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PROPAGATION OF THE STORM SUDDEN COMMENCEMENT OVER THE SOUTHERN POLAR REGION

Takeo HIRASAWA

National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173

Abstract: The storm sudden commencement on June 12, 1982 is extensively studied with the data from the Antarctic and sub-Antarctic stations. A new method is introduced to assign the reasonable onset times of various sc events in polar regions. The resultant spatial dependence of sc onset times obtained through the present method indicates that the sc wave arrives, at first, at the day-side region (08–14, GLT) at geomagnetic latitude from 68° to 73° and propagates towards the night-side with a velocity of about 70–80 km/s on the earth's surface and about ~1500 km/s in the magnetosphere.

1. Introduction

The sudden commencement (sc) of magnetic storm on June 12, 1982 has been extensively investigated with the data from the Antarctic and sub-Antarctic stations. The observational records were presented to the Data Analysis Workshop for SCAR Intervals of Special Interest, led by Dr. L. J. LANZEROTTI (Bell Laboratories, U.S.A.). Antarctic stations, whose data were available in the study, are listed in Table 1. The geographical distribution of the observatories is more uniform in the southern polar region (especially near the pole) than in the northern one because of the Antarctic Continent surrounding the geomagnetic pole, while the Arctic sea occupies the central polar area in the northern hemisphere. The multi-station data in the southern polar region are very useful for investigating the progressive change in the upper atmosphere disturbance pattern in the polar region.

Figure 1 shows the correlation chart of the geophysical phenomena associated with the sc of June 12, 1982, obtained at Syowa Station in Antarctica. The sc occurred around 1442 (UT). Here, we notice that the sc excited magnetic pulsations, cosmic noise absorption (CNA) and VLF emissions with the frequency between 750 Hz and 4.0 kHz (VLF chorus). From the observational results shown in Fig. 1, it is clear that the sc was a typical sc phenomenon associated with upper atmosphere disturbances such as CNA, geomagnetic pulsations and VLF emissions (VLF chorus). Therefore, it is worthwhile studying the characteristics of the sc of June 12, 1982, with the data from the stations distributed widely over the southern polar region.

2. Identification of the Exact Onset Time of the Sudden Commencement in the Polar Region

It is extremely difficult to assign an exact onset time of sc's from the magneto-

Table 1. List of antarctic stations, from which magnetogram is available in the present study. The diple and corrected geomagnetic coordinates and L-values are calculated using the IGRF model for 1982.

Station name	Geograph.		Diple		Corrected Geomag.		L-Value
	Lat.	Long.	Lat.	Long.	Lat.	Long.	
Belgrano	−77.87	325.43	−67.84	19.36	−62.67	24.31	4.75
Davis	−68.58	77.97	−76.71	124.09	−74.46	99.56	13.92
Mawson	−67.60	62.87	−73.21	106.40	−70.18	89.70	8.70
Macquarie Is.	−54.50	158.93	−60.43	244.42	−64.21	247.31	5.28
Dumont d'Urville	−66.67	140.02	−75.02	232.16	−80.61	234.86	37.55
Alfred-Faure	−46.43	51.87	−51.52	111.23	−53.47	105.55	2.82
Martin-de-Vivies	−37.83	77.57	−46.83	142.65	−48.51	137.88	2.28
Port-aux-Français	−49.35	70.20	−57.18	130.62	−58.25	121.55	3.61
Syowa	−69.00	39.58	−69.97	80.48	−66.20	71.21	6.14
Mizuho	−70.70	44.33	−72.30	81.81	−68.06	71.41	7.16
Scott Base	−77.85	166.75	−78.77	293.32	−79.88	327.53	32.38
Campbell Is.	−52.55	169.15	−56.72	254.45	−59.95	258.07	3.99
Sanae	−70.30	357.60	−64.03	46.06	−60.28	43.66	4.07
Faraday	−65.25	295.73	−54.03	4.69	−49.74	8.96	2.39
Halley	−75.58	333.33	−66.24	25.67	−61.28	28.37	4.33
South Pole	−90.00		−78.88	0.00	−73.91	8.08	13.02
Siple	−75.92	276.08	−64.87	352.49	−60.79	3.12	4.20
Mirny	−66.55	93.02	−76.75	150.92	−77.08	122.09	20.00
Novolazarevskaya	−70.77	11.83	−66.58	55.77	−62.65	51.83	4.74

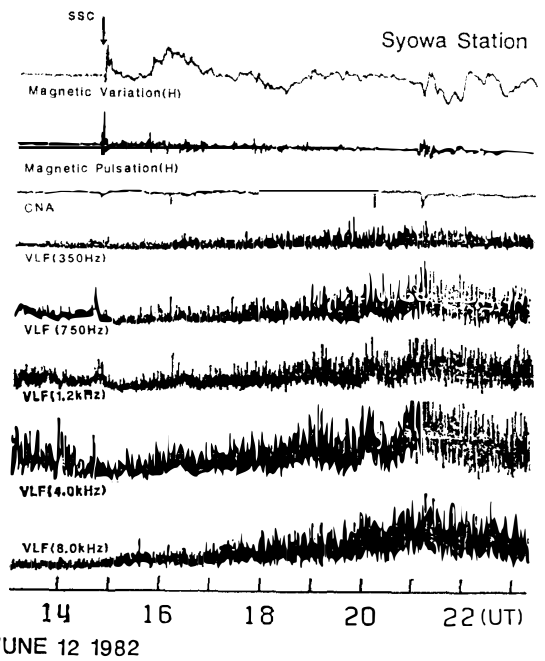

Fig. 1. Correlation chart of polar upper atmosphere phenomena at Syowa Station associated with the sc of June 12, 1982. From top to bottom: (1) Horizontal component of magnetogram. (2) Horizontal component of geomagnetic pulsations. (3) Cosmic noise absorption (30 MHz). (4) Intensities of VLF emissions, f=350 Hz, 750 Hz, 1.2 kHz, 4.0 kHz and 8.0 kHz.

grams of high latitude stations because they show complicated geomagnetic waveforms in the polar region (*e.g.*, MATSUSHITA, 1962; ARAKI, 1977). The sc onset time means the time when HM-waves from the magnetosphere (excited at its outer boundary by the shock or discontinuity of the solar wind) arrives at ground stations. As the first step of the analysis, we examine if we can determine the onset time of sc's with the geophysical data at Syowa Station, which is located at auroral latitudes in the southern polar region.

In Figs. 2, 3 and 4, three examples of geomagnetic sc variations at Syowa are shown along with the simultaneous data of CNA, magnetic pulsations and VLF emissions (the correlation chart of geophysical phenomena). The magnetic variation (H-component) in the top of Fig. 2 shows that a typical sc was observed around 1519 (UT), on July 16, 1982. In this sc event, a preliminary reverse (negative) impulse (PRI) precedes the main positive impulse (MI) in the geomagnetic H-component record. Such an sc is called SC*. Prior to the PRI, the H-component variation showed a slight increase at 1518:15 (UT) of about 20 nT. Almost simultaneously

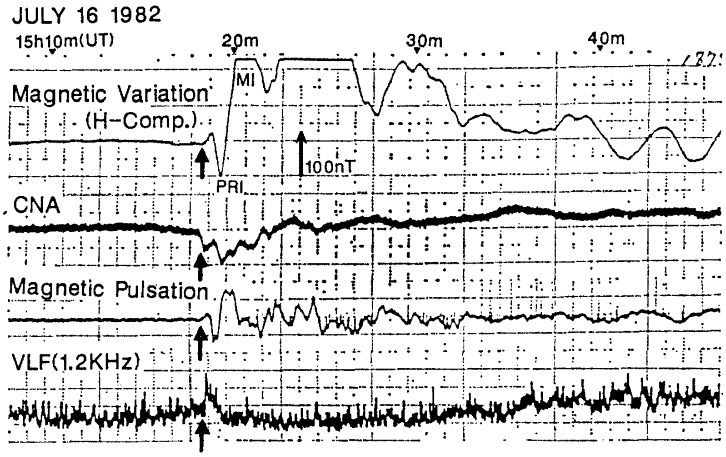

Fig. 2. Example of sc magnetic variation at Syowa, and associated phenomena. From top to bottom: (1) Horizontal component of magnetogram. (2) Cosmic noise absorption (30 MHz). (3) Geomagnetic pulsations. (4) VLF emission (f=1.2 kHz).

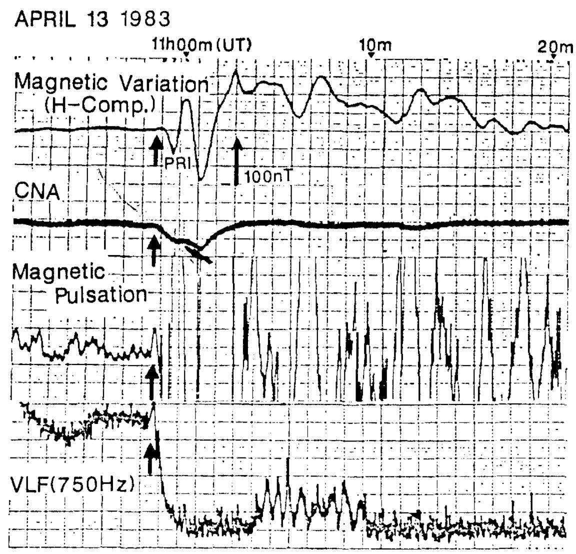

Fig. 3. Example of sc magnetic variation at Syowa and associated phenomena. From top to bottom: (1) Horizontal component of magnetogram. (2) Cosmic noise absorption. (3) Geomagnetic pulsations. (4) VLF emission (f=1.2 kHz).

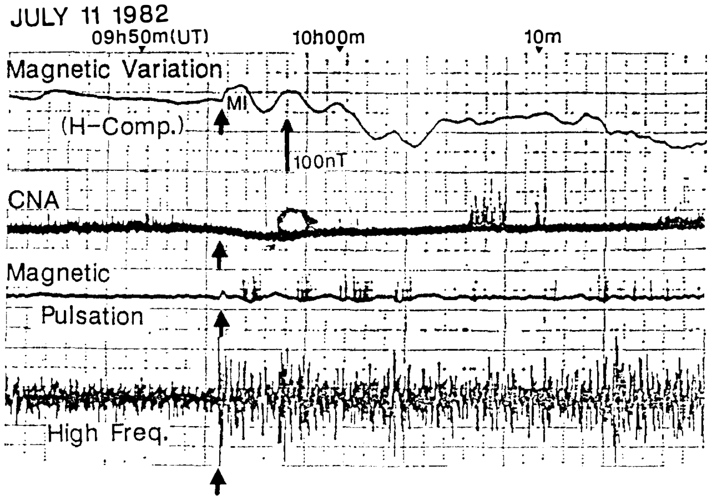

Fig. 4. Example of sc magnetic variation at Syowa and associated phenomena. From top to bottom: (1) Horizontal component of magnetogram. (2) Cosmic noise absorption (30 MHz). (3) Geomagnetic pulsations. (4) Amplitude of high-frequency geomagnetic pulsations (f>0.1 Hz).

with this slight positive magnetic variation, the CNA, magnetic pulsation and VLF emission records in Fig. 2 showed marked and rapid changes. The starting time of these changes were 1518:10 for CNA, 1518:15 for magnetic pulsation and 1518:20 for VLF emission, respectively. The characteristics of sc phenomena similar to this example can be also found in Fig. 3 for the sc of April 13, 1983. The arrows in Fig. 3 show the starting times estimated from the marked changes in various sc-associated phenomena. The sc times assigned in Fig. 3 are 1058:30 (UT) for magnetic variation, 1058:30 for CNA, 1058:25 for magnetic pulsation and 1058:25 for VLF emission. In the magnetic variation in the top of Fig. 4, the sc accompanying PC5 magnetic pulsation was observed from 0954 (UT) to 1006 on July 11, 1982. This sc did not show a preliminary reverse impulse (PRI) preceding the main positive impulse (MI). Only MI appears in this example, so that this sc is denoted simply as SC. Figure 4 indicates that the onset time of SC type can be well defined by the starting time of MI. Using the correlation charts of geophysical phenomena at Syowa in 1981–1985, we investigated 98 sc's with the same procedure as those illustrated in Figs. 2, 3 and 4, and we identified which kinds of geomagnetic *H*-component variations give the reasonable onset times of various sc events in the polar region. The morphological evidence, obtained through the above investigation, suggest that the sc onset time in the polar regions can be well represented by the beginning time of the main positive impulse (MI) in the case of SC and that of the preliminary reverse impulse (PRI) in the case of SC*. However, as is illustrated in Figs. 2 and 3, slight positive variations of *H*-component are frequently found preceding the PRI. The onset time for such sc's is the time when a slight positive variation begins.

3. Propagation of the Storm Sudden Commencement over the Southern Polar Region

From the above morphological inspection, the onset time of sc's can be assigned with the magnetic *H*-component variations at high latitude stations with the time accuracy within 10 s. Figure 5 shows the magnetic *H*-component variations at the time of the sc on June 12, 1982, observed at six Antarctic stations. The triangles

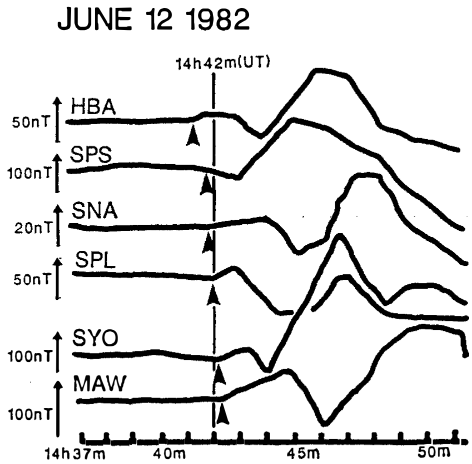

Fig. 5. Magnetic H-component variations of the sc of June 12, 1982, from six Antarctic stations, Halley Bay (HBA), Amundsen-Scott (SPS), Sanae (SNA), Siple (SPL), Syowa (SYO), and Mawson (MAW). The triangles in the figure indicate the estimated onset time of the sc event.

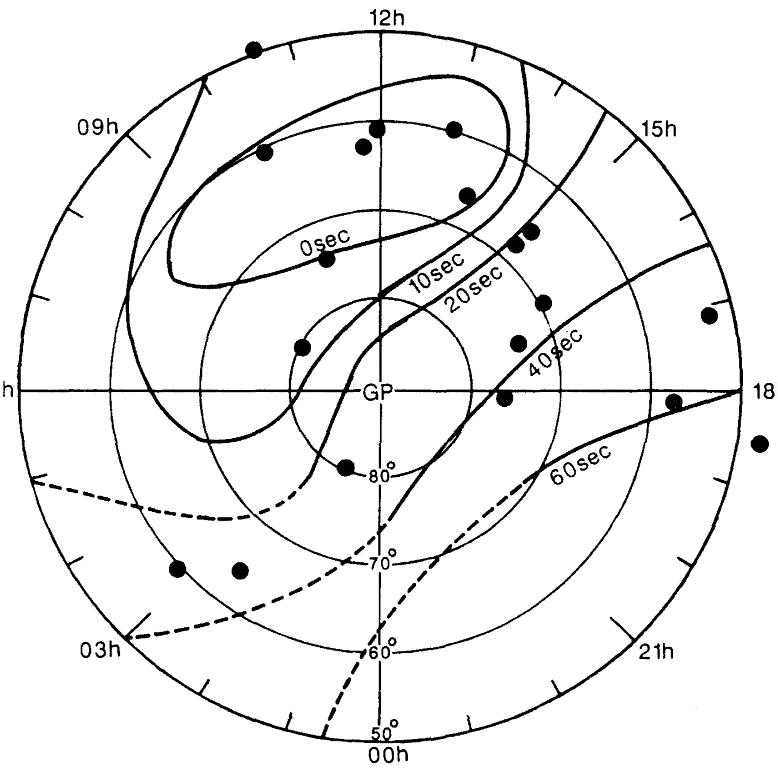

Fig. 6. Locality dependence of the sc onset time on June 12, 1982, view from above the south geomagnetic pole. Solid circles in the figure indicate the locations of the stations whose magnetic data are used.

in the figure indicate the onset time of the sc estimated through the above procedure for each station.

Based on the sc onset times assigned at 19 Antarctic and sub-Antarctic stations listed in Table 1, the onset time contour of the sc of June 12, 1982, is drawn and illustrated in Fig. 6. The figure shows that the sc wave arrives, at first, at the dayside region (08–14, geomagnetic local time, GLT) at geomagnetic latitude from 68° to 73° and propagates towards the night-side across the geomagnetic pole. It takes about 60–70 seconds for the sc wave to propagate from the dayside to nightside region. To study the propagation of sc wave in the magnetosphere, the distribution of the sc onset time in Fig. 6 is projected onto the solar ecliptic plane (Fig. 7). The propagation speed of the sc wave in the magnetosphere is about ~1500 km/s in the equatorial plane.

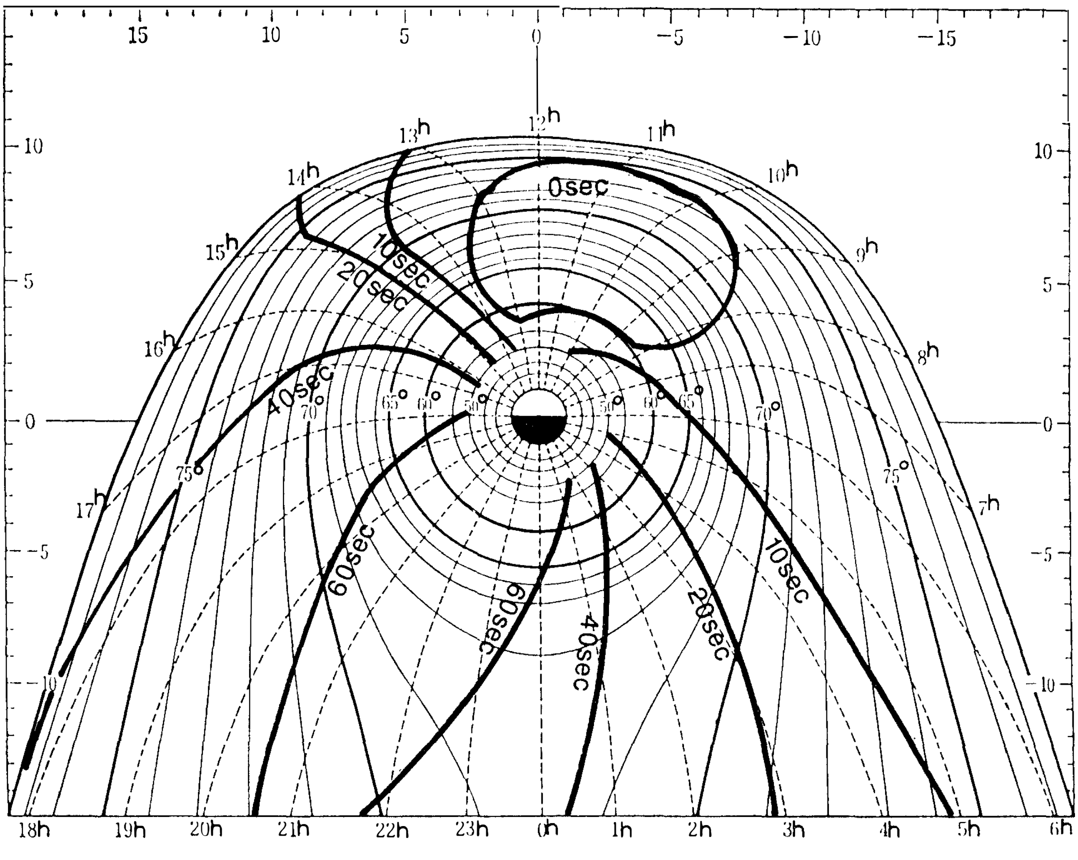

Fig. 7. Projection of the sc's onset time pattern of Fig. 6 onto the solar ecliptic plane.

4. Discussion

It has often been stated that sudden commencements occur almost simultaneously over the earth (*e.g.*, TANAKADATE, 1934; NAGATA and ABE, 1955; GERARD, 1959). NISHIDA and JACOBS (1962) showed that the onset of si(sc) is not simultaneous all over the world and there is a difference of up to 1 min between the onset time at local noon and midnight. ARAKI (1977) investigated, in detail, the differences in the sc onset times in the high, middle and equatorial latitudes with rapid-run magnetograms from eight American zone stations. His result showed that the onsets are almost simultaneous at all stations when they are of simple SC-types from high to equatorial regions. The dayside equatorial SC* took place simultaneously with SC* in afternoon high latitudes and SC in middle latitudes. In such a case the onset of SC in middle latitudes is delayed by several tens of seconds from SC* in high and equatorial latitudes.

In order to show a reliable global pattern of the sc onset delay, it is the essential task how to identify the exact onset time of sc's on the records of geomagnetic variations because the magnetograms are available from stations distributed more densely than for any other data of upper atmosphere disturbances. As is illustrated in Section 2, we succeeded in determining the sc onset time with the time accuracy about 10 s from the morphological evidence of *H*-component magnetic variations at polar stations. Based on the sc onset times thus determined for 19 Antarctic and sub-Antarctic stations the locality-dependence of the sc onset time delay on June 12, 1982 is shown on the polar map (Fig. 6) and also on the solar ecliptic plane (Fig. 7). This result indicates the following.

(1) The sc shock wave in the solar wind arrives, at first, at the dayside (~11 GLT) region of the geomagnetic latitude about 70° and propagates towards the night-side crossing over the geomagnetic pole. Its average velocity on the earth's surface is about 70–80 km/s.

(2) On the solar ecliptic plane, the sc shock encounters, at first, the front side of the magnetosphere at 11 GLT sector and propagates in the magnetosphere towards the tail with a velocity of ~1500 km/s.

Based on the data of energetic particle and magnetic field measurements obtained from a set of instruments on the synchronous satellites and also on some model calculations, WILKEN *et al.* (1982) illustrated the propagation pattern of the sc wave front inside the magnetosphere and in the solar wind. Their propagation pattern of the sc wave is similar to that obtained from the ground-based data in this study. They showed also that the propagation velocity is about 1000 km/s in the region between the magnetopause and the plasmapause, while about ~1500 km/s in the present study. The method adopted in this study will still be useful for determining the onset time of sc's in the polar region in which the sc magnetic waveforms are very complicated.

Acknowledgments

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