

Image Credit: NOAA

Introduction to Lightning Observations and Applications

Part 3: Geostationary Lightning Mapper Observations, Lightning Data Access, and Applications

Scott Rudlosky (NESDIS/STAR)

April 2, 2024



Training Outline

Part 1

Background and
History of Lightning
Measurements

March 26, 2024

Part 2

Overview of Current
Lightning Data
Products from
Remote Sensing and
Ground-based
Measurements

March 28, 2024

Part 3

**Geostationary
Lightning Mapper
Observations and
Applications**

April 2, 2024

Homework

Opens April 2 – Due April 17 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



Review of Part 2

- A breadth of NASA lightning datasets, from spaceborne missions and from ground-based and airborne suborbital datasets.
 - MicroLab1/Orbview-1 Lightning Measurements using Optical Transient Detector (OTD)
 - TRMM and International Space Station Lightning Imaging Sensor (LIS)
 - Geostationary Lightning Mapper (GLM) on GOES
 - NASA Astrophysics instruments like the Gamma-ray Burst Monitor (GBM) on the Fermi satellite (short-term lightning)
- Multiple different global spaceborne lightning climatology datasets for different science and application needs.
- NASA ground-based, long- and short-term, suborbital lightning data from Lightning Mapping Array (LMA), and airborne lightning datasets from Lightning Instrument Package (LIP), Fly's Eye GLM Simulator (FEGS), and Electric Field Change Meter (EFCM).
- The Global Hydrometeorological Research Center ([GHRC](#)) DAAC archives most spaceborne & suborbital lightning datasets and leverages NASA Earthdata Search and other tools to help discover and deliver them.



How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



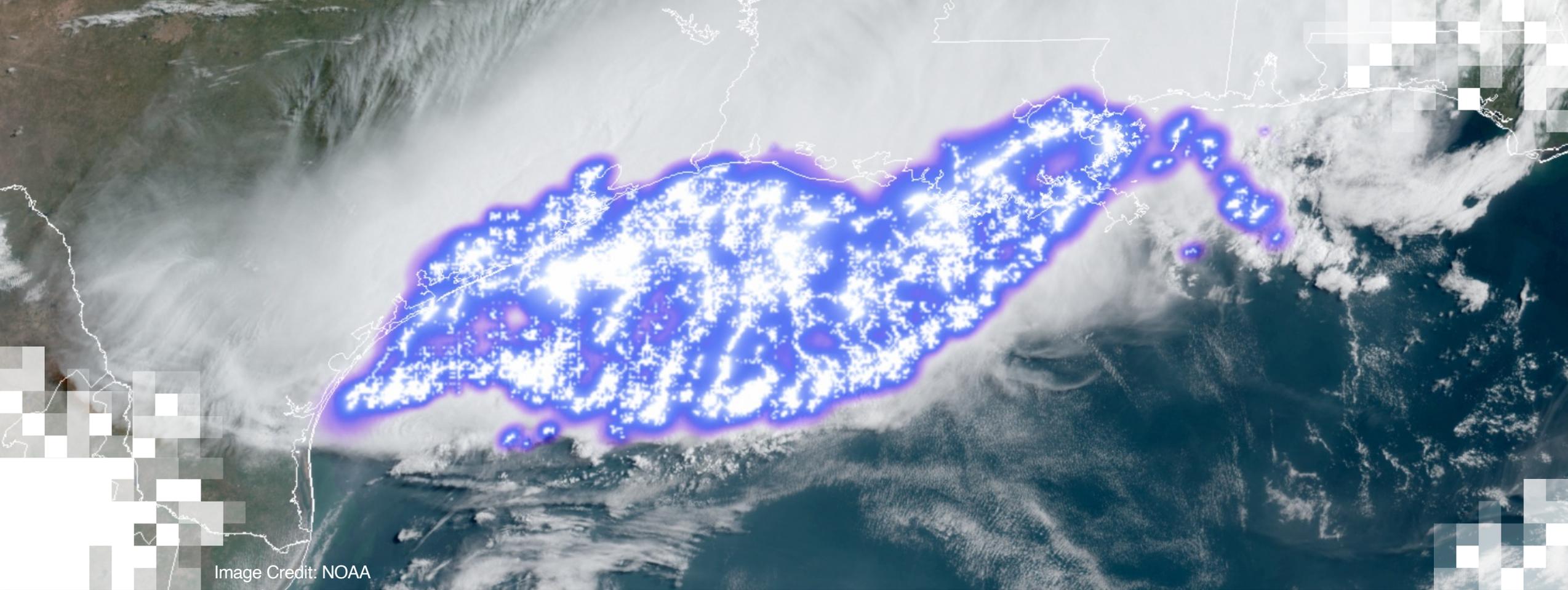
Part 3 – Trainers

Scott Rudlosky
Physical Scientist
NOAA/NESDIS



Christopher Schulz
Guest Contributor
Research AST, Meteorological
Studies
NASA-MSFC





Part 3

GLM Observations and Applications

Part 3 Objectives

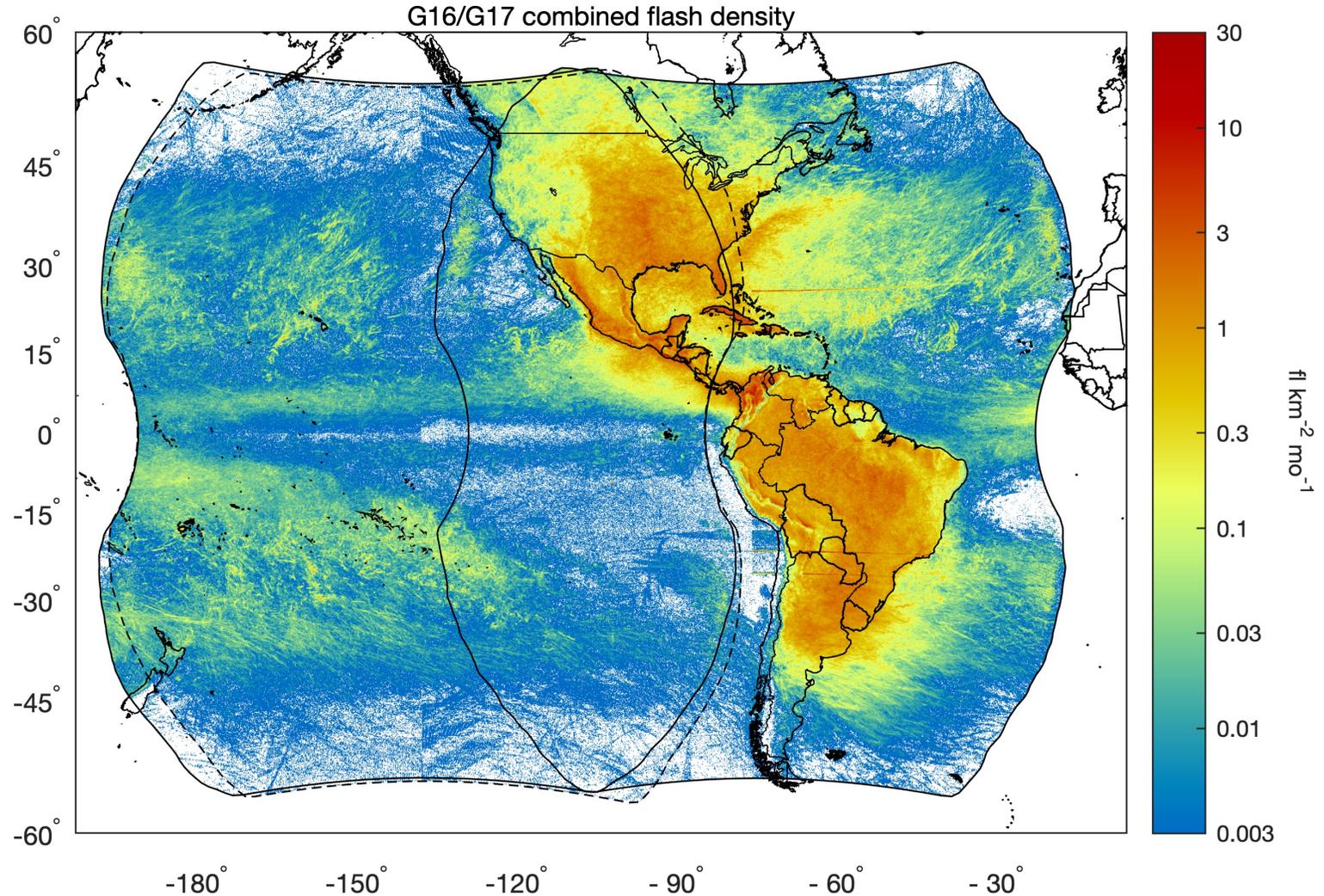
By the end of Part 3, participants will be able to:

- Understand the basics of lightning observation from geostationary orbit
- Recognize the importance of the GLM's broad coverage and rapid updates
- Describe multiple GLM applications
- Access archived and real-time GLM imagery



Geostationary Lightning Mapper

- Two GLMs now provide continuous, real-time lightning monitoring throughout most of the Western Hemisphere.
- First of its kind instrument, discovering new things daily
- GLM capabilities, products, and applications continue to evolve



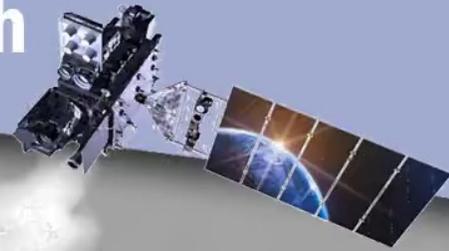
Created by Katrina Virts



Geostationary Lightning Mapper

- Videos clearly show the 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

GLM Daily Lightning Flash

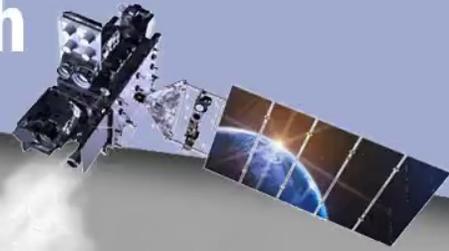


GOES16/GLM 05/23/2020 08:39:22 UTC

291 Series
2817 Groups
16487 Events
6320 ms Duration
302,055 km Group Separation

05/23/2020

GLM Daily Lightning Flash



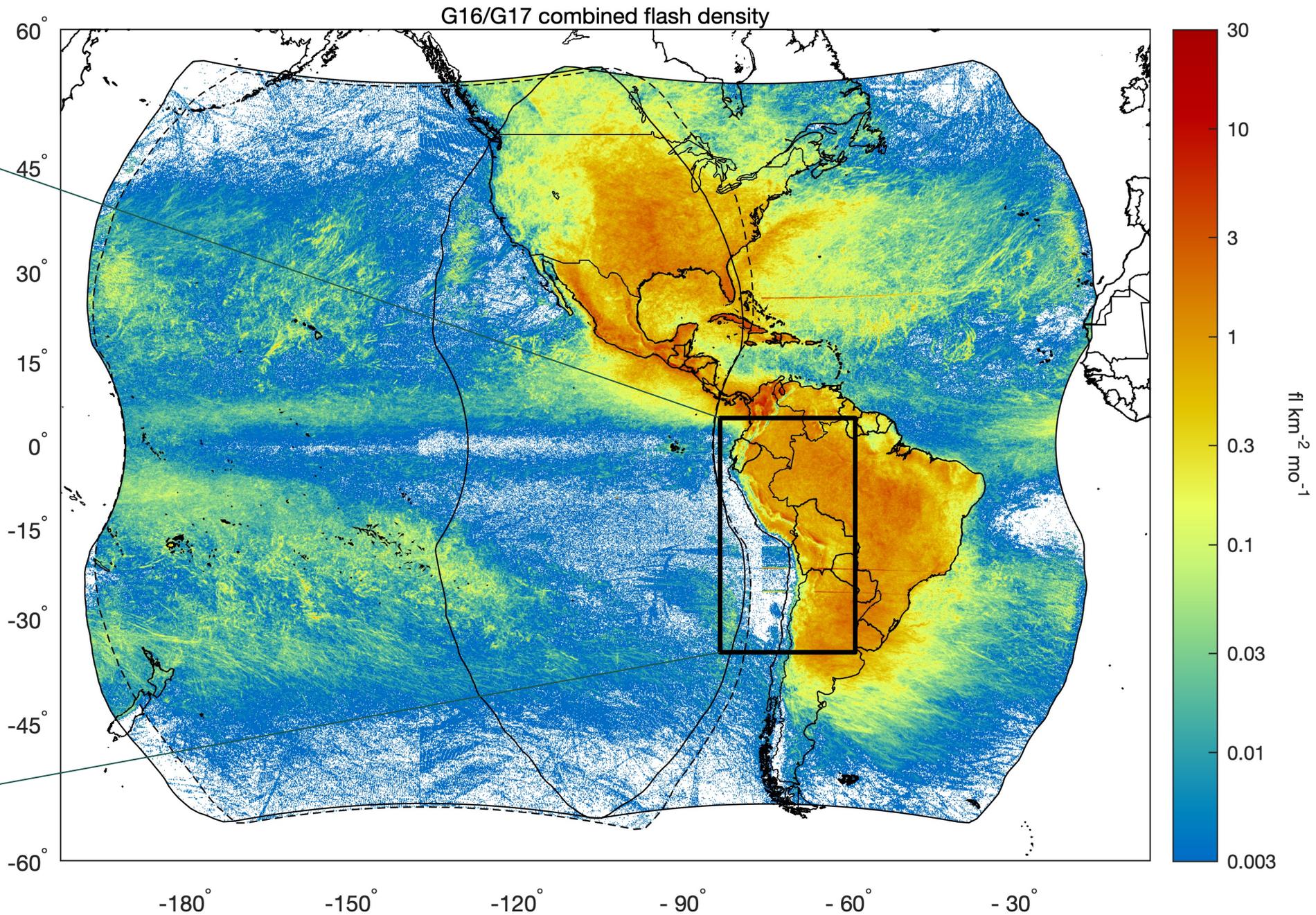
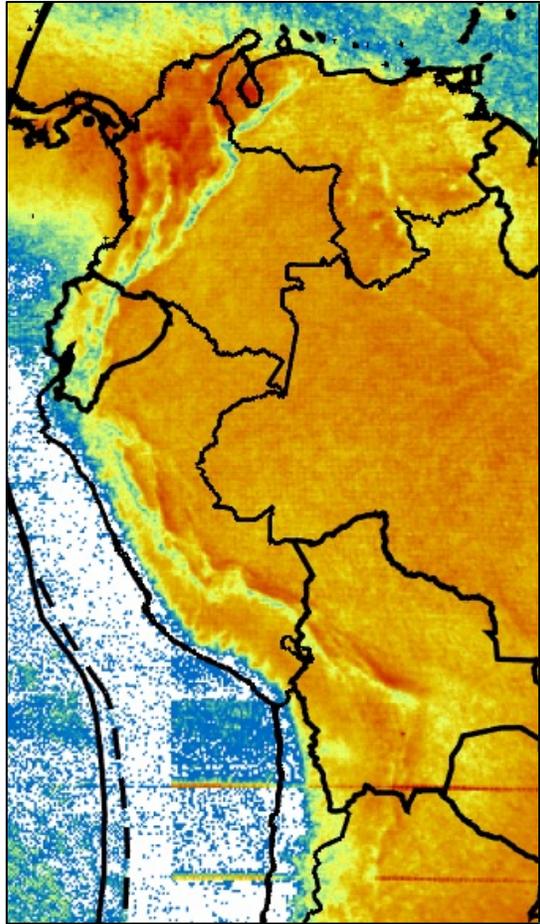
GOES17/GLM 05/23/2020 08:39:22 UTC

308 Series
1799 Groups
9196 Events
6016 ms Duration
299,994 km Group Separation

05/23/2020



GLM FOV

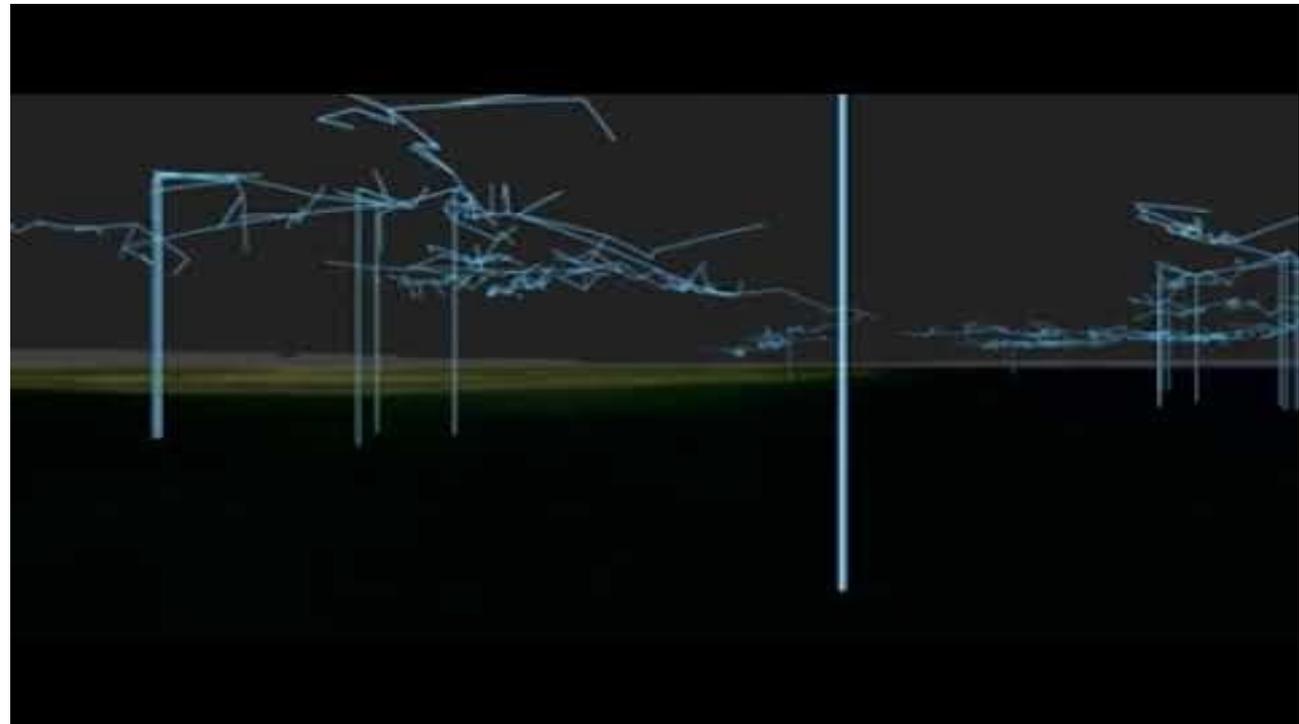
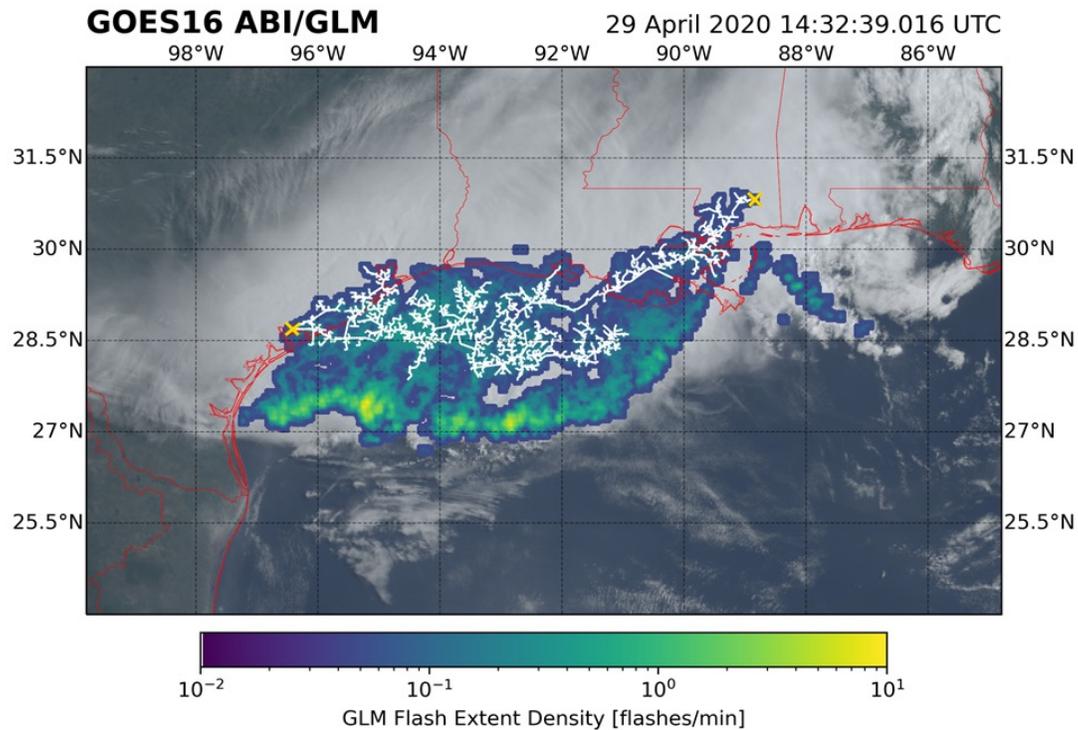


World Record Lightning Flash



World Record Lightning Flash

- Longest Lightning Flash Ever? [ArcGIS Story Map](#)
- World record flash covered a horizontal distance of 768 km (477.2 miles) on 4/29/20

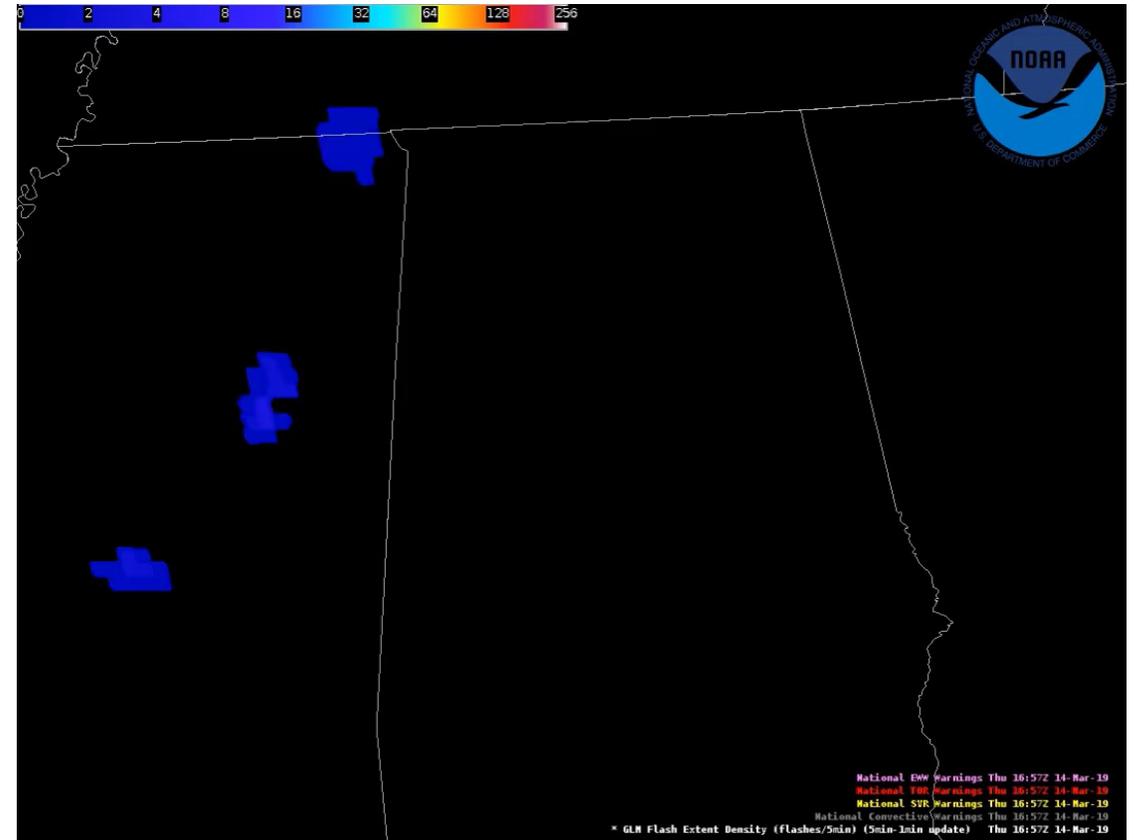


Simulated View from Ground Level (real lightning channels connecting to known ground strike points)



GLM in the National Weather Service

- GLM observations fundamentally differ from the ground-based lightning data most familiar to NWS forecasters
- Developed 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

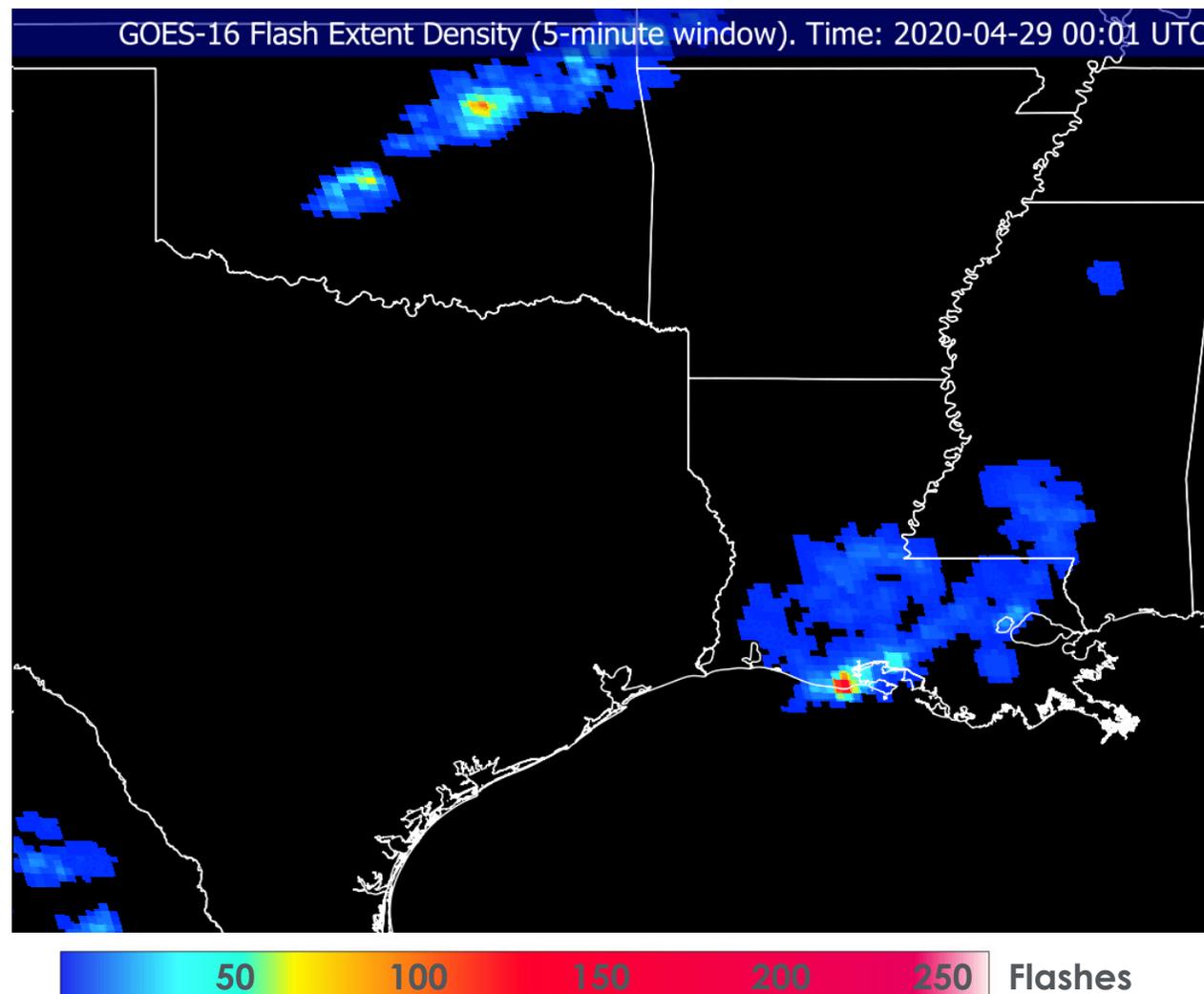


GLM Flash Extent Density (FED) Overlaid with Severe Thunderstorm and Tornado Warning Polygons



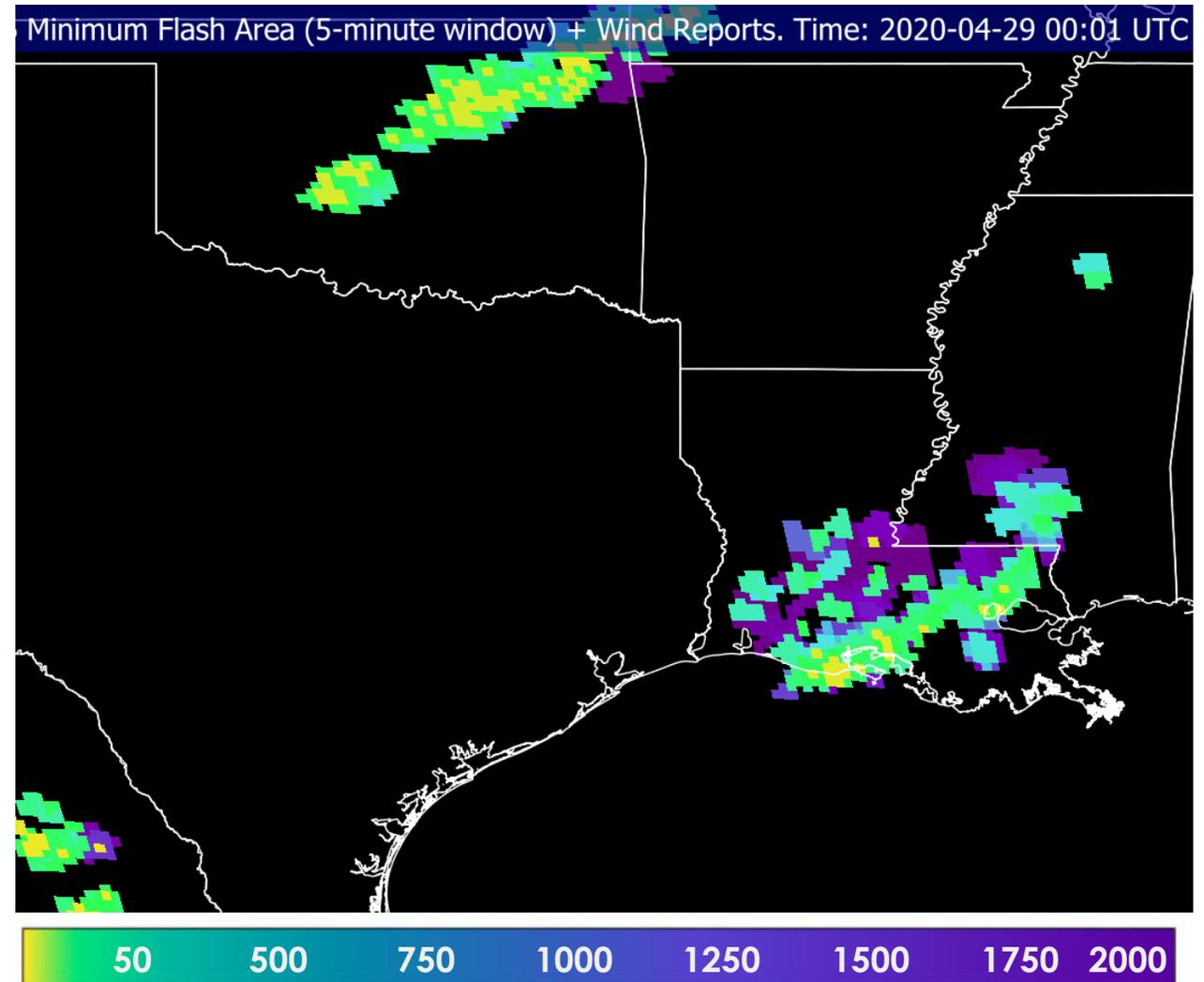
Gridded/Accumulated GLM Products

- **Flash Extent Density (FED)** – Number of flashes coincident with each grid cell during a specified time period
- Updraft cores often indicated by greater FED values (warmer colors)
- Most frequent lightning is often collocated with severe weather
- Rapid updates can be too rapid
- Forecasters typically prefer the 5-min window products due to their smoothness and clearer depiction of trends



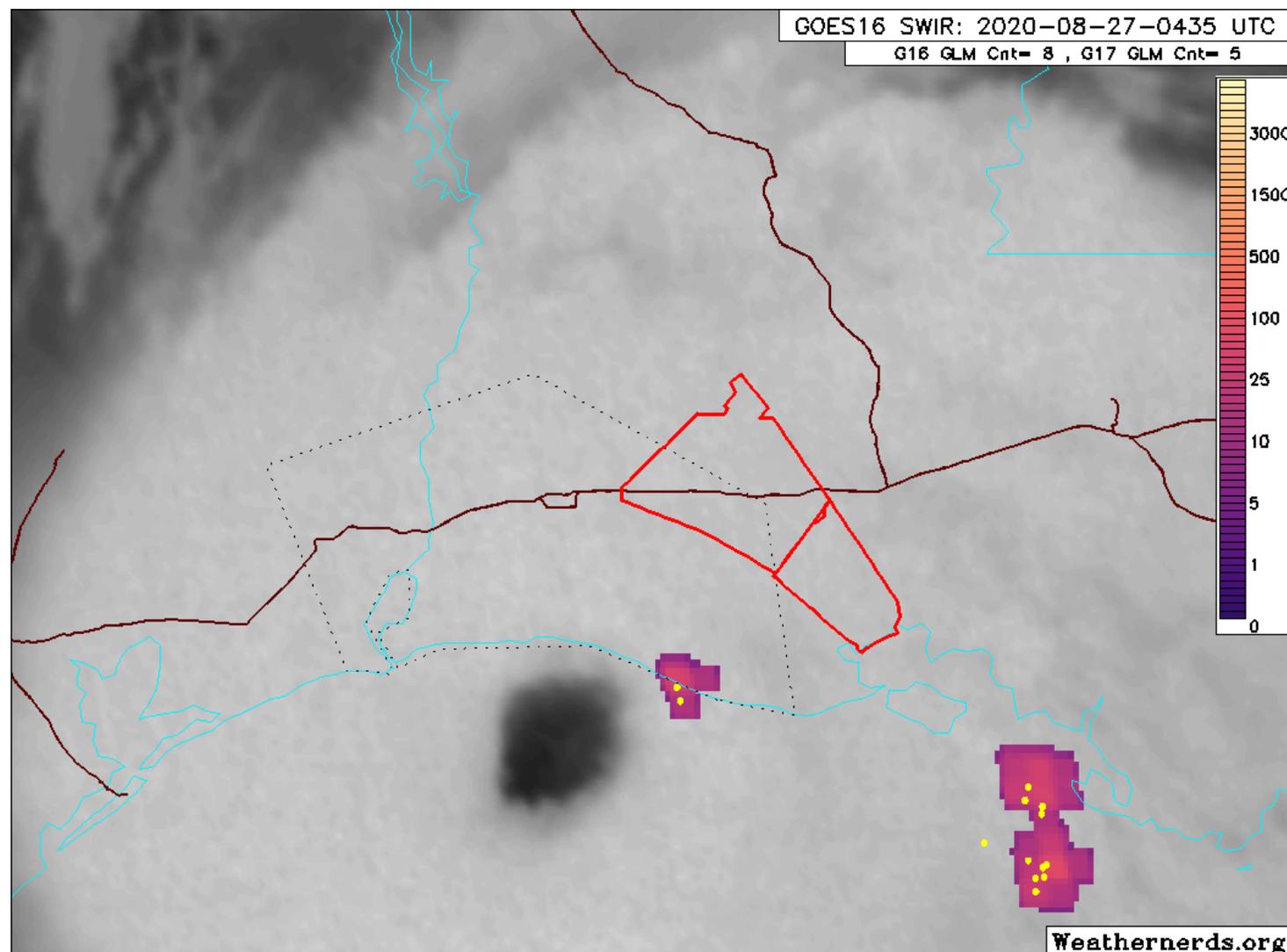
Gridded/Accumulated GLM Products

- **Minimum Flash Area** – Size (km^2) of the smallest flash coincident with each grid cell during a specified time period
- Small flashes in new/intense convection and along the leading line
- Larger flashes in the stratiform/anvil regions and decaying storms



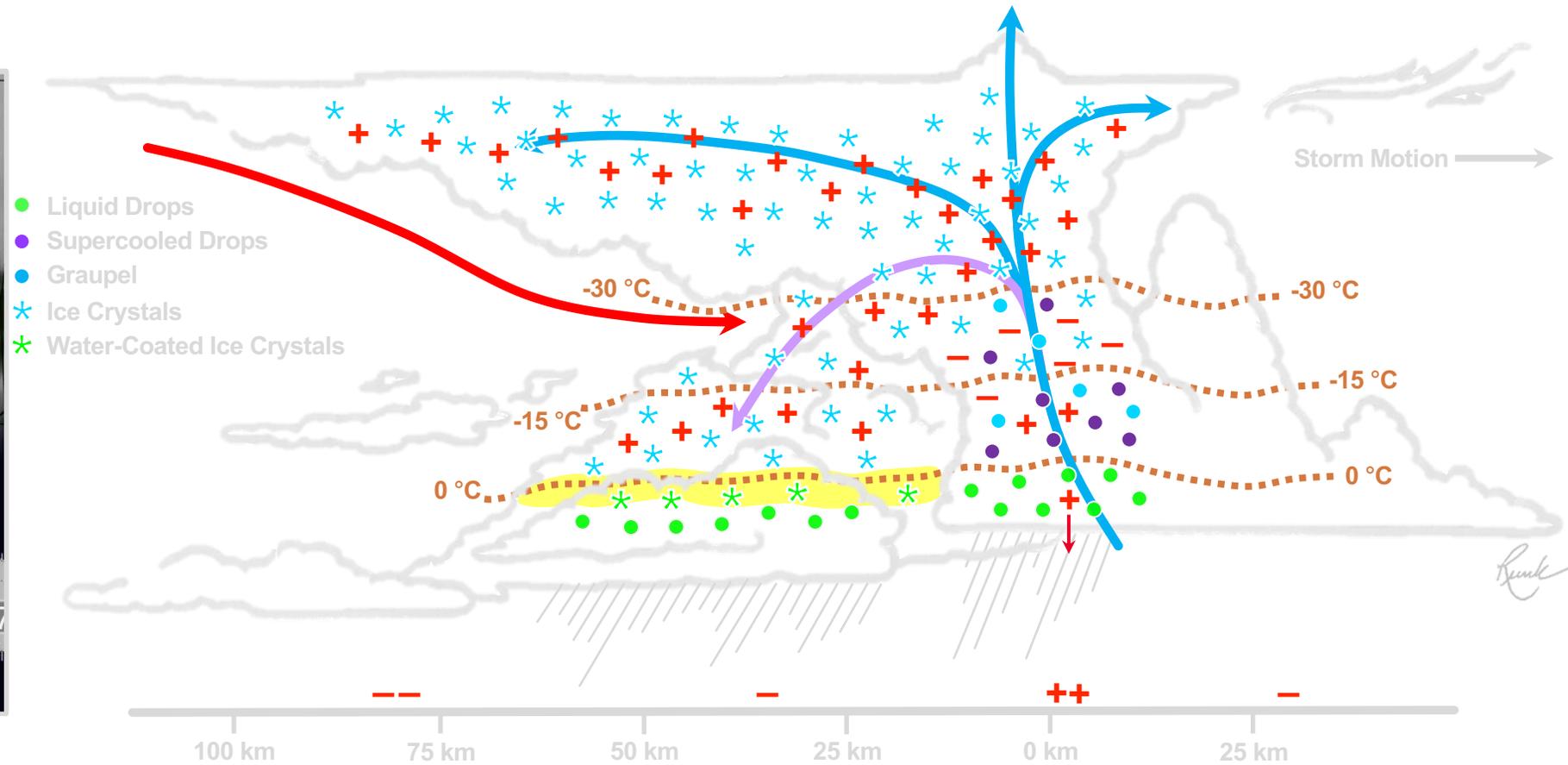
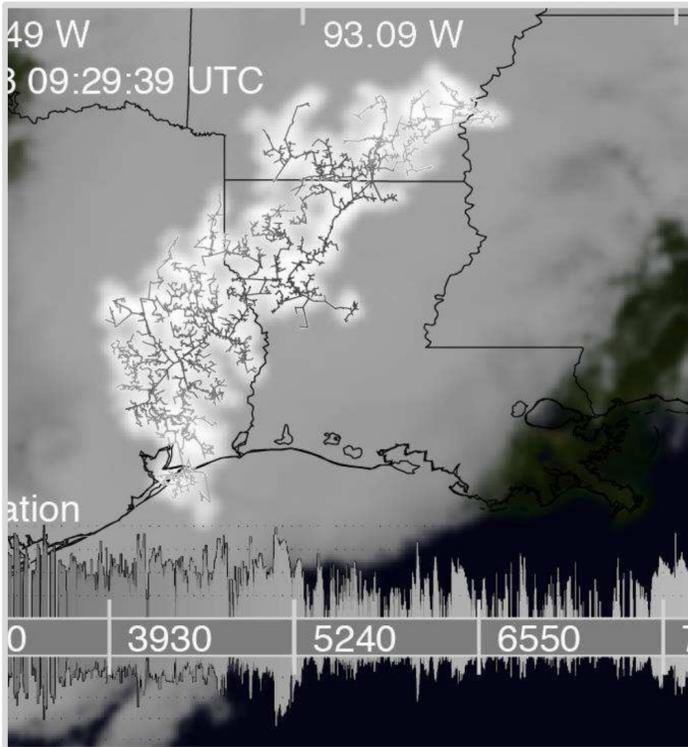
Gridded/Accumulated GLM Products

- **Total Optical Energy** – Sum of all optical energy observed within each grid cell during a specified time period
- Bright regions in the TOE indicate:
 - The most energetic convective cores
 - Lightning channels within extensive stratiform flashes
- Real time imagery available via <https://www.weathernerds.org>



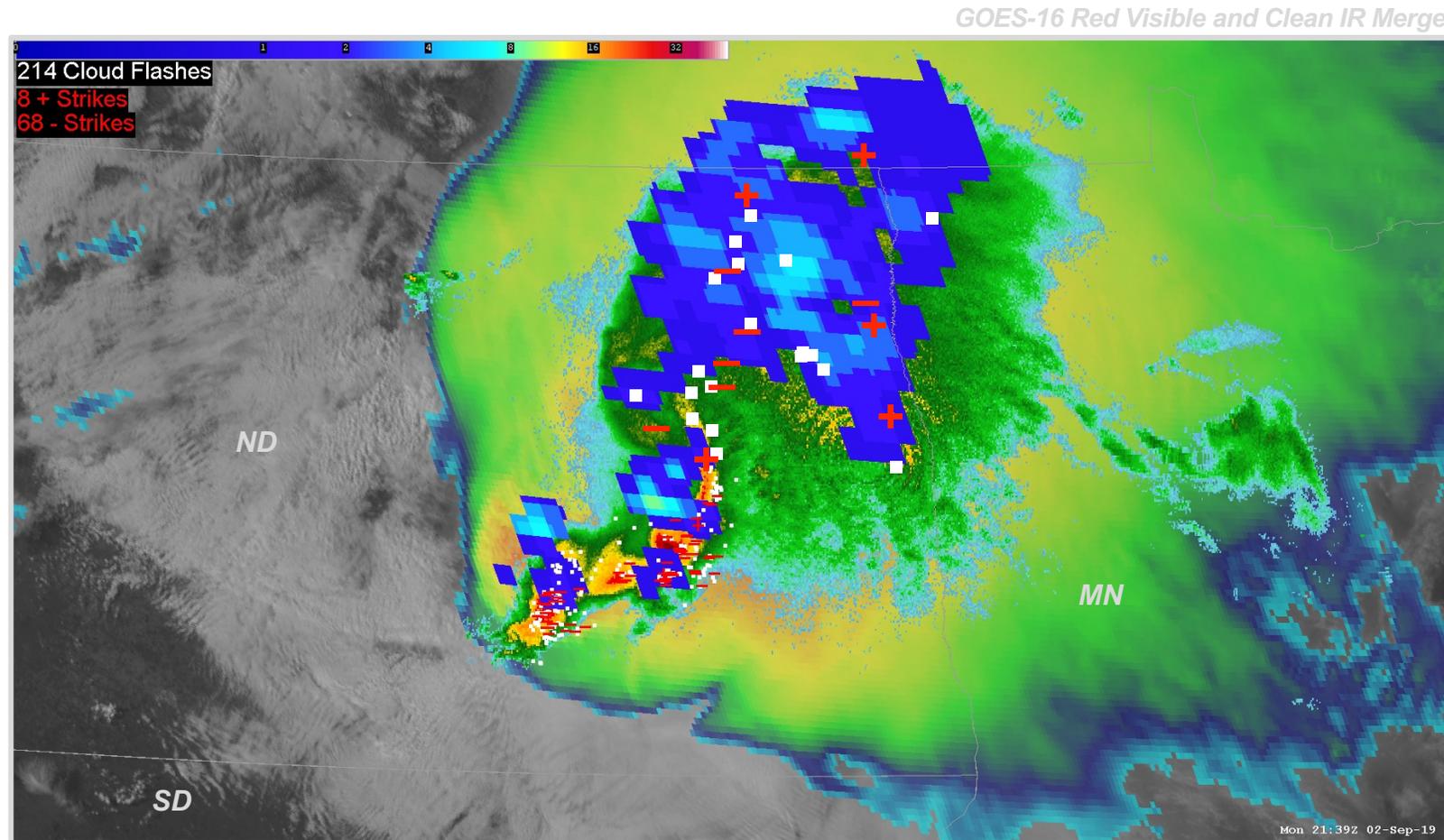
NWS Application: Detecting Long Flashes

- Simplified Conceptual Model



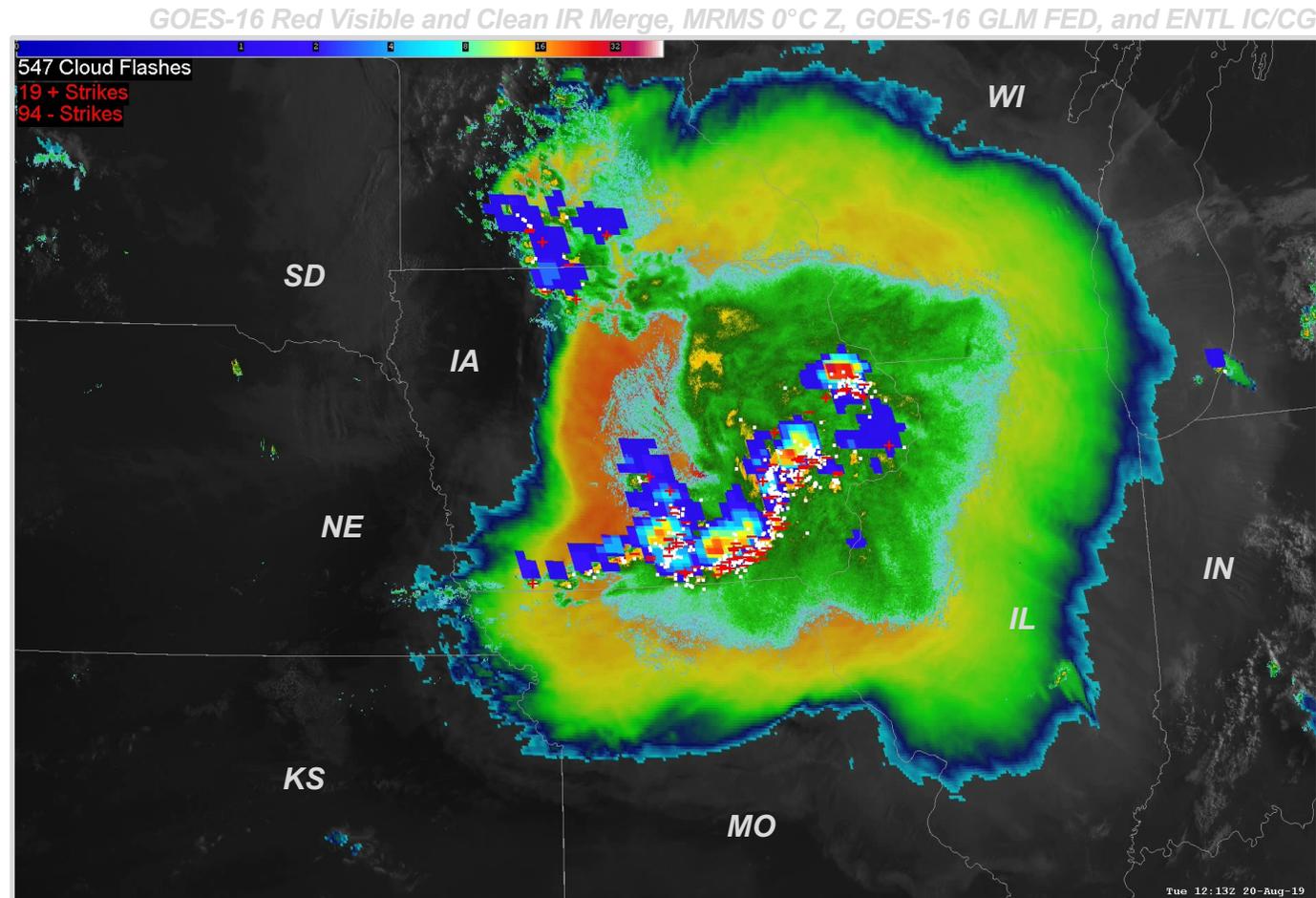
NWS Application: Detecting Long Flashes

- Applying the Conceptual Model to Operations



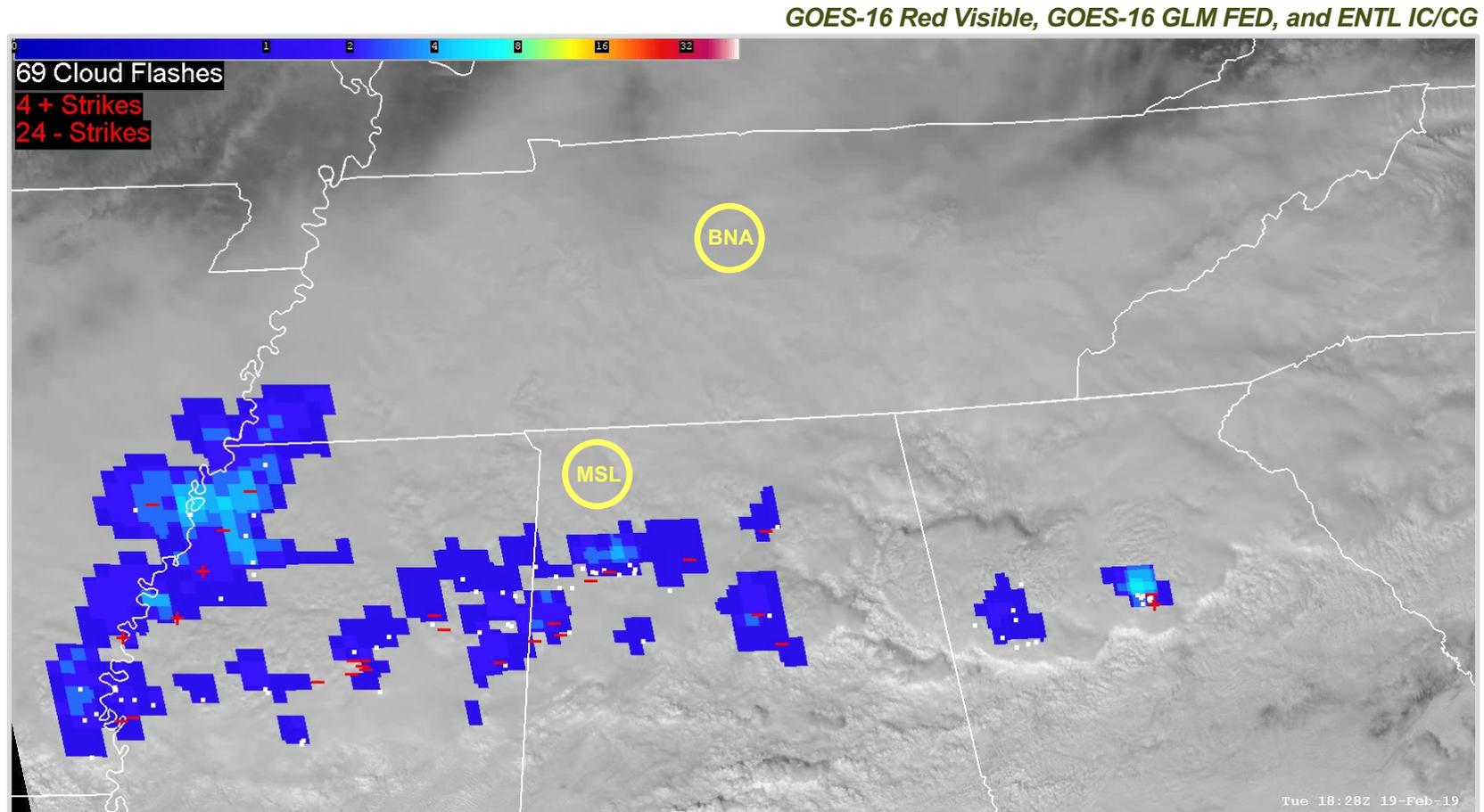
NWS Application: Detecting Long Flashes

- Well-developed storm systems can produce frequent, enormous flashes.



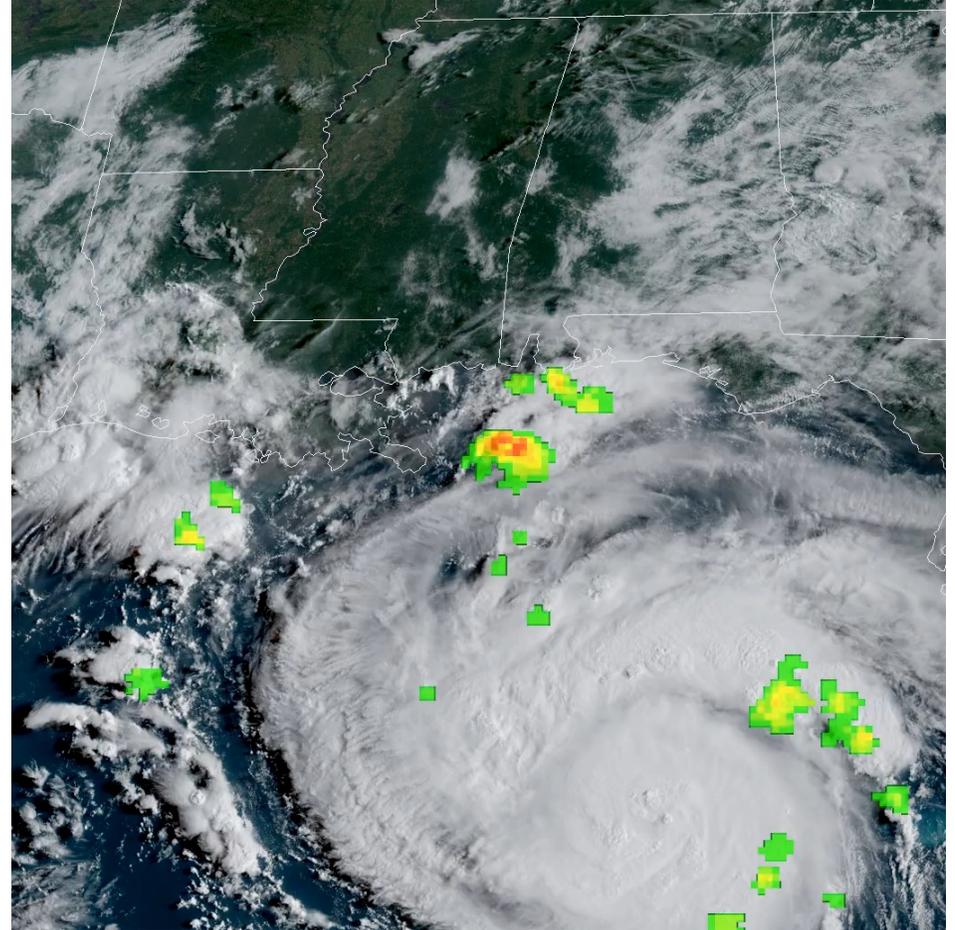
NWS Application: Detecting Long Flashes

- Adding confidence and value to existing NWS products



GLM Value Assessment Overview

- **GLM Value Assessment** aims to advise future satellite architecture decisions
- Study evaluates GLM value by documenting benefits to the public via decisions made by end users
- Identify well-documented benefit pools where the GLM adds value, and suggest analysis required to accurately document which fraction of this value is being realized
- Operational use cases help illustrate GLM value being realized through operational decisions by a wide variety of decision makers (i.e., both NWS and non-NWS)



GLM Applications

- [Recent GLM Value Assessment](#) identified wide-ranging economic and societal benefits, especially when combined with other data

GLM Application Areas

Improving Lightning Safety

Improving Severe Thunderstorm and Tornado Warnings

Improving Safety and Effectiveness of Wildfire Response

Improving Short-term Model Forecasts (Data Assimilation)

Improving Precipitation Estimation

Improving Tropical Cyclone Diagnosis and Warning

Improving Climate Applications

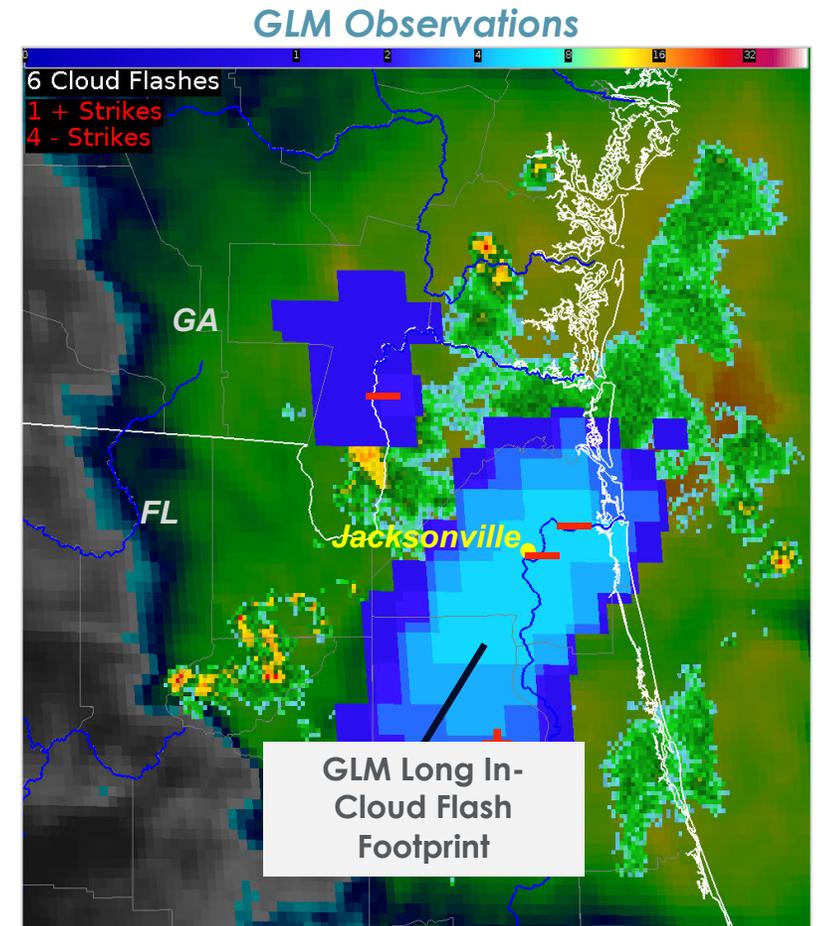
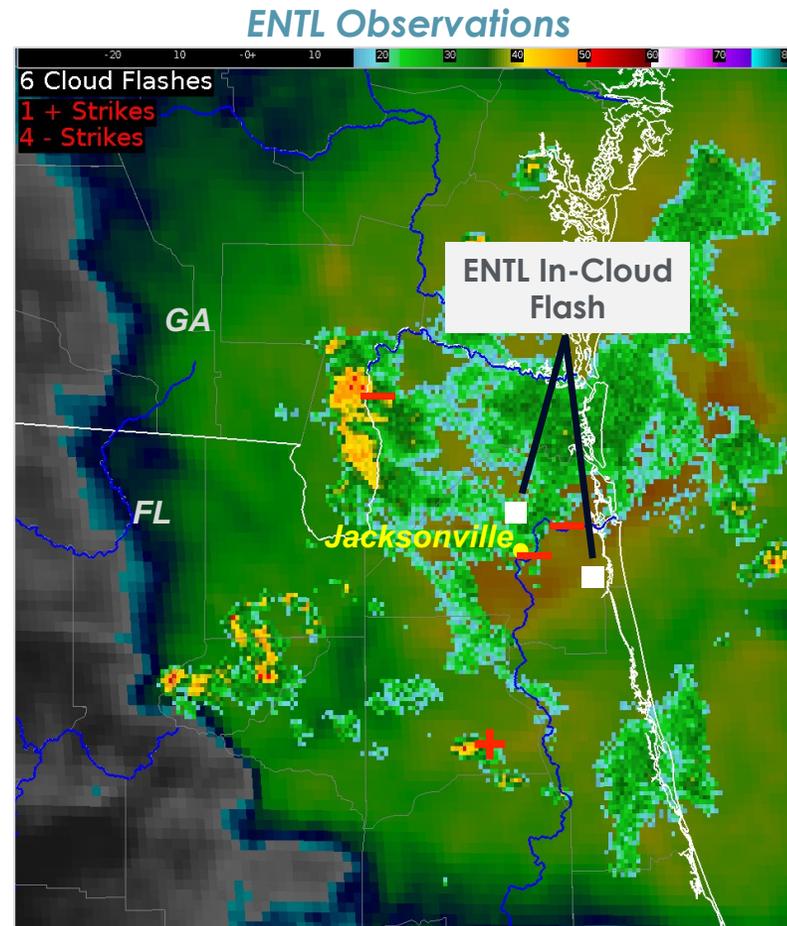
Value of Filling Data Gaps

Value of Mitigating Aviation Hazards



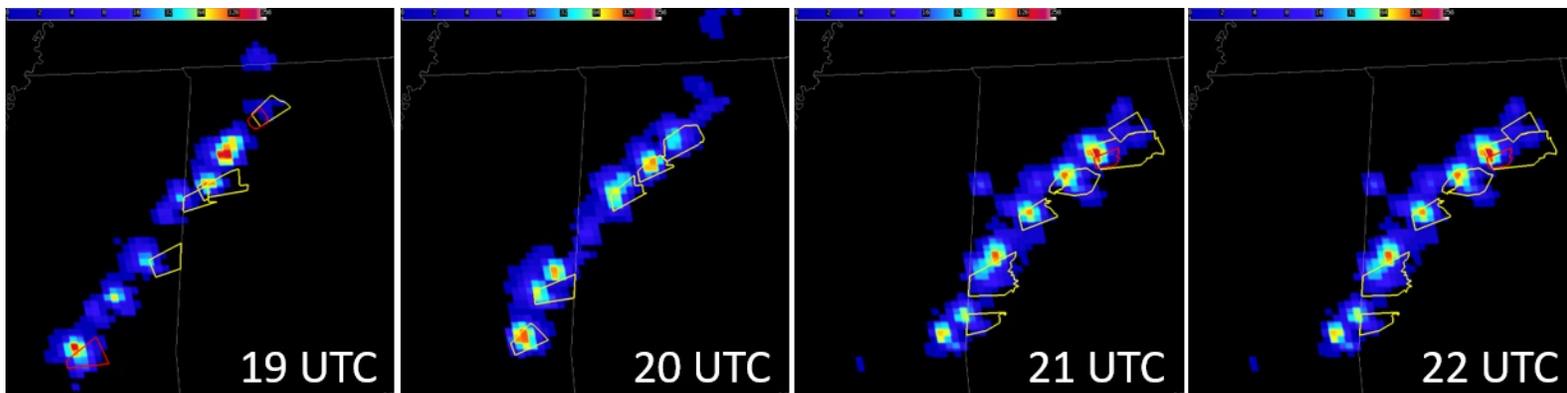
Improving Lightning Safety

- GLM improves public safety across broad segments of society.



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.

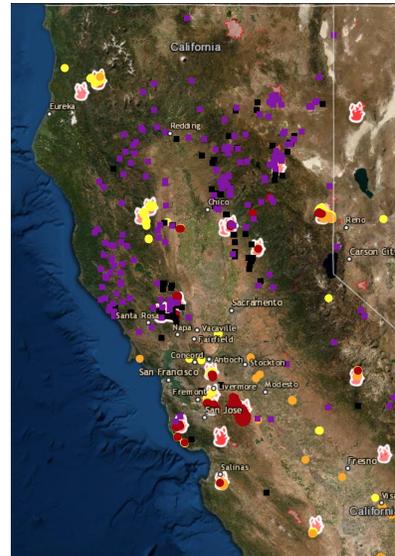
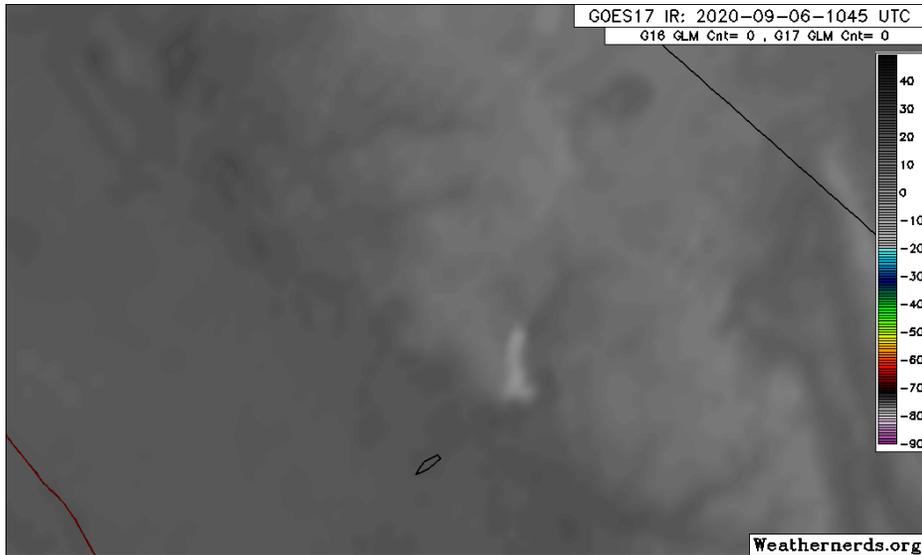
NWS HUN
GLM
Survey

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



Improving Safety and Effectiveness of Wildfire Response

- The GLM benefits the firefighting community through unique identification of continuing current lightning strikes most likely to ignite fires, better pyrocumulonimbus characterization, and thunderstorm tracking in areas lacking robust radar coverage.



CALIFORNIA STATEWIDE FIRE SUMMARY

THURSDAY, AUGUST 27, 2020



OVER 300
DOZERS

270
FIRE CREWS

OVER 15,600
FIREFIGHTERS/PERSONNEL

OVER 370
WATERTENDERS

OVER 2,400
FIRE ENGINES

MORE THAN 15,600 FIREFIGHTERS TODAY ARE BATTLING OVER TWO DOZEN MAJOR FIRES AND LIGHTNING COMPLEXES ACROSS CALIFORNIA. IN THE PAST 24-HOURS THERE WERE OVER TWO DOZEN LIGHTNING STRIKES IN NORTHERN CALIFORNIA. SINCE THE LIGHTNING SIEGE THAT STARTED ON SATURDAY, AUGUST 15, 2020, THERE HAVE BEEN MORE THAN 700 NEW WILDFIRES, WHICH HAVE NOW BURNED OVER 1.35 MILLION ACRES.



California Statewide Fire Summary

Sunday, September 27, 2020

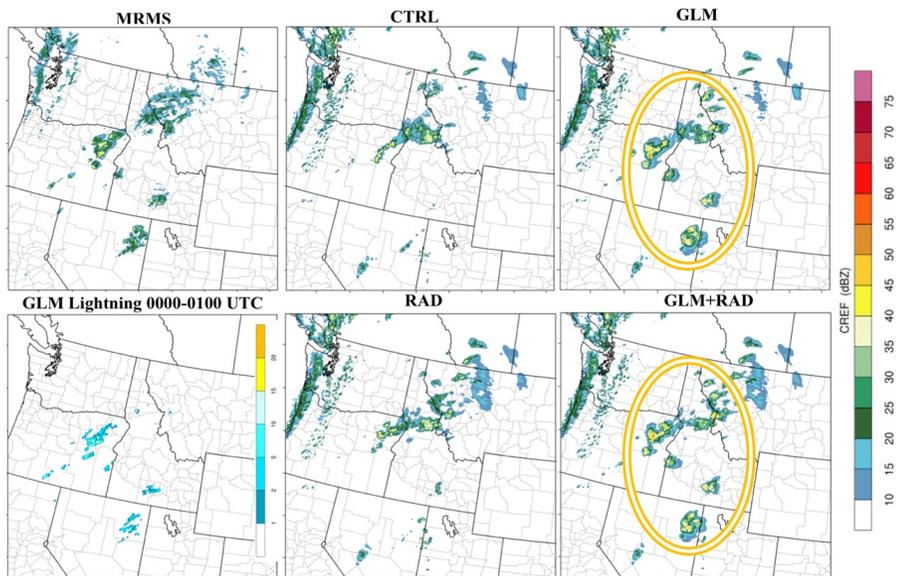
Today there are 17,000 firefighters battling 26 wildfires that in total have burned over 3.3 million acres



Improving Short-term Model Forecasts (Data Assimilation)

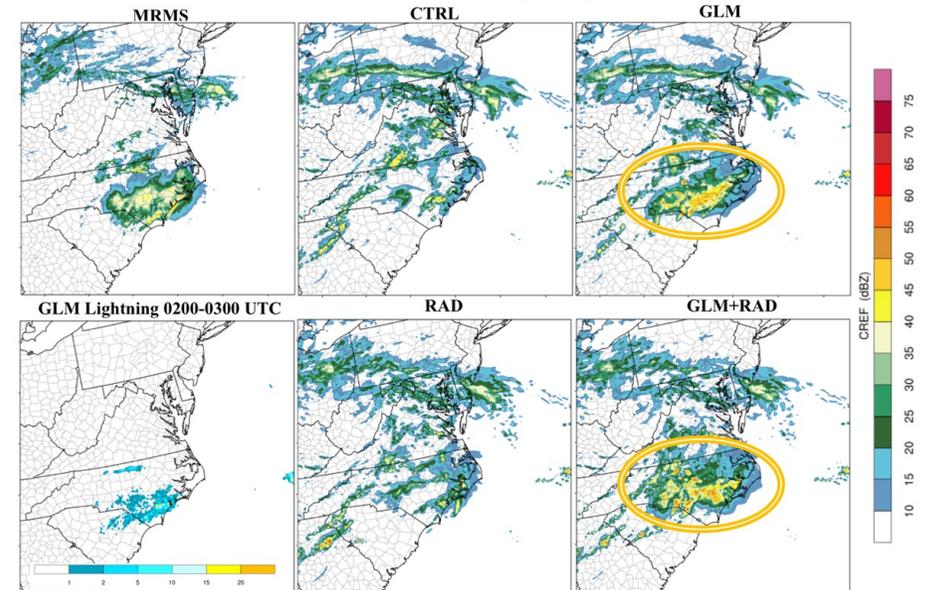
- Lightning data assimilation (DA) is relatively new, especially GLM DA, but early results indicate many benefits, especially for short-range forecasts of radar reflectivity, accumulated precipitation, and lightning threat in convection-allowing models.

1-h Forecast CREF from 00Z April 30, 2020 (subdomain #1)



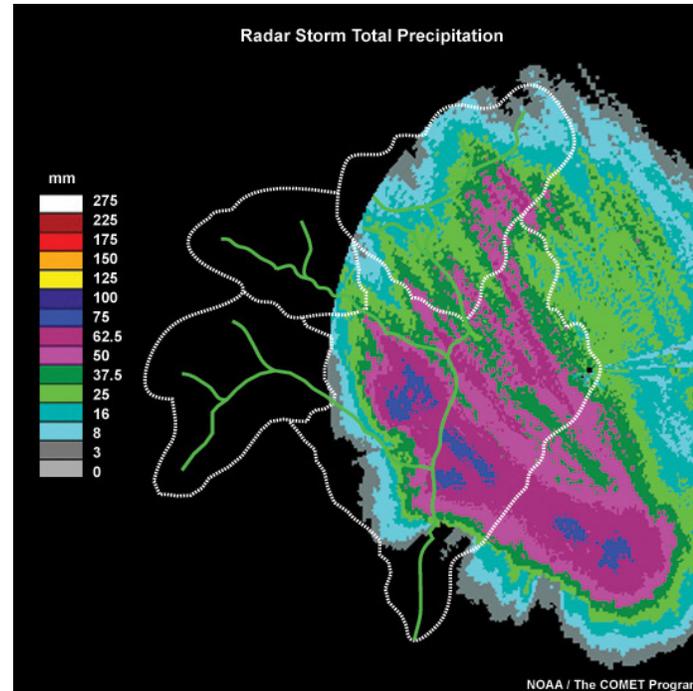
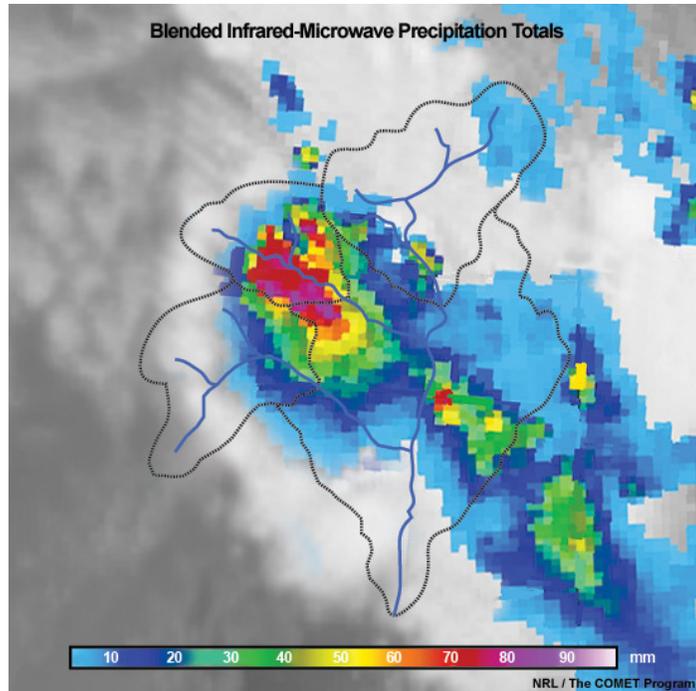
Recent results from Hu et al. 2020 and Fierro et al. (2020) describing experiments at the Hazardous Weather Testbed (presented at the GLM science meeting, manuscripts under review).

3-h Forecast CREF from 00Z, 6 May 2020

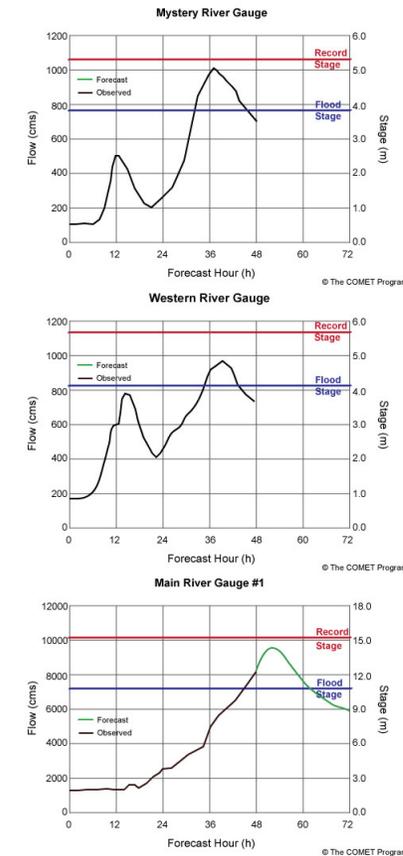


Improving Precipitation Estimation

- The GLM observations improve satellite precipitation estimates, benefiting flash flood forecasting in significant portions of the western US, Hawaii, and US Territorial Islands without adequate radar coverage.

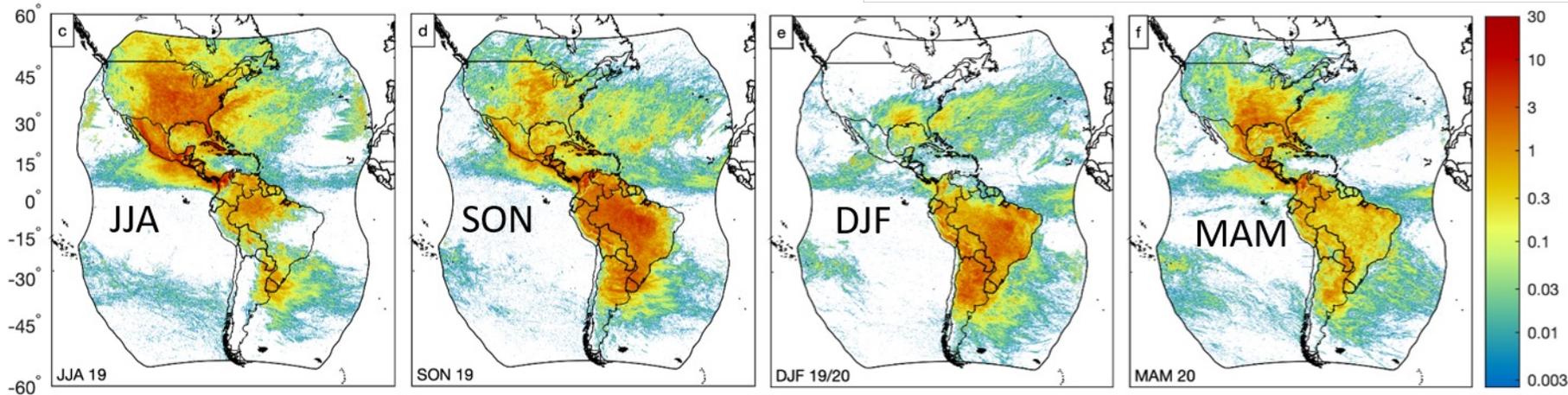
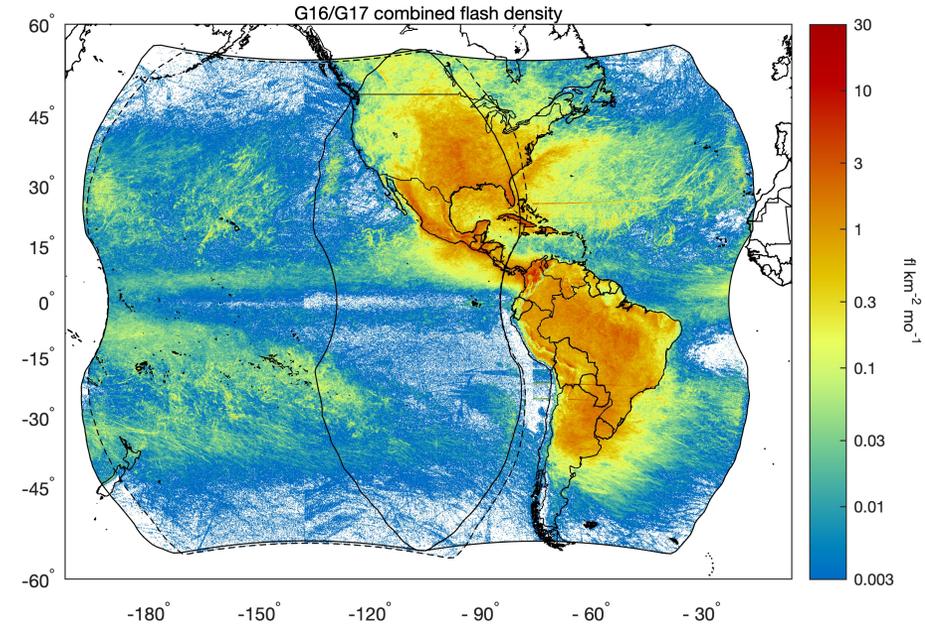


Example from COMET Flood Forecasting Training



Improving Climate Applications

- GLM data offer unique insights for monitoring climate-scale variability and response in a changing climate, a close link between lightning and convective cloud properties makes it an essential indicator of inter-annual to decadal change and a key variable for validating climate models.

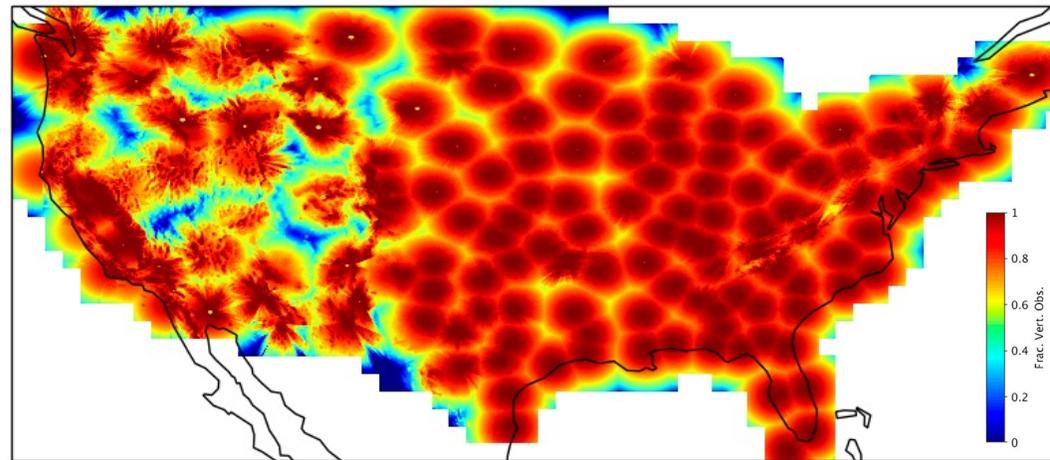


Images from Rudlosky and Virts (2020) – Under Review



Value of Filling Data Gaps

- The GLM's broad spatial coverage and rapid temporal updates complement radar observations over CONUS to better support forecaster warning decisions.
- Rapidly updating GLM observations over vast (often data sparse) regions provide decision makers with information they need to forecast, monitor, and react to thunderstorm hazards.



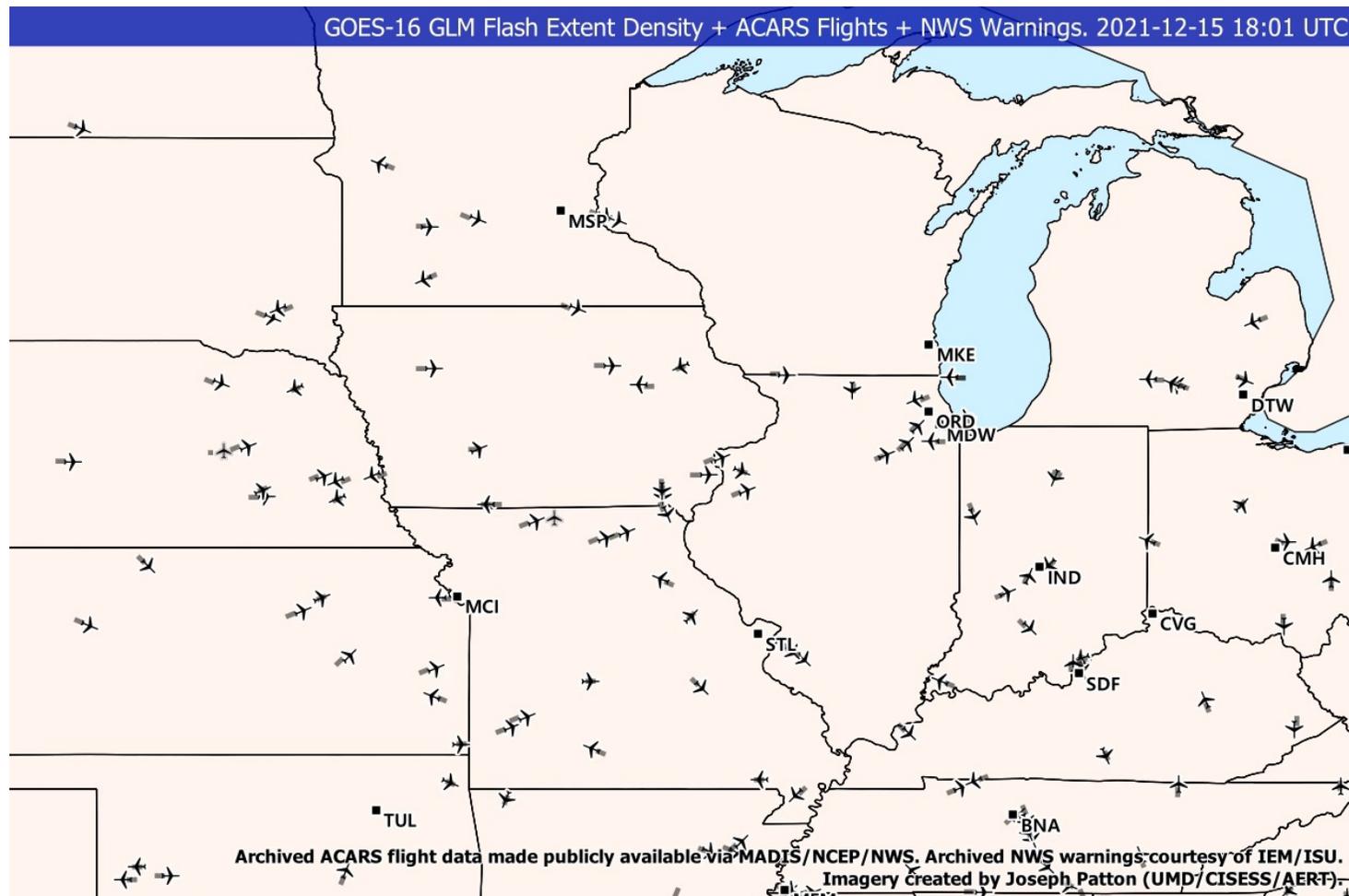
Above: Fraction of vertical volume observed between 0 and 20 kft AGL by current CONUS WSR-88Ds. (Courtesy of Cho and Kurdzo)

Hurricane Maria required FEMA/NWS San Juan to use GLM as a radar replacement to help the restoration crews avoid lightning, and as a proxy for heavy rainfall while the radar was being restored (September – April).



Value of Mitigating Aviation Hazards

- The GLM helps better characterize lightning risk and increase confidence when suspending or continuing ramp operations, leading to enhanced safety, improved efficiency, and cost savings.
- The GLM's broad coverage and rapid updates provide tremendous cost savings to the aviation industry through improved diagnosis and avoidance of thunderstorm hazards, especially over oceans.

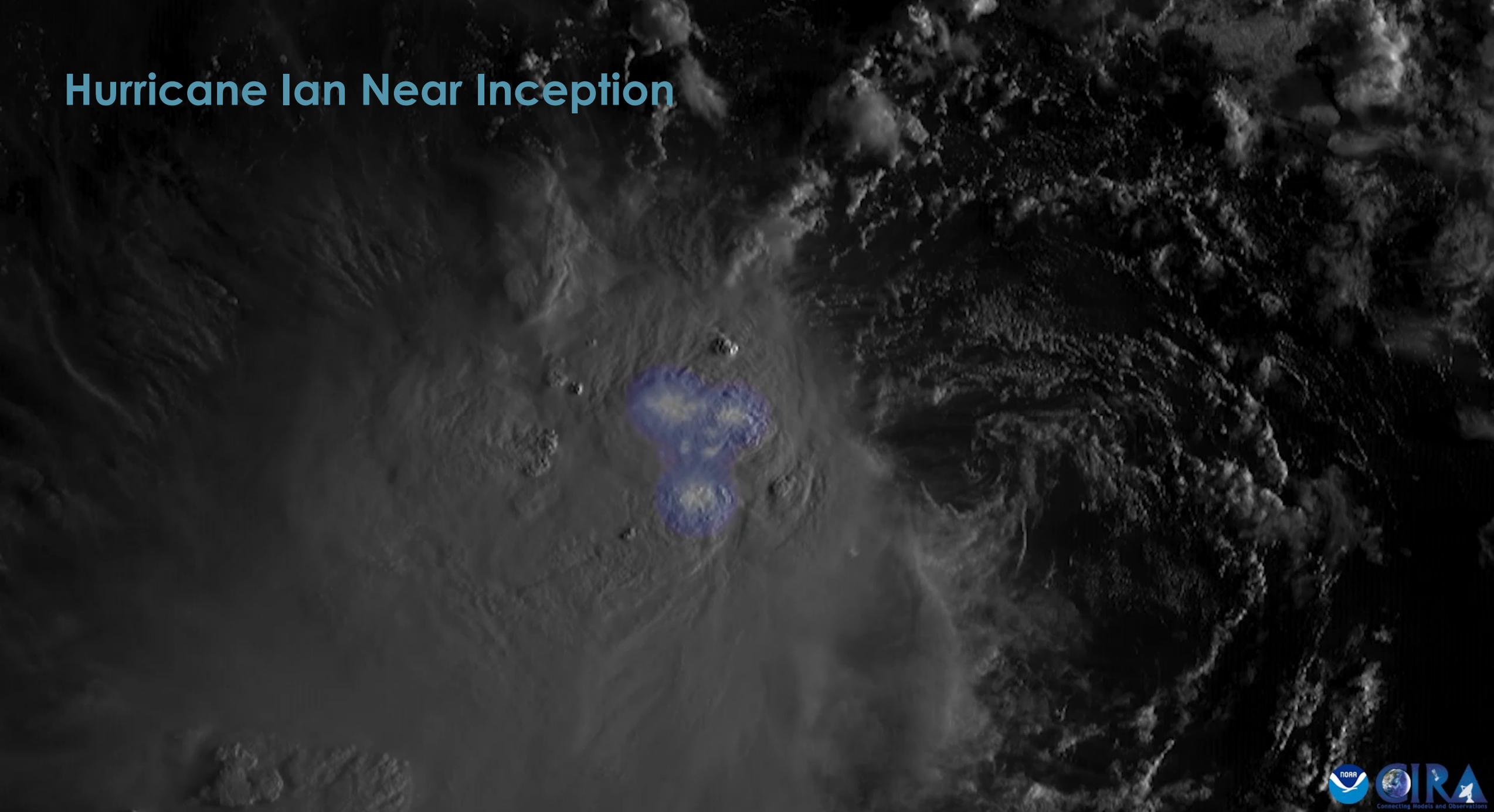


Improving Tropical Cyclone Diagnosis and Warning

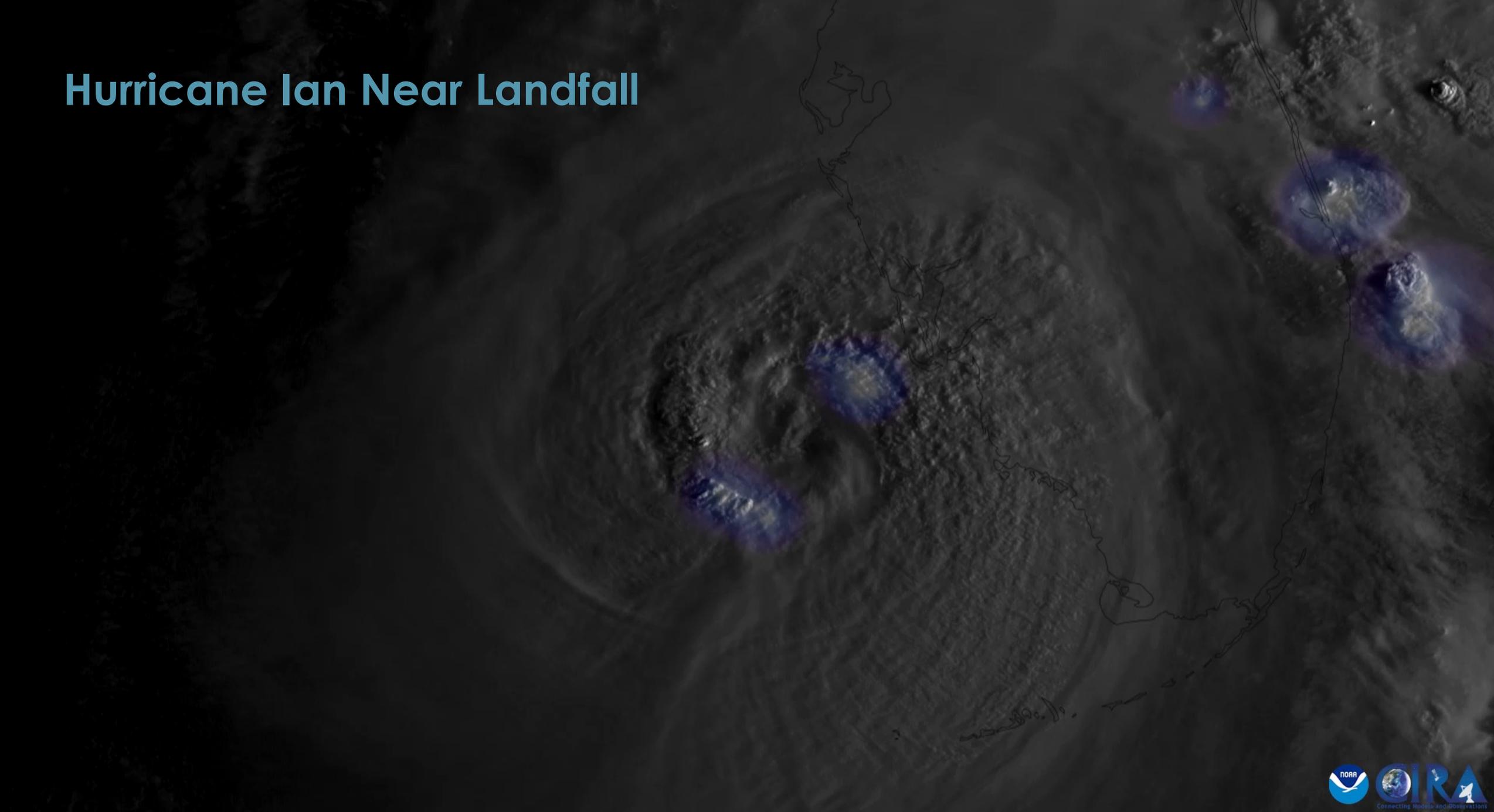
- The GLM clearly conveys convective patterns below cloud top in tropical cyclones (TCs) which helps better diagnosis TC structure and evolution and aids forecasts of TC intensity change including rapid intensification.



Hurricane Ian Near Inception



Hurricane Ian Near Landfall



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 value of GLM 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 has yet to be fully realized.



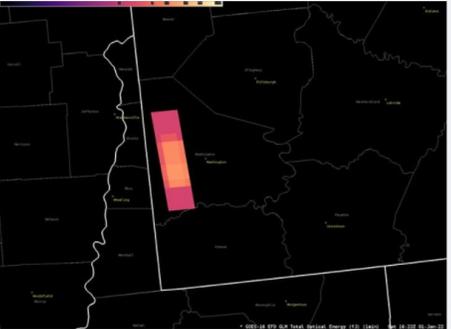
Detecting/Characterizing Bolides

- Jenniskens et al. (2018) showed that the GLM sensors detect **bolides**.
- GLM also geolocates and provides light curves (i.e., a time intensity recording of a bolide impact and disintegration)

US National Weather Service Pittsburgh PA
January 1 at 4:07 PM · 🌐

We have been getting a lot of questions about a loud explosion that was heard over southwest Pennsylvania earlier today. Data from GOES-16 may provide a clue.

This image is a product of the satellite's Geostationary Lightning Mapper function, showing Total Optical Energy (basically, a measure of flash intensity). You can see the flash showing up here in the area of western Washington County, PA at 16:22Z (11:22 EST). This flash does not appear to be connected to any light... [See more](#)



👍 You, John Murphy and 2K others · 1.4K Comments · 7.8K Shares

US National Weather Service Pittsburgh PA
January 3 at 2:34 PM · 🌐

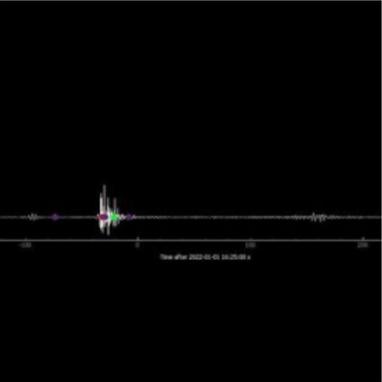
Here is the final update on the New Year's Day meteor from NASA.

NASA Meteor Watch
16 hrs · 🌐

Update on the New Year's Day bolide over Pennsylvania

A nearby infrasound station registered the blast wave from the meteor as it broke apart; the data enabled an estimate of the energy at 30 tons of TNT. If we make a reasonable assumption as to the meteor's speed (45,000 miles per hour), we can ballpark the object's size at about a yard in diameter, with a mass close to half a ton.

Had it not been cloudy, the fireball would have been easily visible in the daylight sky - crude estimate indicates about 100 times the brightness of the Full Moon. [See here](#)



👍 Kelly Ann and 1.3K others · 298 Comments · 2.5K Shares

Bolides | Home / Event List / About / Search

Bolide Detections from Geostationary Lightning Mapper

The Geostationary Lightning Mapper (GLM) aboard the GOES 16 and GOES 17 satellites, is designed to capture natural lightning activity, but it is also capable of detecting bright meteors, called bolides. GLM's large coverage area allows it to capture unprecedented numbers of meteors and its data is publicly accessible. More background about this data, hints on how to use this website, and the latest news and updates can all be found [here](#)



Total number of events: 2744

2744 Events

Year	GLM-16	GLM-17
2017	10	0
2018	23	0
2019	43	113
2020	450	1130
2021	350	520

06/24/2019 23:37:32.000 | Latitude: 34.0 | Longitude: -94.5 | Δ Latitude: 1.0 | Δ Longitude: 1.0

OR_GLM-L2-LCFA_G16_s20191752337200_e20191752337400_c20191752337427.nc (1 / 2)

Start Time: 06/24/2019 23:37:33.027 | End Time: 06/24/2019 23:37:34.291 | Duration: 1.264 seconds | Latitude: 34.8 | Longitude: -95.4

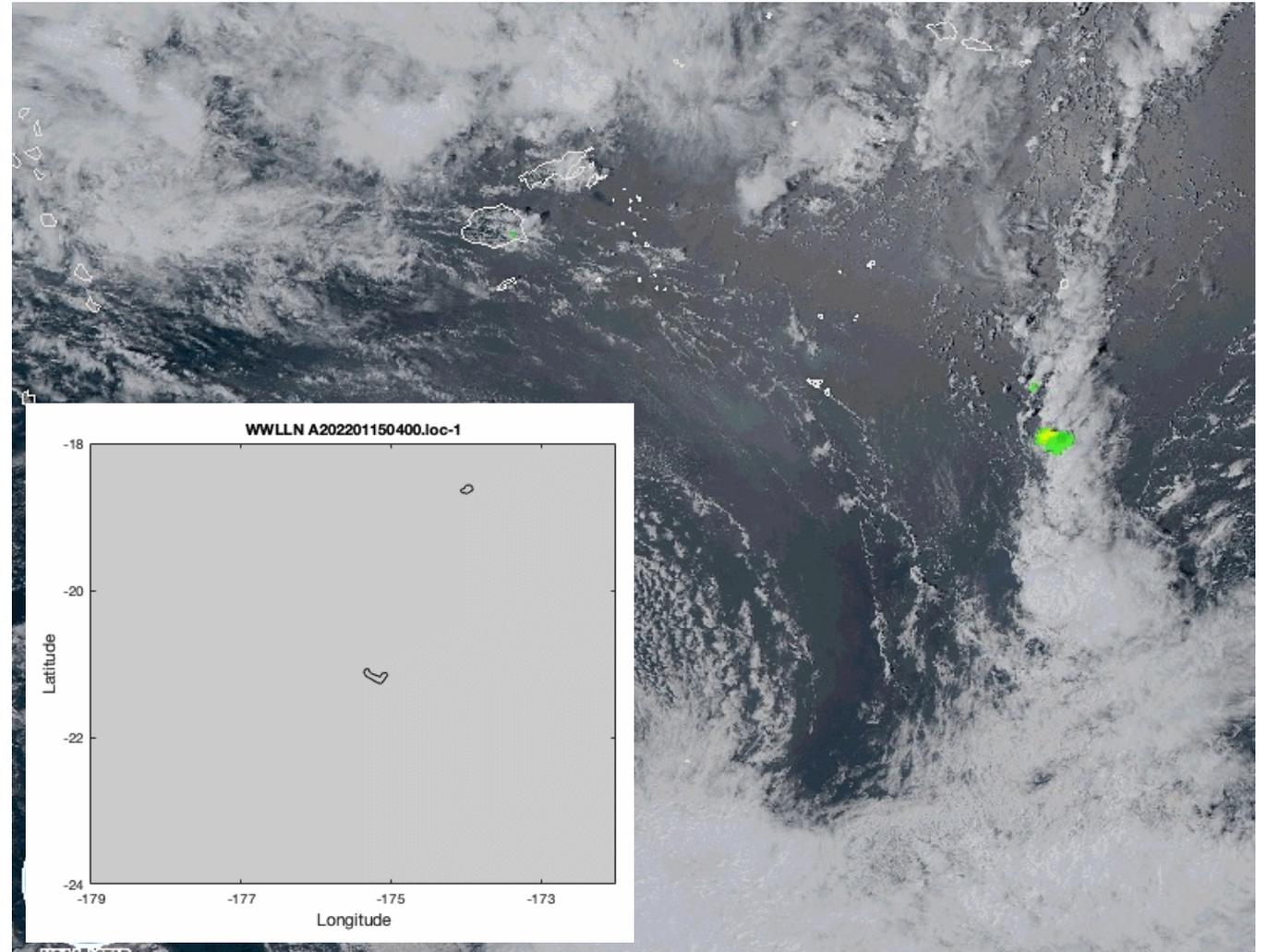


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Monitoring for Volcanic Eruptions

- Explosive volcanic eruptions often generate lightning, so the GLM can help improve eruption detection and characterization.
- Fascinating insights gained during the eruption of Hunga Tonga-Hunga Ha'apai volcano eruption on 1/15/22
- Sonic boom circled the globe twice and an enormous plume of water vapor was blasted into Earth's stratosphere



15 Jan 2022 02:26 NOAA/NES



Accessing GLM Imagery

- STAR GOES Viewer

The screenshot shows a web browser window with the URL <https://www.star.nesdis.noaa.gov/GOES/index.php>. The page features the NOAA logo and the title "GOES Image Viewer". A navigation bar includes links for Home, CONUS, Full Disk, North America, Caribbean, Pacific, South America, Mesoscale, Storms, and Support. Below the navigation bar, the page title "GOES Image Viewer" is displayed, along with a timestamp "3 Jan 2022 - 01:13 EST" and "3 Jan 2022 - 06:13 UTC". A instruction reads: "Click on a region to view images and animations for that region. Coverage area depictions are approximate." The main content area is divided into two sections: "GOES-West" and "GOES-East". The "GOES-West" section lists regions such as PACUS, Full Disk, Pacific Northwest, Pacific Southwest, U.S. West Coast, Alaska, Central Alaska, Southeastern Alaska, Northern Pacific Ocean, Hawaii, Tropical Pacific Ocean, and Southern Pacific Ocean. The "GOES-East" section lists regions such as CONUS, Full Disk, Northern Rockies, Upper Mississippi Valley, Great Lakes, Northeast, Southern Rockies, and Southern Plains. A large satellite image of North America is displayed on the right side of the page.



Accessing GLM Imagery

- [Weathernerds](#)

HOME Videos Satellite Radar Canadian ECENS GEFS ECMWF GFS ICON Mesoscale HWRP HMON Support Weathernerds PATREON

Older Time Weathernerds Satellite Data Storm Floaters Newer Time

Update Plot Zoom In Zoom Out Loop Trajectory Save Image README: Usage Notes

Other Regions
 Satellite Time
 Data Type
 Color Scheme
 Measure
 Animated GIF
 Display Options
 Keyboard Shortcuts

Most Recent GOES16 data 2021-12-14 15:35 UTC

Support Weathernerds PATREON

Choose satellite, turn overlays on/off
 Choose Satellite Source
 Source Mode: Auto Manual
 Source: GOES16 GOES17 Himawari

Geostationary Lightning Mapper (GLM)
 G16 Lightning: On Off
 G17 Lightning: On Off
 Flash Extent Density: On Off
 Total Optical Energy: On Off

Sea Surface Temperature
 SST: On Off

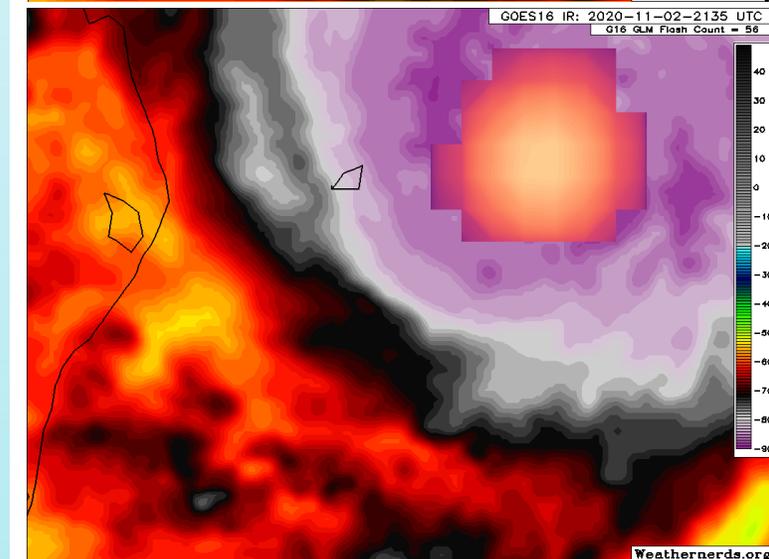
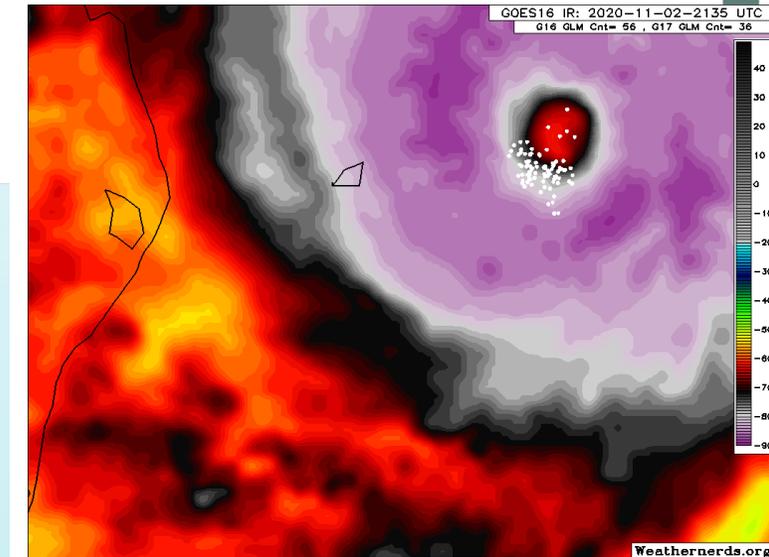
Satellite Winds
 ASCAT-A: On Off
 ASCAT-B: On Off
 ASCAT-C: On Off
 ASCAT-A Amb: On Off
 ASCAT-B Amb: On Off
 ASCAT-C Amb: On Off

Map Options
 Interstates: On Off
 Warnings: On Off
 Lat/Lon Lines: On Off

Note: Interstates/Warnings only appear when zoomed in sufficiently; click

GOES16 IR: 2021-12-14-1535 UTC
 G16 GLM Flash Count=15

Advertisement



Accessing GLM Imagery

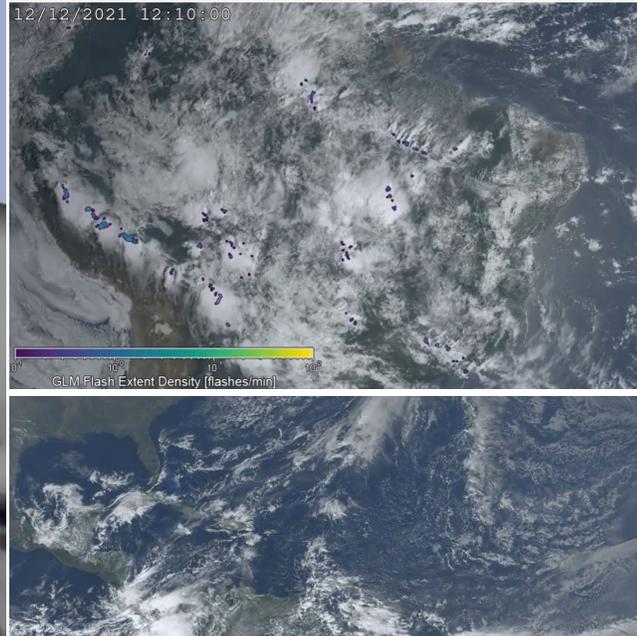
- [College of DuPage \(COD\) Meteorology Webpage](#)

The screenshot displays the NEXLAB Satellite and Radar web interface. The main map shows the continental United States with a grid overlay and various data layers. The interface includes a navigation menu at the top with links for Home, Academics, Weather Data, COD Storm Chasing, Local Weather, and NEXLAB. A left sidebar contains a logo for College of DuPage and NEXLAB, along with a 'Select a Product:' dropdown menu. Below this, there are sections for 'NEXRAD Radar' (Composite Radar, Dual-Pol NEXRAD), 'ABI Bands' (16 different bands), 'RGB Color Products' (True-Color, Airmass, etc.), 'Choose Number of Frames' (6, 12, 24, 48, 96, 200), 'Choose Frame Interval' (All, 2n, 4n, 6n, 12n), and 'Change Slider Type' (Roll, Drag). The bottom of the interface features a 'Mapping' section with various data layers like Cloud Top Height, Cloud Top Temperature, Cloud Top Phase, Aerosol - Dust, Aerosol - Smoke, CAPE, Land Surface Temperature, Rainfall Rate, Sea Surface Temperature, and Total Precipitable Water. A 'GLM Flash Extent Density' slider is also visible.



Accessing GLM Imagery

- [Dropbox Composite Imagery](#)
- [Dropbox Flash Skeletons](#)



GOES16

[Save to Dropbox](#) [Download](#)

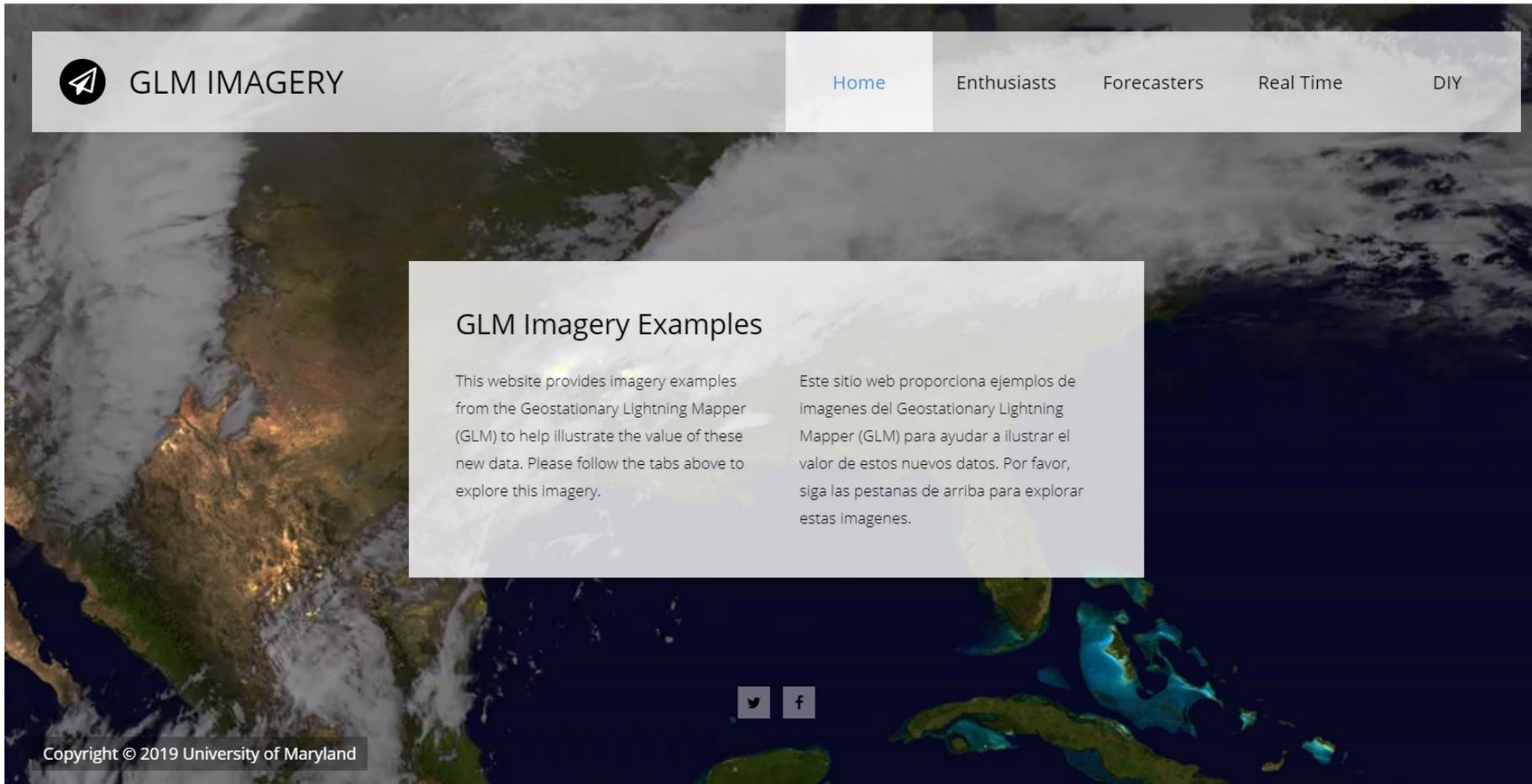
Name

- Amazon
- Atlantic
- CONUS
- FullDisk
- LaPlata



Accessing GLM Imagery

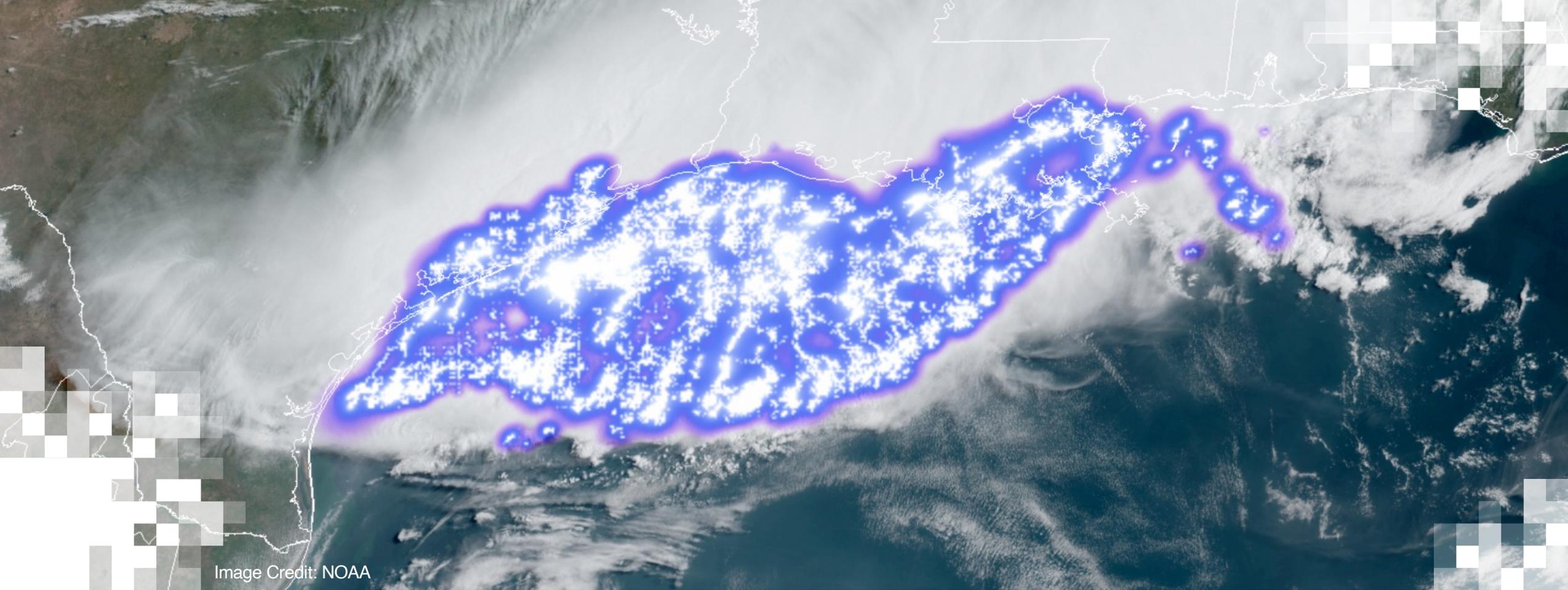
- <https://lightning.umd.edu/glm/> aims to promote proper use and interpretation and provides links to most of the imagery shown today.



Accessing GLM Imagery

- [GLM Vlab](#)
- [UMD GLM Page](#)
- Links to Routinely Available Imagery:
 - [NESDIS/STAR GOES Viewer](#)
 - [Weathernerds Webpage](#)
 - [COD Meteorology Webpage](#)
 - [Cesium GLM Globe](#)





Part 3 Summary

Summary

- An overview of Geostationary Lightning Mapper (GLM)
- Information about lightning data from [STAR GOES Viewer](#).



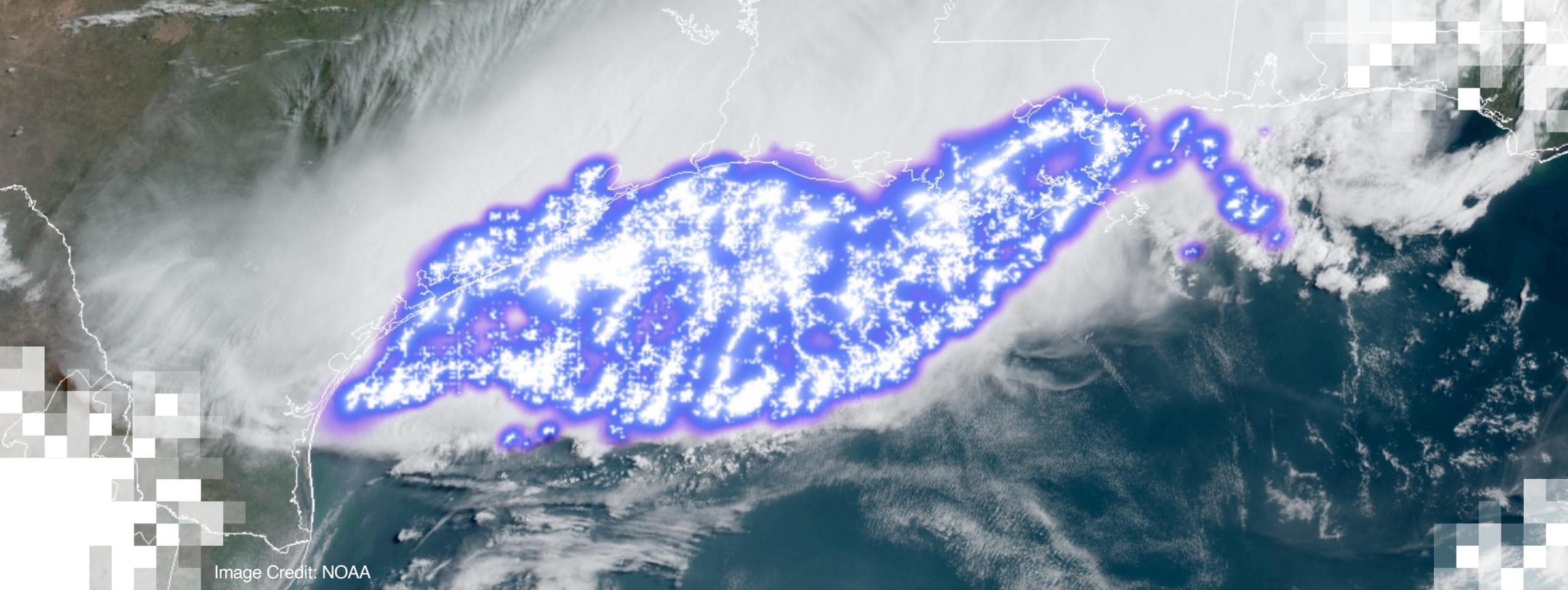


Image Credit: NOAA

Introduction to Lightning Observations and Applications

Summary

Training Summary

- What Lightning Is and How it Forms:
 - High-current electrical discharge between positively and negatively charged regions of a thunderstorm.
 - As ice particles within storm clouds grow, collide, and break apart, they acquire positive and negative charges.
 - Under the influence of gravity and updraft, these charges are separated in layers building electrical potential that results in electrical discharge.
- Background and History of Lightning Detection from 1960s to Present
- NASA Spaceborne Lightning Measurements:
 - Focused lightning measurements started in 1980s from Space Shuttle
 - MicroLab1/Orbview-1 Lightning Measurements using Optical Transient Detector (OTD)
 - TRMM and International Space Station Lightning Imaging Sensor (LIS)
 - NASA Astrophysics instruments like the Gamma-ray Burst Monitor (GBM) on the Fermi satellite (short-term lightning)
 - Geostationary Lightning Mapper (GLM) on GOES
- Future Lightning Measurements from Space:
 - GeoXO Lightning Mapper



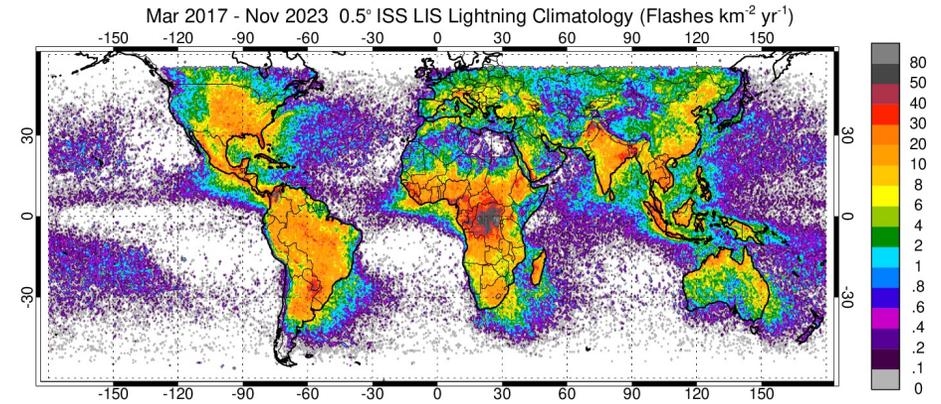
Training Summary

- Sub-Orbital Lightning Measurement from Fixed Lightning Detection Networks, Deployable Lightning Detection Networks, and Airborne Lightning Instruments
 - Lightning Mapping Array (LMA) use Very High Frequency (VHF) antennae
 - Overview of LMA regional networks (e.g., Alabama, Kennedy Space Center, District of Columbia/Wallops Flight, Sao Paulo-Brazil, Cordoba-Argentina, Seoul-Korea)
 - Lightning Instrument Package, measure electrical field change
 - NASA airborne lightning datasets include Lightning Instrument Package (LIP), Fly's Eye GLM Simulator (FEGS), and Electric Field Change Meter (EFCM), and come from short-term campaigns (~10-100 flight hours).
- Lightning Data Access:
 - Global Hydrometeorological Research Center ([GHRC](#)) curates and maintains orbital and suborbital lightning datasets, and a [lightning visualization dashboard](#) and other data exploration tools.
 - GLM lightning data can be viewed and obtained from [STAR GOES Viewer](#).



Training Summary

- Importance and Benefits of Lightning Measurements:
 - For raising lightning safety awareness
 - An indicator of wildfire ignition potential
 - For risk assessment for power outages
 - An indicator of storm intensity
 - An Essential Climate Variable (ECV)
 - For aviation and marine weather safety
 - For monitoring volcanic eruptions



Homework and Certificates

- **Homework:**
 - One homework assignment
 - Opens on 04/02/2024
 - Access from the [training webpage](#)
 - Answers must be submitted via Google Forms
 - **Due by 04/17/2024**
- **Certificate of Completion:**
 - Attend all three live webinars (attendance is recorded automatically)
 - Complete the homework assignment by the deadline
 - You will receive a certificate via email approximately two months after completion of the course.



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Thank You!

