P4.2

USE AND EVALUATION OF LIGHTNING DATA WITHIN THE 2010 EXPERIMENTAL WARNING PROGRAM AND GOES-R PROVING GROUND

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1. Introduction

The primary objective of the Experimental Warning Program (EWP) is to evaluate the accuracy and the operational utility of new science, technology, and products in a testbed setting in order to gain feedback for improvements prior to their potential implementation into National Weather Service (NWS) operations (Stumpf et al. 2010). A developmental product for the GOES-R Geostationary Lightning Mapper (GLM) was demonstrated during the Spring 2010 EWP as part of the GOES-R Proving Ground. This product was created using data from ground-based Lightning Mapping Array (LMA) networks sorted into flashes and displayed at the 8 km resolution expected with the GLM.

During the EWP, forecasters were able to examine the lightning data in conjunction with radar and other multi-sensor products in AWIPS as part of their warning-decision process for both real-time and archive events (Kingfield and Magsig, 2009). Forecasters were then asked to provide feedback through both online surveys following the event and also through discussion with lead scientists. This feedback will help shape the design of the products and educational tools concerning lightning data ahead of the availability of GOES-R data in local NWS forecast offices. In addition to the individual forecaster feedback, all warnings issued by EWP forecasters had their spatial coverage, lead times, and warning performance metrics calculated and compared against the official NWS warnings to assess whether GOES-R products provided any influence to the warning decision making process.

2. Data and Use

2.1 Product Background

A Pseudo-Geostationary Lightning Mapper (PGLM) product was created for testing in the Hazardous Weather Testbed (HWT) during the Spring Experiment (17 May – 18 June 2010). This product utilizes total lightning data from three Lightning Mapping Array (LMA) networks (Central Oklahoma, Northern Alabama, and Washington DC) and the Lightning Detection and Ranging (LDAR) network (Kennedy Space Center, Florida) that detect VHF radiation from lightning discharges (Fig. 1). The real-time lightning data, available in 1 min or 2 min intervals depending on the network, is sorted into flashes using algorithms available through Warning Decision Support System – Integrated Information (WDSS-II; Lakshmanan et al. 2007). A LMA determines the time and location of the individual sources of VHF radiation produced by lightning, with accuracy varying from 50 nanoseconds and 10 m within the network's perimeter to 10 microseconds and 2 km at the system's nominal range of 200 km (Thomas et al. 2004). WDSS-II identifies a group of VHF sources as a flash by using thresholds for the time and distance between sequential mapped points. These

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flashes are then tabulated in a grid with 8-km resolution (a single flash is counted no more than once in each grid box), thus creating the total flash extent density product for the GLM,

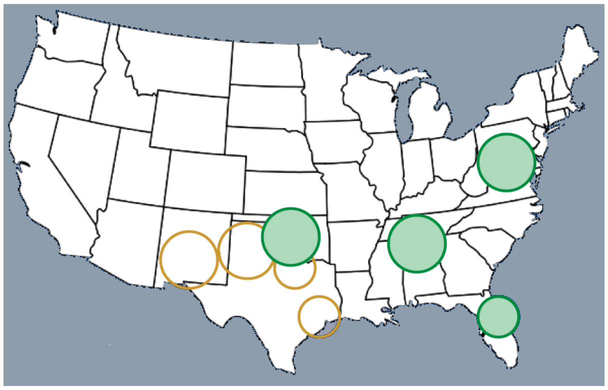

Fig. 1: Locations and range of ground-based lightning mapping systems in the continental United States. Green indicates systems with real-time data available during the 2010 Spring Experiment. Orange circles represent either future systems or those not currently available in real-time.

which we term PGLM.

2.2 Product Use:

National Weather Service (NWS) forecasters evaluated the PGLM product during both real-time operations and for an archive event. The PGLM product was available at 1-minute updates within the Advanced Weather Interactive Processing System (AWIPS). Forecasters were able to choose their own display options, often overlaying the PGLM product with radar and satellite products [see Fig. 2]. Real-time operations focused on regions where activity was expected to be at least marginally severe and preference was given to areas that contained a LMA or LDAR network in order to get the maximum number of PGLM cases possible.

Activities and events that occurred during the previous shift were discussed at the start of each day to get additional feedback on the

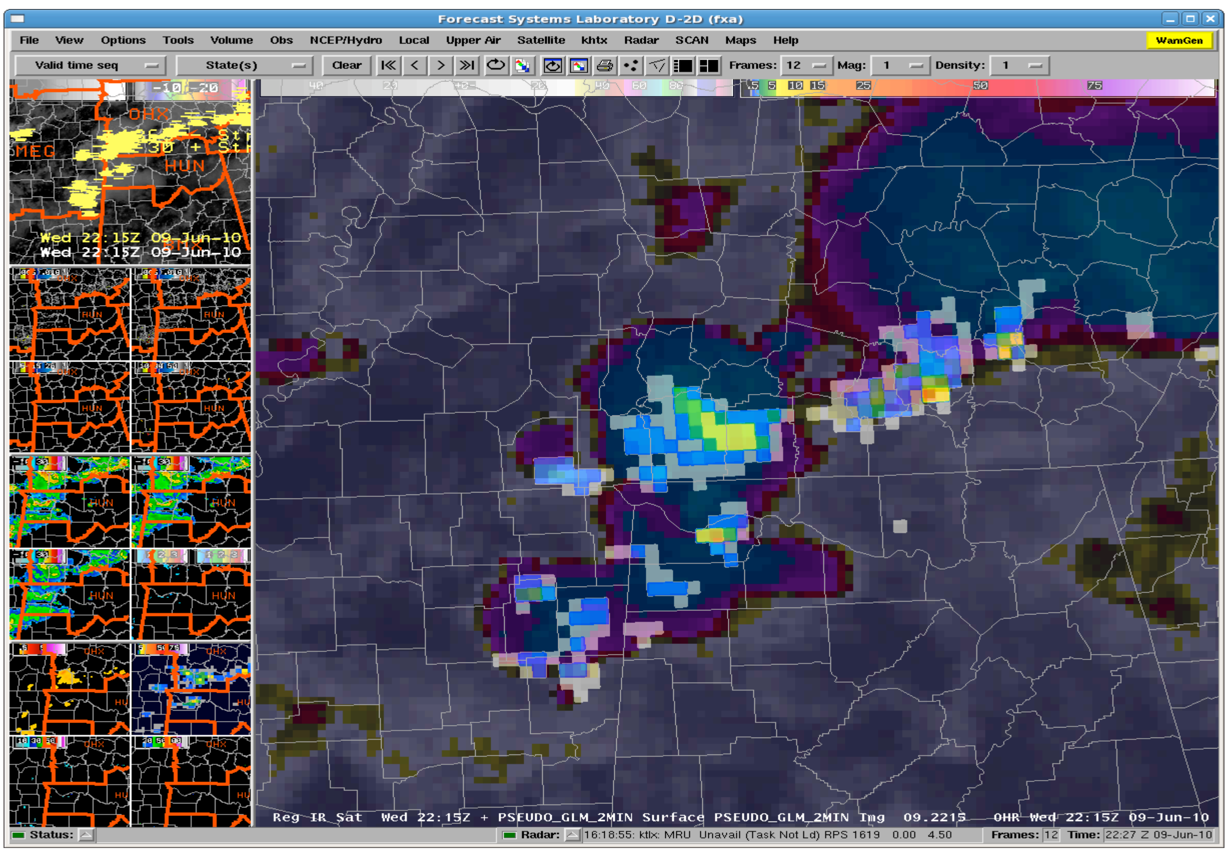

Fig. 2: Forecaster AWIPS display of PGLM flash extent density product and infrared (IR) image over Central Tennessee and Northern Alabama. The overlay of PGLM on IR allowed the forecaster to focus on the most active convective cores.

forecasters thoughts and experience with the PGLM product. Particularly interesting case events that occurred while either the forecasters were not on shift or only a subset of the visiting forecasters worked were discussed during this daily discussion as well [Fig. 3].

3. Results and Feedback:

In general, the PGLM products provided a strong support tool for the forecasters and helped increase forecaster confidence to warn or not warn on a storm. The lightning data was often noted as perhaps being more important with pulse storms or near-severe situations where lightning would be more clearly indicative of important updraft fluctuations. Forecasters viewed future GLM data as a "great tool" or a possible "mainstream product" for "situational awareness" ("making sure no dangerous cells are being missed"). Forecasters also found the PGLM data particularly useful when blended with other products derived from radar, satellite, and the National Lightning Detection Network (NLDN) to provide a complete view of the storm.

Multiple forecaster comments echoed the idea of using the GLM data as an additional tool to radar, particularly during the early stages of storm development. Forecaster evaluations also revealed that the high temporal update (1 min) of the product was useful, but many felt the resolution was too coarse when compared with the available radar data. Still, the PGLM data was found to be "complimentary to the warning process" and forecasters "would like to have it within operations." Specifically, one forecaster noted following a real-time event:

> "The total lightning product gave lead time to a cell that had become electrically active over both traditional radar interrogation methods as well as the ground based lightning network. This is very important since many lightning fatalities are recorded with the first strike. It will also prove very beneficial as we get more into decision support services, especially to support the safety of responders to incidents who are exposed to lightning hazards."

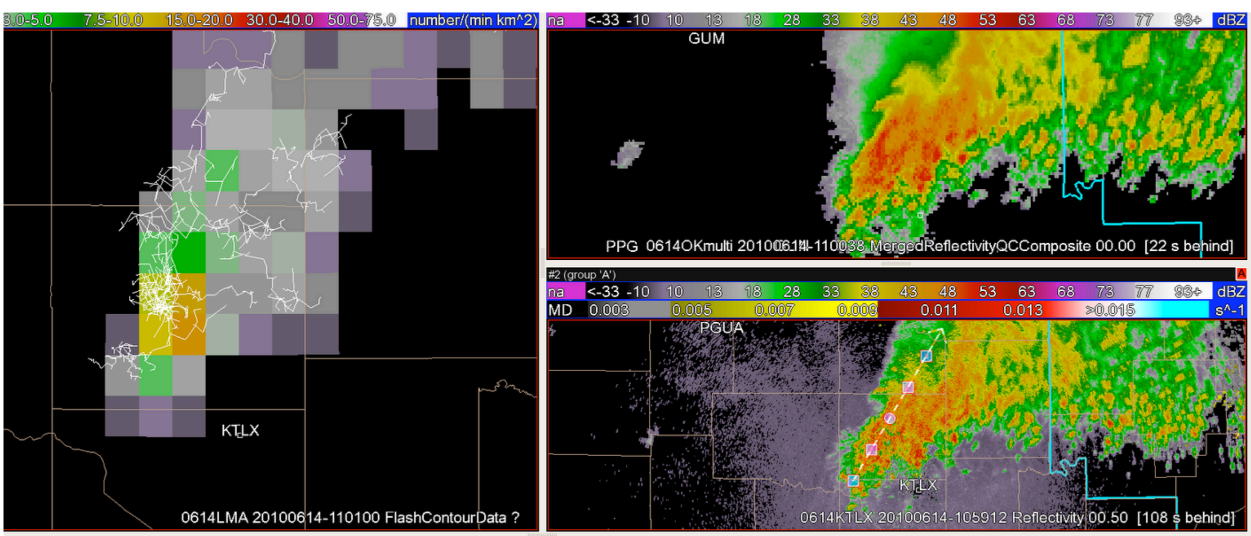

Fig. 3. Flooding Event on 15-16 June 2010 in Oklahoma City Metro region. PGLM total lightning flash extent density overlaid with OKLMA flash contours at 1100 UTC on 16 June [left]. Merged radar reflectivity composite [right, top] and low-level reflectivity from KTLX [right, bottom] at corresponding time. Forecasters noted that the continued convective redevelopment on western side of system was depicted well by higher total lightning activity there signaling an increased threat of flooding in the region.

All forecasters completed post-operation surveys online following a shift where they used the PGLM data. Summary information from these surveys is available online at:

http://www.zoomerang.com/Shared/SharedResultsSurveyResultsPage.aspx?ID=L24DY529G2ZG

4. Results from the Archive Event

An archive event (simulated real-time) was completed using the NWS Weather Event Simulator (WES). Each forecaster issued warnings (Severe and Tornado) for storms that occurred in central Oklahoma on 24 May 2008 between 1700-2100 UTC. The archive event provided a common dataset for forecasters to issue warnings while examining the PGLM product in-depth and voicing their opinions on its effectiveness in storm interrogation.

The warnings issued during the displaced real-time simulation for each forecaster were exported as text files. The coordinates for all Severe Thunderstorm and Tornado Warnings were extracted and plotted in an Albers Equal Area projection. This projection preserves calculated area since all plotted areas are proportional to the same areas on Earth (Fig. 4b). From these plots, unique warned area was calculated (Table 2). That is, the total amount of geographic area under warning during the simulation timeframe.

In addition, there were three recorded tornado events that occurred during the simulation. The locations of these tornado events were added to the warning geographical domain to assess warning performance for each of the forecasters. Comparing warning and event space/time attributes allows for calculation of the three standard NWS skill scores: Probability of Detection (POD), False Alarm Ratio (FAR), and Critical Success Index (CSI) (Table 2). The geographic interrogation also provides maximum lead times for each detected tornado event to be calculated (Table 1).

For the majority of forecasters participating in the EWP the lead time for the first tornado occurring at 1927 UTC was better than the official NWS warnings on 24 May 2008 (Table 1). The average lead-time for this tornado for all forecasters participating in the archive simulation was 13.92 min and as much as 32 min, compared to 6 min from the NWS. While this could be in part attributed to the availability of the additional lightning data, it must also be noted that the forecasters participating in the simulation may have had a higher expectation of severe or tornadic weather than NWS forecasters during real-time operations, as those participating in an archive event have a positive expectation that an "event" of some type would happen. From surveys and feedback, it was indicated by forecasters that they made the most use of the lightning data prior to the first tornado. One forecaster stated that: *"the lightning data showed a clear trend before severe weather occurred. It was easy to discern times of increased activity and their correspondence to tornado/severe weather formation."* After reports of the first tornado were communicated to the forecasters, a majority of forecasters made future warning decisions primarily based off radar signatures for the remainder of the simulation.

Event Lead Times			
Forecaster	Tornado #1 (1927-1939)	Tornado #2 (1945-1956)	Tornado #3 (2007-2016)
A	24	18	22
B	22	17	39
C	20	16	7
D	32	17	14
E	11	29	11
F	20	22	44
G	2	20	42
H	15	18	40
I	20	38	15
J	9	27	35
K	0	15	25
L	0	0	0
ACTUAL	6	24	20

Table 1. Event Lead Times for all forecasters and actual NWS warnings for all three tornadoes occurring during the event simulation.

BREAKDOWN BY WARNINGS, REGARDLESS OF TYPE							
Forecaster	Unverified Warnings	Verified Warnings	Missed Events	Unique Warned Area (Sq. Mi.)	POD	FAR	CSI
A	4	6	0	2215.6799	1	0.4	0.6
B	3	3	0	729.3739	1	0.5	0.5
C	2	4	0	894.1176	1	0.3333	0.6667
D	8	3	0	1089.8920	1	0.7273	0.2727
E	5	4	0	1340.0896	1	0.5556	0.4444
F	3	4	0	1112.2731	1	0.4286	0.5714
G	4	1	0	636.2028	1	0.8	0.2
H	2	2	0	1323.5590	1	0.5	0.5
I	2	3	0	719.1799	1	0.4	0.6
J	2	2	0	526.6912	1	0.5	0.5
K	4	3	0	848.7476	1	0.5714	0.4286
L	3	0	3	324.0761	0	1	0
Actual	3	4	0	1132.2839	1	0.4286	0.5714

Table 2. Standard NWS skill scores of all warnings issued by a forecaster (Severe and Tornado). Unique area warned refers to that area under warning by the forecaster at some point during the simulation.

Overall, the skill scores from the warnings show no major impact, positive or negative, by the inclusion of the lightning data (Table 2). The scores range around that of the actual NWS in both performance and warned area. It is likely the differences are indicative of both forecaster experience and personal preference, not the addition of lightning data. This range across forecasters is also apparent in the storm-based warning area (Fig. 4).

It is important to note that this data set presents an extremely small sample to draw conclusions from, but based the results here as well as on forecaster feedback, it is likely that the addition of lightning data has the ability to act as a new hazard information tool. Initially, lightning data can benefit forecasters by providing a first indication of storm intensification and general situational awareness, then as support for adding "call to action" statements regarding the potential lightning hazard to a warning.

5. Suggestions for future testing:

Additional products: A majority of the forecasters stated that they would like a product depicting the rate of change of the flash rate of a particular storm. The preference was that this product be gridded in plan view or map mode (not a line graph). This product could be either a plot of (1) the flash rate derivative or (2) the number of standard deviations (possibly fractional, e.g., 1.5) relative to the running mean of the current storm flash rate. This could be implemented using the WDSS-II using k-means cell clustering and coloring the cell shape according to the above trend metrics. Another product suggested by forecasters was a 30-60 min track swath, similar to that available in WDSS-II for maximum rotation and hail values.

More Events: Forecasters saw the applicability of GLM data to wide array of weather events. In particular, forecasters were interested in examining: mini-supercells, winter weather and convective snow bands, and land-falling tropical cyclones including tornadic storms in the outer bands. These could be included as archive events in future years.

Increased research guidance: Forecasters would like more background information regarding lightning data. Specifically, what flash rates are expected with different types of convection (e.g., supercell, multicell, squall line) and what correlations do lightning rates and density have with severe weather occurrence? Also, forecasters desired more information on particular lightning signatures and their relationship with radar signatures associated with severe weather.

6. Acknowledgements

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The authors would also like to thank all of the forecasters who participated in the 2010 EWP and gave feedback on the lightning products. This feedback will culminate in much better product implementation in the future.

7. References:

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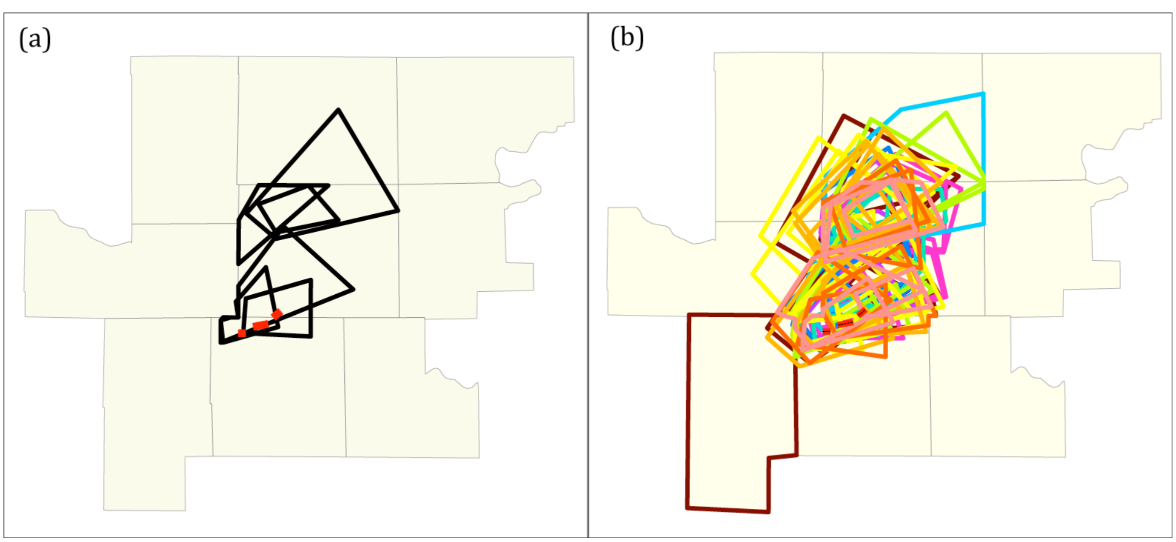

Fig. 4. Storm-based warning polygons and tornado tracks for Archive Event. (a) Actual NWS warnings (black) and tornado tracks (red). (b) Polygons issued by forecasters during the archive simulation, each color indicates a different forecaster.