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# THE EFFECT OF INHOMOGENEOUS MAGNETOSPHERIC-IONOSPHERIC CONDUCTIVITY ON IONOSPHERIC CONVECTION

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**Abstract.** It is known that the evening convection vortex is larger than the morning vortex. This result is confirmed by the numerical simulation of this study. We have also investigated the dependence of convection on the enhanced magnetospheric and ionospheric conductivities at midnight. The high conductivity near the midnight enhances the morning vortex, which became comparable with the evening vortex. The results of our calculations agree with the empirical model of convection during the expansive substorm phase.

## Introduction

The evening cell of the ionospheric convection is larger than the morning cell under the quiet magnetic conditions. Such asymmetry of evening and morning cells is caused by the high ionospheric conductivity on the dayside. The expansion of the morning convection cell takes place when the positive component of By IMF increases. The morning convection cell extends at the time of the substorm growth phase along with the increase of a potential drop across the polar cap. As a result the potential of the morning cell becomes approximately equal to the potential of the evening cell. At the onset of the explosive phase of the substorm the morning cell penetrates into the evening cell on the polar boundary of auroral region at the midnight.

The modelling of the magnetospheric-ionospheric convection for the quiet and perturbed conditions was performed in this study. We obtained that the increase of the morning cell potential during the substorm growth phase can be explained by the magnetospheric conductivity increase, which causes the shielding of the polar electric field and does not allow currents to penetrate into the midlatitude ionosphere. During the substorm explosive phase, the polar cap boundary in the ionosphere midnight sector shifts poleward. The magnetospheric conductivity in this area is decreased; this is why the morning cell penetrates into the evening cell.

## The model description

In the polar cap, on the open magnetic field lines, the homogeneous electric field $E_0$ is directed from morning to evening. The electric potential $\varphi$ in the polar cap is defined as follows:

$$\varphi = E_0 R_E \theta \sin\lambda, \qquad (1)$$

where $R_E$ - radius of the Earth, $\lambda$ - magnetic longitude, which is counted from the midnight.

On the closed magnetic field lines the ionospheric potential distribution is determined from the currents continuity equations for the ionosphere and magnetosphere:

$$div(\hat{\Sigma}\, grad\varphi) = -j, \qquad (2)$$

$$div(\Sigma_m[\mathbf{e}\times grad\varphi]) = j, \qquad (3)$$

where $\hat{\Sigma}$ is the tensor of the integral ionospheric conductivity, $\Sigma_m$ is the effective Hall conductivity of the magnetosphere, **e** is the unit vector directed along the magnetic field line.

The magnetospheric conductivity $\Sigma_m$ for the quiet conditions and for the substorm growth phase is defined as follows:

$$\Sigma_m = \Sigma_0 \quad \text{for } \theta_p < \theta < \theta_p + \Delta\theta \qquad (4)$$
$$\Sigma_m = \Sigma_0 exp(-(\theta - \theta_p - \Delta\theta)^2/\Delta\theta^2) \quad \text{for } \theta > \theta_p + \Delta\theta$$

where $\theta_p$ is the colatitude of the polar cap boundary, $\Delta\theta$ is the characteristic width of the plasma layer, $\Delta\theta = 5^0$. The magnitude $\Sigma_0$ for quiet conditions and for the growth phase of the substorm is 5 mho and 50 mho, respectively.

During the explosive phase of substorm for $\theta_p < \theta < \theta_p + \Delta\theta$ the magnetospheric conductivity is defined as follows: $\Sigma_m = \Sigma_0$ $(1-\exp(-\lambda^2/\Delta\lambda^2))$, where $\Delta\lambda = 100^0$, $\Sigma_0 = 50$ mho.

## Modelling results

The numerical calculations were performed for the model of the ionospheric conductivity by Hardy et al. (1987) for summer conditions. Fig.1 shows the distribution of electric potential under quiet conditions when the electric field magnitude in the polar cap is $E_0$=20 V/km. The value of potentials is in kilovolts.

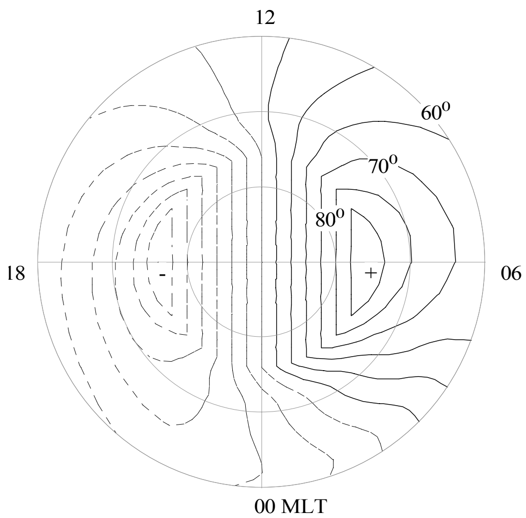


**Fig.1.** The distribution of electric potential for quiet conditions. The values of potentials is in kilovolts, max = 28.3kV, min = -37.1 kV.

Fig. 2 shows the distribution of electric potential during the growth phase of the substorm at the magnitude of the electric field in the polar cap $E_0$=30 V/km.

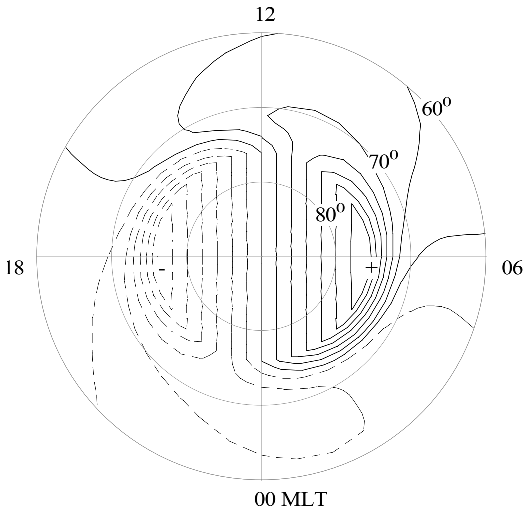


**Fig.2.** The distribution of electric potential during the growth phase of substorm, max = 48.7 kV, min = -44.7 kV.

Fig.3a shows the distribution of electric potential during the explosive phase of substorm. Fig.3b shows the distribution of field-aligned currents on closed magnetic field lines in the auroral zone in this case.

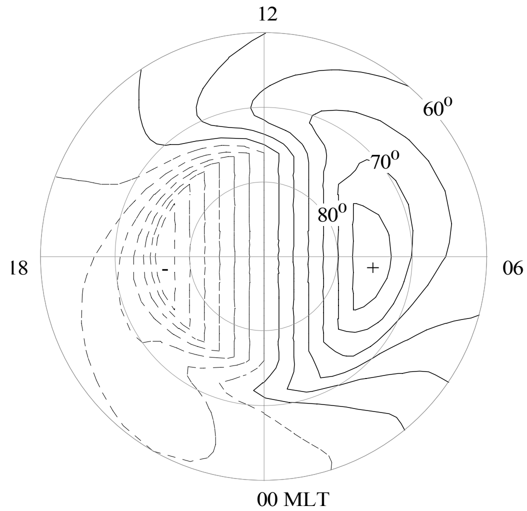


**Fig.3a. T**he distribution of electric potential during the explosive phase of substorm, max = 43.9 kV, min = -49.5 kV.

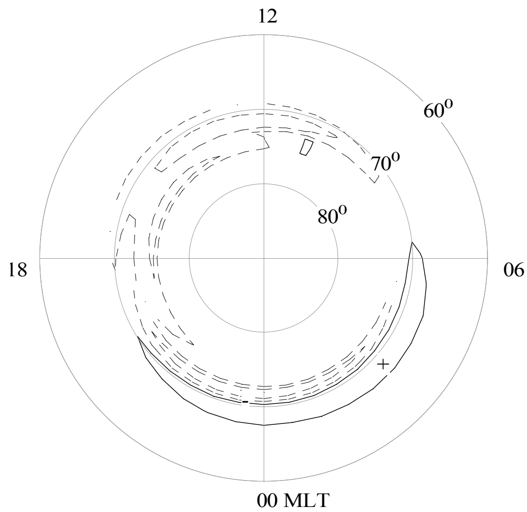


**Fig.3b** The distribution of field-aligned currents on closed magnetic field lines in the auroral zone, max = 0.5 /km$^2$, min = -1.1 /km$^2$.

The values of currents are given in A/km$^2$. Solid and dashed lines denote the boundary of currents that flow out of the ionosphere and into the ionosphere, respectively. Fig.4 illustrates the distribution of the electric potential, constructed on the basis of empirical data under the conditions of an explosive phase of substorm, taken from the paper by *Taguchi and Nishimura, 2002*.

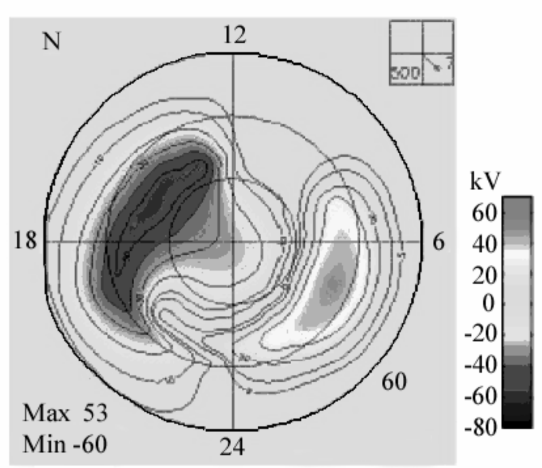


**Fig.4** The distribution of the electric potential, constructed on the basis of empirical data, during an explosive phase of substorm, taken from the paper by *Taguchi and Nishimura, 2002*.

## Summary

1. During the growth phase of substorm the increase of the potential of the morning cell is caused by the increase of magnetospheric conductivity, which plays the role of the Hall shunt, which in turn noticeably decreases the electric fields in middle latitudes.
2. During the explosive phase of substorm the decrease of magnetospheric conductivity on the polar cap boundary near the midnight allows to explain the characteristic behaviour of convection in this area, namely, the morning cell penetration into the evening cell.
3. The obtained field-aligned currents distribution in this area is typical for the explosive phase of substorm, namely, on the poleward boundary of this area the current flows into the ionosphere, on equatorward boundary of this area the current flows out the ionosphere.

## References

Hardy D.A., Gussenhoven M.S., Raistrick R., McNeil W.J. Statistical and functional representations of the pattern of auroral energy flux, number flux, and conductivity // J.Geophys.Res. 1987. V.92.№A11.P.12275

Taguchi,S.,and H. Nishimura, Ionospheric Potential Model for the Development of a Substorm; Proceedings of Sixth International Conference on Substorms, Edited by R.Winglee, Seattle, USA, 115-122, March, 2002