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Interactive comment on "Development of a cloud microphysical model and parameterizations to describe the effect of CCN on warm cloud" *by* N. Kuba and Y. Fujiyoshi

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We would like to thank Referee #1 for the close comments. We are revising our manuscript according to the comments.

In this study, parcel model carries separate CCN size distribution which is modified only by condensation, because parcel model is only used to produce the initial cloud droplet size distribution for bin method and to estimate the inflow of cloud droplets from the windward with no cloud water. To keep track of the CCN lost due to activation and to handle CCN recycling, an aerosol transportation model is needed as SPRINTRAS (Takemura et al. 2000, 2002) in CCSR/NIES/FRCGC-AGCM. Since the dynamical framework designed by Szumowski et al. (1998) does not have an aerosol transportation model, we are searching for an appropriate aerosol transportation model for regional model.

The equations governing the growth rate of droplets by condensation are those in Takeda and Kuba (1982). The potential temperature tendency of an air parcel is calculated. The equation governing the coalescence-forced rate of change of the cloud droplet spectrum over time is stochastic. Collision efficiency is computed from Table 1 in Hall (1980). Fall velocity is estimated by using equations described in FOTRAN code distributed by Bott (1998). Both rain drops and cloud droplets are all handled in one bin scheme.

When the parameterizations mentioned in 4.1 are used in GCM, only updraft velocity and information relating CCN spectrum is needed. Because GCM does not resolve the cloud updraft, turbulent kinetic energy is used to estimate updraft velocity following the method by Lohmann et al. (1999). Supersaturation that can not be given in GCM is not needed here. Necessary information relating CCN spectrum is the cumulative number of CCN that can be activated at S% supersaturation (S is 0.2, 0.4, 0.5 1.0, or 2.0 %, depending on updraft velocity)

We would like to delete the appendix .

Replies to the specific comments

1) Activation of CCN primarily occurs near the cloud base except in cases with strong updraft and low concentration of CCN. We are trying to handle the activation inside the cloud in future study.

2) Parcel model does not use fixed bin. CCN are divided into many classes so that the number of CCN included in one class is smaller than a certain number. The certain number should be small enough compared to activated CCN (cloud droplets number). CCN included in each class grow by condensation. Some of them can be activated

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and grow to cloud droplets.

3) Aerosol particle with lower critical supersaturation are activated earlier. If all CCN prepared as input are activated, there is an opportunity that aerosol particles with higher critical supersaturation than input CCN can be activated. We should prepare CCN small enough to estimate the smallest CCN that can be activated.

4) We would like to rewrite sentences in revised version of our manuscript as follows;

Considering the time required for CCN to reach their equilibrium in the ambient humidity (100% at cloud base) (they are shown in Mordy, 1959), CCN smaller than 0.1 micro meters in radius, and CCN larger than 1 micro meters in radius, are initially assumed to be in equilibrium at 99% and 90% RH, respectively. Intermediate CCN are initially assumed to be in equilibrium between 99 and 90% RH as a function of radius. Mordy (1959) considered how to determine the initial radii of droplets at the cloud base in numerical simulations in detail and described as follows; Radii of the droplets formed on particles 10e-15.6 mol (0.165 micro meters in radius for ammonium sulfate) and smaller were assumed to be at equilibrium at 100 % relative humidity, and droplets formed on particles 10e-12.6 mol (1.65 micro meters in radius for ammonium sulfate) and larger were assigned radii appropriate to equilibrium at 99 % RH. Our assumptions are not contradictory to Mordy's assumptions.

5) We are taking about cloud drop advection in the Eulerian framework. However, cloud base is a kind of source of cloud droplets. We need parcel model to supply new activated droplets for bin method.

6) We would like to make the figures of time change of two dimensional distributions of cloud and rain water for Cases A and C. They are included in revised version of our manuscript.

7) This parameterization needs only updraft velocity and information relating CCN spectrum. Necessary information relating CCN spectrum is the cumulative number

of CCN that can be activated at S% supersaturation (S is 0.2, 0.4, 0.5 1.0, or 2.0 %, depending on updraft velocity). The value can be observed by CCN counter. Full spectrum of CCN is not needed.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 1413, 2006.