GeoXO: The future of NOAA's Geo satellites and benefits for Nowcasting

National Environmental Satellite, Data, and Information Service

CPAM, August 19-23, 2024
Sao Paulo, Brazil

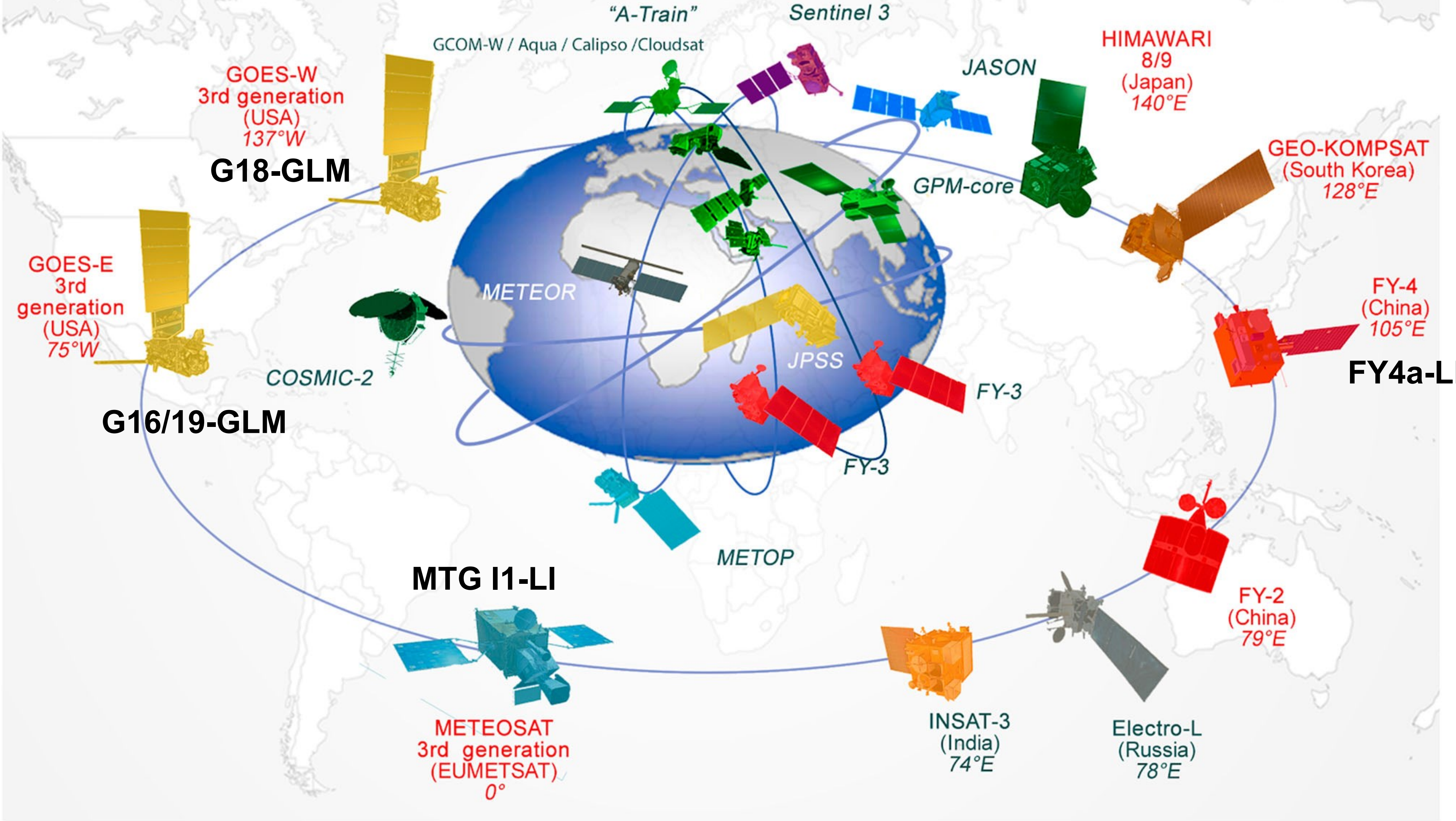
Steven J. Goodman
NOAA/NASA Geo Earth Observations Program
NASA GSFC Code 618
Greenbelt, MD USA

Outline

- Introduction to the Space-based Global Observing System
- Evolution from GOES to GeoXO
- Nowcasting tools, products, and prototyping
- Capacity Building – R2O, User Engagement, Proxy Data, Proving Grounds, Testbeds, Training
- Summary

Space-based Component of the Global Observing System

(source, WMO Space Program)



What is GOES?

GOES = Geostationary Operational Environmental Satellites

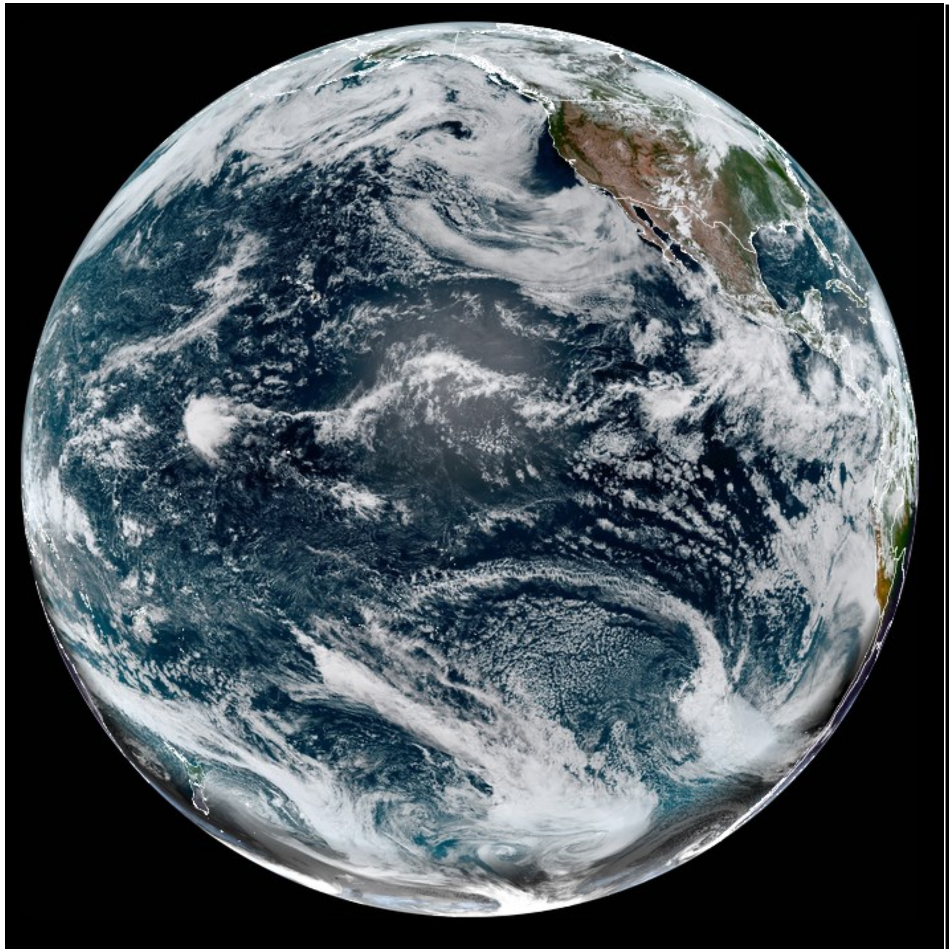
Continuous coverage of the western hemisphere since the mid-1970s

The current series of 4 satellites, known as the GOES-R series, launched in 2016 and continues operating today

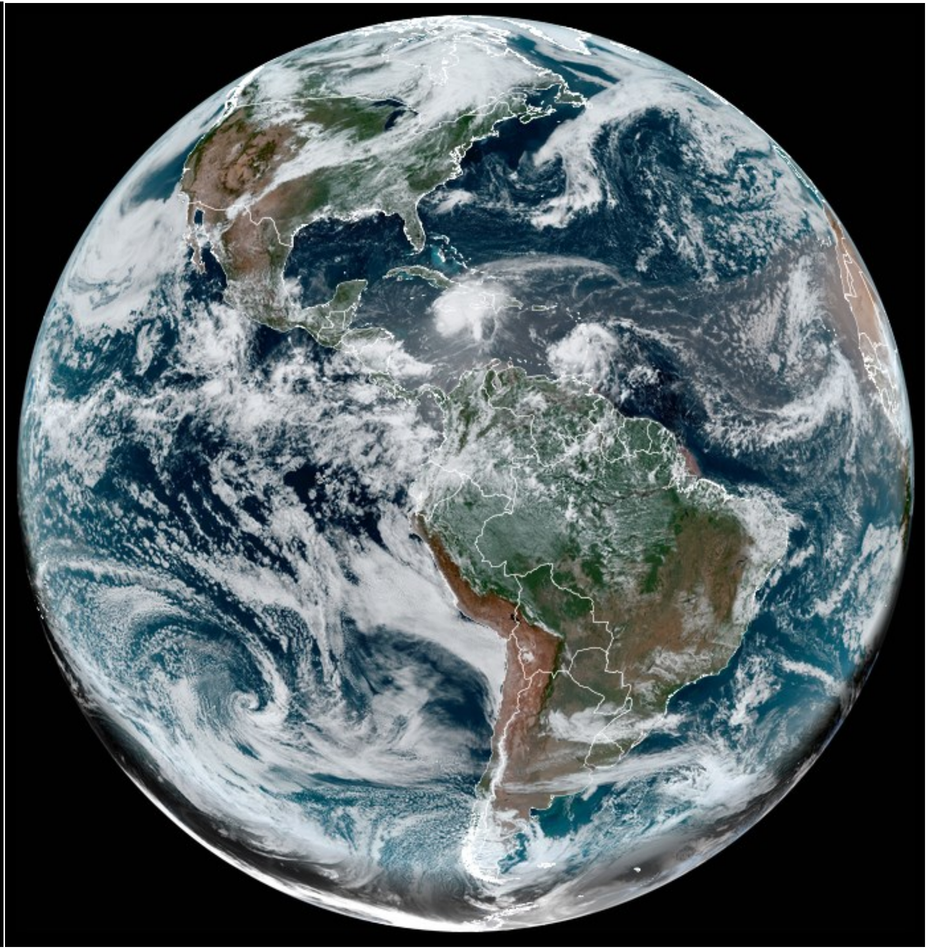
Earth-pointing instruments include the Advanced Baseline Imager (ABI) and Geostationary Lightning Mapper (GLM)

Also carries several space weather instruments

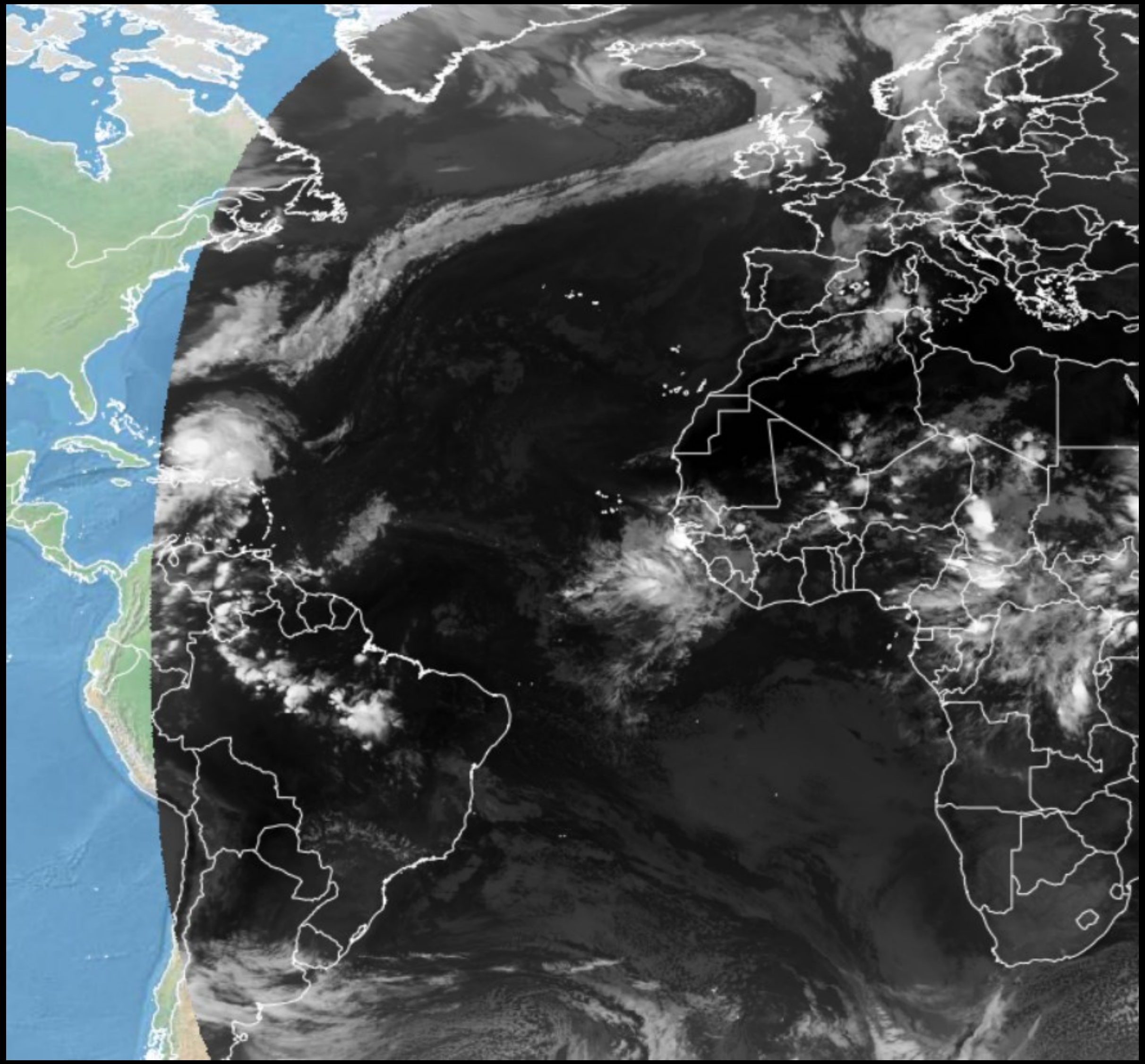
View from GOES west (137 W)



View from GOES East (75 W)



Geo-Ring - Americas

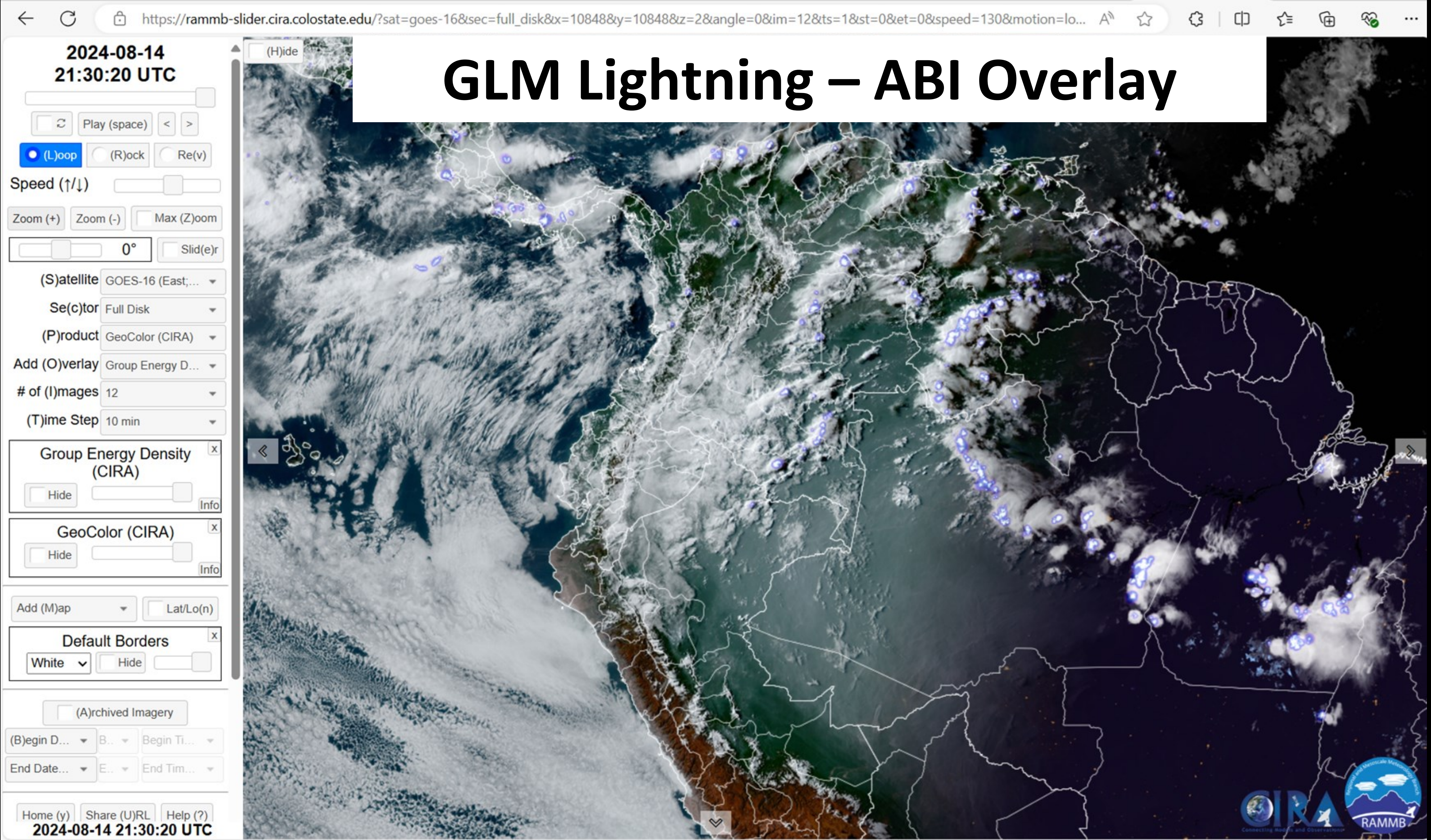


G16 ABI

21:30 UTC August 14, 2024

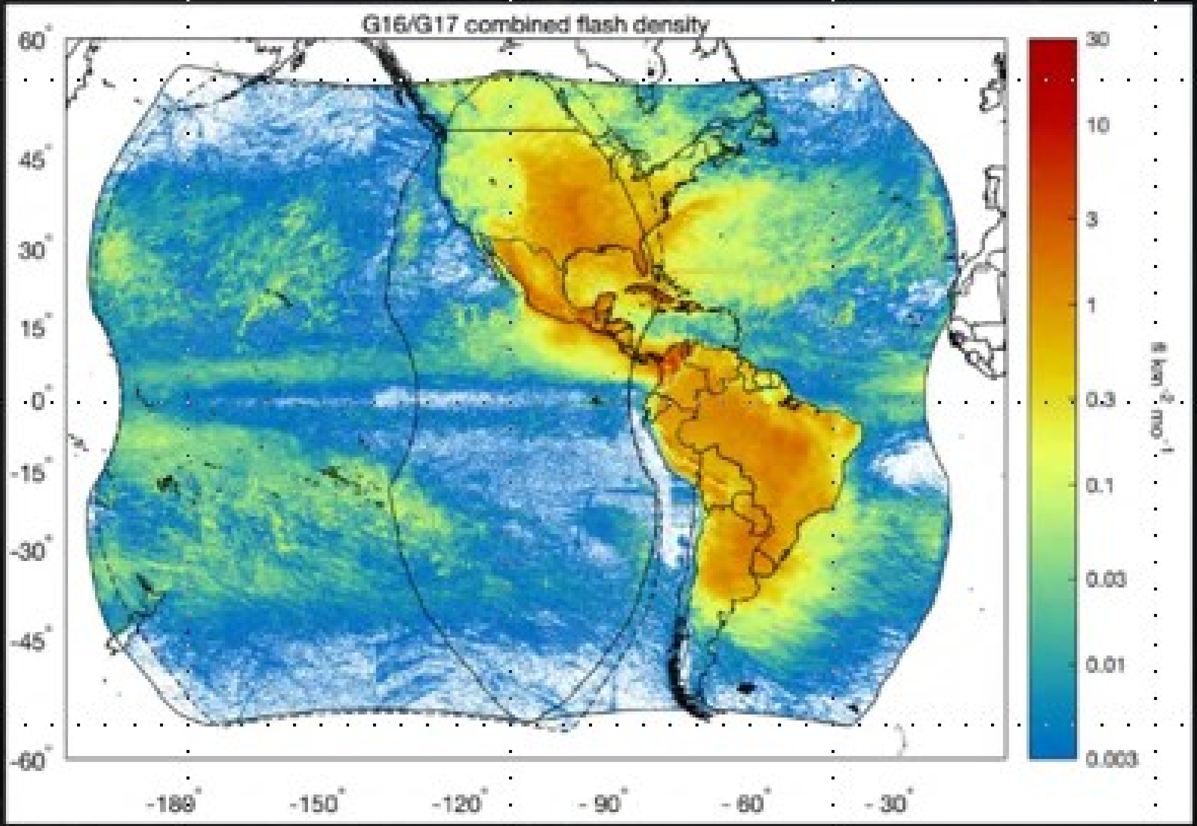
MTG FCI

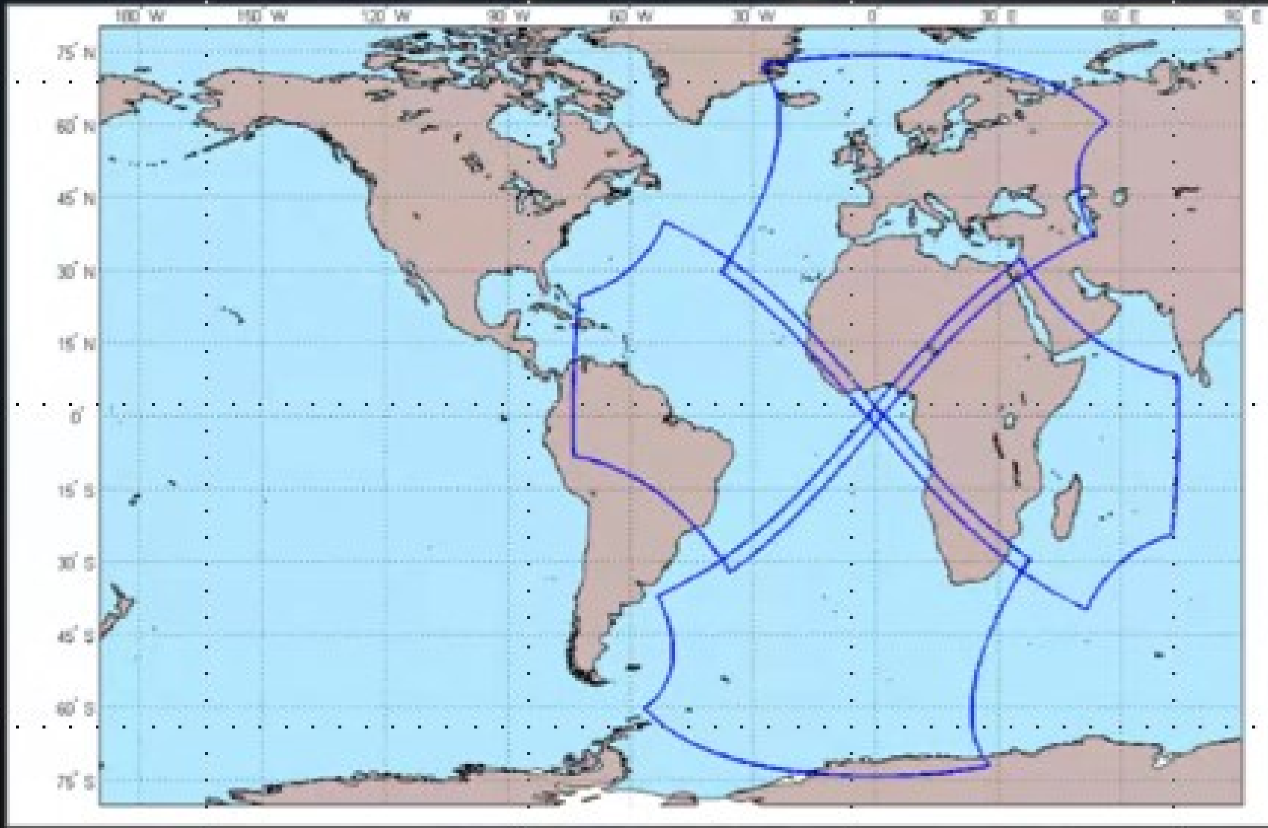
GLM Lightning – ABI Overlay



Coverage Overlap of GLM and MTG-LI

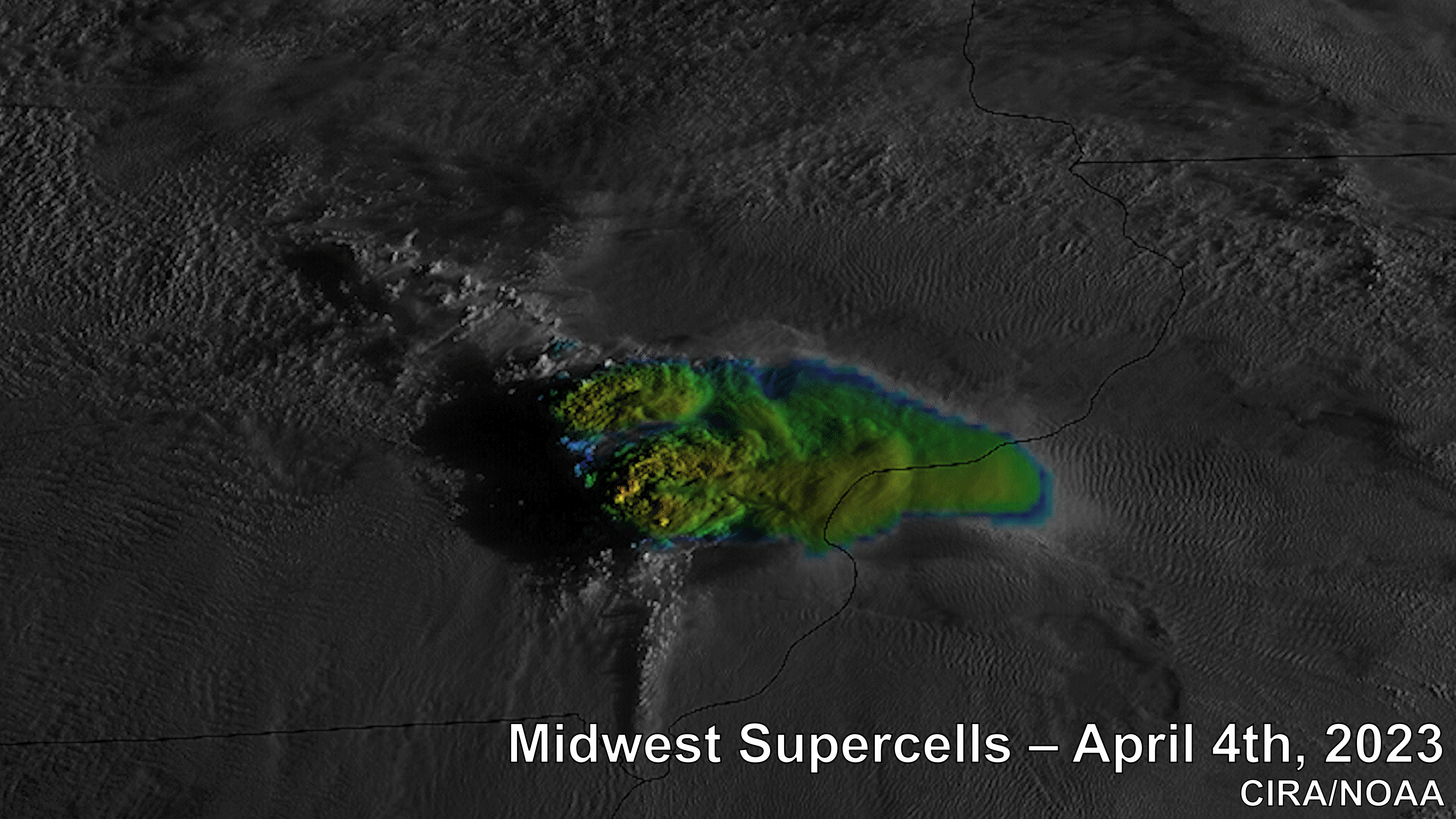
(and of LMX and MTG-LI)

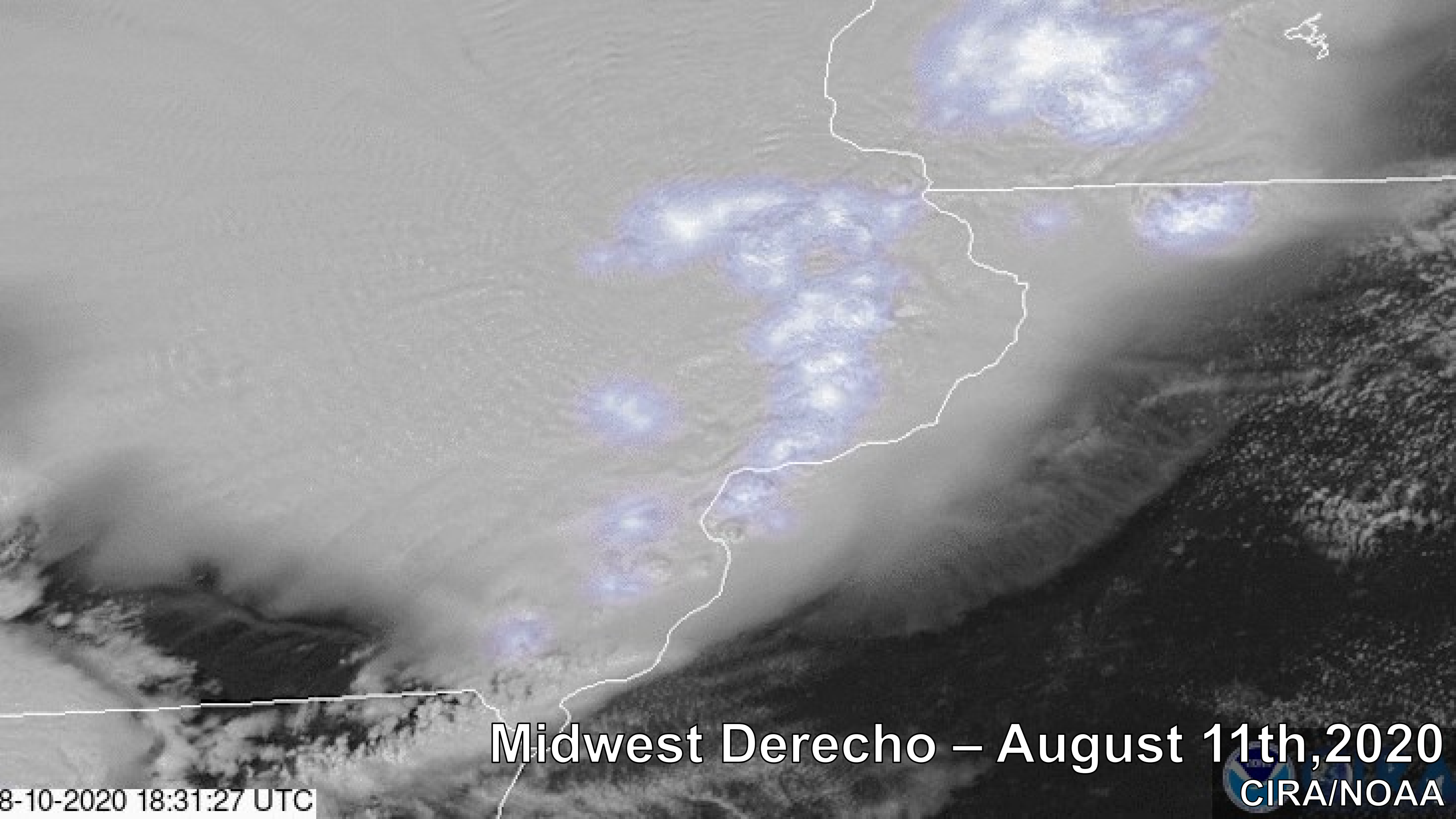




Exploring options for multi-sensor exploitation (GLM, MTG-LI, LMX, and ground based).

Ensuring smooth transition from GLM to LMX.


Midwest Supercells – April 4th, 2023
CIRA/NOAA


Midwest Derecho – August 11th,2020
8-10-2020 18:31:27 UTC
CIRA/NOAA

GOES-U Launch

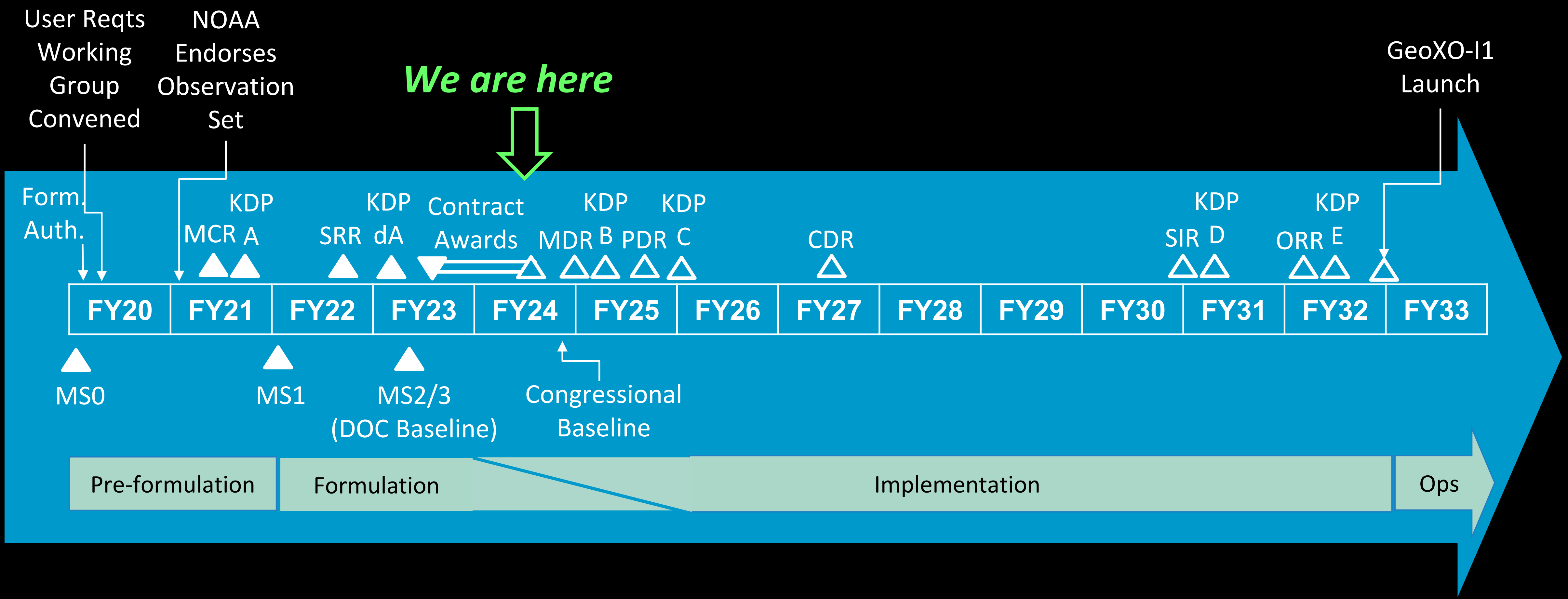
June 23, 2024 (https://www.goes-r.gov)

GOES-19 Post-Launch Test Status

Component	Data Flow Initiated	First Light	First Public Image Release	Beta Certification	Provisional PS-PVR
ABI (L1b & CMI)	8/20/2024	8/20/2024 (VNIR) 8/28/2024 (IR)	9/4/2024	9/4/2024	1/3/2025
GLM	8/20/2024	8/20/2024	10/3/2024	1/21/2025	3/26/2025

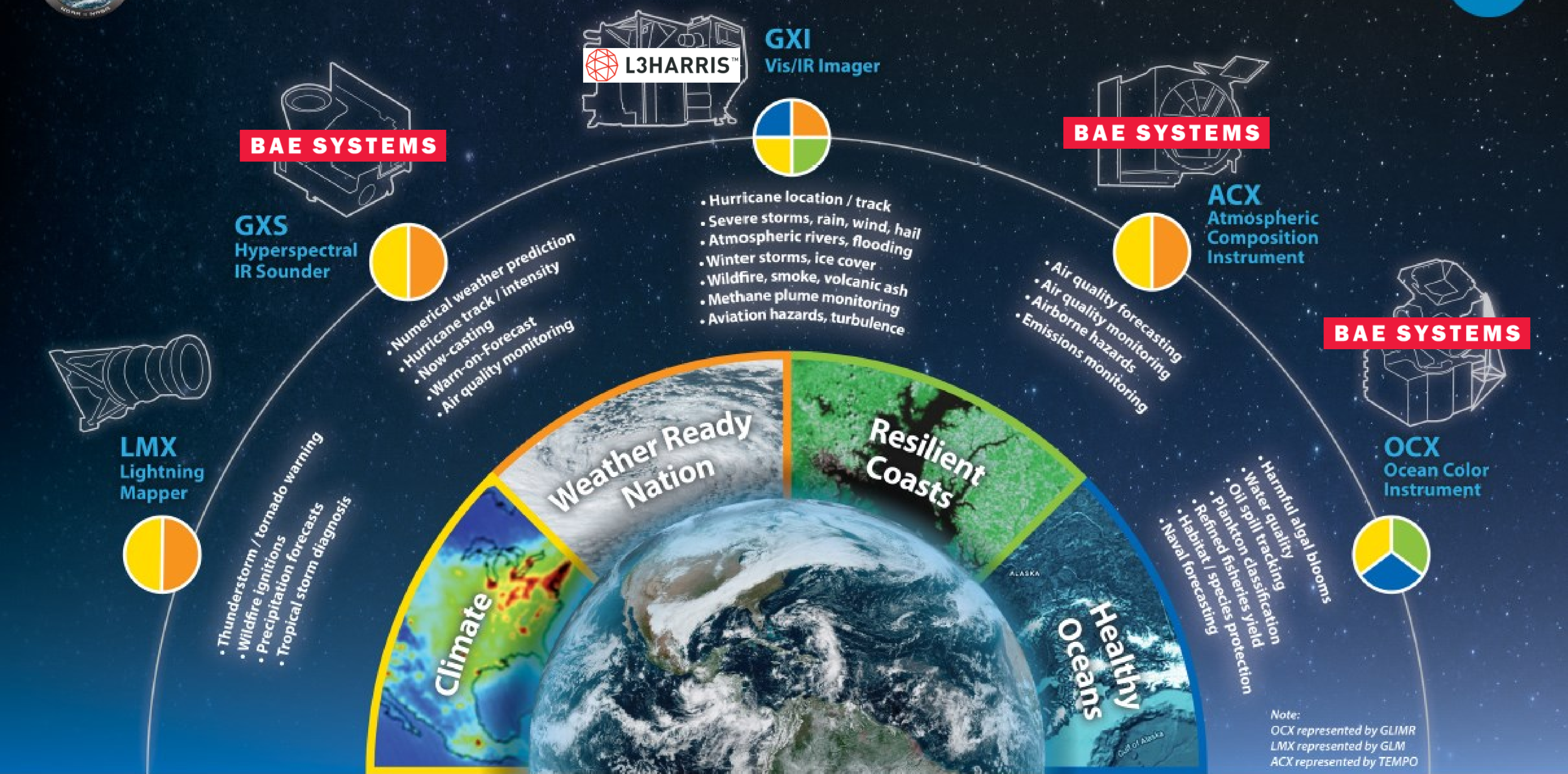
G19 operational 4/4/2025

GeoXO Timeline




GeoXO Constellation
GEO-West
Visible/Infrared Imager
Lightning Mapper
Ocean Color
GEO-Central
Hyperspectral Infrared Sounder
Atmospheric Composition
Partner Payload
GEO-East
Visible/Infrared Imager
Lightning Mapper
Ocean Color
NOAA Satellite Operations Facility, Suitland MD
Command and Data Acq. Station Wallops VA
Consolidated Back-Up, Fairmont WV

Geostationary Extended Observations



GOES-R ABI versus GeoXO Imager (GXI)

ABI CONFIGURATION

	Wavelength (µm)	Band	GSD
VNIR	0.47	Band 1	1 km
	0.64	Band 2	0.5 km
	0.865	Band 3	1 km
	1.378	Band 4	2 km
	1.61	Band 5	1 km
	2.25	Band 6	2 km
MWIR	3.9	Band 7	2 km
	6.185	Band 8	2 km
	6.95	Band 9	2 km
	7.34	Band 10	2 km
	8.50	Band 11	2 km
LWIR	9.61	Band 12	2 km
	10.35	Band 13	2 km
	11.20	Band 14	2 km
	12.30	Band 15	2 km
	13.30	Band 16	2 km

GXI CONFIGURATION

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	11.20	Band 16	2 km
	12.30	Band 17	2 km
	13.30	Band 18	2 km

New and improved

GXI added 2 more water vapor (H_2O) channels, we need to demonstrate their value with and without GXS.

Lake Effect Snow Bands: Visible

MODIS 0.25 km

MODIS 0.5 km

MODIS 1 km

GOES-8 1 km

19 January 2001, 1720, UTC

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New and improved

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Status Quo – no change:

- No loss of any current spectral bands
- No loss of RGBs
- Overall scan rate
- Satellite location, parallax

Confirmed Evolutionary Enhancements:

- Two new water vapor spectral bands
- Band 4 - 0.91 μm, Band 9 – 5.15 μm
- Improved spatial resolution
- Red Vis at 250 m, IR at 1 km

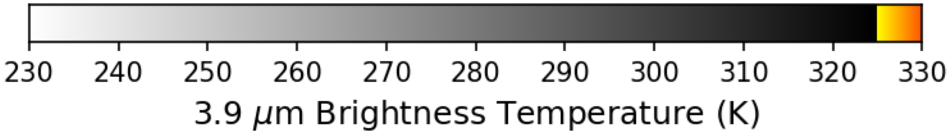
Capability gaps:

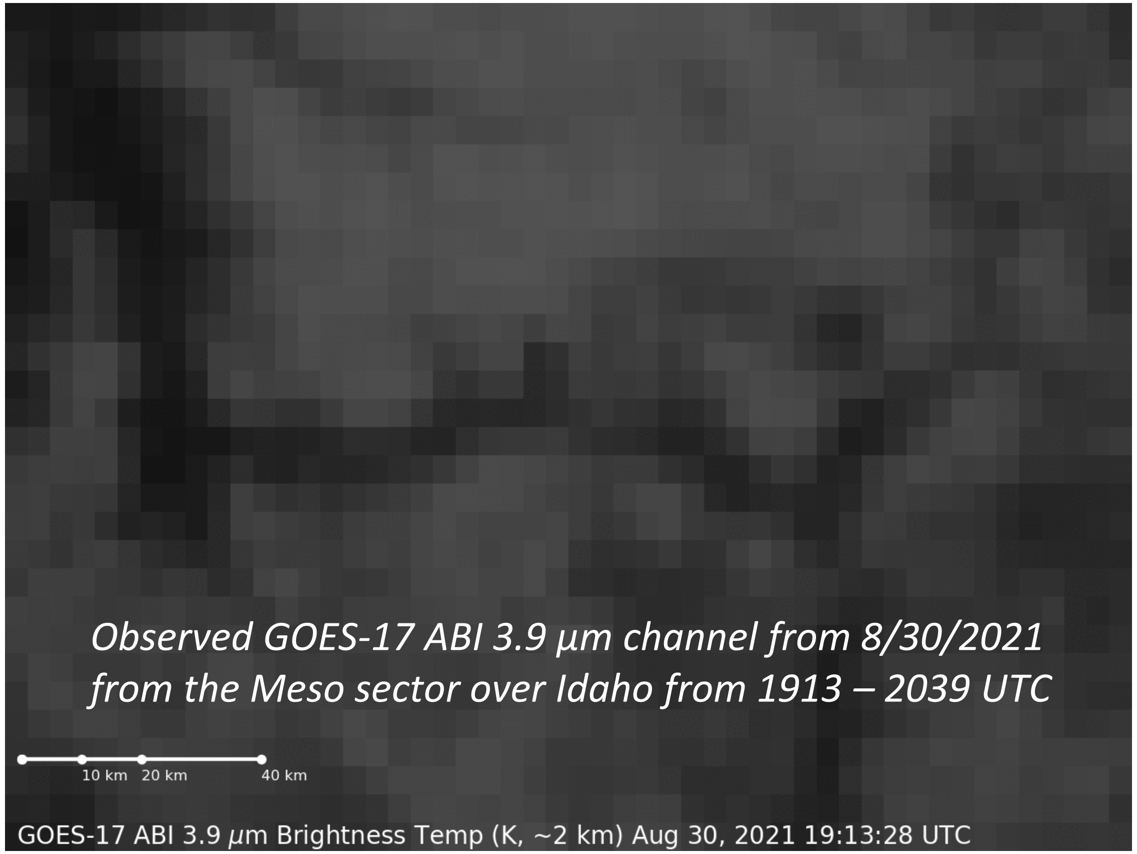
- No low-light imaging, no green (0.55 μm)

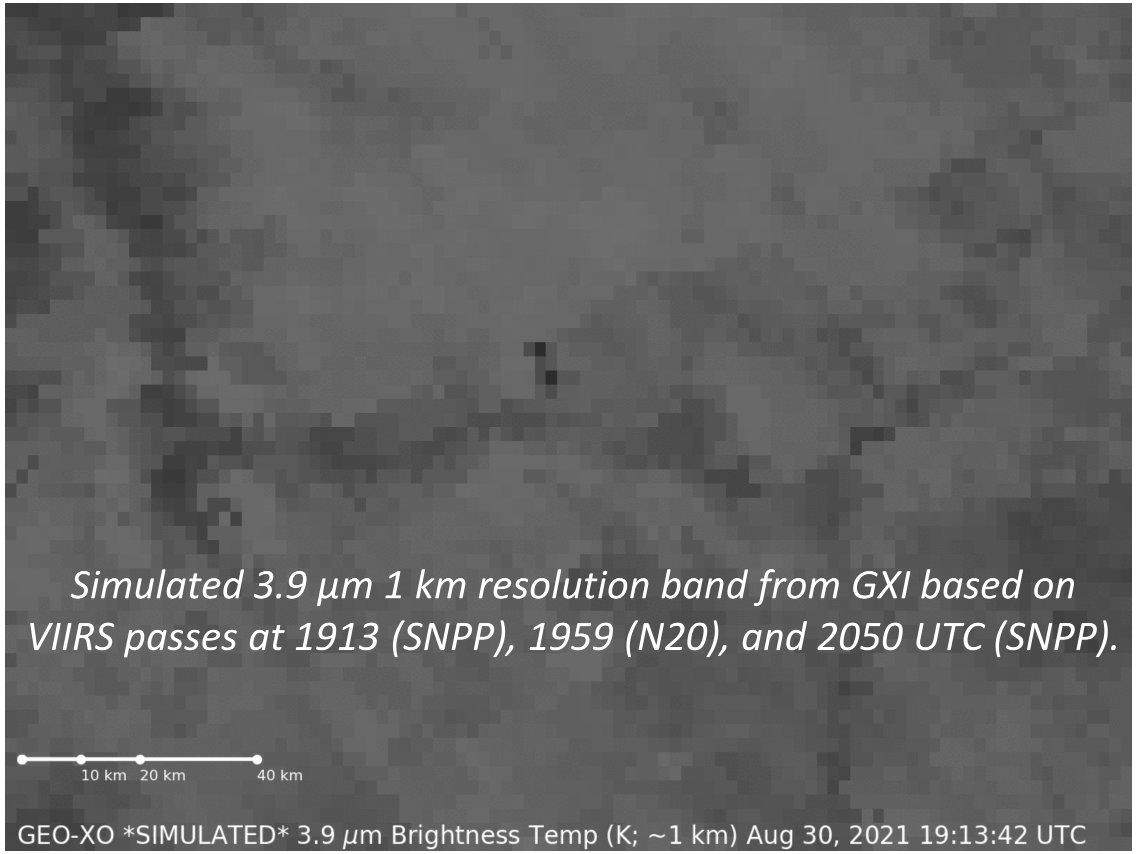
Possible changes:

- Scan strategy - MDS coverage, frequency
- Derived products
- Blended or fused multi-sensor products

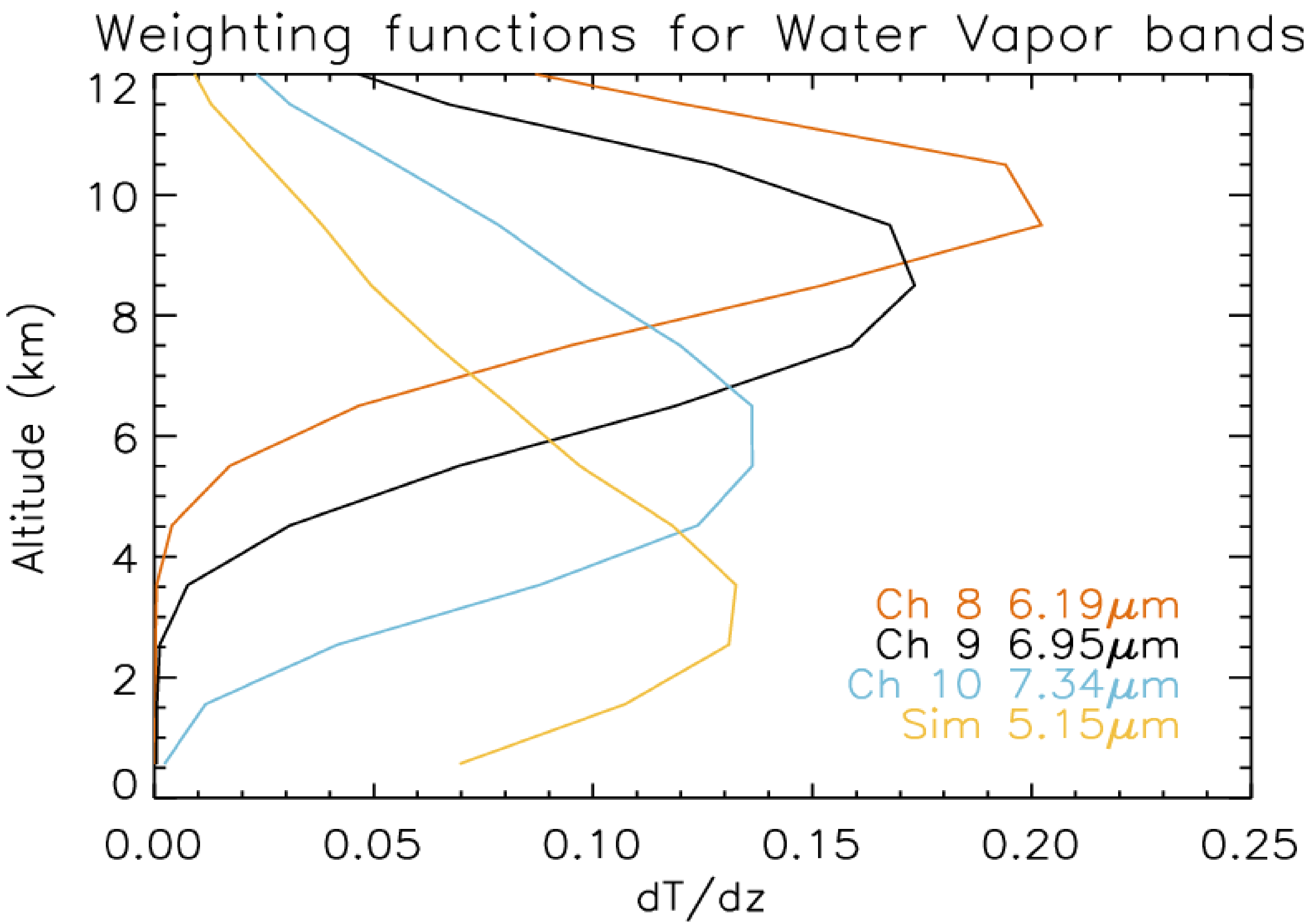
Improved spatial resolution of the 3.9 µm channel
Earlier Feature Detection





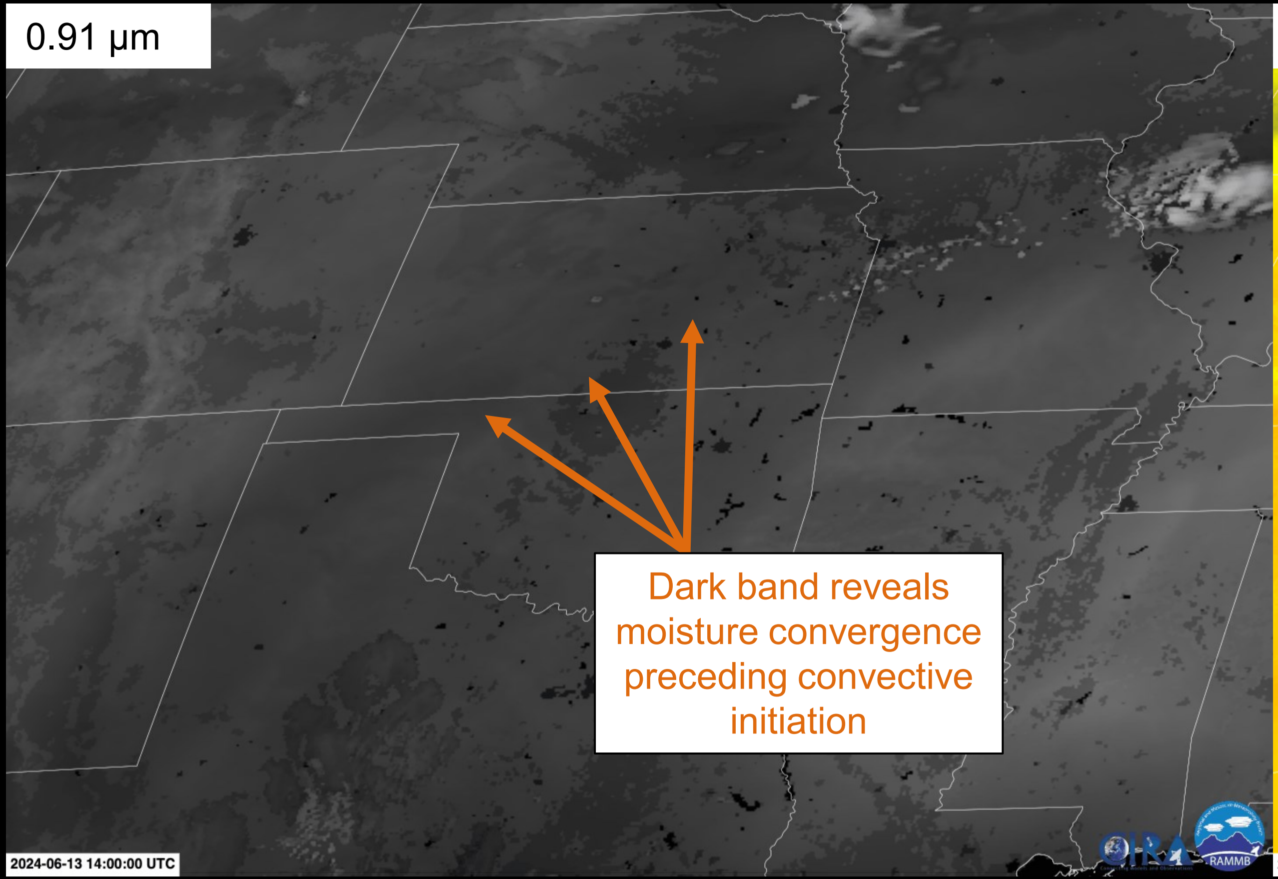


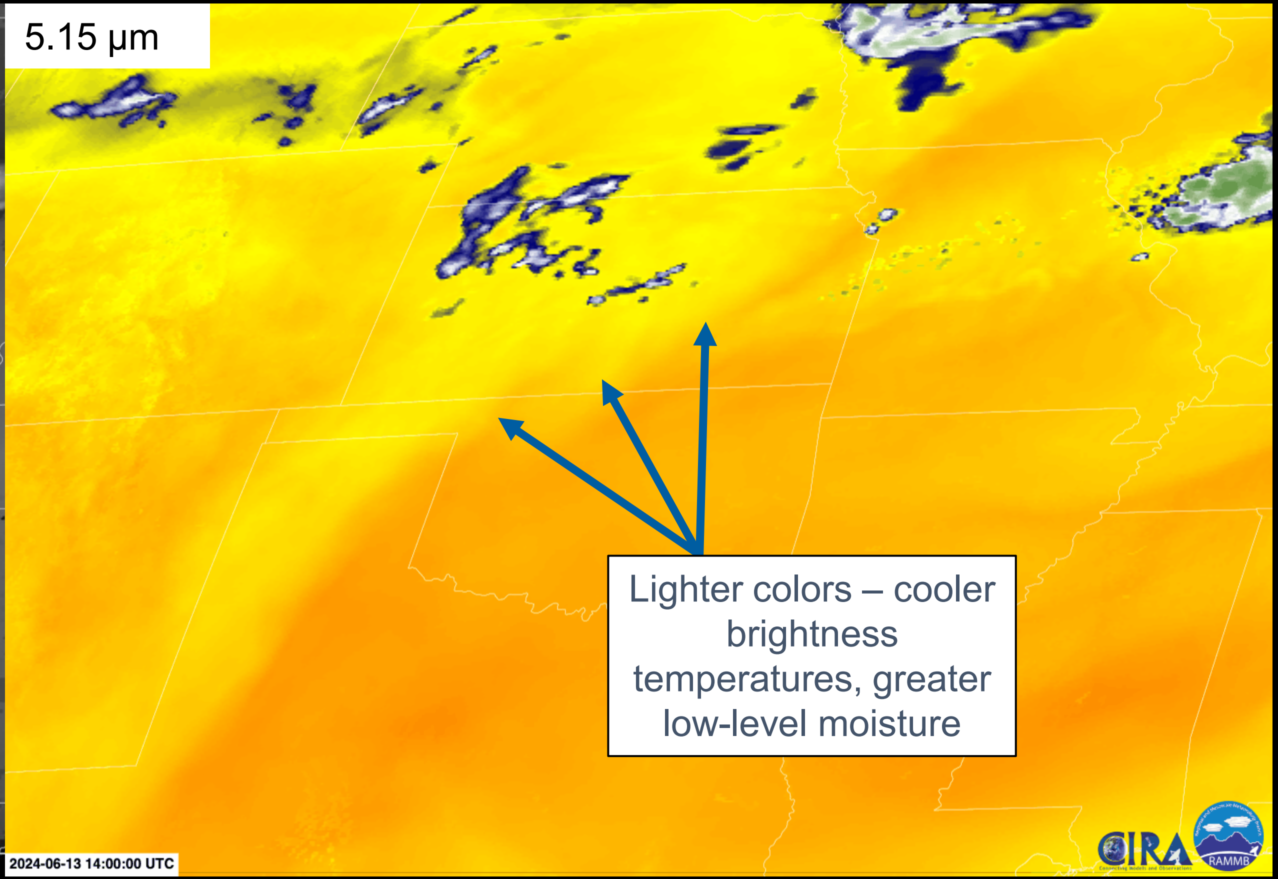
Courtesy of Jason Apke, CIRA



Weighting functions for Water Vapor bands
Altitude (km)
0
2
4
6
8
10
12
0.00
0.05
0.10
0.15
0.20
0.25
dT/dz
Ch 8 6.19μm
Ch 9 6.95μm
Ch 10 7.34μm
Sim 5.15μm

Simulations of new GXI channels





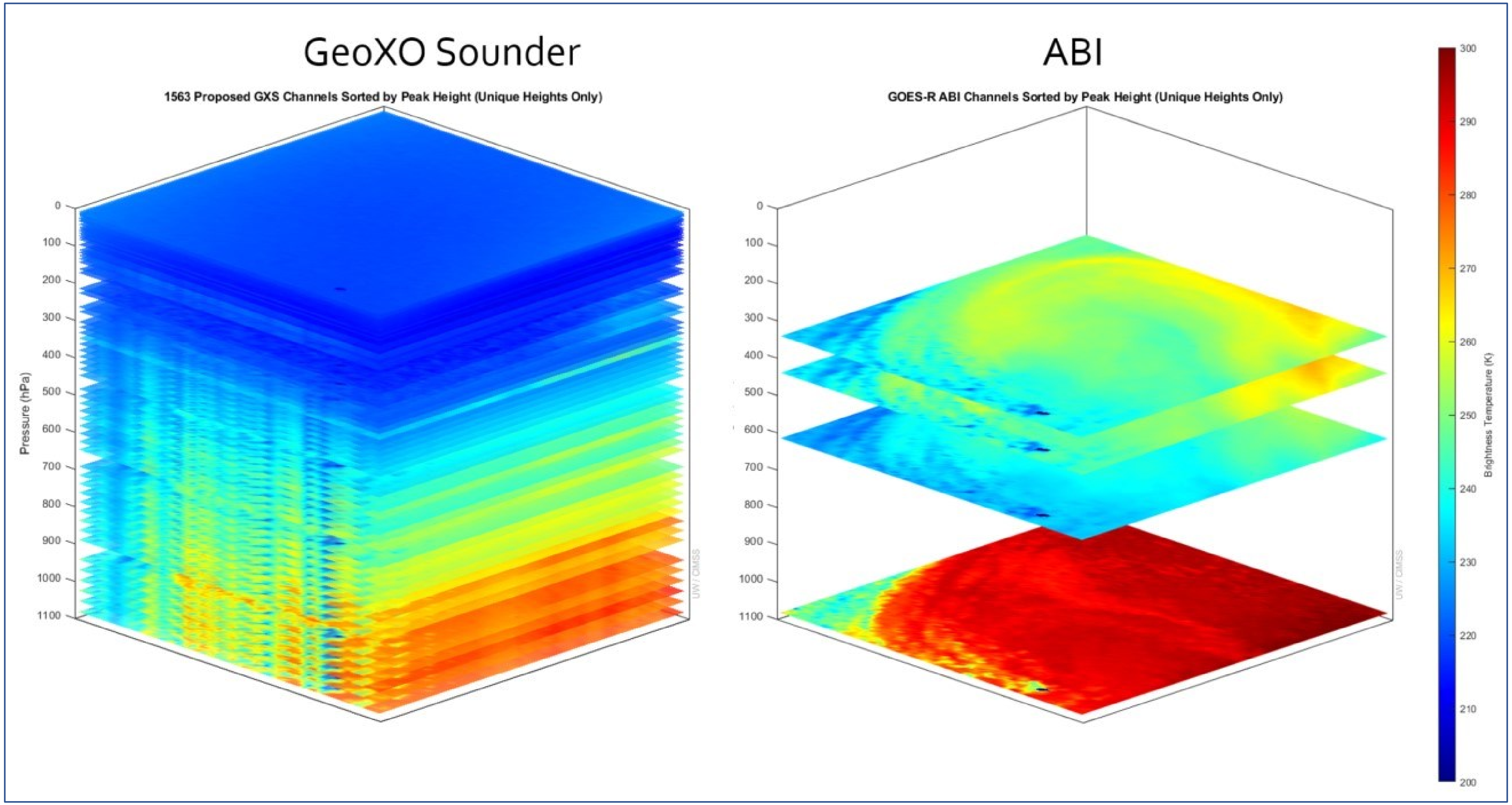
GeoXO Sounder : Summary (What and Why)

Attribute		What		Why
Coverage		Ideally: Sounding Disk as seen from both GOES-East and –West positions; Central satellite position currently planned		The Atlantic for **hurricane development** and **model initializations**, CONUS for the **pre-convective environment monitoring** and the Pacific for both **upstream weather and monitoring moisture (and winds)** over the huge area with little conventional data.
Spatial Resolution		**4 km** (at the satellite subpoint)		Doubling the clear-sky yields, compared to LEO, for a given time. Also, finer moisture gradients to be monitored.
Temporal Resolution		Sounding Disk (30 min) or NH (20 min) + SH (40 min) + Mesoscale (TBD min) (TBD)		Sounding Disk upstream information and hurricane monitoring (**improved track and intensity**), CONUS for pre-convective monitoring and the targeted for regions of extremely active weather. Allows for clouds to move out and obtain more clear sky information.
Spectral Coverage / Resolution		(680 - 1095 cm^{-1} 14.7 – 9.13 μm 1689 – 2250 cm^{-1} 5.92 – 4.44 μm) @ ~0.6 cm-1		Spectral with information related to **temperature, moisture** and support select atmospheric compositions (ozone, NH3, isoprene, HNO3, N20 and CO). Need to resolve, not average out, the critical on/off spectral lines.
Other		Evolution of the radiances		Provides critical vertical information on **atmospheric winds** for both nowcasting and NWP applications.

High Spectral & Temporal Observations

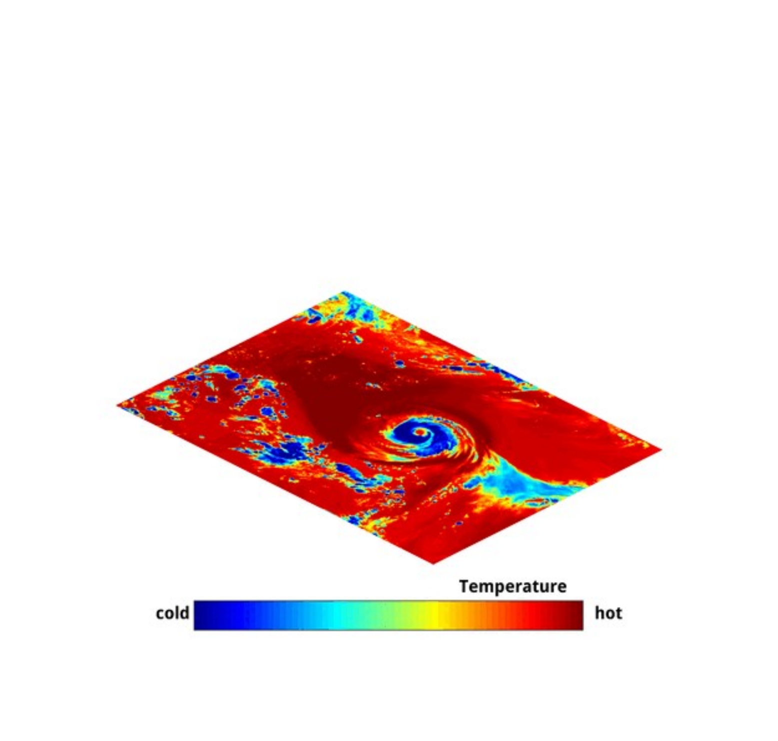
- **High-spectral-resolution observations provide much more information**
  - Imagers average out important vertical information
  - LEO has shown the many benefits, especially on the global scale, lacks time resolution
- Forecasting Applications – fill in critical gaps in vertical moisture, wind and temperature
  - **Nowcasting** and **Numerical weather prediction**, especially on the regional/mesoscales
- Additional applications
  - **improve derived products with only advanced imager data**
    - cloud-top properties, atmospheric motion vectors, dust detection, land and sea surface temperatures
  - **New areas**
    - Moisture flux, capping inversion, surface emissivity, trace gases (Ozone and Carbon Monoxide, etc.) and climate
- **Economic impacts** (“billions”…) More with the benefits of 4dvar analysis …
- Critical Component of the **Global Constellation**

GXS vs ABI



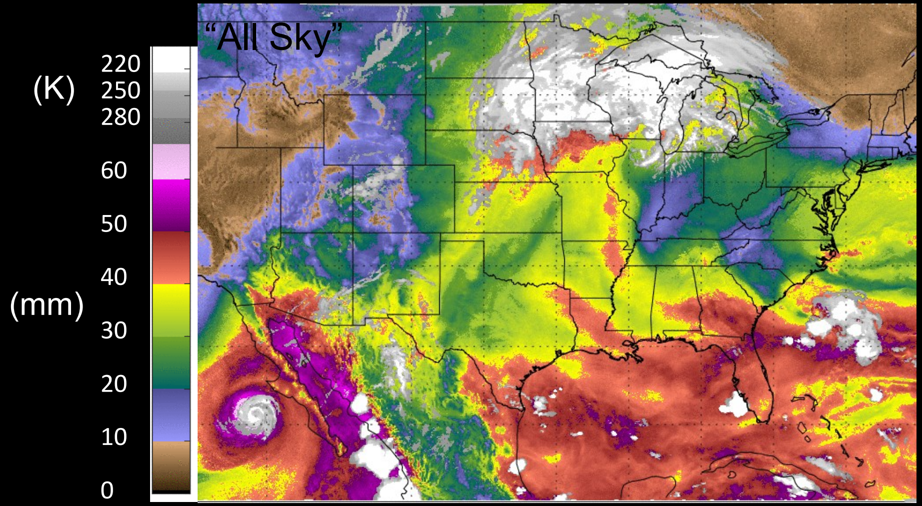
Credit: UW/CIMSS (UW/CIMSS)

GeoXO Hyperspectral Sounder



Temperature, Moisture, and Winds concept

Total Precipitable Water



WFO APPLICATIONS

Near-Storm Mesoscale Analysis (before and during an event; compare to model forecasts)

FACETS/T-I-M (provides nearly constant updates to users, not just one warning)

Precipitation Type (improved temperature, moisture and wind profiles)

Fire Weather/Spot Forecasts (wind surges, low-mid level RH, etc.)

Aviation Forecasts (Icing levels, convective turbulence)

Air Quality (trace gases, ozone, diurnal trends)

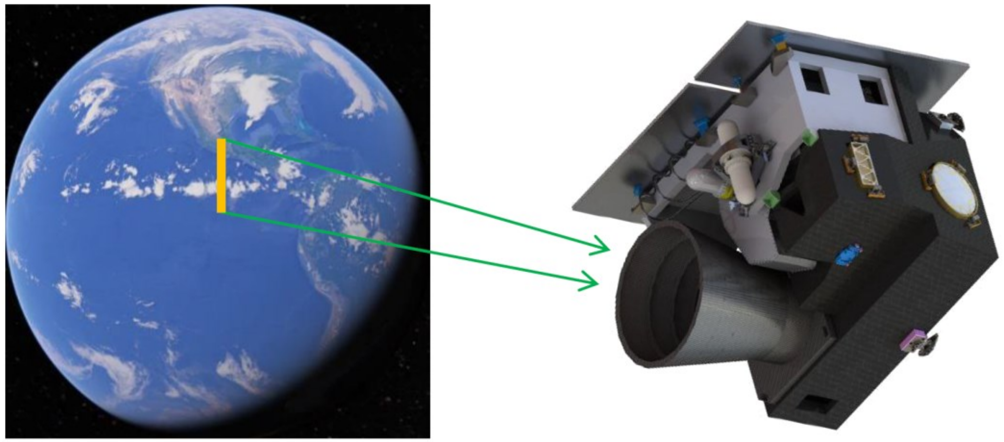
Physical Modeling (input to models, especially on the regional scale)

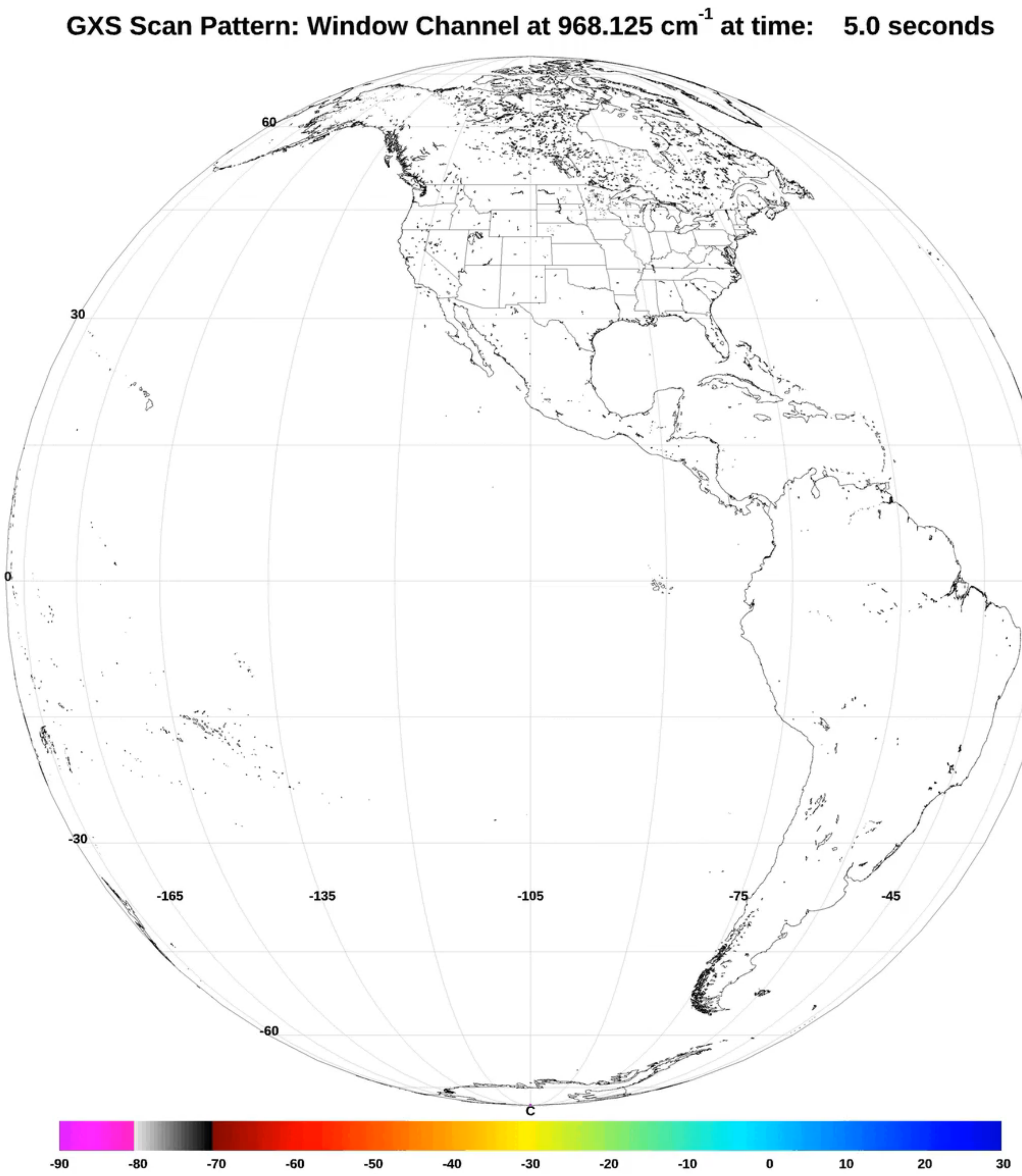
Machine Learning (great opportunity to train with GXS for many critical parameters)

Flash Floods (Moisture transport; Low-mid level boundaries)

Concept of Scanning the Disk (equal swath time intervals)

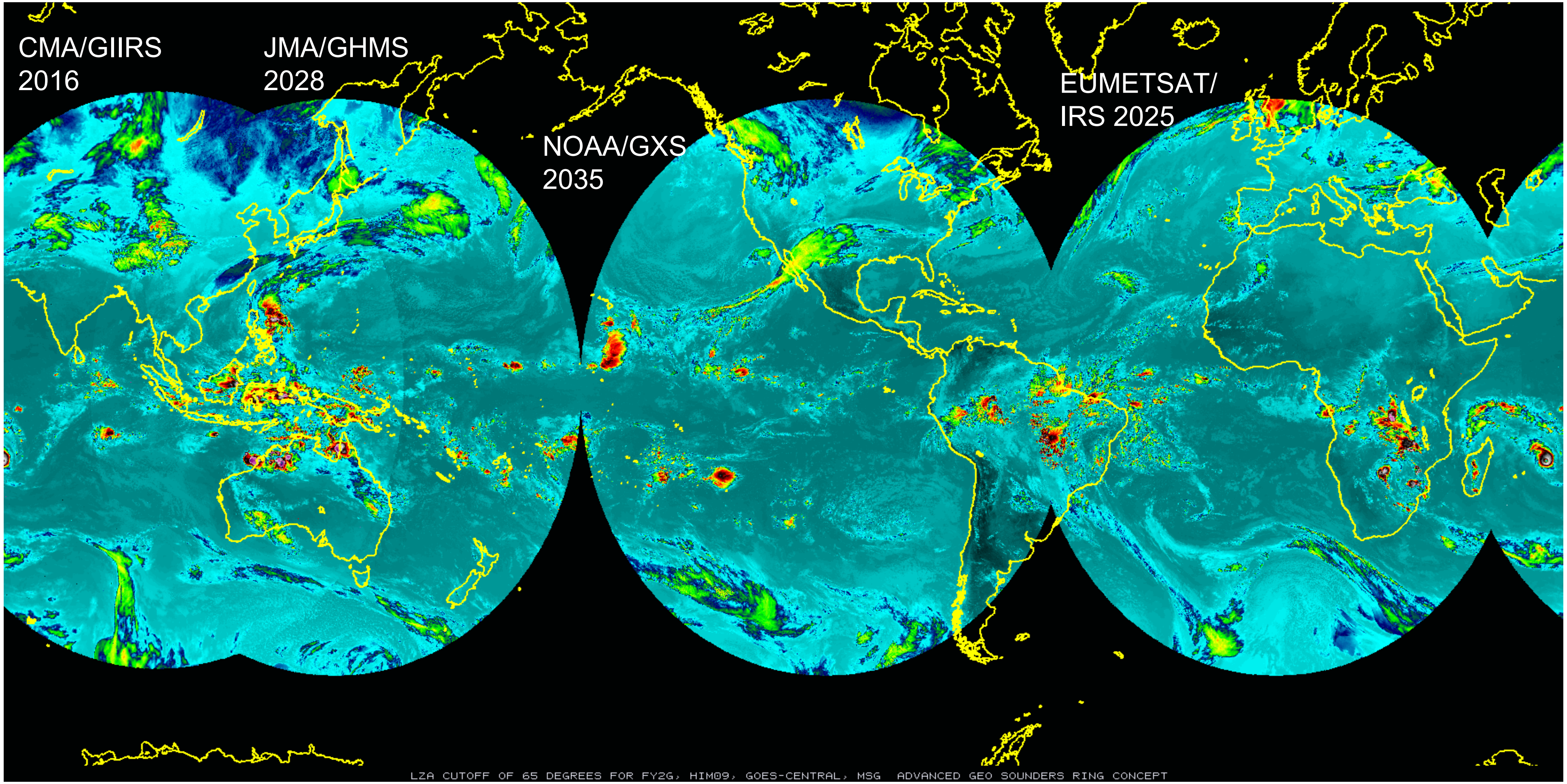
- Slit is oriented N/S and projected onto the field of regard
- One slit image samples 3.48 deg of N/S field of view
- Scan mirror slews slit image from West to East over the scan swath
- Swaths are scanned roughly 3.7 deg per minute
- Approximately 30 min to scan the disk





- Using GXS Simulated data by UW/CIMSS
- Swath overlap not simulated

Future GEO-Ring of IR Sounders

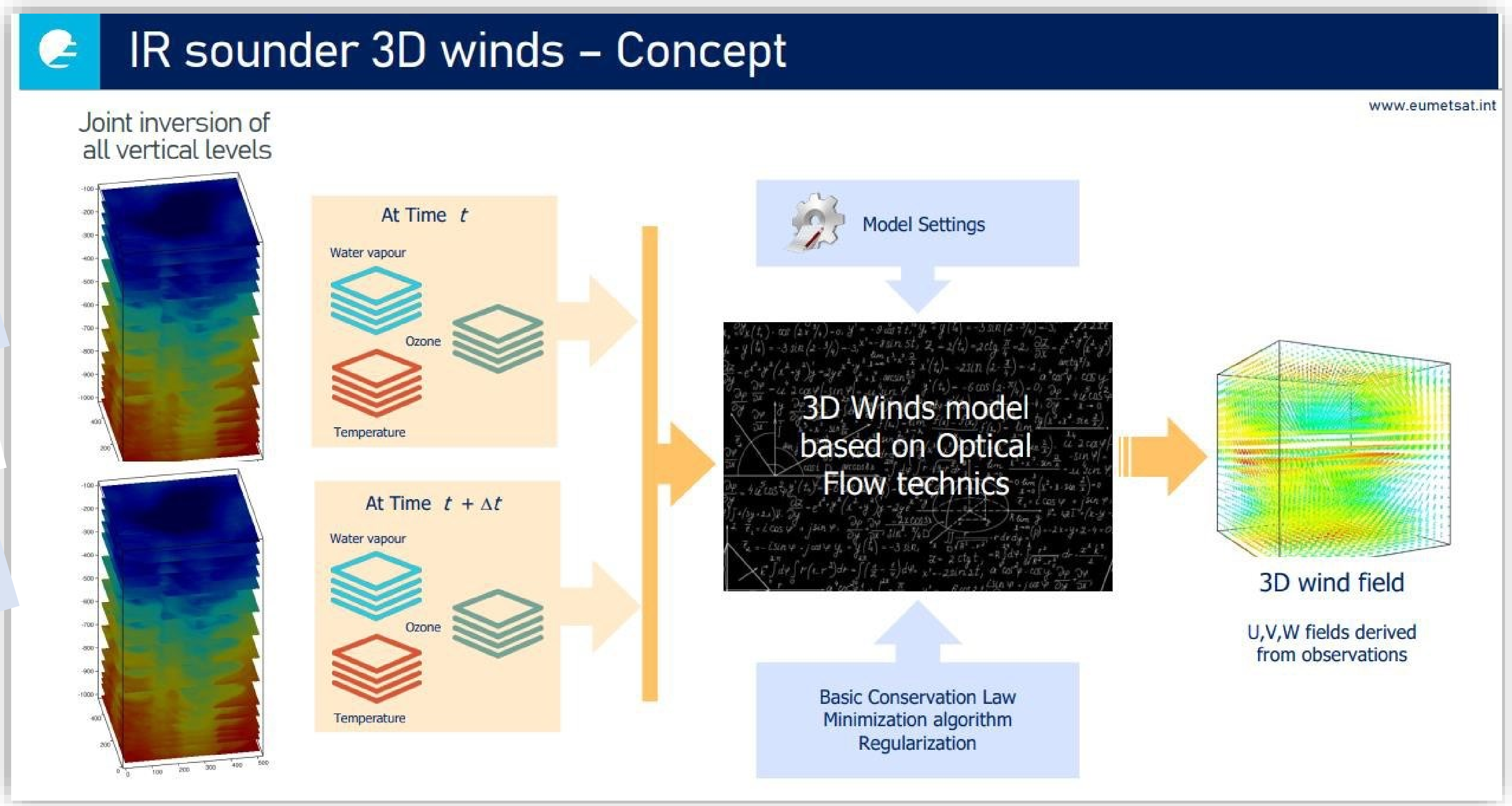


GSX Wind Retrievals

GSX observations at time t

$\Delta t \approx 30min$

GSX observations at time $t + \Delta t$



Slide adapted from Carranza et al. 2023

Current Status of the IASI 3D Winds Product at EUMETSAT

[16th International Winds Workshop, Montreal, Canada]

GeoXO Lightning Mapper (LMX) Capabilitiess

GeoXO LMX will continue providing lightning detection observations in Geo

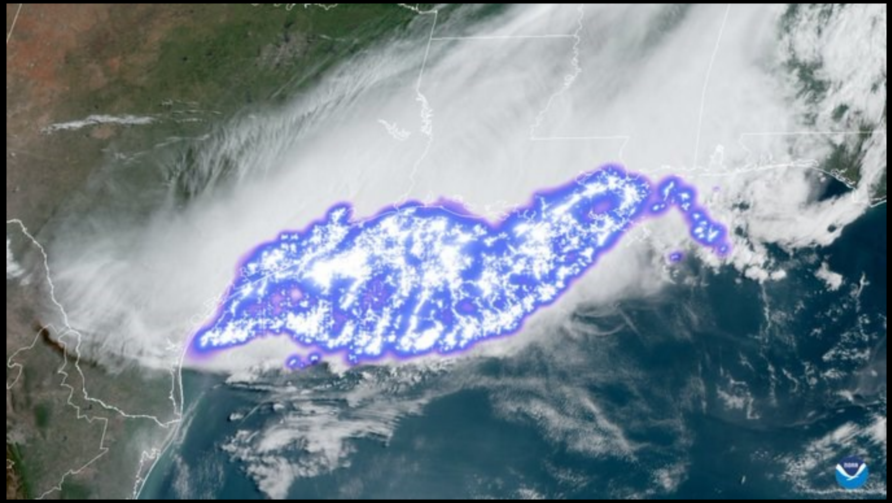
- Full spatial extent of total lightning flashes, both intra-cloud and cloud-to-ground

Flash type ID may be possible with ML/AI techniques

- Temporal resolution to allow tracking of each lightning flash within a specific storm cell
- Earlier warnings of potential severe weather & tornadic activity

Key Performance Features:

- Optical telescope tailored for 777.4 nm observations, with high frame and detector read rate and low latency



World’s longest lightning flash as detected by GLM on 29 April 2022.

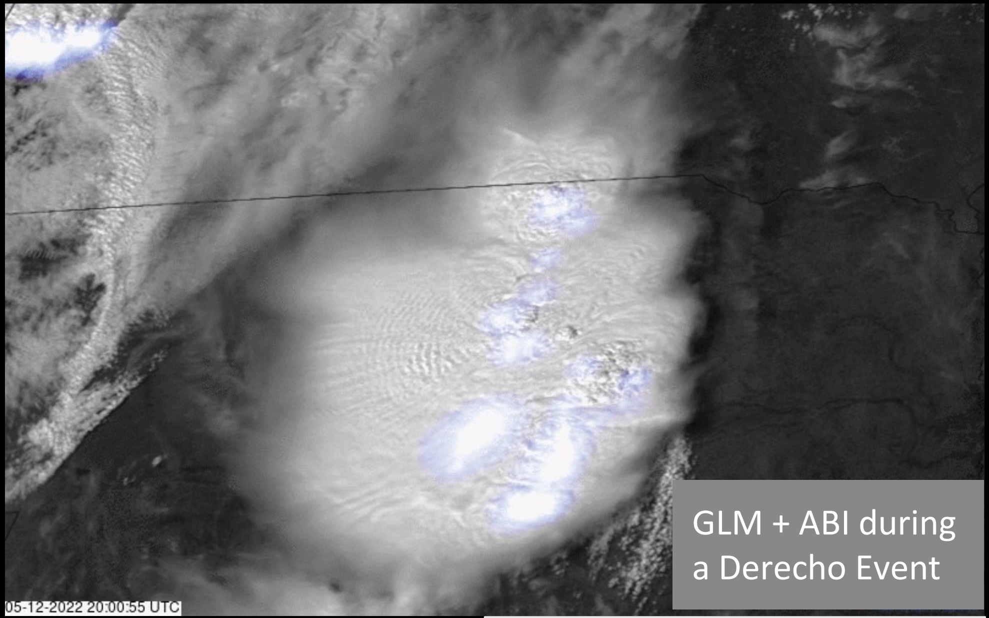
GLM Evolution to LMX

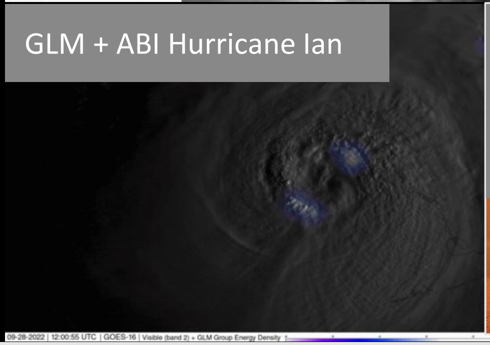
Parameter	GLM	LMX Targets
Resolution/GSD	8 km (FED family at 2 km)	≤ 8 km (224 µrad)
Detection Efficiency	Requirement: detection efficiency > 70%, averaged over full disk and 24hrs (actual performance is in range 70-90% range)	event detection probability over the coverage area shall be greater than 70% after Level 1b processing
Frame Rate	2 msec	≤ 2 msec
Downlink Rate	7.7 Mbps	≤ 75 Mbps when averaged over any 5 sec period
Coverage	coverage up to ~54 deg N/S lat or roughly ~75% of the Earth as seen from geostationary orbit	≥84% of the Earth as seen from geostationary orbit with no internal gaps in coverage.
Product Latency	<20 sec latency in L1b (FED family updated every minute)	<10 seconds …from event detection through generation of Level 1b products.
Navigation (INR)	Navigation error within ±112 µrad (~1/2 pixel or ~4 km)	LMX navigation error shall not exceed 98 µrad, 3-sigma, per axis, except during eclipse periods.
FAR	< 5% averaged over 24 hours	<5% averaged over 24 hours after Level 1b processing

Value of GEO Lightning Imaging

Essential tool for NWS impact-based decision services

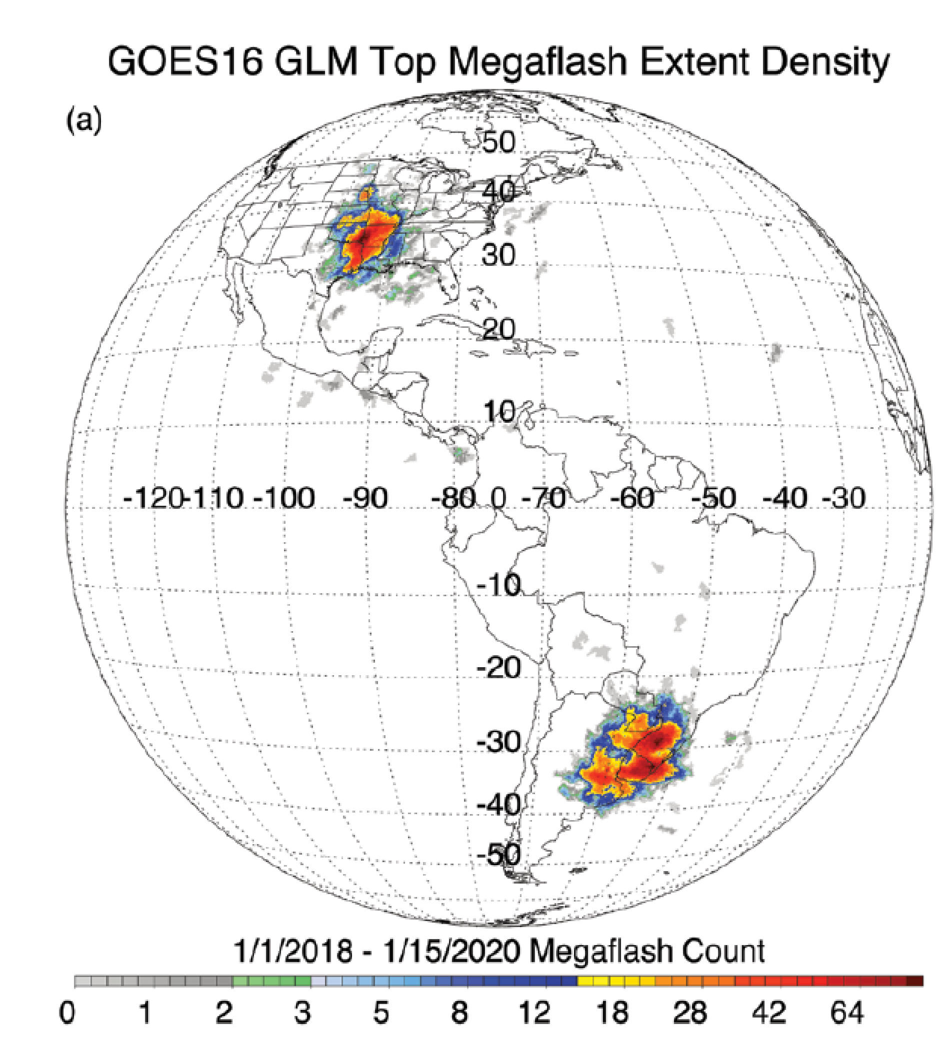
- Lightning is the most prevalent natural hazard on Earth with tens of millions of flashes per year in the U.S. alone
- Aids in issuing severe thunderstorm and tornado warnings
- Helps identify the location of potential wildfire ignitions and provides guidance to early responders
- Improves short-term weather model forecasts
- Improves precipitation forecasts
- Aids diagnosis and warning for tropical cyclones
- Climate: lightning is an indicator of inter-annual to decadal change, and a key variable to validate climate models
- Lightning data (satellite and surface based) provide information on thunderstorms where radar data is absent
- *Geostationary Lightning Mapper Value Assessment* https://repository.library.noaa.gov/view/noaa/27429





*"**If we start to see these lightning jump**s, and we see these updrafts grow, especially combined with the surge in the line we can see on radar, **then there's a good chance we're going to end up with a tornado.**" - NWS Forecaster, Huntsville*

GLM Megaflashes



Flash extent density (FED) distribution for the top GLM flashes that exceed 321 km or 7.74 s.

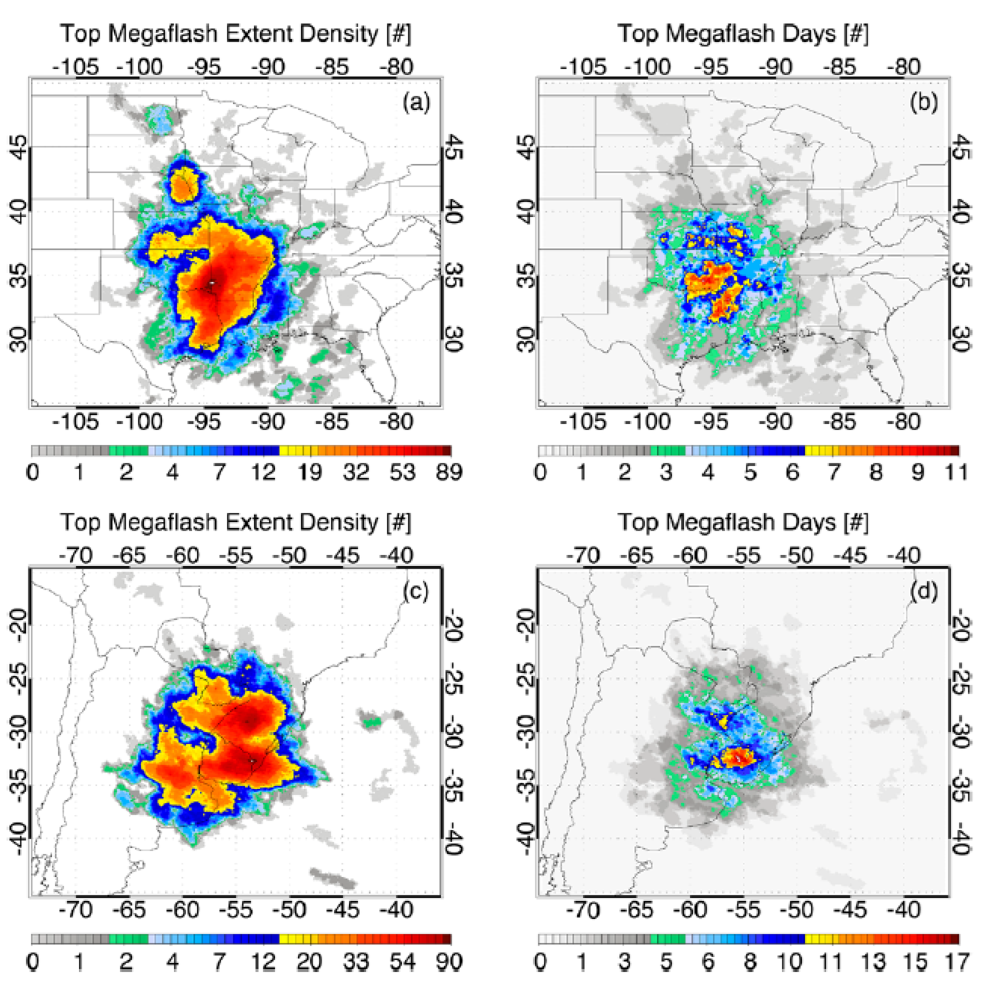
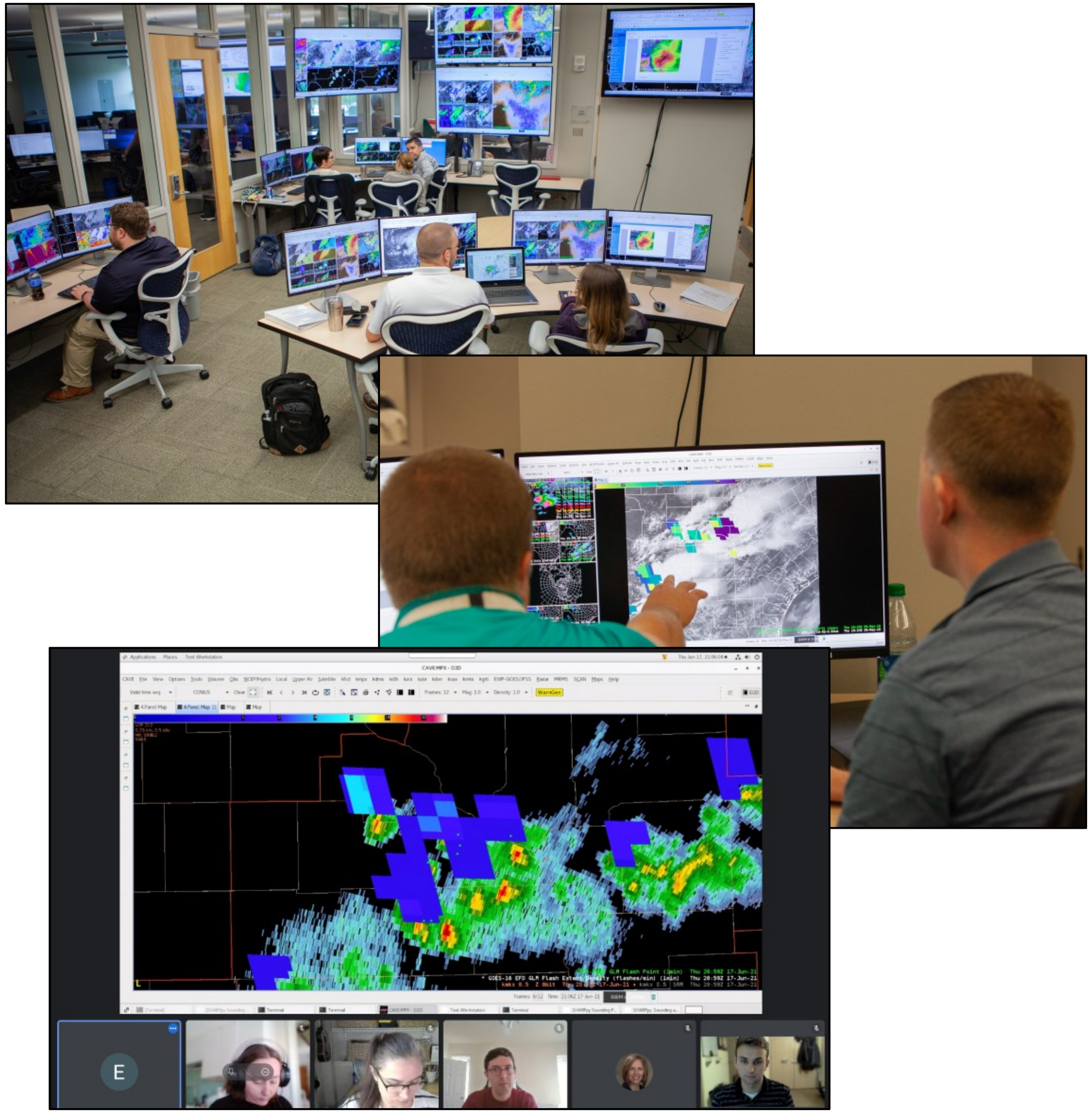


Fig. 2. GLM top megaflash frequency in the (a),(b) North American and (c),(d) South American hotspots. The top megaflash FED from Fig. 1 is plotted in (a) and (c), while the number of unique thunder days with exceptional megaflash activity (megaflash days) is plotted in (b) and (d).

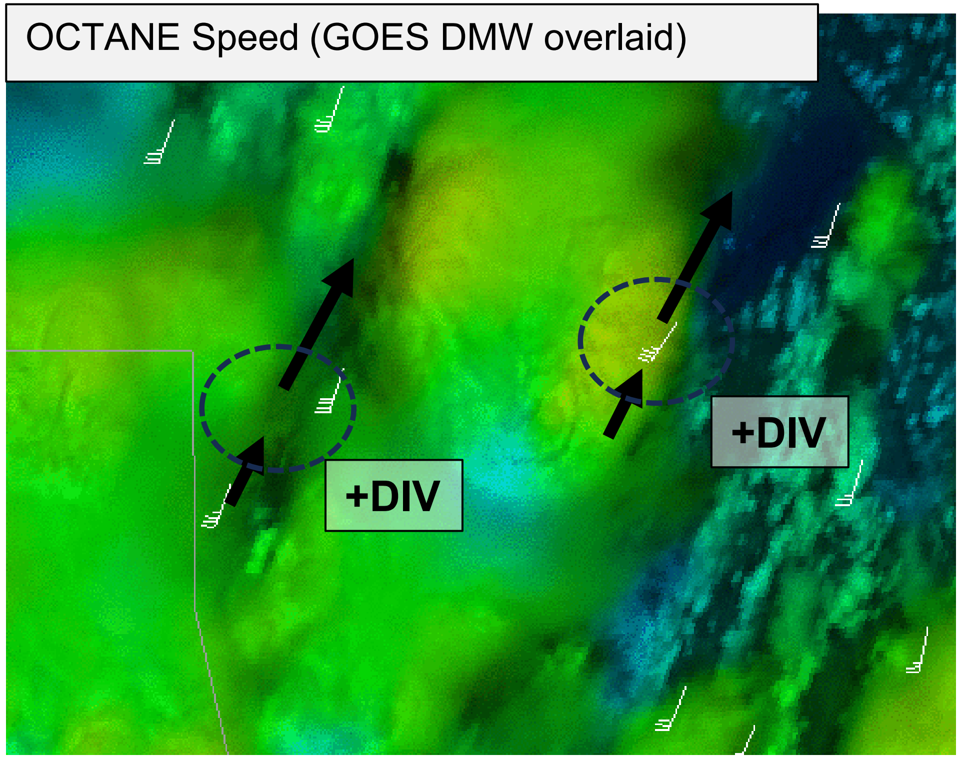
Source, Peterson, Bull. Amer. Meteor. Soc. 2021, https://doi.org/10.1175/BAMS-D-20-0178.1

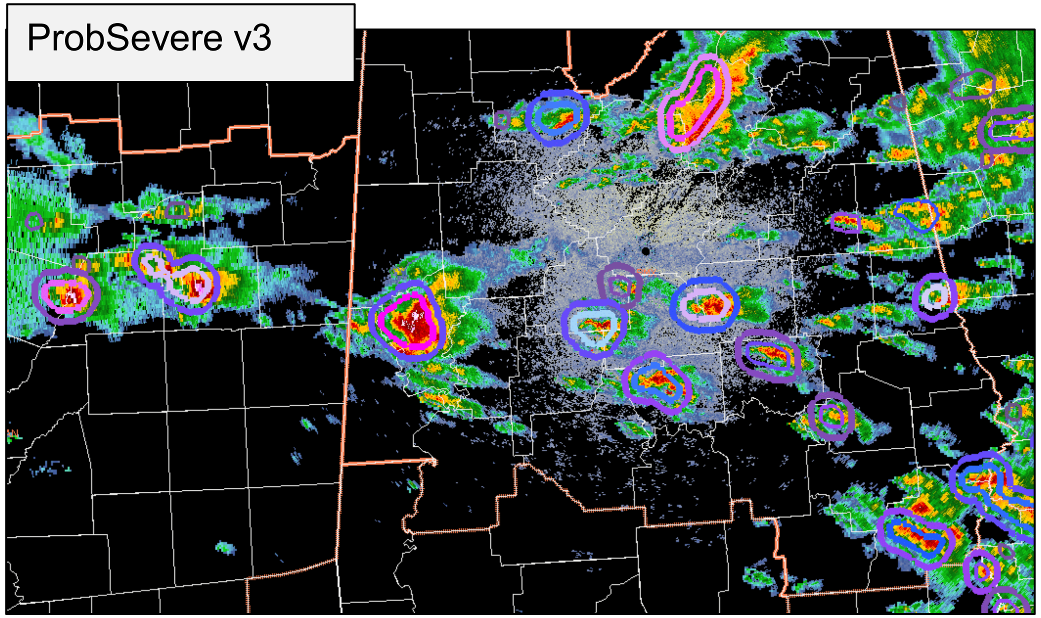
Nowcasting Tools, Products, and Prototyping at NOAA's Hazardous Weather Testbed (HWT)

- Mission: '*to test and evaluate emerging technologies and science for NWS operations*'
- 2023 Satellite Proving Ground Experiment:
  - 3 weeks (1 in-person, 2 virtual)
  - 22 NWS forecasters
  - Live weather in simulated operations
  - Mesoanalysis, warnings , DSS messaging
  - 5 new products



Monitoring Convection with *OCTANE and ProbSevere v3





OCTANE

- Monitoring divergence signals
- Comparing with radar and GOES DMW
- Display techniques

ProbSevere v3

- Cloud top cooling, radar, lightning, NWP
- Triaging storms using trends
- ‘Data dropout’ cases

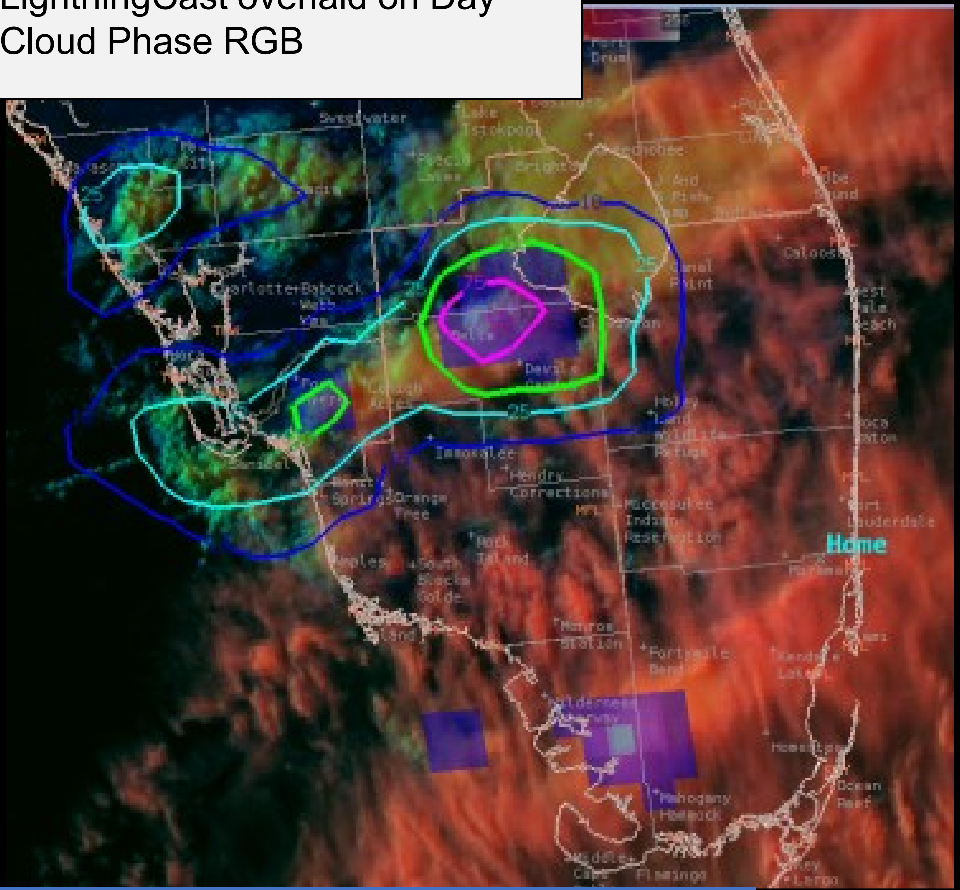
‘ProbSevere helped considerably in triaging which storms deserved attention, and which storms were trending in such a way that warranted a warning decision and/or adjustment.’
BMX Warning Met West Sector on June 14 2023

*Optical flow Code for Tracking, Atmospheric motion vector, and Nowcasting Experiments (OCTANE)

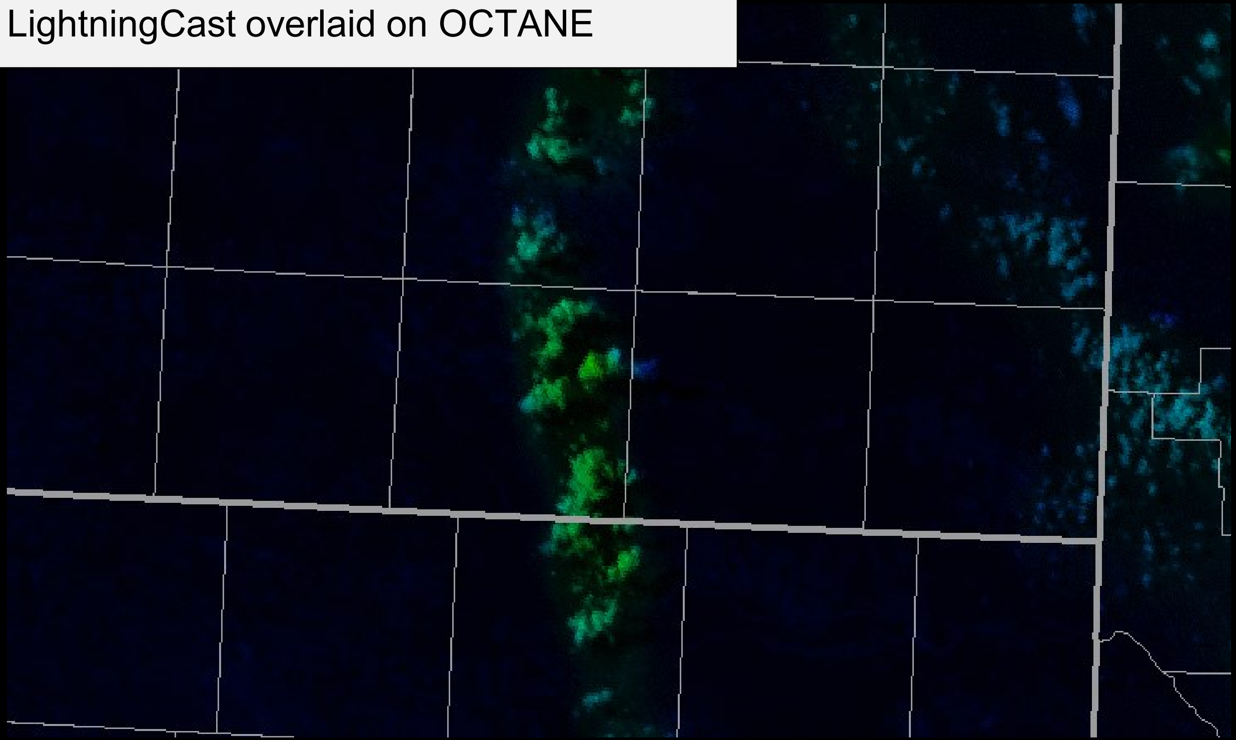
Initiating Convection with OCTANE and LightningCast

- Thermodynamic and kinematic signals of CI
- Timing relative to radar

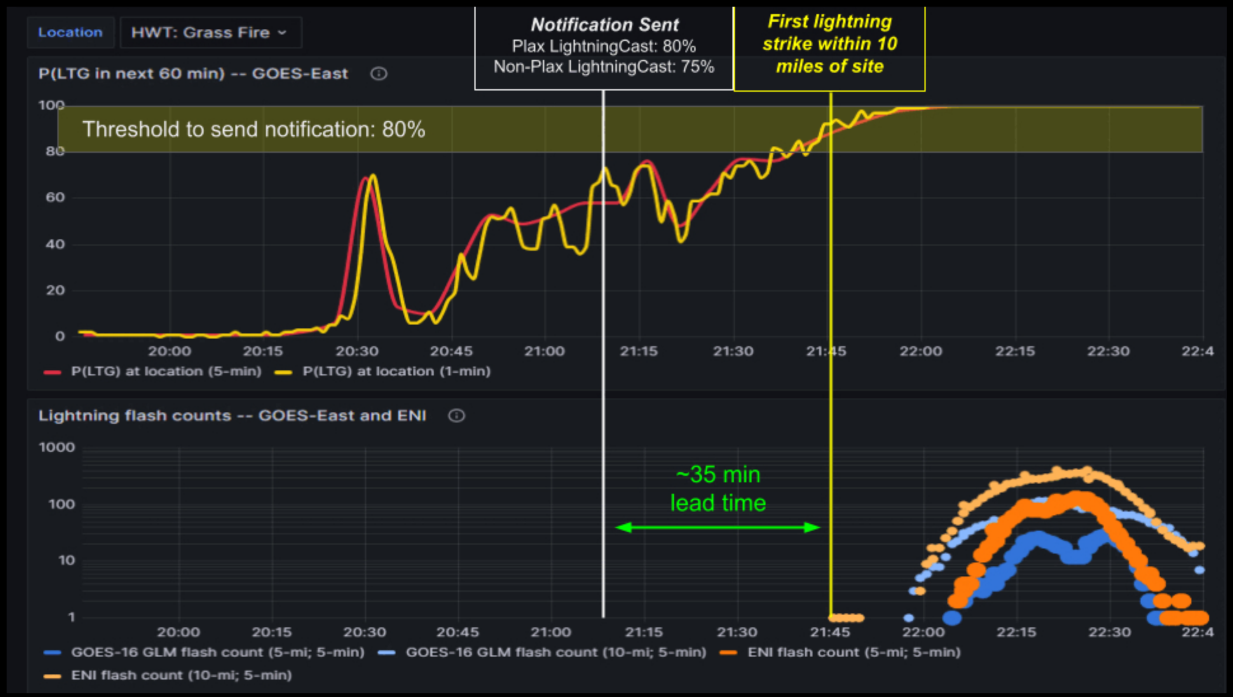
LightningCast overlaid on Day Cloud Phase RGB



LightningCast overlaid on OCTANE



‘One interesting note. There are new cells developing in far SW FL with lightning noted on GLM, however **the cirrus canopy there is too thick** to allow LightningCast to detect this convection.’
6 June 2023, Blog Post: *Monitoring Convection for the South Miami Open*



DSS Messaging with LightningCast

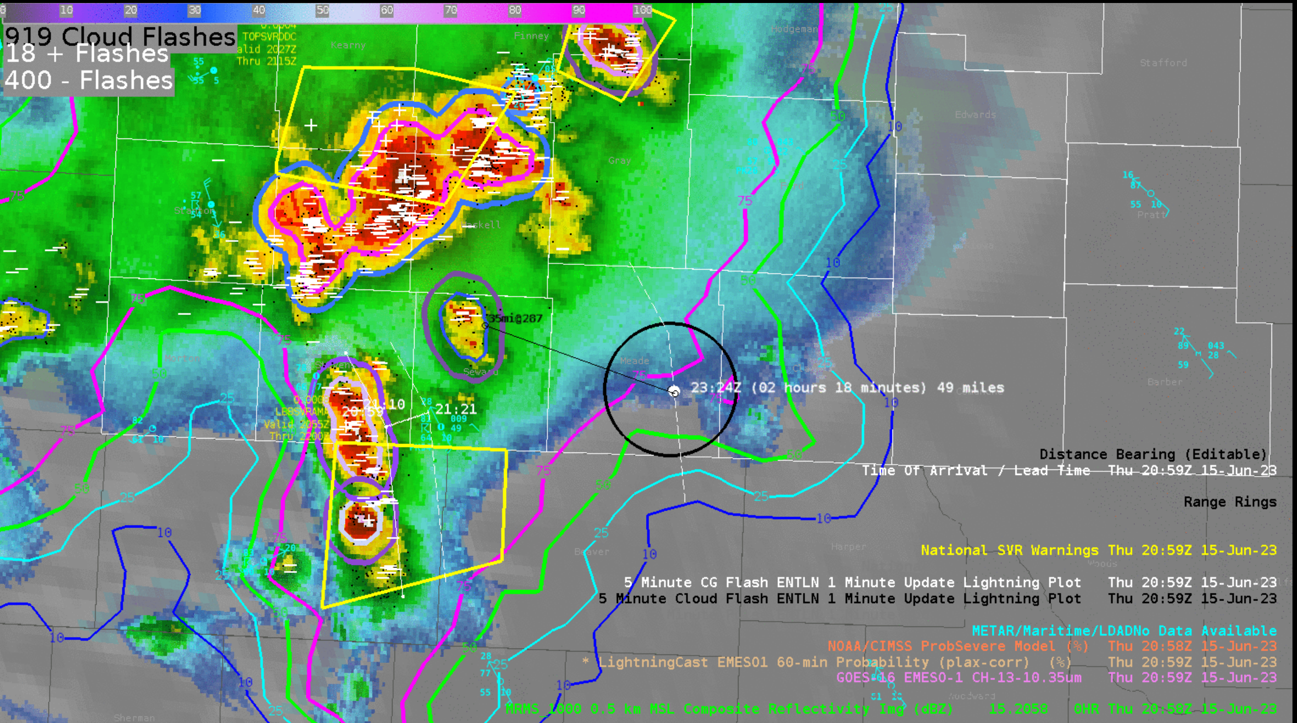
Initiation and advection

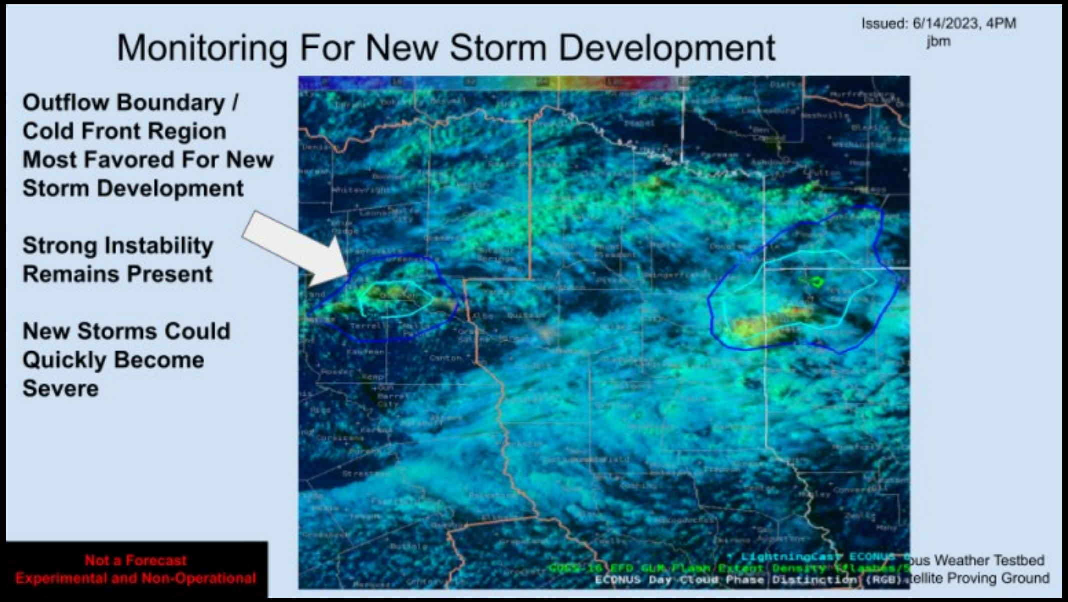
Communicating probabilities

Finding useful thresholds..

Initiation: 10% and 25% (lower)

Advection: 50% and 75% (greater)





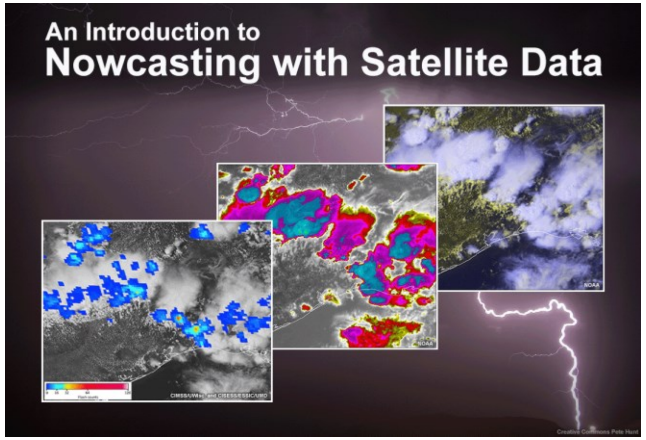
New COMET Micro-Lesson - An Introduction to Nowcasting with Satellite Data

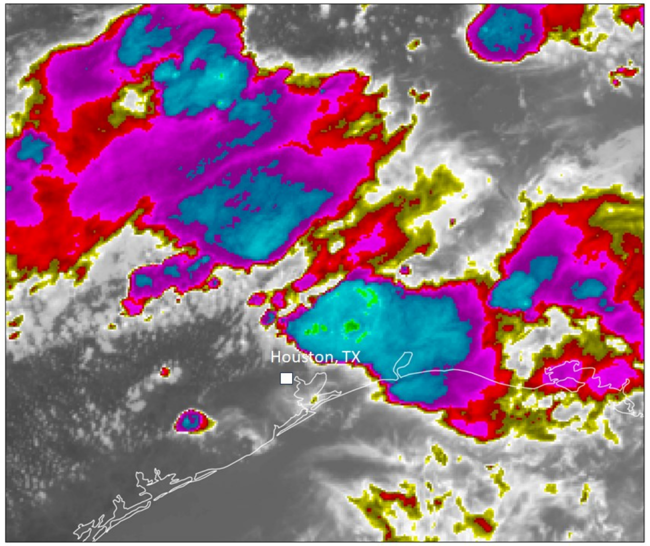
https://www.meted.ucar.edu/education_training/lesson/10296

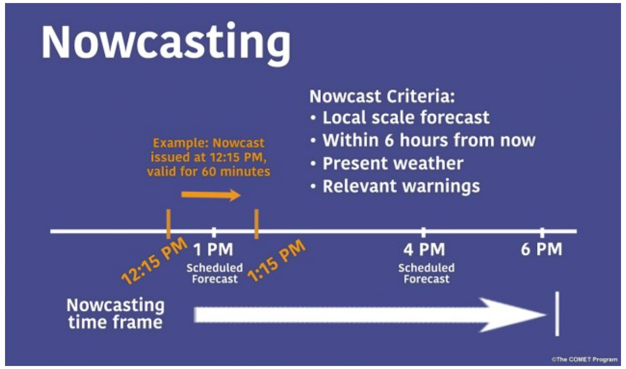
Short lesson (~10 minutes) using video and interactions

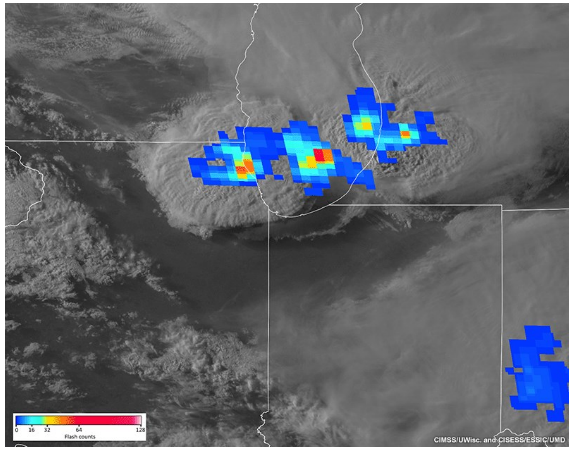
Learning Objectives

1. Define nowcasting as it applies to meteorology
2. Describe the advantages of using a nowcasting process
3. Describe the benefits of using satellite products to support the nowcasting process
4. Explain how satellite products may be used in nowcasting









Training Resources

WMO-CGMS VLAB Regional Focus Group of the Americas and Caribbean: https://rammb2.cira.colostate.edu/training/rmtc/focusgroup/

COMET's MetEd – training modules in multiple languages: https://www.meted.ucar.edu/education_training/

NASA Applied Remote Sensing Training Program (ARSET): https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

WMO VLab Training Calendar: https://wmo-sat.info/vlab/vlab-training-calendar/

NOAA's TOWR-S Satellite Book Club (SBC) Weekly Seminar Series with NOAA Scientists highlighting their work using satellite data

- Satellite Book Club YouTube Page(non-NOAA YouTube site) https://www.youtube.com/playlist?list=PLJzZC8w9vPV3kIBVNmQYzZfHO6vGZeNhN
- SBC subscription form to receive notification of presentations: https://docs.google.com/forms/d/e/1FAIpQLSfLreWtD_SYQ1WhoanQkmRV4nwYIPu0_aW-lD0yNl4XYVSkRA/viewform

Training Resources

Beginner's Guide to GOES-R Series Data - Learn how to access, analyze, and visualize GOES-R Series data:

- Available on the GOES-R website: https://wwww.goes-r.gov
- Spanish (v1.1), Portuguese (v1.1), and French (v1.0) Beginner's Guide in this folder

Online Access to Satellite Products: Español
https://drive.google.com/file/d/1Jd4S1iq1Y7GwWpIYGTJ30A13gNkmg0Tr/view?usp=drive_link

Online Access to Satellite Products: English
https://drive.google.com/file/d/1itiWUu-6brQHIvemoGMW4V6bIHSUjrQ5/view?usp=drive_link

Spanish GOES-R Quick Guides available in "Multilingual Resources > ESP Guia Rapida" folder
https://drive.google.com/drive/folders/1_93rZjXETQIX1mTYH0y72cCx7ChMxGcv?usp=drive_link

WMO RA 3/4 Satellite Data Requirements: https://sdr.ucr.ac.cr/index.php/

Upcoming Training

NOAA/WMO RA III Virtual Satellite Applications Training Workshop, November 2024, Hosted by the Directorate of Meteorology and Hydrology (DMH) and Paraguay Space Agency (AEP), virtual, in Spanish

- NOAA/NESDIS Satellite Applications Training Interest Form to be notified when registration opens: https://docs.google.com/forms/d/e/1FAIpQLSerN2_6fZHAnO4cHXkSGYDBaNMTV6QBQwOFK7MwBNXdt0beow/viewform

AMS Short Course before the AMS Annual Meeting January 2025*: Satellite Applications for Rainfall Rates and Flood Prediction,* in-person in New Orleans, Louisiana

NOAA Satellite Conference August 2025 in collaboration with AMS Satellite Meteorology, Oceanography and Climatology (SatMOC) in San Diego (La Jolla), California

Summary & Conclusions

- The transition from GOES-R to GeoXO is evolutionary, yet substantial
- As GOES-R ends, we need to start innovating with GeoXO to make optimal use of those observations.
- GeoXO intends to support innovation that will lead to new L2 development and key User Readiness Activities.
- Stay tuned for opportunities.
- Points of Contact:

Andy Heidinger, Senior Program Scientist, andrew.heidinger@noaa.gov

Dan Lindsey- GeoXO Deputy Program Scientist, dan.lindsey@noaa.gov

Andrew Latto - User Engagement, andrew.latto@noaa.gov

Sherrie Morris – Training Coordinator, sherrie.morris@noaa.gov

Thank You

For more information visit

www.nesdis.gov/geoxo

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