A New Triple-Moment Scheme (IAP-LACS) in Condensation and Warm Rain Formation Processes

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Introduction

Water vapor condensation growth and warm rain formation are the important processes for precipitation. However, cloud droplet spectra are always spuriously broadened in condensation simulations with double-moment schemes. There are also large errors in the calculations of autoconversion rate and accretion rate with the current parameterization schemes. It makes the correct numerical simulations of condensation and warm rain formation become our big challenges for weather simulations with cloud resolving models and general circulation models. A new triple-moment scheme (IAP-LACS) in condensation and warm rain formation processes is presented to accurately describe the growth of a population of cloud drops. The three parameters-the shape parameter $a$, the slope parameter $b$ and the intercept parameter $N_0$ in the newly developed triple-moment scheme are related to the three moments: the number concentration ($N_0$), the water content ($M_w$) and the reflectivity ($M_o$) of drops. The analytical solutions of autoconversion and accretion rates are obtained.

Mathematical formulations in condensation process

The increase and decrease of cloud droplets during AUTO process:

$$H_A = \int \left[ K(x,y; x') \cdot f(x,y) \right] \cdot (x - y) \cdot dy$$

The increase and decrease of cloud droplets during ACC process:

$$H_C = \int \left[ K(x,t; x') \cdot f(x,t) \right] \cdot (t - x) \cdot dx$$

Analytical Solutions of Autoconversion (AUTO) Rate and Accretion (ACC) Rate

The increase and decrease of cloud droplets during AUTO process:

$$H_A = \frac{\alpha}{\beta} \cdot \left[ \frac{\alpha^2}{\beta} \cdot \frac{\beta^2}{\alpha} \right]$$

The increase and decrease of cloud droplets during ACC process:

$$H_C = \frac{\alpha}{\beta} \cdot \left[ \frac{\alpha^2}{\beta} \cdot \frac{\beta^2}{\alpha} \right]$$

Conclusions

In this study, we developed a new triple-moment scheme in condensation and warm rain formation processes based on the gamma distribution function with the size scale of the drop mass. Diagnostic differential equations for the time-dependent slope and shape parameters have been established in the condensation process. The three parameters of gamma distribution for raindrops are obtained by performing analytical integrations of the microphysical transfer rates. The autoconversion and accretion rates are derived by solving the stochastic collection equation (SCE) with a parameterized collection kernel. These equations were derived by means of the number concentration, the water content and the reflectivity of drops. The simulated autoconversion rate with the new scheme is closest to that of the bin scheme compared the simulated results with the other parameterization schemes. The newly developed triple-moment scheme can be applied to accurately describe the growth of a population of cloud drops.

References