THE GOES-R GLM LIGHTNING JUMP ALGORITHM (LJA): RESEARCH TO OPERATIONAL ALGORITHM

Chris Schultz[1], Larry Carey[1], Dan Cecil[2], Monte Bateman[3], Geoffrey Stano[4],Steve Goodman[5]

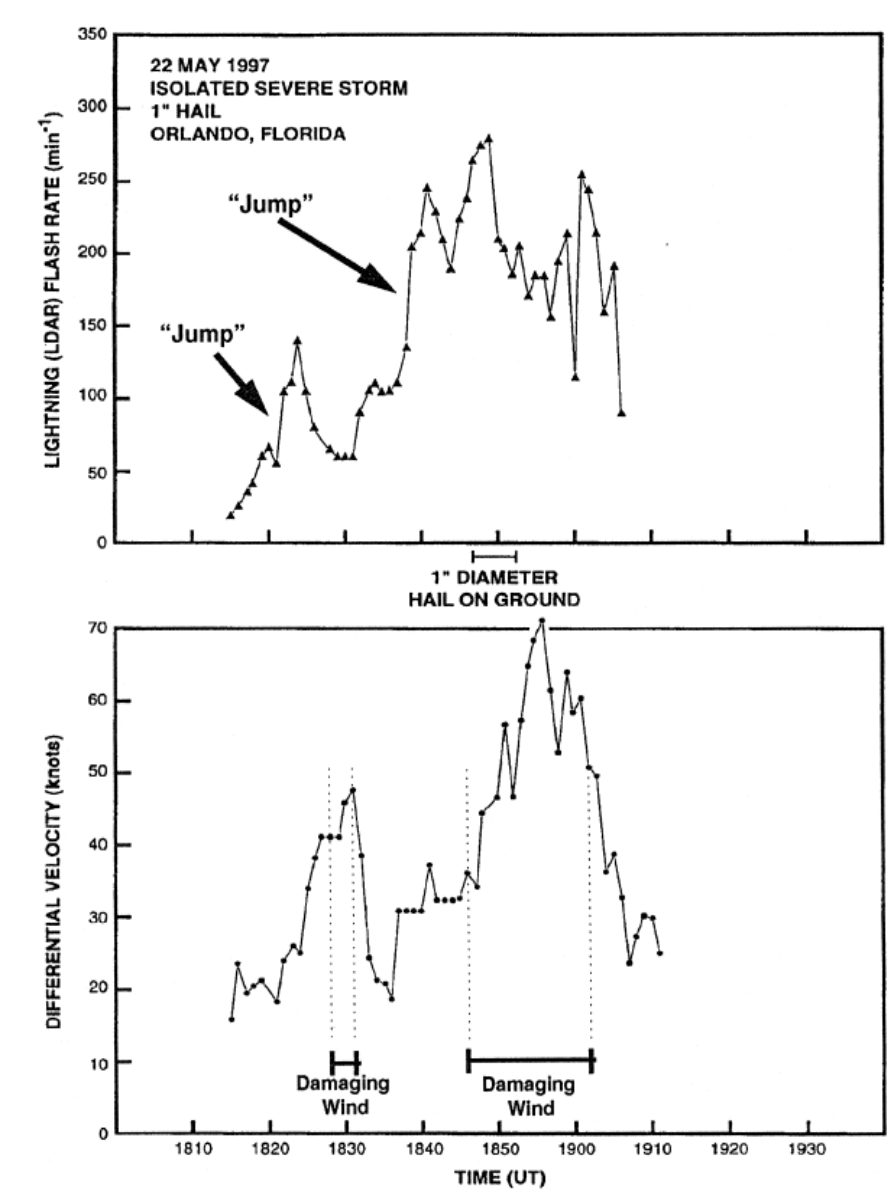
[1] *Department of Atmospheric Science, UAHuntsville*
[2] *Earth System Science Center (ESSC), UAHuntsville*
[3] *USRA/NASA MSFC*
[4] *ENSCO/NASA SPoRT*
[5] *NOAA NESDIS*

Goal of LJA Project

- Objective - To refine, adapt and demonstrate the LJA for transition to GOES-R GLM (Geostationary Lightning Mapper) readiness and to establish a path to operations

- Year 1 Plans – reducing risk in LJA algorithm automation, cell tracking, GLM lightning proxy and data fusion.

The Lightning Jump Concept



- Several studies in the past have correlated increases in total flash rates within a storm to severe weather occurrence , e.g.,
  - Goodman et al. 1988
  - Williams et al. 1989
  - Williams et al. 1999
  - Schultz et al. (2009)
  - Gatlin and Goodman (2010)

- The correlation is between the following
  - Updraft strength and modulation of electrification
  - Updraft strength and ability to produce severe and hazardous weather.

Recent LJA Work

- Schultz et al. (2011) recently demonstrated the feasibility of the lightning jump algorithm (LJA) on a large sample of 711 thunderstorms (severe and non-severe) from across the country.

- POD 79%, FAR 36%, CSI 55%, HSS 0.71.
  - Avg. Lead time 20.65 minutes +/- 15.05 minutes

TABLE 2. Breakdown of thunderstorm sample by type.

Type	Supercell	Airmass/Multicell	Tropical	Linear	Cold	Low Top
severe	82	73	5	47	38	10
nonsevere	12	387	4	24	18	11
number	94	460	9	71	56	21
number of severe wx events	343	128	8	135	149	18

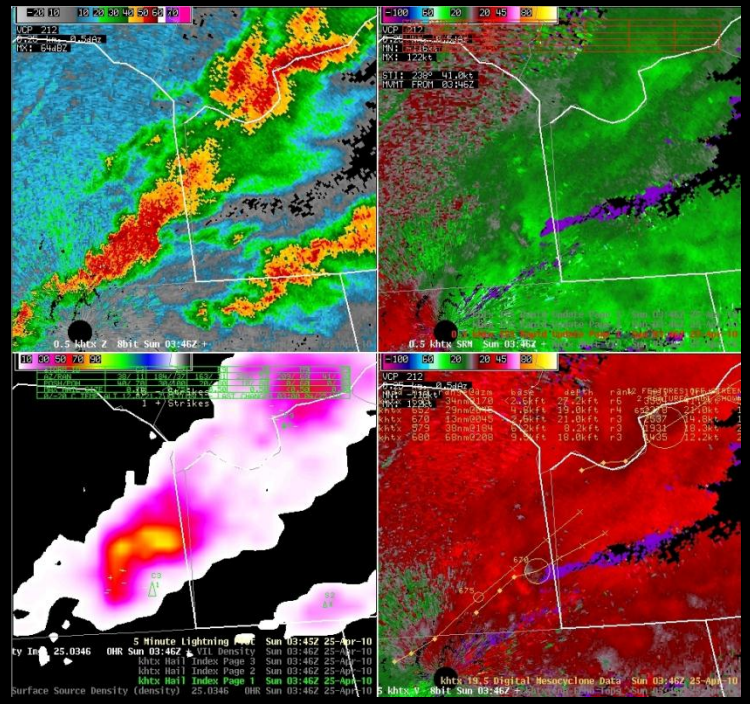
Real Time Situation Awareness Utility

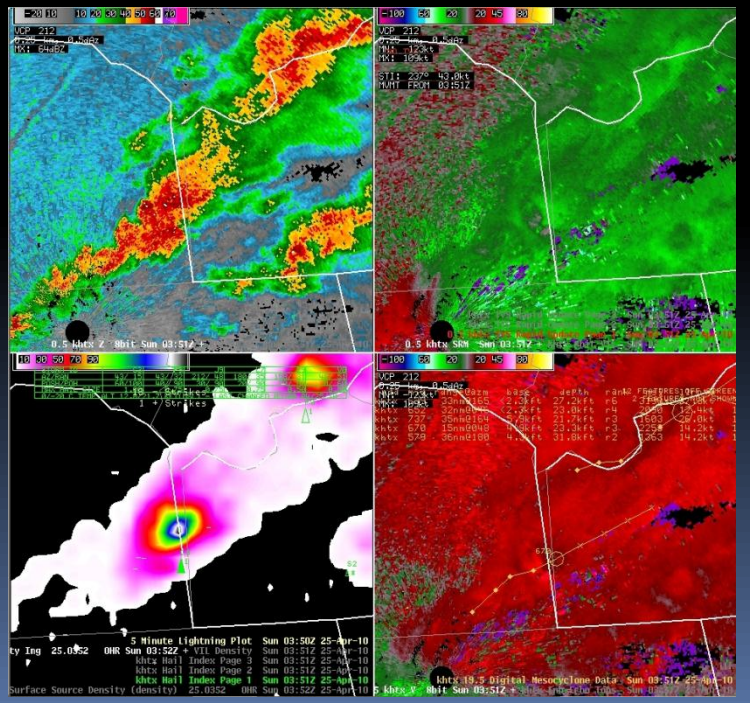
- The LJA Can:
  - Indicate when an updraft is strengthening or weakening on shorter timescales than current radar and satellite
  - Identify when severe or hazardous weather potential has increased
  - "Tip the scales" on whether or not to issue a severe warning
- The LJA Cannot:
  - Predict severe weather potential in every severe storm environment.
  - Discern severe weather types
    - i.e., a certain jump does not mean there will be a certain type of severe weather
  - Issue specific types of severe warnings

April 24, 2010 Southeastern, TN

- "Source density values jumped up over 200. Other radar products did not indicate significant intensification – other than the POSH rising to 60%, just about everything else stayed the same. But based on the big jump in source density values and the slight jump in POSH (and the favorable storm environment), I decided to issue a SVR."
- 20 minutes after warning issued, damaging winds occurred near Jasper, TN

http://nasasport.wordpress.com/2010/04/27/use-of-lma-data-tips-the-scales-toward-a-warning/

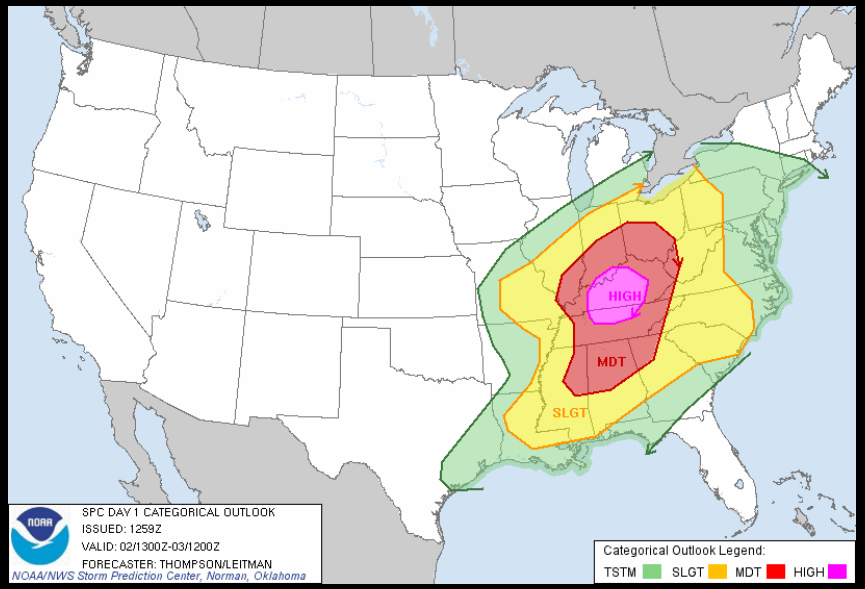




March 2, 2012

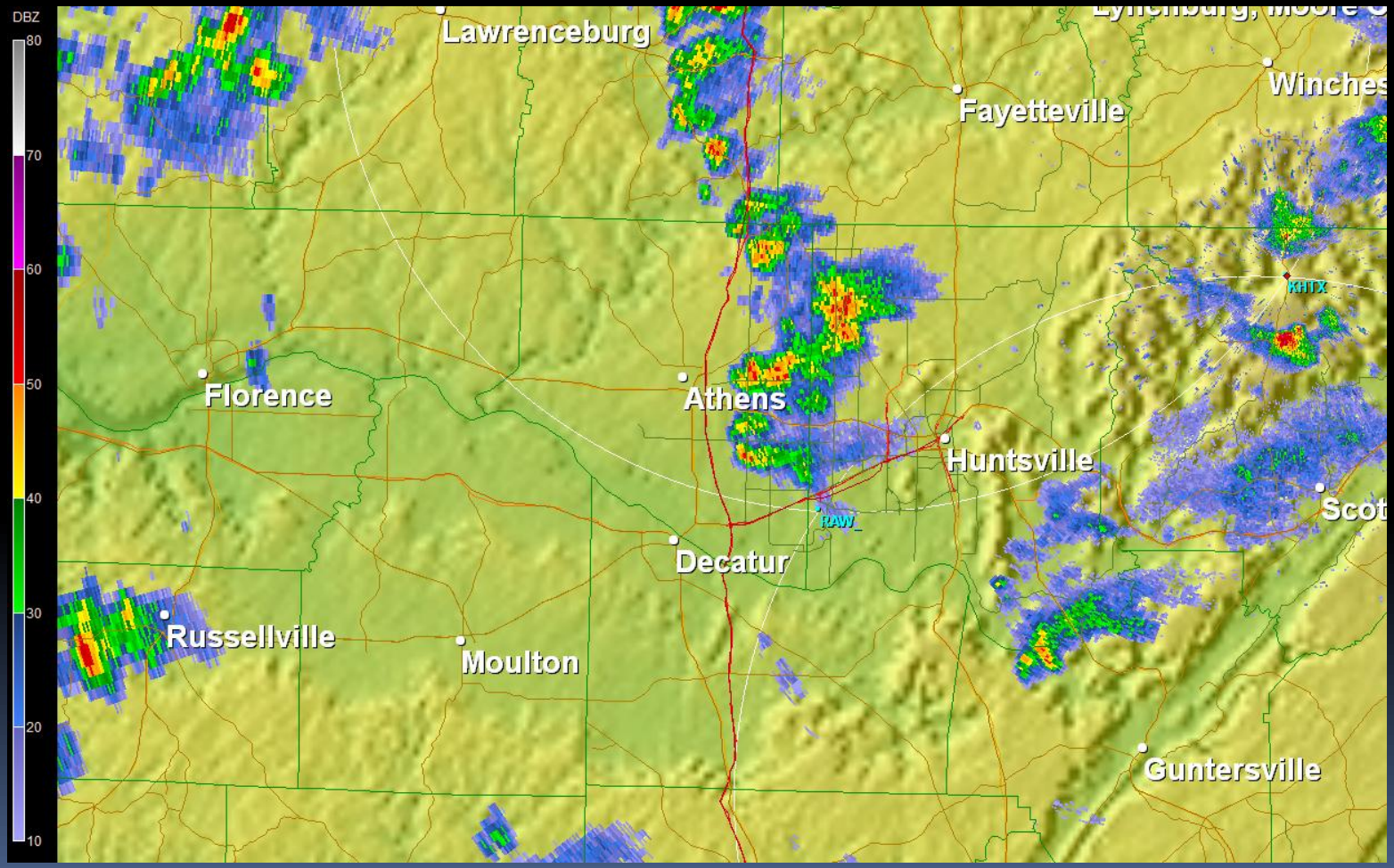
- "…MS/AL/GA LATE THIS AFTERNOON INTO TONIGHT… THE MOIST/UNSTABLE WARM SECTOR IS ALREADY ESTABLISHED ACROSS THE GULF COAST STATES THIS MORNING. THIS AREA WILL REMAIN A LITTLE S OF THE STRONGEST DEEP-LAYER FLOW…AND THE STRONGEST LLJ CORE WILL DEVELOP NEWD TO THE OH VALLEY IN CONJUNCTION WITH THE UPPER JET STREAK AND SURFACE CYCLONE. STILL…INSTABILITY AND VERTICAL SHEAR WILL BE FAVORABLE FOR SUPERCELLS WITHIN IN ONE OR MORE BANDS OF CONVECTION ALONG AND AHEAD OF THE COLD FRONT BEGINNING LATER THIS AFTERNOON AND CONTINUING INTO TONIGHT. RISKS WILL INCLUDE A FEW TORNADOES…DAMAGING WINDS…AND LARGE HAIL THROUGH TONIGHT."

SPC 13Z outlook

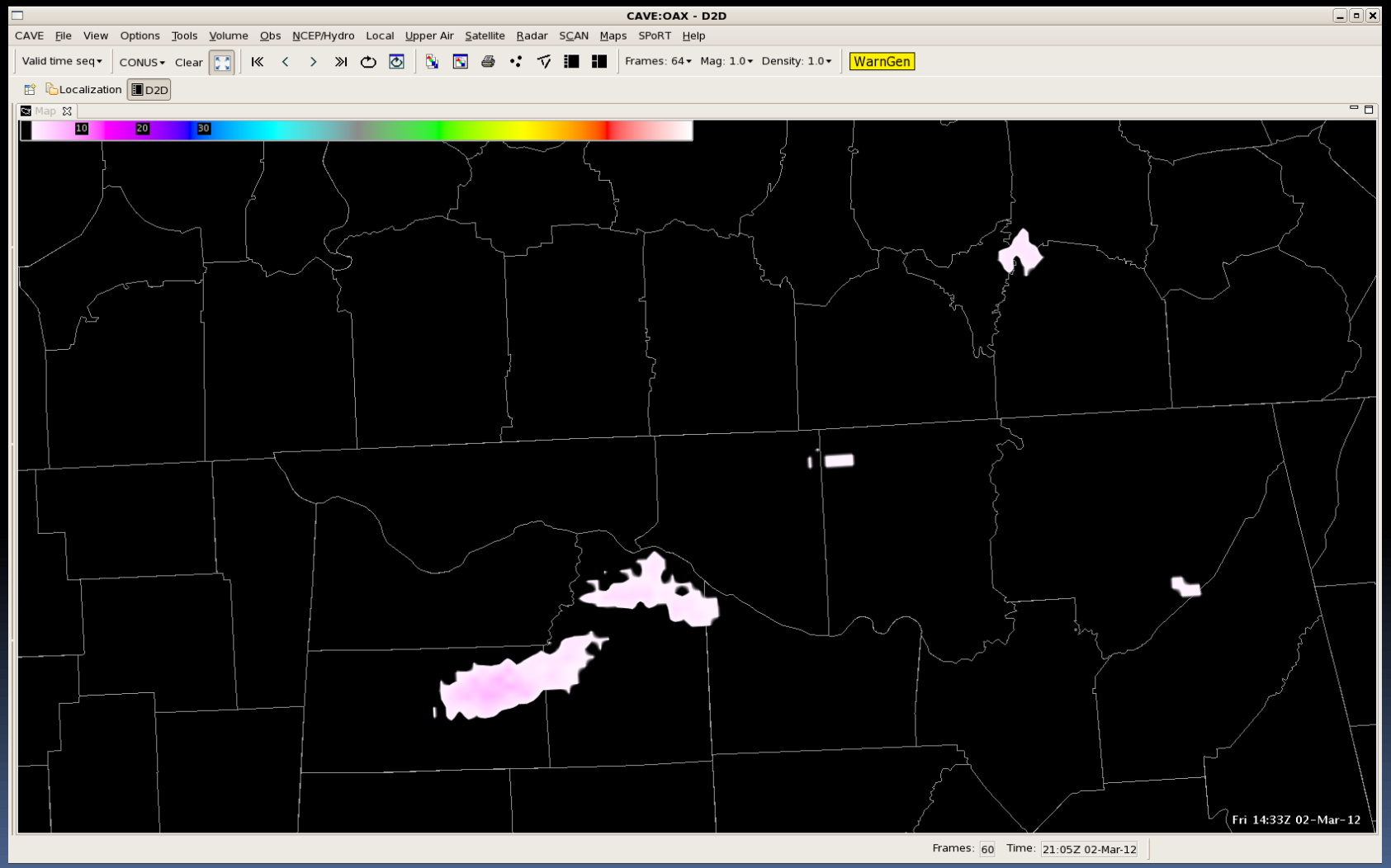


Main threat for AL targeted for the afternoon in association with trailing front

KHTX, 1302 UTC March 2, 2012

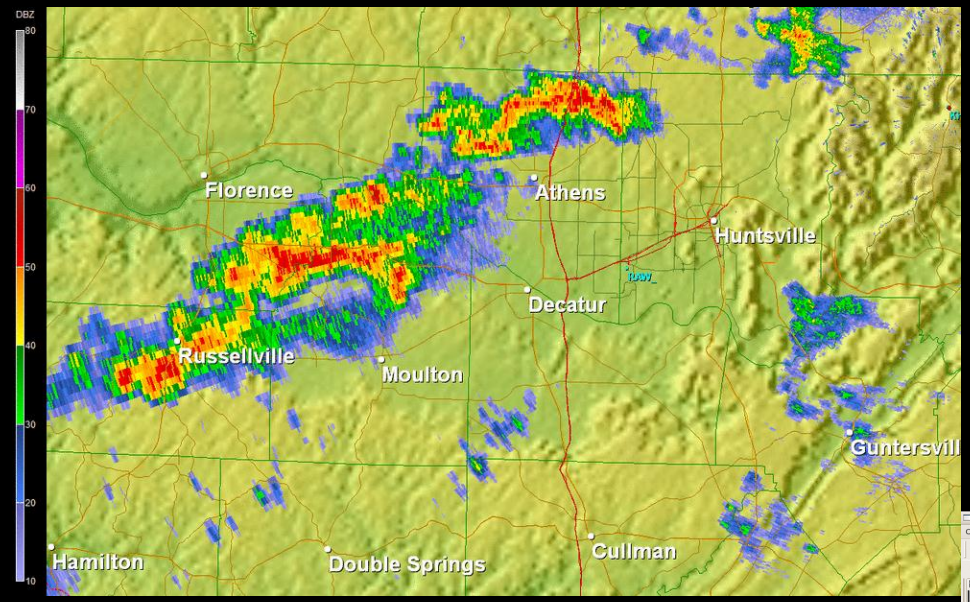


1402-1432 UTC KHTX

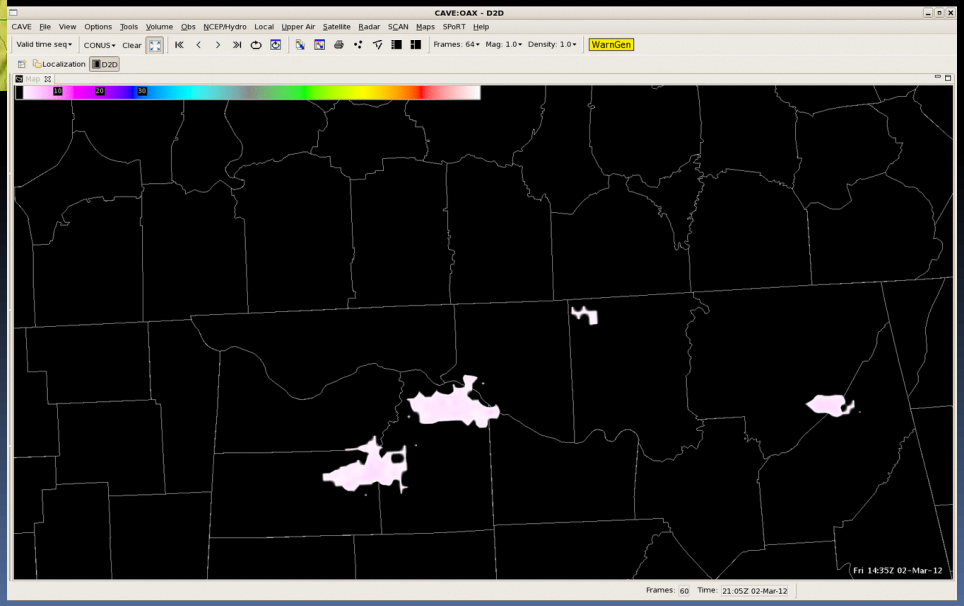


1432 – 1452 UTC

KHTX (every 5 minutes)



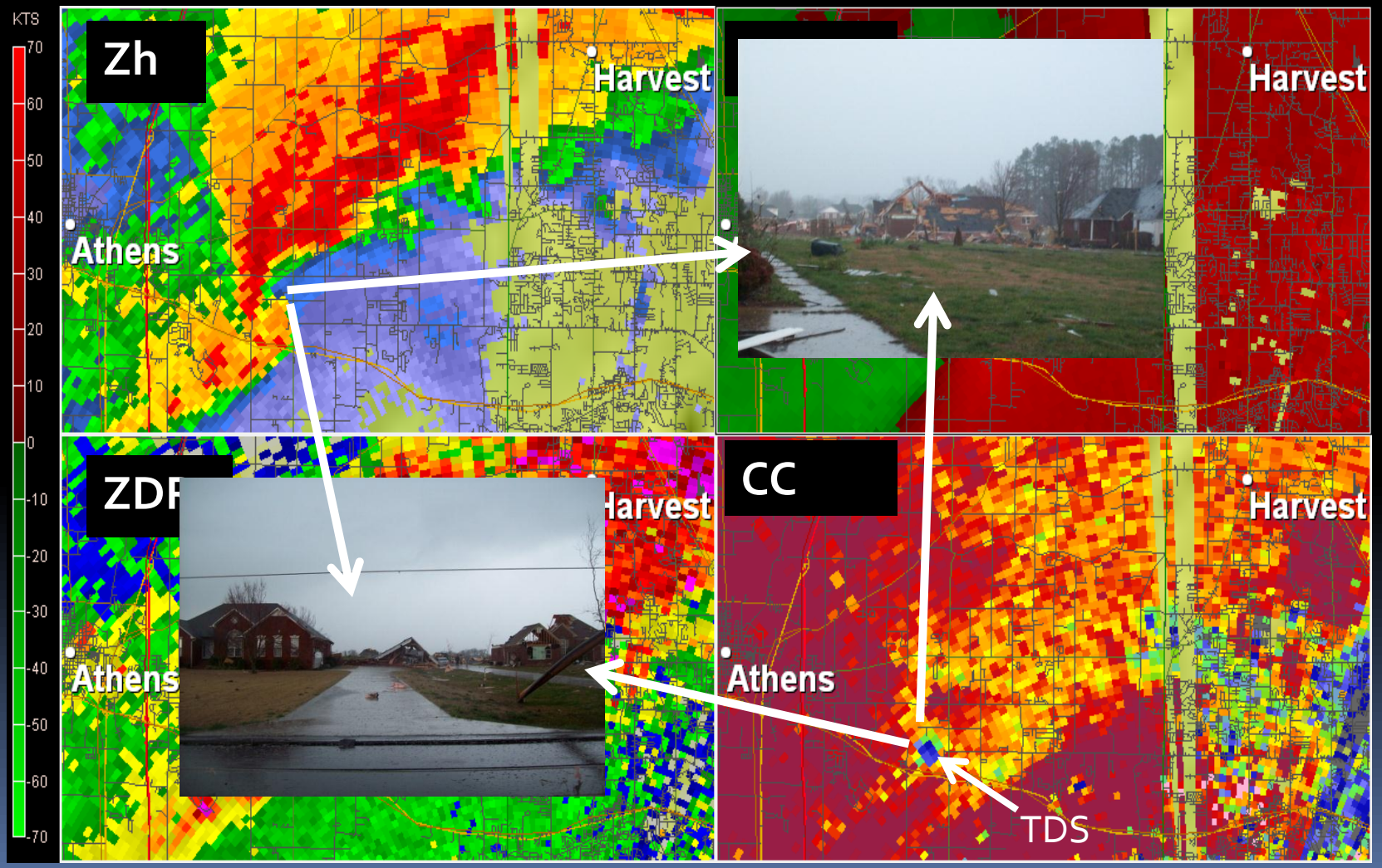
NALMA FED (every 2 minutes)



Lightning jump "tips the scale"

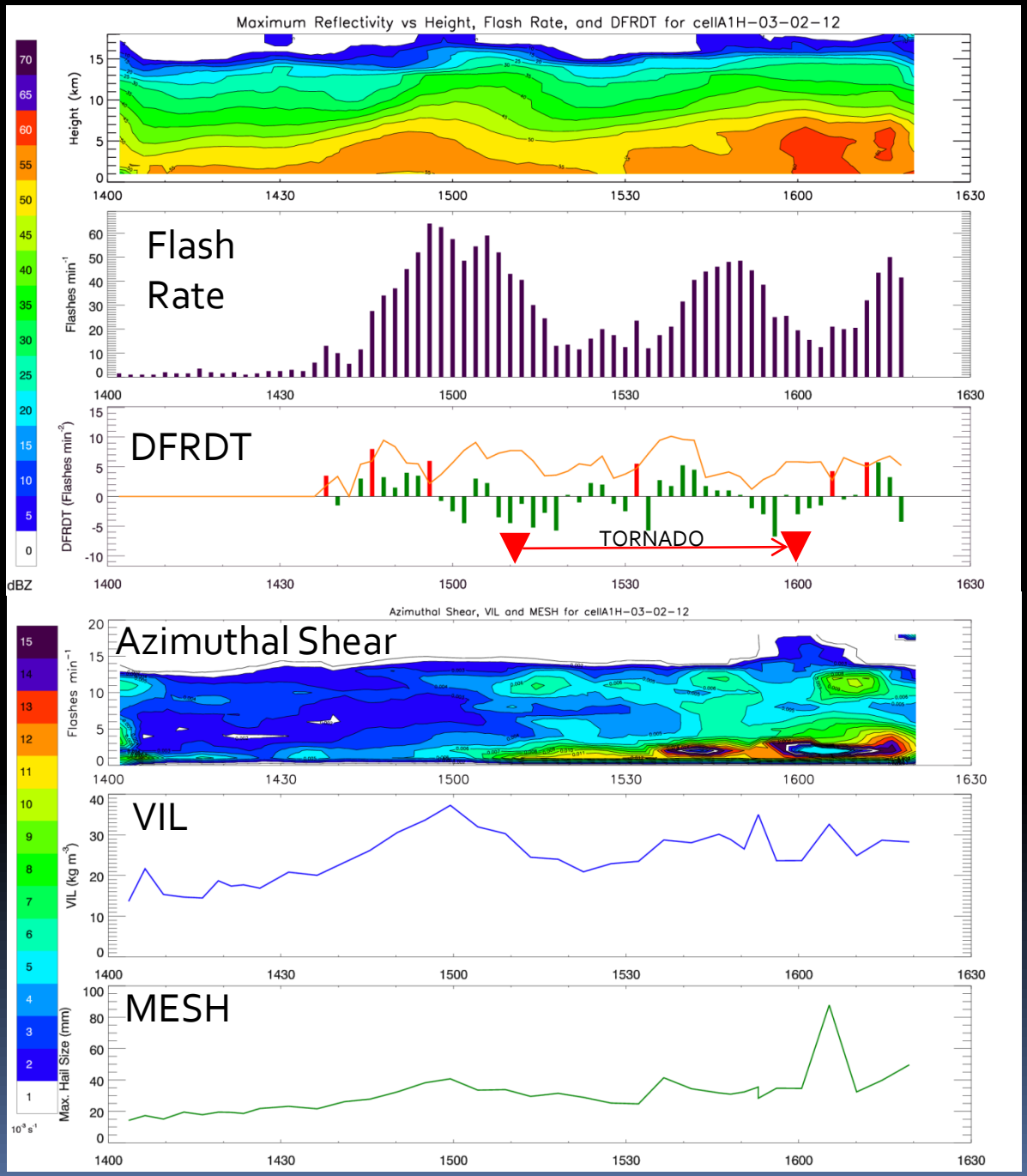
1451 UTC - Forecaster notes increase in lightning
- NWS Huntsville Issues Warning
- First reports of severe weather 1520 UTC
- Debris signature observed on ARMOR at 1513 UTC
- Lead time on event 19 minutes (touchdown 1510)

ARMOR 1517 UTC 3/2/2012



Lightning Jump, lightning rates, and comparisons to radar derived products, March 2, 2012

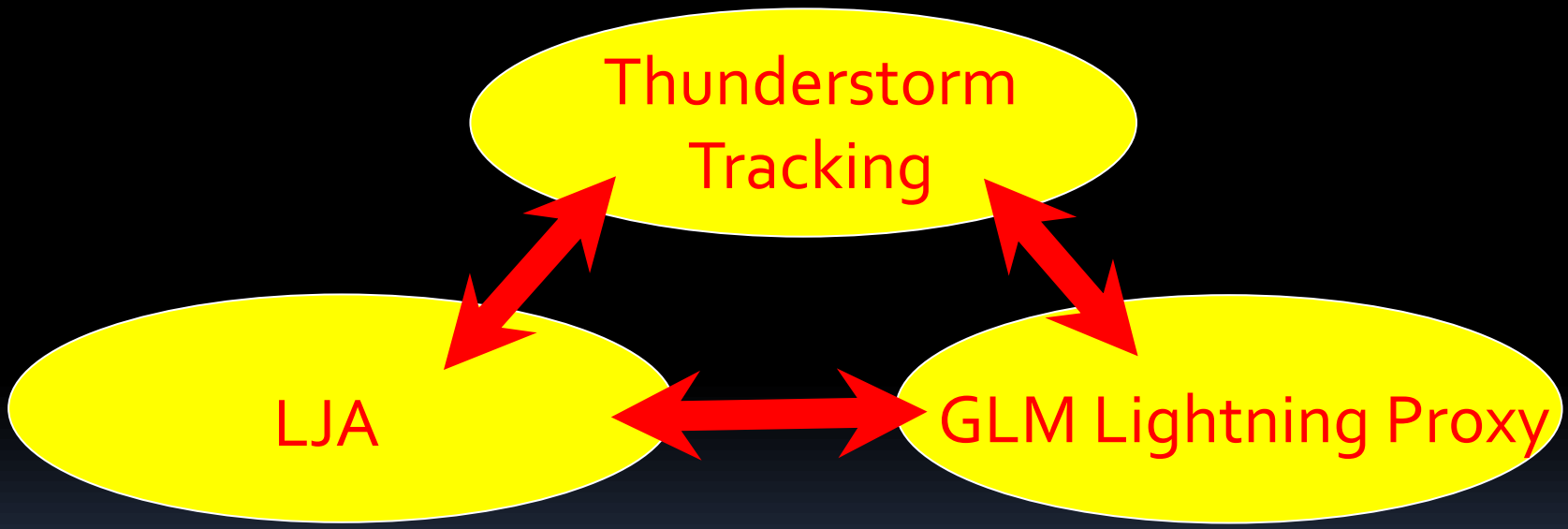
Top – Reflectivity
2 down – total flash rate
Middle – DFRDT, LJ
4 down – VIL trend
Bottom – MESH trend



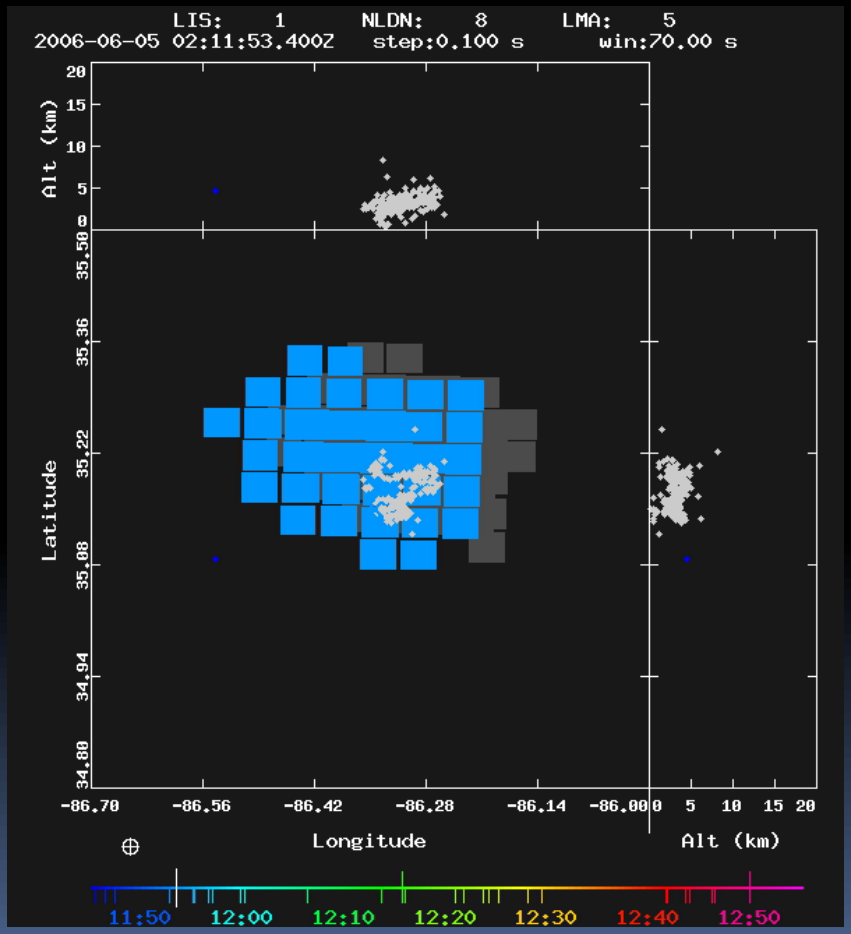
More Feedback from Users

- WFO Huntsville: "This was a particularly good case (March 2, 2012), in which the LMA data helped the warning forecaster to realize that a storm of interest was likely to undergo rapid strengthening, and that a warning was necessary."
- WFO Huntsville: "I believe the density rates were the primary factor in holding off on a warning."
- WFO Nashville: "The LMA often helps 'tip the scales' towards warning an issue.
- Spring Program Participant: "Not necessarily going to be the main warning product, but it will be a good confirmation tool. If I had paid more attention and been more aware I could have issued my tornado warning one scan earlier." (24 May 2008 case event)

Development is more than just an algorithm

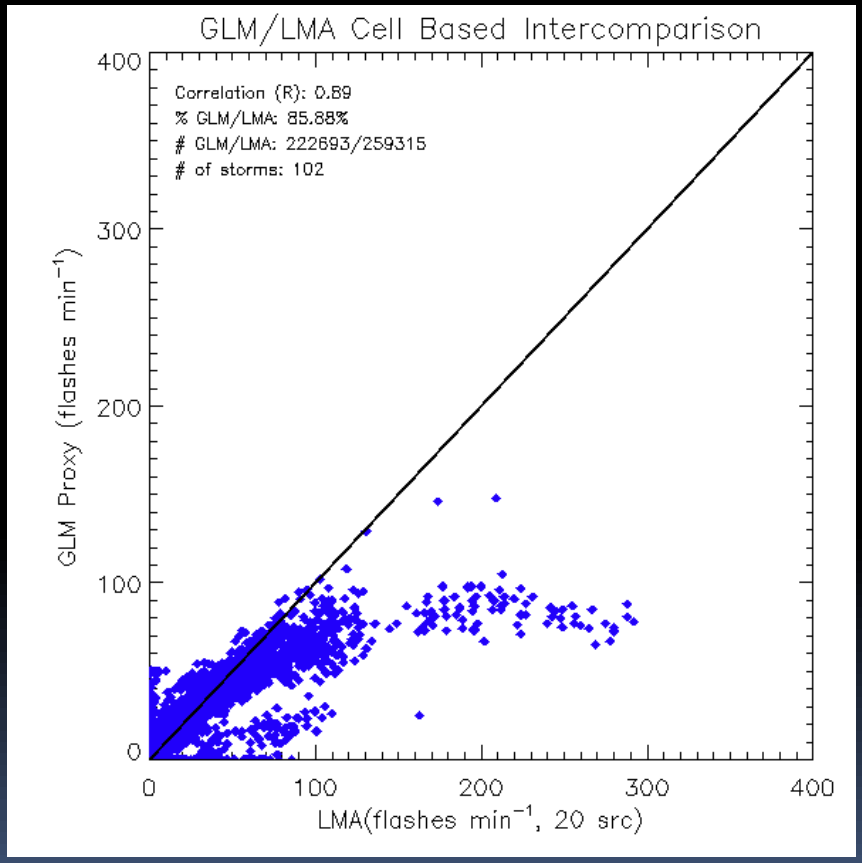


Transition from LMA to GLM Proxy



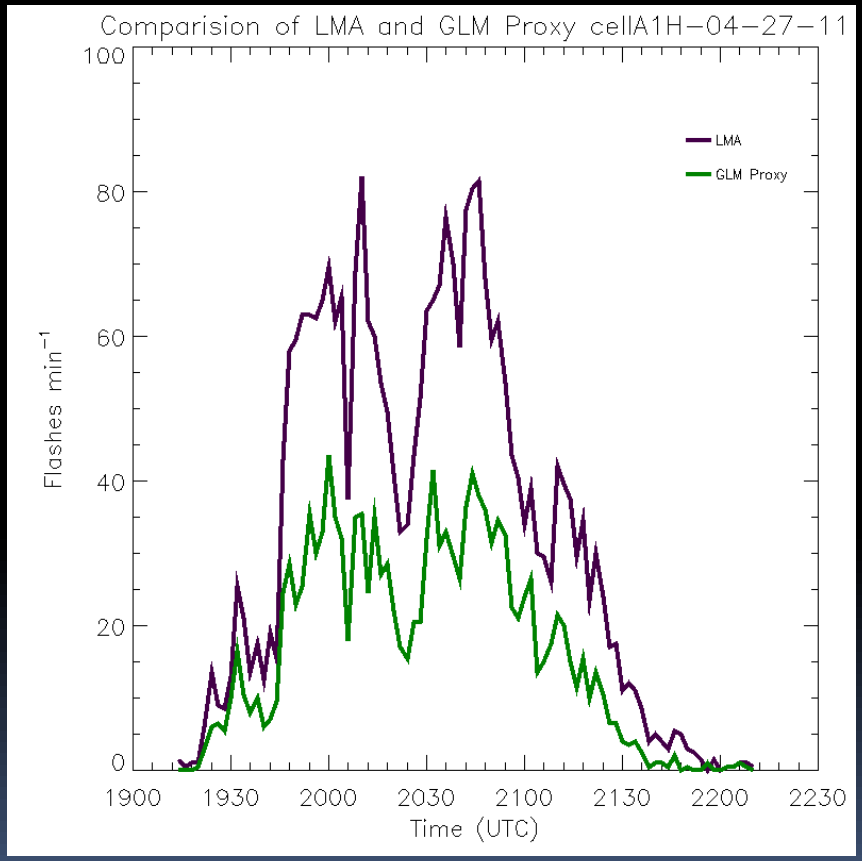
- Observations from LMA ≠ GLM
  - Different instrument
  - Different observation technique
    - Optical vs VHF
  - Different part of flash
- Must transition product from LMA to GLM proxy data stream
- First step, using current GLM Proxy

Transition LJA to GLM Proxy



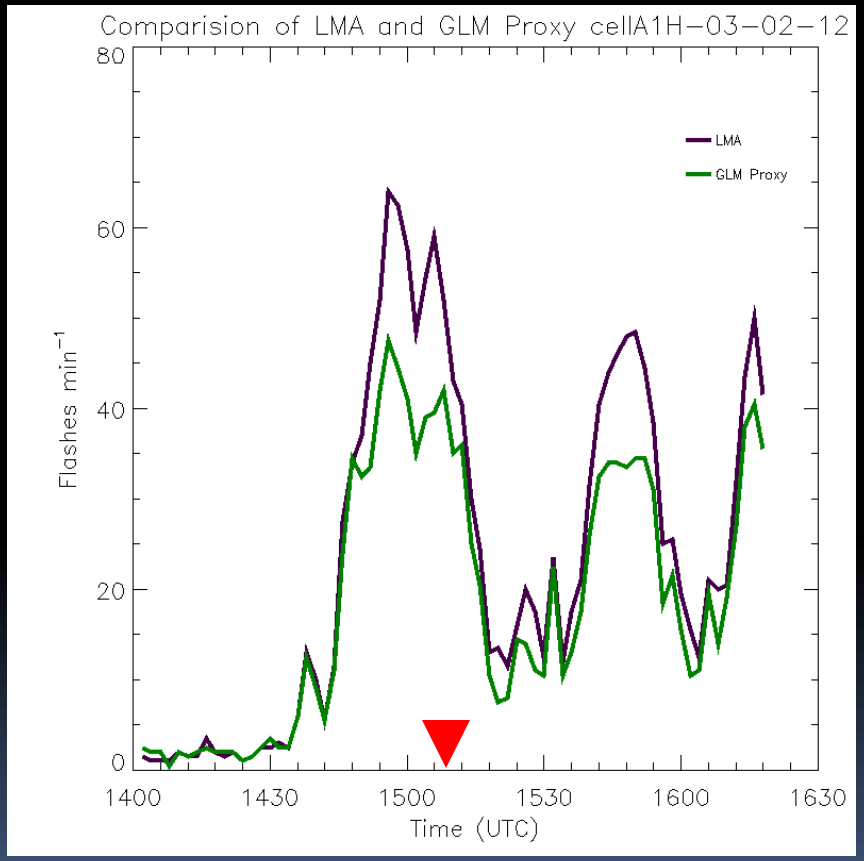
- Compared 1-minute flash rates in LMA and GLM for 102 storms
  - 20+ sources per flash threshold
- GLM Proxy flash count is ~86% of the LMA flash count
- Correlation in the trends are strong
  - R= 0.89
- GLM flash rates have a ceiling at ~100 flashes per minute

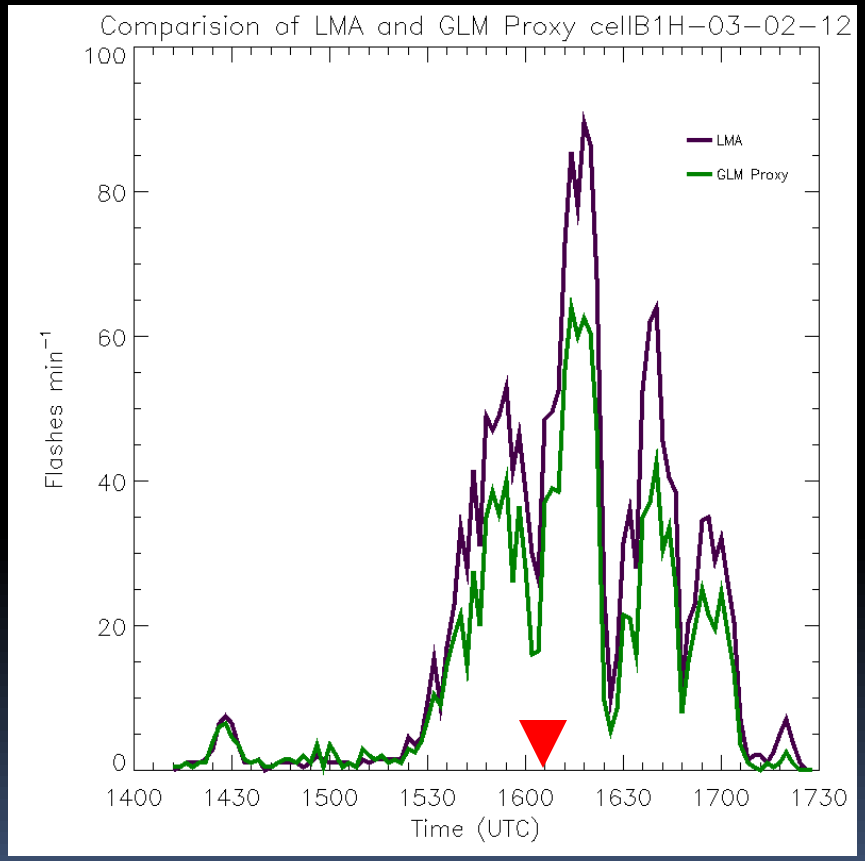
Transition to GLM Proxy



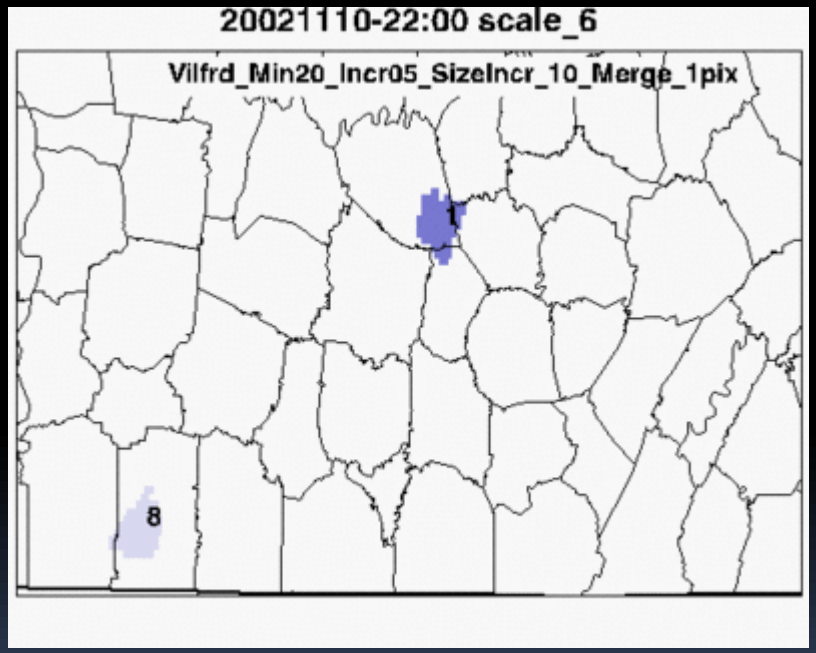
- Lightning trends are still present in the proxy data.
- Magnitudes of lightning jumps are not as pronounced
  - But the standard deviation approach is still robust
- Next step: examine the results of Proch 2009.

GLM Proxy vs LMA trends
March 2, 2012



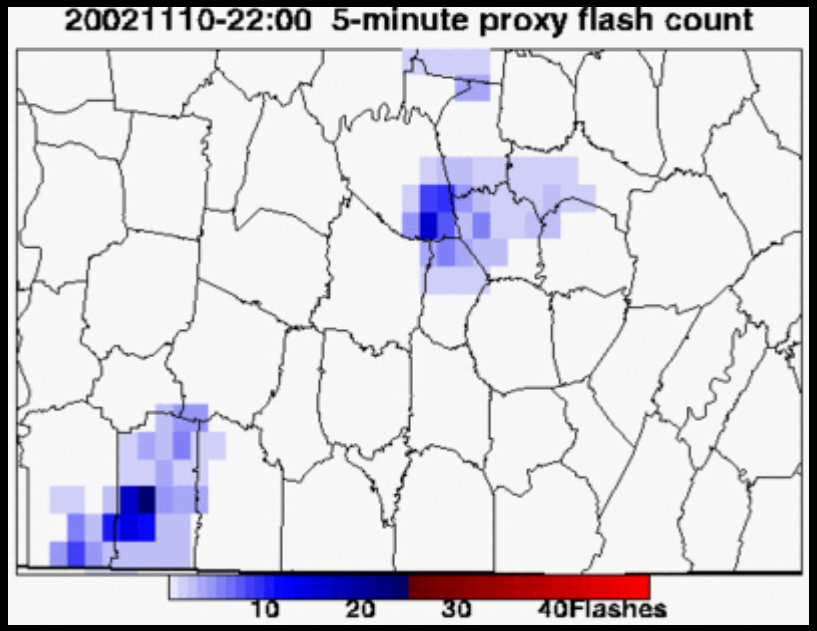


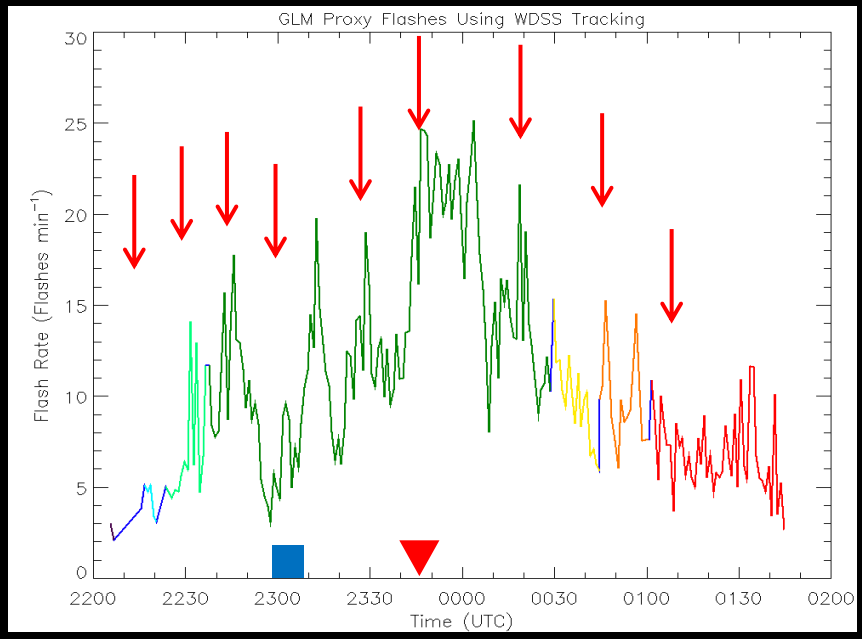
Importance of Cell Tracking

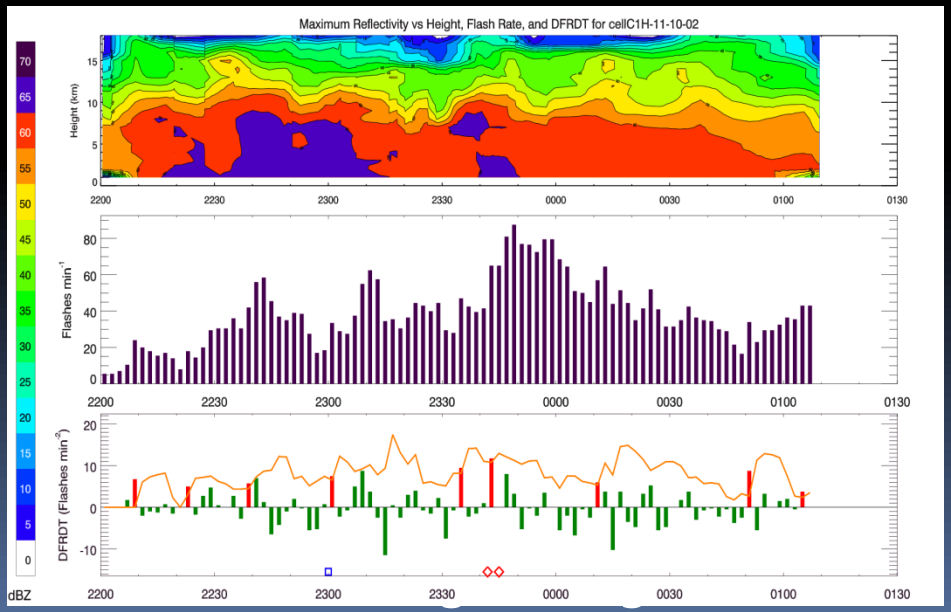


- Schultz et al. '09, '11 studies used TITAN, with manual changes when needed
  - Storm splits, mergers
  - Cells change shape/size
- Ultimate goal: Incorporate LJA into an accurate objective tracking system using GLM proxy.

Integration with Cell Tracking







Above – Total flash rate trend in GLM proxy data. Color changes represent where storm ID changes in WDSS-II.

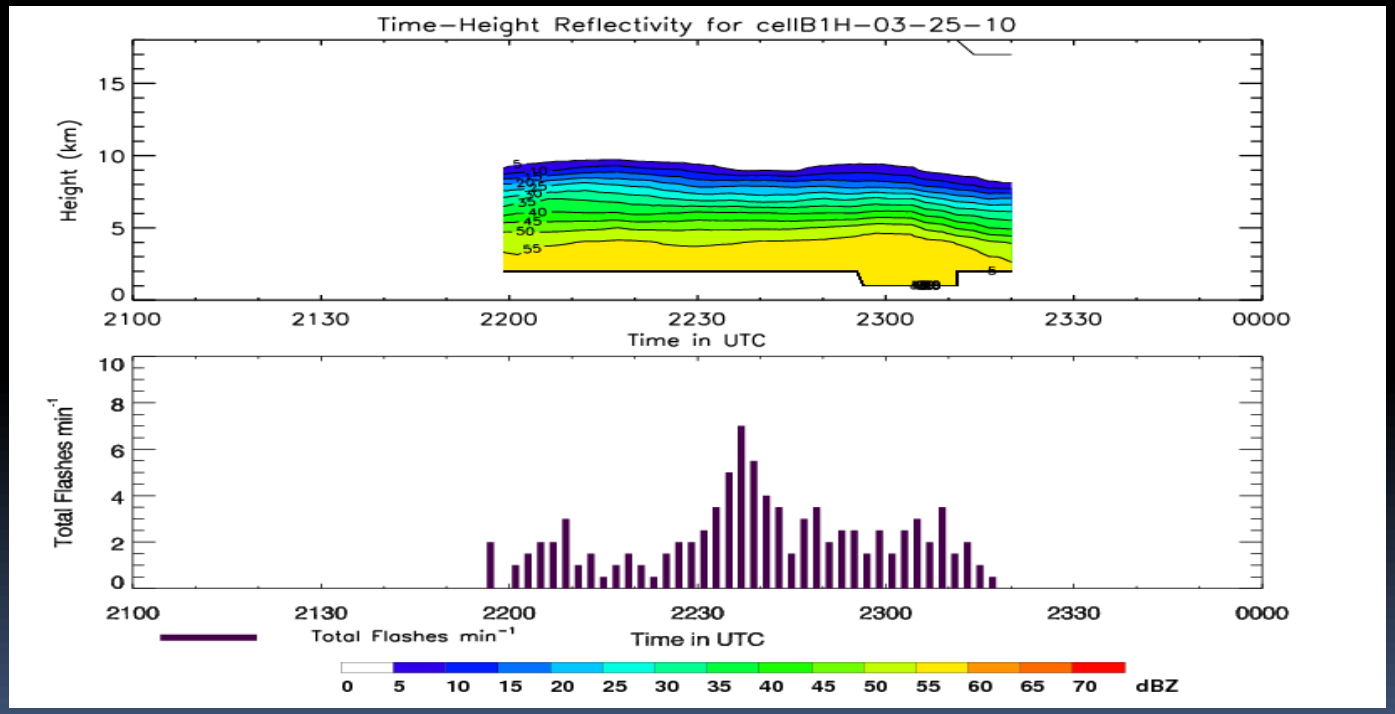
Top left – Cell tracking using a combination of GLM proxy flash rate and VIL.

Fly in – Reflectivity, lightning and DFRDT trends from Schultz et al. (2011). Arrows indicate lightning jump times from the Schultz et al. (2011) study

Current Environmental Limitations

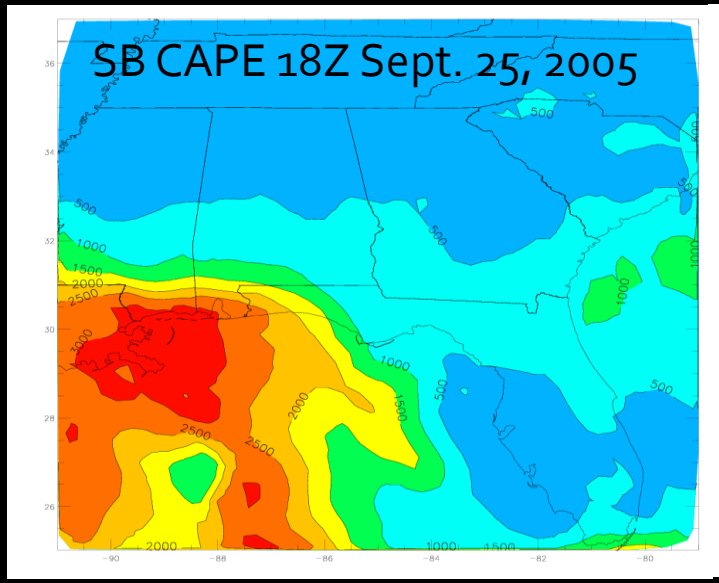
Nearly 40% of misses in Schultz et al. (2011) came from low topped supercells, TC rainband storms, and cold season events

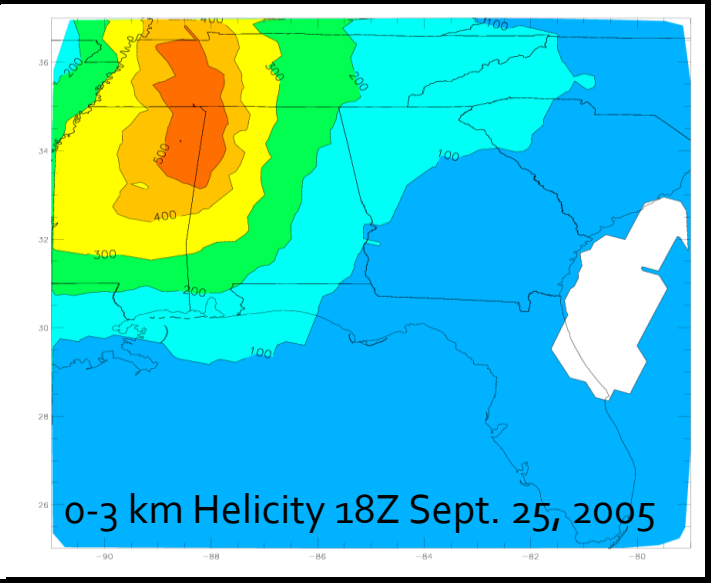
- Lack of lightning activity inhibited the performance of the algorithm
- Lightning can still serve as a situational awareness tool in these environments



Time-height plot of reflectivity (top) and total flash rate (bot) for an EF-1 producing tornadic storm on March 25, 2010. Tornado touchdown time ~2240 UTC.

Environmental Situational Awareness example - Rita





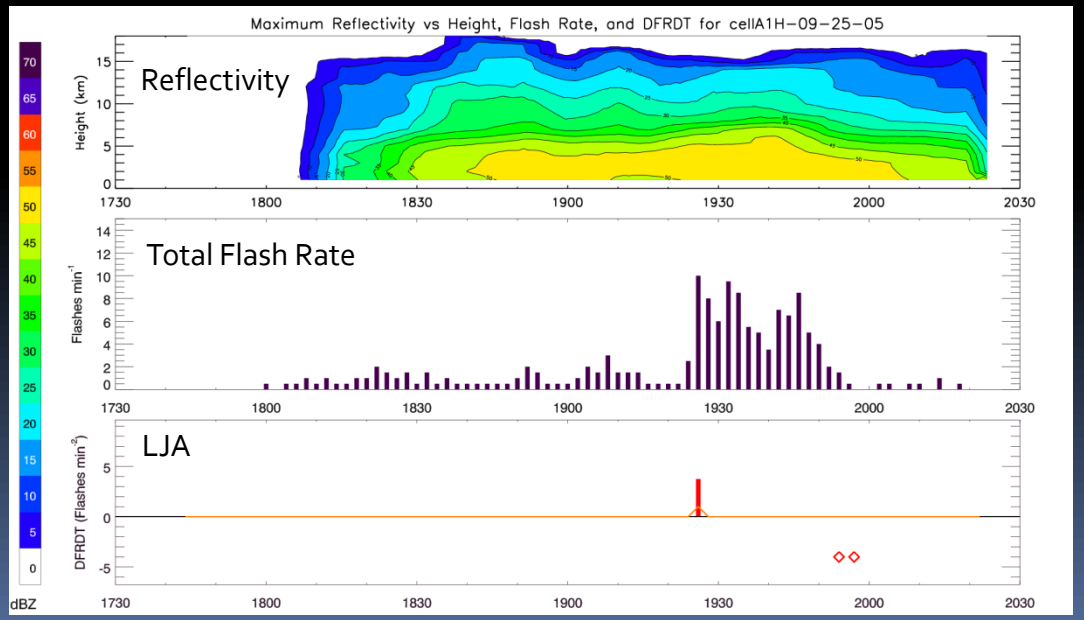
Lightning rates are modest in these situations

- Generally, below 10 per minute
- LJA might not trigger

Total flash rate notably increases before severe weather occurrence.

- Trend in flash rate still important!

Understanding the background environment in these scenarios will provide further utility of lightning trends to the operational forecaster for situational awareness.



Accomplishments to Date

- **Developing LJA as an automated objective system**
  - Began adaptation of LJA (rules, thresholds) to GLM proxy and multi-sensor object tracking improvements
  - Investigated environmental controls on LJA for identification and mitigation of known LJA biases during low topped convection
  - Explored fusion of LJA with radar products
- **Improving multi-sensor (GLM proxy, radar) cell (object)-oriented tracking**
  - Optimized current WDSS-II/K-means cell tracking algorithm to reduce tracking ambiguity for LJA
- **Refining and developing GLM lightning proxy database**
  - Transformed VHF-based NA-LMA to optical lightning proxy using LIS and statistical-physical methods
  - Developed representative proxy lightning (e.g., GLM resolution, 8 km) for 20 events (100's of cells) from 2002-2010 over NA-LMA
- **Participating in NOAA Lightning Jump Test (LJT)**
  - Assisted with implementation of Schultz et al. (2009, 2011) LJA on VHF-based flash data at LMA-native (non-GLM) resolution

Expected Accomplishments for Year 2

- **Complete LJA modifications**
  - Finalize optimal thresholds and logic for representative GLM optical-proxy data at GLM resolution
  - Develop LJA Algorithm Theoretical Basis Document (ATBD)
- **Merge LJA with ongoing WDSS-II cell tracking**
  - Test LJA within cell-tracker in post event "real-time" simulations
  - In collaboration with Carey, Feltz, Bedka GOES-R3 Aviation Project, adapt LJA and cell tracking system to improve GLM/ABI-based hazard products for aviation routing
- **Begin initial planning for Proving Ground (PG) demonstration of GOES-R GLM optical-proxy LJA**
  - User interactions and feedback within NASA SPoRT and local NWS offices
- **Continue participation in NOAA Lightning Jump Test (LJT)**

Expected Outcomes for a Potential Year 3

- **Test LJA/Cell-tracker/GLM proxy system in Proving Ground (PG) and local WFO's**
  - Make improvements to LJA based on direct user feedback
  - Leverage NASA SPoRT's capability in transitioning NASA products to the NWS/PG
  - Create necessary software plug-ins for next generation decision support tool, AWIPS II.
- Develop training materials to educate end users on LJA
  - theoretical basis, methods, expected algorithm performance, strengths/limitations, optimal uses in situational awareness
- **Explore LJA in multi-sensor/multi-parameter forecaster methods and algorithms**
  - Investigate optimal synthesis of LJA with WSR-88D radar and GOES-R ABI algorithms for improved situational awareness