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# THE INFLUENCE OF ELECTRIFICATION ON MICROPHYSICAL AND DYNAMICAL PROCESSES INSIDE THUNDERSTORMS

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## 1. INTRODUCTION

During the past several decades, there have been many efforts in the numerical modeling of electrification inside thunderstorms (e.g., Chiu 1978; Takahashi 1984; Helsdon and Farley 1987; Ziegler and MacGorman 1994; Schuur and Rutledge 2000). These researches focused on possible charging mechanisms and dependence of magnitude and the polarity of charge on microphysical process in thunderstorms. However, not many numerical modeling studies have considered the impact of electrification on microphysical and dynamical processes. Observations (e.g., Ziv and Levin 1974; Willams and Lhermitte 1983) show that terminal velocities of precipitation particles can be modified when the strengths of electrical field approaches to some potential. Variation of terminal velocity results in alteration of mass transformed in collection processes. And consequently, distribution of hydrometeors and buoyancy can be changed inside thunderstorms.

The purpose of this study is to investigate influence of electrification on microphysical and dynamical processes in thunderstorms using a three-dimensional numerical model. For this, two numerical simulations, one with electrification process (EC) and the other without electrification process (NEC) are performed under the same initial condition.

## 2. MODEL AND INITIAL CONDITION

A three-dimensional dynamics-electrification coupled model formulated originally on the basis of a cloud model was developed. It consists of prognostic equations for momentum, potential temperature, pressure perturbation, mixing ratio of hydrometeors, number concentration of hydrometeors, charge density of hydrometeors and number concentration of ions. The hydrometeors considered are water vapor, cloud, rain, ice, snow, graupel and hail. It includes forty-two microphysical processes and five types of charging mechanisms. Convection is initiated using a warm bubble with 1.5 K potential temperature perturbation in the lowest 2 km. The model domain is 36 km× 36 km× 18 km with a constant horizontal grid size of 500m and vertical grid size of 250m. The initial sounding is taken from the Cooperative Convective Precipitation Experiment (CCOPE) on July 19, 1981.

## 3. RESULTS

Figure 1 shows difference of terminal velocity for graupel between EC and NEC simulations (Fig. 1a), charge density of graupel $q_{ge}$ (Fig. 1b) and vertical component of electric field $E_z$ (Fig. 1c) at t = 42 min, respectively. The graupel particles are negatively charged above z = 10 km where positive vertical electric field exists. Therefore, the graupel particles are attracted by negative electrical force ($q_{ge}E_z$), and terminal velocity of graupel increases above z = 10 km with a maximum magnitude of 2.4 m s$^{-1}$. For 6 km < z < 10 km, the terminal velocity of graupel decreases with a maximum magnitude of 1.6 m s$^{-1}$ due to the positive electrical force.

The total amount of graupel mass transferred from cloud water through collection and coalescence process increases by electrification process as much as 21 % of that in NEC simulation. This is mainly because increased terminal velocity of graupel near cloud top has better chance to collect more cloud drops having relatively small terminal velocity. The largest change of total amount of hydrometeor by electrification process is the mass of ice by collecting cloud water which decreases as much as 49 % of that in NEC simulation. This is because ice particles having positive charge are forced upward by electric force in cloud top. Also, electrification process decreases mass of rain water about 23 % and mass of hail about 16 %.

Total amounts of condensation, evaporation, deposition, and sublimation integrated over entire model domain during a life cycle, and total amount of net moisture entering into the thunderstorm through cloud base from the environment outside storms, latent heat released during microphysical processes

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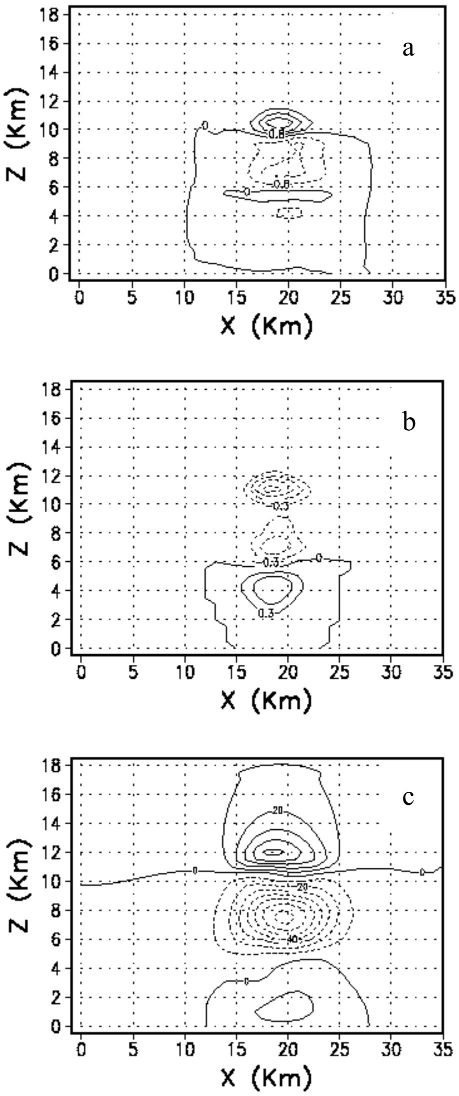

Fig. 1. (a) Difference in terminal velocity of graupel between EC and NEC simulation, (b) Charge density of graupel, (c) vertical component of electric field at t= 42 min. The contour intervals of (a), (b), and (c) are 0.8 m $s^{-1}$, 0.3 nC $m^{-3}$, and 10 kv $m^{-1}$, respectively.

are shown in Table 1. The amounts of condensation, freezing, and deposition in EC simulation increase as much as 108 % and 15 % of those by NEC simulation, respectively. Enhancement of these two processes is reasonably explained by the results that more cloud and rain drops are collected by graupel or hail particles in EC simulation. Contrary, amount of evaporation and melting decreases by electrification process mainly because the mass of rain water decreases significantly through melting of hails in EC simulation. Amount of sublimation is reduced slightly due to the decrease of sublimation from hails. The four classes of physical processes examined above determine not only the distribution of hydrometeors in the cloud but balance the heat released in each microphysical process during life cycle of thunderstorm. Latent heat released during microphysical processes increases from $8.7\times10^{14}$ J to $10.8\times10^{14}$ J because the total mass of conversion increases in deposition and freezing processes and decreases in sublimation and evaporation processes when electrification process is included. The increase of latent heat intensifies buoyancy in thunderstorms, and accumulated amount of net moisture entering into the thunderstorm through cloud base increases from $1.9\times10^3$ to $3.0\times10^3$ kton.

Table 1. The accumulated amounts of some parameters over entire model domain during life cycle of thunderstorm and accumulated amount of net moisture entering into the thunderstorm through cloud base from environment. Unit is Kton except for latent, which is represented in $\times10^{14}$J. Con, Eva, Dep, Sub, Net, and Lat represent condensation, evaporation, deposition, sublimation, net moisture, and latent heat, respectively.

| | Con | Eva | Dep | Sub | Net | Lat |
|---|---|---|---|---|---|---|
| EC | $2.6\times10^6$ | $5.9\times10^6$ | $8.9\times10^2$ | $2.6\times10^2$ | $3.0\times10^3$ | 10.8 |
| NEC | $1.2\times10^6$ | $8.9\times10^6$ | $7.6\times10^2$ | $2.9\times10^2$ | $1.9\times10^3$ | 8.7 |

Intensified updraft by electrification process in the cloud sustains the graupel and hail particles and prevents them from falling out of the cloud earlier. So there is more time for them to be carried up by updraft and more opportunities to grow by collecting super-cooled cloud drops and ice crystals. Figure 3 is the time series of accumulated solid precipitation and maximum diameter of solid precipitation particles on the ground. The accumulated solid precipitation on the surface is larger, and the time that they first reach the surface is delayed by 6 min in EC simulation compared with NEC simulation. The maximum diameter for solid precipitation particles in EC simulation attains about 5.7 mm, while it is about 5.0 mm in NEC simulation. After t = 48 min, maximum diameter of solid precipitation on the surface is consistently larger in EC simulation because stronger updraft and decreased melting process from hail and graupel make the precipitation particles be larger.

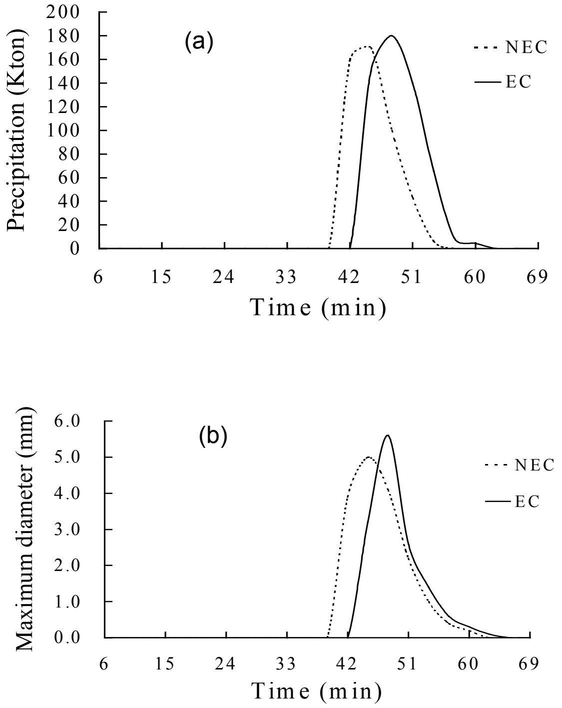

Fig. 3. Time series of (a) total amount of solid precipitation in the model atmosphere, and (b) maximum diameter of solid precipitation in the surface. Solid and dashed lines represent the result in EC and NEC, respectively.

## 4. SUMMARY AND CONCLUSION

Effects of electrification on the dynamical and microphysical processes in the thunderstorms were investigated using electrification-dynamics coupled, three-dimensional numerical model. The results suggest that the terminal velocities of larger hydrometeors such as graupel and hail increase by electrification process. That is responsible for changing mass and number concentration of hydrometeors transformed during microphysical processes and redistribution of condensed hydrometeors. Subsequently, latent heat released in the middle to lower part of cloud increases, and updraft is intensified. The reinforced updraft can sustain growing precipitation particles and prevent them from falling out of the cloud earlier. Therefore, amount of solid precipitation and the diameter of particles on the surface are larger when the electrification are considered.

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