An improvement of mesoscale convective structures of a nonhydrostatic model in the tropical region using satellite data

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Abstract

The cloud microphysics of deep convective systems over the tropical open ocean simulated by a nonhydrostatic model using satellite simulators are evaluated in terms of the joint histogram of cloud-top temperature and precipitation echo-top heights. The control experiment shows biases related to underestimation of stratiform precipitation and a higher frequency of precipitating deep clouds whose top height is higher than 12 km compared with the Tropical Rainfall Measuring Mission (TRMM) data, although it shows good agreement for the horizontal distribution and statistical cloud size distributions of deep convective systems. The biases in the joint histogram are improved by changing the cloud microphysics parameters in the framework of a single-moment bulk microphysics scheme (Fig. 1). In particular, the effects of the size distribution of precipitating hydrometeors are examined. Global simulations are analyzed and examined using a control run and modified microphysics about characteristics of vertical cloud structures among different regions. Finally, characteristics of effective radius in the precipitation and anvil clouds are investigated using satellite data.

Introduction

The horizontal and vertical cloud structures are important for the precipitation and energy budget of atmosphere. One important issue in a cloud modeling is the parameterization of the microphysical processes of hydrometeors. Single-moment schemes that calculate only the mass concentrations of hydrometeors have been widely used for large-scale experiments and long-term cloud simulations. Many efforts toward evaluation and improvement of microphysics schemes based on in-situ aircraft observation data and ground radar observations have been made. Recent research has evaluated and investigated this fact using satellite observation data such as those from the Tropical Rainfall Measuring Mission (TRMM), Cloudsat, and CALIPSO.

Part 1. Evaluation of a stretched NICAM using geostationary satellite and TRMM PR in the tropical open ocean

The cloud and precipitation properties of the stretched NICAM for a single-moment bulk microphysics scheme are evaluated using the TRMM PR and TBB with a satellite simulator in the tropical open ocean. Numerical simulations reproduced a horizontal cloud size distribution similar to those observed by geostationary satellites. The effect of modifications of the size distributions of precipitating hydrometeors is investigated on the joint histogram of TBB and PTH from the TRMM PR for mesoscale convective systems over the tropical open ocean. The control experiment with the default parameters of NSW6 exhibits bias in the joint histogram and the CFADs of deep clouds; that is, in the joint histogram analysis the frequency of the deep cloud category is overestimated and PTH is overestimated above 12 km in the control run. The control run also underestimates the frequency of mid-cold clouds. The modified microphysics simulation improves the structure of joint histogram and CFADs of deep clouds. The modified microphysics affects the average vertical temperature profile and the frequency of strong updraft and downdraft vertical velocities.

Part 2. Analysis of a global simulation

Global NICAM simulations with a 3.5 km horizontal resolution are done and analyzed using TRMM and CloudSat. The T3EF structure is similar to the stretched NICAM results. The modified microphysics improves the joint histogram structures. The OLR of the modified simulation is lower than the control run with a wide range of anvil clouds. The Tropical cyclone Fengshen is reproduced; the bias of upper troposphere is improved and precipitation system is well organized in the modified simulation. The regional differences of T3EF are examined in land and ocean area. The frequency of larger precipitation areas increased and the size of convective core is reduced in the modified simulation.

Discussion

The modified simulation exhibits underestimation of OLR comparing to the NOAA OLR data. There are some solutions to improve the result. One of them is consideration of the terminal velocity of cloud ice. It has strong impact in the stretched NICAM results. The parameterization of size distribution is directly a link to effective radius. Effective radiuses are important parameters for the energy budget of clouds. The effective radius is evaluated using retrieved effective radius from CloudSat and CALIPSO data (Hagihara data). The vertical structure of effective radius distribution is improved than the control run (Fig. 2). The effective radius of the cloud top is examined using MODIS MYD06_L2 data. The effective radius of cloud top height is improved using parameterizations of cloud ice size distribution depending temperatures.

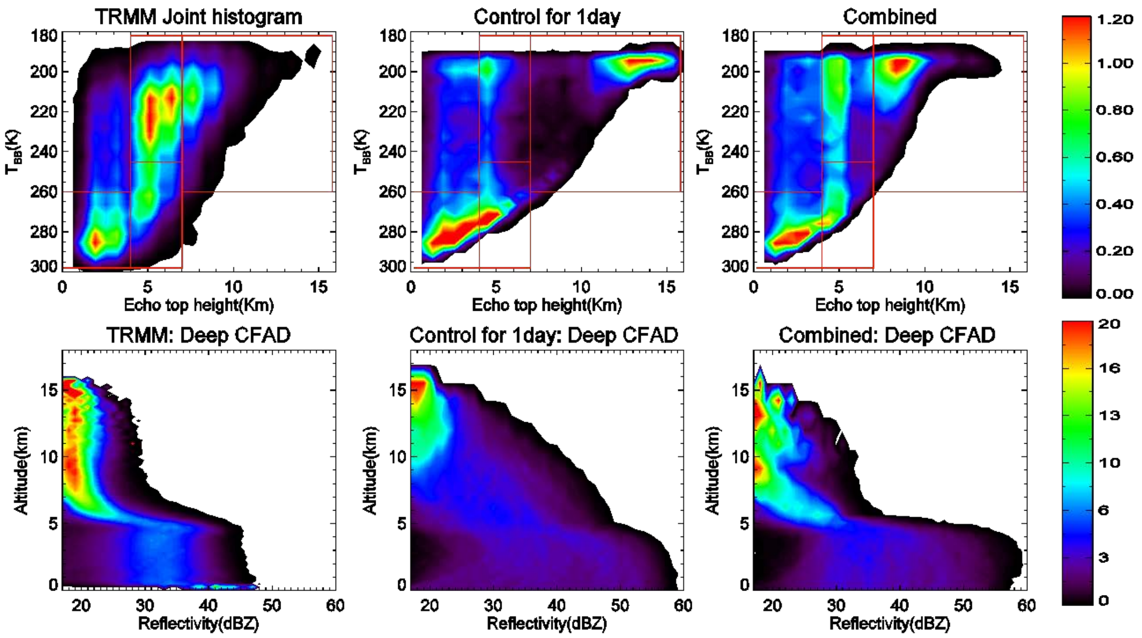

Figure 1. Joint histograms of PTH and TBB from TRMM observation (top left), the control experiment for the 1 day simulation (top middle) and the modified microphysics simulation (top right), and CFADs of deep clouds from TRMM observation (bottom left), the control experiment for the 1 day simulation (bottom middle) and the modified microphysics simulation (bottom right)

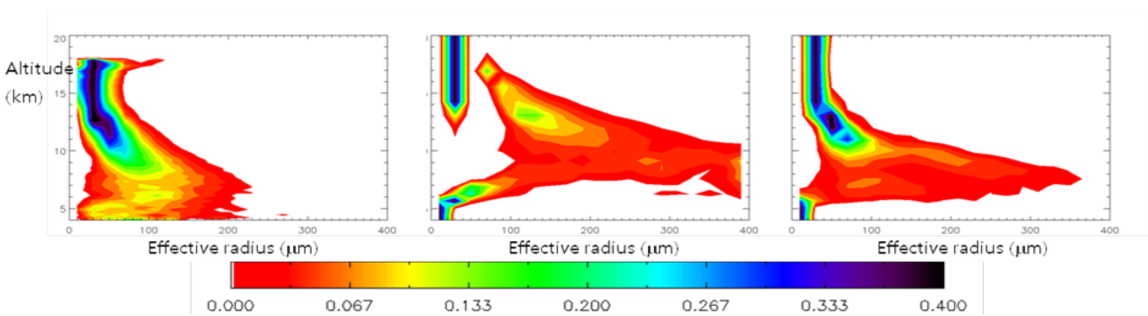

Figure 2. CFADs of effective radius of from Hagihara observation (left), the control experiment for the 1 day simulation (middle) and the modified microphysics simulation (right)