Some results of joint observation for variability of electric field of the atmosphere and aerosol concentration at the South Baikal

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Results of long-term synchronous observations of the atmosphere electric field, concentration of submicron aerosols, and meteorological conditions with high time resolution (minutes) are considered. The correlation and spectral analysis were applied to evaluation of aerosols and electric field interrelation; and some hypotheses on the mechanism of their interaction are under discussion. The mean daily behavior of the considered parameters is presented.

Introduction

The atmosphere electric field is one of the important characteristics of air, closely correlating with many meteorological processes and the character of aerosol admixtures. In particular, the potential of the atmospheric electric field essentially depends on the concentration of charged particles, which can have different origins.

It is known that the increase of the dust particle concentration, neutral as a rule, leads to a decrease of the fraction of light ions and to a decrease of the air electric conductivity. Therefore, the strength of the electric field should increase. At the same time, some fraction of aerosol particles can take electric charge at collisions, contacts, and crushing. Charging of atmospheric aerosol under natural conditions occurs also due to adhering of atmospheric ions generated in the processes of ionization of atmospheric gases.

The researches carried out at A.I. Voeikov Main Geophysical Observatory indicate that the strength of electric field and electric conductivity of air during the periods of active nuclear testing essentially changed in the regions situated thousands kilometers far from the testing place. Observations of atmospheric precipitation carried out by the Russian Hydrometeorologic Service showed the presence of radionuclides in aerosols.

Aerosols can take charge under conditions of industrial pollution, for example, due to systems for cleaning air by electric filters.[1] So, aerosols can affect the electric field during its transfer in the atmosphere. At the same time, charged particles in electric field undergo the effect of Coulomb forces, therefore, charged aerosols move along the force lines of the electric field. The Coulomb forces under some meteorological conditions can have a principal significance in the movement of charged particles, for example, at the absence of strong turbulent mixing. The processes of condensation and coagulation growth of cloud particles having electric charge and the mechanisms of charging particles in an ionized medium and in the electric field have been studied quite well.

A number of theoretical papers and laboratory researches, discussed at conferences of different ranks[2-4] were devoted to the mechanisms of charging aerosol and its interaction with the electric field. Such experiments under natural conditions were carried out more rare, and the researches based on correlation of the electric field with the radiation extinction in the atmosphere should be noted here.[5,6]

In this paper we discuss the results of joint recording of the concentration of near-ground aerosol, the strength of electric field, and meteorological characteristics in the region, comparatively free of industrial pollution: coats of Southern Baikal.

Region of works and measurement methods

Observations of the concentration of near-ground aerosol and the strength of the atmospheric electric field were carried out at Baikal near village Listvyanka at the territory of Baikal Astrophysical Observatory (BAO) of ISTP SB RAS. The height of the observation site was 220 m over the Baikal level. Aerosol sample collector was at a height of 2 m above the ground surface. The aerosol number density was recorded continuously by means of the complex, including laser and diffusion aerosol spectrometers (with condensation growth of particles) designed in L.Ya. Karpov Moscow Scientific-Research Institute of Physical Chemistry.[7]

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The complex allows covering a wide range of particle sizes including fine-dispersion and submicron ranges, approximately up to 5–10 μm (the upper boundary of the particle size range was not determined precisely, because the sampler was designed as a usual turned-over funnel free of separator). At the first stage, mainly the data on the submicron aerosol concentration were attracted for comparison with the atmosphere electric field. Further, a more detailed analysis of correlations between the electric field and the aerosol physical parameters was planned after processing and analysis of all data on the aerosol spectral composition.

The electric field strength was measured by electrostatic fluxmeter installed at a height of 2.5 m on a flat metallic roof. In order to perform comparative observations, the second fluxmeter was installed in a week on the ground surface (next to the first one), and then it was displaced to 1.5 km from the site of recording to the deep valley of river Cheremshanka at the distance of 200 m from the Baikal coast to about a 15 m height hill above the water level. The fluxmeter was installed here at the height of 2 m on the metallic grid smoothing the electric field. All parameters at the first site were recorded using the ADC to computer, and at the second site to autonomous digital recorder with an averaging period of 10 min. The total period of joint recording was 3 months (August–October 2005).

Meteorological parameters of the atmosphere (wind velocity and direction, temperature and humidity of air, atmospheric pressure) in the region of investigations were recorded by means of the ultrasonic meteorological station ("Meteo-2" designed at the Institute of Atmospheric Optics). The intensity of the total solar radiation was also recorded, which allowed to indirectly judge about cloudiness during the observations.

Discussion of the obtained results

Diurnal variations of the aerosol concentration N, strength of electric field at BAO E_{BAO}, wind velocity V, and relative humidity Hu averaged over the entire period are shown in Fig. 1. Diurnal variations of E_{BAO} and E_{val} are presented in the Table. The diurnal behavior of E is constructed from all values including the violated weather, when negative values can be observed. The amplitude of the diurnal behavior of E_{BAO} equal to about 60%, exceeded the amplitude of the aerosol concentration, humidity, and wind velocity.

Electric field represents the electric charge of the atmospheric column and electric charges near the surface, while meteorological conditions and aerosol concentration reflect the near-ground characteristics. The first maximum in the morning coincides with the global one (evening by Greenwich time). The synchronous character of E_{BAO} and N variations is observed at the nighttime, and opposite changes occur in the afternoon.

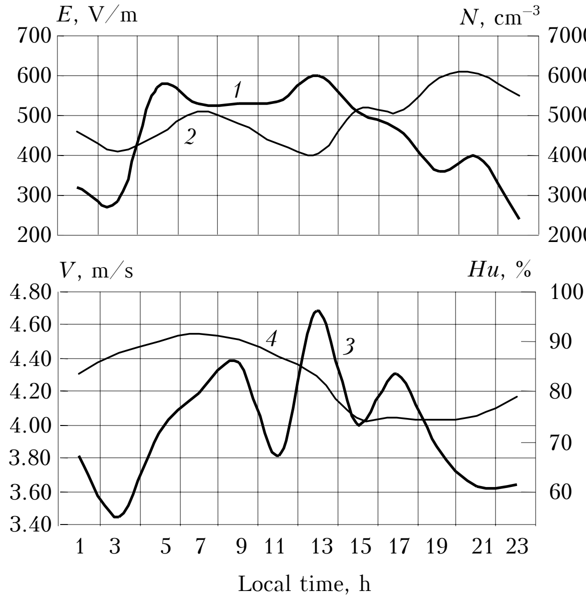

Fig. 1. Mean diurnal behavior of the electric field strength (*1*), aerosol concentration (*2*), relative humidity (*4*), and wind velocity (*3*).

Correlation analysis of the hourly mean values shows a positive correlation between the wind velocity and the aerosol concentration (correlation coefficient is 0.48). The correlation coefficient between the field strength and the aerosol concentration is negative ($r = -0.47$). The correlation coefficients are significant, they are obtained from about 1000 hours of long time series of joint recording in fall. Perhaps, the manner of correlation in other seasons can be another.

It is interesting to note that the cross-correlation analysis of hourly mean values for finely dispersed aerosol (from 3 nm) has not a time shift, while the lag of concentration relative to E by 2–3 hours is observed for cross-correlation function of larger aerosols (from 0.15 μm). Earlier, in measurements at the Irkutsk Hydrometeorologic Observatory, we obtained the inverse correlation between monthly mean E values and the concentration of dust in air.[8] The dust concentration was determined by standard method of sampling on filters.

Table. Normalized mean diurnal variations of *E* assessed from observations at the Observatory and in the valley

Local time, hours	1	3	5	7	9	11	13	15	17	19	21	23
E_{BAO}	0.7	0.6	1.3	1.2	1.2	1.2	1.3	1.1	1.0	0.8	0.9	0.5
E_{val}	1.0	0.8	0.8	0.8	0.6	0.6	1.1	1.8	1.4	1.1	1.0	1.0

The results of the recording show that the majority of E and N variations are opposite.

The example of joint recording of E and N in September, 15–22 (the sum of fine and submicron aerosol) is shown in Fig. 2.

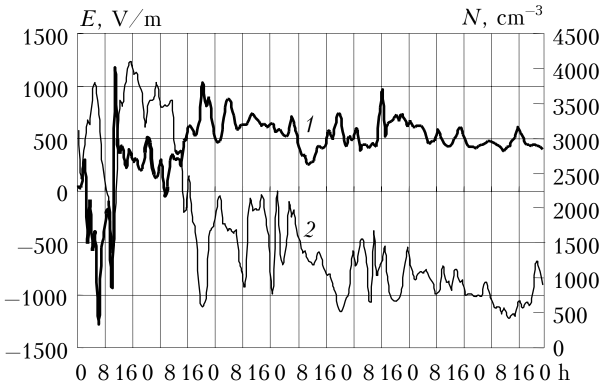

Fig. 2. A fragment of record of the field strength (*1*) and the total concentration of fine and submicron aerosol (*2*) in September 15–22, 2005.

Precipitation were observed in the first half of the day on September, 15, and electric field was negative. The aerosol concentration increased during 5 first hours, which was followed by its decrease, obviously, because of aerosol washing-out. The rain termination was accompanied by transition of the field to the range of positive values and by increase of the aerosol particle number density. The concentration of aerosol particles and the magnitude of the electric field under conditions of stable weather after 5 p.m. changed oppositely.

The problem of physical mechanisms of the relations is quite complicated. The relations can be both direct and indirect via different meteorological factors. The existing classic ideas show that the electric field strength should increase with the increase of the aerosol content in the atmosphere and, hence, with the decrease of the concentration of light ions. The opposite manner of variations of E_{BAO} and N can be explained by a number of reasons. Perhaps, aerosol is somewhat radioactive and can ionize the air. According to the data of geologists, the region near Lake Baikal is characterized by enhanced emission of soil radon, the concentration of which is related with meteorological conditions.

The second explanation is a manifestation of electrode effect, i.e., the quantity of positive ions near the ground surface decreases with the increase of the aerosol concentration or the thickness of the electrode layer increases. It can be also supposed that the variation of E leads to movement of the charged near-ground aerosol. These questions can be elucidated after carrying out complex measurements of electric characteristics (to record additionally the conductivity and the volume charge, or to measure E by devices spaced vertically and horizontally).

The character of manifestation of the volume charge under good weather conditions can be judged from the fragment of E records at the ground level and at the height of 2.5 m on August, 26–27 (Fig. 3).

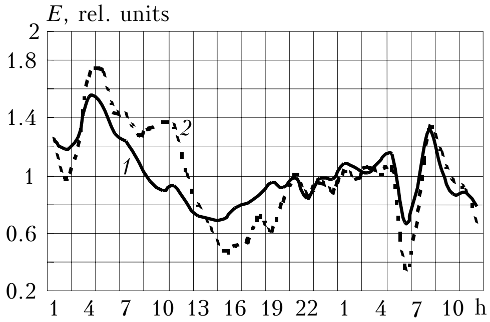

Fig. 3. Example of E variation for 36 hours near the ground surface (curve *1*) and at a height of 2.5 m (*2*).

The curves show that from 5 a.m. to 1 p.m. the E values near the ground surface are approximately by 20% lower. More significant increase of E near the ground in comparison with the level of 2.5 m occurs in the afternoon. The difference in variations of E values in the evening and nighttime decreases. Perhaps, the differences in variations of E at different heights are related with diurnal behavior of the soil radon emission ionizing the air.

The recording of the electric field strength in the valley (200 m lower than the first site) showed a significant difference in the manner of diurnal variations of E. In the valley, under good weather conditions during the period of joint recording it was characterized by quite simple wave with the maximum at daytime and minimum at nighttime. The peculiarity of the diurnal behavior was that the increase and decrease of the strength coincide with the diurnal behavior of sun illumination of the valley: illumination of the valley bottom begins at 11 a.m., and at 5–6 p.m. the sun is closed by another valley slope, and the increase and decrease of the electric field correlate with these facts. Such manner of the diurnal behavior was observed for the first time and is not explained yet.

The manner of variations at both sites of E recording under violated weather conditions (strong wind, cloudiness, precipitation) differ slightly. The moments of the field transition to the range of negative values, amplitudes, and periods of variations are similar. Evidently, the reason of dramatic difference of diurnal variations of E_{BAO} and E_{val} observations at small distance between the sites is determined by the difference in heights of the sites, closeness of the valley by steep slopes (and, hence, the difference in meteorological conditions) and, perhaps, peculiarities in the influence of the electrode effect.

Spectral and cross-correlation analysis of hourly mean values was carried out for the study of correlations between the electric field and the aerosol concentration. The components with the period of 3–5 hours and daily are characteristic of the electric field. The 3–5-hour and half-day components are characteristic of the spectrum of variations of the aerosol concentration.

Conclusion

Preliminary data analysis has revealed additional problems in the study of correlation between the electric field and the aerosol content in the atmosphere.

The inverse dependence of hourly mean values of E and N is difficult to explain. A solution of the problem is possible at synchronous complex measurements of the electric characteristics: the electric field strength, the electric conductivity of air or the density of the volume electric charge, the aerosol concentration, and the meteorological parameters.

Acknowledgements

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