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GEOMAGNETIC SUDDEN COMMENCEMENTS OBSERVED AT THE SYOWA-ICELAND CONJUGATE STATIONS

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Abstract: In order to clarify characteristics of geomagnetic sudden commencements (SC's) at geomagnetically conjugate stations, six SC events were analyzed by the use of digital magnetic data at Syowa Station in Antarctica and Husafell, Isafjördur and Tjörnes in Iceland during the interval from September 1984 to January 1985. SC polarization, waveforms and SC-associated pulsations are examined between the conjugate stations, and the characteristics are discussed in comparison with a model (H. NAGANO *et al.*: Mem. Natl Inst. Polar Res., Spec. Issue, **36**, 123, 1985) suggested for the latitudinal reversal of SC polarization in high latitudes on the ground.

1. Introduction

A geomagnetic sudden commencement (SC) is produced by a contraction of the magnetosphere associated with the passage of a shock or discontinuity traveling in interplanetary space around the earth. SC signatures on the ground and in the magnetosphere have been investigated by a number of researchers (see the reviews of MATSUSHITA, 1967; NAGATA and FUKUSHIMA, 1971; AKASOFU and CHAPMAN, 1972; NISHIDA, 1978). Using the rapid-run magnetograms obtained during the IGY, WILSON and SUGIURA (1961) suggested, from their discovery of elliptical polarization in high latitudes and a longitudinal polarization reversal near noon, that SC perturbations are propagated to the earth primarily by longitudinal hydromagnetic waves in low latitudes and by transverse hydromagnetic waves in high latitudes. Hydromagnetic descriptions of SC have been developed by TAMAO (1964) and ARAKI (1977). Recently, ARAKI and ALLEN (1982) studied latitudinal dependence of the polarization of SC events obtained from the North American IMS magnetometers and showed the existence of a latitudinal polarization reversal between 64° and 72°N in geomagnetic latitude. As one of candidates for the cause of this latitudinal reversal, NAGANO *et al.* (1985) suggested a model of horizontal movement of ionospheric current vortices. Furthermore, NAGANO and ARAKI (1987) found a double structure of demarcation for SC polarization from a statistical analysis of the North American IMS network data. NAGANO *et al.* (1986) also studied statistical characteristics of SC polarization using data from Syowa Station. For SC's observed at the geostationary orbit, KOKUBUN (1983) and NAGANO and ARAKI (1984) examined a local time dependence of the amplitude and polarization, respectively. NAGANO and ARAKI (1986) also studied seasonal variation of the amplitude near midnight.

A study on SC's observed simultaneously at geomagnetically conjugate stations has not been carried out except for NAGATA *et al.* (1966). They studied the conjugate relationship of SC's between Syowa Station in Antarctica and Reykjavik in Iceland, and reported remarkable simultaneity and similarity between these stations. In the present paper, we examine the conjugate relationship of SC polarization, waveforms and SC-associated pulsations between Syowa Station and three stations in Iceland including Husafell which has better geomagnetic conjugacy than Reykjavik. Based on the observed characteristics of SC at conjugate stations, the authors tried to infer the mechanism responsible for the SC phenomenon.

2. Data Analysis

The conjugate relationship of SC signatures is studied using 1-s sampling digital magnetic data from September 1984 to January 1985 obtained at Syowa Station and 2-s digital data obtained at Husafell, Isafjördur and Tjörnes in Iceland, which are located near the geomagnetic conjugate point of Syowa Station. The geographic and geomagnetic coordinates for these stations calculated by the International Geomagnetic Reference Field 1983 model are given in Table 1. The coordinates of Reykjavik are

Table 1. Geographic and geomagnetic coordinates of the stations.

Station	Geographic		Geomagnetic		Magnetic local time
	latitude	longitude	latitude	longitude	
Syowa Station	69.0°S	39.6°E	66.1°S	70.8°E	UT+0006
Husafell	64.7°N	21.0°W	66.0°N	70.1°E	+0003
Isafjördur	66.1°N	23.1°W	67.8°N	69.6°E	+0001
Tjörnes	66.2°N	17.1°W	66.9°N	74.6°E	+0021
Reykjavik	64.2°N	21.7°W	65.7°N	69.1°E	−0001

also included in this table. Husafell is the best geomagnetically-conjugate station among the four stations listed. We examined the events reported as an SC in 'Solar Geophysical Data' (H. E. COFFEY, ed.). The conjugate data were available for six SC's in the period examined. Figure 1 shows an example of an SC event observed in the late evening. The SC occurred at 2126 UT on October 25, 1984. In this case the data at Husafell was lacking to our regret. The magnetograms at Isafjördur and Tjörnes show almost the same SC variation except the Z component. The onset time and rise time of the SC are almost the same between Syowa Station and the two Iceland stations. The H component is in phase and the D component is out of phase. The

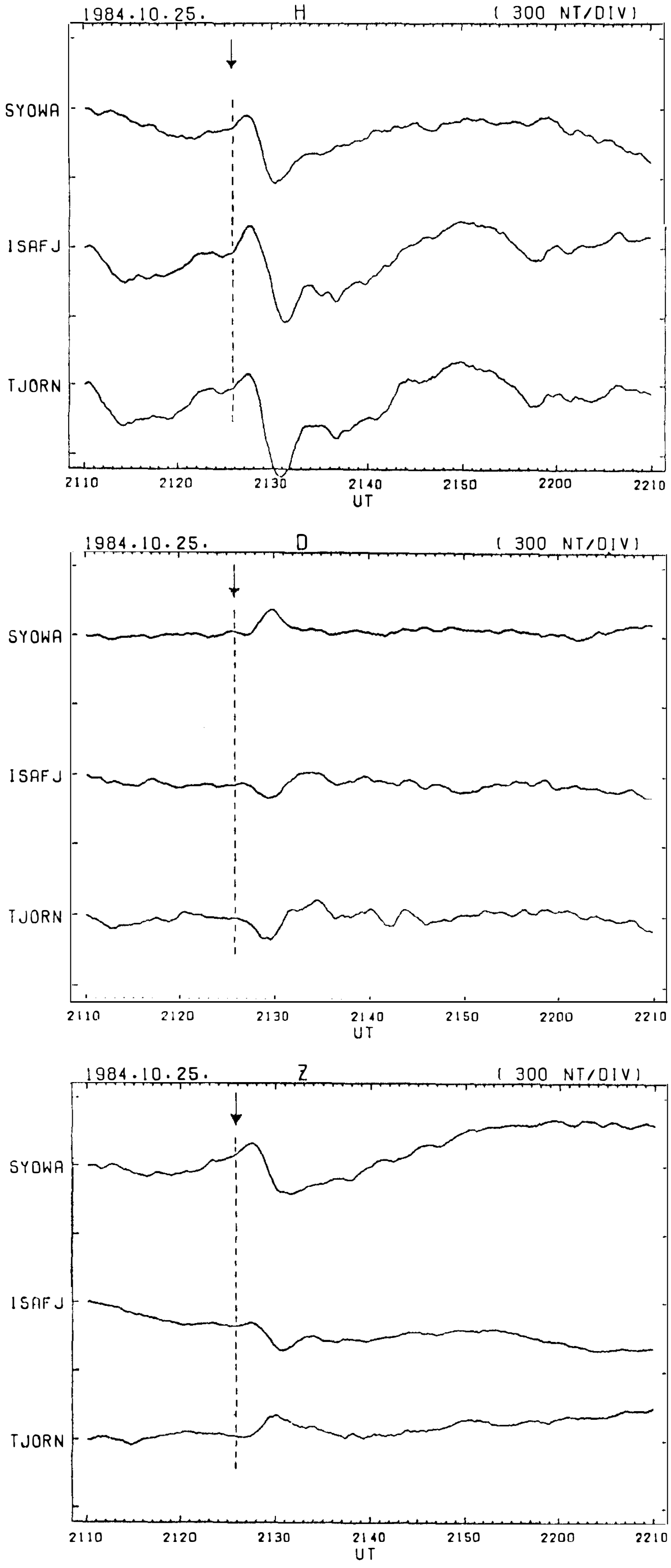

Fig. 1. Magnetograms of three components H, D and Z at Syowa Station, Isafjördur and Tjörnes for an SC at 2126 UT on October 25, 1984.

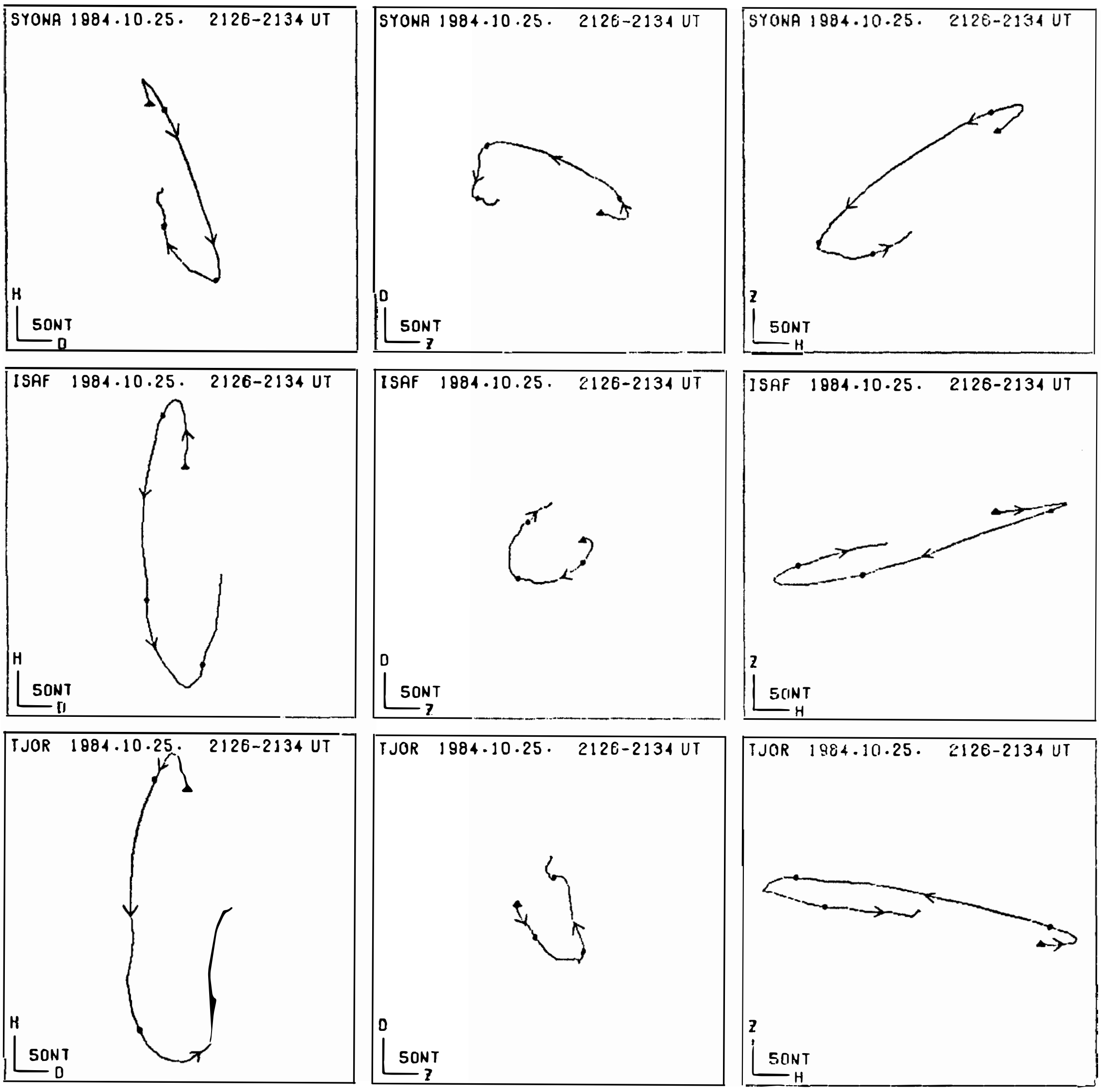

Fig. 2. Rotation of the SC vector in the H-D, D-Z and Z-H planes viewed from the Z, H and D directions, respectively, at Syowa Station, and from the -Z, -H and -D directions, respectively, at Isafjördur and Tjörnes, during the interval of 2126–2134 UT on October 25, 1984.

H component in the present case shows typical inverted SC* (FERRARO *et al.*, 1951) at all the three stations. The *Z* component variation is larger at Syowa Station and is in phase between Syowa Station and Isafjördur and out of phase between Isafjördur and Tjörnes. Figure 2 shows the rotation of the SC vector in the *H-D*, *D-Z* and *Z-H* planes. The polarization is elliptical and the rotational sense is clockwise in the *H-D* plane and counterclockwise in the *D-Z* and *Z-H* planes at Syowa Station, counterclockwise in the *H-D* plane and clockwise in the *D-Z* and *Z-H* planes at Isafjördur, and counterclockwise in all the three planes at Tjörnes. Thus, we can see that the polarization sense in the *H-D* plane reverses between Syowa-Iceland conjugate stations. Figure 3 indicates the power spectral densities of the observed three-component geomagnetic variations at the three stations, which were computed by means of the fast Fourier transform (FFT) method. The spectra for periods longer than 4 min in the *H*

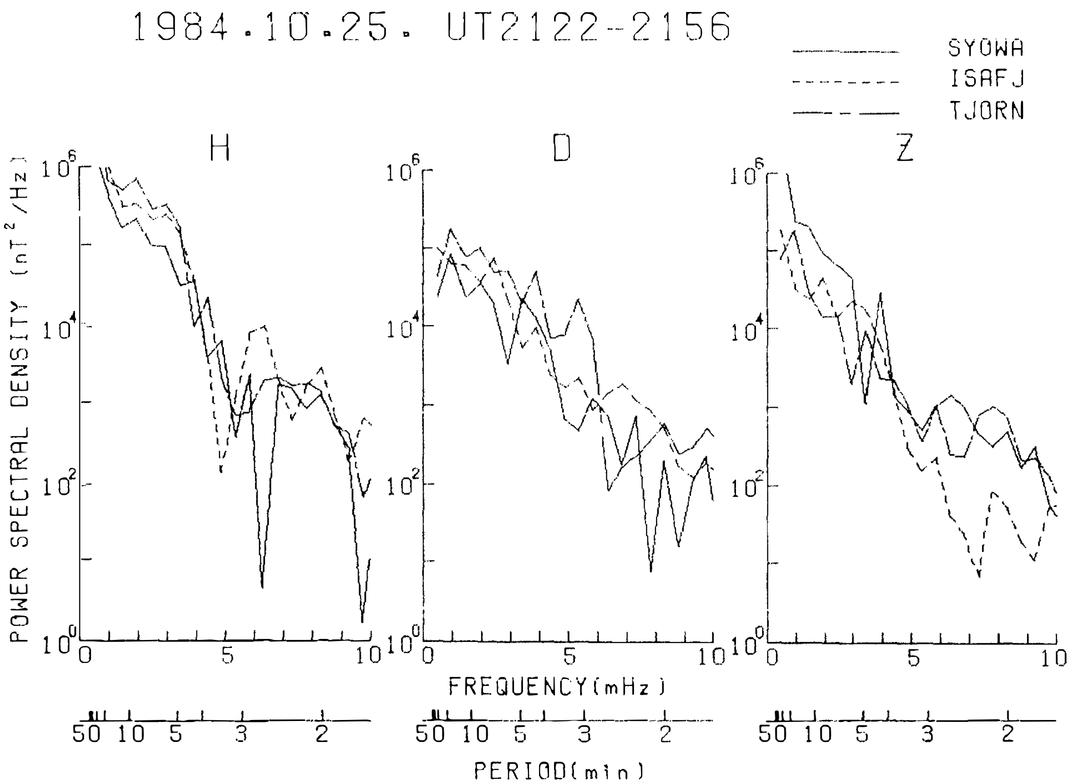

Fig. 3. Power spectral densities for Syowa Station, Isafjördur and Tjörnes during the interval of 2122–2156 UT on October 25, 1984.

component have resemblance among the three stations. This indicates that SC waveforms are similar between the conjugate stations. The spectrum in the H component for Isafjördur has a large peak near 3 min, whereas the spectra for the other stations show a broad peak at the period of 2–3 min. SC events which occurred at 0101 UT on December 13, 1984 and at 1412 UT on January 8, 1985 showed the waveforms and polarization similar to those for this event.

Next example is an SC event observed in the morning as shown in Fig. 4. The SC occurred at 0806 UT on January 23, 1985. The SC waveforms at Husafell and Isafjördur are the same SC* type, while the waveform for Syowa Station has not a negative initial part. The time for the maximum peak in the H component at the Iceland stations is later by about 1.5 min as compared with that at Syowa Station. The Z component variation is out of phase between Husafell and Isafjördur, and is larger at Syowa Station. Figure 5 shows the rotation of the SC vector in the H-D plane. The polarization is very complicated in comparison with the previous example showing in Fig. 2. It seems to be clockwise-like for Syowa Station and counterclockwise-like for Husafell. Figure 6 indicates the power spectral densities of the observed three-component magnetic variations for the three stations. The spectra have a large peak near 2.5 min for all the stations. Figure 7 shows band-pass filtered data for the period range of 60–300 s. It can be seen from this figure that SC-associated pulsations with the period near 2.5 min occurring after 0810 UT are in phase for the H component and out of phase for the D component between the Syowa-Iceland conjugate stations. The phase dif-

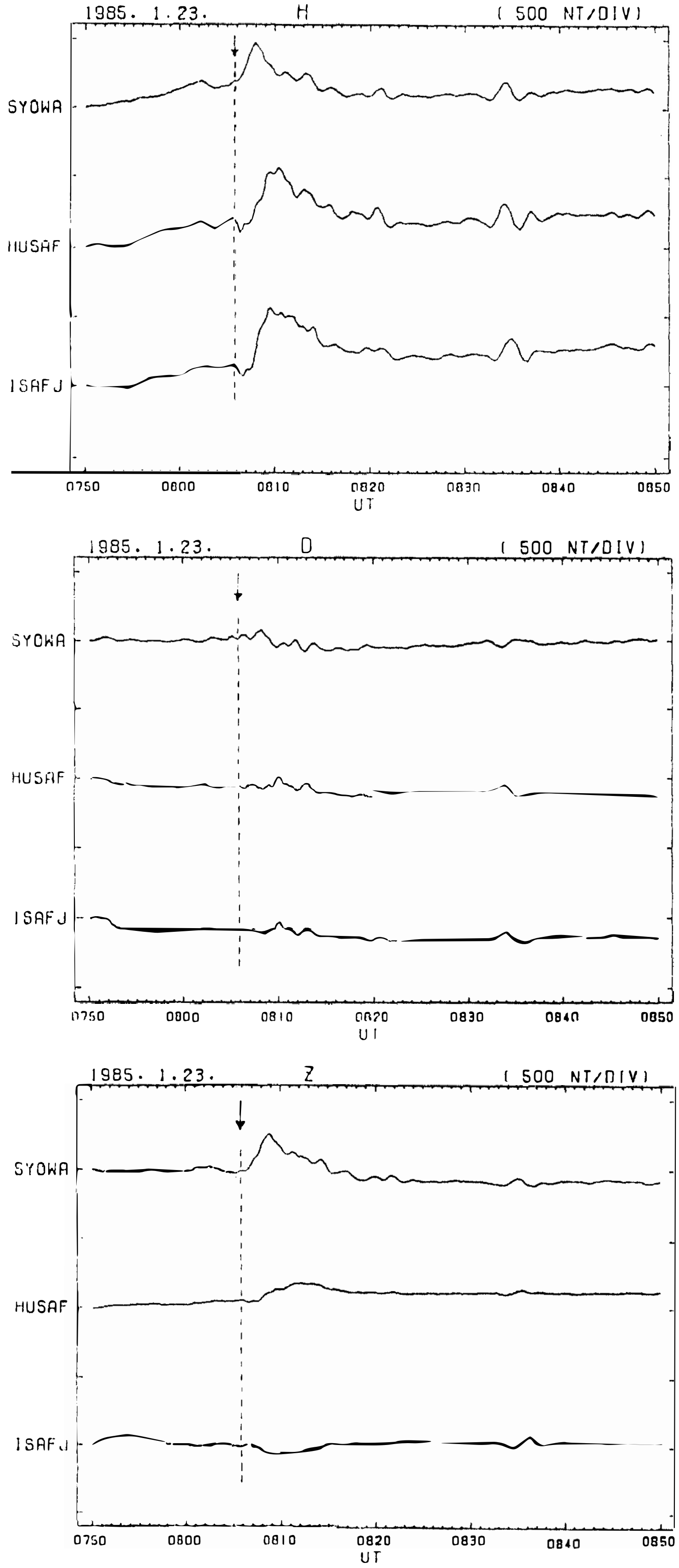

Fig. 4. Magnetograms of three components H, D and Z at Syowa Station, Husafell and Isafjördur for an SC at 0806 UT on January 23, 1985.

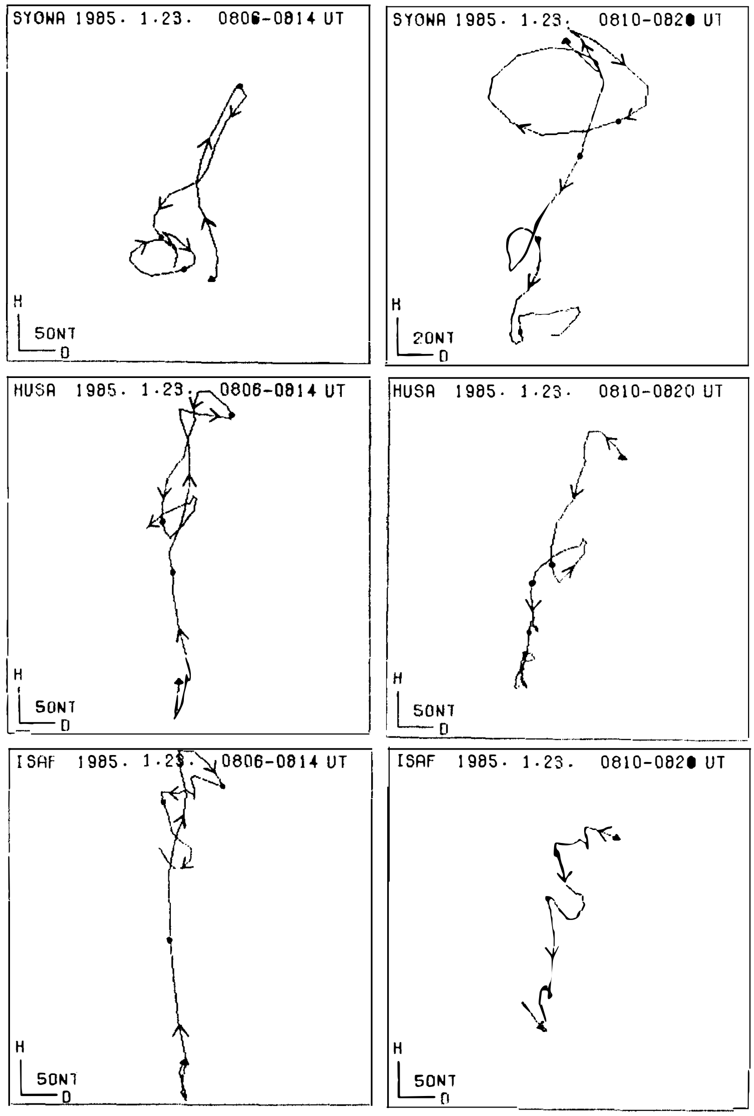

Fig. 5. Rotation of the SC vector and SC-associated pulsations in the H-D plane at Syowa Station, Husafell and Isafjördur during the interval of 0806–0814 and 0810–0820 UT on January 23, 1985.

ference in the *H* component before 0810 UT is caused by the SC itself.

The third example is an SC event observed in the afternoon as shown in Fig. 8. The SC occurred at 1721 UT on December 21, 1984. Magnetic pulsations having the period of 4–6 min were accompanied with the SC. These pulsations were not "damped type". Figure 9 shows the polarization of the SC vector and the pulsations. The rotational sense was counterclockwise before about 1724 UT and clockwise after that time at Syowa Station. It was counterclockwise before about 1731 UT, clockwise during the interval of about 1731–1738 UT and again counterclockwise after about 1738 at Husafell, and clockwise before about 1724 UT and counterclockwise after then at Tjörnes. As far as the polarization is concerned, Tjörnes was probably a better conjugate station than Husafell for Syowa Station. In this case the polarization sense of the SC vector is opposite to that of the following pulsations. An SC event which

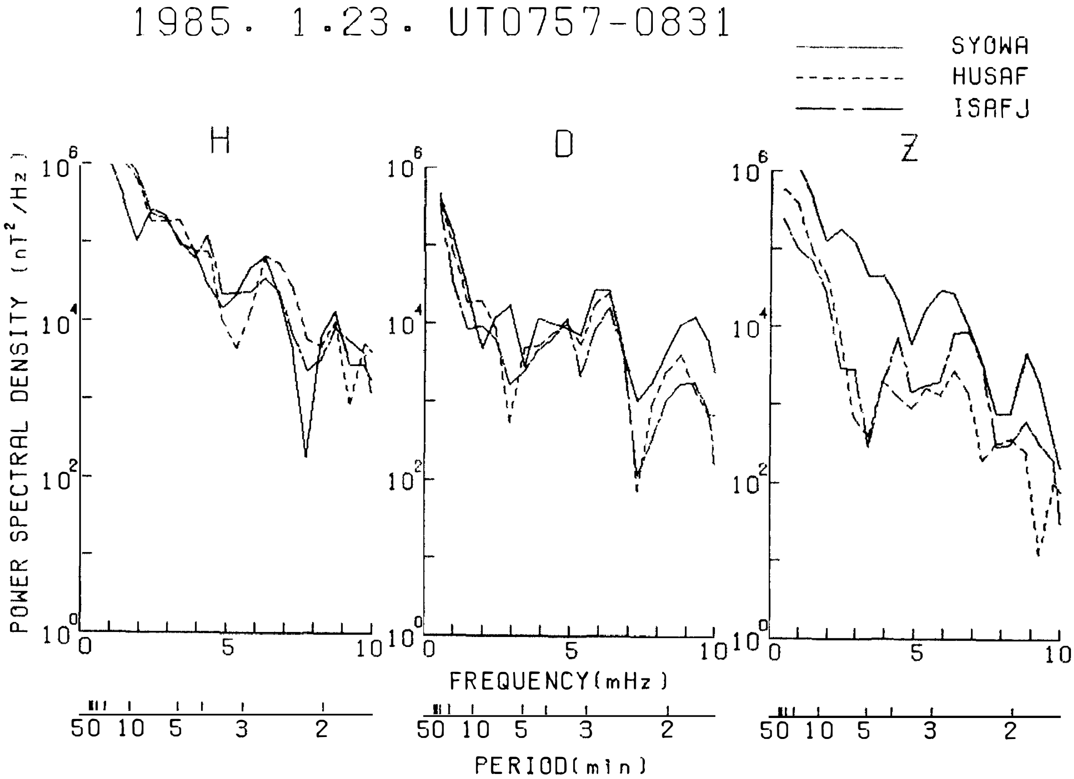

Fig. 6. Power spectral densities for Syowa Station, Husafell and Isafjördur during the interval of 0757–0831 UT on January 23, 1985.

occurred at 0745 UT on September 4, 1984 indicated similar characteristics as this event.

3. Discussions

Using magnetic data obtained by the North American IMS magnetometer network, Araki and Allen (1982) examined 18 SC events and found out the existence of a latitudinal polarization reversal between 64° and 72°N in geomagnetic latitude. As a candidate for the cause of the latitudinal reversal, Nagano *et al.* (1985) suggested a model of horizontal movement of ionospheric current vortices as shown in the upper panel of Fig. 10. When a compressional hydromagnetic wave propagates toward the earth in the magnetosphere, a dusk-to-dawn electric field along the wavefront is transmitted along the lines of force to the northern polar ionosphere and produces twin vortex type ionospheric currents. As the two vortices move from around noon to dawn- and dusk-sides, the magnetic field caused by the current vortices changes its direction at a fixed point on the ground as can be seen in this figure. As the result, the rotation of the horizontal magnetic vector is counterclockwise on the lower latitude side of the locus of the vortex center in the morning and clockwise on the higher latitude side. In the afternoon, the rotation is clockwise on the lower latitude side and counterclockwise on the higher latitude side. The dusk-to-dawn electric field along the wavefront is transmitted to the southern polar ionosphere too, and a similar variation

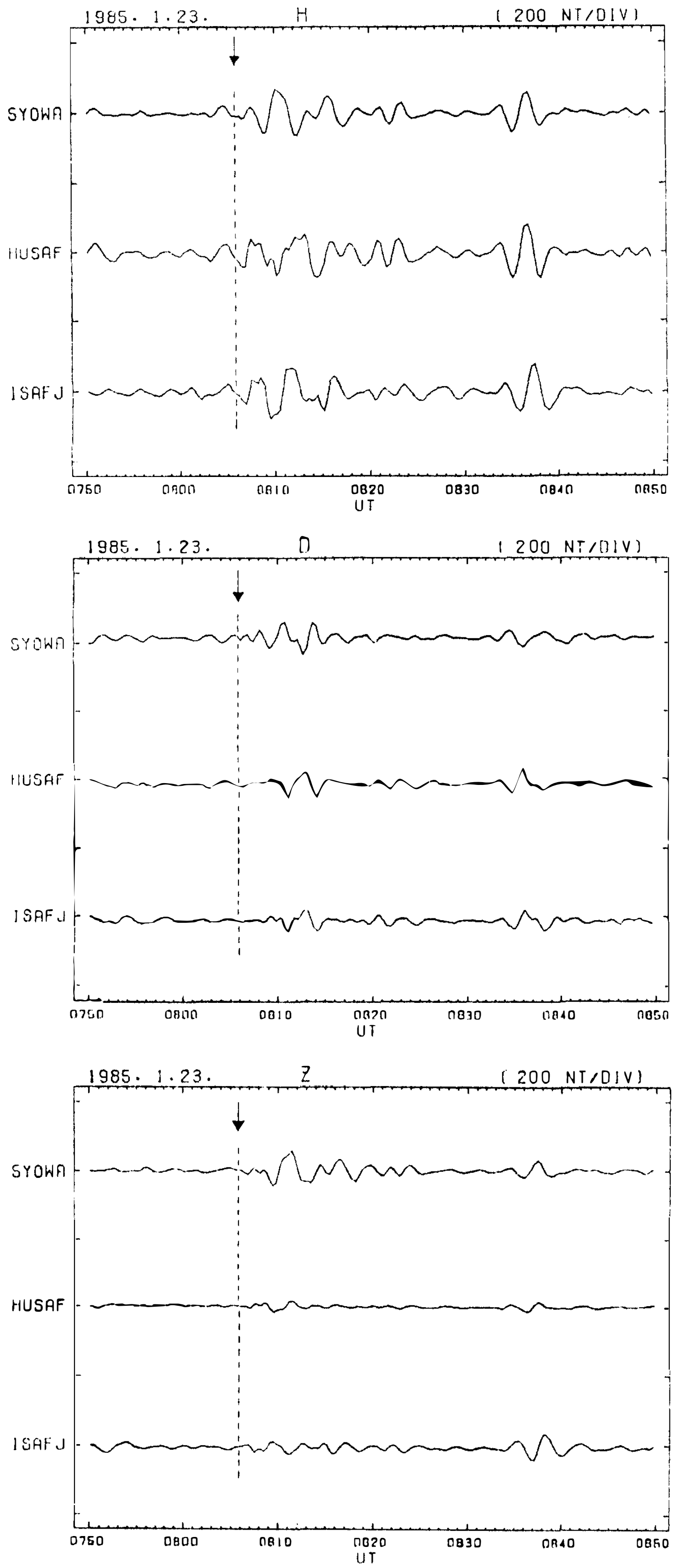

Fig. 7. Band-pass filtered data for the same interval in Fig. 4. The scale for the magnetic intensity is changed by a factor 2.5 from that in Fig. 4.

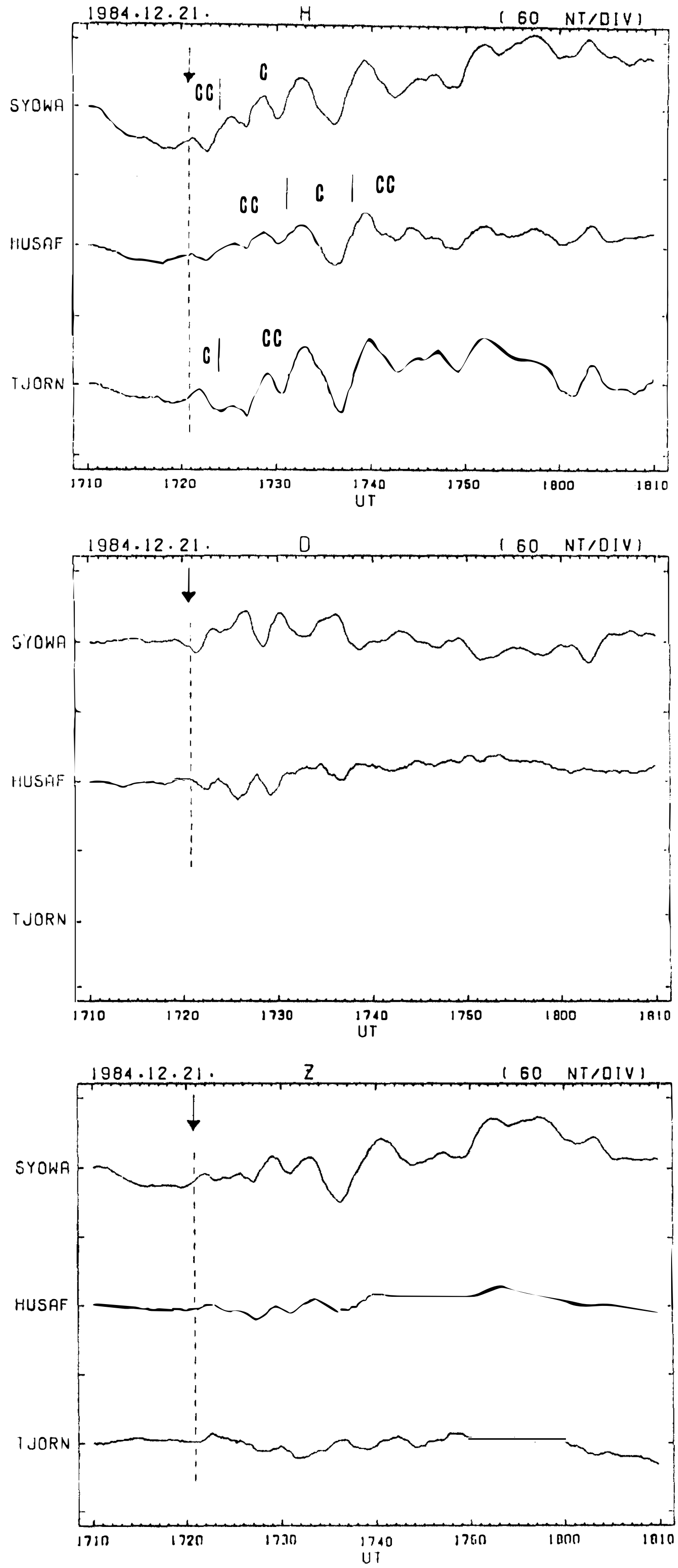

Fig. 8. Magnetograms of three components H, D and Z at Syowa Station, Husafell and Tjörnes for an SC at 1721 UT on December 21, 1984. C and CC represent clockwise and counterclockwise polarization, respectively, of the SC vector and SC-associated pulsations in the H-D plane, which are examined from Fig. 9.

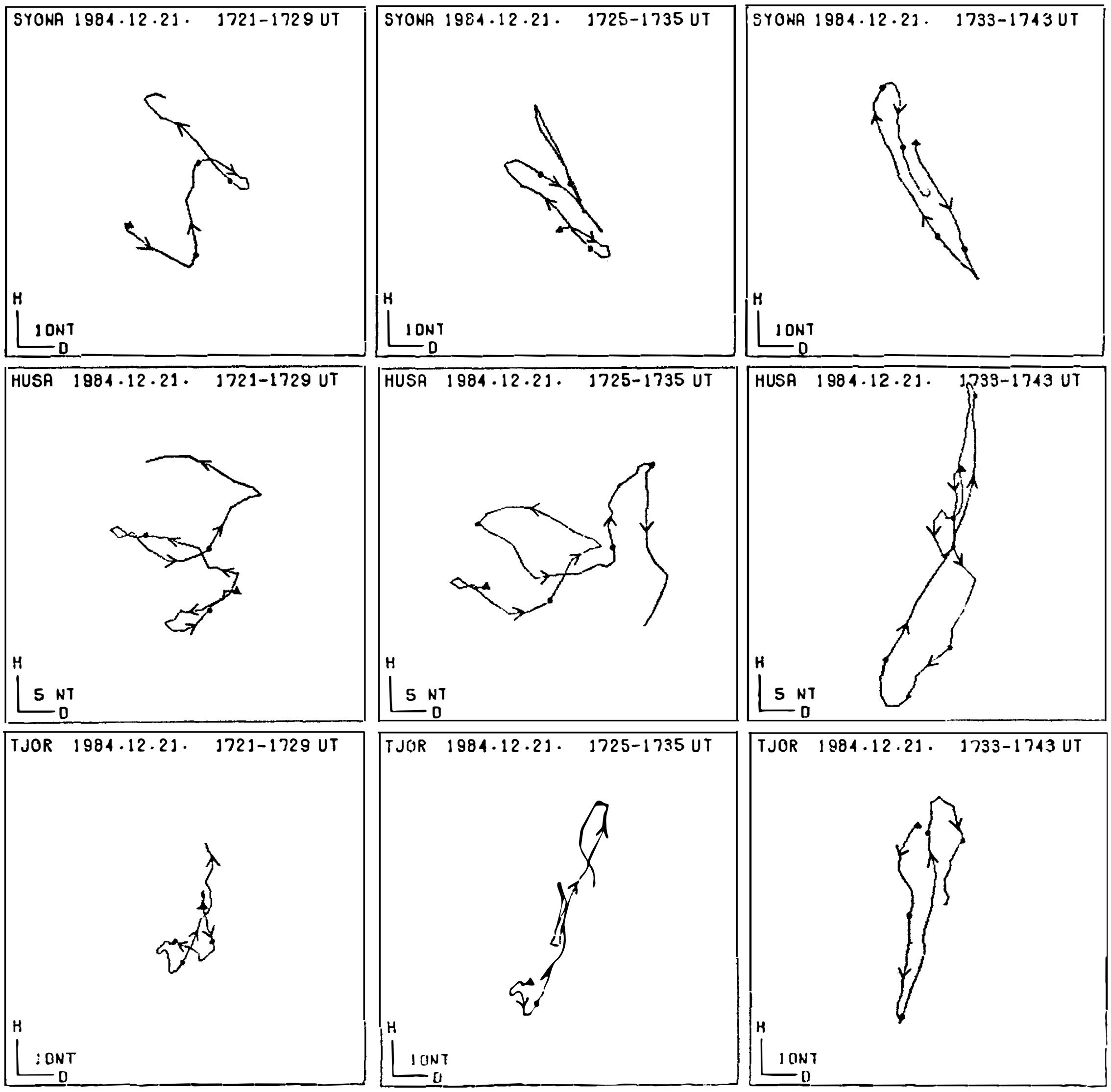

Fig. 9. Rotation of the SC vector and SC-associated pulsations in the H-D plane at Syowa Station, Husafell and Tjörnes during the interval of 1721–1729, 1725–1735 and 1733–1743 UT on December 21, 1984.

of magnetic field is caused on the ground in the same way. As the direction of the magnetic field lines in the south polar region is opposite to that in the northern hemisphere, the rotation of SC horizontal vector in the south polar region has reversed sense in comparison with that for the north polar region, as can be seen in the lower panel of Fig. 10. Recently, NAGANO and ARAKI (1987) examined the polarization for about 50 SC events and reported two types for the latitudinal reversal. One type (*H* type) indicates that the phase of *H* component reverses but the phase of *D* component does not vary along a geomagnetic longitude. This type of the polarization reversal can be interpreted by the schematic model of Fig. 10. In another type (*D* type) the phase of *D* component reverses at the location of the latitudinal polarization reversal. This type can be seen only in the afternoon when SC amplitude or AE index at time of SC is large. The rotation of SC vector in the north polar region is counterclockwise on

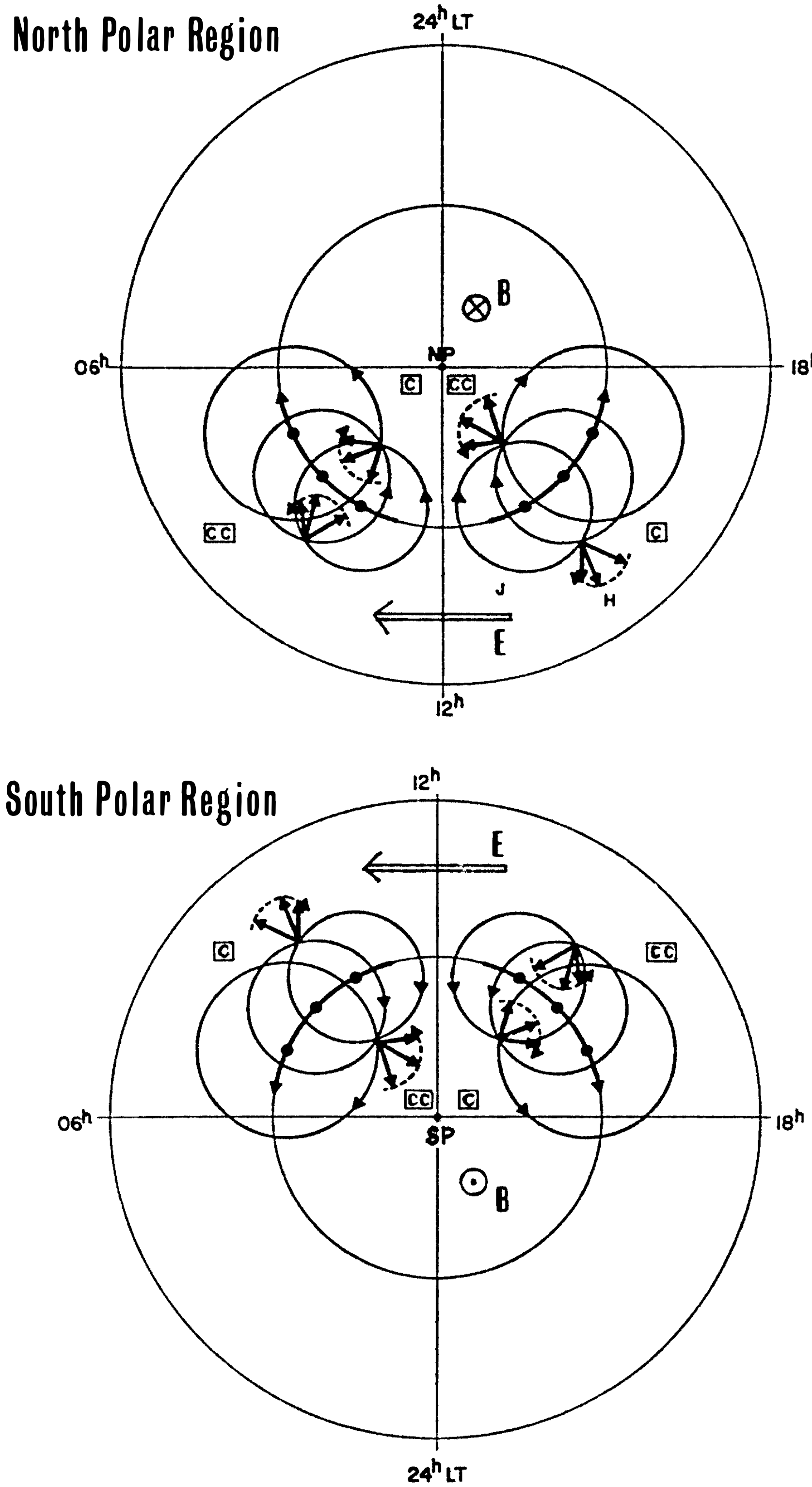

*Fig. 10. A model (H type) for the latitudinal polarization reversal in high latitudes of both hemispheres. The arrows with **E** and the signs with **B** denote the directions of the electric field transmitted to the polar ionosphere and the magnetic field penetrating into the ionosphere, respectively. C and CC represent clockwise and counterclockwise polarization, respectively. The rotational sense becomes opposite at each side of the locus of the center of a current vortex moving in the ionosphere.*

the lower latitude side and clockwise on the higher latitude side, which is opposite from that of *H* type. Another electric field besides the dusk-to-dawn electric field for *H* type has to be introduced to explain *D* type. If the *D*-type magnetic variation also is supposed to be produced by horizontal movement of ionospheric current vortices, the direction of the electric field which causes this current system may be dawn-to-dusk. As the result of the superposition of both electric fields, the phase of the *D* component becomes to reverse along a geomagnetic longitude (NAGANO and ARAKI, 1987). In some cases SC polarization in high latitudes may have a double structure with *H* type in lower latitudes and *D* type in higher latitudes.

Table 2. Conjugate relationship of the six SC events.

SC		SC amplitude at Kakioka	Conjugacy		Type
Date	UT		Waveform	Polarization	
1984. 10. 25	2126	15 nT	○	○	*H* type (higher lat. in the afternoon)
1985. 1. 8	1412	14 nT	○	○	*H* type (higher lat. in the afternoon)
1984. 12. 13	0101	9 nT	○	○	*H* type (lower lat. in the morning)
1984. 12. 21	1721	12 nT	△	△	*D* type (lower lat. in the afternoon (?))
1984. 9. 4	0745	18 nT	×	△	*H* type (lower lat. in the morning)
1985. 1. 23	0806	41 nT	×	△	*H* type (S-lower lat. in the morning (?); I-higher lat. in the morning (?))

Table 2 shows the conjugate relationship for waveform and polarization with respect to the six SC events examined. SC amplitude in the *H* component at Kakioka (26.5°N; 207.6°E in the geomagnetic coordinates) is added in the table, and it is especially large for the last event. The signs of a circle and a cross denote good and poor conjugacy, respectively, between the conjugate stations, and the sign of a triangle means the middle. Good conjugacy means that the waveform is similar in the *H* component and out of phase in the *D* component, and the polarization is reversed sense between the conjugate stations. When observation stations are located near the demarcation line, conjugacy will become poor. The first three events in Table 2 have good conjugacy and can be interpreted by *H* type. Conjugacy of other three events becomes poorer and especially the last event seems to indicate that Syowa Station was located on the lower latitude side and Iceland stations were located on the higher latitude side. On the whole, the conjugacy for polarization is rather fair, which is consistent with the statistical result by NAGATA *et al.* (1966). Thus, SC variation can be considered to be produced by a horizontal movement of ionospheric current vortices due to the electric field transmitted to the polar ionosphere. On the other hand, SC-associated pulsations have been considered to be field-line resonant oscillations excited by an SC compressive impulse (CHEN and HASEGAWA, 1974; FUKUNISHI, 1979). In this case the *H* component is in phase and the *D* component is out of phase for the fundamental mode (SUGIURA and WILSON, 1964). Time variation of waveform conjugacy (January 23, 1985) and polarization sense (December 21, 1984) at one station suggests that the generation mechanism is different between SC's and SC-associated pulsations.

SC variation in the *Z* component is generally complicated due to an influence of the earth's electric conductivity. The greater amplitude of the Z variation at Syowa Station and the phase difference between Isafjördur and other two stations in Iceland must be resulted from the conductivity anomaly, island effect, and coast effect etc.

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