Izvestiya, Physics of the Solid Earth, Vol. 35, No. 10, 1999, pp. 876–878. Translated from Fizika Zemli, No. 10, 1999, pp. 90–92.

SCIENTIFIC COMMUNICATIONS

Possible Changes in the Nighttime Mid-Latitude Ionospheric F2 Region above a Large Crustal Fault

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Received April 29, 1997

Abstract—Possible changes in the concentration of the ionospheric plasma due to an electric field generated by tectonic processes in a fault zone are calculated for the nighttime mid-latitude F2 region of the ionosphere above a large crustal fault. This effect is greatest above faults trending nearly N–S. It is shown that a zone of nonuniformity trending along the fault forms in the F2 region of the ionosphere in response to the field.

INTRODUCTION

According to direct observations [Kondo, 1968; Bonchkovskii, 1954; Chernyavskii, 1955; Hao, 1988], disturbances in the intensity of the vertical atmospheric electric field E_z can arise at the Earth's surface near crustal faults in clear weather. As a rule, these disturbances occurred before earthquakes, and their amplitude ranged from a few tens to 100–150 V/m before moderate earthquakes [Kondo, 1968] and from a few hundreds to 1000 V/m before catastrophic earthquakes [Bonchkovskii, 1954; Chernyavskii, 1955; Hao, 1988]. However, Morgunov *et al.* [1990] reported on an observation of an E_z disturbance in a fault zone with an amplitude of 350 V/m that was not followed by an earthquake. In any case, the observed E_z disturbances are clearly related to tectonic activity. The physical mechanism responsible for such disturbances of the electrostatic field E_z is yet to be elucidated. A review of existing hypotheses concerning this phenomenon is given in [Morgunov *et al.*, 1990].

Kim *et al.* [1995] investigated the possible effects of tectonic activity in the nighttime mid-latitude E region of the ionosphere above a large crustal fault due to the electric field generated by tectonic processes in the fault zone. The electric field intensity at ionospheric heights was calculated for a linear dipole-type along-fault distribution of the vertical electrostatic field at the Earth's surface E_z. It was shown that the horizontal distribution of ionospheric plasma above the fault becomes noticeably nonuniform under the action of the field,.

In this work, we study the effect of the electric field related to a large crustal fault on the nighttime mid-latitude F2 region of the ionosphere.

FORMULATION OF THE PROBLEM

Similar to Kim *et al.* [1995], we define a Cartesian system of coordinates with the x axis directed along the fault axis, the y axis transverse to the fault, and the z axis vertically upward. We examine the ionospheric region above the middle part of the fault, which allows the approximation of an infinitely long fault to be used.

The electrostatic field in the ionosphere above a fault, calculated by Kim *et al.* [1995] for a linear dipole-type distribution of the vertical electrostatic field intensity with an amplitude of 300 V/m at the Earth's surface along a fault, is shown in Fig. 1. As seen from the figure, the field in the ionosphere is directed along the positive direction of the y axis and reaches a maximum (~0.8 mV/m) above the fault axis. If the fault trends strictly N–S, the field is directed strictly westward or eastward depending on the polarity of the dipole-type distribution of the vertical field at the Earth's surface E_z in the fault zone. If E_z is directed upward on the eastern side of the fault and downward on its western side, the field in the ionosphere E_y is directed westward. If the polarity of the E_z distribution is reversed, the E_y field is directed eastward. When the fault trends strictly E–W, the electric field at ionospheric heights will be directed poleward if E_z is directed upward on the southern side of the fault and downward on its northern side; the reversed polarity yields a field directed toward the equator. In the general case of an arbitrary orientation of the fault, the electric field in the ionosphere have both zonal and a meridional component.

The distribution of the plasma concentration in the F2 region can be obtained from the continuity equation for the concentration of O^+ ions because these are the main ions in the F2 region; i.e., $N_i(O^+) \approx N_e$ (N_e is the electron concentration). This equation can be written as

$$\partial N_i/\partial t + \mathrm{div}\{N_i(\mathbf{V}_d + \mathbf{W})\} + \beta N_i = 0, \quad (1)$$

where $\mathbf{V}_d$ is the diffusion rate of O^+ ions along geomagnetic field lines, $\mathbf{W} = (\mathbf{E} \times \mathbf{B})/\mathbf{B}^2$ is the electrodynamic drift rate of the plasma, and β is the linear recombination coefficient. The expression for the diffusion rate is $\mathbf{V}_d = -D_i[\nabla(N_i)/N_i - (m_i\mathbf{g}_{\|})/(kT_i)]$, where $D_i = (kT_i)/(m_i \sum_n \nu_{in})$. Here, m_i is the mass of an O^+ ion, $\mathbf{g}_{\|}$ is the component of the free-fall acceleration vector $\mathbf{g}$ along the geomagnetic field line, k is the Boltzmann constant, and ν_{in} is the frequency of collisions of O^+ ions with neutral particles of the n type. We assume that the electric field is suddenly applied at the time $t = 0$. The values of ν_{in} and β are taken after Schunk [1988].

Equation (1) is numerically integrated by using the Geer finite-difference method at $T_e = T_i = T_n = 800$ K (T_n is the temperature of the neutral atmosphere). We assume that the undisturbed N_i distribution is horizontally homogeneous and is defined by the equation $\mathrm{div}\{N_i\mathbf{V}_d\} + \beta N_i = 0$.

In this case, the meridional electric field in the ionosphere, which causes a horizontal electrodynamic plasma drift, does not affect the N_i distribution. In contrast, the zonal electric field, giving rise to a vertical electrodynamic drift, can appreciably alter the distribution of the ionospheric plasma concentration. Therefore, we examine the case of a fault oriented meridionally. The boundary conditions are as follows: a downward plasma flow of 1.5×10^8 cm^{-2} s^{-1} is specified at the height $h = 700$ m, and the N_i concentration does not vary with time at the height $h = 210$ km, where it equals $N_i(h = 210 \text{ km}) = 5.2 \times 10^3$ cm^{-3}. The latter value is close to N_i averages observed at this height [Fatkulin et al., 1981].

RESULTS AND CONCLUSIONS

Figures 2 and 3 present the calculated plasma concentrations $N = N_i = N_e$ versus the distance y at the heights $h = 250$ and 500 km and at a level of the main ionospheric maximum N_mF2 for the cases when the field in the ionosphere E_y is directed eastward and westward, respectively, two hours after the field is initially applied, i.e., at $t = 2$ h.

Application of the field is seen to give rise to a nonuniform horizontal distribution of the ionospheric plasma above the fault. When the field in the ionosphere is directed eastward and causes an upward electrodynamic plasma drift, the plasma concentration increases at a level of the main ionospheric maximum (N_mF2) and higher, and the concentration of charged particles decreases in the lower part of the F2 region. If the field is directed westward, causing a downward electrodynamic plasma drift, the reverse is true: the plasma concentration decreases at the main ionospheric maximum height and higher and increases at heights below the main maximum. The degree of the ionospheric disturbance is at a maximum above the fault axis and is height dependent. When the plasma drift is directed upward (Fig. 2), changes in the concentration at the height $h = 250$ m reach 35%, whereas the greatest change in concentration at the maximum of the F2 layer is 12%; in the upper part of the F2 region at the height $h = 500$ km, the concentration disturbance reaches 25%. When the plasma drift is directed downward (Fig. 3), the greatest relative change in the concentration of charged particles is about 15% at the F2-layer maximum and at the height $h = 250$ km, and about 20% at a height of 500 km. The figures show that the charac-

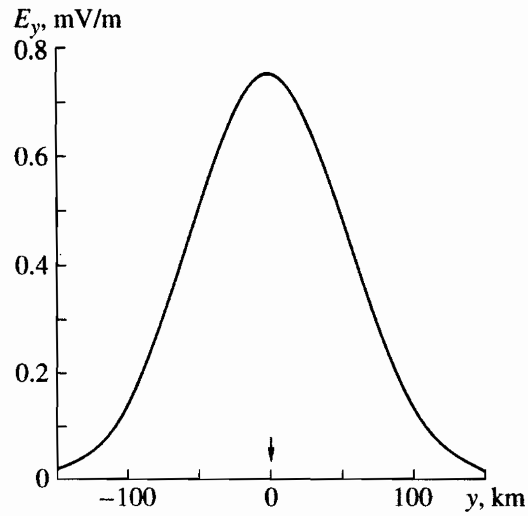

Fig. 1. Intensity of the tectonically induced horizontal electric field in the ionosphere versus distance y [Kim et al., 1995].

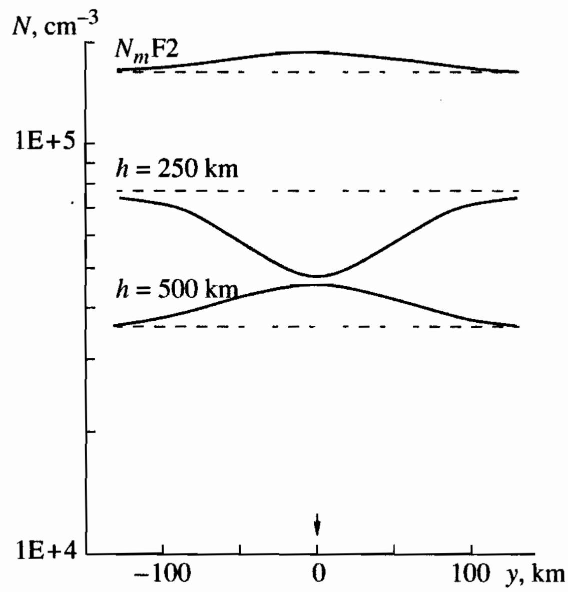

Fig. 2. Horizontal distribution of the ionospheric plasma concentration at a level of the main N_mF2 maximum and at the heights $h = 250$ and 500 km two hours after the initial application of the field. The electrodynamic drift is directed upward, and E_y, eastward. The background plasma distributions, when the drift rate is zero, is shown by dashed lines. The arrow indicates the position of the fault axis projected on the ionospheric levels.

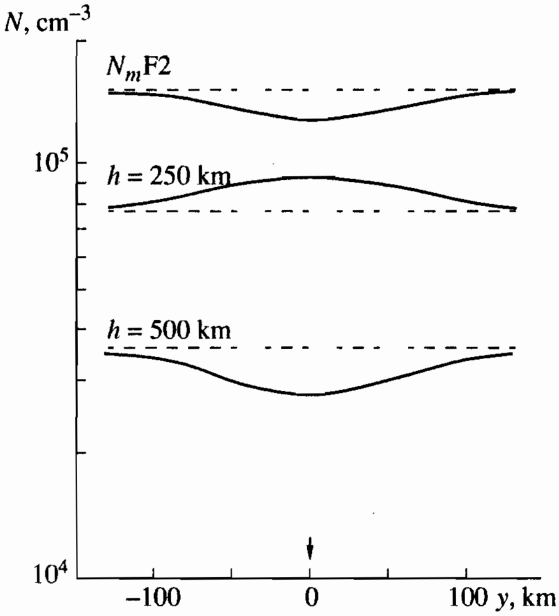

Fig. 3. The same as in Fig. 2, but for a downward electrodynamic drift (E_y is directed westward).

teristic across-fault size of the nonuniformity in the ionosphere F2 region is about 200 km.

The main results of this work can be summarized as follows. We calculated possible changes in the concentration of the ionospheric plasma in the nighttime midlatitude F2 region of the ionosphere above a large crustal fault as a response to the electric field generated by tectonic processes in the fault zone. The effect in the F2 region is greatest above faults trending mainly N–S. The field produces a zone of a nonuniform ionospheric plasma in the F2 region of the ionosphere. The zone is elongated along the fault and has a width of about 200 km. Depending on the distribution of the electric field in the fault zone at the Earth's surface, there is either a decrease or an increase in the ionospheric plasma concentration at various heights. Relative changes in the plasma concentration at the maximum of the ionospheric F2 layer can reach 15%.

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