Numerical simulation of the melting layer with a distorted bright band, observed on February 15, 2014, in Japan

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1. Introduction

A melting layer is typically identified as a narrow horizontal layer showing a strong radar reflectivity factor, namely a bright band, just below freezing level in range–height indicator (RHI). The same melting layer is observed as a circular bright band in a plan position indicator (PPI). The shape of a bright band in PPI is sometimes distorted by some factors such as sloping melting layer and/or nonuniform spatial distributions of hydrometeor and so on (Boodoo et al, 2010; Katsumata et al., 2016; Shusse et al. 2019). Therefore, monitoring a bright band on PPI can provide information about the characteristics of a melting layer in a wide area. On the other hand, since the observed shape of a bright band is a result of integrated effects from various processes such as dynamical, thermodynamical, and microphysical processes, it is necessary to use not only radar observation but also other observations and numerical simulations for understanding connections between physical processes in melting layer and observed bright band.

In the early morning of 15 February 2014, a circular bright band was observed over the Kanto Plain of Japan for several hours. In the beginning, the bright band showed a distorted shape, and then, changed its shape to a circle in a couple of hours. This report gives the preliminary results on the factor affecting the shape of the bright band and its transition in PPI, based on a numerical simulation.

2. Numerical simulations

A numerical simulation system was established based on the Japan Meteorological Agency's nonhydrostatic model (JMA-NHM, Saito *et al*., 2006) using the option of a double-moment bulk cloud microphysics scheme to predict both the mixing ratio and concentration of particles for all hydrometeor classes (i.e., cloud water, rain, cloud ice, snow, and graupel).

Numerical simulations were first performed at a horizontal resolution of 5 km (5km-NHM) over a 2500 km × 2500 km wide domain as shown in Fig. 1. Following this, the simulation with a 1-km horizontal resolution was performed (1km-NHM).

In the 5km-NHM simulation, the top height of the model domain was 22.1 km. The vertical grid spacing ranged from 40 m at the surface to 723 m at the top of the domain. Sixty vertical layers in a terrain-following coordinate system were employed. The integration time was 45 hours, with a time-step of 15 s. The initial and boundary conditions were obtained from the JMA's mesoscale analysis data (MANAL). The initial time was set to 1500 JST (UTC + 9) on 13 February 2014. Boundary conditions were provided with steps every 3 hours.

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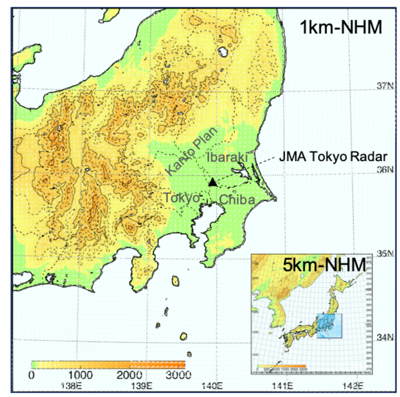

Fig. 1. Computational domains for the numerical simulations: 5km- and 1km-NHM.

The vertical grid arrangement in the 1km-NHM was the same as in the 5km-NHM, and the domain size was 500 km × 500 km (Fig. 1). The integration time used was 30 hours with a time step of 4 s. The initial and boundary conditions were obtained from the 5km-NHM simulation. The initial time for the 1km-NHM simulation was 6 hours later than that of the 5km-NHM.

3. Observed bright band

Figure 2 shows the imageries of radar/raingauge analyzed precipitation intensity during the early morning on 15 February 2014 provided by JMA. Since these imageries are made by including radar reflectivity factor in PPI scans at different elevation angles, bright band features appear in the imageries when a melting layer exists. At 0030 JST, apparently strong precipitation up to several tens mm h^{-1} was detected over a part of Tokyo, Chiba, and Ibaraki prefectures, while most of Kanto Plain and surrounding area were widely covered by weak precipitation. This apparently strong precipitation area looked firstly D-shape (Fig. 2a), then gradually changed its shape, and finally became almost a circle (Fig. 2c), a typical feature of a bright band.

4. Results of numerical simulation

Figure 3 shows the simulated snow and graupel amount below the freezing level (melting snow and graupel) which is plotted as the 3.8^o PPI centered at the JMA Tokyo radar located in Kashiwa city, simply representing the spatial distribution of a bright band in the model. The D-shape appeared at 0100 JST (Fig.3a). It gradually changed and finally became a circle (Fig. 3c). This simulated feature is essentially consistent with that observed (Fig.2). Figure 4 shows the vertical distribution of the mixing ratio of melting snow and graupel particles, exactly representing

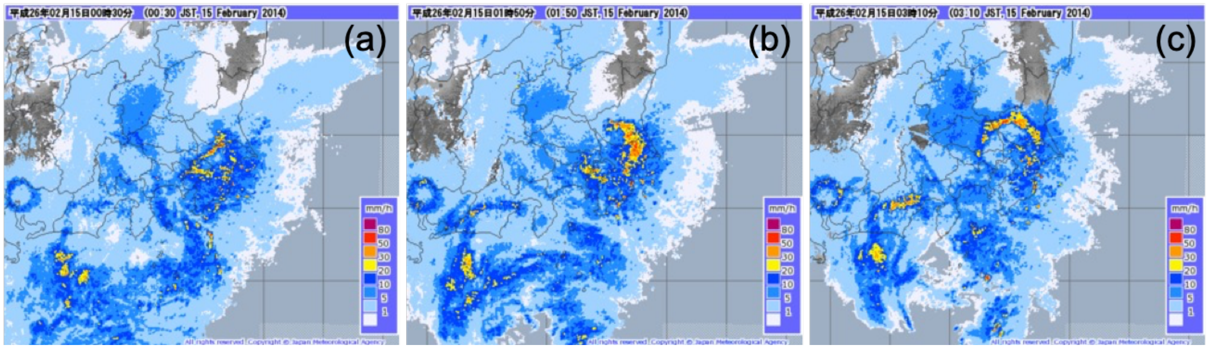

Fig. 2. Imageries of radar/raingauge analyzed precipitation intensity at (a) 0030, (b) 0150, and (c) 0310 JST on 15 February 2014 provided by JMA.

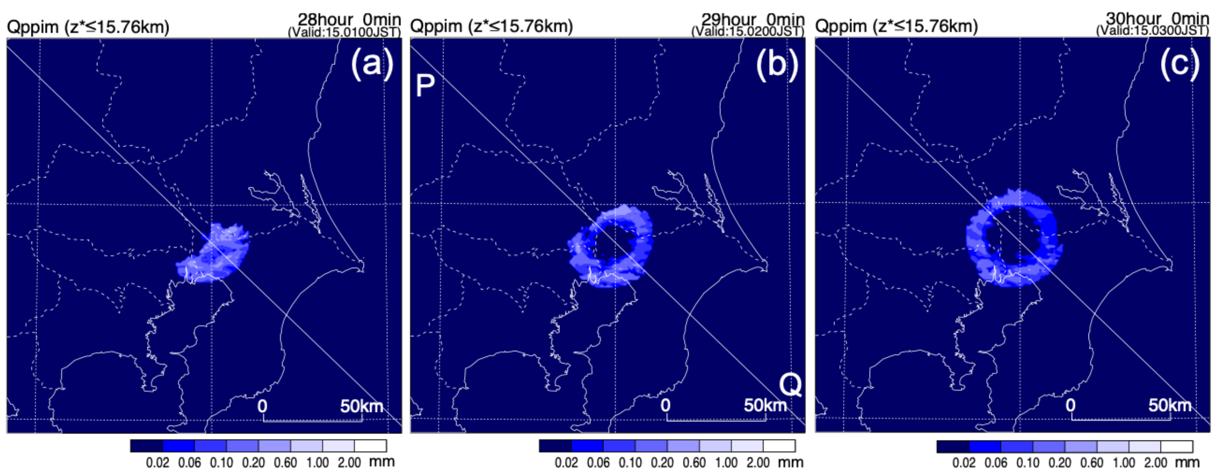

Fig. 3. Simulated PPI of snow and graupel amount below the freezing level at (a) 0100, (b) 0200, and (c) 0300 JST on 15 February 2014.

the melting layer in the model. While, on the southeast side, the melting layer was located at about 1.3 km height, it fell to the ground around the half of line PQ. This system moved to the northwest. On the ground, simulated air temperature declined from the southeast to northwest across the freezing point, which was well consistent with the surface observation (not shown). The results of numerical simulation indicated that the observed D-shape bright band and its transition to a circle were caused by the steeply sloping melting layer moving from the southeast to the northwest.

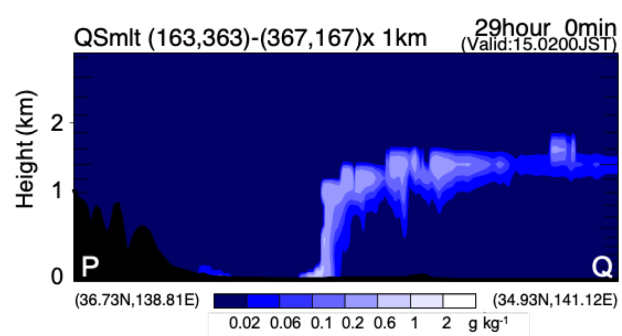

Fig. 4. Simulated distribution of mixing ratio of snow and graupel particles below freezing level in the vertical cross-section on the line P-Q shown in Fig.3b at 0200 JST on 15 February 2014.

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References

Boodoo, S., D. Hudak, N. Donaldson, and M. Leduc, 2010: Application of dual-polarization radar melting-layer detection algorithm. *J. Apple. Met. Clim.*, 49, 1779-1793.

Katsumata, M., S. Mori, B. Geng, and J. Inoue, 2016: Internal structure of ex-Typhoon Phanfone (2014) under an extratropical transition as observed by the research vessel Mirai, *Geophys. Res. Lett.*, 43, 9333–9341, doi:10.1002/2016GL070384.

Saito, K., T. Fujita, Y. Yamada, J. Ishida, Y. Kumagai, K. Aranami, S. Ohmori, R. Nagasawa, S. Kumagai, C. Muroi, T. Kato, H. Eito, and Y. Yamazaki, 2006: The operational JMA nonhydrostatic mesoscale model. *Mon. Wea. Rev.*, **134**, 1266–1298.

Shusse, Y., T. Maesaka, K. Kieda, and K. Iwanami, 2019: Polarimetric radar observation of the melting layer in a winter precipitation system associated with a south-coast cyclone in Japan. *J. Met. Soc. Japan*, 97, 375-385.