Factors of model underestimation of snow fall over the Japan-Sea coastal areas in middle Japan: Comparison with observed precipitation particles

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1. Introduction

Polar air outbreak from the Eurasia Continent often brings heavy snow fall over the Japan-Sea coastal areas during the winter season. The Japan Meteorological Agency (JMA) operational mesoscale model (horizontal resolution: 5 km), however, usually underestimates snow fall amounts over plain areas, while mountainous areas have overestimations. In Snow and Ice Research Center of National Research Institute for Earth Science and Disaster Prevention, located in the plain area (see the location marked by symbol of X in Fig. 2), the size and terminal velocity of precipitation particles have been captured every minute by a charge-coupled device camera and a Parsivel optical disdrometer. Then by using the method of Ishizaka et al. (2013), the main type of solid hydrometeors contributing to precipitation has been identified from the relationship between measured size and fall speed every five minutes (e.g., see Fig. 1a).

In this study, hydrometeor types simulated by JMA nonhydrostatic model (NHM: Saito et al. 2007) with difference resolution are compared with identified observation ones, and the underestimation of snowfall amounts over plain areas is examined.

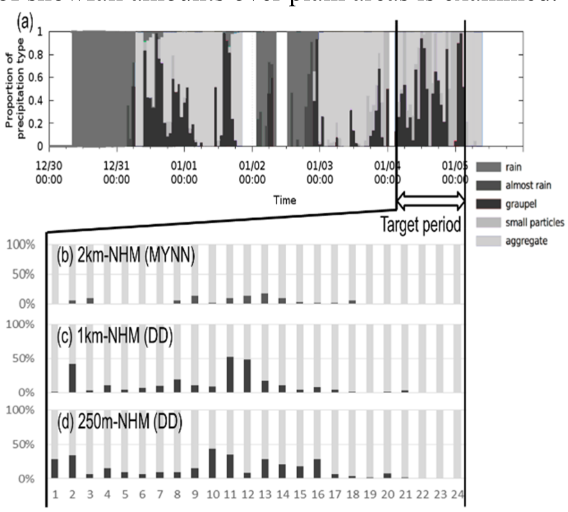


Fig. 1 (a) Identified observation types of hydrometeors between 30 November 2012 and 05 January 2013. Same as (a), but results simulated by (b) 2km, (c) 1km and (d) 250m models during one day from 03 JST January 2013.

2. Experimental designs

One-day forecasts from 03 JST (=UTC+ 9hs) 04 January 2013 were conducted using initial and boundary conditions produced from 3-hourly available JMA mesoscale analyses with a horizontal resolution of 5 km. At first a 5km-NHM with a large domain (2500x 2000km) was run, and then for a small domain of 850x550km 2km and 1km-NHMs were run nested within 5km-NHM forecasts. Further, for a domain of 330x250km 500m and 250m-NHMs were run nested within forecasts of 1km-NHM. A bulk-type microphysics parameterization scheme in which two moments are treated only for ice hydrometeors is used for precipitation processes, and the Kain-Fritsch convection parameterization scheme is additionally used only in 5km-NHM. The turbulence closure scheme of Mellor-Yamada-Nakanishi-Niino level-3 (MYNN: Nakanishi and Niino 2006) is used in 5km, 2km, and 1km-NHMs, while Deardroff (DD) scheme (1980) is used in 1km, 500m and 250m-NHMs.

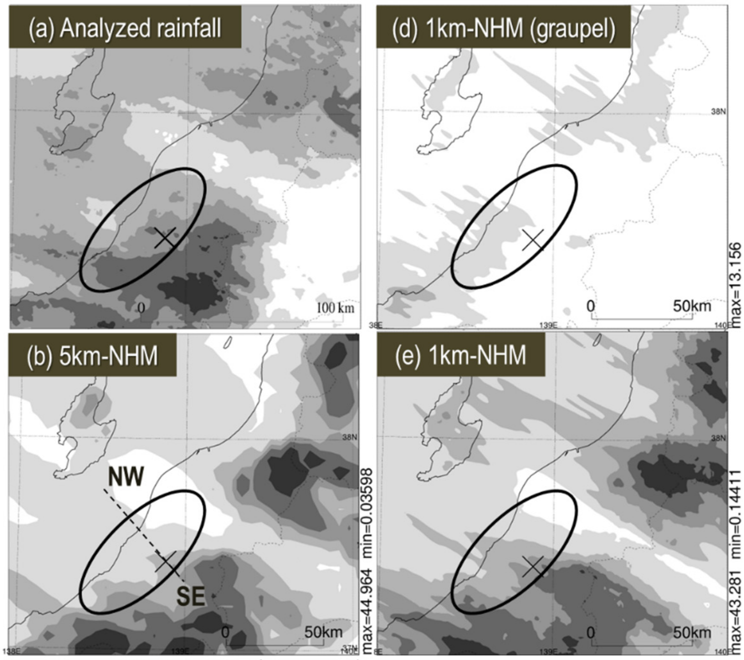
3. Comparison with observations

The underestimation of snow fall amounts including graupel over plain areas indicated by ellipses in Figs. 2a and 2b is improved using 1km-NHM (Fig. 2d). This improvement is mainly caused by the production of graupel around coastal areas (Fig. 2c), while 5km-NHM hardly produces graupel (not shown) and graupel ratios of 2km-NHM (Fig. 2b) are less 50% of those of 1km-NHM (Fig. 1c). The proportion of graupel in 1km-NHM, however, is considerably smaller in comparison with identified observation types of hydrometeors (Fig. 1a). This small ratio is not improved using 250m-NHM (Fig. 1d). These improvements and resolution dependency agree with Kato (2011, 2012).

4. Effect of terminal velocity

In 5km-NHM, instead of graupel, snow particles could be excessively produced and most of them move to mountainous areas without falling down due to the terrain-induced upward motion (Fig. 3a).

To ascertain this hypothesis, a sensitivity experiment in which the terminal velocity of snow on land is replaced with that of graupel was conducted using 5km-NHM. The results (Figs. 2c and 3b) show the improvement of underestimation of snow fall amounts over plain areas, and that of excessively production of snow particles, which suggests that a new parameterization of the production of graupel is necessary for coarse resolution models.



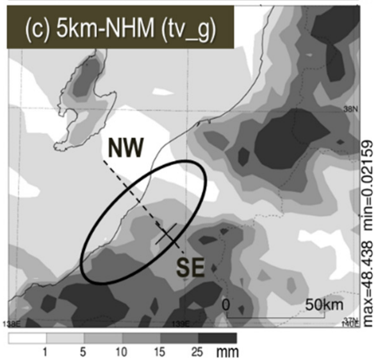


Fig. 2 (a) Distribution of 24-hour accumulated Rain-Raingauge analyzed rainfall amounts at 03 JST 05 January 2013. Same as (a), but total precipitation amounts simulated by (b, c) 5km and (e) 1km models with MYNN scheme. (d) Same as (e), but graupel amounts. For (c), the terminal velocity of snow on land was replaced with that of graupel.

5. Other Impacts on snowfall amounts

Much water cloud is necessary for the production of graupel (i.e. riming process). Since cloud ice hardly exists in warm-rain clouds with the temperature higher than -4°C, cloud ice crystal nucleating activity is restricted above -4°C to increase cloud water amounts. The results of 2km- and 1km-NHMs, however, showed no improvement for the production of graupel. Another sensitivity experiment in which the evaporation of graupel is restricted also hardly impacts the graupel fall amounts on the ground, because low-level humidity around coastal areas is high (~80%). On the other hand, the restriction of the evaporation of snow causes the increase of snowfall amounts over the sea and the decrease over plain areas, which agrees with Kato (2011).

References

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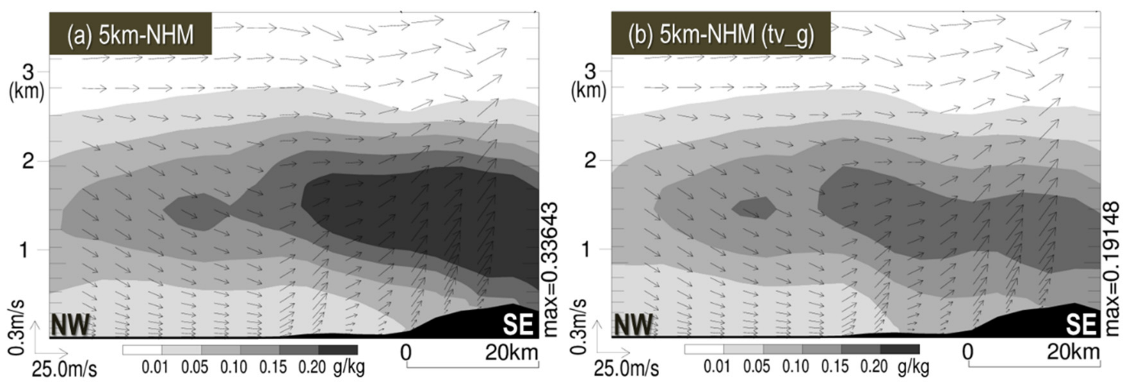

Fig. 3 (a) Vertical cross section of 24-hour mean snow mixing ratios on the dashed line in Fig. 2b, simulated by 5km-NHM. Wind vectors show streams projected on the section. (b) Same as (a), but the terminal velocity of snow on land was replaced with that of graupel.