Integration of the total lightning jump algorithm into current operational warning environment conceptual models

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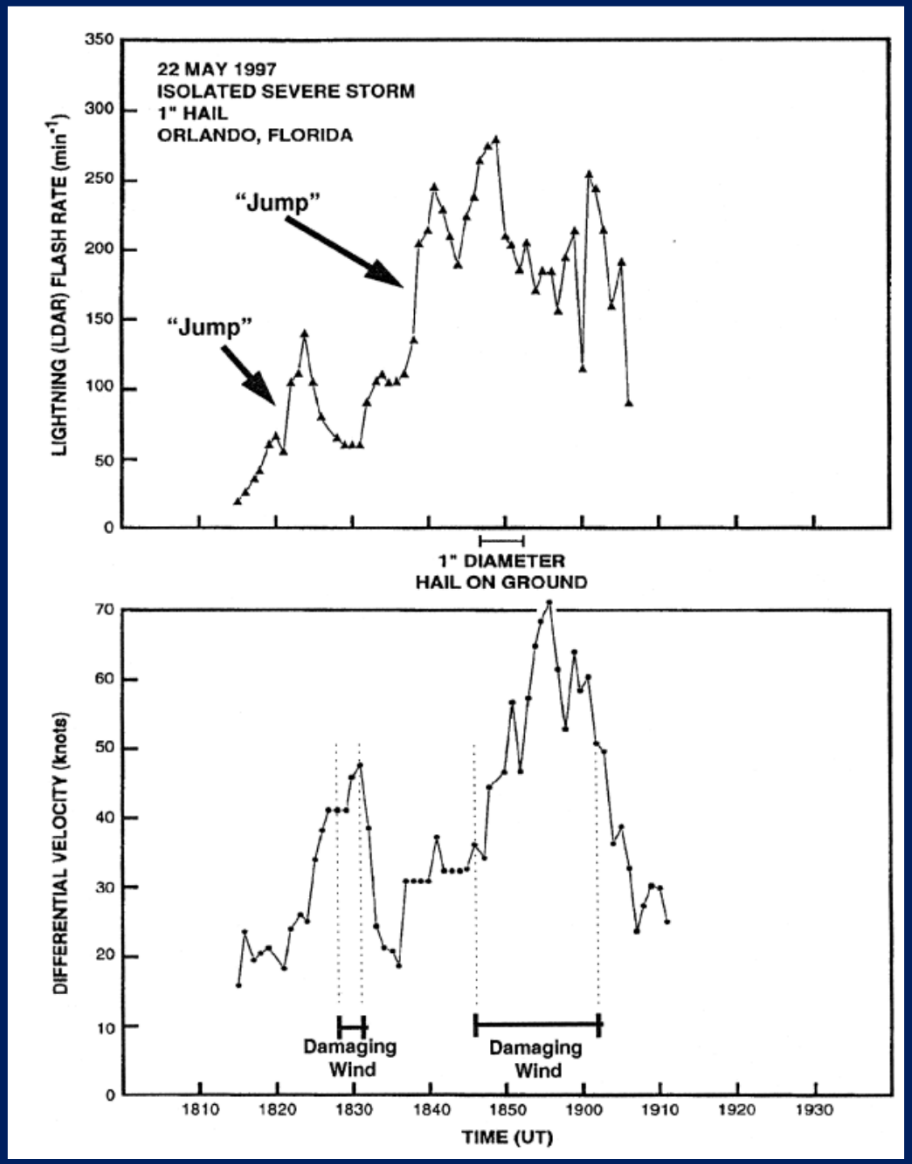
The Lightning Jump Concept



- 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.

The Current Lightning Jump

- Named the 2σ approach, it takes the current flash rate and compares the time rate of change of the total flash rate to the previous 12 minutes of storm history.
- Results are strong, but solely empirically based
  - 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

Motivation

- Provide more direct verification of the central hypothesis that the lightning jump is a direct indicator of rapid updraft intensification
  - Current physical conceptual model for lightning jump based on physical/dynamical inferences
  - Fragmented information in several studies
  - No direct measurement during a lightning jump

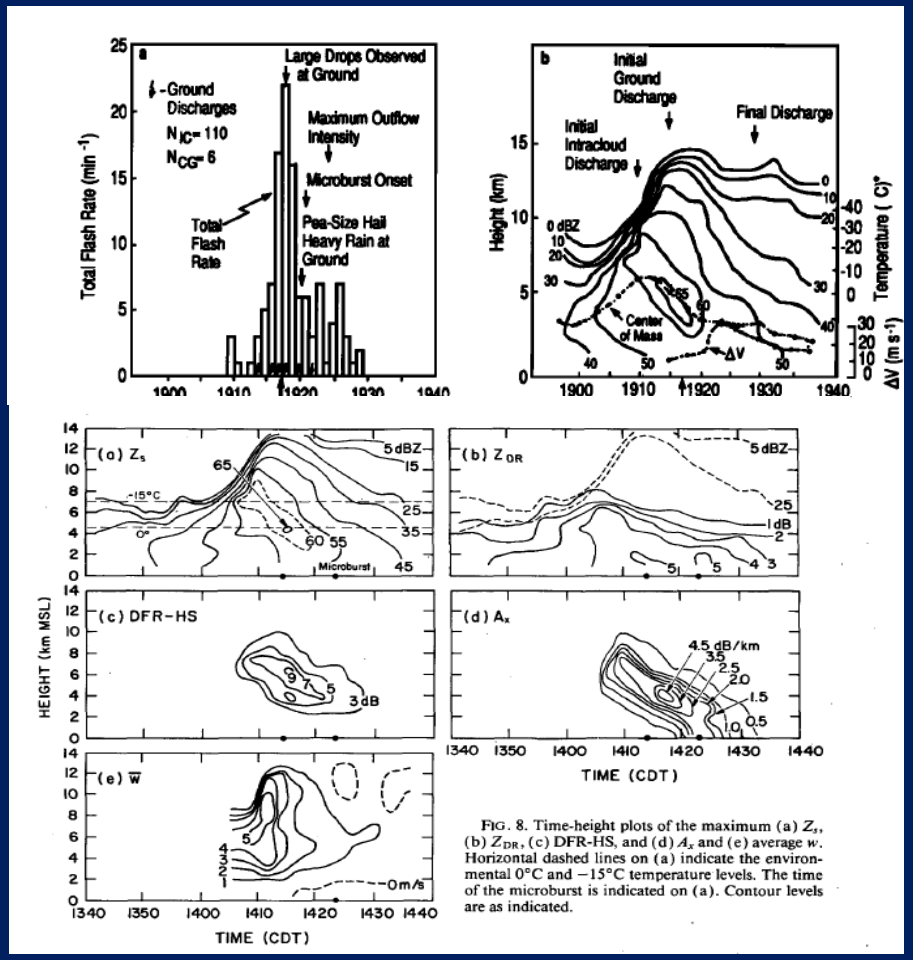
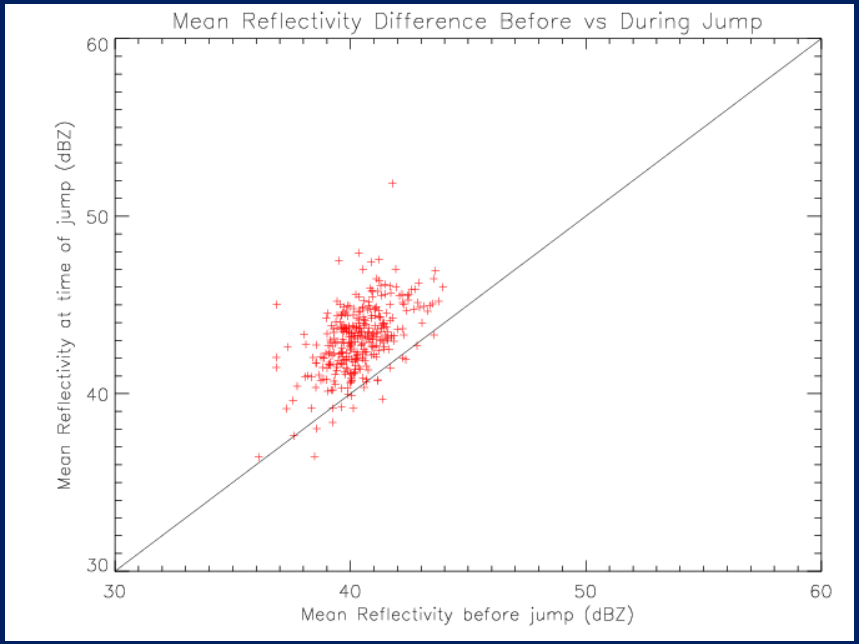
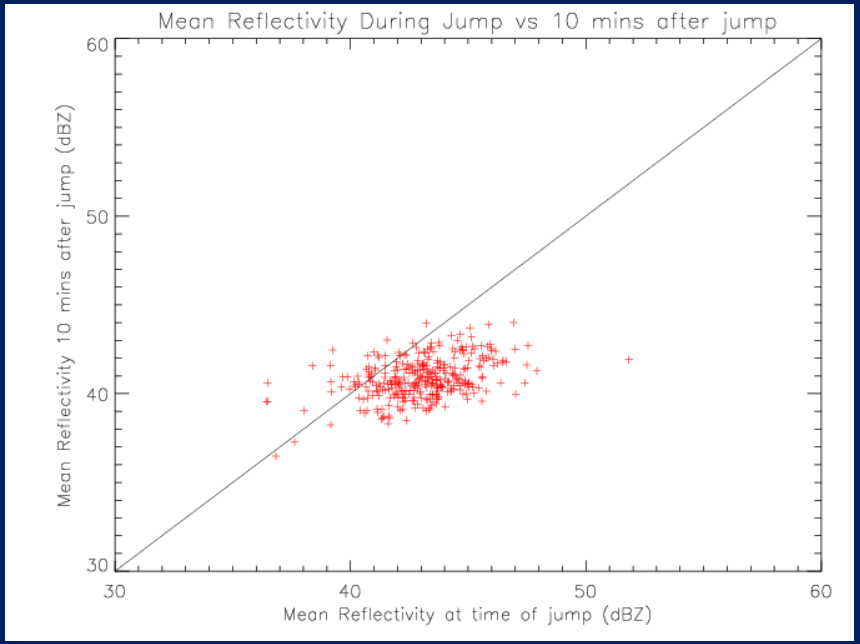


FIG. 8. Time-height plots of the maximum (a) Z_s, (b) Z_{DR}, (c) DFR-HS, and (d) A_x and (e) average w. Horizontal dashed lines on (a) indicate the environmental 0°C and −15°C temperature levels. The time of the microburst is indicated on (a). Contour levels are as indicated.

Goodman et al. 1988, GRL, top; Tuttle et al. 1989, JAS, bottom

1st Jump and Changes in Reflectivity Profiles





Sample size: 329 thunderstorms with at least 1 lightning jump using the mean of all radar pixels above 35 dBZ

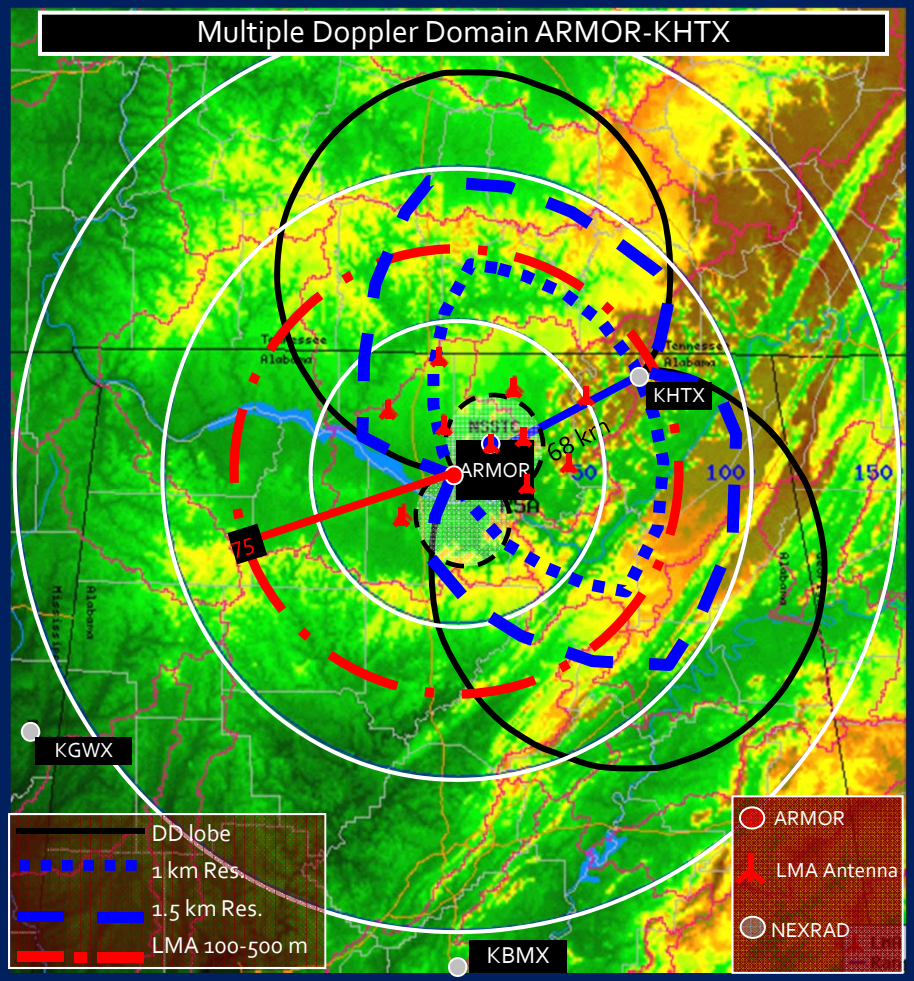
Mean reflectivity increases by an average of 2.72 dB during the 10 minutes prior to the first observed lightning jump

- Standard deviation (+/- 1.60 dB)

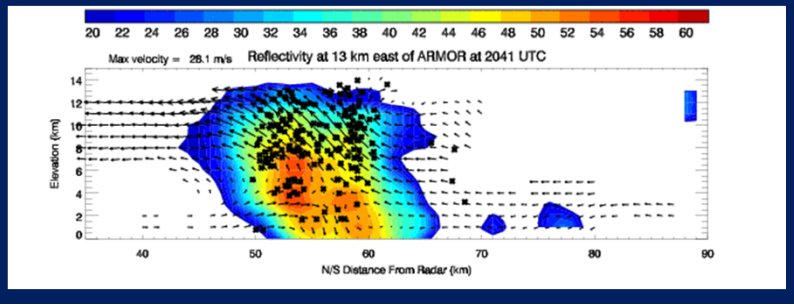
Then the reflectivity profile changes by an average of -2.19 dB during the 10 minute period after the jump

- Standard deviation (+/- 1.80 dB)

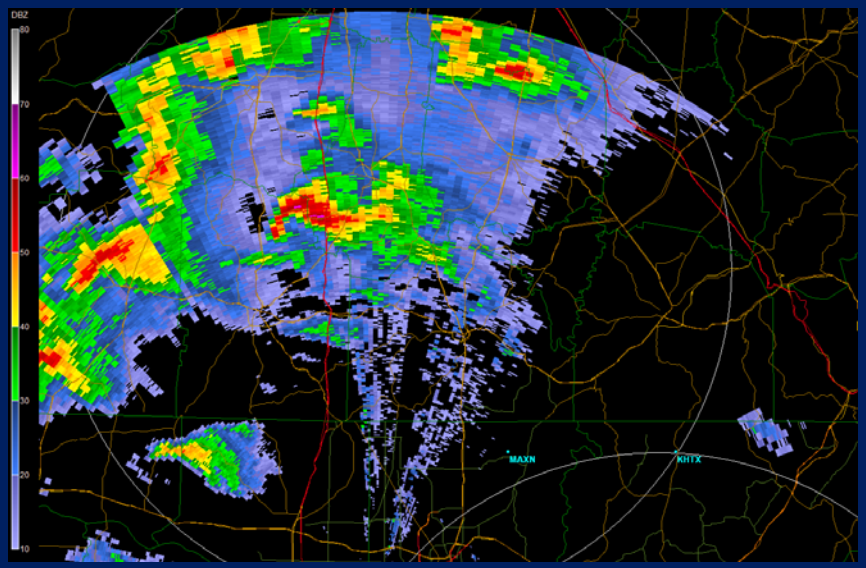
Multiple Doppler

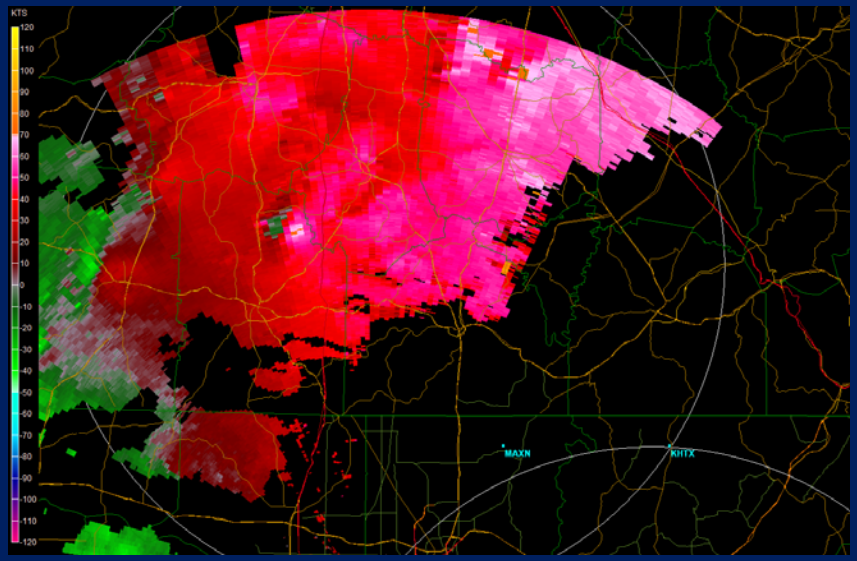


- ARMOR-KHTX Multi-Doppler Domain
- Multi-Doppler synthesis procedure follows that outlined in Mohr et al. (1986), Deierling and Petersen (2008), Johnson (2009)
  - Radar volume scans edited using NCAR SOLOII

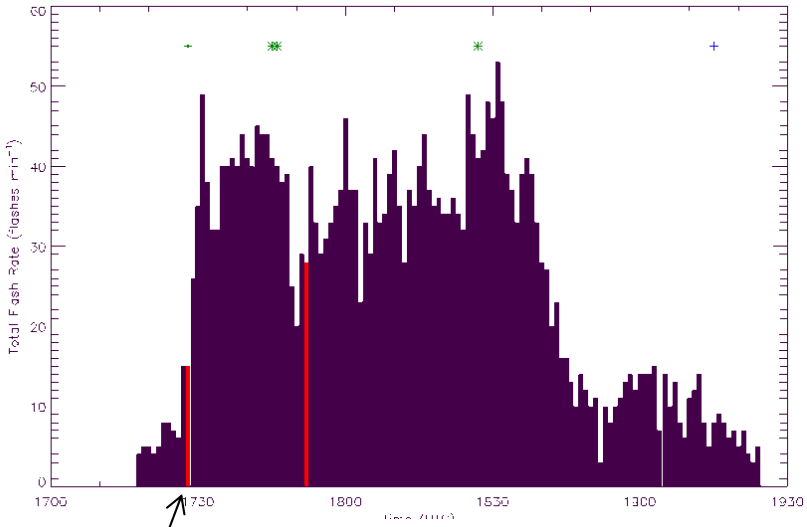


Case 1: April 10, 2009

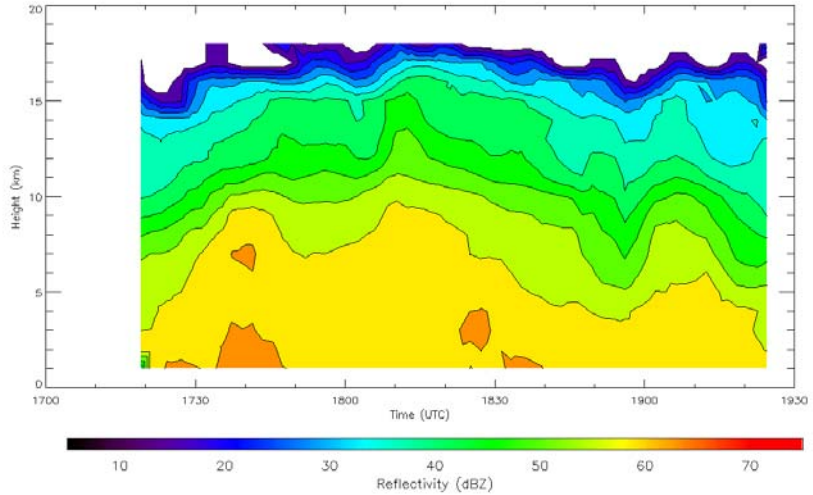




Above: Reflectivity and radial velocity at 1736 UTC

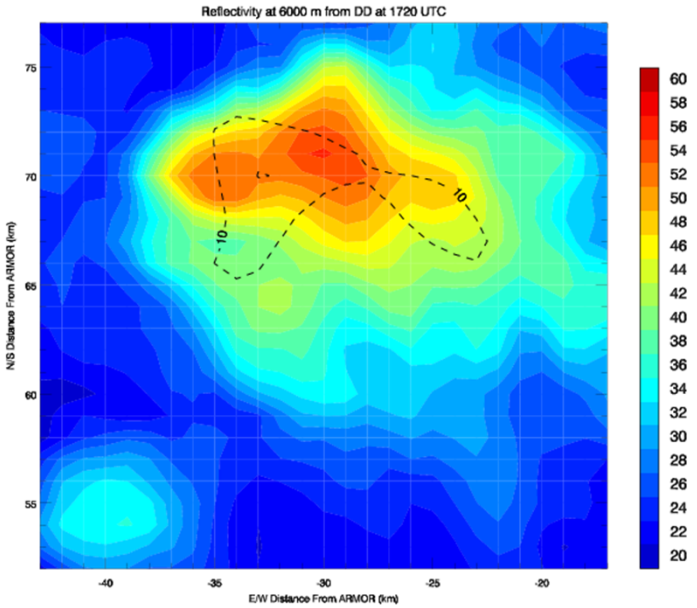


Jump: 10.75 flashes min^{-2}

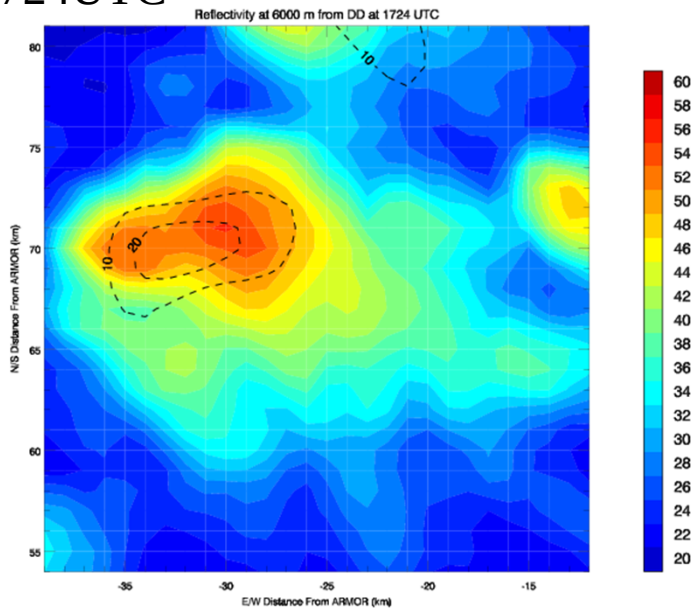


TOP: total flash rate (purple), lightning jump occurrences (red) and severe weather reports (hail, green; wind, blue)
BOTTOM: Time height of maximum reflectivity

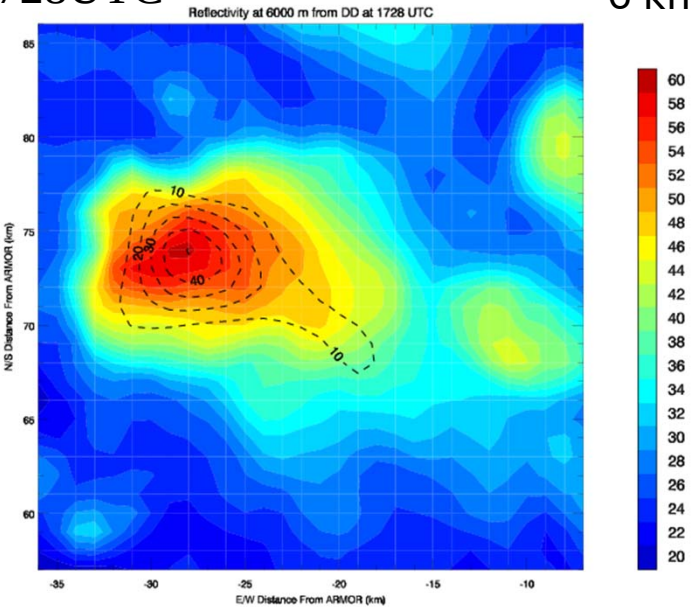
1720UTC 6 km



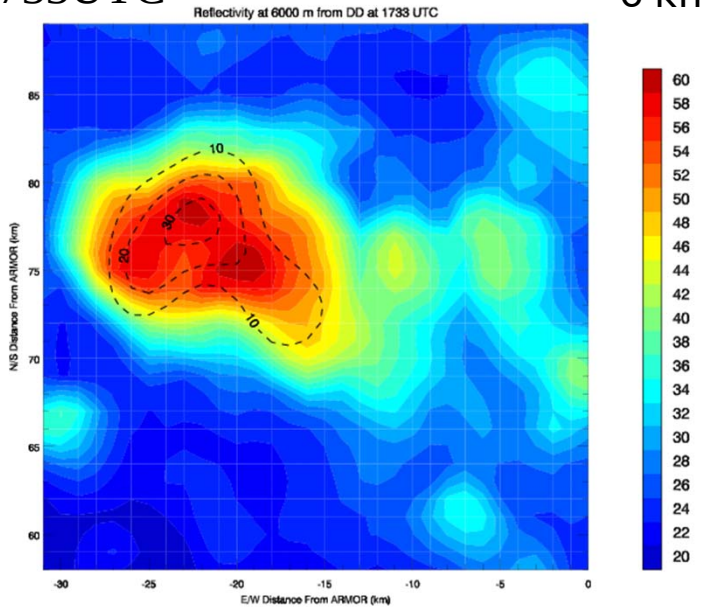
1724UTC 6 km



1728UTC 6 km

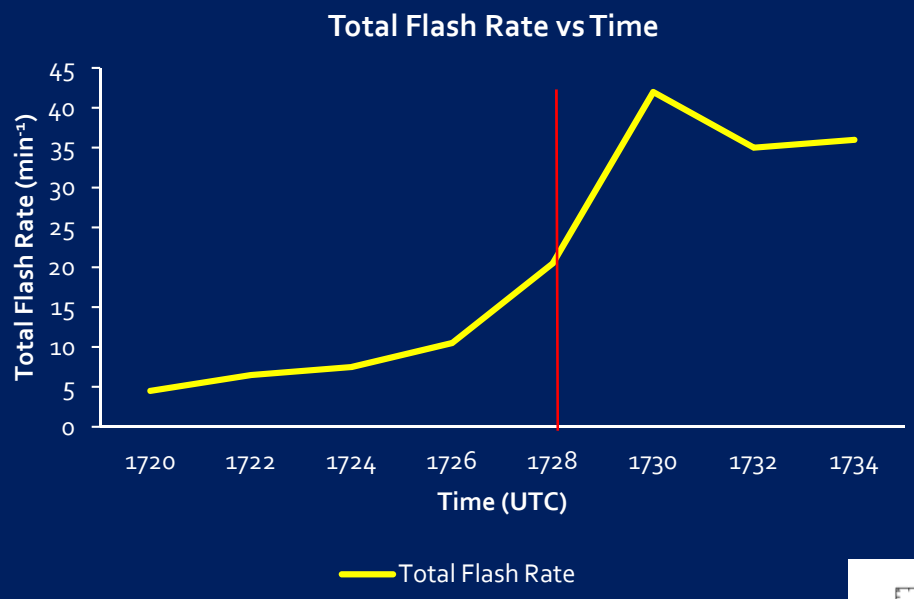


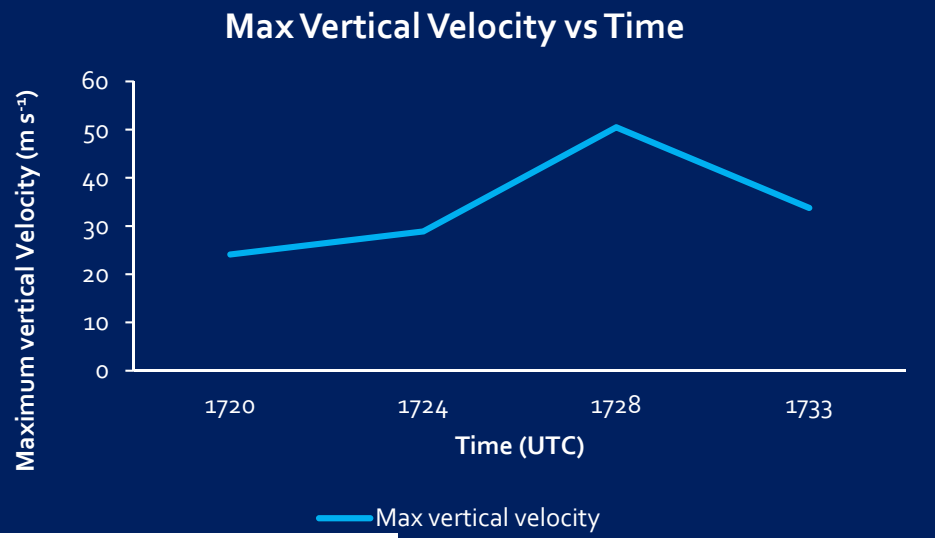
1733UTC 6 km

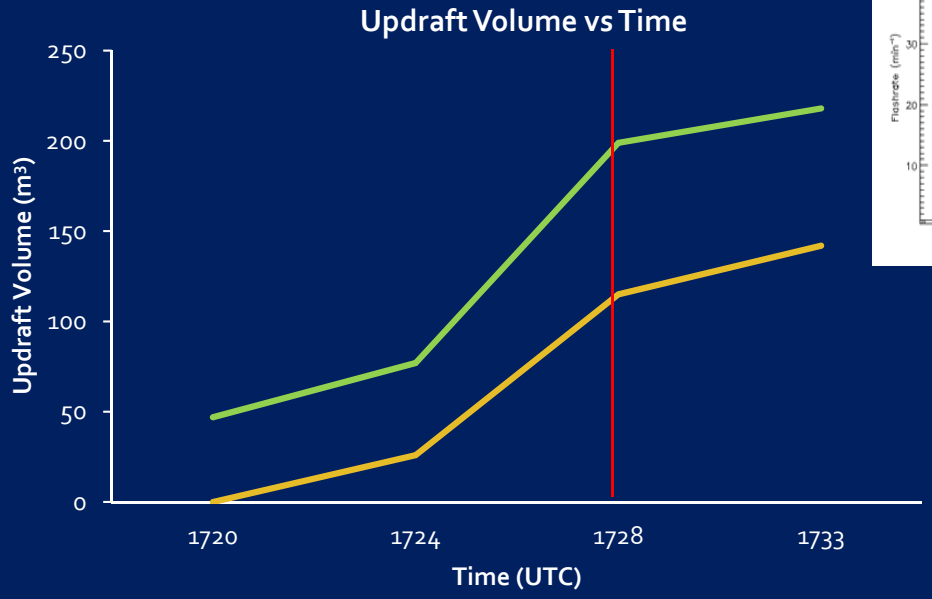


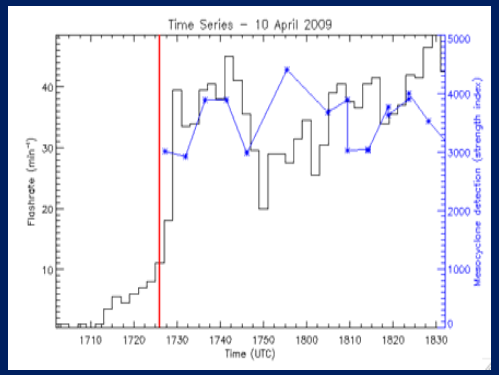
Left – radar reflectivity (shaded) and positive vertical velocity (dash contour; 10 m s^{-1}) at 1720 UTC, 1724 UTC, 1728 UTC and 1733 UTC at 6km.

Note explosive growth and increase in intensity of reflectivity field leading up to and through the time of the lightning jump (1728 UTC).







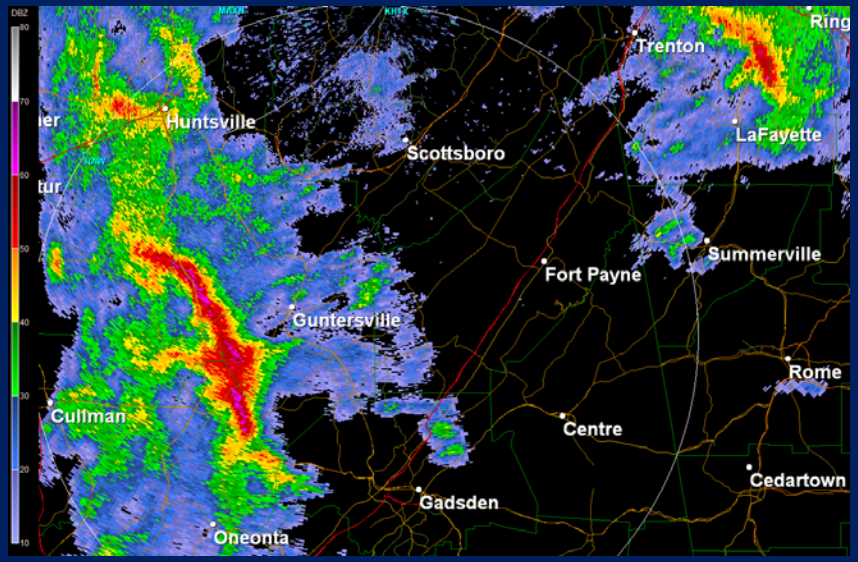


Take Homes:

1) Explosive growth in vertical velocity volume between -10°C and -40°C, just prior to lightning jump
2) Increase in maximum vertical velocity just prior to jump, followed by a decrease after jump time
3) NWS mesocyclone detection immediately after jump.

Total flash rate (top left), maximum updraft speed (top right), Updraft volume (lower left), mesocyclone detection algorithm (lower right) from Stough et al. (2014), 26th WAF

Case 2: March 12, 2010

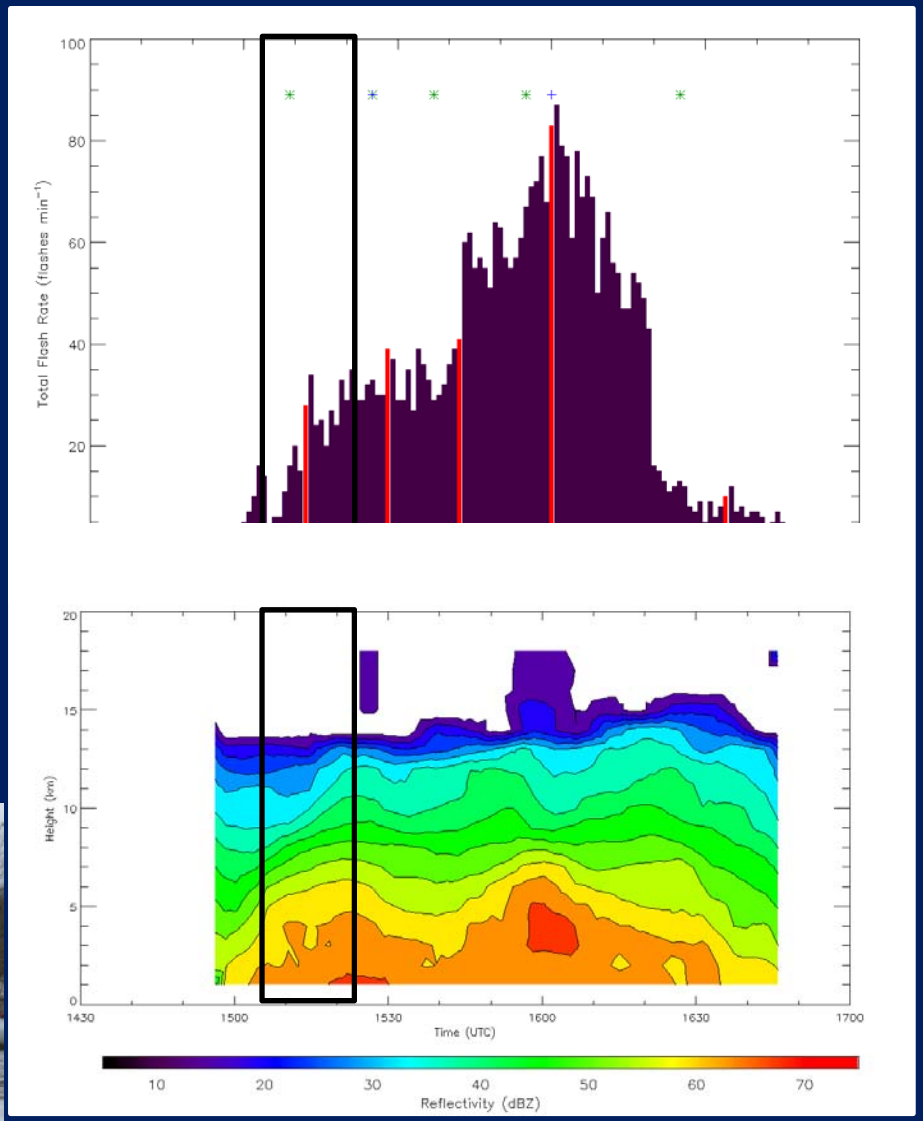


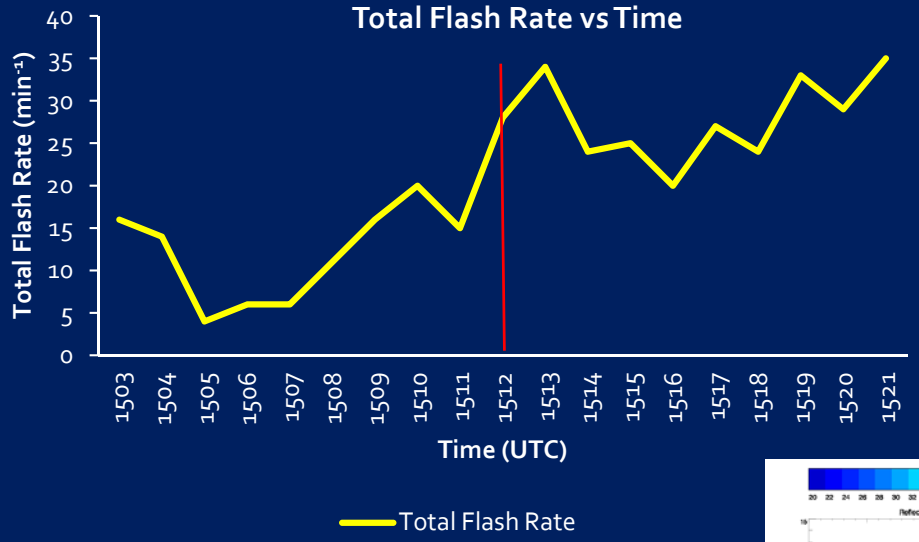
Above– KHTX at 1500 UTC, and 1542 UTC

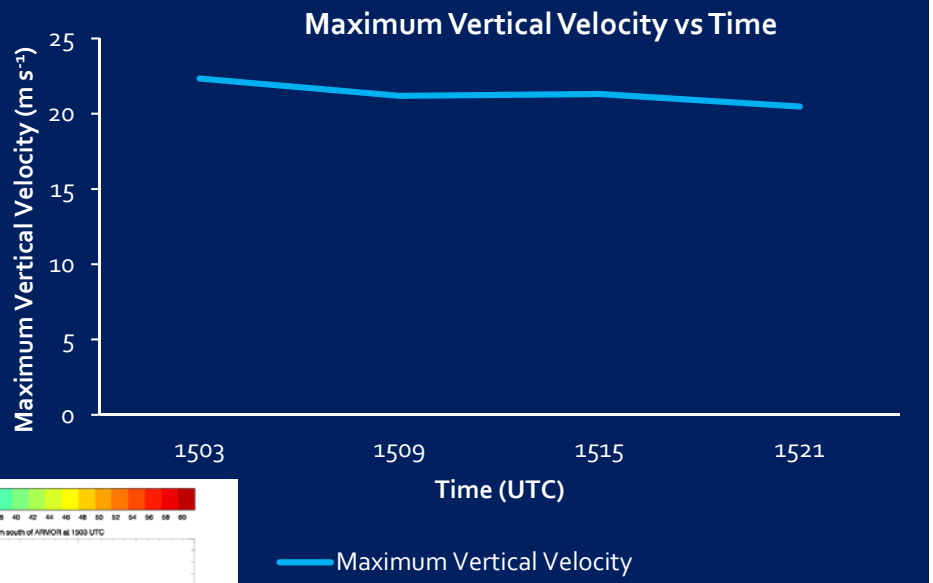
Top right - total flash rate for storm. Red bars indicate jump. Box indicates time of jump.

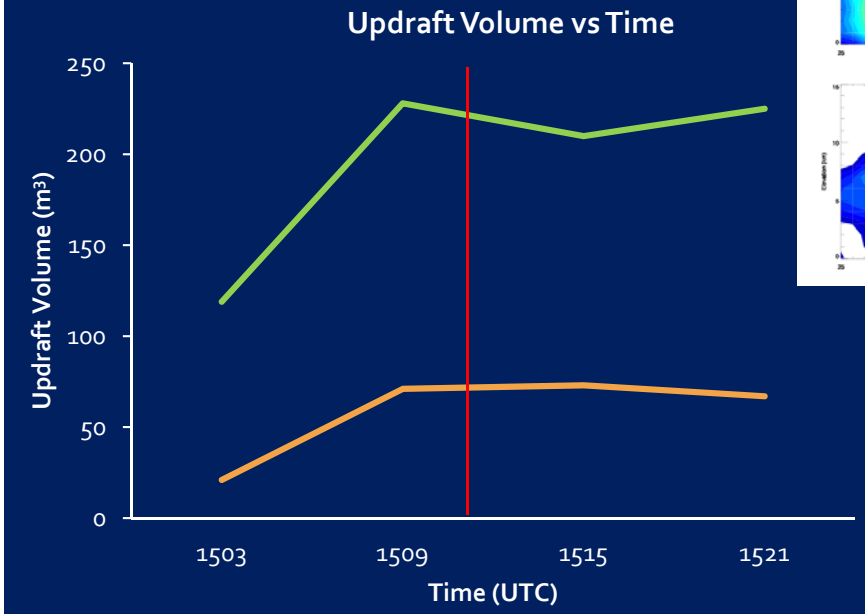
Lower right - Time height reflectivity for cell. Box indicates time of jump.

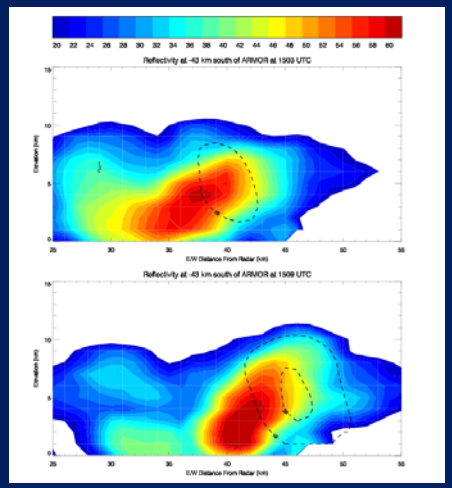
Below – Pictures of the hail and hail damage caused ~3 hours after the storm passed courtesy NWS Huntsville









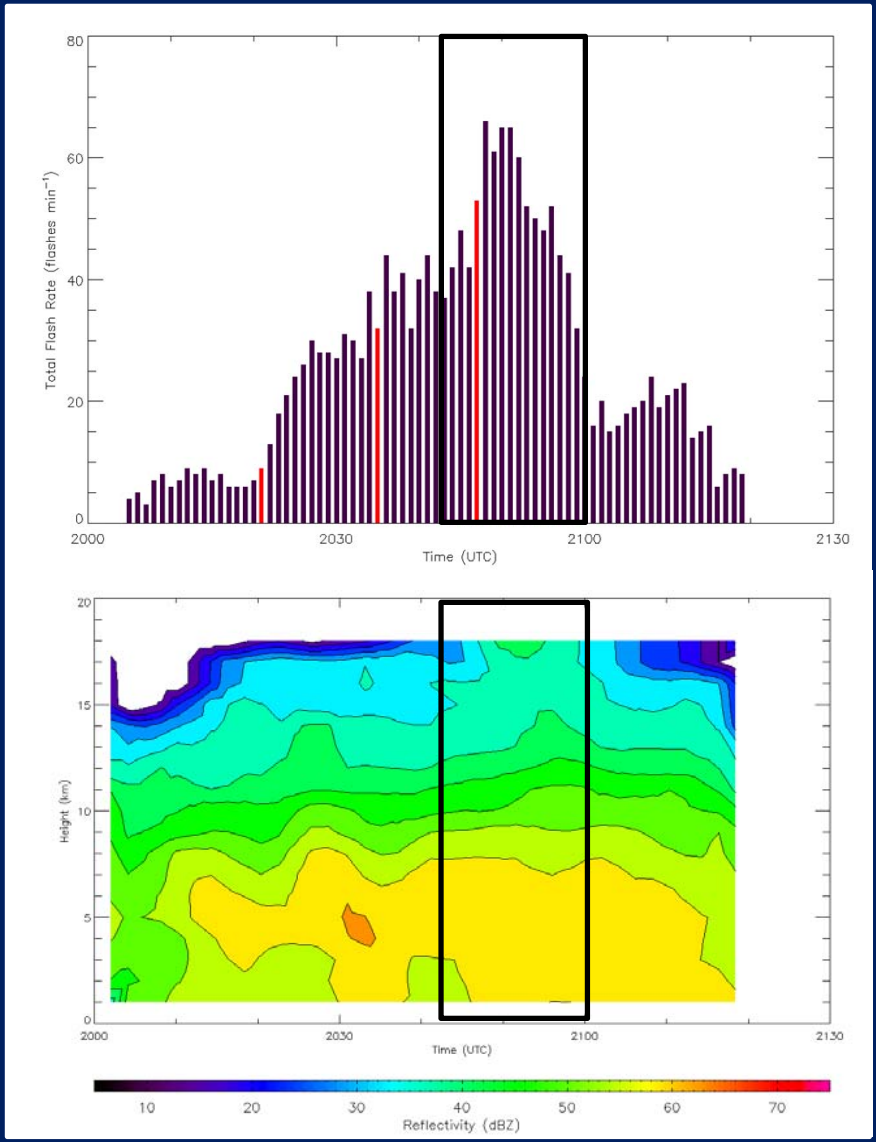


Take Homes:

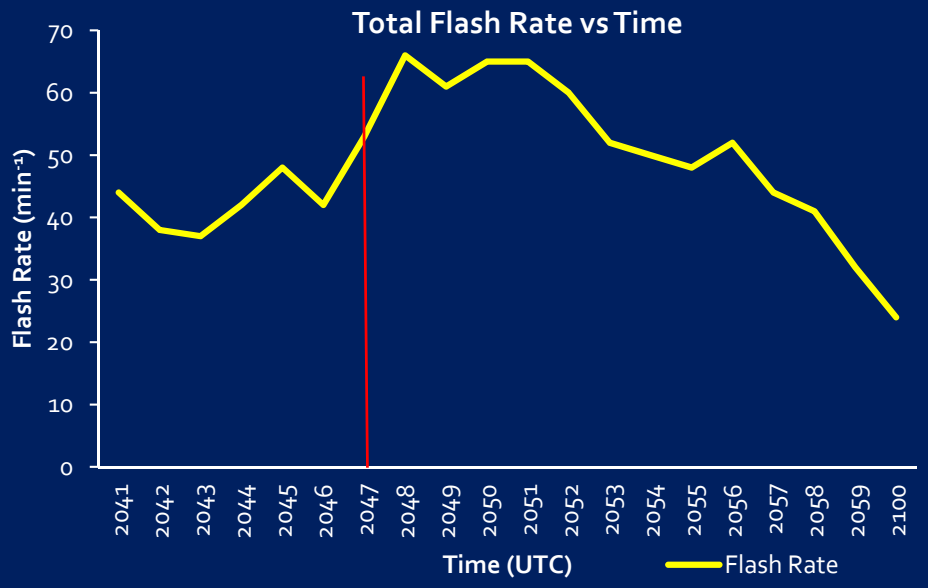
1) Growth in vertical velocity volume, just prior to lightning jump.
2) Slight DECREASE in maximum vertical velocity just prior to jump.

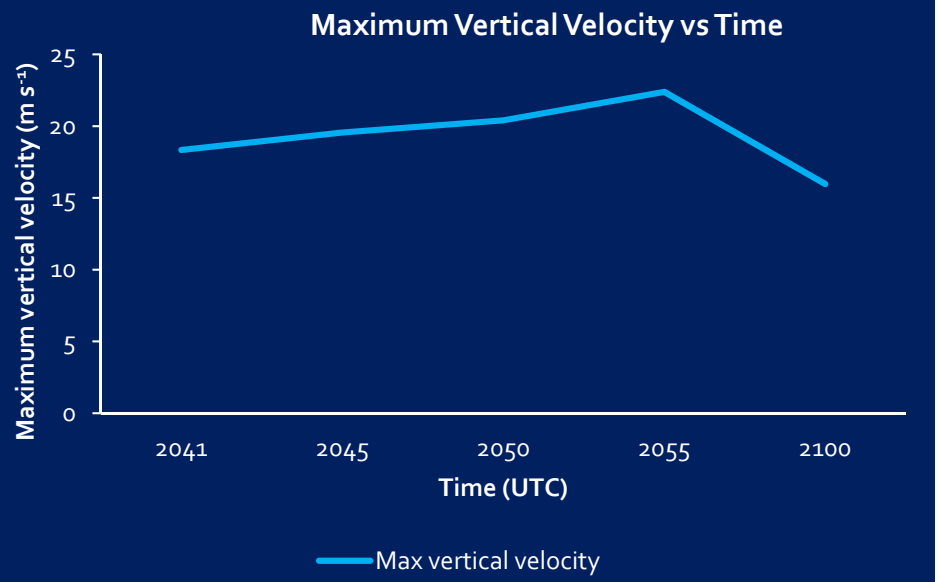
Top left– total flash rate, **Lower left** – updraft volume, **Top right** - maximum updraft speed , **Middle**– RHI of reflectivity (shaded) and updraft velocity (dashed contour) before and at the time of the lightning jump.

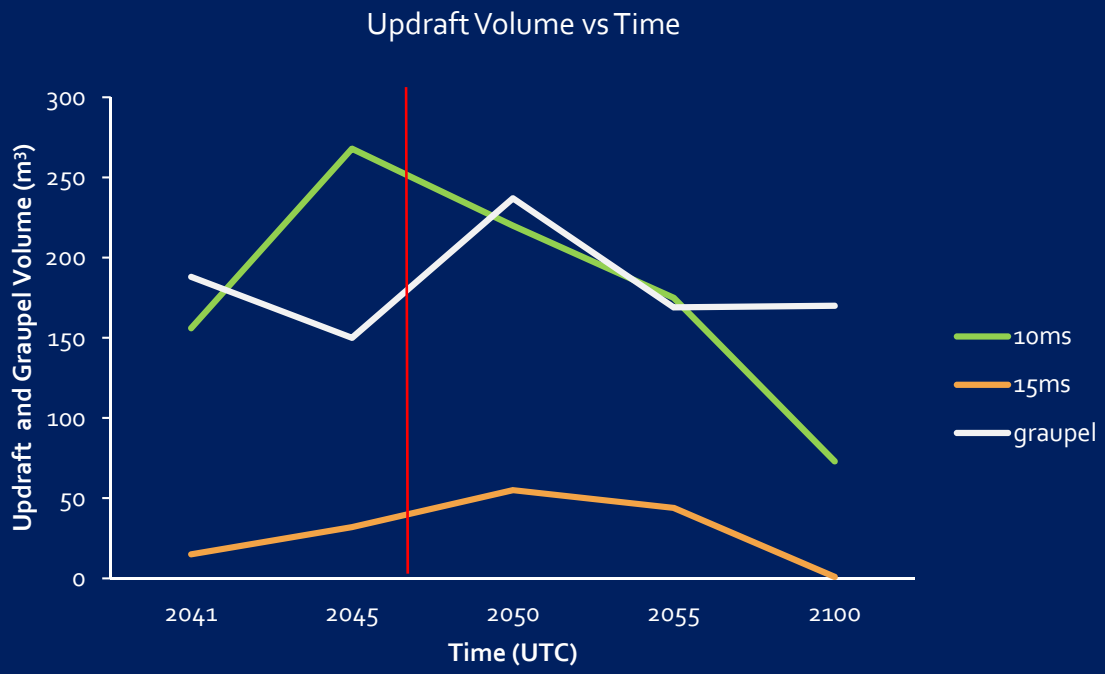
Case 3: July 19, 2006



- Severe multicellular convection
- Focused on the lightning jump at 2047 UTC
  - Because we have multi-Doppler
  - Jump was 7.25 flashes min^{-2}
- Peak flash rate ~65 flashes per minute
- Multiple damaging downbursts
  - 2050 UTC and 2108 UTC





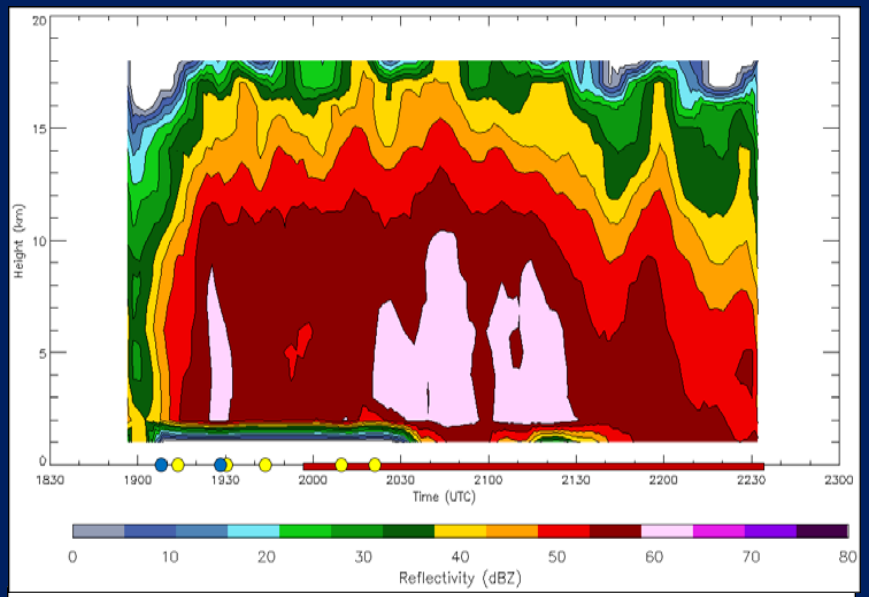


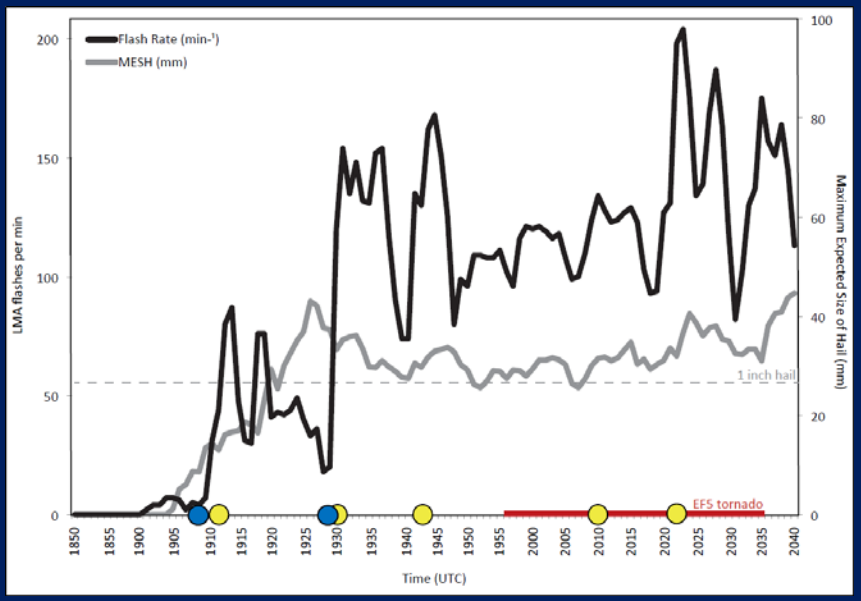
Take Homes:

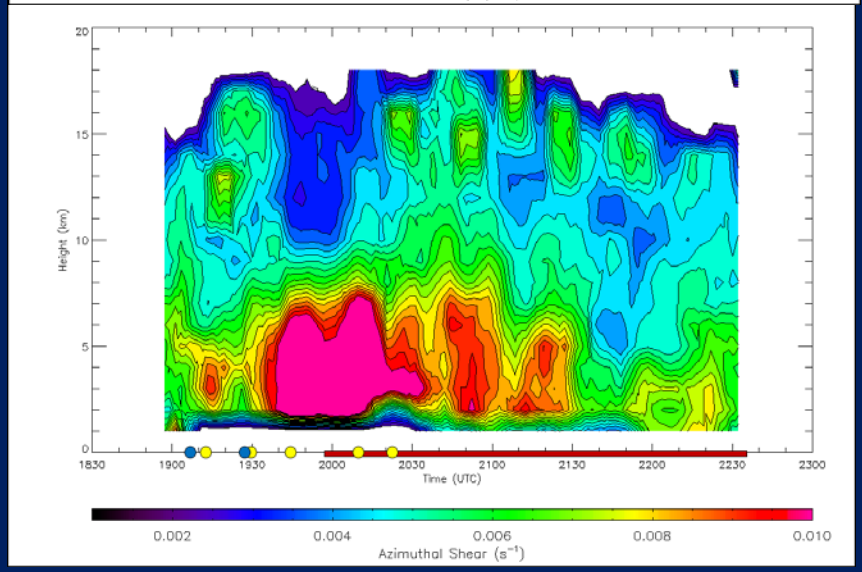
1) Growth in vertical velocity volume, and slight increase in maximum vertical velocity just prior to lightning jump
2) Increase in graupel volume occurs after increase in updraft volume and jump. Higher flash rates follow.

Top left– total flash rate, **Lower left** – updraft volume, **Top right** - maximum updraft speed

Transition to Operations 5/20/2013, Moore Tornado Example (Stano et al. 2014 JOM, in press)







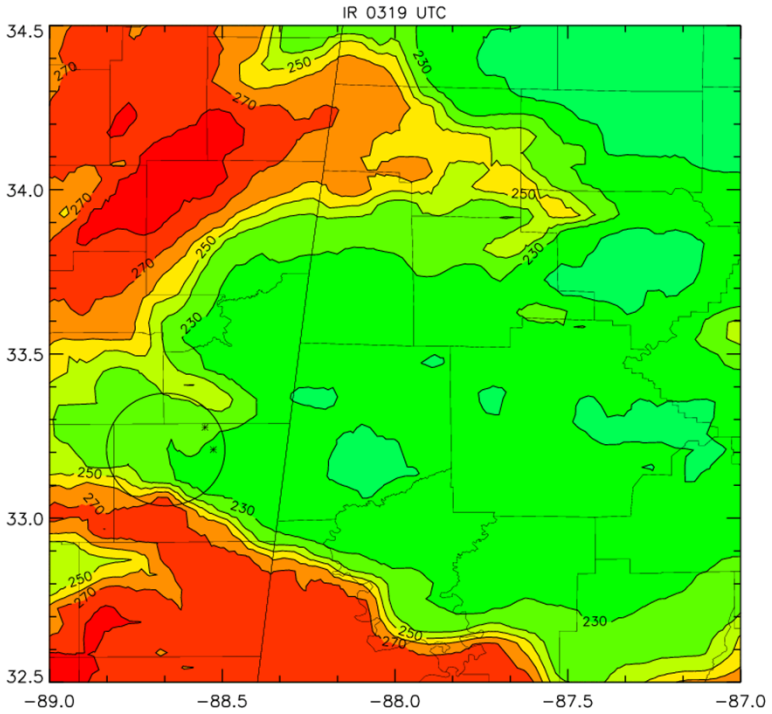
Testing lightning jump in operational setting at NSSL. Here is an example from the Moore tornado. Similar findings to April 10, 2009 case:

-**Jump led development of mesocyclone**

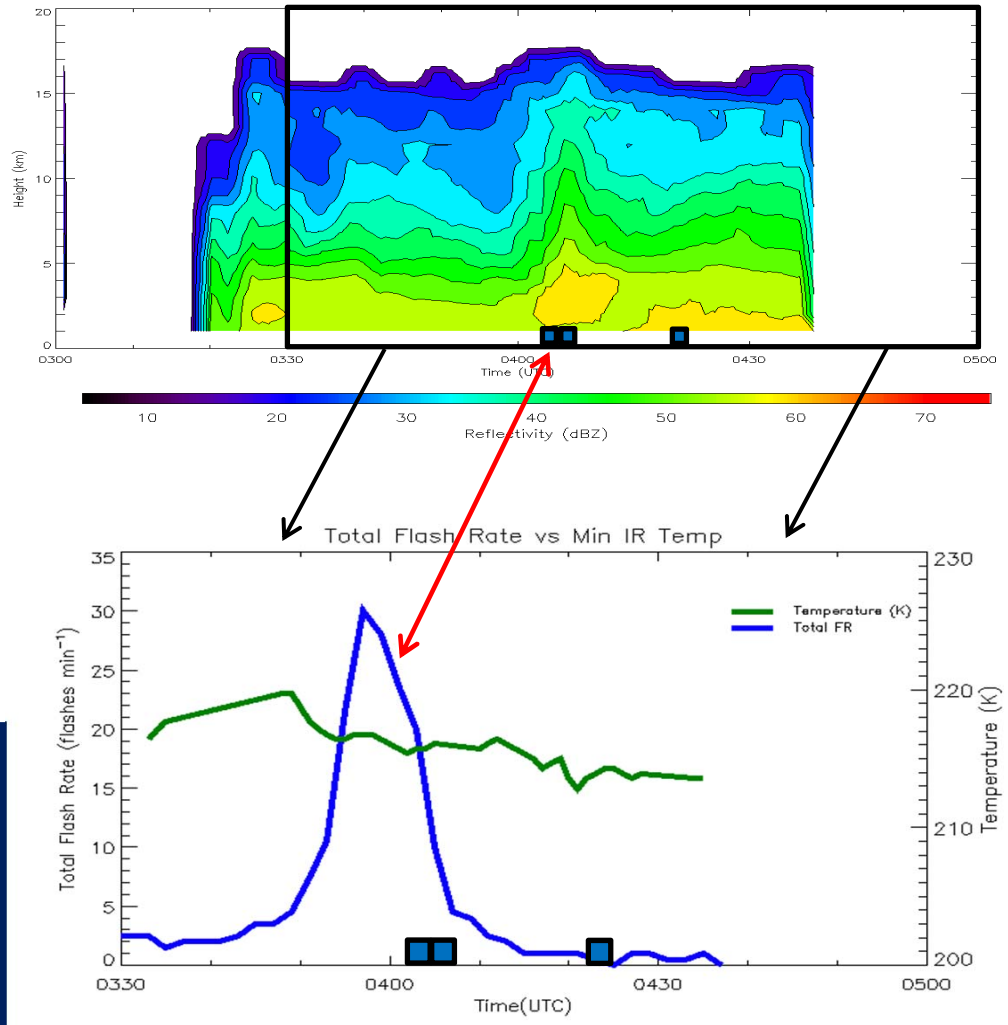
- **Secondary jump was coincident with vertical development and increase in rotation magnitude**

Top right – time height reflectivity , **Lower left** – time height azimuthal shear, **Upper right** - total flash rate (black), MESH (gray), lightning jumps, non operational system (blue), lightning jumps operational system (yellow), red bar, tornado time.

Higher Temporal Satellite Information



Above - 1 minute temporal IR Brightness temperature (10.7 um) from SRSO operations of GOES-O from December 9, 2009. Black asterisks represent lightning flash initiation points observed with the N. AL LMA. Black circle is the radar derived location of the storm.



Above – Time height section of reflectivity (top) total flash rate (purple bars; middle) and flash rate vs minimum 10.7 µm brightness temperature (bottom). Red asterisk indicates time of lightning jump. Blue boxes represent wind reports.

Summary/Ongoing work

- Increases in 10 and 15 m s^{-1} updraft volume observed leading up to time of jump.
- Maximum velocity DOES NOT always increase in magnitude leading up to the jump.
- -10 to -40°C reflectivity profile increases observed leading up to jump (+2.72 dB), followed by a decrease (-2.19 dB) during immediately after jump.
- Additional jumps/peak changes in flash rate to be explored
  - Airmass/multicell, supercells (tropical, low topped), QLCS's to be examined
- Basic physical/dynamical understanding coupled with use of additional intensity metrics leads to robust conceptual model of severe storms and leans toward a probabilistic jump forecast.