Cloud microphysical structure as investigated with a non-hydrostatic cloud resolving model

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Abstract

We've developed a non-hydrostatic model coupled with a detailed cloud microphysical scheme described by an explicit bin method. Model simulations have been carried out for a domain within a radius of 1,400 km whose center is the sea near the Kyusyu region and for the second half of March and the first half of April in 2003. The results have been compared with satellites and aircraft observation datasets for validation.

Keyword: cloud, aerosol

1. Introduction

An increase of tropospheric aerosols, which act as cloud condensation nuclei (CCN), can cause an increase in the cloud albedo and lifetime, through which aerosol has a strong impact on the climate system of the earth, known as the indirect climate effect of aerosols. Because clouds and aerosols are short-lived constituents distributed inhomogenerously, it is difficult to access the accurate forcing by the aerosol indirect effect. General circulation models are insufficient for studying the aerosol-cloud interaction process because of lack of detailed microphysical mechanism in the models. On the other hand, use of a cloud resolving model including an explicit cloud microphysical scheme is promising, because satellite datasets of cloud parameters became available in these days for detailed comparison with simulation results.

2. Model description

In this study, we've developed a non-hydrostatic cloud resolving model based on the Meteorological Research Institute / Numerical Prediction Division unitied Nonhydrostatic Model [Saito et al., 2001] coupled with the cloud microphysical scheme with a spectral explicit bin method of the Hebrew University Cloud Model [Khain et al., 2000] which treats the CCN effect explicitly. In detailed, as cloud microphysical processes this model treats nucleation from CCN, condensation growth, evaporation and collision coagulation growth. The model is nested to the re-analysis data as for dynamical variables such as horizontal velocities, temperature and mixing ration of water vapor. In addition to that, this model can be nested as for CCN. Then, we make use of the output of 3-D aerosol transport model, SPRINTARS [Takemura et al., 2001] for this nesting.

3. Numerical experiments

3.1 Setting

The calculation area is a domain within a radius of 1,400 kilometers whose center is the sea near the Kyushu region (Fig. 1). The calculation periods are from 18:00 to 6:00 (UTC) of each day within the second half of March and the first half of April in 2003.

The horizontal grid size is 7km, and the number of vertical layer is 38 (the interval of bottom layer = 40m; top layer = 580m) and the height of the top boundary is about 12km. The time step is 20 seconds for dynamics and 6.7 seconds for cloud microphysics, with a variable time step for the condensation process. The tracers of cloud microphysics are only CCN and water droplets resolved into 33 size bins, and ice cloud particles (ice crystals, snowflakes, graupels and hails) are excluded because of the problem of calculation cost.

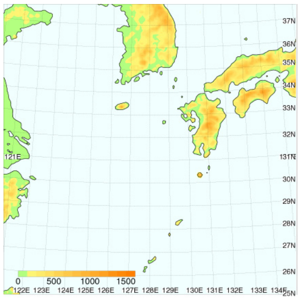

Fig. 1: The calculation area of this simulation.

3.2 Results

Fig. 2 illustrates snapshots of horizontal distribution of some cloud parameters at 3:00 on April 8th, 2003, comparing with the retrieved datasets from TERRA/MODIS satellite-borne imager (Fig. 3). Then, Fig. 4 shows one example of a comparison between CCN concentration as the input of these model simulations obtained from the results of SPRINTARS and that from aircraft observation. Also, Fig. 5 shows a comparison between effective radius of cloud droplets as the output of model simulations and that from aircraft observation.

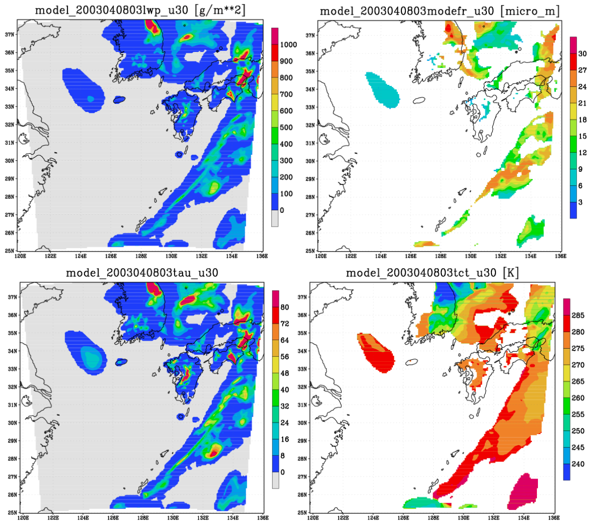

Fig. 2: The snapshots of liquid water path, droplet effective radius on cloud top, optical thickness and temperature on cloud top at 3:00 on April 8th, 2003 by the numerical simulation.

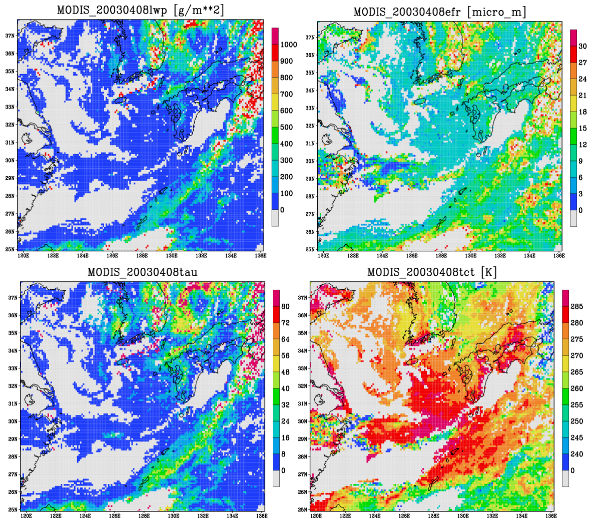

Fig. 3: The snapshots of the same cloud parameter as Fig.2 by TERRA/MODIS retrieval datasets.

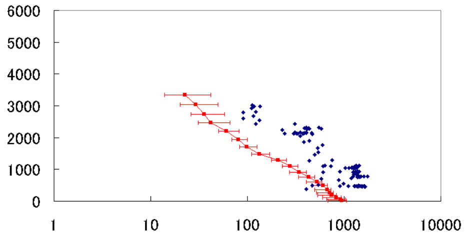

Fig. 4: The vertical distribution of activated CCN concentration. Red line corresponds to the input of this model simulation on April 8th. Blue dots are datasets of aircraft observation.

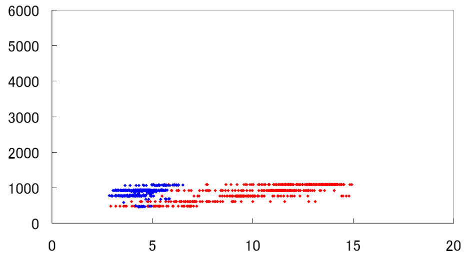

Fig. 5: The vertical distribution of effective radius of cloud droplets. Red dots correspond to the input of this model simulation on April 8th. Blue dots are datasets of aircraft observation.

4. Discussion

A general agreement between numerical simulation results and satellite-retrieved results of cloud liquid water and effective particle radius of low level clouds. However, there are some problems, for example, in Fig.2 low and thin clouds on East China Sea cannot be resolved. As for the comparison between model simulation and aircraft observation, generally the inputs of CCN concentration in model simulations are underestimated than datasets of observations and then the effective radiuses of cloud droplets in model simulations are overestimated than observations due to that.

We will show results on other days also. In addition to that, sensitivity test simulations for an amount of CCN concentration to cloud parameters will be carried out.

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