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Blanketing Sporadic-E Characteristics at the Equatorial Stations—Trivandrum & Kodaikanal

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The ionograms at Trivandrum (dip ~0·6°S) and Kodaikanal (dip~ 3·5°N) have been analyzed to find out the main morphological characteristics of blanketing sporadic-E layers at these equatorial stations. The results bring out three important characteristics of blanketing E_s morphology at these latitudes: (i) Near absence of simultaneous occurrence of the E_s layers at Kodaikanal and Trivandrum; (ii) A prominent late evening maximum in their daily occurrence with a virtual absence of blanketing E_s layers in the forenoon hours; and (iii) A prominent summer maximum in their seasonal variation. The first of these three features points to a "localized" mechanism for the generation of these E_s layers; the second feature clearly indicates the east-west electric field control of the blanketing E_s formation, while the third feature can be interpreted as due to the generating source having its maximum strength in summer months.

1. Introduction

It has been reported recently[1,2] that the occurrence of blanketing sporadic-E layers close to the magnetic equator is not as rare as it was generally supposed earlier. In fact the observations at Trivandrum (dip, ~ 0·6°S; geogr. lat., 8·33°N) show that blanketing E_s occurs on more than 70% of the days in the summer months during the high sunspot activity period of 1969-72. Since the ion convergence due to vertical shears of neutral winds is very inefficient at such low dip latitudes, Reddy and Devasia[1] proposed that horizontal shears of neutral winds associated with short-period internal gravity waves could generate the observed E_s layers. Partly to test this theoretical hypothesis and partly to establish the main morphological characteristics of the blanketing E_s layers within the electrojet latitude range, the occurrence of blanketing E_s traces in ionograms taken at Trivandrum and Kodaikanal has been studied. The results are presented in this paper.

2 Ionogram Analysis and Results

2.1 Method of Analysis

In this study, the ionograms taken at 15-min intervals have been examined and scaled for the four-year period 1969-72 in the case of Trivandrum (dip, ~ 0·6°S; geogr. lat., ~ 8·33°N; geogr. long., ~ 76°52′E) and for the two-year period 1970-71 in the case of Kodaikanal (dip, ~ 3·5°N, geogr. lat., ~ 10°14′N; geogr. long., ~ 77°29′E). Kodaikanal is located within the equatorial electrojet region.

The number of blanketing E_s occurrences shown in Figs. 1-5 are based on counting the occurrences in the 15-min interval ionograms. Only such cases of E_s traces which can be identified unambiguously as blanketing types have been included in the analysis. The criteria for such identification are: the blanketing frequency being clearly above the expected f_0E value, the blanketing E_s traces being distinctly different from other E-region (normal E or E_{sq}) traces, and the presence of multiple reflections which occur only in case of blanketing E_s .

The use of the above stringent criteria might have eliminated from the analysis quite a few cases of weak blanketing E_s traces obscured by E-region or E_{sq} traces.

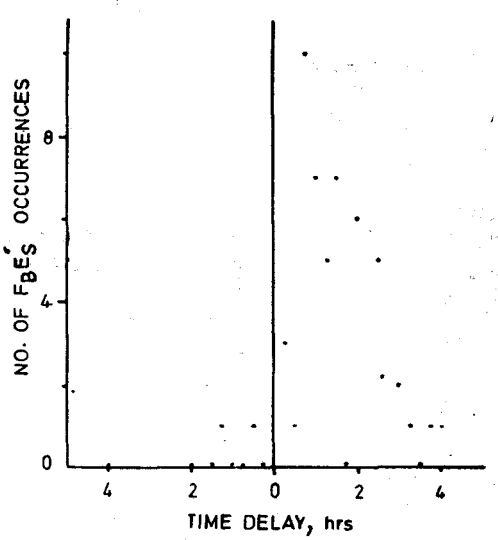

Fig. 1—Plot of the number of "simultaneous" occurrences of blanketing E_s versus the time delay (in hours) between the occurrence times at Trivandrum and Kodaikanal

2.2 Comparison of Blanketing Es Occurrences at Kodaikanal and Trivandrum

For the two-year period of 1970-71, the days and the times of blanketing E^s occurrence at Kodaikanal and Trivandrum have been subjected to a comparative study to find out (i) whether blanketing E_s was present at both places most of the days and (ii) whether there was any indication of a systematic time delay in the first appearance of blanketing E_s at the two stations on such days when it was present at both stations.

With reference to the first question, the factual information as to the number of days blanketing E_s was observed at both places is given in Table 1. The most significant fact to be noticed in Table 1 is that blanketing E_s occurred at *both* the stations only on 53 days as against 231 days on which blanketing E_s occurred only at one station. Alternatively, out of all the days on which blanketing E_s occurred, it was present at both places only on about 18% of the days. On four-fifths of the days, it was present only at one station. This leads to the conclusion that the generating source for these E_s layers is localized at Trivandrum and Kodaikanal. Even on those days when blanketing E_s is present at both stations, it need not necessarily mean a common source; it is more likely that the independent sources at both places are operative on these days.

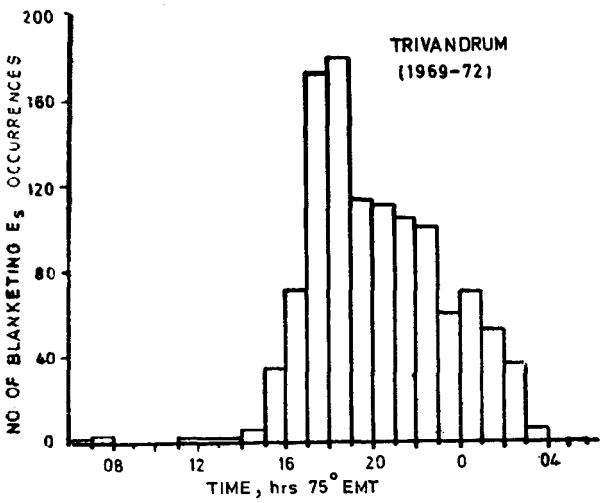

Fig. 2—Daily variation of blanketing E_s at Trivandrum (1969-72)

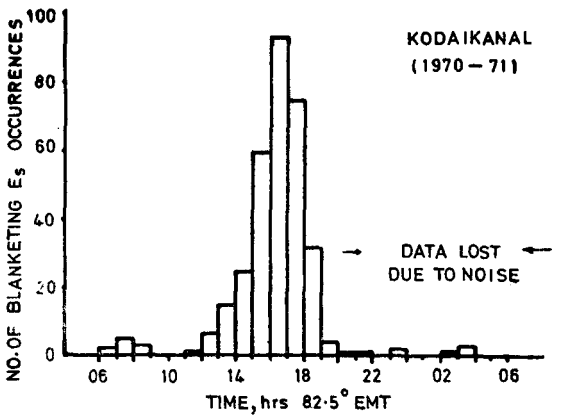

Fig. 3—Daily variation of blanketing E_s at Kodaikanal (1970-71)

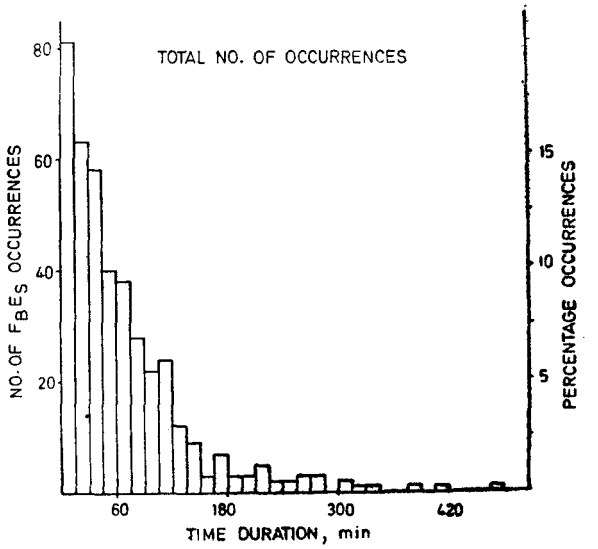

Fig. 4—Plot showing the total number of occurrences in Trivandrum (1969-72) versus observed duration of the blanketing E_s layers

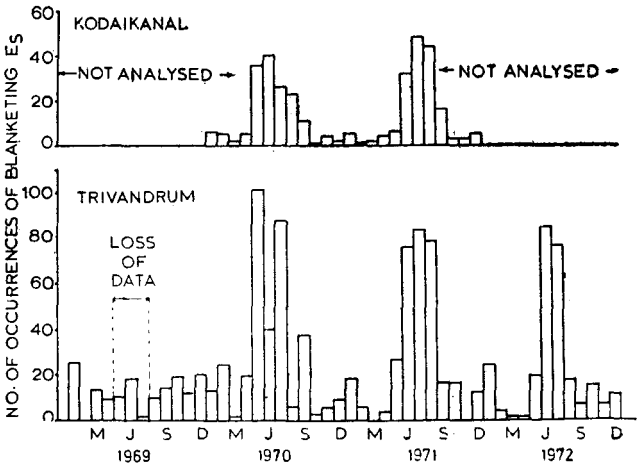

Fig. 5—Seasonal variation of blanketing E_s occurrences at Trivandrum and Kodaikanal

Table 1—List of Days on which Blanketing E_s was Observed at Both Places, viz. Kodaikanal and Trivandrum

Blanketing Es observed at		No. of days
Kodaikanal	Trivandrum	
Yes	Yes	53
Yes	No	126
No	Yes	105
No	No	446
	Total	730

A further analysis has been made to find out wh ether on those days when blanketing E_s occurred at both stations, the occurrences have simultaneity or any systematic time difference. For this study the blanketing E_s data of Trivandrum and Kodaikanal for the years 1970-71 are made use of. If, on a particular day the time difference between the first appearance of blanketing E_s at Trivandrum and that at Kodaikanal is within the time range of $\pm$ 4 hr, such cases have been considered as near simultaneous occurrences of blanketing E_s at both places. The total number of such simultaneous occurrences have been noted for the years 1970 and 1971. The positive values of time delay correspond to the first appearance of an E_s layer at Kodaikanal and the negative values correspond to the first appearance of blanketing E_s at Trivandrum. From the plot (Fig. 1) of the number of simultaneous occurrences versus time delay, it is seen that the maximum number (about 21) out of the 53 simultaneous occurrences are within a time difference of about + 1 hr. This means that in such cases the blanketing E_s first appears at Kodaikanal and after a time delay of about 1 hr, it appears in Trivandrum also. This time delay of 1 hr is too small to permit the interpretation of an E_s layer drifting from Kodaikanal to Trivandrum latitude. In view of the scatter in the time delays and the small number of such near simultaneous occurrences, the only plausible interpretation is that E_s layers occur on the same day at both the places due to independent but similar sources.

2.3 Daily Variation of Blanketing E_s Occurrences

Figs. 2 and 3 show the daily variations of blanketing E_s occurrences at Trivandrum and Kodaikanal. The daily variation of blanketing E_s at the two stations is characterized by two main common features: (i) the near absence of blanketing E_s occurrence in the forenoon hours, and (ii) a prominent maximum in the late afternoon hours. Additional features to be noted from Figs. 2 and 3 are:

(i) Blanketing E_s layers are observed, though rarely, in the morning and noon hours at Kodaikanal; this is in contrast to their virtual absence at these times at Trivandrum.

(ii) The first appearance as well as the peak occurrence (in the afternoon) are earlier at Kodaikanal by about 1 hr compared to those at Trivandrum.

(iii) The occurrence rate decreases gradually during the night hours at Trivandrum; (the nighttime occurrence at Kodaikanal could not be obtained reliably because of the high levels of noise interference in the ionograms).

It has been reported by Oyinloye[2] that the common feature of the daily variations of the occurrence frequency of blanketing E_s in the equatorial region is the absence of a distinct morning peak. Oyinloye's analysis refers to stations outside the electrojet latitudes. This is consistent with the observation that the daily variation of blanketing E_s occurrence in the equatorial regions is different from that for higher latitude stations (dip angle $\geqslant 13°$) as pointed out by Reddy and Matsushita.[3]

A few comments on certain features not brought out in the statistical presentation (in Figs. 2 and 3) are in order here: Firstly, the growth of the blanketing E_s layers seems to be rather rapid (< 15 min) as evidenced by the fact that the growth or development phase of the first E_s layer on any day is seen only in one or two ionograms. Once developed it may persist for a period anywhere between 15 and 120 min, the most frequent values being in the range of 45-75 min (Fig. 4). The same pattern of appearance and disappearance continues in the night hours with decreasing rate of occurrence as night progresses. Presumably, a similar behaviour is present at Kodaikanal, but nighttime blanketing E_s data are lost to a great extent because of the severe noise interference in the Kodaikanal ionograms in the lower hf and broadcast band frequency ranges.

Another remarkable fact is that the height of the blanketing E_s layers is observed to be in the narrow range of 95-105 km, with rare exceptions. The occurrence of double or triple layers is very rare. Both of the above features are common at Kodaikanal and Trivandrum.

2.4 Seasonal Variation

The seasonal variation of the occurrence frequency of blanketing E_s at Trivandrum and Kodaikanal is shown in Fig. 5. The different pattern at Trivandram in 1969 is due to the loss of data in the summer months of that year. There is some indication of a weak secondary maximum in Dec.-Jan. period, but this cannot be accepted as real without further statistical confirmation. A greatly enhanced occurrence in the summer months of June-July, coupled with a year-to-year variability in May and Aug. is the dominant characteristic at both places. In June-July, blanketing E_s occurs almost on three-fourths of the days in a month. Oyinloye[2] has reported maximum and minimum values of blanketing E_s occurrence during the June solstice and during the equinox respectively, for the equatorial stations.

2.5 No Dependence on Magnetic Activity

Extensive analysis has shown that the occurrence or intensity of blanketing E_s layers at Trivandrum has no correlation with the global level of geomagnetic activity as indicated by A_p or K indices.

3. Discussion

Any theory of blanketing sporadic E layers in the vicinity of magnetic equator has to explain satisfactorily the three main features presented in the previous sections. As pointed out already, the fact that blanketing E_s layers occur the same day at both Kodaikanal and Trivandrum less than one-fifth of the time clearly rules out the possibility that the E_s layers originate from such very large scale fields like the dynamo region electrostatic field or wind fields associated with tidal modes. Localized or mesoscale fields like winds associated with internal gravity waves are the likely sources of these E_s layers. Even in the case of E_s occurrences at both places, a common origin or a common layer cannot be assumed. The occurrence of blanketing E_s at each place is so frequent in summer months that many days of E_s occurrence at both places are to be expected naturally.

The near absence of blanketing E_s layers at Trivandrum until 1500 hrs in daytime can be attributed to the inhibiting influence of the daytime eastward electric field on the formation of E_s layers. As the eastward electric field becomes weaker in the late afternoon hours, the E_s layers are formed and they persist into the night or new E_s layers are formed at night when the electric field is westward. The peaking of E_s layer occurrence around 1800 hrs when the reversal of the east-west electric field is expected, lends strong support to this hypothesis. A similar behaviour at Kodaikanal is to be expected and it is observed also. Since Kodaikanal is 3·5° (dip) away from magnetic equator, the vertical polarization field and the inhibiting influence due to the eastward electric field are less at this place and the occasional occurrence of blanketing E_s even in the morning and early afternoon hours can be qualitatively explained. A quantitative theoretical analysis is in progress and the results will be reported later.

The observed seasonal maximum in summer is consistent with the well known summer maximum of temperate latitude blanketing sporadic E (ref. 3 and 4). This maximum in summer can be due to an enhancement of source strength, but in the absence of adequate observational knowledge about the dynamo region winds and electric fields in the vicinity of magnetic equator, no conclusions can be drawn on this aspect.

4. Conclusions

(i) Blanketing sporadic E layers are generated close to the magnetic equator through a mesoscale or localized source like wind shears associated with short period internal gravity waves.

(ii) Formation of blanketing E_s layers near the magnetic equator is strongly inhibited in the forenoon and early afternoon hours by some strong controlling agency; this agency is most probably the daytime eastward electric field in the dynamo region.

(iii) Full theoretical understanding of the above processes can throw considerable light on the complex dynamics of the equatorial electrojet region.

Acknowledgement

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