Characterization of Optical Energy Output in Thunderstorms to Enhance Severe Thunderstorm Identification

Christopher J. Schultz[1], Kelley Murphy[2], Lawrence D. Carey[3], Phillip M. Bitzer[3], Kristin Calhoun[4], Eric C. Bruning[5]

1- NASA Marshall Spaceflight Center

2 - Earth System Science Center, University of Alabama in Huntsville

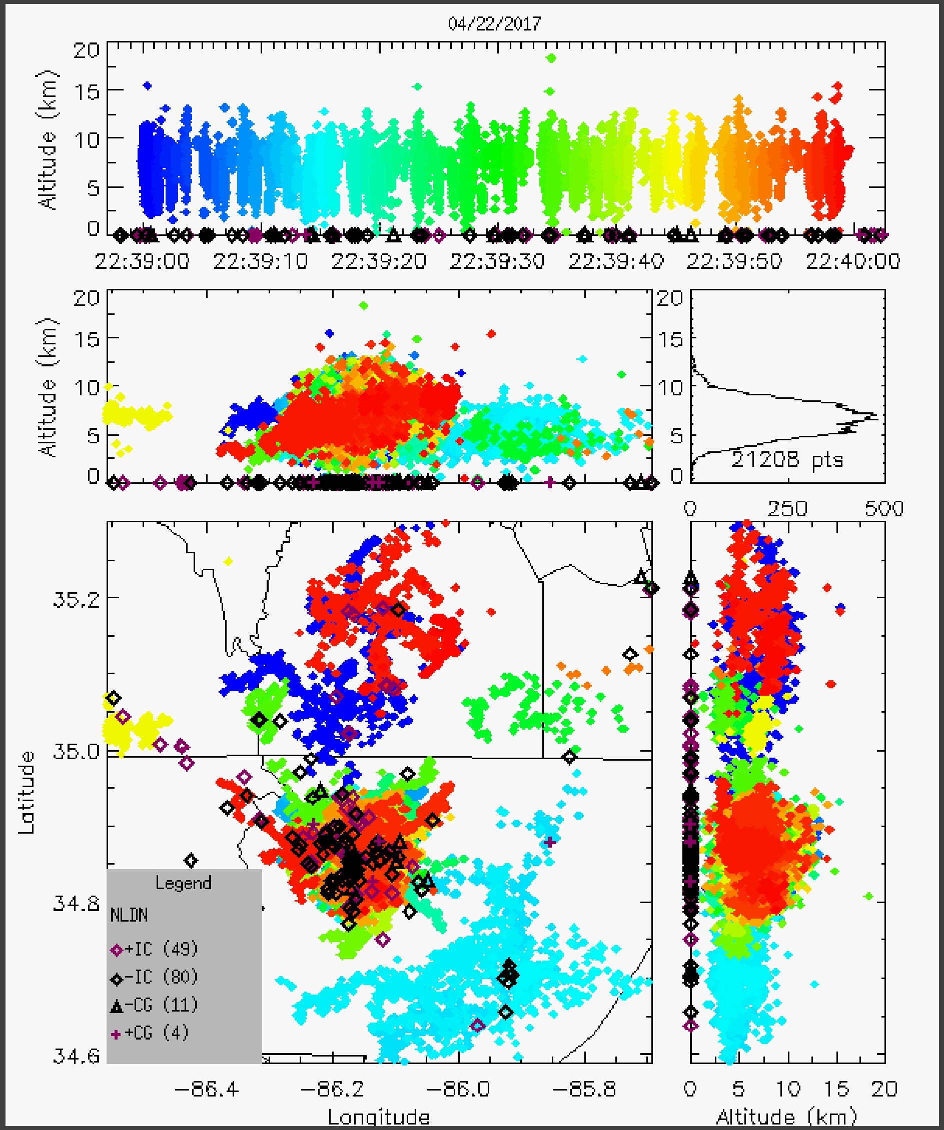
3- Department of Atmospheric Science, The University of Alabama in Huntsville

4 – National Severe Storm Laboratory

5 – Department of Geosciences, Texas Tech University

Why Optical Energy?

- Flash rates are dependent upon the measurement type of the flash.
- Different trends in the flash rate will be observed based on the type of measurement.
  - **Important:** the differences are not solely based on detection efficiency of the different instrumentation.



Flash rate comparison for GLM, LMA, and NLDN on 22 April 2017 between 2239 and 2240 UTC.
GLM flashes: 31
GLM groups: 579
LMA flashes: 86
NLDN flashes: 152

More on this April 22, 2017 case in Conrad et al. 2019, Curtis et al. 2019, and Carey et al. 2019, this conference

Why Optical Energy?

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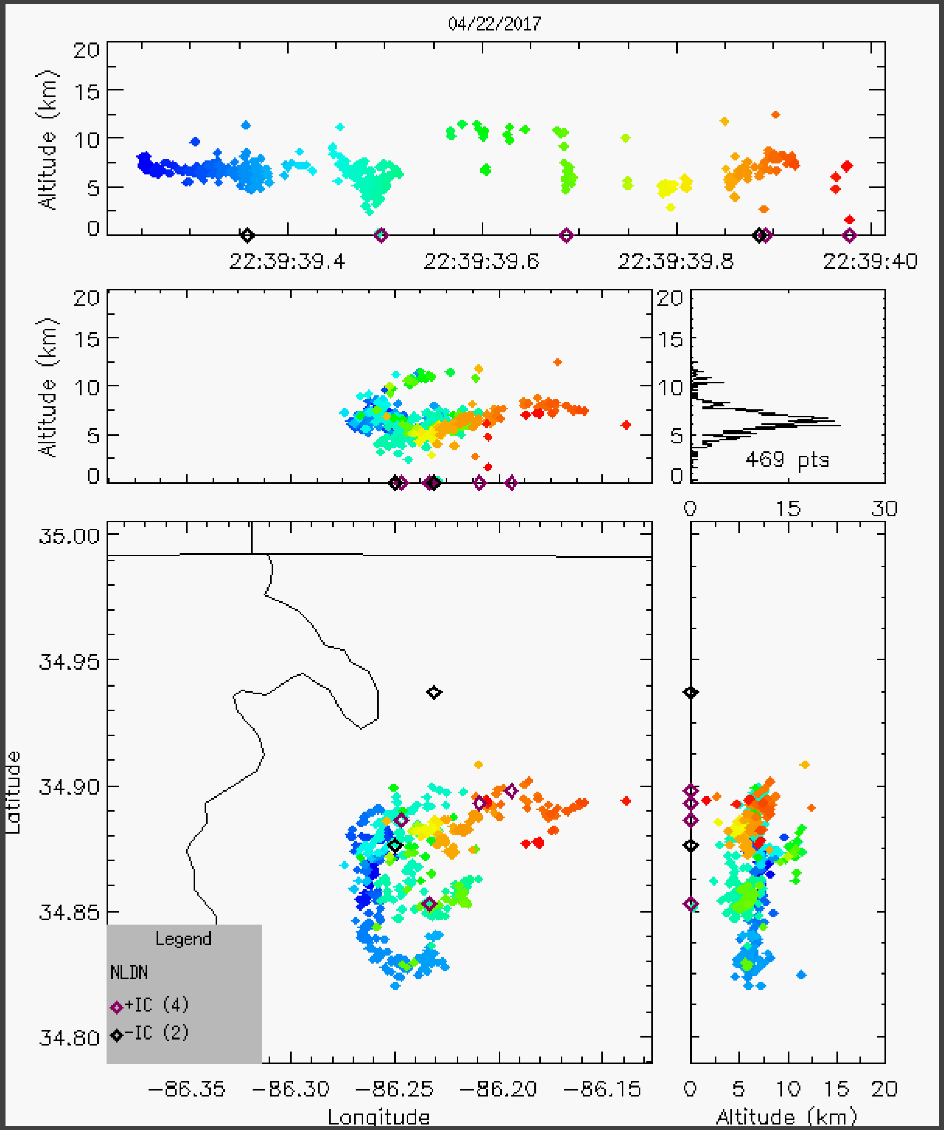
Flash comparison for a single LMA-flash on 22 April 2017 at 22:39:39.3 UTC.
GLM flashes: 1
GLM groups: 27
LMA flashes: 1
NLDN flashes: 6



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Outstanding questions and goals of this work

- What are the energy output and trends in thunderstorms?
  - How does this parameter vary over the spectrum of storm intensity?
  - How does the parameter align with the kinematic and microphysical observations of the storm? (Conrad et al. 2019, This conference)
- How does the total magnitude and trends in energy align temporally with traditional intensity metrics for thunderstorms (e.g., radar and ABI/microwave derived based metrics)?
- What can operational end users use right out of the box in the operational environment to complement their knowledge of the use of flash rates to interrogate storm intensity?

The Setup

Use current GLM thunderstorm tracking methods to identify storms in the GOES-16 GLM field of view.

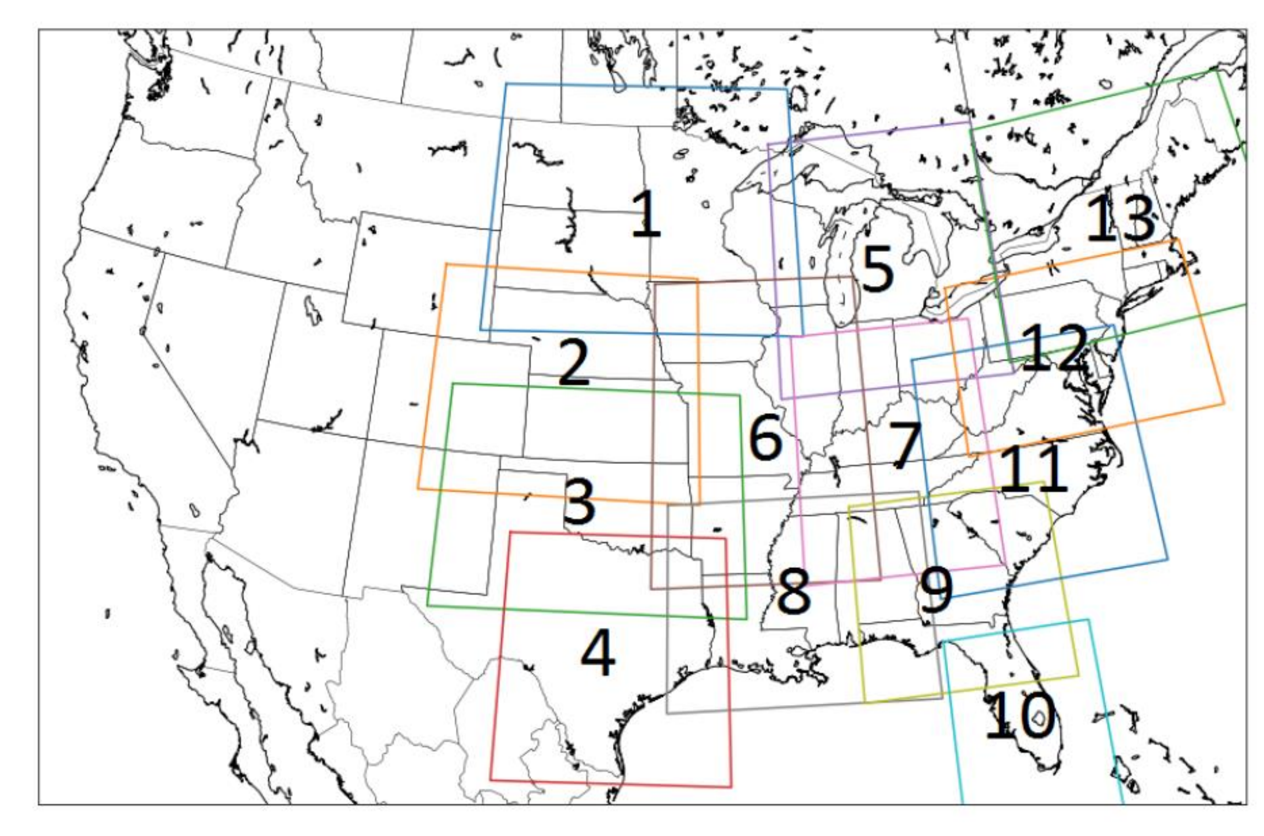
- tracking method: E. Schultz et al. (2016) J. Operational Meteorology: https://doi.org/10.15191/nwajom.2016.0407

GLM level 2 flash products

- flash
- flash energy
- flash area

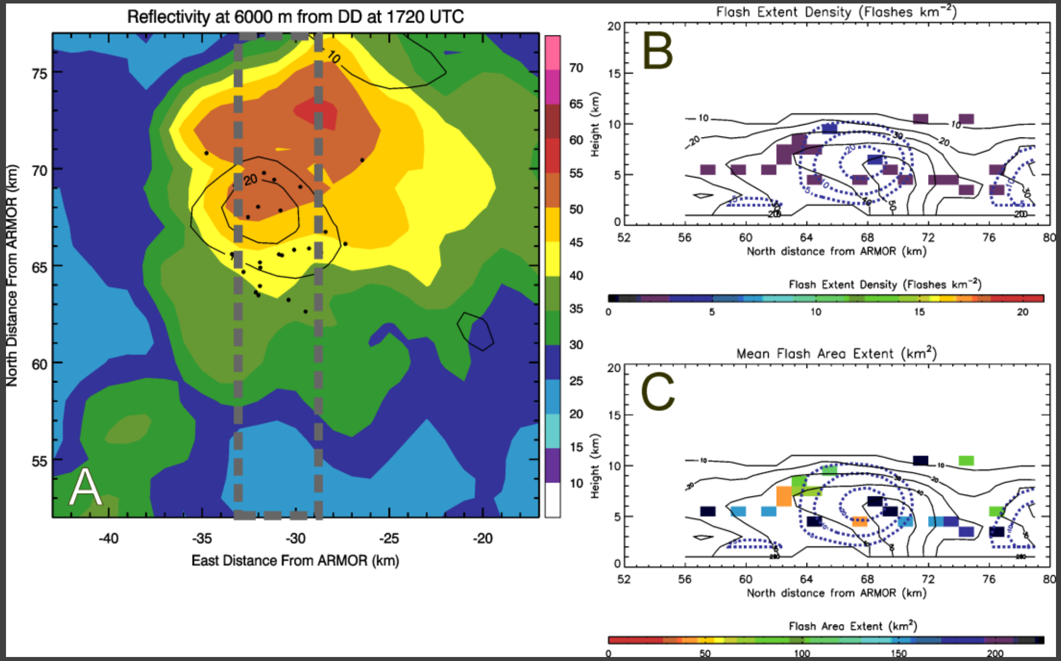
Radar based intensity metrics

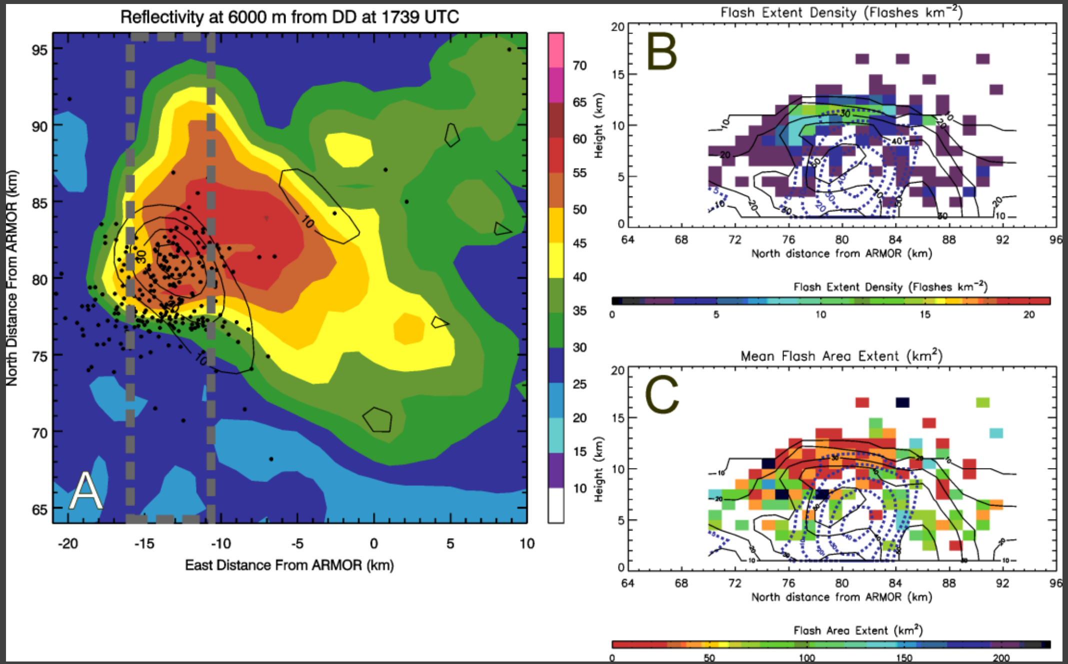
- Maximum reflectivity
- Maximum expected size of hail



Subdomains used by Curtis et al. 2019, this conference for the GOES-16 field of view.

Conceptual model for energy trends in intense storms



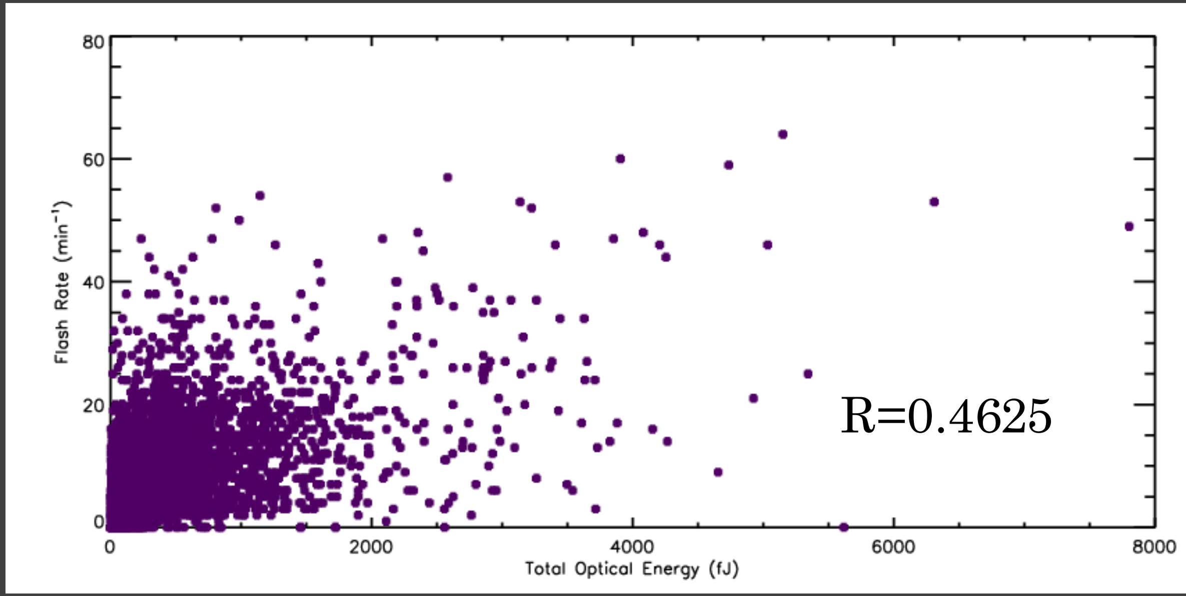


Conceptual example of the relationship between updraft, flash rate and flash size from Schultz et al. (2017), Weather and Forecasting

As storms intensify (e.g., updraft strength, updraft size) the optical energy output of the storm will increase in magnitude just like observed kinematic and lightning relationships using LMA.

Basis for this hypothesis relating updraft strength to generation of current and optical output in a thunderstorm is outlined in Boccippio et al. 2002 (J. Atmos. Sci.).

Flash Rate and Energy Relationships

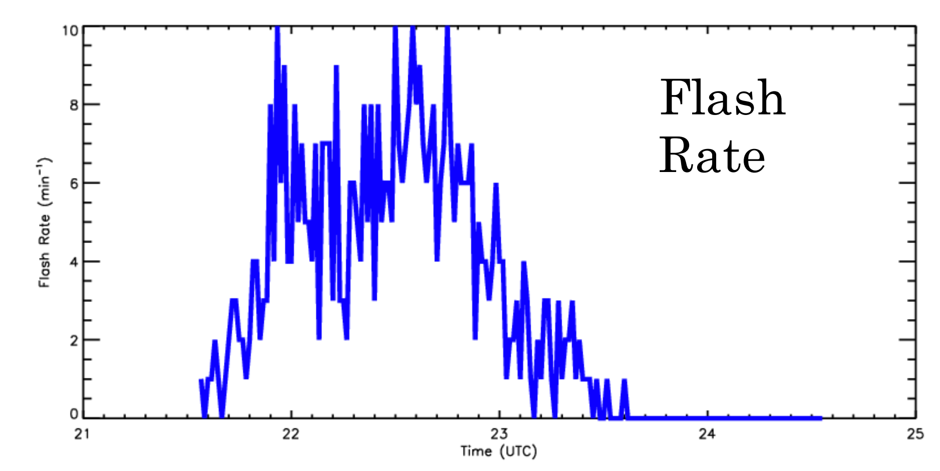


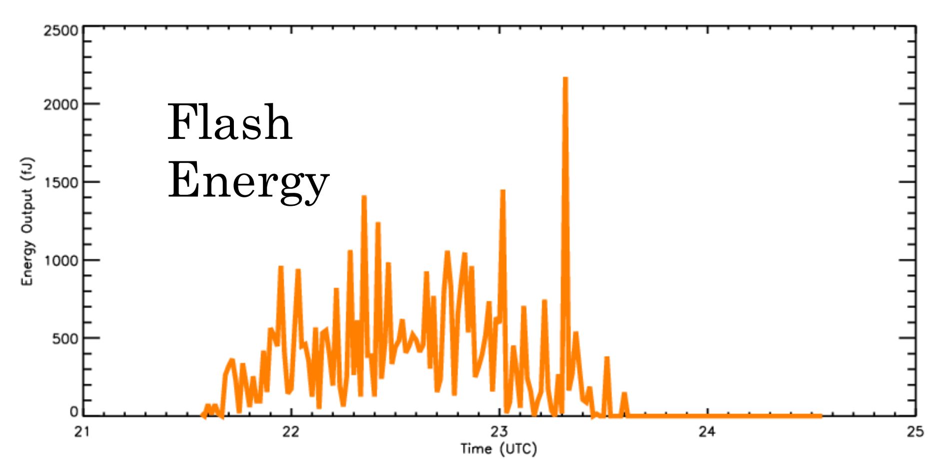
1 minute Accumulated Total Optical Energy vs
1 minute Flash Rate for 3910 1 minute periods

Flash rate and accumulated flash energy are moderately correlated with an R value of 0.46.

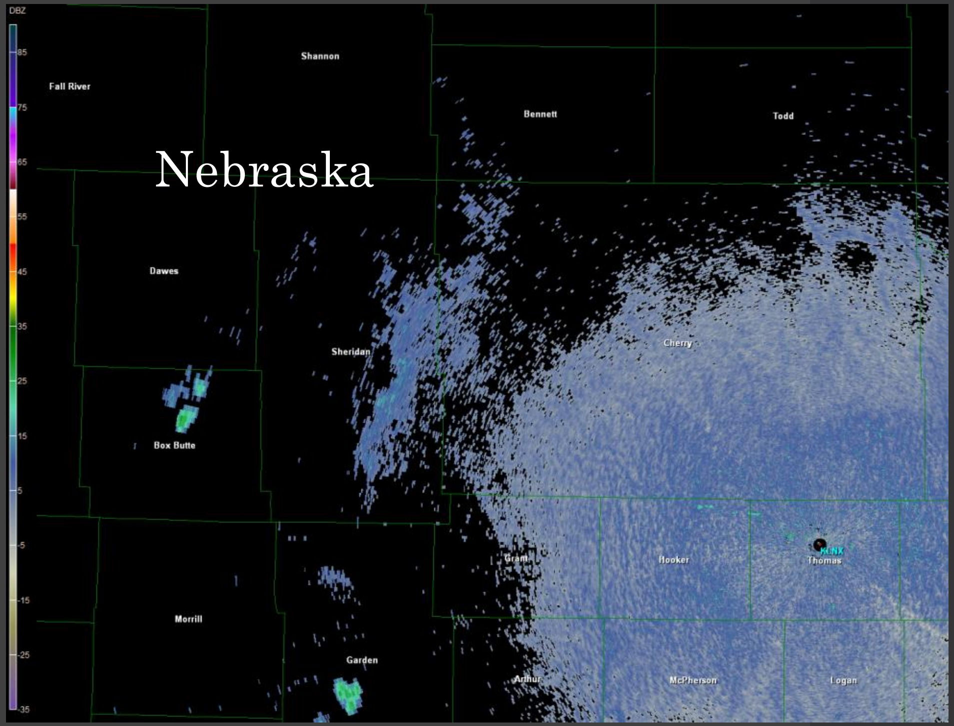
The peak in the accumulated energy typically lags the peak in the total flash rate by approximately 4 minutes in the mean.

Case Example 1
28 June 2018 – High Plains





Severe weather was not reported with this thunderstorm.



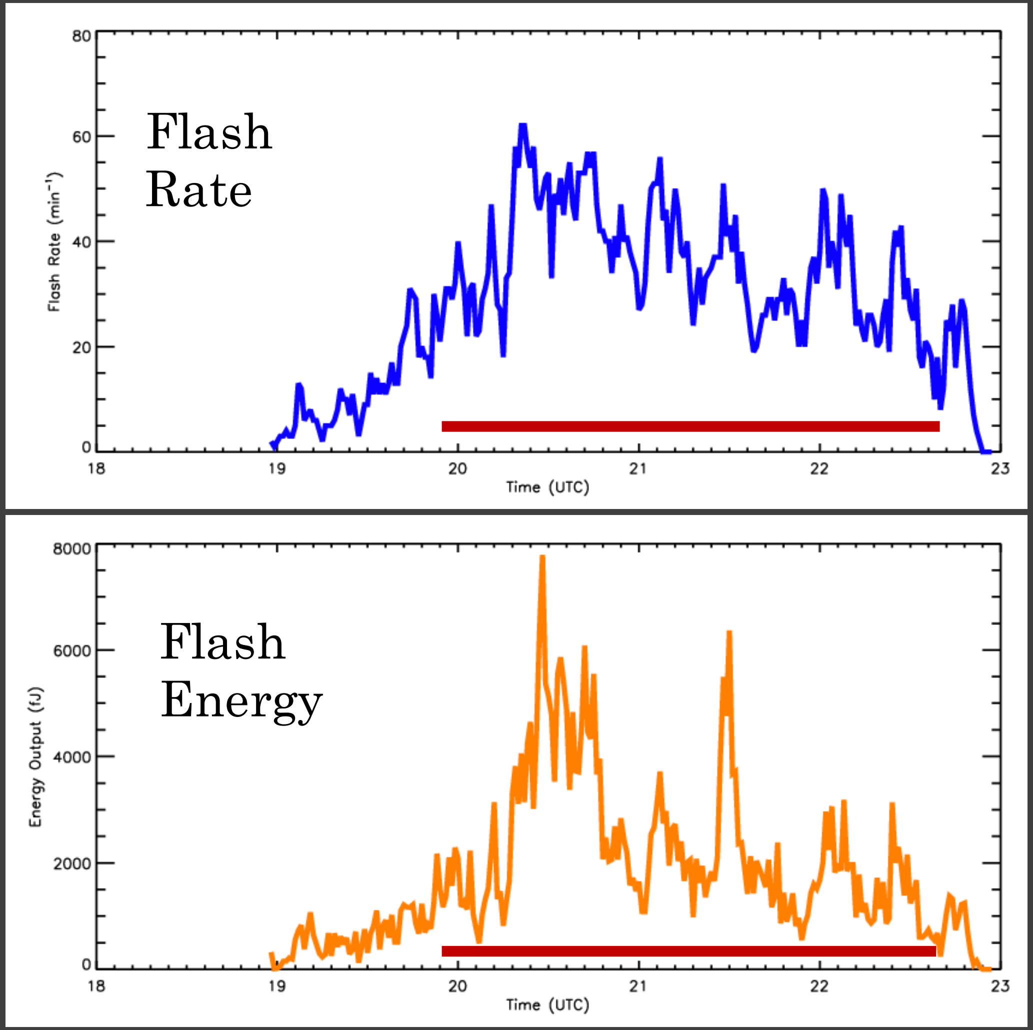
0.5° elevation scan of horizontal reflectivity between 2130 and 0000 UTC every 15 minutes.

No severe reports.

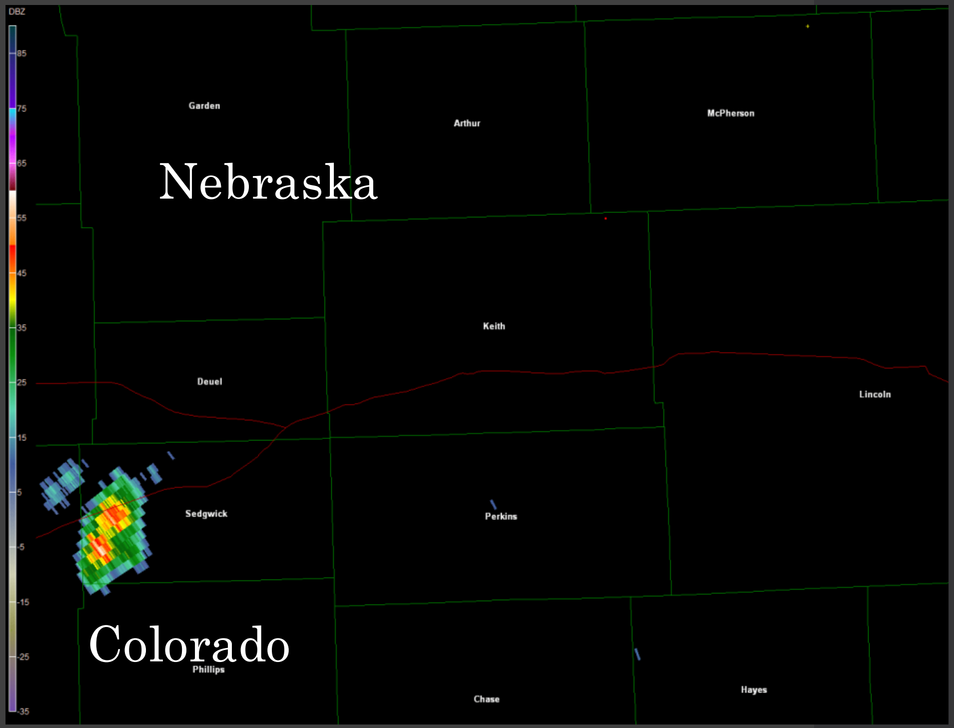
General increase in total flash rate as the storm develops. Maintenance of total flash rates of 4-10 flashes min^{-1} during mature phase.

Trend in energy follows the trend in flash rate, but peak energy value observed during dissipation phase.

Case Example 2
17 June 2018 – High Plains



Red bar indicates the duration of severe storm reports for this storm. All 3 modes of severe weather were observed during this period.



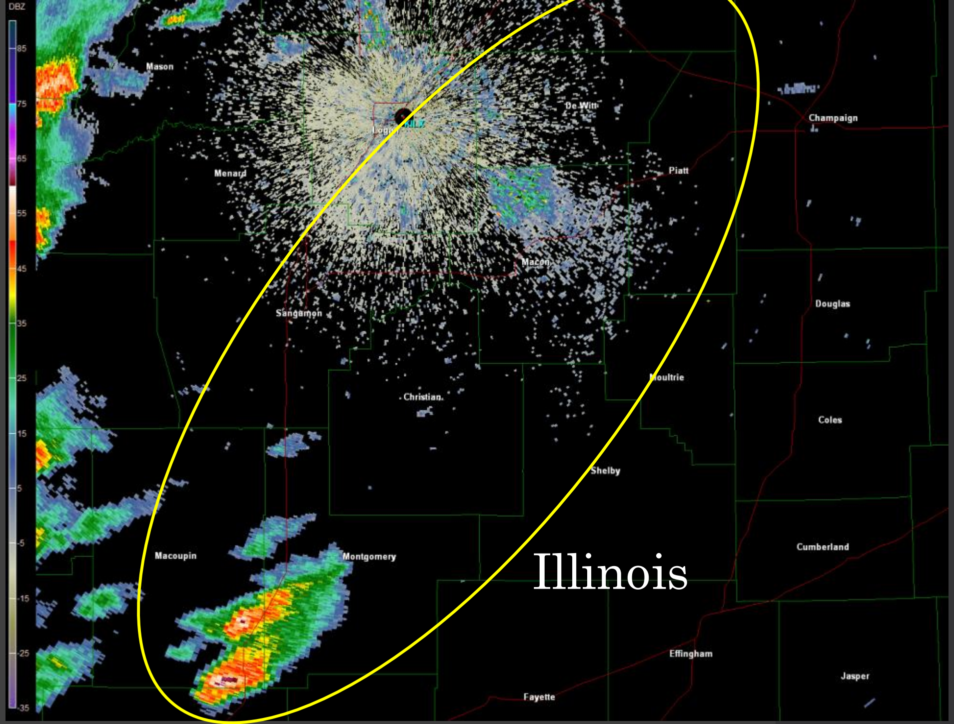
0.5° elevation scan of horizontal reflectivity between 1900 and 2200 UTC every 30 minutes.

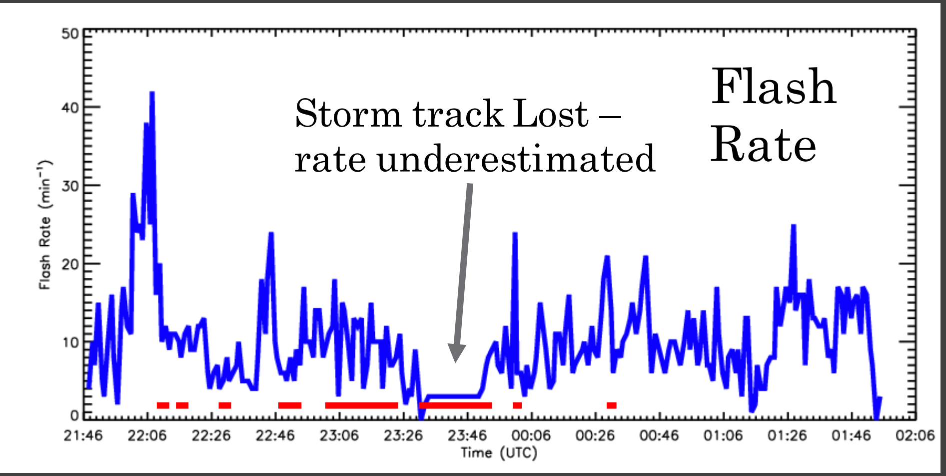
Flash rates rapidly increase prior to a large increase in optical energy.

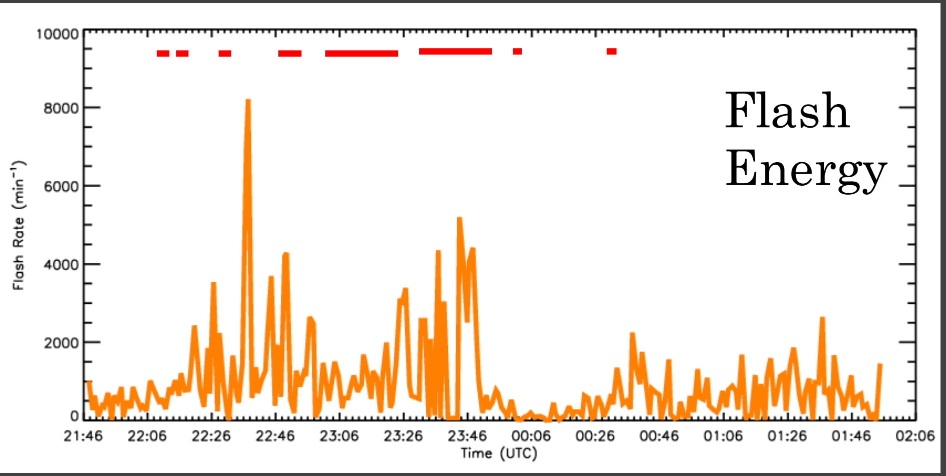
Both quantities peak during maximum intensity of the storm as derived from radar and severe storm reports.

Case Example 3
December 1, 2018
Illinois

Right: KILX 0.5° horizontal reflectivity between 2148 and 0058 UTC on 12/01-02/2018.





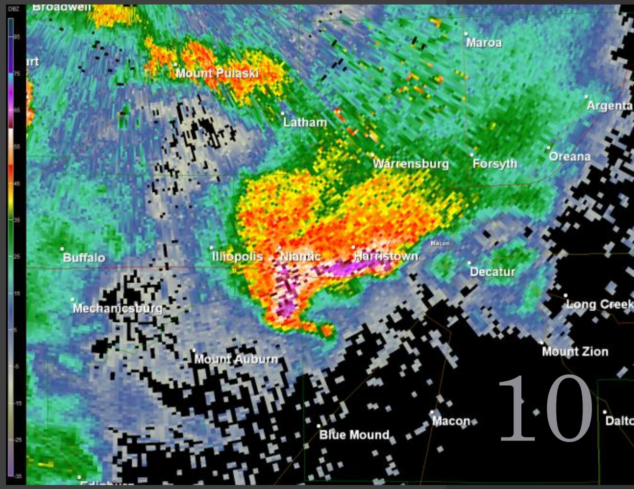


Peaks in flash rate and energy are not collocated in time.

Two district rapid increases in total flash rate prior to severe weather occurrence (tornadoes, red bars).

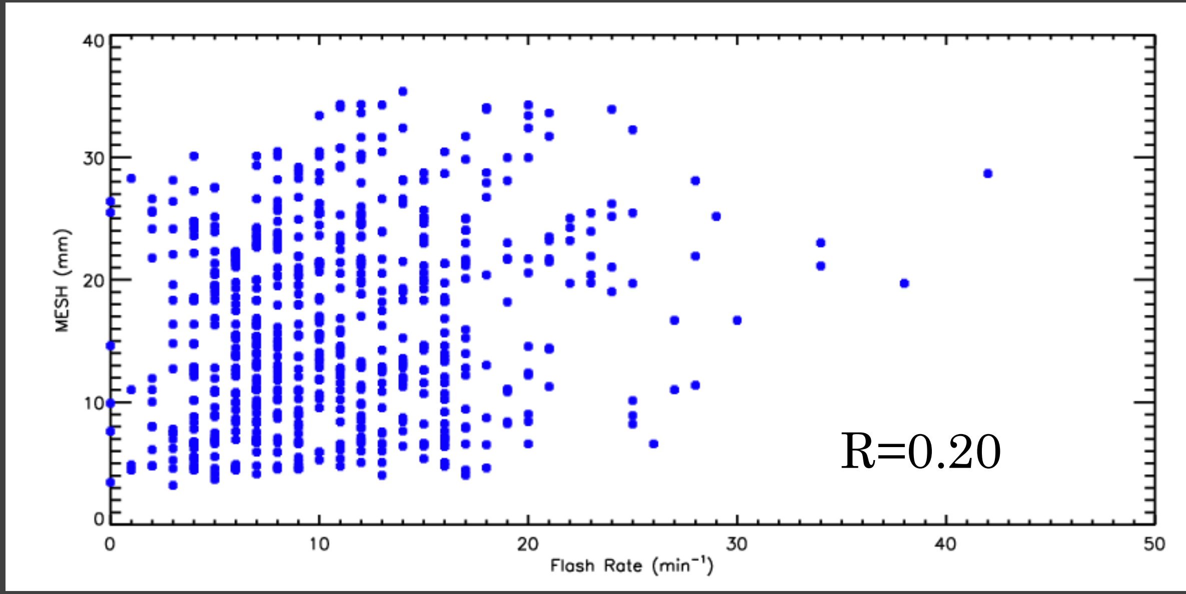
1st flash rate jump coincident with 3 km meso intensification just after 2200 UTC (Stough et al. 2017, WAF). Energy lagged behind ~10 minutes.

Below: KILX 0.5° horizontal reflectivity at 2357 UTC

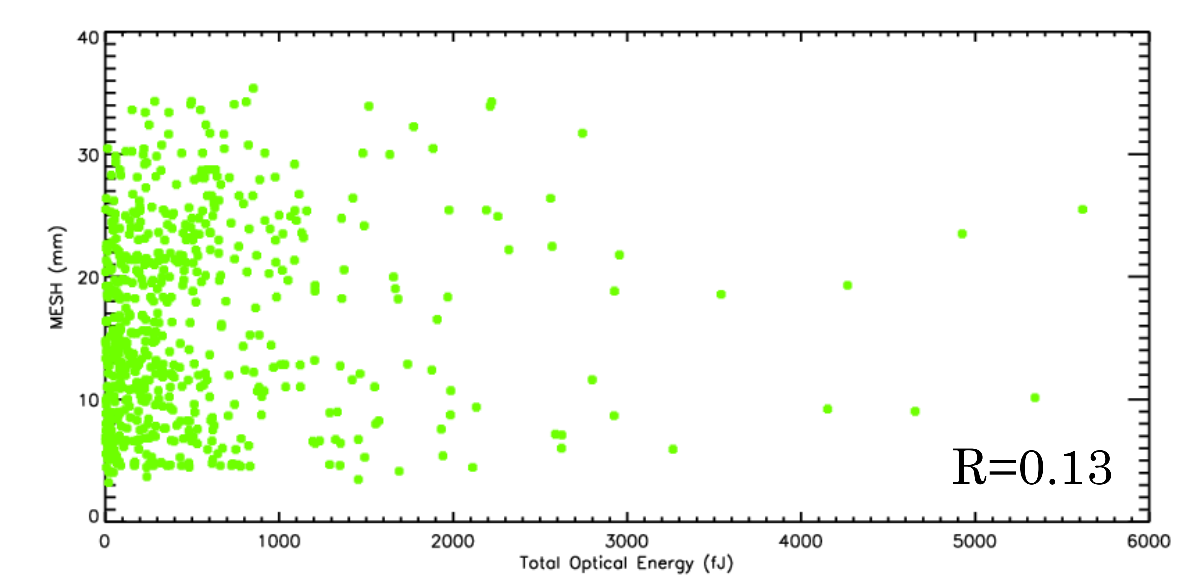


MESH vs Energy

Correlations between energy and MESH are not as strong as flash rate and MESH. Both correlations not very strong either, which is different from the findings of Chronis et al. (2015), where flash rate and MESH were strongly correlated. Further supported by Curtis et al. (2019), this conference, today, 4-6 pm.



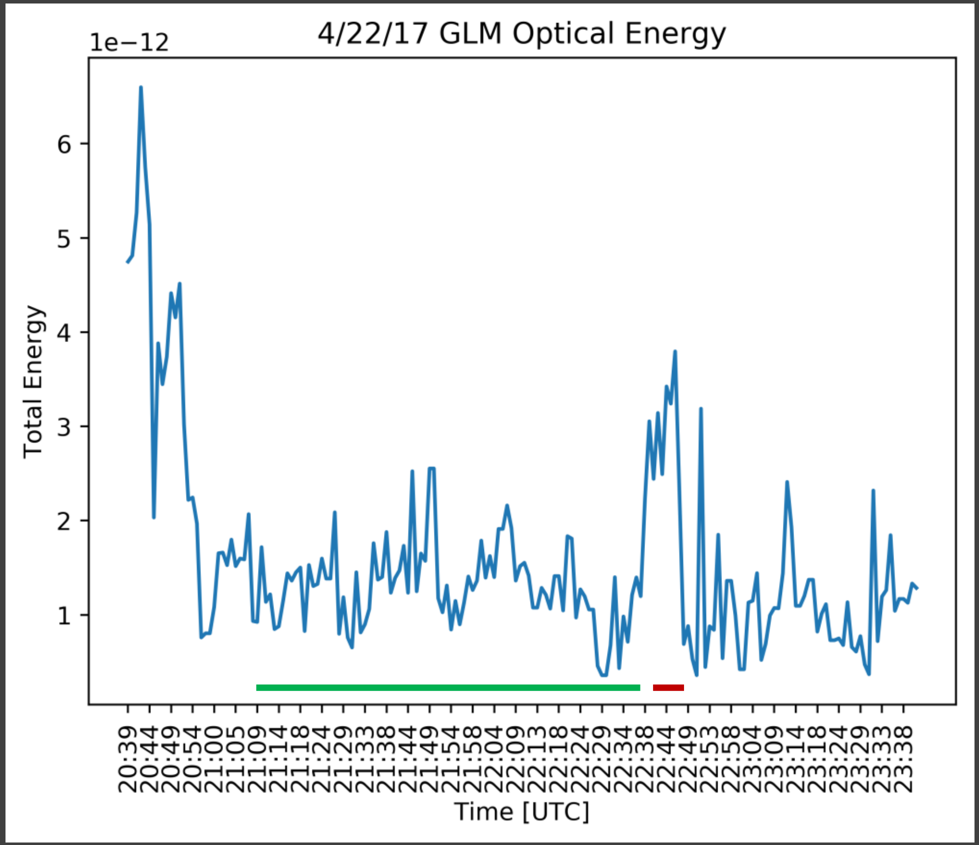
MESH vs Flash Rate

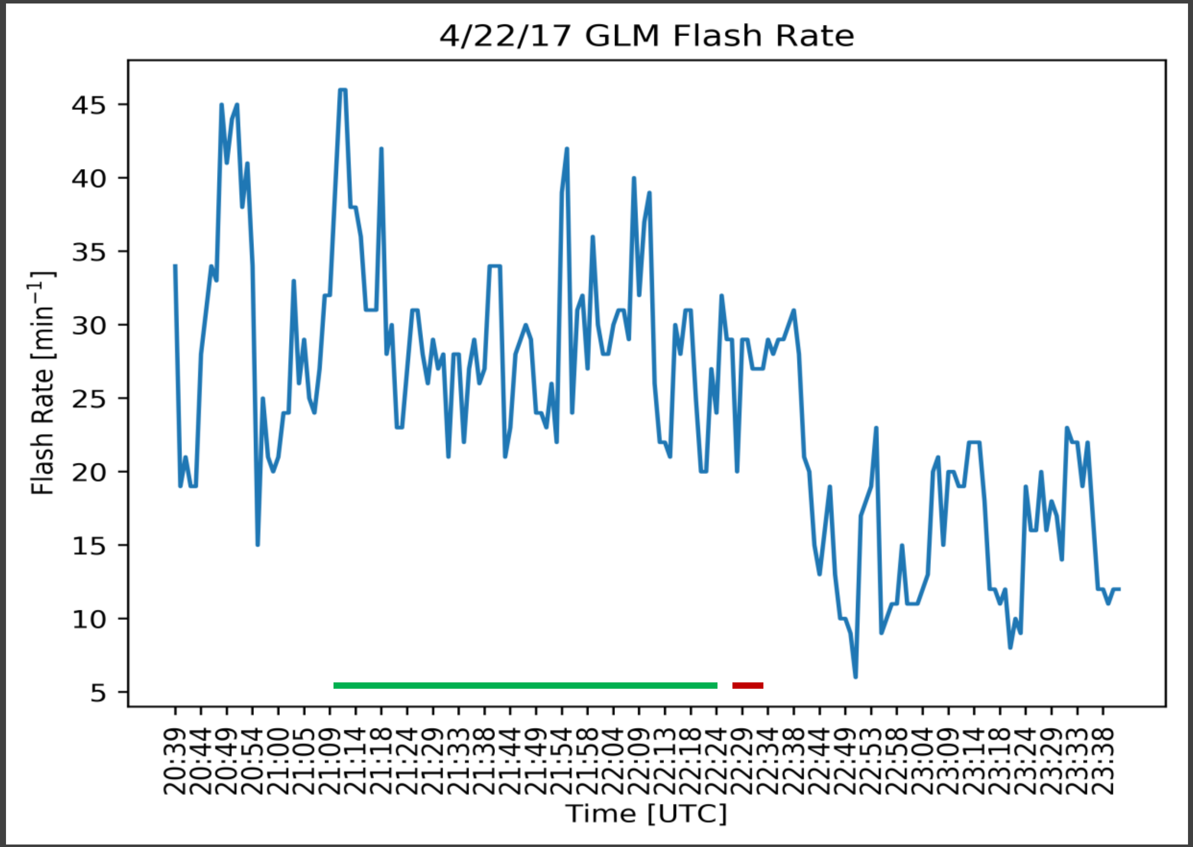


MESH vs Energy Rate

- Total flash rate vs MESH and Total Energy Output vs MESH for a sample of 59 storms.
- The timing of the Peak MESH value lagged the peak flash rate and energy rate by 31 and 27 minutes in the mean.

Further Characterization is necessary





Occasionally, flash energy will decrease as storms intensify…

See Carey et al. 2019 from 4-6 pm today for more details on this specific case

Conclusions and Future Pathways

- In the case examples provided, marked increases in total optical output tended to lag distinct flash rate increases by up to 10 minutes.
- Varying behavior was observed in regard to energy trends prior to the onset of severe weather.

1. Peak energy rates were nearly collocated in time to peak flash rates
2. Energy rates trended downward while the total flash rate increased or maintained its magnitude.
3. Peak energy rates increased while total flash rate decreased.

- MESH magnitude was better correlated to total flash rate from GLM versus total energy rate.
- Main operational takeaway is that increases in total optical energy tended to lag temporally behind increases in total flash rate.
  - Perhaps this can be used as a reinforcing indicator for jump occurrence to mitigate FAR.
- The GLM lightning jump algorithm configuration will have be different from the LMA-based version that is currently applicable to LMA and other ground based lightning measurements.