16D.2 VALIDATION OF VAISALA'S GLOBAL LIGHTNING DATASET (GLD360) OVER THE CONTINENTAL UNITED STATES

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1. INTRODUCTION

Vaisala's Global Lightning Dataset (GLD360) was launched in September 2009. GLD360 is the first ground-based lightning detection network capable of providing both worldwide coverage and uniform, high performance without severe detection differences between daytime and nighttime conditions. The expected detection efficiency and median location accuracy of GLD360 is:

- 70% cloud-to-ground flash detection efficiency
- 5-10 km median cloud-to-ground stroke location accuracy.

This paper describes recent cloud-to-ground (CG) flash detection efficiency and stroke location accuracy validation results over the continental United States. A companion validation study has been carried out in southeast Brazil. These two studies are the first of many such studies that will be carried out around the globe as GLD360 coverage and performance evolve. Vaisala plans to use these validation studies to continually assess GLD360 performance and address differences between expected and validated performance.

2. METHODOLOGY

Vaisala's U.S. National Lightning Detection Network (NLDN) has been used as ground truth for the validation of GLD360 over the continental United States. The NLDN has undergone extensive independent validation over its 20-year history, including several field campaigns in different parts of the U.S. since the last major upgrade of the system (Biagi et al., 2007; Jerauld et al., 2005; Fleenor et al., 2009). The NLDN currently has a detection efficiency of 90-95% for CG flashes and a median location accuracy of 300-500 meters for CG strokes.

GLD360 CG flash detection efficiency and CG stroke median location accuracy were calculated for a subset of days from 1 December 2009 through 31 January 2010 that matched the same days used for a companion validation study in southeast Brazil (Naccarato et al., 2010). These days were selected because they had lightning activity in both the continental United States and southeast Brazil. This ensured GLD360 network operational status was the same for both validation studies. The following days were used for GLD360 validation:

- 3-7, 9-10, 15-16, 20, 22, 24-25 December 2009
- 3, 10, 18-22, 27, 31 January 2010

The detection efficiency analysis first consists of identifying any GLD360 stroke that matches a NLDN CG flash. A GLD360 stroke is defined as matching a NLDN CG flash if the time difference is within 1 second and the distance difference is within 30 km. GLD360 CG flash detection efficiency is then calculated by dividing the number of matched NLDN CG flashes by the total number of NLDN CG flashes. CG flash detection efficiency was calculated as a function of time-of-day (in UTC) to evaluate GLD360 performance during day/night conditions. All comparisons were made over the land mass of the continental United States only, to avoid biasing the results with lower-quality NLDN data from offshore.

The location accuracy analysis first consists of identifying any GLD360 stroke that matches a NLDN CG stroke. A GLD360 stroke is defined as matching a NLDN CG stroke if the time difference is within 200 microseconds and the distance difference is within 60 km. The location error for GLD360 is assumed to be the position difference between NLDN and GLD360 for matched strokes. This implicitly assumes that the NLDN is perfect and that all location error resides in GLD360, which provides an upper bound on the true location error of the GLD360 network.

The time difference used for the location accuracy analysis was much tighter than the time

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difference used for the detection efficiency analysis because we needed to make sure we were only calculating position differences for the same stroke. The distance difference was expanded from 30 to 60 km to make sure the results were not unfairly biased to a value under 30 km. We then calculated the median location accuracy for all matched strokes.

3. DETECTION EFFICIENCY RESULTS

Figure 1 shows GLD360 CG flash detection efficiency as a function of time-of-day for the 22 days during December 2009/January 2010 selected to match the southeast Brazil validation study. All values are collected in time intervals of one hour. There were a total of 278,733 NLDN CG flashes during this time period over the continental U.S.

GLD360 CG flash detection efficiency ranges from 86% to 92% throughout the day, with little day/night variation. This is in sharp contrast to existing ground-based long-range lightning detection networks, as discussed by Cramer and Cummins (1999), Jacobson et al. (2006), and Pessi et al. (2009). Early long-range systems based solely on NLDN-type sensors could have as much as an order of magnitude variation in detection efficiency between day and night. More recent systems that are specifically designed for long-range lightning detection (e.g. WWLLN, PacNet) have less variability, but still a factor of 1.5-2 between day and night. Qualitative statements about variations in the detection efficiency of another VLF long-range network, the U.K. Met Office ATD network, were given by Keogh et al. (2006) but were attributed essentially to limitations of data acquisition.

4. LOCATION ACCURACY

A median location accuracy was calculated for all NLDN/GLD360 matched CG strokes. The total number of CG stroke matches between the two datasets was 770,421. The median (or 50th percentile) location error for GLD360 CG strokes was 10.8 km.

Figure 2 shows a map of NLDN CG strokes overlaying GLD360 lightning strokes from 18-21 UTC 21 January 2010. Most of the lightning detected by both networks occurred in the states of Tennessee and Kentucky in the southeast U.S. As expected, the NLDN shows tighter clustering for detected lightning events occurring within thunderstorms on this day. However, GLD360 shows reasonable clustering on the scale of thunderstorms (i.e. ~10x10 km areas). The number of outliers (or scatter) is also greater within the GLD360 dataset. These GLD360 outlier lightning events tend to be worse in and around high lightning rate storms.

In many parts of the world, especially the open oceans, a high performance lightning detection network does not exist to provide the appropriate ground truth for GLD360 validation. In the absence of that information, the meteorological community often uses radar or satellite data to gain confidence in the location accuracy of lightning datasets. Since radar data is relatively scarce over the North Atlantic and North Pacific Oceans, GLD360 lightning strokes were also overlaid on GOES-11 and GOES-12 infrared satellite imagery. Two examples are shown in Figures 3 and 4.

Figure 3 shows GLD360 lightning strokes overlaying GOES-12 infrared satellite imagery from 2245 UTC 2 January 2010. GLD360 lightning strokes clearly mapped out areas of enhanced convective activity across portions of the North Atlantic and areas over and to the southwest of Mexico. Some areas around stronger (higher lightning rate) convection showed outlier lightning events.

Lightning off the mid-Atlantic coast of the U.S. was associated with the cold pool (cold air aloft) of an extratropical cyclone as it passed over the relatively warm waters of the Atlantic (especially in the Gulf Stream). Copious lightning was also produced within a short-wave heading towards Europe (far right portion Figure 3).

Figure 4 shows GLD360 lightning strokes overlaying GOES-11 infrared satellite imagery from 0230 UTC 29 December 2009. GLD360 lightning strokes clearly mapped out areas of enhanced convective activity across portions of the North Pacific and areas to the southwest of Mexico. Some areas around stronger (higher lightning rate) convection again showed outlier lightning events.

Lightning over the North Pacific, north of the Hawaiian Islands, was associated with several short-waves/extratropical cyclones (Fig. 3). The southern portion of an extratropical system also produced lightning off the southwest coast of Mexico.

5. CONCLUSIONS

Validation of GLD360 cloud-to-ground (CG) flash detection efficiency and stroke location accuracy was performed over the continental United States using Vaisala's National Lightning

Detection Network (NLDN) as ground truth. A companion validation study has been carried out in southeast Brazil (Naccarato et al., 2010). Validation was performed for 22 select days from 1 December 2009 through 31 January 2010 where lightning occurred over both the continental U.S. and southeast Brazil. This ensured GLD360 network operational status was the same for both validation studies.

GLD360 CG flash detection efficiency ranged from 86% to 92% throughout the 24-hour UTC day, with little day/night variation. This variability in detection efficiency as a function of UTC time is much smaller than that observed in other existing long-range lightning detection systems. These results exceed the expected GLD360 70% CG flash detection efficiency over the continental U.S.

GLD360 median location accuracy was 10.8 km for the 770,421 matched GLD360/NLDN CG strokes during December 2009/January 2010 over the continental U.S. These results are slightly larger than the expected GLD360 5-10 km median CG stroke location accuracy over the continental U.S.

Additional maps were shown of NLDN CG strokes overlaying GLD360 lightning strokes and GLD360 lightning strokes overlaying GOES-11/GOES-12 infrared satellite imagery. These maps clearly demonstrate that GLD360 highlights the appropriate areas of enhanced convective activity across the continental U.S., North Atlantic, and North Pacific. Some areas around stronger (higher lightning rate) convection show outlier (or scattered) lightning events. These GLD360 outlier lightning events tend to be worse in and around high lightning rate storms.

6. FUTURE WORK

The continental U.S. and southeast Brazil (Naccarato et al., 2010) validation studies are the first of many such studies that will be carried out around the globe as GLD360 coverage and performance evolve. Vaisala plans to use these validation studies to continually assess GLD360 performance and address differences between expected and validated performance.

7. REFERENCES

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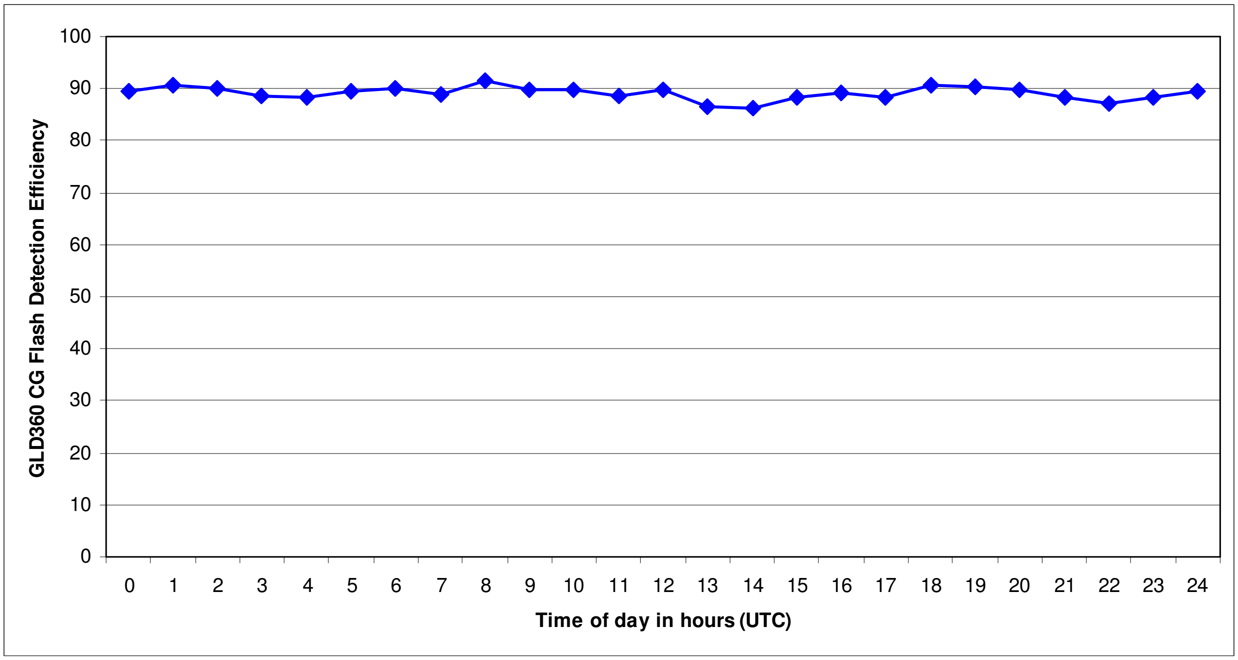

FIGURE 1. GLD360 CG flash detection efficiency over the continental United States as a function of time of day for the 22 days in December 2009/January 2010 selected to match the southeast Brazil validation study.

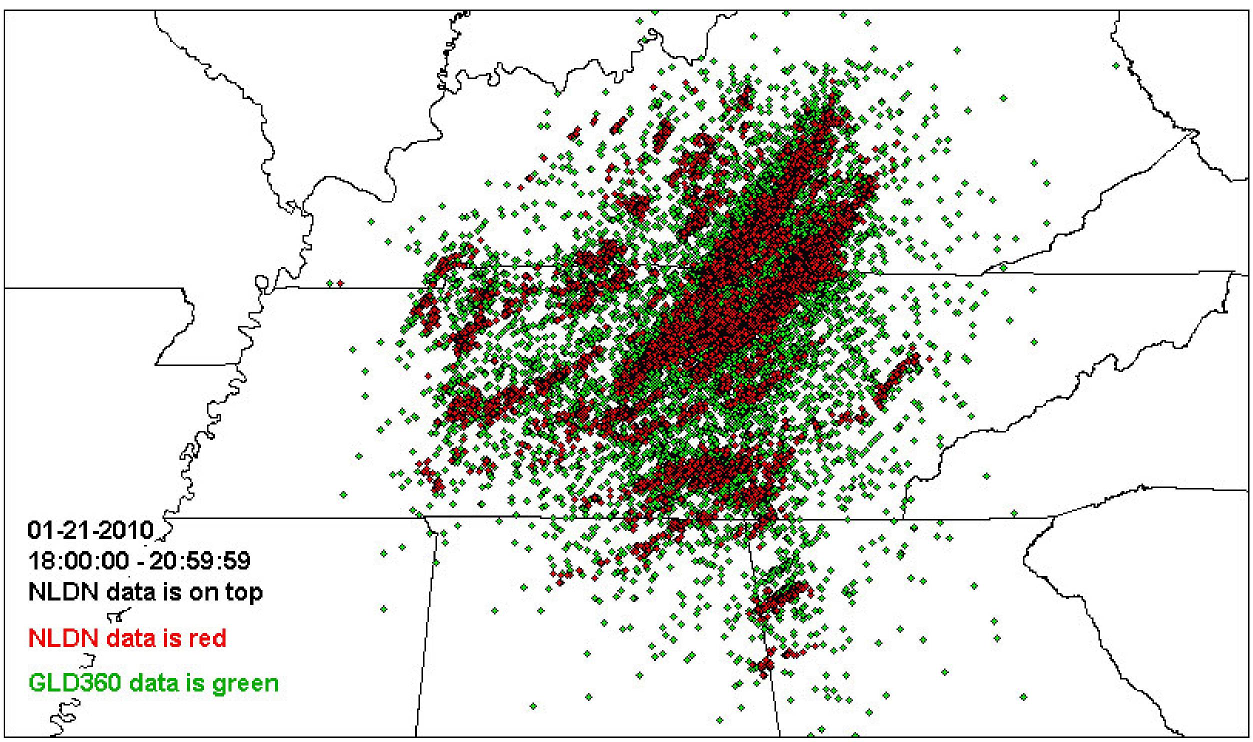

FIGURE 2. Map showing NLDN CG strokes overlaying GLD360 lightning strokes from 18-21 UTC 21 January 2010. NLDN CG strokes displayed as red diamonds and GLD360 strokes displayed as green diamonds.

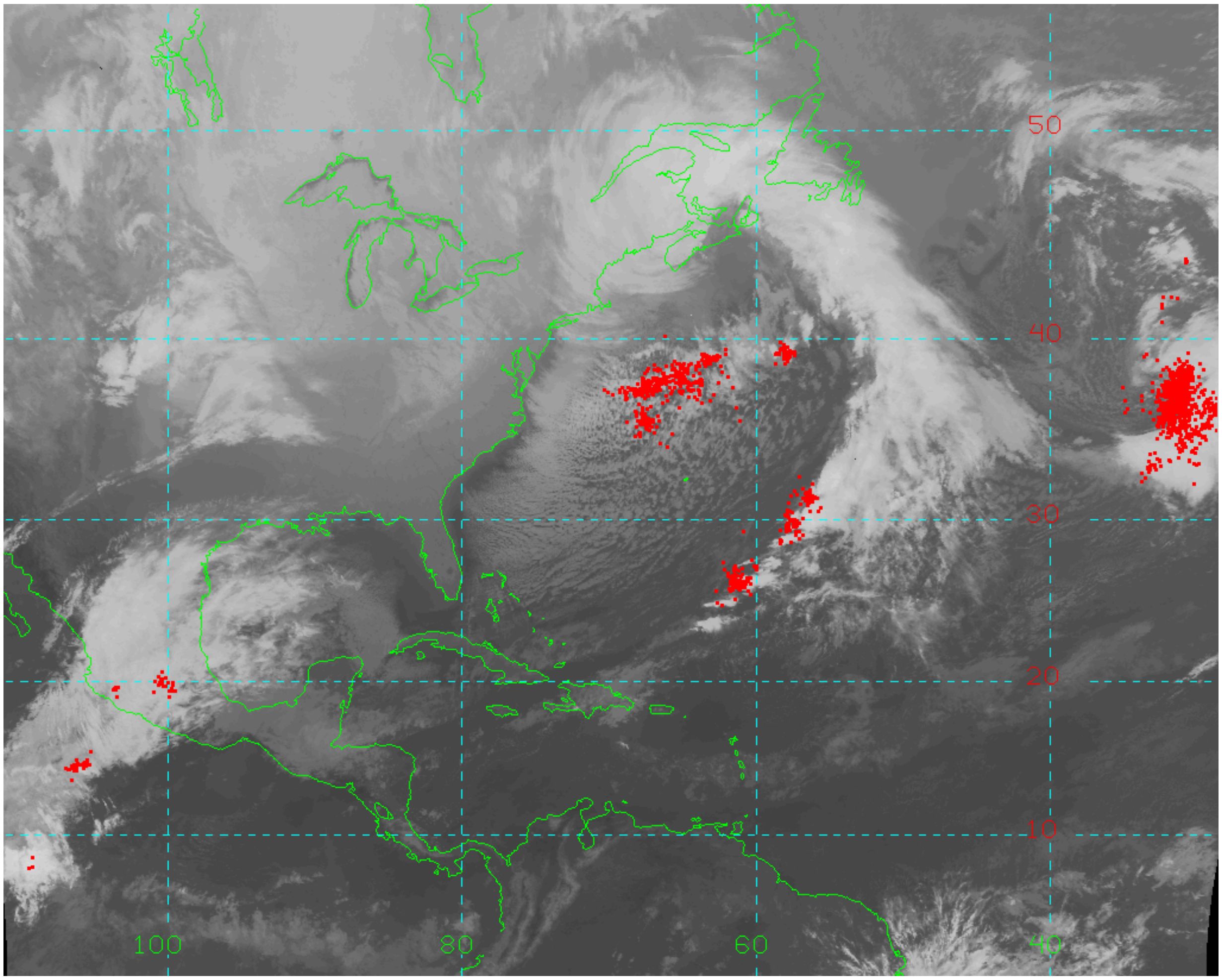

Figure 3. GOES-12 infrared satellite image at 2245 UTC 2 January 2010 with all GLD360 lightning strokes from 2200 to 2300 UTC overlaid as red dots. Image courtesy of the University of Hawaii.

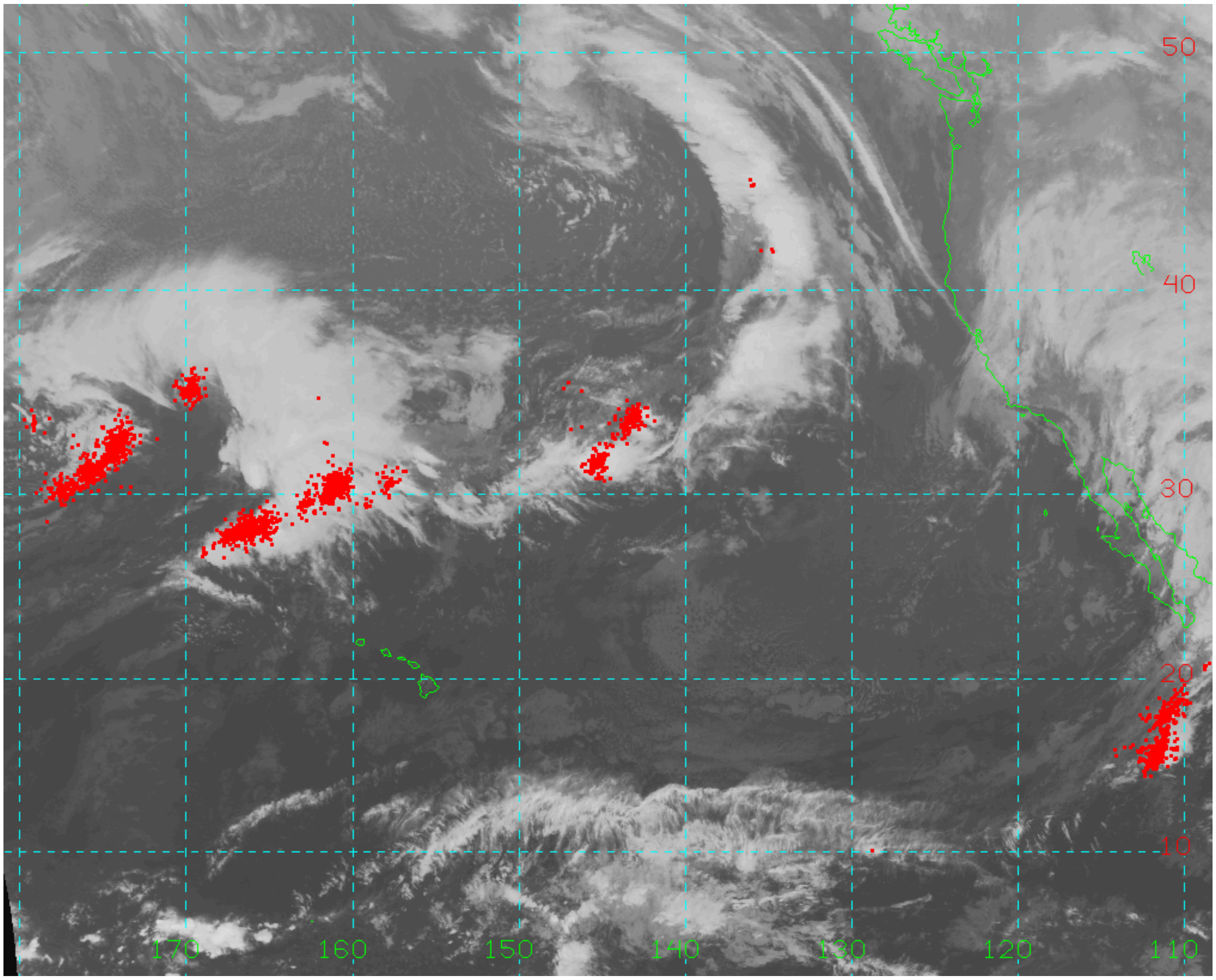

FIGURE 4. GOES-11 infrared satellite image at 0230 UTC 29 December 2009 with all GLD360 lightning strokes from 0200 to 0300 UTC overlaid as red dots. Image courtesy of the University of Hawaii.