P3.14 EFFECTS OF AEROSOLS ON RAIN FORMATION AS SEEN FROM EXPERIMENTS WITH A 2000-BIN CLOUD MICROPHYSICAL MODEL

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INTRODUCTION

Aerosol particles can influence precipitation formation in cumulus clouds (e.g., Khain et al, 1999, 2001). A 2000-bin cloud microphysical parcel model (Pinsky and Khain, 2002) is used to investigate the effect of cloud condensational nuclei (CCN) concentration and size distribution on warm rain formation in cloud parcels under maritime, continental and intermediate environmental thermodynamic conditions.

METHOD

The model equation system includes: the diffusion growth equation used for aerosol particles (APs) and water droplets, the equations for supersaturation, vertical velocity and the temperature of the ascending parcel. The friction force is supposed to be proportional to the square of vertical velocity. The proportionality parameter $\lambda=0.2/R$ is assumed to be inversely proportional to the cross-sectional radius R of parcel. To describe size distribution of both non-activated aerosols and droplets within the radius range of 0.01 μm – 2000 μm, a movable grid of masses containing 2000 bins is used. The drop growth by coalescence is described by the stochastic kinetic equation for collisions. By varying the parameter λ parcels reaching different maximum heights were simulated. Using the values of fall velocities of droplets, the raindrop flux and total rain precipitated from cloud parcels are calculated. The initial CCN spectrum was represented by a superposition of three log-normal distributions (three modes), characterized by the number concentration n_i, mean radius R_i (R_1= 0.006μm, R_2= 0.03μm, R_3=0.5 μm) and the width σ_i. Aerosol particles start growing during their ascending in sub-cloud layer. Concentration of APs in the first two modes was chosen to obtain droplets concentrations typical of maritime (about 100 cm^{-3}), intermediate (500 cm^{-3}) and extreme continental conditions (about 1500 cm^{-3}). The rate of raindrop formation in ascending parcels under different concentrations and distributions of APs is investigated.

RESULTS AND DISCUSSION

Concerning the sensitivity of precipitation formation to the cloud depth, all cloud parcels are separated into three groups (fig.1): in parcels belonging to the first group collision process does not begin and their cloud water content (CWC) does not convert into rain water; in cloud parcels belonging to the second group drop collisions start in the vicinity of maximum top height, and convert only a portion of their CWC into rain water; in cloud parcels belonging to the third group collisions start well below cloud top and convert almost all their CWC into rain water. Results indicate that droplet spectrum formation in maritime parcels is not sensitive to an increase in the concentration of the CCN smaller than about 0.01 μm, since supersaturation values are not high enough to cause the nucleation of these CCN. The increase in the concentration of CCN belonging mainly to the second CCN mode slows down cloud droplet growth rate and increases the time needed to initiate collisions (fig.2). At the same time, an increase in the concentration of large CCN (the third mode) reduces the height of collision triggering (fig.3). Height levels separating the parcels type depend on thermodynamic conditions. Our investigations show that continental and intermediate cloud parcels tended to belong to the first and the second groups. Cloud parcels belonging to the second group are the most sensitive both to changes in the concentration and distribution of the CCN.

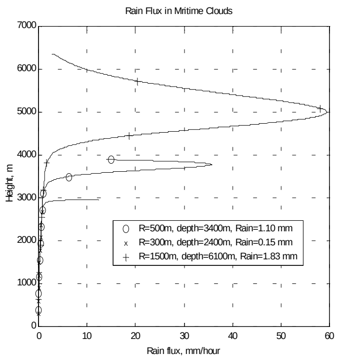

Fig.1. Rain flux in the three cloud parcel types.

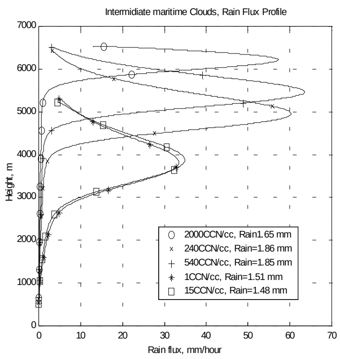

Fig.2. The increase in the concentration of the medium sized CCN increase the height of collision initiation

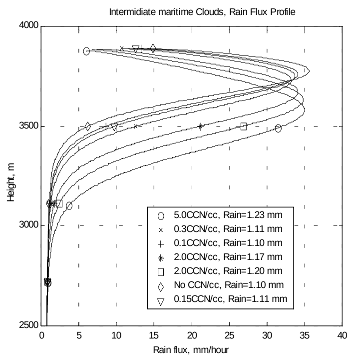

Fig.3. The increase in the concentration of the larger CCN decreases the height of collision initiation.

While an increase in the concentration of medium size CCN (>0.01μm) reduces precipitation formation (fig.4), an increase in the concentration of large CCN can increase the rain formation several times (fig 5). Note that the increase in the concentration of the large CCNs in case of deep clouds (large cloud parcels) can result in a decrease in the mass of collected droplets and in some decrease in rain (fig. 6).

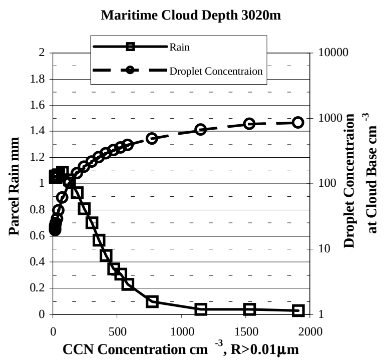

Fig.4. Rain flux and droplet concentration as functions of the concentration of CCNs of the medium size

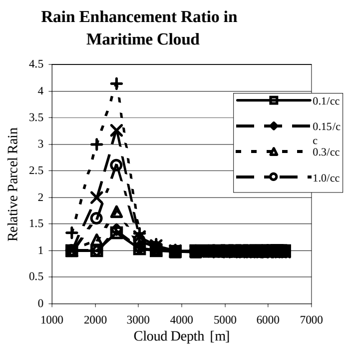

Fig.5. Ratio of rain fluxes as a function of cloud depth (cloud parcel size) under different concentrations of the largest CCN.

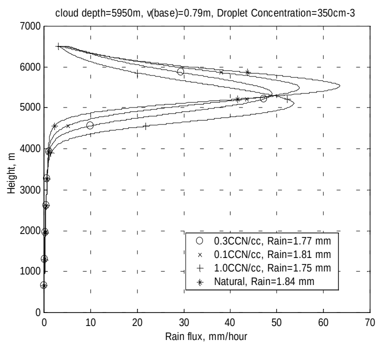

Fig.6. Rain flux as a function of large CCN concentration in deep maritime clouds (large cloud parcels).

CONCLUSIONS

Stability of the atmosphere and the cloud depth determine to a large extent the sensitivity of rain formation in cloud parcels to aerosol particles concentration and size distribution. The effect of APs on precipitation highly depends on cloud parameters and APs size. CCNs of medium size tend to slow droplet spectra broadening and tend to decrease the rate of raindrop formation. Large CCN increase rain formation in cloud parcels of the intermediate size, fostering the decrease in the level of collision triggering. The same effect can decrease warm rain formation in deep clouds (large size) cloud parcels.

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