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THE BEHAVIOR OF F2-LAYER MAXIMUM AT LOW-LATITUDES DURING GEOMAGNETIC STORMS ON SEPTEMBER 9-14, 2005

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Summary: In the given study the calculation results of low-latitude ionospheric effects of geomagnetic storm sequence on September 9-14, 2005 with taken into account solar flares are considered. Under carrying out the calculation of the disturbed ionospheric parameters values the model input parameters were set as function of *AE*- and *Kp*-index of geomagnetic activity according to different empirical models and morphological representations. The calculation results are in a good agreement with experiment.

1 INTRODUCTION

Many papers are devoted to numerical modeling of low-latitude ionospheric storm effects. They modeled: positive and negative effects of ionospheric storms, caused by thermospheric parameter changes; penetration of magnetospheric convection electric field to lower latitudes and disturbed ionospheric dynamo. It has been shown, that the basic formation mechanisms of low-latitude ionospheric disturbances are the electric fields and thermospheric parameter changes. The given research is devoted to numerical modeling of low-latitude ionospheric effects of storm sequence on September 9-14, 2005 at the setting of input parameters as functions of *AE*- and *Kp*-index of geomagnetic activity with taken into account solar flares effects.

2 STATEMENT OF THE PROBLEM

The storms on September 9^{th}-14^{th} were caused the strengthening of auroral activity, radio blackout and strong ionospheric storm. In Fig. 1 the behavior of geomagnetic activity indexes

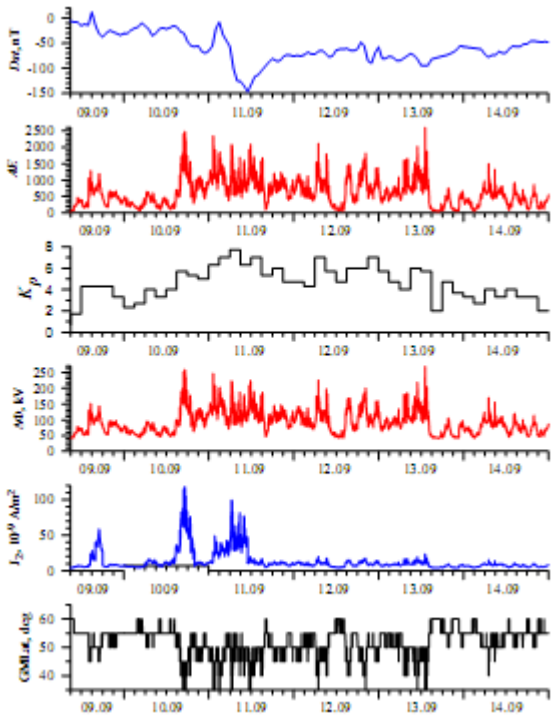

Figure 1: The behavior of *Dst*, *AE* and *Kp* indices of geomagnetic activity, potential drop through polar caps and amplitude and latitudinal location of field-aligned currents on September 9-14, 2005

for the considered time period is shown. Values of a three-hour index of geomagnetic activity *Kp* during storms on September 9, 10 and 11, 2005 reached its maximal values 4.3, 5.7 and 7.7 accordingly. On September 9th, 2005 there was a solar flare of class X17. This flare was one of 10 most powerful solar flares registered for all history. In all this period there were five solar flares.

We carried out the calculation of ionospheric parameters during geomagnetic storm sequence on September 9-14, 2005 with taken into account solar flares. Calculation of ionospheric effects of storm sequence has been carried out with use of the Global Self-Consistent Model of the Thermosphere, Ionosphere and Protosonosphere (GSM TIP) developed in West Department of IZMIRAN. Model GSM TIP was described in details[3,4]. At simulation of ionospheric parameters in quit geomagnetic conditions only the $F_{10.7}$ changes from day to day were considered.

Under carrying out the calculation of the disturbed ionopsheric parametes the model input parameters were set as function of *AE*- and *Kp*-index of geomagnetic activity according to different empirical models and morphological representations. So, the potential difference through polar caps ΔΦ was set according to empirical formula[5]:

$$\Delta\Phi = 38.0 + 0.089 \times AE, \text{kV} \quad (1)$$

field aligned currents of the second region was set according to experimental data[6,7] in quiet conditions and at recovery phase of storm:

$$j_2 = 3.0 \times 10^{-9} + 6.0 \times 10^{-12} \times AE, A/m^2 \quad (2)$$

at SSC phase of storm with 30 min delay

$$j_2 = 3.0 \times 10^{-9} + 1.5 \times 10^{-11} \times AE, A/m^2 \quad (3)$$

in active phase of storm

$$j_2 = 3.0 \times 10^{-9} + 3.6 \times 10^{-11} \times AE, A/m^2 \quad (4)$$

and the particle precipitation fluxes and energy according to the model[8]. The displacement of field aligned currents of the second region to the lower latitudes was set as by[9]:

$$\pm 65^{\circ} \text{ for } \Delta\Phi \leq 40\text{kV} \quad (5)$$

$$\pm 60^{\circ} \text{ for } 40\text{kV} < \Delta\Phi \leq 50\text{kV} \quad (6)$$

$$\pm 55^{\circ} \text{ for } 50\text{kV} < \Delta\Phi \leq 88.5\text{kV} \quad (7)$$

$$\pm 50^{\circ} \text{ for } 88.5\text{kV} < \Delta\Phi \leq 127\text{kV} \quad (8)$$

$$\pm 45^{\circ} \text{ for } 127\text{kV} < \Delta\Phi \leq 165.4\text{kV} \quad (9)$$

$$\pm 40^{\circ} \text{ for } 165.4\text{kV} < \Delta\Phi \leq 200\text{kV} \quad (10)$$

$$\pm 35^{\circ} \text{ for } 200\text{kV} < \Delta\Phi \quad (11)$$

At the SSC moment we set the time delay of variations of the field aligned currents of second region, equal of 30 min. relative to the variations of the potential difference through polar caps[6,10]. In Fig. 1 the behavior of input parameters (potential difference through polar caps, amplitude and latitudinal location of field aligned currents of second region) for the considered time period is shown.

3 CALCULATION RESULTS AND DISCUSSION

In Fig. 2 it is shown the calculation results of critical frequency f_0F and height maximum h_mF above Jicamarca and Vanimo for 9-14 September 2005 with and without taken into account solar flares effect. It is possible to see the effects caused by geomagnetic storms and solar flares. Jumps of maximum height of the F-layer are connected with stratification of the

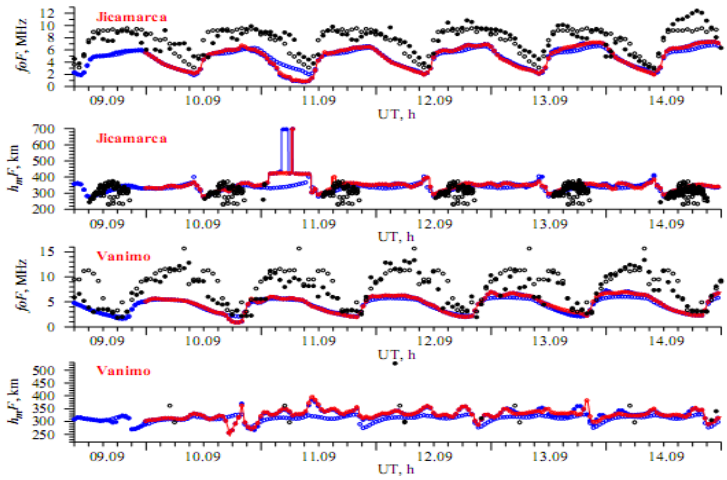

Figure 2: f_0F and h_mF above stations Jicamarca and Vanimo during geomagnetic storms on 9-14 September 2005. Calculation results – quiet conditions (open blue circles), storm-time conditions with and without taken into account solar flares (red and blue circles). Experimental data – quiet conditions (black open circles), storm-time conditions (black circles).

equatorial *F2*-layer and with the appearance of an additional *F3*-layer under action of eastward electric field. It is visible very well in Fig. 3 where the calculated vertical profiles of electron density above station Jicamarca are shown for the moment of the stratification beginning, maximum of stratification and during the moment of time since which critical frequency of the *F3*-layer becomes less than critical frequency of the *F2*-layer. Therefore, the plots of f_0F in Fig. 2 show the behavior of critical frequency *F2*- or *F3*-layer, depending on what of these frequencies is more. The same concerns to the height of maximum h_mF which describes height of maximum *F2*- or *F3*-layer.

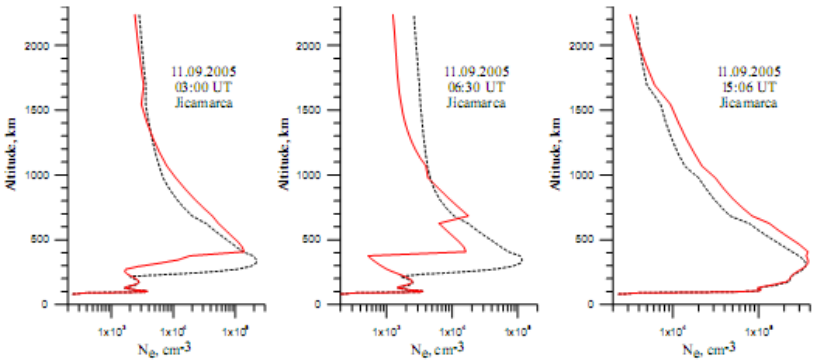

Figure 3: Vertical profiles of electron density calculated in quiet (dotted lines) and storm-time (red lines) conditions with taken into account solar flares.

4 CONCLUSIONS

- The using of the dependence of input parameters from *AE*-index with time resolution one minute allowed approaching the calculation results of ionospheric disturbances during geomagnetic storms to experiment.
- The account of the solar flare ionospheric effects during storm sequence on September 9-14, 2005 improved the description of behavior of low-latitudinal ionosphere parameters in maximum of F2-layer.
- It is shown that during geomagnetic storms there is the stratification of the equatorial F2-layer and the appearance of F3-layer as a result of the eastward electric field action.

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REFERENCES

[1] C.A. Reddy and H.G. Mayr, "Storm-time penetration to low latitudes of magnetospheric- ionospheric convection and convection-driven thermospheric winds", *Geophys. Res. Lett.*, 25, 3075–3078 (1998).

[2] N. Maruyama, A.D. Richmond, T.J. Fuller-Rowell, M.V. Codrescu, S. Sazykin, F.R. Toffoletto, R.W. Spiro and G.H. Millward, "Interaction between direct penetration and disturbance dynamo electric fields in the storm-time equatorial ionosphere", *Geophys. Res. Lett.*, 32, L17105, doi:10.1029/2005GL023763 (2005).

[3] A.A. Namgaladze, Yu.N. Koren'kov, 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 Applied Geophysics, 127, 219-254 (1988).

[4] M.V. Klimenko, V.V. Klimenko and V.V. Bryukhanov, "Numerical Simulation of the Electric Field and Zonal Current in the Earth's Ionosphere: The Dynamo Field and Equatorial Electrojet", *Geomagn. Aeron.*, 46, 457–466 (2006).

[5] E.Yu. Feshchenko and Yu.P. Maltsev, "Relations of the polar cap voltage to the geophysical activity", *Physics of Auroral Phenomena: XXVI Annual Seminar (February 25–28, 2003): Proc./PGI KSC RAS*. Apatity, 2003, 59-61 (2003).

[6] Z.W. Cheng, J.K. Shi, T.L. Zhang, M. Dunlop and Z.X. Liu, "Relationship between FAC at plasma sheet boundary layers and AE index during storms from August to October, 2001", *Sci. China Ser. E-Tech. Sci.*, 51, 842-848 (2008).

[7] K. Snekvik, S. Haaland, N. Østgaard, H. Hasegawa, R. Nakamura, T. Takada, L. Juusola, O. Amm, E. Pitout, H. Rème, B. Klecker and E.A. Lucek, "Cluster observations of a field aligned current at the dawn flank of a bursty bulk flow", *Ann. Geophys.*, 25, 1405-1415 (2007).

[8] Y. Zhang and L.J. Paxton, "An empirical Kp-dependent global auroral model based on TIMED/GUVI FUV data", *J. Atmos. Solar-Terr. Phys.*, 70, 1231-1242 (2008).

[9] J.J. Sojka, R.W. Schunk and W.F. Denig, "Ionospheric response to the sustained high geomagnetic activity during the March'89 great storm", *J. Geophys. Res.*, 99, 21341-21352 (1994).

[10] T. Kikuchi, K.K. Hasimoto and K. Nozaki, "Penetration of magnetospheric electric fields to the equator during a geomagnetic storm", *J. Geophys. Res.*, 113, A06214, doi:10.1029/2007JA012628 (2008).