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The *H* Amplitude of Sudden Commencements of Magnetic Storms at Sabhawala (Dehra Dun)

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Abstract. The storm sudden commencement (SSC) amplitude in H is invariably much larger at Sabhawala, in Northern India, than at the neighbouring low-latitude stations. Examination of ten-year data shows that the ratio of the amplitude at Sabhawala to that at Alibag is persistently higher than unity, on an average about 1.5, both during day and night. The abrupt increase in amplitude from the nearest station, Jaipur, to Sabhawala indicates that neither ionospheric nor magnetospheric currents are directly responsible for the enhancement of the amplitude at Sabhawala. Considering the behaviour of SSC amplitudes in the three components, H, Z, and D at Sabhawala, subsurface electrical conductivity is shown to be the most likely source and the direction of anomalous induced current is determined to be westward. The high conductivity regions may possibly be following the trend of the Himalayas.

Key words: Sudden commencements of magnetic storms – Induced currents – Electrical conductivity anomalies.

The sudden commencement of a magnetic storm, SSC, appears at mid- and low-latitude stations as a sudden increase in the geomagnetic horizontal component, H. Individual SSCs observed simultaneously at different stations all over the world show a considerable local time inequality. A systematic change in the shape of SSCs exists with geographic longitude at higher latitudes, though the shape is more or less the same for any event in low latitudes (Obayashi and Jacobs, 1957). Of the six Indian magnetic observatories with over a decade of data collection, three are in the equatorial electrojet belt and two are at

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Table 1. Location of the Indian Observatories and Mean SSC(H)

Station	Geographic		Dipole		Dip	Mean SSC(H) in nT	
	Latitude	Longitude	Latitude	Longitude		Day-time	Night-time
Trivandrum	8°29′N	76°57′E	1.2°S	146.4°	−0.9°	44±4	27±2
Kodaikanal	10°14′N	77°28′E	0.6°N	147.1°	3.0°	39±5[a]	33±3[a]
Annamalainagar	11°22′N	79°41′E	1.4°N	149.4°	5.4°	44±4	34±3
Hyderabad	17°25′N	78°33′E	7.6°N	148.9°	20.7°	28±2	30±3
Alibag	18°38′N	72°52′E	9.5°N	143.6°	24.3°	27±2	29±3
Ujjain	23°11′N	75°47′E	13.5°N	147.0°	32.7°	–	–
Jaipur	26°55′N	75°48′E	17.3°N	147.4°	39.4°	–	–
Sabhawala	30°22′N	77°48′E	20.8°N	149.8°	48.2°	36±3	46±4

[a] For Kodaikanal, the day-time events are 23 and the night-time events are 27 only, due to non-availability of published data for the years 1968 and 1969 and also because only prominent events are reported in the Bulletins of this observatory

low latitudes; the sixth is the northernmost observatory in the country, situated near Dehra Dun in the Himalayan foothills. Two magnetic observatories were recently started between Alibag and Sabhawala. The locations of these observatories, which are within a narrow (about 7°) longitudinal range, are given in Table 1. The Table also contains the average amplitude in H of about 40 day-time and 50 night-time SSC events, generally recorded at all the six older observatories during the period 1964–1973.

The amplitude at low-latitude stations from Hyderabad to Sabhawala is expected to be nearly constant. But, surprisingly, SSC(H) at Sabhawala is large compared to that at Alibag and Hyderabad. During the night-time, SSC(H) is comparable from Trivandrum to Alibag. But, at Sabhawala, it remains large, and even larger than the day-time amplitude; however, the difference between the day and night amplitudes is not statistically significant.

Mean SSC(H) at different stations, normalized with respect to the amplitude registered at Alibag, is shown in Fig. 1a as a function of dipole latitude, separately for the day- and night-time events. Mean of SSC(Z) – SSC amplitude in the vertical component Z – is also similarly plotted in Fig. 1b. The wellknown day-time enhancement of SSC(H) in the electrojet belt (Sugiura, 1953 and others), evident in Table 1, is clearly seen in Fig. 1a, as also the persistence of the high ratio at Sabhawala. While the former is attributed to the enhancement of the equatorial electrojet at the time of SSC (Jacobs and Watanabe, 1963; Rastogi, 1976), the latter cannot be attributed to the currents in the ionospheric *E*-layer because persistently high values of SSC(H) are observed both during the day and the night.

Mean amplitudes of five SSC events recorded at Ujjain and Jaipur between May and December, 1975, as well as the mean values for the same events for Trivandrum, Annamalainagar, Alibag and Sabhawala, are also plotted in

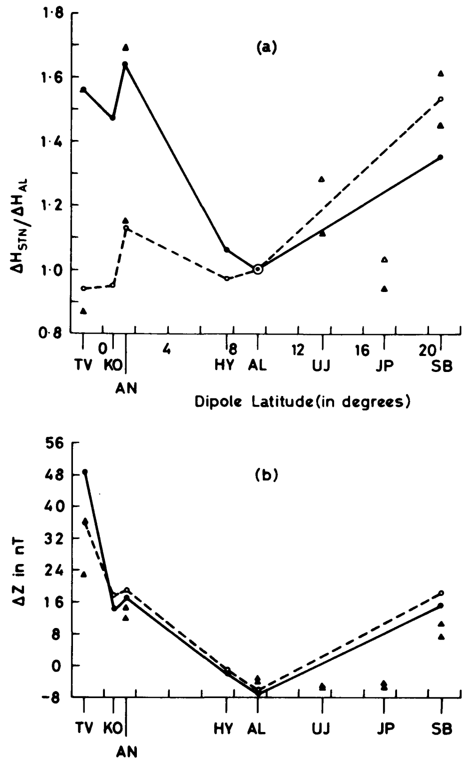

Fig. 1 a and b. Plot, over dipole latitude, of **(a)** the ratio of sudden commencement, SSC, amplitude in the horizontal component at a station, ΔH_{STN}, to the corresponding amplitude at Alibag, ΔH_{AL}, and **(b)** the mean SSC amplitude in the vertical component, ΔZ. Day-time and night-time events are separately shown: Full circles and solid line for day-time events and open circles and broken line for night-time events. Mean values for the five recent events are shown by full triangles and open triangles for the day-time and night-time events respectively. (*TV*: Trivandrum; *KO*: Kodaikanal; *AN*: Annamalainagar; *HY*: Hyderabad; *AL*: Alibag; *UJ*: Ujjain; *JP*: Jaipur; *SB*: Sabhawala)

Fig. 1, normalized SSC(H) in (a) and only SSC(Z) in (b). Figure 1 a shows a sharp increase in the ratio from Jaipur to Sabhawala and the variation over the latitudes is not smooth. This is not expected if the amplitude variation were mainly due to magnetospheric currents.

In contrast to the normalised SSC(H) curve in Fig. 1 a, there is little difference between day- and nigh-time variations of SSC amplitude in *Z* with latitude. The influence of the overhead currents on SSC(Z) is therefore slight. As seen from the mean values for the five recent events in Fig. 1 b, mean SSC(Z) from Alibag to Jaipur remains the same, whereas there is an abrupt increase at Sabhawala. Such anomalous differences in SSC(Z) at neighbouring stations are commonly attributed to variations in the distribution of sub-surface electrical conductivity (Rikitake, 1966). SSC amplitudes in *Z* as large as those at Sabhawala are observed at the equatorial stations, Annamalainagar, Kodaikanal, and Trivandrum. The anomalously large variations at different periods at these equatorial stations are under investigation at present and some preliminary results have been reported (for example, Srivastava et al., 1975 and References therein). Rajagopal et al. (1976) have attributed the anomalous *Z* variations at Annamalainagar and Trivandrum to the complex nature of the subsurface electrical conductivity and also channelling of induced currents through the Palk Straits, a shallow channel separating the tip of the Indian Peninsula from the

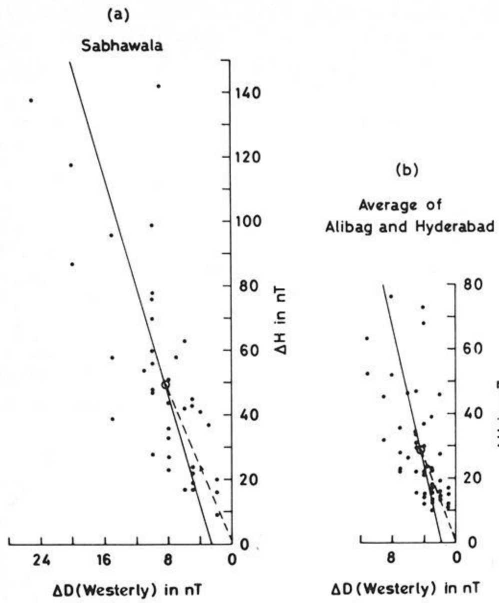

Fig. 2. a and b. Plot of night-time sudden commencement, SSC, amplitude in the horizontal component, ΔH, against the corresponding amplitude in declination, ΔD, **(a)** at Sabhawala and **(b)** average of the corresponding amplitudes at Alibag and Hyderabad. Solid line is the regression line of ΔD on ΔH and the broken line indicates the mean horizontal vector

island of Sri Lanka. A similar explanation may also be valid for large SSC(Z) at Kodaikanal since it is in the same peninsular region. Sabhawala, however, is about 1,600 km inland from any coast and is not affected by the same processes.

The departure of SSC amplitudes in H and Z at Sabhawala from the expected values at low to mid-latitudes is noticeable when these are compared to the corresponding amplitudes at Alibag and Hyderabad. Normally SSC(Z) at low latitudes is expected to be small in the absence of induced subsurface currents. Since SSC(Z) at Alibag as well as Hyderabad is small, the induced anomalous part in SSC(H) and declinational component, SSC(D), may reasonably be assumed to be small and hence the amplitude of SSC at these stations can be considered normal. A plot of SSC(H) against SSC(D) at Sabhawala for all the night-time events is given in Fig. 2a. Taking an average of the amplitudes at Alibag and Hyderabad, a similar plot of the average SSC(H) against average SSC(D) for the night-time events is shown in Fig. 2b. Regression line of SSC(D) on SSC(H) as well as the mean horizontal vector is shown in both the diagrams. The two plots are similar, with almost the same slope for the regression line. The mean vector at Sabhawala is, however, considerably larger in magnitude than the mean vector in Fig. 2b. This indicates that induced part exists in both SSC(H) and SSC(D) at Sabhawala.

SSC amplitude is measured as deviation from pre-storm level. In any component the average of SSC amplitudes at the two stations, Alibag and Hyderabad, may reasonably be taken as the normal amplitude. The difference, for any event, between this average and the corresponding amplitude at Sabhawala is assumed to be the anomalous induced part. In the case of Z, the total amplitude is taken to be anomalous since the average of SSC(Z) at Alibag

Table 2. Induction coefficients in the three components

Coefficient	H	Z	D
A	0.6 ± 0.1	0.5 ± 0.1	-0.1 ± 0.03
B	-0.2 ± 0.5	-0.5 ± 0.3	0.2 ± 0.2

and Hyderabad is small (≈ 0) and is not correlated with the anomalous part at Sabhawala in any of the three components. If X_n represents the normal part of component X, as observed at Alibag and Hyderabad, the anomalous part at Sabhawala, $X_a = X - X_n$. Then, using the equation (Schmucker, 1970):

$$X_a = A_x H_n + B_x D_n + \varepsilon_x$$

where ε_x is the uncorrelated part, A's and B's are evaluated for each of the components H, Z, and D. These together with their standard errors are given in Table 2.

The sign for B's is opposite to that of A's because the change in declination is westerly when SSC occurs. A_H and A_Z are comparable within error limits. This suggests that, at Sabhawala, the induced part of SSC(H) is considerably large. A_D, though small, is statistically significant. The horizontal disturbance vector determined from the anomalous parts of H and D is about 10° west of north, almost the same as the direction of the mean vector in Fig. 2. This indicates that the subsurface induced currents may be flowing westwards about 10° south of west (Schmucker, 1969). A_Z and B_Z determine the induction vector and its direction, determined by $\tan^{-1}(B_Z/A_Z)$ measured clockwise from south, indicates the direction of current concentration (Untiedt, 1970). It varies between about 10° and 60° east of south; this wide variation is due to the large standard error of B_Z.

The results suggest the existence of an anomalous induced part in all the three components of the SSC amplitude at Sabhawala which is situated in the Himalayan foothills. The anomalous induced currents are indicated to flow approximately from east to west and the current concentration, in a good east-west conductor, is to the south-east of Sabhawala. Schmucker (1969) made a detailed study of the conductivity anomaly with special reference to Andes and inferred that anomalous induced currents are channelled into a high conductivity zone which follows the general trend of the mountain range. The Himalayas have a similar geological history to that of the Andes. Therefore, it is likely that regions of high subsurface conductivity, where the induced currents flow, may follow the trend of the Himalayan mountain range. However, a systematic magnetic array study in the neighbourhood of Sabhawala is required to determine the depth and extent of the conductive feature.

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