An Analytical Study of Nighttime Enhancement in foF2 during 23rd& 24th Solar Cycle at Low Latitude Station

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Abstract

This paper presents nighttime enhancement in foF2 during 23rd & 24th high solar activity periodat low latitude station Jicamarca (12°S, 76.90°W). To examine the nighttime enhancement of ionosphere, we have used the ionosonde measurements for critical frequency of F2 layer. The foF2 is an important and most widely used parameter for studying the ionosphere weather. Hourly data for the year 2002 (High solar activity period for 23rd solar cycle) & 2014 (High solar activity period for 24th solar cycle) of foF2 are analyzed to study the Hourly data for the year 2002 (High solar activity period for 23rd solar cycle) & 2014 (High solar activity period for 24th solar cycle) of foF2 are analyzed to study the anomalous nighttime F-region. To examine the seasonal effects, we grouped all data into three seasons' winter, summer and equinox using the four months of data for each season equinox (March .April, September andOctober), winter (January, February, November and December) and summer (May, June, July and August). The enhancements are expressed pre-midnight enhancement and post-midnight enhancement, according to the local time when the enhancement appeared. In 2002 out of 149 enhancements in foF2, 127 enhancements occurred during pre-midnight hours and 22 during post–midnight hours, where as in 2014 Out of 94 enhancements in foF2 91ocurred during pre-mid night hours and 03 during post- midnight hours

Keywords - *Ionosphere, foF2, Solar activity Nighttime Enhancement*

I. INTRODUCTION

We know that the in ionosphere, the free ions are mainly formed as a result of the interaction between solar radiation and gas molecules. But during the night time, when solar radiation is absent to induce photo ionisation, then the electron density would decay steadily as recombination takes place. Many observations show that the electron density does not decay through the night as predicted by simple theory. The electron density in the ionospheric F region occasionally stops its decay and increases pronouncedly during nighttimes, which are known as ionospheric nighttime enhancements. This anomalous phenomenon was first named as the Weddell Sea Anomaly (WSA), which was characterized by the greater electron density in nighttime than in daytime near the Weddell Sea region. The WSA was first discovered as a result of a large number of ionospheric observatories being placed in Antarctica during the International Geophysical Year in 1957 (Bellchambers et al., 1958).

There are several enhancement characteristics that depend on location season, solar and magnetic activity. These enhancement characteristics are frequency of occurrence, time of occurrence, amplitude and duration activity. It is possible to obtain information about processes that causing the dynamical coupling between different regions of the atmosphere by comparison of the variability of parameters of the neutral atmosphere and ionosphere.

The enhancement is caused by different mechanism at different latitude. The important mechanism -are the Post sunset pre reversal enhancement of (E X B) drifts and subsequent plasma diffusion along the field lines. Downward plasma diffusion from protonsphere, Plasma transfer from conjugate hemisphere, Cross L plasma motion due to ionospheric and magnetosphere electric field, Plasma motion due to natural winds. Corpuscular ionisation and Movement of mid latitude ionospheric trough.

Recently, Chen (2015) investigated dusk to-nighttimes enhancement of mid-latitude summer NmF2 (maximum electron density of the F2 layer) within the framework of NmF2 diurnal variation. NmF2 were normalized to two solar activity levels to investigate the dependence of the dusk-to-night time enhancement on solar activity. The dusk-to-night time enhancement of NmF2 is more evident at Northern Hemisphere stations than at Southern Hemisphere stations, with a remarkable latitudinal dependence. The dusk-to-night time enhancement shows both increasing and declining trends with solar activity increasing, which is somewhat different from previous conclusions. The difference in the dusk-to-night time enhancement between Southern Hemisphere and Northern Hemisphere stations is possibly related to the offset of the geomagnetic axis from the geographic axis. hmF2 (peak height of the F2 layer) diurnal variations show that daytime hmF2 begins to increase much earlier at low solar activity level than at high solar activity level at northern Akita and Wakkanai stations where the dusk-to-night-time enhancement is more prominent at low solar activity level than at high solar activity level. That implies neutral wind phase is possibly also important for night time enhancement. The neutral wind play an important role in the variation of inospheric parameter of f2 layer .it sustains the ionization of F region to higher altitude. At this altitude ion neural recombination is significantly decreases and enhanced NmF2.

Recently ZHANG YanYan (2015) investigated night time enhancements in ionospheric electron density at mid- and low-latitudes by using the critical frequency of the F2-layer (foF2) data measured from ionosonde stations at Okinawa (26.3°N, 127.8°E, Geomagnetic 15.3°N), Yamagawa (31.2°N, 130.6°E, Geomagnetic 20.4°N), Kokubunji (35.7°N, 139.5°E, Geomagnetic 25.5°N), and Wakkanai (45.4°N, 141.7°E, Geomagnetic 35.4°N) in East Asia during several solar cycles. The results show that there are obvious seasonal and solar activity dependencies of the nighttime electron density enhancements. The enhancements are termed pre-midnight enhancement and post-midnight enhancement, according to the local time when the enhancement appeared. The former has a higher occurrence probability in summer months than in winter months. In contrast, the latter has a larger occurrence probability in winter months than in summer months. Moreover, the nighttime enhancements in electron density are more likely to occur at lower solar activity. These seasonal and solar activity variations of the nighttime enhancements in electron density can be explained in terms of the combined effects of downward plasma flux from the plasmasphere and the neutral winds.

Singh, et al., (2013) used IEC as well as foF2 data from three locations to study the anomalous night time F-region during low to moderate solar activity period, i.e. from January 2006 to December 2010. The results show that at high and mid-latitude locations, there is maximum percentage of enhancement in IEC and foF2 during winter season, whereas at low latitude location maximum percentage of enhancement in both the parameter is during equinox. The highest total number of enhancements in IEC parameter occurred at high latitude station Chilton, whereas in foF2 parameter, highest total number of enhancement occurred at low latitude station Kwajeli. Out of 1116 enhancement in IEC, 661 enhancements occurred during pre-midnight hours and 455 during post–midnight hours. Although out of 948 enhancementfor foF2, 457 enhancements occurred during pre- midnight hours and 491 during post–midnight hours.

ArturYakovets and Galina Gordienko (2017) have studied behaviour of parameters of Nighttime Electron Density Enhancements of the Ionospheric F2 Layer. Another type of ionospheric disturbances presents the nighttime electron density enhancements in the ionospheric F2- layer maximum (NmF2). This type of irregularities is described in numerous papers. There is a concept that, in spite of the various mechanisms of ionospheric disturbances generation a response of F2-layer parameters exhibits similar features associated with the upward lift and the simultaneous expansion of the layer and then its subsequent downward movement, including layer compression, which results in the formation of the electron density peak in the layer maximum at the moment of greatest compression. The aim of this study is a verification of this concept on the example of disturbances related with the nighttime electron density enhancements, and the definition of precise quantitative relationships between the variations of different F2-layer parameters for such disturbances. By using the data of the ionospheric vertical sounding in Almaty, (76◦ 55'E, 43◦15'N) during 2001-2012, analysis of the behaviour the F2-layer parameters during the night electron density enhancements was carried out within framework of a single concept of effects of various types of ionospheric plasma perturbations in variations of height and half-thickness of the F2-layer, accompanied by increasing and decreasing NmF2 at moments of maximum compression and expansion of the layer. For a quantitative analysis of the parameters of nighttime enhancements we have selected 20 nights characterized by low magnetic activity (Dst> - 50 nT) and evident manifestations of the nighttime electron density enhancements. A comparison of the behaviour of the parameters of the F2-layer is carried out. Quantitative relationships between parameters including a) an enhancement amplitude in the maximum F2 layer and at the altitude, characterized by the maximum rate of enhancement, b) the variation amplitudes at the altitudes of the layer top and basis, the amplitude of variations of the half-thickness and NmF2 are found. Dependence on the altitude of enhancement amplitude is found, showing that the altitude of the enhancement maximum is below the altitude of the layer maximum. Based on comparison of behaviour in time of night enhancements parameters, we made a conclusion that its characteristics repeat features, previously considered for several types of ionospheric plasma disturbances. Thus, we have expanded range of the F2-layer disturbances, the parameters of which, in spite of the various mechanisms of their generation exhibits similar features.

II. DATA AND METHOD

Hourly values of the critical frequency (foF2) parameter are taken over Jicamarca (120S, 76.90W; dip 0.280). Jicamarca is an ionospheric station along the anomaly trough in the American sector. Hourly values of the critical frequency (foF2) parameter are collected from the site NGDC Space Physics Interactive data Resource (SPIDR) website (http://spidr.ngdc.noaa.gov) during period (2002 to2014). We have analyzed all the characteristics of night time enhancement such as time of occurrence of peak mean peak amplitude and duration of enhancement. To examine the seasonal effects, we grouped all data into three seasons' winter, summer and equinox using the four months of data for each season equinox (March, April, September and October), winter (January, February, November and December) and summer (May, June, July and August). The enhancements are termed pre-midnight enhancement and post-midnight enhancement, according to the local time when the enhancement appeared.

We have taken pre mid enhancement (1800-2300 hours) and post-midnight enhancement (0000-06000 hours LT) depending upon time of occurrence prominent peak of the enhancement. In case of double and triple peak only prominent peak is considered.

In characterizing the nighttime enhancement, the similar criterion as that adopted by Unnikrishnan et al., (2002) was applied. Constantly, a nighttime foF2 enhancement was defined as the excess content or mean peak amplitude (ΔfoF2), which remained at the back the exponentially decaying background of the diurnal content was subtracted from the critical frequency of F2 layer. The maximum difference between the enhanced foF2 and the background content gave the excess content, which is called the "amplitude" of enhancement. For the present study, only those enhancements which have amplitude greater than 20% of the background content have been considered.

III. RESULT

We have analyzed night time enhancement in foF2 over Jicamarca (120S, 76.90W; dip 0.280).

We have studied2002 and 2014 high solar active years. December 2014 data is not available. Table 1shows the nighttime enhancement in foF2 during 2002.for parameter foF2out 149 number of occurrence, 127 enhancements occurred during pre midnight hours and 22 enhancements occurred during post midnight hours.

TABLE-

Number of occurrence of enhancement

Year	foF2	Pre-midnight	Post-midnight
2002	149	127	22
2014	94	91	03

A. Monthly percentage of occurrence of nighttime enhancement in foF2

Figure 1a shows the percent of occurrence of each month during 2002 peak solar activity year of 23rd solar cycle. It is seen from the figure that percentage of occurrence nighttime enhancement is the greatest for the period of March and the lowest for the June. Figure 1b shows the percent of occurrence of each month during 2014 peak solar activity year of 24th solar cycle. It is seen from the figure that percentage of occurrence nighttime enhancement is the greatest for the period of September and the lowest for the June. In2014 December data are not available.

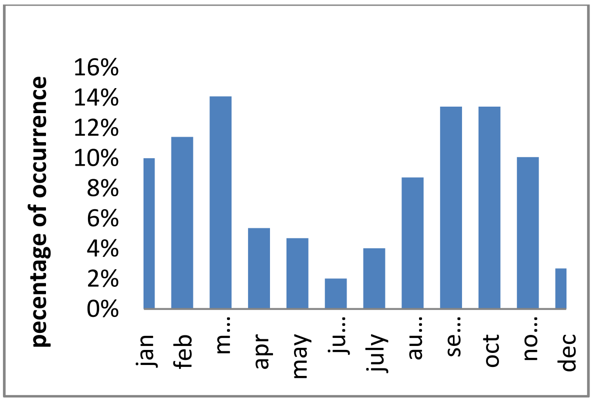

Fig.1.(a) Monthly percentage of occurrence of nighttime enhancement in foF2 during 2002

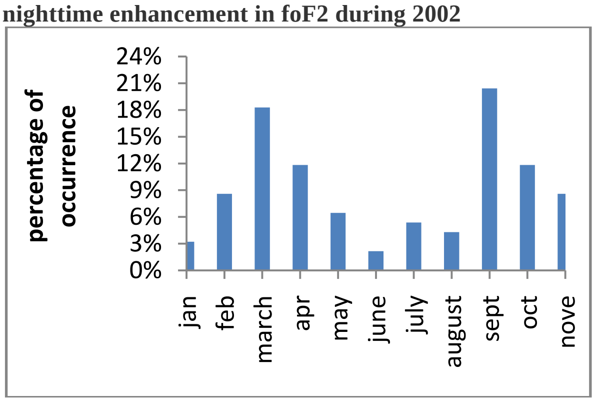

Fig.1 (b) Monthly percentage of occurrence of nighttime enhancement in foF2 during 2014

B. Seasonal percentage of occurrence of nighttime enhancement in foF2

Figure 2a shows the seasonal percentage of occurrence during 2002 peak solar activity year of 23rd solar cycle. It is seen from the figure that percentage of occurrence nighttime enhancement is the greatest for the period of equinox and the lowest during the summer. Figure 2b shows the seasonal percentage of occurrence during 2014 peak solar activity year of 24th solar cycle. It is seen from the figure that percentage of occurrence nighttime enhancement in foF2 is the greatest for the period of equinox and the lowest during the summer. Seasonal percentage of occurrence in both years is maximum in equinox and lowest in summer. Percentage of occurrence of enhancements in winter is 32%, in summer 19% & in equinox 46% during 2002 year. But in 2014 Percentage of occurrence of enhancements in winter is 20%, in summer 18% & in equinox 62%.

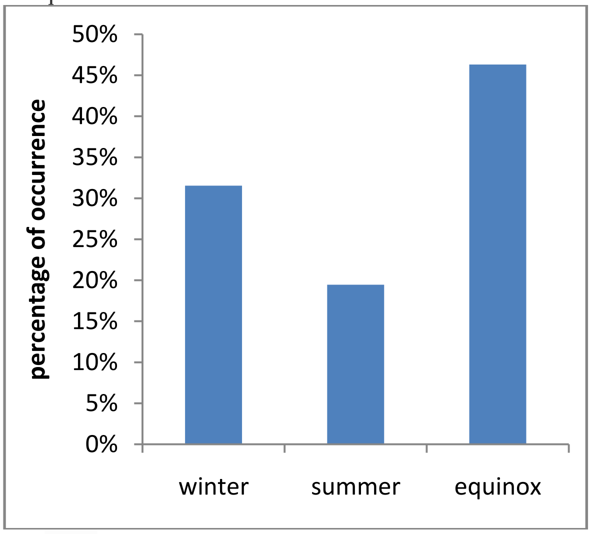

Fig.2 (a) Seasonal percentage of occurrences of nighttime enhancement in foF2during high solar activity period (2002) of 23rd solar cycle

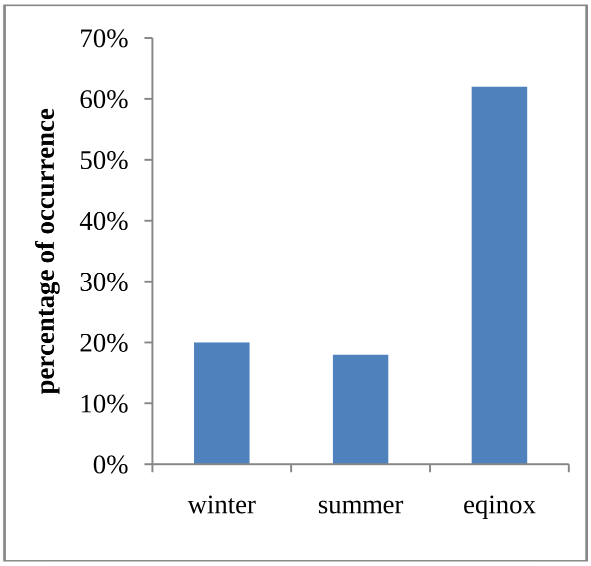

Fig.2 (b) Seasonal percentage of occurrence of nighttime enhancement in foF2 high solar activity periods (2014) of 24th solar cycle

C. Duration of nighttime enhancement in foF2

Figure 3 shows duration of nighttime enhancement in foF2 during high solar activity period of 23rd and 24th solar cycle. Figure 3(a) represents duration of nightime enhancement in foF2 in 2002 peak year of 23rd solar cycle Figure 3(b) represents duration of nightime enhancement in foF2 in 2014 peak year 24th solar cycle. It is seen from the figures that the duration of enhancement varies 2 to 10hr. In 2002 (High solar activity period for 23rd solar cycle) the maximum percentage of duration in foF2 is of 9hr, where as in 2014 (High solar activity period for 24th solar cycle) maximum percentage of duration in foF2 is of 7hr.

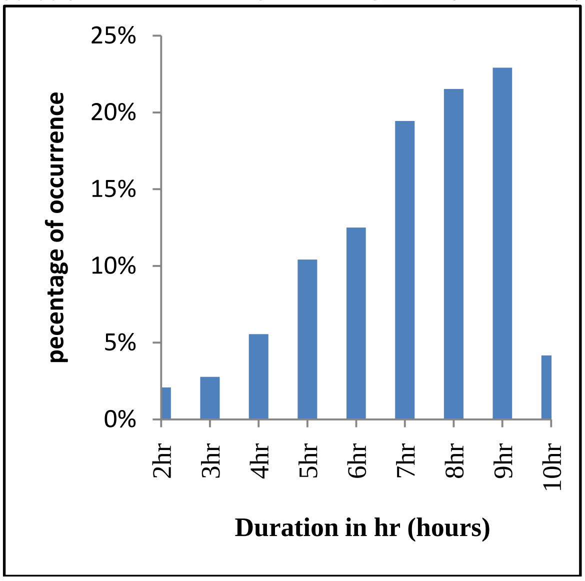

Fig.3 Duration of nighttime enhancement in foF2 high solar activity period (2002) of 23rd solar cycle

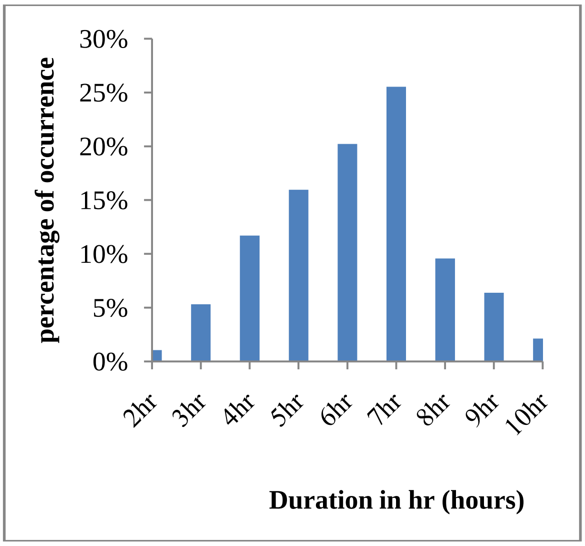

Fig 3 (b) Duration of nighttime enhancement in foF2 high solar activity periods (2014) of 24th solar cycle

IV. DISCUSSIONS

The preset study allows us to examine the morphology of night time enhancement for foF2. The results presented in previous sections give comprehensive picture of the night time enhancement in foF2 from January 2002 to November 2014. At low latitude station Jicamarca

(12oS, 76.90oW). This period has 23rd and 24th solar cycle.

Post sun set increases in the upward equatorial (E X B) drifts due to the polarisation affect, the bottom side start to steepen when the altitude F-region is high enough to overcome the recombination effect. We know that the nighttime ionosphere is under the control of chemical loss and Transport process, so we can say that transport effect must dominate and overcome the recombination processes to form the enhancement in foF2. Recombination processes and the dynamics simultaneously control the variation of nighttime ionosphere. Dynamic processes involve drifts due to natural winds, electric field aligned plasma flux, diffusion,thermal expansion thermal contraction. Drifts and thermal contraction mainly cause of change of hmF2 during night-time. They together with the variation of back

Paulista (-22.4°, -44.6°, magnetic latitude -13.4°), and Sao Jose´ dos Campos (-23.2°, -45.9°, magnetic latitude -14.1°), Brazil; Tucumán (-26.9°, -65.4°, magnetic latitude -16.8°), Argentina. In a more restricted region over Tucumán, the phenomenon was also investigated by the total electron content (TEC) maps computed by using measurements from 12 GPS receivers. A detailed analysis of its height ionosonde plots suggests that travelling ionospheric disturbances (TIDs) caused by gravity wave (GW) propagation could play a significant role in causing the phenomenon both for quiet and for medium/high geomagnetic activity; in the latter case however a recharging of the fountain effect, due to electric fields penetrating from the magnetosphere, joins the TID propagation and plays an as much significant role in causing impulsive electron density enhancements.

According to MuzammilMushtaq(2015) The variation in foF2 due to day time and the night time period in which at day time foF2 is relatively higher than at night time. However, there is an extraordinary trend occurring in the month of June for both solar maxima and minima in which foF2 fluctuates at daytime, but at night time it changes periodically. This enhancement in night time foF2 at mid-latitude is called MSNA, the combined effects of neutral wind and the geomagnetic configuration could be explained by both the daytime depletion and the night time enhancement. At the night time upward wind lifted the ionosphere up to regions of lower recombination rate, but during the daytime at the same location the strong downward wind pushed the ionosphere up to regions of high recombination rate. This potentially leads to electron density enhancement at night and depletion at noon (Liu et al., 2010). For the months of March and September the occurring time of maximum and minimum foF2 are same for solar maximum years and for solar minimum years and the slightest change in hours for maximum values occurs in the months of June and December while the timings of minimum values are remain same for solar maximum and solar minimum years (Muzammil Mushtaq2015)

V. CONCLUSIONS

In the morphological study of night enhancement in foF2, we have collected the critical frequency (foF2) data at low Jicamarca (120S, 76.90W; dip 0.280).

The conclusions can be summarized as below:

1. Number of occurrences at low latitude station is maximum during pre midnight hours than post midnight in both year
2. Number of occurrences in 2002 are greater than 2014
3. Percentage of occurrences in equinox are maximum and minimum in summer
4. Peak size of night enhancement is maximum in March and minimum in June in both years.

In 2002 (High solar activity period for 23rd solar cycle) the maximum percentage of duration in foF2 is of 9 hours, where as in 2014 (High solar activity period for 24th solar cycle) maximum percentage of duration in foF2 is of 7 hours

In 2002 (High solar activity period for 23rd solar cycle) the time of peak enhancement is around 20000-0300 hours LT where as in 2014 (High solar activity period for 24th solar cycle) time of peak of night enhancement is found around 1900-0200 hours LT

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