
Geomagnetic disturbances and its impact on ionospheric critical frequency (foF2) at high, mid and low latitude region

Roshni Atulkar^{1,*}, Shivangi Bhardwaj², Prakash Khatakar², Purushottam Bhawre², P. K. Purohit¹

¹National Institute of Technical Teachers' Training and Research, Bhopal (MP), India

²Space Science Laboratory, Barkatullah University, Bhopal (MP), India

Email address:

roshniatulkar@gmail.com(R. Atulkar)

To cite this article:

Roshni Atulkar, Shivangi Bhardwaj, Prakash Khatakar, Purushottam Bhawre, P. K. Purohit. Geomagnetic Disturbances and Its Impact on Ionospheric Critical Frequency (foF2) at High, Mid and Low Latitude Region. *American Journal of Astronomy and Astrophysics*. Vol. 2, No. 6, 2014, pp. 61-65. doi: 10.11648/j.ajaa.20140206.11

Abstract: A geomagnetic storm is a major disturbance of Earth's magnetosphere that occurs when there is a very efficient exchange of energy from the solar wind into the space environment surrounding Earth. During solar and geomagnetic activities, critical frequency of F2 layer (foF2) varies in a great extent. In this Study, our main aim is to examine the effect of solar and geomagnetic activities on the critical frequency (foF2) during January 2014 to April 2014 respectively. One magnetic intense storm occurred on 19 February with (Dst -112) and other moderate storm occurred on 12 April 2014 with (Dst -80). In our study, we have analyzed these effects on critical frequency of F2 layer for ionospheric monitoring. We have used ionospheric data at Low, mid and high latitude station. The absorption and ionization of the ionospheric medium depends on solar activity. The value of foF2 increased from their normal value at all the three latitudes. This is due to geomagnetic storms that occurred around the same time. A very interesting feature that can be seen in the figures is that the increase of foF2 at Low latitude is much more intense as compare to high and mid latitude. Comparison among all the latitudes shows that the values of foF2 at high latitude are quite less as compared to low and mid latitude. We have found that the effect of solar and geomagnetic storm disturbances is strongest at the low latitude and weakest at the high latitude during the geomagnetic storm time.

Keywords: Geomagnetic Disturbance, Critical Frequency, Ionosphere, Storm

1. Introduction

The continuous nuclear fusion process inside the sun, emit electromagnetic radiation. Earth's magnetosphere, thermosphere and ionosphere are mostly affected by these electromagnetic radiations. Geomagnetic storms are created when the Earth's magnetic field captures ionized particles carried by the solar wind due to coronal mass ejections or coronal holes at the Sun. a geomagnetic storm is caused by a solar wind shock wave which typically strikes the Earth's magnetic field 24 to 36 hours after the event. Although there are different types of disturbances noted at the Earth surface, the disturbances can be characterized as a very slowly varying magnetic field, with rise times as fast as a few seconds, and pulse widths of up to an hour. The rate of change of the magnetic field is a major factor in creating electric fields in the Earth, geomagnetic storm phenomena associated with the variability of the sunspot cycle, and each sunspot cycle is typically ~11 years in duration. The frequency of geomagnetic storms increase and decreases

depends on the sunspot cycle. During the Geomagnetic storm, ionospheric critical frequency foF2 become unstable, fragment and disappear. These ionospheric effects are dependent on the time of storm and intensity as well as the latitude of a station and its location in the summer or in the winter hemisphere (Batista et al.1991). Thermospheric-ionospheric view associated with positive and negative storm effects (Prolss 1993). The storm enhanced density (SED) described by Foster 1993), at mid latitude, storm enhanced plasma densities (SEDs) are 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 mid latitudes (Foster et al., 2002).Although low latitude ionospheric weather phenomenon is related to variations in the $E \times B$ plasma drift, which is prominent during the daytime. The ionization lifts 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 day to day

variations (Khatarkar et al 2014). The largest variability found at high latitudes where convection electric fields originating from the magnetosphere and particle precipitation can dramatically change the plasma distribution. Vertical radio sounding techniques (ionosondes) have provided us with much more of the information about the ionized upper atmospheric layers. Since disturbance of earth magnetosphere associated with geomagnetic storms, they are categorise with negative intensity of Dst index as intense storms (peak Dst<-100nT), moderate storms(-100 nT<peak Dst<-50nT) and weak storms (Peak Dst >-50nT). According to time sequence, Geomagnetic storms can be described in three phases the initial Phase, the main phase and the recovery phase. The initial phase represents the abrupt change in the Dst, called Sudden commencement it appears when change in the geomagnetic field (H) component due to the field of the current, that flow on the magnetospheric. The main Phase of a storm is said to start, when the Dst assumes negative values and ends when it reaches its minimum, during this phase the equatorial ring current is boosted by injection of energized plasma. This occurs two to ten hours after storm commencement and may last several hours. There is characteristic sharp fall in H. The recovery phase, usually the longest one, is characterized by the returning of Dst to its pre-sudden commencement values, this is the stage when the magnetic field returns to normal. It might last days. Kp index represents planetary magnetic activity on a global scale, while Dst records the equatorial ring current variation (Mayaud, 1980). AE describe the disturbance level of horizontal magnetic current component, difference between the two envelopes determine AE (Auroral Electroject) index. Solar and geomagnetic storms can increased errors in Satellite, Phone & internet, mobile location-based services, traffic as well as other satellite and ground-based high-frequency communications.

2. Data and Method of Analysis

In the present work, we have analyzed the ionospheric response features during the periods of two magnetic storm events of 2014 i.e. 24th solar cycle. The storm events studied in the present paper occurred in the months of February and April. In this paper, our main aim is to analyze the behavioral change in ionospheric F2 layer parameter during geomagnetic disturbed days. The following work is started by first collecting and analyzing the magnetic data to identify the storm periods. The ionospheric parameters that correspond to the storm period were collected and analyzed with two quit days before and after those identified storm days. The magnetic storms strength is determined by the variation in Dst index. The ionospheric data used in this study consists of hourly values of the F layer critical frequency (foF2) taken from Data Research (SPIDR) website at <http://spidr.ngdc.noaa.gov/ic> and Omni Data center (website omniweb.gsfc.nasa.gov).

Two different storms and their effects on the ionosphere are discussed in this paper.

Table 1. Selected magnetic storm events of year 2014

S.No	Date	SSC	DST(minimum)	Mode
1	19 /02/2014	9:00 (UT)	-112nt	intense
2	12/04/2014	10:00 (UT)	-80nt	moderate

In order to investigate effects of solar and magnetic activity on ionospheric critical frequency (foF2) variation we have used following latitudes.

Low Latitude:-

Chongqing, China (Latitude: 29.30°N, Longitude: 106.25°E)

Mid Latitude:-

Kokubunji, Japan (Latitude: 35.7°N, Longitude: 139.5°E)

High Latitude:-

Longyearben, Norway (Latitude: 78.2°N, Longitude: 15.9°E)

3. Results and Discussion

A most significant feature of the ionosphere is its ability to reflect radio waves. However, only radio waves within a certain frequency range will be reflected and this range varies with a number of factors. Ionosphere may be described by different parameters. The most widely used description of its state are called critical frequency. Critical frequency is well defined and commonly measured quantity. The CRITICAL FREQUENCY is the maximum frequency that a radio wave can be transmitted vertically and still be refracted back to Earth. critical frequency of a ionospheric layer is the highest plasma frequency of given layer, for example, critical frequency of E, F1, and F2 layer and foE, foF1, foF2 respectively when standard daily stratification is present. We used foF2 values for our analysis. Plasma frequency is directly connected to the electron concentration.

Storm1

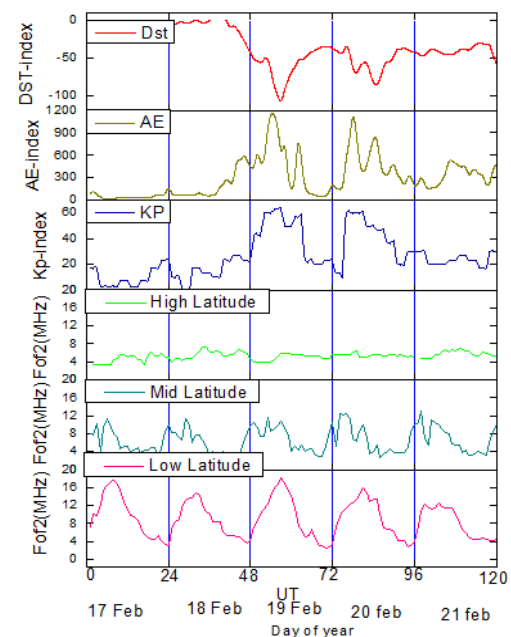


Fig (1). Shows the Fof2 day to day variability from February 17 to 21 along with Dst, AE and the kp index.. The moderate storm of February started with SSC at 09:00 UT on February 19, 2014.

Ionospheric variability during the magnetic storms of February 17-21, 2014 one intense storms was observed in the month of February 19, 2014. Hourly foF2 variation from 17 to 21 are plotted along with AE, Kp and Dst index in Fig.1. The intense storm of February 17 started with SSC at 09:00 UT. With maximum negative excursion of Dst ~ -112 nT is noted and the storm lasted until February 19 which was followed by the recovery phase on February 21. AE value is reaches 520 nT when Dst has more negative. With the main phase of the storm, a kp index reached 6. The hourly variation of foF2 at low, mid and high latitude stations from February 17 to February 21st 2014 is shown in Figure (1). foF2 values started increasing in the positive direction, when maximum negative value of Dst. The values of foF2 at high latitudes are quite low as compared to mid and low latitude.

Storm 2 event.

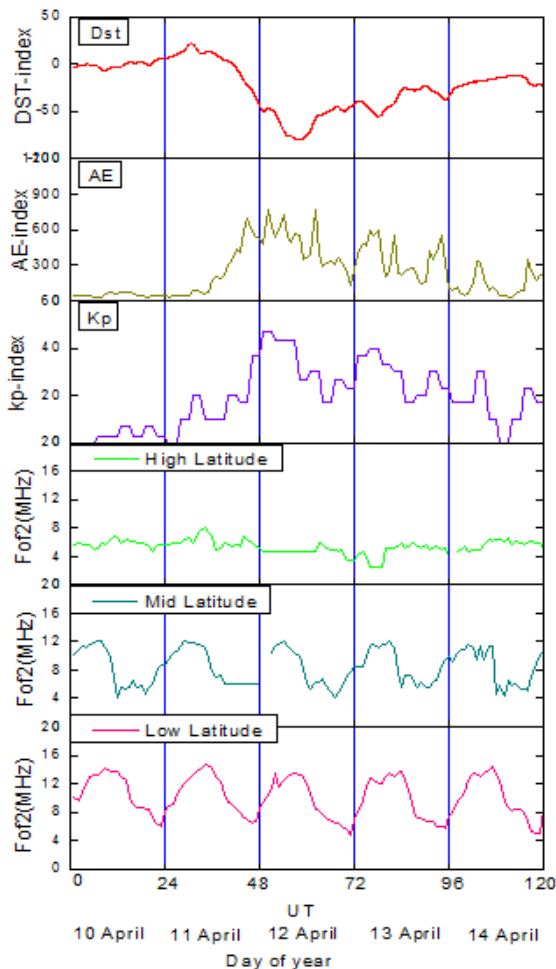


Fig (2). Shows the Fof2 day to day variability from April 10 to 14 along with Dst,AE and the kp index.. The moderate storm of April started with SSC at 10:00 UT on April 10, 2014.

Fig.2 shows the Fof2 day to day variability from April 10 to 14 along with Dst,AE and the kp index.. The moderate storm of April started with SSC at 10:00 UT on April 10, 2014. This resulted in sharp horizontal turning of the AE reaches 549 nT and a maximum negative value on the same

day. The maximum negative excursion in Dst ~ -80 nT is observed at 10:00 UT on April 12, 2014. The Main phase of the storm, kp index reached 5. Ionospheric critical frequency fof2 value started increasing, when maximum negative value of Dst. We found values of foF2, also low at high latitude as compared to mid and low latitude during this

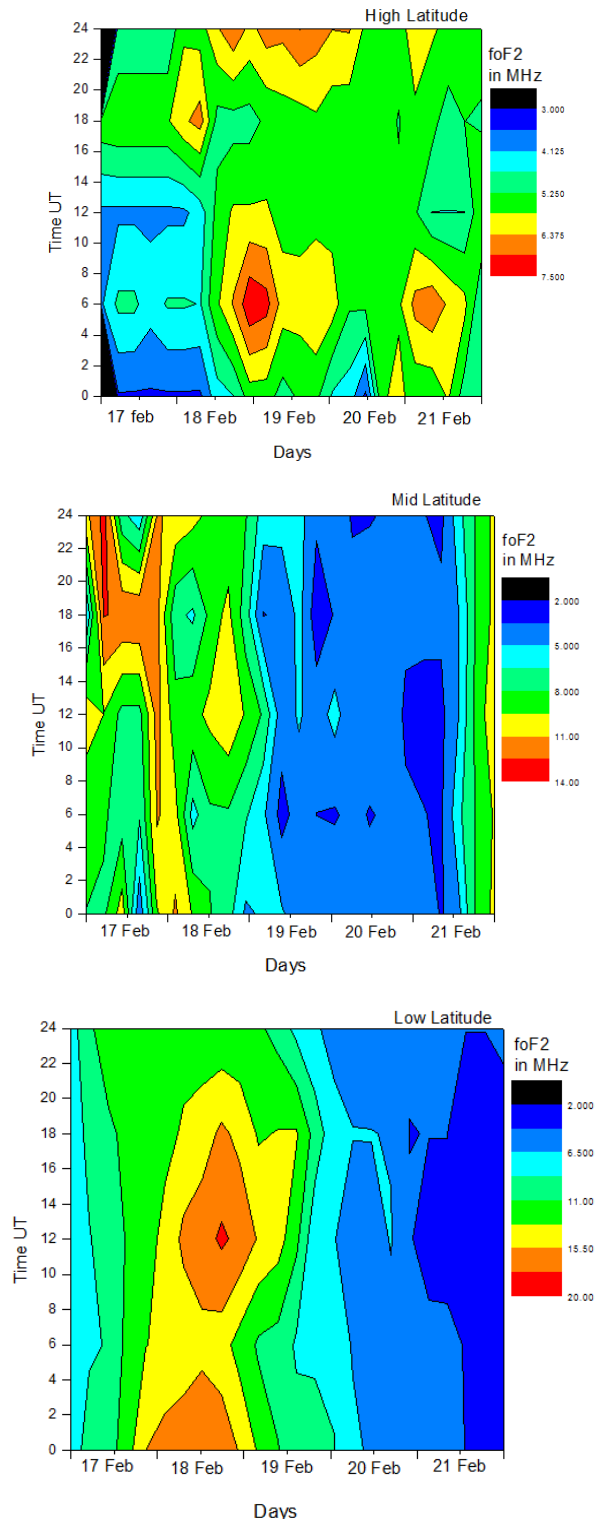


Fig. (3). Contour Plot of hour to hour critical frequency variation 17 -21 Feb 2014, for different latitudes.

Due to Geomagnetic storms ionospheric critical frequency foF2 increase, figure 3 and figure 4 shows that the contour plots of hour to hour critical frequency variation for Low, Mid and High latitude.

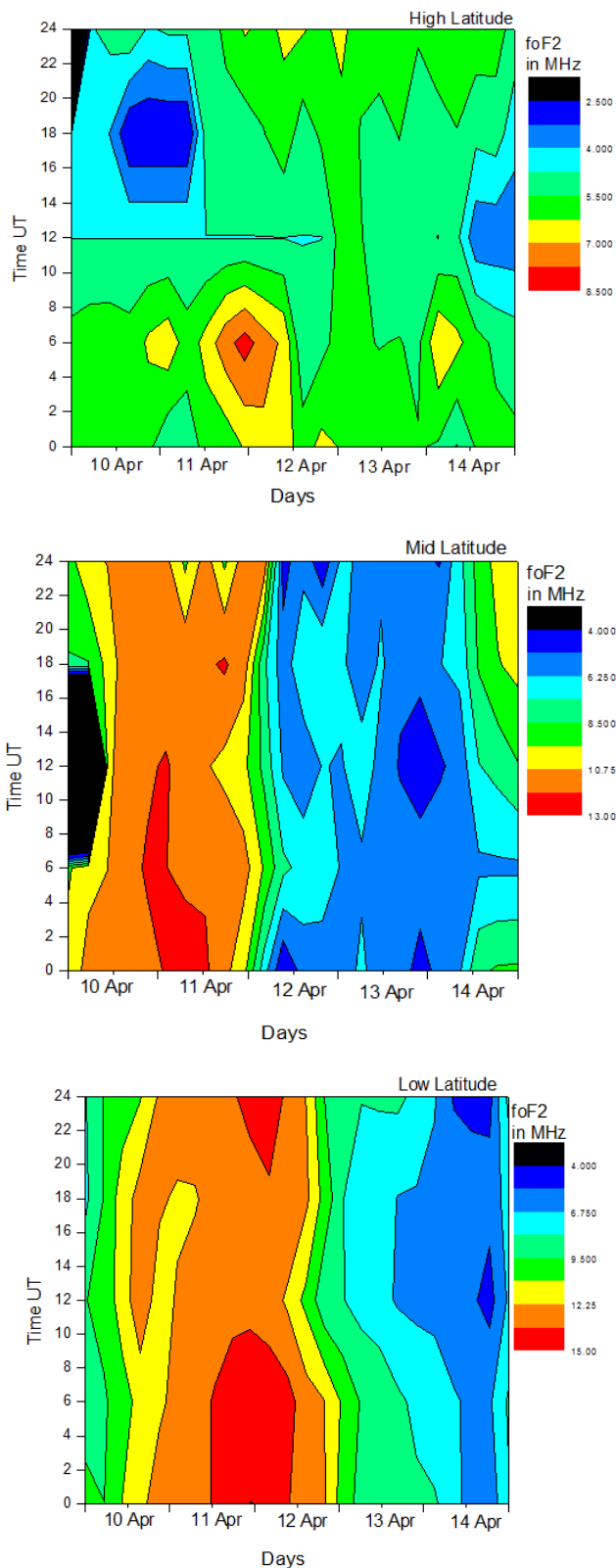


Fig. (4). Contour Plot of hour to hour critical frequency variation 10 -14 Apr;2014, for different latitudes.

Ionospheric critical frequency foF2 increases, due to Geomagnetic storms.

Earth's magnetic field disturbed due to different events of the Sun. Distribution of ionospheric currents and electric field can be altered by the perturbations of the solar wind magnetosphere and ionospheric wind dynamo. The east-west electric field in conjunction with the earth north-south magnetic field lines produces the ExB force that causes vertical plasma drift. Therefore, higher frequencies are most affected by ionospheric storms. The study suggests that wherever possible a lower frequency can be used to minimize the effects of an ionospheric storm on communication.

4. Conclusions

During geomagnetic events the most important phenomena is simultaneous large enhancement of foF2. Thermospheric winds are considered as the main cause of variability in the ionospheric critical frequency. In our analysis we have investigated the day to day variation of ionospheric F2 layer critical frequency (foF2) at low, mid and high latitude region during one intense and one moderate storm with a minimum decrease of Dst -112nT and -80nT. From our analysis we have found that the variation of foF2 parameter is higher at low and mid latitude than at high latitude during the geomagnetic storm days. Therefore the ionospheric effects are dependent on the time of storm and intensity as well as the latitude of a station and its location. It is clear from the observations that a variation in F2 layer parameters at the time of the geomagnetic storm strongly depends upon the intensity of storms.

Acknowledgements

The author (R.Atulkar) would like to thank National Institute of Technical Teachers' Training and Research, Bhopal for MHRD fellowship, National Geophysical Data Center's (NGDC), Space Physics Interactive Prediction (SPIDR) website <http://spidr.ngdc.noaa.gov/ic> , and Omni Data centre website omniweb.gsfc.nasa.gov, for providing data.

References

- [1] Gonzalez, W. and Tsurutani, B.T. *Planet, Space Sci.*, 35, 1987, 1101.
- [2] Batista Sinez, Depaula E.R., Abdu.N.B, Trivedi N.B, Ionospheric effect of the march 13, 1989, Magnetic Storm at Low and Equatorial latitudes, *Journal of Geophysical Research*, Vol.96, no.A8, pp13,943-13952.
- [3] Proless, G.W., On Explaining the local time variation of ionospheric storm effects. *Ann. Geophysics*, 11, 1-9, 1993a.
- [4] Khatarkar P., Purohit P.K., Gwal. A.K., Study of ionospheric F2 layer characteristics at low, mid and high latitudes. *International Journal of Science and Research(IJSR)* vol.3 Issue 9, ISSN 2319-7064, 2014.

- [5] M. M. Fares Saba, W. D. Gonzalez, A. L. Clu  a de Gonzalez Relationships between the AE, ap and Dst indices near solar minimum (1974) and at solar maximum (1979), *Ann. Geophys.* 15, 1265-1270,
- [6] I. Tsagour, A. Belehaki, G. Moraitis and H. Mavromichalaki Positive and negative ionospheric disturbances at middle latitudes during geomagnetic storms. *Geophysical Research Letters*, Vol. 27, No. 21, p. 3579-3582, November 2000
- [7] Matthias Forster and Norbert Jakowski. Geomagnetic storm effects on the Topside ionosphere and plasmasphere: A Compact Tutorial and New results. *Surveys in Geophysics* 21: 47–87, 2000.
- [8] Mukherjee S. , Shivalika S. , Purohit P.K. , Gwal. A.K, Effect of Geomagnetic Storms in the Equatorial Anomaly Region observed from ground based data. *International journal of geomatics and geosciences* Volume 1, No 3, 2010.
- [9] A.O. Adewale, E.O. Oyeyemi, A.B. Adeloye, M.B. Adedokun. Ionospheric effects of geomagnetic storms at Hobart and comparisons with IRI model predictions. *Journal of Sci. Res. Dev.* 2013, Vol. 14, 98 – 105.
- [10] Wang.X, Shi J.k., Wang G.J., Zhrebtsov G.A., Pirog O.M., Responses of ionospheric foF2 to geomagnetic activities in Hainan. *Advances in space research* 41(2008), 556-561.
- [11] Mayaud P.N., Derivation, meaning and use of geomagnetic indices. *AGU Geophys. Monogr.* vol. 22, 1980, 1980.