ON SCATTERING AND POLARIZATION OF LIGHT IN THE ATMOSPHERE UNDER THE CONDITIONS OF THE LIBYAN DESERT

![Fig. 1](image)

1958

SovietRxiv

Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

GEOPHYSICS

E. V. PYASKOVSKAYA-FESENKOVA

ON SCATTERING AND POLARIZATION OF LIGHT IN THE ATMOSPHERE UNDER THE CONDITIONS OF THE LIBYAN DESERT

(Presented by Academician V. G. Fesenkov on 11 VIII 1958)

Observations of the brightness and polarization of a clear daytime sky were carried out by me in October–November 1957 in the Libyan Desert in the Egyptian region of the UAR, 20 km south of Aswan ($\varphi = 23°59', \lambda = 32°52', h \approx$ 200 m above sea level), using a visual photometer (described in (^{1})), equipped with a yellow Schott filter and a Polaroid. To determine the degree and angle of polarization, V. G. Fesenkov' s method (^{2}) was used; it consists in measuring the brightness of the point of the sky under study through a Polaroid at three of its positions, separated from one another by 60°. The brightness of the sky was measured at the three indicated positions of the Polaroid, B_1, B_2, B_3, at various angular distances from the Sun ϑ on the solar almucantar, i.e., at points of the sky having the same zenith distance as the Sun. In addition, the solar illumination of a surface perpendicular to the rays was determined.

Fig. 1

On the basis of these data it was possible to determine, at the observed points of the sky, the degree of polarization and the orientation of the plane of light vibrations, as well as the total brightness B and the scattering indicatrix, and to divide it into two components. One of these is the scattering indicatrix in natural rays, the other in polarized rays. In addition, the total scattering indicatrix was divided into two other components. The first of these is due to molecular scattering, the second to aerosol scattering. An attempt was then made to isolate the degree of polarization caused by aerosols and to divide the aerosol scattering indicatrix into two, namely in natural and in polarized rays.

As an example, in Fig. 1, curve 2 gives the distribution of the degree of polarization P along the almucantar of the Sun, obtained on 10 XI at a zenith distance of the Sun $Z = 74°$ and an atmospheric transparency coefficient $p = 0.88$. The maximum degree of polarization was located near $\vartheta = 90°$ and was equal to

Fig. 2

Figure 2: Fig. 2

74%.

The orientation of the plane of light vibrations relative to the corresponding vertical (angle β) as a function of the angular distance from the Sun ϑ, obtained on the same day on the basis of the same observations, is presented in Fig. 2 (points). Since the formula for determining β includes differences

brightnesses measured at different positions of the polaroid, then for points with a small degree of polarization (small and large ϑ) an uncertain result is obtained, and these values of β have not been plotted. The crosses in the same figure represent β as a function of ϑ, obtained on the following day, 11 XI, at $Z = 61^\circ.5$. The solid curves 1 and 2 were calculated under the assumption of first-order scattering only, when the plane of the light vibrations is perpendicular to the plane of vision, i.e., to the plane passing through the Sun, the observed point of the sky, and the observer' s eye. It is seen that in both cases the values of β in the real atmosphere agree rather well with the theoretical ones.

Determining the total brightness of the sky B along the solar almucantar from measurements of brightness at three positions of the polaroid by the well-known formula

$$B = {}^2/_3(B_1 + B_2 + B_3) \tag{1}$$

and having simultaneous observations of the solar illuminance, one can obtain the absolute indicatrix of light scattering [^1]. In Fig. 3A such an indicatrix is presented in polar coordinates, determined on 10 XI (curve 1).

Fig. 2

Using equation (1), and also the expression for the degree of polarization

$$P = \frac{B''}{B' + B''}, \tag{2}$$

where B' and B'' are, respectively, the unpolarized and polarized components of the total brightness, we have the brightness of the polarized light

$$B'' = {}^2/_3 P(B_1 + B_2 + B_3) = {}^4/_3 \sqrt{B_1(B_1 - B_2) + B_2(B_2 - B_3) + B_3(B_3 - B_1)}. \tag{3}$$

In the same Fig. 3A the component of the total scattering indicatrix due to natural light is shown (curve 2). The shaded part represents the component due to polarized light. This polarized component is shown separately in Fig. 4

Fig. 3

Figure 3: Fig. 3

(curve 1, points). Crosses in the same figure denote similar data obtained on the following day, 11 XI, which fit well the same curve 1.

The author attempted to separate from the observed (total) polarization the polarization dependent on the presence of aerosols in the atmosphere. It is known that if polarization is due to light coming from several light sources, completely or partially polarized, then the total degree of polarization is the weighted mean of the degrees of polarization of all the components, whose brightnesses are the weights. A necessary condition in this case must be the parallelism of the polarization planes of all the components.

As a first approximation we shall assume that atmospheric depolarization is absent and that the total (observed) polarization consists of two components, one of which is due to molecules and the other to aerosols. Consequently, polarization depending on scattering of light of higher orders, which is small at $p = 0.88$, and also on reflection of light from the underlying surface, will in some way enter into the polarization that we shall call aerosol polarization.

For a molecular atmosphere, the direction of the plane of the light oscillations may be taken as perpendicular to the plane of vision and, consequently, for 10 and 11 XI this direction will be represented by curves 1 and 2 in Fig. 2. As can be seen from this figure, the dots and crosses giving the corresponding angles β, determined jointly by molecules and aerosols, coincide within the limits of error with curves 1 and 2. As V. G. Fesenkov has shown (^{3}), in this case the plane of the light oscillations depending on the second component (in the present case, aerosols) is either parallel or perpendicular to the plane of the first component (molecules). It may be thought that, at least when the atmosphere is highly transparent, these planes will not be perpendicular,

Fig. 3

but then they can only be parallel and, consequently, for determining the aerosol degree of polarization the formula may be applied

$$P_a = \frac{PB - P_{mB}m}{B_a}, \tag{4}$$

where P_m and P_a are the molecular and aerosol degrees of polarization; B, B_m, and B_a are the brightnesses of the sky: total, and those due to molecules and aerosols, respectively.

It should be noted that when the planes of the light oscillations of both components are perpendicular, the absolute value of the aerosol degree of polarization remains the same as when these components are parallel; only the sign changes.

Fig. 4

Figure 4: Fig. 4

B_m and P_m were calculated by Rayleigh’ s formula. Figure 1 shows the distribution of the degree of polarization along the observed solar almucantar (curve 2), molecular (curve 1), and aerosol (curve 3). The maximum of P_a lies between $\vartheta = 110^\circ$ and $\vartheta = 120^\circ$ and reaches 40%. The introduction of a correction for the depolarization of air somewhat increases P_a. Neglect of the polarization caused by multiple scattering of light and reflection from the ground, when the atmosphere is highly transparent and in the absence of

the snow cover, apparently, will change the result little. Thus, atmospheric aerosols polarize light quite appreciably.

The indicatrix of light scattering shown in Fig. 3A (curve 1) was separated into two other components, one of them due to molecules and the other to aerosols. In doing so, the depolarization of air, multiple scattering of light, and reflection of light from the ground were neglected. As the author’ s previous works have shown (^{1}), neglecting the last two factors at $p = 0.88$ and in the absence of snow cover gives an error in determining the scattering indicatrix of the order of 1–7%.

Fig. 4

The aerosol scattering indicatrix shown in Fig. 3B (curve 1), in turn, was decomposed into two components. One of them—the indicatrix in natural light—is given in the same Fig. 3B (curve 2). The shaded part of the complete indicatrix represents the component due to light polarized by aerosols, which is shown separately in Fig. 4 (curve 2, dots). Similar data relating to 11 XI (crosses) are plotted on the same figure; they fall quite well on the same curve 2.

Received
8 VIII 1958

REFERENCES CITED

[1] E. V. Pyaskovskaya-Fesenkova, *Investigation of Light Scattering in the Earth’ s Atmosphere*, Publishing House of the Academy of Sciences of the USSR, 1957.
[2] V. G. Fesenkov, *Astron. Zhurn.*, **12**, No. 4 (1935).
[3] V. G. Fesenkov, *Astron. Zhurn.*, **35**, No. 5 (1958).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.