Preparing the Operational Community for Satellite-Based Total Lightning Observations

Dr. Geoffrey T. Stano

NASA Short-term Prediction Research and Transition (SPoRT) / ENSCO, Inc.
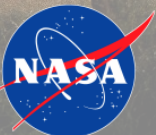
EUMETRAIN Event Week on MTG-I

10 November 2016

Image courtesy of Marcus Hustedde

NASA Short-term Prediction Research and Transition Center

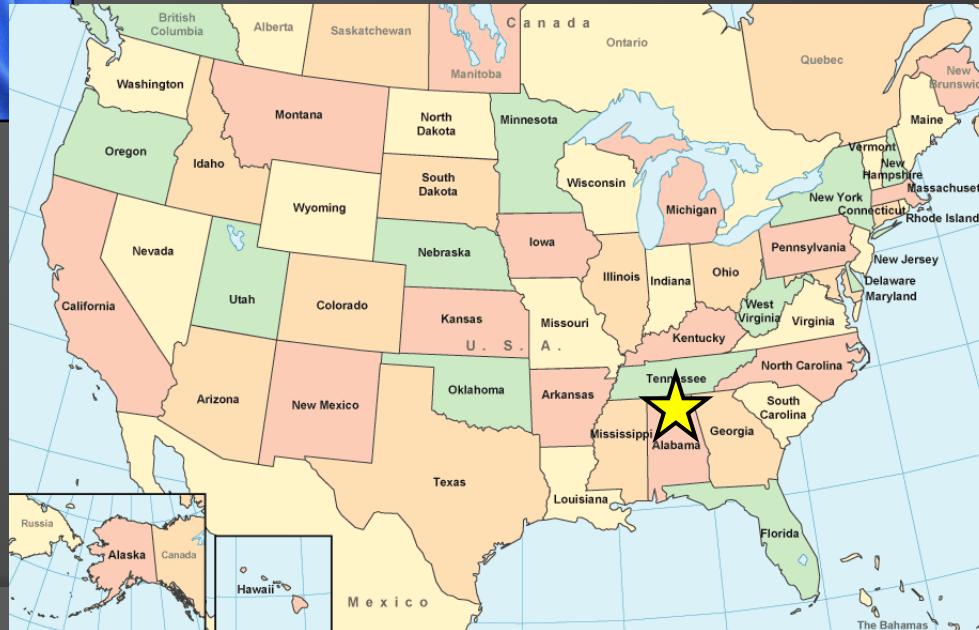# About the Presenter

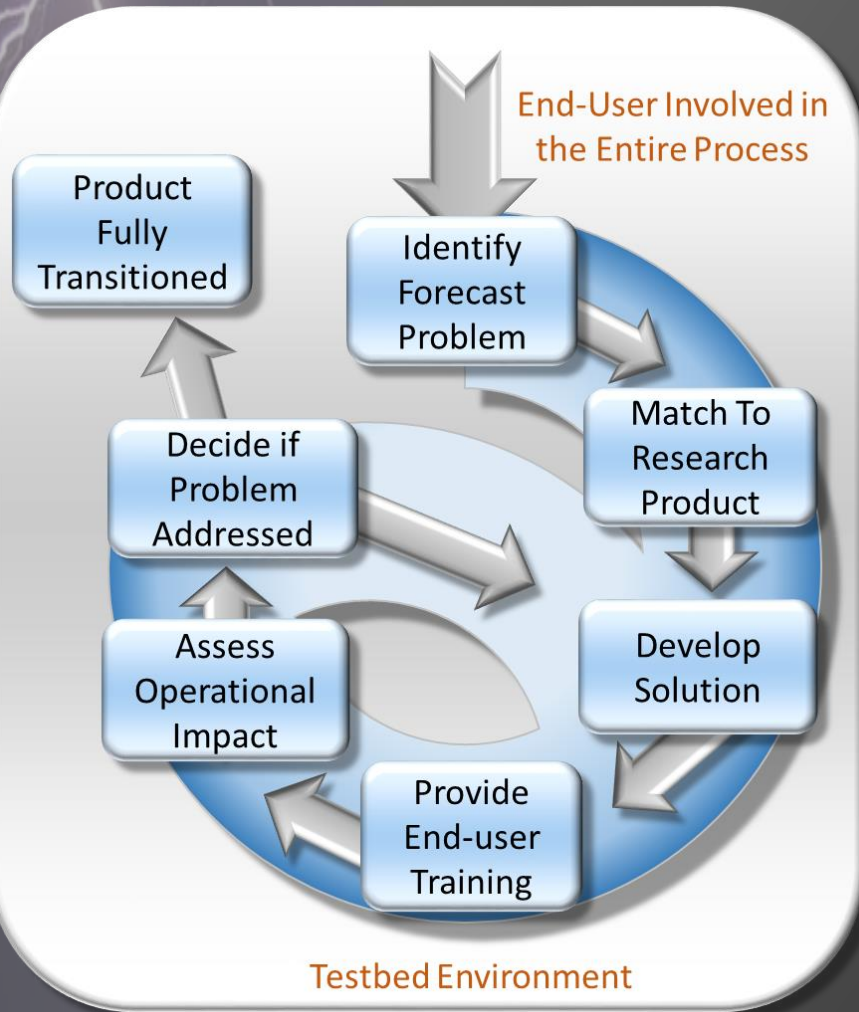- NASA SPoRT total lightning expert
- 13 years of operational applications with lightning data (10 supporting U.S. National Weather Service)
- GOES-R Satellite Liaison (training and awareness) for the GLM
- Key activities
  - Lightning safety for Kennedy Space Center, Cape Canaveral Air Force Station, and Kodiak Launch Complex (Alaska)
  - Aviation and safety applications
 - Severe weather / situational awareness

Dr. Geoffrey Stano

NASA Short-term Prediction Research and Transition (SPoRT) Program

End-User Involved in the Entire Process

Product Fully Transitioned

Identify Forecast Problem

Match To Research Product

Decide if Problem Addressed

Develop Solution

Assess Operational Impact

Provide End-user Training

Testbed Environment

SPoRT is focused on transitioning <u>unique</u> NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

- o Collaborations with weather forecast offices / National Centers across the United States
- o SPoRT activities began in 2002

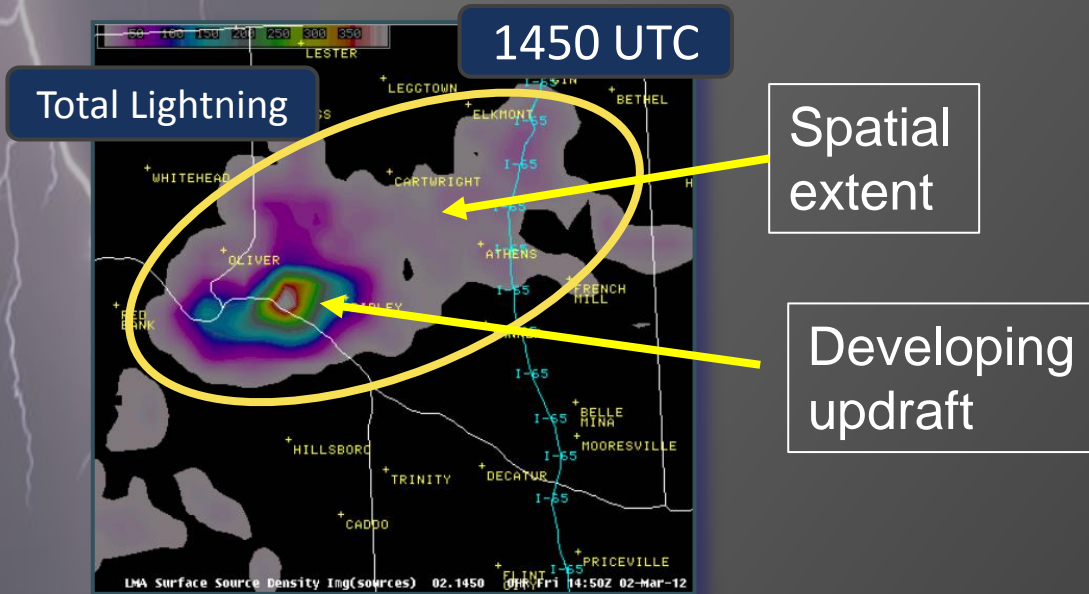**Proven paradigm for transition of research and experimental data to "operations"**
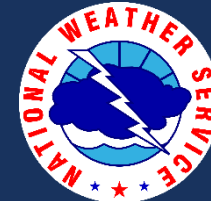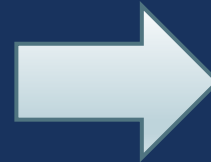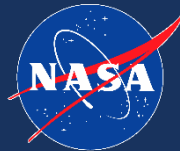
Benefit
- o Demonstrate capability of NASA and NOAA experimental products to weather applications and societal benefit
- o Prepares forecasters for next generation of operational satellites (JPSS, GOES-R)

Total Lightning ... In a Flash

1450 UTC

Total Lightning

Spatial extent

Developing updraft

Total Lightning

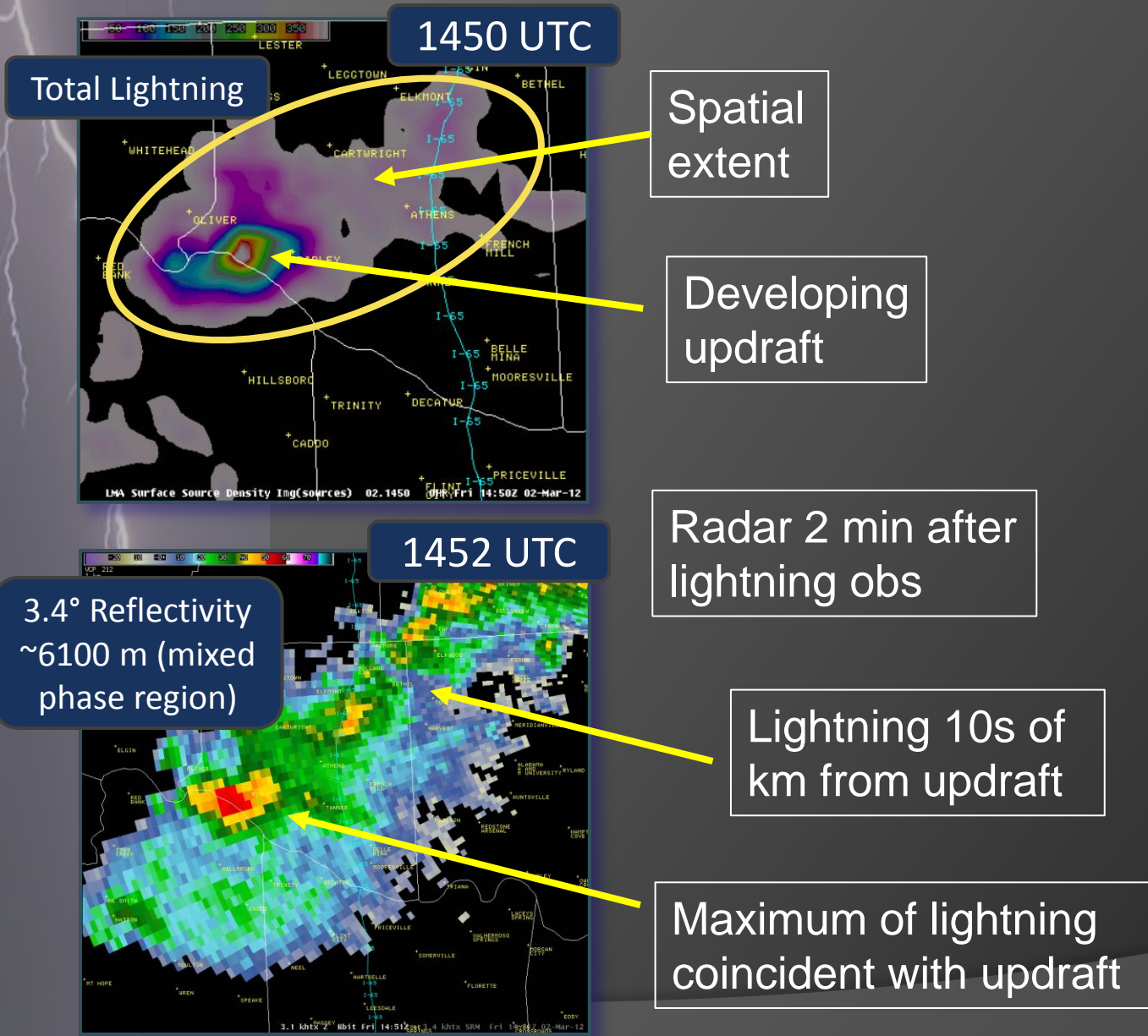- Intra-cloud and cloud-to-ground
- Rapid updates

Physical Reasoning

- Driven by updraft in mixed phase region (above -10°C)
- Stronger, deeper updrafts
  - More lightning
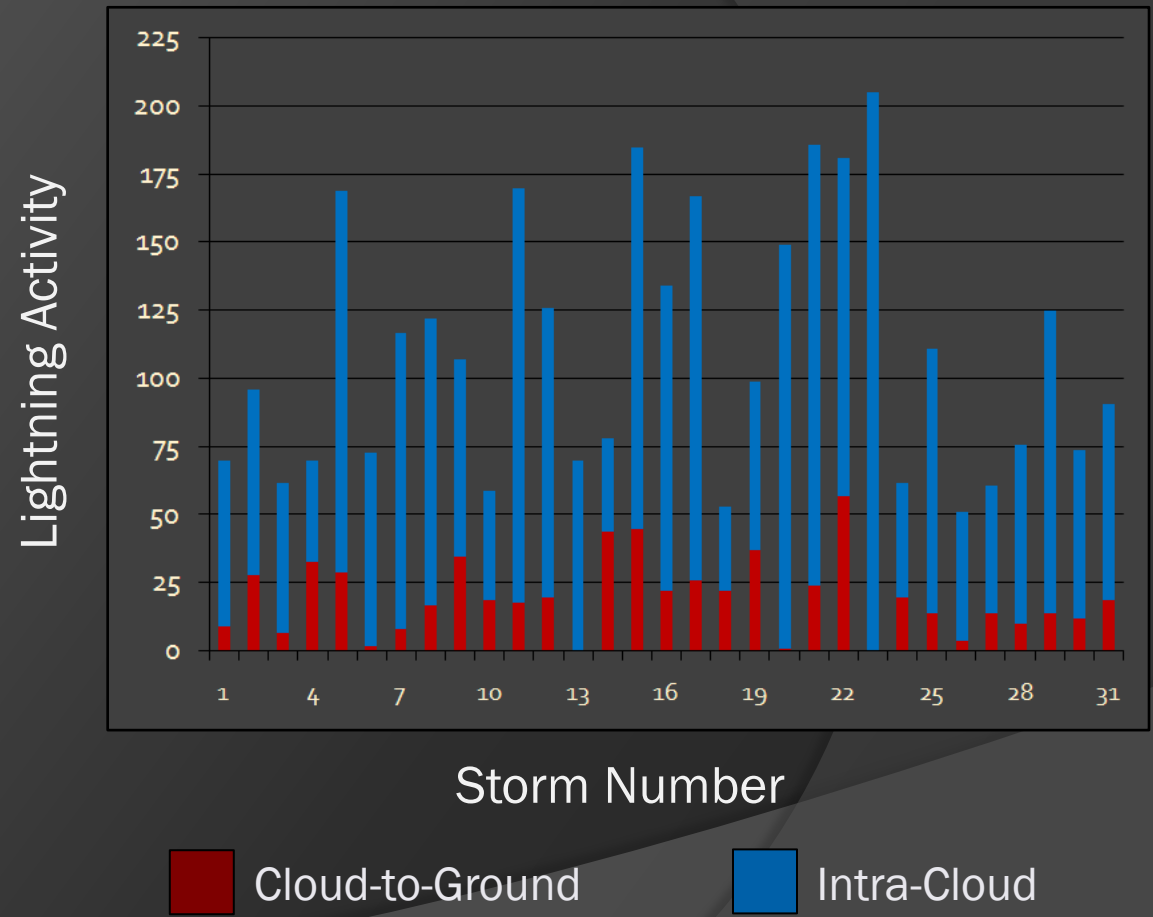- Increase = strengthening updraft

Applications

- Rapid increases = lightning jumps
  - Severe weather decision support
- Lightning safety: Extent and lead time on first cloud-to-ground
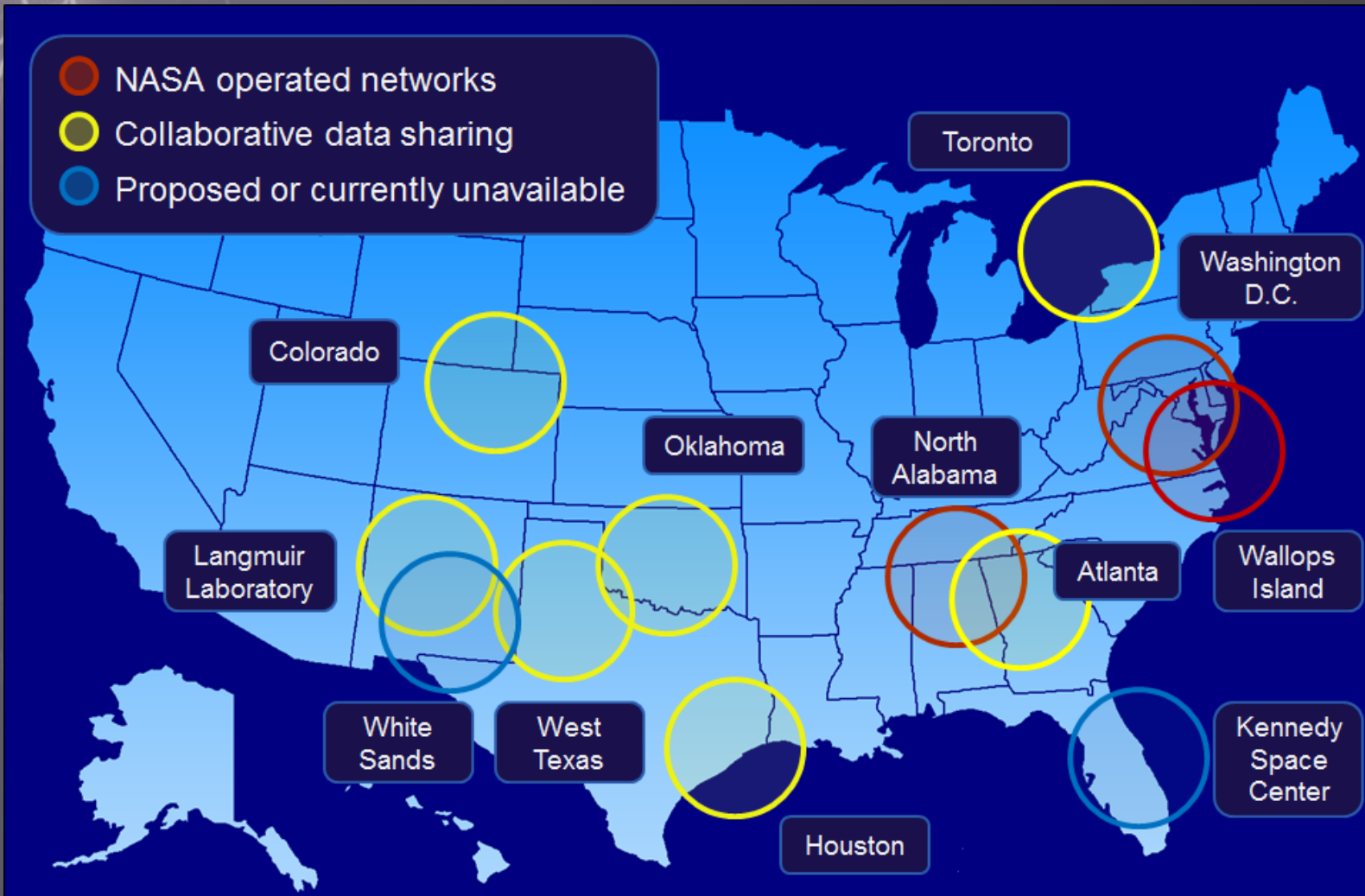- Aviation: Convective activity

Total Lightning … In a Flash

1450 UTC

Total Lightning

Spatial extent

Developing updraft

1452 UTC

3.4° Reflectivity ~6100 m (mixed phase region)

Radar 2 min after lightning obs

Lightning 10s of km from updraft

Maximum of lightning coincident with updraft

Total Lightning

- Intra-cloud and cloud-to-ground
- Rapid updates

Physical Reasoning

- Driven by updraft in mixed phase region (above -10°C)
- Stronger, deeper updrafts
  - More lightning
- Increase = strengthening updraft

Applications

- Rapid increases = lightning jumps
  - Severe weather decision support
- Lightning safety: Extent and lead time on first cloud-to-ground
- Aviation: Convective activity

Advantages of Total Lightning

Advantages of total lightning

- Combination of intra-cloud and cloud-to-ground observations

- Majority of lightning is intra-cloud

- Intra-cloud flashes typically precede first cloud-to-ground flash

- Useful for safety applications

- Spatial extent information is completely new ability to support safety

Where Have We Been?

Legend:
- NASA operated networks
- Collaborative data sharing
- Proposed or currently unavailable

Map labels: Toronto, Washington D.C., Colorado, Oklahoma, North Alabama, Wallops Island, Langmuir Laboratory, Atlanta, White Sands, West Texas, Kennedy Space Center, Houston

Variety of Collaborators
- Forecast offices
- National Centers
- Emergency Managers

NASA SPoRT

Where Have We Been?

Pseudo GLM flash extent density
Earth Networks IC/CG flashes
GOES-14 super rapid scan IR

PGLM – Shaded
ENI CGs – Blue
ENI ICs – Yellow circles

1 Minute ENTLN Lightning Plot   Thu 1808Z 11-Jun-15
1 Minute Cloud Flash ENTLN Lightning Plot   Thu 1808Z 11-Jun-15
" GOES-14 SRSOR IR Imagery   Thu 1808Z 11-Jun-15
PGCO Surface Flash Extent Density Img-9   Thu 1808Z 11-Jun-15

From Hazardous Weather Testbed

Variety of Collaborators

- Forecast offices
- National Centers
- Emergency Managers

Initial Demonstration Work

- Used the NASA SPoRT Pseudo-GLM
- Simple product from ground-based lightning mapping arrays
- Training tool – Using 8 km resolution flash density

Preparing for the GOES-R Launch

35.1265, -87.8058 09/15/2016 21:28:00Z
Animate Mode 20

NASA Marshall Space Flight Center

~16 km

~32 km
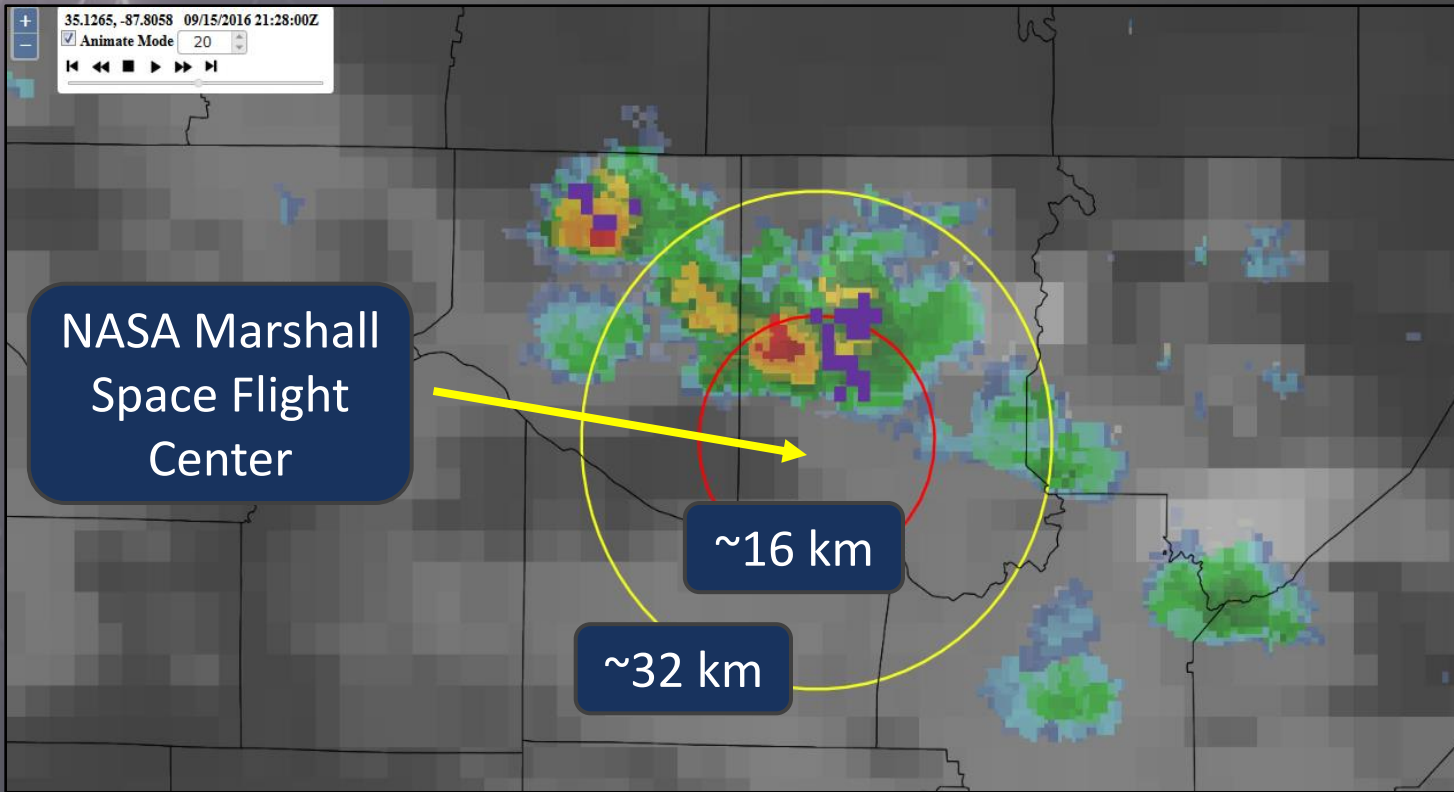
Total lightning internet display for lightning safety
using ground-based lightning mapping array

Later this month!

- Shift to satellite-based total lightning observations
- Internet display (left) for lightning safety at Marshall Space Flight Center
- Older version used by emergency managers during U.S. Women's National Soccer Team game
- Helped decision to evacuate 20 thousand spectators
- But, also need training …

NASA SPORT

Visualizing the Importance of GLM
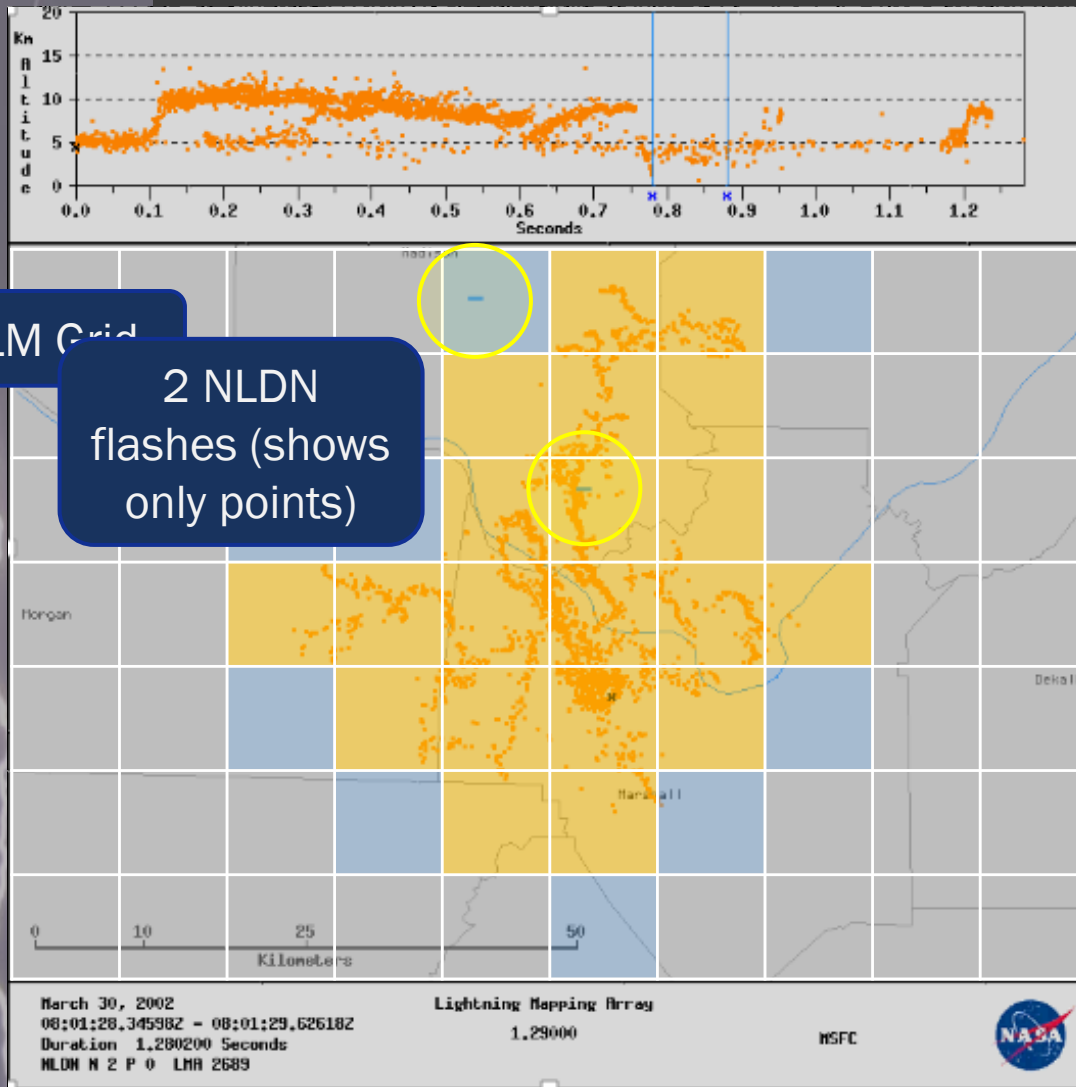
GLM Grid

2 NLDN flashes (shows only points)

- Animation shows ONE flash from a high resolution research network
- Consider:
  - Amount of information not conveyed by NLDN or Earth Networks now
- GLM attempts to give some of that information, albeit at lower resolution
  - Also consider that light will be scattered by clouds

Main flash

Scattered light from flash by clouds

Training Activities

Operational Examples

Part of an "Applications Library" under development

The following two examples use a training GLM "proxy" called the pseudo-GLM

Derived from ground-based lightning mapping arrays

Not an exact GLM replica, but simulates temporal and spatial features

A Severe Weather Example

Nashville, TN
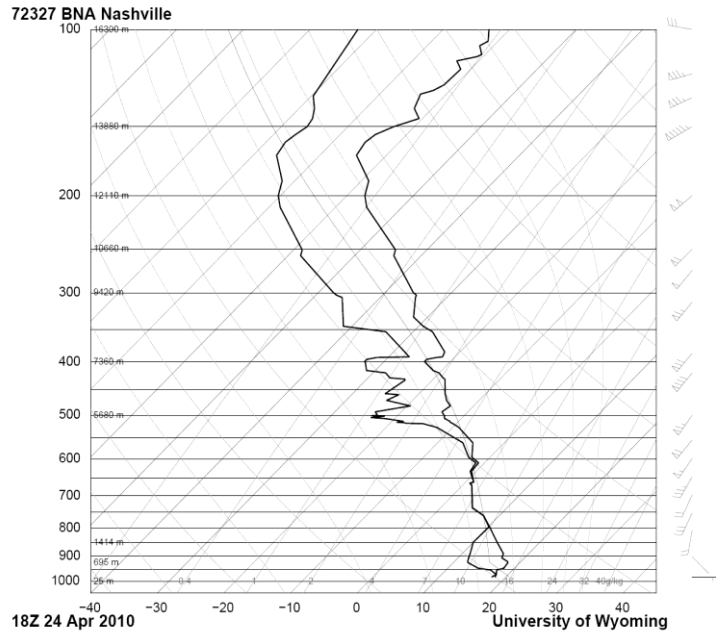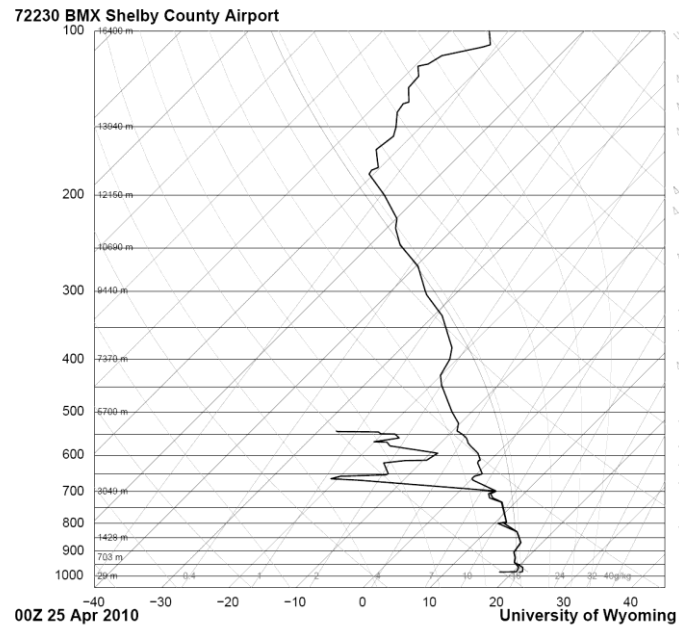
Birmingham, AL

Synoptic Details

- CAPE 300 – 1100 (N to S)
- Moisture through 700 mb
- PW 1.19 – 1.57 in (N to S)
- Indices show severe wx
- Weak vorticity
- Good jet dynamics
  - Diffluence @ 250 mb
- Approaching warm front
- Triple point to west

Initial Overview

PGLM

Reflectivity

NLDN

Velocity

0310 UTC

Weak total lightning (~6 flashes in two minutes)

Several strong but non-severe storms

No NLDN available at this moment
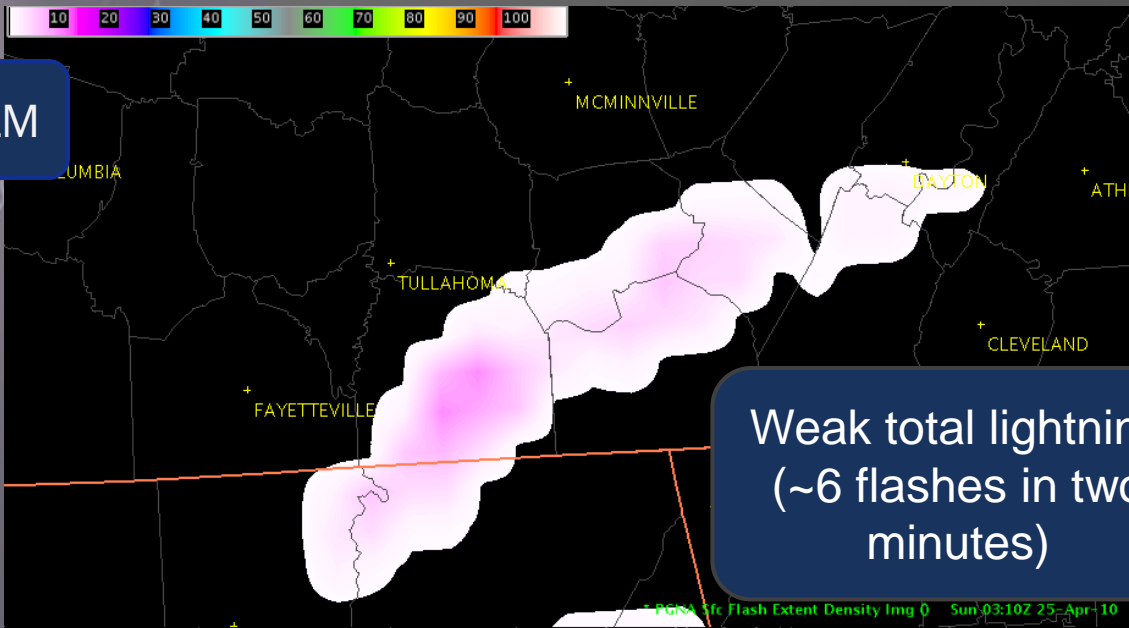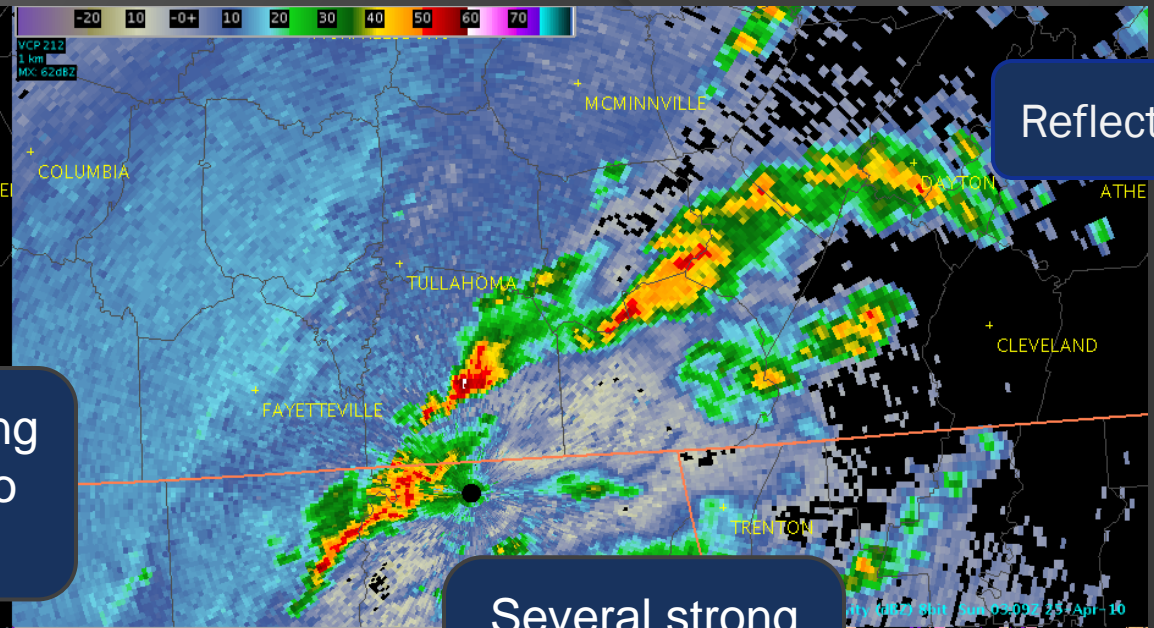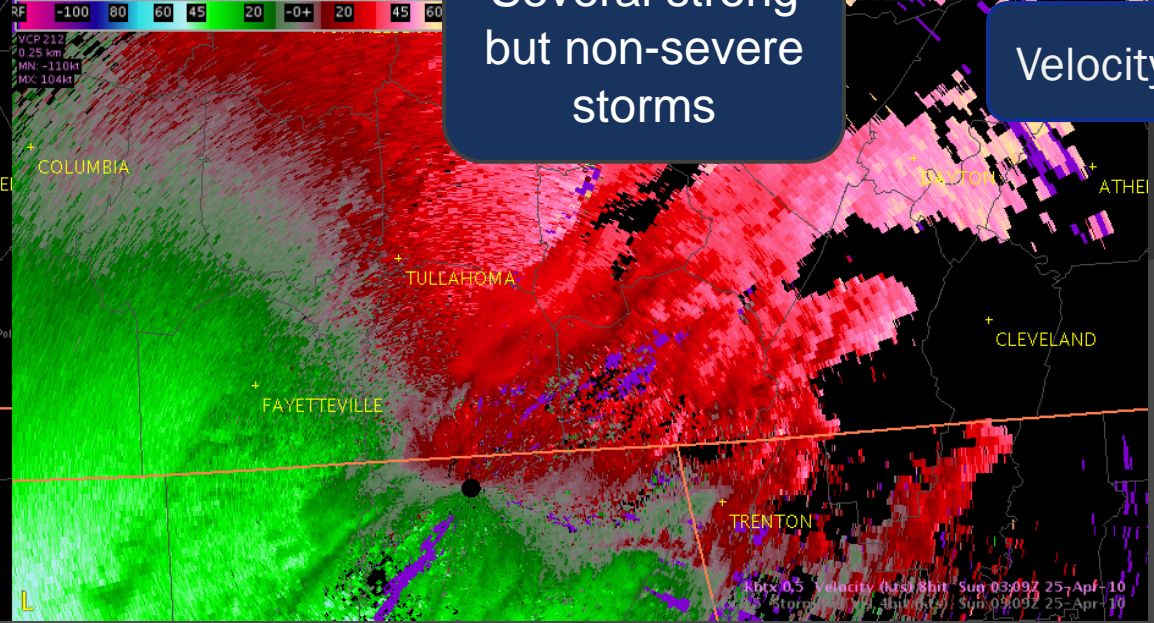
Early Intensification

PGLM

Reflectivity

Notable increase in SW storms

NLDN

Velocity

Pseudo GLM Flash Extent Density

- Favorable environment
- Strong storms but analyzed sub-severe
- Lightning emphasizing SW storms
- What would you do given this trend?

0336 UTC

Handful of NLDN flash
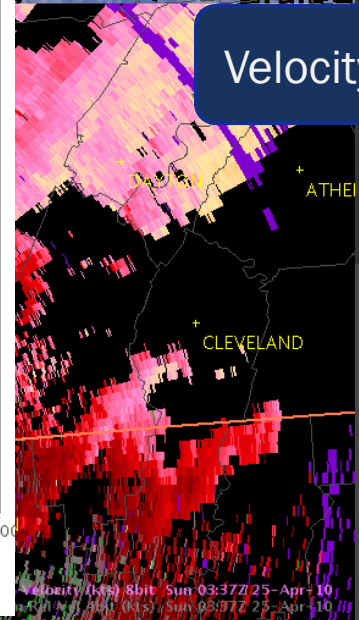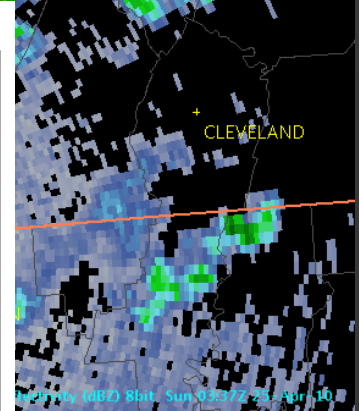
Lightning Activity Decreases

PGLM

Reflectivity

PGLM drop off

NLDN

Velocity

No NLDN trend

0340 UTC
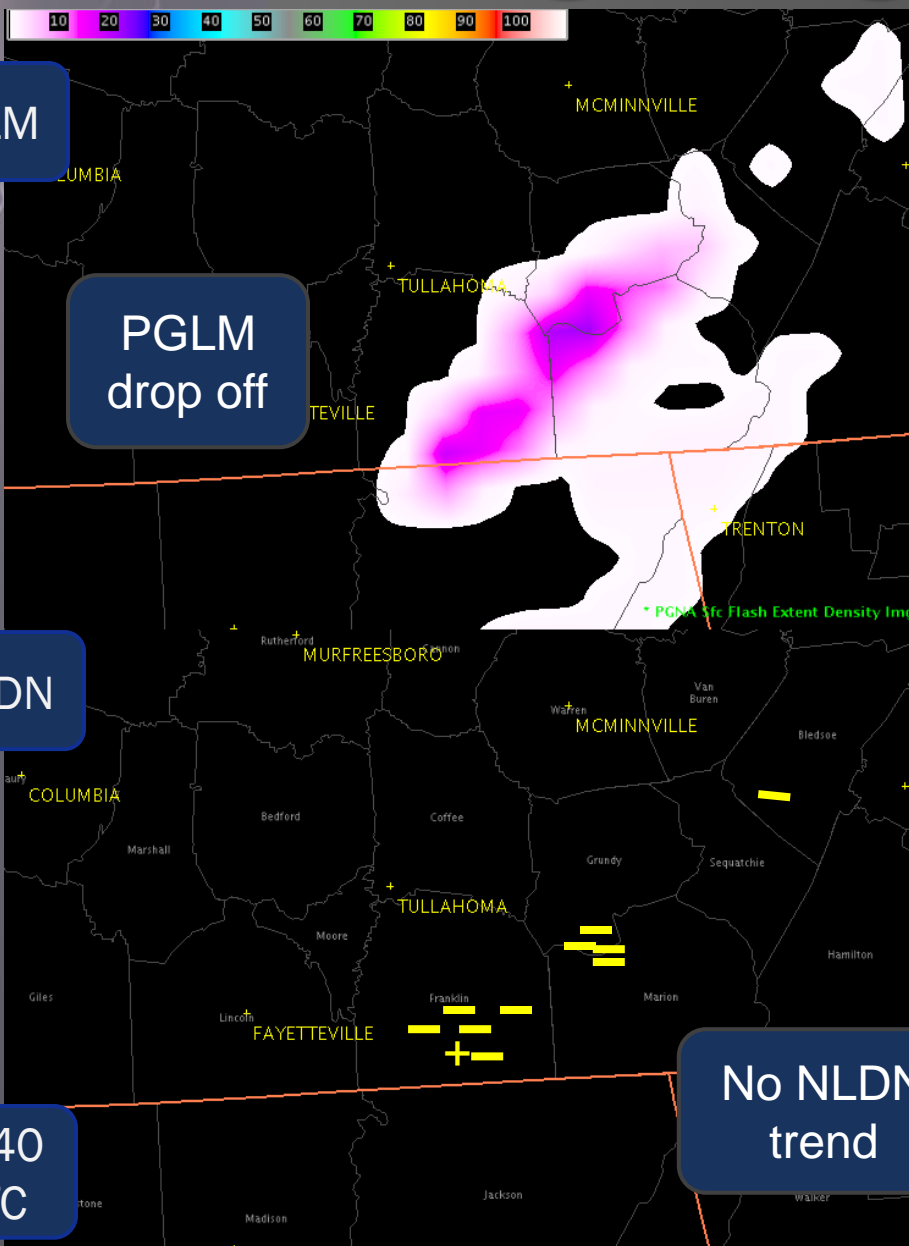
Pseudo GLM Flash Extent Density
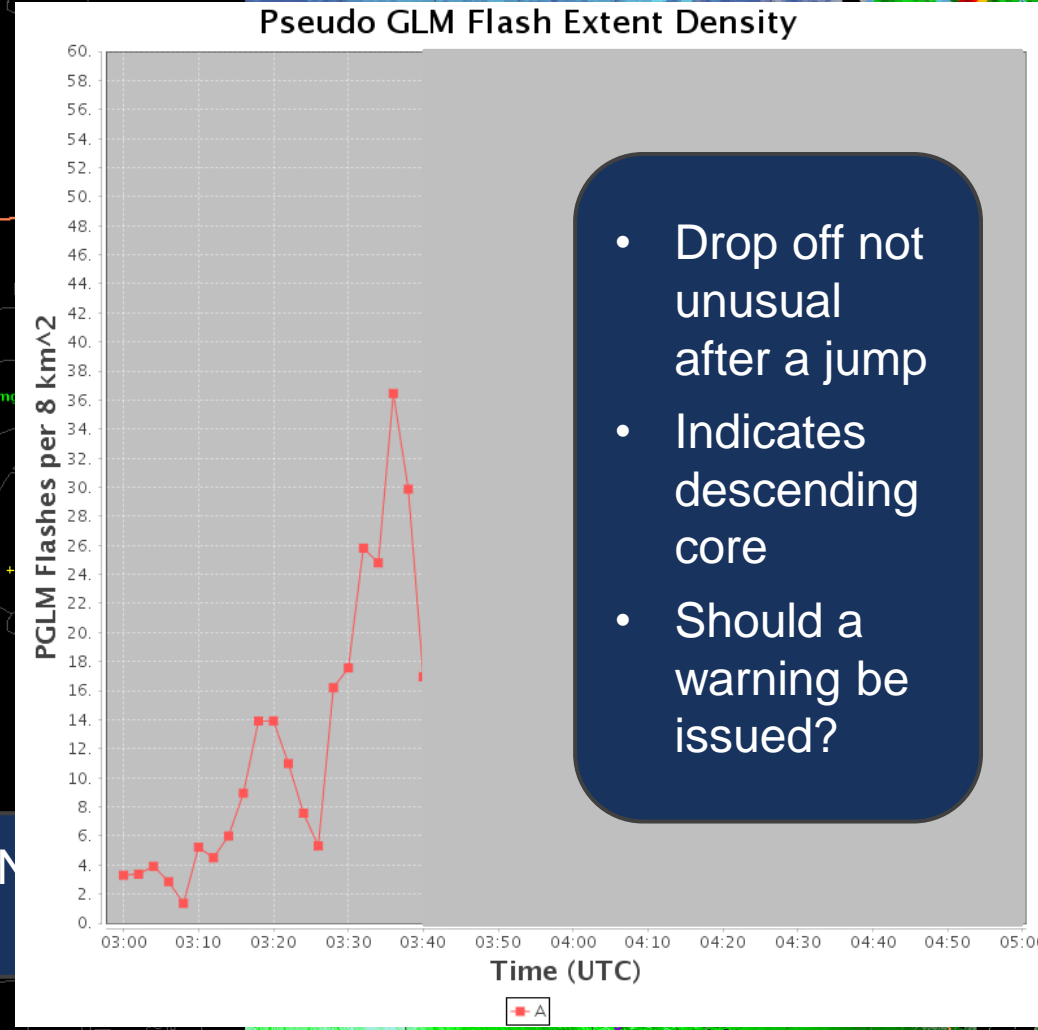
- Drop off not unusual after a jump
- Indicates descending core
- Should a warning be issued?

Storm Is Cycling

PGLM

Reflectivity

NLDN

Velocity

0350 UTC

SW [storm is] cycling [up,] intens[ifying]
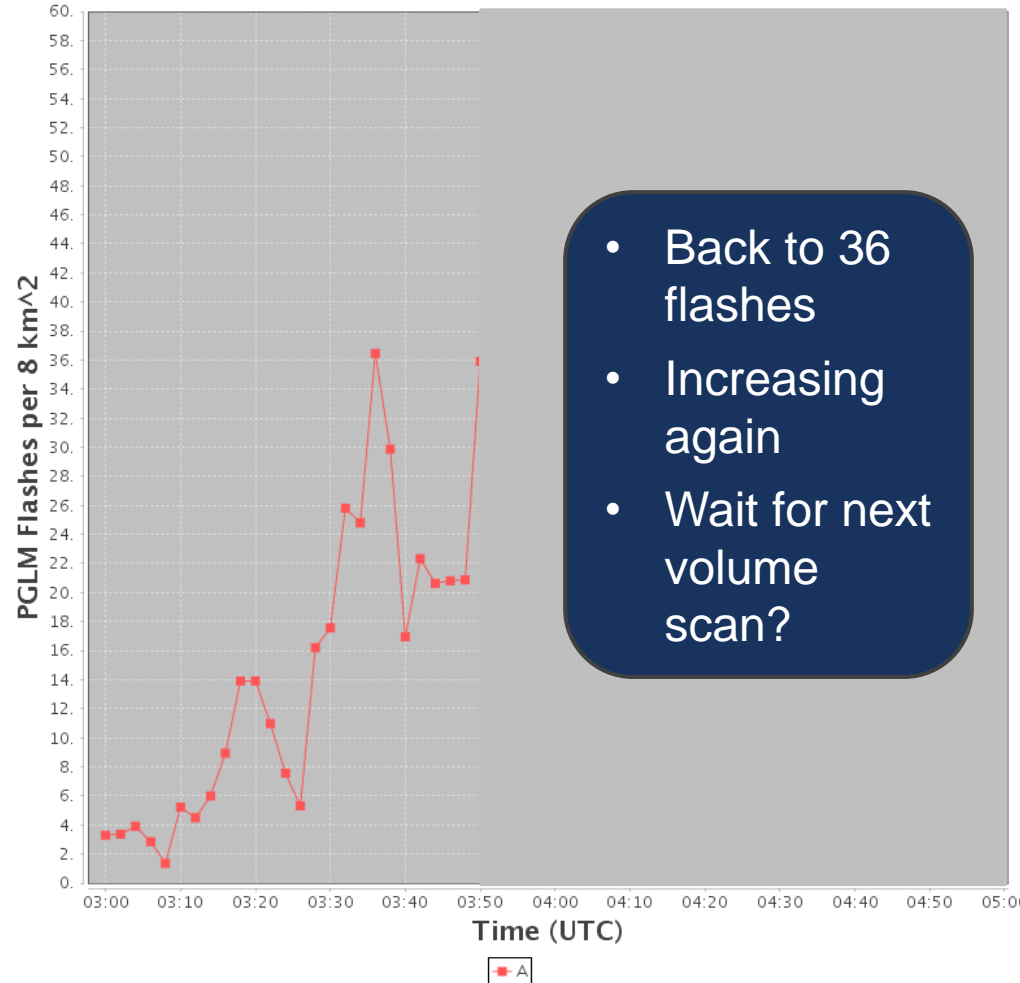
No lightning on developing cell

Overall NLDN tren[d] unchange[d]

Pseudo GLM Flash Extent Density

* Back to 36 flashes
* Increasing again
* Wait for next volume scan?
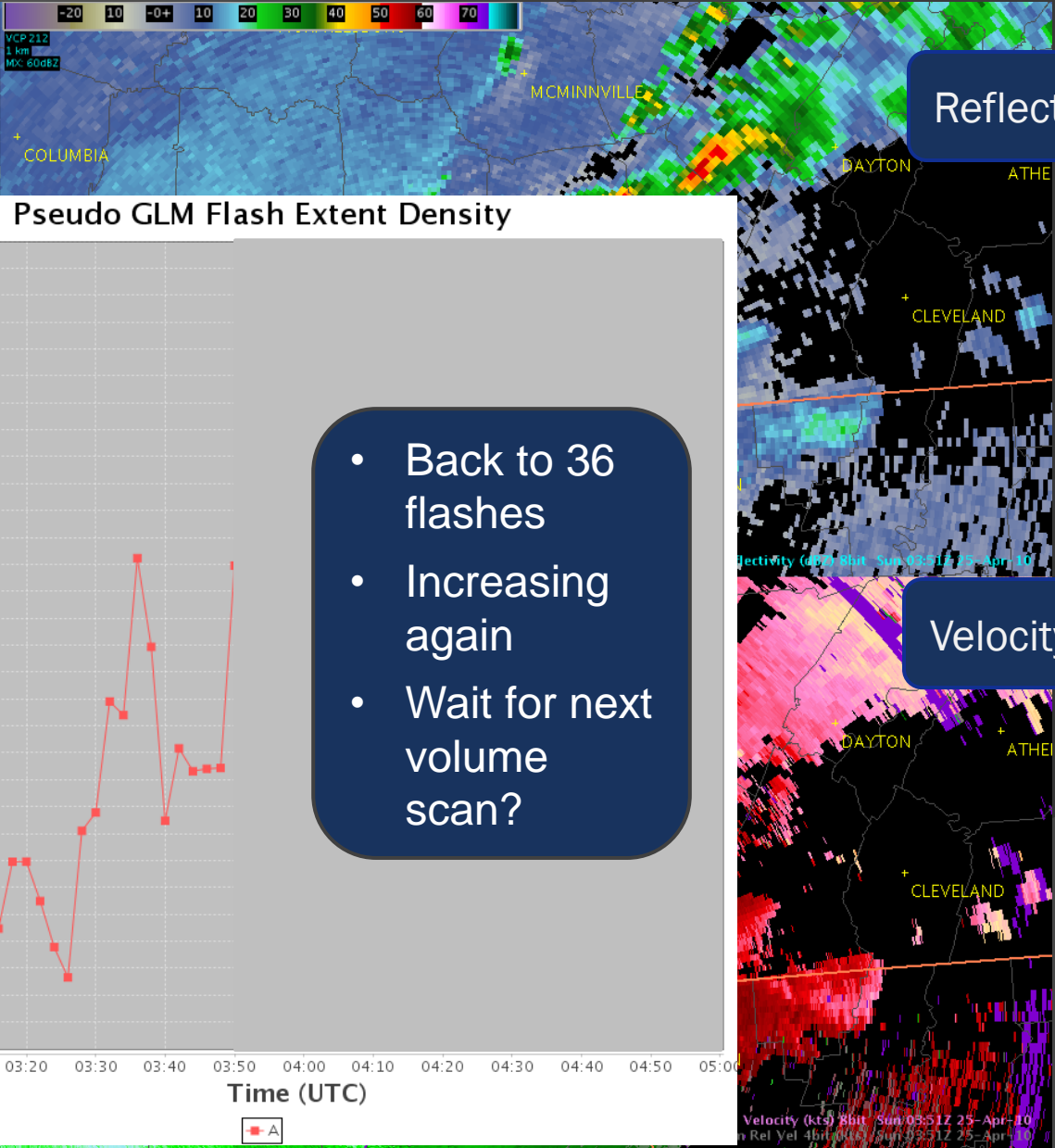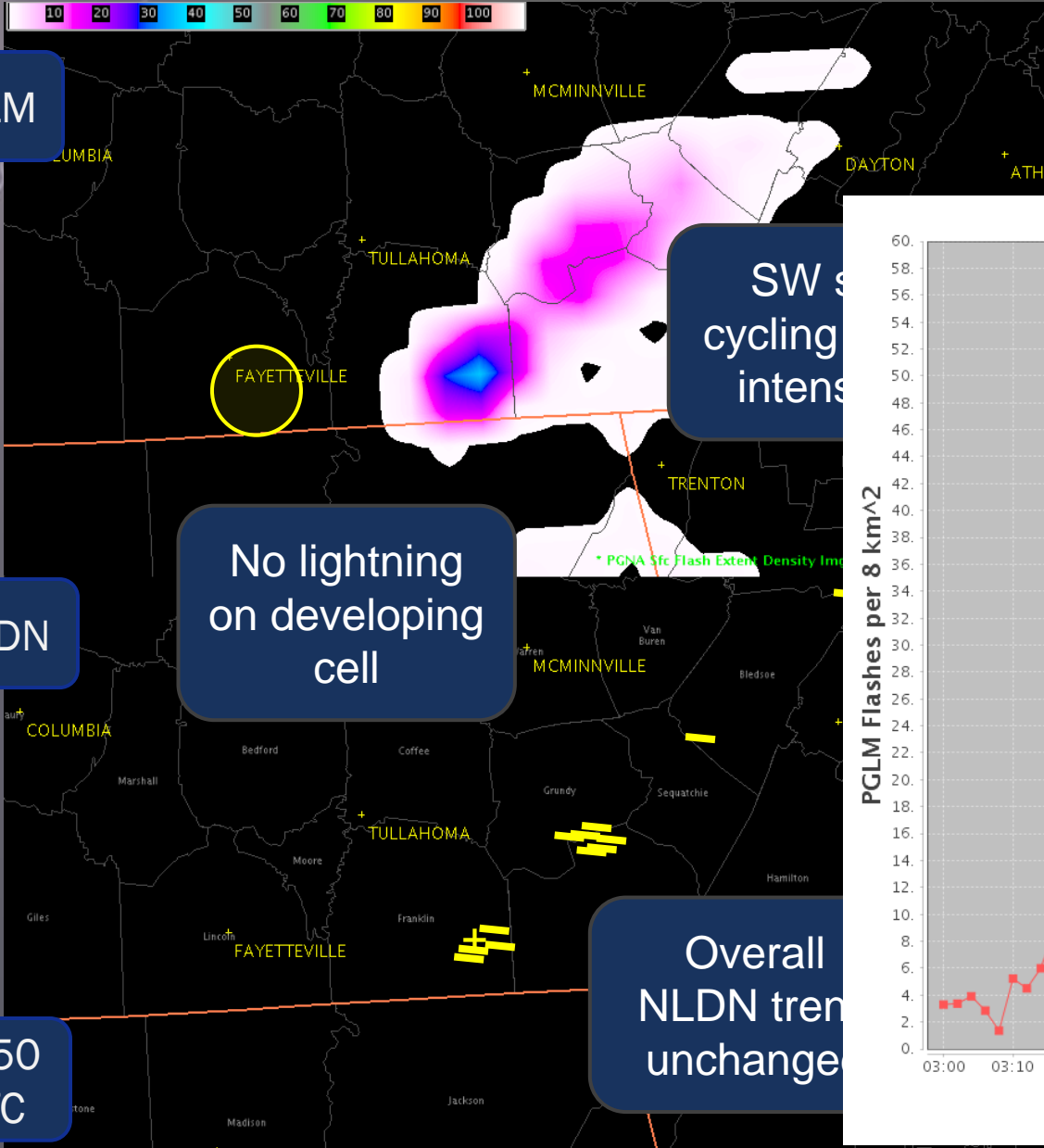
Lightning Jump!

PGLM

Reflectivity

SW cell still increasing; Cell to NE strengthening
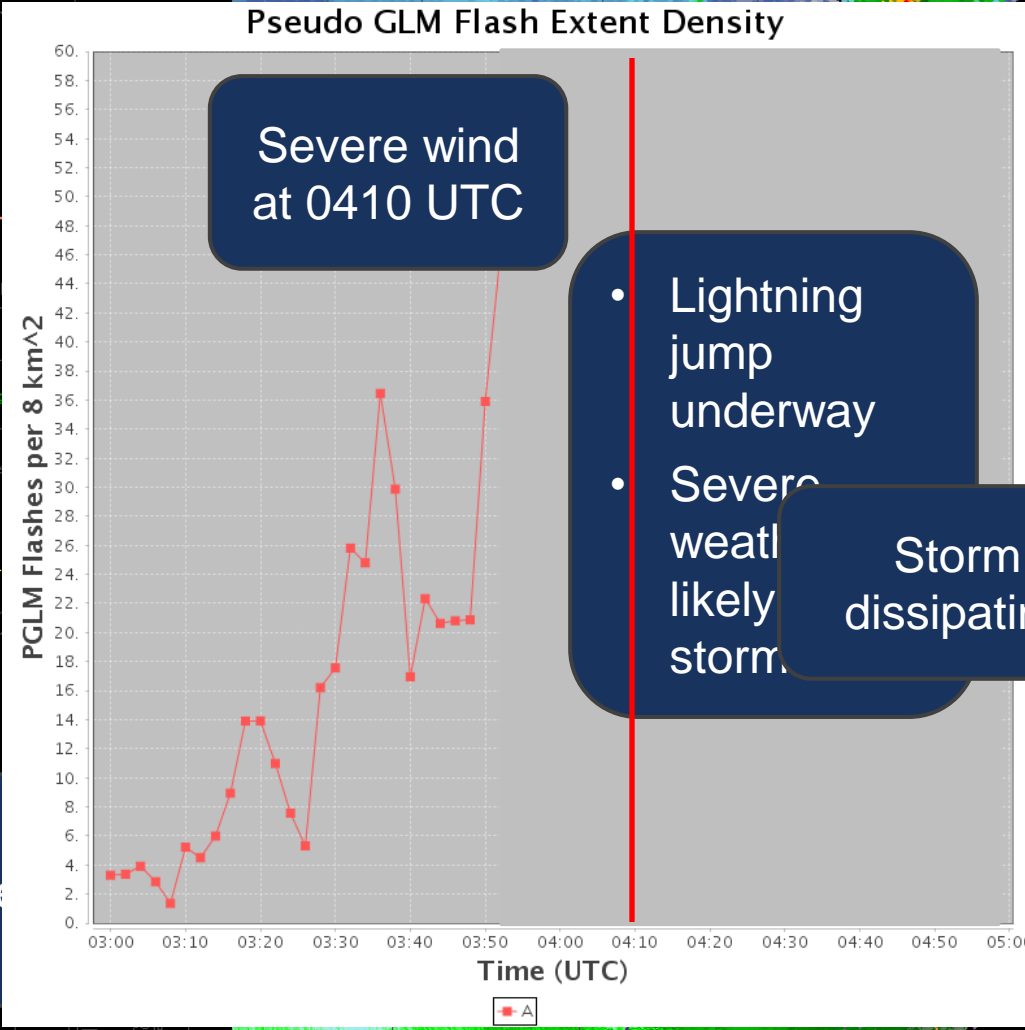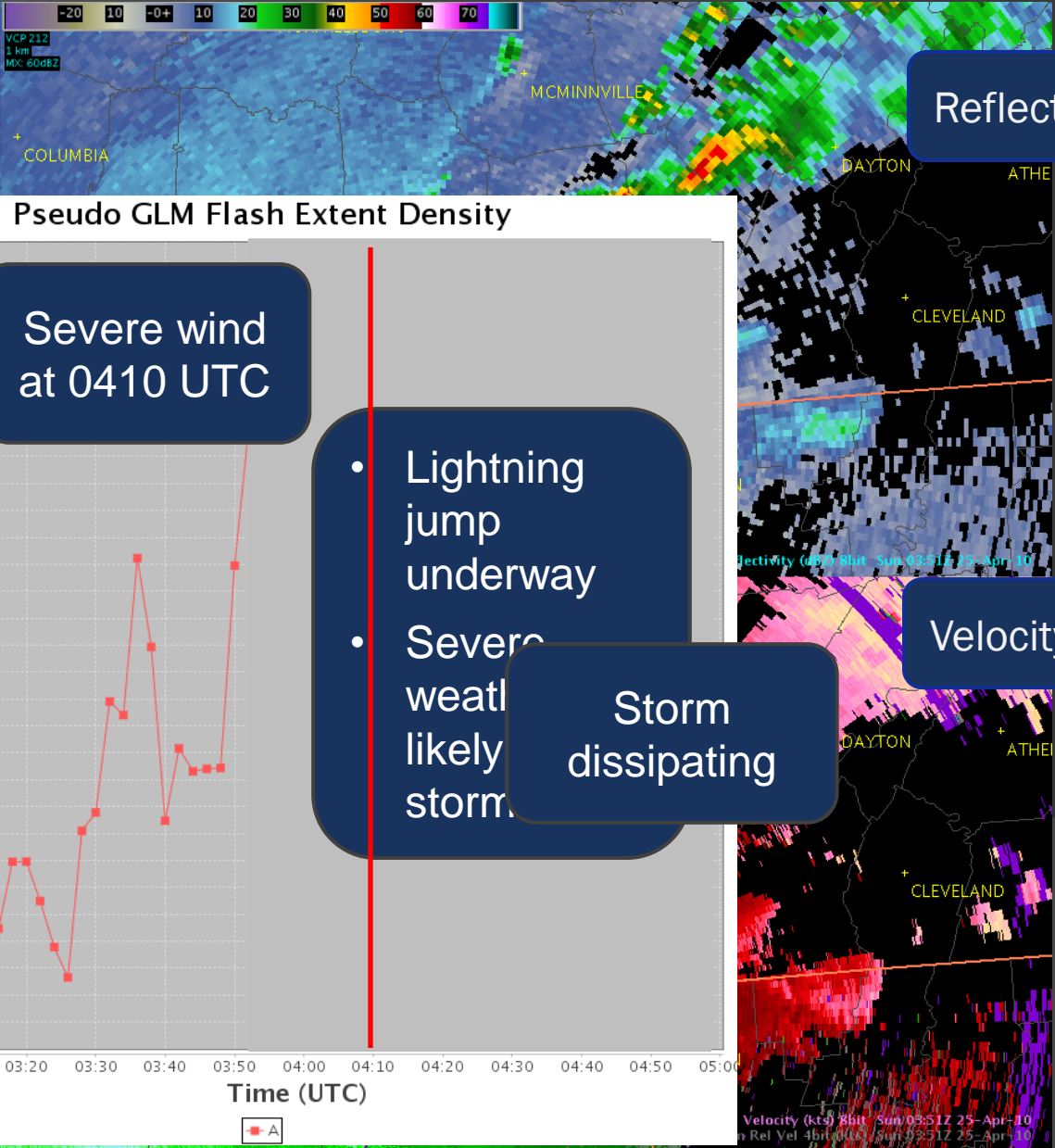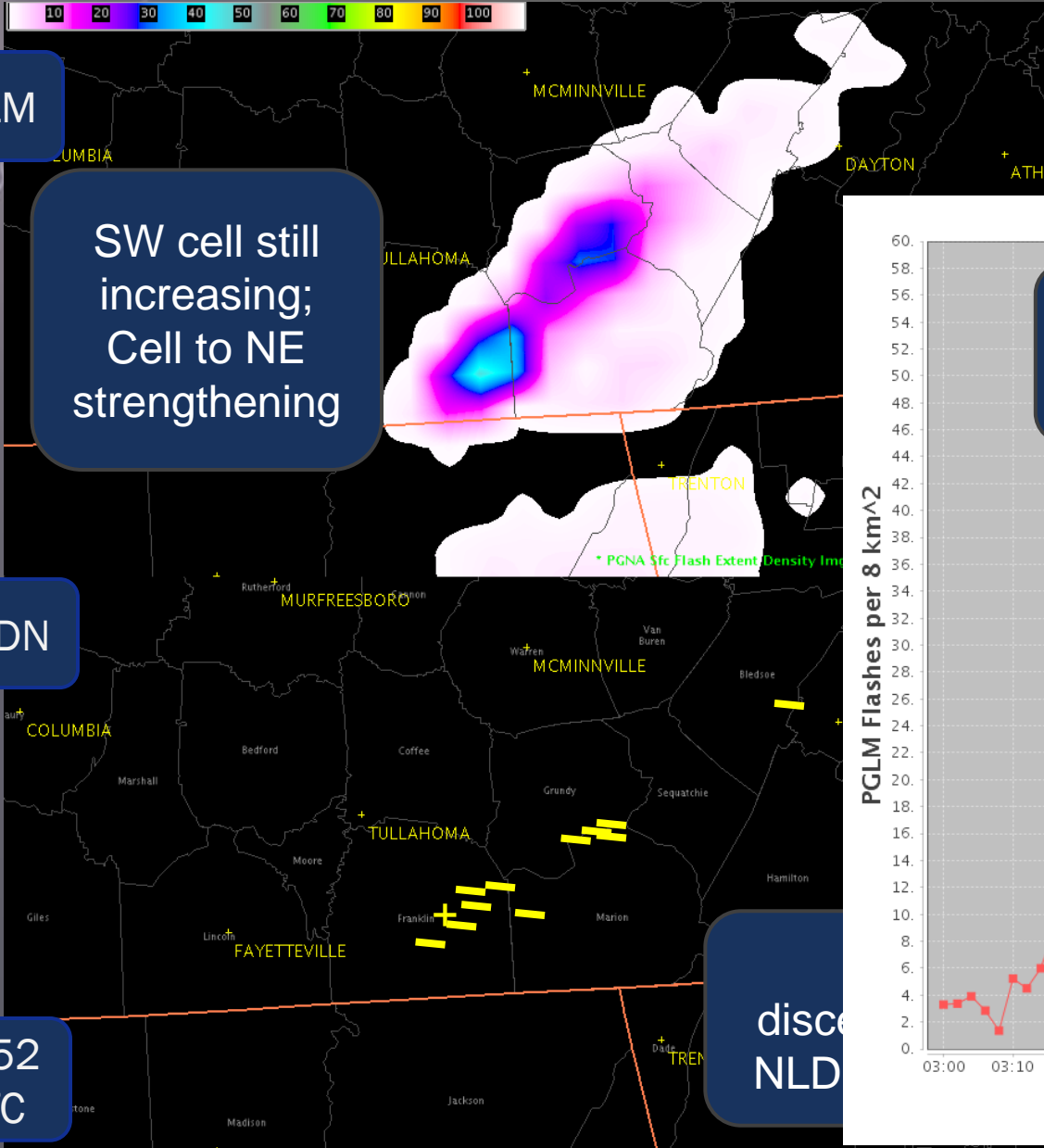
Severe wind at 0410 UTC

- Lightning jump underway

- Severe weath... likely storm...

Storm dissipating

NLDN

Velocity

disc... NLD...

0352 UTC

Pseudo GLM Flash Extent Density

PGLM Flashes per 8 km^2

Time (UTC)

Lightning Safety Scenario
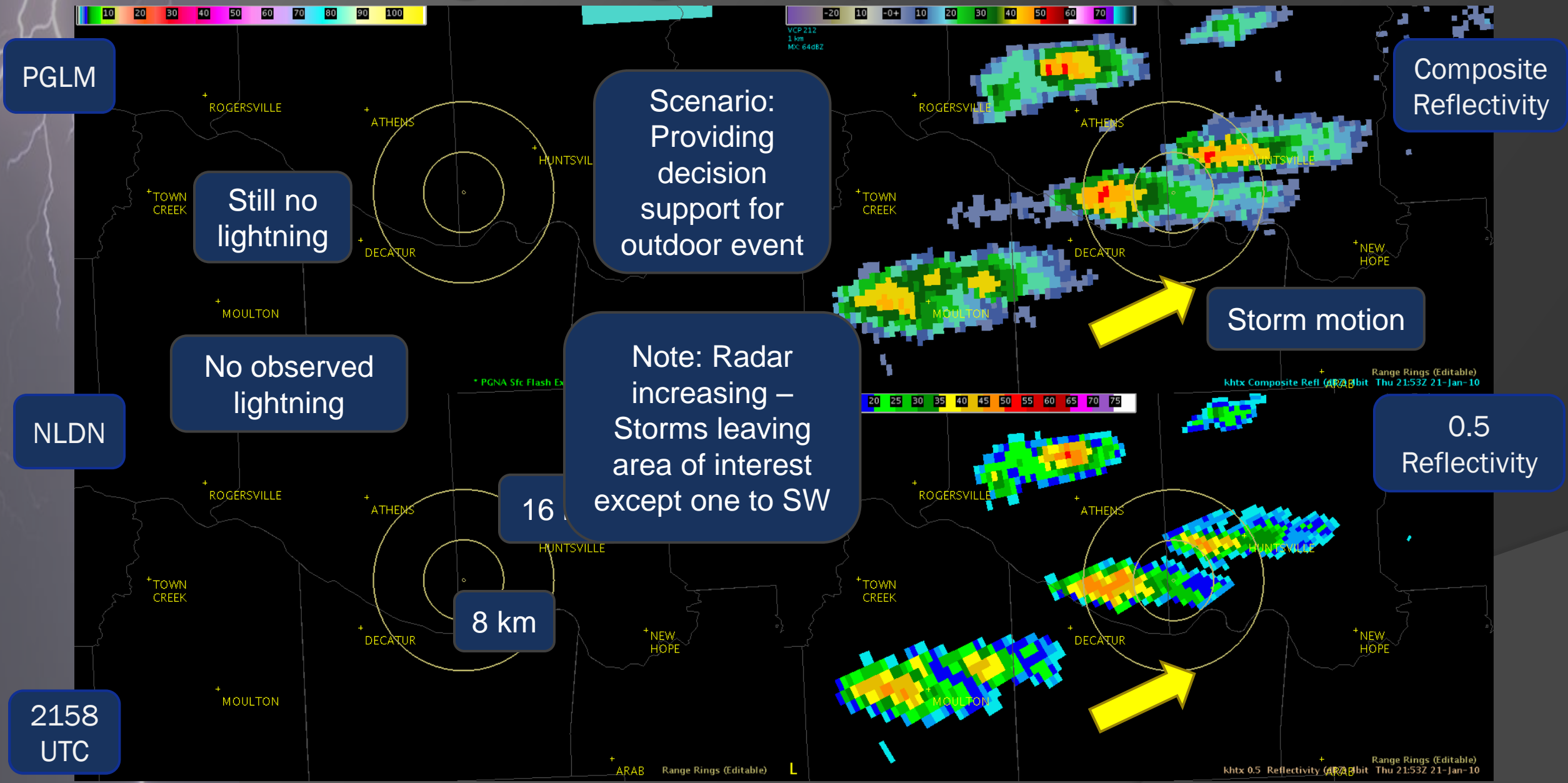
First Lightning
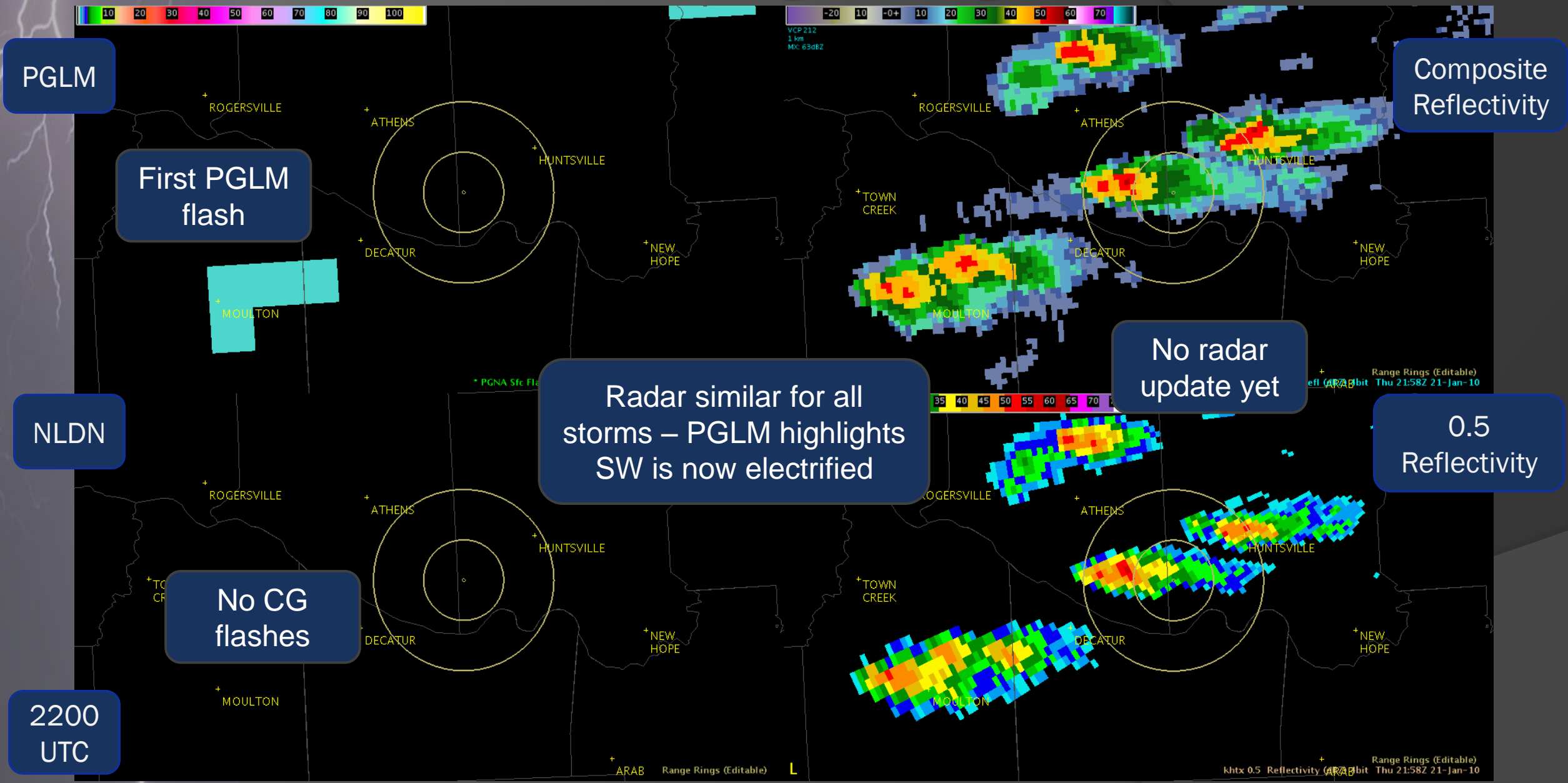
Lightning Continues

PGLM

Composite Reflectivity

Several more PGLM flashes

SW storm still approaching
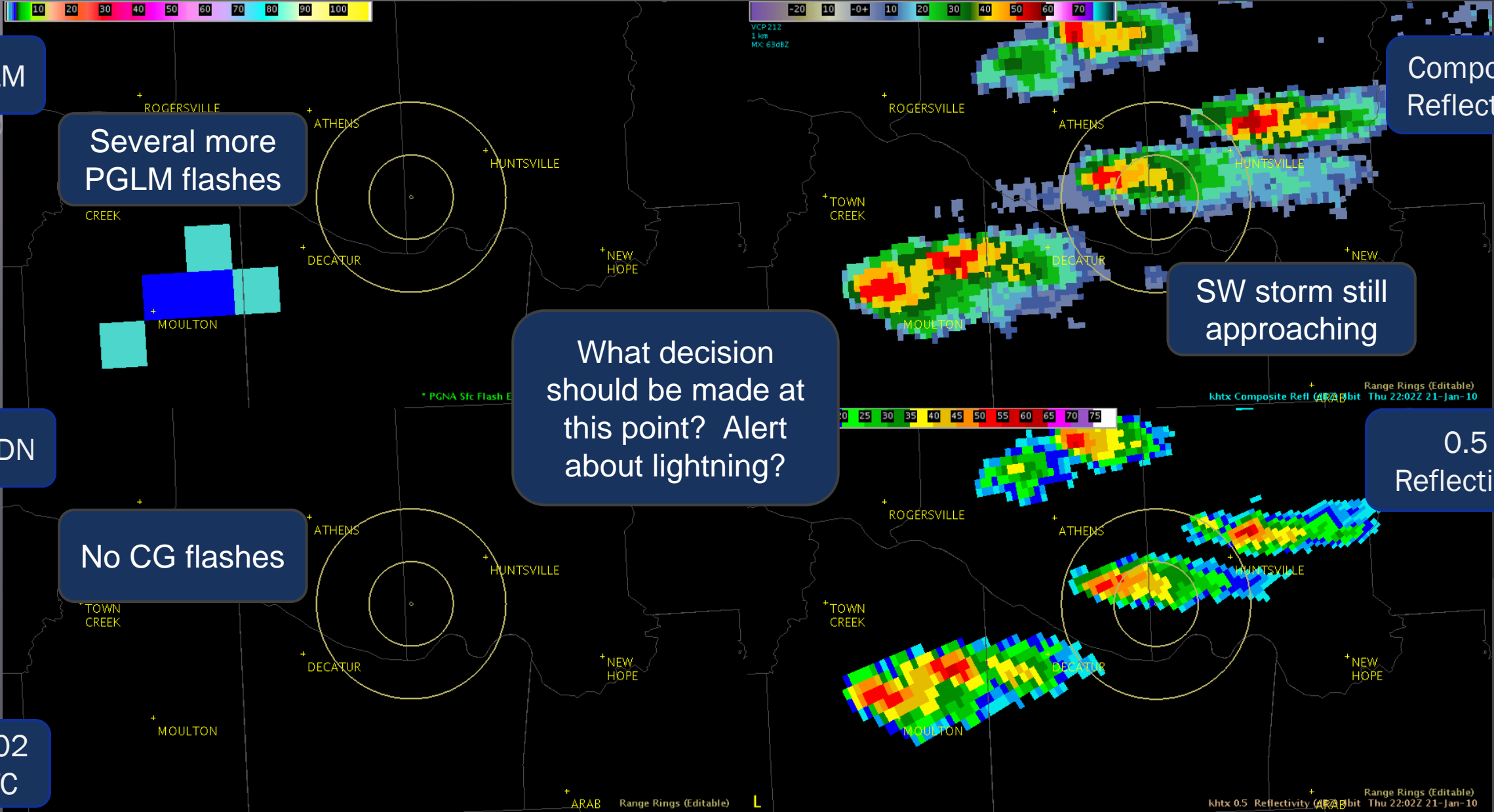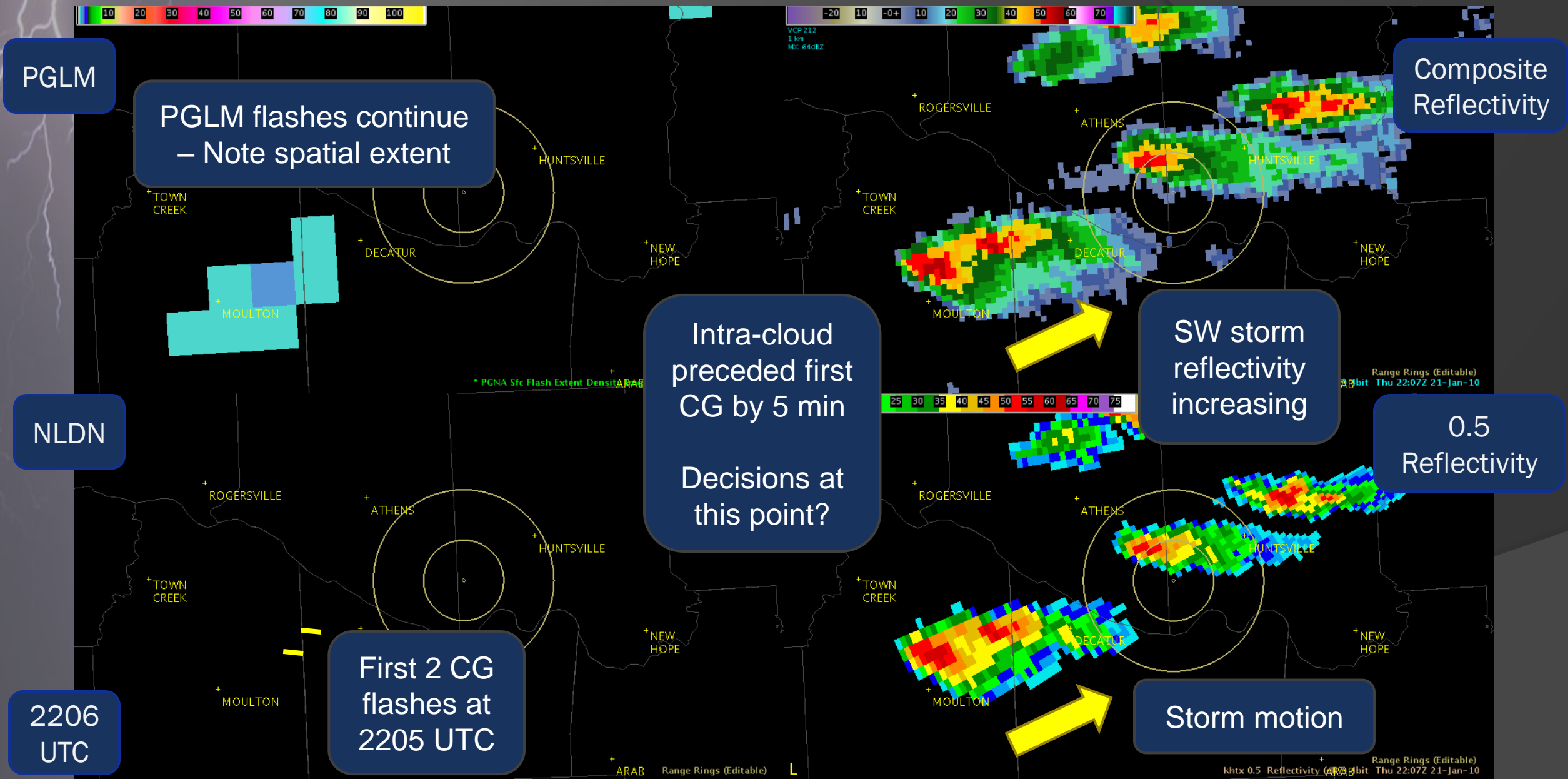
What decision should be made at this point? Alert about lightning?

NLDN

0.5 Reflectivity

No CG flashes

2202 UTC

First Cloud-to-Ground Flash

First Flash Within 16 Kilometers

PGLM

First PGLM flash within 16 km

First PGLM on other storms – Note extent is eastward from cores

Composite Reflectivity

NLDN

CG flashes outside 16 km

0.5 Reflectivity

2216 UTC

First Lightning Within 8 Kilometers

Another Useful Feature – Spatial Extent
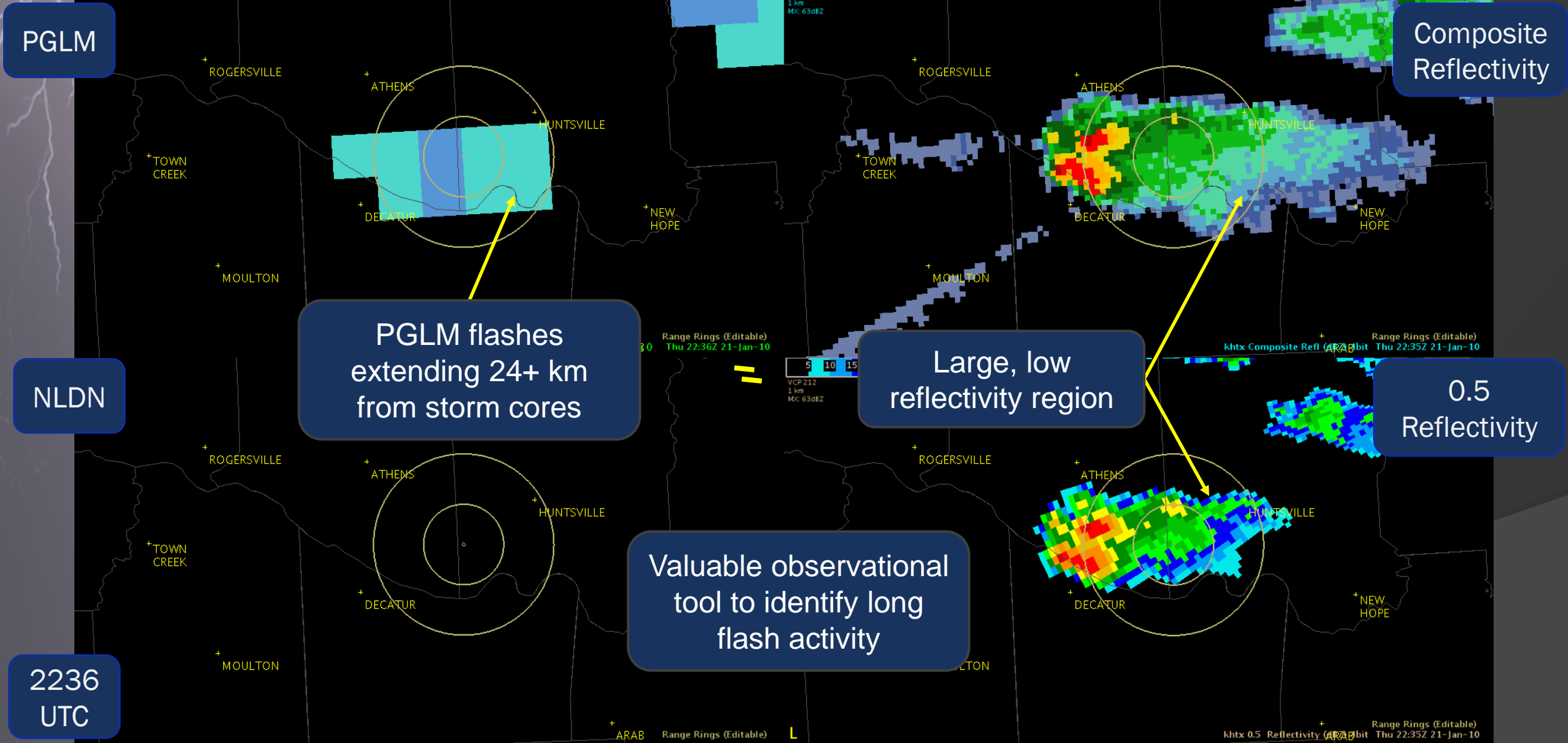
PGLM

Composite Reflectivity

NLDN

0.5 Reflectivity

2236 UTC

PGLM flashes extending 24+ km from storm cores

Large, low reflectivity region

Valuable observational tool to identify long flash activity

The Geostationary Lightning Mapper Proxy

Events
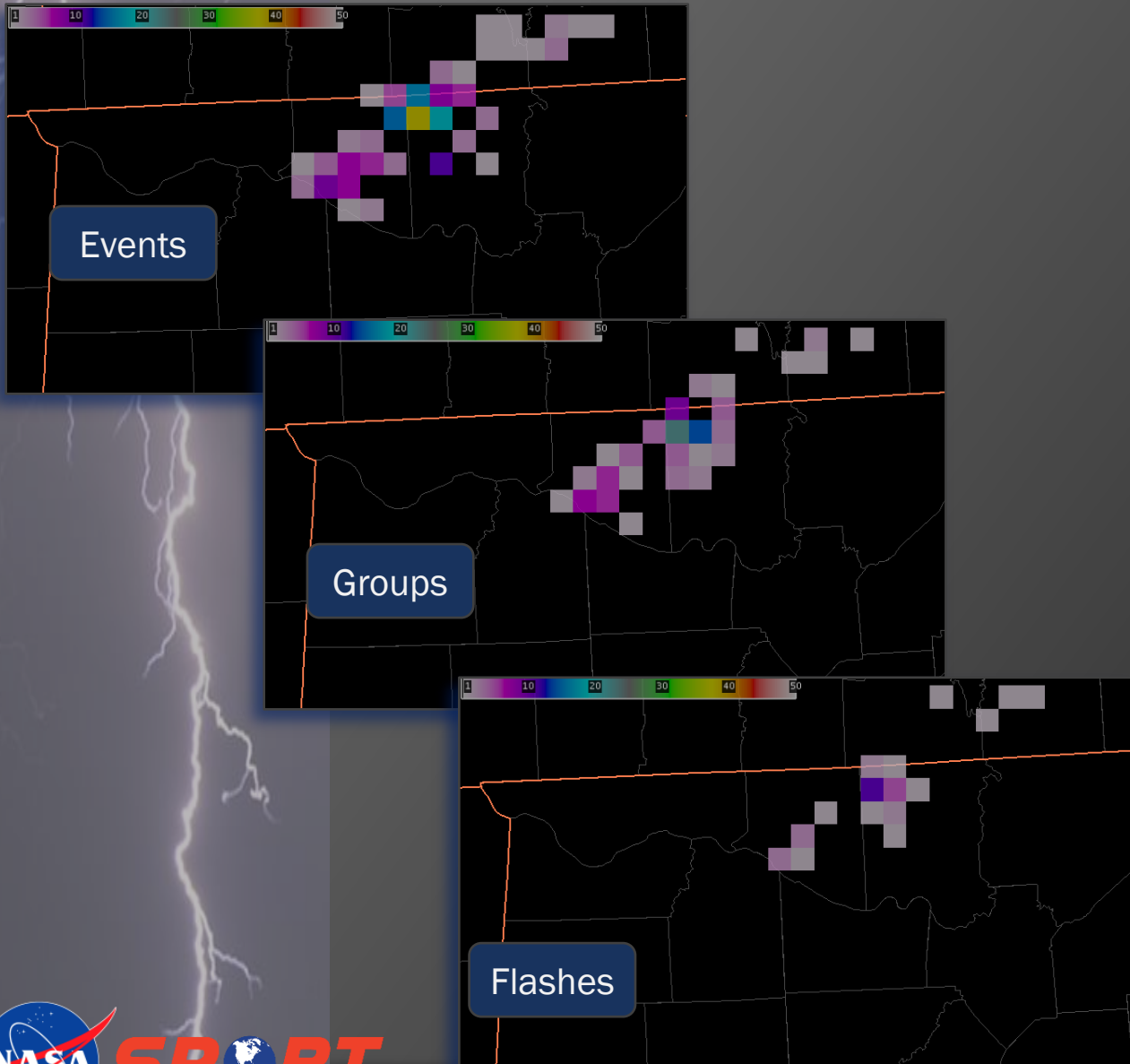
Groups

Flashes

- Convert ground-based lightning mapping array into GLM observations

- Uses LMA calibrated from TRMM-LIS to create events, groups, and flashes similar to GLM

- Developed by lightning group at Marshall Space Flight Center

- Unavailable in real-time

- Excellent training tool

GLM Details: Events, Groups, and Flashes (1)
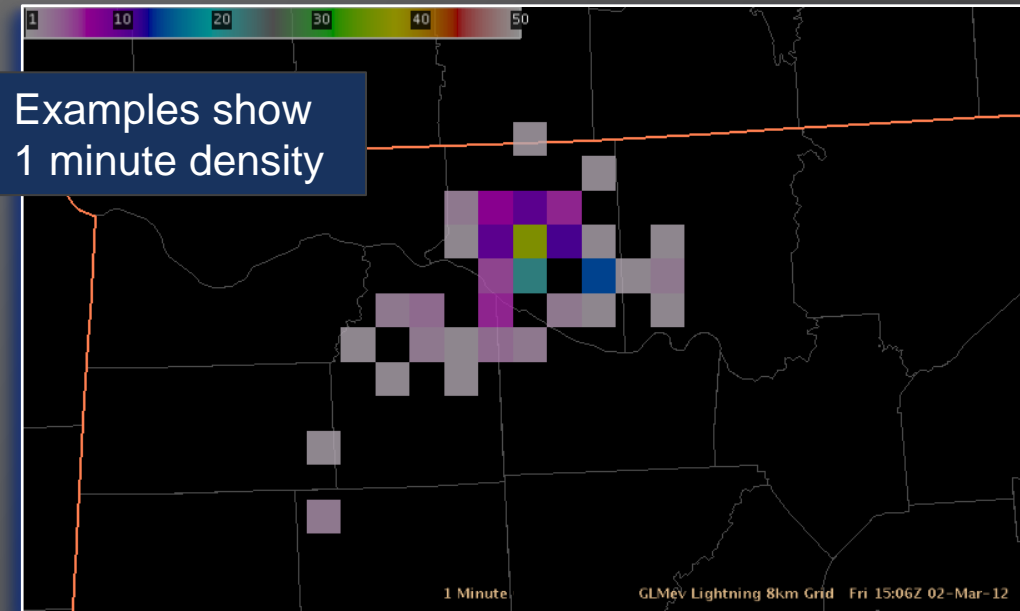
Examples show 1 minute density

- 8 km at nadir, 14 km at edge
- GLM will have no more than 20 s latency
- **Event:** Any illuminated pixel during a 2 ms window – Most basic GLM observation
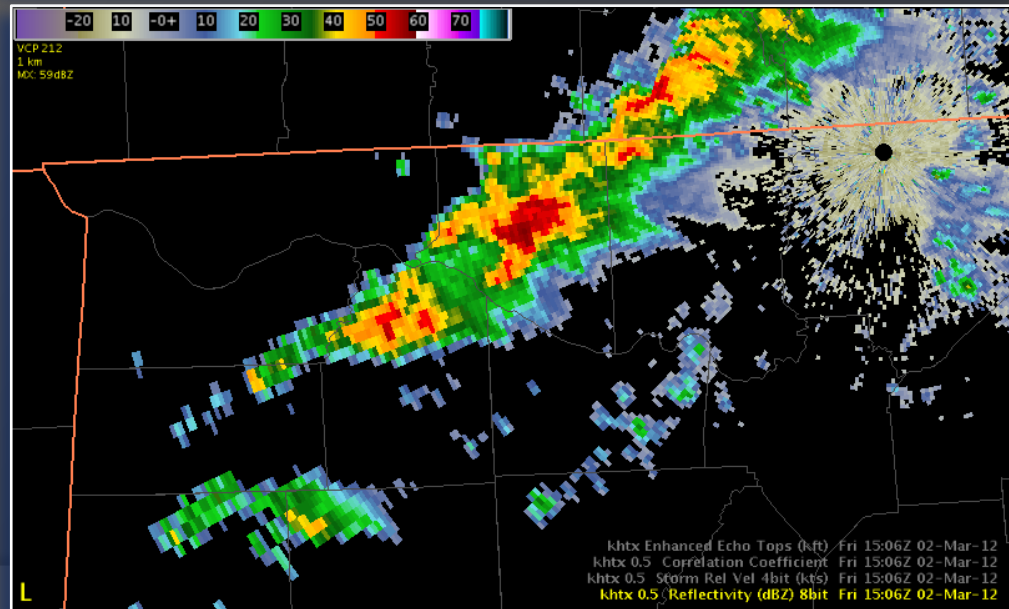
GLM Details: Events, Groups, and Flashes (2)
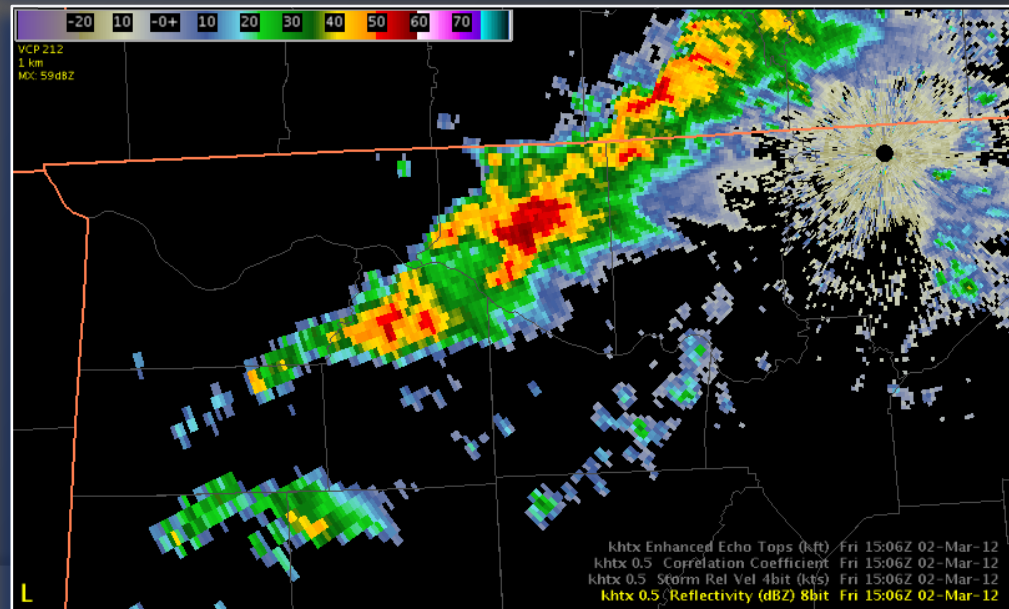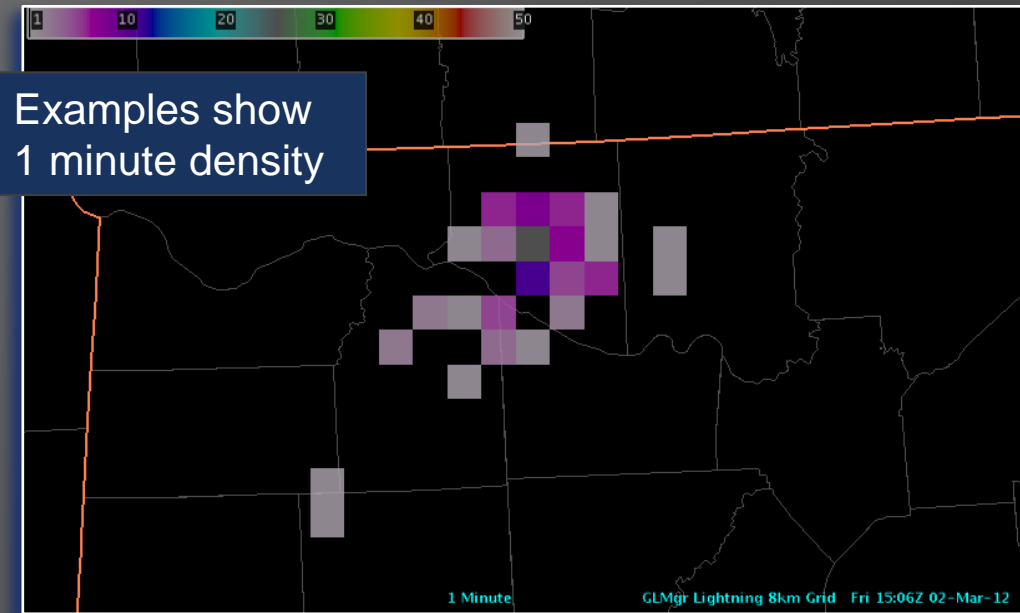
Examples show 1 minute density

- 8 km at nadir, 14 km at edge
- GLM will have no more than 20 s latency
- **Event:** Any illuminated pixel during a 2 ms window – Most basic GLM observation
- **Group:** Cluster of Events in time and space – Weighted by optical intensity

Examples show 1 minute density
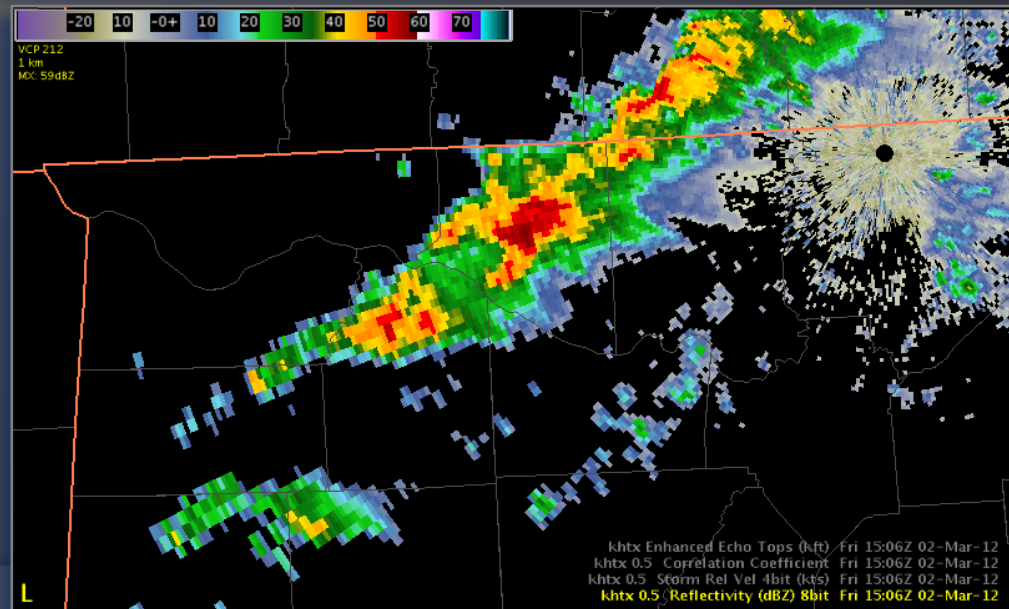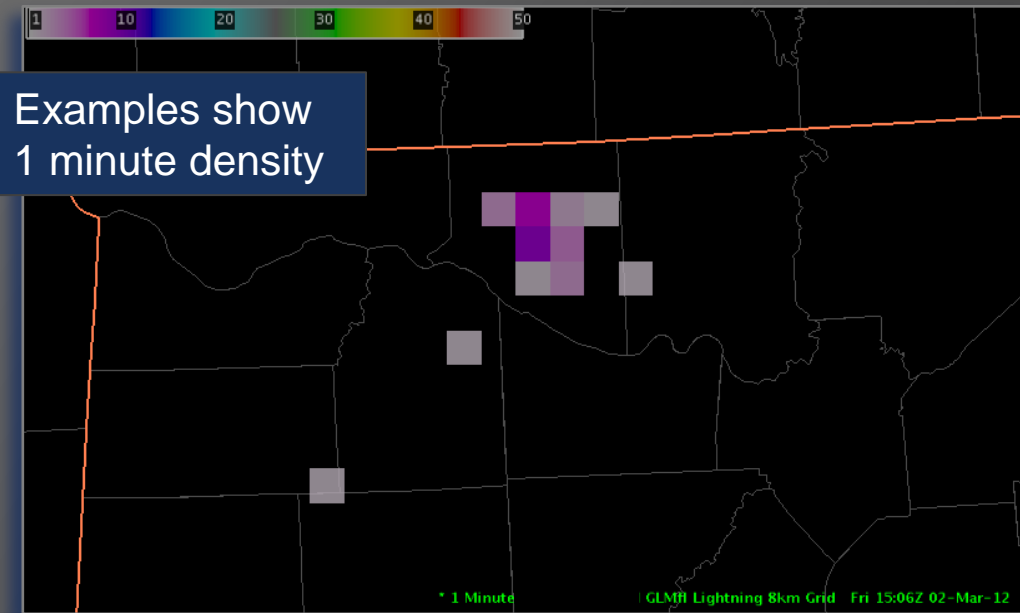
- •8 km at nadir, 14 km at edge
- •GLM will have no more than 20 s latency
- •**Event:** Any illuminated pixel during a 2 ms window – Most basic GLM observation
- •**Group:** Cluster of Events in time and space – Weighted by optical intensity
- •**Flash:** Cluster of Groups in time and space – Location weighted by optical intensity – Currently plotting flash centroid only

GLM Details: Events, Groups, and Flashes (4)
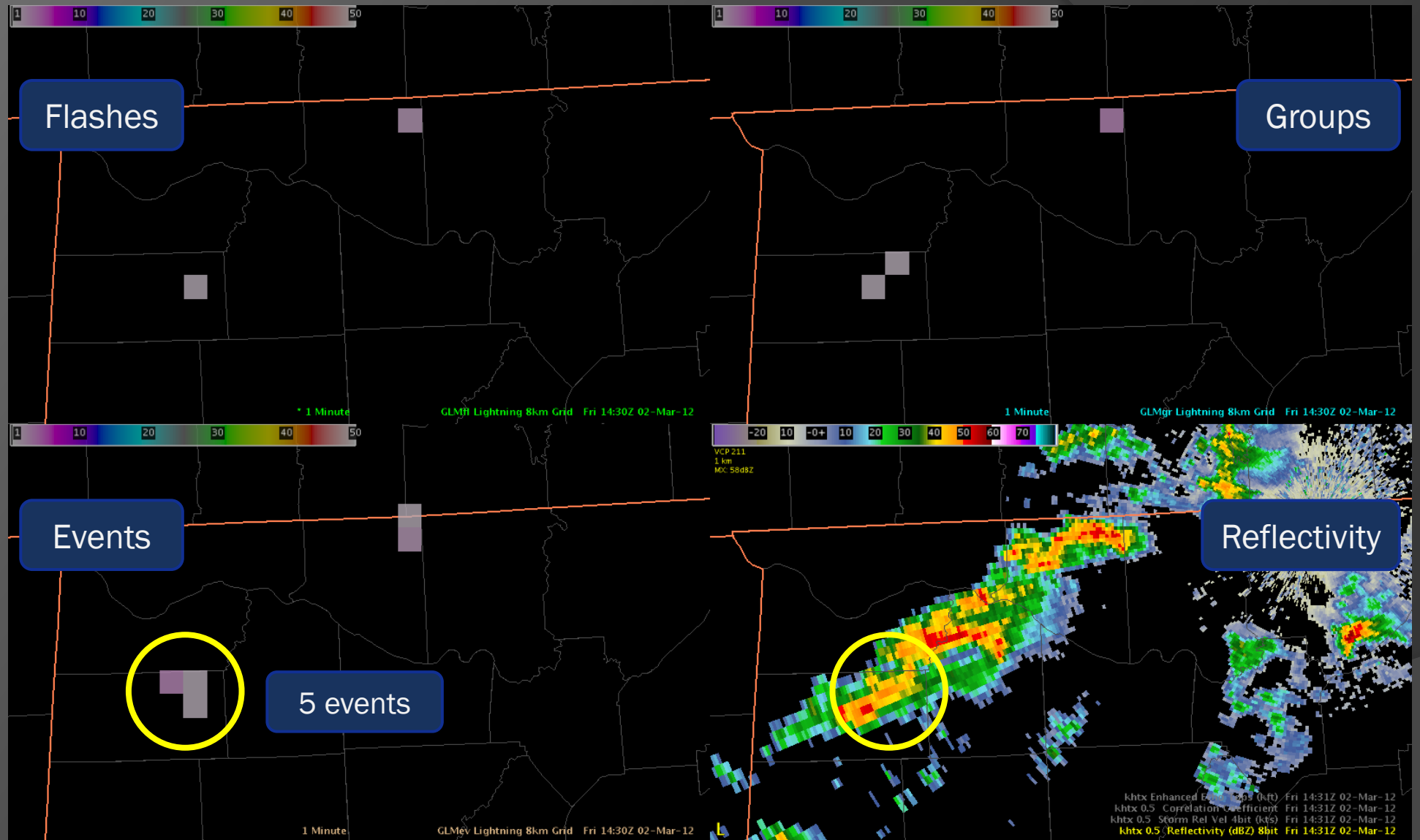
Visual example of events > groups > flash

GLM Details: Events, Groups, and Flashes (4)

Flashes

Groups

2 groups

Events

5 events

Reflectivity

Visual example of events > groups > flash
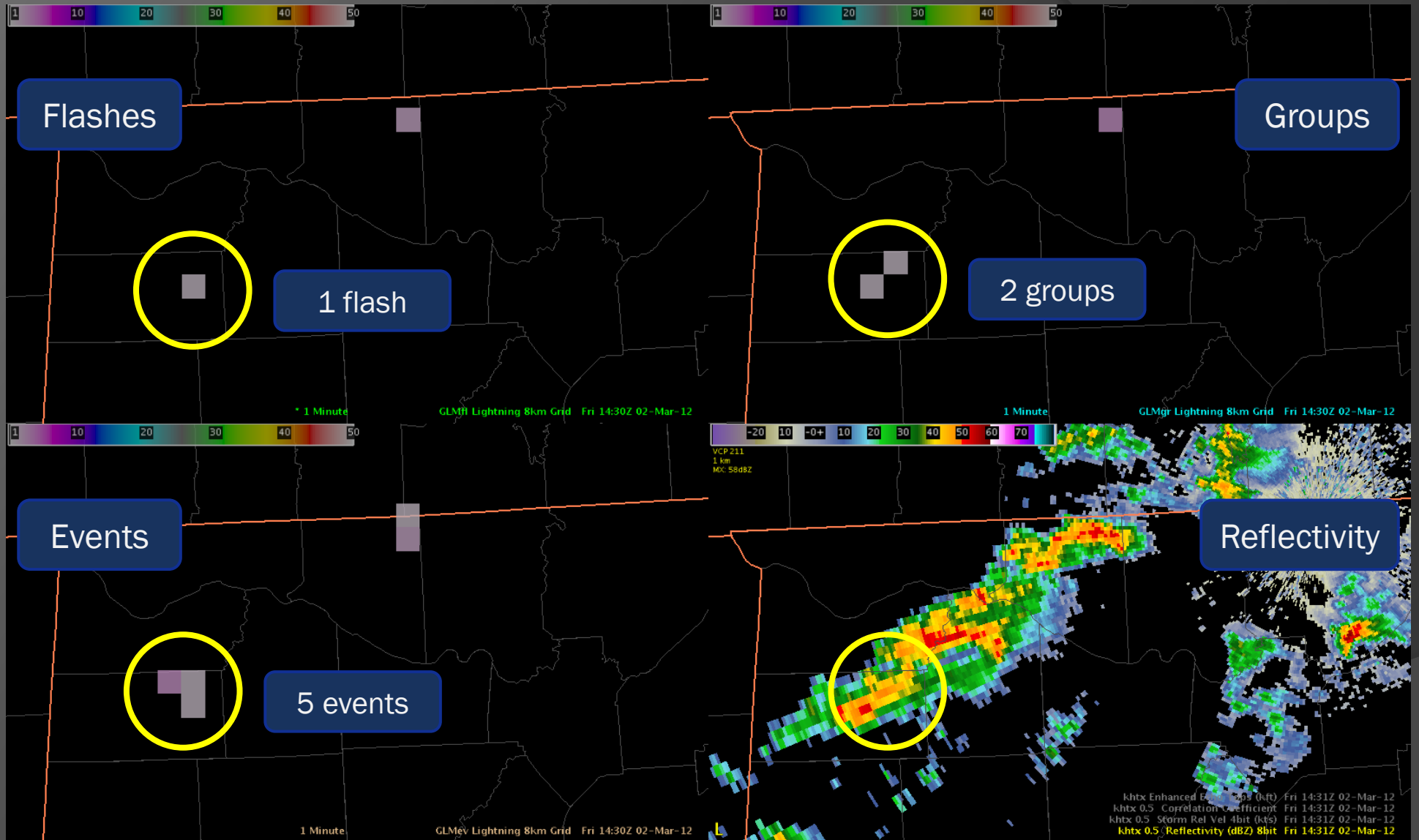
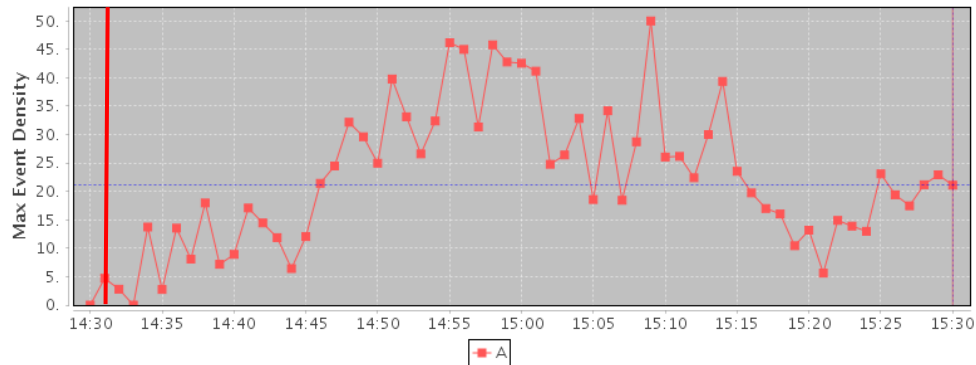Visual example of events > groups > flash

Integrated Example (1)
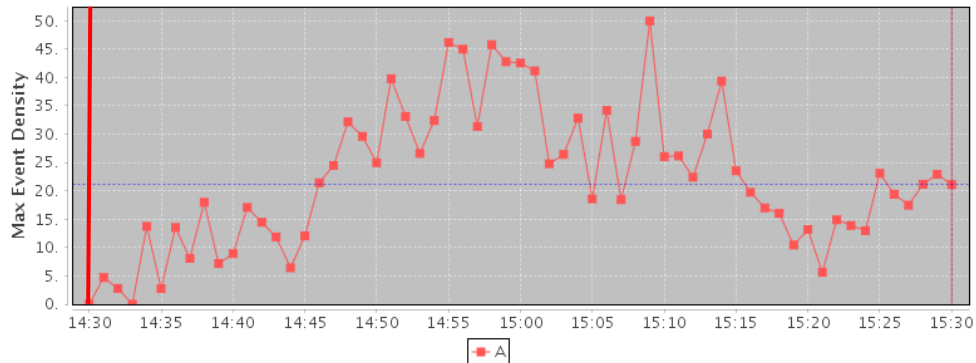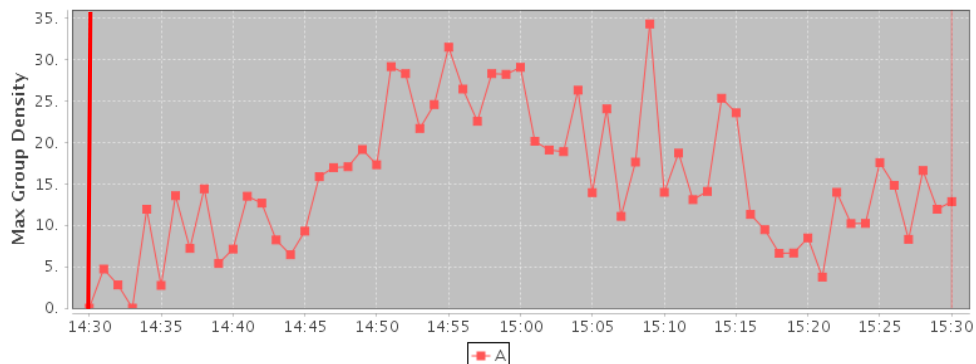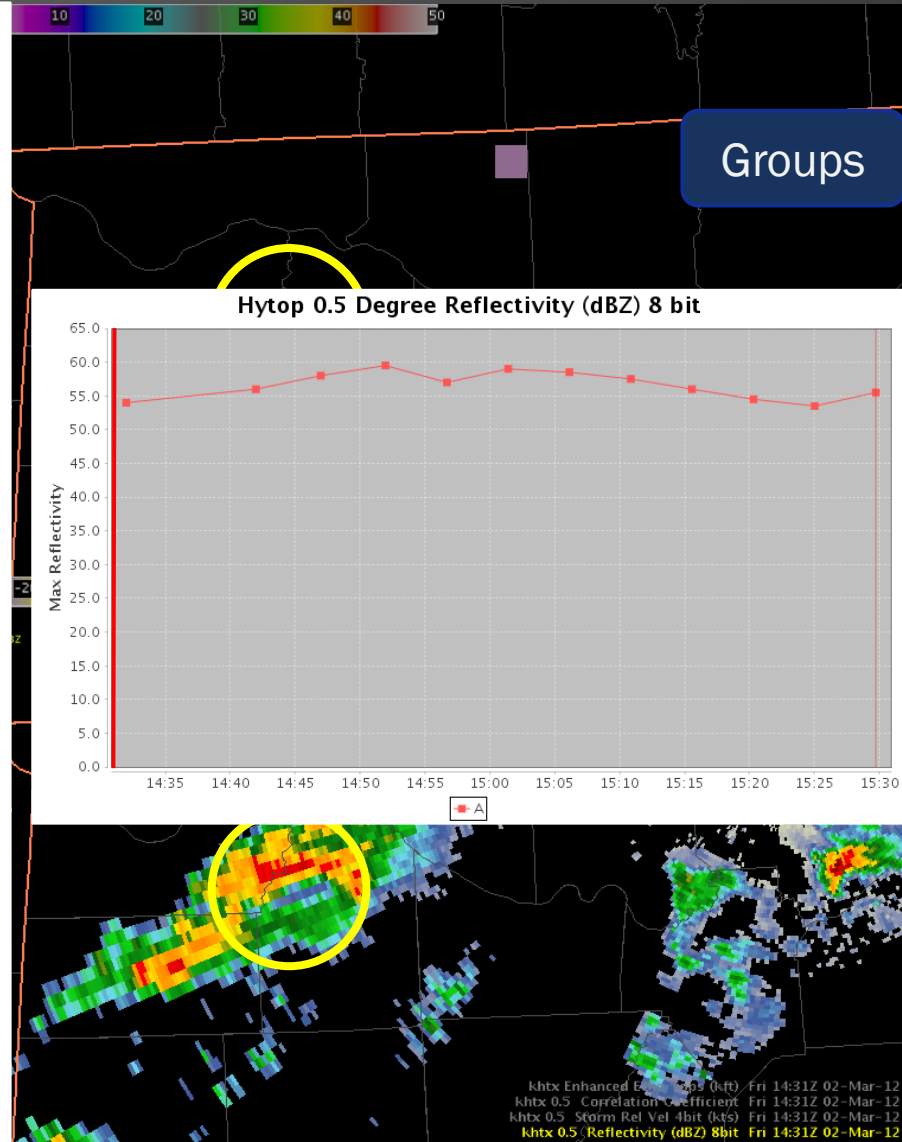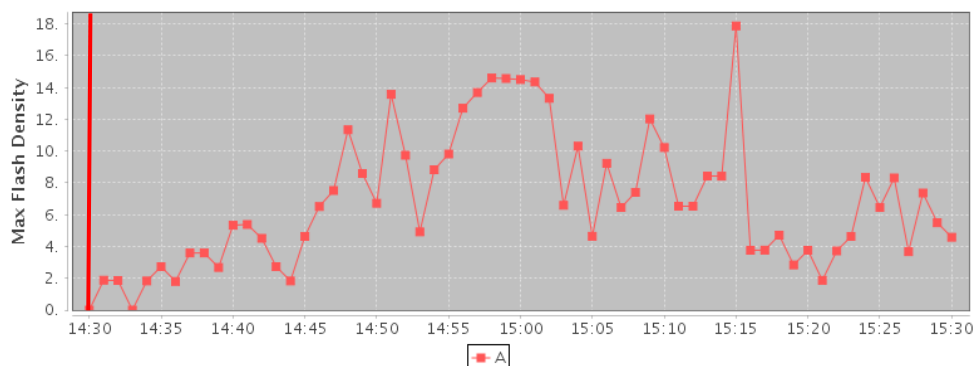
- Initial development
- Identify storms with stronger updrafts
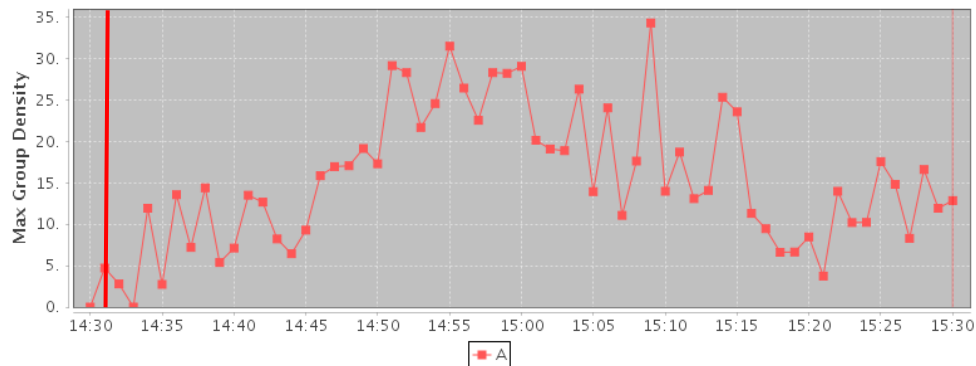
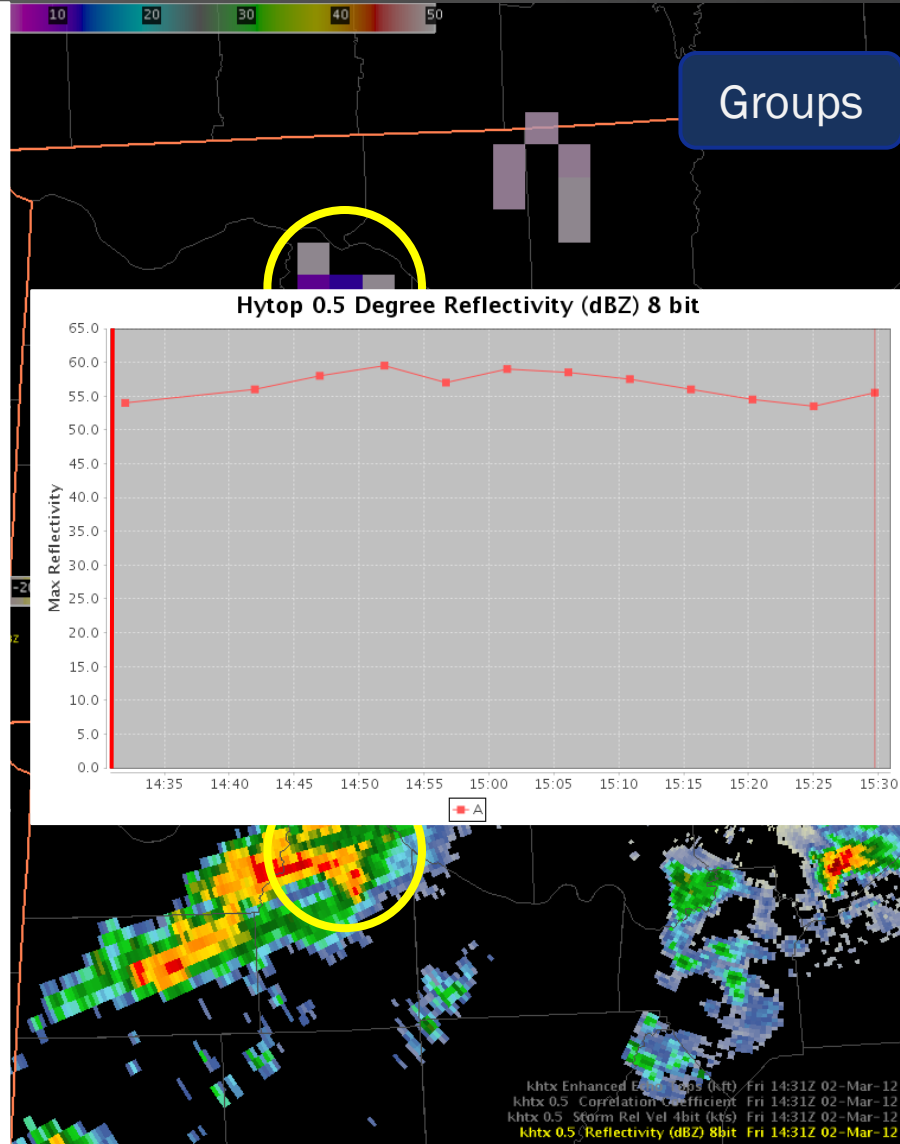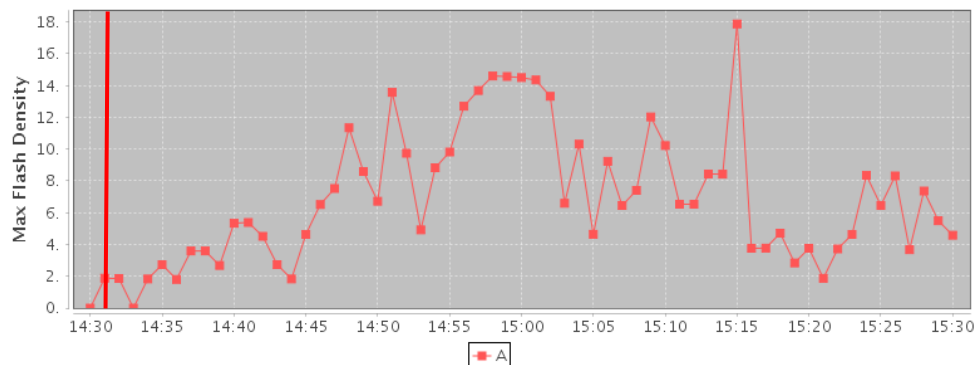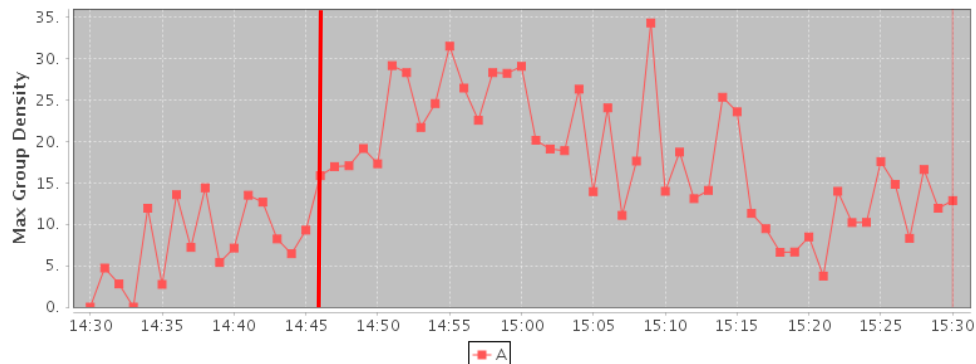- NOTE: Showing GLM-proxy summed over one minute

Integrated Example (2)

- Storms intensifying
- GLM identifying where to focus most attention

- NOTE: Showing GLM-proxy summed over one minute

Integrated Example (3)
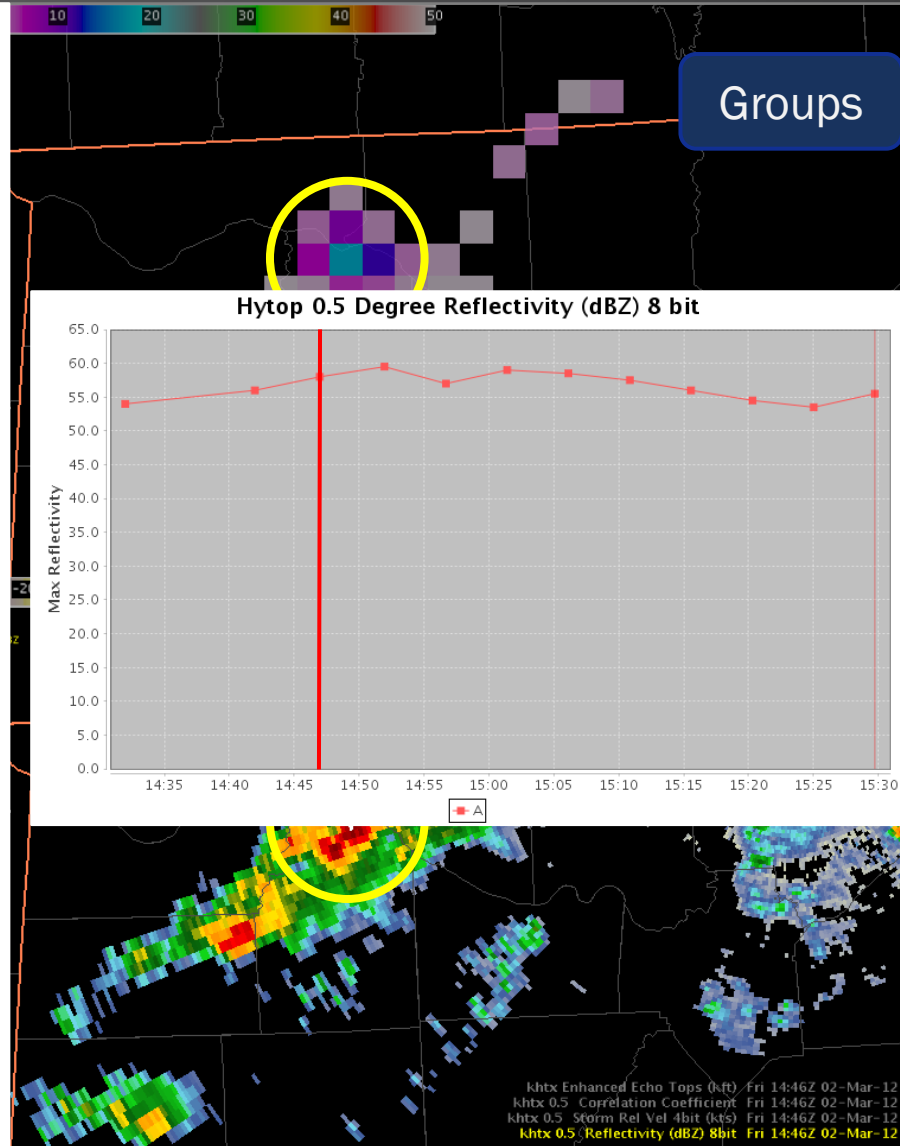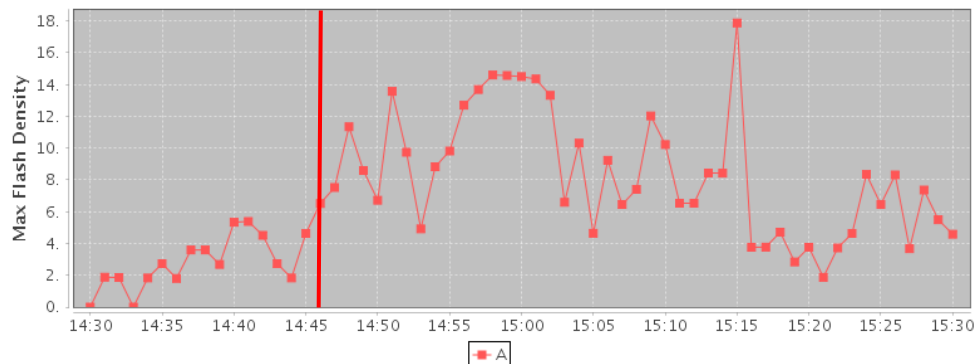

Groups
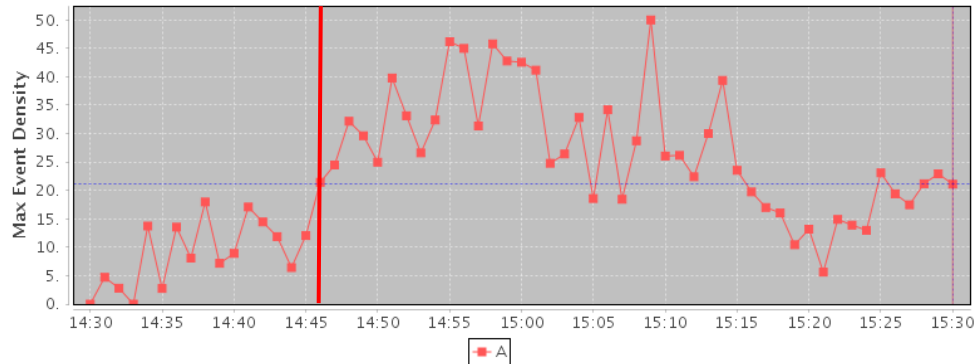
- Rapid increase in all GLM products
- Most likely to lead to severe weather

- NOTE: Showing GLM-proxy summed over one minute

Future Work

- Prepare for first GLM observations
  - Visualization tools
- Build applications library for training using GLM
  - Base concepts on ground-based lightning mapping arrays
- Coordinate with operational partners for a GLM operational evaluation
  - Summer / Fall 2017
- Opportunities for new collaborations

Questions?

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NASA SPoRT web page:
http://weather.msfc.nasa.gov/sport/

Wide World of SPoRT Blog:
https://nasasport.wordpress.com

GOES-R web page:
http://www.goes-r.gov/

The Geostationary Lightning Mapper:
http://www.goesr.gov/spacesegment/glm.html