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# Using Lightning Data as a Tool in Forecasting and Warning Decision-Making

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## 1. Introduction

Lightning, and its relationship to thunderstorm development and severe weather, is a topic that has only recently been extensively investigated. There are several studies that relate lightning to trends in storm formation, severity, and dissipation. They include negative vs. positive flashes (both percentage and fluctuation of positive flashes), flash rates, and the lightning relationship to fire starts. The topic of lightning flash polarity in relation to theta-E ridges has also been well studied in recent years.

This paper will summarize much of the research results that have been presented on lightning and its effects on severe thunderstorm development. It is hoped that some of these findings will be useful tools for forecasting and severe weather warning decision-making.

## 2. Lightning Studies

In recent years, there has been a keen interest in lightning and its relationship to thunderstorm severity. Many of these studies have focused on either lightning flash rates or the polarity of flashes in regards to thunderstorm development and severity. Though many of the findings in these studies are based on a relatively small dataset and the ideas presented are far from conclusive, there are a few relationships that appear to be good indicators about thunderstorm character and strength.

One area of research has focused on Positive Strike Dominated (PSD) storms. A PSD storm is defined as a storm in which at least 50 percent of the cloud-to-ground lightning strikes had positive polarity (Lang and Rutledge 2002). PSD storms occur primarily across the central and western United States. The most prominent area for PSD storms has been found to be across the northern and central plains (Knapp 1994; Carey et al. 2003). Several studies have shown that storms that had predominately positive polarity lightning flashes were often severe (Branick and Doswell 1992; Curran and Rust 1992; Seimon 1993; MacGorman and Burgess 1994; Stolzenburg 1994). Severe PSD storms had accounted for greater than 30 percent of all severe storms over the central United

States, while much lower percentages were noted over the eastern and western United States (Zajac et al. 2002). Figure 1 is a map showing the percentage of large hail and tornado reports associated with PSD storms across the continental United States during the warm seasons from 1989 to 1998.

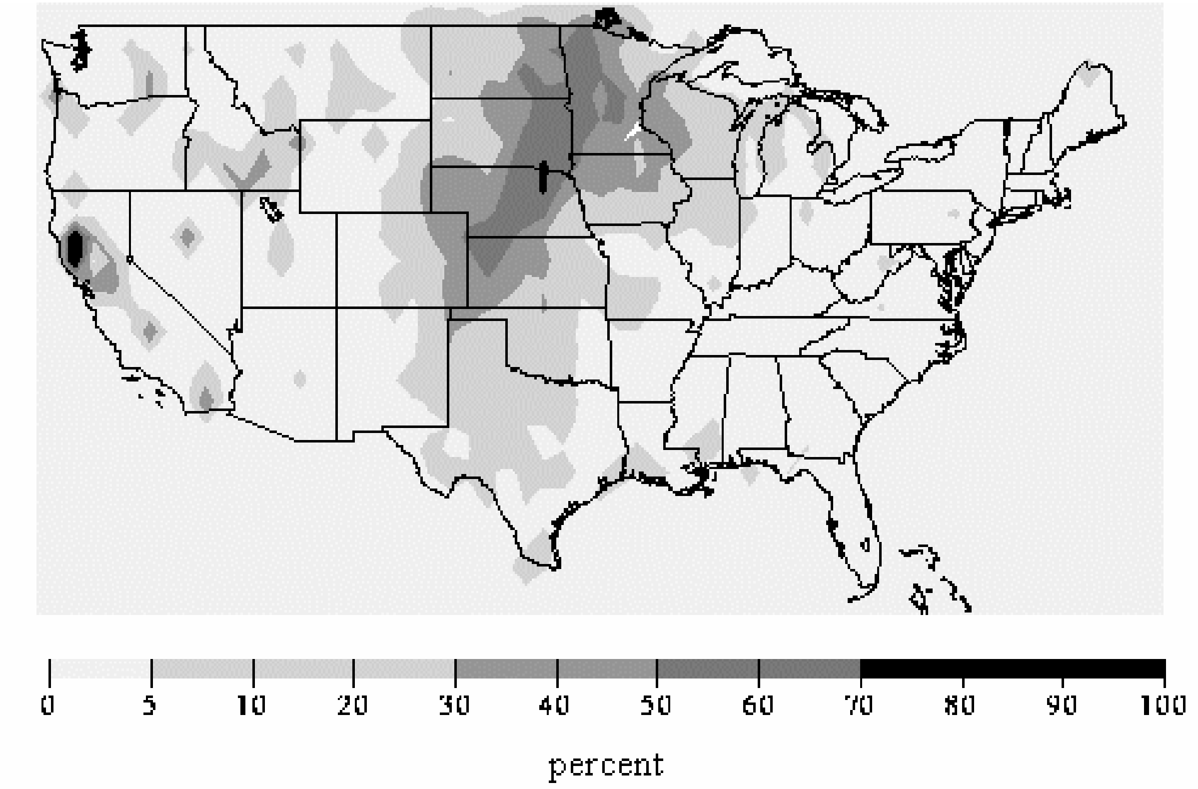

Figure 1. Map showing percentage of large hail and tornado reports associated with PSD storms. Dominant polarity is calculated using CG lightning data during the hour around severe weather. SPC reports were analyzed from April – September 1989-1998. Figure from Zajac et al (2002), which was adapted from Carey et al (2003).

Some research has found that lower dewpoint temperatures were observed with relatively more PSD storms and subsequent severe reports (Branick and Doswell 1992; Curran and Rust 1992; MacGorman and Rust 1994; Zajac et al 2002). A couple of studies have found that low precipitation (LP) supercells tended to produce mostly positive flashes (Curran and Rust 1992; MacGorman and Burgess 1994). Severe PSD storms usually switch to Negative Strike Dominated (NSD) storms at some point. This switch can coincide with severe weather development and also mark a transition from a LP supercell storm to a high precipitation (HP) supercell storm (Lake and MacGorman 2002).

Looking further at the polarity of lightning within storms, several studies have noted patterns with lightning in relation to the location of the storm along theta-E ridges, especially across the central United States. PSD storms tended to be dominant to the north and west of a theta-E ridge axis, while NSD storms were predominant to the east of these ridges (Smith et al. 2000). In some cases, storms crossing the ridge axis switched dominant polarity from positive to negative.

Smith et al. (2000) showed that the majority of PSD storms across the northern and central plains formed in regions where a strong surface theta-E gradient was present and upstream of a theta-E maximum. Storms that moved adjacent to the theta-E maximum remained predominantly positive. Other initially PSD storms appeared to intensify when they moved into high theta-E regions, then the dominant polarity switched from positive to negative as the storms crossed the theta-E maximum (assuming the theta-E field remained relatively constant as the storms moved through it). The majority of storms that were NSD formed in regions where a weak theta-E gradient was present and downstream of a theta-E maximum (Smith et al. 2000). As these storms moved into air with lower theta-E, lightning remained predominantly negative through their lifetimes. This relationship between dominant storm polarity and surface theta-E may provide a means to forecast the most intense period of a thunderstorm (Lake and MacGorman 2002).

The relationship between flash rates and severe weather has not been looked into as extensively as flash polarity, but most studies found that an increase in severe weather occurred either when flash rates increased significantly or minutes after a pronounced peak in flash rates (Kane 1991; MacGorman and Nielsen 1991; Bluestein and MacGorman 1998; Lang and Rutledge 2002). Though an increase in flash rates can be a potential sign of imminent severe weather, this may not be as reliable a relationship as is the PSD storm relationship to severe weather. This is due to more inconsistency in the relationship of flash rate changes to production of severe weather.

Some research has also been conducted on lightning and its relationship to forest fires. Results of these studies can be helpful in the decision making process for issuing Fire Weather Watches and Red Flag Warnings. One study (Rorig and Ferguson 2002) showed that the number of lightning caused fires corresponded more closely to high instability and high dewpoint depressions rather than to the total number of lightning strikes in the region. Other factors also need consideration in evaluating the risk for dry lightning induced fires, such as fuel moisture conditions, rainfall duration and amounts, and fire suppression efforts (Rorig and Ferguson 2002). This study showed that if convection was expected, lower atmospheric moisture content was a very important factor in estimating the risk of dry lightning strikes resulting in fire ignitions.

With respect to flash polarity, positive flashes produce higher peak current than negative flashes on average. Positive flashes also tend to produce longer continuing current durations. Both of these would allow for better fire ignition.

## 3. Lightning Best Practices

Though some of the ideas and theories listed previously are not relevant to every storm or situation, there are some findings in the research that should give some added value in the warning decision process. One key point is that PSD storms have been found to have a higher percentage of severe weather associated with them than NSD storms. In general, if a PSD storm is observed, it likely is or will be severe, especially in the northern and central plains (Fig. 1).

Another important consideration is the location of a theta-E ridge in relation to the storms. The majority of PSD storms form in regions where a strong surface theta-E gradient is present and upstream of a theta-E maximum, with mainly NSD storms downstream of the theta-e ridge. Many initially PSD storms intensified as they moved into high theta-E regions and then switched their dominant polarity after they crossed the theta-E maximum.

Also, look for the transition of dominant polarity in the storm. Severe PSD storms usually transitioned to NSD storms at some point. This transition can be marked by severe weather. A sudden increase in flash rates can also be a good indicator for severe weather to develop in the immediate future.

## 4. Summary

Though looking at the structure, reflectivity, and velocity trends of thunderstorms using Doppler radar are the most important factors in determining thunderstorm strength and severity, the use of lightning data trends can add valuable clues as well. Important discoveries in relation to flash rates, polarity, theta-E, and fire starts have been developed in recent years.

In general, PSD storms are more likely to be severe than NSD storms. Changes in flash polarity in a storm, and in particular PSD storms, can also be a trigger for severe weather occurring. Looking at storm environments, the location of a theta-E ridge has been shown to be a strong indicator of what type of thunderstorms will develop. Other important factors related to lightning include transitions of dominant polarity in storms and changes in flash rates.

More research will continue to be done in relation to lightning and its impact on storm evolution and effects on the production of severe weather. Some important relationships have resulted from previous research and more will likely be developed in the future.

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