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# Merging Processes of Band Echoes Observed by Radar in the Winter Monsoon Seasons in Hokkaido

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**Abstract**

Merging phenomena of band shaped radar echoes were often observed in the cloud streaks during the special radar observation at Haboro, Hokkaido, Japan. The merging processes were classified into two types of band echoes parallel to the monsoon wind direction and parallel to the coast line of west side of Hokkaido.

According to mesoscale features of radar echoes, it was understood that band echoes parallel to the monsoon wind merged under a situation of the generation of new echo cells. While, a situation of the difference of the propagation speed of each band echo was dominant in the case of the convergence band clouds parallel to the coast line.

## 1. Introduction

It is well known that cloud streaks develop over the Japan Sea under the conditions of northwesterly monsoon wind in winter seasons. Some larger cloud bands are often formed in the cloud streaks and maintained for a considerable length of time. In particular, the more larger band clouds formed along the west coast of Hokkaido Island are called the convergence band clouds (hereinafter referred to CBC ; Okabayashi and Satomi, 1971 ; Kobayashi et al., 1987). These band clouds have attracted special interest recently for the short term forecasting of heavy snowfalls around Sapporo City. Considering the formation process of band clouds which have several tens of km in width and several hundreds of km in length, radar observations of cloud bands are very important in understanding the structure of cloud bands and nowcast the heavy

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snowfalls.

Generally, the movement of echoes is strongly influenced by the mountain range or a topography of the bay area. Kikuchi et al. (1987) pointed out that a movement of echo cells influenced by topography around the Shakotan Peninsula shifted by about 10 degrees towards the east. Likewise, Harimaya and Kato (1988) reported the confluence phenomena between band echoes and cell-like echoes of the cloud streaks in the Ishikari Bay.

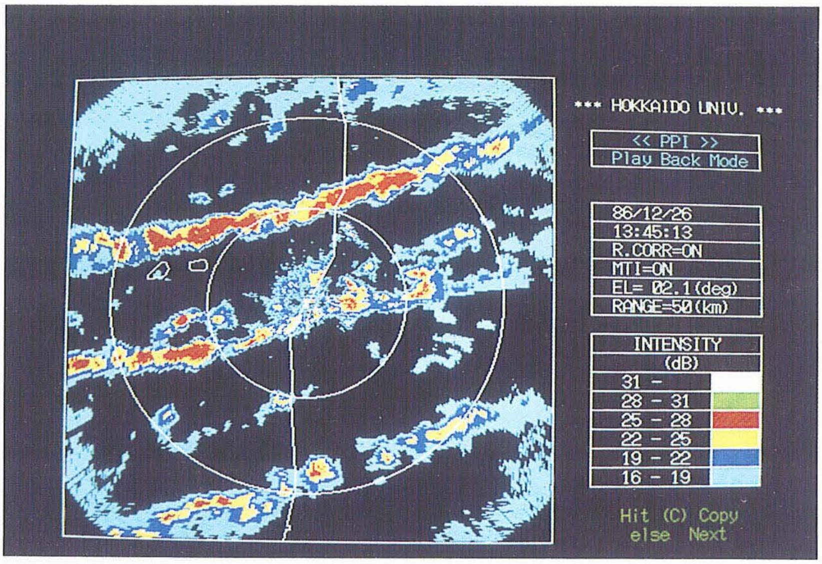
Muramatsu (1978) suggested that the stationary band cloud was caused by the upwind orographic effect. He found that a single large cloud band about 40 km in width and 400 km in length was sometimes recognized in the satellite pictures over the northern part of the Japan Sea on the west coast of Hokkaido in winter monsoon seasons, and discussed the relationship between 8 hourly periodical surface snowfall and the meandering of band clouds. He emphasized a case of large scale cloud bands enhanced by the upwind mountains, but the time change of each echo band was not clarified from the radar data.

Recently, many observations of CBC and precipitating snow clouds were carried out in the Ishikari Plain, for instance, we have the reports by Fujiyoshi et al. (1989) and Tsuboki et al. (1989) and so on. In the Ishikari Plain, as a number of band echoes of snow clouds invade from the northwest direction alone which have already formed a band shape, their formation processes of band echoes were masked frequently by topography in the visual field of radar scanning. And so, a special observation around the northern part of Hokkaido was required to research snow clouds carefully which were under no influence of topographic effects and were at an initial stage of CBC.

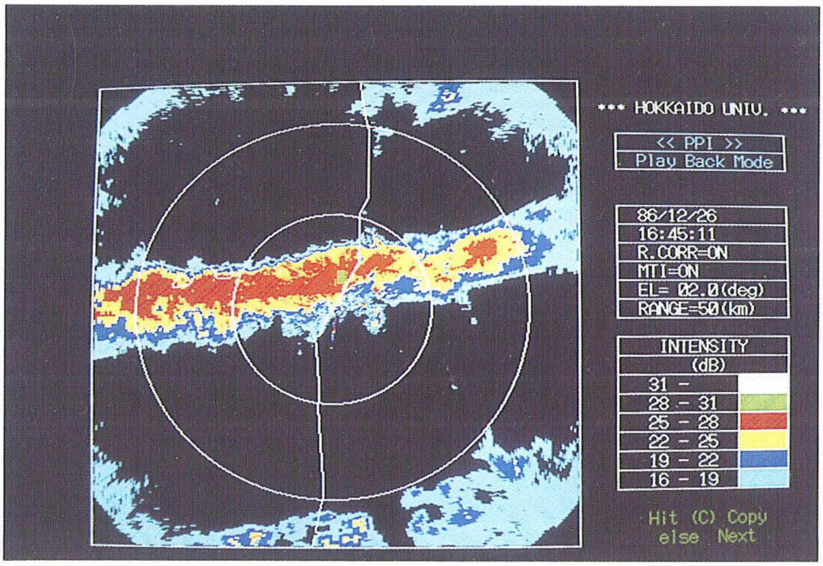
## 2. Radar observations at Haboro

Based on these situations, special radar observations were carried out from the middle of December 1986 to the middle of January 1987 at Haboro Town (44°21′N, 141°42′E) located at the west coast of Rumoi Sub-prefecture of Hokkaido Island about 150 km north from Sapporo. The mobile meteorological radar of the Meteorological Laboratory, Faculty of Science, Hokkaido University was set up on the cliff of 30 m in height along the coast line (Kobayashi et al., 1989).

The range scrutinized by the radar was 63.5 km in radius. Radar data were recorded with CAPPI and RHI modes at every 10 minute intervals. Fortunately, there were no obstacles to hinder radar detection around the radar site. Moreover, radar echo data which scanned over the sea and around the uniform




(a)




(b)

Fig. 1. Radar echo displays at Haboro in the case of December 26, 1986. (a) 13 : 45 JST. (b) 16 : 45 JST. The radar range circles are 20 km and 40 km, respectively.

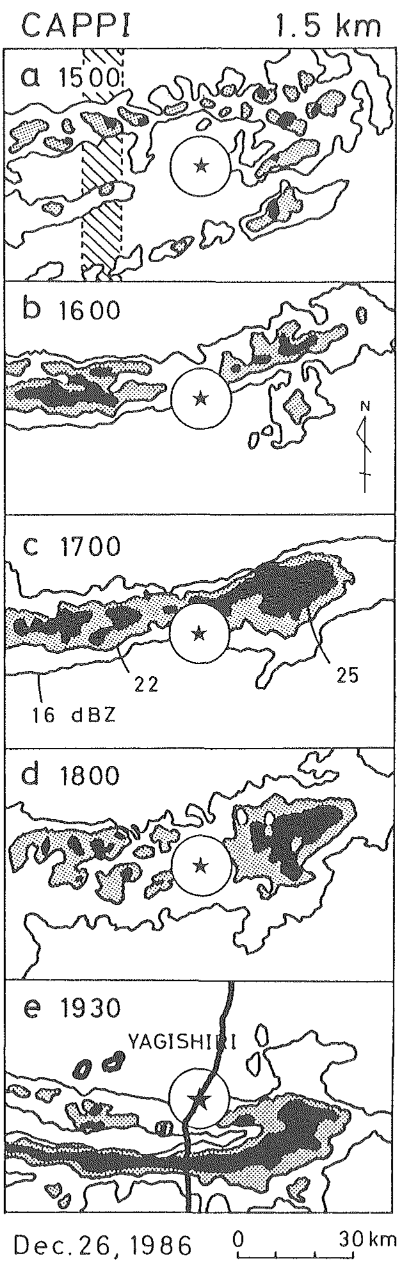


Fig. 2. Time sequence of the CAPPI radar displays on December 26, 1986.

coast line from north to south direction was under no influence of a typical topography.

Figure 1 shows two different time of PPI displays on December 26, 1986. Three parallel line echoes as shown in (a) changed to a larger band echo in (b) during three hours. It was often confirmed that the merging phenomena of the band echoes were observed in cloud streaks during the observation period. In this paper, we note the formation processes of the band echoes in mesoscale feature based on the special radar observation, such as the cases of band echoes parallel to the monsoon wind direction and band echoes parallel to the coast line (perpendicular to the monsoon wind direction) from north to south direction.

## 3. Band echoes parallel to the monsoon wind direction

Figure 2 shows the time changes of CAPPI displays at 1.5 km above sea level from 15 JST on December 26, 1986, under the strong winter monsoon weather situation just after the passage of a cyclone. Cloud streaks which showed three line echoes in the radar range were formed parallel to WSW direction of the monsoon wind as shown in Fig. 1(a) at 13 : 45 JST. Each line echo had less than 10 km in width and the space between band and band was 20 km. Because of the resolution, each line echo was not identified in the cloud streaks by GMS pictures. In the line echoes, each cell moved parallel to each line echo at the speed of 60-70 km/h which was equal to that of monsoon wind at 900-800 mb level. After 15 : 00 JST, when the south side line echo began to dissipate, two line echoes changed into a broad band echo sporadically in (b), and a strong band echo developed in (c). The almost stationary band echo showed 20 km in width and a strong reflectivity area (>25 dBZ). At the radar site, very strong snowstorms with westerly gust wind more than 20 m/s continued. After which, the width of the band spread gradually in (d) and separated into two lines in (e). As a result, each phenomenon occurred at about 2 hour intervals in this case. Considering a typical case of time changing line echoes in the cloud streaks, we defined echo change phenomenon (a) to (c) as "the merging" of line echoes and (c) to (e) as "the separation" of a band echo.

Using the data in the rectangular area drawn by stripes in Fig. 2(a), a time section of the echo from north to south is represented in Fig. 3. About 14 : 00 JST line echo B began to dissipate and new echoes generated on the north and south side of line echo B. After that, it seems that two echo lines merged at 15 : 30 JST and a band echo was formed. Figure 4 indicates that the time change of the echo areas larger than each reflectivity value (>16 to 25 dBZ) were scrutinized to study the development of the band echo. In the figure, an arrow denotes the time of merging. The total area (>16 dBZ) increased before the merging and at the time of the separation again, and decreasing after the time of the merging. While the strong reflectivity area (>22 dBZ) increased gradually after the merging. It is considered therefore that this fact is resulted from the total area of weak reflectivity decreases by the merging and total area of relatively strong reflectivity increases by merging, in other words, the wide weak echo areas turned into narrow strong echo areas through the merging of

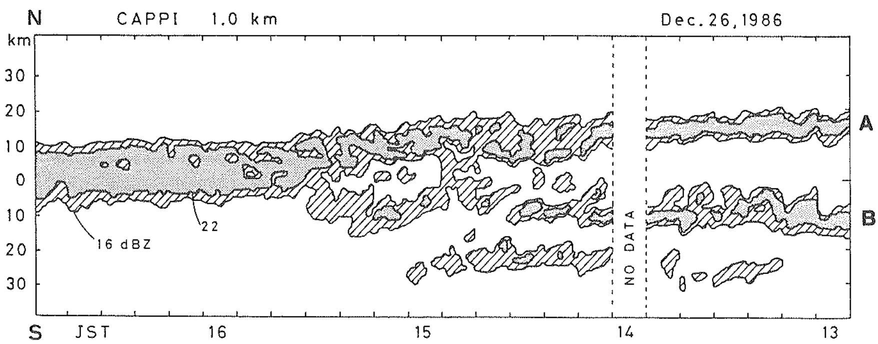



Fig. 3. South-north time section of the echo in the rectangular region in Fig. 2.

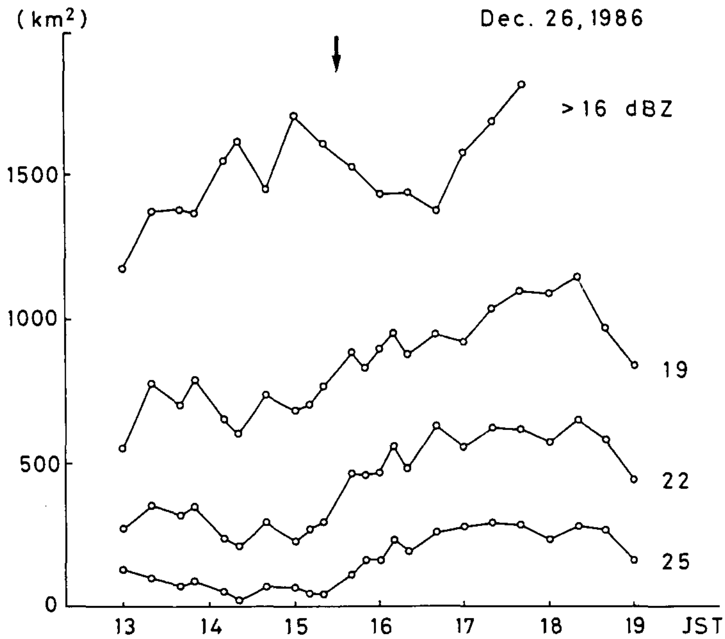



Fig. 4. Time changes of each echo area (>16, >19, >22 and >25 dBZ). An arrow denotes the time of merging.

echo bands. On the contrary, the narrow strong echo areas turned into wide strong echo areas through the separation each other.

Figure 5 represents the time change of radar echoes from north to south at vertical cross sections of the band clouds at 20 km offshore from the radar site. In the figure, the stage of echo development was represented in the life cycle of band echoes. It was recognized that when each echo began to dissipate, a new echo generated between echo lines, for instance, at 14 : 20 JST. That is to say, it was thought that at the developing stage of the line echoes, the updraft existed in the echo areas. On the other hand, at the dissipating stage, the updraft areas were changed into the downdraft areas. It is well known that the lifetime of each echo cell in a band cloud is several tens of minutes, while that of a band echo is several tens of hours. However, a band echo also changed in the inside by itself during its life cycle. It is considered therefore that the band echo changed or shifted in its shape and position repeating the merging and the separation of the echoes. And so, the process in which the old echoes changed places with the new echoes was seen as the merging or separation of band echoes at the time intervals of about two hours in this case.

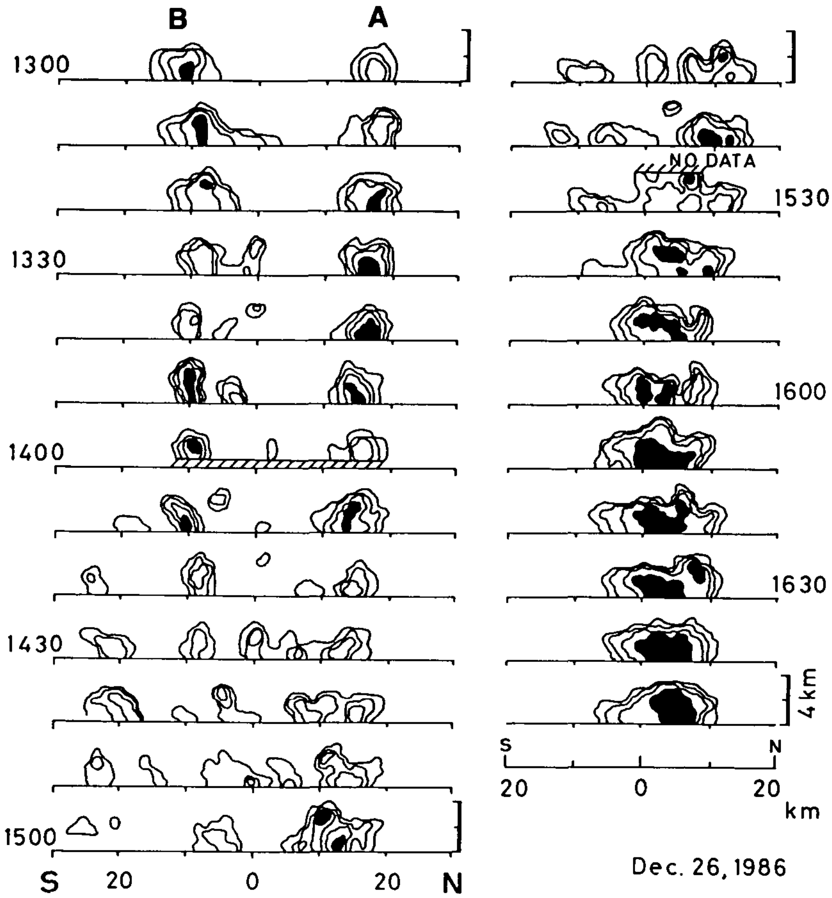



Fig. 5. Time change of south-north vertical cross sections of the band echoes observed at 20 km offshore.

## 4. Band echoes parallel to the coast line

This case corresponds to the merging process of the band echo in CBC. Figure 6 shows the GMS infrared picture on 03 : 00 JST, January 14, 1987 and CBC is recognized from the west side of the Soya Strait to the Shakotan Peninsula along the west coast of Hokkaido. From the GMS pictures the CBC was regarded as a cloud band alone having 50-100 km in width and moved towards the coast line slowly.

From the radar observations of this CBC, as shown in the Fig. 7, it was

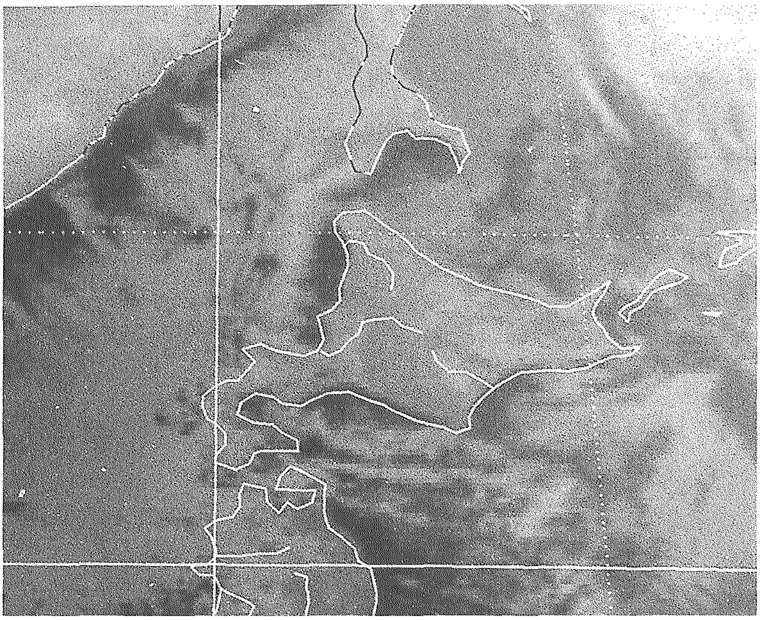


Fig. 6. GMS infrared picture at 03 JST January 14, 1987. (After Meteorological Satellite Center, J.M.A.).

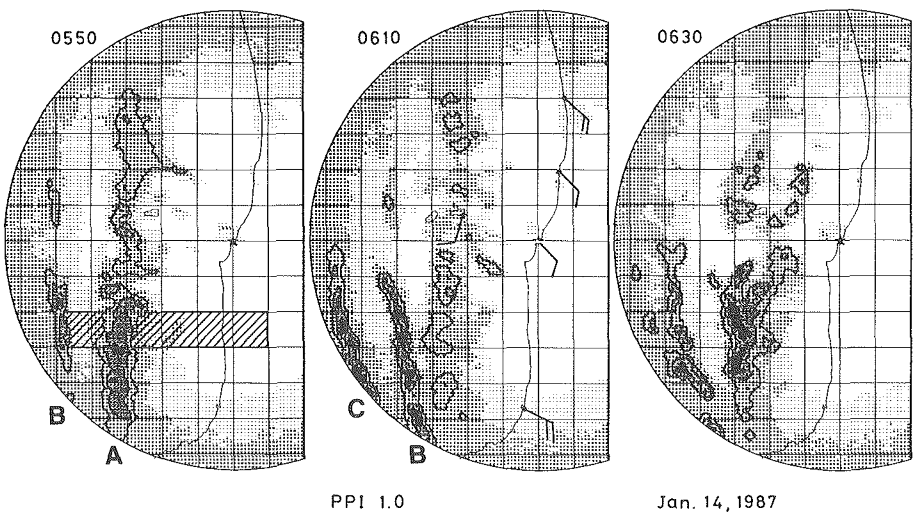



Fig. 7. Time sequence of the PPI radar patterns. Surface winds are shown in the center.

confirmed that two or three band echoes existed in the CBC. According to the figure, three band echoes moved to southeastwards at the average speed of 30 km/h equal to the movement speed and direction of each echo cell. However, approaching to the coast line, the most eastward band (band A) began to be stationary. Consequently, it appeared that the band A and band B merged at the south end of band A, after that, band B and band C merged again. Figure 8 shows the west to east time section of the band echoes of the rectangular area with stripes in the Fig. 7. As seen clearly in the figure, the band A and band B merged at 30 km distance from the coast line at 06 : 20 JST and the band B and band C merged at 20 km distance at 07 : 10 JST. The time interval of the merging in this case was about 1 hour. From the figure, band A moved more slowly, approaching the coast line and merged with the band B, after that, band B and C behaved in the same way. The merging process was understood that the east side echoes were merged with the west side echoes in this case. Because the cold land breeze of south-southeasterly from inland was dominant around the coast line as shown in the Fig. 7, near the coast line at 20-30 km offshore, there was the convergent zone between the two opposite winds, that is, the cold

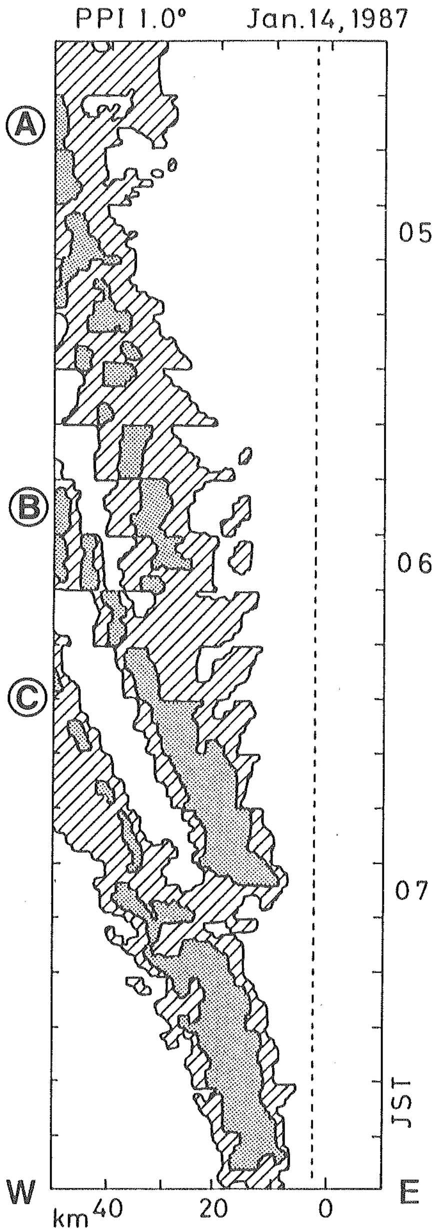



Fig. 8. East-west time section of the echo in the rectangular region in Fig. 7.

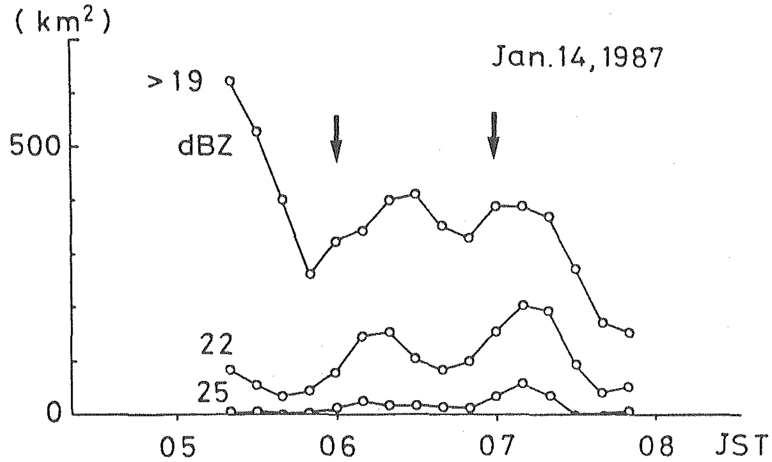


Fig. 9. Same as Fig. 4 except for January 14, 1987.

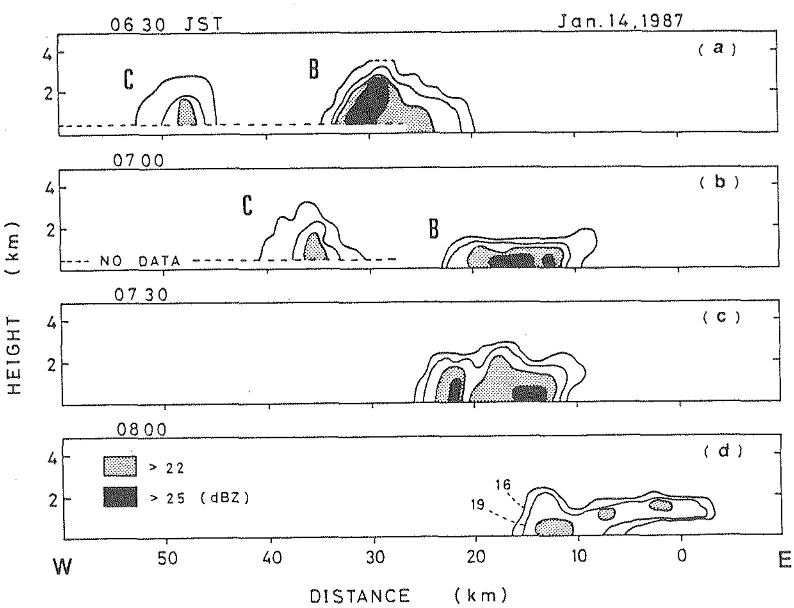


Fig. 10. Time change of west-east vertical cross sections of band B and band C at 20 km southward from the radar site.

breeze from inland and a relatively warm monsoon wind. Although the width of band had not changed before and after the merging, the strong reflectivity area increased after the merging.

From the time change of echo areas as shown in the Fig. 9, it was obvious that each echo area decreased first at the merging and increased after the merging as pointed by arrows. Figure 10 represents the vertical cross sections of the band echoes at the merging of the band B and band C. After the merging of the band A and the band B, band B developed and propagated to the eastward as shown in the Fig. 10(a). At 20 km offshore, band B became stationary and dissipated gradually in (b). Just after the band B was merged with the band C, however, they developed again in (c). As a result, it is considered that the merging of this case occurred under the situation of the difference of the propagation speed and direction of each band echo. So with the repetition of the merging, it seemed that the CBC was almost stationary near the coast line.

## 5. Discussion and concluding remarks

Considering the merging process, the following different situations will be presented in these cases. In the case of cloud streaks parallel to the monsoon wind direction, the band echoes merged and separated under a situation of the generation of new echoes. On the other hand, a situation of the difference of the propagation speed and direction of each band echo was dominant in the case of the CBC parallel to the coast line.

Naturally, it is assumed that the direction of the band propagation was influenced by the location of a synoptic cyclone or an upwind and downwind topography mainly, not the surface weather conditions in the case of band echoes parallel to the monsoon wind. However, regarding the more complicated motions of band echoes in the case parallel to the coast line, it was recognized that the surface weather conditions of the west coast of Hokkaido controlled the speed and direction of the propagation.

Considering the relation between the surface winds and the band formation, three different cases of the echo motion of cloud bands accompanied by the CBC through this observation period are shown in the Fig. 11. Considering the directions of surface wind at Haboro (H), Rumoi (R) and Yagishiri (Y) and 850 mb wind at Wakkanai Local Meteorological Observatory, they were quite different in each case, as shown in the figure. Whereas in the case on January 15 (left hand side in the figure), the band echoes were formed by the convergence between northwest and weaker northeast winds and the band echoes propagated

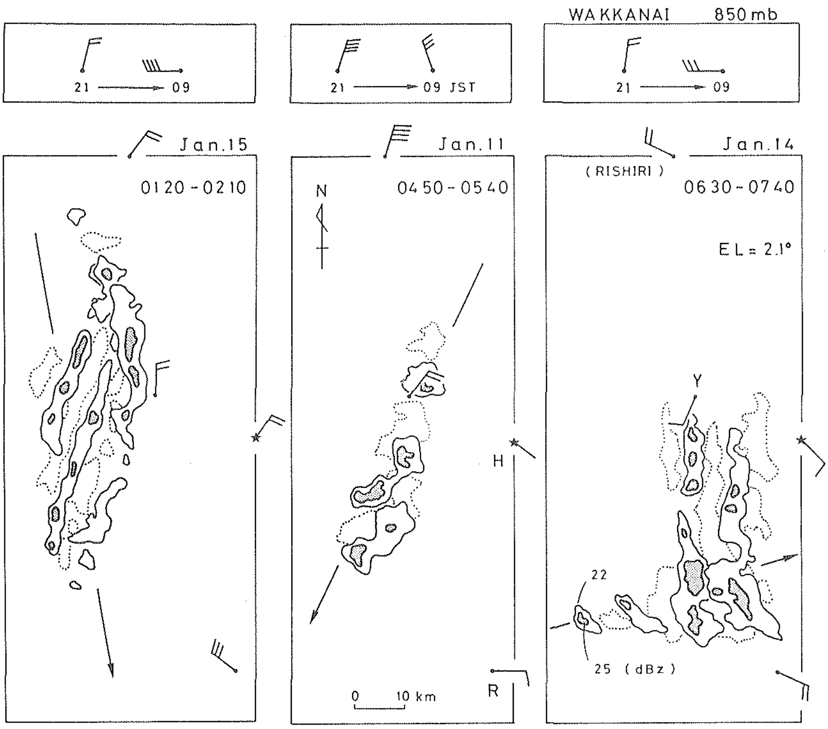



Fig. 11. Echo motions of three cases. The 850 mb wind at Wakkanai (top) and surface winds are also shown.

southward. In the case of January 11 (center), the radar echoes were not a band shape but cell like echoes which moved parallel to the downstream under the uniform strong northeast wind over the sea. And so, this case corresponded with the former case parallel to the wind direction. On the other hand, in the case of January 14 (on the right hand) when the merging of band echoes was observed, the northwest monsoon wind blew over the sea and the southeast cold land breeze blew offshore and the band echoes propagated eastward increasing its area. Generally speaking, the direction of the band clouds is parallel to the shear vector at the low level wind and the direction of echo motion depends on the 850 mb wind. In these cases, the lower winds were not uniform but were different around the coast line which suggested the existence of non-geostrophic winds. The locations of band echoes corresponded with the convergence zone of different directions of the winds. Accordingly, it was recognized that these band echoes were phenomena occurring in the relatively shallow layer above the surface along the west coast of Hokkaido that were affected by the cold land breeze from inland or the land effects of the differential of the friction. In particular, in the case where the monsoon wind and cold land breeze were exactly in the opposite directions, such as seen in the case on January 14, band echoes were developed parallel to the coast line as the balance of two different winds and moreover the location was almost stationary near the coast line as the merging was repeated.

As a result, the characteristic features of the CBC echoes which is the maintenance process of CBC along the west coast of Hokkaido are as follows: (1) The CBC was maintained in the uniform field of the synoptic situation covered by cold airmass over Hokkaido, and the movement of echoes was influenced by the non-geostrophic winds. (2) Band echoes were propagated to the southward under the conditions of surface winds between the northeasterly wind and northwesterly monsoon wind which corresponded to the initial stage of CBC. (3) Band echoes stagnated along the west coast of Hokkaido under the opposite direction of winds of the southeasterly land breeze and the northwesterly monsoon wind in the mature stage of CBC. (4) The CBC consisted of not only a band but two or three band echoes which took place in time repeating the merging near the coast. So a stationary CBC can be regarded as the maintenance process of band echoes at the mesoscale convergence zone formed along the west coast region of Hokkaido.

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