From detection thresholds to detection efficiency

MTG LI Meeting
5-6 December 2022

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This work supported by NASA award 80NSSC19K1576, NOAA JTTI award NA19NES4320002 via CISESS-Maryland, and NOAA NA21OAR4320204 via CIWRO.

Outline

- MTG LI is an optical pulse detector, so a **ceiling** on *detection efficiency* is related to the *detection threshold* - the smallest optical energy (or radiance) that can be observed as a detected transient at each pixel.
- Differences in detection threshold characterize the different baseline sensitivity of optical lightning detectors (MTG-LI, GLM, LIS).
  - Ignores attenuation of optical pulses by the cloud and lower DE compared to VHF mapping systems that see many small, short-lived flashes that don't produce much light. These significant effects vary from storm to storm as a function of meteorology, but are constant across all 777 nm optical systems except for viewing angle differences.
- For discussion and future analysis: how do the optical sensitivity characteristics of MTG LI vary across the field of view?

Detection threshold for GLM

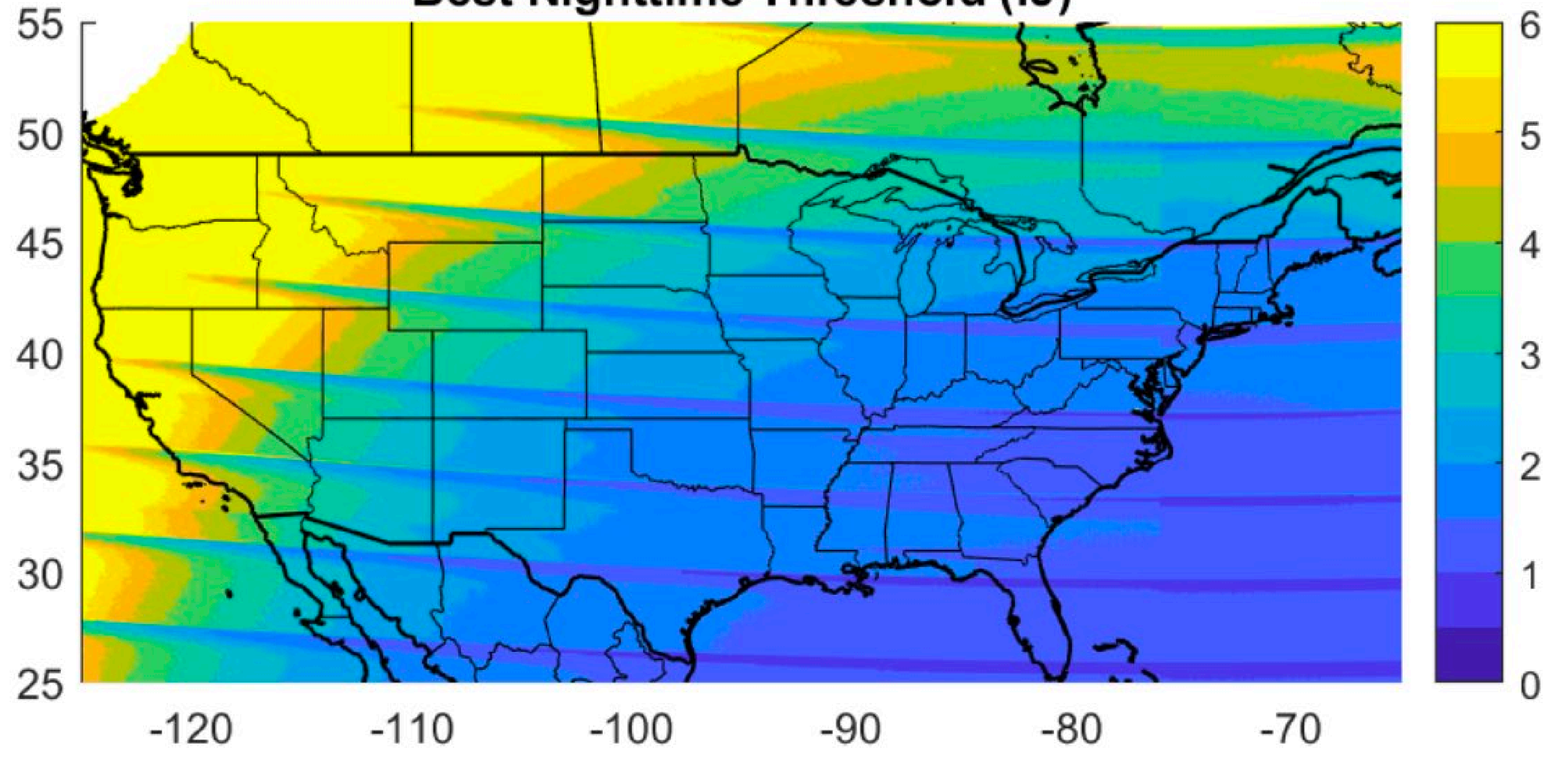
Assesses maximum achievable optical flash detection efficiency (relative to LIS)

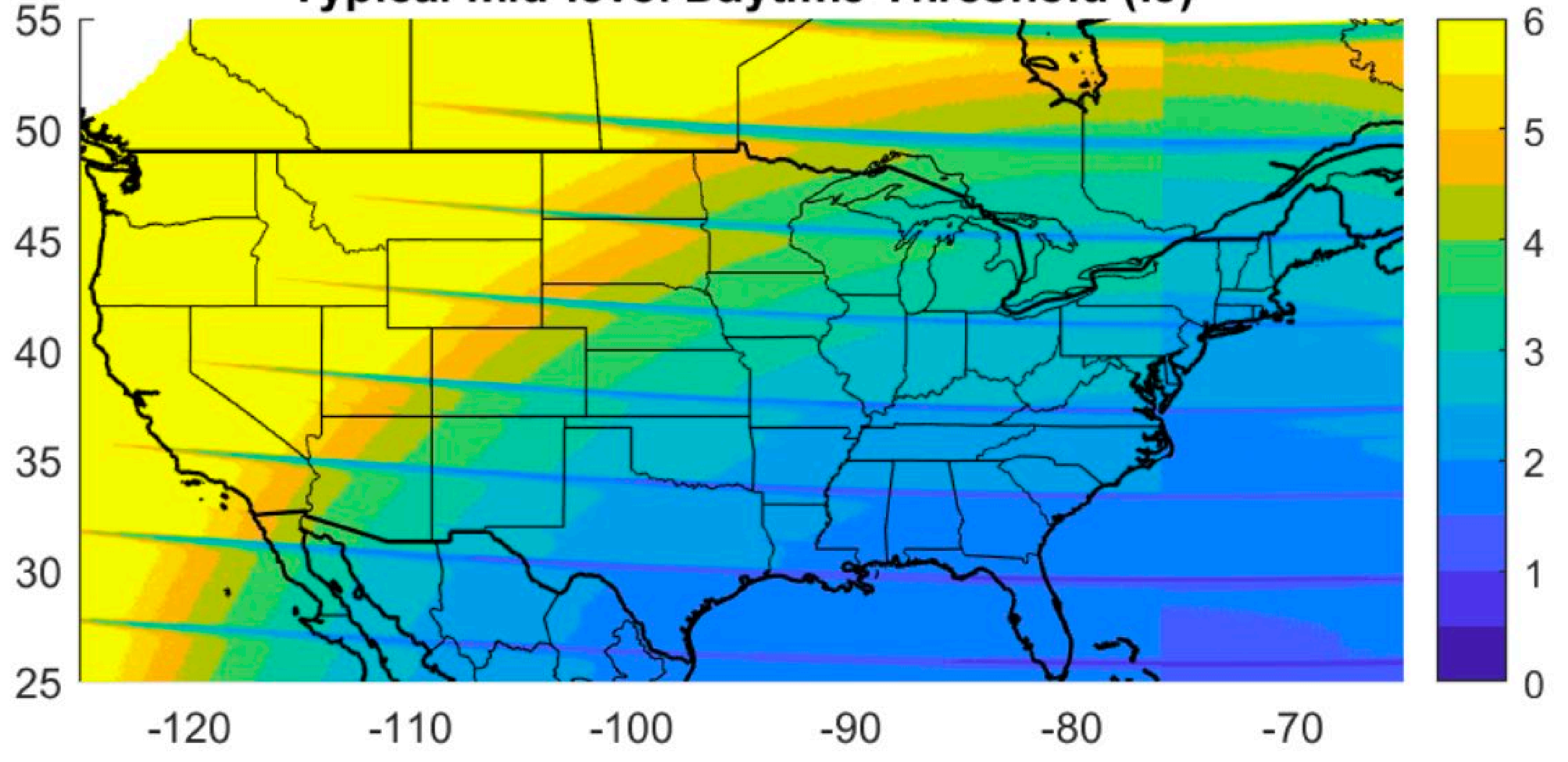
Less-sensitive regions can only detect more energetic groups and therefore will observe fewer flashes.

The **minimum detectable energy**
…varies by time of day, subarray position, etc. Has a characteristic fall-off toward the limb.

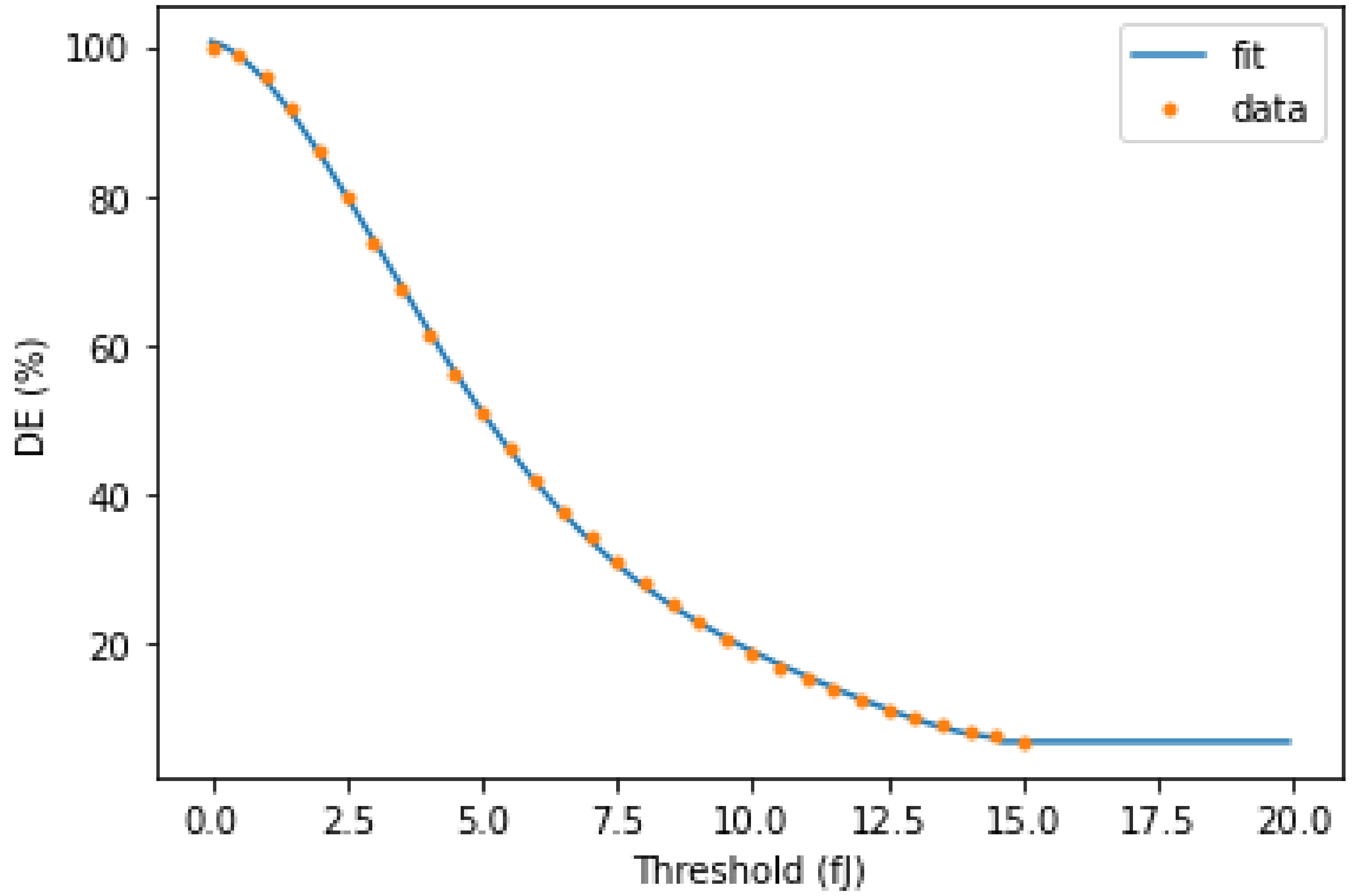
…is independent of meteorology, cloud properties, etc., and **sets a ceiling on DE** at any given location.

Key insight from Ken Cummins (2020, GLM Sci. Mtg.): **Flash DE** can be inferred **from the local minimum event energy (MEE)** using a transfer function built from LIS group energy statistics.





Estimated GLM Flash DE Relative to
Long-term TRMM LIS Group Energy Observations

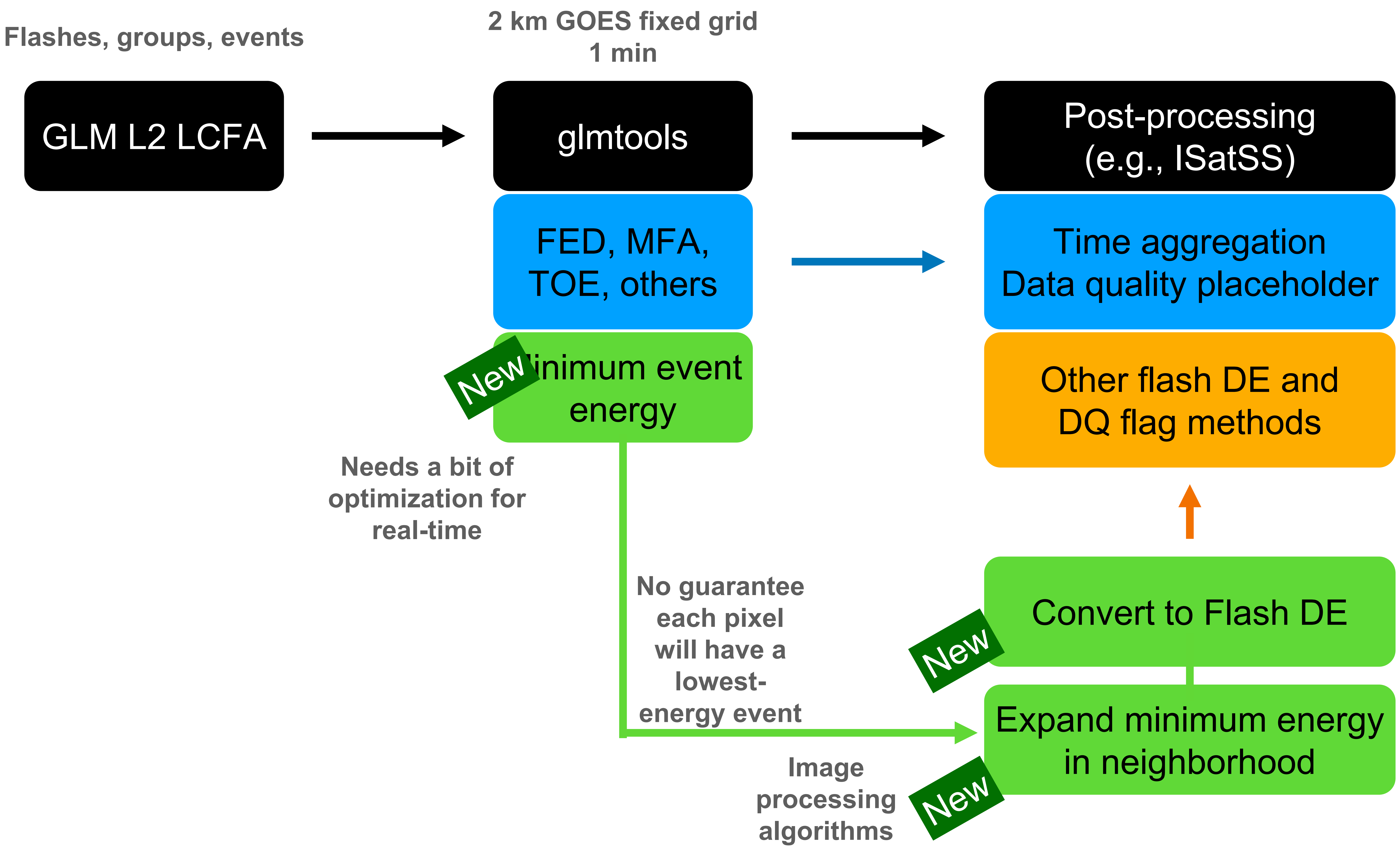


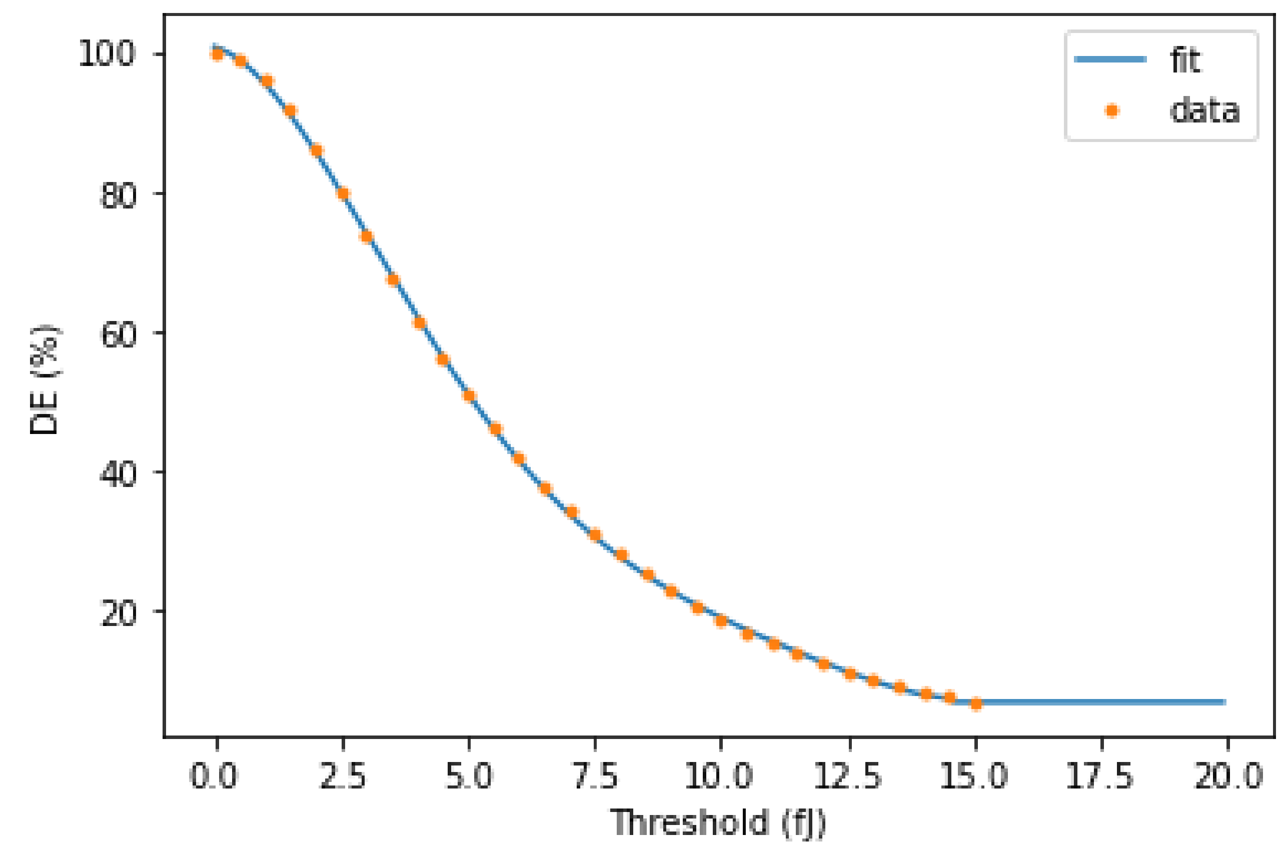
Polynomial fit to
K. Cummins (2020, GLM Sci. Mtg. and personal comm.)

We can reproduce this pattern from relatively small amounts of real-time data

From minimum event energy to flash DE

Product and algorithm steps. Only requires LCFA files for time of interest.



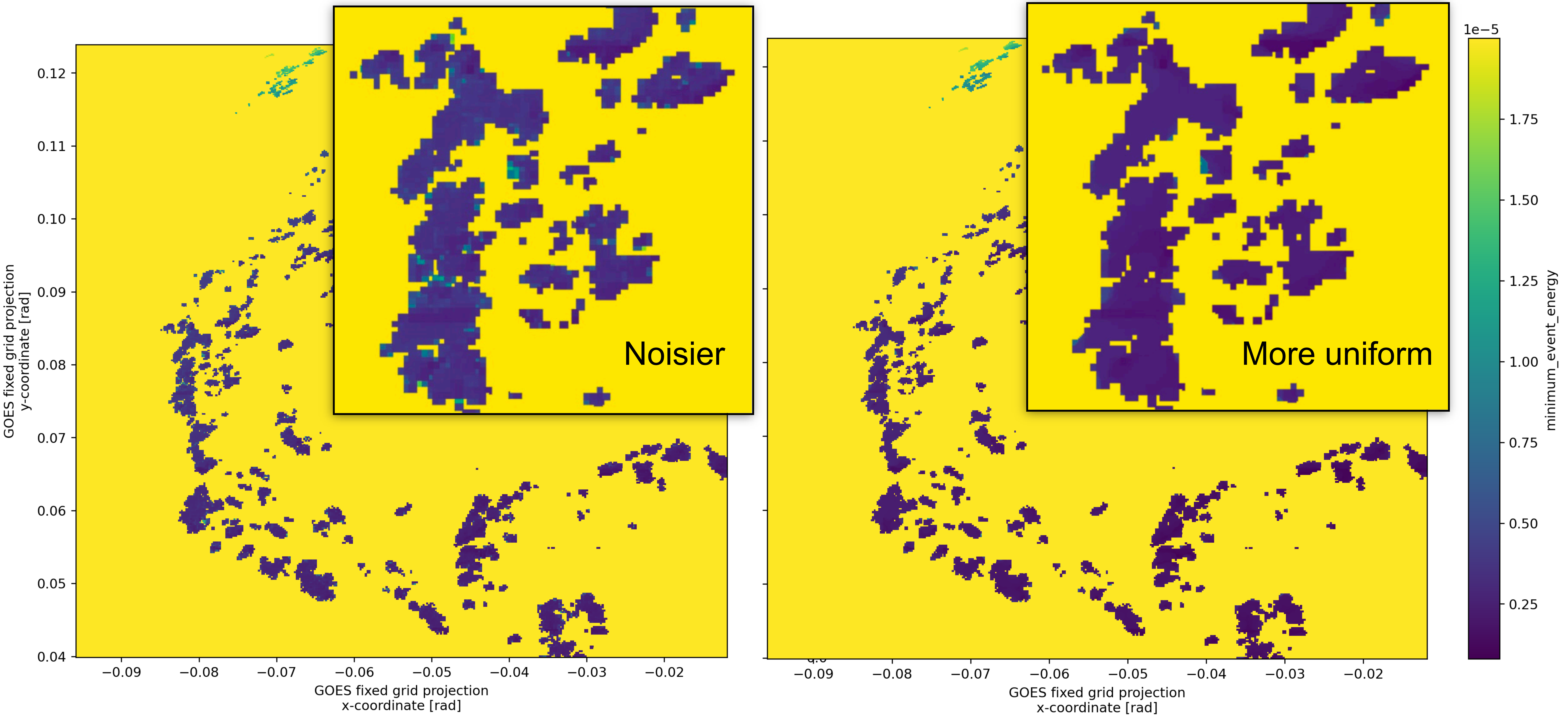


Fit to K. Cummins (2020, GLM Sci. Mtg.)

MEE image processing (neighborhood expansion)

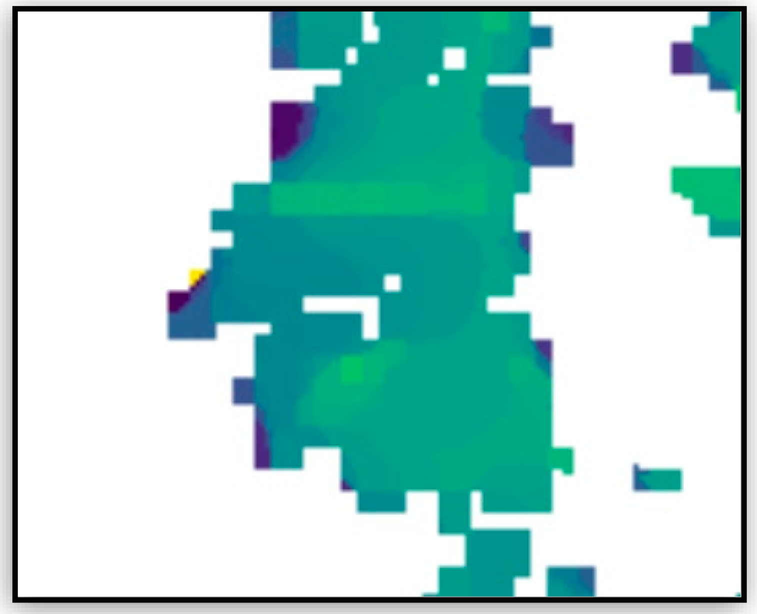
1 hr, 22 UTC on 9 July 2022, North America-ish region

Opening = erosion + dilation: removes bright spots and expands dark cracks using circular neighborhood

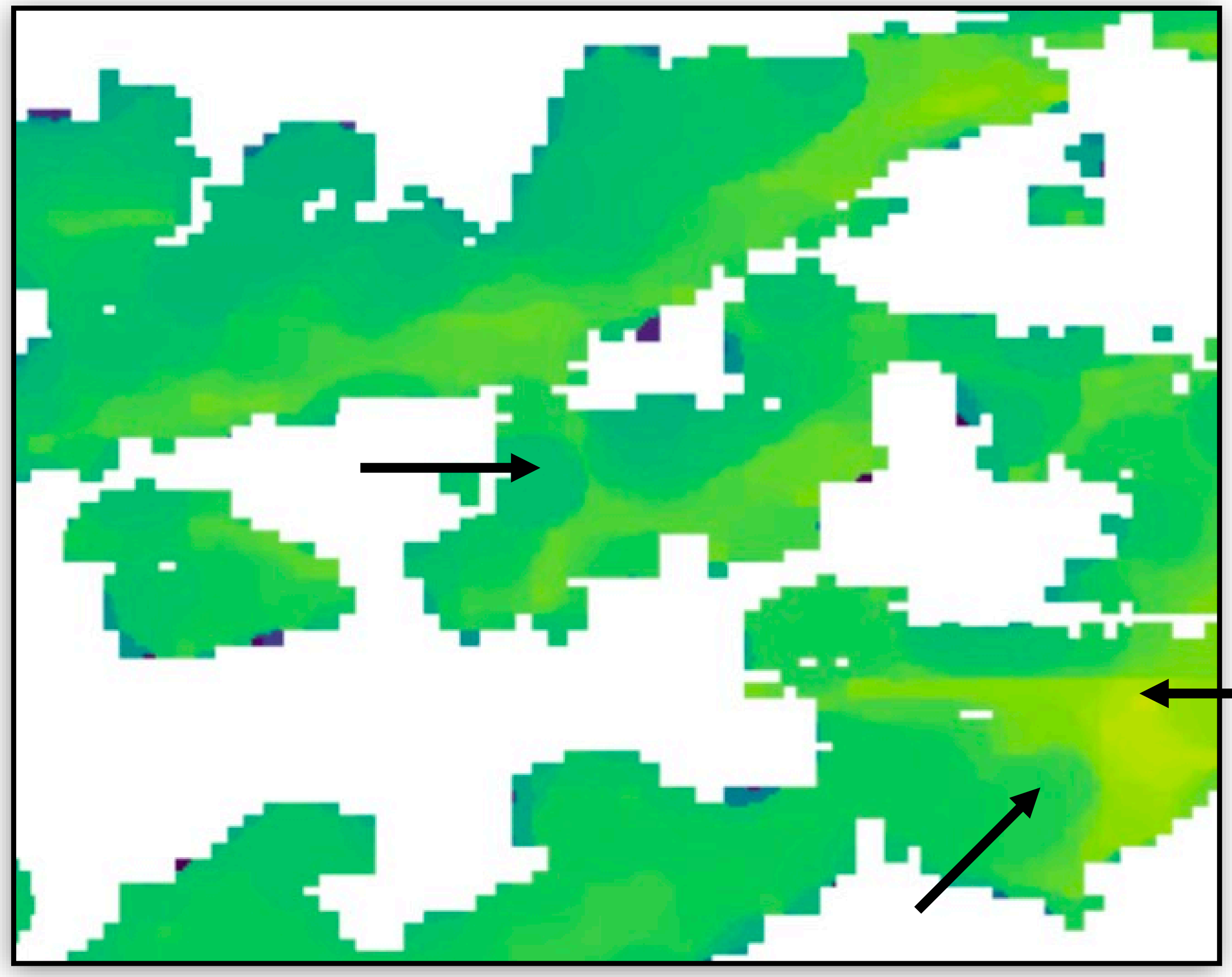


DE after neighborhood expansion

Note expected decrease toward the limb.

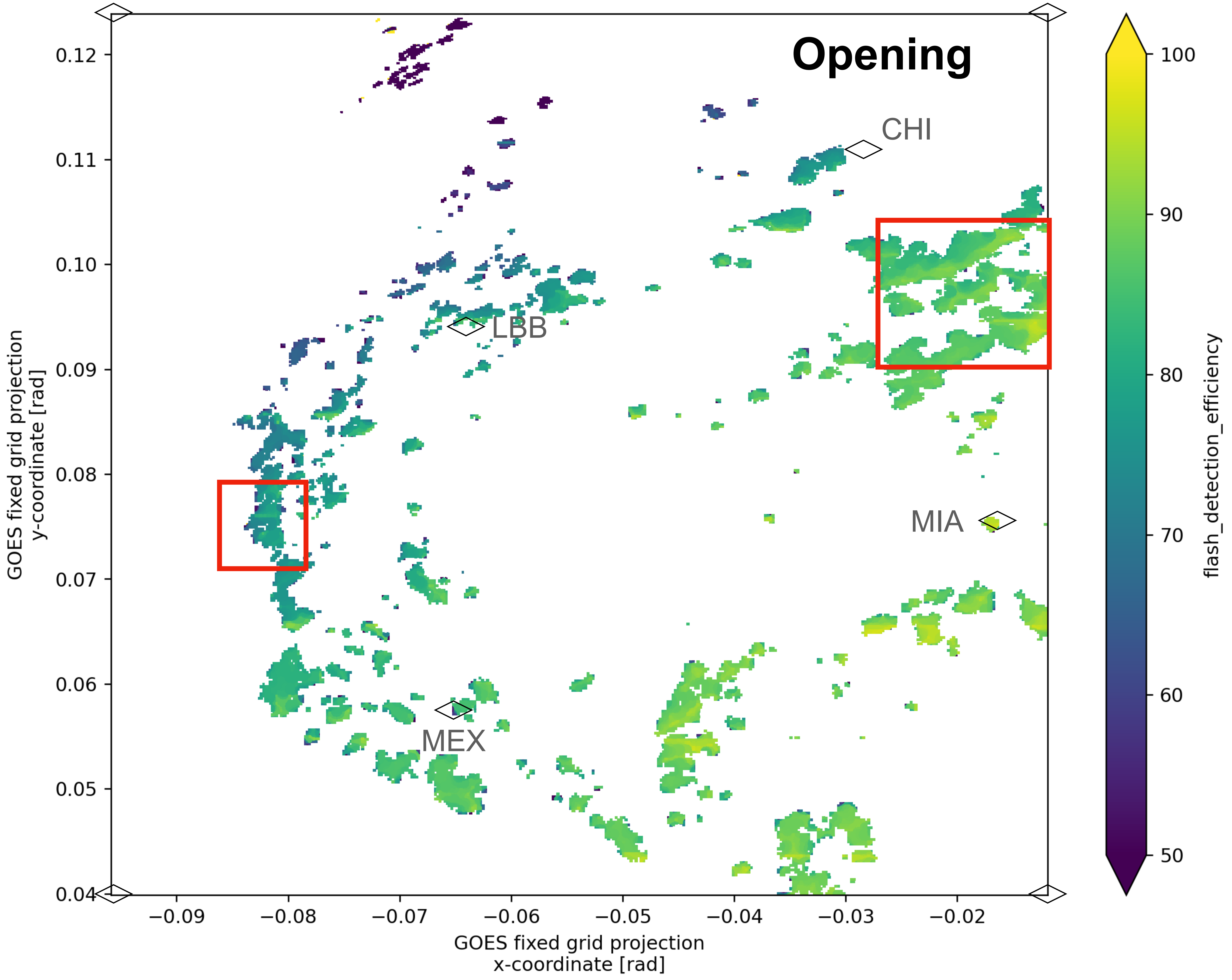


Subarray boundary visible



Note circular neighborhood boundaries due to image processing method

Subarray boundary

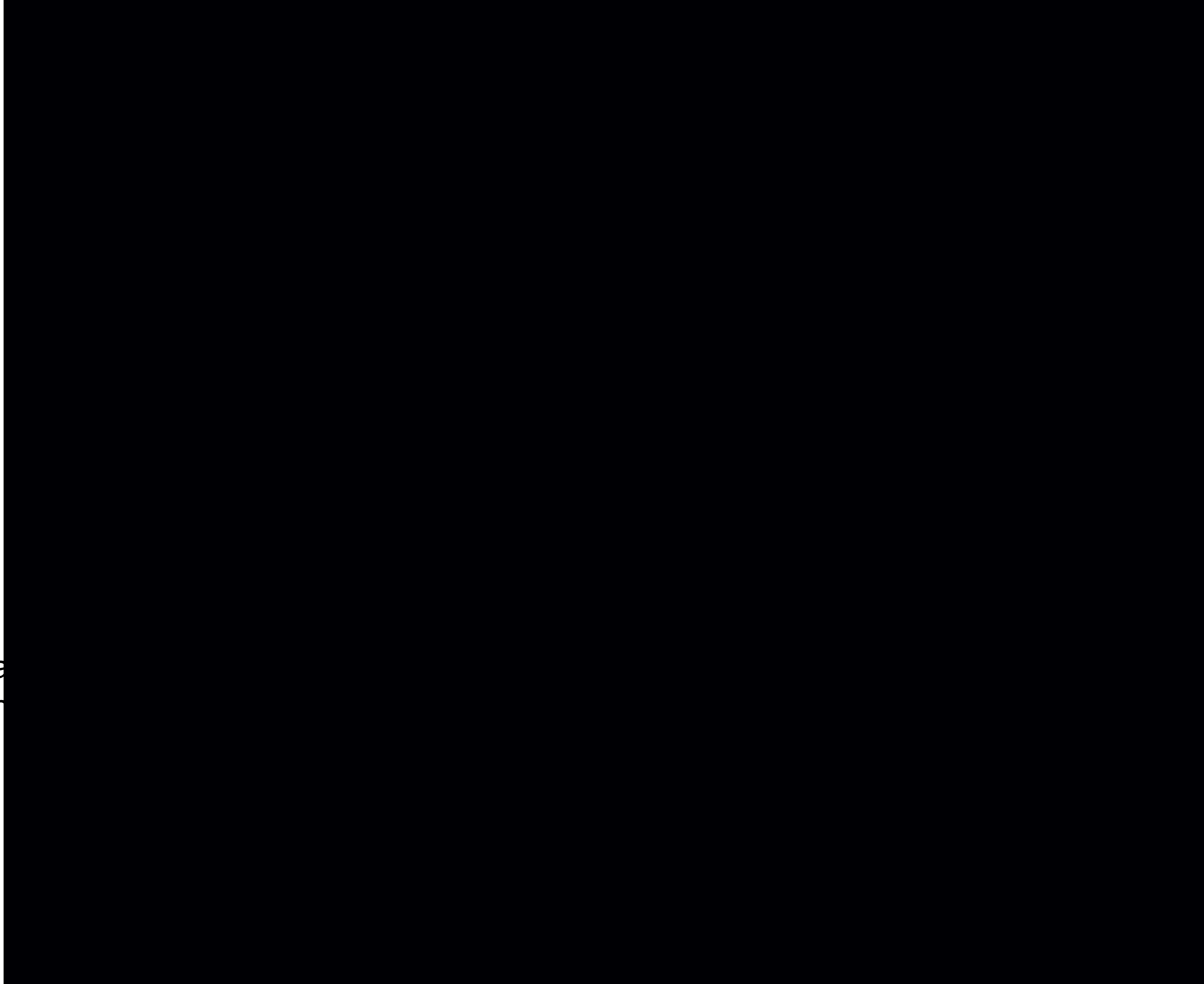


Diurnal variability and lower DE near limb

Hourly windows beginning 20 –
08 UTC, 8-9 July 2022

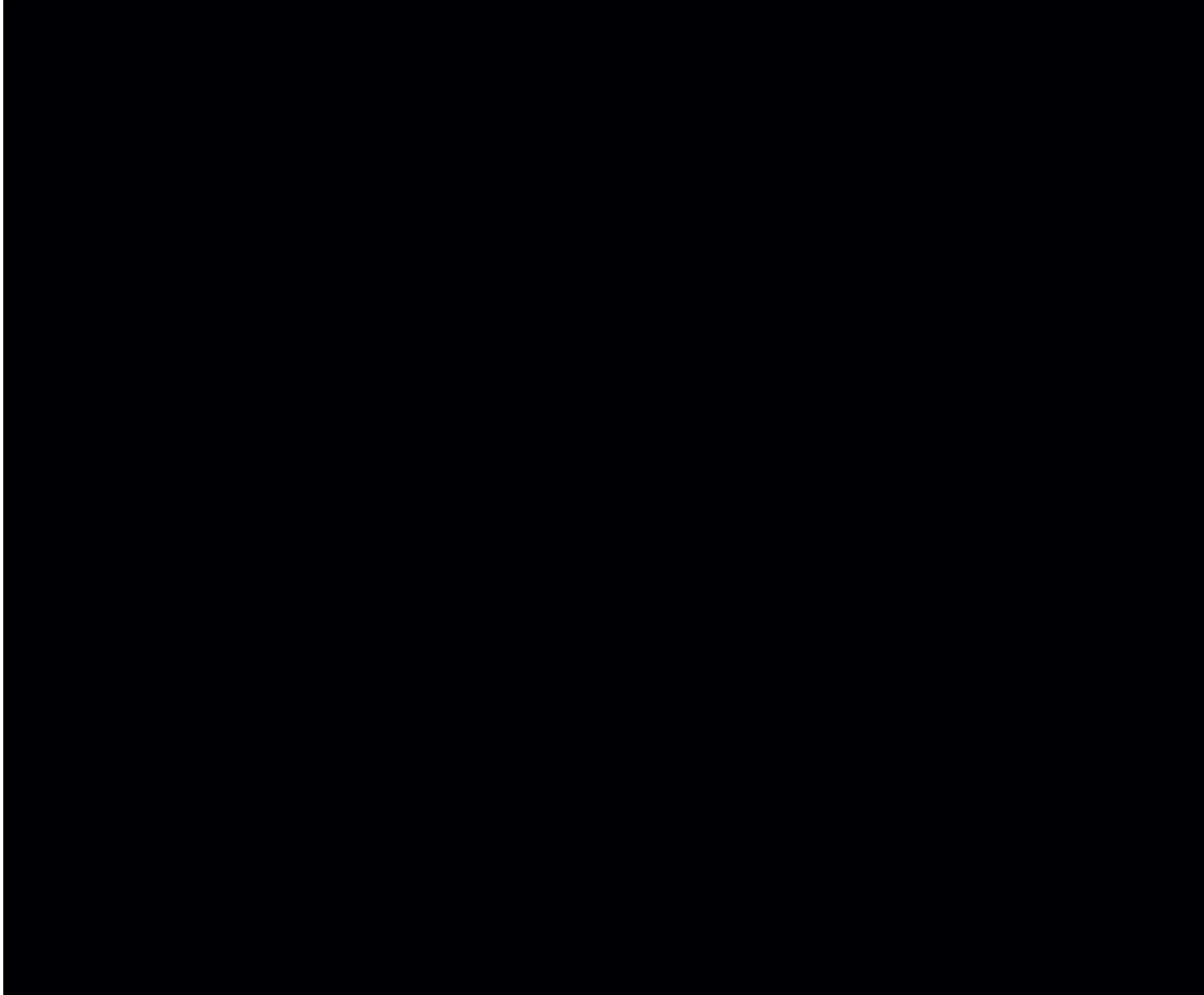
Day-night transition in North America

Subarray
boundaries
obvious at a
(and elsewh



5 min DE

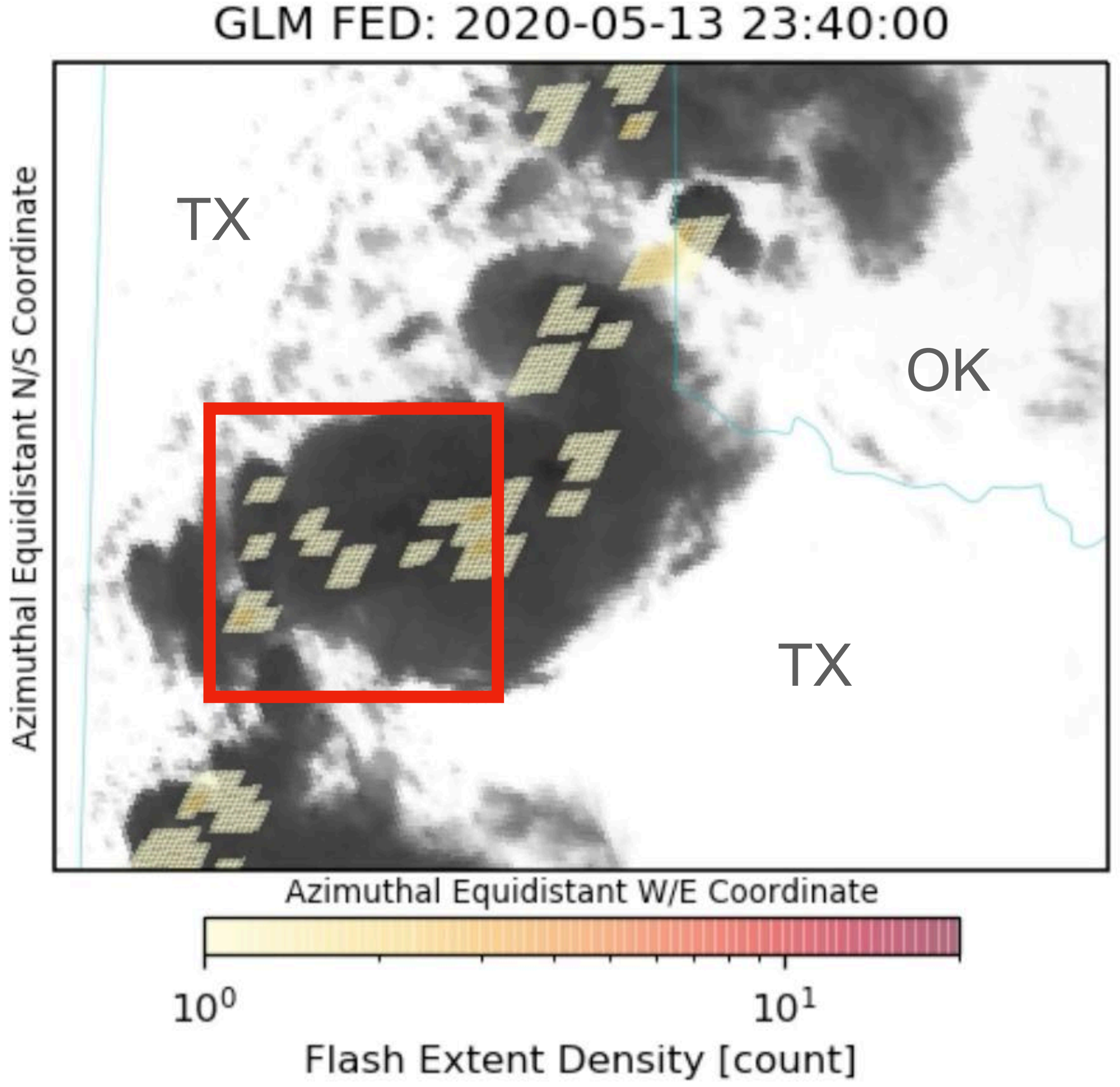
Compared to 1 hr window, a 5 min window shows the same pattern, but is more variable from storm to storm



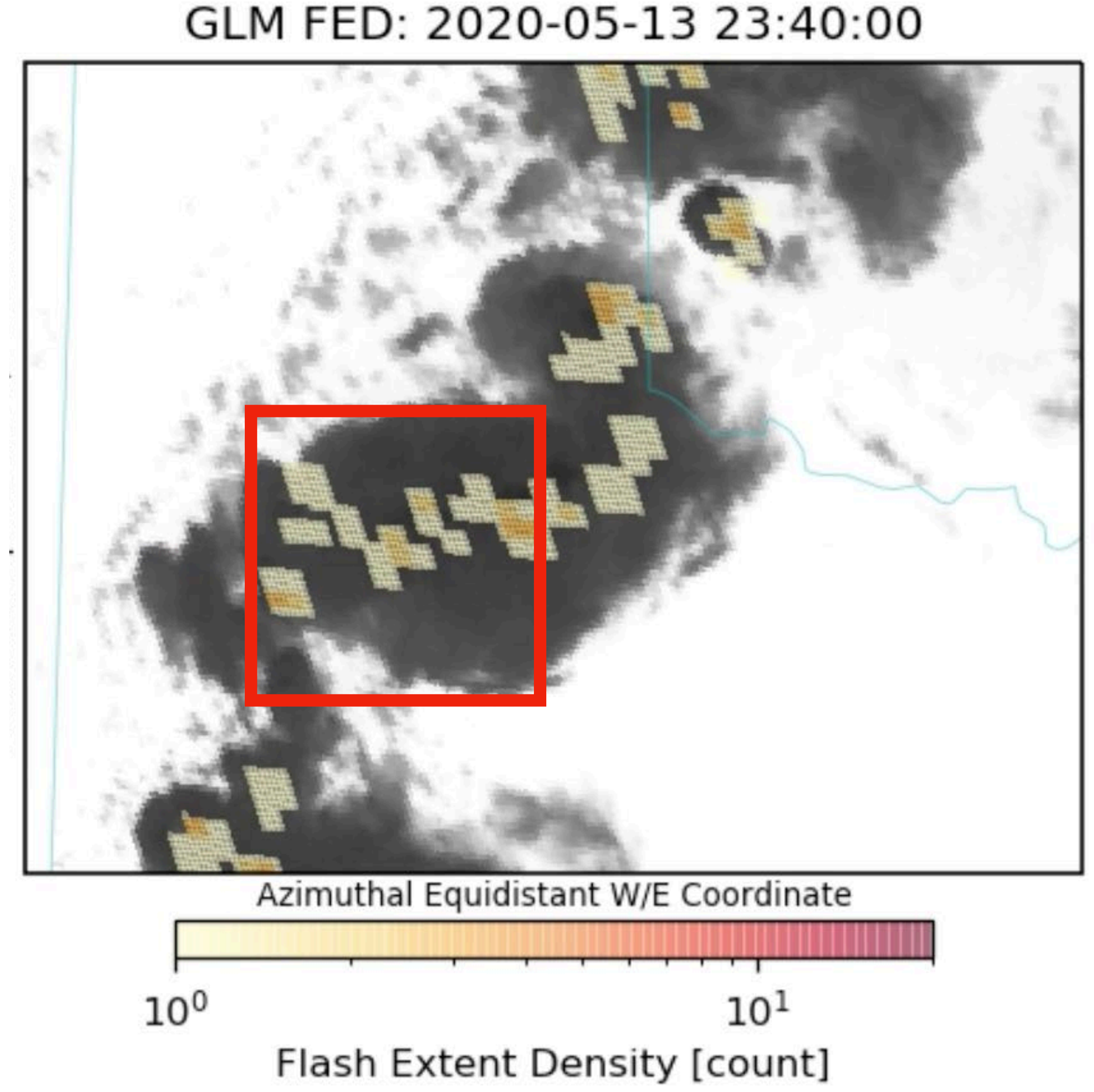
GLM : LMA detection efficiency GOES-17 and GOES-16 14 May 2020

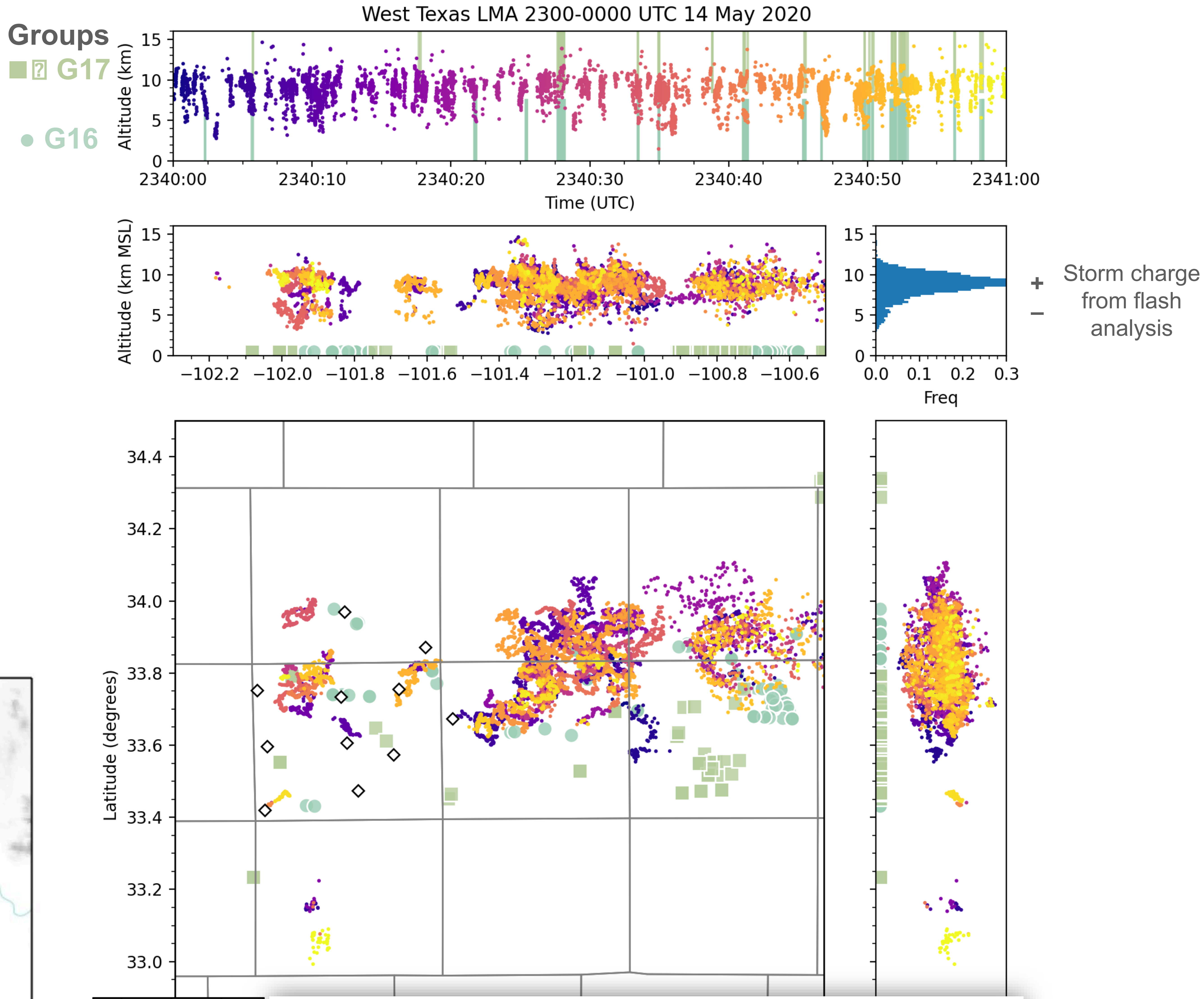
- 131 LMA flashes (width > 1 km)
  61 were larger flashes (width > 4 km)
- 13 GLM-17 flashes, 16 GLM-16 flashes
- GLM-16:LMA detection efficiency is 12% (26%) for LMA flashes with width > 1 km (4 km).
- Speckled GLM appearance and flashes with 1-2 events suggest optical emission is close to GLM detection threshold.

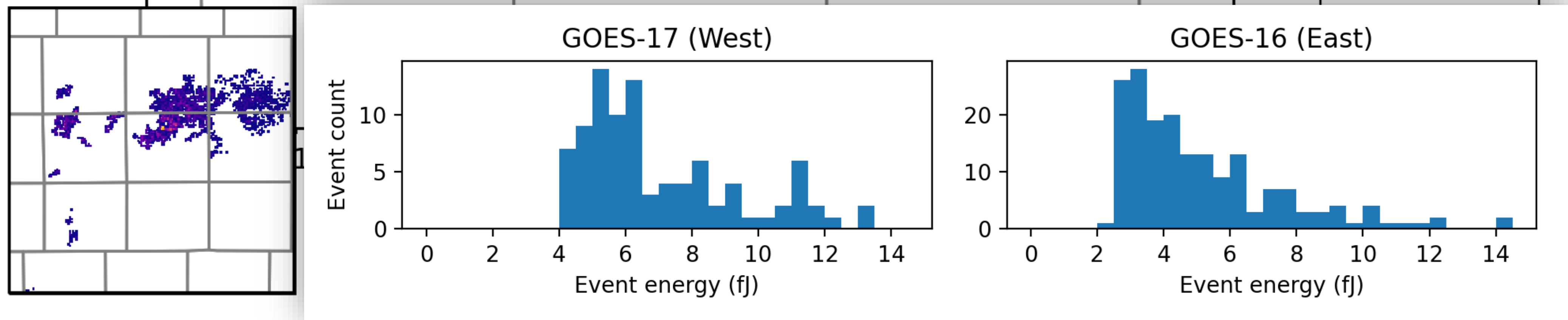
GOES West (17)



GOES East (16)





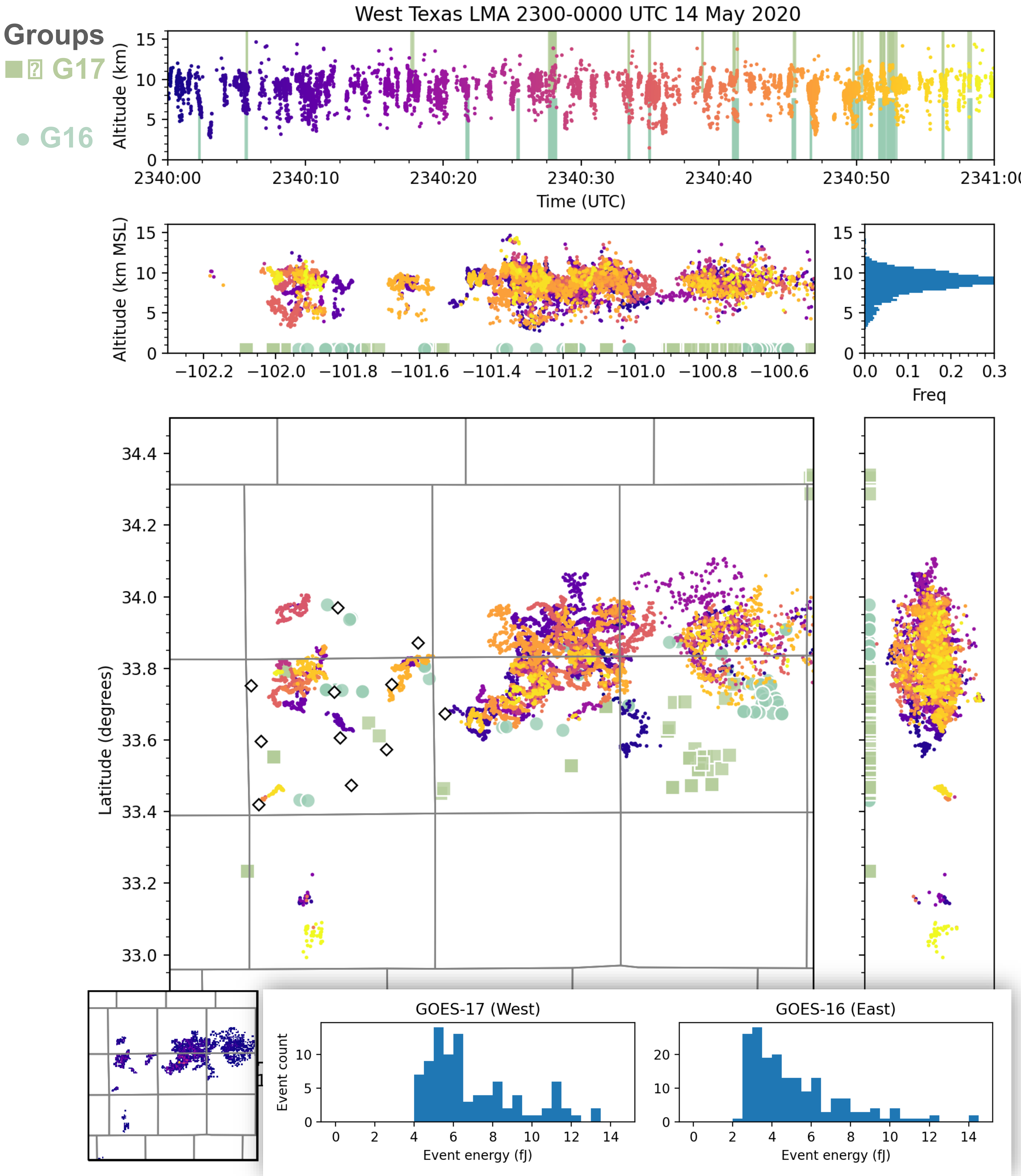


GLM-17 energy threshold is higher than GLM-16.

A rough all-effects DE estimate

Calculated from instrument threshold, flash population, and meteorological effects.

- Apply approximate DE rules from recent studies
  - Energy threshold: 5 fJ = 40% of TRMM LIS DE. Min energy: 10% per fJ (Cummins 2020, personal comm.)
    - 2.5 fJ threshold for GLM-16 implies **65% DE relative to LIS**
    - GLM-17 threshold is 1.5 fJ higher than GLM-16. Implies **15% worse for GLM-17**. 14 GLM-16 flashes, 12 GLM-17 flashes. 2/14 = *observed 14%. Checks out!*
  - For LMA flashes with 0.3 s duration, 10 km flash width as is typical here, detection efficiency is reduced by **50% for medium-small flashes** (Zhang and Cummins, 2020, JGR)
  - 10x ice water path implies 10-30% drop in flash DE. Anvil: 0.05 kg m^{-2}, largest values in Colorado 50 kg m^{-2}. (Rutledge et al., 2020, JGR)
    - These storms were optically thick: 1” hail implies lots of mixed phase precipitation and ice plus supercooled liquid water. Let’s assume we have a **20% drop from optical depth**.
- Combine for **GLM-16**: (0.65)(1.0-0.5)(1.0-0.2) = **26% DE**
- Reduce further for **GLM-17**: (1.0-.15)(0.26) = **22% DE**
- **These estimates are within 10% of the observed GLM:LMA ratio.**

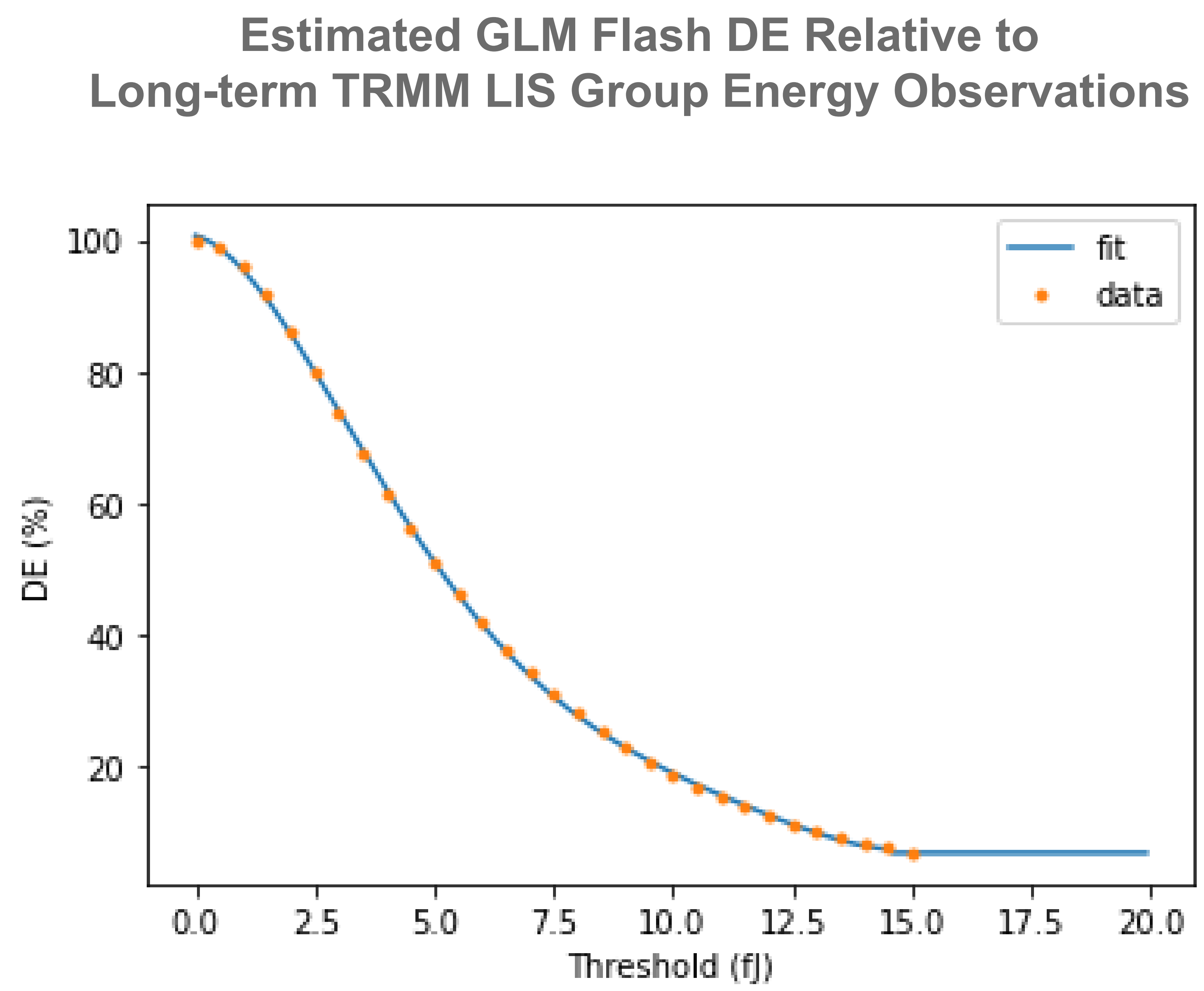


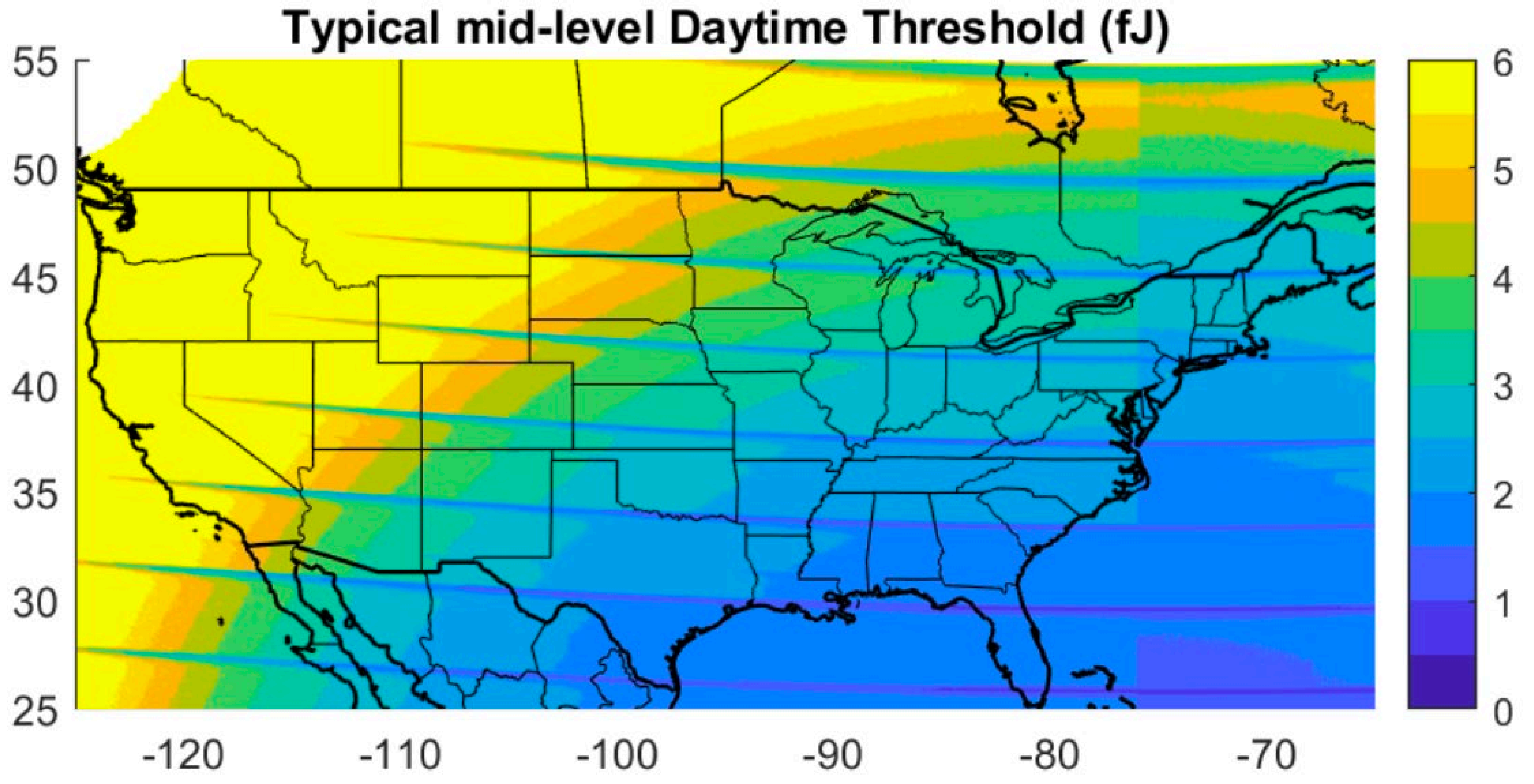
Thresholds
GLM-17: 4.0 fJ
GLM-16: 2.5 fJ

User products

Lessons from GLM

- It has been a common user request to understand data quality, which includes detection efficiency.
- Availability of a real-time product converting the detection threshold in fJ to detection efficiency in % would support user understanding of MTG LI products.
  - Calculate from instrument parameters at each pixel, or from observations.





Summary

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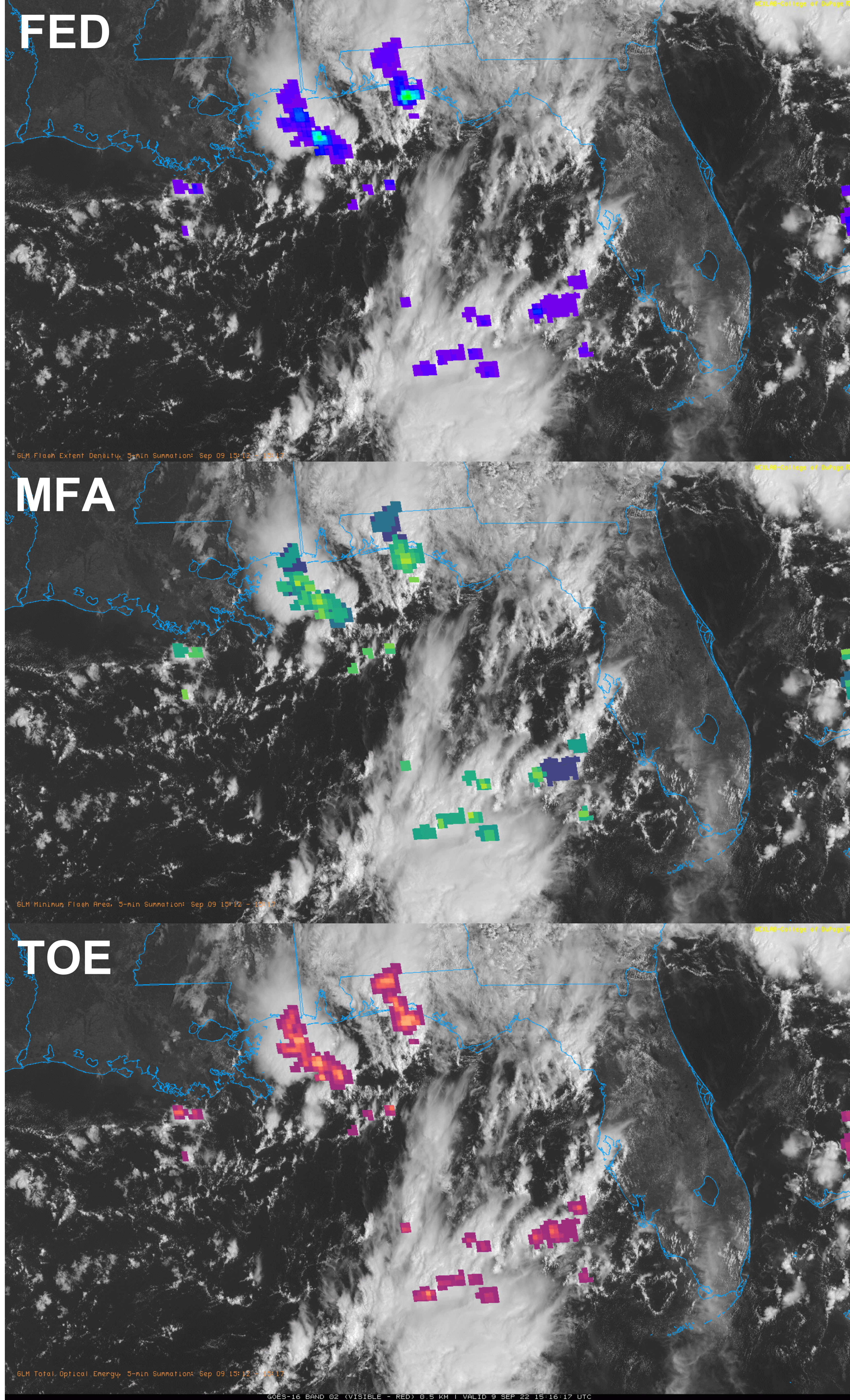
Programming note

Public feed of GLM gridded products

- 1 min and 5 min FED, MFA, and TOE are available for GOES-East and GOES-West
  - Thanks to the teams at Unidata and NWS/ISatSSGLM
  - Distributed through Unidata IDD infrastructure
    - thredds.ucar.edu, LDM
  - Path: /satellite/goes/[E/W]/products/GLMISatSS/
- Enables real-time loops on CoD
  - See Product Overlay -> GOES derived menu at weather.cod.edu/satrad



Loops from CoD, generated directly with their built-in tool to download a GIF of what you're viewing.

Position open

Postdoctoral research associate

NOAA-sponsored project to assess controls on flash rate variability in space and time.

- Lightning mapping, and radar observations
- ERA5 and field campaign characterization of the mesoscale environment
- High resolution modeling for process-level understanding

Goal is to strengthen links between well-understood meteorological principles of storm forecasting and lightning.

Relevant to assessing use of MTG LI in mesoscale forecasting.

Details: http://www.atmo.ttu.edu/bruning/; apply to position 30743BR at Texas Tech.