Improvement of Microphysical Parameterization in a Japan Meteorological Agency Nonhydrostatic Model with a High Resolution and Its Effect on Simulation Result.

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1. Introduction

We are developing a regional climate model with several kilometers mesh on the basis of JMA-NHM (Japan Meteorological Agency NonHydrostatic Model; Saito et al., 2001) in order to examine the change of precipitation intensity around Japan under the situation of global warming, and finally to contribute to IPCC (Kato et al. 2004). Microphysical processes are important for this purpose, because they affect the accuracy of prediction. Some improvements have been made on the microphysical parameterizations which are related to liquid hydrometeors in the model. We also performed a simulation of low-level stratocumulus clouds to examine the properties of improved parameterization, as a preliminary output for the climate prediction.

2. Improvements of microphysics in JMA-NHM

The microphysical processes in JMA-NHM are formulated with a bulk parameterization composed of three solid and two liquid water categories. The ice, snow, and graupel categories are represented by a 2-moment parameterization which has two prognostic variables, mixing ratio Q and number concentration N, to determine size spectra of hydrometeors. However, the cloud and rain categories were represented by a 1-moment parameterization which uses only Q. This old scheme is reformed so as to have 2-moment parameterization for cloud and rain in this study.

The old scheme assumes a size spectrum of cloud droplets to be mono-dispersion with constant number concentration 10^8 m^{-3}, while an exponential function is applied as a rain drop size spectrum. On the other hand, a new introduced scheme uses gamma functions to represent the size spectra of cloud droplets and rain drops, so as to make them more realistic. Figure 1 shows examples of those size spectra in the new and old schemes.

The new scheme has the following improvements in microphysical processes, compared with the old one. Some processes of warm rain such as auto-conversion, accretion of cloud droplets, and self-collection and breakup of rain drops are introduced based on Cohard and Pinty (2000). Increment of number concentration of cloud droplets due to CCN (Cloud Condensation Nuclei) activation is diagnostically calculated based on the maximum super-saturation estimated with updraft velocity. The terms of the interaction with solid hydrometeors are modified so as to reflect the improvements of size spectra of cloud droplets and rain drops.

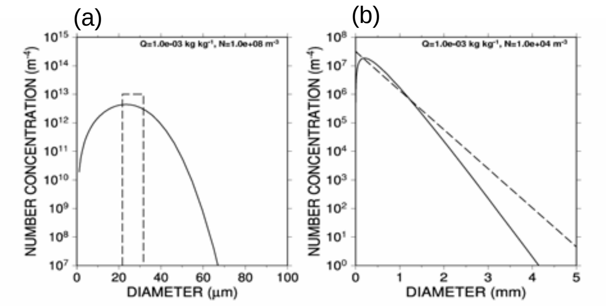

Fig. 1 Size spectra for (a) cloud droplets and (b) rain drops. Solid and broken lines correspond to those in the new and old schemes, respectively.

3. Numerical experiments

Figure 2 shows the model domain of 1-km horizontal resolution with the area of 640x640 km^2. Vertically, 36 layers with variable intervals of 50 m to 220 m are employed. The model top is located at 4.7 km. The domain covers around the sea off the coast of Sanriku, the Tohoku, Japan. In this region, the low-level stratocumulus clouds often appear in the cold air mass flowing on relatively warm sea from the northern high pressure in summer. Integrated time interval is 5 s. The integration is conducted up to 8640 time steps (12 hours). Regional analysis data of JMA are referred as the boundary condition every hour. Initial time is 2100 JST, 1 Aug, 2001.

According to IR image of GMS, low-level clouds covered the sea off the coast of Sanriku at the present and the next days. We consider only warm rain process, because the targeted low-level stratocumulus clouds contain no ice particle.

Simulations with the new and old microphysical schemes are conducted to study the effect of the reformulations in microphysics on the model results.

4. Simulation results

The low-level stratocumulus clouds simulated by the model covers about 40000-km^2 area with the cloud base at about 300-m height and the cloud top at about 600-m height. For both simulations with the new and

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old schemes, the amplitudes of vertical velocity are within 0.3 m/s, and the mixing ratios of cloud water are around 0.1 g/kg. A difference between the two schemes is apparent in the amount of rain water. Figure 3 shows the mixing ratio of rain water at 570-m height. The simulation with the new scheme produces rain water much more than the old one.

Figure 4 shows the relations between mixing ratio, and number concentration in the different ranges of mean-volume diameter. As shown in Figs. 4a and 4b, the new scheme produces large variations in the number concentration of cloud droplets Ncw, although the old scheme assumes no variation in Ncw. This result indicates that the new scheme can give the larger maximum values of mean-volume diameter (Fig. 4a), and that the new scheme can make the value of auto-conversion rate larger than the old one. Additionally, the number concentration of rain drops Nr is generally much larger for the new scheme, as shown in Figs. 4c and 4d. This enhances the accretion of cloud droplets by rain drops. Therefore, the new scheme produces the greater amount of rain water.

5. Summary

The microphysics in JMA-NHM has been improved with respect to the liquid hydrometeors. Its effect was examined in the simulations with low-level stratocumulus clouds in summer.

The new scheme modified the rain water distribution when it is compared with the old scheme. The new scheme produced greater values of the mixing ratio of rain water. This is due to the greater variations in number concentration of Ncw and Nr which are produced in a prognostic manner in the new scheme. The variation in Ncw accelerates auto-conversion, and that in Nr enhances the accretion of cloud droplets by rain drops.

Acknowledgements

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References

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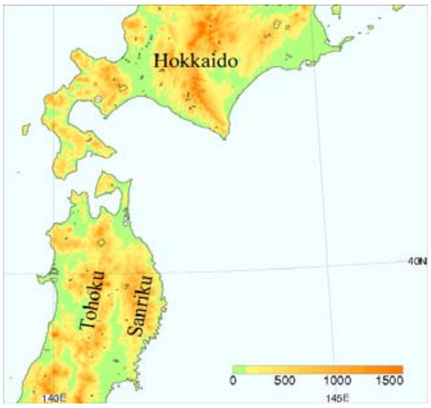

Fig. 2 The model domain and orography.

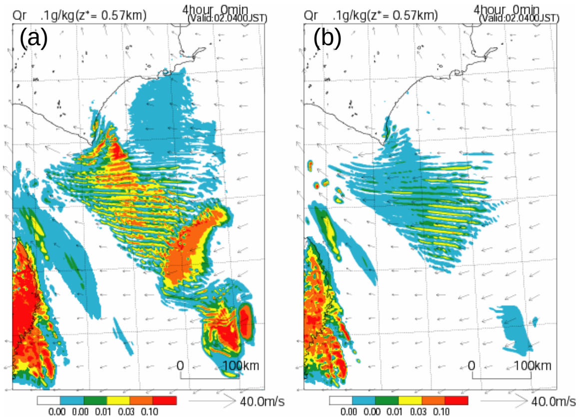

Fig. 3 Mixing ratio of rain water for (a) new and (b) old schemes at 570-m height.

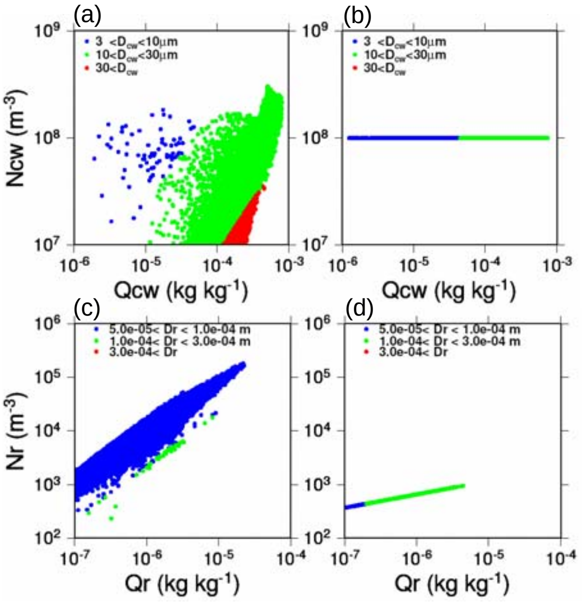

Fig. 4 Relations between mixing ratio Q and number concentration N in the different ranges of mean-volume diameter D which are shown by colors. (a) and (b) indicate the relations for cloud water, while (c) and (d) indicate those for rain water. (a) and (c) correspond to the results with new scheme, and (b) and (d) correspond to those with old scheme.