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A study of Sudden Commencements of Geomagnetic Storms at Trivandrum

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ABSTRACT. The occurrence frequency distribution of SC (+) is not showing any significant variation with local time, while the SC(—+) cases occur, in the equatorial station Trivandrum, during the day-time electrojet. There is a direct relationship between the severity of the SC storm and the rate of field change of the SC amplitude and rise time. At this station, the polarization of the SC field vector in the horizontal plane is linear.

1. Introduction

Several of the severe geomagnetic storms almost always commence with a sudden and sharp change in the geomagnetic field at the surface of the earth. This short impulse or Sudden Commencement (SC) lasts only for a few minutes and occurs in several forms. They are usually classified into four main types, SC(+) SC(—), SC(—+) and SC (+—) (Akosofu and Chapman 1960), in accordance with the nature of the change in the horizontal component of the geomagnetic field. The time, for which this sudden impulse in the case of SC(+) lasts, is termed as the rise time (I) and the change in the field during this interval is called the amplitude (A).

A detailed study is made here of SC's recorded at Trivandrum (dip — 0°36′) in respect of their frequency of occurrence, of the relationships between amplitude and rise time, between the gradient and the storm-range and of the polarization characteristics of the SC horizontal field.

2. Data and Results

Clear cases of SC's were selected after a thorough scrutiny of the normal-run and quick-run magnetograms of Trivandrum for all days during the period 1957 September to 1966 August. There were in all 243 cases of sudden commencements, of whch 226 were SC(+) and 17 were SC(—+). Fig. 1 represents the tracings of three SC(+) cases and four SC(—+) cases in *D*, *H* and *Z*. The arrows by the sides of the *H* and *Z* tracings indicate easterly change. The date and time of start (U.T.) are also given in all the cases.

(1) *Diurnal variation of the frequency of occurrence of SC's* — Fig. 2(A) and (B) shows the frequency of occurrence of SC's according to the local time corresponding to 76°57′E geographic longitude. Irrespective of seasons, day-time is taken to correspond to 0601 to 1800 hr L.T. and the remaining twelve hours to night-time. The hourly interval refers to the sixty minutes duration in that hour, for example, 09^h represents 0901 to 1000.

Of the 226 cases of SC(+) [Fig. 2 A], only 112 occurred during day-time. The histogram depicts two broad maxima, one in the forenoon from 5^h to 7^h and the other in the evening between 16^h to 21^h. The minima occur between 8^h and 15^h, at 2^h and at 22^h. The hourly variations in the frequency of occurrence have, however, very little significance statistically, the average frequency of 9 having a standard deviation of 3. The extreme deviations from 9 ± 3 are just 1 or 2 more or less.

All the 17 cases of SC(—+) [Fig. 2B] occur in the day-time between 7^h and 14^h.

(2) *Rise time and amplitude* — For this study, SC(+) cases only were considered. After elimination due to various factors, only 105 clear cases could be selected. The rise time 'I' in minutes and the amplitude 'A' in gamma, were measured accurately by a two coordinate microscope, reading correct to 0·001 cm, for the elements *H* and *Z*. Fig. 3(A) and (B) indicates the correlation between amplitudes and rise times in *H* for day-time and night-time respectively, while Fig. 3(C) and (D) indicates the same in *Z* again for day-time and night-time respectively. For both *H* and *Z*, there is little correlation between the two parameters. The same result was obtained when day-time and night-time cases for each element were pooled together.

3. Storm-range and gradient

Maeda *et al.* (1962) studied the relation between gradient (time rate of change of SC field) and the range of SC storms. The gradient is given by A/I in γ/min and the range given by

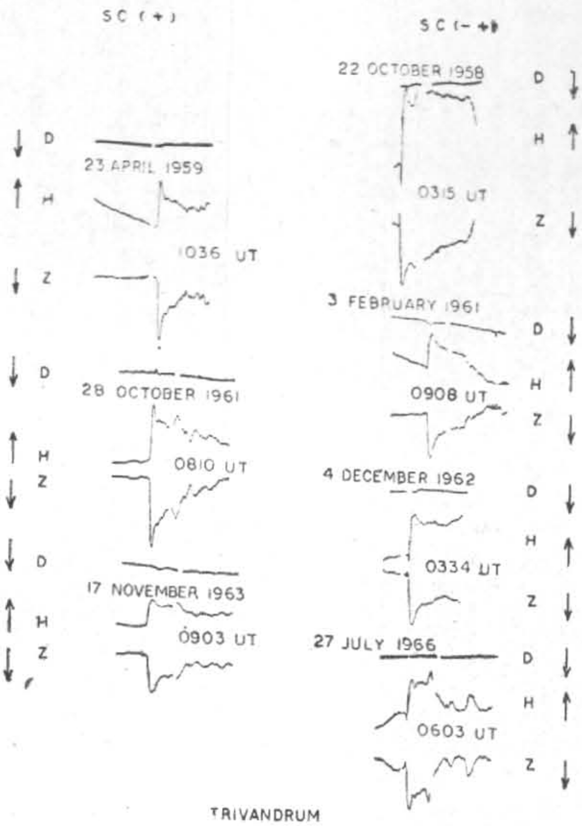

Fig. 1. Tracings of three SC (+) and four (SC (— +) cases at Trivandrum in D, H and Z

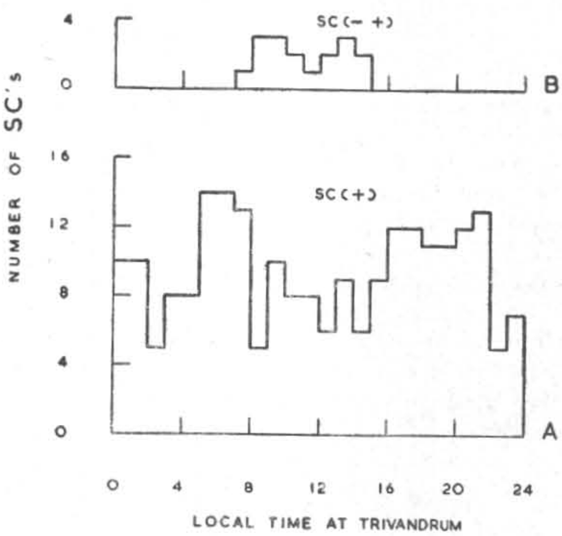

Fig. 2. Local time distribution at Trivandrum
A : SC (+)
B : SC (—+)

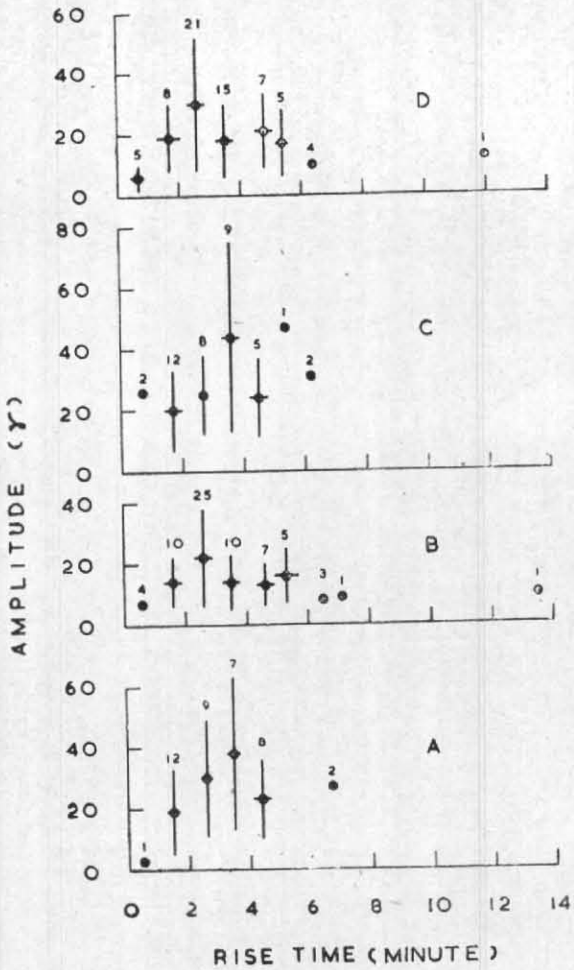

Fig. 3. Rise time and amplitude

Horizontal Forces : A—daytime; B—night time
Vertical Forces : C—daytime; D-night time

the difference between the maximum and minimum values of the field during the storm, representing D_{st} in the equatorial region. In determining the gradient it is assumed that the rate of change of the field components is uniform, during the rise time. All the 105 cases of SC (+) considered for the last study, were used for this investigation both in *H* and *Z*. The results are shown in Fig. 4 (A) for *H* and in Fig. 4(B) for *Z*. A linear positive correlation is indicated for both the elements between SC gradient and storm-range.

4. Polarization of the SC field

For the study of polarization of the SC field in the horizontal plane, measurements were made in *H* and *D*. Changes in *D* being usually very small at Trivandrum during SC's only six very clear cases of SC (+) could be considered for this purpose. Field changes in *H* and *D* were measured for particular intervals of time from commencement time, till the end of the impulse, by using the two coordinate microscope. The values of $\triangle H$ and $\triangle D$ for the corresponding intervals from the onset time were combined, to find the total horizontal disturbance vector ΔH. The plots of these six cases are shown in Fig. 5. The SC field vector in the horizontal plane is linearly polarized in all cases.

3. Discussion

The occurrence frequency distribution of SC (+) is seen to have no particular preference for any part of the day. This result may be on account of the insufficient number of SC's. But considering the fact that the SC's are practically simultaneous

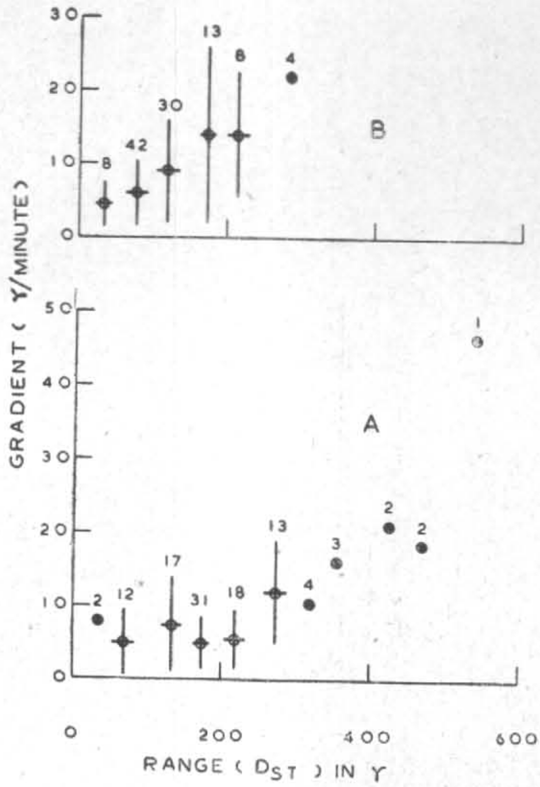

Fig. 4. Storm-range and gradient

A : Horizonal Forces; B : Vertical Forces

In Figs. 3 and 4 the circles represent the mean values of the respective parameters, while the vertical and horizontal straight lines represent twice the standard deviations of them. The number in each position represents the number of classes examined.

TABLE 1

	1958	1959	1960	1961	1962	1963	1964	1965	1966
Number of SC(—+)	3	4	3	1	2	2	1	Nil	1

at all places, it is hardly reasonable to expect a preferential commencement of the storm for any particular local time. The fairly uniform occurrence frequency of SC (+) over the 24 hr LT, arrived at here, is more in the fitness of things.

The notable result in the study of occurrence frequency distribution is in the case of SC(—+). Table 1 gives the distribution of these 17 cases in the various years of study.

Just as the number of SC(+) cases are greater during high sunspot years than the other years, so also there appears to be greater number of SC(—+) cases during the years 1958, 1959 and 1960, than the other years. But this does not indicate any specific preference of occurrence of SC(—+) to any particular epoch of the solar cycle. Further all the 17 cases occur in the daytime between 7^h and 14^h LT. This is in conformity with the finding of Matsushita (1962) who has indicated 7^h to 17^h LT as the occurrence interval of SC(— +) in the equatorial zone (about $\pm 15°$ dip angle), though in the higher latitudes, this type occurred at all local times. The cause of the preliminary impulse in the SC(—+) is generally considered to be ionospheric electric currents set up in the auroral latitudes, by corpuscular radiation impinging on the ionosphere

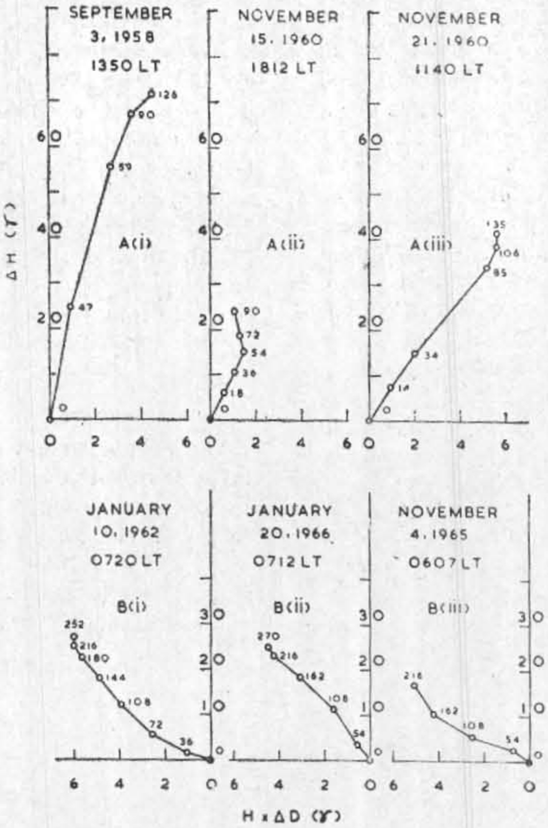

Fig. 5. Vector diagrams representing total horizontal disturbance vector $\triangle H$ during SC's showing lincer polarization of SC magnetic field in the horizontal plane

A—Easterly linear polarisation, B—Westerly lineer polarisation

'o' represents the onset time of each SC and the local time of onset of each SC and the date are indicated in each case. The intervals in seconds from 'o' are represented by the number near each circle. Each circle represents $\triangle H$ and $H+\triangle D$ for that time interval from 'o'

along the geomagnetic field lines. These currents are considered to be set to 2 minutes before the magnetospheric boundary currents (Nagata 1952 and Ondoh 1961). The occurrence times for SC($-+$) in the equatorial region are roughly during the day-time electrojet as seen here. Evidently the high Cowling conductivity around 100-km altitude helps to accentuate the low-altitude westerly return currents of the initial impulse and bring the SC($-+$) into prominence at these times.

The positive linear relationship between the gradient of SC($+$) and the storm-range (Fig. 4 A and B) in both H and Z suggests that the severity of SC storm has a direct dependence on the rate of field change of the SC amplitude. This result has to be expected from a consideration of the causes of SC's and main phase of storms. Interaction of the solar plasma with the magnetosphere gives rise to SC and the main phase of the storm is caused by the ring current eventually set up by the eastward and westward drift of electrons and protons in the plasma. The energy of the solar plasma is dependent on its number density and velocity. If, for two cases of SC, we take the number density to be the same, but of different velocities, the high velocity plasma will obviously compress the magnetosphere earlier and to a greater extent and in the process from the megnetospheric currents more rapidly causing a greater rate of field change in the ground level SC. The resulting ring current will be located closer to the earth and as a result the storm main phase depression and hence range will be greater.

The study of the correlation between amplitude and the rise time of SC's has been made by several investigators in the past. Maeda *et al.* (1962), Pisharoty and Srivastava (1962) and Srivastava (1965) have shown the existence of a negative correlation between the two parameters, which agree with the investigations of Chapman (1960), and Dessler *et al.* (1960). But Jan Bouska (1962,63) has suggested a positive correlation between the amplitude and rise time, after analysing the SC's from the magnetograms of the Budkov Observatory (λ=14°01'E and ϕ=49°04'N) in Southern Bohemia. The analysis for the equatorial station Trivandrum indicates that there is no specific correleation between these two parameters (Fig. 3 A to D), when day-time and night-time cases were separately analysed for both H and Z.

Wilson and Sugiura (1961) presented a model for Storm Sudden Commencements, by studying the polarization characteristics of the SC magnetic field, examining the total horizontal disturbance vector ΔH. The hydromagnetic waves generated, due to the interaction of the solar plasma with the magnetosphere at a few earth radii distance, travel longitudinally to low latitudes and result in the sudden increase of the horizontal component. Hence, in low latitudes, the polarization should be expected to be linear only. At Trivandrum the changes in D are small and simple during SC's and the polarization of the SC field vector in the horizontal plane is the linear (Fig. 5 A and B). It changes from a westerly nature in the early morning hours to easterly in the post-noon hours generally in the few cases examined here.

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