Indian Journal of Radio & Space Physics
Vol 49, March-June 2020, pp 13-18

Characteristic of Sporadic-E over the anomaly crest region during the low solar cycle

Purushottam Bhawre[a]* & Ritesh Yadav[b]

[a]Space Science Laboratory, Department of Physics, Rani Durgawati P.G. College, Mandla, Madhya Pradesh 481 661, India
[b]Department of Physics, A P J Abdul Kalam University, Indore, Madhya Pradesh 452 016, India

Received 13 July 2018

The paper describes the occurrence of the sporadic-E layer for the anomaly crest region Bhopal, (23.2° N, 77.4° E and 18.4°) over four years, covering the waning phase of the 23rd Solar Cycle and the preliminary phase of 24th Solar Cycle. This precise period is very appropriate for observing the sunspot number and it includes periods of stumpy solar activities. We also included space weather activities along with it. We have taken the auroral electrojet index (AE) and, disturbed storm time index (Dst), Interplanetary Magnetic Field (Bz), to characterize the storm intensity. The sunspot number (Rz), solar flux (F10.7) and Proton Density are described in solar activities. The occurrence probability of Sporadic- E, the layer is maximum in the summertime, temperate during the equinox time, and low during the wintertime. Noteworthy occurrence summits appears from June to July in summer and from December to January in winter. The layer occurrence exhibited a dual peak variation with individual layer group, in the morning and the other during the evening. The dawn layer ancestry was related to layering density-increased representative the consolidation of the layer while it decreased during the evening layer ancestry.

Keywords: Ionosphere, Sporadic E, Space weather, Solar cycle, Low solar activity

1 Introduction

A very persistent abnormality of the ionosphere is what is known as abnormal or sporadic E denoted by Es. It has been known since the early days of pulse technique that the E-layer critical frequency undergoes sudden and abnormal increases. The increases may be many times the normal E critical frequency and may sometime be so high as even to screen the frequency the F-echoes. The vertical height of these abnormal echoes varies between 90 km to 120 km. The sporadic-E occurrence in different latitudes may be of different types. However, there are two types, the long duration or the intense type and the transient or the burst type, which are found to occur in all latitudes.

The typical sporadic heavy side layer is extremely slight (2–10 km in height) layers of ionization enhancements concerning the ambient ionization density. An outsized day-to-day variability and distinct features characterize sporadic-E, counting on the altitude and latitude where they are observed. Es layers are found on ionograms due to reflections in a thin layer of increasing plasma concentrations due to ions (Fe +, Mg +, Ca +, Na +)[1]. Layered densities range in magnitude larger than the background density, mainly because their lifespan is higher than the dominant species at E-region elevations[2] (O+, NO +, O2 +).

Based on HF sounders, different types of Es are identified and their classification is mainly based on their shape on the ionograms, which are transparent. Rare layers are subdivided into different types according to different mechanisms of formation and the coordinates they observe. The growth of Es layers is intensely connected with particle precipitation at high latitudes[3]. A comprehensive study[4] shows that in mid and low-latitudes, the vertical shear caused by transverse horizontal and neutral winds causes improvements in E region ionization, an area like gravitational waves[5,6,7] or tidal motions[8].

The E slayers formed by wind shear lead to ionization improvements, which inhibit the upper ionosphere to low-frequency radio noise[9] and lead to diffusion synthesis at frequencies in the GHz frequency[10]. Captures the properties of different types of Es layers found in different latitudes[11]. The most common type of Es layer in the equatorial region is "q" (Esq). However, Es is not a single layer in the sense that it produces an increase in electron density. It does not block the transmission of the radio signal

*Corresponding author (Email: bhawre@gmail.com)

to the upper regions[12]. The Es layer[13,14,15,16] is associated with equatorial electrojet (EEJ) plasma manipulations. In particular, the presence of Es is related to the vertical polarization Hall electric field led to gradient drift instability. Vertical density gradient and two-stream instability[4]. During this period, the plasma disturbances in the EEJ are very strong[17], the deflection of the radio signal at very high during the day is reflected in the ionograms. In addition to increasing the electron density from the formation of intermittent layers, intense solar flares cause rapid changes in ionospheric ionization, leading to global distribution changes[18]. The X-ray and ultraviolet radiation intensities observed between chromospheric flames cause a rapid increase in the ionization process, while the electron density in the F region of the ionosphere increases. Changes in the direction of electric fields during intense solar flares under conditions where the Es layer disappears[19]. The effects of severe X-class solar flares in the ionosphere and low latitudes of the equator were described in a recent study[20]. They show that the echoes of the ionograms vanish during a burst, representing the preoccupation of wireless signals in the D region.

In the current study, ionosonde data (January 2007 to December 2010) were analyzed for the study of hourly, daily, and seasonal fluctuations in terms of percentage occurrence of sporadic E. The equatorial ionosphere is in principle strongly separated from the large mechanical motions of the magnetosphere but has proven to be surprisingly complex with functions such as the plasma fountain, a low-latitude response to geomagnetic storms, powerful daily electric jet, all large-scale functions, and plasma frequencies. The study aims to explain the complete interpretation of the anomalous crest area with the help of sporadic E behaviors on the anomalous areas during periods of very low solar activity in the scientific community.

2 Observation

For this study, ionogram data was recorded by IPS-71 Digital Ionosonde, installed in the irregularity crest region Bhopal (23.2°N, 77.4°E, 18.4°) covering the waning phase of the 23rd solar cycle and the initial phase of 24th solar cycle over four years from January 2007 to December 2010. This particular period feels well suited for investigating the number of sunspots and includes periods of low solar activity. Quarterly ionograms were analyzed for 24 hours during this study and were carefully investigated to record the presence of sporadic E as presented[21]. We also verified meteorological activity with the study.

We have used data sets from both space and ground-based instruments taken from various source, we used the space weather data from the Omni website with daily average resolutions. Sporadic-E data sets used from KEL designed IPS-71. The interplanetary magnetic field has three components Bx, By and Bz, solar wind data consists of the various parameter as like solar wind speed (Vsw), solar wind proton density (NSW), solar wind temperature (Tsw) and solar wind pressure, in this studies we considered only solar wind proton density. The state of the magnetosphere was described by the number of magnetic activities derived specifically both for low and high latitudes. In this study, we have taken only the auroralelectrojet index (AE) with daily average resolution. The disturbed storm time index (Dst) was also taken to characterize the storm intensity. The sunspot number (Rz) and solar flux (F10.7) are described in solar activities.

2.1 Geomagnetic conditions

For the study of the occurrence of sporadic E, we observed the space weather parameter during the study period that is shown in Fig. 1.We noticed that the activity of the auroralelectrojet Index was lower in 2007 (~ 600) than in 2010 (~ 800) Fig. 1. Everyone knows that 2007 was the solar minimum for the 23rd solar cycle and the 2010-year preliminary stage of solar cycle 24th. For the analysis of solar wind conditions during these periods, we observed the minimum solar wind proton density in 2007 (~ 20 n/cm^3) and maximum in 2010 as compared to 2008 and 2009, which depended on solar activities. For the health of geomagnetic field conditions during the period of study, we noticed that the minimum disturbance of the interplanetary magnetic field was in 2007 and lightly increased with solar activity, the magnetic field was high in 2010 as compared to 2008 and 2009. F10.7 (solar flux) is a dignified level of the blast produced by the sun at a wavelength of 10.7 cm at the Earth's orbit, it also depends on the solar cycle so that was observed low in 2007 and was maximum in 2010. Disturbed storm time also denoted minimum in 2007, during the low solar activity period and maximum in 2010, Sunspot numbers are a temporary phenomenon that appears as dark spots compared to the solar system and surrounding areas. They are caused by intense magnetic field disturbance, which

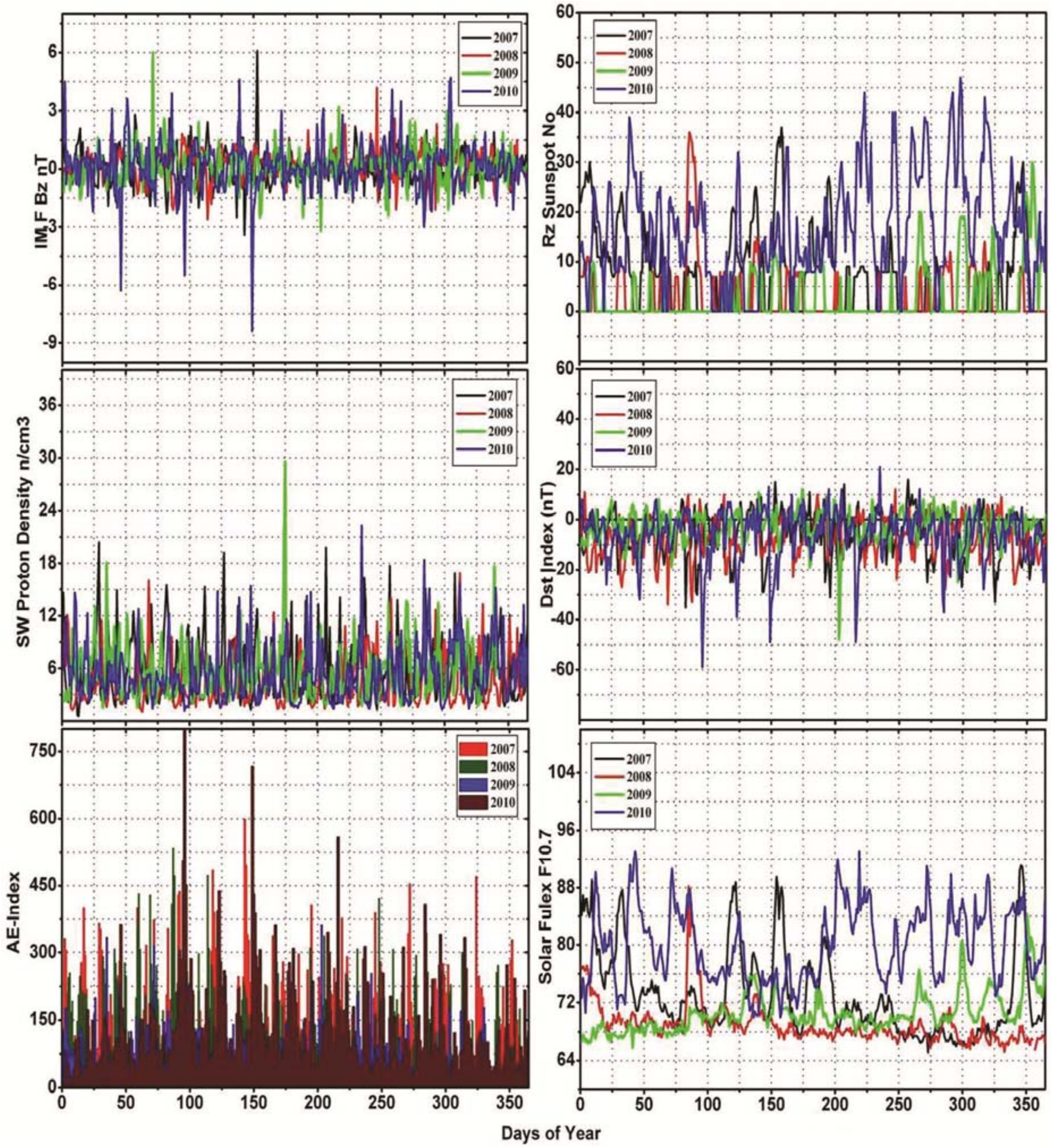

Fig. 1 — Space weather condition during the study periods.

inhibits convective heat transfer comparable to eddy current brake, which lowers the surface temperature. The number of sunspots also decreases during periods of low solar activity, with the lowest and solar activity seen in 2007 and increased with solar activity and sunspot number was observed maximum in 2010 that is visible in Fig. 1. These are the parameters that are defined as the condition of space weather and geomagnetic. They also depend on solar cycle periods.

2.2 Monthly variation of Sporadic E

Data are analyzed for monthly variation of Sporadic E in terms of daily occurrence, which is clearly showing in Fig. 2. According to it, we observed the maximum Sporadic-E activity during May-August between 2007 to 2010, Sporadic–E occurrence decreased with increased solar activity, the maximum occurrence of Sporadic E was noticed during the low solar activity year 2007 and it was decreased in solar active period 2010.

2.3 Yearly occurrence of Sporadic E

A study of the annual occurrence of the Sporadic-E layer is shown in Fig. 3, revealing that in 2007, the year of low solar activity, the incidence of sporadic E peaked and gradually decreased with solar activity. In general, Es activities were observed during the observation period throughout the year.

2.4 Seasonal occurrence

The study is based on the hourly data from January 2007 to December 2010. The monthly average is obtained by analyzing the monthly mean for seasonal, summer months (May, June July and August), winter (November December January, and February) and equinoxes (march April September and October). The occurrence of Sporadic E express as a percentage of total observation of the Es layer, detail studied for a different amount at the hourly interval, Fig. 4 shows the regular percentage occurrence of Sporadic E layer, during 2007, 2008, 2009 and 2010. We noted the maximum occurrence of Sporadic–E in the summer season being higher than winter and equinoxes seasons. It has two maxima, around 07:00 – 08:00 local time in the morning and 17:00 local time in the evening in all seasons, but the additional prominent occurrence of Es was remarked in the summer months as likened to winter and equinox seasons. The amount of Es was high during 08:00 LT and 17:00 LT (Bhawre, 2016)[21]. The existence of Sporadic E also depends on the solar cycle during the low solar activity years 2007, 2008 and 2009, Es being maximum and during the solar active period, Es observed minimum.

3 Results and Discussion

Clouds with a diameter of 50–150 km are small. They can be round, elongated, slender, or irregularly shaped. These clouds occur randomly and dissolve in a few hours; hence, they are called Sporadic-E ionizing clouds. The nature of Es combines the orientation of the magnetic field, electric field, neutral air, wave motions, and distribution of metal ions. Its production method is very different in middle, lower and higher latitudes. It occurs mostly during the day and evening at low and medium altitudes and is most common in summer. At high latitudes, Es forms at night. Sporadic E is an infrequent form of wireless transmission using the properties of the Earth's ionosphere. Whereas most forms of sky wave propagation use general and cyclic ionization properties in the F region of the ionosphere to divert radio signals over the Earth's surface, the Sporadic E propagation increases the signal from the abnormally small "clouds" of ionized atmospheric gas in the lower E region. The present study analyzes the monthly, annual and seasonal occurrence of Sporadic-E above the abnormal station at the equator in Bhopal,

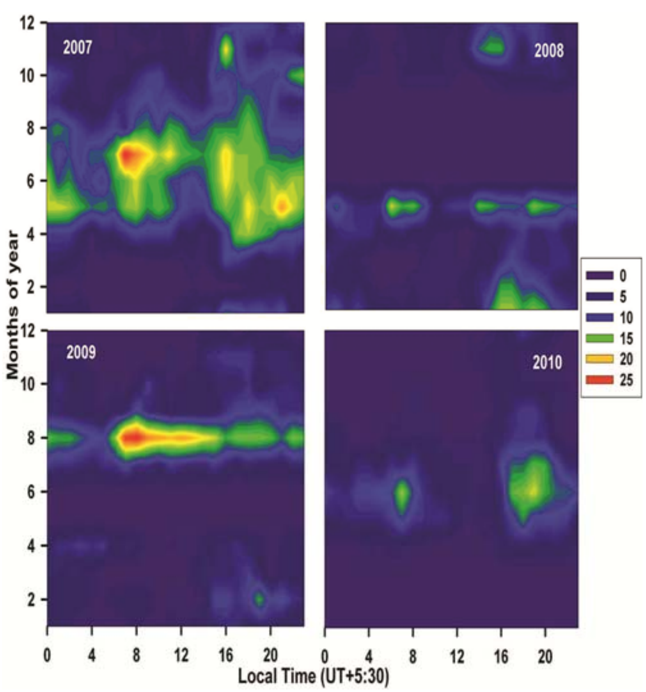

Fig. 2 — Monthly occurrence of Sporadic E over Bhopal region

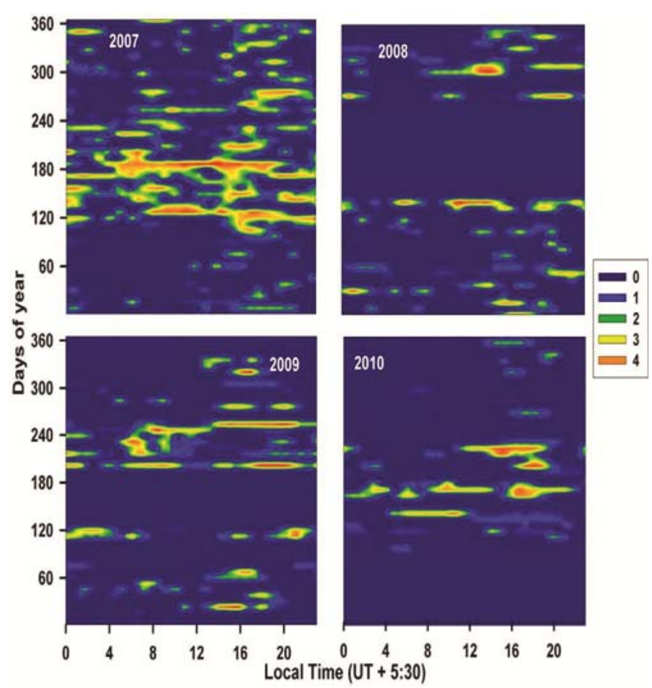

Fig. 3 — Yearly occurrence of sporadic E over Bhopal region

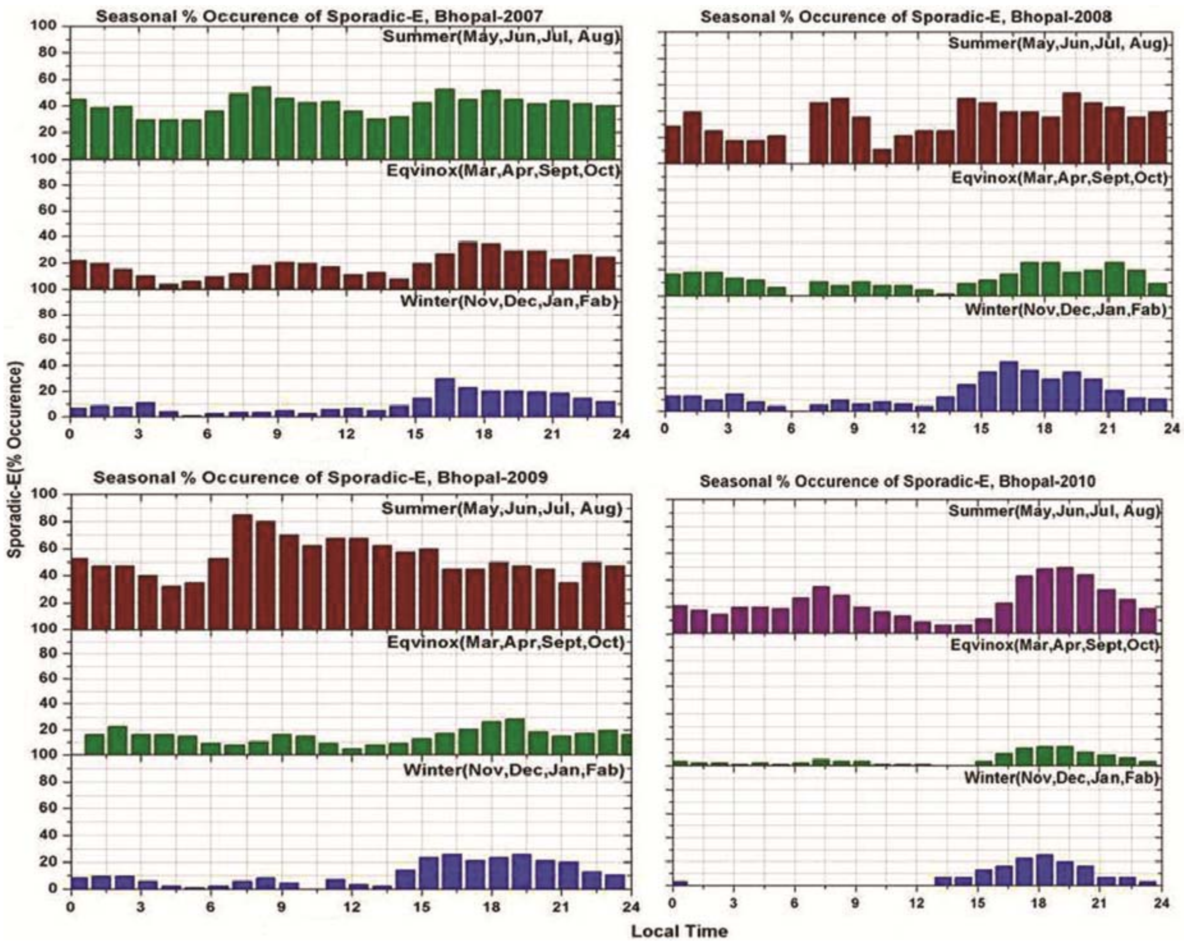

Fig. 4 — Seasonal occurrence of sporadic E over anomaly crest region Bhopal

Madhya Pradesh. According to our observations, the occurrence of Es was observed from May to August, followed by a second peak in December.

The monthly occurrence of Sporadic E layers and local time during a 24 hour day period is summarized in Fig. 2 for the monthly occurrence. The upper panel showing the occurrence of sporadic E layers for 2007 and 2008, the lower panel showing the monthly occurrence of sporadic E in 2009 and 2010. During the study, we observed that the maximum occurrence of Es in 2007, day and night time between April to November, during the year 2008 Es activity was very less in May month only due to negligible sunspot numbers, it was increased again in 2009 between July to September months. In the year 2010 solar active period, the occurrence of sporadic E observed between Aprils to July months, the Es occurrence was not very high as compared with other years due to solar activity.

Sporadic E is a thin, defective layer that forms in the Earth's ionosphere and extends 90 to 150 km. Clouds of unusually intense ionization reflect signal frequencies up to 20 MHz near the ionospheric E layer. It may be due to the reason that in June solstice there are intense solar radiations, which result in the formation of Es clouds having strong ionization; this ionization is highly influenced by the eastward current flow known as equatorial electrojet (EEJ). In the Indian region, the occurrence of counter electrojet is mainly in the afternoon and seasonally maximum during June solstice.

Figure 3 reveals the yearly existence of the Sporadic E layer for the year 2007 to 2010, the maximum occurrence activity was observed in 2007 in between 24 hours of the years. Sporadic E activity gradually decreased as well as an increased in solar activity. The maximum activity was observed in 2007 and a minimum in 2010 (Fig. 3). The years 2007 and 2008 were very quiet in the vision of the solar cycle, so throughout the low solar activity, the ionization process of the ionosphere was very low as compare to the solar active year 2010.

As mentioned, the uncultured future is the nature of variation of Sporadic E is better reflected when studies are made with a large database covering different seasons or solar cycles. With this impartial in interpretation, the average variation of Sporadic E throughout the three dissimilar periods, namely summer, winter, and equinox at the anomaly crest region Bhopal, are presented in Fig. 4. The mean seasonal Sporadic E variation showed higher value during the day time hours in the summer in all the whereas for different seasons and increase in Sporadic E was observed, while the decrease in sporadic E around the 1800 hr LT during the different seasons, Arons and Whitney have shown that, during the midday, summer scintillation is more likely to occur when foEs are above 5 MHz.

The seasonal variation of the Es layer at Bhopal was due to solar radiation might be an important factor controlling the formation of Es. A maximum percentage occurrence of Es observed in the summer season with a secondary equinox peak was noted, the maximum percentage occurrence of 80% was observed in 2009 as compared to the other rest of the years. It can be explained by the effect of the Earth's revolution in which the Earth is facing sunward for the maximum time and thus receiving more solar radiation, affecting the movements of the wind. The occurrence of radar echoes with the variation of Es parameters over a mid-latitude station and showed that the occurrence of radar echoes depends on the strength of the Es parameters and FAI generation is closely related to localizing density gradients within Es.

4 Conclusions

Using 15-minute digital ionogram data IPS-71, over the anomaly crest region, Bhopal, Madhya Pradesh from January 2007 to December 2010, these studies are based on monthly, annually and seasonal existence of Sporadic E. This study area is still very small and therefore has potential developments for many Ionosphere fields. The result will enhance our understanding and knowledge, especially in Sporadic E. A statistical analysis of Sporadic-E has been performed. The main statistics results are:

The probability of occurrence of Sporadic E, the layer is very high in the summer solstice, modest during the equinox and low throughout the winter. Remarkable peaks range from June to July in the summer and December to January in the winter. The appearance of the layer showed double variation with different layer groups, in the morning (02:00 LT) and the evening (18:00 LT). The morning slope is associated with an increase in the layout of the layer, which indicates the solidification of the layer as it descends during the evening descent.

Acknowledgment

Dr. Bhawre is grateful to the National Physical Laboratory (CSIR-NPL), New Delhi India, for installing Digital Ionospnde IPS 71 over Bhopal and the National, Geophysical Data Center (NGDC) for providing a variety of data sets, especially those for solar parameters. Dr. Bhawre also thanked the reviewer for his inspiring comments.

References

1 Tsunoda R T, *Journal of Geophysics Research,* 113 (2008) A093041.
2 Kopp E, *Journal of Geophysics Research,*102 (1997) 9667.
3 Kirkwood S & Nilsson H, *Space Science Review,* 91 (2000) 579.
4 Whitehead J. D, *Journal of Atmospheric and Solar-Terrestrial Physics,* 51 (1989) 401.
5 Hook W H, *Journal of Geophysics Research,* 75 (1970) 7229.
6 Lanchester B S, Nygren T, Huskomen A, Turnen T & Jarvis M J, *Planet Space Science,* 39 (1991) 1421.
7 Jayachandran P T, *Annals of Geophysics Research,* 17 (1991) 519.
8 Chimmonas G, *Journal of Geophysics Research,* 76 (1971) 4578.
9 Devasia C V, Jyoti N, Subbarao K S V, Tiwari Diwakar, Raghava Reddi C, & Sridharan R, *Radio Science,* 39 (2004) 1.
10 Seif A, Tsunoda R T & Abdullah M, *Earth Planet Space,* 67 (2015) 177.
11 Resende L C A, Denardini C M & Batista I S, Journal *of Atmospheric and Solar-Terrestrial Physics,* 102 (2013) 228.
12 Piggot W & Rawer K, U A G, 23A (World Data Center A, N.O.A.A., Boulder, Colorado) Edited by *US, Department of Commerce,* (1978) 352.
13 Fejer B G & Kelley M C, *Review of Geophysics,* 18 (1980) 401
14 Forbes J M, *Review of Geophysics,* 19 (1981) 469.
15 Tiwari P, Tiwari D, Surve G & Nayak C, *Indian Journal of Radio & Space Physics,* 41 (2012) 285.
16 Denardini C M & Resende L C A, Moro J *Earth Planet Space,* 68 (2016) 80.
17 Knecht R. W & Mcduffie R E, *Journal of Atmospheric and Solar-Terrestrial Physics,*14 (1959) 348.
18 Afraimovich E L, Altyntsev A T, Kosogorov E A, Larina N S & Leonovich L A, *Journal of Atmospheric and Solar-Terrestrial Physics,* 63 (2001)1841.
19 Manju G, Viswanathan K S, Response of the equatorial electrojet to solar flare related X-ray flux enhancement, *Earth Planets Space* 57 (2005) 231.
20 Sripathi S., Balachandran N, Veenadhari B, Singh R & Emperumal K, *Journal of Geophys Research,* 118 (2013) 2648.
21 Bhawre Purushottam., ISBN-13: 978-3-659-82223-0 (2016) 88.