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
  - $2\sigma$
  - $3\sigma$
  - Threshold 10
  - Threshold 8

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

For more information see Schultz et al. 2009, JAMC
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

- 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

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

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

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Gatlin</th>
<th>2 Sigma</th>
<th>3 Sigma</th>
<th>Threshold 10</th>
<th>Threshold 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>False Alarms (&lt;100 km) (45 storms)</td>
<td>97</td>
<td>16</td>
<td>10</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>False Alarms (&lt;150 km) (47 storms)</td>
<td>101</td>
<td>16</td>
<td>10</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

- 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 in 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.

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

<table>
<thead>
<tr>
<th></th>
<th>Gatlin 45</th>
<th>2 Sigma</th>
<th>3 Sigma</th>
<th>Threshold 10</th>
<th>Threshold 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>False Alarm</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Misses</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
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<th>2 Sigma</th>
<th>3 Sigma</th>
<th>Threshold 10</th>
<th>Threshold 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>False Alarm</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Misses</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
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.

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<th>2 Sigma</th>
<th>3 Sigma</th>
<th>Threshold 10</th>
<th>Threshold 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>False Alarm</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Misses</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
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 $2\sigma$ configuration yielded the highest results
  - NWS warning statistics (Barnes et al. 2007; WCM Tim Troutman)
    - POD – 80-90%
    - FAR – 48%

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>POD</th>
<th>FAR</th>
<th>CSI</th>
<th>HSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatlin</td>
<td>90%</td>
<td>66%</td>
<td>33%</td>
<td>0.49</td>
</tr>
<tr>
<td>Gatlin 45</td>
<td>97%</td>
<td>64%</td>
<td>35%</td>
<td>0.52</td>
</tr>
<tr>
<td>$2\sigma$</td>
<td>87%</td>
<td>33%</td>
<td>61%</td>
<td>0.75</td>
</tr>
<tr>
<td>$3\sigma$</td>
<td>56%</td>
<td>29%</td>
<td>45%</td>
<td>0.65</td>
</tr>
<tr>
<td>Threshold 10</td>
<td>72%</td>
<td>40%</td>
<td>49%</td>
<td>0.66</td>
</tr>
<tr>
<td>Threshold 8</td>
<td>83%</td>
<td>42%</td>
<td>50%</td>
<td>0.67</td>
</tr>
</tbody>
</table>
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

Questions, Comments?

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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.**