Winter Convective Clouds and Unstationary Electrode Layer

P. M. Nagorskiy[1, 3], V. N. Morozov[2], K. N. Pustovalov[1, 3], A. A. Ryazanov[3], and S. V. Smirnov[1]

1. Institute of Monitoring of Climatic and Ecological Systems SB RAS, Tomsk, Russia
2. Voeikov Main Geophysical Observatory, St. Petersburg, Russia
3. National Research Tomsk State University, Tomsk, Russia

ABSTRACT: Variations of a light ion concentration and a free electic charge density in surface layer on basis of observed data in 2006–2014 were analyzed. The analysis shown an availability of matched oscillations of polar conductions and both increasing and decreasing (down zero) a light ion concentration during a passage of deep convective clouds. A new mechanism describing the properties of unstationary electrode layer during thunderstorms was proposed. It considers the electric field as a driving external force and rainfall as an additional sink of light ions.

INTRODUCTION

Actually there are a fill of approaches and models [Hoppel, 1967; Morozov et al, 2011; Nagorskiy et al, 2013] describing the quasi stationary state of atmospheric electrode layer. However electrization processes and variations of atmospheric electrical quantities in the surface layer in spells of bad weather (thunderstorms, precipitation, fogs, smokes, etc.) are less studied. Meteorological conditions associated with significant variations (not background oscillation) of the characteristics of electrode layer including an electric (field) intencity are also less studied. The previous results of studies [Nagorskiy et al, 2011a] shown some features of electrode layer variations during prestorm environment and thunderstorm situations. This paper presents the results of experimental and theoretical analysis of the state and variability of electrode layer during a passage of deep convective clouds and violent oscillations of electric intencity (to 10 kV/m).

EXPERIMENTAL RESULTS

Primary meteorological, atmospheric electrical, UV radiation and natural radioactivity quantities [Nagorskiy et al, 2011b] recording since 2006 with high temporal resolution in the geophysical observatory of IMCES SB RAS were analyzed. Meteorological data [http://rp5.ru] of the Tomsk weather station were also used.

Measuring data shown that the matched oscillations of electric intensity E (more ±100 V/m) and polar conductivities $\lambda_{\pm}$ were repeated quite often in surface layer in the cold seasons (November–March). Examples of such matched oscillations are represented in Fig. 1: the pattern *a* shows the matched oscillations of E and $\lambda_{\pm}$ when there were Ci and Cs clouds only, and low and medium clouds were absent; the pattern *b* shows the oscillations during snow flurry (Cb and St fr, total amount of clouds is 9–10). Also one feature has been found out connected with a passage of deep convective clouds and snowfall, namely decreasing light ion concentrations (Fig. 1*c*). A possible reason of this decreasing is precipitation (see detailed interpretation below).

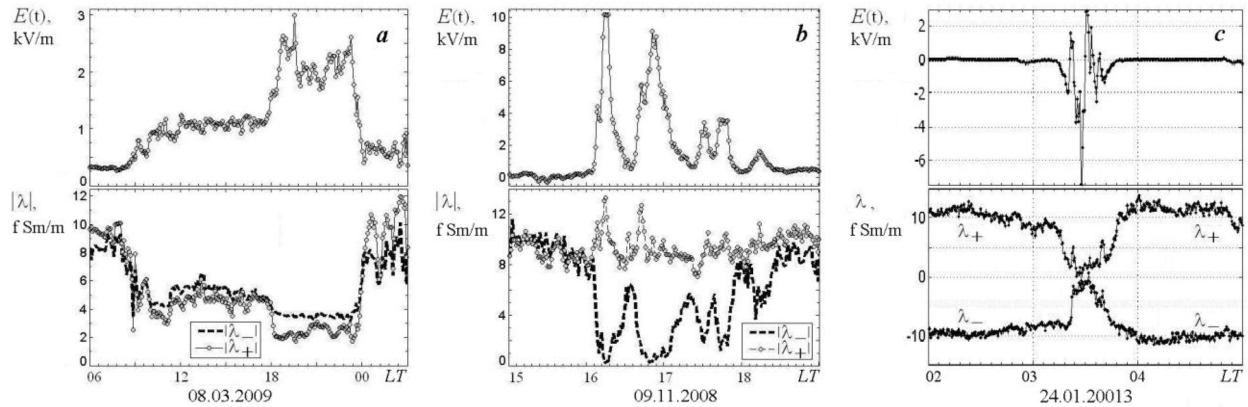

Fig. 1. The matched oscillations of electric intensity and polar conductivities in the cold season.

Consider the temporal characteristics of the variations of the electric field, including the duration of the positive and negative field perturbations, their number during a lightning storm, etc. In this case the data in question were divided into two classes, depending on the processes of formation of convective clouds, the presence or absence of stable snow cover: the warm period (May - September), cool season (November - March). April and October in the study were not used because these months are characterized by restructuring type of weather.

Periods in summer thunderstorms, with sudden changes in the electric field, the conductivity of the electrode layer by changing the number of positive or negative ions as increased sharply and fell almost to zero. In the behavior of $\lambda_{\pm}$ identified four main phases [Nagorskiy et al, 2013]: a) undisturbed concentration of ions, and b) "sweeping" of the electrode layer of ions under the influence of an electric field, and c) the absence of light ions of a certain polarity, and d) restoration of the concentration of ions.

The main statistic characteristics of electric field variations (periods and amounts of positive and negative fluctuations) in the cold season are represented in the Table 1. Here T_{gr} is the period of tunderstorm; T_+ is the period of a positive fluctuation of electric intensity E_+ above 0,7 kV/m ; $T\_$ is the period of a negative fluctuation of electric intensity $E\_$ less than -0,35 kV/m; τ is the period of transitions between E_+ and $E\_$; N_{E+} and $N_{E\_}$ are the amounts of positive and negative fluctuations of electric intensity E, respectively; N_τ is the amount of transitions between E_+ and $E\_$.

Table 1 Main statistic characteristics of electric field variations

Characteristic	Mean	Median	Standard deviation
$T_{\text{гр}}$, min	8,1	5,0	8,6
T_+, min	2,7	1,9	3,1
$T\_$, min	7,8	5,0	6,7
τ, min	34,0	30,0	17,4
N_{E+}	1,8	2,0	0,8
N_{E-}	1,6	1,5	0,7
N_τ	2,3	2,0	1,3

NUMERICAL EXPERIMENT

An ion transfer in the unstationary electrode layer is carried out by both turbulent flows and electric force [Nagorskiy et al, 2011a]. The basic equations described this process are:

$$\frac{\partial n_{1,2}}{\partial t} \pm b_{1,2}\frac{\partial}{\partial z}\left(E(t)n_{1,2}\right) - \frac{\partial}{\partial z}\left(D_T(z)\frac{\partial n_{1,2}}{\partial z}\right) = q(z) - \alpha n_1 n_2 - \eta n_{1,2} N, \tag{1}$$

$$\frac{\partial E}{\partial z} = 4\pi e(n_1 + N_1 - n_2 - N_2), \tag{2}$$

where $n_{1,2}$ is the concentration of positive and negative light ions; $b_{1,2}$ is the ion mobility; $q(z)$ is the rate of an ion generation; $\alpha(z)$ is the recombination coefficient of light ions; z is the altitude; D_T, D_{mol} are the turbulent and molecular diffusion coefficients; $\eta = \varepsilon_1\varepsilon_2$ is the coagulation coefficient (or capture ratio) defining an interaction of light ions and hydrometeors (ε_1 is the collision probability; ε_2 is the cohesion probability); $N = N_0+N_{1,2}$ is the total concentration of neutral and charged hydrometeors. Whereas the hydrometeors are conductive particles, the electrostatic force will intensify a coagulation. The electrostatic coagulation versus the Brownian and gravity coagulations plays a major major role in the precipitation scavenging of light ions. For example, the value of ε_2 at a relative humidity close to 100 % is close on a one.

The numerical experiment data on basis of equations (1) and (2) are shown in Fig. 2.

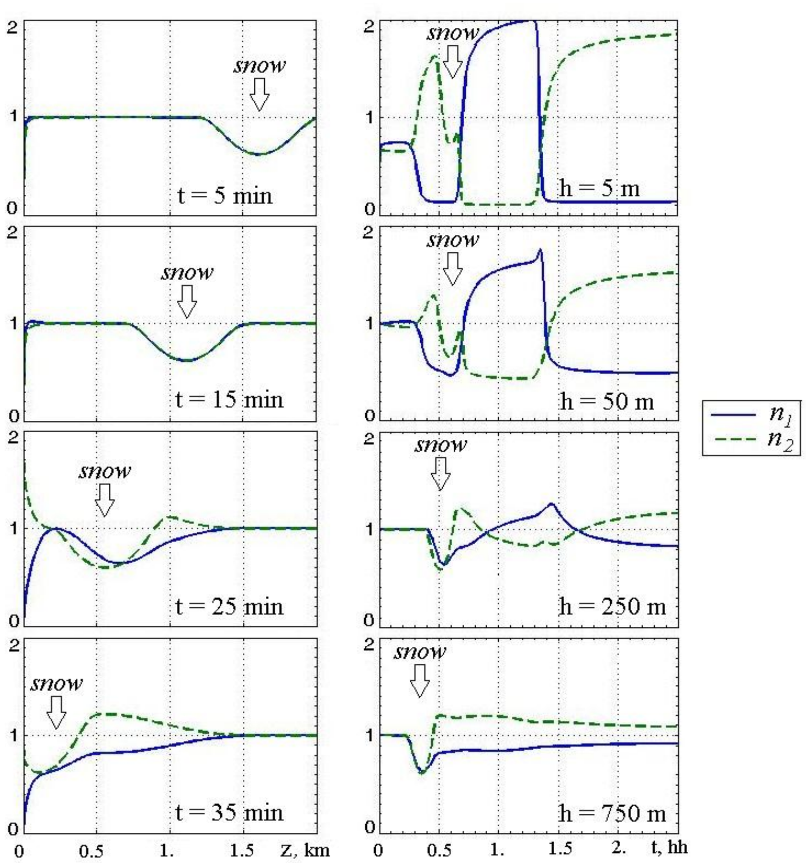

Fig. 2. Temporal (left) and spatial (right) variations of normalized values of light ion concentrations (with respect to values at the upper boundary of electrode layer) during a passage of deep convective clouds and snowfall.

Modeling assumptions:
q=7·10^6 m^{-3}c^{-1};
b_1=1,36·10^{-4} m^2/Vc,
b_2=1,56·10^{-4} m^2/Vc;
η=10^{-4} m^3/c;
α=1,6·10^{-12} m^3/c;
D_T=(Kz+γ)/(z+β);
γ=5·10^{-5} m^3/c; K=5;
N=N_c[1-[z-(z$_c$-$V_c t$)]^2/Δz^2]^2;
N_c=10^2 m^{-3};
z$_c$=1,8 km; β=10 м;
V_c= 50 m/min;
Δz=0,4 km.

This figure shows: the right patterns present a temporal change of normalized values of light ion concentrations according to an altitude, the left patterns present a spatial disturbance of normalized values of light ion concentrations according to a time. As can see a snowfall connected with deep convective clouds changes significantly the light ion concentrations.

CONCLUSION

The deep convective clouds and snowfalls observed sometime in the cold seasons (November–March) affect significantly on temporal and spatial variations of the electrode layer. The main factor of this variations is effects of the electrostatic coagulation and the precipitation scavenging of light ions. It is confirmed by results of the statistical analysis of measuring data and the numerical work with a refined system of equations describing a behavior of the unstationary electrode layer.

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