Relationships between Long-Range Lightning Networks and TRMM/LIS Observations

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Recent advances in long-range lightning detection technologies have improved our understanding of thunderstorm evolution in the data sparse oceanic regions. Although the expansion and improvement of long-range lightning datasets have increased their applicability, these applications (e.g., data assimilation, atmospheric chemistry, and aviation weather hazards) require knowledge of the network detection capabilities. The present study intercompares long-range lightning data with observations from the Lightning Imaging Sensor (LIS) aboard the Tropical Rainfall Measurement Mission (TRMM) satellite. The study examines network detection efficiency and location accuracy relative to LIS observations, describes spatial variability in these performance metrics, and documents the characteristics of LIS flashes that are detected by the long-range networks. Improved knowledge of relationships between these datasets will allow researchers, algorithm developers, and operational users to better prepare for the spatial and temporal coverage of the upcoming GOES-R Geostationary Lightning Mapper (GLM).

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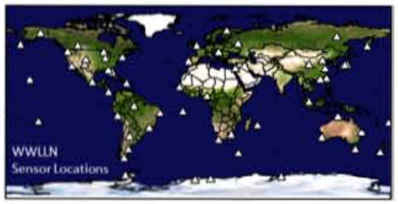
Motivation

- Recent advances in lightning detection technologies have improved our understanding of thunderstorm evolution in the data sparse oceanic regions.
- 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.***

World-Wide Lightning Location Network (WWLLN)

- Observes very low frequency (VLF) radiation (3-30 kHz) emitted by lightning
- Earth-Ionosphere waveguide allows for global coverage with only 50-60 sensors
- Abarca et al. (2010) evaluated the WWLLN DE relative to the NLDN ↓



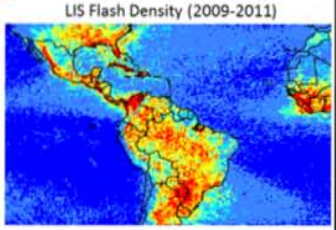
Abarca et al.	2006-07	2007-08	2008-09
CG DE (%)	3.88	4.89	10.3
IC DE (%)	1.78	2.28	4.82
CG+IC DE (%)*	2.31	2.93	6.19

* Analysis required assumptions due to the limited IC detection efficiency of the NLDN

TRMM Lightning Imaging Sensor (LIS)

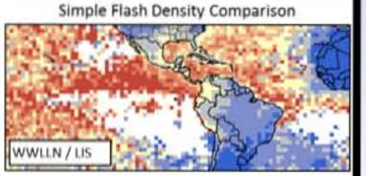
- **Reports the location and timing of lightning events, groups, flashes, and areas**
- **Records both IC and CG flashes, but with limited view time (max = 90 s)**
- **Detection Efficiency** ***(Boccippio et al.)***
  - **Night = 93% ± 4%**
  - **Noon = 73% ± 11%**

LIS Flash Density (2009-2011)



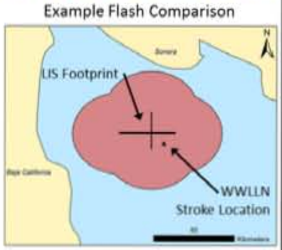
Potential Comparison Methods

Simple Flash Density Comparison



1) **Basic flash density comparison**
   - Requires large sample size
   - No information on location difference (LD) or flash-level characteristics
2) **Flash-by-flash comparison**
   - Match individual LIS flashes with long-range network reported strokes
   - Spatial criteria - within 25 km of any LIS group
   - Temporal criteria - within 330 ms before, during, and 330 ms after the LIS flash
   - *Although our spatial and temporal criteria are liberal, additional caution was taken to avoid double counting. Thus, our DE values represent conservative estimates of the fraction of total lightning flashes (IC and CG) that are observed by ground-based networks.*

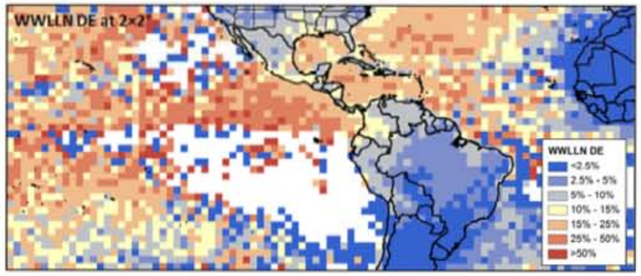
Example Flash Comparison



LIS footprint represents the radiance weighted centroid, and the furthest group north, south, east, and west.

WWLLN Detection Efficiency Relative to TRMM/LIS (2009-2011)

- WWLLN DE is improving with time (6% during 2009 to 8.1% during 2011)

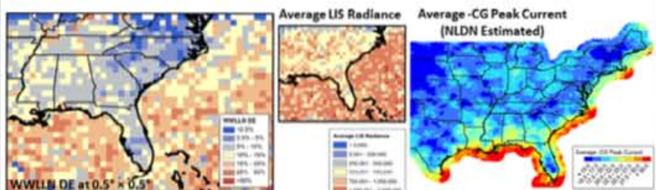


Long-Range Dataset	Detection Efficiency (%)	Location Difference (km)	Multiplicity (Strokes)
WWLLN – 2009	6.0	10.86	1.39
WWLLN – 2010	6.8	11.25	1.43
WWLLN – 2011	8.1	11.01	1.47
WWLLN (2009-2011)	7.0	11.04	1.43
NLDN (2009-2011)	37.5	9.76	1.47

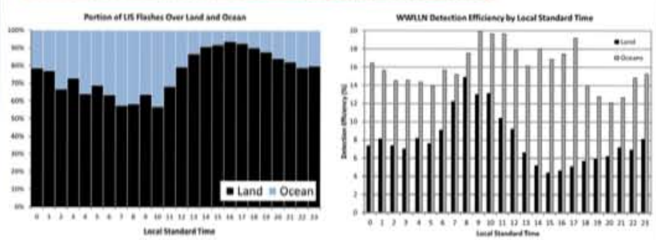
Regional DE (%)	2009-11	2011
North America	8.1	8.7
South America	3.7	4.9
Oceans	13.7	15.2

Greatest WWLLN DE Over the Oceans

- Both meteorological and technological contributions
- Diurnal effects have a strong influence on both of these categories
- Signal propagation (e.g., influence of the surface and ionosphere)
- Results suggest stronger flashes over the ocean (though less frequent)



Diurnal Evolution of LIS Density and WWLLN DE



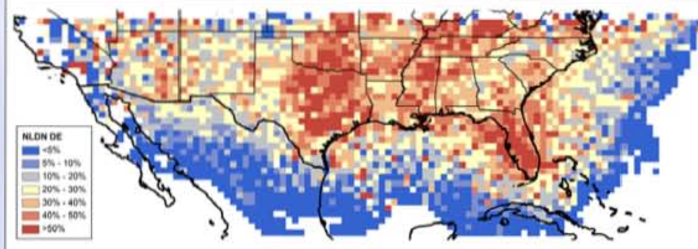
- Majority of LIS flashes occur over land, especially during the afternoon hours
- The diurnal DE variability differs between land and ocean regions
  - Over land – Greatest WWLLN DE during the late night and early morning hours
  - Over land – Lowest WWLLN DE during the afternoon and early evening hours
  - Over ocean – Maximum and minimum values lag the diurnal cycle over land
- Many meteorological and technological factors influence these distributions
- *Difficult to separate meteorological and technological influences on spatial and temporal DE variability*

Baseline Analysis – National Lightning Detection Network (NLDN)

- Apply comparison methods originally developed for long-range network analysis
- Good baseline since the NLDN performance is well documented
- Analysis of NLDN-reported flashes (i.e., not strokes)

Lightning Dataset	Detection Efficiency (%)	Location Difference (km)	Multiplicity (Flashes)
NLDN (2009-2011)	37.5	9.76	1.47***

Detection Efficiency (%)	
Contiguous U.S.	37.5
Within 200 km	32.7
Within 500 km	31.2



*** Despite the use of NLDN flashes for this analysis, a portion of the matched LIS flashes still correspond to multiple NLDN flash reports. This may be due in part to the liberal matching criteria, but also suggests that the LIS algorithm may be *"over grouping"* groups into flashes.

WWLLN Detects the Strongest LIS Flashes

- Table compares average characteristics of LIS flashes detected by WWLLN (Matched) with those not detected by WWLLN (Not Matched)

Flash-Level Characteristic	Matched (a)	Not Matched (b)	*Difference (a-b)*
groups	15.6	10.6	*5.0*
events	97.6	43.8	*53.7*
delta	0.31	0.24	*0.07*
farea	582.8	254.3	*328.5*
mneg	20.4	9.1	*11.3*
mga	497.7	226.9	*270.8*
radiance	1,613,286.0	573,311.3	*1,039,974.7*

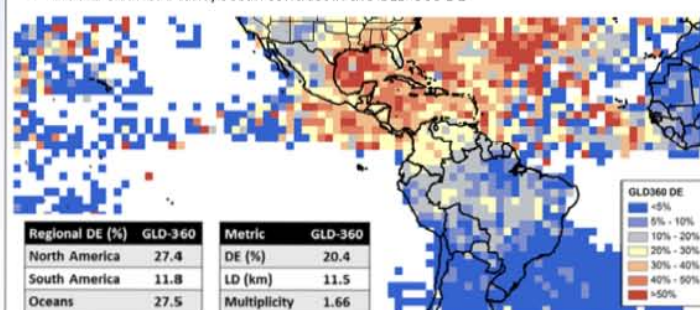
TRMM/LIS Flash-Level Characteristics

groups – Mean number of groups per flash
events – Mean number of events per flash
delta – Mean duration of LIS flashes (sec)
farea – Mean area of LIS flashes (km²)
radiance – Mean radiance of LIS flashes
*mga - maximum group area**
*mneg - max number of events per group**

* Koshak et al. introduced these flash-level characteristics as potential return stroke detectors

Preliminary GLD-360 Analysis (Jun. – Nov. 2011)

- Important Caveat – Data has been post-processed (i.e., not provided in real-time)
- Not as clear of a land/ocean contrast in the GLD-360 DE



Regional DE (%)	GLD-360
North America	27.4
South America	11.8
Oceans	27.5

Metric	GLD-360
DE (%)	20.4
LD (km)	11.5
Multiplicity	1.66