Comparison of Black Carbon Content, Aerosol Optical and Microphysical Characteristics in Moscow and the Moscow Region

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Introduction

Aerosol loading in the atmosphere is determined by particle generation, growth, transport, and deposition processes. Large cities (e.g., Moscow) are significant sources of aerosols because soot acts as the main light-absorbing constituent. The urban effect on the aerosol characteristics may be studied by comparing measurements from the center of a megacity and in rural region, free from powerful anthropogenic aerosol sources.

Experiment

Aerosol scattering characteristics and black carbon (BC) mass concentration were simultaneously measured in May and June 2004 in the center of Moscow and at the Zvenigorod Scientific Station (ZSS) of the Institute of Atmospheric Physics, located 60 km west of the city center. Optical measurements were made using FAN nephelometers. BC content was measured in Moscow with an aethalometer AE-16. At ZSS, aerosol samples were collected on fiber filters around the clock, without breaks. Individual samples were collected for a duration of two hours. Then, the BC mass concentration was determined from extinction measurements. In routine operations, nephelometers measured directed scattering coefficient D at a 45° scattering angle and 510-nm wavelength. In addition, several times a day, directed scattering coefficients at wavelengths of 410 and 630 nm at a 45° scattering angle and their polarized components at a 90° angle and wavelengths of 450 and 520 nm were measured in Moscow. The registered aerosol parameters are close to those of the aerosol dry fraction due to air heating in the nephelometers chamber. The set of parameters measured by a FAN nephelometer allows us to solve the inverse problem and to retrieve the aerosol size distribution in the 0.05–0.7 μm radius range.

Results

During the experiment, the effective radius (i.e., the ratio of the third moment of size distribution to the second) varied in Moscow from 0.05 to 0.17 μm; the refractive index n changed from 1.45 to 1.6, except for a few cases. Typical size distributions, corresponding to the different effective radii, are shown in

Figure 1. Directed scattering coefficient *D* is well correlated with the total volume concentration *V* of particles with radii between 0.05–0.6 μm and can be used to estimate *V* by simple relation:

$$V\,(\mathrm{mm^3/m^3}) = D\,(\mathrm{sr^{-1}km^{-1}})$$

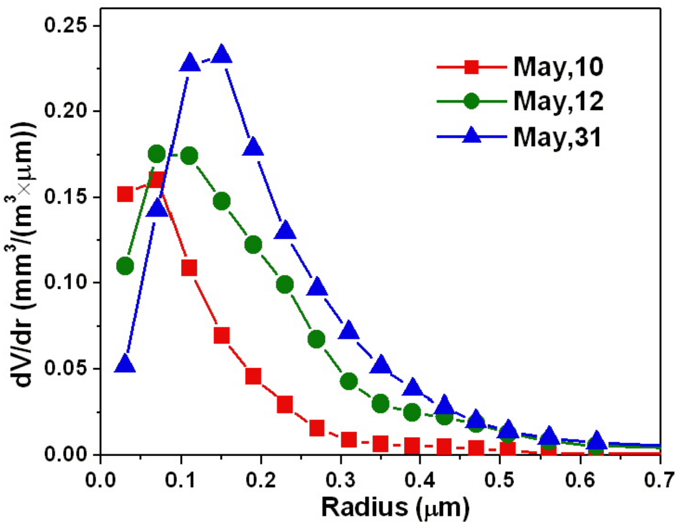

Figure 1. Examples of aerosol volume size distributions.

Correlation between *V* and *D* is shown in Figure 2. This relation was used to calculate the aerosol volume concentration at ZSS. Examples of time series of measured characteristics are shown in Figure 3.

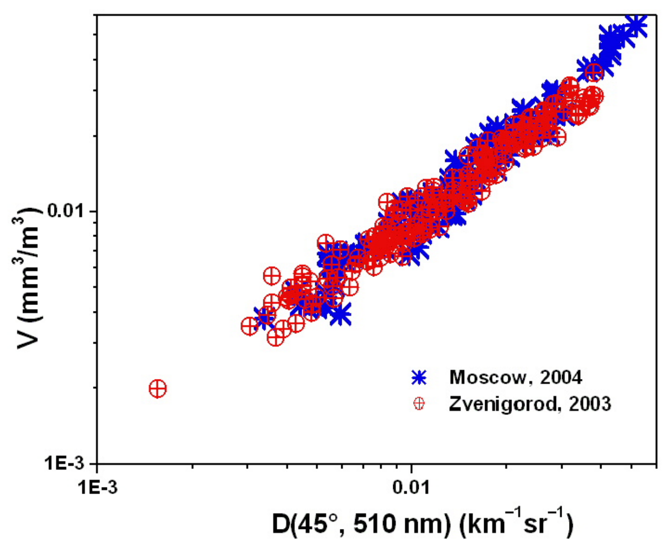

Figure 2. Directed scattered coefficient D (45°, 510 nm) and retrieved volume concentration of aerosol submicron fraction.

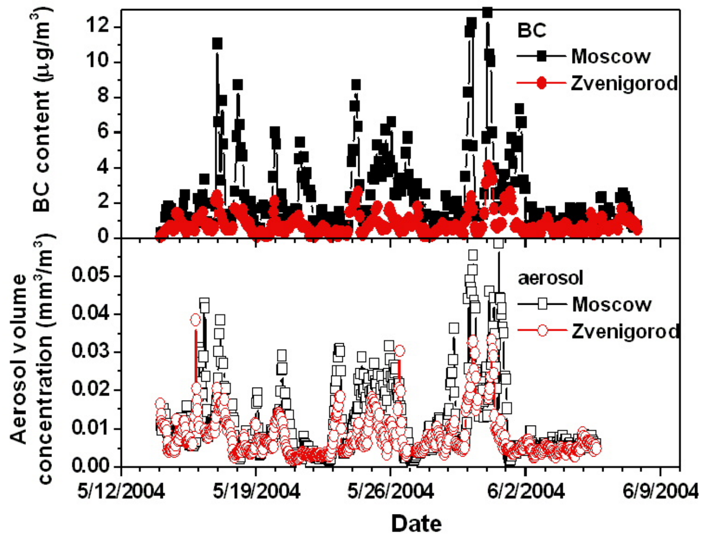

Figure 3. Time series of BC content and aerosol volume concentration at the two sites.

The mean volume concentration *V* of submicron aerosols was about 25% more in Moscow than at ZSS. The mean BC content *M* is about two times greater in Moscow than at ZSS. A scattering plot of *V* versus *M* at the two sites is shown in Figure 4. Correlation coefficients between *M* and *V* exceed 0.8 at the two sites. Mean diurnal behaviors of *M* and *V* are similar in Moscow and ZSS and are characterized by night and morning maximum and afternoon minimum (Figure 5). Correlation coefficients between the aerosol and BC concentrations at the two sites are about 0.7. Maximum correlation is observed during a temporal shift of the Moscow time series for approximately 1–2 hours. Dependences of the correlation coefficients upon temporal shift are presented in Figure 6. Such behavior by the correlation coefficients is evidence that the eastward air transport is prevalent during observation period. Analysis of the back trajectories confirmed this suggestion.

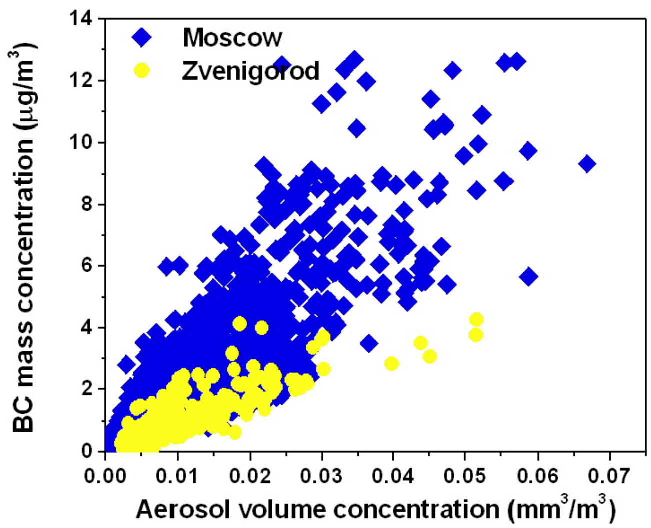

Figure 4. Correlation between BC content and aerosol volume concentration.

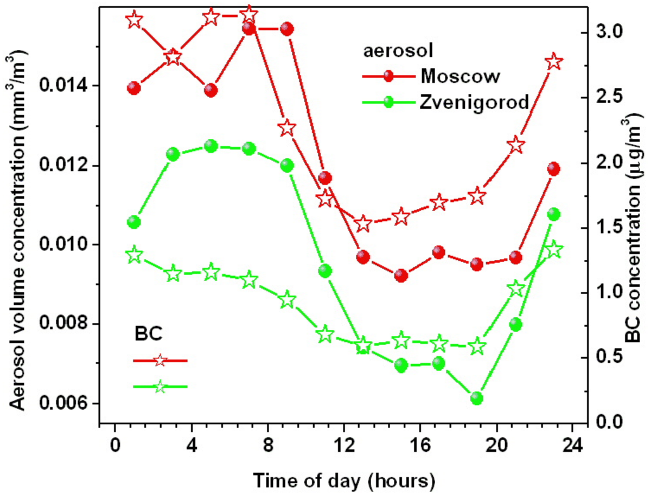

Figure 5. Mean diurnal variations of BC content and aerosol volume concentration.

The correlation between the BC content and the concentration of different-size particles was examined. The maximum correlation is observed for particles with a radius of 0.1 μm. The second maximum is situated at approximately 0.25 μm. Dependence of the correlation coefficient upon particle size is presented in Figure 7. This dependence differs from that between D and differential size distributions, which is also shown in Figure 7. Parallel measurements of aerosol scattering and BC content make it possible to estimate the single-scattering albedo (SSA) of the aerosol. We calculated the SSA assuming the BC mass absorption coefficient was equal to 10 m^2/g. The frequency histograms of SSA are presented in Figure 8. The most probable values of SSA are 0.85–0.9 in Moscow and 0.9–0.95 at ZSS. It must be noted that these SSAs refer to the aerosol dry fraction and must be regarded as the lower limit of SSA.

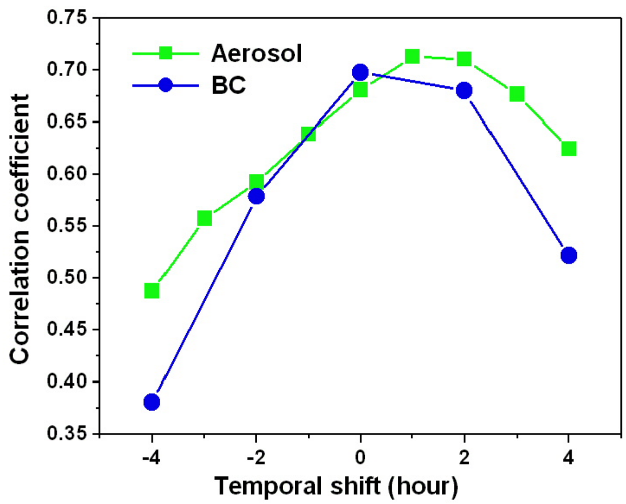

Figure 6. Dependence of correlation coefficients upon temporal shift.

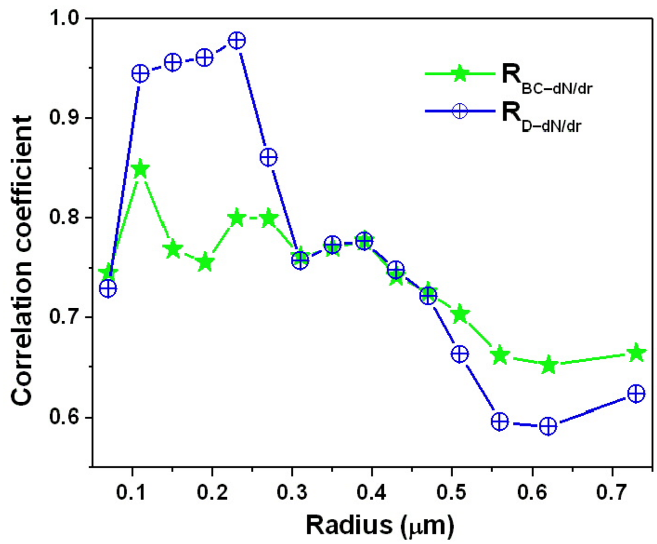

Figure 7. Correlation of BC content and D (45°, 510 nm) with differential size distribution.

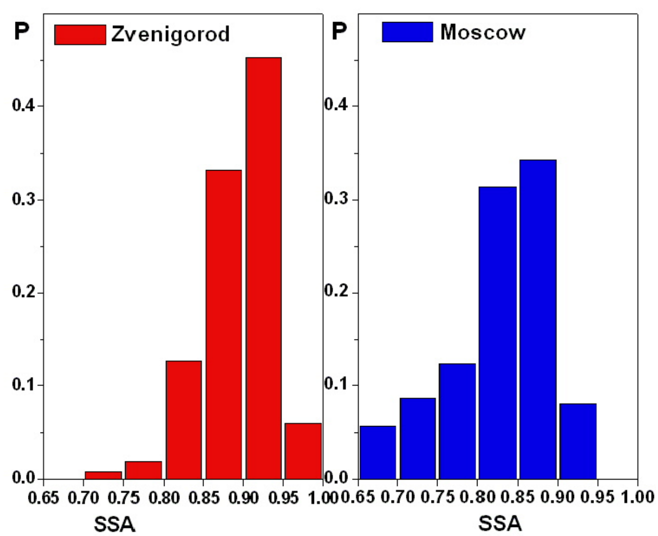

Figure 8. Frequency histograms of SSA.

Conclusions

The levels of aerosol pollution in Moscow and the Moscow region are of the same order. Nevertheless, the relative BC content in Moscow is about two times greater than at ZSS. That leads to a decrease of SSA in Moscow compared to ZSS. The correlation coefficients between submicron aerosol volume concentration at the two sites, as well as BC content, are about 0.7. Maximum correlation between BC content and differential aerosol size distribution is observed for particles with radii of about 0.1 μm.

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