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Comparison of VHF Source Characteristics for a Single-Stroke, Negative CG Flash with Continuing Current to Those for Nearby CG and IC Flashes

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I. Introduction

On 7 May 2008 at 1040:15 UTC, a cloud-to-ground (CG) lightning flash that occurred in central Oklahoma was recorded on high-speed video at 10,000 frames per second. This CG flash, henceforth referred to as the flash of interest or FoI, lowered negative charge to the ground, had a continuing current that lasted for more than 700 ms, and had at least thirteen M-components. The FoI is unique in that it was a single-stroke, negative flash with continuing current. Most negative CG flashes with continuing current have multiple strokes, and the stroke with continuing current is usually one of the subsequent strokes rather than the first stroke (e.g., Rakov and Uman 1990; Saba et al. 2006).

In addition to being captured on film, the flash of interest was observed by the Oklahoma Lightning Mapping Array (OK-LMA). The OK-LMA records the time and position of VHF radiation sources that are radiated by lightning as it propagates through storms. When the OK-LMA data for the FOI is examined, the FoI appears to be unique in its VHF characteristics compared to other flashes observed with the OK-LMA. An analysis and comparison of the VHF characteristics detected by the OK-LMA for the FoI and surrounding flashes is done to determine whether the FoI is statistically different from other CG and intra-cloud (IC) flashes in the same storm cell.

II. Methodology

The data for this analysis consist of all flashes that occurred within 30 minutes of the flash of interest and that were in the same cell of lightning as the FoI. The lightning cell is defined as the lightning that was initiated in approximately the same geographic location as the FoI. The data set includes 266 flashes, including 205 IC flashes and 61 flashes that have at least one channel to ground. Ground flashes were identified using a combination of data from the National Lightning Detection Network (NLDN) and data from the LMA. Where the two systems disagreed about whether or not there was a ground flash, the flash was investigated further to determine whether or not it should be considered a CG or an IC flash.

Once a group of LMA sources was identified as a flash, characteristics of the flash were recorded. For each flash, the following were recorded: start time of the flash, duration of the flash, time since the last flash, horizontal area covered by the flash, vertical extent of the flash, the number and location of in-

cloud charge regions through which the flash propagated, and the number of VHF sources making up each flash. Additional characteristics were recorded for CG flashes, including the time since the last NLDN flash, the number of NLDN locations associated with each flash, and the peak current and number of strokes from each channel to ground (as determined from the NLDN).

Because the flash of interest is visually different from other CG flashes, the LMA data for the flash were examined to determine whether any other VHF characteristics of the flash seem unusual compared to the other flashes that have been observed in the LMA (Figure 1). One characteristic that seems unusual is the number of VHF sources recorded where there was positive breakdown within negative storm charge after the negative channel reached the ground. Positive breakdown is notoriously quiet in the VHF range and is often not directly observed by the LMA. Because the FoI appears to produce more VHF sources during positive breakdown than what has been seen in the past, the horizontal area covered by positive channels produced after the ground flash was also recorded for each negative CG flash.

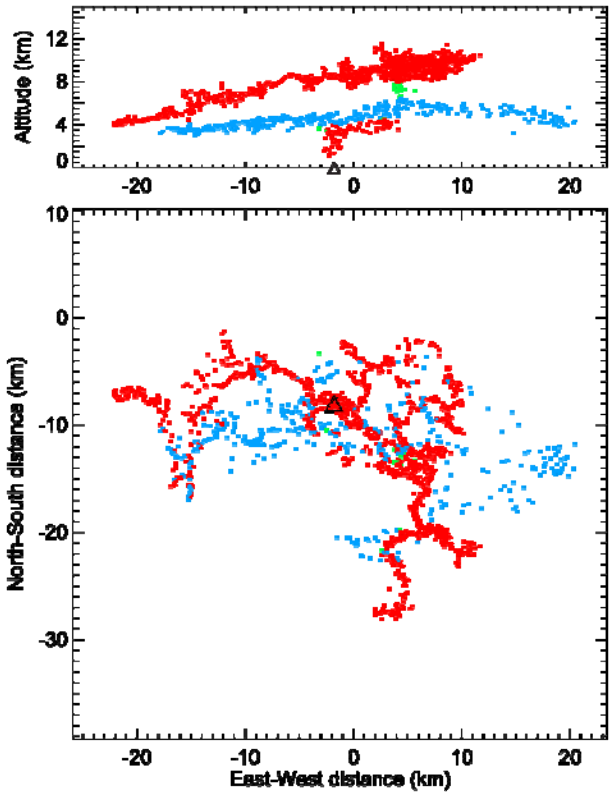

Figure 1. OK-LMA data for the flash of interest, 1040:15 UTC on 7 May 2008. Red dots are VHF sources that indicate where there is negative breakdown, and blue dots are VHF sources that indicate where there is positive breakdown. Green indicates that the polarity of breakdown is unknown. The black triangles map the location of a negative ground flash, as detected by the NLDN.

	Flash of Interest	NLDN		No NLDN		All Flashes	
		Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Duration (s)	1.00	0.76	0.47	0.64	0.39	0.66	0.41
Time Since Last Flash (s)	41.34	19.65	15.45	11.53	13.47	13.38	14.32
Time Since Last NLDN (s)	41.34	58.90	62.12	N/A		N/A	
Horizontal Area (km^2)	1200	630.26	1118.90	545.25	871.63	564.82	932.74
Vertical Extent (km)	12	6.21	1.98	6.19	1.86	6.20	1.88
# Charge Regions	3	2.13	0.40	2.00	0.25	2.03	0.29
# VHF Sources	2142	896.30	804.58	856.36	820.75	865.55	815.71
Absolute Value of Peak Current (kA)	6.2	21.18	15.58	N/A		N/A	
# Strokes	1	3.29	3.13	N/A		N/A	
Horizontal Area of Positive Channels (km^2)	722	165.56	182.71	N/A		N/A	

Table 1. Comparison of VHF flash characteristics between the flash of interest, CG flashes, IC flashes, and all flashes. Green indicates value is more than one standard deviation from the mean of the CG flashes; blue indicates the value is more than two standard deviations from the mean; and red indicates the value is more than three standard deviations from the mean.

III. Observations

The average and standard deviation of each flash characteristic was computed for IC flashes, CG flashes, and all flashes (Table 1). The IC and CG flashes have very similar characteristics; each of the characteristics is within one standard deviation of each other for IC and CG flashes. However, the FoI is different from the other CG flashes in several ways. The FoI's time since last flash and number of VHF sources are more than one standard deviation greater than the mean of all CG flashes in the same category. Also, the FoI has a greater vertical extent and propagates through more charge regions than the average CG flash. The biggest difference between the FoI and the mean CG flash is the horizontal area of its positive channels, which is more than three standard deviations larger than the mean. To visualize these differences, Figure 2 shows the FoI as mapped in the VHF alongside the CG flash that is most representative of average according to these calculations.

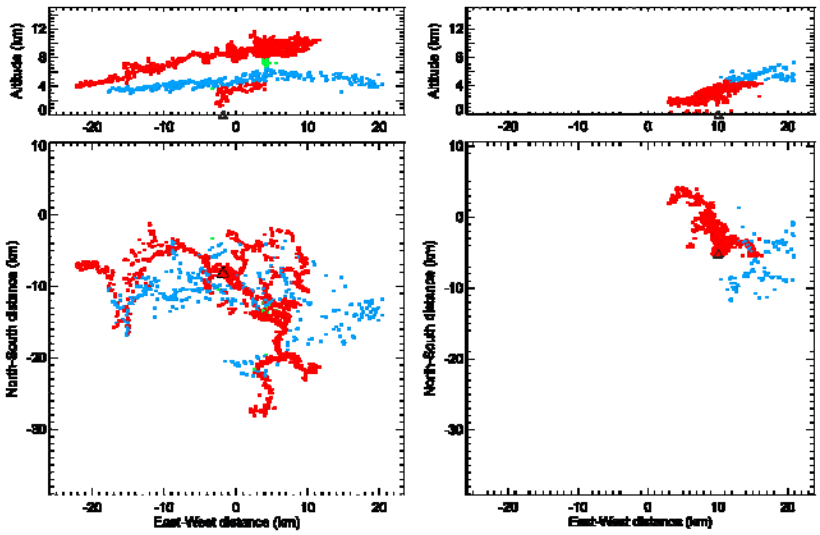

Figure 2. Flash of interest (left) and flash at 1054:06 UTC on 7 May 2008 (right), which is representative of the mean CG flash. Coloring is the same as in Figure 1.

The data were examined to determine whether or not there were other negative ground flashes that radiated an unusually high number of VHF sources as they propagated through negative in-cloud charge. Figure 3 is a plot of the horizontal areas covered by positive channels and the number of strokes to ground for all of the negative ground flashes. There are four flashes, including the FoI, that have a horizontal area encompassing the positive channels that is greater than 531 km^2, which is more than two standard deviations above the mean. Without further data, there is no way to tell which flashes besides the FoI had continuing current, but it is obvious that there are other flashes with similarly unusual VHF characteristics within this lightning cell.

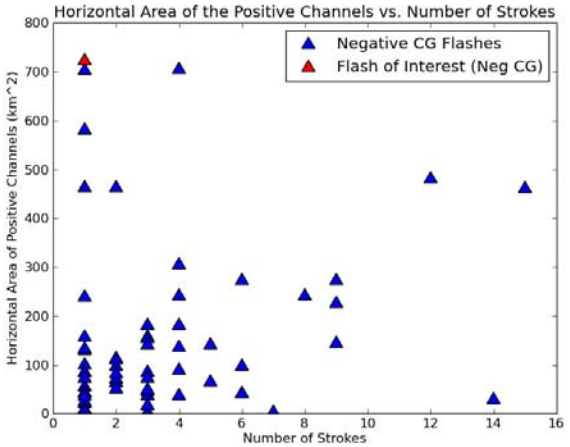

Figure 3. Scatter plot comparing the horizontal area encompassing the positive channels in km^2 to the number of strokes for the negative CG flashes (blue triangles) and the flash of interest (red triangle).

IV. Discussion

The flash of interest is visually different from most negative CG flashes, and it is also different in its VHF characteristics. Particularly, the FoI propagates through a larger area of negative in-cloud storm charge than the other negative CG flashes in the analysis. Whether or not this increased area of propagation is related to the fact that this flash has continuing current cannot be determined without further studies into the topic. We present the hypothesis that flashes with continuing current either propagate over a larger horizontal area in order to tap into more charge than normal CG flashes or have breakdown that is physically different than other flashes, causing them to radiate more VHF sources than normal CG flashes. More CG flashes need to be examined in the future to see whether or not those with continuing current truly have different VHF characteristics than those that do not.

V. Acknowledgments

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VI. References

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