Comparison of Aerosol Optical and Microphysical Characteristics at Different Regions

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Introduction

During the last decade, spectral solar aureole measurements were conducted by the Institute of Atmospheric Physics, Russian Academy of Sciences at different regions: Tadjikistan, Oklahoma, Spitsbergen, Moscow region, and near the Aral Sea. Observations at Tadjikistan in 1989 and near the Aral Sea in 1991 were conducted with a filter solar aureole photometer (Isakov et al. 1993) at four wavelengths: 0.46 mcm, 0.54 mcm, 1.2 mcm, and 1.6 mcm. In other measurements (Oklahoma 1995; Ny Alesund, Spitsbergen, 1997; Moscow region 1997 and 1999), a solar photometer based on an acoustic-optical spectrometer (Golitsyn et al. 1997) was used. The measured characteristics were inverted to the aerosol size distributions in an atmospheric column. The goals of the study are to compare results obtained at different places and in different seasons, to parameterize the size spectra by the sum of several lognormal fractions, and to check the validity of the earlier suggested (Sviridenkov 1993) relation between volume concentration of large particles and directed scattering coefficients (DSCs) (i.e., phase functions multiplied by aerosol optical thickness) for a certain combination of scattering angle and wavelength.

Comparison of the DSC

The greatest coarse dispersed aerosol loading in the atmosphere and hence the brightest solar aureole measurements were registered in Tadjikistan (September 1989) and the Aral Sea region (September 1991) after dust storms. The minimal values of DSCs approximately two orders less were observed at Spitsbergen (March - April 1997) and near Moscow (February 1999). In general, angular dependencies of the DSCs follow the simple approximation of van de Hulst (1951):

$$D(\varphi,\lambda) = C(\lambda)\varphi^{-q(\lambda)} \tag{1}$$

The parameter q varied in Oklahoma, during the Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE), in Tadjikistan and in the Aral Sea region approximately from 1.2 to 2. A much less angular slope of the aureole phase functions—from 0.4 to 1—gave the measurements in the Moscow region and at Spitsbergen. This difference is obviously connected with the increased relative input of the fine particle fraction into the aureole brightness in these regions compared to the Southern Great Plains and semi-deserts of Central Asia. According to the spectral behavior, aureole directed scattering coefficients can be separated into three groups. The first group is characterized by the weak spectral dependence of DSCs. In the second group, the angular slope is increasing with wavelength, and in some cases the spectral dependence for the scattering angle of 2° is inverted to that for 10°. DSCs in the third group have the identical spectral dependence for all scattering angles in the aureole region, and the corresponding curves in the plot of the DSC versus the scattering angle are parallel in logarithmic scale. The examples of different types of solar aureole data are given in Figures 1 to 3.

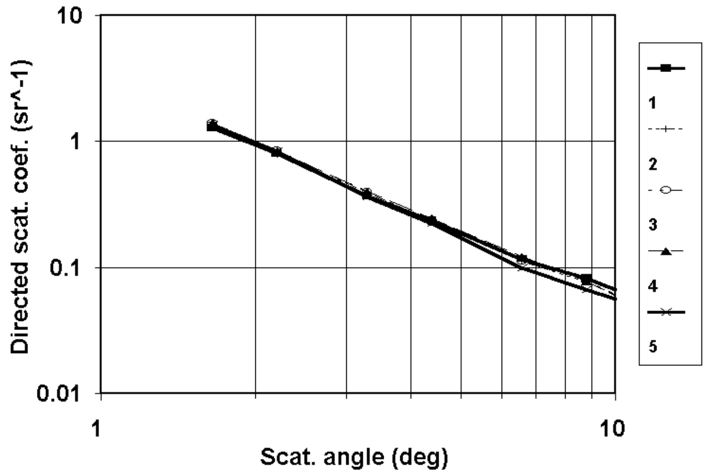

Figure 1. Spectral-angular behavior of the DSCs. ARESE, 09.10.95. 1- λ = 0.46 mcm, 2- λ = 0.54 mcm, 3- λ = 0.61 mcm, 4- λ = 0.66 mcm, 5- λ = 0.75 mcm.

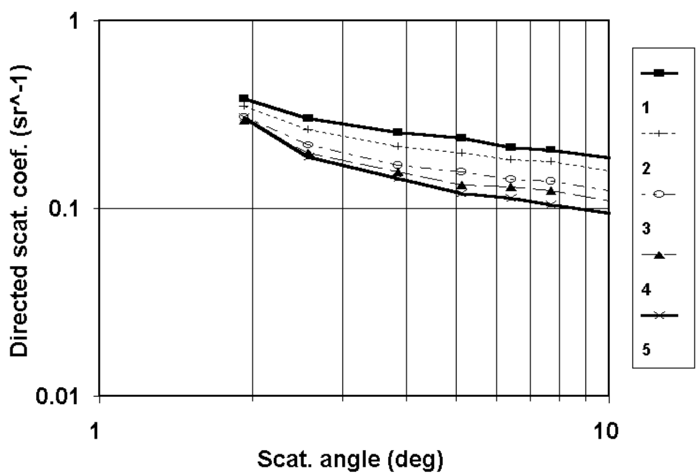

Figure 2. Spectral-angular behavior of the DSCs. Zvenigorod, 22.02.99. 1- λ = 0.46 mcm, 2- λ = 0.54 mcm, 3- λ = 0.61 mcm, 4- λ = 0.66 mcm, 5- λ = 0.75 mcm.

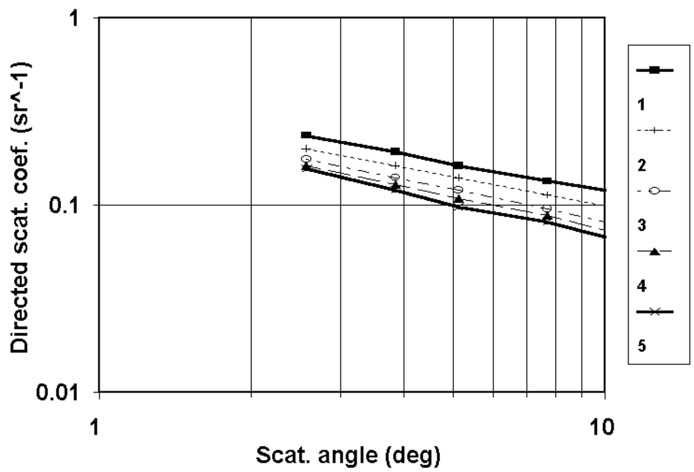

Figure 3. Spectral-angular behavior of the DSCs. Spitsbergen, 31.03.97. 1- λ = 0.46 mcm, 2- λ = 0.54 mcm, 3- λ = 0.61 mcm, 4- λ = 0.66 mcm, 5- λ = 0.75 mcm.

Analytical Approximation of Aerosol Size Distributions

Measured spectral-angular characteristics of the DSCs were inverted to the aerosol size distributions in the atmospheric column using the modified iterative algorithm of Twitty (1975). Beginning in 1995, the aerosol optical thickness was also included in the input data set. In the diffraction limit of near-forward scattering, the parameterization (Eq. 1) corresponds to the power law aerosol size distributions and the size spectra obtained can be roughly described in the radius region r > 0.3- 0.5 by power law

$$d\,S/dr \propto r^{-g}, \qquad (2)$$

where d S/dr is the cross-sectional size distribution with parameter g varying approximately from 1 to 2.

More precise size distributions can be parameterized by the sum of several lognormal fractions. Examples of such approximations are shown in Figures 4 to 6. The parameters of the corresponding number lognormal distribution are given in Table 1.

In Table 1, N, r, and ν are particle concentration, median radius and r.m.s.d of the logarithm of radius, correspondingly. It can be seen from the data in Table 1 that the relative input of the giant particles in the aerosol concentration is much greater in Oklahoma than in the other two locations. In the vicinity of the 10 micron particle radius, the aerosol concentration retrieved from the observations during ARESE, in some situations, was comparable to those observed after a dust storm in Tadjikistan.

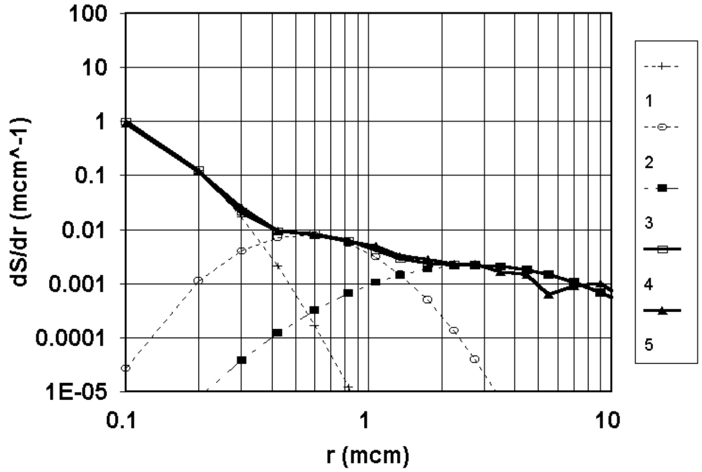

Figure 4. Lognormal approximation of the aerosol size distribution. ARESE 10.10.95. 1-3 - lognormal fractions, 4 - their sum, 5 - experimental data.

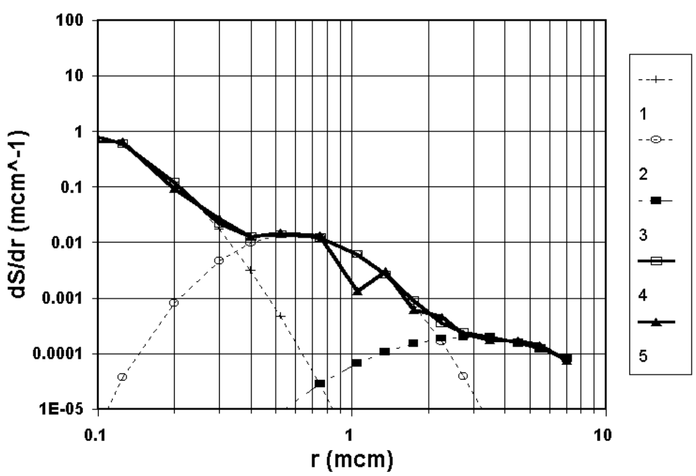

Figure 5. Lognormal approximation of the aerosol size distribution. Spitsbergen, 30.03.97. 1-3 - lognormal fractions, 4 - their sum, 5 - experimental data.

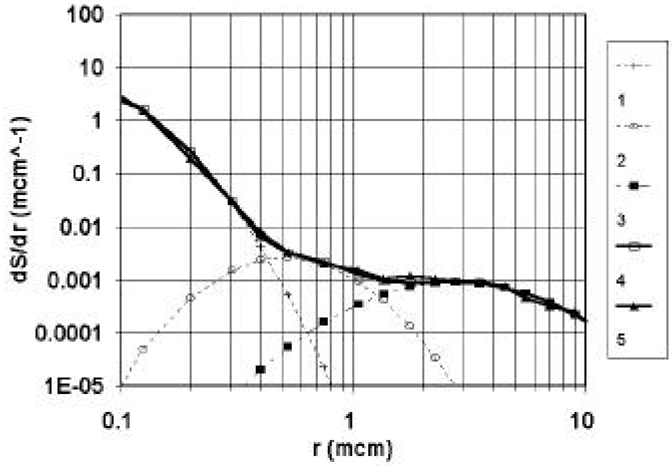

Figure 6. Lognormal approximation of the aerosol size distribution. Zvenigorod, 22.07.97. 1-3 - lognormal fractions, 4 - their sum, 5 - experimental data.

Table 1. Parameters of lognormal distributions.

	ARESE, 10.10.95	**Spitsbergen, 30.03.97**	**Zvenigorod, 22.07.97**
N_1 (cm^{-2})	$1.5 \cdot 10^9$	$1.5 \cdot 10^9$	$5.5 \cdot 10^9$
N_2 (cm^{-2})	$6.8 \cdot 10^5$	$9.6 \cdot 10^5$	$2.4 \cdot 10^5$
N_3 (cm^{-2})	$6.8 \cdot 10^4$	$4.8 \cdot 10^3$	$2.4 \cdot 10^4$
r_1 (mcm)	0.042	0.042	0.04
r_2 (mcm)	0.42	0.48	0.4
r_3 (mcm)	1.5	1.8	1.7
ν_1	0.55	0.55	0.53
ν_2	0.5	0.45	0.5
ν_3	0.78	0.68	0.7

Correlation between Volume Concentration and Aureole Scattering

It was found from the correlation analysis of the data obtained in Tadjikistan (Sviridenkov 1993) that linear relation is valid between volume concentration of large aerosol particles in the atmospheric column and aureole scattering for the wavelength of 1.2 micron and the scattering angle of 2.9°. It follows from the diffraction approximation of the near-forward scattering that analogous relation must be held for other wavelengths and scattering angles with the same ratio. Analyses of the ARESE data confirmed this suggestion (Golitsyn et al. 1997). In order to check the validity of the regression coefficient obtained from measurements in Tadjikistan for other locations, we simulated scattering for the mentioned pair of wavelength and scattering angle from the retrieved size distributions in all regions and compared it with the volume concentration of particles bigger than 0.3 micron. The correlation plot is given in Figure 7.

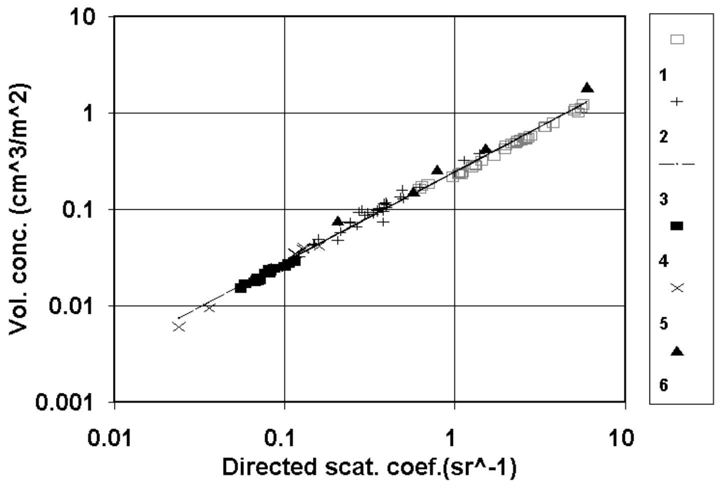

Figure 7. Correlation between volume concentration and aerosol scattering. 1- Tadjikistan, 1989, 2- ARESE, 1995, 4-Spitsbergen, 1997, 5- Zvenigorod, 1997 - 1999, 6- environs of the Aral Sea, 1991, 3 - regression line.

The correlation coefficient between logarithms of DSCs and volume concentration exceeds 0.99. The data in Figure 7 allow the recommendation of this method for the simple retrieval of the volume concentration for monitoring coarse dispersed aerosols.

Acknowledgments

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