Geostationary Lightning Mapper (GLM) Applications to Precipitation Nowcasting in the Tropical Americas

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SRG @ WPC International Desks/NCEP/NOAA

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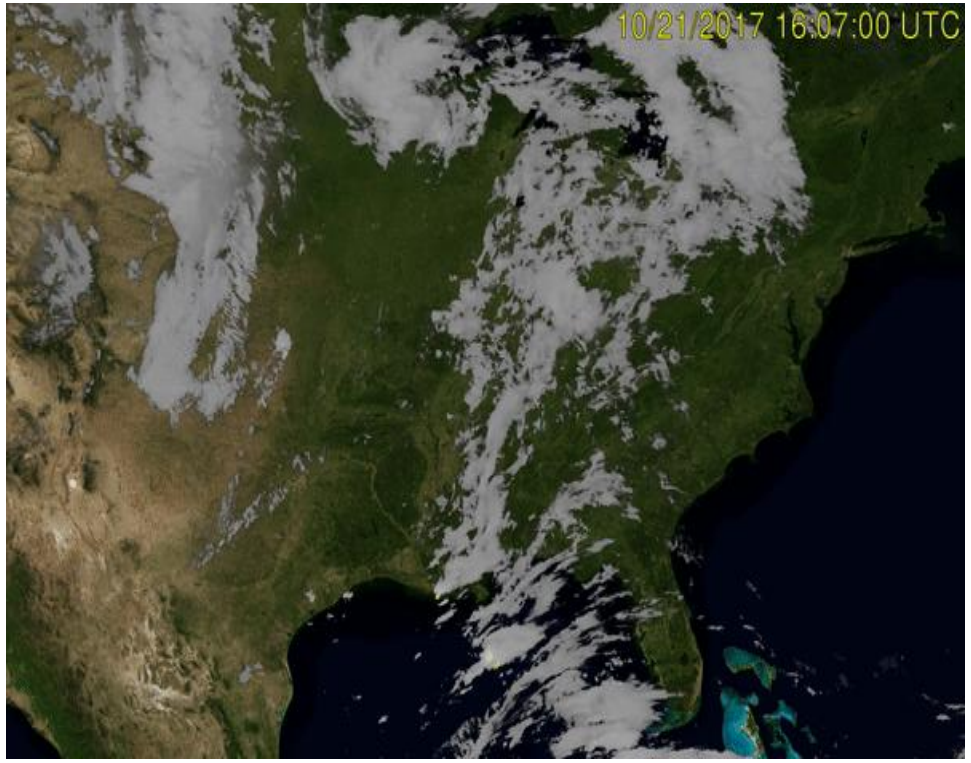
What does the GLM Measure?

- Optical measure of lightning: collects images every 2 milliseconds and compares them with a background image every 2.5 minutes.
- Measures at ~0.777 μm (narrow band in the near IR).
- Since it is an optical measurement, detects total lightning: cloud-to cloud and cloud to ground together.
    - To determine polarity, the use of ground networks is needed.



Is total lightning information useful?

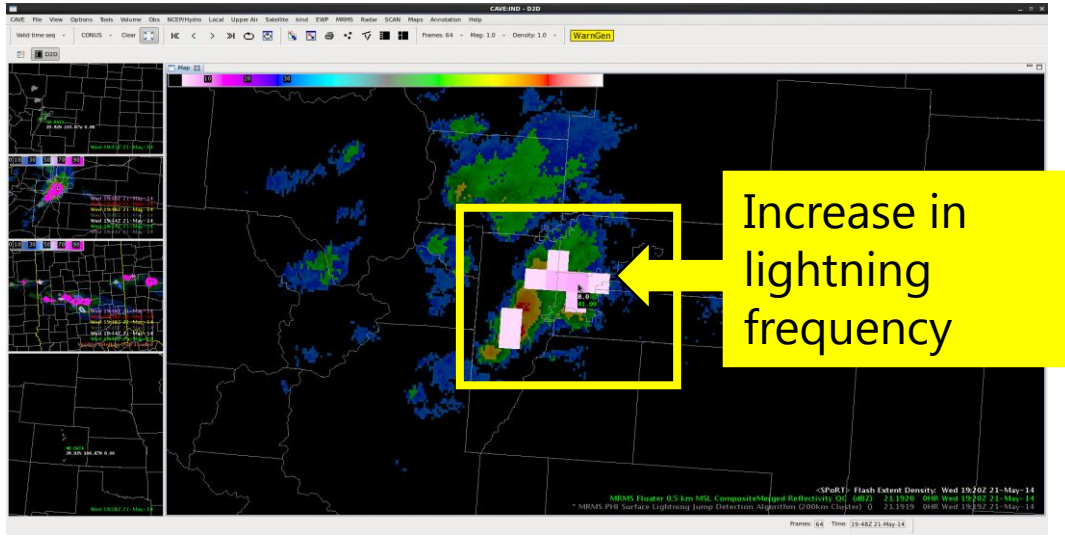
- **YES!** Darden et al. (2010) address that severe weather forecasts improve when considering total lightning information: Cloud-to-cloud + cloud-to-ground .
- Turns out that cloud-to-cloud lightning (CC) relates much better to consequent increases in severity than cloud to ground lightning.

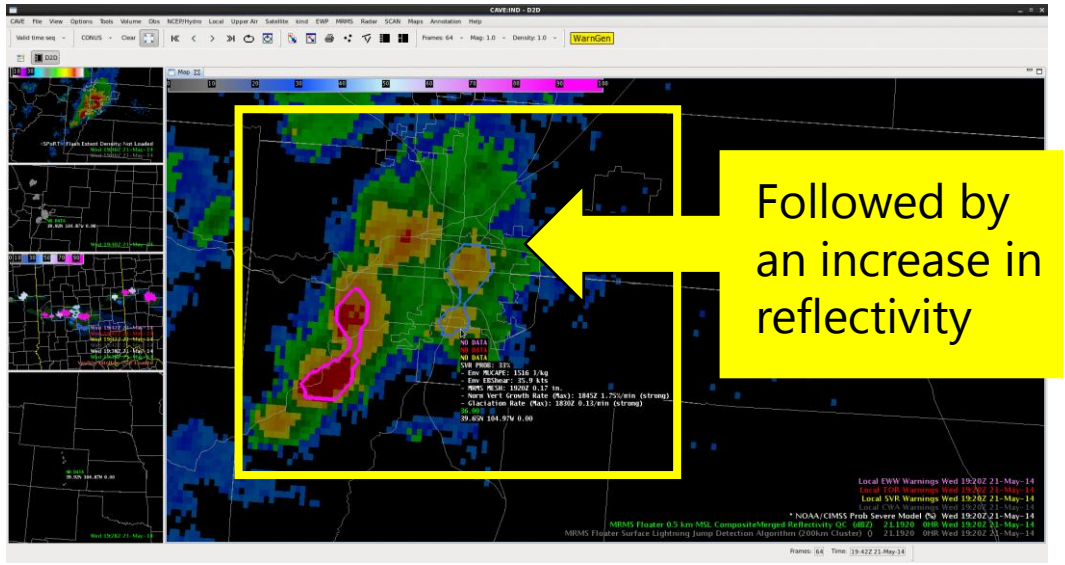
CC discharges cannot be detected with ground networks, thus **GLM total lightning is a better predictor for severity and development of heavy rainfall rates.**

CC Lightning over Washington DC
http://voices.washingtonpost.com/capitalweathergang/2009/07/cloud-to-cloud_lightning.html

Lightning Jump (LJ)

- LJ: Sudden increase in lightning frequency in a storm cell.
- Generally indicates that a convective cell
  - is intensifying rapidly and can become severe within the next 20 minutes.
  - Will likely last at least 1 hour.



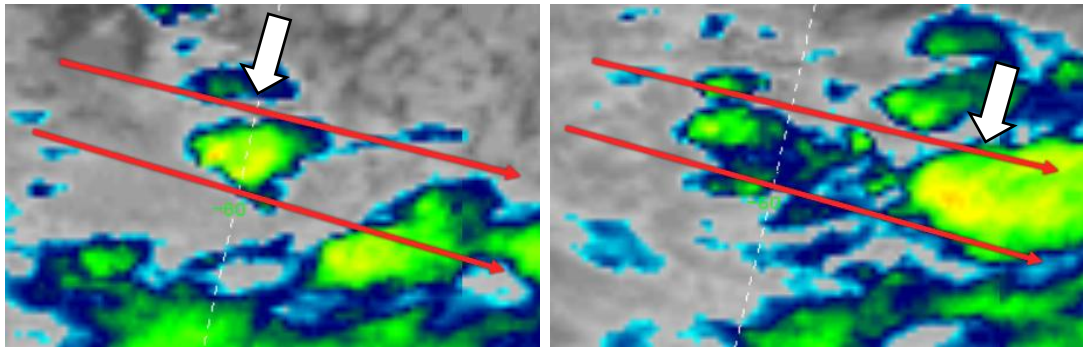


References: Goodman et al. 1988, MacGorman et al. 1989, Williams et al. 1989, Williams et al. 1999, Buechler et al. 2000, Lang et al. 2000, Goodman et al. 2005, Wiens et al. 2005, Tessendorf et al. 2007, Steiger et al. 2007, Gatlin and Goodman 2010, Darden et al. 2010, Schultz et al. 2009, 2011.

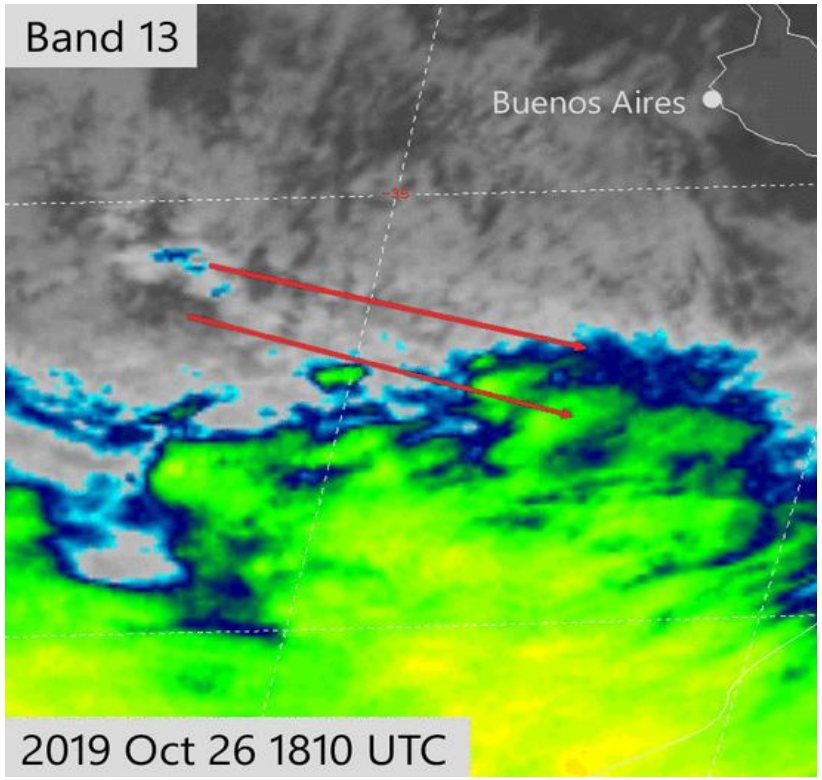
Lightning Jump (LJ)

Example

- Convection in Buenos Aires.
- Series of LJ occur between 1900 and 1920 UTC. Note that the cell is the strongest at 19:40 UTC.



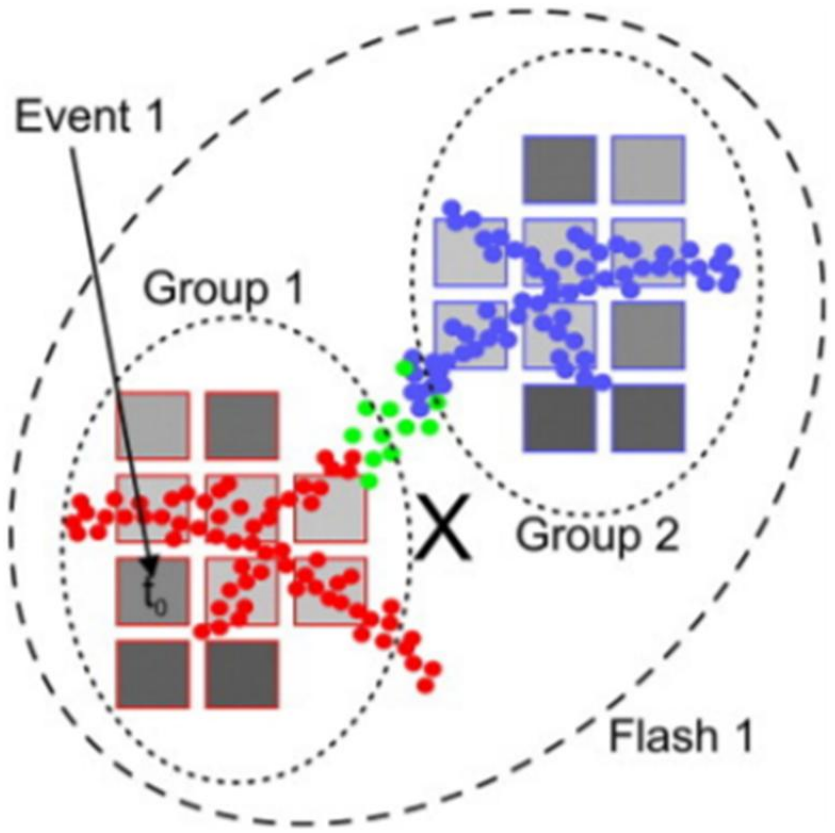
Antes (18:50) UTC Después (19:40 UTC)



Animación: Banda 13 y Group Flash Count Density. Fuente: CIRA.

What does the GLM Measure?

- The algorithm processes the changes in brightness to determine whether lightning is occurring:
  - Event: Individual pixel illuminated
  - Group: simultaneous adjacent events
  - Flash: Consecutive groups occurring within 330 ms and 16.5 km of each other.
  - Exceptionally large and long flashes may not be well resolved.



More about this process in Bruning et al. (2019)

Benefits of GLM to forecasters

- **<u>Coverage over oceanic regions</u>→** ***High impact in Caribbean nations, coastal areas and traffic over oceans.***
- Evaluation the convective mode, storm evolution and intensity of weather systems
- Nowcasting of developing severity and potential for heavy rains (“lightning jump” or sudden increase in total lightning)
- Tracking embedded convection
- Identification of storms that strengthen or weaken
- Understand changes in intensity of tropical cyclones.

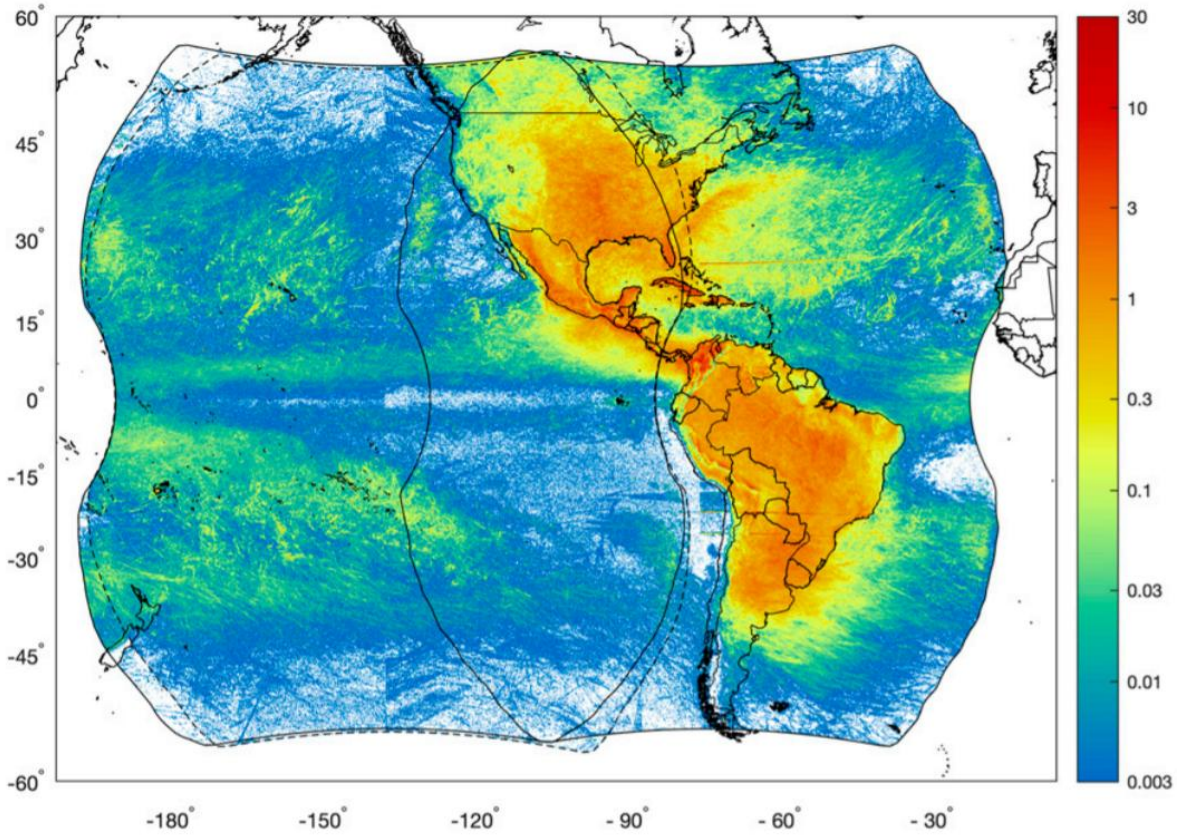


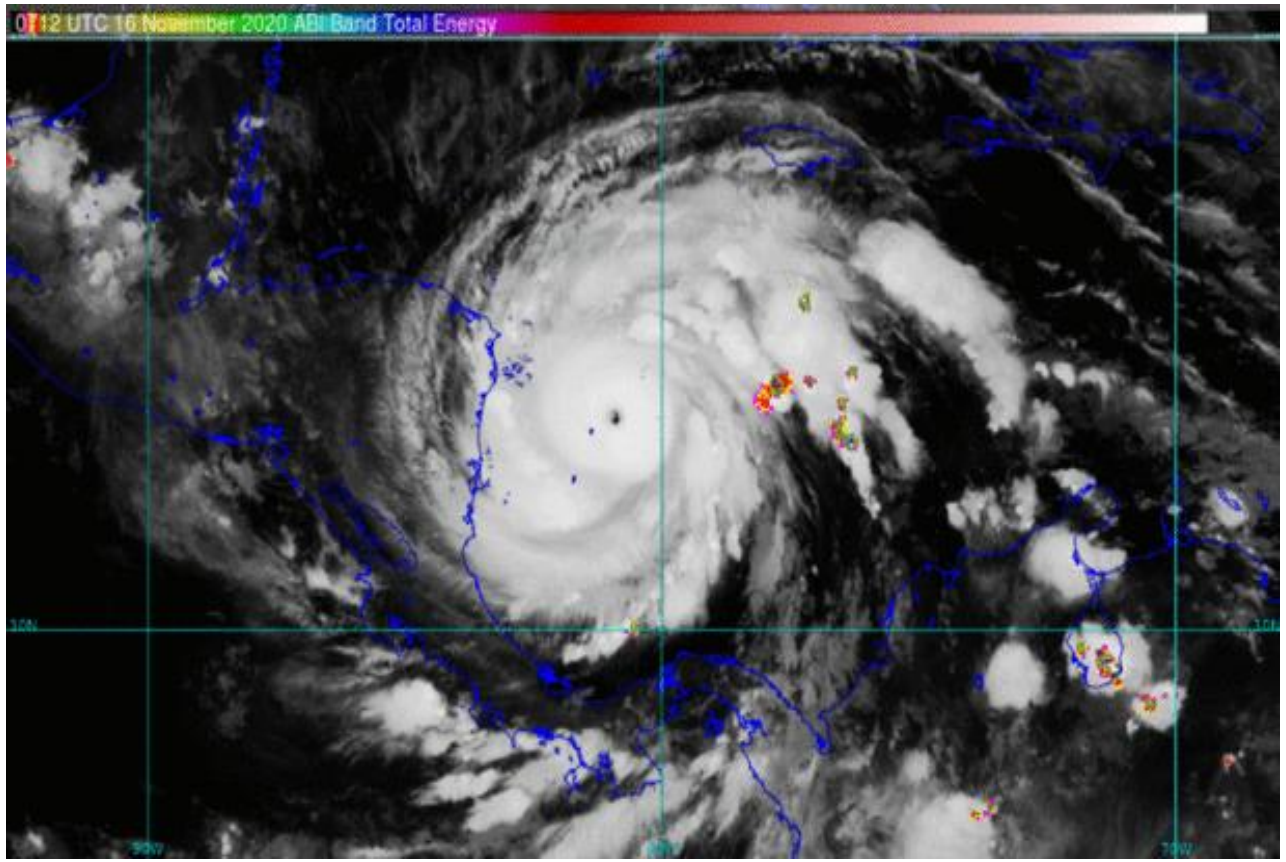
FIG. 1. Combined *G16* and *G17* flash densities during 1 Dec 2018–31 May 2020 with units of flash count per square kilometer per month. Flashes observed by either sensor are included in the overlapping region. Black lines indicate the nominal field of view boundaries for both instruments. For *G17*, the solid (dashed) line depicts coverage during boreal summer (winter).

Rudlosky and Virts, 2021

GLM and Tropical Cyclone Intensification Example

- Most lightning occurs in bands, rarely inside the eye.
  - More cold convection processes and/or more dry air entrainment.
- Lightning in the eye could mean two things:
  - Dry air entrainment (when there is a weakness or opening near the eye wall) and potential weakening
  - Intensification (when the eyewall is thick and solid)

Hurricane Iota, November 2020

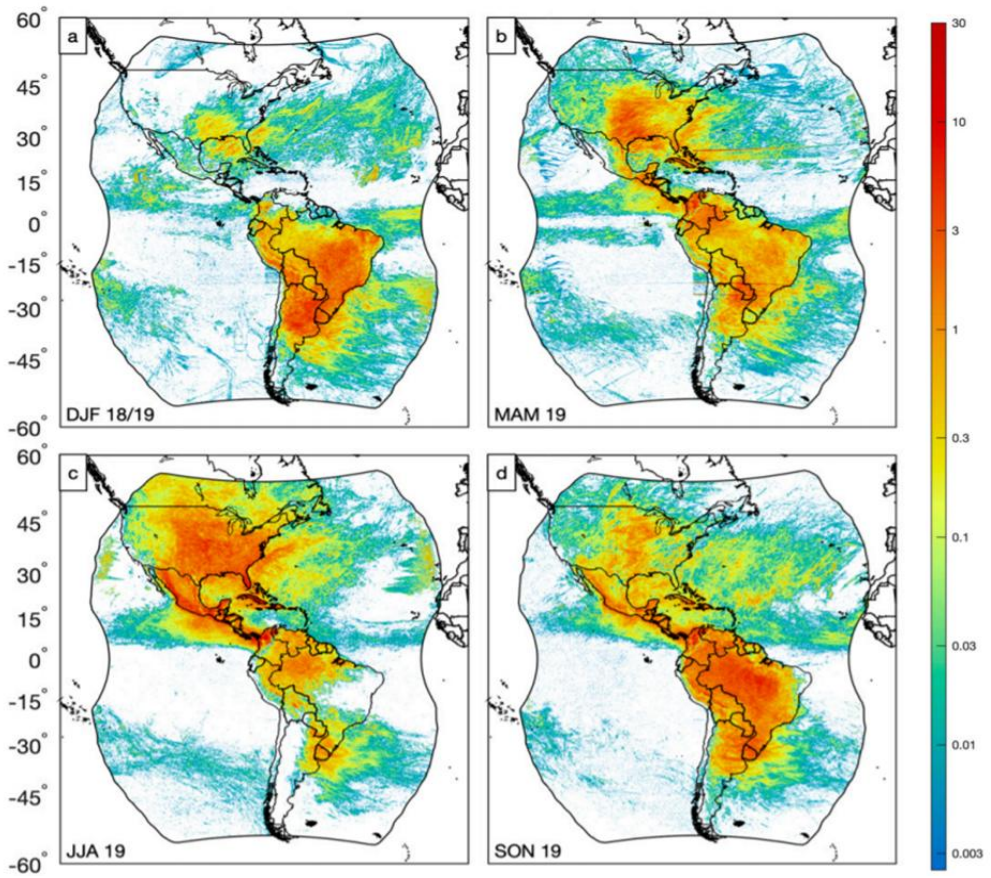


TOE over Band 10.3 um. Courtesy of Scott Lindstrom (CIMSS), prepared for the Colombia 2021 Satellite Applications Workshop.

Annual Cycle of Lightning in the Americas

Lightning as a Climate Analysis Tool

- Deep convection follows solar radiation.
- More lightning in continental regions (more diurnal heating/instabilityband dry air entrainment)
- Maximum in the ITCZ, regions prone to MCS, east coasts, mountains.
- Minima in west coasts.
- Peak at the beginning of the wet season (dry-to-wet transition).



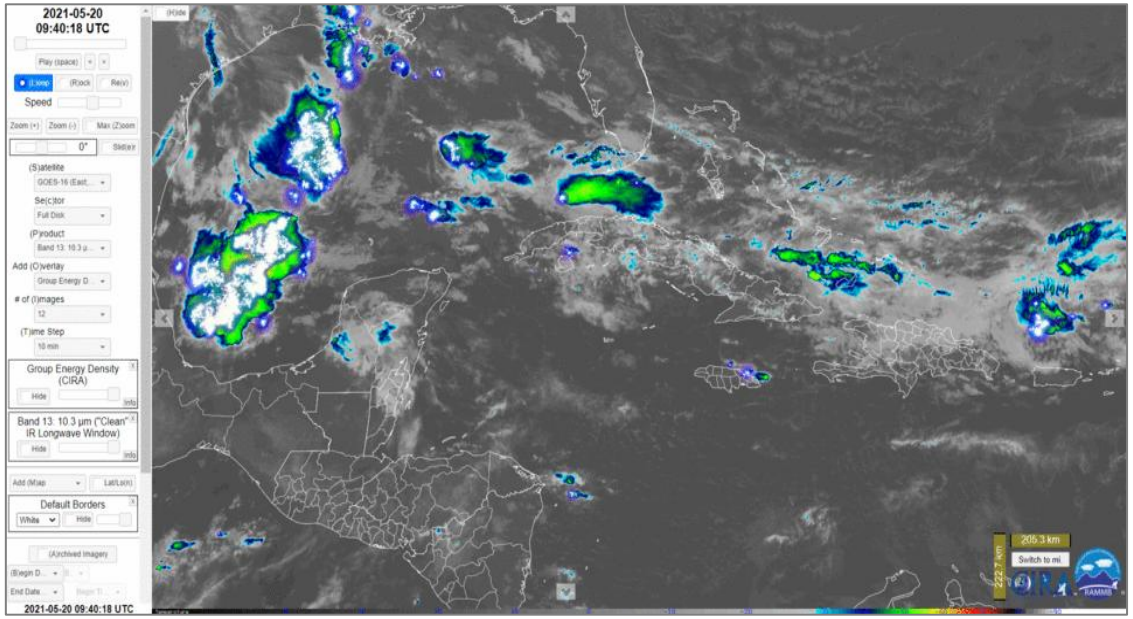
Flash Extent Densities (Rudlosky and Virts, 2021)

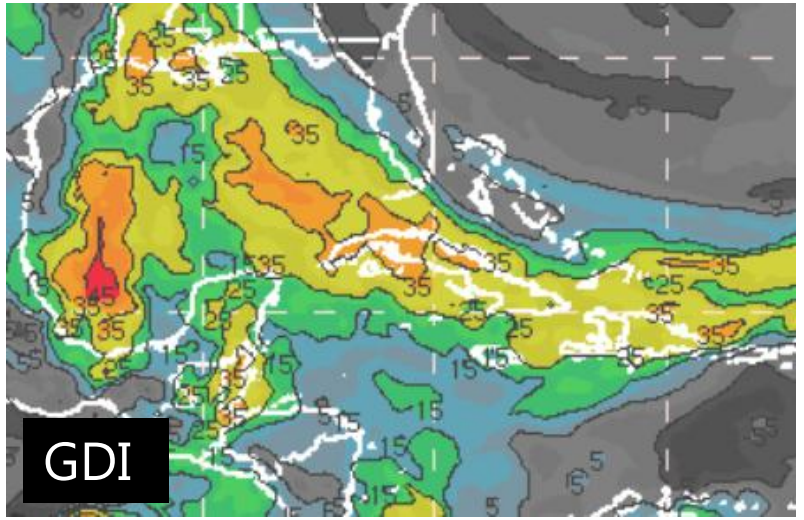
Forecast verification and analysis of intensity

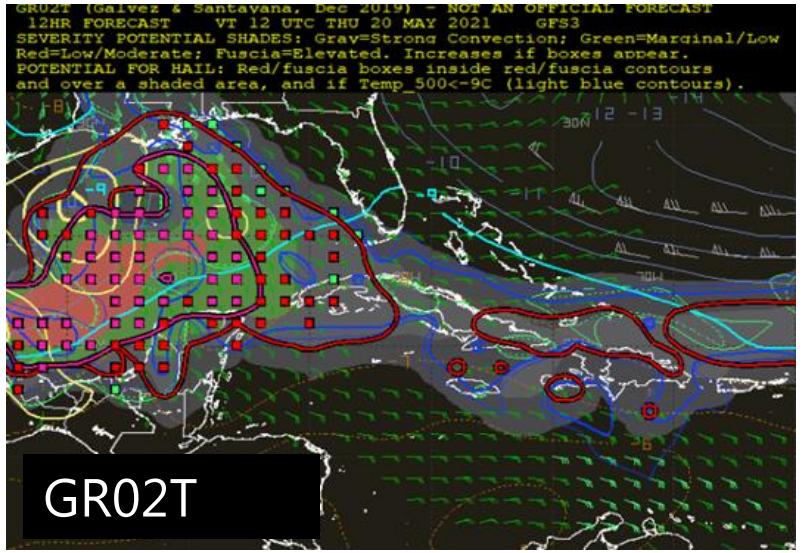
International Desks Forecast Algorithms:

https://www.wpc.ncep.noaa.gov/international/wng/
https://www.wpc.ncep.noaa.gov/international/gdi/

- Galvez-Davison Index (GDI) – Tropical Convection
- Severe Weather Algorithm (GR02T)







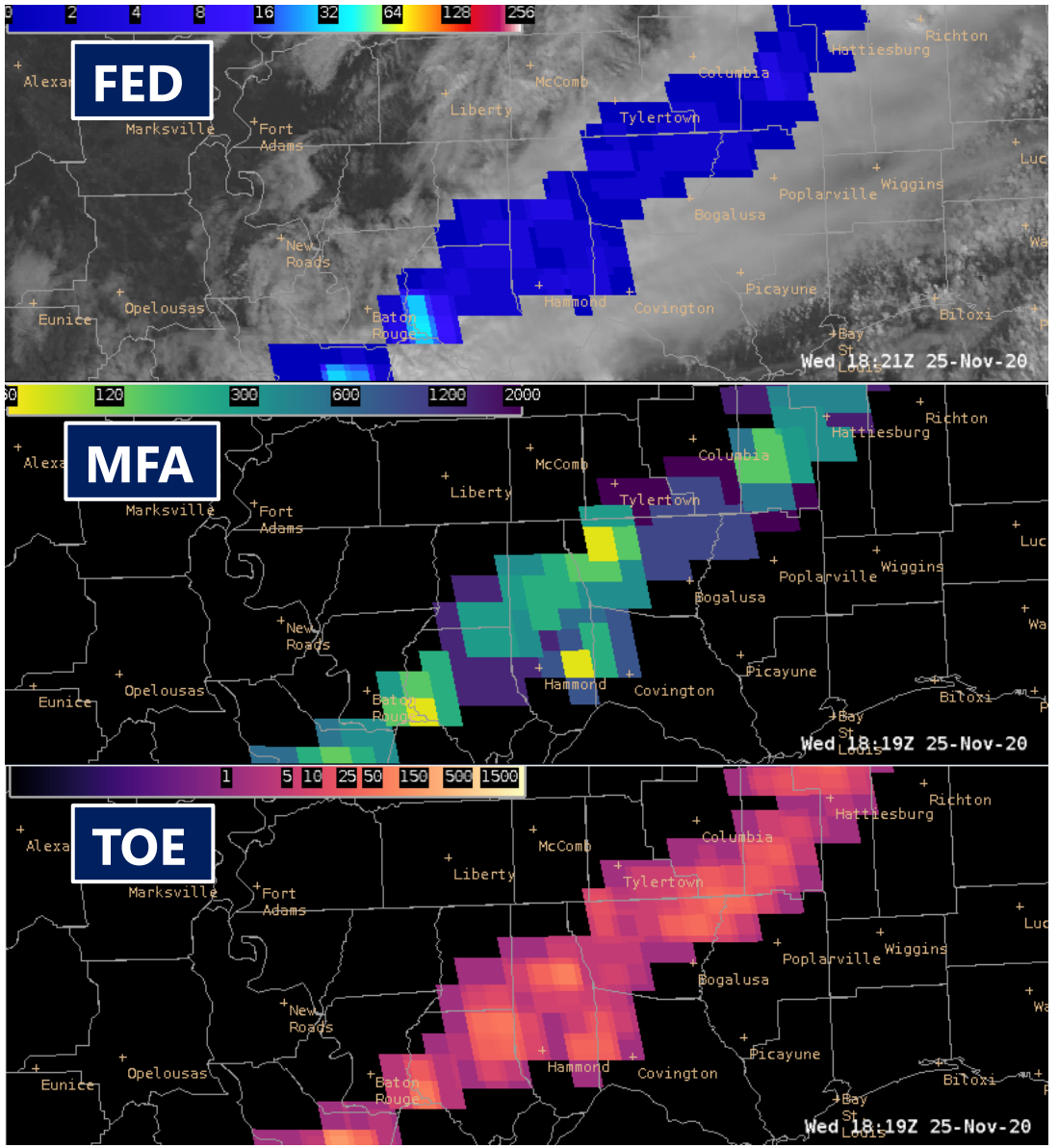
Current GLM Products

Three operational GLM products are produced each minute in real-time:

Flash Extent Density [FED] – Count of how many flashes are coincident with each GLM pixel (8 km by 8 km)

Minimum Flash Area [MFA] – Area (in km^2) of the smallest flash within any given pixel in which a flash was detected

Total Optical Energy [TOE] – Total amount of optical energy (in femtojoules) received by the instrument on the GOES satellites

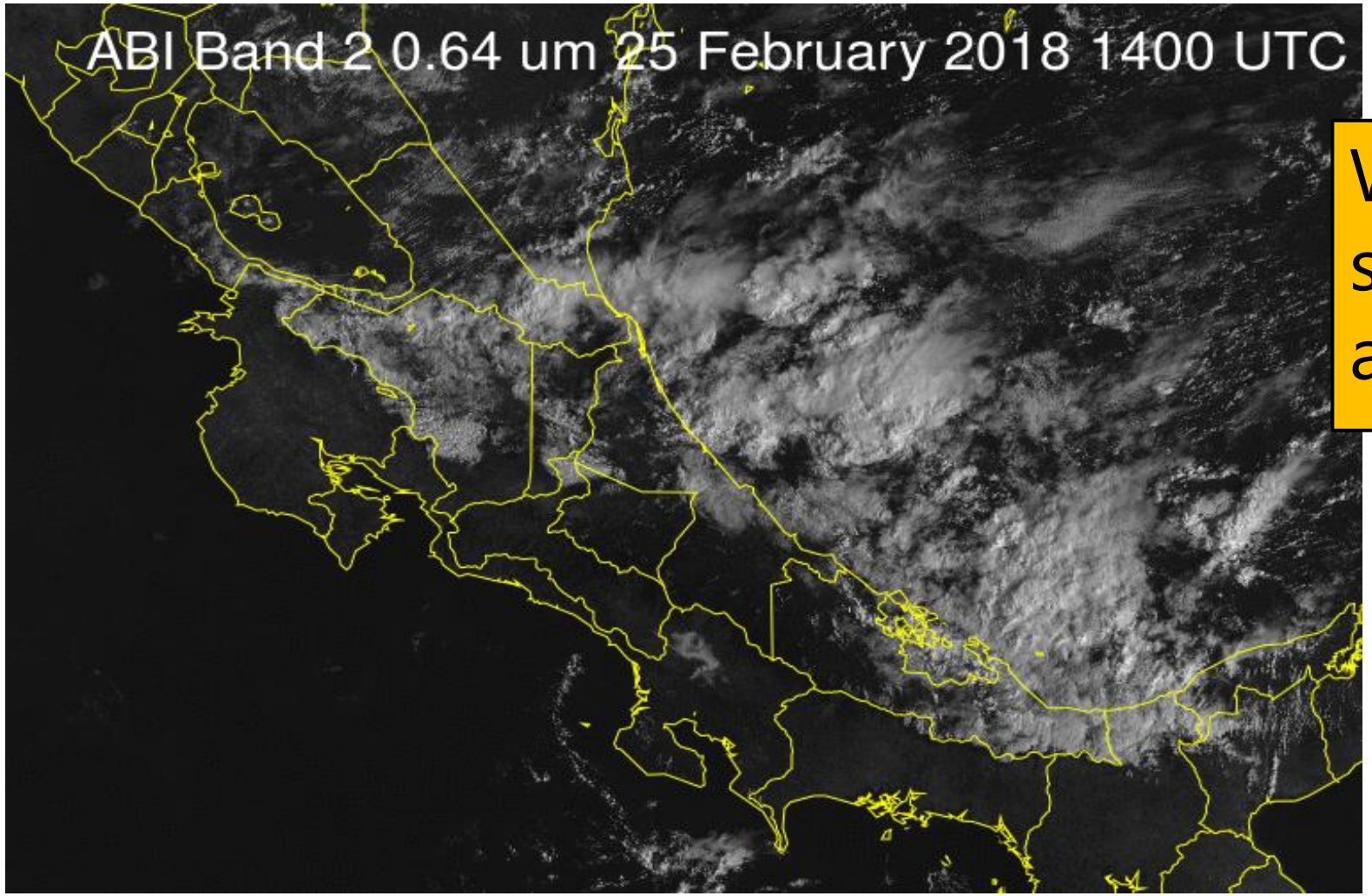


Costa Rica Hail Case Study - 25 February 2018

- In the analysis from the weather service of Costa Rica, there were several reports of hail falling in parts of the Central Valley as well as damage from strong winds.

Costa Rica Hail Case Study - 25 February 2018

- GOES-16 (GOES-East) Channel 02 (visible) 1400 to 2345 UTC

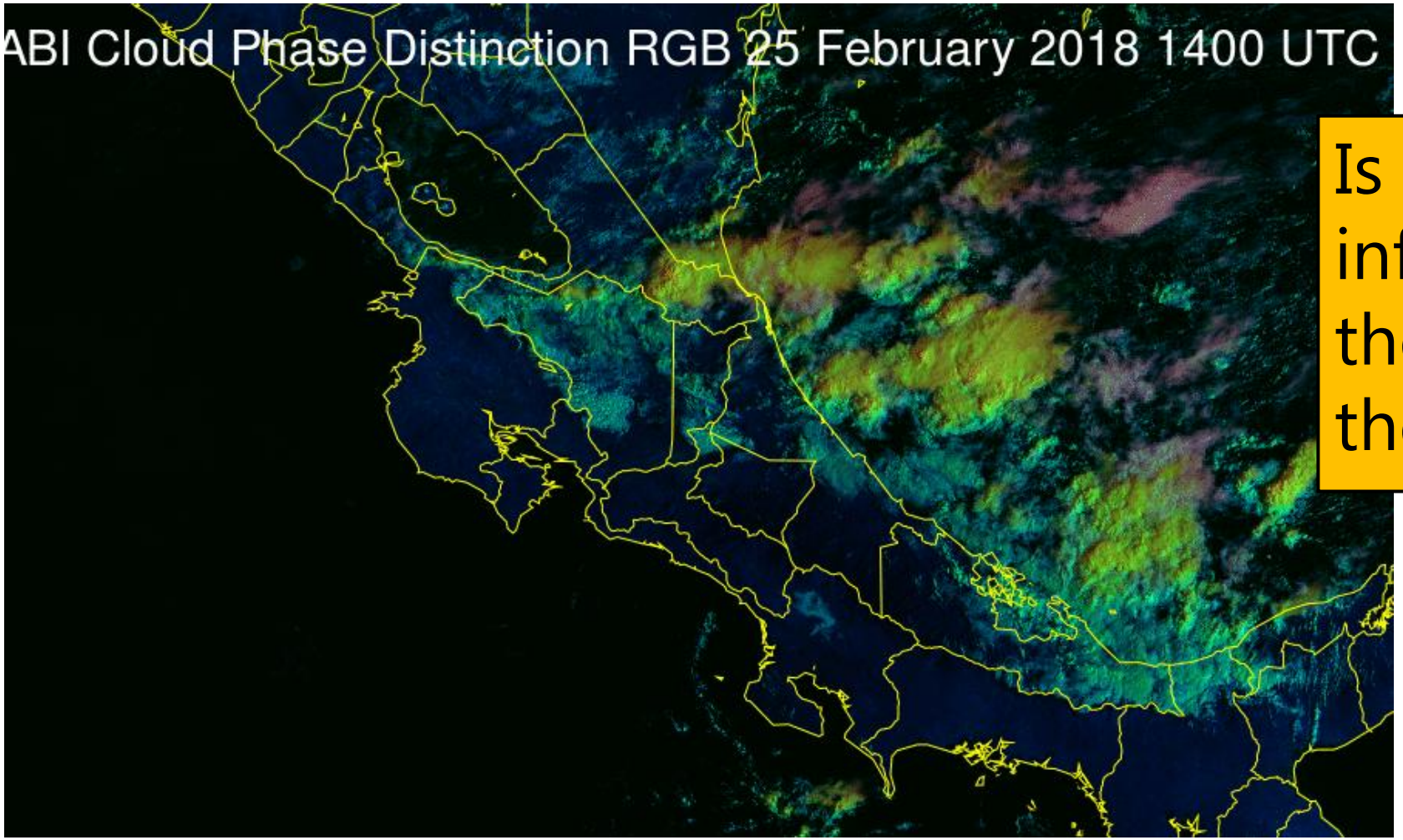


Which storms stick out to you as the strongest?

Prepared by Joseph Patton (UMD)

Costa Rica Hail Case Study - 25 February 2018

- Day Cloud Phase Distinction RGB: Yellows indicate deep convection

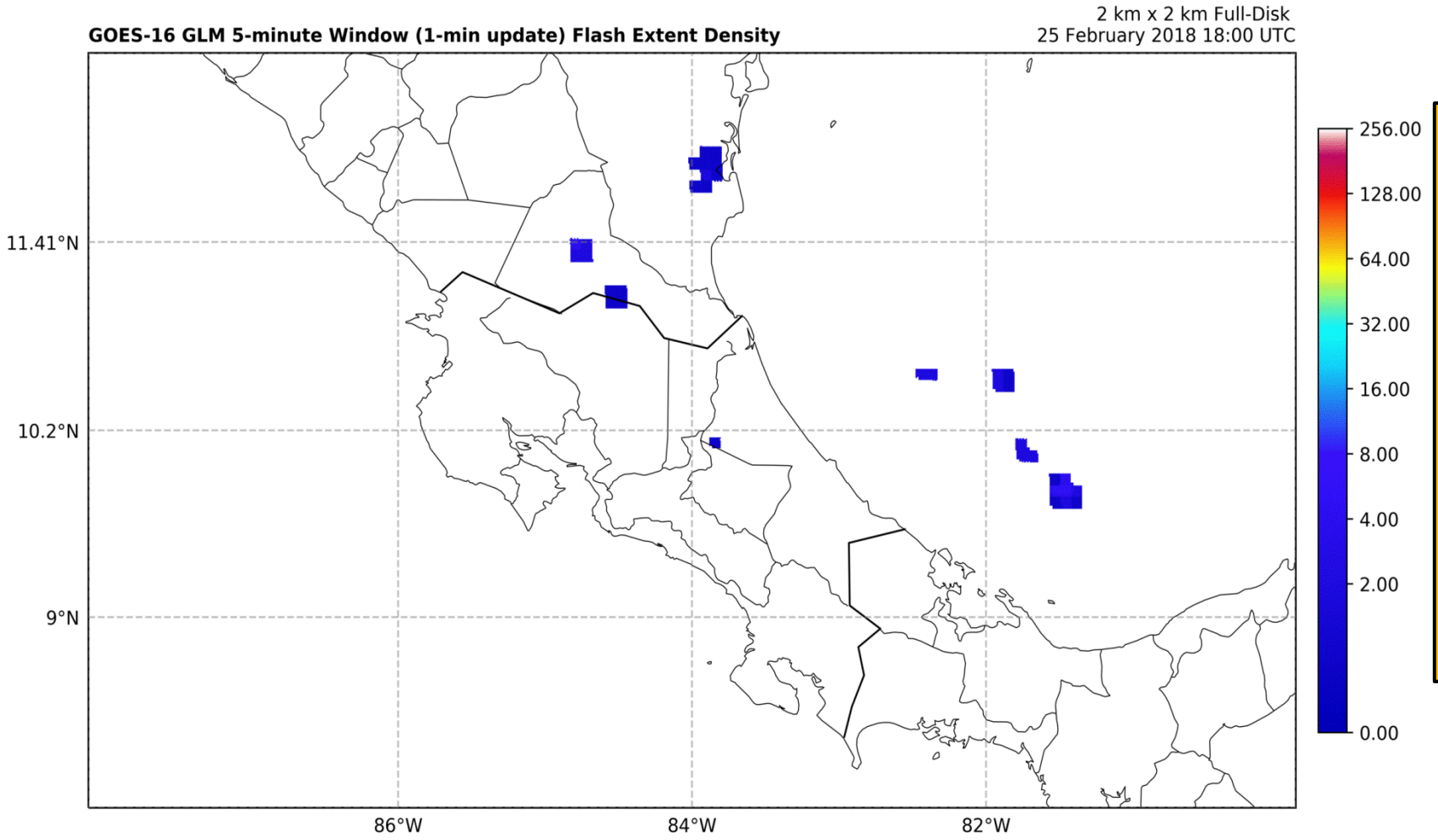


Is there more information on the strength of the convection?

Prepared by Joseph Patton (UMD)

Costa Rica Hail Case Study - 25 February 2018

- GOES-16 (GOES-East) Geostationary Lightning Mapper (GLM) **Flash Extent Density** (FED) 1800 to 0000 UTC

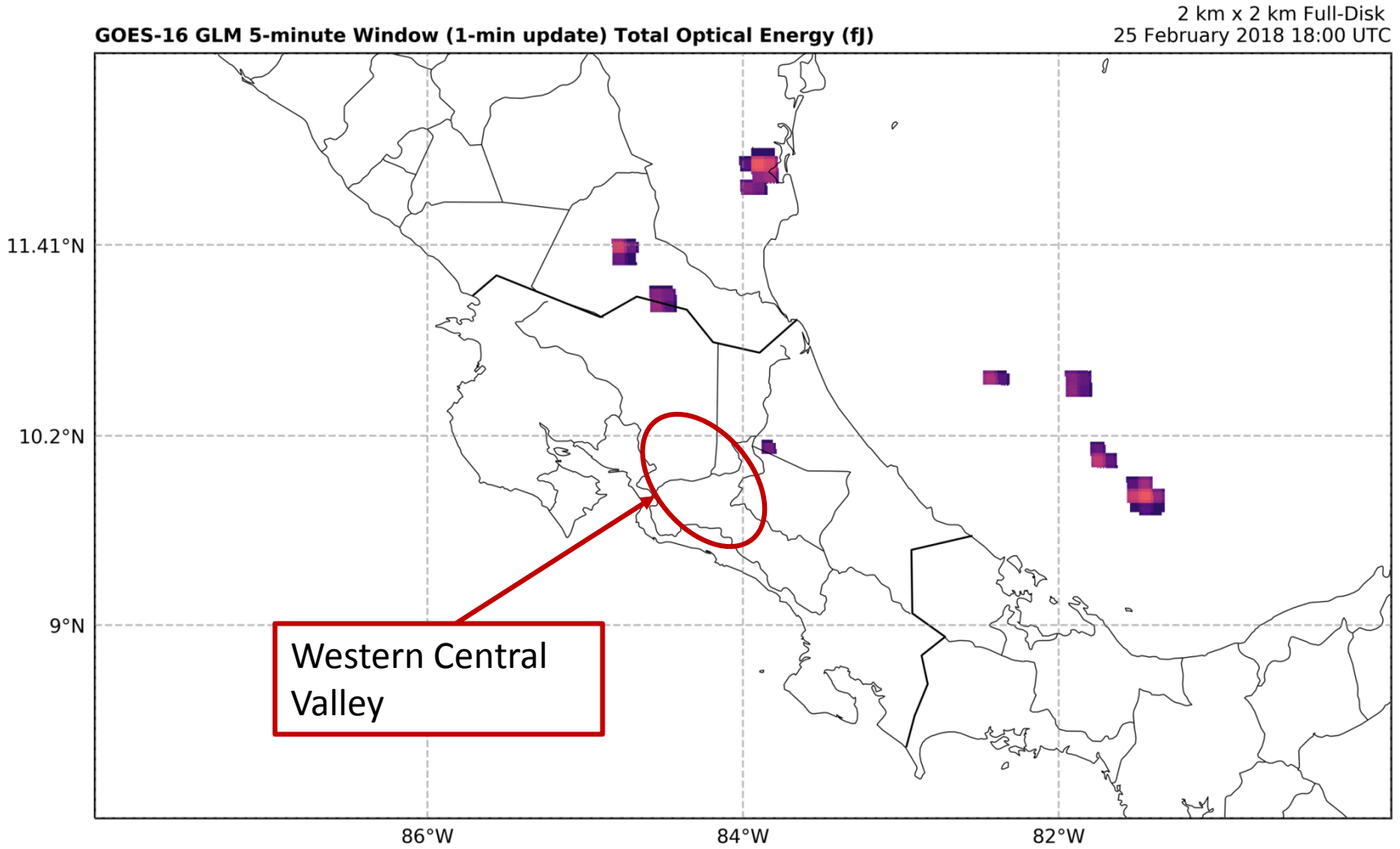


Question: Which storms within Costa Rica stick out to you as the strongest? Has your answer changed from the previous slide?

Prepared by Joseph Patton (UMD)

Costa Rica Hail Case Study - 25 February 2018

- GOES-16 (GOES-East) Geostationary Lightning Mapper (GLM) **Total Optical Energy** 1800 to 0000 UTC

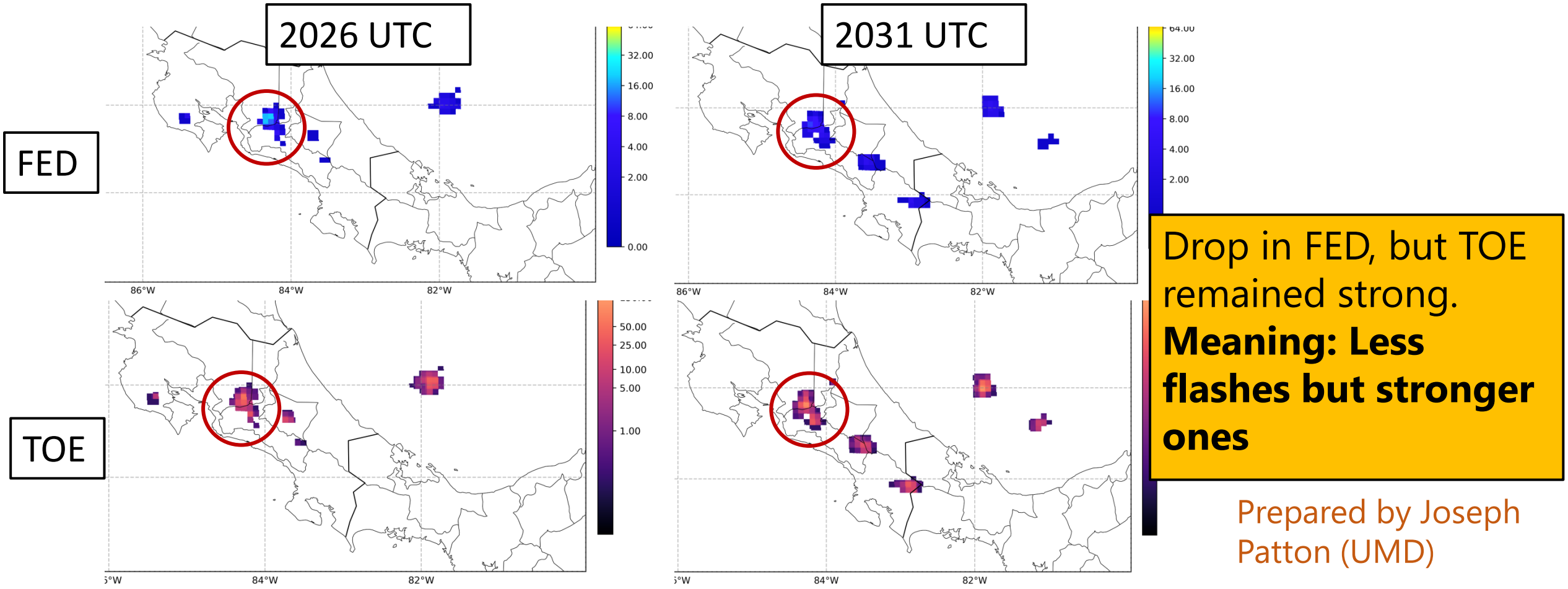


Storm in western Central Valley. Total Optical Energy around 20 to 21 UTC remains high when compared to Flash Extent Density?

Prepared by Joseph Patton (UMD)

Costa Rica Hail Case Study - 25 February 2018

- GOES-16 (GOES-East) Geostationary Lightning Mapper (GLM) **Flash Extent Density** (FED) and **Total Optical Energy** (TOE) at 2026 and 2031 UTC

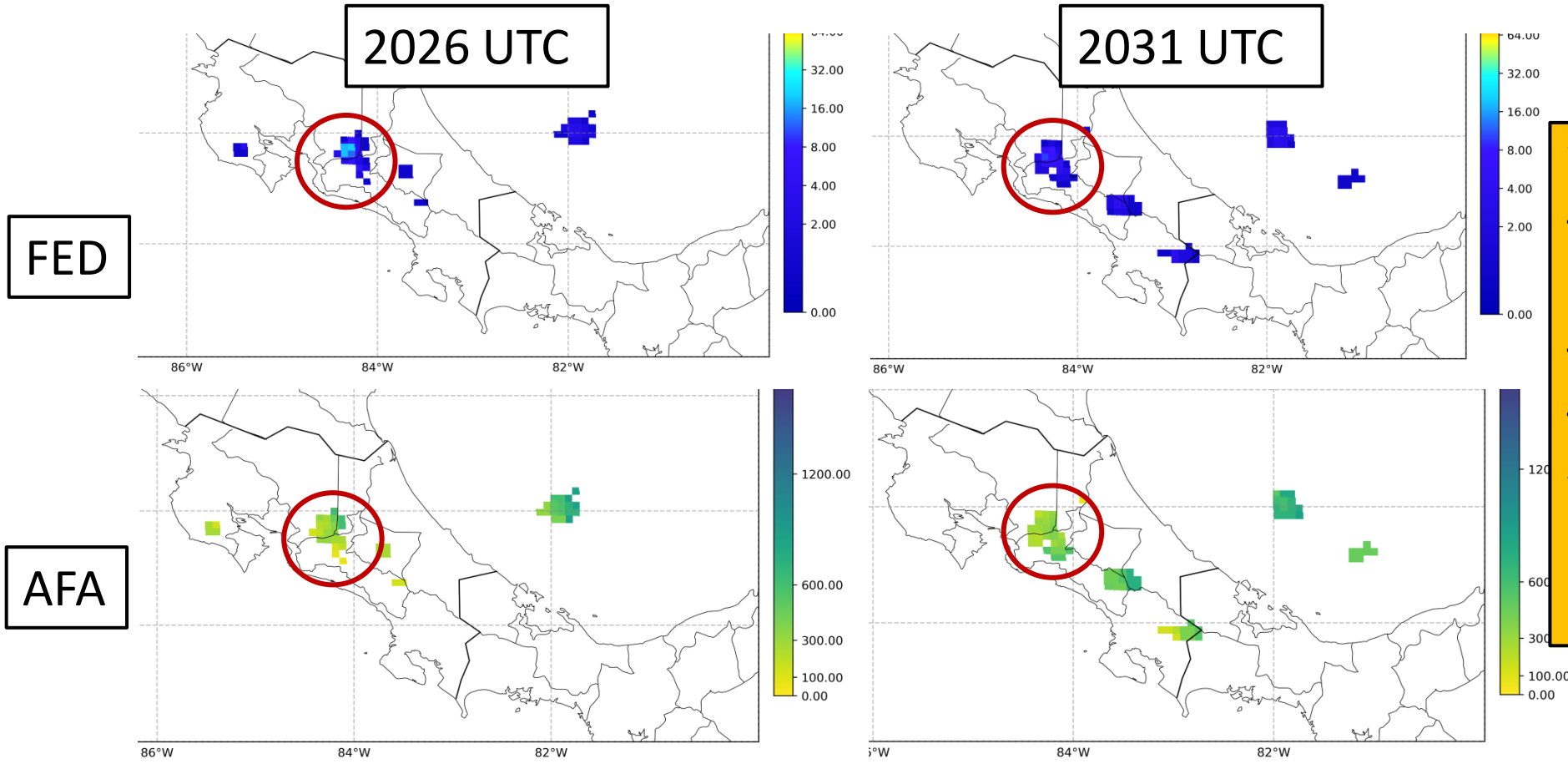


Drop in FED, but TOE remained strong.
Meaning: Less flashes but stronger ones

Prepared by Joseph Patton (UMD)

Costa Rica Hail Case Study - 25 February 2018

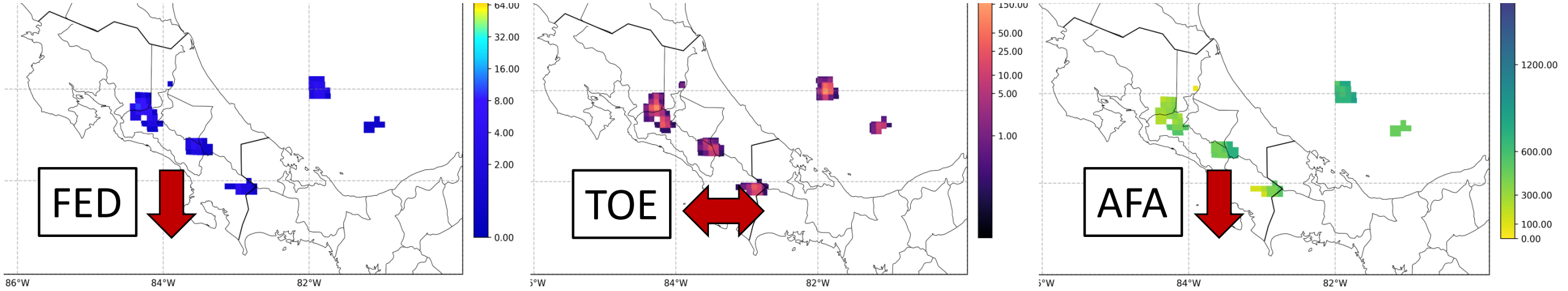
- GOES-16 (GOES-East) Geostationary Lightning Mapper (GLM) **Flash Extent Density** (FED) and **Average Flash Area** (AFA) at 2026 and 2031 UTC



While FED dropped for the storm, AFA was also dropping (green turning to yellow in the core of the storm). Flashes were getting smaller.

Putting All the GLM Products Together

- Drops in Flash Extent Density (FED) and Average Flash Area (AFA) suggest that the flashes were getting smaller and fewer in number.
- However, the Total Optical Energy (TOE) remained the same, if not stronger: increase in strength and brightness of the flashes
- With stronger, more concentrated lightning activity going on, this may be an indication of a **strengthening updraft** which could result in severe weather, such as hail and strong winds.



Thank You!