

Seasonal variation of Ionospheric E Sporadic Layer at Mid Latitude Region during Solar Cycle 24

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Abstract: *In this research the ionospheric sporadic E (Es) layer parameters (foEs, fbEs and h'Es) are studied at mid latitude Yamagawa, Japan (31°N, 130°E) station for a long period (2010-2016) during quiet and disturbed conditions. The data has been analyzed to study the seasonal and annual variations in the occurrence of Sporadic E along the period selected, from results it is found that the maximum values of fbEs and foEs are observed during the summer while the minimum values are observed during winter. About h'Es parameter the maximum values are recorded during the spring and the minimum values are recorded in winter. The variability between foEs and fbEs is studied; it is revealed that there is a correlation between the two parameters foEs and fbEs for all seasons except in summer foEs higher than fbEs also in sunrise and sunset. The occurrence of the sporadic E layer in mid latitude shows that it changes from year to year, strong dependence on local time and season, also found a very good correlation coefficient between fbEs and foEs ≈ 0.9 for all season. And the distribution of frequency ratio is polynomial four degree.*

Keywords: Sporadic E; blanketing frequency; Critical frequency

1. Introduction

Sporadic E layer (Es), is a thin ionized layer in the ionospheric E region, mostly at the height between 95 and 120 km which it vary a little and along with electron density [1, 2]. The research in space weather described sporadic E layer an important ingredient in physical and morphological, which is effect on the ionospheric propagation of high frequency (HF3-30 MHz) and very high frequency (VHF 30-300 MHz) radio waves, there by posing a significant impact on the modern communication, navigation, and radar systems [3]. Es layer is a propagation mode in the ionosphere which can allow VHF signals to propagate over long distances of a reflection from the E layer; also it is able to reflect radio waves at much higher frequencies than normal. These thin layers are in the form of patches, "clouds" of may be 100km in horizontal extent but only a few km thick. This is why sporadic E propagation, is so variable, especially at higher VHF frequencies. For a signal to propagate via Es a cloud of sufficient ionization must exist at the mid-path point [4]. A sporadic E layer with dense ionization blocks the upper ionospheric layers in ionosonde observations and it is called, blanketing sporadic E (Esb) [5] the critical frequency of Es layer (foEs) is another important parameter, which is important in application which based on radio wave communication [6]. The most important characteristics of the Es-layers are their blanketing frequencies fbEs and critical frequencies foFs (i.e. critical frequencies are proportional to square root of electron density). For thin sporadic Es-layers (usually the thickness is smaller than 3 km) where fbEs is the frequency that characterizes the largest plasma density [7]. Radio waves travel more slowly within the ionosphere than in free space therefore, the apparent or "virtual" height (h'Es) is recorded instead of a true height. For frequencies approaching the level of maximum plasma frequency in a layer, the virtual height tends to infinity, because the pulse must travel a finite distance at effectively zero speed, so that the frequencies at which occurs are called the critical frequencies [8]. A general depression of the horizontal magnetic field is one of the most systematic effects on ground-based magnetometer

data (Moos, 1910). The storm-time disturbance index (Dst) is one of the most widely used indices in academic research on the magnetosphere, in part because it is well motivated by a specific physical theory [9]. (Sugiura, 1964). Which define as designed to measure frequently interpreted as a rise of a westward magnetospheric equatorial ring current, whose magnetic field at the Earth's surface slightly cancels the predominantly northerly component of the main field [10]. Dst is not a range index, but Its proportional a range index, however, determined by the difference between the largest and smallest disturbance field.

2. Previous Studies

The first studies of Es layer down by Sir Edward Appleton in (1930) based on observations of the ionospheric E layer showing occasional irregularities. After that In (1930) Ernest K. Smith began work on his master's thesis at Cornell University – he wanted to prove that over 400 reports of the reception of television stations at distances of 500 to 1600 miles was due to Es, he followed this up with his PhD thesis (1957) by doing a macroscopic study of worldwide Es using ionosonde [11]. Late 1950s During the IGY (International Geophysical many more ionosonde came on line to study the diurnal and seasonal probabilities of Es in the northern hemisphere region. [12]. Then many ionosonde came on line in the mid latitude, such as K. Hockett. al (2001) from data analysis of 1900 radio occultation events in two month (June and July) 1995, 1540 events in October 1995, and 2690 events in February 1997 confirms seasonal dependence of sporadic E layers. The meridian slices of average sporadic E activity show a dominance of plasma irregularities in the summer hemisphere. [13]. other researcher have been observed to take place on a routine basis with ionosonde the Arecibo incoherent radar There might be some seasonal differences in the tidal modes involved in Es formation, as recommended for example by the ionosonde studies by Haldoupis et al. [2006] which favored the presence of diurnal tides with short vertical wavelengths in July. Prasad, S N V S et al studied in (2012) the simultaneous hourly ionograms, from three station an equatorial station, a low

latitude station and a mid-latitude station during the high sunspot year 2001, are scaled for the study of E-region parameters, namely the virtual height of sporadic E-layer (h'Es) and the critical frequency of sporadic E-layer (foEs). The diurnal, seasonal and day-to-day variations in h'Es and foEs are studied. It is observed that the sporadic E-layer is absent in the early morning and post sunset hours over an equatorial station during three different seasons. The values of h'Es are more at mid-latitude station as compared to those at equatorial and low latitude stations during the three different seasons. The critical frequency of sporadic E-layer (foEs) over equatorial shows higher values, compared to those over low latitude station and a mid-latitude station during daytime hours, in three different seasons indicating that foEs decrease as the latitude increases. The seasonal variation in foEs shows higher values during daytime hours of equinox and winter months over equator compared to those over low and mid latitude stations. The variations in h'Es and foEs for quiet and disturbed conditions indicate that the h'Es variation during quiet days of equinoctial months at mid-latitude station shows a primary peak around morning hours while it is absent at low latitude station and low latitude station. [14]. Atulkar (2016) studied the ionospheric sporadic E layer parameters from ground based ionosonde at mid latitude station during the ascending phase of 24th solar cycle. The comparison between the E-region parameters has been carried out on a diurnal, seasonal, annual and day night basis, its result found that diurnal maxima of FoEs, FbEs, and h'Es are generally higher during high solar activity also found that the highest values of FbEs are observed during the summer while the lowest values are observed during autumn [15]. Pavlov A. V., Pavlova, N. M., (2017), Study Long-term hourly values of the ionospheric E-layer peak electron density, NmE, measured from 1957 to 2014 by 4 mid-latitude ionosonde in the Northern geographic hemisphere were processed to select periods of geomagnetically quiet and low solar activity conditions using the 3-hour index, Ap, of geomagnetic activity and the daily solar 10.7 cm radio flux index, which calculate several descriptive statistics of NmE close to noon for each month in a year, including the mathematical expectation of NmE, the standard deviation of NmE from the mathematically expected NmE, and the coefficient of variations of NmE.[16].

3. Data Analysis

Although earlier studies have demonstrated that sporadic E layer characteristics occurrence is dependent on solar activity, seasons and local time. Moreover, fewer comprehensive studies are available on low solar activity. Present work is a detailed study of sporadic E layer characteristics during solar cycle 24 (2010-2016) at mid latitude station, Yamagawa, Japan (31°N, 130°E) dependence on Disturbance storm time index (Dst) its value (-20 < Dst < 20) during low solar activity.

In this study we have used the digital ionosonde observations at mid latitude station Yamagawa, Japan. For years from January 2010 to December 2016 for Es layer the three ionospheric parameters which they are FoEs (Critical frequency of sporadic E-layer), FbEs (blanketing frequency of sporadic E-layer), and h'Es (height of sporadic E-layer)

with one hour resolution. The ionosonde data used in this study were obtained from National Geophysical Data Center's (NGDC), Space Physics Interactive Prediction (SPIDR) website. A comparative study between the E-region parameters has been ignored in this study. Each year is divided into four seasons namely spring (February, March, April) summer (May, June, July) autumn (August, September, October,) and winter (November, December, January) respectively. For this analysis we have used local time at yamagawa station (LT=UT+9hours) for calculation. We also compare between foEs (Critical frequency of sporadic E-layer) and fbEs (blanketing frequency of sporadic E-layer) at low solar activity.

3.1 Seasonal variation of critical frequency at yamagawa station

The ionosphere varies hourly, daily, monthly and also seasonally depending on the solar zenith angle (angle measured at the Earth's surface between the Sun and the zenith) has a seasonal variability, and because of the neutral atmosphere from which the ionosphere is created. Usually, the whole year is categorized into four seasons, i.e. spring (February, March, April), summer (May, June, July), autumn (August, September, October) and winter (November, December, January).

From figure (1) shown the Seasonal variability of foEs at mid latitude station (Yamagawa) Japan during 2010 to 2016 at low solar activity. From this figure founded that the lowest values of foEs were observed during winter followed by spring and autumn and the highest values were observed during the summer. and the value of FoEs between (2 Hz -10 Hz) and highest value of foEs appeared in summer season at year 2015. the distribution of foEs showed that The day and night time variability of foEs was maximum during day hours while the minimum in the night hours. The reason of this the critical frequency depended on electron density which is recommended at night and ionization in day time.

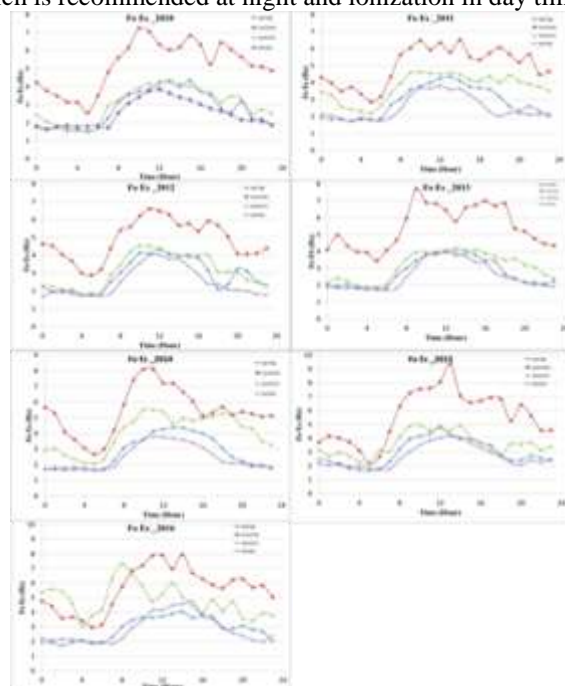


Figure 1: Seasonally variation of critical frequency (foEs) during years 2010-2016

Figure (1) shown the Seasonal variability of foEs at mid latitude station (Yamagawa) Japan during 2010 to 2016 at low solar activity. From this figure founded that the lowest values of foEs were observed during winter and spring then autumn and the highest values were observed during the summer. and the value of FbEs between (2 Hz -8 Hz) and highest value of fbEs appeared in summer season at year 2015.the distribution of fbEs showed that The day and night time variability of FbEs was maximum during day hours while the minimum in the night hours. The reason of this the critical frequency depended on electron density which is recommended at night and ionization in day time.

3.2 Seasonal variation of blanketing frequency of sporadic E-layer at yamagawa station

The ionosphere varies hourly, daily, monthly and also seasonally. This is depended on the solar zenith angle (angle measured at the Earth's surface between the Sun and the zenith) has a seasonal variability, and because of the neutral atmosphere from which the ionosphere is created. Usually, the whole year is categorized into four seasons, i.e. spring (February, March, April), summer (May June, July), autumn(August, September, October,) and winter (November, December, January) respectively.

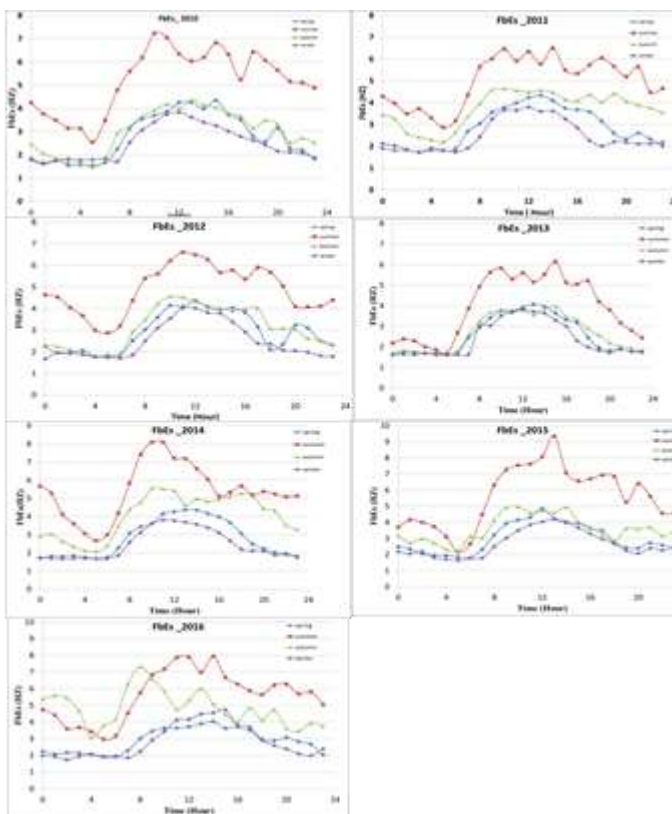


Figure 2: The seasonal variation for Sporadic E-layer blanketing frequency (FbEs) at mid latitude station (Yamagawa) Japan during 2010 -2016

From figure (2) shown the Seasonal variability of fbEs at mid latitude station (Yamagawa) Japan during 2010 to 2016 at low solar activity. From this figure founded that the lowest values of fbEs were observed during winter followed by spring and autumn and the highest values were observed during the summer. and the value of FbEs between (2 Hz -10 Hz) and highest value of fbEs appeared in summer season at

year 2015.the distribution of fbEs showed that The day and night time variability of FbEs was maximum during day hours while the minimum in the night hours. The reason of this the critical frequency depended on electron density which is recommended at night and ionization in day time.

3.3 Seasonal variation of virtual height of sporadic E-layer at yamagawa station

The seasonal variation of virtual height of sporadic E-layer also studied. Usually, the whole year is categorized into four seasons, i.e. spring (February, March, April), summer (May June, July), autumn (August, September, October,) and winter (November, December, January) respectively.

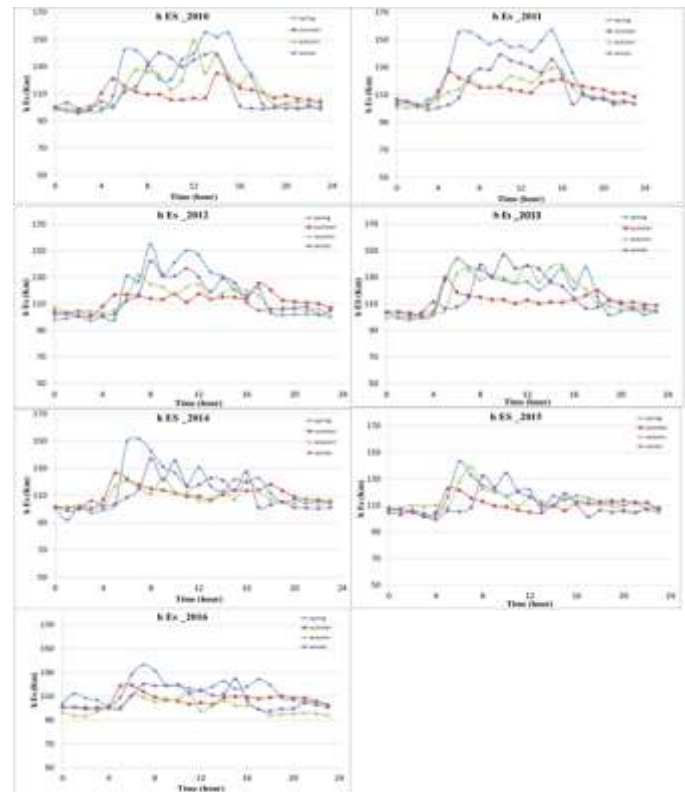


Figure 3: Seasonally variation of sporadic virtual height (h'Es) during years 2010-2016

From figure (3) shown the Seasonal variability of h Es at mid latitude station (Yamagawa) Japan during 2010 to 2016 at low solar activity. From this figure founded that the lowest values of h Es were observed during winter followed by autumn and summer and the highest values were observed during the spring. and the value of h Es between (90 km -150km) and highest value of h Es appeared in spring season at year 2011.the distribution of FbEs showed that The day and night time variability of h Es was maximum during day hours while the minimum in the night hours.

4. Compare between blanking frequency and critical frequency in sporadic E layer

Also compare between blanking frequency and critical frequency in sporadic E layer.The seasonal variation Usually, the whole year is categorized into four seasons, i.e. spring (February, March, April), summer (May June, July),

autumn (August, September, October,) and winter (November, December, January) respectively, as in figure (4).

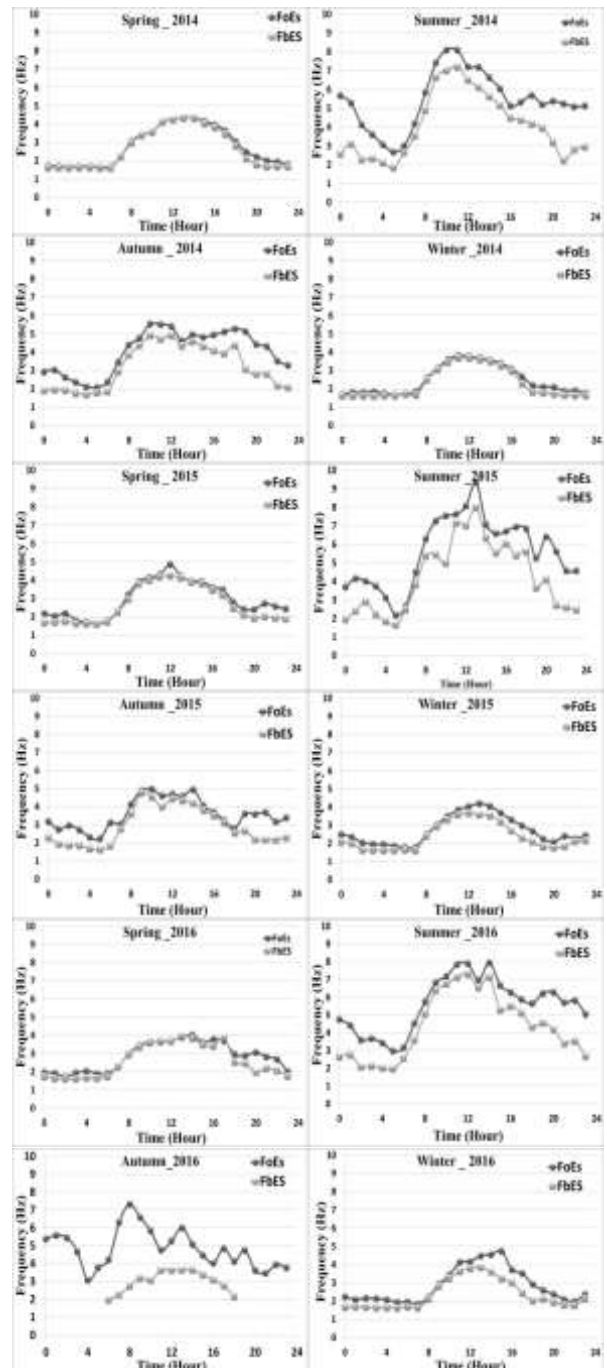
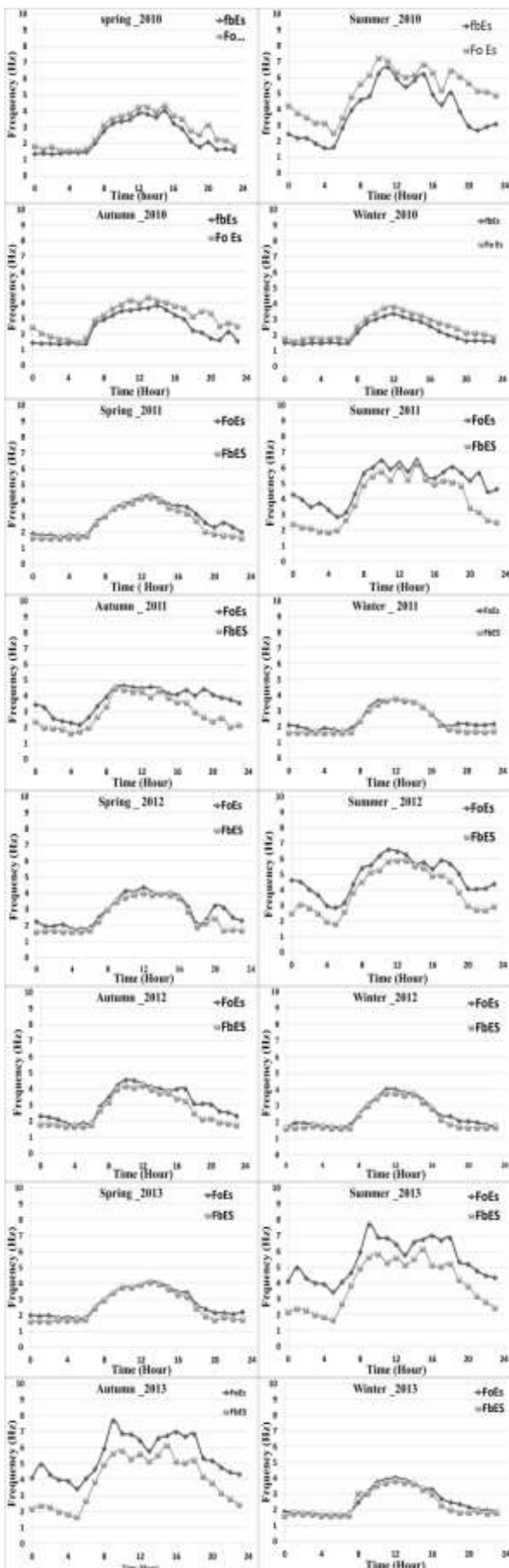


Figure 4: Seasonally comparing between blanketing frequency (fbEs) and critical frequency (foEs) at mid-latitude during years 2010-2016.

From figure (4) shown Seasonally comparing between blanketing frequency (fbEs) and critical frequency (foEs) in spring, autumn, winter and summer nearly the same shape but the window is too small between fbEs and foEs but in spring, and winter. However Summer and autumn window is the wide.

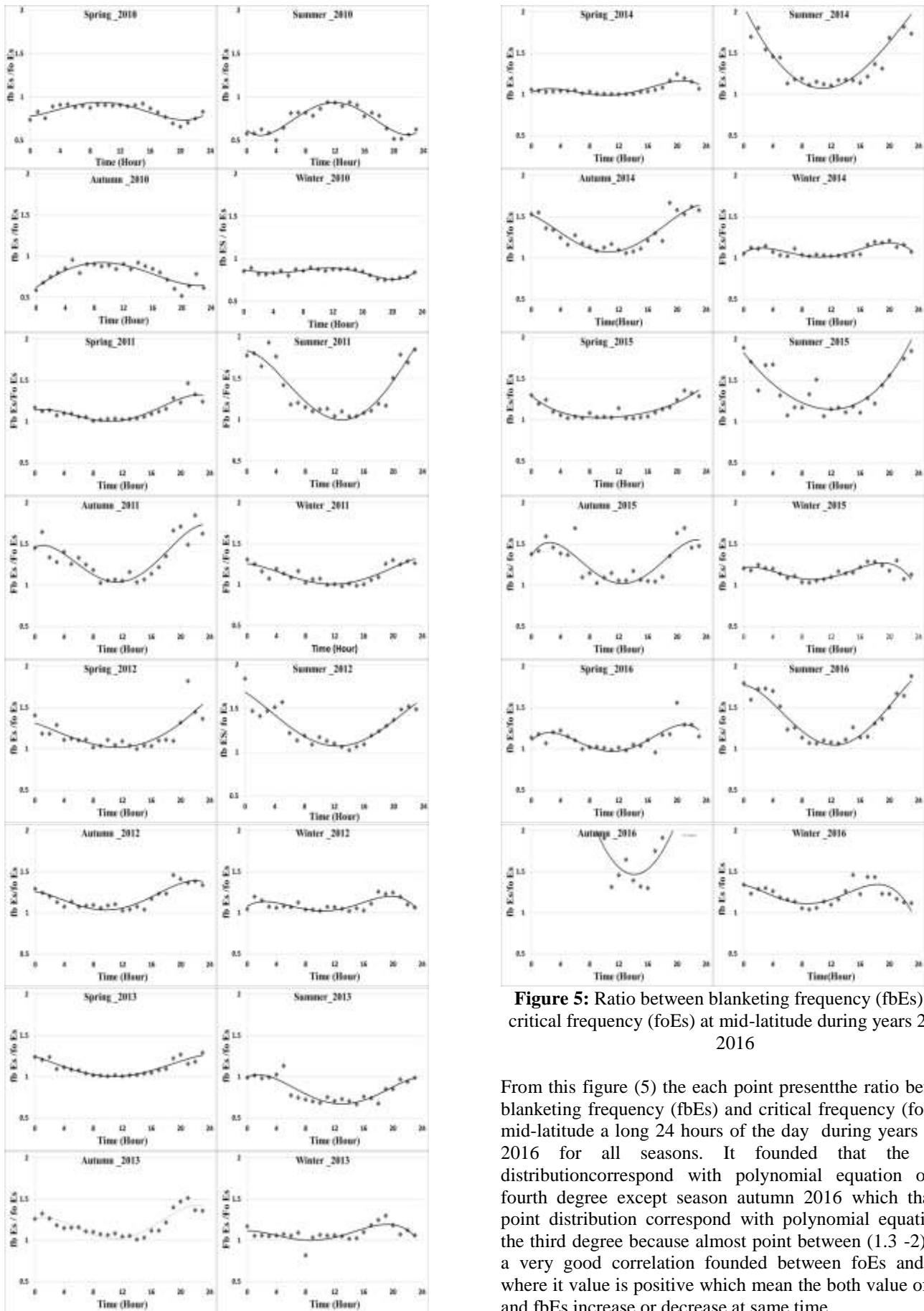


Figure 5: Ratio between blanketing frequency (fbEs) and critical frequency (foEs) at mid-latitude during years 2010-2016

From this figure (5) the each point present the ratio between blanketing frequency (fbEs) and critical frequency (foEs) at mid-latitude a long 24 hours of the day during years 2010-2016 for all seasons. It founded that the point distribution correspond with polynomial equation of the fourth degree except season autumn 2016 which that the point distribution correspond with polynomial equation of the third degree because almost point between (1.3 -2). And a very good correlation founded between foEs and fbEs where it value is positive which mean the both value of foEs and fbEs increase or decrease at same time.

5. Discussion

The Sporadic E is generally start forming during morning hours and appears less by noon time and then appears again during evening hours before they disappear. Their occurrence shows two peaks, one between and the other around and their seasonal occurrence was observed to be maximum during summer.

To explain this behavior many though put on. Since sporadic E layers are mainly due to metallic ions provided by the atmospheric ablation of meteoroids, their mean electron density and occurrence are expected to be directly proportional to the metal ion content. The role of metallic ions is recognized widely as being a key factor in Es occurrence, and often it has been associated with the sporadic nature of the phenomenon [Whitehead, 1989]. The metal ion content is determined by the meteoric deposition, the recombination loss by three body reactions that become more efficient at lower E region heights, and the photoionization of metal atoms, or during nighttime, charge exchange ionization of the metal atoms, MacDougall et al. [2000]. Although the photoionization by itself provides a clue to the explanation of the seasonal Es maximum, because during summer the solar radiation will ionize more of the metal atoms, this is far from sufficient to account for the strong Es summer maximum. Under the assumption that there is no dependence of metal atom ionization on metal ion density, concluded that the photoionization should result to a small increase of a few percent, very much in proportion to that in the critical E region frequencies, foE. This is well below the over 100% increases in foEs observed during summer. With respect to the loss mechanism of metal ions and a possible role on the Es summer maximum, this again requires a peculiarity of the wind profile during the summer in the context of the wind shear mechanism. The metal ions are removed from the formation process by being swept down to lower heights where they recombine by three bodies' collision reactions. Their transport to lower heights is controlled by the downward propagation of wind shear ion convergent nodes associated with the tides. However, there exists no evidence to suggest that something dramatic is happening in the tidal descent of sporadic E during summer which traps the metal ions at a height at which they cannot recombine and thus contribute toward a strong summer maximum in sporadic E. Finally, the increase of metal ion content caused by meteoric input increases was also considered in the past as a possible cause of the Es summer maximum.

6. Conclusion

- 1) Mid-latitude Es (blanking frequency, critical frequency and high) in the northern hemisphere occurred most often in the summer months (May thru August) during the late morning local time and early evening local time. There was a secondary peak in occurrence in December in the early evening.
- 2) There is a good correlation between blanking frequency and critical frequency in sporadic E layer

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References

- [1] Akala, A. O., Somoye, E. O., Adeloye, A. B., Rabin, A. B. " Ionospheric foF2 variability at equatorial and low latitudes during high, moderate and low solar activity, Indian Journal of Radio & Space physics, vol 40,p.p.73-81, 2011.
- [2] Wongcharoen, P., Kenpankho, P., Sepsirisuk, K., Supnithi, P., Noppanakeepong, S., Lerkvaranyu, S., Tsugawa, T., Nagatsuma, T., "The Variation of Critical Frequency of E layer over the Magnetic Equatorial Region, Chumphon, Thailand", International Reference Ionosphere 2013 (IRI2013), June 24-28, 2013,Olsztyn, Poland.
- [3] Hysell, D. L., Munk, J., and McCarrick, M., " Sporadic E ionization layers observed with radar imaging and ionospheric modification" American Geophysical Union.vol.41,p.p.6987-6993, 2014.
- [4] Jursa, A. S., HANDBOOK OF GEOPHYSICS AND THE SPACE ENVIRONMENT, National Technical Information Service,1985, 1 st edition
- [5] Yadav,V., Kakad, B., Bhattacharyya, A., " Quiet and Disturbed Time Characteristics of Blanketing Es (Esb) during Solar Cycle 23", Journal of Geophysical Research: Space Physics, vol. p.p. 2017.
- [6] Prasad, S. N. V. S., Prasad, D. S. V. V.D., Venkatesh, K., Niranjana, K. P., Rao, V. S. R.R., "Diurnal and Seasonal variations in sporadic E – layer (Es layer) occurrence over equatorial, low and mid latitude station – A comparative study", Indian Journal of Radio & space Physics, vol. 41,p.p.26-38, 2012.
- [7] E. V. Liperovskaya, O. A. Pokhotelov, Y. Hobara, M. Parrot," Variability of sporadic E-layer semi transparency (foEs – fbEs) with magnitude and distance from earthquake epicenters to vertical sounding stations", Natural Hazards and Earth System Sciences, vol 3, p.p 279–284,2003.
- [8] <https://data.noaa.gov/datasetsearch>
- [9] Daglis, i.A., "Effect of space weather on Technology infrastructure, Kluwer Academic publisher Springer Netherlands, 1st edition, 2004.
- [10] SUGIURA,N., "A GENERALIZATION OF THE WILCOXON TEST FOR CENSORED DATA, II, Osaka Journal. Mathematics, 165-174, 1964.
- [11] Leighton, H. I., Shapely, A. H. and Smith, E. K.," The Occurrence of Sporadic E during the IGY; Central Radio Propagation Laboratory, National Bureau of Standards, Boulder Colorado, Pergamon press Ink,1st edition 1962.
- [12] Wu, D. L., Ao, C. O., Hajj, G. A., Torre Juarez, M. de. La, and Mannucci, A. J., Sporadic E morphology from GPS-CHAMP radio occultation, Journal Geophysical Research., vol.110, 2005.

- [13] Hockea, K., Igarashia, K., Nakamura, M., Wilkinson, P., Wuc, J., Pavelyev, A., Global, J. W., "sounding of sporadic E layers by the GPS/MET radio occultation experiment", *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 63, p.p.1973-1980 2001.
- [14] Prasad, S N V S, Prasad, D S V V D, Venkatesh, K, Niranjana, K, Rao, P V S Rama, Diurnal and seasonal variations in sporadic E-layer (Es layer) occurrences over equatorial, low and mid latitude stations - A comparative study, *Indian Journal of Radio & Space Physics*, vol.41, p.p.26-38, 2012
- [15] R. Atulkar^{1*}, P. A. Khan², A. A. Mansoori³, P. K. Purohit¹, Mid Latitude Sporadic E-layer Variability during Ascending Phase of Solar Cycle 24, *JOURNAL OF SCIENTIFIC RESEARCH*, vol.9, p.p.27-41, 2016.
- [16] Pavlov, A. V. , Pavlova, N. M., Long-term monthly statistics of the mid-latitude ionospheric E-layer peak electron density in the Northern geographic hemisphere during geomagnetically quiet and steadily low solar activity conditions, *ANNALS OF GEOPHYSICS*, vol. 60, p.p., A0327, 2017.

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