44 to 12 μm, aerosol extinction along horizontal and slant paths was divided into the components caused by submicron and coarse-disperse aerosol fractions using a two-parameter model.[14] The input parameters of the model are the aerosol extinction coefficients in the surface layer and the aerosol optical thickness of the atmosphere at the wavelengths of 0.48 and 0.69 μm.

Figures 1 and 2 depict the spectral dependence of the aerosol extinction coefficients on a horizontal path and the aerosol optical thickness of a slant path in the spectral region from 0.44 to 12 μm obtained with the use of the two-parameter model[14] along with the experimental data[13] for the spectral region from 0.44 to 1.06 μm.

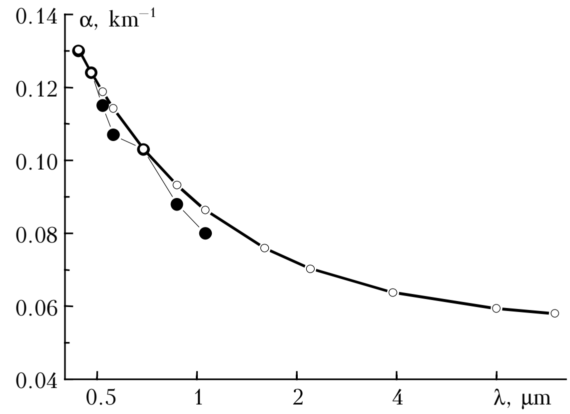

Fig. 1. Spectral dependence of the mean model (open circles) and experimental[13] (closed circles) aerosol extinction coefficients in the atmospheric surface layer.

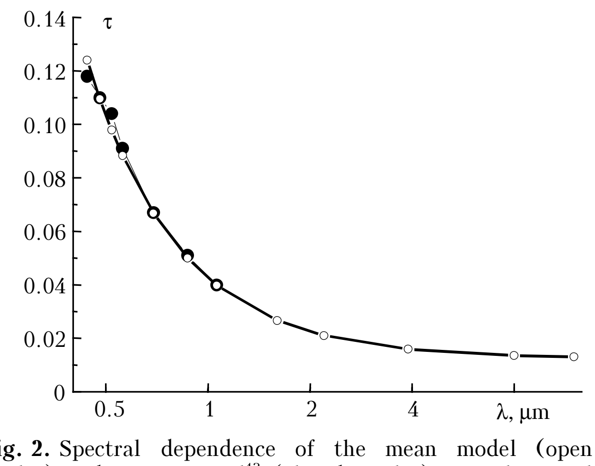

Fig. 2. Spectral dependence of the mean model (open circles) and experimental[13] (closed circles) aerosol optical thickness of the atmosphere.

Figure 3 shows the spectral dependence of the effective atmospheric height for aerosol extinction coefficient in the spectral region from 0.44 to 12 μm as estimated by the model from Ref. 14. For a comparison, it also depicts the effective atmospheric height for the spectral region from 0.44 to 1.06 μm by the data from Ref. 13. One can see a good agreement with the data from Ref. 13 in this spectral region. In the 1.07 to 12 μm region the effective atmospheric height decreases noticeably, and in the 8 to 12 μm atmospheric window it is 0.2–0.3 km.

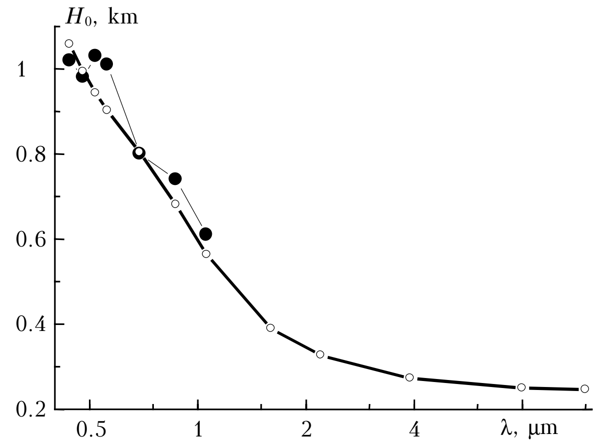

Fig. 3. Spectral dependence of the mean model (open circles) and experimental[13] (closed circles) effective heights of the atmosphere for the aerosol extinction coefficients.

Figure 4 depicts the model spectral dependence of the effective atmospheric height for the extinction components due to coarse and submicron aerosol fractions. The model value of the effective height in the 0.44 to 12 μm spectral region for the extinction component due to coarse aerosol is ~0.3 km, and for the component due to submicron fraction, it decreases roughly from 1.7 to ~0.2 km. For a comparison, we also present the effective atmospheric heights for the extinction components in the 0.44 to 1.06 μm spectral region according to the data of Ref. 13, where the aerosol extinction in the spectral region of 1.06 μm was used as a coarse component.

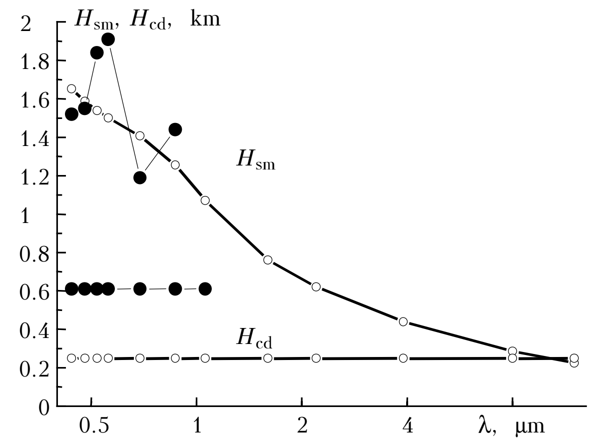

Fig. 4. Spectral dependence of the mean model (open circles) and experimental[13] (closed circles) effective heights of the atmosphere for the coarsely disperse and submicron extinction components.

Thus, in the spectral region from 0.44 to 12 μm the mean model value of the effective height for the aerosol extinction coefficient decreases from 1 to ~0.2 km with the increasing wavelength, for the extinction component due to coarse aerosol it is ~0.3 km, and for the component due to submicron aerosol it decreases from 1.7 to ~0.2 km.

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