DERIVATION OF SCATTERING PHASE FUNCTION FROM CLEAR SKY BRIGHTNESS DISTRIBUTION

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ABSTRACT

Iteration procedure have been applied to obtain the scattering phase function from measurements of sky brightness on solar almucantar. The principle and calculating examples have been discussed.

As early as 1948, Pyaskovskaya–Fesenkov[1] discussed the method of deducing the scattering phase function from the sky brightness on the solar almucantar. At that time he did not consider the influence of multiple scattering. Later this factor has been considered approximately[2]. Recently, Antyufeev et al.[3] suggested an iterative method which would reduce the influence of multiple scattering. In this paper, a scheme using iterative method to deduce scattering phase function from the sky brightness on the solar almucantar is discussed and some examples calculated are shown.

I. PRINCIPLES

For clear sky, the atmosphere may be considered as a plane-parallel medium and the sky brightness may be calculated by the radiative transfer equation. If the single scattering is considered only, the sky brightness on the solar almucantar at an angular distance φ from the sun is

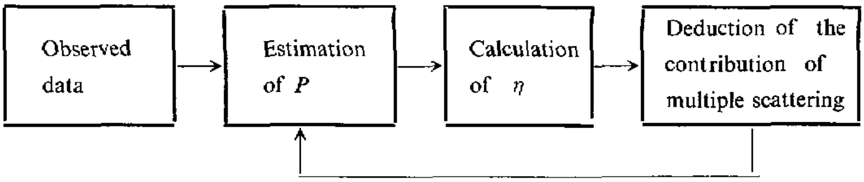
$$I_s(\tau,\mu_0,\varphi)=\frac{\omega_0}{4}S_0\exp\left(-\frac{\tau}{\mu_0}\right)P(\mu_0,\varphi)\frac{\tau}{\mu_0}\ . \tag{1}$$

From Eq. (1), it is easy to deduce scattering phase function from the observational brightness on the solar almucantar.

Generally speaking, the contribution of the multiple scattering is important especially on the half sphere opposite to the sun. The total brightness of the sky is

$$I=I_s+I_m=I_s(1+\eta), \tag{2}$$

where I_s and I_m are the single and multiple scattering brightness of the sky respectively, and $\eta=I_m/I_s$ is the ratio of the multiple to single scattering, indicating the contribution of the multiple scattering in the sky. If we know the scattering phase function and the reflectance of the ground, it is possible to calculate I and η distribution in the sky. Usually, with the increase of the peak of the forward scattering, the distribution of I_s increases proportionally, but the increase of I is rather slow. This indicates that multiple scattering always smooths out the distribution of the sky brightness. If we derive the phase function from the observational brightness according to Eq. (1) ignoring the influence of multiple scattering, the estimated phase function will be smoother than the real one. If we use this estimated phase function to calculate the ratio of multiple to single scattering by the radiative transfer equation, and deduct the contribution of multiple scattering from the observational data, the estimated phase function will be more close to the real one. The scheme of the iterative method is shown as follows



II. CALCULATED EXAMPLES

In Fig. 1, an example of iteration is shown. In this example, the Henyey-Greenstein (H-G) phase function is assumed, and the calculated sky brightness is used as the data observed. The crossline in the figure is the H-G phase function, and the curves show the process of approach to the estimated phase function. The results of this example show that in the range of scattering angles less than 2θ, where θ is the solar zenith angle, the results estimated are good enough for the real phase function.

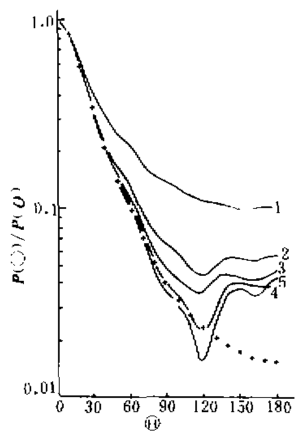


Fig. 1. Approach of the estimated phase function, normalized to P (0).

In Fig. 2 the observational data of sky light distribution is used to derive the phase function[4] and Fig. 3 shows the relative distribution of the sky brightness. The agreement between these two distributions indicates that the estimated phase function can be used.

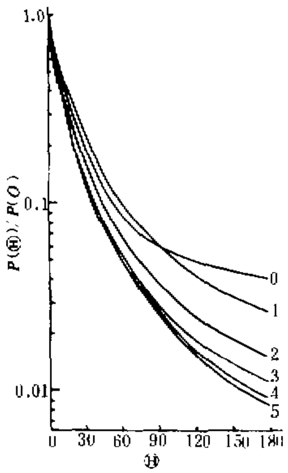


Fig. 2. Approach of the estimated phase function with observed data.

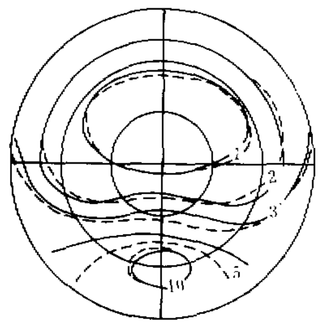


Fig. 3. Relative sky brightness distribution.
——— Observed data,
——— Calculated with estimated phase function.

III. DISCUSSIONS

The method discussed in this paper is useful in practical work. As it only needs the relative distribution of the sky brightness, it will allow the observational equipment to be simplified.

There are some problems which must be considered further. The first problem is that the data observed on solar almucantar only provide the information of phase function at scattering angle less than 2θ. Out of this range, the phase function must be extended. Sometimes we can expand the phase function in Legendre Polynomials with the finite number of terms. But sometimes we can not. If we fail to do this, the extension of the phase function will be done subjectively.

The second problem is that there are a lot of factors which may influence the distribution of the sky brightness. Among them, the reflectance of the ground is the most difficult to determine. Fortunately, this factor does not have great influence on the results of estimated phase function. The results of calculation indicate that when the value of reflectance is between 0.1—0.25, the same result can be obtained within reasonable errors.

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