# A NUMERICAL STUDY ON IMPACT OF HYGROSCOPIC SEEDING ON THE DEVELOPMENT OF WARM RAIN -NUMERICAL SIMULATION WITH A HYBRID MICROPHYSICAL MODEL -

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## 1. INTRODUCTION

To estimate the effect of hygroscopic seeding on precipitation accurately, numerical study needs cloud microphysical model that can estimate nucleation process of cloud condensation nuclei (CCN) accurately. The number concentration of cloud droplets, which influences significantly the precipitation efficiency of clouds, depends on CCN spectrum and the maximum value of supersaturation which the air mass has experienced. This maximum value can not be estimated by values on the grid points with a interval larger than tens meters. In addition, the supersaturation is affected not only by the updraft velocity but also by the number of activated nuclei. Therefore it is desired to calculate the condensation growth of CCN in the Lagrangian framework accurately in order to find out if each nucleus can be activated.

## 2. CLOUD-MICROPHYSICAL MODEL

To accurately estimate the number concentration of cloud droplets and the effect of CCN on the microstructure of clouds, the hybrid microphysical cloud model was developed. Our cloud microphysical model estimates the maximum values of supersaturation and the number concentration of cloud droplets by using the parcel model with Lagrangian framework.

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And our model estimates condensation, coalescence, breakup, sedimentation, and advection of cloud droplets and raindrops by using bin model on the grid points with semi-Lagrangian or Eurelian framework.

### 2.1 *Lagrangian framework*

In our hybrid microphysical cloud model, each grid point has a parcel model to estimate the activation of nuclei. In the case that the relative humidity of the grid point reaches 100% for the first time, or the case that relative humidity of the grid point is larger than 100% and cloud water on the windward side of the point does not exist, air parcel including CCN and vapor starts to rise from the windward side of the point. In each parcel, the condensation growth of CCN is estimated in Lagrangian framework using the microphysical model described in Takeda and Kuba (1982) and Kuba and Fujiyoshi(2006). When droplets condensed on CCN grow enough to be distinguished from embryo, which can not become cloud droplets, the cloud droplets size distribution, the mixing ratio of vapor and potential temperature in the parcel are given to the grid points.

### 2.2 *Semi-Lagrangian framework*

Time changes due to growth by condensation and coalescence on grid points are calculated in the semi-Lagrangian framework by using the two-moment bin method developed by Chen and Lamb (1994) to minimize numerical diffusion of cloud droplet size distribution. There are 71 bins for radii between 1 μm and 3.25 mm. Coalescence efficiency developed by Seifert et al. (2005) is used to estimate coalescence and breakup.

The time steps for growth by condensation and coalescence are 0.5 seconds. To estimate multi-coalescence in one time step properly, two kinds of scheme are used. One is general stochastic coalescence for rare lucky coalescence with a large droplet, the other is continuous coalescence for frequent coalescence with small droplets following to Chen's doctoral thesis. If only general stochastic coalescence scheme is used, very short time step (0,01 s) is needed to avoid the underestimation of coalescence growth caused by the underestimation of multi-coalescence.

Sedimentation and advection of droplets are estimated in the Eulerian framework among grid points.

## 3. CLOUD-DYNAMICAL MODEL

The dynamical framework of this study was based on the model designed to test the warm rain microphysical model in Case 1 of the fifth WMO Cloud Modeling Workshop (Szumowski et al. 1998). The dynamical cloud model predicts an evolving flow for 150 minutes and performs a two-dimensional advection of the temperature and water variables (domain: 9 km x 3 km, dx and dz: 50 m, dt: 3 seconds). The flow pattern shows low level convergence, upper level divergence, and an updraft located in the center of the domain. The magnitude, vertical structure, width and tilt of the flow through the central updraft are all prescribed using simple analytical functions. The updraft is held constant at 0.1m $s^{-1}$ for the first 15 min of the simulation. The updraft intensifies to a peak value of 0.8 m $s^{-1}$ at 25 min and subsequently decays to a value of 0.2 m $s^{-1}$ at 40 min. For 110 minutes at the end of the 150-min simulation, the updraft is held constant at 0.2 m $s^{-1}$

## 4. NUMERICAL EXPERIMENTS

In case of micro-powder seeding, seeding particles are assumed to be NaCl that consist of similar size particles (1.0 or 2.5 μm in radius). Cloud seeding was simulated by adding seeding particles to the original CCN size distribution for 10 minutes (30 – 40 min. for example). To keep total mass of seeding particles constant, number concentration of 1.0 μm – particle is assumed to be 15.6 times as high as that of 2.5 μm –particle. Several kinds of the timing of seeding were tested to find out the optimum seeding condition. Results are going to be shown in my presentation.

## 5. REFERECES

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