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VARIOUS MAGNETOSPHERIC INPUTS TO THE GSM TIP MODEL FOR INVESTIGATION OF IONOSPHERIC RESPONSE TO GEOMAGNETIC STORM EVENT ON 2–3 MAY 2010

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Abstract. Recent modifications to the Global Self-Consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP) resulted in better representation of ionospheric effects during geomagnetic storms. This study presents the GSM TIP numerical simulations of the ionospheric response to the geomagnetic storm event on 2–3 May 2010. We try to investigate the problem of the model input parameters setting at the simulations of geomagnetic storms. In numerical experiments, such model input parameters as electric cross-polar cap potential and R2 FAC were set as function of different geomagnetic activity indices, solar wind and interplanetary magnetic field parameters. Current simulation also uses two empirical models for high-energy particle precipitation. The obtained calculation results were compared with experimental data obtained at different mid- and low-latitude stations.

Introduction

The modeling studies of the ionospheric response to geomagnetic storms with used the first principal self-consistent model of the thermosphere-ionosphere-electrodynamics system need to account for the changes of Cross-Polar Cap Potential (CPCP), Region 2 Field-Aligned Currents (R2 FAC) spatial-temporal variations, energy and flux energy of high-energy particle precipitation. The inclusion of such inputs to the global numerical model allows accurate description of the Joule heating, effects of the prompt penetration electric field, overshielding, and disturbance dynamo electric field. The Global Self-consistent Model of the Thermosphere, Ionosphere, Protonosphere (GSM TIP) (Namgaladze et al., 1988), developed and modified by Klimenko et al. (2006, 2007) in WD IZMIRAN allows modeling studies with all these drivers.

The comparison of the different ionospheric parameters calculated with use the GSM TIP model during geomagnetic storm sequence on September 2005 with the observational data at different mid-latitude locations, presented in earlier study by Klimenko et al. (2011a), has revealed the qualitative agreement. Suggested reasons for model/data differences included the coarse temporal resolution of the model input parameters (e.g. three-hour K_p-index), the use of the dipole approach of geomagnetic field in the GSM TIP model, and the absence of solar flare effects in the model. Subsequent study (Klimenko et al., 2011b) has shown that the use of several updates in the GSM TIP model can significantly improve the agreement between the calculation results and the observational data. These updates are: a) *AE* index with 1-min temporal resolution as an independent variable instead of the 3-hour K_p-index for modeling the time dependence of CPCP; b) the new empirical model of high-energy particle precipitation, depending on the K_p-index (Zhang and Paxton, 2008); c) description of the R2 FAC according to the currently available experimental data and theoretical concepts (Iijima and Potemra, 1976; Sojka et al., 1994; Snekvik et al., 2007; Cheng et al., 2008; Kikuchi et al., 2008); d) inclusion in the model the effects of solar flares. In this paper, we continue our investigation of the ionospheric effects during geomagnetic storm. For this reason, we considered the geomagnetic storm event on May 2–3, 2010.

Description of the storm event and model runs

Figure 1 describes the behavior of *Dst*-, K_p-, *AL*- and *AE*-indices of geomagnetic activity, solar wind velocity V_{SW} and Interplanetary Magnetic Field for the period of 1–3 May 2010. We have used two different dependences of CPCP changes as input model parameters: (1) $\Delta\Phi = 38 + 0.089\times AE$, kV (Feshchenko and Maltsev, 2003); (2) $\Delta\Phi = 10^{-4} \times V_{SW}^2$ (km/s) + 11.7 × $|B_{IMF}|$ (nT) × $sin^3(\theta/2)$ (Boyle et al., 1997), where $\theta = arcos\ (B_{ZIMF}/|B_{IMF}|)$. Current simulations also use two empirical models by Zhang and Paxton (2008) and Vorobjov and Yagodkina (2005, 2007) for high-energy particle precipitation. We performed four different model

Table 1. Geomagnetic latitude of R2 FAC

Condition	GMLat of R2 FAC
$\Delta\Phi \le 40$ kV	±65°
40 kV < $\Delta\Phi \le 50$ kV	±60°
50 kV < $\Delta\Phi \le 88.5$ kV	±55°
88.5 kV < $\Delta\Phi \le 127$ kV	±50°
127 kV < $\Delta\Phi \le 165.4$ kV	±45°
165.4 kV < $\Delta\Phi \le 200$ kV	±40°
$\Delta\Phi > 200$ kV	±35°

runs for quiet conditions and for the storm-time conditions used different model parameters input. In all model runs, we used the dependence of R2 FAC, on the *AE*-index: j_2 (A/m^2) = $3 \times 10^{-8} + 1.2 \times 10^{-10} \times AE$. We also have included the 30 min time delay of R2 FAC variations with respect to the variations of cross-polar cap potential difference during geomagnetic storm (Kikuchi et al., 2008). In addition, according to *Sojka et al.* (1994) we varied the position of R2 FAC maximum depending on CPCP changes such as it is shown in the Table 1.

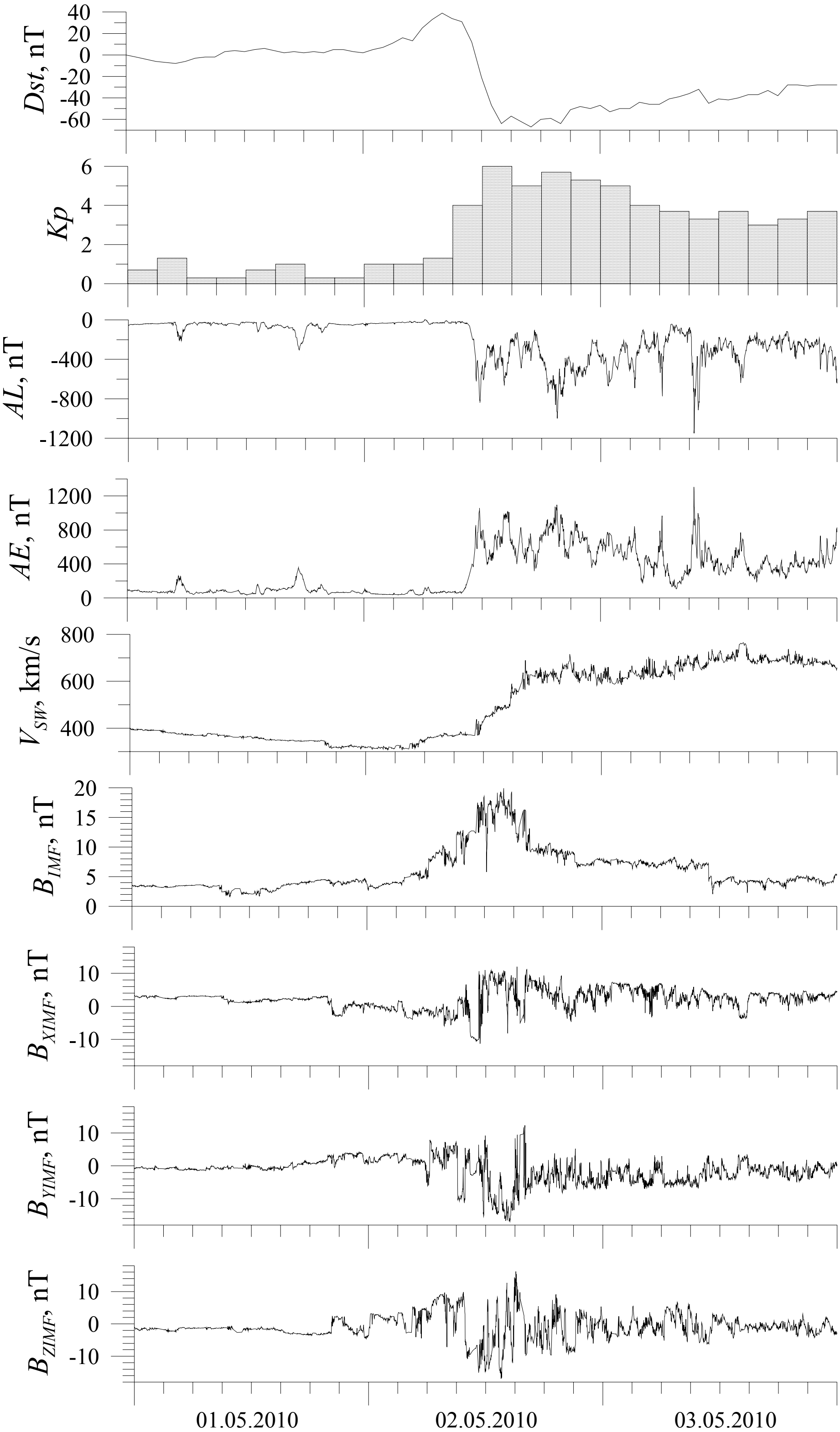

Fig. 1. The behavior of *Dst*, K_p, *AL*, *AE* geomagnetic indices, solar wind velocity V_{SW} and Interplanetary Magnetic Field parameters (B_{IMF}, B_{XIMF}, B_{YIMF} and B_{ZIMF}) on 1–3 May, 2010 geomagnetic storm.

Model results and comparison with observation

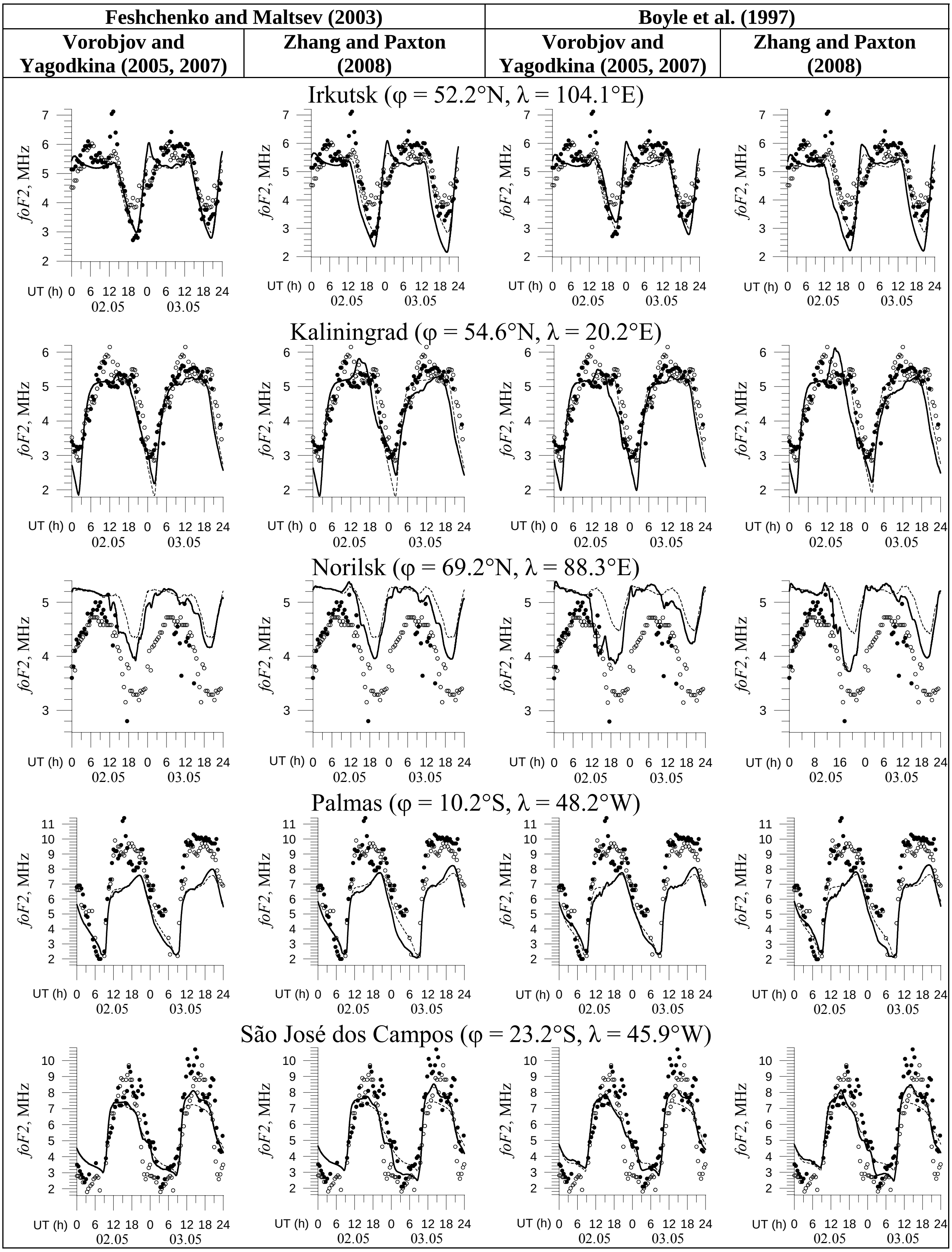

Fig. 2. *foF*2 behavior during 2–3 May, 2010 geomagnetic storm above Irkutsk (Russia), Kaliningrad (Russia), Norilsk (Russia), Palmas (Brazil) and São José dos Campos (Brazil). The observational data are shown by light circles – quiet day 1 May, 2010 and dark circles – disturbed days. The simulated data obtained with different model input parameters are shown by dotted lines – quiet day 1 May, 2010 and solid lines – disturbed days.

As the ionospheric observation data source we used the ionosonde data of Irkutsk, Kaliningrad, Norilsk, Palmas and São José dos Campos to allow us to compare the ionospheric response to the storm event at different latitudes and longitudes. Comparison of model results with observational data (Fig. 2) shows good (some time qualitative and some time quantitative) agreement of ionospheric disturbances caused by storm on May 2–3. It is visible that CPCP dependence from IMF changes allows us to reproduce better *foF*2 values and their disturbances. The *foF*2 values obtained with use the empirical model by Zhang and Paxton (2008) are more close to observations then *foF*2 values obtained with use Vorobjov and Yagodkina (2005, 2007) model. However, Vorobjov and Yagodkina (2005, 2007) model allows us to reproduce better *foF*2 disturbances during geomagnetic storm. It is important to note that the most visible disagreement between model and observation are seen above Norilsk station.

Summary

1. In the given research we investigated the influence of the model input parameters (such as cross-polar cap potential, region 2 field-aligned current and high-energy particle precipitation) on ionospheric effects of geomagnetic storm on 2–3 May 2010.
2. Comparison of model calculation results with experimental data for different mid- and low- latitude ionospheric stations reveal the satisfactory qualitative agreement. We concluded that CPCP dependence from IMF changes at self-consistent model runs allows reproducing better *foF*2 values and their disturbances during geomagnetic storm.
3. The reasons of distinctions of calculation results and observations can be idealizing approach in GSM TIP model runs of the geomagnetic field (dipole approach); the absence in model calculations the effects of the changes in B_{YIMF}; the absence of changes of polar cap sizes during geomagnetic storm.

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