

ON THE NATURE OF AURORAL MAGNETO- IONOSPHERIC DISTURBANCES

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Abstract

Full Text

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GEOPHYSICS

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ON THE NATURE OF AURORAL MAGNETO-IONOSPHERIC DISTURBANCES

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The role of fluxes of energetic particles, which significantly increase the ionization of the auroral ionosphere and play an important role in the formation of magneto-ionospheric disturbances, is generally recognized ⁽¹⁾. Particular attention has recently been attracted by the fact of the "separate" intrusion of electron and proton fluxes ^(2,3). Although, according to experimental data, the regions of electron and proton intrusion often overlap, their geometric centers during moderate disturbances are, as a rule, displaced in the meridional direction ⁽³⁾. Charge separation in a flux of charged particles is apparently the result of gradient drift in the magnetosphere ⁽⁴⁾. In addition, the interaction of particles with the atmosphere at altitudes below 1000 km may lead to charge separation in an initially quasi-neutral flux ⁽⁵⁾.

All this makes it possible to assert that, in addition to increasing the degree of ionization, auroral particles introduce at altitudes of 100–120 km an uncompensated electric charge whose influence must be taken into account. This charge must create a meridional electric field, the existence of which has been experimentally confirmed by rocket measurements using barium clouds ⁽⁶⁾.

Fig. 1. Structure of the region of formation of the auroral electrojet

In the authors' opinion, an auroral disturbance includes three principal groups of processes:

- 1) ionization of the ionosphere under the action of particle fluxes and transfer into it of space charge;
- 2) generation of electric currents by the field of the space charge under conditions of increased conductivity of the ionosphere in the region of intrusion of energetic particles;

Figure 2: Altitude dependences of the ion-formation rate q , electron concentration n_e , Pedersen conductivity σ_1 , Hall conductivity σ_2 , charge-source density Q_e , and horizontal electric field $E_\perp$.

Figure 2: Figure 2: Altitude dependences of the ion-formation rate q , electron concentration n_e , Pedersen conductivity σ_1 , Hall conductivity σ_2 , charge-source density Q_e , and horizontal electric field $E_\perp$.

3) excitation of magnetic fields by auroral current systems.

At the same time, we do not consider electric fields caused by the ionospheric dynamo ⁽⁷⁾.

The rate of ion formation, the electrical concentration, the components of the conductivity tensor, and the volume charge density, which result from the intrusion of an electron flux with a specified spectrum, can be calculated by numerical methods ⁽⁵⁾. Figure 1 gives the results of a calculation for a spectrum of the form:

$$dJ_e = J_\infty \cdot \varepsilon_0^{-1} \exp(-\varepsilon/\varepsilon_0) d\varepsilon, \quad J_\infty = 10^8 \text{ cm}^{-2} \text{ sec}^{-1}, \quad \varepsilon_0 = 10 \text{ keV}$$

and the CIRA-65 atmospheric model.

Figure 1 schematically shows the structure of the electric fields of the space charge carried into the ionosphere by the electron flux and by the conjugate proton flux.

Fig. 2. Altitude dependences of the ion-formation rate q , electron concentration n_e , Pedersen conductivity σ_1 , Hall conductivity σ_2 , charge-source density Q_e , and horizontal electric field $E_\perp$.

In the two-dimensional approximation, in the zone of enhanced conductivity on which the intrusion regions rest, a meridional electric field $E_\perp$ arises, and correspondingly Pedersen and Hall currents arise. The solution of Poisson's equation for $E_\perp$ shows that $E_\perp$ is maximal in that altitude interval where the integral Hall conductivity exceeds the Pedersen conductivity by approximately an order of magnitude (Fig. 2). In this case, the integral density of the Hall current must likewise exceed the integral density of the Pedersen current by an order of magnitude. The latter is easily estimated from the integral density of the longitudinal current carried by the flux of energetic particles: $i_p = i_\parallel = J_\infty e d$, where e is the electron charge and d is the width of the electron-intrusion region; J_∞ is the density of the electron flux beyond the boundary of the atmosphere. Taking $J_\infty = 10^9 \text{ cm}^{-2} \text{ sec}^{-1}$, $d = 1.3 \cdot 10^6 \text{ cm}$ ⁽⁸⁾, we find $i_p = 1.3 \cdot 10^{-2} \text{ A m}^{-1}$. If the integral Pedersen conductivity in the zone between the electron and proton intrusion regions is taken as $\Sigma_1 = 0.1 \text{ S}$, then $E_\perp = 100 \text{ V km}^{-1}$, which agrees with the experimental data ⁽⁶⁾. As for

the Hall-current density, $i_h \approx 10i_p \approx 1.3 \cdot 10^{-1} \text{ A m}^{-1}$. The total Hall current is $I = i_h \cdot D$, where D is the distance between the intrusion regions. For $D = 10^2 \div 10^3 \text{ km}$, $I = 10^4 \div 10^5 \text{ A}$.

When calculating the magnetic field on the Earth, it should be borne in mind that in the auroral region, where the field lines are almost vertical, the magnetic fields of magnetospheric and Pedersen currents compensate one another ⁽⁹⁾, so that the final effect is associated only with the Hall current. The magnetic field directly beneath the auroral zone can be estimated from the formula for a plane current, $H \approx 100\gamma$.

An electrojet of limited extent excites spreading currents in the middle latitudes and in the polar cap, whose direction is opposite—

is opposite to the main current. Accordingly, with increasing distance from the auroral zone, the sign of the meridional component of the magnetic disturbance should change (Fig. 1).

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