Sub-flash discharge processes detected by GLM

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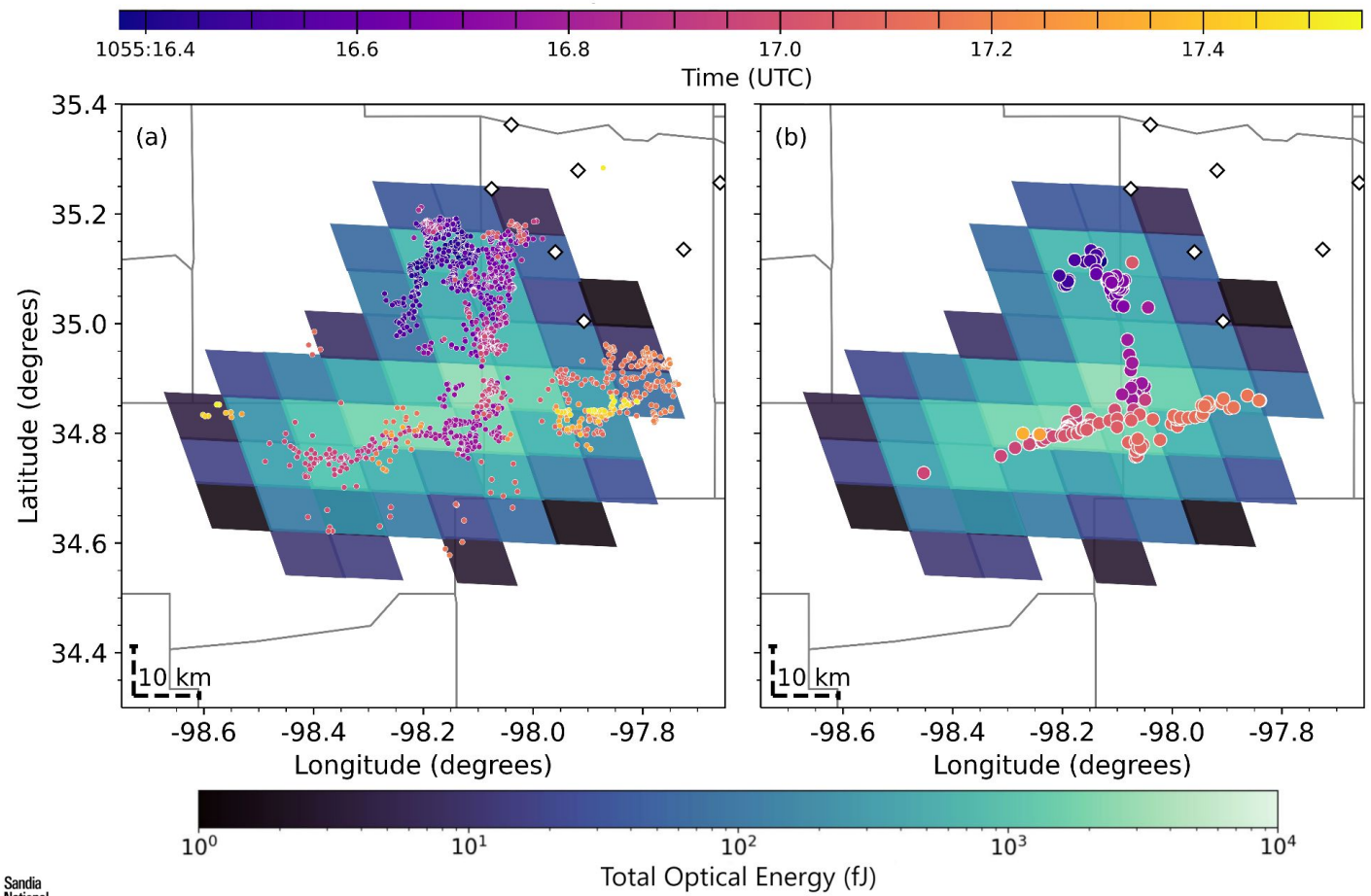
GLM groups map flash development

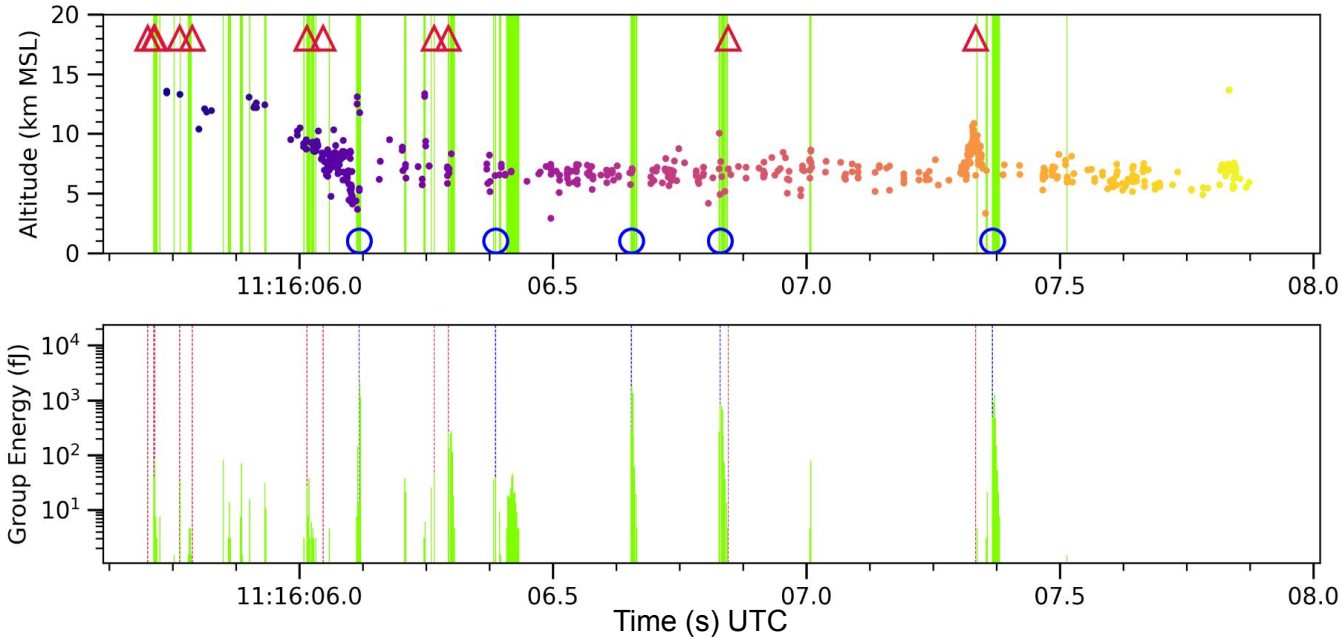


Discharge processes

 # Which lightning processes do we expect GLM to detect?

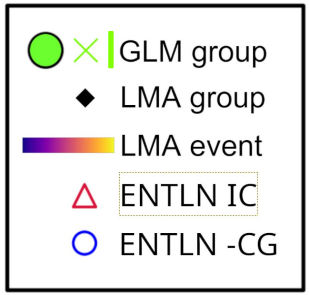
- Initial breakdown?
- ~~Narrow bipolar events?~~
- Stepped leaders?
- Return strokes?
- Dart leaders?
- Continuing current?

Flash 1

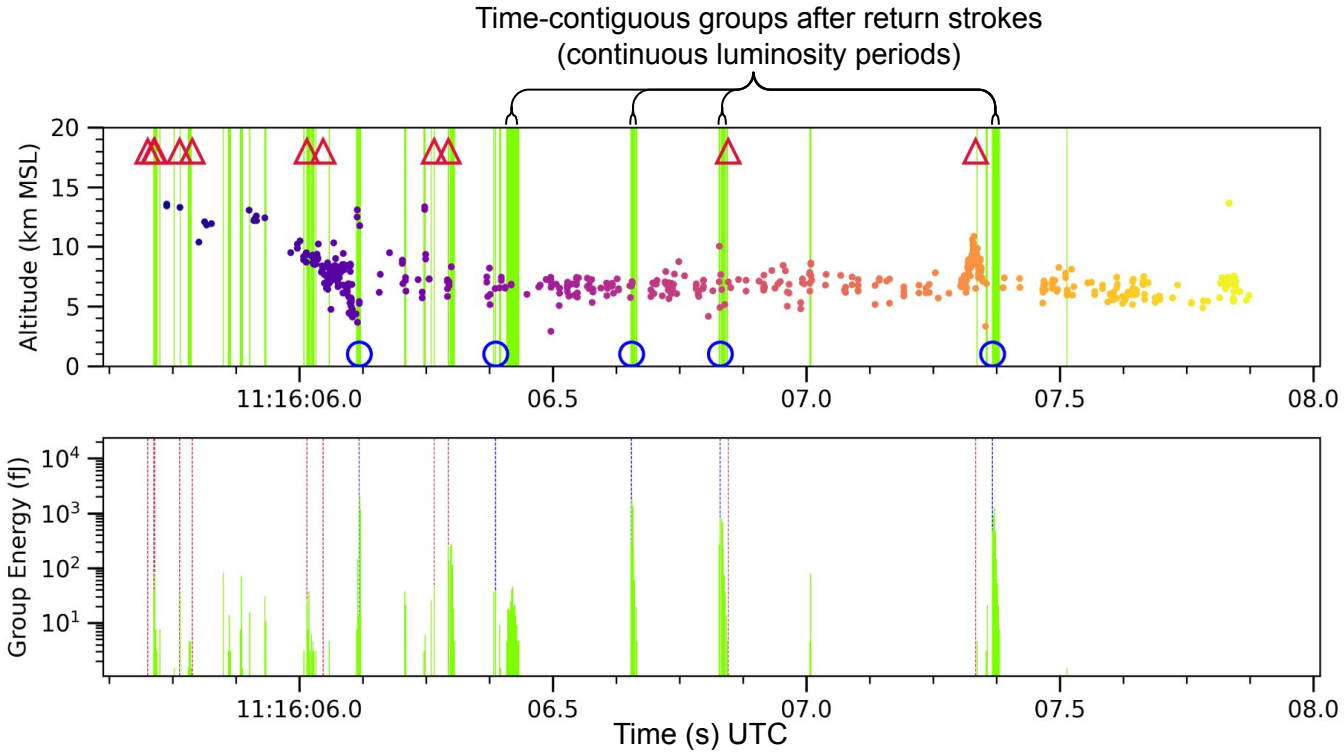


 # LMA and ENTLN shows

- Stepped leaders
- Return strokes
- Dart leaders

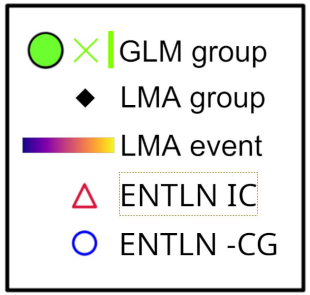


Flash 1



 # GLM triggers during

- Initial breakdown
- Leader stepping
- Return stroke
- Dart leaders
- Continuing current (CC)?



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Flash 1

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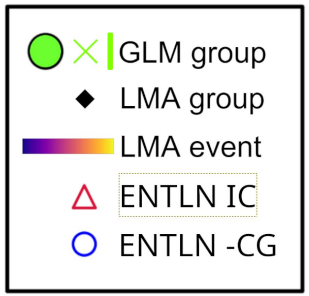
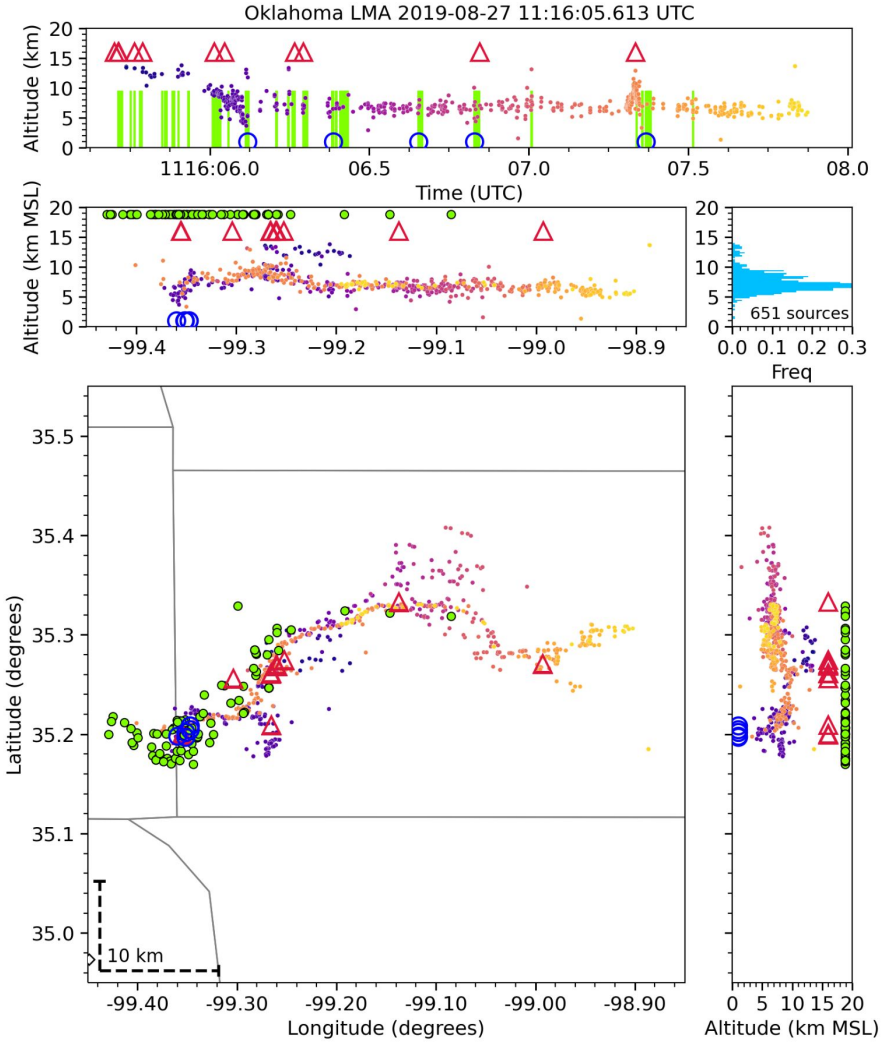
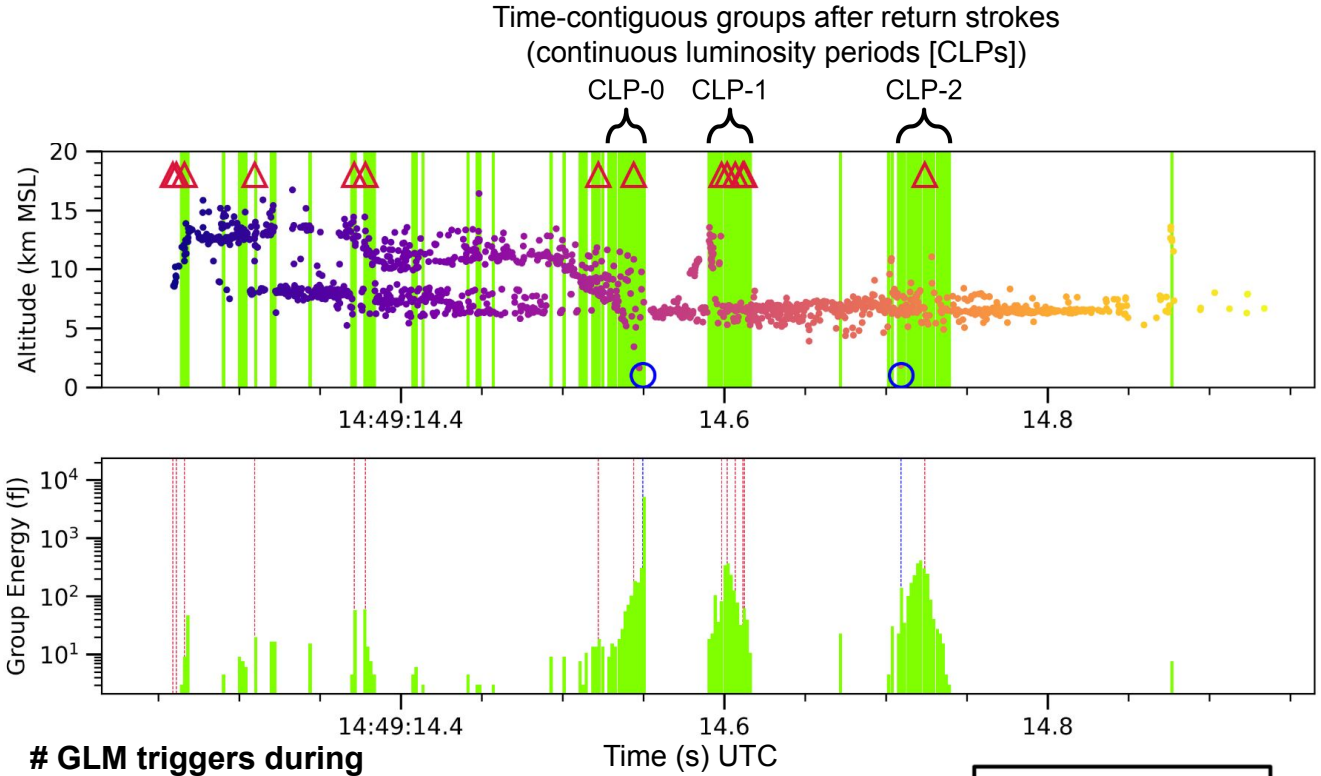




Flash 2



 # GLM triggers during

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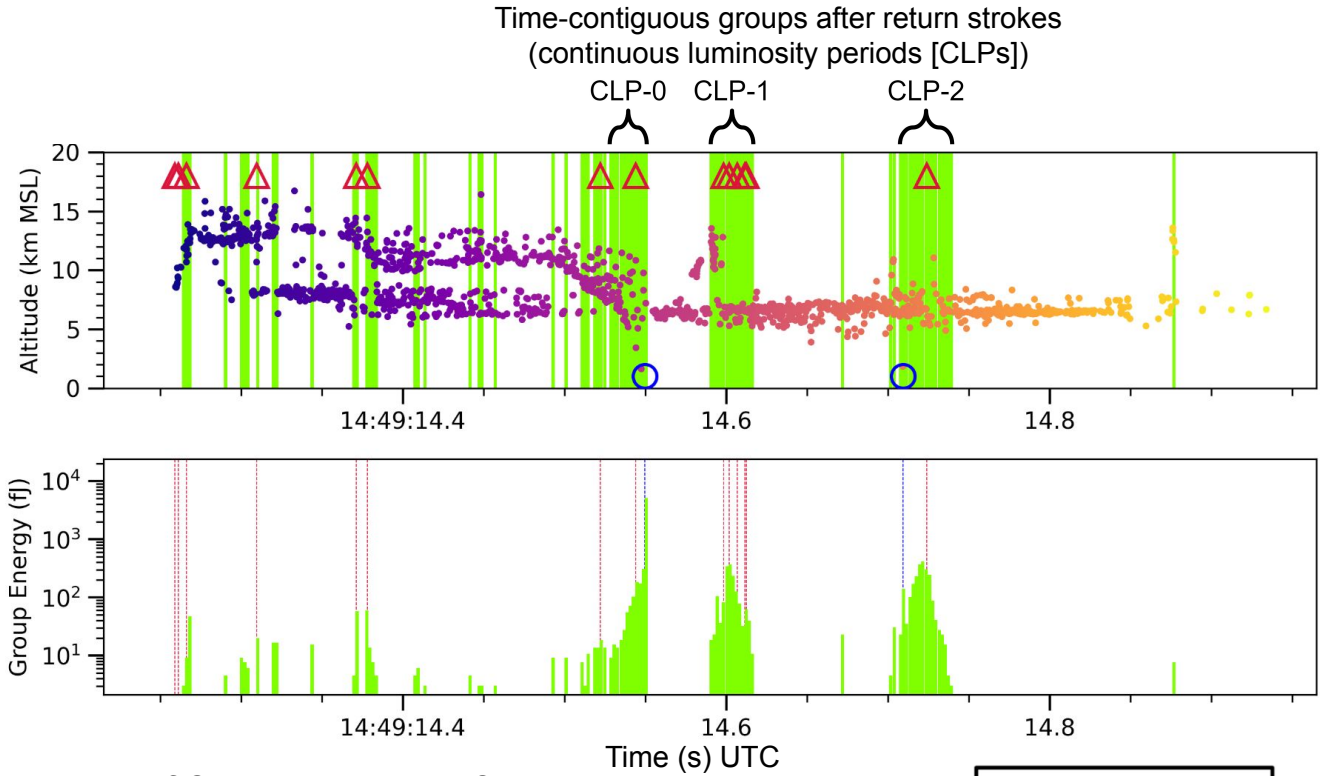
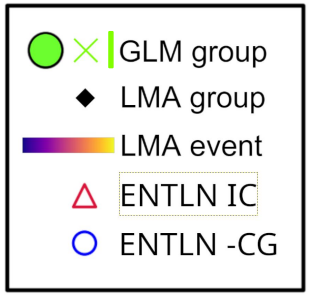
- Leader stepping
- Return stroke
- Dart leaders
- Continuing current (CC)?

Flash 2



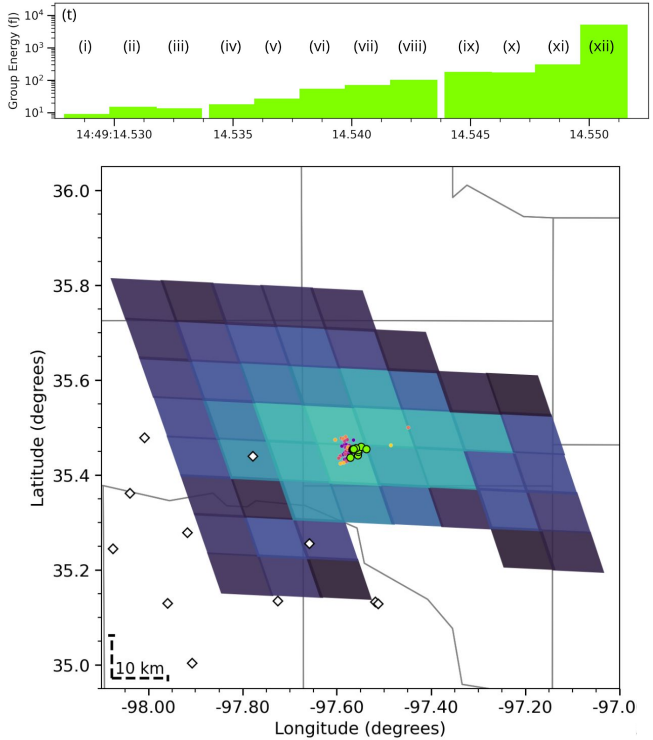
 # Evidence of Continuing current?

- CLPs Occur
  - Prior to first return stroke
  - After subsequent strokes

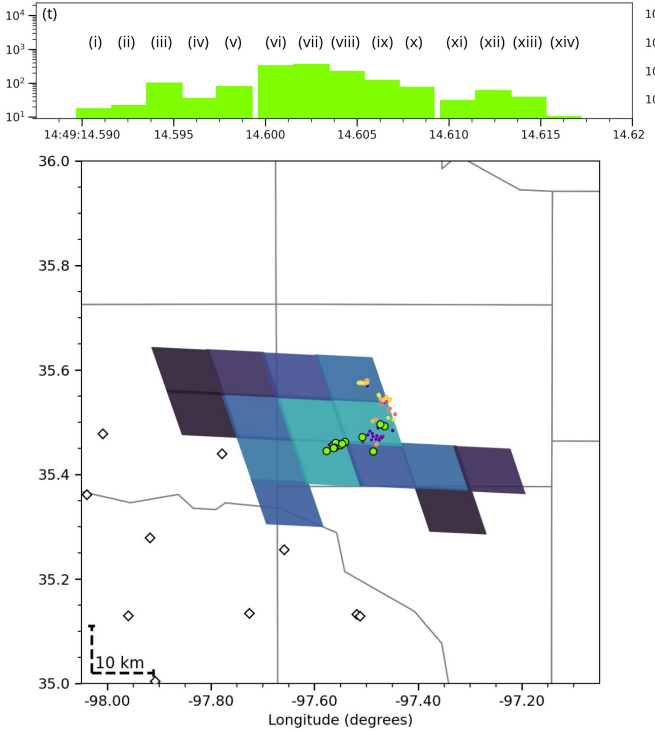


Flash 2 Continuous Luminosity Periods (cumulative integrations)

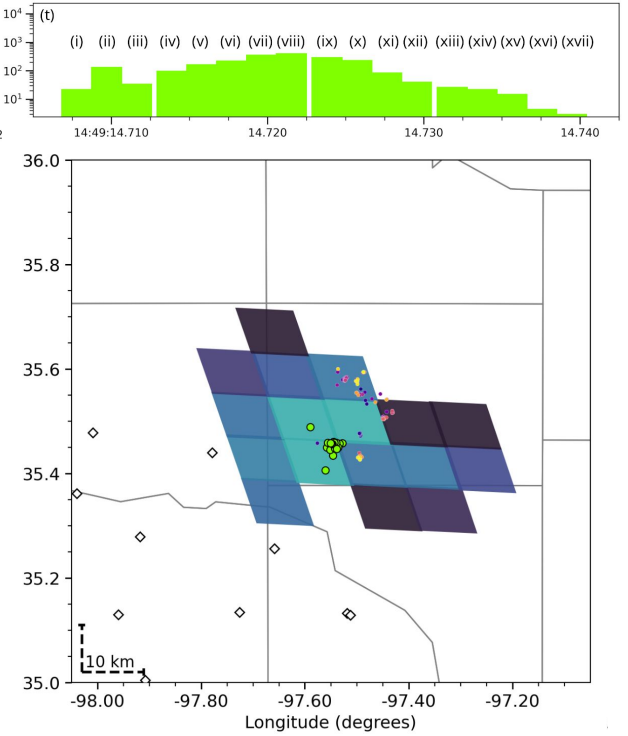
CLP 0



CLP 1



CLP 2



 # Stepped leader detection

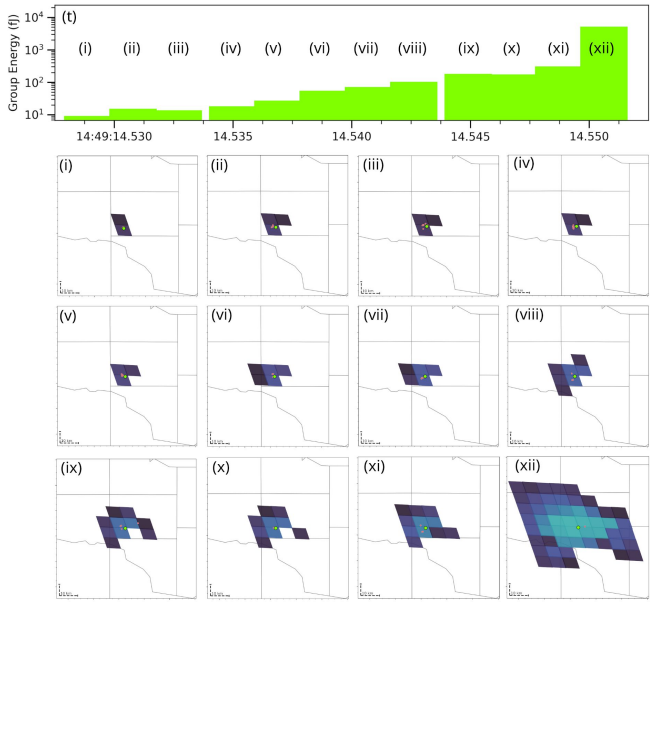
- Increasing group energy
- Increasing group area
- Final group: initial return stroke

 # Continuing current detection

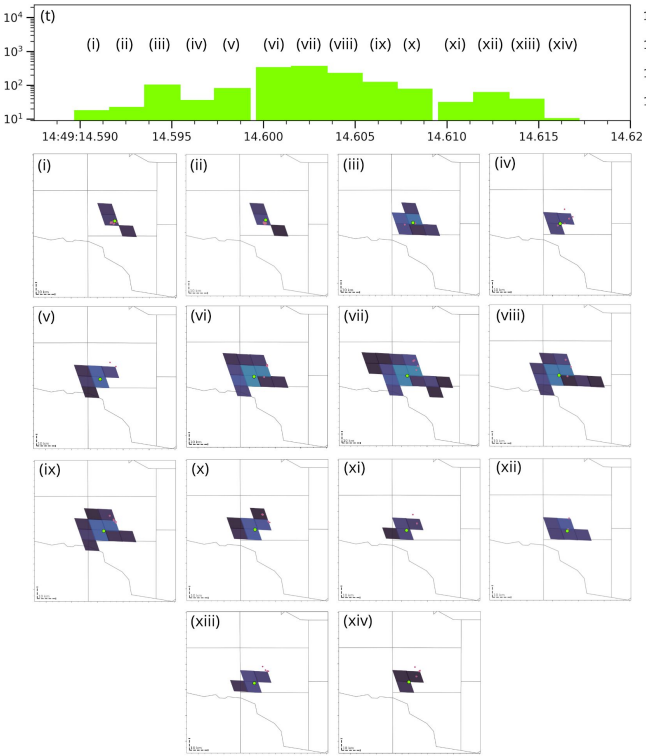
- Peaked group energy profile
- Group area increases, then decreases
- Occur after return strokes

Flash 2 Continuous Luminosity Periods: frame by frame

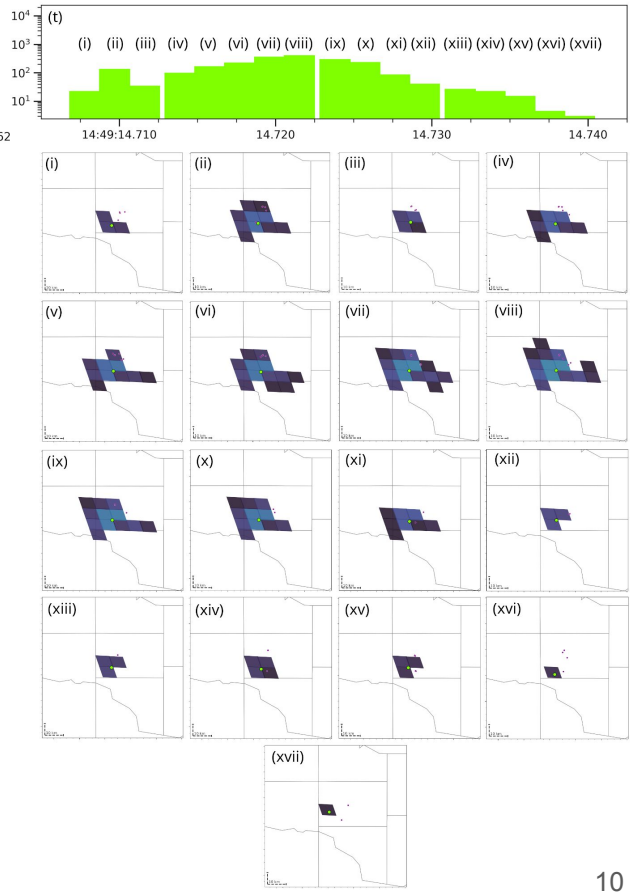
CLP 0



CLP 1



CLP 2

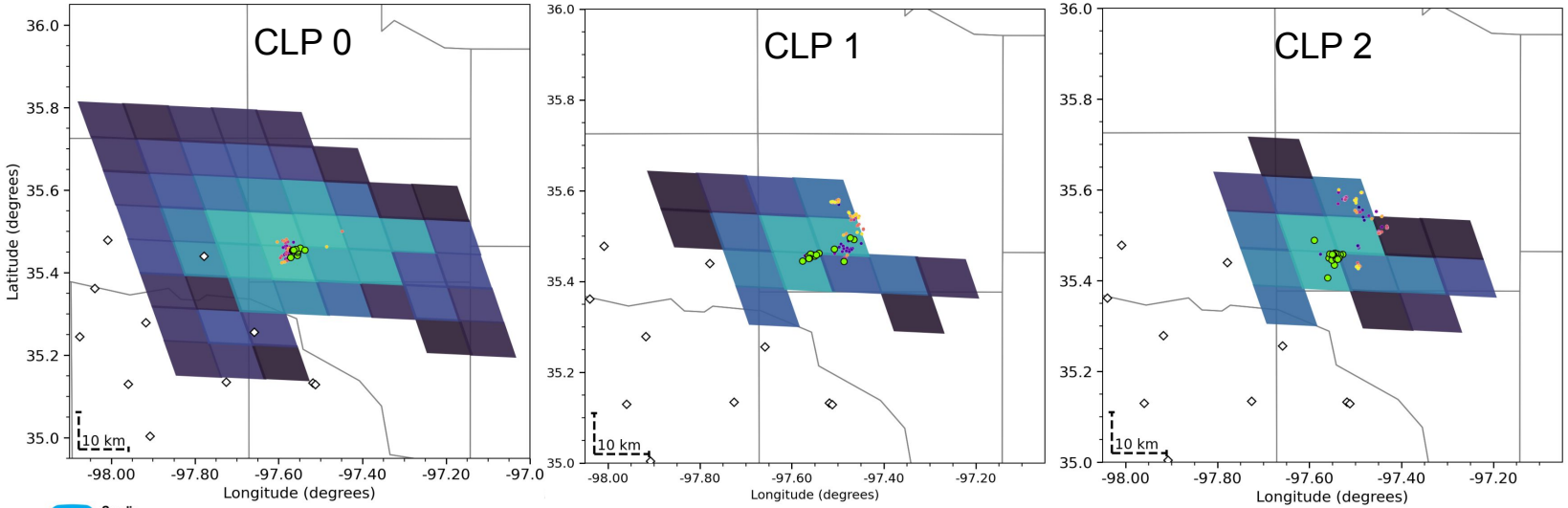


Flash 2 Continuous Luminosity Periods

 # Continuing current detection

- Fairman and Bitzer (2022): **duration** of continuous luminosity and **maximum distance among group centroids** (**Diameter**, $\mathbf{D_G}$) are good predictors of CC in a GLM flash.
- Durations are comparable.
- Diameter is greater for CLP 1 & 2.

CLP	0	1	2
Duration (ms)	24	28	34
D_G^i (km)	3.14	9.18	9.32



Interpretation and Conclusions

- GLM detects light from
  - Initial breakdown
  - Stepped leaders
  - Return strokes
  - Dart leaders (IC and CG)
  - Continuing current
- Continuing current detections have peaked group energy and group area plots.
- A larger spread of GLM group centroids is observed for continuing current detections compared to clusters of time-contiguous groups representing detection of other lightning processes (e.g., stepped leaders), in agreement with Fairman and Bitzer (2022).

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References

[1] Goodman et al., (2013), "The GOES-R Geostationary Lightning Mapper (GLM)", *Atmospheric Research, 125–126*, Pages 34-49, ISSN 0169-8095. https://doi.org/10.1016/j.atmosres.2013.01.006

[2] Thomas, R. J., Krehbiel, P. R., Rison, W., Hunyady, S. J., Winn, W. P., Hamlin, T., and Harlin, J. (2004), "Accuracy of the Lightning Mapping Array", *J. Geophys. Res., 109,* D14207, doi:10.1029/2004JD004549.

[3] Jensen, D. P., Sonnenfeld, R. G., Stanley, M. A., Edens, H. E., da Silva, C. L., & Krehbiel, P. R. (2021). Dart-leader and k-leader velocity from initiation site to termination time-resolved with 3d interferometry. Journal of Geophysical Research: Atmospheres, 126 (9), e2020JD034309.

[4] Fairman, S. I., & Bitzer, P. M. (2022). The detection of continuing current in lightning using the geostationary lightning mapper. Journal of Geophysical Research: Atmospheres, 127 (5), e2020JD033451.

Acknowledgements

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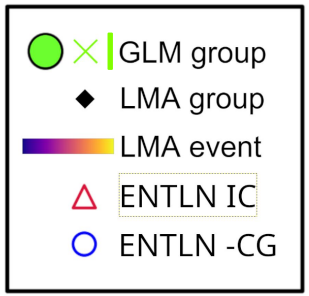
We thank Earth Networks for free use of ENTLN data for scientific purposes.

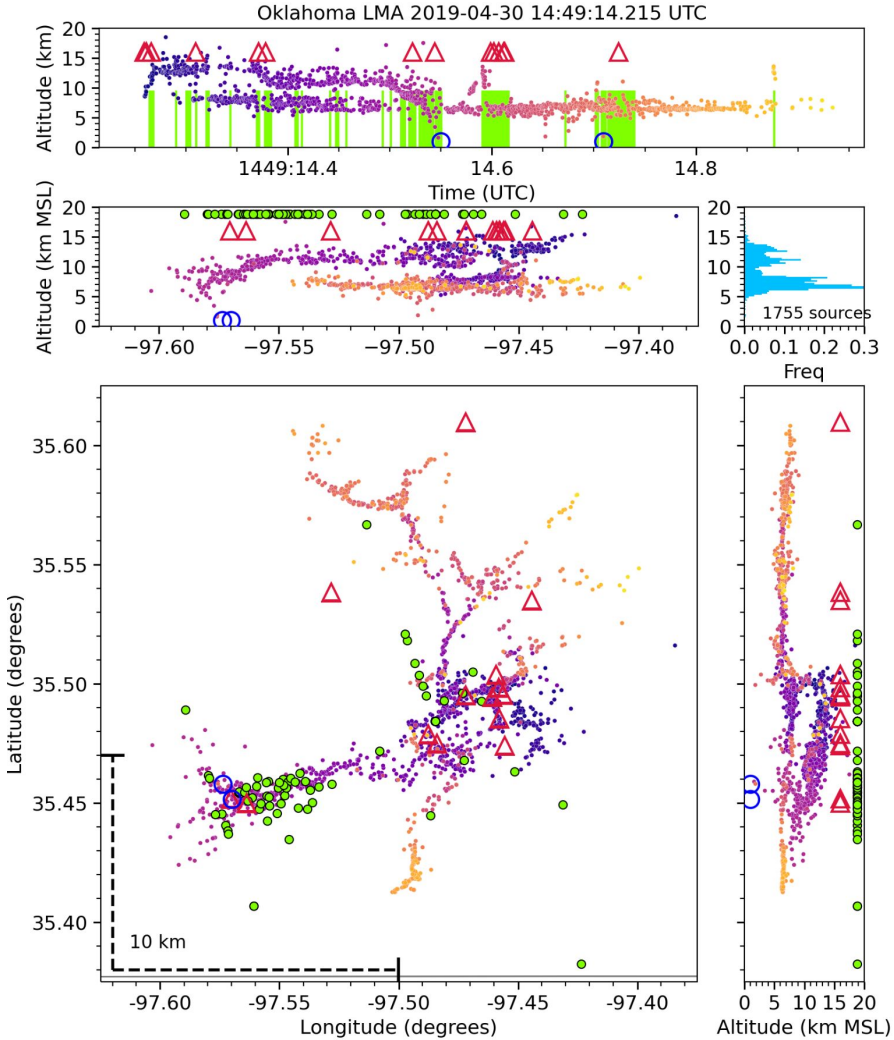
We also thank Doug Mach for additional insights into GLM.

Flash 2

 # GLM triggers during

- Initial breakdown
- Leader stepping
- Return stroke
- Dart leaders
- Continuing current (CC)?

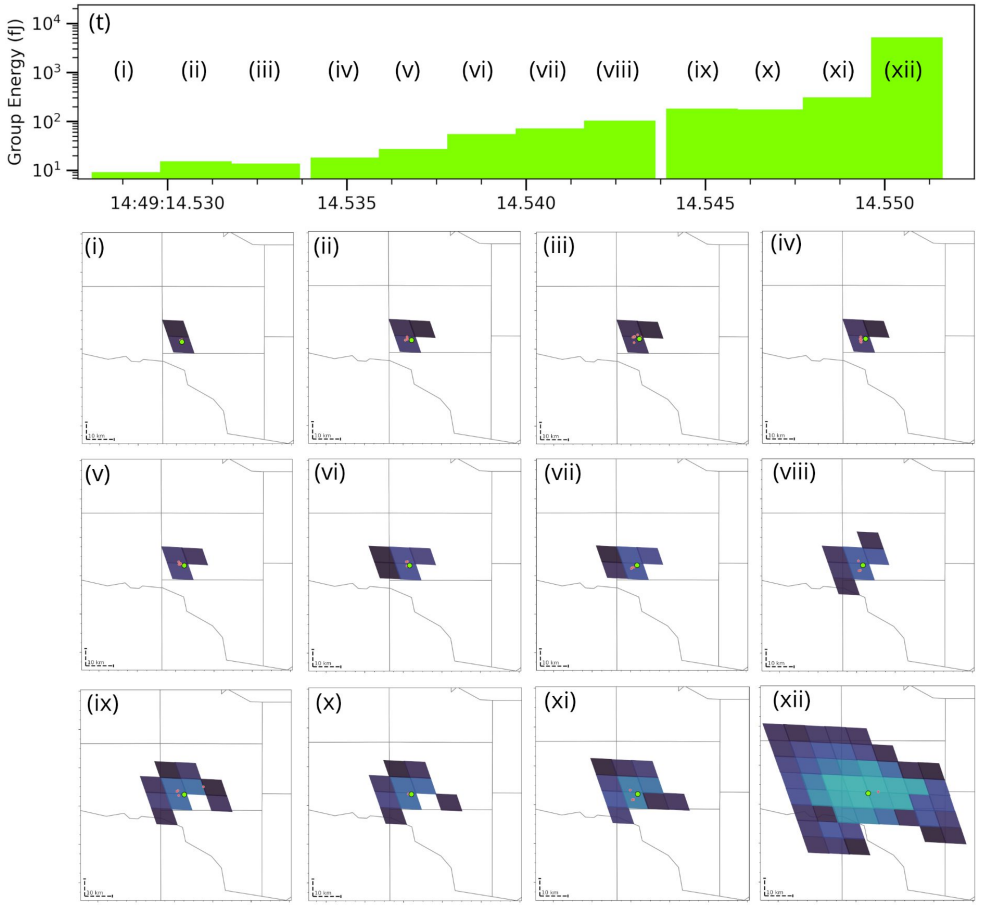




Flash 2: CLP 0 frame by frame

 # Stepped leader detection

- Increasing group energy
- Increasing group area
- Culminates with the initial return stroke



Flash 2: CLP 1 frame by frame

 # Continuing current detection

- Peaked group energy profile
- Group area rises and then falls
- Similar to CLP 2