Inclusion of a Prognostic Equation for the Number Concentration of Cloud Ice in the Mesoscale Model

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The Japan Meteorological Agency operates a nonhydrostatic mesoscale model (MSM) with 5-km horizontal grid spacing (Saito et al., 2007). A bulk parameterization scheme for cloud microphysics based on Lin et al. (1983) and Murakami (1990) has been adopted in the MSM since the advent of the model's predecessor, developed at the Forecast Research Department of the Meteorological Research Institute (Ikawa and Saito, 1991). In this scheme, water classes are categorized into six forms: water vapor, cloud water, rain, cloud ice, snow and graupel. While mono-dispersion is assumed for the size distribution of cloud water and cloud ice, an exponential function is assumed for that of rain, snow and graupel.

Although the original cloud microphysics scheme predicted the mixing ratios of the six water classes and the number concentrations of cloud ice, snow and graupel, the microphysics of the operational MSM before December 2008 predicted only the mixing ratios in order to reduce the computational time taken. Furthermore, some simplification and elimination of the original cloud microphysics scheme were applied. These MSM modifications, especially the simplification of the conversion process of cloud ice to snow, made the growth of snow slow; as a result, excessive amounts of cloud ice remained in the atmosphere, as shown in Fig. 1 (a). When the number concentration of cloud ice (N_i) is not predicted, N_i is determined by the temperature or supersaturation ratio over ice for each step of time integration, and the diameter of cloud ice is determined only by the mixing ratio of cloud ice (q_i). Since an autoconversion concept is assumed in this scheme to parameterize the aggregation of cloud ice to form snow (Lin et al., 1983), the growth of cloud ice cannot be expressed and the conversion of cloud ice to snow becomes slow.

On the other hand, when N_i is predicted, it is independent of q_i, and the diameter of cloud ice is determined not only by q_i but also by N_i, and the growth of cloud ice and conversion of cloud ice to snow or graupel can be sophisticated (Murakami, 1990). Cloud microphysics using a

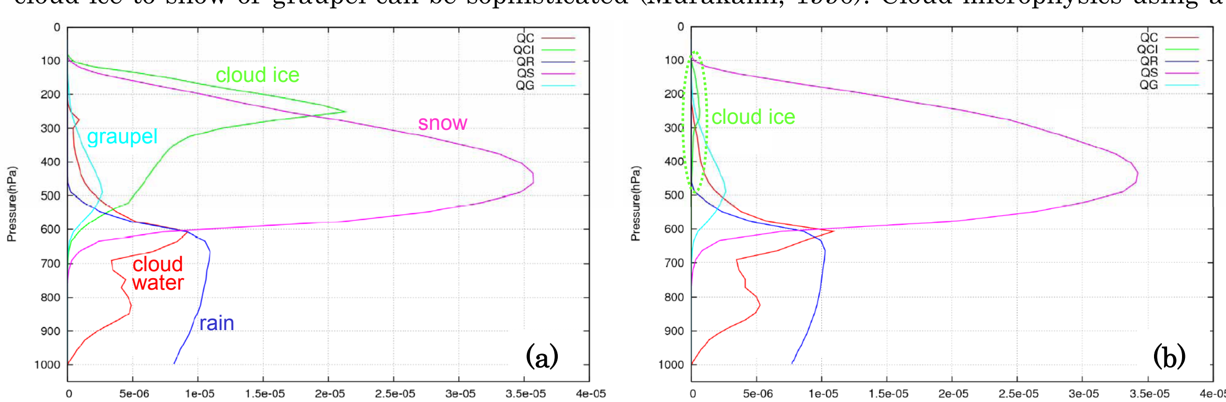

Fig. 1. Area-averaged vertical profiles of mixing ratios of cloud water, cloud ice, rain, snow and graupel [kg/kg] for 21 UTC on 22 August 2004 with MSM runs started at 15 UTC
(a) Number concentration of cloud ice not predicted
(b) Number concentration of cloud ice predicted.

prognostic equation for N_i eliminates excessive amounts of cloud ice, as shown in Fig. 1 (b). Furthermore, as shown in Fig. 2, the efficiency of conversion of cloud ice to snow becomes high, and the distribution of snowfall with the prognostic equation for N_i becomes better than that without prediction of N_i. Inclusion of the prognostic equation for N_i has been adopted in the operational MSM since December 2008.

References

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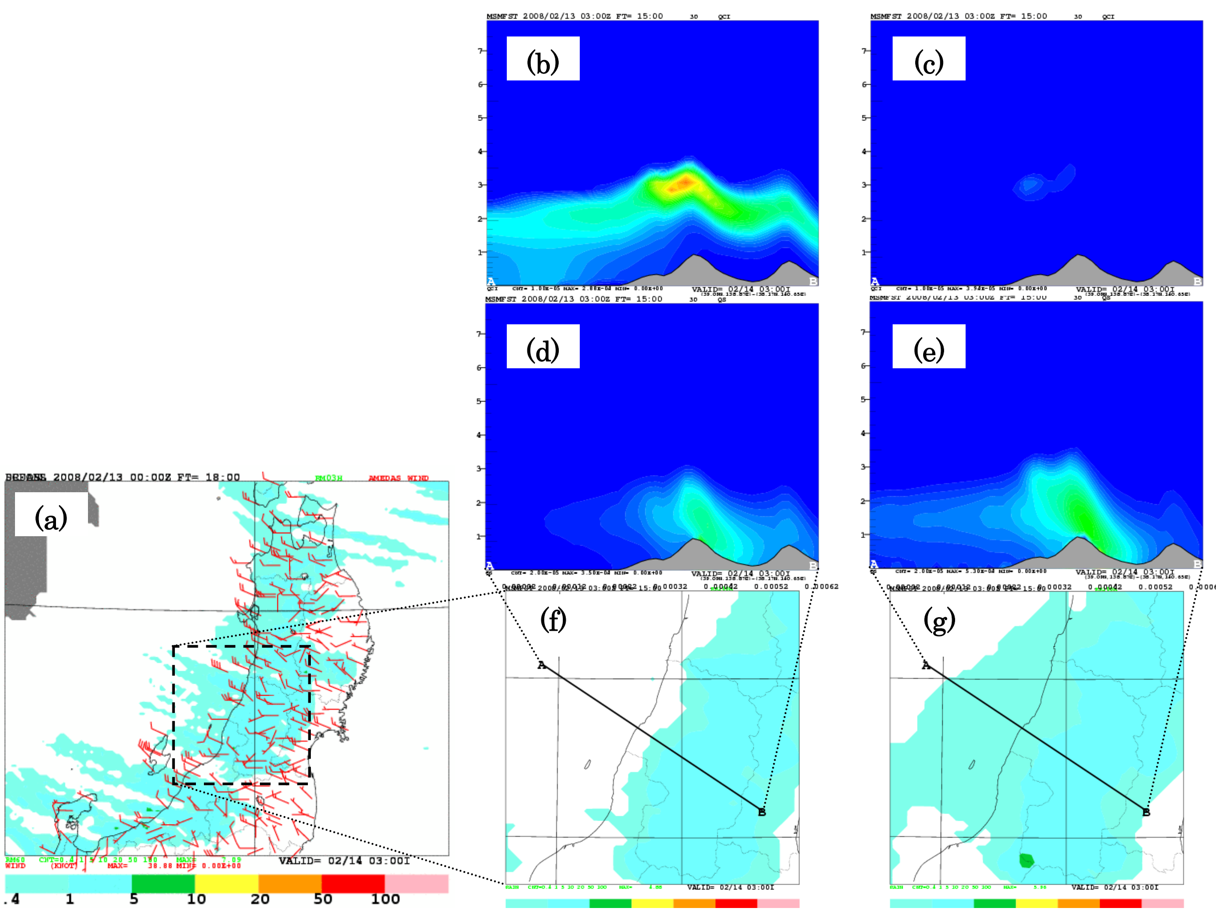

Fig. 2. Horizontal distributions of snowfall [mm/3 h] and vertical cross sections of mixing ratios of cloud ice and snow [kg/kg] at 18 UTC on 13 February 2008
(a) Observation of snowfall
(b), (d) and (f) Predicted vertical cross sections of mixing ratios of cloud ice and snow, and snowfall when the number concentration of cloud ice is not predicted
(c), (e) and (g) Equivalent to (b), (d) and (f), but for the case where the number concentration of cloud ice is predicted.