Investigation of Large-Scale Wave-Like Ionospheric Disturbances over Siberian Region of Russia Using Oblique-Incidence Sounding Data

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Abstract

In this paper we study morphological peculiarities of wave-like ionospheric disturbances with period 1-2 hours and spatial dimentions more than 1000 kilometers. We use oblique-incidence ionospheric sounding data obtained over Siberian region of Russia during several monthly duration experiments in 2006-2010 years. Large-scale travelling ionospheric disturbances recorded in geomagnetically disturbed and geomagnetically quiet conditions over East Siberian region of Russia are investigated. The connection between large-scale travelling ionospheric disturbances and small-scale ionospheric structures is mentioned.

1. Introduction

During decades one of the most effective tools for investigation of ionospheric electron density was vertical sounding using high-frequency radio waves. However, in regions poorly equipped by vertical sounding stations, it is reasonable to conduct oblique-incidence sounding (OIS) experiments, connecting variations of maximum observed frequencies (MOF) for the first hop with changes of critical frequencies near the middle point of the path. Such approach can be efficient for investigation of the ionosphere over the regions which is difficult of access on the continents, and over the seas and oceans.

Large-scale travelling ionospheric disturbances (LS TID), caused by acoustic-gravity waves in the thermosphere of the Earth, have been investigated repeatedly [1,2]. At the Institute of Solar-Terrestrial Physics SB RAS the height structure of TID characteristics was studied on the base of the electron density profiles measured by two beams of the incoherent scatter radar and DPS-4 ionosonde. The height profiles of the TID propagation characteristics were obtained by means of cross-correlation and spectrum analysis of the radar and ionosonde data. The noticeable height variability of the TID parameters is observed [3].

Ionospheric response to geomagnetic disturbances was studied for the north-eastern region of Asia during the minimum of 23rd cycle of solar activity [4]. In works [5,6] variations of high frequency radiowave propagation characteristics recorded over mid-latitude paths in the Russian East-Siberian region during magnetic storms on May 15, 1997, and September 24, 2006, was studied. The sharp wave-like changes in maximum observed frequencies were recorded during the main phase of the investigated storms. Assuming that observed MOF variations can be produced by ionospheric disturbances propagating from the northern to the southern latitudes, a simulation of HF propagation conditions was carried out. According to modelling calculations, foF2 wave-like variations at the midpoint of the path were about 1.2 MHz with a period of wave disturbance of about 2 hours. Wave-disturbance parameters obtained as a result of the critical frequencies correction over the propagation paths agreed with commonly accepted estimations for the velocity and time characteristics of ionospheric wave disturbances.

In work [7] the analysis of oblique-incidence sounding data set was presented. Oblique sounding paths have been operated between New Zealand and Australia since 2002 covering a range of the solar cycle. MOF variations was interpreted in terms of transient upper atmosphere and geomagnetic effects. During solar minimum 2007-2009 the relatively quiet geomagnetic conditions revealed a range of atmospheric driven disturbances.

In this work, we investigate F2 ionospheric region wave-like disturbances for geomagnetically disturbed conditions and for geomagnetically quiet days over several paths of oblique-incidence sounding in the East Siberian region of Russian Federation.

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2. Experimental Data Analysis

Since 2005 at the Department of Near-Earth Space Physics of Institute of Solar-Terrestrial Physics SB RAS sets of monthly duration experiments over oblique-incidence sounding paths have been carried out. These measurements provide a more detailed information about MOF variations and consequently electron density changes near the middle point of each investigated path. For our analysis series of observations from 2006 till 2010 were chosen**.** We investigate three oblique-incidence paths: Magadan – Tory, Norilsk – Tory and Khabarovsk - Tory (Fig. 1). Magadan coordinates are 60° N, 150.7° E, Norilsk coordinates are 69.2° N, 88° E, Khabarovsk coordinates are 48.5° N, 135.1° E, Tory coordinates are 51.8° N, 103° E. Intervals between soundings varied from 4 to 5 minutes. Norilsk – Tory path is oriented meridionally, Magadan – Tory path has meridional-latitudinal orientation, Khabarovsk – Tory path has latitudinal orientation. Measurements over Khabarovsk – Tory path have been carried out since September, 2009. In this paper we study variations of maximum observed frequencies obtained over OIS paths by one-hop reflections from F2-region of the ionosphere (MOF1F2).

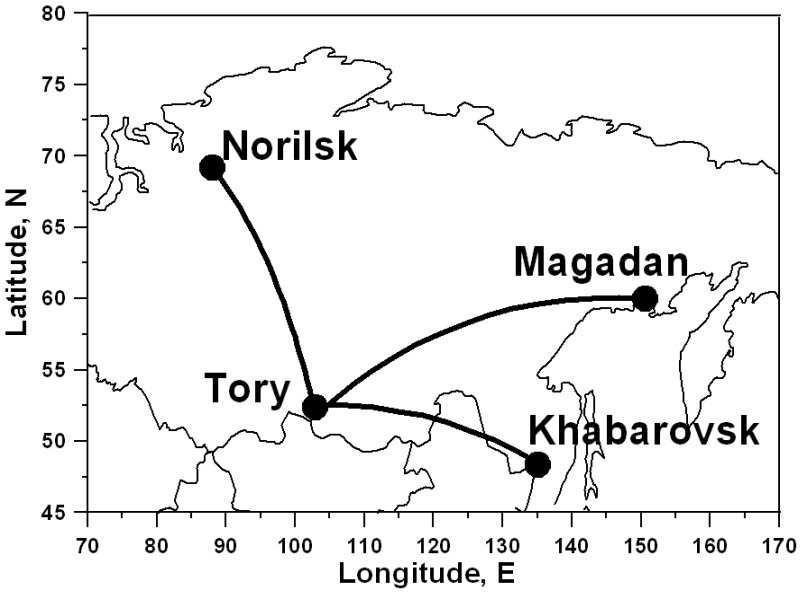

Figure 1. Map showing investigated oblique-incidence paths.

Figure 2 shows MOF1F2 percent deviations from median values for several days, when wave-like ionospheric disturbances were registered. Solid lines are corresponded to MOF1F2 percent deviations of Magadan – Tory path, stroked lines are corresponded to MOF1F2 percent deviations of Norilsk – Tory path, cross signs are corresponded to MOF1F2 percent deviations of Khabarovsk – Tory path. In Table 1 summary values of Kp-index for analyzed days are shown. In according to these data, March 16, 2006, March 12, 2007, March 25, 2007, September 29, 2009, February 7, 2010, and March 20, 2010, were geomagnetically quiet days. In these days large-scale wave-like ionospheric disturbances with periods of 1-2 hours and MOF1F2 relative deviations of 10-30% were registered over Magadan – Tory and Khabarovsk – Tory paths. Wave-like ionospheric disturbance over Norilsk – Tory path was observed on March 25, 2007. The parameters of this disturbance coincide with parameters of LS TID observed at this day over Magadan – Tory path.

Table 1. Summary values of Kp-index for analyzed days.

Date	**16.03.2006**	**12.03.2007**	**24.03.2007**	**25.03.2007**	**23.09.2007**	**29.09.2009**	**07.02.2010**	**20.03.2010**
ΣKp	15	8+	24	17	23-	2-	6	13

Let consider large-scale travelling ionospheric disturbances registered during geomagnetic disturbances. A magnetic storm was observed on March 23-24, 2007. Main phase of the magnetic storm started at 13 UT on March 23, 2007. Minimum value of Dst-index reached -71 nT at 08 UT on March 24, 2007. Kp-index from 03 to 05 UT reached 5- value on March 24, 2007. Negative wave-like disturbance of F2 ionospheric region was registered on March 24, 2007, over Magadan-Tory path. According to OIS data it began at 00:30 UT. Period of this wave-like disturbance was 1.5-2 hours, MOF1F2 relative deviations reached -19% at 03:00 UT.

September 23, 2007, was moderate geomagnetically disturbed day. At 05 UT Dst-index minimum value of -22 nT was registered. Kp-index from 03 to 05 UT was 4+. Maximum MOF1F2 relative deviation from median values over Magadan – Tory path reached 11% at 4:36 UT, 22.3% at 7:56 UT and 23% at 10:11 UT.

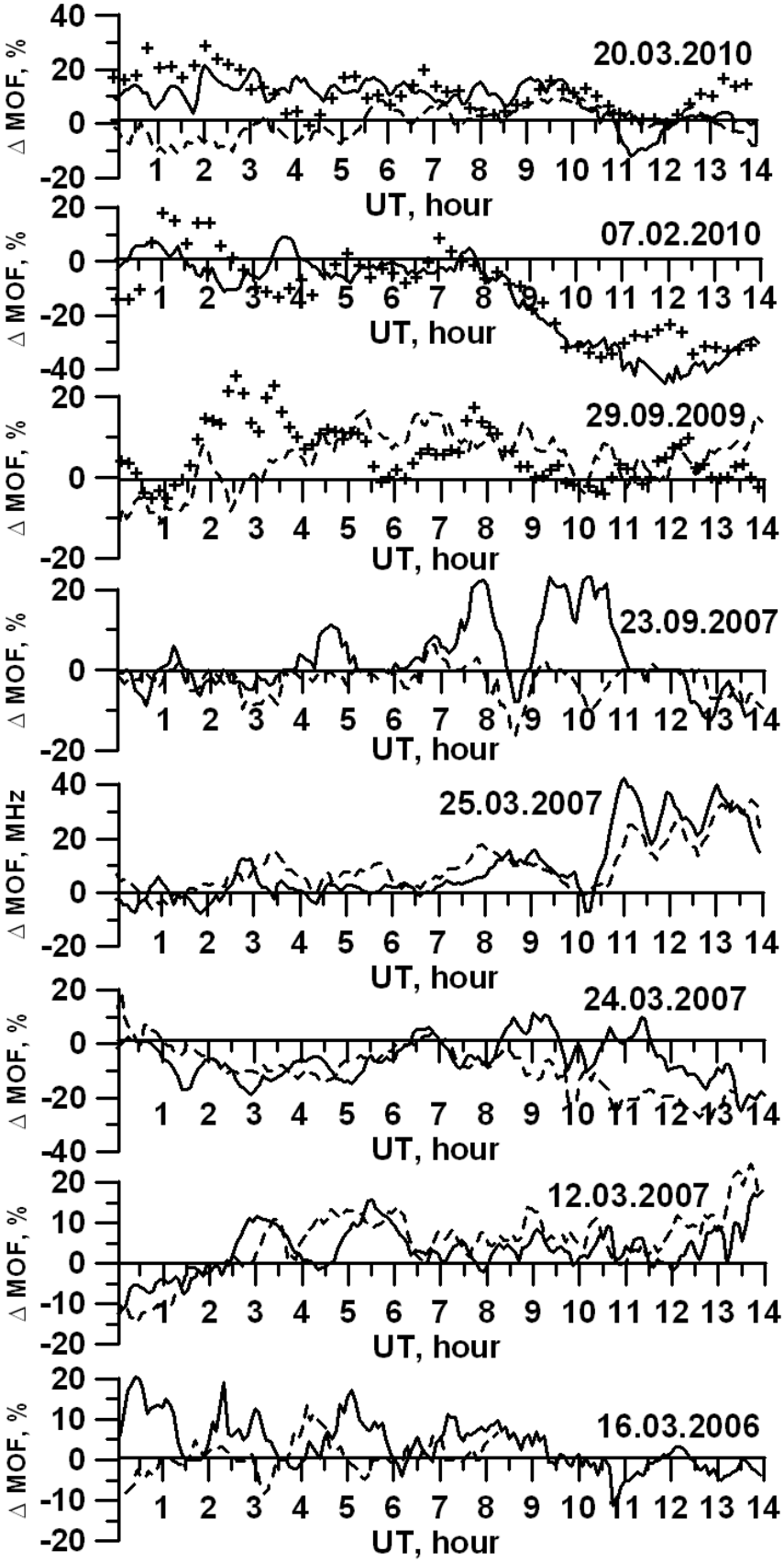

Figure 2. Maximum observed frequencies percent deviations from median values for Magadan – Tory (solid lines), Norilsk – Tory (stroked lines) and Khabarovsk – Tory (crosses) paths.

Changes of large-scale structure of F2-region were supported by small-scale travelling ionospheric disturbances. Ionograms in Figure 3 show examples of this phenomenon.

Small-scale travelling ionospheric disturbances were observed during all investigated large-scale wave-like ionospheric disturbances. But we can not definitely connect appearance of large-scale and small-scale TIDs as the small-scale TIDs are also observed then large-scale travelling ionospheric disturbances are not registered. More detailed study of this problem deviates from the theme. It will be an object for our future investigations.

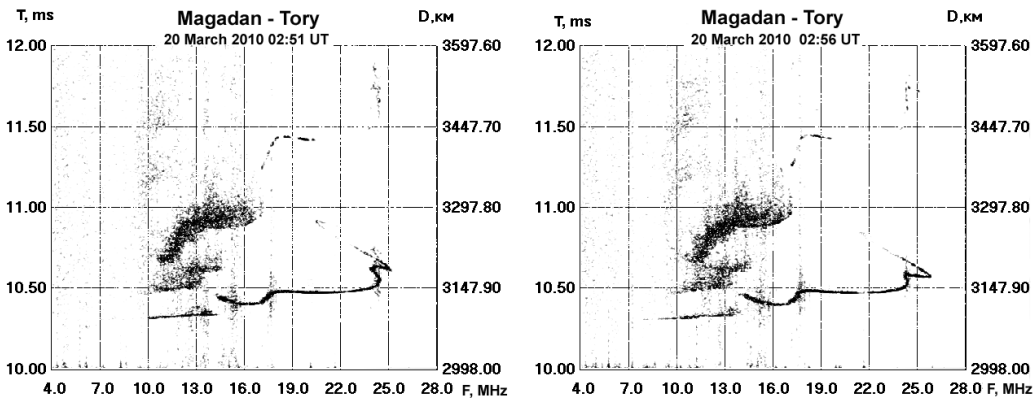

Figure 3. Ionograms obtained over Magadan – Tory path on March 20, 2010.

3. Conclusion

Using experimental data obtained over oblique-incidence paths wave-like variations of maximum observed frequencies were registered. These MOF variations are connected with changes of critical frequencies of F2-region. Three oblique-incidence paths located over Siberian region of Russia have been considered. It was determined that large-scale wave-like ionospheric disturbances is more often observed over paths with meridional-latitudinal and latitudinal orientations. Such large-scale travelling ionospheric disturbances are registered as during geomagnetic storms as at the geomagnetically quiet days. Large-scale travelling ionospheric disturbances were accompanied by small-scale ionospheric structures.

4. Acknowledgment

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