Some Results of Joint Measurements of Aerosol Extinction of Solar Radiation on Horizontal and Slant Paths

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Introduction

It's a well-known fact that the contribution atmospheric aerosol makes in the total extinction of radiation in calculations and models of radiation must be considered; the quantitative measure of this contribution is the aerosol optical thickness of the atmosphere. The near-ground meteorological range or the aerosol extinction coefficient in the visible wavelength range is used in practice of such calculations as an input parameter, which characterizes the aerosol optical thickness. To substantiate the applicability of this approach, statistical data on $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$ obtained in joint measurements are necessary. Busygin et al. (1981) have shown, based on more than 400 realizations of joint measurements, that the correlation coefficient between $\tau^A(\lambda)$ and Sm does not exceed 0.25-0.4. Joint spectral measurements of the parameters $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$ were carried out only by Lukshin et al. (1989). The value $H_0(\lambda) = \tau^A(\lambda) / \varepsilon^A(\lambda)$ that can be defined as the effective height, or the height of homogeneous layer of the aerosol atmosphere, is analyzed in this paper. We show that the range of variations of the height H_0 is 0.44-1.0 km and decreases as the wavelength increases. To study these issues in more detail we have analyzed the results of joint measurements of the atmospheric transparency on horizontal and slant paths obtained in the region of Tomsk (West Siberia) in warm seasons during the years 1995-2000.

Instrumentation and Conditions of Measurements

General information on the quantity of the data obtained in different periods of measurements and on the range of variations of meteorological parameters are shown in Table 1. The meteorological range Sm varied during measurements from ~13 to ~100 km.

Measurements of the spectral atmospheric optical thickness were carried out by means of the multi-wave sun photometer (Kabanov et al. 1997) installed on the roof of the building, at the height of ~18 m above the ground surface. Observations were performed in short ~5-30 min. series, when the sky was free of clouds. Then the hourly mean values were calculated from the data obtained. The techniques for calibration of the photometer and determination of the aerosol optical thickness of the atmosphere using the LOWTRAN-7 software are generalized by Sakerin et al. 2002.

Table 1. Quantity of the Data *N* {$\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$} and the Range of Variations of Air Temperature (T), Absolute Humidity (a) and Relative Humidity (RH).

Year	Period	N	T,°C	*a, g/m³*	RH, %
1995	12.06-15.07	62	10,1÷29,7	5,9÷10,0	46,5÷99,9
1997	18.08-12.09	14	7,7÷21,9	3,7÷7,7	48÷80
1999	22.06-28.06	40	13,1÷24,4	4,5÷7,1	37÷78,5
2000	01.07-17.07	28	12,7÷25,5	4,6÷7,8	35,7÷85,3
1995-2000		144	7,7÷29,7	3,7÷10,0	35,7÷99,9

Measurements of the horizontal transparency of the atmosphere were carried out by means of the automated photometer (Pkhalagov et al. 1992) on the ~830-m-long near-ground path. The path was situated at the height of 5 to 12 m above the ground surface. Total extinction of radiation was determined from the measured values of the transparency of the near-ground atmosphere, then the aerosol extinction coefficients $\varepsilon^A(\lambda)$ were selected using the multiple regression method. Periodicity of measurements was 4 hours in 1995-1999 and 3 hours in 2000. Then the calculated values $\varepsilon^A(\lambda)$ were interpolated to compare them with $\tau^A(\lambda)$. Interference light filters centered at $\lambda = 0.44; 0.48; 0.52; 0.55; 0.69, 0.87$, and 1.06 μm were used in both devices.

Peculiarities of the Spectral Dependencies of $\varepsilon^A(\lambda)$, $\tau^A(\lambda)$ and the Height H_0

To reveal the peculiarities of the variability of $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$ in different wavelength ranges, the joint bulk of data was statistically processed. The mean spectral dependencies of the characteristics $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$ are shown in Figure 1. It is seen that both characteristics have similar spectral dependence characterized by monotonic decrease as the wavelength increases. However, starting from the middle of the visible range, the spectral dependence of $\tau^A(\lambda)$ has more steep behavior and significantly fewer values in the infrared (IR) range in comparison with $\varepsilon^A(\lambda)$. Obviously, these differences are mainly caused by enhanced concentration of coarse aerosol in the near-ground air layer. In principle, this result is expected, and the problem is to determine the quantitative characteristics of the relative contribution of the particles of different size.

One can estimate the optical contributions of fine and coarse aerosol representing the aerosol extinction characteristics in the form of two components (for example, the coefficient $\varepsilon^A(\lambda)$:

$$\varepsilon^A(\lambda) = \varepsilon^F(\lambda) + \varepsilon^C \approx \varepsilon^F(\lambda) + \varepsilon^A(1.06),$$

where the index F indicates the component caused by small particles and C indicates the contribution of coarse fraction. Spectral dependencies of the values $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$ caused by only small particles are shown in Figure 2. In this case, the steepness of these characteristics also is slightly different. Possibly, the variation is caused by the difference in characteristics of fine fraction in the near-ground layer and

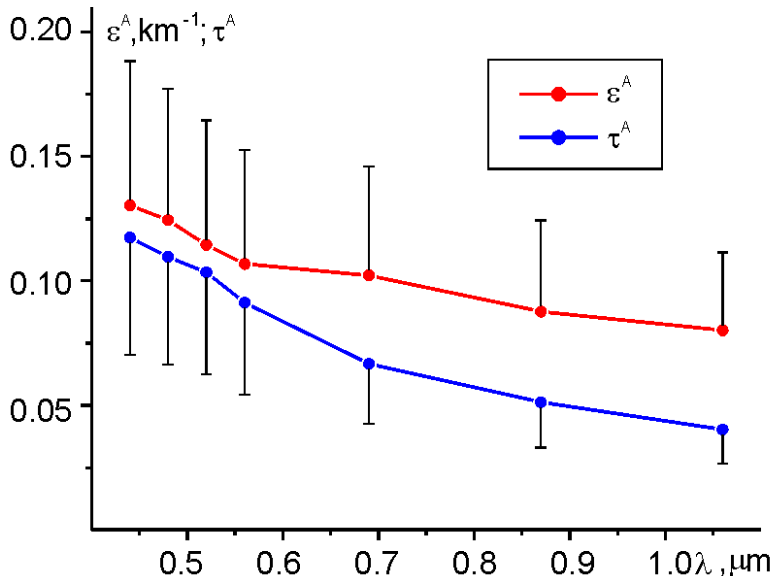

Figure 1. Mean spectral dependencies of the parameters $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$.

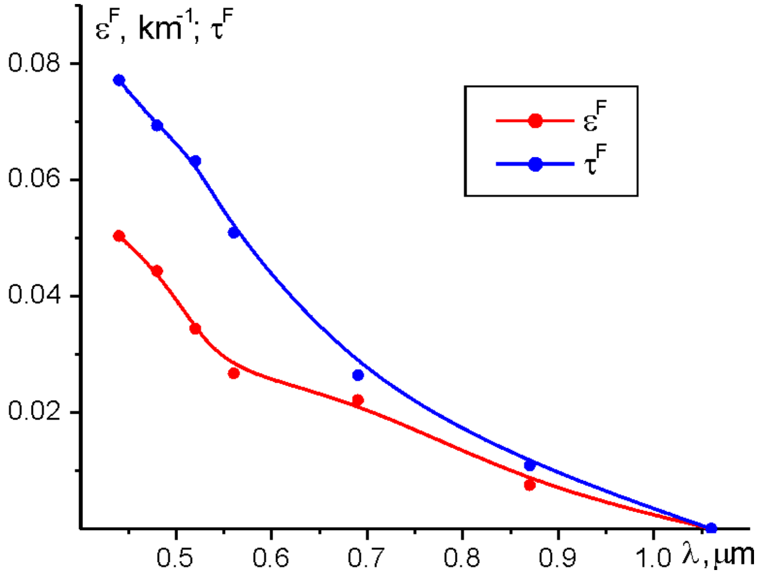

Figure 2. Mean spectral dependencies of the parameters $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$.

in the atmospheric column. The presence of spectral peculiarities of $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$ is also seen in the behavior of the effective height, H_0. The height $H_0 \approx 1$km in the visible range remains at the same level with small maximum in the range $\lambda = 0.55$ μm, then it quickly decreases as the wavelength increases. The decrease of the effective height in IR range is expected, because coarse aerosol is principally concentrated in the near-ground layer, but fine particles are emitted into the higher layers of the atmosphere. Let us note that the presence of the spectral behavior of H_0 represents redistribution of the role of two fractions of particles in different wavelength ranges.

Correlation

The correlation coefficients $\rho\tau(0.44, \lambda i)$ and $\rho\varepsilon(0.44, \lambda i)$, as well as the mutual correlation coefficients $\rho[\tau^A(\lambda),\varepsilon^A(\lambda)]$ were calculated to estimate the correlation between the noted parameters. The results of calculation are shown in Table 2.

Table 2. Correlation coefficients of the aerosol extinction (the level of significance is 0.16).

λ, μm	0.44	0.48	0.52	0.56	0.69	0.87	1.06
ρ_ε (0.44; λ)	1	0,99	0,99	0,96	0,91	0,85	0.83
ρ_τ (0.44; λ)	1	0,99	0,99	0,99	0,91	0,73	0.42
$\rho\ [\tau^A(\lambda);\varepsilon^A(\lambda)]$.	0.37	0,36	0,33	0,26	0,15	0,01	-0.04

As expected, more close correlation is observed in the near-ground layer of the atmosphere between the coefficients ε^A in the entire wavelength range rather than between τ^A. It occurs because of the significant effect of coarse aerosol. As for the statistical relation of $\varepsilon^A(\lambda)$ and $\tau^A(\lambda)$, significant correlation is observed only in the range 0.44 to 0.56 μm. Practically independent dynamics of fine and coarse aerosol (moreover, in different atmospheric layers) and their different contributions into formation of $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$ lead to weakening (Figure 4, $\lambda = 0.44$ μm) and full destruction (Figure 5, $\lambda = 1.06$ μm) of correlation of the optical characteristics. Even selection of only fine components $\tau^F(\lambda)$ and $\varepsilon^F(\lambda)$ practically does not increase their correlation in the range $\lambda = 0.44$ μm (Figure 6).

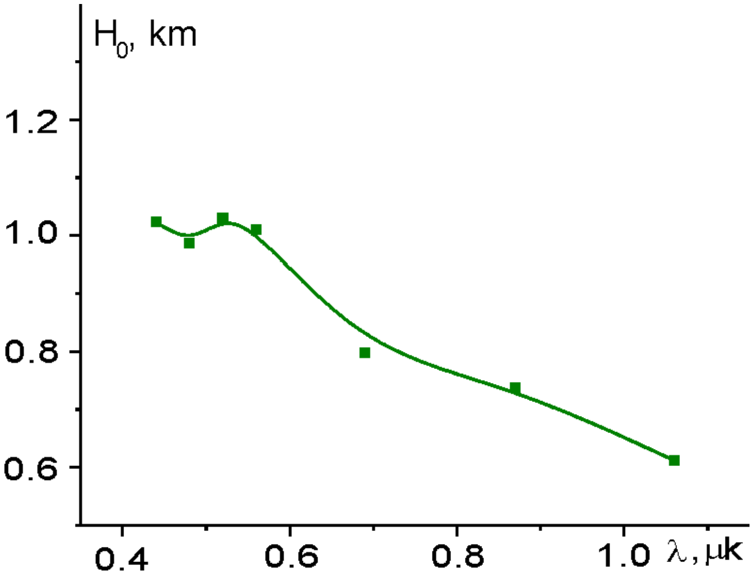

Figure 3. Mean spectral dependence of the effective height of the aerosol atmosphere in West Siberia.

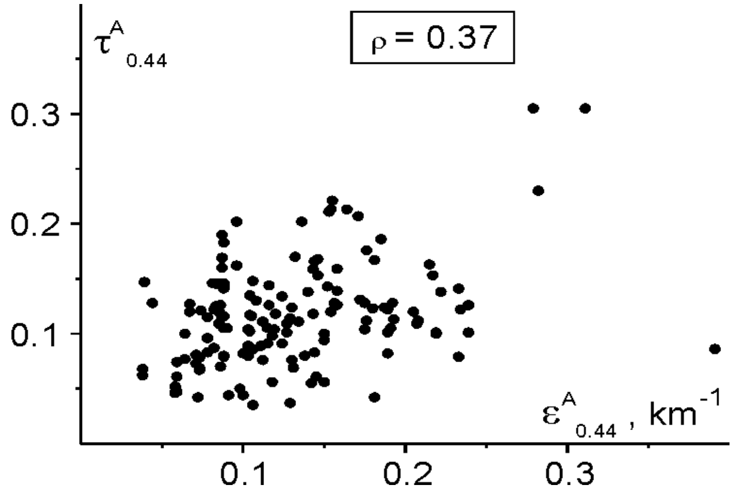

Figure 4. Statistical relation between the parameters ε^A and τ^A in the range λ = 0.44μm (ρ is the correlation coefficient).

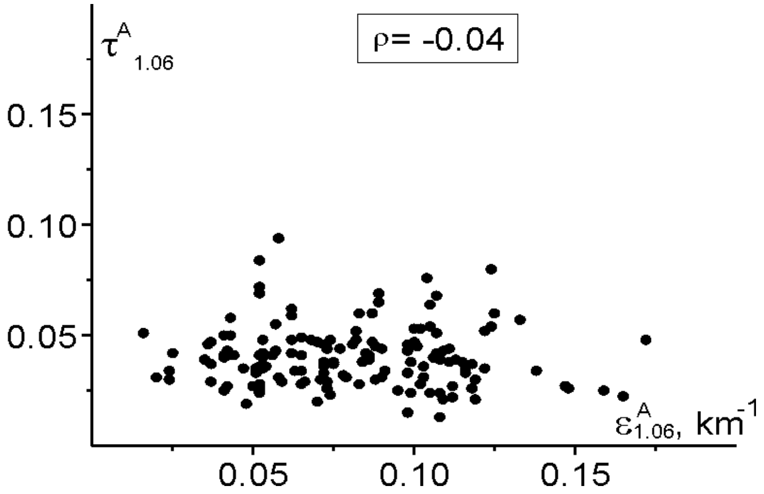

Figure 5. Statistical relation between the parameters ε^A and τ^A in the range λ = 1.06μm.

One should also note the possible methodical reasons for weak correlation between $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$. Obviously, the concentration and variations of coarse aerosol are more significant near the ground surface. So, at different height of the measurement instruments (~8 and 18 m), the portion of aerosol observed in the near-ground layer does not reach the level of the sun photometer. The effect of difference of the measurement paths is observed for submicron aerosol, too. Besides, practically full absence of the increase of correlation between $\tau^F(\lambda)$ and $\varepsilon^F(\lambda)$ in the range 0.44 μm can be related to the fact that selection of the coarse component of aerosol extinction was performed very roughly, assuming that $\varepsilon^C = \varepsilon^A(1.06)$ and $\tau^C(\lambda) = \tau^A(1.06)$.

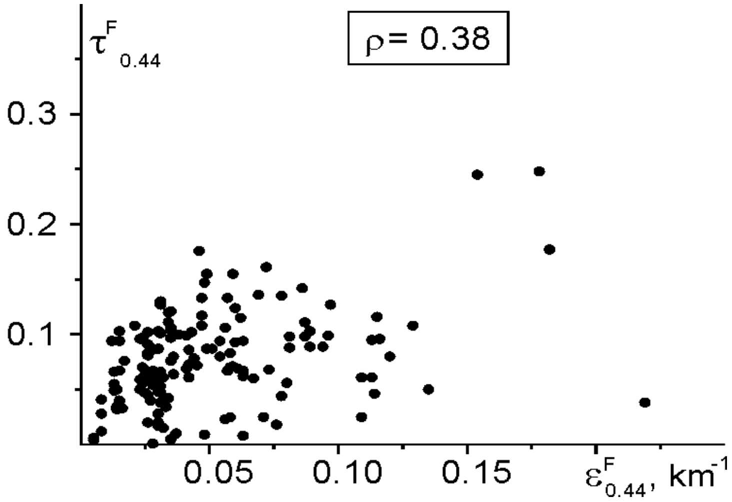

Figure 6. Statistical relation between the parameters ε^F and τ^F in the range λ = 0.44 μm.

The results obtained enable us to state problems and to find approaches to subsequent investigations. First, the necessity of inverting the optical data on $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$ became obvious. It will enable to analyze in more detail the peculiarities of the processes of aerosol transformation. Second, it will be possible to study the peculiarities of diurnal dynamics of the fine and coarse components of $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$ and to determine the most significant meteorological predictors. Third, one can consider the joint variations of $\tau^A(\lambda)$ and $\varepsilon^A(\lambda)$ within separate seasons and synoptic situations.

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