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The Magnetic Disturbance Field at Kodaikanal

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ABSTRACT. The magnetic disturbance field at Kodaikanal has been studied, using the data for the period March 1950 to February 1954. As far as the horizontal magnetic field is concerned, it is found that the form of the disturbance daily variation does not depend on the degree of disturbance. During equinoxes and winter solstices, the disturbance vector, S_D is at right angle to the S_q vector (quiet day diurnal variation) and is at an obtuse angle to the S_q vector during summer solstice. Hence with increasing disturbance there is a pronounced variation of the phase of S (diurnal variation) vector, but the variation in its amplitude is small. This suggests that the phase, rather than the amplitude of the variation may be a better criterion for determining the intensity of a disturbance. It is also noticed that the storm time field too retains its form at various levels of disturbance. The variation in the vertical force is found to be too small to give any significant results.

1. Introduction

Chapman (1918, 1927) made an extensive study of the average characteristics of magnetic disturbances and showed that these characteristics do not differ in type as the intensity of the disturbance varies over a very wide range. Following the method adopted by Moos (1910) for Bombay, he found the difference between the diurnal inequalities on quiet days and ordinary (all) days and also between the diurnal inequalities on quiet days and days of intense magnetic storm for six stations at different magnetic latitudes. The similarity of the two curves showed that the disturbance daily variation (S_D variation) does not vary in form with the intensity of the disturbance. By comparing the difference between the mean values of the horizontal intensity on disturbed and quiet days (D_m) with the difference between the mean values of the horizontal intensity on quiet and ordinary (all) days, he showed that the form of the storm-time disturbance field, too, does not depend upon the intensity of the magnetic disturbance. Cynk (1939) used data from 14 stations. By plotting the mean annual values of the H-component of D_m for the years 1919-1933, he selected two periods 1925-30 as years of greater magnetic activity and 1922-24 and 1931-33 as years of lesser activity. Then he plotted the mean annual values of the H-component of D_m separately for each group of years and for all the 12 years at each observatory as a function of magnetic latitude. The three curves were similar and any one curve could be transformed into one of the other two by multiplying the individual value by an appropriate constant. This demonstrated the independence of the disturbance field due to D_m of the intensity of the magnetic disturbance. The purpose of the present paper is to study the disturbance field (S_D as well as D_m) at Kodaikanal and to show that the form of the field is independent of the degree of disturbance.

2. Data analysed and the method of analysis

The hourly values of the horizontal force at Kodaikanal (10° 14′N, 77° 28′E) for the period March 1950 to February 1954 have been used for this analysis. The days are classified into four groups depending on their international character figures— (*i*) quiet (character figure lying between 0·0 and 0·4), (*ii*) slightly disturbed (character figure lying between 0·5 and 0·9), (*iii*) moderately disturbed (character figure lying between 1·0 and 1·4) and (*iv*) greatly disturbed (character figure greater than 1·4).

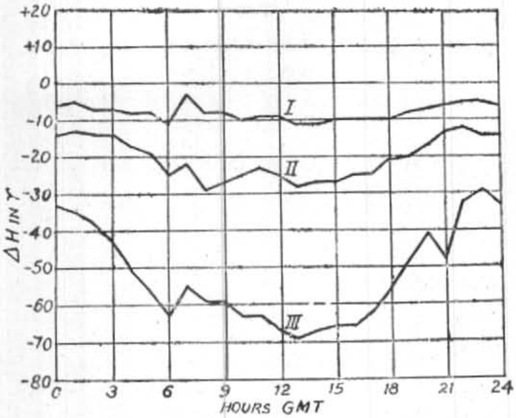

Fig. 1. S_D variation of the horizontal force at equinoxes

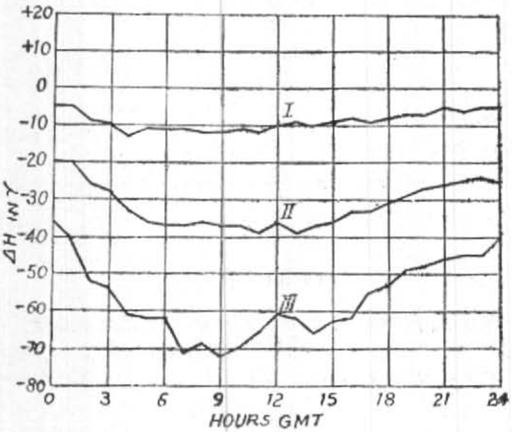

Fig. 2. S_D variation of the horizontal force during summer

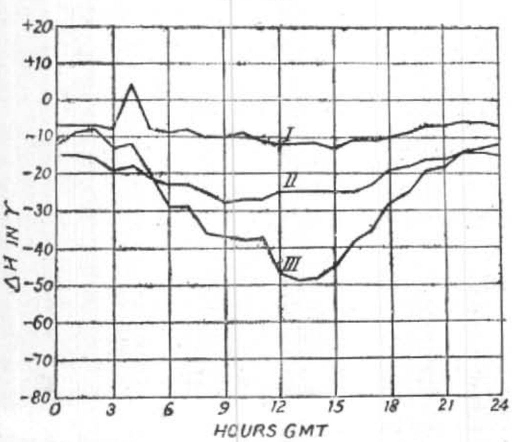

Fig 3. S_D variation of the horizontal force during winter

The year is also divided into 3 seasons—(*a*) equinoxes (March, April, September and October), (*b*) summer (May to August) and (*c*) winter (November to February). For each season, the average daily variation—corrected for non-cyclic variation (Chapman and Bartels, 1940)— for each of the above four groups is determined. Again, for each season, by subtracting the average daily variation for groups (*ii*) to (*iv*) from that for group (*i*), we get the disturbance daily variation (S_D) for (I) slightly disturbed days, (II) moderately disturbed days and (III) greatly disturbed days for the particular season. Similarly, curves showing the disturbance daily variation for the other two seasons may be obtained.

3. Horizontal magnetic force

(*a*) *Disturbance daily variation*—Figs. 1 to 3 show the S_D variation for the horizontal intensity for the three seasons, equinoxes, summer and winter respectively. Curves I and II in each of the above figures are similar to curve III, showing that the form of the disturbance daily variation does not depend upon the intensity of the disturbance.

Figs. 1 to 3 have, in addition to S_D, irregular variations as well. In order to remove them, the curves are analysed harmonically. The phases are expressed in local mean time of Kodaikanal. The results of the analysis are given in Tables 2 and 4.

Table 1 gives the harmonic coefficients of the 24-hourly wave of the diurnal variation, S. It is found, in general, that the phase of the first harmonic coefficient varies much more with increasing intensity of disturbance than the amplitude. The phase angle increases with increased disturbance and the time of maximum occurs earlier on disturbed days than on quiet days. The amplitude remains almost unaltered with disturbance during equinox, decreases slightly in summer and perhaps increases in winter.

TABLE 1

Harmonic analysis of the diurnal variation, *S*
24 hourly wave

	Character figure			
	0·0–0·4	0·5–0·9	1·0–1·4	1·5–2·0
	Equinoxes			
Amplitude, C_1 (γ)	36·2	36·6	36·7	37·9
Phase, φ_1	278°	281°	289°	305°
Time of maximum	11·5h	11·3h	10·7h	9·7h
	Summer			
Amplitude, C_1 (γ)	31·2	29·0	26·4	26·6
Phase, φ_1	279°	282°	295°	307°
Time of maximum	11·4h	11·2h	10·4h	9·5h
	Winter			
Amplitude, C_1 (γ)	25·7	27·2	26·6	33·8
Phase, φ_1	279°	285°	301°	313°
Time of maximum	11·4h	11·0h	9·9h	9·1h

TABLE 2

Harmonic analysis of the disturbance daily variation, S_D
24-hourly wave

	Slighty disturbed	Moderately disturbed	Greatly disturbed
		Equinoxes	
Amplitude, C_1 (γ)	2·2	7·5	17·2
Phase, φ_1	356°	3°	15°
Time of maximum	6·3h	5·8h	5·0h
		Summer	
Amplitude, C_1 (γ)	3·1	7·9	14·3
Phase, φ_1	57°	55°	38°
Time of maximum	2·2h	2·3h	3·5h
		Winter	
Amplitude, C_1 (γ)	3·4	5·7	19·4
Phase, φ_1	347°	7°	0°
Time of maximum	6·9h	5·5h	6·0h

TABLE 3

Harmonic analysis of the diurnal variation, *S*
12-hourly wave

	Character figure			
	0·0–0·4	0·5–0·9	1·0–1·4	1·5–2·0
	Equinoxes			
Amplitude, C_2 (γ)	20·9	20·6	19·3	12·3
Phase, φ_2	116°	113°	115°	101°
Time of first maximum	11·1h	11·2h	11·2h	11·6h
	Summer			
Amplitude, C_2 (γ)	18·6	17·6	16·9	14·9
Phase, φ_2	109°	107°	107°	102°
Time of first maximum	11·4h	11·4h	11·4h	11·6h
	Winter			
Amplitude, C_2 (γ)	13·0	13·4	12·4	14·4
Phase, φ_2	115°	115°	110°	118°
Time of first maximum	11·2h	11·2h	11·3h	11·1h

TABLE 4

Harmonic analysis of the disturbance daily variation, S_D
12-hourly wave

	Slightly disturbed	Moderately disturbed	Greatly disturbed
		Equinoxes	
Amplitude, C_2 (γ)	1·1	1·2	6·1
Phase, φ_2	3°	304°	342°
Time of first maximum	2·9h	4·9h	3·6h
		Summer	
Amplitude, C_2 (γ)	1·1	1·7	3·9
Phase, φ_2	317°	301°	307°
Time of first maximum	4·4h	5·0h	4·8h
		Winter	
Amplitude, C_2 (γ)	0·4	0·9	1·4
Phase, φ_2	105°	310°	116°
Time of first maximum	11·5h	4·7h	11·1h

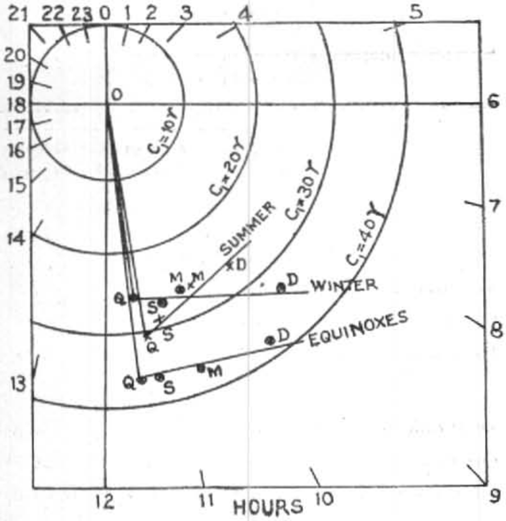

Fig. 4. Harmonic dial for the 24-hourly component of the diurnal variation, S

Table 2 gives the first harmonic coefficients of the disturbance daily variation (S_D) for the three seasons. It is found that in each season the time of maximum of the 24-hourly wave does not vary appreciably with increasing intensity of the disturbance. The amplitude of the disturbance vector on the days with character figure lying between 0·5 and 0·9 is very small. This agrees well with the conclusion arrived at by Bartels (1932) that up to a character figure 1·1 the systematic variation of S with character figure is very little.

Fig. 4 shows the harmonic dial for the 24-hourly sine wave for the solar daily variation, S, for the four groups of days separately for each season. O is the origin, Q the point for the quiet days, S for slightly disturbed days, M for moderately disturbed days and D for greatly disturbed days. OQ represents the S_q vector in sign and magnitude and QD the S_D vector. The points Q,S,M and D are found to be collinear—within the limits of observational error, showing that the disturbance vector S_D does not depend upon the degree of disturbance. During equinoxes the S_D vector is at right angles to the S_q vector and reaches its maximum at about 6 hrs local mean time. During winter also, the two vectors are almost perpendicular. Hence, the change in the phase is very much greater than the increase in the amplitude of the variation. During summer, the S_D vector is at an obtuse angle to the S_q vector. Hence with increased disturbance (unless the disturbance be extremely severe) the amplitude of the diurnal component decreases.

It is the usual practice to consider the range in the horizontal force during the course of a magnetic storm as a criterion for deciding the intensity of the storm. Table 1 and Fig. 4 show that the amplitude of the 24-hourly wave does not vary much with disturbance during equinoxes and winter and actually decreases with disturbance during summer, though there is a pronounced variation of the phase angle with disturbance. It has also been shown by the author (1954) that at Kodaikanal, even on quiet days, the amplitude of the 24-hourly wave varies greatly from day to day, but the phase remains constant. This makes one feel that at least in Kodaikanal, except for very intense magnetic storms, the phase, rather than the amplitude of the variation may be a better criterion for determining the intensity of the storm.

Tables 3 and 4 give the amplitudes and phases for the 12-hourly waves for the S and S_D variations for the four groups of days for each season. As far as the S variation is concerned, the amplitude of the 12-hourly wave is about 50 per cent of the 24-hourly wave. For the S_D variation, however, the contribution of the 12-hourly wave is much less (less than 20 per cent). Still, during equinoxes and summer, the 12-hourly component of the S_D variation is found to retain its type at various levels of the disturbance. During winter, however, the 12-hourly component has too small an amplitude to give any definite information.

The disturbance daily variation at Kodaikanal is found to be similar to the corresponding variation at Bombay, determined by Chambers (1883) and Moos (1910). The only noteworthy difference is that the 24-hourly component of the S_D variation at Kodaikanal during summer is found to reach

TABLE 5

Mean value of the horizontal force

Character figure	Equinoxes	Summer	Winter
	(γ)	(γ)	(γ)
0·0—0·4	39,430	39,417	39,451
0·5—0·9	39,422	39,412	39,442
1·0—1·4	39,413	39,399	39,421
1·5—2·0	39,380	39,393	39,397

TABLE 6

Mean value of the non-cyclic variation

Character figure	Equinoxes	Summer	Winter
	(γ)	(γ)	(γ)
0·0—0·4	+9·6	+5·3	+6·6
0·5—0·9	+3·3	+2·3	+1·1
1·0—1·4	—1·9	—3·0	—3·0
1·5—2·0	—14·9	—15·5	—22·1

its maximum value between two and three hours local mean time, whereas at Bombay, the 24-hourly component attains its maximum at sunrise throughout the year.

(*b*) *Storm-time variation*—In order to determine whether the form of the storm-time field is also independent of the intensity of the disturbance, following Chapman (1927), the mean value of the horizontal force for each of the four divisions of the days in each of the seasons have been determined and are given in Table 5. It is found that during all the three seasons, the mean value of the horizontal force decreases gradually with increasing disturbance, showing the independence of the storm time field of the degree of disturbance.

It is known that, in general, the non-cyclic variation for the horizontal force is positive on quiet days and negative on disturbed days. The mean values of the non-cyclic variation for the four groups of days for the three seasons are given in Table 6. It is found that the non-cyclic variation falls gradually from a high positive value to a high negative value as the intensity of the disturbance increases. This also serves as a confirmation of the independence of the storm-time field of the intensity of the disturbance.

4. Vertical magnetic force

An attempt was made to study the variation of the vertical force in a similar manner. But the variation is much less. The amplitude of the first harmonic coefficients for the solar diurnal variation, S, and the disturbance daily variation, S_D are of the order of 10γ (in winter it is only about 5γ) and 2γ respectively. Since the scale coefficient of the vertical force magnetograph is about 11γ/mm, many more years' data are necessary before we can arrive at definite conclusions regarding the disturbance daily variation of the vertical force. This observatory is likely to get an Askania Earth Magnetic Recording Station where the sensitivity of the vertical force magnetograph is expected to be of the order of 1γ to 2γ/mm. Records obtained with this instrument are likely to give very valuable information.

5. Acknowledgement

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