Hawaii-Pacific Aviation Weather Safety Workshop Presentation

LightningCast & Its Effectiveness in the West Pacific

Presenter:
Edwin Montvila
Meteorologist - WFO Guam

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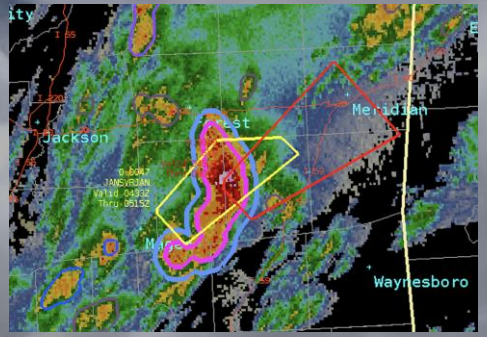
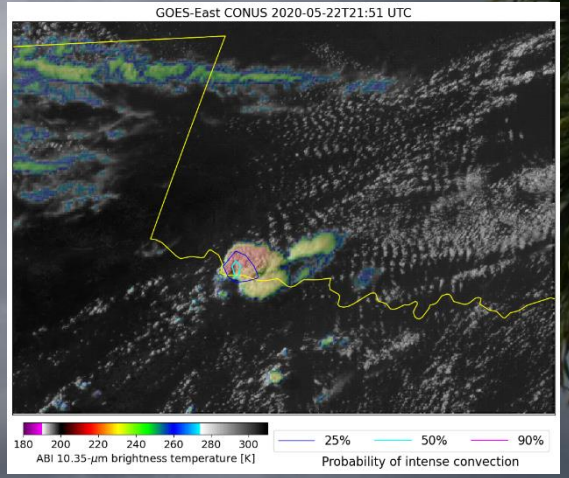
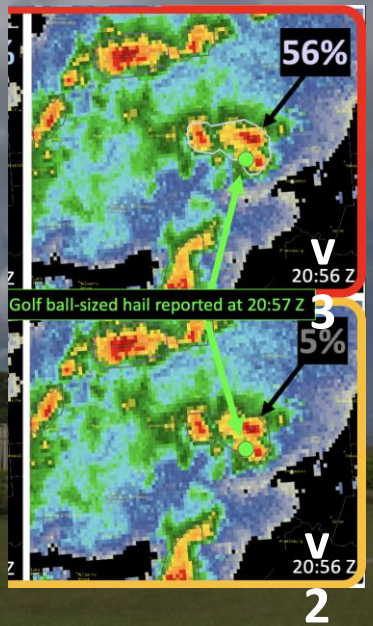
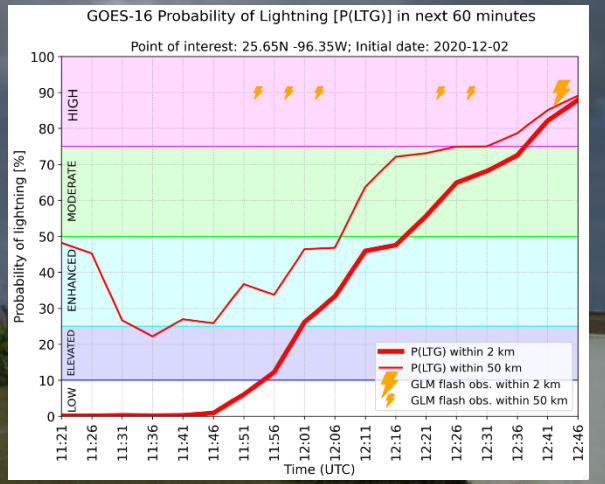
What is LightningCast?

- Model that uses visible, near-infrared, and long-wave infrared channels aboard GOES and Himawari satellites to predict the probability of lightning in the next 60 minutes.
- Created by UW-CIMSS (Cooperative Institute for Meteorological Satellite Studies - University of Wisconsin - Madison)
- Convolutional Neural Network
  - “Fully connected” network where one layer is fully related to layer following another.
  - Used extensively in visual image machine learning.
- Part of the ProbSevere Portfolio
- Been available on AWIPS stations in CONUS since June 2022.
- Guam since September 2022.









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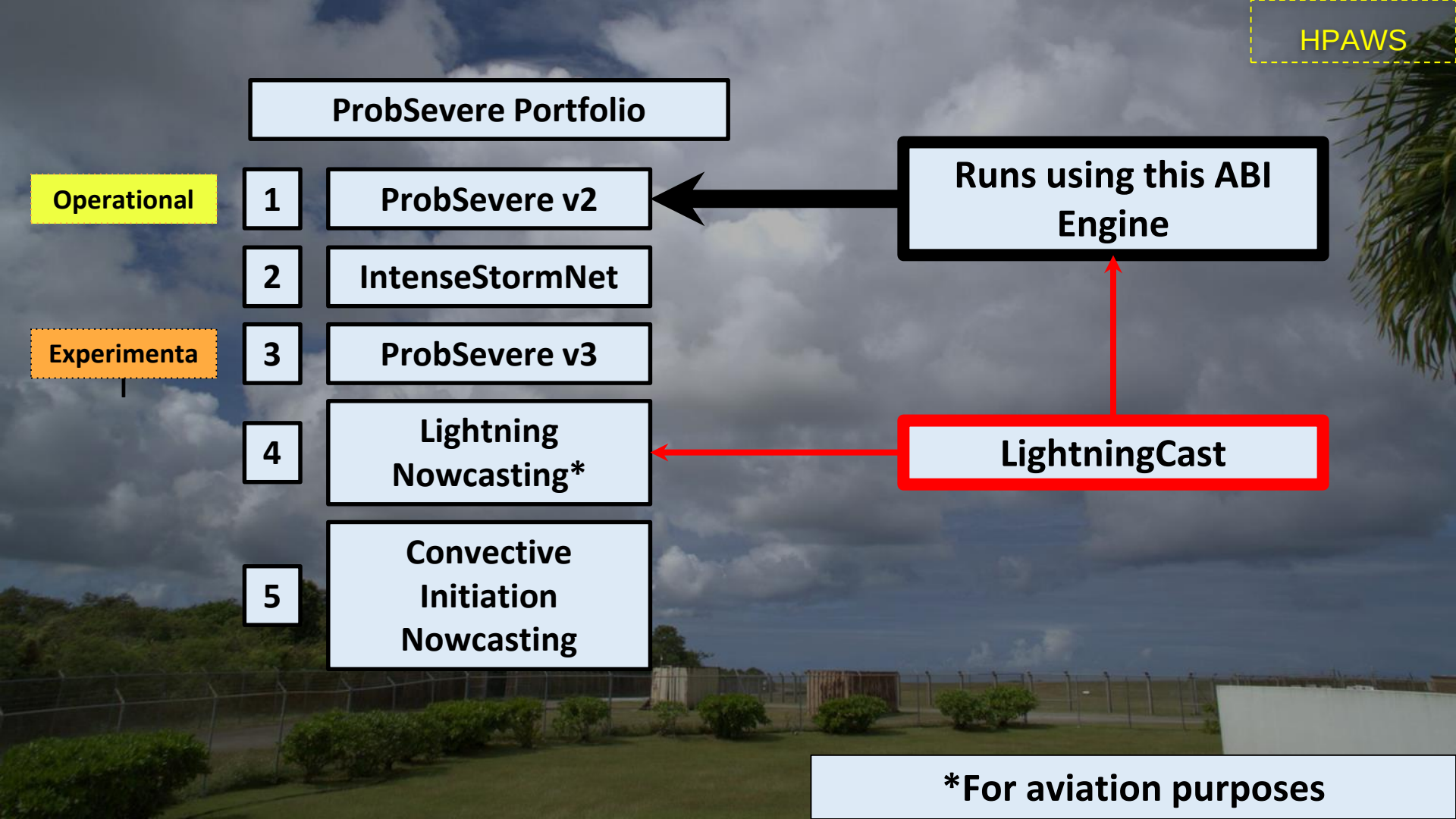
ProbSevere Portfolio
Operational
1
ProbSevere v2
2
IntenseStormNet
Experimenta
3
ProbSevere v3
4
Lightning Nowcasting*
5
Convective Initiation Nowcasting
Runs using this ABI Engine
LightningCast
*For aviation purposes

- Why does it matter?
  - WFO Guam issues Aviation Weather Warning (AWW) products for Guam International Airport.
    - Thunderstorm-based AWWs
      - Thunderstorm Advisory: Thunderstorms are possible or occurring within 20 nautical miles of the airport.
      - Thunderstorm Warning: Thunderstorms are possible or occurring within 5 nautical miles of the airport.
  - Descriptors:
    - Occasional, frequent or continuous cloud-to-ground lightning strikes expected or occurring.

Still… why does it matter?

- Cloud-to-aircraft lightning strikes
  - Guam International Airport supports both commercial and general aviation operations
  - Avionics can malfunction during critical time (approach, takeoff)
    - Could be fatal for smaller, older aircraft
- Cloud-to-ground lightning strikes
  - Threat to airport operations staff
  - Refueling
  - Cargo

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What role does LightningCast play?

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- Moving away from “Nowcasting” lightning that may introduce unprecedented delays in aviation operations.
- Missed lightning events in which AWWs were issued after the fact, rather than being issued to alert used to the developing threat.
- Tropical convection is difficult to decipher for lightning potential.
  - Mid-latitude methodology for analyzing radar and/or satellite imagery. historically produced frequent misses for thunderstorms in the region.
  - A combination of forecaster experience and AI tools can help both the forecaster & model improve

Thunderstorm Climatology: Guam

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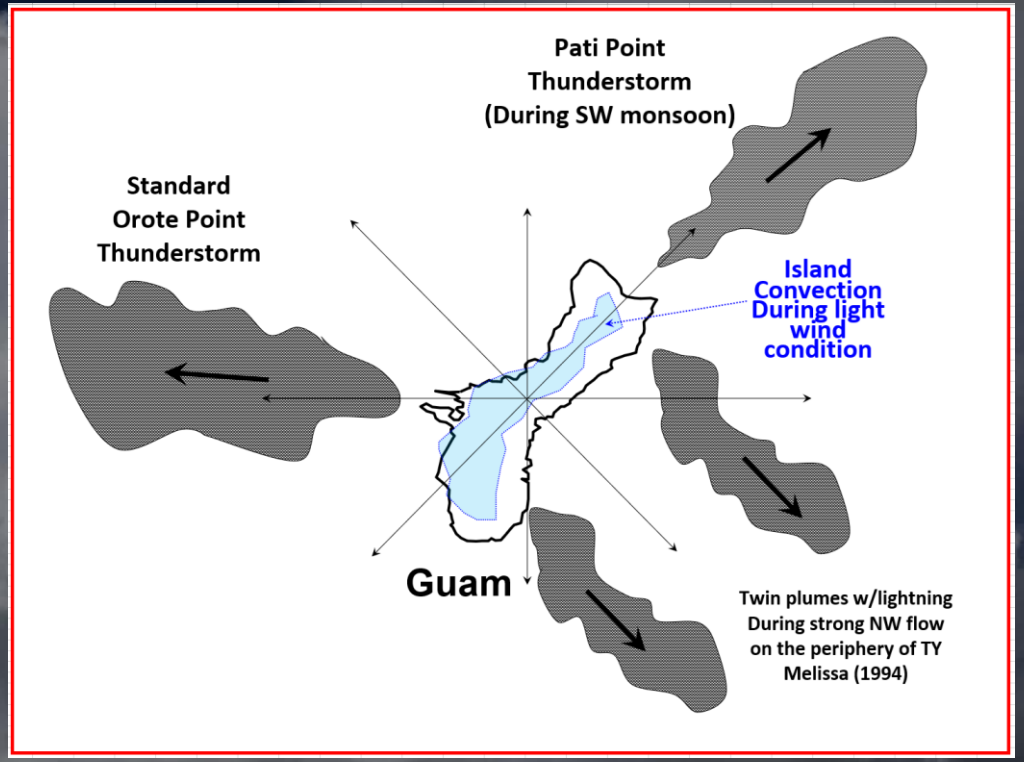
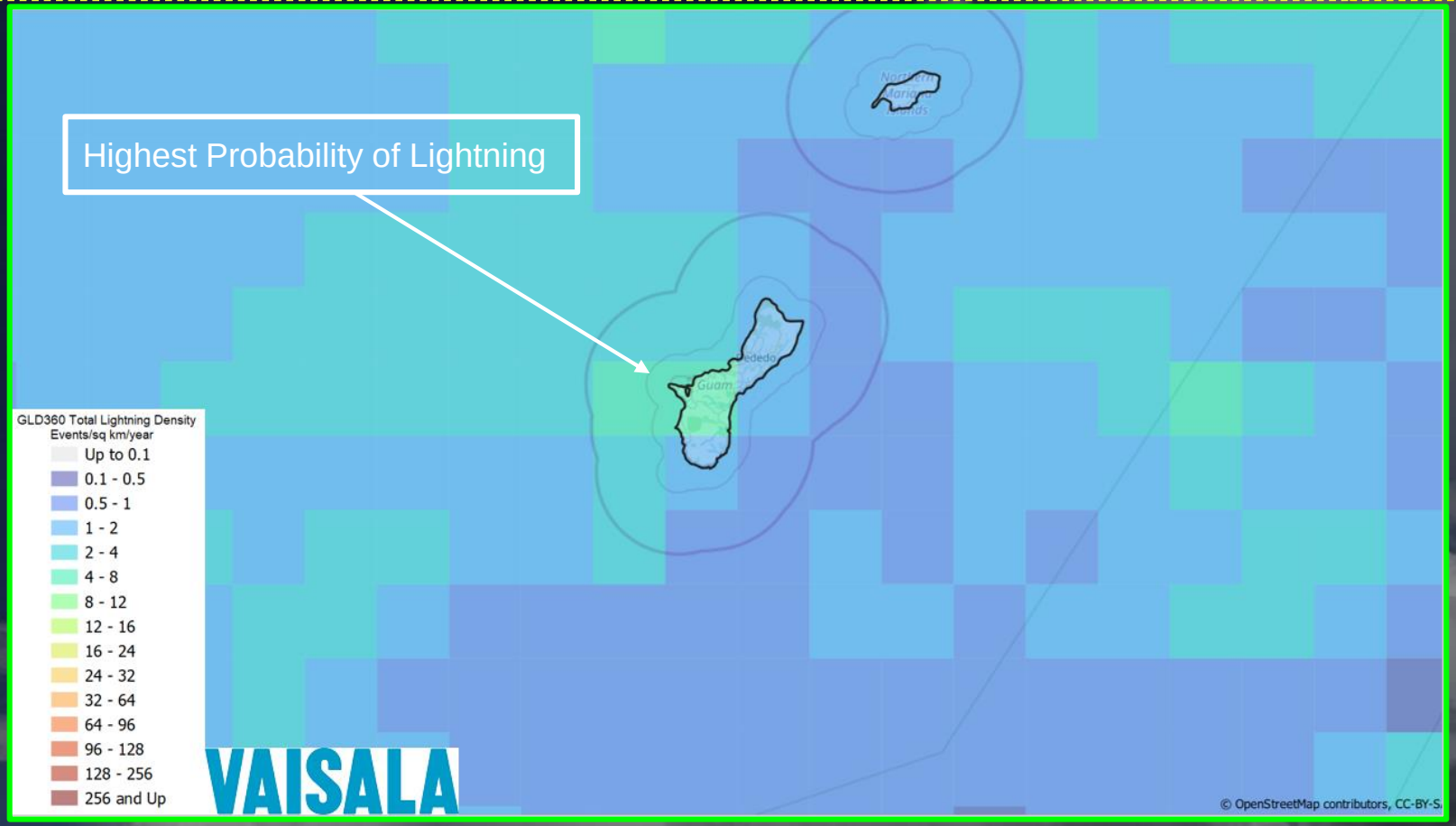
- (**Grey**) Most common non-TC locations during stable wind days with substantial low to mid-level moisture and gentle to moderate island heating.
  - Leading to offshore island thunderstorms, most commonly the Orote Point Thunderstorm.
  - Can happen year-round.
- (**Light Blue**) Most common non-TC location during very light wind conditions, moderate to strong island heating.
  - Sea breeze effect induced by convergence / updrafts along land axis.
  - Continuous cycle until moisture flux weakens and cloud cover shuts down island heating.
  - Most common during “wet” season (Summer thru late Autumn).
- *Not shown*: Thunderstorms induced by Tropical Upper-Tropospheric Trough (TUTT) embedded lows.
  - The June Thunderstorms over Saipan (CNMI, 06/2022).
  - No LightningCast available at the time.
  - Part of reasoning to expand LightningCast capability to the Marianas.



Vaisala GLM Data: Marianas

HPAWS



Vaisala GLM Data: Marianas

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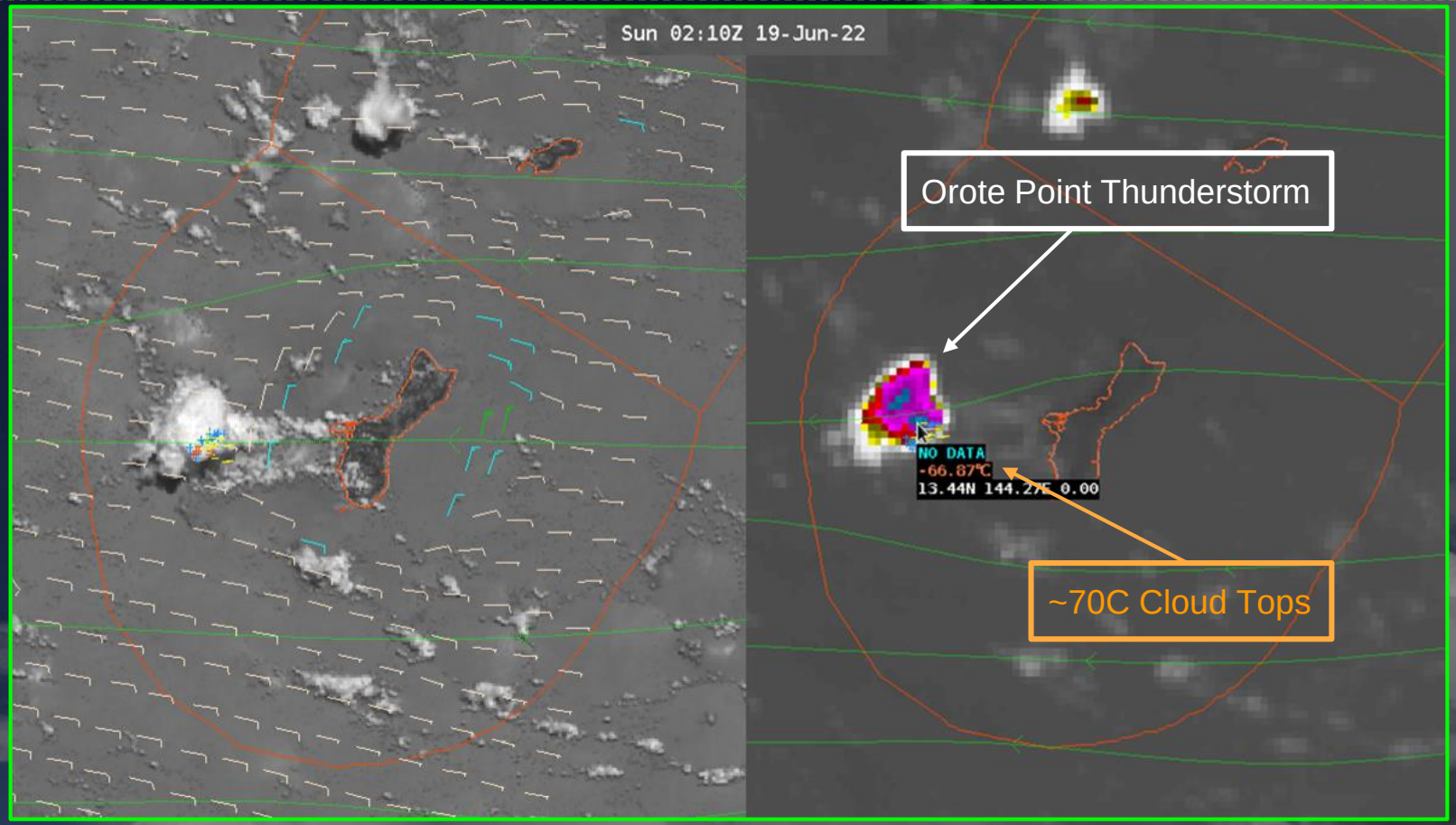

LightningCast Performance: October 6th, 2022 (Prequel)

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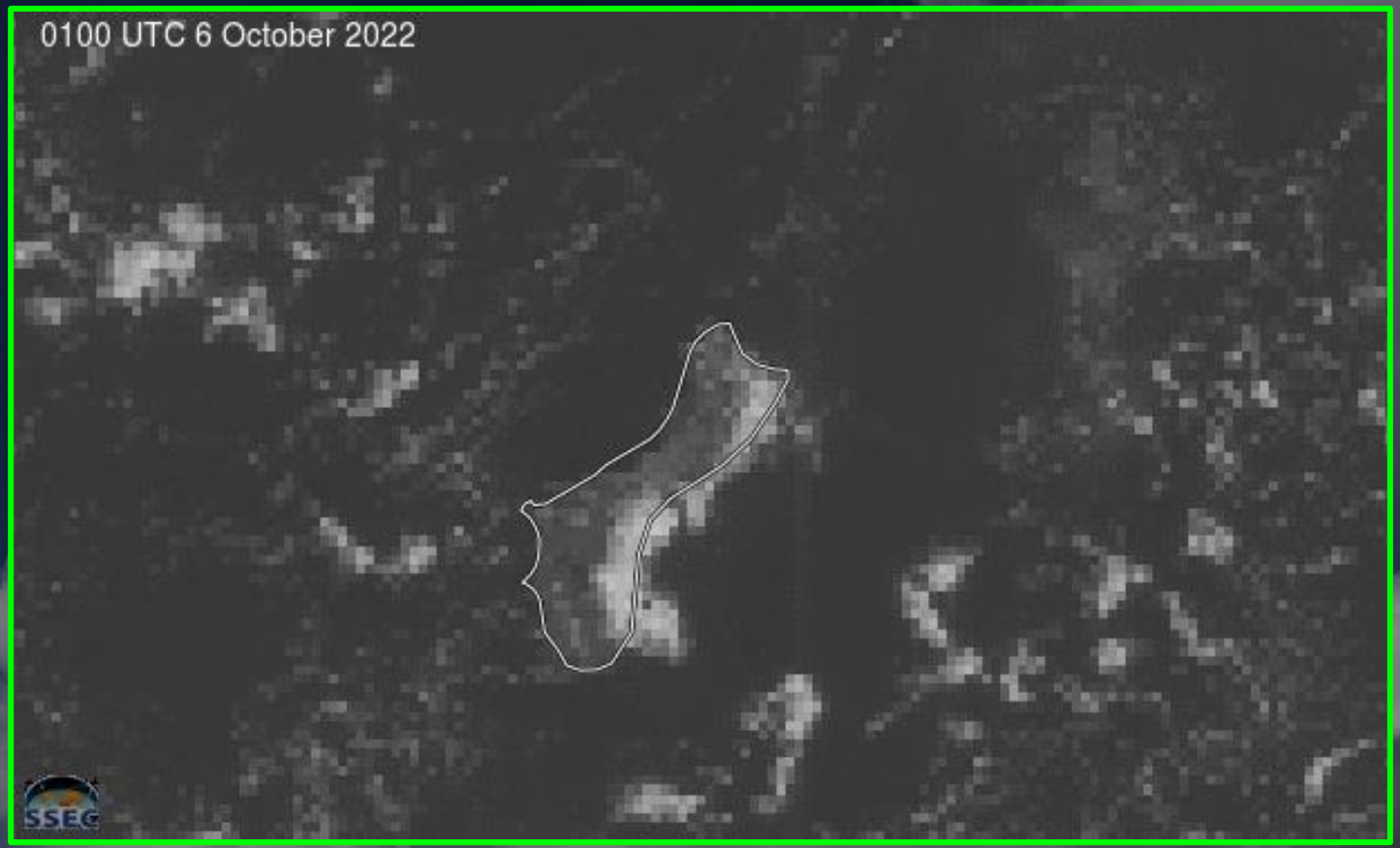

LightningCast Performance: October 6th, 2022 (LC Loop)

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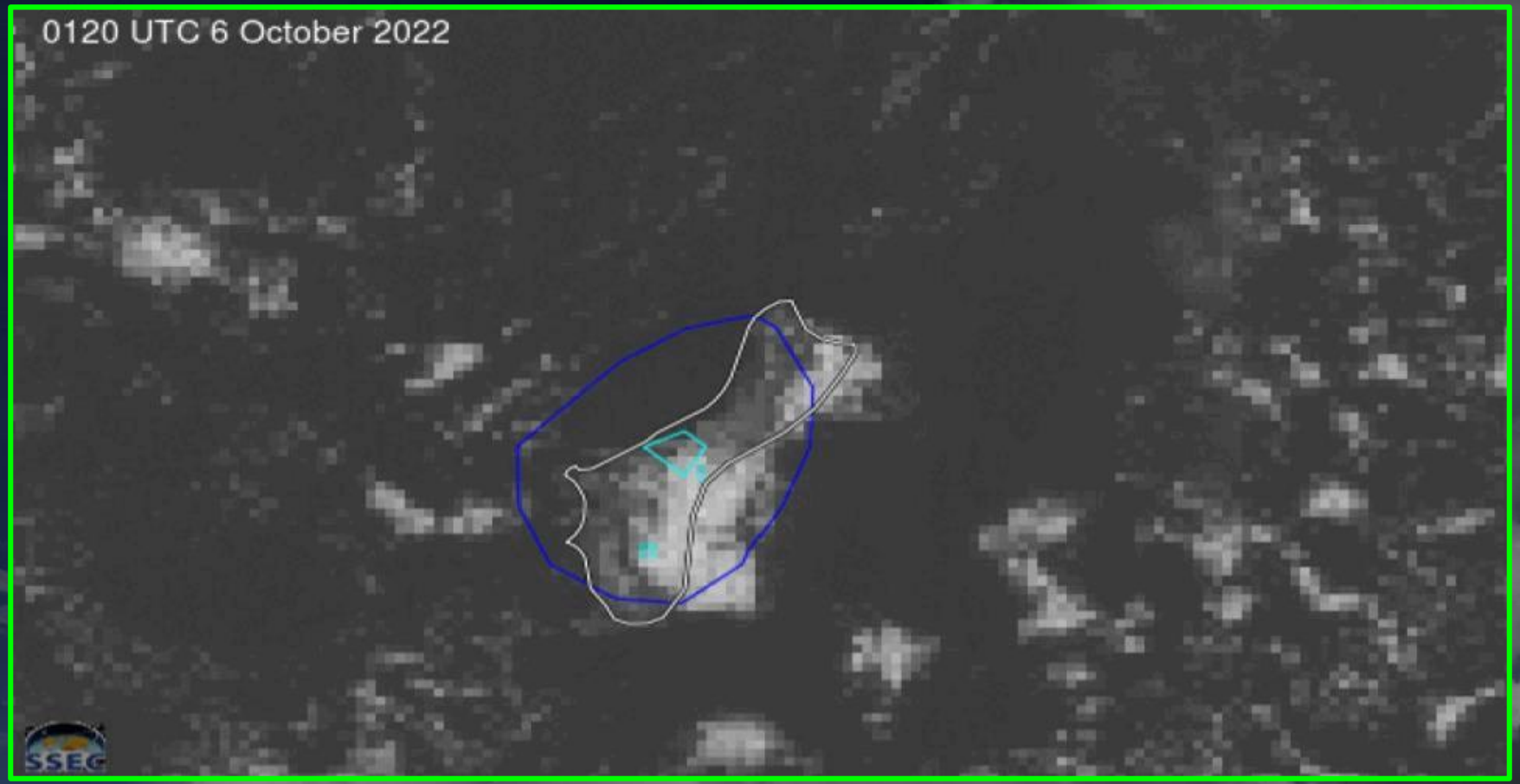

LightningCast Performance: October 6th, 2022 (10-min Himawari Increments)

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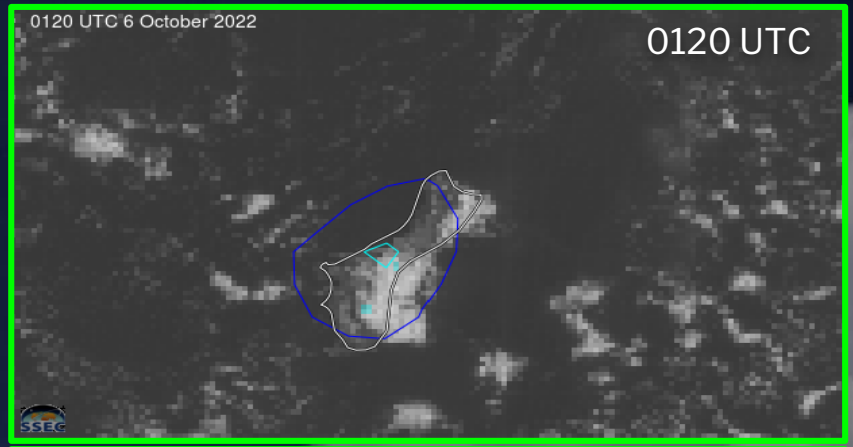
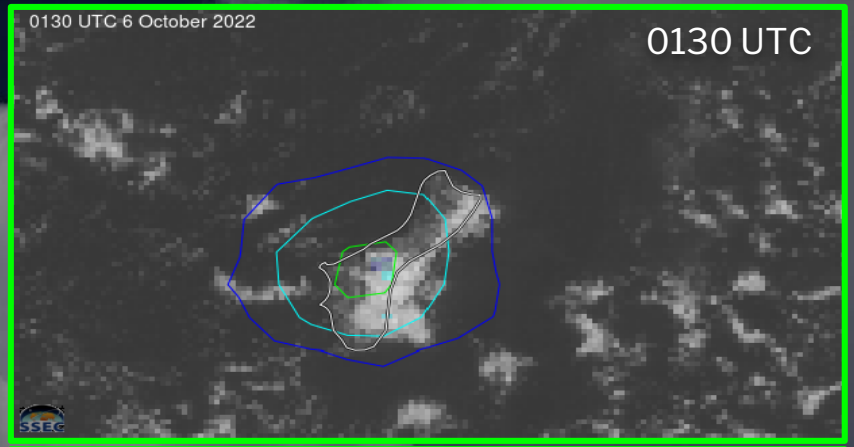
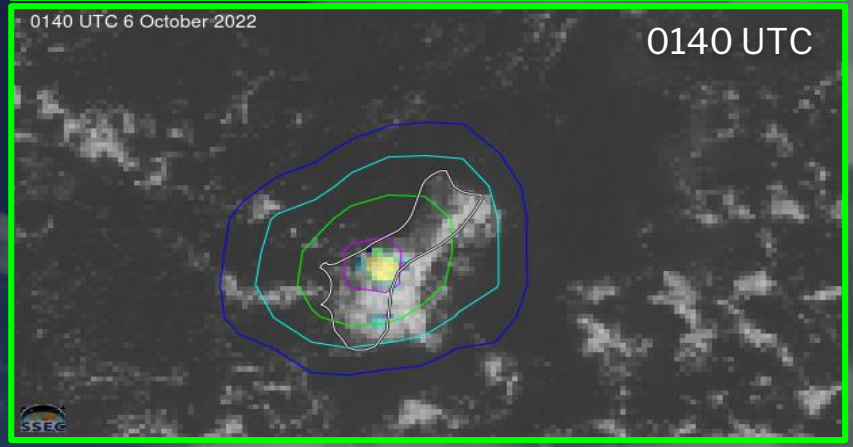
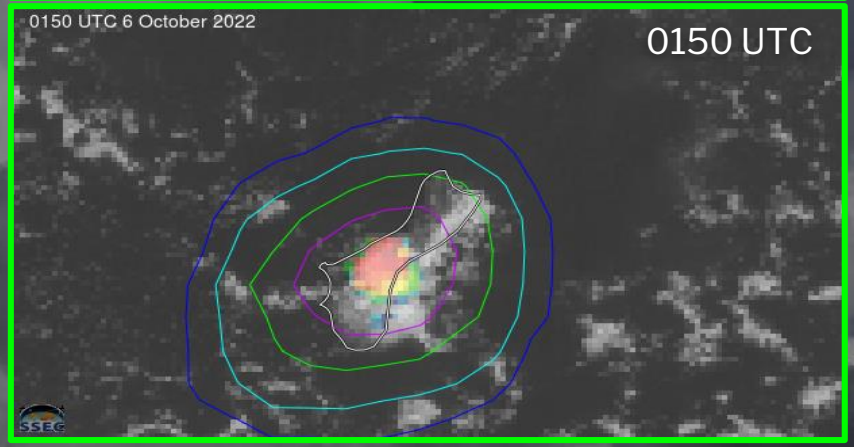
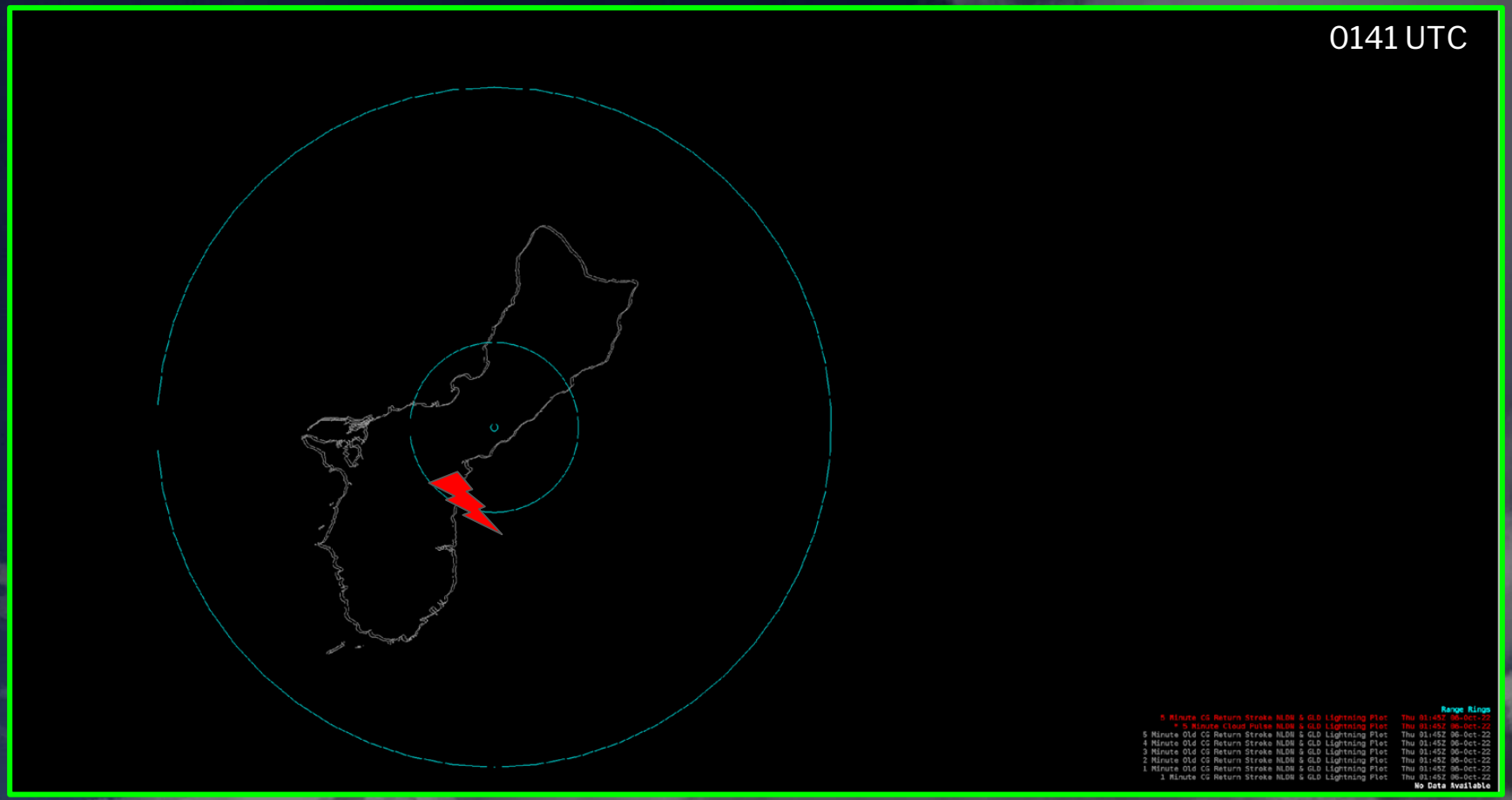


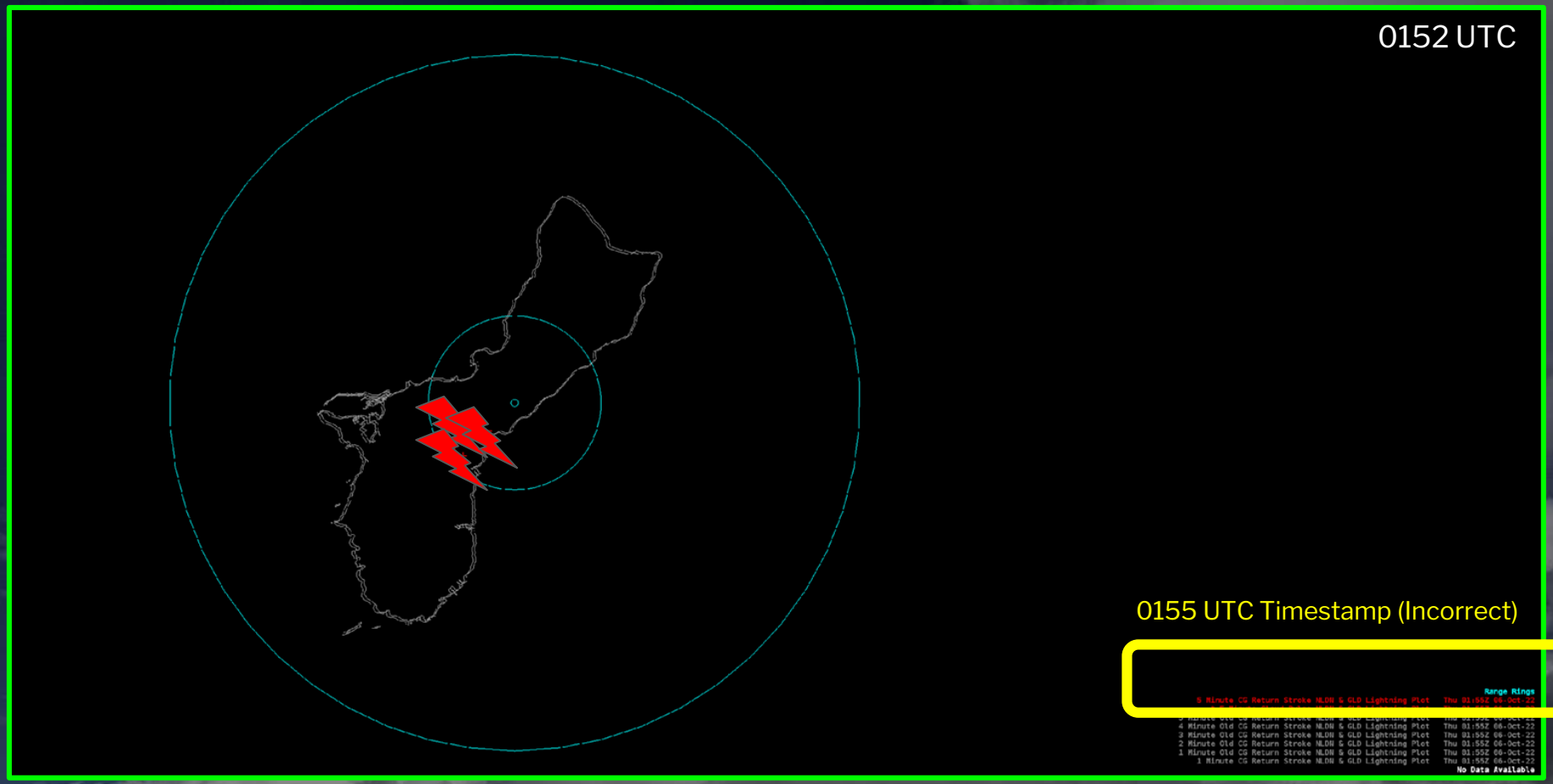








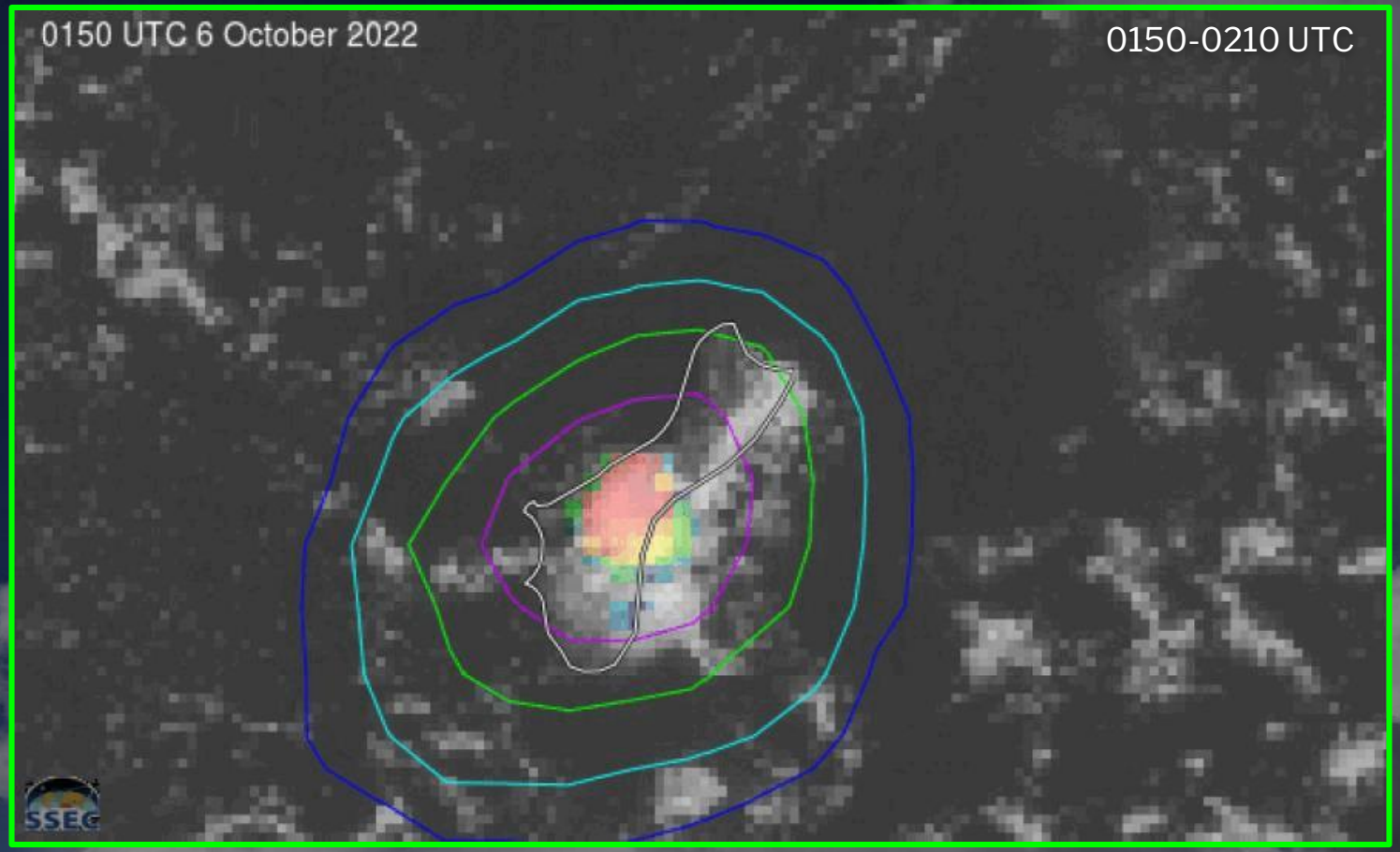
First Detection (Talofofo Coast)



Lightning Cluster (Talofofo)

LightningCast Performance: October 6th, 2022 (Post Event)

HPAWS



No lightning was observed after 152 UTC

Results from previous example:

- Even with the latency, LightningCast provided imaging for a developing event about 10-20 minutes before the first strikes.
- While chance of lightning development remained high for 30 minutes following the event, a downward trend was observed that can be interpreted quite easily by an experienced forecaster.

Speaking of experience…

> How would LightningCast have assisted an experienced forecaster on shift, that may be very familiar with convective evolutions of these events and issued an AWW for thunderstorms nonetheless?

1. Provided the forecaster assurance that what is observed on satellite is a valid concern.
2. Provided the forecaster with predictive polygons that can assist in decision making; do we issue a TS Advisory, or a TS Warning?
3. Provided the forecaster with a chance to assess re-development of more cells that could extend the hazard times.
4. As forecasters build experience from pattern recognition, so does LightningCast.

Post-Event Analysis and Office Dialogue:

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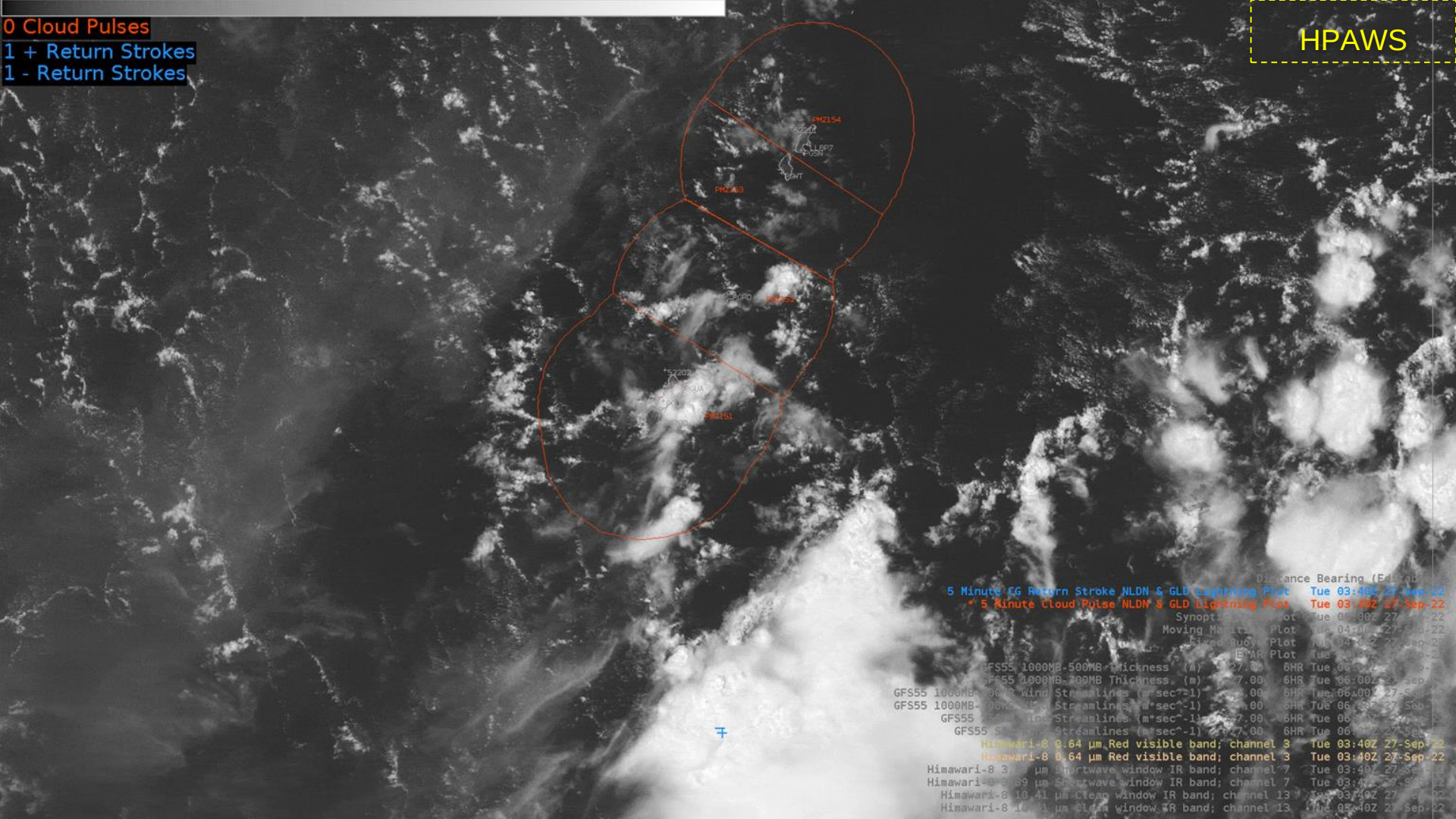
- “Just last night, we had several booms close to the airport, but unfortunately the airport TS warning was issued after the booms. The next morning, looking at radar and LightningCast, I noted the cells developed fairly quickly east of the island and matured to lightning production over the island. Without LightningCast, I'd agree such cases would be difficult to predict by Sat/Rad alone, but LightningCast did show 50% and even 75% just before lightning occurred. Convection was generally short-lived across the region, with cells tending to produce a quick burst of lightning and then dissipating. LightningCast probabilities were expectedly noisy, with all the convection around, but did seem to latch on to the active convective elements with some slight off-centeredness (perhaps bridging multiple areas?).”

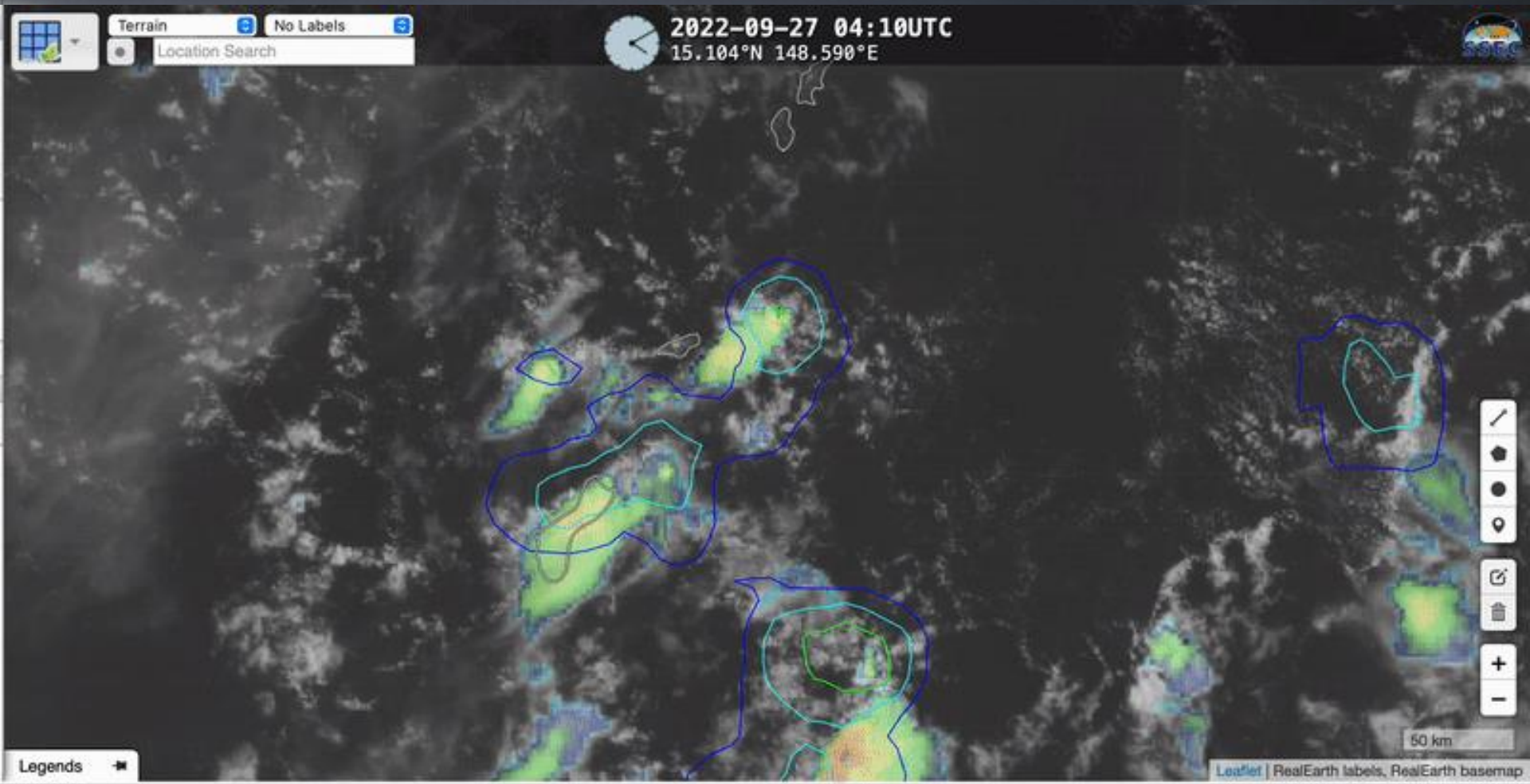
- “One of the lead forecasters had recently cited a 75% polygon that ultimately had no lightning. I believe I loaded the loop or an image on it. I'll admit, tropical convection can be confounding with occasions of widespread convection and -70C to -80C cloud tops and no lightning, and other times, warmer cloud tops and a lot of lightning. ”

- Forecaster feedback was collected and passed along to the LightningCast modelers, as they were looking to improve how LightningCast feeds particular parameters to help improve its tropical regime capabilities.
- As noted previously, LightningCast had a recurring tendency to over-predict lightning potentials based on satellite imagery and incoming GLM data.
- Just like humans, LightningCast’s convolutional neural network continuously verifies and learns from events to further improve visual interpretation of data.


0 Cloud Pulses
1 + Return Strokes
1 - Return Strokes
HPAWS
PM2154
PM2153
PM2152
PM2151
5 Minute CG Return Stroke NLDN & GLD Lightning Plot Tue 03:40Z 27-Sep-22
5 Minute Cloud Pulse NLDN & GLD Lightning Plot Tue 03:40Z 27-Sep-22
Himawari-8 0.64 µm Red visible band; channel 3 Tue 03:40Z 27-Sep-22
Himawari-8 0.64 µm Red visible band; channel 3 Tue 03:40Z 27-Sep-22

LightningCast Performance: September 27th, 2022 (“Guam Defense Shield”)

HPAWS



Post-Event Analysis and Thoughts:

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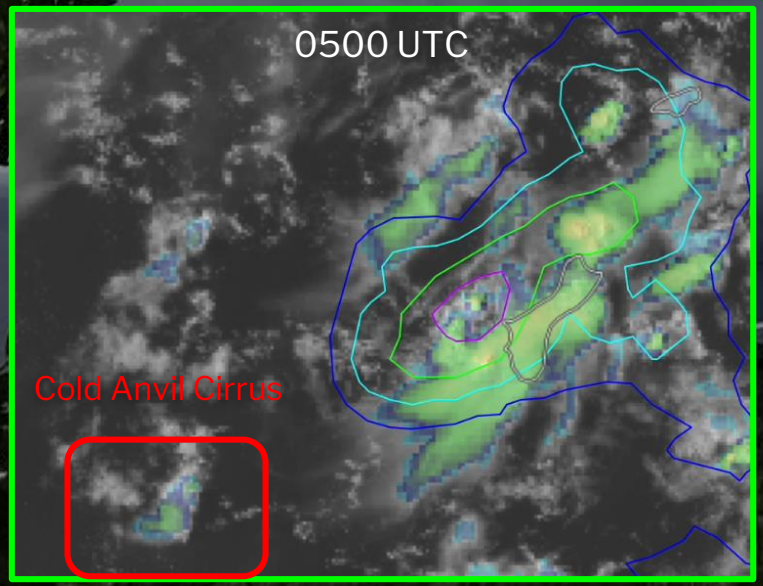
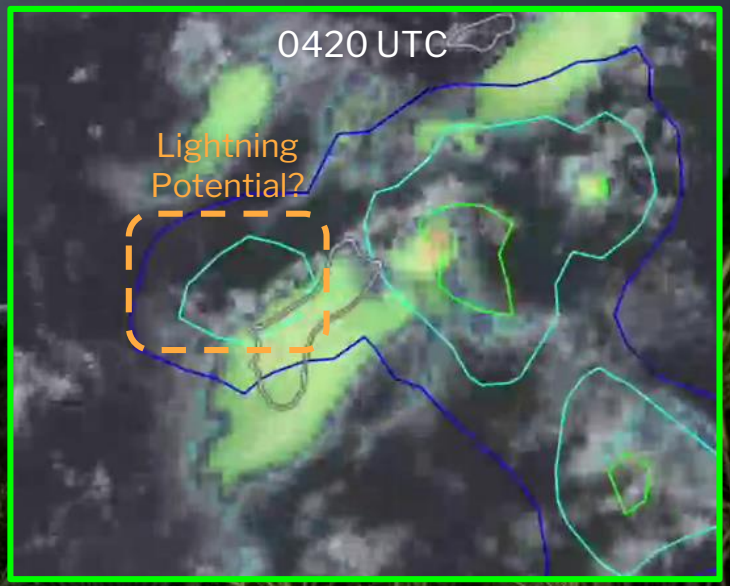
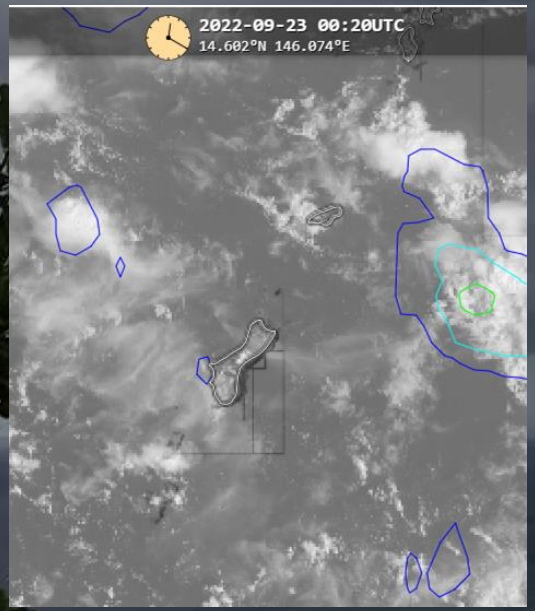
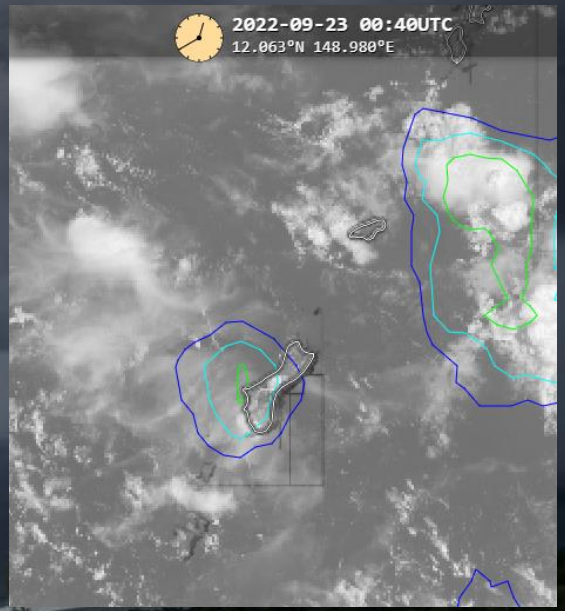
- Polygons appear to precisely capture smaller active convective areas where lightning would be sensibly expected.
  - Areas of cold cirrus anvils spreading well downstream were mostly ignored.
- However, some of the polygons do extend well into clear areas.
- Most likely LightningCast is ascribing 'lead time' of potential lightning in that area based on convective motions?
  - By 0500Z, the area off Guam's western shore was alive with new convection and the burst of lightning evident by 0515Z.

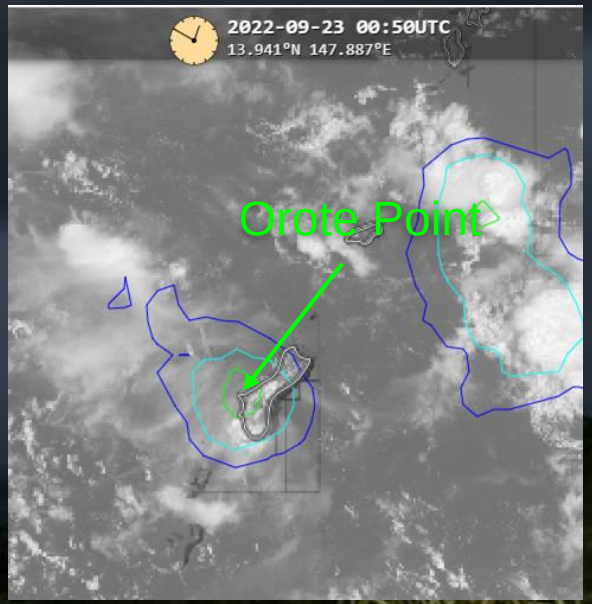




“Sometimes, it can be tough…” - WFO GUM Forecaster (Date: Unknown)



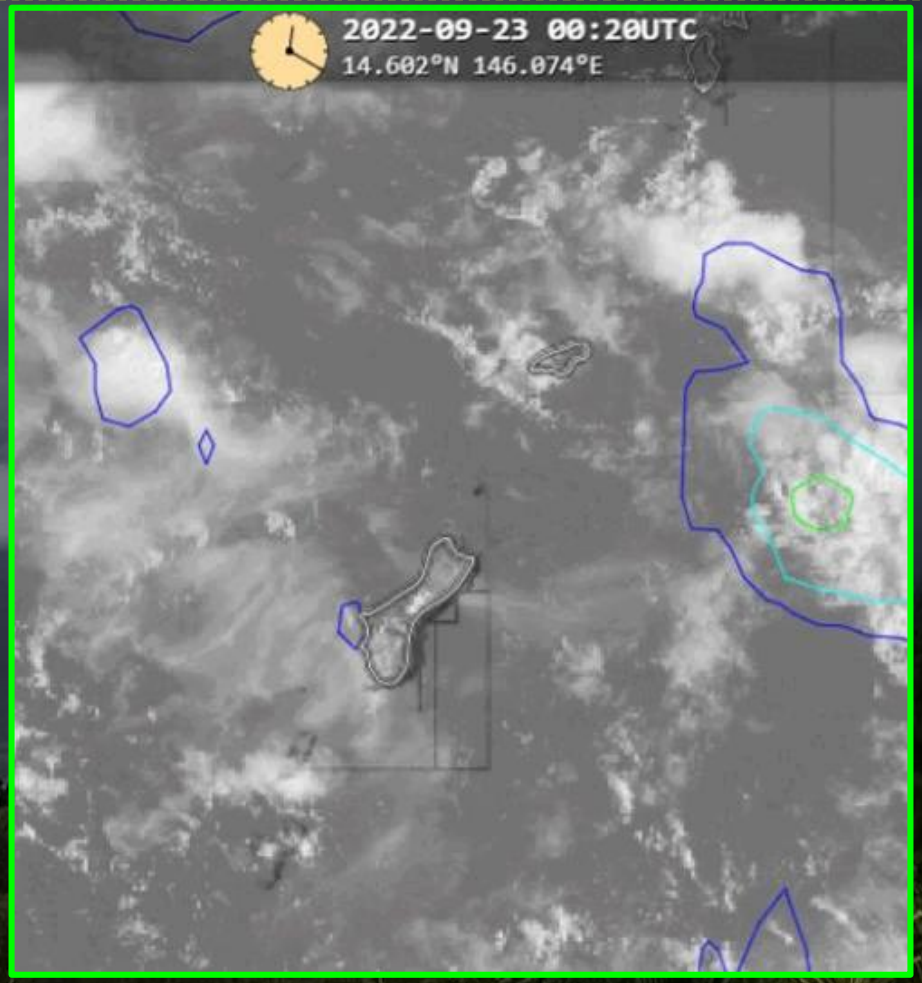




- LightningCast picked up on a chance for thunderstorm formation off of Orote Point.
  - Climatologically highest chance.
- Even with little support from satellite imagery, algorithm decided that this sector continues to have a higher chance of lightning potential.

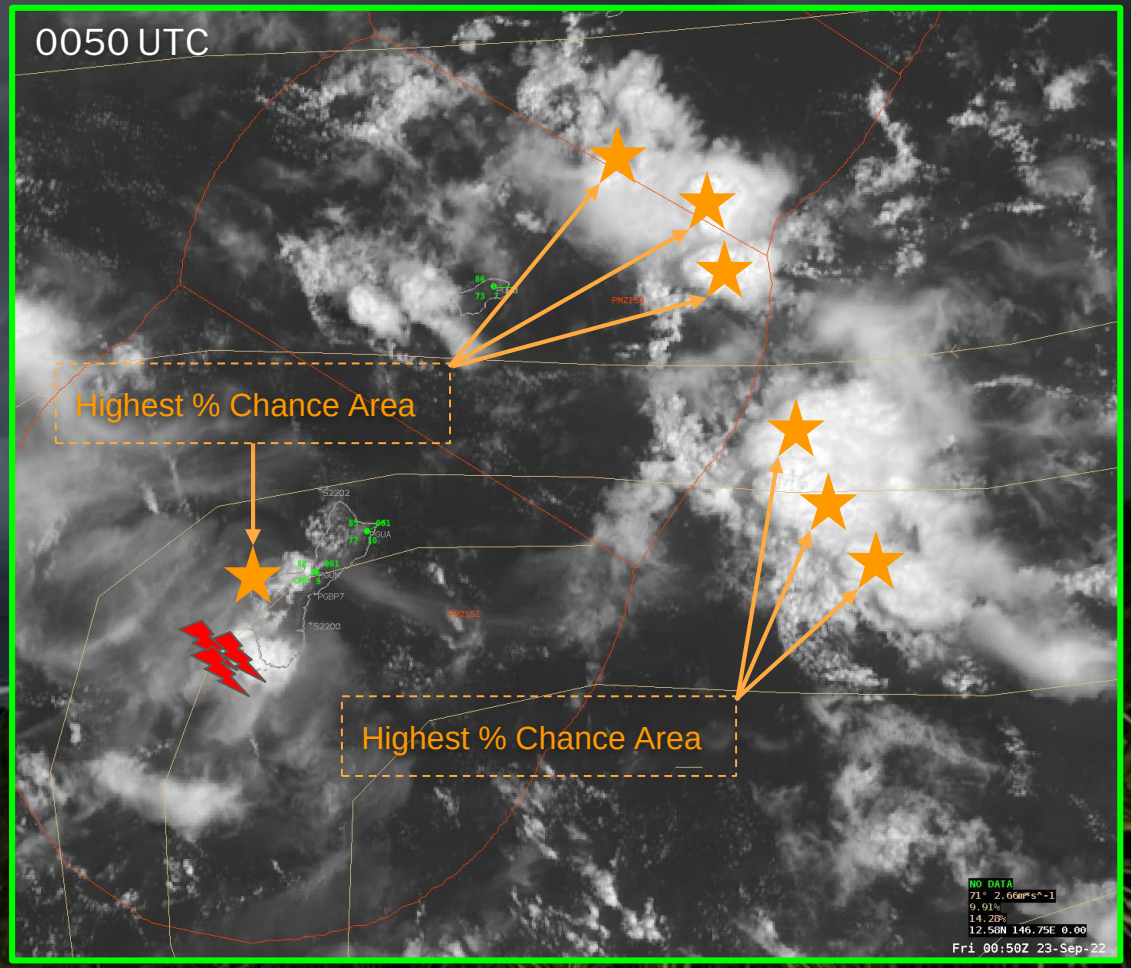
LightningCast Performance: September 23th, 2022 (Part 2)

HPAWS



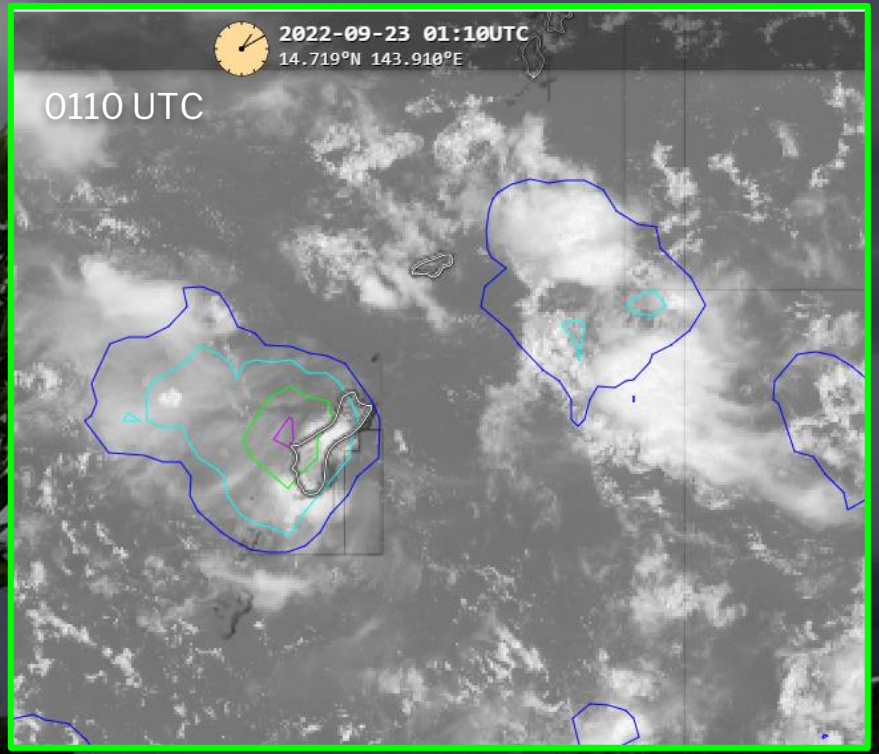
What Actually Happened:

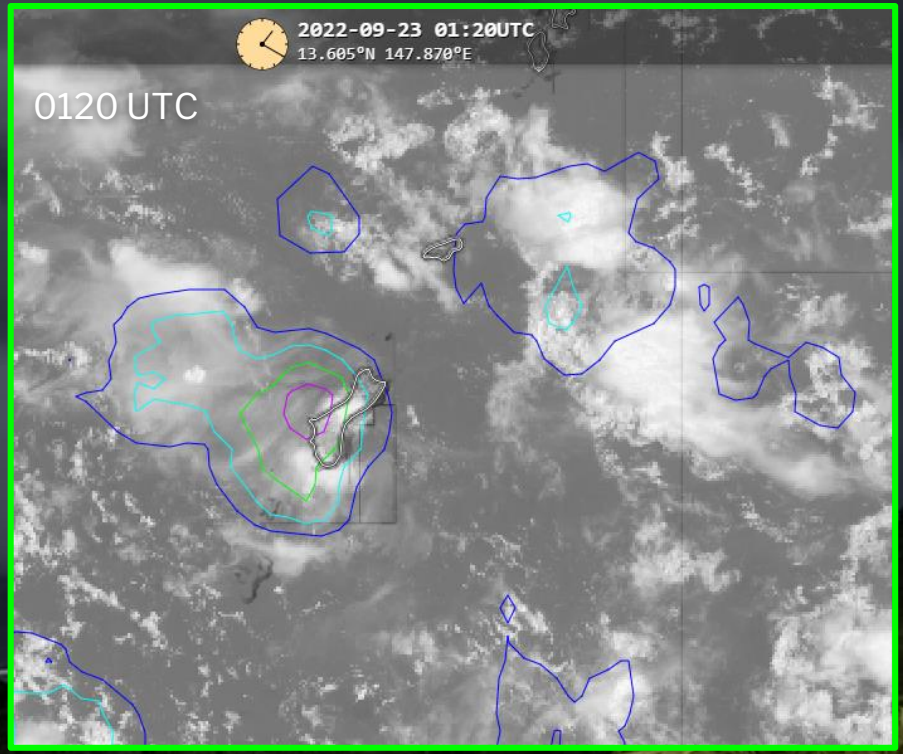
- SW Cell generated multiple lightning strikes.
- Central Cell never developed any lightning strikes, just heavy showers.
- Orote Point Thunderstorm never developed.
- Tropical disturbances in Rota & Tinian waters never developed lightning strikes.



LightningCast Performance: September 23th, 2022 (Post-Event)

HPAWS





- LightningCast indicated 75%+ probability of lightning as convection was winding down.
- Probability expanded moreso, but was largely devoid of convection.
  - *What gives? Let's see what the forecaster on-shift has to say…*

Post-Event Forecaster Comments:

- Being the operational forecaster that day, while seeing even the low probabilities, which factored (to a small extent) into my decision to issue a thunderstorm advisory for the airport, my main reason was instinct/gut, based on the nature of such convective events to build up so quickly."
- "Noting the IR cloud-top temperatures via AWIPS, we had about a 15-20 min latency which makes all the difference in these events – sometimes, lightning being detected in clouds that are still 'liquid' based on the latest frame in AWIPS. With that said, I'm fairly impressed with the lead time, albeit small percentages, that LightningCast indicated for the general area."

– WFO GUM Forecaster

0048 UTC

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AIRPORT WEATHER WARNING FOR GUAM INTERNATIONAL AIRPORT
NATIONAL WEATHER SERVICE TIYAN GU
1048 AM ChST Fri Sep 23 2022

A THUNDERSTORM ADVISORY IS IN EFFECT FOR THE GUAM INTERNATIONAL
AIRPORT UNTIL 1200 PM THIS AFTERNOON. THUNDERSTORMS ARE POSSIBLE OR
OCCURRING WITHIN 20 NAUTICAL MILES OF THE AIRPORT.

BE ALERT AND TAKE PRECAUTIONS AS REQUIRED.
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INITIAL

0156 UTC

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AIRPORT WEATHER WARNING FOR GUAM INTERNATIONAL AIRPORT
NATIONAL WEATHER SERVICE TIYAN GU
1156 AM ChST Fri Sep 23 2022

A THUNDERSTORM ADVISORY IS IN EFFECT FOR THE GUAM INTERNATIONAL
AIRPORT UNTIL 100 PM THIS AFTERNOON. THUNDERSTORMS ARE POSSIBLE OR
OCCURRING WITHIN 20 NAUTICAL MILES OF THE AIRPORT.

BE ALERT AND TAKE PRECAUTIONS AS REQUIRED.
```

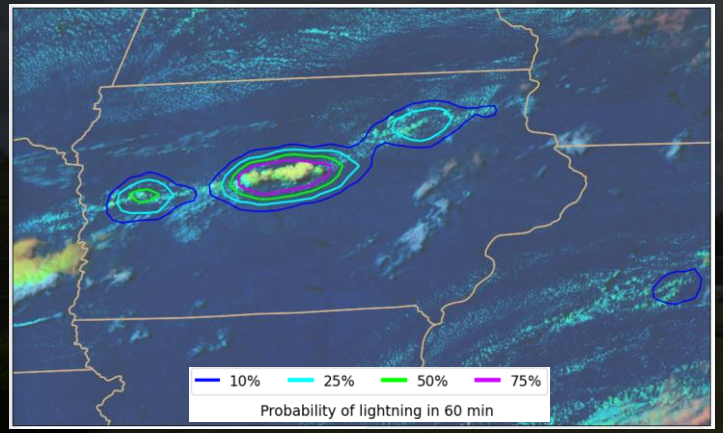
EXTENSION

Next Case Study: Radar Overlay

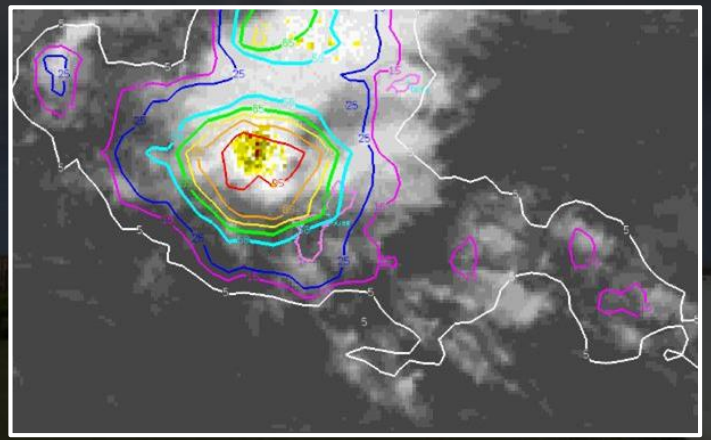
Changes Made:

- Processing speed has been further increased to make up for the latency between satellite imagery and event times.
- AWIPS Focal Points updated range values and isoline polygons to include more precise magnitudes.
  - Instead of generic "**75% or greater**" polygons, now indicates values **up to 95%**.
- Model never stops learning; it continues to ingest tens of thousands of pieces of data per day to continuously improve on near-term forecasting.

BEFORE

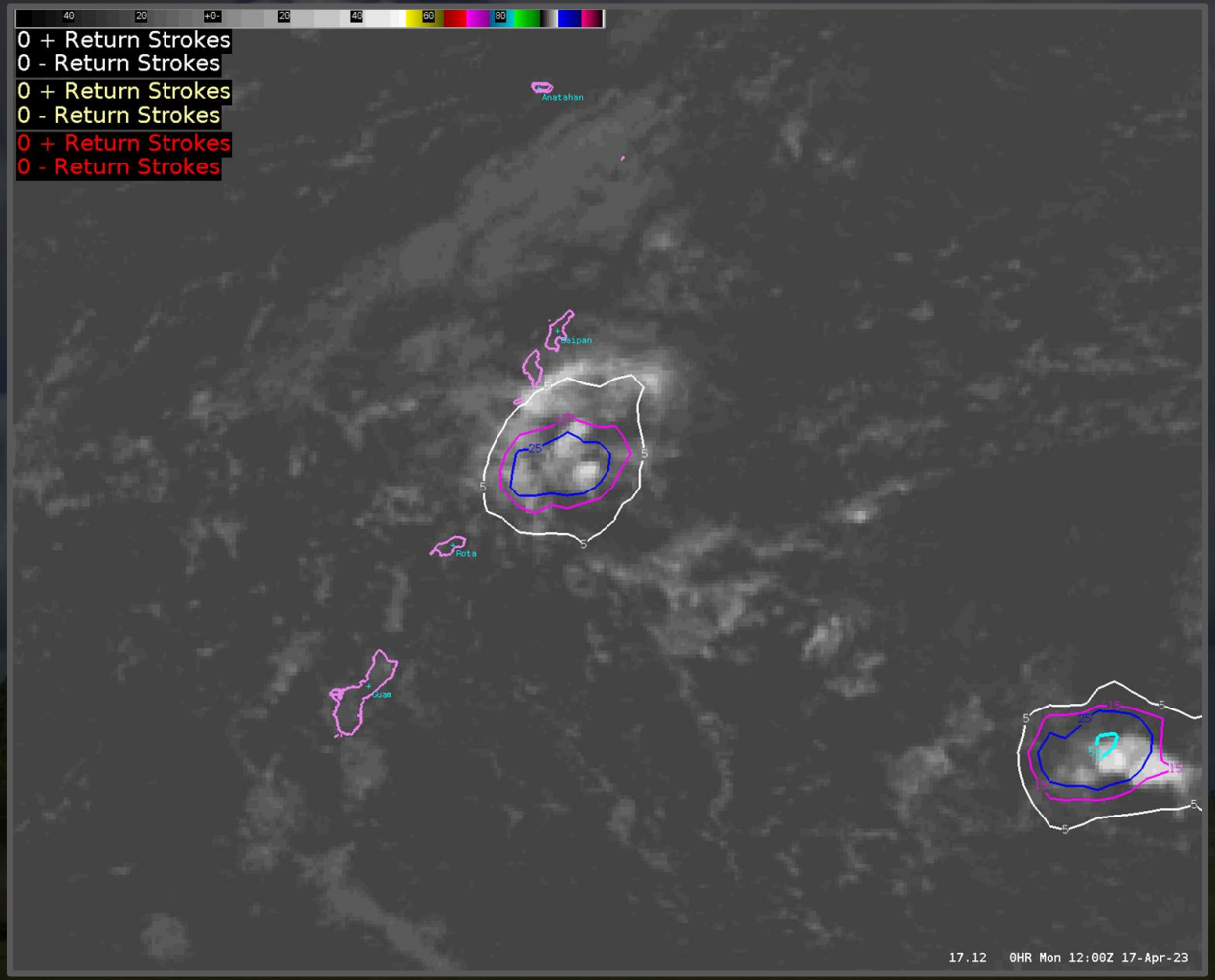


AFTER



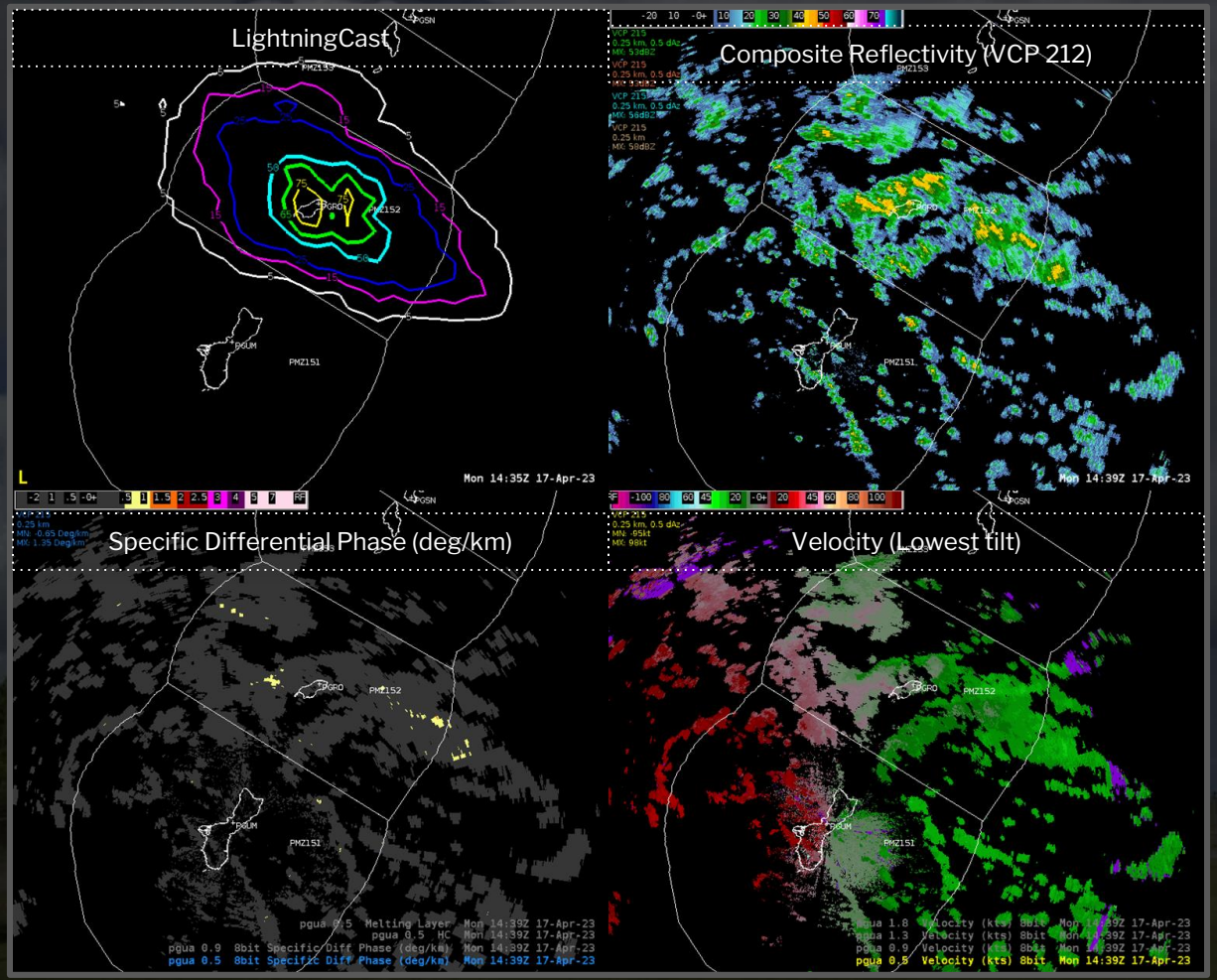
LightningCast Performance: April 18th, 2023 (Event Overview, IR Panel Loop)

HPAWS



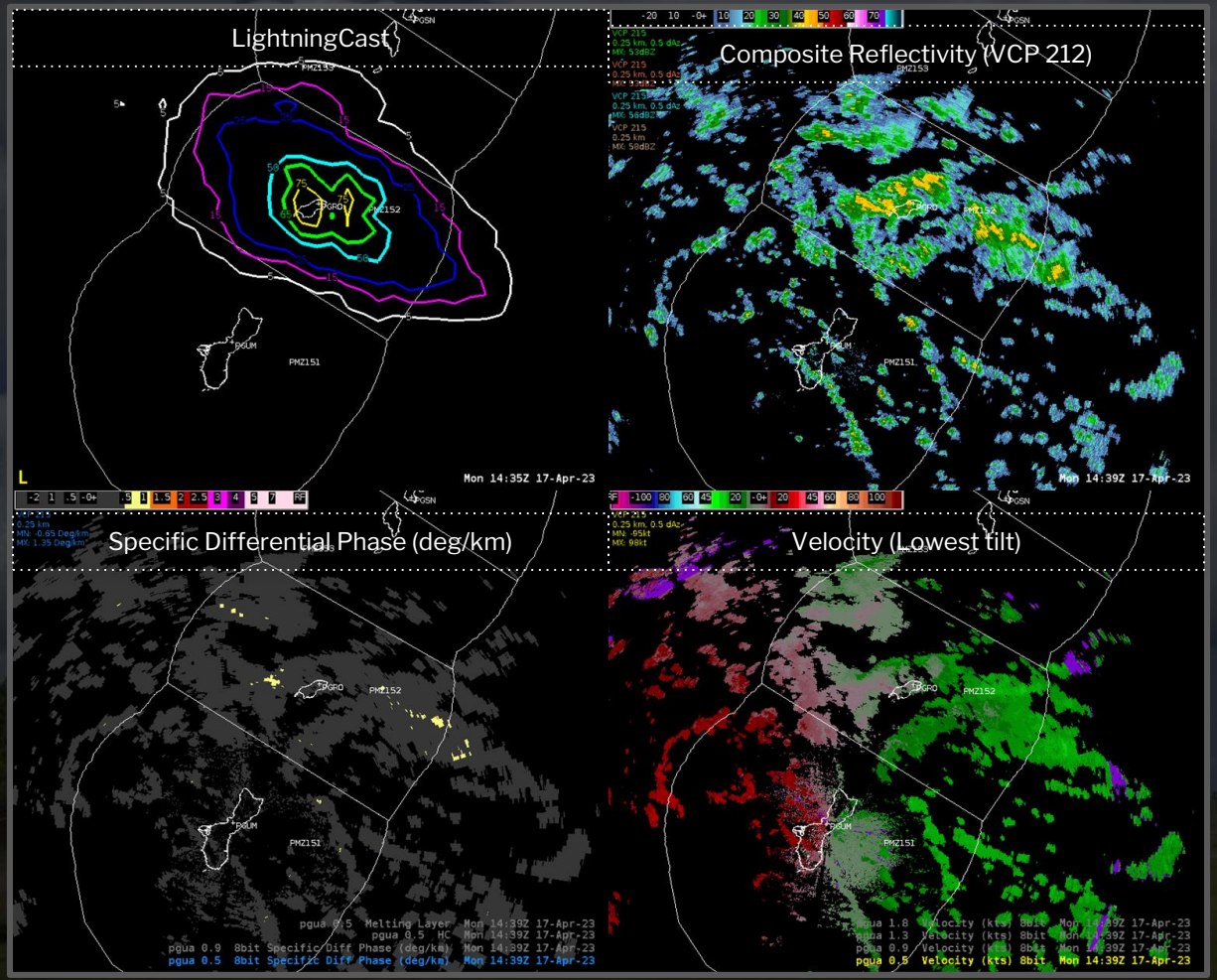
LightningCast Performance: April 18th, 2023 (All-Panel Loop Part 1)

HPAWS



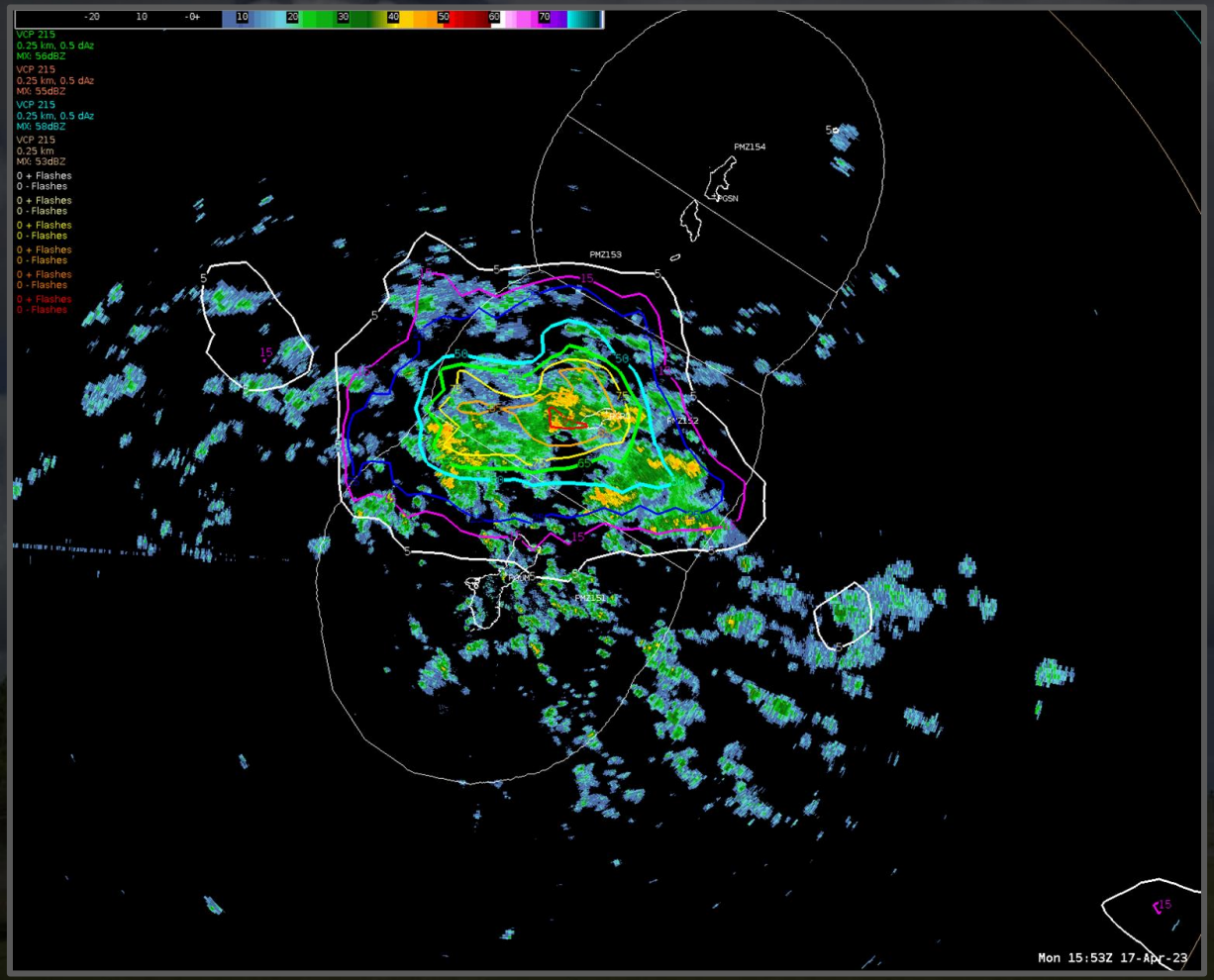
LightningCast Performance: April 18th, 2023 (All-Panel Loop Part 2 - Slowed)

HPAWS



LightningCast Performance: April 18th, 2023 (Composite+LightningCast Loop)

HPAWS



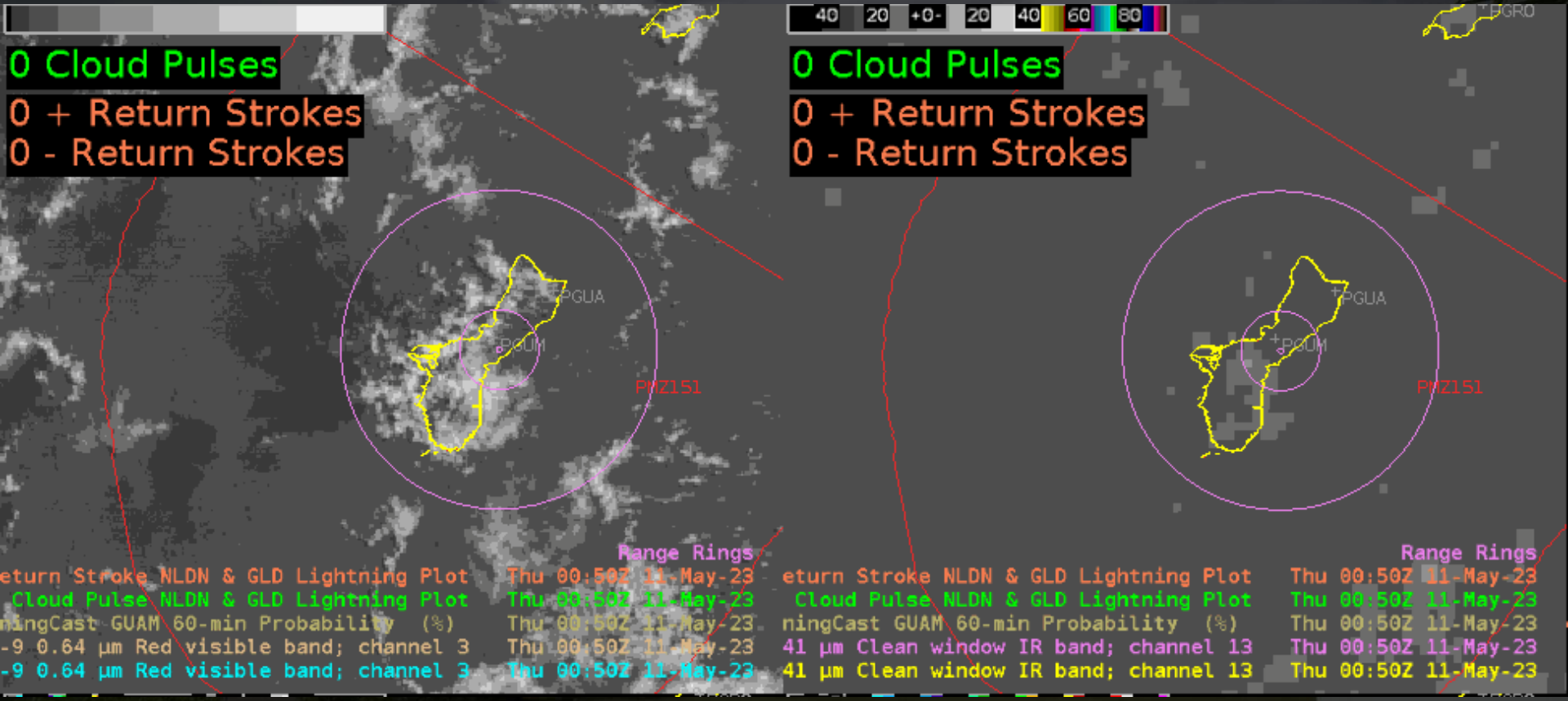
- Sporadic cell development within Guam & Rota waters.
  - 3-5 lightning strikes observed (None near Guam Intl).
- LightningCast consistently indicated 75-95% chance of lightning occurrence over the duration of the event.
- Provided a reasonable heads-up on substantial chance of lightning development
  - Ranging between 12 and 80 minutes, highly dependent on conditions and algorithm interpretation.

- Image-based AI model run as a convolutional neural network that mimics human eyesight when interpreting thousands of layers of satellite data to find a pattern between various channels in Himawari satellite.
- Feeds in GLM data to verify previously-observed satellite imagery to continue improve lightning forecast.
- Used for airport decision support services (DSS) by WFO Guam to continuously improve the quality, timeliness and lead time of AWW issuances for thunderstorms.
- Constantly “learning” and improving, eventually upgraded to ProbSevere V3 ABI engine once it becomes operational.

Some LightningCast eye candy on the next slide…

LightningCast Performance: May 11th, 2023 (Visible + Clean IR + LightningCast Loop)

HPAWS



Questions?

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THANK YOU

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