EXPANDING THE OPERATIONAL USE OF TOTAL LIGHTNING AHEAD OF GOES-R

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1. INTRODUCTION

Total lightning has been most widely used in severe weather decision support (Bridenstine et al. 2005; Goodman et al. 2005; Demetriades et al. 2008; Nadler et al. 2009; Darden et al. 2010; White et al. 2012; Hodanish et al. 2013; Stano et al. 2014). This use derives from the robust correlation between a rapid increase in total lightning (i.e., a lightning jump – Schultz et al. 2009, 2011; Gatlin and Goodman 2010) and severe weather (Goodman et al. 1988, 2005; MacGorman et al. 1989; Williams et al. 1999). The correlation is due to total lightning's dependence on the strength of the updraft in the mixed-phase region of a storm. The correlation is non-linear such that stronger (weaker) updrafts in the mixed-phase region will result in far greater (smaller) values of total lightning. By subjectively looking for lightning jumps, and combining this with additional information such as radar and the near-storm environment, forecasters can receive vital sub-radar volume scan information that a storm is likely to produce severe weather. Additionally, from a situational awareness standpoint, forecasters can use total lightning to help "triage" there limited available time during warning operations as total lightning can identify which storms are more convectively robust and require additional investigation.

Beyond severe weather applications, NASA's Short-term Prediction Research and Transition (SPoRT; Darden et al. 2002; Goodman et al. 2004; Jedlovec 2013) center has emphasized that total lightning can be used for additional purposes, including lightning safety and impact-based decision support (Hodanish et al. 1998; Stano et al. 2010a; Stano 2012; MacGorman 2011). Here, total lightning often precedes the first cloud-to-ground strike by a few minutes. This can be extremely vital for supporting various outdoor events or activities. Furthermore, total lightning provides the ability to monitor convection, which can be applied to aviation needs including air route management and the status of arrival and departure gate regions in the Terminal Radar Approach Control (TRACON) airspace.

This remaining sections of this paper are as follows. Section 2 will discuss the assessment's methodology while section 3 will describe the products used. The results and specific case examples will be described in sections 4 and 5, respectively. The final summary is in section 6.

2. METHODOLOGY

The assessment was conducted between May 12 and August 31, 2014 in order to coincide with the climatologically most active convective period for the evaluators. Two total lightning products were evaluated; the source and flash extent (Stano et al. 2010b) densities. The vast majority of the surveys used the source density and that is the focus for this write-up.

The participants in this assessment were a collection of NOAA/NWS Weather Forecast Offices (WFOs) that have worked with total lightning previously as well as other WFOs and Center Weather Service Units (CWSUs) who received their first operational data from a ground-based lightning mapping array (LMA; Rison et al. 1999; Thomas et al. 2004). Figure 1 shows the location of each of

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the participating WFOs, CWSUs, Spaceflight Meteorology Group and the collaborating LMAs. In addition to these participants and NASA, four universities have collaborated by allowing SPoRT to transition their LMA data. These include Colorado State University (Colorado LMA), New Mexico Institute of Mining and Technology (Langmuir LMA and other data access), Texas A&M University (Houston LMA), and Texas Tech University (West Texas LMA).

This assessment of total lightning applications was conducted with four goals in mind. For each of these goals, an over-arching theme was to introduce total lightning to forecasters in operations in order to serve as a demonstration for the future Geostationary Lightning Mapper (GLM; Goodman et al. 2013) set to launch aboard GOES-R.

- Investigate the utility of total lightning data in operations across different regions and locations.
- Train forecasters to use these data for applications beyond lightning jumps and severe weather.
- Incorporate feedback from aviation focused CWSUs, who have not used these data previously following from Stano et al. (2013).
- Encourage forecasters to recommend changes to existing products or to recommend new products.

The genesis of this evaluation, and the partnerships that made it possible, is a reflection on SPoRT's expertise in providing total lightning observations to operational forecasters (Nadler et al. 2009; Darden et al. 2010; Stano et al. 2011; Stano 2012; White et al. 2012; Carcione et al. 2015) and the availability of several new ground-based LMAs. SPoRT personnel earned funding to all new LMA partners via the GOES-R visiting scientist program. This allowed for on-site meetings and discussions to prepare the new total lightning collaborators for the data they would receive and how to use these data in operations. In addition to the site visits, two training webinars, a print out "quick guide", and self-paced training modules on NOAA's learning management system were provided.

3. PRODUCT DESCRIPTION

The raw total lightning observations came from six ground-based LMAs. Figure 1 shows the six LMAs planned for the assessment and the four that were ultimately online during the assessment. The raw data that SPoRT receives, and hence the final products available to the collaborating locations, were available every minute. The only exception was the North Alabama Lightning Mapping Array (NALMA; Koshak et al. 2004). This network provides observations every two minutes based on feedback from WFO Huntsville when SPoRT first transitioned these data in 2003. Also, based on the line of sight requirement of the LMAs, the domain of observations is limited to approximation 250-300 km from the center of each LMA network depending on the number of sensors in the network.

In order to explain the source density product evaluated, a moment is required to discuss what the ground-based LMAs observe. Total lightning observes both cloud-to-ground and intra-cloud flashes. This sets LMAs apart from the more well-known National Lightning Detection Network (NLDN; Cummins et al. 1998, 1999) that primarily observes cloud-to-ground strikes only. By observing intra-cloud flashes, LMAs can observe all of the lightning in a storm and not a small percentage of lightning activity.

The first, and most widely used product, is the total lightning source density product. The source density product uses a 2x2 km domain that is 480 km wide and 480 km "tall" and centered on the LMA network. There the number of individual sources observed in each grid box is counted over the observation period for the specific network. The resulting sum is the source density. A strength of the source density product, particularly during the original 2003 transition, is that it is very easy to generate and is computationally inexpensive. This minimizes latency, which is extremely important for a data set that can update every 1-2 minutes. What the source density does not show is how many flashes were observed, as a single flash may be composed of dozens to hundreds of sources. However, larger source density values imply more overall lightning and stronger storm updrafts. This is a key point that is emphasized in SPoRT's training materials.

The second product that was available for evaluation during this assessment was the flash extent density (FED) product. Unlike the source density product, the flash extent density provides a count of how many flashes occurred in any one 2x2 km grid box in a 1 or 2 minute period, depending on the specific LMA. The FED is a "derived" product as some processing of the raw observations into flashes is required (e.g., McCaul et al. 2005, 2009). The FED is more intuitive to forecasters as it states how many actual flashes occurred as opposed to parts of flashes. Additionally, the FED product is normalized with range compared to the raw source densities.

The FED has not been used previously as the flash algorithm computation could not occur fast enough. The FED received little feedback during the assessment, emphasizing the need for additional training. Carcione et al. (2015) are taking the first steps to do so following the results from this assessment.

4. RESULTS

During the assessment period, 39 surveys were received. The 39 surveys spanned nine partner offices and were received from 19 different forecasters. This demonstrated the interest the participants had even with the limitations that were faced with hardware issues to the available networks. All but two respondents had taken the available training prior to the assessment. Of the two respondents who had not, one had taken the training by the time of their second assessment.

Two questions are summarized in the following figures. The first asks forecasters to rate their confidence in understanding total lightning (Fig. 2). The second is a follow-up to ask forecasters to rank the impact of total lightning on the event discussed in the survey (Fig. 3). Figure 2 shows that forecasters ranked their confidence as High to Very High (72%) in their use and understanding of total lightning observations. Including the Medium confidence increased the number of surveys to 95%. This implies that the training performed well in teaching the basics of total lightning. Follow-up discussions with the respondents verified that there were no misunderstandings in the use of these data.

Figure 3 shows a follow-up response to ask the forecasters to rate the impact of total lightning data on the event being surveyed. Figure 3 shows more variability compared to the previous question, as the Low to Very Low responses were 20% of all responses. This led to a deeper investigation of the long-form responses to understand these ranks. Still, the impact of total lightning was favorable with 44% of the respondents rating the data as High to Very High and this increases to 80% when the Medium rating is included. Figure 4 summarizes the types of forecast products that were issued while using total lightning observations by the impact rating submitted by the forecasters. One item to note is with the Low and Very Low impact cases. For the single Very Low and three of the seven Low impact cases, the event occurred on the edge of the LMA domain, which limited its utility. An additional Low impact event was determined to be from the LMA in question not functioning properly. This resulted in five of the eight Very Low or Low impact events suffering from technical issues and not an inherent fault in the total lightning observations in particular.

In addition to investigating the surveyed impact of total lightning and the type of event submitted, an analysis of the type of product issued by the various participants is informative. Table 1 shows each of the products that the forecasters issued along with the number of times a particular product was issued during the course of the evaluation. All told, 44 individual products were issued within the 39 surveys received as some events had multiple actions. The breakdown is given in more detail than Fig. 4 above. The first result that stands out is the overall diversity of products that were issued by the forecasters with respect to the use of total lightning. A major push of the pre-assessment training was to emphasize that total lightning had operational uses beyond lightning jumps and severe weather. The results in Table 1 show that the training was successful in this goal, but also demonstrated the versatility of the forecasters working to incorporate and assess this unique data set. Overall, throughout the assessment eight warnings were issued with the aid of total lightning, of which one was a non-traditional use flash flood warning. Additionally, two of the Special Weather Statements were issued by forecasters who used total lightning to *not* issue a severe thunderstorm warning as the observations indicated that the storm would remain below severe criteria. The remaining products are difficult to classify in distinct categories (e.g., lightning safety, situational awareness, and impact-based decision support) as the free form responses indicated that these products were used for multiple reasons. For instance, Special Weather Statements and Nowcasts were used for situational awareness, primarily as information provided to the public, but also fell into the category of lightning safety. The Airport Weather Warnings are impact-based decision support, but also lightning safety. Although difficult to categorize, Table 1 clearly shows that the participating forecasters were investigating the use of these data in numerous ways. Sometimes the impact was minimal, but the overall response by forecasters was positive, even for the Low impact events.

5. HIGHLIGHTED CASES

In addition to providing raw numbers of surveys submitted and answer percentages, three specific events are highlighted below. These emphasize cases beyond the traditional use of monitoring for lightning jumps in support of severe weather decision support.

5.1 WFO Cheyenne Lightning Safety event

This event was submitted by WFO Cheyenne, Wyoming for the evening of July 20, 2014. This case is focused on lightning safety for Cheyenne's Frontier Days Rodeo event. The Frontier Days Rodeo is the largest outdoor rodeo in the world. The event lasts for ten days and can draw over 200 thousand visitors over the course of the event. As such, the rodeo is a major venue for the local forecast office to provide weather safety support.

The critical moment of the event began at 6 PM local time (0000 UTC) on 21 July 2014. Figure 5 shows the situation at 00 UTC with several annotations, including the location of Cheyenne, Wyoming. Early in the day, a boundary observed on radar had moved northward from Colorado. The primary concern became the storms that developed behind the boundary, particularly along the I-80 corridor from the Laramie Range eastward to the Nebraska border. According to the forecaster, there was not much lightning activity on the Wyoming side of the border, aside from a single cluster well west of Cheyenne along the border in Albany County. The concern was that at this time of day the rodeo has usually just ended and the crowds were beginning to venture out of the park. Additionally, crowds were arriving for the night concert. During this time, the night show crew sets up the main stage. Therefore, it was vital to know whether or not lightning or strong winds were approaching the event area. Because of the large number of people outdoors and the storms in the area the forecaster was, *"watching the source density products like a hawk for any lightning approaching Cheyenne."* The storms that had formed were relatively weak, but the LMA observations south of the Wyoming/Colorado border emphasized that a lightning threat may exist. Given this situation, the forecast office provided a verbal phone briefing to emergency managers to keep them appraised of the developing situation.

Figure 6 was observed seven minutes later at 0007 UTC. The storm in Albany County continued to have lightning associated with it, as well as the storms well to the south in Colorado. However, of great interest were the observations of several sources southwest of Cheyenne along the Colorado-Wyoming border. This observation strongly suggested that these small storms were capable of producing lightning. Additional source density observations occurred between 0020-0030 UTC in the southwest corner of Laramie County where Cheyenne is located (not shown). Although more sources were observed, no sources came within 15 miles of Frontier Park in Cheyenne and the forecast office could brief the emergency managers with greater confidence that the lightning threat would remain outside the region of interest. Eventually, a collapsing rain storm would produce a 43 mile per hour downburst in Cheyenne. However, throughout the event *"the total lightning proved extremely useful in enhancing situational awareness and overall forecast confidence."*

5.2 WFO Huntsville Flash Flood Warning

On August 10, 2014 WFO Huntsville was monitoring storms across the region in a low shear environment. This particular event began around 1935 UTC (Figure 7a) as a storm cell developed over northwestern portions of Morgan County. The cell developed directly along the Tennessee River and over the city of Decatur, Alabama. This storm was producing heavy rainfall and was being monitored closely by the forecasters. By 2028 UTC (Figure 7b) forecasters were concerned that the storm cell was not moving and was, in fact, back building. This was resulting in persistent heavy rainfall over Decatur. Additional observations indicated that by 2102 UTC (Figure 7c) the one hour rainfall amounts (not shown) were approaching 2 inches. The fact that the storm showed little movement and continued to produce rain over Decatur prompted the forecast office to consider if a flash flood warning was necessary.

The forecasters were aware that this particular basin could handle the quantity of rain that had occurred so far if the cell were to dissipate and / or begin to move out of the area soon. The major question for issuing the flash flood warning now resided with a determination of the longevity of this particular storm cell. This was where the forecaster employed both the source density and FED products. At 2104 UTC (Figure 8a), the North Alabama LMA source density observations showed the start of an enormous increase in total lightning activity directly over the city of Decatur, Alabama. The values easily exceeded 500 sources in one 2×2 km grid box over 2 minutes. This trend continued for several minutes (Figure 8b). With this knowledge and understanding that the cell was likely undergoing intensification and that moisture-laden updrafts were strengthening directly over Decatur, the forecaster issued a flash flood warning that was officially disseminated at 2115 UTC. The first flash flooding reports were received at 2145

UTC. According to the forecaster who submitted the survey, *"the total lightning data in this case served as a very valuable severe weather application tool. By providing knowledge of the location and likelihood of future deep convection, a flash flood warning was issued in a more timely and effective manner than would have been possible without these data."*

5.3 CWSU Denver Briefing

The cases above highlighted events from WFO participants. However, the participation of three Center Weather Service Units provided a first ever assessment of total lightning in their operations. The surveys submitted by the CWSUs and the follow-up discussions with the forecasters demonstrated the unique needs and concerns for their particular mission. Although the LMAs available did not have the range to cover the entire domain of each CWSU, the LMAs generally covered an important region, such as the Denver International Airport in the case of the Denver CWSU. Unlike the WFOs, the CWSUs function almost exclusively to aid the impact-based decision support of the FAA Traffic Management Coordinators in the Traffic Management Unit. The primary question that is on the scale of LMA observations is, "Will convection interfere with air routes, or gates, of inbound and outbound air traffic?" The more accurate and precise the CWSU forecasters can be, the more options the Traffic Management Coordinator has with air traffic flow.

Inbound and outbound aircraft follow very specific routes to an airport and enter these routes at gates roughly 50 miles from the airport. At this point, the aircraft management is transferred from the Air Route Traffic Control Center (ARTCC) to the Terminal Radar Approach Control (TRACON) center for inbound flights, while the opposite is true for outbound flights. The outbound flights follow the cardinal directions (north, south, east, and west) while the inbound gates are offset to the northeast, southeast, southwest, and northwest. During this time, summer thunderstorms are a major concern as a gate can go from clear to a major impact in 30 minutes. The outflow from storms can also cause problems as planes want to take off into the wind.

This particular case took place on June 21, 2014. The CWSU forecaster was monitoring thunderstorms to the southeast of Denver around 2100 UTC (Figure 9). At this time, storms were active to the southeast of Denver, but the convection still had a gap in it, which allowed air traffic to reach the southeast gate unimpeded (i.e., 20 mile separation from the storms) and follow their approach route to the airport between Arapahoe Park and Watkins, Colorado. The total lightning observations provide a similar overview to radar. The situation began to change at 2116 UTC (Figure 10). The radar image was relatively unchanged, but the total lightning showed a very different perspective. At 2116, the source density product observed the most lightning in the cell southeast of the Denver International Airport near Watkins, Colorado. In addition, the total lightning showed that a long flash was observed from this storm and west-southwestward towards Arapahoe Park, Colorado. This demonstrates that the TRACON route is likely experiencing intra-cloud lightning, even though the main storm cores are not in the approach path. As this occurred, the CWSU forecaster provided a verbal briefing to the Traffic Management Coordinator that lightning is now a threat in the arrival corridor. Five minutes later at 2121 UTC (Figure 11), the forecaster observed a new development. Unlike the long flash in Fig. 10, the total lightning observations (circled) indicated a new storm core developing in the TRACON arrival path as shown by the bull's-eye structure. The corresponding reflectivity at 2121 UTC does not yet observe this new cell. This provides the CWSU forecaster additional information to support their experience and knowledge of the environment that the southeastern arrival corridor was likely to be impacted and potentially closed to air traffic in the near future. The radar began to observe this cell at 2127 UTC and the total lightning continued to fill in (not shown), indicating that the storm was strengthening. These observations serve to reinforce the update the forecaster has already provided to the Traffic Management Coordinator. By 2147 UTC (Figure 12), 31 minutes after the long flash intruded on the flight corridor and 26 minutes after total lightning suggested a new cell was developing, the radar observations show that the entire southeastern arrival corridor is blocked by active convection.

The total lightning observations were used in conjunction with radar in this forecast as the forecaster, using their expertise and knowledge, was able to incorporate these data with the radar observations. Given that the CWSU is requested by the Traffic Management Coordinators to provide yes/no forecasts of convective impact, the total lightning observations gave the CWSU forecaster additional confidence that the southeastern approach routes would be blocked by convection. Total lightning's best impact in this case was to provide an early "heads-up" that a new cell was developing in the approach corridor. This allowed the forecaster a few extra minutes to investigate the region, increase confidence, and then provide a verbal briefing to the Traffic Management Coordinator in order to make adjustments to the arrival pattern at Denver International Airport.

6. SUMMARY AND FUTURE WORK

This collaborative assessment incorporated eight local Weather Forecast Offices (WFOs), three Center Weather Service Units (CWSUs), and the Spaceflight Meteorology Group (SMG). The assessment was supported by SPoRT's collaboration with these forecast entities, the GOES-R / JPSS visiting scientist program that enabled site visits to each partner who had not previously used total lightning (8 locations in total), and the owners of the six ground-based lightning mapping arrays (LMAs). The four objectives of this assessment included:

- Investigate the utility of total lightning data in operations across different regions and locations.
- Train forecasters to use these data for applications beyond lightning jumps and severe weather.
- Incorporate feedback from aviation focused CWSUs, who have not used these data previously following from Stano et al. (2013).
- Encourage forecasters to recommend changes to existing products or to recommend new products.

Included in each of these objectives was the goal of providing forecasters operational experience with total lightning. This will serve as operational training and preparation for the forecasters once the Geostationary Lightning Mapper aboard the GOES-R/S series is launched.

This intensive evaluation period took place from mid-May through the end of July 2014 to coincide with the peak convective season for the majority of the participants. An informal extension kept the assessment running through August to try and capture the southwestern monsoon season and allow some offices more time to use the data due to some networks being offline during the assessment. The assessment evaluated two products, but the vast majority focused on the traditionally used source density over the more recently available flash extent density. The assessment did have to deal with major technical issues. These included some partners switching to AWIPS II and not being allowed to ingest total lightning during their "shakedown" period, and two lightning mapping arrays going offline. While this reduced the number of active participants in this assessment, direct communication with these forecast offices still allowed for valuable, informal feedback.

The 39 surveys demonstrated that the assessment as a whole was very successful. Additionally, the pre-assessment training that ranged from on-site visits to science sharing calls was effective in introducing the concept of total lightning to the numerous new collaborators as well as encouraging forecasters to assess the utility of total lightning for more scenarios than lightning jumps preceding severe weather. Forecasters did raise additional questions that need to be addressed with additional training and time to integrate the data into operations. However, 95% of the respondents ranked their understanding of the data as Medium or better and it was 72% for those indicating a High or better understanding. Post-survey discussions reinforced this mark.

A new development is the National Weather Service implementing a new scan strategy with its WSR-88D radars. In this approach, the radar will forego high elevation angles if returns do not reach a certain threshold. When this occurs, the radar will return to lower scan angles. The overall change is faster update times for radar observations. Future SPoRT training will need to take this into account.

The wide variety of uses and cases depicted by the forecasters in their surveys, as shown in Fig. 6 and Table 1, can only be considered a success. Previous total lightning assessments only focused on the utility of total lightning for severe weather decision support. This assessment demonstrated that the operational forecasters identified a wide selection of scenarios where these data can benefit operations. The impact of total lightning on these events did vary. However, forecaster feedback expressed positive views on total lightning even in cases where the impact was minimal.

The assessment also noted two items with which to improve the total lightning visualization. First, forecasters supporting off-site activities requested an improved web interface for when they are unable to use AWIPS or AWIPS II. This web interface would be highly beneficial to one of the National Weather Service's end users; emergency managers. SPoRT is investigating the effort to produce improved total lightning web graphics based on this feedback. This effort will likely lead to a new assessment with specific emergency managers, such as the collaboration that WFO Morristown, Tennessee is leading with the Chattanooga / Hamilton County emergency managers. The second visualization update is with the data in AWIPS / AWIPS II. The issue was noted particularly with the LMAs that have a one minute temporal update. In many cases, the forecasters noted that the one minute data appeared noisy and difficult to interpret as well as the default color curve not providing enough fidelity. Several offices have implemented local color curves, but SPoRT is investigating if there is an issue with the one minute data. One approach will be to develop a 2 minute summation product that updates every minute (Stano et al. 2015). This solution was suggested independently by both WFO Cheyenne and Melbourne. A majority of the participating offices have expressed interest in evaluating this product in the future.

Lastly, the lessons learned here will be applied to new training activities by NASA SPoRT. This will be used with new total lightning collaborations that will be available in the near future.

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8. FIGURES

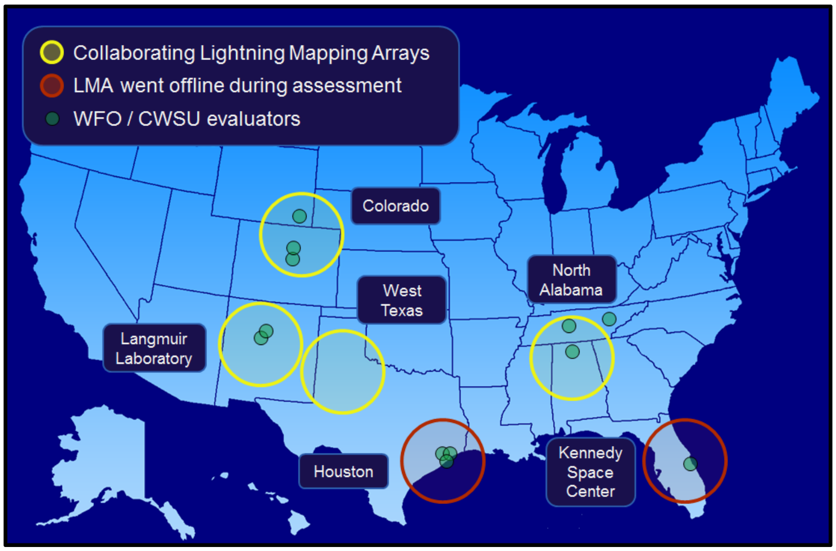

Figure 1: A map showing the rough domain of observations from the six collaborating LMAs (yellow and red circles), the two that went offline for the assessment (red circles), and each evaluating partner (green dots). The evaluators included eight WFOs (Albuquerque, Boulder, Cheyenne, Houston, Huntsville, Melbourne, Morristown, and Nashville), three CWSUs (Albuquerque, Denver, and Houston), and Spaceflight Meteorology Group.

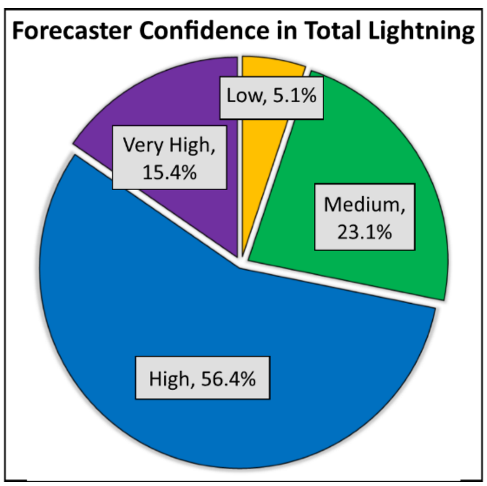

Figure 2: Respondents' feedback for the confidence in understanding and using total lightning observations.

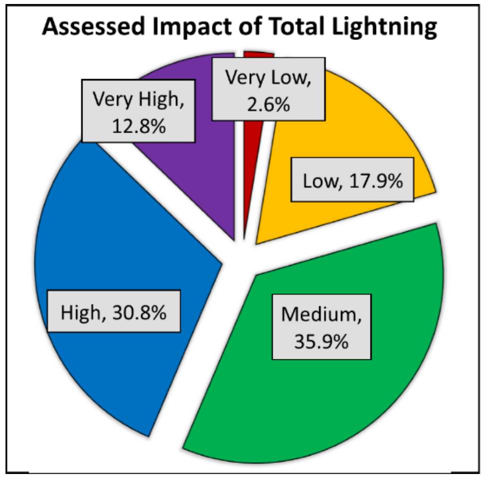

Figure 3: Respondents' feedback on how they rated the impact of total lightning observations in operations during an event.

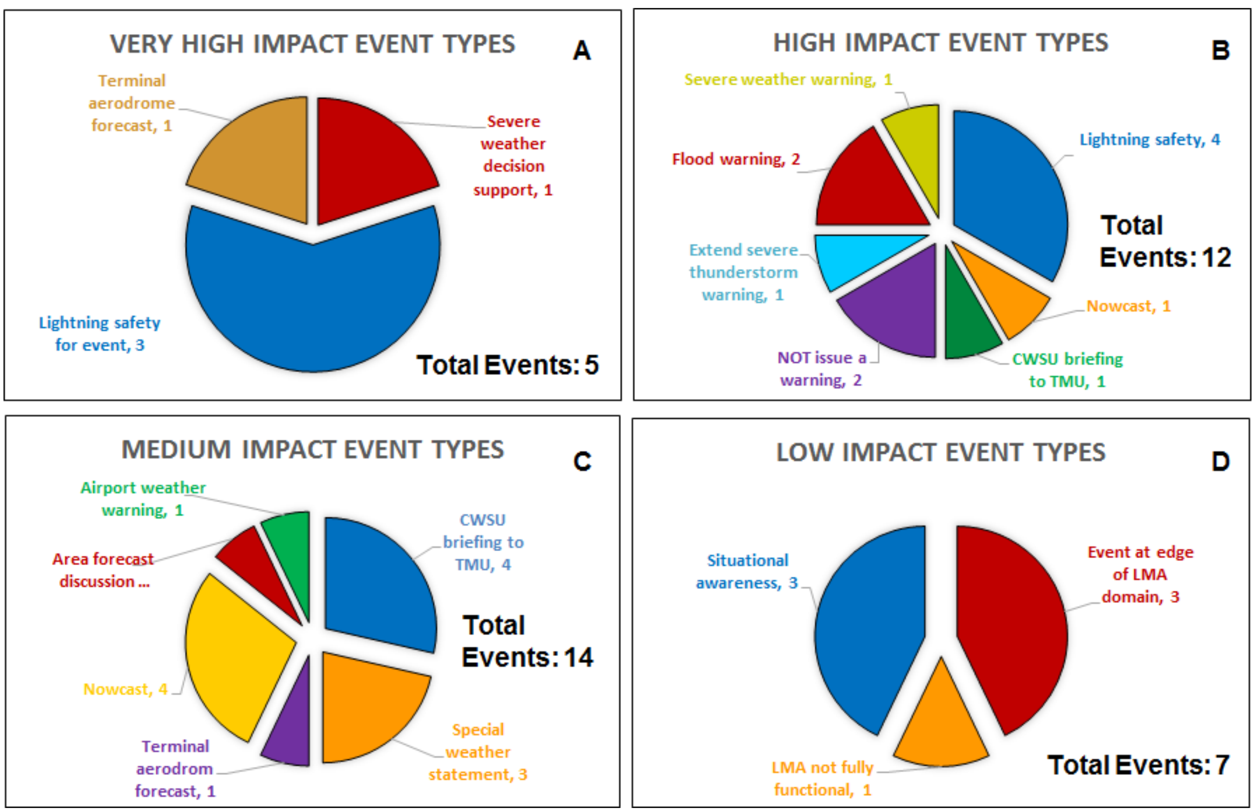

Figure 4: A breakdown of the types of forecast products issued based on forecasters' assessment of the impact of total lightning for specific events. These include Very High (A), High (B), Medium (C), and Low (D) impact events. The single, Very Low impact event is not shown, but the impact was rated Very Low due to the event occurring at the edge of the LMA network's domain.

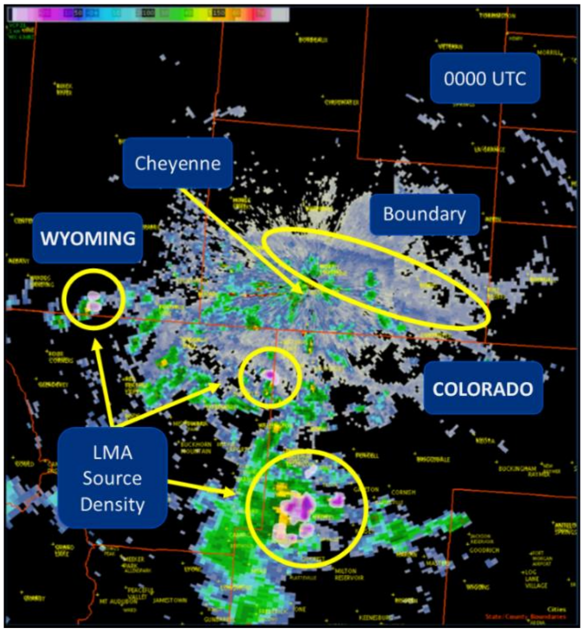

Figure 5: An AWIPS II display, zoomed on Cheyenne, Wyoming showing the KCYS WSR-88D radar reflectivity and the Colorado LMA source densities overlaid on top at 0000 UTC on 21 July 2014.

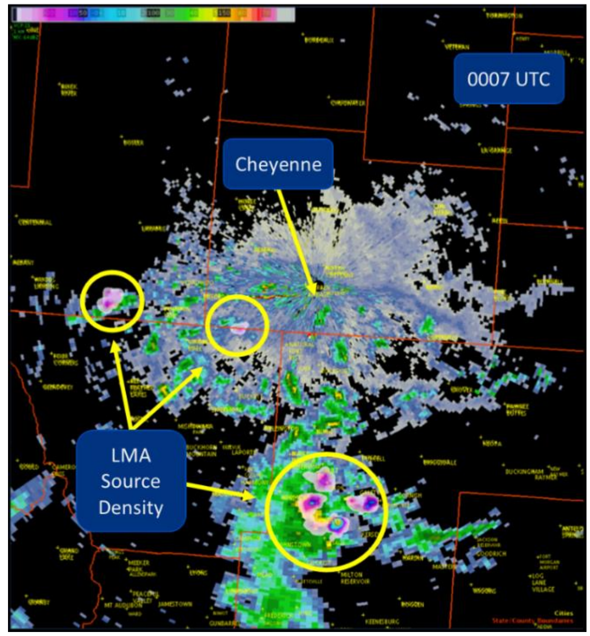

Figure 6: The same as Fig. 5, but now at 0007 UTC on 21 July 2014.

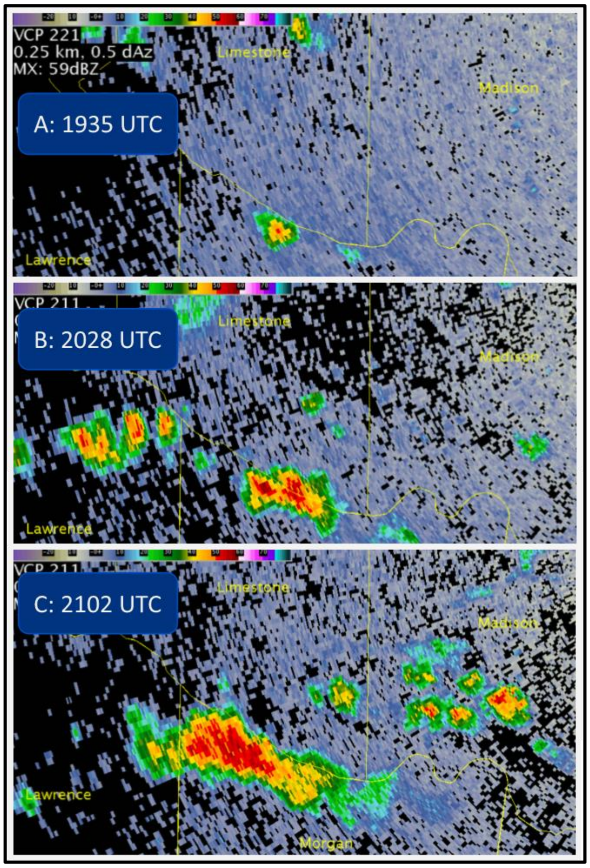

Figure 7: WSR-88D radar reflectivity observations from KHTX on 10 August 2014 showing the evolution of the stationary storm over Decatur, Alabama at 1935 (A), 2028 (B), and 2102 UTC (C).

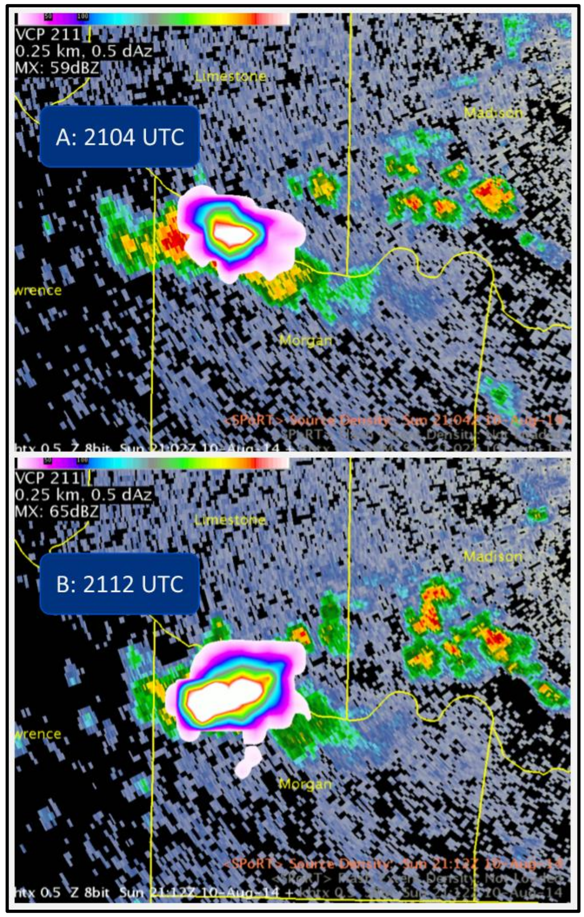

Figure 8: Similar to Fig. 9, this shows the progression of the North Alabama LMA source density observations with the stationary storm over Decatur, Alabama on 10 August 2014 at 2104 (A) and 2112 UTC (B), respectively.

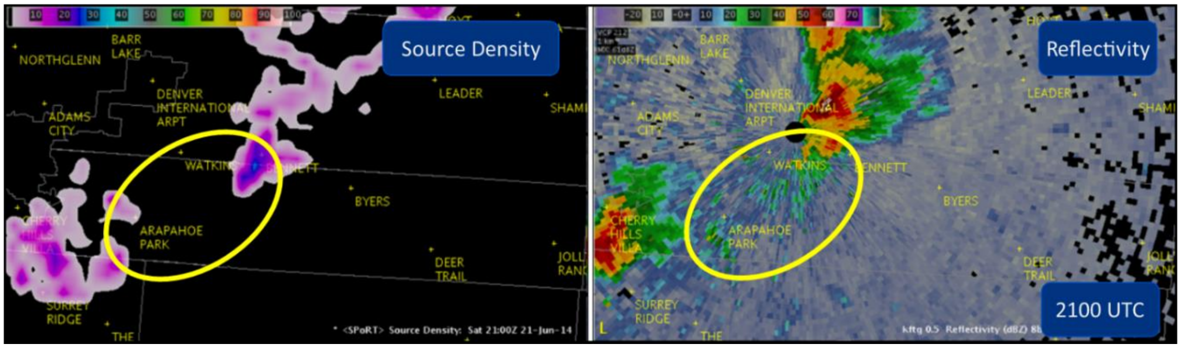

Figure 9: AWIPS II imagery of the Colorado LMA source density product (A) and Denver, Colorado WSR-88D 0.5 degree radar reflectivity at 2100 UTC on 21 June 2014. The circle highlights the area of interest.

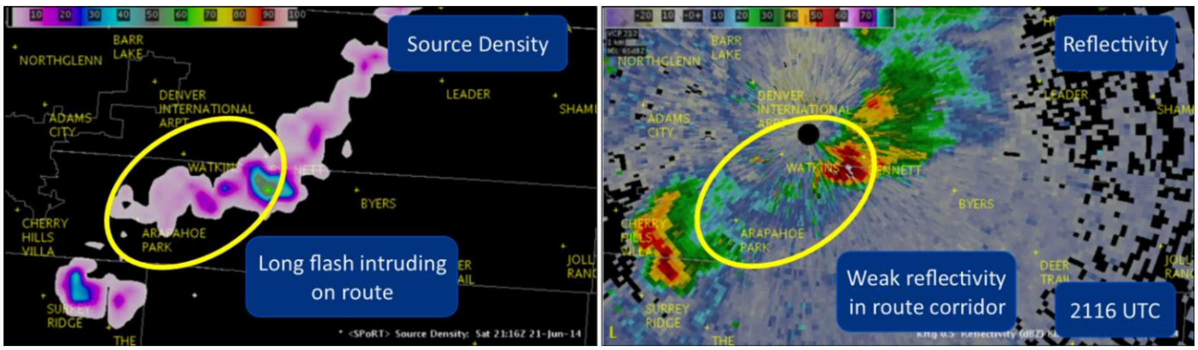

Figure 10: This is the same as Fig. 9, but now at 2116 UTC. The main item of interest is a long flash extending east to west into the flight route corridor.

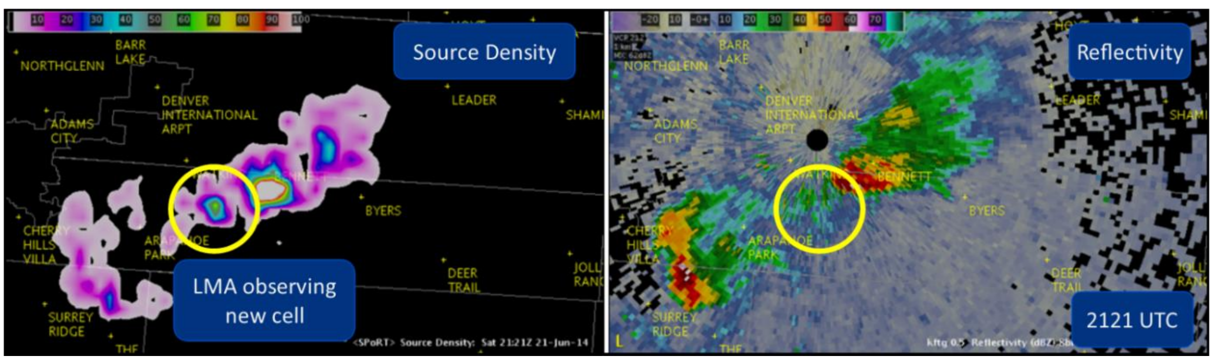

Figure 11: This is the same as Fig. 9, but now at 2121 UTC. The main item of interest is the concentrated region of source density values indicating a new updraft ascending in the flight route corridor.

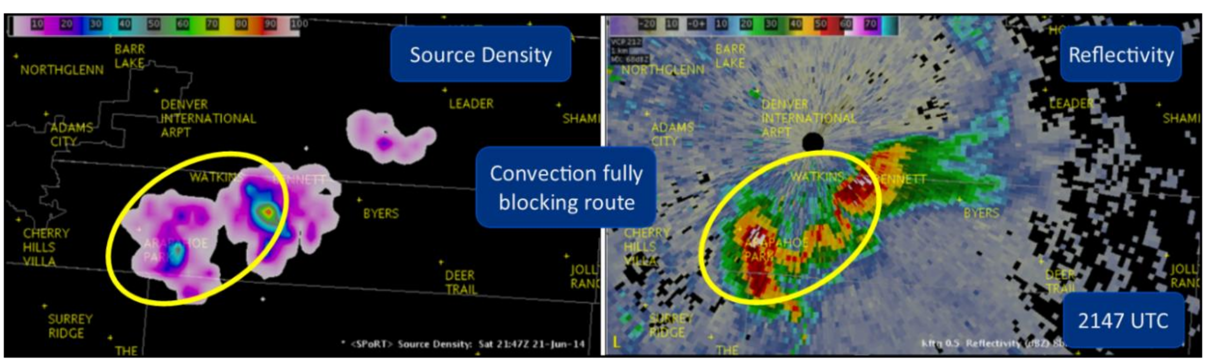

Figure 12: This is the same as Fig. 9, but now at 2147 UTC. Here the total lightning source density and radar reflectivity have completely filled in the flight route corridor.

9. TABLES

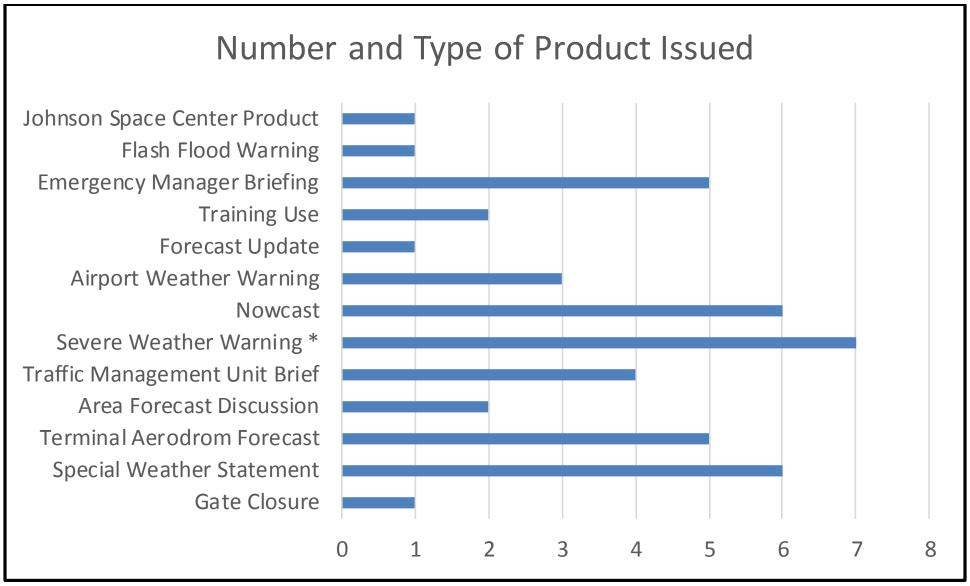

Table 1: The type of products and total number of products issued by type during the 2014 total lightning assessment. There were 44 products issued overall in the 39 surveys received. ("*": Severe Weather Warnings cover both Severe Thunderstorm and Tornado Warnings.)