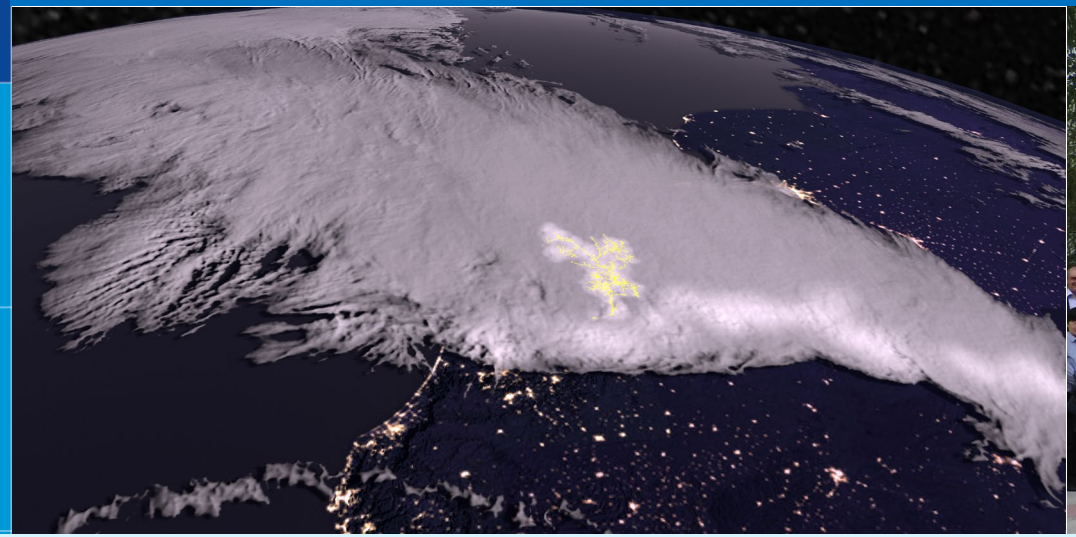
GLM-16 and 17 Early-Life Activities and Overview on GOES-T Cal/Val Plan

Scott Rudlosky, NESDIS/STAR

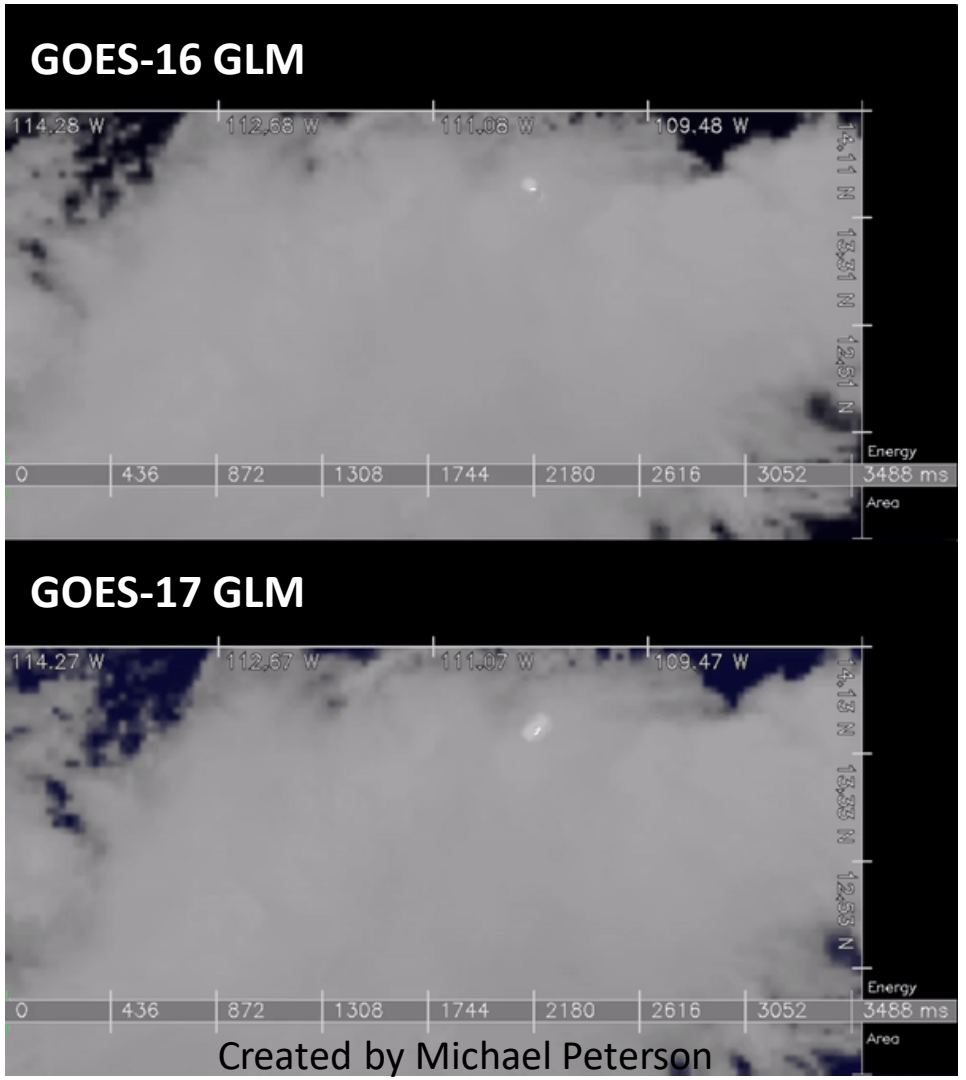
MTG LI MAG Meeting #11

9 February 2021



Geostationary Lightning Mapper

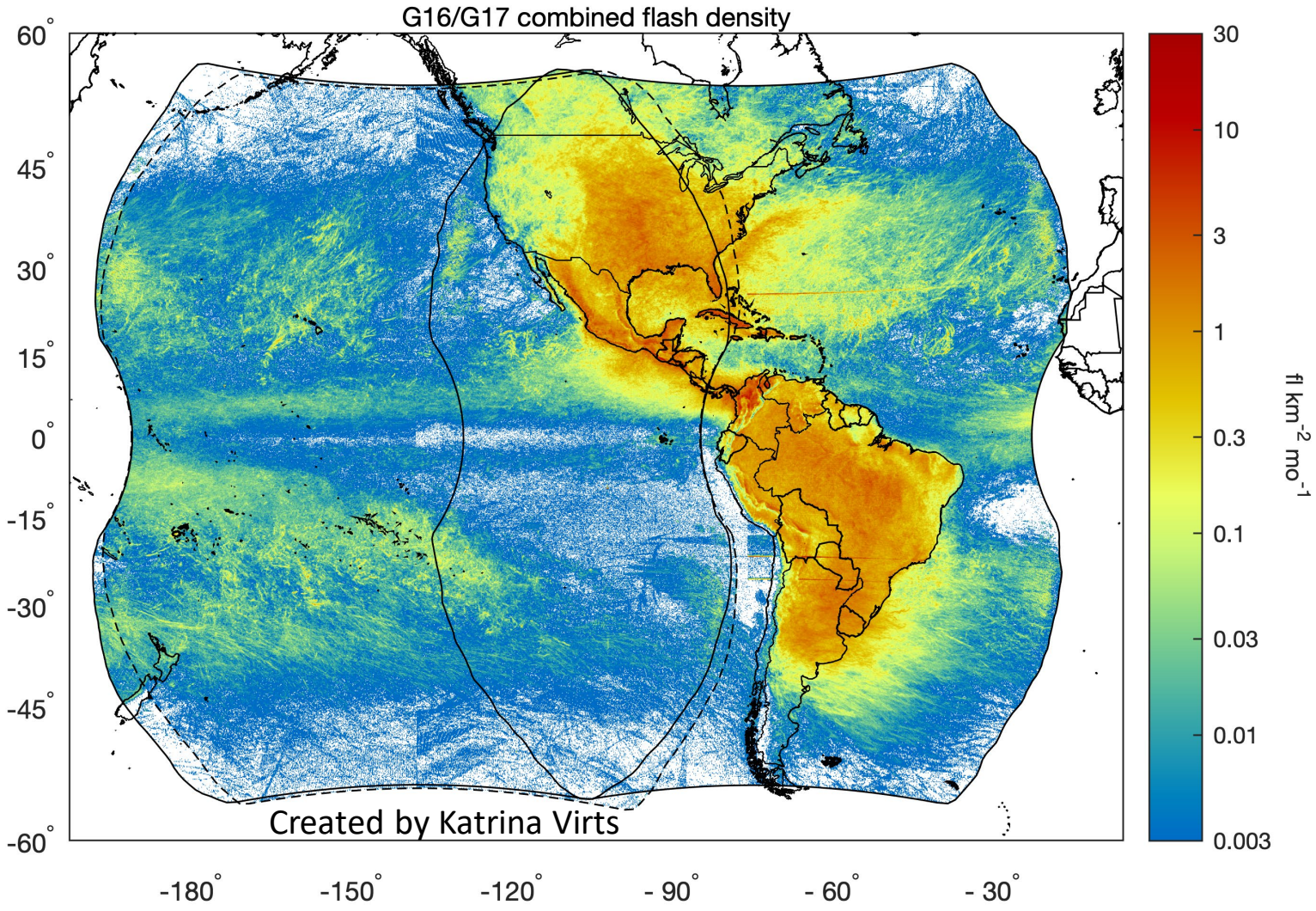
- First of its kind instrument, community is discovering new things daily, two product lines
- Video clearly shows GLM is a lightning imager rather than a detector (with very fine temporal resolution)
- Have only scratched the surface in terms of instrument capabilities and operational applications
- The TRMM Lightning Imaging Sensor (LIS) could require up to 35 years to sample the diurnal cycle for the equivalent of the 257 days (~9 months) studied by Rudlosky et al. (2019)



Created by Michael Peterson

Providing Twice the Coverage

- **Two GLMs now provide continuous real-time lightning monitoring throughout most of the Western Hemisphere**
- **GLM capabilities, products, and applications continue to evolve**

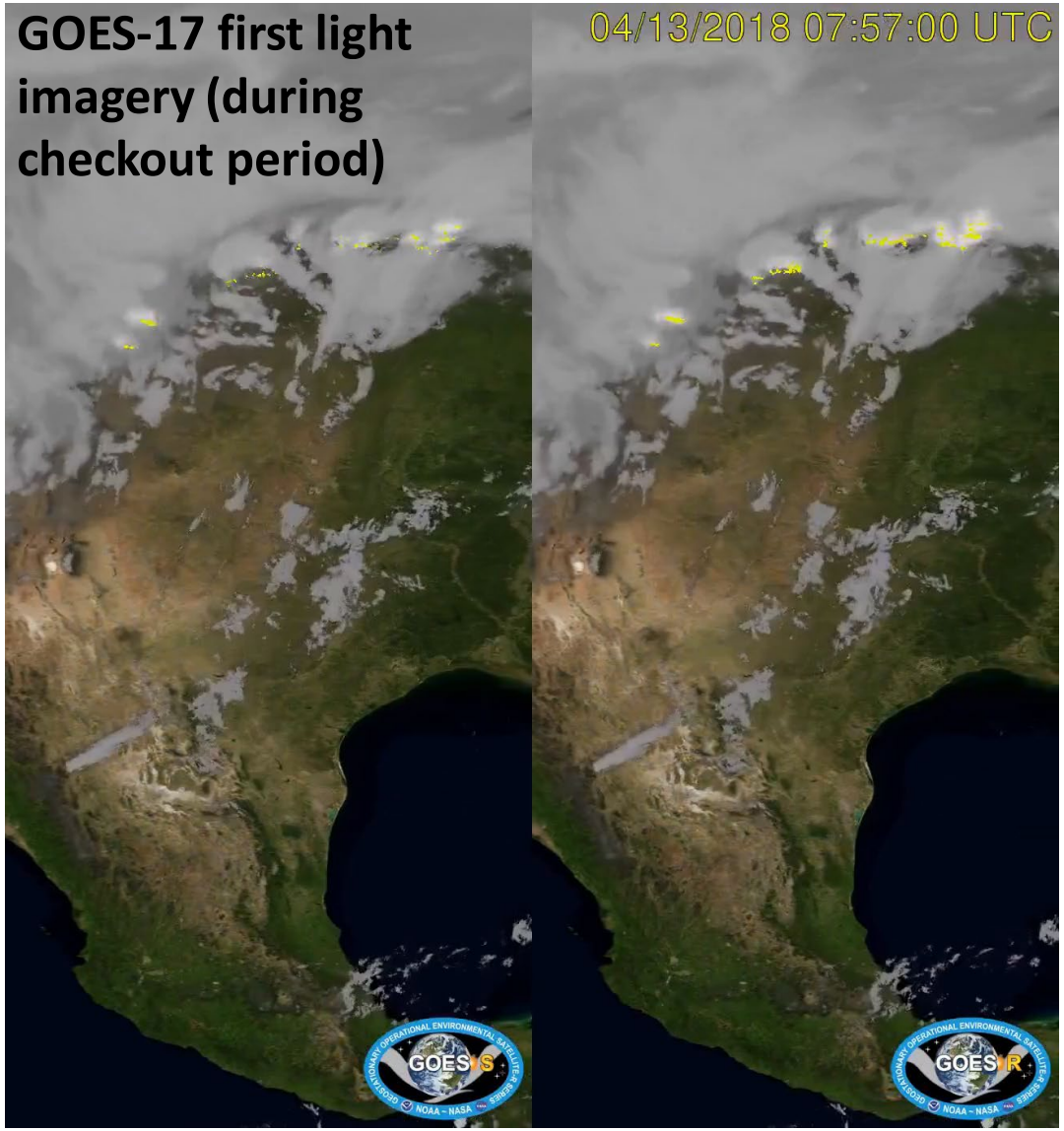


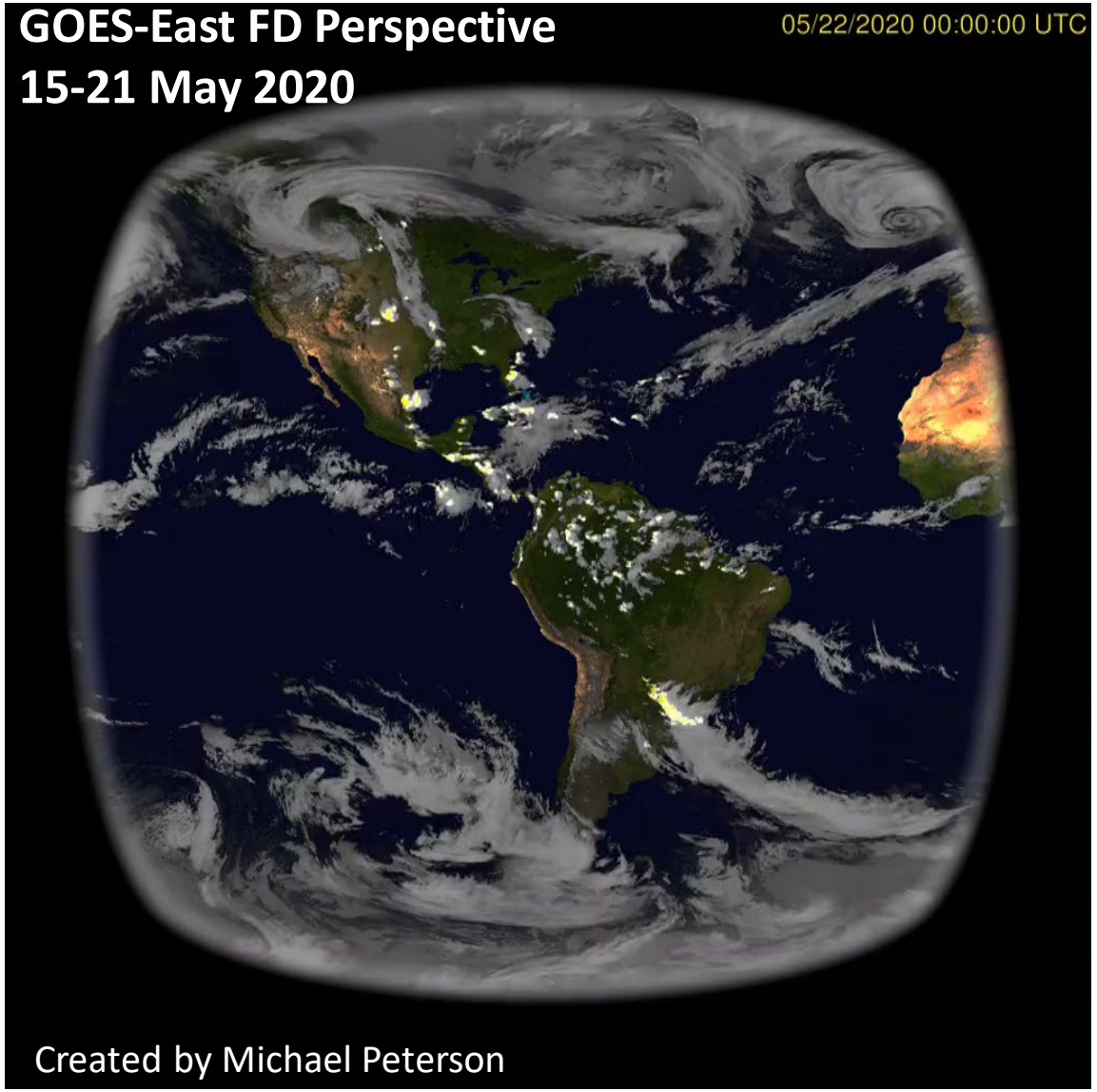
Providing Two Perspectives

- GOES-East (GE) GLM data have been widely available since reaching provisional maturity on 19 January 2019
- GOES-S launched on 1 March 2018, followed by 6 month checkout at 89.5° W, then a move to 137.2°, becoming GOES-West (GW)

Created by Michael Peterson

Providing “Twice” the Data



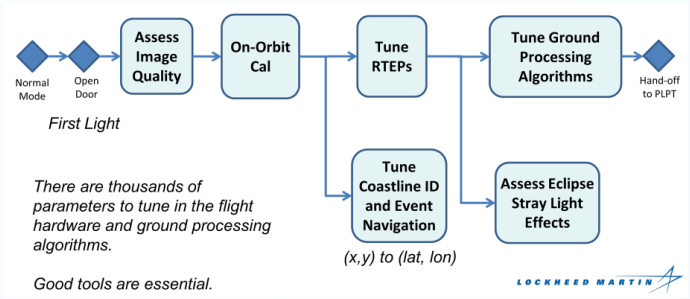


GLM Checkout Process

- **Checkout tasks include both vendor-led post launch tests (PLTs) and post launch product tests (PLPTs) led by the science team, leading to a series of Peer/Stakeholder Product Validation Reviews (PS-PVR – Beta, Provisional, and Full)**

PLT and PLPT Overview

GLM Post Launch Tests (PLTs)
Image Quality
On-Orbit Calibration
RTEP Detection Thresholds
Coastline ID and Navigation
GPA Filter Tuning
Solar Intrusion Assessment



GLM PLPT Categories
Reference Data Comparisons
Algorithm Testing
INR Testing
Long Term Baseline Testing

GLM Post Launch Product Tests (PLPTs)
Validate GLM Timing Settings and Image Quality
Set GLM RTEP Thresholds
Set GLM Second Level Thresholds
Validate GLM GPA Parameters
Verify Solar Intrusion Criteria
GLM Coastline ID INR Characterization Assessment
GLM Event Nav. Coarse Characterization Assessment
GLM Background INR Performance Assessment
GLM Alignment Assessment

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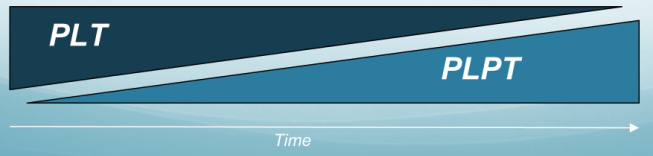
Transition from PLT to PLPT

- **PLT Outputs and PLPT Handoff**
  - **The output of PLT is a GLM calibration parameter file**
  - **PLT may result in algorithm changes, or new algorithms**
- **Some instrument-related PLTs must be completed prior to PLPT related detection efficiency (DE) and False Alarm Rate (FAR) tests**
- **Flexibility is required so that RTEP thresholds can be tentatively set, the DE/FAR tested using PLPT tools, then re-setting the RTEP thresholds accordingly**
- **This back-and-forth "tuning process" is vital for thoroughly optimizing the GLM*****




```
HDF5 GLM_FM1.h5
GLM_CalibrationParameters
  |-- EventFilters
  |     |--
2ndLevelThreshold
  |     |-- Burst
  |     |-- Coherency
  |     |-- ContrastLeakage
  |     |-- Crosstalk
  |     |-- FrameTransfer
  |     |-- Glint
  |     |-- Mask
  |     |-- Overshoot
  |     \-- Radiation
  |-- INR
  |     |-- Coastline
  |     |-- Navigation
  |     \--
UniversalParameters
  |-- InstrumentParameters
  |--
RadiometricCalibration
  \-- SpacecraftParameters
```

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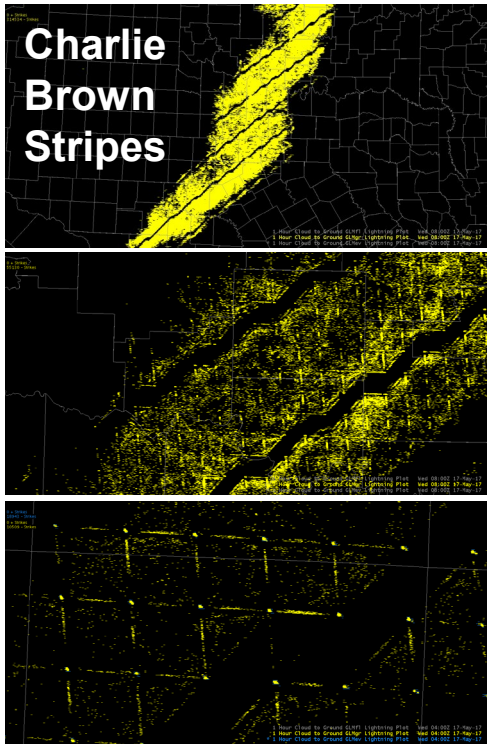
PLPT Tests and Tools

Test ID	Abbreviated Test Titles for GLM
PLPT-GLM-001	Validate DE/FER using med/long-range networks (e.g., NLDN, EN, GLD360)
PLPT-GLM-002	Validate DE/FER using short-range networks (e.g., LMAs)
PLPT-GLM-003	Validate Storm DE and Storm FAR using very long range systems (WWLLN, NEXRAD)
PLPT-GLM-004	Validate DE/FER using very short range optical systems (FEGS)
PLPT-GLM-005	Validate DE/FER using orbit-based optical systems (e.g., ISS/LIS)
PLPT-GLM-006	Validate DE/FER using ground-based E-field networks (e.g. HAMMA)
PLPT-GLM-009	Validate L1b-L2 Cluster/Filter by comparing w/Spec (i.e. Mach) code
PLPT-GLM-010	Validate L0-L1b Filter Algorithms by comparing w/Spec (i.e. Mach) code
PLPT-GLM-011	Validate GLM INR w/comparisons to well-located ground points
PLPT-GLM-012	Validate GLM BG DCC radiances with trendings & comparisons
PLPT-GLM-013	Validate GLM Event Energies with trendings & comparisons

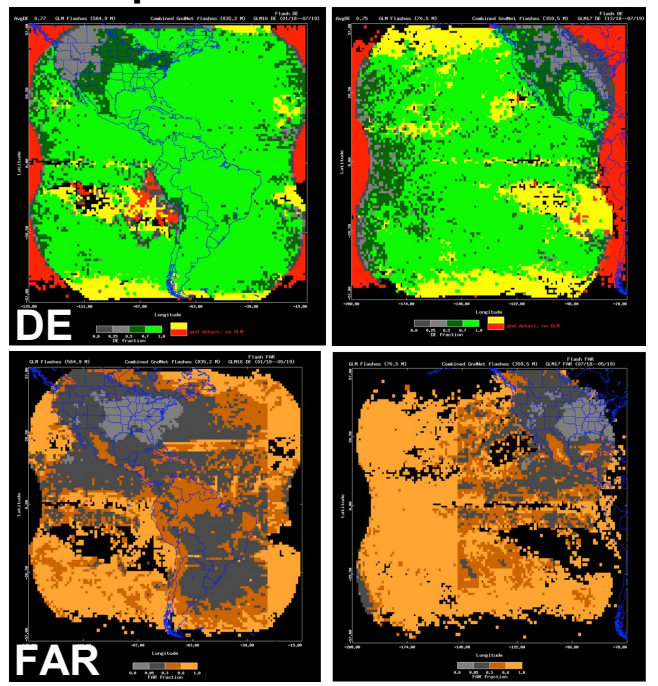
Tool/Application	Developer	Language
VaLiD (Validate Lightning Data)	Monte Bateman	C
Lightning Cluster/Filter Algorithm (LCFA)	Douglas Mach	Matlab, C
L0-L1b Code Validation	Douglas Mach	Matlab, C
HAMMA User Data Analysis Technology (HUDAT)	Phillip Bitzer	IDL
Trending Tool for Deep Convective Clouds (TT/DCC)	Dennis Buechler	IDL
Trending Tool for Lightning (TT/Lightning) analyses	William Koshak	IDL
24/7 Lightning Monitoring Tool (LMT)	NSOF Contractors	Various
Compare LLS (Compare Lightning Location System)	Ken Cummins	Matlab
XLMA tool	P. Krehbiel, B. Rison	IDL
Lmatools	Eric Bruning	Python
INR/Parallax tool	Dennis Buechler	IDL
STorm Retrievals frOm KSC E-Fields (STROKE)	William Koshak	IDL
Fly's Eye GLM Simulator Tool (FEGST)	Mason Quick	IDL
Ancillary Dataset Tools (ADTs)	Doug Mach et al.	Various
Specialized Impromptu Tools (SITs)	Various	Various

GLM L2 Timeline (1/2)

Date	Milestone
11/19/2016	GOES-16 Launch
04/24/2017	First usable GLM data from the GS
06/09/2017	GOES-16 Beta Maturity
06/28/2017	Updated Lookup Tables (CDRL079)
10/31/2017	Fixed “Charlie Brown” stripes
11/28/2017	Removed radiation + duplication “dots”
01/19/2018	GOES-16 Provisional Maturity
03/01/2018	GOES-17 Launch
10/02/2018	GOES-17 Beta Maturity
10/15/2018	Properly account for time of flight



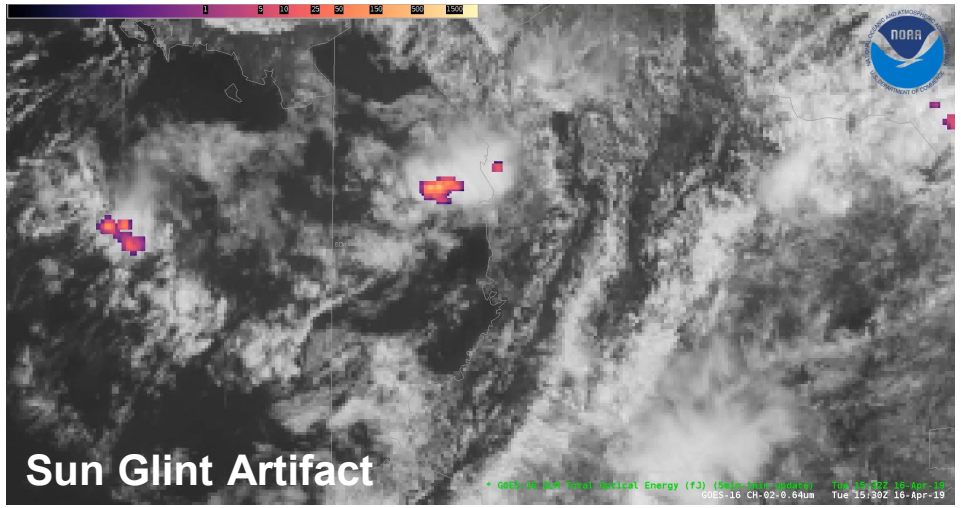
Example Performance Metrics

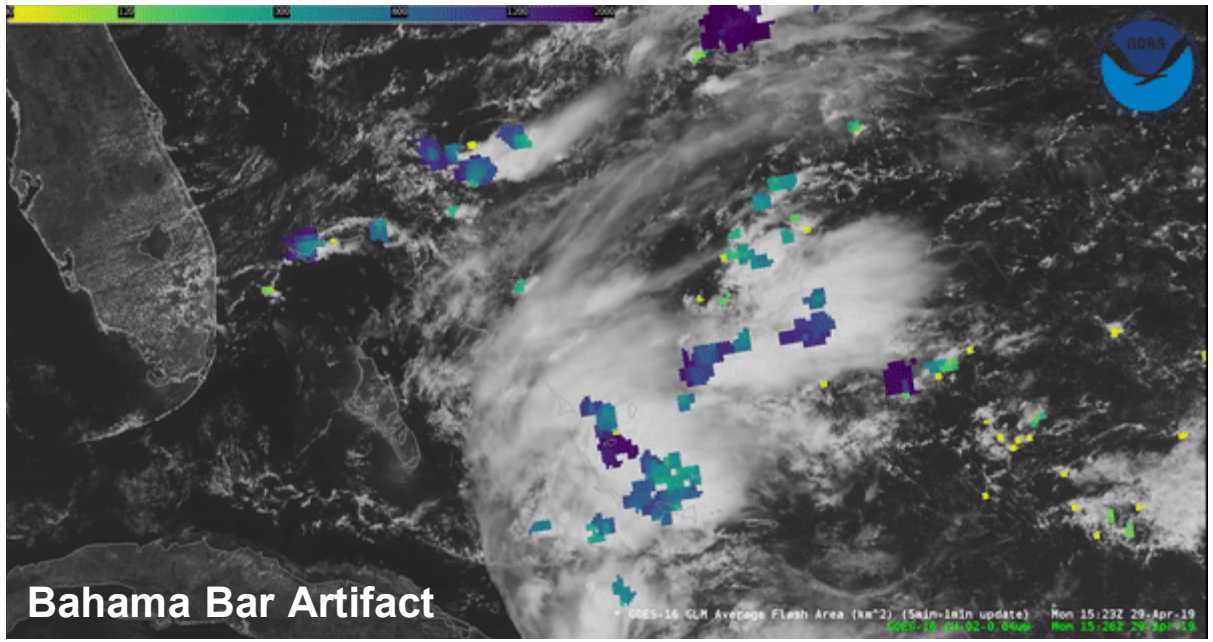


Created by Monte Bateman

GLM L2 Timeline (2/2)

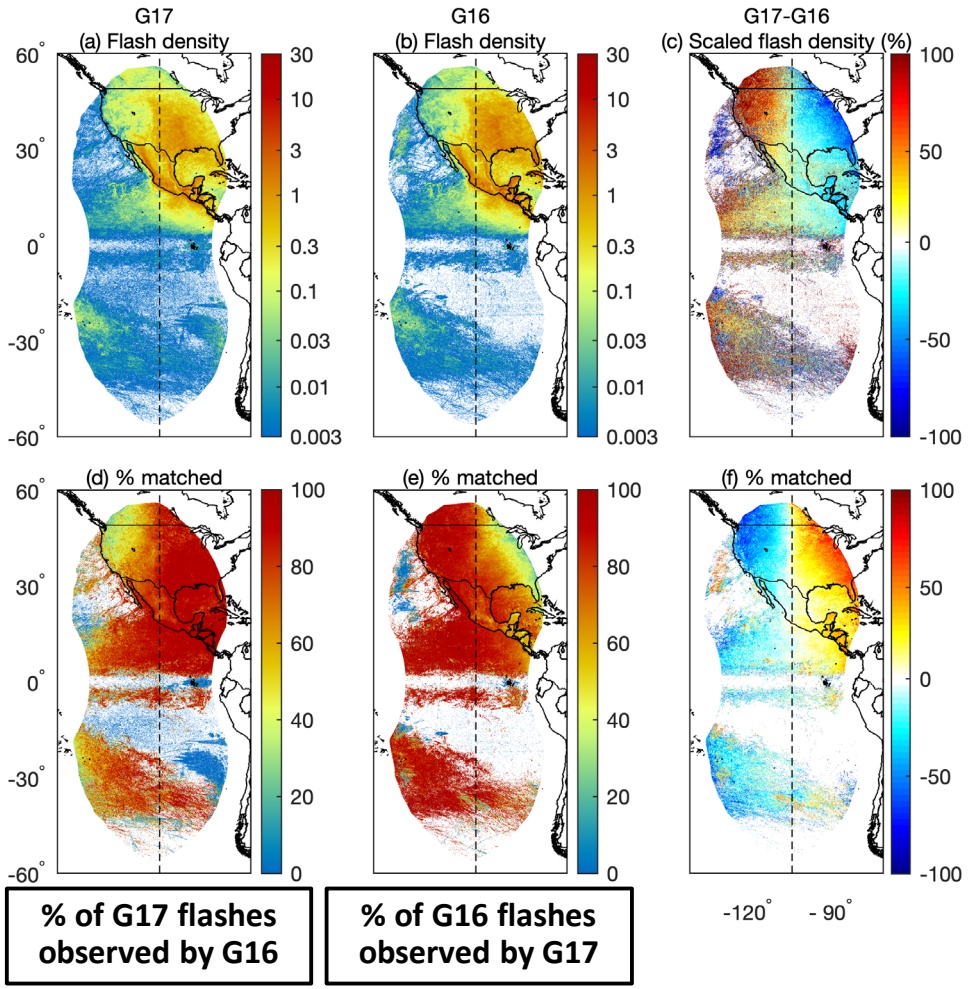
Date	Milestone
10/29/2018	Updated lightning ellipsoid values
11/01/2018	GOES-16 Full Maturity
11/05/2018	Overflow valve for ‘burst events’
11/15/2018	Updated 2nd level threshold
12/20/2018	GOES-17 Provisional Maturity
02/27/2019	2nd-level threshold filter code change
04/30/2019	Updated the second level thresholds
07/25/2019	Implemented GLM Blooming Filter
10/02/2019	Updated event energy scale factor





Data Quality Overview

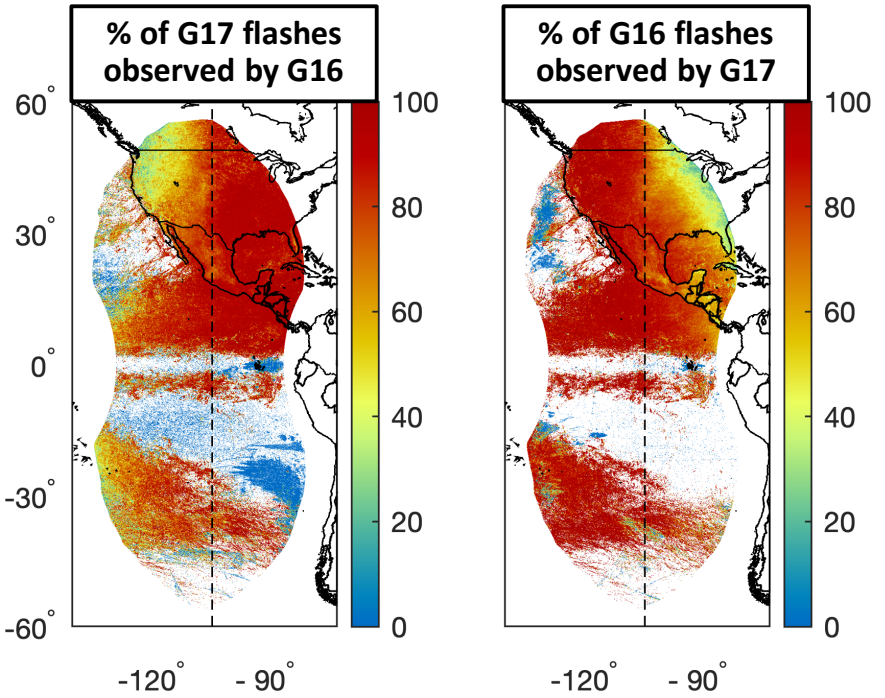
- **Both GLMs detect > 70% of lightning flashes with < 5% false alarms when averaged over the full disk and 24 h**
- **Understanding GLM performance variability is key to confidently applying these data**
- **GLM detection efficiency (DE) ultimately depends on…**
  - **Lightning flash properties (energy, size, duration)**
  - **How efficiently light travels from the lightning channels to the cloud top**
  - **Resulting optical contrast at cloud top**
  - **Relative position in the field of view (i.e., both pixel geometry and viewing angle)**



From Rudlosky and Virts (2021)

Factors Affecting Detection Efficiency

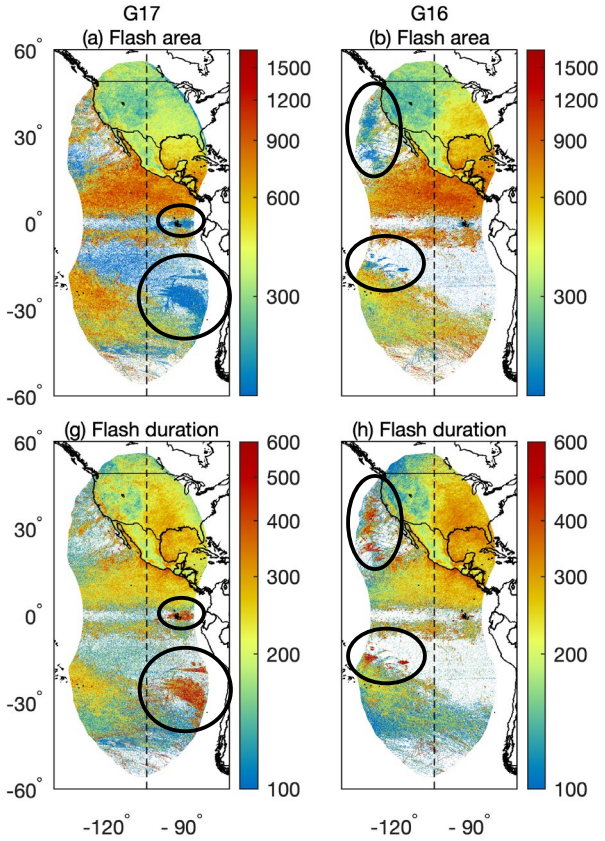
- Environmental conditions that reduce the amount of light reaching the cloud top reduce the GLM DE
- Low GLM DE has been found in some severe storms with very high mid-altitude reflectivity, especially electrically anomalous storms
- GLM DE drops off near the edge of the field of view (FOV), especially over land (e.g., northwest CONUS)
- This reduced DE relates to larger pixels and steeper viewing angles reducing instrument sensitivity
- Flash size and duration are also key parameters influencing DE (i.e., easier to detect larger, longer duration flashes)



From Rudlosky and Virts (2021)

Main Sources of GLM False Events

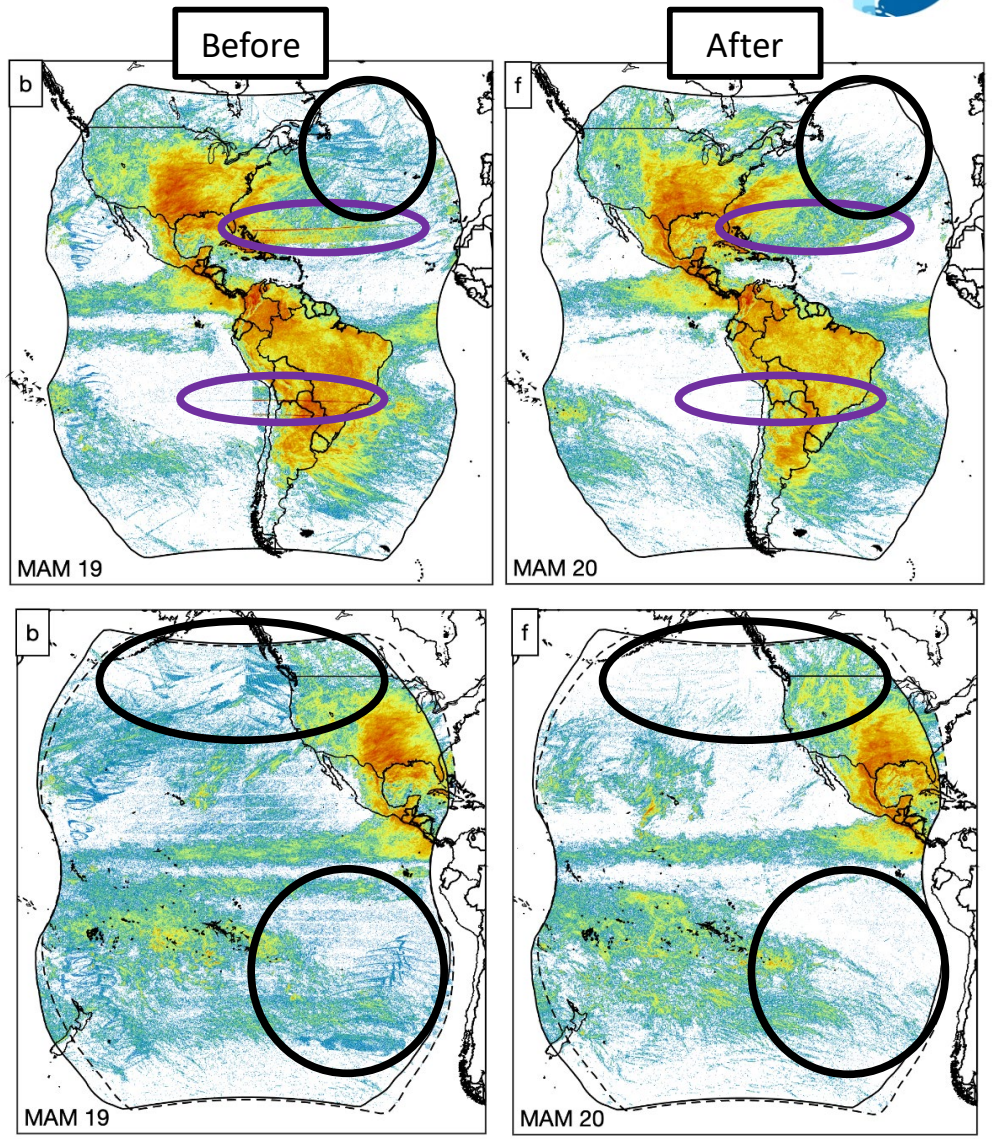
- **Most false GLM flashes occur in common locations at predictable times, so knowledge of these artifacts can help mitigate uncertainties when applying these data**
  - **Sun glint – sunrise/sunset over the oceans, and at satellite nadir / local noon over calm bodies of water**
  - **Solar intrusion – stray light leads to transient false events and temporary (transient) blind spots during the spring/fall eclipse seasons**
  - **Inconsistencies along subarray boundaries (e.g., “Bahamas Bar” artifact)**
- **Other false flashes occur more randomly in space and time**
  - **Radiation dots – high energy particles impacting instrument focal plane**
  - **Bolides – bright meteors (can help confirm reports/inquiries)**



From Rudlosky and Virts (2021)

Improving GLM Performance

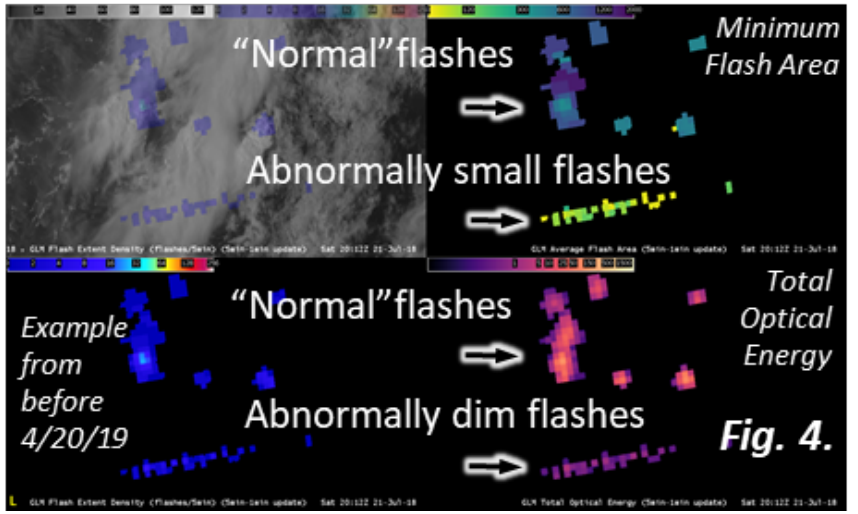
- **Blooming filter (implemented 25 July 2019) quenches the rapid growth of sun glint (mid/low latitudes) and solar intrusion (high latitudes) artifacts (e.g., black ovals in right image highlight before/after)**
- **Second-level threshold filter (applied 20 April 2019) helped mitigate "Bahamas Bar" artifacts (see below, and before/after in purple ovals in right image)**
- **False events are still detected in these places, but are much less pronounced with improved filters**

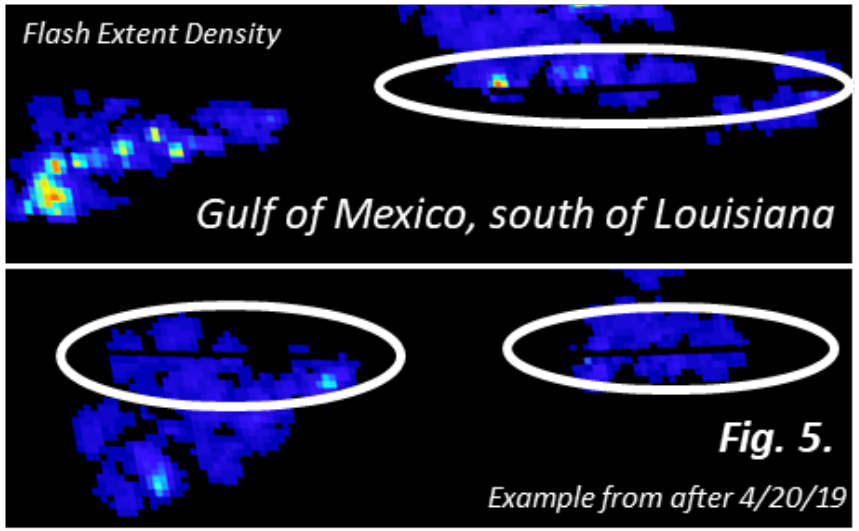


From Rudlosky and Virts (2021)

Additional DQ Considerations

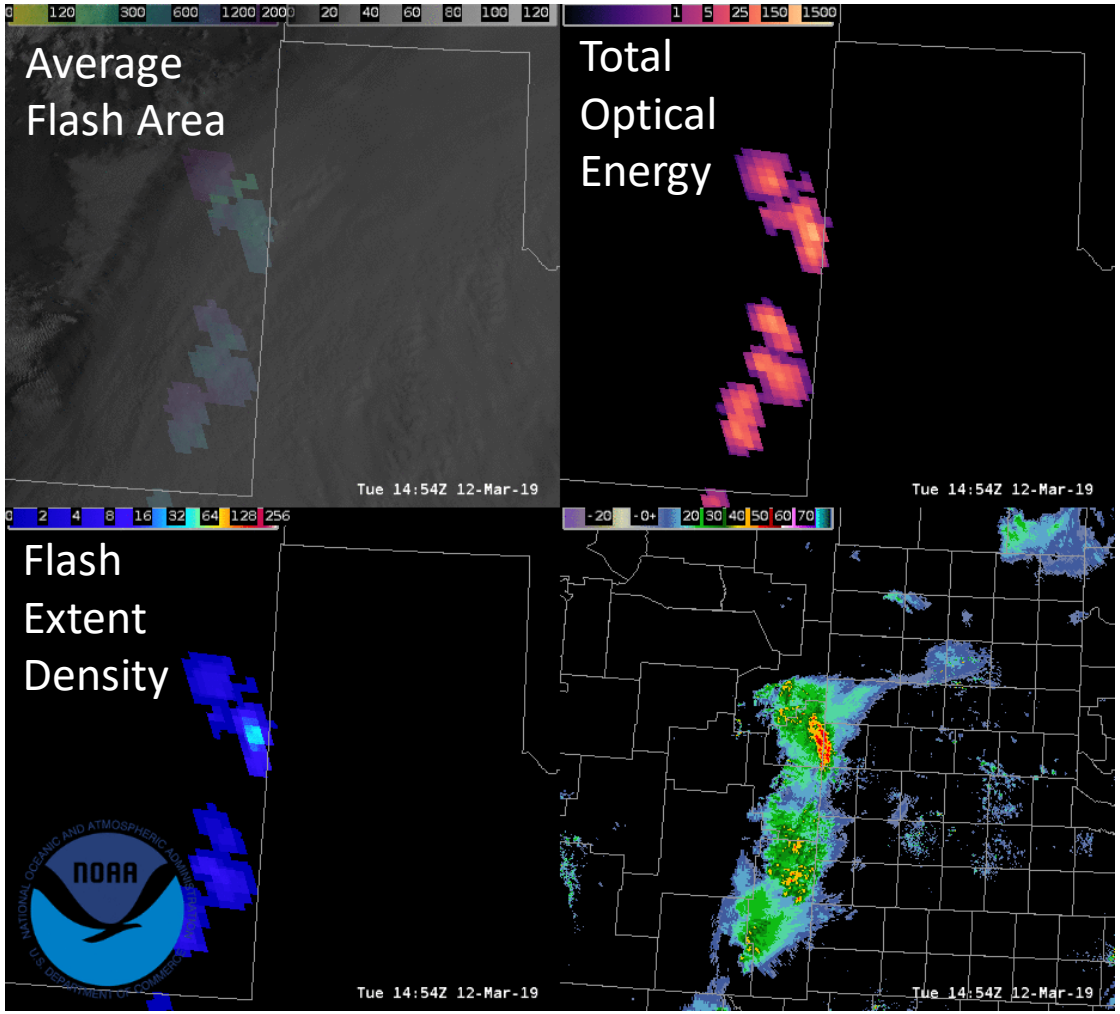
- Most false events are abnormal, so using multiple GLM gridded products helps distinguish false flashes from real lightning
- Suppressing the “Bahamas Bar” artifacts introduces/worsens an “inverse Bar” artifact that results in greatly diminished DE along the same subarray boundaries (~2 hours before/after solar noon)
- Users are encouraged to consult all sources of lightning information (i.e., both GLMs and any available ground-based networks) during warning operations to account for known limitations





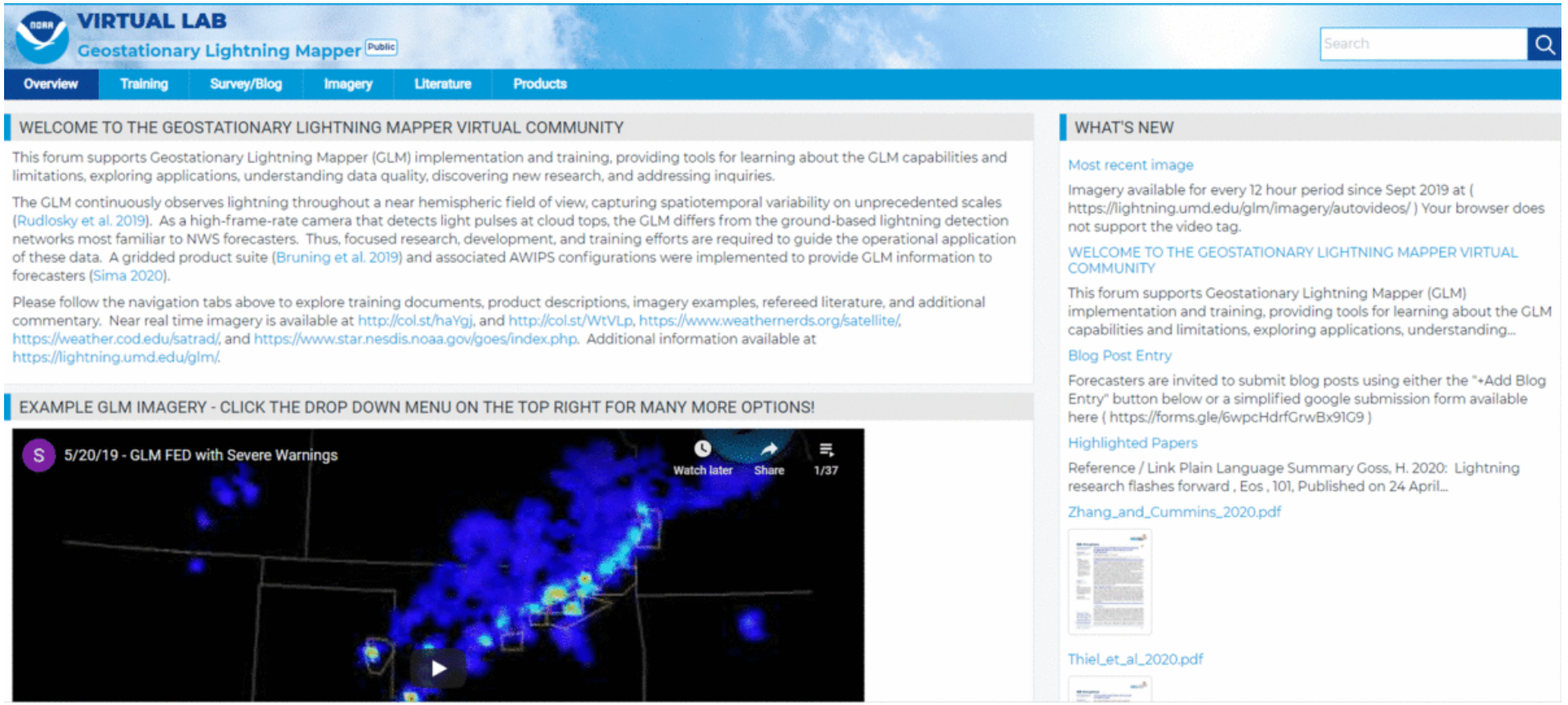
GLM in the National Weather Service

- GLM observations fundamentally differ from the ground-based lightning data most familiar to NWS forecasters
- Initial demonstrations revealed that the early GLM tools were not well suited for real GLM data
- Motivated an intensive effort to develop a new suite of gridded GLM products tailored to NWS operations
- Gridded GLM products disseminate the spatial footprint information and greatly reduce file size
- Gridded GLM products re-navigate the GLM event latitude / longitude to the 2×2 km Advanced Baseline Imager (ABI) fixed grid



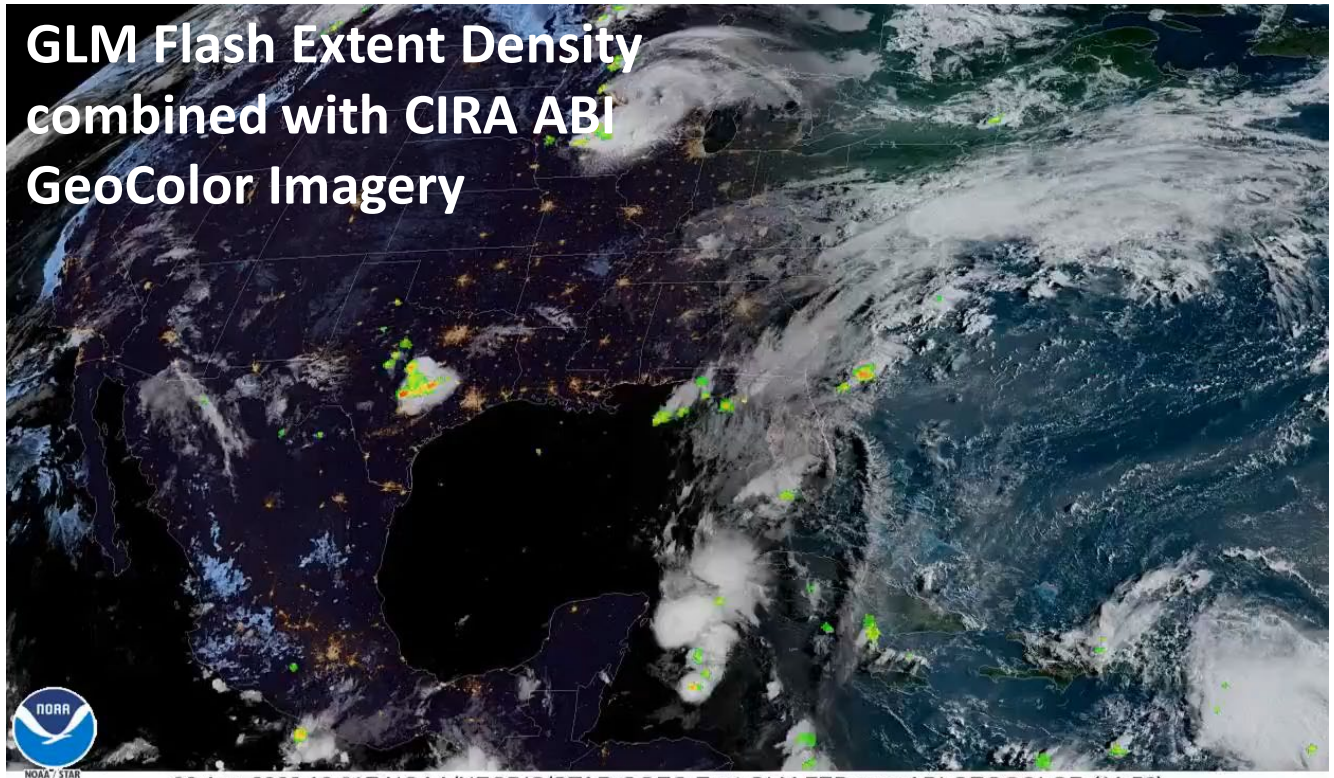
GLM NWS Virtual Lab Webpage

- **GLM VLab page provides additional information on GLM gridded products, example imagery, links to training materials, a literature overview, and example use cases**
  - https://vlab.ncep.noaa.gov/web/geostationary-lightning-mapper



GLM Applications

- **Recent GLM value assessment identified wide-ranging economic and societal benefits, especially when combined with other data**
  - https://repository.library.noaa.gov/view/noaa/27429



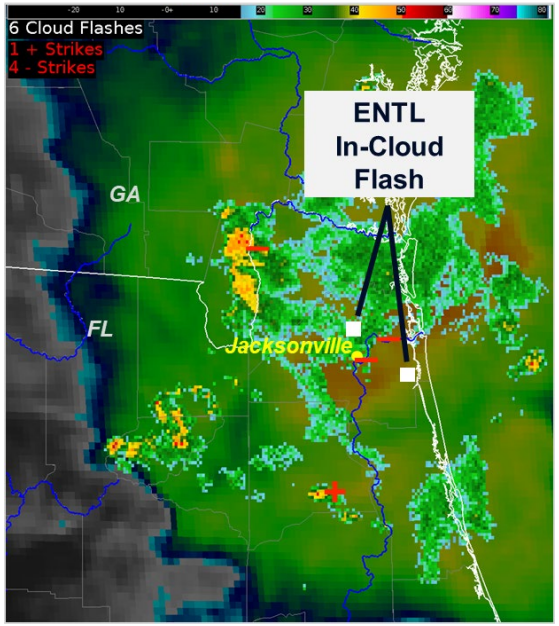
22 Aug 2020 12:01Z NOAA/NESDIS/STAR GOES-East GLM FED over ABI GEOCOLOR (11:56)

GLM Application
(1) Severe Local Storms
(2) Aviation Hazards / Airport Advisories
(3) TC Structure / Rapid Intensification
(4) Data Assimilation / Model Initialization
(5) WSR-88D Outages / Limitations
(6) Wildfire Initiation
(7) Precipitation Estimation
(8) Offshore Convection
(9) Climate
(10) Public Safety

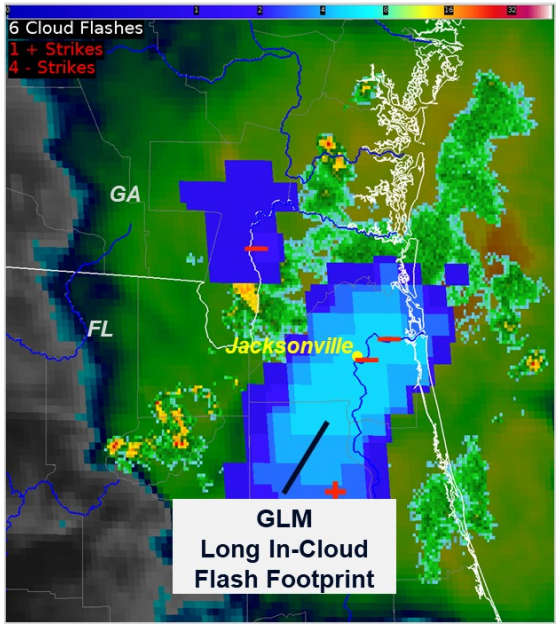
Improving Lightning Safety

- **The GLM improves public safety across broad segments of society, and the socioeconomic benefit continues to grow as access is gained by users traditionally unable to afford lightning data (e.g., emergency managers, event organizers, local athletics officials, and the public)**

ENTL Observations



GLM Observations

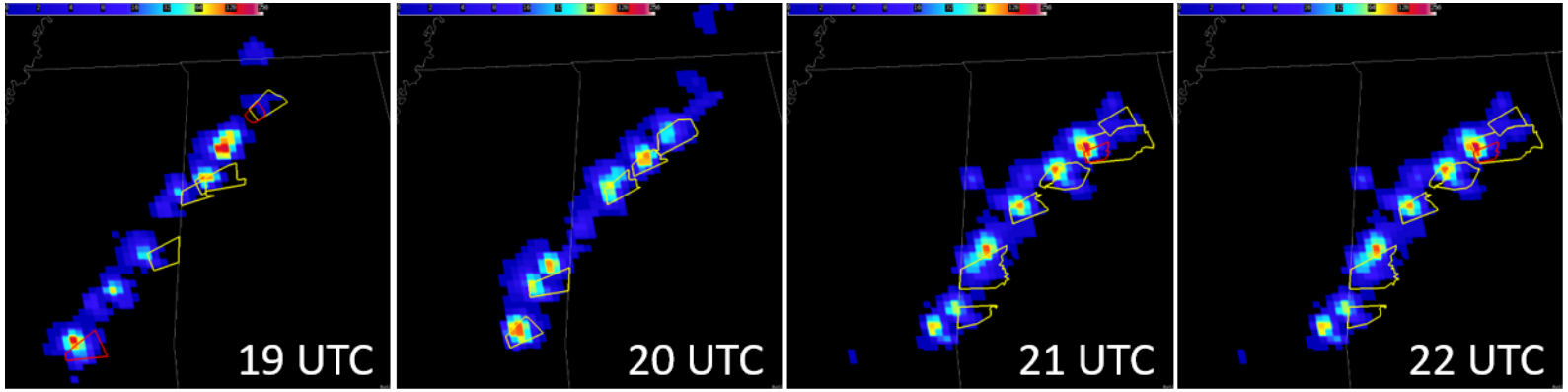


GLM depicts the entire flash footprint, revealing a connection between these distant storm cores not readily apparent with the ENTLN flash locations

Video shows long lightning channel striking ground several km apart

Improving Severe Thunderstorm and Tornado Warnings

- **Integrating GLM data into the severe weather warning process promotes earlier and easier 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.**



Warmer colors in the Flash Extent Density indicate the most frequent GLM flashes, with maxima commonly collocated with severe thunderstorm (yellow) and tornado (red) warning polygons.

NWS HUN GLM Survey

"In what ways do you use GLM during convective events, if any?"

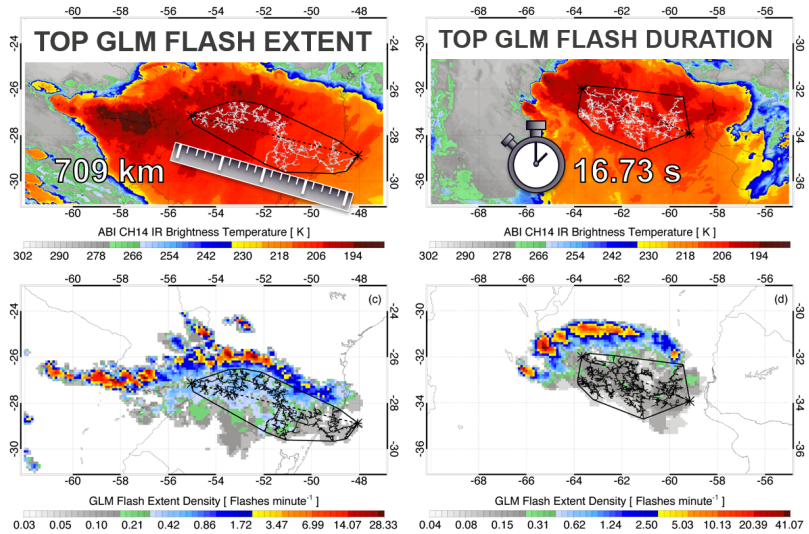
GLM Value Assessment Summary

- **Only four years since becoming reality, the GLM is shown to be establishing a legacy of applications likely to become ubiquitous across a wide variety of meteorological domains.**
- **The GLM now provides a national and international baseline of freely available lightning data and establishes a baseline for widespread government and industry implementation.**
- **The GLM moves from traditional point sources of lightning information to a rapidly-updating 2-D map that accurately portrays the full spatial extent of lightning activity.**
- **Many operational users (e.g., NWS) have eagerly embraced this new source of lightning information and incorporated it into their workflow.**
- **The GLM value will quickly multiply as the realized benefits spread.**
- **Despite widespread use of lightning datasets, the GLM remains in its infancy and much of its value still waiting to be fully realized.**

GLM Plans

- **Harden GLM gridded product path and expand applicability**
  - **NESDIS generation and dissemination**
  - **Integrate with other product lines**
- **Triple wide DC restore testing on G16, then G17 if successful**
  - **FM3/4 testing revealed potential improvement for G16/17 GLMs**
- **G17 Full Maturity Review**
- **GEO-XO Planning**
  - **Better quantify GLM value**
  - **Begin exploring focal plane designs**
- **GOES-T Launch and Checkout**
  - **Process was streamlined during G16 checkout**
  - **Plans/timelines remain similar for GOES-T**

World Record Lightning Flashes



- *Megaflashes can individually produce up to 100 CGs*
- *Larger megaflashes more likely to have more CGs*
- *CGs can occur over 80% of the megaflash extent*
- ***Challenges the 30/30 rule!***

**CG = cloud-to-ground lightning strike*

From Peterson et al. (2020)

Links

- GLM Value Assessment – https://repository.library.noaa.gov/view/noaa/27429
- GLM Vlab – https://vlab.ncep.noaa.gov/web/geostationary-lightning-mapper
- UMD GLM Page – https://lightning.umd.edu/glm/
- Recent publication – https://doi.org/10.1175/MWR-D-20-0242.1
- Links to routinely available imagery (e.g., STAR page)
  - NESDIS/STAR GOES Viewer – https://www.star.nesdis.noaa.gov/GOES/index.php
  - Weathernerds Webpage – https://www.weathernerds.org/satellite/
  - COD Meteorology Webpage – https://weather.cod.edu/satrad/