"Physics of Auroral Phenomena", Proc. XXX Annual Seminar, Apatity, pp. 151 - 153, 2007
© Kola Science Centre, Russian Academy of Science, 2007
Polar Geophysical Institute

MODELING CALCULATIONS OF FIELD-ALIGNED CURRENTS IN WINTER AND SUMMER POLAR CAPS

I.V. Artamonov, O.V. Martynenko, M.A. Volkov *(Murmansk State Technical University, Murmansk, Russia, e-mail: ilyaart@gmail.com)*

1. Introduction

Different illuminance of northern and southern hemispheres leads to the asymmetry in distribution of currents and electrical potential in winter and summer polar caps. According to observations, the field-aligned currents flowing in summer, more illuminated hemisphere are considerably more intensive than the currents flowing in winter hemisphere. On contrary, the cross polar cap potential drop is higher for winter hemisphere, than for summer [*de la Beaujardiere et al.*, 1991]. The distance between upward and downward field-aligned currents on either sides of polar cap, apparently, also has seasonal dependence. According to the observation results [*Christiansen et al.*, 2002], the distance between currents on the night side and day side in summer polar cap is slightly more than in winter. For winter polar cap the asymmetric distribution of field-aligned currents is typical alongside midday-midnight meridian, whereas for the summer polar cap the symmetry is more typical. It is true for the situation, when the interplanetary magnetic field component $B_y = 0$.

In the present paper it is shown, that all these features of electrical potential and currents distributions are interdependent and explained by the different ionospheric conductivity of winter and summer polar caps.

2. Model description and results

The electric potential distributions are set inside polar caps along $\theta_0 = 13°$ and $\theta_p = 15°$ colatitudes. Longitudinal potential distribution along these boundaries is set in the following way:

$$\varphi = \varphi_{0,p} \sin\lambda,$$

where $\varphi_{0,p}$ - half of potential drop along colatitude θ_0 and θ_p, respectively, λ - longitude which is counted from midnight. Along the colatitude θ_0, potential distributions differ in summer and winter hemispheres, and along the colatitude θ_p they are the same, this boundary is supposed to be the boundary between the closed and open magnetic field lines or polar cap boundary. It is possible to consider the closed magnetic field lines to be equipotential, therefore φ_p values for summer and winter polar caps are congruent. Value of φ_0 for winter polar cap is set larger than for summer, as according to observations the potential difference across winter polar cap is higher than across the summer one.

For the other colatitudes inside polar caps the electrical potential distribution is obtained from the ionospheric integral current continuity equation:

$$div(\hat{\Sigma}_{N,S}\, grad\varphi_{iN,S}) = 0,$$

where $\hat{\Sigma}_{N,S}$ - integral ionospheric conductivity tensor in northern (N) and southern (S) hemisphere.

Ionospheric conductivity $\hat{\Sigma}_{N,S}$ for northern and southern polar caps was set according to the Hardy model [*Hardy et al.*, 1987].

Equatorward from the polar caps, the electric potentials of nodes in northern and southern hemispheres, linked by a magnetic field line, are considered identical. The electric potential distribution is obtained from the ionospheric and magnetospheric currents continuity equations:

$$div\{(\hat{\Sigma}_N + \hat{\Sigma}_S) grad\varphi + \Sigma_m [\vec{e} \times grad\varphi]\} = 0,$$

where Σ_m - effective Hall conductivity of magnetosphere, $\vec{e}$ - unit vector along the magnetic field line.

Field-aligned currents of polar caps flow along θ_0 and θ_p colatitudes, and they are obtained from the ionospheric current continuity equation:

$$div(\hat{\Sigma}_{N,S}\, grad\varphi_{iN,S}) = -j_{N,S}$$

The field-aligned currents $j_{N,S}$, flowing up from ionosphere of northern or southern hemisphere, are considered positive.

Magnetospheric conductivity is set in the following way:

$$\Sigma_m = \Sigma_0 \exp(-(\theta-\theta_p)^2/\Delta\theta^2),$$

where $\Sigma_0 = 100$ Sm, $\Delta\theta = 10^0$.

In Figure 1 the distribution of the electrical potential and field-aligned currents is shown for winter hemisphere ($\varphi_p = 24$ kV, $\varphi_0 = 37$ kV).

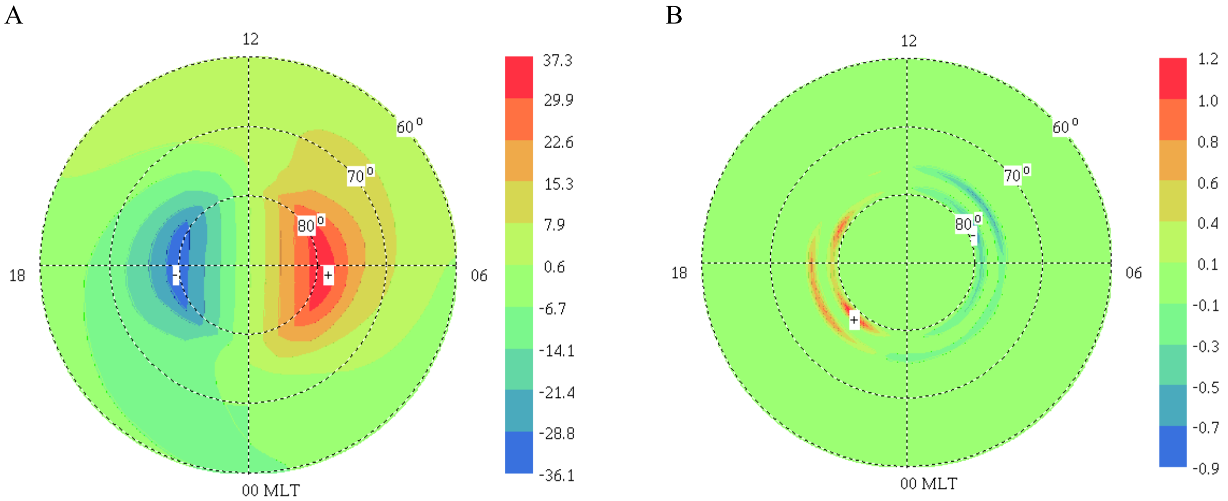

Fig. 1. The electrical potential in kV (A) and field-aligned currents in A/km^2 inside polar cap (B). Winter hemisphere.

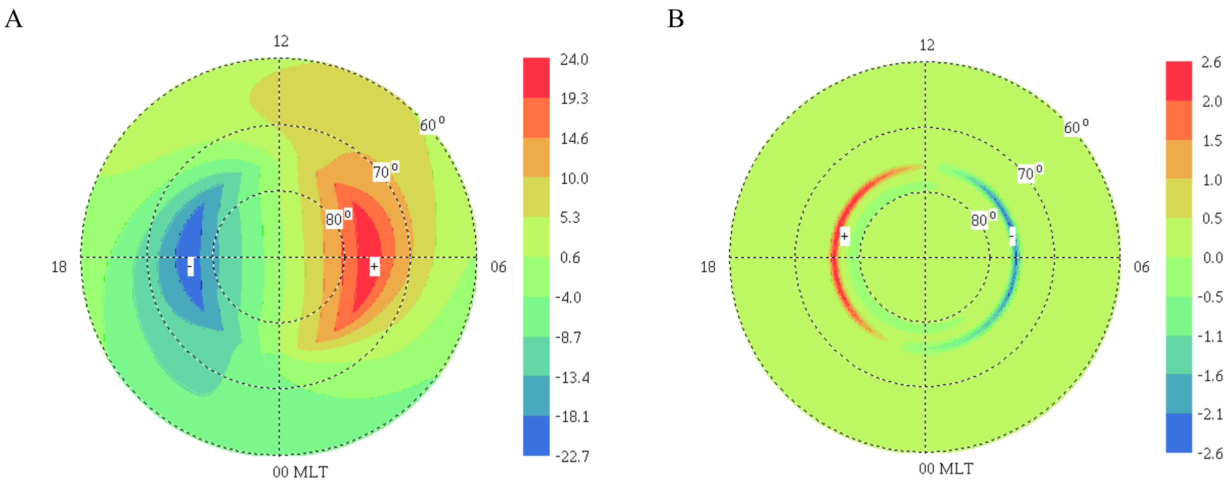

Fig. 2. Same as in figure 1. Summer hemisphere.

In Figure 2 the electrical potential and inside polar cap field-aligned currents distribution is shown for summer hemisphere (φ_p = 24 kV, φ_0 = 17 kV).

3. Conclusion

In the present paper the field-aligned currents distributions are obtained for winter and summer polar caps for the conditions of northern and southern hemispheres asymmetry and close to uniform convection. According to the model that is used in the work, the field-aligned currents in a polar cap flow in the colatitudes range of 13°-15°, strictly, on boundaries of this zone. The maximum electric potential drop across winter polar cap is set approximately 1.5 times higher than at summer, this is confirmed by the experimental data. The boundary of the closed equipotential magnetic field lines lies along the colatitude of 15°. The results can be summarized in the following.

The calculations confirm the well-known fact, that intensity of the field-aligned currents flowing in more illuminated, summer hemisphere is higher than in winter, in our case – almost twice higher.

In winter hemisphere according to the calculations the currents are more uniformly distributed in the 13°-15° area, what is possible to interpret as the offset of the currents center to the pole. It means that the distance is decreased between the currents flowing downward and the currents flowing upward of winter polar cap on the day and evening sides. Such decrease is indirectly indicated by the experimental data, obtained in work by [*Christiansen et al.*, 2002]. According to the observation results in that work, the distance between currents on the day and night sides in winter polar cap is approximately

5° larger than in summer polar cap. If we consider the area of polar caps equal because of similarity of magnetic fluxes in polar caps, then it is possible to assume that the distance between upward and downward currents on the evening and morning sides of winter polar cap would be less than in summer.

The maximum of field-aligned currents intensity in winter polar cap is shifted approximately 2 hours counter-clockwise and is observed on the evening side around 22 MLT and on the morning side at 8 MLT. In summer polar cap maximums are located along morning-evening meridian. In the work [*Papitashvili et al.*, 2002], a similar field-aligned currents distribution in winter polar cap is presented, asymmetric to midday-midnight meridian at B_y=0, but the presented result requires further experimental check.

References

Christiansen, F., V. O. Papitashvili, and T. Neubert (2002), Seasonal variations of high-latitude field-aligned currents inferred from Ørsted and Magsat observations, J. Geophys. Res., 107(A2), 1029, doi:10.1029/2001JA900104.

de la Beaujardiere, O., D. Alcayde, J. Fontanari, C. Leger (1991), Seasonal dependence of high-latitude electric fields, J. Geophys. Res., 96(A4), 5723-5735, 10.1029/90JA01987.

Hardy, D. A., M. S. Gussenhoven, R. Raistrick, W. J. McNeil, Statistical and functional representations of the pattern of auroral energy flux, number flux, and conductivity (1987), J. Geophys. Res., 92(A11), 12275.

Papitashvili V. O., F. Christiansen, and T. Neubert (2002), A new model of field-aligned currents derived from high-precision satellite magnetic field data, Geophys. Res. Lett., 29 (14), doi:10.1029/2001GL014207.