Joint MTG LI Mission Advisory Group
&
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Update on the U.S. NLDN and GLD360

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Update on the U.S. NLDN and GLD360

- U.S. National Lightning Detection Network
  - Performance Improvements
  - Validation Studies
- GLD360
  - Performance Characteristics
  - Validation Studies
  - Future Improvements

U.S. National Lightning Detection Network

- **Continuous CONUS Data Since 1989**
  - The U.S. National Lightning Detection Network (NLDN) has been providing real-time, continental-scale lightning data since 1989.
- **Continuous and Quantified Improvement**
  - Upgrades in 1995, 2003-4, and 2010-12 were coupled with detailed performance analyses.
- **2013 Upgrade to LS7002 Sensors**
  - The LS7002 uses a combination of Magnetic Direction Finding and Time of Arrival techniques to geolocate lightning discharges with as low as two sensors.
  - Advanced Total Lightning dataset containing cloud and cloud-to-ground lightning events now available from the NLDN.
- Cloud lightning detection efficiency was validated to be 50-60% (Murphy and Nag, 2015, AMS Annual Meeting, Phoenix, AZ).

Focus on Calibration and Validation

- Performance validation studies are being conducted using a variety of techniques throughout the network to understand network performance and calibrate models that provide expected performance characteristics.

- Parameters being examined include:
  - Detection Efficiencies
  - Location Accuracy
  - Classification Accuracy
  - Peak Current Estimation Accuracy

Performance Validation Techniques

- LLS Self-Reference
- Rocket-Triggered Lightning and Lightning Strikes to Tall Objects
- Video Camera Measurements
- Inter-Comparison among LLSs

Performance Validation Studies

- **Cloud-to-Ground Lightning**
  - Tower studies - Cramer and Cummins (2014) to validate location accuracy.
  - Rocket triggered lighting studies - Mallick et al. (2014) to validate flash and stroke detection efficiency, location accuracy, classification accuracy, and peak current estimation accuracy.

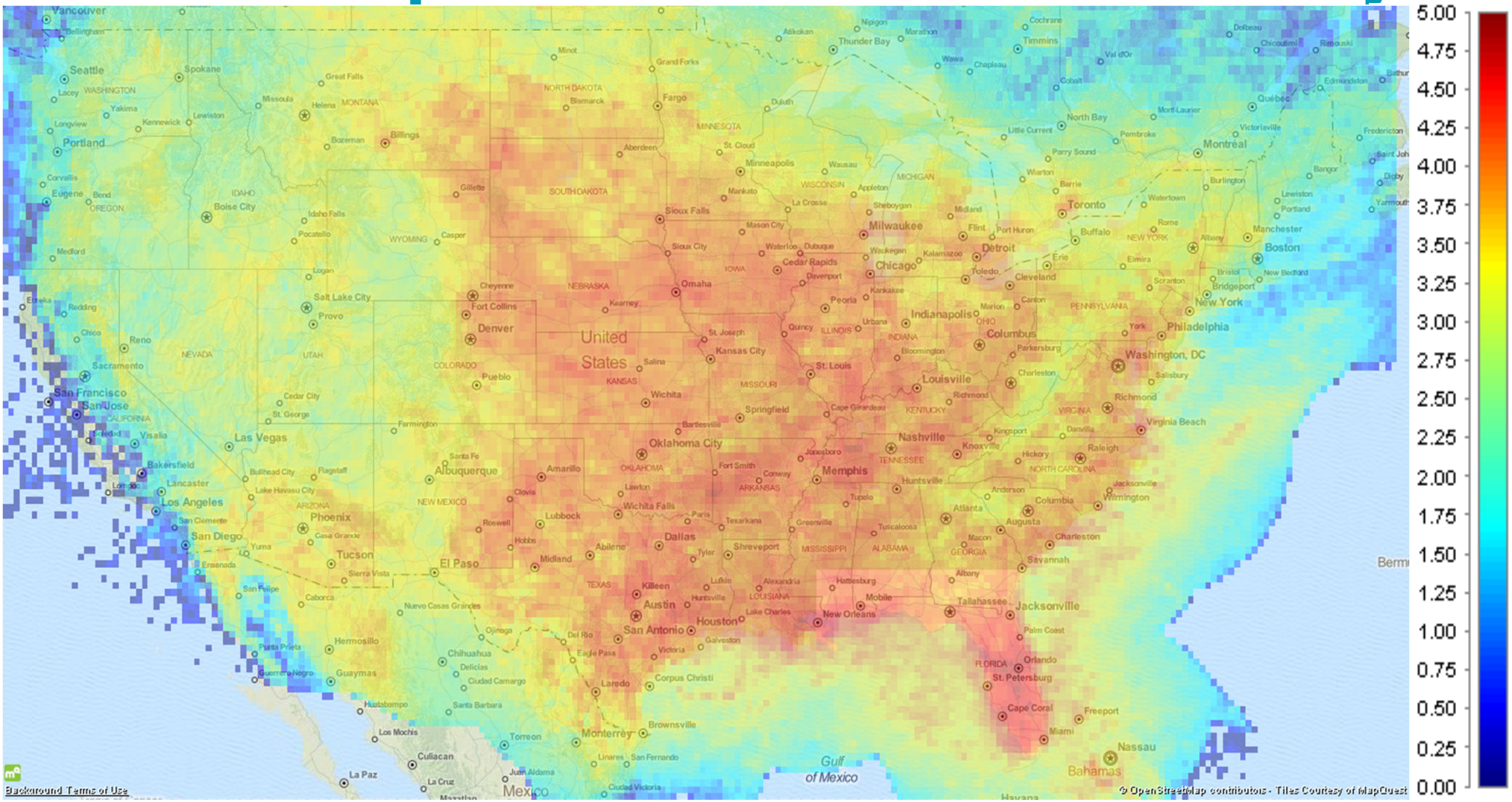
- **Cloud Lightning**
  - Video camera studies - Cummins et al. (2014) and Zhang et al. (2015) to validate detection efficiency and classification accuracy.
  - Comparison against the LMA (Lightning Mapping Array) - Murphy and Nag (2015) to validate cloud lightning detection efficiency.

Cloud Flash DE Validation

Comparison against the LMA

LMA	Date	Time (UTC)	CG flashes	IC DE, CG flashes (%)	Pure IC flashes	IC DE, pure IC flashes (%)	IC DE, all flashes	Total ltng. DE (%)
Oklahoma	2 Sept.	05:25-05:45	45	60.0	302	50.3	51.6	56.8
Oklahoma	22-23 May	23:40-00:27	143	76.2	669	53.5	57.5	61.7
Oklahoma	23 May	19:00-19:20	12	58.3	47	57.4	57.6	66.1
Oklahoma	26 May	15:27-16:06	49	83.7	177	46.3	54.4	58.0
Oklahoma	27 May	03:59-04:35	90	86.7	163	71.2	76.7	81.4
Oklahoma	consolidated		339	77.3	1358	54.1	58.8	63.3
Colorado	10 Aug.	18:00-19:00	42	59.5	77	51.9	54.6	68.9
Colorado	15 Aug.	01:15-03:15	28	82.1	134	61.9	65.4	68.5
Colorado	20 Sept.	00:46-02:00	44	68.2	109	47.7	53.6	62.7
Colorado	29 Sept.	18:00-19:15	26	69.2	59	37.3	47.1	56.5
Colorado	1 Oct.	19:00-20:30	40	80.0	201	42.3	48.5	51.9
Colorado	9 Oct.	18:00-24:00	25	80.0	83	18.1	32.4	37.0
Colorado	consolidated		205	72.2	663	44.8	51.3	57.8

NLDN Reported Cloud Flash Density



One-year (2014) density of cloud flashes in grid boxes of 0.25° latitude by 0.25° longitude.

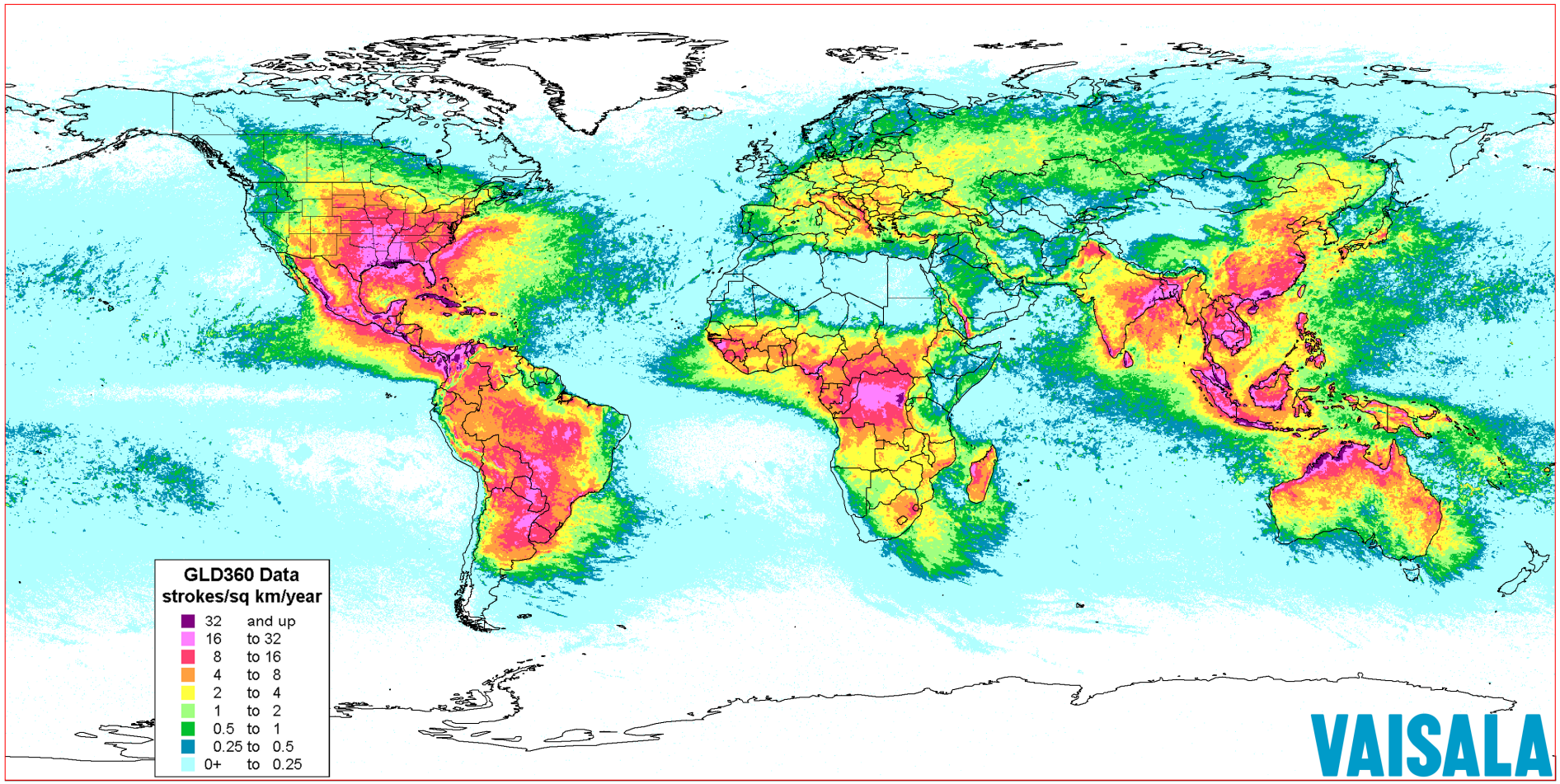
Summary of NLDN Performance Characteristics

CG Flash detection efficiency	>95%
CG Stroke detection efficiency	~80%
Median stroke location accuracy	~200 m
Cloud Flash detection efficiency	50-60%
Cloud versus cloud-to-ground classification accuracy	~90%
Peak current estimation error	~15%

GLD360

- Global, Real-time Lightning Locating System:
  - Sensitive Very Low Frequency (VLF; <50 kHz) sensors measure lightning discharges out to ~6000 km
  - Long baselines give relatively uniform coverage across land-ocean boundaries
  - Combined Time of Arrival (TOA) and Magnetic Direction Finding (MDF) technology help achieve industry-leading long-range lightning detection efficiency
  - Patented waveform recognition technology employed to improve location accuracy
  - Performance characteristics quantified using validation studies

GLD360 Global lightning climatology: Stroke Density (4-year average)



Stroke Density Map - 20 km grid **May 6, 2011 - May 5, 2015** **GLD360 data**

Validation Results

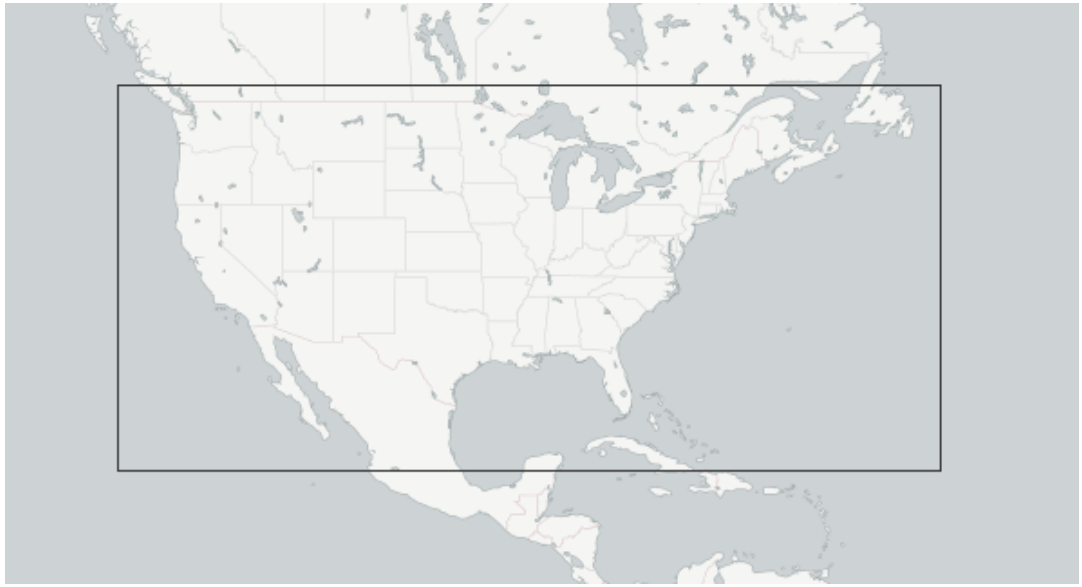
Region	Median LA (km)	CG Flash DE	Peak Current Error	Reference
Florida: Rocket-triggered comparison	2.0	67%	27%	*Mallick et al (*2014)
Belgium: video reference	0.9	96%	NA	*Poelman et al (*2013)
U.S.: comparison with NLDN	2.5	57% (67% for |*I*|p > 15 kA)	21%	*Said et al (*2013)
Europe: comparison with EUCLID	1.5	>60% for |*I*|p>10	R=0.72	*Pohjola and Makela (*2012)

GLD360 Algorithm Update in June, 2015

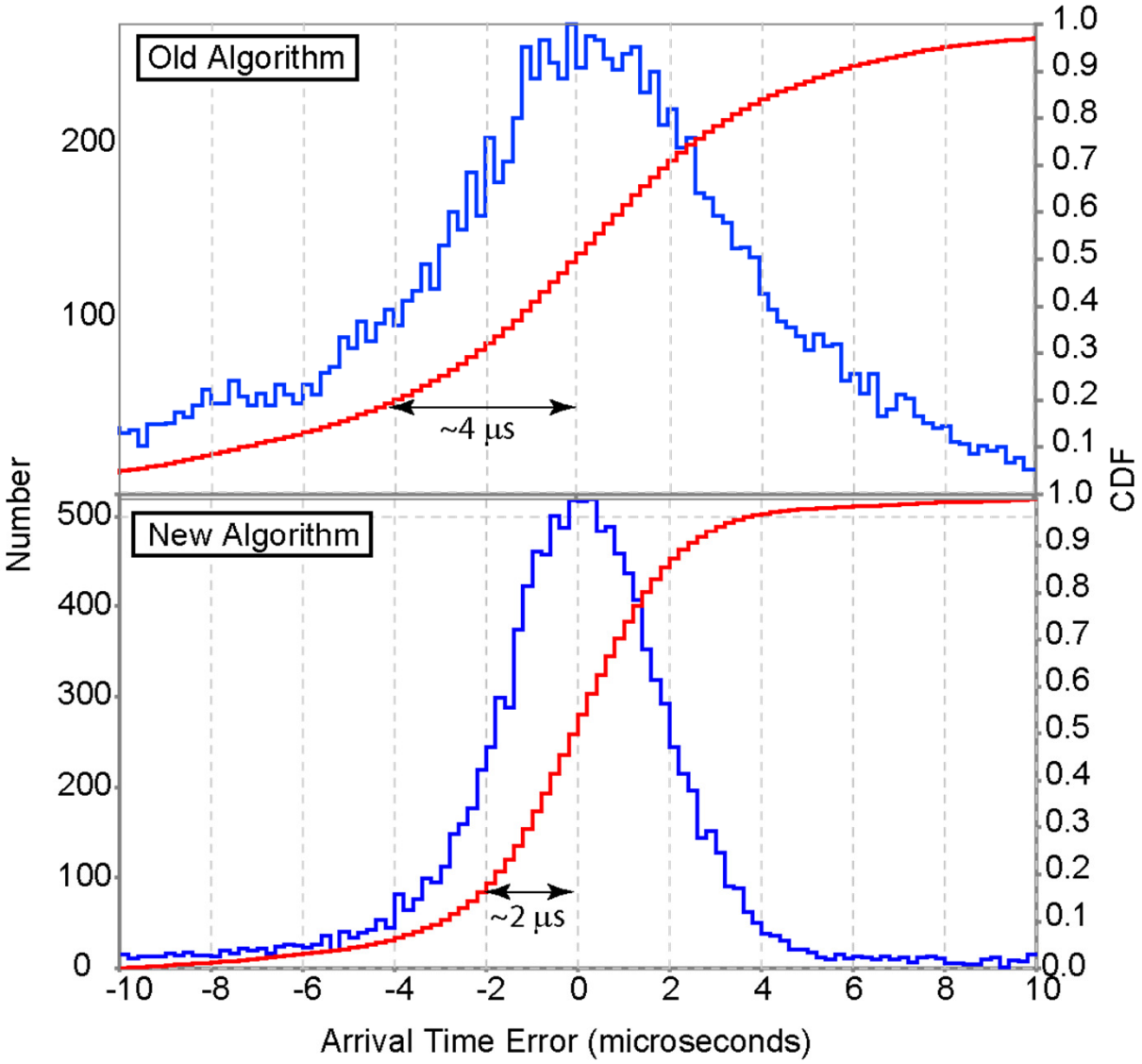
- New sensor and central processor software.
- More detailed Earth-ionosphere propagation model:
  - Improved peak current magnitude estimates.
  - Well-calibrated DE and LA models.
- Sferic detection and location algorithm enhancements will result in:
  - Increasing detection efficiency by reducing sensor thresholds and introducing improvements to the sensor correlation heuristics.
  - Reducing median location error by introducing a refined arrival time propagation correction scheme.
  - Reducing scatter (tail of the location error distribution) due to improved selection of timing feature on sferics and better time-space filtering.

Inter-network Comparison Versus the NLDN

- September 2, 2014
- 20—50 deg N, -130 — -50 deg E
- Reference: NLDN data (Post upgrade)
- Compare new GLD360 algorithm to old algorithm



Comparison against the NLDN

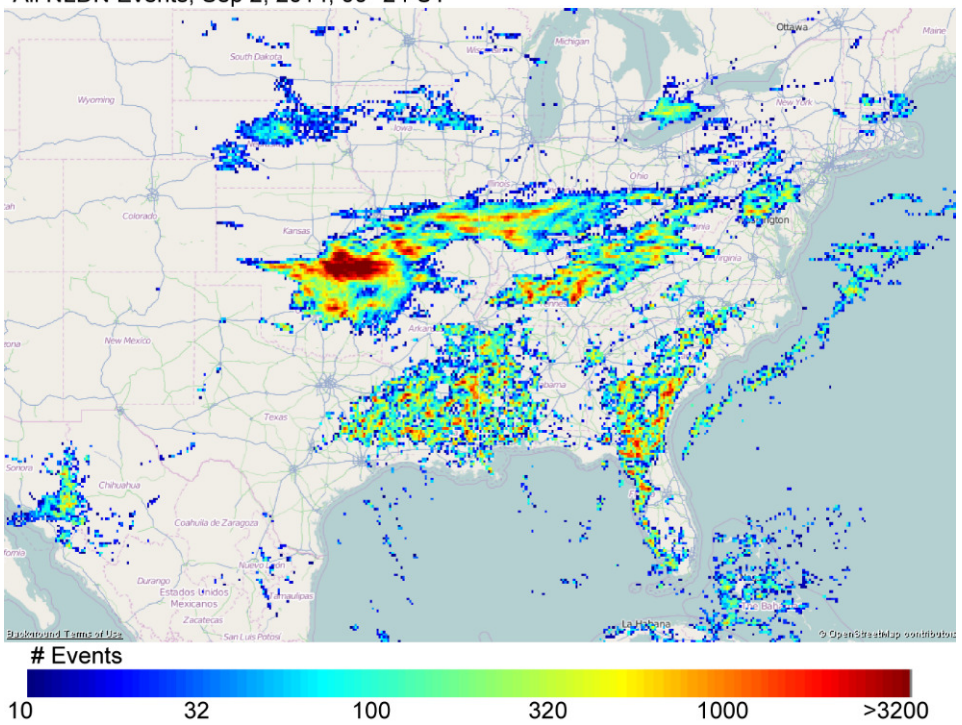


- Reduction in the standard deviation: improved median LA
- Expected: ~2-3 km median LA

Comparison against the NLDN

- 0.1 x 0.1 deg pixels (pixels with < 10 events omitted)
- All NLDN events (left), NLDN CG strokes only (right)

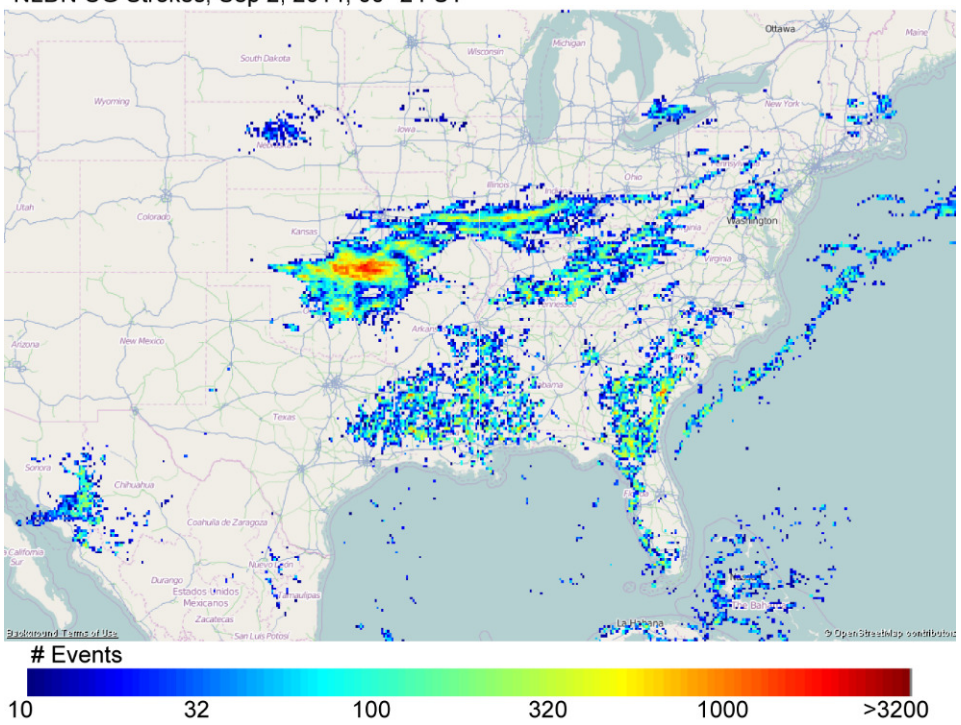
All NLDN Events, Sep 2, 2014, 00--24 UT



Events

10 | 32 | 100 | 320 | 1000 | >3200

NLDN CG Strokes, Sep 2, 2014, 00--24 UT



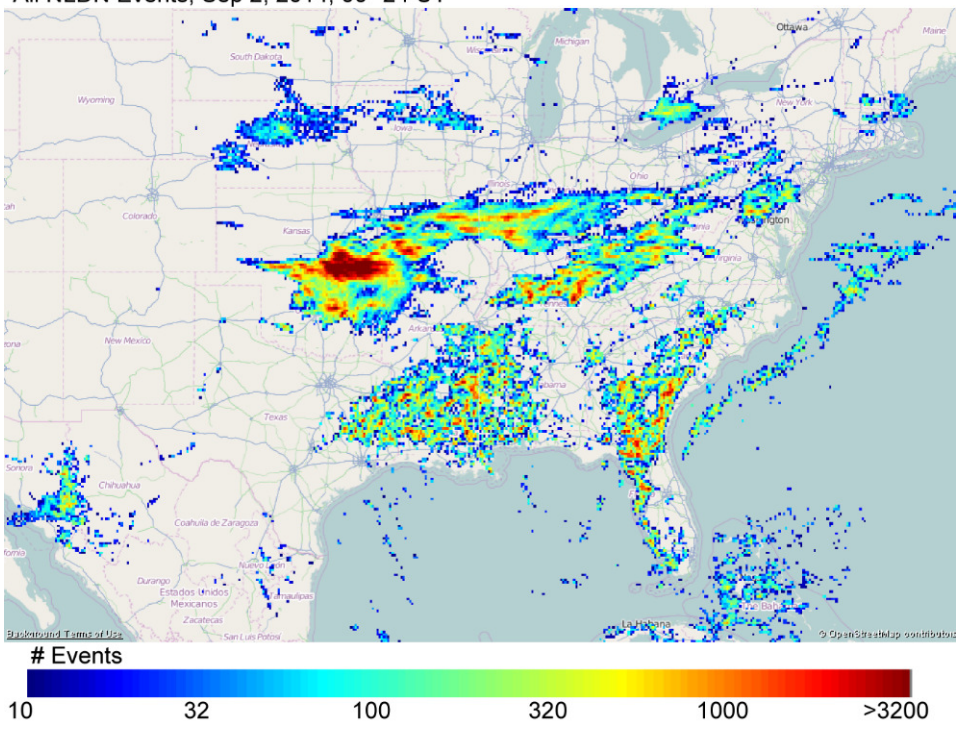
Events

10 | 32 | 100 | 320 | 1000 | >3200

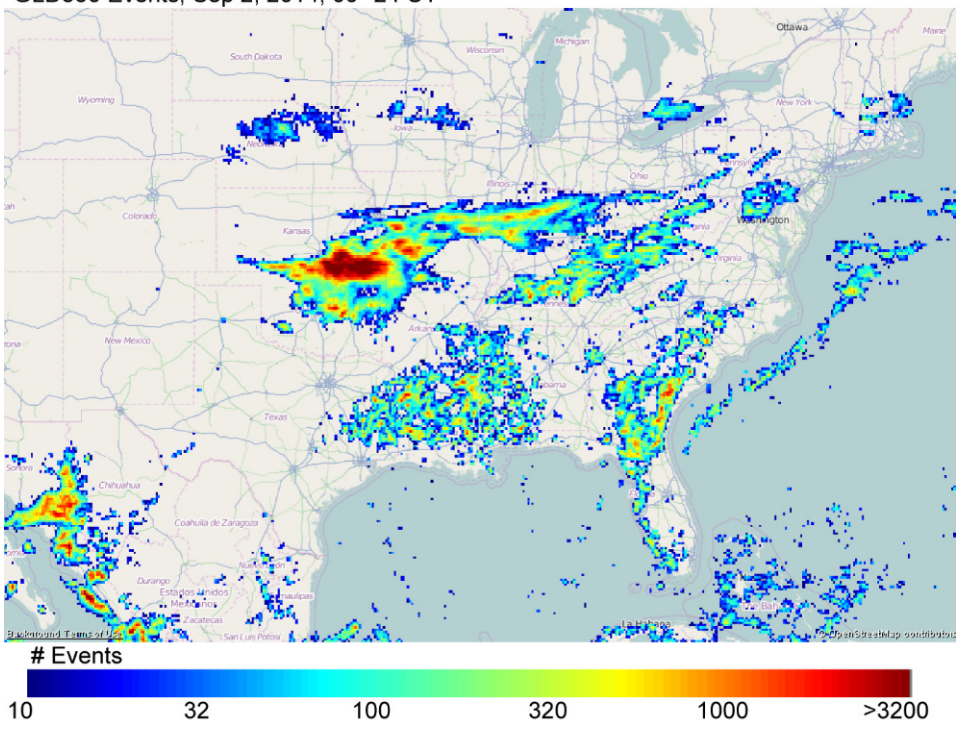
Comparison against the NLDN

- All NLDN events (left), reprocessed GLD360 events (right)
- Closer total count of GLD360 indicates large fraction of cloud pulses in GLD360 data

All NLDN Events, Sep 2, 2014, 00--24 UT



GLD360 Events, Sep 2, 2014, 00--24 UT



Summary

- Improvements were made to the NLDN in 2013.
- Performance validation studies show cloud flash detection efficiency of 50-60% and classification accuracy of ~90%.
- GLD360 has a CG flash detection efficiency of 60-70% and a median location accuracy of 2-5 km.
- Updates will be made to the network in June 2015 leading to improvements in CG detection efficiency (70-80%) and location accuracy (2-3 km).

Thank You