An Automated Pipeline for Detecting Gigantic Jets: Preliminary Results

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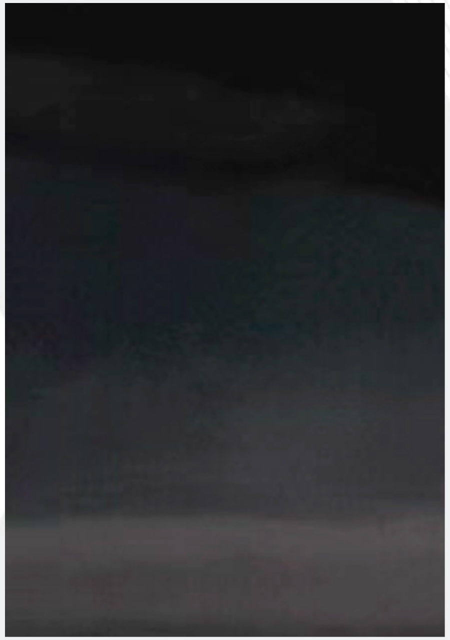
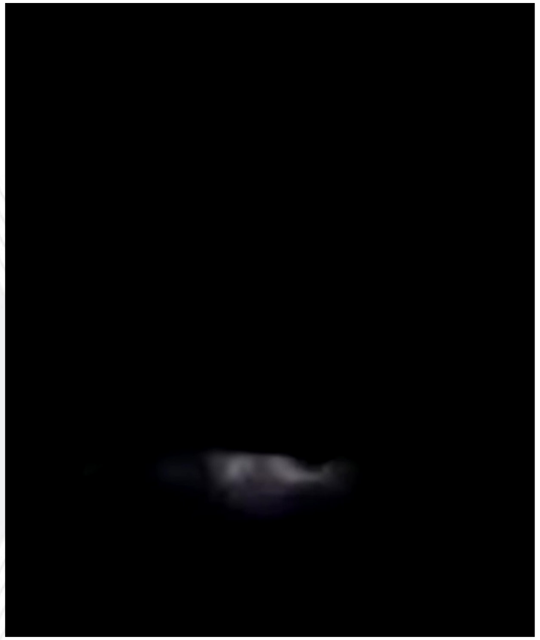
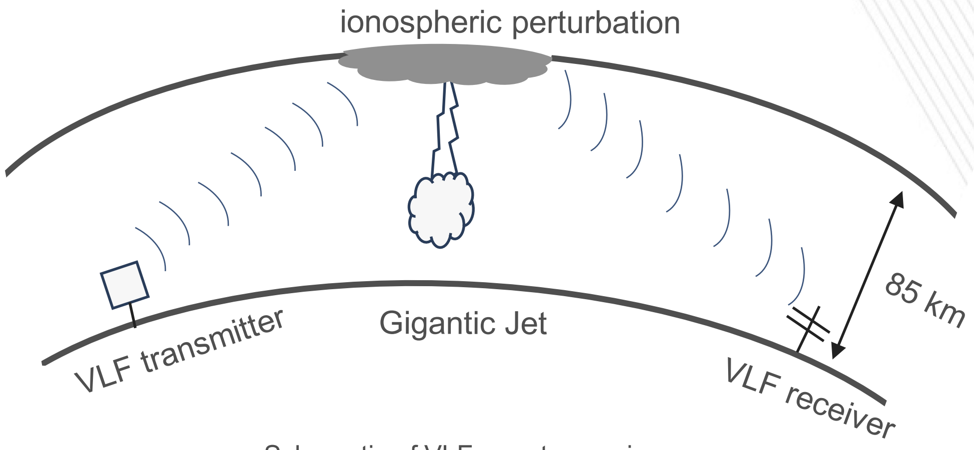
Introduction and Background

GJ over India



GJ over Gulf of Mexico, Chris Holms
(Boggs et al., 2022)

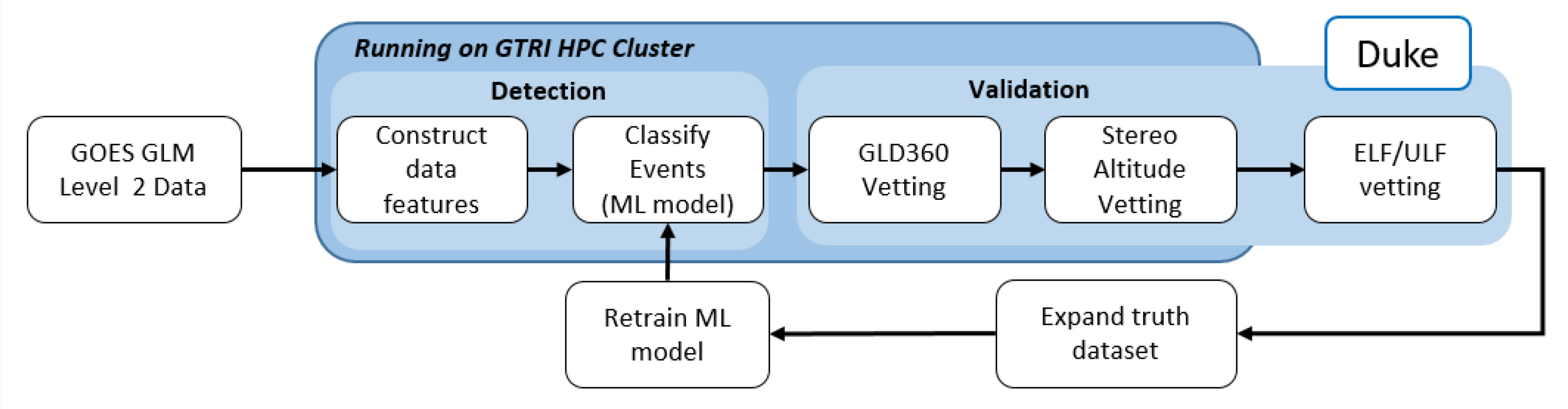




Schematic of VLF remote sensing

- **Questions: What are the upper atmospheric effects caused by GJs? What is the climatology (location, frequency) of GJs?**
- Goal: Significantly increase detections via GLM, machine learning, and ground-based networks
- Perform VLF remote sensing to understand how they perturb the ionosphere and Global Electric Circuit (Cohen et al. 2009)

Detection Pipeline



- **Detection**: supervised machine learning classifier that operates on GLM group data
- **Validation**: vet GJ candidates with GLD360 model, ABI model, stereo altitude model, and finally with ELF/ULF model.
- We are developing in conjunction with the NASA Bolide Pipeline (Smith et al. 2021)

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Truth Database

- We have collected ground-based video from several sources, mostly citizen scientists
- Captures come from cameras located in Puerto Rico, Colombia, Hawaii, Oklahoma, and Brazil
- Currently have 65 ground-truth GJ events
- Find matching GLM flashes
  - Note: we only find clear, unambiguous GJ signatures for 50% of ground-based video captures → most likely only detecting Type I GJs (Chou et al. 2010)

Photographer credit: Chaim Scowcroft

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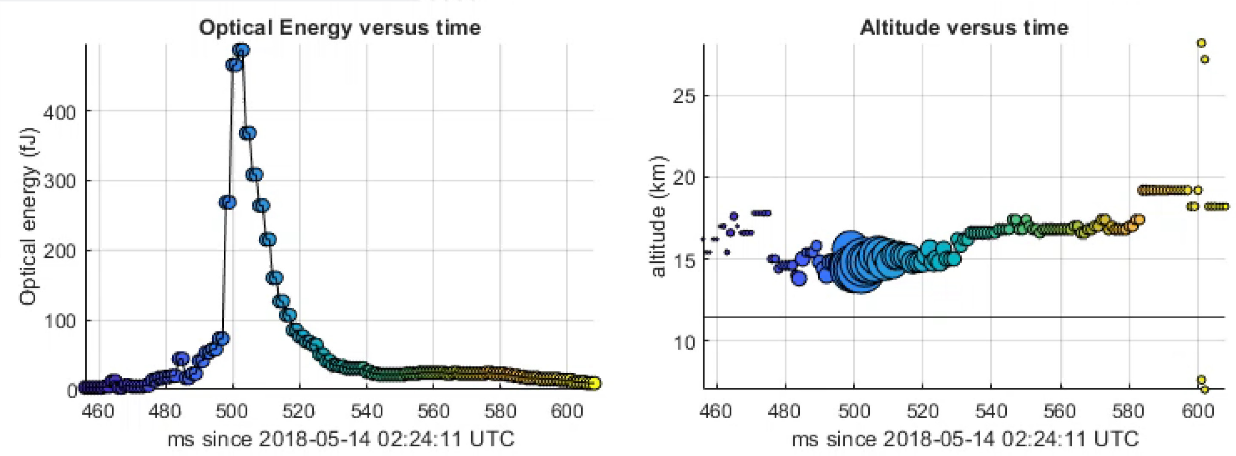
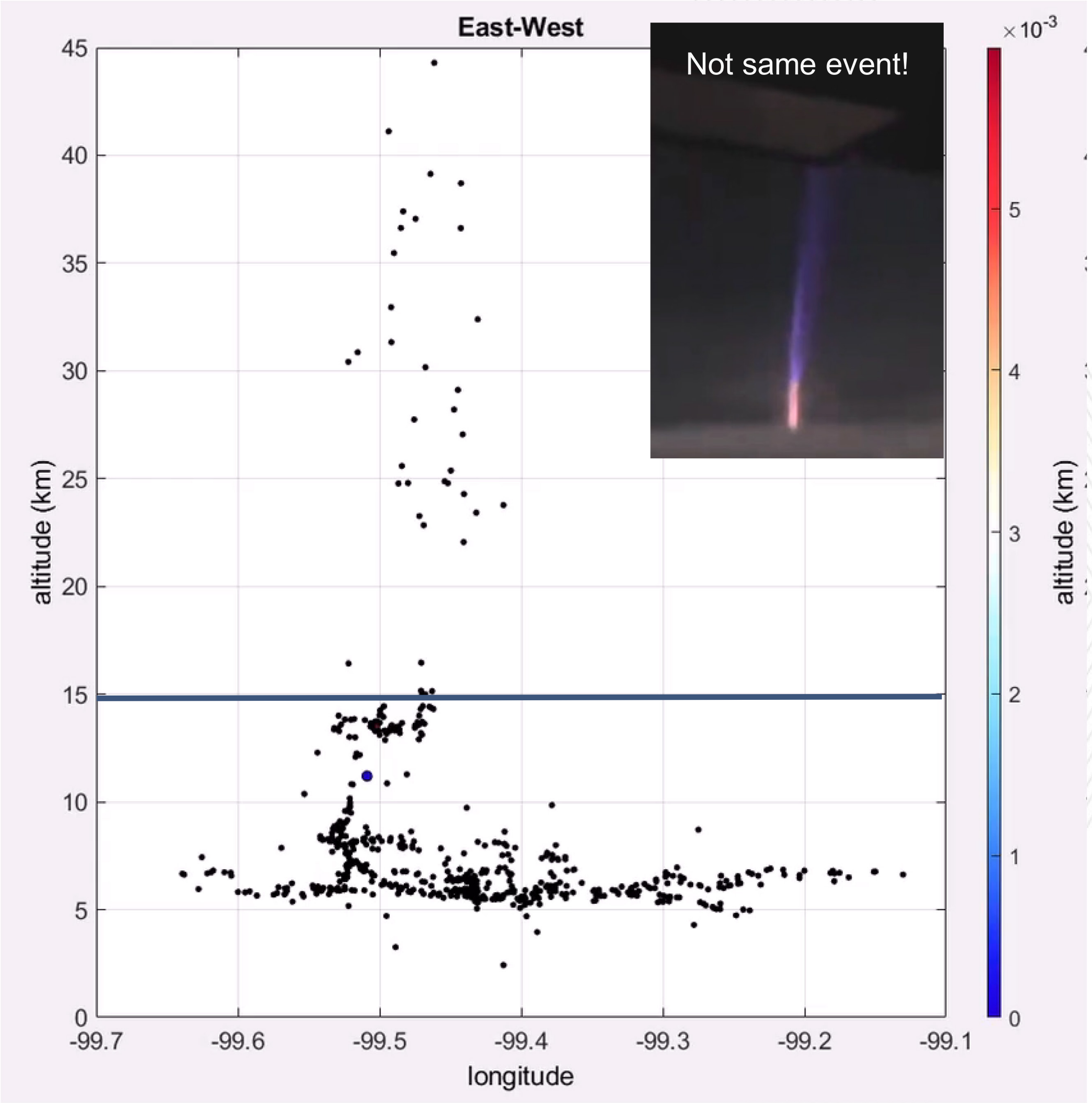
Gigantic Jet Signatures - GLM





- Long continuing current and impulsive lightcurve (Boggs et al. 2019, 2022)
- Stereo altitudes increase over time
- GLM primarily detects the leader above the cloud top

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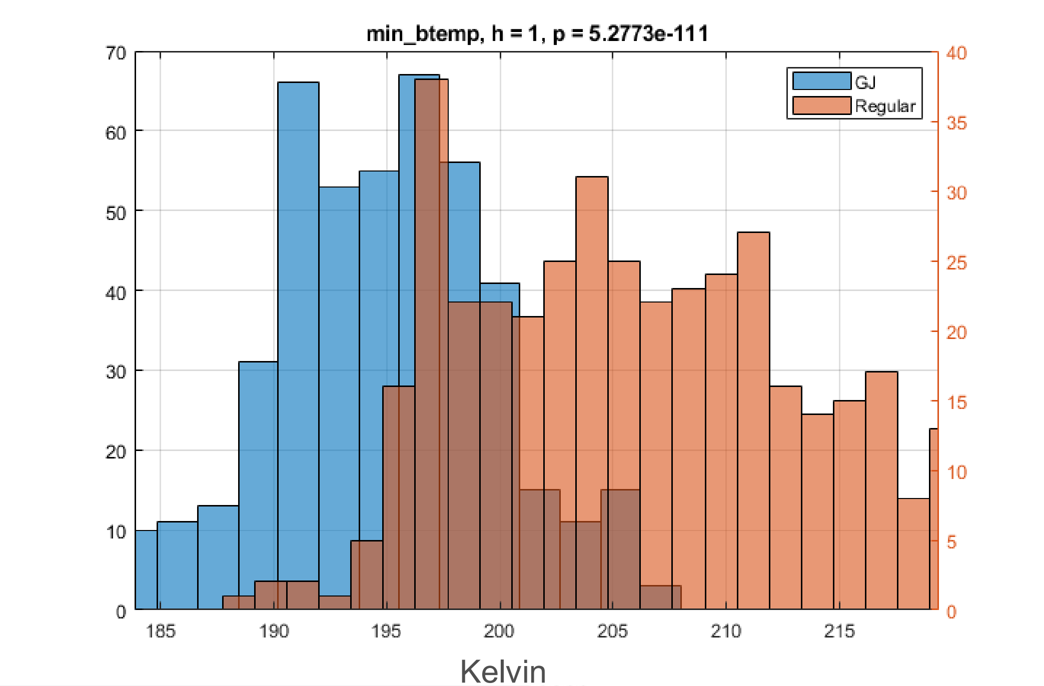
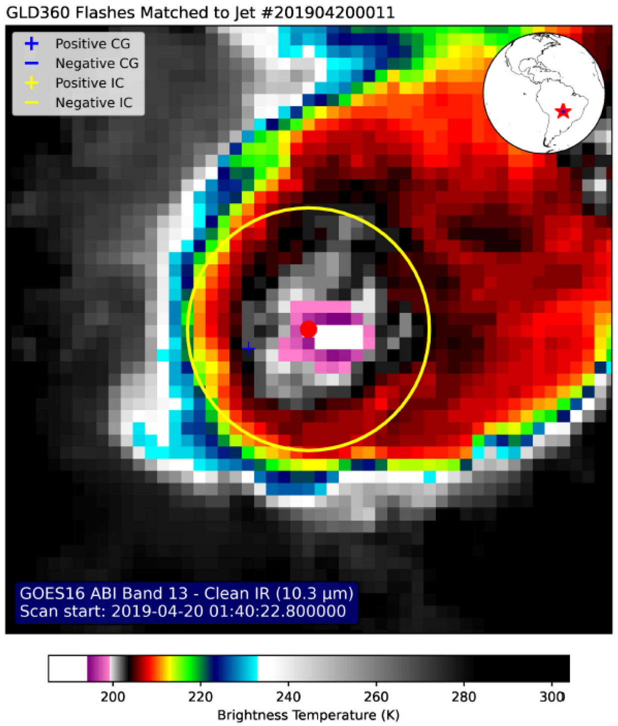
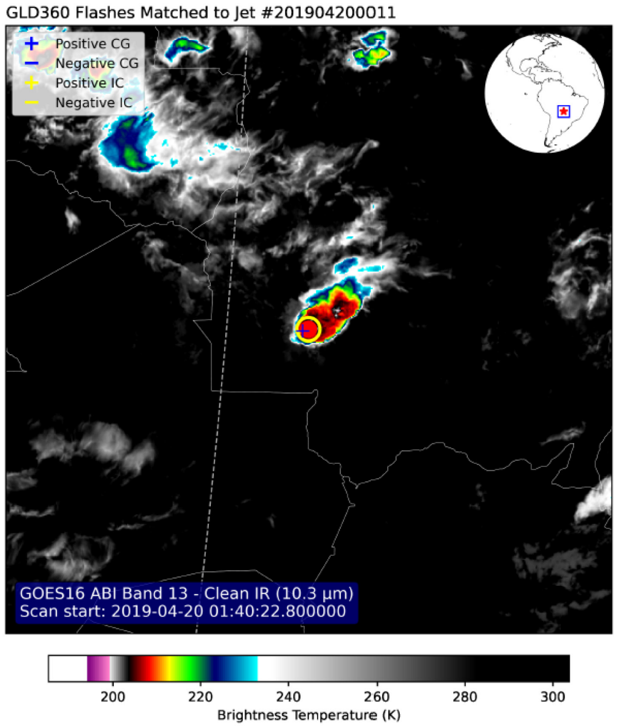
Gigantic Jet Signatures – ABI brightness temperature







- True GJs → Colder cloud tops when compared with traditional flashes
- ABI IR → GJ typically located near tallest cloud top, with large gradient in brightness temperatures

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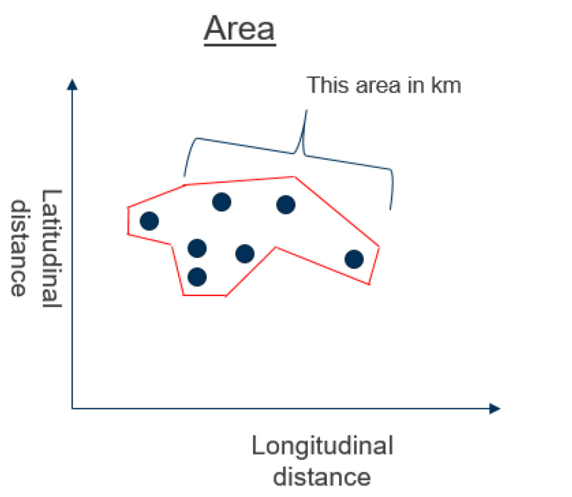
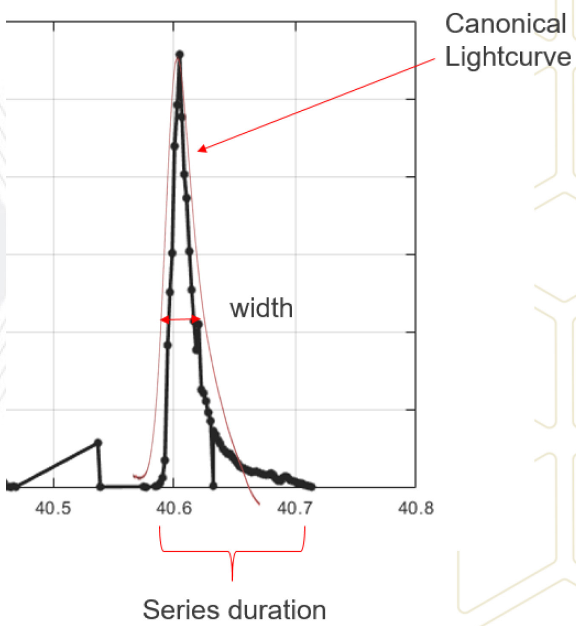
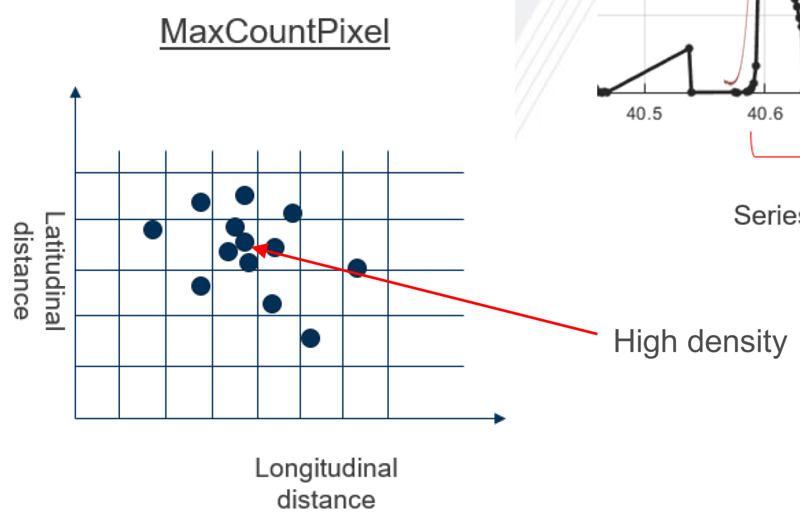
GLM Machine Learning Model

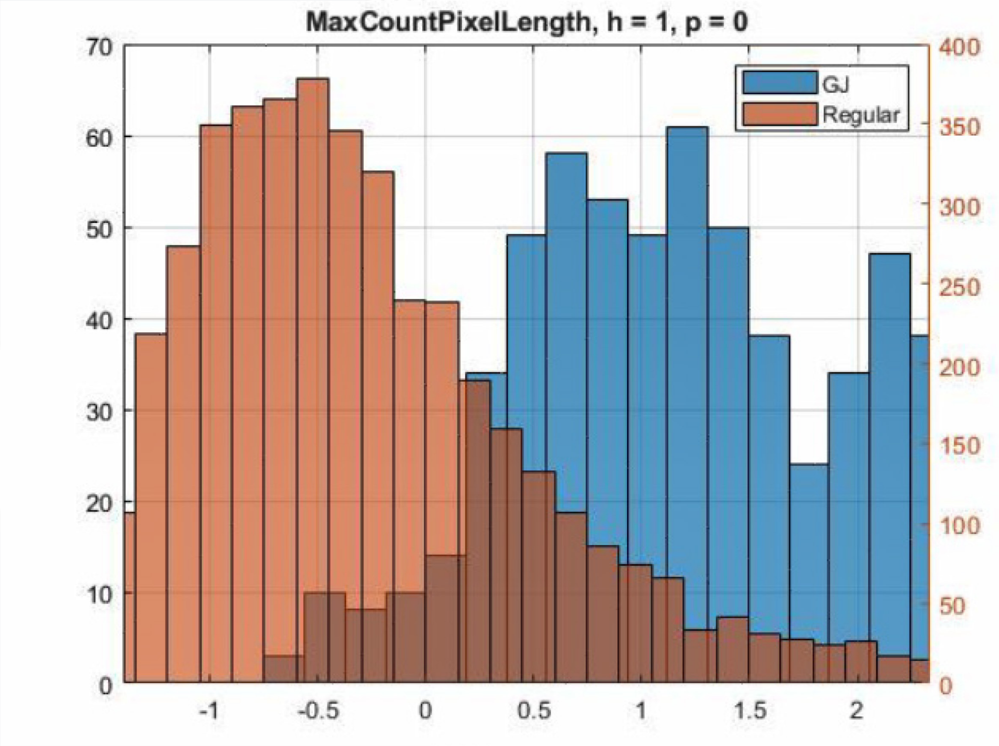




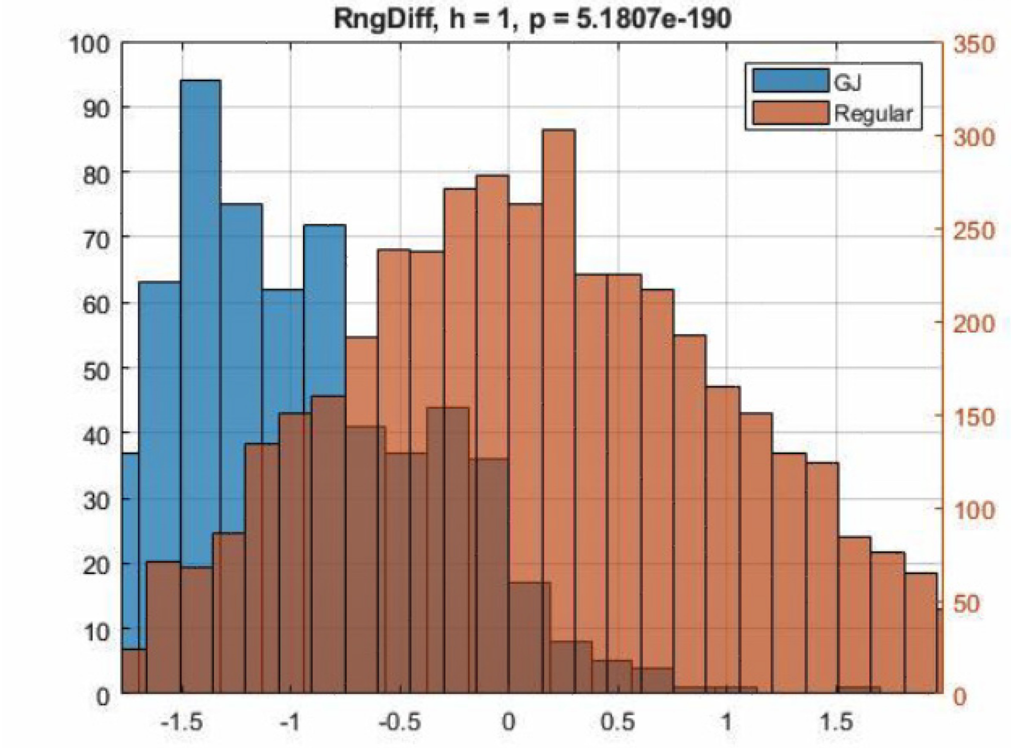


- Many different features capturing spatial and temporal differences between GJ and nonGJ flashes
- Spatial:
  - features that calculate things like flash size, distance traveled, and energy flux
- Temporal:
  - features that calculate properties from the lightcurve, such as FWHM, continuous duration, correlation with canonical jet lightcurve

GLM Machine Learning Model



Example of a spatial feature



Example of a temporal feature

Current Status and Next Steps

- We have deployed a preliminary ML model (random forest) to ~6 months of data
- Currently vetting the data: stereo altitudes, ABI and GLD model, and finally ELF/ULF model
- Continually expanding our ‘truth’ dataset with new vetted events
- Precision is low as expected (~1%), but **goal at this stage is to get more truth data**
- Next two years: begin correlating our GJ detections to VLF remote sensing data, in addition to other lightning physics data (LMAs, ASIM, RF SENSER).

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References

Cohen, Morris B., Umran S. Inan, and Evans W. Paschal. "Sensitive broadband ELF/VLF radio reception with the AWESOME instrument." *IEEE Transactions on Geoscience and Remote Sensing* 48.1 (2009): 3-17.

Smith, Jeffrey C., et al. "An automated bolide detection pipeline for GOES GLM." *Icarus* 368 (2021): 114576.

Chou, J. K., et al. "Gigantic jets with negative and positive polarity streamers." *Journal of Geophysical Research: Space Physics* 115.A7 (2010).

Boggs, Levi D., et al. "Upward propagation of gigantic jets revealed by 3D radio and optical mapping." *Science advances* 8.31 (2022): eabl8731.

Boggs, Levi D., et al. "First observations of gigantic jets from geostationary orbit." *Geophysical Research Letters* 46.7 (2019): 3999-4006.