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GLD360 AIRPORT LIGHTNING WARNINGS

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1. INTRODUCTION

A comparison was made of lightning warnings for areas on the scale of airports using data from two lightning datasets. The datasets were obtained from the National Lightning Detection Network (NLDN) described by Cummins and Murphy (2009), and Vaisala's Global Lightning Dataset GLD360 described by Demetriades and Holle (2010). Analyses during October and November 2009 at ten southeast U.S. locations included a range of types of lightning-producing storms.

NLDN data were used to verify warnings within an inner warning area consisting of a circle whose radius was 4.8 km (3 miles) around simulated airports at these locations. Interviews with airport customers have indicated that at least two minutes lead time is required for grounds crew employees to reach safety during lightning warnings, so a two-minute lead time was used in all analyses. Most results used a 15-minute dwell time, the time when activities are to be suspended at an airport until an all-clear is sounded.

2. ANALYSIS METHOD

2.1. Time

October and November 2009 data from Vaisala's National Lightning Detection Network (NLDN) and Global Lightning Dataset GLD360 were analyzed. Most of the lightning was during October, while the limited amount of November activity was mostly offshore in the Gulf of Mexico. The monthly distributions shown in Figures 1 and 2 are typical of maps for October and November (Holle and Cummins 2010).

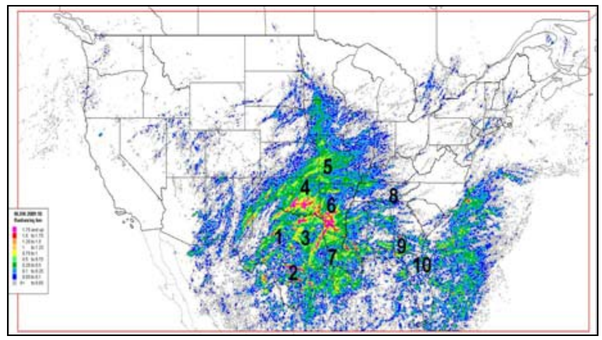

FIGURE 1. October 2009 NLDN flashes and the ten analysis locations.

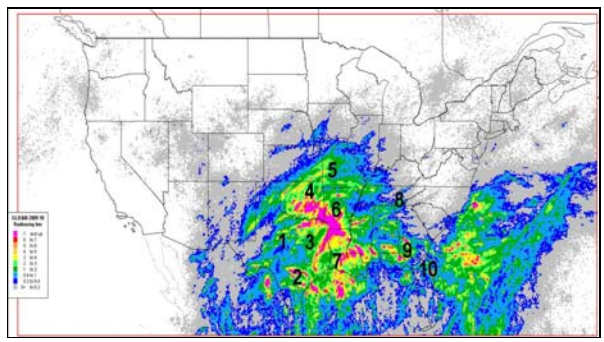

FIGURE 2. October 2009 GLD360 strokes and the ten analysis locations.

2.2. Area

The ten analysis locations in the southeastern U.S. chosen from the October maps are indicated in Figures 1 and 2. The points were within and around areas with frequent lightning activity to develop an adequate sample size. All points are on land, and are located far enough apart to detect different storms. The ten points sampled a mixture of organized moving storms, stationary storm clusters, and more isolated coastal activity.

2.3. Inner warning area

The inner warning area in all ten locations consists of a circle with a radius of 4.8 km (3 miles) around the center to simulate airport locations. This 3-mile verification circle, with NLDN strokes around a point in the center of an airport, can be considered a region where any lightning will be perceived as a danger to airport operations. This verification area is based only on the time of the presence of one or more NLDN flashes within the area, whether NLDN or GLD360 data are used to develop the warnings.

3. NLDN RESULTS

NLDN results were determined by combining analyses at the ten points in Figures 1 and 2 for an outer radius of 8 km (5 miles), 10 km (6.2 miles), and 15 km (9.3 miles). The results are for a two-minute lead time and a 15-minute dwell time, the time when airport activities are to be suspended until an all-clear is sounded. The NLDN flash data during October and November at these ten locations were found to behave similarly to results of previous Vaisala studies, in terms of the probability of detection with at least two minutes lead time (POD2), failure to warn (FTW), false alarm ratio (FAR), and durations of warnings and false alarms (Holle et al. 2003; Lojou et al. 2007; Murphy and Holle 2006). Based on this similarity, the analysis went forward with this two-month ten-point dataset to compare lightning warnings from the NLDN and GLD360.

NLDN results in Table 1 show that a 15-km circle provides the best combination of parameters at a dwell time of 15 minutes. The best combination was determined from a safety-first approach that emphasizes a high POD. The results in Table 1 are as follows:

- As the radius increases from 8 to 15 km, the number of Red Conditions – warnings - increases from 71 to 129,
- The number of storms detected increases from 21 to 32, as shown by the POD2 increase from 0.52 at 8 km to 0.84 at 15 km, which is a high value,
- The failures to warn decrease from 19 to 6 storms, so the FTW decreases to a desirably small value of 0.16,
- The false alarms increase from 31 to 91 storms from 8 to 15 km, as indicated by the increase in FAR to a somewhat high 0.74,
- The improved POD2 and FTW values are accompanied by a 73% increase in the time of valid warnings from 8 to 15 km, as well as an increase by a factor of 3.8 in false alarm duration, and
- The percentage of time during October and November under valid warnings or false alarms reaches no more than 0.27% of those two entire months for all radii.

TABLE 1. NLDN flashes used for lightning warnings at 8, 10, and 15 km during October and November 2009 at ten locations and a 15-minute dwell time. Verification is with NLDN flashes within 4.8-km circles around the locations.

Radius	Red Conditions	# Detected	# Failures to Warn	# False Alarms	Percent Time Under Valid Warnings	Percent Time Under False Alarms
NLDN						
8 km	71	21	19	31	0.15%	0.07%
		POD2=0.52	FTW=0.48	FAR=0.60		
10 km	96	29	12	55	0.21%	0.14%
		POD2=0.71	FTW=0.29	FAR=0.65		
15 km	129	32	6	91	0.27%	0.25%
		POD2=0.84	FTW=0.16	FAR=0.74		

4. GLD360 RESULTS

GLD360 results were also combined at the same ten points for an outer radius ranging from 8 to 15 km at a 15-minute dwell time. The forecast was the same as in section 3, for the presence of NLDN flashes within a 4.8-km radius inner area.

After a series of iterations, results using Vaisala's proprietary algorithm are shown in Table 2 at three radii and a dwell time of 15 minutes. The results of this analysis are as follows:

- The number of red conditions at 15 km for GLD360 is about the same as using NLDN data (123 versus 129),
- The 25 detected storms are somewhat fewer than the 32 with NLDN flash data, as shown by a POD2 of 0.78 instead of 0.84. The reduction in the number of GLD360 storms may be due to the increased spread in GLD360 data combining some NLDN storms.
- The failures to warn are nearly the same (7 versus 6),
- The 81 false alarms are somewhat fewer than NLDN (91); this result may be due to the GLD360 dataset combining NLDN storms as mentioned above,
- Valid warning duration with GLD360 is 232% longer than the NLDN,
- The time under false alarms for GLD360 is 306% longer than false alarm durations using NLDN, and
- The percentage of time during October and November under valid warnings or false alarms reaches no more than 0.77% of those two entire months for all radii.

The comparison shows that POD2, FTW, and FAR for GLD360 are best at 15 km, and are almost as good as for NLDN. However, the time under valid GLD360 warnings is more than twice as long as with NLDN. And the time under false GLD360 alarms are more than three times as long.

TABLE 2. GLD360 strokes used for lightning warnings at 8, 10, and 15 km during October and November 2009 at ten locations and a 15-minute dwell time, compared with NLDN flashes at 15 km from Table 1. Verification is with NLDN flashes within 4.8-km circles around the locations.

Radius	Red Conditions	# Detected	# Failures to Warn	# False Alarms	Percent Time Under Valid Warnings	Percent Time Under False Alarms
GLD360						
8 km	73	17	18	38	0.37%	0.28%
		POD2=0.49	FTW=0.51	FAR=0.69		
10 km	83	20	13	54	0.46%	0.36%
		POD2=0.61	FTW=0.39	FAR=0.73		
15 km	123	25	7	81	0.62%	0.77%
		POD2=0.78	FTW=0.19	FAR=0.76		
NLDN						
15 km	129	32	6	91	0.27%	0.25%
		POD2=0.84	FTW=0.16	FAR=0.74		

5. WARNINGS LONGER THAN 60 MINUTES

For very high lightning rate storms, GLD360 created warning lead times longer than 60 minutes. These did not occur in the NLDN analyses. As the radius increased, the number of such long lead times increased to nearly half of the warnings of NLDN flashes in advance with GLD360 strokes.

Inspection was made of four October 2009 cases at points 6 and 7. Most long lead times occurred when very intense storms containing tens of thousands of strokes were within 10 to 20 kilometers of the 4.8-km inner warning area. Two squall line cases were being correctly anticipated, but the warnings started too early. While GLD360 had fairly distinct cores of strokes within the squall lines, there was a large scatter with quite a few strokes around the squall line that should be mostly concentrated within the squall line.

The dispersion around the correctly-located lightning is caused by the random placement of some GLD360 strokes around the squall line. The number of strokes decreases in frequency steadily outward from the actual squall line, but there are so many strokes in these high-rate storms that some invariably are located within the warning areas at 8, 10, and 15 km. Note again that this spreading of strokes is not present with NLDN data. As a result, the GLD360 dataset's less precise locations spread strokes around the actual lines in space. One result of this dispersion is to spread strokes ahead of the line by up to an hour or more in intense lightning events. While GLD360 has the advantage of covering the entire world, lightning detection at specific points is completely solved by having a regional or local network such as NLDN or VHF total lightning.

6. 10 VERSUS 15 MINUTE DWELL TIME

Previous results were calculated with a 15-minute dwell time. To identify the impacts of a 10-minute dwell time, results were compared for GLD360 from Table 2.

The comparisons in Table 3 for the two dwell times show the following:

- The number of red conditions for 10 minutes is increased by 23% over those at 15 minutes dwell time,
- The number of GLD360 storms detected is about the same (24 versus 25),
- Failures to warn increase for the shorter dwell time from 7 to 10,
- The number of false alarms at 10 minutes grows by 43% from the 15-minute result,
- The duration of valid warnings is reduced by 16%, and
- The duration of false alarms is reduced by 12% from the 15-minute result.

The change to a shorter dwell time for GLD360 data has had a negative effect on POD2 by decreasing it from 0.78 at 15 minutes dwell time to 0.71 at 10 minutes. In addition, the FTW has increased from 0.19 to 0.29, and the FAR has increased from 0.76 to 0.83. However, there are somewhat shorter durations under valid warnings and false alarms for 10 minutes than 15, but they are still longer than with NLDN. Overall, the net effect is that 15 minutes is the preferred time interval to use for dwell time.

TABLE 3. GLD360 strokes used for lightning warnings at 15 km during October and November 2009 at ten locations and 10- and 15-minute dwell time (from Table 2). Verification is with NLDN flashes within 4.8-km circles around the locations.

Radius	Red Conditions	# Detected	# Failures to Warn	# False Alarms	Percent Time Under Valid Warnings	Percent Time Under False Alarms
10-minute dwell time						
15 km	151	24	10	116	0.44%	0.65%
		POD2=0.71	FTW=0.29	FAR=0.83		
15-minute dwell time						
15 km	123	25	7	81	0.62%	0.77%
		POD2=0.78	FTW=0.19	FAR=0.76		

7. CONCLUSIONS

An analysis was made of the ability of the GLD360 lightning detection network to anticipate lightning with a two-minute lead time within a 4.8-km radius circle around a point, such as an airport. Data from October and November 2009 in the southeast half of the U.S. were used. Ten points were chosen to sample different storms and storm types during the period. Verification was made using flashes from the NLDN.

Conclusions from NLDN-only data were similar to those found from previous NLDN studies, and showed a POD2 of 0.84, FTW of 0.16, and FAR of 0.74. With this method, each site was under a lightning warning for 0.52% of the time during the two months, including both correct warnings and false alarms.

GLD360 strokes were then used in the same analysis approach. NLDN data were also used to indicate the presence of a valid lightning warning within a 4.8-km radius around the ten points. The best GLD360 results using Vaisala's proprietary algorithm are compared in Table 4 at 15 km. The GLD360 results are quite similar to NLDN measures, and showed a POD2 of 0.78, FTW of 0.19, and FAR of 0.76, but with longer valid warnings (increased by a factor of 248%) and false alarms (increased by 306%) than with NLDN only. For GLD360, sites were not under lightning warnings for 98.61% of the time during these two months.

TABLE 4. Same as Table 1 for NLDN flashes at 15 km, compared with the best GLD360 configuration at 15 km from Table 3. All results for 15-minute dwell time.

Radius	Red Conditions	# Detected	# Failures to Warn	# False Alarms	Percent Time Under Valid Warnings	Percent Time Under False Alarms
NLDN						
15 km	129	32	6	91	0.27%	0.25%
		POD2=0.84	FTW=0.16	FAR=0.74		
GLD360						
15 km	123	25	7	81	0.62%	0.77%
		POD2=0.78	FTW=0.19	FAR=0.76		

While GLD360 has the advantage of covering the entire world, lightning detection at specific points is completely solved by having a regional or local network such as NLDN or a Vaisala LS8000 VHF total lightning mapping network. Previous Vaisala studies have shown that an LS8000 VHF total lightning mapping network can improve POD and FTW to achieve somewhat better performance, while FAR can be much better with a VHF network. As a result the NLDN is in the middle of the performance spectrum. A regional VHF total lightning mapping network provides the best storm anticipation over a region the size of a metropolitan area, while GLD360 provides less precise storm monitoring than the NLDN, but anywhere in the world. We strongly recommend further studies of this type in other regions and seasons to tune (or improve) lightning warning performance.

In conclusion, the GLD360 lightning warning results were surprisingly good when compared with the standard in lightning detection, the NLDN. POD2, FTW, and FAR results were remarkably similar to the NLDN. The major difference was with respect to longer warning durations with GLD360 data than NLDN, as expected. Nevertheless, GLD360 warning durations accounted for a simulated airport lightning-based downtime of only 1.4% throughout the two-month period. Or put another way, the simulated airport was not under lightning warnings 98.61% of the time during the two-month period of this study.

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