Simultaneous Measurements of Submicron Aerosol and Absorbing Substance in the Height Range up to 7 km

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Introduction

Development of regional models describing the spatial-temporal variability of the aerosol content in air is necessary for solving the radiative and climatic problems. The principal role belongs to the study of the content of an absorbing substance in atmospheric aerosol (let us call it "soot"). It is the important radiative and climatic factor because of the significant effect on the atmospheric transparency and the albedo of clouds and snow.

In this paper we consider the instrumentation, technique, and some results of simultaneous measurements of aerosol scattering coefficient and the content of soot in the height range up to 7 km in Novosibirsk region.

Instrumentation and Technique for Measurement

Measurements of the aerosol characteristics in the height range up to 7 km were carried out by means of the instrumentation installed onboard the AN-30 "Optic-E" airborne laboratory. The setup was created that provides measuring the aerosol characteristics in real time. The data were recorded by a computer. Three-hour flights of the airborne laboratory were performed once every month.

The setup consisted of the FAN nephelometer and the aethalometer (Kozlov et al. 1997). The air samples to be analyzed were collected continuously by direct airflow. The rate was about 10 liter/min in the nephelometer and about 5 liter/min in the aethalometer. Quantitative estimates made taking into account the parameters of the collection path show that the setup measured the characteristics of aerosol particles less than 1 μm.

The nephelometer measured the directed aerosol scattering coefficient at the angle of 45° μ(45°), $km^{-1}ster^{-1}$, and at the wavelength 0.52 μm. The values of the total scattering coefficient σ, km^{-1}, were calculated using the close correlation between μ(45°) and σ. In its turn, the scattering coefficient σ correlates with the mass concentration of submicron aerosol (Gorchakov and Sviridenkov 1981) that makes it possible to estimate the content of aerosol in air. To calibrate the nephelometer, we developed a technique based on recording the scattering coefficients of clear air at different altitudes. The sensitivity of determining the aerosol scattering coefficient was ~0.001 $km^{-1}ster^{-1}$.

The mass concentration of soot C, $\mu g/m^3$ was measured by the modified aethalometer (Figure 1) analogous to that used for ground-based measurements. The aethalometer realizes the method for measurement of diffuse attenuation of light by a layer of aerosol particles directly during the process of collection on the aerosol filter. Wavelength range was 0.4 μm to 1.1 μm with maximum near 0.9 μm. A 100 W halogen lamp was used as a light source.

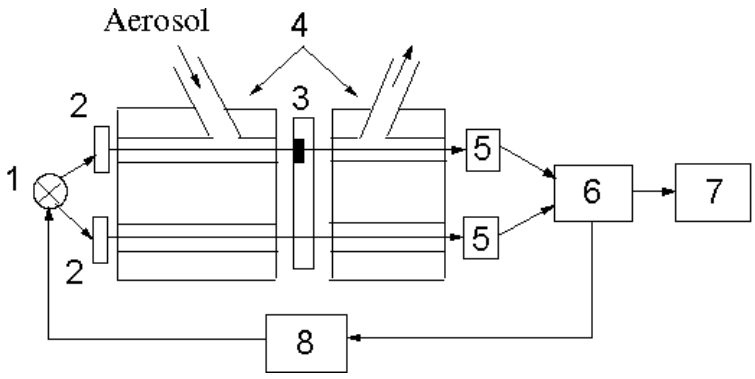

Figure 1. Block-diagram of the aethalometer: 1) halogen lamp; 2) diffuse scatterers; 3) aerosol filter; 4) optical cell; 5) photodiodes; 6) signal transformer; 7) computer; and 8) block of energy supply of the lamp.

Aerosol was settled on the fiber diffuse scattering filter of the AFA-HP type. Measurements were performed in a pulse mode (frequency of 1 Hz). The signal transformer formed and recorded the difference of signals between the operation and reference channels. The sensitivity of the aethalometer is ~0.01 $\mu g/m^3$.

Absolute calibration of the device was performed in the laboratory conditions by means of the pyrolysis generator of soot particles and comparison of the data of simultaneous optical and gravimetric measurements. Soot particles were generated from pyrolysis of butanol in the nitrogen atmosphere at temperature of 1150°C (Figure 2).

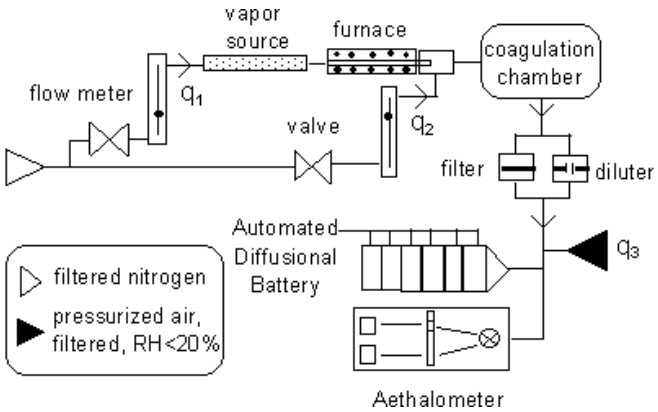

Figure 2. Experimental setup for generation of soot particles.

Passing a coagulation chamber (volume ~ 2L) aerosol is sampled on filter for gravimetric analysis. Initial high particle concentration (106 cm^{-3} to 107 cm^{-3}) is decreased using a set of diluters and filtered air addition. Then aerosol is directed to a screen-type automated diffusion battery (Reischl 1991) that measures particle concentration and size distribution. Aethalometer measured soot aerosol concentration by means of diffusive light absorption detection. The particle size depends on the ratio of the flow rates q_1/q_2 and is in the range 50 nm to 200 nm. The results of optical measurements showed that the behavior of the signal accumulation by the aethalometer was observed for different modes of soot generation in the optical density range up to ATN = 250. This allowed us to use the data of different modes of generation for calibration of the aethalometer. The correlation diagram between the rate of particle mass accumulation and the rate of the change of the optical signal is shown in Figure 3 for 18 modes of generation with different rate of soot accumulation. The calibration constant was estimated as 16.1 $cm^2/\mu g$.

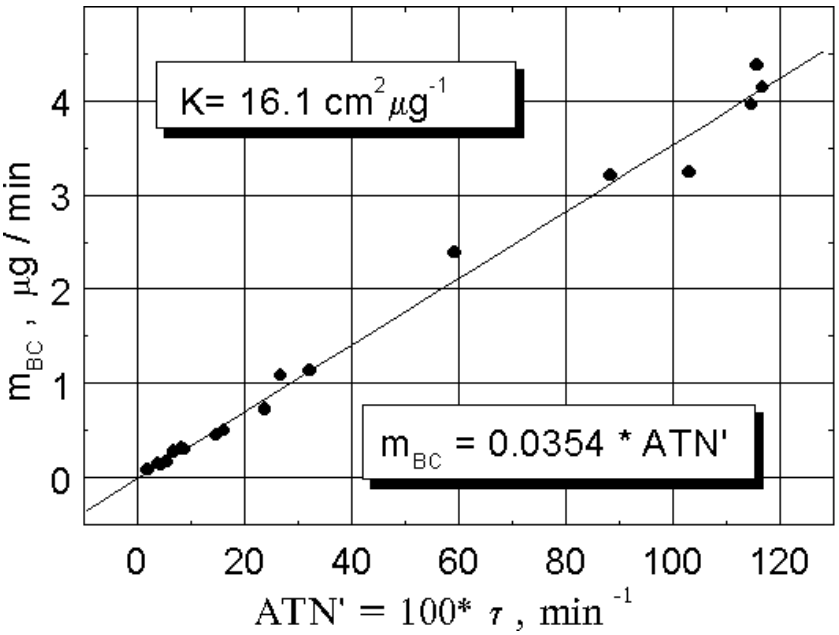

Figure 3. Comparison of the data of optical and gravimetric measurements of the soot concentration.

As a rule, each flight consisted of two stages. At the first stage, the aircraft took off up to 7 km. Then the aircraft flew over a limited area with descending. The aircraft stopped descending every 0.5 km to 1 km for 10 minutes of horizontal flight, then continued descending. The nephelometric data were averaged with the altitude step of 100 m. The data on the soot content were processed for different duration of the signal accumulation (from 1 to 5 minutes) depending on the flight stage.

Results

Profiles of the aerosol scattering coefficient obtained in this experiment are in good agreement with typical seasonal mean profiles characteristics of West Siberian region (Panchenko et al. 1995). At the

same time, preliminary analysis of the data on the soot concentration shows that the character of the change of soot is analogous to the vertical behavior of the submicron aerosol concentration (Figure 4). The mass concentration of soot varies from a few micrograms per cubic meter in the near-ground layer to the values of order 0.01 μg/m^3 to 0.05 μg/m^3 at big height. Then, the variations are, in average, approximately few orders of magnitude. The tendencies of the vertical variations of the soot content are in agreement with some data obtained earlier (Hansen and Rosen 1984). The estimates of the relative content of soot in aerosol particles show that this value is 1% to 7% and weakly changes at different heights. This result requires subsequent experimental investigations including the analysis of the peculiarities of the technique for measurements.

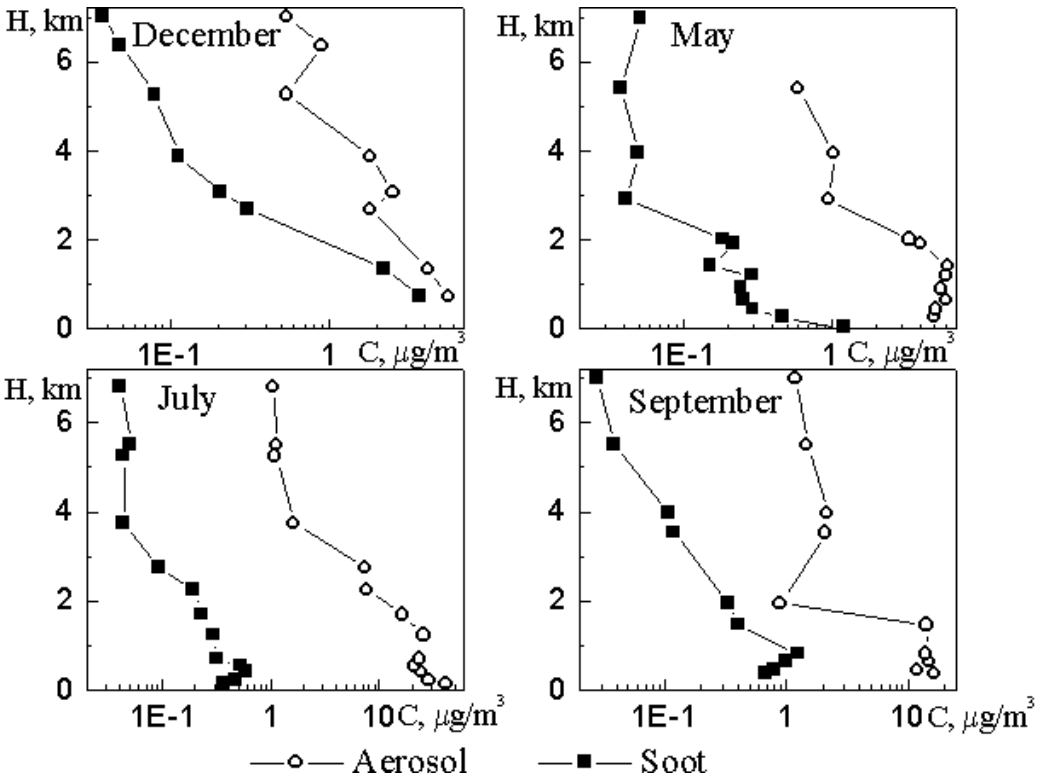

Figure 4. Mass concentration of aerosol and soot measured in different seasons

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