The Magnetic Disturbance Field at Kodaikanal

A. THIRUVENGADATHAN

Astrophysical Observatory, Kodaikanal

(Received 23 July 1955)

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 \( S_H \) vector (quiet day diurnal variation) and is at an obtuse angle to the \( S_H \) vector during summer solstice. Hence with increasing disturbance there is a pronounced variation of the plane 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),
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 particu-
lar 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 hori-
zontal intensity for the three seasons, equi-
noxes, 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 dis-
urbance.

Figs. 1 to 3 have, in addition to \(S_D\), ir-
regular variations as well. In order to re-
move them, the curves are analysed har-
monically. The phases are expressed in
local mean time of Kodaikanal. The re-
sults 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, $N$
24-hourly wave

<table>
<thead>
<tr>
<th>Character figure</th>
<th>0-0-</th>
<th>0.5-</th>
<th>1.0-</th>
<th>1.5-</th>
<th>1.0-</th>
<th>1.4-</th>
<th>2.0-</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.9</td>
<td>1.4</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Equinoxes**
- Amplitude, $C_1 (\gamma)$: 36.2, 36.6, 36.7, 37.9
- Phase, $\varphi_1$: 278°, 281°, 283°, 505°
- Time of maximum: 11.5h, 11.3h, 10.7h, 9.7h

**Summer**
- Amplitude, $C_1 (\gamma)$: 31.6, 29.0, 26.4, 26.6
- Phase, $\varphi_1$: 279°, 295°, 307°, 315°
- Time of maximum: 11.4h, 11.2h, 10.4h, 9.5h

**Winter**
- Amplitude, $C_1 (\gamma)$: 25.7, 27.2, 26.6, 33.8
- Phase, $\varphi_1$: 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

<table>
<thead>
<tr>
<th>Slightly disturbed</th>
<th>Moderately disturbed</th>
<th>Greatly disturbed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equinoxes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, $C_1 (\gamma)$: 3.2, 7.5, 17.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase, $\varphi_1$: 356°, 8°, 18°</td>
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<td></td>
</tr>
<tr>
<td>Time of maximum: 6.3h, 5.8h, 5.0h</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, $C_1 (\gamma)$: 3.1, 7.9, 14.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase, $\varphi_1$: 57°, 55°, 38°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of maximum: 2.2h, 2.3h, 2.5h</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Winter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, $C_1 (\gamma)$: 3.4, 5.7, 19.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase, $\varphi_1$: 347°, 7°, 0°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of maximum: 6.9h, 5.5h, 6.0h</td>
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<td></td>
</tr>
</tbody>
</table>

### TABLE 3
Harmonic analysis of the diurnal variation, $S$
12-hourly wave

<table>
<thead>
<tr>
<th>Character figure</th>
<th>0.0-</th>
<th>0.5-</th>
<th>1.0-</th>
<th>1.5-</th>
<th>1.0-</th>
<th>1.4-</th>
<th>2.0-</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.9</td>
<td>1.4</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Equinoxes**
- Amplitude, $C_2 (\gamma)$: 29.0, 29.6, 19.3, 12.3
- Phase, $\varphi_2$: 116°, 113°, 110°, 101°
- Time of first maximum: 11.1h, 11.2h, 11.2h, 11.6h

**Summer**
- Amplitude, $C_2 (\gamma)$: 18.6, 17.6, 16.9, 14.9
- Phase, $\varphi_2$: 109°, 107°, 107°, 102°
- Time of first maximum: 11.4h, 11.4h, 11.4h, 11.6h

**Winter**
- Amplitude, $C_2 (\gamma)$: 13.0, 13.4, 12.4, 14.4
- Phase, $\varphi_2$: 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

<table>
<thead>
<tr>
<th>Slightly disturbed</th>
<th>Moderately disturbed</th>
<th>Greatly disturbed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equinoxes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, $C_2 (\gamma)$: 1.1, 1.2, 6.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase, $\varphi_2$: 3°, 304°, 342°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of first maximum: 2.9h, 4.9h, 3.6h</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, $C_2 (\gamma)$: 1.1, 1.7, 3.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase, $\varphi_2$: 317°, 301°, 307°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of first maximum: 4.4h, 5.0h, 4.8h</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Winter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, $C_2 (\gamma)$: 0.4, 0.9, 1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase, $\varphi_2$: 105°, 310°, 116°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of first maximum: 11.5h, 4.7h, 11.1h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MAGNETIC DISTURBANCE FIELD AT KODAIKANAL

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 of 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 $S_e$ 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 $S_e$ 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 $S_e$ 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 Kodaijanal, 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 Kodaijanal, 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 Kodaijanal 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 Kodaijanal during summer is found to reach
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.

### Table 5

<table>
<thead>
<tr>
<th>Character figure</th>
<th>Equinoxes</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0—0.4</td>
<td>39.430</td>
<td>39.417</td>
<td>39.431</td>
</tr>
<tr>
<td>0.5—0.9</td>
<td>39.422</td>
<td>39.412</td>
<td>39.442</td>
</tr>
<tr>
<td>1.0—1.4</td>
<td>39.413</td>
<td>39.399</td>
<td>39.421</td>
</tr>
<tr>
<td>1.5—2.0</td>
<td>39.390</td>
<td>39.393</td>
<td>39.397</td>
</tr>
</tbody>
</table>

### Table 6

<table>
<thead>
<tr>
<th>Character figure</th>
<th>Equinoxes</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0—0.4</td>
<td>+0.6</td>
<td>+5.3</td>
<td>+6.6</td>
</tr>
<tr>
<td>0.5—0.9</td>
<td>+3.3</td>
<td>+2.3</td>
<td>+1.1</td>
</tr>
<tr>
<td>1.0—1.4</td>
<td>-1.9</td>
<td>-3.0</td>
<td>-3.0</td>
</tr>
<tr>
<td>1.5—2.0</td>
<td>-14.9</td>
<td>-15.5</td>
<td>-22.1</td>
</tr>
</tbody>
</table>

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 \( 10 \gamma \) (in winter it is only about \( 5 \gamma \)) and \( 2 \gamma \) respectively. Since the scale coefficient of the vertical force magnetograph is about \( 1 \gamma \) in winter, it is only about \( 10 \gamma \). Records obtained with this instrument are likely to give very valuable information.

5. Acknowledgement

It is my pleasant duty to thank Dr. A. K. Das, Deputy Director General, Astrophysical Observatory, Kodaikanal and Messrs. B.N. Bhargava and S. Rangarajan, Officers of the Magnetic and Ionospheric section for all the help rendered during the course of the above study.

### References

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