Study of Ionospheric F2 Layer Characteristics at Low, Mid and High Latitudes

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Abstract: In the present study we have investigated the characteristics of ionospheric F2 layer during the May month of 2010 at low, mid and high latitudes. We have selected six ionosonde station two in each low, mid and high latitude regions. To characterize the behavior of ionospheric F2 layer we have selected three F2 layer characteristic parameters namely foF2 and hMF2 taken by ionosonde measurements at the respective ionosonde stations. From our analysis we found that the storm time and daily variability (quiet time) of all the important ionospheric parameters showed much strong changes either at mid latitudes or at low latitudes. The high latitude ionosphere undergoes only slight deviations. At the same time the effect of storms on foF2 is strongest at mid latitudes followed by high latitudes and then low latitudes. The daily variability of hmF2 remains almost same at all latitudes. The effect of geomagnetic storms on hmF2 is also not much pronounced. The hmF2 was found to be an important parameter that undergoes strongest changes during geomagnetic active condition.

Keywords: Ionosonde, F2 layer, foF2, Ionosphere

1. Introduction

It is well known that there are a lot of variations in the ionosphere due to the effect of solar, geomagnetic and meteorological activities. Apart from such variations there are also seasonal effects, day to day variations, hour to hour variations and latitudinal dependence. Therefore studies on the variation of ionospheric parameters (IEC, NmF2, foF2, hmF2 and Slab thickness (τ) etc.) under different conditions of solar, geomagnetic, day-to-day and seasonal effects are of vital importance over high, equatorial and low latitude regions. These studies help radio scientists and engineers to know to a large extent the expected deviations from the normal values.

The physics of the mid latitude F2 layer has been studied rather thoroughly. This made it possible to develop ionospheric models, in the scope of which analytical dependences of the F2 layer parameters on the aeronomic parameters were obtained, which are applicable in a wide range of helio-geophysical conditions, [6], [11], [14]. These models include explicit expressions for the NmF2 and hmF2 dependences on the composition and temperature of the thermosphere and on the vertical drift velocity, which makes it possible to easily analyze LEs. The adequacy of these models was proved by long term testing.

The critical frequency of the F2-layer (foF2) is yet another very important parameter, because it gives a direct measure of the number density of the electrons, a parameter which is of vital importance in the radio wave communication. This parameter is measured continuously from several locations spread over the globe and global ionospheric maps of foF2 are made available for the purpose of application in the ground based radio wave communication [3], [12]. This parameter also varies temporally and spatially and the characteristic features of foF2 of the low latitude differ significantly from those of the mid-latitude [12]. It was observed that at mid latitudes, foF2 shows nearly a linear relationship with sunspot number, though this relation is nonlinear for low latitudes [10]

The geomagnetic storm effects on the F2- region ionization at a given location depend, in a complicated way, on the time, season, and storm onset time [5],[9] Physical causes of the negative and positive response of the F2- region to a geomagnetic storm have been studied exclusively [4], [5], [8], [1]. At middle latitudes, for example, storm enhanced plasma densities (SEDs) are frequently observed during periods of enhanced geomagnetic activity. These bands of largely increased density structures, caused by storm-time electric fields that transport plasma from low to middle latitudes, [2], [7]. At low latitudes an ionospheric weather phenomenon are often related to variations in the E×B plasma drift, which during the daytime lifts ionization upward near the dip equator and in concert with the parallel motion down the field lines creates the equatorial ionization anomaly. The largest density values occur in the ionization anomaly peaks with typical day to- day variations. Furthermore, during nighttime the low latitude ionosphere often exhibits plasma instabilities and bubbles that largely vary in occurrence and strength from one night to the next. The largest variability, however, is probably found at high latitudes where convection electric fields originating from the magnetosphere and particle precipitation can dramatically change the plasma distribution in a matter of minutes.

It is believed that the ionospheric weather (variability) at low, mid, and high-latitudes is caused by variations in the external forces that originate from the thermosphere, the magnetosphere, and the lower atmosphere [13]. Ionospheric weather and its associated structures, gradients and variability has large impacts on a variety of technological systems and can strongly affect navigation, communication, and radar operations. Over the past decades numerous analytical, parameterized, and global physics-based models have been developed in an effort to better understand and specify ionospheric weather.

2. Data Sources and Method of Analysis

Regular radio soundings are made from a network of hundreds of station across the world. The National Geophysical Data Center maintains a huge database and makes available the data at Space Physics Interactive Data Resource (SPIDR) server. This data has been used since long time to study the ionospheric behavior. In our study, we have also used the Ionosonde data downloaded from National Geophysical Data Center (NGDC). The ionospheric data used in this study consists of 15 minutes values of the F layer critical frequency (foF2) and maximum height F2 layer (hmF2) taken from the National Geophysical Data Center's (NGDC) Space Physics Interactive Data Research (SPIDR) website at http://spidr.ngdc.noaa.gov/. We have used the data of six stations two from each low, mid and high latitude regions. The six stations considered in the study are as:

Low latitude: Jicamarca, Peru (Latitude:-12°, Longitude: 283.2°) Kwajalein Island (Latitude: 9°, Longitude: 167.2°)

Mid latitude: Roquetes, Spain (Latitude: 40.8°, Longitude: 0.3°) El Arenosillo, Spain (Latitude: 37.1°, Longitude: 353.3°) High latitude: Qaanaaq, Greenland (Latitude: 77.5°, Longitude: 290.6°) Gakona, USA (Latitude: 62.24°, Longitude: 214.91°)

We then integrated the data of two stations from each region to from three sets of data for each parameter for low, mid and high latitude regions.

Consecutively we then examined their diurnal and day to day variability of low mid and high latitude ionospheric F2 layer through three different parameters. The time period chosen for our study is the May month of 2010. This month experienced two geomagnetic storms and at the same time had a number of days with quiet geomagnetic conditions. This allowed us to study the ionospheric behavior during magnetically quiet and disturbed conditions.

Ionosonde does not measure NmF2 directly but it can be calculated from foF2. The relationship between NmF2 and foF2 is given by N_{1} = 2 × 1.24 × (M_{1} = 2 × 1.24 × (M_{2} = 2 × 1.24 ×

 $NmF2 = 1.24 \times (f0F2)2 X1010 el/m3$

where foF2 is the critical frequency of F2 layer in MHz.

3. Results and Discussion

Before we begin the presentation of our result for ionospheric behavior let us first check the solar and geomagnetic conditions. It is imperative in any ionospheric related study to know the solar and geomagnetic conditions. The variation of geomagnetic indices, Kp, Dst and AE as well as solar radio flux 10.7 cm from 1ST May – 31ST May 2010 is presented in Figure 1. From the Figure we see that there was an increased magnetic activity at the beginning and end of the month marked by two moderate geomagnetic storms with minimum Dst -67 nT and -83 nT on 2nd May and 28th May 2010 respectively. One of them is a sudden

commencement storm with its initial phase on the May 2, 2010 and the recovery phase extends to May 4, 2010. The second storm has its initial and main phases on May 29, 2010 and early part of the recovery phase on May 30, 2010 which extended to May 31, 2010. While in the middle of the month between 10th to 20th May the magnetic activity was very low. Thus we observe both high and low geomagnetic activities during the May 2010.

Similar feature can be observed in the solar wind parameters and IMF components, as shown in Figure 2. The sharp and abrupt changes are quite evident in these parameters during the start and end of May month. However during the middle of May month i.e. around 15 May 2010 the magnetic and solar activity was low as noticed from geomagnetic and solar indices. It is because of this reason that this month was selected to study the ionospheric behavior during low and high solar geomagnetic activity periods. We have considered different parameters that characterized the state of ionospheric F2 layer under varying solar and geomagnetic conditions. The behavior and variability of all the parameters at low mid and high latitudes is discussed below individually for all the parameters.



Figure 1: Variation of Solar and Geomagnetic indices (a) Disturbed storm time (Dst), (b) Auroral electro-jet index (AE), (c) planetary index (Kp) (d) Solar radio flux (F 10.7),



Figure 2: Variation of interplanetary parameters (a) Interplanetary Magnetic Field (IMF) (b) Proton Density (Nsw) (c) Solar wind velocity (Vsw) (d) Solar wind pressure (Psw) May 1-31

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4. Critical Frequency of F2 layer (foF2)

The critical frequency of F2 layer is an extremely important parameter which describes the state of F2 layer ionosphere. This parameter is thought to be very sensitive to solar influences. The hourly variation of foF2 at low, mid and high latitude stations from May 1^{st} – May 31^{st} 2010 is shown in Figure.3. From the Figure we notice that on 3rd May and 29 May the value of foF2 increased from their normal value at all the three latitudes. This is due to the geomagnetic storms that occurred around the same time. A very interesting feature that can be seen from the contour map is that the increase of foF2 at mid latitudes is much more intense as compare to high latitudes. Comparison among all the latitudes shows that the values of foF2 at high latitudes remain quite low as compared to low and mid latitude. The mid latitude ionosphere undergoes strong changes compared to other two. Thus it may be concluded the effect of solar and geomagnetic disturbances on foF2 are strongest at the mid latitudes and weakest at the high latitudes. The daily behavior of foF2 at all the three latitudes during the May month of 2010 is represented by Figure 4. Here again we notice the similar features as reflected by Figure 3. The smooth variation of foF2 is replaced by rapid fluctuations during the course of solar and geomagnetic disturbances, the maximum effect being at mid latitudes. The hourly variation of foF2 at all the six stations, two in each region (low, mid and high) is shown in Figure 5. It reflects the diurnal pattern averaged over the month at all the stations. In case of low latitudes since the two stations are chosen in the opposite hemisphere, consequently the pattern is almost opposite while in cases of mid latitudes the variation at both station is almost same.





Figure 3: Contour plot of hour to hour critical frequency (foF2) variation for different latitudes.



Figure 4: Day to day variability of foF2 for Low, Mid and High latitudes.



Figure 5: Average diurnal plot of critical frequency (foF2) for Jicamarca, Kwajalein, Roquetes, ElArensillo, Qaanaaq, Gakona during 1-31 May 2010.

5. Maximum height of F2 layer (hmF2)

The hmF2 is another important parameter which represents the peak or maximum height of F2 layer. The hourly

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variation of hmF2 during May 1 to May 31, 2010 is shown in Figure 6 at low, mid and high latitudes. The diurnal behavior of hmF2 almost remained similar at all the three latitudes during May month of 2010. The effect of geomagnetic storms is also not much pronounced. However at high latitudes a couple of red patches could be seen during the storm of May 2, 2010 indicating an increase of hmF2. The daily variation of hmF2 for the complete May month is shown in Figure 7. It reflects the day to day variability of hmF2. The storm effect is again not much noticeable here also. The value of hmF2 usually remains high at high latitudes and lowest at mid latitudes. The hourly pattern averaged over the complete May month for all the six stations is shown in Figure 8. The values start increasing in the morning following the sunrise, peak at around mid day and then gradually decrease as the day progresses and reach to minimum in the post sunset hours.







Figure 7: Day to day variability of hmF2 for Low, Mid and High latitudes.



Figure 8: Average diurnal plot of peak height of F2 layer for Jicamarca, Kwajalein, Roquetes, ElArensillo, Qaanaaq, Gakona

6. Summary and Conclusions

We studied the diurnal and daily variations of three important ionospheric F2 layer parameters foF2, hmF2 and NmF2 at six station selecting two in each low, mid and high latitude regions during the May month of 2010. This month was selected with the view that it observed two moderate geomagnetic storms and at the same had a number of days when the geomagnetic activity was very low. Thus by selecting such a month allowed us to study the diurnal and daily behavior of this ionosphere parameter under high and low geomagnetic conditions. From our analysis we have found that the enhancements of three F2 layer parameters are by larger amounts at mid and low latitudes than those at high latitudes during the course of geomagnetic storms. The day to day variability also showed that values of these parameters are higher at low and mid latitudes during quiet conditions. The day to day variability of foF2 showed that the value of foF2 at high latitudes varies between 3 - 7 MHz while the same at low and mid latitudes varies between 2 -10 and 3 - 12MHz respectively. The effect of storms on foF2 is strongest at mid latitudes followed by high latitudes and then low latitudes. And interesting feature of the study was behavior of hmF2. The daily variability of hmF2 remains almost same at all latitudes with values between 150-400 kilometers. The effect of geomagnetic storms on hmF2 is also not much pronounced. In other words the variability of hmF2 is not much affected by the geomagnetic activity. Although at high latitudes the small enhancements can be noticed.

The storm time and daily variability (quiet time) of all the important ionospheric parameters showed much strong changes either at mid latitudes or at low latitudes. The high latitude ionosphere undergoes only slight deviations. At the same time the peak height of F2 layer (hmF2) shows similar features at all the three latitudes hence appears to be almost latitudinal independent.

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Author Profile



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