Developing an Enhanced Lightning Jump Algorithm for Operational Use

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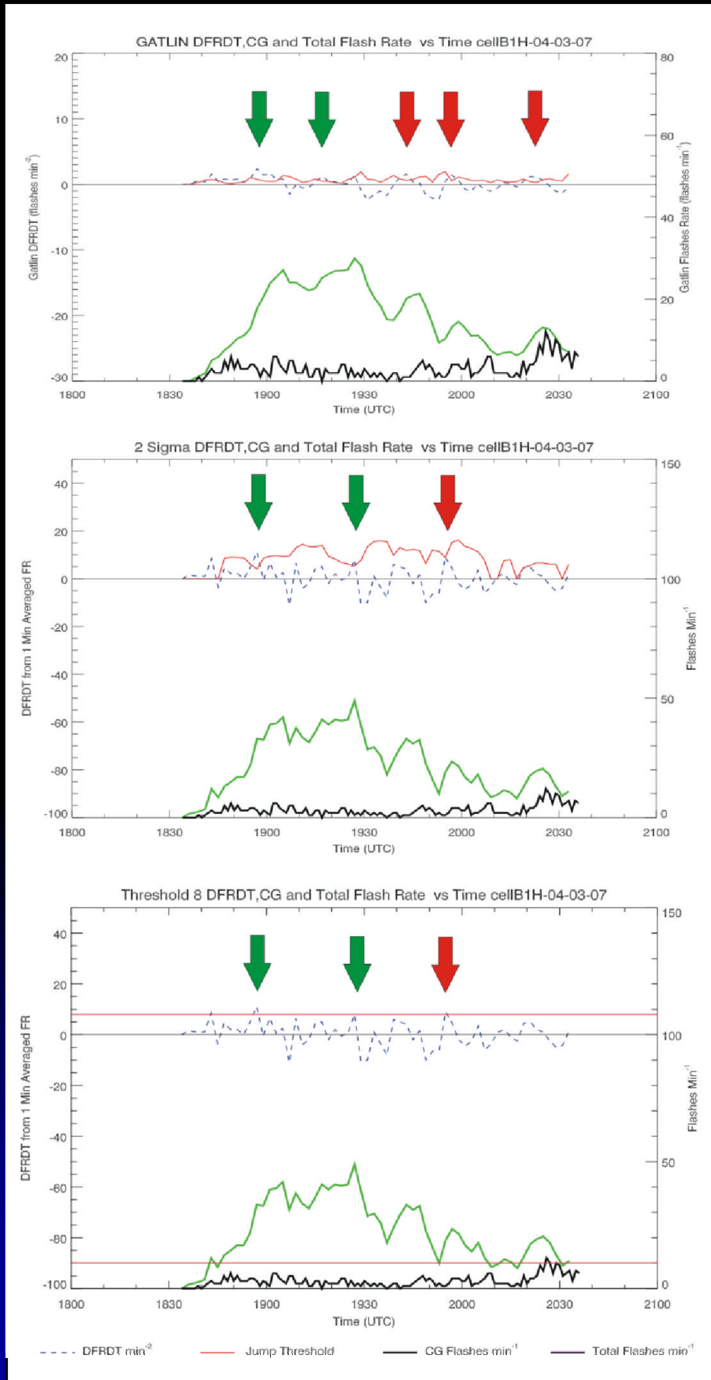
Overall Goals

1. Build on the lightning jump framework set through previous studies.
2. Understand what typically occurs in non-severe convection with respect to increases in lightning.
3. Ultimately develop a lightning jump algorithm for use on the Geostationary Lightning Mapper (GLM)
   - Also for NWS offices with ground based lightning mapping networks available.

Previous Work: Lightning Jump Algorithms

- Gatlin (2006), Gatlin and Goodman (2009) demonstrated that there is utility of total lightning data in severe weather discrimination
  - This method uses the rate of change of the total flash rate (DFRDT).
- Gatlin (2006) developed a “strawman” lightning jump algorithm (LJA) to work toward the development of an operationally applicable algorithm in the future.
- Results were promising for severe weather but:
  - Untested against non-severe thunderstorms
  - High FAR (~50%)
- Four additional algorithm configurations have been created in addition to the Gatlin algorithm for testing on severe and non-severe thunderstorms.



Additional Algorithms and Verification

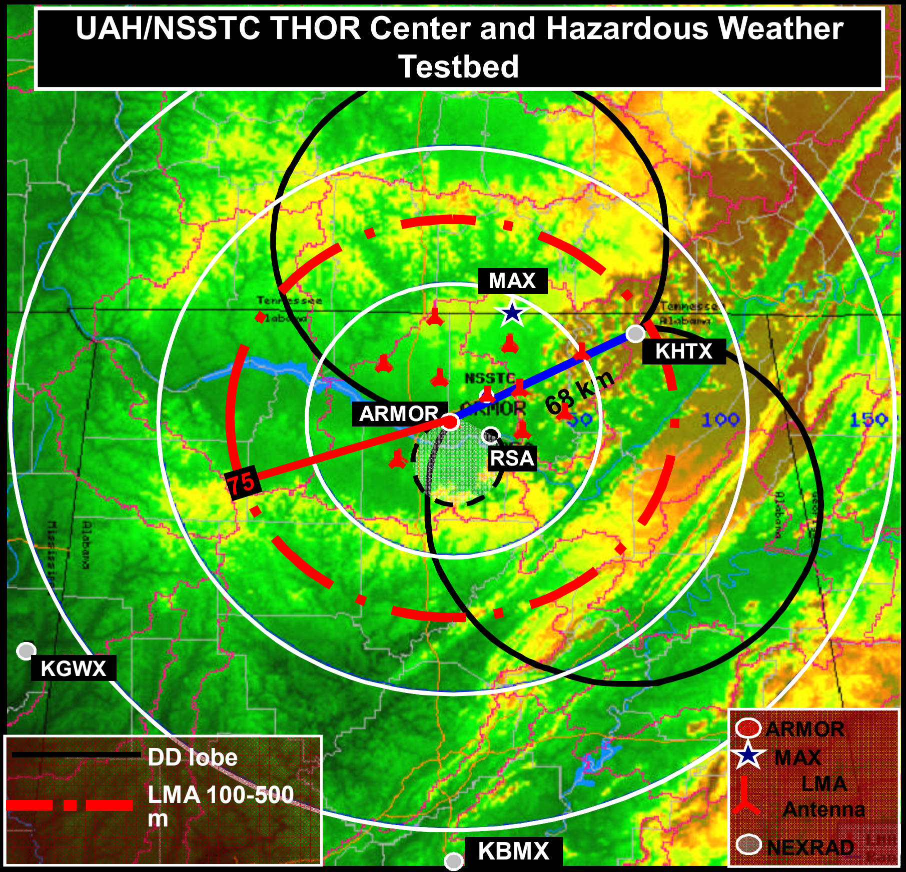
- Four additional algorithms were developed for testing
  - **2σ**
  - **3σ**
  - **Threshold 10**
  - **Threshold 8**

For more information see Schultz et al. 2009, JAMC

- Once a lightning jump is determined to have occurred a “severe warning” is placed on the thunderstorm for 45 minutes
  - One severe weather event cannot verify two warnings
    - earliest warning is used for verification
  - The Gatlin algorithm was also tested at a 30 minute warning length to compare with Gatlin (2006) results

Study Domains

- Two primary Geographic regions
  - North Alabama
    - Period of study from August 2002-February 2008
  - Washington D.C. metro area
    - Two cases taken from this area
      - **July 4, 2007**
      - **July 16, 2007**
- All thunderstorms must occur within 150 km of the LMA center



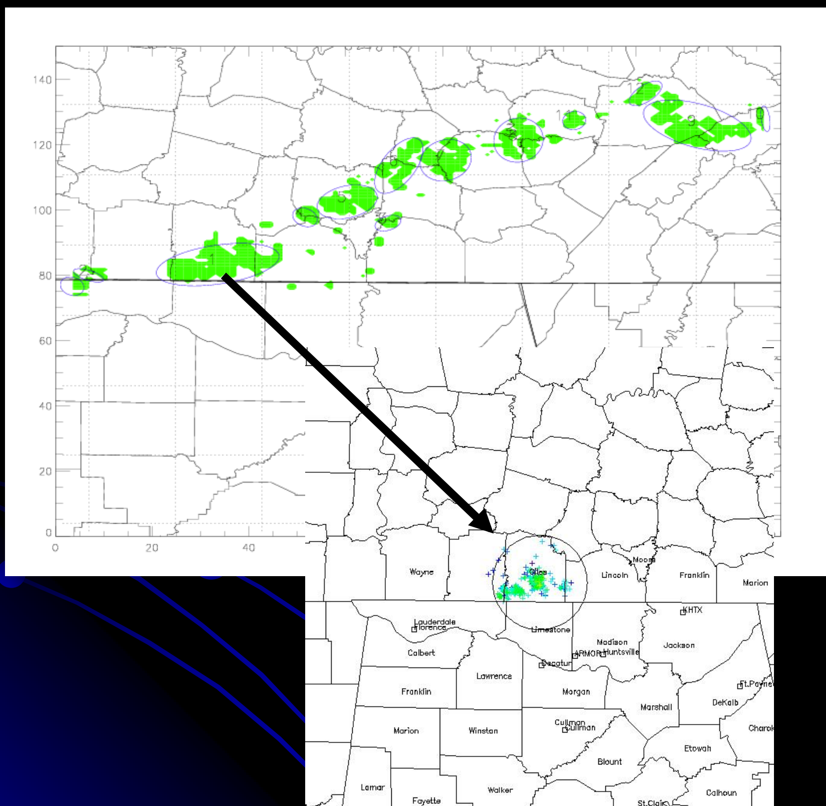
Severe and non-severe thunderstorms used in this study

- **38 Severe Thunderstorms**

  122 Severe weather reports

- **47 Isolated non-severe thunderstorms from N. AL**

Identification and Tracking



Above: TITAN image from 4 April 2007 at 0306 UTC and plot of total flashes identified with this storm

- The Thunderstorm Identification, Tracking, and Nowcasting (TITAN) algorithm

  (Dixon and Wiener 1993)

- Identifies storm characteristics over time:
  - a storm center (lat/lon)
  - a major axis
- Storm characteristics used to count flashes

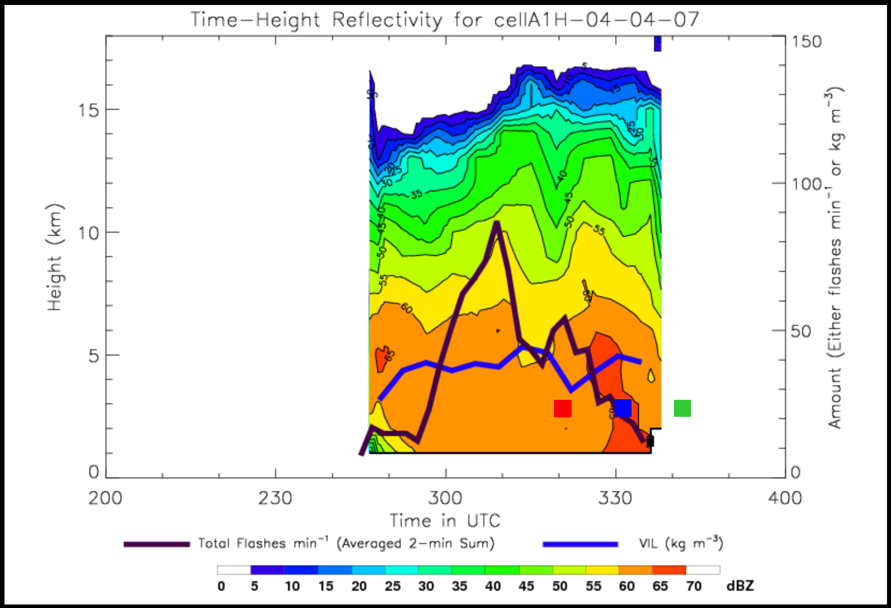
Algorithm Evaluation

- Non-severe thunderstorms
  - (47 North Alabama cases)

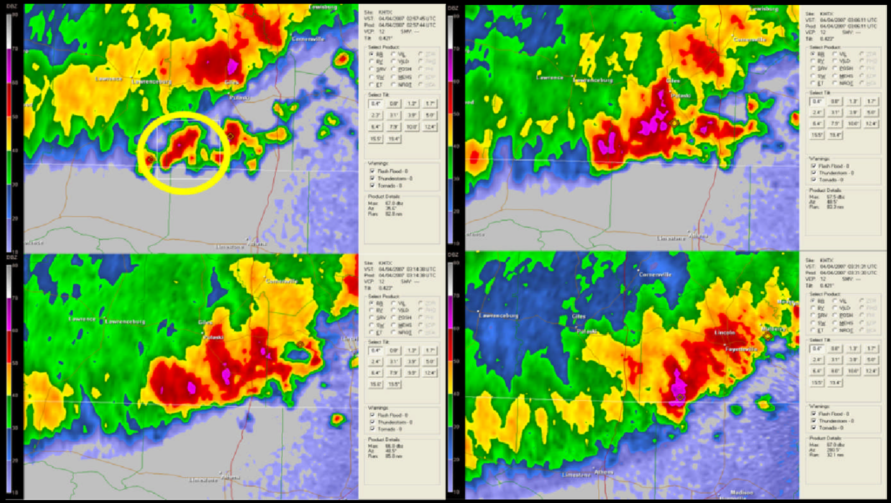
Algorithm	Gatlin	2 Sigma	3 Sigma	Threshold 10	Threshold 8
False Alarms (<100 km) (45 storms)	97	16	10	6	7
False Alarms (<150 km) (47 storms)	101	16	10	6	7

- Each algorithm produces a number of false alarms
  - The Gatlin Algorithm's large number of false alarms are due to its high sensitivity to low flash rates.
- False alarms were expected since there is *NOT* a hard boundary separating severe storms from non-severe.
- **The false alarm values are included the skill score statistics shown later.**

April 4, 2007, MCS



Above: Time height plot of reflectivity, flash rate (purple) and VIL (blue).



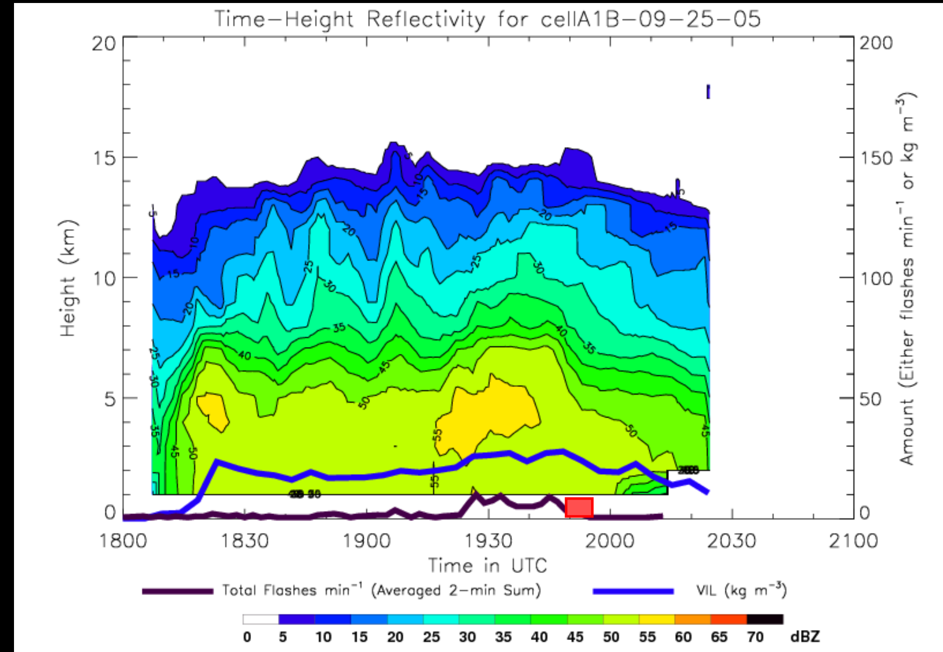
Above: 4 panel of reflectivity images at 0245, 0306, 0314 and 0331 UTC.

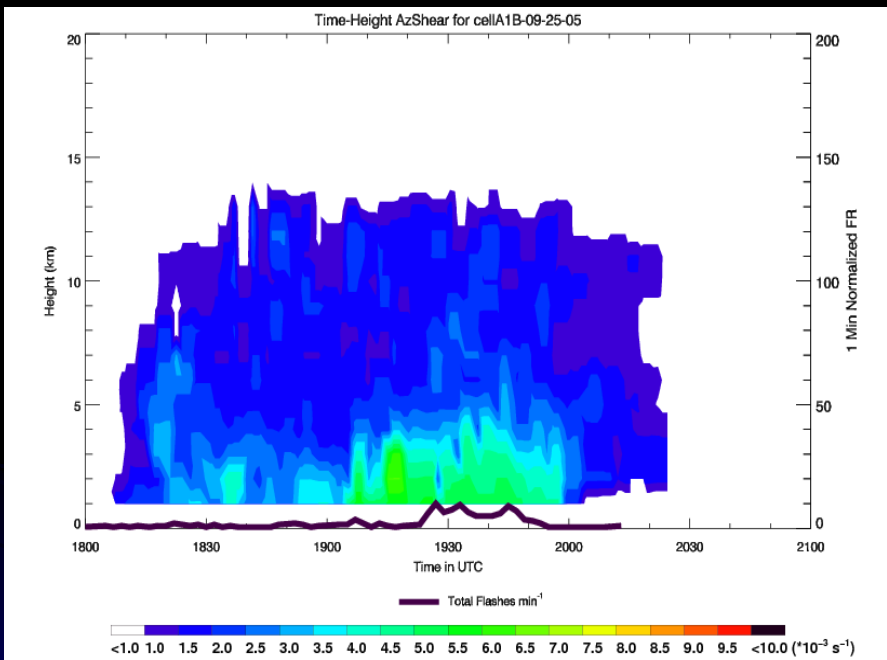
	Gatlin 45	2 Sigma	3 Sigma	Threshold 10	Threshold 8
Hits	3	3	3	3	3
False Alarm	0	0	0	1	1
Misses	0	0	0	0	0

Left: Table of hits, false alarms and misses for each algorithm

Case Example

September 25, 2005
Thunderstorm A (tropical)





Above: Time height plot of reflectivity, total lightning (purple) and VIL (blue)

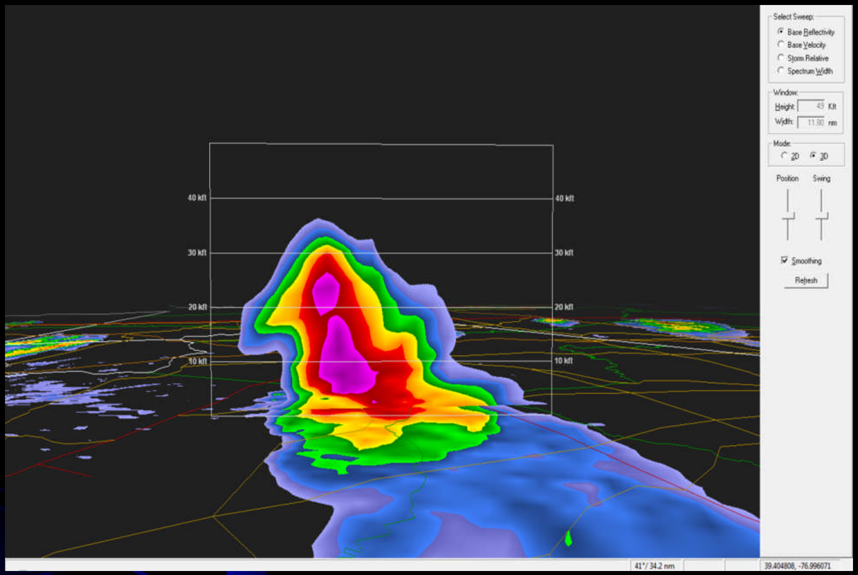
Left: Time height plot of azimuthal shear

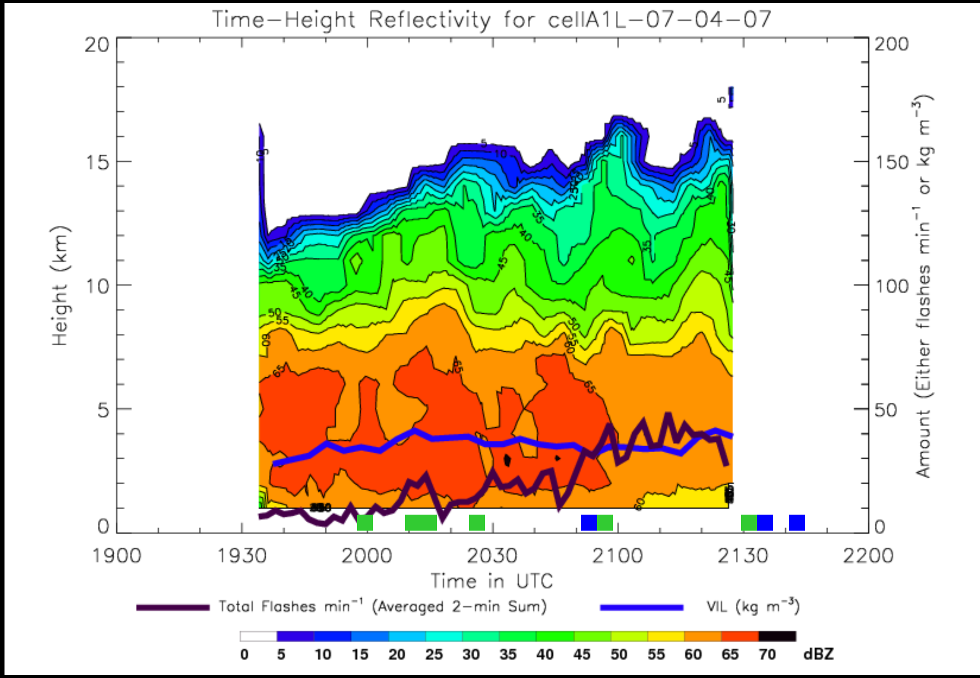
Right: table of hits, misses and false alarms

	Gatlin 45	2 Sigma	3 Sigma	Threshold 10	Threshold 8
Hits	1	1	1	0	0
False Alarm	3	0	0	0	0
Misses	0	0	0	1	1

Case example

July 4, 2007
(small supercell)





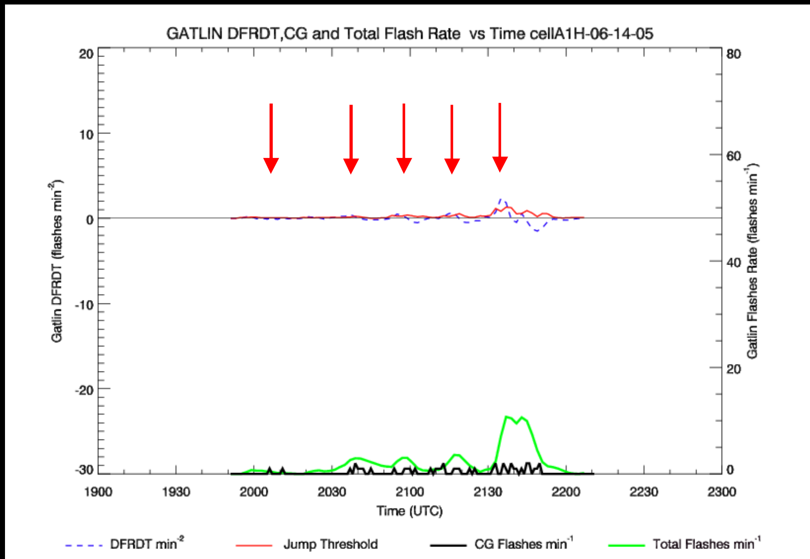
Above: Time/height plot of reflectivity, flash rate (purple) and VIL (blue).

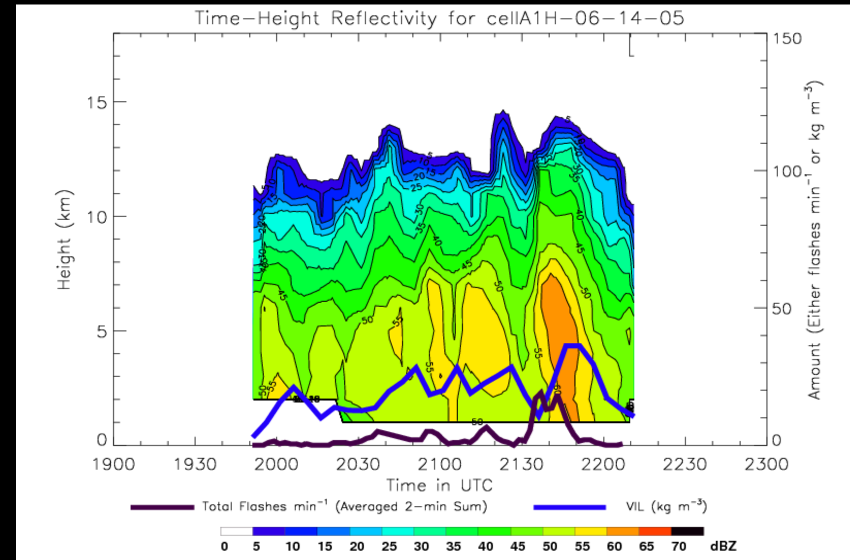
Left: A cross section from KLWX of the supercell at 2016 UTC, 12 minutes before large hail at the surface. The cross section is 12 km wide

Right: Table of hits, false alarms and misses.

	Gatlin 45	2 Sigma	3 Sigma	Threshold 10	Threshold 8
Hits	6	3	2	3	5
False Alarm	3	1	0	1	1
Misses	0	3	4	3	1

June 14 2005, Airmass Thunderstorm



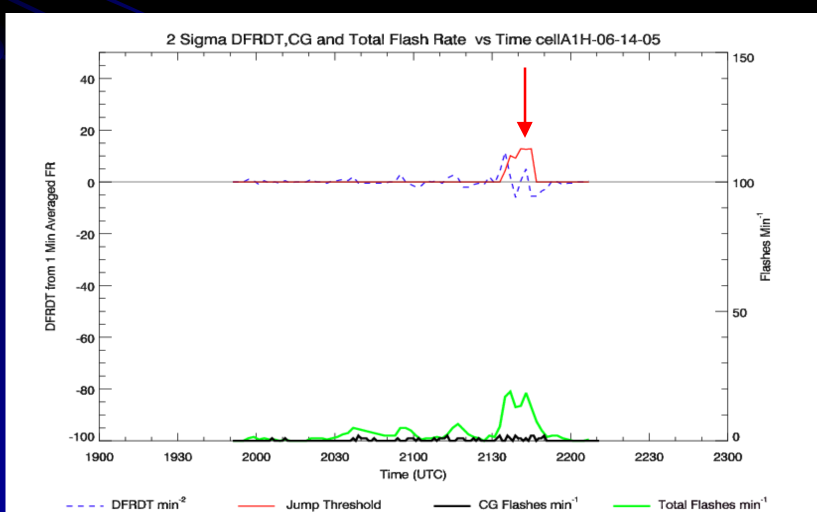


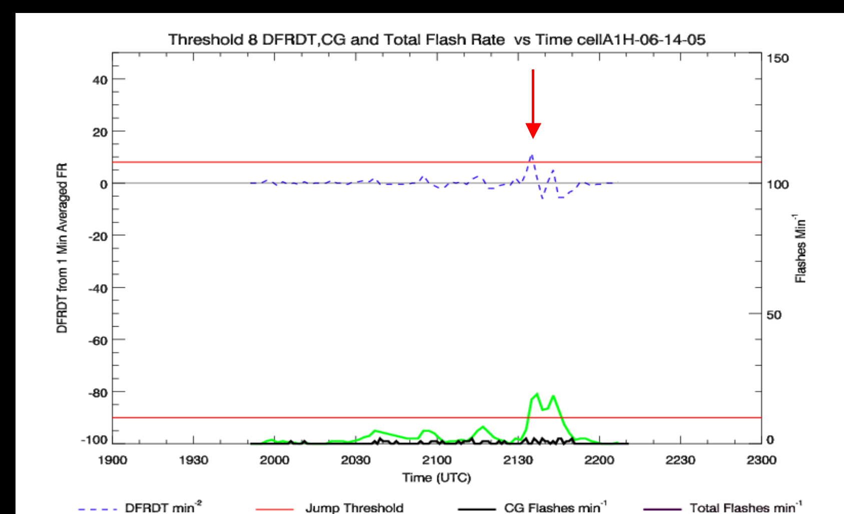
Above: Gatlin Algorithm output

Below: 2σ algorithm output

Above: Time-height of reflectivity

Below: Threshold 8 algorithm output





Evaluation of Algorithm Configurations

- Tested on 85 Thunderstorms (38 Severe, 47 Non-severe
  - Severe Thunderstorms: 38 cases, 122 events, <150 km
- The 2σ configuration yielded the highest results
  - NWS warning statistics (Barnes et al. 2007; WCM Tim Troutman)
    - POD – 80-90%
    - FAR – 48%

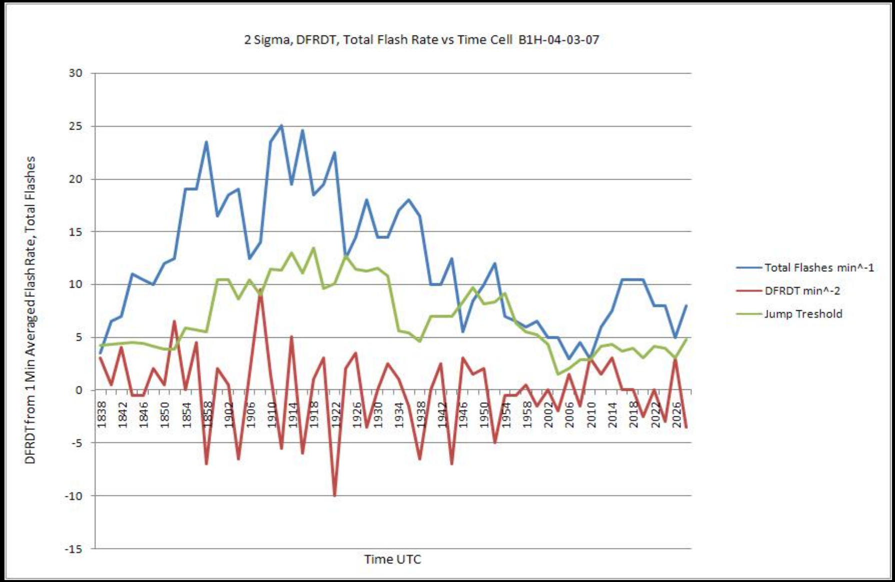
Algorithm	POD	FAR	CSI	HSS
Gatlin	90%	66%	33%	0.49
Gatlin 45	97%	64%	35%	0.52
2σ	87%	33%	61%	0.75
3σ	56%	29%	45%	0.65
Threshold 10	72%	40%	49%	0.66
Threshold 8	83%	42%	50%	0.67

Conclusions

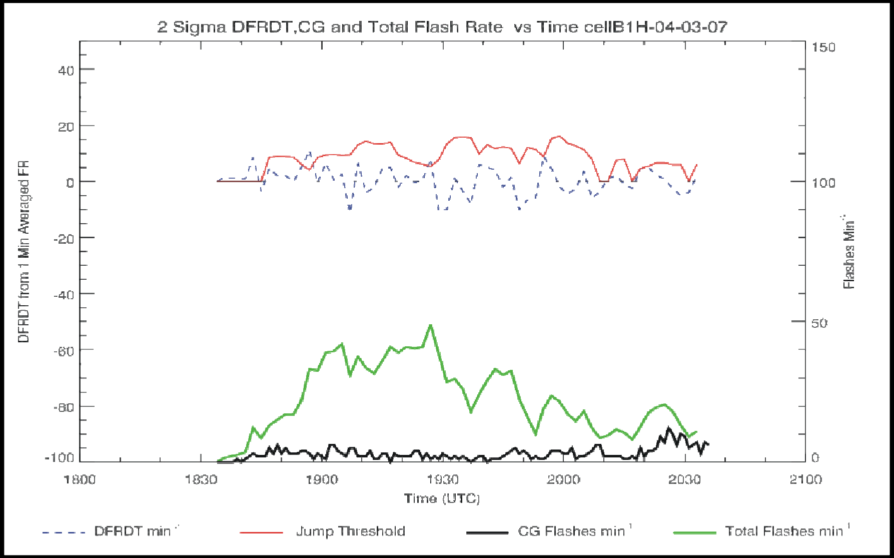
- 4 Lightning jump algorithm configurations were developed (2σ, 3σ, Threshold 10 and Threshold 8)
- 5 algorithms were tested on a population of 47 non-severe and 38 severe thunderstorms
- Results indicate that the 2σ algorithm performed best over the entire thunderstorm sample set with a POD of 87%, a far of 35%, a CSI of 59% and a HSS of 75%.
- See Schultz et. al 2009, JAMC for more information (in press)

Future Work

- **Increase the number of thunderstorms variety of thunderstorm types and locations**
  - Addition of more DC LMA cases (NE US) and cases from the STEPS field program (Mid-Western US).
  - Expansion to other regimes with LMAs and LDARS: Oklahoma (Mid-West), Kennedy Space Center (ST SE US), Socorro and/or White Sands, NM, Tucson, AZ (Desert SW).
- **Application of jump algorithms to recently developed GLM proxy flash products (LMA-LIS based) for algorithm tuning**



Above: Time history of a thunderstorm from April 3, 2007 using GLM proxy flashes. **Below:** 2σ algorithm for the same thunderstorm.



Questions, Comments?

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EXTRA SLIDES

Additional Algorithms for potential improvement of LJA

- 2σ algorithm
  - Higher jump threshold than Gatlin algorithm
    - Lowers FAR
  - 10 flashes min^{-1} minimum must be met to initialize
    - Based on average peak flash rate of 69 non-severe thunderstorms.
  - Longer flash history required to determine jump
    - 10 minutes of data needed for 2σ, as compared to 6 minutes using Gatlin.
- 3σ algorithm
  - Even higher jump threshold than Gatlin and 2σ
    - Lowers FAR even more, however, will also lower POD
  - Same 10 flashes min^{-1} criteria must be met.
  - Same observation period needed as in 2σ

Additional Algorithms (continued)

- Threshold Algorithms
  - Using observed peak flash rates and peak DFRDT rates from 69 non-severe thunderstorms two threshold algorithms are tested
- Threshold 8 Algorithm
  - A value of 10 flashes min^{-1} and a DFRDT value of 8 flashes min^{-2} must be met for a lightning jump.
- Threshold 10 Algorithm
  - A value of 10 flashes min^{-1} and a DFRDT value of 10 flashes min^{-2} must be met for a lightning jump.
- Once a lightning jump occurs, a "severe warning" is placed on the storm for 45 minutes.