COMPARISON BETWEEN THE ARRIVAL DIRECTION OF AURORAL HISS AND THE LOCATION OF AURORA OBSERVED AT SYOWA STATION

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Abstract: From the results of the simultaneous observations of direction finding of 5–8 kHz auroral hiss with aurora at Syowa Station (geomagnetic latitude, −70.4°), the comparison between the exit region of auroral hiss from the ionosphere and the location of aurora has been made. The relation between the exit region of auroral hiss and 8 kHz hiss intensities at Syowa and at Mizuho (geomagnetic latitude, −72.3°) Stations has been investigated. The exit regions of the narrow-band hiss emissions ($\lesssim$20 kHz) which usually occur at geomagnetically quiet times are located at lower latitudes than the location of aurora appearing over or to the geomagnetic south of Mizuho. In this case, the intensities of 8 kHz hiss at Syowa and at Mizuho depend on the propagation distances from the exit region to the two stations. The exit regions of the wide-band hiss emissions ($\lesssim$100 kHz) which usually occur during geomagnetically moderate disturbances are located in a localized active region of aurora or at higher latitudes than the location of aurora appearing around the zenith or to the geomagnetic north of Syowa. In this case, the intensity of 8 kHz hiss at Mizuho is higher than that at Syowa. In order to interprete these observational results, two propagation models have been proposed as regards to auroral hiss emissions which exit through the ionosphere at lower latitudes as well as at higher latitudes than the location of aurora.

1. Introduction

Auroral hiss occurs in close association with auroral displays in the auroral zone. Morphological studies of auroral hiss observed at Syowa Station (geomagnetic latitude, −70.4°), Antarctica and its correlation with other geophysical phenomena have been made by some workers (NISHINO and TANAKA, 1969; HIRASAWA and NAGATA, 1972; TANAKA *et al.*, 1970, 1976; MAKITA, 1979). In particular, the association between auroral activity and auroral hiss is an important clue to understand the contribution of precipitating auroral particles to the occurrence and propagation of auroral hiss. MAKITA and FUKUNISHI (1973) categorized auroral hiss emissions into two types, continuous and impulsive, and they investigated the relation between the location of aurora and the occurrence of the two types. It has been found that the occurrence of continuous hiss with a narrow frequency band ($\lesssim$20 kHz) is associated with an auroral arc appearing to the geomagnetic south of Syowa Station and that impulsive hiss with a wide frequency band ($\lesssim$100 kHz) is associated with active aurora appearing over Syowa Station. These results suggest that direction finding (DF) observations are essential in order to understand the occurrence and propagation mechanism of auroral hiss. A new type of DF observation based on the measurements of time difference of wave arrival among three spaced observing points was carried out in 1978 at Syowa Station (NISHINO and HIRASAWA, 1981). The time difference of wave arrival is determined by cross-correlation of the waveforms of auroral hiss. An early result of the DF observations demonstrated that the DF system could detect the exit region in the lower ionosphere with an accuracy of about 10° for incident angles between 20° and 80°. From the comparison of the DF data with auroral display data (all-sky photographs), it was found that the arrival direction of impulsive auroral hiss, associated with auroral break-up in the negative phase of the great geomagnetic disturbance, coincided well with the localized regions of active electron aurora at the ionospheric level where we found rapid changes in luminosity and in motion. This result suggests a close relation between precipitating auroral electrons and impulsive auroral hiss (NISHINO *et al.*, 1981). The purpose of this paper is to compare the arival direction of auroral hiss with the location of aurora during geomagnetically quiet periods and during moderate disturbances, and to investigate the relation between the exit regions of auroral hiss and the hiss intensities observed at Syowa and at Mizuho (about 270 km distant from Syowa to the geomagnetic south direction), and finally to discuss the propagation mechanism of auroral hiss.

2. Observed Results

2.1. July 30, 1978 (Fig. 1)

The geomagnetic *H*-component is quiet at night at Syowa (Fig. 1a). The all-sky photograph of aurora at Syowa shows an extremely faint auroral arc near the geomagnetic southern horizon of Syowa before and after 2100 UT (Fig. 1d). Narrow-band auroral hiss emissions with short duration are observed at both Syowa and Mizuho (Fig. 1b). Auroral hiss emissions are received at both stations by the loop antennas whose planes are oriented in the geomagnetic N-S direction, and are recorded through the minimum detecting circuits with a long time constant ($\sim$2 s). For comparatively intense events greater than 10^{-15} W/m^{2}Hz on the 8 kHz hiss record at Syowa, arrival directions were obtained (Fig. 1c). Regions of the arrival directions were estimated from about 30 samples of data per minute. The arrival direction regions of sub-events 1 and 2 shown in the panel b indicate incident angles of 45–55° and of 40–70° in the geomagnetic south, respectively. The ionospheric level of the exit region of auroral hiss is assumed to be 100 km, so that the exit regions of sub-events 1 and 2 are located nearer to Mizuho than to Syowa. So, it is reasonable to assume that the hiss intensity at Mizuho is higher than that at Syowa. As the all-sky camera can detect aurora located at about 1000 km distant from Syowa towards the geomagnetic southern horizon, it is estimated that the hiss exit regions are located at lower latitudes by several hundreds km from the faint auroral arc.

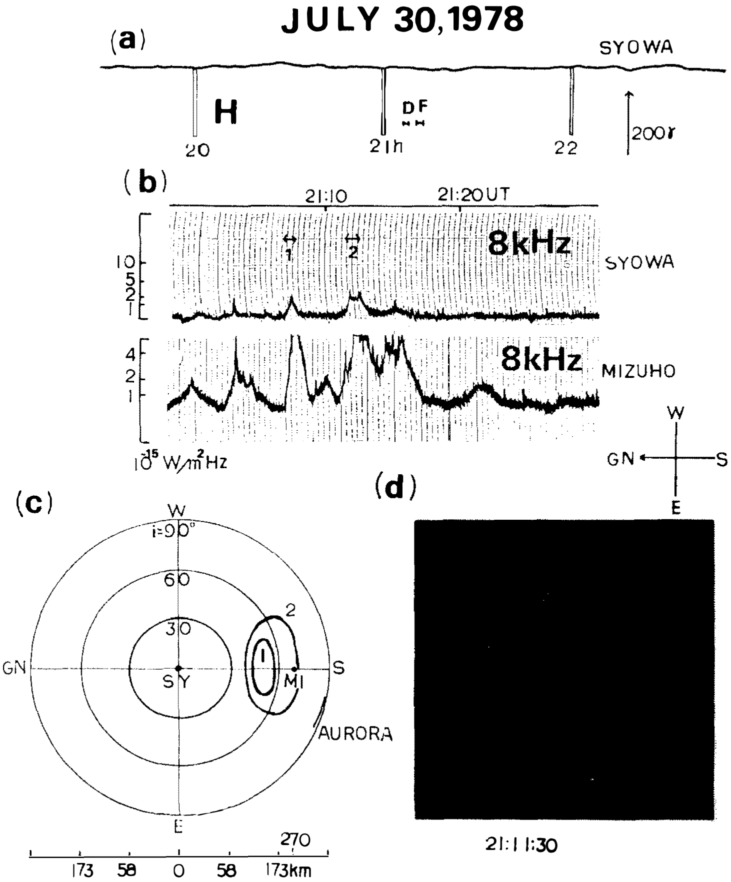


Fig. 1. Temporal evolution of observed results on July 30, 1978.
(a) Variation of geomagnetic H-component at Syowa.
(b) Intensities of 8 kHz auroral hiss at Syowa and Mizuho.
(c) Estimated azimuthal and incident angles of 5–8 kHz auroral hiss at Syowa. The distance (km) represents the horizontal distance from Syowa to the hiss exit region at the ionospheric level of 100 km. SY and MI positions are projected to the 100 km ionospheric level.
(d) All-sky photograph of aurora at Syowa.

2.2. *June 27, 1978 (Fig. 2)*

The geomagnetic *H*-component gradually decreases until 20 UT, and thereafter shows the small variations of several tens of γ at Syowa (Fig. 2a). Comparatively intense narrow-band auroral hiss emissions are observed just before 20 h associated with the band type fragmentary moving aurora which extends from the geomagnetic east to the west over Mizuho (Figs. 2b and 2d). The arrival direction regions of sub-events 1 and 2 shown on the panel b indicate incident angles of 40–50° and of 25–35° to the geomagnetic south of Syowa, respectively (Fig. 2c). Therefore, the exit regions at the ionospheric level are located nearer to Syowa than to Mizuho. So, it is reasonable to assume that the hiss intensity at Syowa is relatively higher than that at Mizuho. The hiss exit regions are located at lower latitudes by 100–200 km from the location of aurora which is to the south.

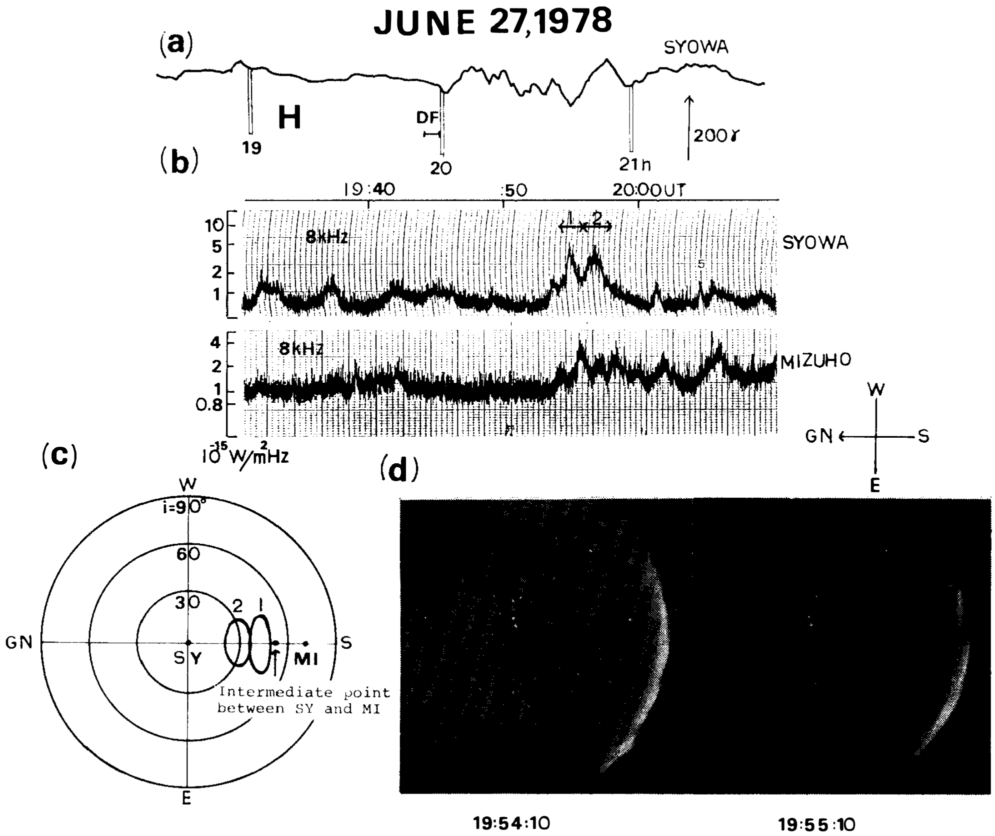


Fig. 2. Temporal evolution of observed results on June 27, 1978.
(*a*) *Variation of geomagnetic H-component at Syowa.*
(*b*) *Intensities of 8 kHz auroral hiss at Syowa and Mizuho.*
(*c*) *Estimated azimuthal and incident angles of 5–8 kHz auroral hiss at Syowa.*
(*d*) *All-sky photographs of aurora at Syowa.*

2.3. September 4, 1978 (*Fig. 3*)

The geomagnetic *H*-component variation is over 100γ before and after 22 UT at Syowa (Fig. 3a). Auroral hiss is observed at Syowa and Mizuho, associated with the aurora extended from the geomagnetic east to the west over Syowa (Figs. 3b and 3d). The arrival direction regions of sub-event 1 shown in the panel b indicate incident angles of 30–40° to the geomagnetic south and of 40–60° to the geomagnetic west (Fig. 3c). It can be considered that the hiss emissions of sub-event 1 come alternatively from the two localized regions. The region in the geomagnetic west is located within aurora, while the one in the geomagnetic south is located at slightly higher latitudes than the relatively active part of aurora at the southerly side over Syowa. The arrival direction region of sub-event 2 is near the zenith of Syowa, and is located within aurora extending in the geomagnetic east to the west direction. In spite of the exit regions of the sub-events 1 and 2 being located nearer to Syowa, the hiss intensities are remarkably high at Mizuho. The hiss intensity of sub-event 2 at Syowa decreased due to the absorption of the hiss energies in the lower ionosphere caused by the enhanced ionization by precipitating auroral particles (Fig. 3b, lower panel).

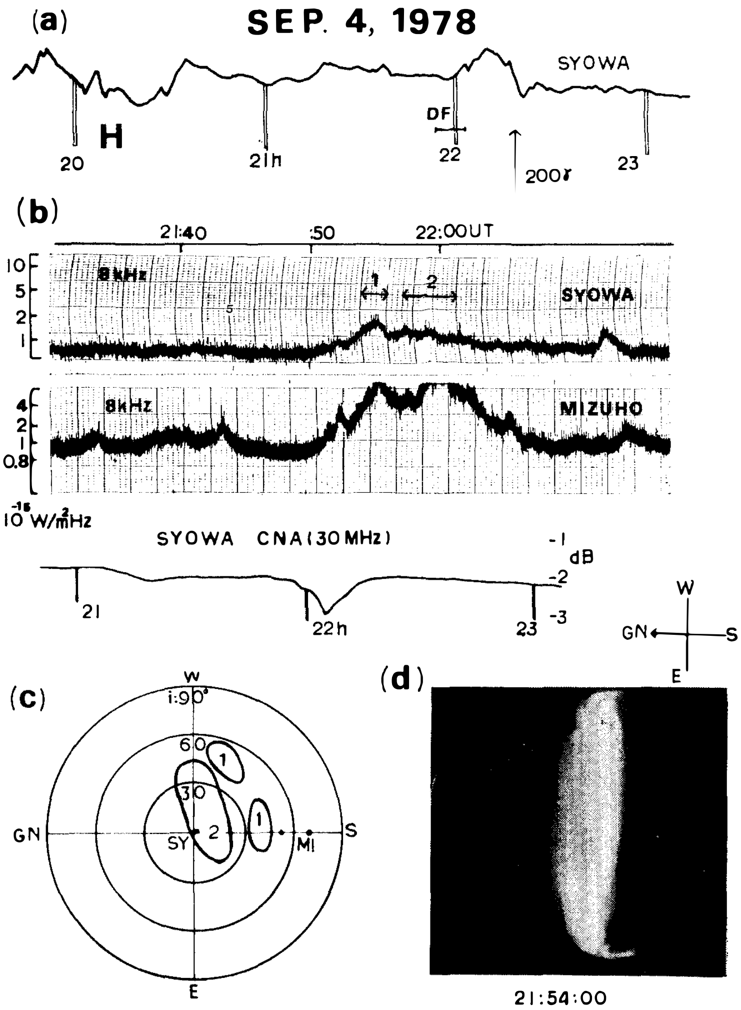
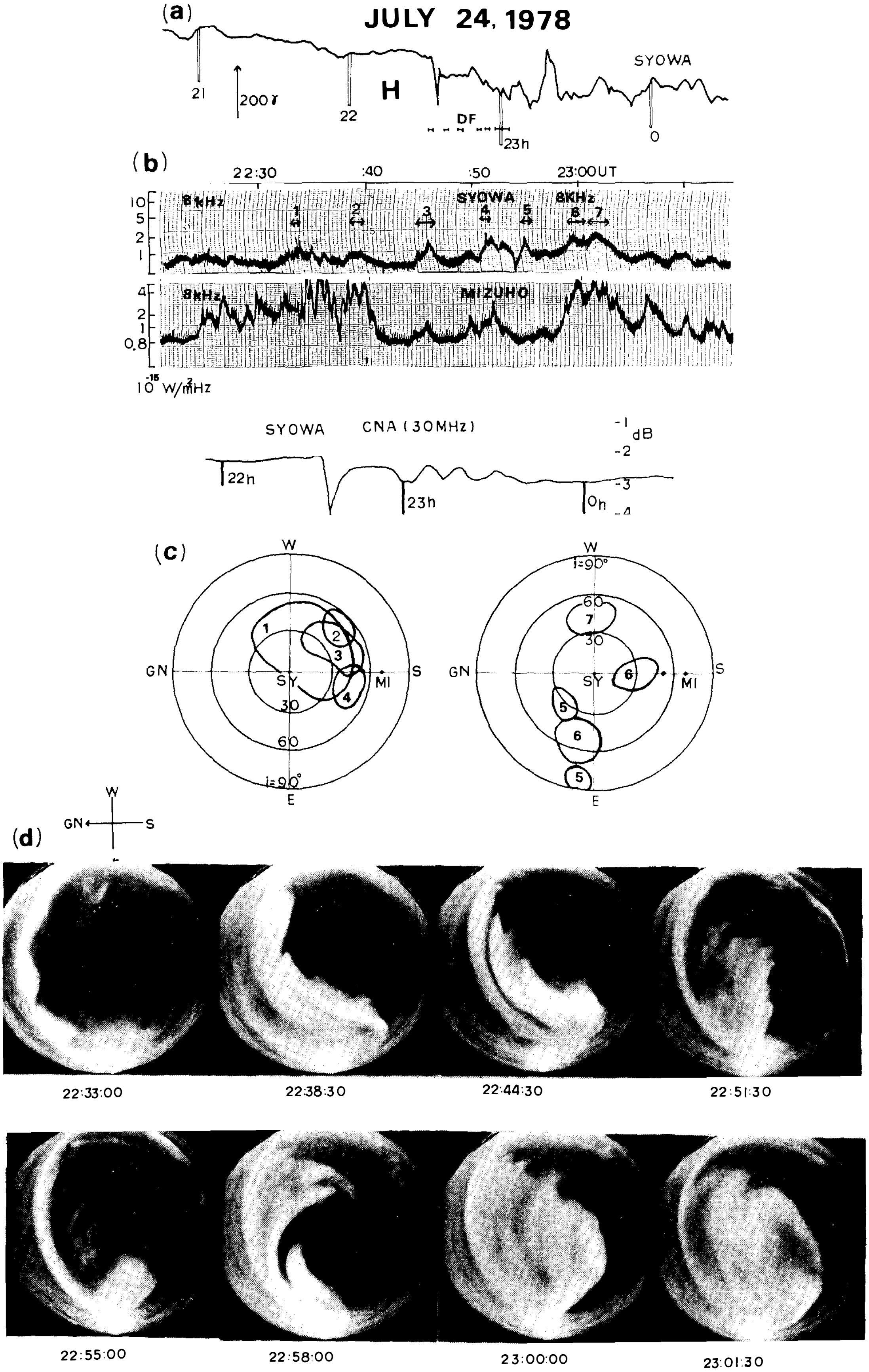


Fig. 3. Temporal evolution of observed results on September 4, 1978.
(*a*) *Variation of geomagnetic H-component at Syowa.*
(*b*) *Intensities of 8 kHz auroral hiss at Syowa and Mizuho, and 30 MHz riometer record at Syowa.*
(*c*) *Estimated azimuthal and incident angles of 5–8 kHz auroral hiss at Syowa.*
(*d*) *All-sky photograph of aurora at Syowa.*

2.4. *July 24, 1978* (*Fig. 4*)

The geomagnetic *H*-component gradually decrease from 21 UT, with a sharp negative decrease at 2233 UT (Fig. 4a). An aurora with the homogeneous band structure appearing to the geomagnetic north of Syowa breakes up simultaneously with the sharp negative decrease, and with increase in luminosity and fragmentary motion at 2233 UT. Subsequently, the aurora moves towards the zenith of Syowa with a multiple band structure. At about 2244 UT, the multiple band auroras split and then after about 2250 UT, the aurora with ray-structure rapidly moves from the geomagnetic east to the zenith of Syowa. At 2255 UT, multiple band auroras reappear in the geomagnetic north-east direction, and then expand towards the zenith with local intensifications in luminosity (Fig. 4d).


(a)
JULY 24, 1978
SYOWA
H
21
200γ
22
DF
23h
0
(b)
22:30
:40
:50
23:00UT
8kHz
SYOWA
8KHz
1
2
3
4
5
6
7
8kHz
MIZUHO
10^{-15} W/m²Hz
SYOWA CNA (30MHz)
dB
22h
23h
0h
(c)
W
GN
S
E
SY
MI
i=90°
60
30
(d)
22:33:00
22:38:30
22:44:30
22:51:30
22:55:00
22:58:00
23:00:00
23:01:30

Impulsive auroral hiss emissions are observed at Syowa and Mizuho, associated with the auroral display, as shown in the panel b. Seven impulsive sub-events of 8 kHz hiss are recorded at Syowa. The arrival directions of sub-events 1 and 2 indicate the wide exit region and a localized exit region in the geomagnetic south-west, respectively (Fig. 4c), whereas the aurora appears in the geomagnetic north. The intensity of sub-event 1 at Syowa decreases suddenly with the auroral break up, due to the heavy absorption of the hiss energies in the lower ionosphere caused by enhanced ionization by precipitating auroral particles (Fig. 4b, lower panel). Intensive and impulsive type auroral hiss emissions with the wide frequency band are, on the other hand, observed at Mizuho. Impulsive auroral sub-events 3 and 4 also arrive from the localized regions in the geomagnetic south, while auroras appear around the zenith and to the north of Syowa. Impulsive auroral hiss emissions of sub-event 5 arrive from a localized region of the ray-structure aurora with incident angles of 20–40° from the geomagnetic north-east direction, and from another at the geomagnetic eastern horizon. The hiss intensity of sub-event 5 is very weak at Mizuho. The auroral hiss emissions of sub-event 6 associated with the multiple band aurora at 2300 UT arrive from a localized region in the geomagnetic east, and from another in the geomagnetic south. Finally, for sub-event 7, the auroral hiss arrives from a localized region in the geomagnetic west which is coincident with an active region of widespread aurora. The hiss intensities in sub-events 6 and 7 are higher at Mizuho than those at Syowa.

Summarizing the above results on July 24, the exit regions of auroral hiss in sub-events 1–4 are located at higher latitudes than the location of aurora appearing around the zenith or in the geomagnetic north of Syowa. On the other hand, the exit regions in sub-events 5–7 are located approximately within auroral active regions. The exit regions in all sub-events are located nearer to Syowa than to Mizuho. Nevertheless, the hiss intensity at Mizuho is higher than that at Syowa except for sub-event 5. This is similar to the result of September 4 shown in Fig. 3.

3. Summary and Discussion

As shown in Figs. 1 and 2, narrow-band hiss emissions associate with auroral arcs appearing over or to the geomagnetic south of Mizuho, and they exit from localized regions at lower latitudes than the location of aurora. These observational results are significant for discussion of the propagation mechanism of narrow-band hiss in the ionosphere. Figure 5 shows the histogram for narrow-band hiss emissions obtained from the DF observations in 1978, of the distance along the geomagnetic meridian plane from the center of the auroral arcs to that of the hiss exit regions. This figure indicate that all of narrow-band hiss associated with auroral arcs exit from the lower latitudinal regions than the location of aurora. Figure 6 shows the distribution of the

Fig. 4. Temporal evolution of observed results on July 24, 1978.
- (*a*) *Variation of geomagnetic H-component at Syowa.*
- (*b*) *Intensities of 8 kHz auroral hiss at Syowa and Mizuho, and 30 MHz riometer record at Syowa.*
- (*c*) *Estimated azimuthal and incident angles of 5–8 kHz auroral hiss at Syowa.*
- (*d*) *All-sky photographs of aurora at Syowa.*

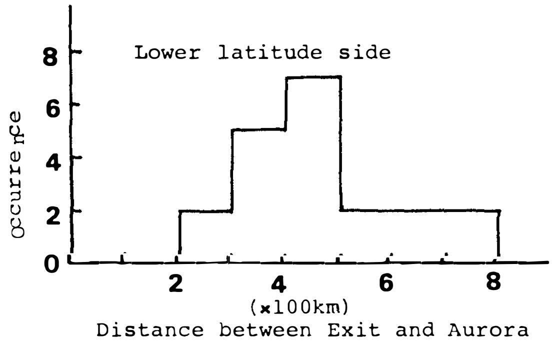


Fig. 5. Occurrence of the located exits of the narrow-band hiss emissions obtained from the DF observations at Syowa in 1978 for various distances from the auroral location to the hiss exit.

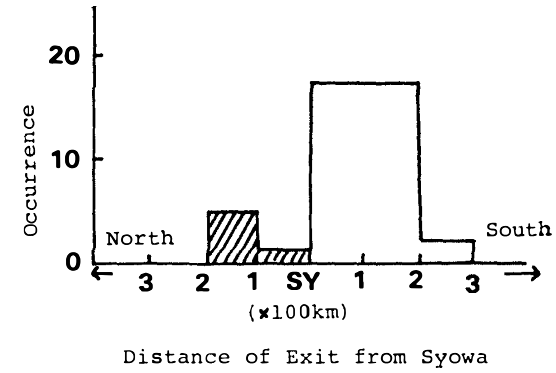


Fig. 6. Distribution of the exit distances of the narrow-band hiss emissions propagated approximately along the geomagnetic meridian plane of Syowa as a function of the distance from Syowa.

exit regions of narrow-band hiss emissions propagated approximately along the geomagnetic meridian plane as a function of the distance from Syowa. The dercease in number over 200 km to the geomagnetic south is due to the intensity of hiss depressed below the threshold level ($\sim 10^{-15}$ W/m^{2}Hz) for the DF observations. It is seen from Figs. 5 and 6 that the exit regions are, in most cases, distributed within 200 km towards the geomagnetic south from Syowa, and 300–500 km from auroral locations towards lower latitudes.

From study of the events and the statistical summary of the DF results, it is suggested that the separation between the narrow-band hiss exits and the location of aurora at the ionospheric level is due to non-ducted mode propagation in the upper ionosphere, as shown in Fig. 7, which has been proposed from the ray path computations by SRIVASTAVA (1974), SINGH *et al.* (1978) and MAKITA (1979). The narrow-band hiss emissions are propagated downwards in the upper ionosphere in a non-ducted mode, deviating from the field-aligned duct. The hiss emissions incident nearly vertically injected within the transmission cone at a boundary at the height of the *F* region, penetrate through the ionosphere and escape from the exit region at the lower edge of the ionosphere, and so reach the ground. The received intensity of auroral hiss on the ground depends on the propagation distance from the exit regions to the ground station which is approximately proportional to the absorption of hiss energies through the lower ionospheric region below about 100 km, as was found from the relation between the hiss exit regions and the hiss intensities at both stations in Figs. 1 and 2.

As shown in Figs. 3 and 4, the exit regions of the wide-band hiss associated with auroras appearing over or in the geomagnetic north of Syowa are located in the localized regions at higher latitudes than the location of aurora or within the auroral display. Figure 8 shows the occurrence of wide-band hiss emissions obtained from the DF observations at Syowa in 1978, for various distances from the active region within aurora to the center of hiss exit regions of the hiss. The distances are very rough because of the complex structure of aurora. In this histogram, the occurrences of wide-band

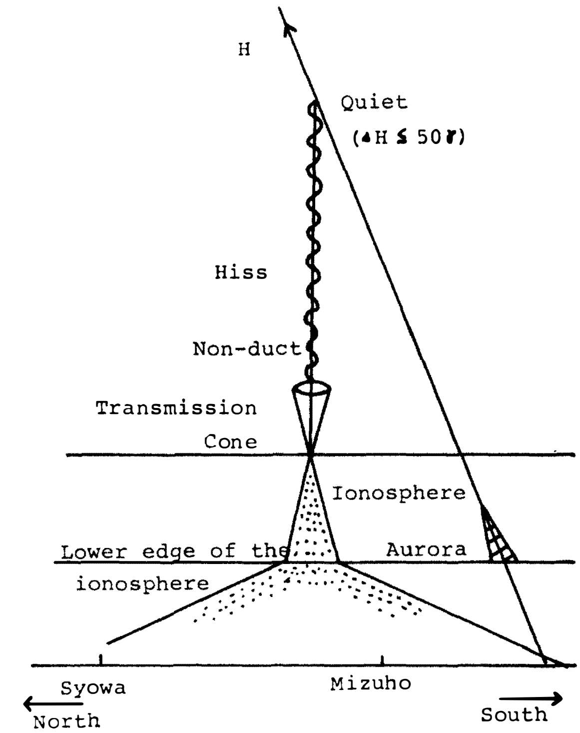


Fig. 7. Proposed propagation model of the narrow-band hiss emissions for a geomagnetically quiet time.

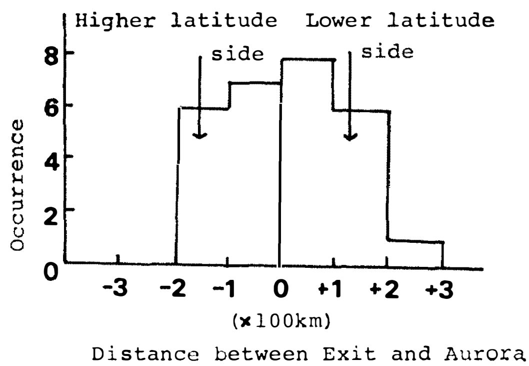


Fig. 8. Occurrence of the located exits of the wide-band hiss emissions obtained from the DF observations at Syowa in 1978 for various distances from the auroral location to the hiss exit. Positive distance represents exit region at lower latitudes than the location of aurora, while negative represents for higher latitudes.

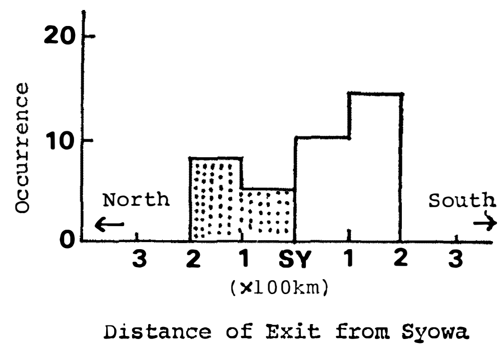


Fig. 9. Distribution of the exit distances of the wide-band hiss emissions propagated approximately along the geomagnetic meridian plane of Syowa as a function of the distance from Syowa.

hiss emissions during the geomagnetic disturbances more than 200γ are included. This figure indicates that the exit regions are located at lower latitudes as well as higher latitudes from the location of the active aurora. This result is different from that for the narrow-band hiss given by Fig. 5. Figure 9 shows the distribution of the exit regions of the wide-band hiss emissions detected approximately along the geomagnetic

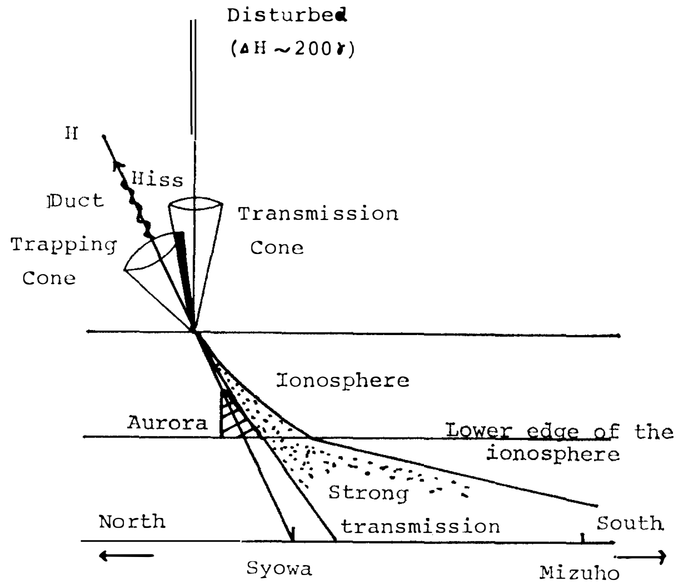


Fig. 10. Proposed propagation model of the wide-band hiss emissions which exit at higher latitudes than the location of auroral display, for geomagnetically moderate disturbances.

meridian plane of Syowa as a function of the distance from Syowa. It is apparently a similar tendency with the distribution for the narrow-band hiss that there are more exits towards the geomagnetic south of Syowa than towards the geomagnetic north. However, it is a different characteristics that the occurrence rate of the wide-band hiss in the geomagnetic north is higher than the rate for the narrow-band hiss in the geomagnetic north shown in Fig. 6.

As for the wide-band hiss being located at lower latitudes than the location of aurora in Fig. 8, it is thought that the altitude in the upper ionosphere where the hiss emissions are deviated from the field-aligned duct must be lower than that for the narrow-band hiss. To explain the wide-band hiss located at higher latitudes than the location of aurora in Fig. 8, the relation between the auroral display and hiss exit regions is represented by the schematic diagram of hiss penetration through the ionosphere shown in Fig. 10. In this figure, it is to be expected that the hiss exits are located at higher latitudes than the aurora, and that the hiss intensities at Mizuho are higher than those at Syowa, due to the coupling between the ionosphere and the earth-ionosphere waveguide described by HELLIWELL (1965).

In order to improve our understanding of the propagation mechanism of auroral hiss, we must carry out detailed analyses by coupling the observed results from the DF observations and intensity measurements of auroral hiss to theoretical results from ray tracings and full-wave calculations of energy abosrption of auroral hiss in realistic models of the auroral ionosphere.

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