NUMBER DENSITY AND SIZE–SPECTRUM OF ATMOSPHERIC AEROSOLS IN SIBERIA

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In summer seasons of 1991, 1992, and 1993, we have measured parameters of atmospheric aerosols in different sites of Siberia, including Lake Baykal and Novosibirsk region. Dynamics of the aerosol number density observed in these measurements can be well explained using the existing theories of the aerosol formation.

The purpose of the present study was to measure the concentration and size–distribution and to investigate the origin of continental aerosol in Siberia. Siberia is characterized by relatively sparse population and a small number of industrial centers. Different locations were chosen for our measurements: near Lake Baykal in 1991 and near Novosibirsk in 1992. Since summer 1993 regular observations of atmospheric aerosol were started near Novosibirsk.

MEASUREMENT TECHNIQUE

For the range of particle radii less than 0.1 μm the measurement equipment used were a TSI 3040 screen diffusion battery (SDB) and a TSI 3020 condensation nuclei counter (CNC). To retrieve the aerosol size–distribution from the SDB set of measurements, the Tikhonov's regularization procedure[2] was used. Single– and two–stage impactors[2] and a free air impactor[3] were used to collect the particles with radii 0.1–100 μm onto glass plates to obtain their number density and size–distribution using an optical microscope. The total light scattering by aerosol particles was measured by a commercially available nephelometer FAN–A.

RESULTS AND DISCUSSION

Measurements of atmospheric aerosol near Lake Baykal were carried out at the end of July 1991 and lasted for two weeks. The measurements were conducted at a place on the west side of Lake Baykal near the village of Listvyanka, 70 km SE of Irkutsk. The measurement devices were located on the mountain at an altitude about 500 m above the lake. The instrumentation, used in this expedition included a CNC TSI 3020, a SDB TSI 3040, a single–stage impactor and a free air impactor. The total aerosol number density was recorded continuously. The mean aerosol number density during the measurement period was about 5700 cm^{-3}. Figure 1 shows the evolution of the daily mean aerosol number density. It shows a density peak between 10:00 hours and 14:00 hours and an increase in the density after this peak in evening. The mean size–distribution of aerosol from SDB data and the measurements done with the impactors is shown in Fig. 2.

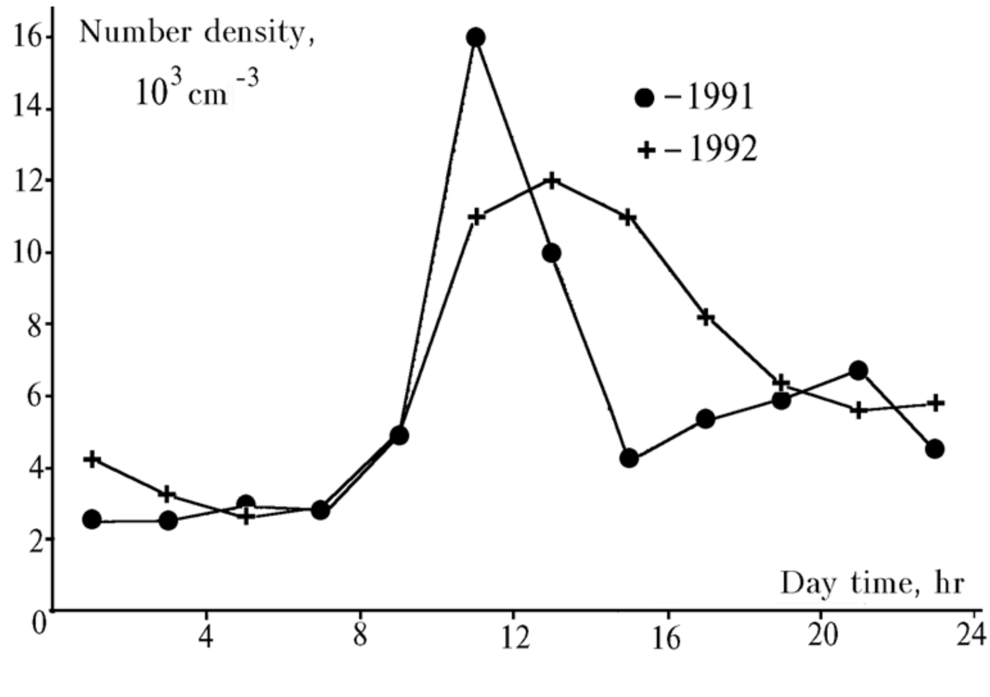

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FIG. 1. Daily mean aerosol number density. Lake Baykal, 1991 and Novosibirsk region, 1992.

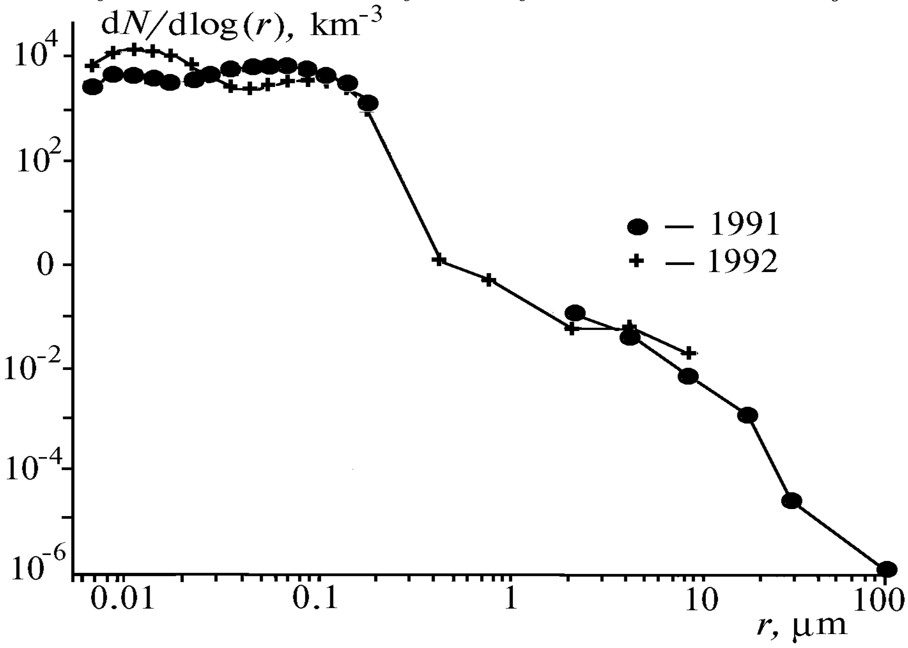

FIG. 2. Mean size–distributions measured near Lake Baykal (1991) and Novosibirsk (1992).

The measurements near Novosibirsk were carried out in June–July 1992 and lasted about one month. The measurement site was about 30 km South of Novosibirsk and about 12 km East of Akademgorodok. Akademgorodok has a population of about 100 000 people and no industry. The measurement devices used in this expedition included a CNC TSI 3020, a SDB TSI 3040, and a two–stage impactor.

The mean aerosol number density during the measurements was about 6500 cm^{-3}. The average results of the measurements are plotted in Fig. 1. The daily behavior of the total number density differs from the results obtained near Lake Baykal. The second density peak is not so pronounced, and it appears as an arm after the noon peak.

The mean size–distribution obtained is shown in Fig. 2, together with the aerosol size–distribution measured near Lake Baykal in 1991. By comparing both distributions one can see that they are very similar in the overlapping ranges. Both curves are two–modal for particles with $r < 0.1$ μm. For larger particles, both curves show a power decrease with a mean exponent of about three. The agreement between the distributions measured at locations more than 1300 km apart is quite surprising, but seems to support the idea of the "Siberian aerosol" model.

It is seen from Fig. 1 that the increase of aerosol number density correlates with the solar radiation. We suggest, therefore, that most of the particles are produced by gas–to–particle conversion. This is supported by the fact that during the first peak of aerosol number density small particles with the modal radius 10–20 nm were mainly observed.

The rate of consumption of precursor gases, as the rate of aerosol production, is proportional to the concentration of precursor gases. If these gases are accumulated during the dark period, their concentration achieves a maximum before sunrise. It means that in the morning the production rate of the particles may be high, although the solar radiation is not so intense as at noon. As such precursors are consumed rapidly in photochemical reactions, the production rate of new particles decreases. At the same time, the particles coagulate.

The main reactive gas components have their sources at the surface. This means that the main aerosol production reactions take place also in the surface layer. The atmospheric convection after sunrise causes the exchange between the surface layer and the higher layers which have low aerosol density. This dilution causes a decrease of the particle density after reaching its maximum.

A further increase of the particle number density in the surface layer occurs in the evening if there is no convection. So the density of aerosol particles increases, and second maximum appears. After sunset, no new particles are produced in photochemical reactions, and the particle number density decreases due to coagulation.

The difference between the results of measurements in 1991 and 1992 may be explained assuming that more intensive dilution at the measurement sites near Lake Baykal occurred because of mountain–valley circulation.

To study more carefully the diurnal behavior of aerosol concentration, depending on season, and the seasonal evolution of aerosol concentration, the series of measurements at the eastern border of Akademgorodok was started in summer, 1993. The aerosol concentration was measured with a nephelometer in terms of total aerosol light scattering at the angle of 45°. This method is mostly sensitive to the aerosol particles in the size range 0.1–1 μm. The measurement results are presented in relative units. As the reference the molecular light scattering of clear air is used.

The first results are shown in Fig. 3, where the daily mean data on aerosol light scattering for June and August are plotted. One can see that daily evolutions also have two–peak structure with more pronounced evening peak. This fact may be explained taking into account that during the morning peak of total number density the main fraction of particles belongs to small particles, produced by gas–to–particle conversion. These small particles scatter light not so strongly as the aged aerosol ones accumulated in the surface layer in the evening.

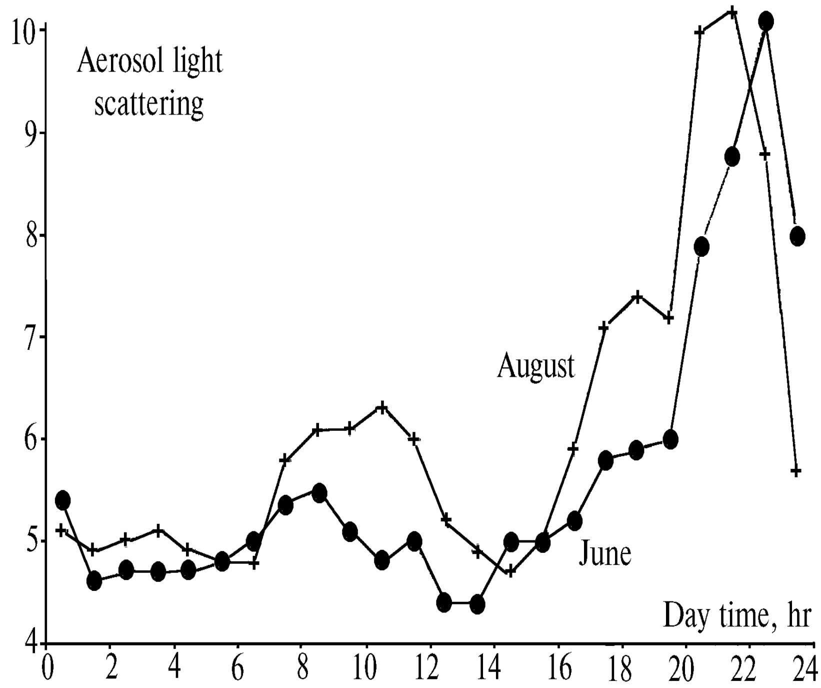

FIG. 3. Daily mean aerosol light scattering in June and August, Akademgorodok, 1993.

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