# ESTIMATING THE APERTURE ANGLE OF THE SOLAR PHOTOMETER

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*To optimize the photometer aperture, the brightness of the solar radiation integrated over the solid angle of the photometer has been calculated for different atmospheric models and the geometries of remote sensing.*

The atmospheric optical thickness is often estimated using the Bouguer technique, which has a simple physical meaning and finds wide practical application. One of the possible sources of errors here is inaccurate separation of the direct solar radiation from the total incident solar flux because of the finite angular aperture of the photometer ($2\beta$) and multiple scattering of radiation in the atmosphere. Simple reduction of the angular aperture $2\beta$ to the angular size of the solar disk Is undesirable because of both technological difficulties and the problems of aiming the photometer at the Sun, particularly at sea. This paper describes a numerical experiment aimed at estimating this error and optimizing the photometer aperture.

Let us consider a plane-parallel horizontally homogeneous atmosphere. A parallel flux of solar radiation is incident on the upper atmospheric boundary. The optical parameters characterizing the continental and marine models of the atmosphere at three wavelengths ($\lambda$ = 0.337, 0.550, and 1.06 μm) were borrowed from Ref. 1. The brightness of the solar radiation scattered by the atmosphere and integrated over the solid angle of the photometer was computed using the Monte-Carlo method[2] at four solar zenith angles ($\theta$ = 20, 40, 60, and 70°). The method of the adjoint trajectory simulation with 100 000 trajectories was used for each set of optical parameters and different observation geometries, so that the computational error was less than 1%. Taking into account the fact that photometers are customarily calibrated in mountainous regions, in which relatively high stability of the atmosphere along with its small optical thickness provide for better conditions of measurements, we also simulate this situation. The photometer was assumed to be positioned at an altitude of $H = 3000$ m, and the continental models of the atmosphere according to Ref. 1 were used.

The upper limit of the error in determining the atmospheric optical thickness may be estimated by differentiation of the well-known Bouguer equation

$$\Delta r \le \left[ \left| \frac{\Delta I_0}{I_0} \right| + \left| \frac{\Delta I}{I} \right| \right] \frac{1}{m}. \tag{1}$$

Taking into account the fact that the errors in estimating the brightness of the solar radiation ($\Delta I$) and the solar constant ($\Delta I_0$) due to the illumination by the multiply scattered radiation only, the magnitudes of $\Delta I$ and $\Delta I_0$ may be interpreted as the brightnesses of the solar radiation multiply scattered by the atmosphere and integrated over the solid angle of the photometer. Expression (1) then assumes the form

$$\Delta r \le (\delta_0 + \delta)/m, \tag{2}$$

where $\delta_0 = \Delta I_0 / I_0$, $\delta = \Delta I / I$.

Figures 1, 2, and 3 show the dependences of the ratio of the brightness of multiply scattered radiation to the direct solar radiation (in per cent) on the solar zenith angle for various atmospheric models and apertures of the photometer (solid lines refer to the marine models and dashed lines refer to the continental models). Here the results of computations which imitate calibration in mountainous regions ($H$ = 3000 m) at $\lambda$ = 0.550 and 1.06 μm are omitted because of the small values of $\delta$ obtained (at these wavelengths they were less than 0.69%).

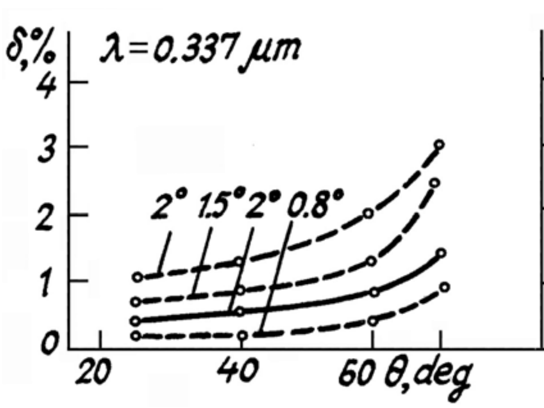


*Fig. 1*

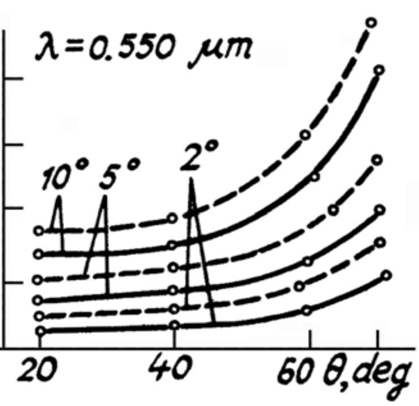


*Fig. 2*

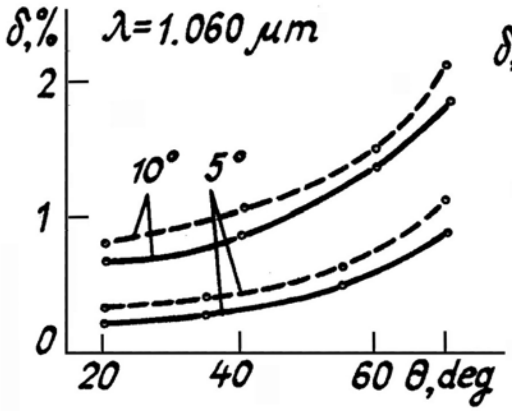


*Fig. 3*

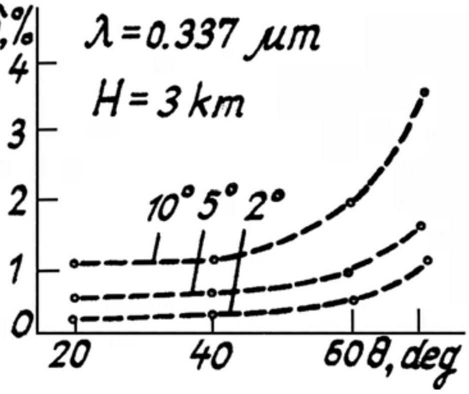


*Fig. 4*

Figure 4 shows the corresponding curves for calibration at $\lambda$ = 0.337 μm.

Since the atmospheric Instability is neglected in our computations, and the effect of the aureole illumination leads to overestimation of the results of measurements of I, we may assume that $\delta_0 \approx \delta$ where $\delta_0$ is the upper limit of the error in measuring the Instrument extra-atmospheric constant with the help of the long–time Bouguer technique, so that taking account of expression (2) we arrive at the expression

$$\Delta r \approx 2\delta/m. \quad (3)$$

As can be seen from Fig. 3, to find, e.g., the value of $\tau$ with an error of not more than 0.01, the suitable angle $2\beta$ may be chosen on the basis of the data shown in Figs. 1–4. Thus, the aperture angle should be less than 5 for the near IR range, less than 2° in the visible range and less than 1° in the UV range. In the case of high–altitude calibration of the photometer a 2° aperture angle would provide the estimate of the instrument extra–atmospheric constant with an error of not more than 0.01 in the entire considered wavelength range (Fig. 4).

Note In conclusion that, to estimate the errors, we have also used the data on the atmospheric optical parameters obtained in the course of the summer experiments performed in 1988 in settlements Kurtna (Estonia) and Narban (Azerbaijan) with the help of the daytime sky filter photometer designed at the Institute of Astrophysics of the Academy of Sciences of the Kazakh SSR. Its spectral range is 0.412–1.1 μm. The aerosol optical thicknesses used in computations varied within the limits 0.112–0.453, and the parameters the Henycy-Greenstein aerosol scattering phase function, which was used as the approximating function, varied within the limits 0.65–0.80. Computations made at $2\beta = 2°$ for all the variants of observations demonstrated that в is not more than 1.5%. This result agrees satisfactorily with the above-indicated estimates obtained on the basis of the model optical parameters of the atmosphere.[1]

## REFERENCES

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2. G.I. Marchuk, G.A. Mikhailov, M.A. Nazaraliev, et al., *The Monte Carlo Method in Atmospheric Optics* (Nauka, Novosibirsk, 1976).