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The Effect of Geomagnetic Storms on foF2 Values over Low Latitude Ionosonde Station

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Abstract

In this reseach, the changes in the low latitude critical frequencies (foF2) was investigated during the geomagnetically active hours (geomagnetic storms). The critical frequency (foF2) data obtained for 1991 over Manila that is low latitude ionosonde station and the planetary geomagnetic indices (K_p) were used. The superposed epoch analysis was used as a statistical method to investigate the change in the critical frequencies during geomagnetically active hours. The analyzes were conducted separately for the night hours, day hours and all hours of 1991 and they were compared with each other. The results from this research show that the highest change (increase or decrease) in foF2 values during geomagnetically active hours occurs at the event time (zero time) and the local time (day or night) has a significant impact on this change of the foF2 values. The foF2 values increase at local day hours, while the foF2 values decrease at local night hours.

Keywords: Geomagnetic storms, low latitude ionospheric critical frequency, superposed epoch analysis method

1. INTRODUCTION

The ionosphere is the ionized layer of the Earth's atmosphere. Because the ionosphere reflects the radio waves, it is very important for the communication. The electron density in this layer is changed by both the solar activity and geomagnetic storms. Their effects on electron density in the ionosphere layer vary depending on local time, latitude and altitude. Therefore, the solar and geomagnetic activity have different results on the different latitudes, local times, and altitudes [1-6].

The changes in the electron density of the ionosphere during the geomagnetically active hours were defined as ionospheric storms. The positive ionospheric storms increase the electron density, while the negative ionospheric storms decrease electron density [7-9]. Three main mechanisms cause to change in the electron density of the ionosphere region during geomagnetically active hours. The change in the composition of ionosphere is the first mechanism. The atomic oxygen (O) is main source for ionization, while the molecular nitrogen (N_2) is main source for recombination.

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Therefore, the electron density in the ionosphere changes depending on the $n(O)/n(N_2)$ ratio. The increase (decrease) of this ratio cause the positive (negative) storm in the ionosphere [4,10]. The disturbance dynamo electric field (DDEF) is the second mechanism that causes change of electron density in the ionosphere. The DDEF was induced by the thermospheric winds. During the geomagnetically active hours, this electric field is westward during day hours, while it is eastward during night hours. The westward electric field leads to decrease of electron density in the ionosphere during local day hours. The eastward electric field leads to increase of electron density in the ionosphere during local night hours [11]. The prompt penetrating electric fields (PPEFs) are the third mechanism that leads to change of electron density in the ionosphere. During the geomagnetically active hours, this electric field is eastward during the day hours, while it is westward during the night hours. The PPEFs change the electrodynamic structure of the ionosphere. The PPEFs cause to increase of electron density in the ionosphere during local day hours, while they cause decrease of electron density in the ionosphere during local night hours [12-14].

In this research, the effect of the geomagnetic activity on low latitude foF2 values was investigated using by the superposed epoch analysis (SEA) method. I believe that the results from this research will provide to a better understanding of the changes in the low latitude foF2 values observed during the geomagnetically active hours and how local time has an impact on these changes.

2. MATERIAL AND METHOD

To examine the effect of geomagnetic activity on the low latitude foF2 values, the hourly critical frequency data measured during 1991 at Manila (14.7 ºN, 121.1 ºE) were used. The reason for using the 1991 data in the analysis is that solar activity is at its maximum during this year and the geomagnetic activity is higher during this year. Thus, the effect of more geomagnetic storms on foF2 was examined. The global geomagnetic activity index (K_p) were used as geomagnetic activity indicator during 1991. These data were taken from the World Data Center (WDC) [15]. The K_p values were divided into several levels that show the geomagnetic activity levels. These geomagnetic activity levels were given in Table 1.

Table 1. Geomagnetic activity levels

Geomagnetic activity level	The ranges of K_P
Quiet	$0^o<K_p\leq 2^+$
Unsettled	$2^{+-}<K_p\leq 3^+$
Active	$3^+<K_p\leq 4^+$
Minor storm	$4^+<K_p\leq 5^+$
Moderate storm	$5^+<K_p\leq 6^+$
Strong storm	$6^+<K_p\leq 7^+$
Severe storm	$7^+<K_p$

In this research, to investigate the effect of the geomagnetic activity on low latitude foF2 values was used superposed epoch analysis (SEA) method. The SEA is a statistical application that is applied to time series. The SEA examines the effect of the geomagnetic activity on the foF2 values and measures the magnitude of response of the foF2 values against geomagnetic activity change. If the events occuring along time series identify properly, the results from the SEA indicate the effects of events on the system. The most important point in the analysis is to decide the concept called the event and to determine this concept as well [5,16,17]. Since the effect of geomagnetic storms on low latitude foF2 values in this study are investigated, the hours with $K_p> 4^+$ were chosen as geomagnetic events in the analysis. The 2338 events were detected during all hours of 1991. The 1072 events occurred during the local day hours, while the remaining the 1316 events occurred during the local night hours. After the geomagnetic events was detected, the hourly K_p and the hourly foF2 time series for 1991 were arranged simultaneously. After the two time series, ie, foF2 and K_p, are simultaneously set, a computer program determines the values of K_p greater than 4^+ in the K_p time series that star at 00:00 on January 01, 1991. When the program finds that K_p value is greater than 4^+, it then aligns all foF2 values 50 hours before and 50 hours after this event in one row. This process continues until the whole period of study is completed by computer. Thus, average foF2 values are obtained for which all events were superposed.

The same method of analysis was then repeated for the data set containing foF2 data at the hours where K_p was equal to 4^+ and smaller than 4^+. This process continues until the whole period of study is completed by computer. Next, the values calculated for the $K_p \leq 4^+$ hours were subtracted from the values calculated for all hours. The results obtained are δfoF2 values. The δfoF2 is defined in following.

$$\delta \text{foF2} = \text{foF2}_{(K_p > 4^+)} = \text{foF2}_{(\text{All})} - \text{foF2}_{(K_p \leq 4^+)} \quad (1)$$

The δfoF2 values indicate the changes in the foF2 values due to the geomagnetic activity change [5,16,17]. To analyze the effect of geomagnetic activity on the low latitude foF2 values depending on local time, this analysis was performed separately for the night hours, daytime and all hours of 1991 and the results were compared.

3. RESULTS

Figure 1 shows the change of δfoF2 values depending on time for all hours of 1991.

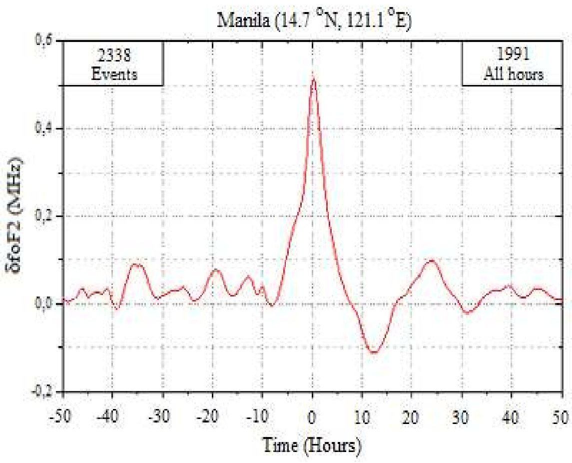

Figure 1. The change of δfoF2 values depending on time for Manila during all hours of 1991

The effect of change in the geomagnetic activity on foF2 values starts about 5 hours before the event moment (time 0) and the their effect on foF2 values reach to maximum at the event moment. The geomagnetic storms cause to increase about 0,5 MHz in the foF2 values. The change in the foF2 values almost disappears after about 30 hours. Figure 2 shows the change of δfoF2 values depending on time for 06-18 local times (LT) of 1991.

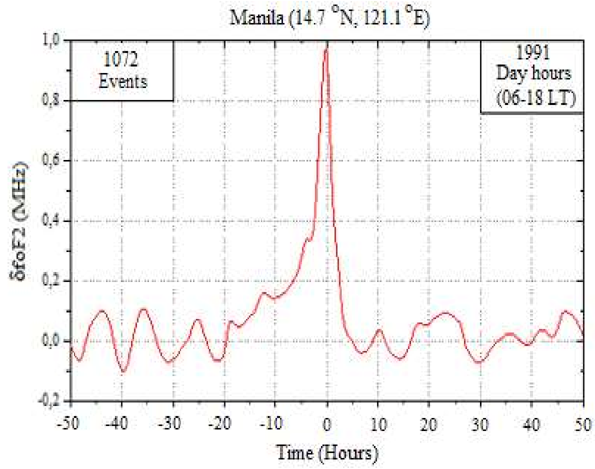

Figure 2. The change of δfoF2 values depending on time for Manila during day hours of 1991

The effect of change in the geomagnetic activity on foF2 values starts about about 10 hours before the event moment (time 0) and the their effect on foF2 values reach to maximum at the event moment. The geomagnetic storms cause to increase about 1 MHz in the foF2 values. That is, geomagnetic storms cause to ionospheric storms in the low latitude foF2 values for day hours. The change in the foF2 values almost disappears after about 5 hours.

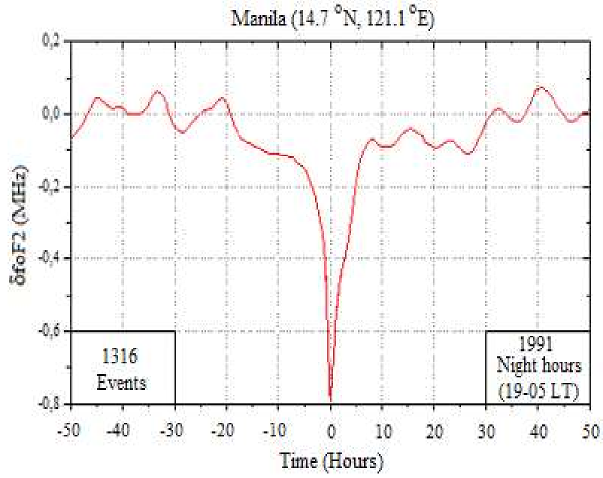

Figure 3. The change of δfoF2 values depending on time for Manila during night hours of 1991

Figure 3 shows the change of δfoF2 values depending on time for 19-05 local times (LT) of 1991. The effect of change in the geomagnetic activity on foF2 values starts about10 hours before the event moment (time 0) and the their effect on foF2 values reach to maximum at the event moment. The geomagnetic storms cause to decrease about 0,8 MHz in the foF2 values. That is, geomagnetic storms cause to negative ionospheric storms in the low latitude foF2 values for night hours. The change in the foF2 values almost disappears after about 10 hours.

4. CONCLUSIONS

The aim of this research is to investigate the effect of geomagnetic activity on low latitude foF2 values. For this, the SEA method was applied to foF2 data obtained during 1991 at Manila. The analyzes were made for different local times and the results were compared with each other. Geomagnetic storms cause significant changes (increase or decrease) in the foF2 values. For all local times, the effect of geomagnetic activity on foF2 values reaches the maximum at the event moment. But, this effect varies depending on local time. For local day hours, the geomagnetic storms cause an increase about 1 MHz in foF2 values at the event moment. The storms cause positive storms in the low latitude foF2 values for local day hours. For local night hours, the geomagnetic storms cause a decrease about 0,8 MHz in the foF2 values at the event moment. That is, the storms cause negative storms in the low latitude foF2 values for local night hours. These results show that the PPEFs are more effective than other mechanisms that cause ionospheric irregularities on low latitude ionosphere.

These results of present study are in good agreement with previous studies that was conducted about foF2 at low latitudes. The previous studies reveal that during geomagnetic storms, the ionospheric critical frequency (foF2) values at low latitudes increase at the day hours and decrease at the night hours [18-23].

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