Recent Lightning Studies at NESDIS/STAR and CICS-MD

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GLM Science Meeting
Huntsville, AL, 24-26 September 2013

Finally published the last of my dissertation research

- Decorrelation times are found to vary by parameter, storm severity, and mathematical operator, but the great majority are between three and six lags, suggesting that consecutive 2-min storm samples are effectively independent after only 6–12 min.
- The 2σ lightning jump algorithm yields 0.92 jumps h^{-1} for non-severe storms and 1.44 jumps h^{-1} in severe storms.
- Applying a 10-mm maximum expected size of hail (MESH) threshold to the 2σ lightning jump algorithm reduces the frequency of lightning jumps in non-severe storms to 0.61 jumps h^{-1}.

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Documenting Storm Severity in the Mid-Atlantic Region Using Lightning and Radar Information

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(Manuscript received 2 October 2012, in final form 17 January 2013)

ABSTRACT

Storm severity in the mid-Atlantic region of the United States is examined using lightning, radar, and model-derived information. Automated Warning Decision Support System (WDSS) procedures are developed to create grids of lightning and radar parameters, cluster individual storm features, and data mine the lightning and radar attributes of 1252 severe and nonsevere storms. The study first examines the influence of serial correlation and uses autocorrelation functions to document the persistence of lightning and radar parameters. Decorrelation times are found to vary by parameter, storm severity, and mathematical operator, but the great majority are between three and six lags, suggesting that consecutive 2-min storm samples (following autocorrelation) are effectively independent after only 6–12 min. The study next describes the distribution of lightning jumps in severe and nonsevere storms, differences between various types of severe storms (e.g., severe wind only), and relationships between lightning and radar parameters. The 2σ lightning jump algorithm (with a 10 flashes min^{-1} activation threshold) yields 0.92 jumps h^{-1} for nonsevere storms and 1.44 jumps h^{-1} in severe storms. Applying a 10-mm maximum expected size of hail (MESH) threshold to the 2σ lightning jump algorithm reduces the frequency of lightning jumps in nonsevere storms to 0.61 jumps h^{-1}. Although radar-derived parameters are comparable between storms that produce severe wind plus hail and those that produce tornadoes, tornadic storms exhibit much greater intracloud (IC) and cloud-to-ground (CG) flash rates. Correlations further illustrate that lightning data provide complementary storm-scale information to radar-derived measures of storm intensity.

1. Introduction

Advances in lightning datasets and storm analysis techniques are improving our understanding of relationships between storm-scale processes and lightning production. The emergence and expansion of total lightning datasets hold great promise for researchers and operational forecasters. Darden et al. (2010) found that incorporating real-time total lightning data into severe weather forecasting procedures improved warning confidence, and suggested potential improvement in short-term warning lead times. However, they also noted the limited use of lightning information in the National Weather Service (NWS) convective warning program. They suggested that this was due to the lack of total lightning information at regional and national scales, limited knowledge about relationships between lightning and severe weather, and a cultural legacy of perceiving lightning data as less important than traditional radar and satellite products.

Many studies have shown that sudden increases in intracloud (IC) lightning flash rate, colloquially known as lightning jumps, often precede severe weather occurrence[1] (e.g., Goodman et al. 1988; MacGorman et al. 1989; Williams et al. 1989, 1999; Buechler et al. 2000; Lang et al. 2000; Goodman et al. 2005; Wiens et al. 2005; Tessendorf et al. 2007; Steiger et al. 2007; Gatlin and Goodman 2010; Darden et al. 2010; Schultz et al. 2009, 2011). The lightning jump signature is a useful proxy for identifying strengthening updrafts and increasing storm

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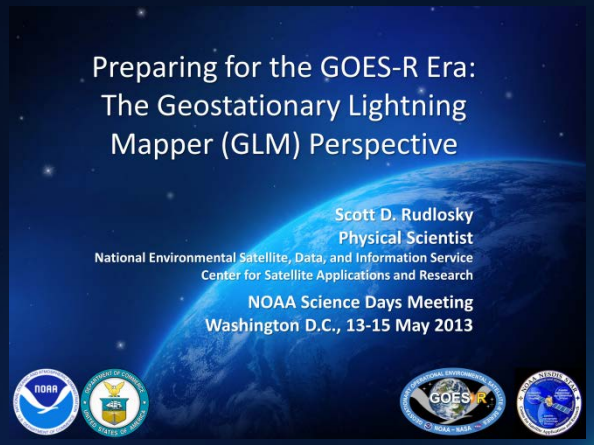
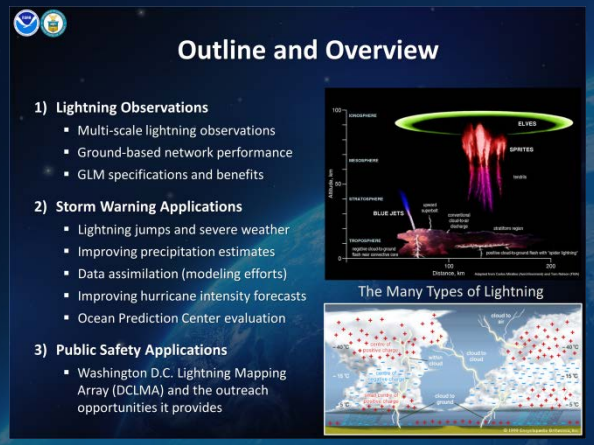
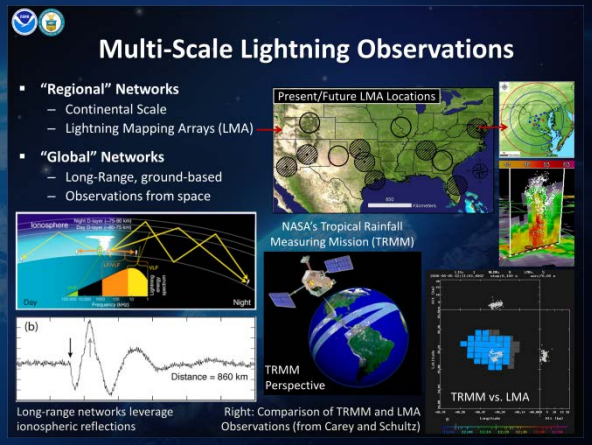
[1] As presently defined by the U.S. NWS, that is, thunderstorms with at least one tornado, hail ≥1 in. (2.54 cm), and/or winds ≥ 58 mi h^{-1} (93.3 km h^{-1}).

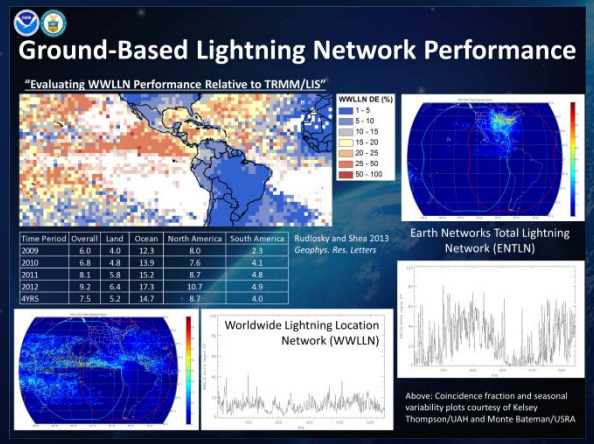
NOAA Science Days 2013

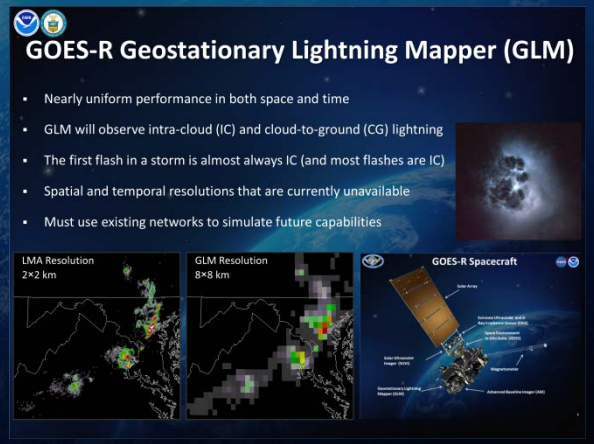
- *"Innovative Science and Technology for Global Observing"*
- Presented both in D.C. and Silver Spring, MD

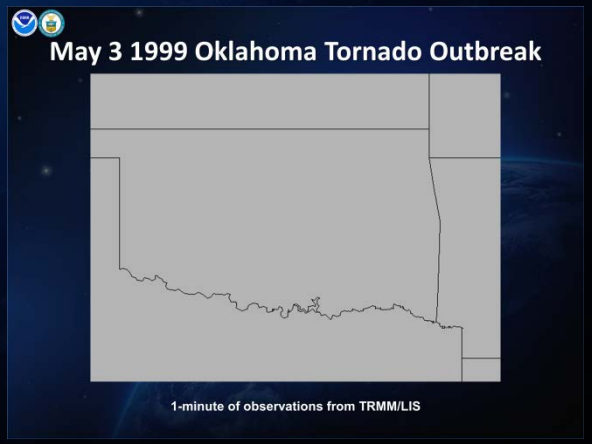












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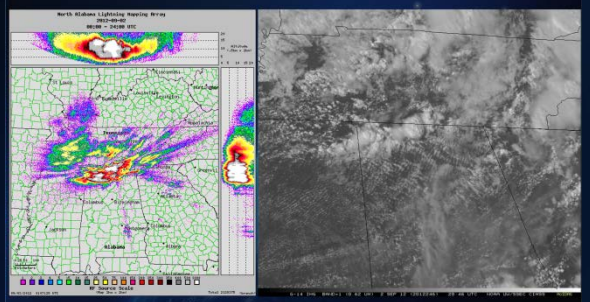
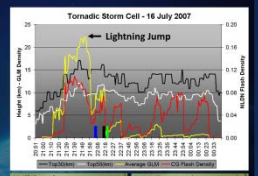
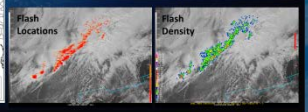
GOES-14 Super-Rapid Scan (SRSOR) Experiment



GLM Mission Benefits

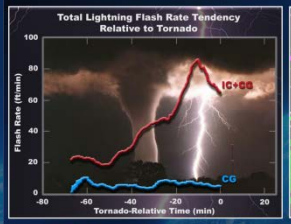
- Lightning Jumps in Severe Storms
- Improving Satellite Precipitation Estimates
- Lightning Data Assimilation (Modeling Efforts)
- Improving Tropical Cyclone Intensity Forecasts
- Evaluation at NWS Ocean Prediction Center (OPC)

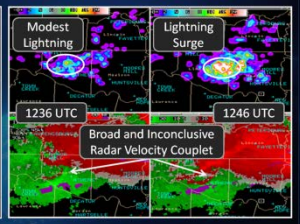




Lightning Jumps and Severe Storms

Improved situational awareness and forecaster confidence results in more accurate severe storm warnings (i.e., improved lead times and reduced false alarms)





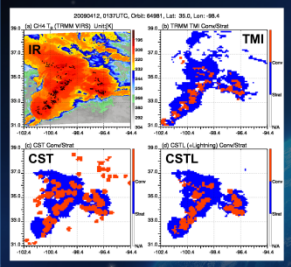
Schultz et al. 2011

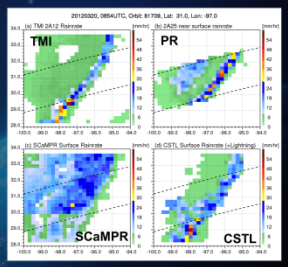
- Using lightning data alone, predicted severe weather with 20.65 min lead time
- 79% probability of detection (POD)
- 36% false alarm rate (FAR)

Rudlosky et al. 2013

- Severe = 1.44 jumps h^{-1}; Non-severe = 0.92 jumps h^{-1}
- Adding a 10 mm Maximum Expected Size of Hail (MESH) threshold:
  Severe = 1.25 jumps h^{-1}; Non-severe = 0.61 jumps h^{-1}

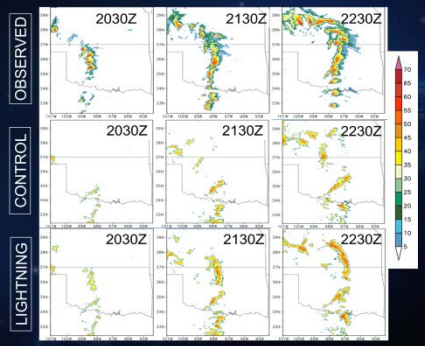
Improving Satellite Precipitation Estimates





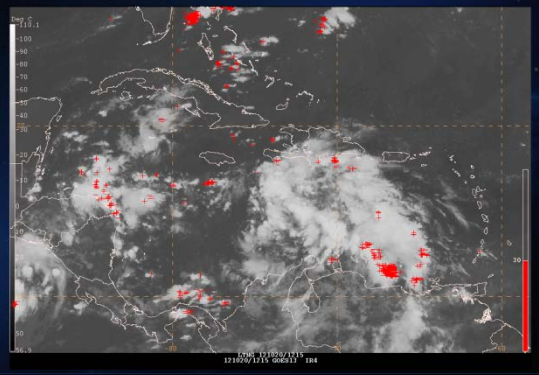
- **Adler et al.** – Convective Stratiform Technique (CST) is confused by thick cirrus, thick anvil debris, or large Mesoscale Convective System (MCS) cloud shields.
- Lightning information consistently improved convective detection (POD) by 8% and lowered false alarm rate (FAR) by 30%.

Lightning Data Assimilation (Modeling Efforts)



Courtesy of A. Fierro, CIMSS/NOAA

Improving Tropical Cyclone Intensity Forecasts



NOAA Science Days 2013

Lightning Product Evaluation at OPC

- **GOES-R Proving Ground Project**
  - Create flash density grids at GLM resolution using a ground-based network (i.e., GLD360)
- **Evaluation during Summer 2013**
  - Develop training materials, shadow forecasters, and compose report
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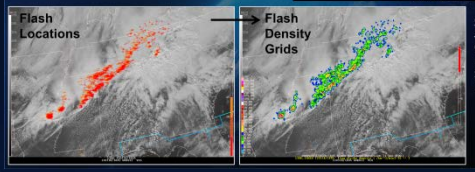
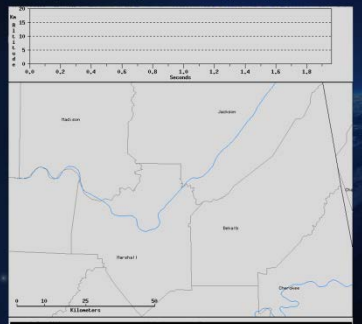


Collaborators
Joe Sienkiewicz
Greg McFadden
Michael Folmer
Scott Rudlosky
Dustin Shea

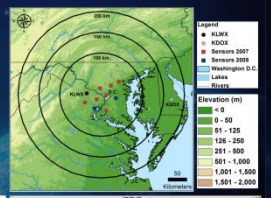
GLM Lightning Safety Applications

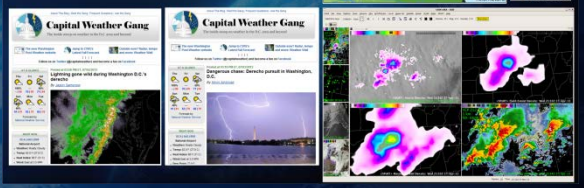


Large horizontal extent of a single lightning flash

Washington D.C. Lightning Mapping Array

- DCLMA is a GOES-R Proving Ground Project
- Provides Outreach Opportunities
- COMET Collaborative Research Project
  - University of Maryland and NWS WFO Sterling, VA
- Washington Post's Capital Weather Gang





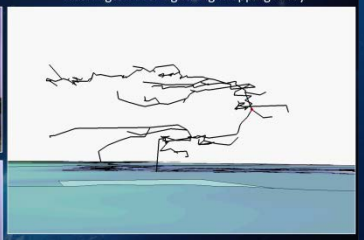
Dissecting a Derecho Bolt, More to Lightning than Meets the Eye (Lens)

Washington Post's Capital Weather Gang – 19 July 2012
Kevin Ambrose and Scott Rudlosky

Lightning flash as seen by…

CWG Photographer Kevin Ambrose

Washington D.C. Lightning Mapping Array



"The folks at @capitalweather have ascended to a new realm of geekery w/ this mind-blowing dissection of lightning: http://t.co/3WEfyTE5"

Summary

- The GLM will provide total lightning observations at spatial and temporal scales that are currently unavailable
- Presently using ground-based networks to prepare forecasters and the general public for the GOES-R era
- **Many applications will benefit from GLM operations**
  - Lightning jumps and severe weather
  - Improving precipitation estimates
  - Data assimilation (modeling efforts)
  - Hurricane Intensity Forecasts
  - National Weather Service Operations
- **GOES-R will help improve public safety**
  - Airport operations
  - Recreational activities
  - Sporting events

NOAA Science Days Summary

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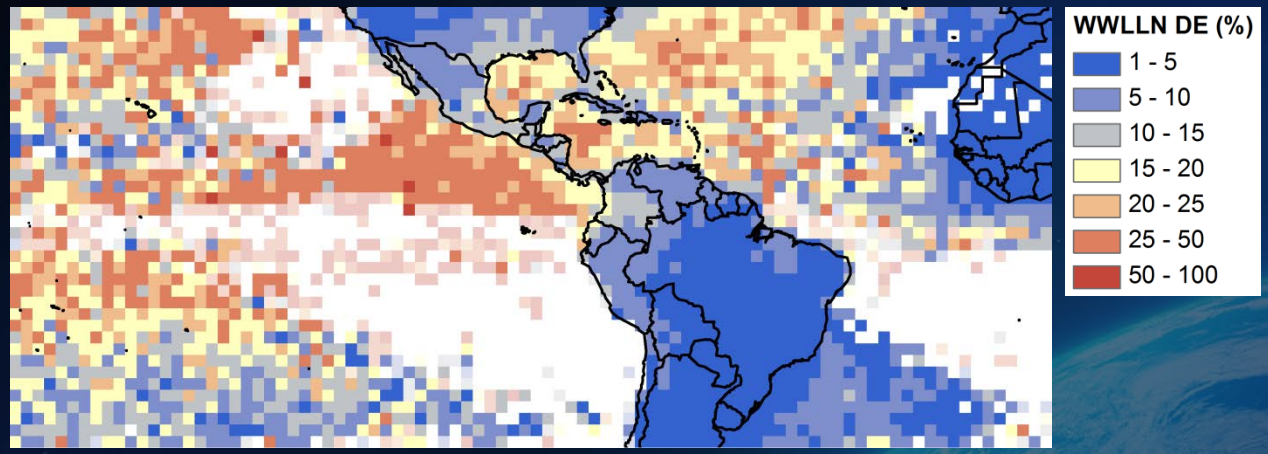
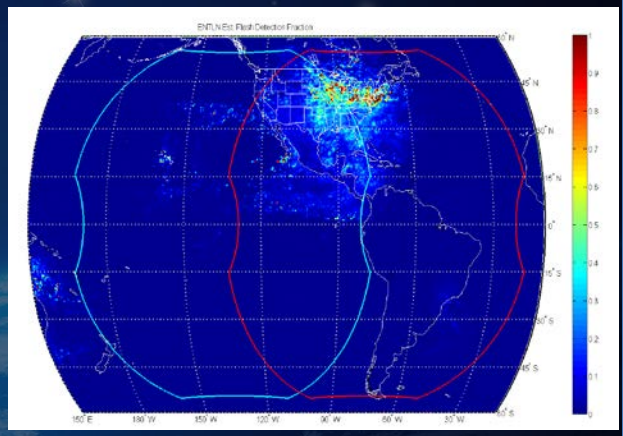
Ground-Based Lightning Network Performance

"Evaluating WWLLN Performance Relative to TRMM/LIS"

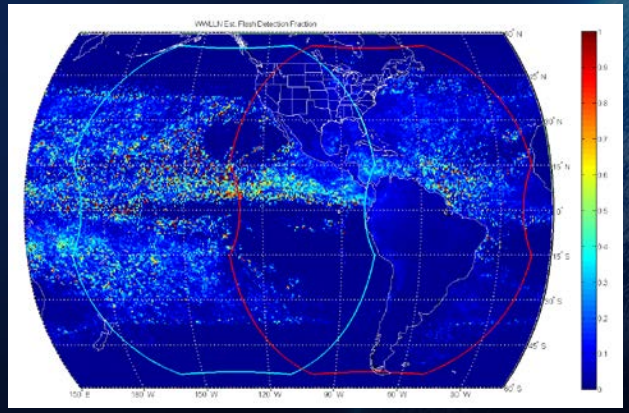


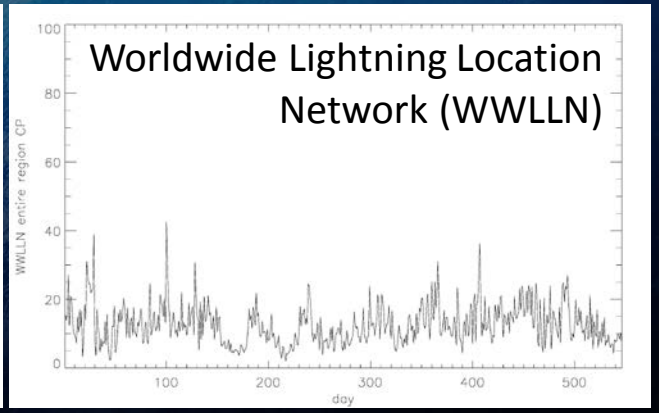
Time Period	Overall	Land	Ocean	North America	South America
2009	6.0	4.0	12.3	8.0	2.3
2010	6.8	4.8	13.9	7.6	4.1
2011	8.1	5.8	15.2	8.7	4.8
2012	9.2	6.4	17.3	10.7	4.9
4YRS	7.5	5.2	14.7	8.7	4.0

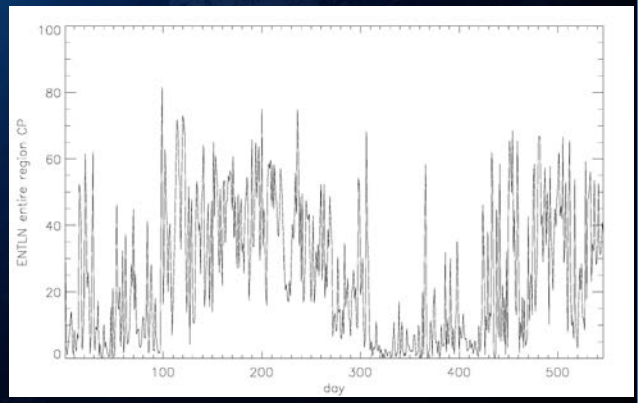
Rudlosky and Shea 2013
Geophys. Res. Letters



Earth Networks Total Lightning Network (ENTLN)







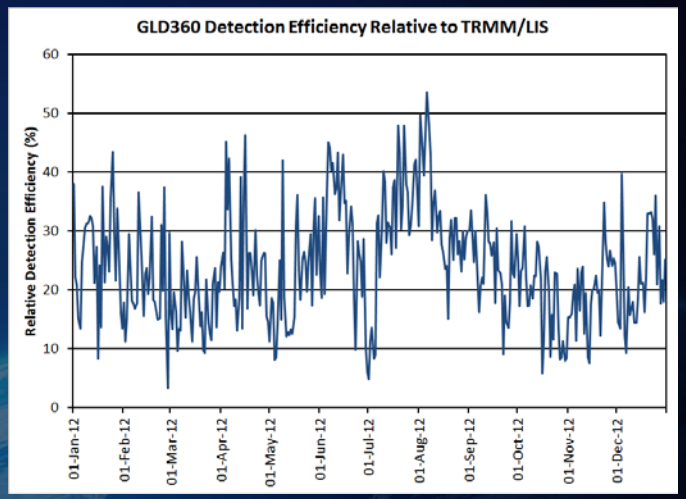
Above: Coincidence fraction and seasonal variability plots courtesy of Kelsey Thompson/UAH and Monte Bateman/USRA

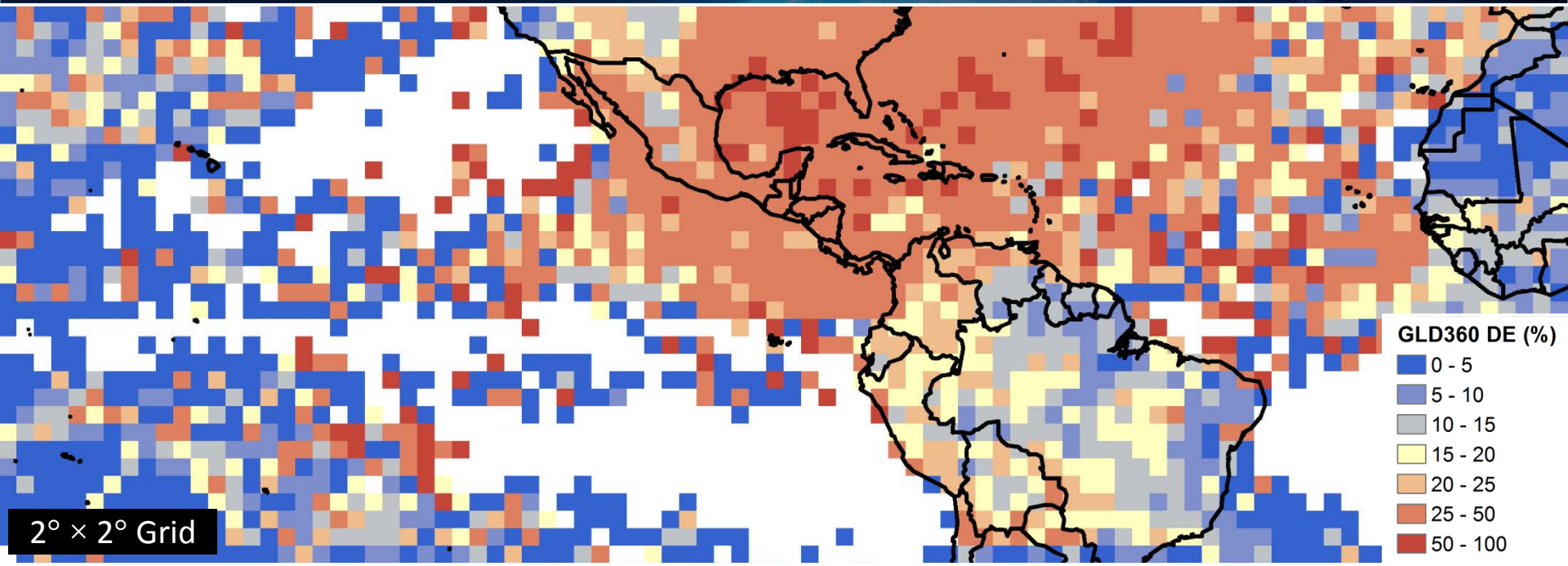
GLD360 Analysis (2012)

- GLD360 performance relative to the TRMM Lightning Imaging Sensor (LIS)
- White grid cells indicate no LIS flashes

Metric	GLD360
DE (%)	25.3
LD (km)	12.6
Multiplicity	1.85

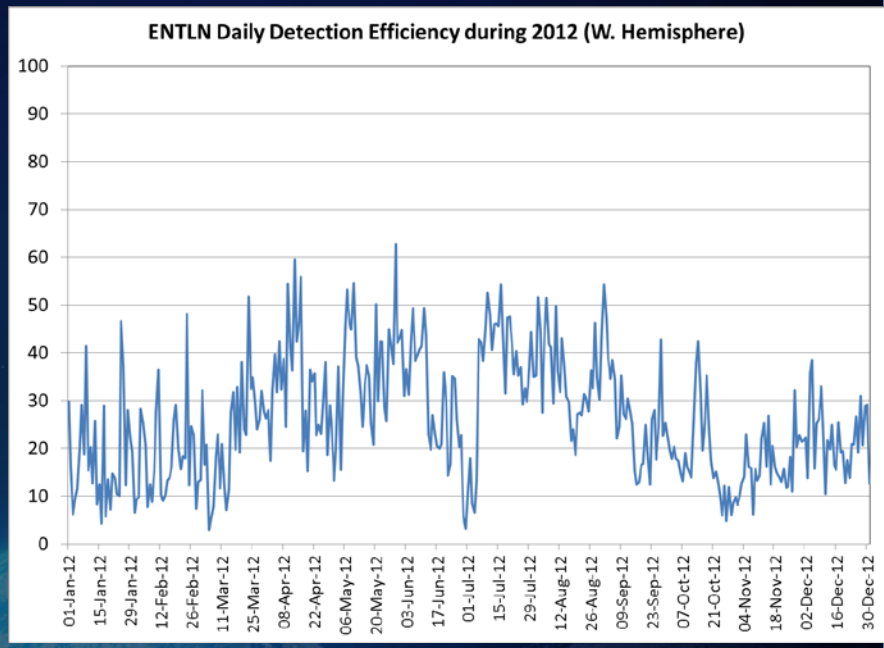
Regional DE (%)	GLD360
North America	33.4
South America	17.5
Oceans	33.0

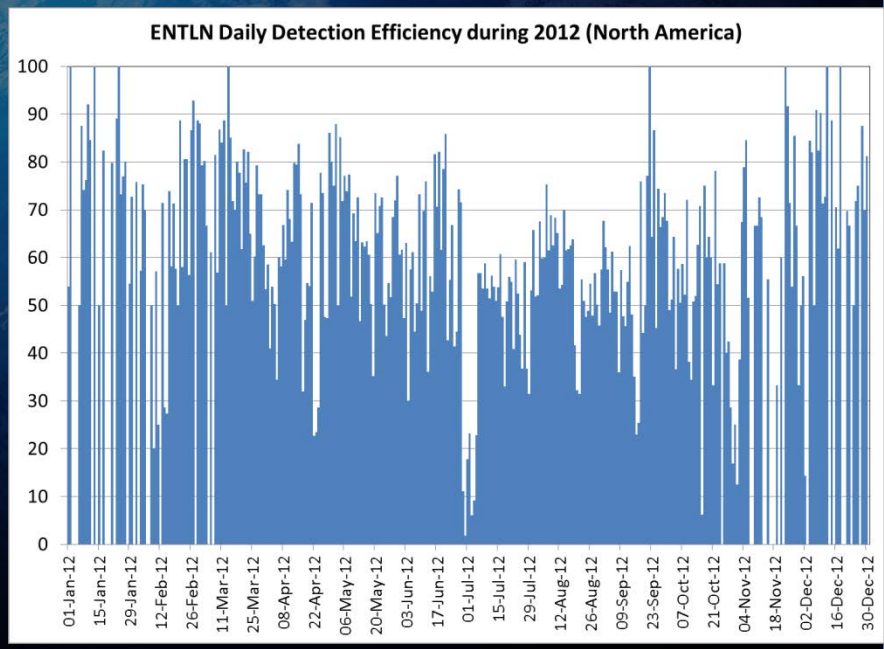




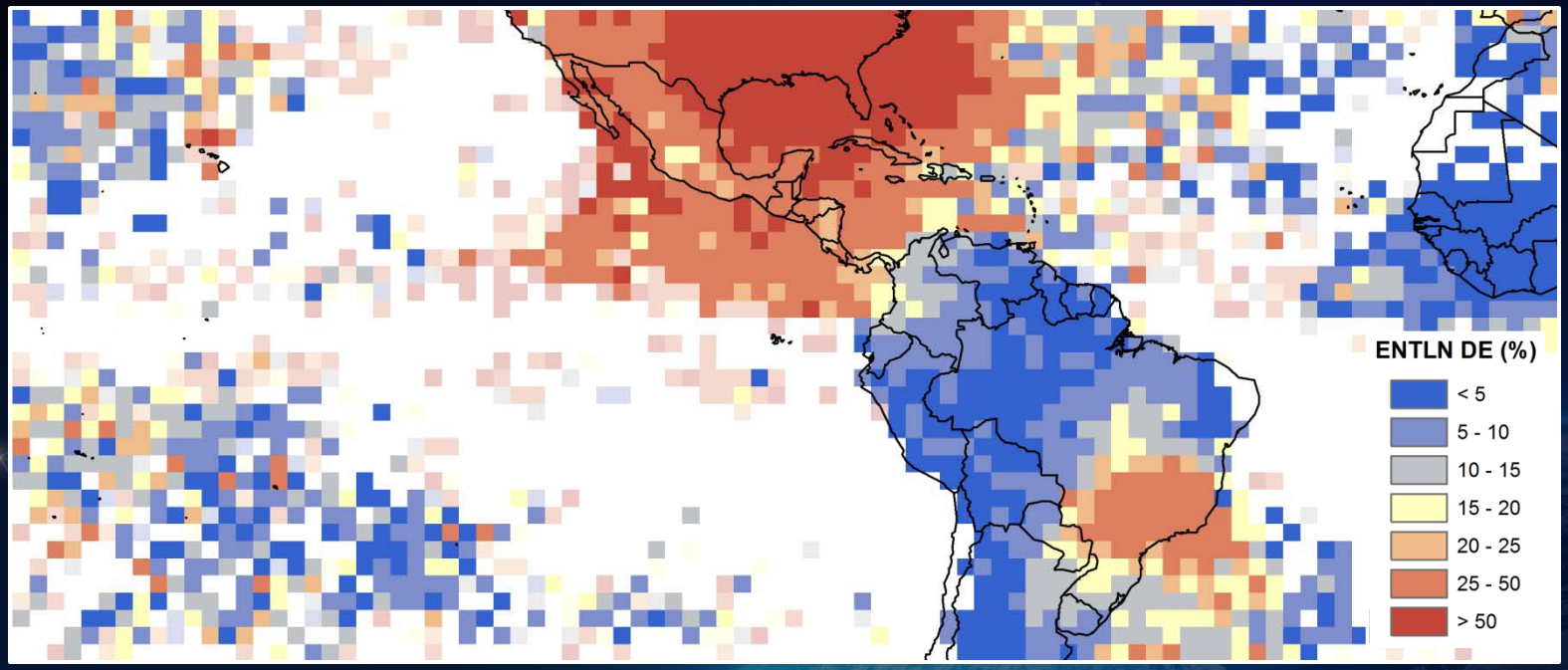
ENTLN Performance during 2012

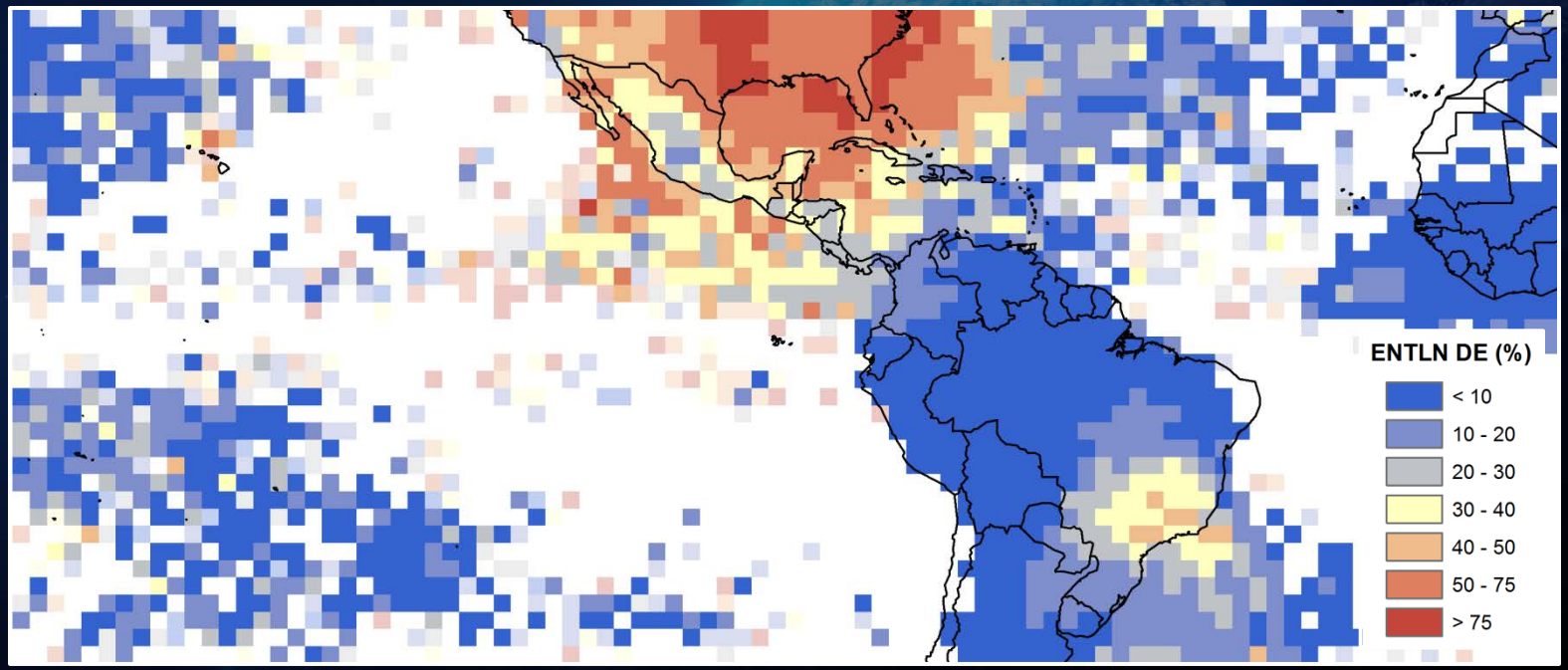
- Relative to the TRMM/LIS, which observes "total lightning" between 38.5°N and 38.5°S
- Relative Detection Efficiency
  - W. Hemisphere – 26.3%
  - North America – 55.6%
  - South America – 10.9%
  - Oceans – 34.0%
- Average location offset – 10.7 km
- Note that for North America some of the very high/low numbers during winter occur on days with few coincident flashes





ENTLN Detection Efficiency Relative to TRMM/LIS (2012 - note the different scales)



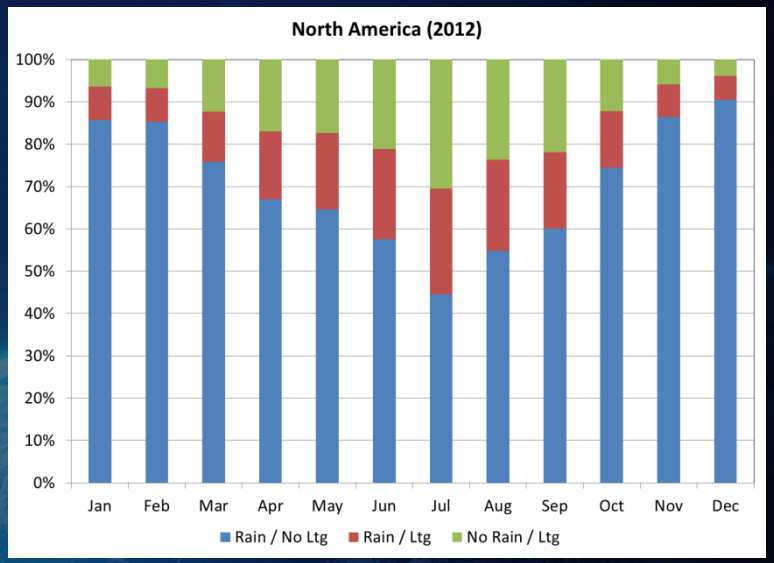


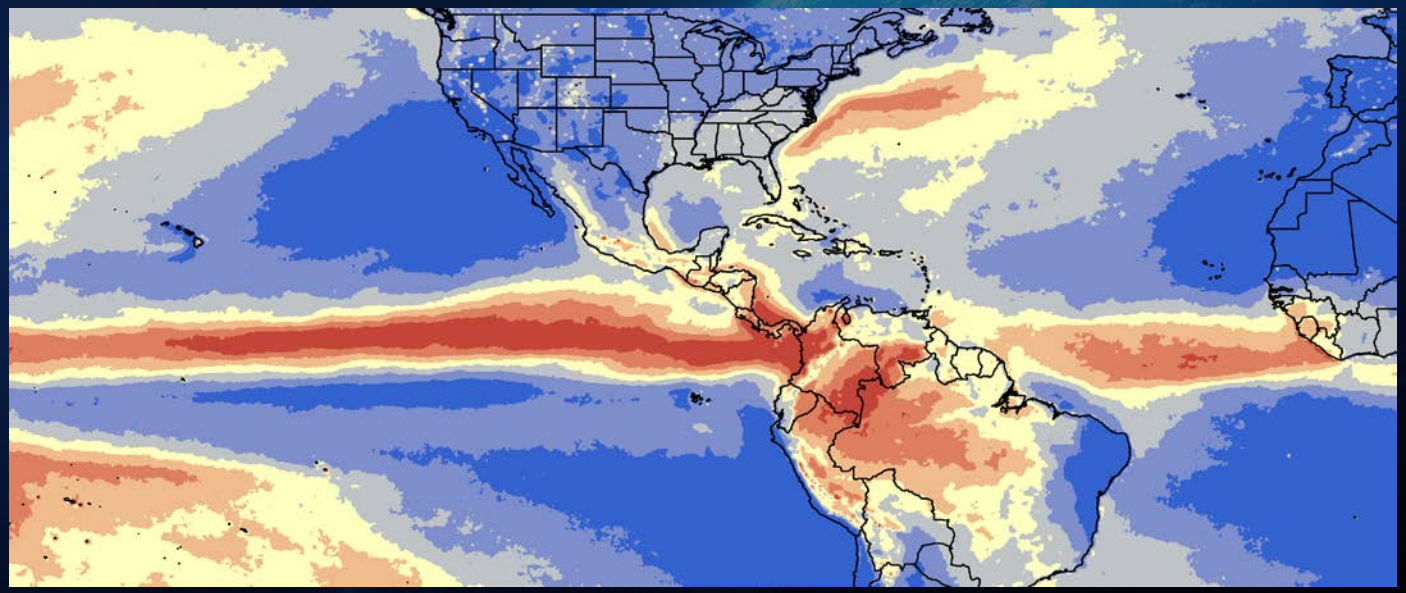
Brightness reduced for pixels with less than 15 LIS flashes

Created by Scott Rudlosky (NOAA)

Comparing Satellite Precipitation Estimates with Lightning Information

- Compared TRMM TMPA (3B42RT) with GLD360 at 3 h intervals
- Original purpose was to characterize the occurrence of dry thunderstorms
- Bonus – Evaluation of both satellite precipitation estimates and lightning datasets

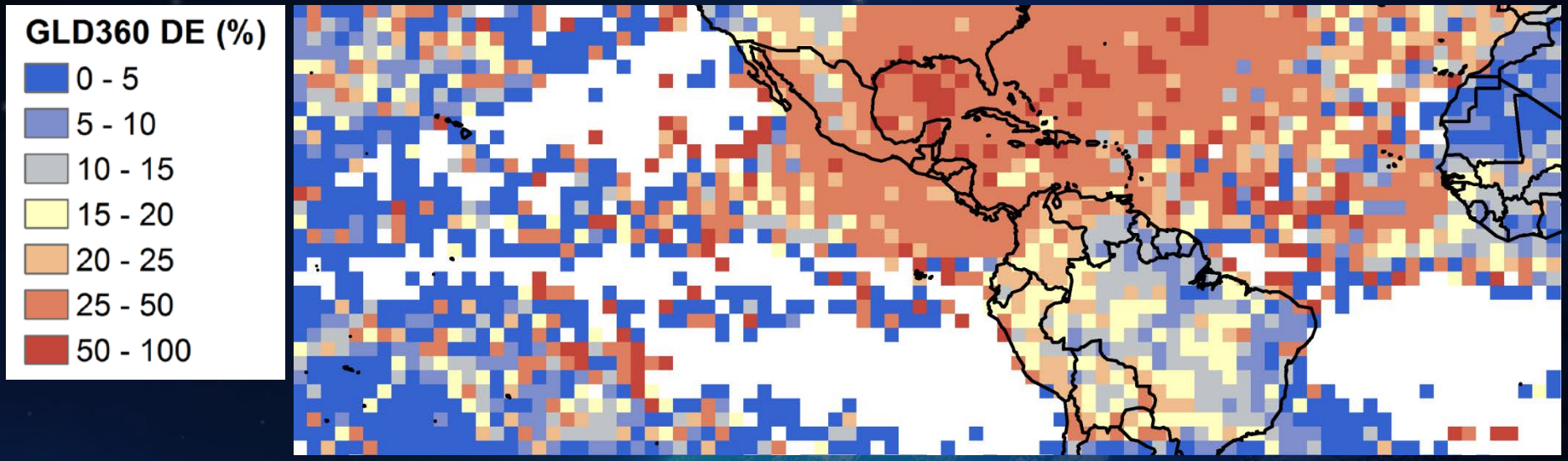


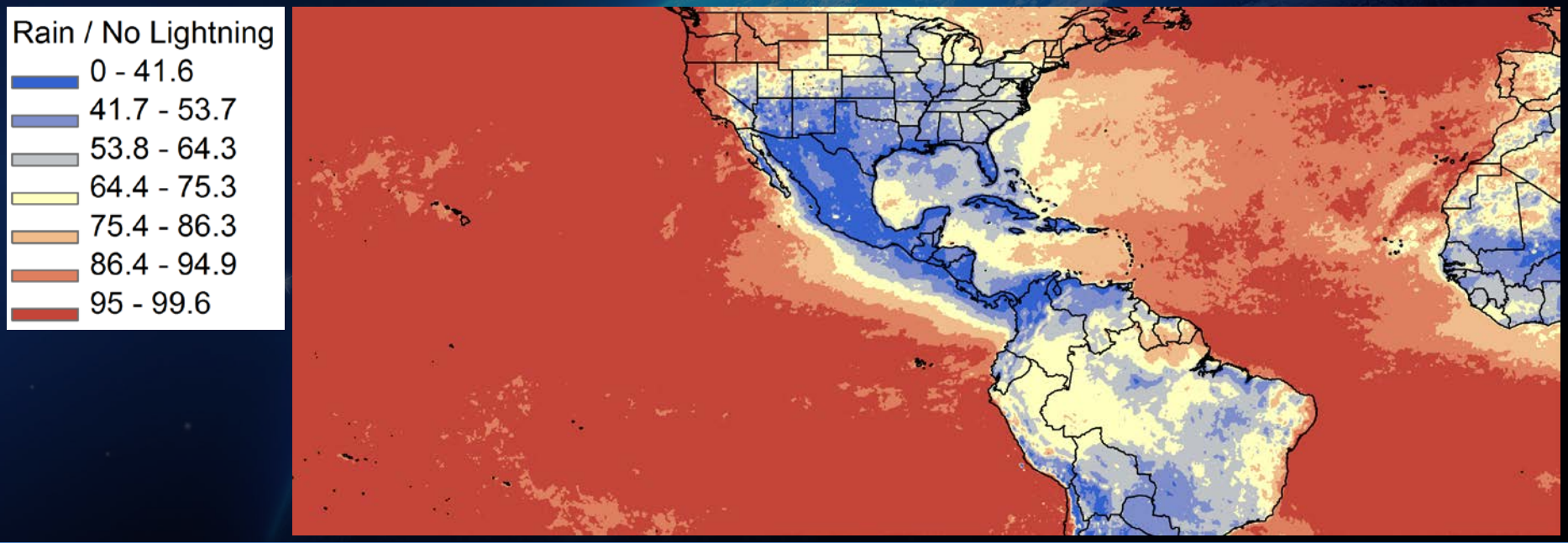


No Rain / No Lightning
- 52.3 - 74.4
- 74.5 - 79.6
- 79.7 - 84.1
- 84.2 - 88
- 88.1 - 91.8
- 91.9 - 95.5
- 95.6 - 100

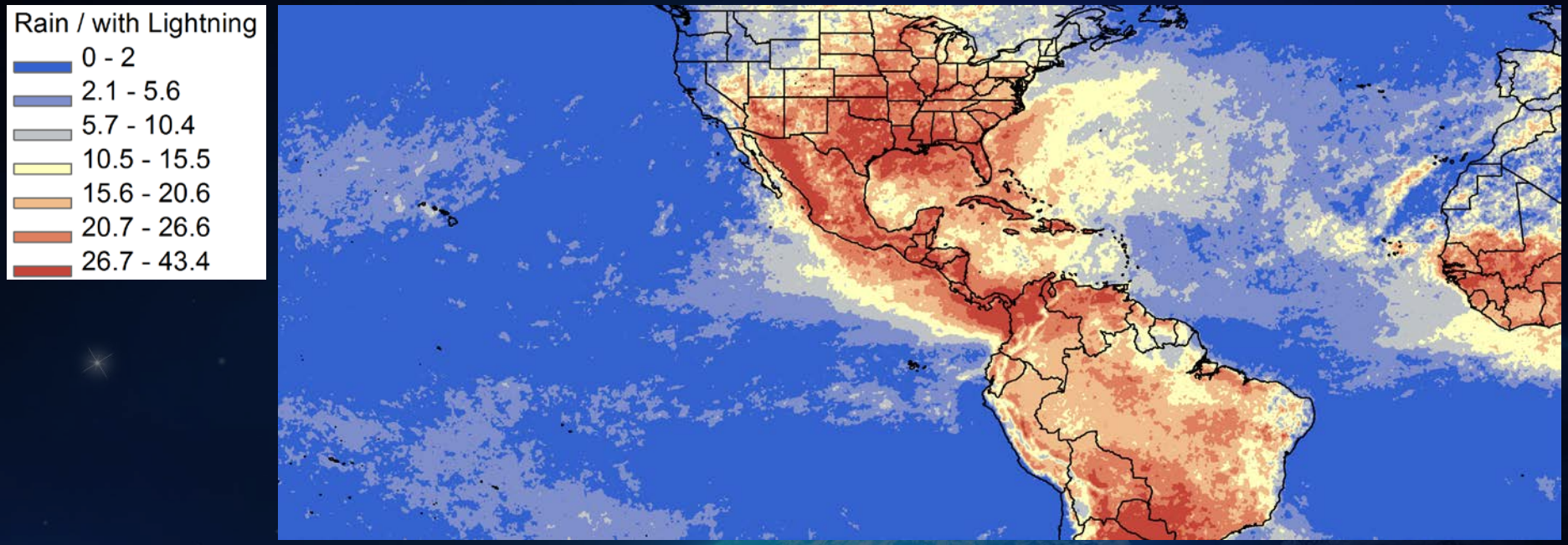
Fraction of 3 h periods with no rain or lightning

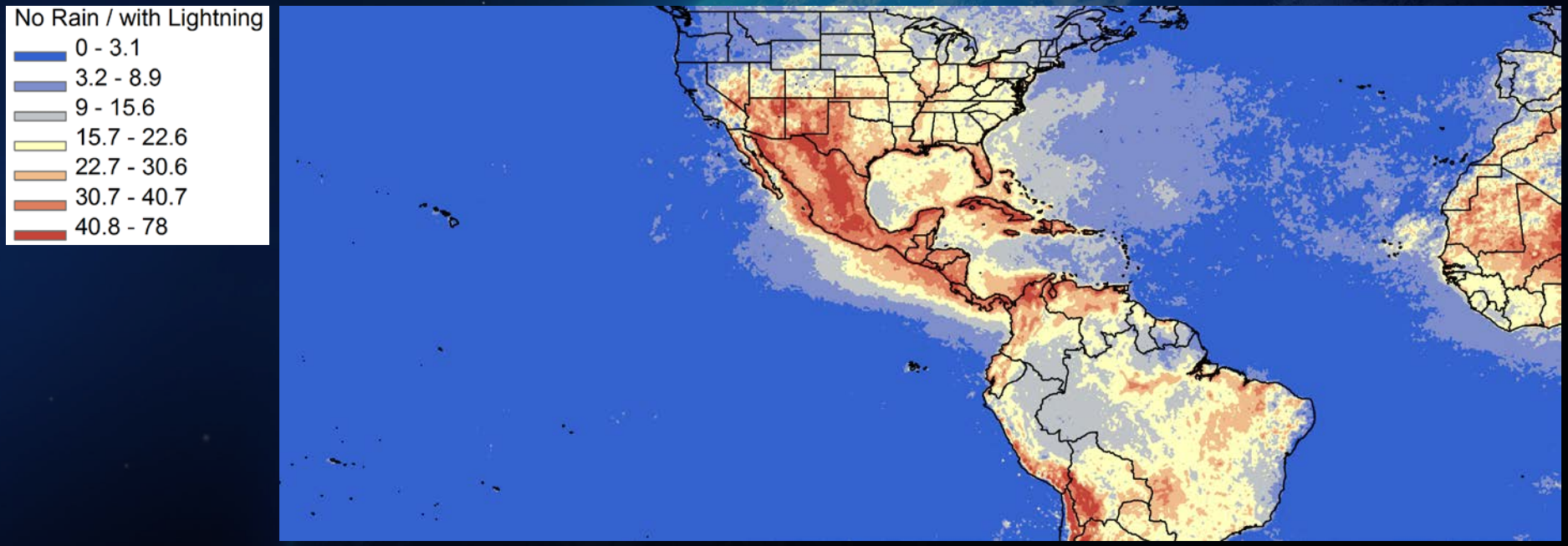
GLD360 DE vs. Rain/No Lightning





Rain with Lightning (top) vs. No Rain with Lightning (bottom)





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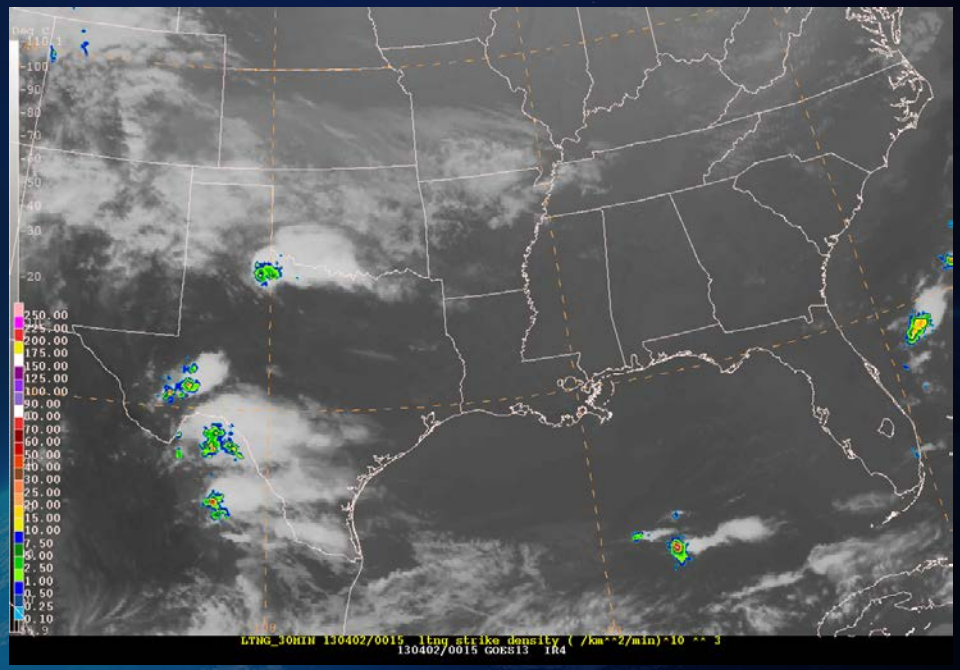

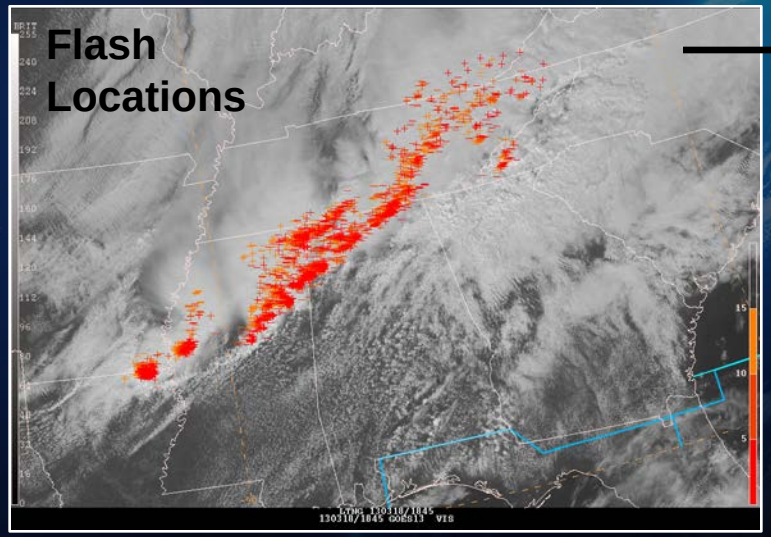

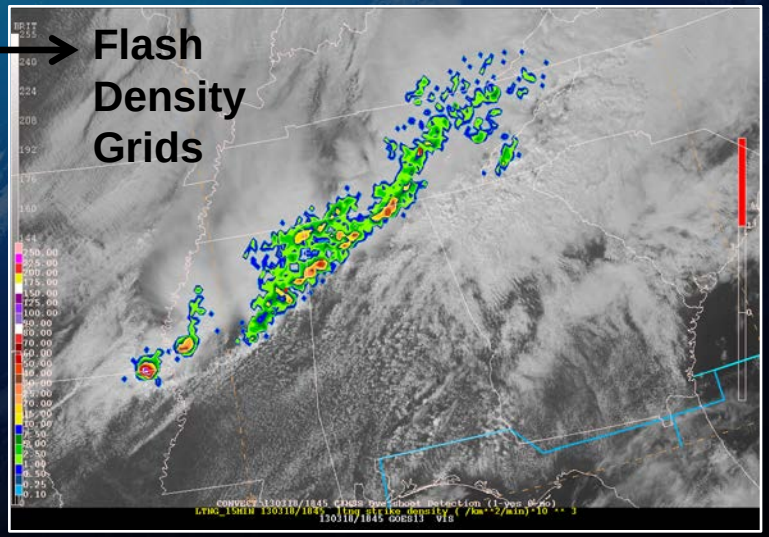

Collaborators
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Dustin Shea

Developed a Training Quick Guide

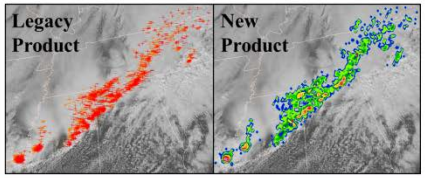
GLD360 Lightning Density Product (Operational Use)

GLD360 Lightning Density Product

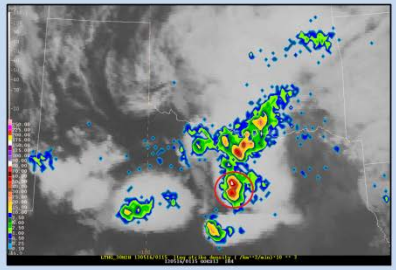
- Lightning density is the number of strokes in a grid cell over a given period of time.
- Density units are strokes per km^2 per min, and are multiplied by a scaling factor to obtain the scale units.
- The frequency of lightning strokes often is indicative of convective intensity.
- Product is provided at 2-min, 15-min, and 30-min intervals on 8×8 km grids.

Suggested Product Pairings

- Visible and IR Imagery
- RGB Imagery
- Wind Vectors
- Surface Map
- Model Precipitation Estimates
- Sea Surface Temperatures
- Overshooting Top Detections
- Convective Initiation
- Cloud Top Cooling



Example Usage: Identify Splitting Supercells

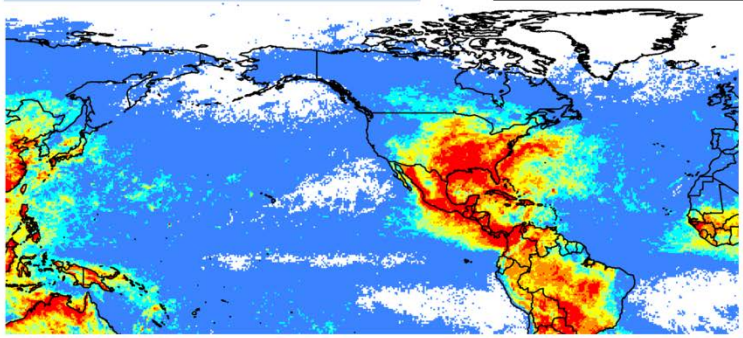


Animated Examples: http://alturl.com/24iqz

Operational Usage and Benefits

- Track convective cells beneath cloud shields
- Distinguish thunderstorms from rain-only areas
- Identify strengthening or weakening convection
- Monitor convective mode and thunderstorm evolution
- Diagnose initial atmospheric conditions
- Supplement/verify short-term model forecasts

GLD360 2012 Stroke Distribution

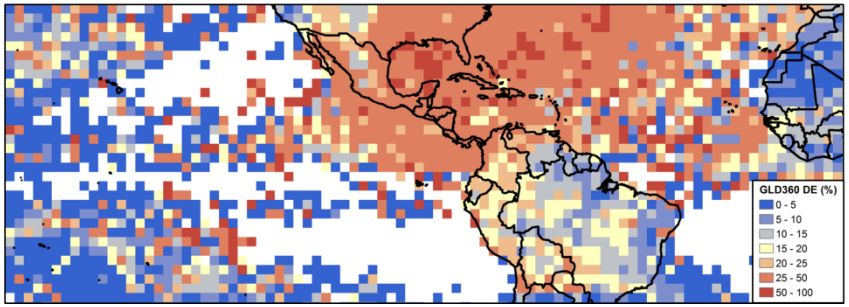


Stroke count per 0.5° grid cell

Domain:
115° E – 0°
80° N – 25° S

Stroke Count
- 0
- 1 - 1,500
- 1,500 - 4,000
- 4,000 - 8,000
- 8,000 - 16,000
- 16,000 - 28,000
- > 28,000

GLD360 Lightning Density Product (Data Properties)



GLD360 Detection Efficiency (DE)

- GLD360 DE was computed relative to the polar-orbiting TRMM Lightning Imaging Sensor (LIS).
- Analysis assumes that LIS observes all flashes, but the actual LIS DE varies from 90% during night to 70% at noon.
- The map above displays the fraction of all LIS flashes that were detected by the GLD360 during 2012.
- White cells indicate no LIS flashes for comparison.
- Regional Detection Efficiencies:
  W. Hemisphere = 25.3% Oceans = 33.0%
  North America = 33.4% South America = 17.5%

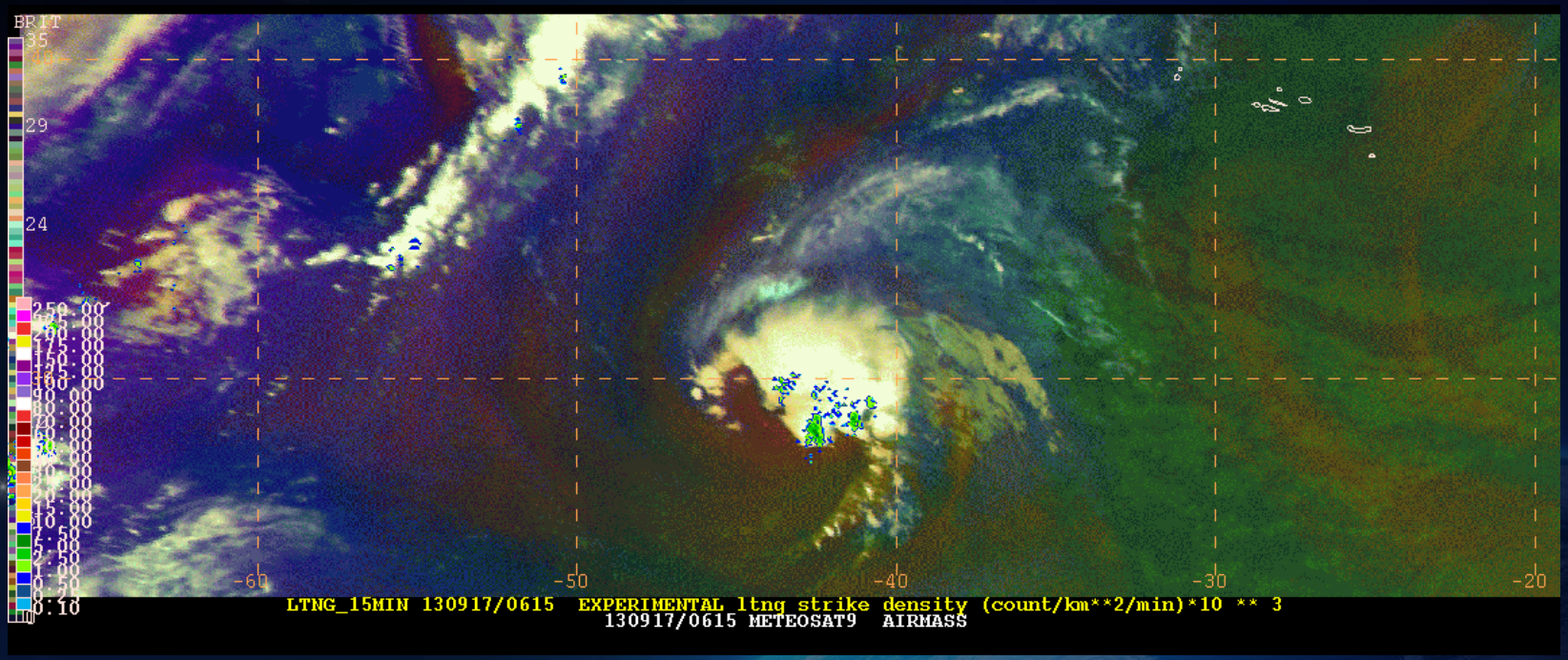
GLD360 is not the GOES-R GLM

- GLD360 detects VLF radio waves emitted by lightning, while the GLM is an optical detector.
- GLD360 detects primarily CG strokes, whereas the GLM will detect total lighting (IC + CG).
- GLD360 detected 25% of LIS flashes in the Western Hemisphere during 2012, while GLM will detect at least 70% of all flashes in its field of view.
- GLD360 detection efficiency varies spatially, while GLM will provide nearly uniform observations.
- Despite these differences, both systems provide instantaneous observations at the same spatial scale.

GLD360 Detection Method

- The GLD360 is a global network of ground-based sensors which detect very low frequency (VLF) radio waves emitted by lightning.
- Global coverage is achieved with relatively few sensors because the VLF radio waves are trapped by the earth-ionosphere waveguide and propagate for thousands of kilometers with minimal attenuation.
- Uses a combination of arrival time, arrival azimuth angle, range estimation, and amplitude to locate strokes. Strokes must be detected by at least three sensors to be accurately located.
- GLD360 detects primarily cloud-to-ground (CG) strokes, but also detects some strong intra-cloud (IC) flashes (network does not distinguish between CG and IC).

Forecaster Notes: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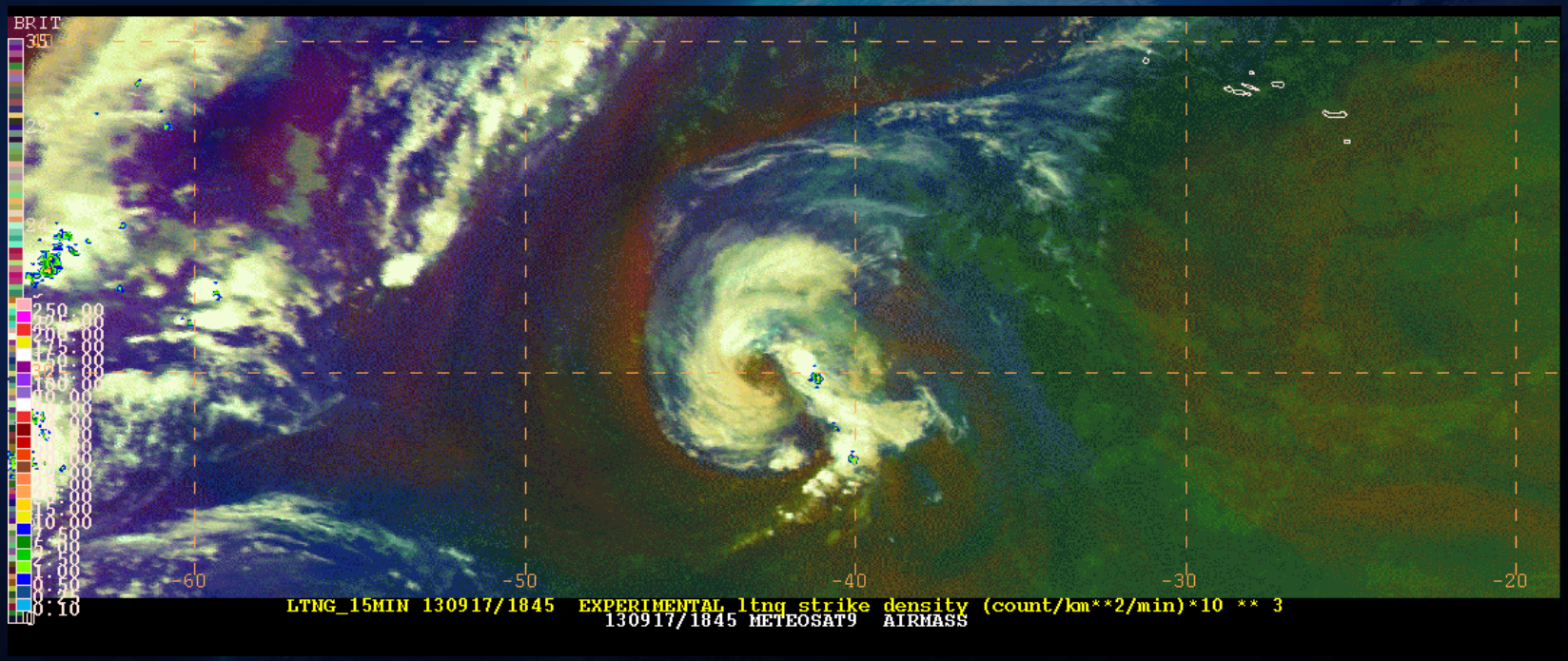
130917/0615 METEOSAT9 AIRMASS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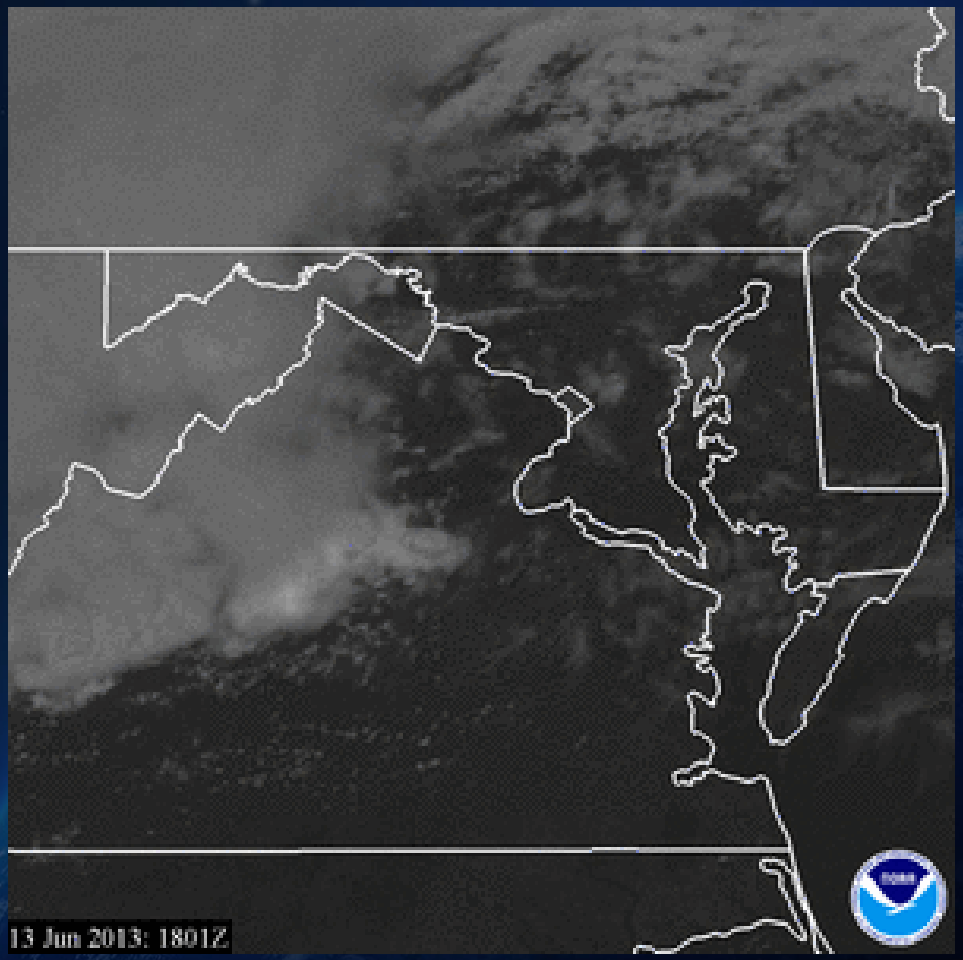
SRSOR plus DCLMA Observations