Resolution dependence of hydrometeor structures generated by cloud resolving model

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1. Introduction

Cloud Resolving Models (CRMs) with complicated cloud physical parameterization forecast various cloud physical variables with high resolution in time and space. Microwave radiometer brightness temperatures (MWR TBs) are sensitive to water vapor, cloud liquid water, and precipitation, assimilation of MWR TBs to CRMs will be of great use. However, cloud physical validation of CRMs has not sufficiently been carried out.

This paper investigates the characteristics of forecasting of hydrometeors and sensitivities with the bulk cloud microphysics scheme of the CRM for observed snow clouds over the Sea of Japan. Special attention will be given to sensitivities of CRM's horizontal resolution to the hydrometeors forecasting.

2. Cloud resolving model

The CRM developed by Japan Meteorological Agency (JMA) is used in this study (JMANHM: Saito *et al.*, 2006.). The bulk cloud microphysics scheme is employed in the JMANHM. This scheme predicts the mixing ratios of six water species (water vapor, cloud water, rain, cloud ice, snow and graupel) and number concentrations of ice particles (cloud ice, snow and graupel).

3. Results

The JMANHM successfully reproduced the observed features of snow clouds. However, in comparison spaceborne microwave radiometer observations and airborne in situ observations with the model simulations, the model overpredicted the mass concentrations of snow, but underpredicted the amount of cloud liquid water and graupel. In the model, depositional growth of snow was dominant due to the increase in the number concentration of snow by conversion of cloud ice to snow. Snowfall speeds, ice nucleation processes and vertical wind velocities related to the horizontal grid size of the model were sensitive to reduction of snow overprediction..

A set of experiments were conducted using different horizontal resolutions to quantify the resolution sensitivities. Initial and boundary conditions for a separate 1-km run, 0.5-km run, 0.25-km run and 0.125-km run are obtained by using hourly forecast from 2-km run. Figure 1 shows time series of area-averaged (135-136E, 37-38N) 1-h precipitation. There is no remarkable difference in each simulation on surface precipitation forecast. Horizontal distributions of vertically integrated total condensed water simulated by the 1- and 0.125-km simulations are shown in Fig. 2. Distribution of total water of 0.125-km simulation is almost similar to that of 1-km simulation except for dominance of smaller scale structures. Vertical profiles of horizontally averaged total condensed water amount and each hydrometeors amount are shown in Fig. 3. There is also no remarkable difference in each simulation on total condensed water forecast. Those simulations with higher resolution have larger amount of graupel and cloud water and smaller amount of snow relative to those with lower resolution; however, the result of 0.5-km run is almost closed to convergence.

Figure 4 shows vertical profiles of horizontally averaged vertical velocities. In the area-averaged vertical velocity field (Fig. 4a), those simulations with higher resolution have larger value of he maximum of averaged vertical velocities relative to those with lower resolution. The result of 0.5-km run is also closed to convergence, which is consistent with result in hydrometeor structures. In contrast, the amplitude of vertical velocity increases with mesh size becoming small (Fig. 4b). Furthermore, the height of peak value lowers. The increasing of amplitude of vertical velocity is remarkable under the bottom of clouds, indicating that it has a small effect on hydrometeor's production. These results suggest that simulation with dx=~0.5-km resolution is enough to produce structures of vertical velocity related to hydrometeors of snow clouds in this case.

Additional cases (e.g. other snow clouds and/or summer deeper convective clouds) will be analyzed to verify microphysical sensitivities of CRM presented in this case.

Acknowledgments

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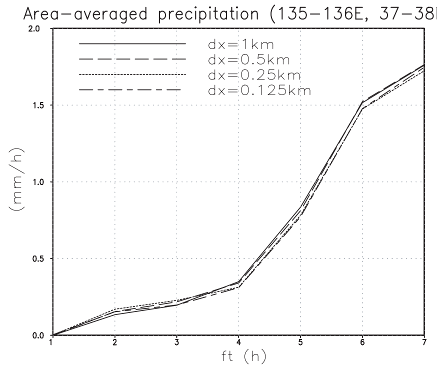

Fig. 1. Time series of area-averaged (135-136E, 37-38N) 1-h precipitation derived from 1- (solid), 0.5- (broken), 0.25- (dotted) and 0.125-km (dashed) experiments until 5 hours forecast.

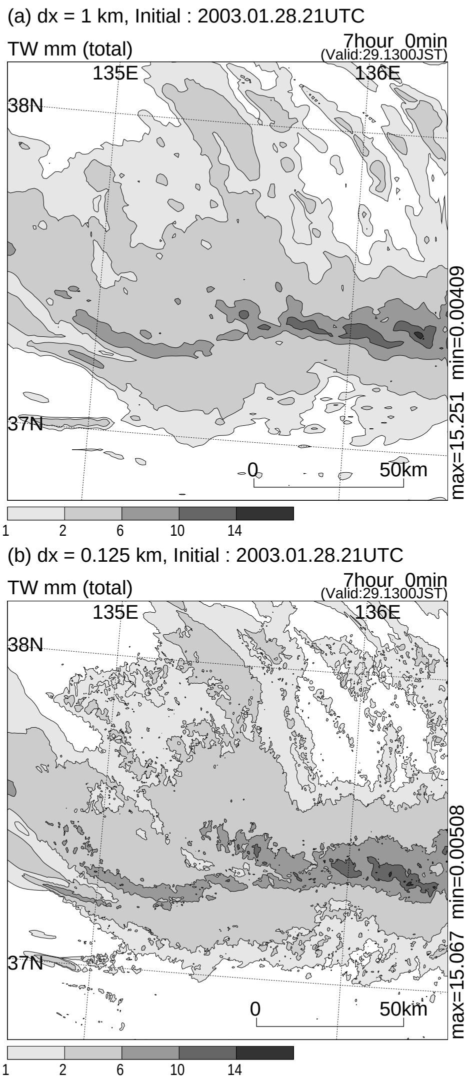

Fig. 2. Vertically integrated total condensed water for the (a) 1- and (b) 0.125-km experiments at 1300 LST 29 Jan. 2003 (5 hours forecast).

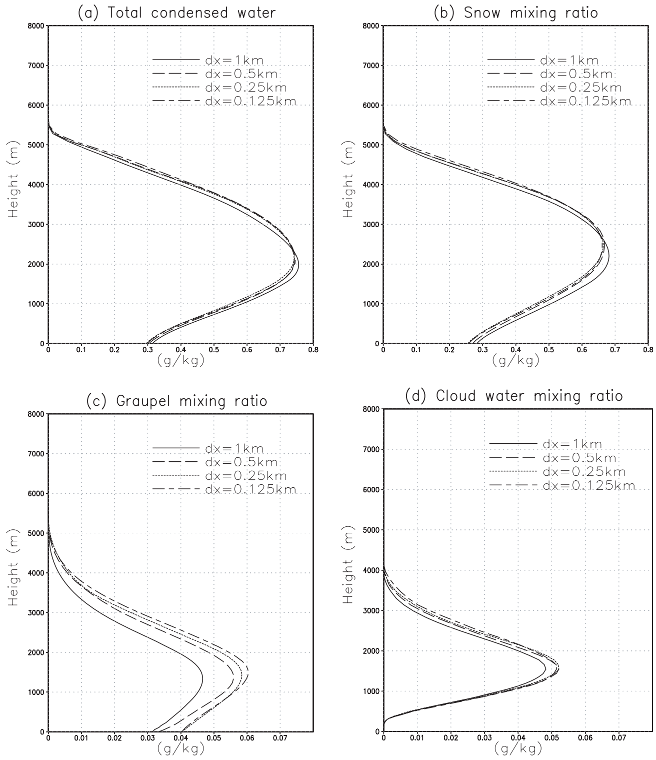

Fig. 3. Vertical profiles of horizontally-averaged (135-136E and 37-38N) (a) total condensed water, (b) snow mixing ratio, (c) graupel mixing ratio and (d) cloud water mixing ratio derived from 1- (solid), 0.5- (broken), 0.25- (dotted) and 0.125-km (dashed) experiments at 1300 LST 29 Jan. 2003 (5 hours forecast).

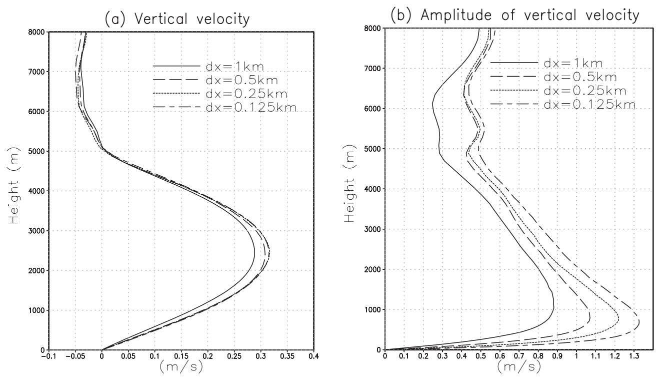

Fig. 4. Vertical profiles of horizontally-averaged (135-136E and 37-38N) (a) vertical velocities and (b) amplitude of vertical velocities derived from 1- (solid), 0.5- (broken), 0.25- (dotted) and 0.125-km (dashed) experiments at 1300 LST 29 Jan. 2003 (5 hours forecast).

Reference

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