Inverted polarity intra-cloud flashes in the Great Plains region of the United States

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ABSTRACT: The Los Alamos Sferic Array (LASA) provides synoptic observations of total lighting and determines individual stroke location information, lightning type, and polarity over its large coverage domain. This ability to directly sense the physical parameters of lightning discharges over the coverage area allows for unique studies of lightning, where investigations can scale up from domain sizes ranging from those of an individual storm cell to an entire geographic region. Data from LASA that were collected in the Great Plains region of the United States during the summer of 2005 (using six fast electric field sensors deployed with approximately 500-km baselines) are examined to investigate the occurrence of inverted-polarity intra-cloud (IC) flashes within the coverage area. As has been reported for the Tibetan plateau in China as well as for the high plains region of the Unites States, storms with a large percentage of inverted-polarity IC flashes are of great interest for their anomalous nature and show a strong geographical dependence. LASA data from the 2005 summer collection, when accumulated into a latitude and longitude grid and viewed over time, show a similar geographic dependence and will be examined in detail in this study.

INTRODUCTION

During the processing and analysis of Los Alamos Sferic Array (LASA) data collected during the summer season of 2005, a pattern began to emerge in the observed occurrence rates of inverted polarity intra-cloud (IC) events. LASA data, after final processing, result in completed product files which contain a total of 5 minutes of data (so 288 files are collected per day). The product files contain located source location, lightning type, and all the requisite information which went into the multi-station detection/location. For the purposes of this study, and in an attempt to normalize detection efficiency as much as possible across the study region, data were gridded into a region 29.5° to 45° latitude, by -110° to -92° longitude in bins 0.5° by 0.5°. This yields a grid containing 1116 “5-minute area pixels”, which were clustered and grouped into a time-evolving picture of a given storm.

Individual storms traveling in and through the central region of the study grid frequently showed time spans where the dominant intra-cloud (IC) activity is consistent with a normally-electrified storm (i.e., IC discharges between a main-level negative and upper positive). However, during other times there can be a distinct phase during the storm where the dominant IC type is of the opposite polarity. When observed *en masse*, it appears that the phase where this occurs is not temporally correlated across the study region, but rather tends to be confined to a specific geographic region. This region, where inverted polarity IC activity seems much more prevalent across many different storms, is maximum in the Colorado, Kansas, Nebraska border region, and continues somewhat down to the southwest into the Oklahoma panhandle and northern Texas.

Figure 1 shows an example from our storm tracking algorithm that demonstrates this behavior. The plots show the temporal and spatial development of 0.5° by 0.5° by 5-minute pixels all found to be associated with the same storm. The circled/highlighted pixels show individual pixel cells where the ratio of inverted IC to total IC count within that given 5 minutes exceeds a fraction of 50%. Note that in many of the examined

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cases there is a region where the dominant IC polarity is normal, but then transitions to being dominated by inverted polarity IC activity. Often, once past what appears to be a transition-zone, the dominant IC polarity returns to normal again.

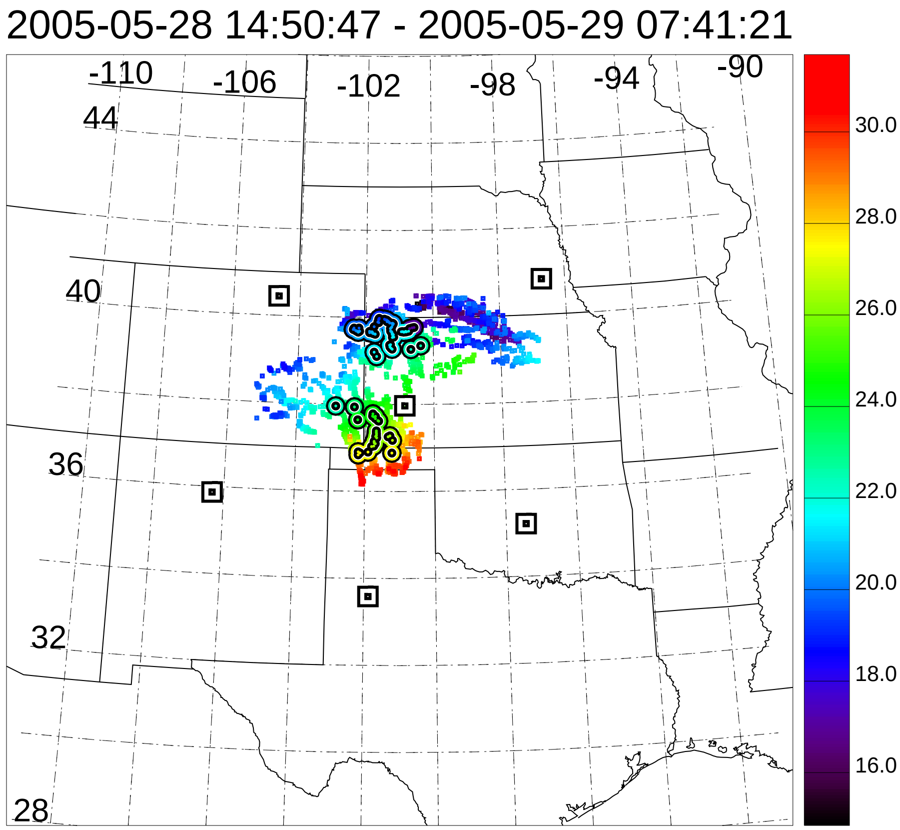

Figure 1: Example tracked storm; the circled pixels show locations within the storm where the ratio of inverted-polarity to total IC activity exceeds 50%. Color represents UTC hour of day, starting from the time of the earliest activity. LASA measurement station locations shown as black/white squares.

CLOUD-TO-GROUND LIGHTNING

The LASA system detects total lightning, and within the tight constraints imposed on this study has excellent detection efficiency within the boundary of the six-station network for both cloud-to-ground (CG) and IC lightning. Figure 2 shows the total aggregated CG activity for the entire May through September 2005 study. The top two panels show +CG and -CG total stroke counts (logarithmic color scale). In the top two panels every 5-minute area pixel from the entire summer has been superimposed onto one another and summed. The lower two panels show the same data, but with the additional filter that only aggregate (whole summer, not individual 5-minute) pixels with a total of 1000 or more events of the specific lightning type (+CG, lower left; -CG, lower right) are shown. This additional filter is used to show regions which are dominated by the accumulation of many storms, and are therefore less susceptible to small number statistics concerns.

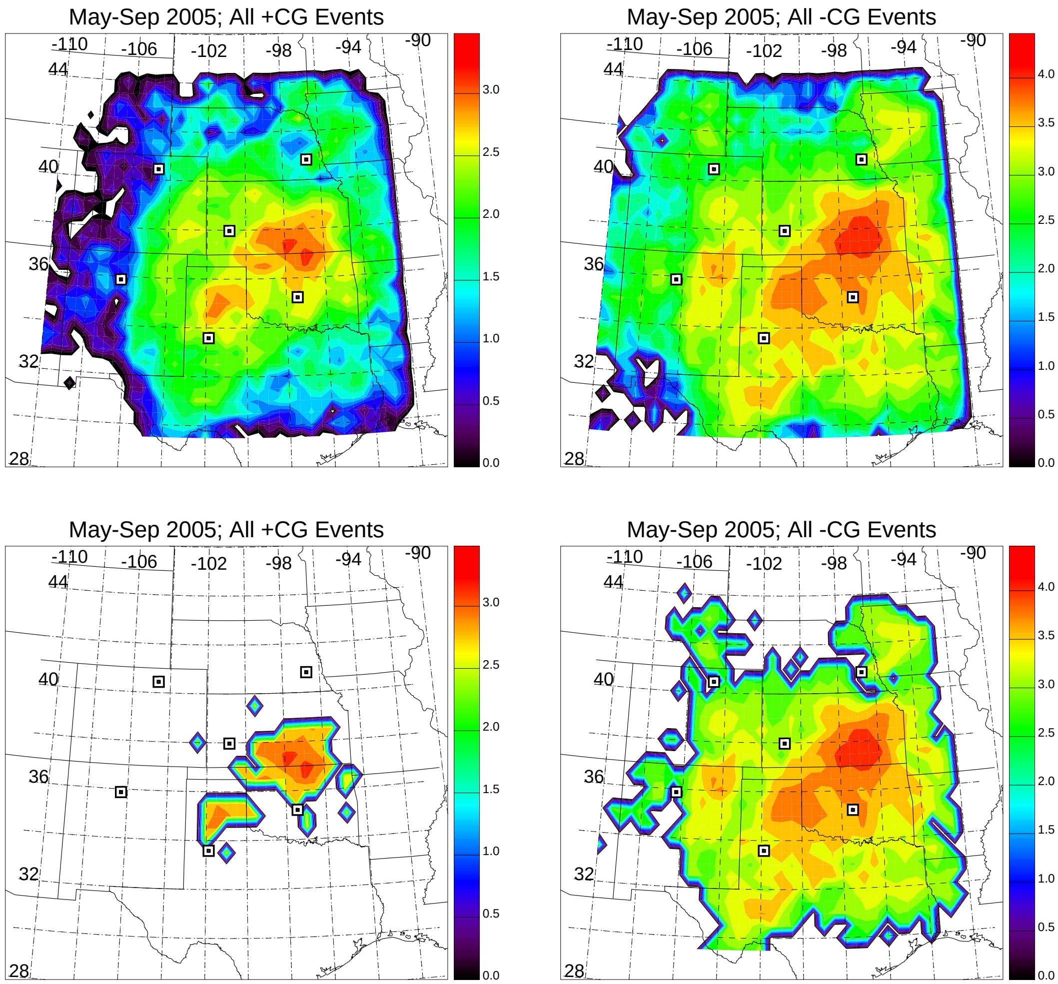

Figure 2: Plots showing positive and negative CG activity from within the geographic study region. The top two plots show all aggregated activity for the summer. The bottom two are the filtered results of the top, where total aggregated stroke count of the given type is more than 1000 events. LASA measurement station locations shown as black/white squares; color scale is the base 10 logarithm of event count.

INTRA-CLOUD LIGHTNING

Figure 3 shows similar plots to those in Figure 2 but for IC instead of CG activity. Additionally, the lower two panels show flash ratio, rather than total flash count. The center- and lower-right panels of Figure 3 show a statistically-significant region of dominant inverted polarity IC activity peaking at the Colorado, Kansas, Nebraska border and extending south and southwest into the panhandle of Oklahoma and the northwestern tip of Texas. This region is dramatically different than the region to the southeast which shows extremely high normal-polarity IC activity, but very little inverted. Similarly, the CG activity shows that the high density +CG activity aligns with the high density normal-polarity IC activity, whereas there is little or no correlation of the high activity density inverted-polarity IC region with either polarity of CG.

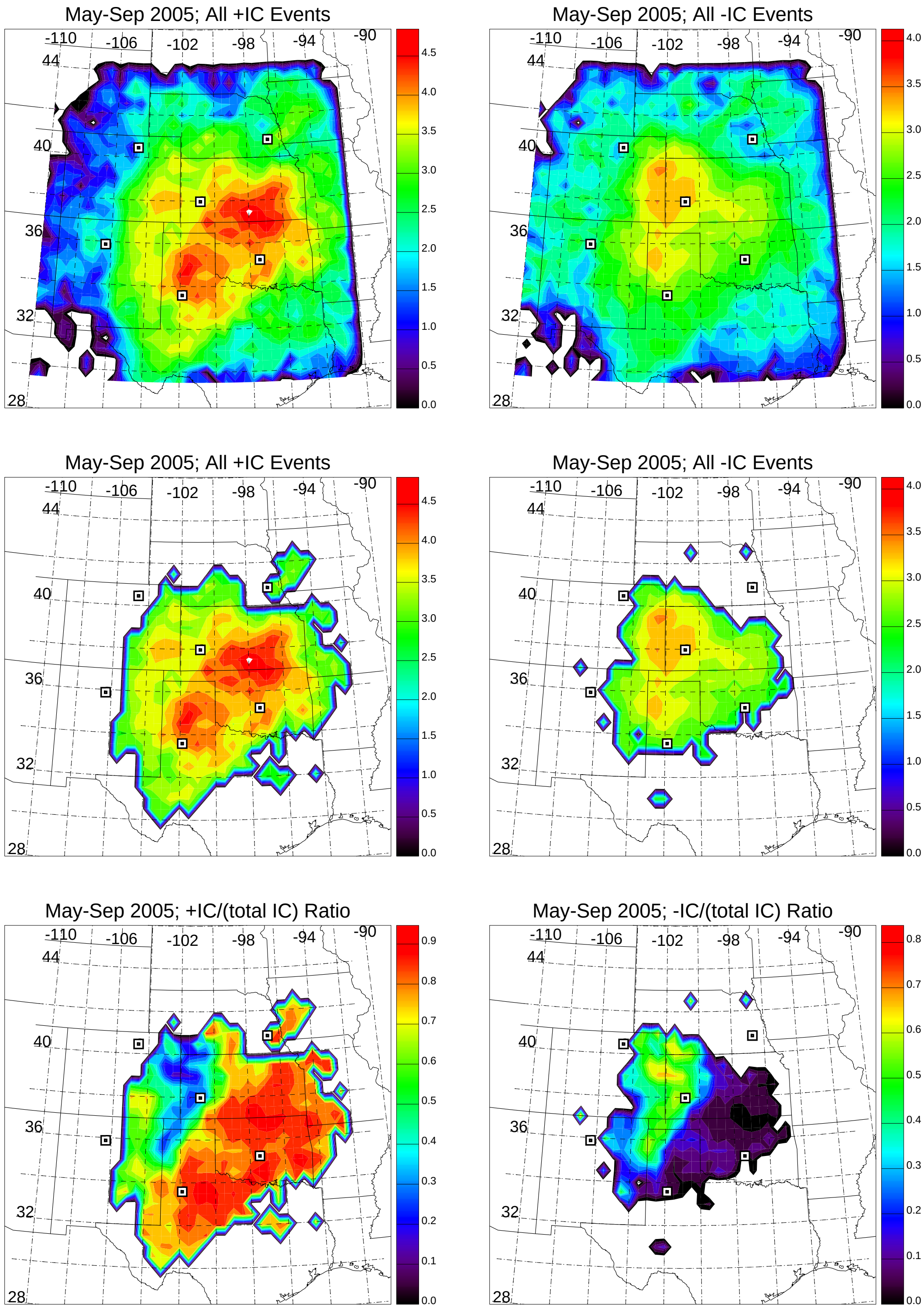

Figure 3: Plots showing positive (normal) and negative (inverted) polarity IC activity. The top two plots show all aggregated activity for the summer. The center two are the filtered results of the top, where total aggregated stroke count of the given type is more than 1000 events. The bottom two plots show the same filtered data as the center, but show the total ratio of events, rather than total count. LASA measurement station locations shown as black/white squares; color scale is the base 10 logarithm of event count (top and center row); and ratio (bottom row).

CONCLUSIONS

The Severe Thunderstorm Electrification and Precipitation Study campaign was conducted in the same geographic region as this study, due to the dramatic and persistent occurrence of storms which are dominated by +CG activity instead of the more typical -CG-dominated storms. The LASA studies show an interesting and persistent additional electrification anomaly along this same transition region. While the LASA data do not necessarily directly demonstrate whether or not a storm itself is inverted in polarity, it is clear that inverted polarity IC flashes demonstrate and highlight the sharp geographical dependence of where storms in this region electrify anomalously.