Daily Variation of Surface Electric Intensity in the Smokes of Summer Forest Fires

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ABSTRACT: The report presents and discusses the results of research of atmospheric electrical values during prolonged forest fires in Siberia in the summer of 2012. The existence of daily variation of the electric field of 300 V/m during the day to –300 V / m at night in heavy smoke in the surface layer of the atmosphere was discovered. It was revealed that the daily variations of the field intensity are different from both the diurnal variations of the field intensity over the oceans ("Carnegie" curve), and from the average field variations at mid-latitudes in the summer with the semi-diurnal period.

INTRODUCTION

The electrical field in the Earth's atmosphere is one of the permanently present factors having an influence on the state and changes in the environment. The complex interrelation between the temporal variations in this field on the one hand and the physical, chemical, and biological processes that form the environmental state on the other hand determines the interest in monitoring atmospheric electricity as both an affecting factor and an indicator of the observed environmental changes. Among the found regularities of temporal variations in the electrical field, the most well-known belong to the "fine weather conditions."

Yet the least known are processes of electrical charge accumulation and variations in the electrical field under disturbed "fine weather conditions" (thunderstorm, dust storm, natural and technogenic smoke, etc.). Since these atmospheric phenomena are episodic and hardly predictable in time, they complicate field studies in the sense of interpretation of their results. Among the insufficiently studied atmospheric processes, there are those implemented in the smoke from forest fires. For example, it was found [Pkhalagov et al. 2006] during the period of forest fires in Tomsk oblast in 2004 that as smoke intensified (the concentration of smoke particles increased), the average daily electrical field intensity in the near-surface layer did not increase with respect to the electrooptical ratio, but reduced in contrast (from 200 to 30–60 V/m). With the great spatial extent of smoking during the vegetation period taken into consideration, studies of variations in the electrical field under these conditions are topical for monitoring and modeling of both meteorological and ecological processes.

The results of these studies will be presented below, and the revealed effect of diurnal variations in electrical field in the near-surface layer from +300 to in the daytime to –300 V/m in the nighttime, under continuous intensive smoking conditions, will be described.

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EXPERIMENTAL RESULTS

The experiment devoted to study of variations in the electrical field in the near-surface layer of the smoke plume from forest fires was carried out at the Institute for Monitoring of Climatic and Ecological Systems, Russian Academy of Sciences, in the framework of comprehensive monitoring of meteorological and actinometrical parameters, and ultraviolet radiation and natural radioactivity. The meteorological optical range was determined by the data of the Tomsk meteorological station, Roshydromet, which is located 1.2 km from the Institute [http://rp5.ru].

Forest fires in summer 2012 in Siberia, with variable degrees of smoke in the town of Tomsk, took place from June until August; however, stable conditions favorable to carry out the experiment emerged only in the third ten-day period of July, when a smoke plume from a distant forest fire source stably dominated above the territory of the town and, therefore, in the vicinity of the observatory located in the eastern part of town [Ippolitov et al. 2013]. The meteorological situation above all of eastern West Siberia in this period was caused by a small gradient pressure field. The air temperature changed from 15°C at nighttime to 30°C in the daytime; wind was northerly (from 300° to 60°) and weak (1–3 m/s); precipitation was absent, and the meteorological optical range decreased to ~ 500 m or less (Fig. 1). In general, meteorological situation in this period can be characterized as stable anticyclonic.

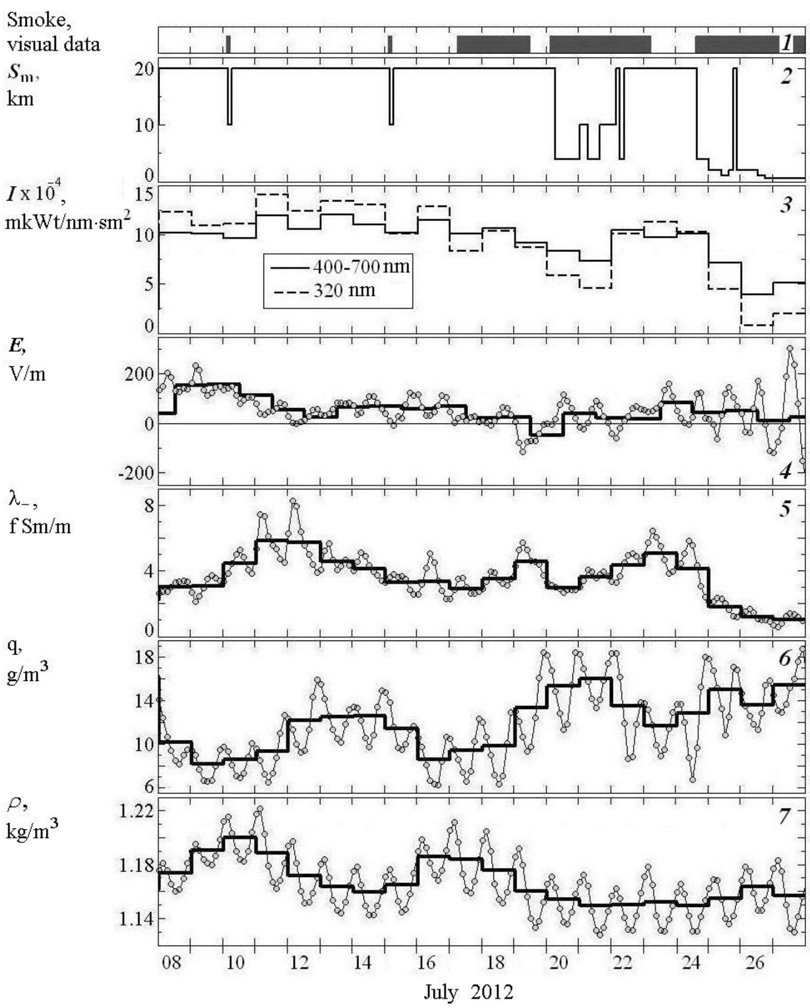

Fig. 1. Actinometrical, meteorological and atmospheric electrical parameters in the summer of 2012: (1) visual registration of smoke; (*2*) meteorological optical range *Sm*; (3) flux of solar radiation in the visible and UV ranges; (4) electrical field intensity ***E***; (5) negative electrical conductivity λ_-; (*6*) absolute humidity *q*; (7) air density ***ρ***.
Thin lines – 3-hourly data; thick lines – average daily data.

The most stable in terms of meteorological conditions were the days of stable smoke (July 25–28, 2012), when the meteorological optical range *S*m was ~ 500 m and variations in the electrical field intensity in the near-surface layer were maximal. The results of such processing are given in Fig. 2.

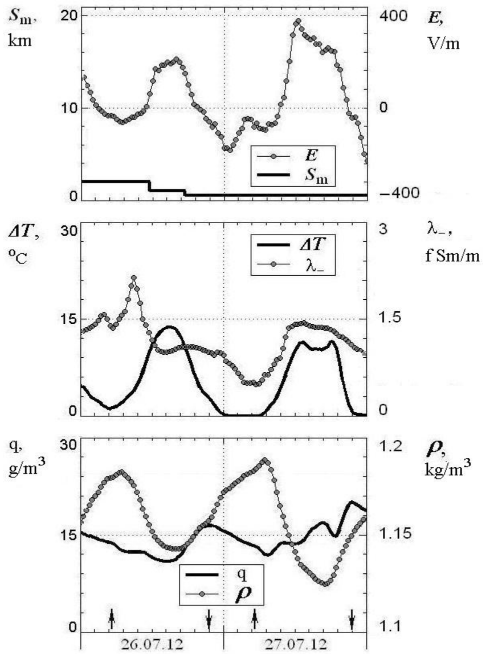

Fig. 2. Variations in atmospheric electrical and meteorological parameters during intensive smoke: (*1*) meteorological optical range *Sm* and electrical field intensity ***E***; (*2*) deficit of dewpoint temperature ΔT and negative electrical conductivity λ_{-}; (*3*) absolute humidity *q* and air density $\boldsymbol{\rho}$. Arrows denote the moments of sunrise and sunset.

As is seen, the electrical field intensity in this period systematically changed from positive values in the daytime to negative ones at nighttime (panel 1). The revealed diurnal variations in electrical field intensity are principally different from those identified above the oceans (Carnegie curve) and the averaged variations in electrical field ***E***, recorded during summer in the middle latitudes with a half-day interval [Anisimov and Mareev 2008]. In the first case, the revealed variations advance the Carnegie curve in shape by approximately π; in the second case, the periods of variations differ about twofold. The absence of similarity based on the diurnal changes of field intensity ***E*** is naturally explained by inhomogeneity of the smoke plume and verified by the observed changes in the meteorological optical range (concentration of aerosol particles). The more regular variations in this period were the diurnal variations in the atmospheric temperature T_a and the difference between the atmospheric temperature and the dew point $\Delta T = T_a - T_d$ (panel 2), accompanied by variations in the atmospheric density $\boldsymbol{\rho}$ and water vapor *q* (panel 3). Variations in negative polar electrical conductivity λ_{-} (panel 2) and vertical heat flow A_T were of less value, but still discernible and nearly coeval to the variations in the electrical field intensity.

DISCUSSION

Spatial and temporal variations in the electrical field intensity in the Earth's atmosphere, having a broad range and characterized by change of polarity sign, refer to known phenomena observed from many natural and technogenic effects. The effect of diurnal variations in the electrical field (from +300 to in the daytime to –300 V/m at nighttime) in the near-surface layer, revealed by us for the first time, differs from the known similar effects by its record during smoke cover from forest fires that often affect vast territories of many regions. Forest fires are sources of aerosol particles, which have electrical charge accumulation owing to thermoemission and friction in powerful convection flows. These particles affect variations in the electrical field intensity in the near-surface atmosphere above the areas covered by the smoke plume. The interrelation between the diurnal variations in the electrical field intensity and the observed variations in meteorological characteristics presented in Fig. 1, 2 suggests the following interpretation of the revealed phenomenon.

After midday, with reduced insolation in the homogeneous air mass, temperature T_a starts to drop and simultaneously q and ρ begin to grow at almost unchanged atmospheric pressure P_a. The decrease in T_a and the increase in $\boldsymbol{\rho}$ continue until sunrise. However, growth of water vapor density q lasts only until sunset. After this, at $\Delta T \to 0$, q starts to drop and lasts until sunrise. In the same time interval, electrical conductivity (amount of light ions) reduces. After sunset, at atmospheric temperature close to the dewpoint, smoke aerosol particles in the near-surface layer begin to accumulate water vapor in themselves. Simultaneously, in the interaction between light ions of both positive and positive charges and aerosol particles, the bigger particles become negatively charged and, due to sinking under the effect of gravity, form a negative voluminous charge near the surface. It is this layer of particles with negative voluminous charge that leads to inversion of the direction of the electrical field intensity at nighttime ($\boldsymbol{E}(t) < 0$). An analogous effect has been observed when studying the dynamics of charged particles during dust storms.

After sunrise, both the water vapor density and the electrical conductivity start to grow. Under the effect of air convective flows that carry smoke aerosol particles upward, and under the rapid dehydration of these particles at $T_a > T_d$, the negatively charged layer formed near the surface at nighttime dissipates and the electrical field intensity becomes of positive sign again. The insignificant deviations of the diurnal variations from the strictly harmonic pattern reflect the unavoidable fine-scale inhomogeneity of the smoke plume and constant local peculiarities of the observation point. The suggested interpretation of the observed effect does not contradict the known results reported for the adiabatic chamber, which are, in turn, consistent with the diffusion-kinetic model of ion charge of aerosol particles.

CONCLUSIONS

The fundamental value of the revealed effect is related to the role of the atmospheric electrical field in both the formation of weather conditions (through evaporation and condensation) and the biosystem processes (osmotic regulation, for example).

ACKNOWLEDGMENTS

The work was supported Program SB RAS VIII.77.1. "*Natural climatic changes and their implications for Siberia in modern global warming and anthropogenic influences*".

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