5.1 Variations in Operational Total Lightning Visualizations

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1. Introduction

The NASA Short-term Prediction Research and Transition (SPoRT) Center has a long history of collaborating with National Weather Service (NWS) weather forecast offices (WFOs) on the operational use of total lightning information (Darden et. al. 2002; Goodman et al. 2004; Jedlovec 2013). SPoRT began furnishing near-real time data from the North Alabama Lightning Mapping Array (NALMA; Koshak et al. 2004; Goodman et al. 2005) to WFO Huntsville, Alabama in spring 2003. For the first time, the data were provided in a format that could be ingested into the Advanced Weather Interactive Processing System (AWIPS) software. NALMA detects VHF radiation sources (produced during lightning breakdown processes), which were processed by SPoRT into 2 × 2 km source density (SD) grids, on a fixed gridded domain, and summed every two minutes (Bridenstine et al. 2005; Goodman et al. 2005).

This marked a milestone in the evolution of real-time total lightning applications. However, operational demands did not permit combining of sources into flashes, or the assignment of flashes to specific storms as is common in many research applications. Still, the source density product has remained popular since its inception in 2003 (Nadler et al. 2009; Darden et al. 2010; White et al. 2012), and its use has spread across multiple SPoRT-partnering WFOs as new Lightning Mapping Arrays (LMAs) have been installed nationwide (Stano et al. 2015).

2. Migration to Flash Density

By 2013, however, SPoRT began to offer more than source density products to partnering WFOs. Improvements in Internet bandwidth, computer software, and computer processing made alternative total lightning products more feasible on an operational basis. Chief among these improvements was the operational test and evaluation of the next-generation AWIPS-2 platform (Tuell et al. 2009). The AWIPS-2 architecture is more flexible than the original AWIPS software, and permits development and deployment of software "plug-ins" which ingest and display additional data types (including the NetCDF data files used by SPoRT for total lightning). WFO Huntsville served as one of the early AWIPS-2 test sites beginning in June 2012, and began using the new total lightning plug-in to ingest NALMA data in March 2013. Faster computers at SPoRT, coupled with the rapid processing of the flash clustering algorithm described by McCaul et al. (2005, 2009), permitted processing on a sufficiently rapid basis for operational use.

Additional factors created an interest in migrating to flash density. Changes to the NALMA sensors, both by weather (the 27 April 2011 tornado outbreak destroyed two sensors) and planned upgrades, created variations in the detection efficiency that were not necessarily well-understood by WFO forecasters. Additional operationally-oriented total lightning research, specifically the lightning jump algorithm from Schultz et al. (2009, 2011), sparked interest in moving toward flash density products more similar to those used in research. Flash density also matches the expected output from the GOES-R Geostationary Lightning Mapper (GLM; Goodman et al. 2013) instrument, and tends to be more intuitive and easier to explain to new forecasters and outsiders. Earlier collaborations demonstrated the potential of using flash products (Stano et al. 2010).

WFO Huntsville began testing flash extent density (FED) products in late spring 2013. This built off of SPoRT's development of the pseudo Geostationary Lightning Mapper demonstration product (Stano et al. 2014) that successfully demonstrated real-time flash products at the Hazardous Weather Testbed in Norman, Oklahoma. Initial testing was limited to the WFO Science and Operations Officer (SOO) and Application Integration Meteorologist (AIM; SPoRT-NWS liaison forecaster) for testing, research, and training purposes. Staffing limitations prolonged the training and testing process, and thus delayed the full implementation on a WFO-wide scale. However, as some LMAs have come online recently, SPoRT has transitioned both SD and FED products simultaneously to partnering WFOs.

3. Operational Considerations and Comparisons

Through the testing process, several operational considerations became apparent. Many stem from one fundamental issue: a single flash is made up of multiple sources, and the number of sources per flash varies with each flash. For example, a single flash in the heart of an LMA network could consist of 30 sources, but the next flash might consist of 50 sources. Flashes on the outskirts of the network are likely to consist of fewer sources due to diminished detection efficiency (e.g., 10-20 versus 30-50 or more). Therefore, sources and flashes tend to differ by an order of magnitude (e.g., 500 sources versus 50 flashes) and trends in the two products may not mirror one another. The differing magnitudes impact data visualizations (see Section 4), as well as overall perceptions of storm intensity; without proper context, a storm with a value of 500 may be perceived as being “stronger” than a value of 50. The differing trends can create confusion because a jump noted in SD may not be reflected in FED, or may be reflected at a different time. Finally, while FED has a greater connection to research (particularly rate-of-change research such as Schultz et al. 2009), SD has been used operationally since 2003, and therefore has a greater operational legacy and knowledge base. This has impacted the use of SD and FED at newer LMAs and WFOs where the products have been introduced simultaneously.

a. 23 July 2013 Case Study

To illustrate these considerations, we will examine a case study from 23 July 2013, from a single storm that impacted Cullman and Blount Counties in Alabama, although no severe weather was reported. Figures 1a and 1b illustrate FED (1a) and SD (1b) time series trend from 1420 to 1456 UTC. While the primary lightning jump beginning around 1445 UTC is apparent in both SD and FED, there are obvious differences between the two from 1430 to 1442 UTC. The initial increase at 1432 UTC is 44 times larger in SD, increasing from 50 sources to 272 sources, whereas FED increases only from 2 to 7 flashes. This could be interpreted in different ways. First, the SD may be showing a jump earlier than FED. Another way to view this is that the FED, being normalized with range by using derived flashes, indicates (i.e., one flash contains many sources) that the storm has not begun to significantly intensify. As such, there is less of a possibility of a false alarm. Schultz et al. (2009) support this view point by indicating that a storm must exceed 10 flashes per minute before activating the lightning jump algorithm. FED trends suggest two additional yet very modest increases at 1436 UTC (6 to 9 flashes) and 1442 UTC (10 to 13 flashes). SD trends only indicate one additional increase ending at 1438 UTC, from 187 sources to 337. The final, most pronounced “jump”, still differs significantly in magnitude. SD increases from 209 sources at 1444 UTC to 861 at 1450 UTC, whereas the FED increases from 10 flashes at 1444 UTC to 53 at 1450 UTC. Even with adequate training or experience, such differences among the data types could be surprising at best, confusing at worst, particularly in a real-time operational environment when these data are used for warning decision-making.

b. 17 June 2013 Case Study

Another interesting tendency was noted during the testing process, and is illustrated in Figure 2. The largest jump in standard deviation (crossing $+2\sigma$) began at 1814 UTC for FED—but at 1816 UTC for SD. This jump in FED preceded the issuance of a severe thunderstorm warning by 10 minutes (8 minutes for SD) and the first report of severe weather (a 52-knot wind gust) by 14 minutes (12 minutes for SD). Additional increases at 1834 and 1838 UTC match one another more closely, though the FED increase did not exceed the $+2\sigma$ threshold suggested by Schultz et al. (2009; 2011).

As in this case, a flash “jump” preceded the corresponding source “jump” 6 times in 18 cases during a very limited study performed in 2013. While the sample size is small, it suggests that further study is warranted and may add to the motivation for the operational use of FED.

4. Color Curve Variations

The testing process yielded another noteworthy concern: minor differences in AWIPS-2 color tables (or color "curves") can create a large difference in perception. This concern was echoed by several participants in SPoRT's 2014 total lightning assessment (Stano et al. 2015).

The color table currently used for SD is the same color scheme used since its introduction in 2003. The table is geared to a large range (0 to 500) suitable for the expected values, particularly since an upgrade to the NALMA in 2009, but it is easily adjusted for each network's characteristics. The same SD color table was used for FED as testing began in 2013. However, as mentioned in Section 3, FED magnitudes vary significantly from SD, and low-range values are much more likely to occur than comparable values of SD. As a result, meaningful changes in FED were "washed out" by using the SD color curve for FED data. The SD color table also made small (less than 5) flash values transparent to the user, despite these data being useful for lightning safety and decision support services applications.

An example of these differences is illustrated in Figure 3a-3d. This storm occurred on the southeastern edge of the NALMA network over Cherokee County, Alabama, so source density data alone would naturally be diminished somewhat due to diminished detection efficiency. Figures 3a and 3b illustrate the storm at 1744 UTC and 1746 UTC, respectively, prior to any substantial increase in total lightning. There is a minor increase in FED at 1746 UTC, from less than 10 to approximately 13, that stands out using the modified color curve. Another modest increase in SD is noted at 1750 UTC (Fig. 3c). Using the original color table, the FED data shows a modest increase at 1752 UTC (Fig. 3d) but again does not warrant much attention. However, an adjusted color curve, favoring low-end values often found in FED, suggests that the increase is much more significant at 1752. Indeed, the values increase from approximately 13 flashes at 1746 UTC to approximately 30 at 1752. This storm later downed trees and power lines in Chattooga County, Georgia, at 1815 UTC.

5. Lessons Learned and Future Work

Two key lessons were learned during the initial testing period. First, training will be critical for this type of migration, as forecasters experienced with using SD data may be required to "re-learn" many of the tendencies they have become accustomed to. In fact, some of the SD-FED differences may need to be emphasized more than originally expected, although differences may hinge on whether forecasters view the SD and FED data simultaneously. Second, color tables must be different for the different data types (e.g., SD and FED). While some initial modifications have already been made to mitigate the issues noted in Section 4 (one such version is illustrated in Figure 3), additional modifications may be required depending on experience, network, environment, user preference, or task. An advantage of the AWIPS II system is that implementing and modifying color curves is far easier "on the fly" than in the legacy AWIPS system.

Future efforts will be focused on migrating FED to operations in 2015 and beyond. WFO Huntsville plans to migrate in spring 2015, with additional training, discussion, and evaluation to follow. With the arrival of new forecasters who have no total lightning history, there will be opportunities to compare the analysis of those with and without total lightning experience, and to determine how that impacts real-time FED and SD data analysis. Additional research is also planned to expand upon the timing difference noted in section 3b. The research will aim to expand the sample size and determine if a meaningful tendency exists.

6. References

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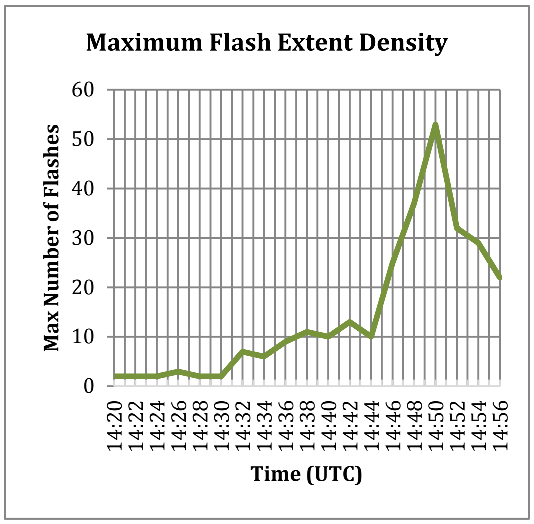
Figures



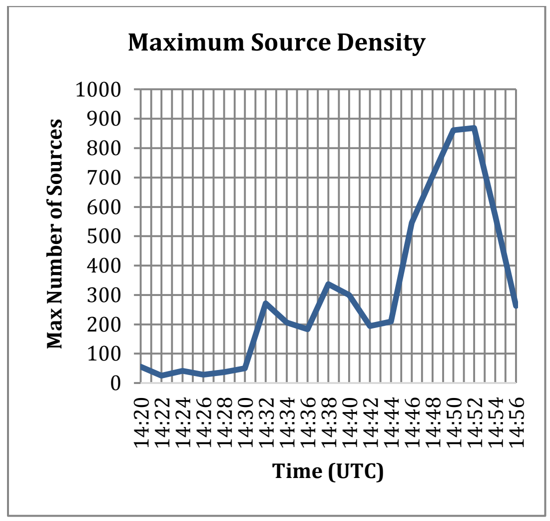


Figure 1: Maximum flash extent density (1a – left) and maximum source density (1b – right) values for a storm affecting Cullman and Blount Counties in Alabama on 23 July 2013, from 1420 UTC to 1456 UTC.

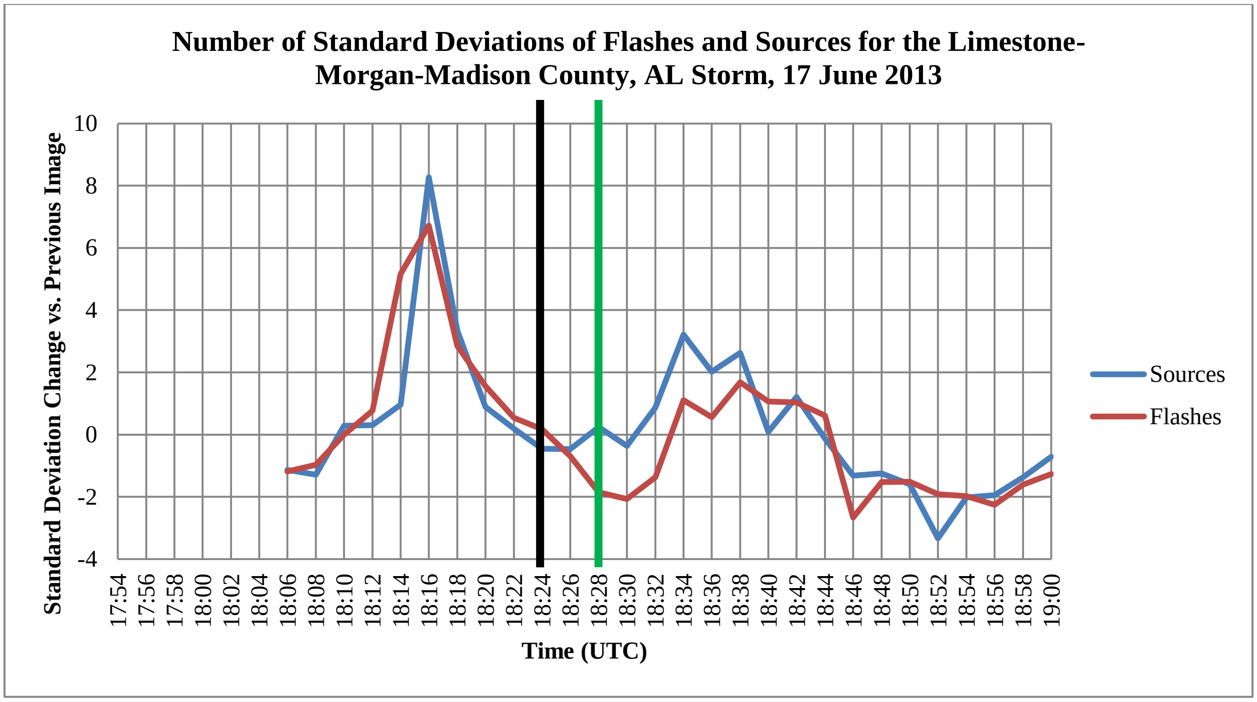
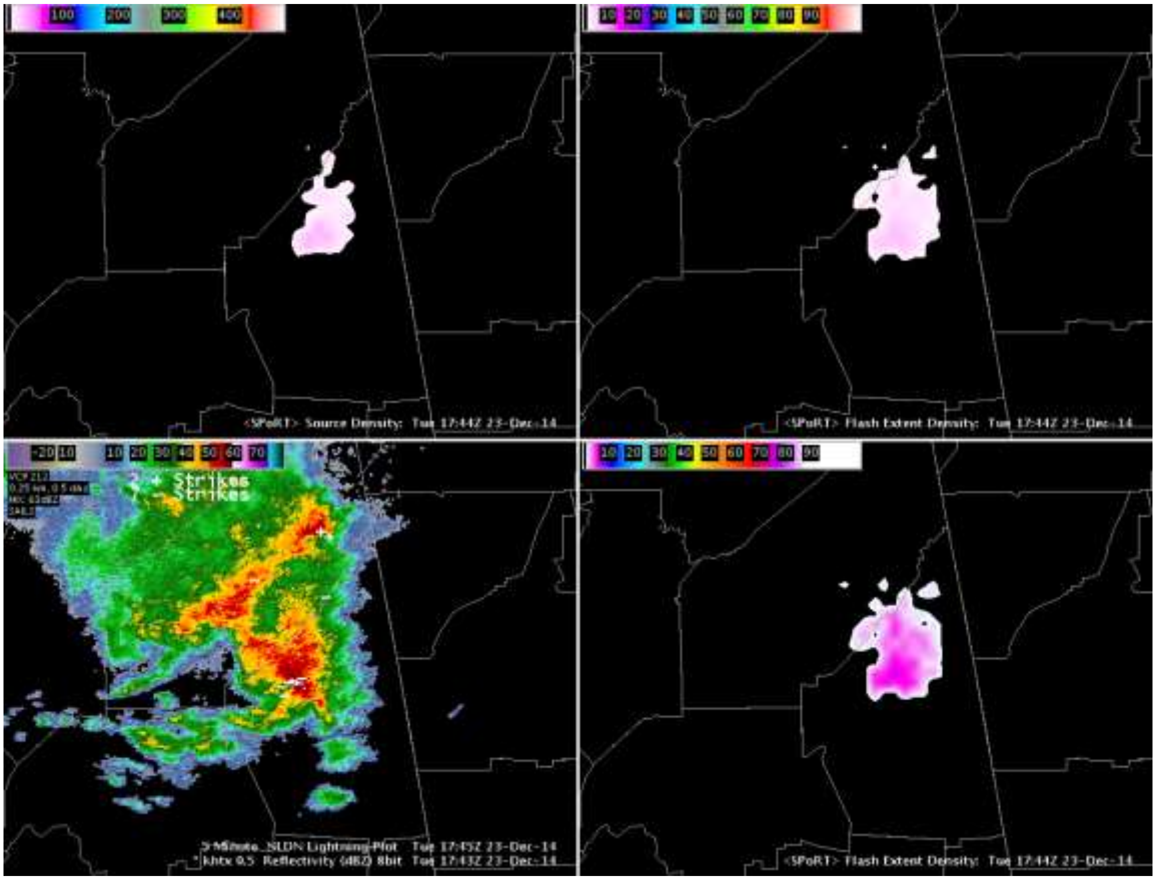


Figure 2: Standard-deviation change in source density (blue) and flash extent density (red) versus time for a severe thunderstorm affecting Limestone, Morgan, and Madison Counties in Alabama on 17 June 2013. In other words, a plotted value of +2 at time T reflects a +2 standard deviation increase compared to the raw value at time T-2 min. Standard deviations are computed for the last 5 data points (10 min). The vertical black line at 1824 UTC denotes the issuance of the severe thunderstorm warning, and the vertical green line at 1828 UTC denotes the first report of severe weather, a 26.8 m s^{-1} (52 kt) wind gust.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10 20 30 40 50 60 70 80 90
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-20 10 10 20 30 40 50 60 70
+ Strikes
- Strikes
khtx 0.5 Reflectivity (dBZ) 8bit Tue 17:43Z 23-Dec-14
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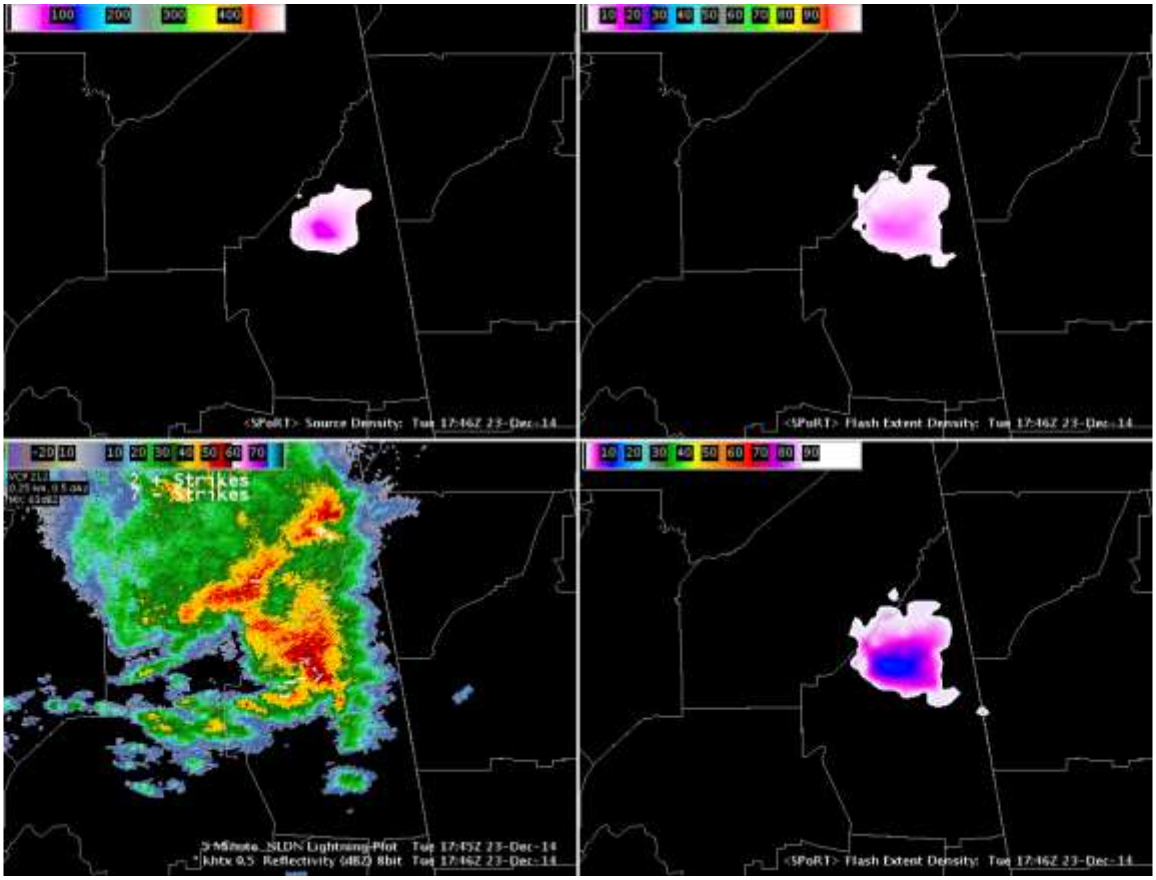
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2 + Strikes
7 - Strikes
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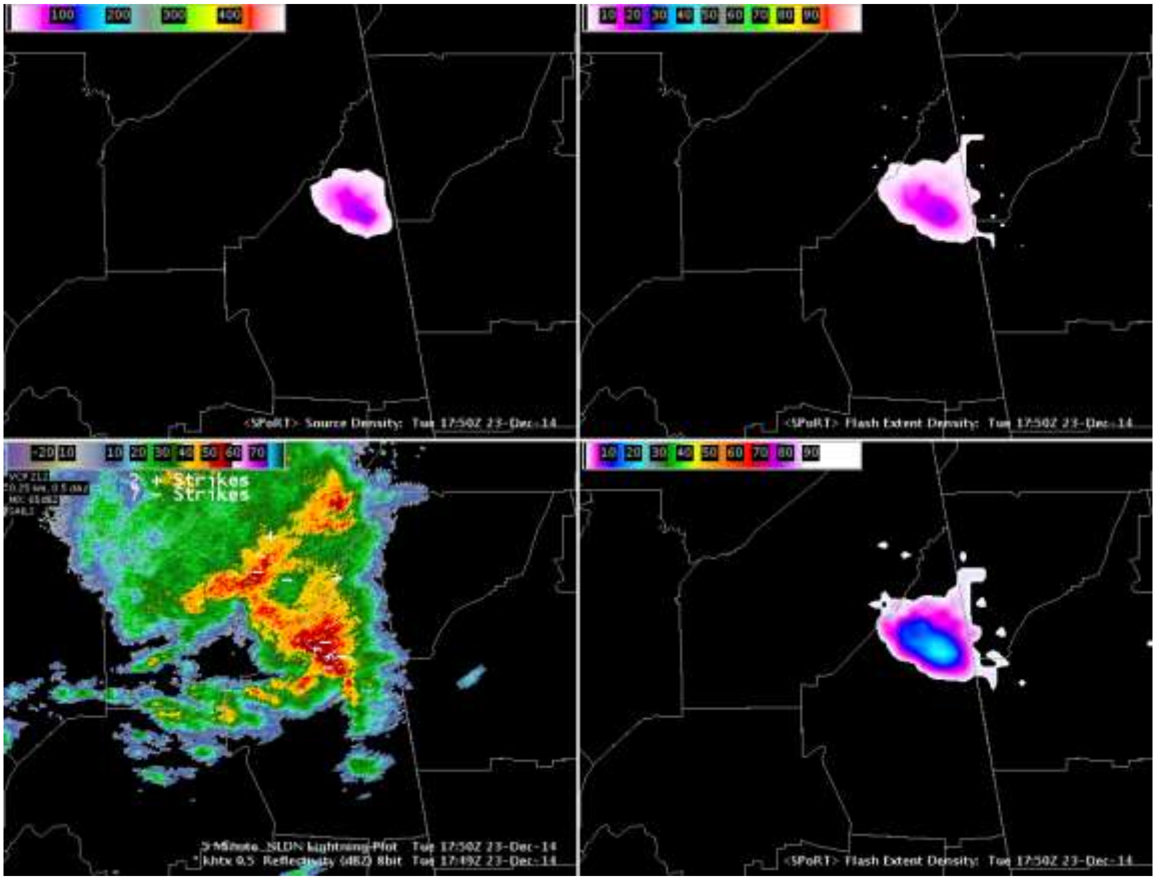
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-20 10 10 20 30 40 50 60 70
+ Strikes
- Strikes
5 Minute_SLDN Lightning Plot Tue 17:50Z 23-Dec-14
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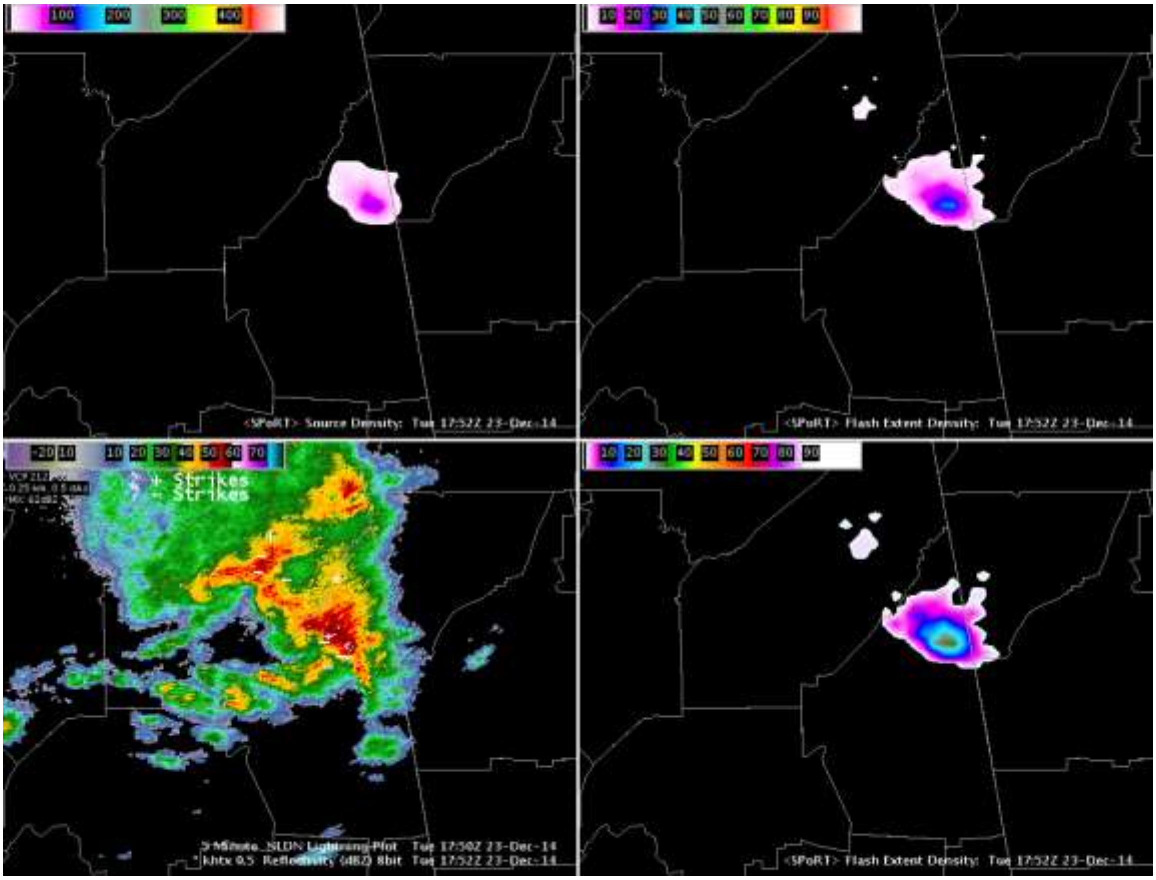

Figure 3a-3d: Clockwise from top-left: North Alabama Lightning Mapping Array (NALMA) Source Density (SD); NALMA Flash Extent Density (FED) using the default SD color curve; NALMA FED using an adjusted FED-specific color curve; KHTX WSR-88D radar reflectivity and Vaisala National Lightning Detection Network cloud-to-ground stroke data. Times are 1744 UTC (a), 1746 UTC (b), 1750 UTC (c), and 1752 UTC (d) and based on the NALMA data valid time.