A Total Lightning Product Monitor

Steven J. Goodman, NOAA/NESDIS, Greenbelt, MD

M. Bateman[1], P. M. Bitzer[2], B. Carcione[3], K. M. Calhoun[4], K. L. Cummins[5], S. D. Rudlosky[6], and K. D. White[3]

[1]USRA, [2]UAHuntsville, [3]National Weather Service-Huntsville, [4]University of Oklahoma, [5]University of Arizona, [6]NESDIS/STAR

Tenth Annual Symposium on New Generation Operational Environmental Satellite Systems, Session 8.4: Use of Lightning Data to Improve Short-Term Prediction of Severe and High Impact Weather

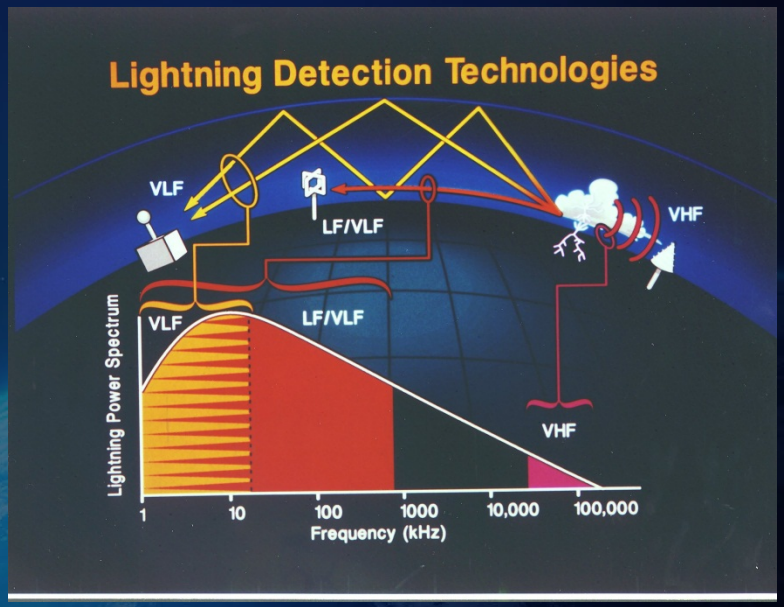
AMS Annual Meeting, Atlanta, GA, February 2-6, 2014

Reducing Societal Impacts of High Impact Weather: Most-Promising GLM Contributions

- Improved Convective Warnings (combine TL, radar, other)
  - Reduced FAR, Increased POD, Increased Lead Time for Tornado Warnings and other Severe Convective Warnings
  - Enhanced Situational Awareness for Aviation Services over broad geographic area (especially trans-oceanic flights)
  - Enhanced Situational Awareness for Convective Precipitation (Flash-Flood)
- Improved Forecasts of Rapid Intensification (RI) and Rapid Weakening (RW) in Tropical Storms
- Short-term numerical weather prediction improvement
  - Assimilation of TL as proxy for strong convection
  - Better initialization of storms approaching CONUS from offshore (e.g. winter storms, heavy precipitation)

Lightning Observing Systems

Available information as input to weather forecasting models (data assimilation), nowcasting systems, and decision support systems

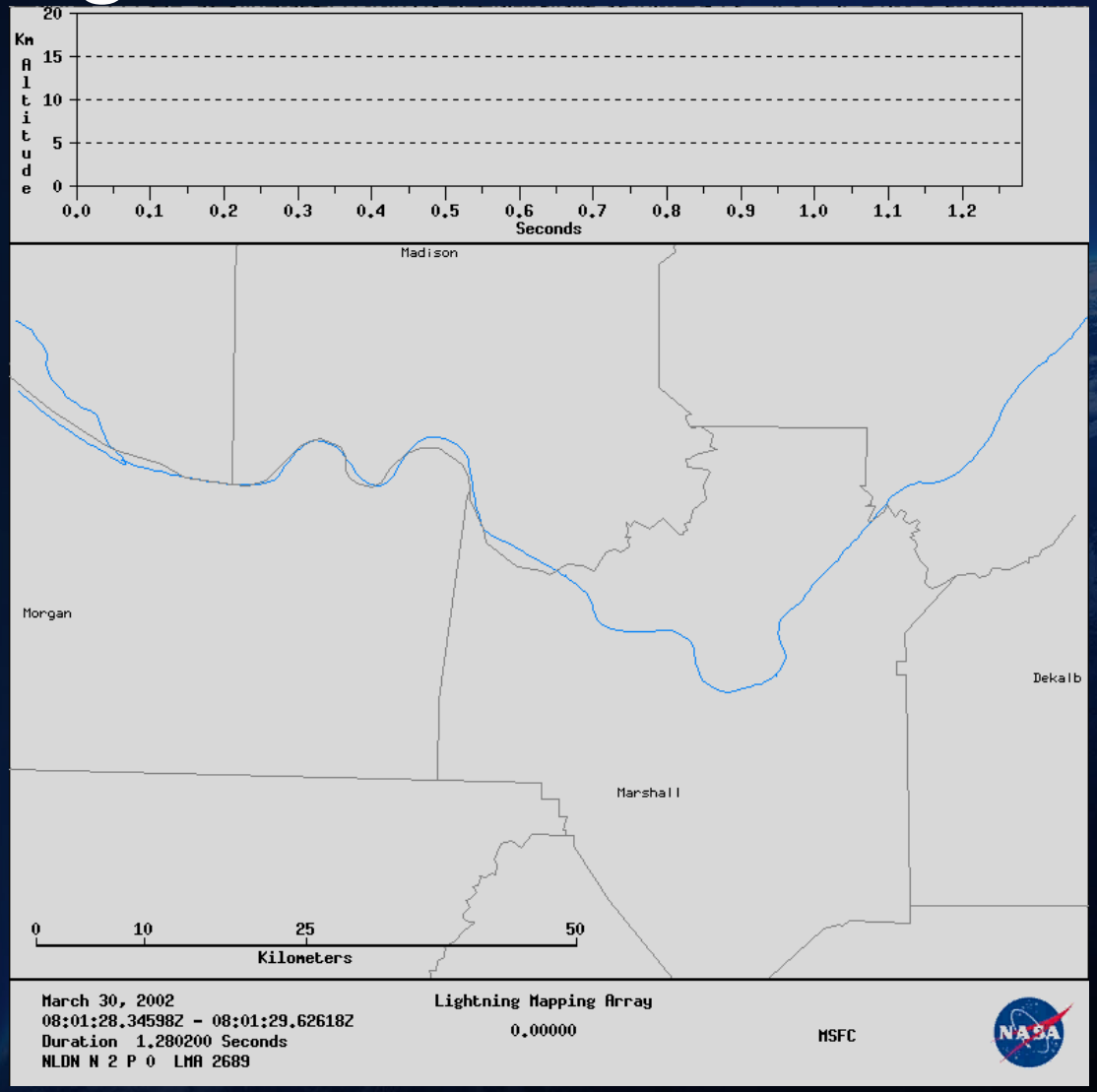


Lightning Detection and Mapping

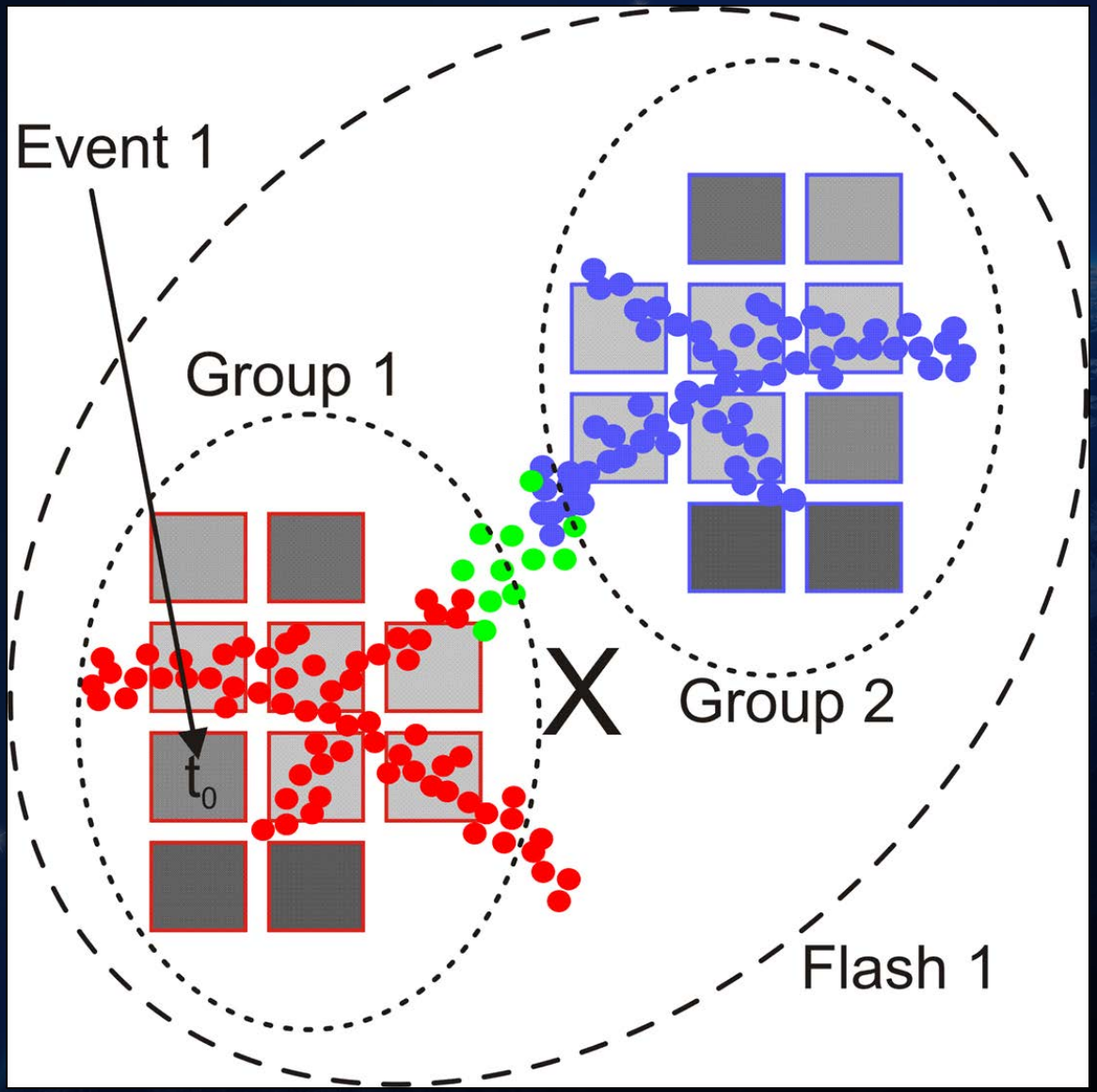
- Local electric field mill networks
- Short-range VHF in-cloud lightning mapping (60-180 MHZ)
- National cloud-to-ground lightning mapping (LF, 500 kHZ)
- International long range sferics networks (VLF, 10 kHZ)
- Sub-orbital: planes, balloons, UAVs (electrical, magnetic, optical)
- Lightning optical imagers orbiting Earth (GEO, LEO)

Key Performance Measures- Detection Efficiency, Location Accuracy, Stability, Consistency

North Alabama -CG with 2 RS Having Horizontal Extent > 50 km



How GLM Represents a Lightning Flash



What makes for a lightning detection system useful and effective for forecasters?

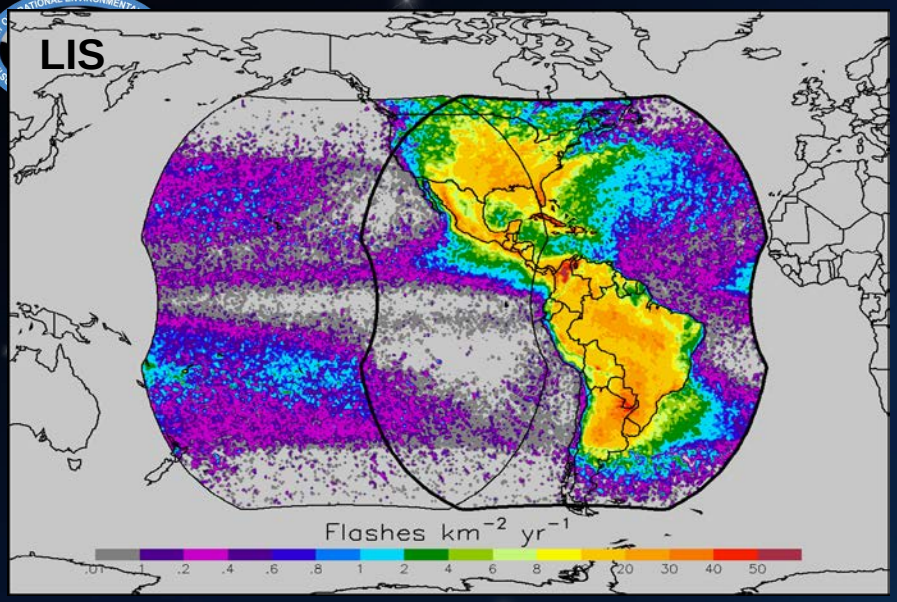
Performance Characteristics

- Detection Efficiency (DE)
- Stability
- Consistency
- Accuracy

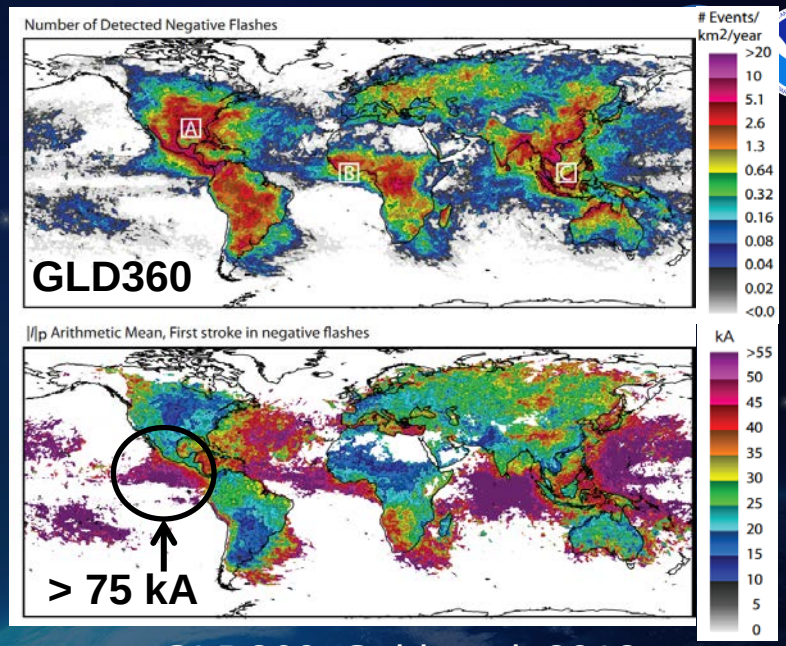
Variations in ground conductivity, topography, ambient noise, and receiver spacing can all affect the accuracy and temporal stability of the received signal.

When the forecaster has high confidence in the data, they may be able to warn sooner

- Accuracy of estimate
  - Location
    - initiation, termination
  - Propagation
  - Amplitude
  - Peak current
  - Energy
  - Polarity
  - Multiplicity
  - Flash Rate
  - Lightning type

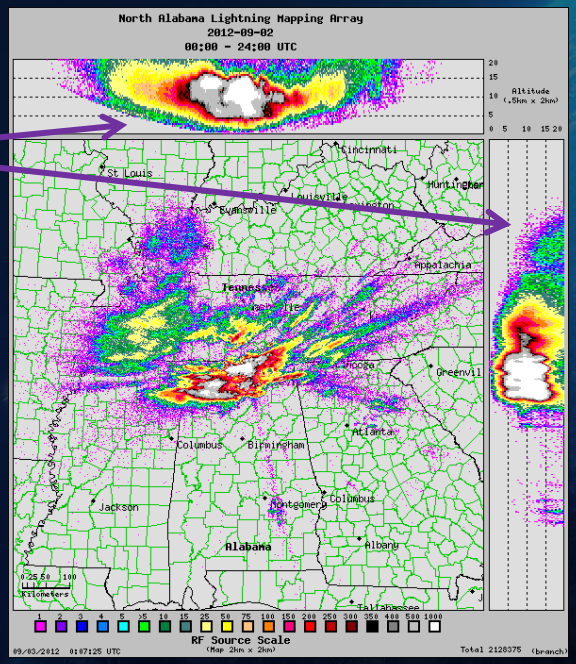


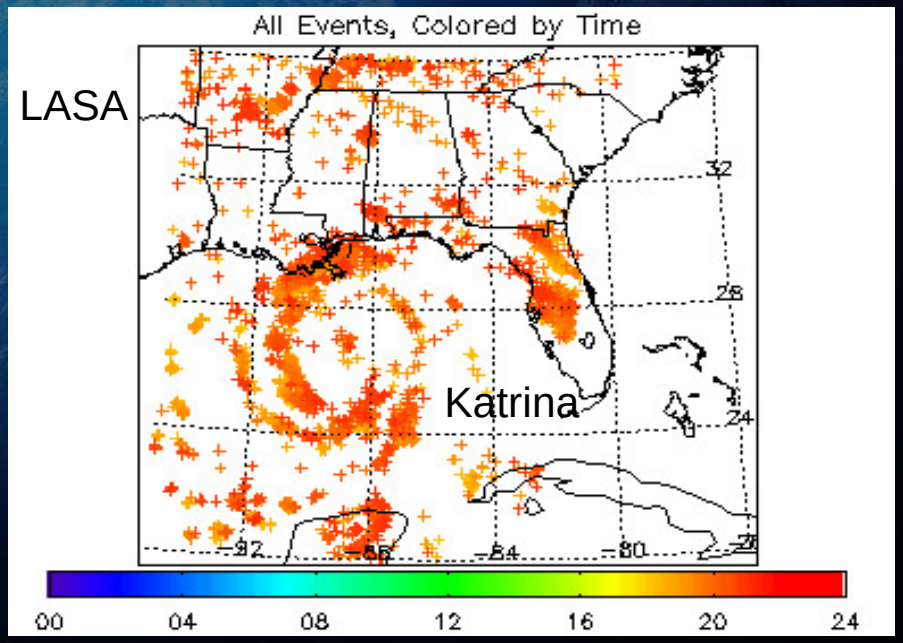
Combined GOES-R + S view, Cecil et al, 2013



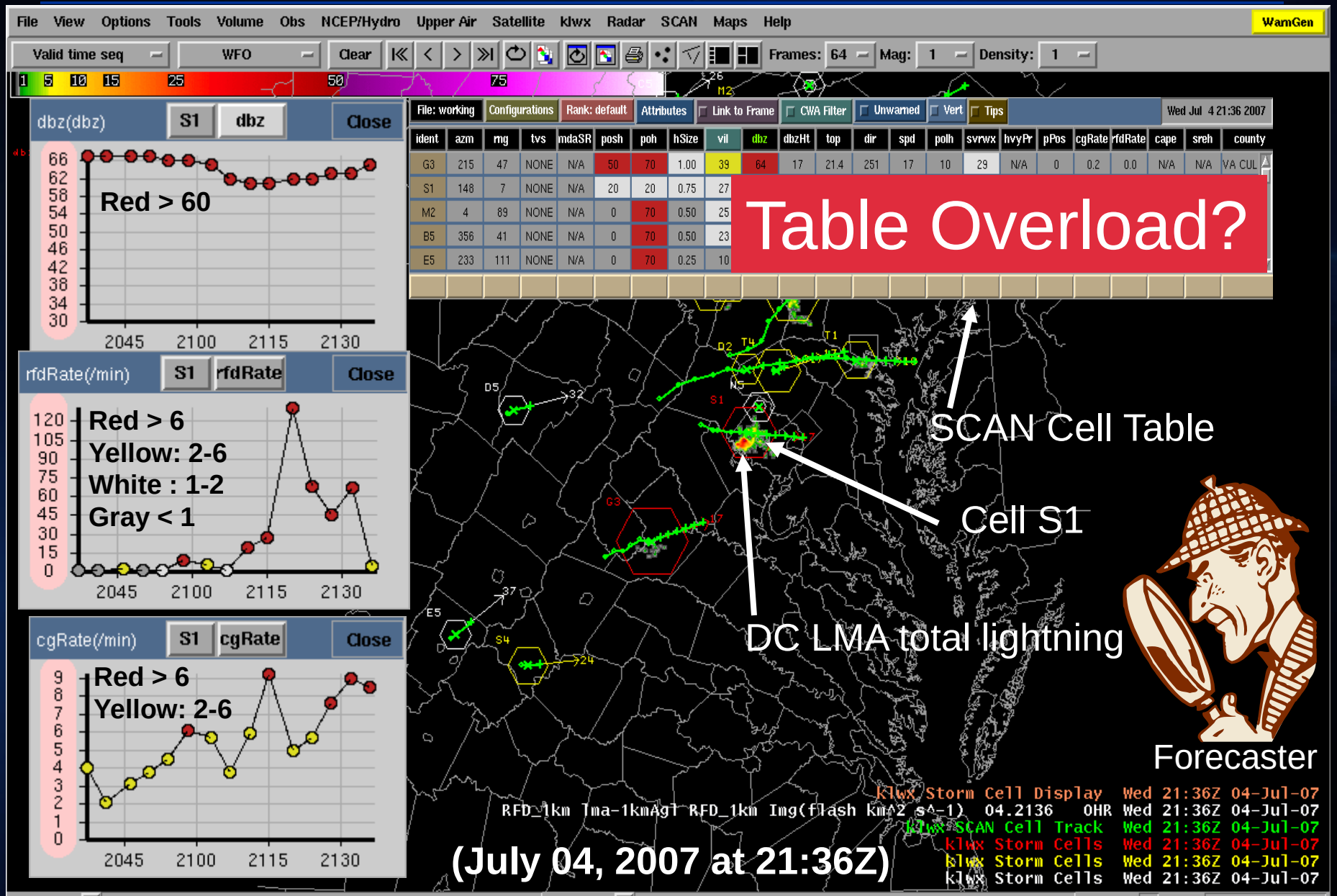
GLD360, Said et al, 2013

LMA VHF line-of-sight, note Earth curvature





Lightning Jump Algorithm:
Experimental Trending Implementation in AWIPS/SCAN



Courtesy Momoudou Ba

North Alabama Supersite LLS Comparison

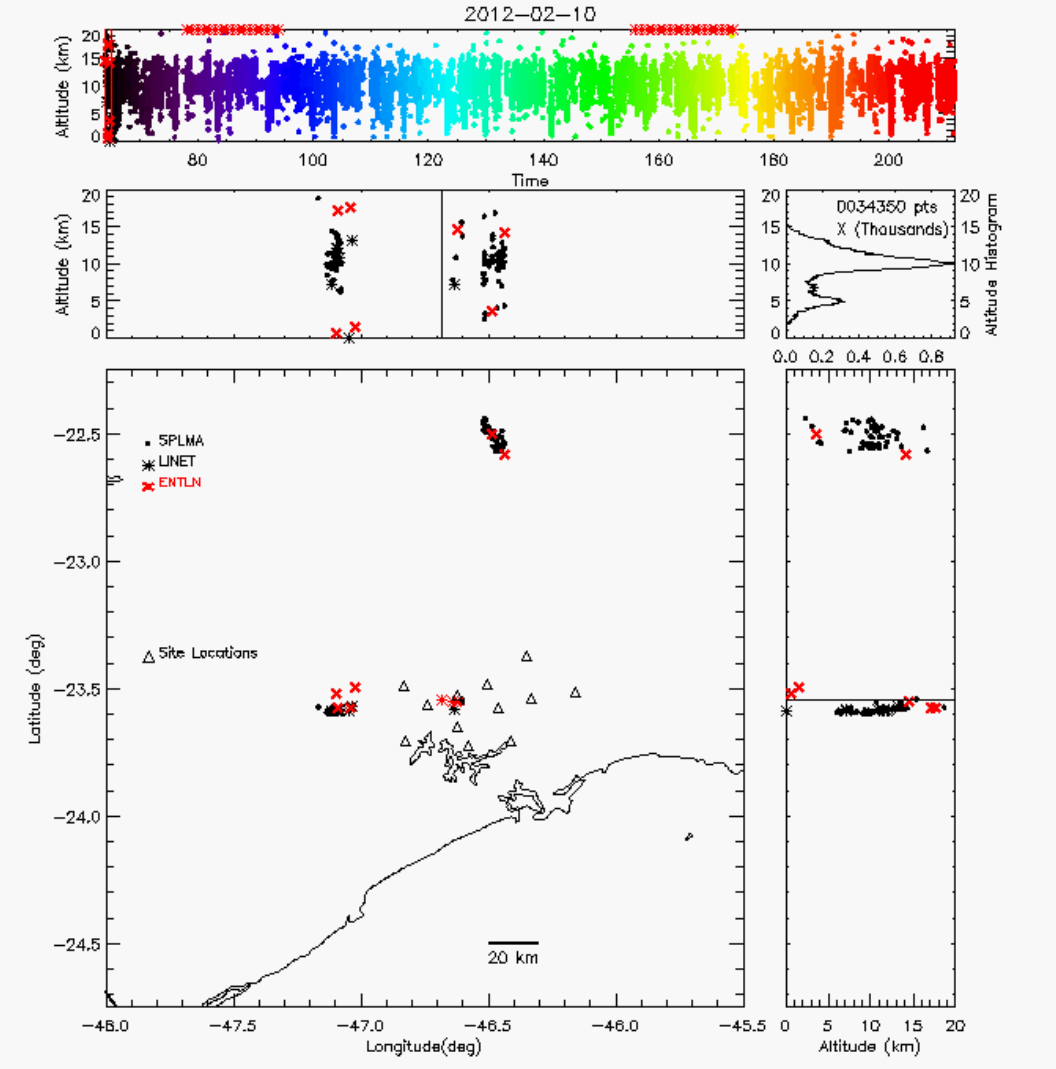
1) HAMMA plots - temporal evolution on the left, spatial evolution on the right
2) HAMMA sources - black dashes (preliminary breakdown), black diamonds (IC sources), black squares (CG strokes)
3) LMA sources - colored circles
4) NLDN strokes - blue X
5) ENTLN pulses - green X and diamand
6) LIS group - gray hatch and diamond on the left
7) LIS event - yellow->red square on the right with event subcomponents

8 return stroke -CG. ENTLN 5 RS (although one is classified as IC). NLDN 6 RS. LIS group associated with 7 RS. LIS, NLDN, ENTLN all miss final, weak RS. LIS detects ICs between RS

LIS Overpass Animation
2012-02-10 (1900 UTC)

- Red vertical lines (top) are the current data being displayed
- At first no lightning in LIS FOV
- Then LIS has full FIFO (no data)
- LIS lower edge of FOV curves
- Another full FIFO later on (no data)

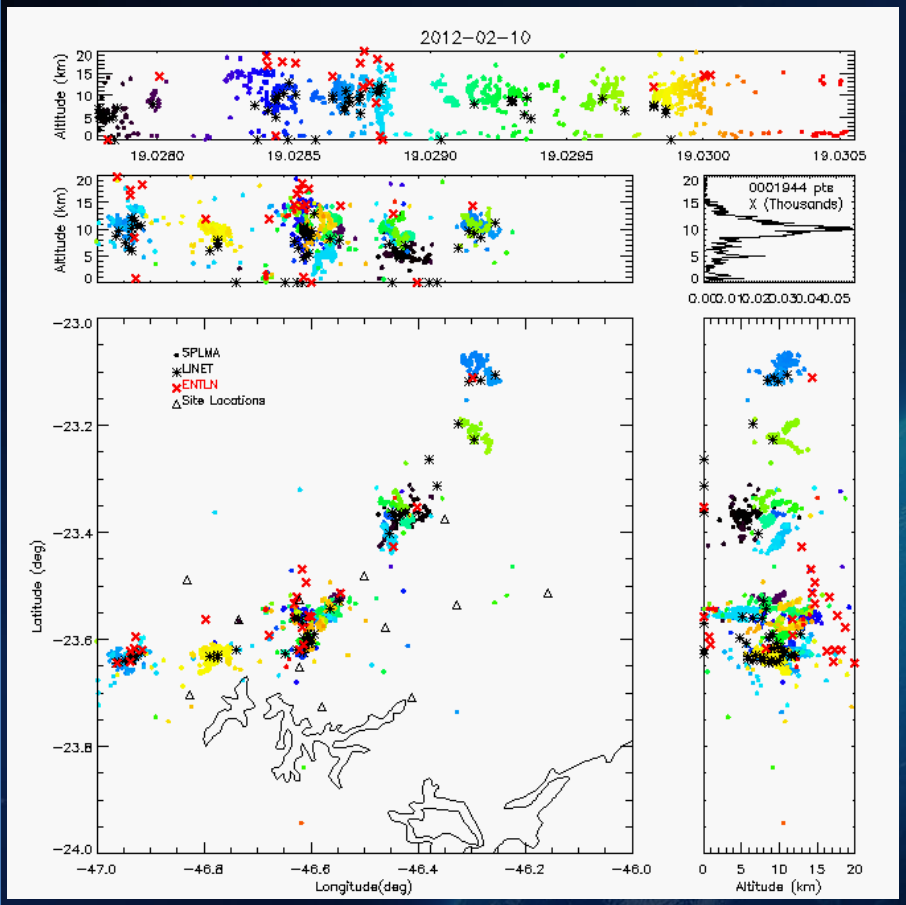
- Other comments:
  - SPLMA does not detect all LIS events
  - SPLMA and TLS200VHF (not shown) are detect about same number of LIS events
  - LIS does not detect all flashes
  - Some singletons correlate with LIS events

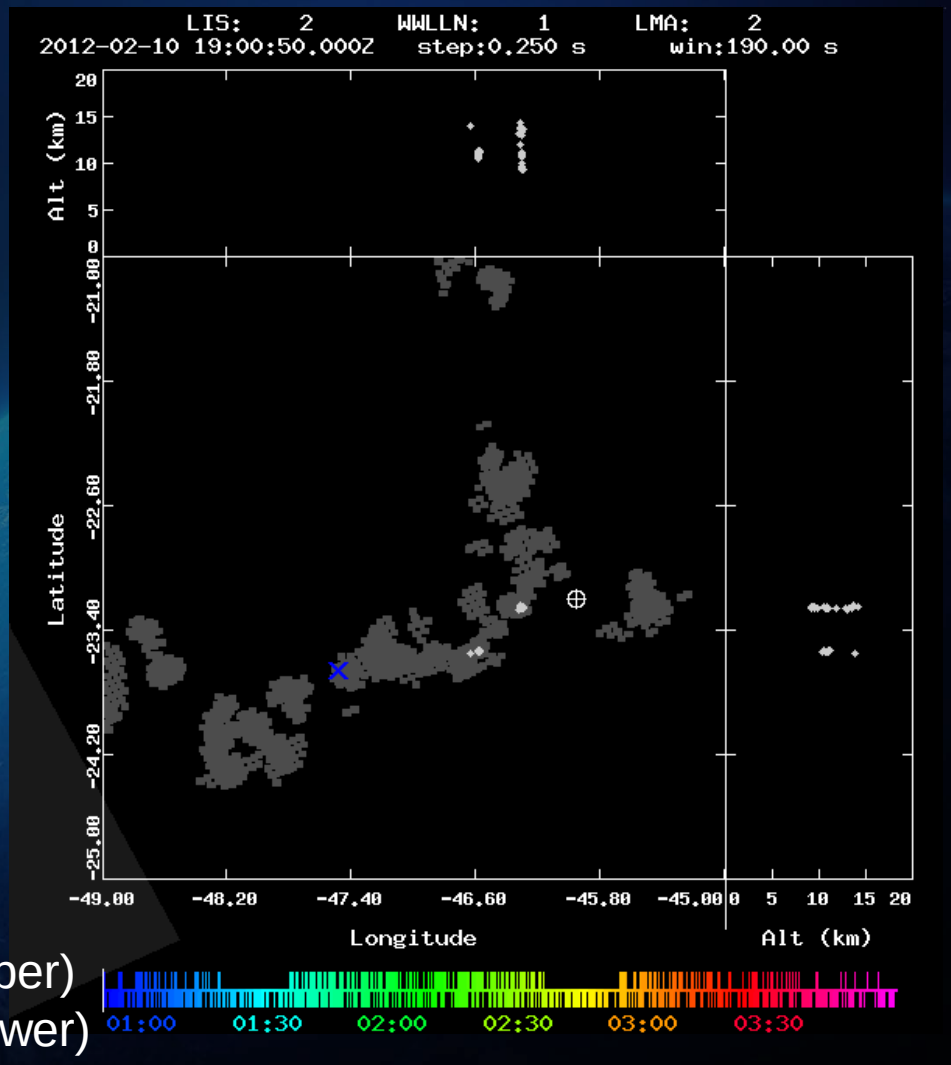


Comparison of Space-Based and Ground-Based Cal/Val Lightning Observations

TRMM/LIS Overpass

February 10, 2012 GLM CHUVA Campaign





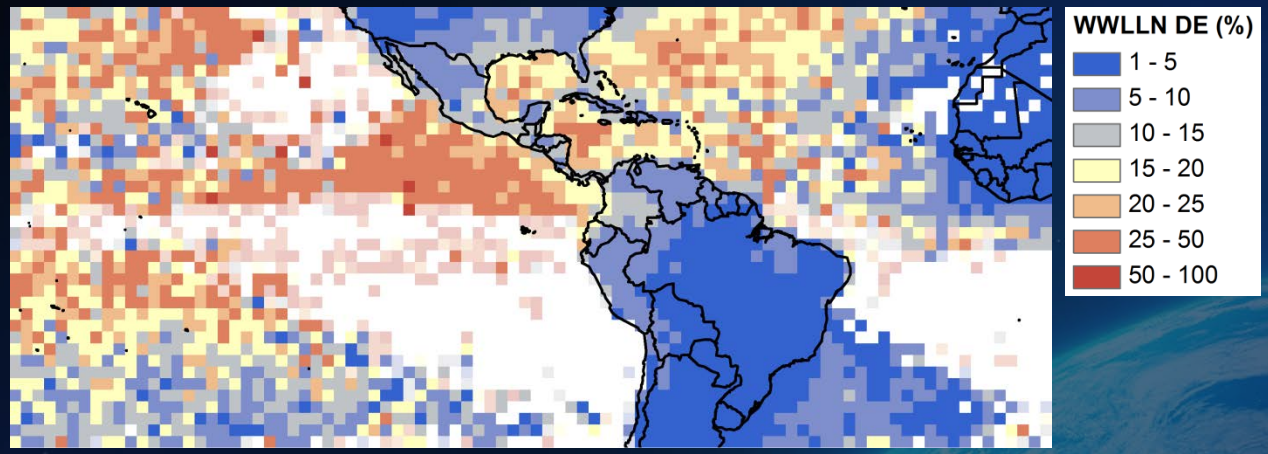
LIS (upper)
LMA (lower)

Jeff Bailey and Monte Bateman

Insert Big Video, CHUVA

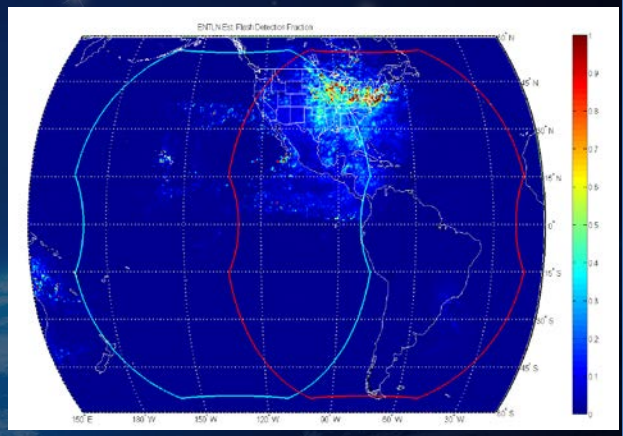
Ground-Based Lightning Network Performance

"Evaluating WWLLN Performance Relative to TRMM/LIS"

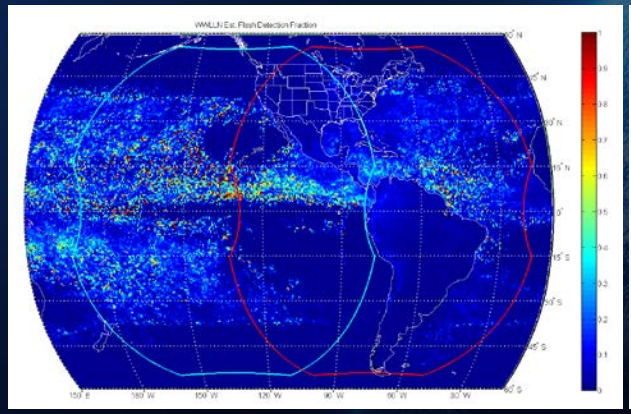


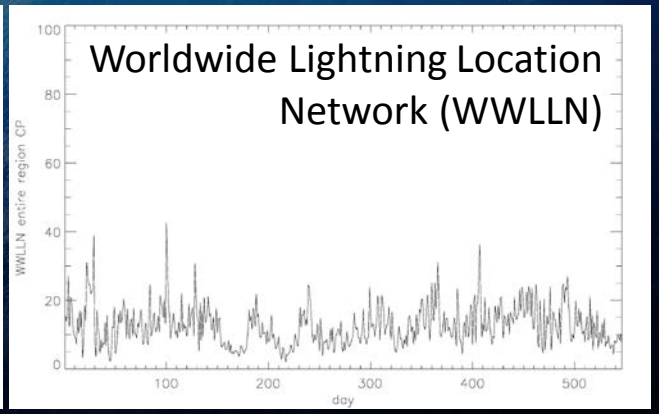
Time Period	Overall	Land	Ocean	North America	South America
2009	6.0	4.0	12.3	8.0	2.3
2010	6.8	4.8	13.9	7.6	4.1
2011	8.1	5.8	15.2	8.7	4.8
2012	9.2	6.4	17.3	10.7	4.9
4YRS	7.5	5.2	14.7	8.7	4.0

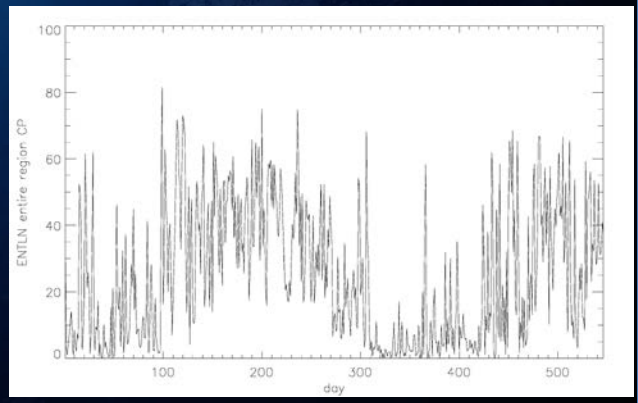
Rudlosky and Shea 2013
Geophys. Res. Letters



Earth Networks Total Lightning Network (ENTLN)







Above: Coincidence fraction and seasonal variability plots courtesy of Kelsey Thompson/UAH and Monte Bateman/USRA

Total Lightning Coincidence
ENTLN and WWLLN compared to LIS

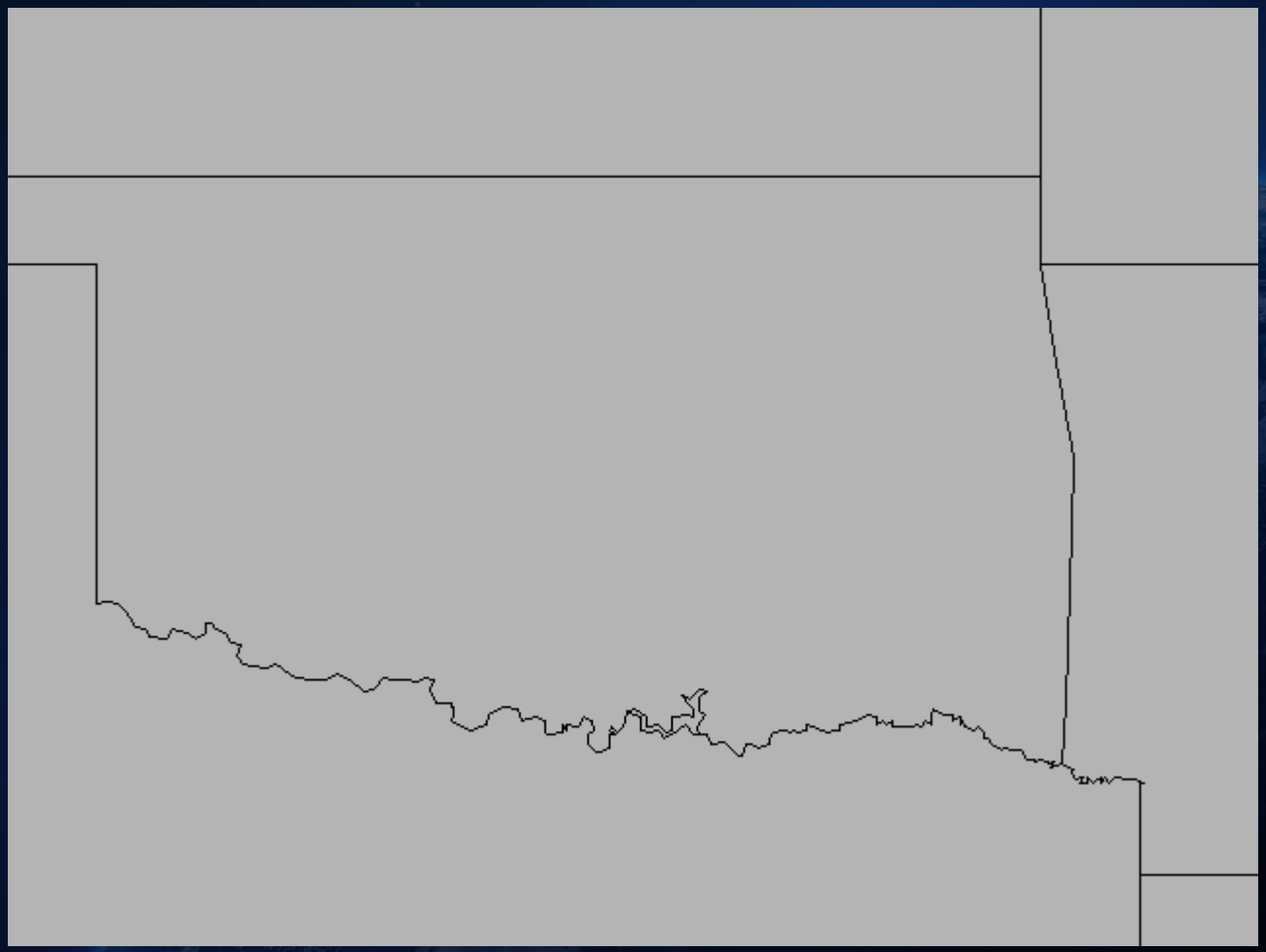
	entire region		North America		South America		Atlantic Ocean		Pacific Ocean	
	WWLLN	ENTLN	WWLLN	ENTLN	WWLLN	ENTLN	WWLLN	ENTLN	WWLLN	ENTLN
Jan-10	14.8	22.4	21.7	69.0	4.7	0.0	21.4	1.6	31.2	13.9
Feb-10	9.6	9.6	27.7	64.5	4.3	0.3	15.2	3.7	28.9	4.8
Mar-10	11.8	15.3	24.5	77.1	7.2	1.0	14.1	1.6	22.6	6.8
Apr-10	14.1	42.6	16.2	76.6	8.5	2.2	12.2	4.6	24.5	3.9
May-10	14.2	40.8	18.8	76.3	7.9	2.5	14.3	1.3	10.8	1.0
Jun-10	6.0	45.8	5.5	56.4	5.7	3.0	12.4	2.3	14.9	0.9
Jul-10	9.5	47.4	9.7	64.0	7.3	4.4	14.6	17.6	15.7	1.9
Aug-10	7.6	37.7	7.6	50.8	5.2	4.2	16.0	13.1	13.3	0.2
Sep-10	8.3	31.2	11.9	67.5	4.3	1.4	13.8	3.9	13.1	1.3
Oct-10	10.6	20.3	21.7	69.0	4.3	2.4	19.9	3.5	17.5	0.8
Nov-10	10.3	7.5	21.1	72.4	5.6	0.9	16.0	1.3	20.5	1.3
Dec-10	13.8	6.1	30.8	65.4	8.2	0.8	16.6	2.4	20.9	0.6
Jan-11	12.1	8.7	29.6	68.6	5.5	1.3	23.4	2.4	21.9	2.0
Feb-11	13.4	8.6	29.3	73.9	8.7	4.3	21.3	0.9	18.2	1.3
Mar-11	16.3	35.6	21.0	82.1	8.7	2.4	20.9	0.1	23.0	1.9
Apr-11	13.0	34.6	19.5	75.3	6.0	5.7	9.7	0.0	16.9	1.6
May-11	13.6	42.4	13.7	60.6	11.5	5.0	15.0	0.6	15.6	2.3
Jun-11	8.0	34.3	7.6	48.1	8.0	8.5	13.6	0.8	8.9	1.6
18 months	11.0	28.5	13.2	63.3	6.2	2.2	16.4	3.0	18.9	2.5

Kelsey Thompson

Total lightning (coincidence percent) observed by the Lightning Imaging Sensor over the GLM fov from 164E to 17W bounded by LIS observations within 39 deg of the equator, that was also observed by ENTLN and WWLLN.

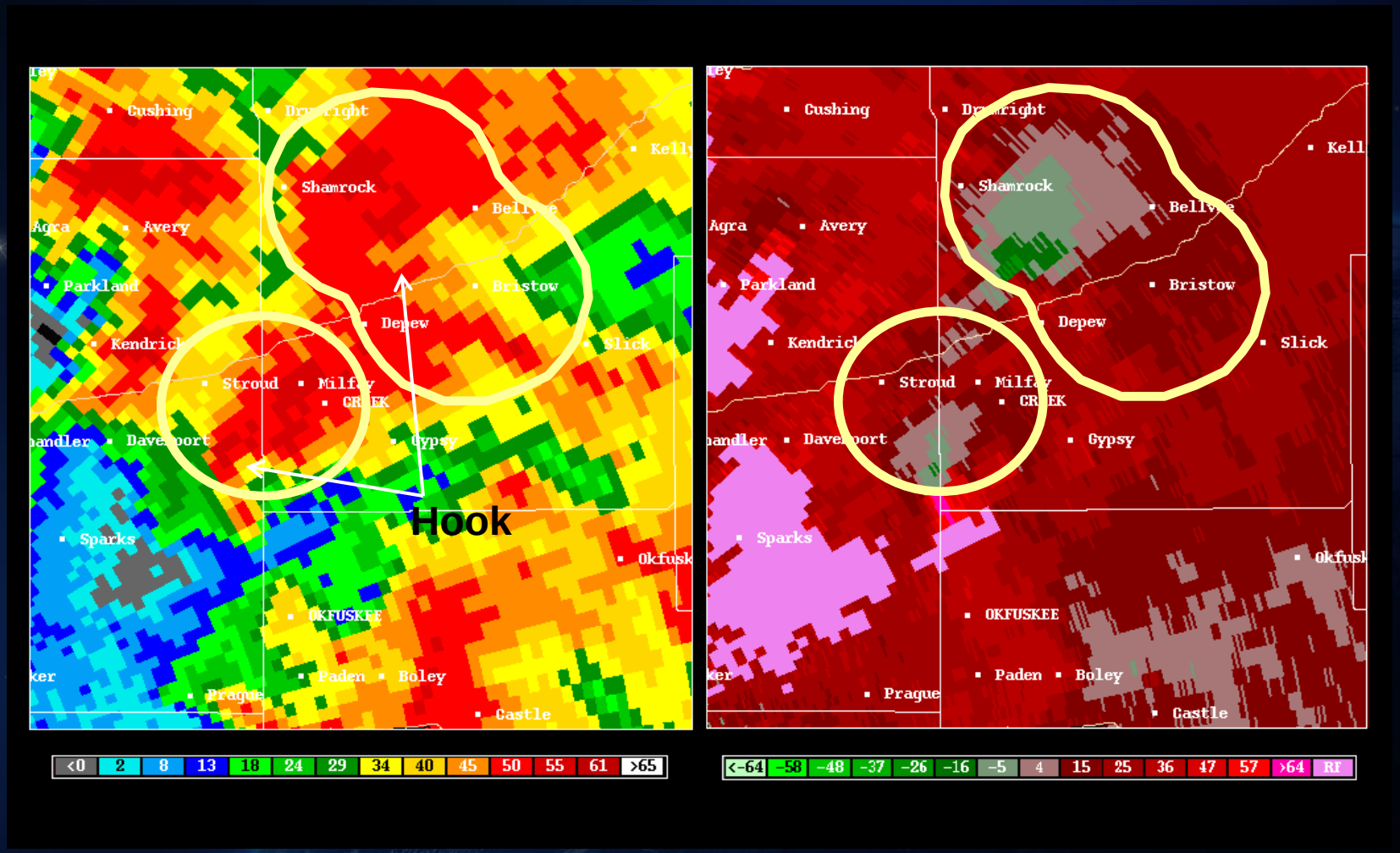
GLM View of MCS

1-min TRMM/LIS overpass, May 3, 1999 tornado outbreak



OK Tornado Outbreak 3 May 1999

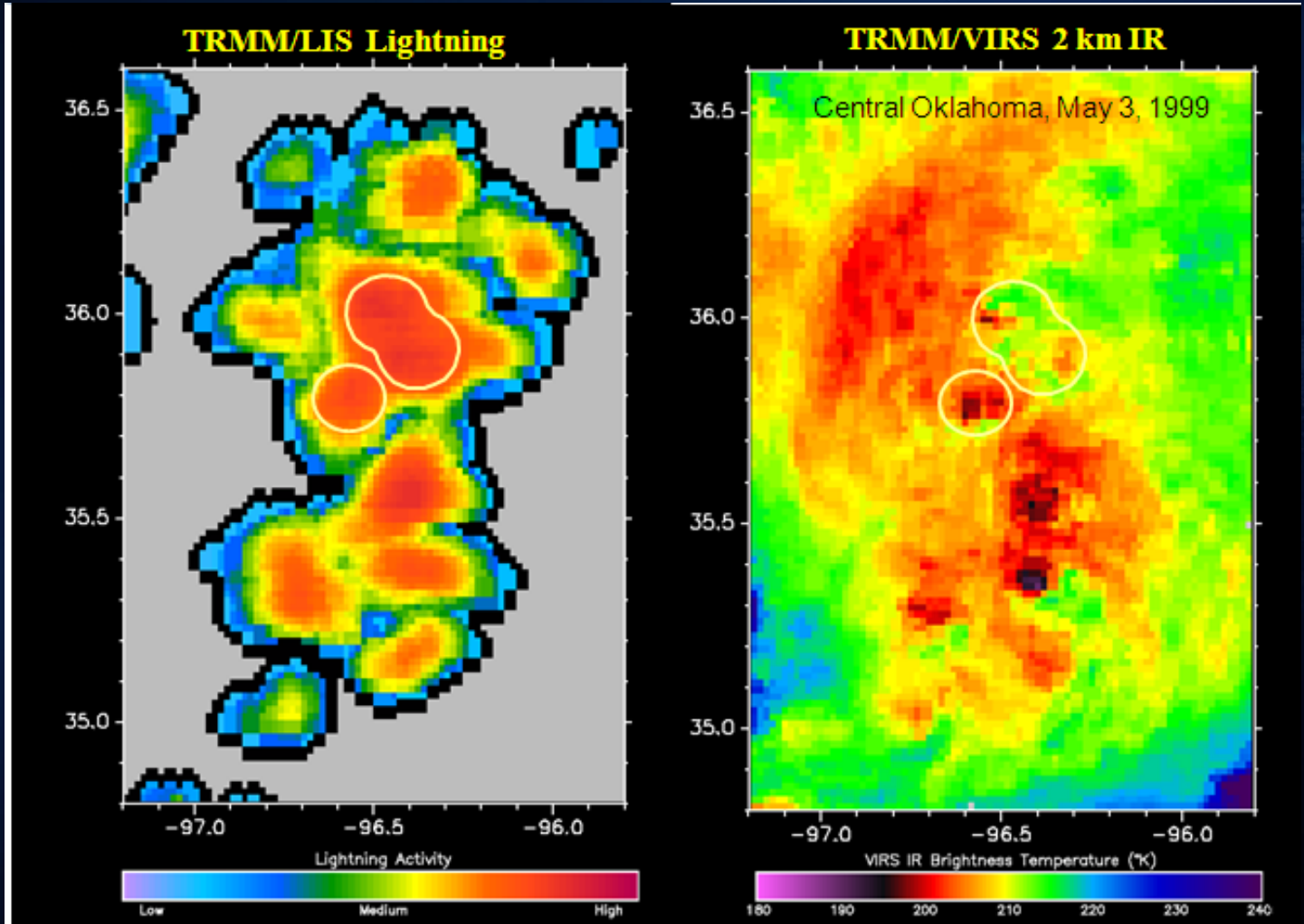
NEXRAD Reflectivity **NEXRAD Velocity**



Active lightning region in tornadic supercell … correlates with radar hook echo and velocity couplet

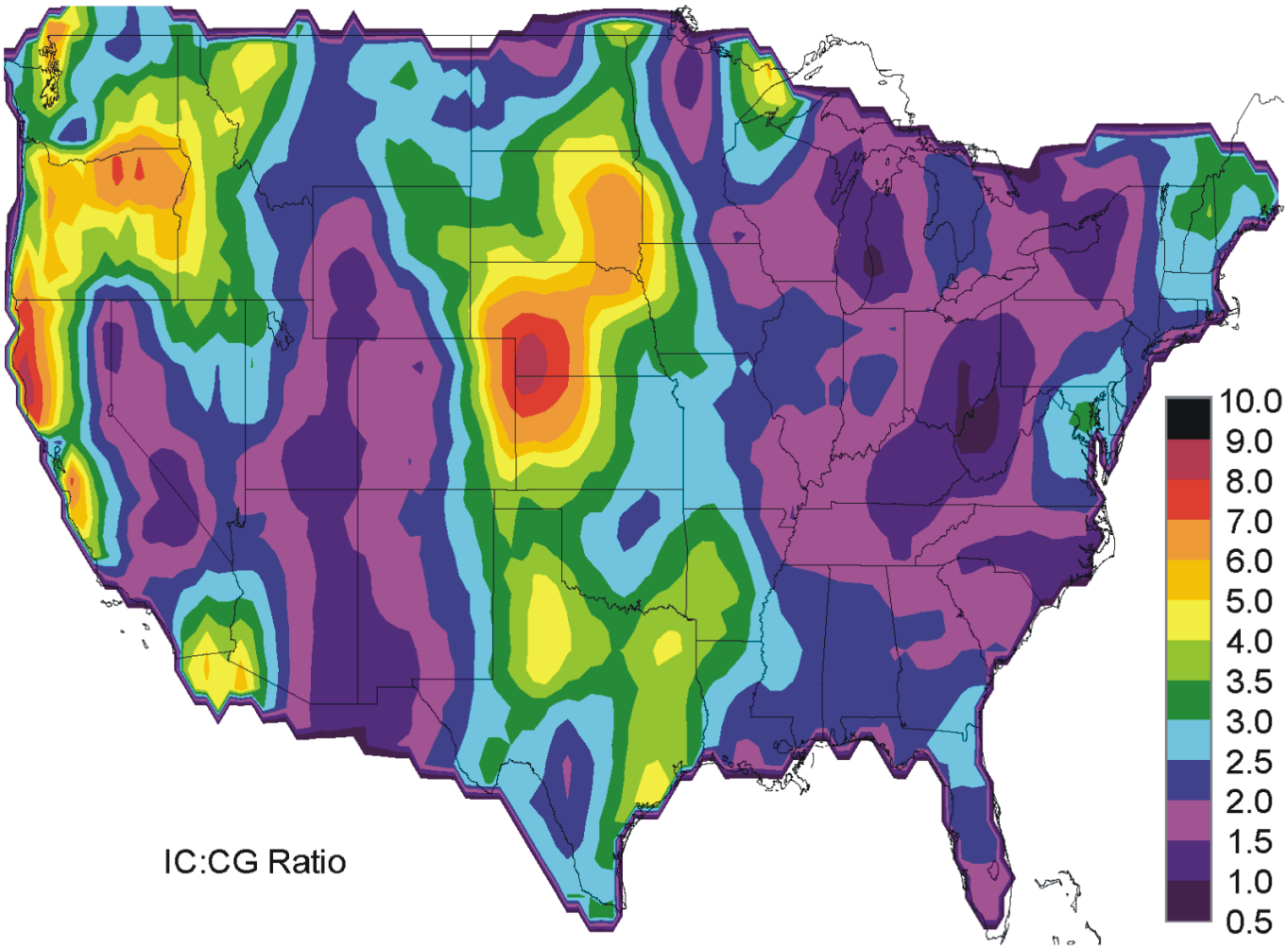
Total Lightning During OK Tornado Outbreak

GLM and ABI Combined (with radar) characterizes storm intensification and decay)



In-cloud lightning dominates tornadic supercell ... 95% of the lightning is in-cloud

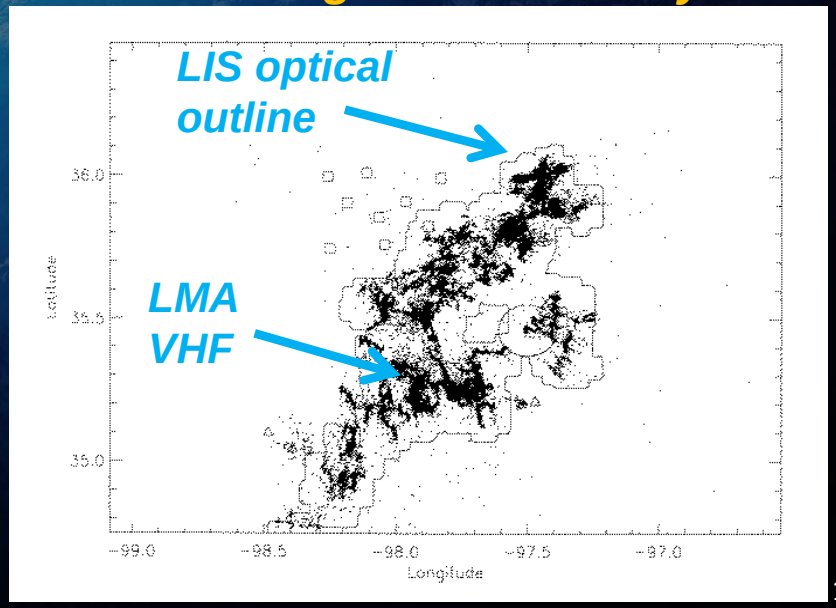
Cloud Flash to Ground Flash Ratio



GLM Validation Data

- **Ground Truth Datasets:**
  - Short-Medium Range Lightning
    - LMA North Alabama (NASA-NOAA), DC (NASA-NOAA), Oklahoma (OU CIMMS-NSSL), West Texas (TTU), NMTech, Camp Blanding (UF-DARPA), Colorado Front Range (CSU), Houston (TAMU), NASA-KSC and Wallops, Atlanta (GTRI)
    - HAMMA/Delta E Array (North Alabama)
    - High Speed Video Cameras
    - KSC Field Mills (KSC Florida)
    - NLDN (CONUS)
  - Long Range Lightning
    - GLD360
    - WWLLN
    - ENTLN

Building the GLM Proxy



GLM Validation Data (cont.)

- **Airborne GLM Simulator**
  - Airborne high resolution optical (and electrical) measurements as a GLM simulator.
  - Deploy on aircraft (e.g., ER2, Global Hawk) to observe cloud-top lightning pulses (field campaigns of opportuntity- 2016, 2017).
- **Satellite Observations**
  - LIS
    - GLM proxy data development
    - Pre-launch validation simulations (including val tool testing)
    - LIS on International Space Station (ISS LIS, launch 2016)-transfer radiometer
    - TRMM Extended Mission
  - TARANIS (Tool for the Analysis of RAdiation from lightNIng and Sprites)
    - Launch 2015, CNES/France; nadir staring (2 cameras, 4 photometers)
    - Directly compare with GLM data

Credit: CNES/Ill. D. Ducros

- **Cross-Calibration Between GLM and MTG LI (at 777.4 nm)**

Summary

- The key attributes of a total lightning monitor for data QC and for forecaster use
  - Detection Efficiency
  - Stability
  - Consistency
  - Accuracy
- Cal/Val tools in Development for Monitoring GLM Performance and for comparison with ground-based measurements/networks
- Pre-launch demonstrations with GLM proxy data benefits users to prepare them to fully exploit all GOES-R instruments and capabilities

QUESTIONS?