SPATIAL AND TEMPORAL PATTERNS IN LIGHTNING DISCHARGES AS A PROXY OF THUNDERSTORM CHARACTERISTICS

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Abstract

Lightning is nature's way of destroying electrical buildup in thunderclouds. Thus, the pattern of lightning activity is inherently a proxy measure of the timescales for charge separation and the lateral extent of the charge reunification in a flash. Using data from lightning stroke geolocation networks such as NLDN and GLD360, we deduce statistically the charge buildup time by observing the suppression of the probability of two nearby flashes (an effect which fades away). We characterize this suppression effect for different storms, and as a function of storm phase and lightning parameters such as peak current and polarity.

1 Analysis

Lightning geolocation data from the National Lightning Detection Network (NLDN) are used for a preliminary analysis. NLDN is a network of ∼150 sensors across the continental USA, detecting the Low-Frequency radio emissions for lightning. The detection efficiency is estimated to be 80% for CG strokes [1], and the polarity and peak current of each event are reported. NLDN also detects a small number (10%) of IC strokes.

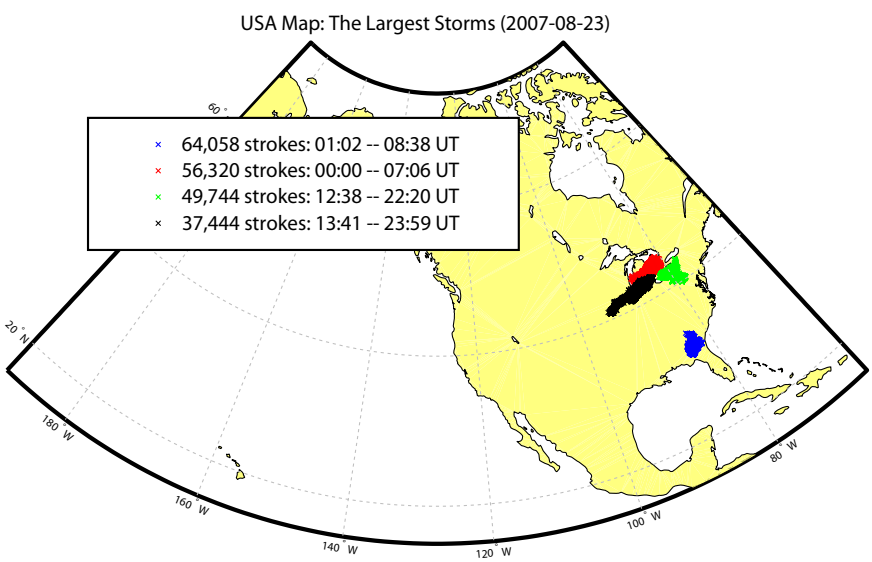

Figure 1: Lightning Activity on 23-August-2007

A large thunderstorm may consist of tens of thousands of lightning strokes. Around each stroke in space and time, other strokes will occur based on the probability of a stroke occurrence at that location and time delay, which we might call neighboring strokes.

Let us begin with a lightning stroke i occurring at time and location

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$$(t_i, x_i, y_i) \tag{1}$$

Another stroke in the storm j can be written by its relative time of occurrence and position compared to j, as

$$(t_j - t_i, x_j - x_i, y_j - y_i) \tag{2}$$

We can thus construct a histogram of stroke locations and time delays relative to its neighbors, by repeating the process for all stroke combinations $\{i, j\}$, and summing up the results. This can effectively be thought of as the autocorrelation function of the thunderstorm [2].

For large time delays or distances, the number of strokes in the histogram should be roughly equal to the expected number given the average stroke rate of the storm. This is because a lightning stroke's effect extends only over a finite distance and time.

Figure 1 shows a map of thunderstorm on a particular day (23 August 2007) with strong lightning activity over the continental USA. Four storms with tens of thousands of NLDN-detected strokes were available, each lasting several hours. The techniques shown here can thus be applied individually to different storms, to get a sense of varying characteristics.

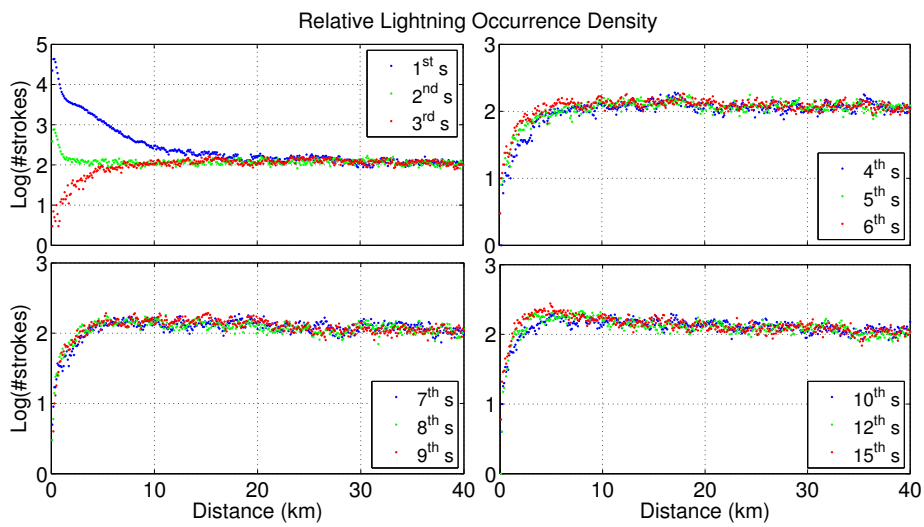

Figure 2: Flash occurrence as a function of time and distance

Figure 2 shows the relative occurrences of lightning strokes, basically a summed histogram of Equation 2. Only negative CG lightning with reasonably small location uncertainty are includes. Small CG events are also removed. In the top left panel, the histograms are parametrized by the first, second, and third seconds after the lightning stroke. Longer delays are shown in the remaining panels.

2 Discussion

Within the first second, there are three notable regimes (1) A very large number of strokes occurring in nearly the same location (i.e., within ∼400 meters corresponding to subsequent strokes along the same channel), (2) An elevated number of strokes within ∼10 km, corresponding to strokes that are part of the same lightning flash but occurring along a different channel, and (3) An essentially independent region

beyond 10 km where the number of strokes occurring simply reflects the expected number given the overall stroke rate of the storm.

Since a typical lightning flash lasts on the order of 1 s, the 2nd second shows a much smaller number of strokes occurring within the same flash. However, for delays longer than 2 s, two strokes in the same location are probably not part of the same flash but rather distinct flashes. For this reason, the third second shows a suppression in the number of strokes, as new flashes are less likely to be established near the previous flash. This suppression effect can be observed to recover over the course of 10s of seconds, as a result of continuing charge separation in the cloud which eventually reestablishes the conditions that lead to lightning.

Thus, by monitoring the distribution of lightning activity, we can observe the charging and discharging in a given thunderstorm. The flash suppression effect is potentially a function of many things, including meteorological parameters, type of storm, the sun's strength and influence, cloud height, stroke current, total charge transfer, and polarity.

In the coming months, data from the GLD360 lightning location network will be utilized, since it includes a large number of IC strokes that are missed by NLDN (but, on the other hand, cannot classify IC and CG strokes) [3]. The combination of the two datasets, along with the analysis technique described here, will be a useful technique for understanding how thunderstorms evolve and change.

3 Acknowledgement

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