The GOES Lightning (and Meteor!) Mapper: The Potential Use of GLM for Bolide Detection and Response

ANITA LE ROY (UNIVERSITY OF ALABAMA IN HUNTSVILLE / NASA SPoRT)
DANIELLE E. MOSER (JACOBS SPACE EXPLORATION GROUP/ NASA MEO)
CHRISTOPHER J. SCHULTZ (NASA SPoRT)

Intro and Motivation

NASA MEO (Meteoroid Environment Office) responsible for rapid characterization of fireballs during the day and night.

Need to respond to all meteors of public interest.

MEO uses a variety of data sources (Allsky camera network, public reports, cell phone images, etc.)

GLM detects some bolides, during the day and night, adding a data source to help MEO characterize meteors.

O2R: MEO contacted NASA SPoRT to help understand GLM data and help characterize these meteor detections.

GLM Background

Geostationary Lightning Mapper on GOES-16 and GOES-17

Available in NRT

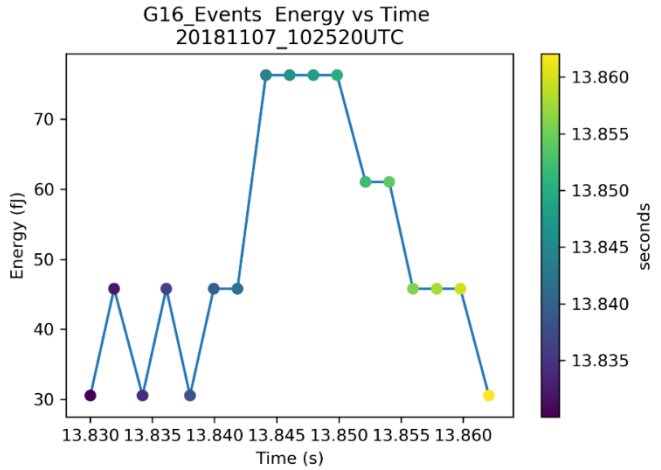
Optical lightning detector at the oxygen triplet (777.4 nm, i.e., a narrow band of optical detection)

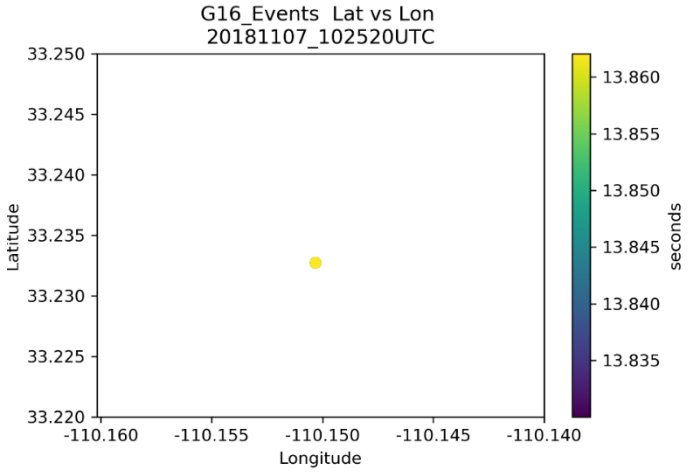
2 ms frame…500 frames a second

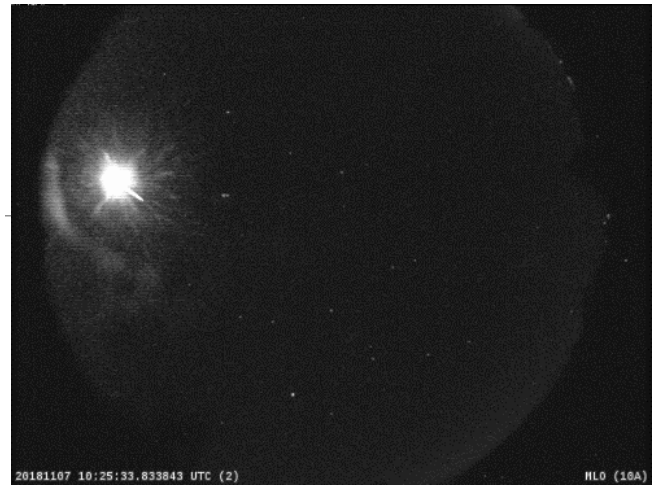
8 km resolution at nadir and 14 km at limbs

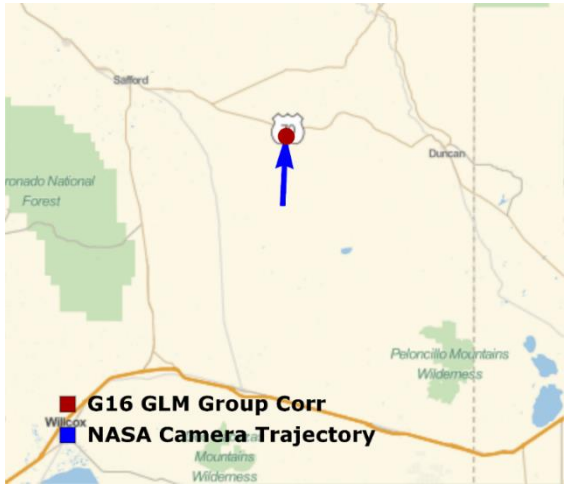
Detects large exploding meteors (called bolides and superbolides) pretty reliably and “in stereo”

- Allows for some trajectory info to be obtained



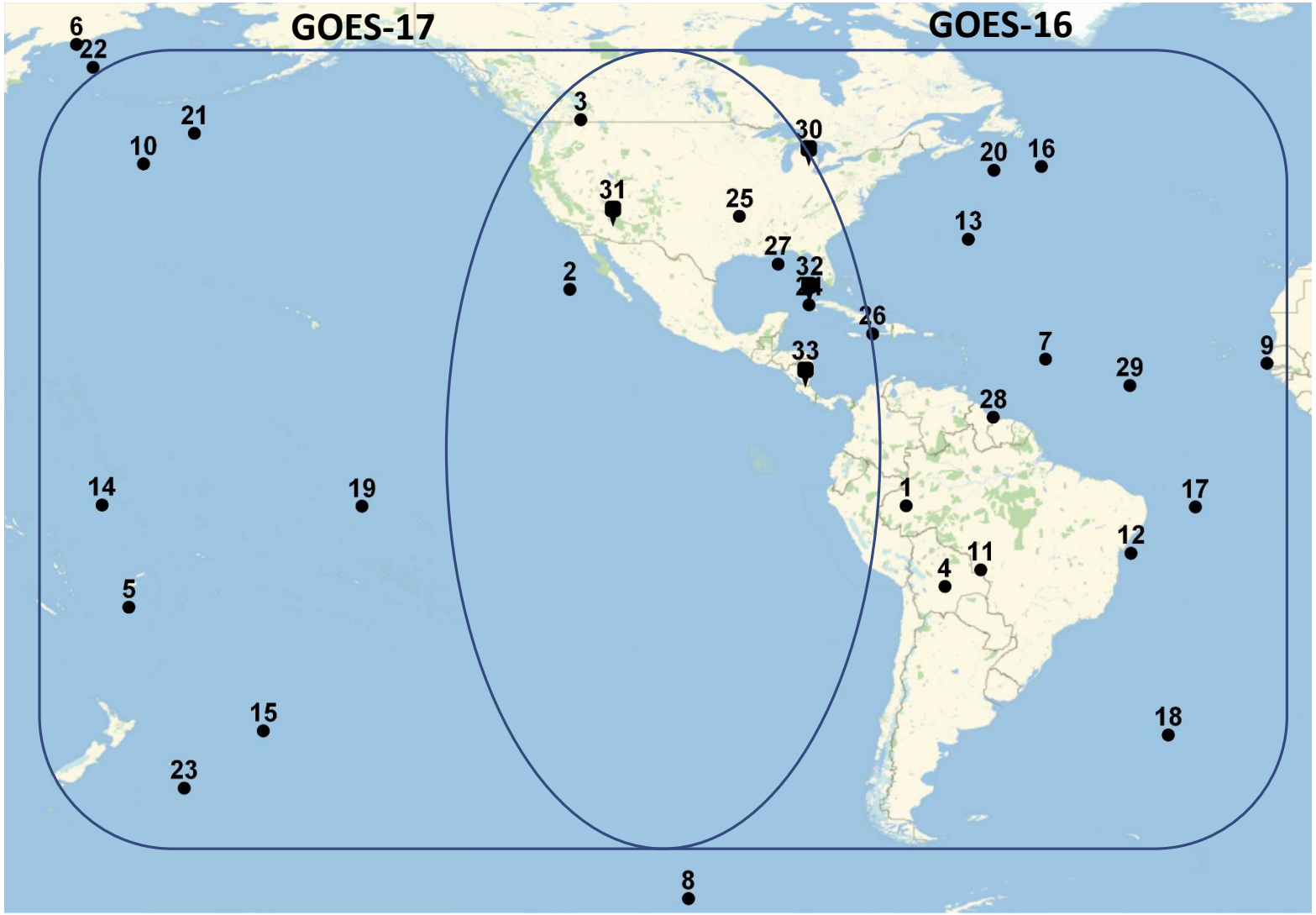






From Moser et al. 2019 (conf. paper)

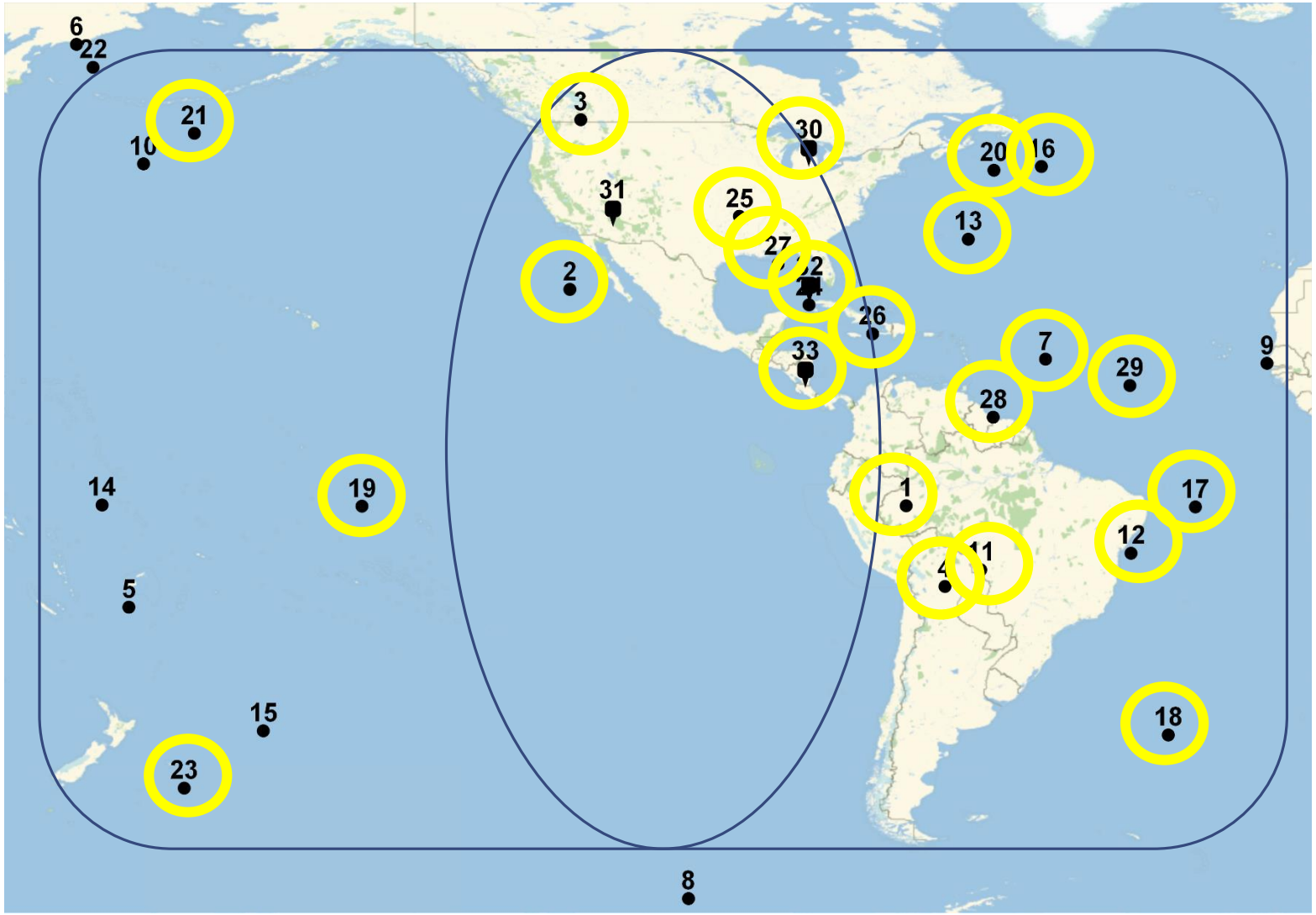
CNEOS and MetSoc Superbolides (meteorite-producers) and GLM Coverage



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

Adapted from Moser et al. 2019 (conf. paper)

Superbolides are almost all detected by GLM



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

Large exploding meteors that produce meteorites (the fragment of rock that impacts the earth's surface) are RELIABLY detected by GLM

Adapted from Moser et al. 2019 (conf. paper)

And if it's not a superbolide…

Large bolides are news-worthy but…

Small bolides are much more common

30+ small meteors detected since 2017

Can detect (although not consistently) bolides as dim as -6 magnitudes, and can back out some useful info…sometimes

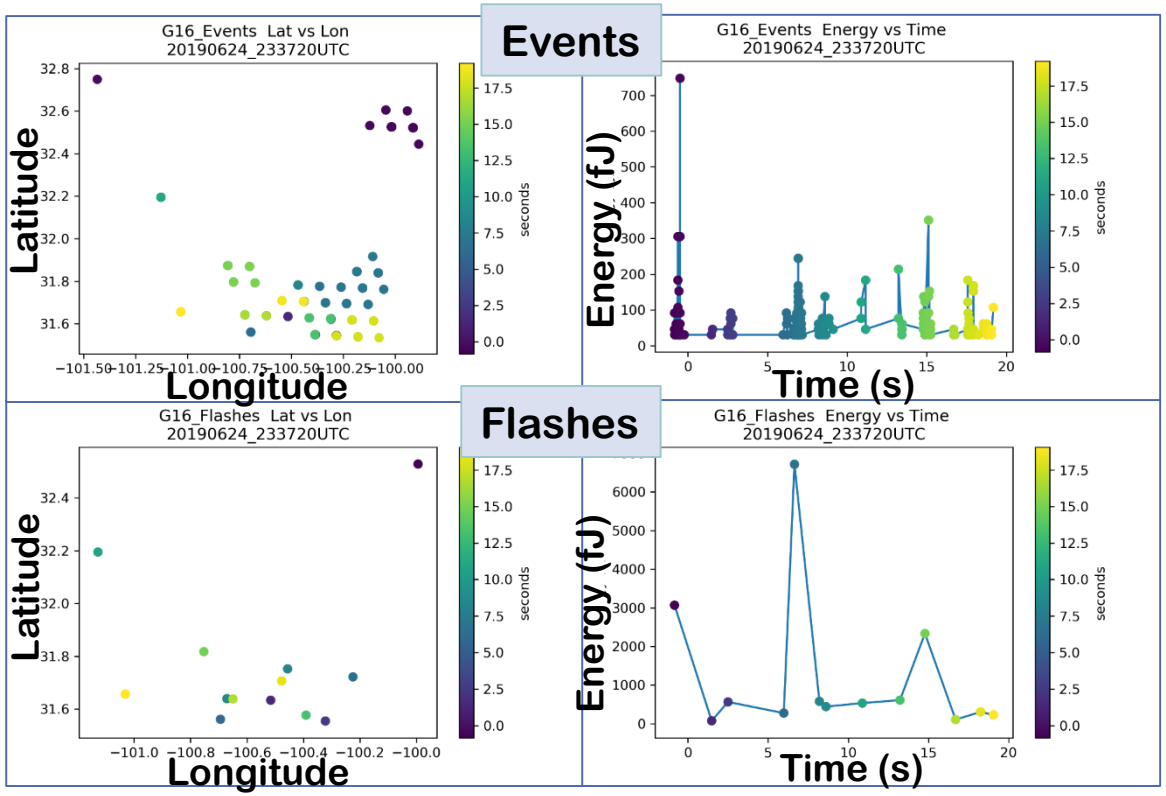
Lightning versus a bolide

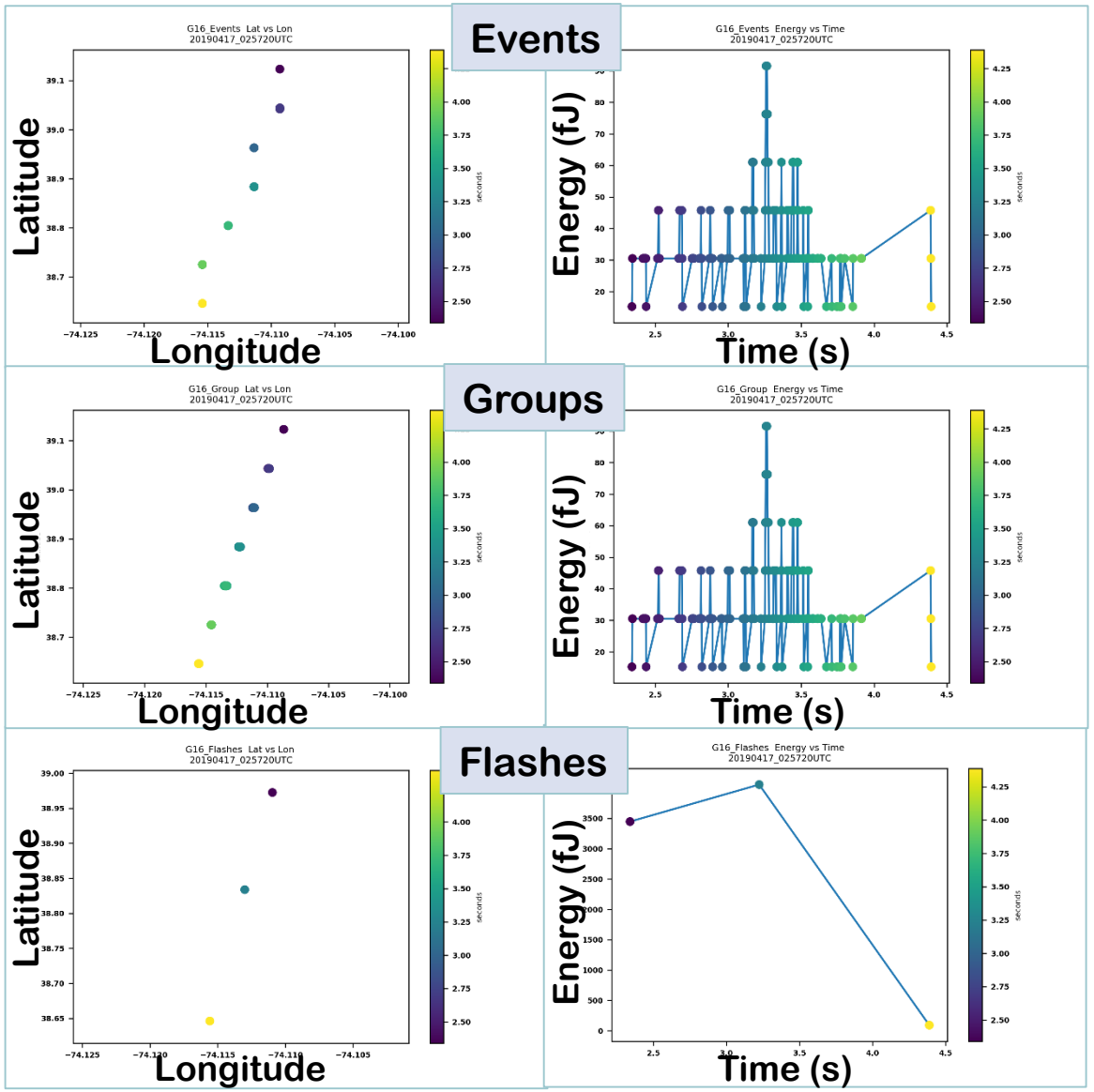
Motion: Bolides are **linear**

Speed: Bolides are **slow**

Energy: Bolides can have **very low** and **very high** energy

L2 LCFA: Bolides **don't cluster**





A Large Bolide

For Large Bolides:

Can often determine trajectory and speed (esp. if we use GOES-16 and GOES-17)

They move more slowly and are more linear than lightning

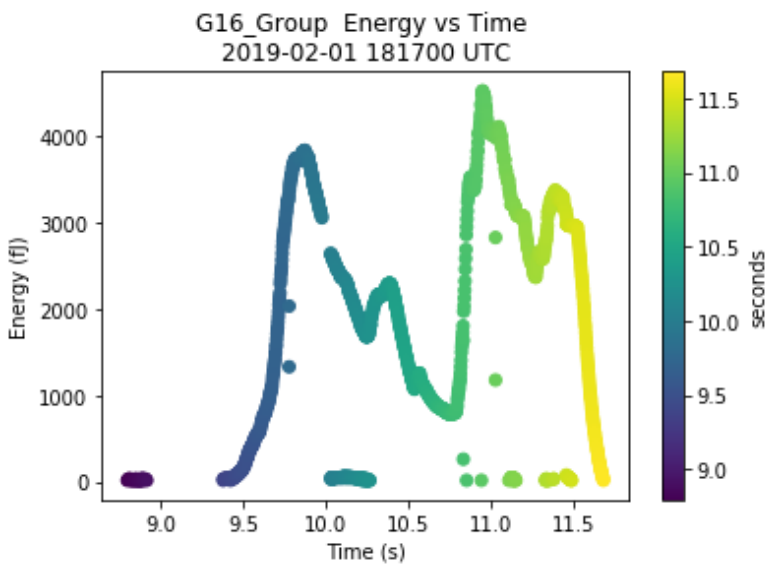
Events don't often cluster into groups (i.e., same number of events as groups)

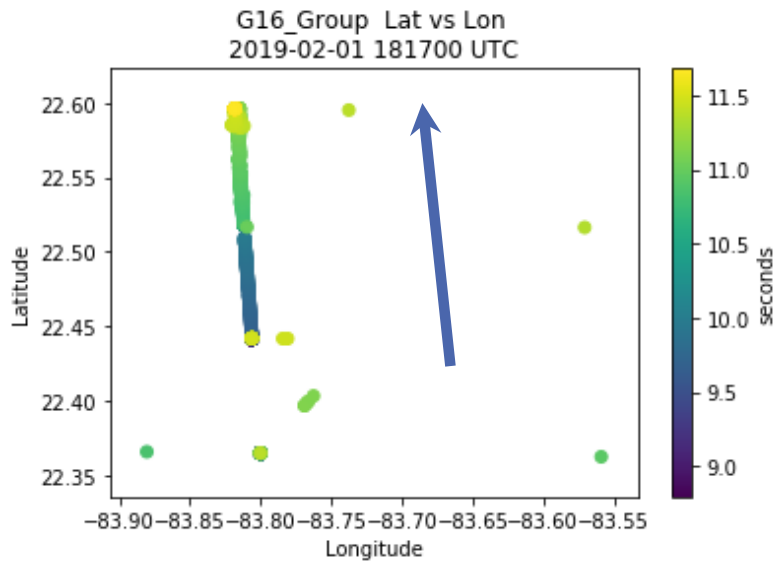
Can be even more energetic than lightning

More likely to detect flaring (exploding) meteors

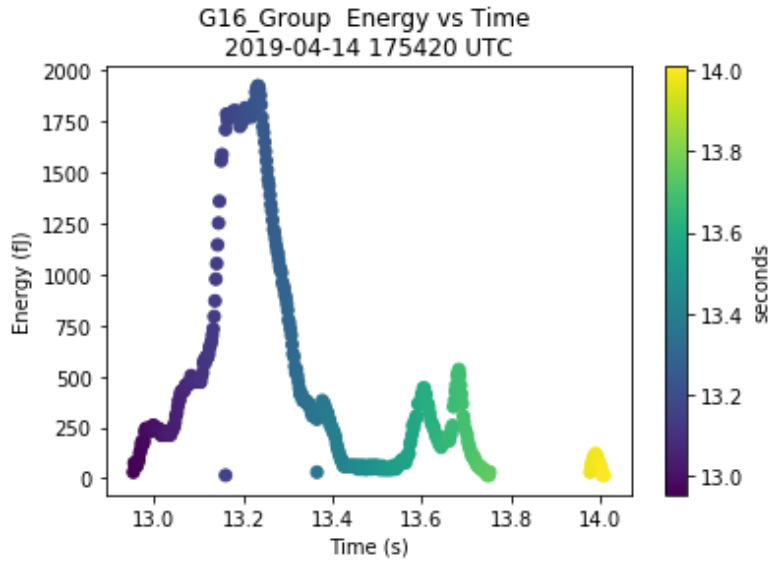
Can last a couple seconds

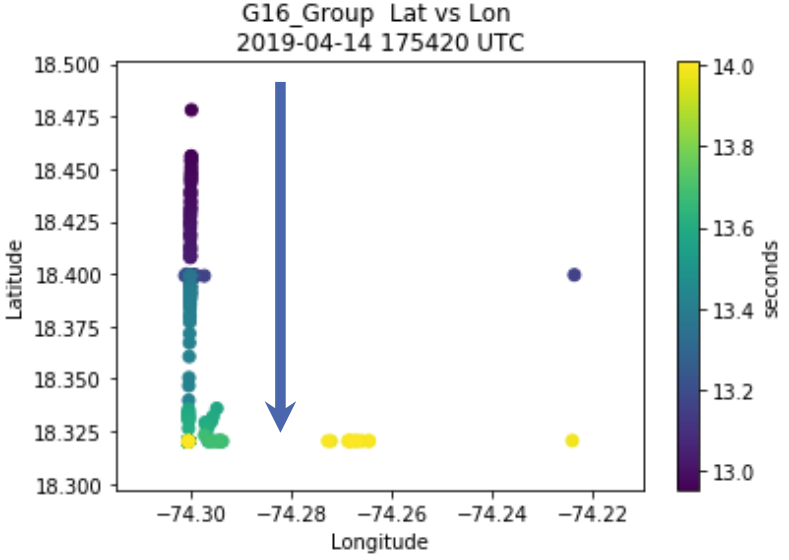
Cuba





Haiti





A Small Bolide

For Small Bolides:

Often can just detect presence of bolide (i.e., very few events)

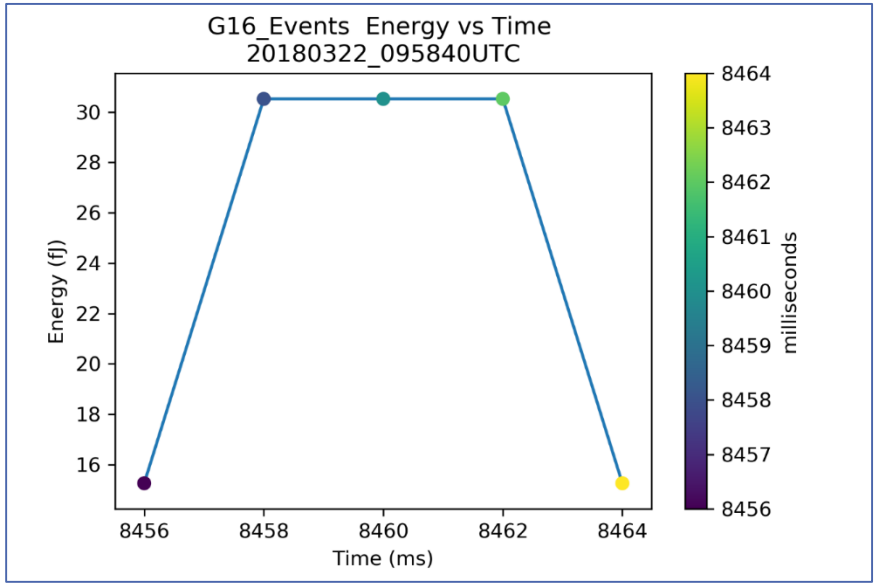
They move more slowly and are more linear than lightning (if they move at all)

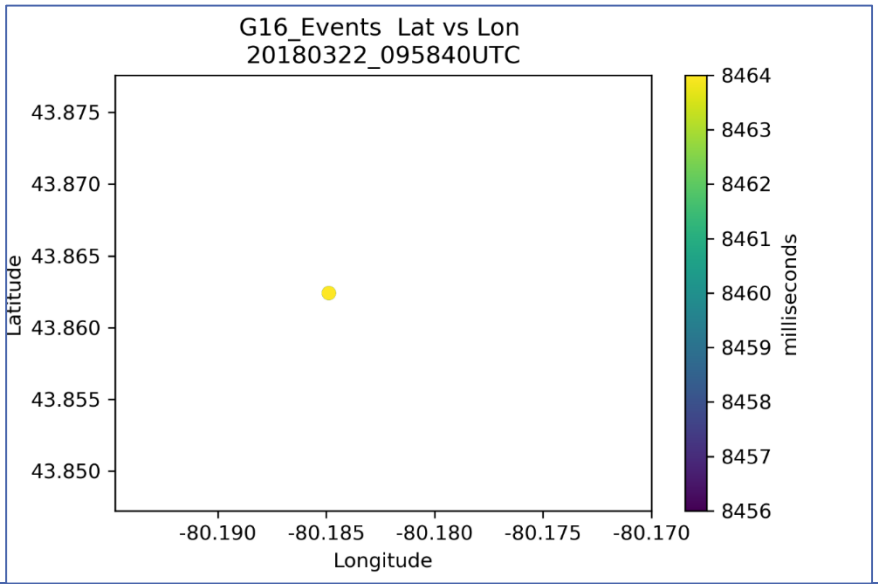
Events don't often cluster into groups (i.e., same number of events as groups)

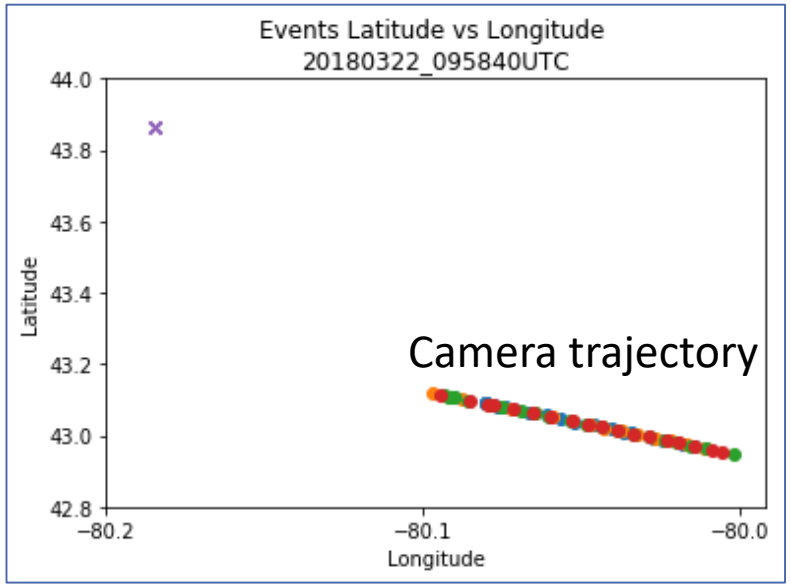
Note that 15 fJ is the minimum energy in L2-LCFA data

More likely to detect flaring (exploding) meteors

Most are very brief (ex. 0.008 s)



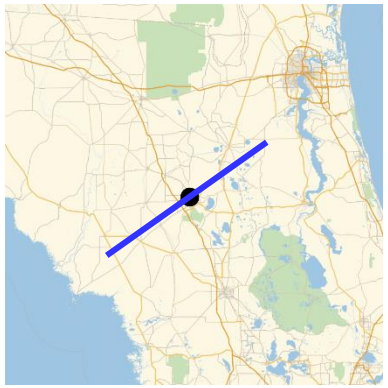




	GLM (5 events)	Cameras (4)
Lat0	43.86241	42.948
Lat1	43.86241	43.121
Lon0	-80.184875	-80.002
Lon1	-80.184875	-80.095
Duration	.008 s	.868 s
Mag0		-5
Mag1		-8
Alt0 (km)		112.424
Alt1 (km)		76.181

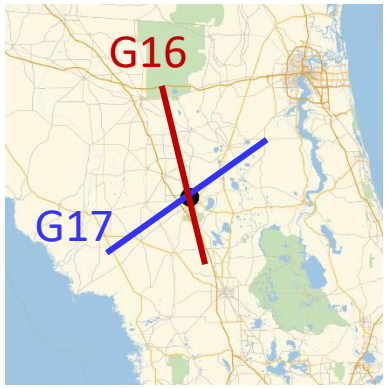
Using GLM to characterize bolide motion

Faint detection, 1 satellite



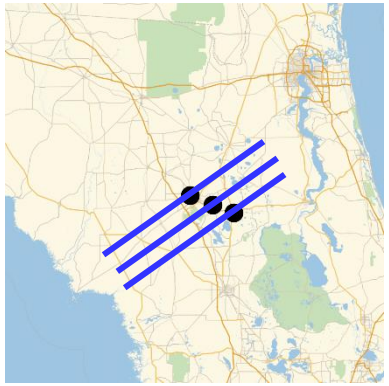
- Few events/groups
- Little-to-no motion in lat-lon space
- Flare located along line determined by common bolide flare heights

Faint detection, 2 satellites



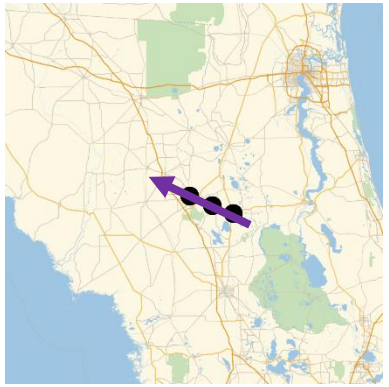
- Few events/groups
- Little-to-no motion in lat-lon space
- Flare location and altitude determined from stereo observations

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

From Moser et al. 2019 (conf. paper)

Algorithm Considerations

The charateristics of bolides described herein are being used to develop faster response when possible

A bunch of stuff in GLM data isn't lightning but isn't likely meteors, although it looks meteor-ish.

"Broad Net" algorithm detected 100s of bolide-like signatures that can't be confirmed as anything…

Conclusions and Ongoing & Future Work

GLM reliably detects large exploding meteors that are likely to create meteorites.

GLM can detect meteors with magnitudes as low as -6, but less reliably.

Stereo use of both instruments help produce useful trajectories.

Working to automate the process of **detection** of bolides using GLM, **characterizing motion** for larger/brighter bolides, and **finding dimmer bolide activity** in L0 data

Other weather-observing assets can detect meteors: ABI is doing a good job of detecting bolides in various channels…could we develop a multispectral geostationary bolide detector?

Thanks for your attention!

Feel free to reach out:
Anita.LeRoy@nasa.gov
Danielle.E.Moser@nasa.gov