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IMPACT OF CLOUD DROPLETS SPECTRAL UNCERTAINTY ON MESOSCALE PRECIPITATION

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1 INTRODUCTION

Cloud radiation is one of the most important and indefinite factors in atmospheric radiation. As shown in a comparative study by Cess et al.[1] with a climate model, differences can be very large in the outcome of varying schemes of cloud parameterization. It is therefore of great significance to have a relatively accurate scheme of cloud parameterization for the atmospheric radiative transfer process. According to the Mie's scattering theory, the scale parameter of the particulate has a very important effect on its optical property. It is then seen that the number concentration and size distribution of cloud droplets play an important in the determination of the optical properties of cloud droplets.

As cloud condensation nuclei and ice nuclei in one of the key rings in the interaction between clouds and radiation, the aerosol particulates in the atmosphere affect the distribution and micro-physical characteristics of the cloud and by means of it the radiative transfer of the atmosphere. It can then be stated that changes in the spectrum of cloud droplets are also, to some extent, an indicator of anthropogenic role in precipitation.

Some of the Chinese scientists have done significant numerical modeling on cloud models with detailed processes of microphysics (as in [2] and [3]) while others have worked extensively and fruitfully on the computation of the radiative properties of gases and aerosols as well as the effect of radiation on weather and climate (as in [4] and [5]). In the issue of mechanisms responsible for cloud and radiation interactions, Zhao et al.[6] and Ding[7] studied the interactions between clouds, radiation and precipitation using convective cloud models. There has been little investigation, however, into the interactions between cloud and radiation in mesoscale models, especially the influence of cloud radiation processes on surface precipitation.

In this work, two cases of heavy rain, one taking place in South China on June 8th, 1998 and the other in the Yangtze River Delta on July 22nd, 2002, are simulated to understand the effect of uncertainties of cloud droplets spectrum on precipitation on the ground in mesoscale models. It is of some application value for the improvement of capabilities of forecasting mesoscale precipitation.

2 PARAMETERIZATION OF THE EFFECTIVE RADIUS OF CLOUD DROPLETS

The scale parameter of the particulate is very important in the Mie scattering theory. As important parameters such as the optical depth, albedo of single scattering and phase function are subject to the effective radius of the particulate (r_e) during radiative transfer process. The effective radius that is accurately determined is significant for the accuracy of the radiative transfer calculation. Existing parameterization schemes for the microphysics of clouds are incapable of forecasting the effective scale or number density of cloud droplets. Parameterization is an alternative to solve the problem. Setting r_w = 1.0

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$\times 10^3$ kgm^{-3}, $[q]$ = gm^{-3}, $[r_e]$ = mm and $[N]$ = cm^{-3}, the equation for effective radius can be expressed as $r_e = 62.04\frac{(1+2e^2)^{2/3}}{(1+e^2)^{1/3}}(\frac{q}{N})^{1/3}$.

It is known from the equation for effective radius that r_e is dependent on q and N, and e and q are model predictands. N and e are the quantities which are not forecast in the existing schemes of parameterization and need to be assumed. It is from the uncertainty of the two quantities that the current paper studies their effect on precipitation.

3 DATA AND NUMERICAL SIMULATION

The two selected cases of heavy rain are used to understand the common features of the effect of uncertainty of cloud droplets spectrum on mesoscale precipitation.

The MM5V3 non-hydrostatic equilibrium model from PSU/NCAR is used in the modeling, with dynamic time steps taken at 60 s and radiation step at 20 min. The following physical schemes are chosen: the CAMS scheme for microphysics, Betts/Miller scheme for cumulus convection parameterization, MRF boundary layer scheme and soil scheme with multi-layer thermal dissipation.

To discuss the change in surface precipitation due to the distribution of cloud droplets spectrum, numerical experiments are designed. During the simulation, the effective radius of each experiment is updated based on the number density and relative dispersion of cloud droplets. The initial number densities of cloud droplets are also changed to coordinate the cloud and radiation.

4 DISCUSSIONS AND ANALYSES

The MM5V3 model from PSU/NCAR is used to simulate the two heavy rains in South China and Yangtze River Delta for the effect of uncertain cloud droplets spectrum on mesoscale precipitation. The experiments are designed in the radiation experiments to represent cloud droplets under homogeneous, normal condition, homogeneous, highly-polluted condition and extremely inhomogeneous maritime condition (free from pollution). As shown in the simulation, the distribution of cloud droplets spectrum affects the surface precipitation significantly during the cloud radiation. The uncertainty of cloud droplets spectrum results in large change in mesoscale surface precipitation.

As shown in the comparison of the distribution of surface precipitation, differences in the distribution of cloud droplets spectrum do not have much effect on the coverage of surface precipitation, which is consistent in the simulation by all experiments; it has considerable effect on rain rate, especially the center of rainfall. Differences are obvious among the results for the center of rainfall whether it is in terms of accumulated rainfall or rain rate; large errors are also observed in the start time and duration of maximum rain rate as well as rain location. In addition, in the centers where there has been more than one rain, large differences exist in both the starting and ending time of precipitation when experimental condition changes. It shows that the cloud droplet spectrum has a role to play here.

As shown in regional averages, differences are large in both accumulated rainfall and rain rate due to changes in the spectrum and large diurnal variations can also be found in rain rate. Effective radius and number density change surface rain rate by up to 10% and mainly during daytime. With the solar radiation, large effective radius and small number density of cloud droplets tend to decrease and then increase the rain rate over the modeling duration while small effective radius and large number density will have a reversed pattern of variation. It is shown in this work that cloud droplet spectrum interacts with the radiation so that precipitation will be changed. It is necessary to use more detailed and accurate models of cloud microphysics and radiation to improve the numerical simulation and forecasting of mesoscale precipitation. It also requires more understanding of the interaction between clouds and radiation on mesoscale models.

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