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USE OF TOTAL LIGHTNING DATA AT CHATTANOOGA, TENNESSEE EMERGENCY MANAGEMENT FOR PUBLIC SAFETY AND DECISION MAKING

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Abstract

Lightning is often an underrated threat when it comes to dangerous weather phenomena. The National Lightning Detection Network has recorded an average of 600,000 cloud-to-ground lightning flashes per year across Tennessee during the past ten years, with over 700,000 flashes in 2011. While attention is given to the dangers associated with large weather systems, such as hurricanes and tornadoes, lightning is the second leading cause of weather related deaths in the United States.

Given the high death toll associated with this phenomenon, several steps can be taken to improve lightning safety in a community. One improvement in lightning detection is the relatively new network of sensors called Lightning Mapping Arrays (LMAs). LMAs detect intra-cloud lightning in addition to cloud-to-ground lightning strikes, and combined, these observations are called "total lightning." The NASA Short-term Prediction Research and Transition (SPoRT) Center has been collaborating with the Huntsville, Alabama National Weather Service (NWS) office on the use of data from the North Alabama LMA since 2003. This collaboration has led to several other NWS offices to incorporate data from the LMA into real-time operations. Much of the research into how to use total lightning data has been directed towards improving severe weather warnings, but total lightning can also be used to improve lightning safety.

A collaborative project is underway with the NASA SPoRT Center and WFO Morristown, Tennessee assisting Hamilton County Emergency Services to evaluate the use of total lightning data during real-time operations in support of making public safety decisions for their respective communities. The effort is starting with LMA observations, but can serve as a demonstration for future GOES-R GLM observations. Additionally, the techniques developed here can then be used with GLM data and shared with other emergency managers. Our presentation will share details of the project, as well as preliminary findings to date.

INTRODUCTION: EMERGENCY MANAGEMENT COLLABORATIONS

NASA's Short-term Prediction Research and Transition Center (SPoRT; Darden et al. 2002; Goodman et al. 2004; Jedlovec 2013) is a leader in transitioning ground-based total lightning observations (intra-cloud and cloud-to-ground) to National Weather Service (NWS) collaborators with access to lightning mapping arrays (LMA; Rison et al. 1999). These LMAs serve as excellent demonstration networks to prepare the National Weather Service for the soon to be available Geostationary Lightning Mapper (GLM; Christian et al. 1989; Goodman et al. 2013) observations aboard GOES-R series of weather satellites. These collaborations have involved close collaboration with various NWS local forecast offices, such as the Morristown, Tennessee office, national centers, and center weather service units. More recently, SPoRT has developed training for the NWS as part of the GOES-R foundational course as well as the prep course for the Science and Operations Officers.

During these efforts, the Morristown forecast office discussed several ways in which they utilize the LMA data in their operations. One in particular was in support of their regional emergency managers, who are direct "customers" of the NWS forecasts. Although the emergency management community does not issue forecasts, they are heavy users of meteorological information in support of their activities. The Morristown office recommended that a focused collaboration with one of the emergency managers in their county warning area would be extremely beneficial. This led to the initial collaboration with the Chattanooga / Hamilton County, Tennessee emergency managers. This office has close ties to the Morristown NWS and is with the range of the short-ranged North Alabama Lightning

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Mapping Array (NALMA; Koshak et al. 2004). Figure 1 shows the approximate coverage of NALMA with respect to the Morristown, Tennessee NWS office and Hamilton County, Tennessee.

The initial collaborations began in 2014 and primarily focused on each organization discussing their roles, capabilities, and unique missions. NASA SPoRT focuses on the transition of unique NASA data sets to improve regional and local forecasts at the 0-24 hour time scale. The LMA activities have tied in very well to the NWS mission of protecting lives and property. The LMA and future GLM data are highly effective in monitoring convection; both to monitor storm intensity trends as well as aiding in severe weather decision support (Goodman et al. 2005; Darden et al. 2010; Stano et al. 2010; White et al. 2012; Stano et al. 2014). However, these data can also be used in support of lightning safety (Stano 2012). This again ties into the NWS mission, but also the emergency management mission to, "Save lives and property in the event of a natural or man-made disaster through a comprehensive emergency operations plan." The total lightning observations from the LMA and the future GLM instruments allow for a direct focus on impact based decision support for outdoor events or local city and county events.

Since this initial effort, the collaboration has grown to address three primary issues. The first is training. Unlike the more familiar National Lightning Detection Network (NLDN; Cummins et al. 1998) both the LMA and GLM observe total lightning. The NLDN does have a limited capability to identify intra-cloud flashes, but does not have the spatial extent information that the LMA and GLM have. This new capability requires solid training for the emergency management community to understand what is being observed, such as the spatial extent of lightning. Secondly, unlike SPoRT's traditional partners in the NWS, the emergency management community does not use the Advance Weather Interactive Processing System or AWIPS. As such, a new display system is needed that fits the emergency managers' needs. Lastly, the ultimate goal of this project is to prepare the emergency management community, guided by NWS forecasters and emergency managers, for GLM. The following sections of this extended abstract will outline the activities that have been done to address these three issues.

INITIAL TRAINING FOR EMERGENCY MANAGERS

At the start of this collaboration, the GLM was not available. As such, the ground-based NALMA data have been used to demonstrate the utility of total lightning. The demonstration product that has been derived from NALMA is the pseudo-geostationary lightning mapper (PGLM; Stano et al. 2010, 2014; Terborg and Stano 2017) product. Although not a perfect replica of GLM, the PGLM allows the collaboration to emulate the GLM's general spatial and temporal features. This allows the end users to better understand total lightning, how GLM will operate, and to develop operational knowledge in preparation for the GLM observations that will be available in 2017.

The initial training for the emergency managers was conducted with on-site training by SPoRT and attended by the authors from both Morristown and Hamilton County. The emphasis was on explaining what total lightning is, how it has been used by the NWS, and how it could potentially be used by emergency managers. Furthermore, the training discussed the differences between the NLDN and the LMA and GLM.

This was not, however, a one-way conversation. The face-to-face meeting provided training to SPoRT in understanding the emergency management role, time scale of operations, and information on how meteorological data, including lightning, are visualized and used. These efforts combined set the stage for how the collaboration would advance and identify areas of additional work.

VISUALIZING GROUND-BASED LIGHTNING MAPPING ARRAY OBSERVATIONS

A key issue facing this work was creating a visualization that supported the needs of the emergency managers. As mentioned previously, using AWIPS was not an option. Furthermore, the emergency managers are often out of the office in support of various activities, whether that is a planned event or managing a accident like an overturned tanker truck. This meant that an internet based visualization would be the most appropriate.

The first visualization turned to an earlier SPoRT activity to display NALMA data online to monitor the LMA's status. This utilized Google Earth and allowed for a traditional flash extent density display that showed both how much lightning was occurring in each grid box as well as the spatial extent of the lightning activity (Fig. 2). The Hamilton County managers worked with this display, but quickly noted several short comings. First, the auto-update feature was difficult to implement and would eliminate the user's zoom level when it auto-updated. This was a major concern given the NALMA data updated every two minutes. Secondly, the emergency managers primarily relied on iPads when in the field to obtain meteorological information. This and security features for the iPads meant that Google Earth could not be installed. As a result, the Google Earth display was not available to them when they were in the field.

A follow-up task aimed to address this issue and resulted in the display in Fig. 3. Here, SPoRT did away with any proprietary software and focused on using geo-referenced images over a shapefile that provided various geo-political fields (county boundaries, roads, cities, etc.) The display was also tested to ensure that it could function on multiple platforms from PCs, tablets, and other mobile devices. This was provided in 2015 and was an immediate success. The total lightning observations were now readily available and were far easier to implement in various operations. The Hamilton County emergency managers were able to use these data regularly for events as well as their own personal activities. The display allowed for a simple auto-update and a pan and zoom capability that allowed individuals to focus on a specific location or to focus on the wider situation. This has been the default tool since 2015 and the subsequent assessments have indicated several recommendations for improvement. These recommendations are discussed in the Future Work section.

DEMONSTRATION EXAMPLES TO PREPARE FOR THE GLM

Spatial Extent of Lightning

As discussed, this effort aims to introduce total lightning to the Chattanooga / Hamilton County emergency managers for them to identify ways to utilize these data in their own operations. Figure 4 shows a feature of total lightning that was a great interest; spatial extent. Although outside the area of interest for Hamilton County, it was an excellent training example. Figure 4a shows the radar reflectivity at 1857 UTC on 1 July 2015. This shows a variety of storms cells across Alabama, Georgia, and Tennessee. The radar imagery draws attention to a line of storms extending from north-central Alabama into Tennessee. The corresponding total lightning observations are shown in Fig. 4b. Initially, the total lightning observations identify which storms observed by radar are electrically active, particularly around Huntsville, Alabama (i.e., within the range of the NALMA network). In particular, only two cells north of Birmingham, Alabama are electrically active.

Another feature, circled in Fig. 4, stands out in south-central Tennessee. Strong radar reflectivity is observed just north of the Alabama / Tennessee border. This has a corresponding maximum of total lightning activity. The key feature is to the north where the total lightning shows several branches of lightning extend out and away from the main storm core. Here, lightning is extending tens of miles from the main storm core and well into the stratiform region. This type of information is extremely valuable to emergency managers to identify where lightning is occurring and to see that lightning is not being confined to the strongest reflectivity regions.

Lightning Safety Example

The Hamilton County office provided a local from 19 August 2015. On this day the U.S. Women's National Soccer team was playing in Chattanooga, Tennessee at Findley Stadium. The game drew 20 thousand fans to watch the game. Activities began at 2300 UTC with kickoff occurring at 2310 UTC. The emergency management office was in close contact with the Morristown forecast office as the environment was favorable for thunderstorms and, in fact, storms were already in the vicinity of Findley Stadium (Fig. 5). Figure 5 includes a 5 and 10 mile range ring around Findley Stadium in Chattanooga, Tennessee. The total lightning observations show that at 2200 UTC, approximately 70 minutes before kickoff, intra-cloud lightning is within 10 miles of the stadium while the NLDN observes a flash right on the 10 mile ring. This was a concern for the emergency managers, but this particular storm was transitioning away from the stadium. The primary concern at this time were the storms to the west-southwest where there were 20 total lightning observations and four corresponding NLDN observations. The emergency managers wanted to monitor these storms as they approach the stadium and to determine if any actions would need to be taken.

By 2228 UTC (Fig. 6), the storm to the west-southwest of the stadium was weakening in all three observations. The radar reflectivity had decreased, only a single NLDN cloud-to-ground flash was observed, and the total lightning observations were down to no more than 5 flashes. This indicated that the storm was weakening. Should this trend continue, the threat of lightning to the game would be diminishing. The emergency managers now shift their focus to new storms developing or for this storm to redevelop. For the next ten minutes the weakening trend continued. The NLDN's last observation was 2228 UTC while the total lightning continued to show flashes through 2238 UTC (not shown).

This weakening trend began to quickly reverse right at kickoff at 2310 UTC (Fig. 7). Here, the radar reflectivity had returned to nearly 60 dBZ. Additionally, a single NLDN-observed cloud-to-ground flash was observed. Of particularly note, the NALMA total lightning did not have a flash, which was due to the status of the network and the range from the network's center. This demonstrates an advantage of GLM in that its detection efficiency will not vary based on sensor distribution. The emergency managers were at a critical decision point as a redeveloping cell was approaching the stadium. By 2328 UTC (Fig. 8), the radar reflectivity and total lightning observations were within 10 miles of the stadium. At this point, the managers called to postpone the game and to move the crowd to safety. This was based on consultations with the NWS as well as the reinforcing information provided by the total lightning observations. The game would remain postponed for 83 minutes. During this postponement, the total lightning observations were vital to monitoring when lightning activity had moved beyond 10 miles of Findley Stadium.

FUTURE WORK

This presentation has focused on the collaboration between NASA's Short-term Prediction Research and Transition (SPoRT) center, the National Weather Service office in Morristown, Tennessee, and the Chattanooga / Hamilton County, Tennessee emergency management office. The effort, started in 2014 has been designed to reach out to the emergency management community to help prepare those users for the Geostationary Lightning Mapper (GLM) that will become operational in 2017. This activity has used the ground-based North Alabama Lightning Mapping array to provide an approximation of what GLM data will look like both temporally and spatially using a web display that is available on PCs, tablets, and other mobile devices.

The focus has been on training the emergency managers on what is total lightning (intra-cloud and cloud-to-ground observations), how they differ from the more well-known National Lightning Detection Network observations, as well as for the collaborators to better understand the emergency managers' operational requirements.

The project has been successful as the Hamilton County managers now use these total lightning data regularly for lightning safety applications. With this success, several new activities are being pursued. First, two additional emergency management offices are being included that are covered by the North Alabama Lightning Mapping Array. These are Bedford and Coffee Counties in Tennessee. They will help provide additional feedback once GLM observations are available as well as to test the effectiveness of the training that has been developed for Hamilton County on new users. Secondly, Hamilton County has requested additional updates to the web display. They are interested in visualizing other meteorological data (e.g., radar and satellite) along with the total lightning as well as adding range rings. SPoRT has been developing a web mapping server display for safety applications at the Marshall Space Flight Center in Huntsville, Alabama (Fig. 9). This is still in development, but will likely be the method to address Hamilton County's requests.

Lastly, the authors plan an operational assessment of the GLM data in the summer of 2017. This will focus on the utility of the GLM observations for emergency managers as well as compare differences to the ground-based data they are familiar with. Conceptually, this assessment will identify cases for future training as well as needs that must be addressed by training. The ultimate goal is establish a training guideline for emergency managers, nationally, to use the GLM data in operations.

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IMAGES

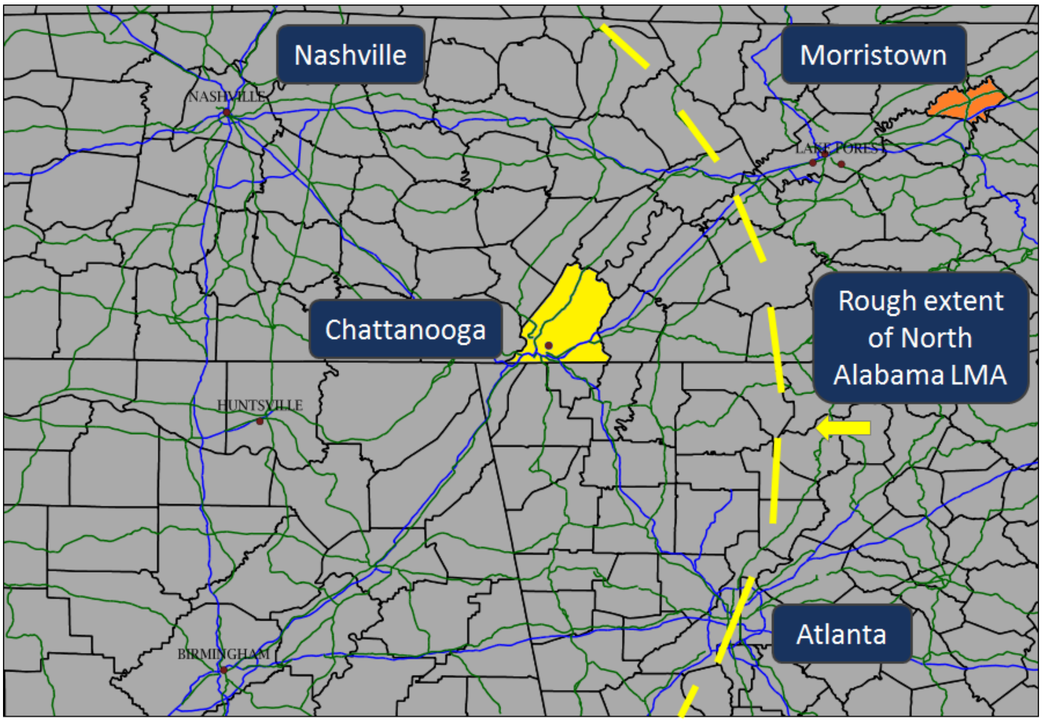

Figure 1: A map showing the locations of the Morristown, Tennessee forecast office (orange), Hamilton County, Tennessee (yellow), and the extent of the NALMA observations (dashed yellow line).

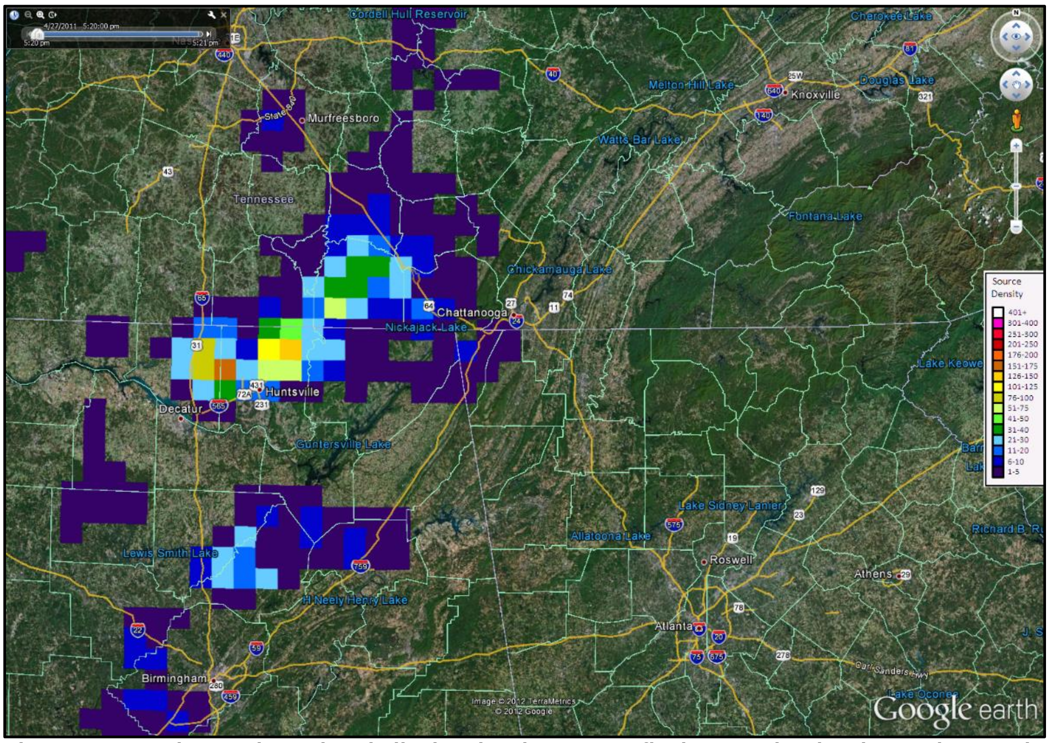

Figure 2: An early Google Earth web display showing NALMA flash extent density observations on the GLM resolution approaching Chattanooga, Tennessee.

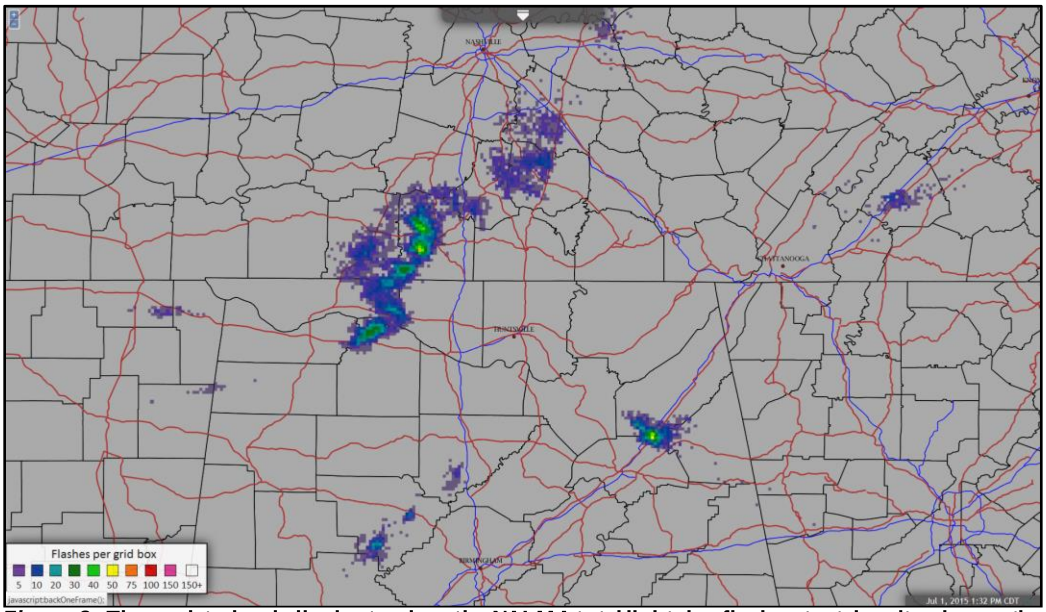

***Figure 3*: The updated web display to show the NALMA total lightning flash extent density observations available on PCs, tablets, and other mobile devices.**

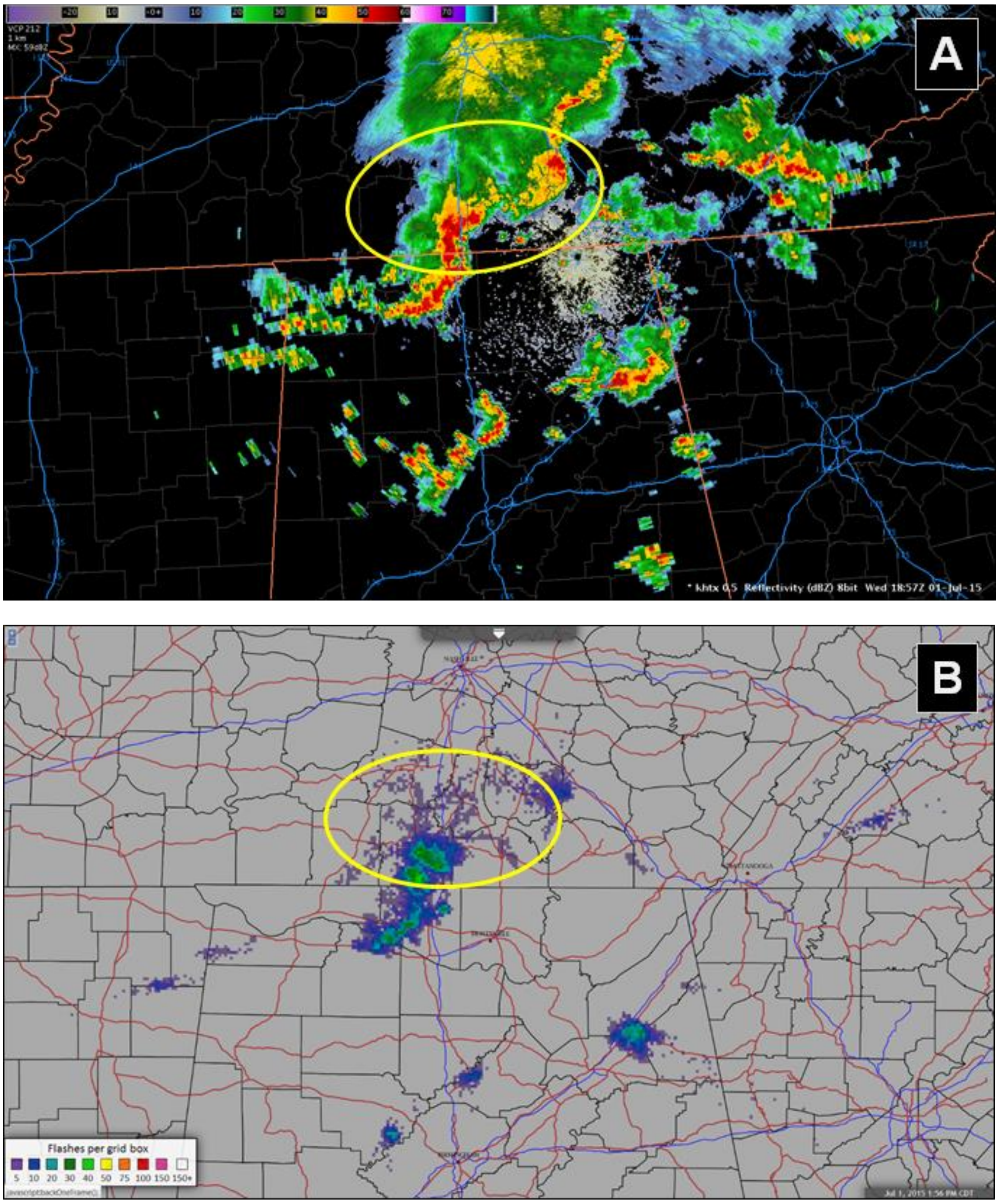

***Figure 4*: An example of radar reflectivity (A) from 1 July 2015 at 1857 UTC with the corresponding GLM demonstration flash extent density product (B) at 1856 UTC. The yellow circle indicates the location showing where the total lightning observations are extending well into the stratiform region away from the main storm cores.**

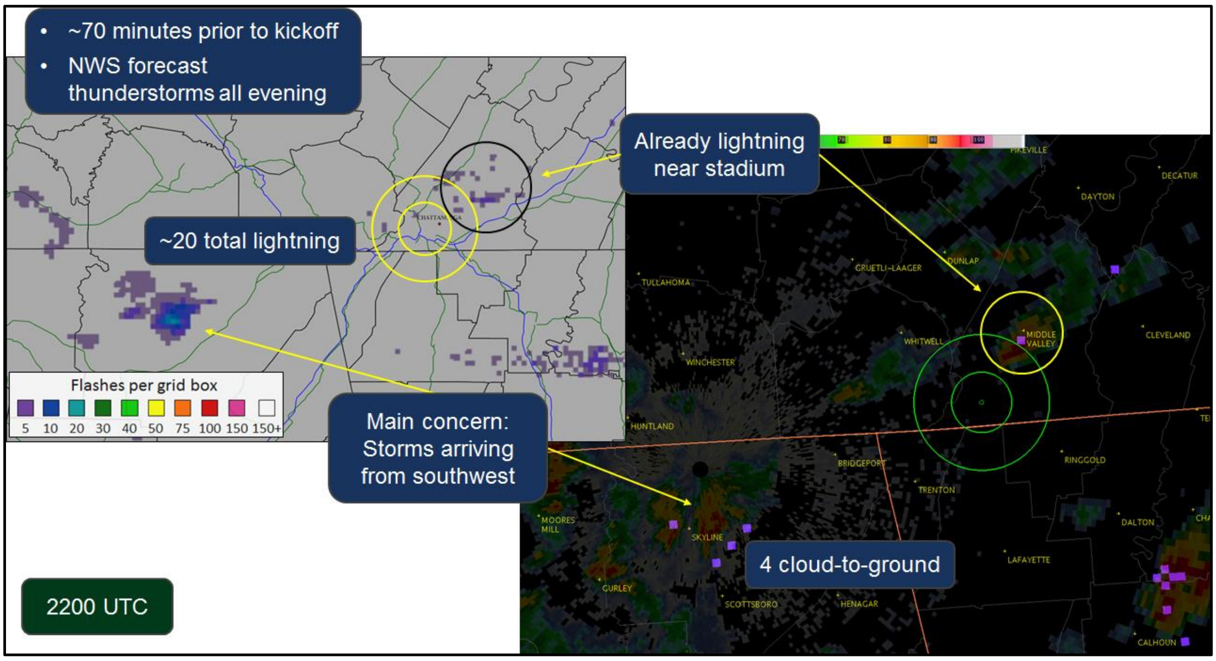

***Figure 5*: This is taken at 2200 UTC on 19 August 2015 with the total lightning images in the upper left and the radar reflectivity and 2x2 km National Lightning Detection Network density in the lower right. The yellow rings in the upper left and green rings in the lower right represent range rings of 5 and 10 miles centered on Findley Stadium in Chattanooga, Tennessee.**

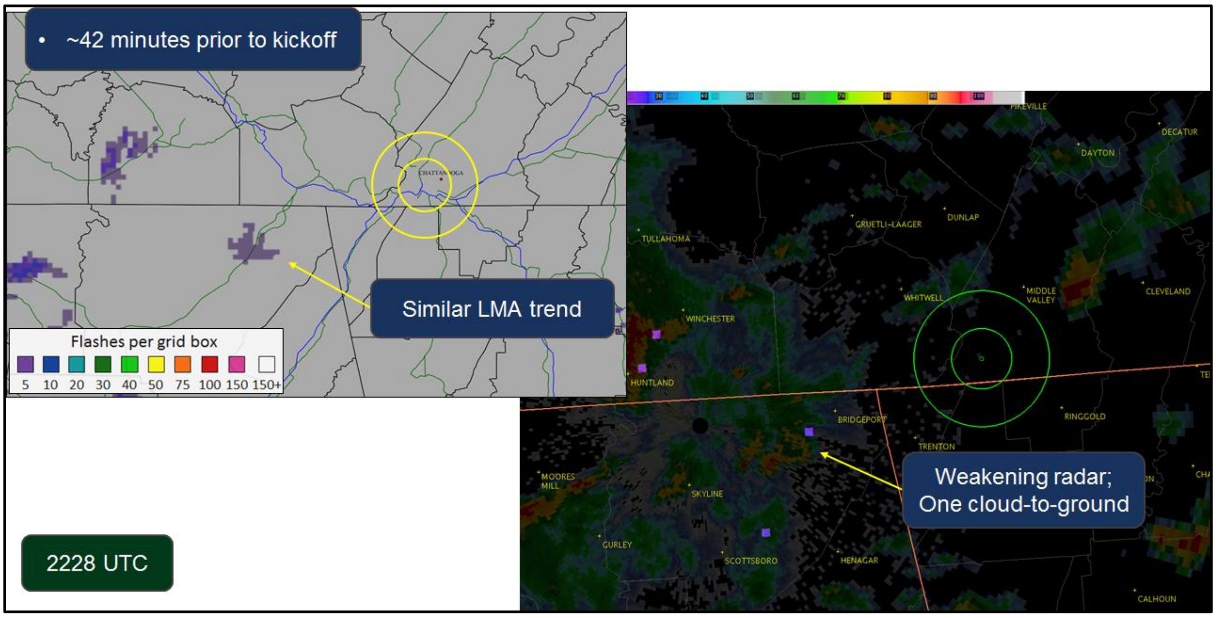

***Figure 6*: Same as Fig. 5 but for 2228 UTC.**

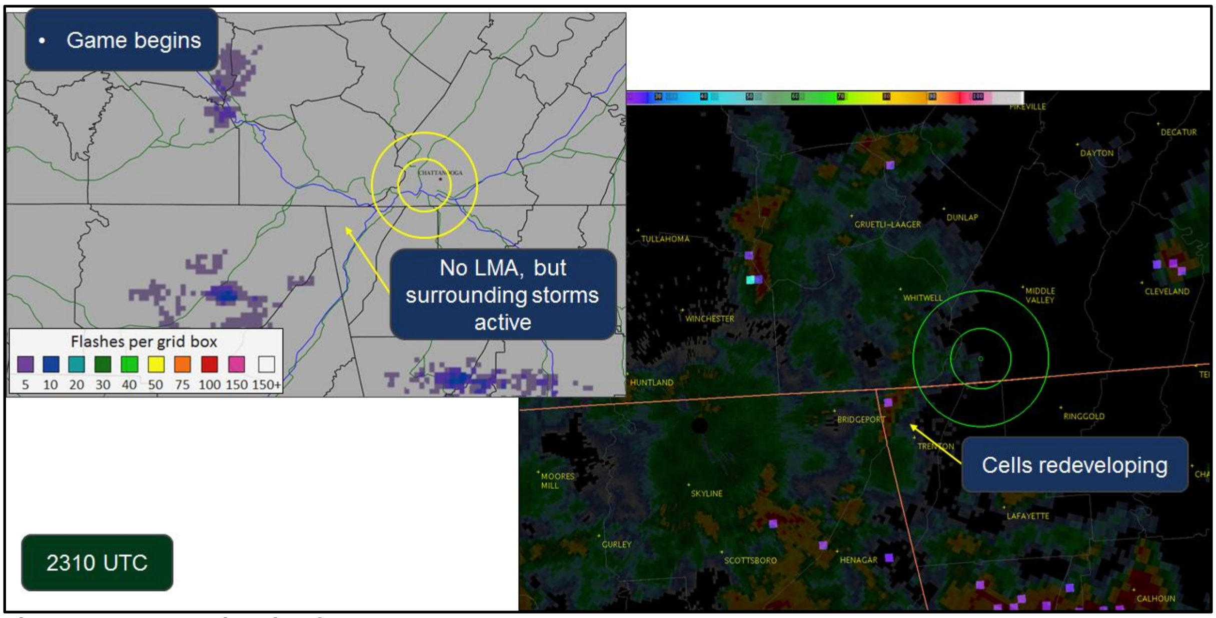

Figure 7: **Same as Fig. 5 but for 2310 UTC.**

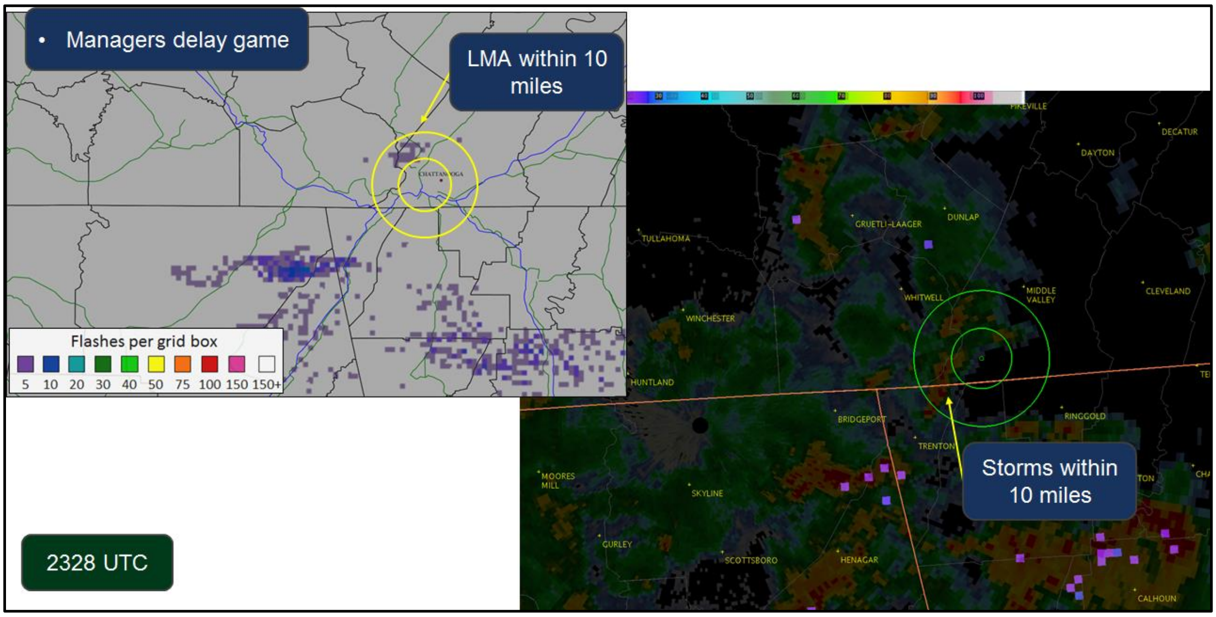

Figure 8: **Same as Fig. 5 but for 2328 UTC.**

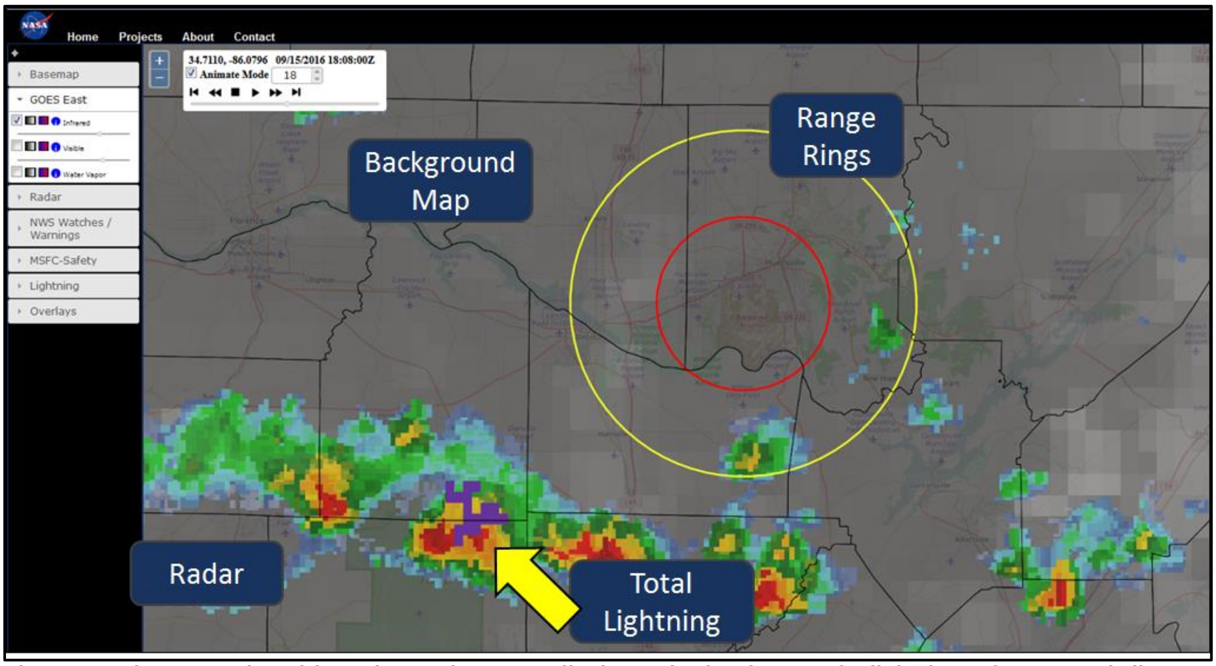

***Figure 9*: A demonstration of the web mapping server display under development for lightning safety at Marshall Space Flight Center showing the background geo-political information (e.g., roads, cities, county boundaries), range rings centered on Marshall Space Flight Center of 10 and 20 miles, as well as infrared satellite imagery, radar reflectivity, and total lightning flash extent density.**