Algorithmic approach for detecting bolides with GLM

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GLM Bolide TIM
Lockheed Martin,
Feb 7th 2019
Historical Note

One planned sensor system which undoubtedly will prove to have an extremely good capability for detecting and locating meteoroid impacts is the NASA Lightning Mapper. This instrument, developed by the Marshall Space Flight Center for the Geostationary Observational Environmental Satellites (GOES) weather satellites [...].

Bolide vs Lightning Signature

### Bolide

- **Distance:** 12.29 km
- **Velocity:** 14.39 km/s

### Lightning

- **Distance:** 14.03 km
- **Velocity:** 16.66 km/s

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**Graphs:**

- **Bolide:**
  - **Graph (a):** Latitude vs Longitude
  - **Graph (b):** Luminous Energy vs Time
  - **Details:** T=0.854s

- **Lightning:**
  - **Graph (a):** Latitude vs Longitude
  - **Graph (b):** Luminous Energy vs Time
  - **Details:** T=0.842s

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**Dates:**

- **Bolide:** 18-09-17 01:08:01
- **Lightning:** 18-05-20 00:01:26
Definition: Flash – Group – Event
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Processing Pipeline

- L2 Data
- Extract Groups
  - Ground Track
  - Light Curve

Multiple tests assess similarity with bolide signature

- Ground Track Straightness
- Regularity of Light Curve
- Energy Profile
- ...

Bolide Candidate Bucket

Bolide-similar?
- Yes
  - Bolide Candidate Bucket
- No
  - Discarded
Algorithm Architecture
Filter Functions

- **Group Count Filter**
  - Score vs. Group Count

- **Line Fit Residual Filter**
  - Score vs. Mean Residual

- **Energy Balance Filter**
  - Score vs. Energy Balance Ratio

- **Line Distance Ratio Filter**
  - Score vs. Distance Ratio

- **Polynomial Fit Filter**
  - Score vs. Mean Fit Residual

- **Signature Duration Filter**
  - Score vs. Duration

Categories:
- Meta
- Ground Track
- Light Curve
Filter 1: Group Count

- 8864 flashes
- 3 minutes and 20 seconds worth of data
Filter 1: Group Count

- 8864 flashes
- 3 minutes and 20 seconds worth of data
Filter 2: Line Fit

Lightning

Bolide

14.03 km
16.66 km/s

9.81 km
90.79 km/s
Filter 3: Energy Balance
Filter 4: Line Distance

Lightning

Bolide

12.29 km
14.39 km/s

9.81 km
90.79 km/s
Filter 4: Line Distance

**Lightning**

- 0.34 km
- 0.07 km/s

**Bolide**

- 12.29 km
- 14.39 km/s

- 9.81 km
- 90.79 km/s
Filter 5: Polynomial Fit

Lightning

Bolide

(a) 1.202s

18-05-08 02:27:12

(b) T=5.084s

18-05-30 06:56:41
Performance

- In performance test, algorithm identified an interesting signature in 1.44% of the input files.
  - 144845 files (34 days worth of data)
  - 2252 flagged files

- A human has to look at data to judge if true or false positive.

Likely meteor discovered by algorithm

- 12.25 km
- 59.48 km/s

Ground Track Lat/Lon

Light Curve

1e-14

0.206s

18-07-30 14:09:12
## Performance in November

<table>
<thead>
<tr>
<th>Date/Time (UT)</th>
<th>Julian day</th>
<th>Latitude (deg)</th>
<th>Longitude (deg)</th>
<th>Time Duration (sec)</th>
<th>Total Radiated Energy (J)</th>
<th>Available Data sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/1/18 18:36:44</td>
<td>305</td>
<td>51.0N</td>
<td>58.9W</td>
<td>0.462</td>
<td>1.05E-11</td>
<td>GLM-16</td>
</tr>
<tr>
<td>11/3/18 12:36:21</td>
<td>307</td>
<td>5.0N</td>
<td>102.3W</td>
<td>0.155</td>
<td>1.49E-12</td>
<td>GLM-16</td>
</tr>
<tr>
<td>11/11/18 7:58:29</td>
<td>315</td>
<td>34.1N</td>
<td>35.6W</td>
<td>0.078</td>
<td>7.25E-13</td>
<td>GLM-16</td>
</tr>
<tr>
<td>11/12/18 4:58:15</td>
<td>316</td>
<td>29.1N</td>
<td>85.9W</td>
<td>0.837</td>
<td>2.09E-12</td>
<td>GLM-16, all-sky</td>
</tr>
<tr>
<td>11/15/18 8:02:44</td>
<td>319</td>
<td>42.4N</td>
<td>52.8W</td>
<td>0.877</td>
<td>1.33E-10</td>
<td>USG, GLM-16</td>
</tr>
<tr>
<td>11/20/18 12:17:52</td>
<td>324</td>
<td>34.9N</td>
<td>118.4W</td>
<td>0.36</td>
<td>9.55E-12</td>
<td>GLM-16, GLM-17, all-sky</td>
</tr>
<tr>
<td>11/22/18 13:10:46</td>
<td>326</td>
<td>33.1N</td>
<td>122.2W</td>
<td>0.324</td>
<td>1.14E-11</td>
<td>GLM-16, GLM-17, all-sky</td>
</tr>
</tbody>
</table>

![Graphs](https://via.placeholder.com/150)
Challenges

- **True Positive**
  - Challenging ground track issue
  - Rethinking of approach to handle ground track data

- **True Negative**
  - Recovered after tip-off
  - Challenging ground track
  - Atypical light curve
Feb 1\textsuperscript{st} Cuba event

- GLM based data enabled to be first to publish light curve and ground track
- Corrected initial assumption of a North \rightarrow South trajectory
Parallel Approaches

- Logistical regression model
- Neural network

- Main issues at the moment are number of training samples.
Currently Publishing

• Title: “Algorithmic Approach for Detecting Bolides with the Geostationary Lightning Mapper”

• Send me an email if interested and I will send you a copy once published.
• Clemens.rumpf@nasa.gov
Open Question

- How do we confirm if a good signature is actually a bolide?
Thanks for your attention

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