Geostationary Lightning Mapper (and other lightning products): Products and Best Practices in Operations

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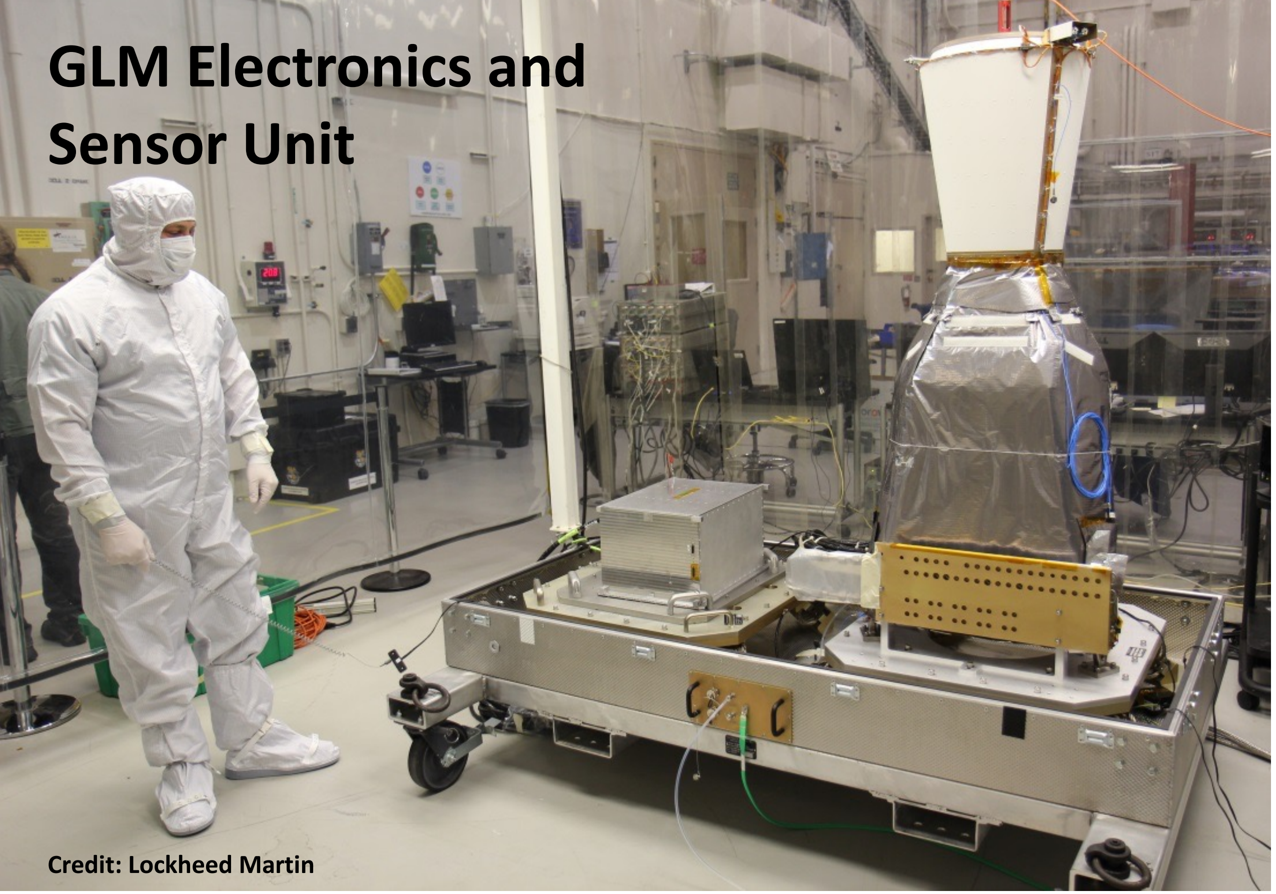
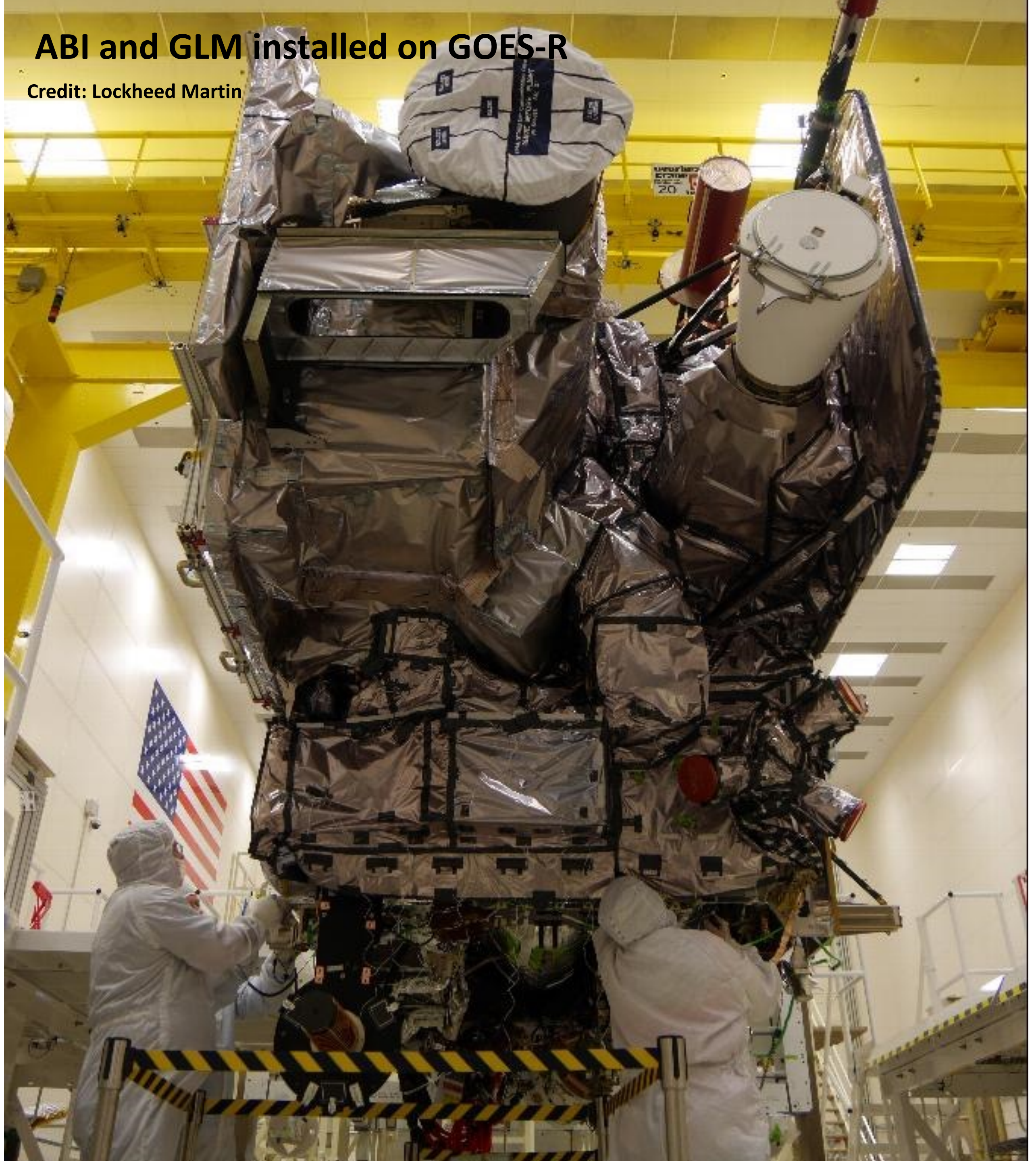
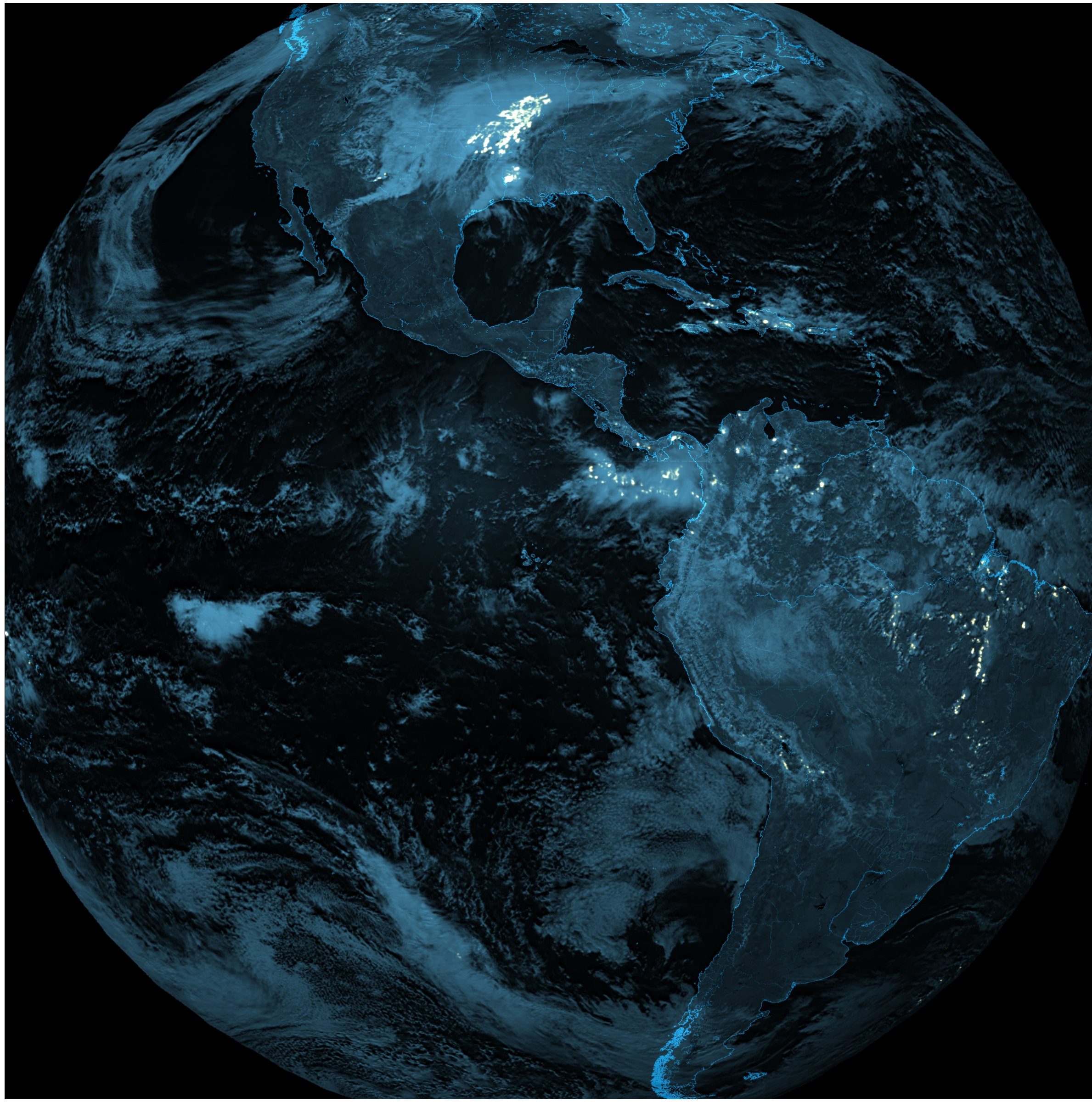


Geostationary Lightning Mapper



GLM is a 500 fps lightning camera

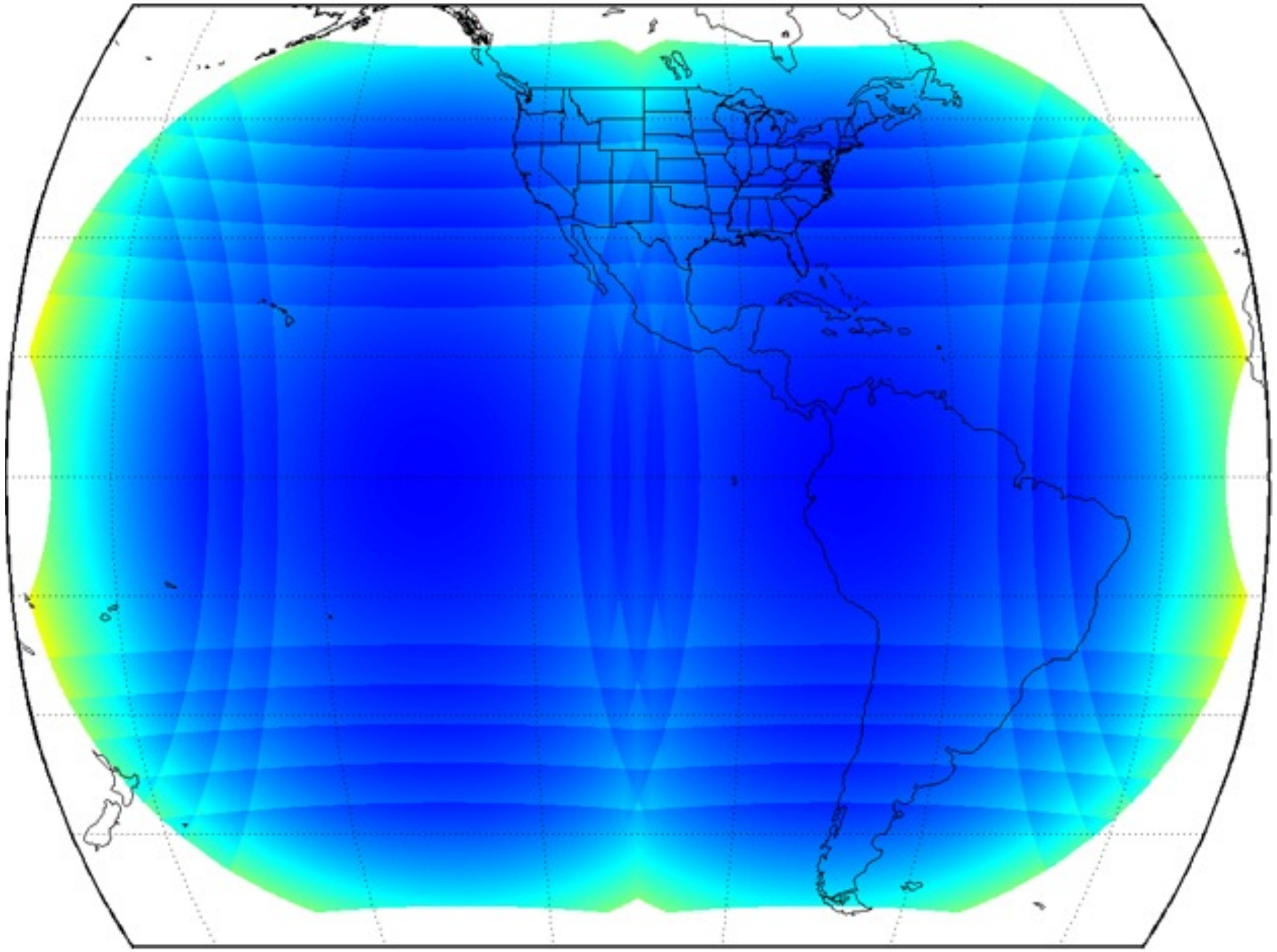


On-board processing reduces raw video by a factor of > 1000x

GLM Instrument Overview

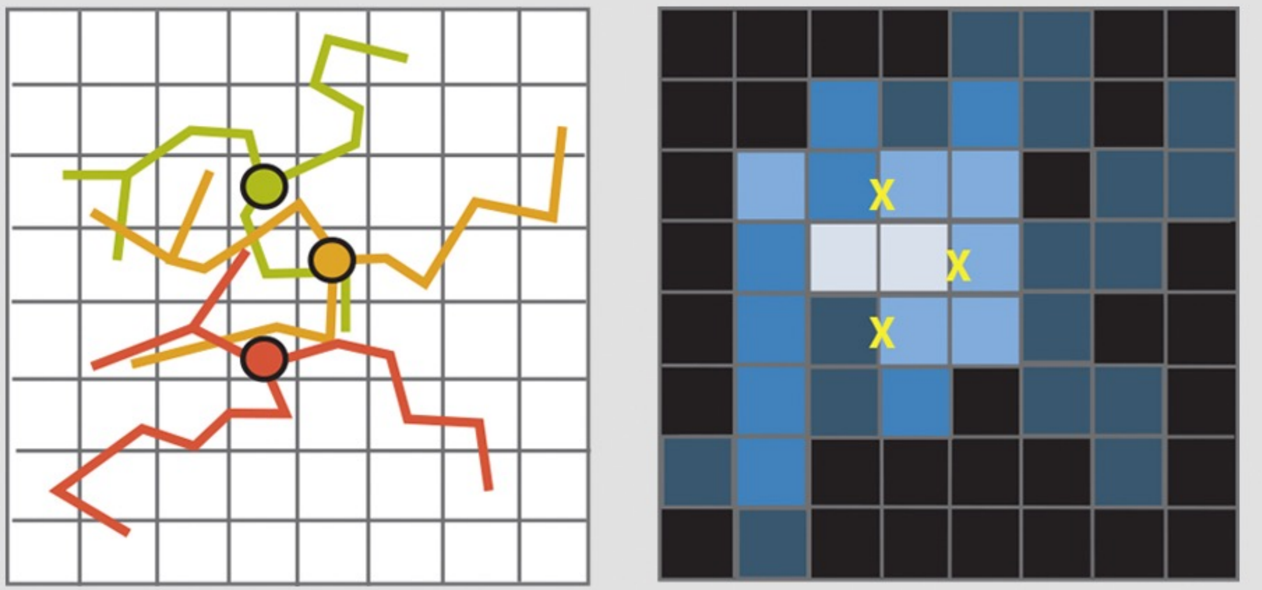
Design Parameter	Value	Unit
Flash detection efficiency	80	%
CCD imaging area size	1372 x 1300	pixels
Frame rate	500	fps
ADC resolution	14	bits
Filter center wavelength	777.4	nm
Filter band pass	1	nm
Lens field of view	+/- 8	deg
Ground sample distance	8 – 14	km
Lens focal length	134	mm
Lens f number	1.2	-
Pixel size (variable)	30 x 30	µm
Well depth (variable)	2e6	electrons
Event rate	1e5	sec^{-1}
Downlink rate	7.7	Mbps
Product latency (level 1b)	<10	s
Mass	125	kg
Operational power	290	W

Field of view coverage from GOES-E and Goes_W



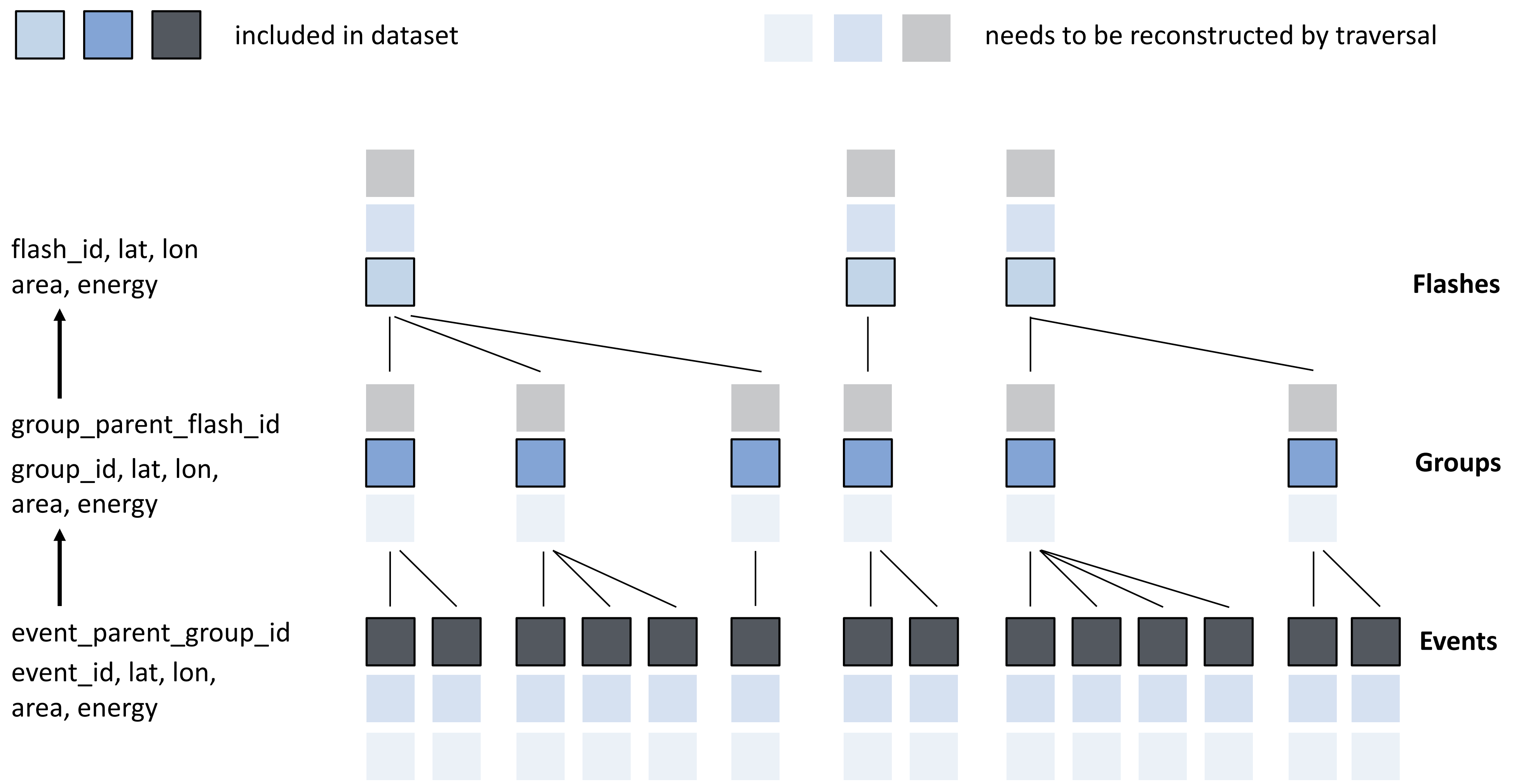
GLM data:

- Event – single optical detection (every 2 ms)
- Group – One or more ’events’ on adjacent pixels occurring in a single time integration
- Flashes – One or more groups occurring within 330 ms and 16.5 km. Location given as a single, centroid point weighted by optical intensity (energy) of the associated groups.



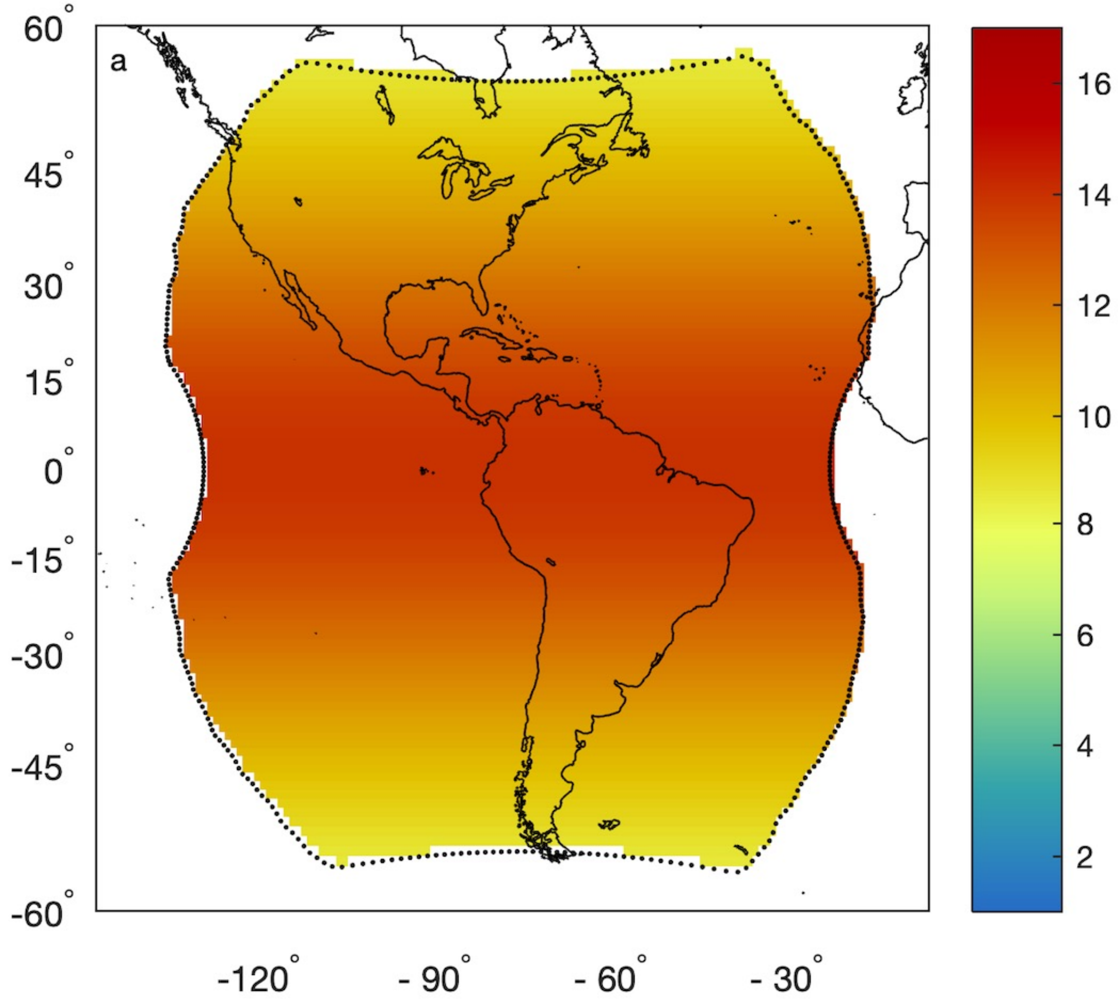
3 flashes: cartoon of lightning initiation points (circles) and leaders, left;   GLM combined, right.

GLM data: Events > Groups > Flashes

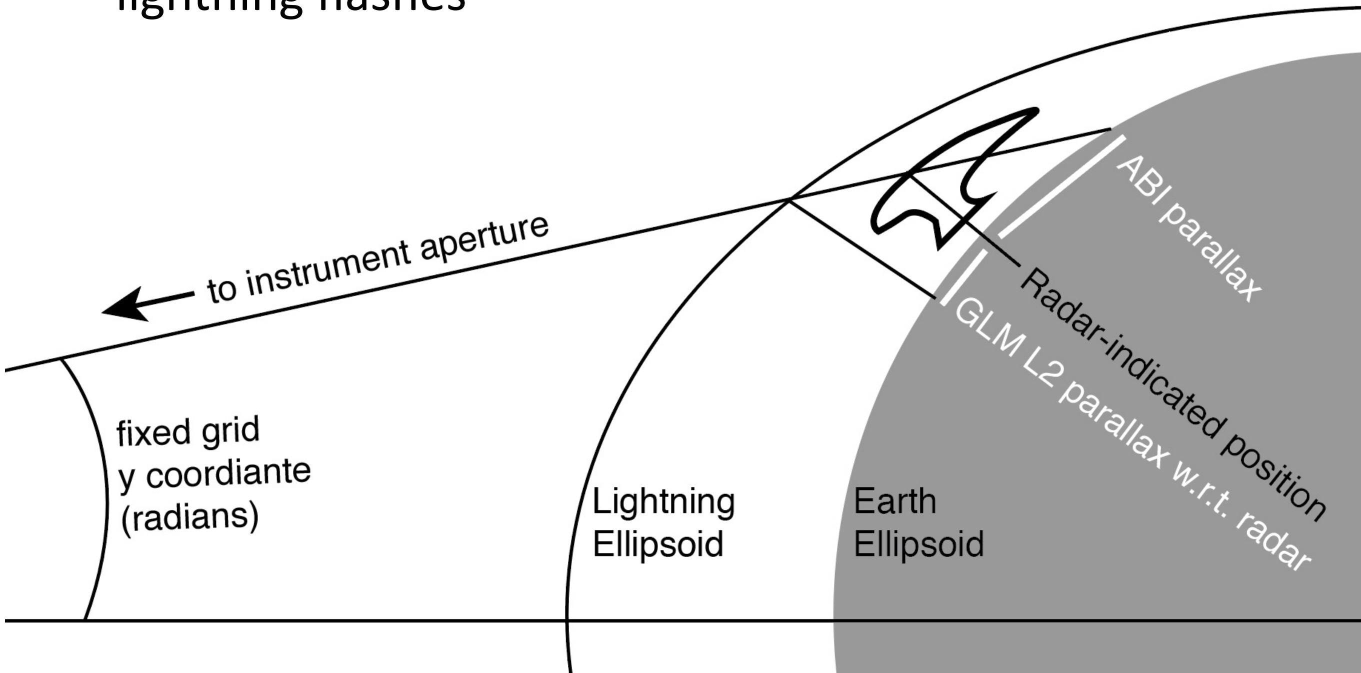


The GLM L2 NetCDF files contain all the necessary information, but one must reconstruct the hierarchy to (for instance) find which events go with each flash.

GLM location errors & the "lightning ellipsoid"



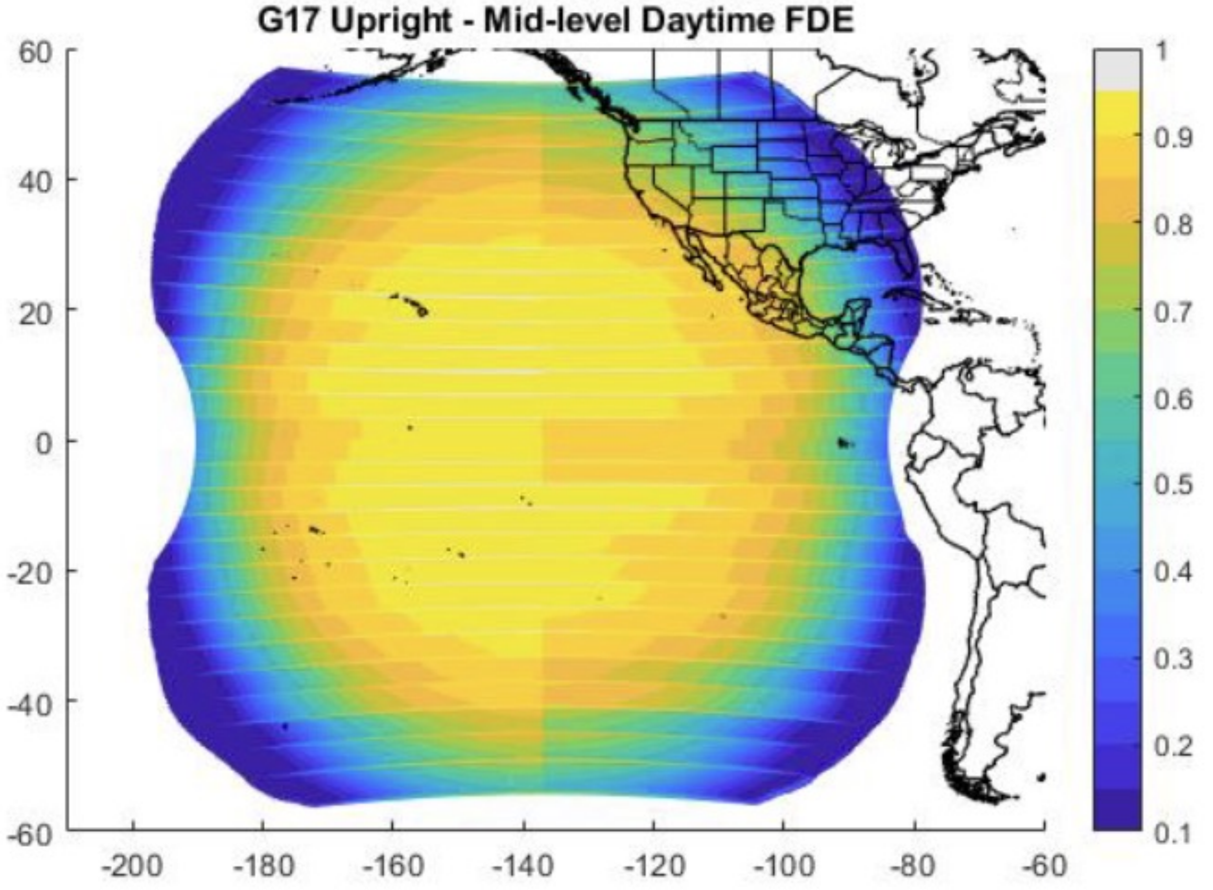
- Assumes GLM detects illumination at cloud top, approximated as:
  - Originally: 16 km (equator) and 6 km (poles)
  - As of fall 2018: 14 km and 6 km
- Lowest ellipsoid height in GLM FOV is ~9 km
- Produces location errors if:
  - Cloud top is below/above the ellipsoid
  - GLM observes side-cloud illumination or below-cloud lightning flashes

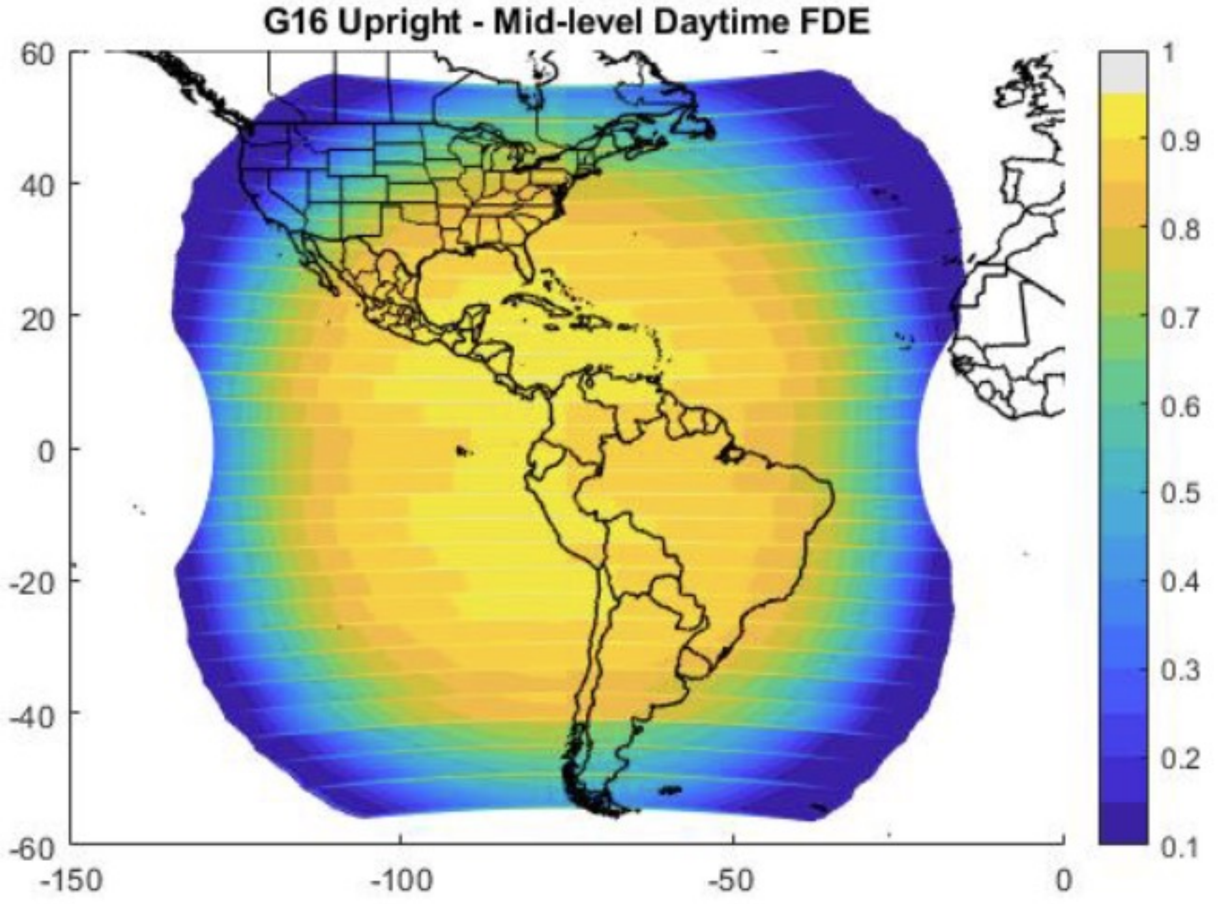


In this example, the GLM L2 position is offset to the south of the desired radar-indicated position because the storm top was below the lightning ellipsoid.

Credit: K. Virts & E. Bruning

GLM Flash Detection Efficiency [Daytime]

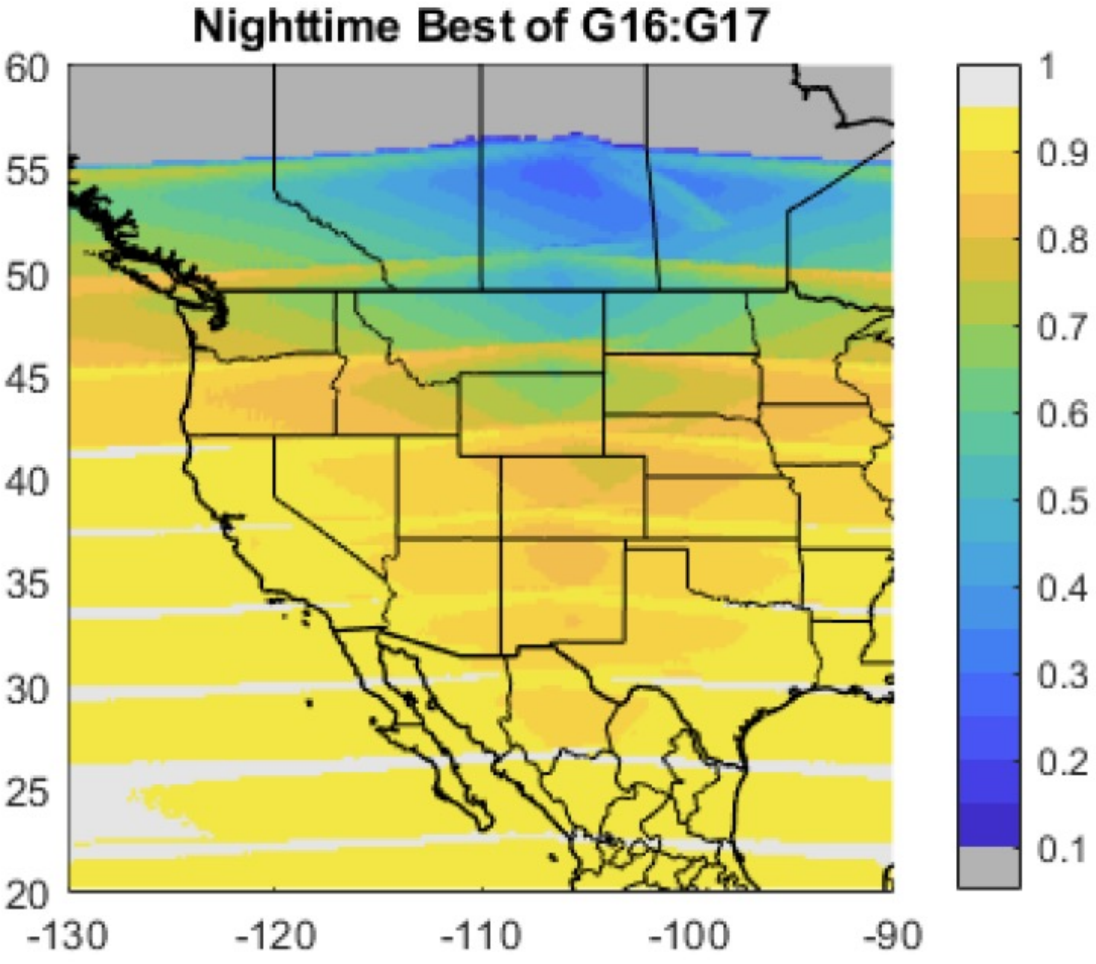


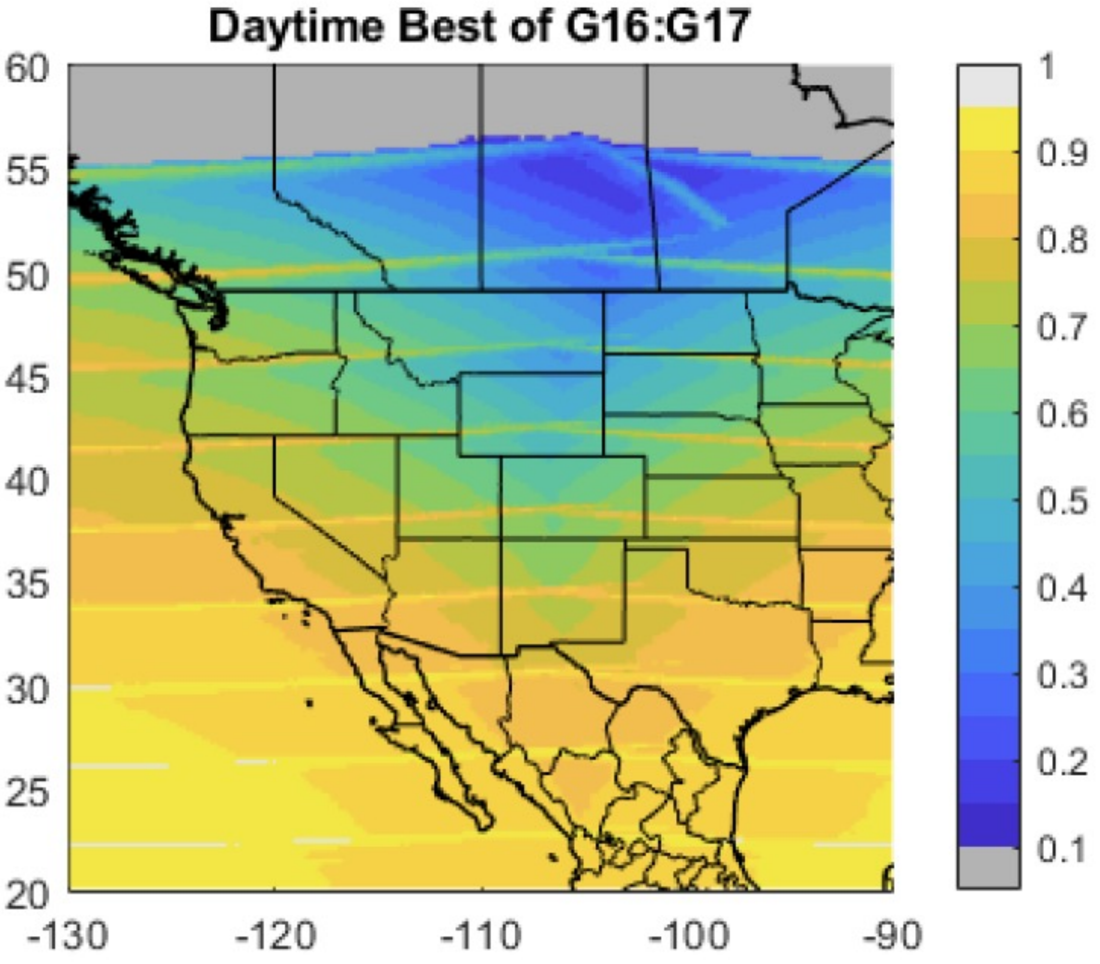


(Detection efficiency is better overnight)

Images: K. Cummins (U. of Ariz.)

GLM Flash Detection Efficiency [Merged]

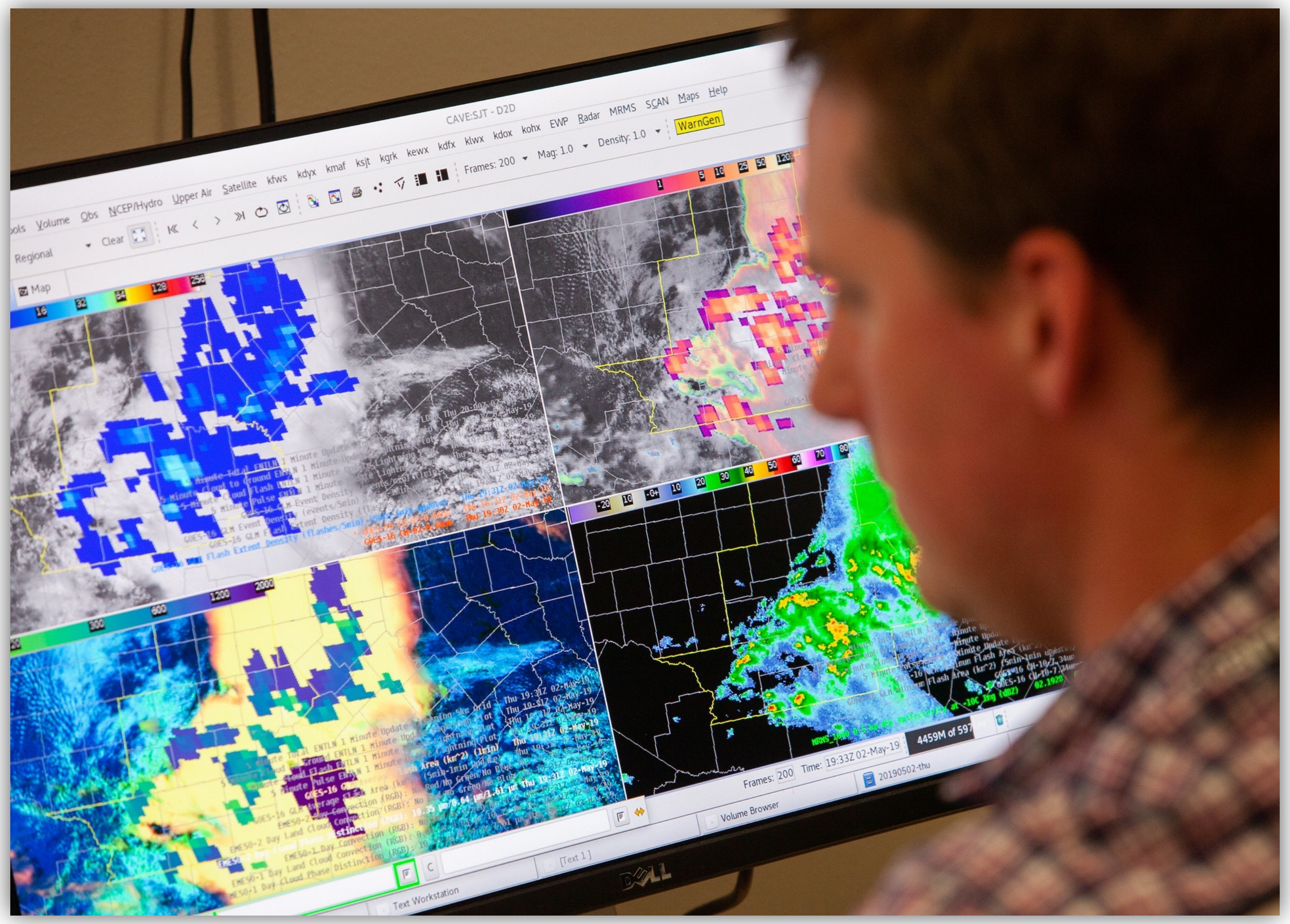




(Detection efficiency is better overnight)

Images: K. Cummins (U. of Ariz.)

What do you see with the Geostationary Lightning Mapper vs other networks?



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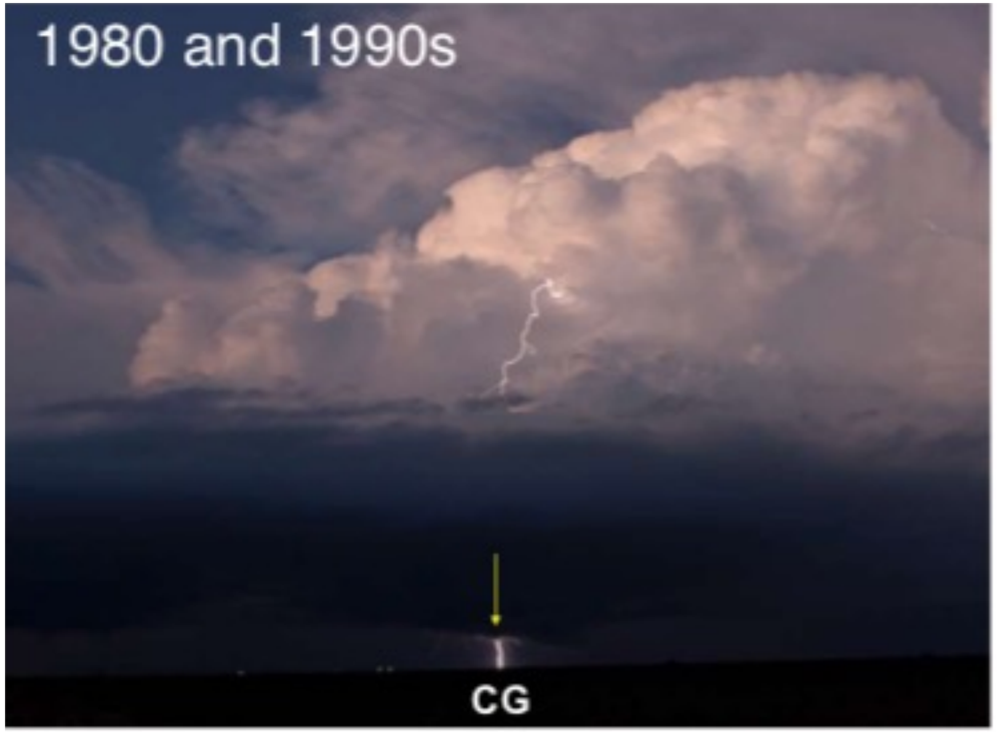
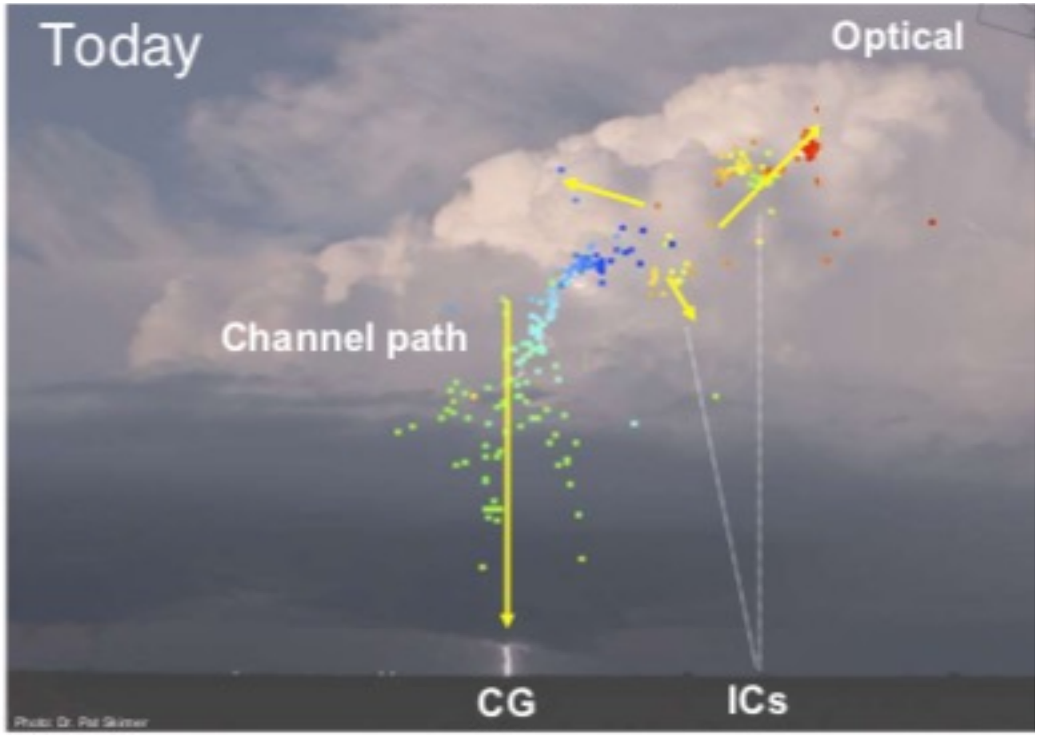
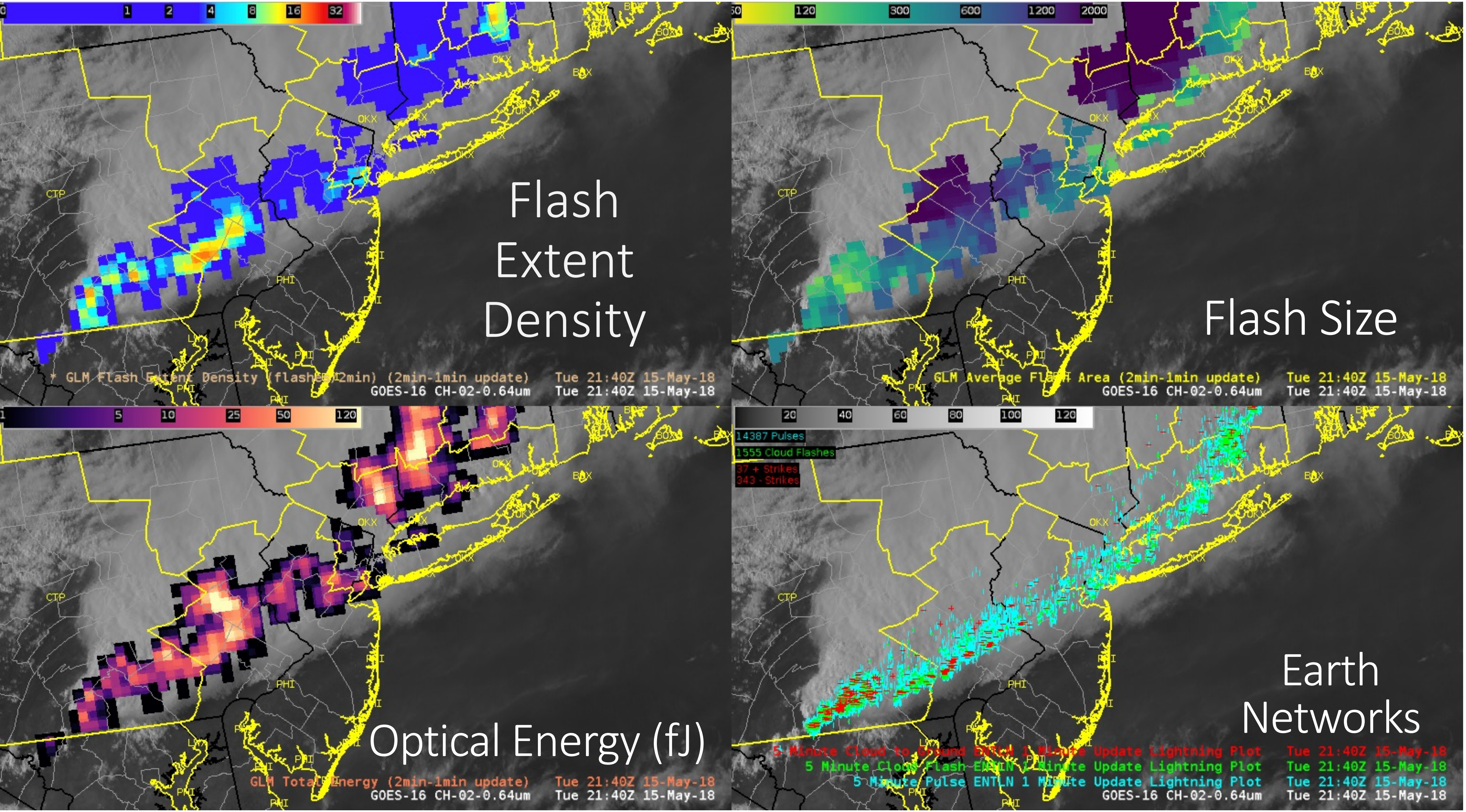


NLDN only: focus on cloud-to-ground only
provided location, time, peak current



GLM (optical – flash extent, optical brightness/energy, flash size)
NLDN (CG, IC, location, polarity, *continuing current*)
ENTLN (CG, IC, location, polarity, *height*)
Lightning Mapping Array (leader breakdown/extent)

Figure from E. Bruning (TTU)


Flash Extent Density
GLM Flash Extent Density (flashes/2min) (2min-1min update) Tue 21:40Z 15-May-18
GOES-16 CH-02-0.64um Tue 21:40Z 15-May-18
Flash Size
GLM Average Flash Area (2min-1min update) Tue 21:40Z 15-May-18
GOES-16 CH-02-0.64um Tue 21:40Z 15-May-18
Optical Energy (fJ)
GLM Total Energy (2min-1min update) Tue 21:40Z 15-May-18
GOES-16 CH-02-0.64um Tue 21:40Z 15-May-18
Earth Networks
14387 Pulses
1555 Cloud Flashes
37 + Strikes
343 - Strikes
5 Minute Cloud to Ground ENTLN 1 Minute Update Lightning Plot Tue 21:40Z 15-May-18
5 Minute Cloud Flash ENTLN 1 Minute Update Lightning Plot Tue 21:40Z 15-May-18
5 Minute Pulse ENTLN 1 Minute Update Lightning Plot Tue 21:40Z 15-May-18
GOES-16 CH-02-0.64um Tue 21:40Z 15-May-18

Comparison with ground-based networks

Forecasters in the Hazardous Weather Testbed were encouraged to overlay the ground-based systems (including both IC lightning from ENTLN and CG data from NLDN) over the GLM data to provide a holistic view of lightning activity - the spatial extent from GLM and IC / CG ratio and locations from the ground-based networks.

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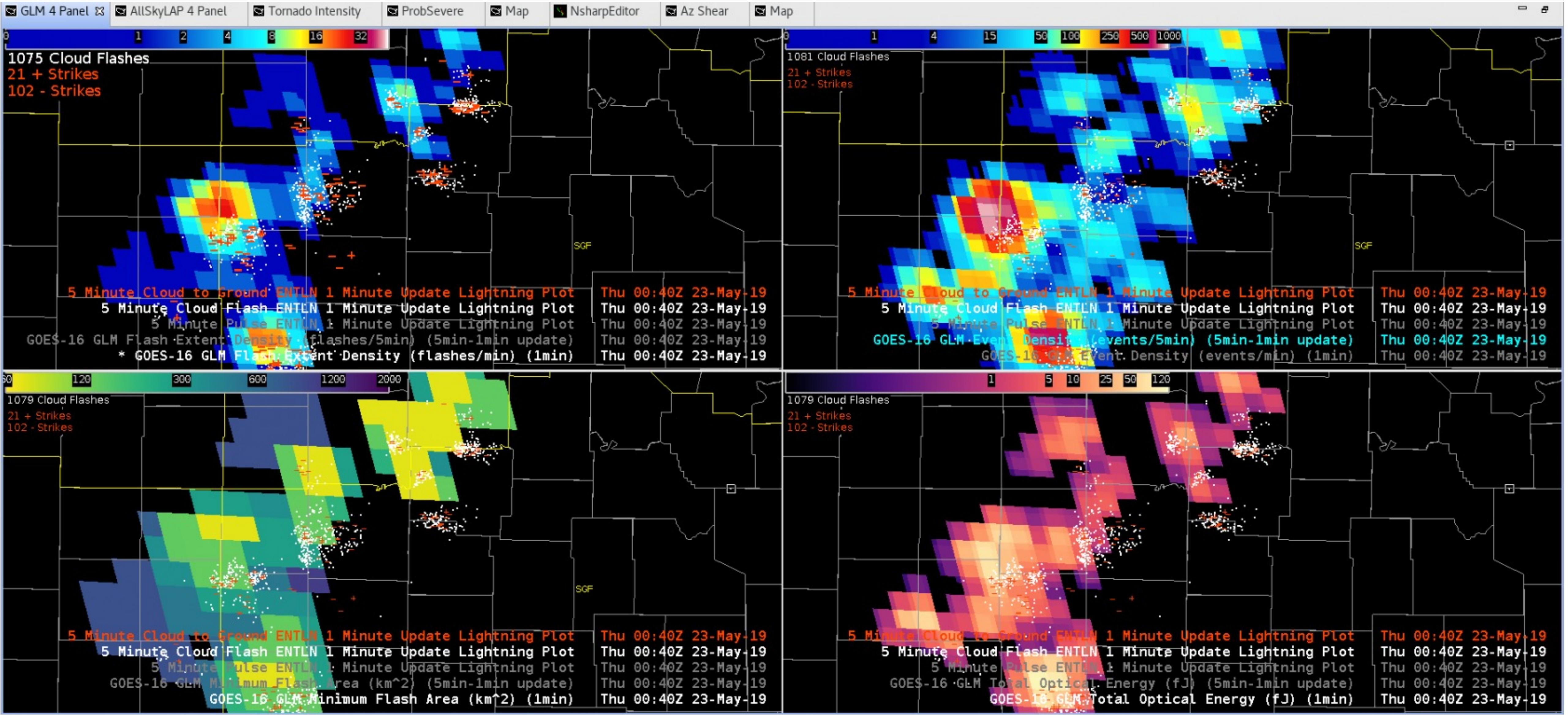
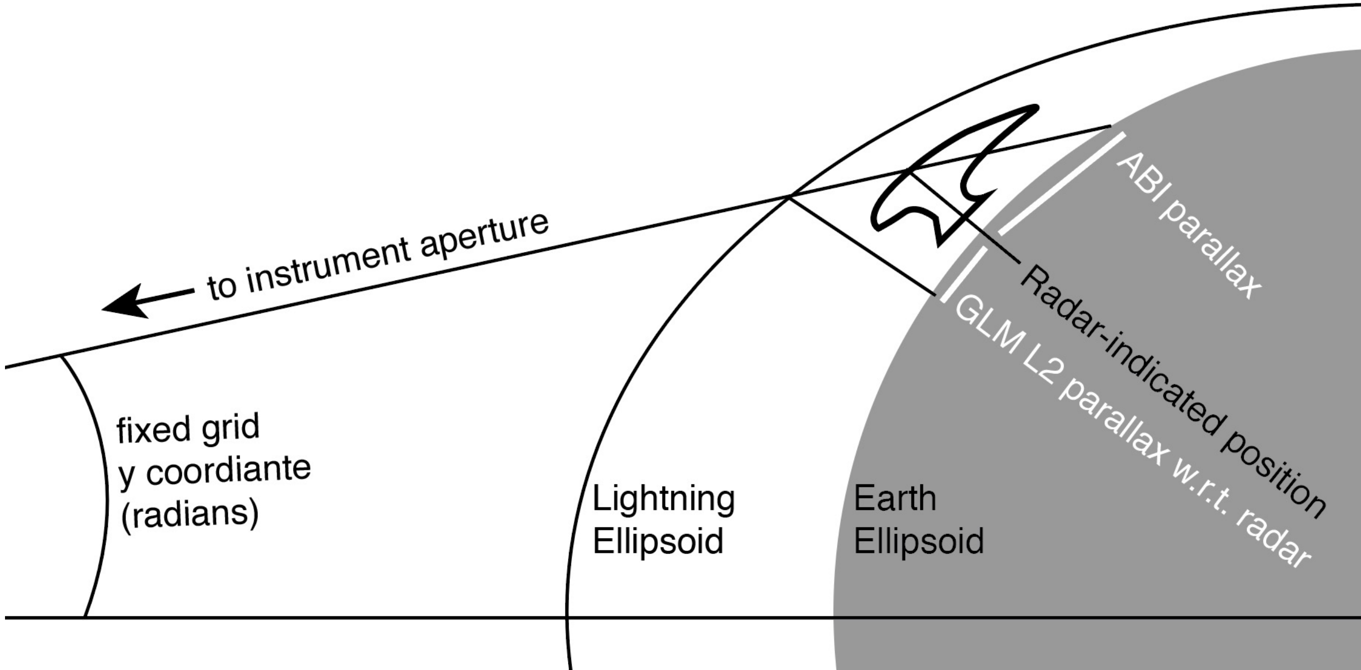
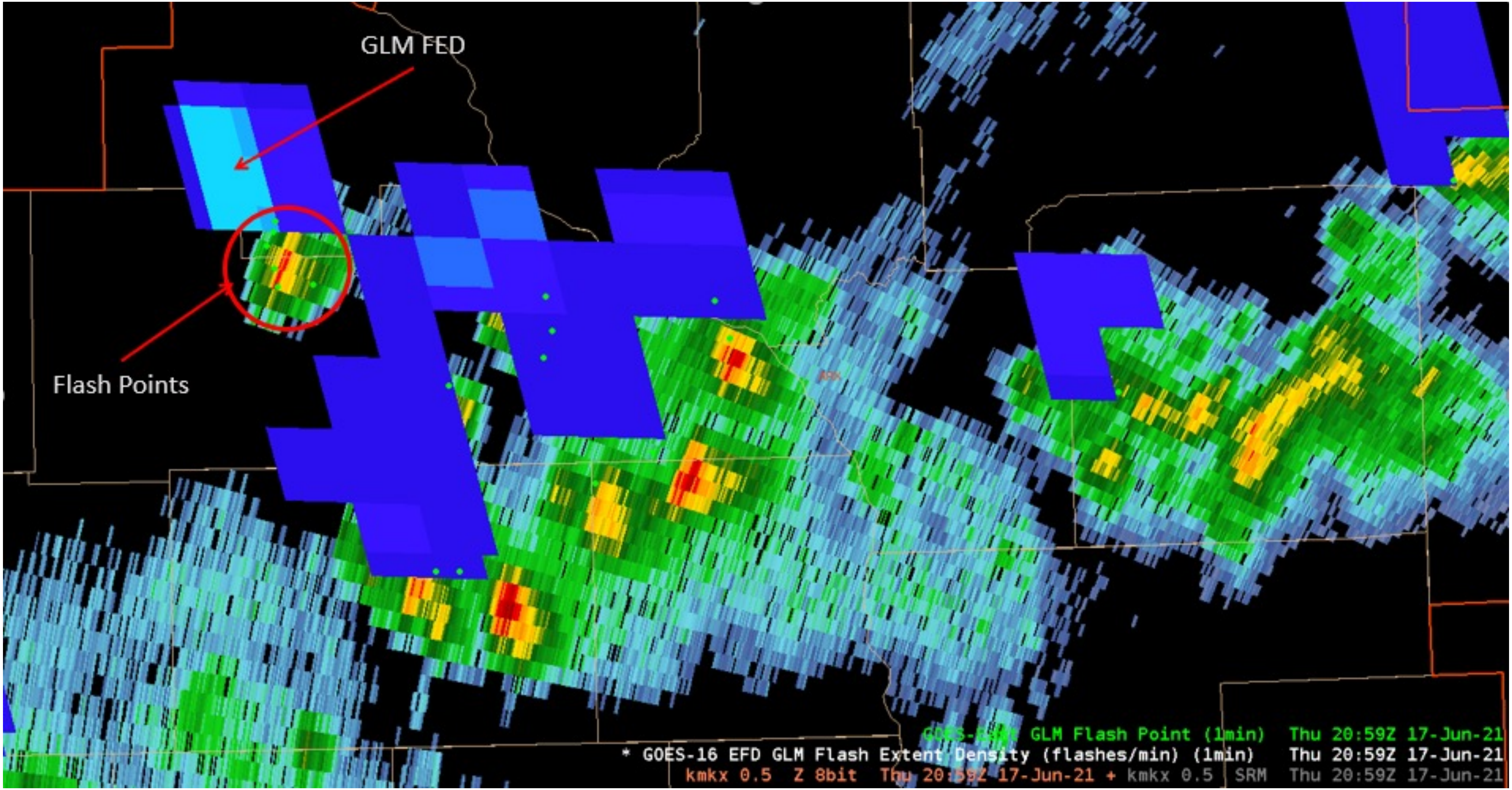


Understanding Parallax

The HWT experiment included 'GLM points' – these use the elliptical height assumption to correct for parallax. The gridded GLM products are not parallax corrected.

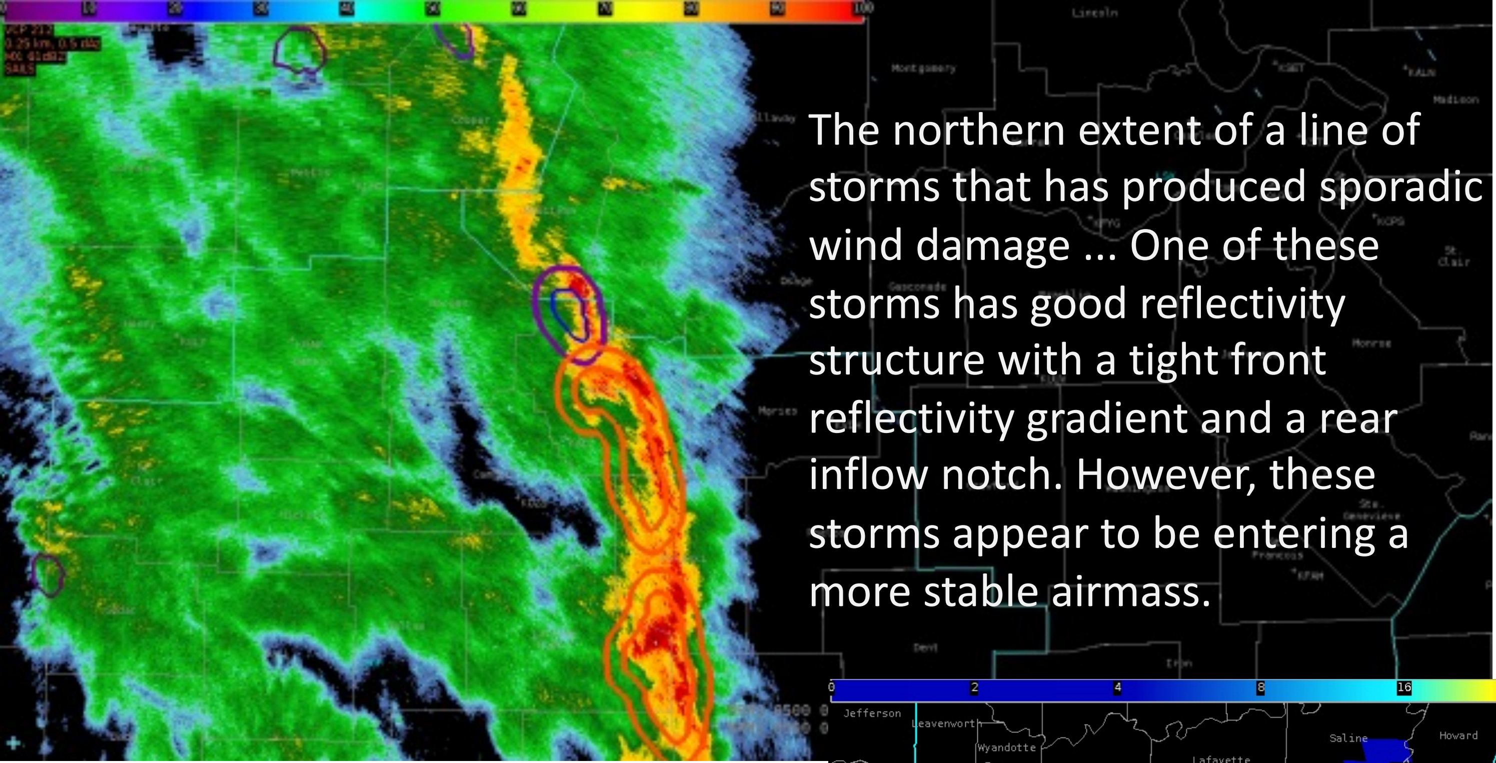



GLM FED
Flash Points
GOES-East GLM Flash Point (1min) Thu 20:59Z 17-Jun-21
* GOES-16 EFD GLM Flash Extent Density (flashes/min) (1min) Thu 20:59Z 17-Jun-21
kmkx 0.5 Z 8bit Thu 20:59Z 17-Jun-21 + kmkx 0.5 SRM Thu 20:59Z 17-Jun-21

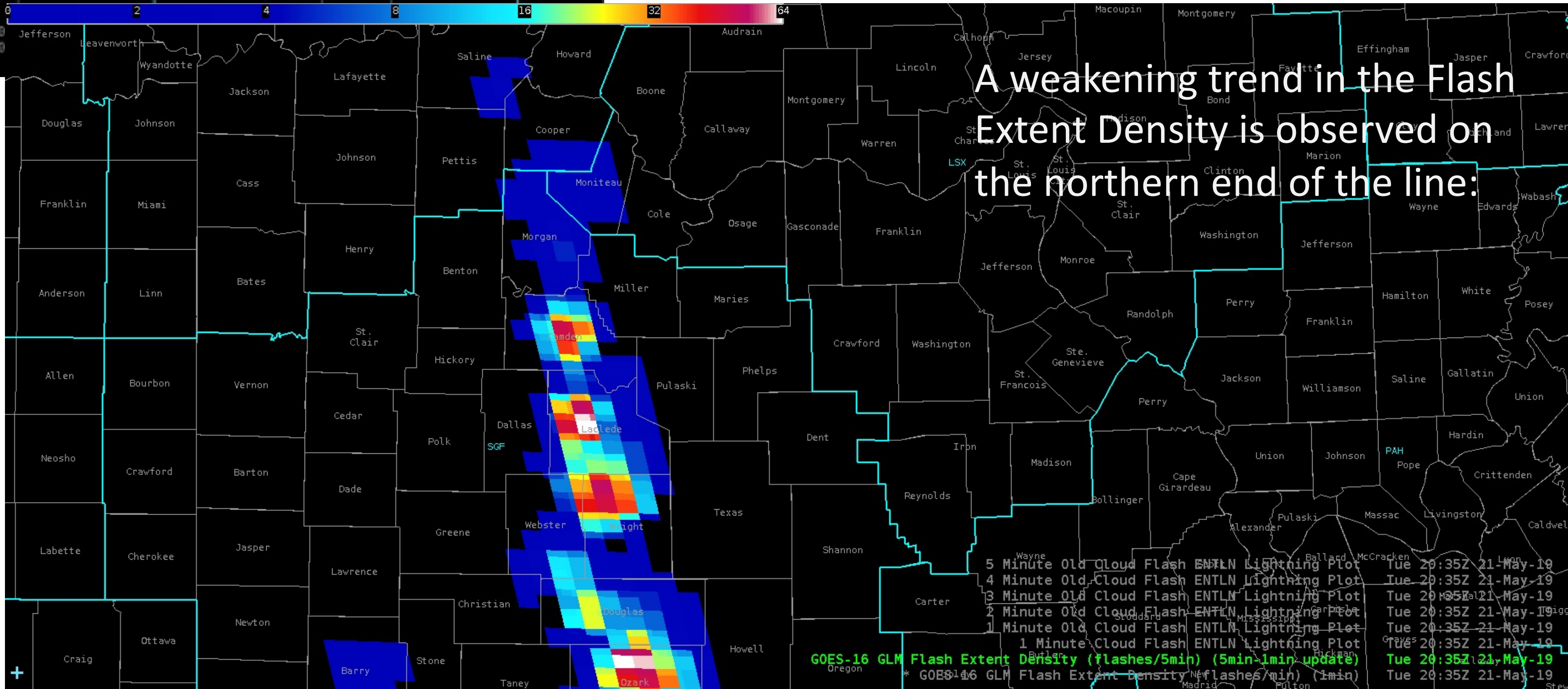
Increased confidence in warning decisions when GLM products match trends from other observational platforms.

The gridded GLM products allowed forecasters to efficiently match the GLM data with satellite, lightning and radar trends. In cases where the total flash rate trends, as noted from FED, matched trends from either base radar or ProbSevere, forecasters commonly noted increased confidence and easier warning decisions.

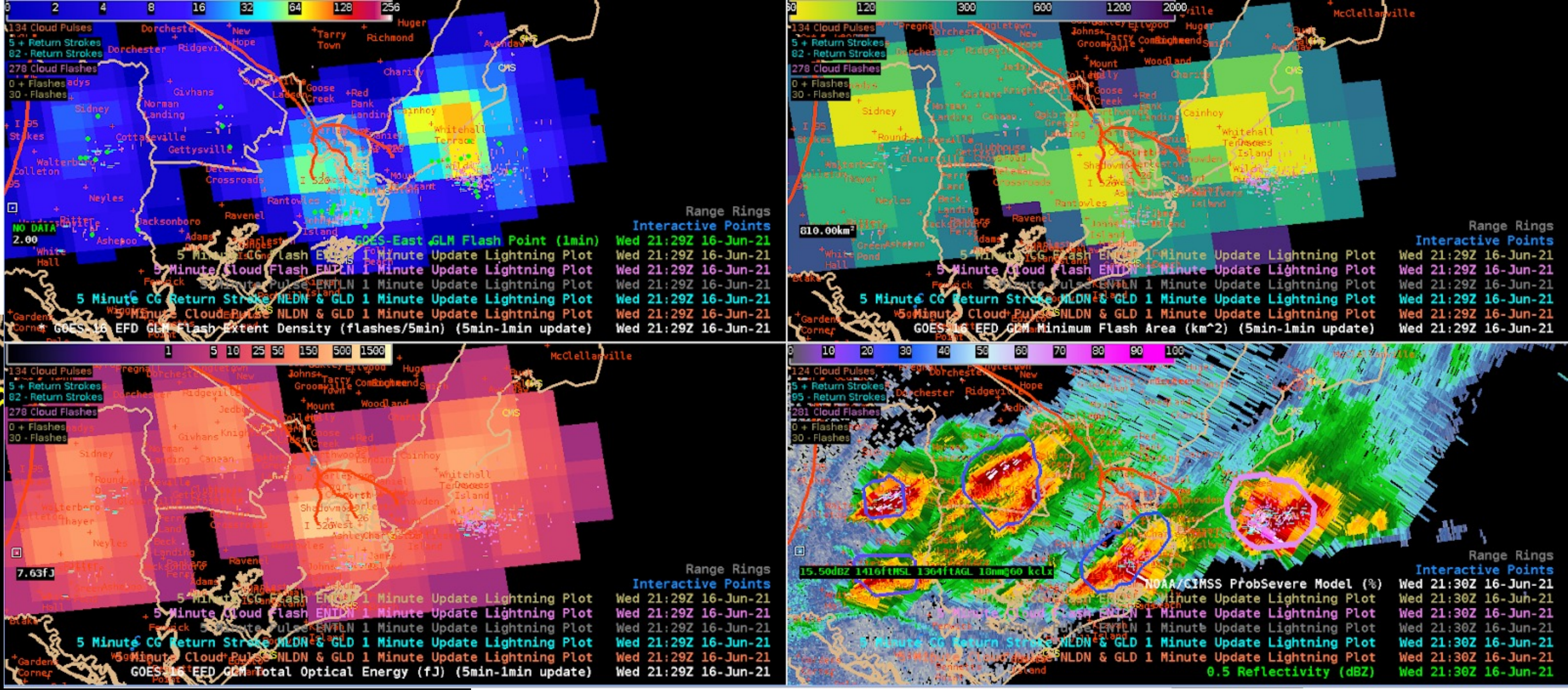
Forecaster use of GLM Flash Extent Density in the HWT.

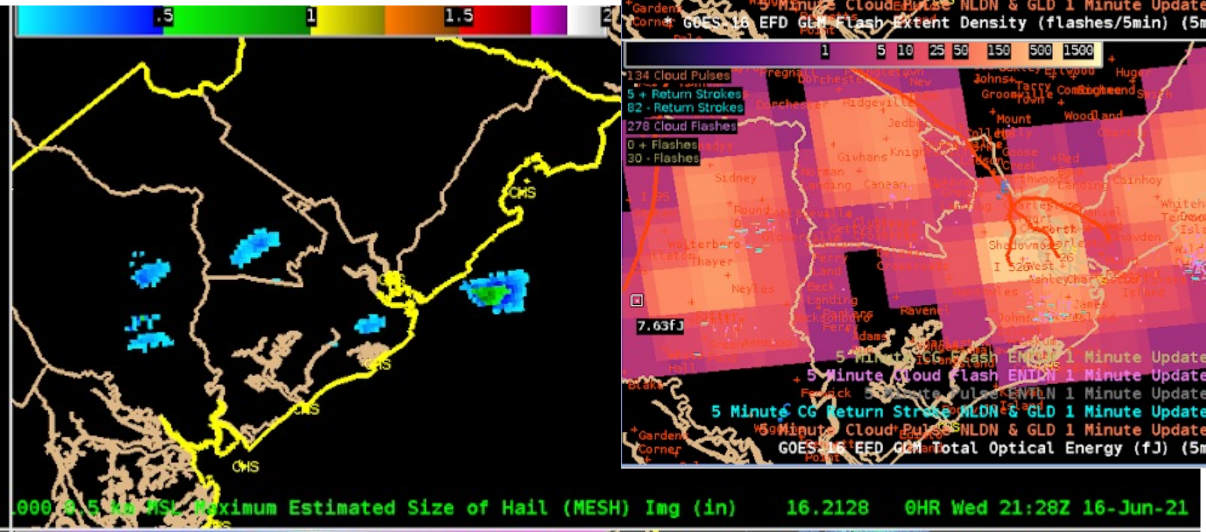


The northern extent of a line of storms that has produced sporadic wind damage ... One of these storms has good reflectivity structure with a tight front reflectivity gradient and a rear inflow notch. However, these storms appear to be entering a more stable airmass.

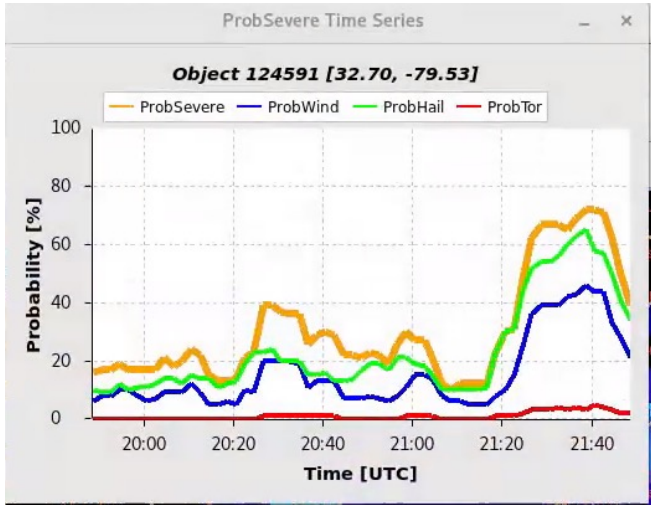


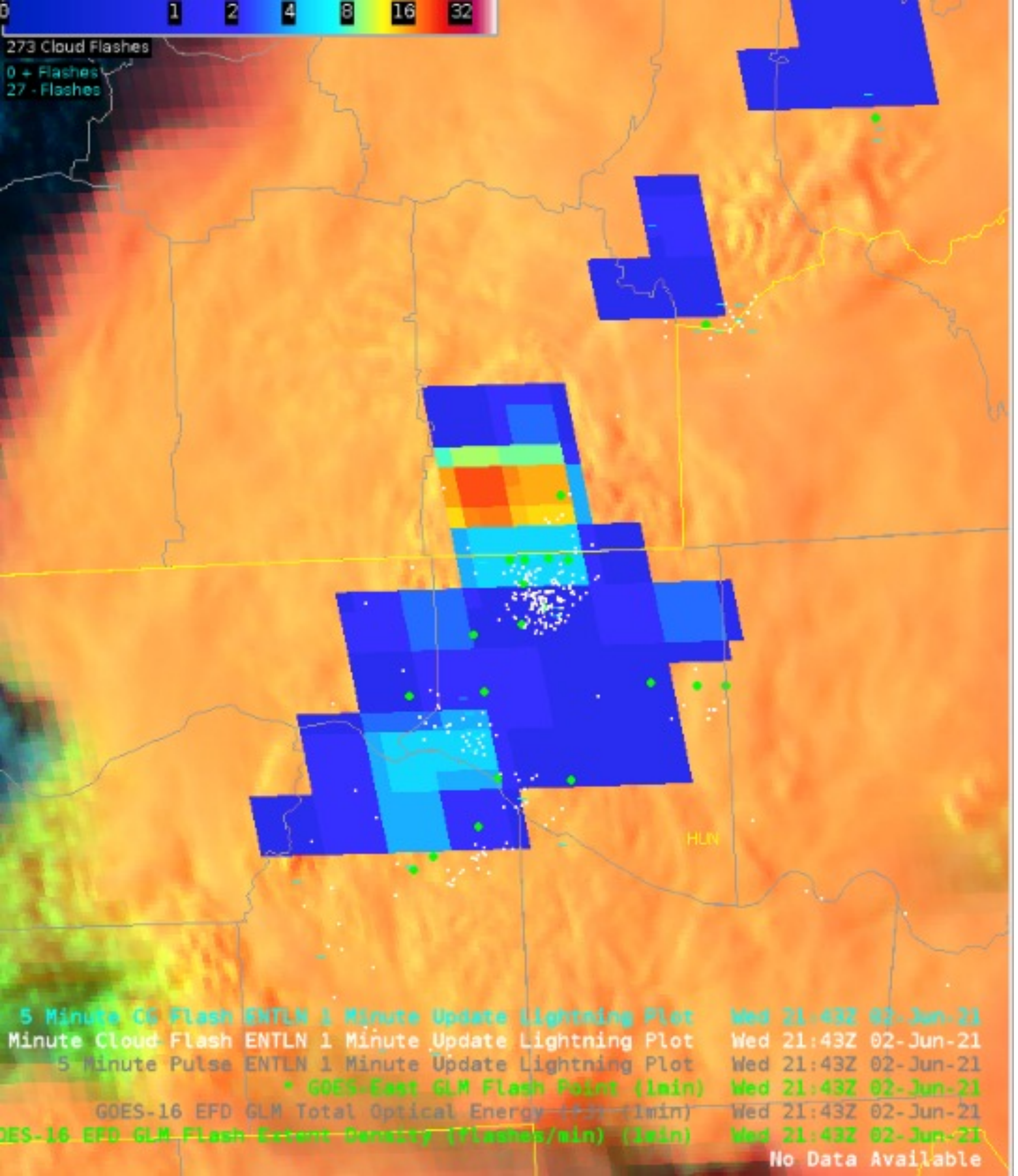
A weakening trend in the Flash Extent Density is observed on the northern end of the line:





Charleston, SC: The storm to east (now offshore) consistently had the highest FED, MESH, and ProbSevere values. When lightning FED 'jumped' – other values followed. Blog Post





Huntsville, AL area (2 June 2021):

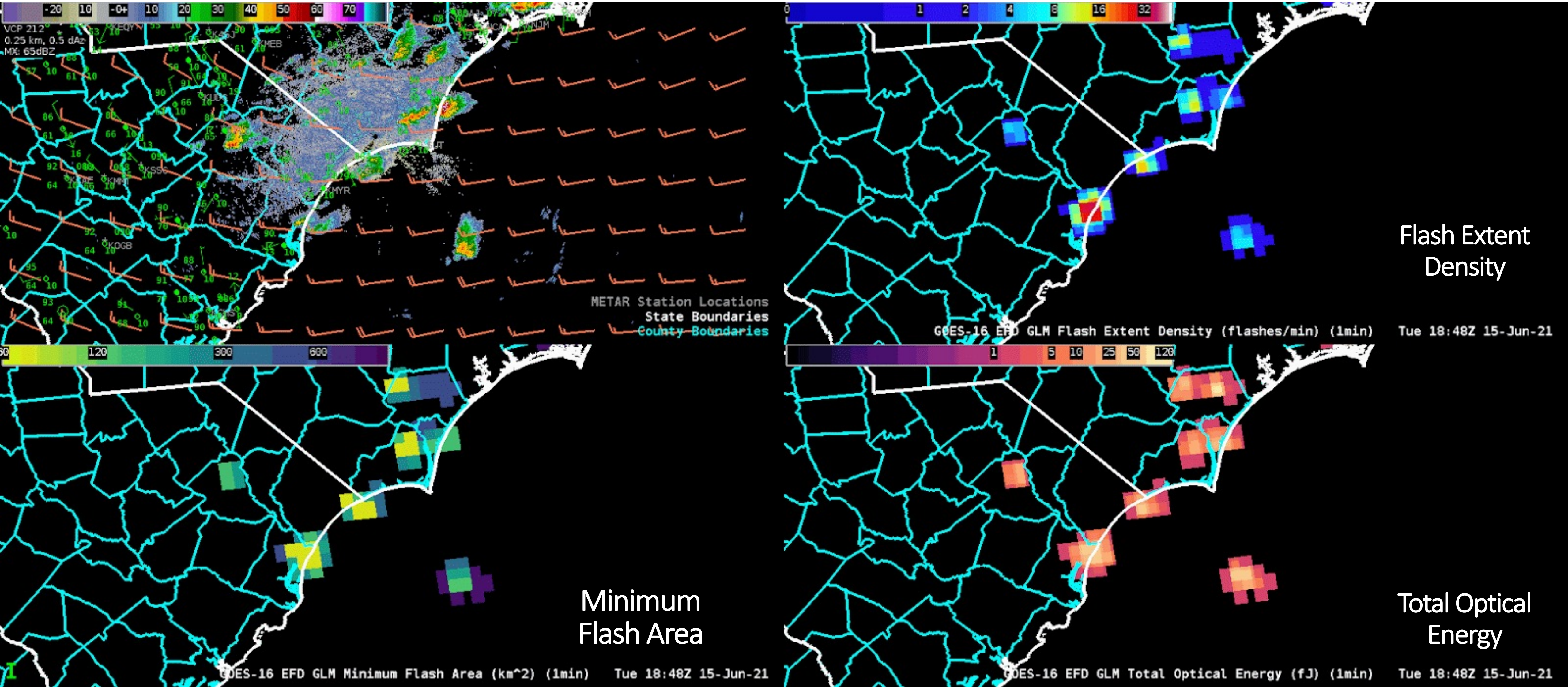
"Saw a steady lightning jump depicted in the GLM FED… Several mPING reports of wind damage … which raises confidence that storms are intensifying."

Note: FED grid (not parallax corrected, matches ABI-visible location) while GLM points (green dots) match location of ground network (ENTLN, here)

[Blog Post]

Utility of GLM products in pulse convective environments, anticipating storm growth or dissipation, and IDSS applications

Forecasters frequently found GLM the most useful in situations where issues within intense thunderstorms were not a consideration…



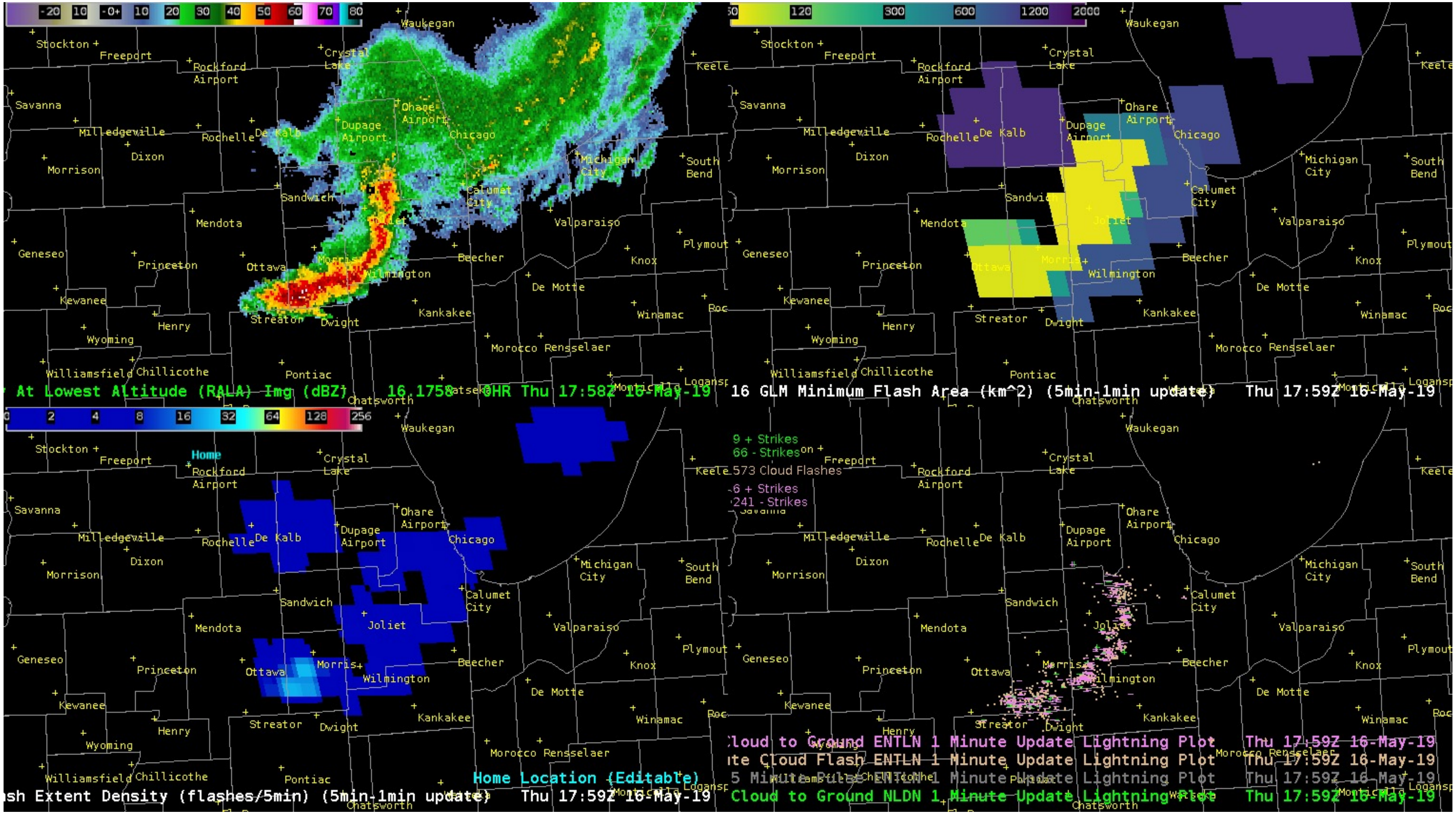
Wilmington, NC (15 June 2021): Forecasters modified the default colormap of the **minimum flash area** so that we could identify the updrafts more easily since the minimum flash areas were under 100km^2 and the default map was set to cover images up to 2000km^2.

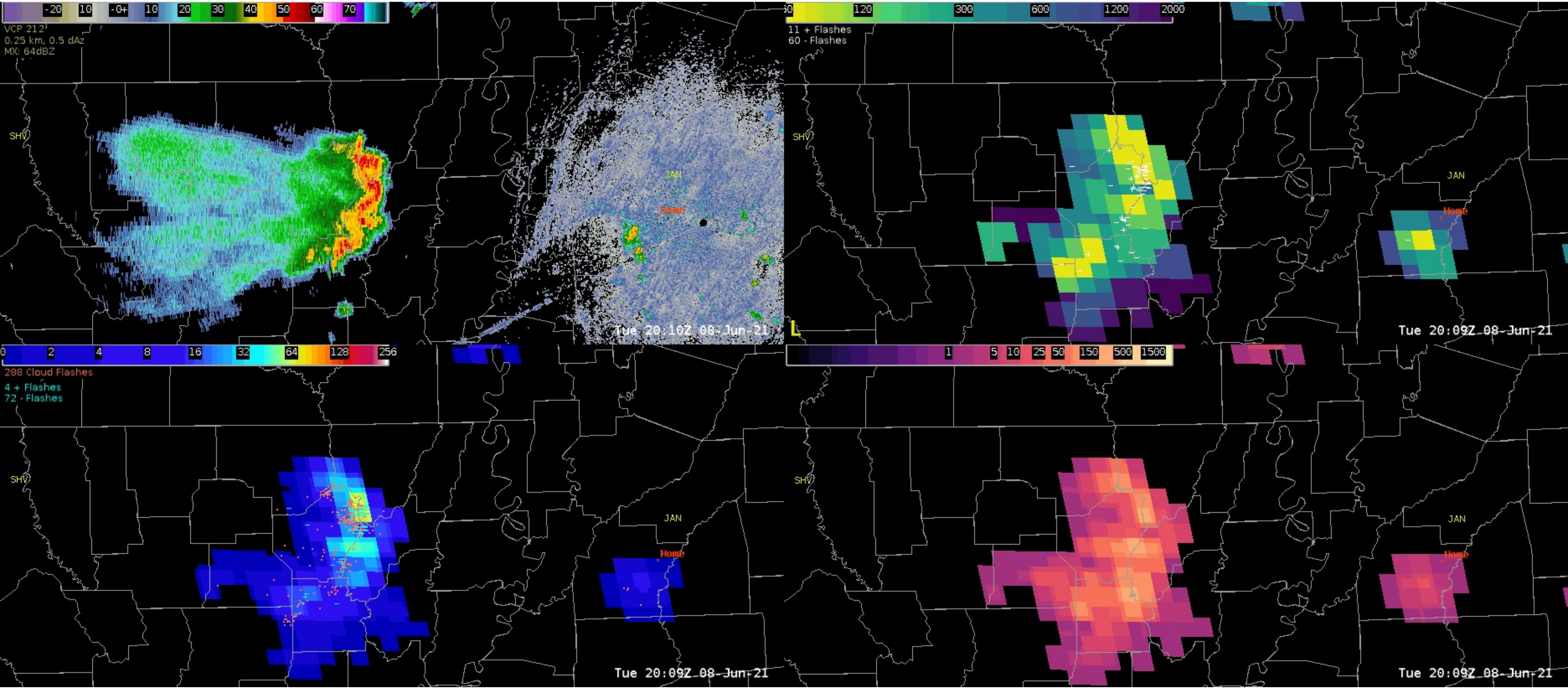
This allowed us to identify which storms featured the strongest updrafts which when combined with data from the Flash Extent Density, we could watch for storms that were strengthening and thus posed a greater need for a warning. Blog post

"IDSS standpoint, the Minimum Flash Area and FED proved that it's necessary to look at both GLM products and ground based lightning products to see the "total" picture. The GLM products captured a larger flash that extended out into the stratiform area behind the main line that is not seen in the ENTLN and NLDN products. This information can be especially important for Airport Weather Warnings and/or outdoor venues."

16 May 2019, Blog Post: 'IDSS usage from GLM minimum flash area

https://blog.nssl.noaa.gov/ewp/2019/05/16/idss-usage-from-glm-minimum-flash-area/



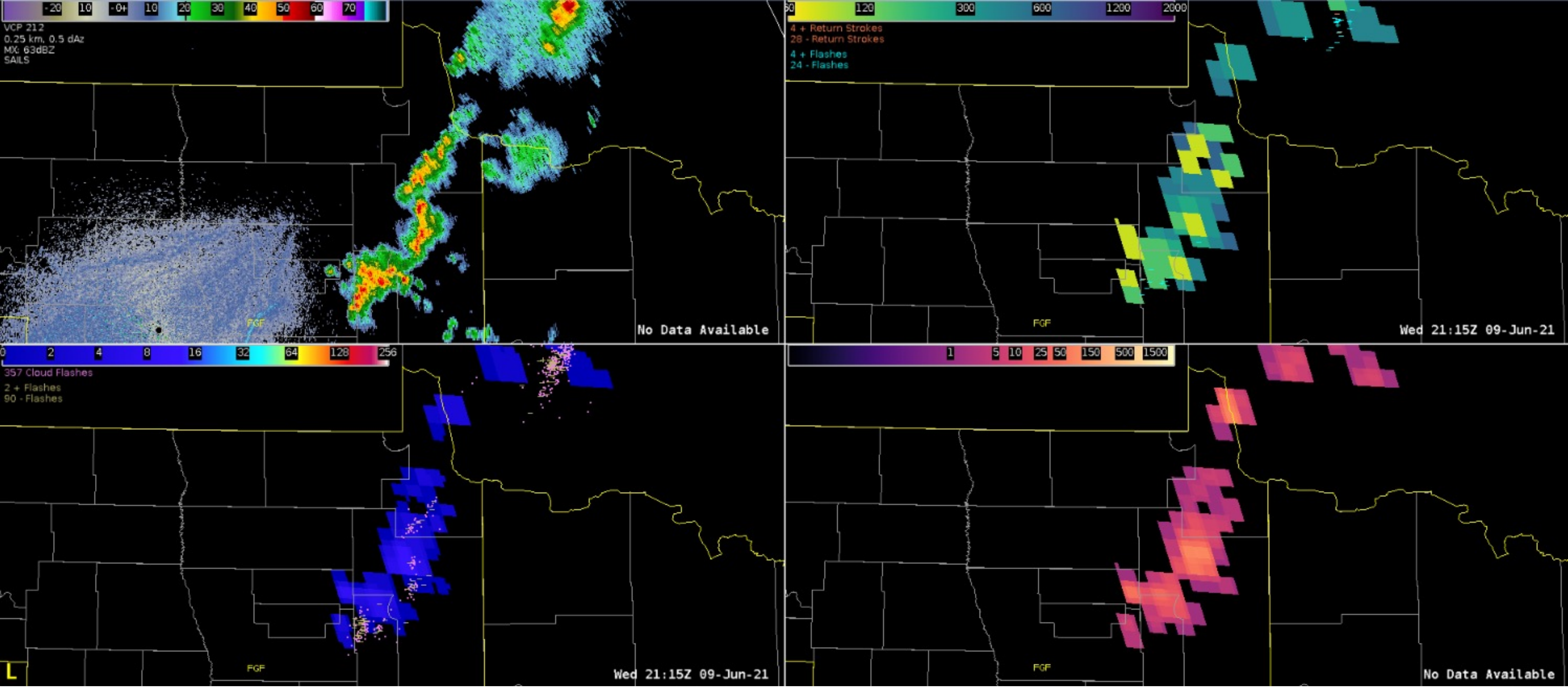


Northeast Louisiana (8 June 2021): Formation of trailing stratiform region and lightning begins to extend westward.

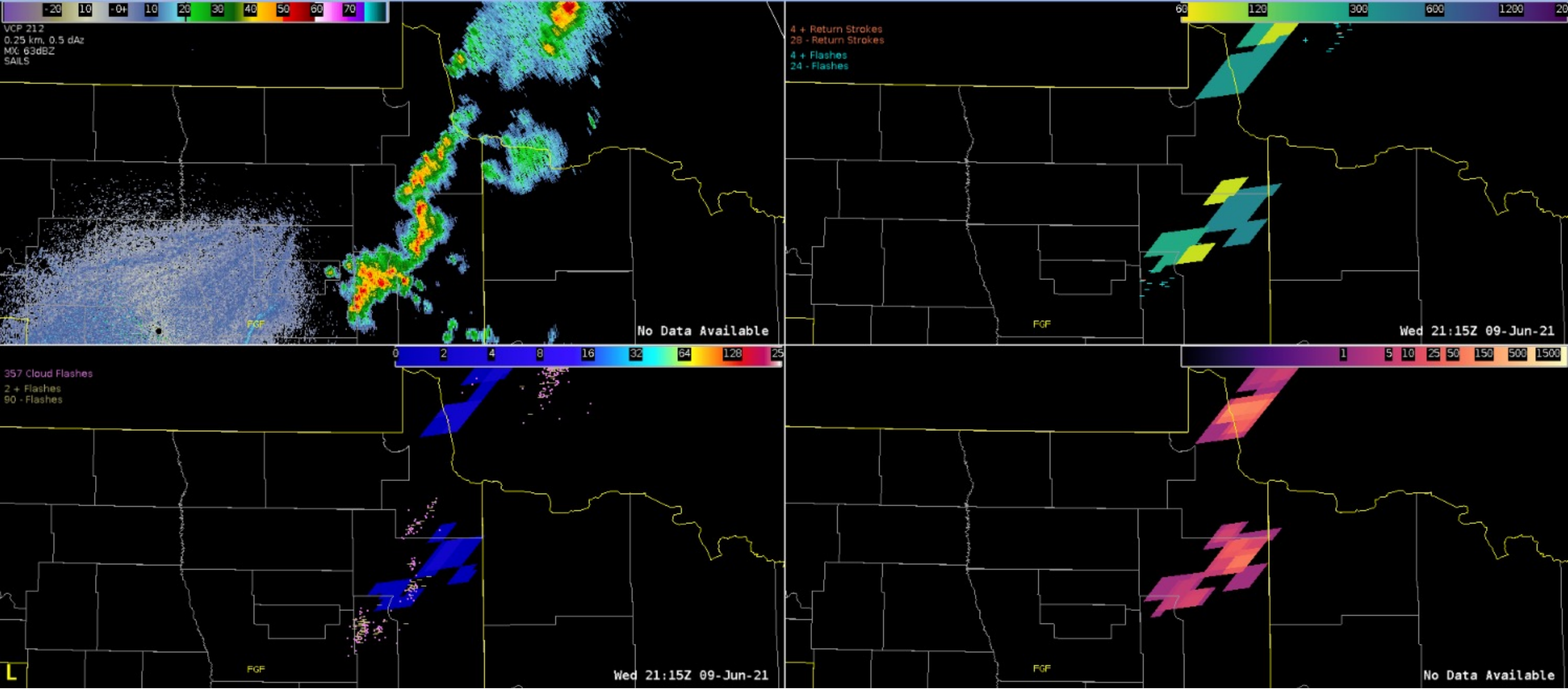
GLM can be helpful in time when you may have a DSS event and the main line has passed through, but lightning is still present in the trailing light rain. Pairing the ground networks with the GLM extent and area allows a forecaster to give DSS on the latest CG stroke within the large area. Blog post

In regions of poor GLM detection efficiency and G16/G17 overlap, it can be difficult to pick one product/satellite. Ground-based Lightning Detection Systems will be more reliable in these regions.

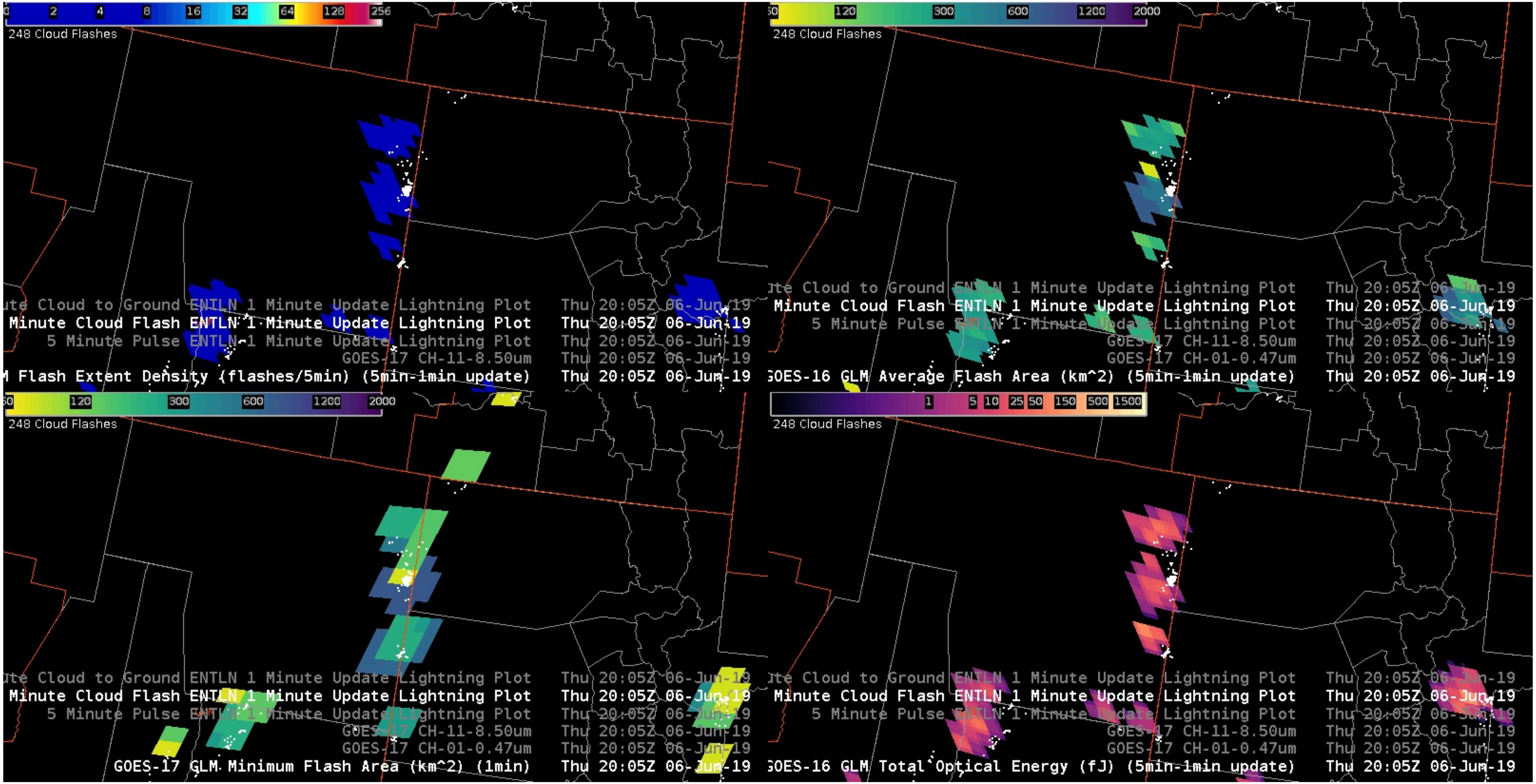
It is important to check out both satellites when possible, but take into account where the storms are in respect to the satellites coverage.



Northern North Dakota/Minnesota/Canada: Marginal storms GOES16 slightly better than GOES17 for region, but neither system adequately picks up the the higher number of flashes seen in the ground networks. [Blog Post]


VCP 212
0.25 km, 0.5 dAz
MX: 63dBZ
SAILS
FGF
No Data Available
4 + Return Strokes
28 - Return Strokes
4 + Flashes
24 - Flashes
Wed 21:15Z 09-Jun-21
357 Cloud Flashes
2 + Flashes
90 - Flashes
Wed 21:15Z 09-Jun-21
No Data Available

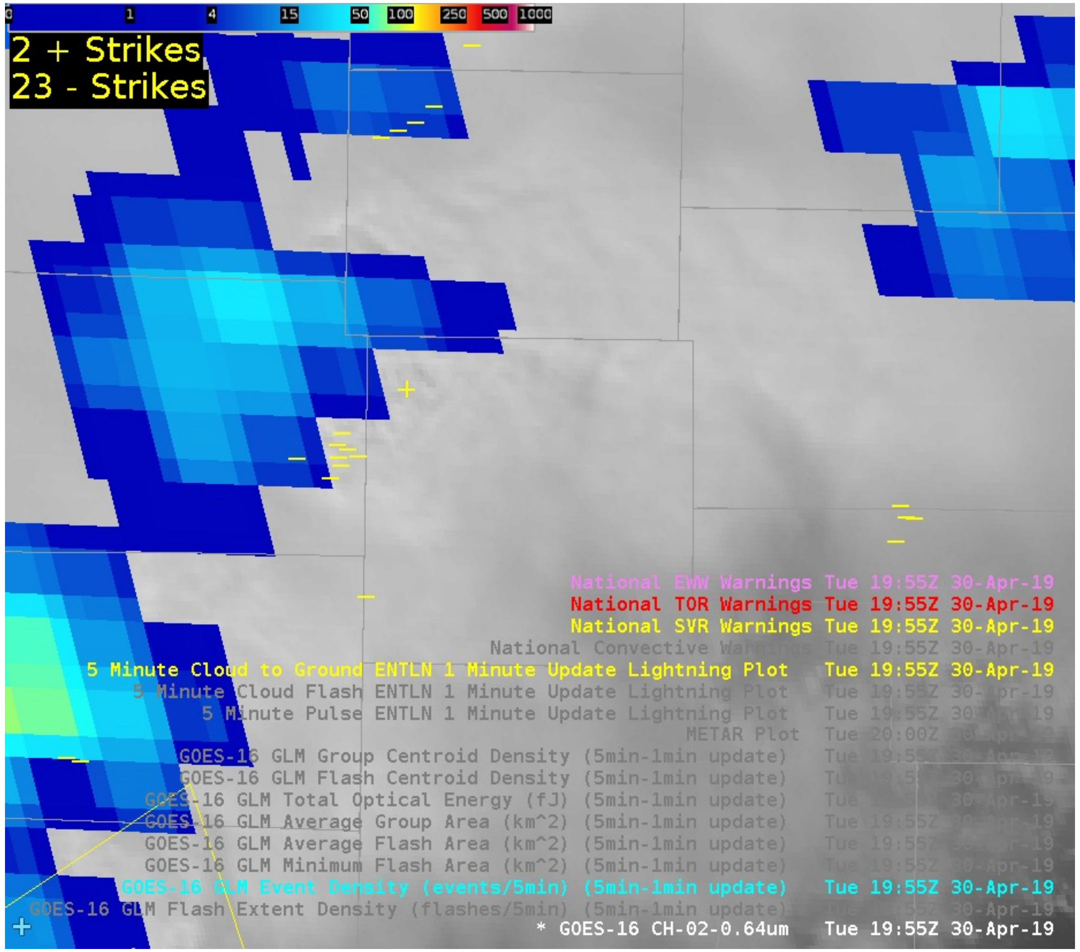
The Minimum flash areas are hinting at growing convection just downwind. That growth leads to me to anticipate further growth as these storms move into a more favorable environment in eastern Idaho. – Blog post



Some Final Takeaways

1. Flash Extent Density is a great base GLM product

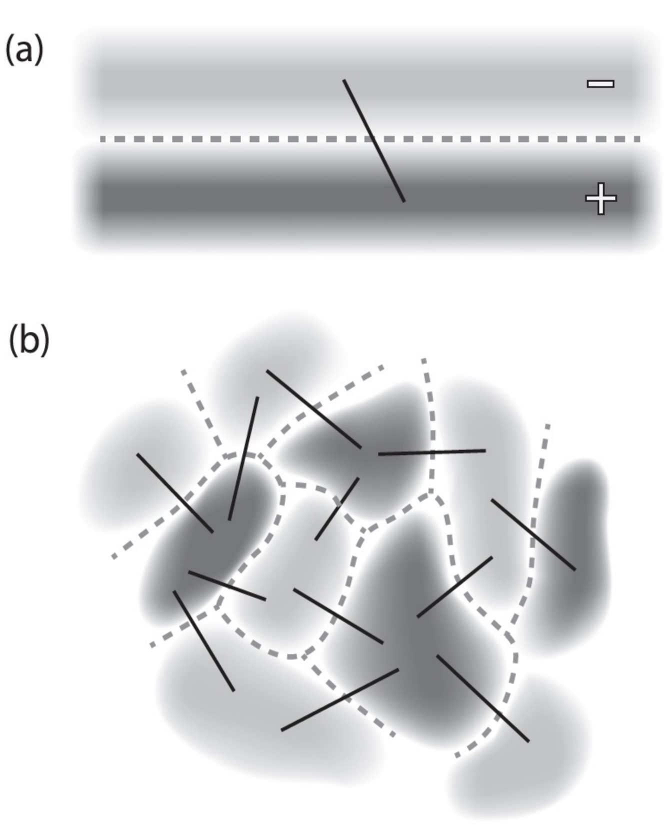
It provides insight on peak lightning activity (which is tied to updraft microphysics/dynamics) and also spatial extent (which is important for lightning safety/DSS).

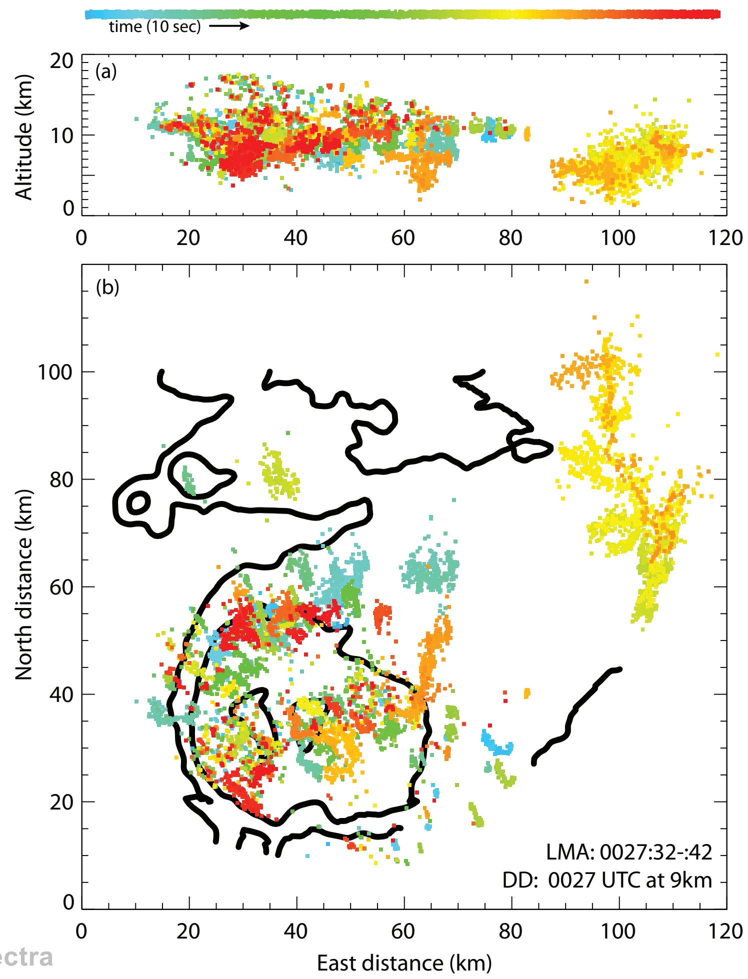


FED can depict the cyclic nature of storms, with the increase in lightning density signaling intensification of the storm's updraft.

2. Flash Size is Helpful

Flash Size reflects the net charge structure, it is 3-dimensional and very tied to storm updraft and related trajectories.





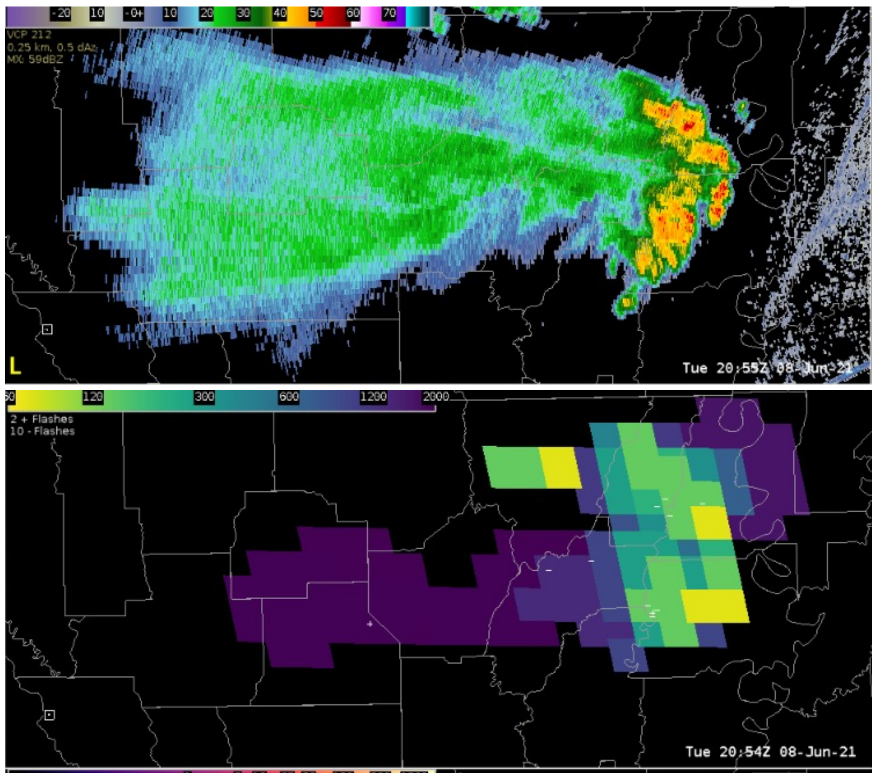


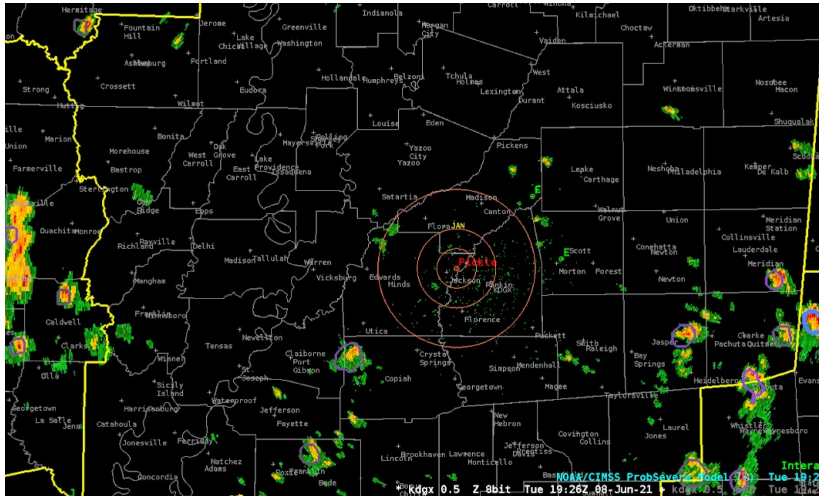
Fig. 1; Bruning and MacGorman (2013)

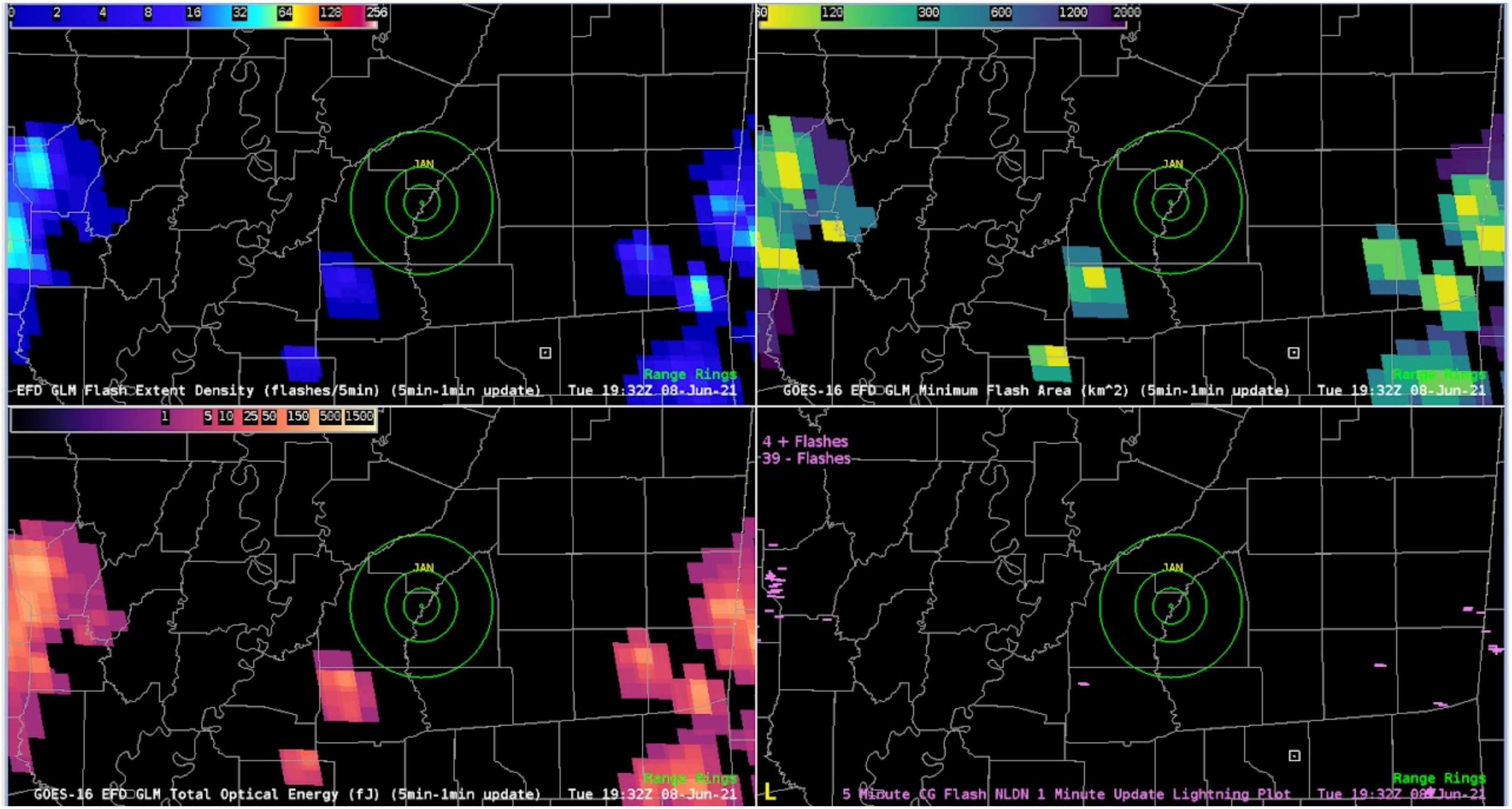
Theory and Observations of Controls on Lightning Size Spectra

3. Use GLM combined with other lightning location systems for a holistic understanding of lightning activity

Gridded GLM data provides extent and size information.

Ground-based systems can separate between cloud-to-ground and in-cloud lightning.

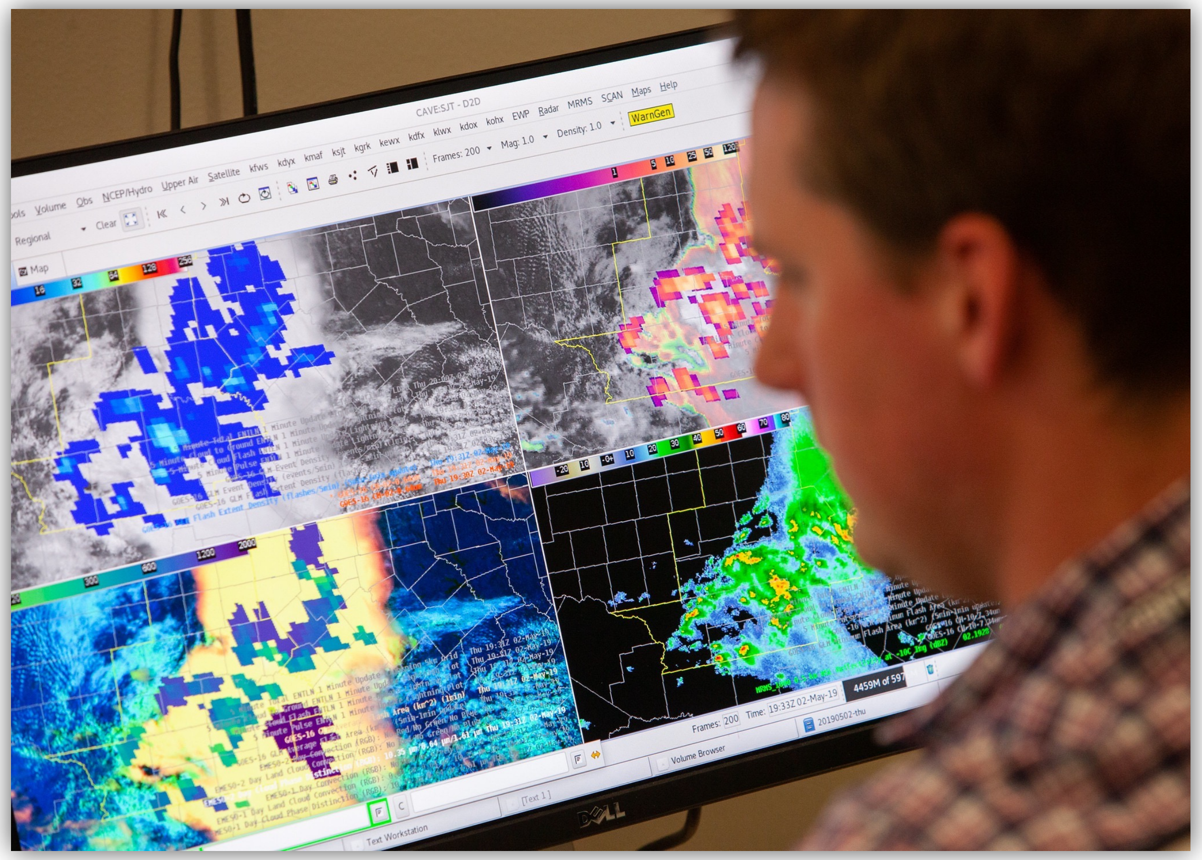




[Pickle Festival – Blog Post]

Recommendations for Operational Implementation

- Product rollout of GLM gridded products should become integrated into the ground processing and the baseline products (Level2) from GLM
  - **Flash Extent Density, min flash size,** event density, and flash energy
- Continue training efforts with local offices (develop and use local subject-matter experts); stress impact of extent information for Decision Support Services
- Use the GLM products in conjunction with the ground-based lightning products to help with parallax and provide full picture of storm intensity and threat.



Integrating Geostationary Lightning Mapper data into the severe weather warning process promotes earlier warning decisions, better assessment of the areal coverage of hazards, and fewer false alarms, especially during radar outages and in regions of poor radar coverage. [GLM Value Assessment, NESDIS]