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CHARACTERISTICS OF CNA ASSOCIATED WITH GEOMAGNETIC SUDDEN COMMENCEMENTS

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Abstract: In order to clarify the characteristics of cosmic radio noise absorption (CNA) associated with geomagnetic sudden commencements (SC's), 142 SC events were analyzed with 1-second data observed at Syowa Station from April 1981 to December 1986. Local time dependence can be seen in the SC occurrence rate and average intensity of CNA increase. The occurrence rate is highest near midday and shows a secondary small peak near midnight. The average intensity is strong in the daytime and also near midnight. A strong absorption occurs at the time of large SC's with high pre-SC *AE* index. The intensity of CNA increase tends to be stronger as the rise time of CNA is shorter. Furthermore, it tends to be stronger when the absolute value of the ratio of vertical component to horizontal component for magnetic SC preliminary impulse at Syowa Station is smaller.

1. Introduction

Cosmic radio noise absorption (CNA) increases in association with geomagnetic sudden commencements (SC's) in and near the auroral zone. MATSUSHITA (1961, 1962) suggested that charged particles from outside the earth's atmosphere seem to penetrate into the lower ionosphere at high latitudes and cause ionization there at the time of sudden commencements. ORTNER *et al.* (1962) reported that CNA accompanying SC's is observed simultaneously on the day and night sides of the earth, and is associated with bremsstrahlung X-rays created by electrons entering the lower ionosphere. The absorption events often indicate the occurrence of SC-triggered poleward expansion of auroral absorption region (BROWN, 1978a) and the influence of electron precipitation at the lower cleft boundary (BROWN, 1978b). As for CNA events associated with SC's at the geomagnetic conjugate locations, about one third of the events in one hemisphere seem to be accompanied by a detectable increase in absorption at the conjugate location in the other hemisphere (BROWN, 1973a).

Increase in CNA associated with SC's can be thought to be expressible as a function of the following parameters:

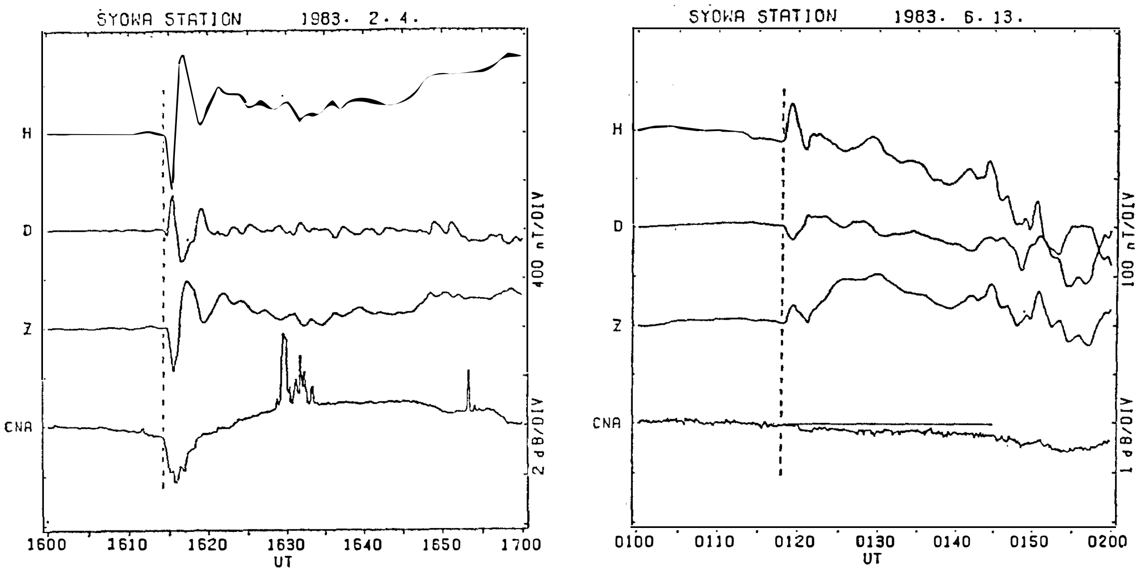
$$f\,(\text{MLT, pre-SC condition}, \Delta H, \Delta H/\Delta T).$$

Here, MLT denotes magnetic local time, and pre-SC condition means the condition of fields and particles in the magnetosphere and ionosphere before SC onset. *AE* index or *Dst* index is used to represent the pre-SC condition in the present paper. ΔH and ΔT indicate SC amplitude and rise time in the *H* component of magnetic field in the magnetosphere or on the ground, respectively. ΔH and $\Delta H/\Delta T$ will depend on the characteristics of interplanetary shocks or discontinuities, and the magnetospheric response. We use magnetic data obtained at Honolulu to represent these values. In the present paper, we analyze digital riometer and magnetic data at Syowa Station for a statistical examination to obtain the local time dependence of CNA for 142 SC events and the relationship between the absorption strength and the above-mentioned parameters. Characteristics of SC's observed at Syowa Station have been studied by NAGANO *et al.* (1986).

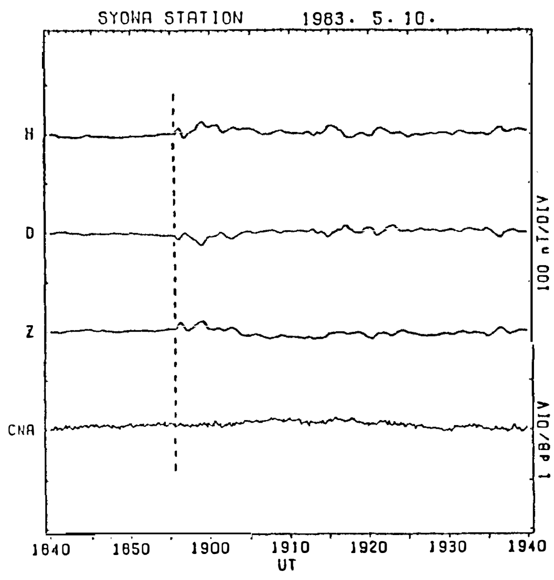
2. Data Analysis

The characteristics of CNA associated with SC's are statistically studied with 1-second digital riometer and magnetic data obtained at Syowa Station from April 1981 to December 1986. Syowa Station in Antarctica is located at 66.1°S and 70.8° E in the geomagnetic coordinates. The magnetic local time (MLT) at Syowa Station is the universal time (UT) plus 6 min. We examined the events reported as an SC in "Solar Geophysical Data" (H. E. COFFEY, ed.). The number of available events was 142 in the period examined. Two types of CNA events associated with SC's are demonstrated in Fig. 1, with the *H*, *D* and *Z* components of magnetic field variation, and the intensity of CNA at 30 MHz. In one type CNA begins to increase promptly at SC onset time and reaches its maximum value after several minutes, as shown in Fig. 1a. Another type of CNA indicates a slow increase and a long duration as shown in Fig. 1b. Figure 1c shows a case in which CNA does not increase in association with an SC. Figure 2 shows the local time dependence of the occurrence rate and intensity of CNA for 142 SC events. The local time distribution of the occurrence of the SC's examined is indicated in the top panel. The number of SC's during each 3-hour interval is from 13 to 24. As shown in the middle panel of Fig. 2, the CNA occurrence rate is classified into three cases according to the degree of CNA increase associated with SC's as follows: the case of the maximum intensity more than or equal to 0.2 dB, the case of the intensity less than 0.2 dB or gradual increase, and the case of no increase. The occurrence rate is highest for 12–15 MLT, and the rate becomes lower on both sides of MLT towards dawn or dusk hours, and there is a small peak near midnight (21–24 MLT). As a whole, the occurrence rate of CNA increase was about 66% and the rate for the intensity more than or equal to 0.2 dB was about 38%. The bottom panel indicates the statistical appearance of strong absorption in the daytime and also near midnight (21–24 MLT).

Figure 3 shows the dependence on SC amplitude (ΔH) at Honolulu (21.4°N; 270.0°E in the geomagnetic coordinates) and pre-SC $\overline{AE(6)}$ (6 hour-averaged *AE* index before SC onset) of the associated CNA intensity for 94 SC events from April 1981 to July 1984. As shown in Fig. 3a for 45 SC's occurred during 06–18 MLT,



(a) (b)



(c)

Fig. 1. Magnetograms of three components H, D and Z, and riometer data at 30 MHz obtained at Syowa Station. (a) indicates data for an SC at 1614 UT on February 4, 1983; (b) for an SC at 0118 UT on June 13, 1983; (c) for an SC at 1856 UT on May 10, 1983.

no SC-associated CNA increase appears when ΔH is less than 20 nT and pre-SC $\overline{AE}(6)$ is less than 200 nT. On the other hand, for 49 SC's during 18–06 MLT there exist many cases of no CNA increase even when ΔH and pre-SC $\overline{AE}(6)$ are greater than the threshold values of 20 nT and 200 nT (Fig. 3b). Thus a noticeable difference exists between daytime and nighttime CNA. As a whole, it can be seen from these figures that strong absorption tends to appear for large ΔH and pre-SC $\overline{AE}(6)$ values. This result remained almost the same even when 3 hour-averaged

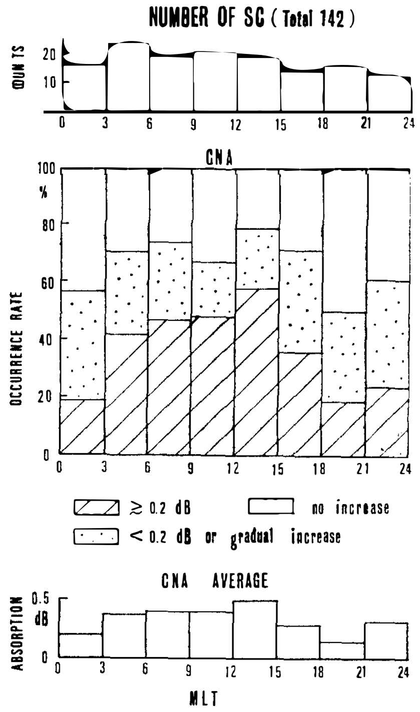


Fig. 2. Magnetic local time dependence of the occurrence of total 142 SC's observed at Syowa Station (top panel), the occurrence rate for each type of CNA increase (middle panel), and the average intensity of CNA (bottom panel).

AE index before SC onset was used instead of pre-SC $\overline{AE}(6)$. In order to estimate the magnetic SC amplitude in the magnetosphere from the value of ΔH on the ground, ΔH was transformed into SC amplitude (ΔH^*) at the geostationary orbit by multiplying an empirical amplitude ratio (satellite amplitude / ground amplitude) introduced by KOKUBUN (1983). Figure 4 shows the dependence on ΔH^* and pre-SC $\overline{AE}(6)$ of the CNA intensity. For 06–18 MLT, no SC-associated CNA increase appears when ΔH^* is less than 20 nT and pre-SC $\overline{AE}(6)$ is less than 200 nT, which is almost the same as that of Fig. 3a. On the other hand, as ΔH^* becomes less than ΔH for 18–06 MLT, no CNA increase appears for $\Delta H^* < 10$ nT. However, with regard to pre-SC $\overline{AE}(6)$ no CNA increase can be seen still at the values greater than 200 nT. Figure 5 indicates the case of taking 6 hour-averaged Dst index (pre-SC $\overline{Dst}(6)$) as the ordinate instead of pre-SC $\overline{AE}(6)$ in Fig. 3. For 73 SC events during 06–18 MLT, no SC-associated CNA increase appears when ΔH is less than 20 nT and pre-SC $\overline{Dst}(6)$ is larger than -40 nT. For 69 SC's during 18–06 MLT, no CNA increase appears even outside the threshold values for daytime.

Figure 6 shows the dependence on SC amplitude (ΔH) and ratio of SC amplitude to rise time ($\Delta H/\Delta T$) at Honolulu with regard to the CNA intensity for 142 SC events. For 06–18 MLT no SC-associated CNA increase appears when ΔH is less than 20 nT and $\Delta H/\Delta T$ is less than 6 nT/min. On the other hand, for 18–06 MLT there exist many cases of no CNA increase even when ΔH and $\Delta H/\Delta T$ values are greater than the daytime threshold values. Figure 7 indicates the relation between intensity of CNA increase and the rise time of CNA (ΔT_m) for 53 SC events. It can be seen from this figure that the CNA intensity tends to be stronger as ΔT_m is shorter. Figure 8 shows the relation between the CNA intensity and the ratio of vertical component to horizontal component of magnetic preliminary impulse ($\Delta Z/$

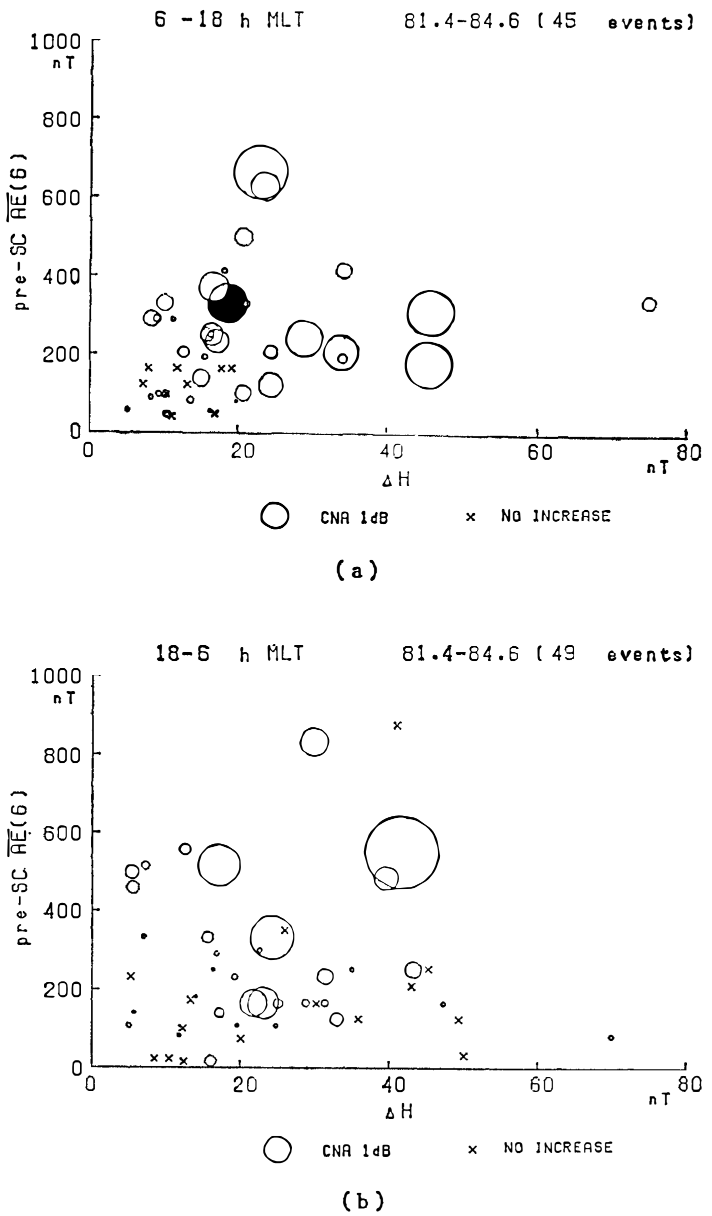


Fig. 3. (a) Diagram of intensity of CNA increase taking 6 hour-averaged AE index before SC onset (pre-SC $\overline{AE}(6)$) in the ordinate and SC amplitude (ΔH) of magnetic H component at Honolulu in the abscissa with regard to 45 SC events occurred in 06–18 MLT from April 1981 to July 1984, and (b) diagram with regard to 49 SC events in 18–06 MLT during the same interval. Each circle under the horizontal axis indicates a CNA increase of 1 dB intensity, and the circle diameters in the diagrams are linearly proportional to individual CNA increases. Cross signs denote no SC-associated CNA increase. The same way of illustration is used also in the following figures.

$\sqrt{(\Delta H)^2+(\Delta D)^2}$) observed at Syowa Station for 59 SC's. The CNA intensity tends to be stronger as the absolute value of $\Delta Z/\sqrt{(\Delta H)^2+(\Delta D)^2}$ is smaller.

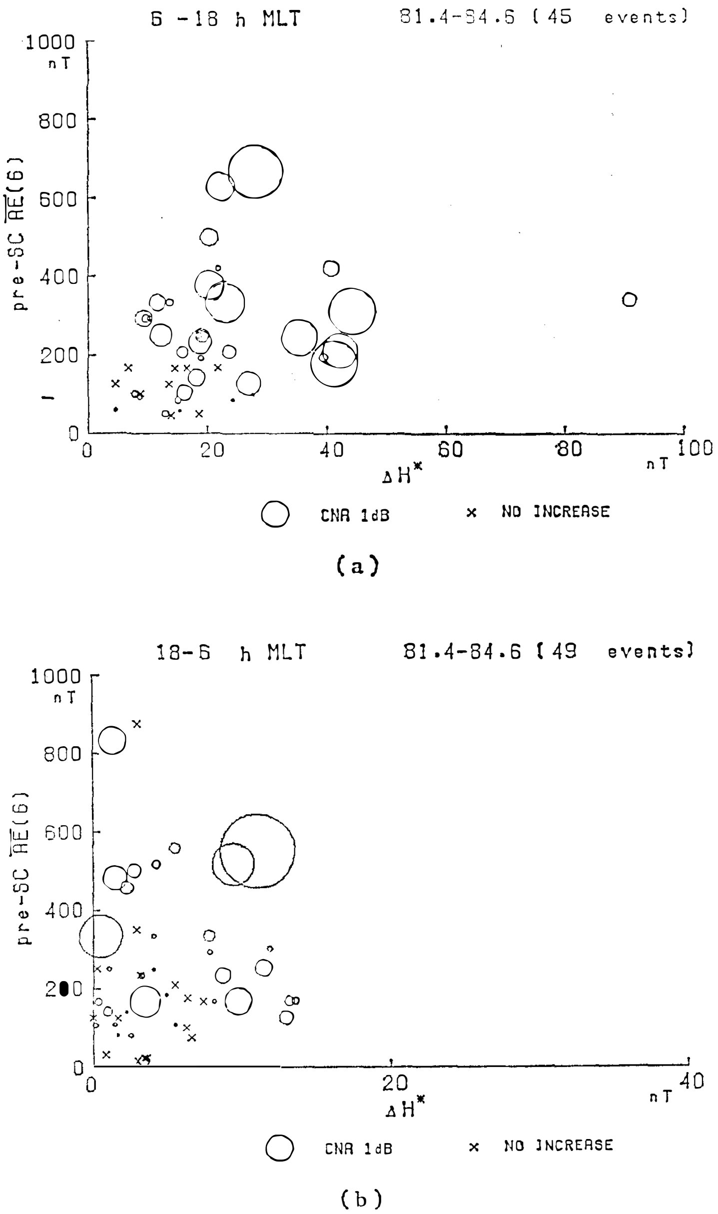


Fig. 4. (a) Diagram of the intensity of CNA increase taking pre-SC $\overline{AE}(6)$ in the ordinate and magnetic SC amplitude (ΔH^*) at the geostationary orbit in the abscissa, which is estimated from ΔH at Honolulu through a conversion relation introduced by KOKUBUN *(1983), for 45 SC events occurred during 06–18 MLT of the same interval as that in Fig. 3 and (b) diagram with regard to 49 SC events during 18–06 MLT of the same interval.*

3. Discussion

Local time dependence can be seen in the occurrence rate and average intensity of CNA increase as shown in Fig. 2. In the daytime the CNA increase indicates a high occurrence rate and a strong average intensity, due probably to the precipitation of daytime magnetospheric electrons into the ionospheric D region by pitch angle

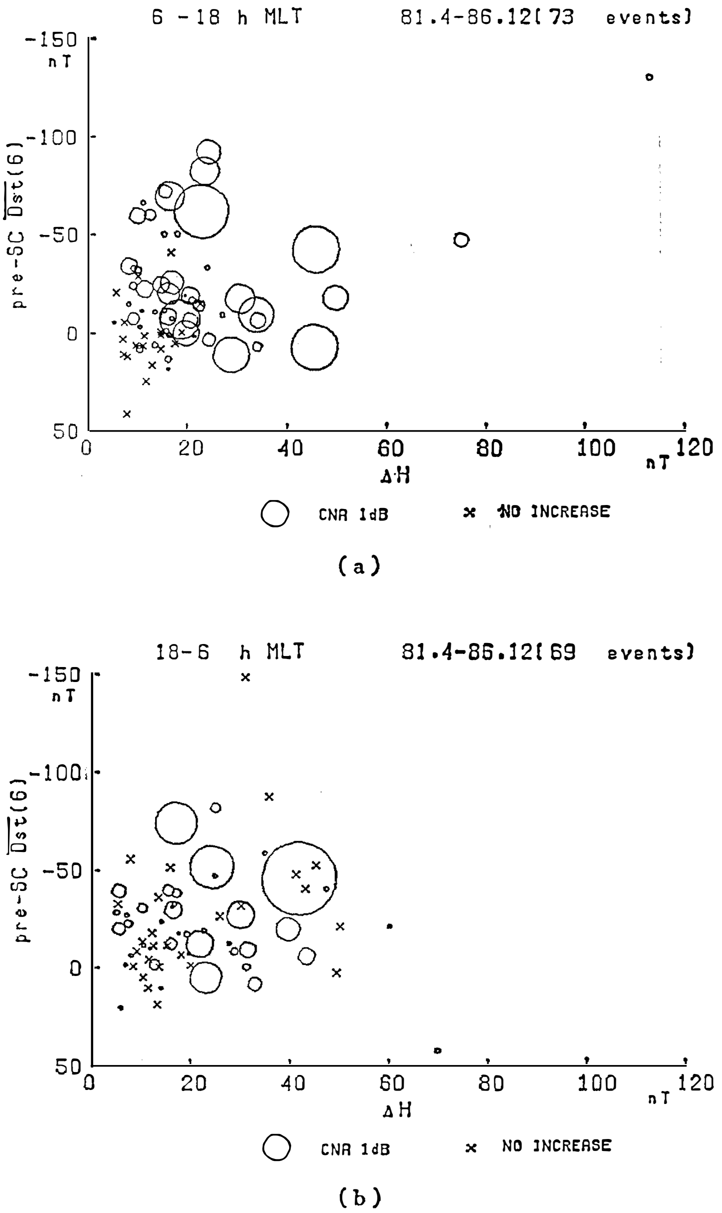


Fig. 5. (a) Diagram of intensity of CNA increase taking 6 hour-averaged Dst index (pre-SC $\overline{Dst}(6)$) in the ordinate and ΔH at Honolulu in the abscissa with regard to 73 SC events occurred during 06–18 MLT from April 1981 to December 1986, and (b) diagram with regard to 69 SC events during 18–06 MLT of the same interval.

diffusion from the magnetosphere following its sudden contraction. CNA indicates a high occurrence rate and a strong intensity also near midnight, which is considered to be related with the precipitation of electrons from the magnetospheric tail, in association with magnetospheric substorms. These results are almost the same as those introduced by Ortner *et al.* (1962) and Brown (1973b). In the daytime no SC-associated CNA increase appears when ΔH, $\Delta H/\Delta T$ at Honolulu and pre-SC *AE* index are smaller, and pre-SC *Dst* index is larger, than each threshold value as

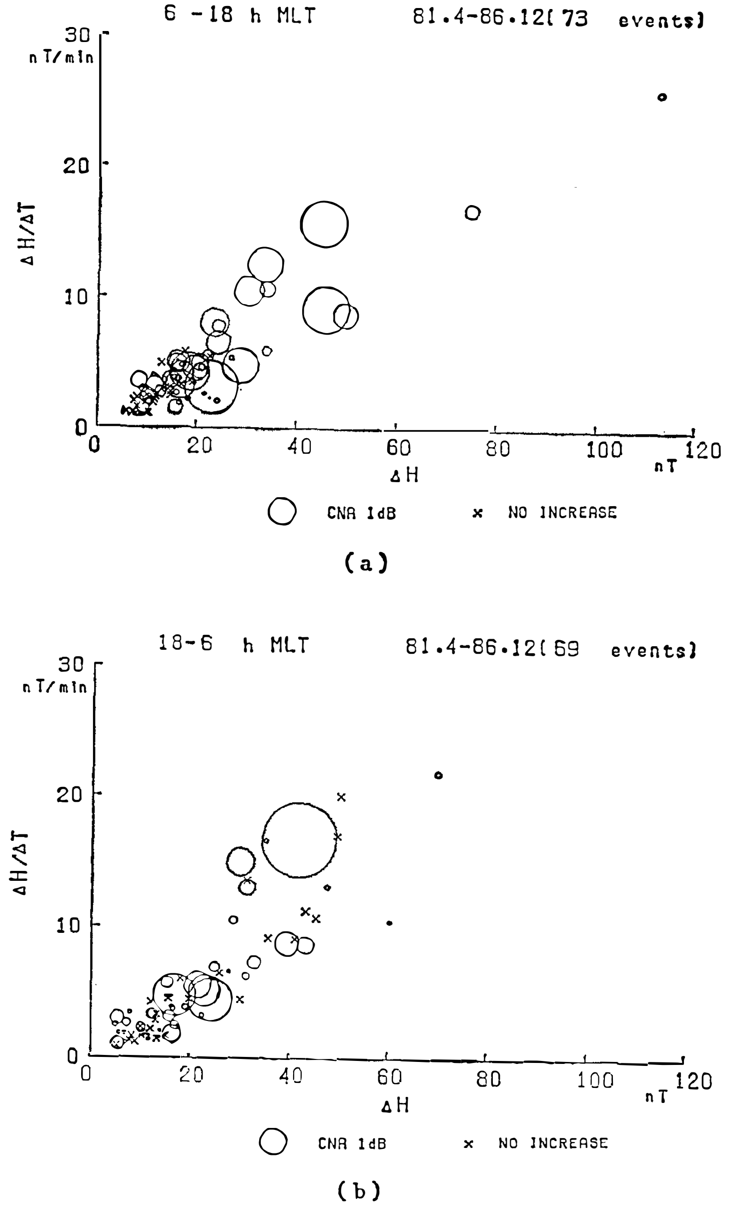


Fig. 6. (a) Diagram of intensity of CNA increase taking the ratio of SC amplitude to rise time ($\Delta H/\Delta T$) at Honolulu in the ordinate and ΔH in the abscissa with regard to 73 SC events occurred during 06–18 MLT from April 1981 to December 1986, and (b) diagram with regard to 69 SC events during 18–06 MLT of the same interval.

shown in Figs. 3 to 6. Thus CNA increase does not seem to occur if some condition is unsatisfied. On the contrary, it can be said that the increase surely occurs if the condition is satisfied in the daytime. In the nighttime, the increase does not always occur even if the condition is satisfied. Strong absorption tends to occur when ΔH at Honolulu and pre-SC AE index are large. This indicates that it may be caused by a strong contraction of the magnetosphere, which will result in the precipitation of electrons to the lower ionosphere. As shown in Fig. 6, $\Delta H/\Delta T$ and

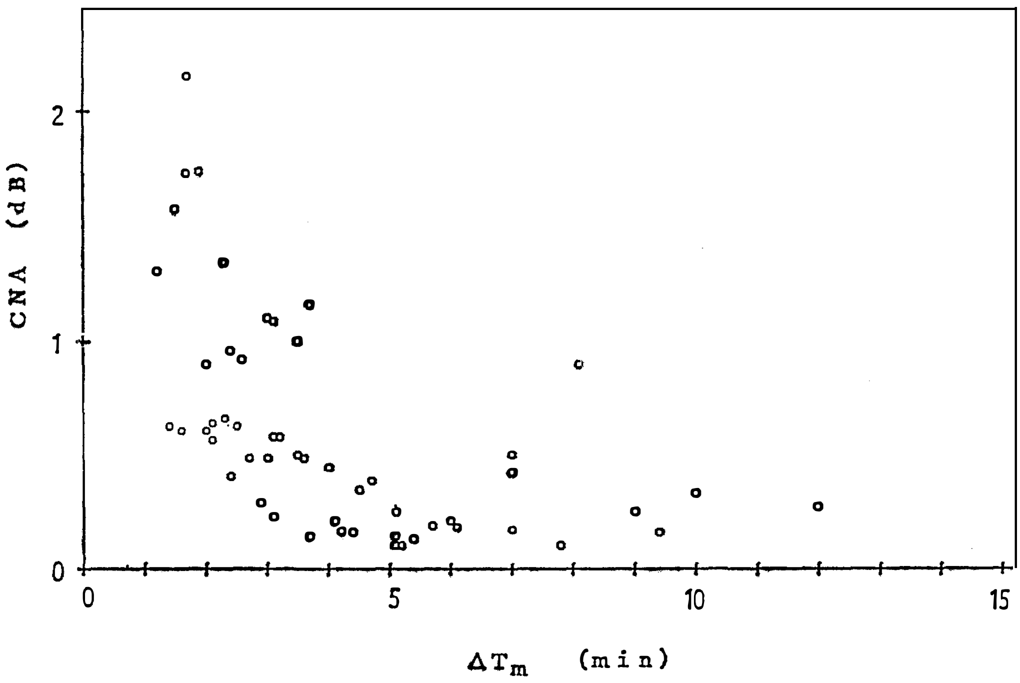


Fig. 7. Relation between intensity of CNA increase and the rise time of CNA (ΔT_m) observed at Syowa Station.

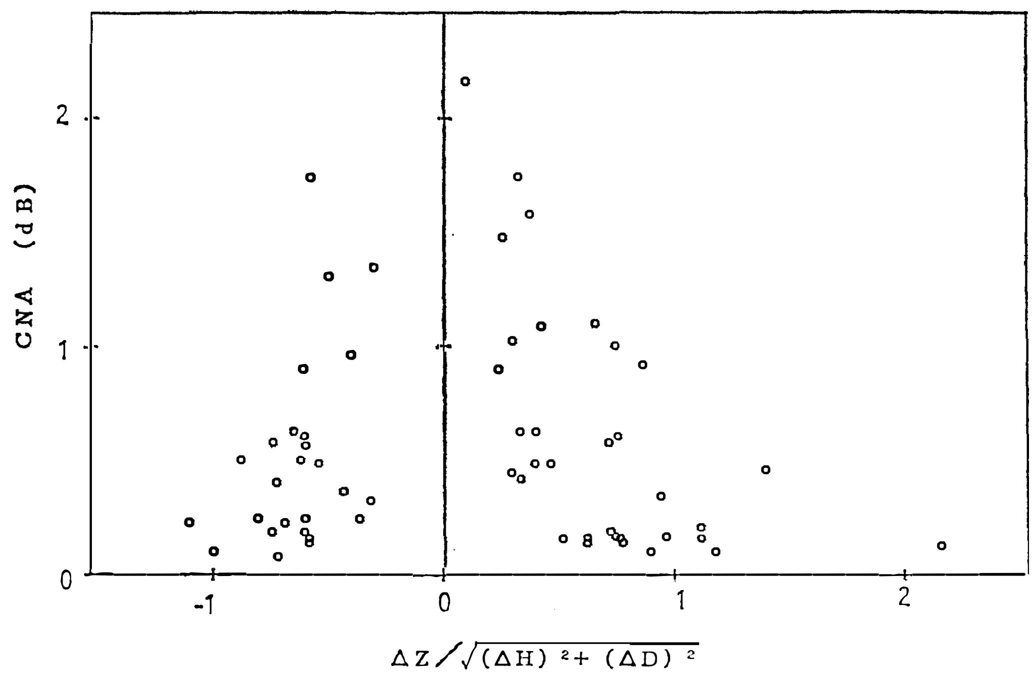


Fig. 8. Relation between intensity of CNA increase and the ratio of vertical component to horizontal component of magnetic preliminary impulse ($\Delta Z/\sqrt{(\Delta H)^2+(\Delta D)^2}$) observed at Syowa Station.

ΔH values seem to be strongly correlated with each other. This is due probably to a specific characteristic of the response of the magnetosphere at its collision with interplanetary shocks or discontinuities.

CNA intensity tends to be stronger when its rise time is shorter, as shown in Fig. 7. This will mean that a strong absorption likely starts to increase promptly at SC onset and becomes a maximum shortly, due probably to the electrons precipitating immediately and abundantly into the lower ionosphere. Furthermore, the CNA intensity tends to be stronger when the ratio of vertical component to horizontal component of magnetic SC preliminary impulse at Syowa Station is smaller, as shown in Fig. 8. This will mean that the absorption induced by the precipitating particles maximizes beneath the ionospheric currents.

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References

BROWN, R. R. (1973a): A study of ionospheric absorption in conjugate regions produced by storm sudden commencements and sudden impulses in the geomagnetic field. J. Geophys. Res., **78**, 1668–1672.

BROWN, R. R. (1973b): Sudden commencement and sudden impulse absorption events at high latitudes. J. Geophys. Res., **78**, 5698–5702.

BROWN, R. R. (1978a): On the poleward expansion of ionospheric absorption regions triggered by sudden commencements of geomagnetic storms. J. Geophys. Res., **83**, 1169–1171.

BROWN, R. R. (1978b): On sudden commencement absorption events at the south pole and their relation to the latitude of the lower cleft boundary. J. Geophys. Res., **83**, 2205–2207.

KOKUBUN, S. (1983): Characteristics of storm sudden commencement at geostationary orbit. J. Geophys. Res., **88**, 10025–10033.

MATSUSHITA, S. (1961): Increase of ionization associated with geomagnetic sudden commencements. J. Geophys. Res., **66**, 3958–3961.

MATSUSHITA, S. (1962): On geomagnetic sudden commencements, sudden impulses, and storm durations. J. Geophys. Res., **67**, 3753–3777.

NAGANO, H., ARAKI, T., IYEMORI, T., FUKUNISHI, H., SATO, N. and AYUKAWA, M. (1986): Characteristics of polarization of geomagnetic sudden commencements observed at Syowa Station. Mem. Natl Inst. Polar Res., Spec. Issue, **42**, 67–78.

ORTNER, J., HULTQVIST, B., BROWN, R. R., HARZ, T. R., HOLT, O., LANDMARK, B., HOOK, J. L. and LEINBACH, H. (1962): Cosmic noise absorption accompanying geomagnetic storm sudden commencements. J. Geophys. Res., **67**, 4169–4186.

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