Sudden Commencements and Impulses in Kodaikanal magnetograms - their hourly frequency

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ABSTRACT. The diurnal variation in the frequencies of sudden commencements (SCs) and sudden impulses (SIs) at Kodaikanal (10·2°N, 77·5°E) is analysed from the data for the period 1949-1957. The hourly frequency curve of SCs and SIs (combined) has little resemblance to the curve obtained by Newton from his analysis of Greenwich-Abinger records. The results of harmonic analysis show a nearly semi-diurnal trend in the distribution of storm sudden commencements (SSCs); this, however, is small. The hourly frequencies of SIs show a significant diurnal variation with an afternoon maximum and a forenoon minimum and a secondary minimum around 18h local time and a secondary maximum around 08h. These results are also compared with those obtained by Ferraro Parkinson and Unthank.

1. Introduction

Rapid movements in the magnetograms marking the onset of perturbations have been termed SCs and those which are not followed by perturbations SIs, the period preceding them being normally quiet. A slight tendency for SCs to occur more frequently at 13^h local time was first reported by Moos (1910) from his study of 113 SCs recorded at Bombay. Chakrabarty (1951) also found a similar maximum separating minima around 4^h to 7^h and 17^h LMT which is in full agreement with Newton's (1948) results based on Greenwich-Abinger records. Much the same results were obtained by Rodés (1932) and McNish (1933) from the records of Ebro and Watheroo respectively. Ferraro, Parkinson and Unthank (1951) from an examination of records from six stations, *viz.*, Cheltenham, Tucson, San Juan, Honolulu, Huancayo and Watheroo for the period 1926-1946 found for SCs a small afternoon maximum and for SIs minima around 08^h and 20^h; they, however, concluded that any local time variation in the hourly frequency is likely to be small. Forbush and Vestine (1955) concluded from a Chi-square test applied to bihourly frequencies of SCs and SIs (combined data at Watheroo and Huancayo that the hypothesis of equal frequency cannot be rejected.

2. Data and tabulation

SCs and SIs at Kodaikanal are generally of the ordinary type in which there is an increase in H, V and westerly D. There is quite a sizeable number of impulses reported by other stations which show up as drops in H, strokes, pinnacles or waves. The important ones among these have been grouped under miscellaneous SIs. Most of the SCs reported by five or more stations were also recorded at Kodaikanal. As regards SIs the agreement was not always found, the reported impulses often appearing as slow rise, hump or kink. All abrupt movements simulating sudden commencements need not be preceded by a quite trace; they may presumably occur during perturbations too, making identification difficult. Marked impulses occurring during slight agitations have also been selected following the reports of other stations, published by I.A.G.A. In all 229 SCs, 218 SIs and 125 miscellaneous SIs were collected as shown in Table 1.

The figures in brackets give the number of SSCs, storm sudden commencements—sudden commencements of perturbations which have been grouped at Kodaikanal as magnetic storms of range in $H > 100\ \gamma$.

Of the 229 SCs, 13 are of SC* type showing a small preliminary negative movement

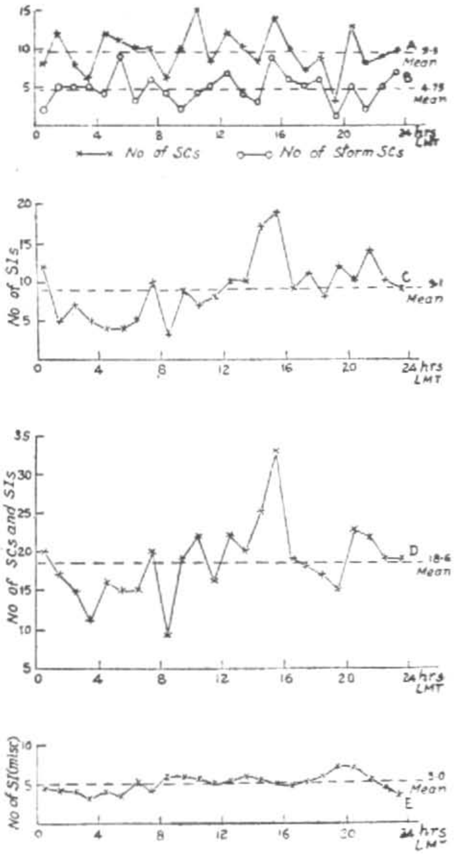

Fig. 1. Hourly frequencies of impulses

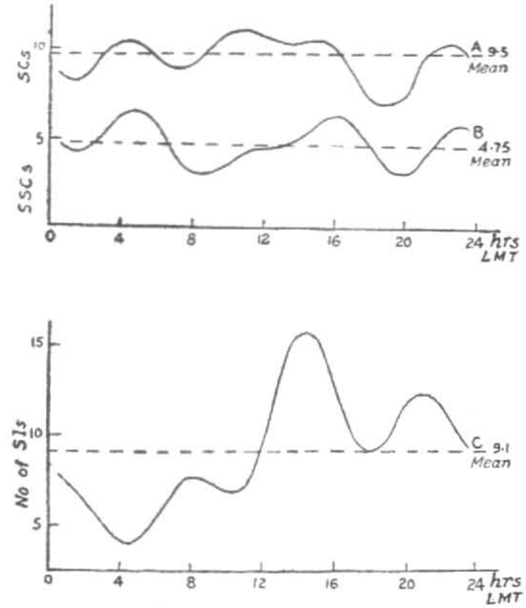

Fig. 2. Hourly frequencies of impulses (smoothed values)

TABLE 1

Period	SCs	SIs	Misc. SIs
1949-51	79 (55)	99	44
1952-54	37 (12)	45	37
1955-57	113 (47)	74	44

TABLE 2

	(A) SCs		(B) SSCs		(C) SIs	
	R	$\frac{R}{\sigma'}$	R	$\frac{R}{\sigma'}$	R	$\frac{R}{\sigma'}$
I term	0·882	1·10	0·261	1·45	3·829	3·62
II term	0·714	0·91	1·003	5·57	1·036	0·98
III term	0·591	0·76	0·509	2·83	1·872	1·77
IV term	0·928	1·20	0·902	5·01	1·261	1·19

followed by the main impulse as in the ordinary SC. The local time frequencies of SCs, SSCs, SIs and miscellaneous SIs are plotted in Fig. 1. Fig. 1D for all SCs and SIs (combined) shows little resemblance to the curve obtained by Newton (1948) from Greenwich-Abinger records.

3. Results and Discussion

In order to find out trends in diurnal variation and test their significance the hourly frequencies of SCs, SSCs and SIs were separately subjected to harmonic analysis. The following expressions were obtained for the number U_t recorded in each hour—

For SCs :

$$U_t = 9{\cdot}54 - 0{\cdot}882 \cos(\theta + 34°54') + 0{\cdot}714 \times \cos(2\theta - 14°40') - 0{\cdot}591 \cos(3\theta - 82°2') - 0{\cdot}928 \cos(4\theta - 68°57') \quad \text{(A)}$$

For SSCs :

$$U_t = 4{\cdot}75 + 0{\cdot}261 \cos(\theta - 9°21') - 1{\cdot}003 \times \cos(2\theta + 85°12') + 0{\cdot}509 \cos(3\theta + 74°19') + 0{\cdot}902 \cos(4\theta + 73°54') \quad \text{(B)}$$

And for SIs :

$$U_t = 9{\cdot}08 - 3{\cdot}829 \cos(\theta - 71°30') + 1{\cdot}036 \times \cos(2\theta - 11°54') + 1{\cdot}872 \cos(3\theta + 71°39') - 1{\cdot}261 \cos(4\theta + 43°23') \quad \text{(C)}$$

where, $t = 0, 1, 2 \ldots\ldots\ldots\ldots 23$ and

$$U_t = (t + \tfrac{1}{2})\, 15°$$

Smoothed values given by the above expressions are plotted in Fig. 2

In curve 2A for SCs a broad maximum around noon and a minimum around 19^h are seen. These, however, are not markedly different from the average level. The other minima around 07^h and $01\text{-}02^h$ and maxima around $04\text{-}05^h$ and $22\text{-}23^h$ are even less noteworthy. Sivaramakrishnan (1956) noticed minima in the bihourly intervals $08\text{-}10^h$ and $18\text{-}20^h$ from his analysis of Kodaikanal data for 1949-53. From curve 2B it is seen that the distribution of SSCs is nearly semi-diurnal, with minima around $08\text{-}09^h$ and $19\text{-}20^h$ and maxima around 16^h and $04\text{-}05^h$.

The distribution of SIs given in 2C is mainly diurnal with forenoon minimum and afternoon maximum. There are also a minor maximum around 08^h and a minor minimum around 18^h.

Distribution of miscellaneous SIs shows a maximum during $18\text{-}21^h$ and a minimum during the early hours of the day.

In order to test the significance of the local features mentioned above, the standard deviation σ of the set of observations and the standard deviation σ' of the coefficients given by $\sigma\sqrt{2/n}$ (n being the number of observations) were found for each of the expressions (A), (B) and (C). The magnitudes of the several coefficients R were then compared with their standard deviations as shown in Table 2.

It is seen from Table 2 that all the coefficients in (A) are much less than twice their standard deviation and hence are not statistically significant. In (C) the diurnal term alone is significant. In (B), though all except the diurnal term are significant, any local-time effect on the distribution is likely to be small as the amplitudes of the harmonic terms are small compared with the mean value.

A study of the curves in Fig. 2 shows that the post sunset minimum is present in the distribution of SCs, SSCs and SIs. This minimum is, however, not a feature of any statistically significant trend in the case of SCs.

Table 1 shows that the number of SCs and SIs are both small during 1952-54 which corresponds to the minimum sunspot period. Thirteen SC*s found during the course of this analysis occurred during local mid-day (1000-1400 hrs). The average ratio of the magnitude of the preliminary impulse to that of the main impulse is about 0·15. The ratio of the number of SC* to all SCs, *viz.*, 13/229 is very small compared to 1/4 that might be expected from the suggestion of Ferraro and Parkinson (1950) that (number of SC*)/ (number of SC) depends on geomagnetic longitude. This suggestion is at least not true in the equatorial regions as already pointed out by Chakrabarty (1951) who found no SC*s among the 800 SCs at Bombay during 1905-44.

4. Conclusion

The frequency of SCs has no significant trend in diurnal variation. The distribution of SSC is very nearly semi-diurnal whereas that of SIs is significantly diurnal. On the other hand, Ferraro, Parkinson and Unthank (1951) obtained a slight diurnal variation for SCs and a semi-diurnal variation for SIs. The differences in the criteria of selection of the impulses by different observers leave one in doubt as to the genuineness of the observed local time variations. In view of this, the interpretation of any observed diurnal variation cannot be conclusive. Such local time effects have been attributed to electromagnetic shielding of the ionosphere by Jackson (1950) and to causes of terrestrial origin by Ferraro, Parkinson and Unthank (1951).

It is felt that the data used in the present analysis are not as extensive as one could have wished. However, considering the importance of Kodaikanal as the only magnetic observatory close to the magnetic equator (geomagnetic latitude 0·6°N) in South Asia, the conclusions that can be drawn from the available data, though not very extensive, are likely to be of interest to workers in geomagnetism.

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