The Temporal and Probabilistic Relationship between Lightning Jump Occurrence and Radar-Derived Thunderstorm Intensification

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The Lightning Jump

- Rapid increases in total lightning (i.e., “lightning jumps”) are physically related to updraft intensification and well-correlated to severe weather occurrence.
  - Williams et al. 1999, Schultz et al. 2009, Gatlin and Goodman 2010, Schultz et al. 2015

1) Helps NWS forecasters identify rapid intensification of storms.

2) Increases forecaster confidence in a warning decision

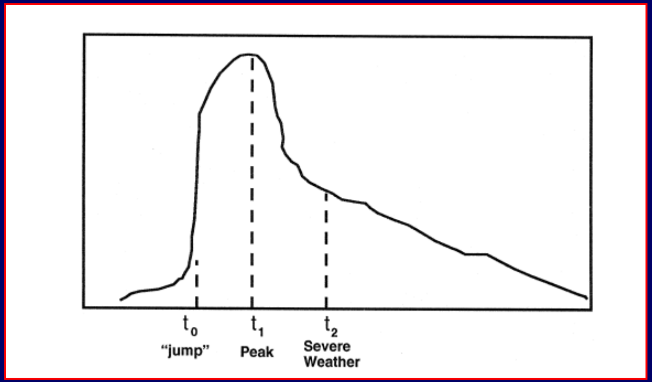


Figure credit : Williams et al. 1999, Atmos. Res.

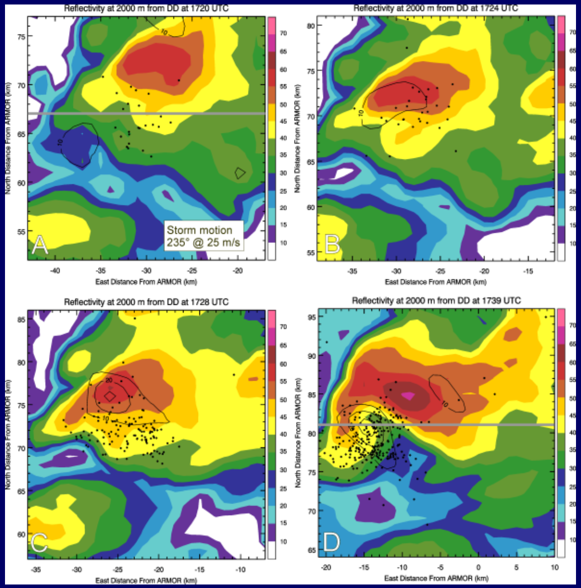
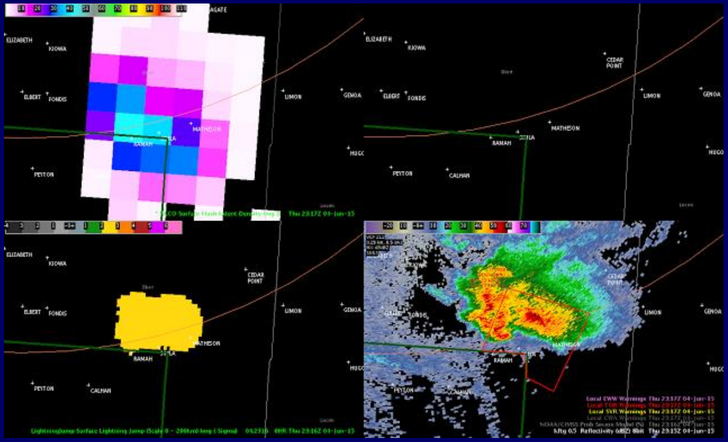


Figure credit : Schultz et al. 2015, WAF

The Lightning Jump Algorithm

- Automated detection of these rapid increases in total lightning have been a focus now for over a decade
  - Current version used is the “2σ” algorithm (Schultz et al. 2009, 2011)
- Recent work has focused on implementation within the NWS framework.



Images courtesy GOES-R Hazardous Weather Testbed blog

Motivation

- NWS wants fused decision making tools which combined observations and NWP.
  - Goal: Increase the amount of information a forecaster can use for decisions without increasing the work load.

- What is the potential impact of fusing the lightning jump in datasets and algorithms used in severe weather forecasting?

Multi-Radar MultiSensor (MRMS) and ProbSevere

- MRMS – National Severe Storms Laboratory product which combines data streams from radar, satellite, lightning, models, and rain gauges to produce gridded output every 2 minutes readily available to National Weather Service offices for improved decision making.
  - Some products include:
    - Reflectivity
    - Maximum expected size of hail (MESH)
    - Azimuthal Shear (AzShear)

Image from http://www.nssl.noaa.gov/tools/decision/

- ProbSevere – NOAA/CIMSS product which uses a statistical model to predict the probability that a storm will first produce severe weather in the near term (next 60 minutes).
  - Uses radar, model output and satellite derived information to calculate probabilities (e.g., cloud top cooling, MESH, CAPE) of a storm becoming severe. (Cintineo et al. 2014)

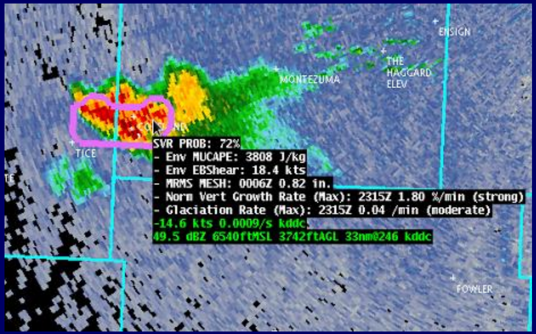
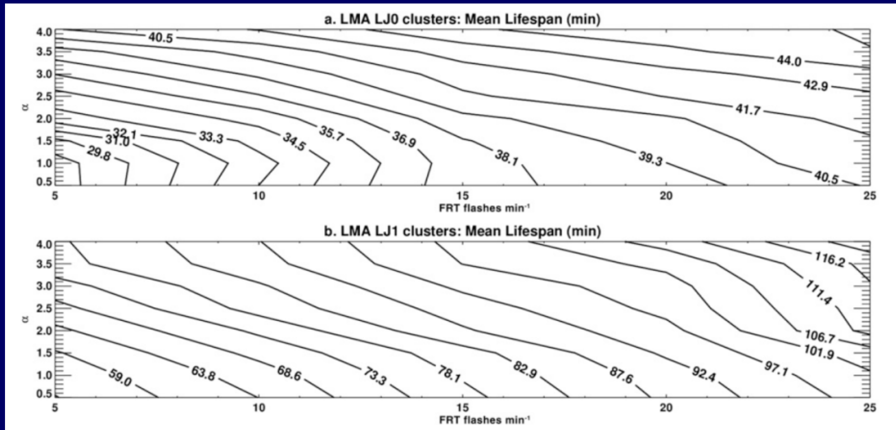
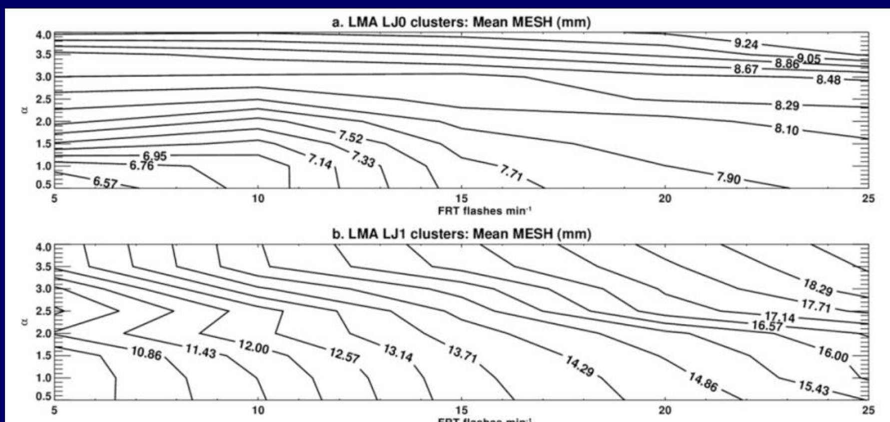


Image courtesy of the GOES-R HWT Blog

Previous Work



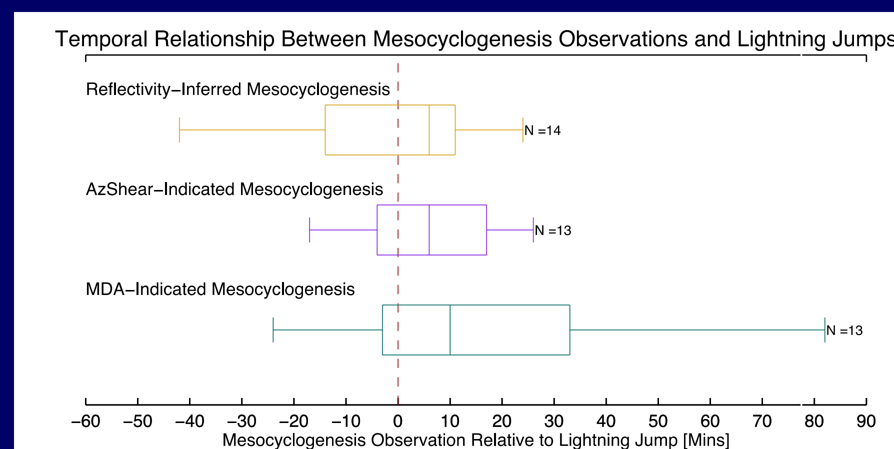


Chronis et al. (2015)

- Thunderstorms with lightning jumps had larger mean MESH values and lasted longer than storms without lightning jumps

Stough (2015)

- Over half of the time, mesocyclogenesis occurs 6-8.5 minutes after the 1st lightning jump occurrence.



Data and Tools

- 1501 tracked thunderstorms from Schultz (2015) with storm based radar, lightning and severe weather characteristics.
  - Total lightning data from 4 lightning mapping arrays.
  - The Thunderstorm Identification Tracking, Analysis, and Nowcasting (TITAN; Dixon and Wiener 1993) was the tracking algorithm.
  - Warning Decision Support System-Integrated Information (WDSS-II) produced gridded reflectivity, MESH and AzShear.
  - Severe weather reports were taken directly from the National Climatic Data Center severe report database.

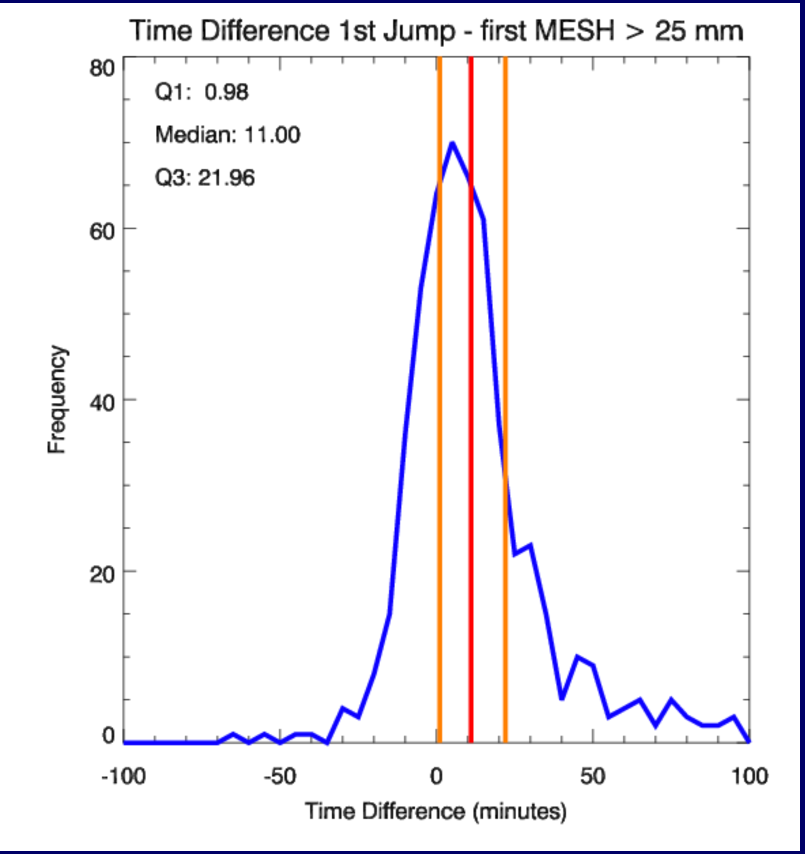
Question 1: The conditional probability that a storm has MESH ≥ 25.4 mm and at least 1 lightning jump?

- 1105 of 1501 storms had MESH ≥ 25.4 mm (74%).
  - 396 storms do not have MESH exceed 25.4 mm.
- 630 of the 1501 storms had at least 1 lightning jump (42%).
  - 871 storms do not contain at least 1 lightning jump.
- 583 of 1501 have at least 1 lightning jump and MESH≥ 25.4 mm (39%).

Question 2: What is the timing of the first MESH ≥ 25.4 mm and the first lightning jump?

- 537 of the 583 storms with MESH and 1 jump were tracked prior to the flash rate reaching 15 fpm.

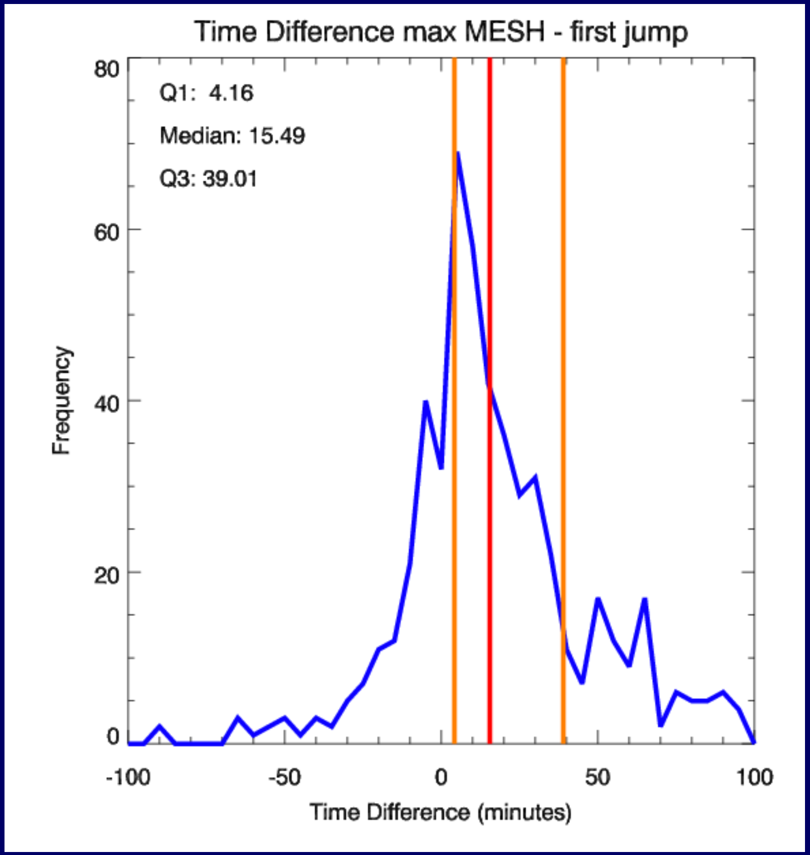
- 25th percentile - 1 minute
- Median - 11 minutes
- 75th percentile - 22 minutes



Question 3: What is the difference in timing of the maximum MESH and the first lightning jump?

- When does the maximum in MESH (i.e., intensity) occur relative to the 1st jump?

- 25th percentile - 4 minutes
- Median - 16 minutes
- 75th percentile - 39 minutes



Question 4 – What is the verification of these parameters using severe weather reports?

- If MESH ≥ 25.4 mm was observed what is the probability the storm was severe:
  - POD 428/453 = 94%
  - FAR 677/1105 = 61%

- If a lightning jump was observed, what is the probability the storm was severe:
  - POD 342/453 = 76%
  - FAR 288/630 = 46%

- If MESH ≥ 25.4 mm and a lightning jump were observed what is the probability the storm was severe:
  - POD 334/453 = 74%
  - FAR 249/583 = 43%

Question 5 – What if objective metrics for severe weather were used?

- If MESH ≥ 25.4 mm was considered "severe" and lightning jump used to objectively warn:
  - POD 583/1105 = 53%
  - FAR 47/630 = 7%

- If a lightning jump was considered "severe" and MESH ≥ 25.4 mm was used to objectively warn:
  - POD 583/630 = 93%
  - FAR 583/1105 = 47%

Summary

- The inclusion of the lightning jump has the potential to reduce FAR in a fused algorithm like ProbSevere.
- Relative to future fusion of algorithms and forecasting using multiple parameters the general conceptual model for timing of events should be:
  1. First MESH ≥ 25.4 mm
  2. Lightning jump
  3. Maximum MESH/Severe weather