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Empirical model of the main ionospheric trough for the nighttime winter conditions

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ABSTRACT

For the first time we developed an empirical model of the main ionospheric trough, MIT, for quiet (Kp=2) nighttime (18:00–06:00 LT) winter conditions in the Northern and Southern hemispheres for all levels of solar activity. The model consists of two parts: (1) the MIT position model in terms of geographical latitude and longitude; (2) the MIT shape model in terms of the latitudinal–longitudinal *foF*2 variations in the range of 45–75 °N latitudes in the Northern hemisphere and of 40–80 °S in the Southern hemisphere. Thus, an empirical model of the quiet nighttime subauroral ionosphere has been developed. To construct this model the Interkosmos-19 and CHAMP satellites data have been used. The *in-situ* N_e measurements at the CHAMP heights were transformed to the electron density at *F*2 layer peak height (i.e. to N_mF2 and then to *foF*2). In the frame of the model the diurnal and longitudinal variations in the MIT minimum position were revealed and studied in detail. Also the longitudinal and latitudinal variations in *foF*2 in the MIT region were investigated. Accuracy of the model was tested according to the ground-based ionospheric stations data. It is shown that the constructed model much more adequately reproduces the variations in the winter nighttime subauroral ionospheric structure, including the MIT position and shape variations, than the International Reference Ionosphere model (IRI-2012). The online version of the MIT model is available on the IZMIRAN website: http://www.izmiran.ru/ionosphere/sm-mit/ for free using and more detailed testing.

1. Introduction

The Main Ionospheric Trough, MIT, has been firstly detected from the Alouette I data by Muldrew (1965). The MIT is the main structural feature of the subauroral ionosphere due to its very high level of occurrence probability in winter nighttime conditions: MIT observed in 90–95% of cases at high solar activity; MIT is almost always observed at low solar activity (Karpachev and Afonin, 1988). A construction of the MIT empirical model is an extremely difficult task, because the MIT is very variable structure. Many competing mechanisms are involved in a MIT formation, as a result "studies of the diurnal, seasonal and altitude variation of the trough have led to somewhat confused results" (Ahmed et al., 1979). A lot of works are devoted to the investigations of MIT morphological characteristics and formation causes that are described in the reviews (Ahmed et al., 1979; Moffett and Quegan, 1983; Rodger et al. 1992). The repeated attempts to develop a MIT model have been made by different groups of scientists (Halcrow and Nisbet, 1977; Feichter and Leitinger, 2002; Wielgosz et al., 2004; Pryse et al., 2006). However, each of them is a local empirical model but not a global main ionospheric trough model for all geophysical conditions. In our opinion, there are two main reasons for this. The first one is well known: a lack of data for all longitudes in the Northern and especially in Southern hemisphere. The required data spatial coverage can be obtained only from the satellite observations. The second reason is that in order to develop a MIT model we should be know exactly a MIT position, because owing to the large gradients on the trough equatorial and especially polar wall, the errors in predicting foF2 values can reach an order of a magnitude (Eliseev et al., 1995). The MIT position depends on the local time, longitude, solar and magnetic activity. During strong geomagnetic disturbances the MIT dynamics is extremely complicated (Deminov et al., 1995a, 1995b, 1996a, 1996b; Annakuliev et al., 1993). It is best of all controlled by magnetic activity index DR or modified index Kp* (which takes into account the prehistory). Therefore, a complete MIT model for all levels of

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magnetic activity is not yet on the agenda. But if we deal with long-term quiet geomagnetic conditions ($Kp \leq 3$, average $Kp \sim 2$), we can describe the MIT position by the current magnetic activity index Kp. For the fixed $Kp=2$ we need to determine the dependence of the MIT position on local time, longitude and solar activity. Based on the MIT position we developed the model of the latitudinal cross-sections of *foF*2 for each local time and longitude for winter nighttime conditions. For model development we used topside sounding data obtained onboard the Interkosmos-19 (IK-19) satellite for high solar activity and the CHAMP satellite data for high and low solar activity. The IK-19 topside sounding provides *foF*2 data coverage for all longitudes of mid-latitude and subauroral ionosphere both in the Northern and Southern hemispheres. However the amount of *foF*2 data from the IK-19 topside sounding is not enough for development of high-resolution *foF*2 empirical model in the region of the main ionospheric trough. Therefore IK-19 data were supplemented with CHAMP data for high solar activity. The CHAMP data set is large, but it consists of *in-situ* electron density measurements from the Planar Langmuir Probe at fixed heights that must be transformed to *foF*2. These and other, described below problems, strongly complicated the empirical model development. Nevertheless the task was successfully solved and we constructed: (1) the MIT position model; (2) the MIT shape model, i.e. the model of *foF*2 latitudinal–longitudinal distribution. As a result of the problem solution we developed in fact an empirical model of the winter night-time subauroral ionosphere for all levels of solar activity.

2. Observation data

The use of satellite data allows us to develop the empirical model of the latitudinal and longitudinal *foF*2 variation in the MIT region for both high and low solar activity. The data were collected and then averaged for the periods from November to February in the Northern hemisphere and from May to August in the Southern hemisphere. The IK-19 satellite operated from February 1979 to March 1982 during high solar activity period ($F_{10.7}=170$–230,

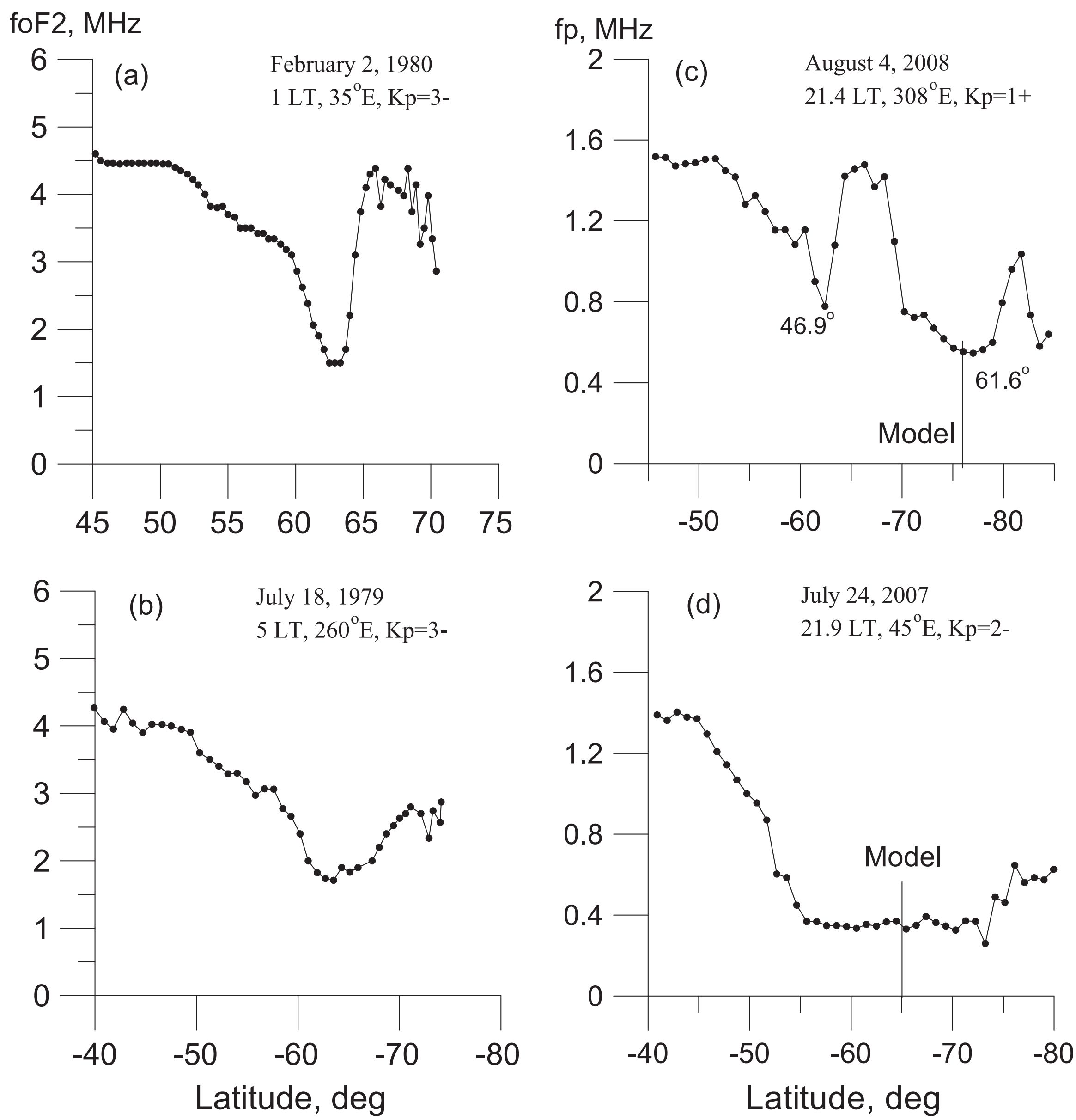

Fig. 1. Examples of the latitudinal variation in *foF*2 according to the IK-19 satellite data (left panel) and in plasma frequency, f_p, at height of ~350 km according to CHAMP satellite measurements (right panel) at high latitudes of the Northern and Southern hemispheres. The vertical lines show the trough minimum model position.