

Ionospheric Disturbances associated with Magnetic Storms at Kodaikanal

B. N. BHARGAVA AND U. V. GOPALA RAO

Kodaikanal Observatory, Kodaikanal

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ABSTRACT. *F*₂ layer disturbances at Kodaikanal have been analysed for a study of the behaviour of the critical frequency and the virtual height during geomagnetic storms. The disturbances have been classified for this purpose into two categories namely, the positive and negative. The characteristics of *Dst* and *SD* variation of *f*₀*F*₂ and the *SD* variation of *h'**F* at night have been discussed. The results have been explained in terms of the quiet and disturbed day vertical drift velocities.

1. Introduction

The relationship between geomagnetic and ionospheric disturbances in the *F*₂ layer has been studied by many workers. Appleton and Ingram (1935), using Slough *f*₀*F*₂ and Greenwich magnetic character figure, found that intense magnetic storms were followed by reduced noon *f*₀*F*₂. Appleton, Naismith and Ingram (1937) observed seasonal effect in the correlation between noon *f*₀*F*₂ and magnetic activity. Berkner and Seaton (1940) found that for Huancayo, in the equatorial zone, increased magnetic activity was followed by an increase in *f*₀*F*₂ and for Watheroo, the behaviour was different in summer than in winter. The seasonal character of such relationships was confirmed by Appleton and Piggot (1952) who also found that while the number and intensity of various types of ionospheric disturbances were different at different longitudes, there were no significant differences in the activities in the northern and southern hemispheres. Martyn's (1953 a) analysis of data from several moderate latitude stations indicated that disturbance-daily variations (*SD*) in the *F*₂ layer were mainly diurnal in type and the storm variations (*Dst*) were appreciable for about three days after the commencement of the magnetic storm. Martyn (1953 a) also pointed out that the ionospheric storms begin almost simultaneously at all latitudes, a result which was con-

firmed by Lewis and McIntosh (1953). Matsu-shita (1954) studied *SD* and *Dst* at Huancayo and explained the sharp maximum in *SD* theoretically by consideration of the drift resulting from calculated *SD* and the earth's field. Apart from Huancayo, the storm phenomena in *F* layer have hardly been studied at or near geomagnetic equator. In the present investigation, therefore, Kodaikanal (Lat. 10°28'N, Geomag. Lat. 0°·6N) *F*₂ layer data have been analysed for a study of the behaviour of disturbance-daily and storm-time variations in the *F*₂ region critical frequencies and virtual heights.

2. Treatment of data

The virtual heights and critical frequencies of *F*₂ layer during 26 S.C. storms of moderately severe or severe type (Range in *H* at Kodaikanal $\geq 200 \gamma$) were used for the analysis. Since there was no appreciable bifurcation of the *F* layer during day time, only night time *h'**F* values (1800 to 0600 hrs 75°E time) were used. For *SD* variation, the hourly values of virtual height of the *F* layer on the evening immediately following an S. C. were selected and the monthly median values for the corresponding hours were subtracted from these and averaged for the selected storm. For *Dst* variation in *f*₀*F*₂, the critical frequency at the hour nearest to the S.C. was selected and the median value for the month was subtracted from it. This process was followed for all

the hourly values during the next 48 hours and during the preceding 24 hours. For each one of the storms, this process was repeated and departures averaged out for D_{st} variation. The same departures for each storm were arranged in solar time for S_D variation and averaged for the storms for the preceding 24 hours and succeeding 48 hours.

On scrutiny of the departures, it was noticed that the F layer disturbances could be classified into two categories, *viz.*, (1) the positive type in which the critical frequency had a tendency to increase in day time and some times at night and (2) the negative type where f_0F_2 decreased from the mean value during the day and recovered during the evening or night. The storms were, therefore, classified into these two groups for the averaging process. There were twelve storms of the positive type and fourteen of the negative type. The average departures for critical frequencies for the 72-hour period for D_{st} variation are shown in Fig. 1. The S_D variations in f_0F_2 for the 72-hour period for both positive and negative disturbances are shown in Figs. 2 and 3. For $h'F$ no significant differences were noticed for negative and positive disturbances and therefore all 26 sets of values were averaged together for this parameter. S_D variation so obtained is shown in Fig. 4.

3. D_{st} variation in critical frequency

It will be seen from Fig. 1 that storm time variations in f_0F_2 during the 24 hours following the S. C. are irregular for both positive and negative disturbances and the ionization density is subnormal about two hours after the S. C. The 24-hour period prior to S.C. is characterised by an increase 2 to 6 hours before the S.C. whereas during the second 24 hours, the ionization remains irregular but above normal. For the negative disturbances the change of phase appears to take place about 22 hours after the S. C., the total range in the D_{st} variation being of the order of 2 Mc/s. Harmonic analysis indicated that no single harmonic is significant.

4. S_D variation in critical frequency

The characteristics of disturbance-daily variation in f_0F_2 are different for positive and negative type disturbances. The values of Δf_0F_2 for the two types of disturbances for the three separate 24-hour periods were subjected to harmonic analysis. The amplitudes and phases of first four harmonics are shown in Table 1. For positive disturbances, there are two significant harmonics, the diurnal and the third harmonic. There are two prominent maxima around 05 and 12 hours local time. During the second 24 hours there is a small but significant diurnal harmonic. For the first 24 hours of the negative type of disturbance, the significant harmonics are the diurnal and semi-diurnal. The critical frequencies are highly depressed around 03 hours local time and high about 16 to 17 hours later, the total variation being over 3 Mc/s. During the second 24 hours, the diurnal harmonic is significant as in the case of positive storms but with a different phase.

5. S_D variation in $h'F_2$

The disturbance-daily variation in the height of F_2 layer during the night are comparatively regular in nature; there is a pronounced minimum around 20 hours and maximum around 04 hours local time, the total variation in $h'F_2$ being of the order of 90 km. The occurrence of maximum at 04 hours agrees fairly well with the time of maximum at Huancayo (05 hrs) for which place Matsushita (1954) has calculated that the value of the eastward component of the electrostatic field of S_D has a maximum around 05 hours in the equatorial zone.

6. Discussion

The S_D variations at Kodaikanal appear to be somewhat different from those reported from other low latitude stations. It is known for example, that at Huancayo, only positive disturbances occur whereas we find that at Kodaikanal about half the disturbances are of negative type. Further, for the S_D variations, at Huancayo the diurnal amplitude was predominant and at Ibadan the diurnal

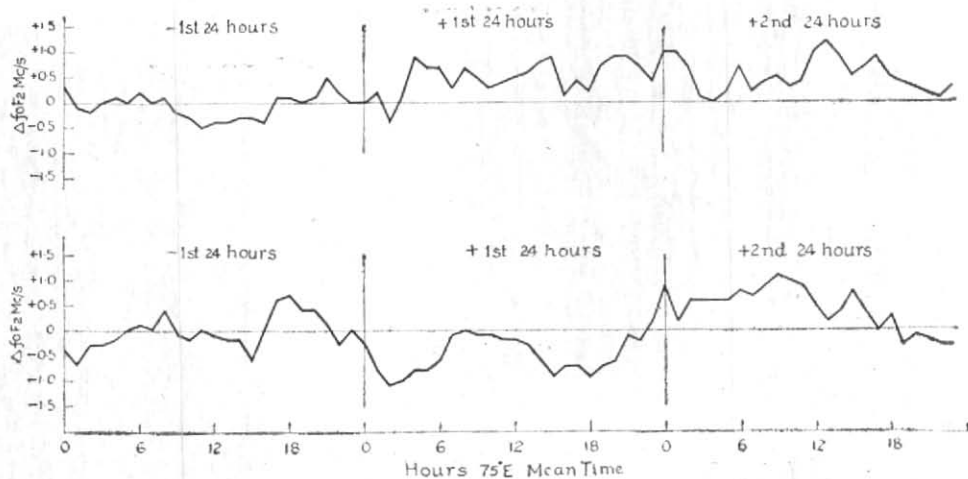


Fig. 1. D_{st} variation of f_oF_2 Positive disturbance (upper curve) and Negative disturbance (lower curve)

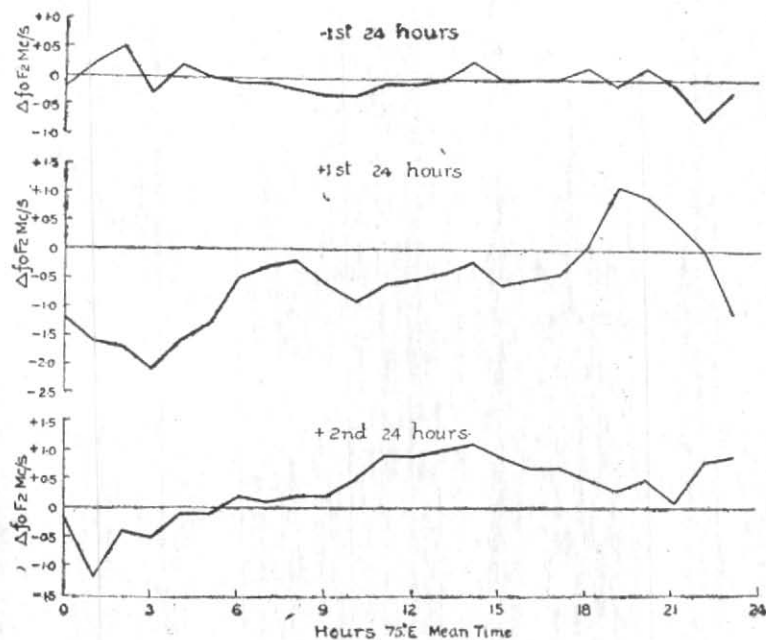


Fig. 2. S_D variation of f_cF_2 —Positive disturbance

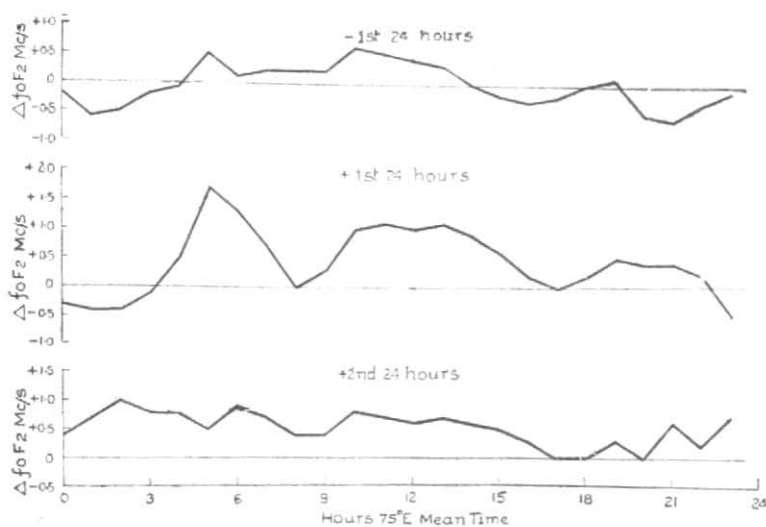


Fig. 3. S_D variation of f_oF_2 — Negative disturbance

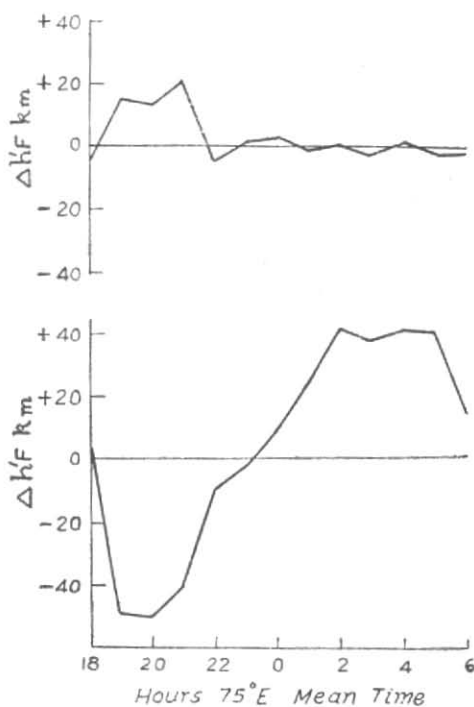


Fig. 4. S_D variation of $h'F$ during the 24 hours preceding the storm (upper curve) and during the first 24 hours (lower curve)

TABLE 1
Harmonic analysis of S_D variations

	P_0 (Mc)	P_1 (Mc)	t_1 (hrs)	P_2 (Mc)	t_2 (hrs)	P_3 (Mc)	t_3 (hrs)	P_4 (Mc)	t_4 (hrs)
Positive disturbance									
-1st 24 hrs	0	0.388	10.0	0.091	8.7	0.151	2.8	0.180	5.5
+1st 24 hrs	+0.4	0.513	10.7	0.158	6.3	0.494	4.8	0.174	5.4
+2nd 24 hrs	+0.5	0.260	5.92	0.176	0.29	0.072	3.26	0.038	2.1
Negative disturbance									
-1st 24 hrs	0	0.037	18.0	0.187	3.4	0.079	2.8	0.140	1.3
+1st 24 hrs	-0.6	0.708	16.6	0.711	8.0	0.266	5.2	0.292	1.6
+2nd 24 hrs	+0.3	0.613	14.6	0.138	10.1	0.279	5.7	0.197	4.6

and semi-diurnal amplitudes were of comparable order. At Kodaikanal, as stated earlier, first and third harmonics are significant for positive and first and second for negative disturbances.

According to the theory developed by Martyn (1953 b) currents in the lower ionosphere associated with geomagnetic disturbances result from an electrostatic field which originates in the polar regions and spreads all over the earth. The interaction of this field with the earth's magnetic field produces a vertical ionic drift with a velocity V_d which can be deduced from the disturbance-daily variation of the earth's field. The actual vertical drift on a disturbed day takes place with a velocity ($V_d + V_q$) where V_q is the quiet day drift velocity derived from geomagnetic S_q variation. When V_d and V_q are set up with a phase difference of 180° there is a reduction in the drift velocity resulting in an increase in maximum electron density which accounts for positive type disturbances. According to Martyn (1953 b) Dst (F_2) variations are simply due to non-linear effects occasioned by SD (F_2) variations which are the primary cause of all F_2

variations associated with magnetic disturbances.

All the 26 storms, data for which have been analysed, occurred between January 1956 and September 1957, a period of comparatively high sunspot activity. Sato (1957) has indicated that the disturbance-daily variation and consequently V_d increases with the increased geomagnetic activity and the magnitude of V_q becomes negligible compared to that of V_d . The magnitude of $V_d + V_q$ becomes, therefore, comparable to V_d . If therefore, a disturbance starts in the morning hours the disturbance-daily variation and V_d are large during the time following the commencement and negative type of disturbance should result. This is precisely happening at Kodaikanal, where most of the negative type disturbances occurred following an S. C. in the morning.

Again for storms starting in the late evening hours, the magnitude of disturbance-daily variation is likely to be comparatively smaller in the course of the next day. It therefore follows that during the day time in the first 24 hours V_d will also be comparatively smaller for such storms and comparable

in magnitude to V_q . If V_d and V_q are set up with a phase difference of about 180° the resultant drift velocity will tend to zero and an increase in f_0F_2 will follow. This is

confirmed from our observations. Most of the storms commencing in the evening hours at Kodaikanal have been found to be of positive type.

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