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VARIATIONS OF THE ELECTRIC FIELD ZONAL COMPONENT, THE VERTICAL COMPONENT OF THE PLASMA DRIFT AND NEUTRAL WIND VELOCITIES IN IONOSPHERE OVER KHARKOV (UKRAINE) DURING AUGUST 5 – 6, 2011 AND NOVEMBER 13 – 15, 2012 MAGNETIC STORMS

The modeling results of the zonal electric field and the vertical component of the plasma transfer velocity due to electromagnetic drift during August 5–6, 2011 and November 13 – 15, 2012 magnetic storms were presented. Confirmed that has a penetration of electric fields from magnetospheric origin in the mid-latitude ionosphere during strong geomagnetic disturbances. For the considered disturbed periods the neutral wind parameters were calculated using Kharkov incoherent scatter radar data.

Keywords: ionosphere, geospace storm, zonal electric field, plasma drift.

Introduction. It is well known that in quiet conditions the contribution of magnetospheric sources in electric fields and currents in the middle and low latitudes is fairly small. As the presented in [1 – 4], the results of experimental studies and theoretical calculations, the magnitude of the electric field in the mid-latitude ionosphere without geomagnetic disturbances does not exceed several mV/m. At altitudes of the ionospheric F2-peak the plasma drift caused by these fields is small compared to the transport processes of charged particles due to ambipolar diffusion and neutral winds. During strong geomagnetic disturbances has penetration of electric fields at the altitudes of the mid-latitude ionosphere and, consequently, increasing the plasma velocity in crossed electric and magnetic fields. It should be noted that the transfer of the plasma due to the electromagnetic drift during geomagnetic storms have a significant impact on the altitudinal distribution of the parameters of the mid-latitude ionosphere.

The aim of this work is to calculate the parameters of the zonal electric field in the ionosphere over Kharkov (Ukraine), as well as modeling the transport velocity variations due to the electromagnetic plasma drift and neutral wind during August 5 – 6, 2011 and November 13 – 15, 2012 magnetic storms.

The observation means. For modeling of the neutral wind parameter variations were used the Kharkov incoherent scatter radar (ISR) (geographic coordinates: 49,6º N, 36,3º E; geomagnetic coordinates: 45,7º, 117,8º) data. At present time the Kharkov ISR is the only reliable and most informative data source of the geospace plasma state at the mid-latitudes of Central Europe.

Radar allows measuring with high accuracy (usually error is 1 – 10%) and acceptable altitude resolution (10 – 100 km) the following ionospheric parameters:

electron density N, electron T_e and ion T_i temperatures, a vertical component of the plasma drift velocity v_z, and ion composition. The investigated altitude range is 100 – 1500 km.

The general information about magnetic storms parameters. *The magnetic storm on August 5 – 6, 2011*. Super-strong magnetic storm (MS) began on August 5, 2011 at 19:03 UT. The K_p index of geomagnetic activity during the MS main phase reached magnitude 8 – and D_{st} = –113 nT. The solar wind (SW) velocity during the main phase ranged 570 – 620 km/s, the SW particle temperature reached a value 6,4·10^5 K, the density of SW particles $N_{sw} \approx 1{,}9 \cdot 10^7$ m^{-3}. The value of the interplanetary magnetic field (IMF) B_z-component was –(15–18) nT, and the IMF magnetic induction by modulus was 25 – 27 nT. The auroral activity index $AE_{\max} \approx 1740$ nT. The value of the Akasofu function $\varepsilon \approx 37$ GJ/s.

The magnetic storm on November 13 – 15, 2012. Geomagnetic storm began on November 13 at 15:00 UT. The main phase of the magnetic storm took place from 18:00 UT on November 13 to 06:00 UT on November 14. The extreme values of the geomagnetic activity indices during the MS were: $AE_{\max}$ = 1009 nT, $K_{p\,\max}$ = 6+, D_{st} = –108 nT. The value of the IMF B_z-component was –(17 – 18) nT. The value of the Akasofu function was ~26–30 GJ/s.

Initial theoretical relations. As is known, without perturbation the electric fields effects in the mid-latitudes can be neglected. However, during strong geomagnetic storms have amplification of electric fields due to the magnetospheric convection, which significantly affects on dynamics of the mid-latitude ionosphere. During disturbed conditions in the mid-latitudes, and neglecting the effects of the geomagnetic field declination the main contribution to the vertical transport of plasma makes zonal electric field. Electric field directed to the east, causing the plasma drift upwards and field directed to the west – the transfer of ionospheric plasma down. We estimate the value of the zonal component of the electric field, as well as the contribution of the vertical component of plasma motion due to the electromagnetic drift in the dynamic mode of the ionosphere during magnetic storms on August 5 – 6, 2011 and on November 13 – 15, 2012.

As shown by the calculations presented in [5], there is a correlation between AE index and the values of the zonal component of the electric field E_y. In this case, the electric fields of magnetospheric origin and geomagnetic plasma heating are the main sources of dynamic processes in the ionosphere in mid-latitudes during strong geomagnetic disturbances.

To calculate E_y use the empirical relation between the magnitude of the electric field and auroral activity index, given in [5]:

$$E_y = (0{,}55 - 0{,}01AE)\cdot 10^{-3},$$

where AE – auroral activity index (in nT).

Expression to calculate the velocity of plasma transport due to electromagnetic drift neglecting effects declination has the form [6]

$$v_{EB} \approx (E_y/B)\cos I,$$

where B – the geomagnetic field modulus, I – the geomagnetic field inclination (for Kharkov city $I = 66{,}85^{o}$).

In mid-latitudes the drag wind velocity vertical component of ions due meridional component of the velocity of the neutral gas horizontal motion. Neutral wind directed toward the equator causes the plasma upward along magnetic field lines, and the wind, having the direction of the pole down motion of the plasma along the geomagnetic field lines [6].

Expression for calculating the meridional component of the neutral wind velocity v_{nx} neglecting the effects of the geomagnetic field decline has the form [6]:

$$v_{nx} = (v_z - v_{dz} - v_{EB})/(\sin I \cos I),$$

$$v_{dz} = -D_a \sin^2 I \left(\frac{1}{H_p} + \frac{1}{N}\frac{\partial N}{\partial z} + \frac{1}{T_p}\frac{\partial T_p}{\partial z} \right).$$

Here v_z – the vertical component of the plasma velocity (Kharkov ISR data), v_{dz} – the vertical component of the plasma transport velocity due to ambipolar diffusion, D_a – ambipolar diffusion coefficient, $H_p = kT_p/mg$ – the plasma scale height, k – Boltzmann constant, $T_p = T_e + T_i$ – the plasma temperature, T_e and T_i – the electron and ion temperatures (Kharkov ISR data), m – the oxygen ion mass, ν_{in} – the total ion collision frequencies with the major components of the neutral gas, g – the free fall acceleration, N – the oxygen ions density (Kharkov ISR data), z – the altitude, v_{EB} – the velocity of plasma transport due to electromagnetic drift.

Calculation results. Figures 1 and 2 shows the temporal variations of the zonal component of the electric field in the mid-latitude ionosphere at the altitude of 300 km during August 5 – 6, 2011 and November 13 – 15, 2012 magnetic storms.

The calculations show that the value of E_y reached –17 mV/m during the main phase of the MS on August 5 – 6, 2011. Whereas in quiet conditions, the magnitude of the zonal component of the electric field does not exceed –5 mV/m. During the November 13 – 15, 2012 MS the value of the electric field zonal component was –9,5 mV/m. In quiet conditions, the value of E_y does not exceed units of mV/m.

In general, the results agree well with the results obtained by other authors [1, 3, 6].

Figures 3 and 4 shows the calculation results of the temporal variations of the plasma velocity vertical component due to the electromagnetic drift during the considered magnetic storms and quite conditions at altitude of 300 km.

In the main phase of August 5 – 6, 2011 magnetic storm the v_{EB} velocity reached values of –150 m/s, while the magnetically quiet conditions, plasma transport due to electromagnetic drift practically absent. For November 13 – 15, 2012 magnetic storm obtained that the v_{EB} velocity reached its peak shortly after the beginning of the magnetic storm and equaled –85 m/s.

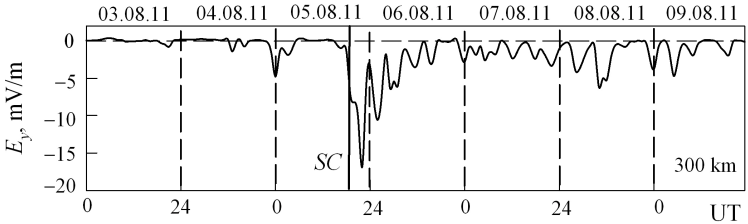

Fig. 1 – The temporal variations of the zonal component of the electric field during August 5 – 6, 2011 magnetic storm

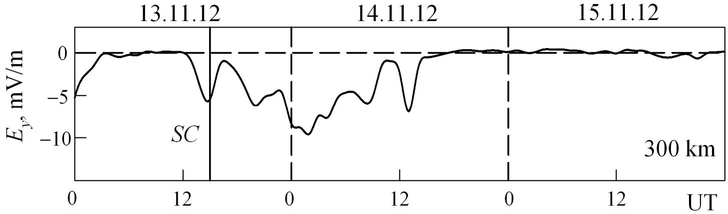

Fig. 2 – The temporal variations of the zonal component of the electric field during November 13 – 15, 2012 magnetic storm

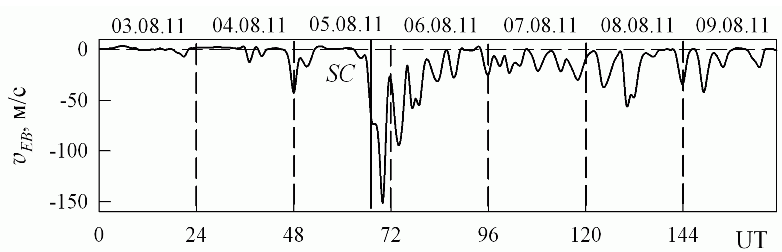

Fig. 3 – The temporal variations of the plasma velocity vertical component due to the electromagnetic drift during the magnetic storm on August 5 – 6, 2011

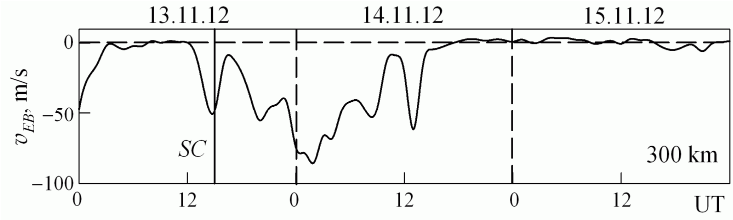

Fig. 4 – The temporal variations of the plasma velocity vertical component due to the electromagnetic drift during the magnetic storm on November 13 – 15, 2012

Figures 5 and 6 shows the temporal variation of the meridional component of the neutral wind during August 5 – 6, 2011 and November 13 – 15, 2012 magnetic storms. Calculations showed that in quiet conditions v_{nx} velocity ranges from 0 to –150 m/s. The highest rate of v_{nx}, as shown by calculations, reaching a value of 350 m/s on August 6, 2011 and 150 m/s on November 14, 2012. This behavior of v_{nx} indicates that the effects of the magnetic storm well manifested in the variations of the global thermospheric circulation parameters. Such behavior of the neutral wind velocity was also observed during September 25, 1998 magnetic storm [7]. The calculation results agree with the results of other authors presented in [8, 9].

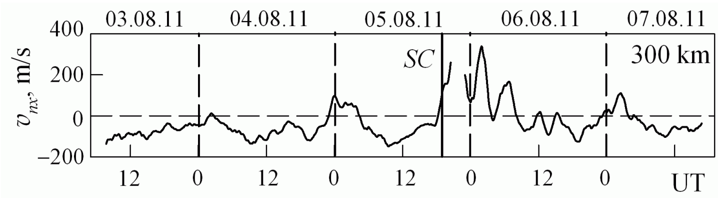

Fig. 5 – The variations of the neutral wind velocity meridional component during August 5 – 6, 2011 magnetic storm

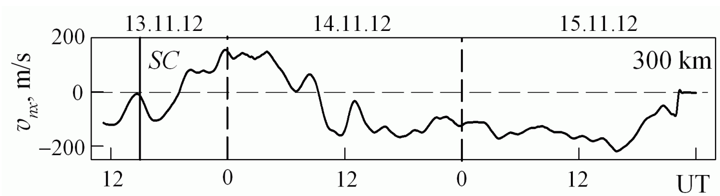

Fig. 6 – The variations of the neutral wind velocity meridional component during November 13 – 15, 2012 magnetic storm

Conclusion. 1) The calculations show that the magnitude of the electric field zonal component reaches the value of –17 and –9,5 mV/m in the main phase of magnetic storms on August 5 – 6, 2011 and November 13 – 15, 2012, respectively. In quiet conditions, the E_y value does not exceed units of mV/m.

2) The effects of considered magnetic storms were well manifested in variations of dynamic processes in the ionosphere. The magnitude of the vertical component of the plasma velocity due to the electromagnetic drift reached values of –150 and –85 m/s during magnetic storms on August 5 – 6, 2011 and November 13 – 15, 2012, respectively. In undisturbed conditions plasma transport due to electromagnetic drift was negligible.

3) The effects of magnetic storms were well manifested in the variations of the global thermospheric circulation. During magnetic storms occurred strengthening the neutral wind, toward the poles. The calculations show that the neutral wind velocity reached values 350 and 150 m/s during magnetic storms on August 5 – 6, 2011 and November 13 – 15, 2012, respectively.

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Представлено результати моделювання варіацій зонального електричного поля та вертикальної компоненти швидкості переносу плазми за рахунок електромагнітного дрейфу під час магнітних бур 5 – 6 серпня 2011 р. та 13 – 15 листопада 2012 р. Підтверджено, що під час сильних геомагнітних збурень має місце проникнення електричних полів магнітосферного походження у середньоширотну іоносферу. Для розглянутих збурених періодів розраховано параметри нейтрального вітру з використанням даних Харківського радара некогерентного розсіяння.

Ключові слова: іоносфера, геокосмічна буря, зональне електричне поле, дрейф плазми.

Представлены результаты моделирования вариаций зонального электрического поля и вертикальной компоненты скорости переноса плазмы за счет электромагнитного дрейфа во время магнитных бурь 5 – 6 августа 2011 г. и 13 – 15 ноября 2012 г. Подтверждено, что во время сильных геомагнитных возмущений имеет место проникновение электрических полей магнитосферного происхождения в среднеширотную ионосферу. Для рассмотренных возмущенных периодов рассчитаны параметры нейтрального ветра с использование данных Харьковского радара некогерентного рассеяния.

Ключевые слова: ионосфера, геокосмическая буря, зональное электрическое поле, дрейф плазмы.