"Physics of Auroral Phenomena", Proc. XXIX Annual Seminar, Apatity, pp.36-39, 2006

Polar Geophysical Institute

NUMERICAL MODELING OF AURORAL ELECTROJET DURING GEOMAGNETIC DISTURBANCES WITH PARTICLE PRECIPITATION INCLUDED

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Abstract. Model studies of particle precipitation effect in auroral electrojet dynamics during magnetospheric substorms have been performed. The calculations were conducted using the Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP) designed at the West Department of IZMIRAN, with the calculations of electric fields in the Earth's ionosphere included. It is shown, that taking into account particle precipitation, one can reproduce in the model such a well-known morphological feature as a much greater strengthening of the westward electrojet during a substorm than of the eastward one. It is also demonstrated that substorms associated with precipitation effects in the F2-layer of the ionosphere are connected with the redistribution of the electric field potential in the Earth's ionosphere. Based on the results obtained, a conclusion is made that for the correct description of the substorm-time behavior of auroral electrojets and F2-layer of the ionosphere both at high and middle and low geomagnetic latitudes, particle precipitation should be taken into account.

Introduction

In (Klimenko et al., 2006a) we had presented the results of numerical modeling of auroral electrojet behavior during a substorm, obtained with a model of GSM TIP, developed at the West Department of IZMIRAN (Namgaladze et al., 1988). Thus, there was not taken into account the particle precipitation during a substorm that resulted in the contradiction between the obtained results of calculations and the data of observation. Namely, instead of noticeable strengthening of counter (western) electrojet which connect with particle precipitation and which considerably surpasses growth of the east electrojet during geomagnetic disturbances (Kamide, 1991), in the results of calculations we obtained an opposite picture was observed. To bring the results of calculations in correspondence with observational data and to investigate the particle precipitation influence on the auroral electrojet dynamics during substorms, we perform new calculations, which results are presented in the given paper. The calculations were carried out self-consistently for equinoctial conditions (March 22, 1987) under low solar activity ($F_{10.7}$ = 76).

Model

The results of calculations carried out with a modified model of GSM TIP developed at WD IZMIRAN (Namgaladze et al., 1988) in which the block of calculation of electric fields is changed are presented. In the new block (Klimenko et al., 2005; Klimenko et al., 2006b,c) the solution of the 3D equation of density preservation of a full current in the Earth's ionosphere is carried out by its reduction to 2D by integration not by height of a current-carrying layer of the ionosphere as it had been earlier, but along the pieces of geomagnetic field lines lying in a current-carrying layer. Besides, in the new block the distribution of linear and surface density of a zonal current in the ionosphere are calculated. The spatial distribution of particle precipitation is set according to (Newell et al., 1991).

Results and Discussion

Fig. 1 shows on the left the behavior during a modeled substorm of a potential difference through polar caps in kV (top) and field aligned currents of the second zone in 10^{-7} A/m^2 (bottom), which are input parameters of the model. The ratio of the particle precipitation flux during a substorm to the undisturbed one on the right is shown for the first variant of the particle precipitation – above and for the second – below. In the first variant of particle precipitation after a phase of linear growth 30 minutes later the flux remains invariable. In the second variant after a growth phase the particle precipitation flux within the next 30 minutes does not vary, then the recovery phase follows.

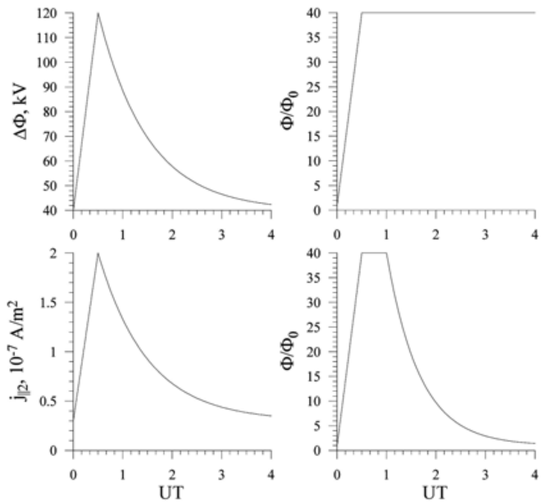

Fig. 1. A modeled substorm: on the left above – a potential difference through polar caps, on the left below – field aligned currents of the second zone, on the right above and below – two variants of particle precipitation, presented by the ratio of a particle precipitation flux during a substorm to the undisturbed one.

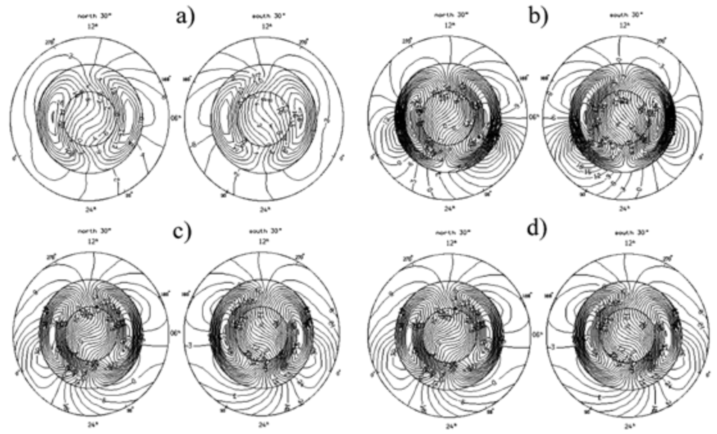

Fig. 2. Distribution of potential of the electric field calculated in model 30 minutes after the beginning of a substorm: a) quiet conditions, b) the disturbed conditions without taking into account particle precipitation, c) and d) the disturbed conditions in view of the first and second variants of particle precipitation, respectively.

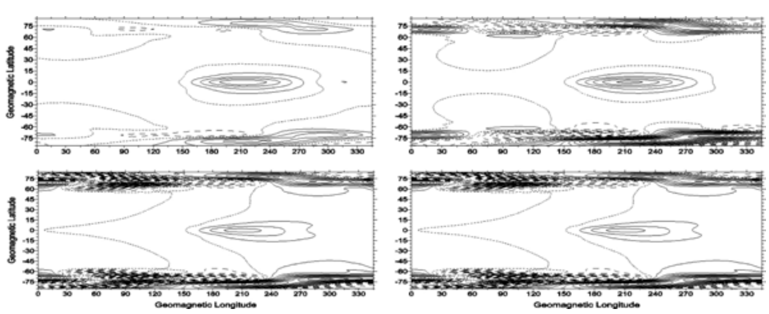

Fig. 3. The global distribution of linear density of a zonal current calculated in the model in A/km, positive in the east direction, appropriate to distributions of the electric field potential, shown in Fig. 2.

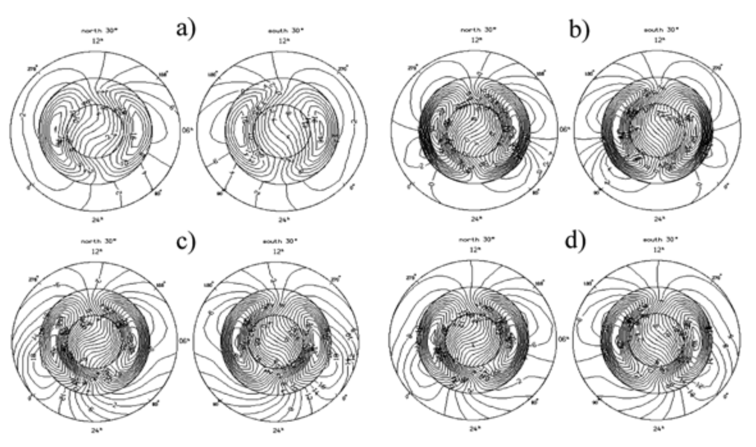

Fig. 4. The same, as in Fig. 2, 1 hour 30 minutes after the beginning of a substorm.

The following figures show above on the left the quiet conditions, and on the right the disturbed conditions without taking into account particle precipitation, and below on the left and on the right – the disturbed conditions taking into account the first and second variants of particle precipitation, respectively.

Fig. 2 shows in polar geomagnetic system of coordinates latitude – longitude the distributions of the electric field potential calculated in the model, generated by magnetospheric sources and ionospheric dynamo, in kV, in the northern and southern polar caps 30 minutes after the beginning of a substorm, that is at the moment of its maximum intensity. One can see the distinctions between these distributions of the potential about which value we shall talk later.

Fig. 3 shows in the Cartesian geomagnetic system of coordinates longitude - latitude the calculated global distributions of linear density of a zonal current in A/km, positive in the east direction, appropriate to distributions of the potential of the electric field, shown in Fig. 2. Continuous lines show positive currents, the shaped ones– negative and dotted – zero. The step between next isolines is 5 A/km. One can see, that at the maximum of a substorm without taking into account particle precipitation there is a significant strengthening of auroral electrojet, thus, the east electrojet grows more strongly western (in the upper right). Taking into account particle precipitation also results in the bottom distributions' strengthening of auroral electrojet as a whole, however, thus, the western electrojet grows stronger east, as well as it is observed in the experiment (Kamide, 1991). The bottom distributions do not differ between each other as 30 minutes after the beginning of a substorm both variants of particle precipitation have identical background.

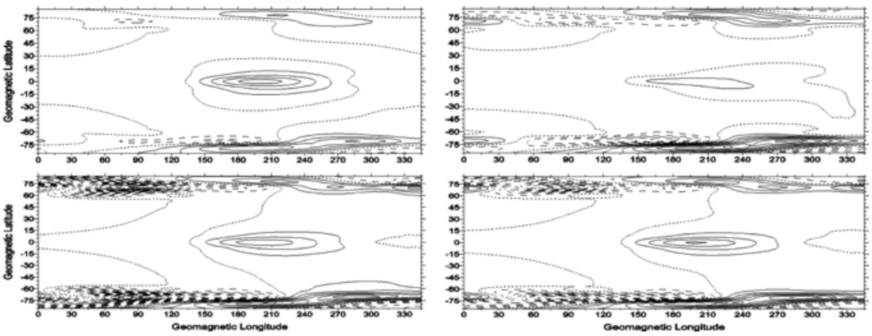

Fig. 5. The calculated distributions of a zonal current appropriate to distributions of the potential, presented in Fig. 4.

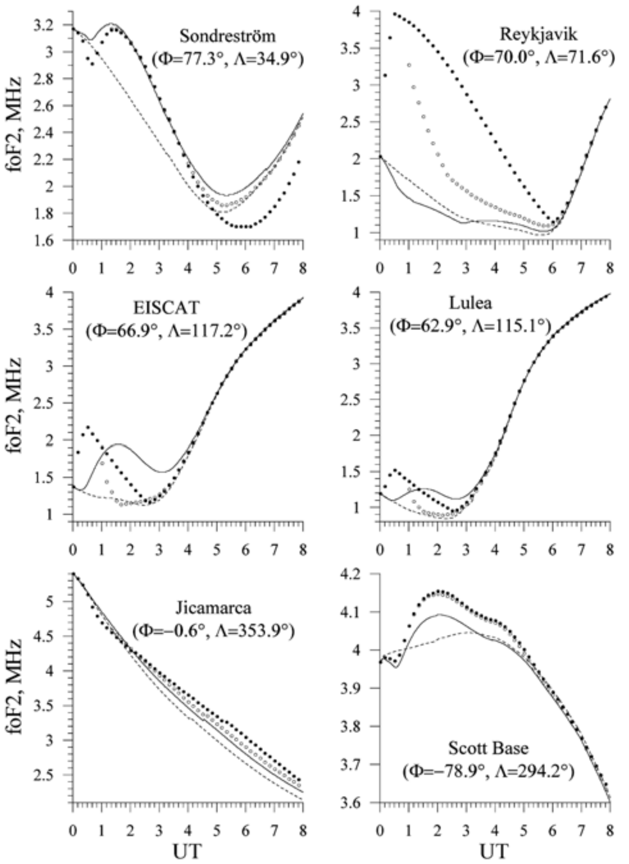

Fig. 6. The calculated foF2 time course for various stations: a quiet course (dotted curves), the disturbed course without particle precipitation (continuous curves) and the disturbed course with the first and second variants of particle precipitation (dark and light circles, respectively).

Fig. 4 shows the calculated distributions of the potential of an electric field in the northern and southern polar caps 1 hour 30 minutes after the beginning of a substorm, that is at the recovery phase. We shall dwell later on distinctions which, as well as in Fig. 2, can be seen here.

In Fig. 5 in the Cartesian geomagnetic system of coordinates the calculated global distributions of linear density of the zonal current, appropriate are shown the distributions of the potential presented in Fig. 4. It is seen, that at the recovery phase of a substorm there is a significant easing of auroral electrojet in comparison with the moment of the maximum intensity of a substorm, thus in all variants of calculations the features we marked at the previous considered moment of time (1 hour back) are kept. Besides it is possible to notice, that at the account of both variants of particle precipitation the east electrojet is practically identical and is a little bit stronger, than without taking into account particle precipitation, whereas the western electrojet is much stronger. Thus, in the first variant of particle precipitation the counter electrojet has a bigger intensity, than in the second one.

We carry out calculations of all the key parameters of the near-Earth environment for separate stations in both hemispheres, mainly the high-latitude ones. The most interesting results of calculations are presented in Fig. 6 where the dashed lines show a quiet course of critical frequency of F2-layer of the ionosphere in MHz for various stations, continuous lines – the disturbed course without particle precipitation, dark and light circles – the disturbed course with the first and second variants of particle precipitation, respectively. In Fig. 6 the data for stations Sondreström (Greenland), Reykjavik (Iceland), EISCAT (Norway), Lulea (Sweden), Jicamarca (Peru) and Scott Base (Antarctica) are presented. It is seen, that auroral particle precipitation during a substorm renders a strong influence on the behavior not only of auroral electrojet, but also on foF2 behavior, especially at high-latitude stations.

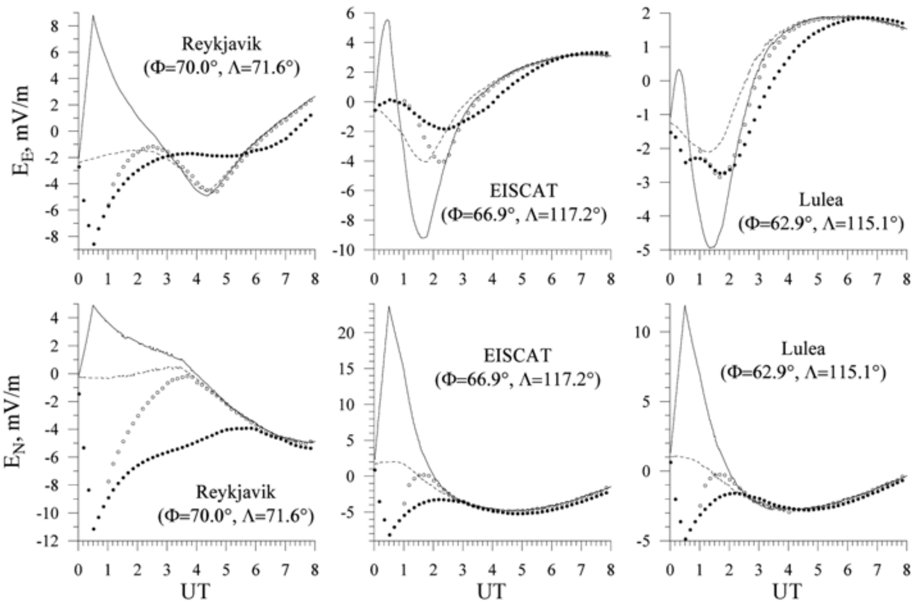

Fig. 7. The calculated time course of zonal (above) and meridional (below) components of the electric field for various stations. The legend is the same, as in Fig. 6.

It is connected to those changes of distribution of the electric field potential to which we paid attention in Fig. 2 and 4 and which are caused by the account of particle precipitation. A confirmation to this is Fig. 7 in which for the three high-latitude stations - Reykjavik, EISCAT and Lulea the time courses of zonal and meridional components of the electric field are shown. It is seen, the results of calculation of the electric field without taking into account and taking into account the particle precipitation, down to the change of a sign of the electric field are significantly different.

Summary

Thus, it is shown, that when modeling the substorm effects the careful taking into account of the high-energy particle precipitation is necessary as particle precipitation influence both electrodynamics of the ionosphere, and the distribution of thermal plasma in the ionosphere – in the bottom ionosphere the influence is direct due to ionization, and in F-region – by means of electric fields which distribution changes under the action of particle precipitation.

References

Kamide, Y., The Auroral Electrojets: Relative Importance of Ionospheric Conductivities and Electric Fields, *Auroral Physics, Ed. C.-I. Meng, M.J. Rycroft and L.A. Frank,* 385-399, 1991.

Klimenko, M.V., V.V. Klimenko, and V.V. Bryukhanov, Comparison of two variants of model of the electric field in the ionosphere of the Earth, *KSTU News*, №8, 59-68, 2005.

Klimenko, M.V., V.V. Klimenko, and V.V. Bryukhanov, Numerical modeling of auroral electrojet during geomagnetic disturbances, Proceedings of the 29th Annual Seminar “Physics of auroral phenomena”, 27 February – 3 March 2006, Apatity, (in this issue), 2006a.

Klimenko, V.V., M.V. Klimenko, and V.V. Bryukhanov, Numerical modeling of the electric field and zonal current in the Earth’s ionosphere – Statement of the problem and test calculations, Mathematical Modeling, **18**, №3, 77-92, 2006b.

Klimenko, M.V., V.V. Klimenko, and V.V. Bryukhanov, Numerical modeling of electric field and zonal current in the Earth’s ionosphere – Dynamo field and equatorial electrojet, Geomagnetism and aeronomy, **46**, №4, 2006c.

Namgaladze, A.A., Yu.N. Korenkov, V.V. Klimenko, I.V. Karpov, F.S. Bessarab, V.A. Surotkin, T.A. Glushchenko and
N.M. Naumova, Global Model of the Thermosphere–Ionosphere–Protonosphere System, *Pure and Appl. Geophys. (PAGEOPH)*, **127**, № 2 / 3, 219-254, 1988.

Newell, P.T., C.-I. Meng, and D.A. Hardy, Overview of electron and ion precipitation in the auroral oval, *Auroral Physics, Ed. C.-I. Meng, M.J. Rycroft and L.A. Frank,* 85-95, 1991.