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GEOMAGNETIC DISTURBANCES AT F1-LAYER HEIGHTS UNDER DIFFERENT SOLAR ACTIVITY CONDITIONS OVER NORILSK

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Abstract. We analyze the influence of geomagnetic disturbances on the electron density N_e at Norilsk ionospheric station (69° N; 88° E) at F1-layer heights (120–200 km). For the analysis, we have selected 25 moderate and weak geomagnetic disturbances for two seasons — spring and fall — of 2003–2014. Using the N_e values obtained from measurements made with the Norilsk digisonde during this period, we analyze N_e variations during geomagnetic disturbances in spring and fall for a long period of time. We determine the effect of spring-fall asymmetry occurring in all solar activity phases and manifesting itself in a significant decrease in the electron density during the main phase of fall storms at all heights in comparison with quiet days: up to 2.6 times at a height of 200 km and slightly less at lower heights. This phenomenon is not observed during spring disturbances: Ne variations are much weaker.

Keywords: geomagnetic disturbances, electron density, spring-fall asymmetry.

INTRODUCTION

The main cause of electron density variations during geomagnetic disturbances is known to be a change in the neutral composition of the thermosphere. Each ionospheric region has its unique structural features and different neutral composition and therefore responds to disturbances generated by geomagnetic storms on its own way.

Effects of geomagnetic storms at F1-layer heights have little been studied until recently. As derived from [Kushnarenko et al., 2012, 2013; Buresova, Lastoviska, 2001; Buresova et al., 2002; Mikhailov, 2008], manifestations of the disturbances in the lower part of the F layer are complex and ambiguous, and responses to geomagnetic disturbances at heights 120–200 km are much less studied than those in the F2 layer. During low solar activity, effects of the disturbances have been found to manifest themselves only slightly at a height below 170 km. Regular measurements with digital ionosondes at the ionospheric stations Irkutsk and Norilsk and accumulation of electron density data provided the opportunity to examine the effects of geomagnetic disturbances on N_e at F1-layer heights (120–200 km) under different solar activity conditions in 2003–2014.

Kushnarenko et al. [2018] have analyzed N_e variations during geomagnetic disturbances at F1-layer heights in 2003–2014, using data from the digital ionospheric station Irkutsk (52° N, 104° F). They have found the spring-fall asymmetry of geomagnetic storm effects at these heights.

In this paper, we continue studying the ionization response at these heights to geomagnetic storms at the high-latitude station Norilsk under different solar activity conditions in 2003–2014.

DATA

We have examined the electron density response at F1-layer heights (120–200 km) in the vicinity of Norilsk to geomagnetic disturbances during two seasons — spring and fall. To do this, we have used the N_e values obtained from measurements made with a digisonde (69° N, 88° E) at Norilsk station in 2003–2014. We have identified and analyzed 25 moderate and weak geomagnetic storms of the period under study. Characteristics of these disturbances are given in Table 1. From all the studied disturbances (25 events) as a vivid example we have chosen storms for three periods corresponding to different solar activity phases (Table 2): decrease (2003), minimum (2008), and maximum (2014).

When processing the N_e data array, we came up against numerous gaps and lack of data even for weak geomagnetic disturbances. The impact of severe storms on ionization at F1-layer heights is very difficult to trace because there are no data for these heights owing to absorption effects in the lower ionospheric layers.

SPRING-FALL ASYMMETRY OF GEOMAGNETIC DISTURBANCES

Figure 1 shows N_e variations for Norilsk station in spring for the three selected periods corresponding to different solar activity phases: decrease (2003), minimum (2008), and maximum (2014). On the left are N_e variations at 150, 180, 190, and 200 km during the maximum development of three spring storms; on the right are N_e variations at the same heights on quiet days corresponding to each storm.

At F1-layer heights there are no marked effects of spring geomagnetic storms on electron density. Note that at 12 LT N_e decreased on average 1.6 times at 190

Table 1

Geomagnetic disturbances under study

Quiet days	Day of the storm onset	Indices (A_p, *Dst*)	Storm maximum (date and UT)
October 10–12, 2003	October 14, 2003	A_p=66, *Dst*=–85	October 14 at 23:00
April 18–20, 2003	April 30, 2003	A_p=45, *Dst*=–67	April 30 at 03:00
May 04, 2003	April 23, 2003	A_p=27, *Dst*=–39	April 23 at 06:00
March 06–08, 2004	March 10, 2004	A_p=94, *Dst*=–105	March 10 at 08:00
September 12, 2004	September 14, 2004	A_p=56, *Dst*=–50	September 14 at 19:00
April 28, 2005	May 01, 2005	A_p=39, *Dst*=–47	May 01 at 04:00
April 02, 2005	April 04, 2005	A_p=80, *Dst*=–55	April 04 at 23:00
August 30, 2005	September 01, 2005	A_p=67, *Dst*=–80	September 01 at 24:00
April 12, 2006	April 14, .2006	A_p=80, *Dst*=–111	April 14 at 10:00
March 05, 2006	March 10, 2006	A_p=39, *Dst*=–37	March 10 at 23:00
October 12, 2006	October 13, 2006	A_p=56, *Dst*=–49	October 13 at 23:00
March 06, 2008	March 09, 2008	A_p=67, *Dst*=–72	March 09 at 05:00
October 26, 2008	October 29, 2008	A_p=32, *Dst*=–24	October 29 at 08:00
April 10, 2010	April 06, 2010	A_p=56, *Dst*=–59	April 06 at 11:00
October 01, 2010	September 24, 2010	A_p=27, *Dst*=–30	September 24 at 17:00
October 29, 2010	October 23, 2010	A_p=48, *Dst*=–35	October 23 at 14:00
October 01, 2010	September 24, 2010	A_p=27, *Dst*=–26	September 24 at 17:00
April 04, 2012	April 05, 2012	A_p=27, *Dst*=–54	April 05 at 10:00
September 10, 2012	September 04, 2012	A_p=32, *Dst*=–63	September 04 at 08:00
September 15, 2013	September 13, 2013	A_p=22, *Dst*=–7	September 13 at 17:00
September 29, 013	September 24, 2013	A_p=32, *Dst*=–24	September 24 at 14:00
March 06, 2013	March 02, 2013	A_p=27, *Dst*=–16	March 02 at 02:00
April 18, 2014	April 20, 2014	A_p=48, *Dst*=–28	April 20 at 14:00
March 11, 2014	March 13, 2014	A_p=27, *Dst*=–29	March 13 at 02:00
August 26, 2014	August 29, 2014	A_p=27, *Dst*=–33	August 29 at 11:00

The A_p, *F*10.7, and *Dst* indices were taken from the WDC-C2 database in Kyoto [http://wdc.kugi.kyoto-u.ac.jp].

Table 2

Annual average *F*10.7 in 2003–2014

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
*F*10.7	128	106	98	80	74	69	71	80	113	120	123	146

and 200 km for all the three storms and changed 1.1–1.4 times at lower F1-layer heights (150 km). Such N_e behavior is observed in almost all spring storms considered.

N_e variations during fall geomagnetic disturbances differ significantly from spring ones. The electron density decreases considerably at all heights during storm main phase (Figure 2). The fall effect involves a decrease in N_e 2–2.6 times at 200 km and a marked decrease — 1.4–1.8 and 1.5 times — at 180 and 150 km respectively. Such variations are typical for almost all fall storms.

The observed spring-fall asymmetry of geomagnetic storms may be connected with seasonal variations in the height of the region in which atomic ions predominate over molecular ions [Buresova, Lastovicka, 2001]. This leads to a change in the height of the F1-layer maximum. During the disturbances, the electron density at F1-layer heights is affected by changes in the neutral atmosphere composition and ionization rate as well as photochemical processes.

The effect of photochemical processes when F1 layer is lowering becomes predominant in denser atmospheric layers due to shorter lifetime of free electrons.

Another possible cause of the observed asymmetry is deeper penetration of the disturbances from auroral regions into lower latitudes in fall seasons. In the disturbed region, as derived from satellite measurements [Goncharenko et al., 2006], the proportion of the neutral component of the thermosphere rises, which entails a change in the ionic composition at F1-layer heights and a decrease in the electron density at the heights considered.

CONCLUSIONS

Near Norilsk, the effects of geomagnetic storms on the electron density exhibit spring-fall asymmetry at F1-layer heights, which manifests itself in all solar activity periods of 2003–2014.

During fall geomagnetic disturbances, the electron density decreases markedly (to 2.6 times) at 190 and 200 km; the effect is weaker at lower heights. On the contrary, spring storms feature a slight decrease in N_e at

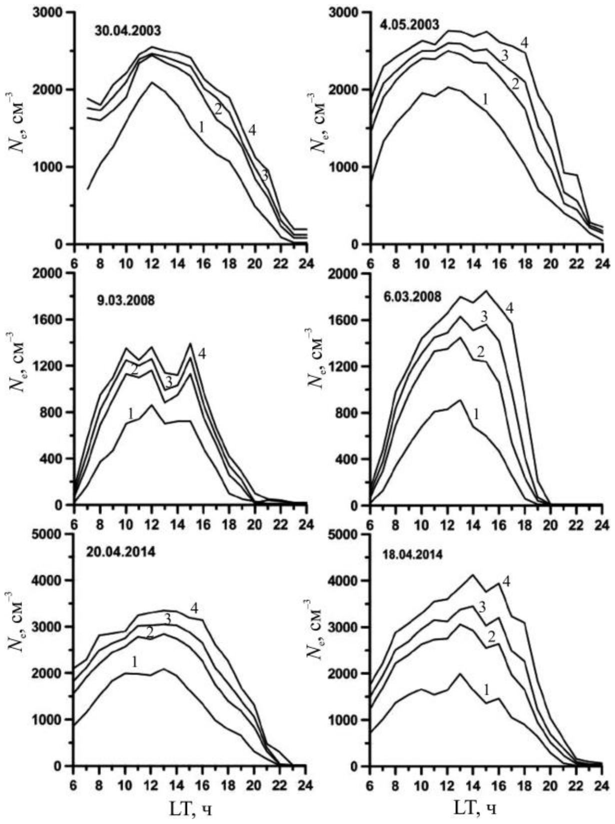

Figure 1. N_e behavior during the maximum development of three spring storms (left panel) and on quiet days corresponding to these storms (right panel) at 150 km (1) , 180 km (2), 190 km (3), 200 km (4)

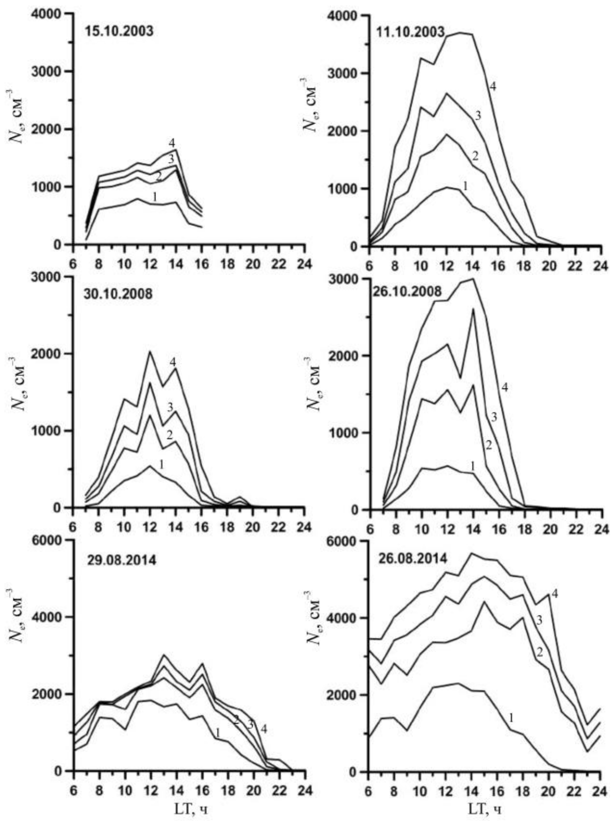

Figure 2. The same as in Figure 1 for the fall period: 150 km (1) , 180 km (2), 190 km (3), 200 km (4)

150–200 km in comparison with quiet conditions.

The electron density in all the periods of disturbances considered always decreases at the F1-layer heights.

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