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Characteristics of Night Sporadic-E at Kodaikanal

J. HANUMATH SASTRI & B. SURYANARAYANA MURTHY
Indian Institute of Astrophysics, Kodaikanal 624 103

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The characteristics of nighttime sporadic-E (E_s) (2000-0400 hrs LT) at Kodaikanal (dip : 3·5 N) for the periods of high and low solar activities have been studied using published ionospheric data. The blanketing frequency as well as the transparency range of night E_s reflections are found to be independent of solar activity. A distinct local time variation of the distribution of virtual height of night E_s, which is different for the periods of high and low solar activities, is noticed.

1. Introduction

THE CHARACTERISTICS of night sporadic-E (E_s) in the equatorial zone have been studied by Bandyopadhyay and Montes[1] for Huancayo, Awe[2] for Ibadan and Chandra and Rastogi[3] for Kodaikanal, representative of the American, African and Asian zones respectively. These studies have shown that equatorial nighttime E_s is mostly of the flat (E_{sf}) type of a low blanketing frequency and its occurrence is more or less independent of solar activity. A definite longitudinal dependence in the occurrence of nighttime E_s is evident from these studies in that, while in the Asian zone the occurrence of night E_s is a maximum in the pre-midnight period with a seasonal maximum in J-months[3], the occurrence has a maximum in the post midnight period in the African and American zones and the seasonal maxima are found to be in equinoxes and D-months for the African and American zones respectively[1,2]. It is reported that for Ibadan, the blanketing frequency (f_b E_s) as well as top frequency (f_0 E_s) shows negative correlation with solar activity but are unaffected by magnetic disturbances[2]. It follows, therefore, that the partial transparency ($f_0E_s - f_b$ E_s) of night E_s at Ibadan is negatively correlated with solar activity. In this paper, we present the results of our investigations on the characteristics of night E_s, viz. (i) blanketing frequency (f_b E_s), (ii) virtual height ($h'E_s$) and (iii) transparency range ($f_0E_s - f_bE_s$), at Kodaikanal (geomag. lat: 0·6 N; dip:3·5 N) using published ionospheric data. The main aim is to see whether the longitudinal dependence of night E_s exists in its other characteristics also besides in occurrence. The present study covers both the periods of high solar activity (July 1957-June 1959) and low solar activity (January 1964-December 1965), which is done to infer the solar cycle dependence of the characteristics of nighttime E_s.

2. Study of Ionograms

Although nighttime E_s is known to manifest on bottomside ionograms usually as flat type (E_{sf}) with a low blanketing frequency (f_bE_s), our careful examination of quarter-hourly ionograms of Kodaikanal for the two 2-yr periods mentioned earlier showed that it manifests in a few other forms also, typical examples of which are presented in Fig. 1. Configuration A of Fig. 1 is typical of the many occasions noticed, wherein besides the flat type (E_{sf}), a layered structure is also seen. In this case, additional layers are noticed at about 115, 125 and 150 km. In configuration B, the value of the blanketing frequency (f_b E_s) is about 4·0 MHz indicating a thin slab of ionization, completely blanketing the nighttime lower F region. Configuration C closely resembles the retardation type of sporadic-E (E_{sr}) usually observed at auroral latitudes.

It is noticed that the total duration of the occurrence of night E_s on individual nights ranges from a minimum of less than 30 min to a maximum of 6-8 hr. A typical event showing two interesting features of a long enduring night E_s observed at Kodaikanal on 3 July 1958 is presented in Fig. 2. First its manifestation on ionograms varies with time. Secondly, the occurrence of nightE_s is frequently not continuous in that it suddenly disappears and reappears after a lapse of time which ranges from half an hour to a couple of hours. In Fig. 2 at 2130 hrs, i. e. at the start of the event, night E_s is of blanketing type (E_{sb}) with a blanketing frequency of about 3·5 MHz and this configuration is found to continue at 2215 hrs also. But, by 0100 hrs night E_s disappears and reappears at 0130 hrs with a E_{sb} configuration (blanketing frequency about 2·5 MHz which feature continues till 0315 hrs. By 0400 hrs, however, the night E_s, although of the flat type exhibits a layered structure.

3. Results

In Fig. 3 is shown the frequency distribution of virtual height of night E_s (represented by h' E_s) for each hour of the night from 2000 to 0400 hrs and for the entire night for the 2-yr period of high solar

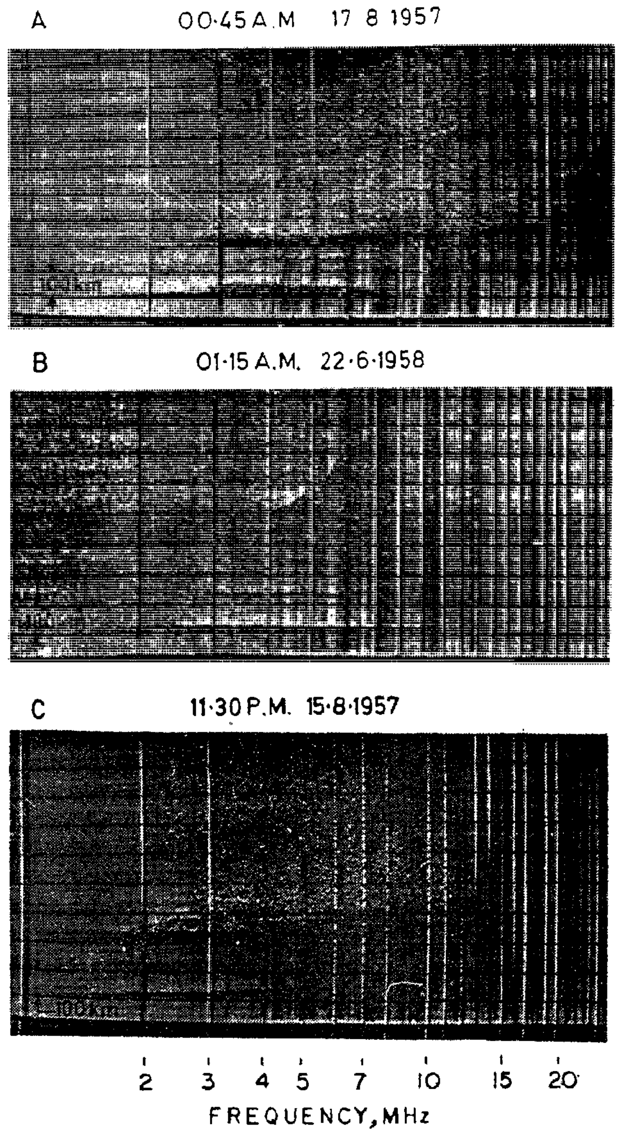

Fig. 1—Typical configurations of nighttime E_s at Kodaikanal

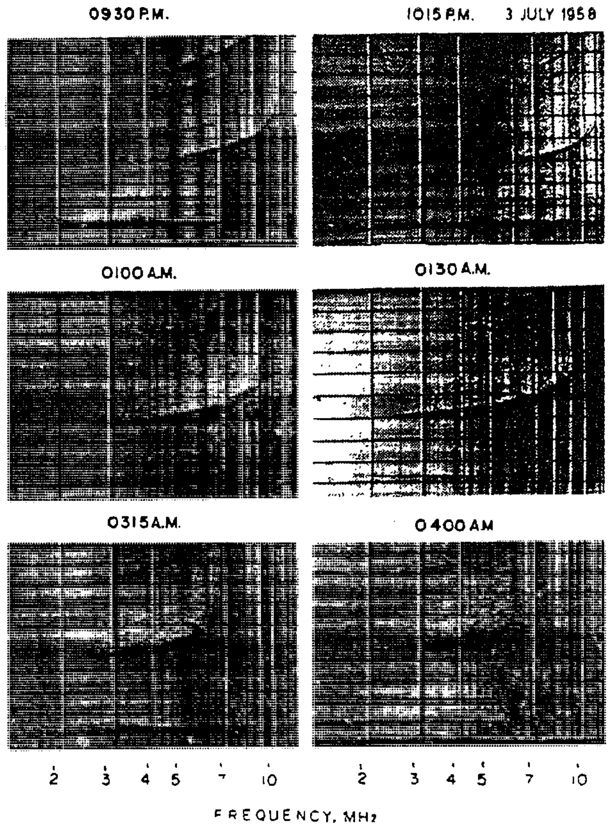

Fig. 2—Sequence of ionograms on 3 July 1958 at Kodaikanal illustrating the variability of the characteristics night E_s

activity (July 1957-June 1959). It may be seen that 100 km is the preferred virtual height during the early part of night (2000 hrs) and during early morning (0400 hrs) and 120 km is the preferred virtual height in the pre-midnight period, while at midnight and during post midnight period there is no marked preference for any height. This indicates a distinct local time dependence of the virtual height of night E_s in the equatorial zone. From the distribution of virtual height for the entire night, it can be seen that the virtual height lies mainly between 100 and 120 km with 120 km as the most preferred height; similar type of distributions for the 2-yr period of low solar activity are presented in Fig. 4. It can be seen that the behaviour of virtual height of night E_s during low solar activity is different from that during high solar activity. In other words, although 100 km is the preferred virtual height during the early part of night and early morning both during high and low solar activity, there is no preferred virtual height of night E_s during the rest of the night for the low solar activity period while 120 km is the preferred height during the pre-midnight period for the period of high solar activity. Further, it can be seen from Figs. 3 and 4 that the virtual height distribution of night sporadic-E for the entire night extends from 100 to 120 km with 120 km as the preferred height during high solar activity period, and during low solar activity period the distribution is mainly restricted to heights 100, 110 and 120 km without any preference for any one of these heights.

In Fig. 5 is shown the distribution of the observed values of blanketing frequency (f_b E_s) of night sporadic-E for the 2-yr periods of high and low solar activity. It may be noticed from Fig. 5 that the nature of the distribution of f_b E_s is more or less the same for the two epochs, indicating that the blanketing frequency of night E_s does not depend on solar activity. This inference is all the more evident from the relevant statistics of the distributions presented in Table 1. The transparency range of the night E_s reflections is studied by evaluating the parameter (f_0 E_s $-f_b$ E_s) from half-hourly values of f_0 E_s and f_b E_s, available from published ionospheric data. In

Fig. 6 are shown the distributions of this parameter for the 2-yr periods of high and low solar activity. It can be seen that the value of (f_0 $E_s$$-$$f_b$ E_s) ranges from 0·1 to 9·0 MHz and the nature of its distribution is more or less the same for the epochs of high and low solar activities. This feature can also be clearly seen from the relevant statistics of the distributions presented in Table 1.

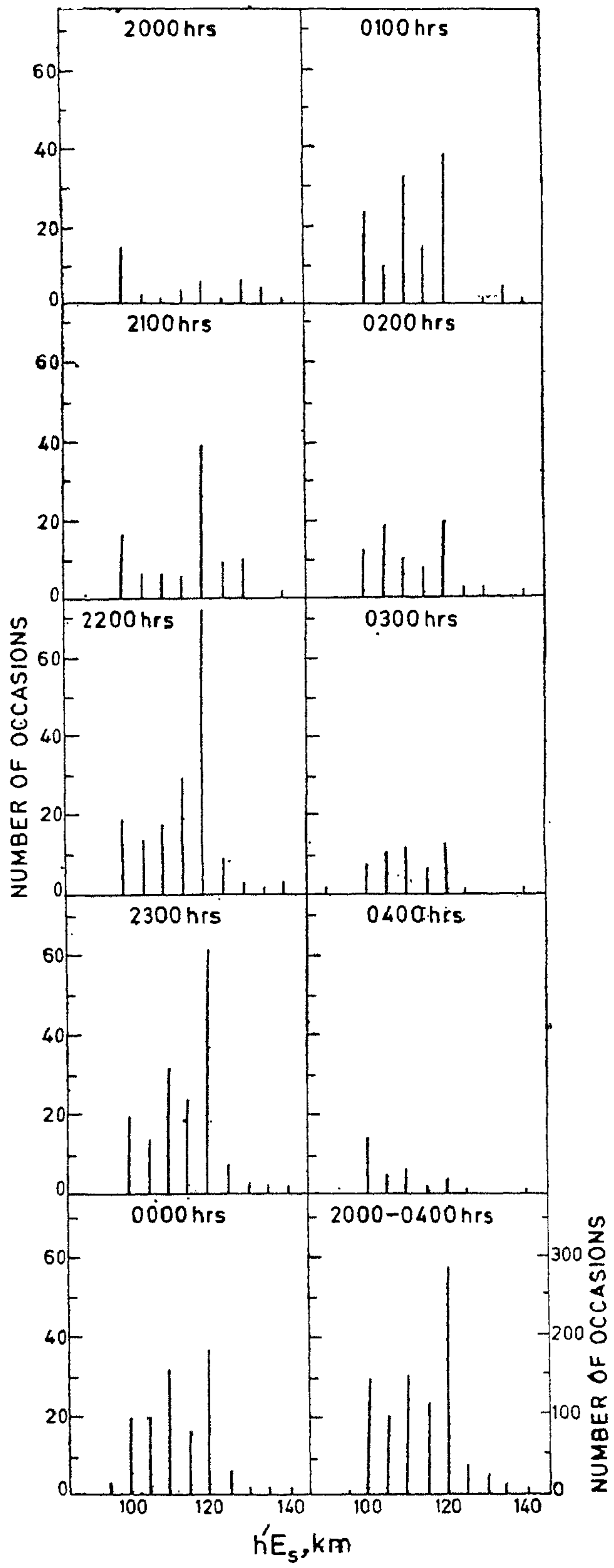

Fig. 3 – Frequency distribution of h' E_s for each hour and for the entire night for the period of high solar activity (July 1957-June 1959)

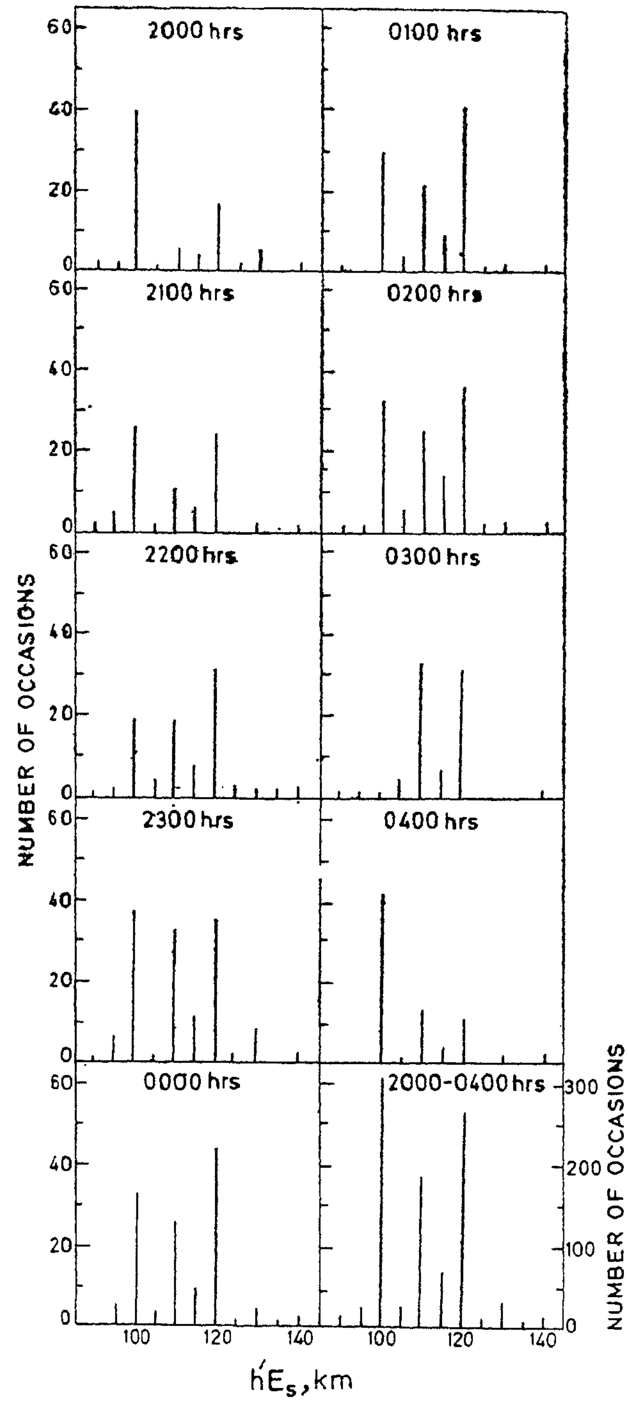

Fig. 4 – Frequency distribution of h' E_s for each hour and for the entire night for the period of low solar activity (January 1964-December 1965)

Table 1 – Statistics of f_b E_s and (f_0 $E_s - f_b$ E_s) at Kodaikanal for the Epochs of High and Low Solar Activities

Period	f_b Es			(f_0 Es $-f_b$ Es)			
	Lower quartile	Median	Upper quartile	Percentage occurrence of f_b Es 2·0 MHz	Lower quartile	Median	Upper quartile
High solar activity (July 1957-June 1959)	1·75	2·05	2·32	45	1·19	2·19	3·44
Low solar activity (Jan. 1964–Dec. 1965)	1·73	2·03	2·39	41	—	1·51	2·62

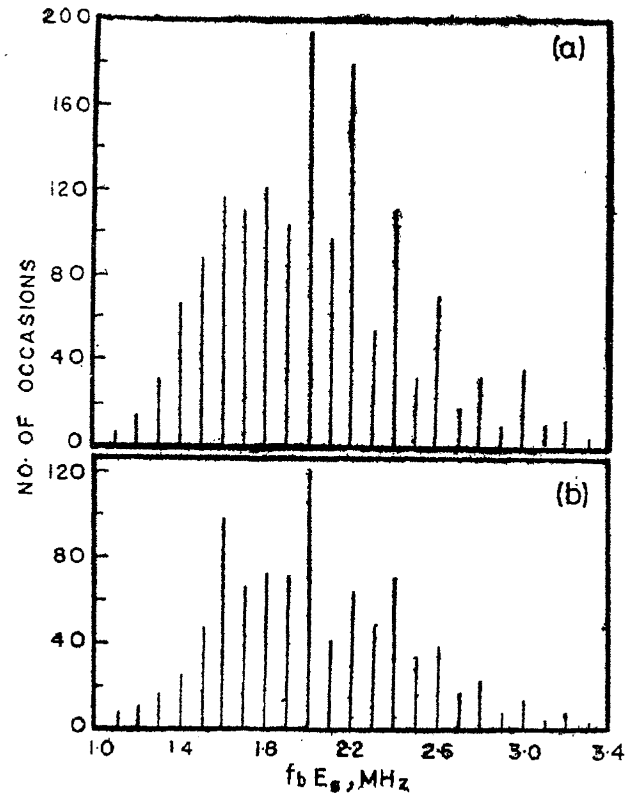

Fig. 5 – Frequency distributions of the values of f_b Es (a) for high solar activity period (July 1957-June 1959; (b) for low solar activity period (January 1964-December 1965)

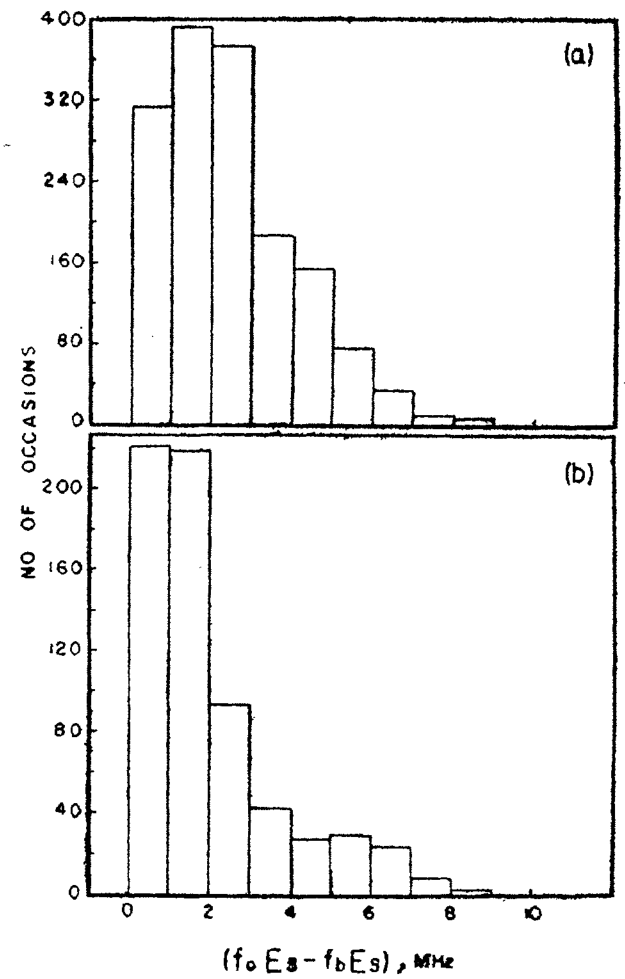

Fig. 6 – Frequency distributions of the values of (f_0 Es $-f_b$ Es) (a) for high solar activity period (July 1957-June 1959); (b) for low solar activity period (January 1964-December 1965)

4. Discussion

The results of the present investigation on the blanketing frequency of night E_s at Kodaikanal (dip:3·5 N) show that it is independent of solar activity. This feature is contrary to the earlier finding of Awe[2] for Ibadan (dip : 6 S) that f_b E_s is negatively correlated with solar activity and also to the results of Reddy and Matsushita[4] who found a negative correlation of the average f_b E_s at night with solar activity for most of the various temperate latitude stations studied by them. The present investigation also shows that the distribution of virtual height of night E_s has a distinct local time variation during the night, dependent on solar activity. Although, the earlier work of Awe[2] for Ibadan also showed a local time dependence of the distribution of virtual height of night E_s, on solar activity, the details are different (refer to Figs. 5 and 7 of his paper). To conclude, a consideration of the salient results of the present study with those of Awe[2] further confirms the feature of a longitudinal dependence of the characteristics of night Es mentioned in the introduction to this paper.

The present study shows that night Es in the equatorial zone manifests in two other configurations: blanketing type and multiple layered structure, besides the flat and low blanketing type. The origin of these various night E configurations is yet to be established. The blanketing type of sporadic-E so frequently observed at temperature latitudes whose origin is ascribed to vertical convergence of ionization due to vertical shears of horizontal neutral winds in the E region, is not expected to occur at and close to the dip equator due to the ineffectiveness of the ion convergence mechanism at these latitudes[5,6]. However, observational evidence now exists to indicate that blanketing type E_s does occur at and close to the dip equator both during day and night and alternative mechanisms have been proposed to account for this[7]. The night E_s may be understood as due to cross-field instability as already suggested[3]. In the equatorial zone the vertical electric field (due to Hall polarization in the presence of horizontal electric field) is directed upwards during day and downwards during night and the reversal generally takes place late in the evening[8]. Hence, conditions for cross-field instability will be found during nighttime if the electron density gradient is negative; and cross-field instability is inhibited if one of them changes its direction. Recent rocket studies of Satya Prakash *et al.*[9] at Thumba showed the existence of irregularities at the altitudes of negative electron density gradients favouring the above interpretation. In view of the existing evidence for the presence of a nighttime electrojet in the equatorial ionosphere[10], we have investigated whether the occurrence of night E_s is controlled by the electrojet using our La Cour magnetograms in the following way. First, we have seen whether there are any short duration perturbations in the *H*-field coincident with the occasions when the night E_s suddenly disappears and reappears after a lapse of time, but failed to notice any such changes in the *H*-field. Secondly, during J-months when the occurrence of night E_s is maximum[3], at Kodaikanal, we have selected two groups of days in each month, one with a high incidence of night E_s and the other with a low incidence of night E_s and evaluated the mean level of the *H*-field for the two groups. No significant difference is noticed in the mean level of the *H*-field for the two groups. These observations clearly indicate that there is no threshold limit for the nighttime electrojet for the occurrence of night E_s in the equatorial region. It follows from the above that the occurrence of night E_s is mainly controlled by the electron density gradient alone, following the understanding that night E_s is due to cross-field instability.

Detailed investigations of equatorial E region during nighttime by rocket measurements supplemented by ground-based ionogram observations will throw more light on the plausible mechanisms responsible for various types of night E_s noticed in the present study.

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