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INTENSIVE MHD-STRUCTURES PENETRATION IN THE MIDDLE ATMOSPHERE INITIATED IN THE IONOSPHERIC CUSP UNDER QUIET GEOMAGNETIC CONDITIONS

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ABSTRACT

In connection with the recently detected quasiperiodical magnetic disturbances in the ionospheric cusp, the penetration of compressional surface MHD-waves through the middle atmosphere is modelled numerically. For the CIRA-72 model the respective energy density flux of the disturbances in the middle atmosphere is determined. On the basis of the developed model certain conclusions are reached about the height distribution of the structures (energy losses, currents, etc.) initiated by intensive magnetic cusp disturbances.

Some of the most intensive small-scale magnetic disturbances (SSMD) recorded in the winter cusp are systematically investigated by SAFLEKOS et al. (1978). Intense small-scale magnetic disturbances and associated variations in the electric field have been recorded at height h=850 km on board the Intercosmos Bulgaria 1300 satellite (ARSHINKOV et al., 1985, NENOVSKI et al., 1987). The periodicity and the specific polarization state in some cases suggest that those disturbances have wavelike pattern. A model of compressional surface MHD-waves ducting in the cusp to the ionosphere has been proposed (NENOVSKI and MOMCHILOV, 1987).

However,the ionosphere and middle atmosphere conductivity cannot be considered infinite. The distribution of the SSMD energy transferred to the lower atmosphere layers is controlled by the conductivity variations and if reaching Earth surface - by induced telluric currents. The purpose of the present work is to demonstrate a quantitative picture of the surface MHD waves energy distribution in height within the low ionosphere and middle atmosphere.

In determining energy losses magnitude δW, evaluation of SSMD electric field components and current density in height is needed. The problem has been discussed in regard to the geomagnetic pulsations by HUGHES and SOUTHWOOD,(1976) and POOLE et al. (1988). Those components and the losses δW are determined numerically by the Maxwell equations and the Ohm's law.We introduce the Pedersen /σ_P/, Hall /σ_H/and the direct /$\sigma_{\parallel}$/ conductivities as a function of height. The parameters, determining the conductivity, collision frequencies, etc. components are density, mean molecular weight and temperature. CIRA-Cospar 1972 International Reference Atmosphere data is used for neutral atmosphere. Electron density profiles N(z) under night winter conditions and high solar activity are taken from rocket measurements /BELROSE (1972), HARRIS and TOMATSU,(1972)/at high latitudes.

As in the ionosphere cusp the precipitating particles energy is lower than 1-2 KeV, their ionizing influence under 300 km is ignored. On the opposite - we have considered the galactic cosmic ray ionizing effect, considerable in middle atmosphere using the results obtained by VELLINOV and MATEEV (1989). The galactic cosmic rays effect on ionization is dominating in the region under 80 km. At 60-80 km height they form separate electron concentration layer /CR- or C-layer/ and positive and negative ion concentrations at 0-60 km with a maximum at about 20 km height. Herewith, ion densities from ARNOLD and KRANKOVSKY (1977) are used that correspond to the earlier ROSE and WIDDLE (1972) and later BRASSEUR and SOLOMON (1984) and BALACHANDRA SWAMI and SETTY (1984) results.

For the N(z)-profiles calculation /70-90 km/ except galactic cosmic rays we have included the effect of the scattered H_{α} Lyman-alpha radiation /POTEMRA and ZMUDA, 1972/ and the cosmic X-rays /GX333+25, SCO-XR-1, etc./, /MITRA and RAMANAMYRTY (1972)/. The electron density profiles N_e/h/, the positive ions N+/h/, the negative ions N-/h/ are given in Table 1.

The spatial and temporal variations of localized MHD-disturbancies, type

$$f(k_x, z)\exp(ik_x x - i\omega t)$$

are initiated at the upper ionosphere border. We are investigating the penetration of separate Fourier disturbance components $f(k_x, z)$ in the low ionosphere and the middle atmosphere, considered as horizontally homogenious, i.e. the medium is vertically stratificated.

We are investigating the variations in the electric field of the separate Fourier components in height /NENOVSKI and MATEEV, 1989/. According to the HUGHES AND SOUTHWOOD /1976/ model we are giving the initial values at z=0 /Earth surface/. Supposing that the Earth crust is an ideal conducter the boundary conditions for the transversal electric field components are $E_x, E_y = 0$ the vertical magnetic field component $b_z=0$. The electric field vertical component /$E_z=10^{-4}$.V/m/ and the magnetic field transversal component /$b_y=5.10^{-10}$G/. The Maxwell equations, including the Ohm law are integrated with adaptive step and boundary values at z=0.

The method applied is Runge -Kutta with precision of fourth order. The choice of integration step is made considering the pre-condition for step error. That is valid for each value obtained for the unknown function. With the experimentally verified factor we obtain further precision compensating the truncation error /PRESS et al., 1987/. The sensitivity towards identical sign error accumulation due to drastic step reduction is considered. Due to the adaptivity a definite precision is reached with computational work economy. Thus, efficiency of algorithm run-time is optimized. The higher algorithm order from 4 to 5 is reached on account of the greater number of calculations of the right part of the system of ordinary differential equations (factor 1.375). The efficiency of the applied method is proved in practice /PRESS et al., 1987/. The results from the numerical analysis are shown on Figures 1 and 2. The electric and magnetic field variations in the 0-100 km interval are shown on Figure 1,2 and the losses distribution - on Figure 3. That figures demonstrate the middle atmosphere influence on the MHD-disturbance long-wave harmonics transition: $k_x=1000.^{-1}$km^{-1}, $k_y=0$. Figures show that the Earth magnetic disturbance b_y reduces about 5 orders in magnitude towards the value at 100 km height. It is characteristic that while on the Earth the b_x component is 0, at 100 km height it is one order in magnitude greater than b_y. The electric field is characterized basically by two of its components - E_x and E_z. E_x reaches 0,1 V/m at 100 km height, while the E_z component is dr-astically reduced /by three orders at about 20 km

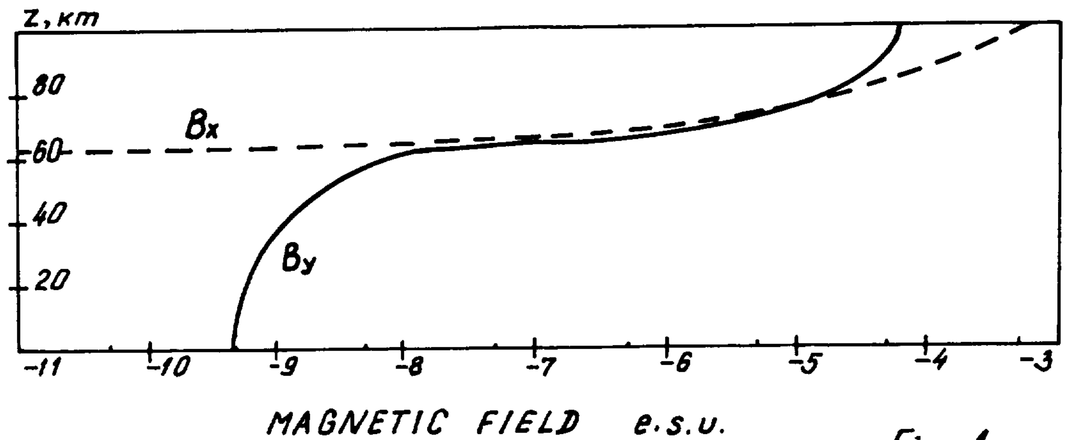

Fig. 1.

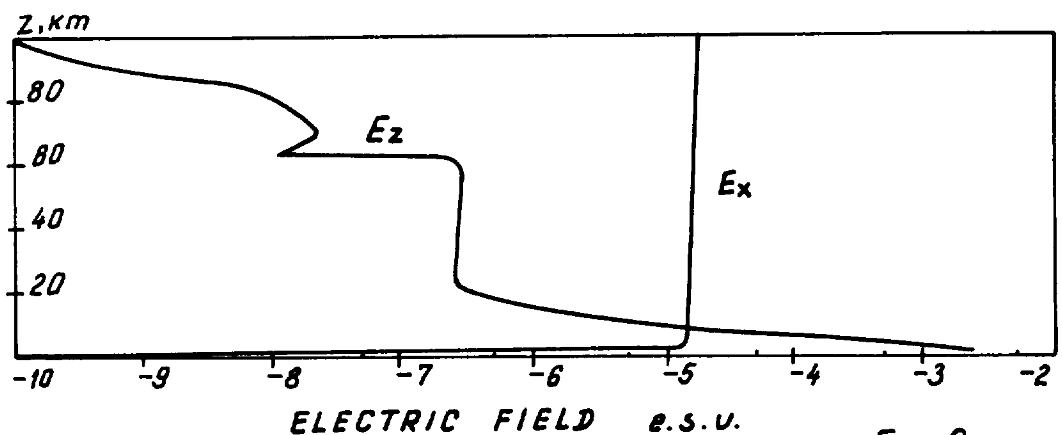

Fig. 2.

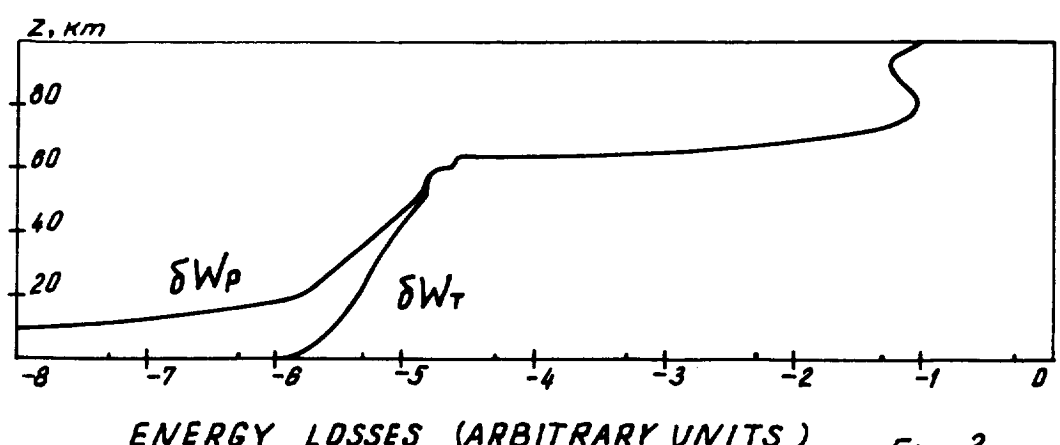

Fig. 3.

height/.

The losses /δW/ from the transition of long-wave MHD disturbances us due, as it can be supposed, to the Pedersen conductivity. That losses prove comparatively high in the middle atmosphere upper region, i.e. – the mesosphere D-region. At about 70 km height the losses are only 20% smaller than in the maximum at 100 km height. Under 70 km the losses reduce drastically. At lower altitudes the MHD-disturbances propagation is not connected with the presence of considerable energy losses. Here the role of the losses caused by the presence of electric field longitudinal component is greater. These results refer to a definite case and consequently are of preliminary character.

The basic conclusion is that the process of MHD-disturbances energy dissipation is not localized only in the E-layer. Under some conditions the middle atmosphere – mesosphere and the D-region participate actively in that process.

Table 1

Height	Density Number		
Z, km	electrons	positive ions	negative ions
100	$3\ 10^3$	$3\ 10^3$	–
90	$2\ 10^3$	$2\ 10^3$	–
80	$6\ 10^2$	10^3	$4\ 10^2$
70	$0.5\ 10^2$	$5\ 10^2$	$4.5\ 10^2$
65	–	$3\ 10^2$	$3\ 10^2$
60	–	$3\ 10^2$	$3\ 10^2$
55	–	$5\ 10^2$	$5\ 10^2$
50	–	$7.5\ 10^2$	$7.5\ 10^2$
45	–	$1.2\ 10^3$	$1.2\ 10^3$
40	–	$1.8\ 10^3$	$1.8\ 10^3$
35	–	$2.5\ 10^3$	$2.5\ 10^3$
30	–	$3\ 10^3$	$3\ 10^3$
25	–	$5\ 10^3$	$5\ 10^3$
20	–	$5\ 10^3$	$5\ 10^3$
15	–	$3\ 10^3$	$3\ 10^3$
10	–	$2.1\ 10^2$	$2.1\ 10^2$
5	–	$1.5\ 10^1$	$1.5\ 10^1$
0	–	$1\ 10^0$	$1\ 10^0$

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