A numerical experiment of the cumulus clouds observed during RICO (Rain in Cumulus over the Ocean) experiment

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1. Introduction

Understanding the effect of boundary layer clouds on radiation budget is important for a climate study. In order to improve the boundary layer cloud models, many studies of model intercomparison are performed for several cases by the Boundary Layer Cloud Working Group (BLCWG) of the GEWEX Cloud System Study (GCSS). Using a cloud convection resolving model, Cloud Resolving Storm Simulator (http://cf.tokyo.rist.or.jp/CReSS.top.html) called CReSS, we performed a numerical experiment for RICO, 'Rain In Cumulus over the Ocean' (RICO) measurement campaign, which is selected for the intercomparison case for a precipitating shallow cumulus convection.

2. Model and setting of the experiment

The basic equation system of CReSS is quasi-compressible one, and advection terms are in the advective form. The time integration is performed by horizontally explicit and vertically implicit scheme. The subgrid scale turbulence is formulated in Deardorff scheme. We used the centered-difference advection scheme at first. However, using the scheme, the boundary layer deepens rapidly, and in order to diminish the large entrainment rate we adopted the modified centered-difference advection scheme (used in NHM, developed by JMA) in which the values calculated are modified to lie between the maximum and minimum of the values in the upstream neighboring grid boxes.

We used a two-moment bin microphysical scheme for warm rain. We use 71 bins for radii between 0.001mm and 3.25 mm. In the scheme, condensation and coalescence are calculated in the semi-Lagrangian framework by using the two-moment bin method developed by Chen and Lamb (1994). The initial cloud droplet size distribution is determined by the parameterization scheme proposed by Kuba and Fujiyoshi (2006) in terms of CCN number concentration and vertical velocity. The model setting is the same as the one for the GCSS intercomparison experiment (http://www.knmi.nl/samenw/rico/).

3. Results and new bulk parameterization scheme

Fig. 1 shows the results of the bin model with the 15 model results of GCSS intercomparison. Although the cloud and rain water mixing ratios are largest in the models, the model works generally well. In our model results, the number concentrations of cloud droplets and rain

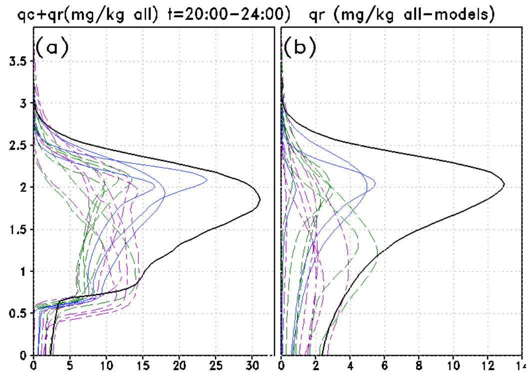

Fig. 1 Vertical profiles of (a) total water mixing ratio and (b) rain water mixing ratio, averaged for the last 4 hours of the 24 hours run for LES models of GCSS intercomparison added the results of this experiment. Purple dash-dotted line: 1-moment bulk model, green dashed line: 2-moment bulk model, blue solid line: bin model, and black thick line: this experiment.

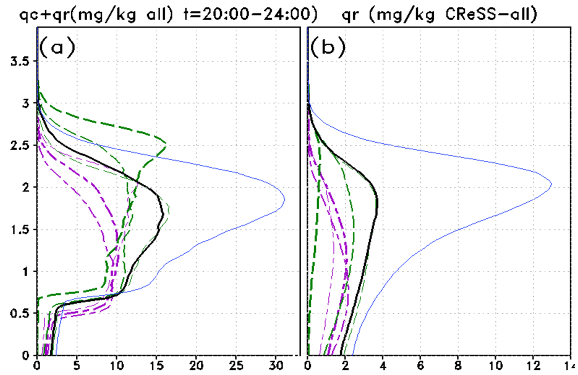

Fig. 2 Same as Fig. 1, except for the results of CReSS using several autoconversion schemes, and our bin scheme. Purple dash-dotted line: 1-moment bulk model (3 schemes included in NHM, Kessler 1969, Berry and Reinhardt 1974, Richard and Chaumerliac 1989), green dashed line: 2-moment bulk model (3 schemes in Wood 2005), blue solid line: bin model, and black thick line: new bulk model.

drops are large and there remains a large amount of water around the top of cloud because the development of precipitation is not so active. We are now examining the results by comparing the results with NHM.

Using the bin model results, we are developing a new bulk scheme. For the first step, we consider a two groups and two moments bulk scheme. The condensed water are classified into two groups, i.e., cloud and rain, by its radius, and their mixing ratios and number concentrations are used as prognostic variables. All microphysical processes and physical variables at every grid point are stored. For the microphysical process, we consider condensation (cloud→cloud, cloud→rain,rain→rain), evaporation (cloud→no cloud, cloud→cloud, rain→cloud, rain→rain), and collision (between clouds → cloud, between clouds → rain, between cloud and rain → rain, and between rains → rain). Then linear fittings for each process as a function of physical variables are tested and we determine the combination which gives the largest correlation coefficient for each process.

In order to investigate the model dependence on autoconversion scheme, we performed several experiments using different autoconversion schemes. Fig. 2 shows the results. It is shown that the effect of autoconversion parameterization is very large. The results of the two moment scheme determined from the bin model results agree well with other model results.

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