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DETECTION OF GRAUPEL IN WINTER THUNDERCLOUDS USING A DUAL POLARIZATION RADAR IN HOKURIKU, JAPAN

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1. INTRODUCTION

In early winter season, thunderclouds are frequently generated in Hokuriku, where locates on the south of the sea of Japan (Fig. 1). These thunderclouds are remarked with a high occurrence of positive lightning and huge amounts of electric charge which rushes toward the ground, hence accidents associated with such a lightning frequently happen in Hokuriku during this season. For warning of the lightning, it is important to detect a generation of graupel, because a riming process caused an electrification. The C-band dual polarization radar of Hokuriku Electric Power Company (HEPC) is available for the study on the winter thunderstorm.

In this paper, we investigate a geographical distribution of precipitation particles by the polarization method around the coastline in Hokuriku during the late December (cold air out breaks begin in this period) in 1999, 2000 and 2001 to derive the physical process of the thundercloud generation. Moreover, we make a comparison between the radar data and ground-based observation on precipitation particles to investigate a detectability of the graupel in the winter thunderclouds by the radar.

2. DATA AND METHOD

In this study, we use the horizontal reflectivity factor (Z_{h}) and the differential reflectivity (Z_{DR}) data of HEPC's dual polarization Doppler radar installed at Goishigamine (Fig. 1). This radar is located at 486 m in Above Sea Level (ASL) and covers within a range of 120 km; this enable to observe the precipitation at lower altitude (below 2 km in ASL) in almost whole coastal zone of the Hokuriku district. We mainly use the data of the radar at Goishigamine, though the same type of the radar was additionally operated at Mikuni (Fig. 1) during the period in 2000. For classifying the precipitation particle, a lookup table which

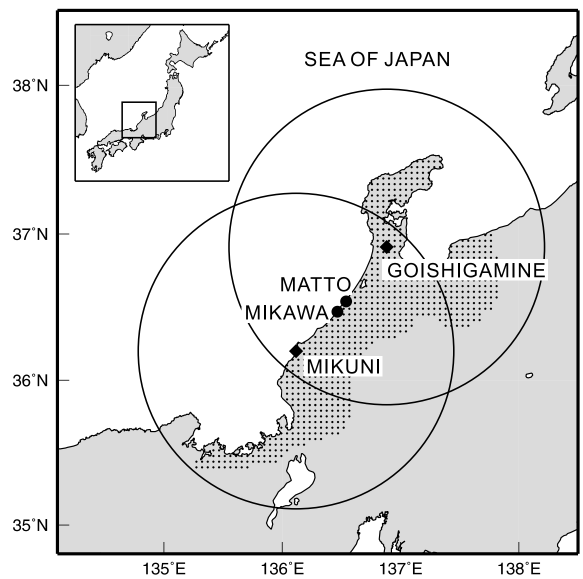

Figure 1: A map of the Hokuriku district (dotted area). Solid diamonds denote the locations of the C-band dual polarization Doppler radars installed at Goishigamine and Mikuni. In this study, we mainly use the data of the radar at Goishigamine. Large Circles represent the observation ranges (120 km) of each radar. Solid circles denote the locations of the ground-based observations (Matto and Mikawa).

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HEPC operationally uses is applied. With this table, a pair of $Z_{\mathrm{h}}$and $Z_{\mathrm{DR}}$is converted to 12 categories: rain, drizzle, rain or snow, dry snow, wet snow, dense snow, dry graupel, wet graupel, rain or graupel, wet hail, large wet hail, and rain or hail. In this period, the particles classified as “drizzle” apparently includes the small spheric ice particle, because of the temperature condition in winter.

Furthermore, grand-based observation for the precipitation particle carried out at Matto (in 1999 and 2000) and Mikawa (in 2001) during late December. In this observation, snow and graupel was recorded by a digital camera to validate the classification with the dual polarization radar.

3. AVERAGED DISTRIBUTION OF PRECIPITATION PARTICLES

The classification of the precipitation particles is applied in the region shown in Fig. 2. Figure 3 represents the vertical cross-section of the averaged distribution of the precipitation particles from December 24 to December 26, 2000. The horizontal axis denotes a distance from coastline defined as the vertical axis of Fig. 2. The contours denote a detection frequency averaged parallel to the coastline.

As for the distribution of snow particles on the land, the dry snow (ice crystal) tended to distribute in 1.0 – 2.5 km in ASL (Fig. 3a). Below the dry snow, small spheric ice particles (classified as drizzle) were located around 1 km in ASL (Fig. 3b). Moreover dense snow tended to exist below the small spheric ice particles (below 1.0 km in ASL as shown in Fig. 3c). These distribution means that ice crystal was generated above 1 – 2.5 km in height and the snow particles were developing and aggregating when they were falling to the ground.

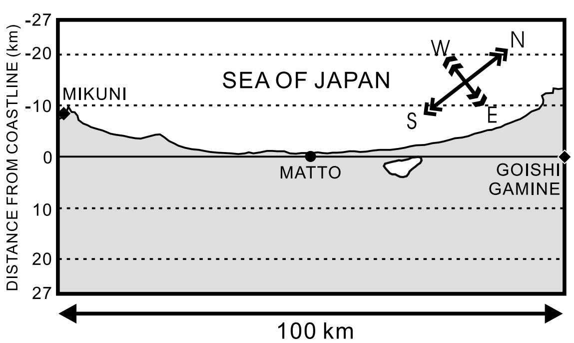

Figure 2: A region in which the classification of the precipitation particles is applied to investigate their geographical distribution. Coordinates of this region are rotated to be parallel to the coastline.

As to the existence of the graupel, almost all graupels were detected within 5 km from the coastline (Fig. 3f, g). Furthermore, detection height of the graupel was higher (Max. 2.5 km in height) than that of other precipitation particles. This existence of the graupel indicates that ascending wind usually generated around the coastline, since tremendous cloud water which is necessary for the generation of the graupel by riming process is generated in the updraft. Thereby, other precipitation particles also tended to concentrate around the coastline.

Comparing the dry snow on the land to that on the sea (Fig. 3a), the detection height on the land (Max. 2.3 km in ASL) was higher than that on the sea (Max. 0.6 km in ASL). During this period, northwesterly monsoon prevailed around this region, therefore convective precipitation systems tended to propagate from the sea to the land. Considering with this background, the convective precipitation system on the sea was shallow (the top height is about 1.5 km), then this precipitation system developed rapidly around the coastline to generate the graupel. This graupel fell to the ground immediately, because the falling velocity of the graupel is larger than other particles. Therefore, the convective precipitation system on the land consisted of only snow particles.

Discussing on a mechanism of updraft generation around the coastline, the Sea Surface Temperature (SST) around the Hokuriku district was over 10 °C, because of the warm current in the sea of Japan. On the other hand, the temperature on the land area was about 1 – 4 °C during this period. This means that the temperature gradient usually existed around the coastline and lower convergence zone was usually formed by

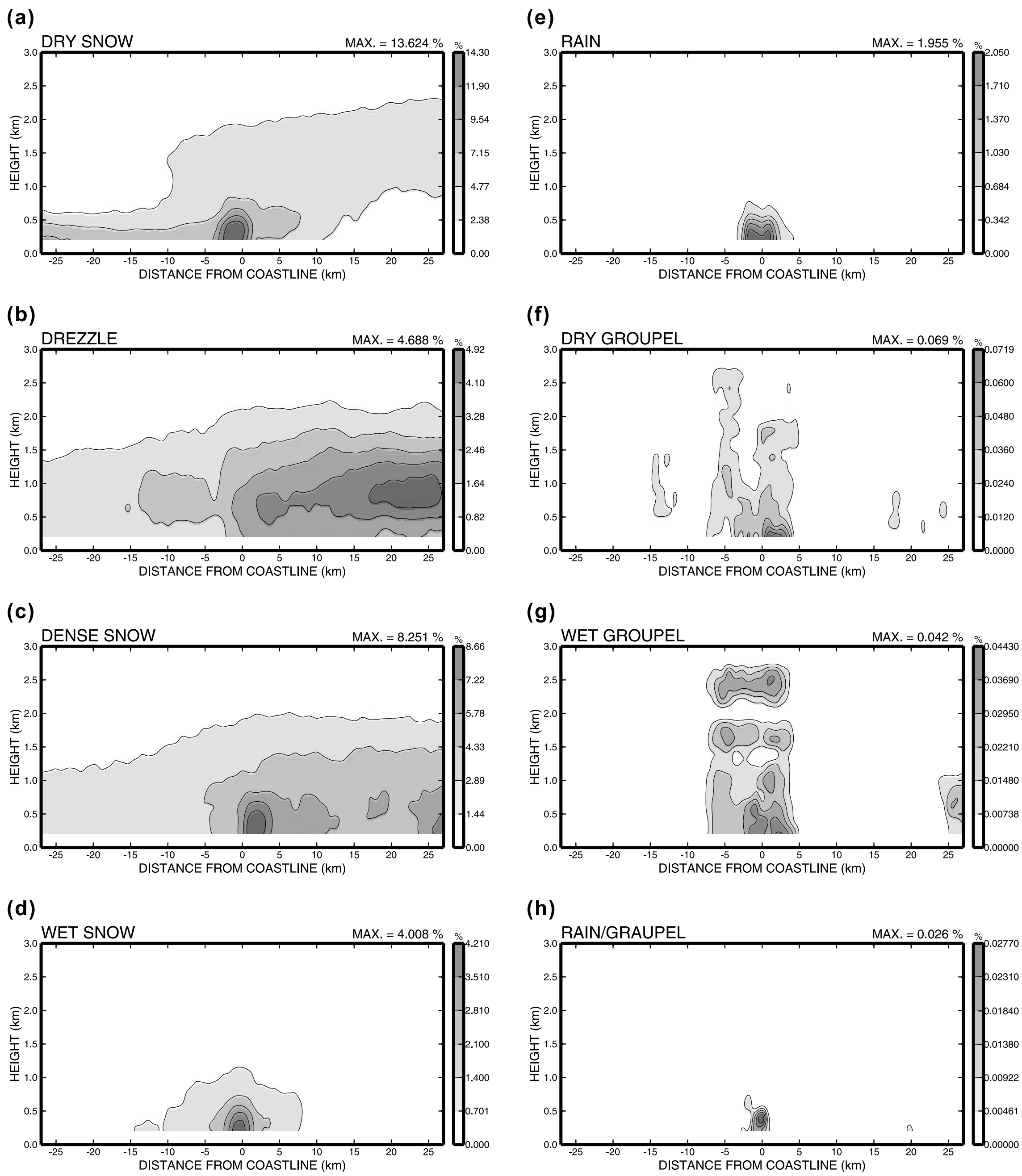

Figure 3: Vertical cross-section of the averaged distribution of the precipitation particles from December 24 to December 26, 2000. The horizontal axis denotes a distance from coastline defined as the vertical axis of Fig. 2. Contours denote a detection frequency averaged parallel to the coastline. a) Dry snow, b) drizzle, c) dense snow, d) wet snow, e) rain, f) dry graupel, g) wet graupel, and h) rain or graupel.

the local land breeze front. It is suggested that the convective precipitation system was enhanced by the lower convergence when it arrived around the coastline.

4. GRAUPEL EXISTENCE AND POSITIVE/NEGATIVE LIGHTNING

On 24 and 26 December 2000, the graupel was detected by using the classification method, when the lightning occurred near the ground observation site. Interestingly, it was observed that the thundercloud including the graupel caused the both positive and negative lightnings (Fig. **??**a), while the thundercloud in which the graupel had already fallen to the ground caused a positive lightning with large current only once (Fig. **??**b). As a result of riming process, the graupel has a negative electric charge in the temperature condition during early winter (Takahashi 1978). Therefore, this result supports the hypothesis that it causes the positive lightning with large current that the ice particle with the positive electric charge stays in the thundercloud for a long time after the graupel with the negative electric charge falls to the ground (Kitagawa 1996).

5. CONCLUSION

This study derived the generation mechanism of the thunderclouds around the coastline on the south of the sea of Japan during early winter and indicated the detectability of the graupel by the dual polarization radar. The analysis of the averaged distribution of the precipitation particles suggested that the lower convergence around the coastline generate the graupel to cause the lightning. Furthermore, it is indicated that the positive lightning with large current was associated with the convective precipitation system without the graupel.

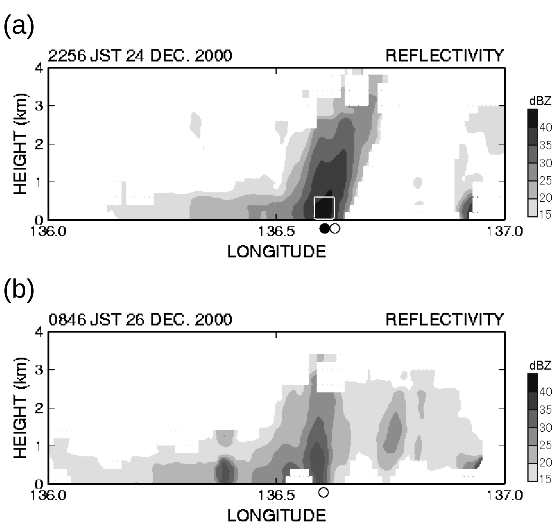

Figure 4: Vertical cross sections (West–East) of radar reflectivity of the thundercloud with lightning. Open and solid circles denote the locations of positive and negative lightning, respectively. a) 2256 JST (Japan Standard Time) 24 December 2000. b) 0846 JST 26 December 2000.

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