2010 21st International Lightning Detection Conference
19 – 20 April • Orlando, Florida, USA
3rd International Lightning Meteorology Conference
21 – 22 April • Orlando, Florida, USA

VALIDATION OF THE NEW GLD360 DATASET IN BRAZIL: FIRST RESULTS

[1]K. P. Naccarato; [1]O. Pinto Jr.; [2]S. A. M. Garcia
[3]M. Murphy; [3]N. Demetriades; [3]J. Cramer

[1] Instituto Nacional de Pesquisas Espaciais - INPE (Brazil)
[2] Furnas Centrais Elétricas (Brazil)
[3] Vaisala Inc. (AZ, USA)
E-mail: kleberp@dge.inpe.br

1. INTRODUCTION

Vaisala's Global Lightning Dataset (GLD360) was launched in September 2009. It consists of sensors strategically placed around the world for optimal detection of cloud-to-ground (CG) lightning strokes. These wideband sensors detect cloud-to-ground (CG) lightning using magnetic direction finding (MDF) and time-of-arrival (TOA) methodologies combined with proprietary lightning recognition algorithms in the VLF (Very Low Frequency) band. 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 (DE) and median location accuracy (LA) of GLD360 are:

- 70% CG flash DE
- 5-10 km median CG stroke LA

In addition, GLD360 is also the first ground-based system capable of estimating the polarity and peak current of lightning discharges from well outside the limited range (~600 km) where traditional lightning detection systems are capable of providing such information.

After its first integration in September 1998, the Brazilian lightning detection network (originally named RINDAT) was composed of 25 low-frequency (VLF-LF) sensors, which cover the entire southeastern region of Brazil. In October 2004, the SIPAM (the Amazon basin protection agency) regional network started to operate with 12 VLF-LF LPATS IV sensors, covering part of the mid-north of the country. Finally, in June 2005, the SIDDEM (a consortium of power utilities companies and research institutions) regional network, composed of 11 IMPACT VLF-LF sensors, was installed in the south and middle-west regions. After about 4 years of operation (June 2005 to Apr 2010), the new Brazilian lightning detection network (BrasilDAT) covered almost 60% of the country, except to the Amazon basin and the northeastern region (Pinto et al., 2006a,b, 2007).

Figure 1 shows the present configuration of BrasilDAT, which is composed by 47 VLF-LF sensors as a result of the integration of three other regional networks: SIDDEM, SIPAM and RINDAT. Thus, the whole network has both LPATS and IMPACT sensors, which are based on the TOA and MDF technologies, respectively (Cummins et al., 1998; Naccarato, 2006).

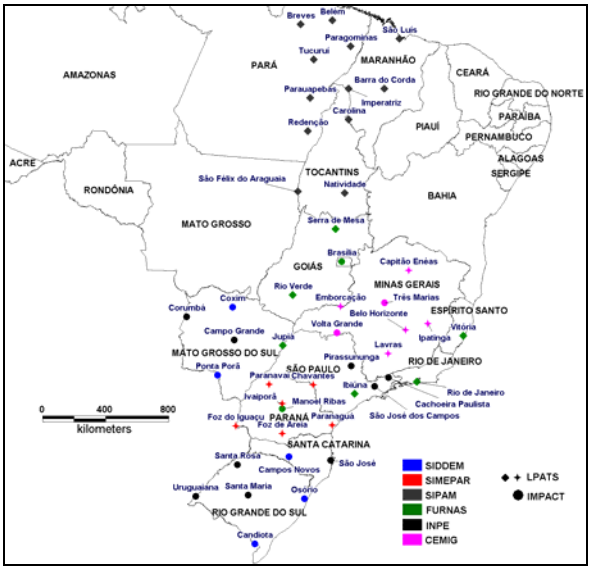

Figure 1 - The Brazilian Lightning Detection Network (BrasilDAT), which is composed by 47 sensors from the integration of three regional networks: SIDDEM, SIPAM and RINDAT.

Some works have shown that BrasilDAT reaches about 85% of CG flash detection

efficiency (Ballarotti et al., 2006). Very recent unpublished studies have shown that the CG flash detection efficiency have reached about 92% due to the introduction of the new Vaisala LS7000 sensors.

Figure 2 presents the BrasilDAT flash detection efficiency computed by the new ELAT / INPE numerical model (Naccarato and Pinto, 2008a). The magenta represents the DE values up to 30%. The white color represents DE values up to 88%. It can be observed that the network has a very high performance in mid-southern Brazil, decreasing significantly towards the north due to the small network composed of only LPATS sensors. In general, almost 40% of the country is actually covered by a network with about 80-90% DE.

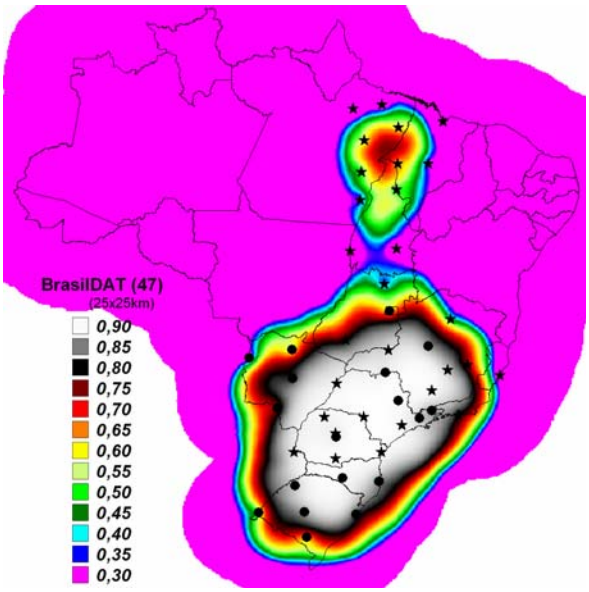

Figure 2 - BrasilDAT CG flash detection efficiency computed by the ELAT / INPE model (25x25km).

Recently, the BrasilDAT network went through a comprehensive performance analysis which revealed that the mid-southern portion of the network presents the best detection efficiency (Naccarato and Pinto, 2008b). This analysis also revealed that BrasilDAT also can detect intra-cloud (IC) discharges, which correlate to the peak current distribution shown in Figure 3.

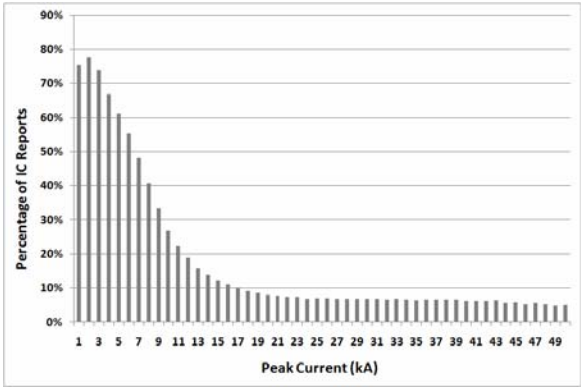

Figure 3 – Percentage of IC reports in BrasilDAT as a function of the peak current (kA).

This paper describes recent CG flash detection efficiency and CG stroke location accuracy validation results of GLD360 over southeastern Brazil. No IC discharge data was used in the validation process. A related validation study has been carried out in the continental U.S. (Demetriades et al., 2010). These two studies are the first of many such studies that will be carried out around the globe as GLD360 coverage and performance evolve. These validation studies will help to continually assess GLD360 performance and address differences between expected and validated performance.

2. METHODOLOGY

The comparison between GLD360 and BrasilDAT was carried out by identifying CG flashes that match between the two networks. A matching GLD360/BrasilDAT flash is defined as having a time difference and a location distance difference lower than pre-defined values which are chosen based on the CG lightning data set characteristics. The comparisons were made for the polygon indicated in Figure 4, which corresponds to the region of higher DE of BrasilDAT network (Figure 2). Furthermore, because the polygon defines a region closer to the network, any bias error will make the DE of the GLD360 network go lower rather than higher. Only 12.5% of the total GLD360 data set was located outside of the polygon, thus the region chosen does not restrict the data set very much.

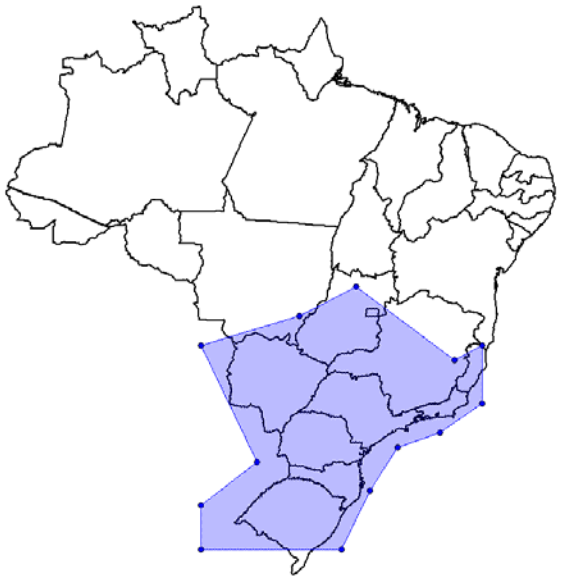

Figure 4 - Polygon used for validation of the GLD360 dataset based on the CG lightning data of BrasilDAT.

GLD360 CG flash DE and CG stroke median LA were calculated for a subset of days from 1 December 2009 through 31 January 2010 (the thunderstorm season of Brazil) that matched the same days used for the continental U.S. validation (Demetriades et al., 2010). These days were selected because they represented days with 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 GLD360 validation: 3-7, 9-10, 15-16, 20, 22, 24-25 December 2009 and 3, 10, 18-22, 27, 31 January 2010.

The DE comparison between GLD360 and the BrasilDAT is carried out by identifying any GLD360 stroke that matches a BrasilDAT CG flash. A GLD360 stroke is defined as matching a BrasilDAT CG flash if:

- the time difference is within 1s - in order to be consistent with the total time window used in the flash algorithm as described by Cummins et al. (1998)
- the distance difference is within 30 km - in order to try to eliminate the possibility of matching events from different storms

Note that this method does not credit the GLD360 for detecting any flashes that the BrasilDAT misses, and therefore, it is expected that the assessed DE values represent a lower bound on the true flash DE of the GLD360.

The LA comparison between GLD360 and BrasilDAT is carried out by identifying any GLD360 stroke that matches a BrasilDAT CG stroke. A GLD360 stroke is defined as matching a BrasilDAT CG stroke if the time difference is within 200μs and the distance difference is within 60km. The location error for GLD360 is assumed to be the position difference between BrasilDAT and GLD360 for matched strokes. This implicitly assumes that the BrasilDAT is perfect and that all location error resides in GLD360, which provides an upper bound on the true location error of the GLD360.

The time difference used for the location accuracy analysis is much tighter than the time difference used for the DE analysis because we needed to make sure we were only calculating position differences for the same stroke. The distance was expanded from 30 to 60 km to make sure the results were not unfairly biased to a value under 30 km. Then the median LA was calculated for all matched strokes.

3. RESULTS AND DISCUSSIONS

The results of the CG flash DE analysis are summarized in Table 1. The weighted overall flash DE is simply the total number of matched flashes (for all of the days shown in the table) divided by the total number of flashes observed by BrasilDAT for the same days. The GLD360 CG flash DE varies from ~2.5% (03 January) up to ~40% (31 January) with an overall value of 15.9%. Figure 5 shows that there is no direct correlation between the CG flash DE and the number of daily flash counts. Figure 6 graphically shows the GLD360 CG flash DE for each analyzed day.

The GLD360 stroke LA results are summed up in Table 2. The mean location error was 12.5 km, which varies from 10.2 km (10 December) to 16.7 km (05 December). Similar to the DE analysis, the LA did not show a direct correlation to the number of daily stroke counts (Figure 8). Figure 9 graphically shows the GLD360 CG stroke LA for each analyzed day.

Table 1 - GLD360 flash DE for BrasilDAT validating network.

Date	BrasilDAT CG Flashes	Matching GLD360	GLD360 DE
12/03/09	32,346	3,202	9.9%
12/04/09	5,595	421	7.5%
12/05/09	1,140	195	17.1%
12/06/09	15,106	3,378	22.4%
12/07/09	10,611	1,993	18.8%
12/09/09	11,949	2,148	18.0%
12/10/09	12,989	549	4.2%
12/15/09	10,445	2,218	21.2%
12/16/09	52,649	9,415	17.9%
12/20/09	16,503	3,515	21.3%
12/22/09	15,614	4,567	29.2%
12/24/09	17,870	2,999	16.8%
12/25/09	17,235	3,068	17.8%
01/03/10	2,944	69	2.3%
01/10/10	17,741	693	3.9%
01/18/10	29,116	4,075	14.0%
01/19/10	42,565	5,965	14.0%
01/20/10	36,794	6,583	17.9%
01/21/10	21,217	3,271	15.4%
01/22/10	18,367	2,069	11.3%
01/27/10	25,873	785	3.0%
01/31/10	19,570	7,852	40.1%
Overall Flash DE	**434,239**	**69,030**	**15.9%**

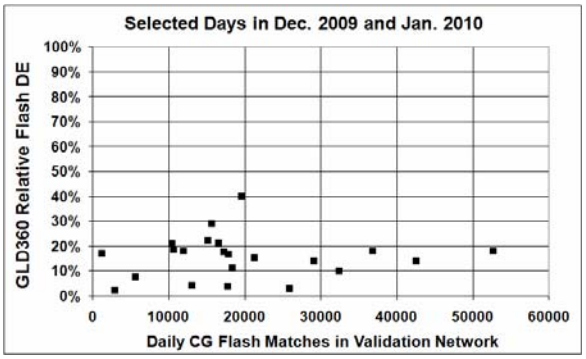

Figure 5 - Scatter plot of GLD360 flash detection efficiency as a function of the number of daily flash counts for BrasilDAT validating network

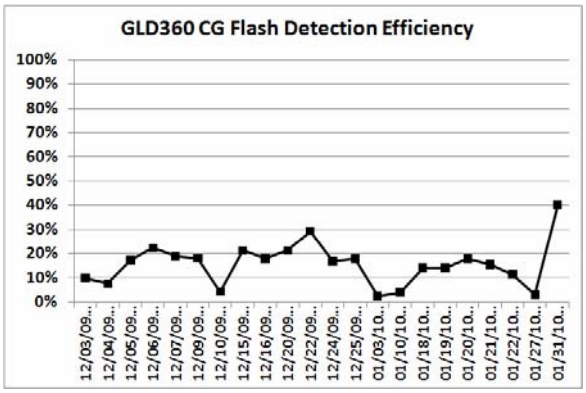

Figure 6 - GLD360 flash DE for BrasilDAT validating network.

Table 2 - GLD360 stroke LA for BrasilDAT validating network.

Date	Matching GLD360	GLD360 LA (km)
12/03/09	3,188	13,0
12/04/09	85	12,0
12/05/09	249	16,7
12/06/09	3,377	13,7
12/07/09	2,245	11,7
12/09/09	2,097	12,6
12/10/09	452	10,2
12/15/09	2,099	11,7
12/16/09	7,966	11,8
12/20/09	2,971	14,6
12/22/09	4,364	11,8
12/24/09	3,483	11,6
12/25/09	3,173	12,7
01/03/10	86	14,4
01/10/10	645	11,0
01/18/10	3,562	13,5
01/19/10	5,305	11,7
01/20/10	5,263	11,3
01/21/10	3,465	13,6
01/22/10	1,950	11,9
01/27/10	695	10,6
01/31/10	6,053	12,2
Overall Flash DE	**62,773**	**12,5**

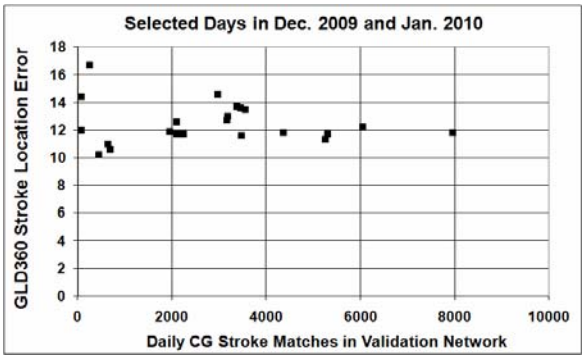

Figure 7 - Scatter plot of GLD360 flash detection efficiency as a function of the number of daily flash counts for BrasilDAT validating network

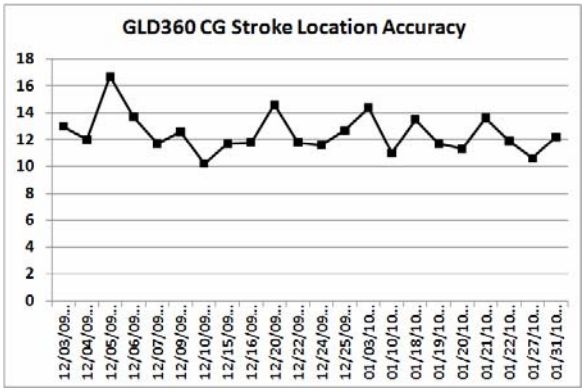

Figure 8 - GLD360 stroke LA (in km) for BrasilDAT validating network.

The validation of CG lightning peak current and polarity is still under progress and the results will be presented in the near future.

4. CONCLUSIONS

The main goal of this paper was to discuss the scientific methodology and to present the preliminary results of the GLD360 validation over Brazil. GLD360 CG flash DE and CG stroke median LA were calculated for a subset of days from 1 December 2009 through 31 January 2010 over the southeastern Brazil, the region with higher BrasilDAT network DE.

The GLD360 flash DE in Brazil for all of the days analyzed was 16% and it reached 40% on 31 January. For the stroke LA analysis, it was obtained a mean location error of 12.5 km, with the lowest error of 10.2 km on 10 December.

5. REFERENCES

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