Abstract:
Using the Geostationary Lightning Mapper data to calculate orbit and trajectory of bolide events and study fragmentation

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An interesting new space-based data source for bolide detection has emerged within the past few years. Called the Geostationary Lightning Mapper (GLM) instrument, it resides aboard both National Oceanic and Atmospheric Administration (NOAA)'s Geostationary Operational Environmental Satellite (GOES) 16 and 17, and has been shown to be a legitimate detector of bolide events across the contiguous United States [1]. While it is clearly beneficial to be able to detect and verify bolide events using space-based remote sensing, the ability to use GLM data to build trajectory and orbital determinations for events would be an even greater advantage, as it would give us a uniquely independent view of the bolide event from space, and could add substantially to any pre-existing ground-based information available for the event. We will analyze light curves constructed from GLM data to find about fragmentation of these bodies, which might provide novel insights into the nature of the materials that comprise bolides and the physics behind fragmentation. We shall investigate both of these new avenues of approach-- orbit and trajectory calculations, and fragmentation analysis, both with GLM data.

Background and Introduction

- We have been calculating trajectories and orbits [3] with ground-based data from the Spalding Allsky Camera Network (SACN) [7] according to the methods established by Ceplecha (1987) [4], while using calibration method outlined in Borovička 1995 [5], and determining orbits with REBOUND n-body Integrator [6]
- Jenniskens et al 2018 [1] paper established the possibility of using the GLM to detect bolides
- Rumpf et al 2019 [2] created a new algorithm to automatically detect bolides from GLM data, and this is used to populate NASA's new Bolides web portal [8] to enable us select the stereo events
- This paper aims to find a way to use the GLM data to calculate a trajectory and orbit for bolide events
- When available, GLM observations will be compared with ground-truth observations from the SACN

Methodology

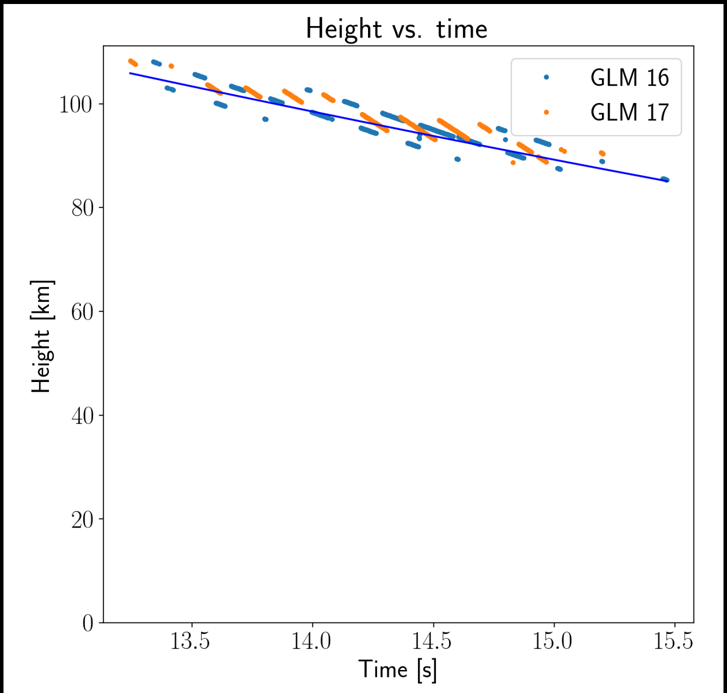
- The trajectory of the bolide can be calculated solely from GLM data provided both GLM instruments observe the event (a stereo event)

- The trajectory from the two observations is determined by where the line-of-sight between the two satellites and the object intersect, and a best fit is calculated and corrected for assumed height of 16 km (top of troposphere where lightning is observed)

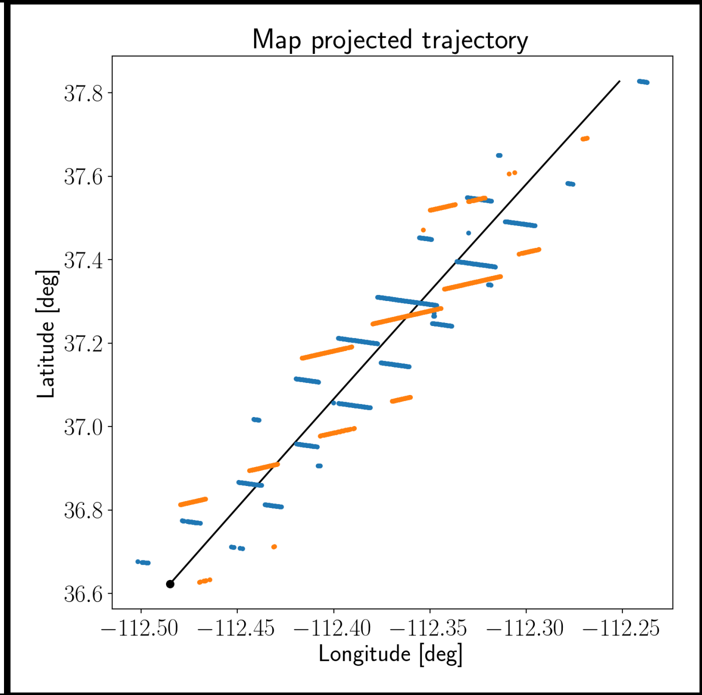
- The code minimizes the residuals for each datapoint along the path as it produces the solution

- In the event stereo information is not available, we can combine GLM data from one satellite with one or more nodes from SACN

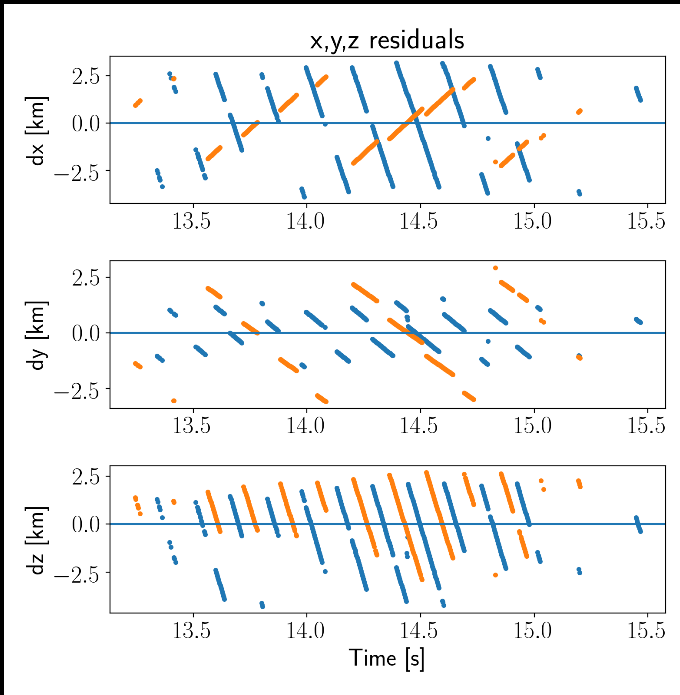
GLM captured event
18 Feb 2020, UT, USA



Height vs. Time plot for event. GLM instrument aboard GOES-16 is in blue, GLM aboard GOES-17 is in orange.



Map-projected trajectory for the event.



Residuals in the x, y, and z directions for each point, approx. +/- 2.5 km.

Discussion and Conclusion

- We have been able to use GLM to lock down trajectory to within approx. +/- 2.5 km, which is in line with the resolution limits of the data points themselves, as pixel size for GLM image is between 8 and 12 km [1].
- Level 0 data, which is not publicly available, might hold greater insight into the bolide track information, since level 2 is highly processed, filtered and auto centroided
- More events with stereo GLM observations will help us continue to test and refine trajectories produced with GLM data
- Having ground-based observations available to assist in verifying and refining trajectory is a major benefit, and works in harmony with GLM data to produce a better trajectory solution
- Much more work is to be done, as new bolide events and data become available

References

[1] P. Jenniskens, J. Albers, C. E. Tillier, S. F. Edgington, R. S. Longenbaugh, S. J. Goodman, S. D. Rudlosky, A. R. Hildebrand, L. Hanton, F. Ciceri, R. Nowell, E. Lyytinen, D. Hladiuk, D. Free, N. Moskovitz, L. Bright, C. O. Johnston, E. Stern, Detection of meteoroid impacts by the Geostationary Lightning Mapper on the GOES-16 satellite, Meteoritics and Planetary Science 53 (12) (2018) 2445–2469. doi:10.1111/maps.13137

[2] C. Rumpf, R. Longenbaugh, C. Henze, J. Chavez, D. Mathias, An algorithmic approach for detecting bolides with the geostationary lightning mapper, Sensors 19 (5) (2019) 1008. doi:10.3390/s19051008. URL http://dx.doi.org/10.3390/s19051008

[3] C. Palotai, R. Sankar, Palotai C., Sankar R., Free D. L., Howell J. A., Botella E., Batcheldor D., 2019, MNRAS, 487, 2307

[4] Z. Ceplecha, Geometric, Dynamic, Orbital and Photometric Data on Meteoroids From Photographic Fireball Networks, Bulletin of the Astronomical Institutes of Czechoslovakia 38 (1987) 222.

[5] J. Borovička, P. Spurny, J. Keclikova, A new positional astrometric method for all-sky cameras., 112 (1995) 173

[6] Rein H., Liu S.-F., 2012, A&A, 537, A128

[7] The Spalding Allsky Camera Network is managed by SkySentinel, LLC., www.goskysentinel.com

[8] See NASA Bolides web portal site at https://neo-bolide.ndc.nasa.gov/#/