Post-midnight Occurrence of Equatorial Spread-F

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Evidence is presented to point out that the presence of an elevated F-region with reduced peak electron density in the equatorial region does not always result in the occurrence of spread-F condition in the post-midnight period.

An aspect of the phenomenon of equatorial spread-F that is being studied with considerable interest in recent times is its sudden onset in the post-midnight period[1-9]. The morphological studies made so far consistently show that the sudden post-midnight onset of equatorial spread-F occurs in close association with an increase in F-region height[3-6,8], a feature similar in nature to the one noticeable around the sunset period. However, there is no agreed opinion at the moment among the workers as to the physical mechanisms underlying the uplift of equatorial F-region in the post-midnight period and the associated occurrence of spread-F. Rastogi and Woodman[5], from a comparative study of ionogram data and F-region vertical drift data, found that the increase in F-region height is due to an anomalous reversal in the vertical drift from negative to positive values (upward), and contended that the presence of a strong eastward electric field (represented by an upward vertical drift and a prominent increase in h'F) is an essential condition for the sudden post-midnight onset of the equatorial spread-F. They suggested that the eastward electric field coupled with a positive value of the electron density gradient at the bottom of the F-region generates irregularities and hence spread-F through a gradient drift plasma instability mechanism. Bowman[1,6], on the other hand, obtained evidence from statistical analyses to show that the presunrise increase in h'F and spread-F occurrence in the equatorial region are associated with travelling ionospheric disturbances (TIDs) that originate in the auroral regions at times of enhanced geomagnetic activity. Recently, Booker and Ferguson[7] and Booker[9] explained the presunrise occurrence of equatorial spread-F in terms of long field aligned irregularities in F-region electron density, i.e. the irregularities maintained by TID of acoustic gravity waves origin. They asserted that the presence of an elevated F-region with reduced peak electron density is an excellent condition for the development of spread-F in the presunrise period. Recent detailed case studies made by the author[10] using ionogram data at Kodaikanal, ionosonde data from a chain of stations extending from high latitudes down to the dip equator, and magnetogram data in the auroral region pertaining to the same longitude zone, suggested that the increase in F-region height associated with the sudden post-midnight onset of equatorial spread-F, particularly under quiet to relatively quiet geomagnetic conditions, is due to anomalous reversal in F-region vertical drift rather than due to TID of auroral origin. The case studies further showed that, occasionally, the occurrence pattern of spread-F at Kodaikanal and Trivandrum situated very closely in the equatorial region is markedly dissimilar, particularly in the post-midnight period. This observation which was assessed to be a genuine one from a thorough examination of published ionosonde data enabled us to draw the qualitative inference that although the sudden post-midnight onset of equatorial spread-F occurs quite consistently in close association with an increase in F-region height (indicative of the presence of an eastward electric field in the equatorial region), such a situation need not always be a sufficient condition for the generation of irregularities responsible for spread-F. If this is to be true, there are to be a good number of occasions when the equatorial F-region experiences an increase in height in the post-midnight period, but without the onset of spread-F condition. In this communication, evidence in support of such a possibility is presented.

The original quarter-hourly ionogram data at Kodaikanal (lat., 10°14′N; long., 77°28′E; dip. 3.5°N) pertaining to a 4-hr period of high sunspot activity (1957-60; mean sunspot number ≈ 178), as used in our earlier study[8], had been thoroughly examined for the nocturnal behaviour of h'F on individual nights. Since the work of Booker and Ferguson[7] and Booker[9] emphasized particularly on the presence of reduced peak electron density in the F-region for the

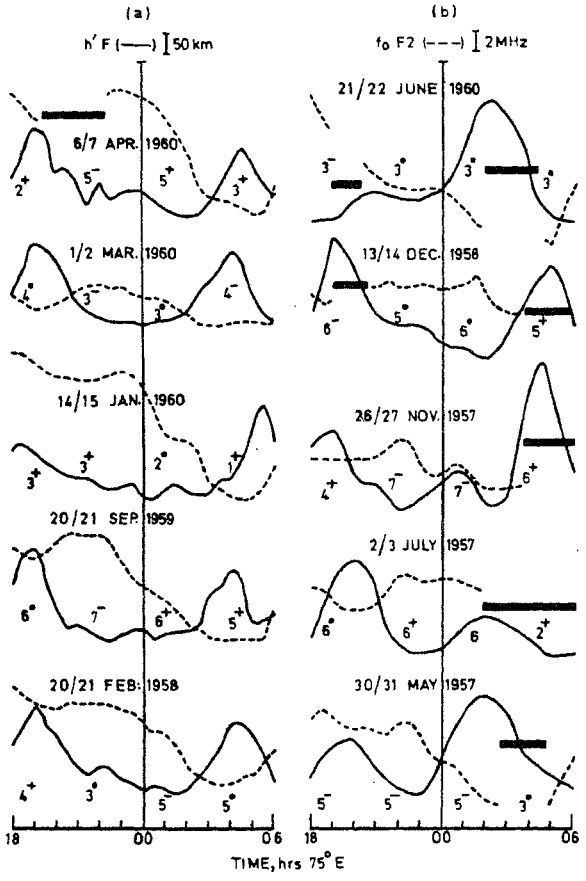

Fig. 1—Typical examples of the nocturnal variation of h'F and f_0F2 at the equatorial station, Kodaikanal, showing the presence of an increase in F-region height in the post-midnight period: (a) without the occurrence of spread-F and (b) with the occurrence of spread-F (The black patches on the plots indicate the presence of spread-F. Values of the 3-hourly planetary geomagnetic index, K_p, are also shown)

development of post-midnight spread-F, the behaviour of peak electron density (represented by f_0F2) has also been examined. The ionogram data surveyed clearly showed the existence of a sizeable number of occasions when the F-region underwent a prominent increase in height with reduced f_0F2 in the post-midnight period, but without the onset of spread-F conditon as anticipated from the results of our recent case studies[10]. Typical examples illustrative of this behaviour are presented in Fig. 1(a). To facilitate a comparison, typical examples (when the increase in F-region height is accompanied by the onset of spread-F) reported earlier[8] are shown in Fig. 1(b). The post-midnight increase in h'F depicted in Fig. 1[(a) and (b)] is found to be genuine, since a similar increase in h_{max} (not shown here) is noticed for all the events from (N-h) profile analysis. The data presented in Fig. 1(a) enables us to emphasize that the presence of the equatorial F-region at an increased height and with reduced peak electron density in the post-midnight period does not always result in the occurrence of spread-F condition, and this behaviour is noticeable during quiet as well as disturbed geomagnetic conditions. The possibility that a prominent increase in height with reduced peak electron density of F-region need not always be necessary for the onset of spread-F may also be seen from the behaviour on the night of 2/3 July 1957 [Fig. 1(b)]. If, as interpreted by Rastogi and Woodman[5], the sudden post-midnight onset of equatorial spread-F is due to a gradient drift instability mechanism, the observations reported here lend further support to our earlier inference that the nature and magnitude of the electron density gradient, rather than the presence of an eastward electric field, could pay a critical role in the onset of spread-F. On the other hand, if the irregularities generated by TID of acoustic gravity waves origin are responsible for the sudden post-midnight onset of spread-F as envisaged by Booker and Ferguson[7] and Booker[9], the results imply that although favourable conditions exist in the F-region, TIDs are not always present in the post-midnight period in the equatorial region. Further detailed case studies of the evidence presented here [Fig. 1(a)] are required to clarify and provide a better picture of the physical mechanisms and factors influencing the sudden onset of equatorial spread-F in the post-midnight period under varying geomagnetic conditons.

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