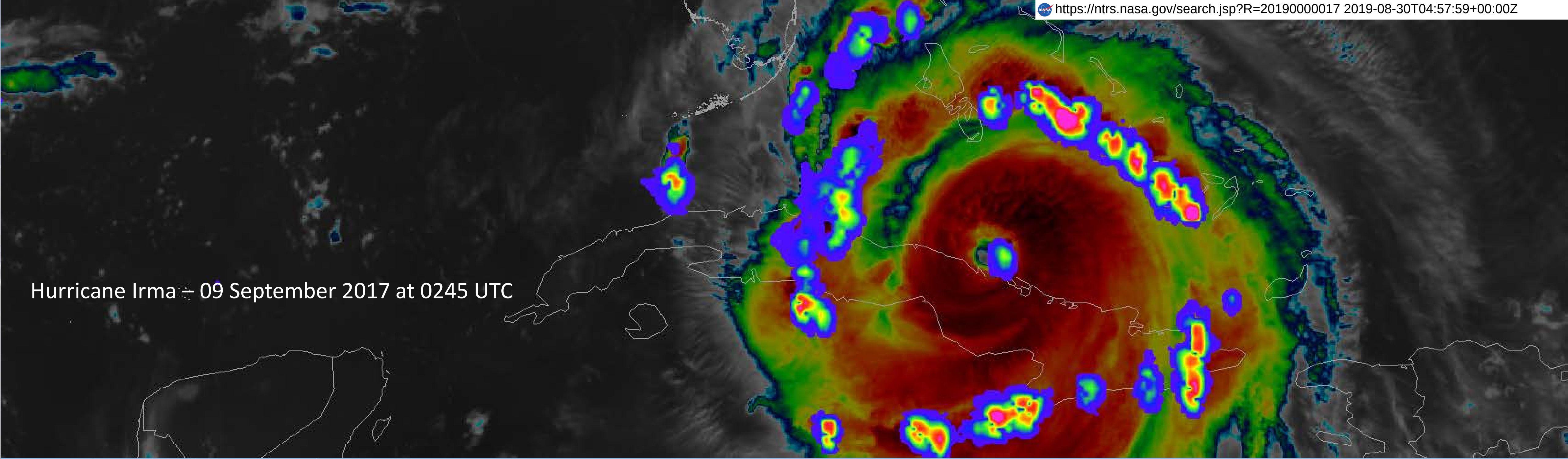


American Meteorological Society GOES-R Series Short Course (6 January 2019)

Overview of the Geostationary Lightning Mapper (GLM)

Dr. Geoffrey Stano – GLM Satellite Liaison

NASA SPoRT / ENSCO, Inc., Huntsville, Alabama

https://vlab.ncep.noaa.gov/group/geostationary-lightning-mapper/

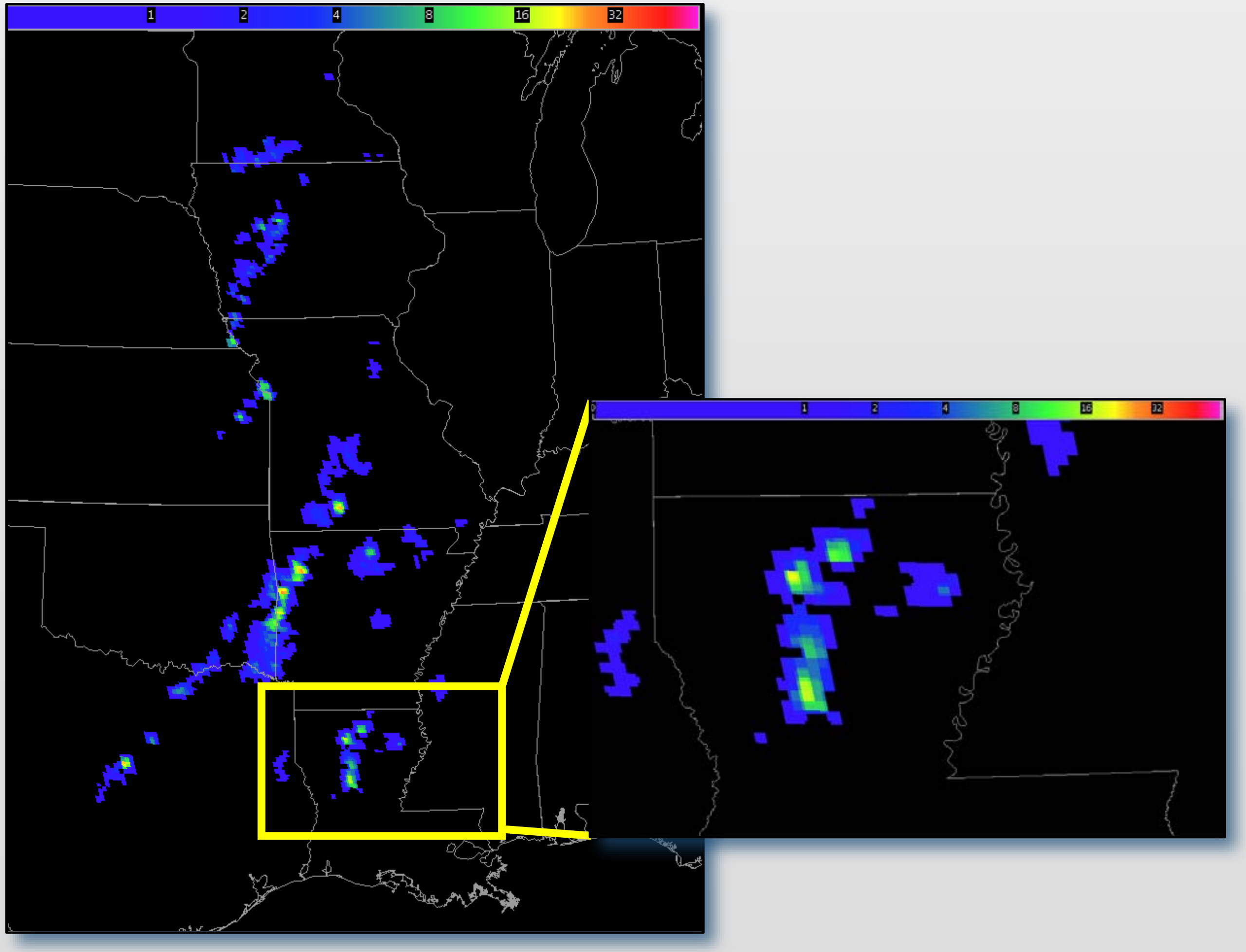
A Short Outline

- Role with the GOES-R Proving Ground
- The Geostationary Lightning Mapper
- Physical reasoning of GLM observations
- Basic differences with ground networks
- Early, potential uses (examples)
- Future Work

Short-term Prediction Research and Transition Center

Objectives

- **Objective 1**: What is the GLM?
- **Objective 2**: Physical reasoning of GLM observations
- **Objective 3**: Basic differences with ground networks
- **Objective 3**: Basic GLM operational applications (Flash extent density)
- **Objective 4**: Additional GLM products
- **Objective 5**: Limitations and Advantages

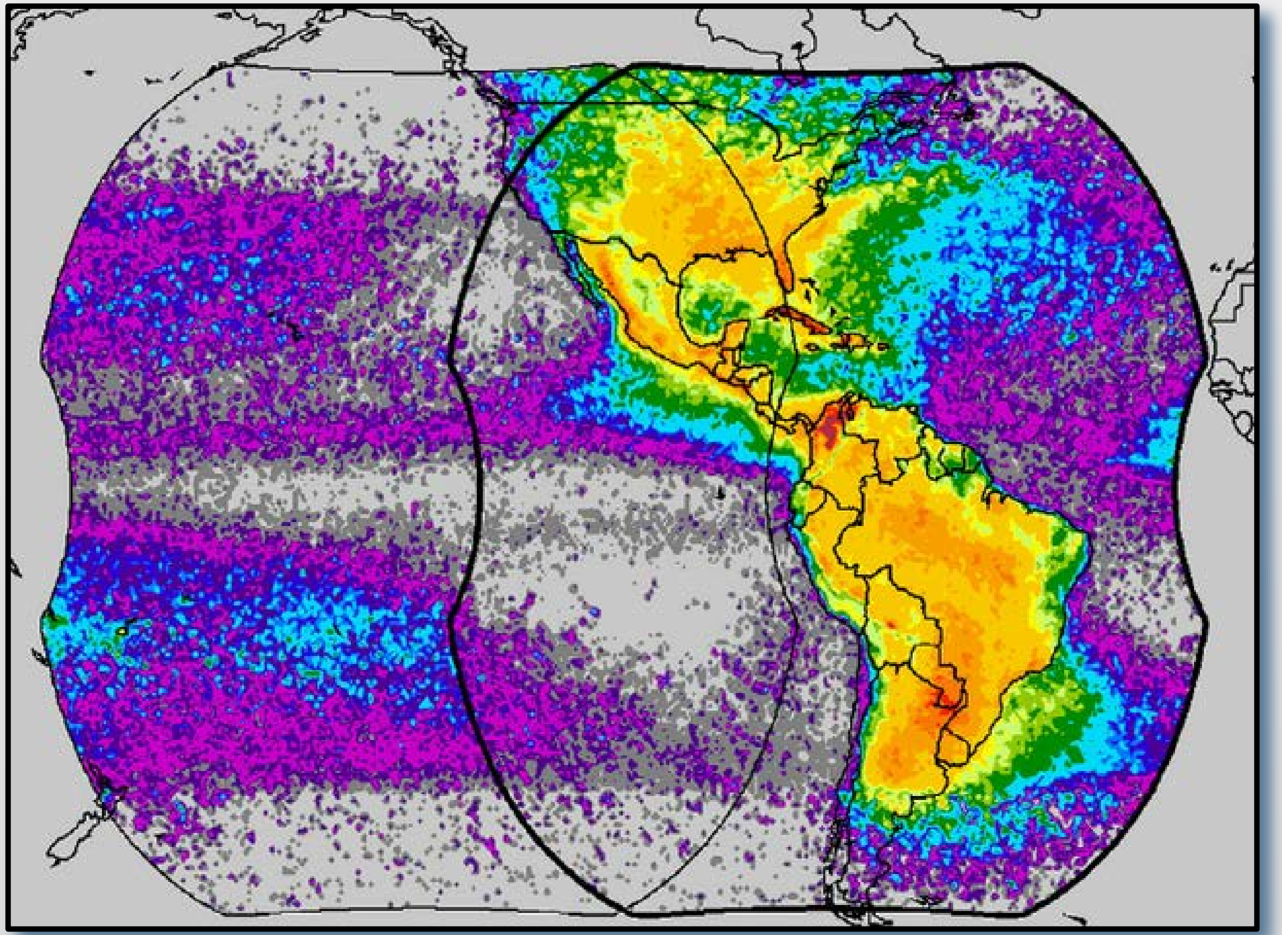


One minute of GLM flash extent density observations across the central U.S. and northern Louisiana (inset)

The Geostationary Lightning Mapper

Geostationary Lightning Mapper (GLM)

- Large digital camera to detect cloud top brightness differences
- Covers 54˚ N/S
- Observes both intra-cloud and cloud-to-ground lightning – Does not distinguish the difference
- Specifications: >70% detection over the full disk over 24 hours (>90% at night)
    - Initial review exceeding specifications



GLM field of view for GOES-16 and -17

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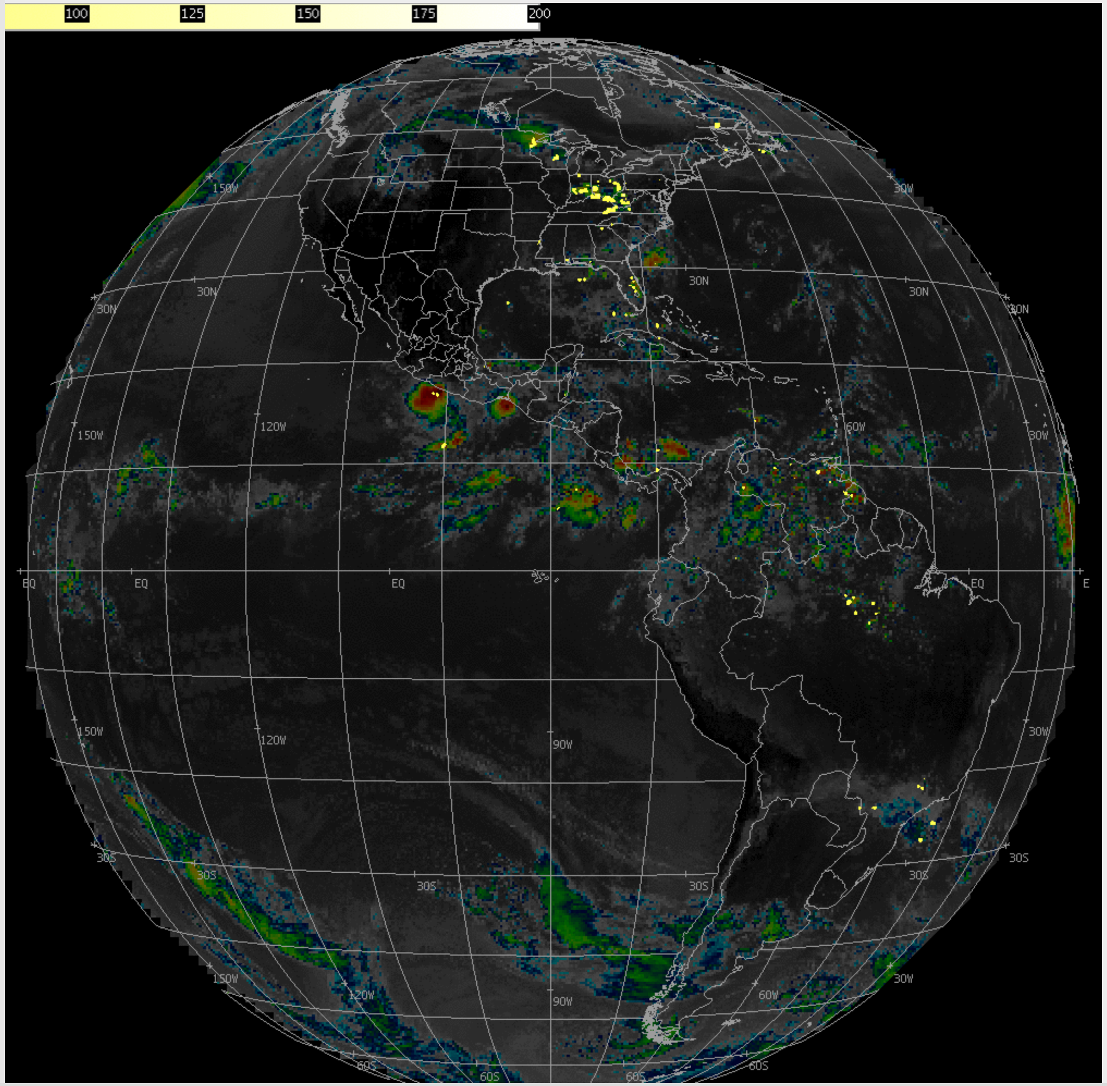
Geostationary Lightning Mapper (GLM)

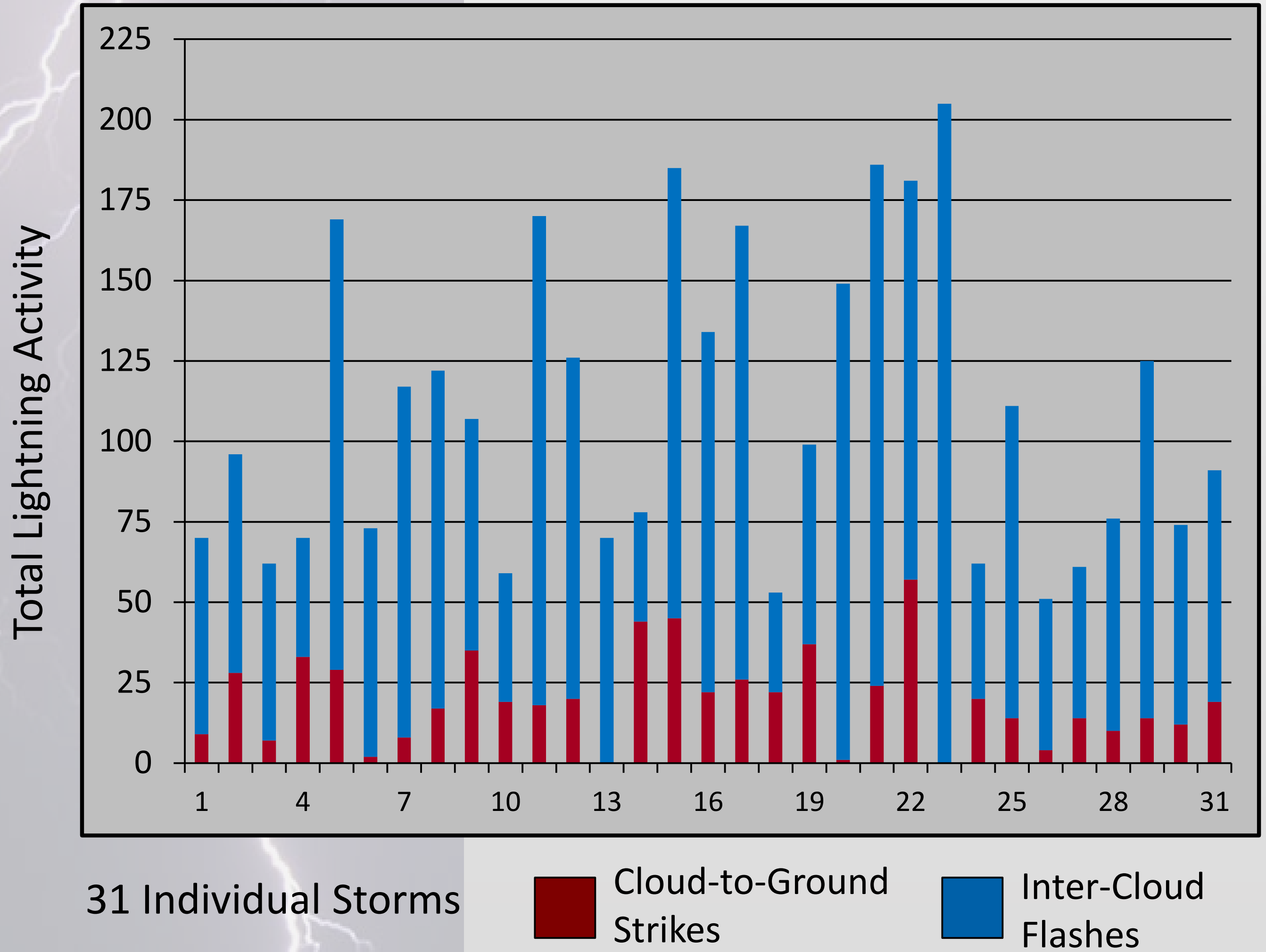
- The GLM provides near hemispheric coverage
  - Generally consistent detection efficiency over most of the field of view
  - Available in data spare regions
  - 1 minute updates
  - Not proprietary (can show in real-time)
- Compared to traditional ground networks
  - GLM observes total lightning
  - GLM provides spatial extent
  - GLM detections consistent over land and water



13 June 2017 from 1719-1819 UTC (Preliminary, non-operational)

NASA SPORT Short-term Prediction Research and Transition Center

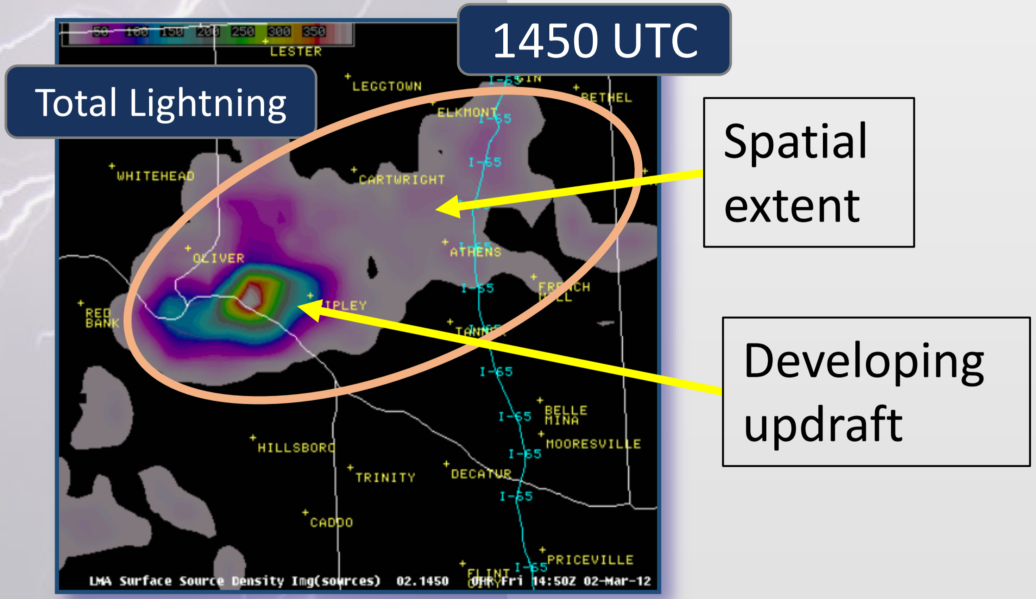
What Is Total Lightning

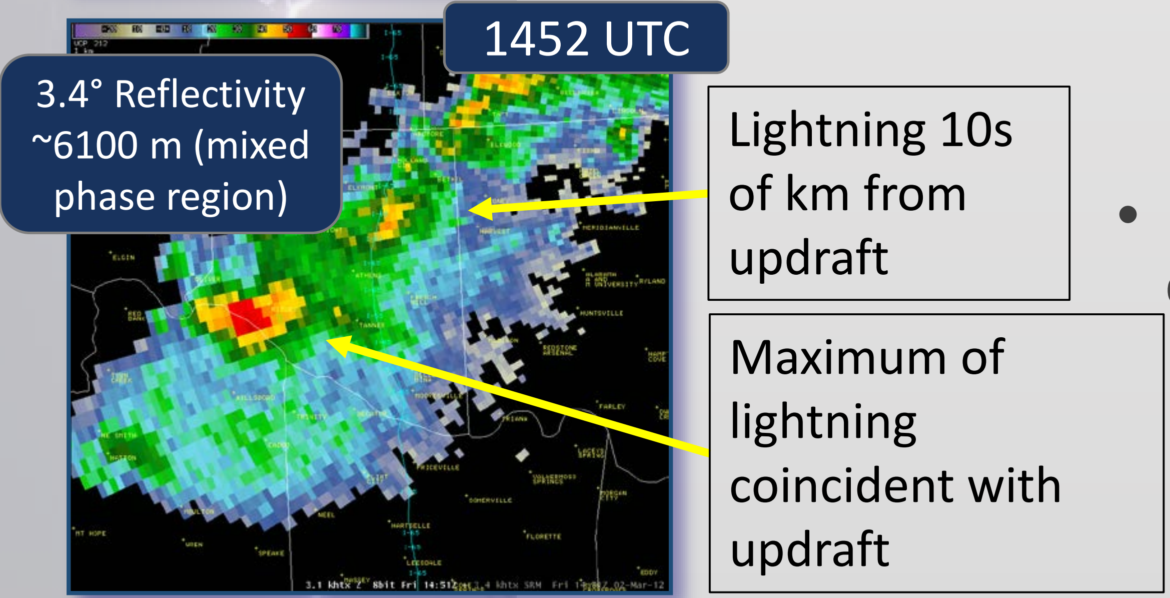


Total Lightning

- Combination of cloud-to-ground and intra-cloud observations
- Intra-cloud typically far outnumbers cloud-to-ground in any given storm
- <u>Reminder</u>: GLM observes total lightning, but does not distinguish between the two

Total Lightning





- Total lighting = cloud-to-ground **and** intra-cloud
- Physical reasoning for total lightning
  - Charging occurs in mixed phase region
  - Larger, stronger updrafts = more total lightning
- Advantages
  - Intra-cloud often precedes first cloud-to-ground
  - Total lightning proxy for storm strength
  - Monitor convective development / weakening
  - Observe the spatial extent
- Early training matches GLM to forecaster conceptual model
  - Builds trust in GLM, particularly for data sparse areas

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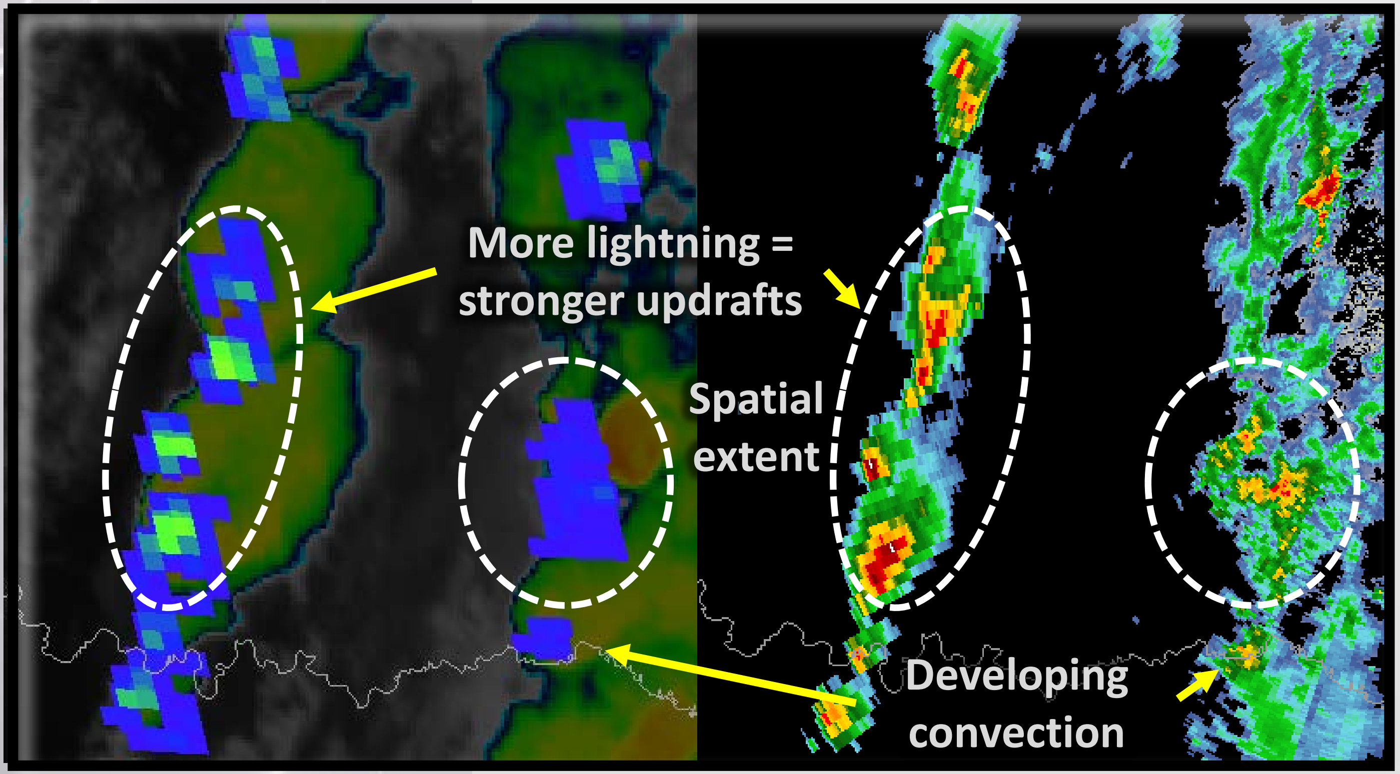
Key GLM Features



Example of GLM flash extent density overlaid on 10.3 micron ABI IR (left) compared to radar reflectivity (right)

- Identify spatial extent of lightning
  - Can extend well into the stratiform region
- Lightning driven by strength / volume of updraft in the mixed phase region
  - Bigger updraft = more lightning
  - GLM observations can serve as proxy for convective activity
- Monitor convective updrafts
  - Use GLM in data sparse regions
  - Identify convective / non-convective
  - Monitor development

Comparison with Ground Networks

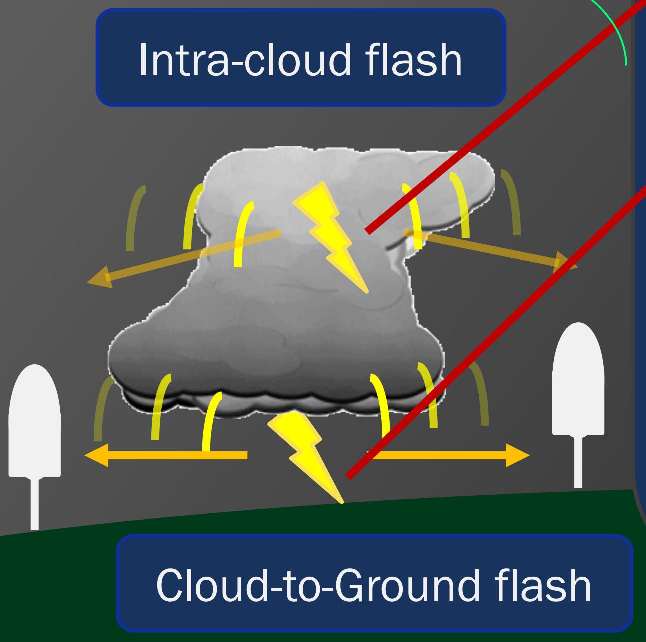
Distinguishing GLM, NLDN, and ENTLN

- Very Low Frequency (VLF) – Earth Networks, GLD360
- Best for long-range (>500 miles)
- Only observes strongest flashes (mostly cloud-to-ground)
- Dependent on Ionosphere (best at night)

22,200 miles up

Ionosphere

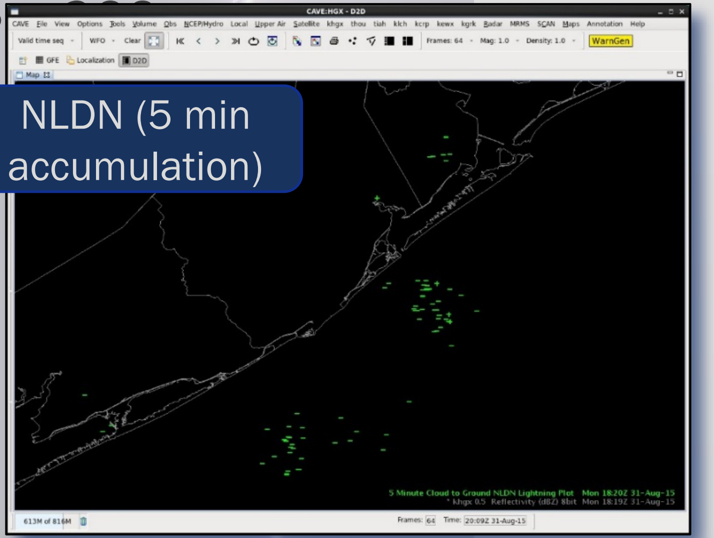
- Low to Very Low Frequency (LF, VLF) – Earth Networks, GLD360, NLDN
- Good range and accuracy with a sensor network
- Signal distinguishes ground versus intra-cloud
- Intra-cloud generally weaker than cloud-to-ground and harder to observe



Basic Differences Between Observation Systems

National Lightning Detection Network (NLDN)

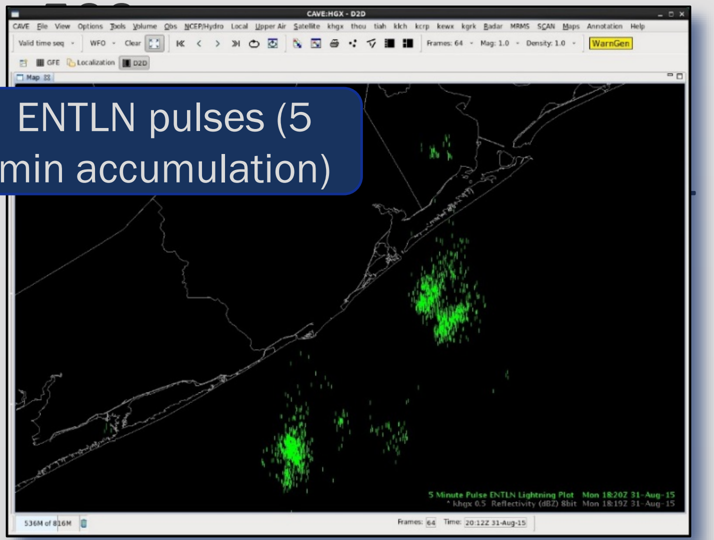
- CONUS and near-shore
- DE: >95% of cloud-to-ground within 200 km of CONUS
- 1 min update



NLDN (5 min accumulation)

Earth Networks Total Lightning Network (ENTLN)

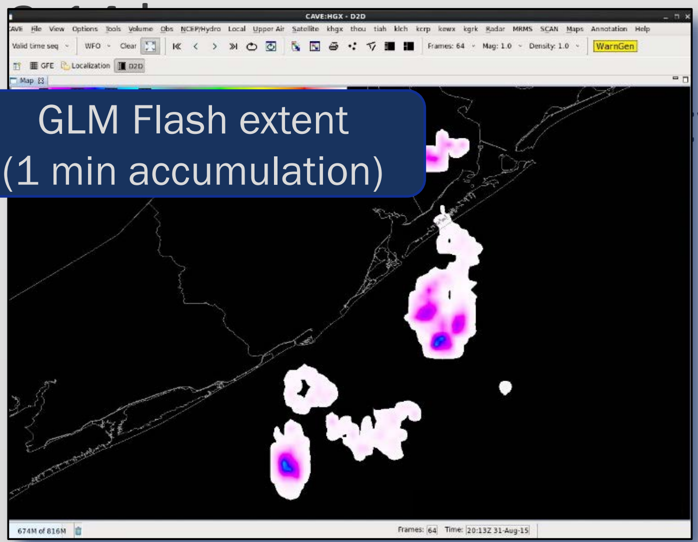
- Near global, but best over CONUS
- DE: 90% cloud-to-ground, >50% intra-cloud
- 1 min update



ENTLN pulses (5 min accumulation)

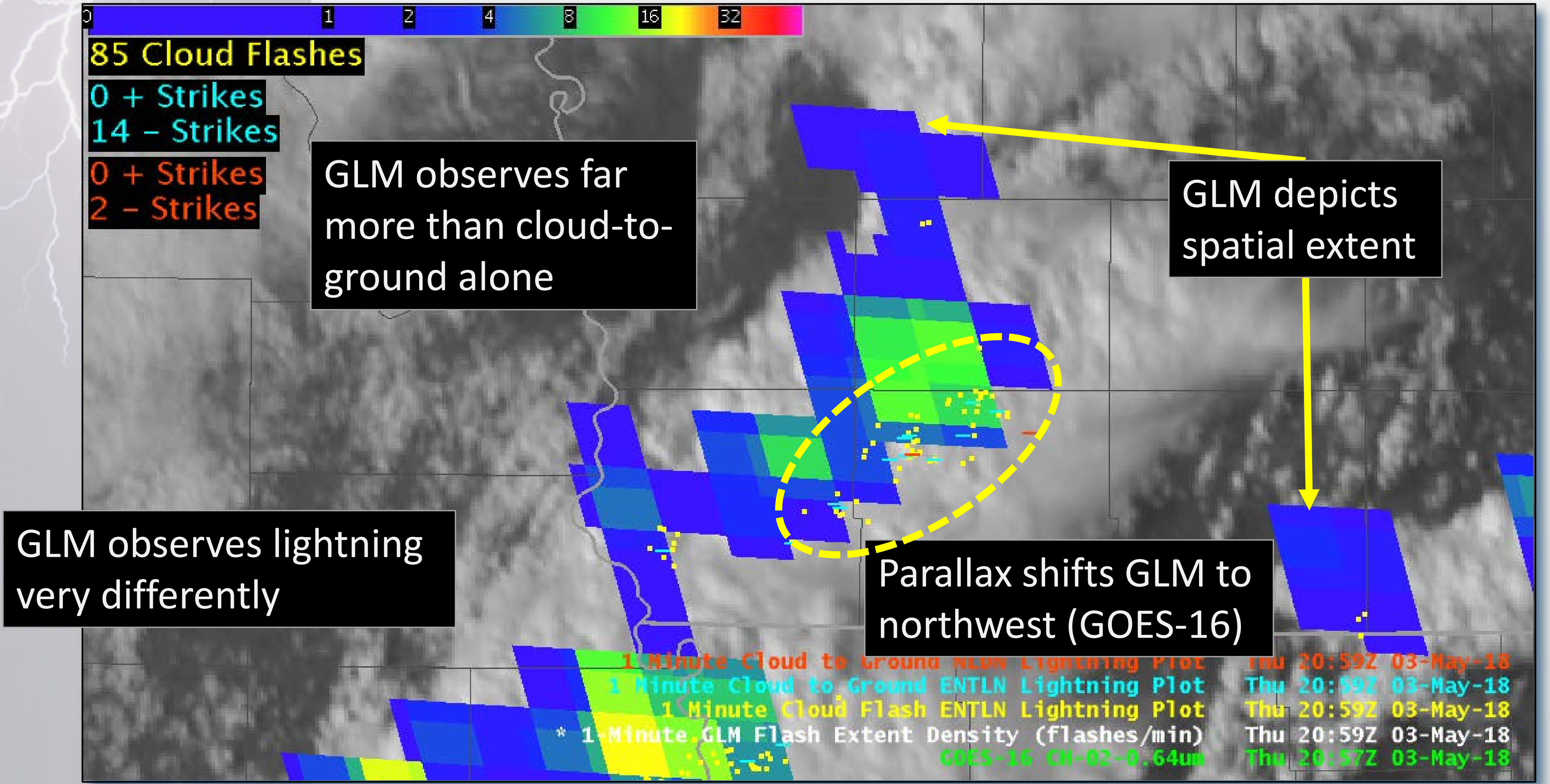
Geostationary Lightning Mapper (GLM)

- 55˚N/S in GOES field of view
- DE: ~70% (daytime) and 90+% (nighttime) of total lightning
- 20 s update (1 min AWIPS)



GLM Flash extent (1 min accumulation)

Simple GLM and Ground Network Comparisons



What Does GLM Observe

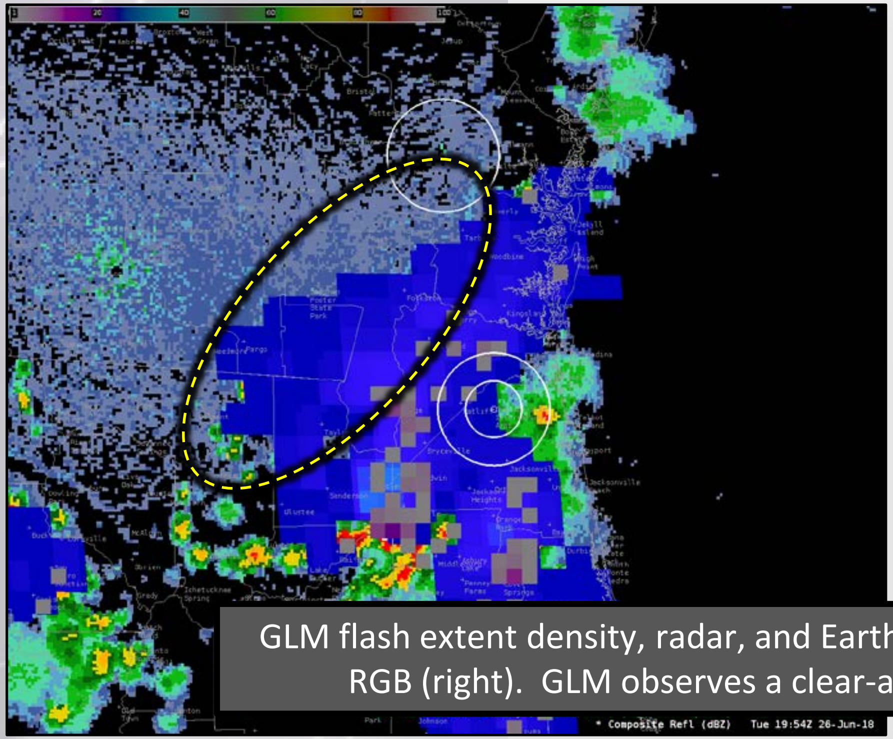
Nadir view of lightning from the International Space Station

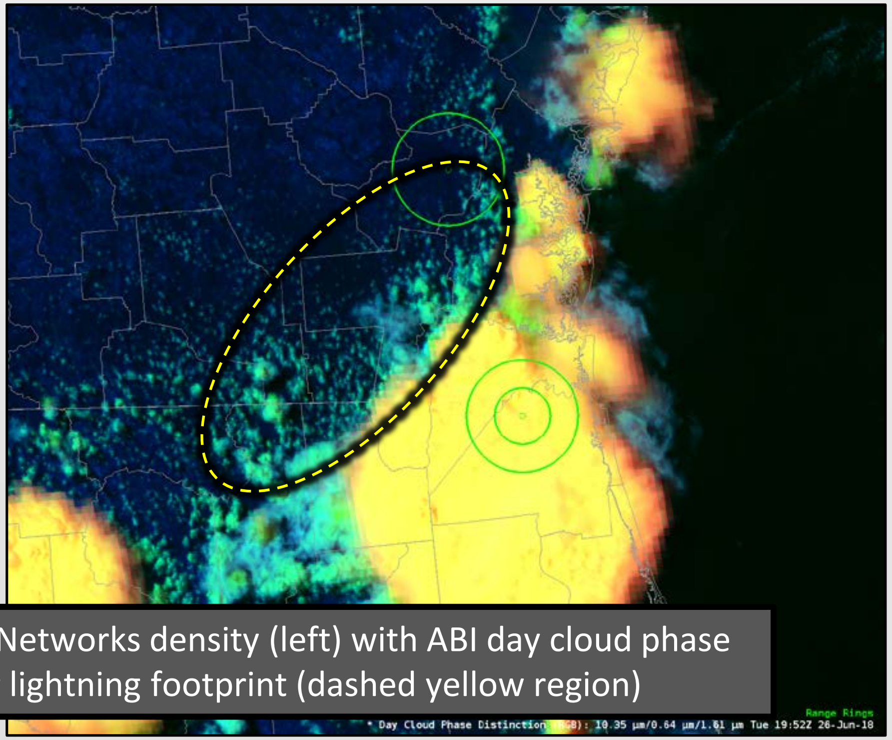
Limb view of lightning from the International Space Station

Examples courtesy of NASA and ESA

- GLM observes lightning very differently than ground-based networks
- GLM observes light emitted through a cloud by a lightning flash
- The light is both scattered and attenuated by the cloud
- Results in the lightning flash appearing as a “pool of light” in the cloud

Flash Footprint: Clear-air Discharges





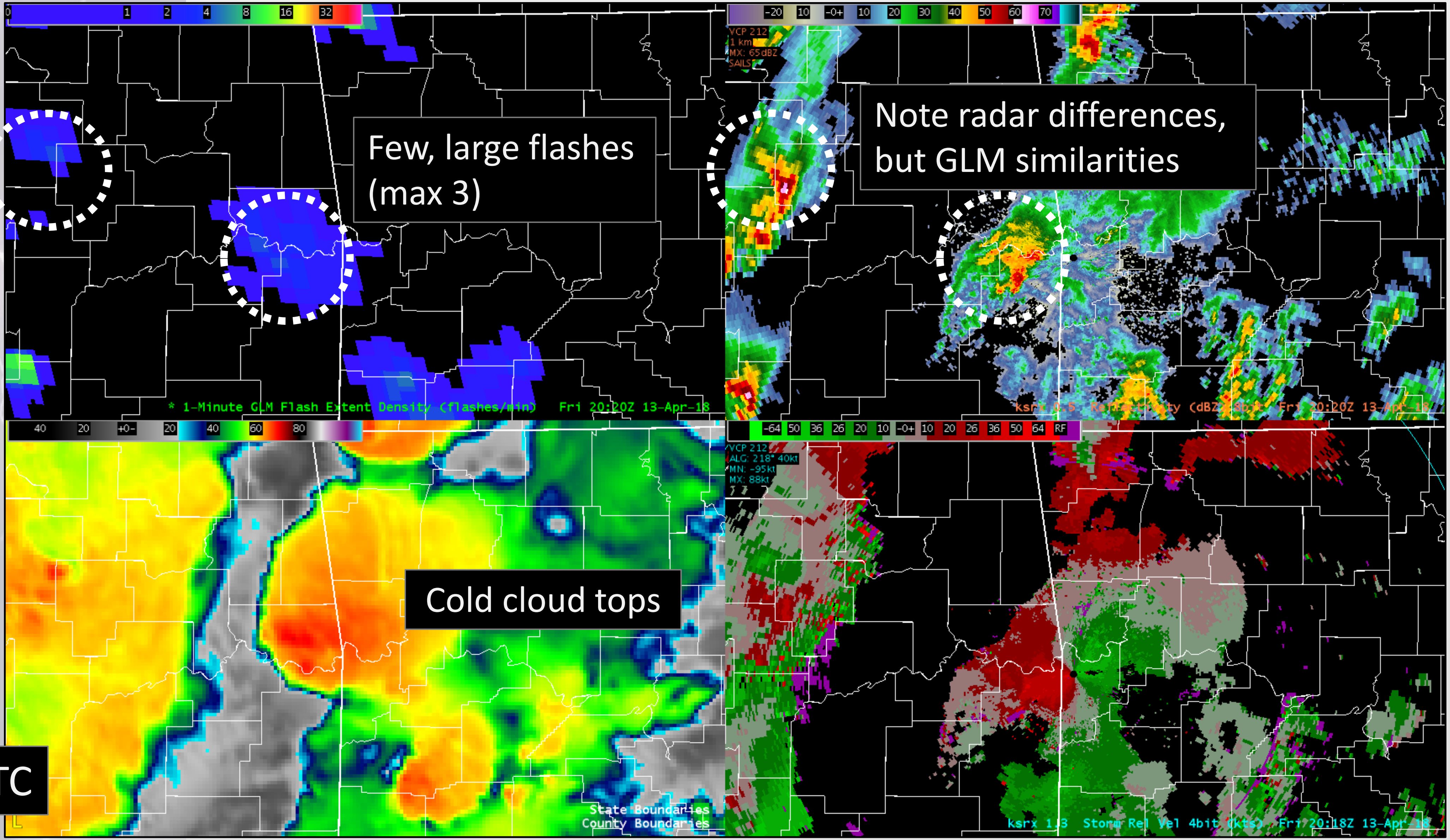
GLM flash extent density, radar, and Earth Networks density (left) with ABI day cloud phase RGB (right). GLM observes a clear-air lightning footprint (dashed yellow region)

- Large spatial extent (or footprint) into a clear-air region to the north-west
- Why is GLM observing lightning beyond the edge of the cloud?

- Large spatial extent will be seen with flashes into the stratiform region and can be 100s of km long.
- However, clear-air cases (above) can occur. Likely due to GLM observing light from flash.
- Light emitted throughout cloud and can reflect off of lower clouds adjacent to main thunderstorm.

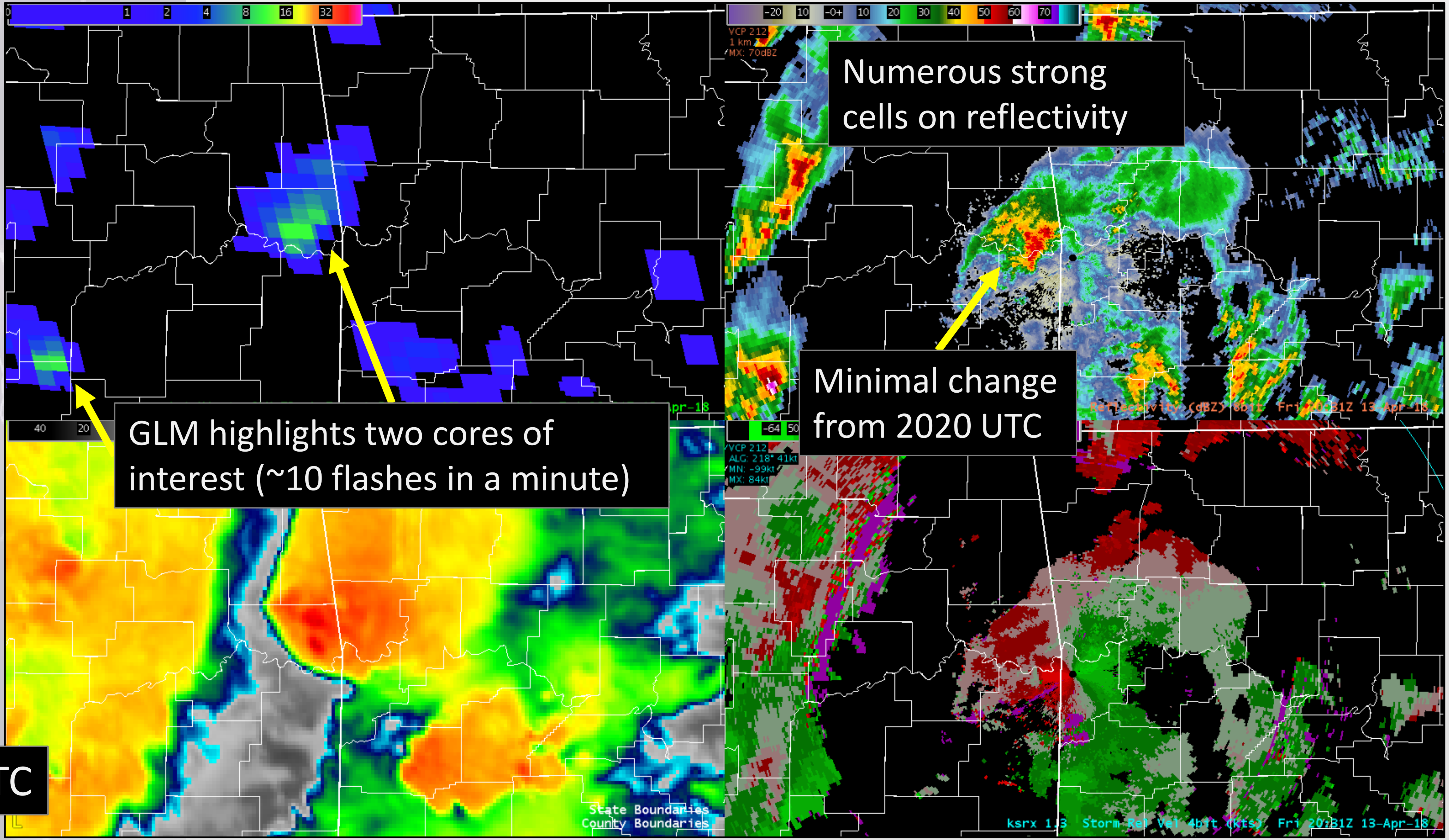
Potential Operational Uses

Severe Weather Decision Support (1)



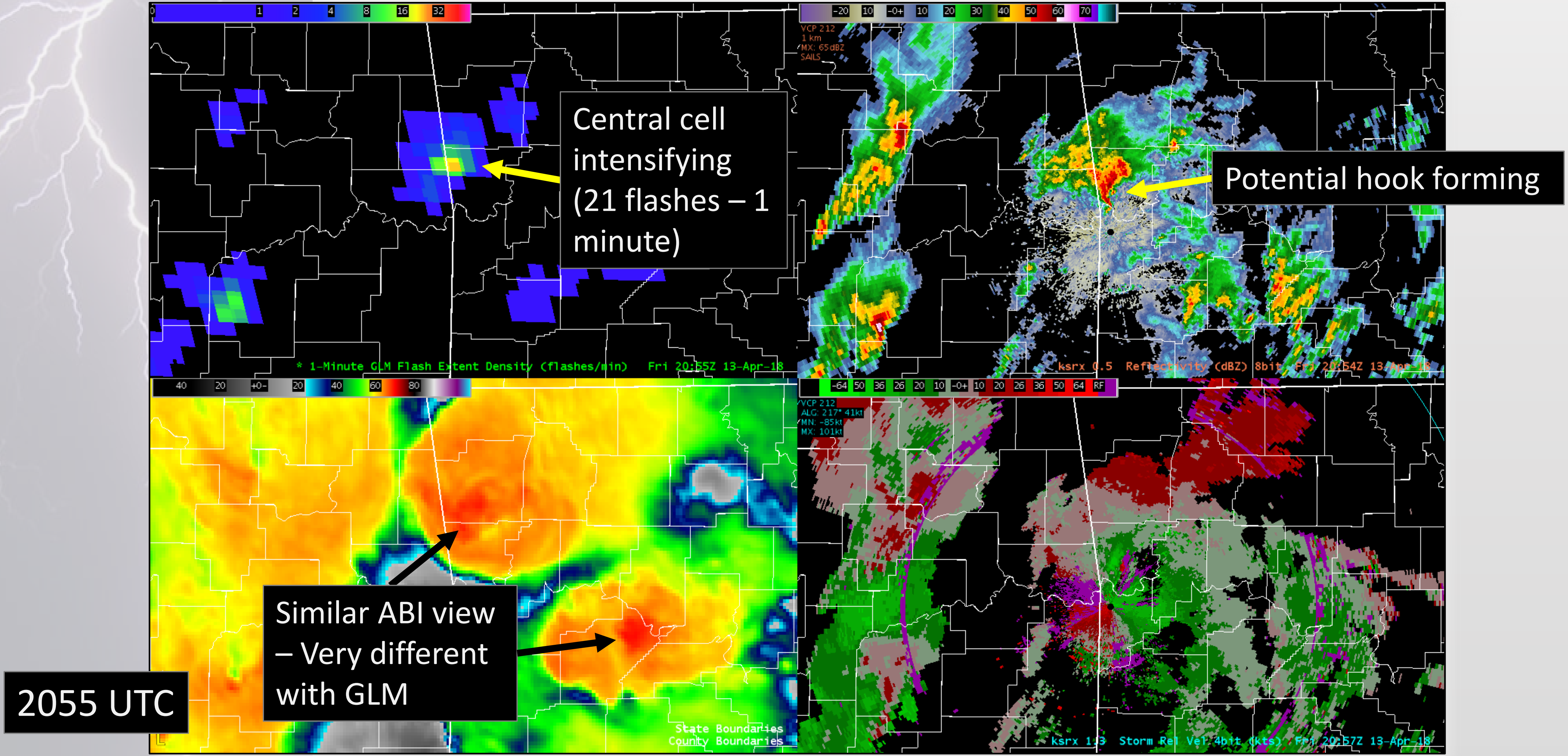
2020 UTC

Severe Weather Decision Support (2)

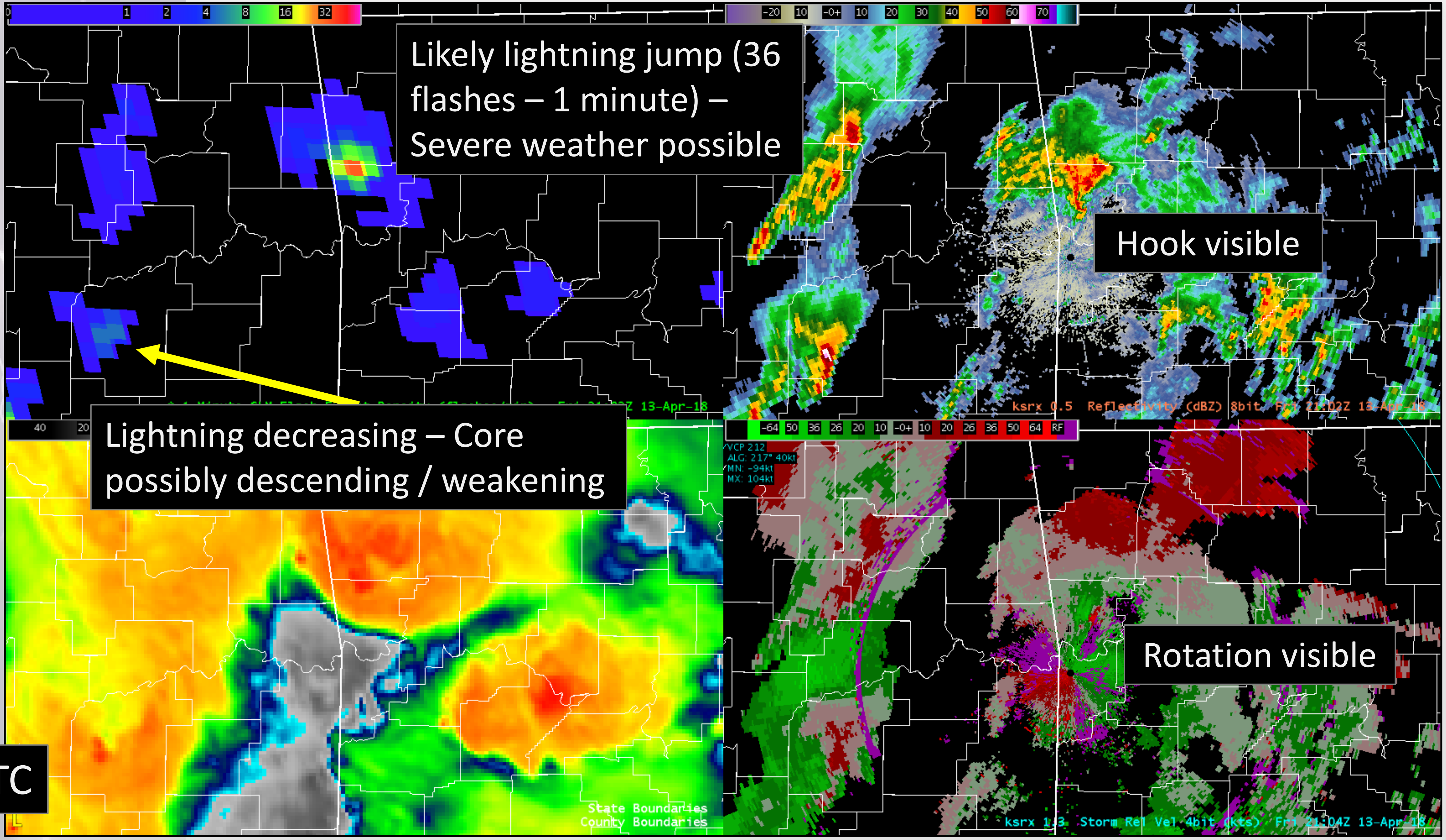


2031 UTC

Severe Weather Decision Support (3)

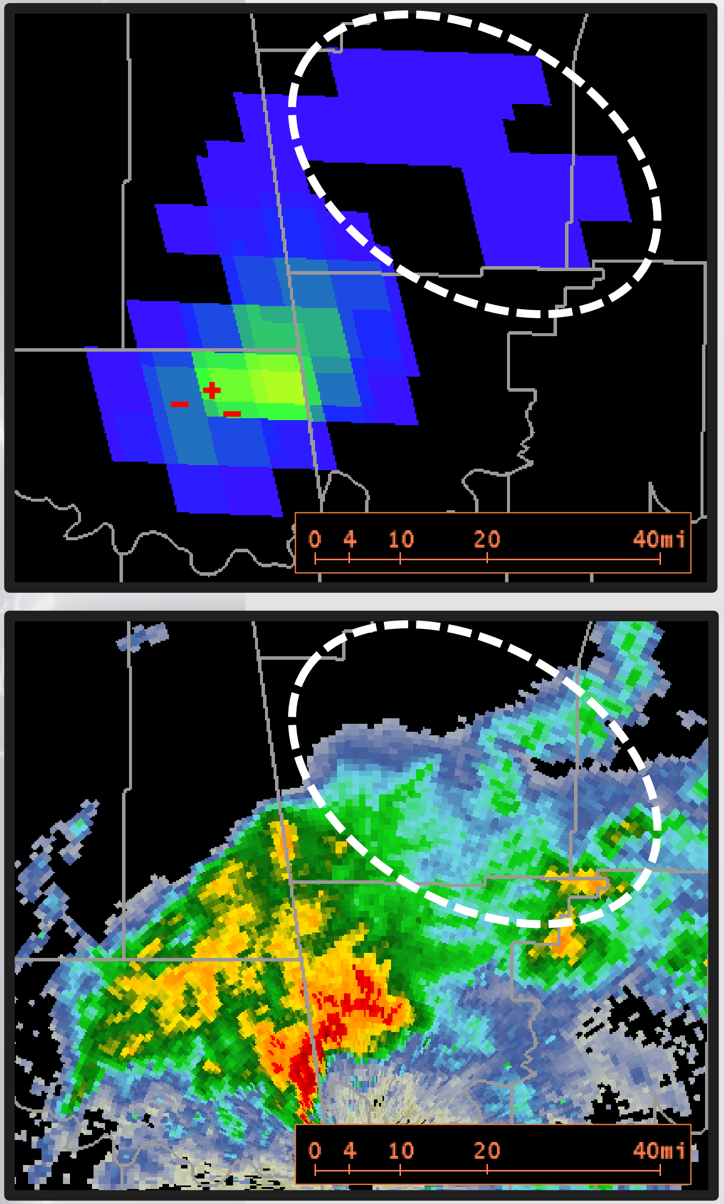


Severe Weather Decision Support (4)



2102 UTC

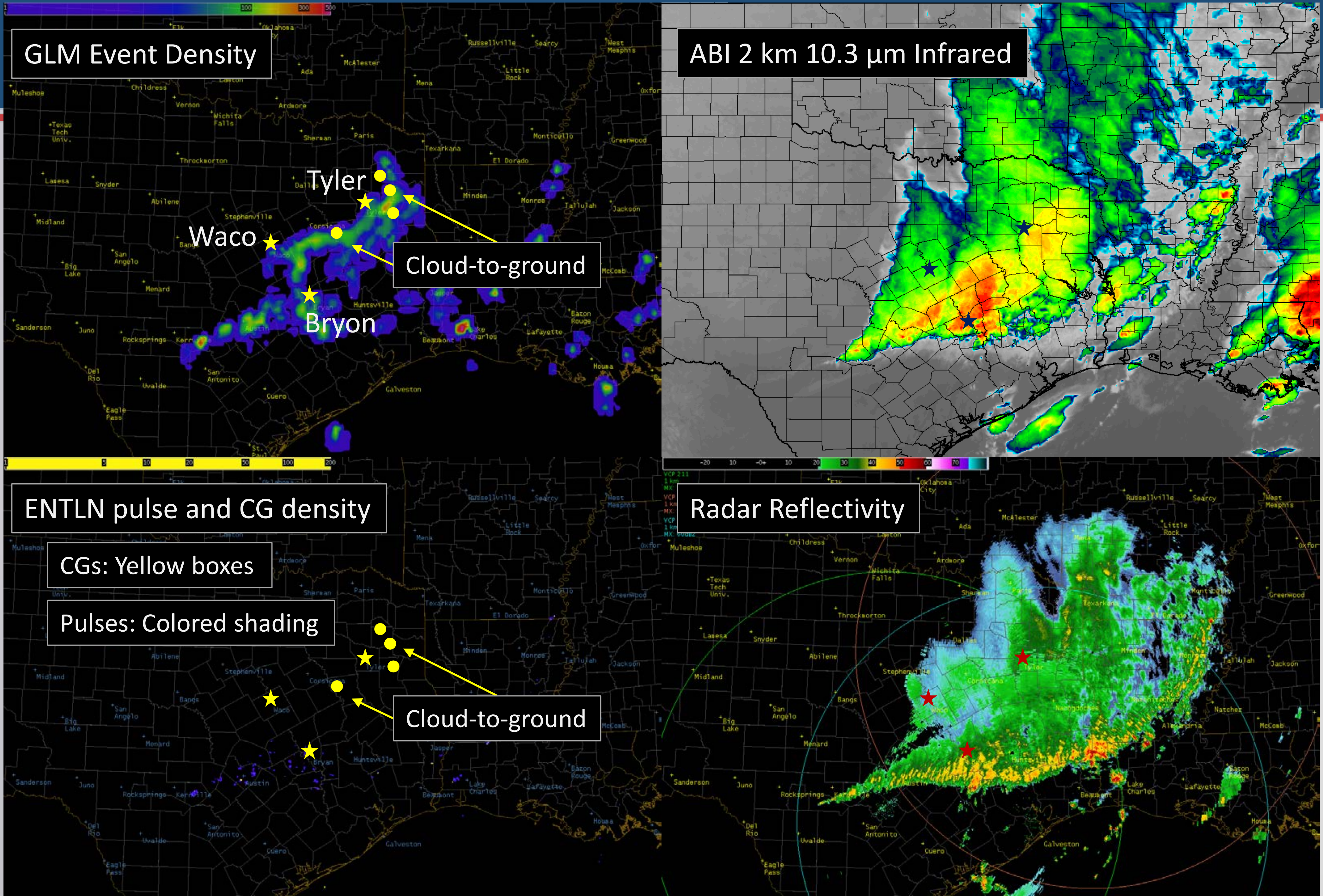
Lightning Safety – Spatial Extent



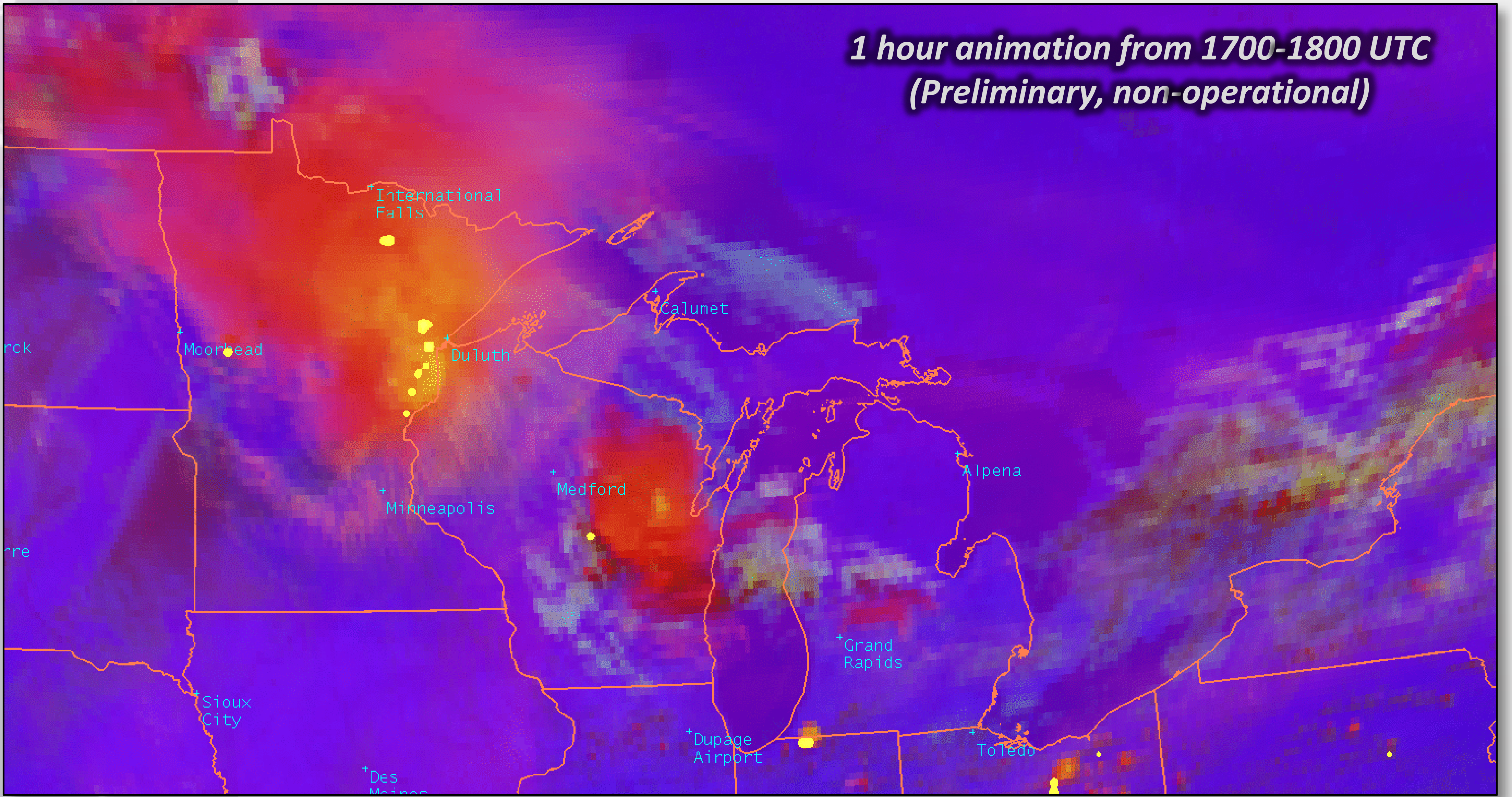
- Completely new ability – **Spatial Extent**
- NLDN and Earth Networks primarily point observations
- Lightning can, and does, travel many miles from its point of origin
- Can extend far into the stratiform region
- These flashes can also come to ground
- GLM is not proprietary – Can be shown on web in real-time
- Beyond safety, can impact avaition

Lightning Safety

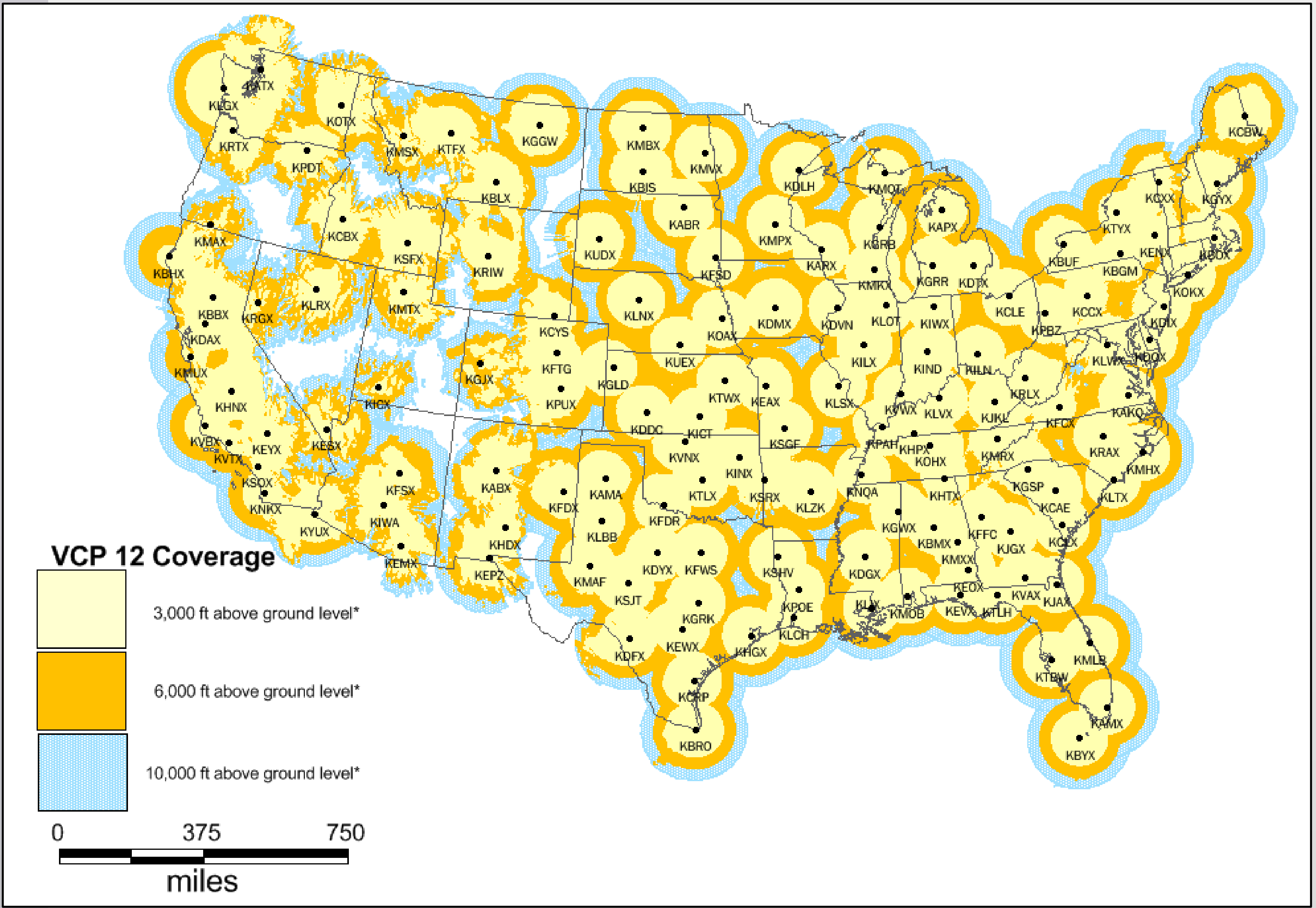
- Spatial extent is new ability
- Flash is 100+ miles
- GLM “connects the dots” – ENTLN individual obs part of 1 contiguous flash



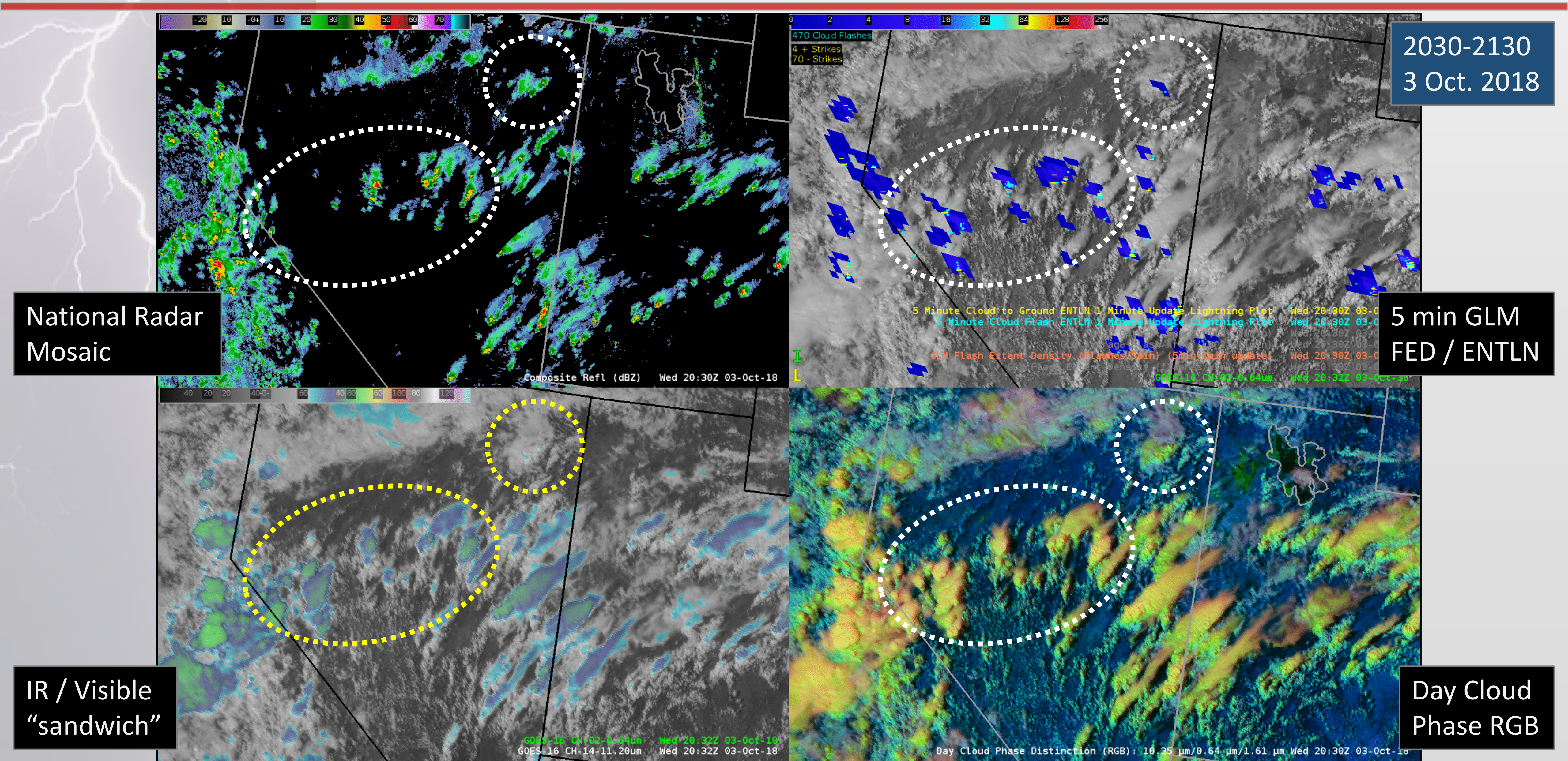
Long Flash Example Animation (Lightning Safety)



U.S. Radar Coverage

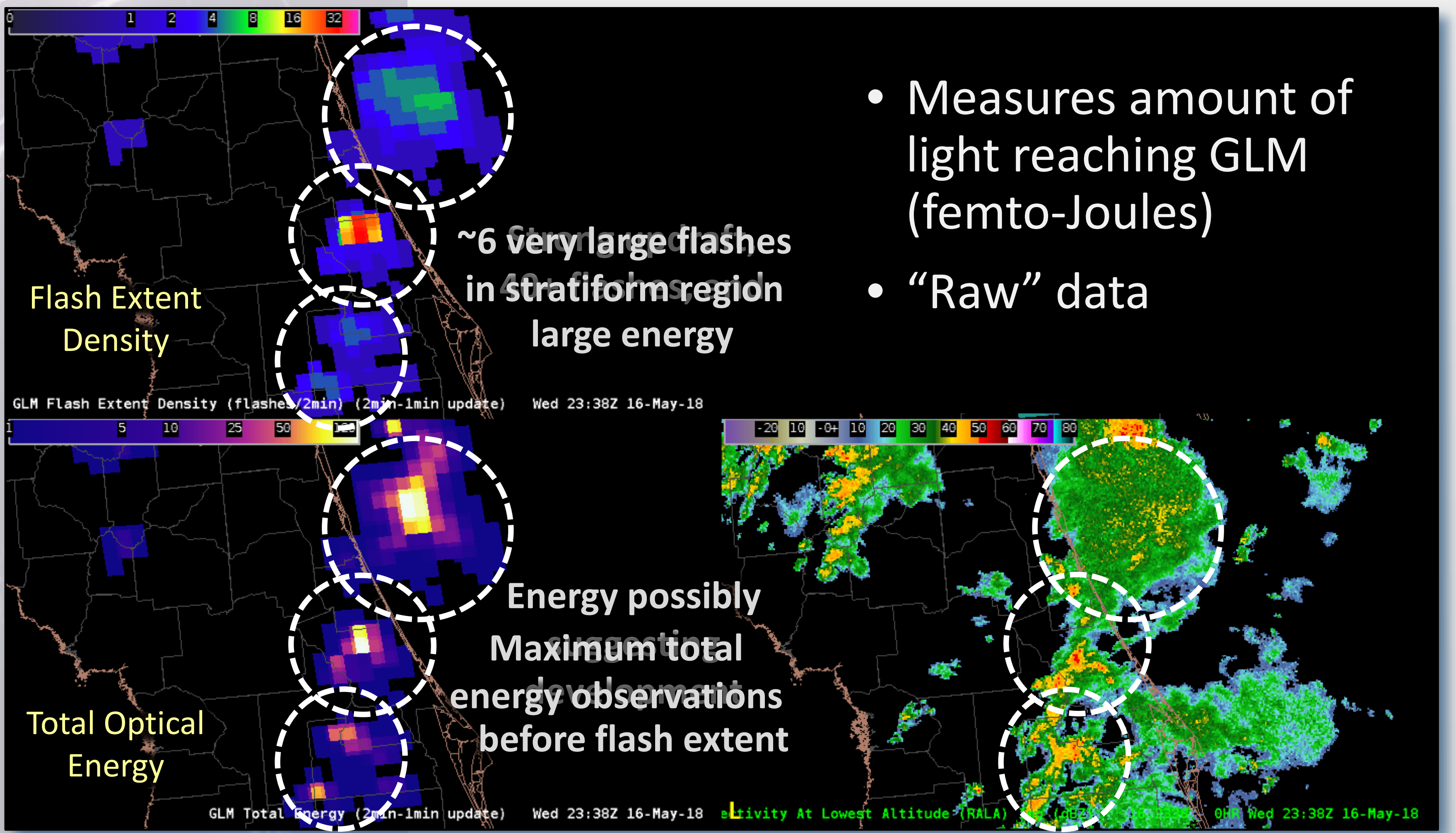


Western Region Convective Monitoring



Additional Products

Additional Products: Total Optical Energy



GLM flash extent density (upper left) with total energy (lower left) and radar reflectivity (lower right)

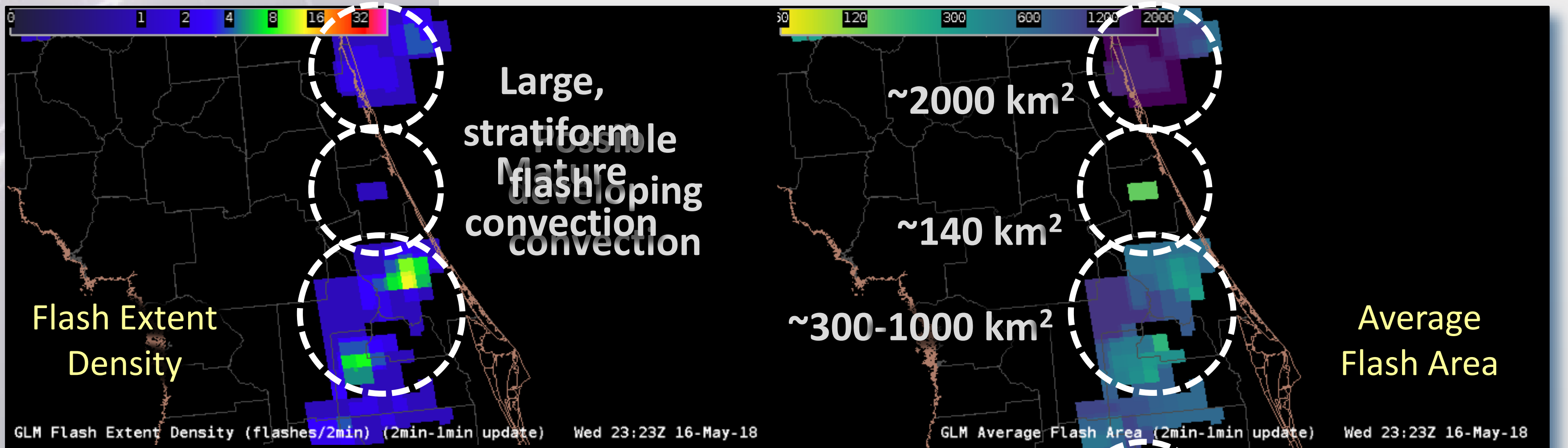
ADVANTAGES

- Identify energetics
- More energy likely is a stronger storm
- Reinforce flash extent observations

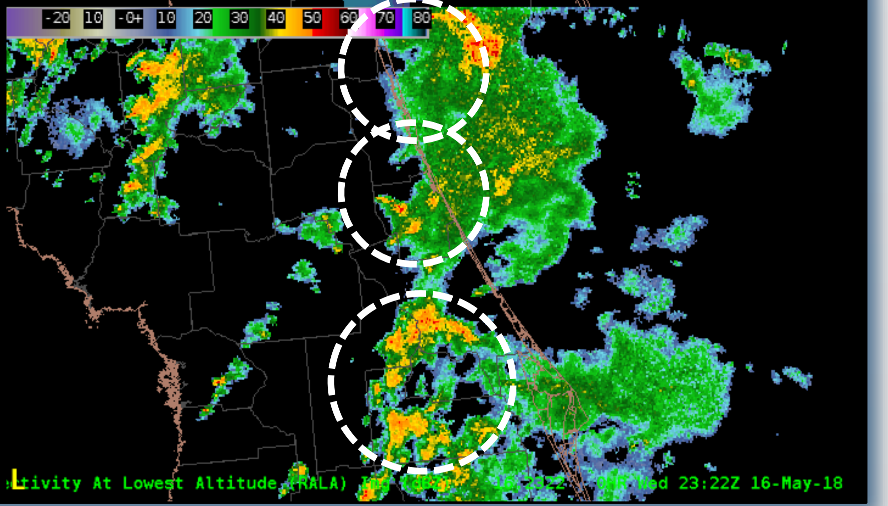
DISADVANTAGES

- More work needed to identify "significant" values
- Large area flashes can look like storm cores (less cloud for light to be attenuated in stratiform)

Additional Products: Average Flash Area



- Averages the area of all flashes in a given grid box (km^2)



GLM flash extent density (upper left) with average flash area (upper right) and radar reflectivity (lower right)

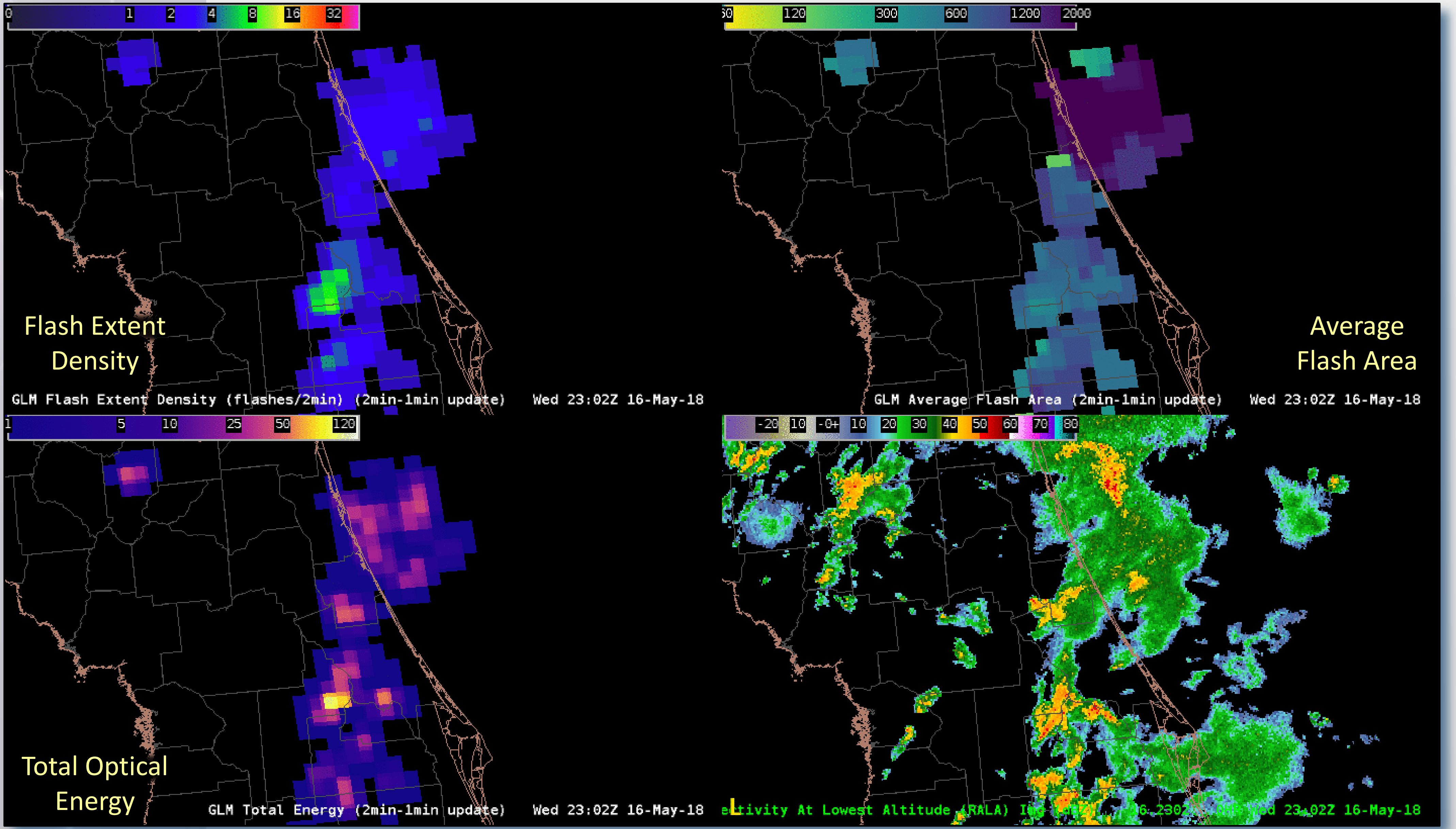
ADVANTAGES

- Developing convection – More, smaller flashes
- Weakening convection – Fewer, larger flashes

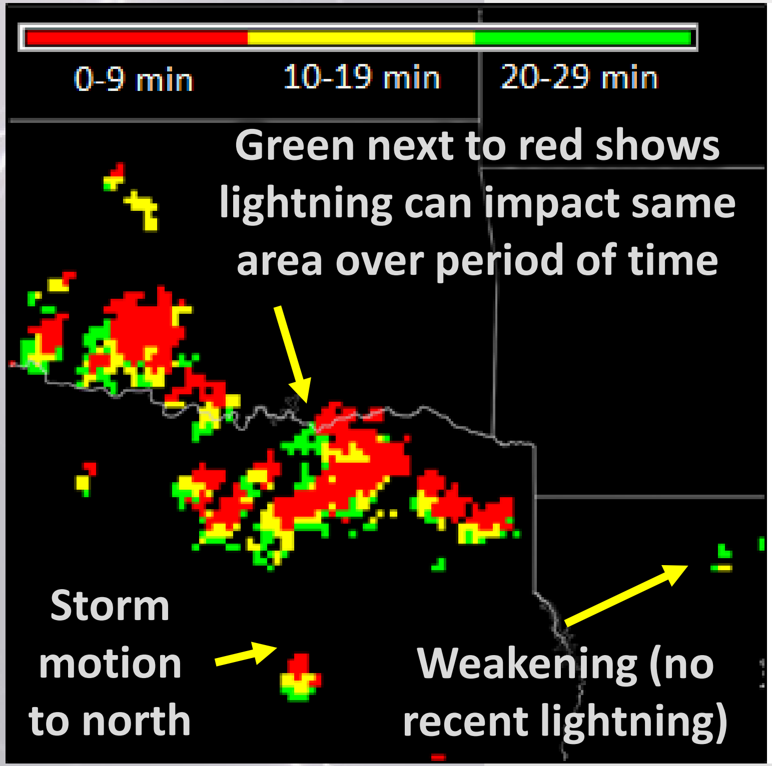
DISADVANTAGES

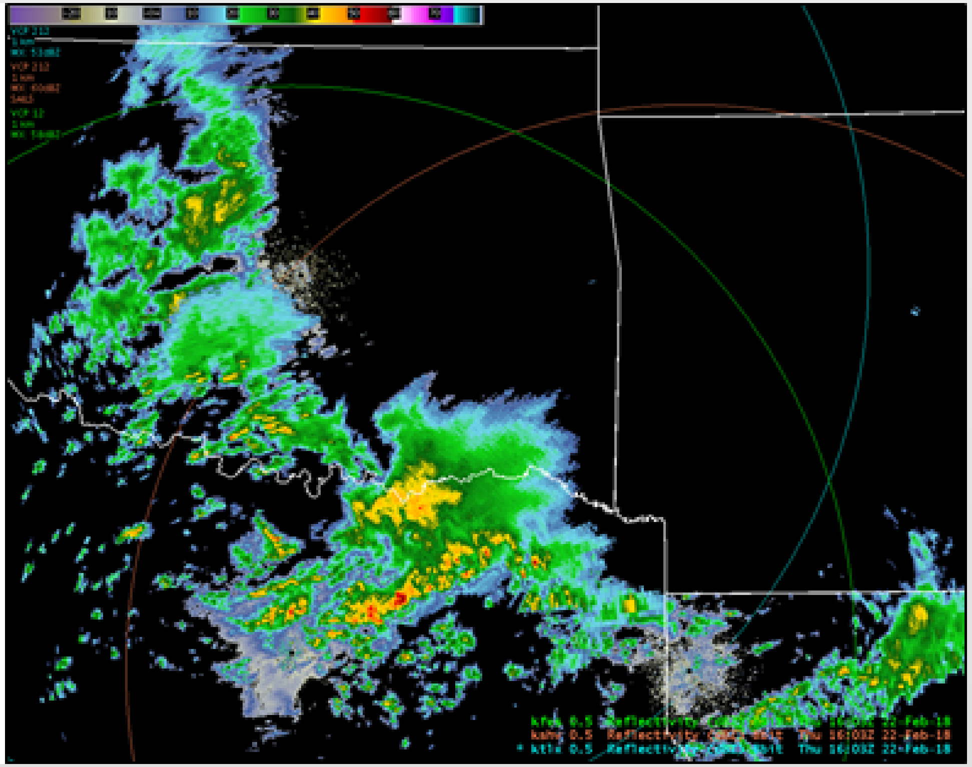
- Averaging can mask the desired signal – Very true if using a 5 minute summation
- Additional work needed for “significant” values of “small” flashes

Additional Products: Combined Animation



GLM Capabilities: The "stoplight" product



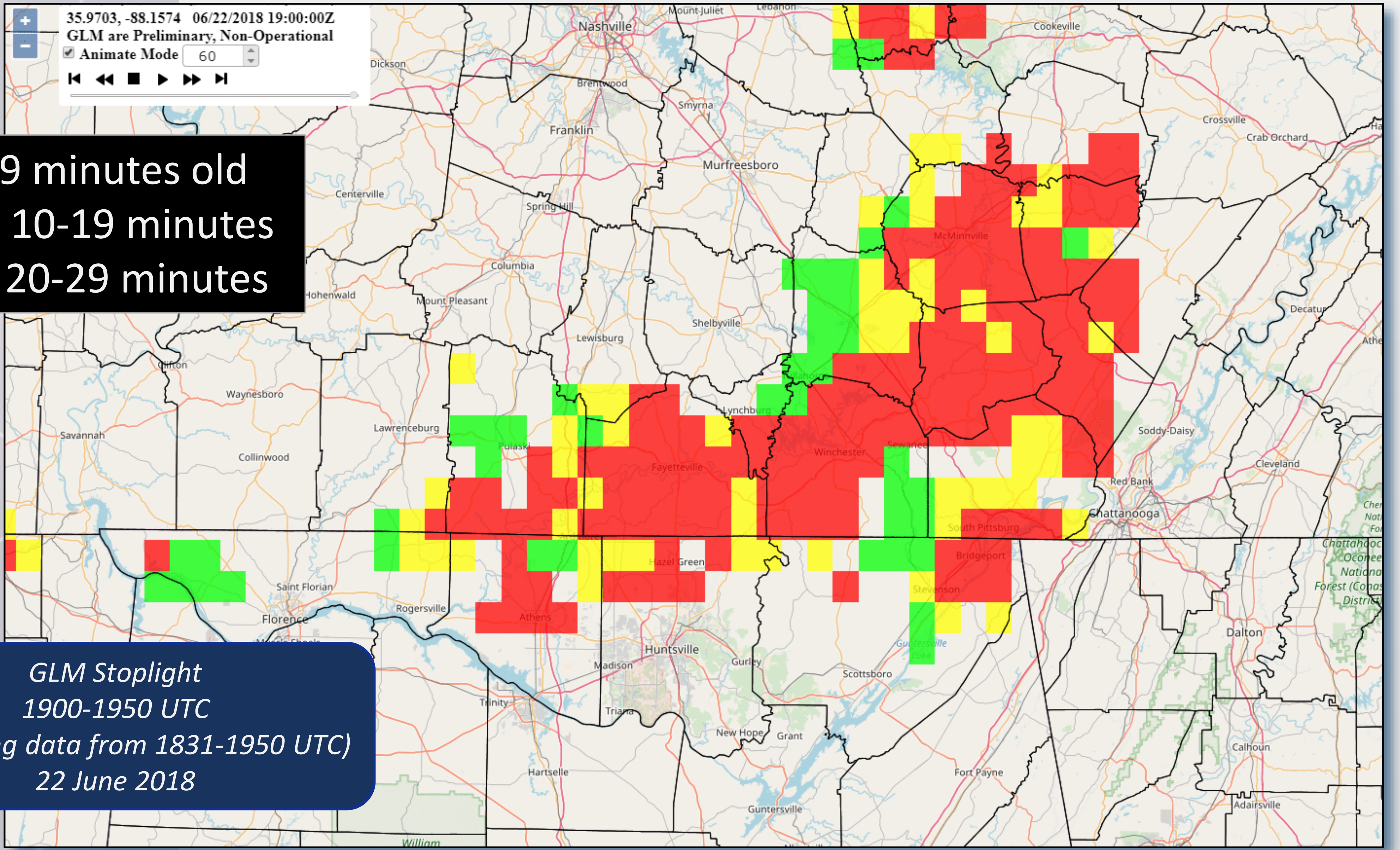


Example of the GLM stoplight product (left) with radar reflectivity covering 30 minutes from 1743-1813 UTC on 7 March 2018.

- New SPoRT ability
- Collaboration with local emergency managers
- Based on 30 min rule
- Show location and age of lightning obs in a single image
  - 0-9 min (red)
  - 10-19 min (yellow)
  - 20-29 min (green)
- Early reviews suggest not using green (may suggest safe)

SPoRT Short-term Prediction Research and Transition Center

GLM Stoplight Animation – Lightning Safety

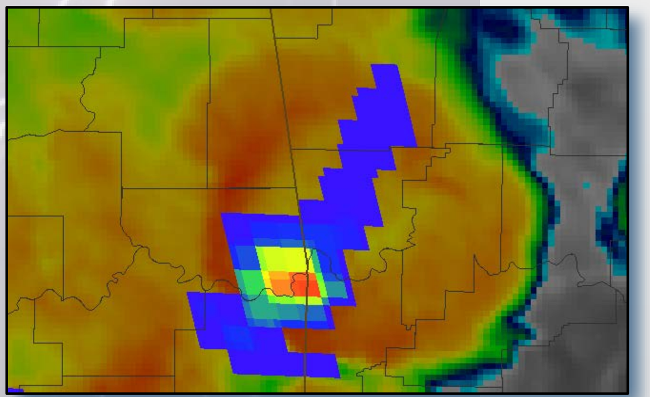


Red: 0-9 minutes old
Yellow: 10-19 minutes
Green: 20-29 minutes

GLM Stoplight
1900-1950 UTC
(containing data from 1831-1950 UTC)
22 June 2018

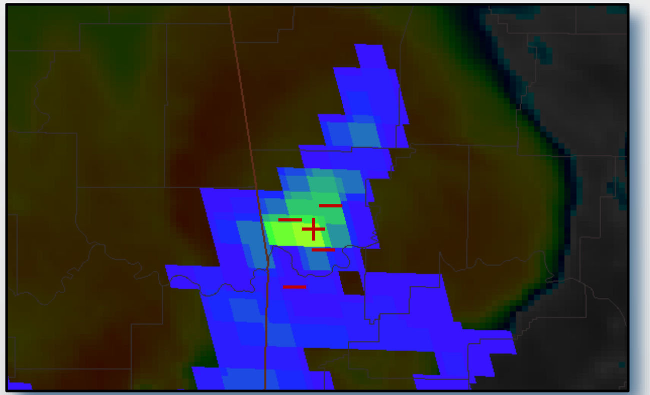
Summary

Advantages



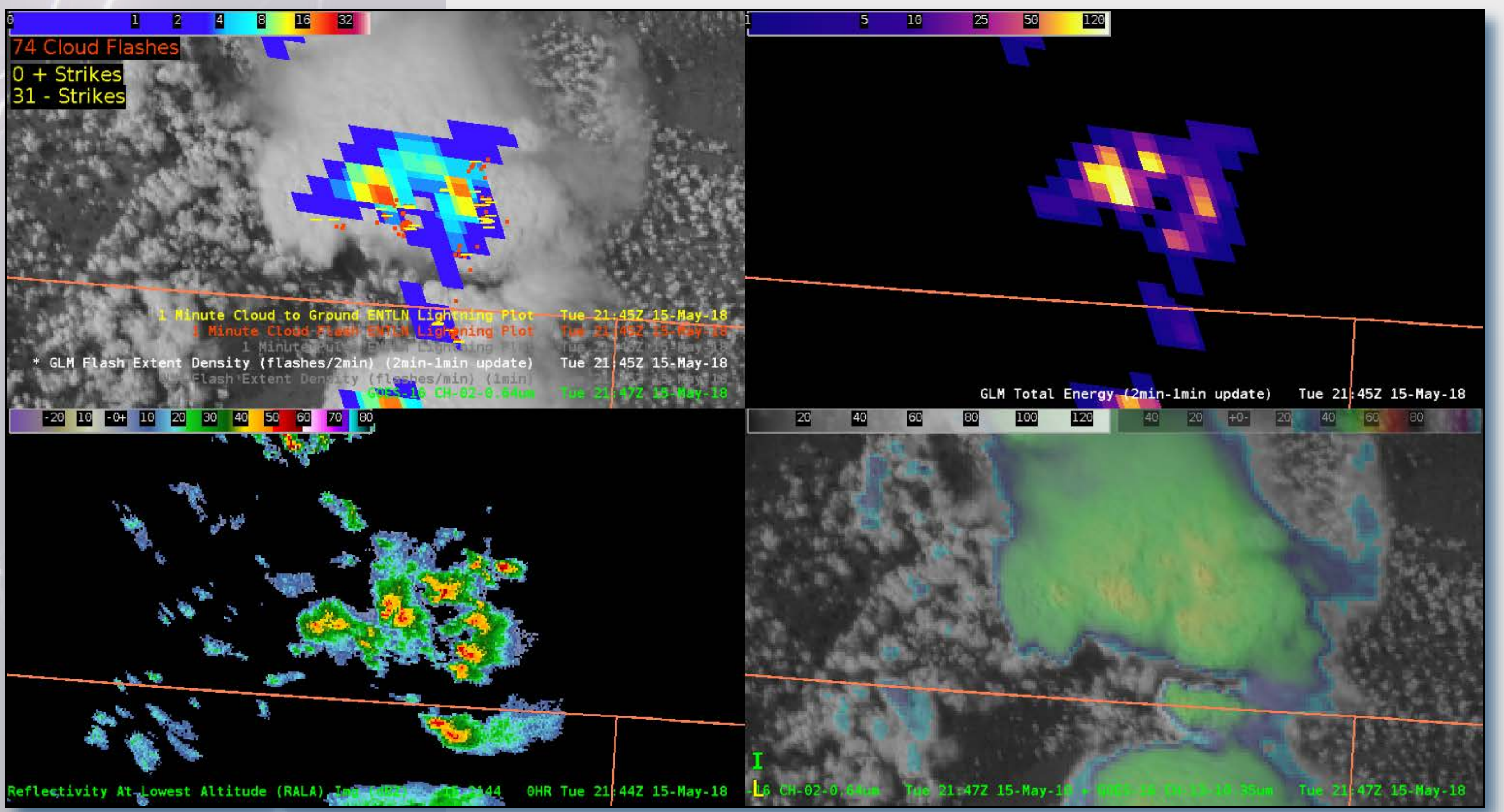
- Lightning tied to storm intensity – jumps signal potential severe weather
- Situational awareness to “triage” time to investigate specific storms
- Lightning safety with spatial extent and intra-cloud often precedes first cloud-to-ground
- Available in data sparse regions

Limitations



- Does not distinguish intra-cloud or cloud-to-ground
- No polarity observations
- High shear / low CAPE can result in null events (severe weather with limited lightning observed)
- Best detections at night

Questions?



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NASA SPoRT

https://weather.msfc.nasa.gov/sport

(Quick look GLM page)

NASA SPoRT Blog

https://nasasport.wordpress.com

Maryland – CICS

https://lightning.umd.edu/

GOES-R

http://www.goes-r.gov/

GLM Virtual Lab page

https://vlab.ncep.noaa.gov/group/geostationary-lightning-mapper/home