Australian VLab Centre of Excellence Regional Focus Group meeting, 02UTC 9th July 2023

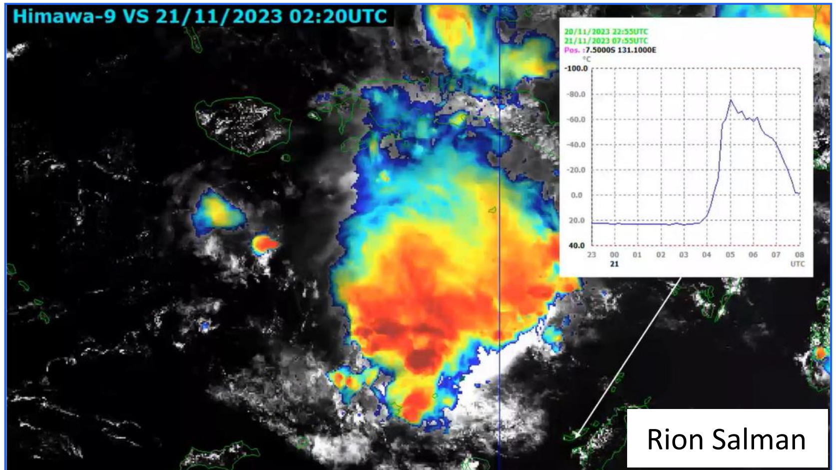
Contents

- **Utilization of Meteorological Satellite Data in Cloud Analysis** (presented by Mr Shiro Omori, Senior Coordinator for Satellite Data Quality, Meteorological Satellite Center, Japan Meteorological Agency (JMA))

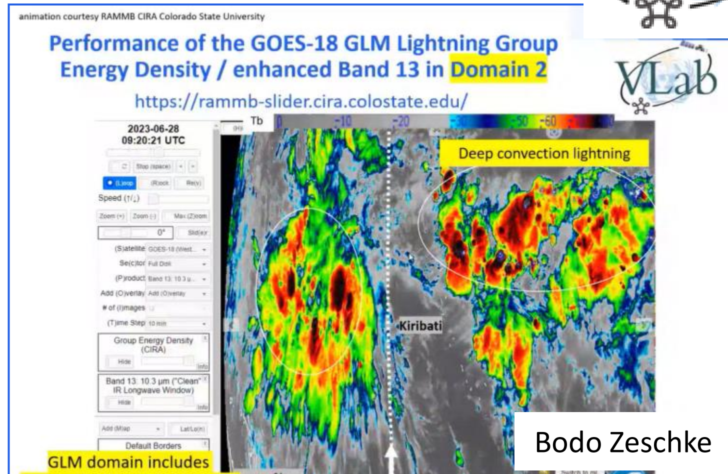
- **Verification and Case Studies of JMA's Rapidly Developing Cumulus Area (RDCA) Product** (presented by Mr Hiroshi Suzue, Scientific Officer, Office of Meteorological Analysis and Application Development, Administration Division, Atmosphere and Ocean Department, Japan Meteorological Agency)

- **Thunderstorms and associated Lightning over Maritime Areas with a Pacific Ocean Case Study** (presented by Mr Bodo Zeschke, Australian Bureau of Meteorology Training Centre)

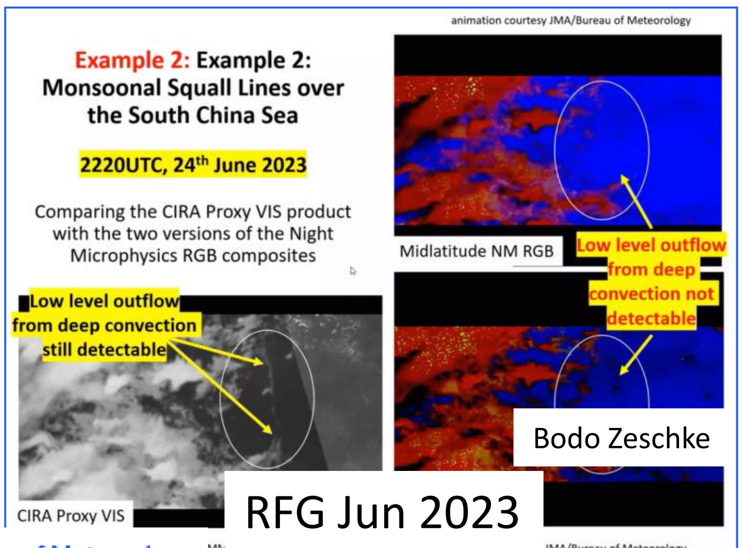
Past VLab case studies dealing with thunderstorms over maritime regions.



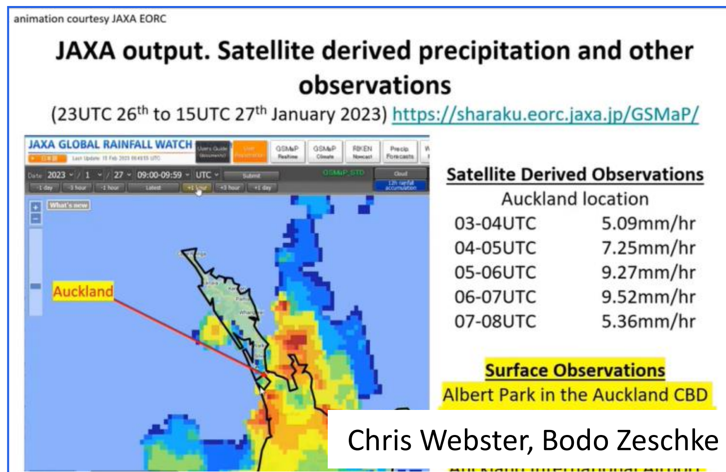
MCS over Banda Sea, RFG Dec 2023



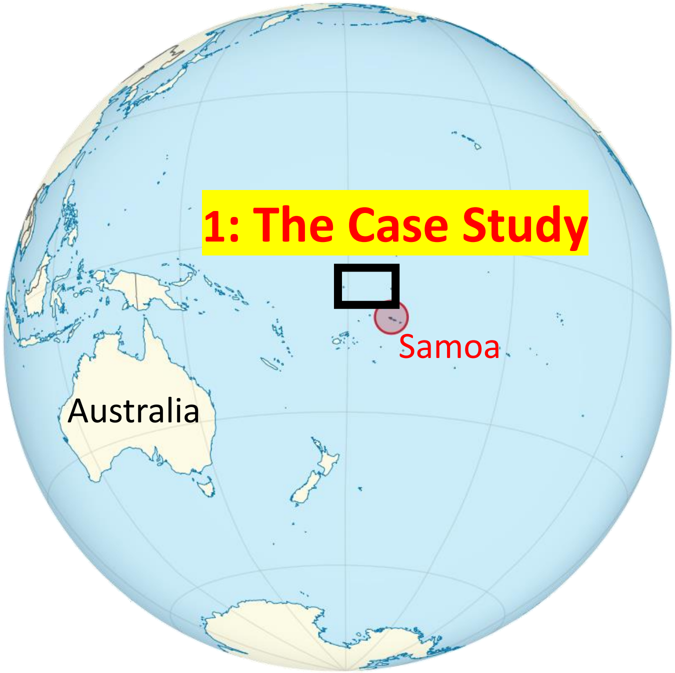
Pacific storms RFG Aug 2023



RFG Jun 2023



Auckland flooding RFG Feb 2023



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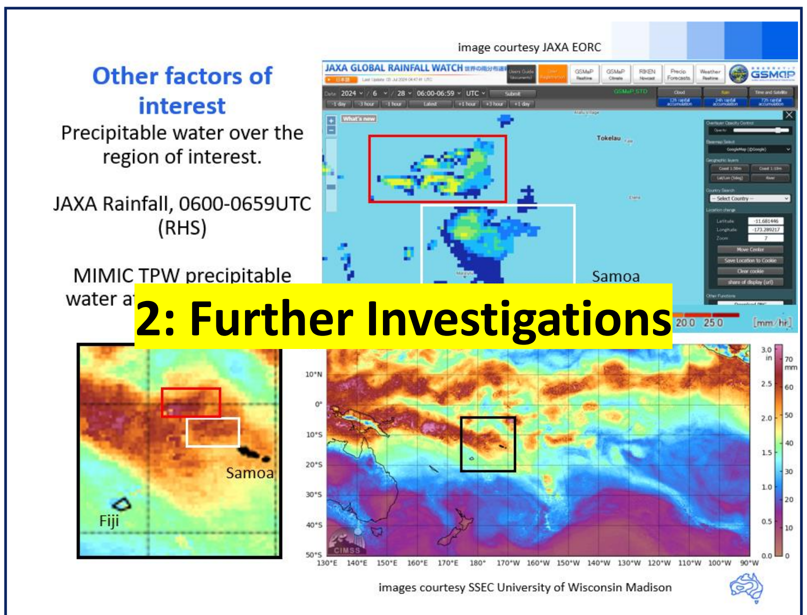
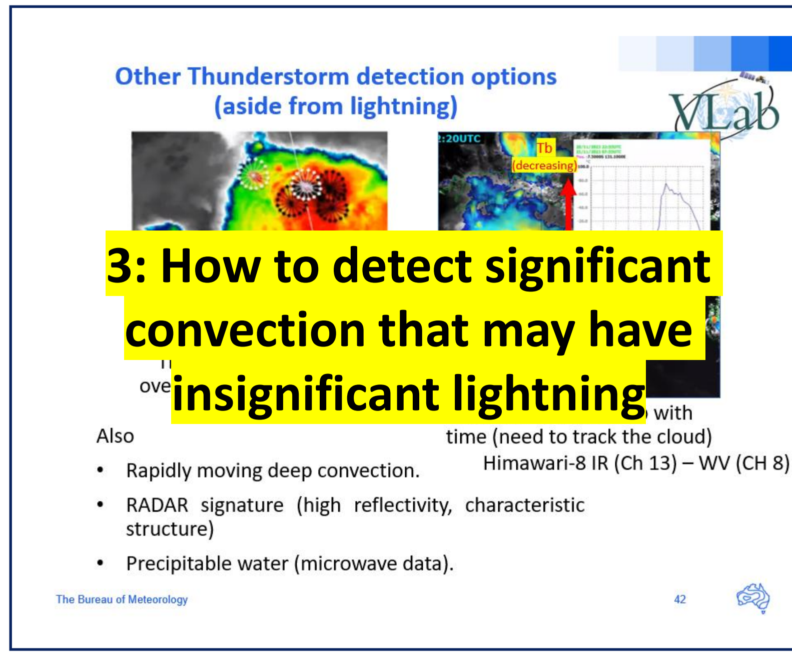
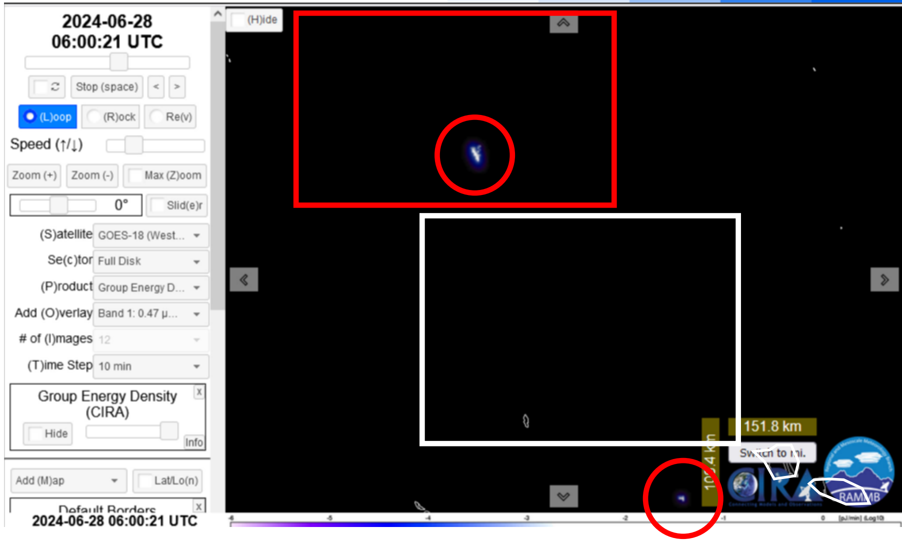




Development of convection northwest of Samoa.

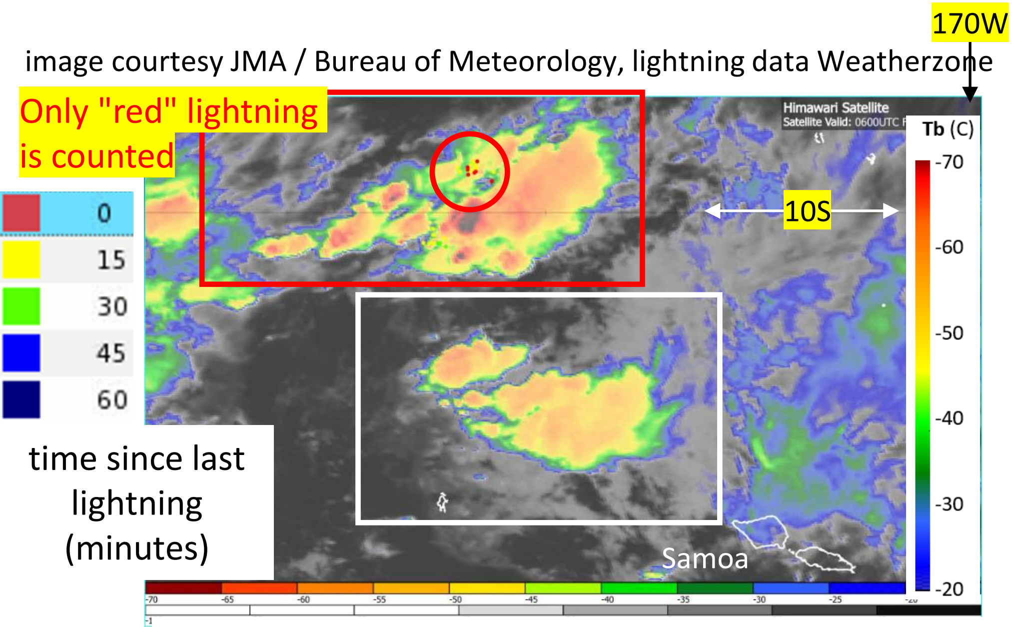
0600UTC 28 June 2024



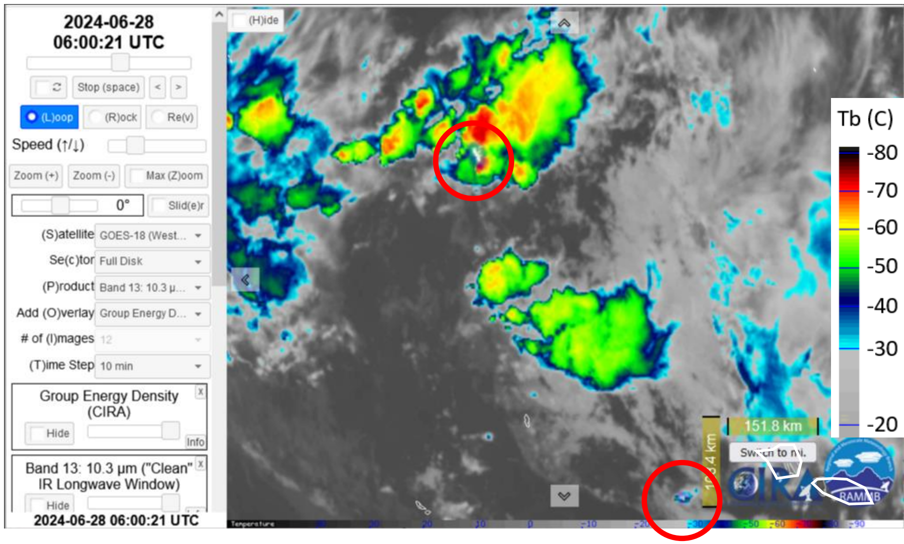
GOES-18 Group Energy Density

images courtesy RAMMB/CIRA

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



Himawari-9 Band 13 and lightning



GOES-18 Band 13 and Group Energy Density

Products used in this case study (1)

Weatherzone lightning

(below notes taken from the Science to Services talk "Operational Utilisation of High Resolution and Global Lightning Detection Technology" by Martin Palmer from Weatherzone, October 2019)

- Weatherzone deployed full network in 2014.
- Weatherzone provides global dataset and high-resolution dataset for Australia. Global dataset has embedded within it the high resolution data.
- Weatherzone total lightning network in Australia is able to detect total lightning (cloud to cloud, cloud to ground).
- Fiji is within the Global Dataset (combination of World Wide Lightning Location Network (WWLLN) and Earth Networks Total Lightning Network (ENTLN) sensors). Detection efficiency 40-50% over the mid-Pacific, accuracy 5-10km)
- Delay between lightning occurring and registering into Weatherzone. Within 15 seconds.

Products used in this case study (2)

Group Energy Density (CIRA)

- Accumulation of GOES-18 Geostationary Lightning Mapper (GLM) Level-2 'Group' energy over ABI's scan duration (10-min for full-disk), inverse-distance weighted over a given area for each centroid point and normalized to have [picoJoules/min] [pJ/min] for all sectors.

GeoColour (CIRA)

- GeoColor imagery provides as close an approximation to daytime True Color imagery as is possible from GOES-16, and thus allows for intuitive interpretation of meteorological and surface-based features. At night, instead of being dark like in other visible bands, an IR-based multispectral product is provided that differentiates between low liquid water clouds and higher ice clouds. A static city lights database derived from the VIIRS Day Night Band is provided as the nighttime background for geo-referencing.

Group Energy Density and GeoColour RGB

https://www.star.nesdis.noaa.gov/goes/documents/GLM_Quick_Guides_May_2019.pdf
https://rammb.cira.colostate.edu/training/visit/quick_guides/QuickGuide_CIRA_Geocolor_20171019.pdf

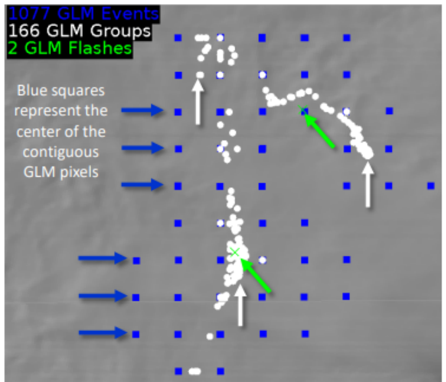
Geostationary Lightning Mapper: Definitions and Detection Methods

GOES-R · NOAA – NASA

Quick Guide

GLM Detection Methods

- The GLM detects changes in brightness every ~2 ms relative to a continuously updating background image
- Individual pixels illuminated above the background threshold during 2 ms frames are termed GLM events
- Filters then remove non-lightning events leaving only those most likely to be lightning
- Lightning Cluster Filter Algorithm combines events into groups and groups into flashes



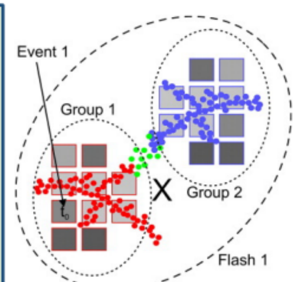
- Green X's depict the location of two GLM flashes
- GLM groups appear as white dots (which typically do not occur at the center of GLM pixels)
- GLM events are depicted as blue squares on the GLM fixed grid – there were >1000 GLM events during these 2 GLM flashes, only 50 pixels were illuminated, so most pixels were illuminated for multiple 2 ms frames

GLM Definitions

- Event: occurrence of a single pixel exceeding the detection threshold during one ~2 ms frame
- Group: 1+ simultaneous GLM events observed in adjacent (neighboring/diagonal) pixels
- Flash: 1 or more sequential groups separated by less than 330 ms and 16.5 km
- <u>GLM flash rates are most closely tied to updraft and storm evolution, and GLM event locations best depict the spatial extent</u>

Event, Group, and Flash Locations

- While GLM events are reported as the center points of GLM pixels, the group and flash locations represent radiance weighted centroids
- In this image the red, green, and blue dots represent a lightning mapping array depiction of a lightning flash; the red squares with grey shades indicate GLM events with lighter shades being brighter
- The GLM flash location considers the brightness of all events from both groups to locate the brightest part of the flash, or radiance weighted centroid, indicated by the black X in this image
- Note that the flash location may not always fall along the lightning channel, but will always fall within the flash footprint



Author: Dr. Scott Rudlosky
NOAA/NESDIS/STAR (CICS-MD)

Version 3 – May 9, 2019

NESDIS

GeoColor Product

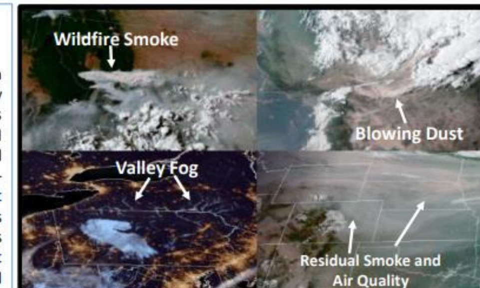
GOES-R · NOAA – NASA

Quick Guide

CIRA

Why is the GeoColor Product Important?

GeoColor imagery provides as close an approximation to daytime True Color imagery as is possible from GOES-16, and thus allows for intuitive interpretation of meteorological and surface-based features. At night, instead of being dark like in other visible bands, an IR-based multispectral product is provided that differentiates between low liquid water clouds and higher ice clouds. A static city lights database derived from the VIIRS Day Night Band is provided as the nighttime background for geo-referencing. The 5-min imagery is mapped into a 1.5 km Mercator grid over the Continental U.S. for AWIPS.



Four examples of operational applications of the GeoColor product. The valley fog example is nighttime, and the other three are daytime.

How is the GeoColor product created?

GeoColor uses a total of five channels from the GOES-R ABI. For the daytime imagery, channels 1, 2, and 3 (0.47 - blue, 0.64 - red, and 0.86 µm – near IR) are first corrected for Rayleigh scattering; this is a key step in order to maximize the contrast between clear sky and clouds, and it results in vibrant colors. Next, the green component is simulated using a lookup table that was built using data from Himawari-8 AHI, which does have a green channel at 0.51 µm. Finally, the red, green, and blue components are combined to create the pseudo-true color RGB. At night, the window IR channel 13 (10.3 µm) and the traditional fog product (10.3-3.9 µm) are used to identify both ice and liquid water clouds, and they are made partially transparent and placed atop a static city lights background. Note that power outages will not be reflected by the city lights since it's a static dataset.

Impact on Operations

<u>**Primary Applications**</u>

Daytime Aerosol Detection: Identify smoke, blowing dust, smog, and anything that has a unique color property

Nighttime cloud detection: Differentiate low liquid water clouds from higher ice clouds at night

Nighttime Geo-Location: City lights aid geo-referencing by helping determine whether clouds (such as fog) are affecting populated areas

Intuitive Interpretation: Since the colors of features in the daytime are what we intuitively expect them to be, the product requires little to no training, and has proven to be excellent for social media posts

Limitations

Shallow Water Colors: Since a lookup table is being used for the green component, sometimes shallow water colors may show up as noisy or incorrect

Thick vs. Thin clouds at night: The nighttime cloud layer is made partially transparent, and the amount of opacity is a function of the cloud top temperature. Sometimes optically thick clouds in the lower atmosphere may show up as being partially transparent (including precipitating convection).

Sunrise/Sunset: Near sunrise and sunset, the daytime and nighttime portions are blended, which may cause certain clouds (e.g., the blue low cloud enhancement) to briefly change colors or disappear.

Contributor: Dan Bikos, Steve Miller, Dan Lindsey CIRA/RAMMB, Ft. Collins, CO

CIRA

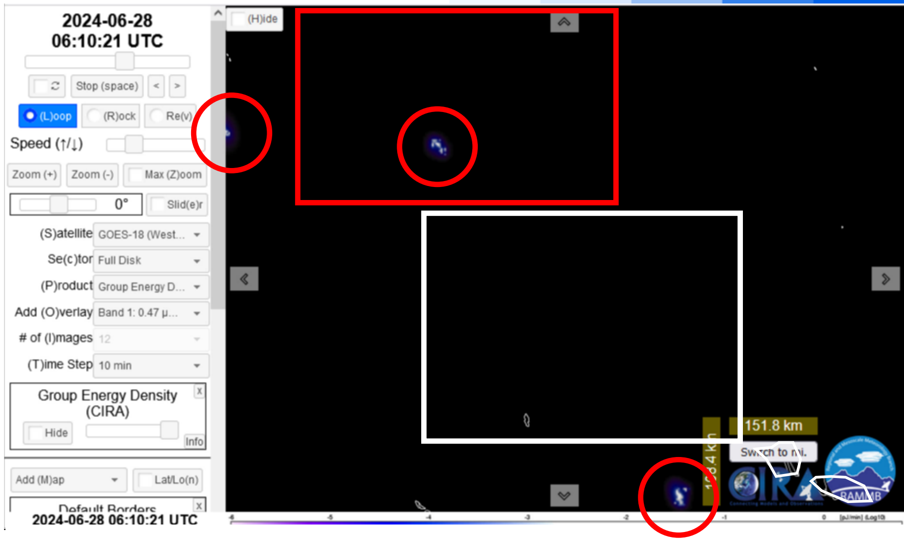
Products used in this case study (3)

<u>The NOAA/CIMSS ProbSevere LightningCast</u>

- ProbSevere LightningCast is an GOES Advanced Baseline Imager (ABI) -based machine-learning model.
- This model predicts where the Geostationary Lightning Mapper (on GOES-18) will observe lightning up to 60 minutes in the future.
- This is based on the evolution of ABI cloud imagery.
- Human eyes/brains already do this.
- The model attempts to mimic this capability objectively.
- Scott Lindstrom covered LightningCast during the June 2024 Regional Focus Group meeting.

Development of convection northwest of Samoa.

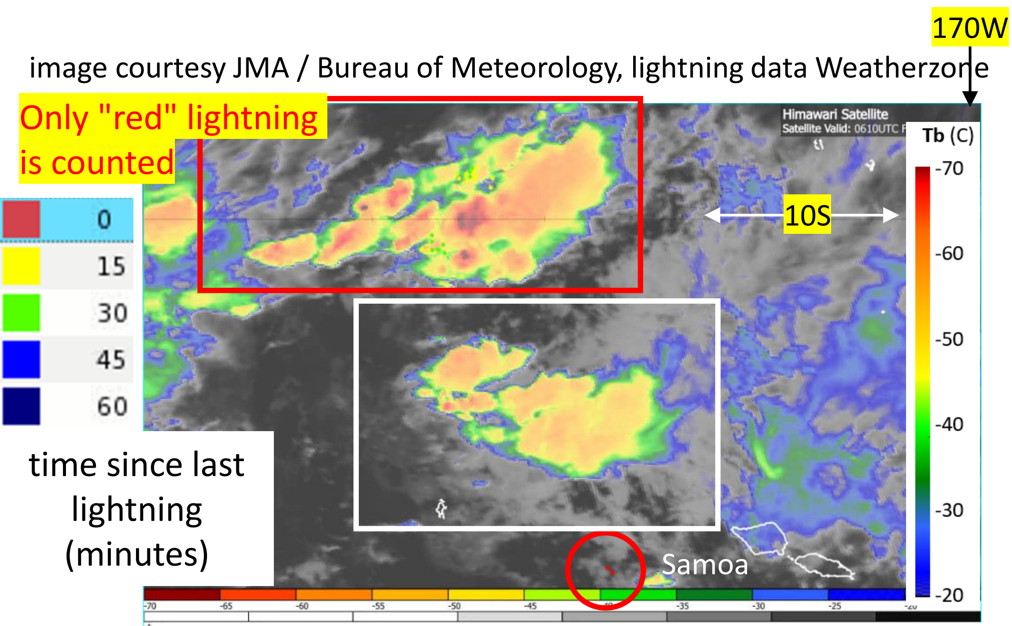
0610UTC 28 June 2024



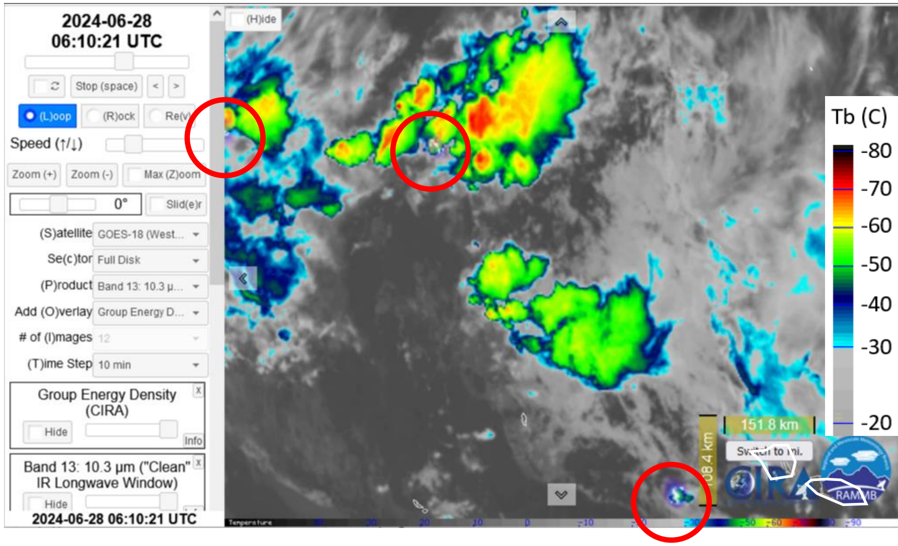
GOES-18 Group Energy Density

images courtesy RAMMB/CIRA

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



Himawari-9 Band 13 and lightning



GOES-18 Band 13 and Group Energy Density

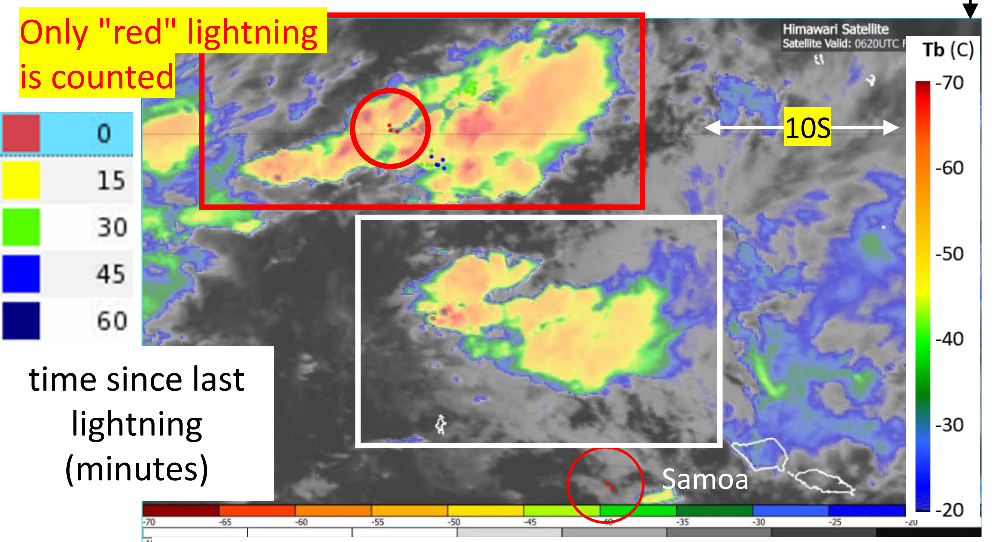
Development of convection northwest of Samoa.

0620UTC 28 June 2024

GOES-18 Group Energy Density

images courtesy RAMMB/CIRA

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



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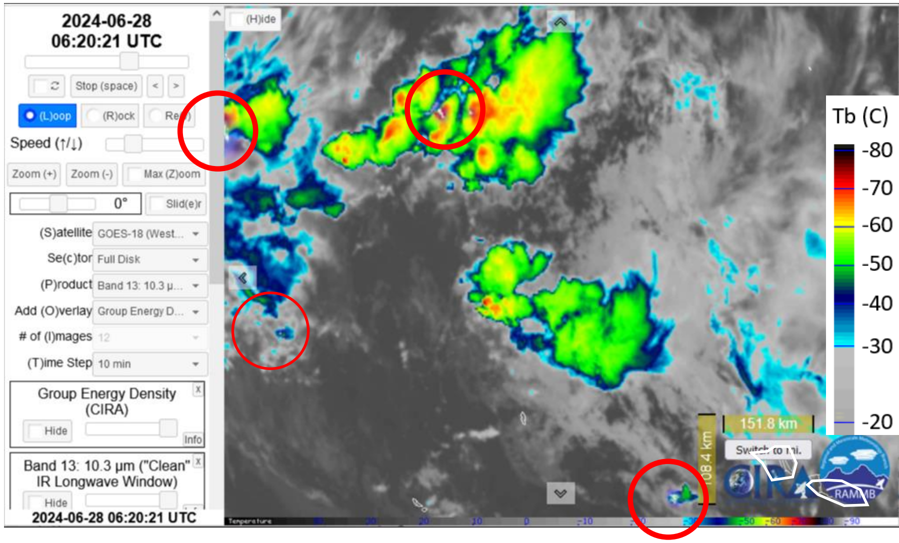
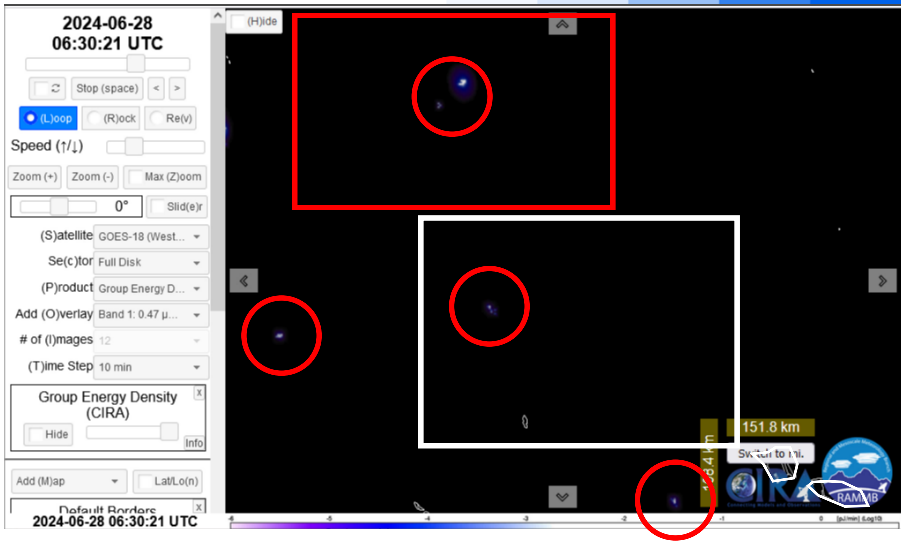


GOES-18 Band 13 and Group Energy Density

Development of convection northwest of Samoa.

0630UTC 28 June 2024



GOES-18 Group Energy Density

images courtesy RAMMB/CIRA

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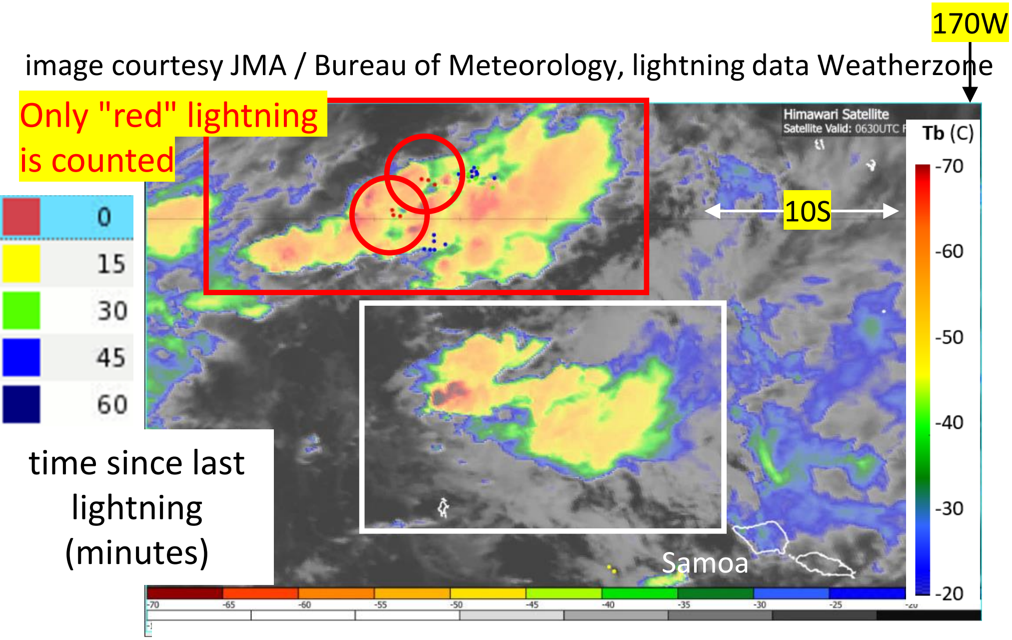

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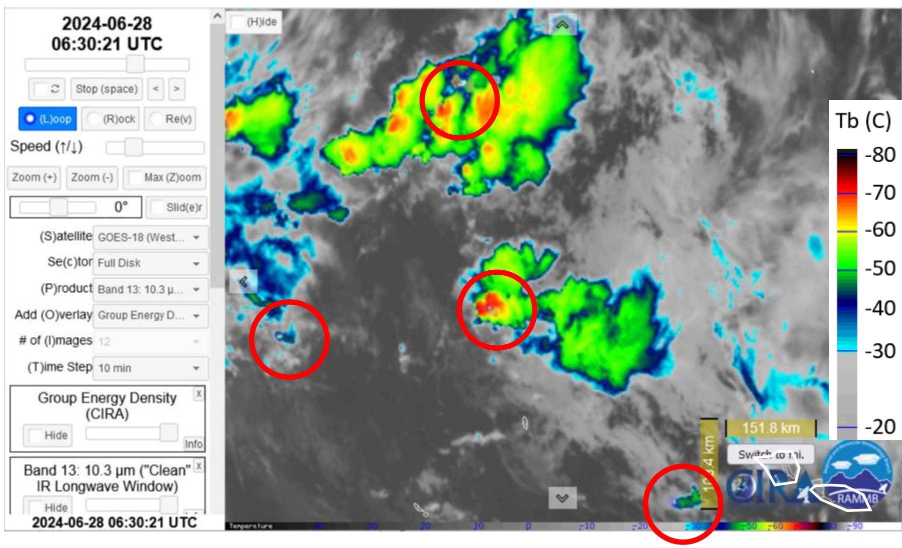


GOES-18 Band 13 and Group Energy Density

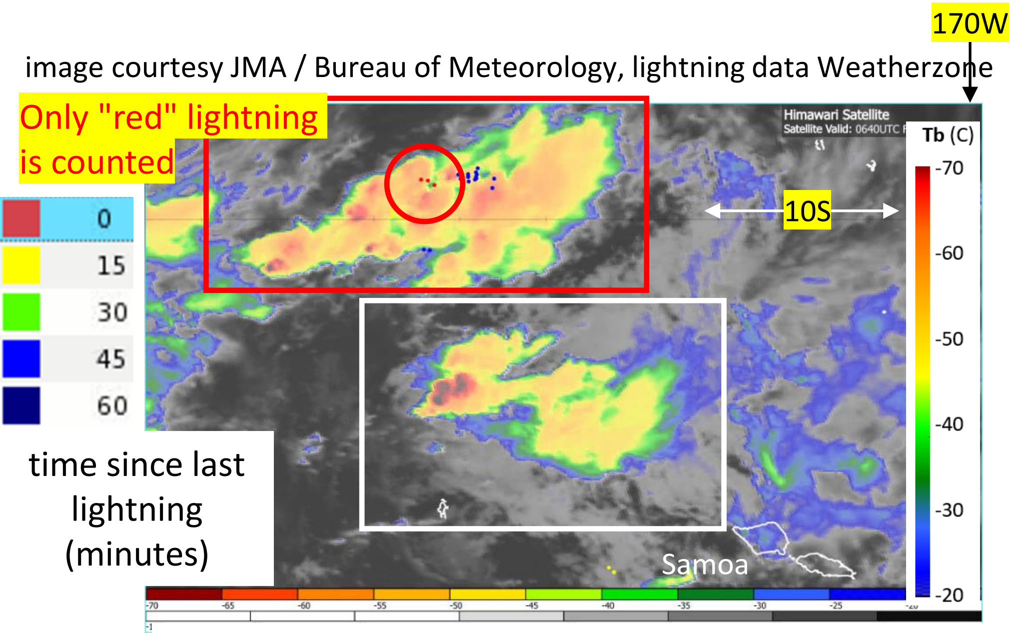
Development of convection northwest of Samoa.

0640UTC 28 June 2024

GOES-18 Group Energy Density

images courtesy RAMMB/CIRA

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



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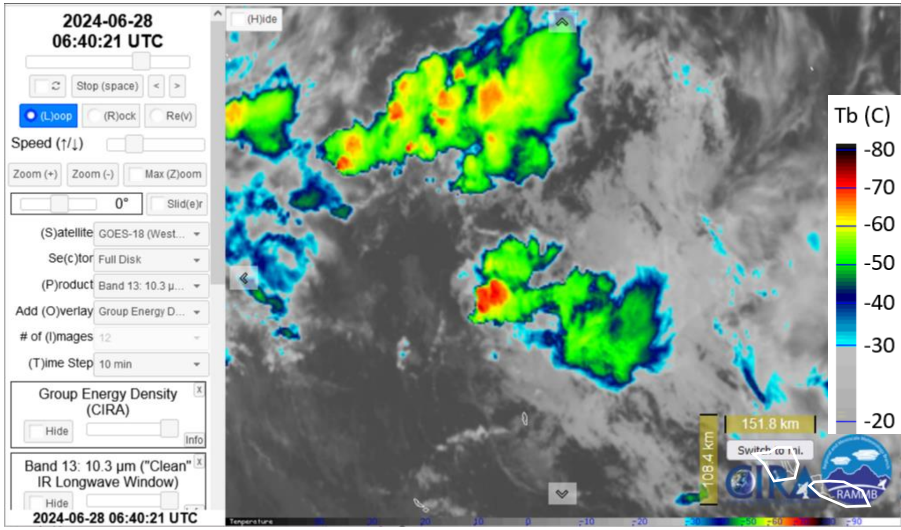
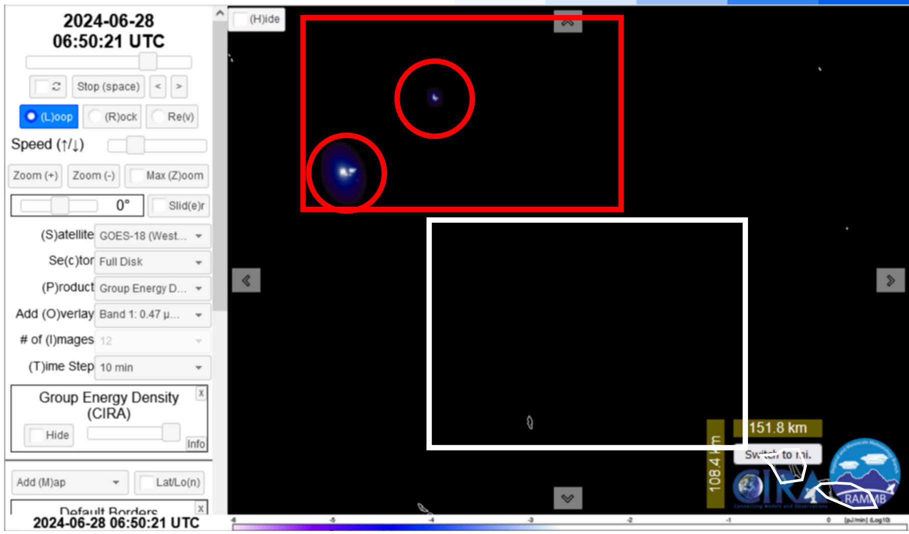


GOES-18 Band 13 and Group Energy Density

Development of convection northwest of Samoa.

0650UTC 28 June 2024

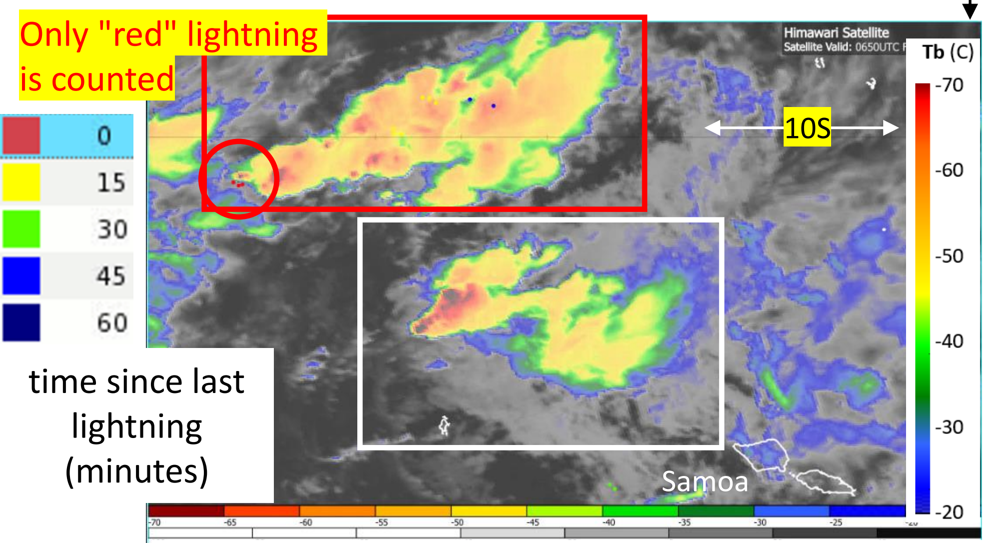


GOES-18 Group Energy Density

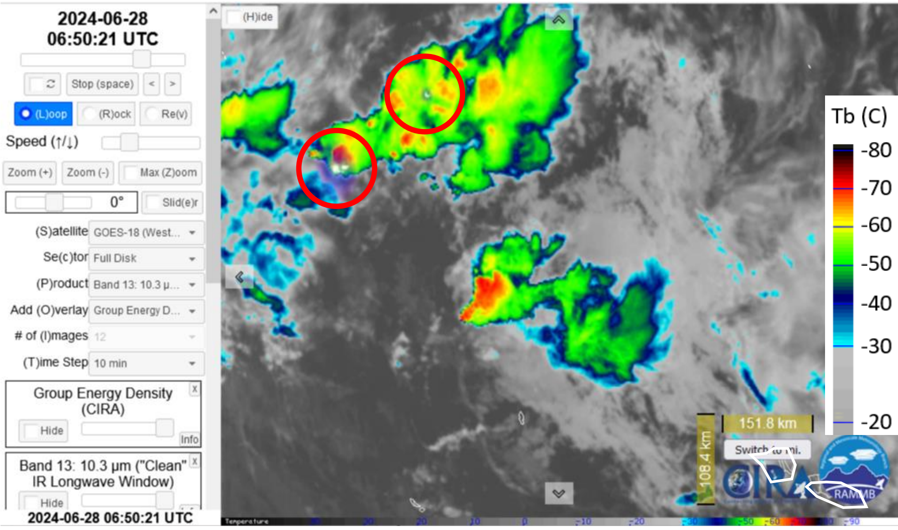
images courtesy RAMMB/CIRA

170W

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



Himawari-9 Band 13 and lightning



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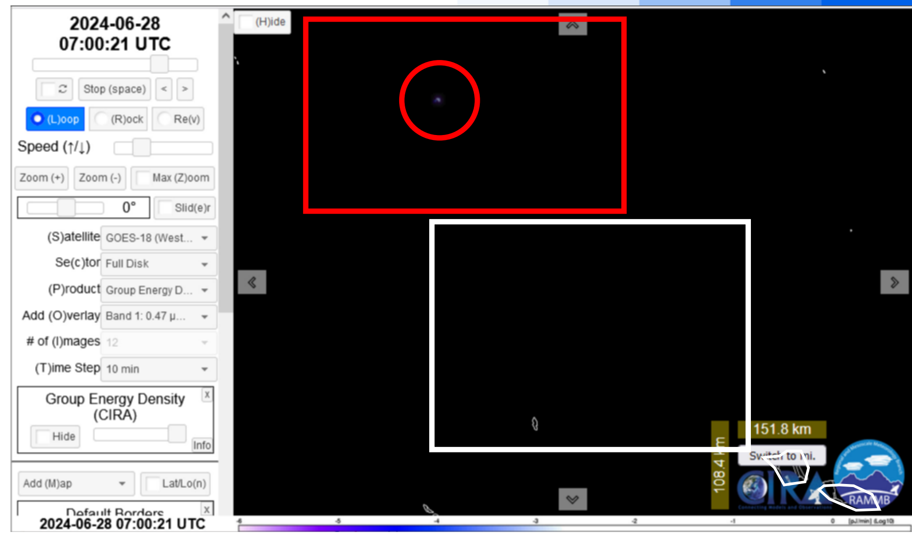
Development of convection northwest of Samoa.

0700UTC 28 June 2024



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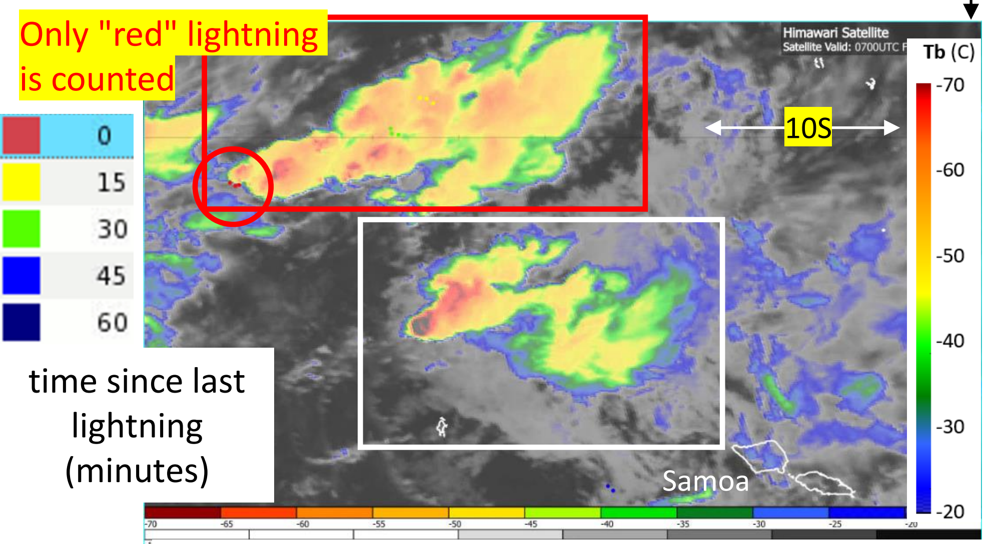

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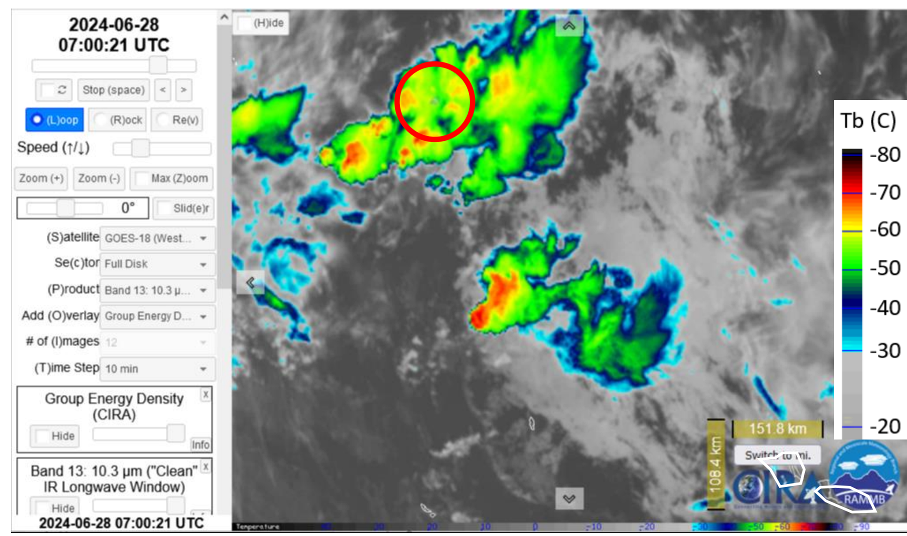

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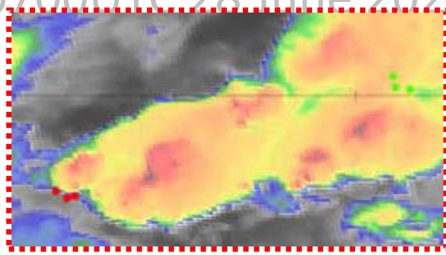
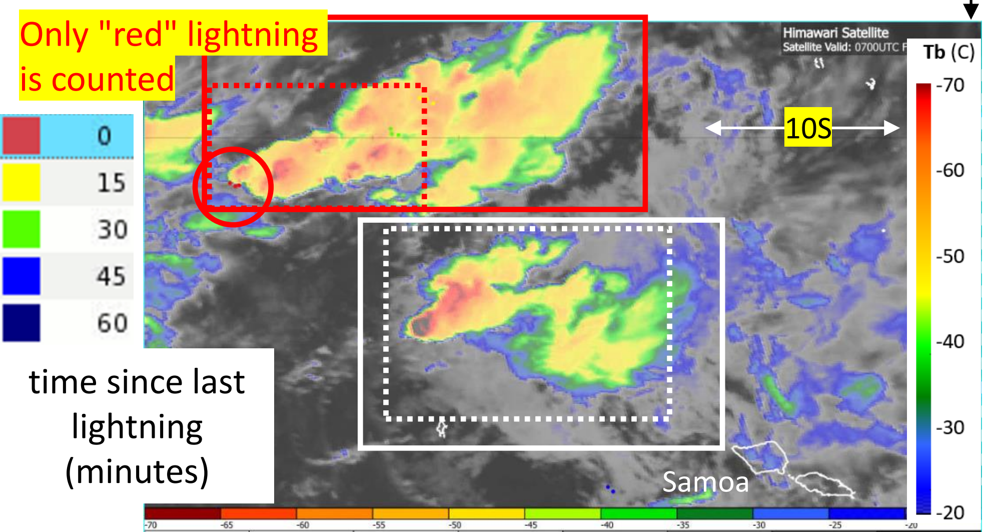


image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



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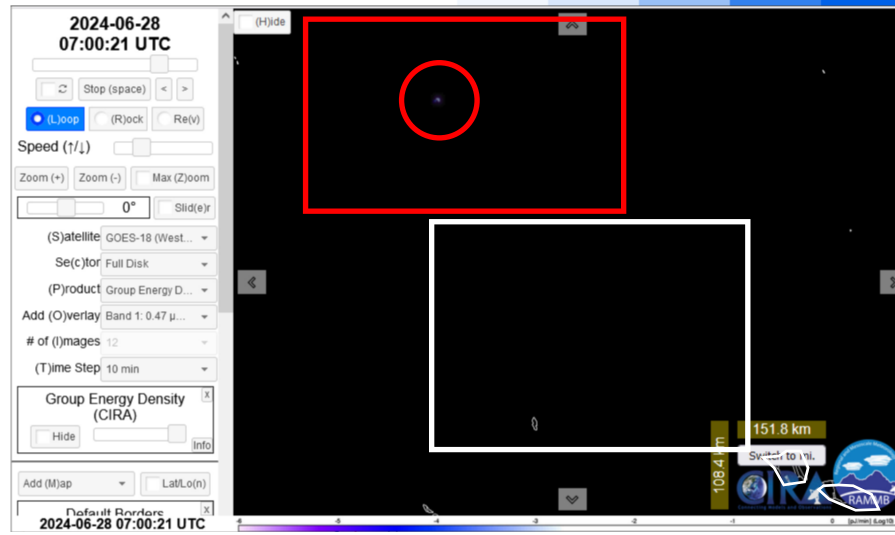

GOES-18 Group Energy Density

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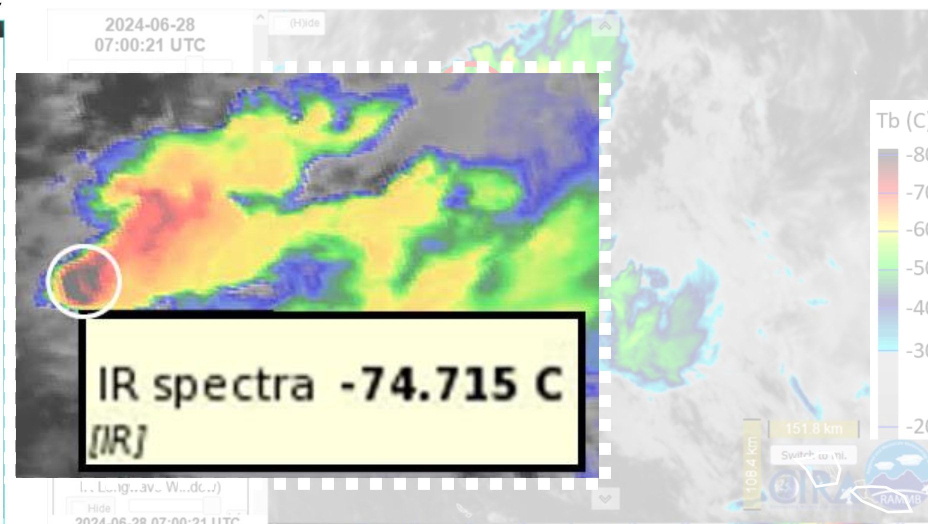

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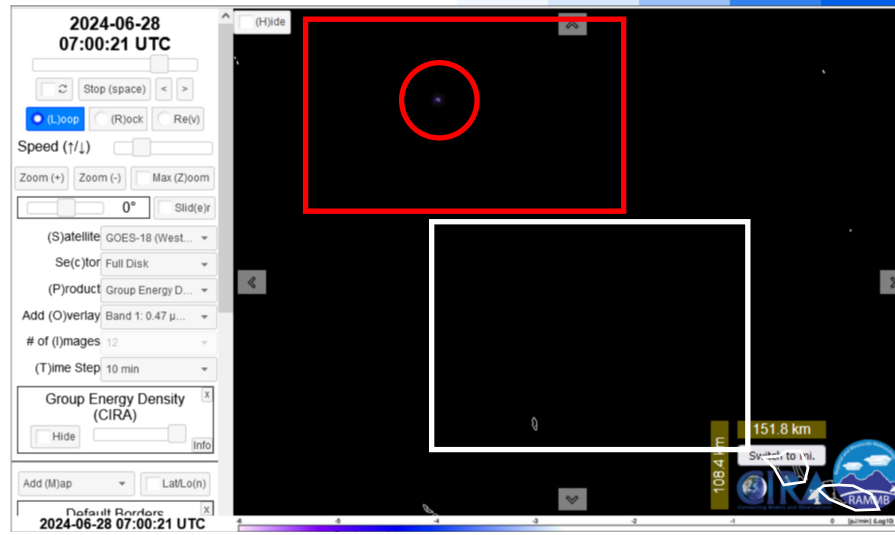

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images courtesy RAMMB/CIRA

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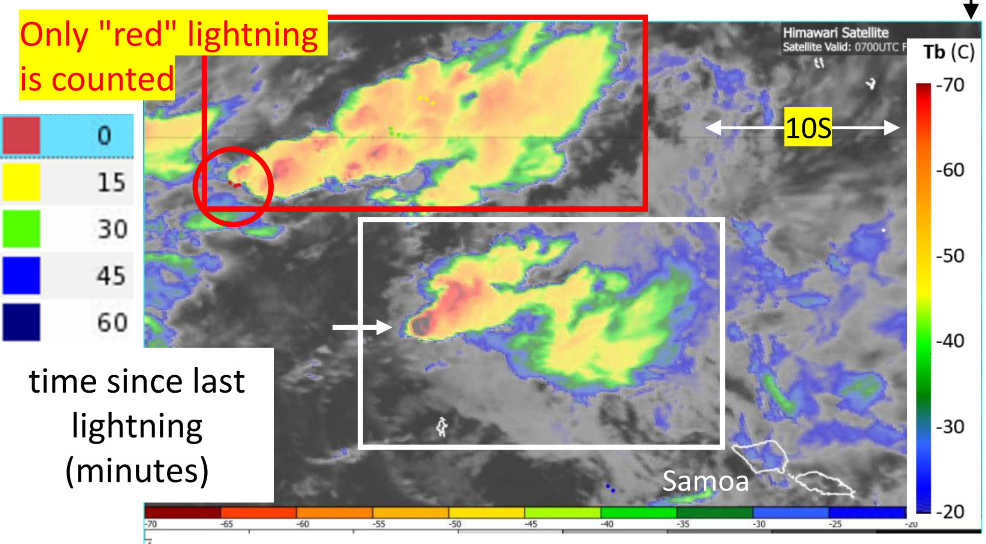

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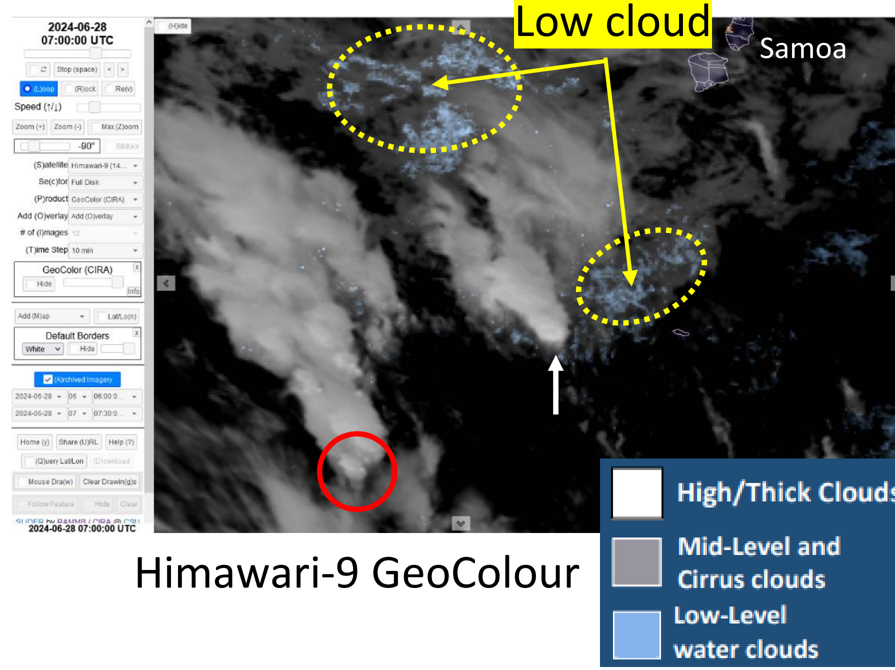


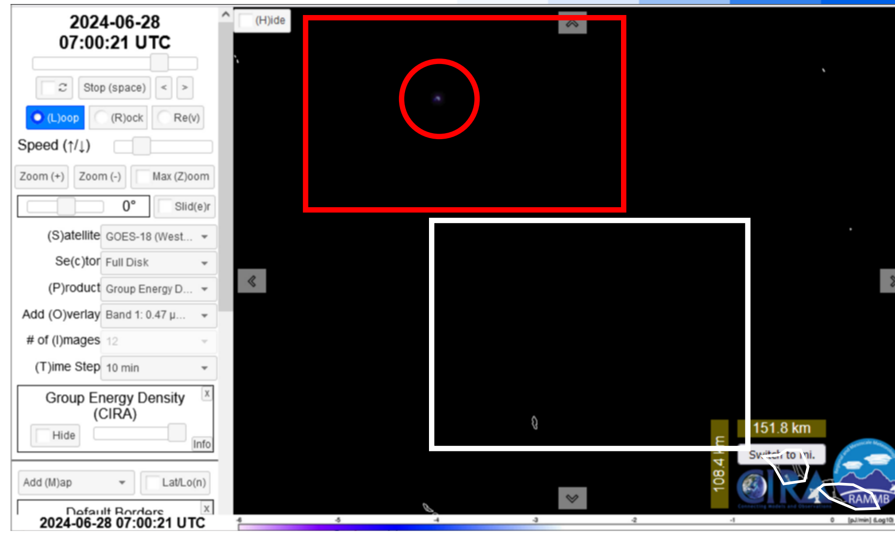
Himawari-9 GeoColour

Development of convection northwest of Samoa.

Challenges for the LightningCast model

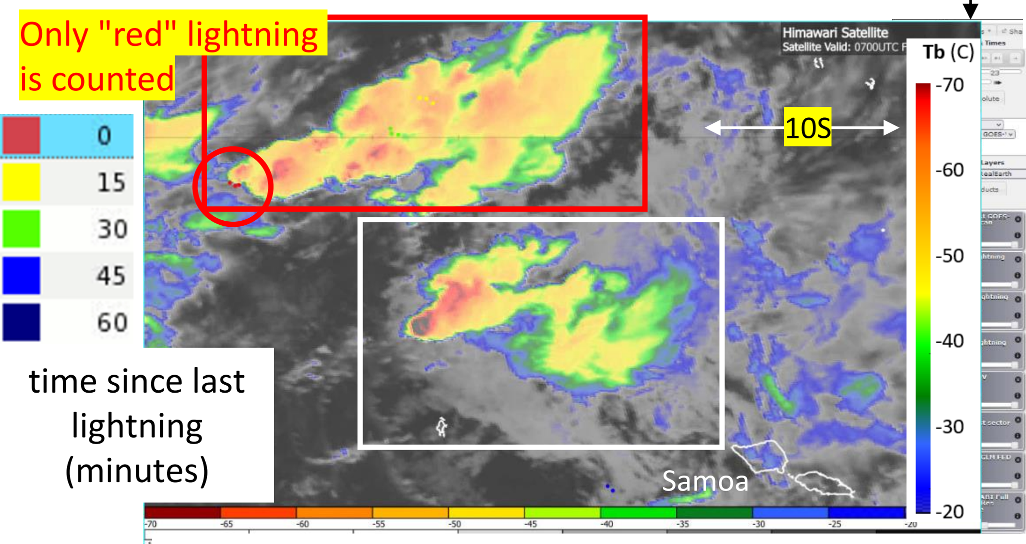
0700UTC 28 June 2024

image courtesy RAMMB/CIRA



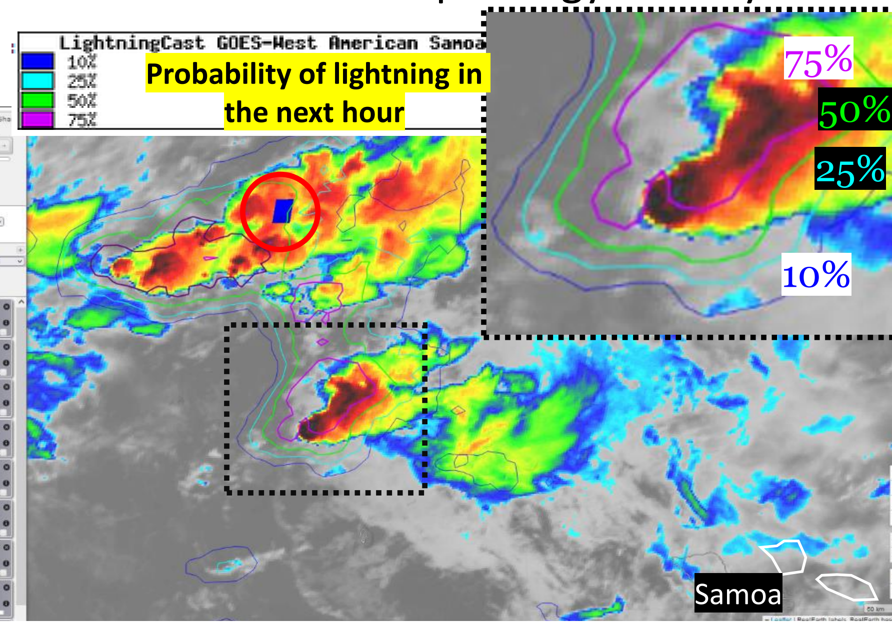
GOES-18 Group Energy Density

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



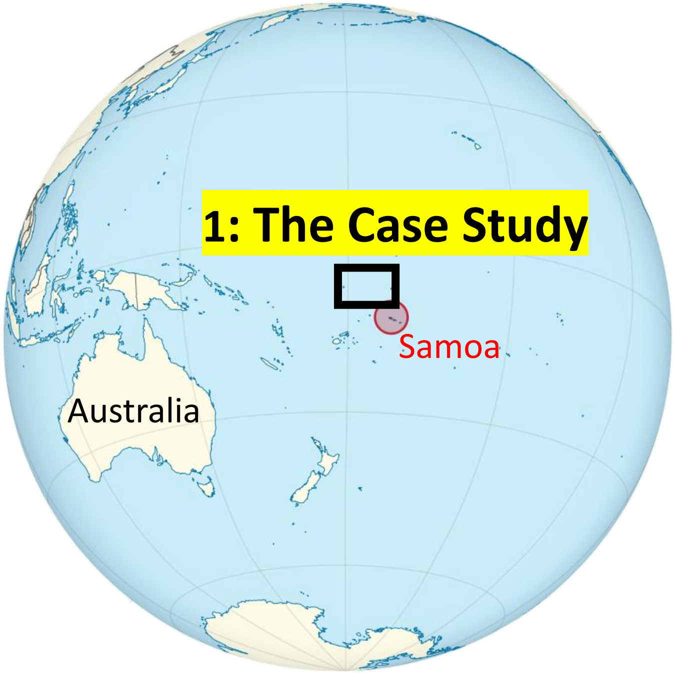
Himawari-9 Band 13 and lightning

The Bureau of Meteorology



GOES-18 Band 13, LightningCast and GLM

image courtesy NOAA/CIMSS



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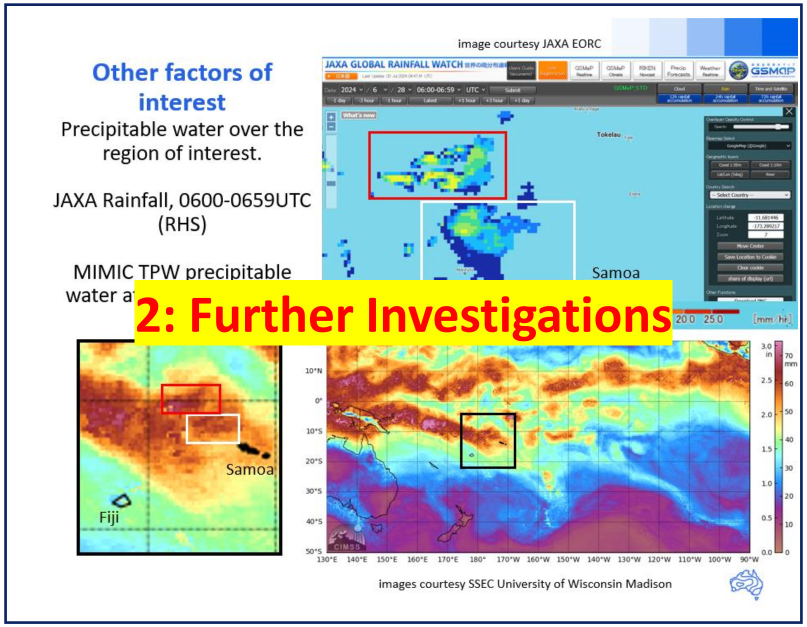
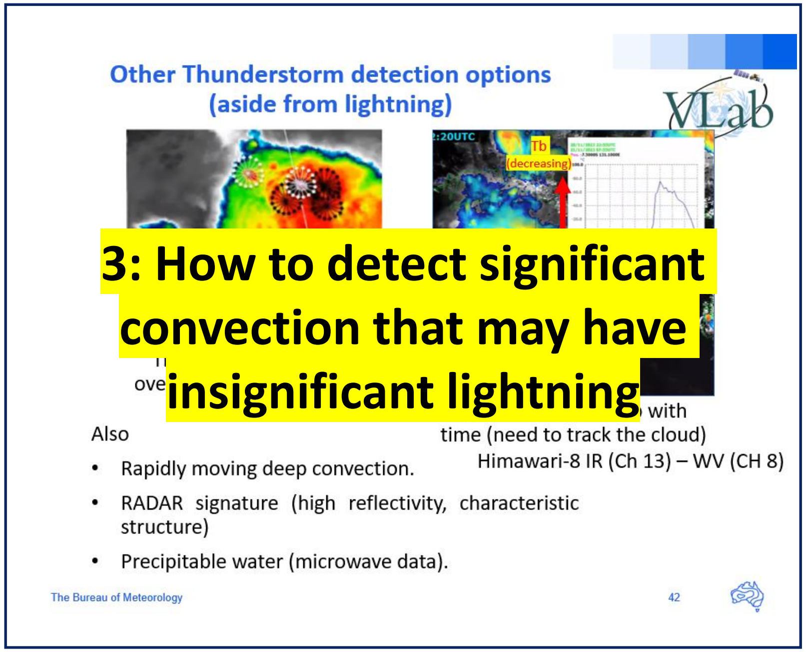
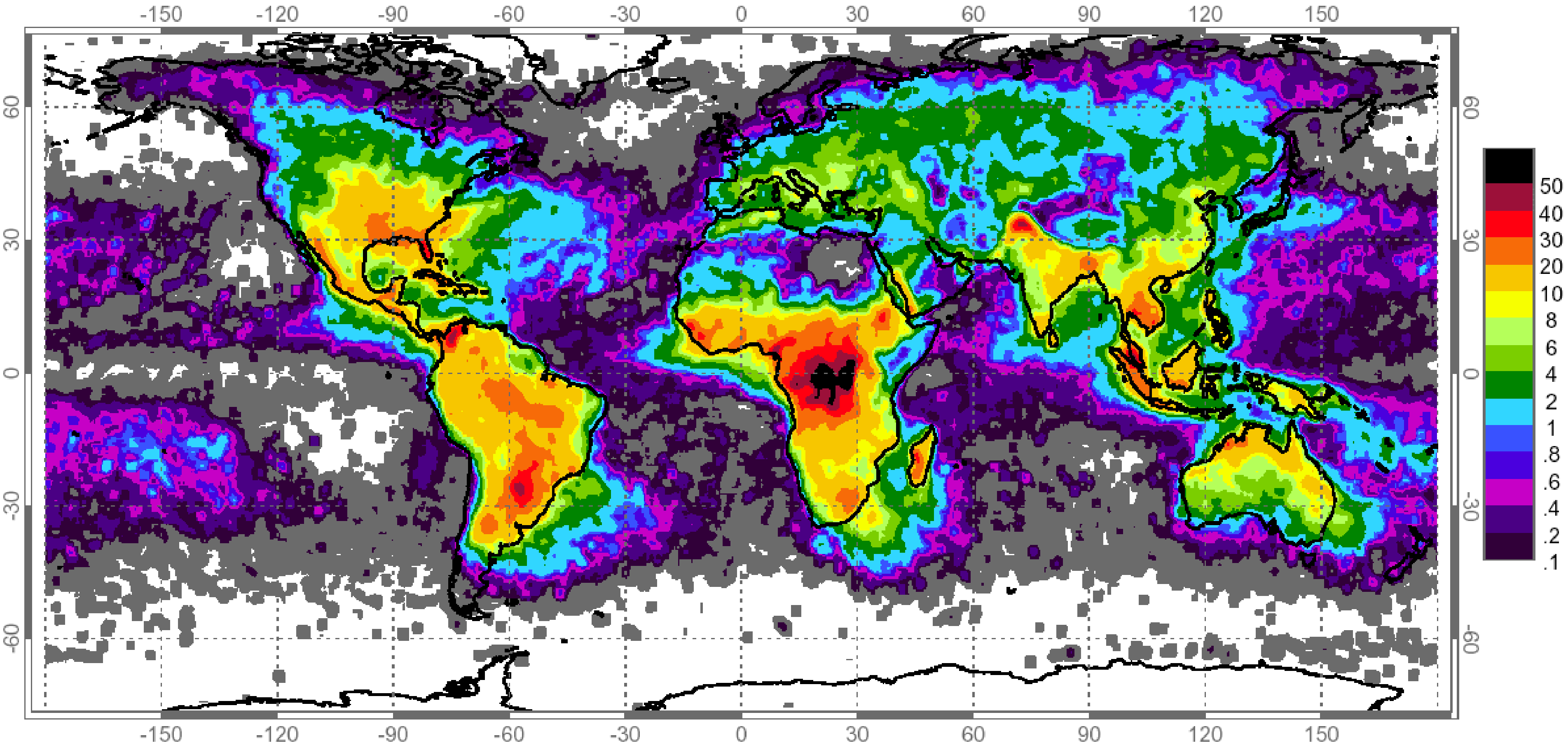




Lightning Observations for April 1995 to February 2003

from the combined observations of the NASA optical transient detector (April 1995–March 2000) and land information systems (January 1998–February 2003) instruments

CREDIT: NASA MSFC Lightning



Units = flashes / km2 / year

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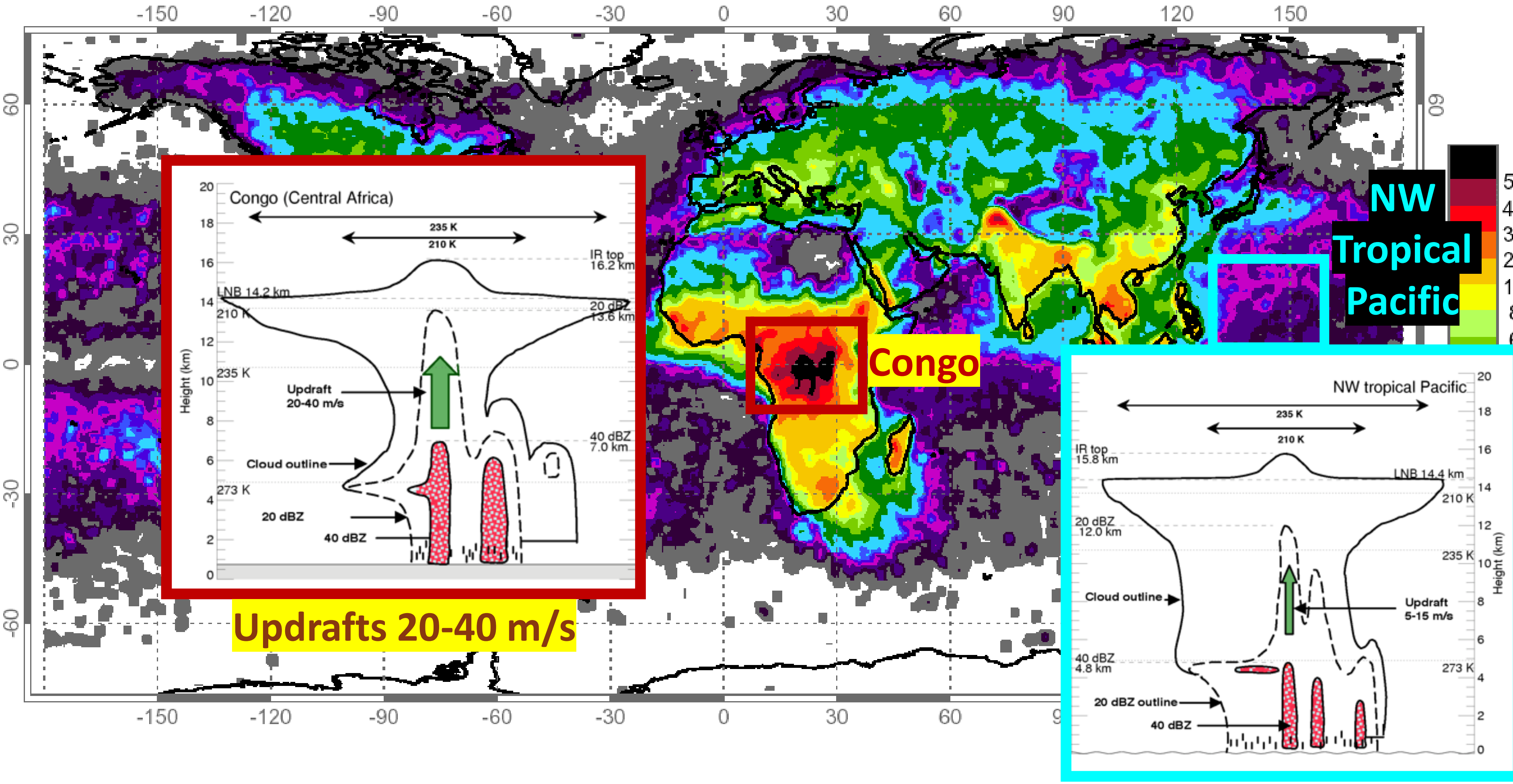


Units = flashes / km2 / year

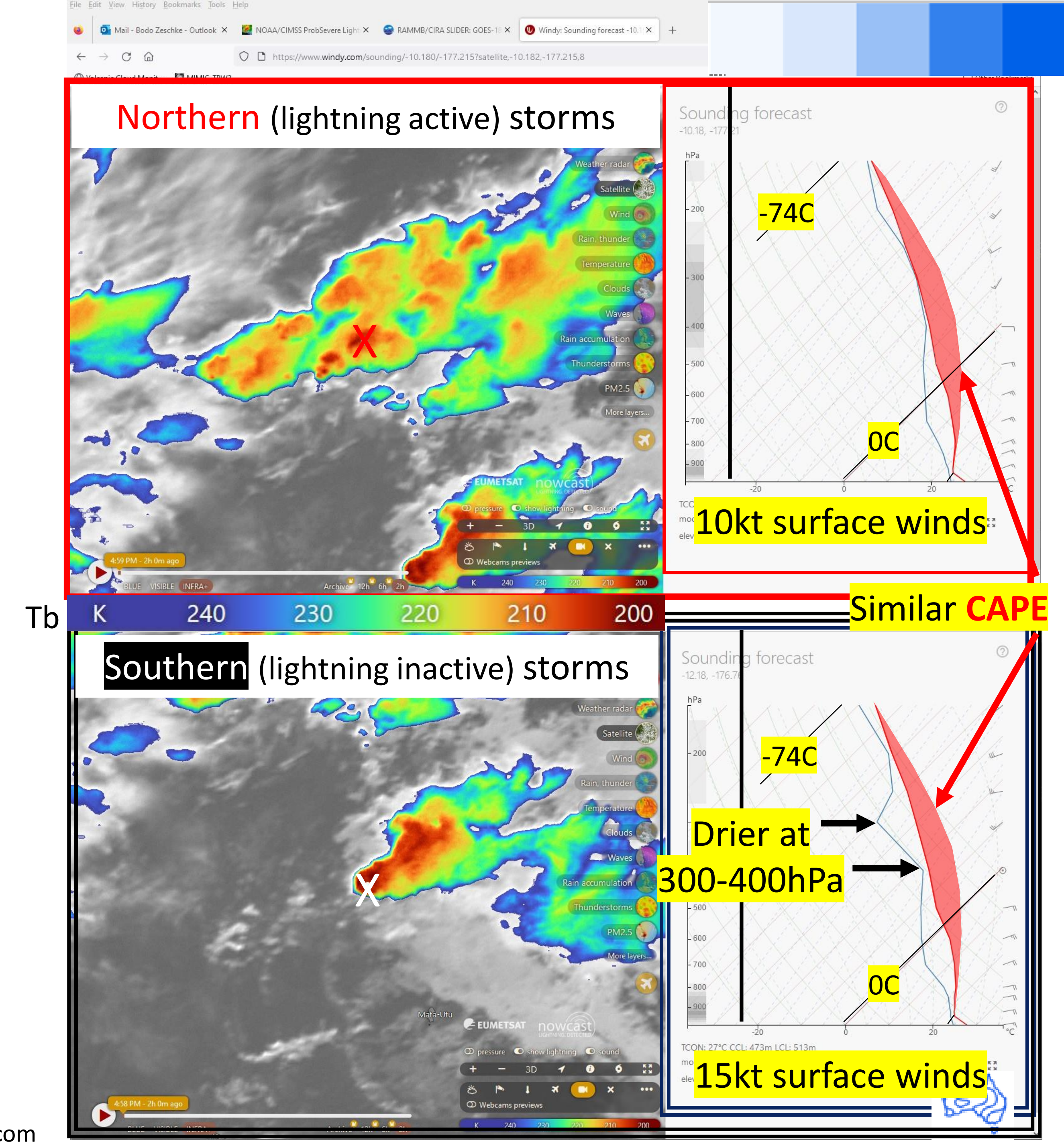
Updrafts 5-15 m/s

images courtesy Ed Zipser

Convection over land and over ocean

- Convection over tropical continents (Congo): Updrafts 20-40 m/s. Larger fraction of convective precipitation, smaller stratiform precipitation area (Zipser, E 1997)
- Convection over tropical oceans (NW Tropical Pacific): Updrafts 5-15 m/s. Smaller fraction of convective precipitation; larger stratiform precipitation area (Zipser, E 1997. Where are the most intense thunderstorms on earth? Darwin RFC Friday Forum session Feb 2007)
- Weaker updraft strength due to 'skinny CAPE' over the ocean compared to over the land https://journals.ametsoc.org/view/journals/wefo/37/7/WAF-D-22-0019.1.xml
- Lightning frequency has been shown to significantly increase with CAPE[16], which dominates the updraft intensity. https://www.nature.com/articles/s41467-022-31714-5

Comparing the Soundings for the Northern (lightning active) storms to the Southern (lightning inactive) storms



Enhanced IR images (LHS) and ECMWF NWP soundings at 07UTC, 28th June 2024

The Bureau of Meteorology

images courtesy Windy.com

Lightning Observations for April 1995 to February 2003

from the combined observations of the NASA optical transient detector (April 1995–March 2000) and land information systems (January 1998–February 2003) instruments

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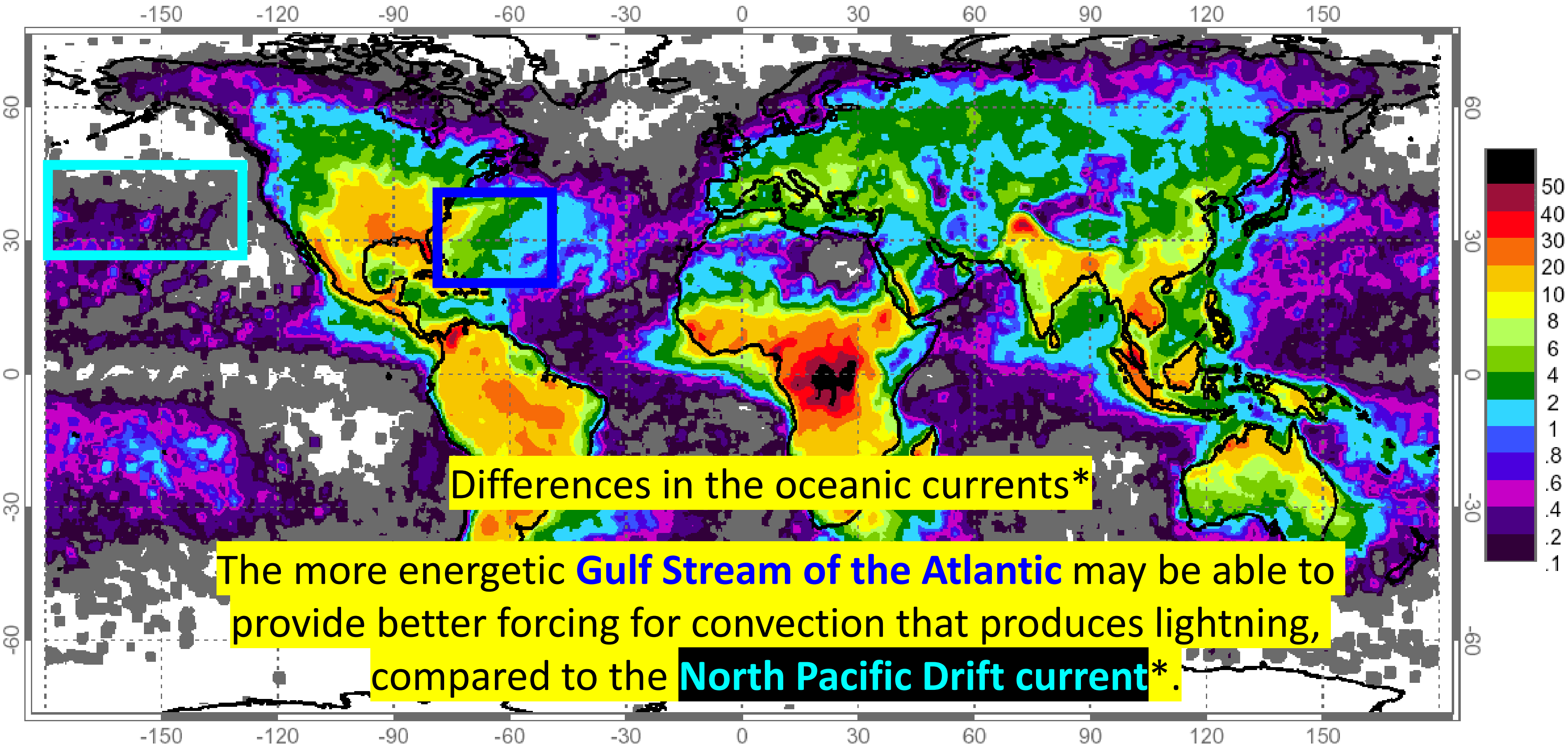


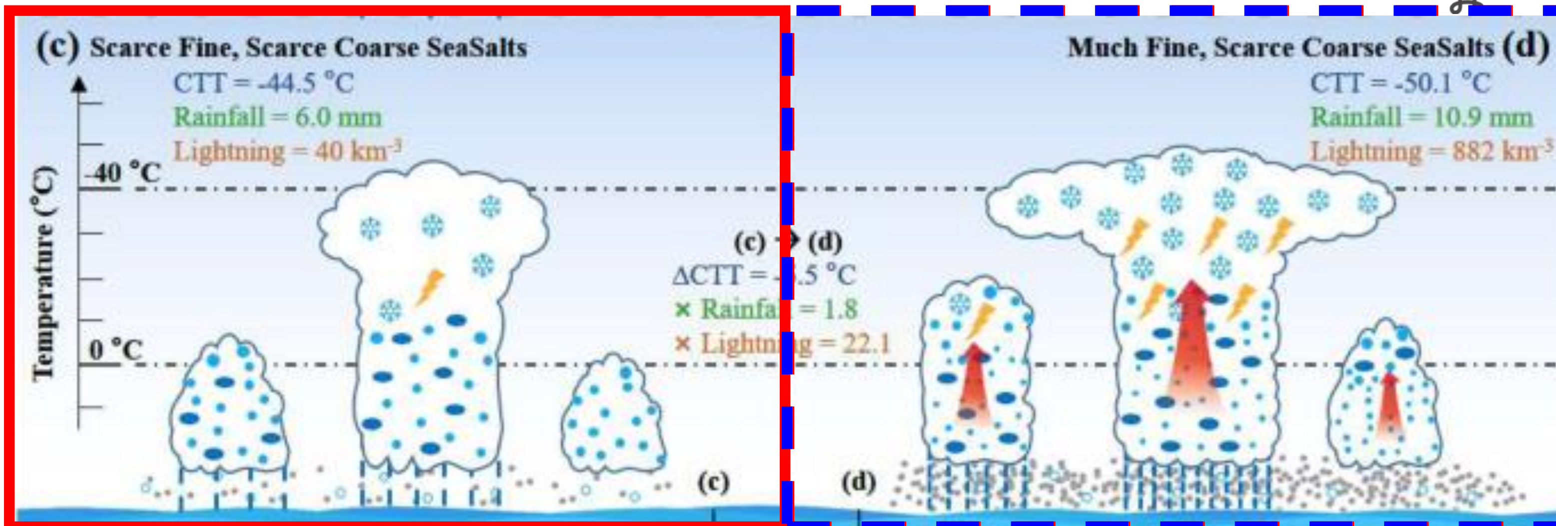
Differences in the oceanic currents*

The more energetic **Gulf Stream of the Atlantic** may be able to provide better forcing for convection that produces lightning, compared to the **North Pacific Drift current***.

Units = flashes / km2 / year

*Cintineo et al 2022 https://journals.ametsoc.org/view/journals/wefo/37/7/WAF-D-22-0019.1.xml

Aerosols and Coarse Sea Spray



Lightning frequency increases with fine aerosols (dry radius < 1 micron). **C to D transition above.**

Coarse sea salt (sea spray) inhibits lightning, resulting in warm rain instead. **D to F transition above**.

Image from Pan et al. 2022 https://www.nature.com/articles/s41467-022-31714-5

Impact of Aerosols on lightning in storms

- Adding fine aerosols significantly increases lightning density for a given rainfall amount over both ocean and land. https://www.nature.com/articles/s41467-022-31714-5

- Lightning frequency increases with fine aerosols (dry radius < 1 µm), which act as cloud condensation nuclei (CCN). More cloud droplets, slower to coalesce into drops. Survive higher in the updraft. Enriches Supercooled Liquid Water Content in clouds. More cloud droplets enhance condensation efficiency. More latent heat release. Stronger updraft. https://www.nature.com/articles/s41467-022-31714-5

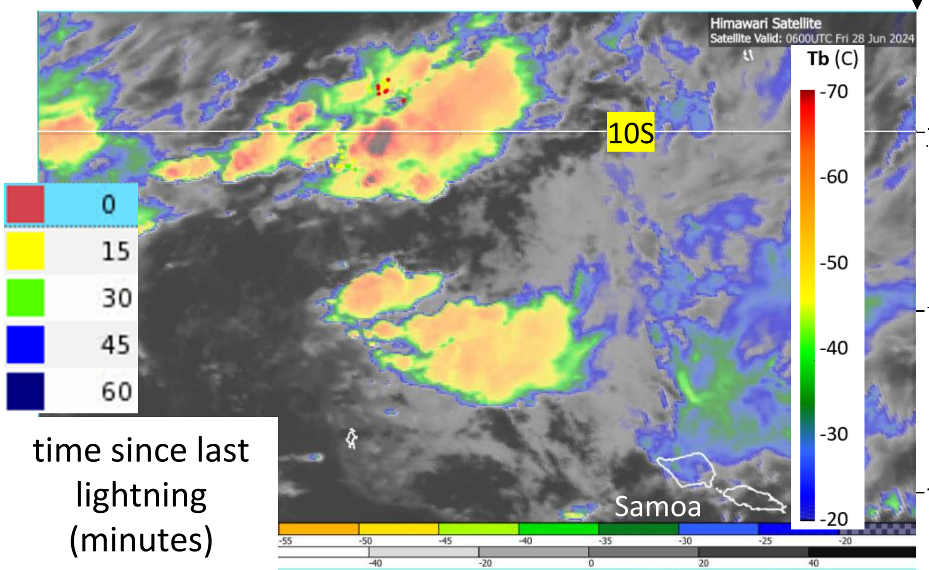
- Despite the much weaker invigoration of Cloud Top Temperature and rainfall per fine aerosol increase over ocean, the lightning density over ocean increases much more than over land. Lightning density increases by a factor of ×11 from low to high mass concentrations of fine aerosols over ocean, compared to only ×2.6 over land for a given rainfall amount https://www.nature.com/articles/s41467-022-31714-5

Impact of Coarse Sea Spray on lightning in storms

- Coarse sea spray can reduce lightning (maritime regions). https://www.nature.com/articles/s41467-022-31714-5
- Coarse sea salt (sea spray) results in larger drops. Warm rain instead of mixed phase precipitation. https://www.nature.com/articles/s41467-022-31714-5
- If fewer ice particles form, there is less chance for cloud electrification. https://sitn.hms.harvard.edu/flash/2022/seaspray-lightning-away-salt-may-explain-why-lightning-strikes-less-over-the-ocean/

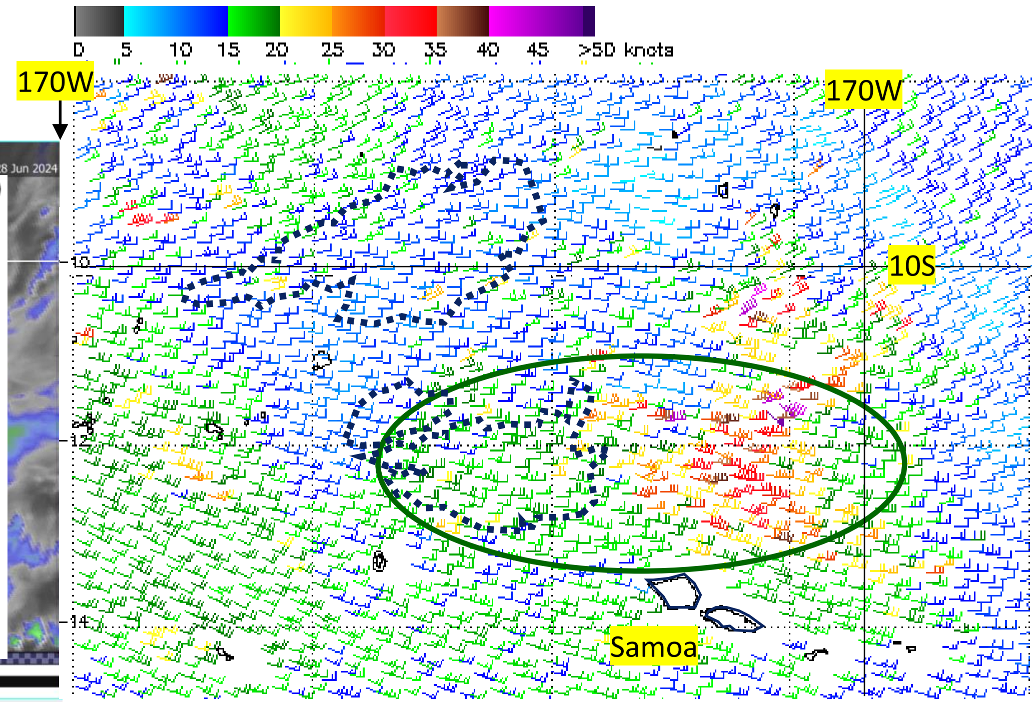
Possible surface winds resulting in sea spray?

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



Himawari-9 Band 13 and lightning 06UTC 28th June 2024

image courtesy NOAA NESDIS STAR



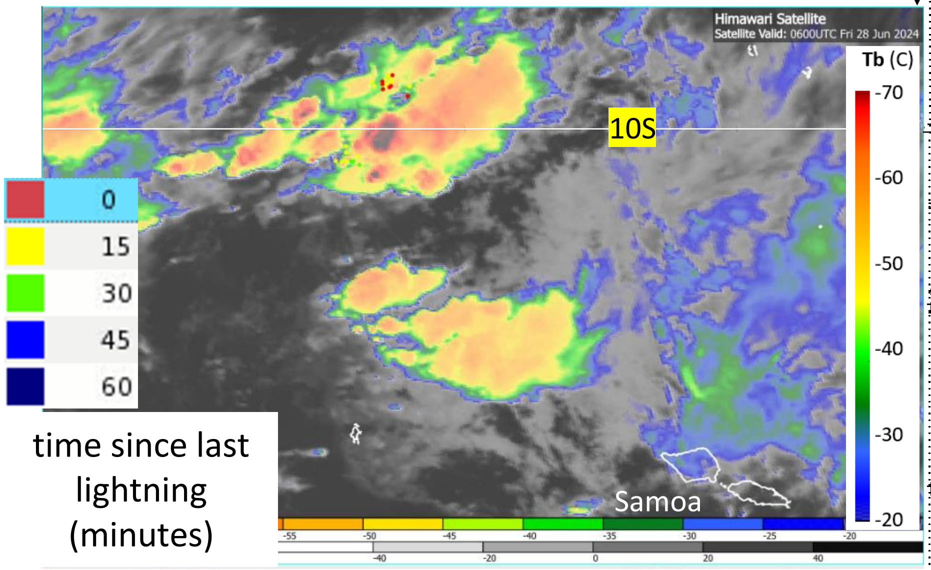
OSCAT-3 pass, 2330UTC 27th June 2024

····· 06UTC location of cold cloud tops

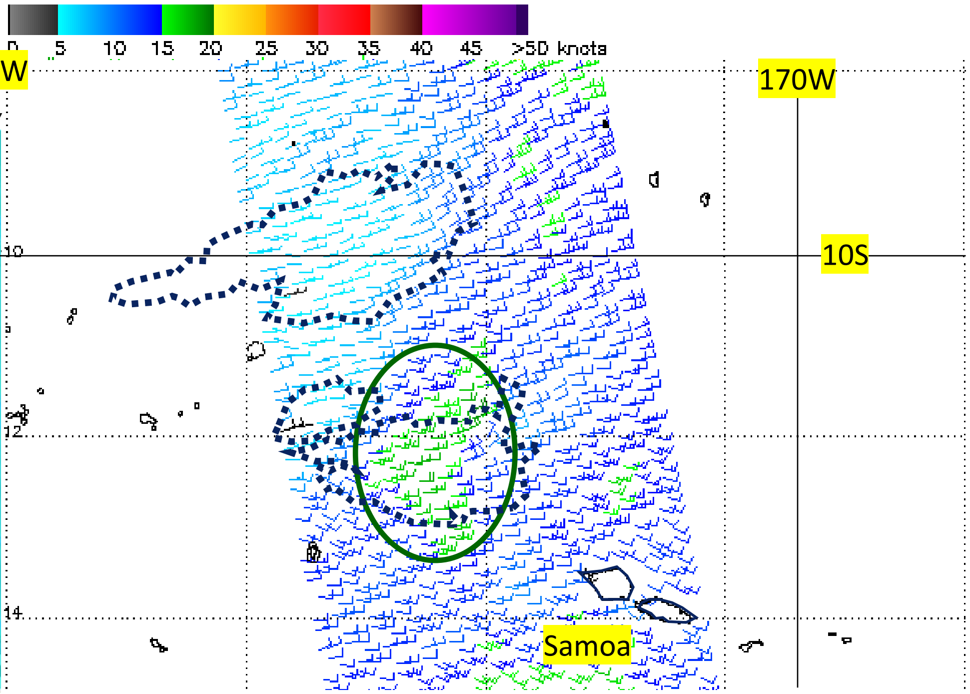
Possible surface winds resulting in sea spray?

image courtesy NOAA NESDIS STAR

image courtesy JMA / Bureau of Meteorology, lightning data Weatherzone



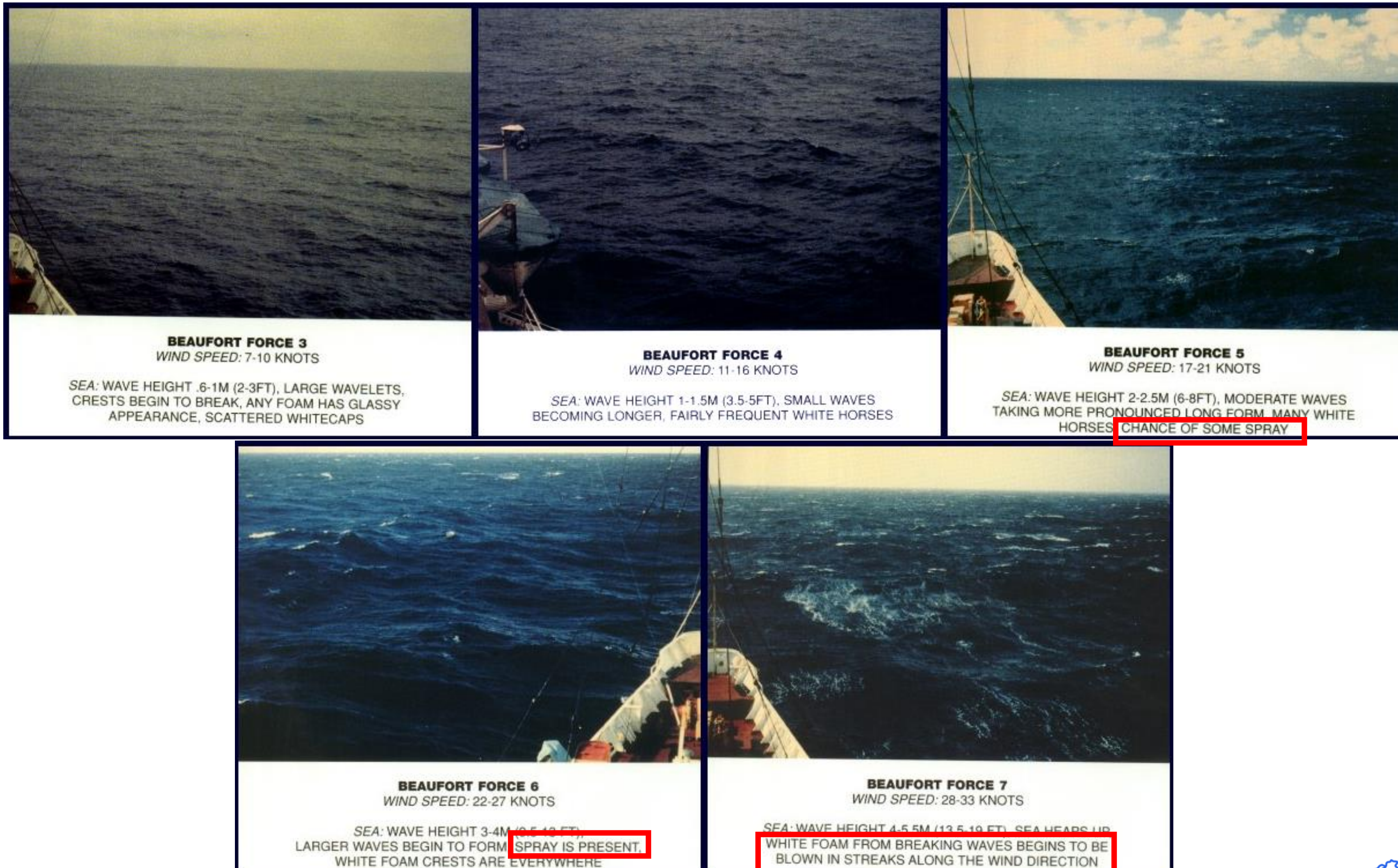
Himawari-9 Band 13 and lightning 06UTC 28th June 2024



ASCAT B pass, 0840UTC 28th June 2024

····· 06UTC location of cold cloud tops

Beaufort Scale and Sea Spray



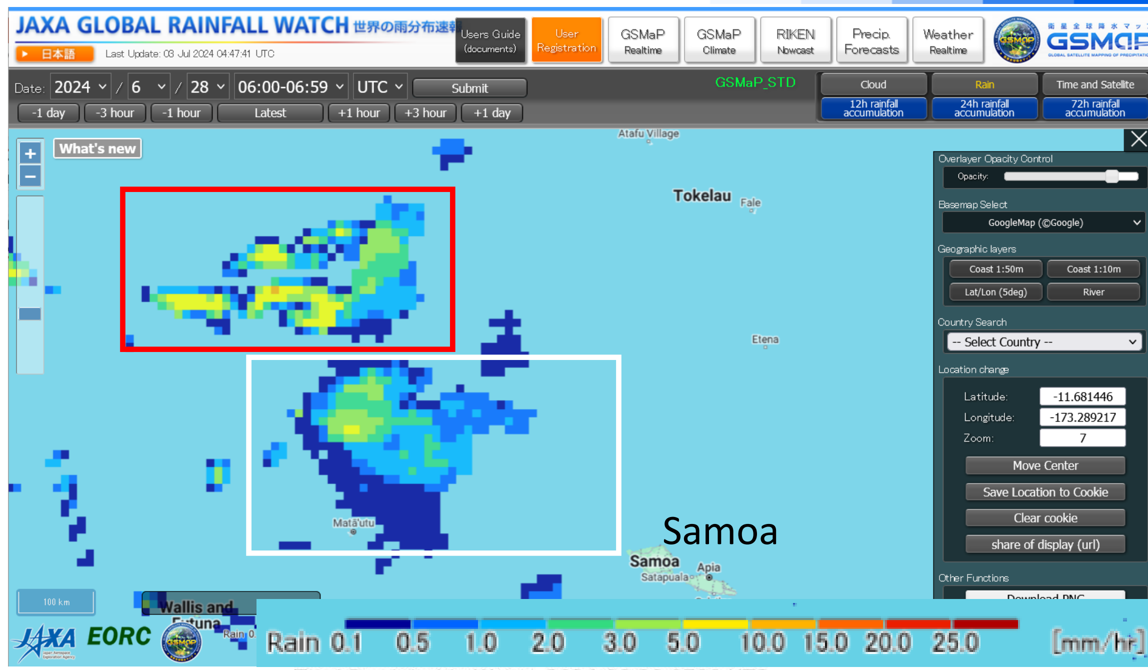
images courtesy http://insydney.com.au/Weather/Beaufortscale/default.htm image courtesy JAXA EORC

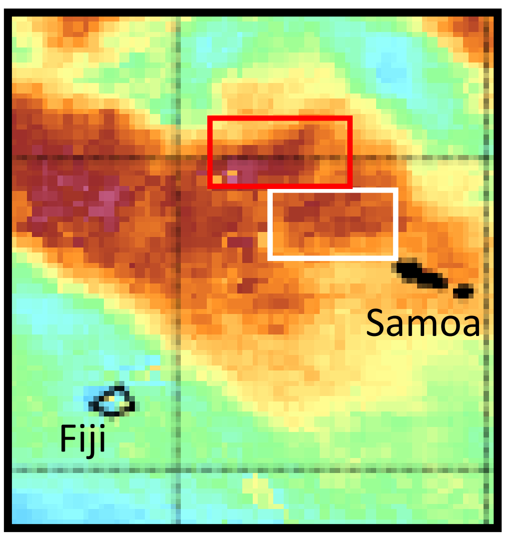
Other factors of interest

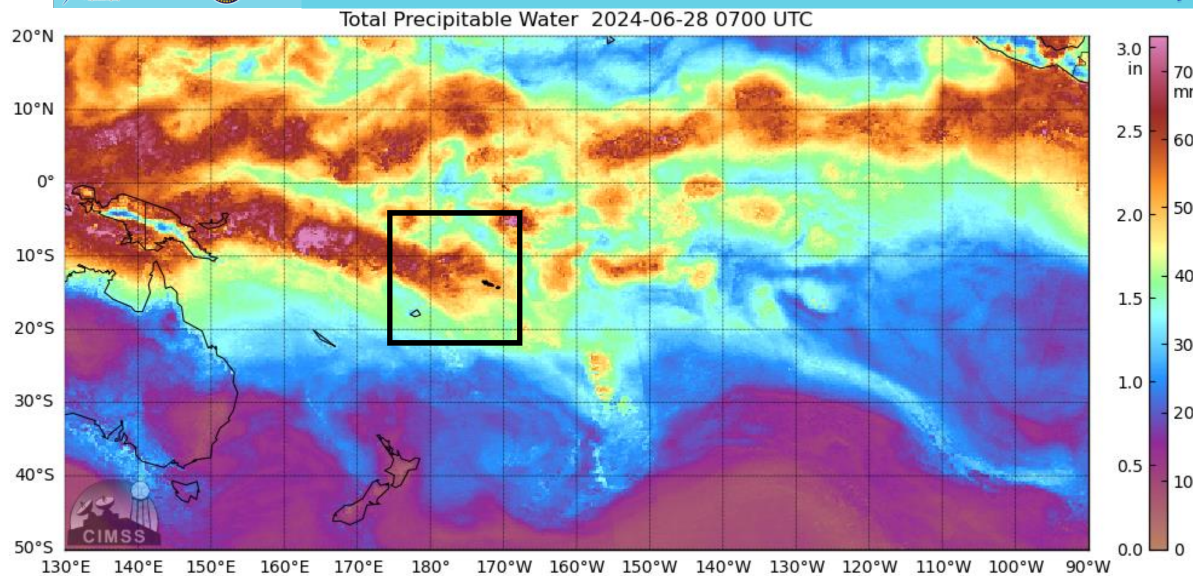
Precipitable water over the region of interest.

JAXA Rainfall, 0600-0659UTC (RHS)

MIMIC TPW precipitable water at 0700UTC (below)



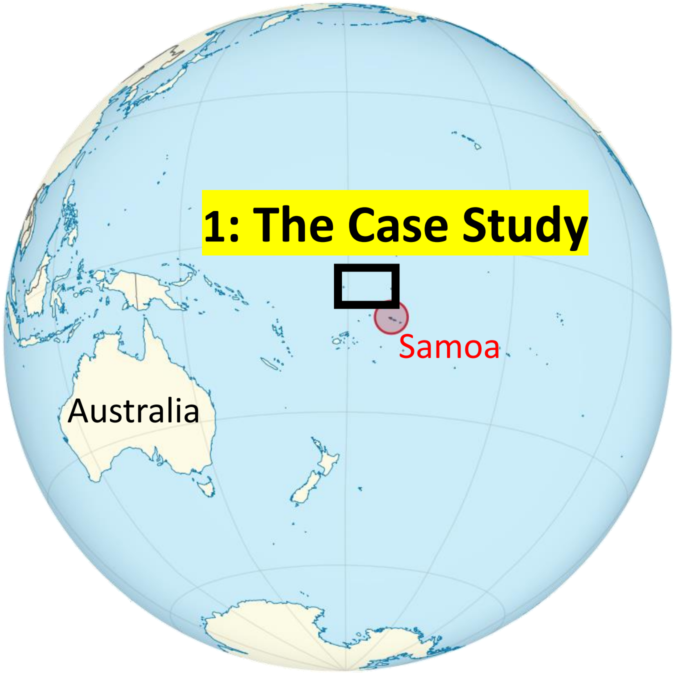




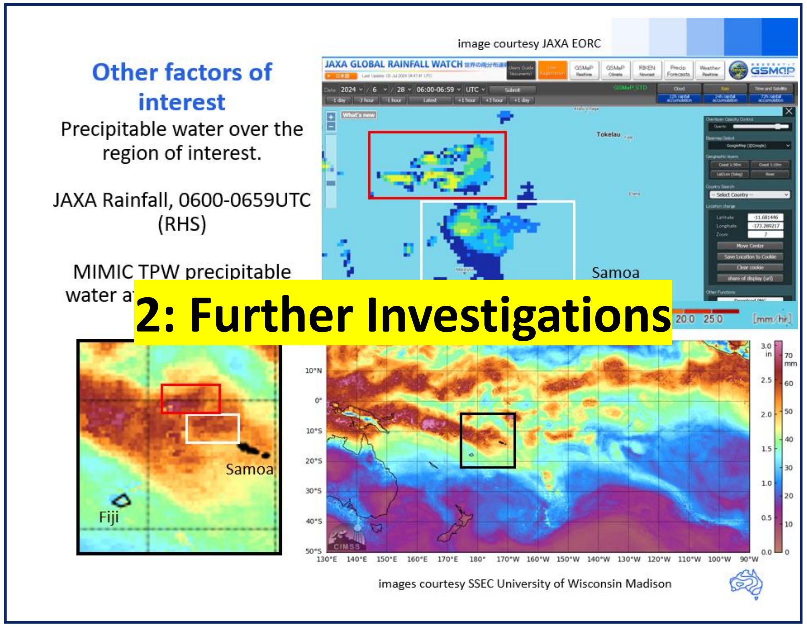
images courtesy SSEC University of Wisconsin Madison

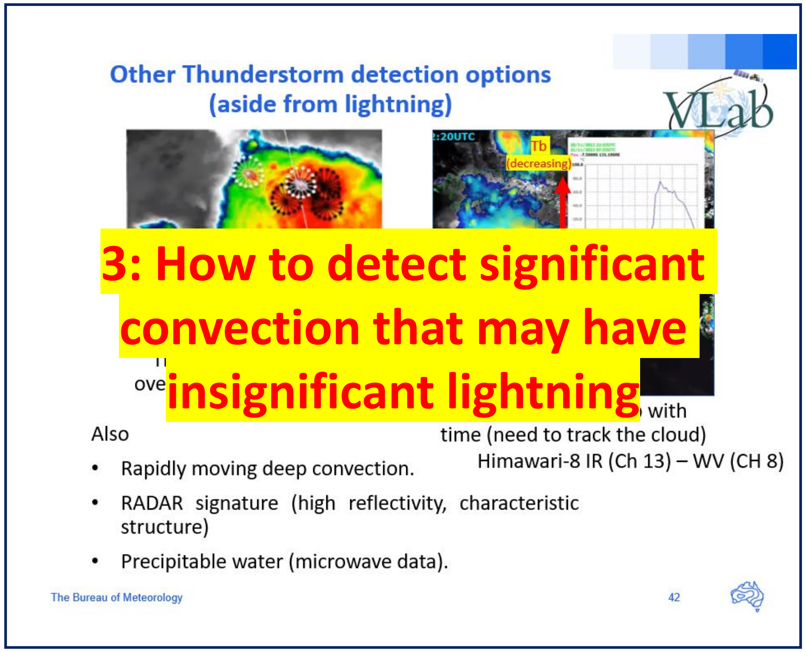
Other factors favourable for development of convection with strong updraft

- Other favorable meteorology conditions also contribute to the development of convection with strong updraft, such as high precipitable water (PW) and low wind shear[17,18] https://www.nature.com/articles/s41467-022-31714-5
- Other relevant meteorological factors are examined referring to the previous studies[18,23], including 450 hPa vertical motion, surface and 450 hPa relative humidity, and 850–200 hPa wind shear. https://www.nature.com/articles/s41467-022-31714-5



For this discussion we will cover the following…

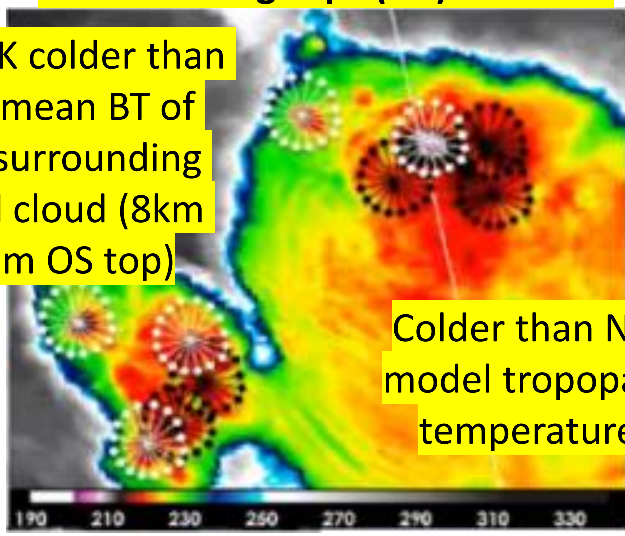




Other Thunderstorm detection options (aside from lightning)

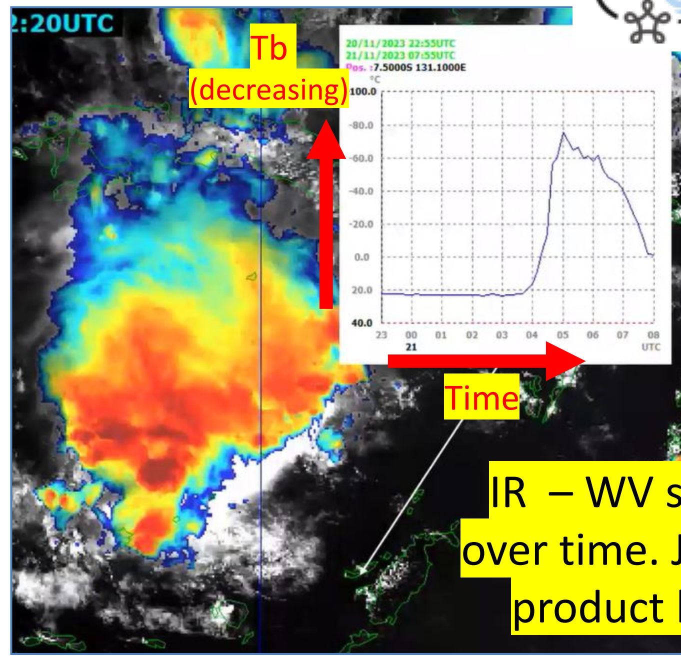
image courtesy Rion Salman BMKG Indonesia and JMA

Overshooting tops (OT) must be:



Tb difference between overshooting top and anvil

Bedka et al. 2011, image forwarded by Geoff Feren Bureau of Meteorology



Rate of change of Tb

- need to track the cloud

Also:

- RADAR signature (high reflectivity, characteristic structure)
- Precipitable water and surface winds (microwave data).

Australian VLab Centre of Excellence Regional Focus Group meeting, 02UTC 9 July 2024

Contents

- **Utilization of Meteorological Satellite Data in Cloud Analysis** (presented by Mr Shiro Omori, Senior Coordinator for Satellite Data Quality, Meteorological Satellite Center, Japan Meteorological Agency (JMA))
- **Verification and Case Studies of JMA's Rapidly Developing Cumulus Area (RDCA) Product** (presented by Mr Hiroshi Suzue, Scientific Officer, Office of Meteorological Analysis and Application Development, Administration Division, Atmosphere and Ocean Department, Japan Meteorological Agency)
- **Thunderstorms and associated Lightning over Maritime Areas with a Pacific Ocean Case Study** (presented by Mr Bodo Zeschke, Australian Bureau of Meteorology Training Centre)

The next Indonesian VLab CoE Regional Focus Group meeting will be held during the latter half of July 2024