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# LATITUDINAL FEATURES OF COSMIC NOISE ABSORPTION AT THE TIME OF SSC-TRIGGERED SUBSTORM AS OBSERVED WITH SCANNING BEAM RIOMETER

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***Abstract:*** The scanning beam riometer at Syowa Station, Antarctica (Inv. Lat. = 66.1°) detected spatial and temporal variations of the precipitation of energetic electrons responsible for the cosmic noise absorption (CNA) associated with the storm sudden commencement (SSC) at 2353 UT, November 3, 1986 and the subsequent substorm. The SSC-associated precipitation was restricted equatorward of Syowa Station, while the substorm-associated precipitation started equatorward and was displaced poleward with stronger intensity at higher latitudes. It is deduced that the SSC-associated precipitation shifted equatorward at a speed of 500 m/s, while the substorm-associated precipitation rapidly poleward at a speed of 5.8 km/s. These results clearly indicate two kinds of energetic electrons associated with the SSC-triggered substorm. Particularly, the latitudinal feature of precipitation indicates that the energetic electrons associated with an SSC originate in the trapped radiation belt, which are forced to precipitate by a hydromagnetic shock propagated from the magnetopause.

## 1. Introduction

The scanning beam riometer constructed at Syowa Station, Antarctica (Inv. Lat. = 66.1°, $L$=6.1) has narrow beams of 13° width that scan the ionosphere in the range of ±30° in zenith angle at a speed of 6°/s. The scanning beam illuminates an ionospheric region in a horizontal range of 120 km with the spatial resolution of 10 km (Fig. 1). This high spatial resolution enabled us to detect a new type of CNA pulsation in the Pc 5 range which propagated eastward at a speed of 300 m/s–2 km/s in the morning sector (KIKUCHI *et al.*, 1988). This riometer also revealed that the auroral absorption drifted westward in the afternoon sector and eastward in the morning sector, indicating that the auroral absorption drifted with the magnetospheric convection (KIKUCHI *et al.*, 1989).

This paper reports another observational fact showing a distinct latitudinal feature of the energetic electron precipitation associated with a storm sudden commencement (SSC) and substorm. As will be shown below, the precipitation of energetic electrons took place equatorward of Syowa Station at the time of SSC, while predominantly in the poleward region at the time of substorm.

## 2. Scanning Beam Riometer

Observations of CNA events have usually been made with a riometer with a broad beam antenna (beam width is >60°), and spatial features have been detected with a chain of riometer stations several hundred km apart (*e.g.*, OLSON *et al.*, 1980). If the ionospheric height for the most effective absorption is assumed to be 90 km, the beam of 60° width illuminates an ionospheric region with a diameter of 100 km. The riometer chain consisting of this type of riometer detects a spatial feature of CNA extending over several hundred km. On the other hand, small-scale auroral absorption events such as an absorption spike associated with the substorm expansion phase were observed with a multi-narrow beam riometer (NIELSEN, 1980). The antenna of this system has narrow beams of 8° width between half-power points. The antenna system has 16 beams lying in the meridian plane and a single beam pointing eastward at a zenith angle of 30°.

At Syowa Station, we constructed a multi-narrow beam riometer in January, 1985. This system is similar to that of NIELSEN (1980), but our system is characterized by two beams that scan along the magnetic north-south and east-west, in addition to four fixed direction beams (Fig. 1). The beam width is 13° between half-power points and the wave frequency is 30 MHz. The fixed direction beams point to the zenith and to the north, south and west at a zenith angle of 30°, along with two scanning beams pointing to between ±30° in zenith angle in the north-south and east-west directions. If the height of the absorption region is assumed

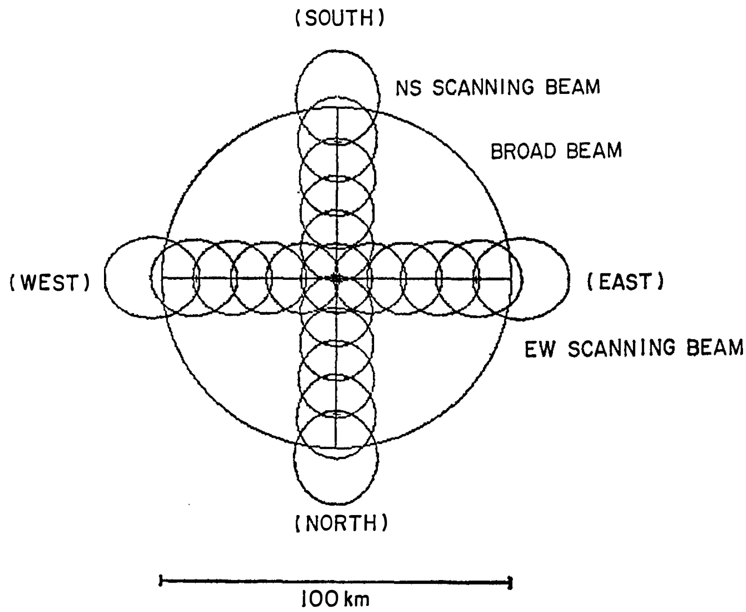


*Fig. 1. Field of view at the ionospheric height (90 km) of the scanning beam (small circles) and conventional broad beam (large circle). Two scanning beams cover a range of about 120 km in the north-south and east-west directions with a spatial resolution of 10 km.*

to be 90 km, the beam illuminates the ionosphere with a diameter of 20 km above the antenna and 27 km at a zenith angle of 30°. The scanning beam surveys an ionospheric region with a diameter of 120 km with a spatial resolution of 10 km, although the scanning is restricted along the fixed meridian and equi-latitudinal planes. Figure 1 shows a projection of scanning antenna beams on the ionosphere, along with a broad beam used for the conventional riometer system. The high spatial resolution of the scanning beam antenna system made it possible to detect a new type of CNA pulsation with a short wavelength (KIKUCHI *et al.*, 1988).

## 3. Observations

A storm sudden commencement took place at 2353:07 UT, November 3, 1986, and this SSC triggered a substorm at 0001:32 UT at Syowa Station. Figure 2 shows cosmic noise absorptions (CNA's) observed with the scanning beam riometer at the time of the SSC-triggered substorm. The SSC-associated CNA moved equatorward at a speed of 500 m/s, while the subsequent substorm-associated CNA was displaced poleward at a speed of 5.8 km/s. The equatorward displacement of the SSC-associated CNA in the midnight coincides with the propagation of hydromagnetic waves in the nightside magnetosphere (WILKEN *et al.*, 1982), although the speed seems to be much slower than expected in the ionosphere and magnetosphere. The poleward movement of the substorm-associated CNA corresponds to the poleward expansion of auroras at the time of auroral breakup. It is interesting to note that the SSC-associated CNA took place in the equatorward portion of the field of view of the

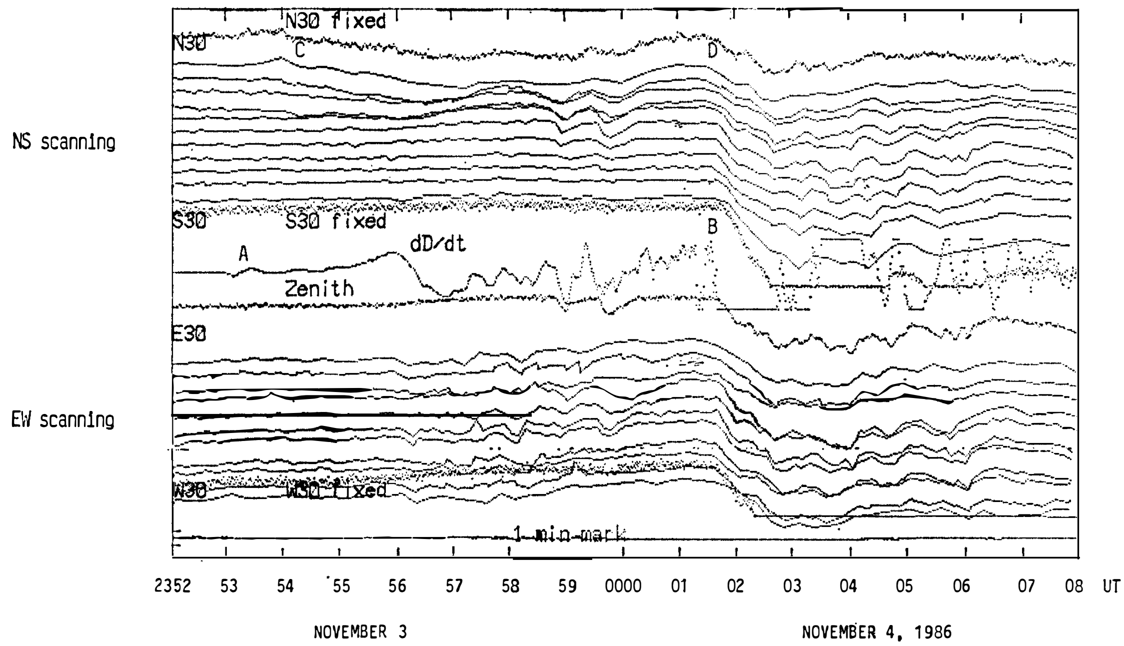


*Fig. 2. Cosmic noise absorptions associated with a storm sudden commencement (denoted by C in the figure) and substorm (D), observed by the north-south and east-west scanning beams. The onsets of the SSC and substorm are indicated with A and B by the curve of ULF D-component (dD/dt).*

scanning beam. On the other hand, the magnitude of the substorm-associated CNA is larger on the poleward side within the field of view (Fig. 3). This result suggests that the SSC-associated energetic electrons originate in the trapped radiation belt, while those for substorm must come from the plasma sheet.

Figure 4 shows the magnetic *H*-component and CNA observed with the conventional broad beam riometer at Syowa Station. It is interesting to note that the magnetic decrease started at 2354 UT (indicated with arrow a), but the onset of the CNA started at 0001 UT (arrow b), 7 min later than the onset of the magnetic decrease. The SSC-associated precipitation of energetic electrons produced only small effects on the conventional broad beam riometer. This is because the SSC-associated precipitation is restricted in the equatorward portion of the field of view of the antenna (Fig. 3). It should be noted that the onset of the magnetic decrease coincides with the onset of the SSC-associated precipitation, but not with the onset

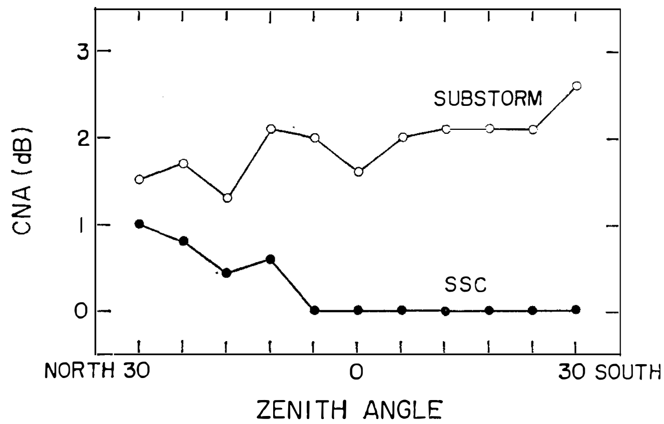


*Fig. 3. Latitudinal dependence of CNA associated with SSC and subsequent substorm. The SSC-associated CNA is observed in the lower latitude portion of the field of view, while the substorm-associated CNA has a larger intensity at higher latitudes.*

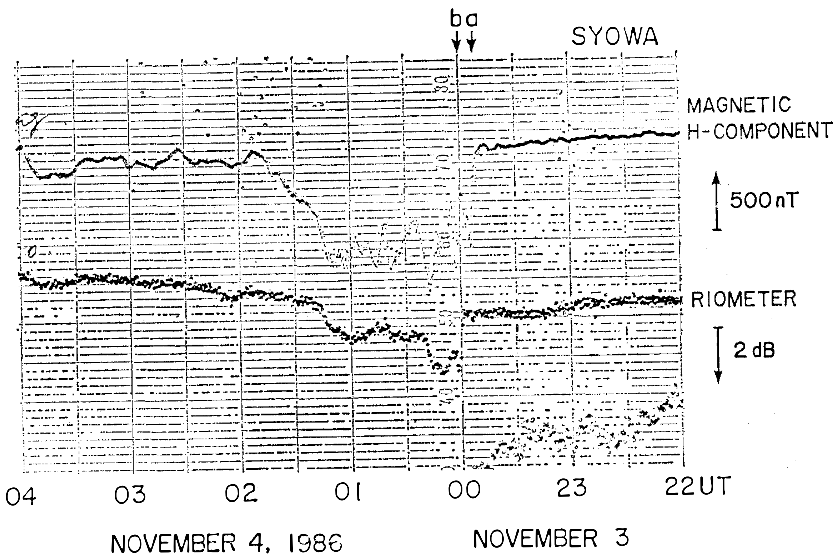


*Fig. 4. Negative change in the magnetic H-component starting at the time of SSC (denoted with a) and the CNA observed with the conventional broad beam riometer (b) starting 7 min later than the onset of SSC.*

of CNA substorm (Fig. 2). This result will suggest an enhancement of ionospheric currents at the time of the SSC equatorward of Syowa Station.

## 4. Discussion

It has been revealed that two kinds of electrons precipitate during an SSC-triggered substorm. One is associated with the SSC and the other is associated with the subsequent substorm. These two types of electrons are distinguished by the time delay of precipitation and by a difference in latitude of their appearance that can be observed with the scanning beam riometer. The time difference in the precipitation of the two types of electrons were also detected by a VLF phase measurement during this SSC-triggered substorm event. Figure 5 shows the phase deviation of the Omega Norway (66°25′N, 13°08′E) received at Inubo, Japan (35°42′N, 140° 52′E). It is clearly observed that the phase deviation started at 2354 UT and another started at 0007 UT as denoted with a and b. These phase deviations correspond to the SSC and the subsequent substorm, respectively. The onset of the SSC-associated phase deviation coincides with the onsets of the SSC-associated CNA observed with the scanning beam riometer and of the magnetic decrease at Syowa Station (Figs. 2 and 4). On the other hand, the onset of the substorm-associated phase deviation is delayed by 6 min compared to the substorm defined by the CNA at Syowa Station. This difference is due to that the VLF signal propagated in the morning

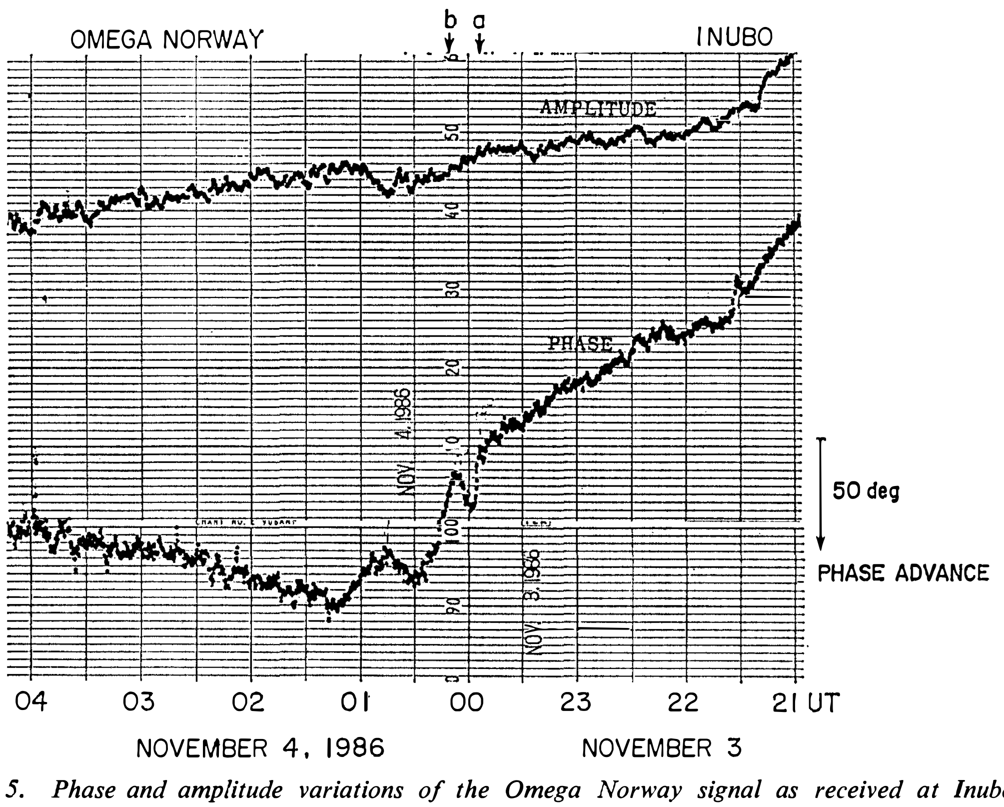


*Fig. 5. Phase and amplitude variations of the Omega Norway signal as received at Inubo, Japan. The phase advanced simultaneously with the SSC (denoted with a), while the phase advance associated with the substorm is delayed by about 6 min from the onset of the substorm in the midnight (b).*

sector (highest latitude part of the path was in the 4 LT meridian). The source electrons responsible for the VLF phase advance must have been injected into the midnight sector and drifted eastward at a speed of 5°/min (HARGREAVES, 1968; KIKUCHI, 1981). The time delay of the VLF signal must be due to this drift of the electrons. Consequently, the successive appearance of two VLF phase anomalies indicates two kinds of electron precipitation at the time of SSC-associated substorm, which supports the conclusion obtained from the observation by the scanning beam riometer.

It is interesting to note that the onset of the abrupt geomagnetic decrease coincides with the onset of the SSC-associated CNA, but not with the CNA substorm (Figs. 2 and 4). The magnitude of this geomagnetic decrease was about 800 nT, which seems to be much greater than the magnitude of SSC observed at the high latitude (~100 nT) (NAGATA, 1952). However, several cases of magnitude of 400 nT were reported by SANO (1964) based on the magnetogram from College. The large magnitude of SSC at high latitudes may partly be caused by enhanced ionospheric currents due to increased conductivity. This problem will be further examined by analysing the magnetogram from Syowa Station.

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