Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 60 (2017) 2437–2451

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Ionospheric parameters as the precursors of disturbed geomagnetic conditions

D.V. Blagoveshchensky [a], M.A. Sergeeva [b,c,*], A. Kozlovsky [d]

[a] Saint-Petersburg State University of Aerospace Instrumentation, 67, Bolshaya Morskaya, Saint-Petersburg 190000, Russia
[b] SCiESMEX, LANCE, Instituto de Geofisica, Unidad Michoacan, Universidad Nacional Autonoma de Mexico, Antigua carretera a Patzcuaro 8701, Morelia, Michoacan C.P. 58089, Mexico
[c] CONACYT, Instituto de Geofisica, Unidad Michoacan, Universidad Nacional Autonoma de Mexico, Antigua carretera a Patzcuaro 8701, Morelia, Michoacan C.P. 58089, Mexico
[d] Sodankylä Geophysical Observatory of the University of Oulu, Tähteläntie 62, FIN-99600 Sodankylä, Finland

Received 20 March 2017; received in revised form 5 September 2017; accepted 9 September 2017
Available online 18 September 2017

Abstract

Geomagnetic storms and substorms are the principal elements of the disturbed Space Weather conditions. The aim of the study was to reveal the ionospheric precursors that can be used to forecast geomagnetic disturbance beginning. To study the ionospheric processes before, during and after magnetic storms and substorms data from Sodankylä Geophysical Observatory was used (geomagnetic coordinates: 64.1°N, 119.2°E). In earlier works the Main Effect (ME) was revealed for substorms. It consists of the following steps: (a) the increase of critical frequency foF2 from its quiet median before and during the substorm growth phase, four-five hours before To moment that is the moment of the expansion phase onset, (b) the foF2 decrease to the level lower than its median just after To and until Te that is the moment of the end of the expansion phase, (c) the issue "a" repeated during the recovery phase (d) two bell-shape spikes in the cutoff frequency values foEs: first spike occurs three hours before To, second spike – during the expansion phase within the interval between To and Te. In the present work it is shown that ME manifestations can be used as precursors of magnetic substorms at high-latitudes (geomagnetic latitudes 50°N–65°N). In particular, the foF2 growth some hours before To can be used as a precursor of substorm development. The first foEs bell-shaped spike also can be used for short-term forecasting, two–three hours in advance of a substorm. Furthermore, the storms between 2008 and 2012 were studied. It was revealed that the similar ME also takes place in the case of magnetic storms but within the different time scale. More specifically, the first ME maximum in foF2 values occurs one-two days before the storm beginning and can be used as its precursor. In addition, the foEs spike takes place approximately ten hours before a storm and also can be used for the prediction of the storm beginning.

Keywords: Main Effect; Ionosphere; Magnetic storm; Magnetic substorm

1. Introduction

The study of the Earth's ionosphere response on the magnetospheric disturbances manifestations such as storms and substorms is one of the key tasks of the scientific problem in Solar-Terrestrial Physics and Space Weather program. Recently these studies have significantly developed. The valuable achievements were reflected in (de Abreu

* Corresponding author at: SCiESMEX, LANCE, Instituto de Geofisica, Unidad Michoacan, Universidad Nacional Autonoma de Mexico, Antigua carretera a Patzcuaro 8701, Morelia, Michoacan C.P. 58089, Mexico.
E-mail address: maria.a.sergeeva@gmail.com (M.A. Sergeeva).

https://doi.org/10.1016/j.asr.2017.09.013
0273-1177/

et al., 2014, 2017; Blanch and Altadill, 2012; Ban et al., 2011; Zolotukhina et al., 2011; Buonsanto, 1999; Danilov and Laštovička, 2002; Danilov, 2013; Fox et al., 1998; Gonzalez et al., 1994; Goncharenko et al., 2007; Jakowski et al., 1999; Jin et al., 2008; Laštovička, 2002; Ma et al., 2002; Prölss, 1993; Szuszczewicz et al., 1998; Yeh et al., 1994) as well as in other works. In the majority of works mentioned above the emphasis was put on the physical mechanisms of the processes in the ionosphere during magnetospheric perturbations. In the reviews (Buonsanto, 1999; Gonzalez et al., 1994; Danilov and Laštovička, 2002) the physical mechanisms of the ionospheric processes were analyzed during the periods of magnetospheric disturbances. Though there are many of studies performed, the question about what specific ionospheric parameters variations observed before the disturbances and can be used to predict the beginning of these disturbances remains open. This problem was addressed in some works, for instance in (Liu et al., 2008; Blagoveshchensky and Kalishin, 2009; Mandrikova et al., 2015), but still the task of predictions at high latitudes is far from being completely solved and still is of great practical interest.

Earlier, in (Blagoveshchensky et al., 2003) the question of the ionosphere response on the magnetospheric substorms was studied comprehensively based on data obtained from the Sodankylä Geophysical Observatory (SGO), Finland (lat 67° 22′N, lon 26° 38′E). 41 isolated substorms from the interval of 1998–1999 were chosen for the analysis. The characteristic pattern of variations of the critical frequency of the ionosphere foF2 during substorms was revealed. This pattern was called the Main Effect (ME) in the ionosphere during magnetospheric substorm. The focus at issue is as follows.

There is an increase of foF2 values from its quiet median 6–8 h before To that is the moment of the expansion phase onset. Further, foF2 values reach their maximum two–three hours before the To. After that a sharp decrease occurs to the level lower than the quiet level and then the growth of values is observed during the expansion phase. The second maximum of values takes place one-two hours after Te that is the moment of the end of the expansion phase. Then the decrease of foF2 values to the quiet level occur again during three-four hours after the second maximum. The presence of the first foF2 maximum before To is an important factor from the point of view of forecasting of the beginning of substorms disturbances. The present work is focused on the study of effects of foF2 variations using SGO data during the interval of 2008–2012 (minimax) not during substorms as before, but during magnetic storms. The objective was to reveal the storms precursors, analogous to those that were revealed for substorms.

In addition, the behaviour of the sporadic layers in the E-region of the ionosphere was studied during storms and substorms. It is known, that for high-latitudes the sporadic layers Es occurrence is quite characteristic, especially during the night hours of winter periods. A number of works, for example, (Hunsucker and Hargreaves, 2003; Hunsucker et al., 1996; Razuvaev, 1991; Pirog et al., 2000; Rodger et al., 1983) were dedicated to the studies of sporadic Es-layers. These works studied the wide scope of questions from the morphologic picture of sporadic layers formation, their structure and main parameters to the statistical features of their occurrence under different conditions. However, there are still few results obtained for the periods of magnetic disturbances and, consequently, there are still pending issues on this matter. Such issues include, for example, revealing the particular features in the change of the cutoff frequency values, foEs, before the beginning of Space Weather disturbances – an issue that is touched on in this study.

The relevancy of the mentioned tasks and of the corresponding analysis is explained by the lack of statistical and physical data about the character of variations of the high-latitude ionosphere during magnetic disturbances that occur quite often. The main aim of the present study is to learn how the ionosphere parameters proceed before the disturbances (find precursors) to use the regularities in their behaviour to predict the beginning of Space Weather disturbances. In total, in the present work we considered: (a) 88 storms between 2008 and 2012; (b) 31 substorms between 1992 and 1997 and 41 substorms analysed in (Blagoveshchensky et al., 2003) between 1998 and 1999.

Previous results (Blagoveshchensky et al., 2003) concerned mostly substorms. This work gives a review of the previous results and contains new ideas that are as follows. (1) It was of interest to confirm the ME presence for storm events. (2) Another task was to compare ME manifestations for storms and substorms to reveal its specific features for each type of event. (3) Third task was to provide particular recommendations as to how the revealed effect can be used to predict the disturbances onset.

It is worth mentioning that ionospheric disturbances during storms and substorms that occur in high latitude ionosphere can move towards the equator, but in most cases loose their intensity with latitude being more pronounced at high latitudes. This is why it seemed useful to perform the analysis of data from high latitudes as it was done before.

As we address geomagnetic storms in this study, we briefly note that these are the periods of specific fluctuations in the Earth's magnetic field (mostly in the appearance of its H-component) that follow three phases: initial (not always), main and recovery (Campbell, 1997; Gonzalez et al., 1994). The main geomagnetic indices (Dst, Kp, AE) obtained from different sets of observatories serve to describe the magnetic activity (H-component field depression) worldwide. The main purpose of these indices is to quantify the intensity of geomagnetic perturbation (Hunsucker and Hargreaves, 2003). Storms are classified according to Dst values into weak, moderate and intense storms (Gonzalez et al., 1994). In this study Dst values are provided for the considered storm examples in order to illustrate perturbation on a global scale. At the same