Observation and simulation on hydrometeor properties of snow clouds

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1. Introduction

Structure and evolution of hydrometeor properties as well as those of dynamics are important to understand precipitation systems. Cloud resolving models, which represent complicated microphysical processes, are a powerful tool to examine microphysical properties. On the other hand, polarimetric radar can obtain 3-dimensional information of microphysical properties such as shape, phase, and attitude of particles, and is a useful instrument to observe hydrometeor properties. Some hydrometeor classification methods have been recently developed using polarimetric parameters.

A polarimetric radar of Nagoya University was installed from December 2008 to March 2009 in Hokuriku, which is located in the coastal region of central Japan, to observe snow clouds over the Sea of Japan during cold air outbreak. Daily numerical simulation is also performed during the observation period. In this study, a case study is shown to compare hydrometeor properties in observation with numerical simulation result.

2. Observation and daily numerical simulation

New X-band polarimetric radars were introduced in November 2007 to Nagoya University. In the winter from December 2008 to March 2009, a polarimetric radar with a frequency of 9375 MHz (X-band) is installed at Oshimizu, Ishikawa of Hokuriku. The radar is referred to as “Oshimizu radar.” The specifications of Oshimizu radar is shown in Table 1. Oshimizu radar was operated with 12 Plan Position Indicator (PPI) scans in 5 minutes, and Range Height Indicator (RHI) scans were occasionally performed by manual operation.

During the observation period, numerical simulation was daily performed using Cloud Resolving Storm Simulator (CReSS) developed by Nagoya University (e.g., Tsuboki and Sakakibara 2002). The domain has 260 × 240 × 26. A horizontal resolution is 5 km. Variable vertical grid intervals with 150 m at the bottom are used and its average interval is 500 m. A microphysical process is formulated by a bulk method of cold rain parameterization. Hydrometeor types included in the model is cloud, rain, ice, snow, and graupel. These mixing ratios and solid hydrometeors’ number densities are predicted.

Table 1 Specifications of the Nagoya University polarimetric radar installed at Oshimizu.

Frequency	9375 MHz
Peak power	200 W
Pulse length	32 μs
Pulse compression	chirp(FM)
PRF	500 to 2000 Hz
Antenna diameter	2.0 m
Beam width	1.2°
Polarimetric wave	45°
Parameters	Z_{hh}, Z_{vv}, V, W, ϕ_{DP}, $\rho_{hv}(0)$, Z_{DR}, K_{DP}

3. Case study of a broad cloud band

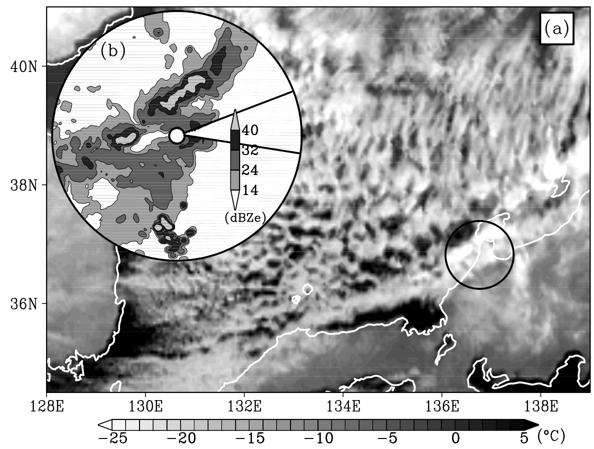

Fig. 1 (a) MTSAT infrared-1 image at 06 JST, 25 January 2009. The circle shows observation range of Oshimizu radar. (b) Radar reflectivity (dBZe) at a height of 1 km at 0530 JST, 25 January 2009.

During cold air outbreaks from 24 to 27 January 2009, the westerly to west-southwesterly wind was maintained in the western Sea of Japan. Figure 1a shows a satellite image at 06 JST (Japan Standard Time), 25 January 2009. A cloud band formed near the coast along the westerly to west-southwesterly wind in the western Honshu Island. The width of the cloud band was wider than the other cloud bands. At the landing part of the broad cloud band, brightness temperature is much low. This indicates localized development of the cloud band at the landing part. This development occurred within the observation range of Oshimizu radar. Figure 1b shows radar reflectivity at a height of 1 km. The reflectivity more than 40 dBZe is seen, which corresponds to low brightness temperature region shown in Fig. 1a. This reflectivity value is strong for clouds during cold outbreaks.

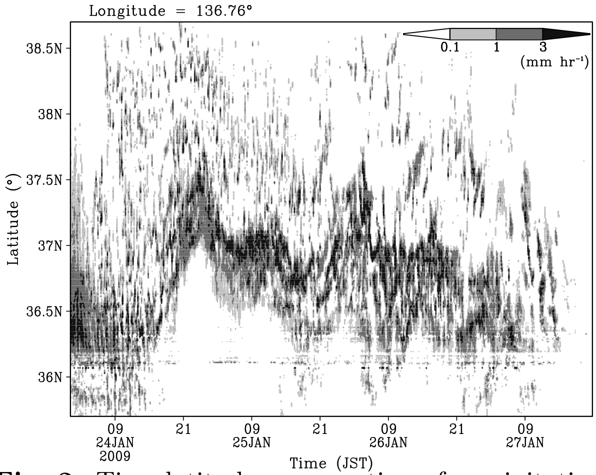

Fig. 2 Time-latitude cross section of precipitation intensity (mm hr^{-1}) of JMA radar along a longitude of 136.76°E. This longitude corresponds to the landing part of the broad cloud band.

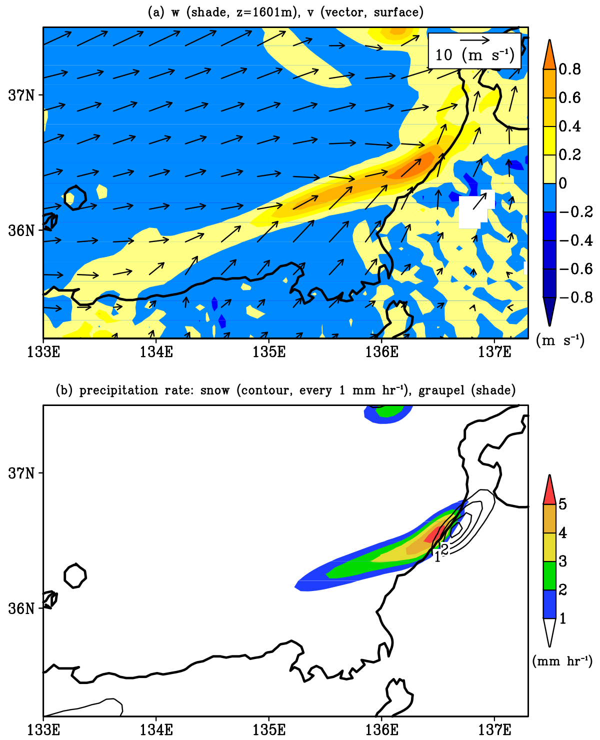

Fig. 3 (a) Vertical velocity (shade, m s^{-1}) at a height of 1601 m and surface horizontal velocity (arrows, m s^{-1}), and (b) precipitation rates (mm hr^{-1}) of snow (contours, every 1 mm hr^{-1}) and graupel (shade) in the simulation results. The corresponding time is 21 JST, 25 January 2009.

Figure 2 is time-latitude cross section of precipitation intensity (mm hr^{-1}) of JMA radar along the landing part of the broad cloud band. Although the cloud band slightly moves to the south, the broad cloud band was located between 36.5°N and 37°N from 00 JST, 25 to 09 JST, 27 January 2009.

The daily simulation results successfully reproduced the cloud band, although the cloud band in the simulation was not stagnant for a long time. The banded updraft extends toward Hokuriku (Fig. 3a), which corresponds to the cloud band. Surface wind vectors shows that southwesterly wind blowing from the land to the sea. The offshore southwesterly wind makes a convergence zone with the westerly wind. This results in the updraft zone along the cloud band. The updraft is intensified just before the landing. Surface precipitation rates of snow and graupel are shown in Fig. 3b. The maximum precipitation rate of graupel is located just behind of the intensified updraft maximum. The maximum of snow precipitation rate is located more inland than that of graupel. Frequent intensifications of the cloud band near the coast would result in a lot of precipitation along the cloud band, and graupel would account relatively large amount in the coastal region.

4. Summary

An observation of snow clouds were performed in Hokuriku, Japan from December 2008 to March 2009, using a polarimetric radar of Nagoya University. Daily numerical simulation experiments were simultaneously performed using CReSS with a horizontal grid spacing of 5 km.

From 00 JST, 25 to 09 JST 27 January 2007, a broad cloud band stayed in the southwest Sea of Japan near the landing part. The landing part of the broad cloud band was intensified. In the CReSS simulation, the updraft along the cloud band forms between southwesterly offshore wind and westerly wind to the north of cloud band, and is intensified near the landing part. The corresponding precipitation at the surface shows graupel accounts relatively large amount in the coastal region.

In the intensified precipitation region around the landing part, examination of polarimetric parameters' distribution would provide useful information associated with distributions of snow and graupel. This is left as a future work.

Acknowledgments

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References

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