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Dynamic and Thermal Processes in the Mid-Latitude Ionosphere over Kharkov, Ukraine (49.6° N, 36.3° E), During the 13-15 November 2012 Magnetic Storm: Calculation Results

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Abstract

Calculation results of the variations of dynamic and thermal process parameters in geospace plasma during the 13-15 November 2012, magnetic storm (MS) over Kharkov are presented. The calculations were based on experimental data obtained on the Kharkov incoherent scatter radar, single in the European mid-latitudes. Calculations showed that during the MS there took place an increase, by modulus, of the values of vertical component of transfer velocity, due to ambipolar diffusion, up to a factor of 1.4-2.1. During the MS there took place a decrease of the values of energy input to the electron gas by about 20-35%. During the main phase of MS, the heat flux density transferred by electrons increased up to a factor of 2-2.5. Results of estimates of the zonal component electric field value E_y are presented. During the MS the value of E_y was –9.5 mV/m. The vertical component of plasma velocity due to electromagnetic drift v_{EB} has been calculated.

Key words: magnetic storm, dynamic and thermal processes, geospace.

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1. INTRODUCTION

Dynamic and thermal processes play an important role in the formation of spatial structure of the ionospheric plasma at altitudes of the F2 region of the ionosphere. Parameters of the physical processes have characteristic variations depending on the season, time of the day, place of observation, as well as by space weather conditions. As shown by experimental studies, the effects of strong geospace disturbances (geospace storms) are well manifested in variations of the dynamic and thermal processes in the ionosphere. Strong magnetic storms lead to significant changes in the dynamic and thermal modes of the ionospheric plasma. Such effects have been recorded not only in the high latitudes, but in the middle and low latitudes too.

For investigation of the effects of the strong geospace storms, various tools of remote and local sounding of the near-Earth space have been used (ionosondes, worldwide network of incoherent scatter radars (ISRs), satellites, *etc.*).

Incoherent scatter radars are the most informative radiophysical tools for ionospheric plasma investigation. At present, about fifteen incoherent scatter radars operate over the word. The results obtained by a worldwide network of ISRs allow extending our knowledge about global processes in the ionosphere during strong geomagnetic disturbances in polar, middle and low latitudes (Buonsanto 1999, Buonsanto *et al.* 1999a, b; Goncharenko *et al.* 2005, Grigorenko *et al.* 2005a, b, 2007; Immel *et al.* 2015). Results of observations of the magnetic storm effects in ionospheric plasma variations obtained on ISRs have been described in numerous publications (Buonsanto 1999, Buonsanto *et al.* 1999a, b, Goncharenko *et al.* 2005, Grigorenko *et al.* 2005a, b, 2007; Immel *et al.* 2015).

In the middle latitudes of Europe, the incoherent scatter radar (ISR) in Kharkov, Ukraine (49.6° N, 36.3° E), is the only means for radio sounding of the ionosphere, providing almost entire set of basic parameters of the ionospheric plasma (Emelyanov and Zhivolup 2013). The experimental data obtained at the Kharkov incoherent scatter radar were used earlier for the study of unique events in the geospace − partial solar eclipses (Lyashenko 2013, Lyashenko and Chernogor 2013, Domnin *et al.* 2014a), geospace storms of different intensity (Grigorenko *et al.* 2007, Chernogor *et al.* 2007), as well as the wave processes in the ionospheric plasma (Burmaka and Chernogor 2012).

The aim of this study was the calculation of parameters of the dynamic and thermal process in the geospace plasma during the 13-15 November 2012 magnetic storm.

2. GENERAL INFORMATION ABOUT THE 13-15 NOVEMBER 2012 GEOMAGNETIC STORM

The magnetic storm began on 13 November at 15:00 UT. The main phase of the magnetic storm took place from 18:00 UT on 13 November to 06:00 UT on 14 November. The extreme values of the geomagnetic activity indices during the magnetic storm 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. The solar radio flux index $F_{10.7}$ ranged from 141 to 146.

For comparison of the magnetic storm effects in the variations of dynamic and thermal processes, the reference period from 21 to 23 November was chosen, which was characterized by quiet heliogeophysical conditions. Geomagnetic and solar activity indexes for this period were $A_p = 2\text{-}7$, $K_p = 0\text{-}3$, $F_{10,7} = 126\text{-}140$.

3. THE OBSERVATION MEANS AND EXPERIMENTAL RESULTS

For modeling the parameters of dynamic and thermal processes, the Kharkov ISR (geographic coordinates: 49.6° N, 36.3° E; geomagnetic coordinates: 45.7°, 117.8°) data were used. At present, the Kharkov ISR is the only reliable and most informative data source of the geospace plasma state in the mid-latitudes of Central Europe. Radar allows measuring with high accuracy (usually, the error is of 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 transfer velocity v_z, and ion composition. The investigated altitude range is 100-1500 km (depending on the solar activity level).

Domnin *et al*. (2014b) presents observation results of ionospheric plasma parameter variations during 13-15 November 2012 magnetic storm obtained on Kharkov incoherent scatter radar.

The magnetic storm was accompanied by ionospheric storm with two positive phases (δfoF2 > 0) and one negative phase (δfoF2 < 0).

The electron density in the F2-region maximum of the ionosphere, N_mF2, during the first positive phase of the ionospheric storm increased up to a factor of 3. Then there was a significant decrease in the N_mF2 up to a factor of 5 (negative phase of ionospheric storm). During the second positive phase of the ionospheric storm, the electron density N_mF2 increased up to a factor of 2.8. The greatest increase of F2-peak height h_mF2 (up to 400 km) took place at 03:30 UT, while during quiet conditions h_mF2 have not exceed 275 km.

During magnetic storm, the electron density N in the altitude range of 200-250 km decreased up to a factor 5. At altitudes of 300 and 350 km, the reduction of N was up to a factor of 3.5 and 3. The electron temperature in-

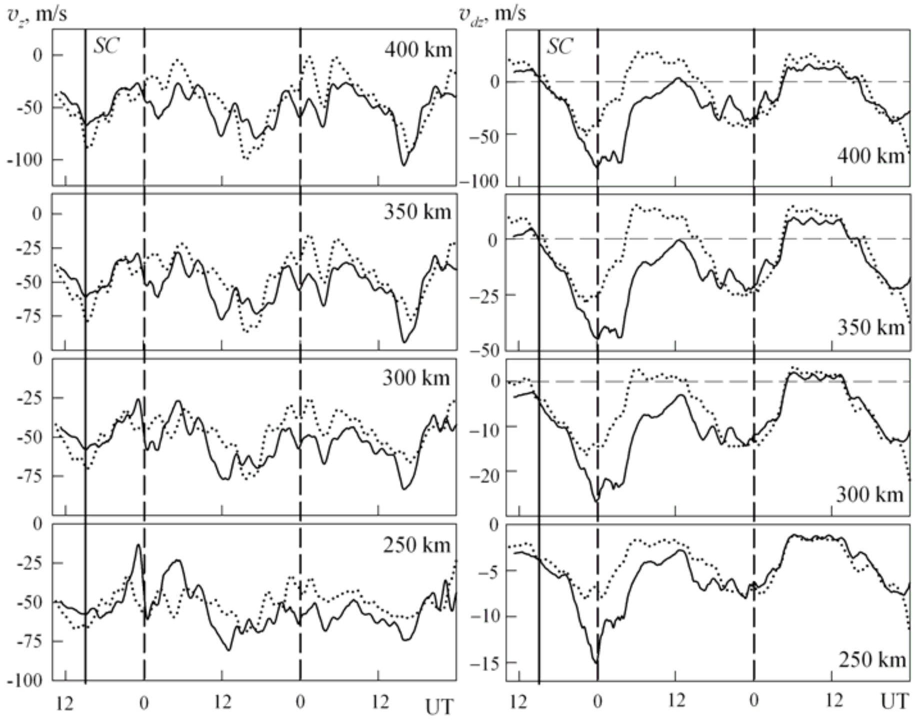

Fig. 1. Temporal variations of the vertical component of the plasma transfer velocity v_z (experimental results) and the vertical component of the plasma transfer velocity due to ambipolar diffusion v_{dz} (calculation) during 13-15 November 2012 magnetic storm (solid line) and quiet condition period on 21-23 November 2012 (dots).

creased up to 200-300 K in the altitude range of 200-700 km. The ion temperature for the considered altitudes increased up to 100-200 K.

The variations of the vertical component of plasma transfer velocity v_z during magnetic storm were small (see Fig. 1, left panel). In the main phase of magnetic storm (from 23:50 UT on 13 November to 16:30 UT on 14 November) the quasi-harmonic oscillations with a period from 3 h 30 min to 5 h 15 min and amplitude of 12-40 m/s were detected.

In greater detail, the results of the 13-15 November 2012, magnetic storm effects in variations of the main parameters of the ionospheric plasma have been described by Domnin *et al.* (2014b).

4. INITIAL THEORETICAL RELATIONS

To calculate the dynamic and thermal process parameters in geospace plasma, the following theoretical relations were used.

Plasma flux densities. Expressions for calculation of the plasma flux density in the vertical direction and the particle flux due to ambipolar diffusion are of the form:

$$\begin{aligned}\Pi_p &= v_z N \\ \Pi_d &= v_{dz} N\end{aligned},$$

where v_z is the vertical component of the plasma velocity (Kharkov ISR data). Expression for calculating the plasma transfer velocity due to ambipolar diffusion v_{dz} has the form (Schunk and Nagy 2000)

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

where $D_a = (kT_p)/(m_i v_{in})$ is the longitudinal component of the ambipolar diffusion tensor, k the Boltzmann constant, $T_p = T_e + T_i$ the plasma temperature, m_i the O^+ ion mass, I the Earth's geomagnetic field inclination (for the Kharkov ISR coordinates $I = 66.85°$), $H_p = (kT_p)/(m_i g)$ the plasma scale height, g the gravity acceleration, and v_{in} is the total collision frequency of ion with neutrals. Expression for ν_{in} has the form

$$\nu_{in} = \nu_{\mathrm{O^+,O}} + \nu_{\mathrm{O^+,O_2}} + \nu_{\mathrm{O^+,N_2}} + \nu_{\mathrm{O^+,H}} + \nu_{\mathrm{O^+,He}}, \tag{1}$$

where $\nu_{\mathrm{O^+,O}}$, $\nu_{\mathrm{O^+,O_2}}$, $\nu_{\mathrm{O^+,N_2}}$, $\nu_{\mathrm{O^+,H}}$, $\nu_{\mathrm{O^+,He}}$ are the collision frequencies of oxygen ions in the parent gas, with atoms and molecules of oxygen, nitrogen, hydrogen and helium, respectively. Each of the summands in Eq. 1 can be calculated from the following relations (Stubbe 1968):

$$\nu_{\mathrm{O^+,O}} = 1.86 \cdot 10^{-9} N(\mathrm{O}) \left(\frac{T_i + T_n}{2000} \right)^{0.37},$$

$$\nu_{\mathrm{O^+,O_2}} = N(\mathrm{O_2}) \cdot 10^{-9},$$

$$\nu_{\mathrm{O^+,N_2}} = 1.08 \cdot 10^{-9} N(\mathrm{N_2}),$$

$$\nu_{\mathrm{O^+,H}} = 2.19 \cdot 10^{-9} N(\mathrm{H}),$$

$$\nu_{\mathrm{O^+,He}} = 0.88 \cdot 10^{-9} N(\mathrm{He}),$$

where T_n, $N(\mathrm{O})$, $N(\mathrm{O_2})$, $N(\mathrm{N_2})$, $N(\mathrm{H})$, and $N(\mathrm{He})$ are the temperature of neutrals, concentrations of atomic oxygen, molecular oxygen and nitrogen, atomic hydrogen and helium calculated from NRLMSISE-00 model (Picone *et al.* 2002).

Zonal component of electric field. 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 small. As follows from experimental studies and theoretical calculations (Blanc *et al.* 1977, Blanc and Amayenc 1979, Ogawa *et al.* 1975, Richmond *et al.* 1980), 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, the electric fields have penetration at the altitudes of the mid-latitude ionosphere, increasing the plasma velocity in the electric and magnetic fields they cross. It should be noted that the transfer of the plasma due to the electromagnetic drift during geomagnetic storms has a significant impact on the spatial distribution of parameters of the mid-latitude ionosphere.

As it is known, without perturbation the electric field effects in the mid-latitudes can be neglected. But during strong geomagnetic storms there is an amplification of electric fields due to the magnetospheric convection, which affects the dynamics of the mid-latitude ionosphere. During disturbed conditions in the mid-latitudes, and neglecting the effects of geomagnetic field declination, the main contribution to the vertical transport of plasma comes from the zonal electric field and neutral winds. Electric field directed to the east causes the plasma drift upwards and the field directed to the west causes 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 storm on 13-15 November 2012.

As shown in the calculations presented by Sergeenko (1982), there is a correlation between the *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 mid-latitude ionosphere during strong geomagnetic disturbances.

To calculate E_y we use the empirical relation between the magnitude of the electric field and auroral activity index, given by Sergeenko (1982):

$$E_y = \left(0.55 - 0.01AE\right) \cdot 10^{-3} ,$$

where *AE* is the auroral activity index (in nT).

Velocity of plasma transport due to electromagnetic drift. Expression to calculate the velocity of plasma transport due to electromagnetic drift has the form (Schunk and Nagy 2000)

$$v_{EB} = \left(E_x/B\right)\cos I \sin D + \left(E_y/B\right)\cos I \cos D \ ,$$

where B is the geomagnetic field modulus ($B \approx 4.4 \cdot 10^{-5}$ nT at $z = 300$ km (Finlay *et al.* 2010)), E_x and E_y are the meridional (positive direction to equator) and zonal (positive direction to east) components of electric field, and D is the declination of the magnetic field. Neglecting the effects of declination (for Kharkov city $D = 8.14°$), the expression for the calculation of the vertical component of the velocity of plasma transport by the electromagnetic drift has the form

$$v_{EB} = \left(E_y/B\right)\cos I \ .$$

Neutral wind in the ionosphere. In mid-latitudes, the vertical component of the velocity of ion wind drag is determined by the meridional component of the velocity of the neutral gas horizontal motion. Neutral wind directed toward the equator moves the plasma upward along the magnetic field lines, and poleward wind moves the plasma downward.

Expression for calculating the meridional component of the neutral wind velocity v_{nx}, upon neglecting the effects of the geomagnetic field declination, has the form (Schunk and Nagy 2000):

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

Energy influx to the electron gas. In the ionospheric F region, the collision frequency of electrons with neutrals is smaller than electrons with ions. In this case, the main mechanisms of electron gas cooling are the heat loss in collisions of electrons and ions, excitation of the fine structure of the oxygen atoms and electron gas heat conductivity (Schunk and Nagy 2000). There is also the photoelectron transfer and the non-local heating of the electron gas, related to this transfer.

At altitudes $z \leq 350$ km, the heat conductivity of the electron gas can be neglected and the electron energy balance equation in the stationary case in the SI system has the form (Schunk and Nagy 2000)

$$Q = L_{ei} + L_e \ ,$$

$$L_{ei} = 8 \cdot 10^{-32} N^2 (T_e - T_i) T_e^{-3/2} \ ,$$

$$L_e = 6.4 \cdot 10^{-37} N N(\mathrm{O}) \left(T_e - T_i\right) T_n^{-1} \ ,$$

where Q is the energy transferred to the thermal electrons at the Coulomb collisions with photoelectrons, L_{ei} – the energy lost in electron-ion collisions, L_e – the energy needed to excite the fine structure of the oxygen atoms, N – the electron density (Kharkov ISR data), N(O) – the density of oxygen atoms, T_e and T_i – the electron and ion temperatures (Kharkov ISR data). The neutral temperature T_n and N(O) density has been calculated by the NRLMSISE-00 model (Picone *et al.* 2002).

Heat flux density. The heat balance of the electron gas depends on the heat flux carried by electrons from the plasmasphere into the ionosphere. The heat in the plasmasphere accumulates by suprathermal electrons escaping from the place of their formation in the topside ionosphere. Some of the electrons lose their energy in Coulomb collisions with thermal electrons and ions. Another part of the electrons fall into the magnetic flux tube. In the magnetic tube, trapped electrons become thermalized in multiple reflections from the ends of the tube. Thus, accumulated heat in the plasmasphere fed back into the ionosphere by means of the heat conductivity of the electron gas (Schunk and Nagy 2000).

Heat flux can be defined by the kinetic equation with the transport of suprathermal electrons. The expression to calculate the heat flux density from the plasmasphere in the vertical direction has the form (Schunk and Nagy 2000):

$$\Pi_T = -\kappa_e \sin^2 I \frac{\partial T_e}{\partial z} , \tag{2}$$

where $\kappa_e = (2.08 \cdot k^2 N T_e)/(m \nu_{ei})$ is the longitudinal component of the heat conductivity tensor of the electron gas, and m is the mass of the electron.

The collision frequency between electrons and O^+ ions to calculate the longitudinal component of the conductivity tensor in Eq. 2 can be found by using the expression (Lyashenko 2013, Lyashenko and Chernogor 2013, Domnin *et al.* 2014a):

$$\nu_{ei} \approx 5.5 \cdot 10^{-6} N T_e^{-3/2} \ln\left(2.2 \cdot 10^4 T_e N^{-1/3}\right) .$$

5. CALCULATION RESULTS

Particle transport velocity due to ambipolar diffusion. Temporal variations of the vertical component of the plasma transport velocity due to ambipolar diffusion v_{dz} at altitudes of 250-400 km during the 13-15 November 2012 magnetic storm is presented in Fig. 1 (right panel).

The calculations show that in quiet conditions (22 November 2012) at night there was a downward plasma transport ($v_{dz} < 0$). The velocity v_{dz} was about –7, –15, –25, and –50 m/s at altitudes of 250, 300, 350, and 400 km, respectively. In the daytime, the transfer plasma velocity due to ambipolar diffusion was negligible at altitudes of 250 and 300 km (no more than 2-3 m/s) and at altitudes of 350 and 400 km v_{dz} it was 15-25 m/s.

After the beginning of the magnetic storm (around 18:00 UT on 13 November), the behaviour of v_{dz} changed. On the night of 14 November at altitudes of 250, 300, 350, and 400 km, v_{dz} reached values of –15, –25, –40, and –70 m/s, respectively. During the daytime on 14 November, v_{dz} also differed from the variations in quiet conditions.

Plasma fluxes. Figures 2 and 3 show temporal variations of the density of the full plasma flux Π_p and the density of the plasma flux due to ambipolar diffusion Π_d in the altitude range of 250-400 km during 13-15 November 2012, magnetic storm and quiet condition period on 21-23 November 2012.

The full plasma flux Π_p is the total flux of charged particles caused the transfer of plasma due to ambipolar diffusion Π_d, neutral wind v_{nx} and plasma drift v_{EB} in crossed electric and magnetic fields. It should be noted that during the strong magnetic storms the contribution of neutral winds and electromagnetic drift in the plasma transfer is significant and comparable to the contribution of the diffusion flux.

The variations of full plasma flux density Π_p during the magnetic storm were as follows. After the magnetic storm beginning (November 13), there was a slight increase of Π_p by modulus compared to the reference day. On 14 November near midday (during the recovery phase of magnetic storm) there was a decrease in plasma flux density $|\Pi_p|$ by 55 and 25% at altitudes of 250 and 300 km.

On 15 November, diurnal variation of the plasma flux density began to recover.

The variations of the charged particle flux density due to ambipolar diffusion Π_d (Fig. 3) during the 13-15 November magnetic storm were complicated.

Temporal variations of the Π_d flux on 22 November kept their basic features of diurnal behaviour: upward flux after sunrise and during daytime and downward flux after sunset during nighttime. It can be seen that during the magnetic storm the Π_d flux values significantly differed from the values under quiet conditions. As can be seen from Fig. 3, the magnetic storm has led to the fact that on 13 and 14 November in the altitude range of 300-400 km there was a downward plasma flux due to ambipolar diffusion, both at night and daytime hours. On 15 November variations of Π_d were similar to the variations in plasma flux density due to ambipolar diffusion in quiet conditions.

The calculations show that in the nighttime (13 November) during the magnetic storm main phase, the Π_d value increased compared with the reference day about 1.25, 3 and 5.9 times at 300, 350 and 400 km. At $z = 250$ km, the magnetic storm effects in variations of Π_d were invisible.

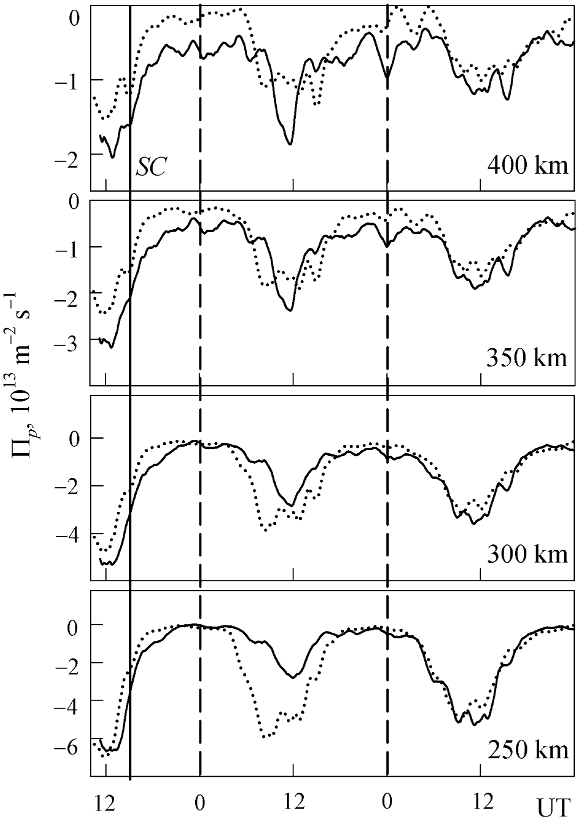

Fig. 2. Temporal variations of the full plasma flux density during 13-15 November 2012 magnetic storm (solid line) and quiet condition period on 21-23 November 2012 (dots).

Figure 4 shows the variation of the zonal electric field component E_y, the vertical component of the velocity of plasma transport due to the electromagnetic drift v_{EB}, and neutral wind velocity v_{nx} during the 13-15 November 2012 magnetic storm and the reference days on 21-23 November 2012.

Zonal component of the electric field. Figure 4 (top panel) shows the calculation of temporal variations of the electric field zonal component. Calculations showed that the value of the electric field zonal component was –9.5 mV/m during the 13-15 November 2012 magnetic storm. In quiet conditions, the value of E_y does not exceed a few mV/m.

Plasma drift velocity. Figure 4 (middle panel) shows the calculation results of the plasma drift velocity vertical component during magnetic storm and quiet conditions. It was found that during the main phase of the storm

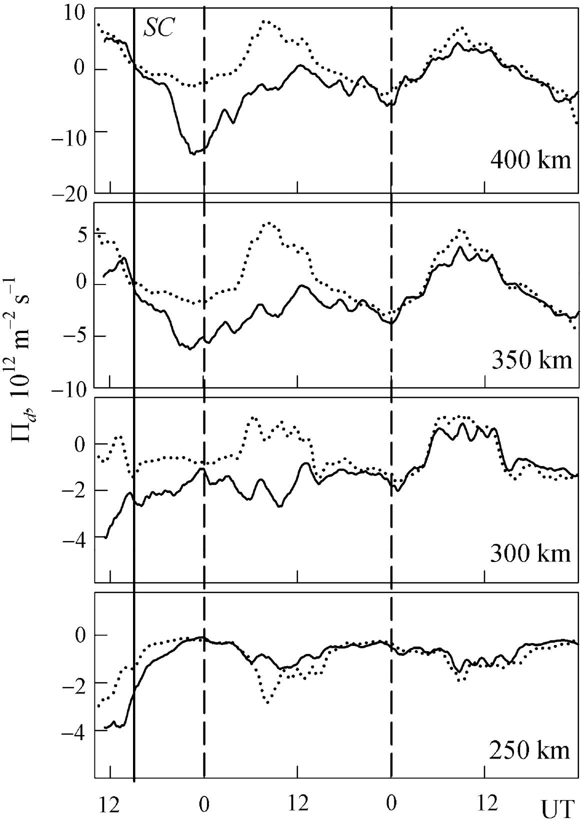

Fig. 3. Temporal variations of the plasma flux density due to ambipolar diffusion during 13-15 November 2012 magnetic storm (solid line) and quiet condition period on 21-23 November 2012 (dots).

the values of v_{EB} reached –85 m/s, whereas in quiet conditions the plasma transport due to the electromagnetic drift is absent.

Neutral wind. Figure 4 (bottom panel) shows the temporal variation of the meridional neutral wind velocity v_{nx} during the magnetic storm and quiet days at an altitude of 300 km. We see that in quiet conditions the wind velocity has poleward direction and ranges from 0 to –150 m/s. After the beginning of the magnetic storm and during the main phase, there was a change of the neutral wind direction to the equator, and calculations showed that the highest rate of v_{nx} was 150 m/s.

Variations of the meridional component of the neutral wind during 13-15 November 2012 magnetic storm are like the variations of v_{nx} during the 5-6 August 2011 magnetic storm. In both cases there is a change in the

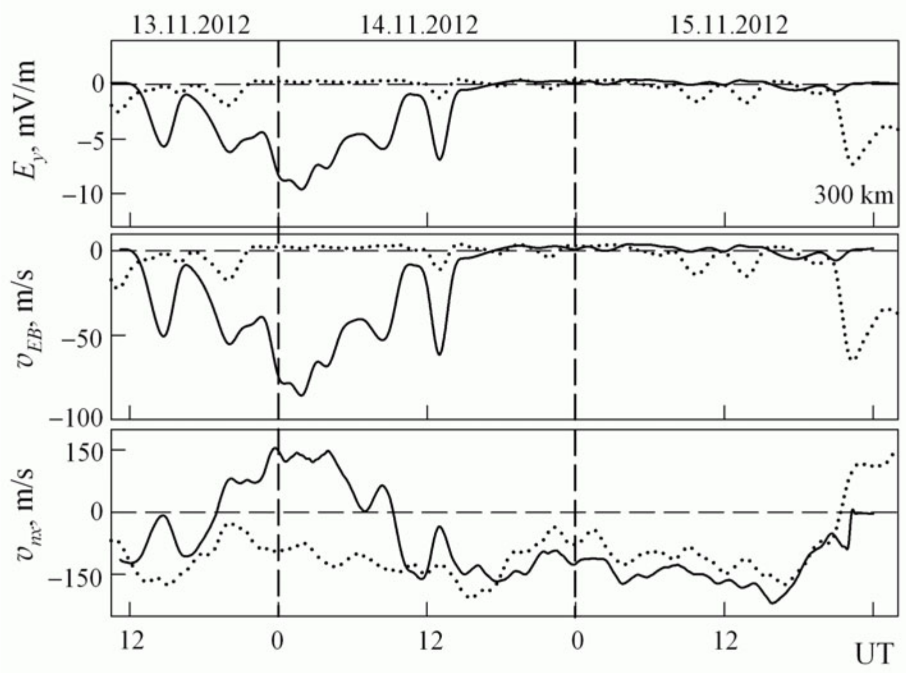

Fig. 4. Temporal variations of the electric field zonal component values, vertical component of the plasma drift velocity and neutral wind velocity during the 13-15 November 2012 magnetic storm (solid line) and quiet condition period on 21-23 November 2012 (dots).

direction of the neutral gas transport in the main phase of the magnetic storm (Domnin *et al.* 2014c).

Energy influx to the electrons. Figure 5 shows the calculation results of the energy *Q/N*, supplied to the electrons during the 13-15 November 2012 magnetic storm and quiet period of 21-23 November 2012.

In the disturbed day on 14 November 2012, during the negative phase of ionospheric storm and depressions of the electron concentration (F2-layer critical frequency *f*oF2 ≈ 4 MHz at 07:30 UT) there was observed a dip in the *Q/N* variations to values of $2.5 \cdot 10^{-21}$, $1.2 \cdot 10^{-21}$, $0.7 \cdot 10^{-21}$, and $0.4 \cdot 10^{-21}$ J/s at altitudes of 200, 250, 300, and 350 km, respectively. On 22 November at the same time the values *Q/N* at the same altitudes were as follows: $3.5 \cdot 10^{-21}$, $1.8 \cdot 10^{-21}$, $0.9 \cdot 10^{-21}$, and $0.5 \cdot 10^{-21}$ J/s. At noon on 14 November the values of *Q/N* were $2.95 \cdot 10^{-21}$, $1.35 \cdot 10^{-21}$, $0.7 \cdot 10^{-21}$, and $0.5 \cdot 10^{-21}$ J/s. During the recovery phase of magnetic storm (15 November 2012) the value of *Q/N* increased and around noon the values of *Q/N* reached $4.2 \cdot 10^{-21}$, $1.9 \cdot 10^{-21}$, 10^{-21} and $0.5 \cdot 10^{-21}$ J/s at the corresponding altitudes.

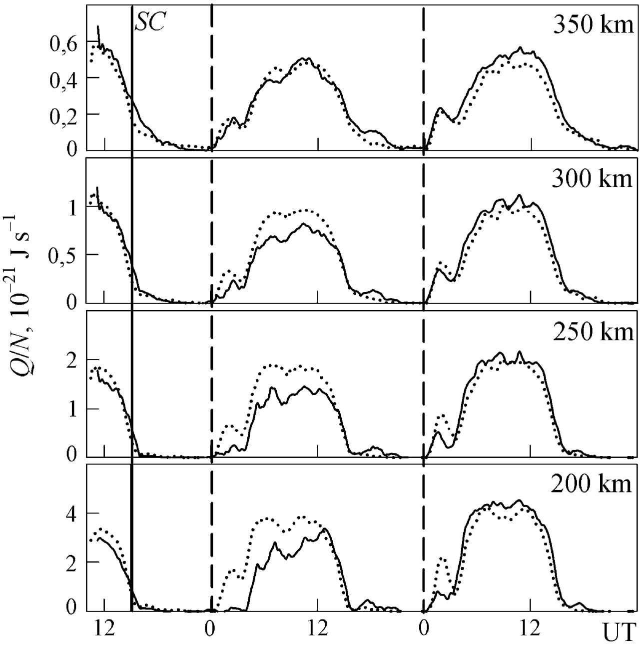

Fig. 5. Temporal variations of the energy supplied to the electron gas, *Q/N,* at the fixed altitudes during 13-15 November 2012 magnetic storm (solid line) and quiet condition period on 21-23 November 2012 (dots).

In general, the reduction of *Q/N* during the main phase of the magnetic storm compared to the reference days amounted to approximately 35, 25, and 20% at altitudes of 200, 250, and 300 km, respectively. At an altitude of 350 km the magnetic storm effects in the variations of the *Q/N* were not discernable.

Heat flux. The calculation results of the heat flux density Π_T transferred by electrons from the plasmasphere into the ionosphere during the 13-15 November 2012 magnetic storm and the quiet period of 21-23 November 2012 are shown in Fig. 6.

Calculations show that during the main phase of magnetic storm (14 November 2012), the absolute values of the heat flux density $|\Pi_T|$ increased relative to the values of Π_T in quiet conditions. This phenomenon is due to the unusual heating of the plasma in the night, when the temperatures of T_e and T_i almost reached the daily values. Plasma heating took place against the backdrop of a deep depression of the electron density in the F-region of the ionosphere (*N* decreased more than 5 times). During the greatest decrease in the electron density, the heat flux density Π_T was $-(1.3\text{-}1.2)\cdot 10^{-5}$ W/m^2 in the altitude range of 200-350 km. The least value of Π_T on 14 November was

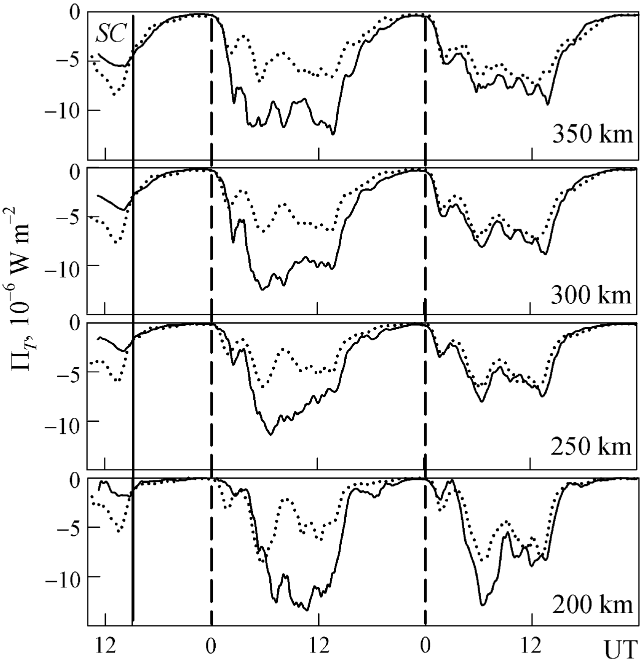

Fig. 6. The temporal variations of the heat flux density Π_T during 13-15 November 2012 magnetic storm (solid line) and quiet condition period on 21-23 November 2012 (dots).

observed at $z = 200$ km around 11:00 UT and was of about $-1.3 \cdot 10^{-5}$ W/m^2, whereas on 22 November the value was $\Pi_T \approx -0.5 \cdot 10^{-5}$ W/m^2.

On 15 November the absolute values of $|\Pi_T|$ were greater than on the reference day of 23 November. At $z = 200$ km, the least value of Π_T was about $-1.3 \cdot 10^{-5}$ W/m^2, and in the reference day at the same time $\Pi_T \approx -0.8 \cdot 10^{-5}$ W/m^2. In the afternoon, there was a recovery of values of heat fluxes.

6. CONCLUSIONS

The effects of the strong geospace storm on 13-14 November 2012 were well marked in variations of the electron density, electron and ion temperatures, and the vertical component of the plasma transfer velocity in the ionosphere over Kharkov.

Calculations show that during the magnetic storm on 13-14 November 2012 there has been a significant change in the dynamic and thermal modes of the ionospheric plasma in a wide altitude range.

On the background of a significant decrease in the electron density during the main phase of the magnetic storm on 14 November 2012, the rate of heating of the electron gas, Q/N, was approximately 2 times less than in the reference day on November 15. This led to an increase in the heat flux density caused by the electron temperature increases.

Due to the decrease in electron density, the full plasma flux values on 14 November were generally less than for undisturbed conditions. At altitudes of 350 and 400 km in the noon hours there was an upsurge in the Π_p variations, which is higher than the value observed on 22 November.

Strong geomagnetic storm on 13-14 November 2012, has caused a whole range of processes accompanying the plasma disturbances, electric and magnetic fields in various areas of the near-Earth space. The storm effects in the variations of dynamic and thermal processes in the ionosphere are evident. Temporal variations in the absolute values of the vertical component of velocity due to ambipolar diffusion and plasma transfer due to the electromagnetic drift during ionospheric disturbance have increased. There was an increase in the v_{dz} velocity by two times at $z = 250$ km and v_{EB} from –85 to 0 m/s at an altitude of 300 km. In turn, the meridional component of the neutral wind velocity changed in the opposite direction and became directed to the equator. The highest value of v_{nx} was about 150 m/s.

The results of calculations of dynamic and thermal process parameters in mid-latitude ionosphere during 13-14 November 2012 geospace storm supplement the global picture of the storm and its effects in the geospace.

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