P14.5 LIGHTNING SIGNATURES IN CONVECTIVE STORMS ON THE HIGH PLAINS

Maribel Martinez * and John L. Schroeder
Texas Tech University, Lubbock, Texas

1. INTRODUCTION

Year after year, lightning has been the most constant and widespread threat to people compared to all other weather events. Between 1959 and 1994, lightning caused 3239 deaths, 9818 injuries, and 19814 property-damage reports (Curran and Holle, 1997). Forecasters have access to real-time lightning displays that show lightning location, polarity, and age of lightning strikes. These displays give a forecaster a feel for the electrical activity associated with each cell and determine an overall trend in lightning. Currently, no lightning forecasting system is commonly available, other than prediction based on observed trends in lightning activity.

Personal communication with several National Weather Service (NWS) offices located across the U.S. has revealed that forecasters feel increased confidence that a thunderstorm is producing large hail or severe weather when there is excessive lightning. Some offices take into account polarity changes in cloud-to-ground (CG) lightning, detected by the National Lightning Detection Network (NLDN), as a general characteristic of storm severity. Lightning frequency itself is not yet a parameter used to issue warnings. However, lightning programs in weather offices such as those in Pueblo, Colorado and Melbourne, Florida, currently use real time CG lightning activity to warn the public about lightning potential when they issue hazardous weather outlooks or nowcasts (Hodanish, 2000; Sharp, 2002).

An understanding of the association between storm intensity and lightning activity may help forecasters better distinguish between severe and non-severe storms. This study aimed to look into this issue by involving analysis of total lightning behavior in both severe and non-severe storms. The following questions are addressed:

- Are there distinguishable variations in flash and VHF radiation rates before hail and/or tornadic events occur?
- Do the majority of the storms that exhibit severe warning criteria, produce a majority of positive (+)CG lightning?
- Does the height distribution of lightning impulses vary in different phases of storm evolution and severity?

2. DATA DESCRIPTION AND METHODS

The data for this study consists of lightning data from seven thunderstorms that occurred during the Severe Thunderstorm Electrification and Precipitation Study (STEPS) 2000 based out of Goodland, Kansas. Lightning observations from the NLDN, operated by Global Atmospherics, Inc., and the Lightning Mapping Array (LMA), deployed by the New Mexico Institute of Mining and Technology, were used. Based on radar images and lightning comparisons, only CG lightning strikes and radiation that occurred in the storm were included in the research.

The NLDN operates by detecting electromagnetic signals that are emitted when lightning strikes the earth's surface. A NLDN sensor discriminates the electromagnetic structure of a CG lightning flash from other forms of lightning or noise by a sharp voltage rise as the return stroke is triggered (Anderson, 2002). Flash rates and peak currents were computed from the lightning ground strike locations and polarity given by the NLDN. Lightning flash rates were computed every 5-minute intervals for +CG, negative (-) CG, and all CG lightning. Peak currents were calculated, as discussed by Cummins et al. (1998). To maintain consistency with other research studies, +CG discharges less than 10 kA were omitted in the analysis procedures.

The LMA is different from the NLDN in that it detects total lightning activity by locating the sources of impulsive VHF radiation events produced by lightning (Krehbiel et al., 2000). The radiation (movement of charge) points are lightning segments 10's of meters in length. By being able to map the location of lightning in three dimensions, the LMA allows one to study the initiation and development of lightning flashes and determine the initial CG lightning and in-cloud (IC) flash rates for storms (Rison et al., 1999). This data was then used to determine radiation rates and height distributions for each storm. Radiation rates were computed every one minute interval. Height distributions were determined by counting the number of radiation points that occurred every 0.5 km from a height of 0 to 15 km and contoured with an interval of 50. Over time this reveals the location of the maximum concentration of lightning and the vertical variations of the temporal lightning activity relative to severe and non-severe cases.

NWS warning information and public reports of large hail, damaging wind, and tornadoes related storm severity to lightning evolution. A total of seven storms (11 June, 12A June, 12B June, 24A June, 24B June, 29 June, and 5 July) were analyzed. One storm (12B June) did not produce any severe weather. Out of the seven storms, total lightning behavior was analyzed for five. Five of the cases with CG lightning observations had at least one severe weather report of hail, tornado, or wind. In most of the cases there were several reports of severe hail and the NWS issued numerous warnings.

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*Corresponding author address: Maribel Martinez, Texas Tech University, Atmospheric Science Dept., Lubbock, TX 79409; email: maribel.martinez@ttu.edu.

It is important to note that the STEPS project occurred in an area that was sparsely populated, and therefore large hail or high wind could have occurred, but not reported to the NWS.

3. RESULTS

The 12B June case did not produce any CG lightning, but VHF radiation was observed. Radiation rates did not exceed 2000 flashes per minute at any time and activity stayed between 5 to 10 km. No severe weather was reported for this case. The 24B June case also did not produce any CG lightning strikes, but a severe weather thunderstorm warning was issued for it. VHF radiation rates showed a rapid increase from minimal flashes to 4000 points per minute in about a 5-minute window. During this increase in radiation rates, the VHF radiation spread and filled the 4-10 km height regions. Figure 1 below shows the VHF radiation rates for both cases.

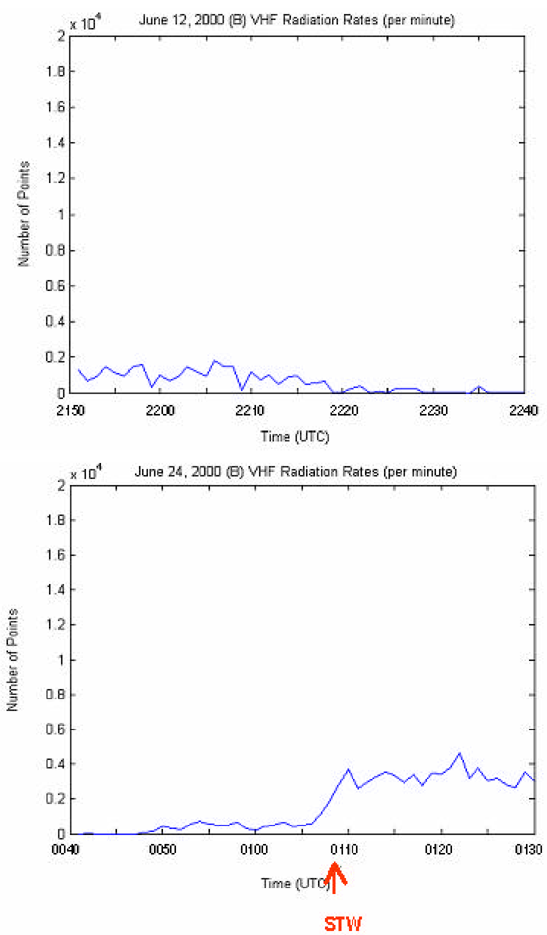

Figure 1: VHF radiation rates for 12B June and 24B June.

Other storms that produced both CG lightning strikes and VHF radiation showed that as +CG lightning flash rates increased, more hail was reported and more severe thunderstorm warnings were issued. This result was true for the 11 June and 12A June cases. In the 11 June case, as the storm increased in intensity, the +CG lightning peak currents increased in strength. More severe weather occurred after a polarity reversal from –CG to +CG. The 12A June case also had a tornado warning issued after a decrease in +CG flash rates and less peak currents. After the tornado warning, +CG flash rates increased rapidly as seen in Figure 2 below. LMA analysis for both cases was not able to be performed due to a greater storm coverage area.

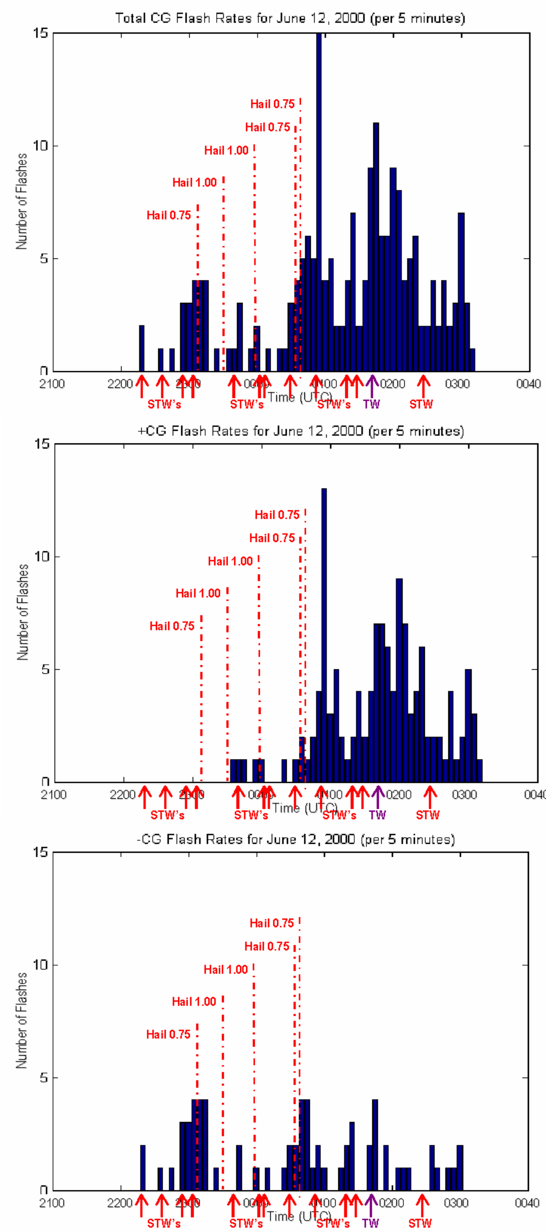

Figure 2: Total CG, +CG, and –CG flash rates for 12A June.

VHF radiation rates increased rapidly from minimal to 2000-3000 points per minute in a 5-minute window in the 29 June and 5 July cases. Also at this time the VHF radiation spread and filled the 4-10 km height regions as seen below in Figure 3. For both of these storms a

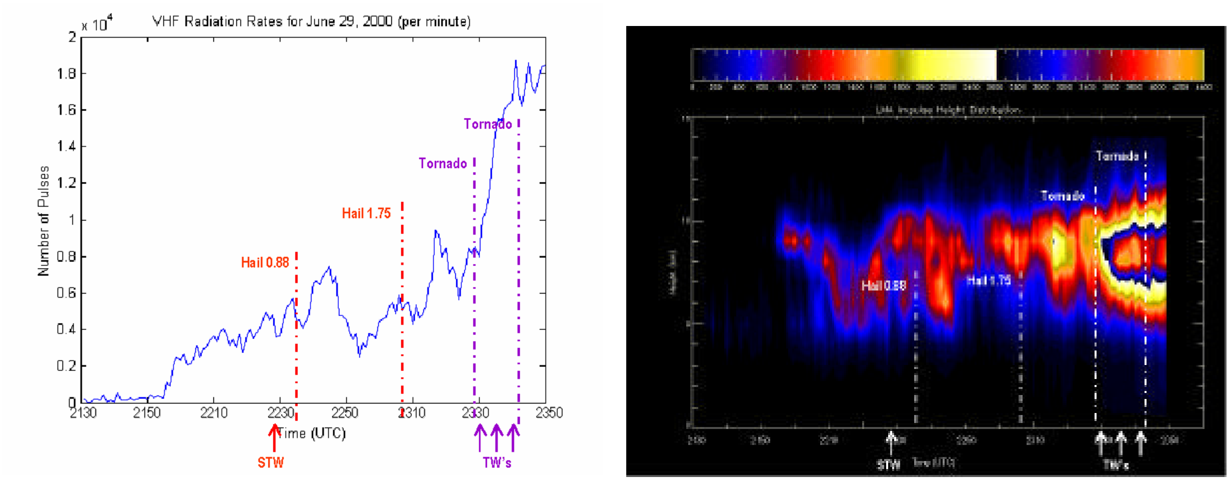

Figure 3: VHF radiation rates and height distributions for 29 June.

tornado warning was issued and an actual tornado was reported for the case of 29 June. The tornado touchdown coincided with an increase in +CG flash rates and VHF radiation rates and VHF concentration in the 8-9 km height region. In the 5 July case, a tornado warning was issued as the first –CG lightning strike occurred.

4. DISCUSSION AND CONCLUSION

The purpose of the study was to examine total lightning behavior and determine its relationship to storm severity. Table 1 summarizes the results of this study. The difference in total lightning behavior between a non-severe and severe storm is that in a severe storm VHF radiation rates exceeded 2000 flashes per minute and VHF radiation began to spread and fill the region between 4-10 km. This flash rate increase and radiation spread were the main distinguishing factors. One storm that did not become severe did not produce any CG lightning. Each of the other cases also experienced a polarity reversal. Although in some cases the reversal was during or after hail was reported, the polarity reversal always occurred before tornadic events (warnings or ground reports). The polarity reversal itself was associated with a decrease in lightning in the mid-levels of the VHF radiation temporal height distributions. Peak currents also increased at this point. With reports of hail, lightning behavior varied. In a few cases hail occurred when –CG lightning dominated, but in the majority of the cases, +CG lightning was present. Hail reports coincided with the vertical extent of VHF radiation distribution in two cases which produced the most severe weather.

The reason for the polarity reversal remains unknown. Liquid water contents were not examined, but may be implicated in the reversal. Non-inductive graupel ice interactions can cause graupel to be positively charged and ice crystals to be negatively charged due to microphysical charging at specific temperatures and liquid water contents. Rapid graupel and hail growth occur in regions of large liquid water content (Miller et al., 1990). The reversal of charge would mean that more graupel (or less depending on the reversal type) would be produced and moved by the storm environment. The absence or decrease of VHF radiation points at these mid-levels could be the sign of an updraft which aids graupel growth and thus produces the reversal.

Although the seven cases presented here support the hypothesis that lightning activity could indicate whether or not a storm will become severe, more studies are needed to confirm the results. This study examined the use of lightning in convective storms on the High Plains. Because of the differences in environmental conditions, results will likely differ in different geographic regions. As more detailed lightning detection networks and radars emerge, the intricate processes involved in lightning production and the underlying effects of the dynamics of these severe storms should be further clarified.

Date	Severe Weather	Polarity Reversal	First CG Polarity	VHF Radiation Rates/Height Distributions	Polarity Reversal and Height Distributions	Peak Current Significance
11 June	STW, hail, wind	Yes, before severe weather	Neg	--	--	1. More severe weather >+CG current 2. After reversal to –CG again stronger currents
12A June	STW, TW, hail	Yes, before TW	Neg	--	--	1. Weaker currents before TW issued and during decrease in flash rates 2. +CG > 50 after TW issued
12B June	NONE	--	--	<2000 per min	--	--
24A June	STW	Yes, 20 min before STW	Pos	1. Rates >2000 in 10 min window 2. VHF 4-10 km	Decrease in mid-levels	+CG > 50 after polarity switch and before severe weather
24B June	STW	--	--	1. Rates >2000 in 10 min window 2. VHF 4-10 km	--	--
29 June	STW, TW, hail, tornado	Yes, 15 min before TW	Pos	1. Rates >2000 in 10 min window 2. VHF 4-10 km	Decrease in mid-levels	Peak currents remained constant
5 July	STW, TW, hail	Yes, just before TW	Pos	1. Rates >2000 in 10 min window 2. VHF 4-10 km	Decrease in mid-levels	+CG ~ 50 after polarity switch and before severe weather

Table 1: Summary of results.

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