Airborne Studies of Submicron Aerosol in the Troposphere Over West Siberia

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Introduction

Submicron fraction particles that have the longest lifespan and are included in almost all atmospheric processes (Rosenberg et al. 1980; Rosenberg 1983) are of special importance among the great variety of sizes of particles present in the atmosphere. Submicron particles mainly determine the optical state of the atmosphere in the visible spectral range, essentially cause the absorption of infrared radiation (Rosenberg et al. 1980; Panchenko 1988) and, since they are the products and participants in all aerosol-to-gas transformations, accumulate a lot of various chemical compounds and transfer them to large distances.

Investigation of the processes of the spatial-temporal variability of aerosol particles for different climatic zones of the earth is the experimental base for studying their effect on climatically and ecologically significant factors and estimating their unfavorable tendencies. The increasing anthropogenic loading of the earth's atmosphere is creating an urgency for aerosol research. Regardless of how perfect the analytical and numerical methods of solving radiation problems may be, success in forecasting climatic change is mainly determined by the reliability of the experimental data on optical parameters of the atmosphere and of the description of their variability under the effect of external factors.

Experiment

Complex airborne investigations carried out during a comprehensive geophysical experiment in the characteristic climatic zones of the northern hemisphere made it possible to obtain new information on the optical properties of atmospheric aerosol (Belan et al. 1995).

Taking into account the accumulated experience in investigating aerosol processes and using the characteristic lifetime of submicron aerosol particles in the troposphere as a guide, analyzing the factors that determine the variability of aerosol characteristic in the regional scale should be our primary concern. We chose West Siberia as the region for investigations because we performed monitoring observations there from onboard an aircraft-laboratory (total amount of the data obtained is 602 vertical profiles of aerosol scattering coefficient) during 1986-1988. The applied instrumentation and measurement technique is described by Panchenko et al. (1994).

The most significant examination of the bulk of data obtained was based on the comparison of meteorological parameters and synoptic attributes observed during the experiment with analogous long-term data obtained by the Russian Meteorological Network (Guterman 1980). Average values of meteorological parameters (temperature and specific humidity of air) in our bulk of data are close to the average climatic data for our region (Panchenko et al. 1994). This fact provides reason enough to analyze in detail the hierarchy of external processes determining the transformation of the scattering coefficient stratification $\sigma(H)$ and the variations of aerosol content in the lower troposphere. The analysis was carried out in order to develop a model that would adequately take into account the role of any factor in general variability of aerosol characteristics.

Results and Discussion

The monthly average values of the optical thickness τ ($\lambda = 0.52\,\mu m$) and isolines of the scattering coefficient at the same wavelength are shown in Figure 1.

It follows from the analysis of these data that near the ground the greatest aerosol content is observed in winter and is caused by intensification of anthropogenic aerosol sources and by the fact that the inverse temperature profile in the near-ground atmospheric layer prevents penetration of aerosol emission into upper layers of the atmosphere.

The elevated aerosol content in spring at heights above 2.5 km is connected with the movement of the snow melting boundary and is caused by the aerosol coming to the atmosphere of West Siberia from the remote sources under the effect of the westward transfer.

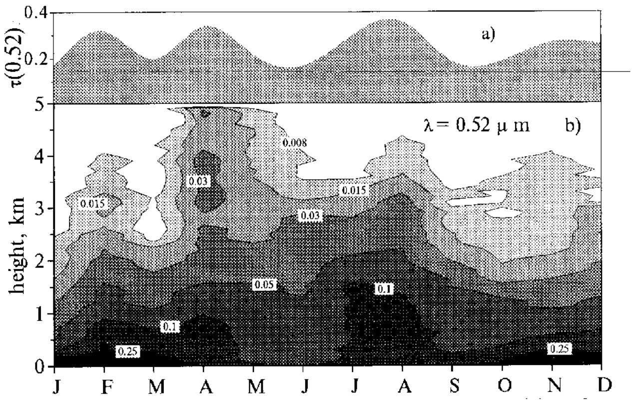

Figure 1. Annual behavior of optical thickness (a) and isolines of aerosol scattering coefficient, km^{-1} (b).

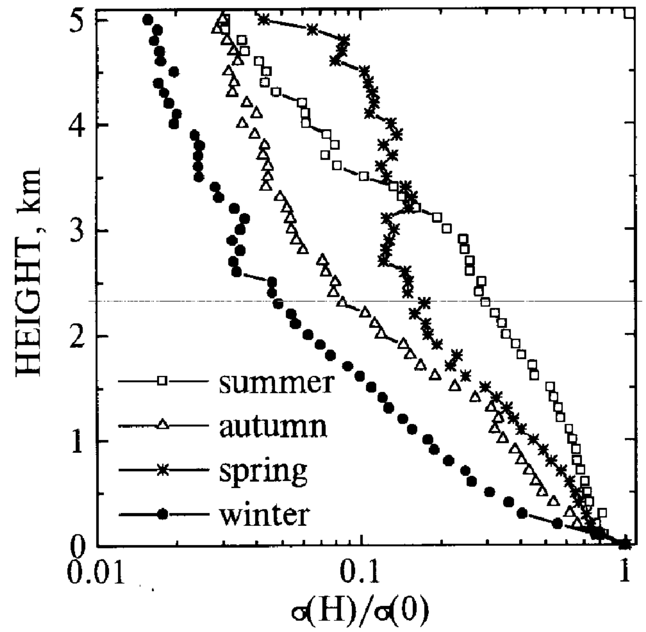

Figure 2. Normalized vertical profiles of aerosol scattering coefficient.

It is noted that in the majority of realizations the vertical profile σ(H) has the layer structure, and the layers are situated near the levels where the alternation of stable and nonstable microareas (ΔH ~ 100 m) is observed in the temperature stratification.

Season peculiarities of formation of σ are caused mainly by the temperature regime of the atmosphere, and one can use the three-layer concept of aerosol height distribution as the first approximation for their description. Within the frameworks of this approach, one can select the following height ranges: up to H_1 is the ground layer, H_2 is the height of the layer of intense turbulent exchange, above H_2 is the layer of free atmosphere (Figure 2).

Aerosol characteristics in different air masses coming to West Siberia in different seasons have reliable differences. In particular, we revealed the differences in vertical profiles of aerosol scattering coefficient in Arctic and polar air masses (Figure 3).

In the winter, above ~500 m, Arctic air contains, on average, more aerosol particles than observed in polar air. In the spring, above 2.5 km, there are observed differences in the Arctic air from the characteristic of the winter conditions, but in the lower 1-km layer the air becomes similar to the summer air. In the summer, Arctic air masses bring air to the region under investigation that is clearer in all height ranges in comparison with polar air masses.

The estimate of season peculiarities of aerosol accumulation in the Arctic atmosphere assessed from the data of airborne nephelometric measurements over West Siberia showed that the estimated values of the mass content are close to the values that are observed immediately in the Arctic area. The analysis showed that in winter there is no daily behavior of the aerosol vertical profile above the ground layer. This makes it possible to take into account only variations of the relative humidity when modeling optical characteristics.

Principal features of daily transformation of aerosol vertical profile in the spring and autumn are similar to the summer daily behavior, but the amplitude of variations is much less. In summer, as a result of the heating of the underlying surface and the atmosphere during the day, the height of the mixing layer increases and the layers are filled by aerosol. In the evening, the aerosol emission from the near ground layer stops, and the lower atmospheric layers (below H ~ 1.5 km in average) start to empty. Above this layer up to H ~ 3.5 km, some increase of the height of the mixing layer continues.

Conclusion

The data obtained provide evidence of the fact that taking into account all these factors is favorable for increasing the accuracy of the developed regional models of the optical characteristics of atmospheric aerosol.

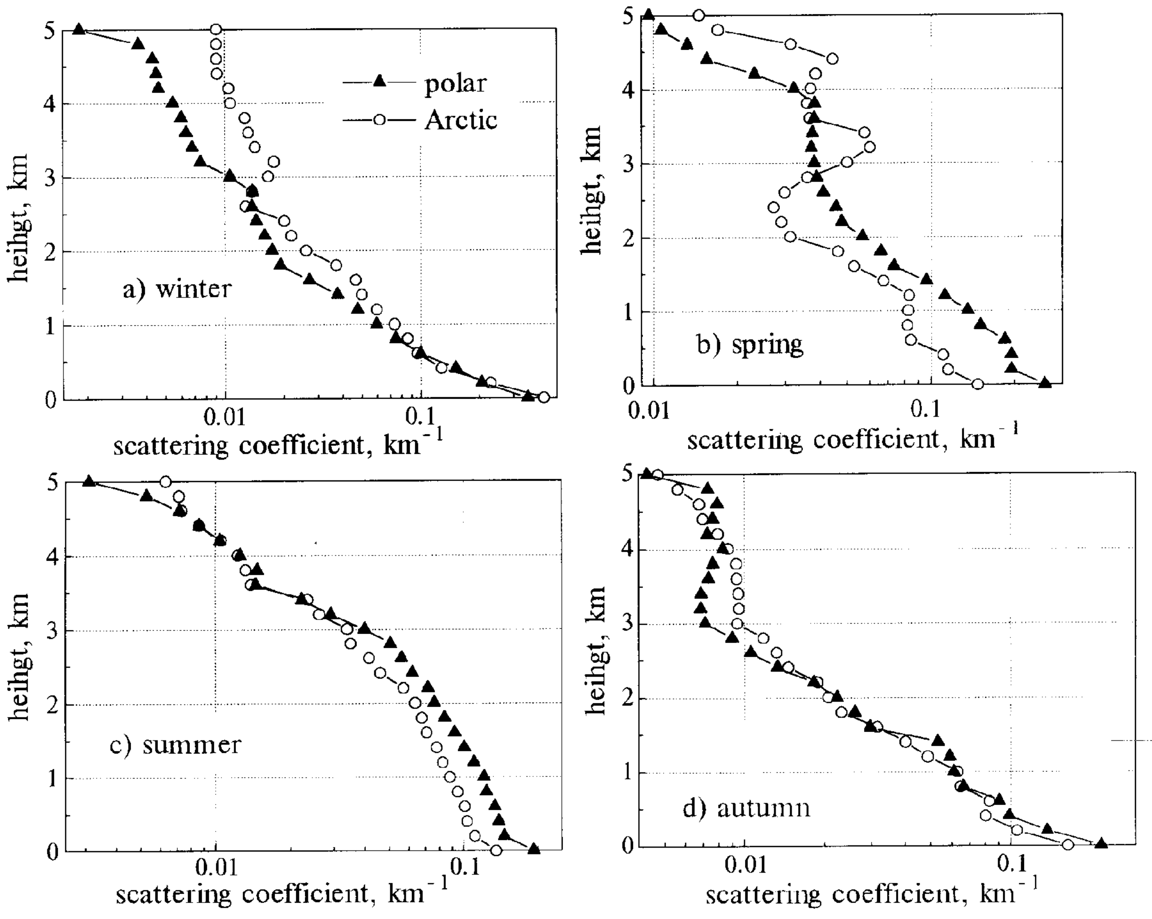

Figure 3. Vertical profiles of aerosol scattering coefficient in different air masses.

References

Belan, B. D., V. E. Zuev, and M. V. Panchenko. 1995. Main results of airborne aerosol sounding conducted at the Institute of Atmospheric Optics SB RAS from 1981 to 1991, *Atmos. Oceanic Optics*, **8**, 66-79.

Guterman, I. G. (Ed.). 1980. *New Aeroclimatic Handbook of the Free Atmosphere over USSR*. Gidrometeoizdat, Moscow.

Rosenberg, G. V., G. I. Gorchakov, Yu S. Georgievskii, and Yu.S. Lyubovtseva. 1980. Optical characteristics of atmospheric aerosol. In *Atmospheric Physics and Climatical Problems*, p. 216-257. Nauka, Moscow.

Rosenberg, G. V. 1983. Appearance and development of atmospheric aerosols — kinetically caused parameters. *Atmos. Oceanic Phys.*, **19**, 21-35.

Panchenko, M. V. 1988. Relative humidity and IR absorption by submicron aerosol, *Atmos. Opt.*, **1**, 25-29.

Panchenko, M. V., S. A. Terpugova, A. G. Tumakov, B. D. Belan, and T. M. Rasskazchikova. 1994. Some aspects of a technique for airborne nephelomatric studies of the tropospheric aerosol on a regional scale, *Atmos. Oceanic Optics*, **7**, 546-551.