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

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Motivation

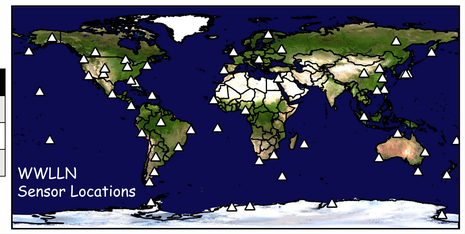
- Recent advances in lightning detection technologies have improved our understanding of thunderstorm evolution in the data sparse oceanic regions.
- Although the expansion and improvement of long-range lightning datasets have increased their applicability, a wide range of meteorological applications 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 50-60 sensors
- Abarca et al. (2010) evaluated WWLLN 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

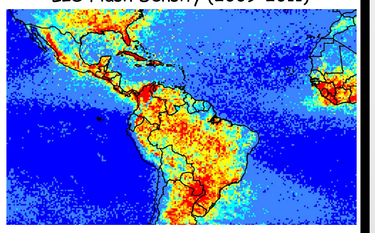
* Analysis required assumptions due to limited IC detection efficiency by the NLDN



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%
- *Imperfect location accuracy contributes to the location differences between satellite and ground-based observations.*

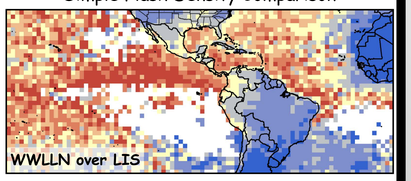
LIS Flash Density (2009-2011)



Potential Comparison Methods

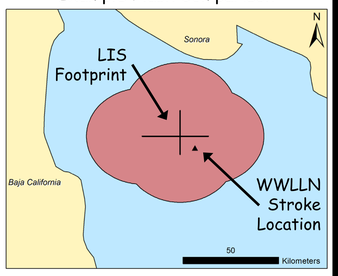
1) **Basic flash density comparison**
   - Requires large sample size
   - No information on location difference (LD) or flash-level characteristics

Simple Flash Density Comparison



2) **Flash-by-flash comparison**
   - Match individual LIS flashes with long-range network reported strokes
   - Spatial criteria – Located within 25 km of any group in a given LIS flash
   - Temporal criteria – Occurs within 330 ms before, during, and 330 ms after a LIS flash
   - *Our liberal spatial and temporal criteria required additional caution to avoid double counting. In turn, our DE values represent conservative estimates of the fraction of total lightning flashes (IC and CG) that are observed by the ground-based networks.*

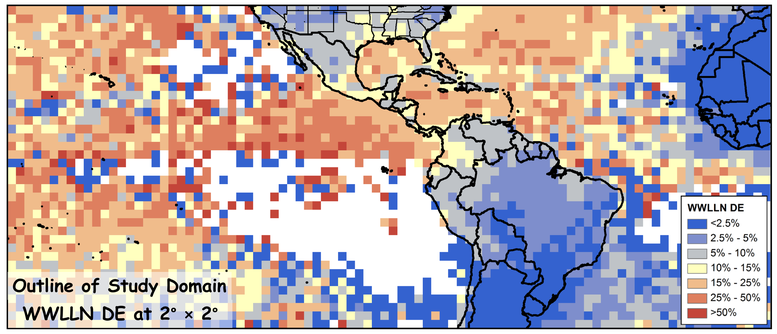
Example Flash Comparison



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

WWLLN Performance Relative to TRMM/LIS (2009-11)

- WWLLN DE improved from 6% during 2009 to 8.1% during 2011

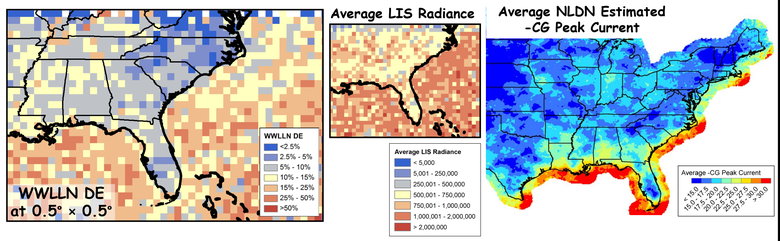


Lightning Dataset	Detection Efficiency (%)	Location Difference (km)	Multiplicity (Strokes)
WWLLN – 2009	6.0	10.86	1.39
WWLLN – 2010	6.8	11.25	1.43
WWLLN – 2011	8.1	11.01	1.47
WWLLN (2009-11)	7.0	11.04	1.43
NLDN (2009-11)	37.5	9.76	1.47

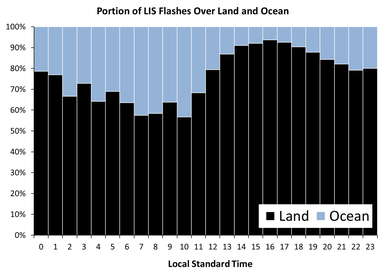
Regional DE (%)	2009-11	2011
North America	8.1	8.7
South America	3.7	4.9
Oceans	13.7	15.2

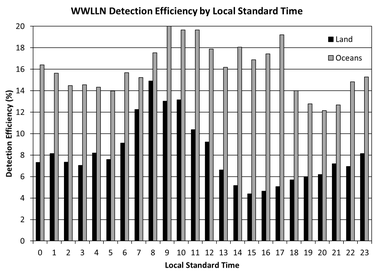
Greatest WWLLN DE Over the Oceans

- Both meteorology and technology contribute to this observation
- 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





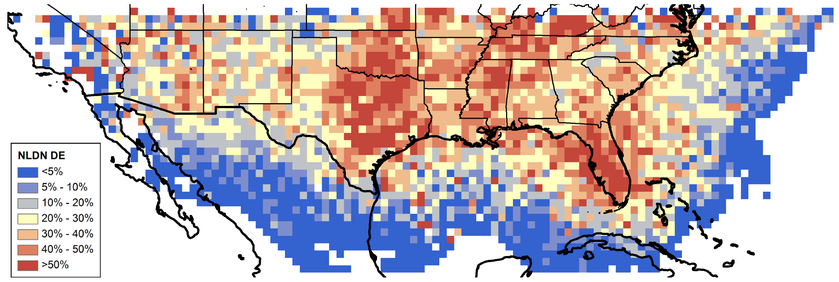
- Most LIS flashes occur over land, especially during afternoon hours
- Diurnal DE variability differs between land and ocean regions
  - Land – Greatest WWLLN DE during the late night and early morning hours
  - Land – Lowest WWLLN DE during the afternoon and early evening hours
  - Oceans – Maximum and minimum values lag the diurnal cycle over land
- *The number and variety of meteorological and technological factors influencing these distributions makes it difficult to isolate their relative influence on spatial and temporal DE variability.*

Baseline – National Lightning Detection Network (NLDN)

- Provides a good baseline since NLDN performance is well documented
- Apply comparison methods originally developed for long-range analysis
- Analysis of NLDN-reported flashes (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 below 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*

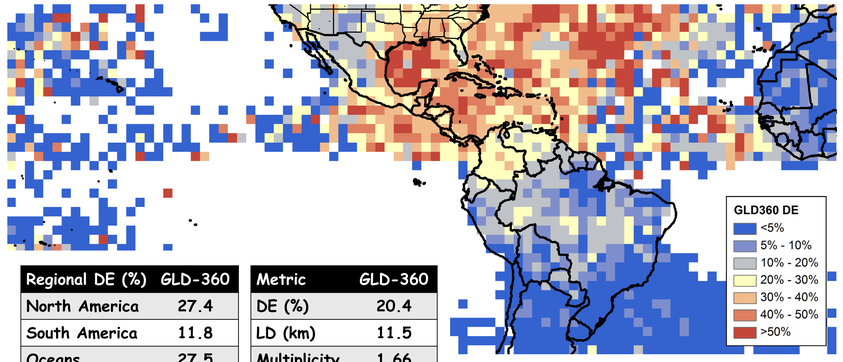
TRMM/LIS Flash-Level Characteristics

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 (km^2)
radiance – Mean radiance of LIS flashes
mga - maximum group area*
mneg - max number of events per group*

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

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

- Main 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

Above: GLD-360 Detection Efficiency