The Construction of WRF-Electric Model and Its Preliminary Application

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1. Extended Abstract

The processes of cloud electrification and lightning parameterization are introduced into the Advanced Weather Research and Forecasting (ARW-WRF) model, in which the ideal and real cases are simulated. The numerical formulation of the electrical processes includes the non-inductive graupel-ice, hail-ice, hail-snow and inductive graupel-cloud, hail-cloud charge separation mechanisms coupled with the Milbrandt two-moment microphysical scheme. In the meantime, a bulk lightning parameterization is considered in the model. The model coupled with the electrical processes is referred to as the WRF-Electric model (WRF-Elec). The 3-dimensional charge structure and vertical electric field of the storms can be simulated by the coupled model.

The simulation of supercell produced a normal tripolar charge structure, consisting of a main negative charge region (−10°C to −30°C) with an upper main positive charge region (−40°C to −60°C) and a lower positive charge region (near 0°C). The maximum total charge density is approximately 2nC/m^3. The majority of hail and graupel charge negatively and most of the ice and snow charge positively. In the whole charging process, the noninductive charge separation mechanism between graupel (hail) and ice plays a vital role, while the effect of the inductive charge separation mechanism is very weak in the simulation. The simulated vertical profile of charge structure is in accordance with the previous classical structure observed in the severe convective weather.

As a devastating weather system, the tropical cyclone (TC) and its dynamical and microphysical characteristics have long been of interest. It is also found that lightning activity is associated with the formation and development of TCs. The charge structure is the bridge between lightning activity and the dynamical and microphysical characteristics of TCs. This study makes an attempt to illustrate the evolution of the charge structure of TCs.

Evolution of the electrification of an idealized TC is simulated by using the WRF-Electric model. Results indicate that the TC eyewall generally exhibits a negative dipole charge structure with negative charge above the positive. In the intensification stage, however, the extremely tall towers of the eyewall may exhibit a normal tripole structure with a main negative region between two regions of positive charge. The outer spiral rainband cells display a simple positive dipole structure during all the stages. It is further found that the differences in the charge structure are associated with different updrafts and particle distributions. Weak updrafts, together with a coexistence region of different particles at lower levels in the eyewall, result in charging processes that occur mainly in the positive graupel charging zone (PGCZ). In the intensification stage, the occurrence of charging processes in both positive and negative graupel charging zones is associated with strong updraft in the extremely tall towers. In addition, the coexistence region of graupel and ice crystals is mainly situated at upper levels in the outer rainband, so the charging processes mainly occur in the negative graupel charging zone (NGCZ).

The charge structure and formation in Typhoon Molave (2009) before and after landfall and during the decaying stage are also investigated using satellite, lightning detection data and WRF-Electric model. Results show that Molave was intensifying prior to landfall, with a well-defined eye and relative high-frequency lightning activity in the eyewall. Convection near the eyewall exhibited positive tripole charge structure, with negative charge located between the levels of −25°C and −10°C sandwiched by two positive charge regions. However, the charge structure of convection becomes negative bipole, along with negative charge in the middle and positive charge at the bottom of convection clouds after Molave reaches its maximum intensity. The charge structure of eyewall convection is closely associated with typhoon intensity, but not in a direct correlation to landfall. The outer spiral rainband cells display a positive tripole charge or a positive bipole in different stage of Typhoon. Previous studies suggested that outer rainband only features a positive bipole charge structure. The positive tripole charge structure is formed with different mechanisms: one resembles that in the eyewall, and the other has a positive charge region composed by hail and a positive bipole region composed by graupel and ice crystals in the upper levels, thereby forming a positive tripole charge structure. During the decaying stage of typhoon, weak convection is mainly featured by a negative bipole, similar to the terrestrial thunderstorms in the dissipative stage. In addition, different charge structures and corresponding convection intensity are also discussed.