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STUDY OF THE PARAMETERS OF HIGH LATITUDE IONOSPHERE BY METHOD OF SPACE-DIVERSITY RECEPTION

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1. Introduction

The method of space-diversity reception is the most widespread way of measuring the speed of the ionosphere irregularities by ground radio stations (Mitra, 1955). It is well known that in the E- layer of ionosphere the drift of irregularities with middle velocity of approximately 50-100m/s was observed (Kazimirovskiy, 1963; Kushnerevskiy and Mirkotan, 1963 ; Brekke et al., 1994). The drift velocities depend on the geographical position of radio stations, on the time of day and on the height. Hereat, the turbulence chaotic motion in the lower ionosphere is superimposed on the comparatively firm system of drift at fixed heights (Fujii et al., 1998). Nearly full absence of high-latitude data is explained by the small number of stations, registering ionosphere drift in the polar auroras zone. In the polar auroras zone the drift of irregularities has been registered by radar method.

During magnetic perturbations at the height of around 100-km the ionosphere drift with the speed of approximately 500-1000m/c are observed in the latitude direction (Greenwald, 1982; Uspensky et al., 2004). As far as the direction of drift is observed by radar method in the opposite direction of electric currents, it is possible to consider that these drifts are electron drifts along the disturbed zone (Cole, 1963). These ionosphere drifts are comparable rather with current curls of magnetic storm, than with the wind displacement of electric currents during a bay for this system in the ionosphere and they can not be used for calculation of the dynamo electric field.

Pudovkin (1960) offered a method of measurement of the wind velocity in ionosphere. Using the velocity of the centre of perturbation there was defined a bay, where δH takes the maximum value, but δZ is near zero. From the magnetic data it is only possible to define the component of the velocity wind $V_\perp$ perpendicular to the current band. This method has an advantage that the velocity of winds $V_\perp$ is defined based on the data of magnetic stations, which are numerous at high latitudes.

The given paper considers the characteristics of plasma motion in the dynamo-region of the E layer for disturbed days on 22.03.04, 21.09.03 and 24.09.03.

2. Equations for calculations

In the E -region ionosphere plasma is considered as ambience consisting of electrons, ions and neutral particles. The equation of motion for each of them is written. The equation of motion for j-component of velocity motion of the charged particles in can be written a simplified form, if the collision of electrons with ions is neglected (Krasrogorskaya, 1972):

$$d\mathbf{V}_j/dt = (1/\tau_{jH} H)(\mathbf{E}_\perp + \mathbf{V}_j \times \mathbf{H}) + (\mathbf{V}_n - \mathbf{V}_j)/\tau_{jn} \quad (1)$$

Where: τ_{jH} -time of rotation of the charged particles around the power line of the magnetic field, τ_{jn} -efficient time between collisions of ions with neutral particles, $\mathbf{V}_j$ -velocity of motion of the charged particles, $\mathbf{V}_n$ - velocity of motion of the neutral particles, **E, H** –tension of electric and magnetic fields.

In the dynamo- region the magnitude velocities of electrons $\mathbf{V}_e$ in electric field are close to drift velocities ($\mathbf{V}_{dr}$) at the same time the velocity of motion of the ions $\mathbf{V}_i$ to a greater degree is defined by the collisions. Therefore, in the dynamo-area the electric field is of primary influence upon electrons and the current is defined mainly by their motion. We use the equation of the electron motion for the electrical field calculation. From this the drift velocity is found:

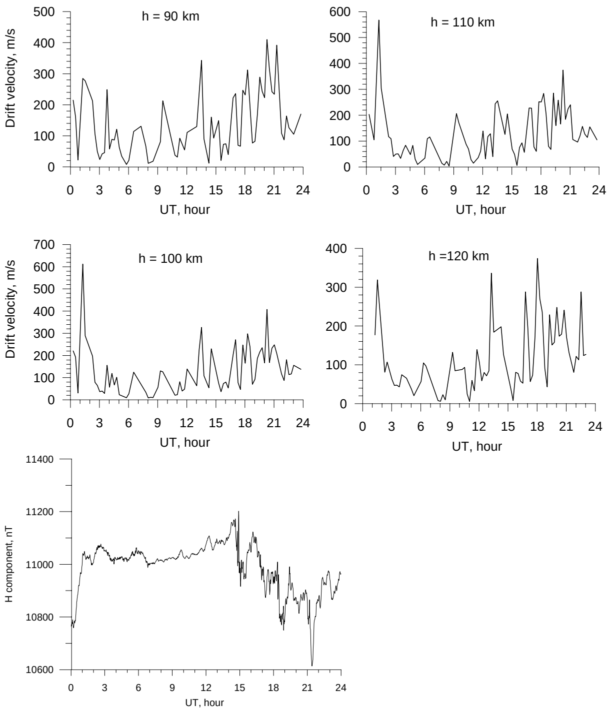
$$\mathbf{V}_{dr} = (c\,[\mathbf{EH}]\,/H^2) \quad (2)$$

3. Drift velocity measurements

Studies of motion of irregularities in the high-latitude ionosphere are conducted using an HF- radar located in Tymanny (69.0 ° N, 35.7° E). Measurement of the horizontal motion of irregularities is based on the method of partial reflections reception by three reception points. These points are located at vertexes of isosceles triangle with sides 164m and 232m. The radiating elements of the aerial consist of two horizontal Nadenenko dipoles, crossing under the angle of 90°. The width of the aerial direction diagram in the vertical plane, oriented along the line north-east and south-west constitutes 19.26°, whereas in the vertical plane, directed northwest it makes 30.2° (Yakimov et al., 2003).

The calculation of anisotropy irregularities, velocity and directions of the drift is done using the method of correlation analysis in the plane perpendicular to the direction of the wave spreading (Bogolyubov et al., 1982).

Figure 1 presents the daily drift velocity variations (top) and horizontal component of magnetic field (bottom) on 22.03.04 for heights of dynamo-region (90, 100, 110, 120 km). From figure is seen that the several maximums in daily drift velocity variations at considered heights are existed, which correspond to change H-component of magnetic field. The drift velocities vary in time quickly, as other wind velocity (Pudovkin, 1960). In figure 2 are shown daily variations of angles deflection of vector drift velocity from direction on north. The angles of deflection vector drift velocity few vary in height. Under positive values angles the vectors drift velocity of south-east direction has been observed. Under negative values angles the vectors drift velocity of south-west direction is observed.



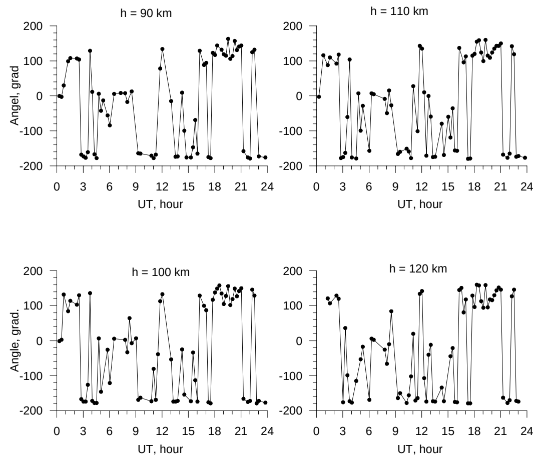


Fig. 1.The daily variations of drift velocity (top); horizontal component of magnetic field on 22.03.04 (bottom).

Fig. 2. The daily variations of angles deflection of vector drift velocity from north direction (22.03.04)

4. Calculation of magnetic and electric fields

The characteristic of magnetic field of the Earth is its tension $\mathbf{H_T}$. The magnetic data of the Tromse observatory (69.6° N, 19.2° E) were used for calculation of the tension of the magnetic field, since there are no absolute measurements at the Tymanny observatory. Daily variations of horizontal component of the magnetic field on 22.03.04 are presented in figure 1 (bottom). This day was a disturbed one. The negative bays in the geomagnetic field with values of 200- 400 nT were observed for the interval of 0-3UT and for the interval of 17- 23 UT, and bays at Tymanny were observed up to 180 - 330 nT.

Figure 3 shows the electric field daily variations for different heights (90, 100, 110 and 120 km). At heights of 100 and 110 km the maximum value of the electric field makes around 30mV/m during the interval of 0-3UT and around 20mV/m in the interval of 17-23UT. The maximum value of the electric field at heights of 90 and 120 km makes around 15-17mV/m and 20 mV/m at the same time. The magnitude of the calculated electric field through heights E layer varies considerably at night and in the morning.

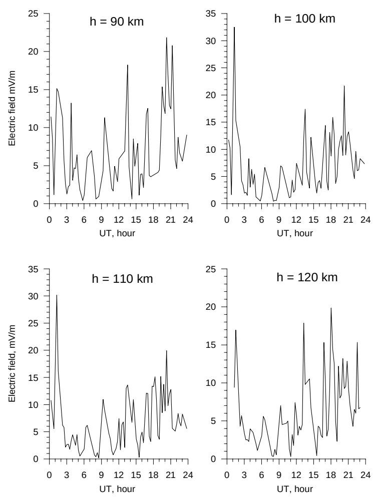


Fig. 3. Daily variations of the electric field.

At such heights the data (drift velocity, deflection of drift velocity vector from the north direction and the electric field) are considered on other disturbed days 21.09.03 and 24.09.03. The index of perturbation for these days is Σ Kp=30 and Σ Kp=35 respectively. The direction of drift velocity on 21.09.03 at 13.44UT and on 24.09.2003 at 13.33 UT for all considered heights changed from the south-east to the north-east (Fig.4. on the left). The direction of drift velocity on 21.09.03 at 03.40UT for the considered heights changed from the south-east to the north-west. In the first event 24.09.03 the magnitude of drift velocity increased from 40m/s to 100m/s, the electric field increased from 2mV/m to 5mV/m. The reduction of drift velocity is observed on 21.09.03 when its direction is changed (13.44UT). In the second event 21.09.03 at 3.40UT the magnitude of drift velocity at height 110 km does not vary and makes up to 70m/s and the electric field up to 3,5mV/m, when its direction is changed.

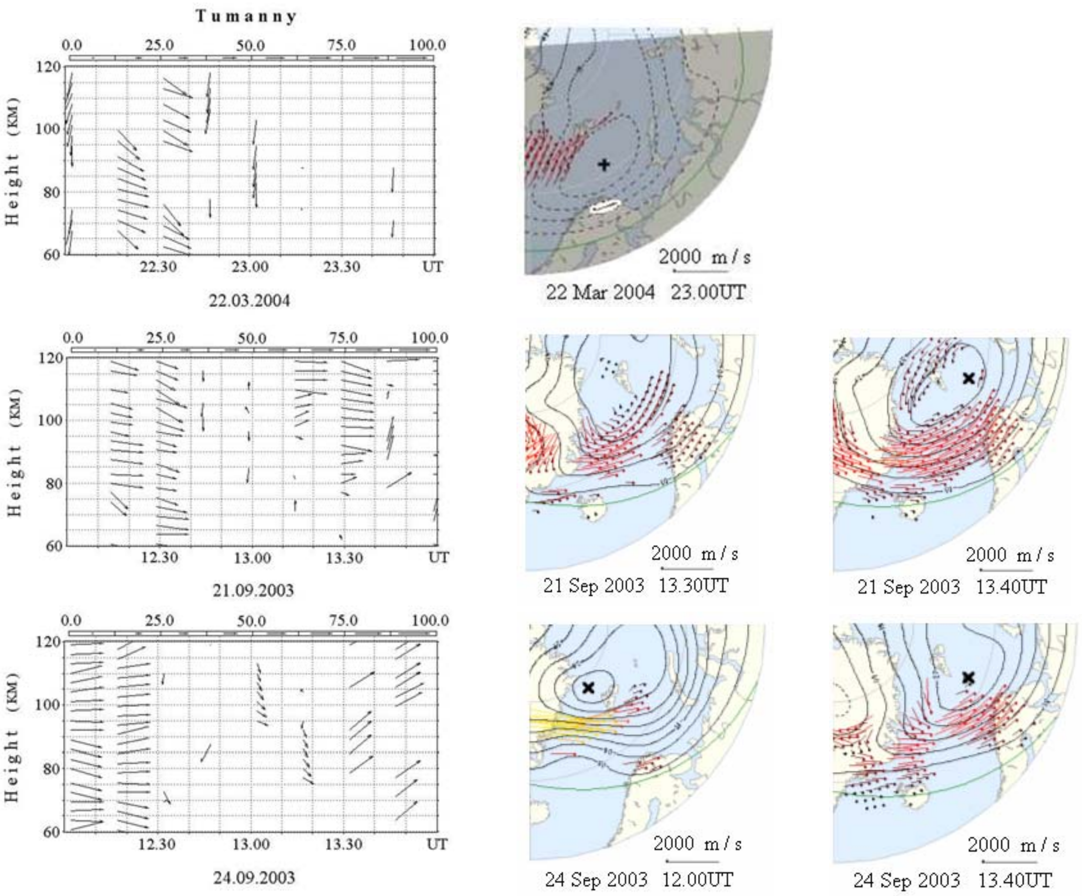


Fig. 4. Drift velocities in Tymanny and the Doppler velocity coherent echo (SuperDARN).

During a magnetic bay (H>100nT) the integral resistance of power lines of the geomagnetic field becomes so considerable that electric fields are transferred from the magnetosphere to ionosphere significantly weakened (Barsykov and Pudovkin, 1970). Thus, the dynamo-action of ionosphere winds during a magnetic bay becomes the main source of electric field in the auroral ionosphere.

5. Comparison of calculated parameters with experimental data.

As well known, the main mechanism of the electric field generation directly in the ionosphere is the dynamo-action of winds (Mishin, 1971; Fujii et al., 1998.). Using the EISCAT data Fujii showed that the amplitude of neutral winds connected with electric field of polarization's (**V*B**) in the polar ionosphere at heights of E-layer varies much through height. The magnitude of electric field at heights of E layer, that we have calculated, varies significantly at night and in the morning. In the daytime electric field variations are of the same order. The studies of intensity and distribution of the electric field at high-latitudes were executed by Heppner (1972), Caufmann, Gurnett (1971, 1972), Frank (1971), using data of «Ogo-6» and «Injun-5» satellites Based on these data, the authors chose two regions: auroral zone (geomagnetic latitudes- 60º-75º) and the polar cap (geomagnetic latitudes 75º-80º), where the behavior $\mathbf{V}_{\perp}$ is essentially different. In the auroral zone the convection of plasma is inhomogeneous (Caufmann, Gurnett, 1971, 1972; Kustov et al, 1998). Rocket's measurements of the electric field component, perpendicular to the magnetic field of the Earth at high latitudes from Heysa showed that there are several local maxima in the profile of electric field on March 10 1979 at 18.43UT (Kopaev et al., 1985). At heights of 100-120 km the magnitude of the electric field constitutes 50 mV/m. The authors consider that the magnetosphere processes have a dominating role in the generation of the electric field. The distribution convection, received by a system of HF radars (SuperDARN) above the Kola peninsula is considered. This system use data of the Doppler velocity coherent echo in the F-layer ionosphere. In paper (Makarevitch, et al., 2004) it is shown that in the E region the Doppler velocity magnitude of coherent echo is approximately five times smaller than in the F-region. Above the Kola Peninsula the necessary conditions for measuring convection by SuperDARN at night are uncommon. In fig. 4 (on the right) the distributions of convection measured by SuperDARN system radars are presented. The Doppler velocity coherent echo above the Kola Peninsula 22.03.04 at 23.00UT constitutes 890m/s. Drift velocities, measured by radar in Tymanny at the height of 100 km at 23.00UT, make 180m/s (top, on the left). This figure shows the distributions of convection measured by SuperDARN 21.09.03 (at 13.30UT, 13.40UT) and 24.09.03 (at 12.00UT, 13.40UT) as well. The Doppler velocity coherent echo above the region of the Kola Peninsula constitutes 400-500 m/s and 500-600 m/s respectively. The magnitude of the drift velocity in the E-region in Tymanny at this time at the height of 100km constitutes 120-130m/s. Thus, in the E-region of the ionosphere the magnitudes of drift velocity, measured in Tymanny agree with those of the Doppler velocity coherent echo.

From the above analysis of all the data it is possible to make the following conclusions:

Drift velocities vary in time very quickly.

The predominant direction of the drift towards the south (the eastern or western one) is observed.

The calculated electric field in the E region using the drift velocity measurements is basically defined by the ionosphere wind.

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