Dependency of horizontal and vertical resolutions, and turbulence schemes on snowfall forecasts

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1. Introduction

Kato and Hayashi (2007) showed that the Japan Meteorological Agency (JMA) nonhydrostatic model with a horizontal resolution of 5 km overestimated snowfall over mountainous regions on the Japan-Sea side of the Japan Islands and underestimated it over plane regions, whereas such forecast tendencies are improved when a horizontal resolution of 1 km was used. In this study, the dependency of horizontal resolution (5km, 2km, 1km, 500m), the lowest vertical level of the model (LV: 20m, 10m), number of vertical layers (NV: 50, 70), and turbulence scheme (Mellor-Yamada level 3: M-Y3, Deardroff: DD) on snowfall forecasts is examined.

2. Experimental designs

At first, 12-hour forecasts are performed every 6 hours during 16-20 December 2009 in a 2500 x 2500 km^2 domain including the Sea of Japan (not shown) by the 5km-model. Their initial and boundary conditions are produced from 6-hour available JMA mesoscale analysis with a horizontal resolution of 5 km. The other models whose model domains are shown in Fig. 1b are nested with the 3-hour forecast of the 5km-model. Verification datasets for 5 days are produced from hourly output of the last 6-hour forecasts. A bulk-type microphysics parameterization scheme in which two moments are treated only for three ice-phases is used for precipitation processes, and the Kain-Fritsch convection parameterization scheme is additionally used in the 5km-model. In the experiment with 70 vertical levels, many vertical layers are set in the lower level for the depth of 41st vertical layer to be 100 m.

3. Results

The control simulation (LV: 20m, NV: 50, M-Y3) of the 1km-model well reproduces the horizontal distribution of raingauge observed accumulated precipitation amounts (Fig. 1), although the amounts are slightly underestimated in the Hokuriku area. The precipitation amounts averaged over plain region with a height lower than 100m are about 90 mm both in observations and 1km-model control simulations (Fig. 2), indicating that the 1km-model has also quantitatively high forecast accuracy. Among simulated hydrometeors, the ratio of graupel to snow + graupel increases as the horizontal resolution becomes higher, and it exceeds 50 % around coastal regions. This ratio of graupel agrees with observations.

Figure 2 shows the precipitation amounts of rain, snow, graupel and their total, averaged over the sea and over plain regions with a height lower than 100m. The difference between total precipitation amounts simulated by 1km-model (dx01) and 500m-model (dx005) with DD is small, whereas the 5km-model (dx05) considerably underestimates the amounts. It should be noted that the graupel is rarely simulated by the 5km-model because strong updrafts to be necessary for its production are suppressed. In the cases of DD = 10m (thin lines in Fig. 2), precipitation amounts for M-Y3 increase compared with that for DD independent of the horizontal resolution. This is because M-Y3 transports strong winds to the near surface due to the vertical mixing, and increase latent heat flux from the sea (not shown).

The differences of precipitation amounts among over the sea, plain region (< 100 m), mountainous region (> 500 m) and middle height region are compared with the control experiment of the 1km-model (Fig. 3). The case with DD = 10m increases the amounts for all regions, and the other cases increase the amounts over the sea and decrease them on land. The differences are small for NV=70 (L70) and the case in which evaporation rates of snow and graupel are set half (fac0.5). This is because the water vapor flux into the land decreases associated with the increase of precipitation amounts over the sea for L70 and the suppression of the evaporation over the sea for fac0.5. The precipitation amounts over the sea are considerably larger for DD than for M-Y3. This is because M-Y3 forcibly produces convective mixing layer over the sea to reduce the atmospheric instability, and consequently snow clouds more easily form and develop for DD than for M-Y3 to increase precipitation amounts.

References Kato, T. and S. Hayashi, 2007: *CAS/JSC Research Activities in Atmospheric and Oceanic Modeling*, **37**, 5.13-5.14.

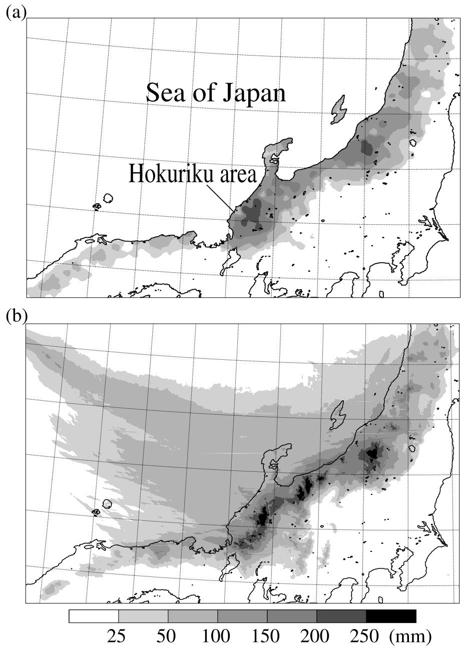

Fig. 1 Five-day accumulated precipitation amounts (a) observed by raingauges and (b) simulated by 1km-model.

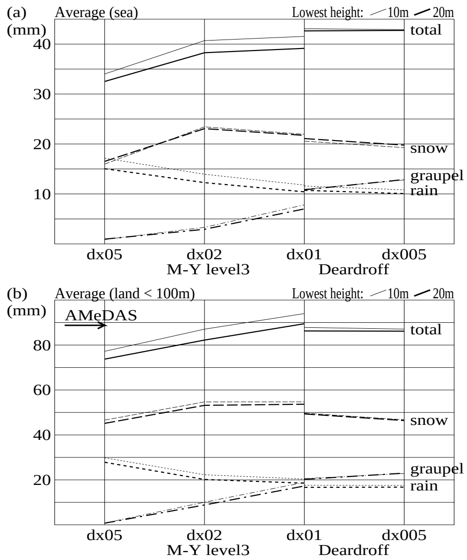

Fig. 2 Precipitation amounts averaged over (a) the sea and (b) the plain region with height lower than 100 m. AMeDAS denotes the raingauge observation.

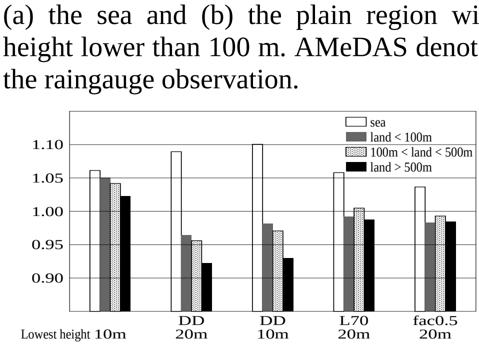

Fig.3 Comparison with the control experiment of 1km-model (LV: 20m, NV: 50, M-Y3). Axis of ordinate shows the ratio of averaged precipitation amounts.