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Research on "Jumps" Characteristic of Lightning Activities in a Hailstorm

YAO Wen, MA Ying , MENG Qing
(Chinese Academy of Meteorological Sciences, Beijing, China)

1. INTRODUCTION

In hail cloud, there exist not only strong updrafts but also complicated micro-physical processes involving ice particles, which consequently make the electrification process more intense and the discharge phenomena more active in hail cloud. In recent years, a large amount of observations have revealed that during strong storms like hail and cyclone there often occur high proportions of positive cloud-to-ground lightning. Some strong storms lead to very low frequency of CG lightning, which contradicts to the common belief that the stronger the convection is the stronger the CG activities are in thunder clouds. In the meantime, there exists high frequency of IC lightning. Thus, it can be concluded that lightning activities in hailstorms have complicated relations with dynamics , cloud micro-physical processes and precipitation.

SAFIR (Systeme d'Alerte Fondre par Interferometrie Radioelectrique) is a multi-sites location VHF (very high frequency) lightning detection system. Compared with the general low frequency lightning location system, SAFIR can detect more IC flashes and have advantages and characteristics in detection efficiency and accuracy. SAFIR system has high time resolution, and can provide spatial distributions of lightning location (2 dimensional and 3 dimensional), as well as time distribution of lightning frequency. This can provide important information source for the description and surveillance of thunder storm areas.

Facilitated by SAFIR lightning detection system in the region of Beijing, Tianjin and Hebei Province, and together with radar data of Beijing, this paper analysed the evolution characteristics of lightning activities during the hail storm in Zhang shanying town of Yanqing County, Beijing,on June 23,2004. In the meantime, it also discussed the possibility of using the total lightning frequency observed by SAFIR to diagnose strong weather.

2. LIGHTNING ACTIVITY IN HAILSTORM

On 23 June, 2004, a classic thunderstorm weather began from Xuanhua County of Hebei province, then moved across Beijing from west to east. It shot strong hailstorm with gale from 8:20 to 8:32,UTC, the diameter of hail was 0.5-3.0cm, economic loss was up to 260.45 million yuan. This case provided an opportunity for study the lightning characteristics by SAFIR and Radar evolution data.

Figure 1 showed the map of Beijing-tianjin-hebei region with lightning detection by SAFIR and the storm path from7:30 to 9:30, UTC on 23 June, 2004. Lightning activity developed from west to east of Yanqing county, and crossed south after 9:00 UTC.

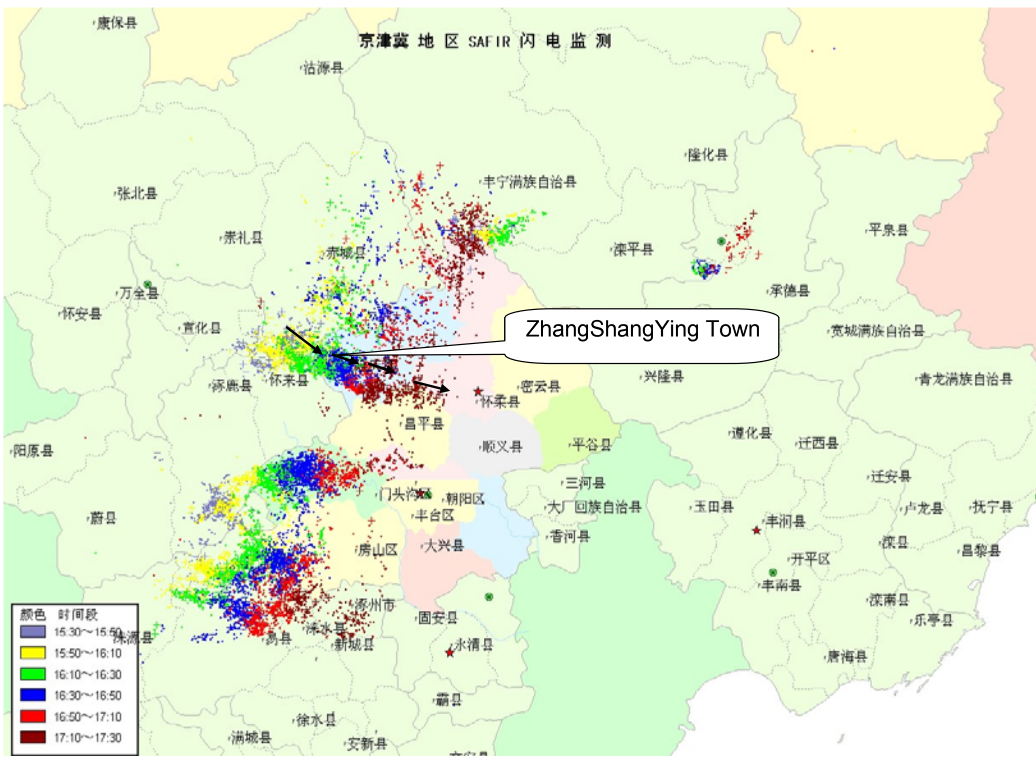


Figure 1 Map of Beijing-tianjin-hebei region with Lightning detection by SAFIR and the storm path from 07:30 to 09:30 UTC on 23 June, 2004.

（Red start symbol show SAFIR3000 installation sites）

2.1 SIGNATURES IN LIGHTNING ACTIVITY

In this hail storm, there were 6037 total lightning flashes observed, including 5851 IC flashes, accounting for 96.9%, and 186 CG lightning, accounting for 3.1%. CG flashes had very little frequency, while IC flashes accounted for the most part. IC flashes were mostly distributed on the height of 7.5km~11.5km. Figure 2 showed the time series of the total lightning frequency (the frequency per minute) during this hail storm.

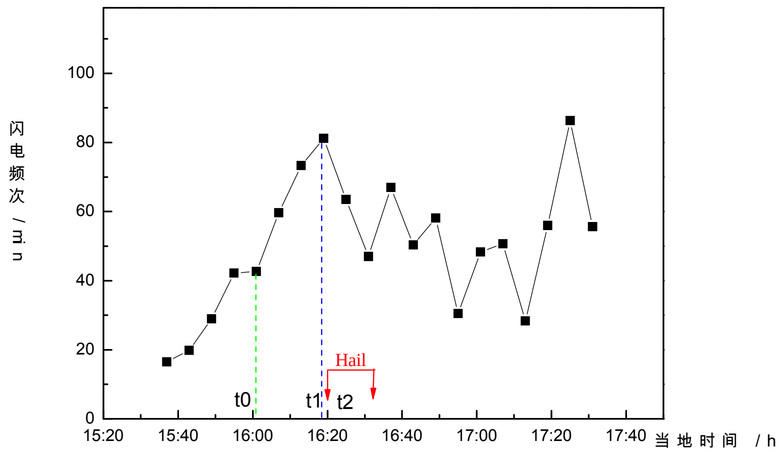


Figure 2. Time series of the total lightning frequency

Three characteristic time points were found, that is t0, t1 and t2. Many researches revealed that the most obvious and systematic characteristics of thunderstorms occur 1-15 minutes before the strong weather onset. t0 was the time when lightning frequency increases rapidly, which could be termed as lightning “jumps”. The time point of t0 (08:01 UTC) was the time for lightning jump, while t1 (08:19 UTC) was the time when lightning peak frequency occurs, and t2 was the time when the hail storm shooting the ground. The lightning jump during this hail storm changes from 40 times per minute to 80 times per minute in 18 minutes.

In view of total lightning frequency, it increased continuously before occurrence of hail, up to 80 flashes per minute ,which was the maximize value by 08:19 (UTC). At the time of hail shooting, the frequency of total lightning decreased suddenly, lightning activity had weakened a few minutes before the hail shooting, which indicated that the peak in the lightning activity was prior to severe weather at the ground, and this time interval was probably the period during which the hail shot from the clouds to the ground. With the hail falling down, ice particles within the cloud suddenly decreased, which led to the lower lightning frequency. After the end of hail(08:32 UTC), a sharp decrease of the lightning flash rate from roughly 80 flashes per minute to 55 flashes per minute, but after that it increased to 80 flashes per minute suddenly, Then although lightning activity fluctuated, the overall performance was more active.

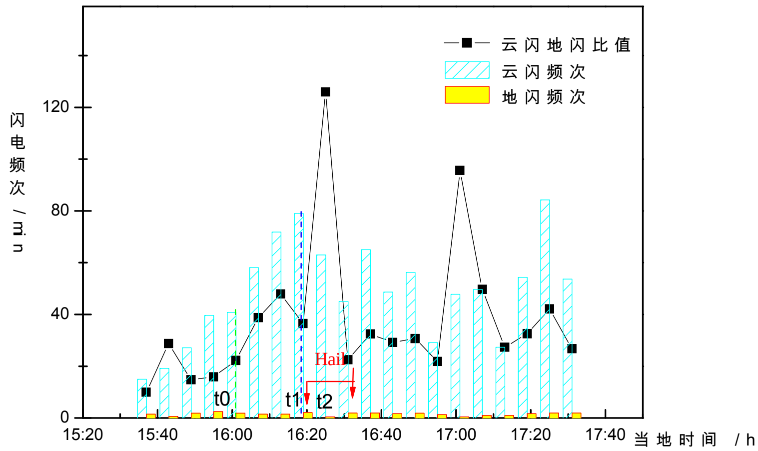


Figure 3 Time series of IC and, CG flashes rate

From figure 3, it was noted that CG flashes had very little frequency, while IC flashes accounted for the most part in this hailstorm. The change of CG flashes was consistent with the total flashes, It also had a peak just before the hail occurrence, and then a shark decrease at the moment of hail falling down, At the end of hail shooting, a rapid decrease followed by a sharp increase in the CG flashes. Numerous studies had shown that IC flashes made up the majority of the lightning activity within thunderstorms, in view of IC flashes, at the moment of t0, IC flashes began increased rapidly, with the first peak of IC flashes frequency at t1up to 79 flashes per minute. This peak was higher than the IC flashes rate of the general thunder storm. The ratio of IC flashes to CG flashes (Z value) was an important thunder storm parameter. The Z value is about 3 in general thunder storm, but the Z value of this process kept above 20. It could be concluded that high Z value was one of the important lightning characteristics during this hail storm. The Z Value also increased rapidly at t0, but the peak did not appear at the moment of t1, which was the time when the total flashes and IC flashes reaching the peak. The peak of Z was 126 during the hail was falling down. This characteristic was worthy of further study.

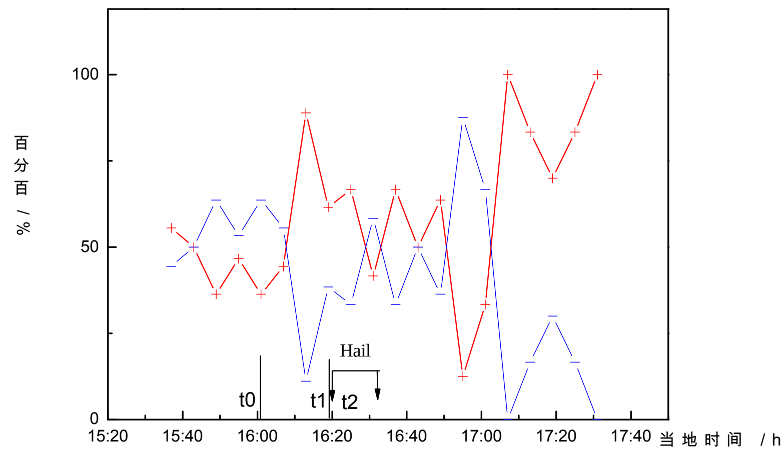


Figure 4. Time series on the proportion of PCG and NCG among the total CG flashes

Figure 4 showed that the proportion of positive and negative CG flashes among the total CG flashes varied with time series. The PCG accounted for 59.7% of the total CG lightning, while the NCG lightning accounted for 40.3%. From the graph 4, it could be seen that the two curves intersect with each other, with high and low values of their own. From the moment of t0, the PCG proportion rose rapidly, accounting for over 50%. Just 1 minute before hail occurrence, the proportion of PCG was up to the peak, and then it was decreasing during the hail falling down, and reached the lowest (12.5%). After the end of hail, the proportion of PCG was higher than that of NCG, even reaching 100%. Overall, the activity of PCG was very unstable, and had a higher ratio than normal.

2.2 ANALYSIS ON LIGHTNING CHARACTERISTIC COMBINED WITH THE RADAR ECHO

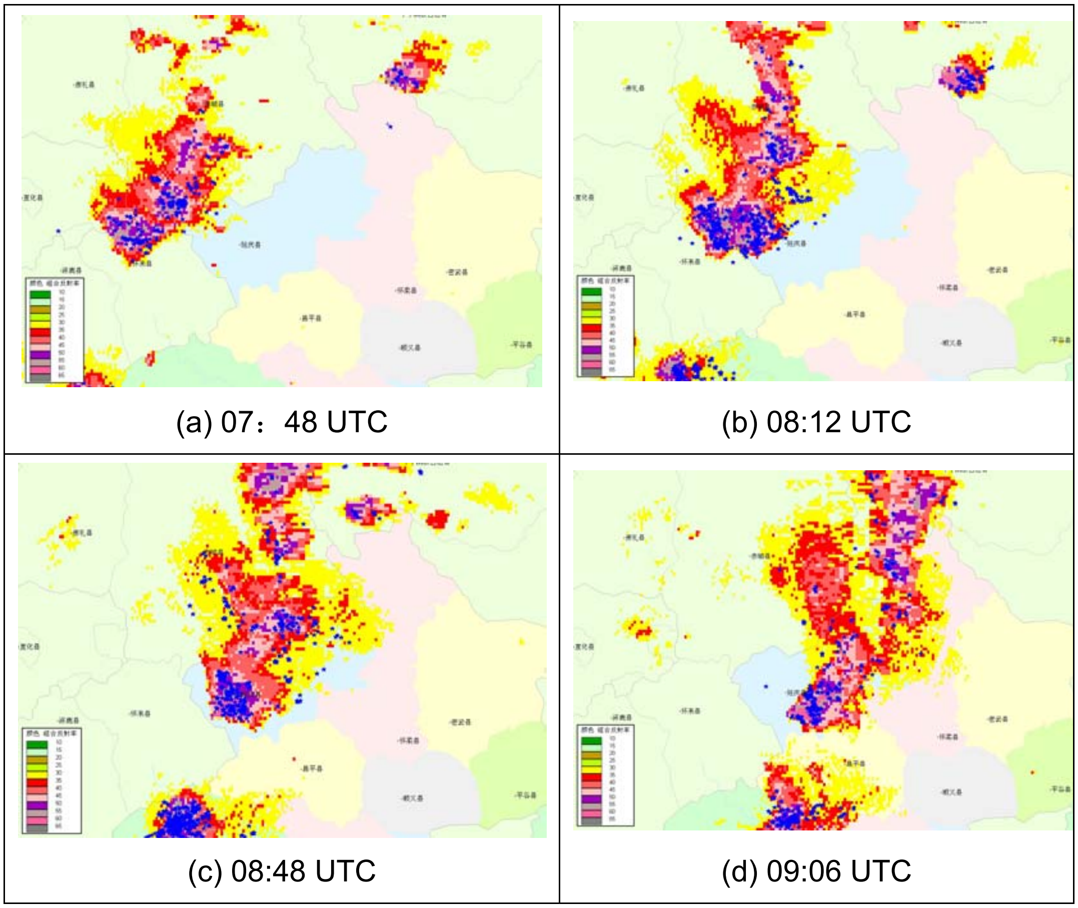
The radar data were collected with the CINRAD/SA located in Southeast of Beijing. The reflectivity was gridded, and the track region with the reflectivity echo of the storm centroid ≥ 30 dBz, was calculated for lightning statistics at each vertical level. The flash rate was calculated by dividing the total number of flashes occurring during each volume scan.

In the northwest of radar station, reflective echoes greater than 50 dBz appeared at 07:54 UTC, moving east-south accompanied by an increase of strong echo area. The change of CG frequency during this period was stable relatively. The spatial distribution of CG was relatively sparse, but the total lightning frequency was increasing slowly and the spatial distributions of the total flashes were more concentrated. Reflective echoes reached 65 dBz, Strong echo area was further increased by 07:48 UTC (Fig 5a), then CG flash ,Mainly NCG flash, increasing from (2~4)/6min to 11/6min, maintained at around 10 / (6min). From figure 5, it was noted that lightning aggregated in the vicinity of strong echo area. Afterward the total flashes and the PCG started to rise rapidly by 08:01 UTC, The flash rates increased from 2/6min to 8/6min, but the frequency of NCG began to weaken, and Followed by 08: 06 UTC strong echo area, ET, the area of strong VIL had a noticeable increase, between 08:12-08:18 UTC, the flash rate of CG was 9~13/min,and that of PCG was 4~8/min,but that of NCG declined from 5/6minto 1/6min.then the hail occurred between 08:20~08:32 UTC. it was pointed out Particularly before and after 08: 20 UTC, the strong echo cloud experienced a new, merged, developed again, but Lightning jump of total flashes and PCG were occurred only a few minutes before (almost simultaneously) hail. The total flash rates increased from 40 fpm at 08:01 to 80 fpm at 08:19 UTC, 18 minutes prior to the touchdown of the hail, in the hail weakening stage, coincident with a large decline Of total flashes, the PCGs were not active (1~2/6min), but the proportion of NCG was a marked increasing, up to 7/6min (fig 5c). After 09: 06 UTC (Figure 5d), Strong echo area became loose, scattered, the intensity began to weaken, lightning detected began to disperse, the total flash frequency gradually reduced, but the ratio of PCG was very high (7~10/6min), which was obviously more than NCG. The reason might be that after thunderstorms dissipated, its residual cloud anvil was still with a lot of positive charge, and broken clouds dissipated also carried a large number of graupel particles, hail block, water droplets, and not yet fully released from the charge, which had been transported to the lower cloud with the subsiding air, resulting in enhanced lower positive charge region, increasing the number of PCG.

3. RESULTS

The research reveals that the most obvious and systematic characteristics of lightning activity in hailstorm. That is :

1. There are two active periods in this hailstorm, the previous active period from 06:00 to 09:00 UTC, mainly characterized by frequent lightning and hail. After 9 o'clock UTC, that was another active period when the main feature was



(a) 07：48 UTC (b) 08:12 UTC

(c) 08:48 UTC (d) 09:06 UTC

Figure 5. the doppler radar and lightning evolution of the hailstorm.
(a. before the hail b. at the moment of hail occurrence
c. hail weaken d. hail dissipation)
(The blue start symbol show lightning flashes.)

active in lightning activity with ups and downs, but without hail. And the lightning activity was weak between these two periods.

2. The largest Lightning-density area was before the position of the hail location. The spatial distribution and time series of the Lightning activity identified the development and the path of hail. Lightning distribution was in the radar echo area, but not in correspondence to the strongest radar reflectivity echo.

3. In this hailstorm CG flashes had very little frequency, while IC flashes accounted for the most part. In the general thunder storm, the ratio of IC flashes to CG flashes (Z value) was about 3, but the Z value of this process kept above 20. It could be concluded that high Z value was one of the

important lightning characteristics.

4. From the analysis of this case, it could be proposed that t1-t0 was the rising time and this rising time was 18 minutes. This could be used as an alarm index for the peak of lightning frequency during this hail storm. Meanwhile, t0 was 19 minutes before t2 at which time the ice storm comes to the ground. This is also a useful alarm index, which might facilitate the prediction of hail storm disasters by using lightning detection data.

4. ACKNOWLEDGMENT

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