

COMPUTATIONAL STUDY OF THE RESPONSE OF THE HIGH-LATITUDE F-LAYER TO A POWERFUL HF WAVE

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Abstract. The effect of heating by high power radio waves on the ionospheric plasma at the F-layer level are investigated using a numerical model of the convecting high-latitude ionosphere.

1. Introduction

The modification of the ionospheric plasma at the F-layer level by HF heating has been studied both experimentally and numerically in recent years [Mantas *et al.*, 1981; Shoucri *et al.*, 1984; Hansen *et al.*, 1992; Blaunshtein *et al.*, 1992]. It is known that the majority of investigations of the F-region were mainly directed to study the mid-latitude ionosphere. However, it may be expected that principal distinctions between mid-and high-latitude ionospheres as for the F-layer modification by a powerful HF wave do exist. One of the specific features of the polar ionosphere that is unusual for the mid-latitude ionosphere is the plasma convection at high latitudes. The purpose of this paper is to study the response of the high-latitude F-layer to a powerful HF wave using the numerical model of the polar ionosphere which takes into account the convection of the ionospheric plasma.

2. Numerical model

We utilize the improved version of the numerical model of the convecting high-latitude F-region which can be heated by the high-power, high-frequency waves. The model allows to calculate the behaviour of the ionospheric plasma in the part of a magnetic field tube carried around the polar region by the convection electric field. Our model produces time variations of the electron density, positive ion velocity, ion and electron temperature profiles within the magnetic field tube, moving along a convection trajectory through the neutral atmosphere over an ionospheric heater. The profiles of ionospheric quantities versus distance from the earth along the geomagnetic field line are obtained by solving the appropriate system of transport equations of ionospheric plasma. This system consists of the continuity equation, the equation of motion for the ion gas, and the heat conduction equations for ion and electron gases. By analogy with the study by Blaunshtein *et al.*[1992], we take the point of view that the main fraction of the energy of the powerful HF wave is absorbed when the wave frequency is equal to the frequency of the electron hybrid resonance.

3. Results of simulations

In this study we use the pattern B of the empirical convection models of Heppner [1977]. We choose the convection trajectory, which intersects the F-layer volume illuminated by the heating facility at Ramfjordmoen near Tromsø, Norway, when it is located near the midnight magnetic meridian. The time history of the plasma in the given magnetic field tube is traced during its moving along the convection trajectory not far from the ionospheric heater. We consider the part of the magnetic field tube of ionospheric plasma at the distances from the earth along the magnetic field line between 100 and 700 km. The calculations are for equinox, at high solar activity, and low geomagnetic activity conditions. We assume that the ionospheric HF heater is turned on, when the considered magnetic field tube is over it, and operates for 20 seconds. The calculations were done for two distinct values of the effective absorbed power (EAP): 60 and 120 MW. The ionospheric heater is assumed to operate at the frequency of 5 MHz.

Results of simulation of perturbation of the nocturnal high-latitude F-region following the turn-on of the powerful 20-sec square HF pulse for the case when the EAP is 120 MW are presented in Figure 1. It can be seen that pronounced peak arises in the electron temperature profile. The electron temperature in its peak can increase up to 9000 K in 20 sec. The maximum energy input from the powerful HF wave is to occur at the level of about 316 km. The great increase of electron temperature results in appreciable electron concentration changes which are conditioned by arising of specific ionospheric plasma fluxes. The considered HF pulse should lead to decrease of more than 7% in electron concentration at the level of the F-region peak. Increase in the ion temperature is rather small.

It is found that the characteristic times for changes in the calculated ionospheric quantities caused by HF heating depend on the height. The disturbance caused by the powerful 20-sec square the HF pulse is expected to continue for about 20 minutes at the F-region peak level. During this period, the disturbed plasma volume was displaced for the distance of more than 500 km from the HF heater.

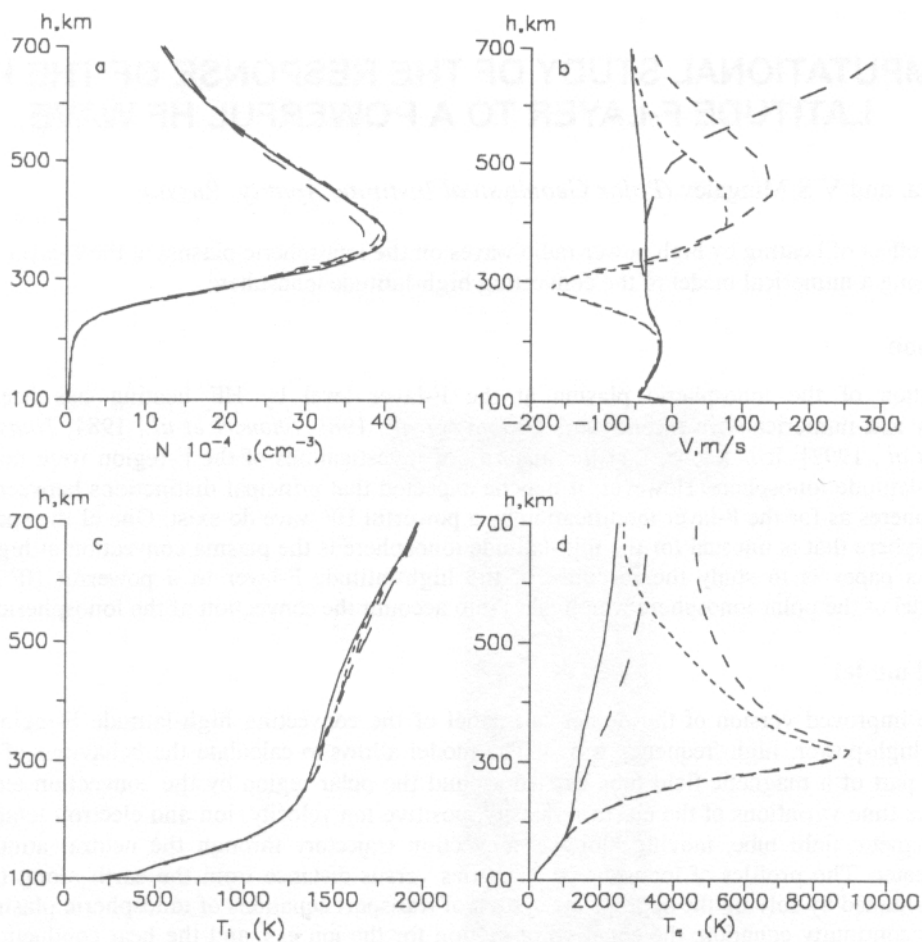


Fig.1. Profiles versus distance from the earth along the geomagnetic field line of electron concentration (a), parallel component of the positive ion velocity (b), ion temperature (c), and electron temperature (d) at four distinct moments after turn on: 0 sec (solid line), 10 sec (dotted line), 20 sec (dashed line), and 100 sec (long dashed line).

The results of simulation for the case when the EAP is 60 MW are analogous to those described above. However, the electron temperature in its peak increases only up to 7300 K. The decrease of electron concentration at the level of the F-region peak is only about 5%.

4. Conclusions

The results of numerical simulations indicate that significant variations in the electron temperature and positive ion velocity profiles can be produced by HF heating in the convecting high-latitude F-layer. These variations can ultimately lead to detectable decrease in the electron concentration at the level of the F-region peak.

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