THE ABSORPTION AND DISPERSION OF SOLAR RADIATION IN THE ATMOSPHERE

THE LAW OF WEAKENING

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ABSTRACT

This article provides information on changing the parameters in the law of weakening caused by the absorption and dispersion of solar radiation in the atmosphere. As a result of the absorption and dispersion of solar radiation in the atmosphere, it is weakened and the spectrum shifts towards longer wavelengths. A number of optical phenomena (the color of the sky, the color of the disk of the Sun and the Moon depending on the position relative to the horizon, etc.) are associated with the absorption and dispersion of solar radiation in the atmosphere.

Keywords. *Mass attenuation index, Burger's formula, optical mass of the atmosphere, optical thickness of the atmosphere, Burger-Lambert law, atmospheric transparency coefficient.*

INTRODUCTION

Solar radiation passes through the atmosphere and changes before reaching the earth's surface. Air molecules in the atmosphere and solid and liquid mixtures (aerosols) scatter solar radiation. Solar radiation is partially absorbed by gases and aerosols in the air. Since the processes of dispersion and absorption are selective, the spectral composition of solar radiation passing through the atmosphere also changes.

As a result of the processes of scattering and absorption in the atmosphere, solar radiation is weakened. The weakening of solar radiation depends on the composition and density of the air and the distance traveled by the sun's rays.

Theoretical part

For a monochromatic radiation flux (with a certain wavelength λ), the formulas for weakening solar radiation have the most logical form.

Let's look at the attenuation of radiation dJ'_λ in a thin layer of the atmosphere dS with density ρ due to changes in the composition and density of air with height (Fig. 1):

$$dJ'_\lambda = -\alpha_\lambda J'_\lambda \rho \cdot dS, \tag{1}$$

where J'_λ - is the amount of radiation falling on the upper boundary of the considered layer, α_λ - is the proportionality factor, measured in m^2/kg, which is called *the mass attenuation index.*

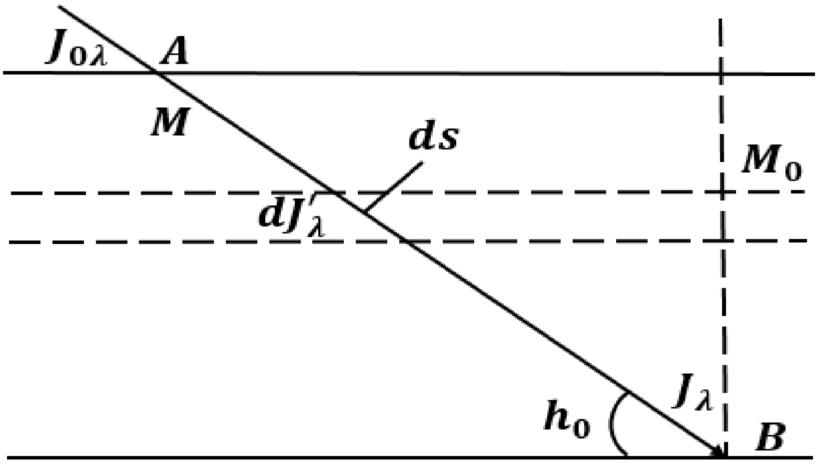

Figure 1. On the origin of the Burger formula.

The coefficient α_λ takes into account the total dispersion and absorption of solar radiation. It depends on the wavelength, because the processes of dispersion and absorption are selective. Let us take the average value of this coefficient for the entire atmospheric layer. We integrate expression (2) from point A, where solar radiation is equal to $J_{\lambda 0}$, to point B, where solar radiation is equal to J_λ:

$$\int_{J_{\lambda 0}}^{J_\lambda} \frac{dJ'_\lambda}{J'_\lambda} = -\alpha_\lambda \int_A^B \rho \cdot dS \quad \text{yoki} \quad J_\lambda = J_{\lambda 0} e^{-\alpha_\lambda \int_A^B \rho \cdot dS} \tag{2}$$

$\alpha_\lambda \int_A^B \rho \cdot dS = M$ the expression is the mass of air in the atmospheric column with a unit surface. Let's determine the physical meaning of the coefficient α_λ.

Let $\rho \cdot dS = 1\ kg/m^2$, then (2) can be written as follows:

$$\alpha_\lambda = -\frac{dJ'_\lambda}{J'_\lambda} \tag{3}$$

So, the mass weakening index is equal to the relative decrease in radiation over a unit mass of air.

Let's introduce the ratio $m = M/M_0$, where M_0 is the mass of air in a vertical column with a unit area. m - value is called *the optical mass of the atmosphere*, it depends on the height of the Sun above the horizon h_*.

If the height of the sun above the horizon exceeds 30^0, the optical mass of the atmosphere can be expressed in terms of h_*. (see fig.1):

$$M = M_0 cosec\, h_* \text{ yoki } m = cosec\, h_* . \tag{4}$$

RESULTS

At different angular heights of the sun, the optical mass of the atmosphere has the following values:

h_*	90	80	60	50	40	30	20	10	5	3	0
m	1,00	1,02	1,06	1,16	1,30	1,55	2,00	2,90	5,60	15,40	35,40

We change the expression (1.3) using the expressions *M* and *м*:

$$J_\lambda = J_{\lambda 0} e^{-\alpha M_0 m} \qquad (5)$$

Let us introduce the value $\tau_\lambda = \alpha_\lambda \cdot M_0$, called *the optical thickness of the atmosphere* (or weakening coefficient), and write expression (1.6) as:

$$J_\lambda = J_{\lambda 0} e^{-\tau_\lambda m} \qquad (6)$$

This formula represents the Bugge-Lambert law, or the law of weakening.

n practice, to characterize the attenuation of solar radiation in the atmosphere, the concept of the atmospheric transparency coefficient is introduced:

$$P_\lambda = e^{-\tau_\lambda}. \qquad (7)$$

In that case (7) is expressed as follows:

$$J_\lambda = J_{\lambda 0} P_\lambda^m \qquad (8)$$

if the sun is upright (m=1):

$$J_\lambda = J_{\lambda 0} P \text{ yoki } P_\lambda = \frac{J_\lambda}{J_{\lambda 0}}. \qquad (9)$$

So, the transparency coefficient shows what part of the radiation flux reaches the Earth's surface when the Sun is upright.

The transparency coefficient describes the physical properties of the air mass. The more gases and aerosol mixtures in the air that absorb solar radiation, the lower the transparency coefficient. At the same time, the transparency coefficient for a monochromatic flow does not depend on the angular height of the Sun, i.e., on the optical mass of the atmosphere.

The transparency coefficient depends on the wavelength. Theoretical calculations show the following relationships for an ideal (clean and dry) atmosphere:

λ mkm	0,35	0,39	0,45	0,50	0,60	0,70	0,80	1,00	2,00
$P_\lambda =$	0,551	0,685	0,812	0,874	0,938	0,966	0,980	0,992	0,999

This relationship is explained by the fact that scattering in an ideal atmosphere is the main weakening process, most pronounced for short waves.

To form the expression for the total (integral) attenuation of the radiation flux, it is necessary to integrate it over all wavelengths:

$$J = \int_0^\infty J_\lambda \, d\lambda = \int_0^\infty J_{\lambda 0} P_\lambda^m \, d\lambda. \qquad (10)$$

The calculation of this integral is quite difficult due to its wavelength dependence. Therefore, some average value P_λ is introduced and the following expression is formed:

$$J = J_0 P^m. \qquad (11)$$

Here P-integer is the transparency coefficient.

CONCLUSION

As a result of absorption and scattering of solar radiation in the atmosphere, it weakens and the spectrum shifts towards longer wavelengths. A number of optical phenomena (the color of the sky, the color of the disk of the Sun and the Moon depending on the position relative to the horizon, etc.) are associated with the absorption and scattering of solar radiation in the atmosphere.

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