The sensitivity of passive microwave responses to the hydrometeor properties simulated by a cloud resolving model in real rainfall systems associated with Baiu front

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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; therefore, CRMs serve as a valuable tool to be used in satellite remote sensing of precipitation for inferring information about clouds that cannot be directly observed. However, it is indispensable that CRM's outputs are verified with observational data to ensure the information being inferred from them is of the highest possible quality. Several observational data should be used fully to improve CRMs by estimating biases within the models and conducting needed adjustments to their physics and parameters to reduce those biases.

This study investigates the sensitivity of microwave brightness temperatures (TBs) simulated by a radiative transfer model to the hydrometeor properties simulated by CRM for the cloud microphysical validation of CRM. The sensitivity of simulated equivalent radar reflectivity (Ze) is also analyzed. TBs and Ze simulations are conducted for real rainfall systems associated with Baiu front around Okinawa Islands, Japan on 8 June 2004, which are compared to the timely corresponding satellite radiometer and grand-based radar observations, respectively Special attention will be given to the characteristics and sensitivities of CRM's ice hydrometeors forecasting.

2. Models

The CRM used in this study is JMA-NHM (Saito *et al.*, 2006), which is an operational nonhydrostatic mesoscale model developed by Japan Meteorological Agency (JMA). Rainfall systems associated with Baiu front has been simulated with double nested models, with a horizontal grid size of 5 and 2 km. In the inner model, explicit cloud microphysics scheme is only used as precipitation process. Results presented here are from the inner model only.

The bulk cloud microphysics scheme is employed in the JMA-NHM. 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). The size distributions for each hydrometeors are represented by exponential functions. Mixing ratios and number concentrations are predicted for each ice particles, the slope and intercept of a given particle distribution are calculated, respectively.

Radiative transfer model (RTM) developed by Liu (1998) that used plane-parallel and spherical particle approximations is used for TBs simulations in this study. TBs are calculated for output from the JMA-NHM model simulations, compared to the timely corresponding AMSR-E observations on board Aqua.

3. Comparisons of simulations with observations

The JMANHM successfully reproduced the location and precipitation intensity of observed rainfall systems. The results of comparison of JMA-NHM simulation with AMSR-E observation. are shown in Fig. 1. Figure 1a shows the absorption index retrieved from 18 GHz data of AMSR-E. Colors varying from blue to red correspond to increasing absorption. The areas with large absorption index denote a large amount of liquid water in precipitation clouds. Simulated absorption index. is shown in Fig. 1c. In comparison with AMSR-E observation, the area with larger absorption index in simulation is a little smaller; however, the magnitude of simulated absorption index is in almost agreement with the observation. This result indicates that JMA-NHM well simulates the particle characteristics in liquid phase. Figure 1b shows the scattering index retrieved from 89 GHz data of AMSR-E. Colors varying from red to blue correspond to increasing scattering. The areas with large scattering index denote a large amount of ice hydrometeors. Figure 1d shows simulated scattering index. The location of the area with large scattering index is well simulated; however, the simulated scattering index is larger than observed one. This feature indicates that JMA-NHM overestimates an amount of ice hydrometeors.

The JMA-NHM simulation is also compared with ground based radar observations. Figure 2a shows a contoured frequency with altitude diagram (CFAD; Youter and Houze, 1995) computed by the radar reflectivity observed by NICT Okinawa Bistatic Polarimetric Radar (called COBRA). The highest probabilities follow a coherent pattern with the peak density steadily decreasing with height from between 25 and 35 dBZ near the melting level to between 10 and 20 dBZ near the strom top around 13 km. Below the melting level, peak probabilities are almost constant to the surface, indicating that evaporation is small. Figure 2b shows the simulated reflectivity CFAD. The highest probabilities also show a coherent pattern with the peak density like the observation. Below the melting level, there is an overall good agreement between the observation and the simulation. However, peak probabilities are shifted high between 4 km and 8 km, while low above 8km. Maximum simulated reflectivities around the melting level are higher than observed. This result indicates that the model accurately calculates the particle characteristics in liquid phase but overestimates the ice particle's size.

Investigation of profiles of simulated hydrometeors indicates that the dominant form of ice in this simulation is snow with much smaller amount of graupel and cloud ice (not shown). The overprediction of snow contents result in the overestimate of snow size, scattering index and radar reflectivity.

4. Sensitivity experiments

Comparison with radiometer and radar observation suggests the model overprediction of snow size. In this study, sensitivity experiments (named FVS and PSACW) are conducted that involved adjustments to the ice microphysical parameters that are important to snow growth.. In the FVS experiment, larger snowfall speed is used so that snow particles hardly remain in the air. In the PSACW experiment, riming threshold for snow to graupel conversion is reduced. Reducing this threshold favors more snow to graupel. In both sensitivity experiments, snow contents are reduced (not shown), indicating the both adjustments have a positive impact for reduction of snow content. In the experiment involved both adjustments (named FVS & PSACW), snow contents are significantly reduced from control experiment.

Figure 3a shows the reflectivity CFAD for the FVS & PSACW experiment, denoting some improvements over the control experiment shown in Fig. 2b. The improvement is the shift of probability from stronger echo to weaker echo between 4 km and 8 km above the melting level, and maximum reflectivities are also reduced around the melting level. However, the probability of reflectivities above 8 km is still lower than observation.

Figure 3b shows the scattering index retrieved from 89 GHz TBs for sensitivity experiment. The overestimate of the scattering index is reduced in the sensitivity experiment, reflecting the reduction of simulated snow diameters. However, despite the improvements of the sensitivity experiment, the simulated scattering index is still slightly higher than observation.

4. Summary

TBs and Ze simulations were conducted for real rainfall systems associated with Baiu front around Okinawa Islands, Japan, which were compared to the timely corresponding AMSR-E and COBRA radar observations, respectively. An almost good agreement is obtained between the simulated and observed TBs and Ze; however, JMA-NHM slightly overestimated a diameter of ice hydrometeors, especially a diameter of snow particles. The overestimation of snow diameters were reduced by some ice microphysical process adjustments of JMA-NHM such as larger snowfall speed and reduced riming threshold for snow to graupel conversion.

Additional cases will be analyzed to verify microphysical sensitivities of the model presented in this case and to improve the CRM and RTM by estimating biases within the models and conducting needed adjustments to their physics and parameters to reduce those biases.

Acknowledgments

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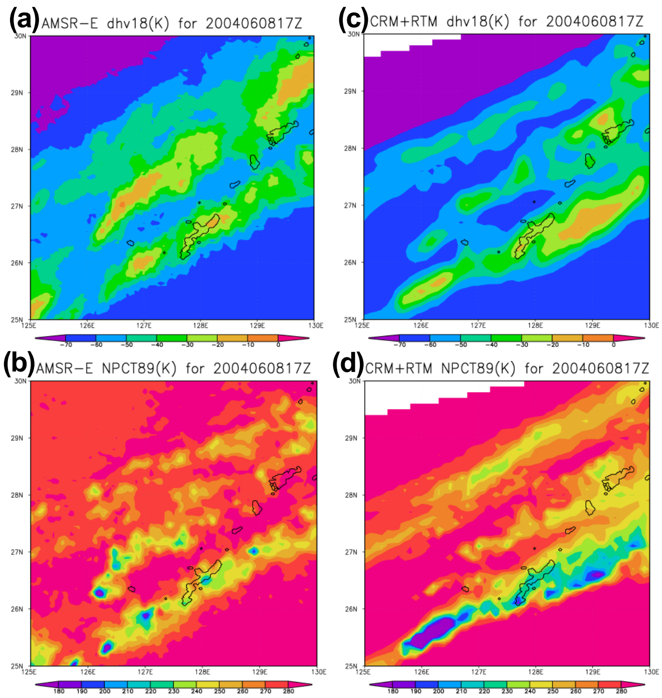

Fig. 1. (a) 18 GHz Absorption index and (b) 89 GHz scattering index retrieved from brightness temperatures observed by AMSR-E at 17 UTC on 8 June 2004. (c) 18 GHz Absorption index and (b) 89 GHz scattering index simulated by JMA-NHM at 17 UTC on 8 June 2004.

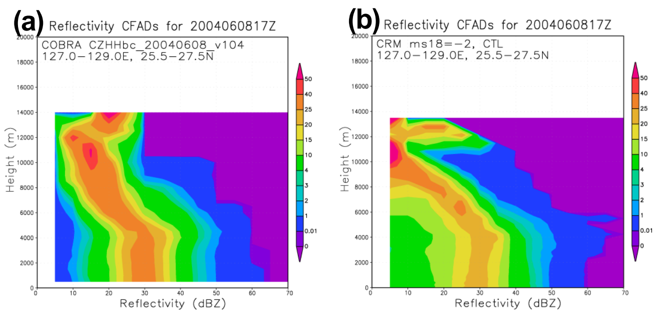

Fig. 2. Reflectivity CFADs in 127-129E and 25.5-27.5N at 17 UTC on 8 June 2004 derived from (a) observed CORBA radar reflectivity data and (b) the JMA-NHM simulation.

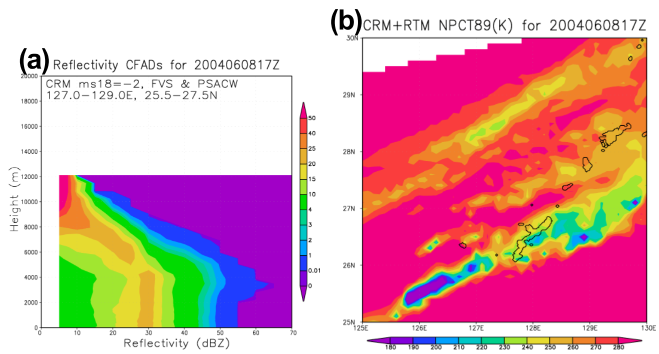

Fig. 3. (a) Reflectivity CFAD in 127-129E and 25.5-27.5N at 17 UTC on 8 June 2004 derived from the JMA-NHM sensitivity simulation (FVS & PSACW). (b) 89 GHz scattering index simulated by the JMA-NHM sensitivity simulation (FVS & PSACW) at 17 UTC on 8 June 2004.