COLOR TEMPERATURE AND PSEUDORADIATIVE PROPERTIES OF A RAYLEIGH ATMOSPHERE

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The results of modeling of the interaction of solar radiation with the earth's atmosphere are discussed. The situation when the observer is located on the surface of the planet and the atmosphere is a Rayleigh atmosphere is studied. Representing the atmosphere as a secondary source of optical radiation, two parameters, with whose help the brightness distribution of the atmosphere in the visible region of the electromagnetic spectrum can be reliably described, are derived: the color temperature and a coefficient that characterizes the emissive properties of the atmosphere. Some properties of the angular distribution of these parameters in the plane of the solar meridian of the observer are analyzed. It is concluded that these parameters are useful for solving different problems in atmospheric optics.

Investigations of natural objects often require information about the energy distribution in their electromagnetic emission spectrum. Many sources of radiation in nature are thermal emitters. The energy distribution in the spectrum of an ideal thermal source of radiation, which an absolute black body (ABB) is, can be evaluated in accordance with Planck's law:

$$M_{ABB}(\lambda,\ T) = c_1\lambda^{-5}\left[\exp\left(c_2/\lambda T\right) - 1\right]^{-1}, \tag{1}$$

where M_{ABB} is the energy luminosity of the ABB; T is the temperature of the thermal source of radiation; $c_1 = 3.7415 \cdot 10^{-16}$ Wt $\cdot$ m^2; $c_2 = 1.43879 \cdot 10^{-2}$ m $\cdot$ K.

The energy brightness B not of an ideal, but rather a real source of radiation is related with the luminosity of an ABB by the following relation:[1,2]

$$B(\lambda,\ \varepsilon,\ T) = 1/\pi \cdot \varepsilon(\lambda,\ T) \cdot M_{ABB}(\lambda,\ T), \tag{2}$$

where ε is a spectral function that characterizes the emissive properties of a real body whose temperature is equal to T with respect to an ABB whose temperature is also T.

If the selective properties of emission (absorption) of a real body within the spectral interval $\Delta\lambda$ can be neglected, then e is a coefficient that establishes the similarity between the spectrum of the ABB and the spectrum of the real source of radiation; in this case, the coefficient ε is known as the emissivity. It follows from the relations (1) and (2) that in order to describe the energy distribution in the spectrum of a nonselective thermal source of radiation, only two parameters are required: ε and T. In solving practical problems one of these parameters is, as a rule, employed; both parameters are not often used simultaneously. Many natural objects do not radiate in the visible region of the spectrum, but rather they reradiate energy (scatter and reflect), i.e., they appear as secondary sources of optical radiation. If such objects do not contain strong absorption bands in the visible region of the spectrum, then the spectral distribution of the energy luminosity and brightness of these objects can be evaluated with the help of the relations (1) and (2) given above.[1,2] In this case, pseudoparameters are employed: the color temperature T_c and the pseudoemissivity ε_p. The color temperature is now widely employed, for example, in the investigation of natural resources.[3]

In this paper we discuss the results of the determination of the parameters ε_p and T_c for the earth's atmosphere, illuminated by the sun. We study the situation when the atmosphere is a purely Rayleigh atmosphere and the observer is located on the surface of the planet. The color temperature was evaluated based on a comparison of the ratios of the spectral brightnesses of the atmosphere and an ABB for two wavelengths $\lambda_1 = 0.42$ μm and $\lambda_2 = 0.69$ μm. Then, based on the value obtained for T_c for one of the wavelengths, ε_p was evaluated using the relations (1) and (2). To calculate the spectral brightness of the atmosphere we used a relation from Ref. 4. The computer programs were written in FORTRAN-77.

Figure 1 shows the angular dependences of the values of T_c, which are realized in the plane of the solar meridian for three zenith angles of the sun $z_\odot = 30$, 60, and 90°. It is interesting that the color temperature decreases as the direction of observation approaches the horizon $z_v \to 90°$. The maximum values of T_c are observed in the region near the zenith at zenith angles of the sun close to zero. The values of T_c change by

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approximately a factor of 270 as the zenith angle of the sun varies from 30 to 90°. Figure 2 shows the angular dependences of the emissivity ε_p for the same conditions. Here one can also see the inverse, with respect to T_c, dependence of the values of ε_p as a function of the zenith angle of observation. The minimum values of ε_p are observed in the region of the sky near the zenith. As the direction to $z_v = 90°$ is approached the values of ε_p increase; under the same conditions the dynamic range of the values ε_p of is much larger than that of T_c.

The large range of values of these parameters suggests that they would be very useful for monitoring the optical state of the atmosphere and for solving different problems in atmospheric optics. Although T_c is not the true temperature of the atmosphere and ε_p is not the true emissivity of the atmosphere, these parameters nonetheless can be used to describe quite simply the character of the spectral distribution of the brightness of the atmosphere in the visible region of the spectrum.

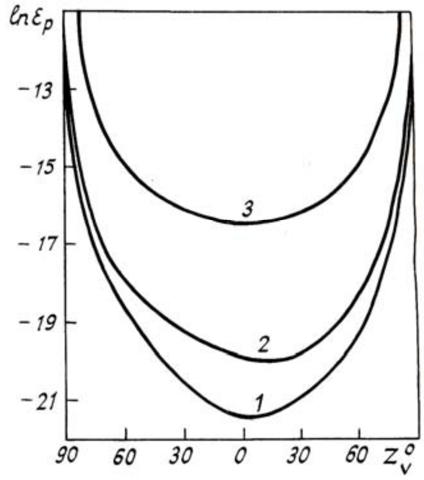

FIG. 1. The angular dependence of the color temperature T in the plane of the solar meridian for the following zenith angles of the sun: 30° *(1),* 60° *(2), and* 90° *(3).*

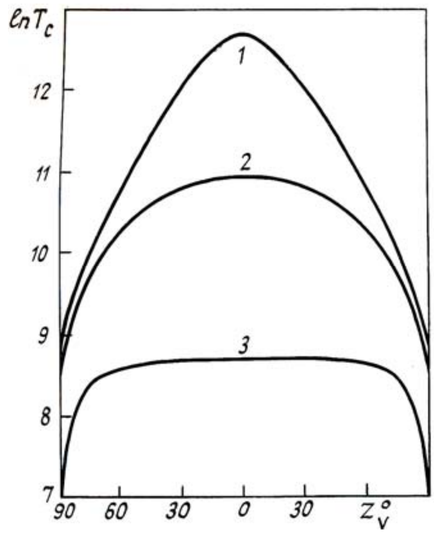

FIG. 2. The angular dependence of the pseudoemissivity in the plane of the solar meridian for zenith angles of the sun equal to 30° *(1),* 60°*(2), and* 90° *(3).*

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