550.38 : 551.510.535

A comparative study of Geomagnetic and Ionospheric changes at Kodaikanal and Huancayo

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(Received 19 April 1955)

ABSTRACT. A study of geomagnetic field variations for five years, 1949 to 1953, and ionospheric changes during 1952-1954 at Kodaikanal reveals that Kodaikanal, situated near the geomagnetic equator, shows more or less the same anomalous behaviour as Huancayo. The sudy shows—(*i*) The abnormal large range in the horizontal intensity *H* during quiet days, (*ii*) No abnormality in *H* during geomagnetic disturbances, (*iii*) Amplitudes of S.C.'s during noon are greater near the geomagnetic equator than at stations further away from it, (*iv*) A mid-day decrease of foF2 on quiet days (the bite-out effect), (*v*) Increase in the electron density of F2 layer with increase in geomagnetic activity conducive to better conditions for radio propagation, and (*vi*) Occurrence of the lunar stratification of the F2 layer and its disappearance at the lunar times 07C0 and 1930 hours.

1. Introduction

The abnormally large range of the daily variation of the horizontal (north) component of the magnetic force over Huancayo in Peru (12°·0 S, 75°·3 W, geomagnetic latitude -0°·6 S) has prompted Prof. Chapman (1948) to ask whether there is any northern counterpart of Huancayo. The S_q variation in the vertical intensity Z and declination D is, however, normal. Geomagnetic disturbance, on the contrary, is apparently normal at Huancayo in all the three elements (Chapman 1951). Ionospheric changes associated with geomagnetic activity, the large lunar stratification of the F2 layer, the mid-day decrease of critical frequency of the F2 layer and pre-dawn abnormal decrease of foF2 at Huancayo are so puzzling to ionospheric workers that it made Mcnish (1950a) remark that Huancayo is one of the most important geomagnetic observatories in the world which has contributed a great deal to the "dynamic characteristics of the ionosphere".

The purpose of the present paper is to indicate that Kodaikanal (Lat. 10°·14 N, Long. 77°·28 E, geomagnetic latitude +0°·6 N)in the northern hemisphere shows more or less the same anomalous behaviour as Huancayo both in geomagnetic field variations and ionospheric changes.

2. Geomagnetic field variations at Kodaikanal

(*1*) *Abnormal large range of variation of the horizontal component of magnetic force on quiet days*

Table 1 gives the mean diurnal range of H at Kodaikanal for the international quiet days during the years 1949 to 1953. The average range of H at Kodaikanal may be taken as about 10Cγ as compared with 125γ for Huancayo. It is about 2·5 times as great as that at Alibag (Lat. 18°·6 N, Long. 72°·9 E, geomagnetic latitude, +9°·5), *viz.*, 38·5γ (Chapman 1951, Egedal 1947). At Kodaikanal the $S_q(H)$ is abnormal in its range, not in its type; as at other tropical stations, the $S_q(H)$ variations during night are small, and during day they consist of a rise to and a fall from a maximum value at about 11 A.M. From Pramanik's recent survey (1952) in South India, it is seen that the diurnal variation is a maximum in the region of the magnetic equator and extends over about 5° to 6° on either side of the magnetic equator.

(*2*) *Geomagnetic disturbances at Kodaikanal*

Though the solar daily variation of H is large at Kodaikanal on a quiet day as compared with those at other stations to the north of the magnetic equator, *e.g.*, Alibag,

TABLE 1

Table showing the mean diurnal ranges of *H* at Kodaikanal for the international quiet days

Month	Year 1949 (γ)	1950 (γ)	1951 (γ)	1952 (γ)	1953 (γ)	Mean (γ)
January	95	121	125	74	87	100
February	107	116	131	68	79	100
March	131	134	136	99	104	121
April	166	146	136	111	110	134
May	123	141	119	85	93	112
June	100	80	112	71	76	88
July	113	106	95	61	79	91
August	160	91	126	77	69	105
September	155	123	98	108	114	120
October	137	114	96	89	92	106
November	111	83	71	71	61	79
December	96	87	72	67	65	77

Mean range of H.F. at Kodaikanal = 103γ

TABLE 2

Table showing the normality in geomagnetic disturbance at Kodaikanal as compared with that at Alibag

Serial No.	Date	Time of commencement of S.C. storm (GMT)	Range in horizontal intensity *H* in gammas: Kodaikanal	Degree of activity	Alibagh	Degree of activity
1	21- 3-49	2121	263	ms	216	ms
2	12- 5-49	0640	510	s	607	s
3	3- 6-49	2150	326	ms	247	m
4	13-10-49	2002	421	s	352	ms
5	27-10-49	0452	272	ms	204	m
6	1-11-49	0951	268	ms	234	ms
7	23- 1-50	0702	340	ms	264	ms
8	19- 2-50	2342	476	s	410	s
9	23- 2-50	1040	193	m	197	m
10	19- 3-50	0546	554	s	468	s

Storm described by three degrees of activity : m—for moderate, ms —for moderately severe and s—for severe

it is observed that the variations due to geomagnetic disturbances are nearly the same at Kodaikanal and Alibag. Fig. 1 shows the similarity in the traces of the magnetograms of the great S.C. storm of 19 March 1950 recorded at Alibag and Kodaikanal. Table 2 shows the ranges in *H* at Kodaikanal and Alibag during a few magnetic storms. The similarity in the variations during the geomagnetic disturbance noticed at the two places is in accordance with the observations of Chapman at Huancayo (1951).

(3) Amplitudes of sudden commencement during noon

Sugiura (1953) examined 183 S.C.'s during 1922 to 1946 at Huancayo and Cheltanham which are situated in the same meridian but at different distances from the magnetic equator. He has shown that the ratio of the amplitude of the S. C. at Huancayo to that at Cheltenham is a maximum for storms occurring *during noon*. Table 3(a) shows the mean amplitudes and frequencies

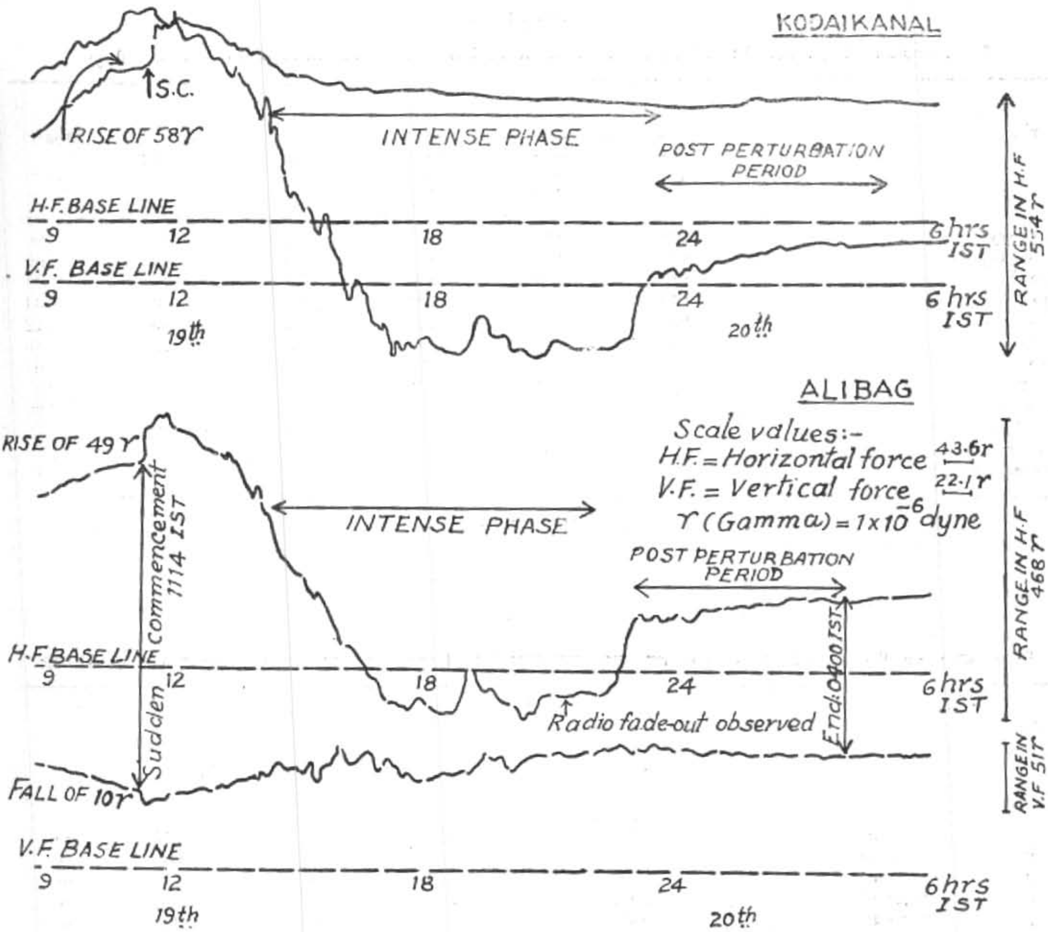

Fig. 1. Typical H. F. magnetograms of the great storm of 19 March 1950 recorded at Kodaikanal and Alibag, showing the similarity of the traces in every detail

Fig. 2. The diurnal variation of amplitudes (——) and number (– – – – –) of S.C.'s at Kodaikanal (1949-53)

TABLE 3(a)

Table showing the diurnal variation of amplitudes and frequency of S.C.'s at Kodaikanal (1949-1953)

Local time (hrs)	Frequency of S.C.	Mean amplitude of S.C. (γ)
0—2	4	26
2—4	7	20
4—6	3	15
6—8	3	36
8—10	2	21
10—12	5	45
12—14	6	44
14—16	4	28
16—18	8	29
18—20	2	20
20—22	6	27
22—24	6	30

TABLE 3(b)

Table showing variation of amplitude of simultaneous S.C.'s at Kodaikanal and Huancayo when it is near noon hour at Kodaikanal

Serial No.	Date	Time of commencement of S.C. storm			Amplitude of S.C. in gammas	
		GMT	Local time (approx.) Kodaikanal	Local time (approx.) Huancayo	Kodaikanal	Huancayo
1	11- 4-49	0736	1246	0236	+62	+28
2	12- 5-49	0640	1150	0140	+82	+72
3	27-10-49	0452	1012	2352	+40	+28
4	19-11-49	0604	1114	0104	+38	+13
5	23- 1-50	0702	1212	0202	+34	+22
6	18- 4-51	0650	1210	0150	+83	+38

TABLE 3(c)

Table showing variation of amplitude of simultaneous S.C's at Huancayo and Kodaikanal when it is near noon hour at Huancayo

Serial No.	Date	Time of commencement of S.C. storm			Amplitude of S.C. in gammas	
		GMT	Local time (approx.) Kodaikanal	Local time (approx.) Huancayo	Kodaikanal	Huancayo
1	24- 1-49	1829	2339	1329	+53	+297
2	16- 3-49	1530	2040	1030	+25	+173
3	13-10-49	2002	0112	1502	+37	+158
4	23- 6-50	1800	2310	1300	+27	+100
5	30- 9-50	1747	2257	1247	+15	+ 83
6	17- 6-51	1658	2208	1158	+41	+101
7	15- 8-51	2006	0116	1506	+33	+ 78
8	29- 6-52	1926	0036	1426	+20	+ 46

TABLE 3(d)

Table showing variation of amplitude of simultaneous S.C.'s at Kodaikanal and Alibag when it is near noon hour at both places

Serial No.	Date	Time of commencement of S.C. storm			Amplitude of S.C. in gammas	
		GMT	Local time (approx.) Kodaikanal	Local time (approx.) Alibag	Kodaikanal	Alibag
1	11- 4-49	0736	1246	1228	+62	+37
2	12- 5-49	0640	1150	1132	+82	+39
3	27-10-49	0452	1002	0944	+40	+24
4	1-11-49	0951	1701	1443	+22	+16
5	23- 1-50	0702	1212	1154	+34	+21
6	19- 3-50	0548	1058	1040	+58	+49

of S.C.'s during different hours of the day at Kodaikanal, based on the data for the period 1949 to 1953. It will be observed from this table that the amplitude at Kodaikanal is largest during the noon (Fig. 2).

Table 3(b) gives the amplitudes of S. C.'s at Kodaikanal and Huancayo which occurred *during the noon hours at Kodaikanal*. From this it will be observed that the amplitudes at Kodaikanal are generally higher than those at Huancayo. A similar comparison between the two places during *noon hour at Huancayo* (Table 3c) shows that the amplitudes at Huancayo are greater than those at Kodaikanal.

Table 3(d) shows the amplitudes of S.C.'s at Kodaikanal and Alibag during noon. Both these places are almost on the same meridian, Kodaikanal being about 0·6° N and Alibag about 9°·5 N from the geomagnetic equator. It is interesting to note that the amplitude of the S.C.'s are generally higher during noon at Kodaikanal than at Alibag.

The above observations show that the increase in the amplitude of S.C.'s *during noon* is greater near the geomagnetic equator than at stations more distant from it.

Another interesting feature of the S.C. at Kodaikanal similar to that at Huancayo is that while the value of H increases, the vertical force Z also increases (Figs. 3(a), 3(b), Sivaramakrishnan, 1952). But at Alibag the value of Z decreases while H increases during the sudden commencement (Fig. 1).

3. Ionospheric changes at Kodaikanal

(*1*) *Decrease of critical frequency of the F2-layer (foF2) during noon at Kodaikanal on quiet days*

Ionospheric observations are being made at Kodaikanal from January 1952 with the automatic multi-frequency ionosphere recorder (Type C-3) made by the National Bureau of Standards (U.S.A.). In middle latitudes, the critical frequency (foF2) increases from shortly before dawn to a maximum value during noon after which it decreases. However, at Kodaikanal which is situated just to the north of the geomagnetic equator, the variations of foF2 are almost similar to those at Huancayo (Mcnish and Gautier 1949) which is situated just to the south of the geomagnetic equator. On quiet days, the critical frequency increases from dawn up to about 0900 hours (local time) after which there is a slight decrease, followed by another rise, reaching the maximum value for the day at about 1600 to 1800 hours.

(*2*) *Proximity of Kodaikanal near the Ionospheric equator like Huancayo*

Appleton (1950) has identified the ionospheric equator in the F2 layer from a consideration of the seasonal variation of the noon equivalent heights of the F2 layer at a number of stations, situated in the northern and southern hemispheres. It is shown that the change over from one type of variation to the other occurs in a region which is more coincident with the magnetic equator than with the geographical equator. The position of ionospheric equator according to Appleton is the region where (*a*) the two maxima of h'F2 occur in June and December and are of equal value (*b*) the two minima of h'F2 occur in March and September and are of equal value. However, no station has been found with the above characteristics. But Huancayo, which is situated slightly to the north of the magnetic equator and slightly to the south of the geomagnetic equator, the heights of the two maxima in July and January are very nearly equal. Judged by this criterion, Kodaikanal resembles exactly Huancayo. Figs. 4 and 5 show the annual variation of noon foF2 and h'F2 at Kodaikanal and at Huancayo for the same period 1952 to 1954, showing the double maxima in h'F2 during (June–July) and (December–January).

(*3*) *Ionospheric changes associated with geomagnetic activity*

Berkner and Seaton (1940), Berkner (*see reference*), Martyn (1953) and Appleton and Piggott (1953) have shown from their study of Huancayo data that electron densities increase during magnetic disturbance at equatorial latitudes. Berkner and Seaton have used the international C figure as a measure of geomagnetic activity for the

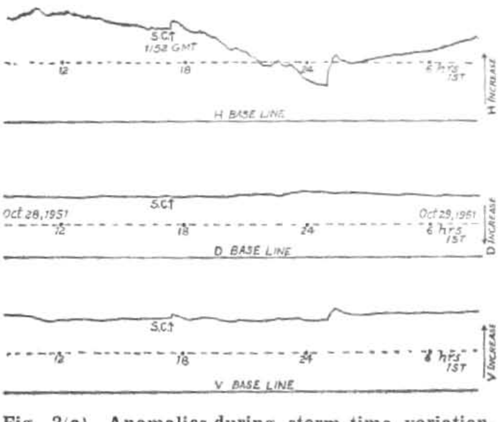

Fig. 3(a). Anomalies during storm-time variation. Kodaikanal La Cour magnetogram showing increase in H and V and increase in D (westerly) at the time of sudden commencement of the great storm of 28 October 1951

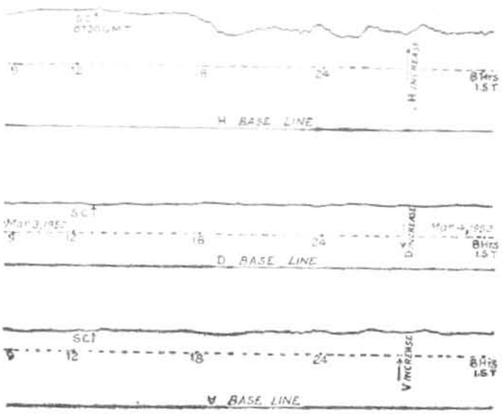

Fig. 3(b). Kodaikanal La Cour magnetogram of 3 March 1952 showing increase in H and Z at the time of the sudden commencement and similarity of the H and Z traces afterwards

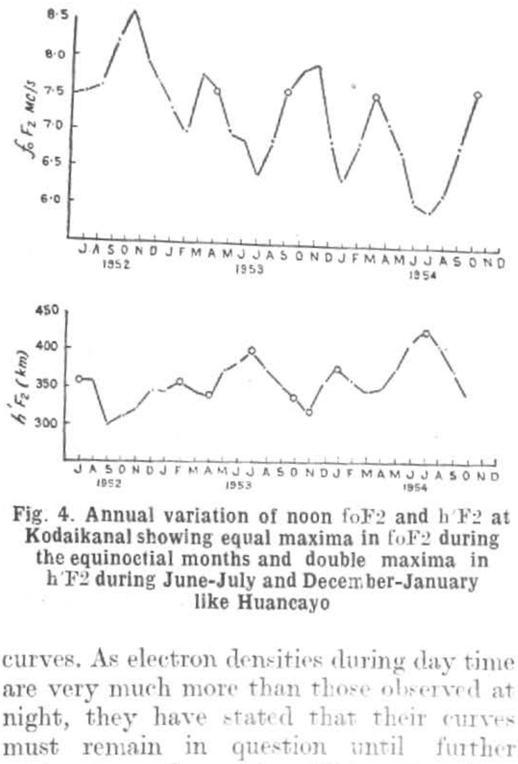

Fig. 4. Annual variation of noon foF2 and h'F2 at Kodaikanal showing equal maxima in foF2 during the equinoctial months and double maxima in h'F2 during June-July and December-January like Huancayo

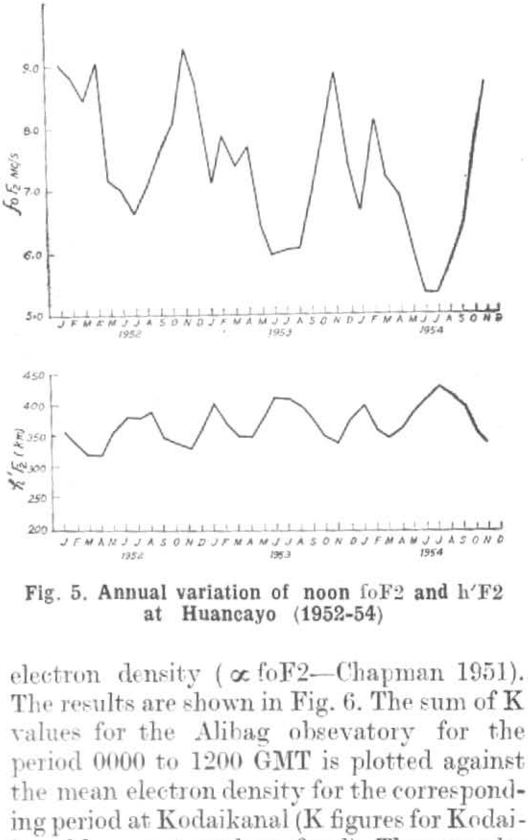

Fig. 5. Annual variation of noon foF2 and h'F2 at Huancayo (1952-54)

curves. As electron densities during day time are very much more than those observed at night, they have stated that their curves must remain in question until further analyses can be made utilising the three hour range magnetic index K. Curves are drawn for Kodaikanal using the method of Berkner and Seaton showing the relation between C figures of geomagnetic activity and electron density ($\propto$ foF2—Chapman 1951). The results are shown in Fig. 6. The sum of K values for the Alibag obsevatory for the period 0000 to 1200 GMT is plotted against the mean electron density for the corresponding period at Kodaikanal (K figures for Kodaikanal have not yet been fixed). These results are also shown in Fig. 7 (p. 145). It will be seen from these that the electron density increases

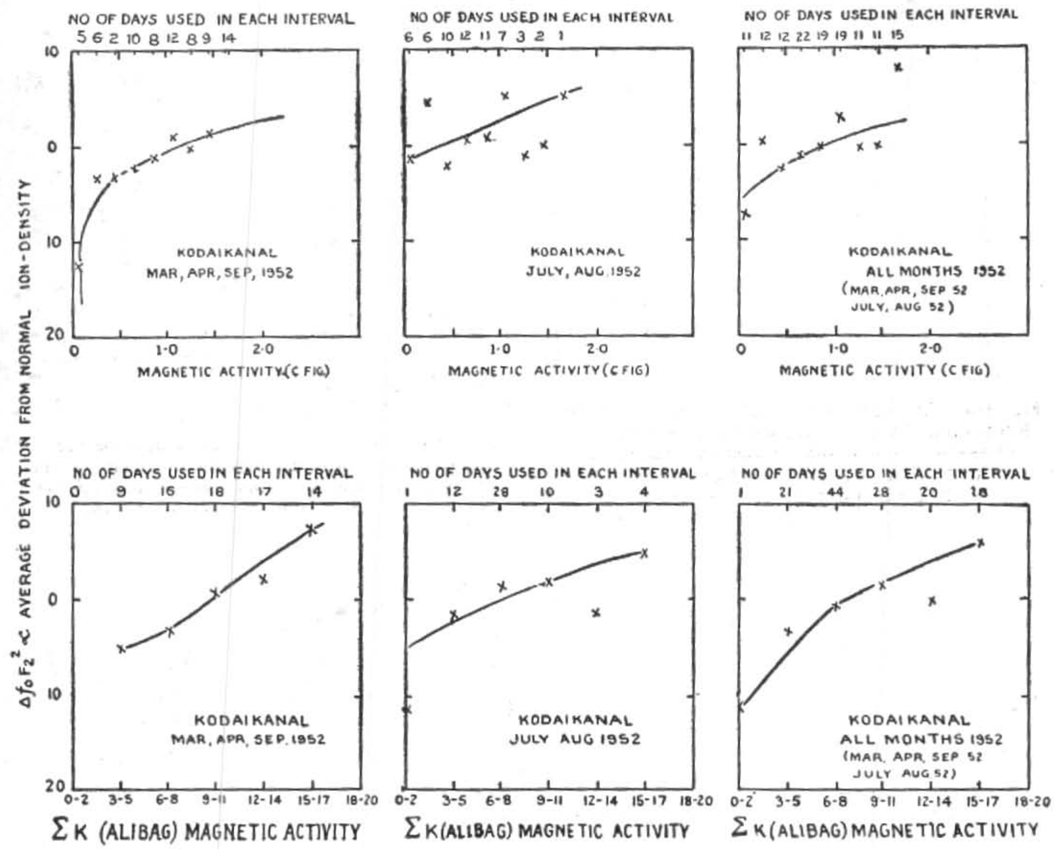

Fig. 6

with geomagnetic activity as indicated by C figures or the K figures of Alibag. As Alibag and Kodaikanal are almost on the same meridian, and the effects of geomagnetic disturbances are also similar, as shown in the previous paragraphs, the relation between electron density at Kodaikanal and the K figures of Alibag may be considered as significant. It is also interesting to note that the normal electron density over Kodaikanal occurs for value of C approximately equal to 0·6. This is in agreement with the observations of Berkner and Seaton (1940) for Huancayo.

Based on Huancayo observations, Ferrell (1951) has shown enhanced radio propagation across the equator in the western hemisphere during or immediately following geomagnetic storms. It is likely that similar enhanced radio propagation is possible over the eastern hemisphere across the equator during geomagnetic storms indicated by Kodaikanal.

(4) *Lunar stratification of the F2 layer at Kodaikanal*

Mcnish (1950b) and others have shown from the ionospheric observations at Huancayo that there is strong F2 layer stratification during the day during certain definite positions of the moon. They found that the disappearance of the stratification occurred most frequently near about the lunar times 0815 and 2045, an interval of $12\frac{1}{2}$ hours which is half the lunar day. An examination of the records of Kodaikanal for 1952 showed an almost similar feature. Table 4 shows the frequency of disappaarance of lunar stratification during different lunar hours at Kodaikanal (Fig. 8, p. 146 and Fig. 9 may be seen in this connection).

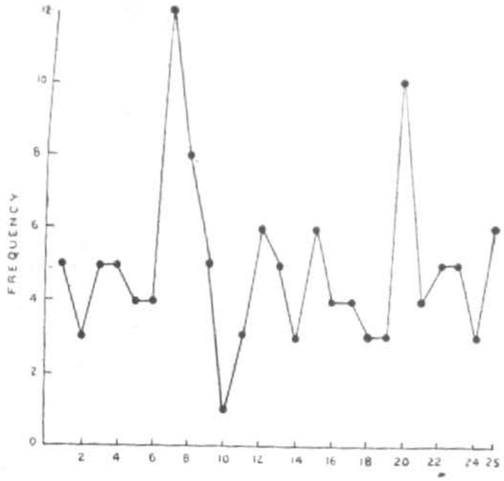

Fig. 9. Lunar hours of disappearance of lunar stratification at Kodaikanal (1952)

TABLE 4

Table showing frequency and lunar hours of disappearance of Lunar Stratification at Kodaikanal during February to December 1952

Lunar hours	Frequency	Lunar hours	Frequency
0—1	5	13—14	3
1—2	3	14—15	6
2—3	5	15—16	4
3—4	5	16—17	4
4—5	4	17—18	3
5—6	4	18—19	3
6—7	**12**	19—20	**10**
7—8	8	20—21	4
8—9	5	21—22	5
9—10	1	22—23	5
10—11	3	23—24	3
11—12	6	24—25	6
12—13	5		

4. Conclusions

From the examination of the geomagnetic and ionospheric observations at Kodaikanal, it is observed that the conditions over Kodaikanal are different from other stations far removed from the geomagnetic equator. They are, however, similar in many respects to those observed at Huancayo, a station almost equally near the geomagnetic equator, but on the southern side. The data bring out also certain special features in the regions of the geomagnetic equator.

5. Acknowledgements

I am very thankful to Dr. A. K. Das, Deputy Director General of Observatories (Astrophysics), for allowing me the use of some of the data discussed in the paper and for the opportunities I had for this investigation at Kodaikanal.

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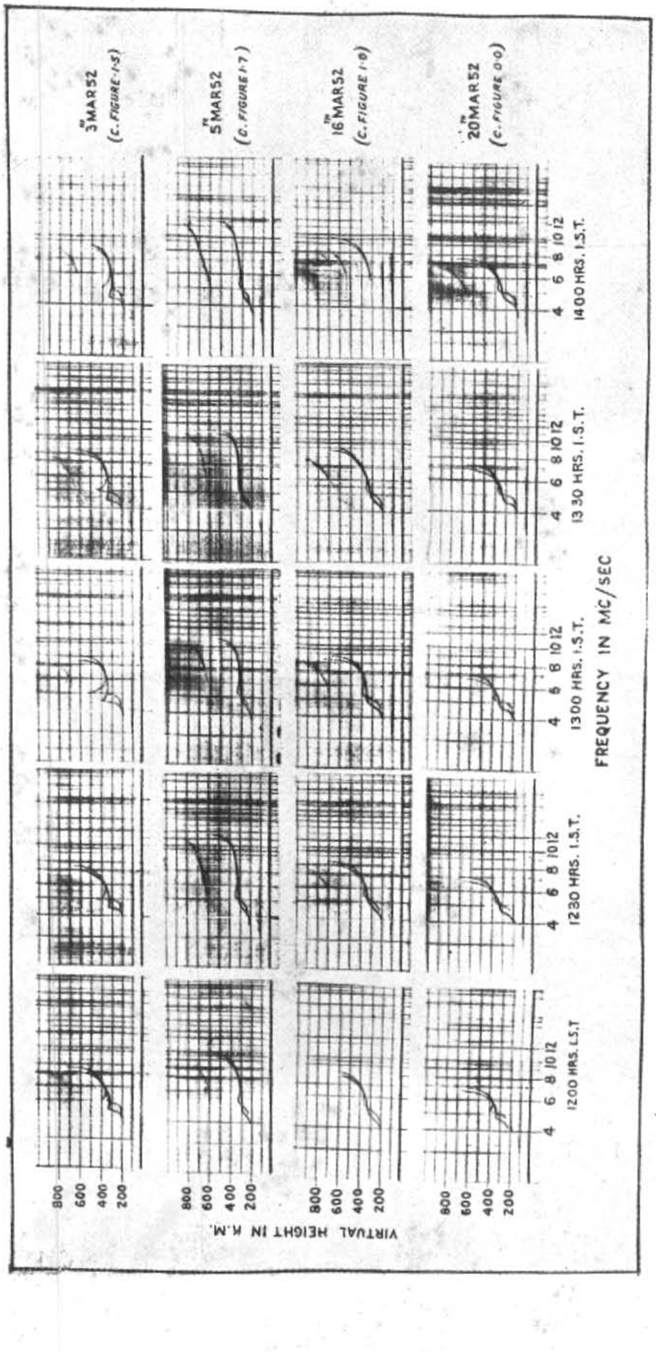

Fig. 7. Typical ionospheric records taken with C3 ionosphere recorder at Kodaikanal showing increase in foF2 with increase of magnetic activity. 1300 IST ionogram on 3-3-1952 shows slight increase in foF2 synchronous in time with the sudden commencement of the storm of that date

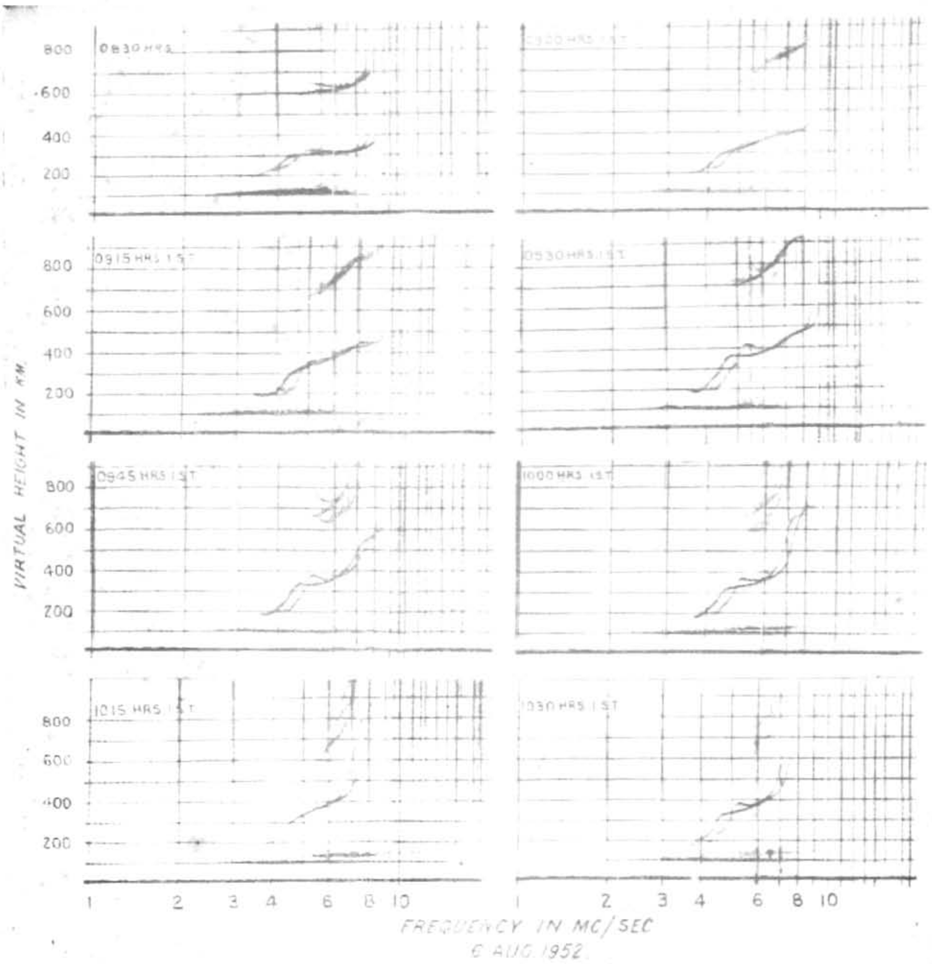

Fig. 8. Typical Kodaikanal ionograms showing development of lunar stratification on 6 August 1952