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TRANSLATION

ON THE NEW FORMULA OF THE INTENSITY OF RADIATION
AND NEW CHARACTERISTICS OF THE
TRANSPARENCY OF THE AIR

By

Kh. Myurk

FOREIGN TECHNOLOGY
DIVISION

AIR FORCE SYSTEMS COMMAND

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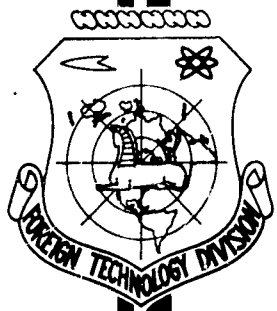
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ON THE NEW FORMULA OF THE INTENSITY OF RADIATION AND NEW CHARACTERISTICS

OF THE TRANSPARENCY OF THE AIR

by

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In actinometry there are used various formulas for determining the direct radiation of the sun in the case of atmosphere of invariable transparency.

Some of these formulas were obtained empirically, and some of them theoretically.

In the latter case one starts generally with the weakening of the monochromatic radiation in the atmosphere. The intensity, however, of the integral radiation is found by the monochromatic radiation.

In the present report the author derives a formula of the intensity of the integral radiation somewhat differently, namely, assuming that the coefficient of the weakening of the integral radiation, with invariable transparency of the atmosphere, is a function of the number of masses $\underline{m}$. After determining the suitable conditions relative to the weakening of the integral radiation it was possible to derive a formula of intensity sufficiently well in agreement with actuality. This formula contains a magnitude almost independent of $\underline{m}$, which one can make use of as a new characteristic of the atmosphere.

Let the coefficient of the weakening of the integral radiation of the sun in the atmosphere be $\underline{k}$, whereby $\underline{k}$ corresponds to a certain unit of the number of masses. By assuming that $\underline{k}$ under invariable transparency depends on the number of masses $\underline{m}$ one can write the equation for the integral radiation:

$$dS = -k(m)S dm. \qquad (1)$$

By integrating this equation in accordance with $\underline{m}$ within the limits

from m_1 to m, we obtain $\qquad S_m = S_{m_1} \exp\left[-\int_{m_1}^{m} k(\mu)\,d\mu\right].$ $\qquad$ (2)

On the other hand it is known that the intensity of the integral radiation under invariable transparency is expressed by the intensity of the monochromatic radiation in the following fashion

$$S_m = \int_0^\infty S_{0,\lambda} \exp(-k_\lambda m)\,d\lambda,\qquad (3)$$

where $S_{0,\lambda}$ represents, as corresponds to the length of the wave λ, the intensity of the radiation on the upper boundary of the atmosphere, and k_λ is the coefficient of weakening corresponding to the length of the wave λ.

From the equations (2) and (3) we obtain:

$$S_{m_1} \exp\left[-\int_{m_1}^{m} k(\mu)\,d\mu\right] = \int_0^\infty S_{0,\lambda} \exp(-k_\lambda m)\,d\lambda. \qquad (3\lambda)$$

For determining $k(m)$ we will differentiate this expression in accordance with m:

$$-S_{m_1} \exp\left[-\int_{m_1}^{m} k(\mu)\,d\mu\right] k(m) = -\int_0^\infty k_\lambda S_{0,\lambda} \exp(-k_\lambda m)\,d\lambda. \qquad (3b)$$

Hence

$$k(m) = \frac{\int_0^\infty k_\lambda S_{0,\lambda} \exp(-k_\lambda m)\,d\lambda}{\int_0^\infty S_{0,\lambda} \exp(-k_\lambda m)\,d\lambda}. \qquad (4)$$

The equation (4) determines the dependence of k on m in invariable transparency. Hence it is possible to draw some conclusions:

1. If $k_\lambda = $ const, i. e., the weakening of the radiation is not selective, then the coefficient of the weakening of the integral radiation of the integral radiation $k(m) = $ const. Under selective absorption and dispersion the coefficient of weakening of the integral radiation k depends on m.

Consequently the assumption made in the derivation of the formula (1) that k depends on m is correct.

2. In accordance with the formula (4) $k(m)$ are determined by $S_{0,\lambda}$ and k_λ. As a result of the fact that the dependence of $S_{0,\lambda}$ and k_λ on λ is composite, in the determination of $k(m)$ we come up against great difficulties.

In taking the formula (4) it is necessary to have recourse to great sim-

plifications relative to $S_{0,\lambda}$ and $\underline{k}_\lambda$, as a result of which there is basis

for doubt as to the correspondence of the results of the calculation with

actuality.

In this report in determining $\underline{k}(\underline{m})$, proceeding from the indicated assump-

tions, there is derived the corresponding expression for $\underline{k}(\underline{m})$ and found the

corresponding formula of the intensity of direct radiation.   In comparing

the results of the computations by this formula with the actually measured

intensities one can judge as to the agreement of the assumption made with

the actual facts.

Let us introduce the following assumptions relative to the earth's at-

mosphere from the point of view of the weakening of the radiation:

1. The atmosphere consists of layers in which the amount of substance

weakening radiation in the horizontal direction is constant, and

2. in the indicated layers the amount of substance weakening radiation

does not change in the course of the period under consideration, for example,

a day.   This condition is identical with the requirement of the invariable

transparency of the atmosphere.

In considering the real atmosphere from the point of view of the con-

ditions mentioned one should note that the air layers which are next to the

surface of the earth contain some kind of a substance which weakens the ra-

diation ununiformly.   This circumstance affects the weakening of the radi-

ation in proportion as the path of the beam in the layer under consideration

is greater and as the gradient of the amount of substance weakening the ra-

diation is greater.   The first depends on the thickness of the layer and

on the height of the sun, the second, however, on the homogeneity of the

soil and on local factors.

Over a more or less uniformly covered surface in the absence of sources

of smoke or dust with the sun as high as possible, one may consider that the

air layer next to the earth's crust weakens the radiation uniformly.

With the increase in the height the effect of the soil and local factors decreases, and at the same time the gradient of the substance which weakens the radiation of the air layers remains more uniform.

With regard to another condition, under certain conditions of the weather in the course of a short interval of time one can also consider the transparency of the atmosphere as constant.
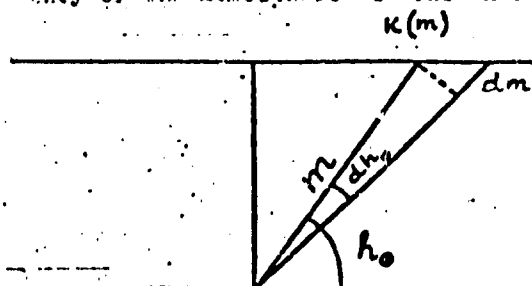

Fig. 1. For deriving the formula of intensity of direct solar radiation (16)

In conclusion one may say that in real atmosphere under certain situations the above-mentioned conditions are observed.

With the number of masses $\underline{m}$ let the coefficient of the weakening of the integral radiation in the layer under consideration be $\underline{k_i}$, and the number of masses with the lowering of the height of the sun be increased to the magnitude $\underline{dm}$. Since $\underline{k_i}$ depends on $\underline{m}$ it also changes by some value $\underline{dk_i}$. Let us assume that the decrease in the coefficient of weakening is proportional to the relative increase in the number of masses $\frac{dm}{m}$ (Fig. 1).

In that case

$$dk_i = - B_i \frac{dm}{m},\qquad (5)$$

where B_i is a magnitude not dependent on $\underline{m}$.

By integrating the latter expression in accordance with $\underline{m}$ we will get:

$$k_i = - B_i \ln m + t_i \qquad (6)$$

One can determine the constant integration of c_i from the condition: with $\underline{m} = 1$ let us take $\underline{k_i} = A_i$. In that case

$$k_i = A_i - B_i \ln m. \qquad (7)$$

If the atmosphere consists of $\underline{n}$ layers the coefficient of weakening of

the whole atmosphere

$$k(m) = \sum_{i=1}^{n} k_i = \sum_{i=1}^{n} A_i - \left(\sum_{i=1}^{n} B_i \right) \ln m. \qquad (7a)$$

By designating

$$\sum_{i=1}^{n} A_i = A \text{ и } \sum_{i=1}^{n} B_i = B, \qquad (7b)$$

we get:

$$k(m) = A - B \ln m. \qquad (8)$$

By substuting in the formula (2) instead of $\underline{k}(\underline{m})$ the respective expression from the formula (8) we get:

$$S_m = S_{m_1} \exp \left[- \int_{m}^{m} (A - B \ln m) \, dm \right]. \qquad (9)$$

By performing the integration in the exponent and designating

$$e^{-(A-B)} = a_m, \qquad (10)$$

we get:

$$S_m = S_{m_1} a_{m_1}^{m-m_1} \left(\frac{m^m}{m_1^{m_1}} \right)^B \} \qquad (11)$$

This formula is noticeably simplified if we take $\underline{m}_1 = 1$:

$$S_m = S_1 a_1^{m-1} m^{Bm} \qquad (12)$$

or

$$S_m = \frac{S_1}{a_1} (a_1 m^B)^m. \qquad (13)$$

By comparing the formula (12) with Bouguer's formula

$$S_m = S_0 p_m^m, \qquad (14)$$

we see that

$$\frac{S_1}{a_1} = S_0, \text{ и } a_1 m^B = p_m. \qquad (15)$$

By taking $\underline{m} = 1$ we reveal the physical essence of $\underline{a}_1$; then $a_1 = p_1$, i. e., $\underline{a}_1$ is the coefficient of the transparency of the air with $\underline{m} = 1$.

Keeping in mind the latter one may write the formula (13) in the following form:

$$S_m = S_0 p_1^m m^{Bm}. \qquad (16)$$

The formula found contains two unknowns, $\underline{p}_1$ and B, for the finding of which one should determine the value of the intensity for two numbers of masses. For facilitating the computations by the formula (16) a corre-

sponding nomogram has been prepared $\underline{/1\_/}$. The validity of the formula (16) has been checked on the basis of the data of S. I. Sivkov $\underline{/2\_/}*$ and Sh. M. Chkhaidze $\underline{/3\_/}*$. The results of the computations are given in the tables 1 and 2.

Deviations of the intensity computed by the formula (16) from

Sivkov's figures

P_2	m							Cpeд- нее(a) откло- нение
	1.0	1.5	2	3	4	5	8	
0.60	−0.010	0.009	0.013	−0.013	−0.009	− 0.002	0.001	± 0.009
0.65	−0.021	−0.001	0.011	−0.002	−0 009	−0.002	0.004	± 0.006
0.70	−0.012	0 006	0.011	−0.003	−0.012	−0.003	0.002	± 0.007
0.75	−0.012	0.009	0.003	−0.003	− 0.009	− 0.004	0.003	± 0.006
0.80	−0.010	0.007	0.002	−0.003	− 0.005	−0.003	0.001	± 0.004
0.85	−0.011	0.005	−0.007	0.000	−0.002	0.004	0.000	± 0.004

Key: (a) average deviation.

Deviations of the intensity computed by the formula (16) from

Chkhaidze's figures

P	m							Cpeд- нее откло- нение
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	
P_1	0.005	0.000	0.000	0.000	0.002	0.000	−0.005	± 0.003
P_2	0.005	0.000	0 000	−0.002	0.000	0.000	0.000	± 0.002
P_3	−0.002	−0.006	−0.004	0.000	0.003	0.000	0.000	± 0.003
P_4	−0.002	−0.003	−0.002	0.003	0.003	0.000	−0.005	± 0.003

The value B which depends on the transparency of the atmosphere, and determinable by the formula (16) can be used as a new characteristic of the atmosphere. The physical value B is apparent from the formula (5). B shows the decrease in the coefficient of weakening $\underline{k}$ if the relative change in the number of masses $\frac{dm}{m} = 1$.

By comparing B of the real atmosphere with B* of the ideal atmosphere

*Translator's note: The text has the references numbered incorrectly.

one can determine the new characteristic of transparency $\tau = \frac{B}{B_0}$. (17)

More detailed data relative to B are given in the article by the author $\lfloor 2 \rfloor$.

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