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On the relationship between geomagnetic activity and spread-F configurations at Kodaikanal

by

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ABSTRACT. – *A study is made of the seasonal and sunspot cycle trends in the effect of geomagnetic activity on the nocturnal occurrence of spread-F configurations at Kodaikanal (Geo. Mag. Lat. 0.6° N, dip 3.5° N), using ionogram data for the period 1957-1963. It is found that, in overall behaviour, the peak occurrence of range spread shows a systematic decrease with increase of Kp (upto a value of 6) during D and E months. Such a trend in the peak occurrence of frequency spread is noticed only during E months. The occurrence of range spread in the presunrise period is nearly independent of Kp during D and E months, while in J months it is relatively more for frequent quiet to moderately disturbed conditions (Kp in the range 1 to 6) compared to very quiet and highly disturbed periods (Kp 0 and above 6). A comparison of these and other features observed at Kodaikanal with those at Huancayo, reported recently, indicates marked differences in the seasonal and sunspot cycle trends of the effect of geomagnetic activity on spread-F configurations in the Indian and American equatorial regions.*

RESUME. – *On a fait une étude des influences saisonnière et du cycle solaire sur l'effet de l'activité géomagnétique sur la fréquence nocturne des configurations Spread-F à Kodaikanal (Latitude géomagnétique 0,6° Nord, dip 3,5° Nord), en utilisant les données d'ionogrammes pour la période 1957-1963. On a trouvé que, de façon globale, la fréquence maximale de l'élargissement en étendue montre une décroissance systématique avec l'augmentation de K_p (jusqu'à la valeur de 6) pendant les mois D et E. Un tel effet dans la fréquence maximale pour l'élargissement en fréquence n'est noté que pendant les mois E. L'apparition d'élargissement en étendue avant le lever du soleil est à peu près indépendante de K_p pendant les mois D et E alors que pendant les mois J elle est relativement plus fréquente pour des conditions calmes à modérément perturbées (K_p dans la gamme de 1 à 6) par rapport à des périodes très calmes ($K_p = 0$) et à des périodes très perturbées ($K_p > 6$). Une comparaison de ces caractéristiques et d'autres observées à Kodaikanal avec celles observées à Huancayo, publiées récemment, montrent de nettes différences dans les influences saisonnière et du cycle solaire de l'effet de l'activité géomagnétique sur les configurations Spread-F dans les régions équatoriales Indiennes et Américaines.*

Introduction

The morphology of spread-*F* (appearance of diffuse traces on ionograms) at equatorial latitudes has been studied by several workers since its first identification on Huancayo ionograms by Booker and Wells (1938). Excellent articles reviewing the status of the phenomenon have been written from time to time (Clemesha and Wright, 1966 ; Farley *et al*, 1970). The earlier studies, based on published ionospheric data, have shown a longitudinal effect in the seasonal and sunspot cycle associated occurrence patterns of equatorial spread-*F* (Rangaswami and Kapasi, 1969 ; Chandra and Rastogi, 1970). A resourceful approach, that is now being adopted for synoptic studies of equatorial spread-*F*, is to make use of original ionogram data, which provide information on the type of spread-*F* and hence a better insight into the phenomenon (e.g. Skinner and Kelleher, 1971 ; Chandra and Rastogi 1972 ; Sastri and Murthy, 1975). It is well known that spread-*F* on equatorial ionograms mostly manifests itself in two basic configurations namely, range and frequency types (Clemesha and Wright, 1966). The range type of spread-*F* is characterized by the presence of spread either only at the low frequency end of the *F*-layer trace with clearcut *foF2* cusps or over the entire frequency range of the *F*-layer trace. The frequency type of spread-*F*, on the other hand, is characterized by the presence of spread only at and around the critical frequency of the *F*-layer trace. Recent studies of spread-*F* configurations at Kodaikanal and Huancayo have shown significant differences in the

seasonal and sunspot cycle trends of the nocturnal behaviour of range and frequency types of spread-*F* in the Indian and American equatorial regions (Rastogi and Vyas, 1977, 1978 ; Sastri *et al*, 1979 *a*, *b*).

It is known from earlier studies, based on published ionospheric data, that there is an inhibiting effect of geomagnetic activity on the occurrence of equatorial spread-*F*, whose influence was reported to be most apparent during the premidnight period of high sunspot activity conditions (see references in Skinner and Kelleher, 1971). We have recently studied the effect of geomagnetic activity on spread-*F* configurations at Kodaikanal by evaluating cross correlograms between daily *Ap* and percentage occurrence (for the whole night) of range and frequency types of spread-*F*, for each year from 1957 to 1963. It was found that the occurrence of both range and frequency spread shows a significant negative correlation with *Ap* but only during periods of high sunspot activity i e.a marked sunspot cycle trend was noticed (Sastri *et al*, 1978). The recent studies, using *f*-plots, of Rastogi *et al*, (1978) and Chandra *et al* (1979) showed the nature of the influence of geomagnetic activity on the occurrence of range and frequency spread at Huancayo to depend prominently on local time and season. It is therefore felt desirable to further examine the occurrence of spread-*F* configurations at Kodaikanal in relation to geomagnetic activity as a function of local time, season and phase of the sunspot cycle. In this paper, we present the results of such a study and highlight the strikingly different nature, that became apparent from the study, of the response of spread-*F* configurations to geomagnetic activity in the Indian and American equatorial regions. The effect of geomagnetic activity is inferred by examining the variation of the occurrence of spread-*F* configurations with the geomagnetic disturbance index, *Kp*

Analysis

Quarter-hourly ionograms for the period 1957-1963, which encompasses years of high (1957-1959, mean $Rz = 177$), moderate (1960-61, mean $Rz = 83$) and low (1962-1963, mean $Rz = 33$) sunspot activity, constitute the basic data for the present study. Ionograms for each night over the seven year period have been carefully examined and the type of spread is noted down as and when it occurred. In an earlier study of spread-*F* configurations at Kodaikanal for the period 1957-63. it was noticed that the occurrence of range spread shows a prominent peak around 2030-2230 hrs I S.T (Sastri *et al*, 1979 a). To examine the effect of geomagnetic activity as a function of local time, the percentage occurrence (defined as the ratio of the number of ionograms exhibiting spread-*F* to the total number of ionograms examined,multiplied by 100) of range spread in the interval 2030-2315 hrs I.S.T and of frequency spread in the interval 2330-0215 hrs I.S.T have therefore been evaluated for each night. From this material, the seasonal and sunspot cycle trends are studied by clubbing the data according to season and level of sunspot activity and obtaining the mean percentage occurrence of either type of spread-*F* for the different *Kp* groups. The seasonal groups of months adopted are *D* (November through February), *E* (March, April, September, October) and *J* (May through August) months. The occurrence of range spread in the pre sunrise period (0230-0515 hrs I S.T) in relation to *Kp* is also studied in a similar manner to facilitate a comparison with the behaviour at Huancayo, where a conspicious positive effect of geomagnetic activity was noticed by Chandra *et al* (1979)

Results and discussion

In Figure 1 are shown the seasonal patterns in the variation of the mean percentage occurrence of range and frequency spread with *Kp*, averaged for the entire period 1957-63. The error of the mean values are indicated in the figure by vertical bars. It can be clearly

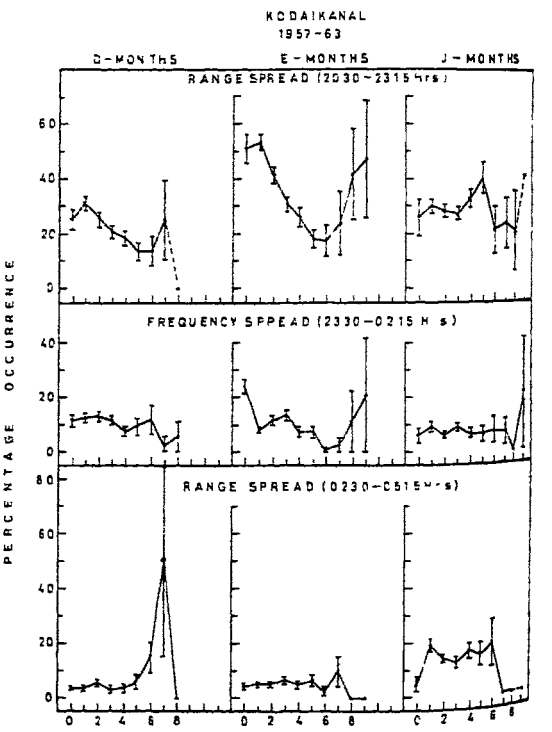

Fig 1

Variation with *Kp* of the mean percentage occurrence of range spread (2030-2315 hrs I.S.T), frequency spread (2330-0215 hrs I S T) and range spread (0230-015 hrs I.S.T) during different season, averaged for the period 1957-63. The vertical bars represent errors of the mean values The points joined to by dashed lines correspond to a single observation.

seen from Figure 1 that during *D* and *E* months, the occurrence of range spread (2030-2315 hrs) shows a systematic decrease with increase of *Kp* upto a value of 6. The occurrence shows a tendency to increase with further increase of *Kp* but only during *E*-months. An inhibiting influence of enhanced geomagnetic activity on the occurrence of frequency spread (2330-0215 hrs) is also apparent but only during *E*-months. The peak occurrence of both range and frequency spread is more or less unaffected by geomagnetic activity during *J*-months as can be seen from Figure 1. These gross features of the response of the occurrence of range and frequency spread at Kodaikanal to geomagnetic activity are markedly different from those at Huancayo, where the occurrence of both range and frequency spread shows a systematic and significant decrease with increase of *Kp* during *D* and *E* months and a conspicuous increase during *J*-months (see Fig. 1 of Chandra *et al*, 1979) The occurrence of range spread in the presunrise period (0230-0515 hrs), as may be seen from Figure 1, is more or less independent of *Kp* during *D* and *E* months, while during *J*-months, it is relatively more for quiet to moderately disturbed conditions (*Kp* range from 1 to 6) than for very quiet and highly disturbed conditions (*Kp* 0 and above 6). This behaviour is also different from that at Huancayo where the occurrence of range spread in the presunrise period shows a systematic increase with increase of *Kp* during all seasons (see Figure 1 of Chandra *et al.*, 1979).

In Figure 2 are depicted the changes in the mean percentage occurrence of range spread (2030-2315 hrs) with *Kp* during different seasons, for periods of high, moderate and low sunspot activity. The changes in the occurrence of frequency spread (2330-0215 hrs) and presunrise range spread are presented in the same format in Figure 3 and 4 respectively. The reuslts presented in Figure 2 clearly show a systematic and significant decrease of the occurrence of range spread with increase of *Kp* upto a value of 6, and a tendency to increase thereafter during *E*-months of high and low sunspot activity. The changes with *Kp* for moderate sunspot activity are rather irregular although a tendency to decrease with increase in *Kp* is noticeable. Decreases with increase of *Kp* are also evident during *D* months of high and moderate sunspot activity and in *J* months of high sunspot activity. A comparison of these features at Kodaikanal with those at Huancayo reveals that the response of range spread-*F* to geomagnetic activity is markedly different during *J*-months at the two stations. At Huancayo, the occurrence of range spread shows a systematic increase with increase of *Kp* irrespective of sunspot activity conditions although this trend is prominent during low sunspot activity conditions (see Fig. 3 of Chandra *et al*, 1979) ; at Kodaikanal, on the other hand, the occurrence decreases with increase of *Kp* and this pattern is evident only during years of high sunspot activity.

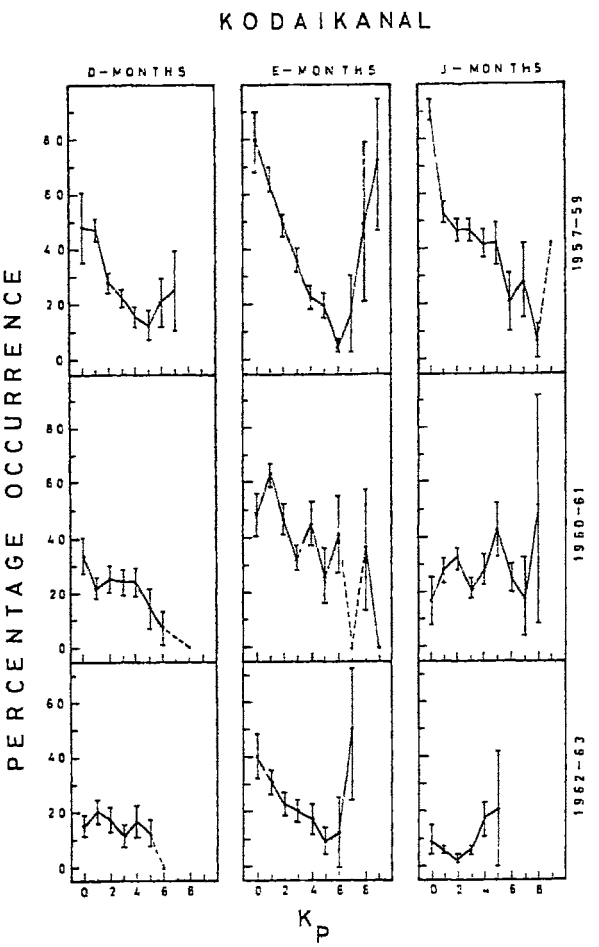

Fig 2

Variation with *Kp* of the mean percentage occurrence of range spread (2030-2315 hrs I S T) during different seasons for periods of varying sunspot activity

A rather systematic trend of reduction in the occurrence of frequency spread with increase of *Kp* is evident during all seasons of high sunspot activity, as may be seen from Figure 3. There is no obvious dependence of the occurrence on *Kp* during all seasons of low sunspot activity, and during *D* and *J* months of moderate sunspot activity. This behaviour of frequency spread at Kodaikanal is again significantly different from that Huancayo where its occurrence shows an increase in *J* months and a decrease in *E* months with enhanced geomagnetic activity, irrespective of the phase of the sunspot cycle (see Figure 2 of Chandra *et al*, (1979)

The occurrence of range spread in the presunrise period, as may be seen from Figure 4 is nearly independent of *Kp* during *E* months, irrespective of the phase of the sunspot cycle During *D* months, it shows a tendency to decrease with increase of *Kp* for high sunspot activity and an increase for low sunspot activity conditions The changes however are not marked. In

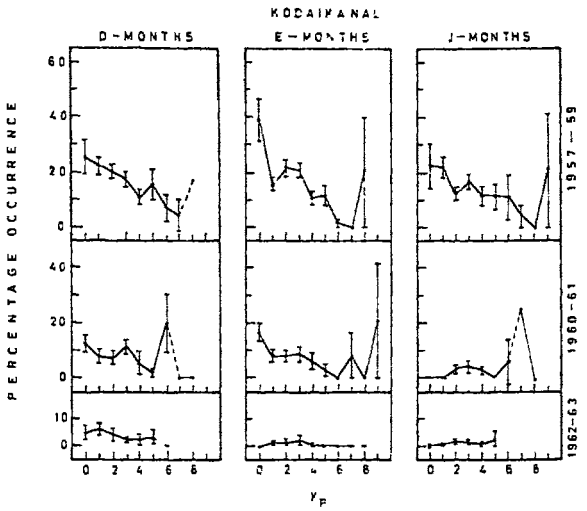

Fig 3

Same as in Figure 2 but showing the behaviour of frequency spread (2330-0215 hrs I.S.T.)

J months, its occurrence is relatively more for the *Kp* range 1 to 6 than for *Kp* 0 and above 6 and this behaviour is apparent only for the periods of high and moderate sunspot activity. These trends in the response of the occurrence of range spread in the presunrise period at Kodaikanal to geomagnetic activity are also different from those at Huancayo, where the occurrence of presunrise range spread shows a systematic and significant increase with increase of *Kp* (from 1 to 9), irrespective of season and phase of the sunspot cycle (see Figure 4 of Chandra *et al.*, 1979)

To conclude, the results of the present study for Kodaikanal, considered in the light of those for Huancayo

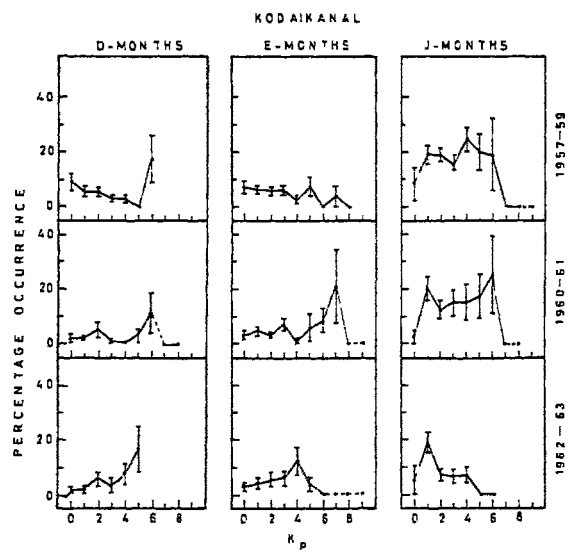

Fig. 4

Same as in Figure 2 but showing the behaviour or range spread in the presunrise eriod (0230-0515 hrs I.S T).

reported very recently by Chandra *et al.* (1979), clearly demonstrate the presence of a striking longitudinal effect in the seasonal and sunspot cycle trends of the effect of geomagnetic activity on the nocturnal occurrence of spread-*F* configurations in the equatorial region This constitutes an interesting aspect of the phenomenon of equatorial spread-*F* that merits further investigations as to its origin.

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