LIGHTNING JUMP ALGORITHM AND RELATION TO THUNDERSTORM CELL TRACKING, GLM PROXY AND OTHER METEOROLOGICAL MEASUREMENTS

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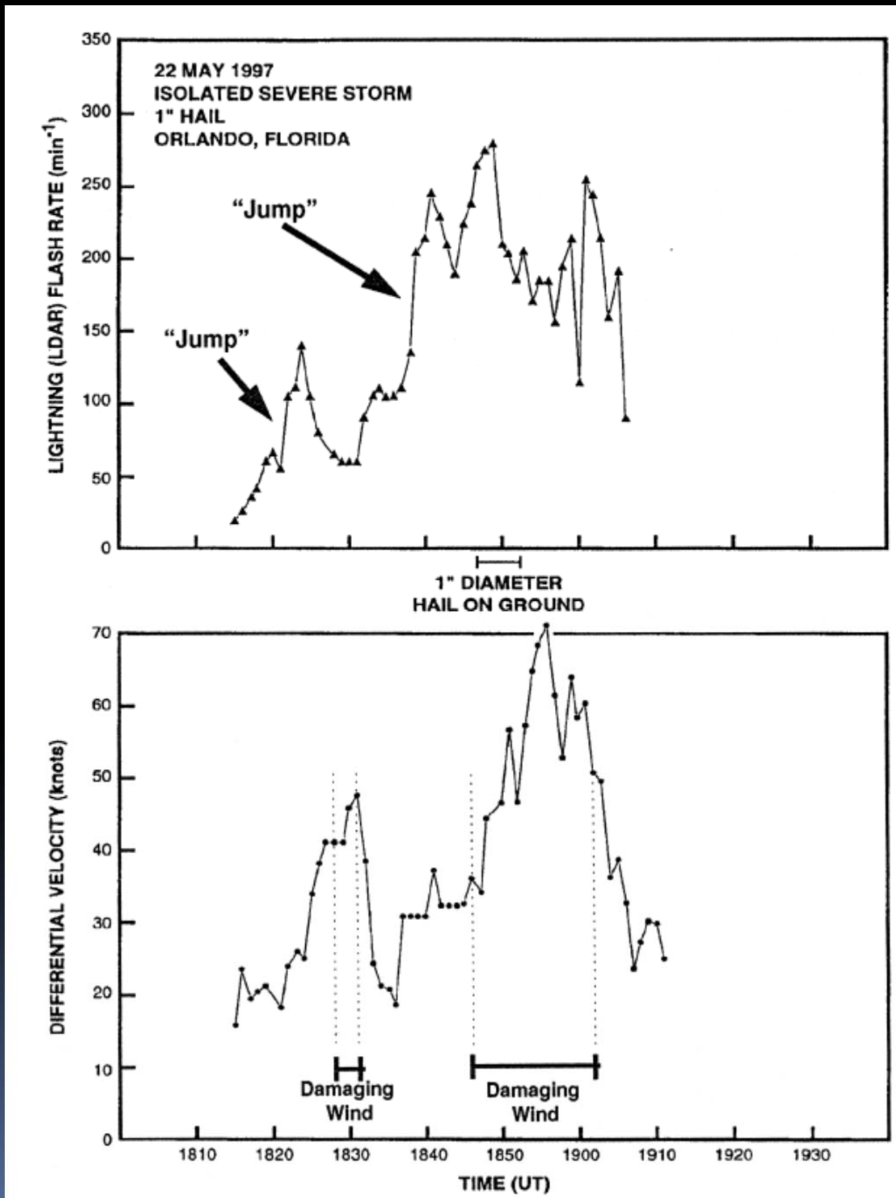
Goal of LJA Project

- 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
  - Ongoing work – reducing risk in GLM lightning proxy, cell tracking, LJA algorithm automation, and data fusion (e.g., radar + lightning).

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 2σ 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
- Schultz et al. (2009, 2011) used native LMA total lightning and TITAN cell tracking, with manual changes when needed
  - Storm splits, mergers
  - Cells change shape/size

TABLE 2. Breakdown of thunderstorm sample by type.

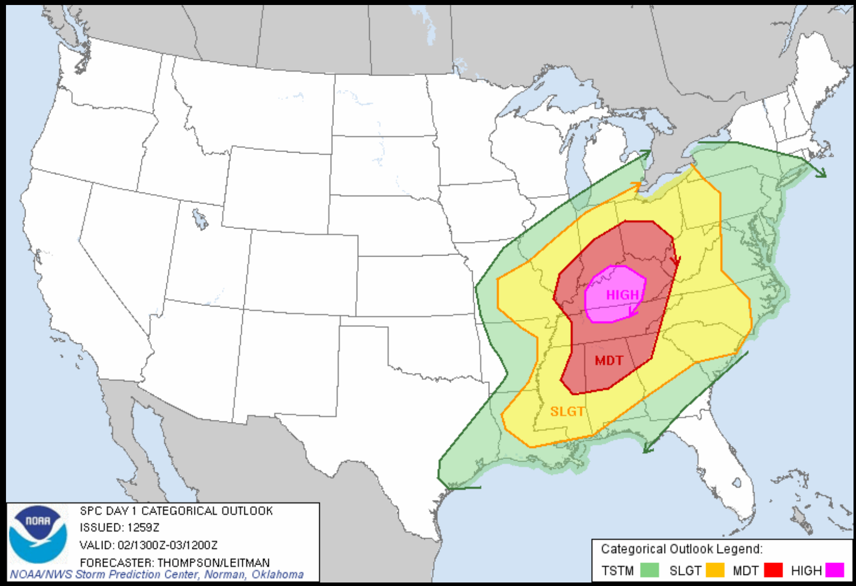
Type	Supercell	Airmass/Multicell	Tropical	Linear	Cold	Low Top
severe	82	73	5	47	38	10
nonsevere	12	387	4	24	18	11
number	94	460	9	71	56	21
number of severe wx events	343	128	8	135	149	18

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

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."

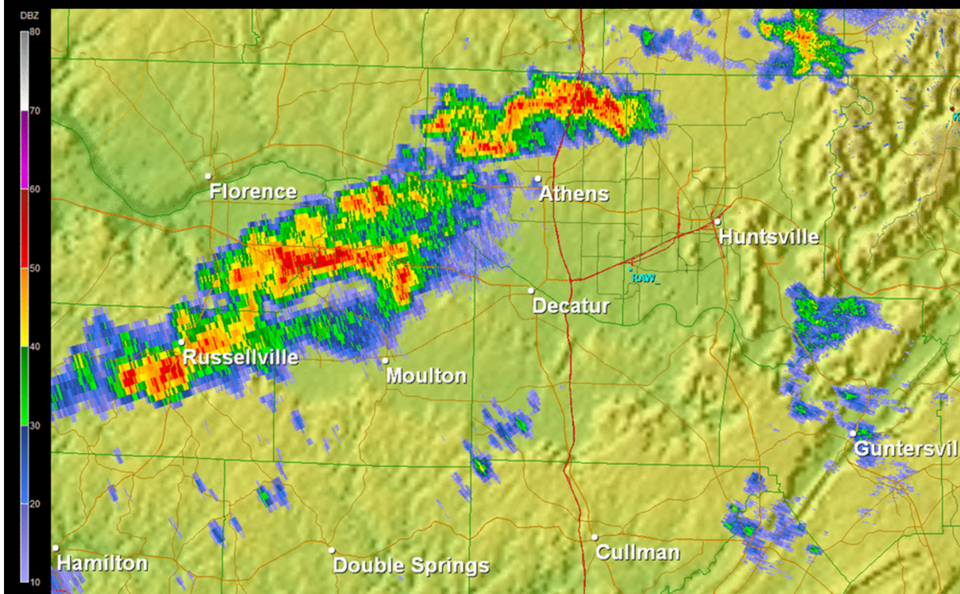


Main threat for AL targeted for the afternoon in association with trailing front

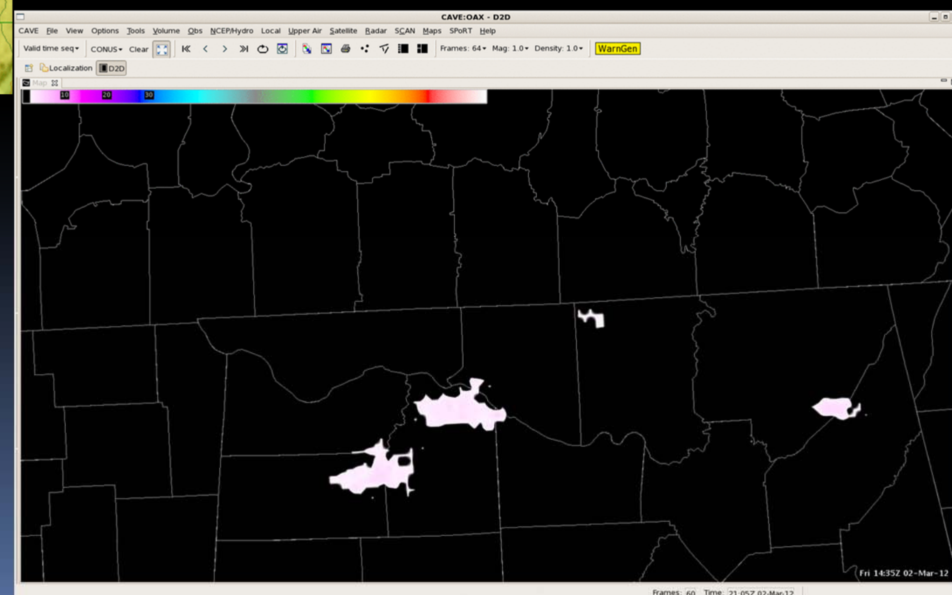
SPC 13Z outlook

1432 – 1452 UTC

KHTX (every 5 minutes)



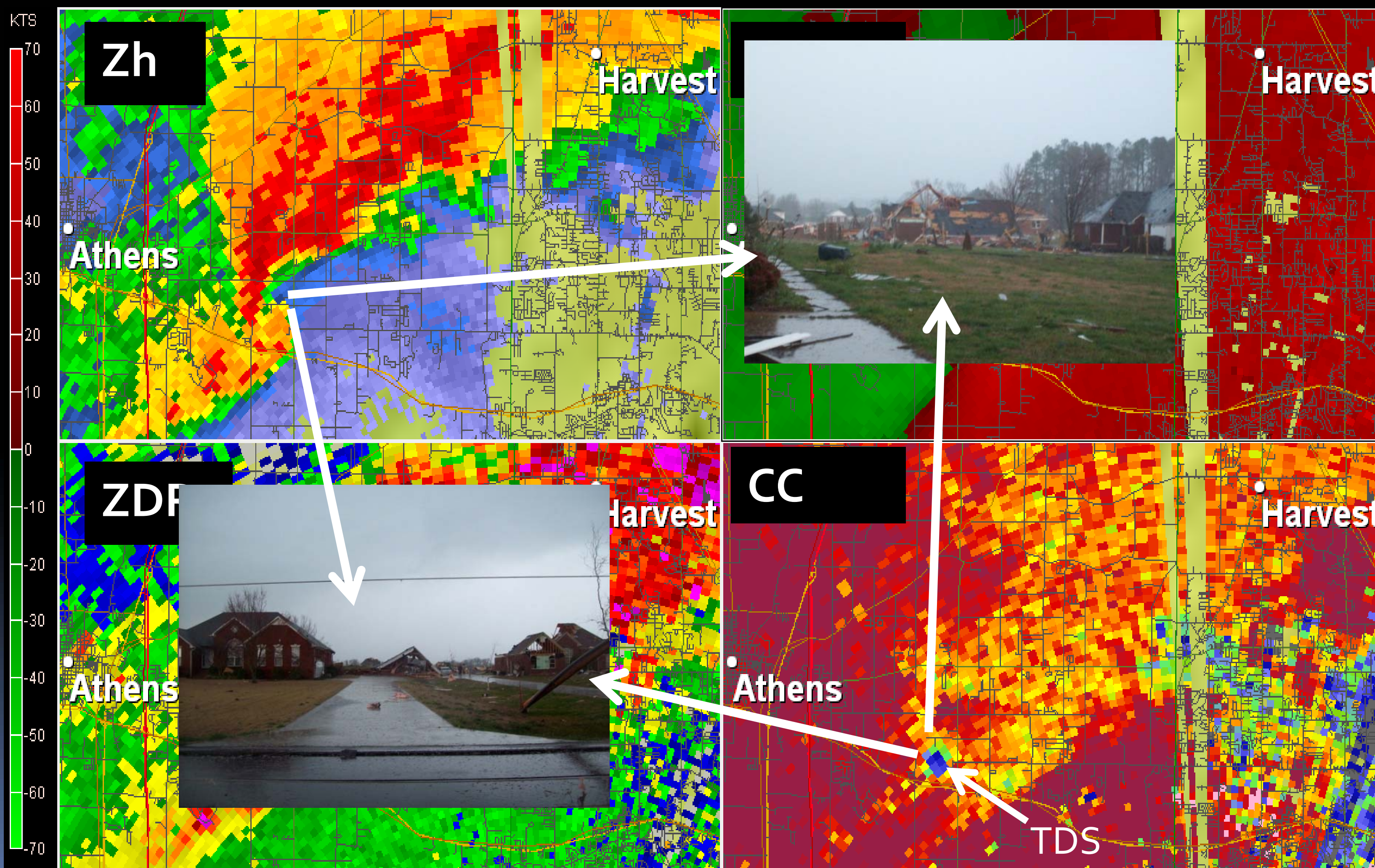
NALMA FED (every 2 minutes)



Lightning jump "tips the scale"

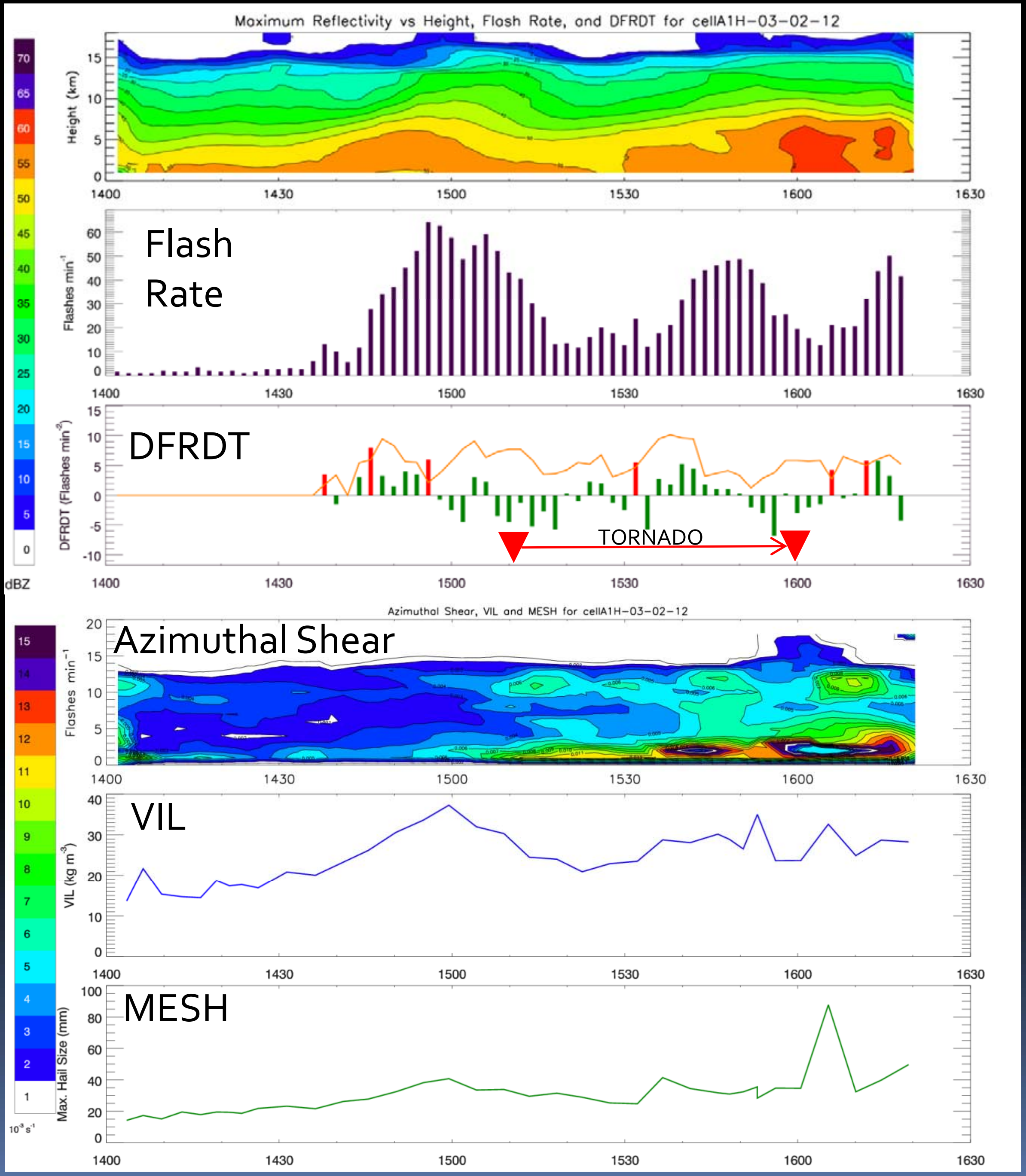
1451 UTC – NWS Huntsville Issues Warning
- Forecaster notes increase in lightning
- First reports of severe weather 1520 UTC
- Debris signature observed on ARMOR at 1513 UTC
- Lead time on event 19 minutes (touchdown 1510)

ARMOR 1517 UTC 3/2/2012



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

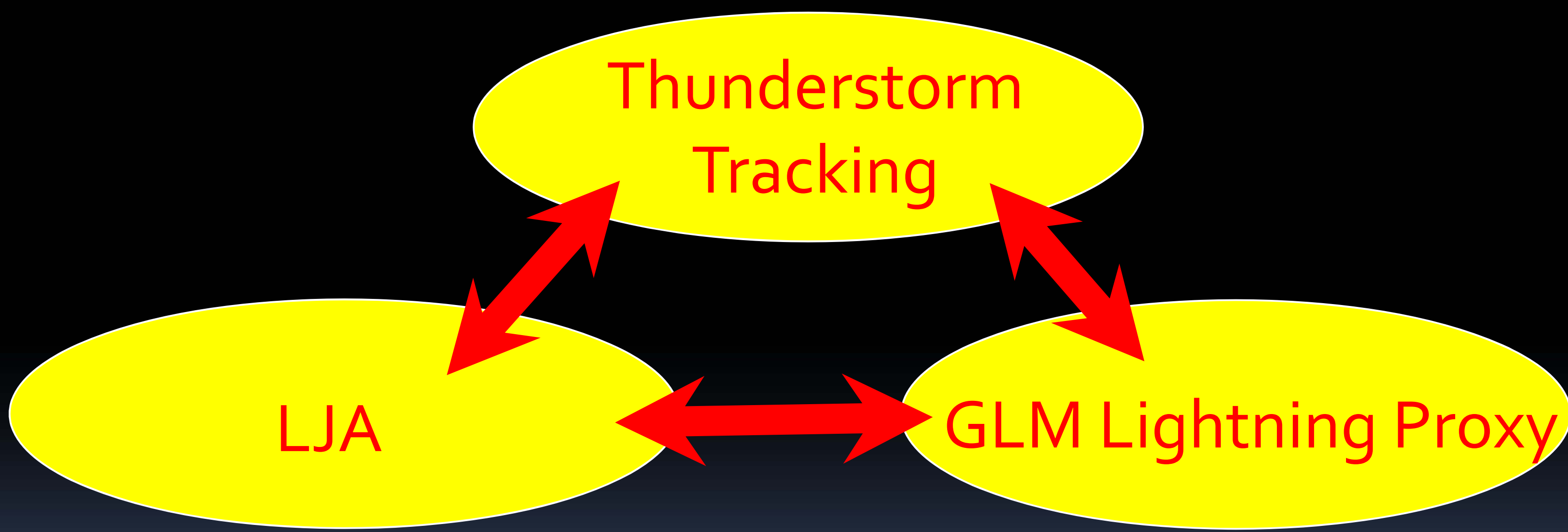
Top – Reflectivity
2 down – total flash rate
Middle – DFRDT, LJ
4 down – VIL trend
Bottom – MESH trend



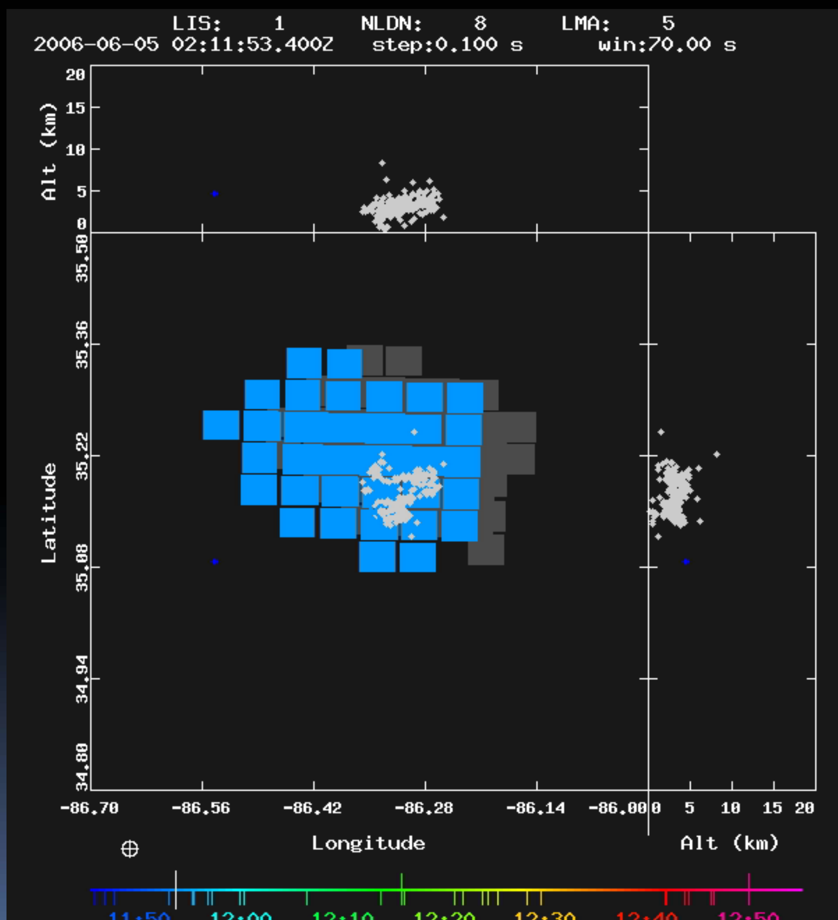
More Feedback from Users

- WFO Nashville: "The LMA often helps **'tip the scales'** towards warning an issue."
- 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 Morristown: "…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 (April 24, 2010)**
  http://nasasport.wordpress.com/2010/04/27/use-of-lma-data-tips-the-scales-toward-a-warning/
- WFO Huntsville: "I believe the density rates were the primary factor in **holding off on a warning**."
- 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

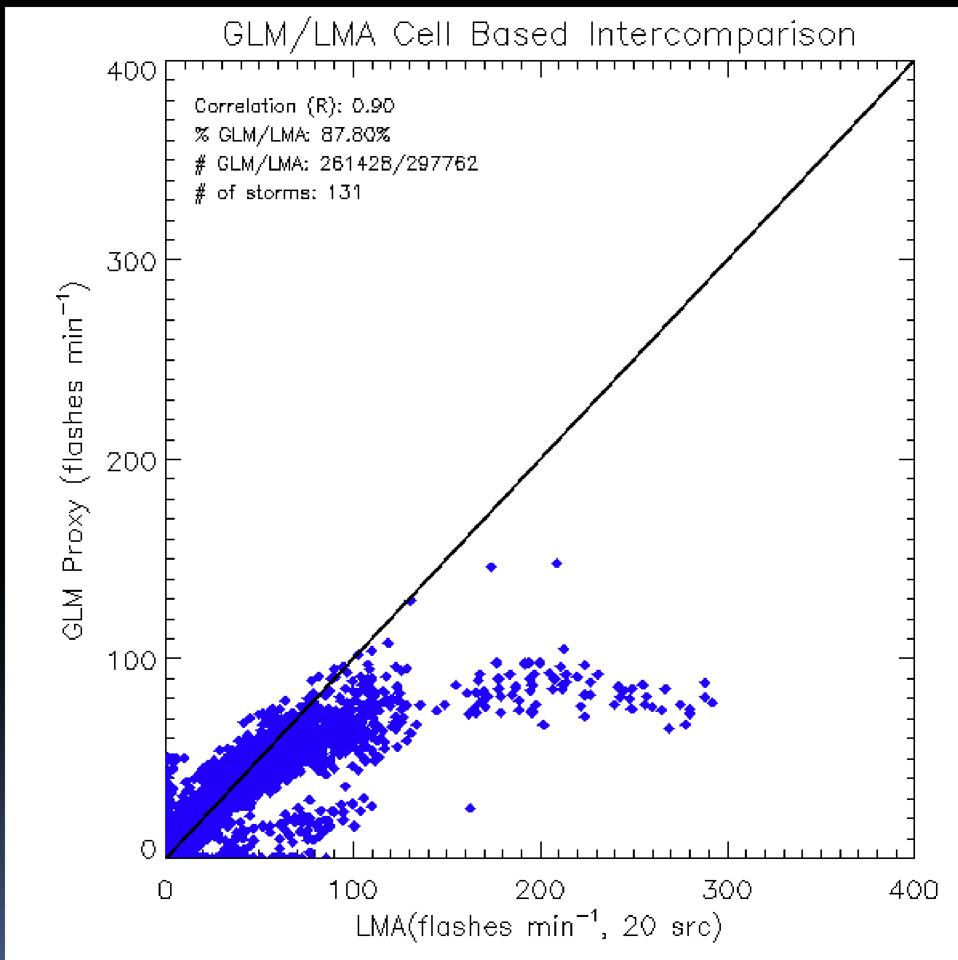


Transition from LMA to GLM Proxy



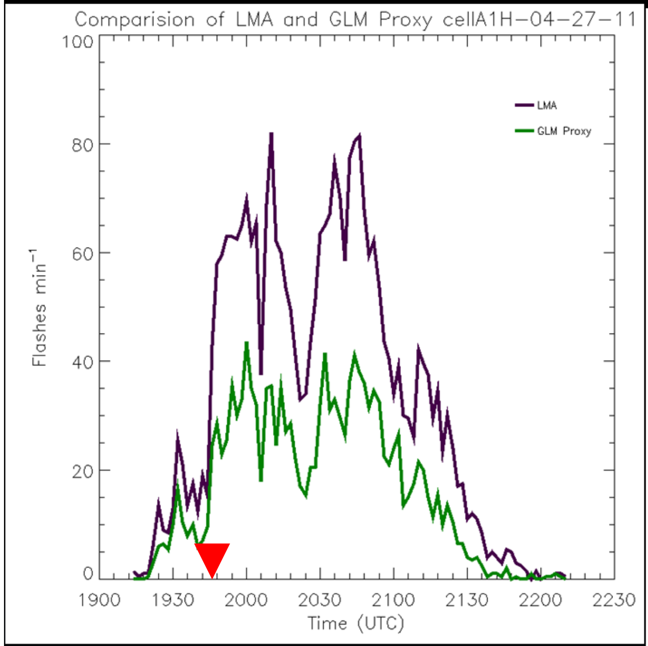
- Observations from LMA ≠ GLM
  - Different instrument
  - Different frequency
  - Different part of flash
- Must transition product from LMA to GLM proxy data stream
- First step, using current GLM Proxy

Transition LJA to GLM Proxy

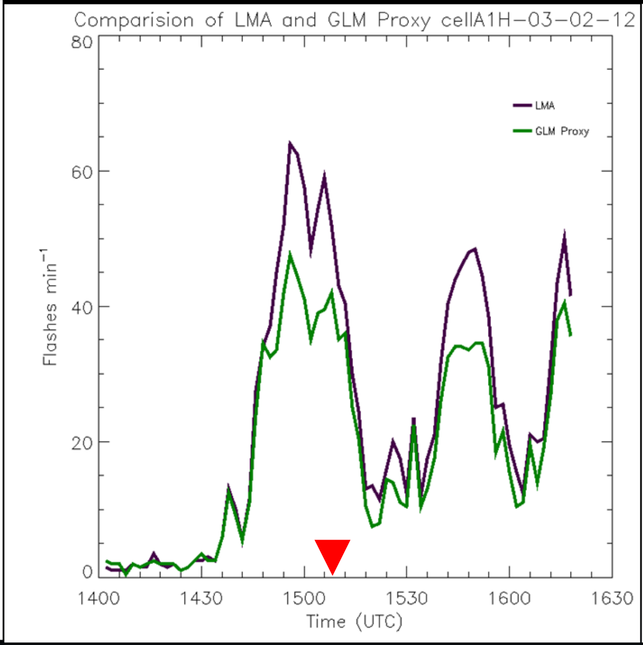


- Compared 1-minute flash rates in LMA and GLM for 131 storms
  - 20+ sources per flash threshold
- GLM Proxy flash count is ~88% of the LMA flash count
- Correlation in the trends are strong
  - R= 0.9
- GLM flash rates have a ceiling at ~100 flashes per minute

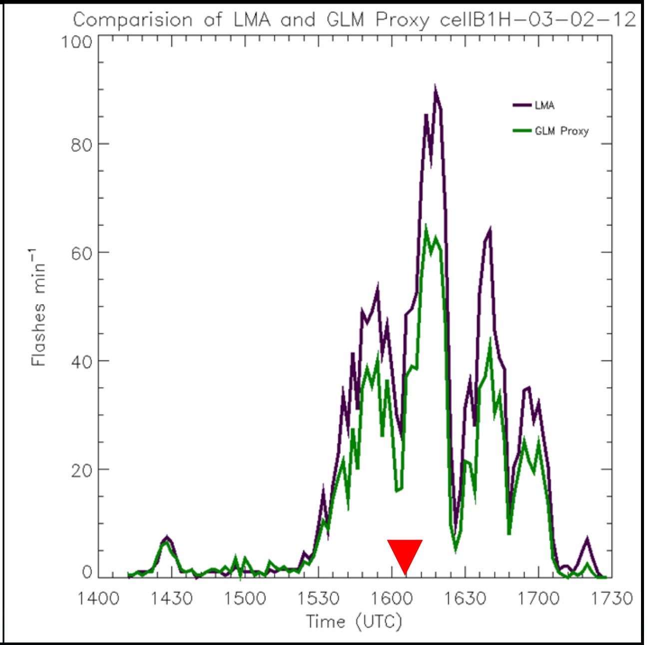
Transition to GLM Proxy:
GLM Proxy vs. LMA trends



2011-04-27 Cell A1H



2012-03-02 Cell A1H



2012-03-02 Cell B1H

- Lightning trends are still present in the GLM proxy data.
- Magnitudes of lightning flash rates and jumps are not as pronounced in GLM proxy as LMA
  - But the standard deviation (2σ) approach is still robust

Fields Used for Cell Tracking

2002-11-11 00:58 UTC

Flct5: 5-minute GLM proxy flash count, updated every minute

VIL: Vertically Integrated Liquid (radar)

VILFRD: VIL combined with 5-minute Flash Rate Density

$$VILFRD = 100 * (((VIL/45) \le 1) + (sqrt(Flct5/45) \le 1))$$

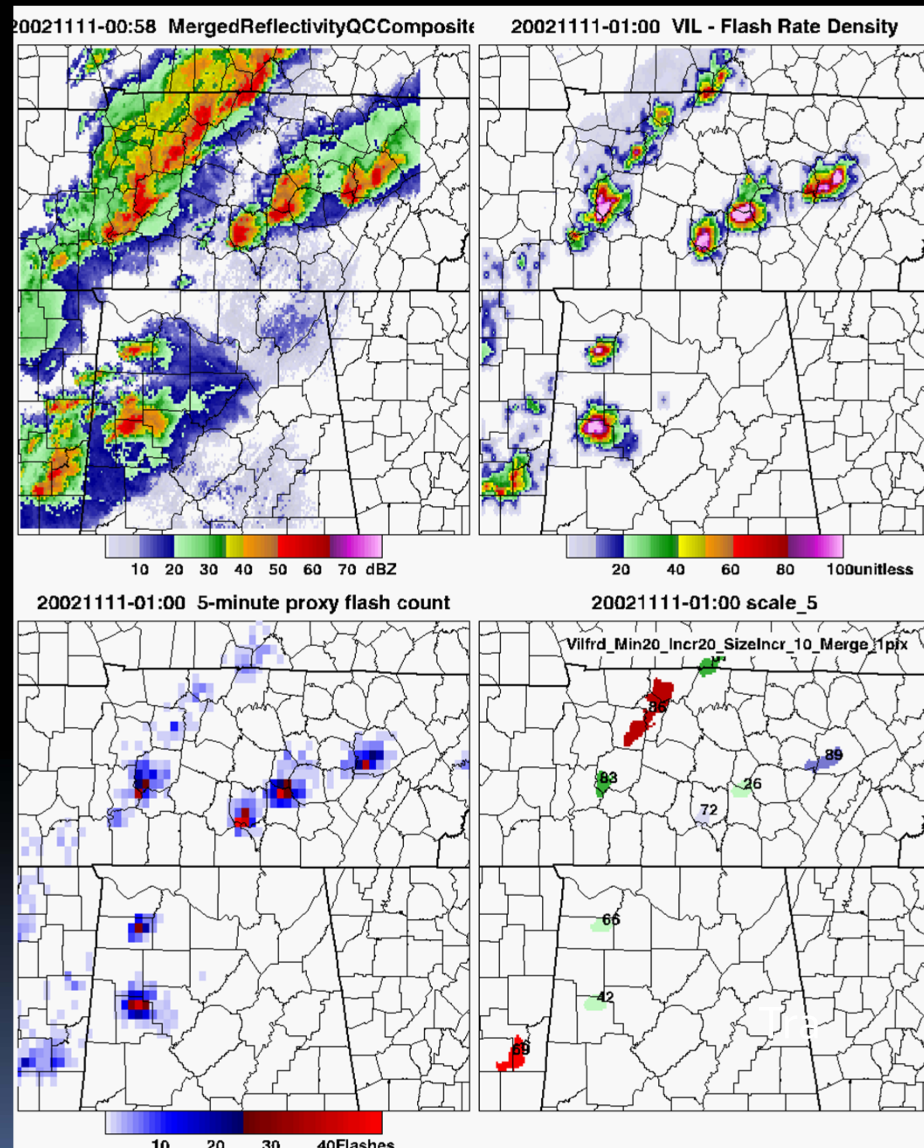
Track values where VILFRD ≥ 20, using increments of 20, with anything over 100 set to 100.

Tracker (WDSSII *w2segmotionll*) builds cells until a minimum size threshold is met. Several sizes tested; we use ~200 km^2 for large storms, ~80 km^2 for smaller storms.

First see if values exceeding 100 cover large enough area (e.g., cells 26, 42, 72, 83)

If not, include values exceeding 80 (e.g., cells 66, 89)

If not, include values exceeding 60 (e.g., cell 66, 89), 40 (e.g., cell 69), or 20 (e.g., cell 36).

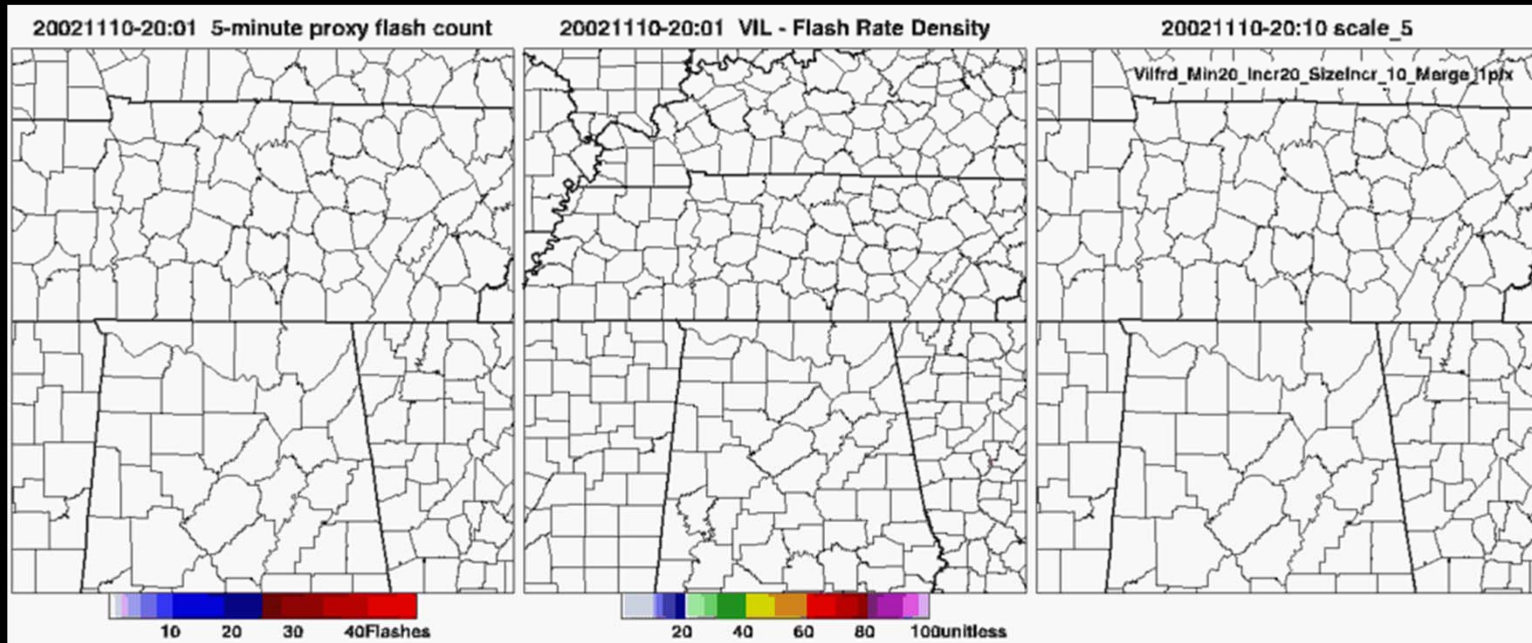


Cell Tracking

Left: *GLM Proxy Flash Count*

Middle: Combined *VIL-Flash Density Field*

Right: *Tracked Features*



Tracking uses WDSSII *w2segmotionll*, with **maximum overlap** approach for associating cells from one time step to the next.

Cells are projected forward from time *t* to *t+1* (1-minute increments, so projected motion has very little effect)

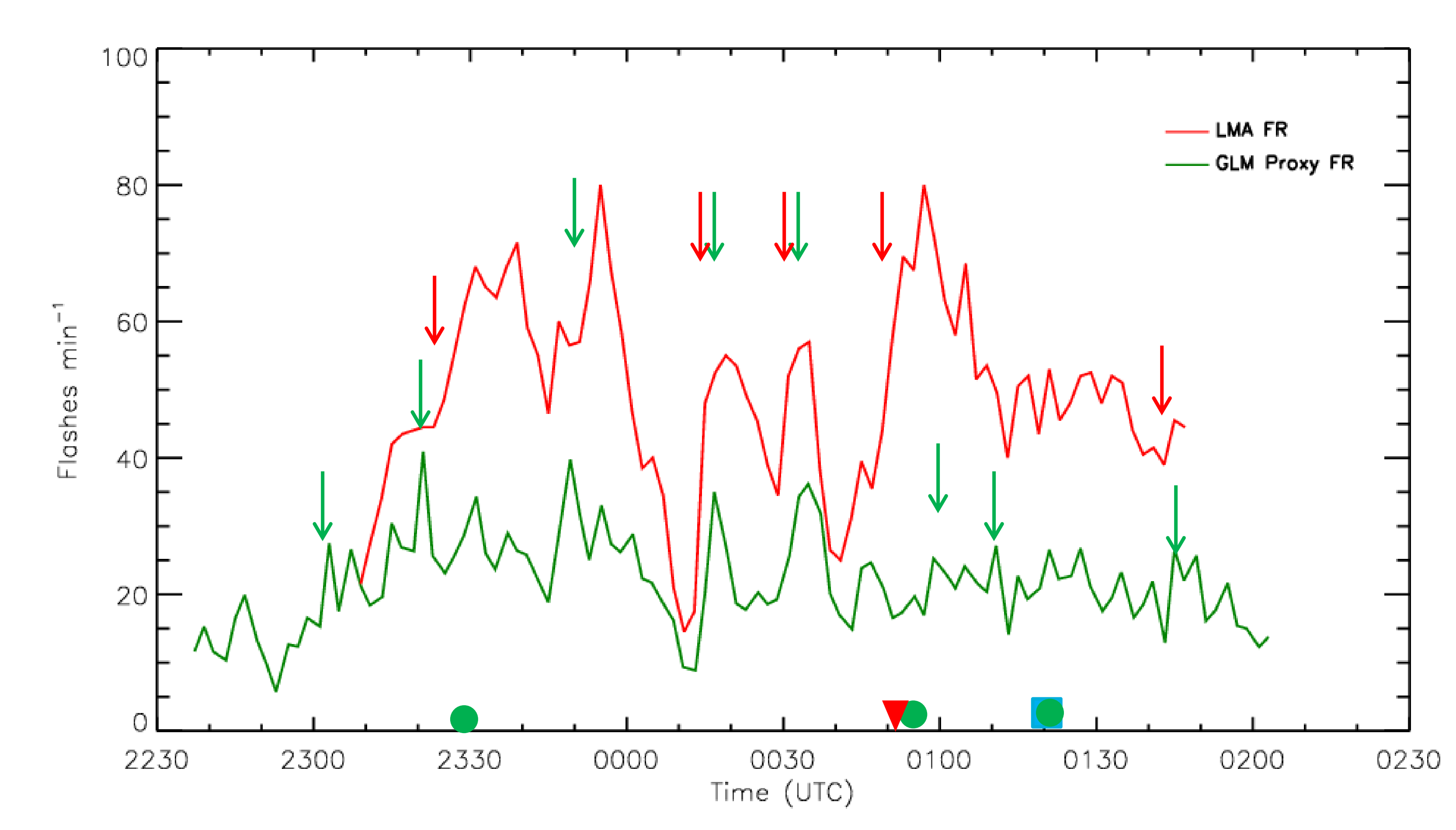
If an observed cell at *t+1* matches a cell location projected forward from *t*, within (5 km) or (1 x Size of Cell), then it is associated with that previously identified cell's history.

If a cell disappears in one time step, it cannot re-appear later.

Outside WDSSII, "broken tracks" are objectively merged. If WDSSII has a new cell begin at *t+1* within 20 km of where a previous cell track ended at time *t*, those cell histories are tied together. (This last step is not reflected in animation, but is in flash rate time series .)

LMA vs. GLM Proxy Flash Rate and Jumps

Cell 4 / Cell D 11-11-02



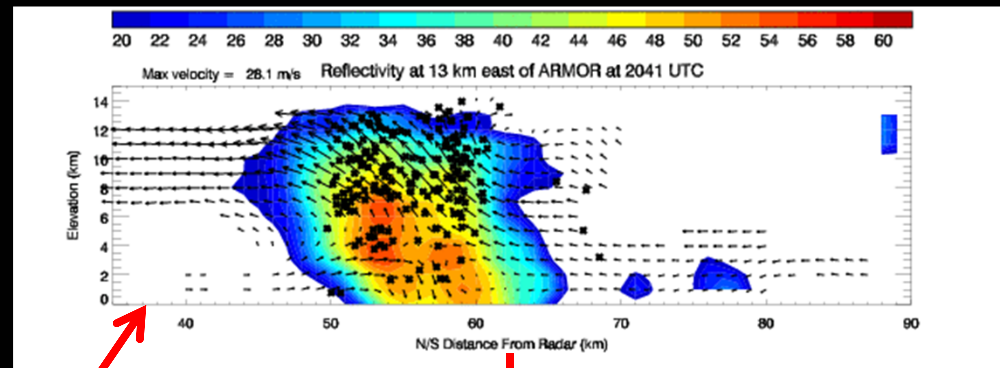
GLM Jump: ↓ LMA Jump: ↓ Tornado: ▼ Hail: ● Wind: ■

The Next Step: Understanding the Physics Behind the Jump

Key points this analysis will address:

1) What physically is going on in the cloud when there is a jump in lightning?
   - **Updraft variations, Ice fluxes**
2) How do these processes fit in with severe storm conceptual models?
3) What would this information provide an end user?
   - **Relate LJA to radar observations, like changes in reflectivity, MESH, VIL, etc. based multi-Doppler derived physical relationships**

KHTX-ARMOR dual-Doppler analysis July 19, 2006



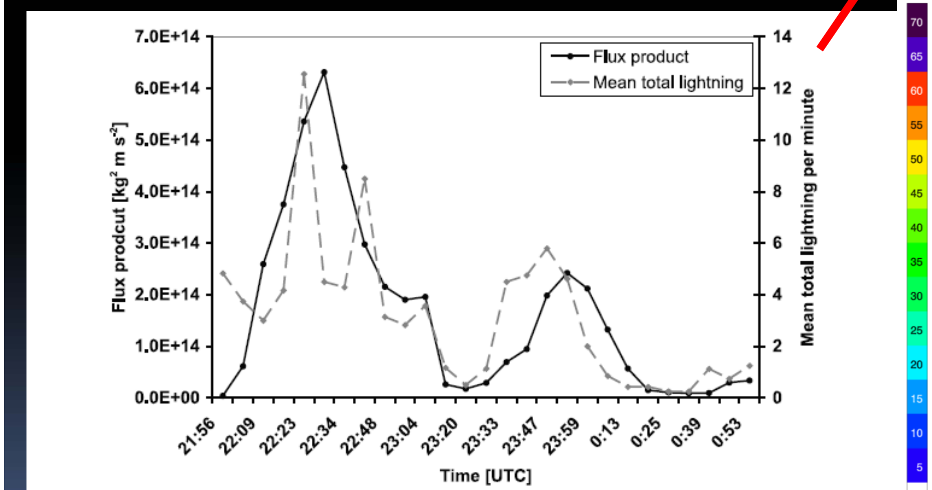
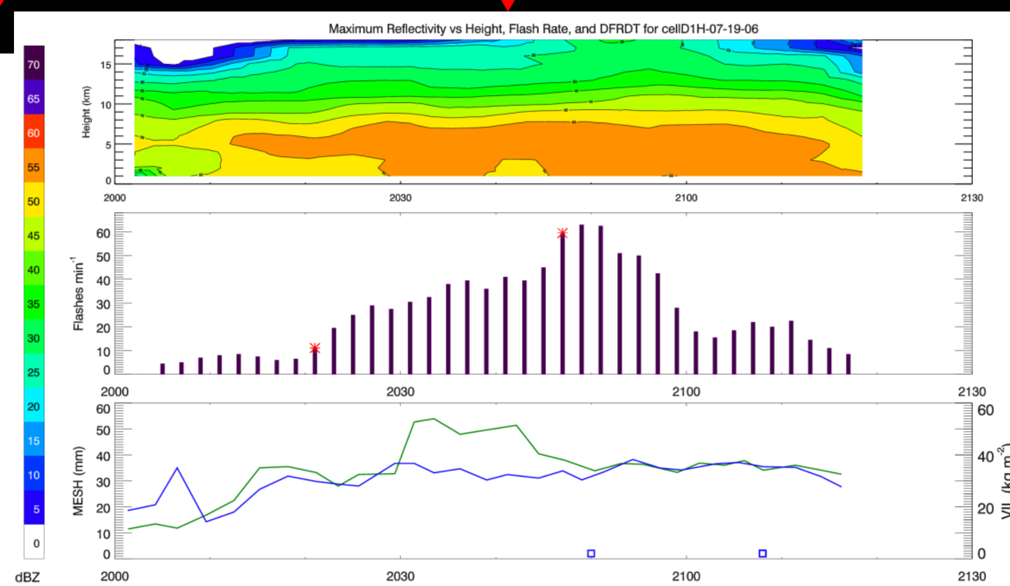


Figure 10. Mean total lightning rate per minute averaged over the radar volume time (gray dashed line) and the product of the fluxes of precipitation ice mass above the −5°C level and nonprecipitation ice mass above the −5°C level calculated with the divergence method (black solid line) of an ordinary single cell thunderstorm that occurred on 6 June 2000.



Adapted from Deierling et al. 2008, JGR

Time height of reflectivity (top) flash rate w/ lightning jumps (red asterisks; middle) and VIL (blue; bottom) and MESH (green; bottom)

Summary of Ongoing Work

- **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 37 events (100's of cells) from 2002-2010 over NA-LMA. Turn-key for new cases, as needed.
- **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
- **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

Summary of Ongoing Work

- **Studying fusion of LJA with radar data and products**
  - Reflectivity-based, dual-Doppler, dual-polarization
  - For operational use and solidifying the LJA conceptual model
- **Exploring use of LJA and LJA/radar in forecasting process and operational situational awareness**
  - User interactions and feedback within NASA SPoRT and local NWS offices