GEOPHYSICS

E. V. PYASKOVSKAYA-FESENKOVA

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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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E. V. PYASKOVSKAYA-FESENKOVA

SOME DATA ON THE POLARIZATION OF LIGHT BY THE ATMOSPHERE

(Presented by Academician V. G. Fesenkov, December 3, 1959)

The author carried out observations of the brightness and polarization of the clear sky along the almucantar of the Sun at the mountain observatory of the Astrophysical Institute of the Academy of Sciences of the Kazakh SSR in the vicinity of Alma-Ata ($h = 1450$ m) in August 1956, at the Aksenger state farm in the vicinity of Alma-Ata ($h = 500$ m) in June–July 1957, and in the Libyan Desert of the Egyptian region of the UAR ($h = 200$ m) in October-November 1957. The observations were carried out with a visual photometer with a yellow Schott filter ([1]).

Fig. 1. *a*—observations; *b*—

$$0.685\,\frac{\sin^2\vartheta}{1+\cos^2\vartheta}$$

To determine polarization, the method of V. G. Fesenkov ([2]) was used, which consists in measuring the brightness of the investigated point of the sky through a polaroid at three of its positions, separated from one another by 60°. By this method it was possible to determine both the degree of polarization and the orientation of the plane of polarization. The degree of polarization $P(\vartheta)$ was determined by the formula

$$P(\vartheta) = \frac{2\sqrt{B_1(B_1-B_2)+B_2(B_2-B_3)+B_3(B_3-B_1)}}{B_1+B_2+B_3}, \qquad (1)$$

where B_1, B_2, B_3 are the brightnesses of the observed point of the sky at the three specified positions of the polaroid.

As is known, the degree of polarization in a clean dry atmosphere $P_R(\vartheta)$, according to Rayleigh, is expressed as follows (without allowance for molecular anisotropy):

$$P_R(\vartheta) = \frac{\sin^2\vartheta}{1+\cos^2\vartheta}, \tag{2}$$

where ϑ is the scattering angle.

It turned out that on some days, in the real atmosphere, the influence of aerosols on the degree of polarization $P(\vartheta)$ was manifested only in a certain lowering of $P_R(\vartheta)$ in the same ratio for all scattering angles ϑ. Thus, for these days

$$P(\vartheta) = kP_R(\vartheta), \tag{3}$$

where k is the maximum degree of polarization on the almucantar of the Sun (for $\vartheta = 90°$).

Such proportionality does not depend on the transparency of the atmosphere. In some cases the dependence of $P(\vartheta)$ on ϑ is expressed rather accurately by equ-

···expression (3) even with very poor transparency of the atmosphere; in other cases, even with high transparency, such a dependence differs somewhat from that described by this expression. As examples, two figures are given in which the observed degree of polarization is satisfied rather well by expression (3). These figures refer

Fig. 2. a—observations; b—$0.325\,\frac{\sin^2\vartheta}{1+\cos^2\vartheta}$

Fig. 3. a—observations; b—$0.742\,\frac{\sin^2\vartheta}{1+\cos^2\vartheta}$

to days with high (Fig. 1) and low (Fig. 2) atmospheric transparency. In addition, Fig. 3 is also given, where the distribution curve $P(\vartheta)$ differs, although only slightly, from that given by expression (3), despite the high transparency of the atmosphere, namely it proves to be flatter. In all three figures, points a are the values of $P(\vartheta)$ obtained from observations, and b are those calculated from expression (3). The multiplier k in this expression is respectively equal to 0.685; 0.325 and 0.742.

Table 1

ϑ	$a = 0$	0.031	0.0415
ϑ	$P(\vartheta)$	$P(\vartheta)$	$P(\vartheta)$
20 and 160°	0.043	0.044	0.044
40 and 140°	0.178	0.182	0.184
50 and 130°	0.284	0.289	0.291
60 and 120°	0.411	0.416	0.418
80 and 100°	0.645	0.646	0.646

Fig. 4. 1 $-\mu'$; 2 $-\mu''$

Figure 2: Fig. 4. 1 $-\mu'$; 2 $-\mu''$

ϑ	$a = 0$	0.031	0.0415
90°	0.685	0.685	0.685

The points of Fig. 1 were obtained from observations on 6 VIII 1956 before noon at the mountain observatory, with a transparency coefficient $p = 0.88$. The curve is the mean of two, determined one after the other at solar zenith distances $z = 69$–$58°$.

The points of Fig. 2 refer to 16 VIII 1956 before noon (mountain observatory), when $p = 0.57$; a strong dry haze was observed, and the sky was pale, pale blue. The curve is also the mean of two, determined one after the other at $z = 54$–$50°$.

The points of Fig. 3 were obtained from observations on 10 XI 1957 before noon in Egypt, with $p = 0.88$, $z = 80$–$73°$. On these three days the sky was cloudless. When the anisotropy of molecules is taken into account, according to Cabannes, Rayleigh' s formula (2) is replaced by the expression

$$P_{R-C}(\vartheta) = (1 - a)\frac{\sin^2\vartheta}{1 + \cos^2\vartheta + a\sin^2\vartheta}, \tag{4}$$

where a is the depolarization factor. For air $a = 0.0415$, or, according to de Vaucouleurs' measurements, $a = 0.0310$.

As indicated above, the observations of 6 VIII give values of $P(\vartheta)$ that are satisfied rather well by expression (3), where $k = 0.685$, and $P_R(\vartheta)$ was calculated by formula (2). If instead of $P_R(\vartheta)$ one substitutes the quantities $P_{R-C}(\vartheta)$ from formula (4), then expression (3) will also be satisfied rather well. This is confirmed by Table 1, in which are given the values of $P(\vartheta)$ calculated from expression (3) for three cases: 1) $a = 0$, $P(\vartheta) = 0.685P_R(\vartheta)$; 2) $a = 0.031$, $P(\vartheta) = 0.729P_{R-C}(\vartheta)$; 3) $a = 0.0415$, $P(\vartheta) = 0.745P_{R-C}(\vartheta)$.

On the basis of observations of the brightness of the sky along the almucantar of the Sun, for the three above-mentioned positions of the polaroid it was possible to deter-

···to separate the scattered luminous flux $\mu(\vartheta)$ for different scattering angles ϑ (1) and divide it into two parts, namely in the natural rays $\mu'(\vartheta)$ and the polarized rays $\mu''(\vartheta)$. The ratio between these two scattered fluxes also changes with the change in the transparency of the atmosphere. Figure 4 shows the dependence of $\mu'(\vartheta)$ and $\mu''(\vartheta)$ for $\vartheta = 90°$ on the transparency coefficient p.

Fig. 4. 1 $-\mu'$; 2 $-\mu''$

of transparency p. It is seen that, with increasing turbidity of the atmosphere, $\mu'(90^\circ)$ increases more rapidly than $\mu''(90^\circ)$. Approximately we have: for $p > 0.79$, $\mu'(90^\circ) < \mu''(90^\circ)$; for $p = 0.79$, $\mu'(90^\circ) = \mu''(90^\circ)$; for $p < 0.79$, $\mu'(90^\circ) > \mu''(90^\circ)$.

Such a relation can probably be explained by the fact that aerosols have weaker light-polarizing properties than molecules. Therefore, when the transparency of the atmosphere decreases, and consequently when the amount of aerosols increases, the scattered flux in polarized rays will increase more slowly than in natural rays. As Fig. 4 shows, it may be assumed, to a good approximation, that $\mu'(\vartheta)$ and $\mu''(\vartheta)$ vary linearly with the change in atmospheric transparency.

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