

Investigating the Midlatitude Night Time IEC Enhancements with Conjugate Location



Physics

KEYWORDS : Nighttime IEC Enhancement, Ionospheric Electron Content, Low Solar Activity

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ABSTRACT

The ionosphere is rather changeable, especially during disturbed periods and is considered an important object of experimental exploration. The ionospheric electron content observation provides data on position and structure of ionospheric regions. Nighttime enhancement in ionospheric electron content (IEC) has been studied by various researchers in the mid-latitude regions. Ionosonde data of ITEC for nighttime enhancement at mid-latitude is considered in the present study from two conjugate station Athance (38°N-24°E) and Grahmstorm(33°S-27°E) during low solar activity from January 2009 to December 2013. The events were taken as in terms of their duration, their time of occurrence of peak and their dependence on local time. Most of the nighttime enhancement events in ionospheric electron content are observed in equinox season during pre-midnight hours at Northern hemisphere with maximum between 2100-2200 hours (LT) and southern Hemisphere during pre-midnight hours with maximum between 2200-2300 hours(LT). The duration of enhancement is often large in Northern as compared to Southern.

1 Introduction

The atmosphere, in which we live, is influenced by the sun dynamic and violent sun that produces energy for life on earth. The ionosphere is an important layer of atmosphere that plays a unique role because of strong coupling processes to region below. The ionospheric plasma is formed by photoionization of the neutral atmosphere by the solar EUV and UV. As the photoionization acts as the major production of the ionospheric plasma, it was expected that the ionosphere varies with solar intensity and zenith angle. However, observations show that numerous ionospheric plasma structures deviate from the predicted solar controlled morphology. Deviation of the ionospheric plasma structure from expected solar controlled behavior is often named as the "Anomaly" in the ionosphere society. Nighttime enhancements in ionospheric electron content (IEC) have been studied by various workers in the equatorial anomaly and mid-latitude regions. At mid-latitudes the primary source has been identified as a downward flow of plasma from the proton sphere to the ionosphere. In addition, neutral air winds modulate these enhancements at all latitudes (Anderson and Klobuchar, 1983; Bailey et al., 1991). At mid-latitudes (Essex and Klobuchar et al., 1980) reported that nighttime IEC enhancements, which they observed mostly around 03:00 LT during the December months, are accompanied by large increases in peak density of the F layer and a lowering of layer height, which shows that the enhancement takes place in the F-region of the ionosphere. Use of IEC and NmF2 in such studies tells us about such enhancements over that particular location only, but in reality, it is observed in a wider area in space. Therefore, it is difficult to tell exactly where in the latitude range its peak occurs. In the recent past the technique of topographic imaging of the ionosphere, which gives latitude versus height distribution of ionospheric electron density, has proved its potential in studying the ionospheric properties, like the mid-latitude trough (Kersley et al., 1997; Pryse et al., 1998 and references therein), as well as its modeling in a much wider area used to study. In general, after nighttime (LT), Ionospheric electron content (IEC) starts increasing and post-noon period, it becomes maximum, after

that it start decreasing and attains minimum or low value around 2200-2400 hrs LT, simple theory suggested that after sunset when thermosphere is no longer bare to radiation from the sun electron content would decay steadily as recombination occurs. It is recognized that IEC does not decrease throughout the night as predicted by simple theory by shows anomalous enhancements under a broad range of geophysical conditions (Arendt et al., 1964; Balan et al., 1991). One explanation, that receive attention, is that the ionization is lifted up by an equatorward neutral wind or an eastward electric field to regions of small loss rate (Hanson et al., 1964). However, vertical drifts alone cannot fully explain the persistence of nighttime ionosphere (Kohl et al., 1969; 1968). The formation of pre-midnight peaks in winter is mainly due to heights with a lower recombination rate (Mikhailov et al., 2000b; 2000a). Large amplitudes during equinox may be associated with the highest efficiency in the interaction between the earth and the solar wind that occurs during these periods (Hargreaves et al., 1992).

Nighttime enhancement (pre-midnight and post-midnight) is a unique phenomenon for the mid to low latitude F2 region which has long been observed in IEC. In the equatorial anomaly region, the most important source of such nighttime enhancement is the evening increase in the upward $E \times B$ drift at the equator (Balan et al., 1994). At mid latitudes, the chief source has been identified as a downward flow of plasma from the protonosphere to the ionosphere (Bailey et al., 1991). The behavior of the nighttime enhancement in ionosphere does not agree with the predicted by simple theory, and is known as anomalous nighttime increase (ANI). A possible explanation for this ionosphere phenomenon is the electric fields in the plasmasphere squeeze the plasma from high to low magnetic L shells. The nighttime enhancement is ITEC is the northern and southern hemispheric studied and concluded that when an enhancement occurred in one hemisphere then either no enhancement or only a weak enhancement may occur in conjugate hemisphere (Tyagi et al., 1974). Increase in various characteristics such as frequency of occurrence,

time of occurrence, amplitude and duration of increase in electron content are found to depend not only on location and season but also on solar and magnetic activity (Balan et al., 1991). All the characteristics of nighttime enhancement, like time of occurrence of peak, their duration of enhancement have been analyzed. The main aim is morphological study of nighttime enhancement in IEC during low solar activity period 2009-2013.

Most of the nighttime enhancements in ionospheric electron content are observed in winter season during post midnight hours at Northern Hemisphere, during pre midnight hours with maximum between 0100-0200 hours(LT) and in Southern Hemisphere during pre mid night hours with maximum between 1900-2100 hours(LT). The duration of enhancement is often large in Northern Hemisphere as compared to Southern Hemisphere (Nuzhat et al.,2013).

2 Data and Analysis

IEC data for this study , for the period January 2009 to December 2013 for mid latitude zone were obtained from national geophysical data centers space physics interactive data resources <http://ngdc.noaa.gov/>

Case of nighttime enhancement was grouped in to three seasons as winter, summer and equinox. Nighttime enhancement for IEC is also divided into pre-midnight (1900-2300) hours (LT) and post mid (0000-0600) hours (LT)

Period, depending on the time of prominent peak of enhancements occurred. In the current study, the prominent peak is considered for statistical purpose, only those enhancements were taken into consideration, which had amplitudes greater than 10% of the background value.

3 Result

In the conjugate location number of enhancements occurred during the period of study i.e. from January 2009 to December 2013, for IEC during pre-midnight and post-mid hours are shown in table -1, it is clearly seen from the table that highest total no. of enhancement in IEC parameters occurred at station Athance(38N-24E).

IEC enhancement

Station	Total	Pre-mid	Post-mid
Athance	297	212	85
Grahmstorm	287	165	122

Table 1-Number of occurrence of enhancements

3.1 Percentage of night time enhancement in IEC

FIG.1 show the average monthly variation of percentage of night time enhancement in IEC from January 2009 to December 2013.It is seen from the figure that, at mid latitude location Athance (38N-24E) percentage of enhancement is maximum in IEC during the month of March, while at mid latitude location Grahmstorm (33S-27E) percentage of enhancement is maximum in IEC during the month of October and November.

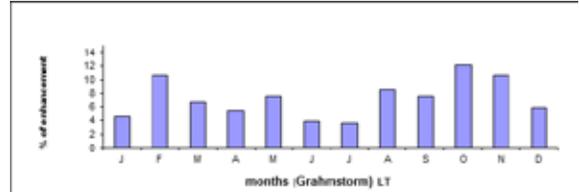
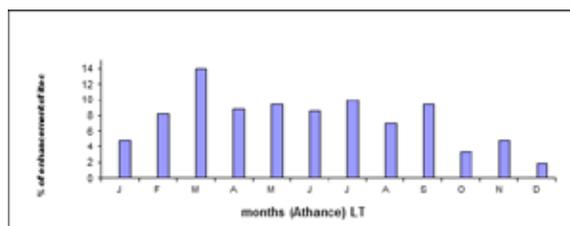


Fig.1
Monthly variation of percentage of nighttime enhancement in IEC during January 2006-december 2013

3.2 seasonal variation of night time enhancement in IEC

Fig. 2 represent the average seasonal variation of nighttime enhancement in IEC from January 2009 to December 2013 . it is seen that at mid latitude location Athance (38N-24E) maximum percentage of enhancement in IEC during equinox season also at Grahmstorm(33S-27E) maximum percentage of enhancement in IEC during equinox season.

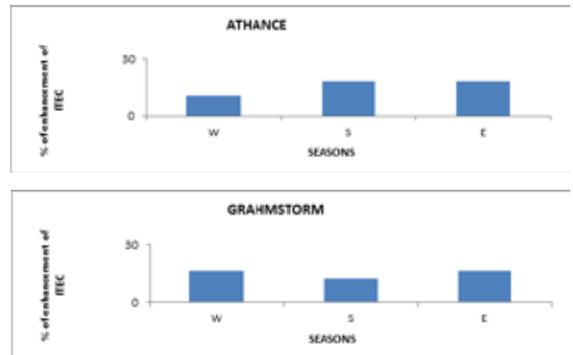
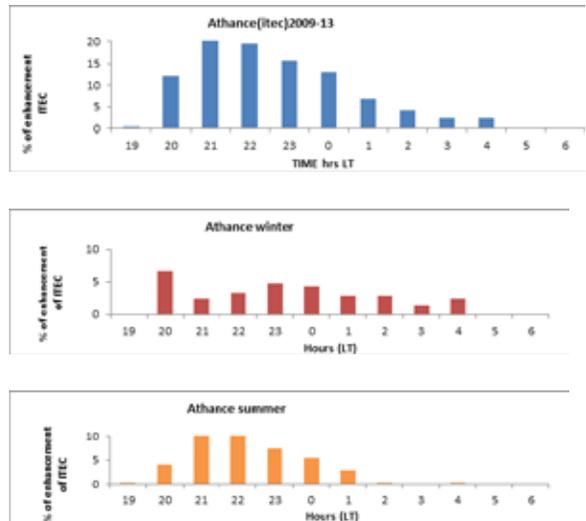


Fig.2
Seasonal variation of nighttime enhancement in IEC during January 2006-december 2013

3.3 Time of peak of enhancement in IEC

FIG.3 present latitudinal and average seasonal variation of time of enhancement peak in IEC for the period of January 2009 to December 2013.It is clear from the figure that at mid latitude location Athance (38N-24E) pre-mid night events are dominating average pattern of IEC shows that the maximum percentage of occurrence of enhancement peak occurred around (2100-2200) hrs LT. whereas at Grahmstorm(33S-27E) the maximum percentage of occurrence of enhancement peak occurred around (2200-2300) hrs LT.



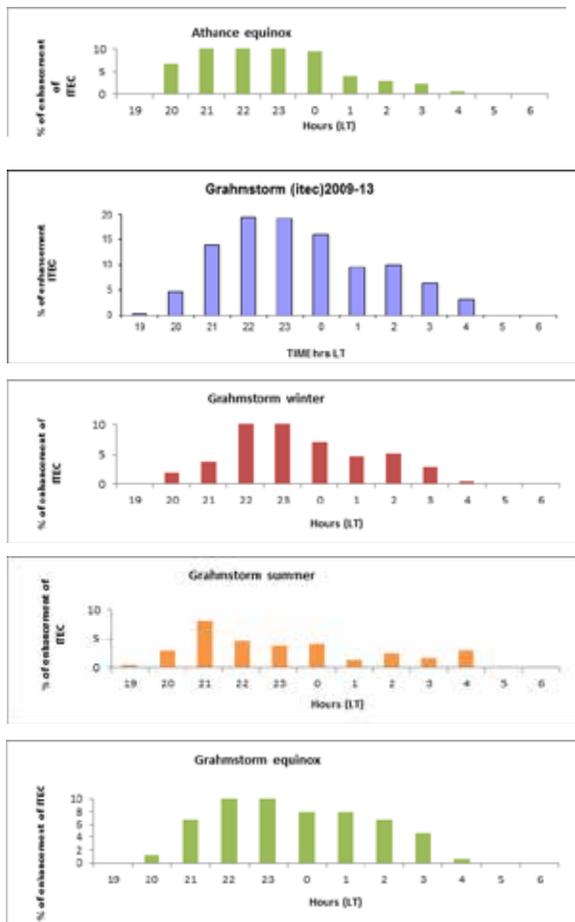


Fig.3 Time of peak nighttime enhancement in IEC during january2006-december 2008

3.4 Duration of night time enhancement in IEC

FIG.4&5 represent the average percentage of duration of enhancement during pre mid night and post mid night hours. It is seen from these figures that the duration of enhancement varies between 2 to 11 hours . At Athance (38N-24E) maximum percentage of duration during pre-mid night hours. maximum percentage of duration in IEC is of 5 h during post midnight hours. where as a at Grahmstorm(3327E) maximum percentage of duration in IEC is of 2h during pre mid night hours .And during post midnight hours the percentage of duration in IEC is of 6h.

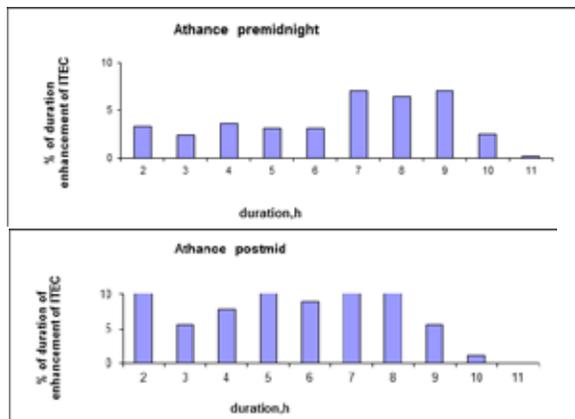


Fig.4 Duration of nighttime enhancement in pre-midnight and post-midnight hours during january 2006-december 2013

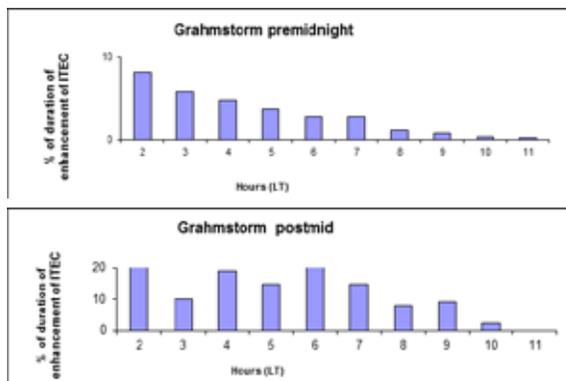


Fig.5 Duration of nighttime enhancement in pre-midnight and post-midnight hours during january 2006-december 2013

4 Discussion

The present study investigating the morphology of nighttime enhancement of IEC. The result obtained provide the convincingly comprehensive picture of the effect of the solar activity, seasonal and local time variation of IEC, on various characteristics of nighttime enhancement at mid latitude location during low solar activity period i.e January 2009 to December 2013. (Balan et al.,1991) observed that there is little latitudinal variation in the time of occurrence of peak enhancement in IEC during summer . But in equinox and winter, the time of peak enhancement occurrence shows latitudinal variation. At mid latitude location pre-midnight occurrences are predominant.

The neutral wind plays an important role in the variation of ionospheric F region parameters by sustaining (lowering)the F region ionization to higher (lower) altitudes where the ion neutral recombination rate is significantly decreased (increased), leading to enhance (reduced) electron densities at magnetic mid-latitude regions, the electron density enhancement could be produced by the longer duration of photoionization from solar radiation(Sojka et al.,1985; Horvath and essex,2003; Chen et al.,2011,2012). At mid-latitudes during all seasons the meridonal neutral winds is equatorward during nighttime and attains its maximum speed at around mid-night (Hernandez and Roble,1984). Thus, the strong downward diffusion of plasma from the protonosphere, combined with the neutral air winds interaction, can easily produce enhancements in nighttime ionosphere electron density at min-latitudes during winter at solar minimum. Bailey et al.(1990a) have modeled winter nighttime values of TEC for ray paths which traverse the mid-latitude ionosphere. The modeled values for magnetically quiet solar minimum conditions show enhancements, which peak durind the post-midnight period, when the downword flow of plasma through the 2500km altitude level exceeds that which is lost chemically at lower altitudes.

(Balan et al., 1986) had observed that at the low-latitude station, 77% of the nights had TEC enhancements of which 55% occurred during pre-midnight hours and 22% during post-midnight hours during a solar maximum year. However, during a solar minimum year only 16% of the nights had TEC enhancements of which 7% occurred during pre-midnight hours and 9% during post-midnight hours. On global maps nighttime enhancement are clearly visible in the form of the enhanced electron density region (EEDRs) at the geomagnetic mid-latitudes 25^o-45^o (Wilson et al., 1995; Davis, Hartmann, 1997; Ho et al.,1996;1998; Brunini et

al.,2003). The EEDRs extend from evening sector to morning one. The EEDRs are observed more often in the quiet winter condition under low solar activity (Balan et al.,1991; Mikhaailov et al.,2000; Farelto et al.,(2002).

(Sudhir Jain et al., 1995) had conducted a study of nighttime enhancements and found that the correlation between amplitude and magnetic activity is negligible. But contrary to the other studies (Balan et al., 1991) found that the enhancement was mainly a post-midnight phenomenon and that the occurrence of the enhancement as a whole is negatively correlated with solar activity.

At mid-latitude location Athance(38°N-24°E),percentage of enhancement is maximum in IEC around 1900-2100 hrs LT. Although, during equinoctial month at high latitude location, percentage of enhancement during post mid-night hrs around 0100-0200 hrs LT. At mid-latitude shows maximum percentage of enhancement peak during pre-midnight hours around 1900-2300hrs (K singh et al.,2013).

The observed features, particularly the time of occurrence and solar activity dependence of the enhancements at the different latitudes, indicated that the enhancements are caused by different mechanisms at different latitudes.

The important mechanisms are following-

- (a) Plasma diffusion from protonosphere.
- (b) Electrodynamical drifts and plasma motion due to neutral winds.
- (c) Plasma transfer from conjugate ionosphere.
- (d) Movement of the mid-latitude trough.
- (e) Cross-L plasmaspheric compression and subsequent enhancement in plasmasphere-ionosphere plasma flow.

Corpuscular ionization for the first two mechanisms were found significant for nighttime enhancements at low latitudes. Generally, during the nighttime, two peaks were observed first is the post-sunset peak varies in the range 15-50%, while the second is post-midnight peak varies in the range 22-70%, for all the seasons. These two peaks can be attributed to the steep electron density gradients that are caused by the onset and turn-off solar ionization(Bilitza et al.,2004 and Chou et al.,2008).

6 Conclusion

Present study provides us a comprehensive picture of the effect of season, solar activity on IEC. The main results are summarized as, enhancement are more frequent in equinox season as compared to winter and summer at mid latitude. At mid latitude location small peak size both during pre-midnight and post-midnight. At mid latitude location pre-midnight is of shorter duration and post-midnight hours are of longer duration.

7 Acknowledgement

The authors thank to national geophysical data centers space physics interactive data resources <http://ngdc.noaa.gov/> for providing data of ionospheric parameter value for the duration under consideration in present study.

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