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INFLUENCE OF MAGNETOSPHERIC INPUTS DEFINITION ON MODELING OF IONOSPHERIC STORMS

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Abstract. Model calculations of the ionospheric response to the magnetic storm on September 24-27, 1998 have been carried out for a set of ionospheric stations located in the Northern hemisphere. Two methods of magnetospheric inputs definition for simulation of ionospheric storm were used. The first version of calculations was performed on the basis of Magnetogram Inversion Technique (MIT) and the second one was done according to the empirical models of magnetospheric convection and electron precipitation. The results of calculations showed that there is no noticeable advantage among magnetospheric inputs definition methods for mid-latitude stations. For subauroral ionospheric stations the use of magnetospheric inputs obtained by MIT-method leads to less errors than when using empirical models.

Introduction

The numerical simulation of ionospheric storms is one of the most complex problems of ionospheric physics. The main processes governing the mechanism responsible for the formation and evolution of an ionospheric disturbance have been essentially understood to date (Prolls, 1993; Buonsanto, 1999). But the wide variability of ionospheric responses to the storms leads to one of the main difficulties in modeling the real-time spatial distribution of the ionosphere. As a result of the numerous experimental and theoretical investigations, it has been ascertained that the character of the ionospheric response to a particular geomagnetic storm depends quite crucially on the sequence and intensity of the effects of these factors under given geophysical conditions. For that reason, interpretation of observational data on every ionospheric storm is of independent scientific interest and constitutes a rather challenging problem.

Usually for numerical modeling of ionospheric storms corresponding empirical models specify parameters of neutral atmosphere and magnetosphere. Statistical kind of these models renders them impractical for simulation of the individual storm. Furthermore, standard statistical methods become ineffective for describing the distribution of ionospheric parameters because during magnetic storms the quantity of ionospheric data markedly decreases. Therefore one has to correct the empirical models using various additional speculations to simulate the partial ionospheric storms. To remedy this difficulty, the set of global models of the magnetosphere-ionosphere-thermosphere coupling have been developed for over two decades now (Schunk, 1988; Richards and Torr, 1996; Fuller-Rowell et al., 1996; Roble and Ridley, 1994; Sojka et al., 1997).

The influence of the magnetospheric inputs definition such as distributions of electric potential and electron energy fluxes on the results of the ionospheric storm simulations has been investigated in this study.

Experimental evidence and input data

For the solution of the given problem the parameters measurement data of the mid-latitude ionosphere during the major magnetic storm on September, 24-27, 1998 have been considered. In the given work the observation data of hour values of the critical frequency of the F2 layer during the storm under consideration at a number of mid-latitude ionospheric stations located in Europe, Siberia and in the Far East were used. The list of stations is given in Table 1. In addition to the data of vertical-incidence sounding the measurements of ionospheric parameters received on the Irkutsk incoherent scattering radar in the same time period were used. In order to define a realistic picture of the magnetospheric inputs (such as global spatial and temporal variations of the convection electric field and electron precipitation) we used an array of the hourly magnetograms, which are recorded during September 18-27, 1998 from about 70 magnetic stations globally distributed in the northern hemisphere. Based on these data we

Table 1. List and locations of ionospheric stations

Station name	Geographic		Geomagnetic	
	Latitude	Longitude	Latitude	Longitude
Magadan	60.1	151.0	50.8	210.8
Yakutsk	62.0	129.6	51.0	194.1
Tunguska	61.4	90.0	50.8	165.6
Salehard	66.6	66.7	57.6	149.8
Lycksele	64.7	18.8	62.7	111.4
Juliusruh-Rugen	54.6	13.4	54.4	99.1
Chilton	51.5	358.7	51.8	78.8

have calculated global distributions of electric potential, both number and energy fluxes of the precipitating electrons for each hour from September, 18 till September, 27, 1998, using the magnetogram inversion technique (MIT method) developed by Mishin (1990). Some global distributions of the electric potential (corotation is added) and electron energy flux calculated by MIT-method are shown at the bottom of the Fig.1. For comparison at the top of the Fig.1 similar global distributions calculated for the same times, but using empirical models for both convection potential (Sojka et al., 1986) and electron precipitations (Hardy et al., 1987) are presented.

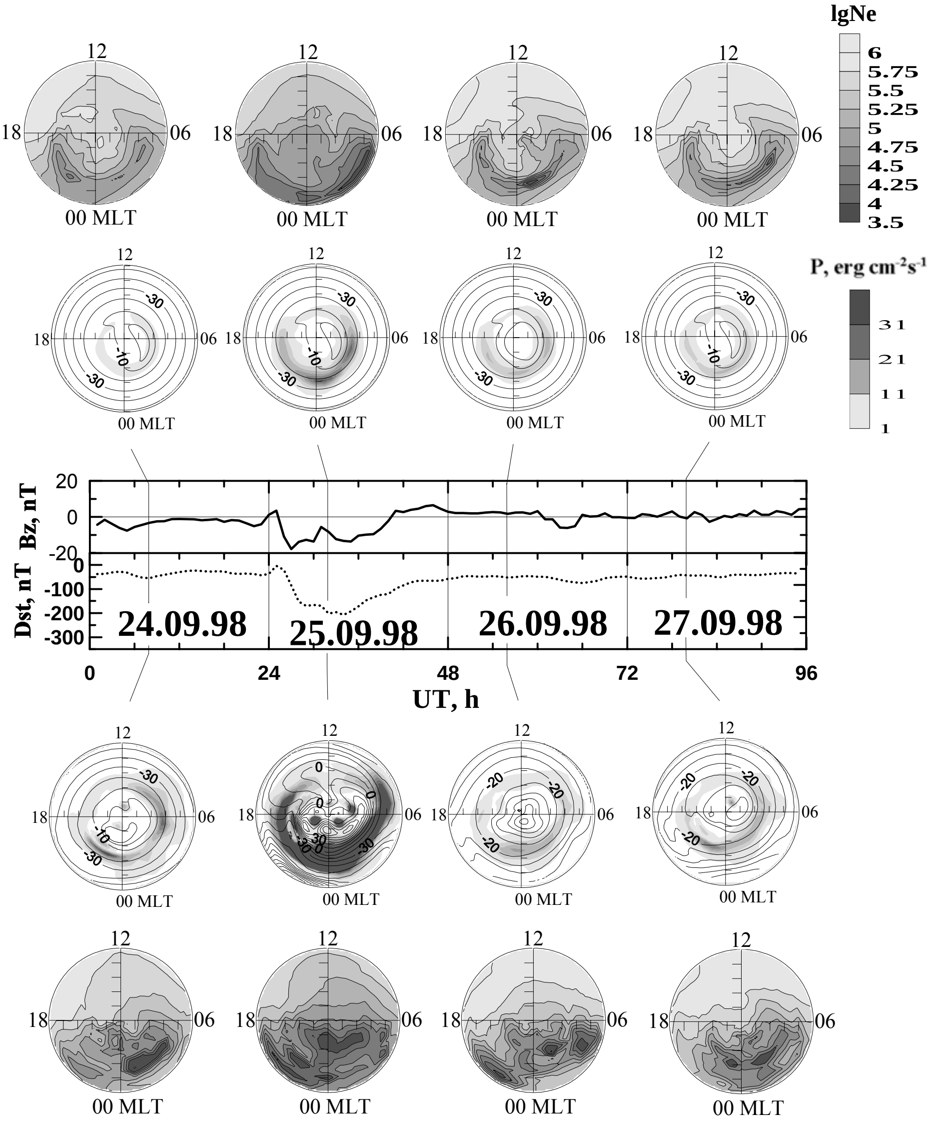

Fig.1. Changes of the Dst index and B_z component of IMF during the storm on September, 24-27, 1998 (the central panel). At the top: distributions of the electric potential (with corotation) and energy flux of the precipitation electrons in coordinates geomagnetic latitude - MLT, obtained according to empirical models for four specified UT moments. At the bottom: the same magnetospheric inputs, but calculated according to MIT - method.

Analysis of the patterns of the magnetospheric inputs obtained according to MIT method and empirical models has revealed the following qualitative distinctions:

1. The electric potential distributions by empirical model have both the dawn cell and weak dusk cell in the course of the storm period. The equatorial boundary of the convection zone therewith locates northward of the geomagnetic latitude of about 60°. It should be noted that practically all statistical models of magnetospheric convection are not applicable under condition of strong disturbances with Kp ≥ 4. The principal differences of electric potential picture calculated by MIT-method consist in much larger expansion of the convection zone towards the equator and in that convection in the polar cap has one-vortex structure and is very irregular.
2. There are considerable differences of global distributions of the electron precipitation energy flux calculated by MIT-method for the main phase of this storm event. During this time interval precipitation zone reached its maximal size in the night and dawn sectors especially.

Discussion of the modeling results

Two versions of a calculation of the ionospheric response to the storm under consideration were realized on the 3-D ionospheric model. In the first version, the variations of magnetospheric inputs were specified according to the empirical models of the convection electric field (Sojka et al., 1986) and electron precipitations (Hardy et al., 1987). In the second version, ionospheric response to this storm has been simulated using MIT data.

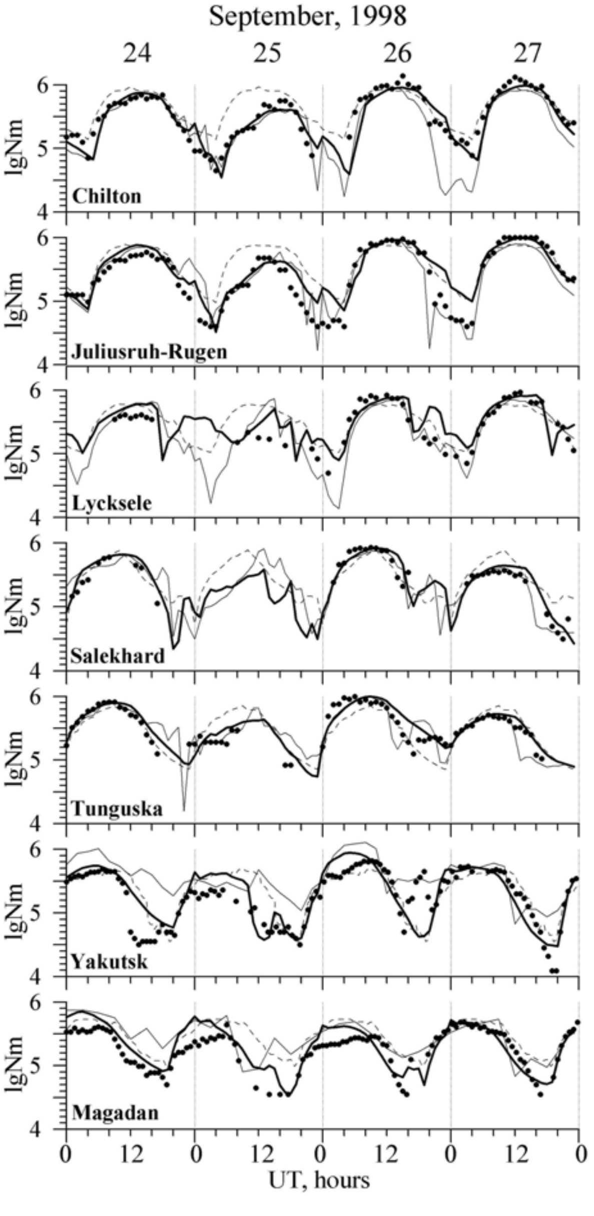

Fig.2. Variations of the measured NmF2 (dotes) and calculated ones using the empirical magnetospheric inputs (heavy line) and according to MIT (thin lines). Dash line is a median for September, 1998.

The used model is based on the numerically solving system of nonstationary balance equations of particles and thermal plasma energy within closed geomagnetic flux tubes whose bases are located at 100 km altitude (Taschchilin and Romanova, 2002a). A global empirical model of the thermosphere MSIS-86 was used for space-time variations in neutral temperature and in densities of the thermospheric constituents, whereas the velocities of the horizontal thermospheric wind were determined in terms of the HWM-90 model.

The simulation results of the ionospheric responses to the magnetic storm under consideration for ionospheric stations listed in the Table 1 are presented in the Fig.2. In the previous paper (Tashchilin et al., 2002b) we have analyzed measured by Irkutsk IS radar variations of the electron density, electron and ion temperatures. It was showed that for achieving the best correspondence between calculated and observed electron density variations near the F2-layer maximum on undisturbed days, the EUV fluxes for all spectral intervals in Richards et al. (1994) were reduced by a factor of 0.75, whereas the neutral composition had to be modified in such a way that the ratio of O/N2 decreased by a factor of 2.5 compared with the MSIS-86 model. These corrections of the EUV radiation and the thermospheric composition were used for simulation with both types of the magnetospheric input. To quantitative analyze the difference between modeling results and measured data the hourly values of the relative error were calculated by the formula

$$\varepsilon_{mit/\mathrm{mod}} = \frac{\left|N_{mit/\mathrm{mod}} - N_{obs}\right|}{N_{obs}},$$

where $N_{mit/\mathrm{mod}}$ are values of NmF2 obtained by MIT-method or with help the empirical models for magnetospheric inputs; N_{obs} is observed value of NmF2. Time average errors $\bar{\varepsilon}_{mit/\mathrm{mod}}$ over a period lasted from September 24 to 27 for the stations under consideration are presented in the Table 2.

It is evident that the most considerable differences is will be for the stations located in the auroral and high latitudes where the roles of convection and electron precipitations are dominant. Salekhard and Lycksele can be considered as those ones. According to the Table 2 the applying of magnetospheric inputs for these stations obtained by MIT-method reveals less error than using empirical models. For other stations located at the mid latitudes none of the methods considered above for magnetospheric inputs definition has noticeable advantage. The reason is that ionosphere over these stations can be effected by electron precipitation and convection only for some hours of the main magnetic storm phase. For the rest time of the storm mid-latitude ionospheric response is controlled mainly by disturbance of thermospheric composition.

Table 2. Time-average errors $\bar{\varepsilon}_{mit/\mathrm{mod}}$

Station name	$\bar{\varepsilon}_{mit}$ (%)	$\bar{\varepsilon}_{\mathrm{mod}}$ (%)
Magadan	108	46
Yakutsk	166	70
Tunguska	35	29
Salekhard	27	29
Lycksele	36	50
Juliusruh-Rugen	48	72
Chilton	39	28

Conclusions

Model calculations of the ionospheric response to the magnetic storm on September 24-27, 1998 have been carried out for a set of ionospheric stations located in the Northern hemisphere. Two methods of magnetospheric inputs definition for simulation of ionospheric storm were used. The first version of calculations was performed on the base of MIT-method and the second one was done according to the empirical models of magnetospheric convection and electron precipitation. The results of calculations showed that there is no noticeable advantage among magnetospheric inputs definition methods for mid-latitude stations. For subauroral ionospheric stations the using of magnetospheric inputs obtained by MIT-method leads to less error than when using empirical models.

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