Aerosol optical thickness of the atmosphere in the city of Barnaul

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Received February 2, 2001

The results of measurements of the vertical aerosol optical thickness of the atmosphere in the city of Barnaul by a NASA sun photometer are analyzed. It is shown that the reproducibility of the AOT values is in agreement with the normal-logarithmic law (and not with the normal law). The average and probable AOT values and their variances are obtained. Spectral AOT profiles show a wide spread of urban particle scales.

Measurements of the atmospheric optical characteristics were performed at the Altai State University together with the Institute of Water and Ecological Problems SB RAS over the period from March 1999 to March 2000 using a sun photometer CE318 (NASA) under monitoring conditions. Using the sun photometer in the city of Barnaul, extensive experimental material was collected.

This material contains more than 2000 series of measurements of optical thickness, total ozone and water vapor content in the atmosphere, sky brightness in the almucantar and in the vertical of the Sun.

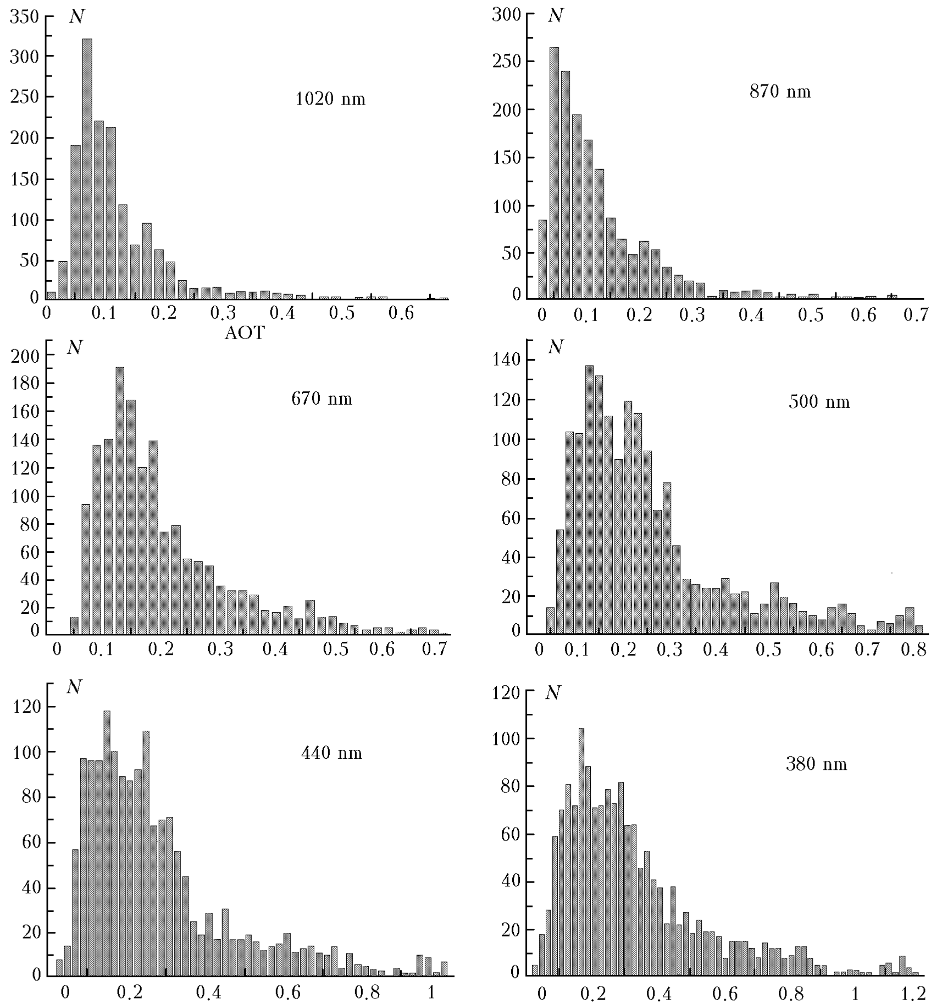

Fig. 1. Histograms of AOT reproducibility.

0235-6880/01/06–07 501-03 $02.00

This paper presents the results of processing of data on the spectral dependence of the aerosol optical thickness (AOT) $\tau_a(\lambda)$ based on observations at seven wavelengths: 340, 380, 440, 500, 670, 870, and 1020 nm. The absolute error of the AOT measurements is 0.01. The final results do not include data obtained during days with broken cloudiness.

Figure 1 displays histograms of the reproducibility of values of $\tau_a(\lambda)$ in six spectral ranges for the entire period of the observations. It is clear that the distributions are asymmetric relative to their maxima with a smooth decrease to the side of increasing atmospheric turbidity. The form of the distributions is of a lognormal rather than a normal character. This is confirmed by Fig. 2 where the reproducibility of the AOT values is presented as a function of $\ln\tau_a$. In this case the mean values $\bar{\tau}_a(\lambda)$ differ from the probable values $\tilde{\tau}_a(\lambda)$. Both the mean and probable values, as well as the natural logarithm of the probable value $\ln\tilde{\tau}_a(\lambda)$ and its variance $\tilde{\sigma}$, are given in Table 1. This fact clearly should be taken into account when constructing optical models of the atmosphere in industrial centers.

Traditionally, in publications where AOT measurement data are reported for some region, only the mean values $\bar{\tau}_a(\lambda)$ are given.[1] This is most likely due to the limited usefulness of the observed material or to the specifics of its selection, for example, on the basis of indicators of the “stability” of the optical characteristics of the atmosphere[2–4] during the half day from sunrise to culmination – a phenomenon which is often observed under the low-turbidity conditions of steppe or high mountains, but not typical of urban atmospheres.

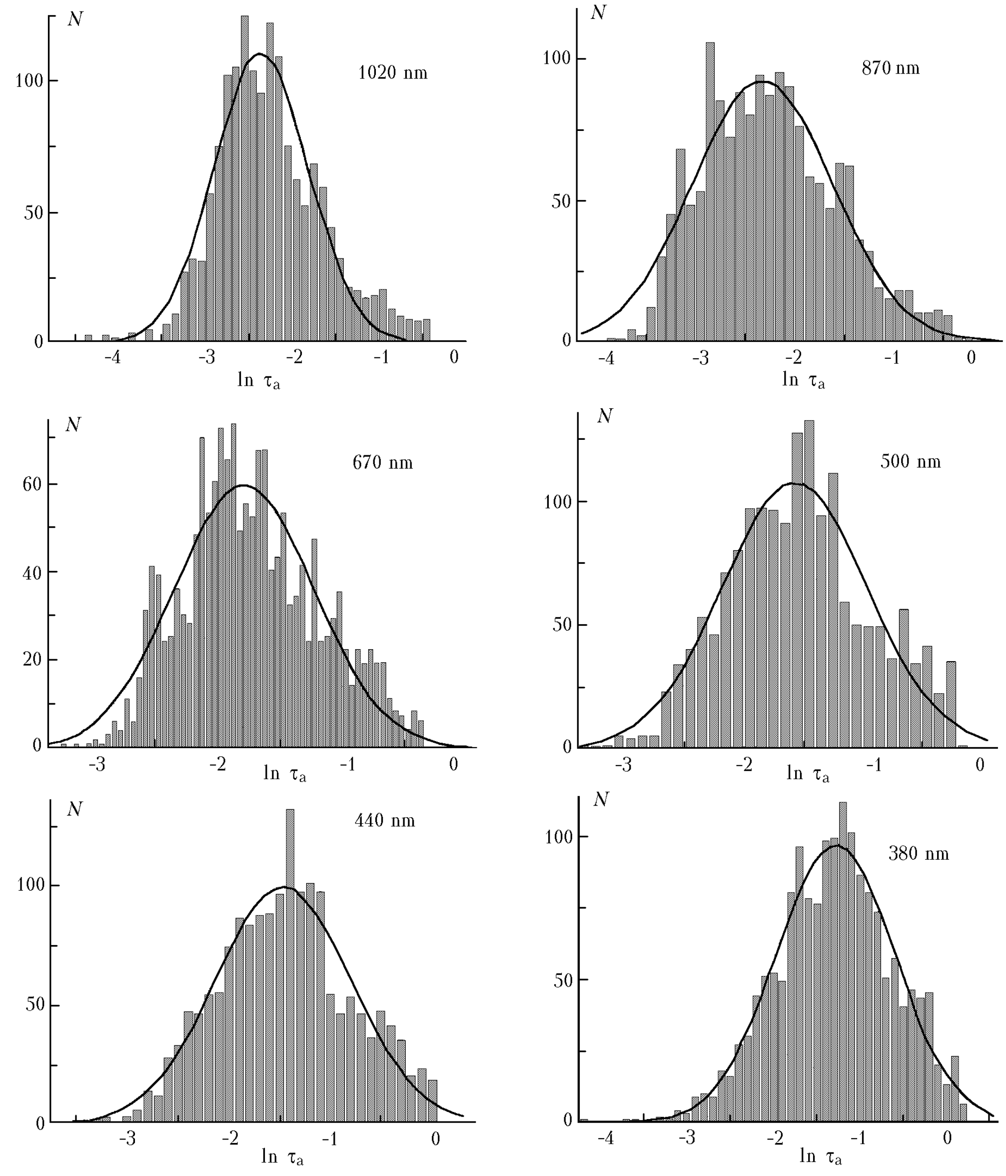

Fig. 2. Histograms of the reproducibility of the AOT natural logarithms.

Table 1. Values of $\bar{\tau}_a(\lambda)$, $\tilde{\tau}_a(\lambda)$, $\ln\tilde{\tau}_a(\lambda)$, and the variance $\tilde{\sigma}$

λ, nm	1020	870	670	500	440	380	340
$\bar{\tau}_a$	0.131	0.136	0.208	0.259	0.290	0.339	0.372
$\tilde{\tau}_a$	0.105	0.107	0.178	0.216	0.230	0.272	0.293
$\ln\tilde{\tau}_a$	−2.254	−2.235	−1.726	−1.532	−1.470	−1.302	−1.228
$\tilde{\sigma}$	−0.541	−0.706	−0.557	−0.612	−0.676	−0.689	−0.746

From Table 1 it follows that the values $\bar{\tau}_a(\lambda)$ and $\tilde{\tau}_a(\lambda)$ decrease smoothly with increasing wavelength. In the literature this dependence is often represented by the known Angström formula

$$\log\tau_a(\lambda) = \log A - n\log\lambda, \quad (1)$$

where A is a coefficient of turbidity.

As the analysis of the material has shown, this dependence is realized in 60% of cases with an accuracy of not less than 15%. For the mean values $\bar{\tau}_a(\lambda)$ and the most probable values $\tilde{\tau}_a(\lambda)$ the appropriateness of this formula is illustrated by Fig. 3.

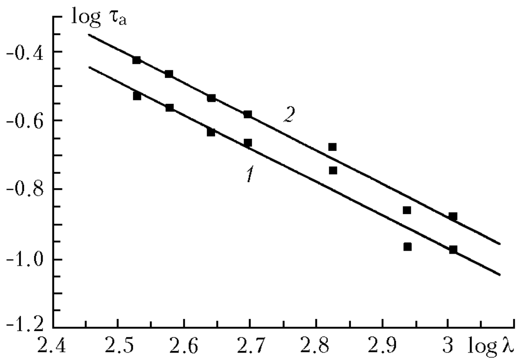

Fig. 3. Feasibility of the Angström formula for $\bar{\tau}_a$ (*2*), $\tilde{\tau}_a$ (*1*).

Figure 4 shows histograms of reproducibility of the values of n and $\log A$. The total number of values N is 926. It is clear that the distribution of the parameter n is normal and the distribution of A is lognormal.

In the remaining 40% of cases, when the Angström formula is not realized, the dependence of AOT on the wavelength, as a rule, is of a not systematic nature. Cases of a bell-shaped dependence of $\tau_a(\lambda)$ are only very rarely encountered.

The variations of the parameter n fall in the range from 0.13 to 2.2 with a mean value $\bar{n} = 1.3$, which is typical for a highly turbid atmosphere. Traditionally, continuous spectral dependences of τ_a (λ) without extrema are indicative of a wide particle size distribution in the atmosphere. On the assumption of the simplest form of the distribution[5]

$$\frac{dM}{d\log r} = cr^{-\nu}, \quad (2)$$

where r is the particle radius and M is the particle number, under conditions of weak and nonselective light absorption, the parameters n and ν are related by the equation[6]

$$\nu = n + 2. \quad (3)$$

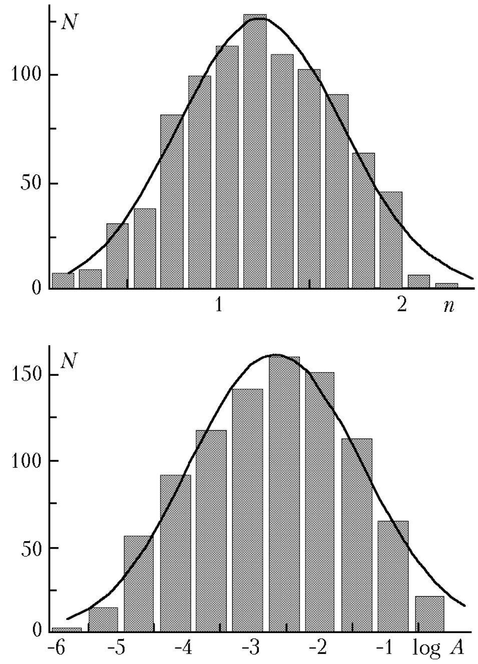

Fig. 4. Histograms of the reproducibility of the values of n and $\log A$ in the Angström formula for an urban particles.

Thus the mean value $\bar{\nu}$ is equal to 3.3, i.e., the particle spectrum is close to a so-called normal Junge distribution with $\nu = 3$ (Ref. 5). To solve the inverse problem of reconstructing the real form of the particle size distribution function from observations of the spectral atmospheric transmittance,[7–8] we must first estimate the role of the absorption in the total light extinction due to aerosol. Such an estimate can be made from an analysis of the daytime sky brightness, which is proposed as future work.

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