10. Magnetic and Ionospheric Disturbances in Low Latitudes

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Abstract—The report contains a brief summary of studies on the meridional profiles of f_0F2 and $hpF2$ in the eastern zone in different seasons of the years 1954 and 1957, and at different times of the day. The daily variation of the f_0F2 equatorial anomaly is discussed. It has been found that the effect of magnetic disturbances is to reduce the sub-equatorial anomaly.

From a statistical study of f_0F2 data on magnetically disturbed days, it has been shown that the increase of day-time f_0F2, which takes place near the equator, changes to a decrease at about geomagnetic latitude 7°N, or magnetic dip 20°N. This is also the

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latitude at which the phase reversal of lunar variation of f_0F2 occurs. Sudden disturbance (SD) variations of f_0F2 at Ahmedabad are derived from records of days of sudden commencement (SC) type magnetic storms, and also from other magnetically disturbed days, and compared with results obtained at other places. Storm time variations (Dst) are also studied.

The occurrence of spread-F at Ahmedabad is found to decrease with increase in magnetic activity; the opposite to that at Slough. The change-over takes place somewhere near magnetic dip 45°N or geomagnetic latitude 25°N.

IN 1954, we had six ionospheric sounding stations in India. This number was increased to eight in 1957. The magnetic dip at four of these stations was less than 11°. Figure 1 shows the f_0F2 and $hpF2$ profiles between stations in the eastern zone with magnetic dip varying from 0° to 60°N, in 1954 and 1957 at different hours of the day and in each of the months January, April, July and October. The data of all the Indian and of four Japanese stations have been used in preparing this diagram.

The profiles were regular in 1954. The day-time upward motion of the equatorial ionosphere ($hpF2$) occurred mainly to the south of the latitude of Ahmedabad (dip 34°N). The peak value of f_0F2 occurred in the neighbourhood of Ahmedabad at about 1500, and at 2100 the ionosphere was calm.

By contrast, the ionosphere in 1957 was much more disturbed and dilated, the level of $hpF2$ was much higher and the peak in f_0F2 remained strong even at 2100. It is probable that the lower rate of recombination of electrons at the higher levels of maximum electron density in 1957 was responsible for this. It is obvious that while the f_0F2 peak was to the south of Ahmedabad in 1954, it was to its north in 1957.

In some of the diagrams of $hpF2$, the lines of force of the earth's magnetic field are shown by dotted lines. They show that the peak value in f_0F2 occurs on the polar side of the equatorial upheaval and suggest that the electron accumulation at the peak is due to northward and downward flow of electrons and ions along the lines of magnetic force.

It is known that during times of magnetic disturbance, the f_0F2 region near the geomagnetic equator is raised, and above a certain latitude it is depressed (APPLETON and PIGGOTT, 1955).

Figure 2 shows the mean profiles of f_0F2 on magnetically disturbed days at different times of the day compared with monthly medians. The data plotted are the mean values of f_0F2 on 43 days in 1956 on which the values of K at Alibag were > 25. It will be seen that the sub-equatorial anomaly of f_0F2 is slightly reduced on magnetically disturbed days, the maximum depression being near the peak of f_0F2 at Ahmedabad. South of dip 20°N, the day-time values of f_0F2 increase, while north of it they decrease. The effect of magnetic disturbances is to flatten out the equatorial anomaly of f_0F2.

The same result is shown by the superposed-epoch method for the relative variations of midday f_0F2 at Delhi, Ahmedabad, Bombay, Madras and Tiruchirapally. The relative variations of f_0F2 at the different places are shown in Fig. 3 using twenty-seven epochs in 1954, round days when the midday value of f_0F2 was more than 10 per cent below the median midday value at Ahmedabad. It is found that the change-over from positive to negative in f_0F2 takes place at the geomagnetic

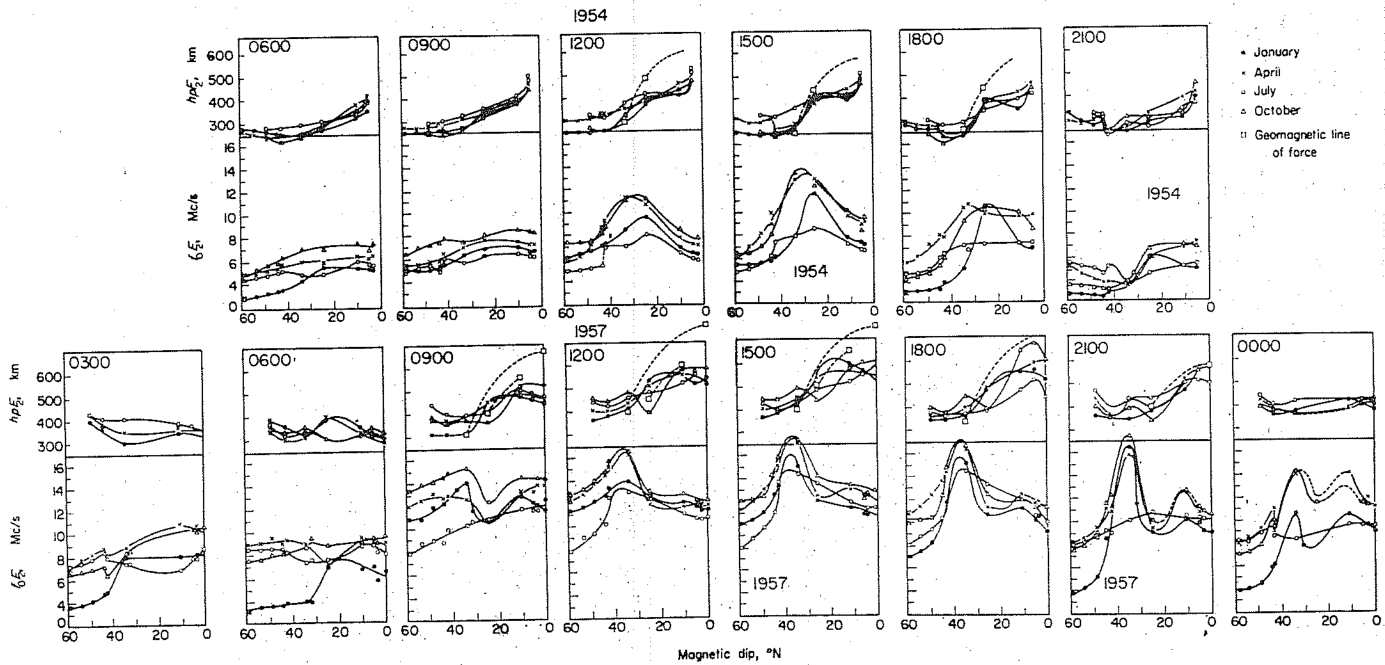

Fig. 1. Meridional profiles of f_0F2 and h_pF2 in the eastern zone at different times of the day in January, April, July and October, 1954 and 1957.

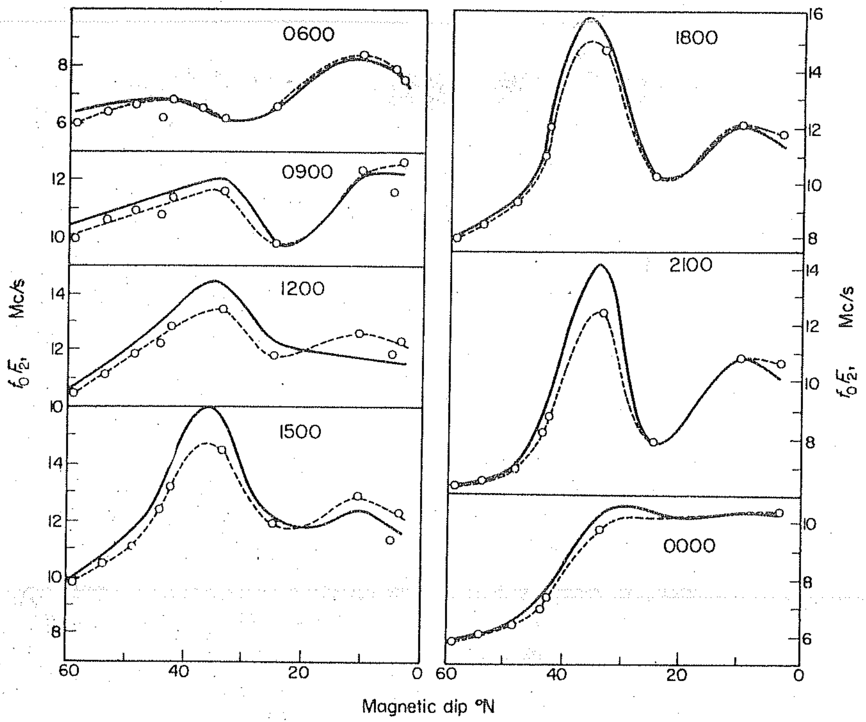

Fig. 2. Mean profiles of f_0F2 on normal and magnetically disturbed days in 1956: ——— average monthly median; - - - - - - average of days having $K > 25$ (43 days), 1956.

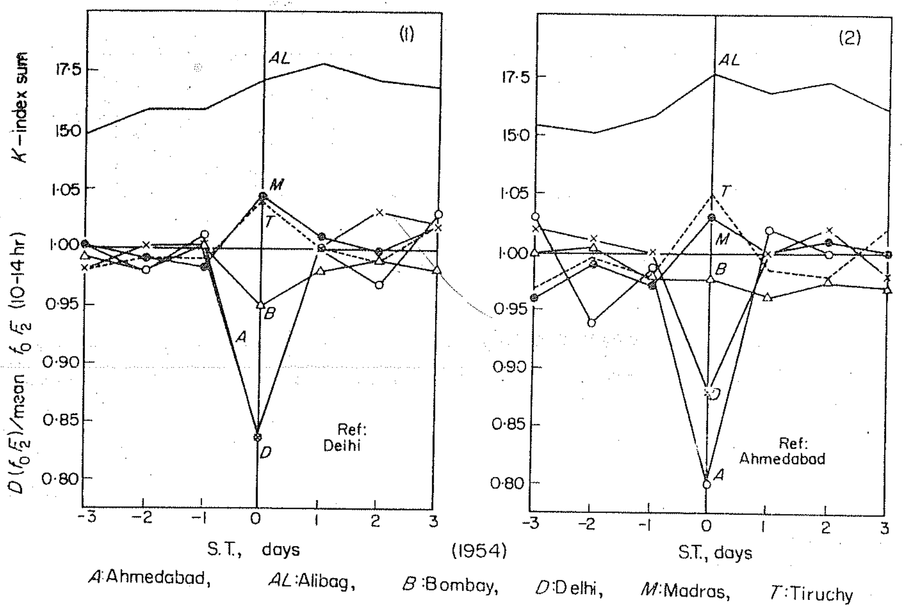

Fig. 3. Variation of midday f_0F2 (superposed epoch) on disturbed days in low latitudes (1) with Delhi and (2) with Ahmedabad as reference station, when the midday depression in f_0F2 was more than 10 per cent of the monthly median value.

latitude of about $\Phi = 7°$N or magnetic dip $\Phi = 20°$N. The local time at each of the above places is nearly the same.

It is curious to note (Fig. 4) that the reversal of phase of lunar diurnal variations also takes place between Bombay and Madras at a latitude where the value of the dip is about 20°N (KOTADIA and RAMANATHAN, 1956).

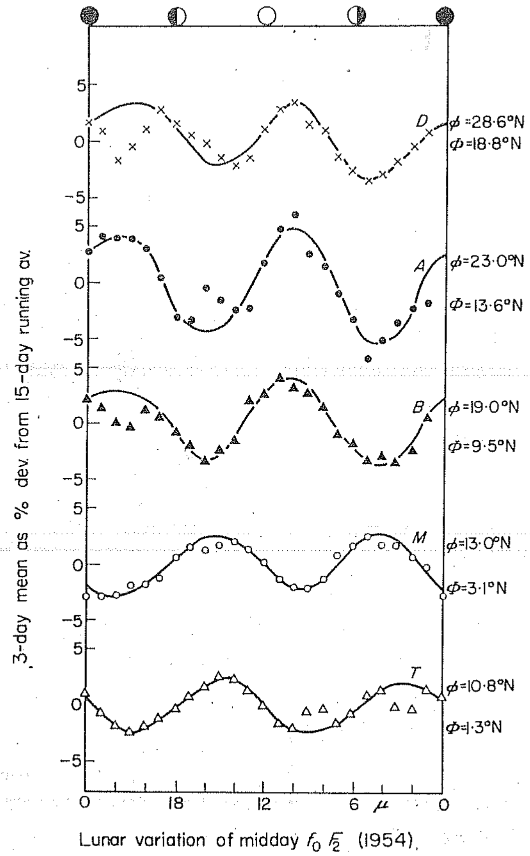

Fig. 4. Variation with lunar phase of midday f_0F2 (10–14 hr)—at low latitude stations in Indian zone. Note the reversal of phase between B (Bombay) and M (Madras).

Diurnal Variation of f_0F2 *and* hpF2 *during a Few Selected Magnetic Storms*

Figures 5, 6 and 7 show the variations of f_0F2 and $hpF2$ at Kodaikanal, Ahmedabad, Delhi and Kokubunji during three sudden commencement magnetic type storms in 1956 and 1957, superposed on the curves of monthly median variations in the same months. The times of commencement and of maximum severity of the storms are indicated on the curves.

	(1)	(2)	(3)
Dates	27–4–56	30–6–57	21–4–56
	28–4–56	1–7–57	22–4–56
		2–7–57	23–4–56
Times of SC (75°EMT)	27 (0200)	30 (1030)	21 (1600)

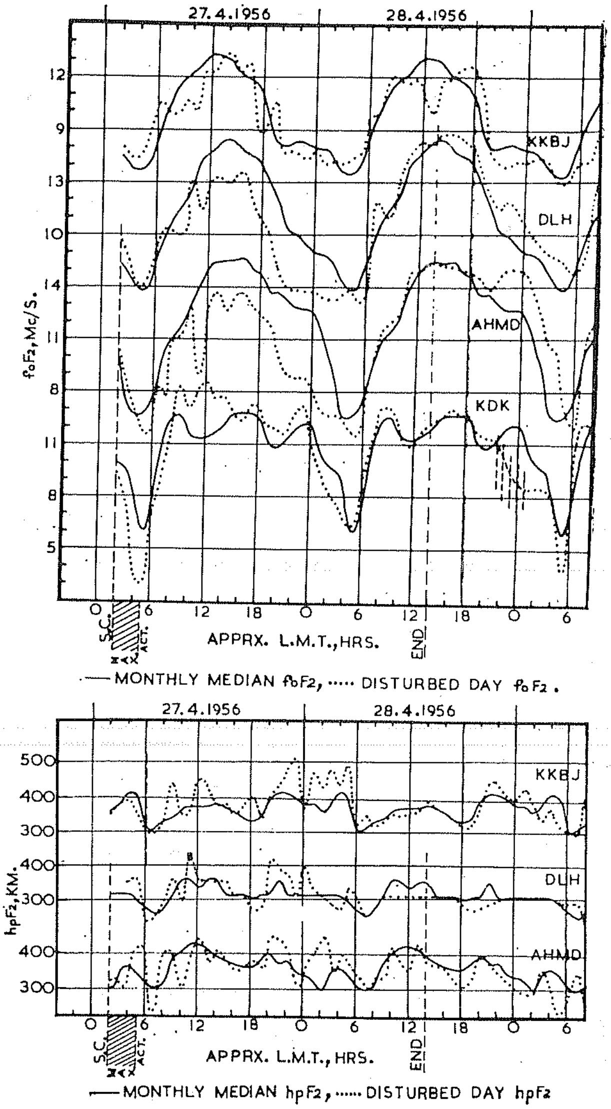

Fig. 5. Diurnal variation of f_0F2 and $hpF2$ on a sudden commencement type magnetically disturbed day (27–28 April 1956) superposed on monthly median variations: KKBJ: Kokubunji, DLH: Delhi, AHMD: Ahmedabad, KDK: Kodaikanal, SNGP: Singapore, TRC: Tiruchirapalli.

Attention may be drawn to the following features:

(1) The largest changes in the ionosphere occur on the day of, or the day following the commencement of the magnetic storm. At Singapore and Kodaikanal, the change is generally a daytime increase in f_0F2, while at Ahmedabad, Delhi and Kokubunji, it is a decrease. The changes at Kokubunji are generally smaller than at Delhi or Ahmedabad.

(2) On many storm days, the morning, post-sunrise increase in f_0F2 at Ahmedabad and Delhi is much steeper, and there is a pronounced tendency for oscillations of f_0F2 in the forenoon.

(3) After the main phase of the storm, there is a tendency for increased night-time F-scatter.

(4) The variations of $hpF2$ are more irregular on storm days and the heights are generally greater.

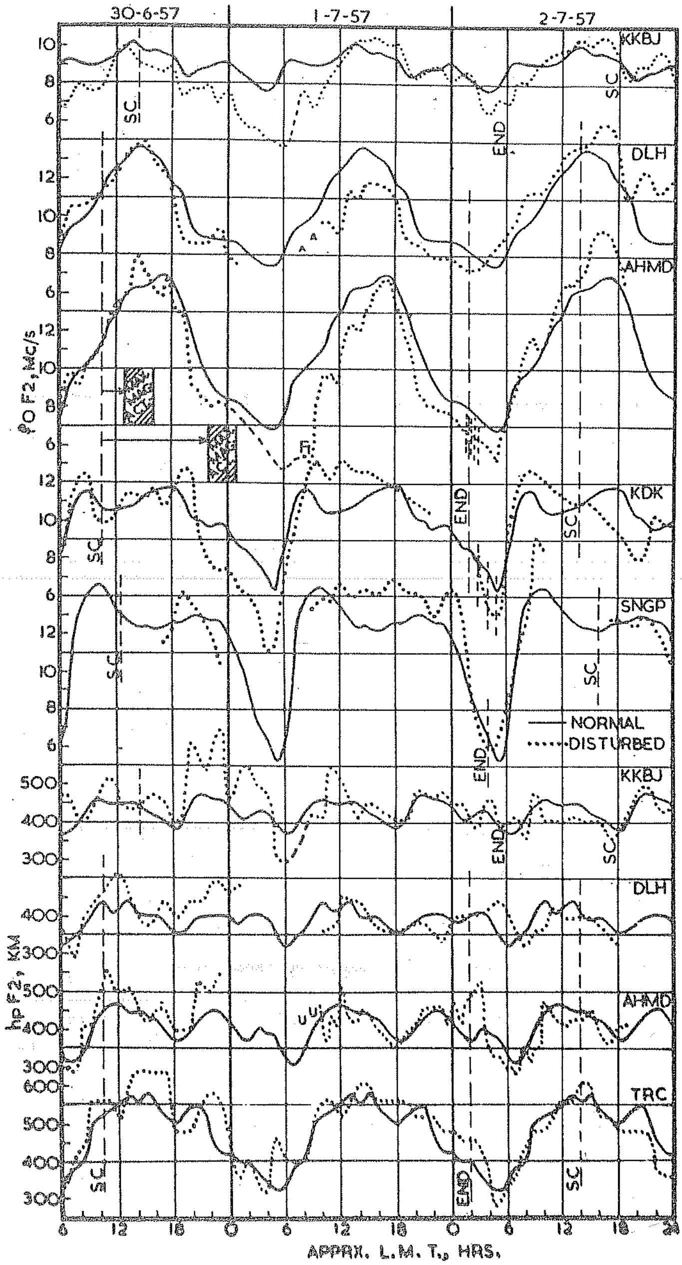

Fig. 6. Diurnal variation of f_0F2 and $hpF2$ on a sudden commencement type magnetically disturbed day (30 June–2 July 1957) superposed on monthly median variations: KKBJ: Kokubunji, DLH: Delhi, AHMD: Ahmedabad, KDK: Kodaikanal, SNGP: Singapore, TRC: Tiruchirapalli.

The behaviour of the ionosphere during magnetic storms depends, as is well known, on the severity of the storm and also on its time of commencement.

It is possible to analyse, as has been done by APPLETON and PIGGOTT (1952), and by MARTYN (1953), the disturbance variations of an observed ionospheric characteristic by expressing its deviation at any hour on the disturbed day from the monthly median value at that hour as a percentage deviation.

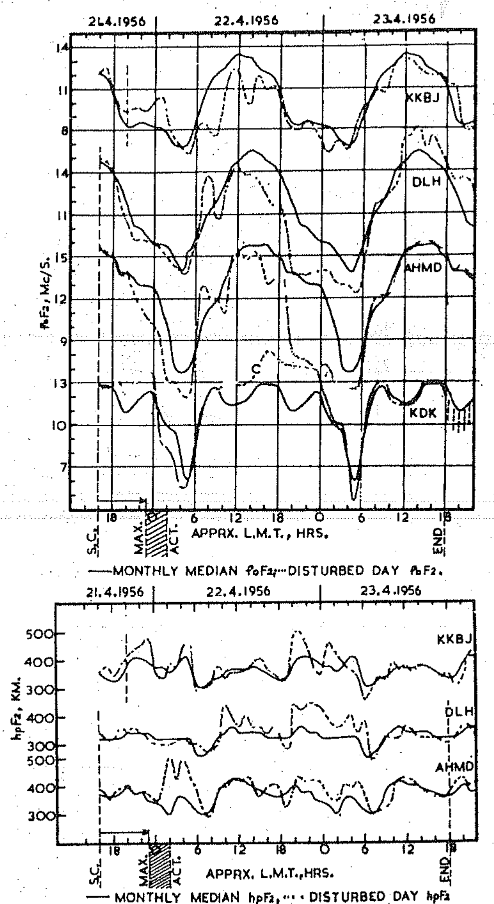

Fig. 7. Diurnal variation of f_0F2 and $hpF2$ on a sudden commencement type magnetically disturbed day (21–23 April 1956) superposed on monthly median variations: KKBJ: Kokubunji, DLH: Delhi, AHMD: Ahmedabad, KDK: Kodaikanal, SNGP: Singapore, TRC: Tiruchirapalli.

The ionospheric disturbances in f_0F2 at Ahmedabad corresponding to sixty-five sudden commencement magnetic storms in 1953–1957 were analysed this way, dividing the storms into four groups;

sixteen storms commencing between 0000 and 0500;
fifteen storms commencing between 0600 and 1100;
twenty storms commencing between 1200 and 1700;
fourteen storms commencing between 1800 and 2300.

The mean deviations in the 48 hr following the sudden commencement are shown in Fig. 8. The mean disturbance curve on the second day after the sudden commencement is also drawn. It shows a maximum positive deviation of f_0F2 of about 7 per cent at 0600 and a maximum negative deviation of 7 per cent at 1500.

The variations discussed above refer to sudden commencement storms. Analysis of SD variations on ninety disturbed days in 1953–1956 at Ahmedabad and Delhi and on forty-seven disturbed days in 1956 at Bombay, Ahmedabad and Kodaikanal on which ΣK was greater than 25 (without consideration of times of sudden commencement) was also made and the results are shown in Fig. 9. It will be seen that the SD variations had appreciable amplitudes both at Ahmedabad and Kodaikanal

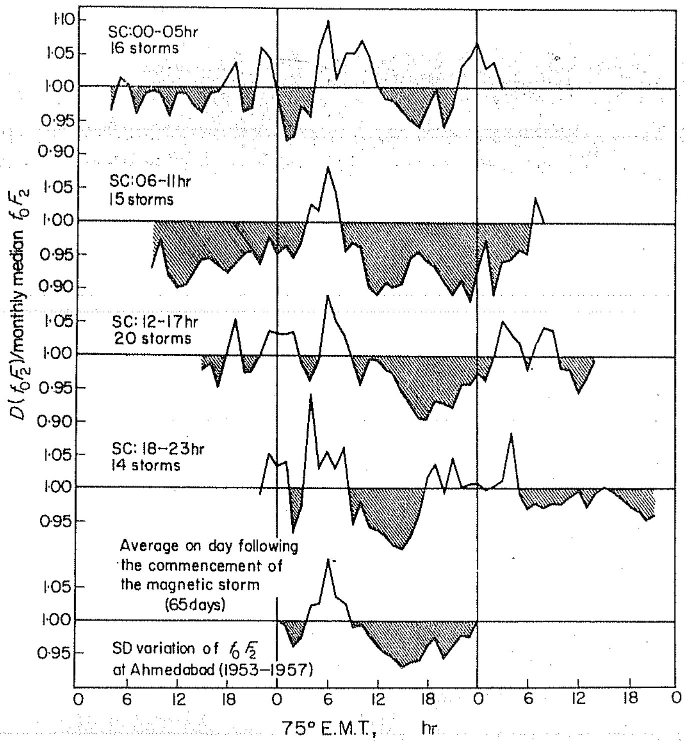

Fig. 8. Disturbance variation of f_0F2 at Ahmedabad for magnetic storms commencing at different times of the day. Also mean SD variation of f_0F2 on day following SC storms. (sixty-five storms, 1953–1957).

but that they were in opposite directions from 0800 to 2300. Night-time f_0F2 at Kodaikanal was depressed more than at Ahmedabad. The peak at 0600 was prominent at Kodaikanal, Ahmedabad and Delhi. The mean SD variations at Bombay was small compared to those at the other places.

Figure 10 shows the actual average values of f_0F2 at Kodaikanal and Ahmedabad on disturbed days and on normal days in 1956. The differences $A-K$, $A'-K'$, $A'-A$ and $K'-K$ are also shown. The dashed values refer to disturbed days.

In Fig. 11, a comparison is made of the SD variation of f_0F2 in middle, low and equatorial latitudes. The stations considered and their magnetic dips are:

Washington	71°·4N (Appleton, 1956)
Wakkanai	59°·5N (Appleton and Piggott, 1953)
Yamagawa	44°·3N (Sinno, 1953)
Delhi	42°·4N } writers
Ahmedabad	34°·0N } writers
Ibadan	5°S (Skinner and Wright, 1955)
Kodaikanal	3°·5N (writers)

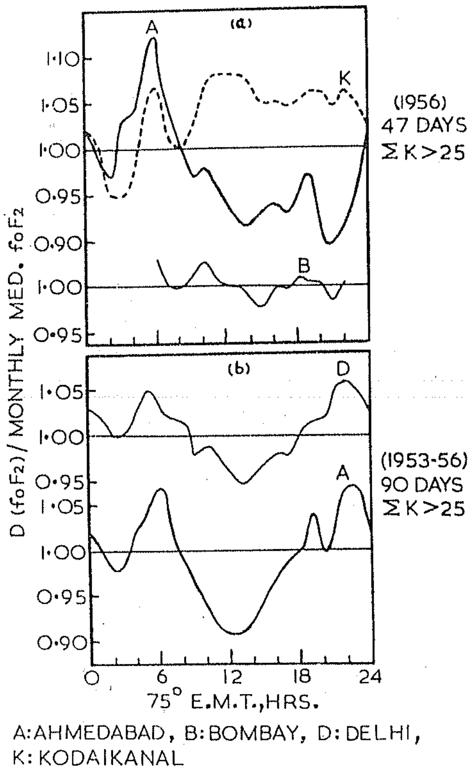

Fig. 9. (a) SD variation of f_0F2 at Ahmedabad, Bombay and Kodaikanal, 47 days with $K > 25$ (1956). (b) SD variation at Delhi and Ahmedabad, 90 days with $K > 25$ (1953–1956).

The SD variations for the middle latitude stations are for winter, but the shape of the curves is similar to the mean curve for all the seasons. It will be seen that while the curves for Washington and Wakkanai are similar, an important change of phase *during day-hours* takes place at Yamagawa, Delhi and Ahmedabad. There is yet another change on the equatorial side of Ahmedabad. The day-time decrease of f_0F2 changes into an increase. Ibadan and Kodaikanal behave similarly, but the changes at Ibadan are larger. One reason for this may be that in preparing the Ibadan curve, only days for which $K > 30$ have been considered, while for Kodaikanal, all days with $K > 25$ have been taken into account.

Finally in Fig. 12, a comparison is made between the storm-time (D_{st}) variations of f_0F2 at Ahmedabad, Watheroo and Washington. The curves for the latter two places are taken from MARTYN (1953).

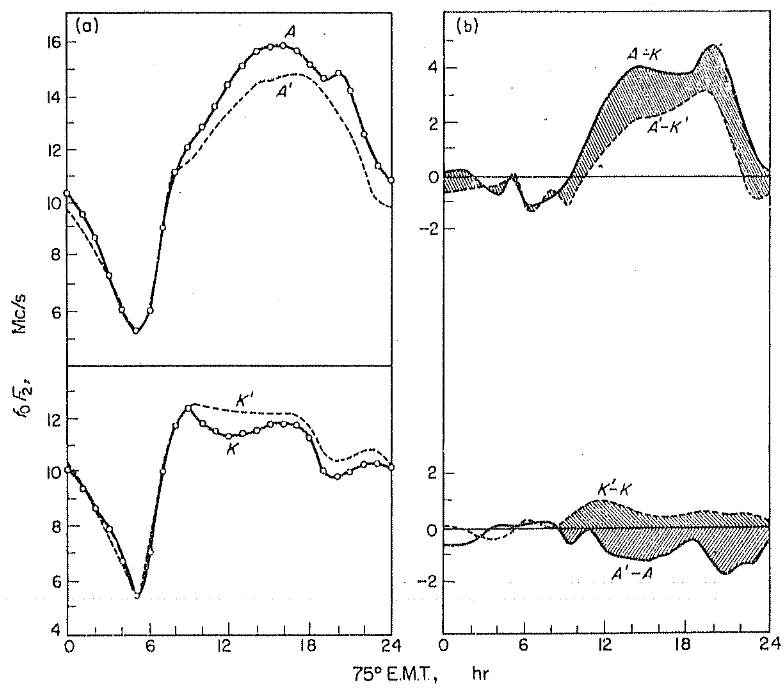

Fig. 10. Average diurnal variations of f_0F2 at Kodaikanal and Ahmedabad on 43 magnetically disturbed days compared with average monthly medians (1956) and their differences. A: Ahmedabad, K: Kodaikanal (median curves). Dashed curve refers to disturbed day variation.

Magnetic Activity and Occurrence of Spread-F Echoes in Low Latitudes

A study was first made of the occurrence of night-time spread-F echoes at Singapore, Kodaikanal, Ahmedabad, Delhi and Yamagawa in January, March, July and October 1956. The results are shown in Figs. 13 to 16 and it will be seen that:

(1) In March and October 1956, spread-F echoes were frequent in low latitudes and there was fair to good correlation between the day-to-day occurrence of spread-F at Ahmedabad, Kodaikanal and Singapore. Spread-F activity decreased at Delhi and became negligible at Yamagawa.,

(2) In January and July, spread-F was less frequently observed at Ahmedabad and the correlation between spread-F at Ahmedabad, Kodaikanal and Singapore was much less evident. At Yamagawa, however, there were more occasions with spread-F in January and July than in March and October.

An examination of spread-F and magnetic activity at Ahmedabad was also carried out. In 1956–1957, on 118 days, ΣK at Alibag was less than 15, on 132 days ΣK was $\geqslant$ 25 and on 25 days ΣK was $\geqslant$ 35. The daily variation of spread-F on

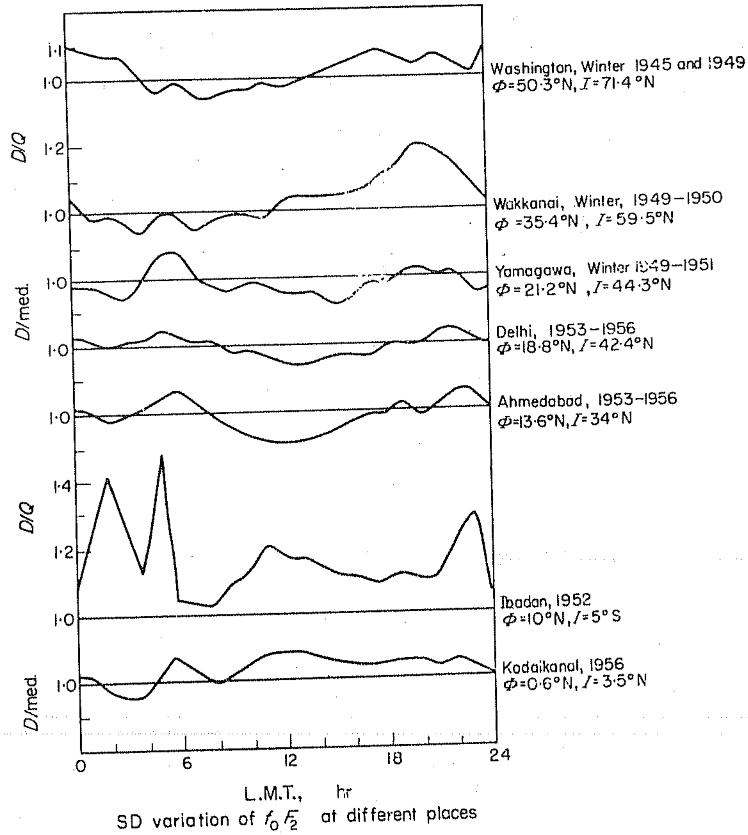

Fig. 11. SD variation of f_0F2 at different latitudes.

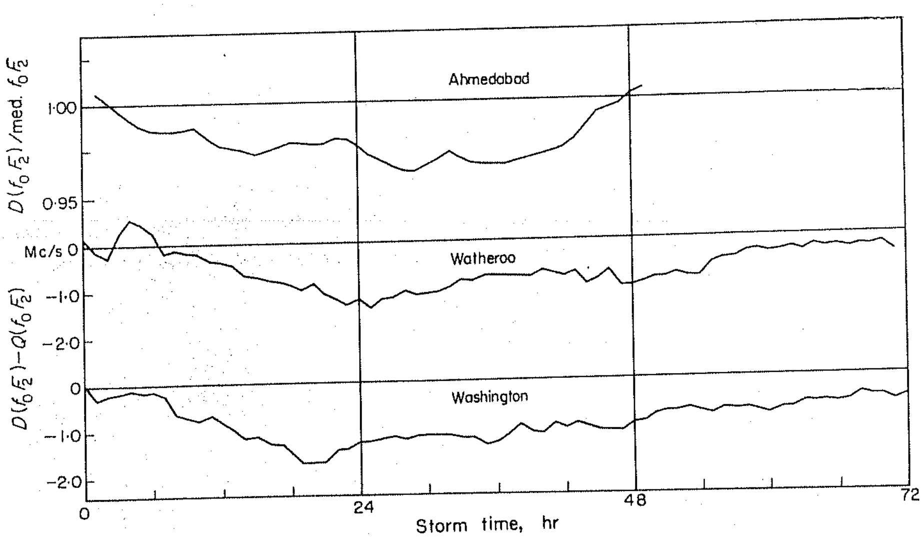

Fig. 12. D_s variation of f_0F2 at Ahmedabad, Watheroo and Washington.

each of these three groups of days is shown in Fig. 17. It can be seen that the spread-F activity on magnetically disturbed days was only about one-third of that on quiet days. This result has also been observed at Singapore, Kodaikanal (Figs. 13 to 16)

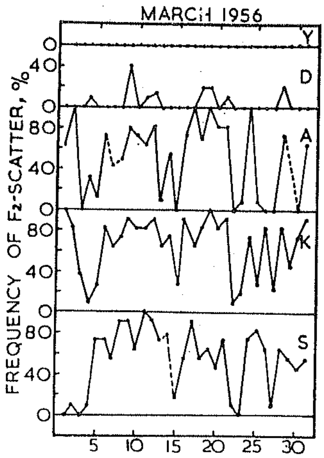

Fig. 13. Occurrence of spread-F echoes at Yamagawa, Delhi, Ahmedabad, Kodaikanal and Singapore in March 1956.

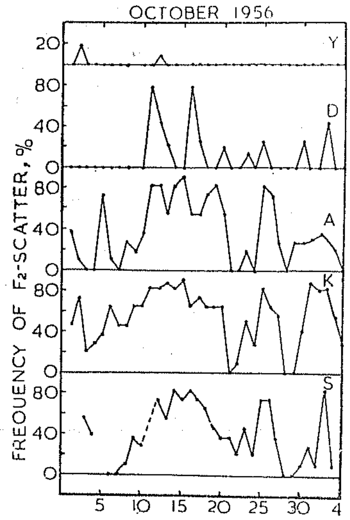

Fig. 14. Occurrence of spread-F echoes at Yamagawa, Delhi, Ahmedabad, Kodaikanal and Singapore in October 1956.

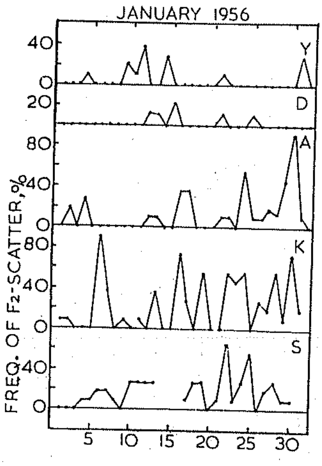

Fig. 15. Occurrence of spread-F echoes at Yamagawa, Delhi, Ahmedabad, Kodaikanal and Singapore in January 1956.

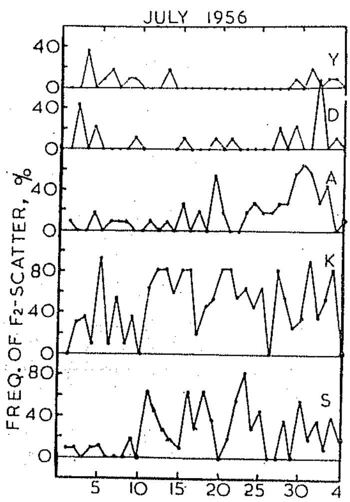

Fig. 16. Occurrence of spread-F echoes at Yamagawa, Delhi, Ahmedabad, Kodaikanal and Singapore in July 1956.

and Ibadan (WRIGHT *et al*, 1956). It differs from that observed in middle latitudes. Using the superposed-epoch method, the spread-F data of Ahmedabad ($\Phi = 13°·6$ N), Kokubunji ($\Phi = 25°·5$N) and Slough ($\Phi = 54°$N) were examined. Data were available for eighty-one epochs in 1956–1957 on which $K \geqslant 25$. The results ere shown in Fig. 18. It is clear that spread-F at Ahmedabad decreased with increase in K, while at Slough, it increased with increase in K. Spread-F at Kokubunji was

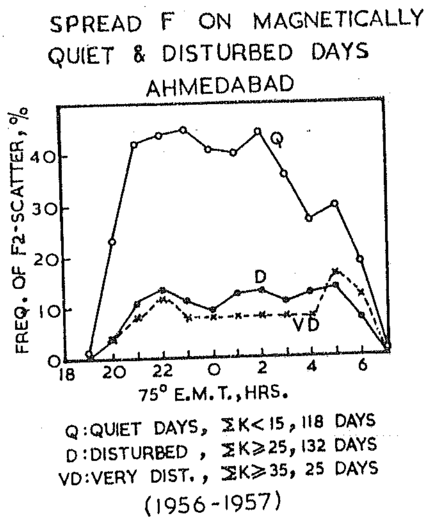

Fig. 17. Occurrence of spread-F at Ahmedabad on magnetically quiet and disturbed days.

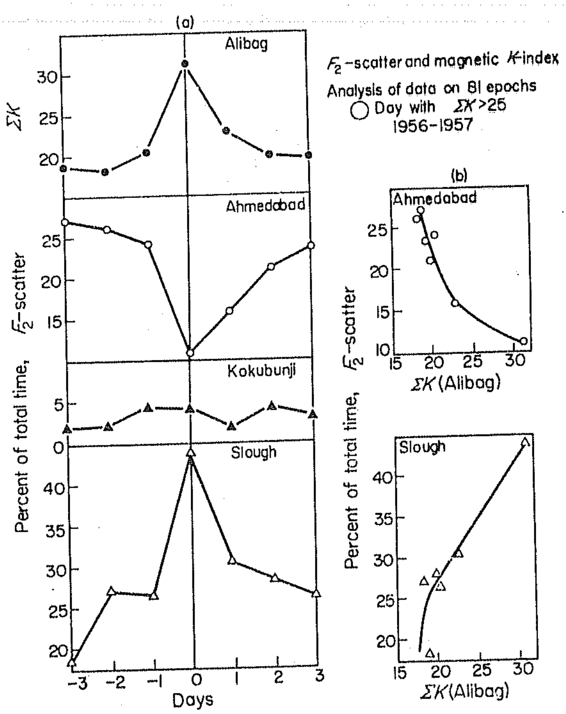

Fig. 18. (a) Spread-F and magnetic activity at Ahmedabad, Kokubunji and Slough with magnetic K-index at Alibag (superposed epoch method). (b) Relation between K-index and spread-F at Ahmedabad and Slough.

small and not appreciably affected by magnetic activity. The change-over from positive to negative correlation takes place at about $\Phi = 25°N$ or $I = 45°N$.

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