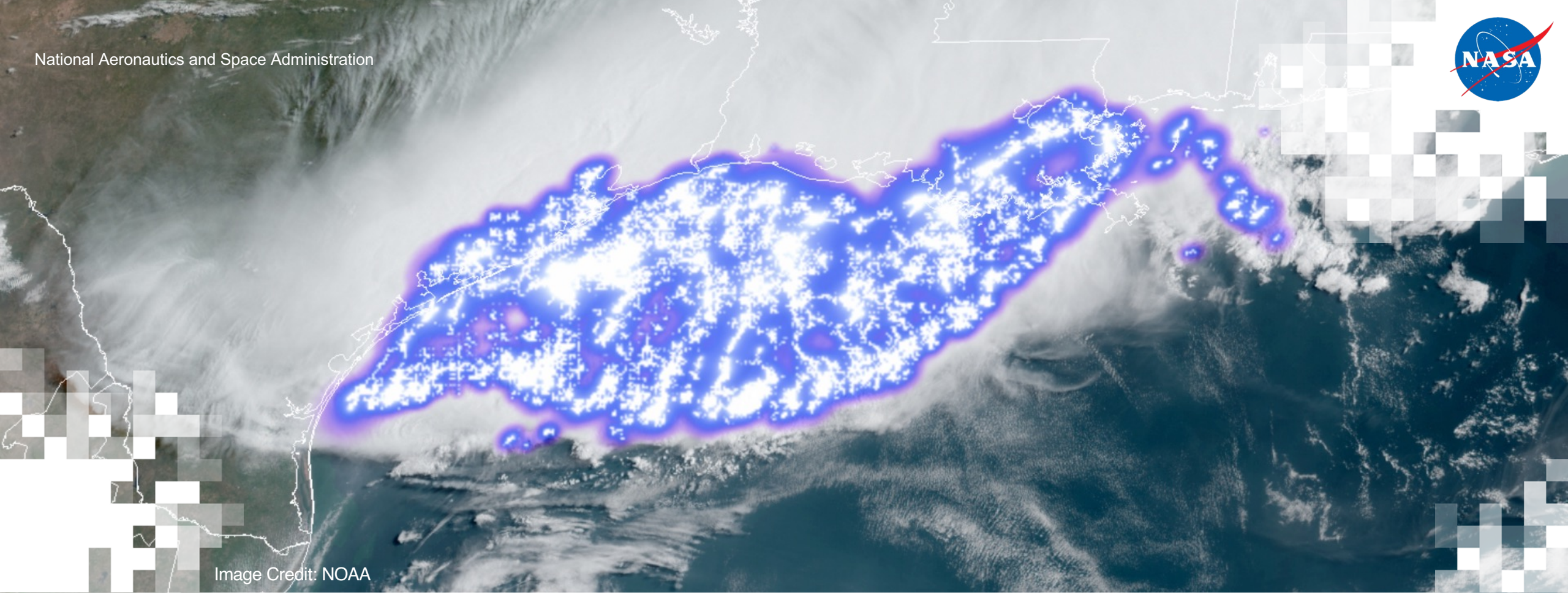
National Aeronautics and Space Administration



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

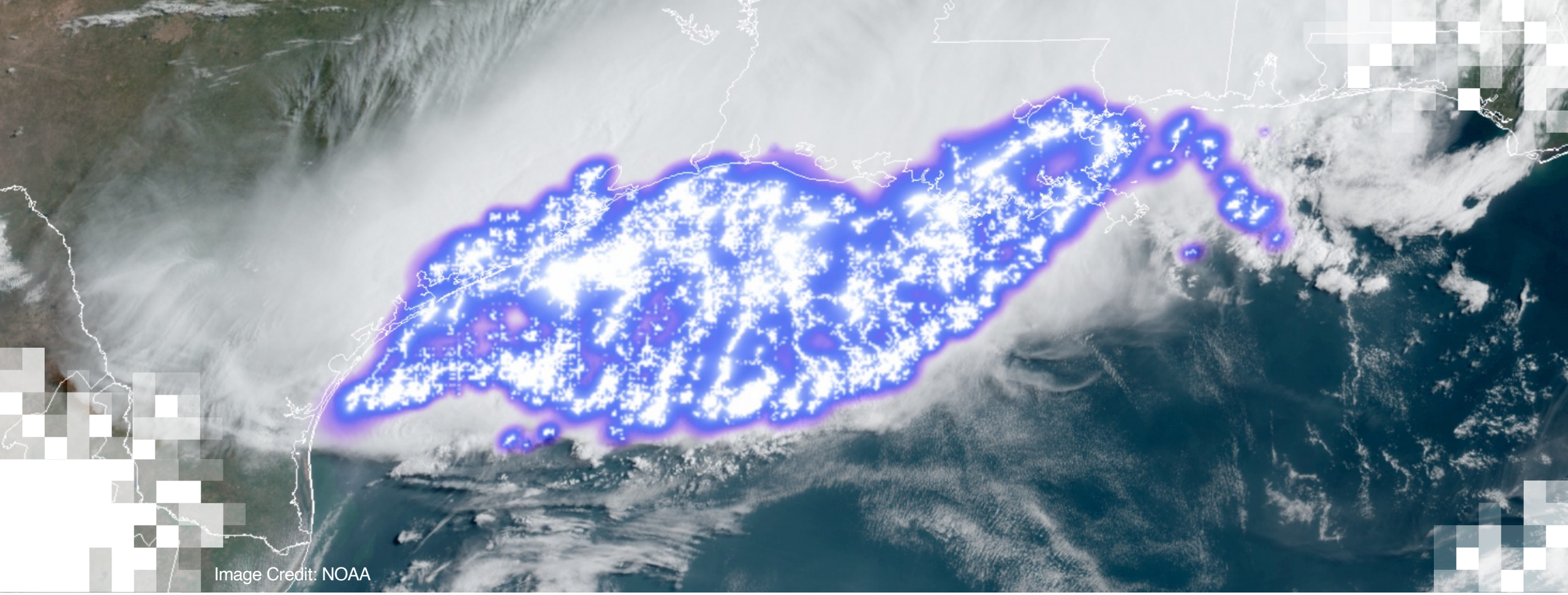
NOAA/NESDIS

Christopher Schulz

Guest Contributor

Research AST, Meteorological Studies

NASA-MSFC



Part 3

GLM Observations and Applications

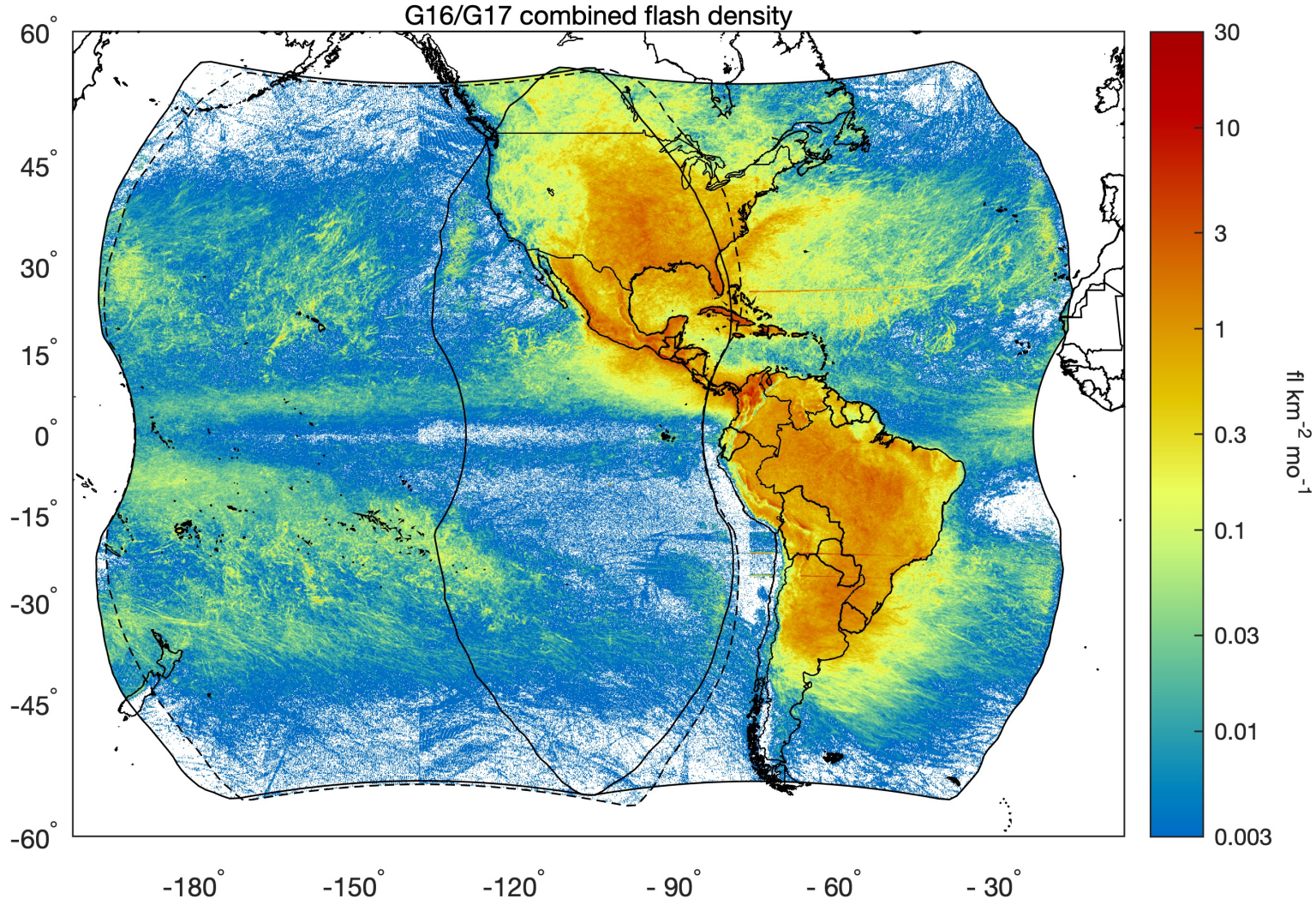
Part 3 Objectives

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

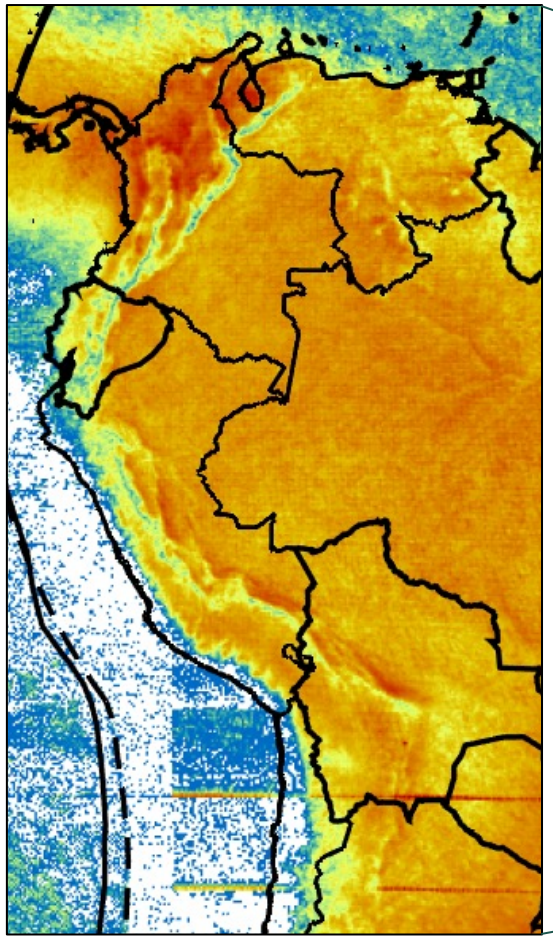


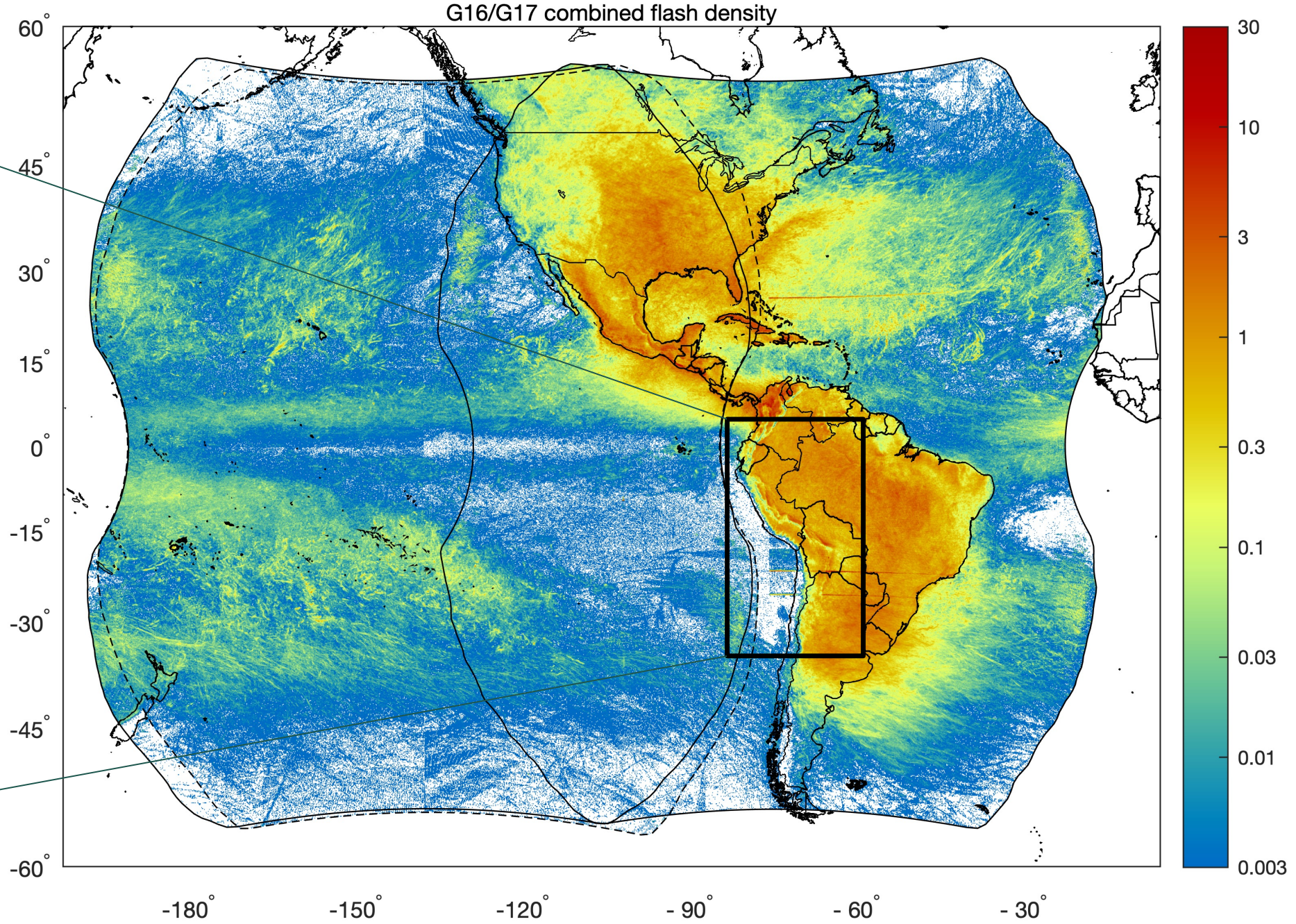
Created by Katrina Virts

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

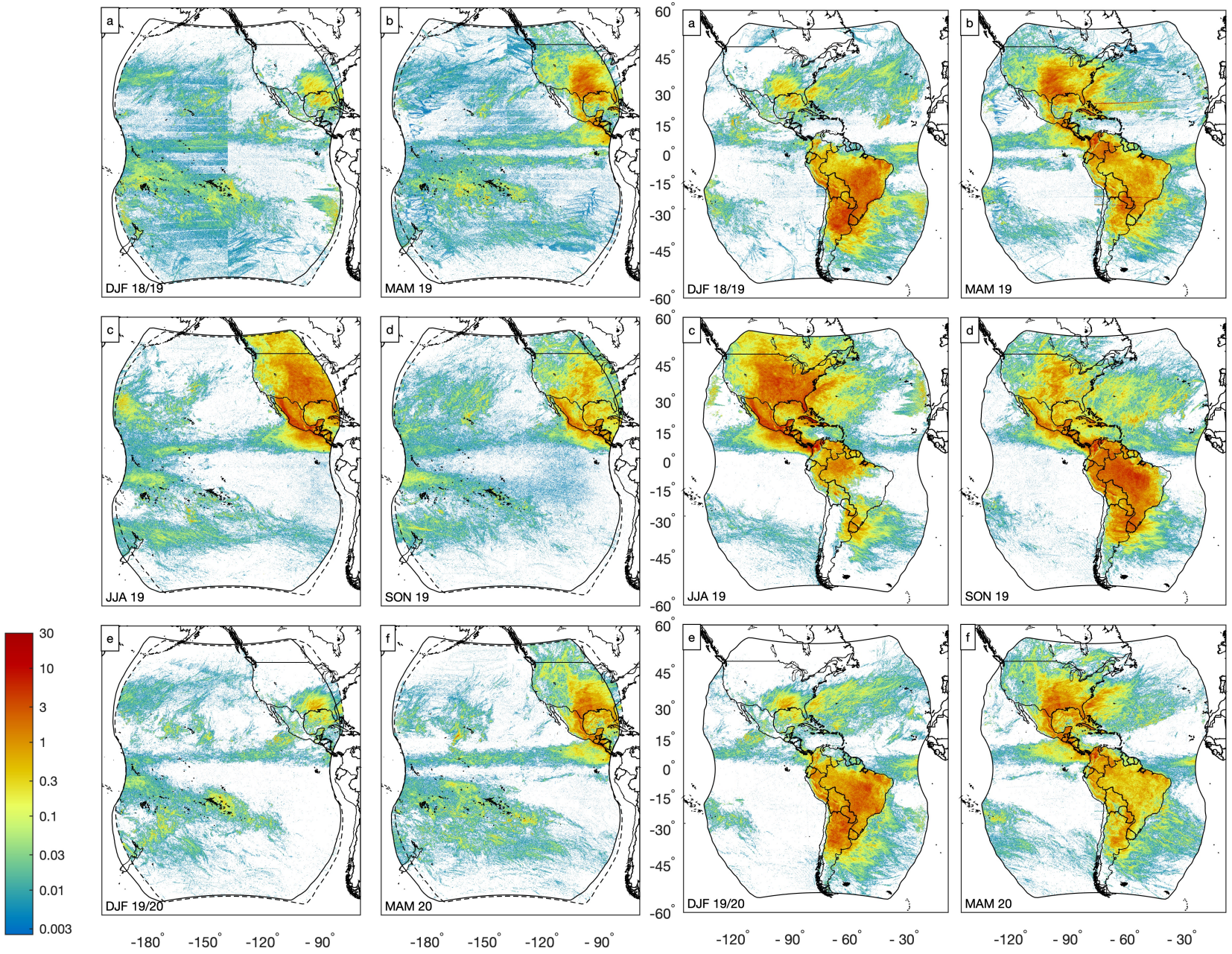
GLM FOV




G16/G17 combined flash density
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-180°
-150°
-120°
- 90°
- 60°
- 30°
30
10
3
1
0.3
0.1
0.03
0.01
0.003
fl km-2 mo-1

GLM Patterns

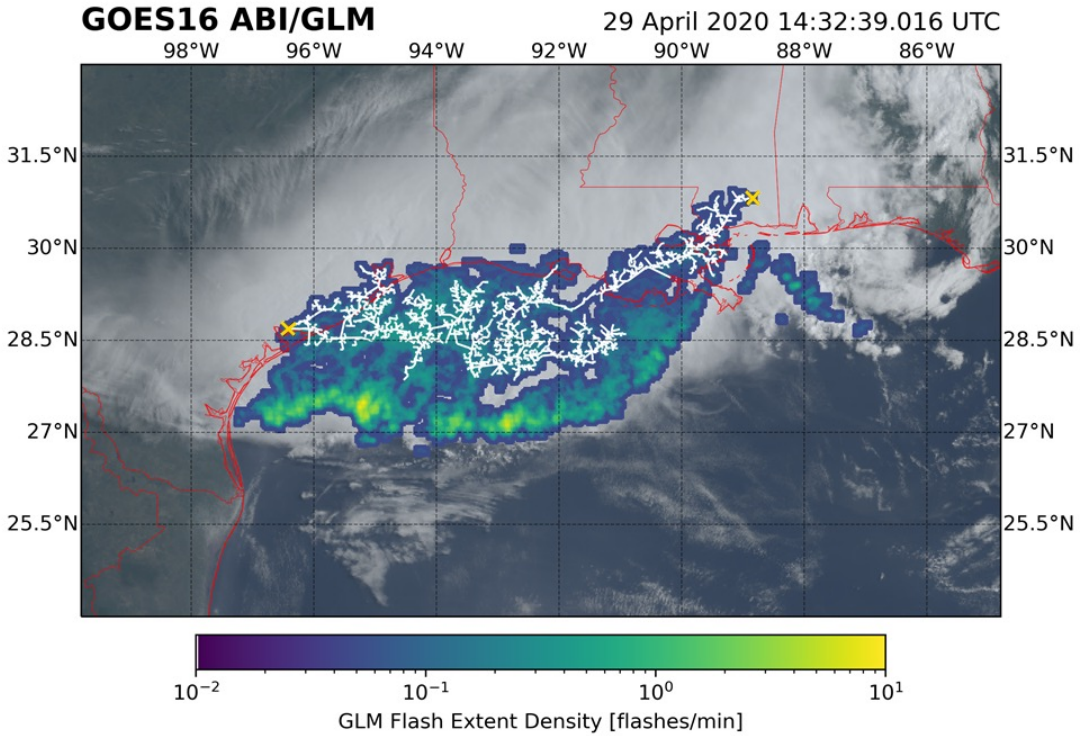
- Seasonal shifts in lightning match expectations
- GLM data quality has steadily improved
- Blooming and second level threshold filters provided the greatest impact
- Help mitigate sun glint, solar intrusion, and artifacts at subarray boundaries

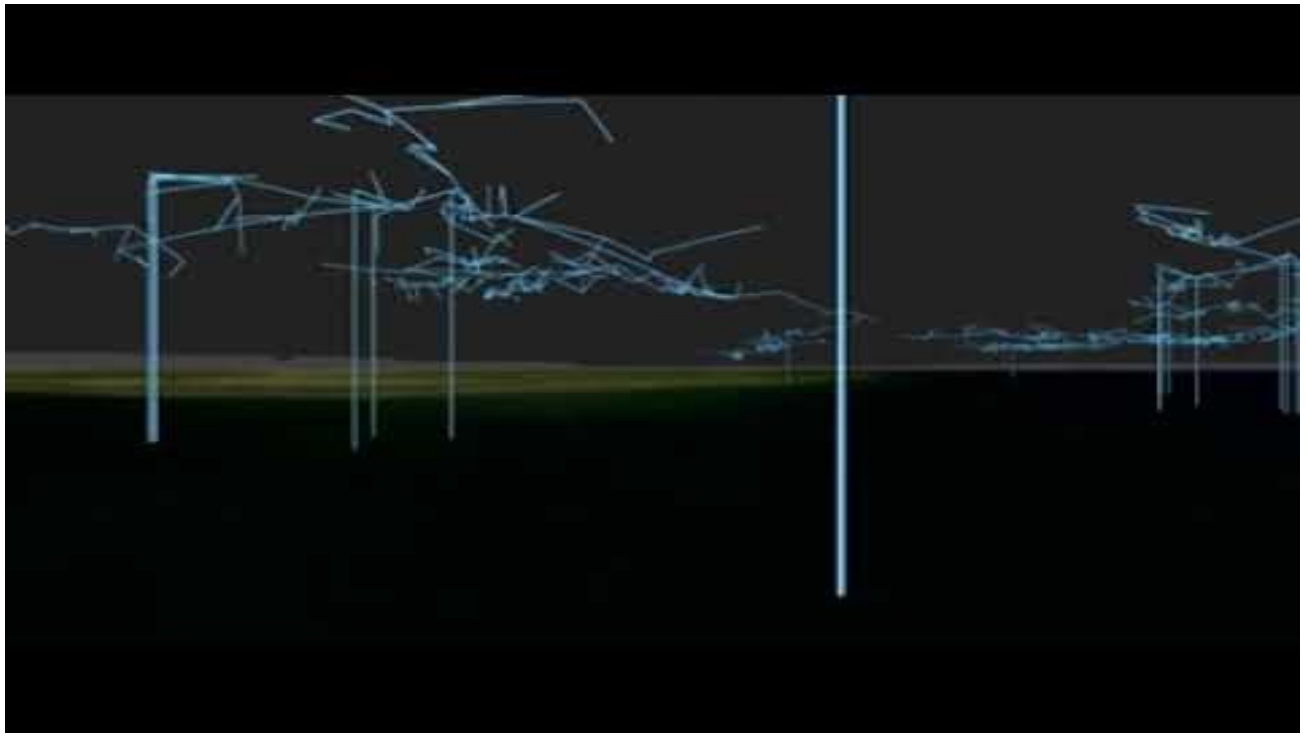


World Record Lightning Flash

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

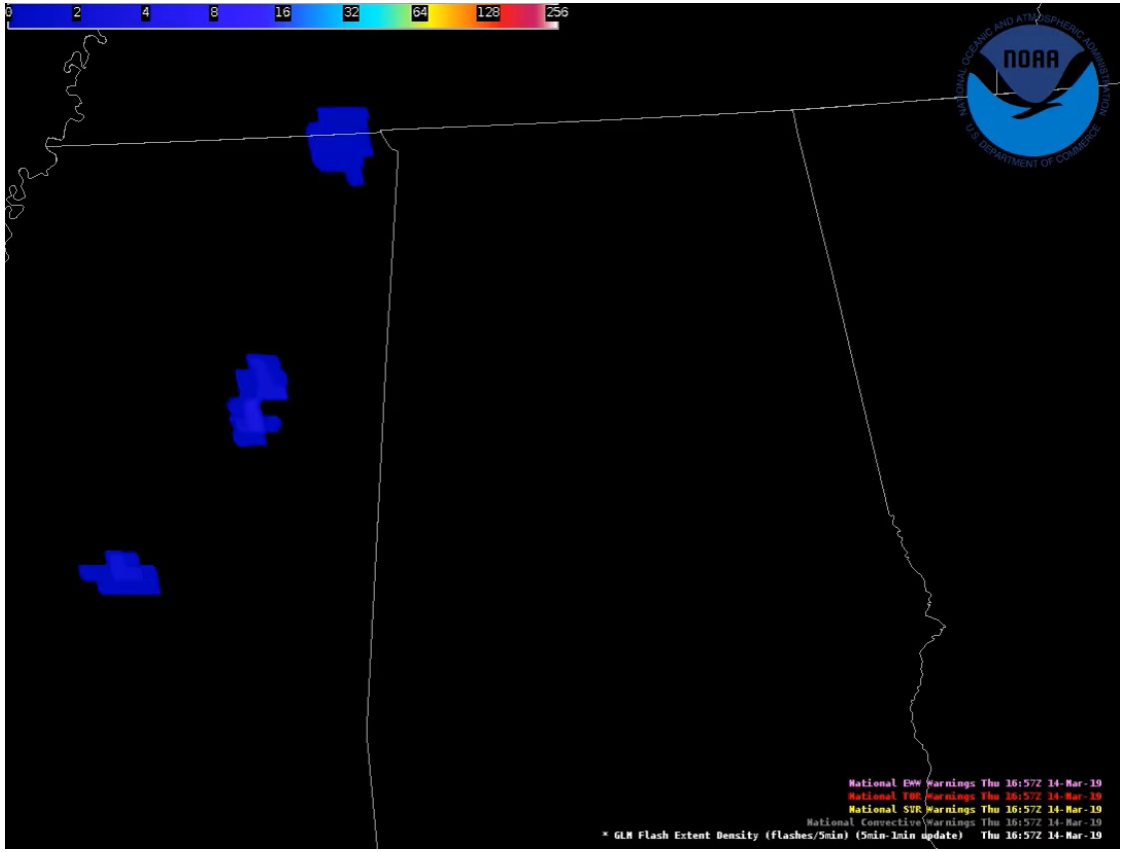




Simulated View from Ground Level (real lightning channels connecting to known ground strike points)

GLM in the National Weather Service

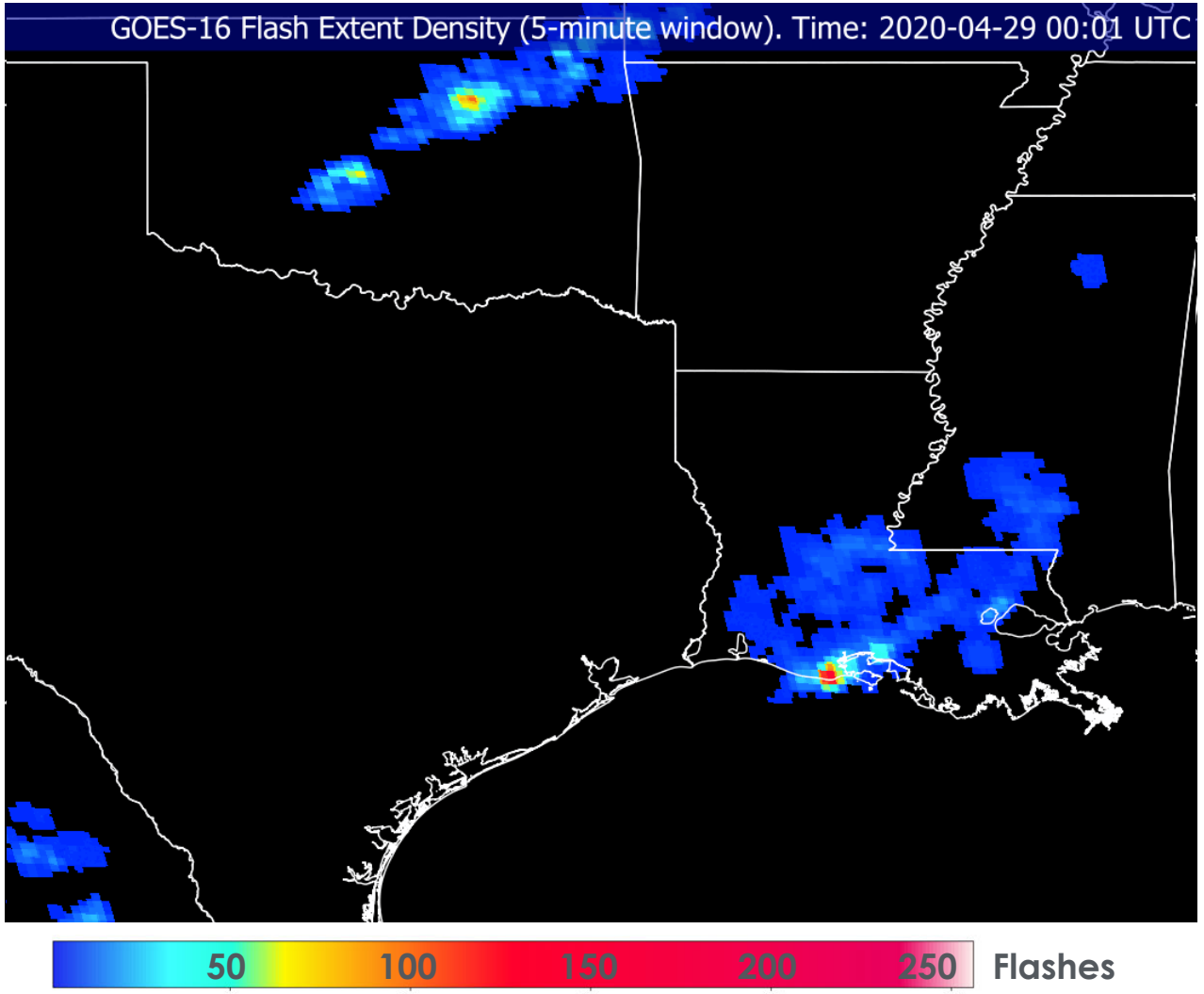
- GLM observations fundamentally differ from the ground-based lightning data most familiar to NWS forecasters
- Developed a new suite of gridded GLM products tailored to NWS operations
- Gridded GLM products disseminate the spatial footprint information and greatly reduce file size
- Gridded GLM products 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

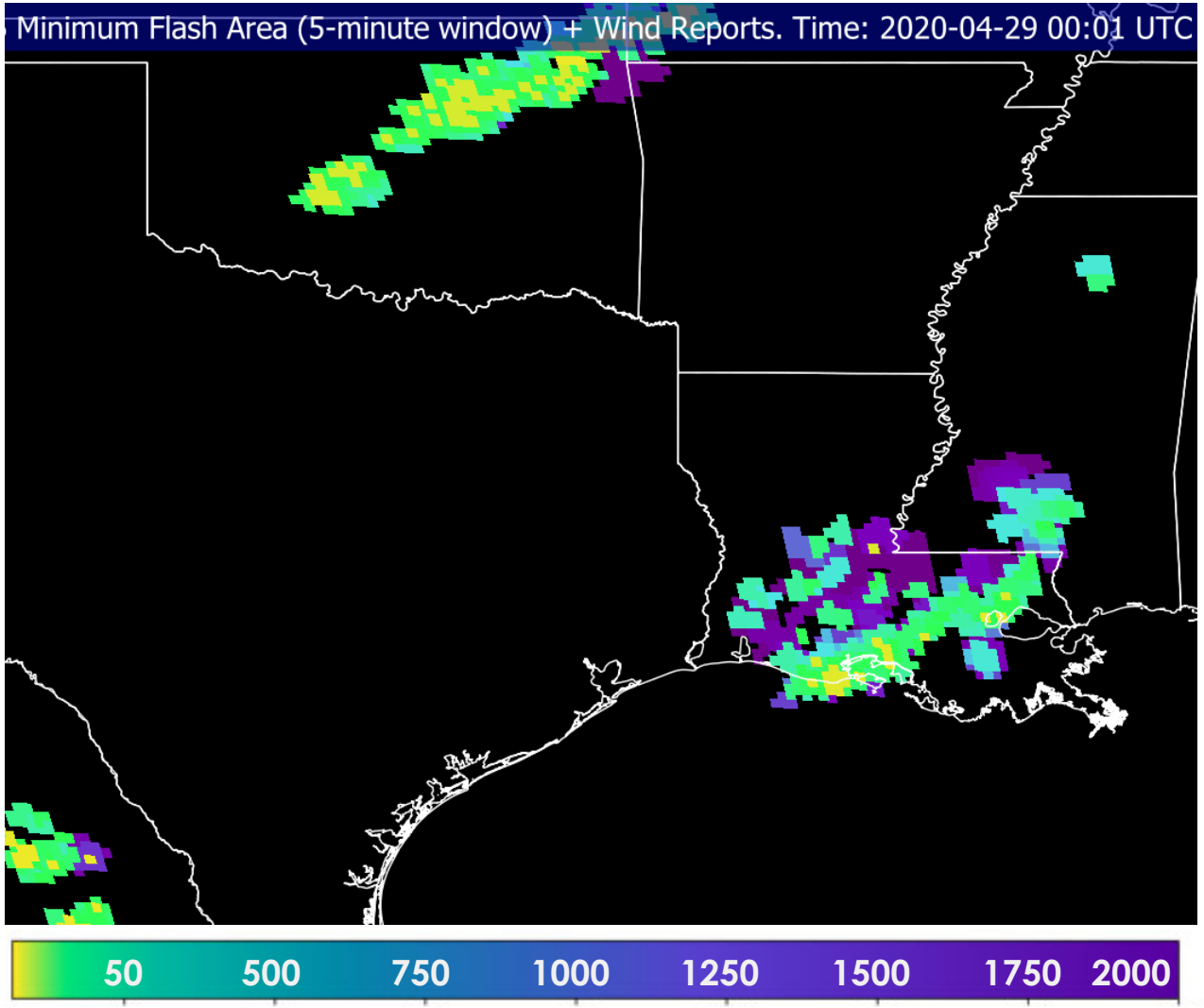
Gridded/Accumulated GLM Products

- **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



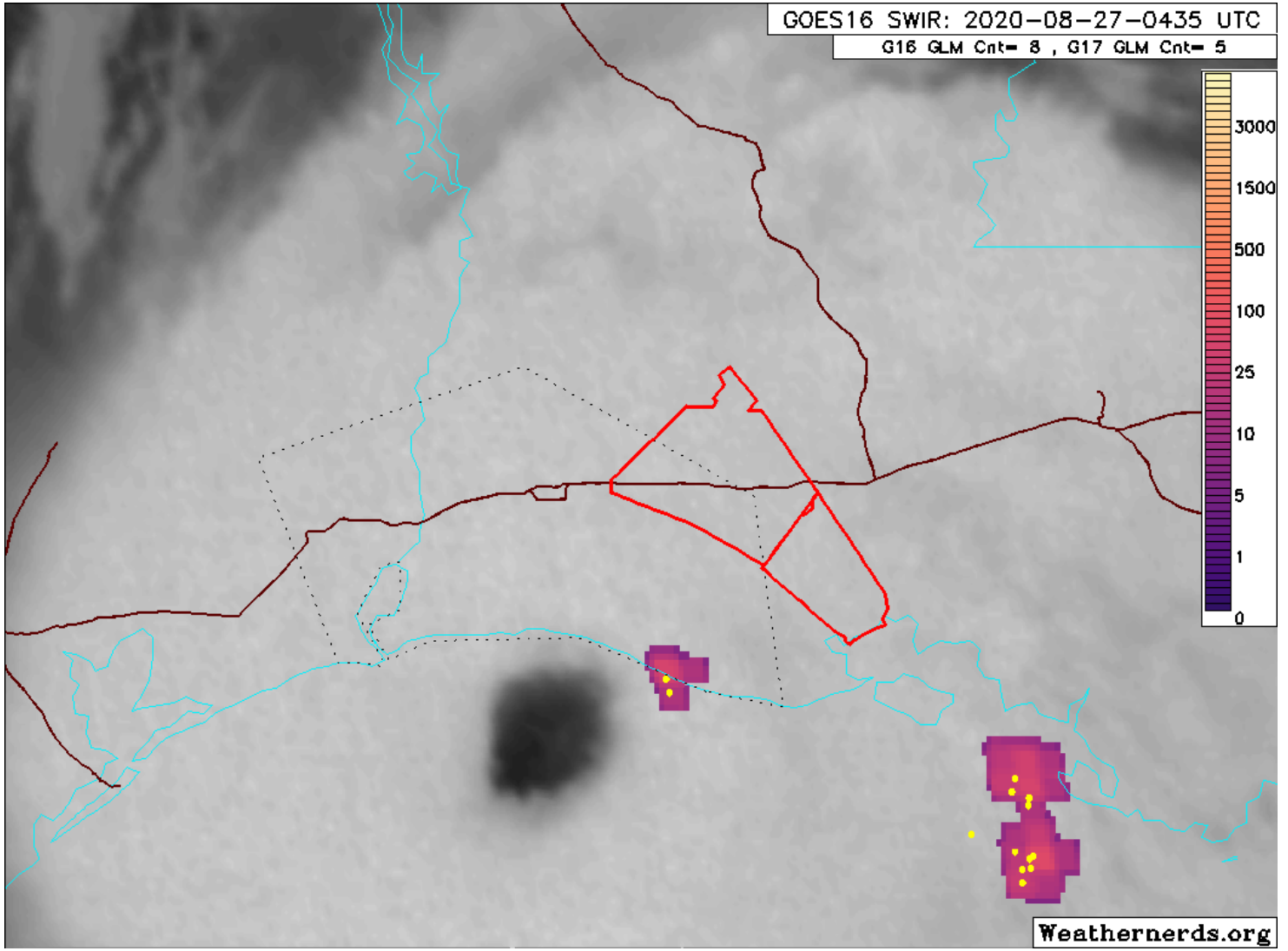
Gridded/Accumulated GLM Products

- **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



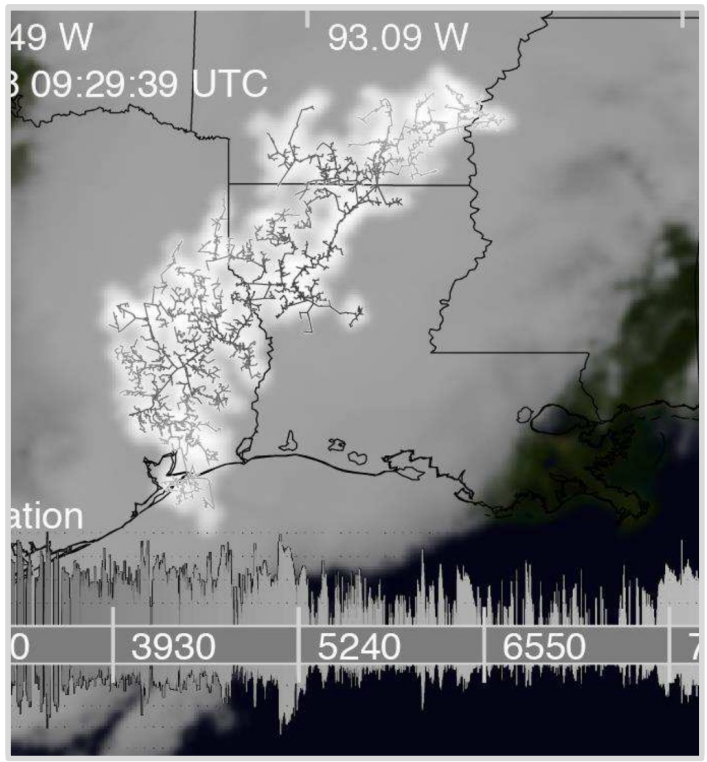
Gridded/Accumulated GLM Products

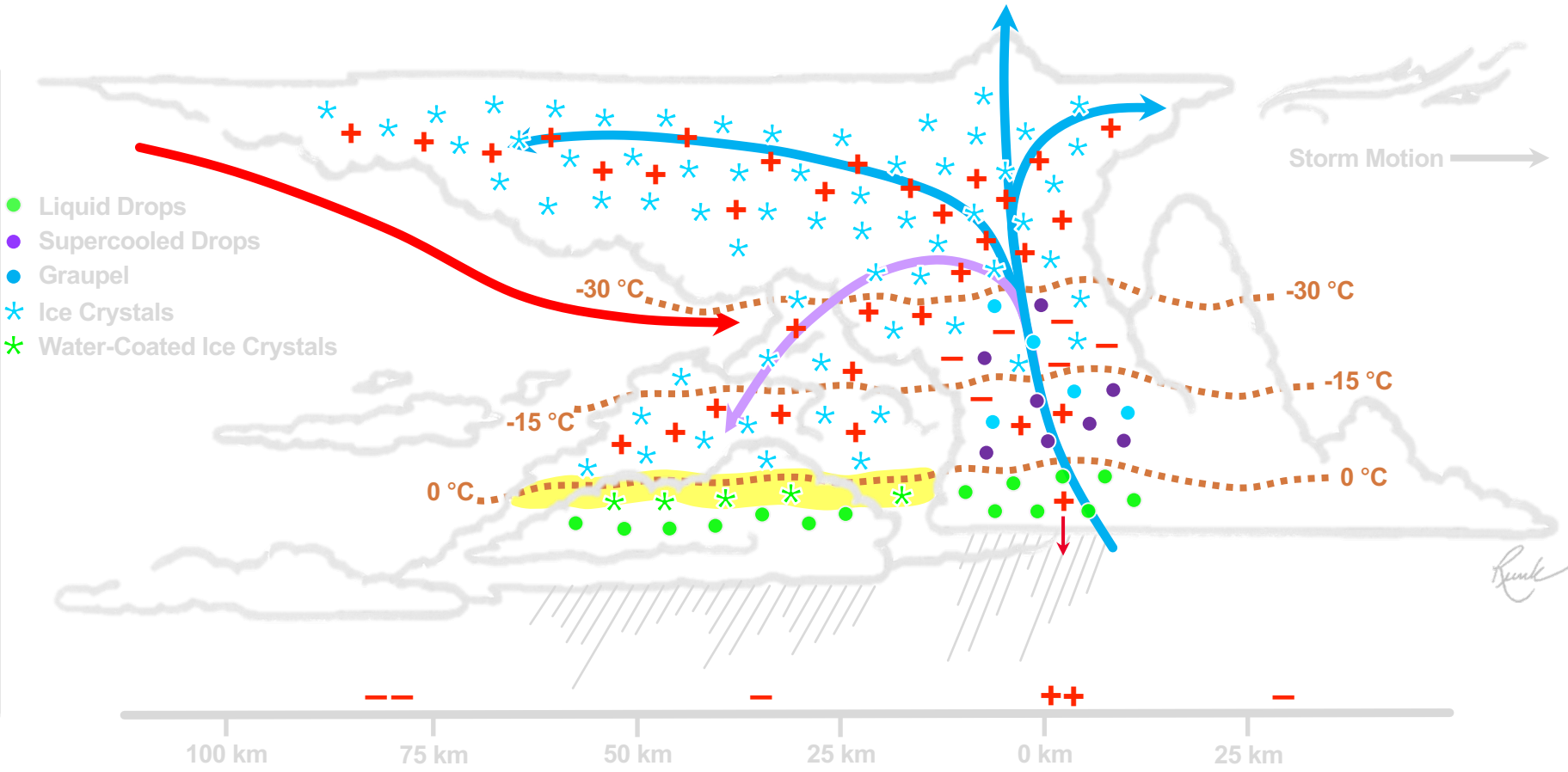
- **Total Optical Energy** – Sum of all optical energy observed within each grid cell during a specified time period
- Bright regions in the TOE indicate:
  - The most energetic convective cores
  - Lightning channels within extensive stratiform flashes
- Real time imagery available via https://www.weathernerds.org



NWS Application: Detecting Long Flashes

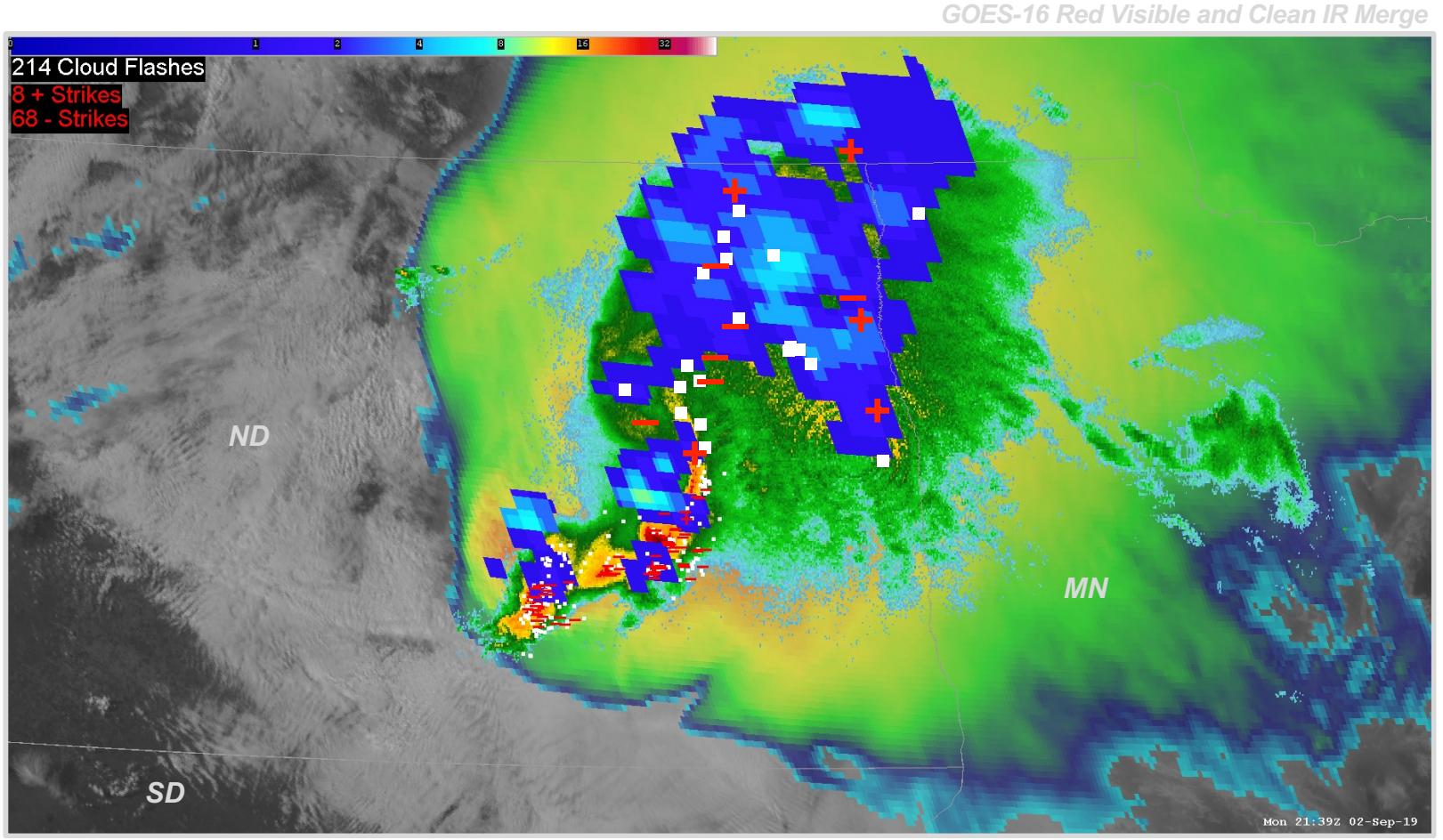
- Simplified Conceptual Model





NWS Application: Detecting Long Flashes

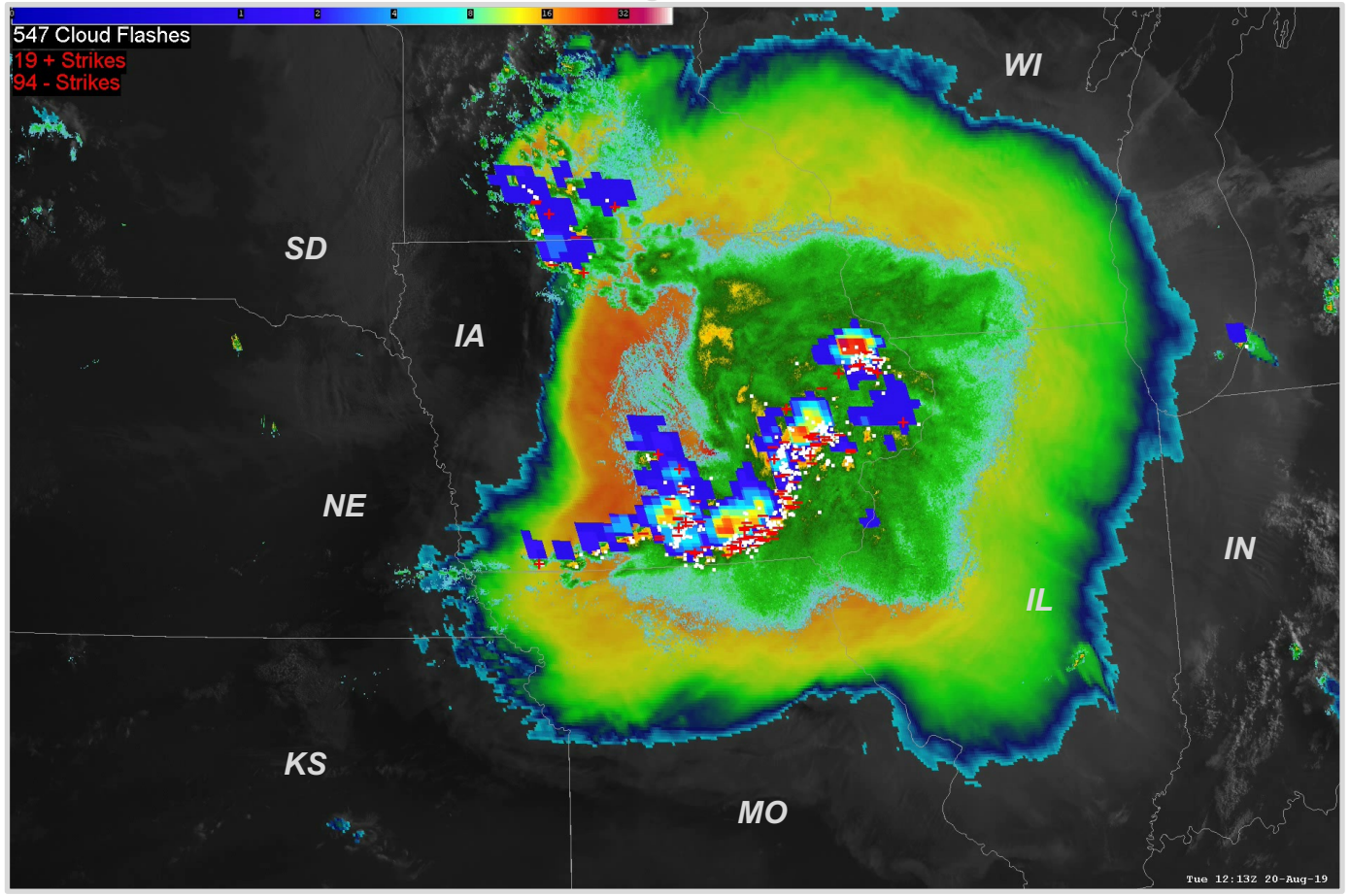
- Applying the Conceptual Model to Operations



NWS Application: Detecting Long Flashes

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

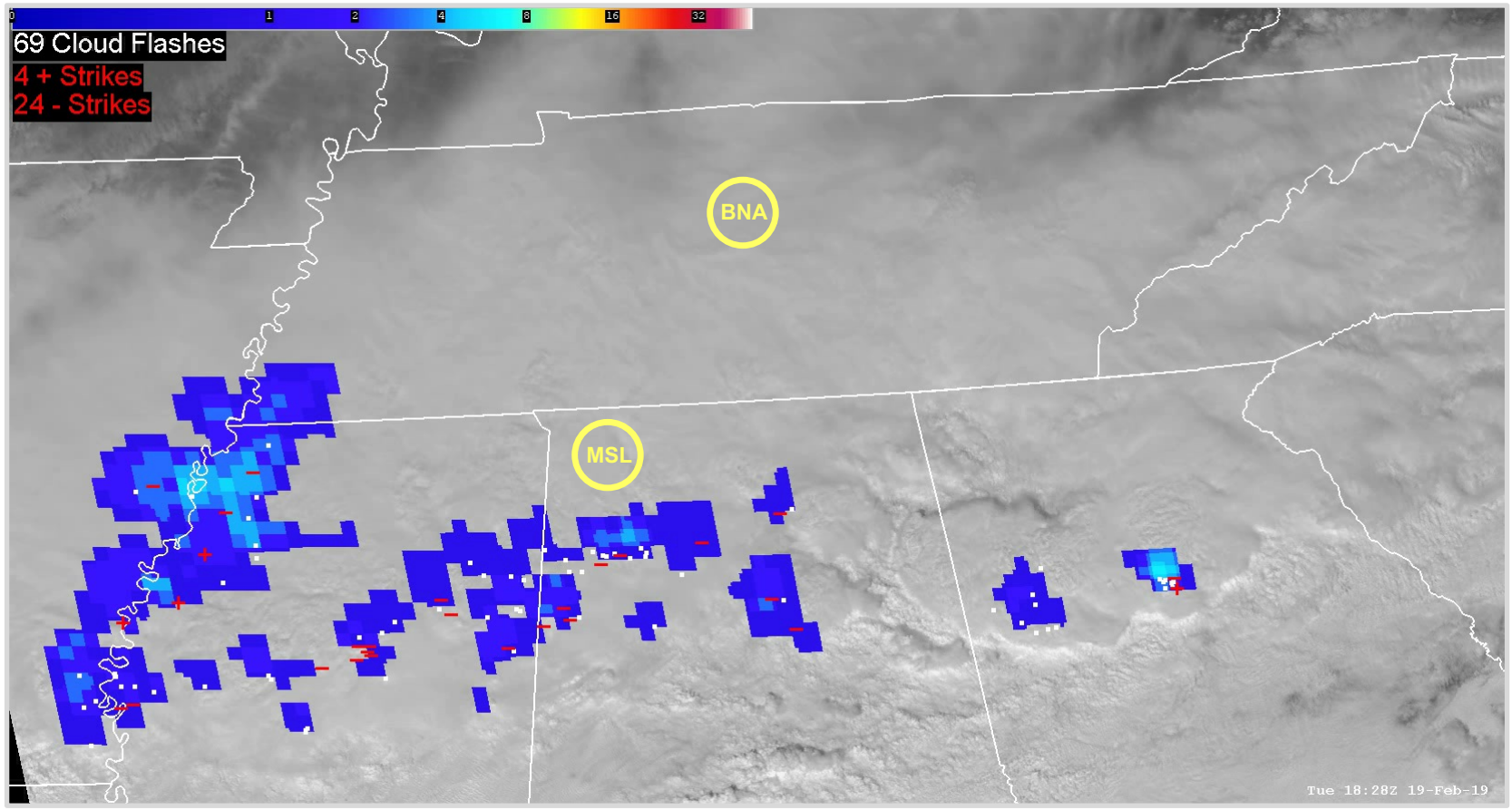
GOES-16 Red Visible and Clean IR Merge, MRMS 0°C Z, GOES-16 GLM FED, and ENTL IC/CG



NWS Application: Detecting Long Flashes

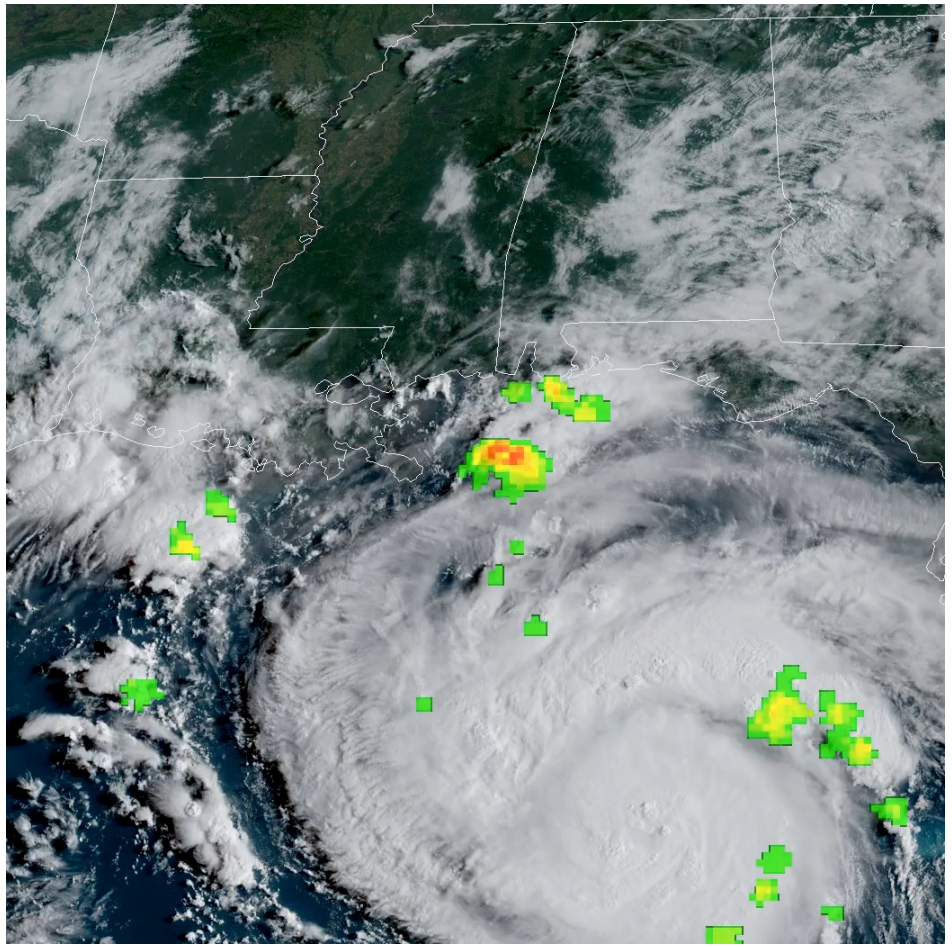
- Adding confidence and value to existing NWS products

GOES-16 Red Visible, GOES-16 GLM FED, and ENTL IC/CG



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

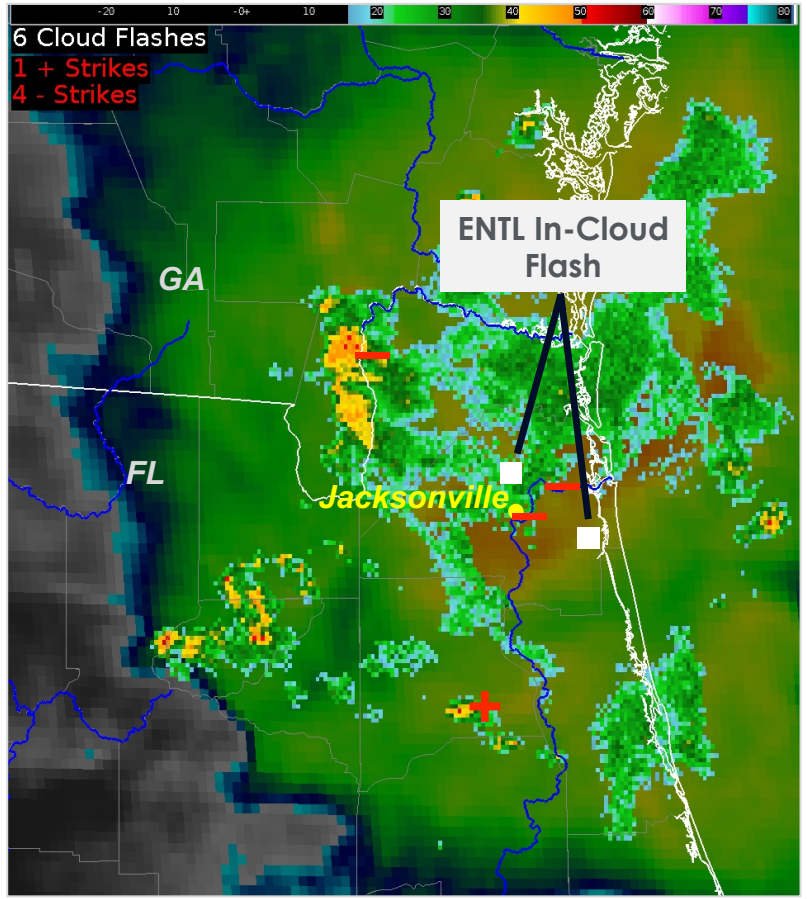
- Recent GLM Value Assessment identified wide-ranging economic and societal benefits, especially when combined with other data

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

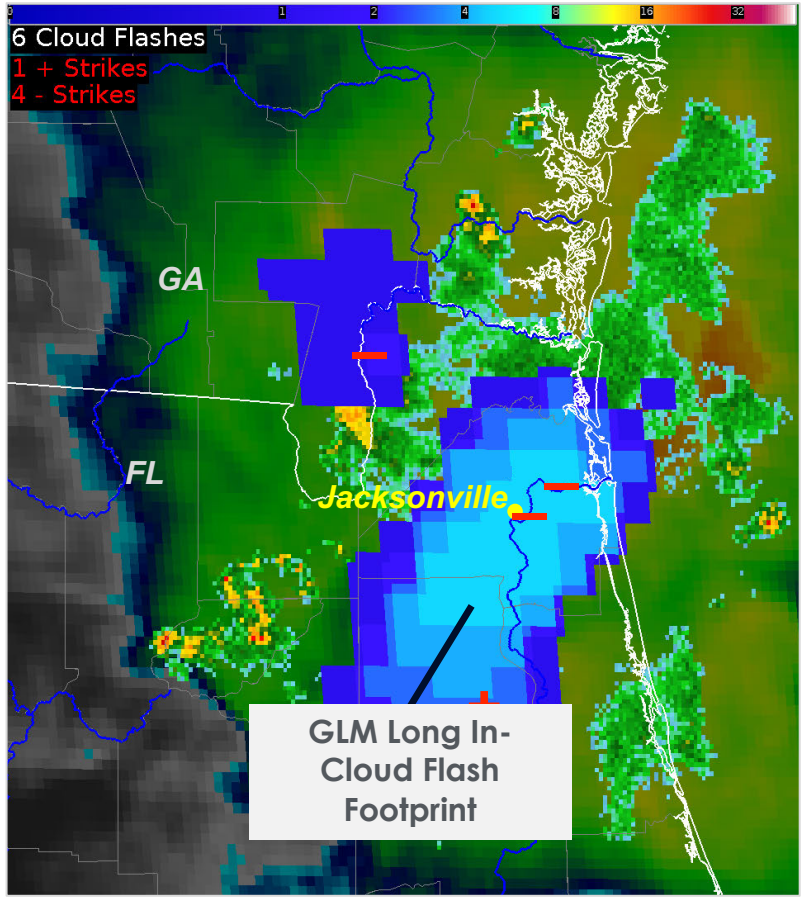
Improving Lightning Safety

- GLM improves public safety across broad segments of society.

ENTL Observations

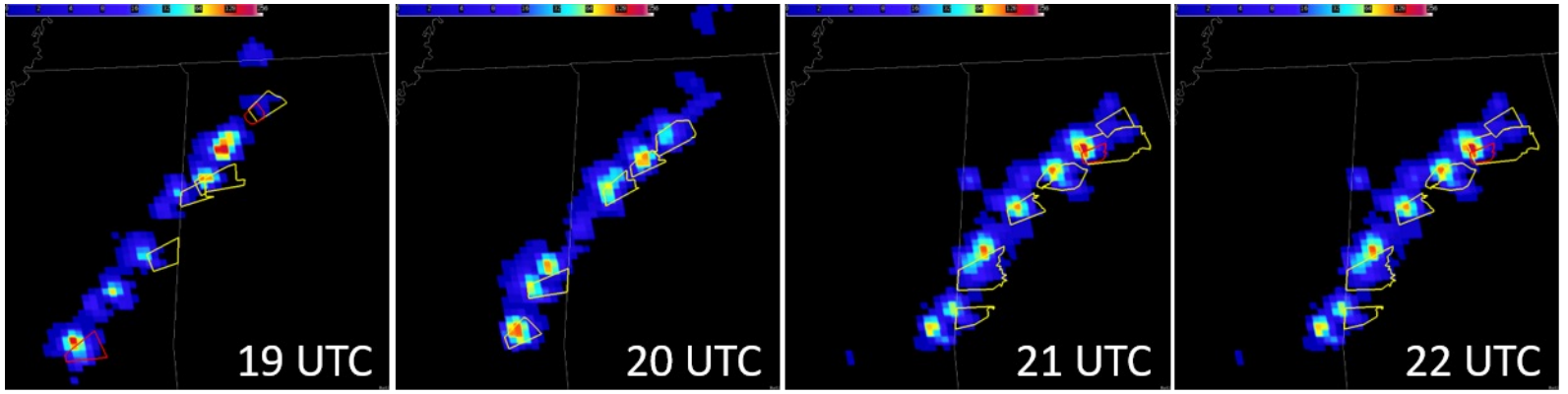


GLM Observations



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.



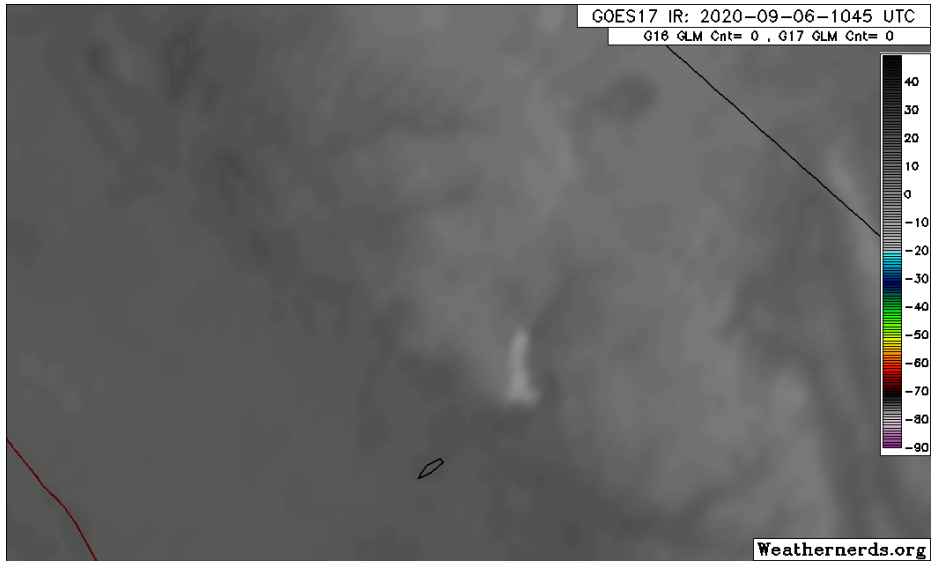
Warmer colors in the Flash Extent Density indicate the most frequent GLM flashes, with maxima commonly collocated with severe thunderstorm (yellow) and tornado (red) warning polygons.

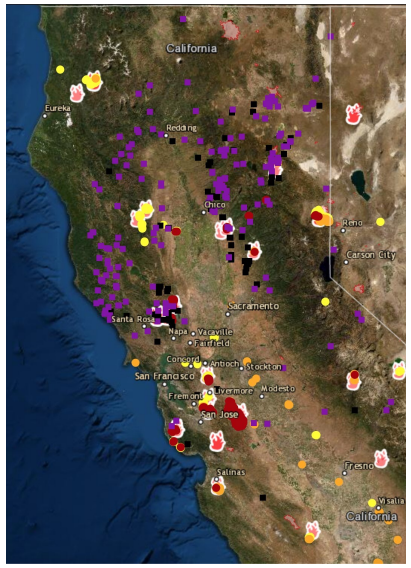
NWS HUN GLM Survey

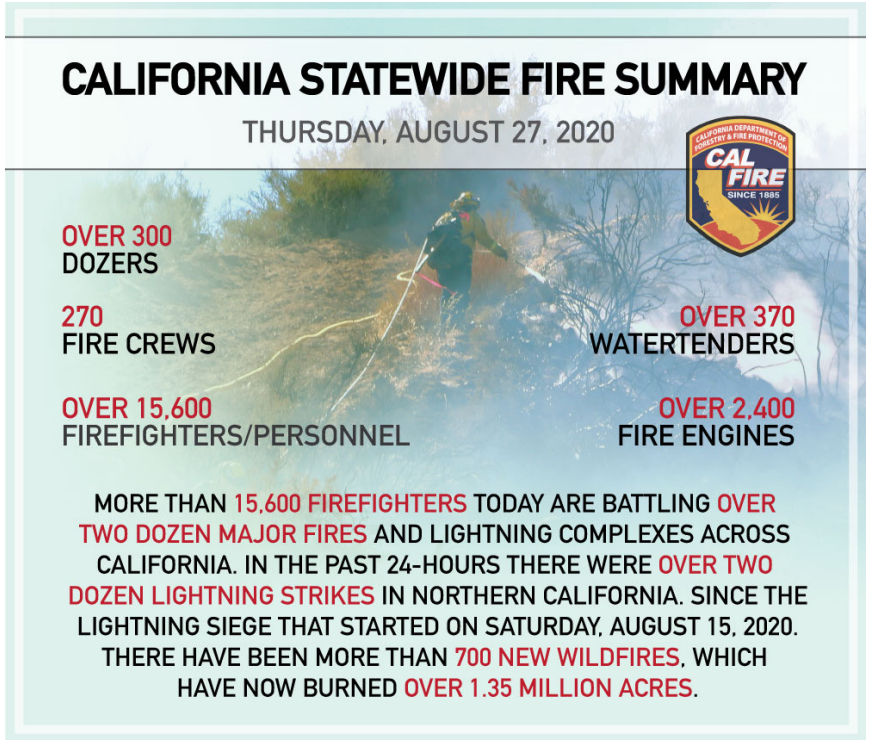
"In what ways do you use GLM during convective events, if any?"

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.

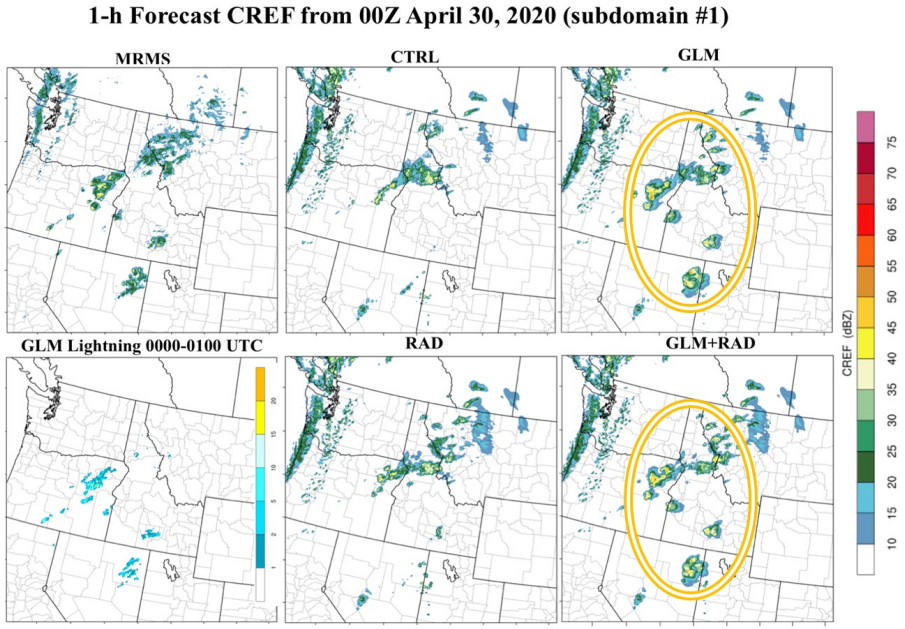




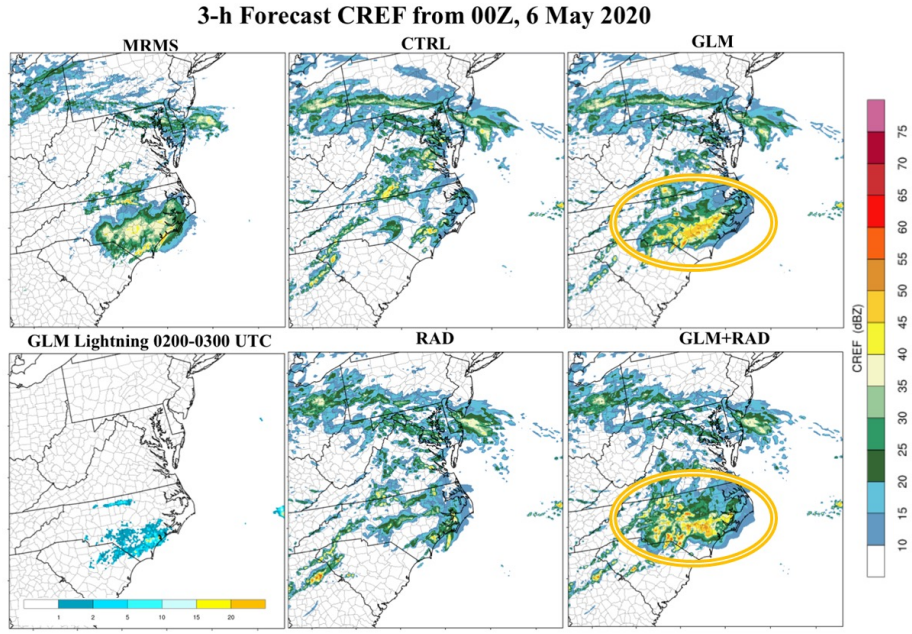


Improving Short-term Model Forecasts (Data Assimilation)

- 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.

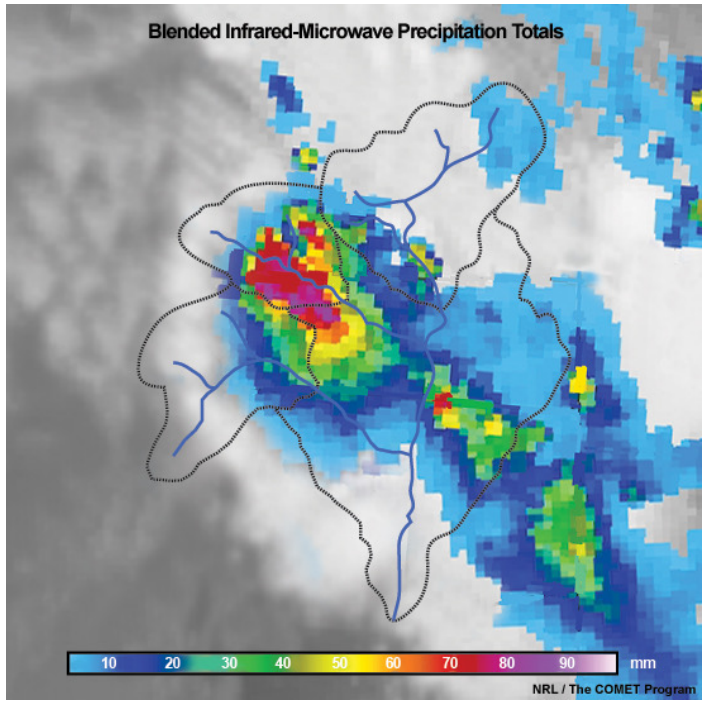


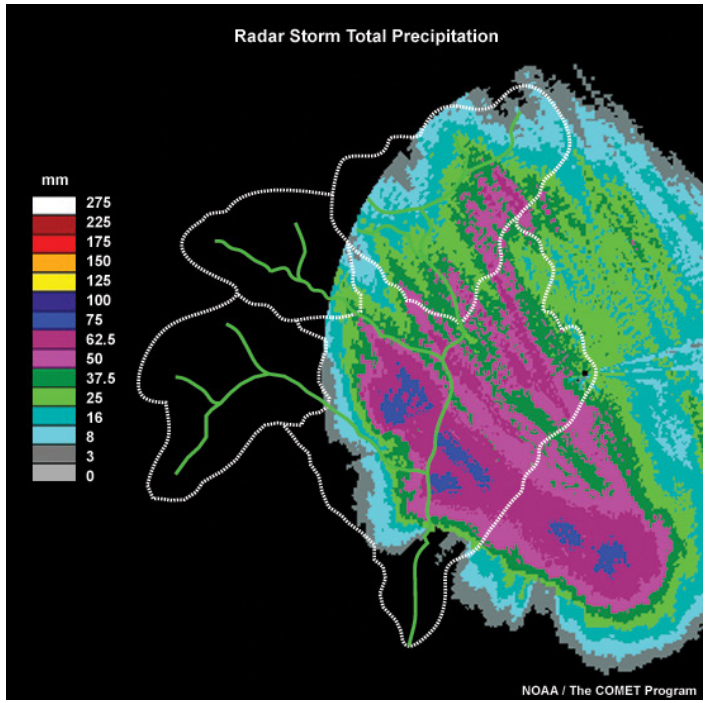
Recent results from Hu et al. 2020 and Fierro et al. (2020) describing experiments at the Hazardous Weather Testbed (presented at the GLM science meeting, manuscripts under review).

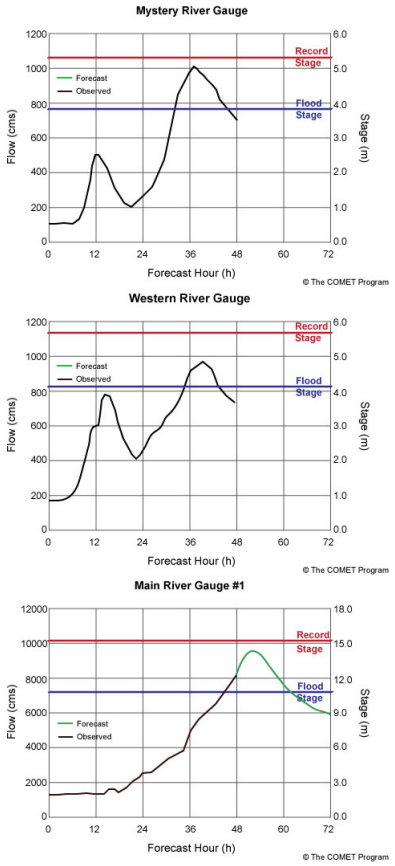


Improving Precipitation Estimation

- 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.



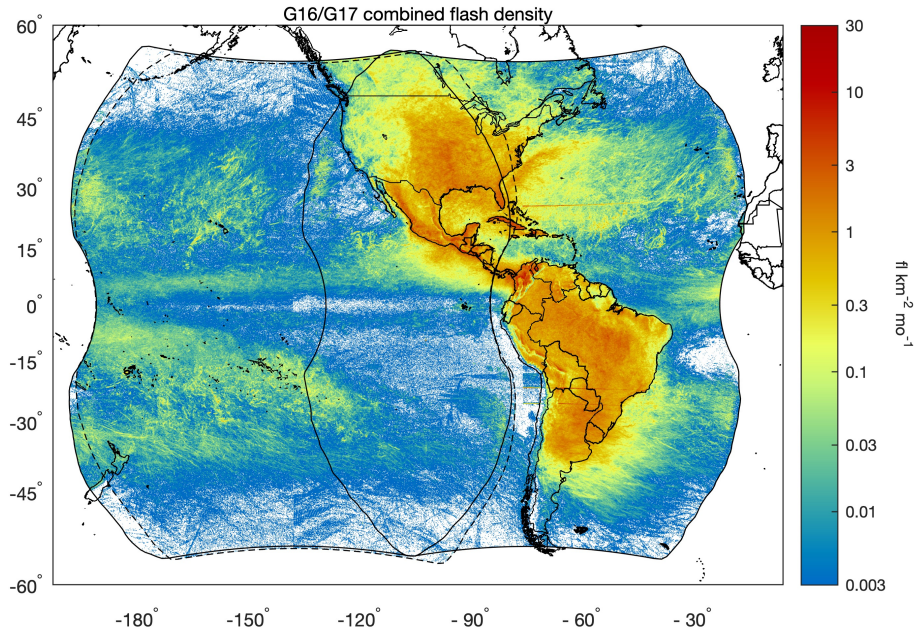


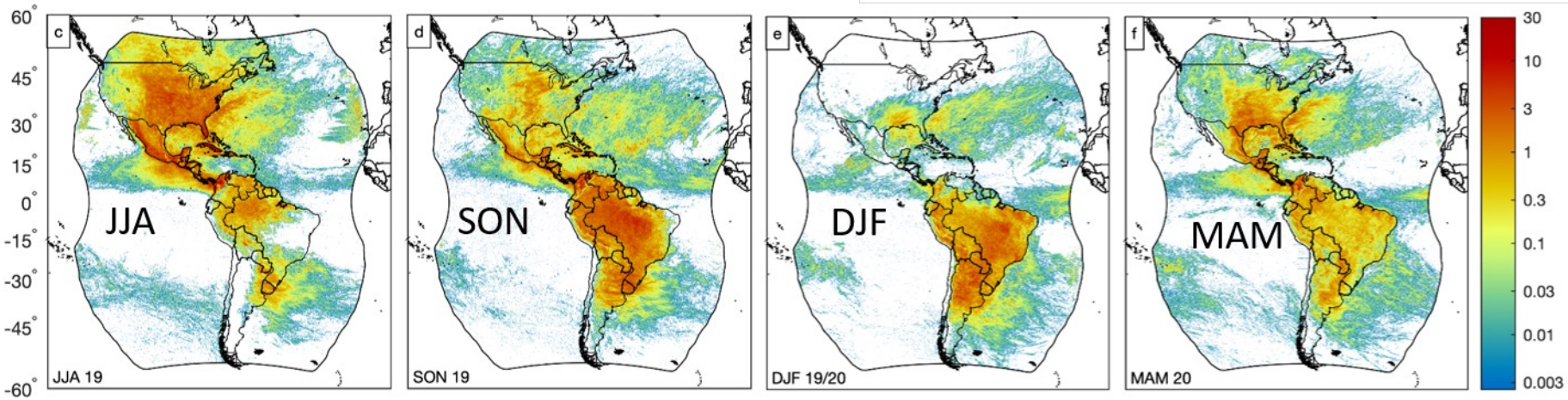


[Example from COMET Flood Forecasting Training]

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.

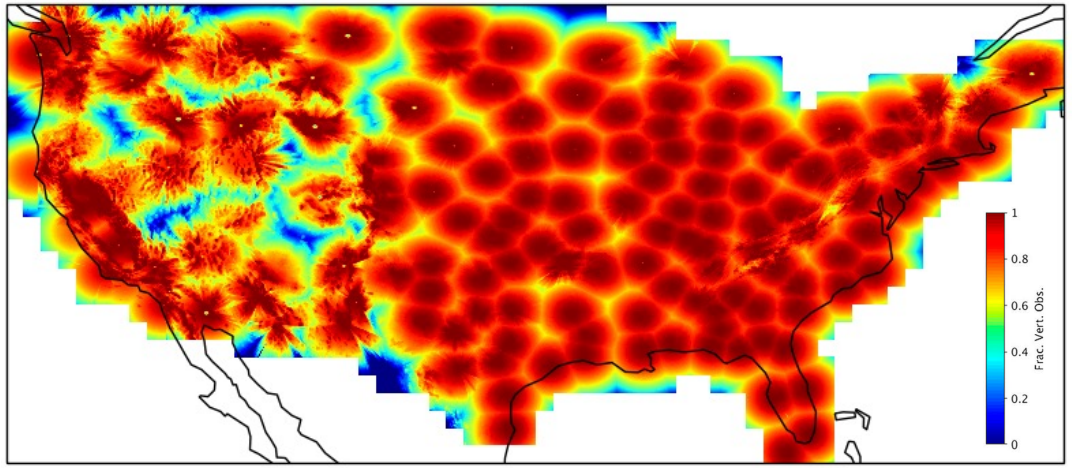




Images from Rudlosky and Virts (2020) – Under Review

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.

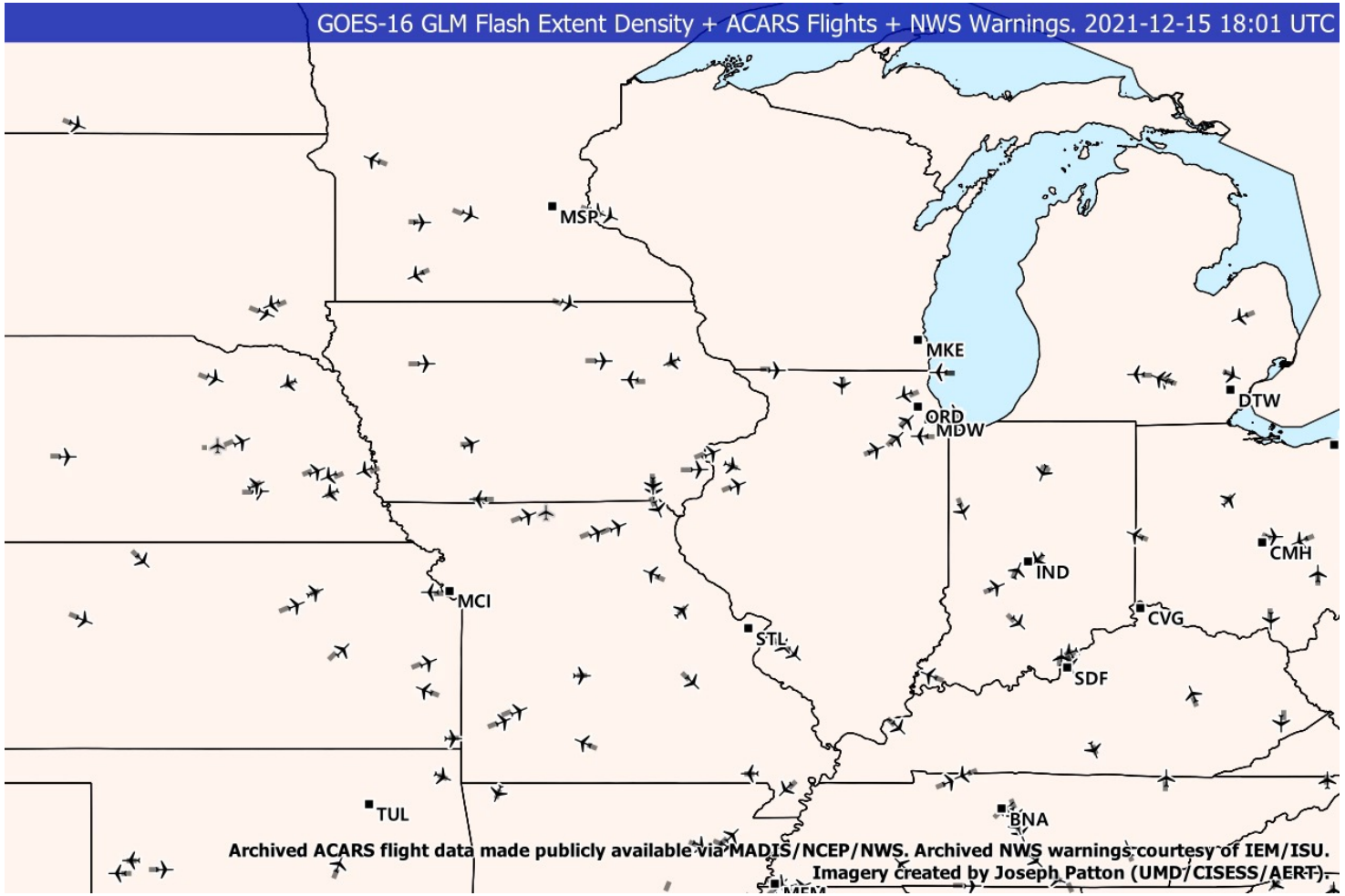


Above: Fraction of vertical volume observed between 0 and 20 kft AGL by current CONUS WSR-88Ds. (Courtesy of Cho and Kurdzo)

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

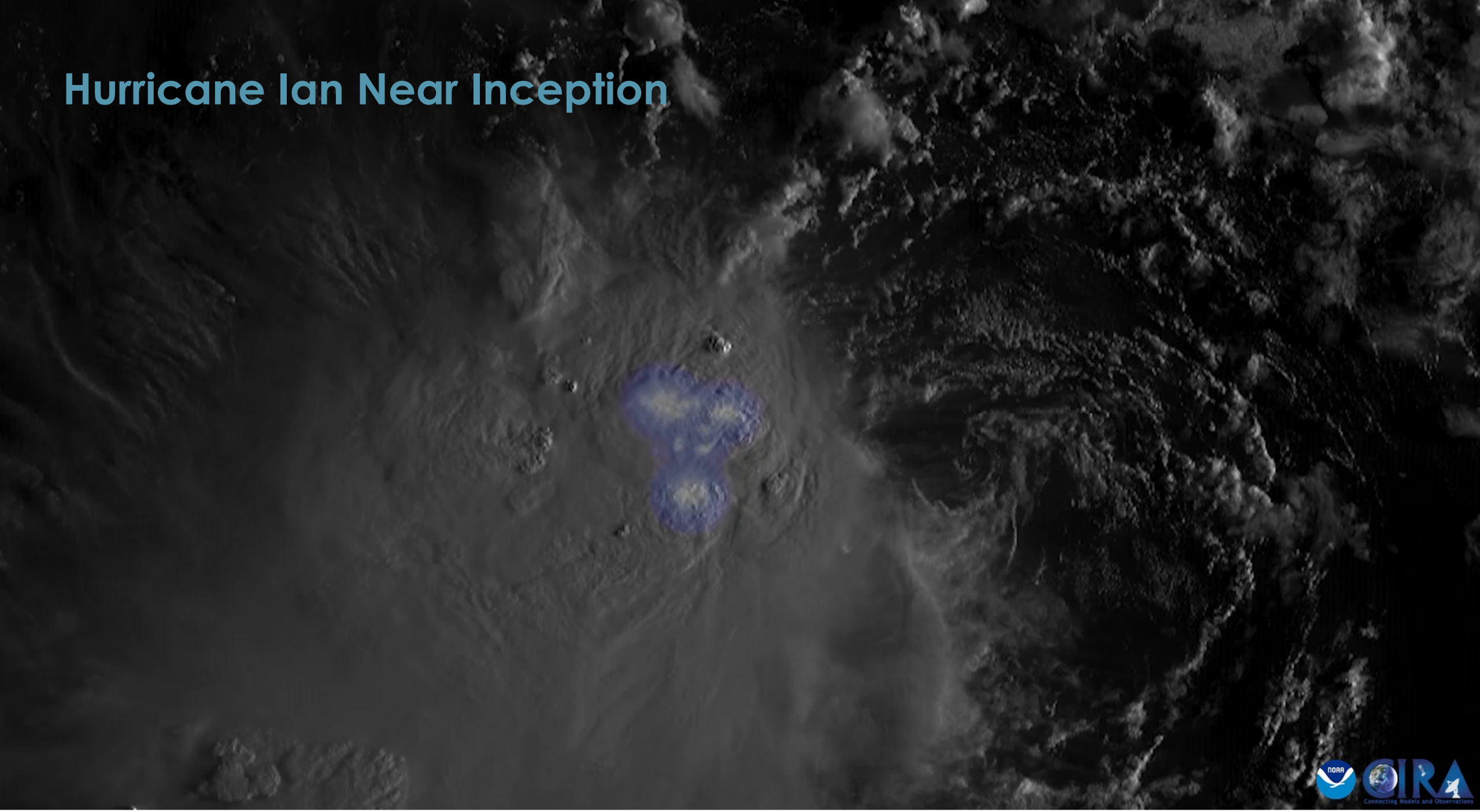
- The GLM helps better characterize lightning risk and increase confidence when suspending or continuing ramp operations, leading to enhanced safety, improved efficiency, and cost savings.
- The GLM's broad coverage and rapid updates provide tremendous cost savings to the aviation industry through improved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



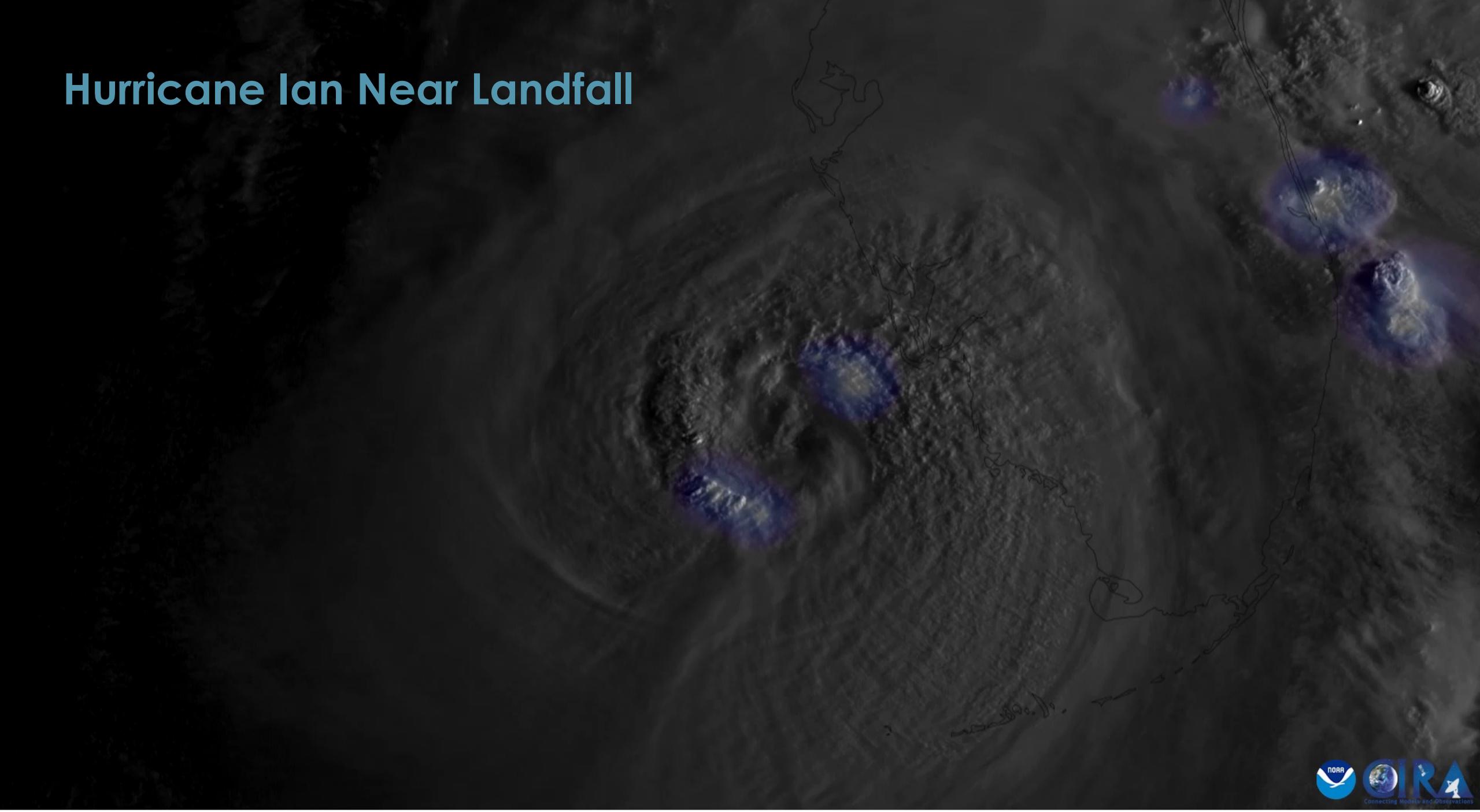
Improving Tropical Cyclone Diagnosis and Warning

- 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

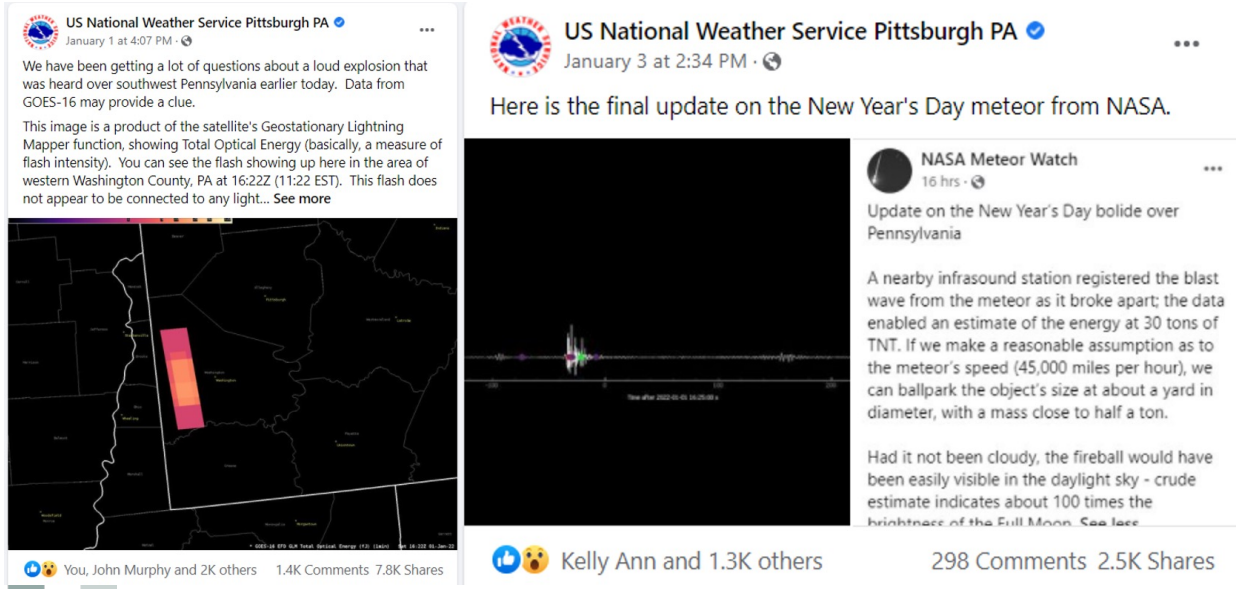


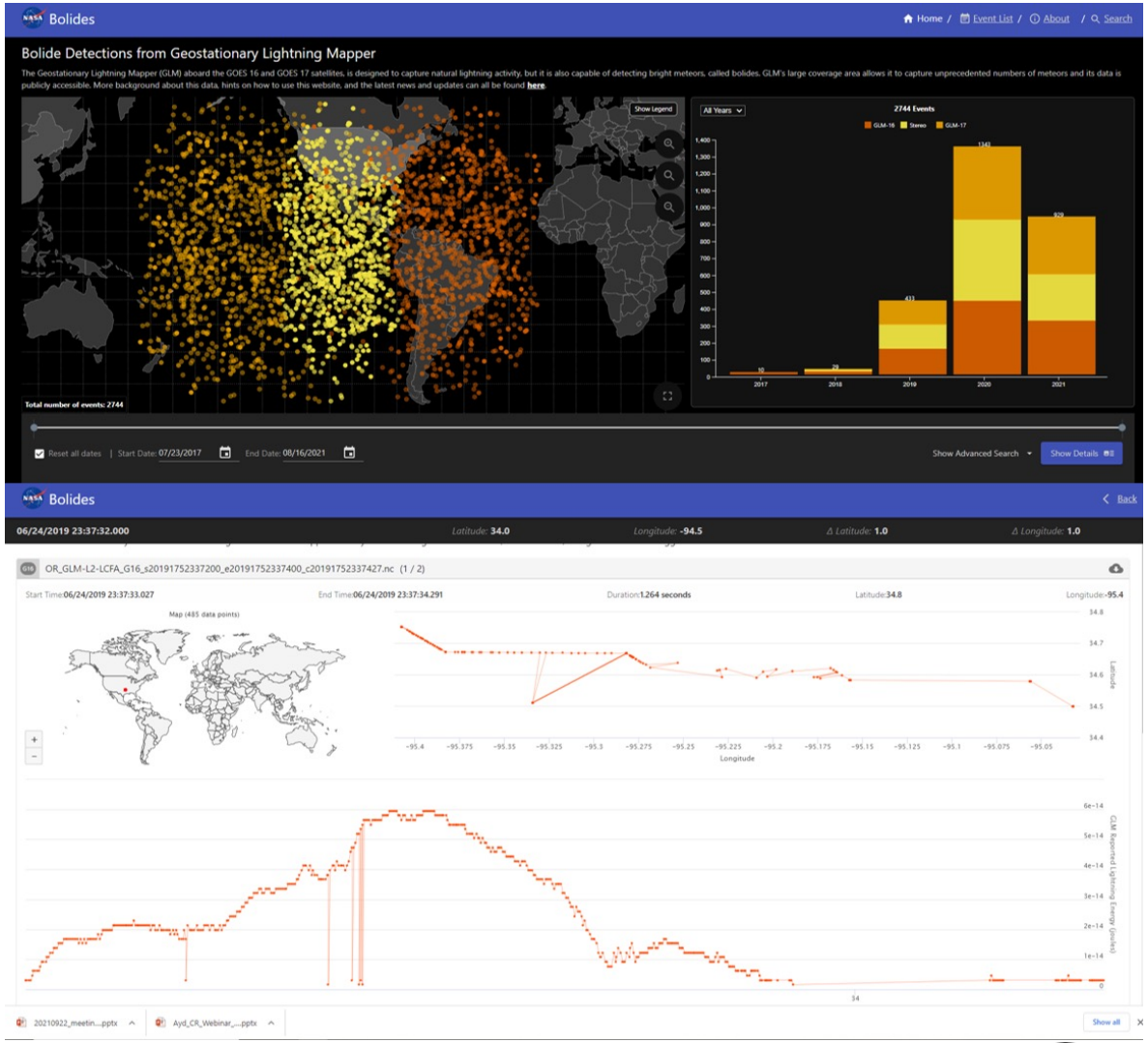
GLM Value Assessment Summary

- 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

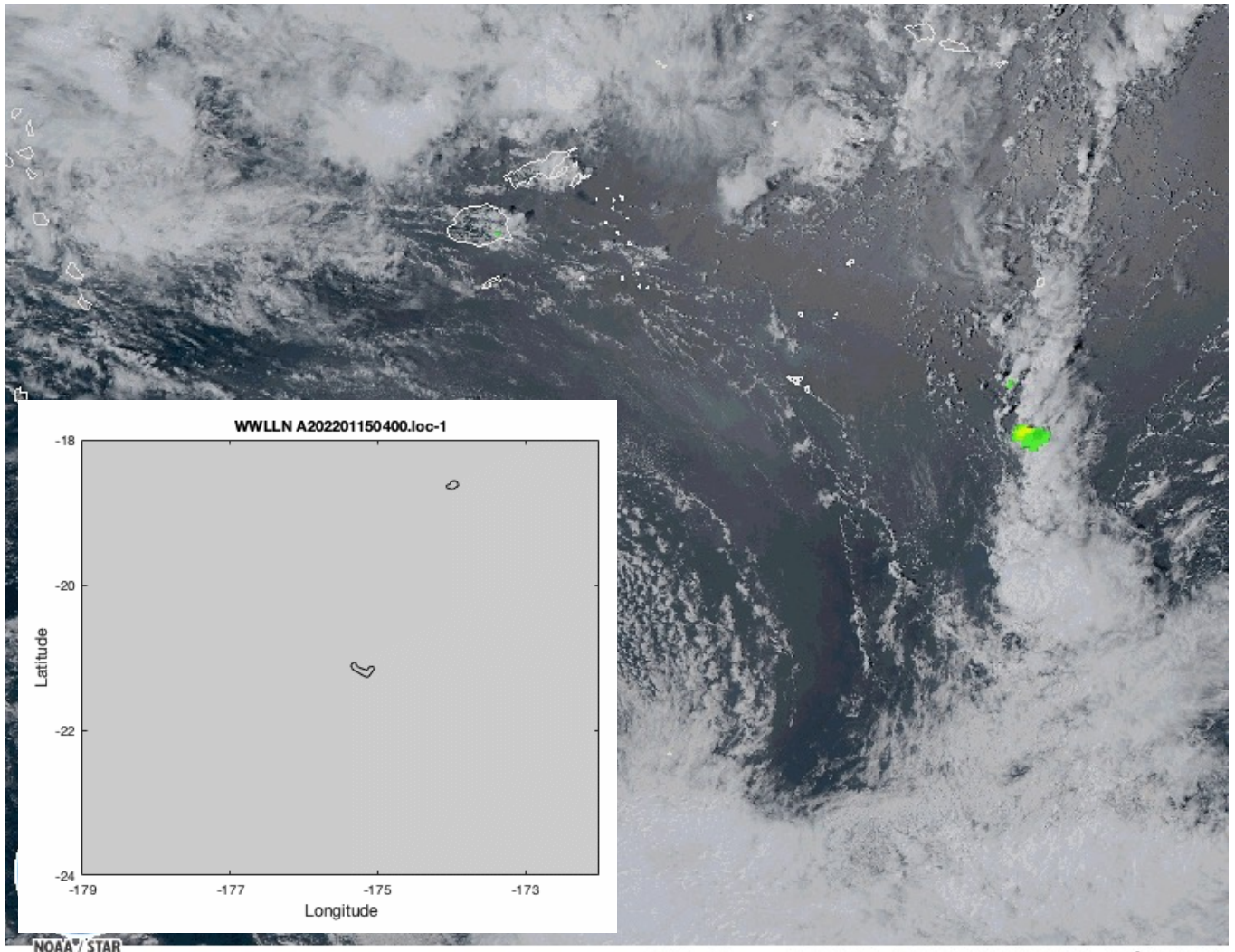
- Jenniskens et al. (2018) showed that the GLM sensors detect **bolides**.
- GLM also geolocates and provides light curves (i.e., a time intensity recording of a bolide impact and disintegration)





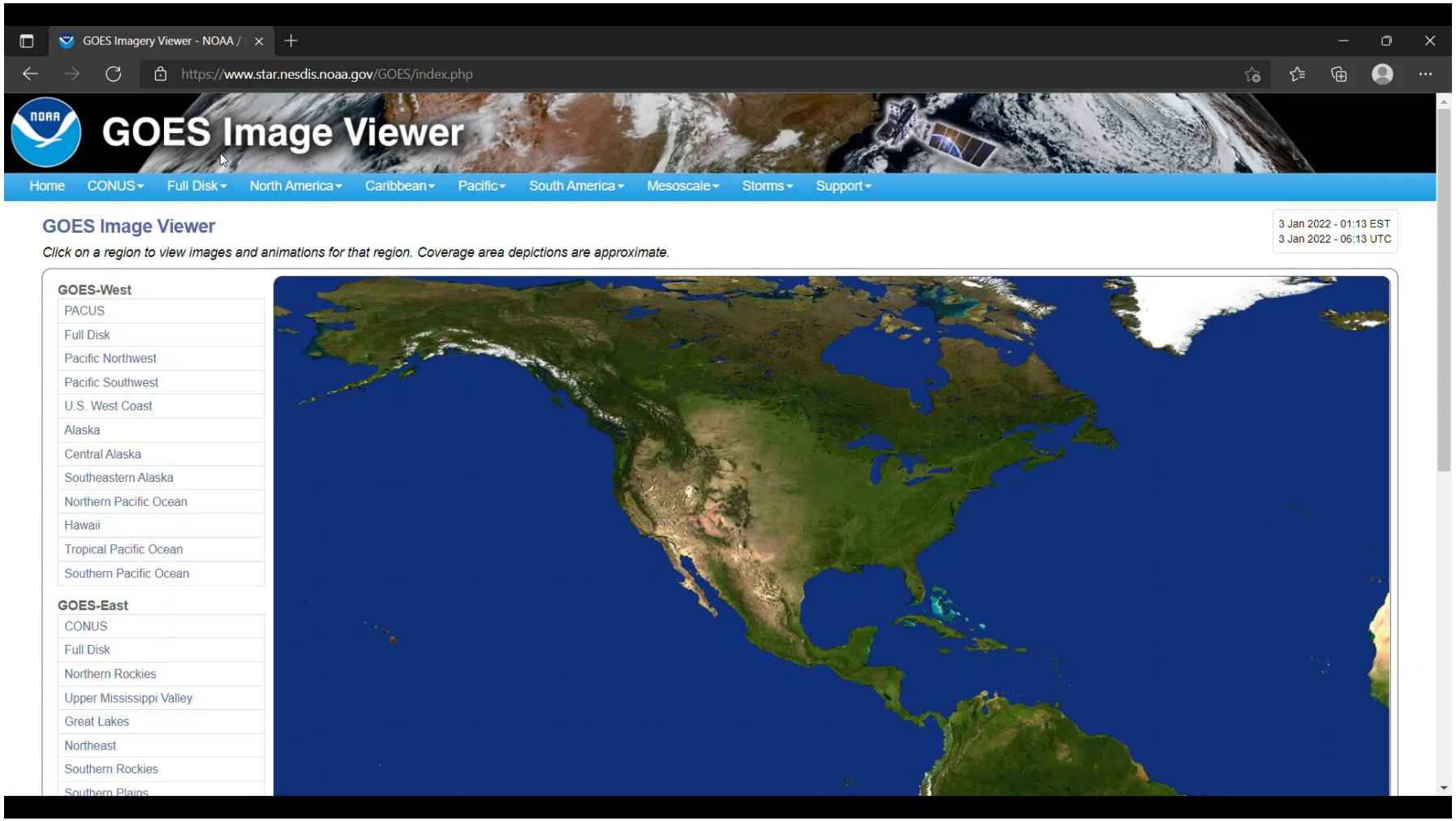
Monitoring for Volcanic Eruptions

- 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



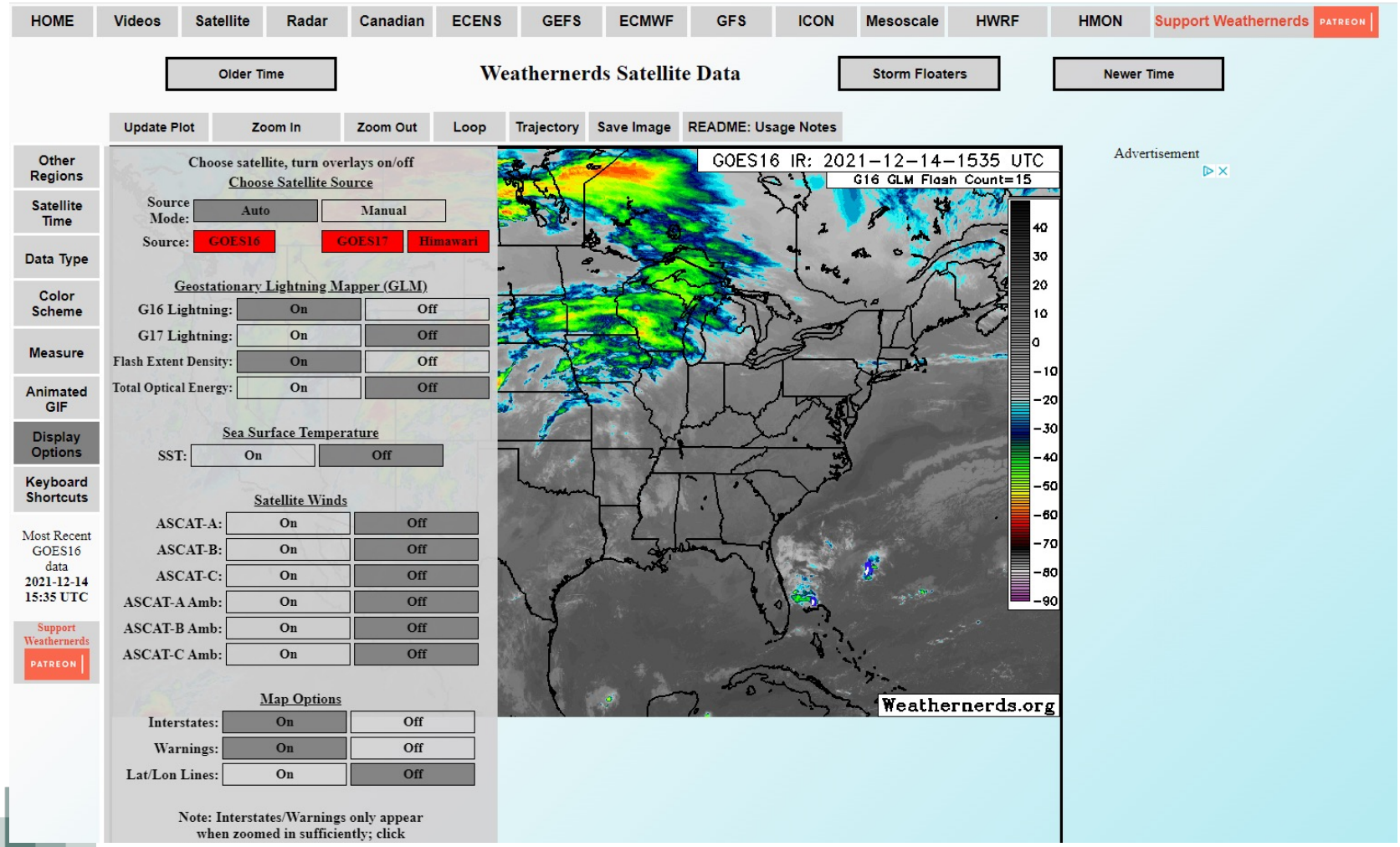
Accessing GLM Imagery

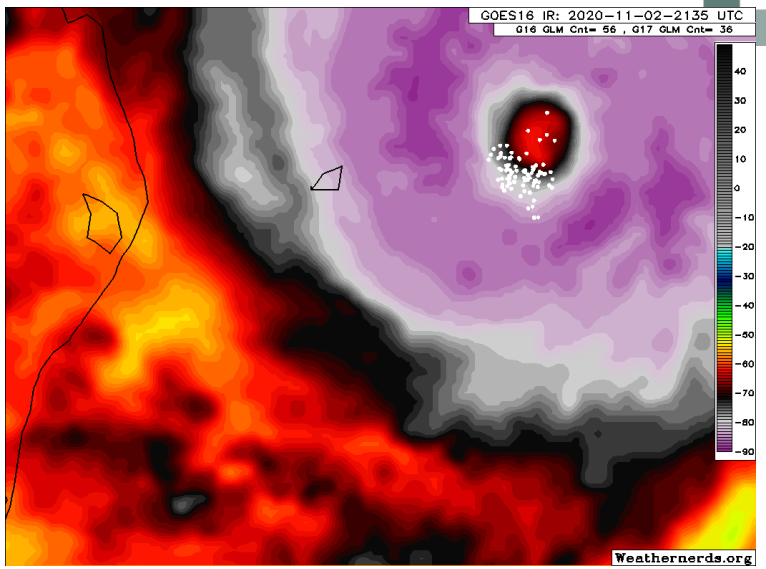
- [STAR GOES Viewer]

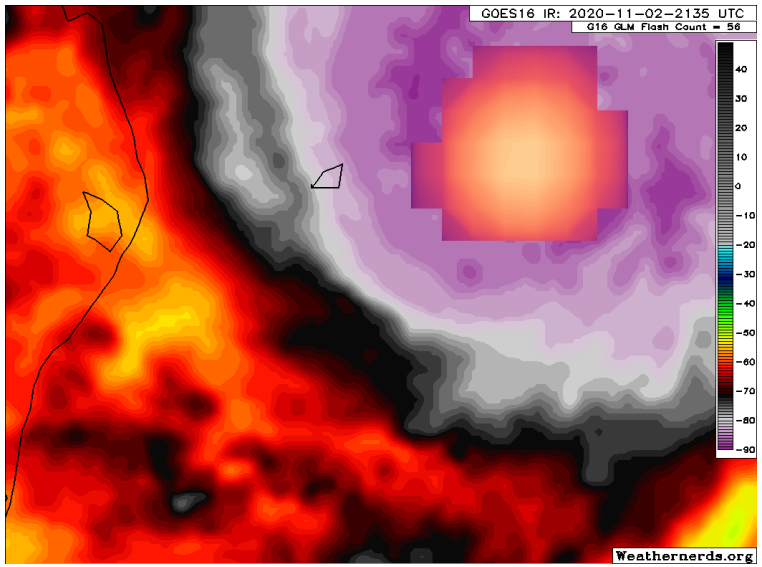


Accessing GLM Imagery

- [Weathernerds]

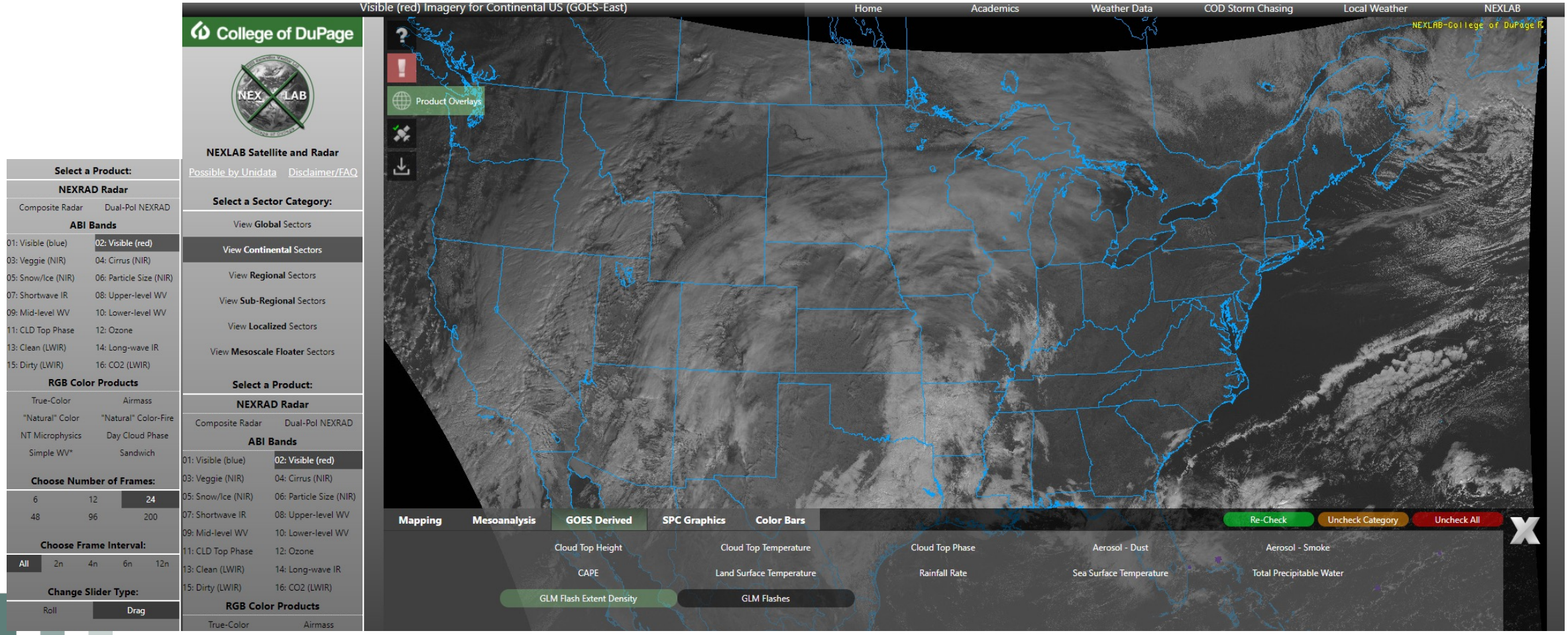






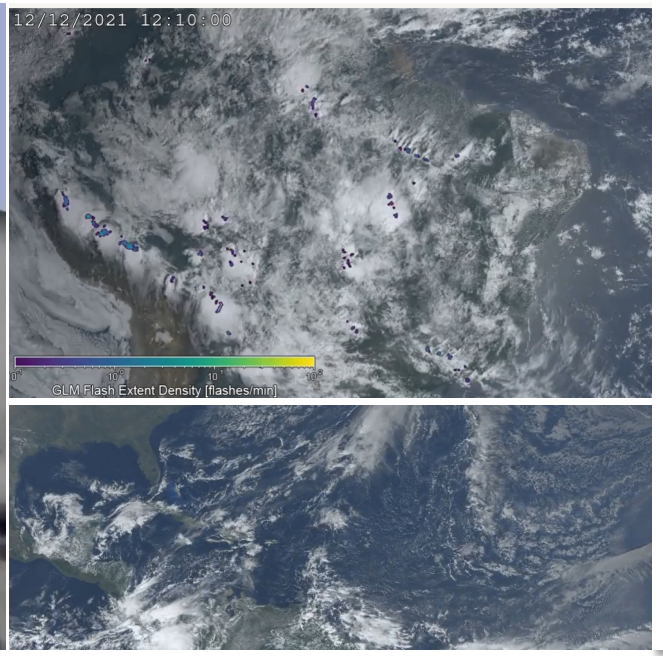
Accessing GLM Imagery

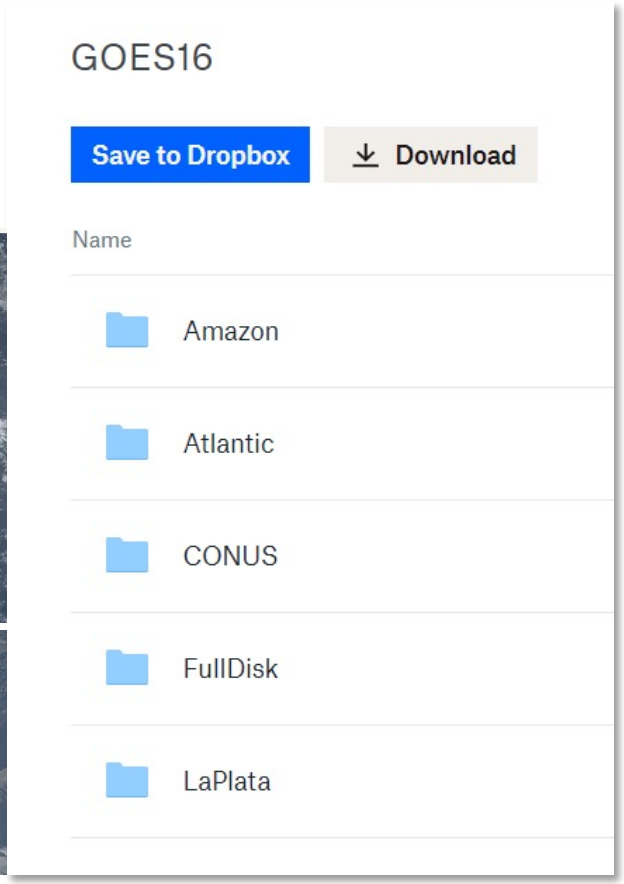
- College of DuPage (COD) Meteorology Webpage



Accessing GLM Imagery

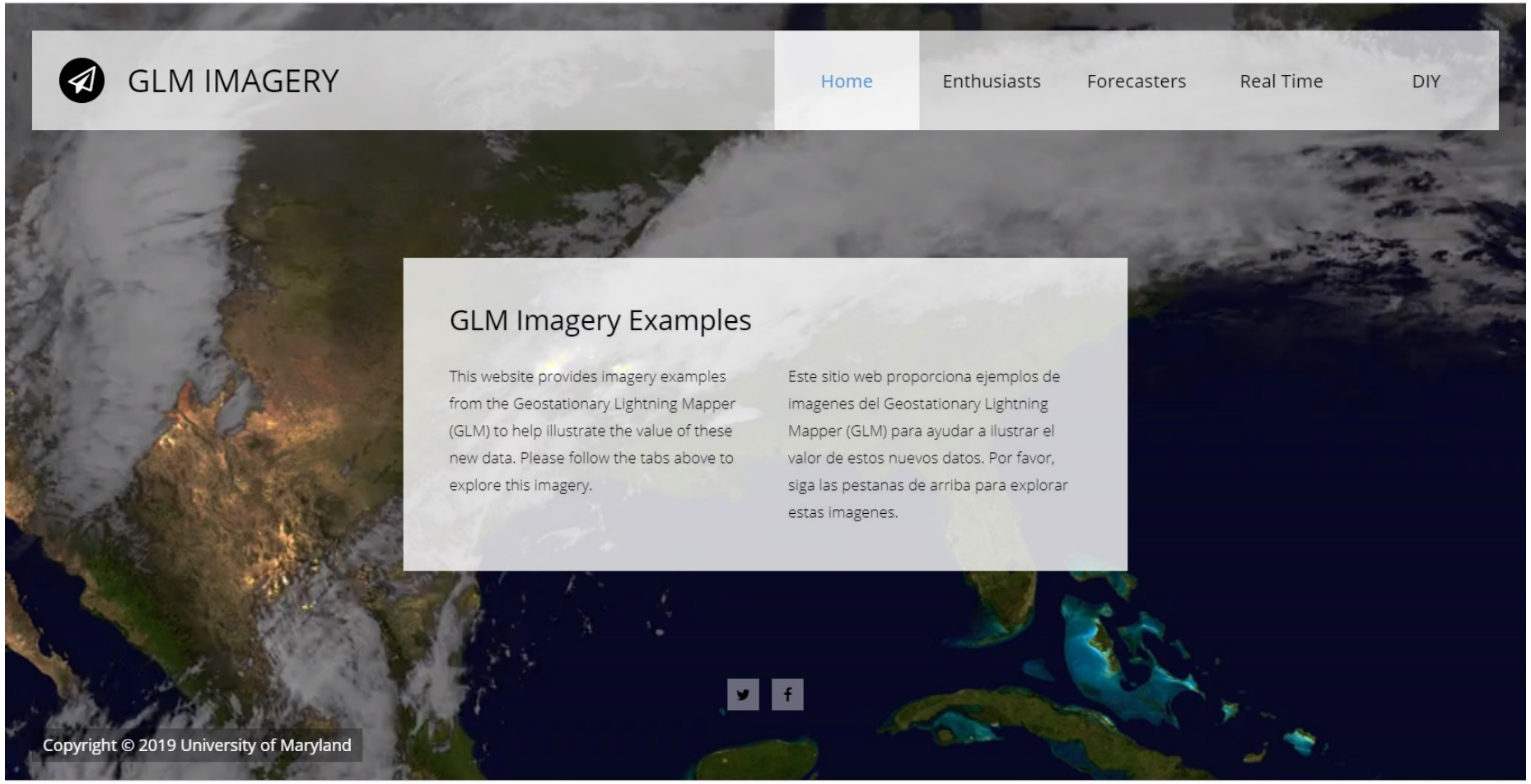
- [Dropbox Composite Imagery]
- [Dropbox Flash Skeletons]





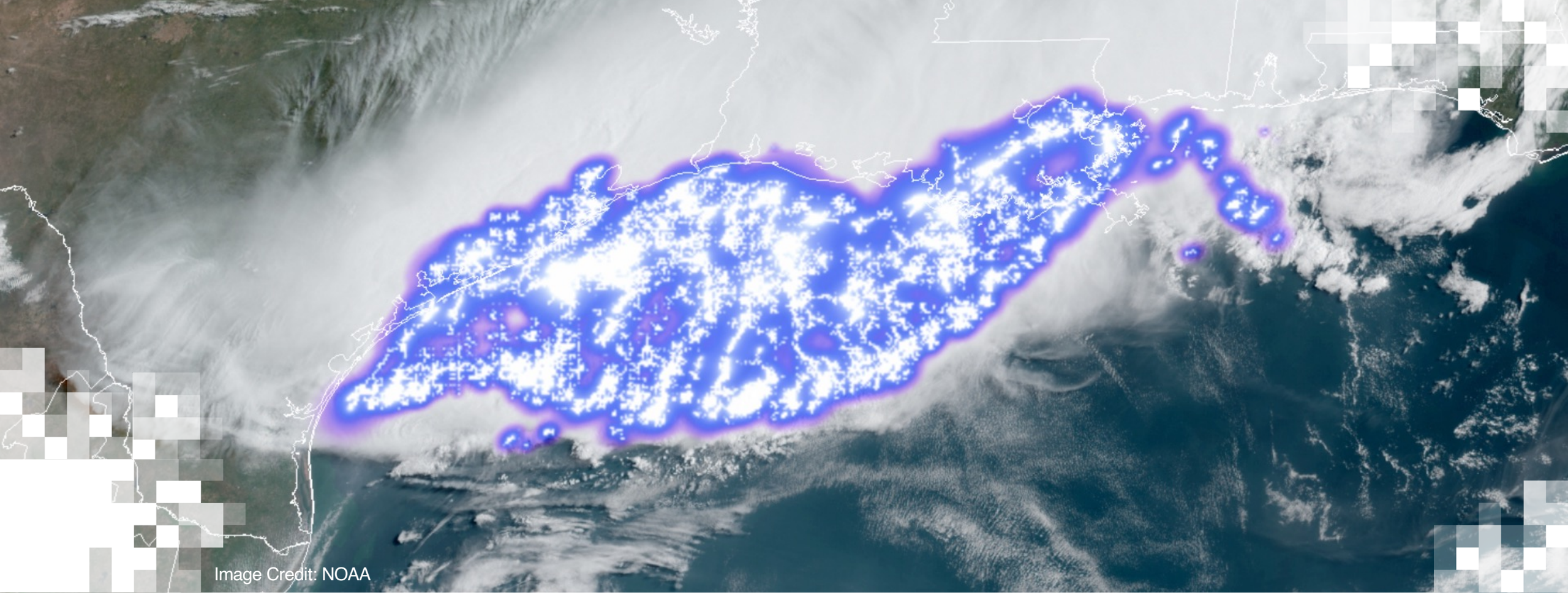
Accessing GLM Imagery

- 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

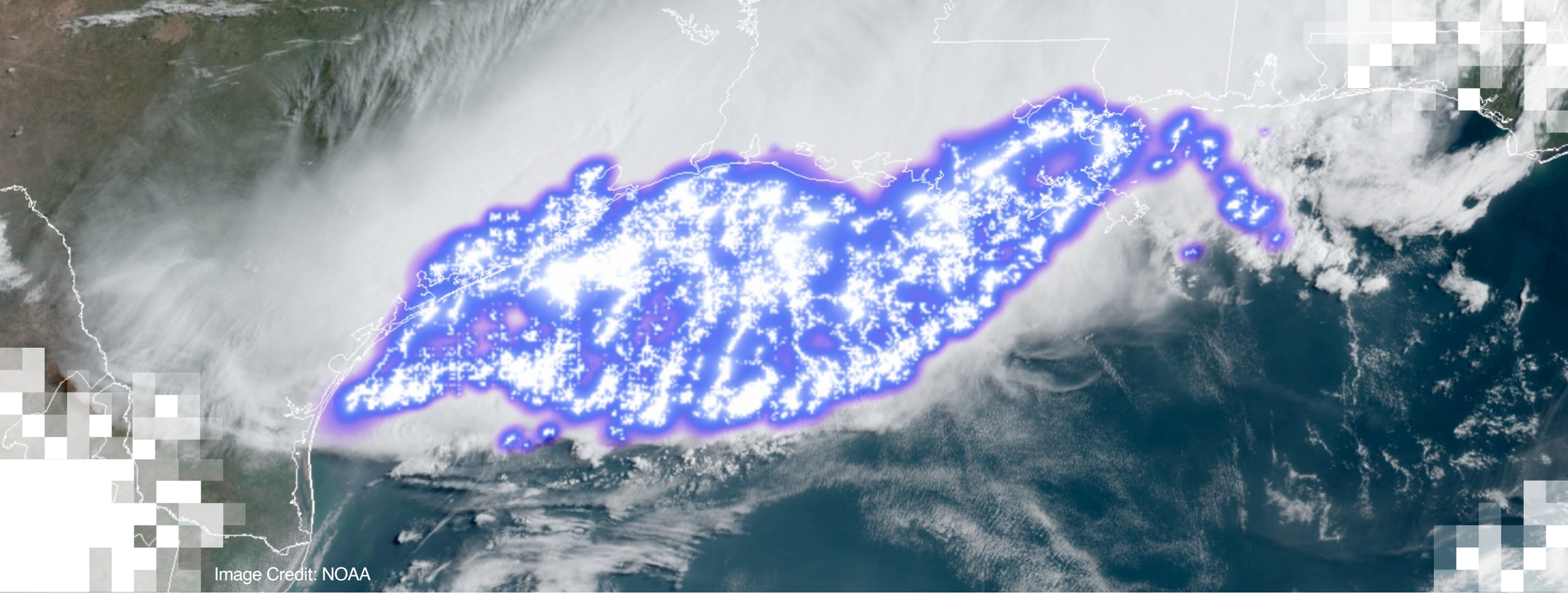
- GLM Vlab
- UMD GLM Page
- Links to Routinely Available Imagery:
  - NESDIS/STAR GOES Viewer
  - Weathernerds Webpage
  - COD Meteorology Webpage
  - Cesium GLM Globe



Part 3
Summary

Summary

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



Introduction to Lightning Observations and Applications

Summary

Training Summary

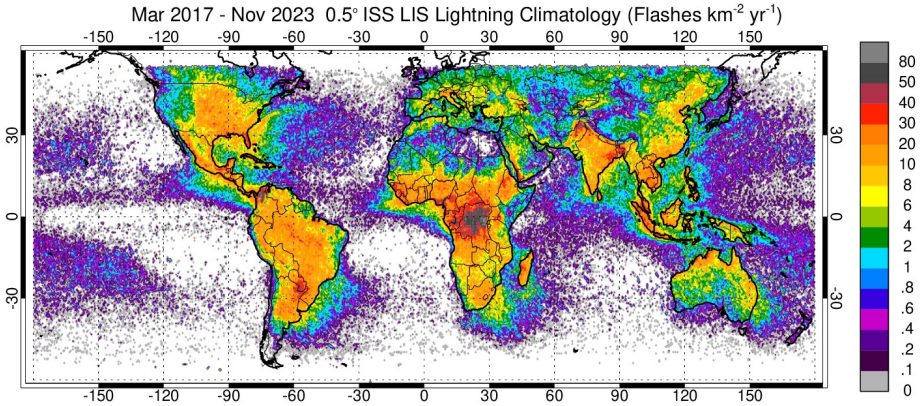
- What Lighting Is and How it Forms:
  - High-current electrical discharge between positively and negatively charged regions of a thunderstorm.
  - As ice particles within storm clouds grow, collide, and break apart, they acquire positive and negative charges.
  - Under the influence of gravity and updraft, 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

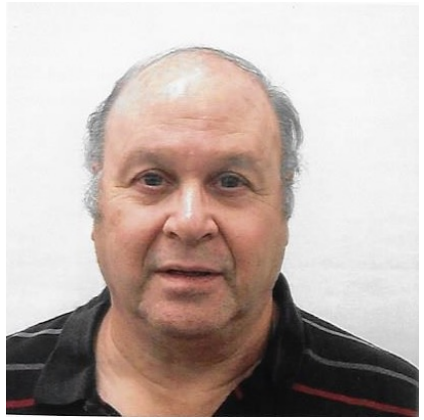


Homework and Certificates

- **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.

Acknowledgements



Dr. Steven Goodman
Thunderbolt Global Analytics
NASA-GSFC

Dr. Scott Rudlosky
NOAA

Dr. Timothy Lang
NASA-MSFC

Dr. Christopher Schultz
NASA-MSFC

Contact Information

Guest Speakers:

- Scott Rudlosky
  - scott.rudlosky@noaa.gov

ARSET Trainers:

- Amita Mehta
  - amita.v.mehta@nasa.gov

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Thank You!