VARIABILITY OF THE EARTH'S ATMOSPHERIC ELECTRIC FIELD AND ION-AEROSOLS KINETICS IN THE TROPOSPHERE

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Summary: *The paper deals with the mechanism of generating a ground potential gradient electric field in regions of seismic activity and its penetration into the ionosphere. The mechanism is based on the electrode effect of charge separation under the action of the natural atmospheric electric field. A large, non-compensated, space charge is formed following a chain of ion-molecular reactions as a result of the anomalous increase of radon and aerosol emanation from the crust. This space charge leads to anomalous variations of the electric field ground level, which is supported by the experimental observations made in the seismo-active regions. In turn the variations of the strong electric field over the large earthquake areas lead to the modification of ionospheric parameters due to penetration of the anomalous electric field into the ionosphere. A theoretical model of these phenomena is proposed in this paper.*

1. INTRODUCTION

Disturbances in the vertical electrostatic field near the Earth's surface within the range of 50 – 150 Vm^{-1} are often observed before earthquakes and major volcanic eruptions (*Bonchkovsky, 1954*; *Kondo, 1986*). The magnitude of such disturbances before severe earthquakes may be as high as 1000 Vm^{-1}; unusual behavior of the electric field, in particular, a decrease or even sign reversal of the vertical field component several hours before severe earthquakes has been reported (*Hao, 1988*; *Vershinin et al., 1997*). We are thus faced with the urgent problem of explaining the anomalous behavior of the electric field near the Earth's surface in seismo-active zones before earthquakes.

The epicenters of earthquakes are usually located near fractures in the Earth's crust (tectonic faults). A significant amount of metal aerosols of types Cu, Fe, Ni, Zn, Pb, Co, Cr, etc., as well as of radon, is introduced into the ground layer of the atmosphere through these fractures, radon being the main source of α-particles. Each α-particle emitted by ^{222}Rn with an average energy of $E_\alpha = 6$ MeV can produce theoretically about 2×10^5 electron-ion pairs. The output of radon can reach 12 eman before an earthquake, which corresponds to an ionization rate of about 7.6×10^3 $cm^{-3}s^{-1}$ (*Alekseev and Alekseeva, 1992*; *Alekseev et al., 1995*).

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A mechanism of formation of the atmospheric field at ground level, induced by radon and metal aerosol emanation from rifts in the Earth's crust, is proposed. A model of ion kinetics in the ground layer of the troposphere is also considered in the paper.

2. ION COMPOSITION GROUND LEVEL

At the initial moment of time, generates a large number of O_2^+ ions in the atmosphere near the Earth's surface. This process takes place both by direct ionization and by the reaction of recharging involving primary N_2^+ ions,

$$N_2^+ + O_2 \rightarrow O_2^+ + N_2$$

and electrons, which rapidly attach to oxygen atoms, because oxygen is characterized by a high affinity to electrons. The relevant three-body reaction, most probable in the dense lower atmospheric layers, can be expressed as

$$e + O_2 + O_2 \rightarrow O_2^- + O_2 ,$$

where an oxygen molecule is involved as the third body. The efficiency of nitrogen molecules is lower by a factor of 40 in this case. If the molecule of oxygen captures the electron directly, without participation of the third body, the surplus energy results in a molecule in excited state, and the ion is able to dissociate

$$e + O_2 \rightarrow O^- + O \quad .$$

Free electrons also attach to metal atoms emanated from the rift in the Earth's crust. Such processes lead to the formation of negative ions.

Thus, primary free electrons, as well as positive and negative elementary ions are generated in the air at ground level. Various ion-molecular reactions, typical for this layer, then take place. These reactions, which take about 10^{-5} s, result in the formation of a stable ion content in the atmosphere near the Earth's surface (*Boyarchuk and Svirko, 1996*; *Boyarchuk, 1997a*; *Boyarchuk, 1997b*): O^-, O_2^-, O_2^+, NO^+, CO_3^-, NO_2^-, NO_3^-, NH_4^+ and H_3O^+. The contents of other types of ions is negligible.

The troposphere contains a quantity of water vapor molecules (~10^{17} cm^{-3}), with an appreciable dipole moment $p = 1.87\ D$. The hydration of elementary ions and formation of ion complexes of the $NO_3^- \cdot (H_2O)_n$ and $H_3O \cdot (H_2O)_m$ types, with characteristic values $n = 2 \div 3$ and $m = 3 \div 6$, then occur rather quickly. In general, ammonium ($p = 1.47\ D$), sulfuric oxides ($p = 1.63\ D$), nitric acid vapor ($p = 2.17\ D$), with the exception of water vapor may be considered as molecules attached to ions (*Smirnov, 1992*). However, under usual conditions the concentration of these impurities is lower by 5 to 10 orders of magnitude, than the concentration of molecules of water. Metallic aerosols may also act as the central ion of water clusters, as they frequently have energy affinity to electron exceeding this energy even at oxides of a nitrogen $M^- \cdot (H_2O)_n$, where M^- is ionized atom of metal. Numerical analysis with the detailed account of the real contents of the extrinsic gases specifies an opportunity of formation in troposphere of more difficult structures of the type $NO_3^- \cdot (HNO_3)_n \cdot (H_2O)_m$, $HSO_4^- \cdot (H_2SO_4)_n \cdot (H_2O)_m$ (*Kawamoto and Ogawa, 1986*).

3. ELECTRODE LAYER FORMATION

The mobility of negative ions on the average is 1.3 – 1.4 times higher than that of the positive ions. Apparently, this difference of the mobility can be attributed to the asymmetry of the arrangement of ions with charges of different signs with respect to the oxygen atom in water molecule. Consequently, negative ions are characterized by lower energy, i.e., by the smaller number of attached water molecules, than positive ions (*Smirnov, 1992*). We can assign the considered ion to the class of small or intermediate ions with mobilities of 0.05 – 5 $cm^2V^{-1}s^{-1}$.

Thus, due to the difference in the mobilities of ions with charges of different signs, the atmospheric electric field E under certain conditions may induce a non-compensated spatial charge near the surface. Let us consider a simplified model of this effect in the case of the weak turbulent diffusion, e.g., in early-morning hours, when a cloud of a radioactive gas spreads within a thin near-ground layer where ions are produced. Under the effect of the natural field of the Earth E the spatial distribution of charges can be formed at the surface: positive ions will be drift to the Earth surface where they will recombine, but as their mobility is low, a spatial layer of positive ions forms at the surface. The negative ions will move vertically upwards (we do not consider electrons in this model since their concentration at the Earth surface is small). The "electrode layer" with a local field E_L will be formed near the ground. The local field E_L compensates the basic field E. The field in the area above this layer will be amplified due to the presence of a non-compensated negative charge (Fig. 1).

In this model, we assume that the conductivity of the Earth's surface is much less than of the air, and thus the time required to recover the charge density on the Earth's surface is much less than the characteristic times of all the other processes considered in the atmosphere *(Boyarchuk et al., 1997)*. Therefore, we can assume that this charge density remains constant. As a consequence, a non-compensated spatial negative charge is produced in the atmosphere. Turbulent and regular airflow can spread this spatial charge over the atmosphere, inducing an anomalous electrode layer over large areas. Apparently, such situation can occur only within short time intervals, because airflow eventually destroys the electrode layer by mixing up all the ions. Let us represent the equations that describe the kinetics of such a system in the form

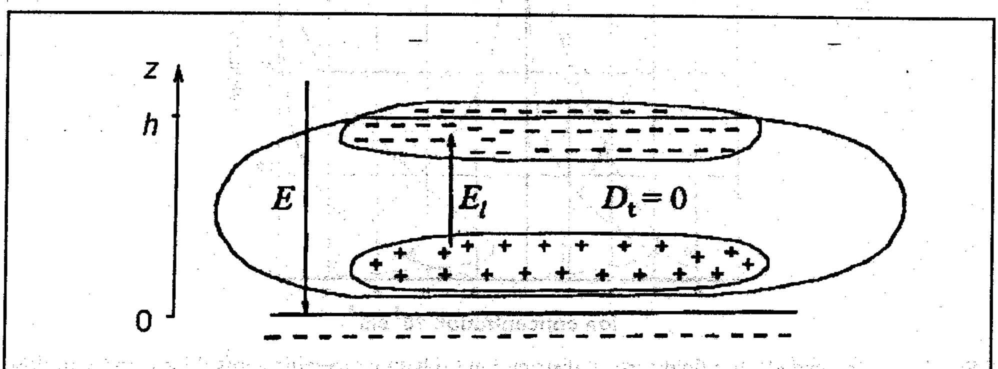

Fig. 1. Near-ground space charge formation.

$$\frac{\partial n_1}{\partial t}=\frac{\partial}{\partial z}\left((D_t+D_1)\frac{\partial n_1}{\partial z}\right)-\mu_1\frac{\partial}{\partial z}(En_1)+q-\alpha n_1 n_2,$$
$$\frac{\partial n_2}{\partial t}=\frac{\partial}{\partial z}\left((D_t+D_2)\frac{\partial n_2}{\partial z}\right)+\mu_2\frac{\partial}{\partial z}(En_2)+q-\alpha n_1 n_2, \qquad (1)$$
$$\frac{\partial E}{\partial z}=4\pi e(n_1-n_2)$$

where e is the electron charge; z is the vertical coordinate; $n_{1,2}$ are the positive and negative ion concentrations; q is the ionization rate (radon is emanated in a layer of thickness h ($h = 10$ cm), therefore we consider $q = q_0 \exp(-z/h)$, were q_0 is the ionization rate at the ground level); $\mu_{1,2}$ ($\mu_2 = 3.8\times\cdot 10^{-1}$ cm^2(Vs)$^{-1}$ and $\mu_1 = 2.4\times 10^{-1}$ cm^2(Vs)$^{-1}$) and $D_{1,2}$ ($D_1 = 2.8\times 10^{-2}$cm^{2}s^{-1}, $D_2 = 4.3\times 10^{-2}$cm^{2}s^{-1}) are the mobility and diffusion coefficient of the corresponding ions, respectively; D_t is the coefficient of turbulent diffusion, which was determined as $D_t(z)=\dfrac{Kz+\gamma}{z+\beta}$, were $\beta = 10.0$ m, $\gamma = 5\times 10^{-5}$ m^{3}s^{-1} and K is the turbulence coefficient (*Atmosphere, 1991*); and α (~10^{-6} cm^{3}c^{-1}) is the recombination coefficient of ions (*Boyarchuk, 1997a*).

The boundary conditions for the field near the Earth's surface and on the boundary of the considered layer are written as $E|_{z=0} = 100$ Vm^{-1}. The initial concentrations of positive and negative ions are set equal to the background level (~ 450 cm^{-3}).

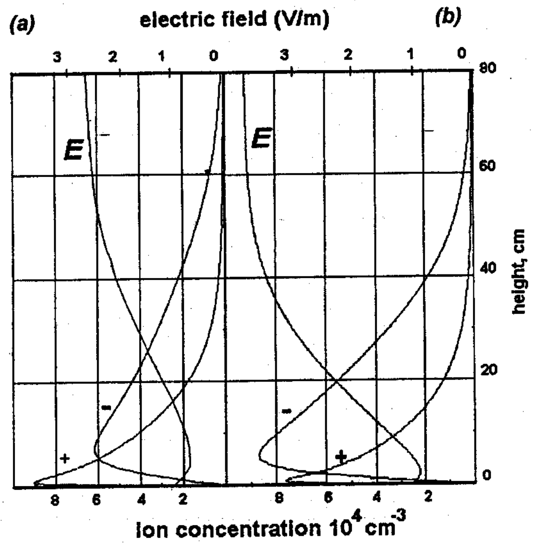

Fig. 2. Ion and electric field vertical distribution (a) without metallic aerosol flow, (b) with flow of metallic aerosols.

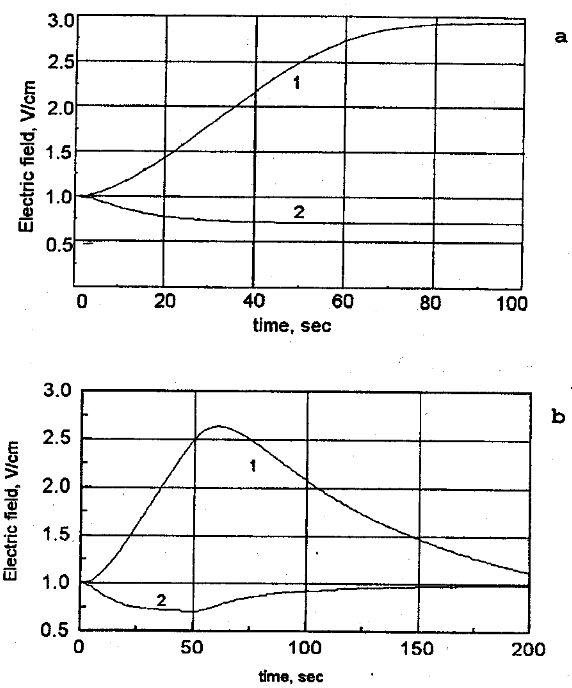

Fig. 3. Dynamics of space charge formation at heights 60 cm – 1, and 3.5 cm – 2, (a) continuous source of the ionization, (b) ionization source is switched off after 50 s.

Figure 2 (a, b) presents the results of simulations performed within the framework of the model described above. This figure shows the concentrations of positive (+) and negative (–) ions and the amplitude of the electrostatic field (E) as functions of the altitude in the near-surface layer 50 s after the onset of ionization. The presented plots clearly demonstrate the formation of a near-surface electrode layer. The electric field decreases in this layer and noticeably increases above this layer. This effect can exist due to the existence of mobile and long-life ions. The presence of the metallic aerosol flux can appreciably increase the concentration of negative ions. This noticeable negative spatial charge enhances the electric field above this layer. However, the electric field inside the electrode layer decreases to a lesser degree. This effect is shown in Figure 2(b).

Figure 3(a) displays the change of the field amplitude at the altitude corresponding to the maximum effect (~ 3.5 cm) and at the altitude corresponding to the area of non-compensated negative charge (~ 60 cm). As can be seen from this figure, the process for the anomalous field becomes stabilized within a time interval of about 40 s. (line 2). Figure 3(b) presents the time dependence of the change of the electric field when the generation of ions is switched off 50 s after the onset of this process. As can be seen from this figure, the natural electric field is recovered at a slower time scale and requires more than 200 s.

The considered natural phenomenon of the formation of atmospheric earthquake precursor can be successfully modeled by such techniques as artificial ionization of the atmosphere by X-ray emitters (*Soloviov, 1941*) and changes of the atmospheric electric field, that accompany nuclear weapon tests (*Holzer, 1972*).

4. PENETRATION OF THE ELECTRIC FIELD OF SEISMIC ORIGIN INTO THE IONOSPHERE.

Our analysis gives the new explanation of the formation mechanisms of an anomalous electric field in the atmosphere at the ground level near the epicenter of anticipated earthquake (*Bonchkovsky, 1954*; *Vershinin et al., 1997*). This seismogenic electric field could penetrate into the ionosphere as well as the electric field from the thunderstorm cloud (*Park and Dejnakarintra, 1973*; *Hegai et al., 1990*). It will produce modification of the whole geomagnetic tube leant on the region of the electric field generation. This includes effects within the *D* (*Fux and Shubova, 1994*), *E* (*Kim et al., 1994*), *F* (*Pulinets et al., 1994*) regions of the ionosphere, as well as effects in plasmasphere and magnetically conjugated points (*Kim and Hegai, 1997*; *Pulinets et al., 1997*).

The problem of the penetration of the vertical electrostatic field E_z, localized in the epicenter region of the forthcoming earthquake on the Earth's surface, could be solved using the approach developed by *Kim et al. (1994)*.

Let's take cylindrical coordinates (r,φ,z) centered at the epicentre of the forthcoming earthquake and z-axis directed upward. In the approximation of the horizontal stratification of medium and the vertical geomagnetic field we obtain the following equation for electrostatic potential ϕ from the equation of the current continuity

$$\frac{\partial^2}{\partial r^2}\phi + (1/r)\frac{\partial}{\partial r}\phi + (1/\sigma_1)\frac{\partial}{\partial z}(\sigma_0\frac{\partial}{\partial z}\phi) = 0 \quad , \tag{2}$$

where σ_1 is the Pedersen conductivity and σ_0 is magnetic field- aligned conductivity.

It is assumed that the distribution of the vertical electric field strength E_z on the Earth's surface caused by pre-earthquake phenomena has the Gauss-like form

$$E_z = E_0 \cdot \exp\{-d(r/a)^2\} \quad ,$$

where E_0 is E_z value in the epicenter, $d = 4\ln(10)$, a is a characteristic size of the field-localizing region (Fig. 4).

The distribution of the conductivities with height is adopted in the following form:

$$\sigma_0 = \sigma_1 = b \cdot \exp(z/h) \qquad \text{for } 0 \le z \le z_1 \ ,$$

$$\sigma_{0,1} = b_1 \cdot \exp\{(z - z_1)/h_{0,1}\} \qquad \text{for } z_1 \le z \le z_2 \ ,$$

where $z_1 = 50$ and 65 km for the day and night conditions, respectively, $z_2 = 90$ km, $h = 6.5$ km, $h_0 = 3$ km, h_1=4.5 km, $b = 2\times10^{-13}$ mo/m, $b_1 = b - \exp\{z_1/h\}$. This distribution of conductivity nearly fits the empirical conductivity model (*Cole and Pierce, 1965*).

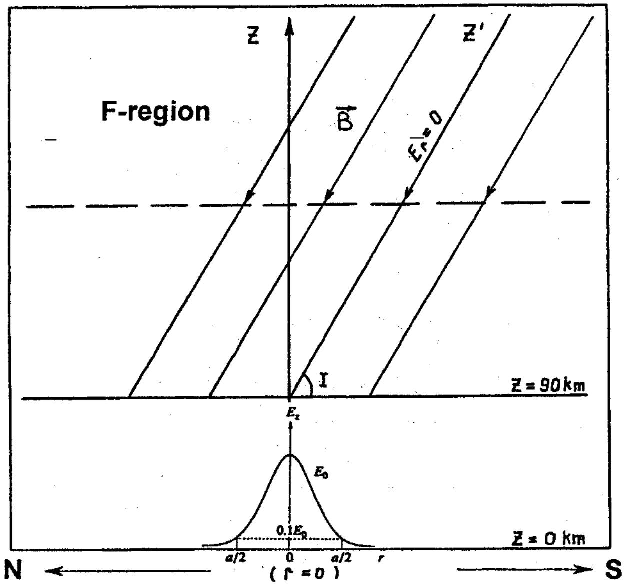

Fig. 4. Electric and geomagnetic field configuration used in calculations.

In this case the general solution of equation (2) can be given as

$$\phi(0 \le z \le z_1) = \int_0^\infty J_0(kr) \cdot \{A_1(k)\exp(c_1 z) + B_1(k)\exp(c_2 z)\} dk$$
$$\phi(z_1 \le z \le z_2) = \int_0^\infty J_0(kr) \cdot \{A_2(k) I_\nu(kf) + B_2(k) K_\nu(kf)\} f^\nu dk \quad (3)$$

where J_0 is Bessel function of the zero order, I_ν and K_ν are modified Bessel functions of the first and second kind respectively with order ν,

$c_1 = -1/(2h) - [1/(4h^2) + k^2]^{1/2}$,

$c_2 = -1/(2h) + [1/(4h^2) + k^2]^{1/2}$,

$\nu = h_1/(h_1 - h_0)$,

$f = [2\, h_1\, h_0/(h_1 - h_0)] \cdot \exp\{-[(h_1 - h_0)/(2\, h_1\, h_0)] \cdot (z - z_1)\}$,

A_1, B_1, A_2, B_2 – coefficients.

Above the level $z = z_2 = 90$ km the magnetic lines of force can be assumed equipotential, hence the distribution of ϕ at $z \ge z_2$ is the same as at $z = z_2$. We therefore

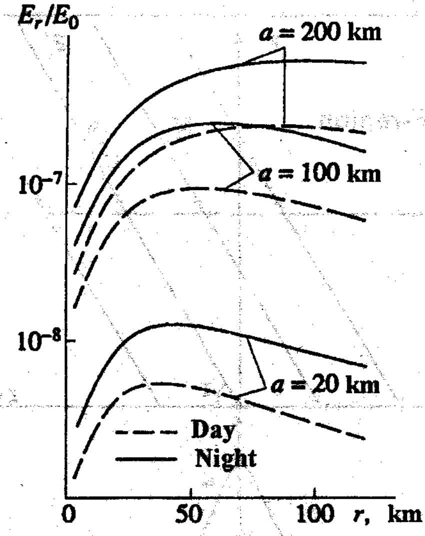

Fig. 5. Seismogenic electric field in the E-region in dependence on the characteristic ground electric field source size a.

Above the level $z = z_2 = 90$ km the magnetic lines of force can be assumed equipotential, hence the distribution of ϕ at $z \geq z_2$ is the same as at $z = z_2$. We therefore obtain the following expression for the electric field of the seismic source at the ionospheric heights $z \geq 90$ km:

$$E_r = -\frac{\partial}{\partial r}\phi(z = z_2) = \int_0^\infty J_1(kr)\{A_2(k)I_\nu[kf(z = z_2)] + B_2(k)K_\nu[kf(z = z_2)]\}\times$$

$$\times f^\nu(z = z_2)kdk \quad , \tag{4}$$

where J_1 is Bessel function of the first order and coefficients $A_1(k)$, $B_1(k)$, $A_2(k)$, $B_2(k)$ are determined from the boundary conditions

$$-\frac{\partial}{\partial z}\phi|_{z=0} = E_0 \exp\{-d \cdot (r/a)^2\} \quad ;$$

continuity of ϕ at $z = z_1$;

$$\frac{\partial}{\partial z}\phi|_{z=z_2} = 0 \quad .$$

The results of the calculations of the field strength E_r normalized on E_0 for different sizes of the field E_z localizing region on the Earth's surface are presented in Fig. 5 for both day and night conditions. It is seen that in the daytime the degree of the field penetration into the ionosphere is considerably lower than at night. The value of the field strength depends in a critical manner on the characteristic size a. For example at $a = 100$ km the maximum value of E_r (E_r^{max}) exceeds E_r^{max} at $a = 20$ km by more than one of magnitude order, and is by one third as large as E_r^{max} at $a = 200$ km both in the day and at night. The dependence of E_r on r is characterized by the quick initial growth and slow lowering after the maximum value. The absolute value of E_r^{max} is only about 0.07 mV/m even at $a = 200$ km in the night conditions when $E_0 = 100$ V/m, i.e. the effectiveness of the field penetration into the ionosphere is extremely low. Thus, the electric field strength of the seismic origin will be noticeable at the ionospheric heights only under the condition that the field E_z localization region on the Earth's surface is great enough ($a \geq 100$ km) and the value of E_0 is $\geq 500 - 1000$ V/m.

To study the influence of calculated electric field on the night-time E-region we shall consider the continuity equation for the total density of the molecular ions

$$\mathrm{N} = \mathrm{N(NO^+)} + \mathrm{N(N_2^+)} + \mathrm{N(O^+)} \approx \mathrm{N_e}$$

with the account of the fact that masses and collision frequencies of the ions are about the same. In the stationary conditions this equation is as follows

$$\mathrm{div}(\mathrm{N} \cdot \vec{\mathrm{V}}) = q - \alpha \mathrm{N}^2 \tag{5}$$

Here $\vec{\mathrm{V}}$ is the ions drift velocity due to the electric field, q is the rate of night ionization, α is the recombination quadratic coefficient. In our case

$$\vec{V} = (e/m_i) \cdot \left(\frac{\nu_{in}}{\omega_i^2 + \nu_{in}^2}\right) \cdot E_r \vec{e}_r + (1/B) \cdot \left(\frac{\omega_i^2}{\omega_i^2 + \nu_{in}^2}\right) \cdot E_r \vec{e}_\varphi \quad ,$$

where e is an elementary charge, m_i is ion mass , ν_{in} is the frequency of ion collisions with neutrals, ω_i is the ion gyrofrequency, B is the geomagnetic field induction , $\vec{e}_r$ and $\vec{e}_\varphi$ are the coordinate unit vectors. Therefore, the continuity equation is reduced to

$$\frac{\partial}{\partial r}(N \cdot V_r) + N \cdot V_r / r = q - \alpha N^2 \, , \tag{6}$$

where $V_r = (e/m_i) \cdot \left(\frac{\nu_{in}}{\omega_i^2 + \nu_{in}^2}\right) \cdot E_r$.

Fig. 6 shows the results of numerical integration of the last equation in the form of electron density N_e dependencies on the distance r for the three heights $z = 115$, 125 and 135 km. When the direction of E_z is positive, N_e decreases above the field E_z localization region (Fig. 6a). The smallest value of N_e is above the epicenter of the foregoing earthquake ($r = 0$). When r increases, the value of density N_e increases smoothly up to the undisturbed level at $r \sim 100$ km for $a = 100$ km and $r \sim 160$ km for $a = 200$ km. The

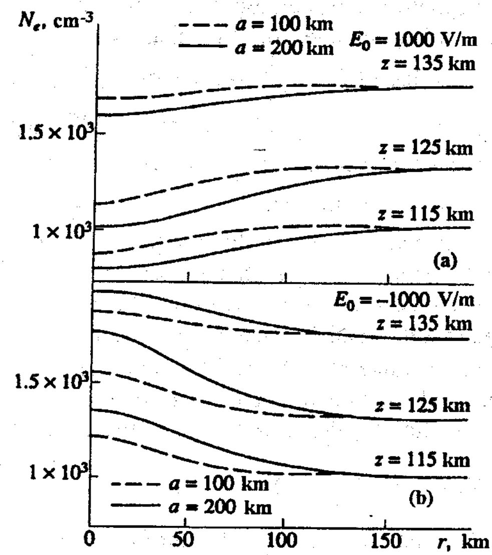

Fig. 6. Electron density modification in the E-region: (a) electric field at the ground surface directed up, (b) electric field at the ground surface directed down.

greatest change occurs at $z = 125$ km, where $N_e\,(a = 100$ km) and $N_e\,(a = 200$ km) is less than the undisturbed value of N_e by about 15% and 25% respectively.

At $E_z < 0$, i.e. when the field is directed downward, the electron density above the epicenter region increases, reaching its maximum above the epicenter (Fig. 6b). At the height z=125 km the value of N_e exceeds the undisturbed level by about 20% if $a = 100$ km and 30% if $a = 200$ km.

At the heights below 110 km the N_e disturbance is small as it follows from calculations. Thus, the effect of the electrostatic field of the seismic origin is the greatest in the upper part of the night-time E-region. It is due to the fact that the Pedersen drift is maximum at these heights.

Under the same initial conditions the effect of seismogenic electric field was calculated. In this case the configuration of the geomagnetic field should be taken into account (see Fig. 4). Let us take cylindrical coordinates (r, φ, z) centered at the imminent earthquake epicenter. The angle φ is counted from the equatorward direction and z-axis is directed upwards. It is assumed that at the ionospheric level $z = 90$ km the seismogenic electric field distribution $\mathbf{E}_i$ is the same as calculated in previous section of the paper for the nighttime conditions, $a = 200$ km and $E_0 = 1000$ V/m. One should keep in mind that at this height the electric field $\mathbf{E}_i$ is radial with respect to the z-axis and axially symmetrical. Above the altitude $z = 90$ km the Earth's magnetic field lines are equipotentials.

As a result of $\mathbf{E}\times\mathbf{B}$ drift induced by the electric field, the ionospheric plasma in the F_2 region will move along quasi-circular trajectories around the geomagnetic line force z'

cutting the z-axis at the height $z = 90$ km. The z'-axis is a line of zero electric field strength.

The F_2 region plasma density is governed by the O^+ ion continuity equation because O^+ is the dominant ion in the F_2 region, so that $N_i(O^+) \approx N_e$ (N_e is the electron density). For nighttime conditions this equation can be written as

$$\partial N_i/\partial t + \nabla\cdot\{N_i(\mathbf{V}_D + \mathbf{W})\} + \beta N_i = 0$$

where $\mathbf{V}_D$ is the velocity of ion diffusion along geomagnetic field lines, $\mathbf{W} = \mathbf{E}_i \times \mathbf{B}/\mathbf{B}^2$ is the $\mathbf{E}\times\mathbf{B}$ drift velocity, $\mathbf{B}$ is the geomagnetic induction and β is the linear recombination coefficient. The electric field is assumed to be "switched on" by step way at the time $t = 0$, i.e. , $E_0 = \text{const} \neq 0$ for $t \geq 0$ and $E_0 = 0$ for $t < 0$. The expressions for $\mathbf{V}_D$ and β are adopted following *Schunk (1988)*.

The continuity equation is numerically solved for the case of the upward vertical electric field $\mathbf{E}_z$ with $T_e = T_i = T_n = 800$°K (T_n is the neutral atmosphere temperature) and the magnetic inclination $I = 60°$. The initial ion density distribution is assumed to be given by the equation

$$\nabla\cdot\{N_i \cdot \mathbf{V}_D\} + \beta N_i = 0$$

For the upper boundary condition at $z = 700$ km the downward plasma flux of 1.5×10^8 cm^{-2}s^{-1} is specified. At the lower boundary $z = 200$ km the ion density is obtained from the equation of local ionization production and loss equilibrium.

Figure 7 shows contours of the calculated electron density in the Cartesian coordinate system (x, y) at the horizontal plane $z_n = 500$ km two hours after "switching on" the electric field. The black circle indicates the epicenter vertical projection. The x-axis is in the geomagnetic meridian plane and points to the south and the y-axis points eastward. The coordinate system origin is located at the z'-axis and horizontal plane intersection

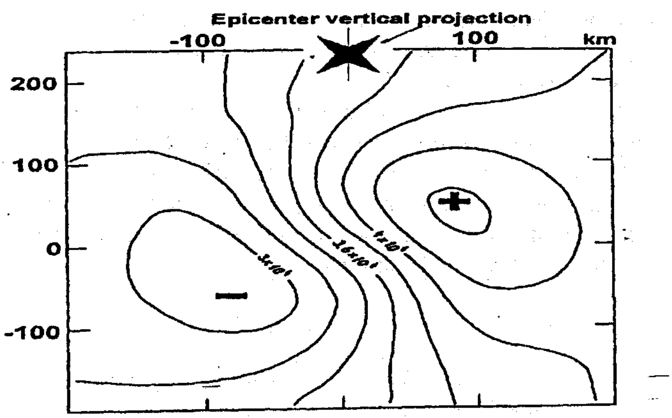

Fig. 7. Distribution of electron density at 500 km under action of seismogenic electric field.

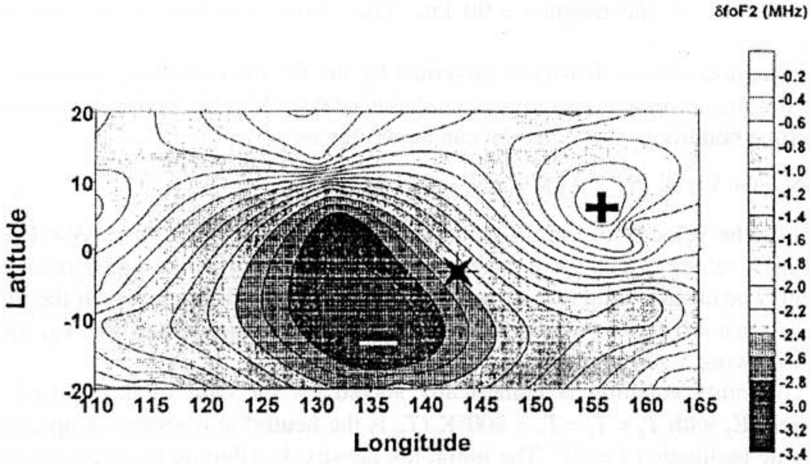

Fig. 8. Distribution of deviations of electron density in the F_2-layer maximum as measured sounder from Intercosmos-19 satellite two days before the earthquake.

point with the cylindrical coordinates ($r = \Delta z \, \mathrm{ctg} I$, $\varphi = 0$, $z = z_p$ where $\Delta z = z_p - 90$ km). It can be seen that as a result of the seismogenic electric field influence, the horizontal distribution of electron density changes substantially in an irregular manner over the area of horizontal size of about 400 km. The maximum change of electron density in respect to undisturbed value is more than 20% at altitude 500 km. There are two distinct regions: within one of them the electron density increases, whereas in the other one it decreases. The foci of these regions are ~ 150 km from each other. The foci are displaced equatorwards of the epicenter by a distance of about 100 km. At $z_p = 500$ km the eastern "positive" focus is displaced equatorwards of the epicenter by 150 km, and displacement of the western "negative" focus is more than 200 km.

The calculated distribution of the electron density at 500 km height modified by the seismogenic electric field one can compare with empirical distribution of the peak electron density obtained with the help of topside sounder onboard Intercosmos-19 satellite two days before the earthquake in the New Guinea region (Fig. 8). It is obvious that plasma configuration is very similar to that obtained theoretically, but the size of modified region area is larger. It indicates that the size of the region on the Earth's surface occupied by the seismogenic electric field a is larger than put in calculations. The displacement of the modified region to south from epicenter projection is lower in comparison with calculations because the data are collected for F_2 layer maximum which was lower than 500 km taken in calculations.

5. CONCLUSION

As it was shown above, the ion and aerosols kinetics in natural vertical electric field in presence of ionization source (in case of seismo-active regions it is radon emanation from the crust) can give rise to the anomalous electric field. Radon itself cannot change substantially the electric field within atmosphere but it could be used as a tracer and indicator of preparing earthquake. Taking into account that metallic aerosol emanations always accompany the radon emanations, one could expect the changes in electric field over the region of preparing earthquake. The anomalous electric field penetrates into the ionosphere and produces modification of vertical distribution of ionization. This anomalous variation within the ionosphere could be registered both by ground based measurements and onboard satellites.

Satellite monitoring of the ionosphere, especially with topside sounding technique, could be a good opportunity of operative spatial mapping of the region within the ionosphere disturbed by seismic activity. If the regularities of such disturbances will be well established and systematized and clearly distinguished from disturbances of other origins, they could be used in future for the seismic prediction and warning with the help of satellite technique.

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