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The comparison and the analysis of the simulation results of two thunderstorm cells and a non-thunderstorm cell *

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***Abstract*—for investigating the impact of updraft on lightning activity, a 3D cloud resolution numerical model, coupled charging and discharging processes, is used to simulate three storms, including two thunderstorms and a non-thunderstorm. The results show that the appearance of strong updraft above 0 ℃ isotherm should be a good directive to indicate whether a cell could develop into a thunderstorm or not. Strong updraft is benefit for charging processes between ice particles, but strong net charge layers, which will cause lightning initiation directly, always form in the regions with relatively low updraft speed. It might make the first lightning in a weak thunderstorm with shorter transform distance for charged ice particles from updraft to the regions with weak updraft speed occur earlier because the separation between opponent polar charges on ice particles with different scales will be easier if the charging processes in the weak thunderstorm could be strong enough firstly.**

Keywords—updraft, lightning, net charge layer

I. INTRODUCTION

Strong updraft is an important energy source for convective system development. It provides water vapor and enough buoyancy for ice particle growth. Many observations have confirmed that a strong updraft in the mixed-phase region is necessary to produce lightning (Workman and Reynolds, 1949; Williams and Lhermitte, 1983; Black and Hallett, 1986, 1999; Dye et al., 1989; Willams et al., 1992; Rutledge et al., 1992; Zipser, 1994; Baker et al., 1995, 1999; Carey and Rutledge, 1996; Petersen et al., 1996, 1999; Lang and Rutledge, 2002; Tessendorf et al., 2005; Wiens et al., 2005; Deierling and Petersen, 2008). But the detail, such as how strong updraft affects the start of lightning activity, is still not very clear.

II. NUMERICAL SIMULATION

A cloud-resolution numerical model is used here (Tan, 2006) to simulate three cells based on the different atmospheric sounding data. Among them, two cells grow into thunderstorms with more than 100 lightning flashes (the strong thunderstorm) and only 12 lightning flashes (the weak thunderstorm) in the whole simulation period respectively; there is no lightning flash simulated in the third cell (the non-thunderstorm). The evolutions of the lightning frequencies in the thunderstorms are showed in Fig. 1. The lightning activity in the strong thunderstorm starts in the 19th minute and lasts for about 17 minutes. The frequency peak, 23 flashes/min, appears in the 24 minutes. For the weak thunderstorm, the lightning activity only continues for about 6 minutes from the 18th minute to the 23rd minute. A very weak frequency peak, which is not significant comparing with its neighbors, emerges in the 20th minute.

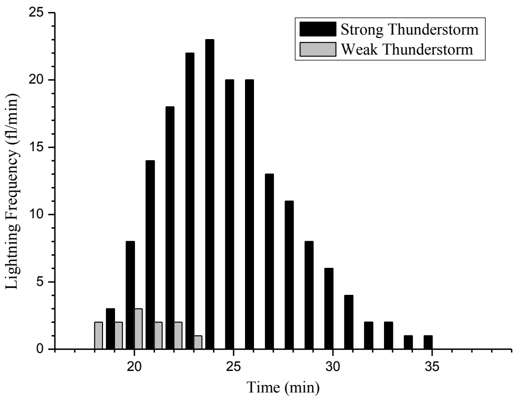

Fig. 1 lightning frequencies of the strong thunderstorm and the weak thunderstorm

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III. RESULT ANALYSIS

In this study, we define the regions, where the updraft speeds are greater than 1 m/s, as the normal updraft, and the regions, where the updraft speeds are greater than 5 m/s, as the strong updraft.

A. Comparison of Updraft

The comparisons in three simulations indicate that the appearance of the strong updraft above the melting level is the key factor to lead a cell to a thunderstorm. Fig. 2 illustrates the evolutions of the volumes of the normal updraft and the strong updraft in three simulations. In the non-thunderstorm, there is no volume of the strong updraft above the melting level; in another two thunderstorms, they all have the volumes of the strong updraft above the melting level before lightning occurrence. Simultaneously, more the maximum volume of the strong updraft is, more lightning flashes will occur in the later. Also, the same characteristic is showed in the evolution of the volume of the normal updraft. But even in the non-thunderstorm, the volume of the normal updraft is evident before lightning activity starts although the volume is very small.

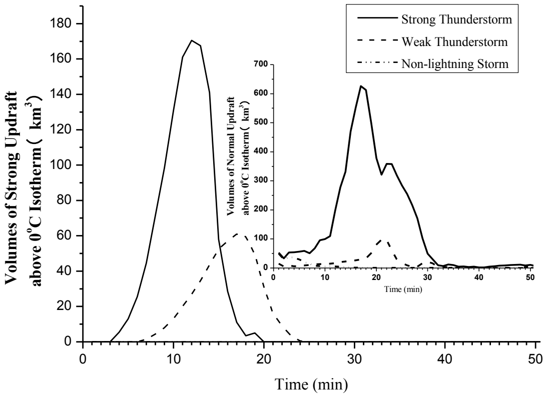

Fig. 2 evolutions of the volumes of the strong updrafts and the normal updrafts in three simulation storms

Although the appearance of the strong updraft above 0℃ isotherm in the strong thunderstorm is earlier than the weak thunderstorm, the first lightning of the weak thunderstorm is slightly earlier than the one of the strong thunderstorm. The first lightning in the strong thunderstorm occurs when the volume of the strong updraft above 0℃ isotherm is decreasing. But the first lightning in the weak thunderstorm occurs when the volume gets its peak. The time span between the volume peak and the first lightning occurrence in the weak thunderstorm is much shorter than the time span in the strong thunderstorm.

B. Evolution of Net Charge Concentration

The high net charge concentration will lead to high electric field which will initiate lightning directly. Especially when high positive charge concentration and high negative charge concentration coexist, the electric field will be easier to get a high value.

The evolutions of the volumes of high charge concentration in the strong thunderstorm and the weak thunderstorm indicate that the appearance of high positive charge concentration and high negative charge concentration coexistence in the weak thunderstorm is evidently earlier than the appearance in the strong thunderstorm although the coexistence time in the strong thunderstorm is much longer than the coexistence time in the weak thunderstorm, and the volumes with high charge concentration in the strong thunderstorm are also much larger than the volumes in the weak thunderstorm (Fig. 3). Within several minutes after the appearance of coexistence of high positive and high negative charge concentration, first lightning flashes occur in both of thunderstorms.

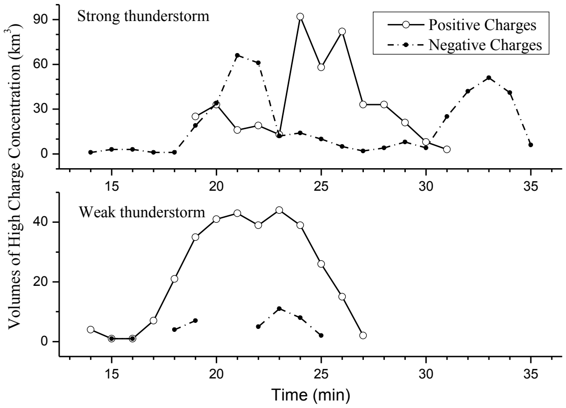

Fig. 3 evolutions of the volumes of high net charge concentration (>1 nC/m^3)

The horizontal distance between net negative/positive charge core and updraft core is analyzed. Only the samples, in which the net negative/positive charge concentration is greater than 1 nC/m3, are displayed according to time series (Fig. 4). It shows that the net charge core in the weak thunderstorm appears more closely to the updraft core than the net charge core in the strong thunderstorm. The maximum distance in the weak thunderstorm is never larger than 6 km and the mean distance is about 3.2 km. The mean distance in the strong thunderstorm is about 3.6 km and the max is more than 9 km.

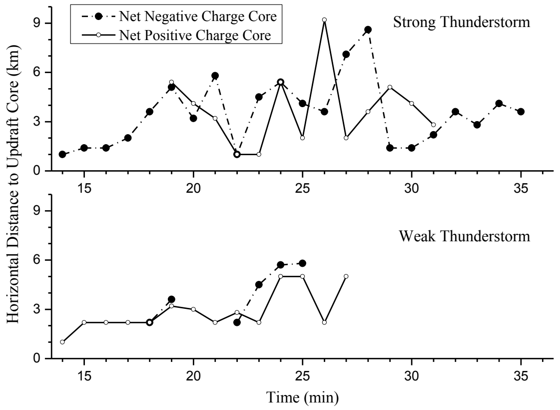

Fig. 4 evolutions of horizontal distance of net charge core to updraft core

IV. CONCLUSION AND DISCUSSION

Strong updraft is essential for thunderstorm growing. Especially for strong updraft in the height above 0 ℃ isotherm, it might be an iconic factor to indicate whether a storm could develop to a thunderstorm or not. Strong updraft above 0 ℃ isotherm could not only provide enough water vapor to form super-cooled water, which is also benefit for ice particle growth, but promote the collision between ice particles. Both of them are important for charging processes. So thunderstorm with stronger updraft always has more lightning flashes and more intensive lightning frequency.

On the other hand, strong electric field necessary for lightning initiation needs net charge layer with net charge concentration high enough. Low updraft speed is always more advantageous for the separation of big ice particles and small particles, which are charged with contrary polar charges, through gravity. In thunderstorm with weak updraft, charged ice particles walk a shorter way to complete the separation process and form net charge layers. It might cause the first lightning in a thunderstorm with weak updraft happens earlier if the updraft produces enough charged ice particles.

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