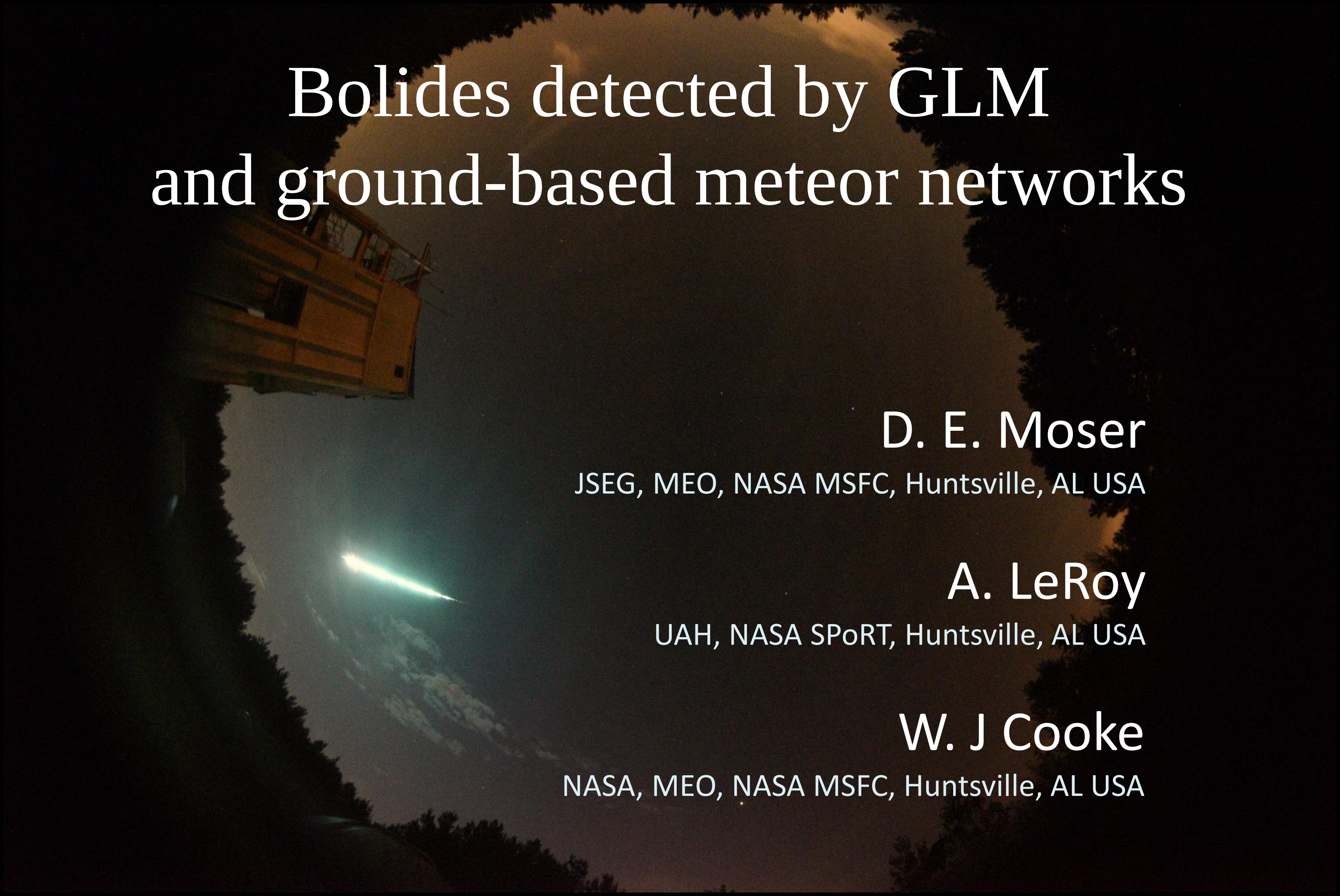

Bolides detected by GLM and ground-based meteor networks

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JSEG, MEO, NASA MSFC, Huntsville, AL USA

A. LeRoy

UAH, NASA SPoRT, Huntsville, AL USA

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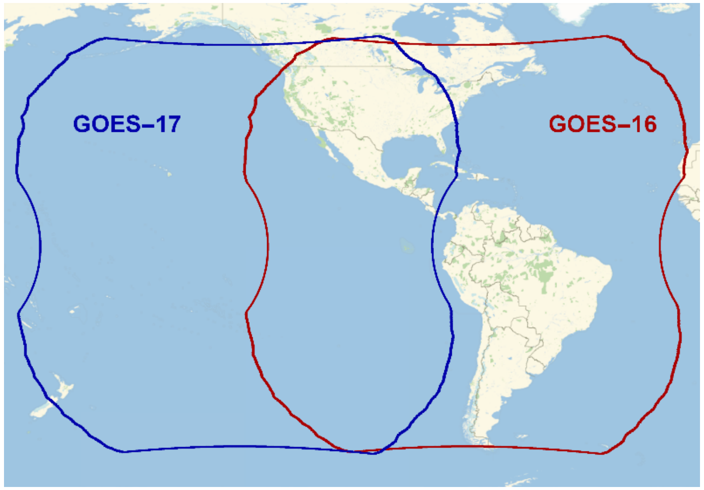
NASA, MEO, NASA MSFC, Huntsville, AL USA

Geostationary Lightning Mapper (GLM)

- Operational lightning detection instrument onboard weather satellites GOES-16 and GOES-17 in geostationary orbit
- Purpose: Continuous high-resolution measurements of transient events
  - Weather forecasting
  - Meteorology research
- Data: Publicly releases real-time L2 data
  - Google BigQuery
  - NOAA CLASS
- Data coverage/maturity:
  - GOES-16: beta 7/2017; validated 11/2018
  - GOES-17: beta 10/2018; validated 3/2019



CCD size	1372 x 1300 pixels
Spatial resolution	8 km nadir 14 km edge FOV
Passband	777.4 nm center 1.1 nm width
Exposure Frame rate	2 ms 500 fps
Latency	20 s

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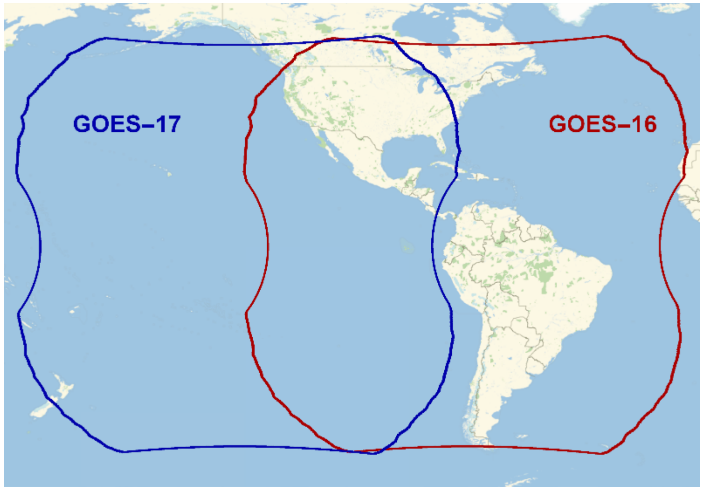

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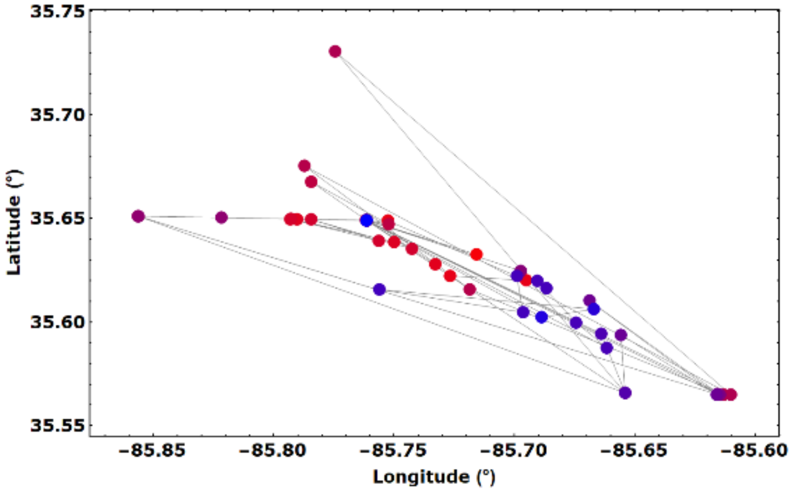
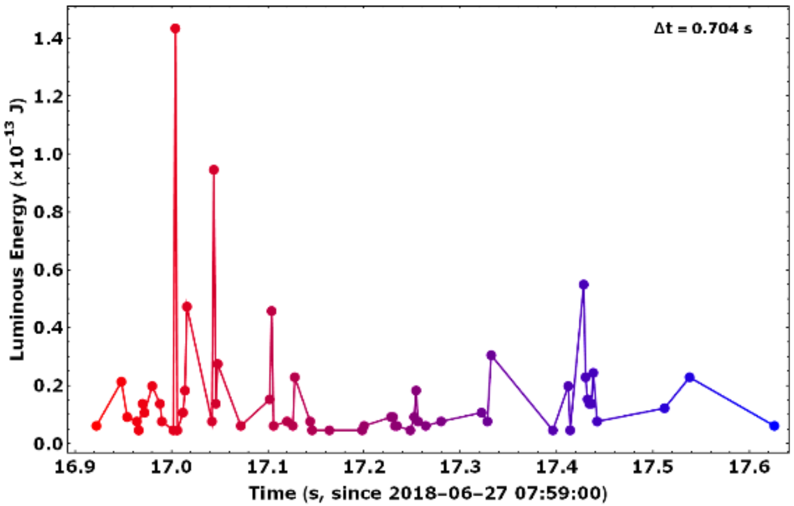
GLM is also a bolide detector

Jenniskens et al. (2018), Rumpf et al. (2019), Brown et al. (2019)

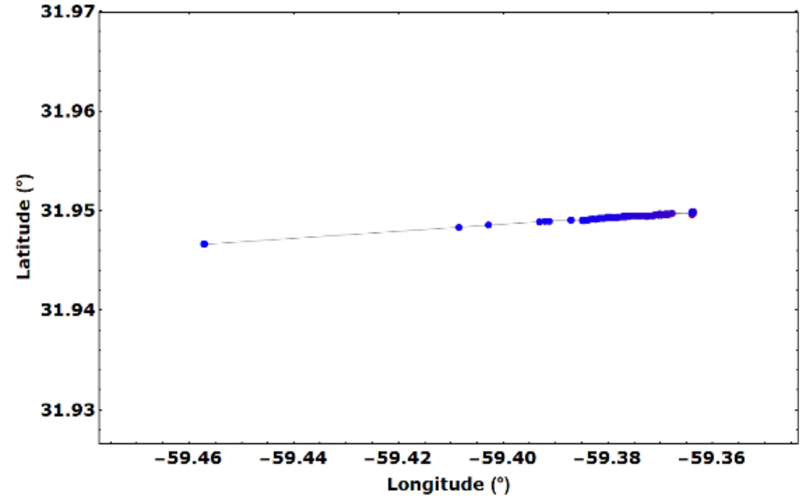
GLM detections: lightning vs. superbolide

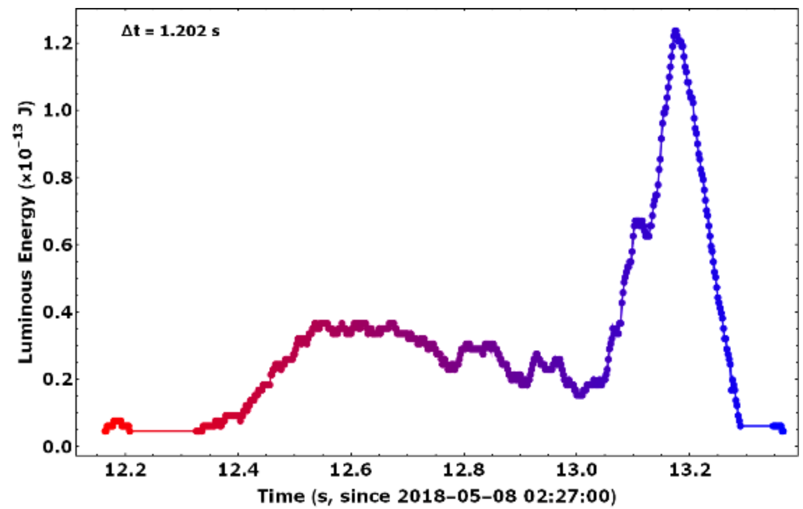
Lightning



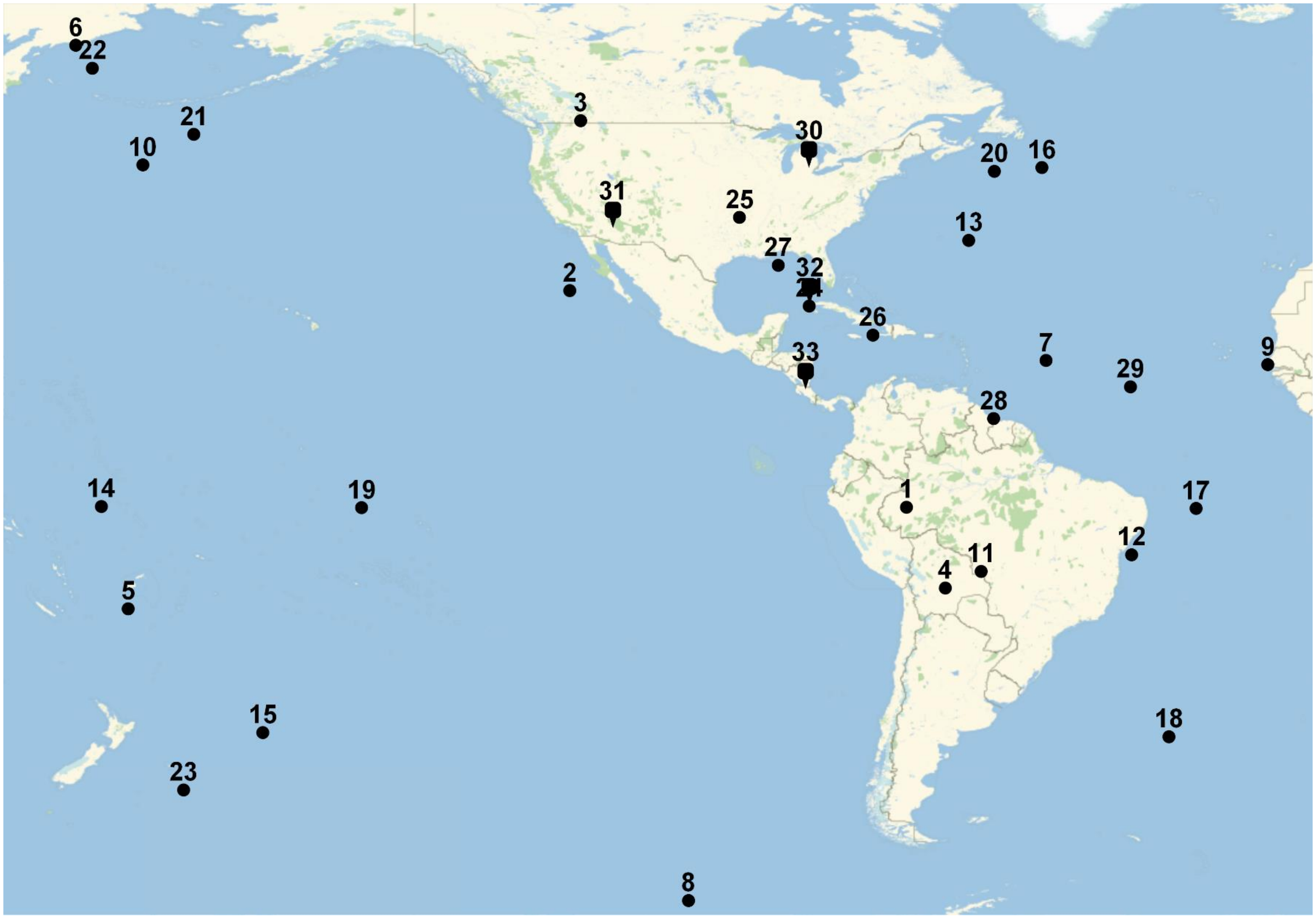


Superbolide





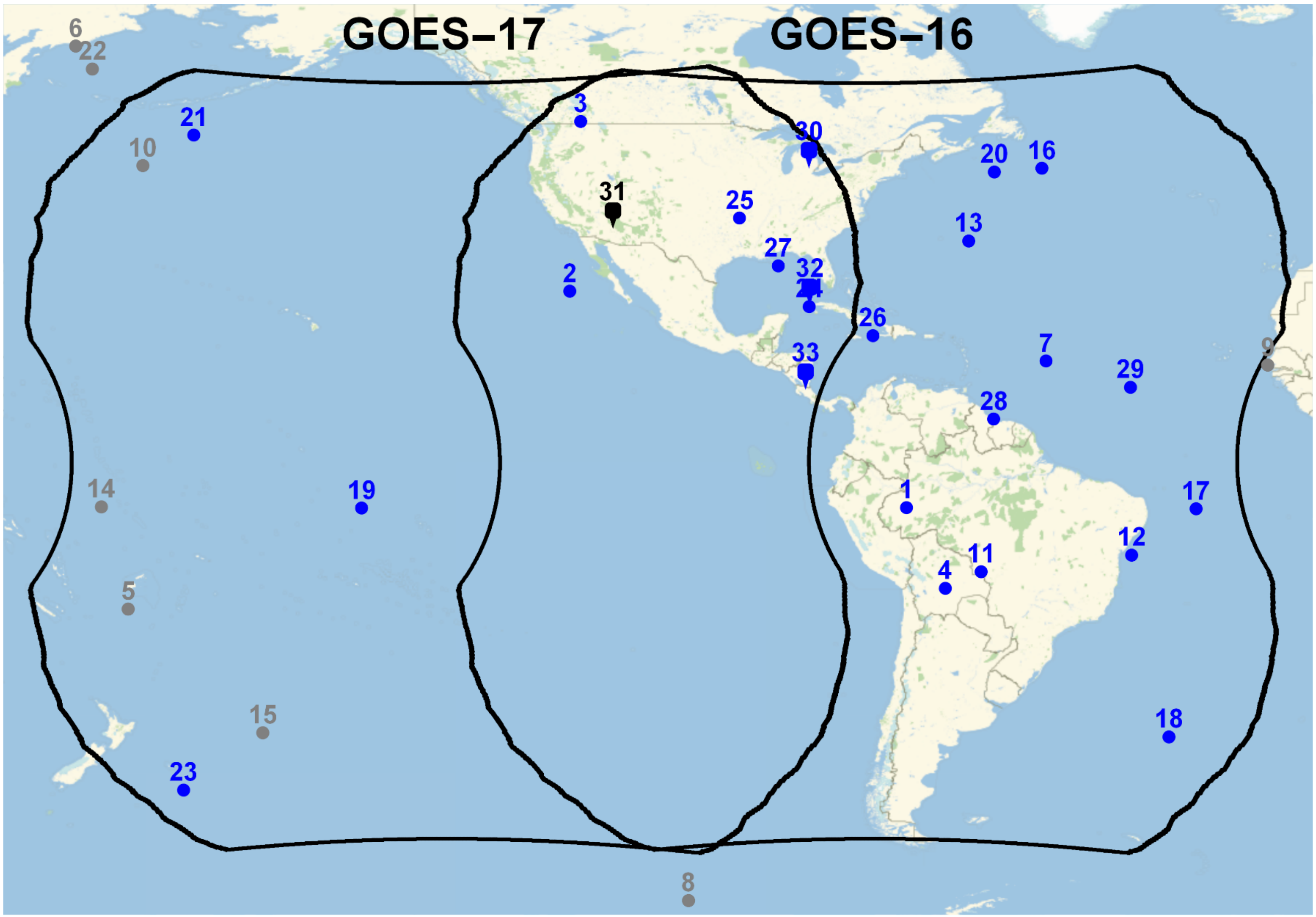
CNEOS: Superbolides & MetSoc: Meteorite falls



1	2017-07-23
2	2017-07-31
3	2017-09-05
4	2017-10-09
5	2017-10-26
6	2017-12-15
7	2017-12-29
8	2017-12-31
9	2018-01-22
10	2018-02-08
11	2018-02-12
12	2018-02-21
13	2018-05-08
14	2018-05-12
15	2018-08-21
16	2018-09-13
17	2018-09-17
18	2018-10-05
19	2018-10-24
20	2018-11-15
21	2018-11-17
22	2018-12-18
23	2018-12-23
24	2019-02-01
25	2019-04-04
26	2019-04-14
27	2019-05-04
28	2019-05-12
29	2019-05-22
30	Michigan
31	Arizona
32	Cuba
33	Costa Rica

Data from: CNEOS: https://cneos.jpl.nasa.gov/fireballs/ and MetSoc: https://www.lpi.usra.edu/meteor/

GLM detects superbolides & meteorite-producers



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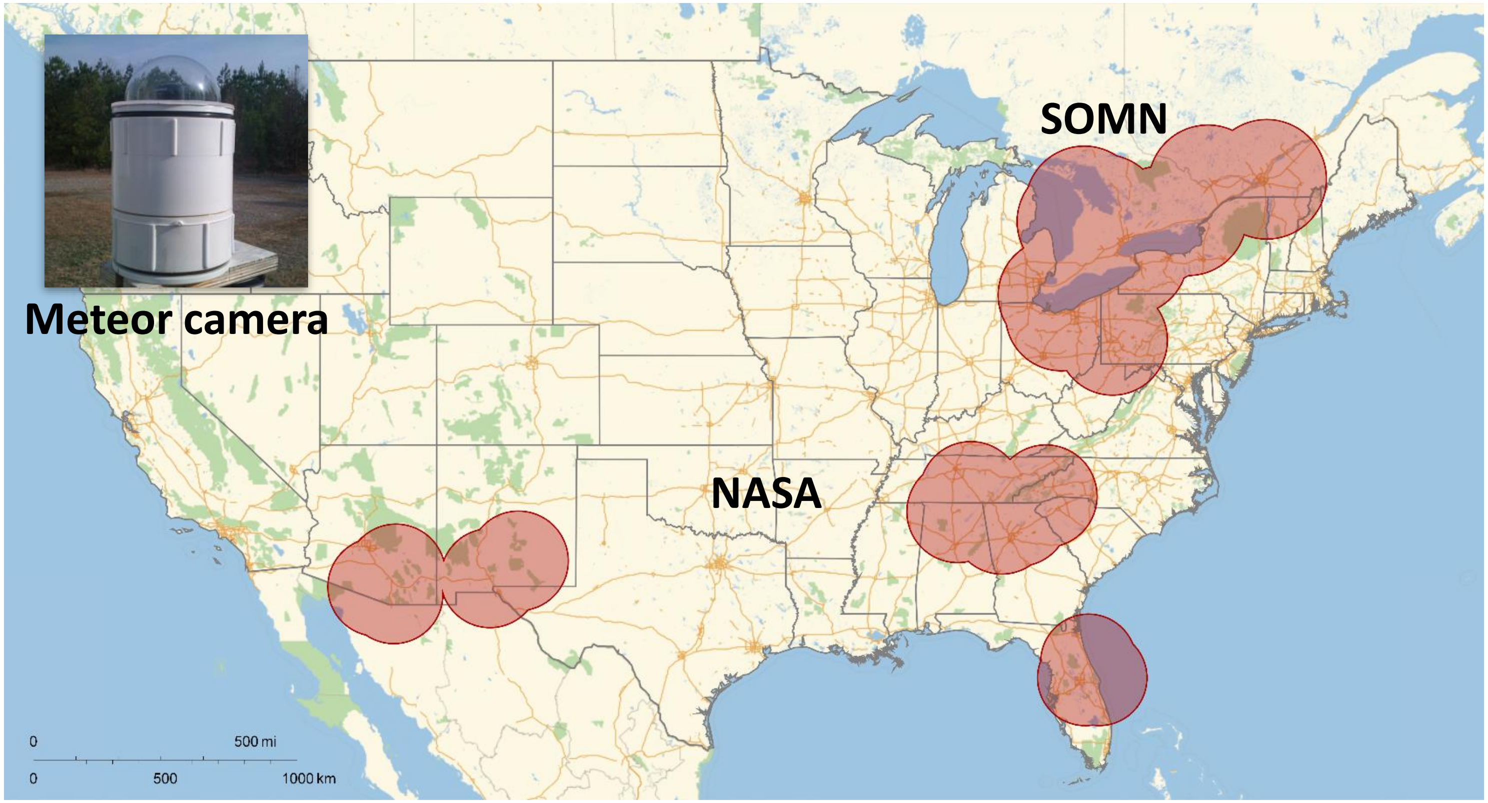
Does GLM detect fainter bolides?

- NASA MEO and NASA SPoRT/UAH partnered to undertake a study to correlate GLM detections with bolides observed by:
  - NASA All Sky Fireball Network (Cooke & Moser 2011)
  - Southern Ontario Meteor Network (Weryk et al. 2008)
- Results will support NASA MEO task: rapid fireball characterization

Study details:
Bolide data selection from camera networks

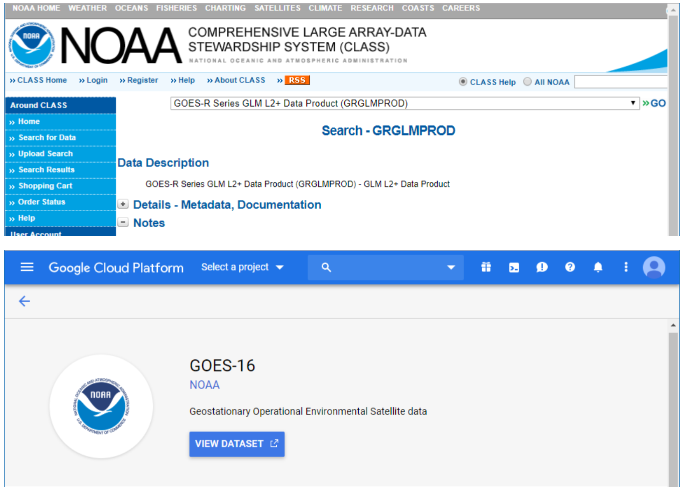
Networks	NASA All Sky Fireball Network Southern Ontario Meteor Network (SOMN)
Date range	July 5, 2017 - present
Brightness	Brighter than instrumental M = -5



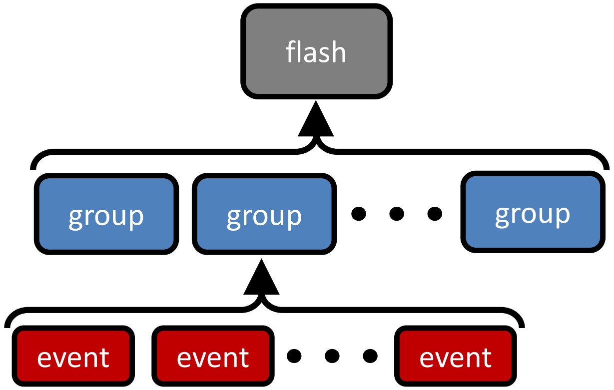
Approximate coverage of NASA and SOMN cameras

Study details: GLM data extraction steps

1. Bolide detected in camera network
   - Detection & camera correlation via ASGARD
   - Date/time and imagery saved
   - Trajectory (MILIG) & orbit (MORB)
2. Download public L2 data bracketing bolide time
   - NOAA CLASS
   - Google Cloud / BigQuery
3. Import netCDF file format
   - Python, Matlab, Mathematica…
4. Extract transient data including
   - Events, groups, flashes
   - Time of occurrence
   - Latitude & longitude
   - Luminous energy



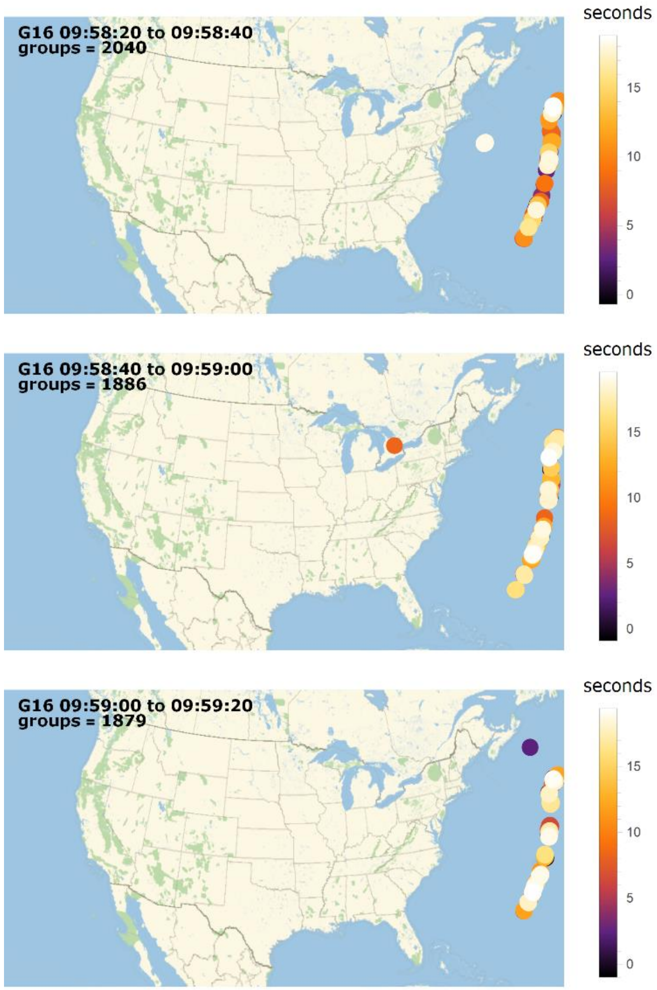
Sources of public GLM L2 data



GLM L2 data relationships

Study details:
GLM data preliminary analysis steps

1. Plot all GLM detections bracketing bolide time on map
2. Identify detections within
   - 5 sec of bolide time
   - 1.5 deg of bolide end lat/lon
3. Plot position(t), energy(t)
   - Rule out lightning based on erratic position and energy
   - Identify timing match between GLM detection and peak in bolide brightness
4. Correct GLM detection altitude to bolide height(s) and re-navigate detection position
   - GLM assumes lightning at top-of-atmosphere heights of 6-16 km
   - Must correct to bolide heights > 20 km
5. Compare re-navigated GLM position to bolide ground track



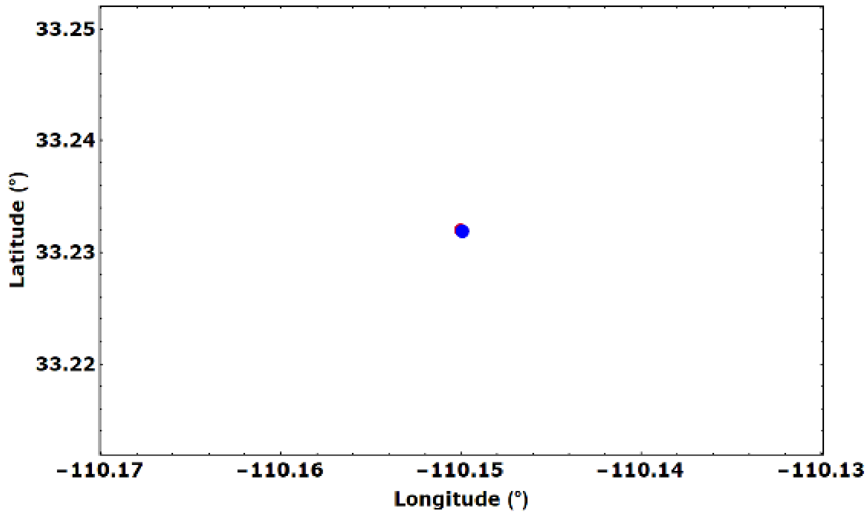
GLM detection time sequence

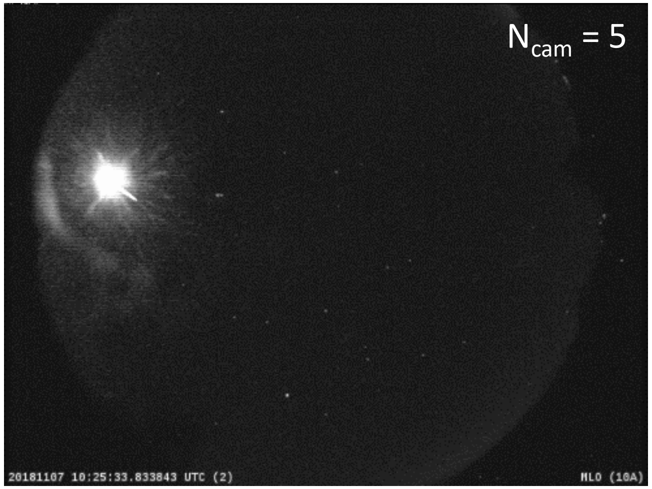
Search results

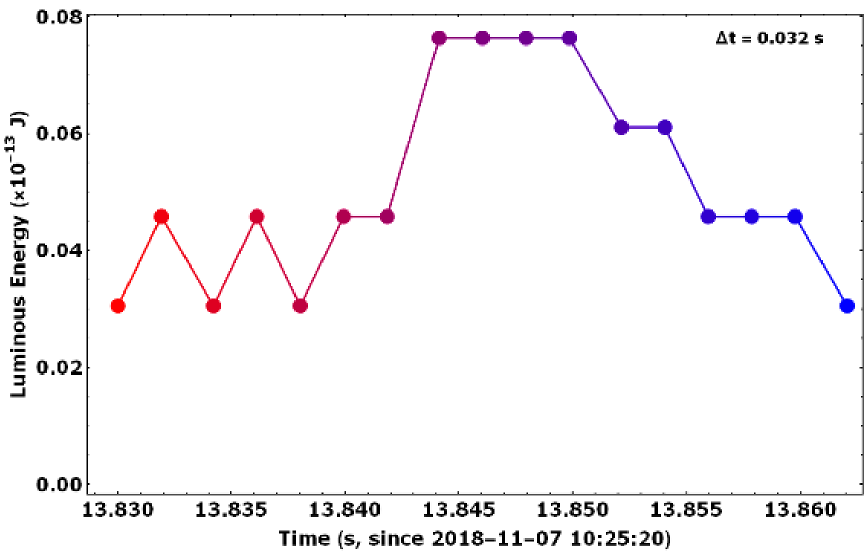
- Found 33 bolides with GLM data
  - 27 NASA
  - 3 SOMN
  - 3 NASA + SOMN

- Majority of GLM detections with GOES-16
  - 28 GOES-16 only
  - 1 GOES-17 only
  - 4 GOES-16 + GOES-17

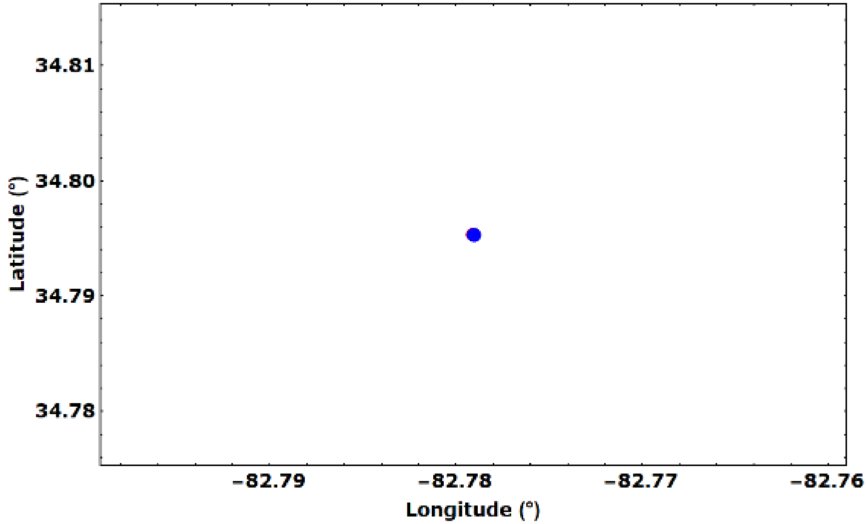
Case studies: 20181107_102533 AZ

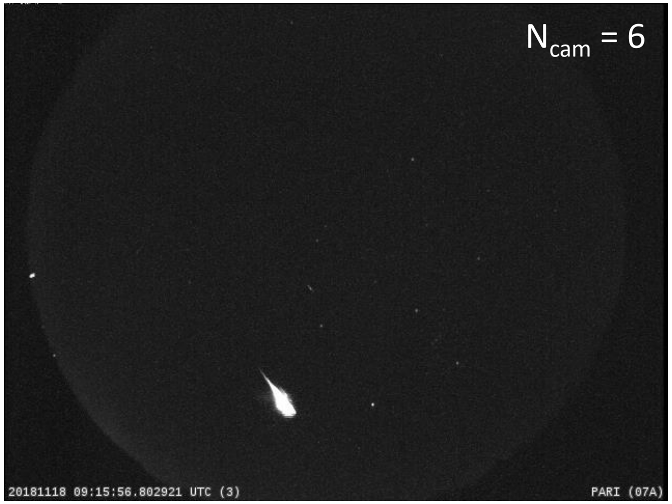


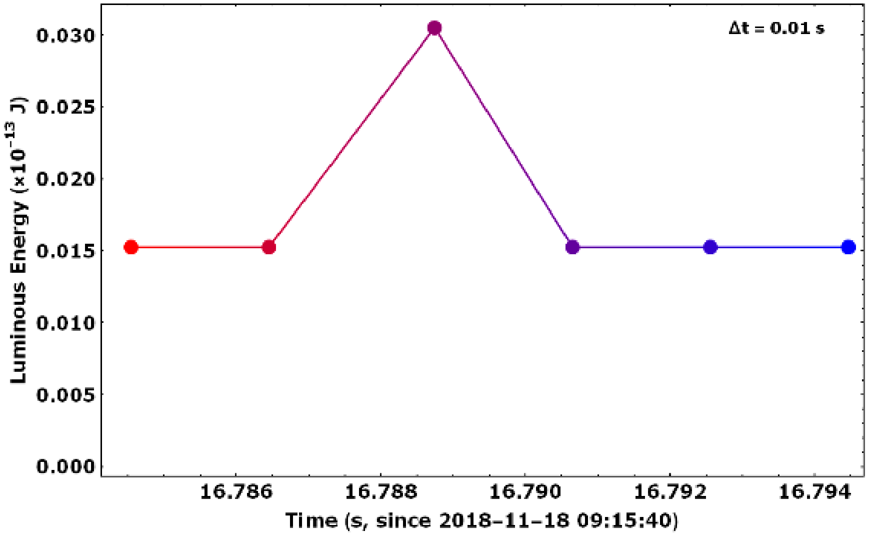




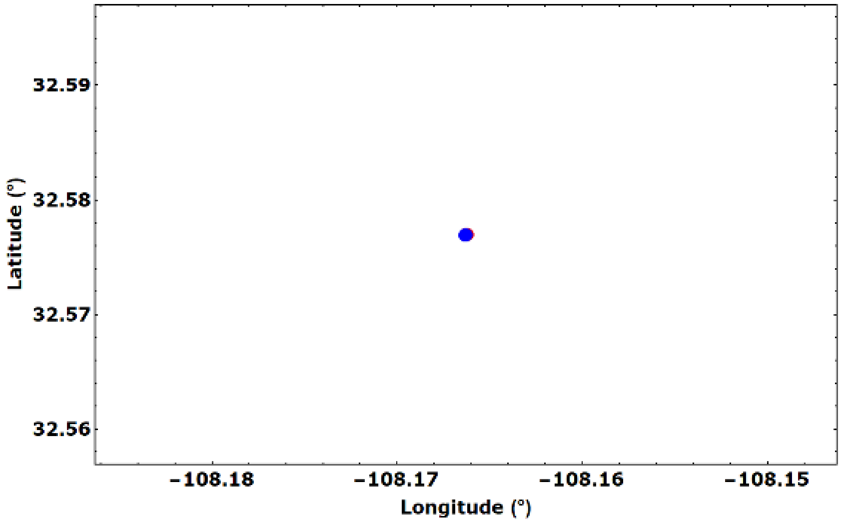
Case studies: 20181118_091556 SC

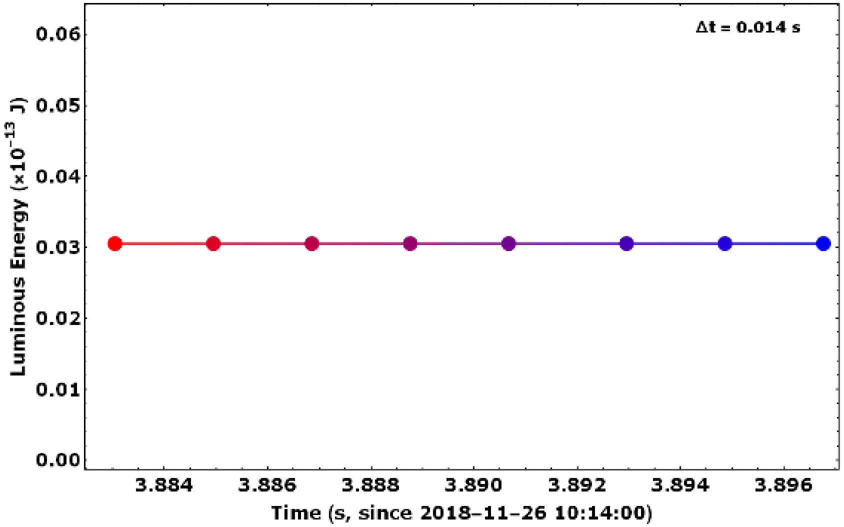






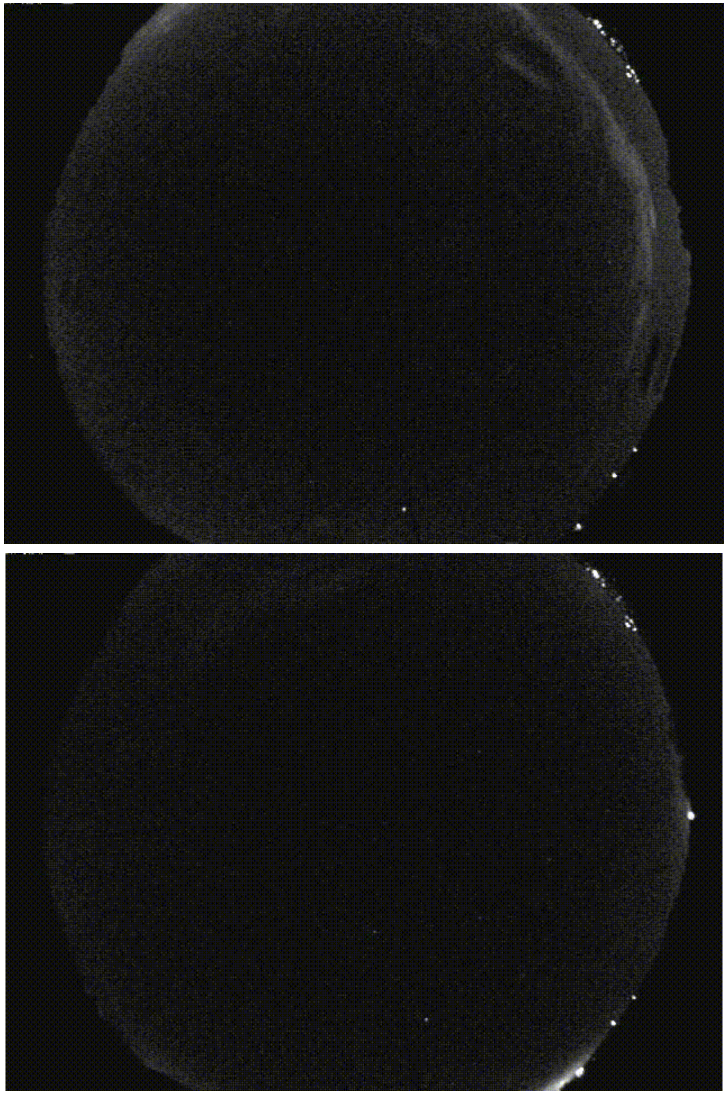
Case studies: 20181126_101403 NM





Some unexplained "misses"

NASA video



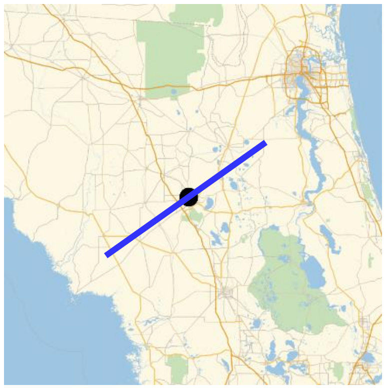
Desert Fireball Network camera

Preliminary conclusions

- Fainter bolides *are* sometimes in GLM L2 data
  - Correlated cases examined so far show flaring
  - Missed cases in L2 data may be present in L0 or L1 data
- Cases are generally "in the noise" of GLM L2 data
  - Few associated events/groups/flashes (short duration)
  - Little-to-no motion in lat/lon space
  - Few points in the lightcurve, bolide lightcurve shape not always obvious
- Cases are typically saturated in NASA and SOMN cameras
  - *Preliminary:* 4 cases with 1 unsaturated camera station indicates limiting M of -6 to -7 in instrument passband
  - Previous superbolide work with USG sensors put limiting M at -14 (Jenniskens et al. 2018)
- End heights: 79% with H_{end} > 60 km
- *Preliminary* shower association: mostly sporadic, but PER, LEO
- General conclusion: GLM L2 detections of bolides can assist with rapid fireball characterization to some degree, depending on the strength of the detection and number of instruments involved.

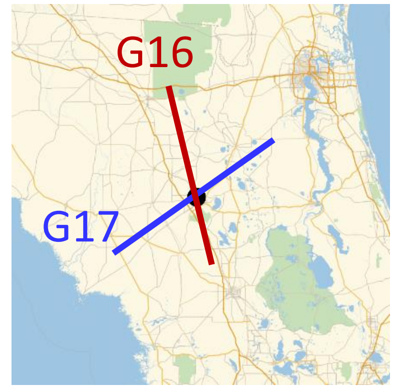
Utility for characterizing bolide trajectory

Faint detection, 1 satellite



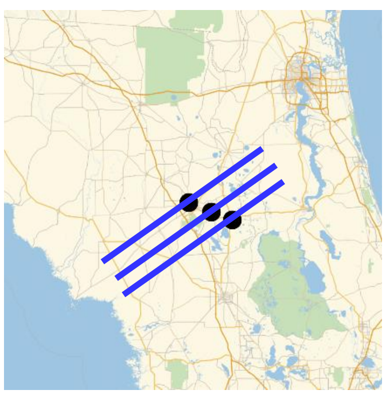
- Few events/groups
- Little-to-no motion in lat-lon space
- Flare located along line determined by common bolide flare heights

Faint detection, 2 satellites



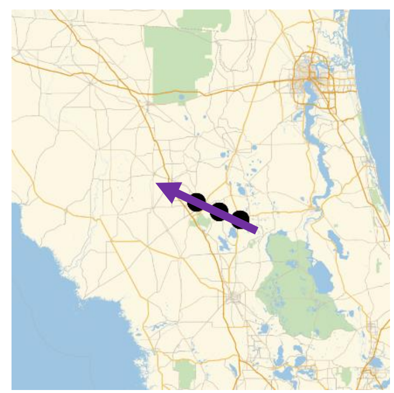
- Few events/groups
- Little-to-no motion in lat-lon space
- Flare location and altitude determined from stereo observations

Strong detection, 1 satellite



- Multiple events/ groups
- Motion in lat-lon space may indicate travel direction
- Bright portions located along fan of lines determined by common bolide flare heights

Strong detection, 2 satellites



- Multiple events/ groups
- Motion in lat-lon space may indicate travel direction
- Portion of bolide trajectory determined from stereo observations

Future work

- In-depth look characterizing all GLM-bolide correlations in NASA network and SOMN
- Automate search through data using Google BigQuery
- Streamline data analysis tools for rapid-response fireball characterization