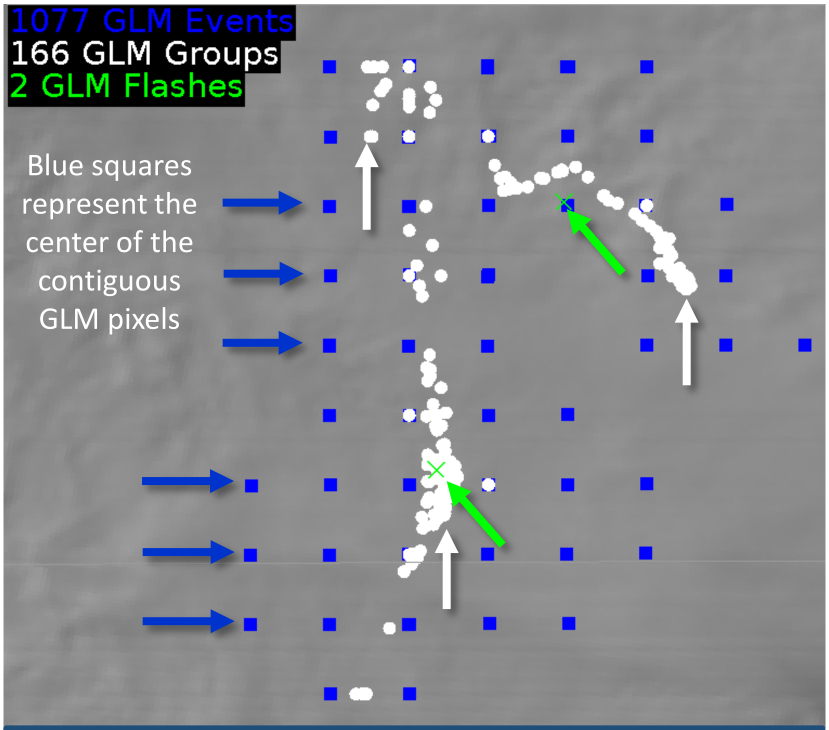
Geostationary Lightning Mapper: Definitions and Detection Methods

Quick Guide

GLM Detection Methods

- The GLM detects changes in brightness every ~2 ms relative to a continuously updating background image
- Individual pixels illuminated above the background threshold during 2 ms frames are termed GLM events
- Filters then remove non-lightning events leaving only those most likely to be lightning
- Lightning Cluster Filter Algorithm combines events into groups and groups into flashes



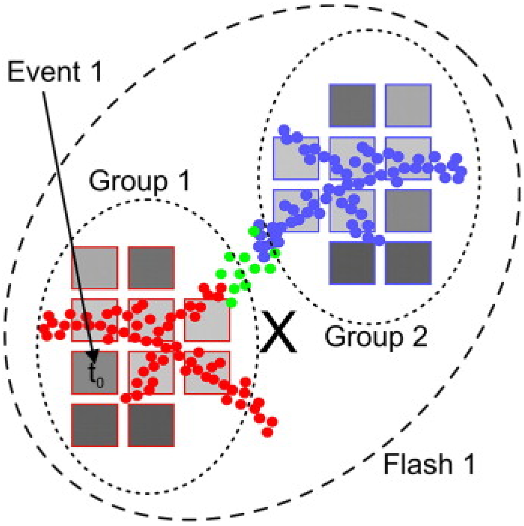
GLM Definitions

- Event: occurrence of a single pixel exceeding the detection threshold during one ~2 ms frame
- Group: 1+ simultaneous GLM events observed in adjacent (neighboring/diagonal) pixels
- Flash: 1 or more sequential groups separated by less than 330 ms and 16.5 km
- <u>GLM flash rates are most closely tied to updraft and storm evolution, and GLM event locations best depict the spatial extent</u>

- Green X's depict the location of two GLM flashes
- GLM groups appear as white dots (which typically do not occur at the center of GLM pixels)
- GLM events are depicted as blue squares on the GLM fixed grid – there were >1000 GLM events during these 2 GLM flashes, only 50 pixels were illuminated, so most pixels were illuminated for multiple 2 ms frames

Event, Group, and Flash Locations

- While GLM events are reported as the center points of GLM pixels, the group and flash locations represent radiance weighted centroids
- In this image the red, green, and blue dots represent a lightning mapping array depiction of a lightning flash; the red squares with grey shades indicate GLM events with lighter shades being brighter
- The GLM flash location considers the brightness of all events from both groups to locate the brightest part of the flash, or radiance weighted centroid, indicated by the black X in this image
- Note that the flash location may not always fall along the lightning channel, but will always fall within the flash footprint



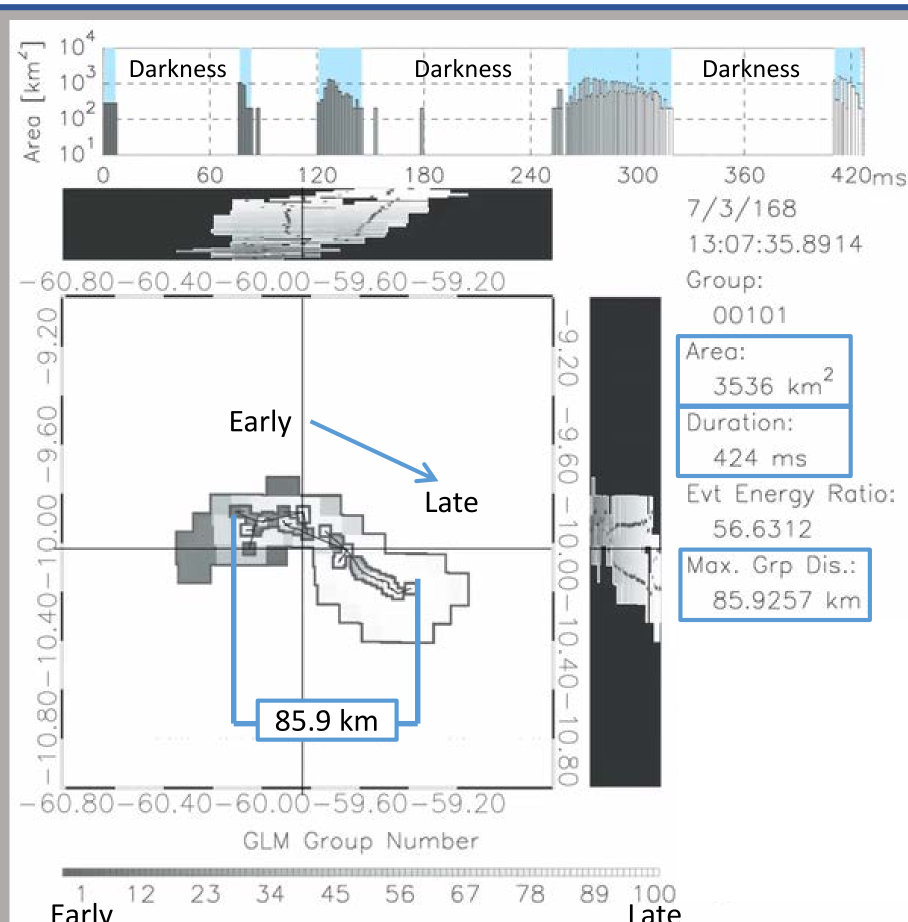
Author: Dr. Scott Rudlosky
NOAA/NESDIS/STAR (CICS-MD)

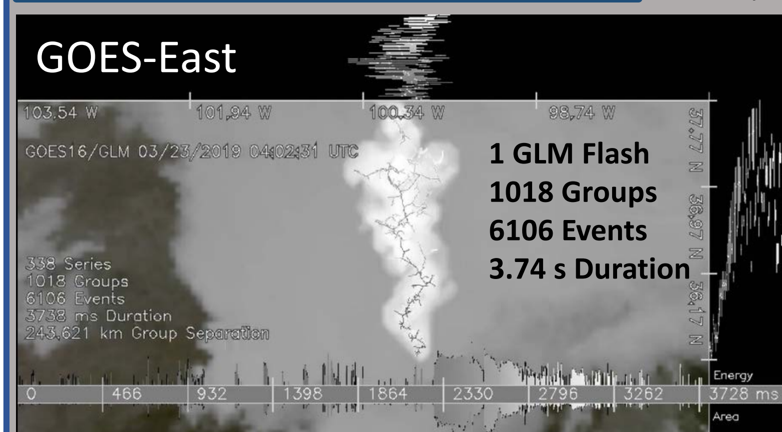
Version 3 – May 9, 2019

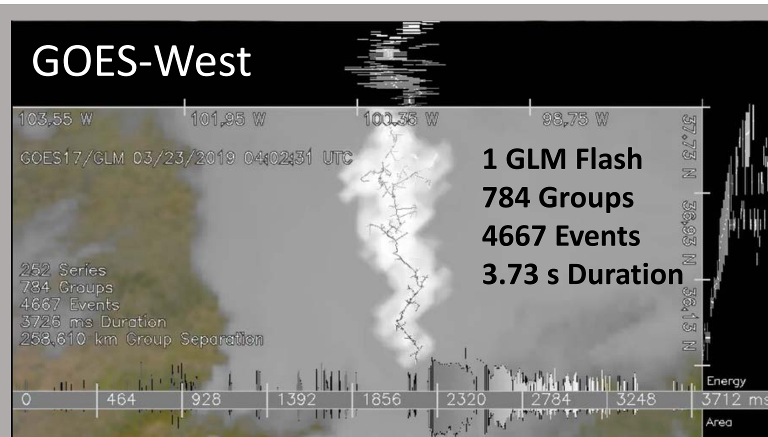
Geostationary Lightning Mapper: Definitions and Detection Methods

Quick Guide

- The GLM maps the extent of the cloud illuminated by individual lightning flashes
- Despite a relatively coarse spatial resolution, the GLM provides rapid temporal updates, allowing it to map flash structure
- Groups within individual flashes are connected to create flash skeletons
- This image depicts the evolution of one flash in space and time, the top panel illustrates an important feature of most lightning flashes, this 0.4 second flash produces discrete optical emissions separated by periods of darkness
- This is an example of how optical GLM lightning observations provide helpful insights into the flash structure, these insights can in turn be used to make inferences regarding lightning physics and storm structure







Observing Exceptional GLM Flashes

- Flash skeletons (see example above) clearly illustrate that the GLM is an imager rather than a detector
- The variety of lightning composition and time evolution provide important insights into convective mode and storm structure
- Scientists are working to quantify this information to develop products that aid forecasters (e.g., gridded GLM products)

Additional Information

GLM Virtual Lab Community:
https://vlab.ncep.noaa.gov/web/geostationary-lightning-mapper

Imagery Examples:
https://twitter.com/goesglm
https://twitter.com/weatherarchive

Geostationary Lightning Mapper: Gridded Products (FED)

Quick Guide

Gridded GLM Products

- GLM Level 2 data (events, groups, and flashes) are produced as points, resulting in a loss of information concerning the spatial extent
- Gridded GLM products restore and disseminate the spatial footprint information while greatly reducing the file size
- Gridded GLM products involve re-navigating the GLM event latitude / longitude to the 2×2 km Advanced Baseline Imager (ABI) fixed grid
- Flash extent density (FED), the number of flashes that occur within a grid cell over a given period of time, is the first NWS product

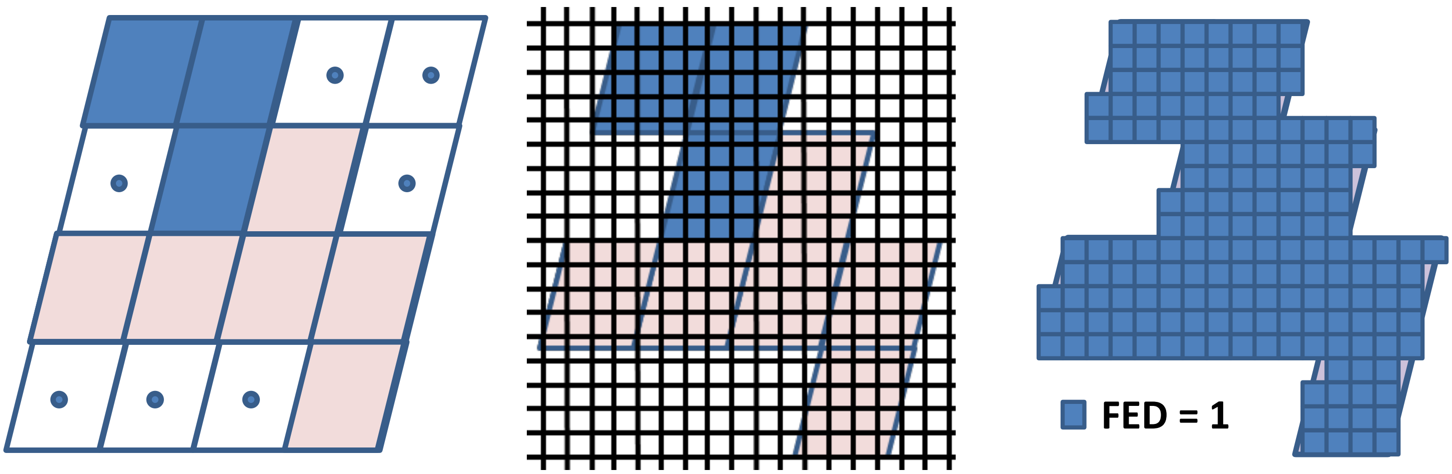
Gridding Procedures

- A corner point lookup table is used to re-create event polygons from the L2 points
- Parent-child relationships are used to combine the event polygons into group and flash polygons
- These polygons are then subdivided at the flash, group, and event levels by slicing them with the ABI fixed grid
- The next step accumulates and weights the sliced polygons at the flash, group, and event levels to create the gridded products
- FED values are rounded to the nearest integer

(1) Re-create event, group, and flash polygons from L2 points

(2) Slice GLM polygons with the ABI fixed grid

(3) Accumulate/weight sliced polygons to create FED product



Motivation for Gridded Products

- Many years of research and operational LMA demonstrations have shown the FED to be the preferred total lightning product
- FED best portrays, in a single product, the quantity/extent of GLM flashes/events
- The initial plan is for 1-min and 5-min window FED grids to reach AWIPS within ~1 minute
- More gridded products will be incorporated later

Primary GLM Applications

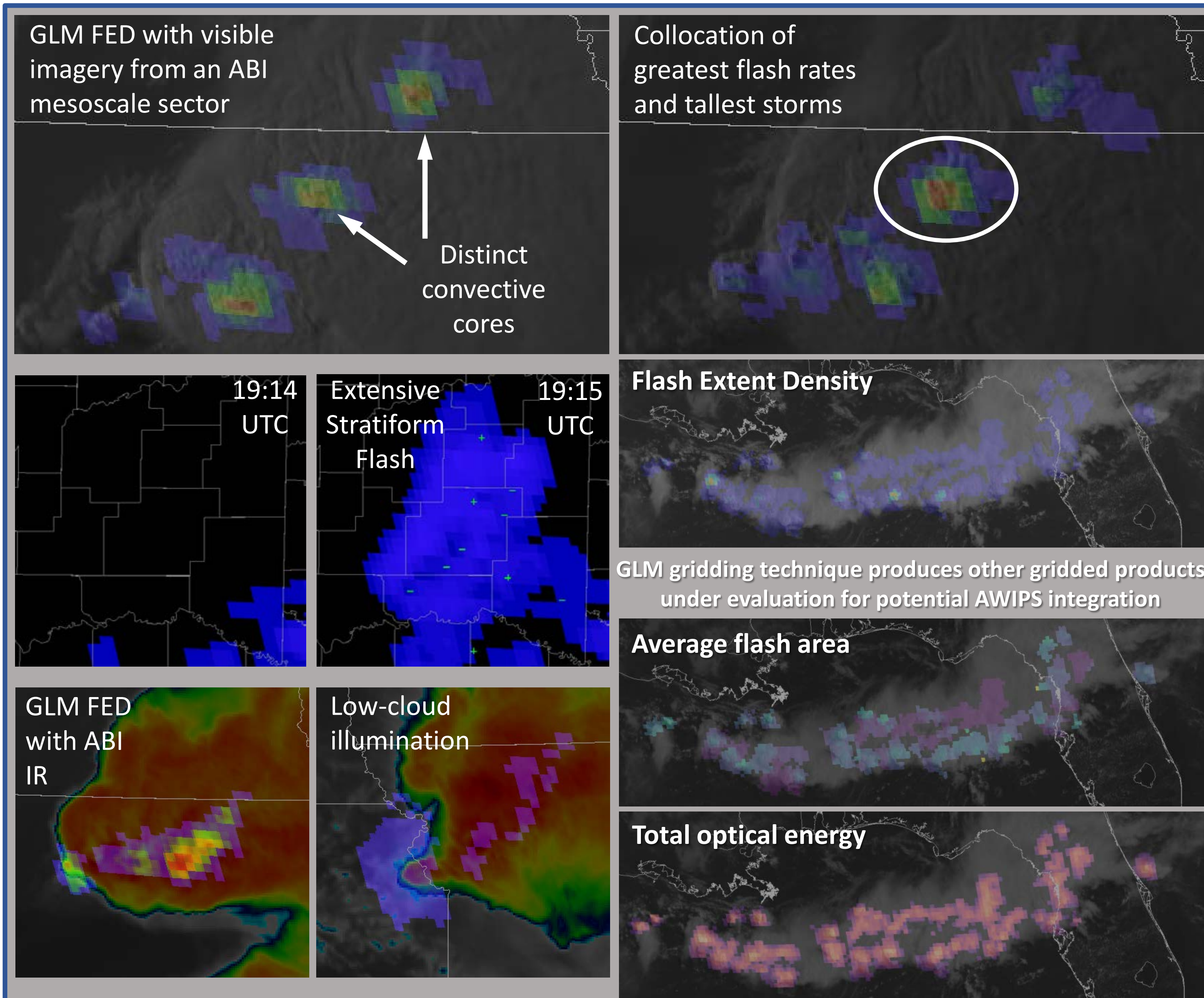
- Detect electrically active storms
- Observe the areal lightning extent
- Track embedded convective cells
- Identify strengthening and weakening storms
- Monitor convective mode and storm evolution,
- Characterize storms as they transition offshore,
- Provide insights into TC intensity changes

Author: Dr. Scott Rudlosky
NOAA/NESDIS/STAR (CICS-MD)

Version 3 – May 9, 2019

Geostationary Lightning Mapper: Gridded Products (FED)

Quick Guide



<u>**Nocturnal effects**</u>:

- **The increased sensitivity induced by the nighttime background makes nocturnal flashes appear larger than identical flashes during the day**
- **Some of this signal also relates to the tendency for nocturnal storms to produce larger flashes as they grow upscale into mesoscale convective systems or weaken into messier convective scenes**
- **Another nocturnal feature is low cloud illumination by nearby deep convection**
- **Rebound events appear as spikes stretching southward from strong flashes, most common at night and indicative of flashes with continuing current**

Additional Resources

GLM VLab Community:

https://go.usa.gov/xU5MF

GLM Faculty Virtual Course

NESDIS/STAR - CICS-MD

NASA SPoRT Home Page

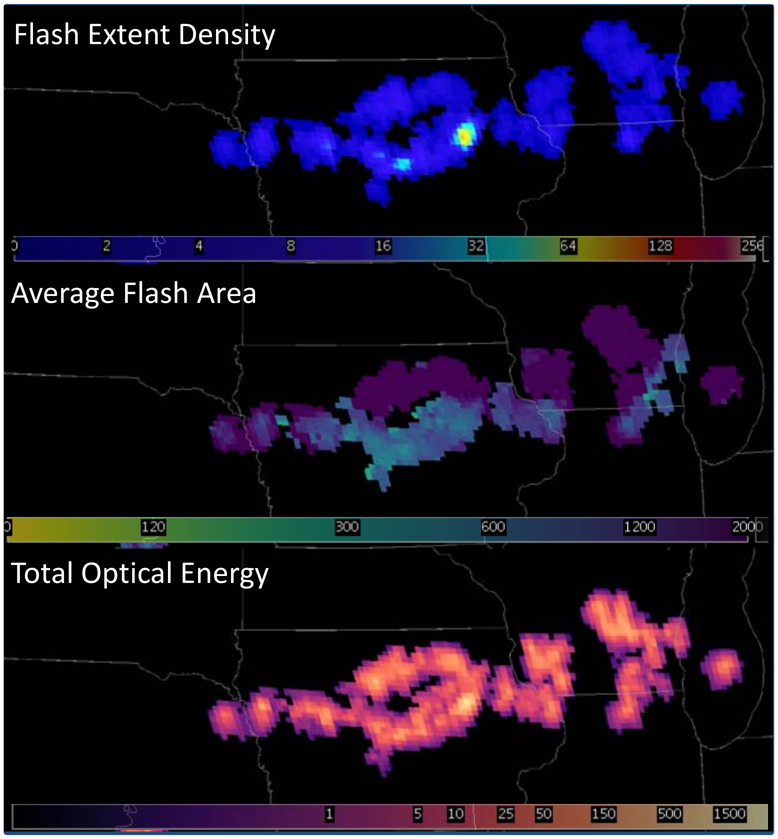
Hyperlinks not available when viewing material in AIR Tool

Geostationary Lightning Mapper: Gridded Products: AFA and TOE

Quick Guide

AFA and TOE Background

- **Average flash area (AFA) is the average area of all GLM flashes spatially coincident with each 2×2 km grid cell during a specified time period**
- **AFA has units of km^2, with values ranging from a minimum of 1 pixel or ~64 km^2 to several thousand km^2 for regions with extensive stratiform flashes**
- **Total optical energy (TOE) is the sum of all optical energy that the GLM observes within each grid cell during a specified time period**
- **TOE has units of femtojoules (fJ; 10^{-15} J), with values on the order of decimals for the dimmest flashes to over 1000 fJ for regions with many bright flashes**
- **<u>AFA and TOE complement flash extent density (FED) to maximize the insights provided by the GLM</u>**
- **<u>AFA and TOE also provide context for understanding GLM data quality and the subtleties of space-based optical lightning observations</u>**



Primary AFA Applications

- **<u>Detect/Monitor Thunderstorm Growth</u> – the AFA color map accentuates small flashes to highlight the earliest flashes, AFA also provides a visual que to help quantify subsequent storm growth**
- **<u>Observe the areal lightning extent</u> – the AFA indicates the occurrence of large/long flashes and helps differentiate anvil/stratiform flashes from embedded, newly-developing convection**
- **<u>Monitor convective mode and storm evolution</u> – the AFA trends are indicative of storm life cycles [e.g., frequent small flashes within the most intense convection (< 300 km^2) and a tendency for larger flashes as storms weaken (> 600 km^2)]**

Primary TOE Applications

- **<u>TOE directly depicts optical lightning observations</u> – provides the most intuitive GLM portrayal**
- **<u>Identify strengthening and weakening storms</u> – forecasters have likened the use of TOE to watching a light bulb brighten/dim as the storms grow/decay**
- **<u>Characterize convective scenes</u> – the TOE helps make inferences regarding the surrounding cloud scene [e.g., the TOE helps distinguish between deep convection and the dimmer low level clouds it often illuminates (most common at night)]**
- **<u>Analyze the cloud-to-ground lightning threat</u> - TOE indicates lightning channel locations within extensive stratiform flashes, along which these flashes commonly strike ground [e.g., FED often illuminates large cloud areas (especially at night), TOE illustrates the actual lightning channel extent**

Author: Scott Rudlosky, Ph.D.
NOAA/NESDIS/STAR (CICS-MD)

Version 2 – May 9, 2019

Geostationary Lightning Mapper: Gridded Products: AFA and TOE

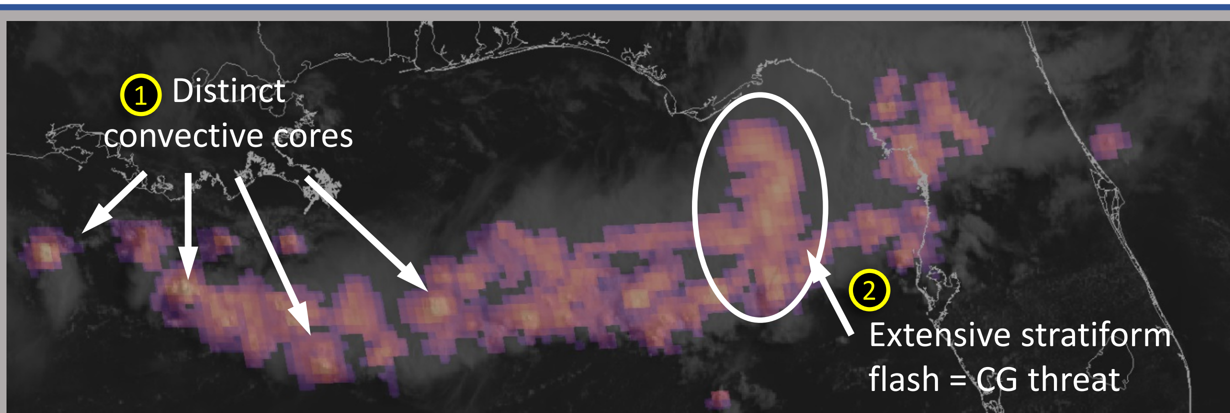
Quick Guide

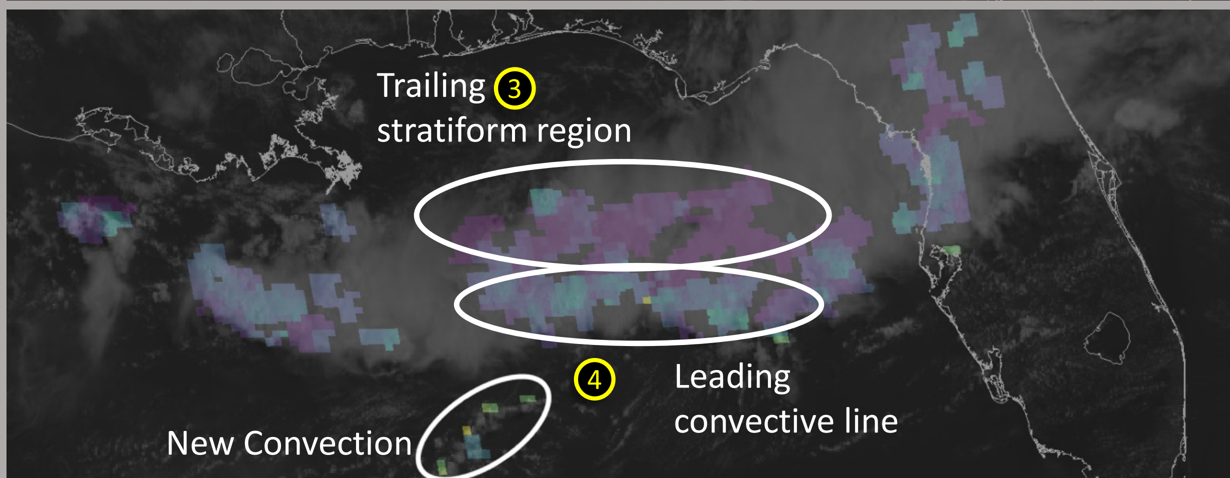
Bright TOE regions indicate

1. The most energetic convective cores
2. Lightning channels within extensive flashes

AFA reveals

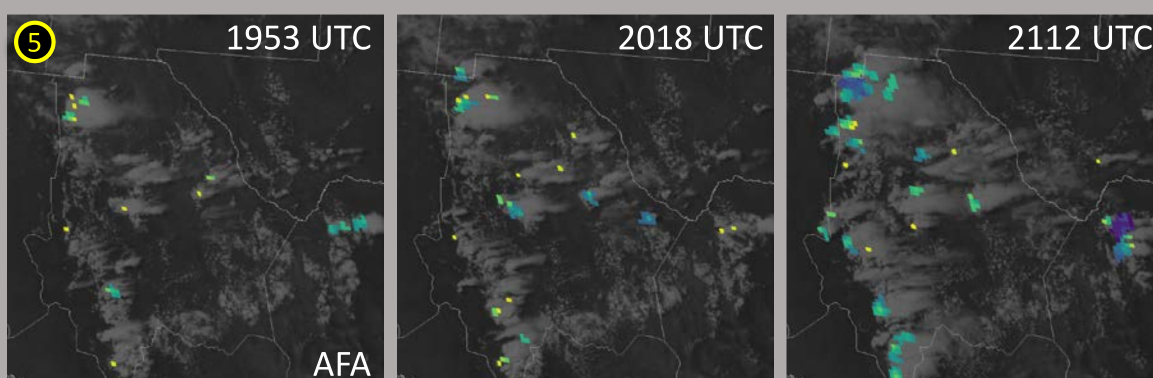
3. Large flashes in the stratiform / anvil regions and decaying storms
4. Small flashes in new convection (see below) and along the leading line





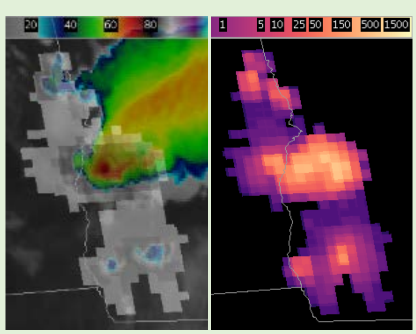
Detect and Monitor Storm Growth

5. AFA accentuates small flashes to highlight earliest convection, also provides a visual que to help quantify storm growth



Understanding Optical Emissions

- AFA and TOE help understand how the optical lightning signals interact with the convective scene
- For example, TOE helps confirms when dim areas in nocturnal scenes represent illuminated low-level clouds rather than lightning channels ahead of the storm



Additional Resources

GLM VLab Community:
https://go.usa.gov/xU5MF

GLM Faculty Virtual Course

NESDIS/STAR - CICS-MD

NASA SPoRT Home Page

Hyperlinks not available when viewing material in AIR Tool

Geostationary Lightning Mapper: Data Quality (May 2019)

Quick Guide

GLM Data Quality Evolution

- GLM calibration and validation efforts continue with all known issues being worked (e.g., recently mitigated the “Bahama Bar” artifacts)
- The GLM appears to meet its performance requirements despite the data quality issues illustrated in this document
- False events (pg 1) and geospatial considerations (pg 2) are described

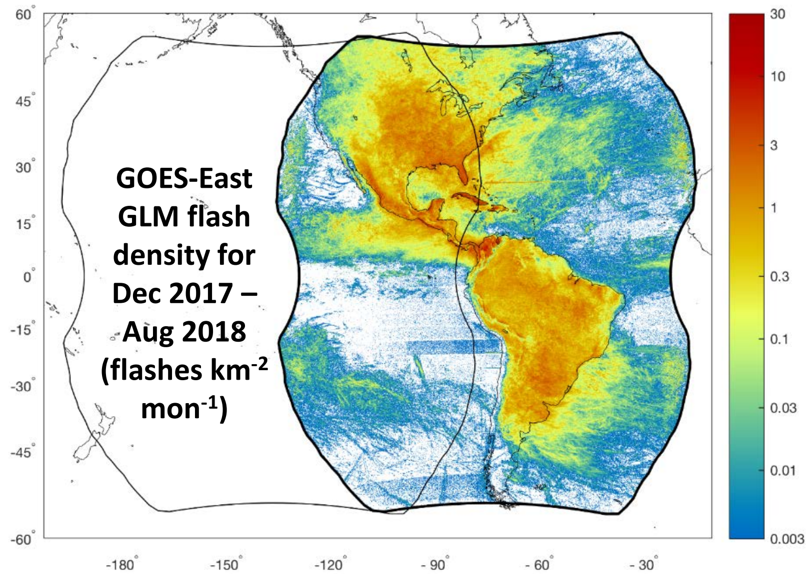
Performance Requirements
Detection efficiency > 70%, averaged over full disk and 24 h
Flash false alarm rate less than 5%, averaged over 24 hours
Navigation error within ±112 microradians (~1/2 pixel or ~4 km)

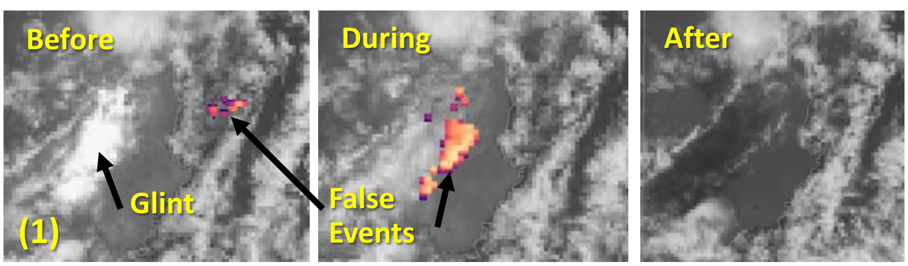
False GLM Event Sources

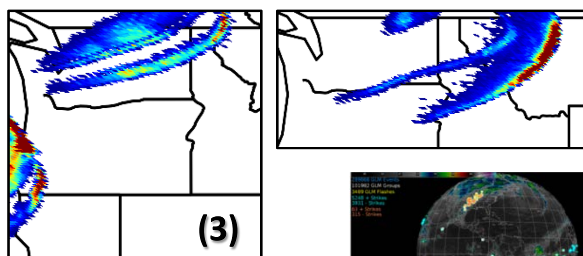
- GLM seeks to maximize detection efficiency while minimizing the false alarm rate
- False alarm rate is the number of false flash detections divided by the average true flash rate
- Each of the 56 subarrays are independently tuned
- Images below illustrate known false event sources

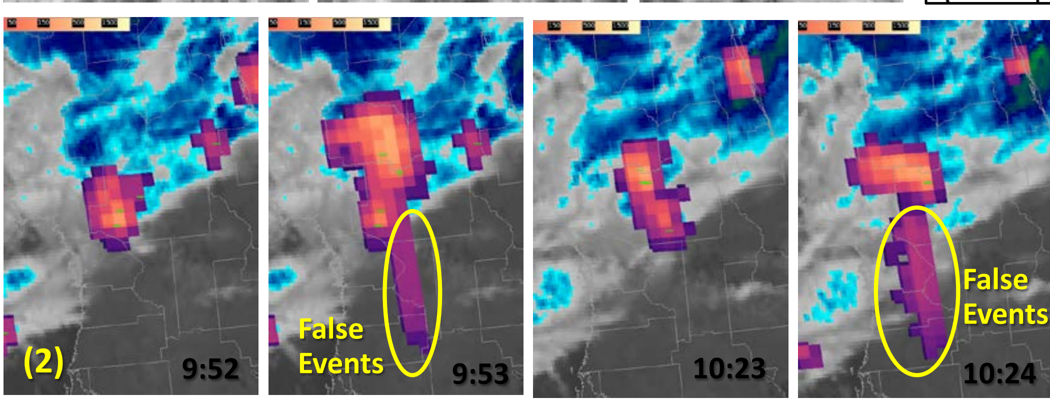
1) Sun glint – sunrise/sunset over the oceans and at satellite nadir / local noon over bodies of water
2) Rebound events (occur at night, indicative of flashes with continuing current = fire hazard)
3) Solar intrusion – transient false events that occur during the spring/fall eclipse seasons

GOES-East and GOES-West GLM Field of View

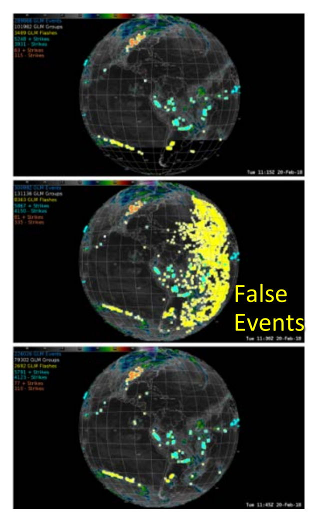








4) Platform Stability → Disturbances: Sudden false events along cloud edges during day caused by spacecraft maneuvers



Author: Dr. Scott Rudlosky
NOAA/NESDIS/STAR (CICS-MD)

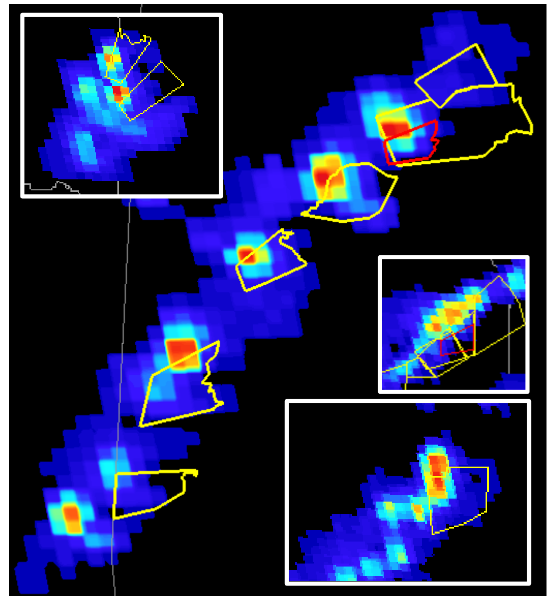
Version 3 – May 8, 2019

Geostationary Lightning Mapper: Data Quality (May 2019)

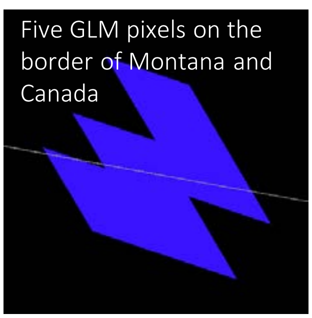
Quick Guide

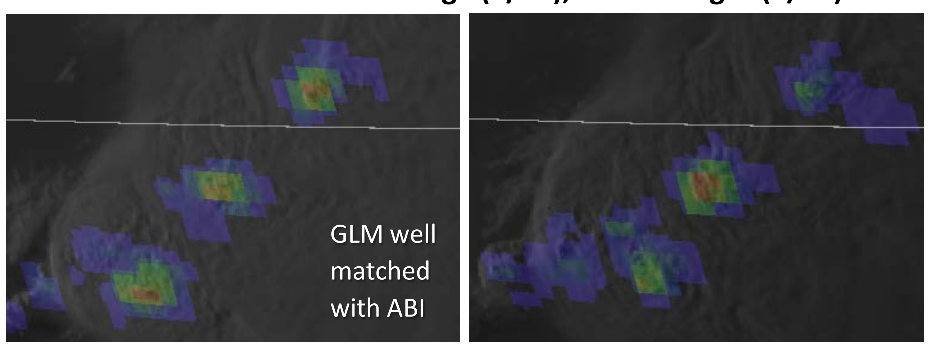
Geospatial Considerations

- **Each GLM has footprint of 1372 by 1300 pixels**
- **The instrument was designed to reduce the growth of GLM pixel footprints away from nadir, but the pixel size and shape still vary as shown by the two images below (*bottom left*)**
- **Although the GLM Level 2 product attempts to navigate the observations to an estimated cloud top, the <u>GLM gridded products do not, resulting in a similar parallax effect to the Advanced Baseline Imager (ABI)</u> – as illustrated by two screen captures of the collocated GLM FED and visible ABI imagery (*bottom right*)**
- **Parallax results in the gridded GLM products appearing shifted away from satellite nadir relative to radar and ground-based lightning networks – this offset must be considered when using the GLM gridded products for IDSS and during warning operations (*right*)**

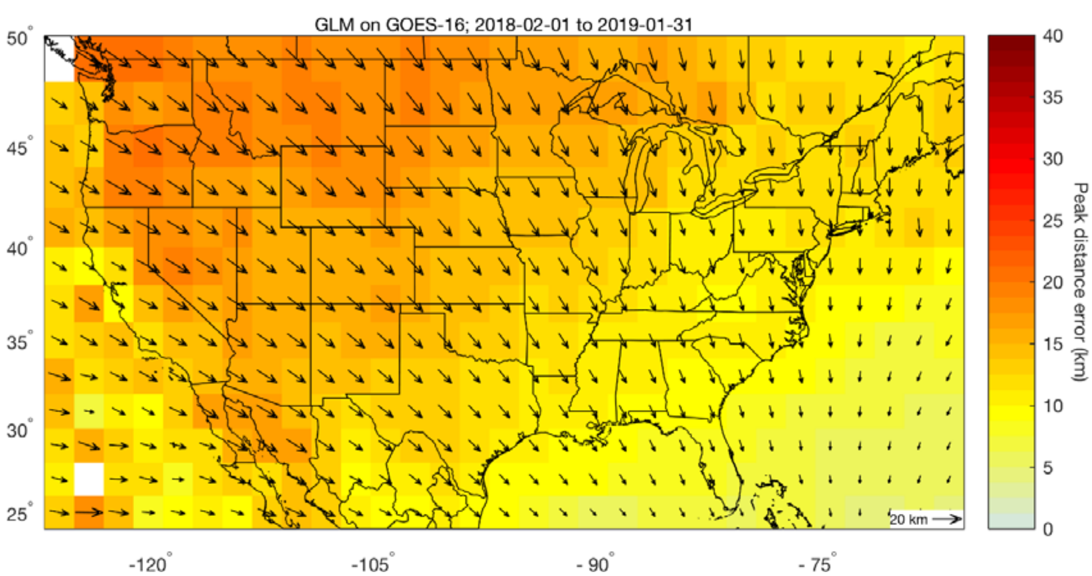


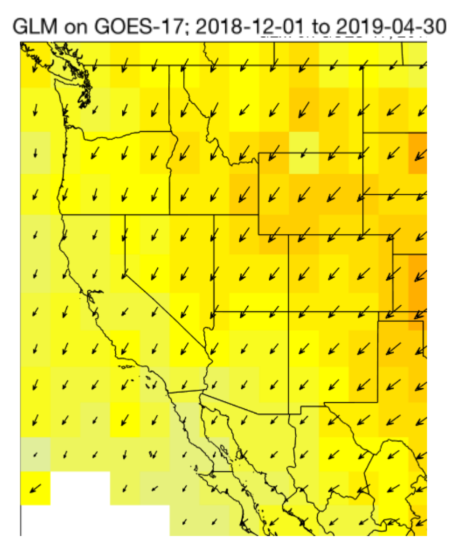
Above: GLM FED and severe thunderstorm/tornado warnings, main image (3/14), inlaid images (4/18)





Below: Direction vector and peak distance offset that must be applied for the GLMs to match the ground networks





Additional Information: https://vlab.ncep.noaa.gov/web/geostationary-lightning-mapper/