THE EFFECT OF CHOICE BETWEEN AEROSOL MODELS ON THE CALCULATION OF ATMOSPHERIC RADIATION CHARACTERISTICS

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The effect of choice between aerosol models of the atmosphere on the angular–dependent variability of the radiation influx and outgoing radiation fluxes is examined. It is shown that the diversity of the optical characteristics of aerosol has no significant effect on the angular dependences of the influx and the fluxes of outgoing radiation, while the absolute values of these quantities depend on the mean values of the optical thickness and the single–cattering albedo.

The necessity of taking into account scattering and absorption of light by atmospheric aerosols when constructing climatological models as well as when solving many other problems in atmospheric optics is without doubt. However, an implementation of this problem in practice encounters great difficulties owing to the fact that aerosol is the most variable component of the atmosphere.

The existence of a great number of models of the optical parameters of the atmospheric aerosols, which have been proposed by various authors, does not guarantee that a chosen model actually corresponds to the atmospheric aerosol state in the place under consideration. Moreover, many models which have been published in literature lack the information required for their use. Most often this concerns the phase function of light scattering by aerosol, which is usually ill–posed, and the microphysical aerosol characteristics, which are not complete enough to compensate for the above gap in our knowledge. For this reason, it is important to know, how an error in choosing an aerosol model and completeness of its description can affect the atmospheric radiation field characteristics under consideration.

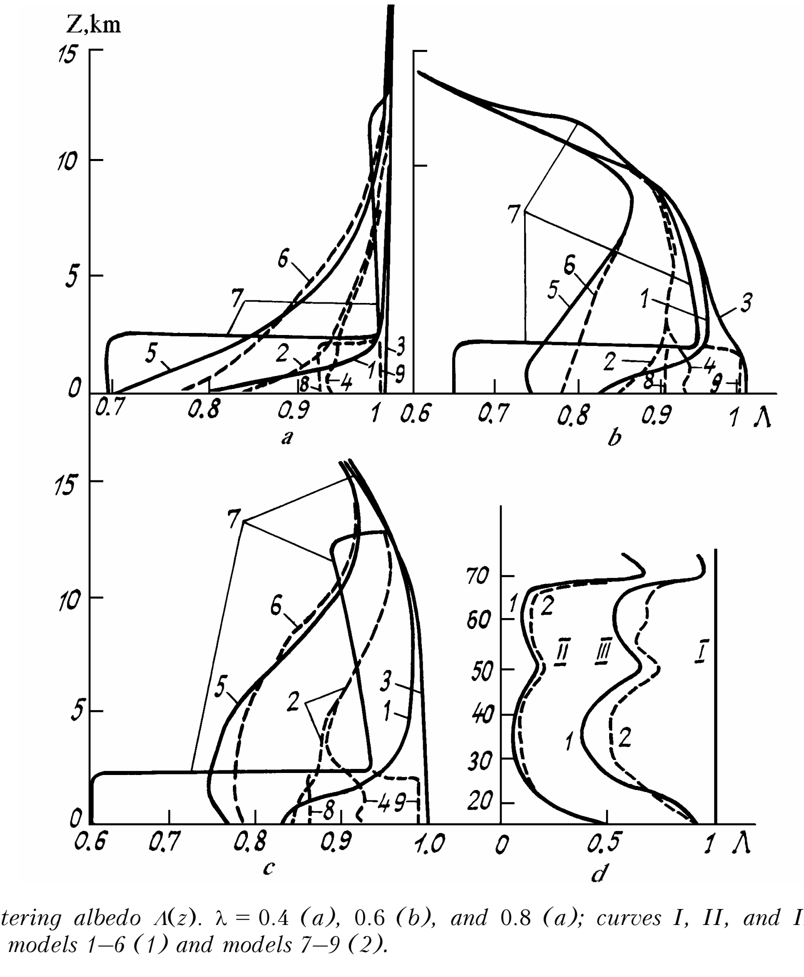

FIG. 1. The single–scattering albedo Λ(z). λ = 0.4 (a), 0.6 (b), and 0.8 (a); curves I, II, and III (d) correspond to λ = 0.4, 0.6, and 0.8 μm; models 1–6 (1) and models 7–9 (2).

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If, in order to solve the problems of remote sensing of the atmospheric aerosol composition successfully, the strong dependence of the measured radiation field characteristics on the vertical aerosol structure is important, then when constructing climatological models it is desirable that the radiation parameters depend only on a small number of averaged aerosol parameters.

This paper presents the results of calculations of some integrated radiation–field characteristics (radiation energy influx, atmospheric albedo, and illuminance of the surface) for six atmospheric aerosol models which have been described in detail in Ref. 1 and for three well–known models URB, CONT–1, and MAR–1 (see Ref. 2). Five aerosol types are employed in the models[1] of intra–atmospheric origin, marine, soil, stratospheric, and urban aerosols. These types, in turn, consist of several modes. It is assumed that the aerosols of different origin do not interact. The total aerosol concentration is obtained by summing over different types of aerosols with fixed weight, which depends on geographical coordinates and season.[3] The calculations were performed in the visible spectral range 0.4–0.8 mm for the following aerosol models:
1)soil + stratospheric, 2) soil + stratospheric + intraatmospheric, 3) marine + stratospheric, 4) marine + stratospheric + intra–atmospheric, 5) urban + soil + stratospheric, 6) urban + soil + stratospheric + intraatmospheric, 7) URB, 8) CONT–1, and 9) MAR–1.

For the above–indicated models we have calculated the following optical characteristics: the vertical behavior of the optical thickness $t(z)$, the scattering phase function $x(g, z)$, and the single–scattering albedo $L(z)$, which enter directly into the calculational algorithm:

$$\Lambda(z) = \frac{\sigma_a(z) + \sigma_m(z)}{\sigma_a(z) + \sigma_m(z) + k_a(z) + k_m(z)}, \tag{1}$$

$$x(\gamma, z) = \frac{x_a(\gamma, z)\cdot\sigma_a(z) + x_m(\gamma)\cdot\sigma_m(z)}{\sigma_a(z) + \sigma_m(z)}, \tag{2}$$

where $\sigma_a(z)$, $\sigma_m(z)$, $k_a(z)$, and $k_m(z)$ are the volume coefficients of light scattering by aerosol and molecules, $x_a(\gamma, z)$ is the phase function of light scattering by aerosol, and $x_m(z)$ is the phase function of light scattering by molecules. The values of $\sigma_m(z)$ and $k_m(z)$ has been calculated for the profiles of the temperature, pressure, and ozone concentration given in Ref. 4.

The profiles of the quantity $\Lambda(z)$ for the enumerated nine models are shown in Fig. 1. The mean model parameters, i.e., the total optical thickness τ, the optical thicknesses of scattering τ_{sc} and absorption τ_{abs}, and the mean single–scattering albedo $\overline{\Lambda} = \tau_{sc}/\tau_{abs}$, are given in Table I.

TABLE I.

Model	λ = 0.4 μm				λ = 0.6 μm				λ = 0.8 μm			
	τ	τ_{sc}	τ_{abs}	$\overline{\Lambda}$	τ	τ_{sc}	τ_{abs}	$\overline{\Lambda}$	τ	τ_{sc}	τ_{abs}	$\overline{\Lambda}$
1	0.069	0.056	0.013	0.970	0.050	0.043	0.008	0.664	0.043	0.036	0.006	0.875
2	0.300	0.359	0.041	0.938	0.179	0.154	0.025	0.750	0.122	0.104	0.019	0.858
3	0.068	0.068	1.6–5	1.000	0.059	0.059	5.0–5	0.999	0.048	0.048	3.6–5	0.999
4	0.298	0.270	0.028	0.957	0.188	0.170	0.018	0.782	0.128	0.115	0.012	0.905
5	0.195	0.124	0.071	0.872	0.190	0.135	0.055	0.664	0.187	0.138	0.048	0.761
6	0.426	0.326	0.100	0.873	0.319	0.246	0.072	0.723	0.266	0.205	0.061	0.784
7	1.742	1.167	0.575	0.726	1.053	0.689	0.364	0.648	0.712	0.438	0.274	0.625
8	0.366	0.330	0.035	0.951	0.236	0.210	0.025	0.791	0.165	0.142	0.023	0.867
9	0.104	0.100	0.004	0.991	0.084	0.081	0.003	0.743	0.073	0.070	0.003	0.950
Molecular atmosphere	0.360	0.360	0.000	1.000	0.117	0.068	0.048	0.585	0.023	0.021	0.002	0.922

The scattering phase function $x_a(\gamma, z)$ has been expanded in a system of the Legendre polynomials. The coefficients $x_i(z)$ of this expansion have been calculated from the algorithm proposed in Ref. 5.

The zeroth–order intensity harmonic, which is needed for calculation of the radiative influx and the outgoing radiation fluxes, has been obtained using the method of layer summation over the layers.[6] In order to employ this method, the atmosphere was divided into twenty layers with identical optical thicknesses. Each layer was assumed to be uniform, and the following mean optical characteristics were calculated for it:

$$\Lambda_n = \tau_{scn}/\tau_n ; \tag{3}$$

$$x_n(\gamma) = \frac{x_{an}(\gamma)\cdot\tau_{ansc} + x_m(\gamma)\cdot\tau_{mnsc}}{\tau_{ansc} + \tau_{mnsc}}, \tag{4}$$

where τ_n is the total optical thickness of the layer, $\tau_{n\,sc}$ is the optical thickness of scattering of the layer, being equal to $\tau_{a\,n\,sc} + \tau_{m\,n\,sc}$, and $x_{an}(\gamma)$ is the mean aerosol scattering phase function of the layer.

For each layer we calculated the illuminance factors by means of the method of doubling.[7]

We have made calculations at the following three wavelengths: λ = 0.4, 0.6, and 0.8 μm and for the nine above–indicated aerosol models.

Figures 2, 3, and 4 show examples of the dependences of the radiation energy influx within the entire atmospheric layer, the atmospheric albedo, and the illuminance of the underlying surface for the surface albedo $A = 0$ on the solar zenith angle Θ° at λ = 0.4 and 0.6 μm.

As one can see in Fig. 1, the aerosol models substantially differ from each other within the lower 15–km layer. This corresponds to the actual diversity of the aerosol content in the atmosphere. However, this diversity has no significant effect on the angular dependence of the radiative influx and of the outgoing radiation fluxes. The absolute values of the examined quantities depend strongly on the mean optical characteristics of the atmosphere, i.e., the total optical thickness and the mean single scattering albedo.

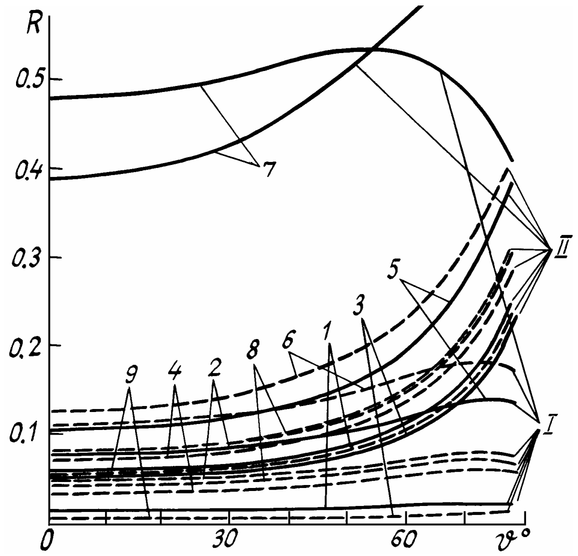

FIG. 2. The influx of radiation energyscaled to the solar radiation flux $\pi S \cos \Theta^\circ$ which is incident on the upper boundary of the atmosphere; $\lambda = 0.4$ (I) and $\lambda = 0.6$ μm (II). Curves 1–9 correspond to models 1–9.

Thus, the obtained results indicate that it is unreasonable to employ the angular dependences of the outgoing radiation fluxes in order to retrieve the vertical aerosol distribution. It is obvious that additional more detailed measurements of the radiation field are needed for this end.

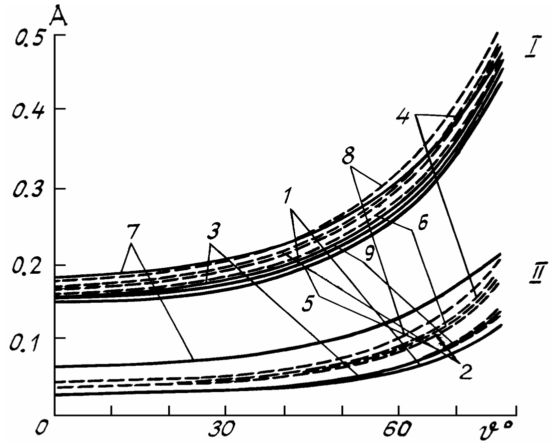

FIG. 3. The atmospheric albedoscaled to $\pi S \cos \Theta^\circ$. Notation is the same as in Fig. 2.

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