Cloud-to-ground lightning activity in a hailstorm over the Central Lower Latitude Plateau of China

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ABSTRACT: A thunderstorm that developed over the central Lower Latitude Plateau of China on 16 July 2006 is analyzed in detail using the data from a CG lightning location network and Doppler radar. This severe thunderstorm produced hailstones as large as 15 mm and had a lifetime of 3 h and 20 min. The thunderstorm exhibited strong vertical development with cloud top reaching 15.9km. The CG parameters considered are the flash rate, the flash polarity, the multiplicity, and the peak current. The thunderstorm produced especially low positive CG proportions associated with negative CGs with high values of peak current and multiplicity.This second part is mostly centered on the detailed analysis of the CG lightning behavior, its relationship with radar-derived storm parameters, and CG lightning correlation with hazardous weather. The analysis of the storm cells life cycle has showed similar trends between the CG lighting flash rates and radar-derived parameters like the area of reflectivity above 30dBZ at the -10℃ isotherm height. There is a distinct increase in CG flash rate during the rapid development stage of hailstorms. The CG lightning "jump" pattern seems more robust to forecast in a short-term basis the possible occurrence of severe weather.

Key words: CG lightning; Hailstorms; Radar echo

1. INTRODUCTION

Many studies have reported severe thunderstorms usually present positive cloud-to-ground (CG) flashes for several tens of minutes during their mature phase（Liu et al., 2009; Soula et al., 2004;Zhang et al.,2004）. Recently, Feng et al.(2007) found that the percentage of +CG lightning in 10 severe hailstorms in Henan Province was high with an average values of 45.5% while it was 8.15% on average over a 3-year period for all storms occurring in the same area. Reap et al. (1989) found that the probability of severe weather increases rapidly with the increase of positive CG flash density by studying thunderstorms in warm seasons in the Great Plain. However, Carey and Rutledge (1998) suggested that some severe storms do not produce large numbers of positive CG lightning. Qie et al. (2002) also discovered that weak thunderstorms in the Chinese inland plateau are often characterized by a relatively high ratio of positive CG lightning.

A noted feature of severe storms is the presence of abrupt increases in the total flash rate in advance of the maximum rate of the storm and severe weather, and has been reported in many studies (Schultz et al.,2011). Williams et al. (1999) had called these rapid increases as lightning "jumps". This feature has

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been used in algorithm to identify severe weather (Gatlin et al., 2010).

The Lower Latitude Plateau of China is the Yunnan-Guizhou Plateau which is the region from 21°N to 30°N with the altitude of 2000m.a.s.l.It is a typical monsoon climatic region with the distinct dry and wet season. The goal of the present paper is to present a detailed study of one thunderstorm that occurred on July 16th of 2006 over the central Lower Latitude Plateau of China, and to show more evidence about the important role of CG lightning in severe weather monitor tasks.

2. DATA AND ANALIZING MEOTHDS

The CG lightning data were from the Yunnan Province Lightning Detection Network, which consists of 23 CG lightning sensors and one data processing center (Xie et al., 2013). In order to avoid the contamination of the +CG data set with intra-cloud (IC) flashes, the +CG flashes with peak current values less than 10 kA were filtered out as recommended by Cummins et al. (1998). The radar data obtained from C-band Doppler radar, located at Kunming(102.58°E，25.05°N), performed synchronized full volumetric scans of the storm every 6 min.

3. RESULTS

3.1 LIGHTNING CHARACTERISTICS OF HAILSTORMS

The Supercell storm developed around 16:07 LT over the Central Lower Latitude Plateau of China and moved west-southward until 19:19LT. During the 3 h and 20 min of the cell lifetime it covered a distance of 60 km with an estimated average speed of 20km/h. The 18-dBZ reflectivity echoes reached an altitude of 15.9 km at 17:57 LT. About 17:08 LT, hailstones with diameters up to 15 mm were reported at the ground. Table 1 summarizes different characteristics of thunderstorm, related to its structure and lightning activity. The thunderstorm produced 818 –CG flashes, 11 +CG flashes. The percent of positive CG lightning was only 1.3% in the thunderstorm, which is below the climatic average value of 3% in its surrounding region (Xie et al., 2013).

Table 1 Overall Characteristics of the cell

Cell duration	3h20min
-CG flashes	818
+CG flashes	11
Average multiplicity(maximum)	2.3(15)
Average peak current for -CG(kA)(median)	23.2(20.8)
Maximum cloud top(km)	15.9
60-dBZ maximum altitude(km)	8.2

There was an obvious jump in CG flash rate during the rapidly developing stage of a hailstorm. The peak CG flash rate was 79flashes/ 5nin at 17:02LT. The CG lightning trend information provided nearly 6 min of lead time (Figure 1).

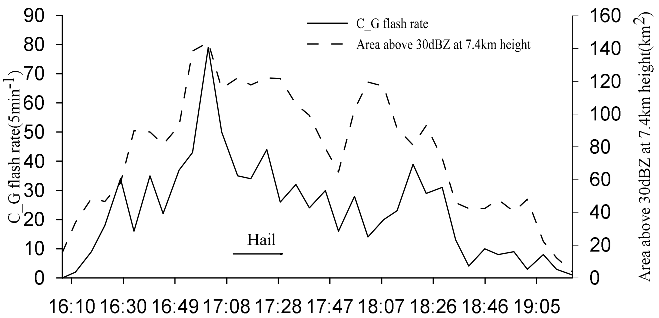

Figure 1 Evolution of CG flash rate and area of reflectivity above 30dBZ at 7.4km height (LA-30)

Figure 2 displays the horizontal distribution of the maximum of the radar reflectivity at 17:07 LT i.e. at the time of hail precipitation. No +CG flash occurred around 17:07 LT and 50 -CG flashes occurred around 17:07 LT. The CG flashes seem to be located closer to the high reflectivity regions.

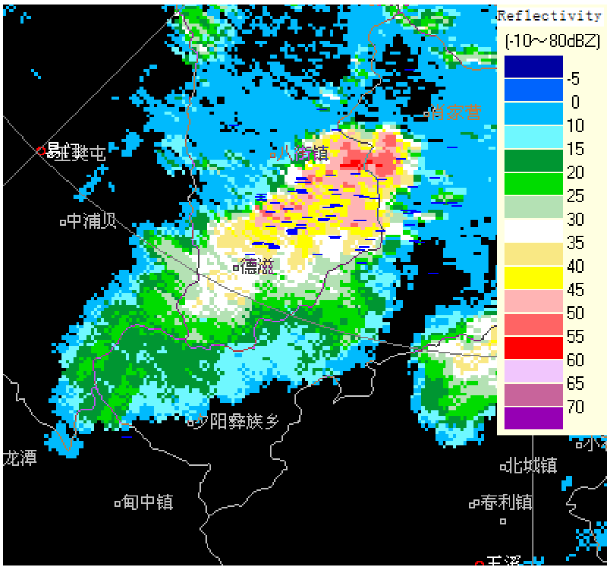

Figure 2 Radar reflectivity and lightning activity around 1707 LT, "+" for +CG flashes, blue "-" for –CG flashes.

3.2 Lightning and radar correlation analysis

A correlation analysis was made between total CG flash rate (CGFR) and different radar-derived storm parameters (VIL, LA-30).

A correlation analysis was made between total CG flash rate (CGFR) and different radar-derived storm parameters (Etop, Top-30, LA-30, VIL).CGFR has shown a slightly better correlation with Etop than Top-30(R^2 of 0.47 and 0.43 respectively, with 35 samples).For the LA-30, the linear fitting showed a better correlation with the CGFR, With a coefficient (R^2) of 0.67(Figure 4.)

The VIL pattern, looking to the cells life cycle (Figure 3b) follows a different trend to those of CGFR. The maximum of VIL occurs around 17 min before the CGFR surge. Moreover, the VIL starts to decrease while the CGFR is still growing. The correlation between VIL and CGFR(Linear fitting R^2 =0.22) is less good than with Top or LA-30.MacGorman et al.(2007) found that a poor relationship between VIL and the

CG flash rate, and pointed out that the VIL may be more related to the total lightning flash rate.

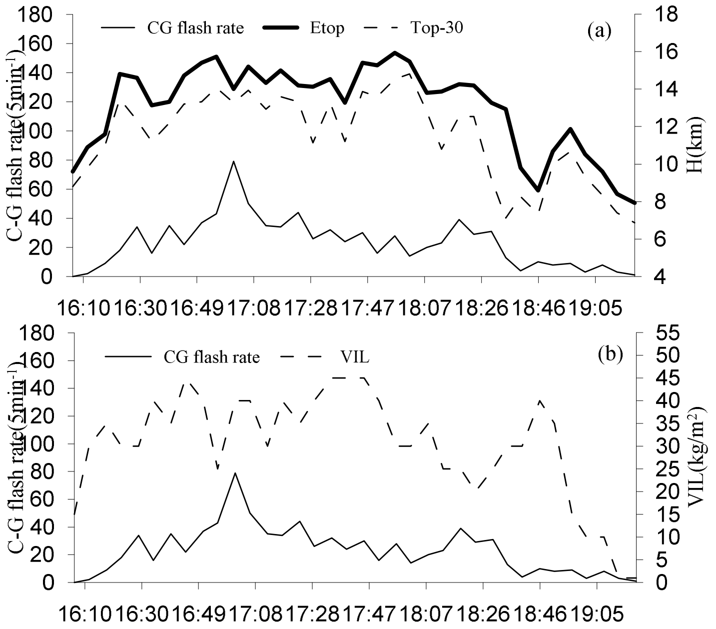

Figure 3 Radar and lightning life cycle evolution, Radar-derived parameters:(a)Etop: the top height of 18-dBZ reflectivity echoes, and Top-30: the top height of 30-dBZ reflectivity echoes;(b)VIL

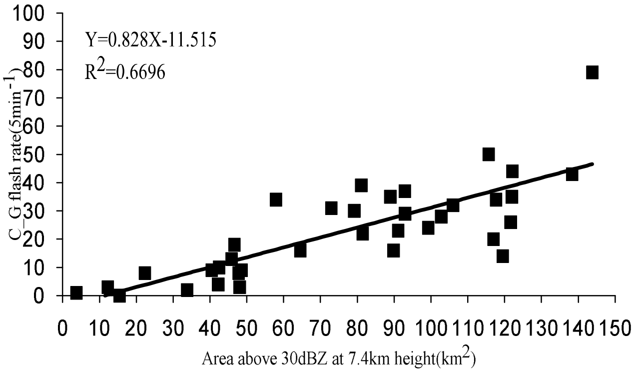

Figure 4 Total CG flash rate vs. Area of reflectivity above 30dBZ at 7.4km height

4. CONCLUSIONS

The CG flash activity and the reflectivity structure from C-band weather radar, related to a thunderstorm producing large hail, have been described. The following results have been obtained.

(1)The thunderstorm produced especially low positive CG proportions associated with negative CGs with high values of peak current and multiplicity.

(2) The CG lightning "jump" pattern seems more robust to forecast in a short-term basis the possible occurrence of severe weather.

(3)The analysis of the storm cells life cycle has showed similar trends between the CG flash rates and radar-derived parameters like the area of reflectivity above 30dBZ at 7.4km (LA-30). The good correlation found between CGFR and the LA-30 suggests that one of the important properties of convection related to thunderstorm charge generation is particle interactions resulting in reflectivity growth at the −20 °C region. It also suggests that, in the absence of total lightning records, such a radar parameter can be used as an indicator of severe weather.

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