Solar Aureole Measurements and Coarse Dispersed Aerosol Size Distributions in ARM Enhanced Shortwave Experiment Intensive Observation Period

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Introduction

Dust aerosol, produced mainly by a soil, may considerably affect radiative properties of the atmosphere and the climate of the Earth. Modeling of the climatic and radiative effects of coarse aerosol needs knowledge of its optical and microphysical characteristics. Solar aureole measurements enable to estimate the aerosol size distributions averaged through the atmospheric column in the size range 1 10 mcm, giving the main input into the volume (mass) concentration of dust aerosol.

Solar Photometer

During the Atmospheric Radiation Measurement Program Enhanced Shortwave Experiment (ARESE) intensive observation period (IOP) (October 1995) solar aureole measurements were carried out with photometer based on the acoustic-optical spectrometer Quartz-4. Spectral range of spectrometer - 415 - 790 nm, spectral resolution - 0.25 nm. Field of view was about 1°. The recording time for seven scattering angles from 1.6° to 10.5° doesn't exceed 10 min. Spectrometer was mounted on the active tracking system. The instrument was calibrated by diffuse reflector with albedo close to unit. Directed scattering coefficients $D(\phi,\lambda)$ were found according to the formula:

$$D(\phi,\lambda) = \frac{I(\phi,\lambda)K(\lambda)}{\pi I_o(\lambda)\sec(Z)} \tag{1}$$

(ϕ - scattering angle, λ - wavelength, $I(\phi,\lambda)$ $1_o(\lambda)$ - signals from the sky and Sun respectively, $K(\lambda)$ calibration constants, Z - solar zenith angle). The mean estimated uncertainties in $D(\phi,\lambda)$ are about 10%. In situations of small aerosol loading they may increase after subtracting of molecular scattering to more than 20% for largest angles of scattering. In such cases measurements were restricted to angular range 1.6º - 9º.

Results of Observations

From September 28 to October 19, 1995, the set of 40 aureole measurements was obtained, including both situations with high atmospheric transparency and moderate aerosol loading, caused by wind soil erosion. The examples of typical angular dependencies of directed scattering coefficients for wavelength of 0.54 mcm are given in Figure 1. They are in a good agreement with the approximation of Van de Hulst (1951):

$$D(\phi\lambda) = C(\phi,\lambda)\phi^{-q(\lambda)} \tag{2}$$

with parameter q varying from 1.4 to 1.9. Our measurements of solar aureole at Dushanbe (Tadjikistan) gave similar values of q for λ = 0.54 mcm (Sviridenkov 1993).

But the highest absolute values of D observed in Dushanbe during a dust storm were more than five times as during ARESE.

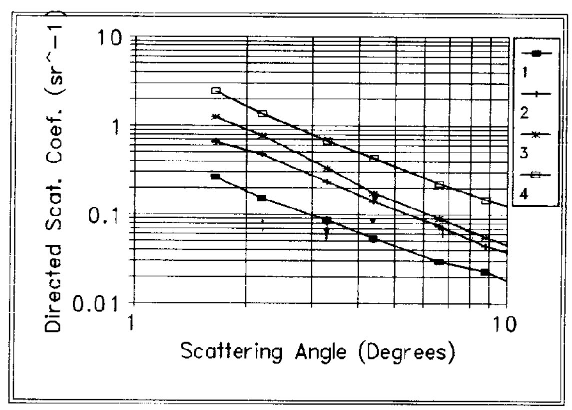

Figure 1. Angular course of aureole scattering. ARESE, October 1995 (1 - 10/4, 2 - 10/18, 3 - 10/17, 4 - 10/19).

Retrieval of Aerosol Size Spectra

Spectral-angular dependencies of the directed scattering coefficients in aureole region were inverted to the aerosol size spectra using the iterative method of Twitty (1975). For inversion were chosen D (ϕ,λ) for Eve wavelengths λ = 0.46 mcm, 0.54 meM, 0.61 mcm, W66 mcm, A75 mcm. The maximal number of input parameters was equal to 35 (seven angles and Eve wavelengths The real and imaginary parts of refractive index were assumed to be equal to 1.53 and zem. These values are not critical because the aureole phase function for particles larger than wavelength depends mostly on the particle's size but not on the optical constants of material. Size distributions were evaluated for 13 intervals of particle's radii with centers from 0.6 to 11 mcm. The retrieved size spectra are shown in Figure 2. On the average they follow the inverse power law:

$$\frac{dN}{d\ln(r)} \sim r^{-\nu} \qquad (3)$$

with $\nu \approx 2$ (N - number particle concentration). The r.m.s. discrepancy between measured and recalculated from the size spectra directed scattering coefficients changed from 5% to 10%.

Volume aerosol concentration in the atmospheric column V may be found as integral of $dV/dr=4/3\pi^3 dN/dr$. The largest values of V were registered on October 13 (0.2 cm^3/m^2) and October 19 (0.25 cm^3/m^2) at very windy conditions. The minimal concentrations was about 0.02 cm^3/m^2. As it was shown earlier (Sviridenkov 1993), a linear relation exists between D(ϕ = 2.9, λ = 1.2 mcm) and volume concentration of coarse particles V. During ARESE we couldn't measure at wavelength of 1.2 mcm. But from the diffraction approximation of near forward scattering, it follows that analogous relation must be valid for V and D(ϕ = 1.6°, λ = 0.66 mcm). Figure 3 illustrates this result. Using regression analysis we obtained:

$$V[cm^3/m^2]=0.09D(\phi)=1.6^o,\lambda=0.661\ mcm)[sr^{-1}] \qquad (4)$$

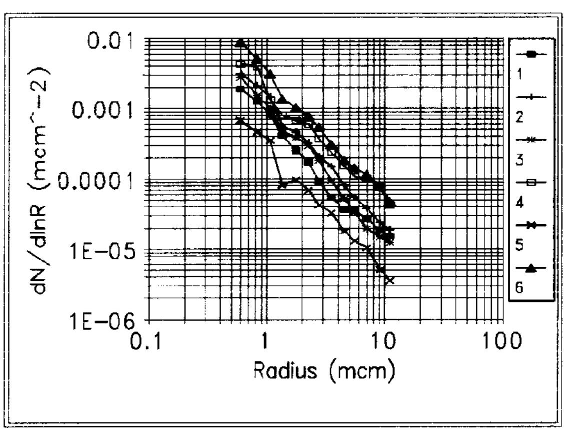

Figure 2. Aerosol size distributions derived from aureole measurements. ARESE, October 1995 (1 - 10/7, 2 - 10/8, 3 - 10/9, 4 - 10/13, 5 - 10/15, 6 - 10/19.

Conclusion

The period of ARESE was characterized by low loading of the coarse dispersed aerosol. Volume concentration in atmospheric column did not exceed 0.25 cm^3/m^2. Largest values of volume concentration were reached in conditions of a strong wind producing the erosion of the soil. Aerosol size spectra in the radius interval 0.6 - 11 mcm may be approximated by inverse power law.

Acknowledgment

This work was supported by U.S. Department of Energy's Atmospheric Radiation Measurement Program.

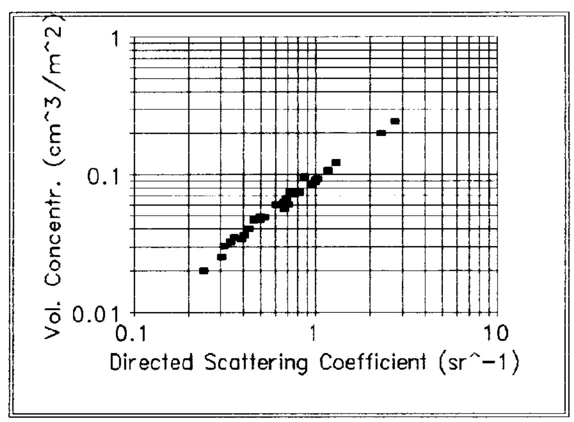

Figure 3. Correlation between directed scattering coefficients for ϕ = 1.6°, λ = 0.66 mcm and aerosol volume concentration in the atmospheric column.

References

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