Comparison of aerosol characteristics retrieved from measurements of scattering in local volume and extinction on horizontal path

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Keywords: atmospheric aerosol, light scattering, light extinction, aerosol size distribution

Nephelometers with limited scattering volume are widely used in practice of aerosol optical research. However, due to some reasons, the optical parameters measured with the nephelometers represent, first of all, the submicron aerosol fraction. The data on spectral transparency of the atmosphere in visible and infrared wavelength range enable to extend the size range of aerosol under study.

The results of parallel measurements of light extinction on a horizontal near-ground path and the light scattering parameters in a local air volume in 2005 – 2006 are considered in this paper, as well as the retrieved aerosol refractive indices and size distributions.

The spectral extinction coefficient $\varepsilon(\lambda)$ was measured by means of the multi-wavelength transparency meter on 830 m long near-ground path in the wavelength range 0.45 to 3.91 µm. Then the aerosol extinction coefficients $\beta(\lambda)$ were isolated using the original statistical technique developed by authors (Pkhalagov & Uzhegov, 1988).

The coefficients of directed scattering, at the angle of 45° at three wavelengths (0.41, 0.5, and 0.63 µm) and polarized and cross polarized components of the scattered light at 90° scattering angle at two wavelengths (0.44 and 0.51 µm), were measured by means of the nephelometer equipped with the device for artificial humidification in the range of relative humidity from $RH = 20 – 30$ to 90% (Panchenko et al, 2004).

Comparison of the two datasets has shown that the correlation coefficient between aerosol scattering and extinction in visible wavelength range is $\sim 0.7$.

The measured optical parameters (spectral extinction coefficients measured on the near-ground path and seven parameters of light scattering obtained with the nephelometer) were inverted to the size spectrum and the refractive index of the aerosol particles. Measurements of spectral transparency do not provide for obtaining the refractive index $n$ of particulate matter. Solution of the inverse problem in this case needs its a priori setting. In our study, $n$ was evaluated by the inversion of nephelometric data. It was done both for the dried particles (at relative humidity $RH \sim 20 – 30\%$) and for humidified aerosol at $RH \sim 90\%$. Then the refractive index in situ was estimated, i.e. at outdoor relative humidity. To do it, the light scattering parameters in situ were retrieved from the data of measurements at two values of humidity using the Kasten’s parameterization (Kasten, 1969):

$$\mu = \mu_0(1 – RH)^γ,$$

where $\mu$ is the directed scattering coefficient, $\mu_0$ is the directed scattering coefficient of the dry aerosol fraction, $RH$ is relative humidity of air, $γ$ is the parameter of condensation activity, the index “$γ$” means the respective measured scattering characteristics. Parameters $γ$ were determined from this formula using the initial and final values of the respective directed scattering coefficient or its polarized component, as well as the initial and final values of relative humidity. Then the parameters $μ$ at outdoor relative humidity were calculated. Solution of the inverse problem for these data provided for the in situ refractive index and size distribution of accumulative aerosol fraction. The obtained values $n$ were used for inverting the data on the spectral extinction coefficient on horizontal path.

Analysis of the results of inversion has shown that, in significant part of cases, in the radius range $r = 0.1 – 0.5$ µm, the particle size distributions retrieved from the aerosol extinction coefficients are close to those obtained from the light scattering brought to outdoor humidity. At the same time, the data on extinction, which cover the wider wavelength range including near IR, make it possible to obtain also the size spectrum of intermediate dispersed aerosol fraction. However, the correctness of estimation of the size distribution function in the range $r > 1$ µm significantly depends on how close the refractive index of these particles to the value $n$ of submicron particles retrieved from nephelometric measurements.

The work was supported by Russian Foundation for Basic Research under grant No. 06–05–64393.