Results of Long-term Airborne Research of Aerosol Characteristics of the Lower Troposphere over Former Soviet Union

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Introduction

The improvement of general atmospheric circulation models is mainly determined by the quality of the block of radiation calculations, where it is necessary to take into account optical properties of atmospheric aerosol, in addition to clouds and greenhouse gases.

In this paper we discuss the main results of the study of optical and microphysical parameters of aerosols in the lower troposphere, which were obtained at the Institute of Atmospheric Optics from 1981 to 1991 while carrying out the airborne sounding of the atmosphere over the former Soviet Union.

Spatial Variability of Aerosol Number Density

The instrumentation complex of the aircraft-laboratories of the Institute of Atmospheric Optics and the bulk of data obtained allowed us to analyze the aerosol processes of different scales in space and time, i.e., from fluctuation (microscale) variations to long-term variations occurring in the atmosphere (Zuev et al. 1992). The map of suspended matter distribution over the former USSR is shown in Figure 1. Data of vertical sounding of the atmosphere in different geographical regions from 1988 to 1991 were used to make the map. The data were averaged over the height range up to 3 km. ln order to understand the regional aerosol content, the profiles obtained directly above the industrial centers were excluded from the data processing.

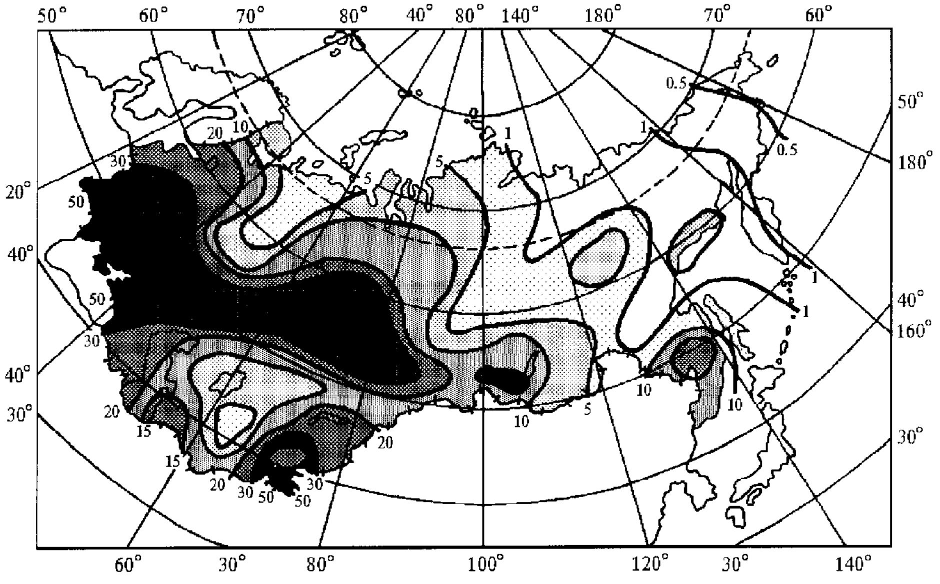

Figure 1. Distribution of the aerosol number density $\overline{N} = \frac{1}{3}\text{km} \int_{0}^{3\text{km}} N(h)dh$ **(1)** over the former USSR.

It is clear that under this approach to formation of the data arrays (different statistical provision both of the amount of measurements and the statistical weight of different weather and season events in each of geographical sites) the isolines shown in the map and the conclusions drawn based on them are preliminary. Nevertheless, even under such an approach to analysis, it can be seen from Figure 1 that several zones of enhanced content of suspended matter can be isolated over the territory under study. The principal zone is located over the west regions of the European part of the USSR and it is caused by addition of the enhanced background concentrations of aerosol being transferred from West Europe and from emissions of the Donetsk-Dnepropetrovsk industrial zone taking into account west-to-east transfer of the aerosol.

The effect of this zone spreads to the southern regions of East Siberia. It should be noted that the strengthening effect of the Ural industrial zone is added as well as the effect of the industrial plants located in the Northern Kazakhstan and southern West Siberia. This effect manifests itself as the appearance of two additional zones of enhanced aerosol concentration. The background concentration of suspended particles in the region affected by Irkutsk industrial zone is somewhat lower. One more clearly pronounced zone of enhanced aerosol concentration is over the territory of the Middle Asian republics. Its appearance can be explained by air stagnation in the mountain valleys where the industrial enterprises are concentrated.

In spite of the fact that we have excluded all the profiles measured over the "caps" of the industrial cities from data processing, Figure 1 shows that the anthropogenic activity is manifested in the regional background of pollution.

Variability of the Aerosol Optical Depth

The distribution of the optical depth at the visible wavelengths correlates with the spatial distribution of aerosol number density in the lower troposphere. But this parameter has more complex distribution and more strongly depends on the seasonal variations of the atmospheric circulation and distant transport of aerosol particles (Gushchin 1988; Panchenko and Terpugova 1994).

The regional spatial inhomogeneity of aerosol number density distribution is also manifested in its other characteristics, i.e., chemical composition particle size distribution, etc.

Variability of Aerosol Chemical Composition

Figure 2 represents mean concentrations of different chemical components of aerosol substance for three regions such as Kamchatka, West Siberia, and Kazakhstan, where the greatest number of samples (867, 642, and 167, respectively) were collected.

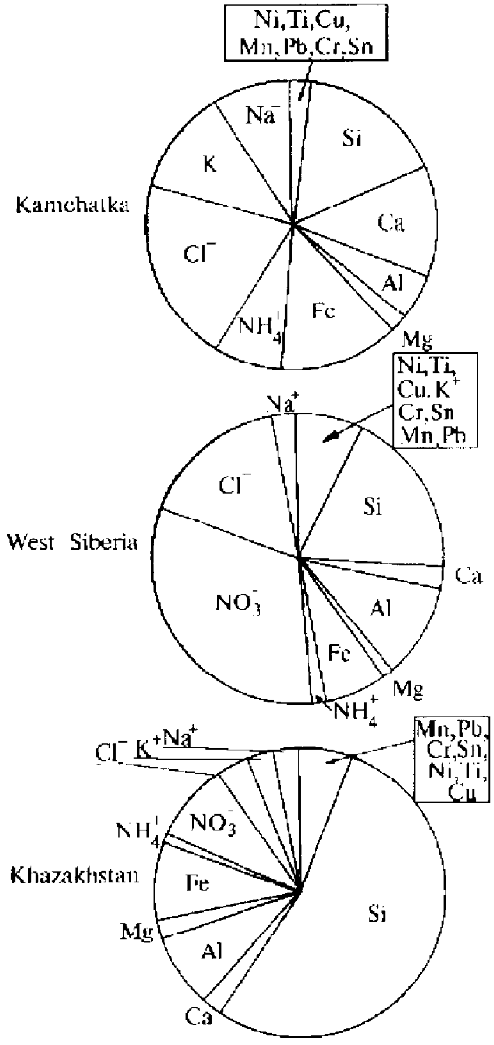

Figure 2. Chemical composition (%) of aerosol over different regions (Kamchatka, Western Siberia, and Kazakhstan).

Kamchatka is marked by the lowest particle number density. The analysis of data from Kamchatka revealed that aerosol particles over this region possess two basic sources of formation, i.e., sea surface (Na^+, K^+, Cl^-, and NH_4^+) and underlying surface of the peninsula (Fe, Mg, Al, Ca, and Si).

As indicated earlier (Figure 1), Western Siberia, especially its South, is affected by anthropogenic discharges from local sources, and it possesses high background of admixtures brought by the system of west-to-east transport. This is clearly manifested in a sharp increase of concentration of such components as Cl^- and NO_3. The concentration of soil fraction also increases with the increase of total concentration.

Kazakhstan is in an intermediate position here. All of the three fractions can be separated out in aerosol over this region. They are the marine, soil, and photochemical (anthropogenic) ones that can be accounted for by the proximity of the Caspian and Aral Seas and the existence of large industrial objects in its territory. Sharp increase of Si concentration over this region can be explained by the presence of vast deserts.

Inter-annual Variations

The more complex issue in solving the problems connected with the prediction of global climate change is the problem of correct estimation of the relationship between natural and anthropogenic factors (in our case, estimation of the aerosol optical properties). On the one hand, the aforementioned data show that the contribution of anthropogenic sources is well pronounced on the regional scale. On the other hand, the analysis of inter-annual variations of the aerosol number density in the lower troposphere over western Siberia (we have the most statistically representative bulk of experimental data for this region) shows that the amplitude of inter-annual variations of both the number density and the optical depth are noticeably greater than the spatial and seasonal variations observed (Panchenko and Terpugova 1994).

The inter-annual behavior of aerosol number density over Western Siberia is shown in Figure 3. As seen from this figure, the aerosol number density decreased from 1981 to 1988 and then increased, this increase was particularly sharp in 1991.

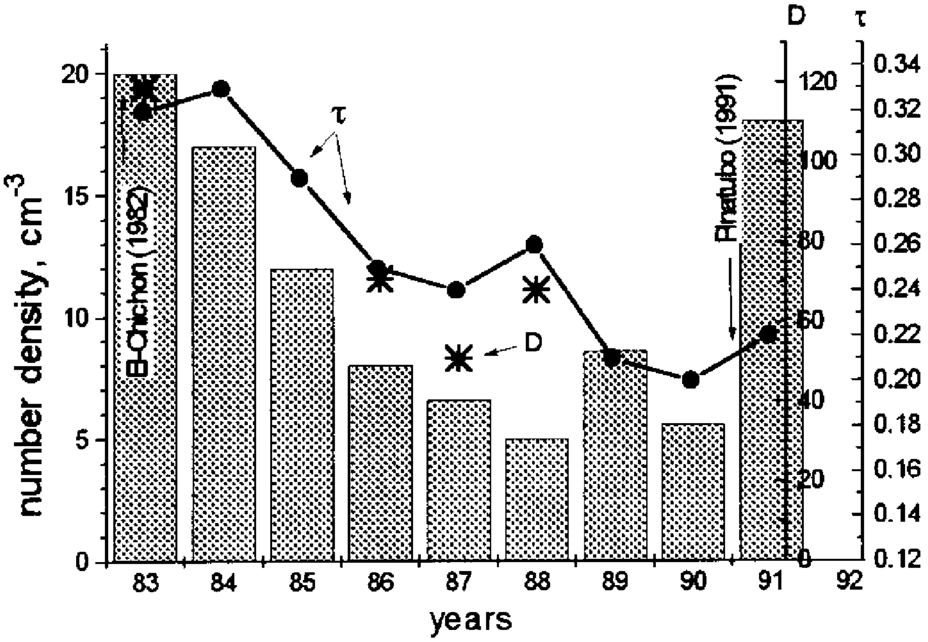

Figure 3. Temporal behavior of average aerosol number density in the layer up to 3 km over Western Siberia; optical depth of the atmosphere over Moscow (τ) (Abakumova and Yarkho 1992) and aerosol optical density over Western Siberia (D) (Gushchin 1988)

In the climate theory, some variations in the meteorological parameters with periods exceeding one year are known (Monin 1969). The curve shown in Figure 3 most likely follows the 11-year cycle. At the same time, the analysis of the data on the optical depth observed during this period over different sites (Gushchin 1988; Abakumova and Yarkho 1992) allows us to suppose that the principal changes are related to the consequences of the great volcanic eruptions (El-Chichon 1982 and Pinatubo 1991). Noticeable temperature variation were also observed in our region at this time. The periods of the greatest aerosol content were characterized by more “warm” winters and “cool” summers. When the atmosphere was more “clear,” the situation was inverted.

Conclusion

Now we can not unambiguously answer the following questions. Is the observed increase of the aerosol concentration in the lower troposphere over Western Siberia a direct result of the increase of the aerosol matter amount over all of the northern hemisphere due to the volcanic eruptions? Or has the increase of the stratospheric aerosol content, changing the radiative regime of the hemisphere, caused the change of the atmospheric circulation, and, hence, the coming of air masses with another aerosol filling to our region?

Some data analyzed, in particular, the analysis of aerosol chemical composition, forces us to support the second hypothesis. But we demonstrate the revealed inter-annual variability of aerosol and thermodynamic parameters of the atmosphere over the specific region in order to show that the amplitude of variations of the whole complex of atmospheric parameters caused by “natural” (not anthropogenic) reasons can noticeably exceed the variability caused by the anthropogenic impact.

References

Abakumova, G.M., and E.V. Yarkho, 1992: Measurements of the aerosol optical depth over Moscow during 37 last years. *Meteorologia I gidrologia*, **11**, 107-113.

Gushchin, G.P., 1988: The methods, instrumentation and results of atmospheric spectral measurements. Leningrad, Gidrometeoizdat, 200 pp.

Monin, A.S., 1969: Weather prediction as a physical problem. Moscow, Nauka, 184 pp.

Panchenko, M.V., and S.A. Terpugova, 1994: Annual behavior of the content of submicron aerosol in the troposphere over West Siberia. *Atmos. Oceanic Optics*, **7**, 552-557.

Zuev, V.E., B.D. Belan, D.M. Kabanov, V.K. Kovalevskii, O.Yu. Lukyanov, V.E. Meleshkin, M.K. Mikushev, M.V. Panchenko, I.E. Penner, E.V. Pokrovskii, S.M. Sakerin, S.A. Terpugova, G.N. Tolmachev, A.G. Tumakov, V.S. Shamanaev and A.I. Shcherbatov, 1992: An airborne laboratory AN-30 “Optic-E” for ecological investigations. *Atmos. Oceanic Optics*, **5**, 658-663.