IMPACT OF EARTH NETWORKS LIGHTNING DATA AND DANGEROUS THUNDERSTORM ALERTS ON FORECASTERS' WARNING DECISION AND CONFIDENCE

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ABSTRACT

Increases in total lightning activity indicate an increase in updraft strength, and may, therefore, indicate that severe weather is about to occur. Earth Networks Incorporated (ENI) has multiple networks, including Earth Networks Total Lightning Detection (ENTLN), designed to detect total lightning. They also create decision-assistance products such as lightning cell tracking and Dangerous Thunderstorm Alerts to show enhanced severe weather conditions. A controlled experiment of 18 National Weather Service forecasters was run in the NOAA Hazardous Weather Testbed during 2014 to better understand the influence of these products on forecasters. For each simulation, the forecasters were separated into three different groups and provided access with different levels of data: 1) radar data only; 2) radar data plus total lightning data; or 3) radar data, total lightning and ENI guidance products (lightning cell, motion history and projection and DTAs). Forecasters worked through six cases with varying severe weather conditions. Two out of the six cases were reviewed in detail here: Fort Worth-Dallas, TX (FWD) and Birmingham, AL (BMX). Results from each of these cases suggest lightning data and ENI decision-assistance products could have either a positive or negative effect on forecasters' warning decisions and confidence. For FWD, there was a clear and evident increase in confidence in their warnings with the use of lighting data; most of these warnings were verified. However, during the BMX case, forecasters may have issued more warnings due to lightning data and ENI decision-assistance products. Their confidence fluctuated, and no warnings verified. There were no severe reports received, and the marginal environmental conditions.

1. Introduction

Increases in total lightning activity, which includes both in-cloud (IC) and cloud-to-ground (CG) flashes, may signal severe weather potential due to the inherent link between storm electrification and updraft size and strength (e.g., Schultz et al. 2009). The Earth Networks Total Lightning Detection Network (ENTLN) was designed to detect both CG and IC lightning across the continental United States (CONUS). In addition to lightning detection, Earth Networks, Inc. (ENI) has also developed decision-assistance products. These products include: lightning cell tracking, which consists of total lightning flashes and flash rates, motion history and projection and three levels of thunderstorm alerts (Fig. 1). The alerts are meant to indicate an increased potential for dangerous weather conditions.

ENI uses a clustering algorithm based on flash rate and density to generate lightning cells and complete the cell tracking. From this algorithm, three levels of alert polygons are produced when the lightning cell intensity reaches its maximum threshold:

- Level 1: thunderstorm alerts
- Level 2: significant thunderstorm alerts
- Level 3: dangerous thunderstorm alerts (DTA)

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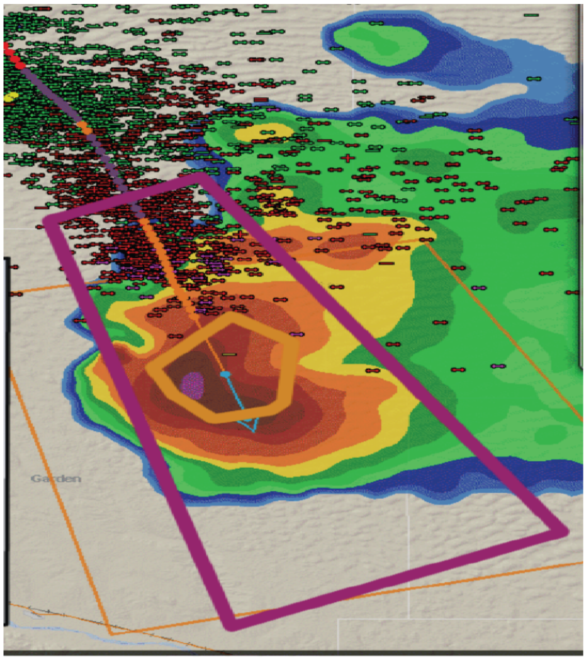

Fig. 1 ENI decision-assistance products: total lightning flashes— scattered green and red dots, llightning cell— orange circle, motion history — red, purple and orange dots in a linear structure; motion projection — light blue arrow, third level of thunderstorm alert — purple polygon. Photo credits Earth Networks, Streamer RT ™

These thresholds depend on the flash rate thresholds within the lightning cell, and are set to different values for each level due to differing detection efficiency East and West of the US CONUS (Table. 1)

Region	Level 1	Level 2	Level 3 (DTAs)
US CONUS West	3	12	25
US CONUS East	3	20	40

Table 1. Flash rate thresholds for lighting cell and thunderstorm alerts East and West of the US CONUS.

Currently, National Weather Service (NWS) forecasters are provided with CG lightning data from the National Lightning Detection Network (NDLN). An experiment conducted by Earth Networks Incorporated (ENI) showed that additional lightning products (cell tracking and DTAs) increases NWS forecasters warning lead times between 3 to 27 minutes (Earth Networks, 2015). These lightning products may influence forecasters' warning decision processes as well as their confidence issuing those warnings.

Bowden et al. (2014) developed a 2x2 diagram of the forecasters confidence against their correctness. A forecaster with high confidence but with an incorrect warning is considered misinformed, whereas low confidence but still incorrect is uninformed. A forecaster with high confidence and correct is mastery, but low confidence and still correct is uninformed.

The data for this study were collected by Kingfield et al. (2015). This experiment was conducted in controlled environment in the NOAA'S Hazardous Weather Testbed (HWT) in Norman, OK during 2014. The objectives were to:

1. develop and produce both the raw Earth Networks flash locations and the ENI DTA system inside of the NWS software platform
2. determine of the impact, if any, of total lightning data and the ENI decision-assistance tools on forecaster confidence and warning performance.

Based on initial comparisons by ENI of increased DTA lead times and probability of detection compared to NWS warnings (Liu 2013, Liu and Heckman 2015), we hypothesized that forecasters provided with total lightning data and ENI guidance products (lightning cell tracking and DTAs) should have more confident and accurate warnings with better lead times for severe weather events.

The data collected was scrutinized using several strategies (see Section 2) and results/conclusions from this experiment are presented in section 3 and 4 of this paper.

2. Data and Methods

The HWT experiment involved 18 forecasters from 13 forecast offices located in all NWS CONUS regions; they had a range of severe weather experience and expertise. Three forecasters per week analyzed six two-hour long cases presented to them in random order each week. The cases were in the following areas: Fort Worth-Dallas, TX (FWD), Birmingham, AL (BMX), Grand Junction, CO (GJT), Grand Rapids, MI (GRR), Sterling, VA (LWX) and Paducah, KY (PAH). The severe weather conditions in each of these cases varied. This experiment had a control and two experimental groups. The data provided in each group were:

- control — radar only

- experimental 1 — radar and total lighting data,
- experimental 2 — radar, total lightning data and ENI decision-assistance products.

Each forecaster worked each case once, but data group varied across the six cases so that each forecaster was in every group twice during the week.

Recordings of every forecaster's computer screens were taken during each simulation, including all mouse movements so that warning issuance and individual product use could be reviewed. Videos were reviewed; specific moments were highlighted in order to better understand the time it took for a forecaster to issue a warning. This was recorded as the time between when the forecaster clicks the WARNGEN button to the time he/she hit "send" from the warning textbox. Since some of the cases involved more than one storm at the same time, each storm was labeled.

During the experiment, as the forecasters worked through each case, detailed observations of the various products used by each forecaster, as well as selected verbal comments made by each forecaster during their analysis were recorded in observer forms. These were then reviewed with the forecaster after the case and to determine the key judgment points and factors in their warning decisions. Using those key judgment points, notes on product use, and the forecasters' comments, the influence lightning had on their decisions—if any—was identified.

After every warning, each forecaster completed a self-evaluation of his or her confidence using a continuum chart. This continuum contained three major categories: less than usual confidence, usual confidence and more than usual confidence. Each of those categories had their own subdivisions (Fig. 2). All the subdivisions within the major categories were numbered 1 through 9, with 1 being a lot less than usual and 9 a lot more than usual. Using Bowden et al.'s 2x2 confidence-correctness graph, warnings from all three data levels was plotted. Verified warnings are plotted on the right-hand side of the graph whereas, non-verified warning are on the left hand side of the graph. The area in which these warnings are found on either side of the graph depicts the confidence level of the forecasters as they issued the warnings. Hence, the lower half of the graph ranges from a lot less than usual confidence (1) to usual or average confidence (5), and the upper half of the graph ranges from usual or average confidence (5) to a lot more than usual confidence (9). The primary goal was to determine if available lightning data influenced the forecasters correctness and confidence positively.

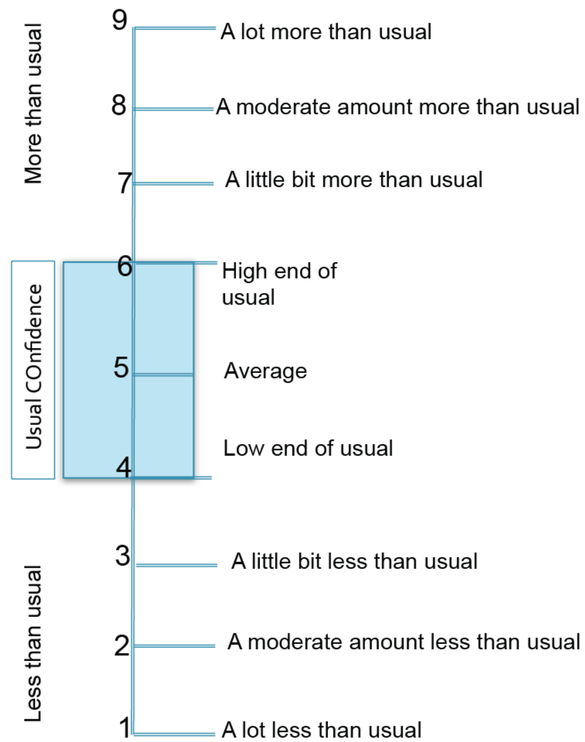

Fig. 2 Confidence contiuum forescaters used to rate their confidence levels after issung warnings

3. Results

Two out of the six cases were analyzed for this project. These included the Fort Worth-Dallas, TX and Birmingham, AL cases. Each case will be examined separately below.

3.a. Fort Worth-Dallas, TX (FWD)

The two-hour FWD case consisted of the development of an isolated supercell storm that produced extreme damaging hail, but no tornadoes. It occurred on 27 April 2014 from approximately 21 UTC to 23 UTC. Counties within FWD that were affected by this storm were Ellis, Dallas, Kaufman, Henderson, Van Zandt and Rains. Forecasters issued 53 severe thunderstorm and 10 tornado warnings during this case (Fig. 3).

Overall, the forecasters had confidence levels ranging from usual (5) to a lot more than usual (9) for the verified warnings. However, most non-verified warnings ranged from less than usual (2) to usual (5) with one warning in the more than usual confidence (7).

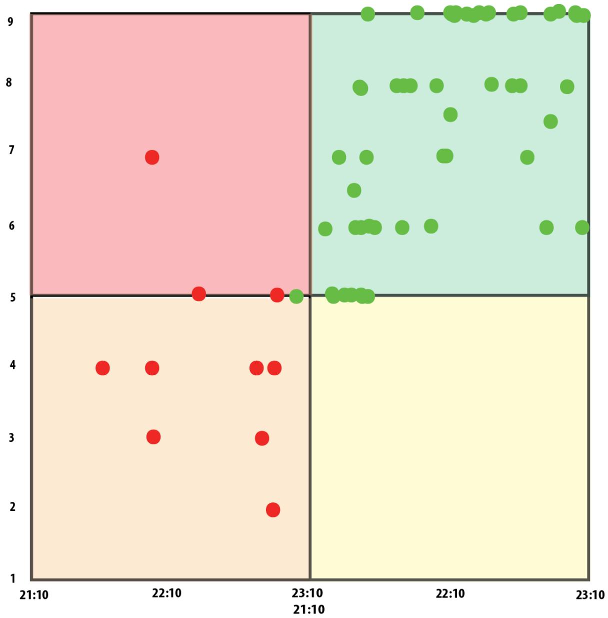

Fig. 3: Type of warnings issued, where green dots are severe thunderstorms and red dots are tornado warnings. The x-axis is confidence level. The y-axis is split such that the case duration shows in both the left and right half of the graph. Incorrect warnings are plotted on the left half, correct on the right half.

Forecasters in the control group for this case, that is, those that were provided with radar data only, mostly issued severe thunderstorm warnings that verified (Fig 4a). These verified warnings had at least usual confidence (5), up to a lot more than usual confidence (9). Warnings in this group did not cluster in a specific confidence level range, but spread throughout the entire upper half of the graph. The non-verified warnings were issued with a moderate amount less than usual confidence (2) to low end of usual confidence (4).

In the Experimental 1 group, which had access to radar and total lightning, all but one severe thunderstorm warning were verified; the non-verified warning was issued close to the end of the case (Fig. 4b). The verified warnings had usual confidence (5) to a lot more than usual confidence (9) with more of these warnings having just more than usual confidence (average=7.8). The non-verified warnings, which include the one severe thunderstorm warning along with the three other

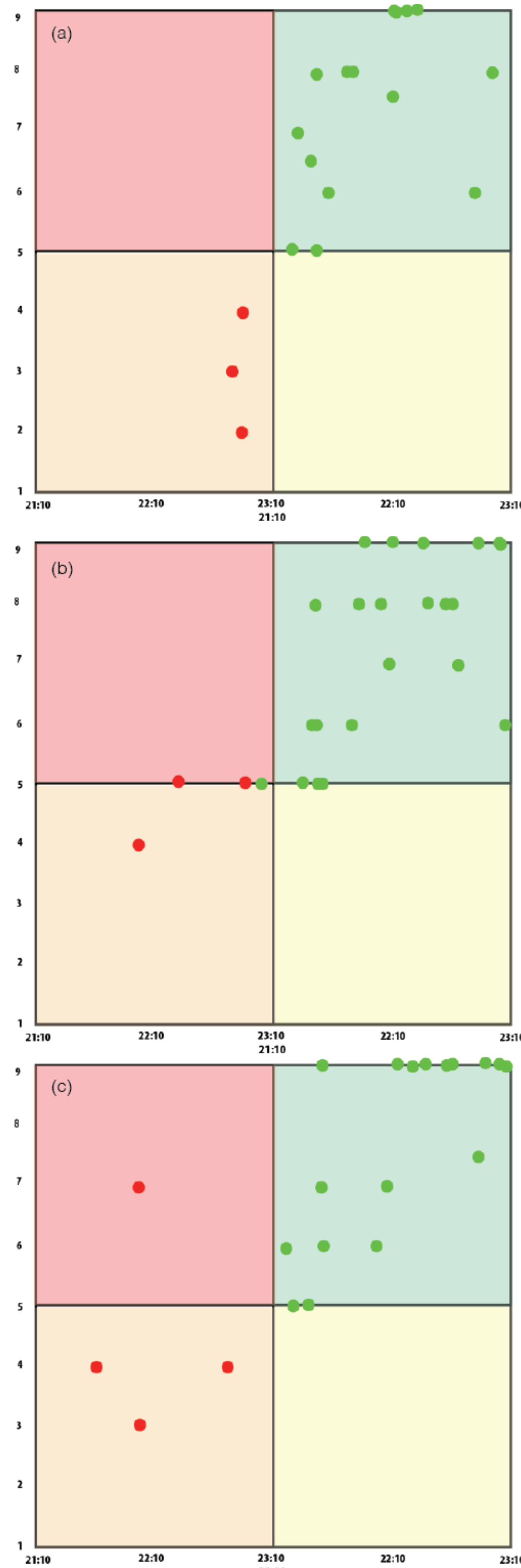

Fig 4. Warnings issued in FWD case by data groups
(a) control— radar only, (b) experimental 1— radar + total lightning, (c) experiemntal 2— radar, total lighting and ENI decision-assistance products. Green dots –severe thunderstorm, red dots –tornado.

tornado warnings, all had usual confidence (average=4.8). However, in comparison to the control group, the confidence levels in both the verified and non-verified warnings slightly increased from usual (average=7.2) to more than usual confidence (average=7.8) and less than usual (4) to usual (5) respectively.

Experimental 2 group, had access to the ENI decision-assistance products in addition to radar and raw lightning data. Similar to the control group, all severe thunderstorm warnings verified and all tornado warnings did not. (Fig. 4c) The verified warnings ranged from usual confidence (average=5.6) to a lot more than usual confidence (average=8.5), but very few on the usual end and many more on the a lot more than usual end. This group of forecasters issued the most severe thunderstorm warnings (9 warnings) and did so with a lot more than usual confidence (9) compared to the other two groups. The missed tornado warnings in this data group mostly had less than usual or low end of usual confidence. However, one forecaster issued a tornado warning with more than usual confidence (7). This is also the only non-verified warning with such high confidence. According to the 2x2 confidence-correctness graph forecasters in this case had high confidence levels in issuing severe thunderstorm warnings in particular, which placed majority of them in the mastery corner of this graph.

During the simulations, forecasters in all groups were also provided storm reports at the same points in the event. Thus, in addition to the lightning data and guidance products, storm reports may have also played an integral part in forecasters issuing confident and accurate warnings. Some warnings were issued before storm reports are actually received (Fig 5) and many after with an increased confidence-level in the warnings forecasters issued after storm reports. Looking at the severe thunderstorm warnings, confidence levels are in the usual confidence range (average=5.5) before the first storm report. During the case the second through fourth storm reports were received closed together in time. After these reports, the confidence level in 17% of the severe thunderstorm warnings increased from a little more than usual (8) to a lot more than usual (9). Storm reports may also have affected when the warnings were issued. Storm reports provide confirmation that the severe weather conditions do exist and therefore gives the forecaster a boost in confidence.

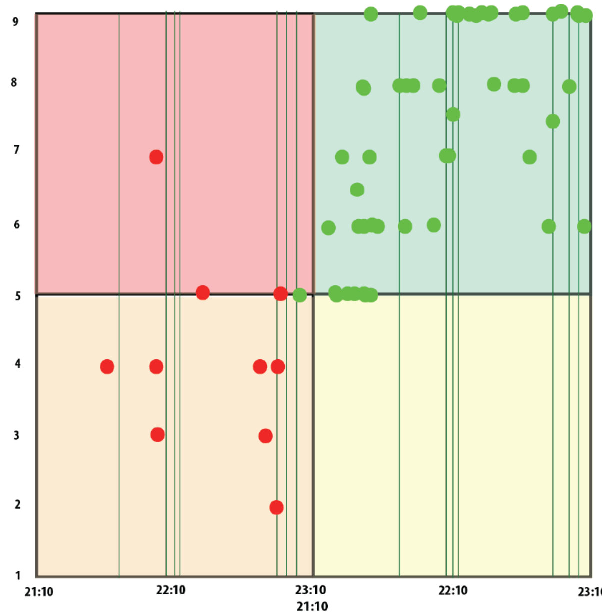

Fig. 5 Warnings (red and green dots) are plotted as seen in Figs 3and 4. Green lines are the timeshail storm reports were received during the FWD case. reoprts are plotted at the same times on left and right hand side of the graph.

Confidence levels of individual forecasters severe thunderstorm warnings are plotted in Figure 6. In every data group evaluated above, most warnings issued were severe thunderstorm warnings; the confidence level in each warning may differ from warning to warning. Ten forecasters correctly issued only severe thunderstorm warnings while eight issued both severe thunderstorm and tornado warnings. Forecasters' confidence in tornado warnings were less than usual confidence (average=3.7), except for one warning. To better provide a comparison, only the confidence levels for severe thunderstorms are shown in Fig. 6 a—c.

Five control group forecasters' confidence levels increased throughout the case, however, there was one forecaster whose confidence increased then decreased by three levels in each direction (Fig. 6a). For Experimental 1 group, there is a similar trend in forecasters' confidence level; however, those who had a decrease in confidence level did not decrease as dramatically. Three forecasters' confidence levels increased but the other three increased then decreased by two levels (Fig. 6b). In Experimental 2 group, all six forecasters confidence levels increased or stayed the same (Fig. 6c). Overall, most forecasters confidence level in any of the three data groups, increases as this case progressed.

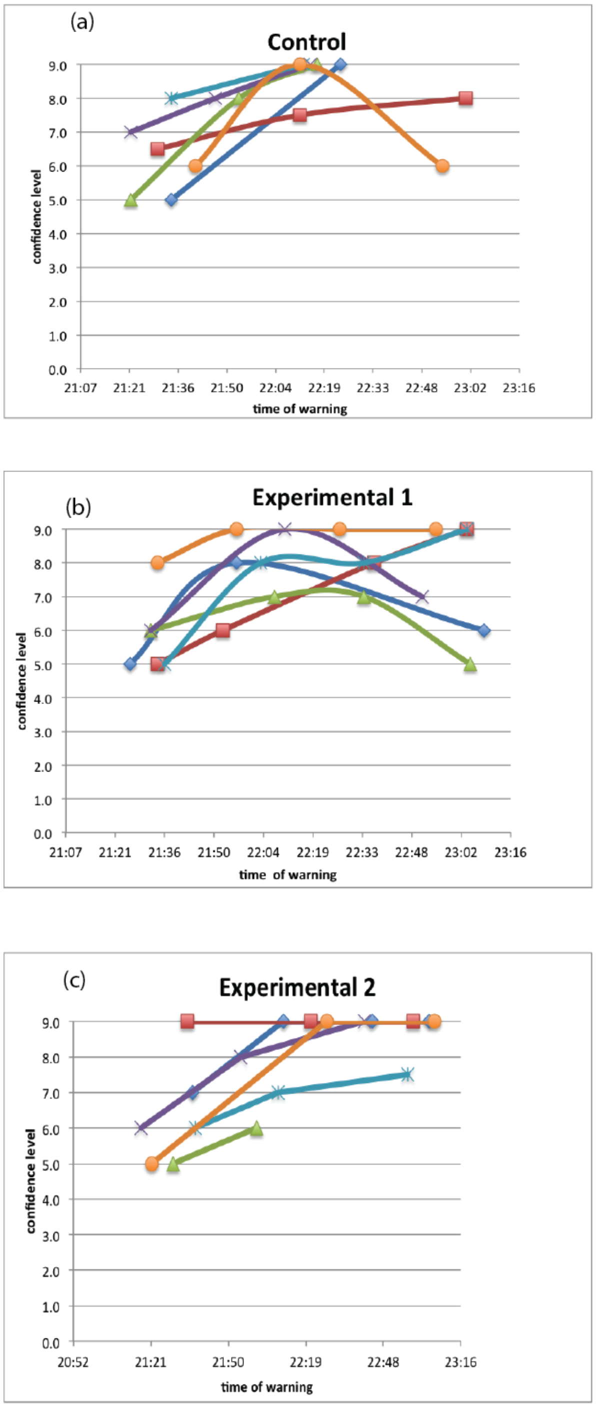

Fig. 6 Individual confidence level of severe thunderstorm warnings issued in the FWD case(a) control – radar only, (b) experimental 1 group — radar and total lightning, (c) experimental 2 group — radar, total lightning and ENI decision-assistance products

3.b. Birmingham, AL (BMX)

Weather conditions in BMX case were multiple sub-severe storms, no extreme damaging hail or wind neither any tornado; making is a null event that occurred on 17 May 2013. There were approximately seven storms in the BMX area that the forecasters focused on during the experiment. Counties that were affected by these storms were: Pickens, Bibb, Hale, Tuscaloosa, Marengo, Perry, Dallas and Greene. A total of 65 severe thunderstorm and 12 tornado warnings were issued in this case. None of them were verified, so all the warnings are placed on the left hand side of the 2x2 confidence / correctness graph (Fig 7). One forecaster correctly did not issue any warnings. The remaining discussion is about the 17 forecasters who issued warnings.

The confidence level for the warnings from all three data groups ranged from less than usual (3) to more than usual (9). Most of these warnings were in the usual confidence range (4–6). Forecasters in the control group (radar only) mostly issued severe thunderstorm warnings, approximately 30. More of these warnings clustered around the usual confidence range (4–6), though a small number of them had less than usual confidence (3; Fig 8a).

Experimental 1 group issued fewer warnings (about 13) than the control group. While these warnings were sparse, they are still within the usual confidence range (Fig 8b).

Experimental 2 group, those who had access to the ENI decision-making products together with radar and raw total lightning issued many more warnings (about 25) than the experimental 1 group but less than the control group. The confidence level of these warnings had a wider range, from less than usual confidence (3) to a lot more than usual confidence (9). This is the only data group that had a wide spread in their confidence level. They also had the least number tornado warnings issued (only two; Fig 8c).

There were no storm reports received for the particular areas that the forecasters were evaluating. Thus, all warnings were placed on the left hand side of the graph in both the misinformed and uninformed corners.

Fig.7 Warnings issued in BMX case from all three data levels. Green dots –severe thunderstorm, red dots — tornado

Another way to look at confidence levels is to plot individual forecasters on the times warnings were issued (Fig. 9). Forecasters' individual confidence levels fluctuated quite a bit throughout all three data groups.

3.c. Lightning Influence

In the two cases presented above, the severe weather conditions were very different. While in the FWD case the supercell did produce wind and hail, the storms in BMX were only rotating showers. Taking into consideration the primary objective of this project, whether or not total lightning data plus ENI decision-assistance products influence forecasters' warning decision and confidence, the above cases may or may not have clearly given a solution: lightning influence differs in each case. Before the experiment, a background survey was carried out and information such as forecasters expertise and usual use of lightning in their warning decision was collected. This, along with the verbal comments made by forecasters and key judgments during their warning decision process, to determine whether lightning impacted forecasters warnings.

Use of lightning data was classified into four major categories:

- no influence — forecaster did not use the lightning data or it was not available

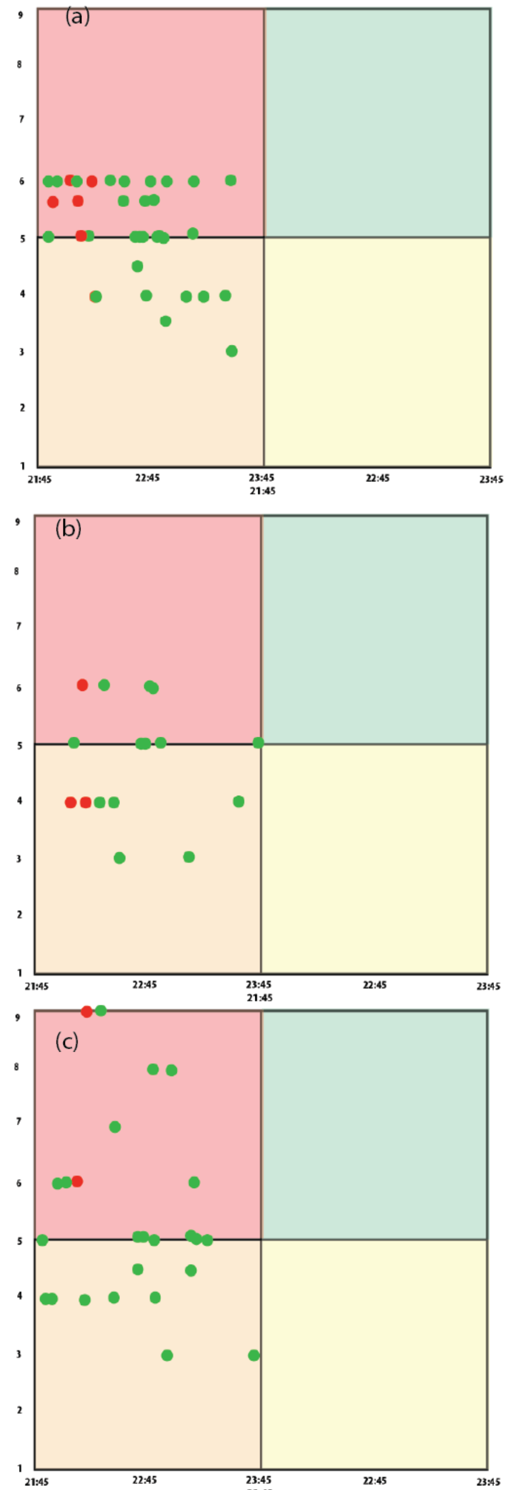

Fig.8 Warning issued in BMX case by data groups. (a) control – radar only, (b) experimental 1 group — radar and total lightning, (c) experimental 2 group – radar, total lgihtning and ENI decision-assisstance products. Green dots —severe thunderstorm, red dots (tornado)

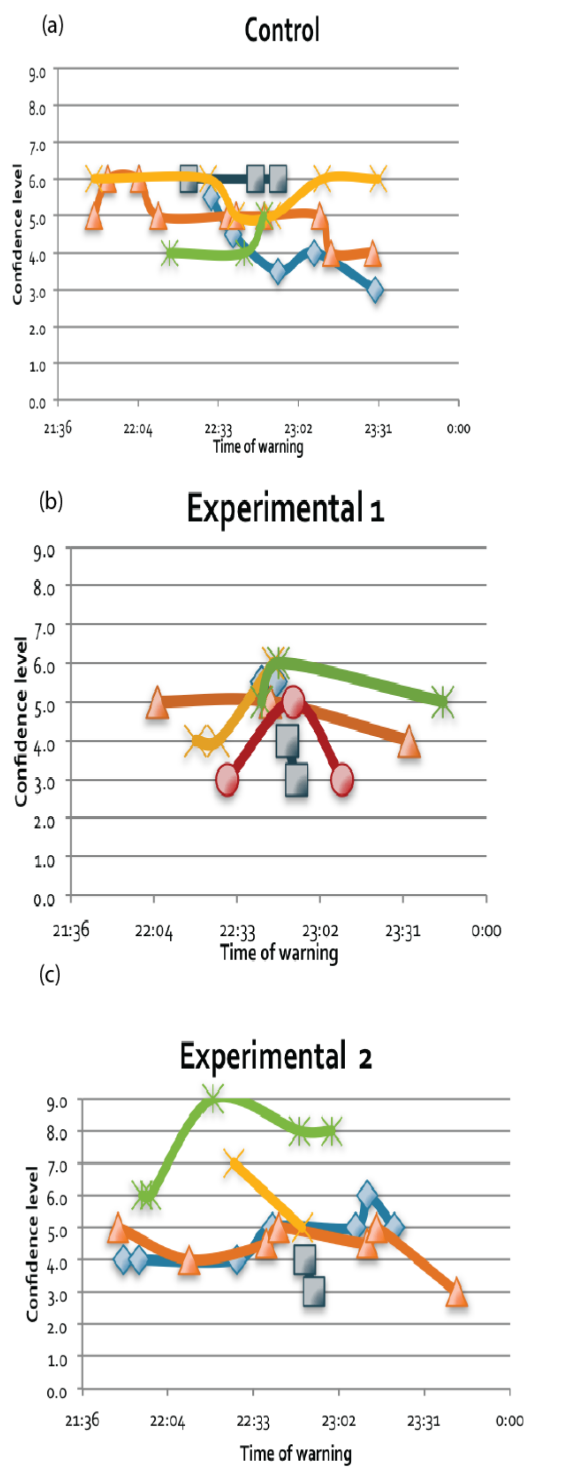

Fig. 9 Individual confidence level of all warnings issued in the BMX case (a) control—radar only, (b) experimental 1 group— radar and total lightning (c) experimental 2 group — radar, total lightning and ENI decision-assisstance products

- might have influence — forecasters looked at the lightning but never or rarely mentioned it
- likely influenced — forecasters cited something about lightning close to issuing warning
- influenced — forecasters mentioned lightning having direct influence in their warning decision

In the FWD case, five forecasters were influenced by the lightning data, four was likely influenced, three might have had influence and six did not have (Table 2). The five forecasters, who was influenced by the lighting data never usually uses it in their warning decision, had an average confidence of more than usual (average=7.6) in issuing warnings. In the BMX case, four forecasters were influenced by the lightning data, four were likely influenced, two might have had influence, one was not influenced and six did not have. Since noon of the warnings were verified, one forecaster (Hugo) out of the four that were influenced had an average confidence of more than usual (7.7; Table 3). All other forecasters that issued warnings had usual confidence (average=4.8)

4. Discussion and Conclusion

Total lightning data and dangerous thunderstorm alerts (DTAs) influenced forecasters' warning decision processes and confidence in varying ways. This data sometimes encouraged issuance of warnings and increased confidence in those warnings, though it was misleading at times. When forecasters were in experimental groups 1 or 2, their confidence in issuing warnings was higher. Their confidence was also higher when environmental conditions were more clearly favorable for severe weather.

The BMX case is an example of how forecasters might be misled by lightning data. In events like this one, where the weather conditions were sub-severe, the guidance products produced within their highest level of severity or intensity appeared to encourage forecasters to believe that severe conditions might occur, and in turn caused them to be more confident in issuing warnings. The opposite was demonstrated in FWD. Forecasters that had access to lightning and guidance products generally issued more confident and correct warnings.

Lightning Influence on Forecasters' Confidence in FWD Case

Forecasters	Usually uses lightning in warning decision	Used lightning in FWD case/ lightning influence	Avg confidence in warnings
Opal	-	Yes – influenced	8.8
Hazel	Never	Yes – influenced	8.5
Stan	Never	Yes – influenced	7.5
Floyd	Never	Yes – influenced	7
Juan	N/A	Yes – influenced	6.3
Janet	Frequently	Yes – likely influenced	6.8
Gloria	N/A	Yes – likely influenced	6.8
Fran	Frequently	Yes – likely influenced	6.5
Bob	Frequently	Yes – likely influenced	5.5
Hugo	Occasionally	Yes – might have influenced	8.5
Mitch	Never	Yes – might have influenced	7.3
Cleo	Rarely	Yes – might have influenced	5
Carol	Rarely	No – did not have	7.3
Keith	Never	No - did not have	7
Dennis	N/A	No – did not have	7
Charley	-	No- did not have	6.8
David	Occasionally	No- did not have	6.5
Camille	Occasionally	No – did not have	6.3

Table 2: Forecasters usual use of lightning in their warnings compared to the use in the FWD case and influnence on their confidence level

Lightning Influence on Forecaters' Confidence in BMX Case

Forecasters	Usually uses lightning in warning decision	Used lightning in BMX case/ lightning influence	Avg confidence in warnings
Keith	Never	Yes- did not sway him	X
Hugo	Occasionally	Yes – influenced	7.7
Camille	Occasionally	Yes – influenced	4.7
Floyd	Never	Yes- influenced	4.4
Hazel	Never	Yes – influenced	6
Cleo	Rarely	Yes – likely influenced	3.8
Fran	Frequently	Yes – likely influenced	5
David	Occasionally	Yes – likely influenced	6
Charley	-	Yes – likely influenced	4.7
Mitch	Never	Yes – might have influenced	5
Dennis	N/A	Yes – might have influenced	3.5
Janet	Frequently	Yes – no influence	5.6
Opal	-	No- did not have	6
Stan	Never	No- did not have	5.6
Juan	N/A	No – did not have	5
Carol	Rarely	No – did not have	4.6
Bob	Frequently	No- did not have	4.3
Gloria	N/A	No – did not have	4

Table 3: Forecasters usual use of lightning in their warning compared to the use in BMX case and its influence on their confidence level

Trends in individual confidence levels for each forecaster were different between the two cases. For the FWD case, most of forecasters' confidence increased, whereas in the BMX case most of the forecasters' confidence level fluctuated. Storm reports provide verification, therefore, the lack of storm reports in BMX case may have caused forecasters confidence to waver and remain in the usual confidence range, whereas in the FWD case, forecasters' confidence level in all groups increased after storm reports were received.

The expertise of the forecasters did not appear to directly influence their warning decisions and confidence, with one exception. One forecaster correctly did not issue any warnings in the BMX, because he had experienced a similar case before.

Overall, lightning data and ENI decision-assistance products influenced forecasters warning decisions both positively and negatively. In some instances, it correctly increased forecasters' confidence other times the influence was not as evident. At other times influence of lightning was not evident. It occasionally incorrectly increased forecasters' confidence. The influence of lightning data and decision-assistance products on forecasters' warning confidence will be better understood after the other four cases are studied.

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