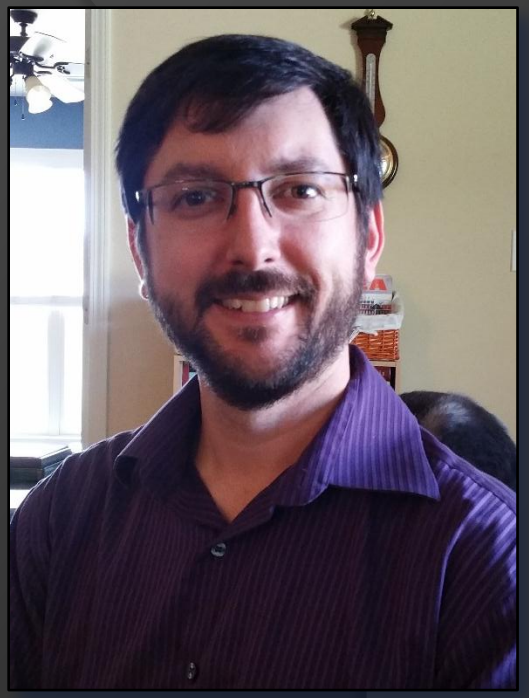
Total Lightning

What is it, operational uses, and preparing for satellite based observations

Dr. Geoffrey T. Stano
NASA SPoRT / ENSCO, Inc. Huntsville, Alabama
United States

EUMETrain Convection Week
8 June 2015

Introductions



- Work with NASA's Short-term Prediction Research and Transition Center (SPoRT)
- Coordinate partnerships with end users
- Lead total lightning activities
- Previously supported applications research for lightning cessation at Kennedy Space Center

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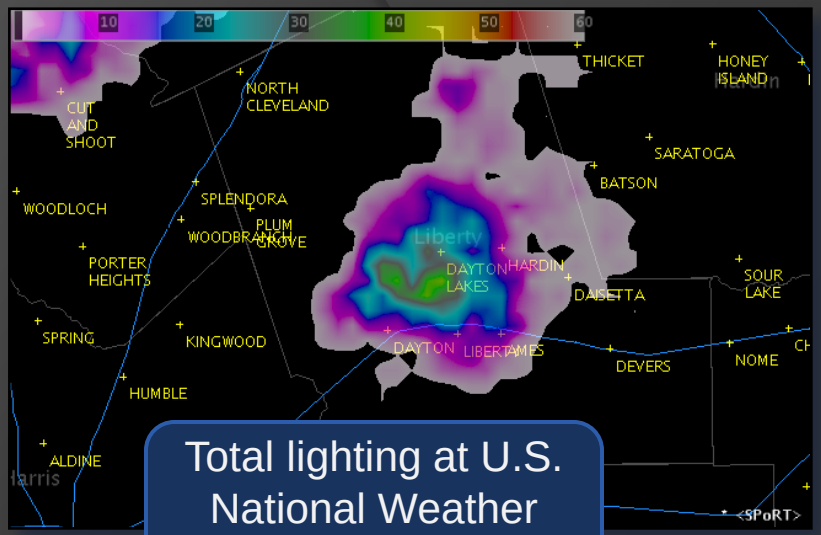
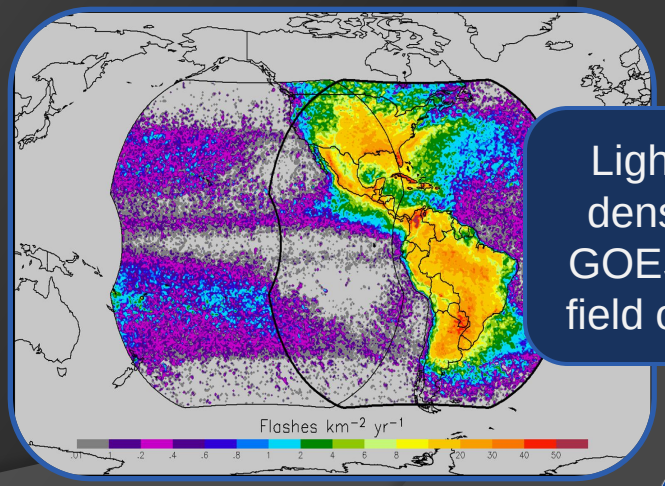
Outline

- What is NASA SPoRT?
- What is total lightning?
- Training and operational transition
- Operational examples
- Future work / Summary

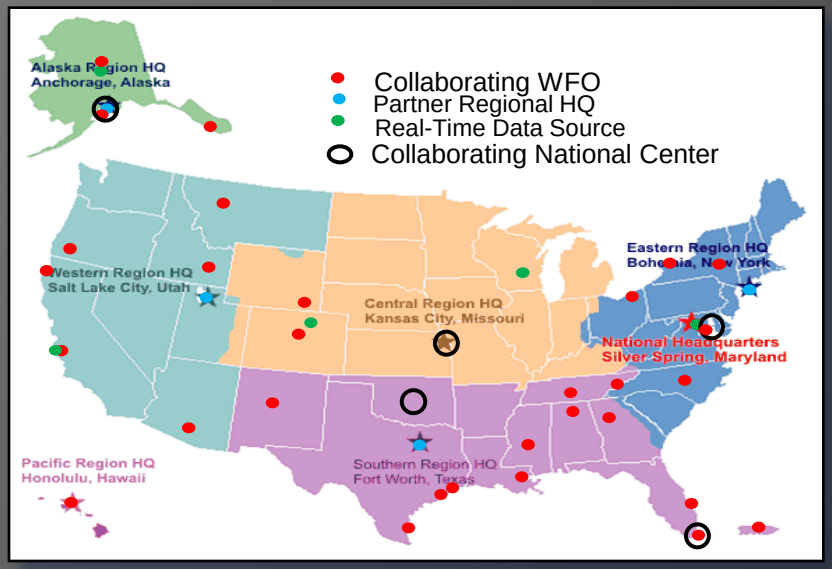


Total lighting at U.S. National Weather Service Office

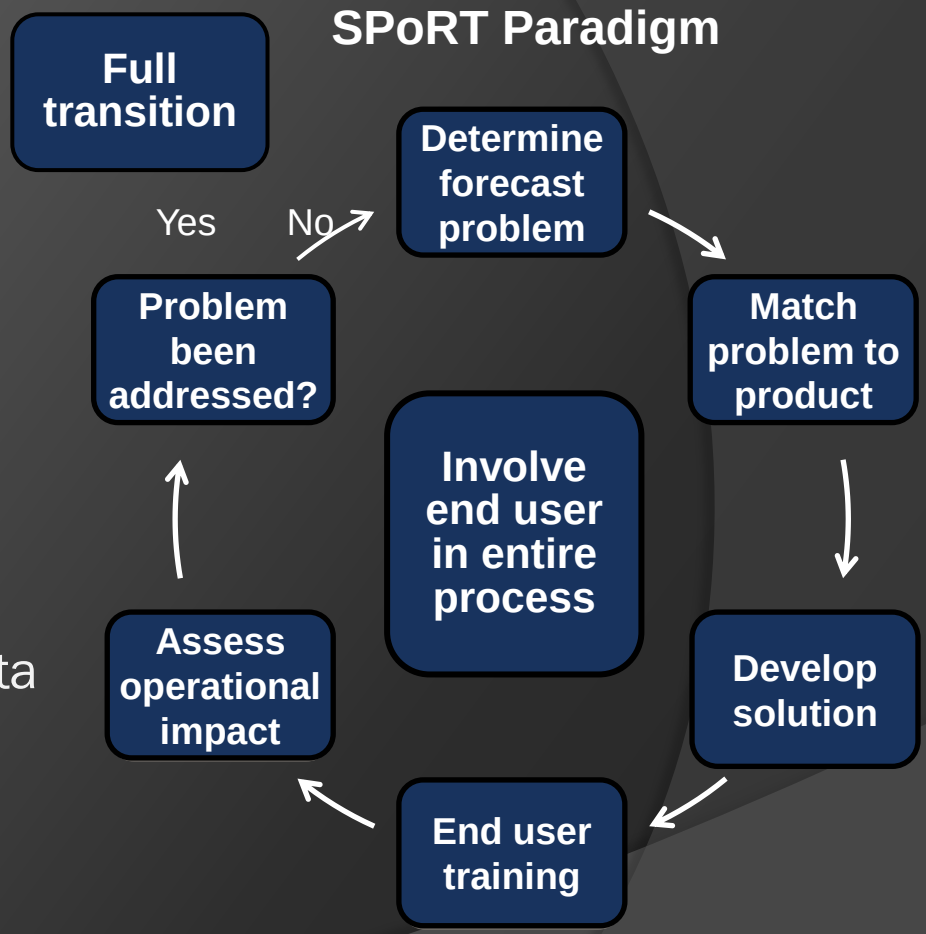


Lightning density in GOES-E/W field of view

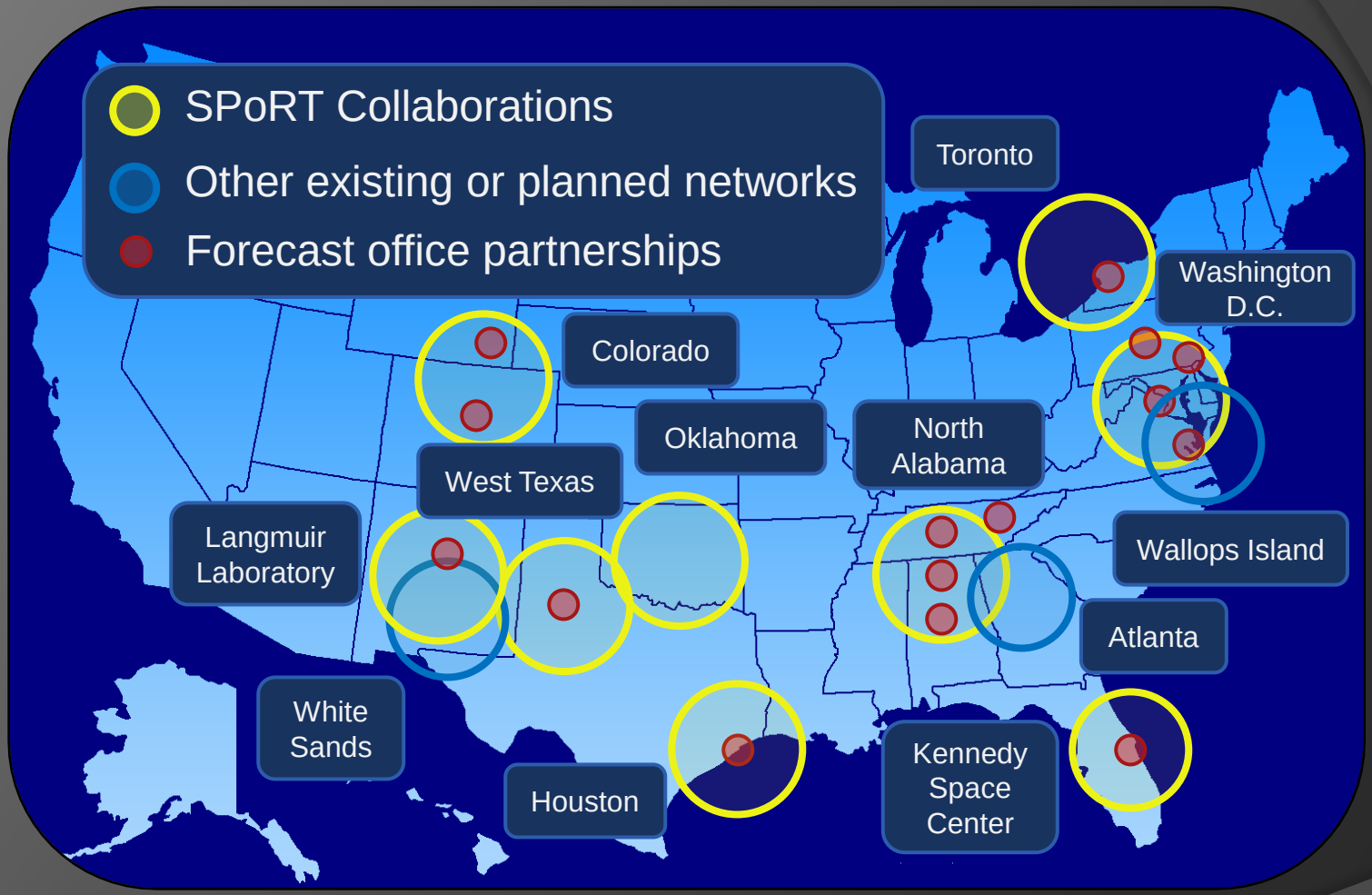
NASA Short-term Prediction Research and Transition Center (SPoRT)



- Testbed environment
- Transition unique NASA and NOAA data to operations
- Demonstrate capabilities for weather applications and societal benefit
- Preparations for future missions



Lightning Mapping Arrays – Data for this Talk



Advantages

- Spatial extent observations
- High temporal resolution

Disadvantages

- 250 km maximum radius
- No national network planned

Collaborations started in 2003, now 8 active partner networks

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Mechanisms for Intra-Cloud Versus Cloud-to-Ground Lightning

Intra-cloud flashes

Driven by mass flux through mixed phase region

Increased flux, increased flash rate

Related to updraft strength

Cloud-to-ground strikes

Driven by precipitation development at mid-storm level that descends

Stronger updrafts can delay formation of precipitation

Both

Driven by non-inductive charging

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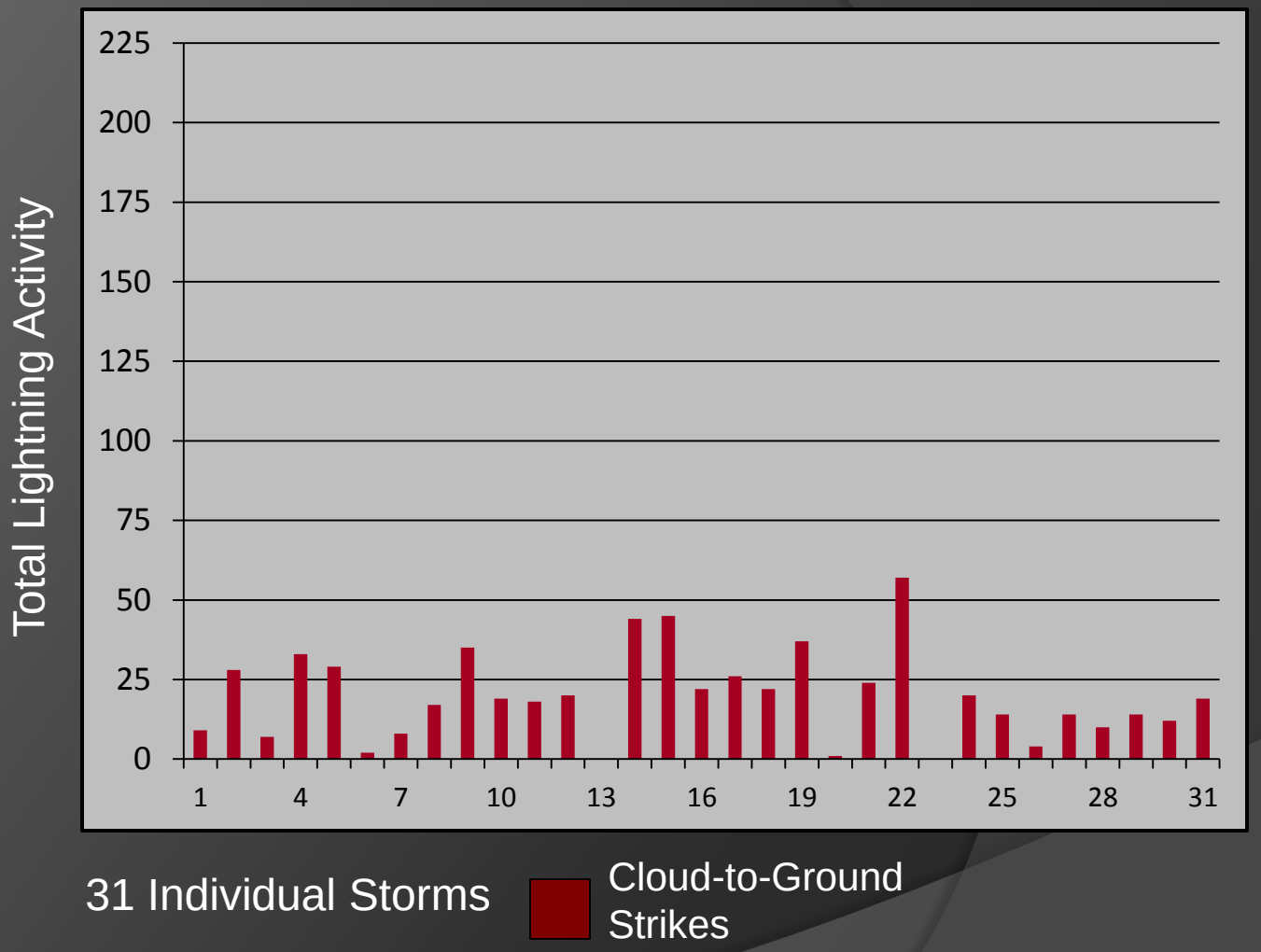
What is Total Lightning?

Total Lightning

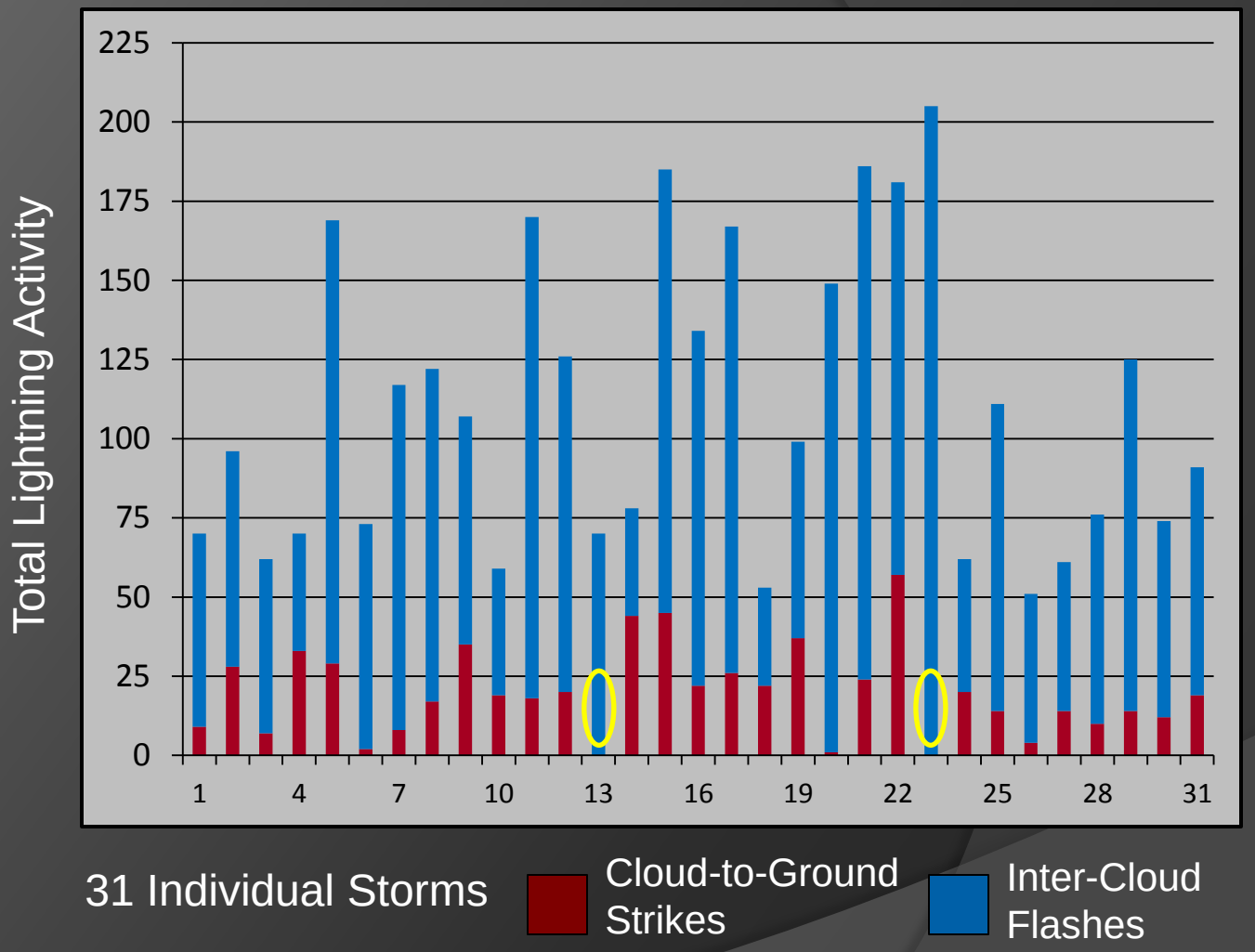
Intra-cloud AND cloud-to-ground



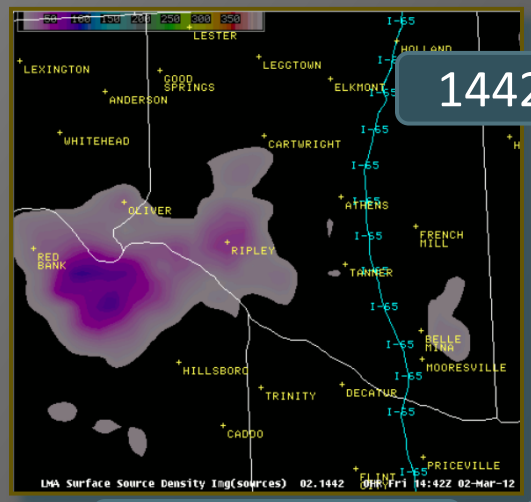
What is Total Lightning?

Total Lightning

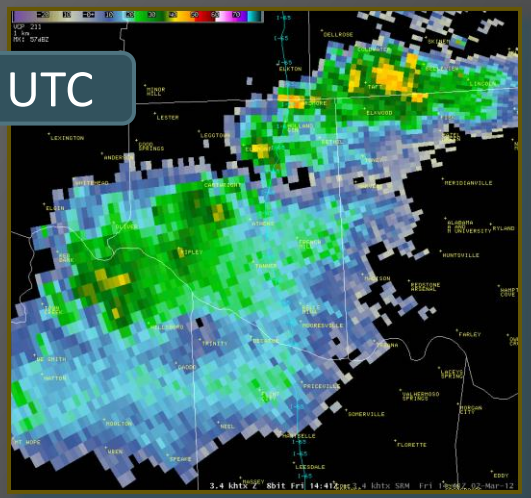
Intra-cloud AND cloud-to-ground



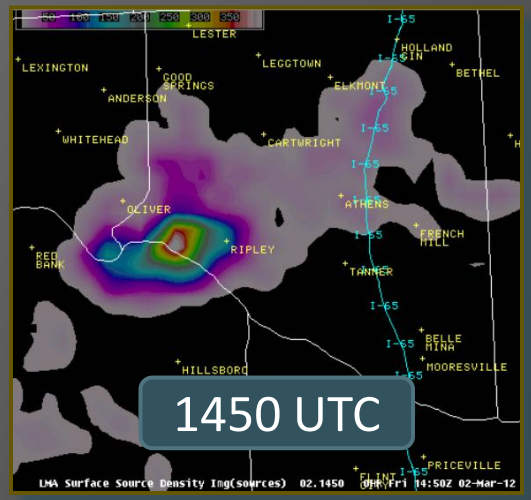
Importance of Total Lightning

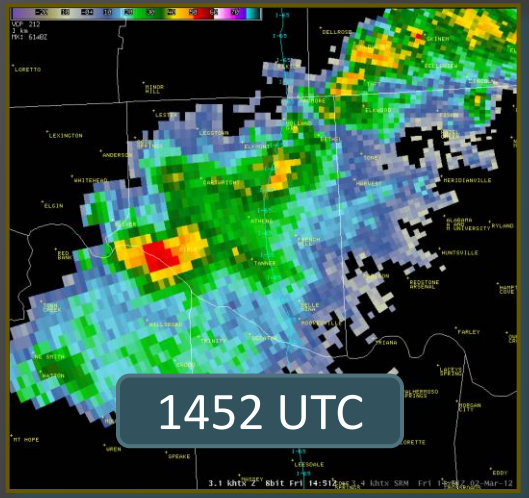


Total Lightning



3.4° Reflectivity, ~20 kft





Total Lightning

- Observes intra-cloud (IC) and cloud-to-ground (CG) lightning

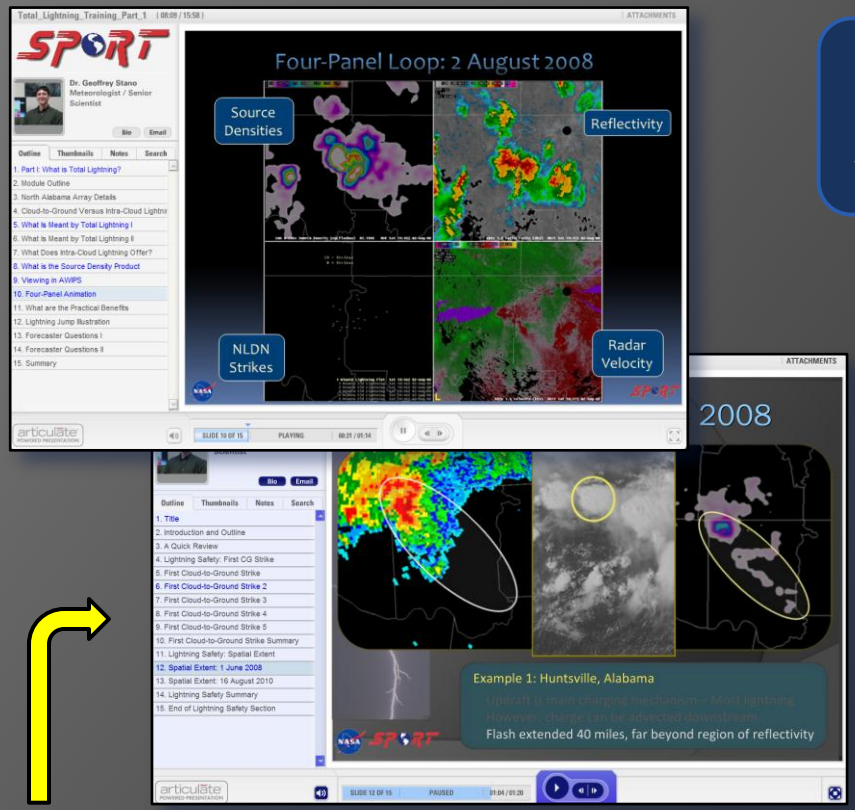
Physical Reasoning

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

Application

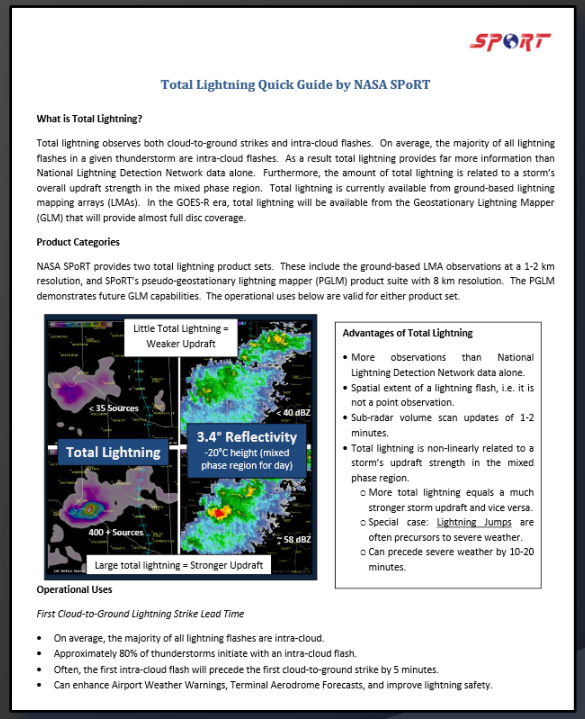
- Increase in total lightning signifies strengthening updraft
- Important for severe weather and lightning safety

Operational Transition - Training



New capabilities require training

SPoRT uses several methods



Total Lightning Quick Guide by NASA SPoRT

What is Total Lightning?

Total lightning observes both cloud-to-ground strikes and intra-cloud flashes. On average, the majority of all lightning flashes in a given thunderstorm are intra-cloud flashes. As a result total lightning provides far more information than National Lightning Detection Network data alone. Furthermore, the amount of total lightning is related to a storm's overall updraft strength in the mixed phase region. Total lightning is currently available from ground-based lightning mapping arrays (LMAs). In the GOES-R era, total lightning will be available from the Geostationary Lightning Mapper (GLM) that will provide almost full disc coverage.

Product Categories

NASA SPoRT provides two total lightning product sets. These include the ground-based LMA observations at a 1-2 km resolution, and SPoRT's pseudo-geostationary lightning mapper (PGLM) product suite with 8 km resolution. The PGLM demonstrates future GLM capabilities. The operational uses below are valid for either product set.

Little Total Lightning = Weaker Updraft
< 35 Sources
< 40 dBZ
Total Lightning
3.4° Reflectivity
-20°C height (mixed phase region for day)
400 + Sources
~ 58 dBZ
Large total lightning = Stronger Updraft

Advantages of Total Lightning

- More observations than National Lightning Detection Network data alone.
- Spatial extent of a lightning flash, i.e. it is not a point observation.
- Sub-radar volume scan updates of 1-2 minutes.
- Total lightning is non-linearly related to a storm's updraft strength in the mixed phase region.
  - More total lightning equals a much stronger storm updraft and vice versa.
  - Special case: Lightning Jumps are often precursors to severe weather.
  - Can precede severe weather by 10-20 minutes.

Operational Uses

First Cloud-to-Ground Lightning Strike Lead Time

- On average, the majority of all lightning flashes are intra-cloud.
- Approximately 80% of thunderstorms initiate with an intra-cloud flash.
- Often, the first intra-cloud flash will precede the first cloud-to-ground strike by 5 minutes.
- Can enhance Airport Weather Warnings, Terminal Aerodrome Forecasts, and improve lightning safety.

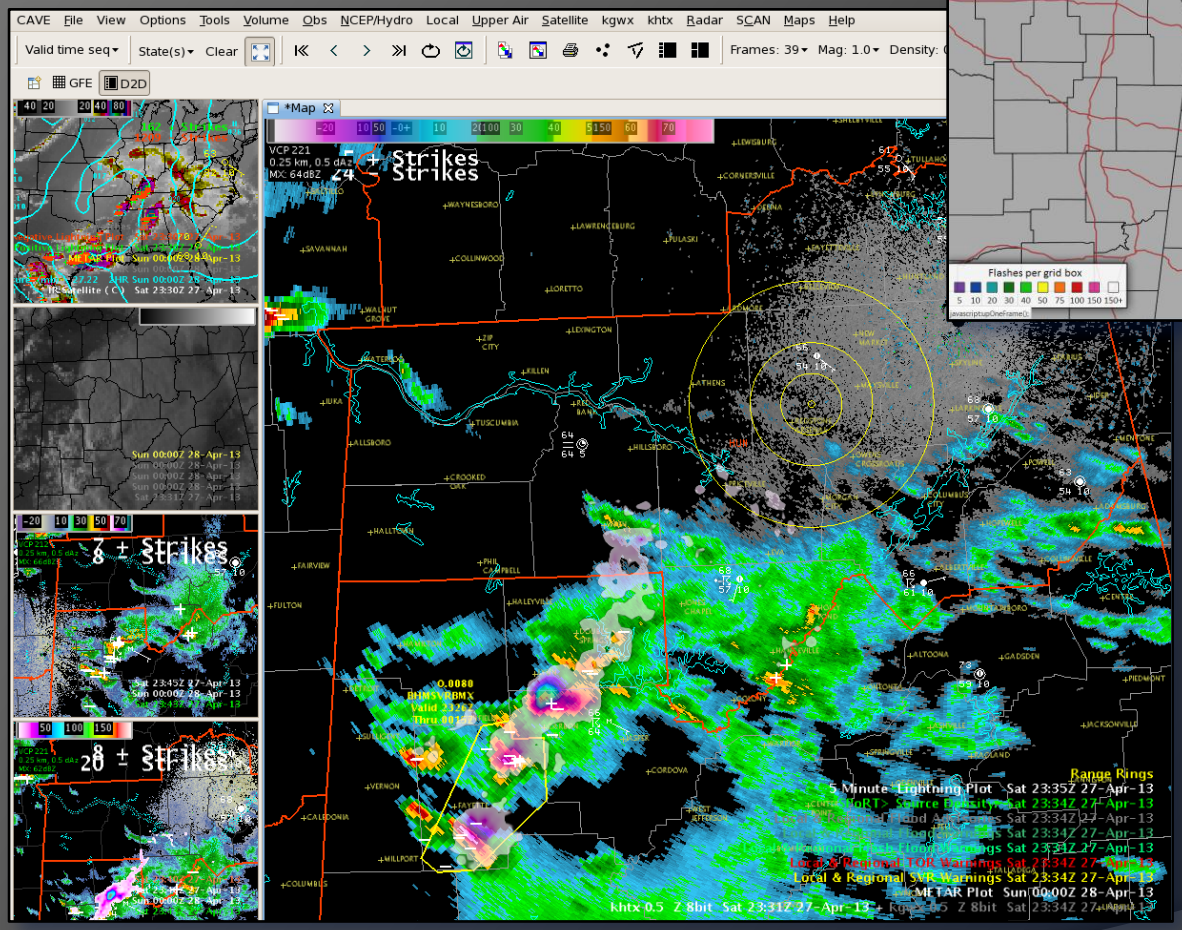
- 1 page "Quick Guides"
- Print out at forecast desk
- Reminder information

- Online, self-paced training modules
- Aim for 15-20 min in length
- Also, 5 min "micro modules

- Site visits
- Calls like this!

Operational Transition - Availability

Data provided in partner's visualization system



Web displays requested by some partners

- "AWIPS" for United States National Weather Service
- Allows integration with other meteorological data sets
- Examples today from AWIPS

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Preparing for the future

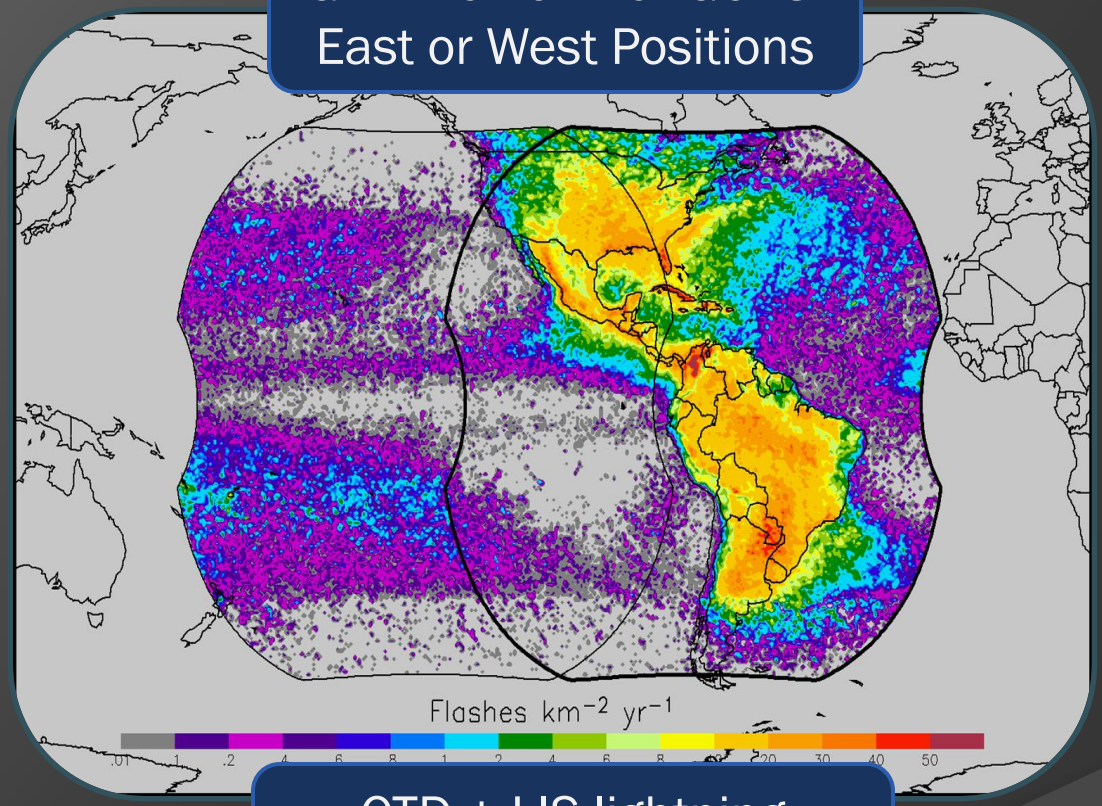
Goals

- Demonstrate use of total lightning in operations
- Improvements for:
  - Severe weather forecasts
  - Safety
  - Aviation
  - Many more

Preparation

- Effort for the GOES-R Geostationary Lightning Mapper
- Lessons learned applicable to Meteosat Lightning Imager

GLM Domain for GOES-East or West Positions



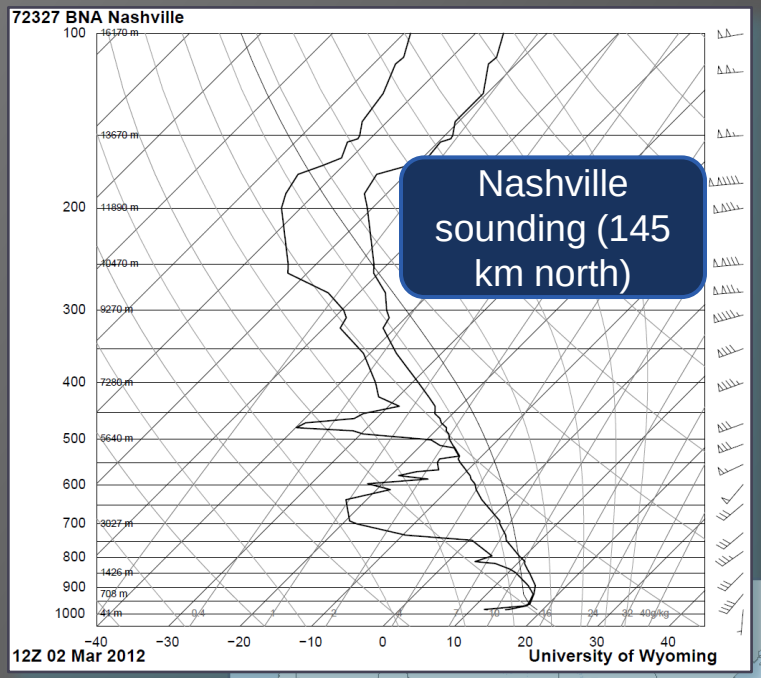
OTD + LIS lightning climatology (1995-2005)

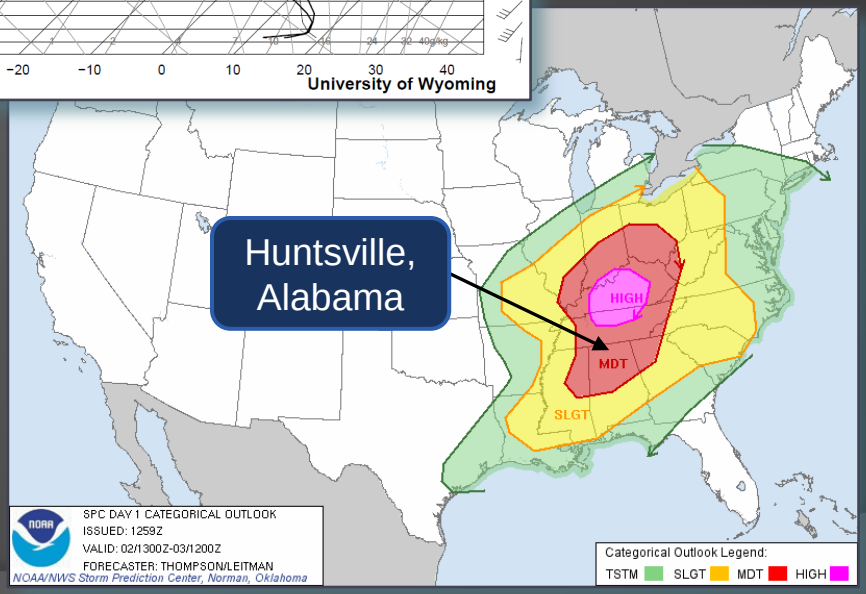
- http://www.goes-r.gov/spacesegment/glm.html

Operational Examples

(Provided by Forecasters)

Severe Weather Example – 2 March 2012

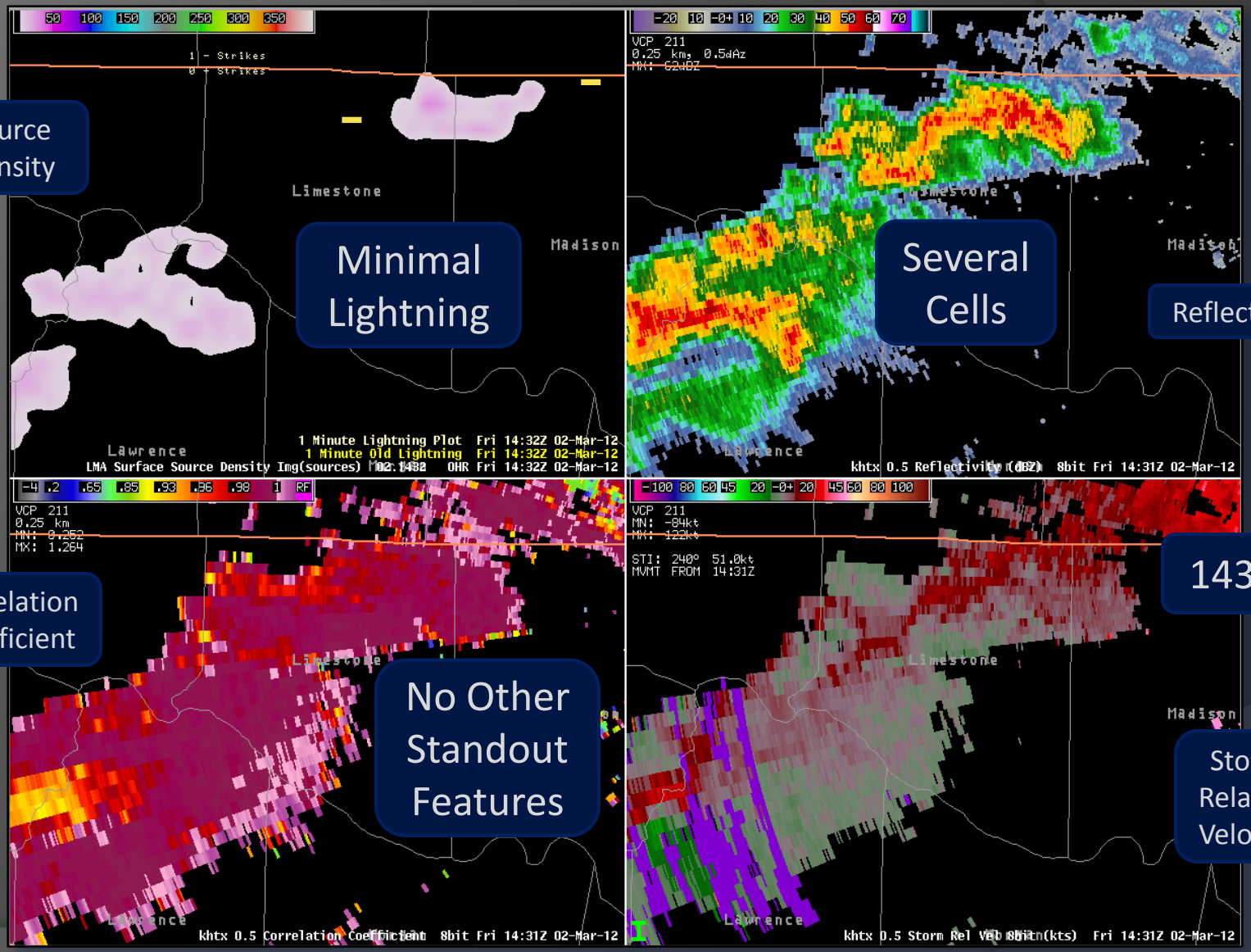




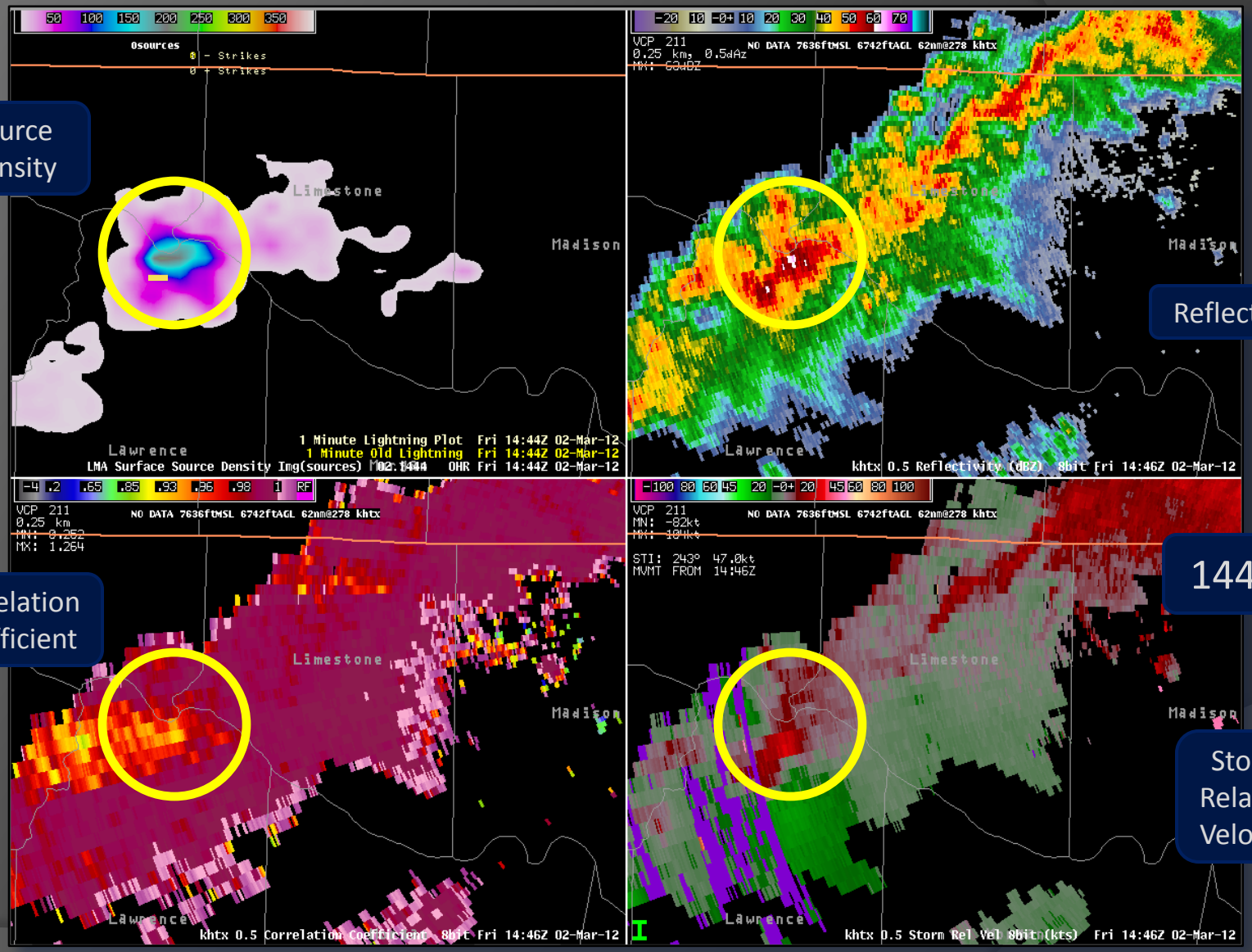
Huntsville, Alabama Overview

- SPC Moderate Risk
  - Widespread severe storms likely
- In warm sector
- Moist southerly flow
  - Tds ≥ 16°C
- Temperatures almost 21°C
- Low level lapse rates
  - 5.5 to 6°C
- CAPE: 550 (BMX) to 1200 (BNA) J/kg
- ~400 m^2/s^2 SRH (0-1 km)
- Very favorable for tornado development

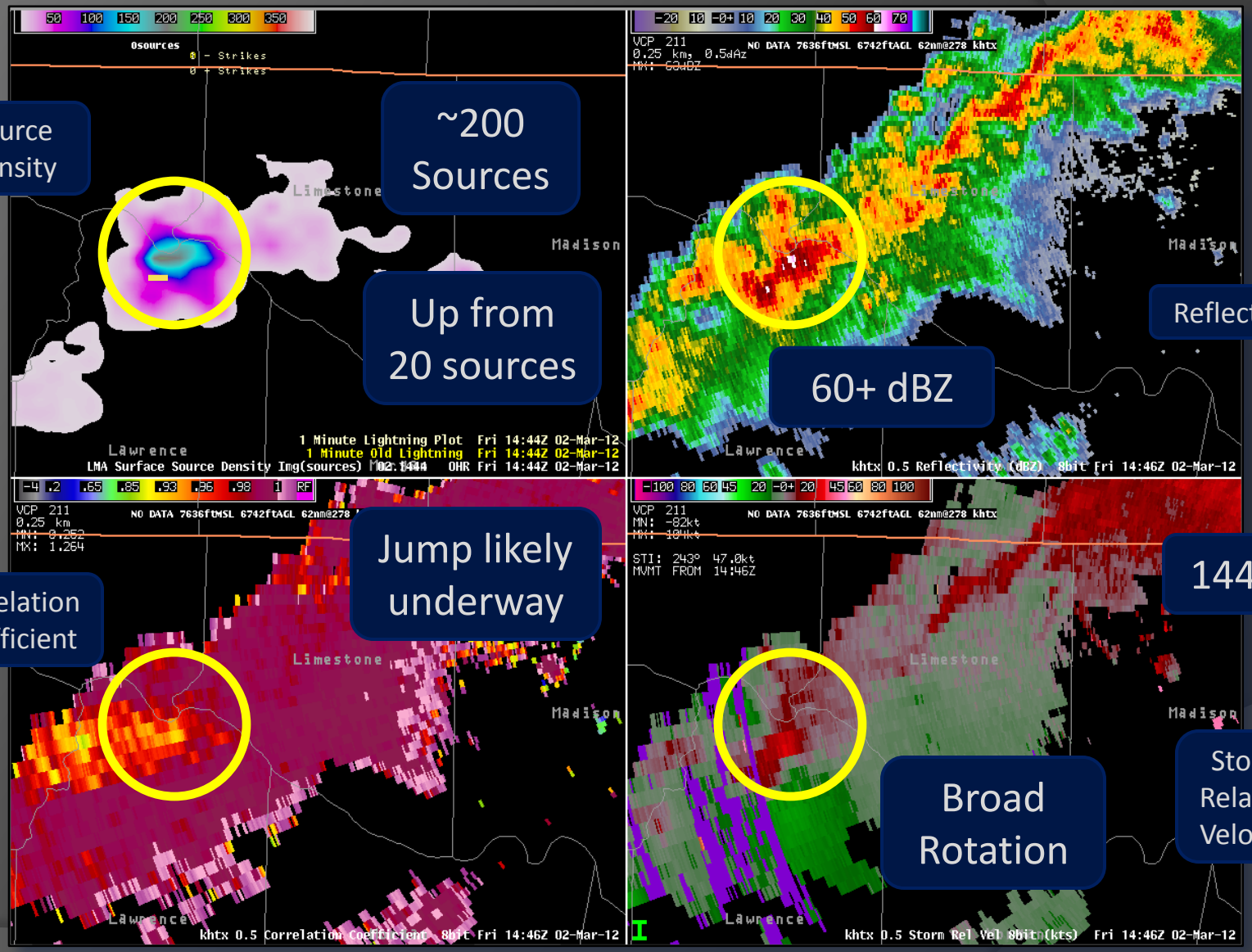
Initial Storm Development



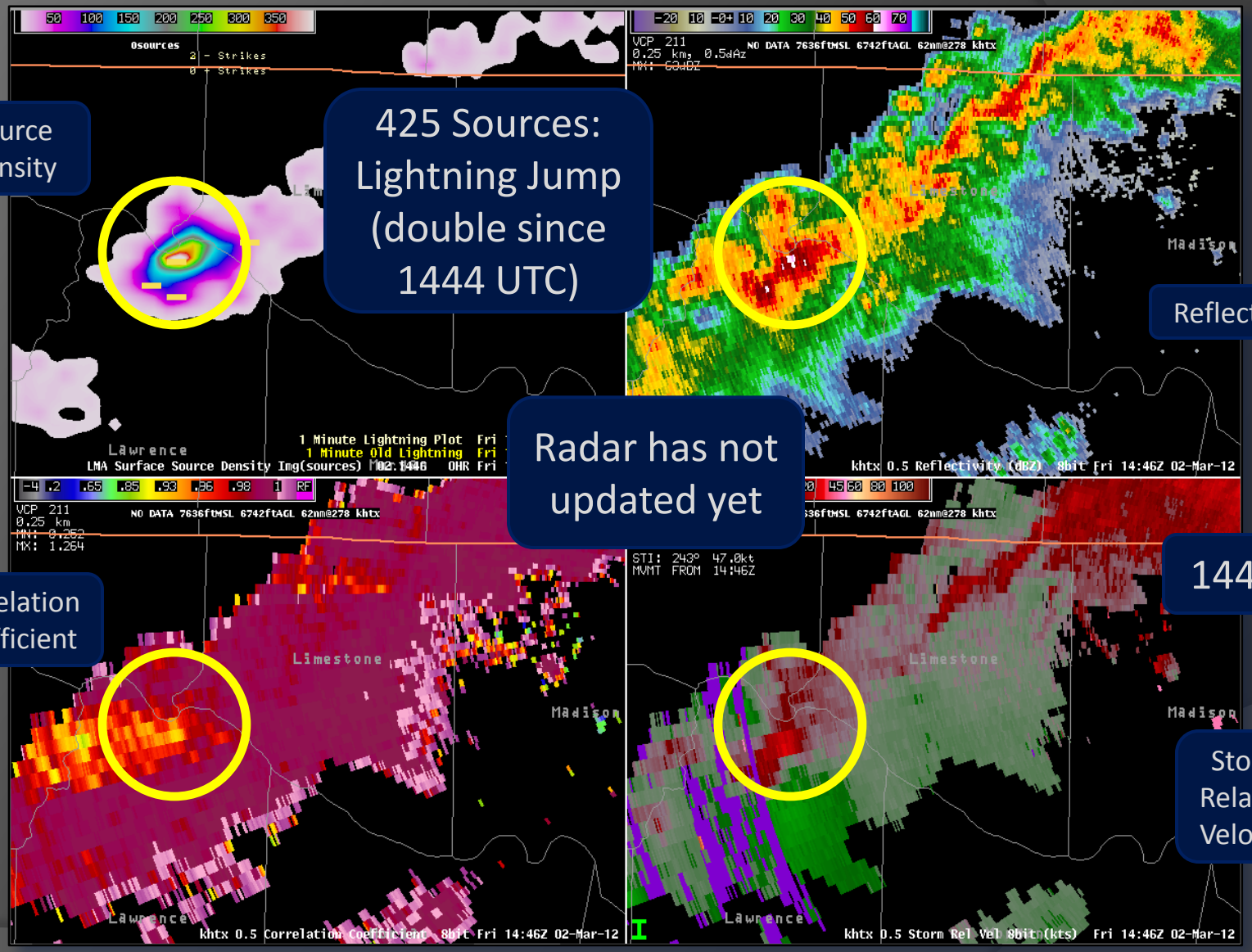
Storm Begins to Intensify



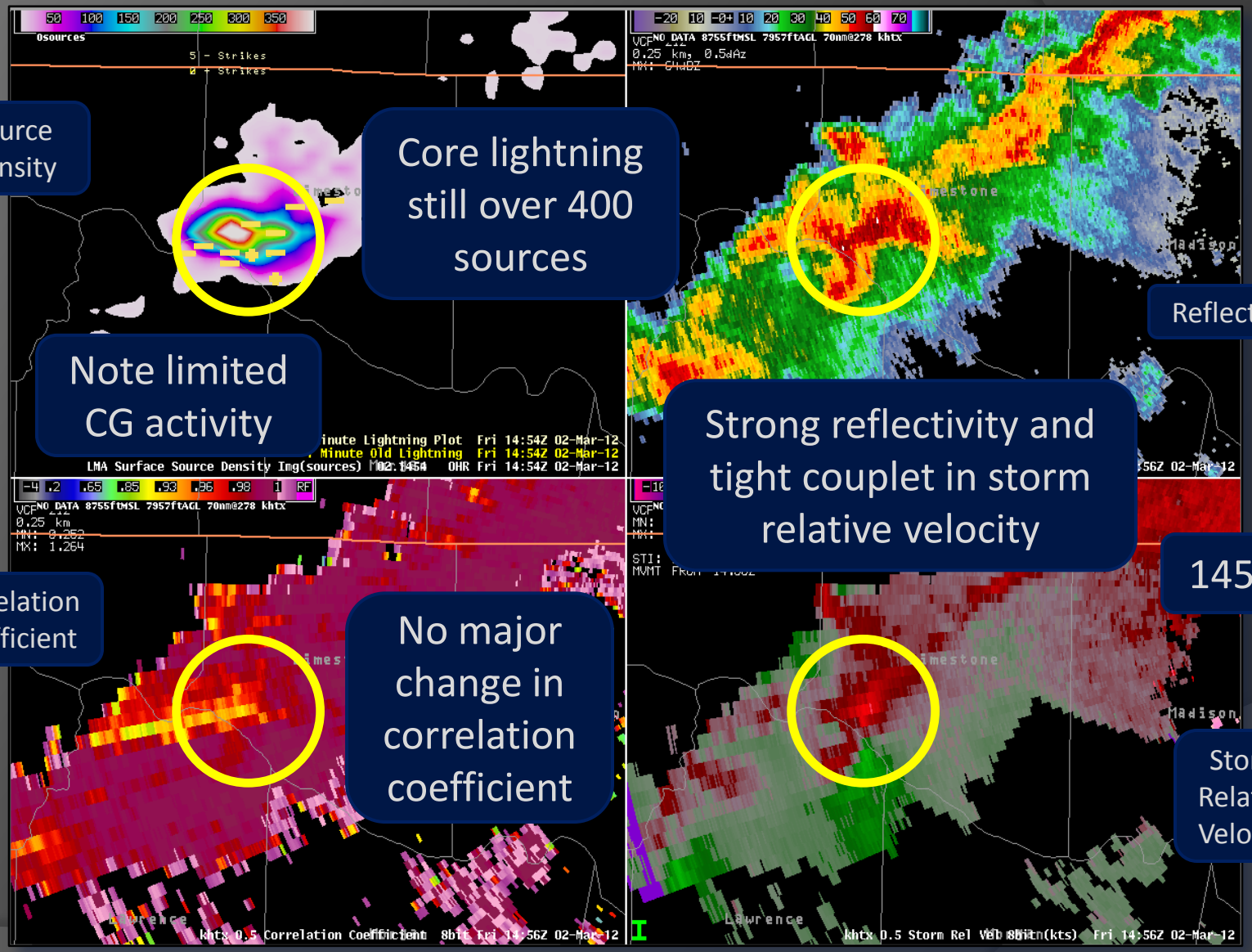
Lightning Jump Likely Underway



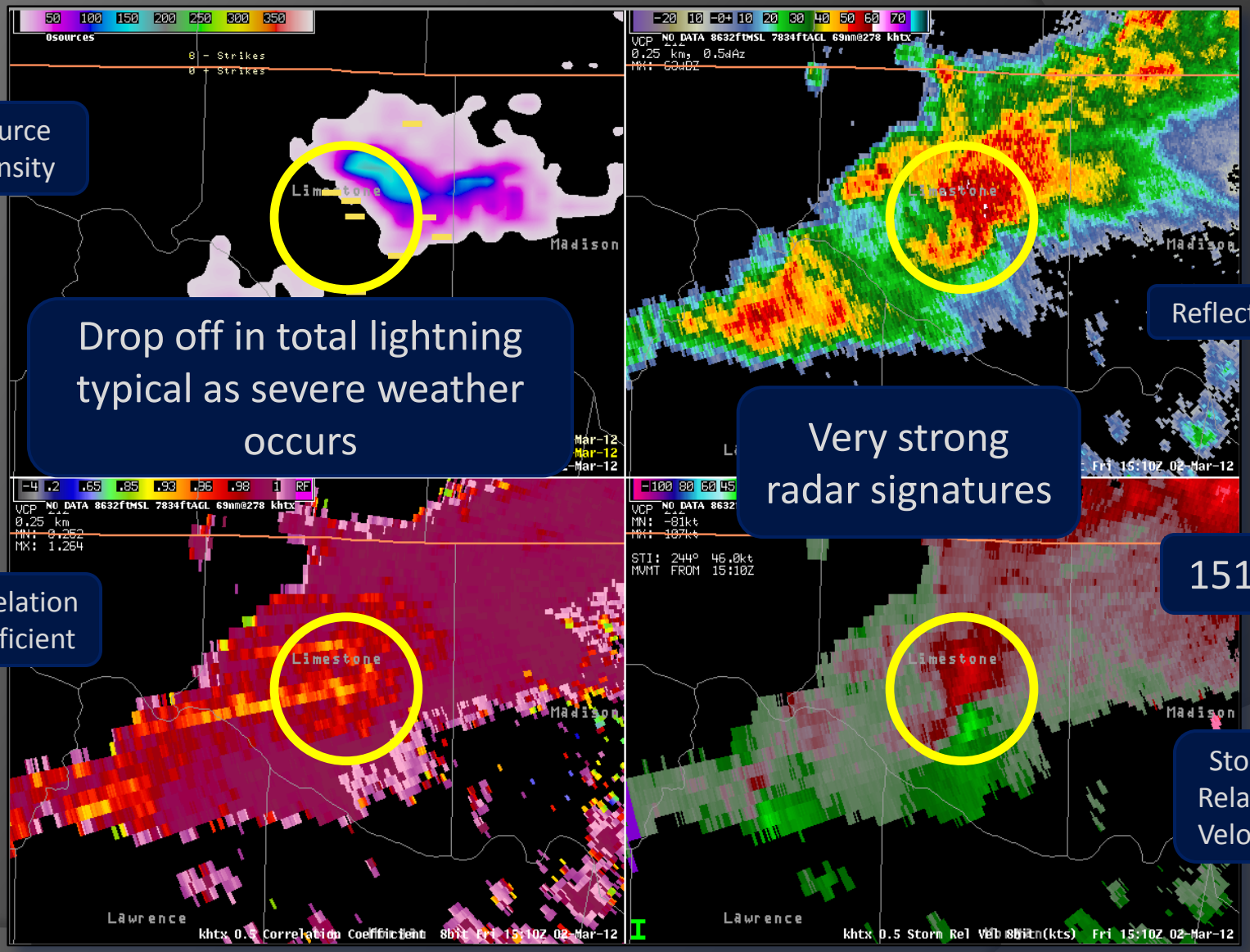
Lightning Jump Confirmed



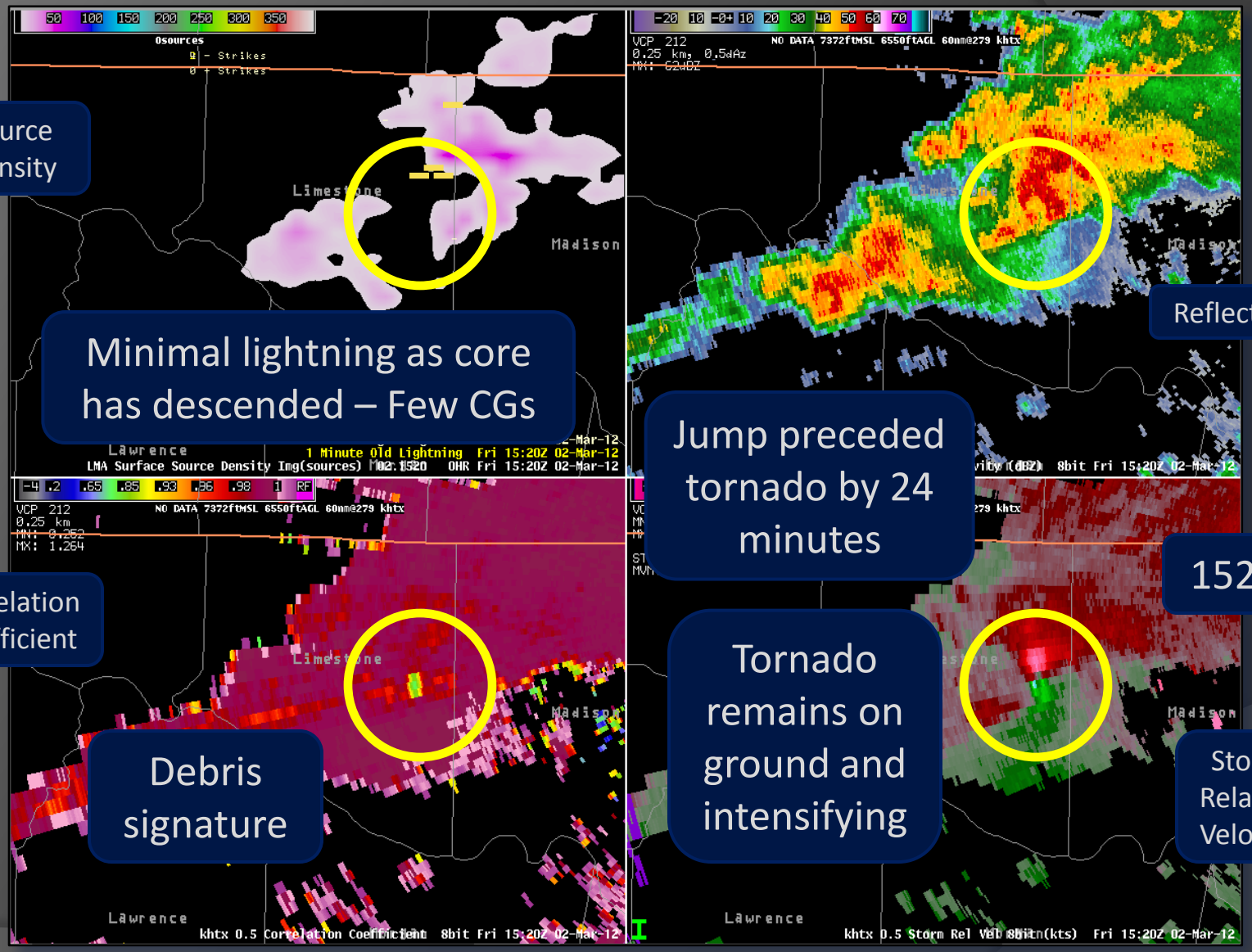
Storm Continues to Intensify



Tornado Touchdown



Tornado Touchdown



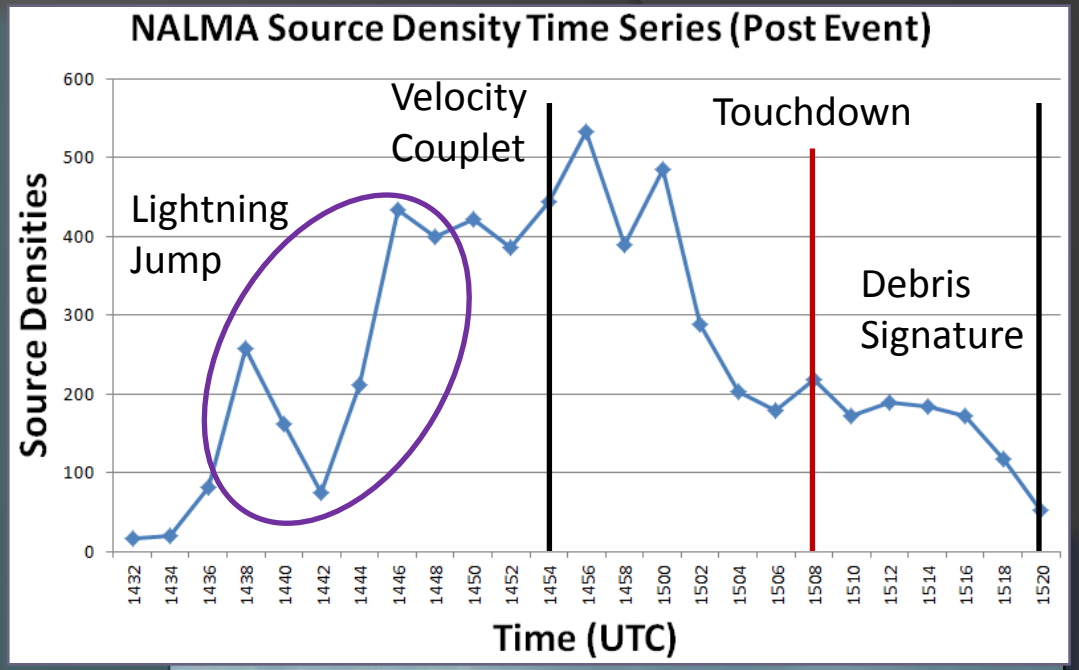
Severe Weather Event Summary

Summary

- Favorable storm environment
- Total lightning coincided with radar in pointing out main cell
- Lightning jump preceded definitive radar signature
- Lead time of 24 minutes
- No cloud-to-ground trend

Forecaster Quote

- "… data from 1446 UTC made it clear that the storm was indeed strengthening."



EF-3 Tornado (216-266 km/hr)

Photo: National Weather Service

Lightning Safety: First Cloud-to-Ground Strike

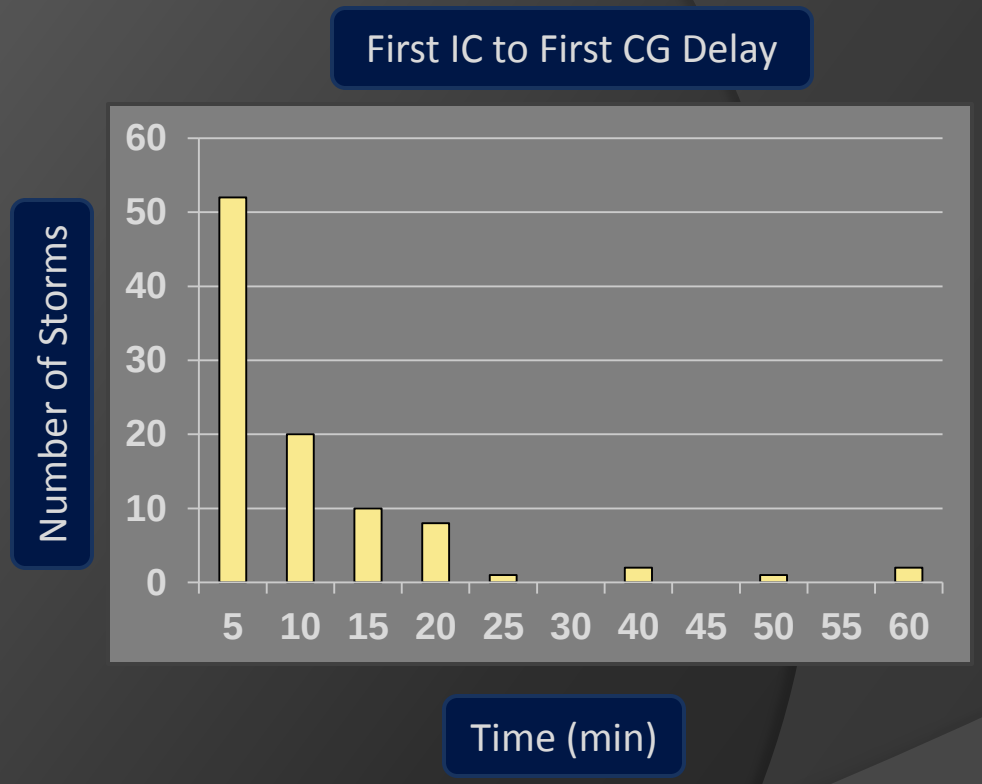
"First Strike" Forecasting

- Majority is intra-cloud
- Lead time for initial cloud-to-ground strike
- First IC typically precedes first CG by 5-10 min

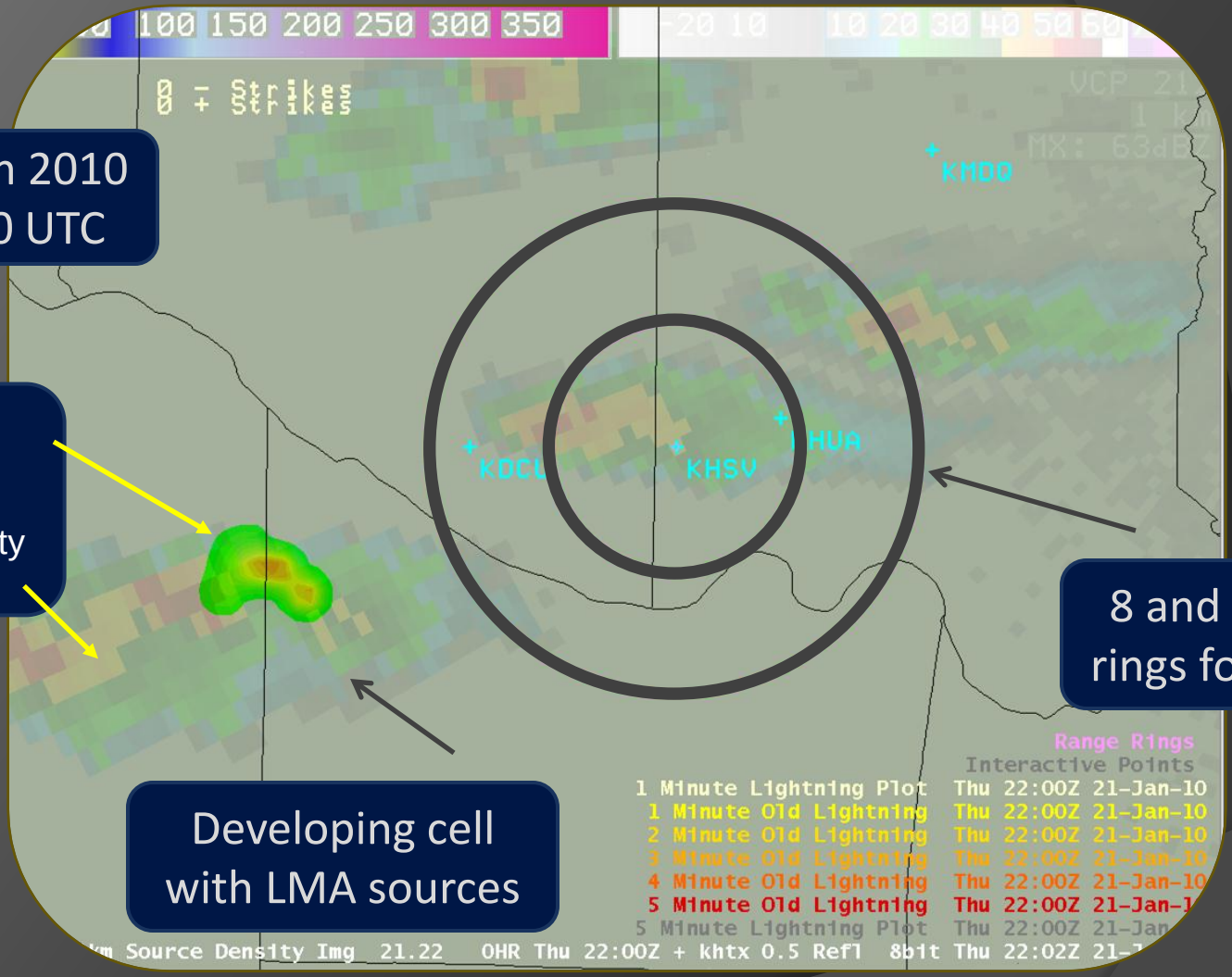
Aviation applications

- Update TAFs
- Airport Weather Warnings

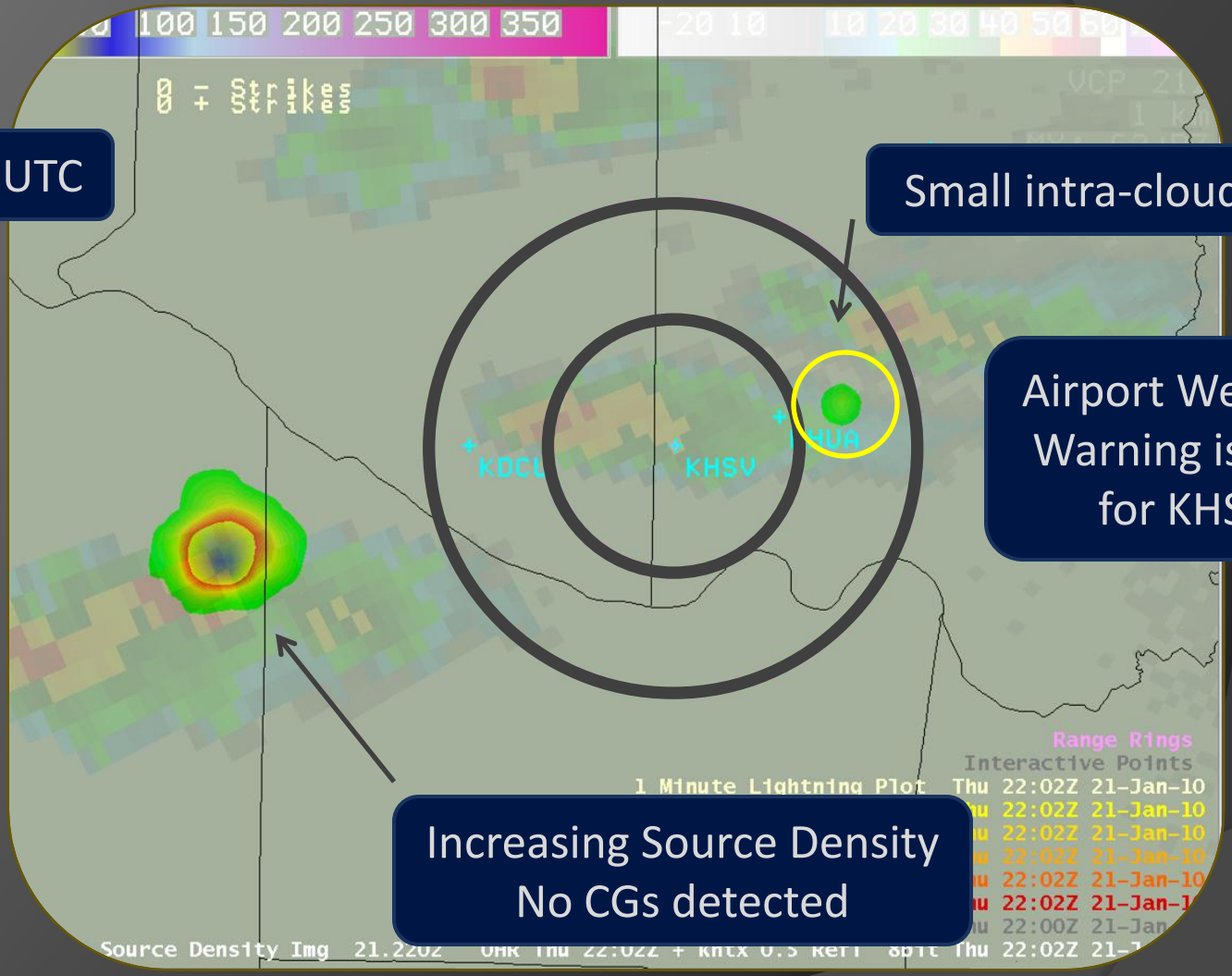
Public service applications



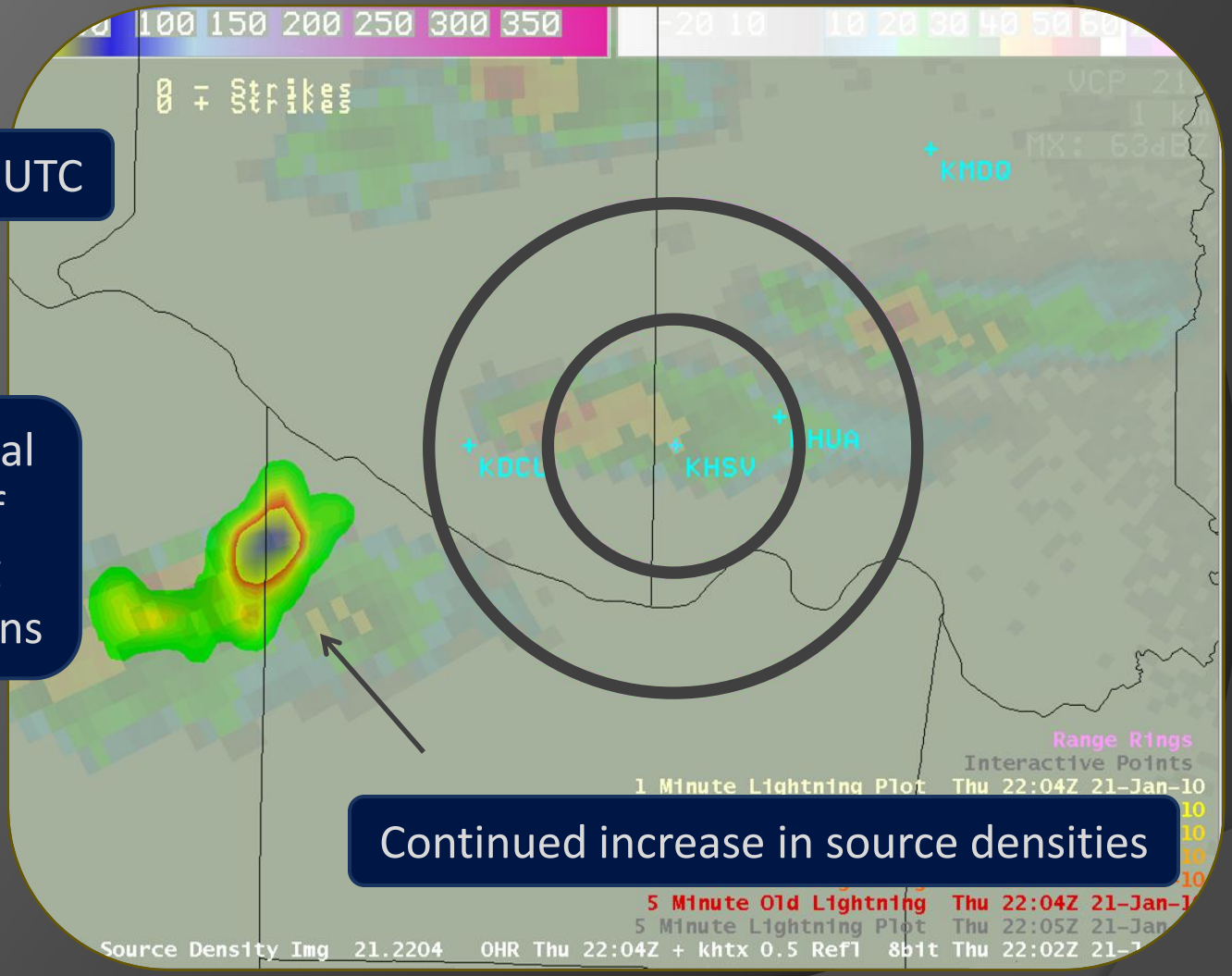
Storm Approaching Airport



Safety Alert Issued



Intra-cloud Lightning Continues

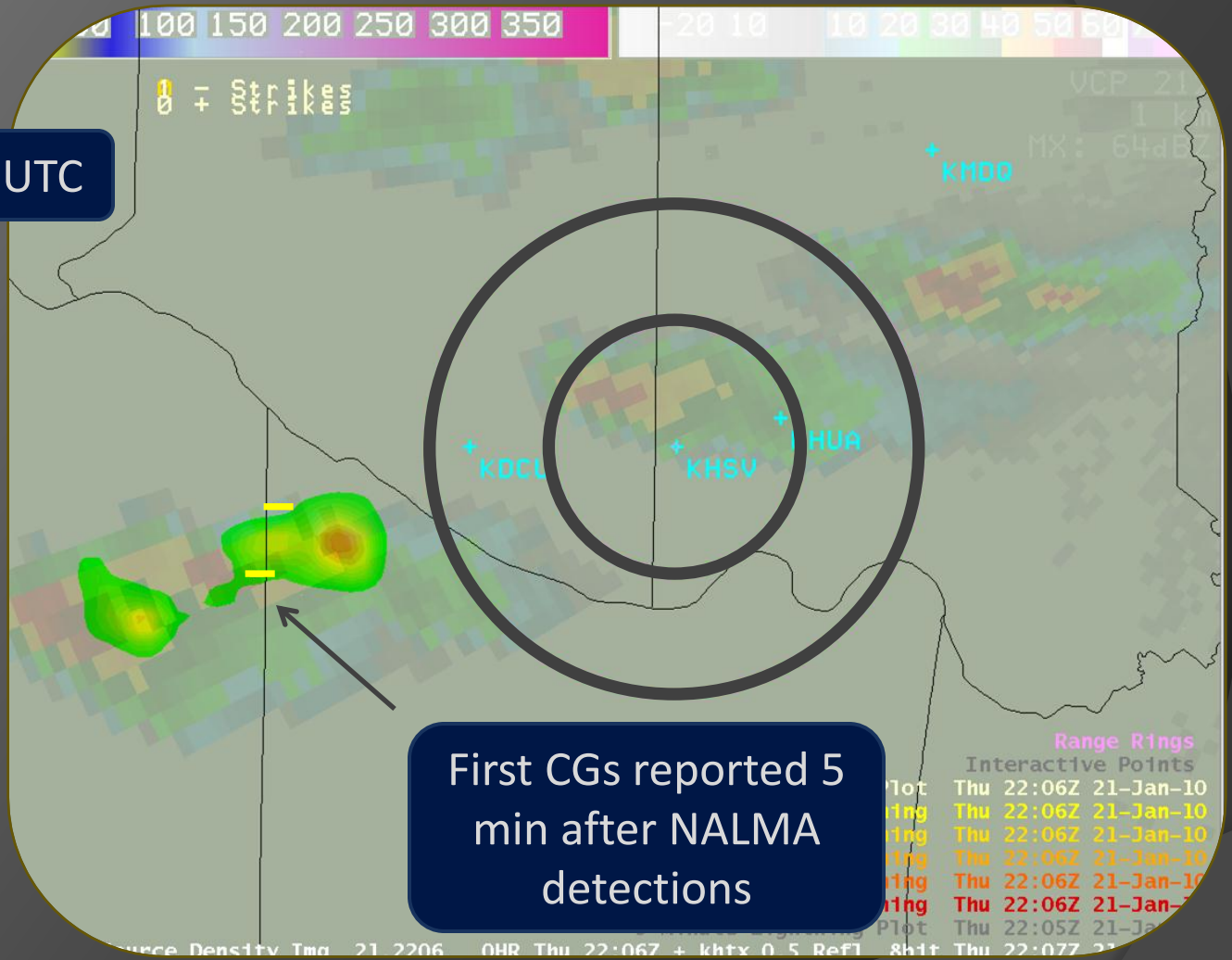


2204 UTC

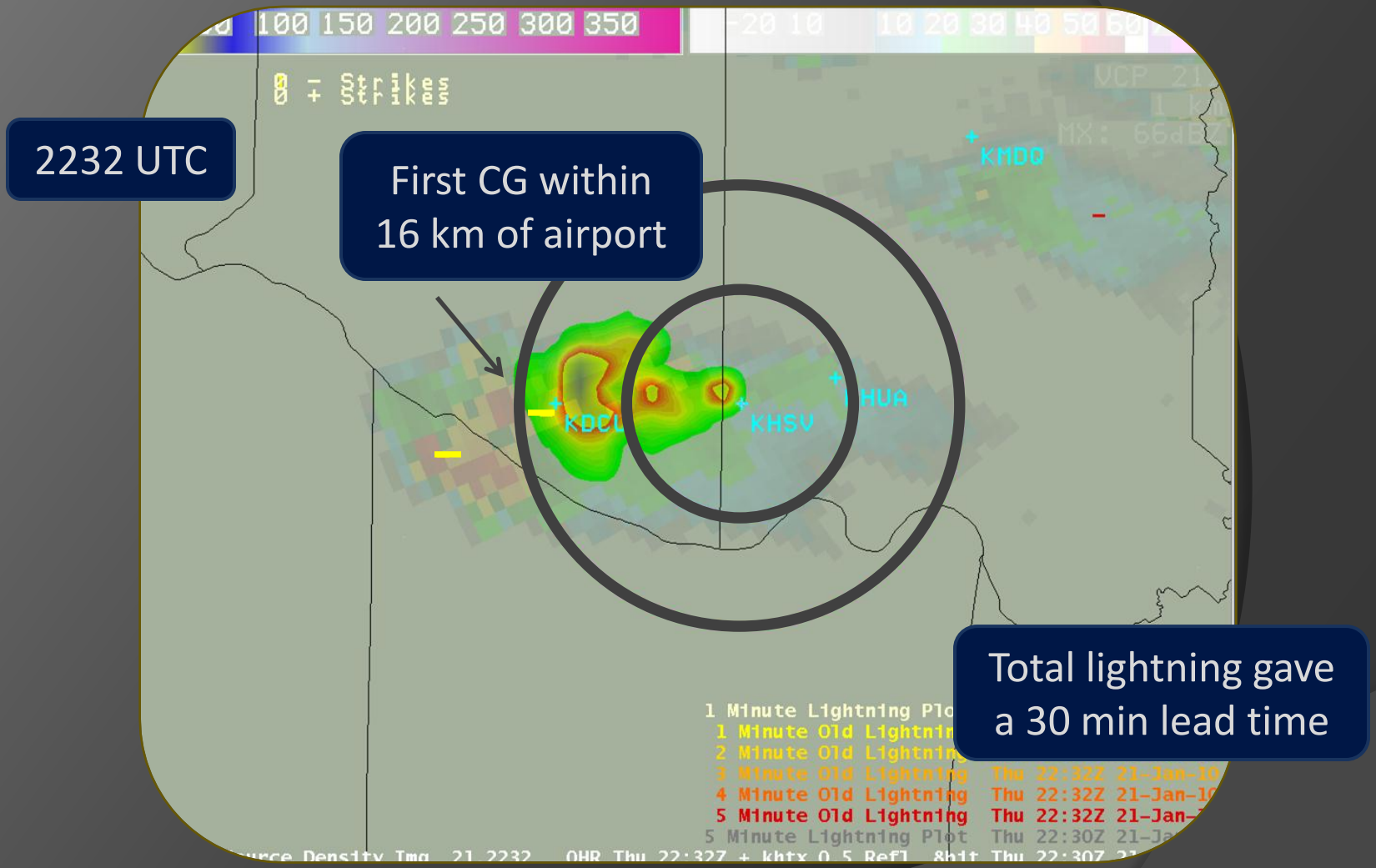
Note spatial extent of lightning observations

Continued increase in source densities

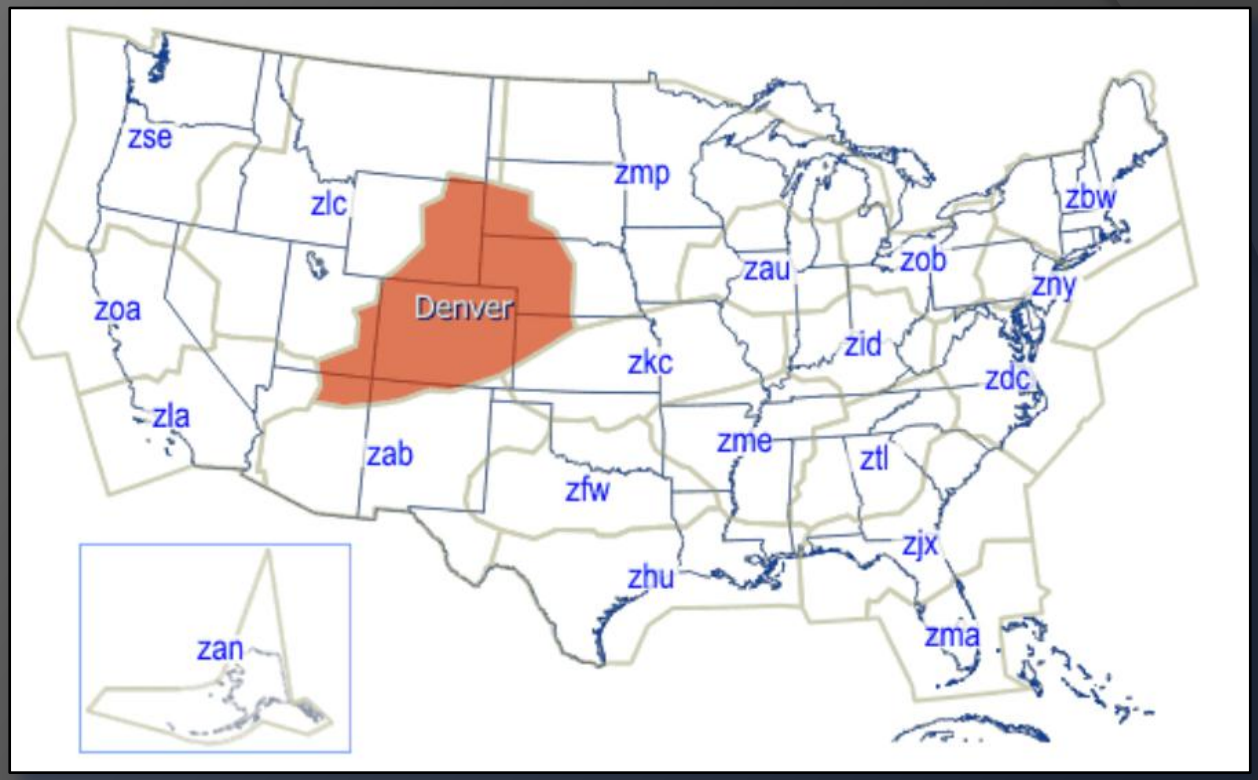
First Cloud-to-Ground Strike



First Cloud-to-Ground Strike Near Airport

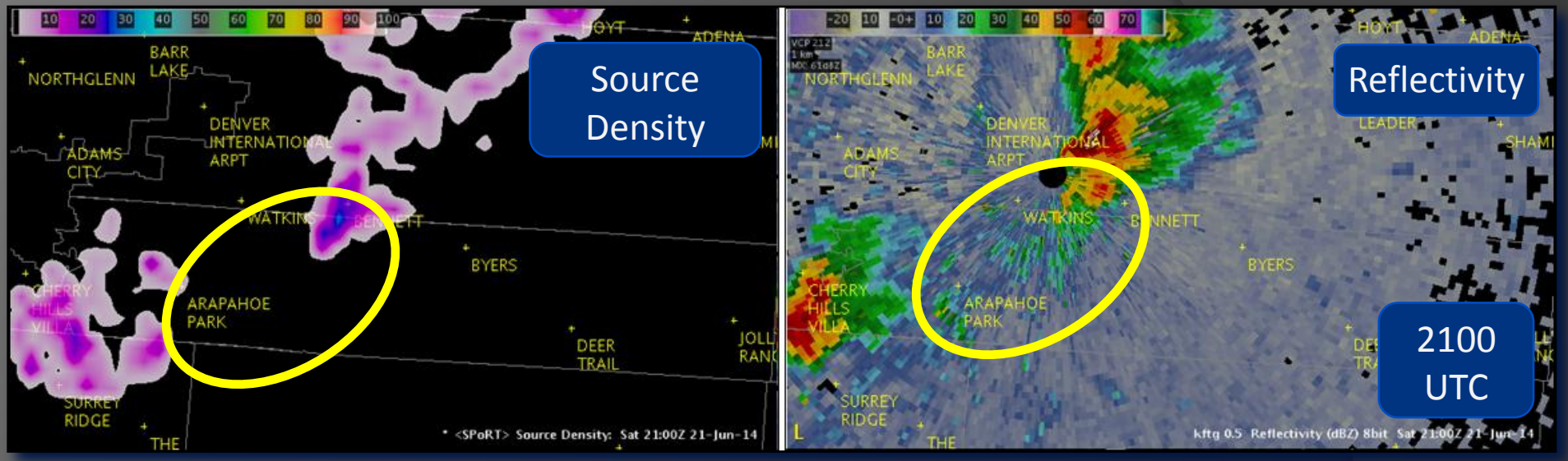


Aviation Weather Example: Introduction



- Example from Denver, Colorado
- Forecast group is a Center Weather Service Unit (CWSU)
- Support Federal Aviation Administration
  - Air traffic support, convective forecasts
  - Air traffic landing/taking off and flying through

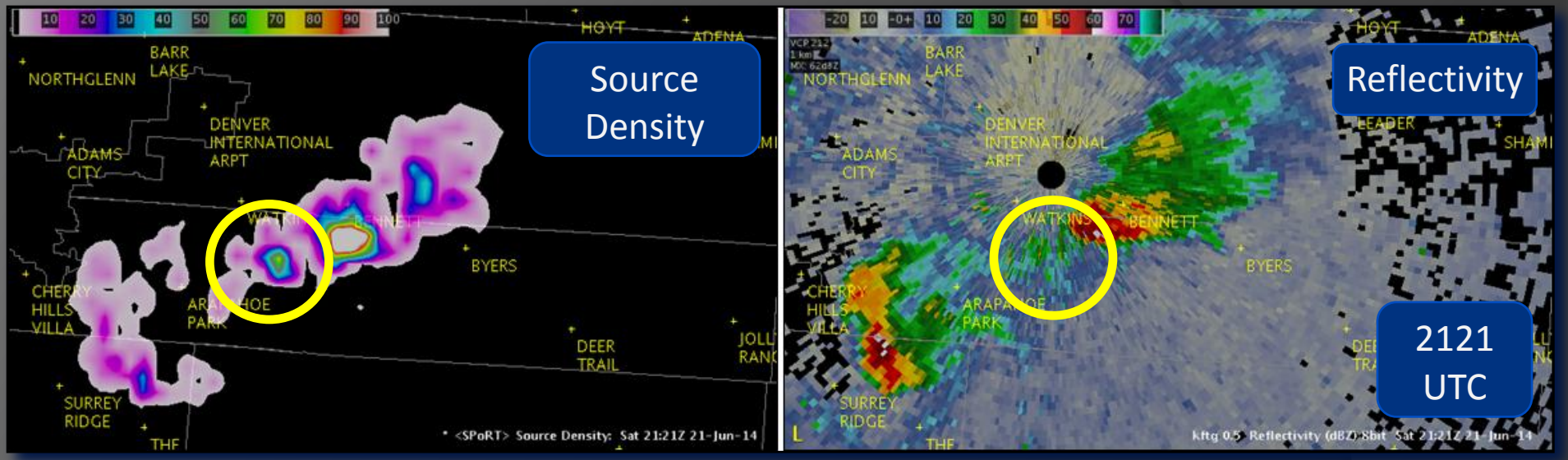
Aviation Weather Example



2100 UTC

- CWSU monitoring storms southeast of Denver International Airport
- Gap in storms allowing continued traffic through Terminal Radar Approach and Control (TRACON) gate
  - Air routes at roughly 80 km from the airport

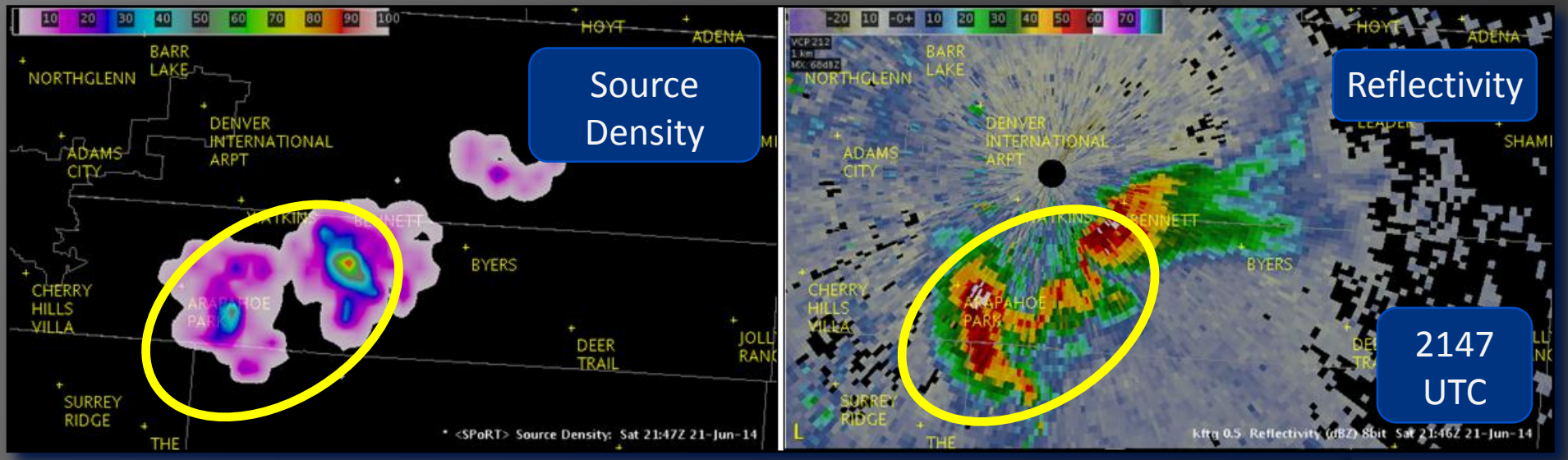
Outline



2121 UTC

- CWSU notes a new storm core observed in the LMA observations
- Radar shows intense convection on either side of this new cell
- LMA further shows lightning nearly filling entire gap between storms
- CWSU informs the Traffice Management Unit that convection is beginning to impinge on the TRACON gate and will likely close to all traffic

Outline



2147 UTC

- Air route completely closed by convection
- LMA provided CWSU greater confidence of timing and intensity of convection

Additional Quote from CWSU Houston

- *"The source density helped show the sustainability of these storms (to the SW) and gave me confidence that it was likely to impact this arrival point at least 1 1/2 to 2 hours after peak heating"*

Summary and Future Work

- Total Lightning: Observes both intra-cloud and cloud-to-ground lightning
  - Not a point source – Good for lightning safety
  - Related to storm updraft strength
  - More total lightning = stronger updraft
  - Special case: Lightning Jump
    - Rapid increase over ~10 minutes
    - Usually precedes storm becoming severe
  - Rapid updates (~1 minute)
  - Improves situational awareness
  - Useful in warning decision support
- Future work
  - SPoRT's efforts have been demonstration work for the Geostationary Lightning Mapper
  - Lessons applicable to Meteosat Lightning Imager
  - New efforts to generate GLM products for the community

Questions?

Thank you again for the opportunity to speak!!

Dr. Geoffrey Stano: geoffrey.stano@nasa.gov

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

Wide World of SPoRT blog: http://nasasport.wordpress.com/