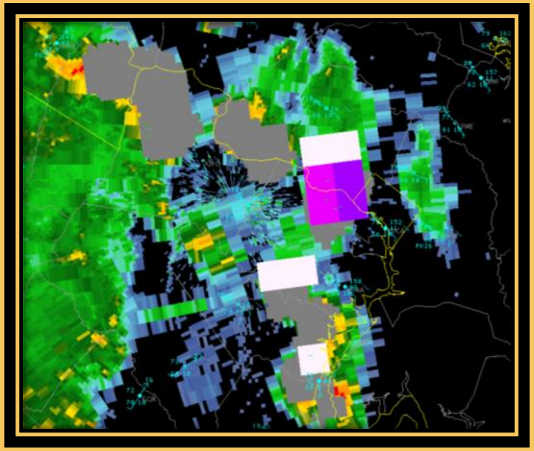
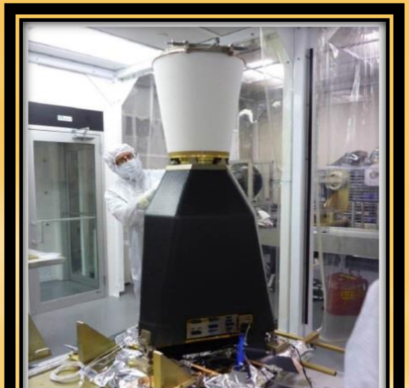




The GOES-R GLM prepares to undergo vibration testing in May. Credit: Lockheed Martin

Identification and Forecasting of High Impact Weather with Total Lightning: Future Opportunities in the GLM Era

Dr. Larry Carey

University of Alabama in Huntsville

Motivation

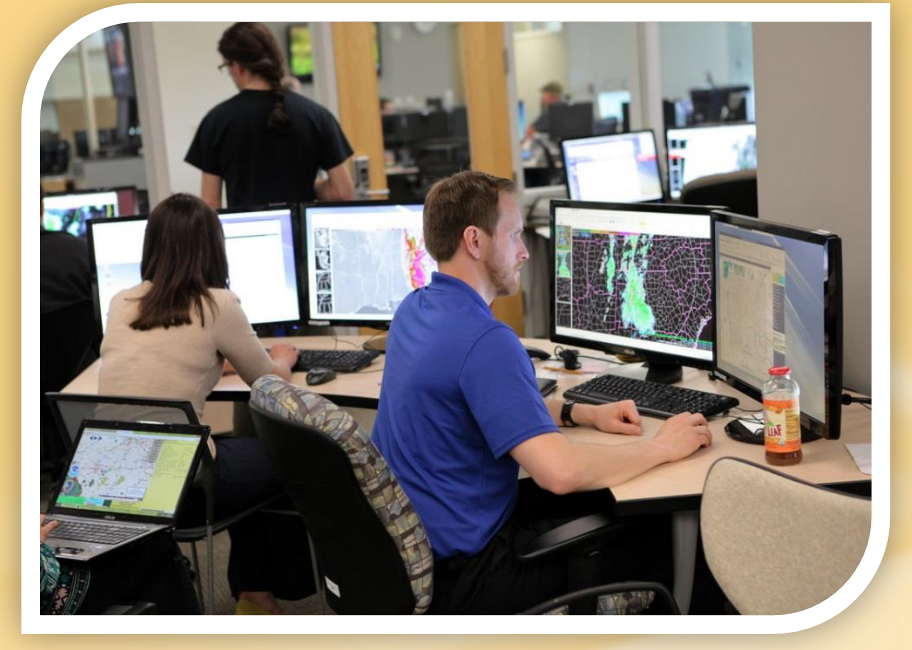
- Why lightning? Why GLM?
  - Improve temporal observations of storm intensity
    - GLM: 20 second latency
    - NEXRAD radar: 4-6 min radar volume update time
  - Improve spatial coverage
    - Continuous observations on the hemispheric scale
      - i.e., uniform detection across measurement FOV
      - Provide spatial information on lightning as opposed to a point source (e.g. NLDN, ENTLN)
  - Strong correlation between rapid increases in lightning and storm severity

(Image by Tamworth)

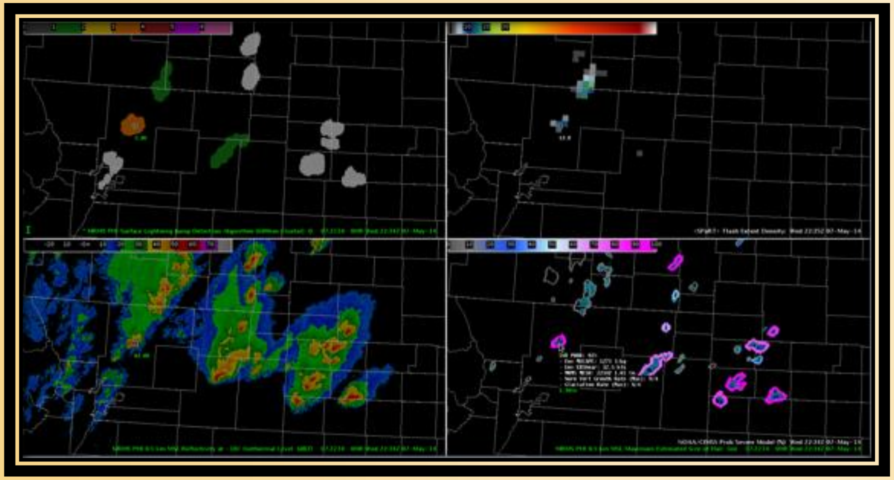
Objectives

Use total lightning information to

- Increase situational awareness during convective weather
- Build upon and enhance current tools for monitoring severe storms during warning operations
  - Data fusion
    - Lightning and Radar
    - Lightning and IR ABI
  - Integrating lightning in the forecast paradigm
  - Increase performance – increase forecast skill, increase lead-time, and reduce warning false alarm
- Provide storm intensity observations in data sparse regions



Forecasters at the Hazardous Weather Testbed



What is total lightning?

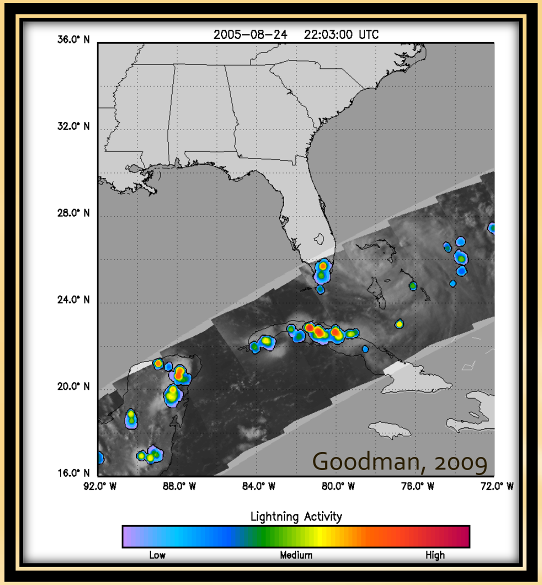
(Image by Tamworth)

Cloud-to-ground: Documented as a single contact point at the ground.

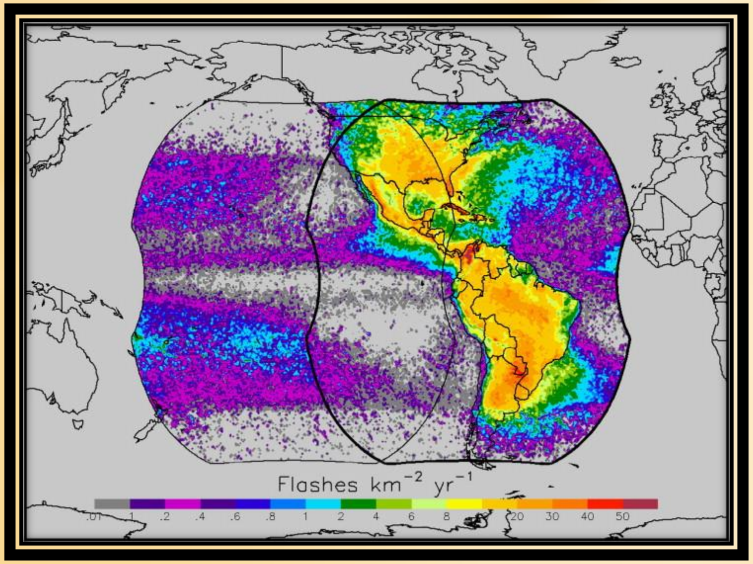
Total lightning: Documented as individual points along all branches of the lightning flash throughout the cloud.

GLM: The instrument

- Previous space-based optical measurements from the Lightning Imaging Sensor (LIS) of lightning provide only a snapshot of storms. (upper right)
- GLM detects optical pulses from lightning flashes over nearly the full GOES-R field-of-view (lower right)

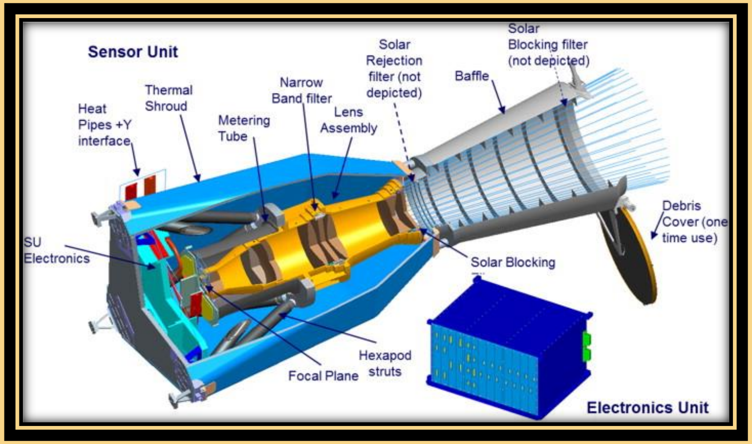


Example of a LIS orbit



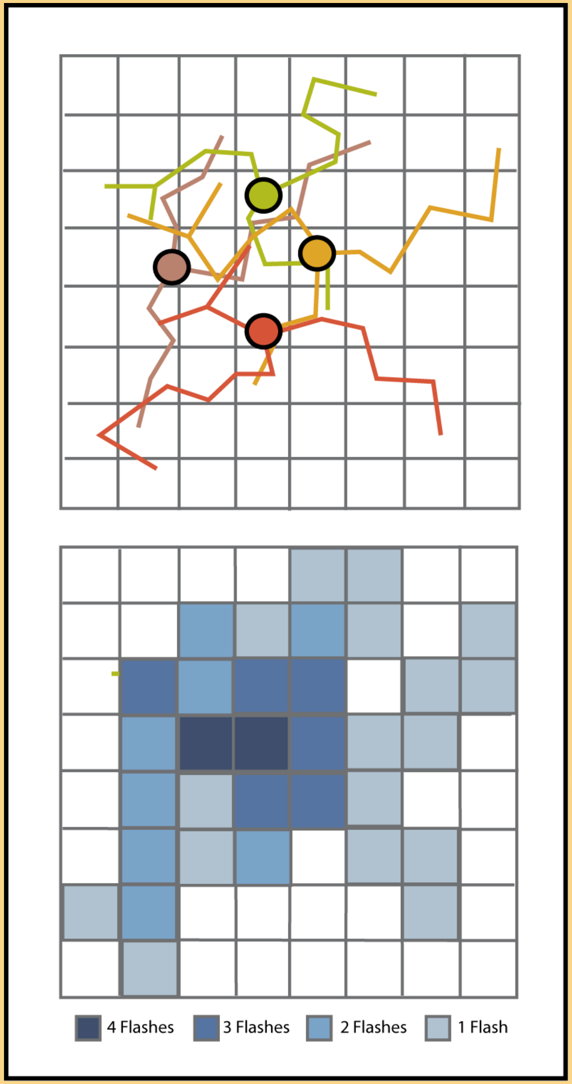
Goodman and Coauthors, 2013

Optical Transient Detector (OTD) and LIS lightning climatology (1995-2005) for GOES-R combined FOV



Goodman and Coauthors, 2013

Lightning Flash from GLM



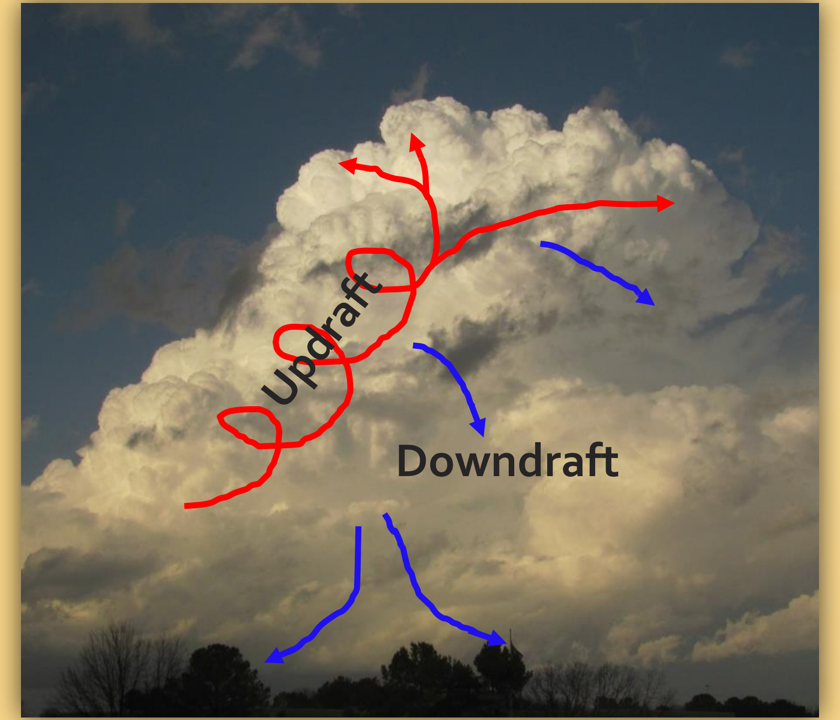
- Top image: Lightning flashes with flash initiation locations identified. Similar to type of structure seen from a VHF detection network.
- Bottom image: Pixels illuminated by lightning flashes as will be seen in the GLM
- Provides spatial coverage of lightning
  - Situation awareness
  - Lightning safety applications
- Products created from GLM
  - Flash Extent Density (FED)
    - Spatial structure or flash footprint
    - Total number of flashes that cross a particular grid box or point location.
  - Flash Initiation Density (FID)
    - Location of lightning initiation
    - Equivalent to lightning flash rates

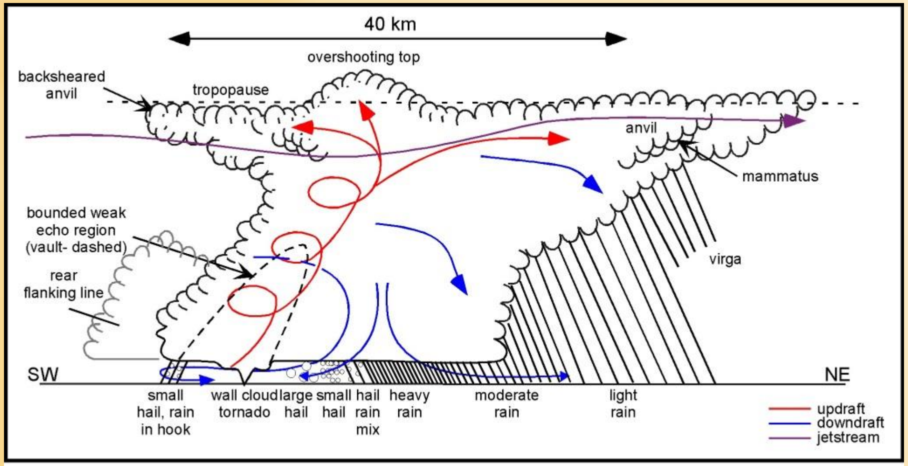
How Can Lightning Help Predict Storm Intensity?

Thunderstorm Development

- Updraft plays a key role in storm intensity.
  - Link between severe weather such as hail and tornadoes and thunderstorm charging and lightning production.


Courtesy of Alan Moller

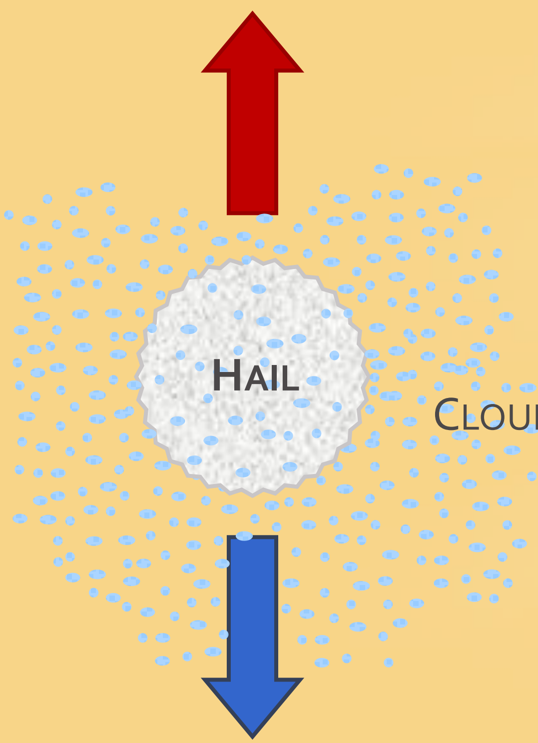




The updraft is the engine of the thunderstorm.

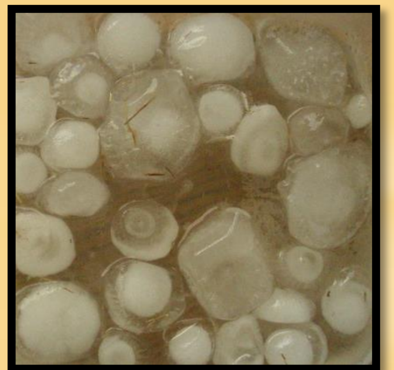
Hail Formation

Updraft



Fall Speed

Melting 1.25" hail

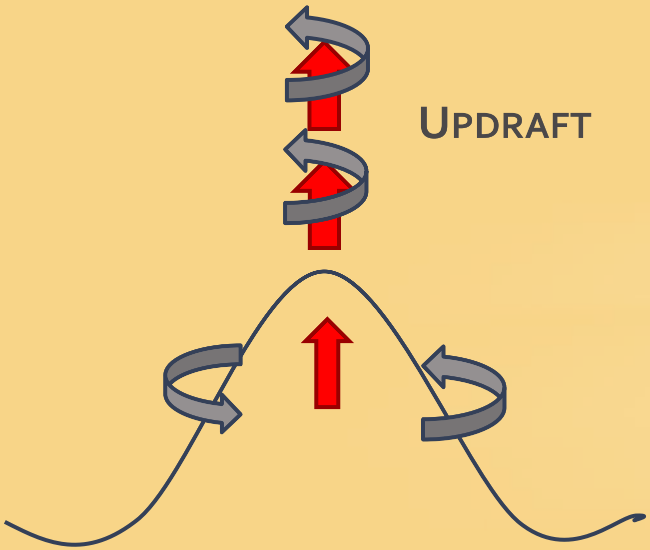


Record Hailstone
Vivian, SD – 23 July 2010

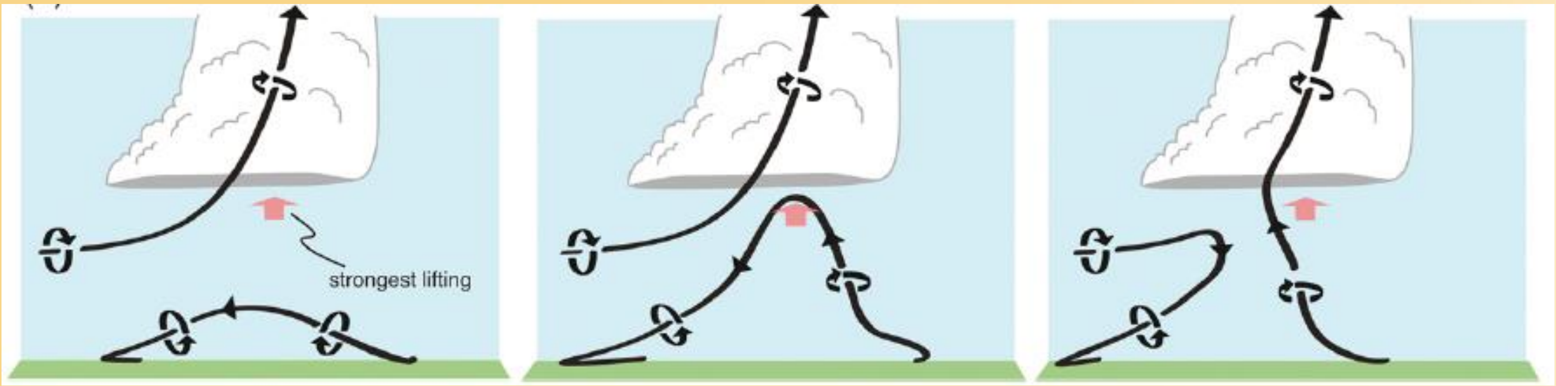
Courtesy of NOAA

- Hail grows by colliding with other small hail stones and/or the collection and freezing of cloud water droplets
- When a hailstone becomes too heavy to be lofted by the updraft, its falls out of the storm.
  → Stronger updrafts can suspend heavier hailstones

Tornado formation

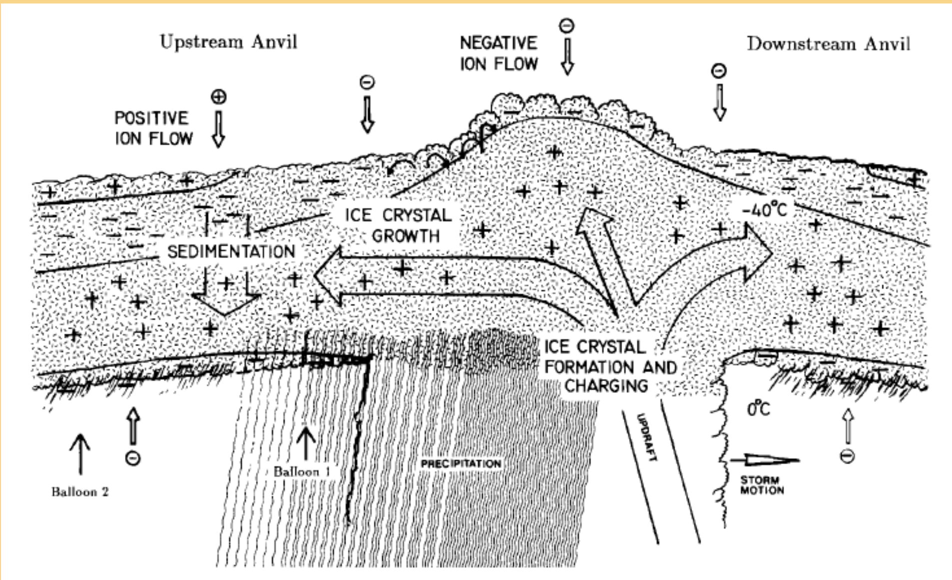


- The updraft tilts vorticity (the spin in atmosphere) from the horizontal to the vertical
- Updraft serves to stretch the vorticity column (like an ice skater)

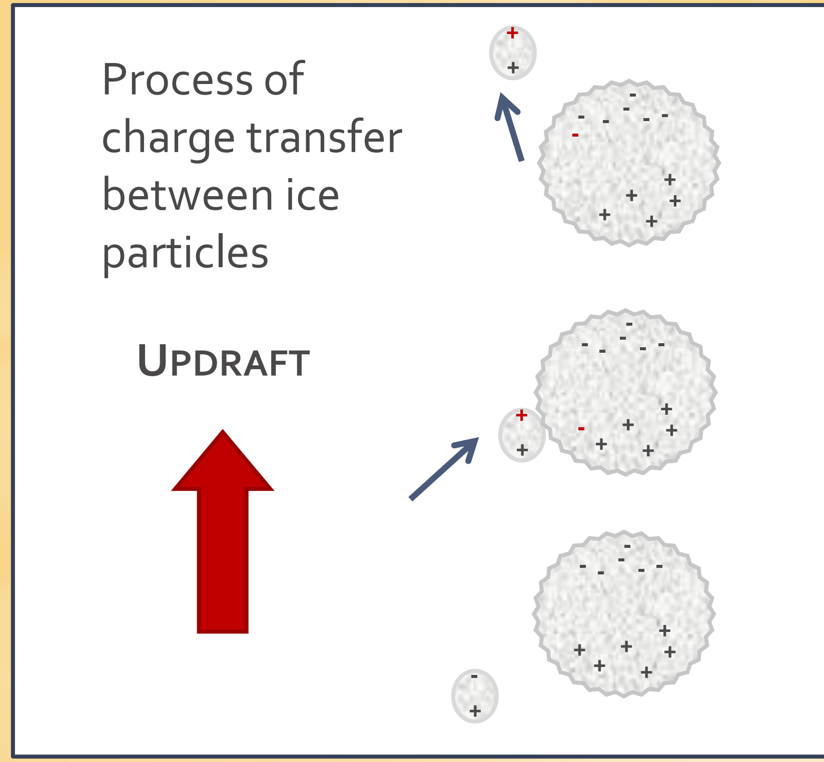


Markowski and Richardson, 2014

Thunderstorm Electrification



Byrne et al. 1989

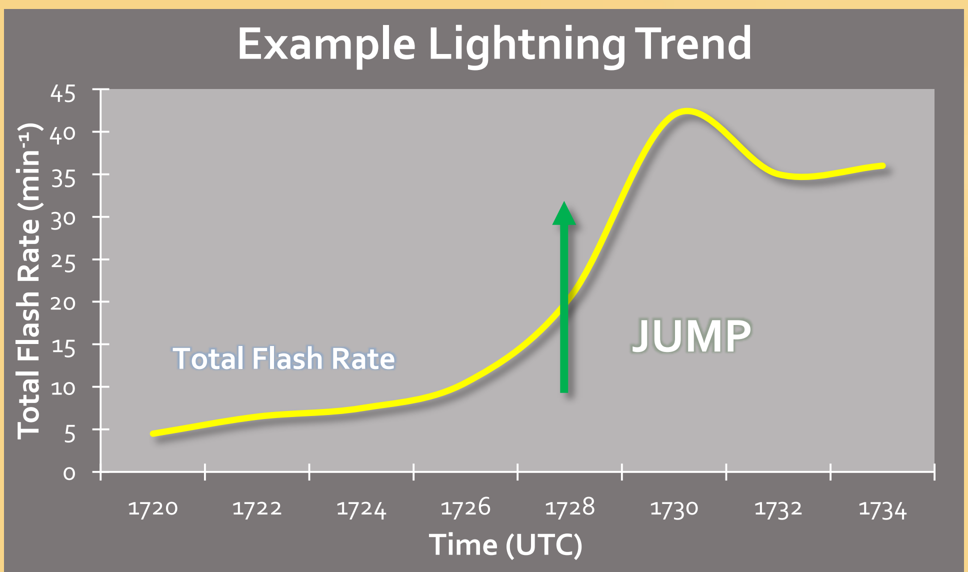


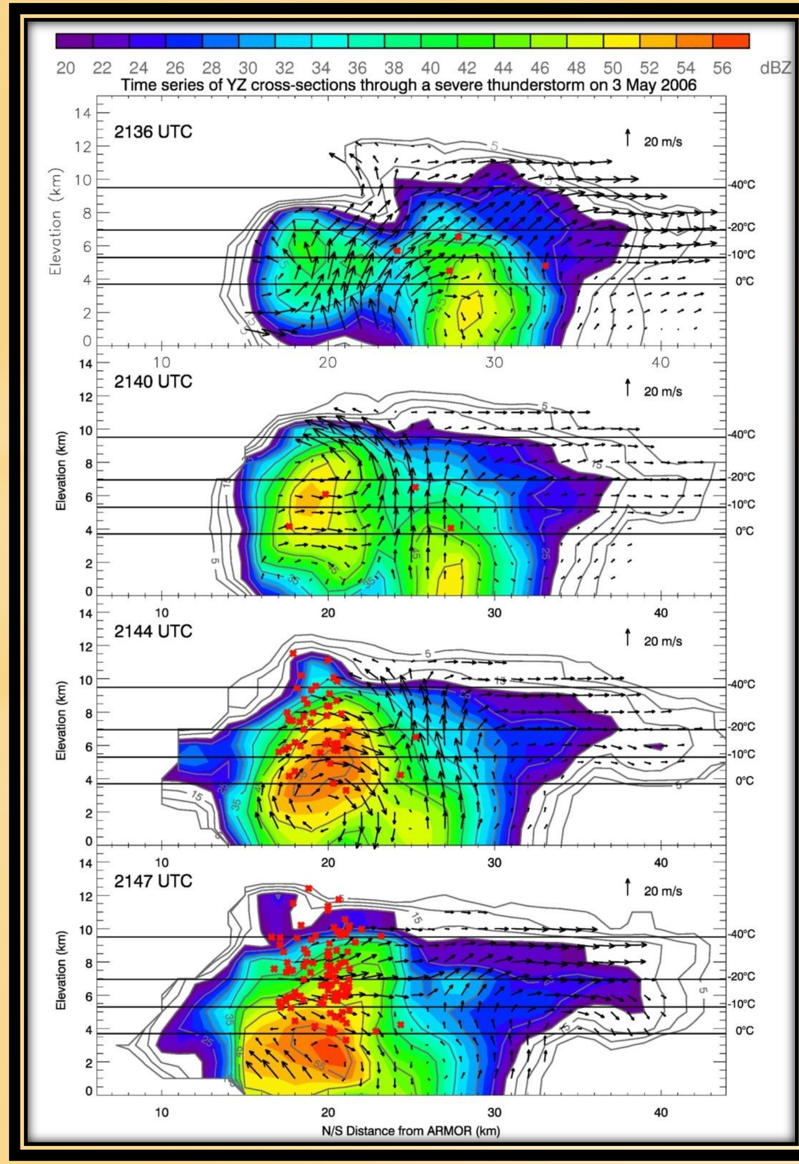
- Lightning occurs when the difference between areas of charge in a thunderstorm are great enough.
- Charge is transferred between ice particles to create these charge differentials.

- Increases in the updraft strength and volume allows for more charge transfer and the potential for increased need for lightning discharge within a thunderstorm to achieve balance.
    - Thus, increased lightning flash rates

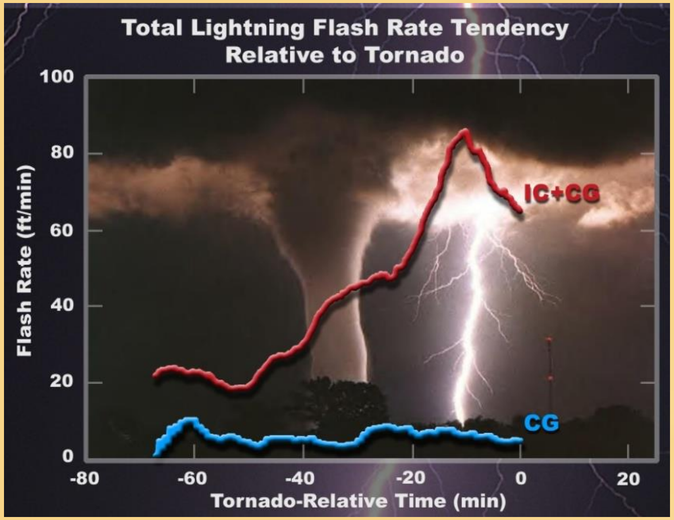
Lightning Jump

- Rapid increases in total lightning strongly correlated to the manifestation of severe weather (Schultz et al. 2009, 2011)
- Physically tied to increases in updraft volume and storm ice content
  - Hail production, strong convective winds





Lightning Detection



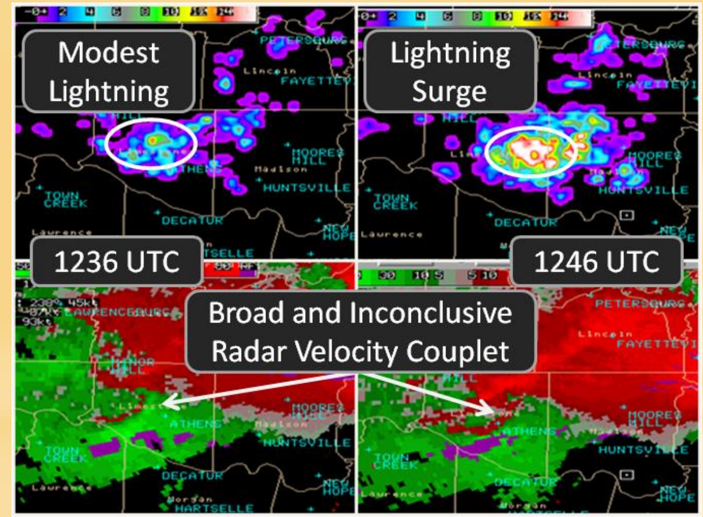


TABLE 3. Skill scores and average lead times using the sample set of 711 thunderstorms for both total lightning and CG lightning, correlating trends in lightning to severe weather.

	POD	FAR	CSI	HSS	lead time (all)	lead time (tornado)
Total lightning	79%	36%	55%	0.71	20.65 mins	21.32 mins

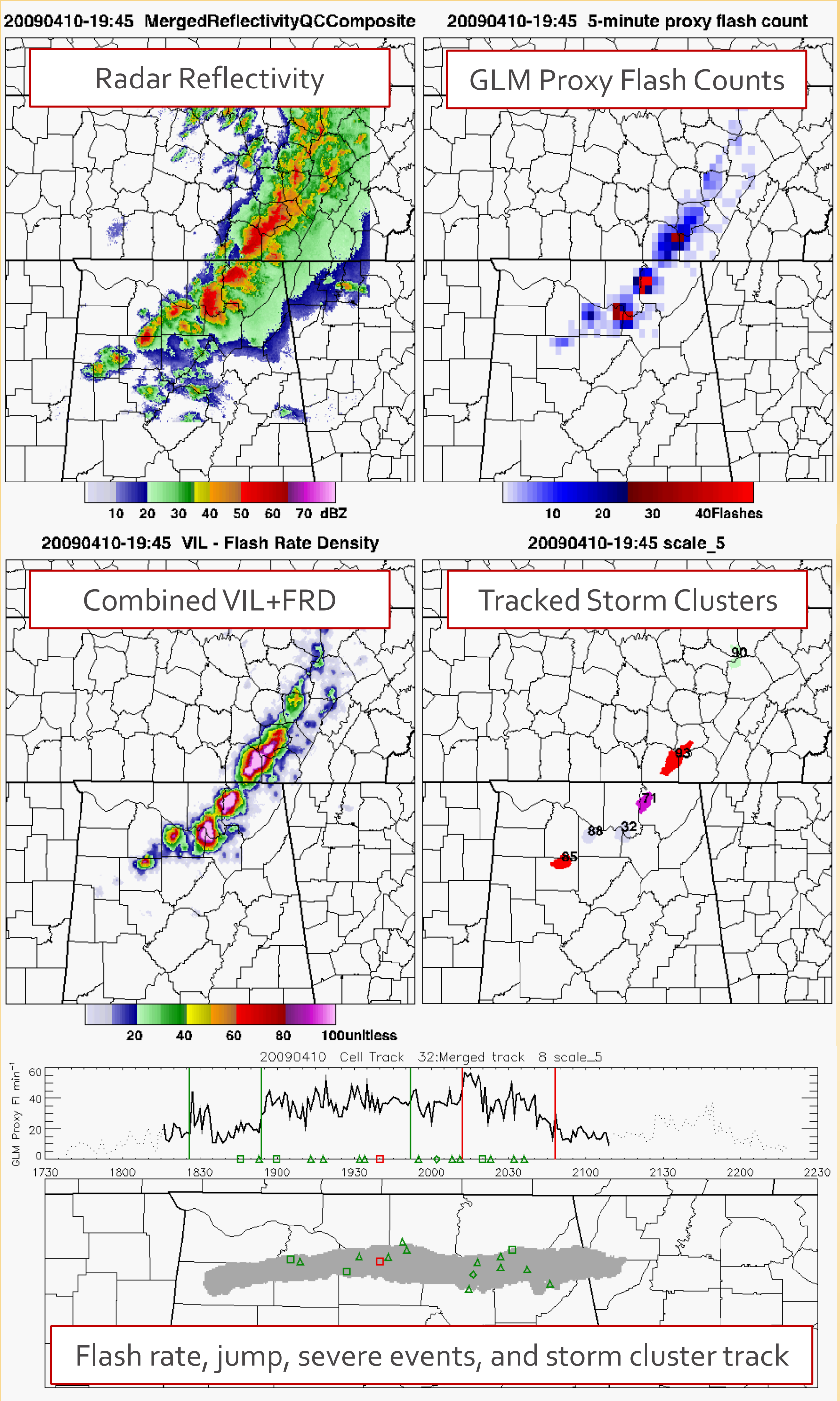
National Average for Tornado warning lead-time is only 14 minutes

Operational demonstration underway of the total lightning algorithm at the Hazardous Weather Testbed (at request of NWS)

Courtesy of S. Goodman and C. Schultz

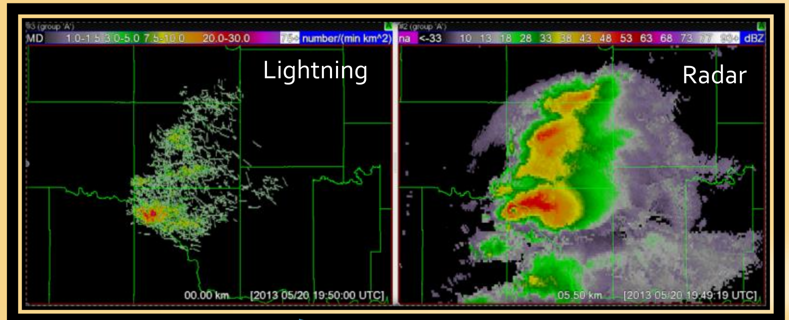
Moving the Lightning Jump to the GLM Framework

- Evaluating the Lightning Jump System at GLM resolution
  - Objective, automated tracking
    - Hands-off approach
  - Simulates GLM using GLM Proxy data
  - Combines lightning flash rate density with vertically integrated liquid (from radar measurements)
    - Radar – lightning data fusion
  - Automated verification
  - Large sample
    - Processed >90 event days, >700 tracked clusters

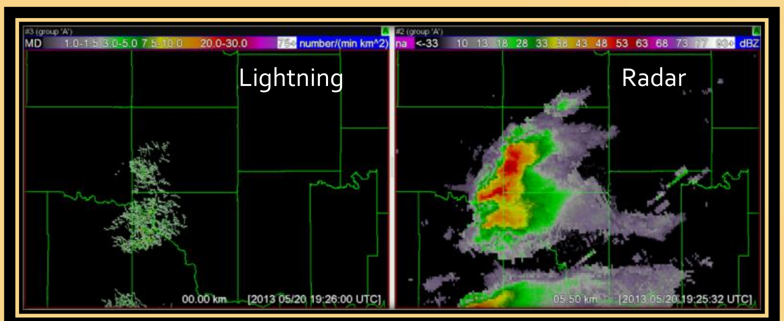


Lightning Related to Mesocyclone Strength

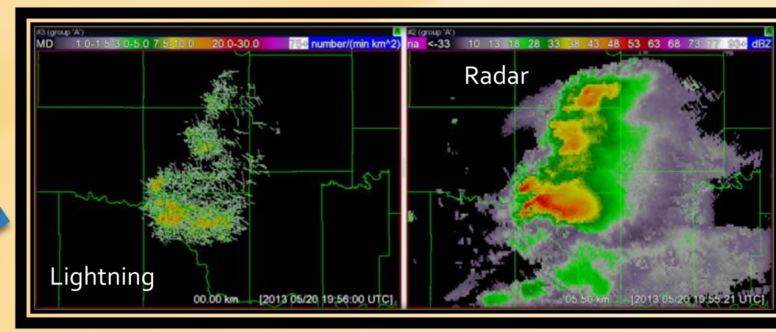
Maximum <u>storm rotation</u> following peak in flash rate

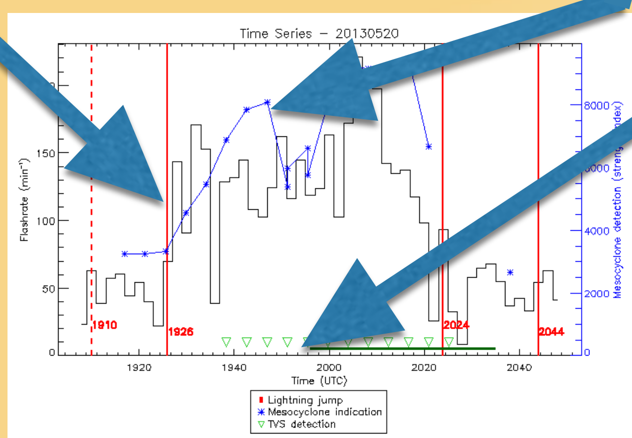


Lightning Jump: Rapid increase in lightning flash rate



Tornado reported <u>5 minutes after peak</u> in mesocyclone strength

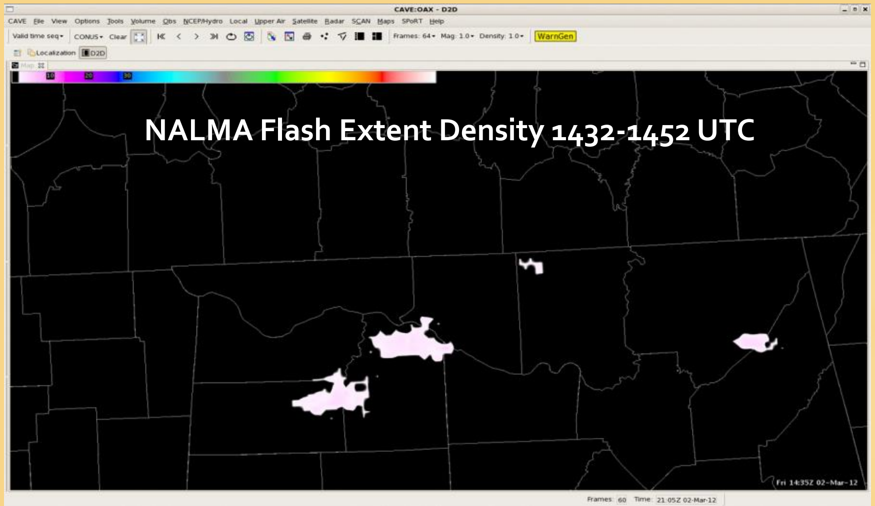


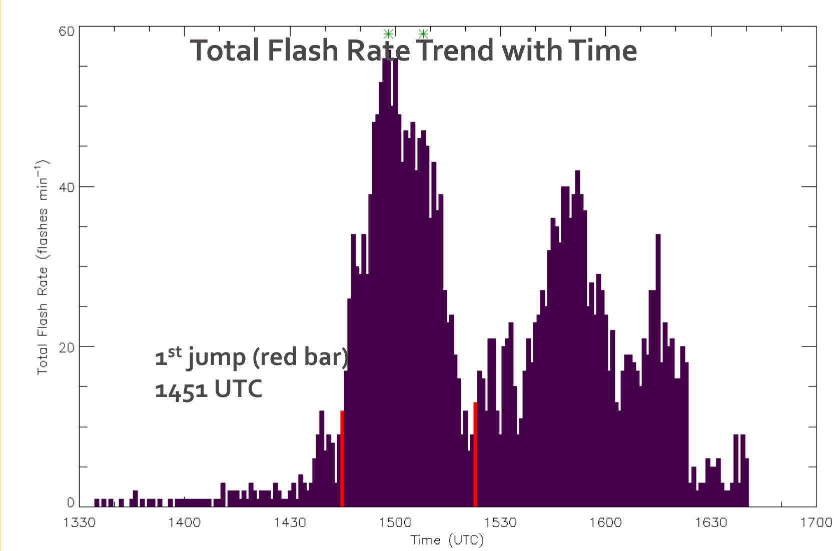


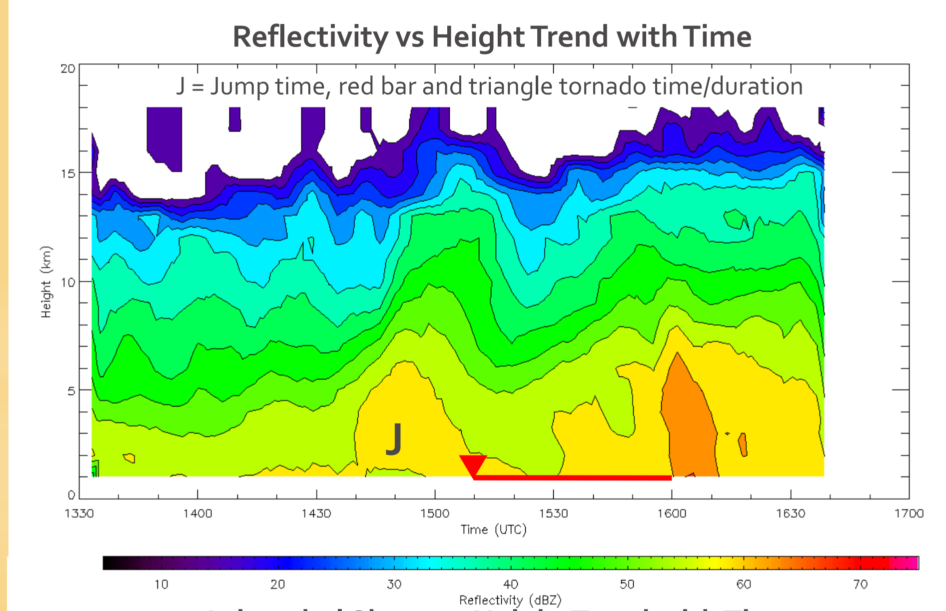
<u>Increases in flash rate</u> concurrent with <u>increases in storm rotation</u>

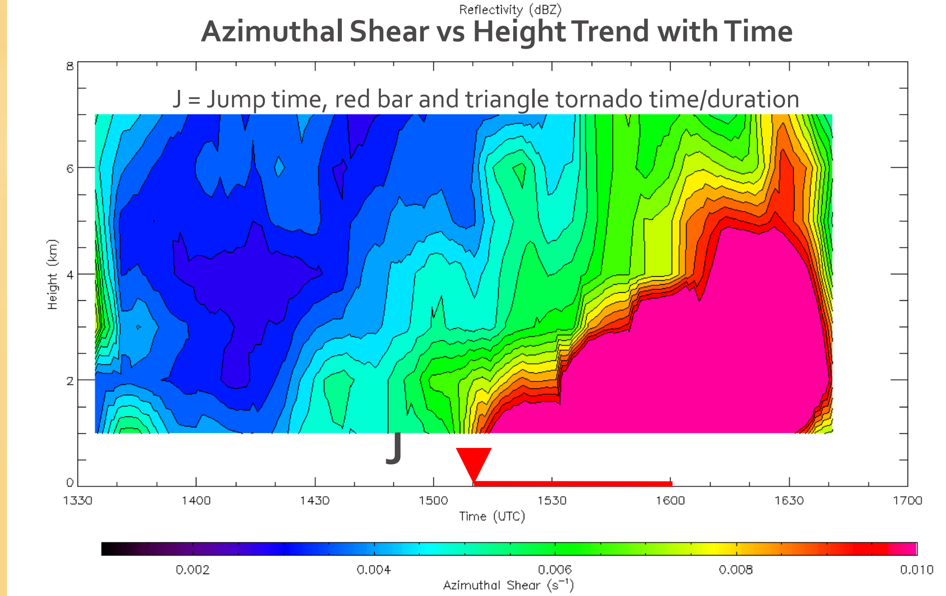
Lightning jump "Tips the scale"

- 1451 UTC – NWS Huntsville Issues Warning
  - Forecaster notes rapid increase in lightning
- First reports of severe weather 1520 UTC (wind damage)
  - Tornadic debris sig. observed on ARMOR at 1513 UTC
- Lead time on events: 1" hail 7, minutes, tornado, 20 minutes



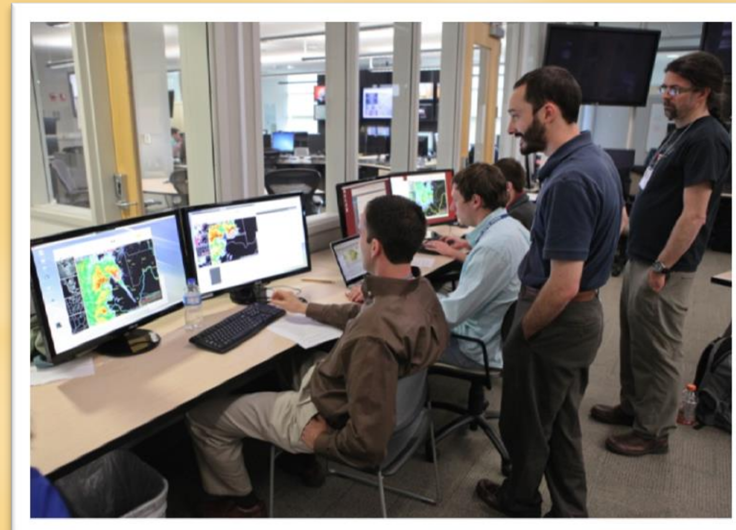


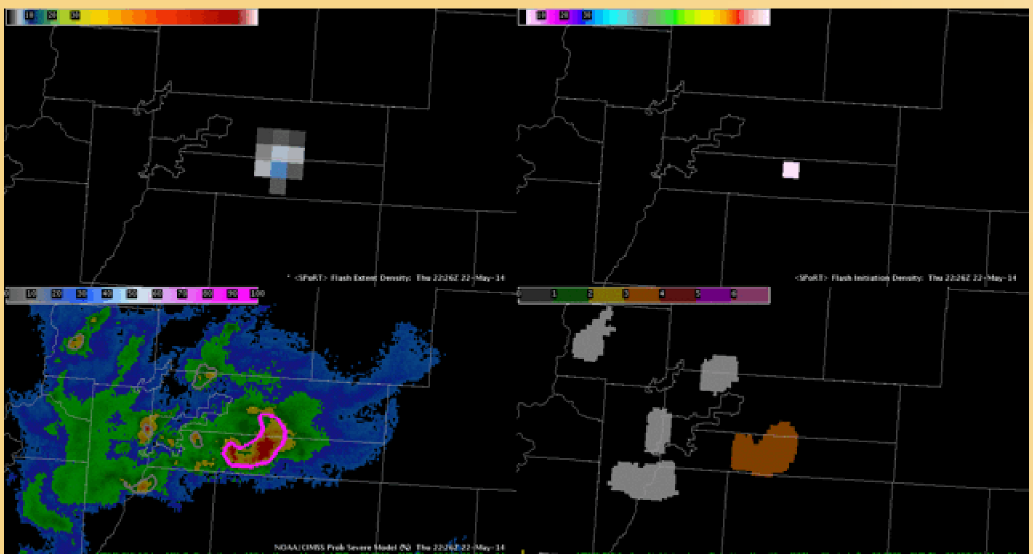


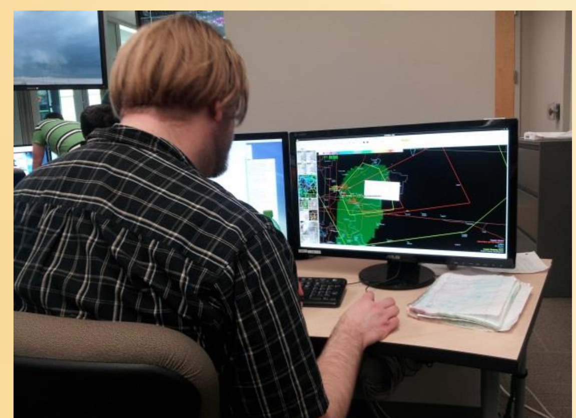


Hazardous Weather Testbed (HWT)

- Previously evaluation performed in select local offices. In 2014, Lightning Jump was evaluated in the HWT
  - Program included NWS forecasters with some or no lightning jump experience







Comments from the 2014 Lightning Jump Evaluation:

“When I saw the jump and maybe a couple scans in a row, I was confident to issue a severe t'storm warning. It also drew my eye to the storm in general!”

“The jumps were very helpful in identifying quickly intensifying storms. ... it provided valuable information that, to my knowledge, is not displayed elsewhere.”

“I really think this could be one of the most valuable tools in WFO operations. Once a jump - or more precisely a series of jumps occurred - there seem to be excellent correlation to an increase in storm intensity.”

Slide Courtesy of K. Calhoun

Acknowledgments

- Steve Goodman, NOAA/NESDIS/GOES-R Program Office, Greenbelt, MD
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- Dan Cecil, NASA/MSFC, Huntsville, AL
- Monte Bateman, USRA, Huntsville, AL