

The Evaluation of Lightning Networks and Implications for GOES-R GLM

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Abstract

Many meteorological applications use lightning observations from both ground- and space-based lightning detection systems. These systems detect optical or radiometric emissions from lightning, and their data are growing in importance to scientists and operational weather forecasters. Total lightning observations are useful for both storm warning and public safety applications. As the variety of users expands, it becomes increasingly important to understand the detection capabilities of these networks. This presentation briefly introduces multi-scale lightning observations, and then describes the performance of ground-based lightning detection networks. This study evaluates data from the Global Lightning Dataset 360 (GLD360), World Wide Lightning Location Network (WWLLN), and Earth Networks Total Lightning Network (ENTLN) relative to the Tropical Rainfall Measuring Mission (TRMM) Lightning Imaging Sensor (LIS). Direct flash-by-flash comparisons allow analysis of the relative detection efficiency (i.e., assuming LIS is truth), the location and timing differences between matched flashes, and the characteristics of matched and unmatched flashes. This information will help lightning vendors better characterize their network performance, and will provide operational users with important insights as lightning data use continues to grow. Since these ground- and space-based networks detect lightning differently (i.e., optical emissions versus electromagnetic pulses), the close proximity of matched flashes is important for GOES-R Geostationary Lightning Mapper (GLM) risk reduction activities that seek to blend satellite- and ground-based lightning observations.

Motivation and Objectives

- Motivation**
 - Although the expansion and improvement of long-range lightning datasets have increased their applicability, these applications require knowledge of network detection capabilities.
 - Improved knowledge of relationships between satellite and ground-based lightning datasets will allow researchers, algorithm developers, and operational users to better prepare for the spatial and temporal coverage of the upcoming GOES-R GLM.
- Objective**
 - Document the present ground-based network (GBN) performance and illustrate how it varies in space and time. Improved understanding of GBN detection capabilities will enhance their use in weather research and operations.

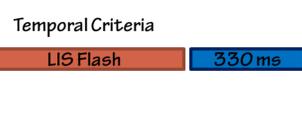
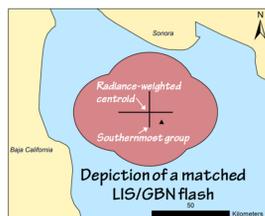
Domain and Data

- Domain**
 - ~38° N to ~38° S
 - Prime Meridian to -180° W
- Datasets**
 - TRMM/LIS Flashes
 - Group times and locations
 - ENTLN Strokes
 - Originally examined flashes
 - GLD360 Strokes
 - Reduced domain (only to 25° S)
 - WWLLN Strokes



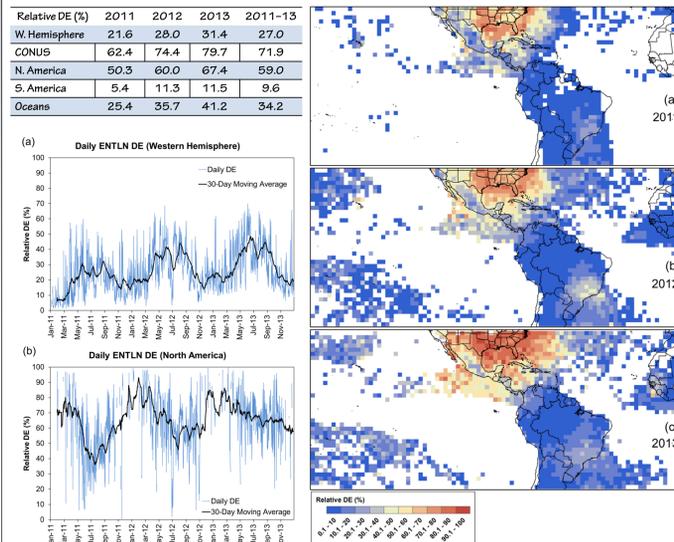
Methods

- Flash-to-stroke comparison**
 - Match individual LIS flashes with GBN reported strokes
 - Relative detection efficiency (DE) is the number of LIS flashes seen by the GBNs
- Spatial criteria**
 - Within 25 km of any LIS group (i.e., the furthest north, south, east, and west)
- Temporal criteria**
 - Within 330 ms before, during, and 330 ms after a LIS flash



ENTLN Results (2011–2013)

- Most notable spatial feature is the expansion of the region surrounding CONUS with relative DE >50%
- Performance improves in each geographical subdomain, with the best regional performance (71.9%) over CONUS
- The daily relative flash DE generally exceeds 15% (50% in the Western Hemisphere (North America), but large day-to-day variability is evident
- Average distance and timing offsets between matched LIS/ENTLN events are 10.8 km and 25.0 ms (not shown)
- The average timing offset is positive, but the ENTLN reports its first event before 48.6% of LIS flashes begin

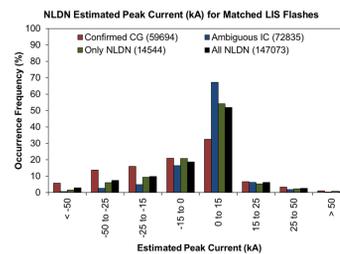


Matched LIS/ENTLN Distributions

- NLDN data helps characterize flash type (CG vs. IC), allowing investigation of the LIS characteristics of IC and CG flashes
- The ENTLN detects the strongest LIS flashes, and the LIS characteristics also indicate that CG flashes transfer more charge than IC flashes
- MNEG = Maximum Number of Events per Group
- MGA = Maximum Group Area

Year (Stroke Count)	Confirmed CG	Ambiguous IC	Ambiguous CG	Confirmed IC	Unmatched	Only NLDN
	ENTLN CG NLDN CG	ENTLN IC NLDN CG	ENTLN CG No NLDN	ENTLN IC No NLDN	No ENTLN No NLDN	No ENTLN NLDN CG
3YRS (351542)	17.0%	20.7%	8.1%	26.1%	24.0%	4.1%
LIS Characteristics						
Duration (ms)	24.0	21.8	18.3	11.8	5.1	12.2
Area (km ²)	428.4	293.2	288.8	230.2	197.3	316.0
MNEG (count)	14.9	9.8	9.6	7.7	6.8	11.0
MGA (km ²)	378.4	251.9	249.3	200.4	176.1	282.9

- This comparison provides important insights into the ambiguity of flash classification in both datasets
- 67.2% of the Ambiguous IC flashes have NLDN estimated peak currents in the ambiguous weak +CG range (0–15 kA)
- Ambiguous IC flashes appear to be mostly IC, with some true CG flashes mixed in
- Findings illustrate the challenge of classifying IC and CG flashes



Year (Stroke Count)	Confirmed CG	Ambiguous IC	Ambiguous CG	Confirmed IC	Unmatched	Only NLDN
	ENTLN CG NLDN CG	ENTLN IC NLDN CG	ENTLN CG No NLDN	ENTLN IC No NLDN	No ENTLN No NLDN	No ENTLN NLDN CG
2011 (122707)	13.3%	15.9%	6.6%	26.7%	30.8%	6.8%
2012 (118958)	19.3%	17.4%	10.4%	27.4%	22.9%	2.6%
2013 (109877)	18.6%	29.7%	7.3%	24.0%	17.5%	2.9%
3YRS (351542)	17.0%	20.7%	8.1%	26.1%	24.0%	4.1%

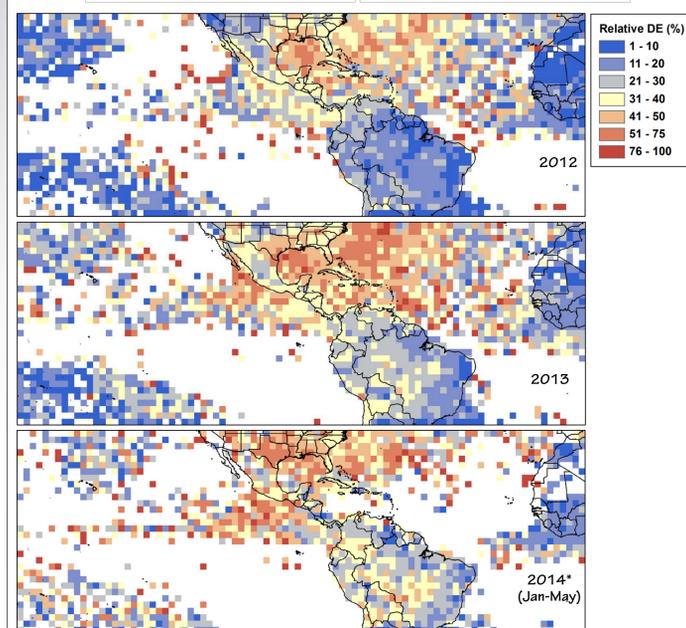
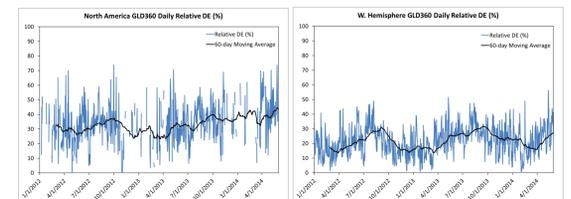
Disclaimer

- Each of the ground-based networks has strengths and weaknesses in terms of detection efficiency and location accuracy, types of lightning detected, and areal coverage, this study does not attempt to quantify or explain any differences between these networks.
- The networks are continuously evolving, and our analysis describes performance during fixed periods of time, so caution must be taken when interpreting results.

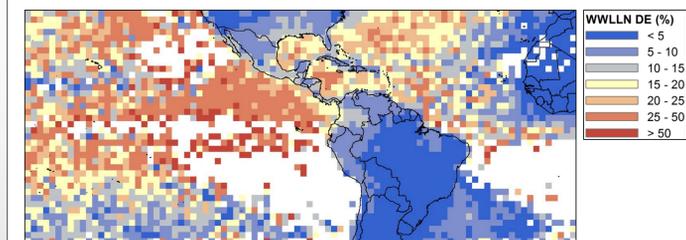
GLD360 Results (2012–2014*)

- The GLD360 has a large region with relative DE greater than 30%, with no clear land/ocean contrast
- Performance appears to be improving, although the partial 2014 disguises this trend
- Daily relative DEs further illustrate the improving GLD360 performance
- The daily relative flash DE generally exceeds 25% in North America (10% in the Western Hemisphere), but large day-to-day variability is evident

Relative DE (%)	2012	2013	2014*
W. Hemisphere	20.4	24.4	22.1
CONUS	35.8	38.6	48.5
N. America	33.5	35.5	47.4
S. America	11.7	16.8	16.4
Oceans	26.8	30.6	23.2



WWLLN Results (2009–2012)



Time Period	Overall	Land	Ocean	N. America	S. America	Metric (2012)	WWLLN
	DE (%)	LD (km)	Multiplicity	Single Stroke %			
2009	6.0	4.0	12.3	8.0	2.3	9.2	9.2
2010	6.8	4.8	13.9	7.6	4.1	10.8	10.8
2011	8.1	5.8	15.2	8.7	4.8	1.60	1.60
2012	9.2	6.4	17.3	10.7	4.9	67.5	67.5
4YRS	7.5	5.2	14.7	8.7	4.0		

Summary

- WWLLN detected 17.3% of all LIS flashes over the oceans (2009–12), with most oceanic grid cells having relative DE values above 15%.
- The ENTLN and GLD360 had large regions of relative DE greater than 25%, with no clear land/ocean contrast.
- The GBNs detect the strongest LIS flashes, and the LIS characteristics indicate that CG flashes transfer more charge than IC flashes
- 67.2% of the Ambiguous IC flashes have NLDN estimated peak currents in the ambiguous weak +CG range (0–15 kA)
- Improved ENTLN performance likely reflects the implementation of new waveform processing algorithms, the addition of sensors, and the incorporation of waveforms from WWLLN (beginning in December 2011).
- Despite the variability, each network appears to provide the coverage necessary for many meteorological applications on many different scales.

References

Rudlosky, S. D., 2015: Evaluating ENTLN performance relative to TRMM/LIS. *J. Operational Meteor.*, **3** (2), 11–20.
Rudlosky S. D., and D. T. Shea, 2013: Evaluating WWLLN performance relative to TRMM/LIS. *Geophys. Res. Lett.*, **40**, 2344–2348, doi:10.1002/grl.50428.