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THE SOLAR WIND MAGNETIC CLOUD OF OCTOBER 18-20, 1995: EFFECT ON IONOSPHERE OF THE RUSSIAN ASIAN REGION

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ABSTRACT

Based on data from a chain of ionospheric stations we investigate the response of ionospheric parameters to the magnetic storm of October, 18-23, 1995. During this storm an abrupt decrease in critical frequencies to 35-45% in the F-region in the daytime hours and intense sporadic E-layers of the auroral type at night were recorded by the entire chain of stations. The analysis of experimental data suggests that the trough boundaries are displaced as far as 41° magnetic latitude.

INTRODUCTION

This paper present observations and analyses of the response of the ionosphere over the Russian Asian region to a major interplanetary magnetic cloud, observed during 18-20, 1995 (Lepping et al., 1997). The prolonged southward magnetic field observed in the early part of the cloud produced a geomagnetic storm of *Kp*, equal 7. In recent years much attention has been given to the study of magnetosphere-ionosphere coupling during the strongest ionospheric disturbances based on coordinated measurements using ground-based and satellite-borne instruments (Buonsanto et al., 1992; Ma et al., 1995). The diversity of ionospheric disturbances is associated with different mechanisms for transferring the energy of high speed solar wind streams through the magnetosphere to the ionosphere. The principal mechanisms are: the drift of ionospheric plasma associated with an enhancement of electric fields on the magnetospheric boundary; a change in the dynamic regime of the atmosphere due to Joule heating in the case of the dissipation of auroral currents; and variations in neutral composition of the upper atmosphere as a consequence of its heating during the dissipation of auroral currents and of the equatorial ringcurrent.

It is commonly accepted that the main reason for disturbances is the variation in global thermospheric circulation which is caused by the heating of the high-latitude atmosphere during magnetic storms (Matuura, 1972; Prolss et al., 1991).The negative phase is associated largely with changes in neutral composition of the upper atmosphere. As a consequence of a significant heating of the atmosphere in the storm main phase the F-region becomes enriched with molecular species (O_2 and N_2), which leads to an increase in recombination rate and hence to a decrease in electron density (Forbes, 1989). The analysis of the strongest ionospheric disturbances that occurred in March and October, 1989 (Ma et al., 1995) showed that an abrupt decrease in electron density in the daytime is difficult to explain by a variation in neutral composition alone; a significant role must be played by electric fields.

SOLAR AND GEOPHYSICAL CONDITIONS

In this paper we study ionograms from a chain of ionospheric stations from 17 to 23 October, 1995 (solar minimum). On October, 20 a class M1.5/SF proton flare occurred. The magnetic storm onset occurred after a sharp change in solar wind flux density and a change in sign of the interplanetary magnetic field.

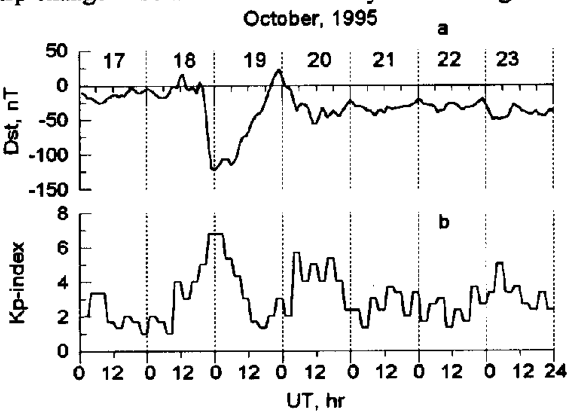

Fig.1 The 3-hour Kp and D_{st}-variation during October, 17-23, 1995.

It commenced on October 18, at 11:21 UT and lasted for about two days. The time history of the D_{st}-variations and planetary magnetic index Kp are shown in Figure 1 a, b. Two magnetic storms occurred during 18-23 October, one major and one moderate, athough in the subsequent days the magnetic field was also disturbed.

EXPERIMENTAL DATA

The quarter-hourly ionograms from a chain of ionospheric stations were used in this study. Their geographical and geomagnetic locations are listed in Table 1. The locations of the stations is such that they encompass the region of high, subauroral and middle latitudes. This provides the means to trace the character of the development of disturbances from polar to middle latitudes.

Table 1. List of stations from which ionospheric data were used in this study

Code and station name	Geographic coordinates, Latitude	Longitude	Geomagnetic coordinates, Latitude	Longitude
NO Norilsk	69.4	88.1	58.5	165.1
SD Salekhard	66.5	66.7	57.3	149.3
YA Yakutsk	62.0	129.9	51.0	194.1
TZ Podkamennaya	61.6	90.0	50.7	164.7
MG Magadan	60.1	151.0	50.1	210.7
IR Irkutsk	52.5	104,0	41.1	174.9

Fig. 2 presents diurnal variations of critical frequencies f_oF2 and E_s-layer limiting frequencies f_oE_s for all the stations during the storm. Under quiet geomagnetic conditions, daytime critical frequencies for all stations were about 6-7.5 MHz; sometimes the F1-layer, with 3-4 MHz frequencies, was observed in some hours. In the night hours f_oF2 did not exceed 4 MHz. For high latitude stations the critical frequencies show characteristic behaviour. Depending on magnetic activity and latitude, these stations are in the region of the main ionospheric trough (MIT) or in the zone of precipitating auroral particles in the evening and night hours. After 14:00 UT, blanketing sporadic E-layers of the auroral type are recorded over Salekhard, Norilsk and Yakutsk. Over Podkamennaya in the evening hours the F2-layer critical frequency decreases slowly, and at night it becomes smaller than the lower frequency limit of the ionosonde, equal to 1 MHz ("E-condition"). Over Magadan, the night-time ionization is sustained at the level of 1-1.5 MHz. On October, 18 the commencement of the ionospheric disturbance is defined by the breakdown of the diurnal variation of f_oF2 immediately after 13:00 UT and by the appearance of blanketing E-layers with limiting frequencies over 6 MHz over Salekhard and Norilsk, the appearance of anomalous reflections in the F-region and intense E_s over Yakutsk, a decrease in electron density in the F2-layer, and by the appearance of E_s over the other stations. The subsequent development of the storm led to a total absorption of F2-layer frequencies over Salekhard and Norilsk ("B-condition"). The other stations observed a decrease in F2-layer critical frequencies by 2 -3.5 MHz, which makes up 35-45% of the undisturbed level in the daytime. Besides intense sporadic E-layers were recorded at night. The analysis of the ionograms from the Irkutsk station showed that on October, 19, in the daytime the F2-layer electron density was decreasing to become smaller than that in the F1-layer ("G-condition").

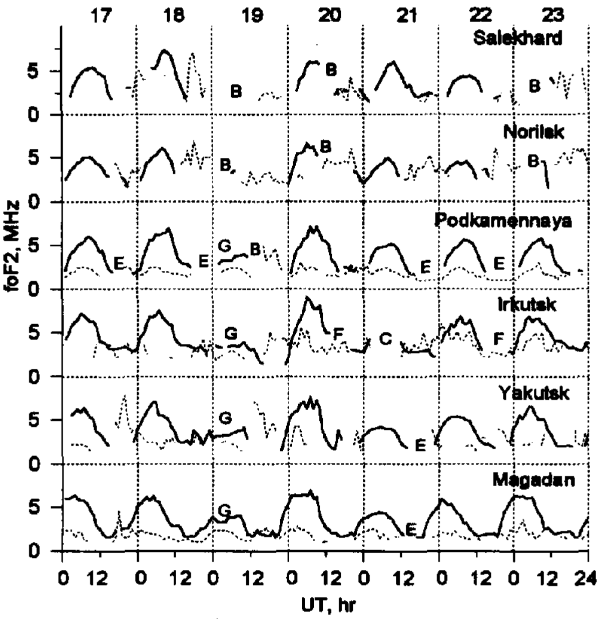

Fig.2. The variations of f_oF2 (solid line) and f_oE_s (dashed line) during October, 17-23, 1995.

Separations into sublayers were also observed in the lower part of ionosphere. In the evening and night hours, ionogram traces had the shape characteristic of the stations located in the main ionospheric trough. From 14 to 22 UT, powerful sporadic layers, usually observed during auroras, were recorded in the E-region. On October, 20, reflections from the regular E-, F1- and F2-layers were observed over Salekhard and Norilsk in the morning and daytime hours, but after 11 UT (17 LT) only reflections from sporadic E-layers with limiting frequencies of 4-6 MHz were recorded. Such a regularity continued till the end of the period under consideration. On October 20, the stations farther to the south observed an increase in F-region electron density in the morning and daytime hours by 10-15%, on the average. On October, 21 there was a further decrease, albeit not so significant as that on October, 19.

Fig. 3 presents diurnal variations in the maximum height and in critical frequencies of the F-layer under disturbed conditions, Δh_{max} and Δf_oF2, for the Magadan and Irkutsk stations. One can see that the decrease in F-region critical frequencies on October,18-19 was accompanied by an increase in the height of the layer maximum. Unfortunately, because of the "G-condition" it was impossible to follow the exact variation of Δh_{max} in the daytime, but one can conclude that it was about 40 km for Magadan and more than 60 km for Irkutsk. On the subsequent days, the dependence is less pronounced, and on October 20-21 one can even notice a tendency for an in-phase variation of Δh_{max} and Δf_oF2 for Magadan. Such behaviour of Δh_{max} and Δf_oF2 have sometimes been observed during geomagnetic storms (Forbes, 1989; Buonsanto et al., 1992). It was possible that deviations of h_{max} and f_oF2 were caused by high-latitude intense electric fields and this influence must be taken into account for such cases.

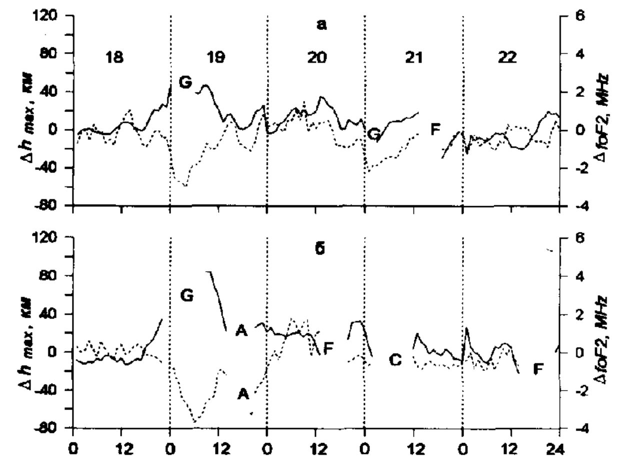

Fig.3. The variations of $\Delta h_{max}F2$ (solid line) and Δf_oF2 (circles) during this geomagnetic storm for Magadan (a) and Irkutsk (b).

DISCUSSION AND CONCLUSION

Satellite measurements and data from meridional chains of stations have shown that the most favourable conditions for the development of the main ionospheric trough are realized at the longitudes of East Siberia during the dark time of day (Benkova and Zikrach, 1983). Therefore, the distribution of critical frequencies during disturbances is conveniently viewed as resulting from MIT movement. The displacement of the trough during magnetic storms causes strong ionospheric disturbances, both positive and negative. Strong electric fields (about 100 mV/m) observed during disturbances over subauroral latitudes trigger a fast plasma drift. An increase in recombination rate in the region of fast plasma drift through the neutral atmosphere due to an increase in the reaction rate of ion-molecular exchange leads to the formation of a decreased density region. Joule heating at high latitudes and heat input from the ring current decay zone acts to enhance this process. The low density region that formed in the evening and premidnight hours, while conserving its shape in the night-time ionosphere, is carried away by the terrestrial rotation into the morning sector. The trough boundaries in this case are displaced into lower latitudes. Such phenomena were observed during the geomagnetic storms of March and April 1990 (Buonsanto et al., 1992). The variations of ionospheric parameters at East-Siberian stations, and particularly the appearance of type E_s aurora over Irkutsk testify that the electron density distribution in the ionosphere observed on 18-19 October is associated with the southward movement of the main ionospheric trough. On the basis of analyzing data from the "Cosmos-900" satellite it was suggested that during storms the main ionospheric trough consists of two troughs (Deminov et al., 1995). One of them is located near the electron precipitation boundary, and the other (the ionospheric ring trough) is characteristic for the storm recovery phase and is located farther to the south. Possibly, a manifestation of the ionospheric ring trough was observed at the Irkutsk latitude on October, 19, during the magnetic storm recovery phase.

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