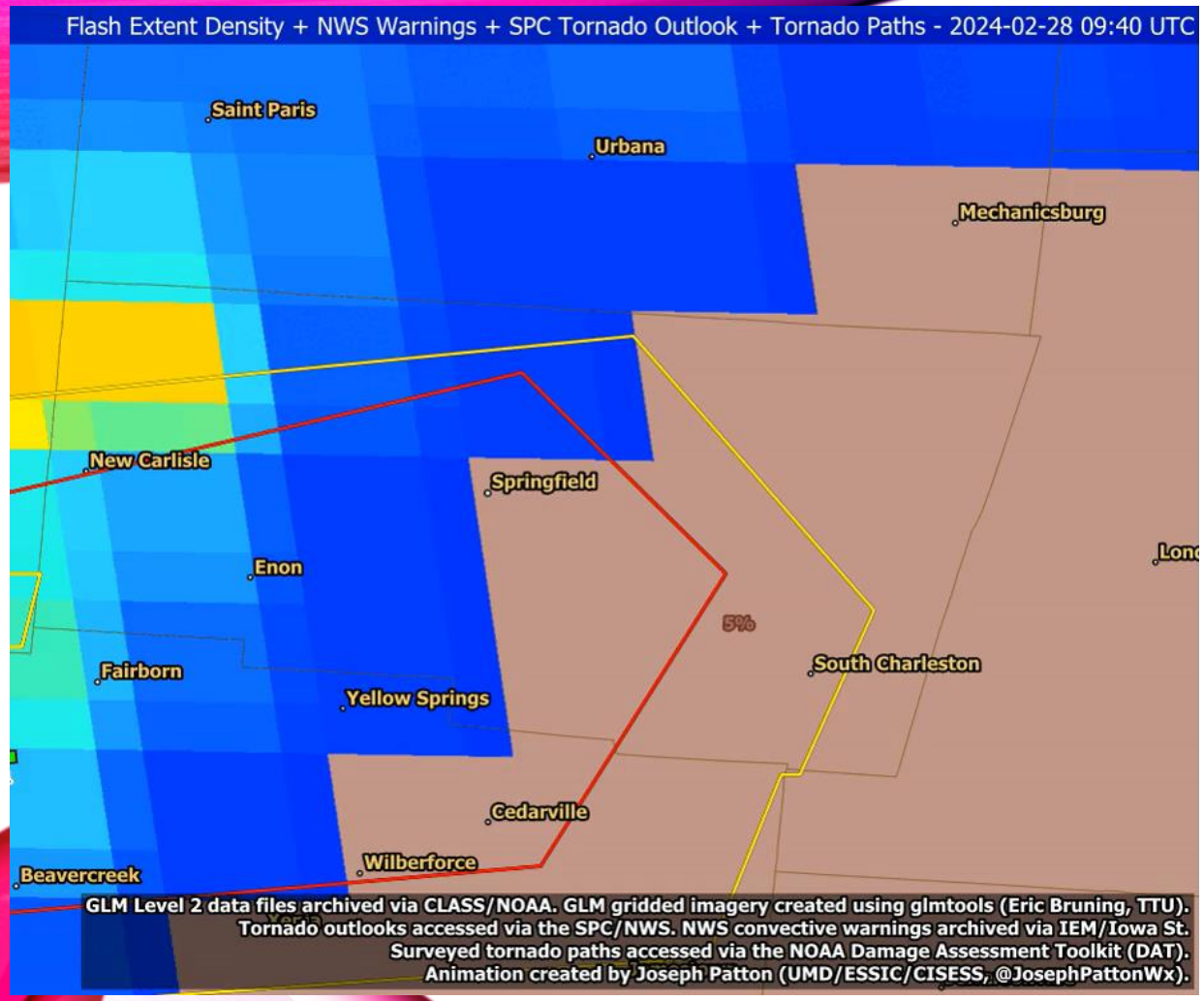


Analyzing Geostationary Lightning Mapper Gridded Product Values throughout the Tornado and Extremely Large Hailstone Lifecycles

Joseph Patton[1], Scott Rudlosky[2]
[1]Univ. of Maryland, ESSIC, CISESS
[2]NOAA/NESDIS/STAR

January 15, 2025

AMS Annual Meeting 2025

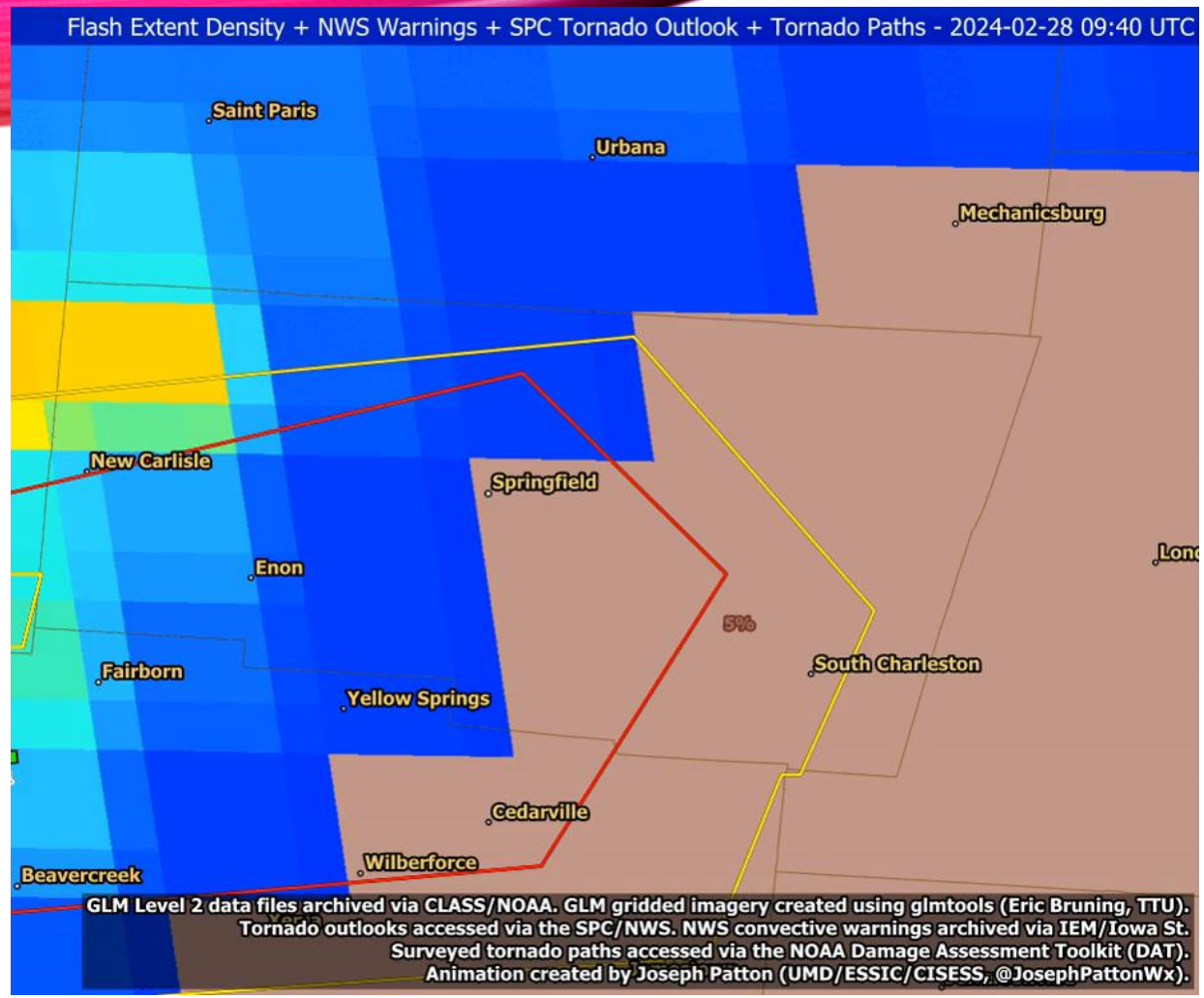
UNIVERSITY OF MARYLAND

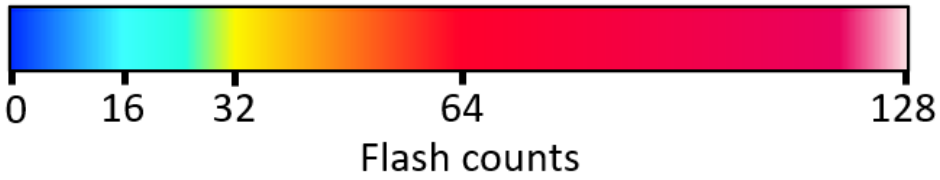
cisess
Cooperative Institute for Satellite Earth System Studies

NOAA / NESDIS / STAR
Center for Satellite Applications and Research

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE-R SERIES
GOES R
NOAA ~ NASA

TRACKED GLM VALUES





- Maximum/minimum lightning characteristic values were tracked before, during, and after each event
- Tracked values include:
  - Maximum Flash Extent Density (FED)
  - Minimum Minimum Flash Area (MFA)
  - Maximum Total Optical Energy (TOE)
- All gridded products shown/analyzed are 5-minute windows
- Values tracked by hand from 10 minutes before tornado touchdown to 10 minutes after tornado cessation and 30 minutes before to 30 minutes after each recorded extreme hailstone

A TALE WITH TWO PARTS

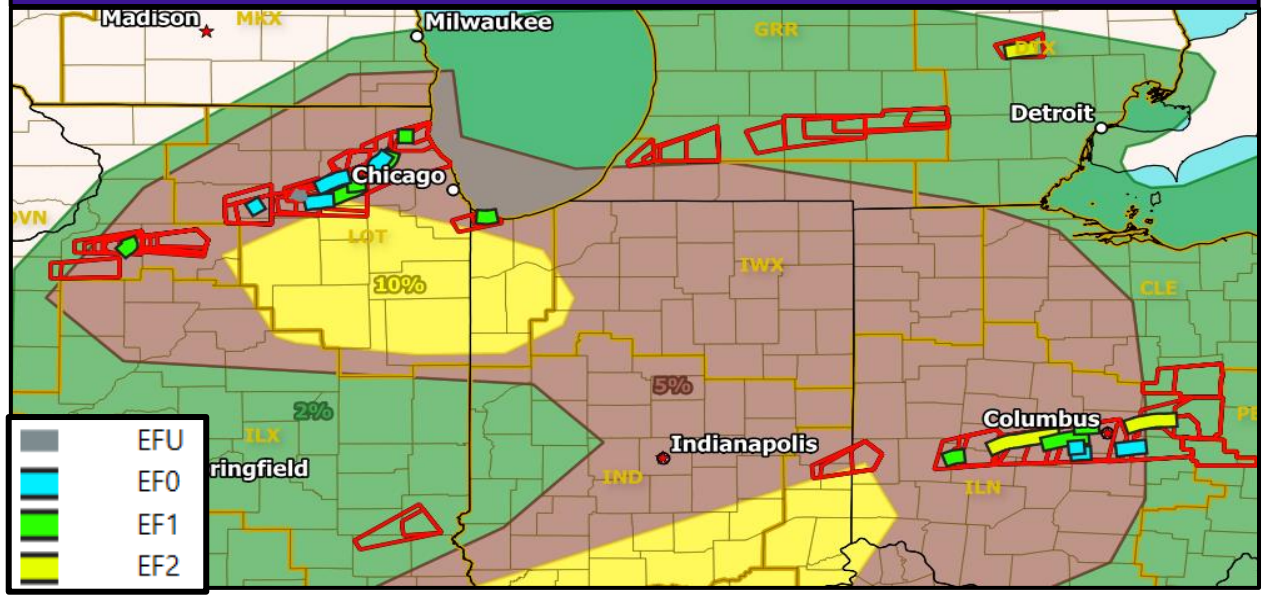
Tornado Outbreak

- 21 events tracked from the 27-28 February 2024 late-winter outbreak across the US Midwest
- Detailed tornado tracks from the NOAA DAT database of damage surveys

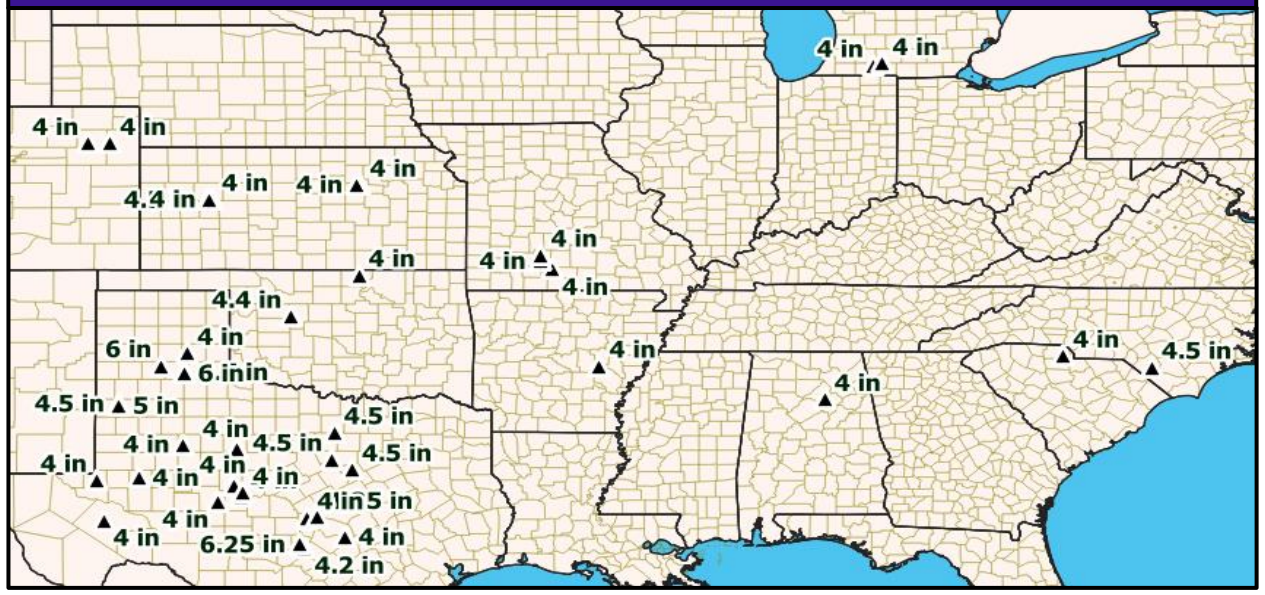
Very Large Hailstones

- 41 events of 4+ inch hailstones tracked April-June 2024 spread out across the central and eastern US
- Hailstone diameters ranged from 4 inches to 6.5 inches

Tornado Tracks + Warnings + 20Z SPC Tornado Outlook

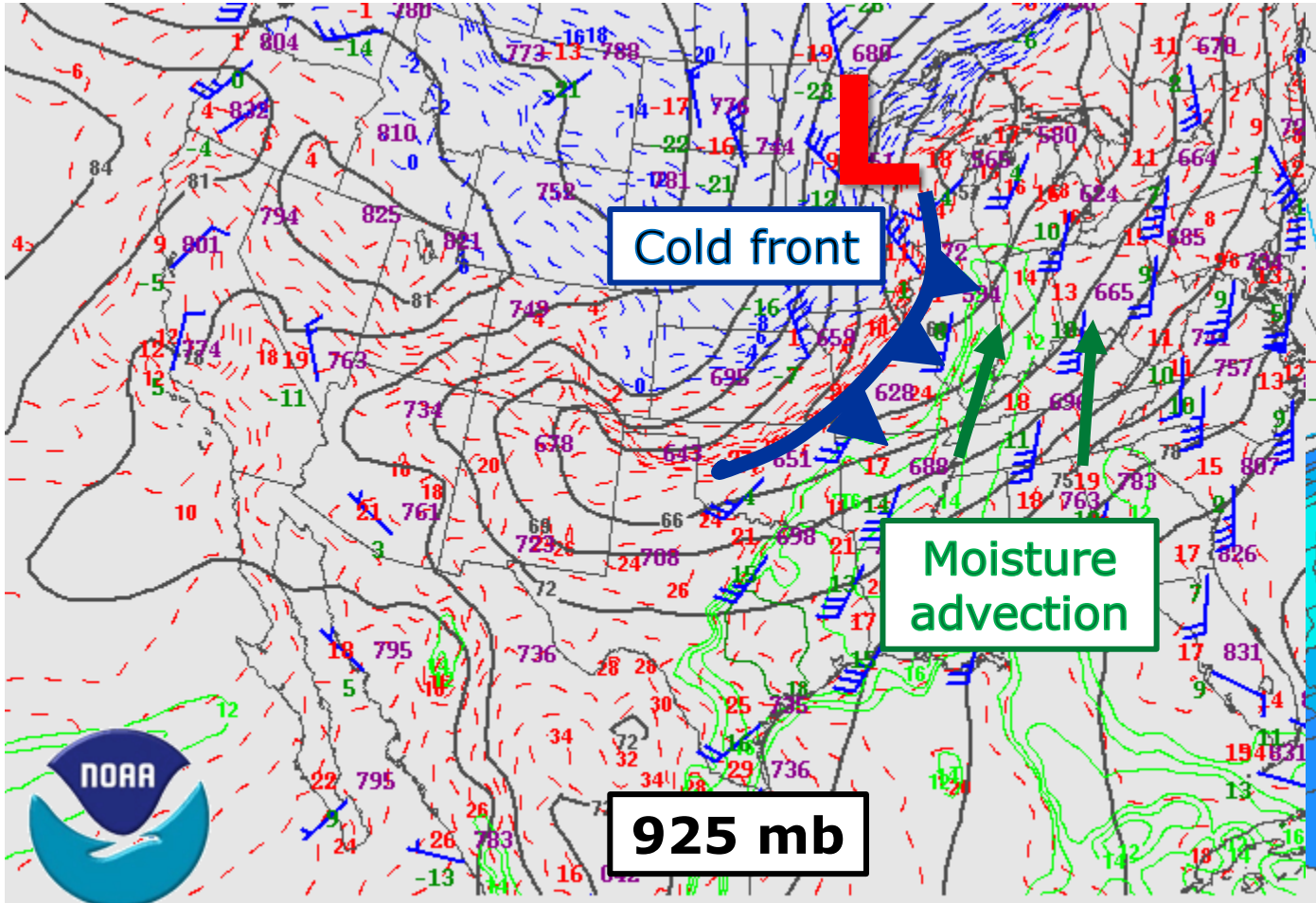


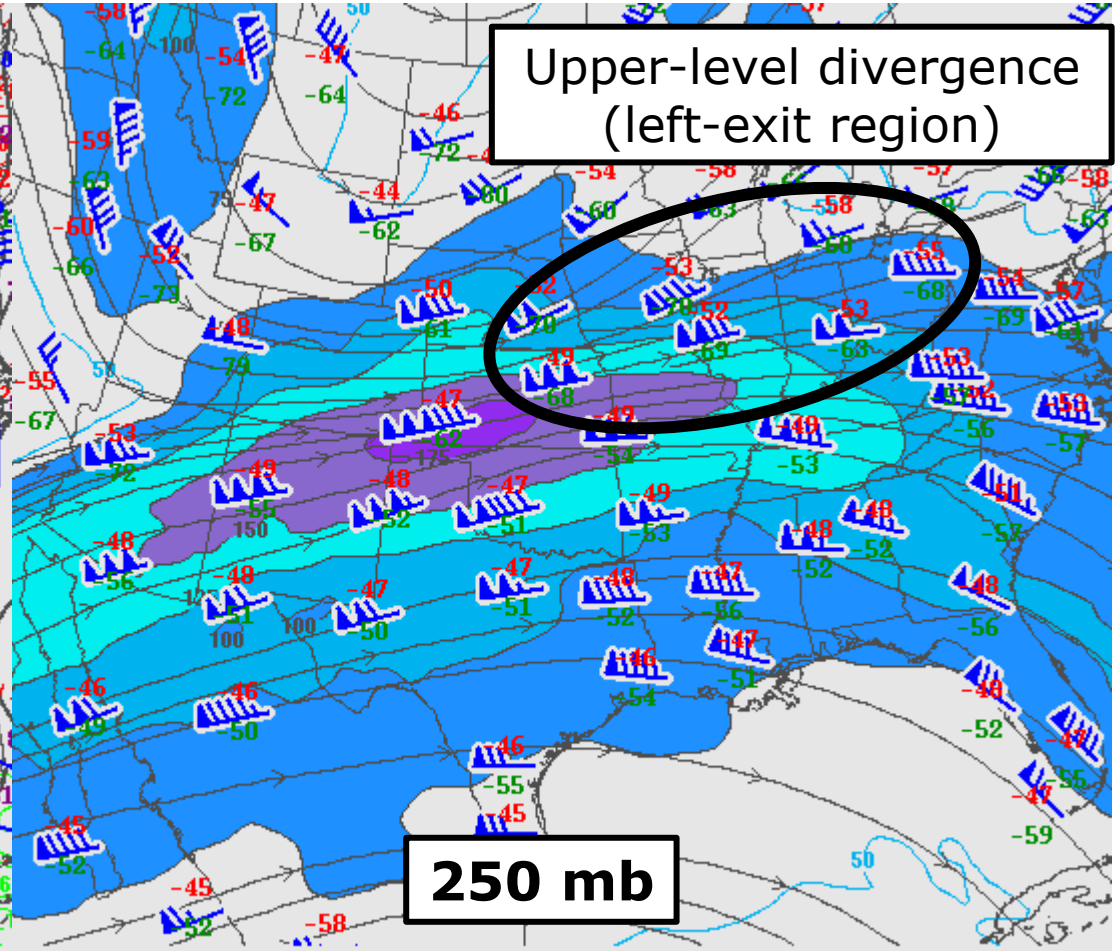
Hailstone Reports ≥ 4 Inch Diameter - Spring 2024



TORNADO OUTBREAK

27-28 February 2024 Environmental Analysis

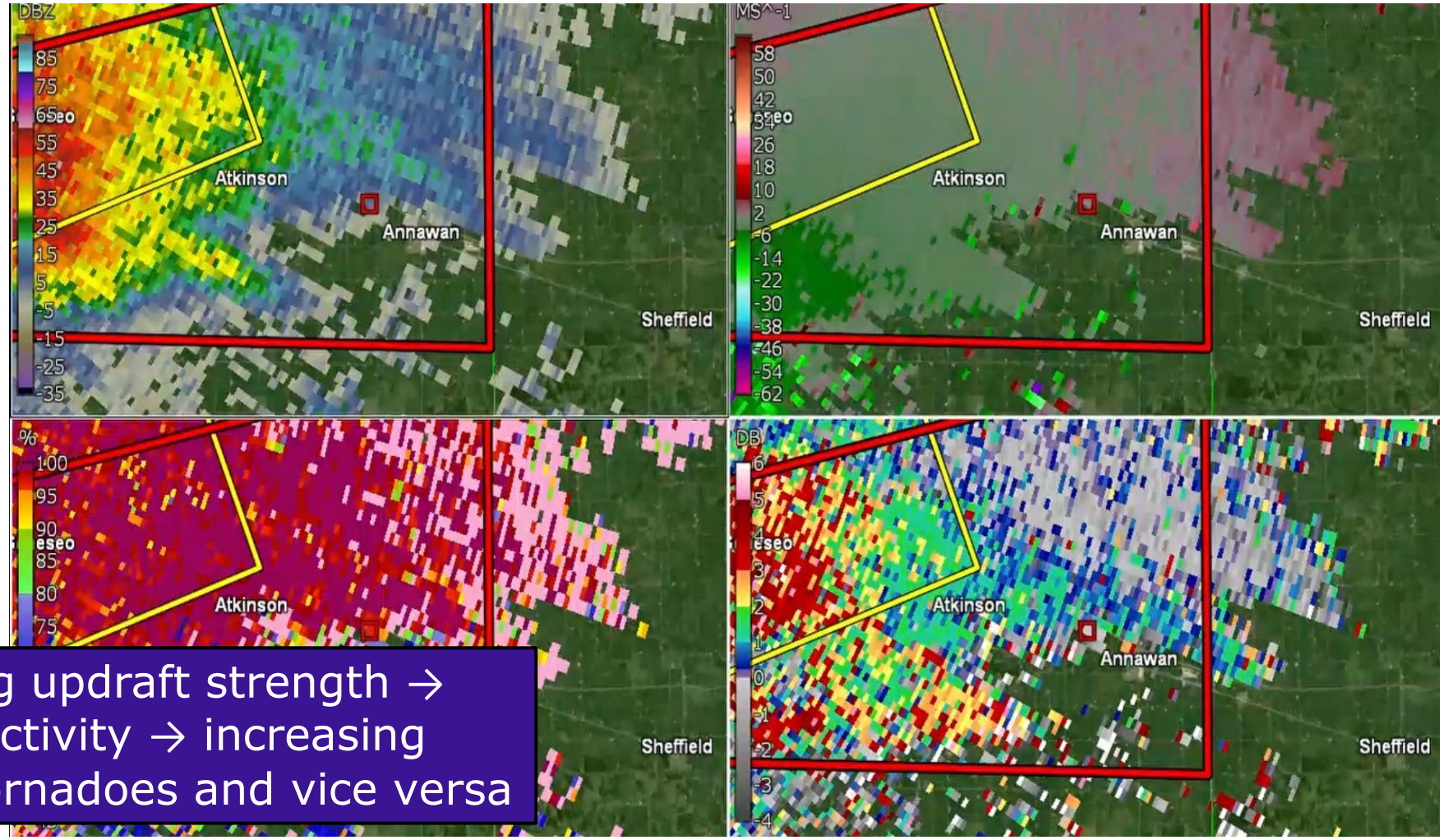




TORNADO OUTBREAK

Annawan/Atkinson, IL (EF1) – Radar Analysis

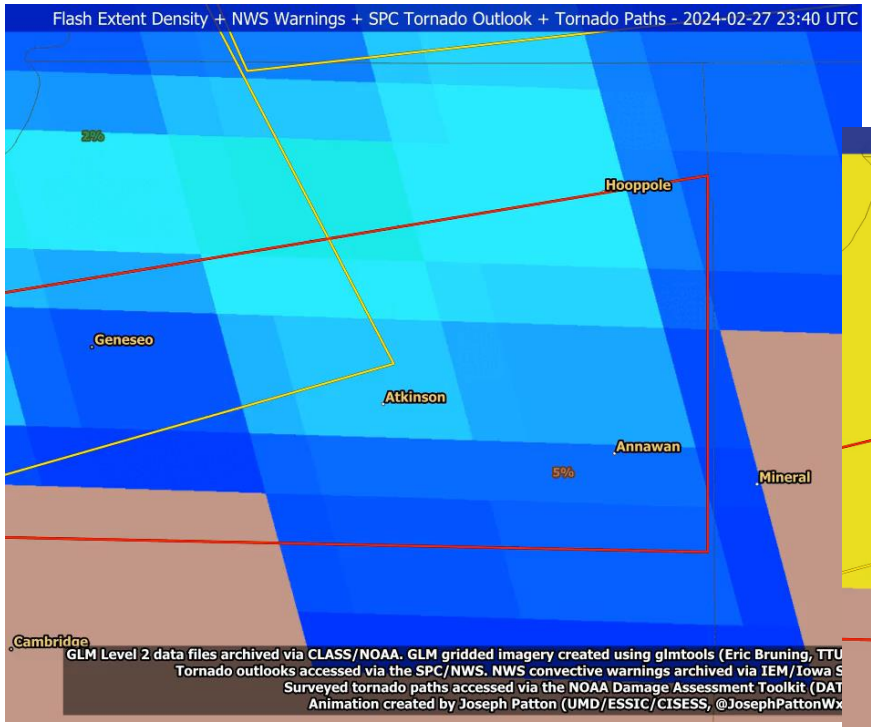
- Closest radar (KDVN) able to confirm tornado
- Classic hook echo on radar reflectivity and velocity couplet
- Noticeable drop in correlation coefficient near velocity couplet, near-zero ZDR correlated w/ large hail

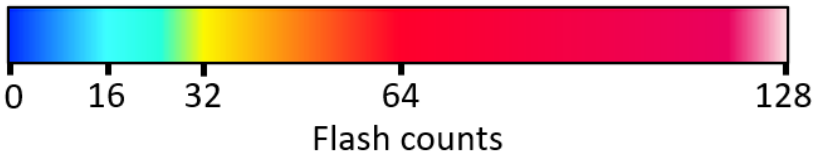


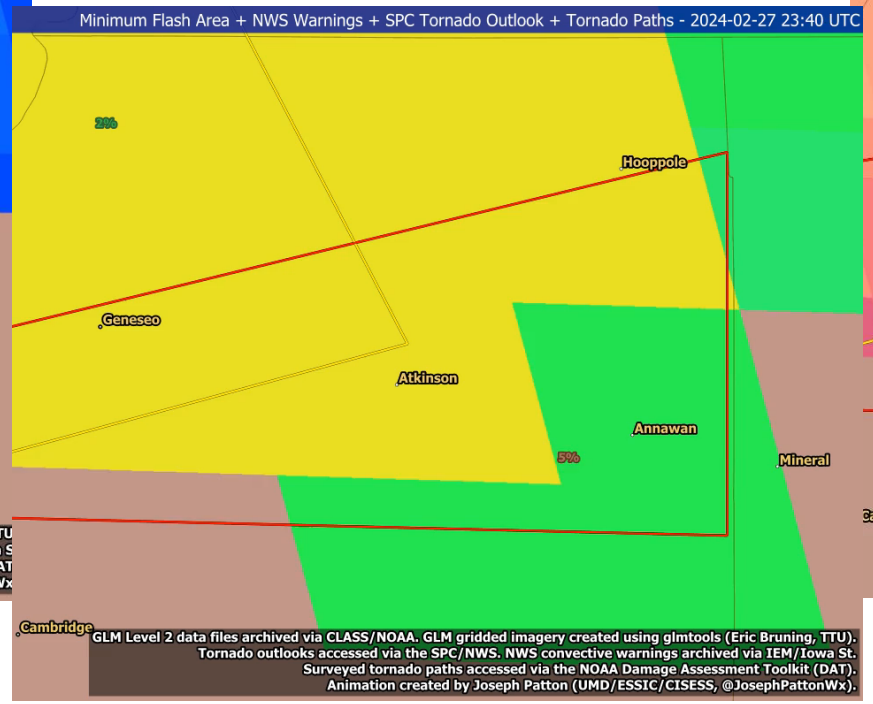
Hypothesis: Increasing updraft strength → increasing lightning activity → increasing FED/TOE leading up to tornadoes and vice versa

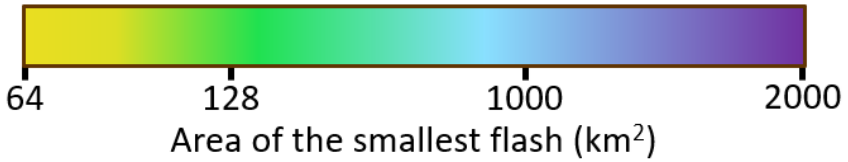
TORNADO OUTBREAK

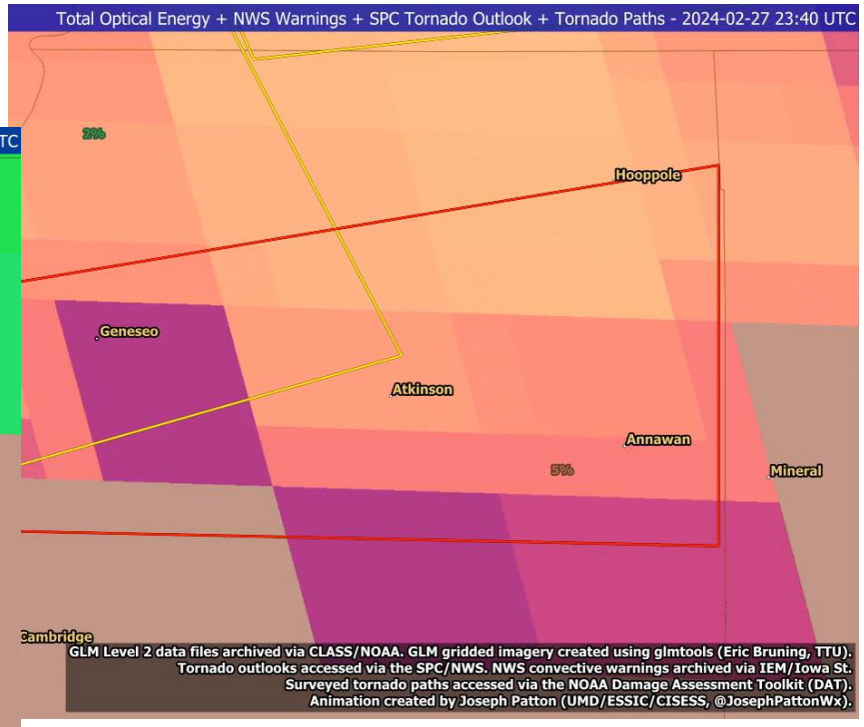
Annawan/Atkinson, IL (EF1) – GLM Gridded Products

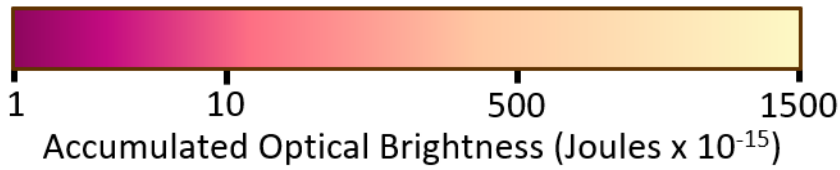








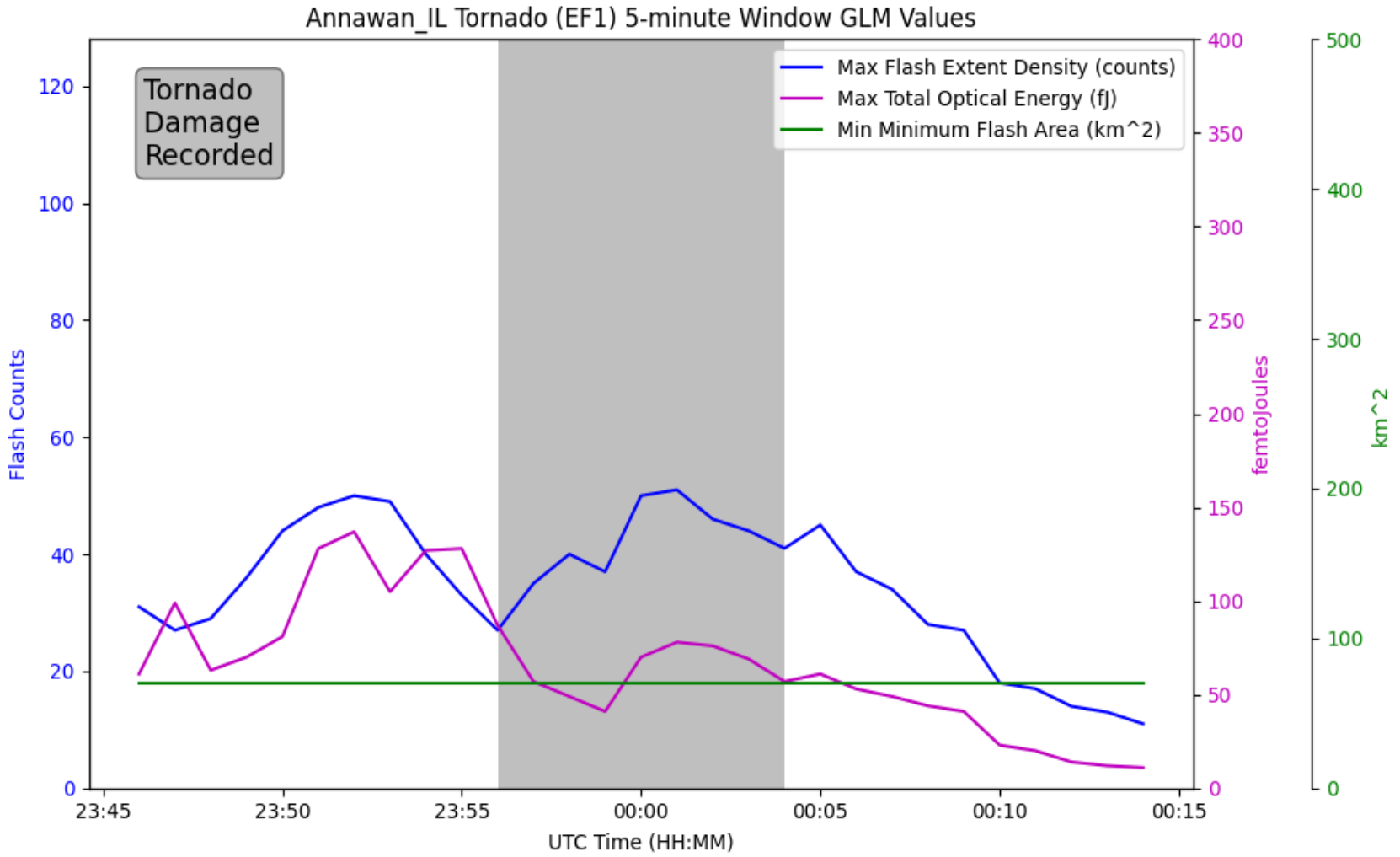




TORNADO OUTBREAK

Annawan/Atkinson, IL (EF1) – GLM Gridded Products

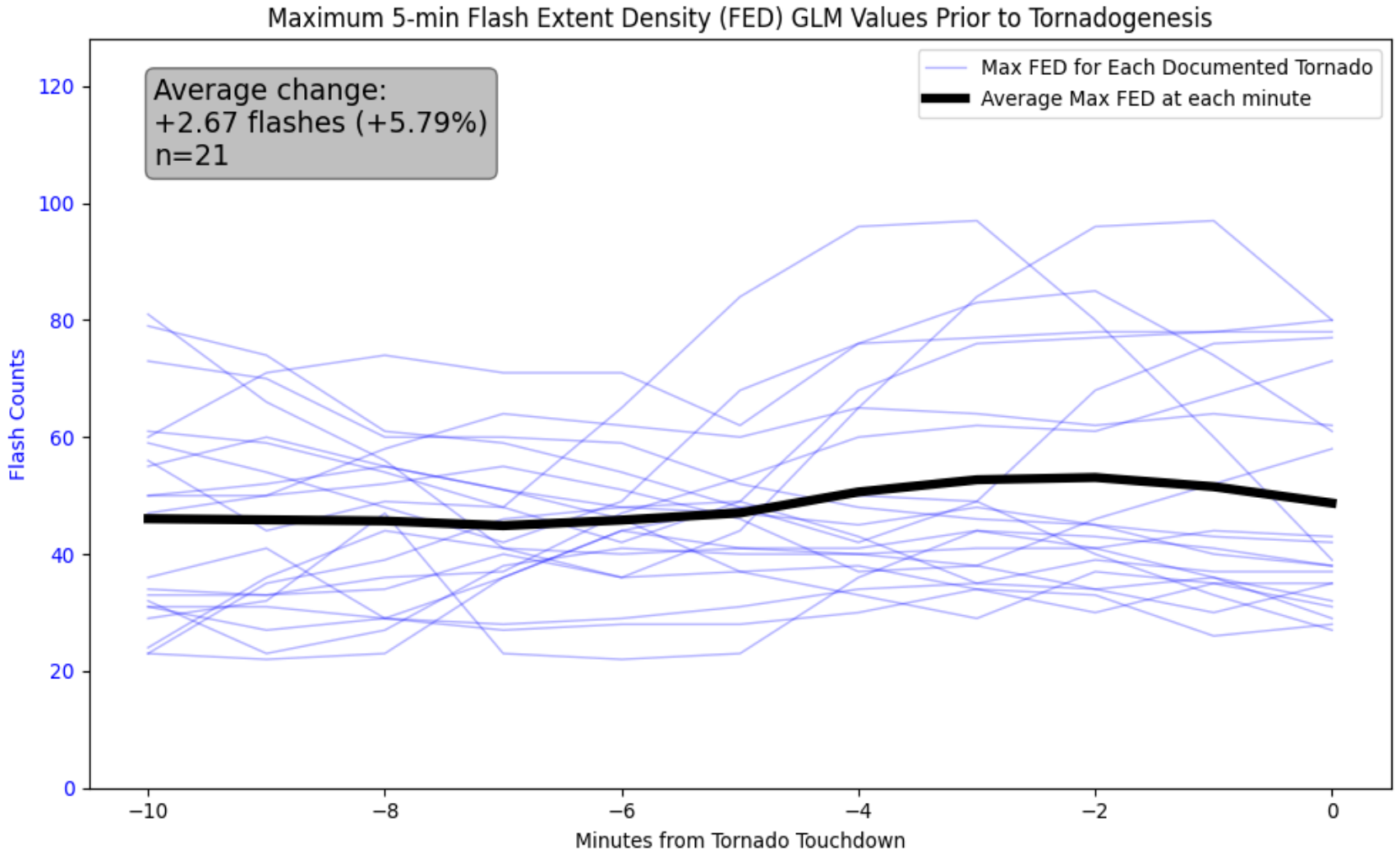
- Maximum Flash Extent Density (blue) and Total Optical Energy (magenta) pixels from the parent mesocyclone were elevated, but variable in the 10 minutes prior to tornadogenesis
- Max FED and TOE dropped off quickly after tornado damage was no longer documented



TORNADO OUTBREAK

FED & TOE Before All 21 Documented Tornadoes

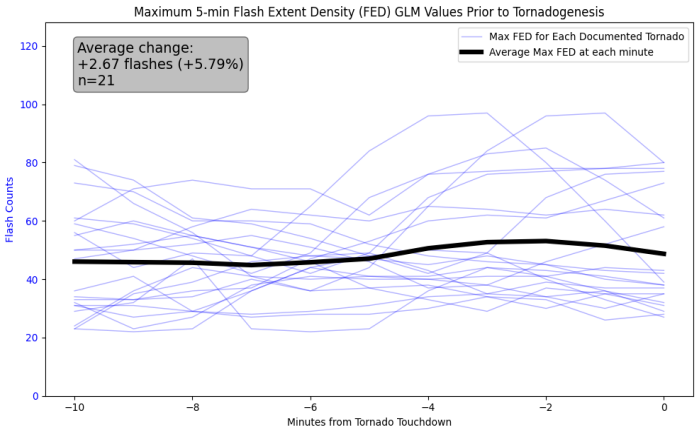
- Maximum Flash Extent Density varied in the 10 minutes prior to tornado touchdown
- Average increase of 5.8% (~2.7 flashes in 5-minute window)
- Modest increase in maximum flash counts, but not very significant

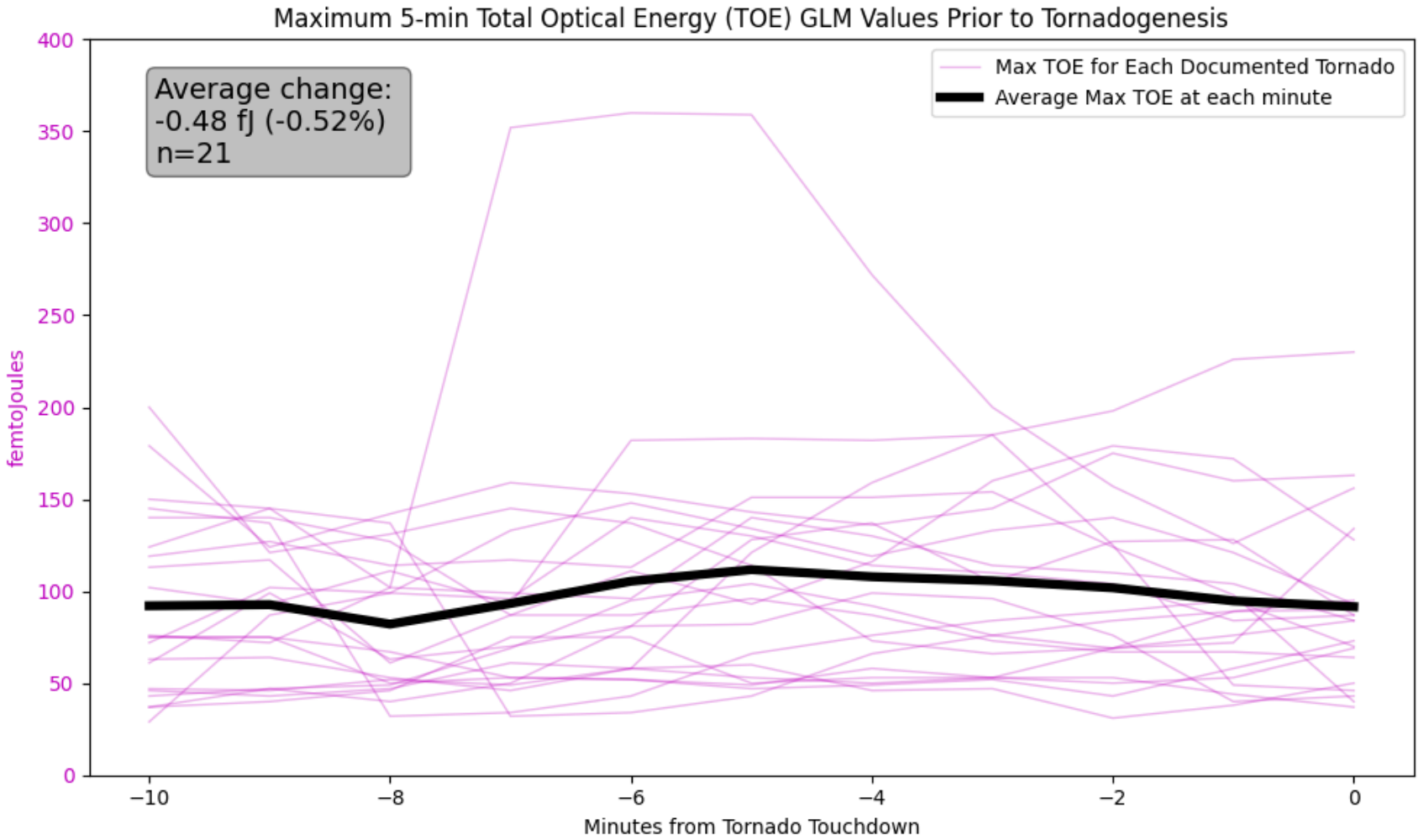


TORNADO OUTBREAK

FED & TOE Before All 21 Documented Tornadoes

- Maximum Total Optical Energy also varied in the 10 minutes prior to tornado touchdown
- Average **decrease** of 0.5% (~0.5 fJ in 5-minute window)

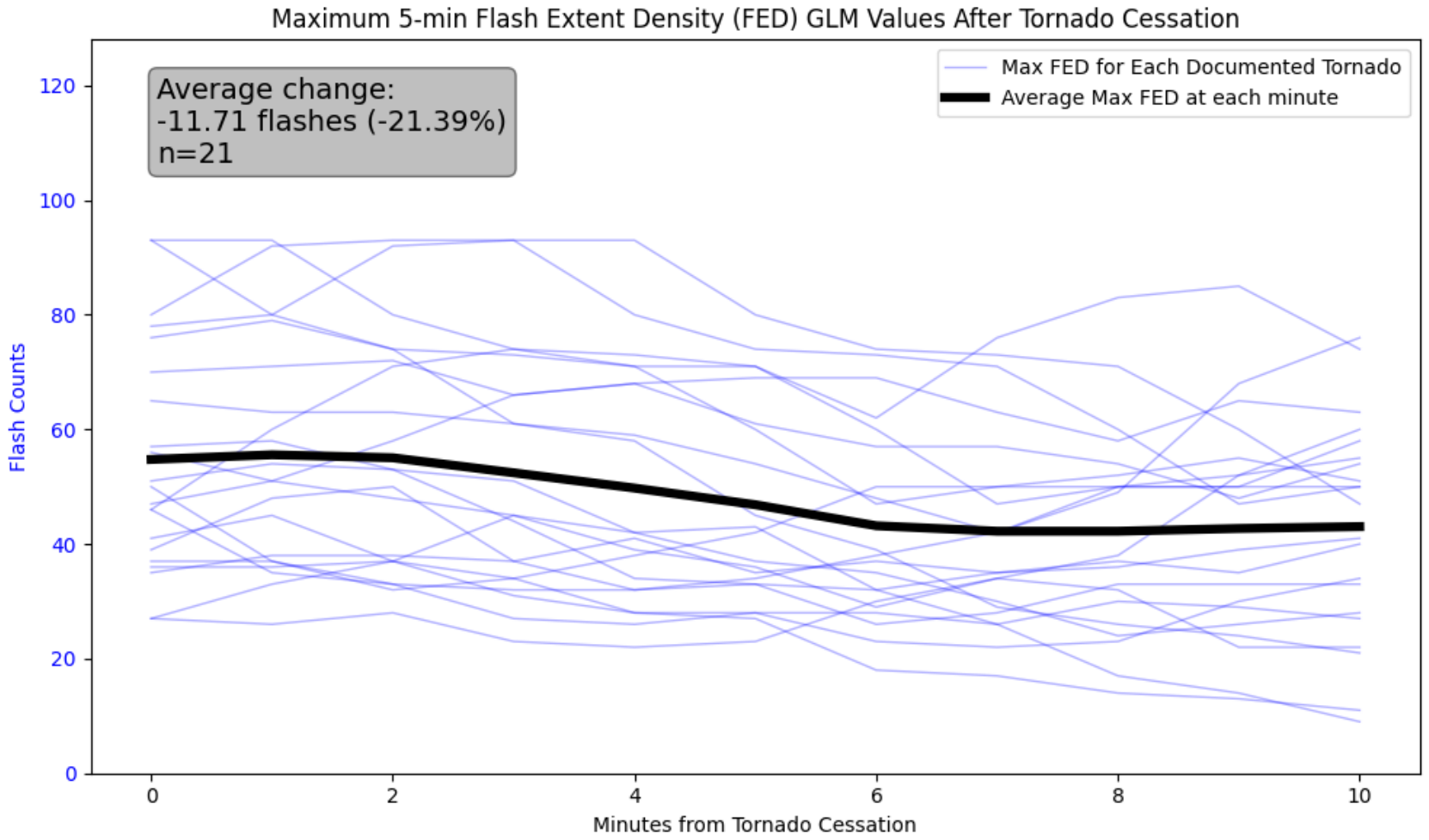




TORNADO OUTBREAK

FED & TOE After All 21 Documented Tornadoes

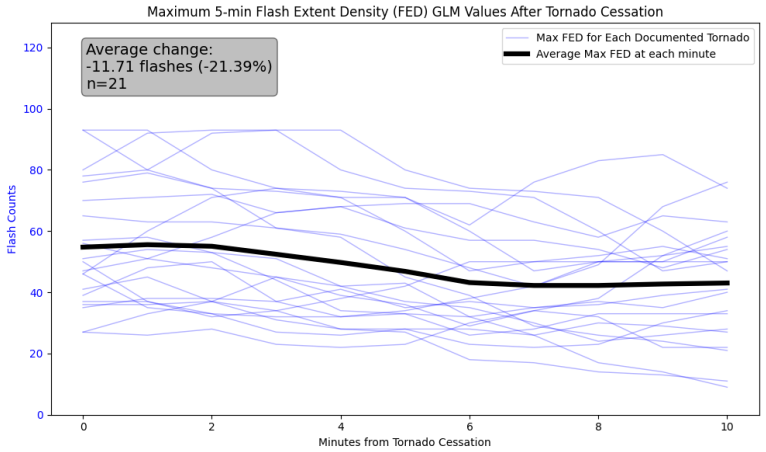
- Maximum Flash Extent Density consistently decreased in the 10 minutes after tornado cessation
- Average decrease of 21.4% (~11.7 flashes in 5-minute window)
- Could be an actionable drop for operational forecasters

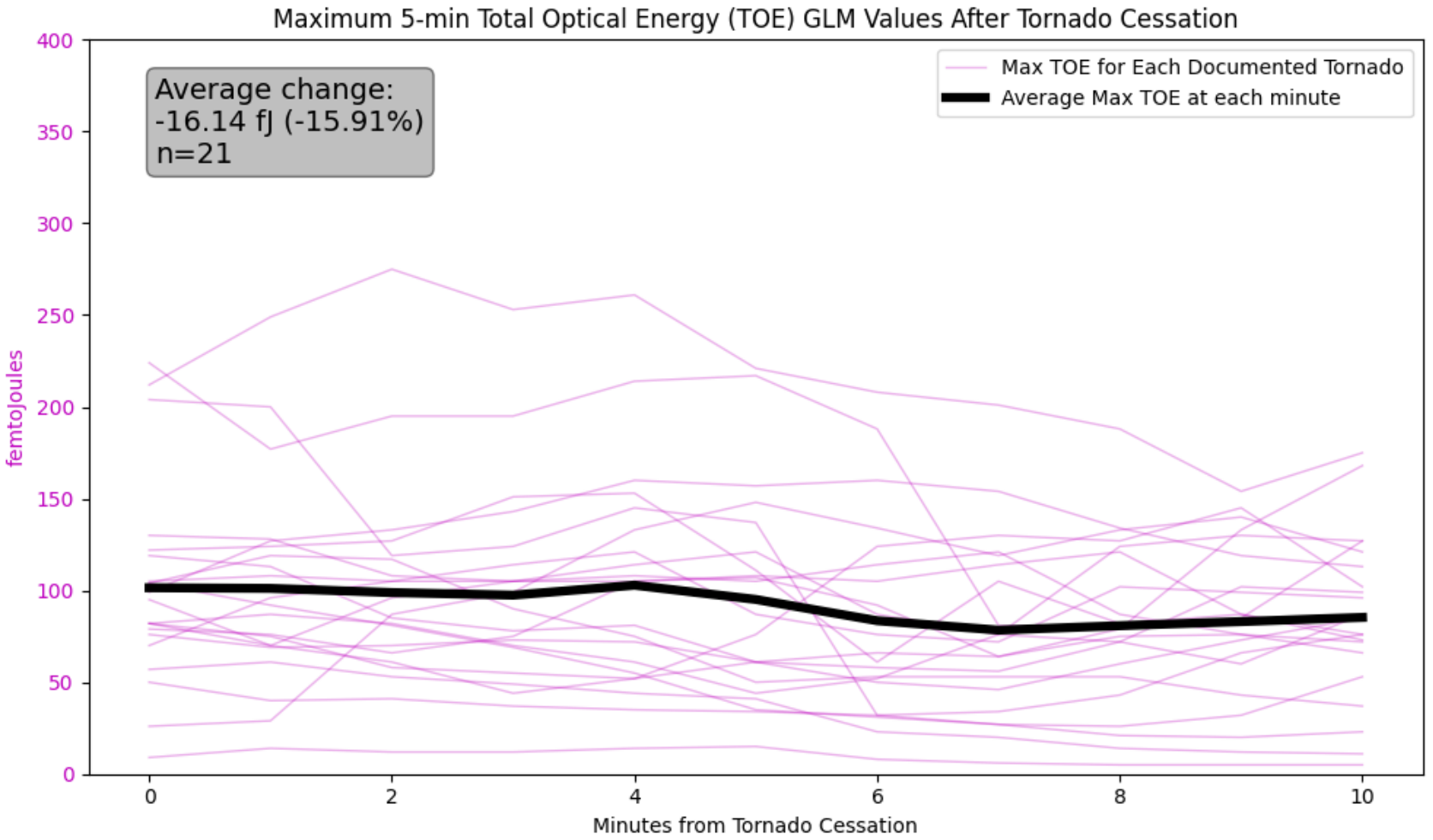


TORNADO OUTBREAK

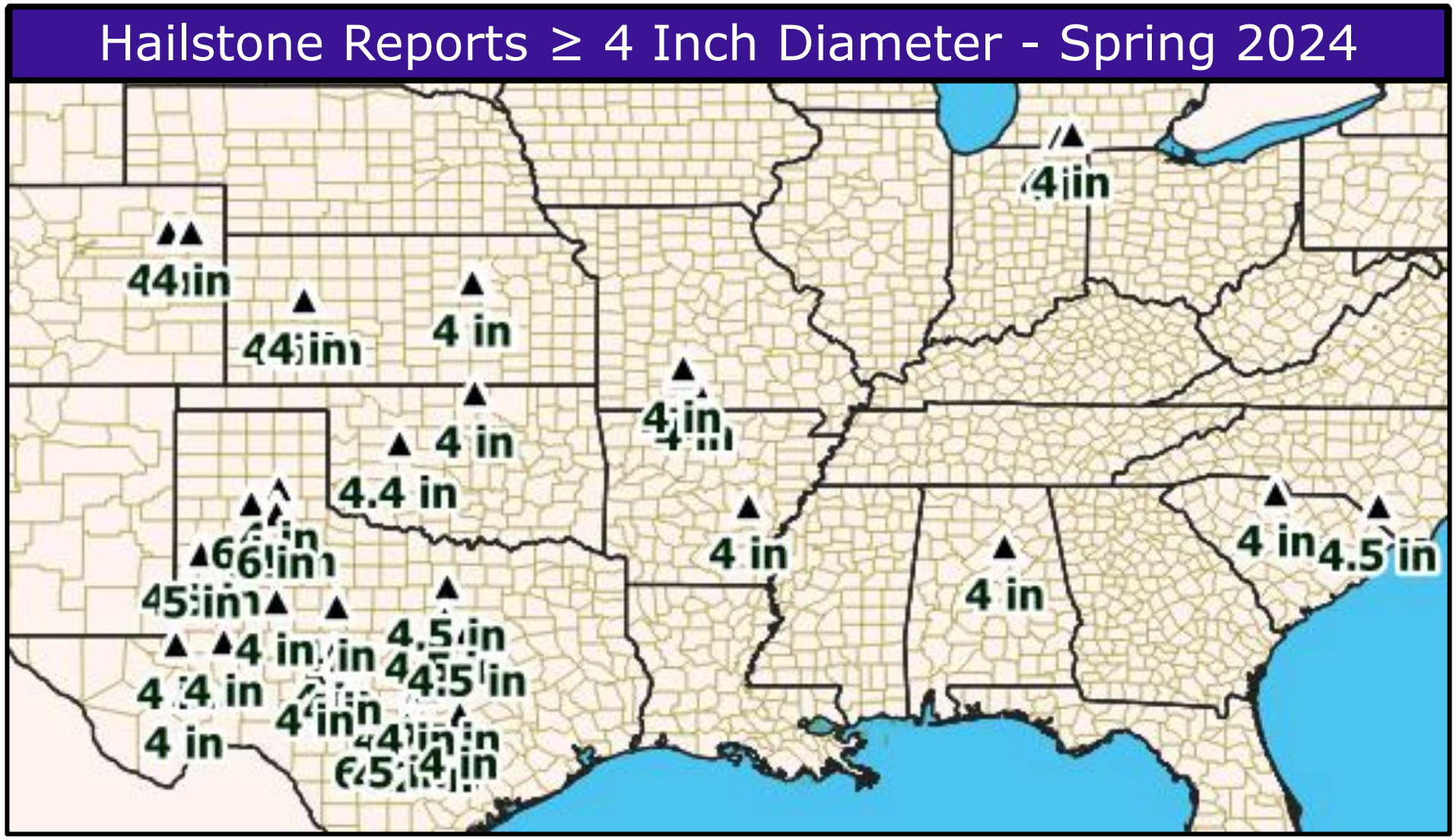
FED & TOE After All 21 Documented Tornadoes

- Maximum Total Optical Energy also decreased
- Average decrease of 15.9% (~ 16.1 fJ)
- Could be an actionable drop for operational forecasters



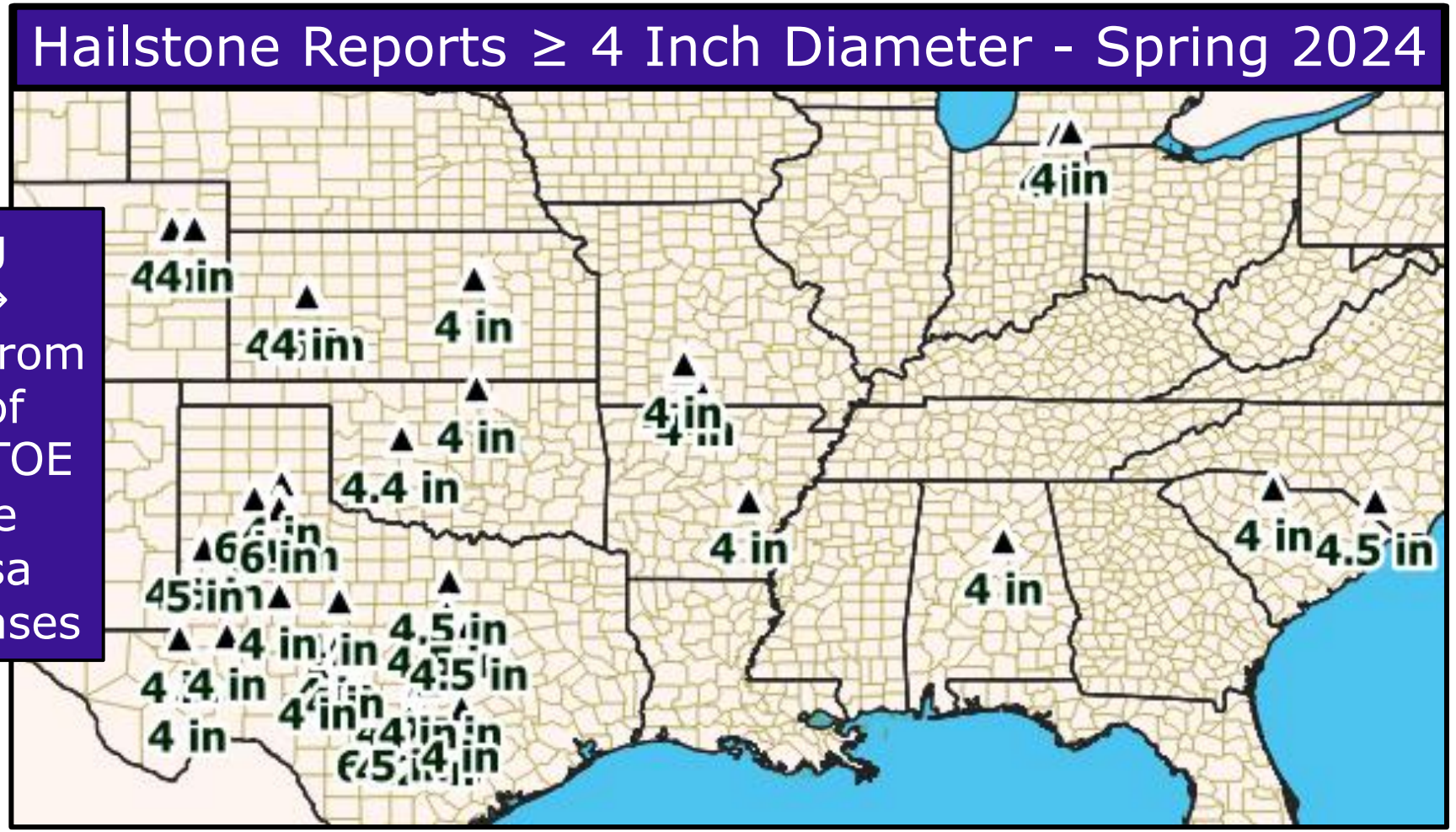


VERY LARGE HAILSTONES



VERY LARGE HAILSTONES

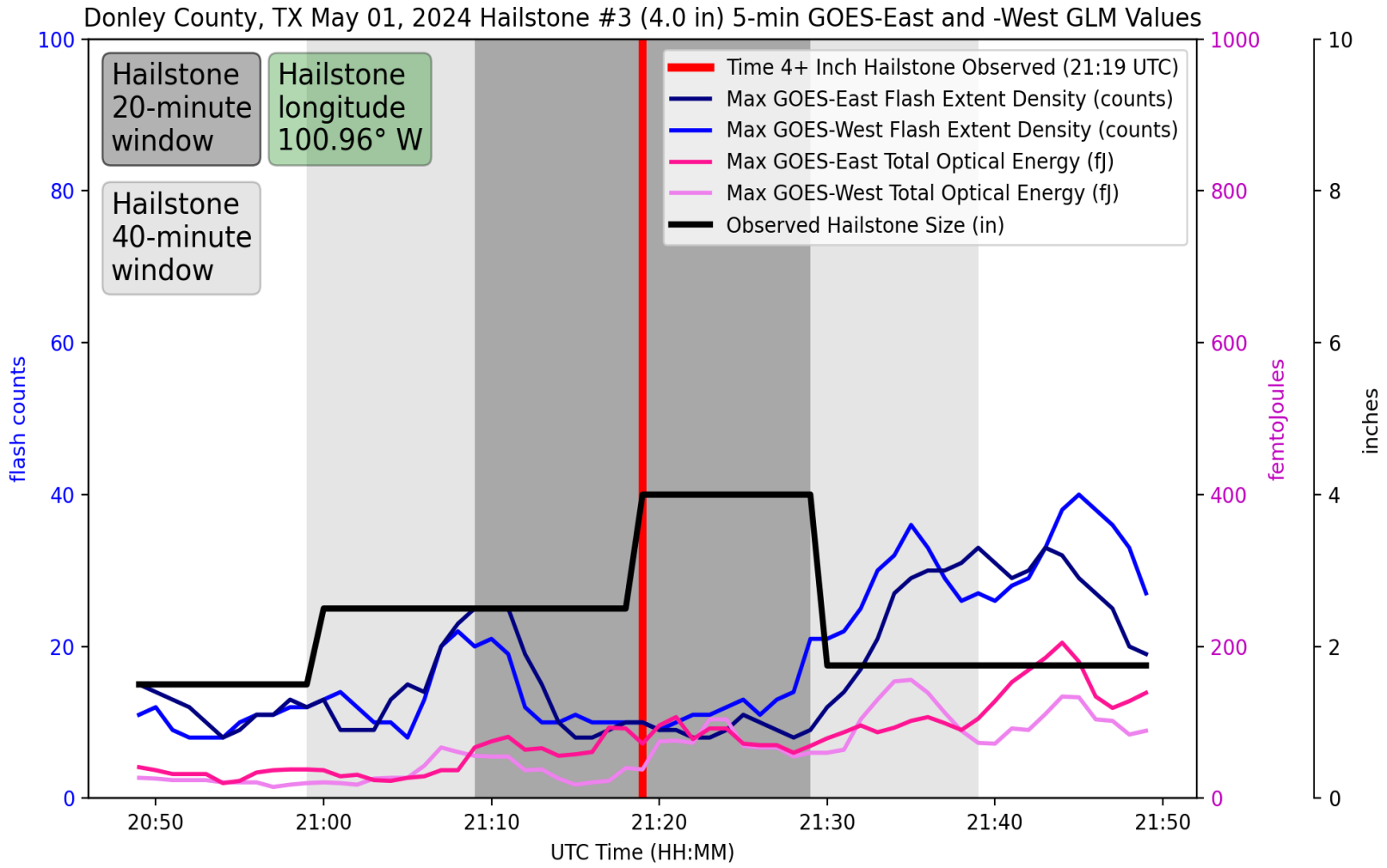
Hypothesis: Increasing hydrometeor density → diminished optical signal from lightning reaching top of cloud → decreasing FED/TOE leading up to very large hailstones and vice versa after hailstone size decreases



VERY LARGE HAILSTONES

Donley County, TX (4 in) – GLM Gridded Products

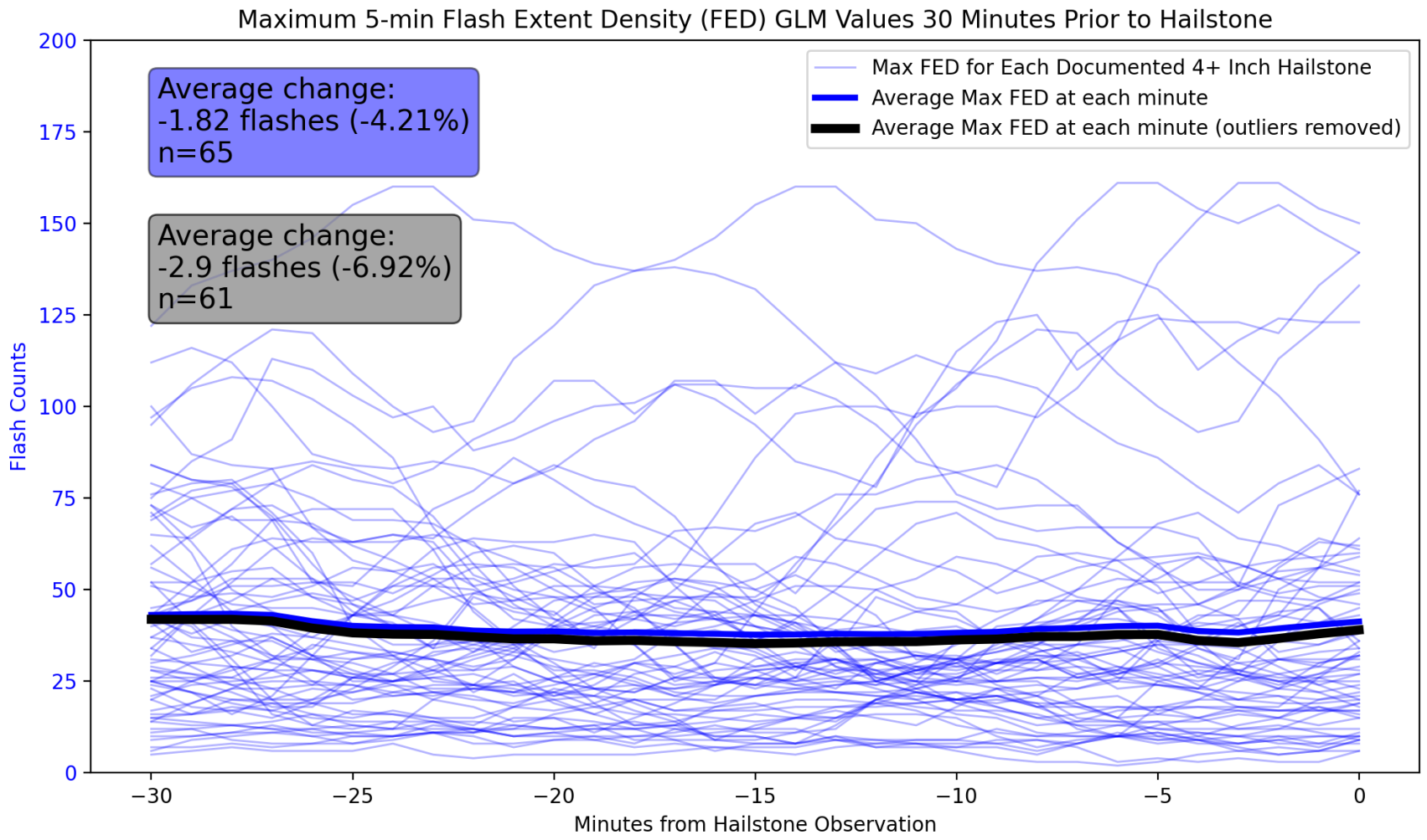
- Hailstone near 101°W, in overlap region of GLMs
- GOES-East: Dark shades GOES-West: Light shades
- Max FED/TOE followed similar patterns between east/west GLMs (not always the case)
- Flash counts/brightness appears to be reduced during 20-minute window around large hailstone, then increased after



VERY LARGE HAILSTONES

FED & TOE Before All 41 Documented Hailstones

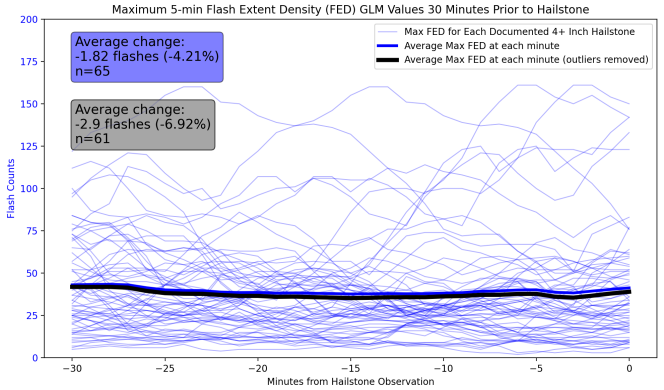
- Graphs include values from GOES-East and GOES-West GLMS (n=65)
- Max FED generally decreased in the 30 minutes before each large hailstone by a modest 4.2% (6.9% if outliers are removed)

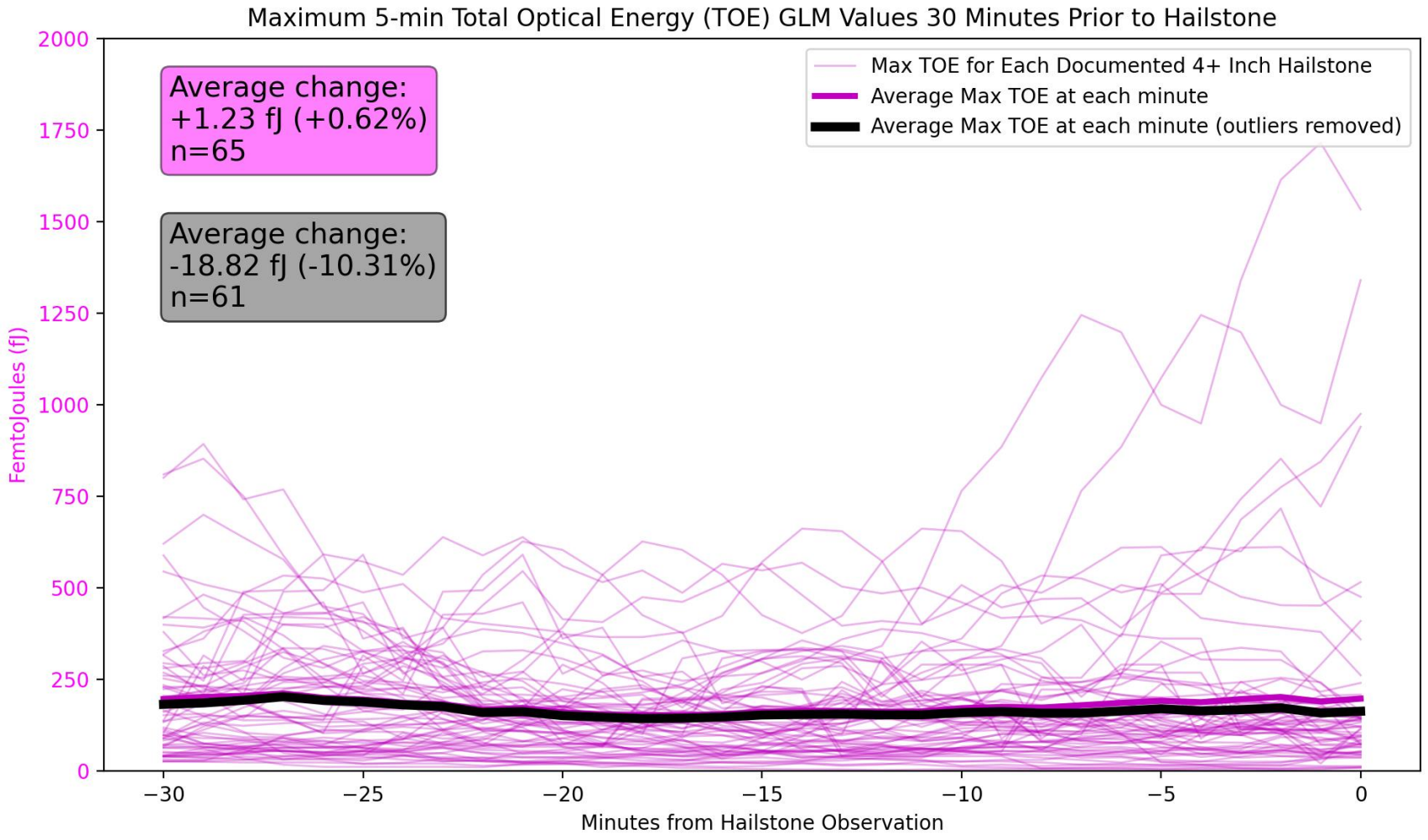


VERY LARGE HAILSTONES

FED & TOE Before All 41 Documented Hailstones

- Graphs include values from GOES-East and GOES-West GLMS (n=65)
- Max TOE highly variable before each hailstone, but there was an average decrease of ~10% with outliers removed

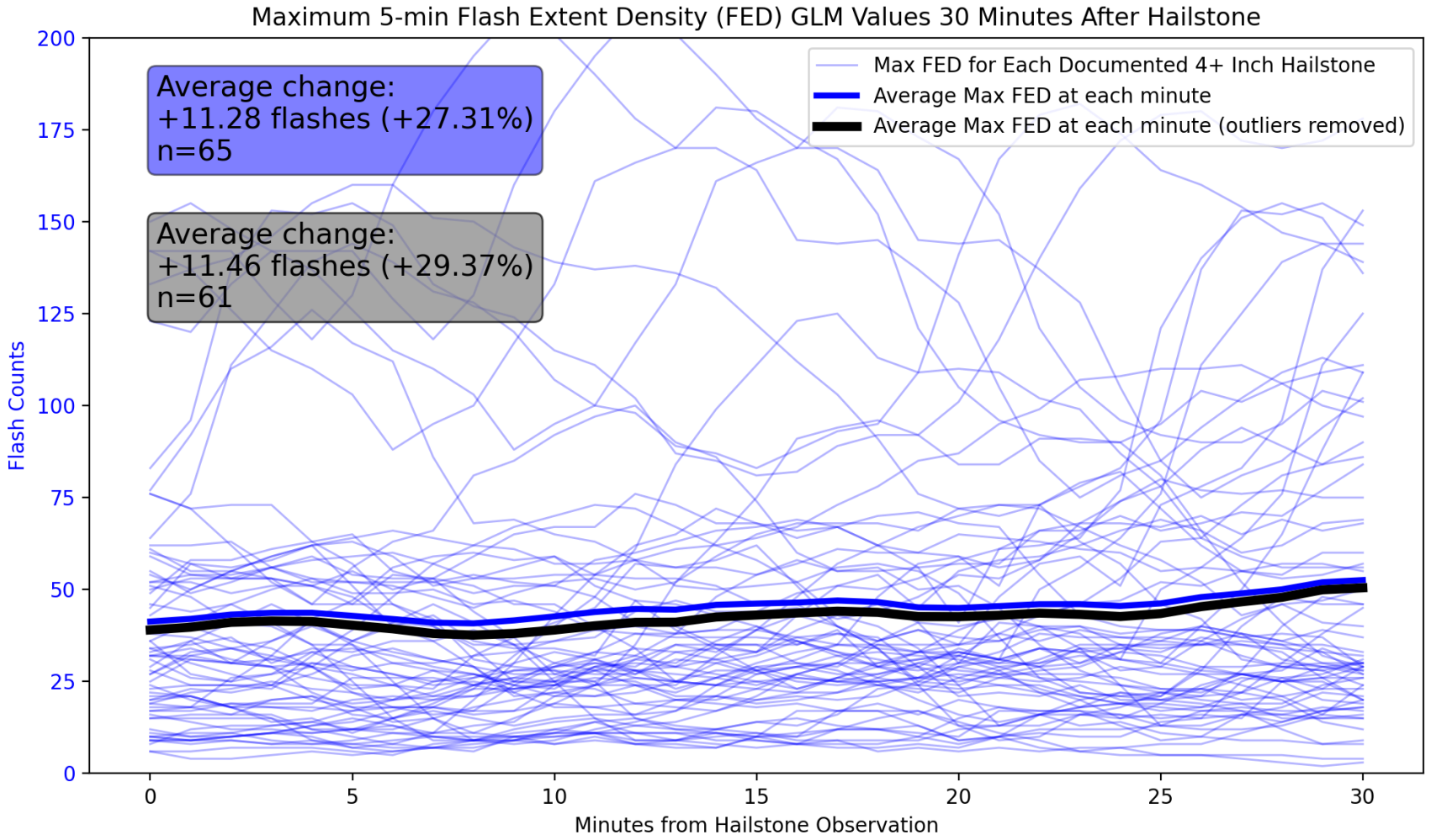




VERY LARGE HAILSTONES

FED & TOE After All 41 Documented Hailstones

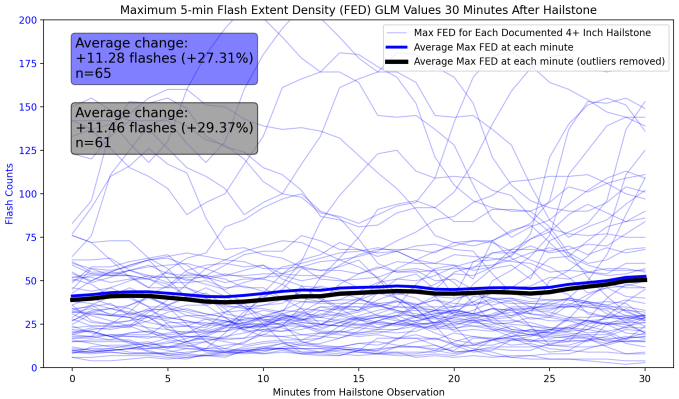
- Max FED on average markedly increased in the 30 minutes after each large hailstone by 27% (29% if outliers are removed)
- Greater number of flashes could indicate a stronger optical signal reaching the top of the cloud/GLM sensor

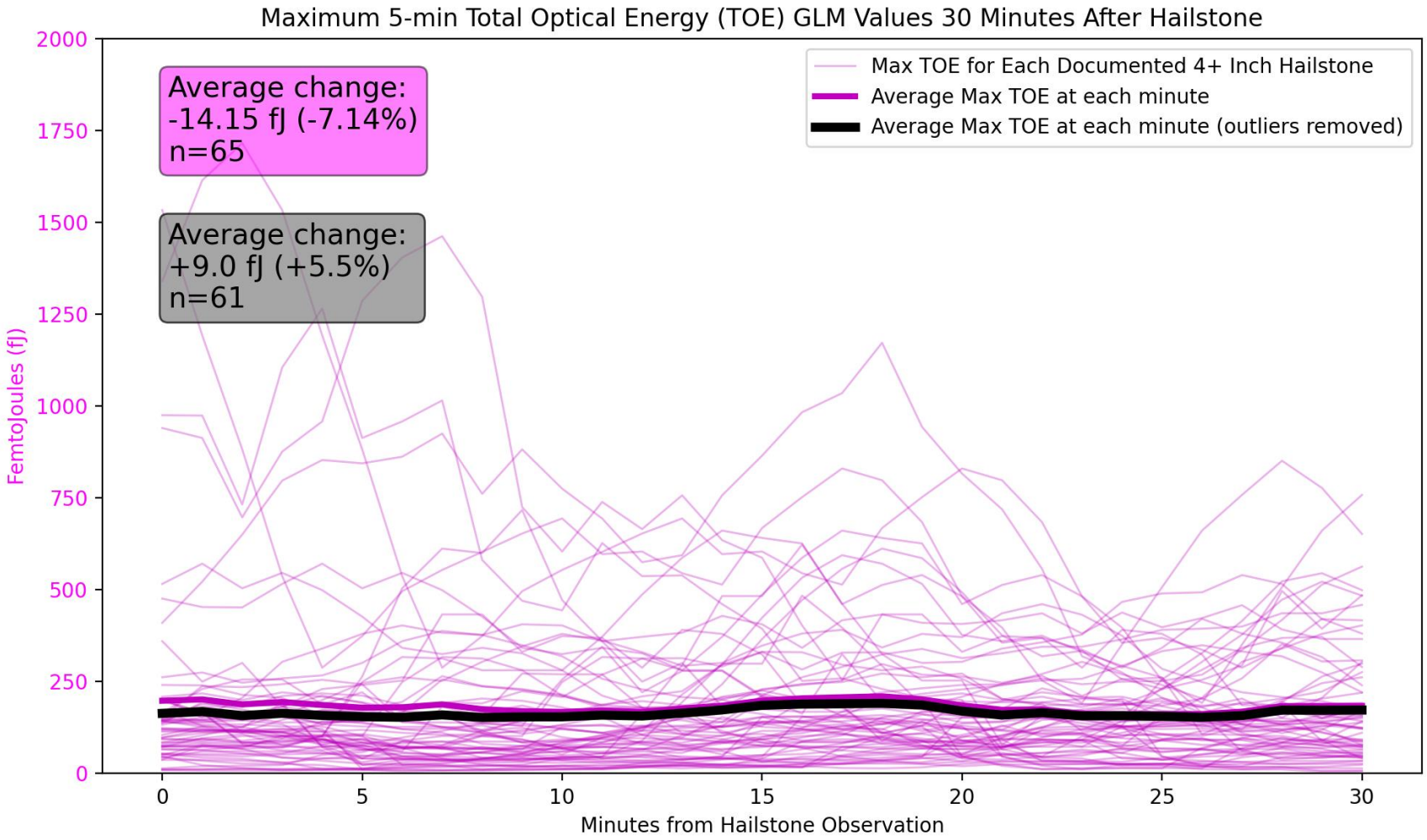


VERY LARGE HAILSTONES

FED & TOE After All 41 Documented Hailstones

- Max TOE showed mixed changes, with a 7% decrease in the 30 minutes after hailstone (5% increase with outliers removed)
- Something more to these changes?

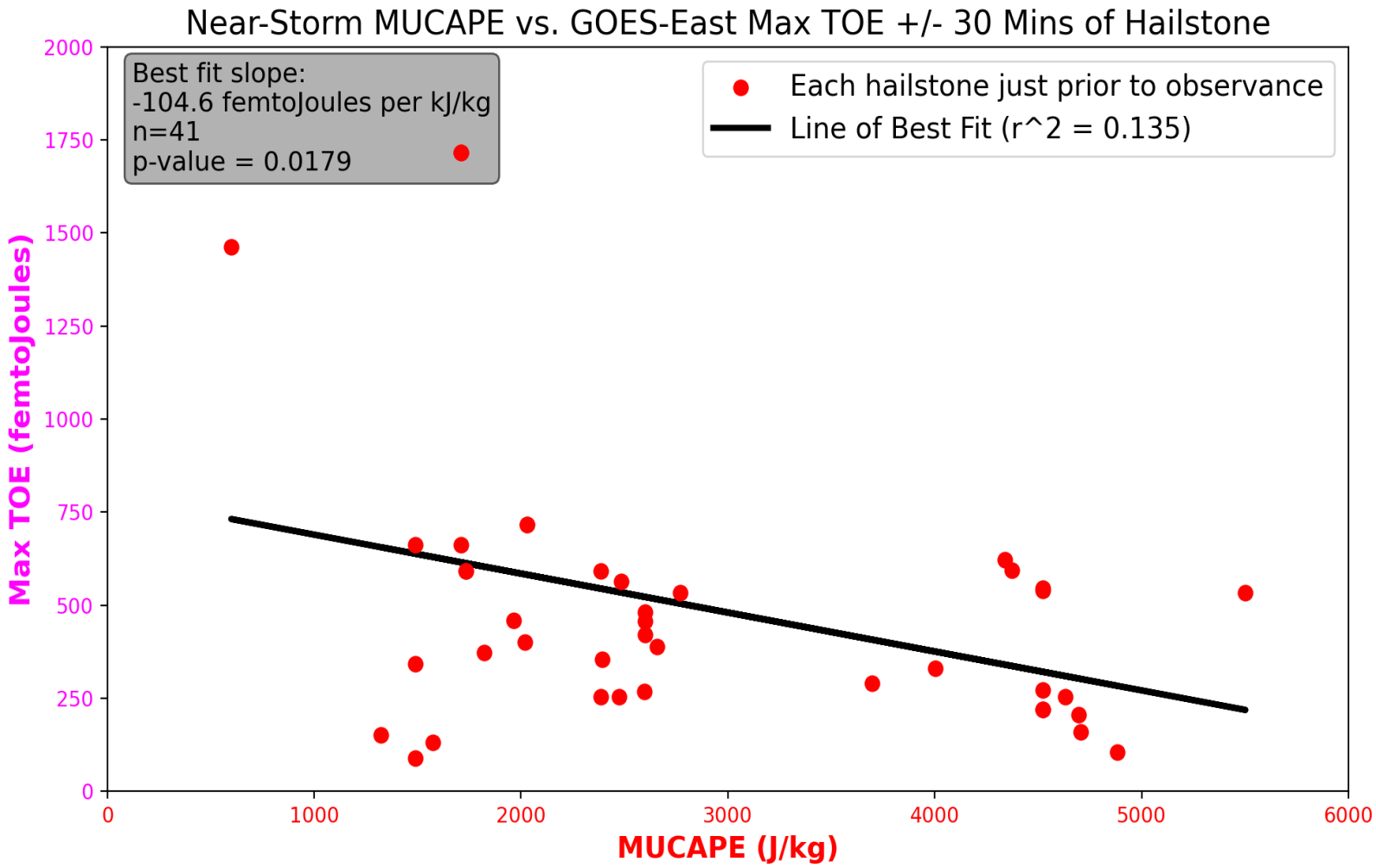




VERY LARGE HAILSTONES

Environmental Analysis – MUCAPE

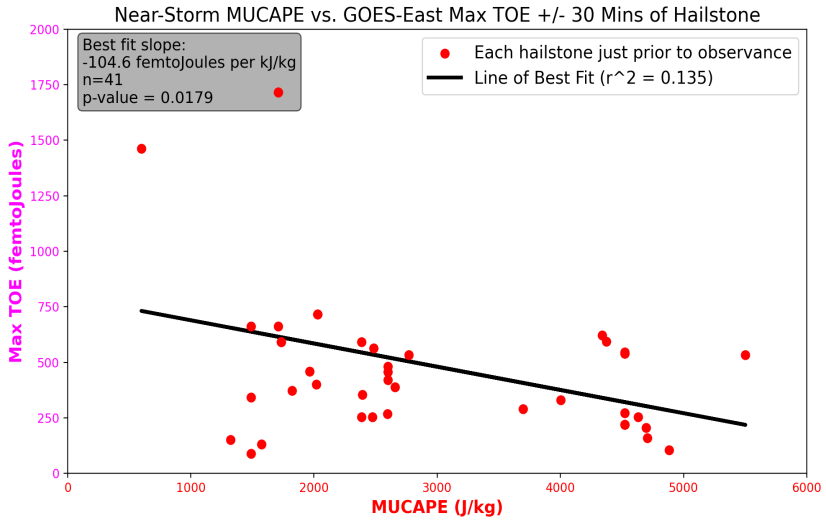
- Used SHARPpy to find sounding from near-storm environment for each stone
- Found max TOE/FED value within 30 mins of report
- Compared those values to near-storm environment thermodynamics
- MUCAPE: greater instability strongly correlated with lower max TOE (statistically significant at $\alpha = 0.05$)

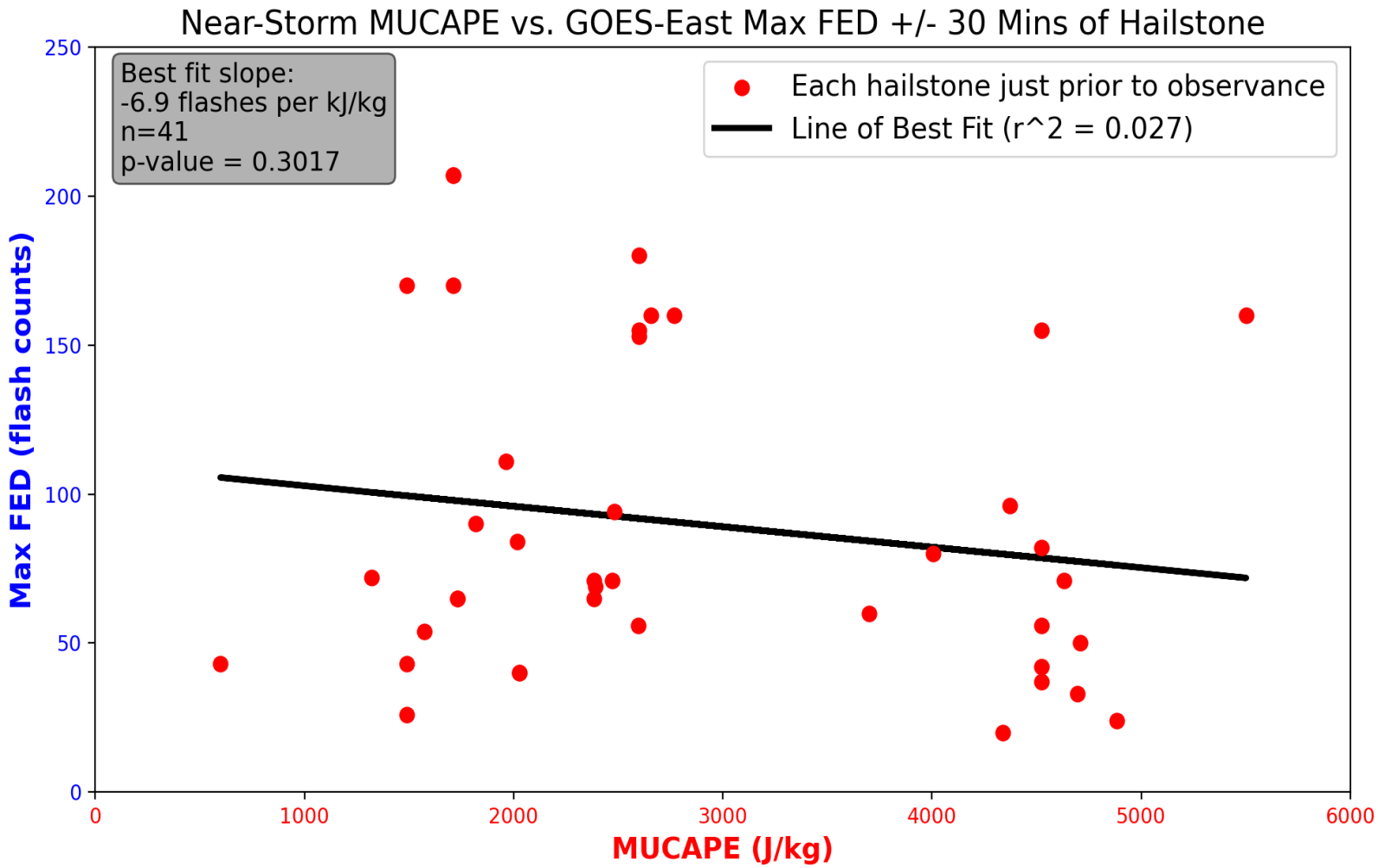


VERY LARGE HAILSTONES

Environmental Analysis – MUCAPE

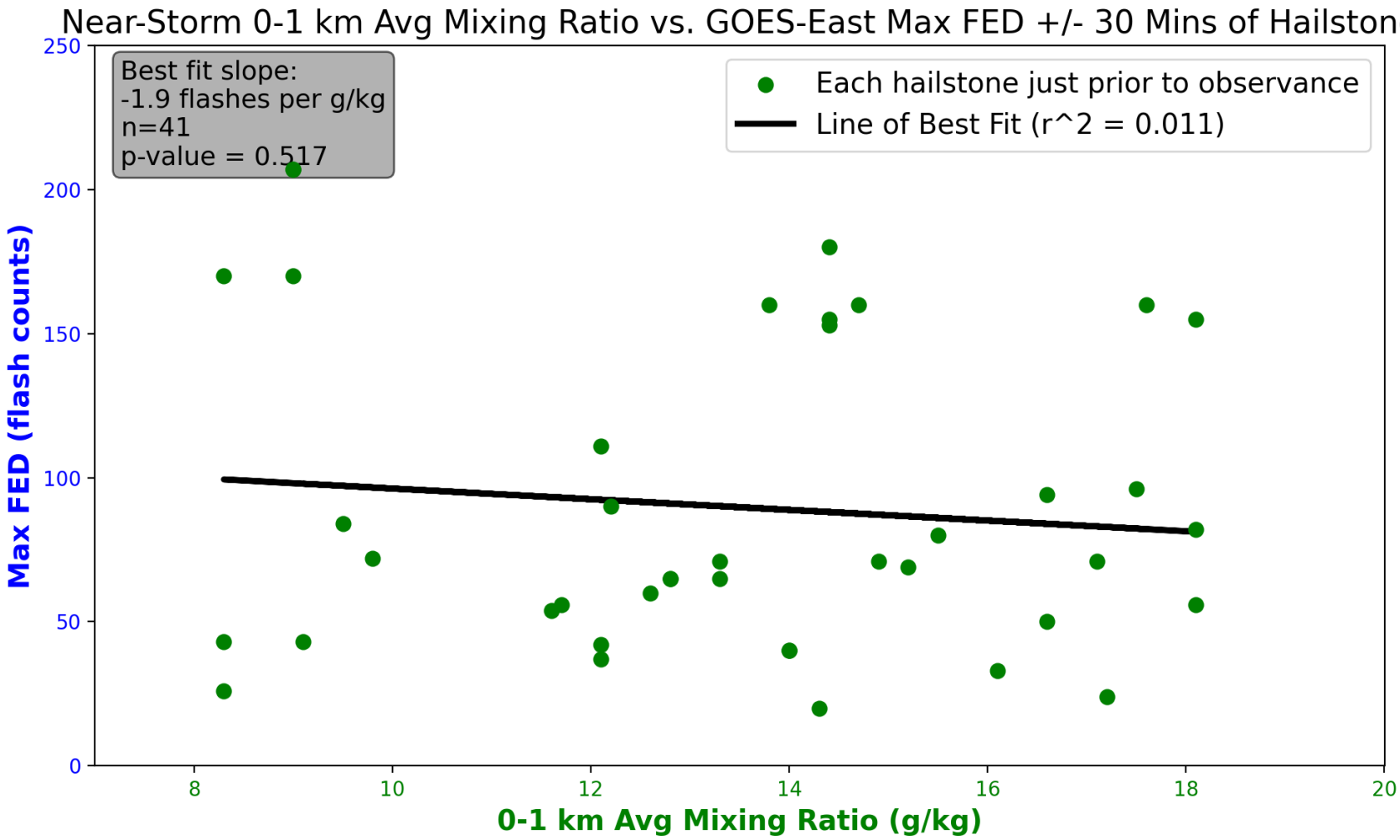
- Not as strongly correlated with max FED – dimmer optical signal with MUCAPE, not necessarily fewer flashes
- Seems to fit original hypothesis





VERY LARGE HAILSTONES

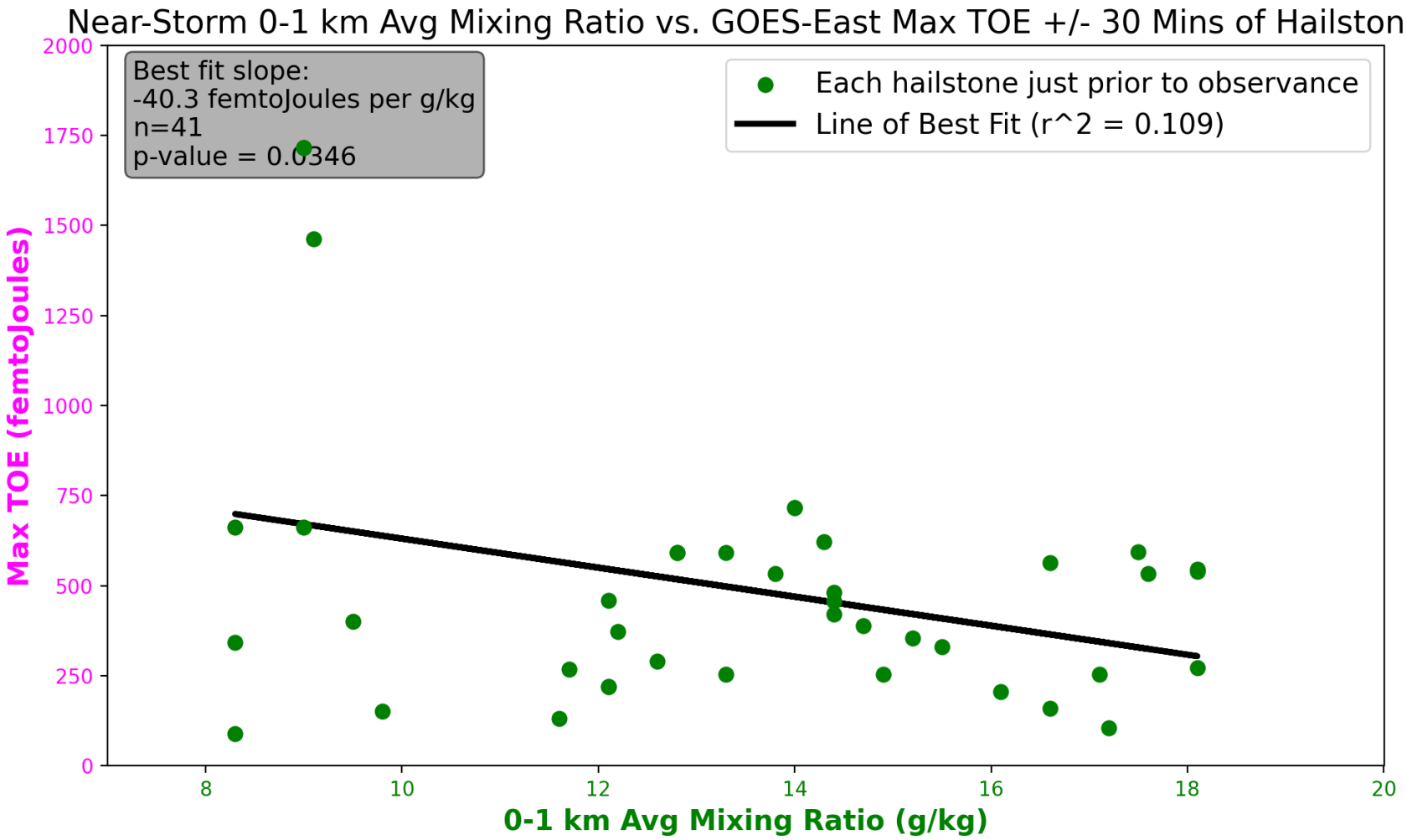
Environmental Analysis – 0-1 Km Avg Mixing Ratio



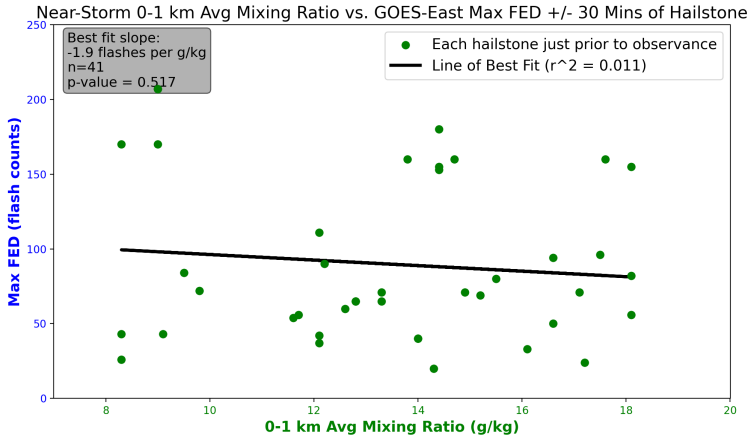
- Increasing low-level specific humidity not statistically significantly correlated with a change in max FED (flash counts)

VERY LARGE HAILSTONES

Environmental Analysis – 0-1 Km Avg Mixing Ratio

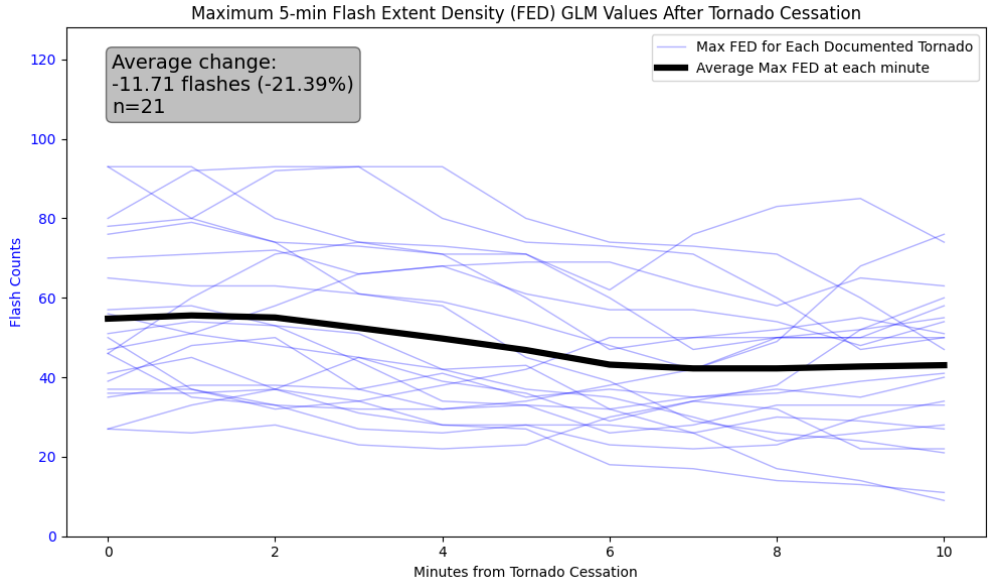


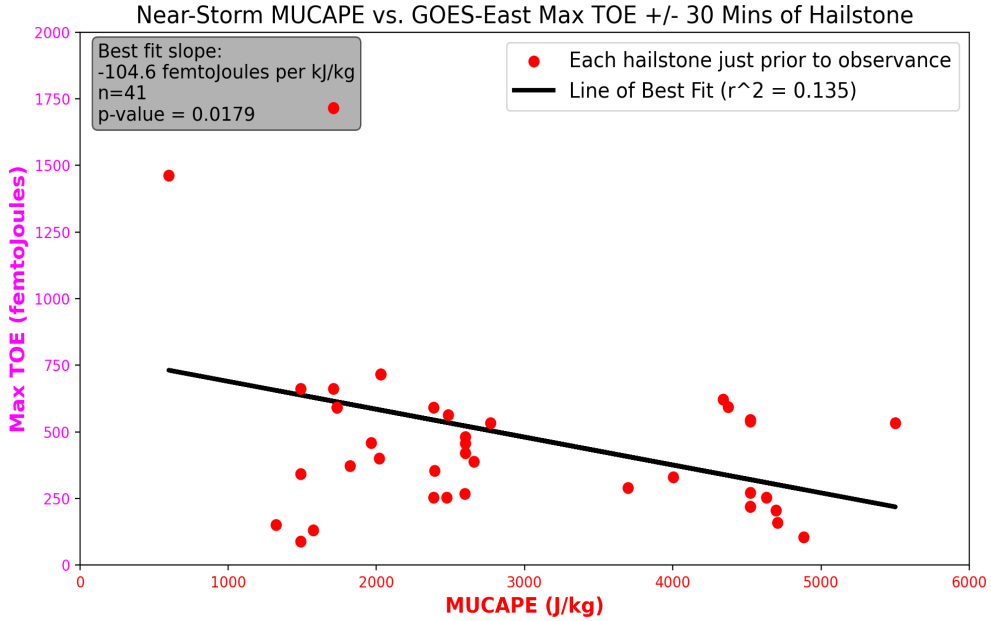
- Increasing low-level specific humidity **is** statistically significantly correlated with a change in max TOE (flash energy)
- Decreasing optical signal w/ more humidity



SUMMARY

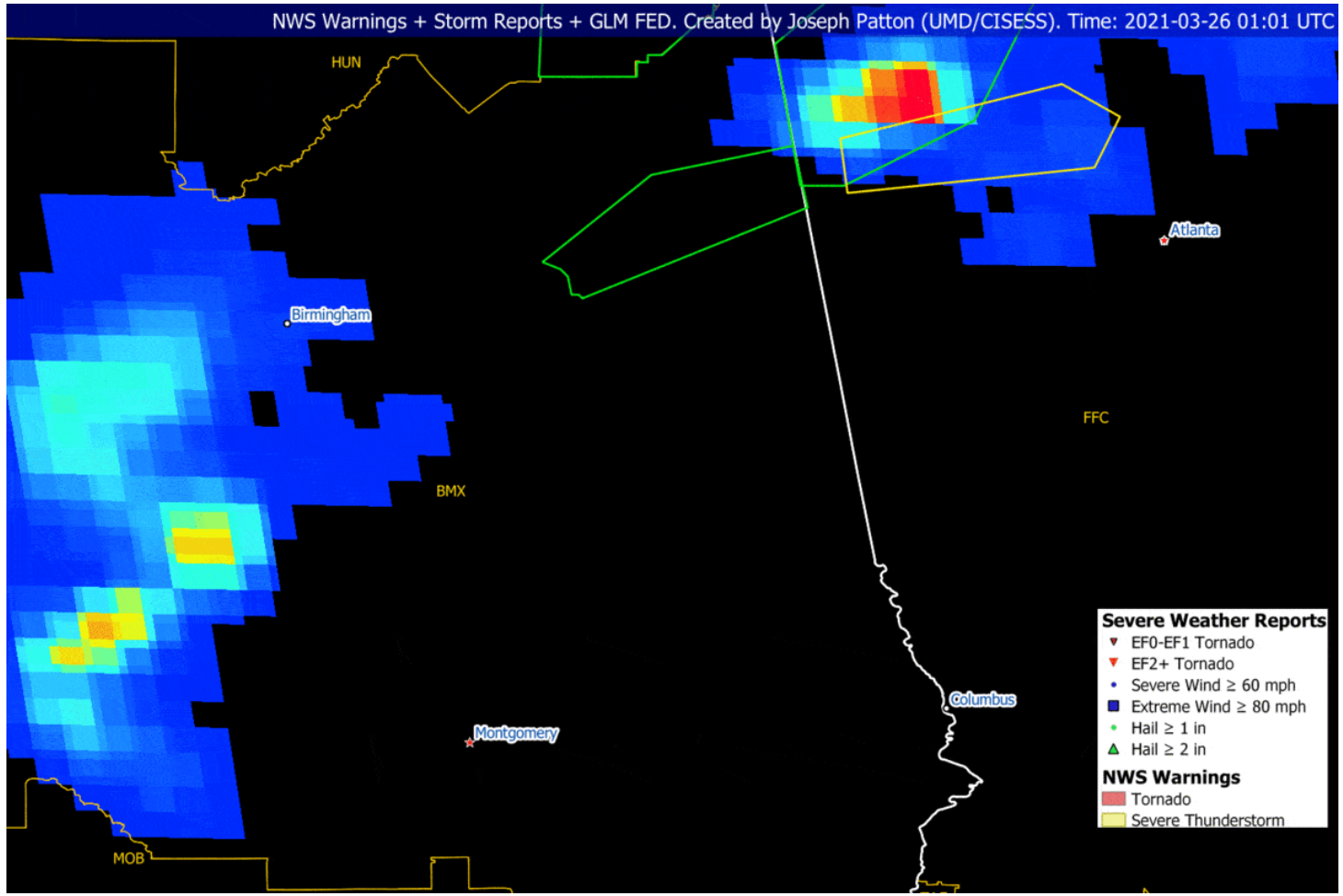
- GLM gridded products of FED, MFA, and TOE were tracked from 21 tornadoes from a late-winter outbreak and 41 very large hailstones from across Spring 2024
- For tornadoes, marked declines in max flash counts of parent storms (~21%) and max optical brightness (~16%) 10 minutes after
- For large hailstones, max flash counts increased by ~27% in the 30 minutes after
- Environmental analyses show that significant changes in observed max lightning optical brightness may be associated with increasing instability, low-level mixing ratios, and thus hydrometeors attenuating light
- Future work: more robust analysis of trends in operational GLM gridded products to find actionable decision-making signals for forecasters





THANK YOU!

- For more analysis on GLM trends, see Satellite Book Club sessions like Session #186 with me or Session #26 with Steve Cobb (NWS Tulsa)
- To talk more, email me at jpatton4@umd.edu or follow me on Bluesky @josephpattonwx.bksy.social or on Twitter @JosephPattonWx



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