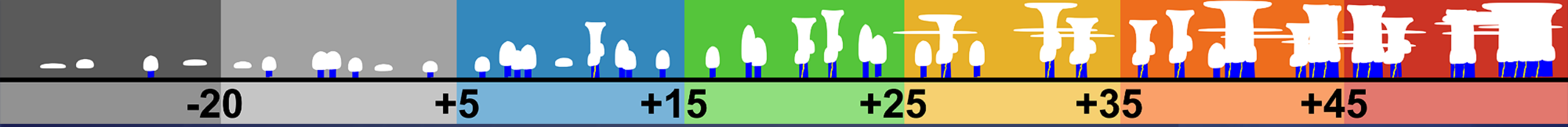



# The Galvez-Davison Index (GDI)

## Stability Index for Tropical Environments

**By José Manuel Gálvez**

Cooperative Institute for Research in the Atmosphere (CIRA)

Fort Collins, CO, 17 June 2025

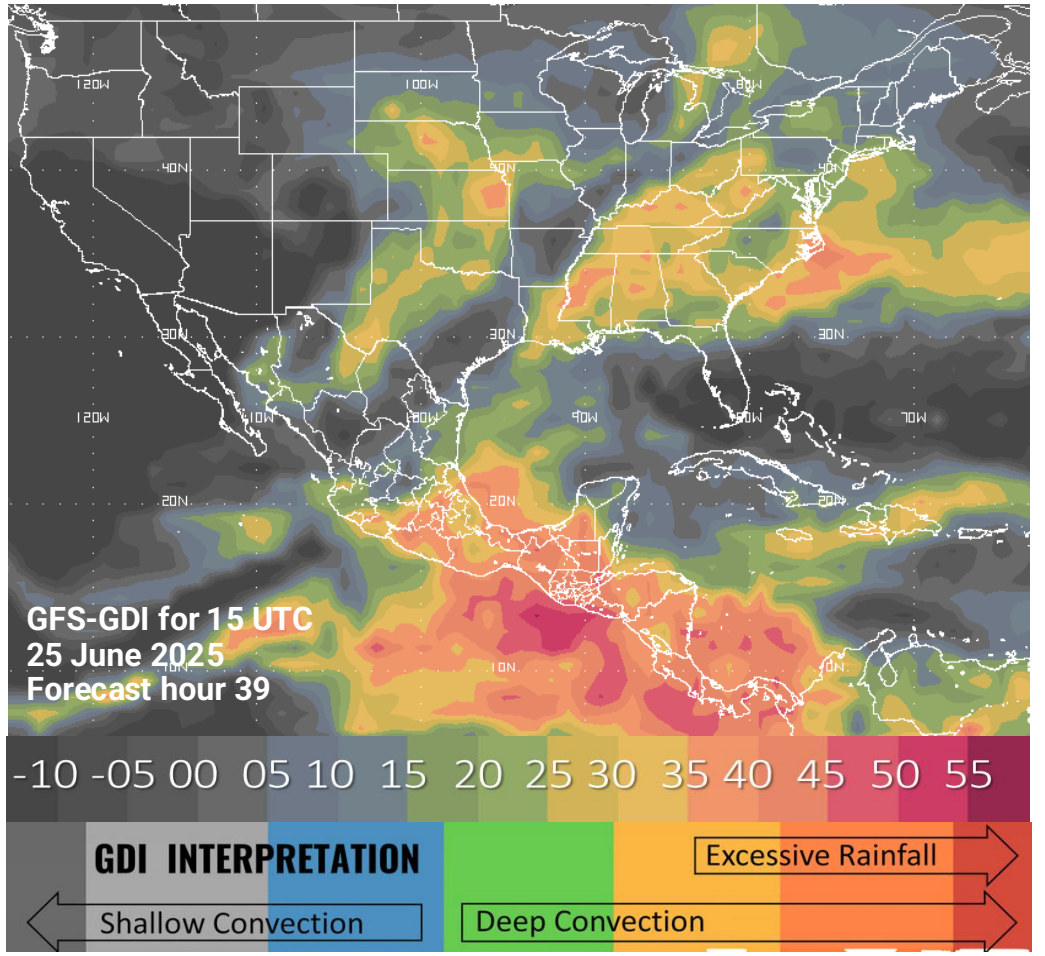
# Today's Session

## Goals

- Revisit the science behind the calculation of the GDI, emphasizing the role of its subindices.
- Show the importance of integrating complementary tools to optimize GDI applications: an analysis of atmospheric dynamics and moisture availability.
- Apply the concepts learned to evaluate regions of convection occurring during the session.

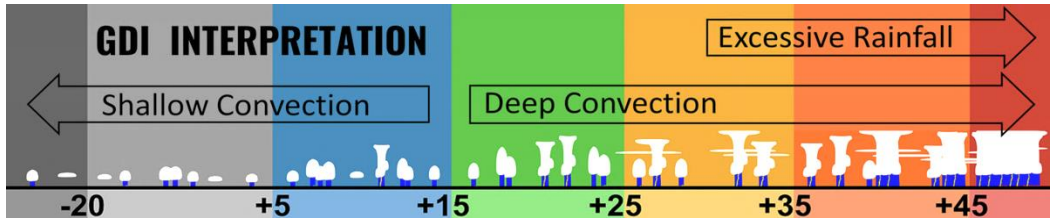
# What is the Galvez-Davison Index (GDI)?

- Stability index, developed at NOAA's Weather Prediction Center in 2014, to improve forecasts of tropical convection (Galvez and Davison, 2016).
- But it has skill in the extratropics too, when warm and moist air masses are present. Thus, it can help US forecasters gain confidence when forecasting impactful rainfall events.
- The GDI describes whether the environment is ready to host shallow convection, deep convection of deep convection with a heavy rain potential.




**Web: https://www.wpc.ncep.noaa.gov/international/gdi/**

# What can GDI detect?




Front

Moist Plumes of tropical characteristics

Front

Moist and unstable environment over the warm pool

Dry and stable air masses

ITCZ

ITCZ

Tropical Storm Erick

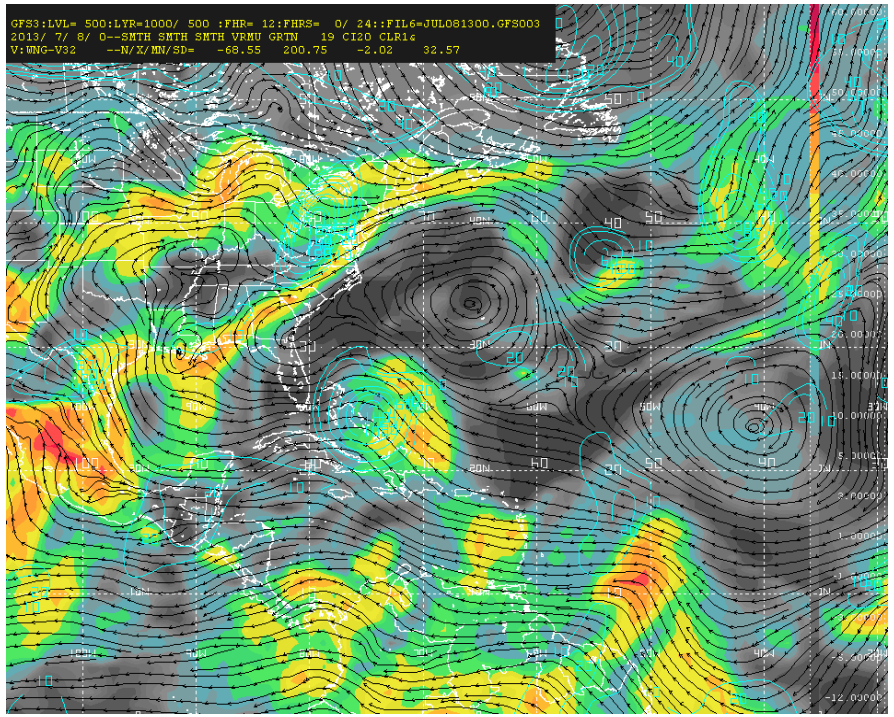
SPCZ

Very moist and unstable air mass in Central America

GFS-GDI for 15 UTC 25 June 2025
Forecast hour 30
Courtesy: WPC

# The GDI is great to track tropical waves and captures the convective structure of well established cyclones

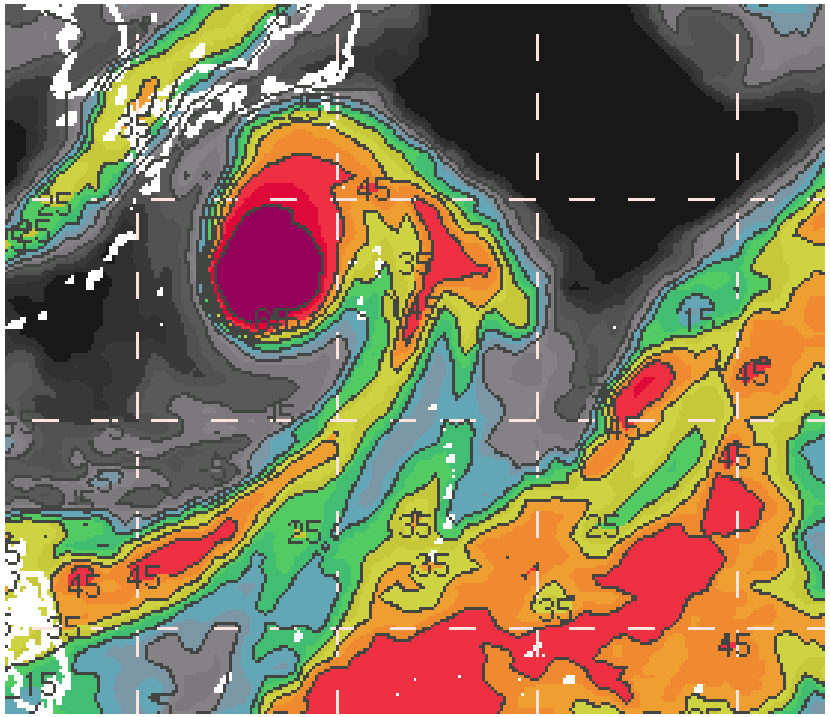
## Tropical Wave Tracking




GFS GDI and 850-700 hPa Averaged Flow

July 8-10, 2013

## Tropical Cyclone Convective Structure

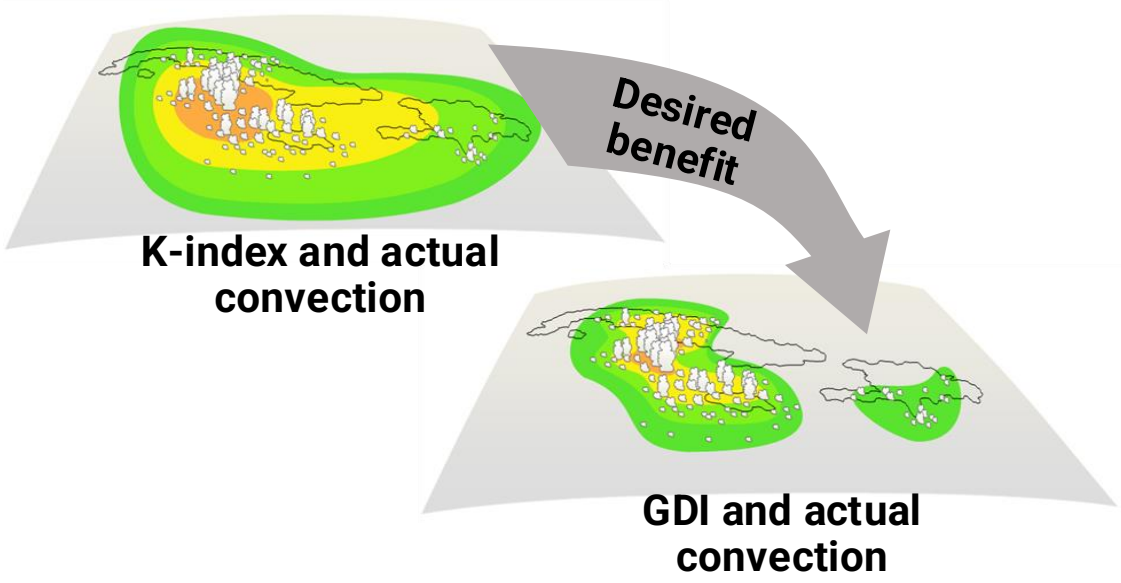


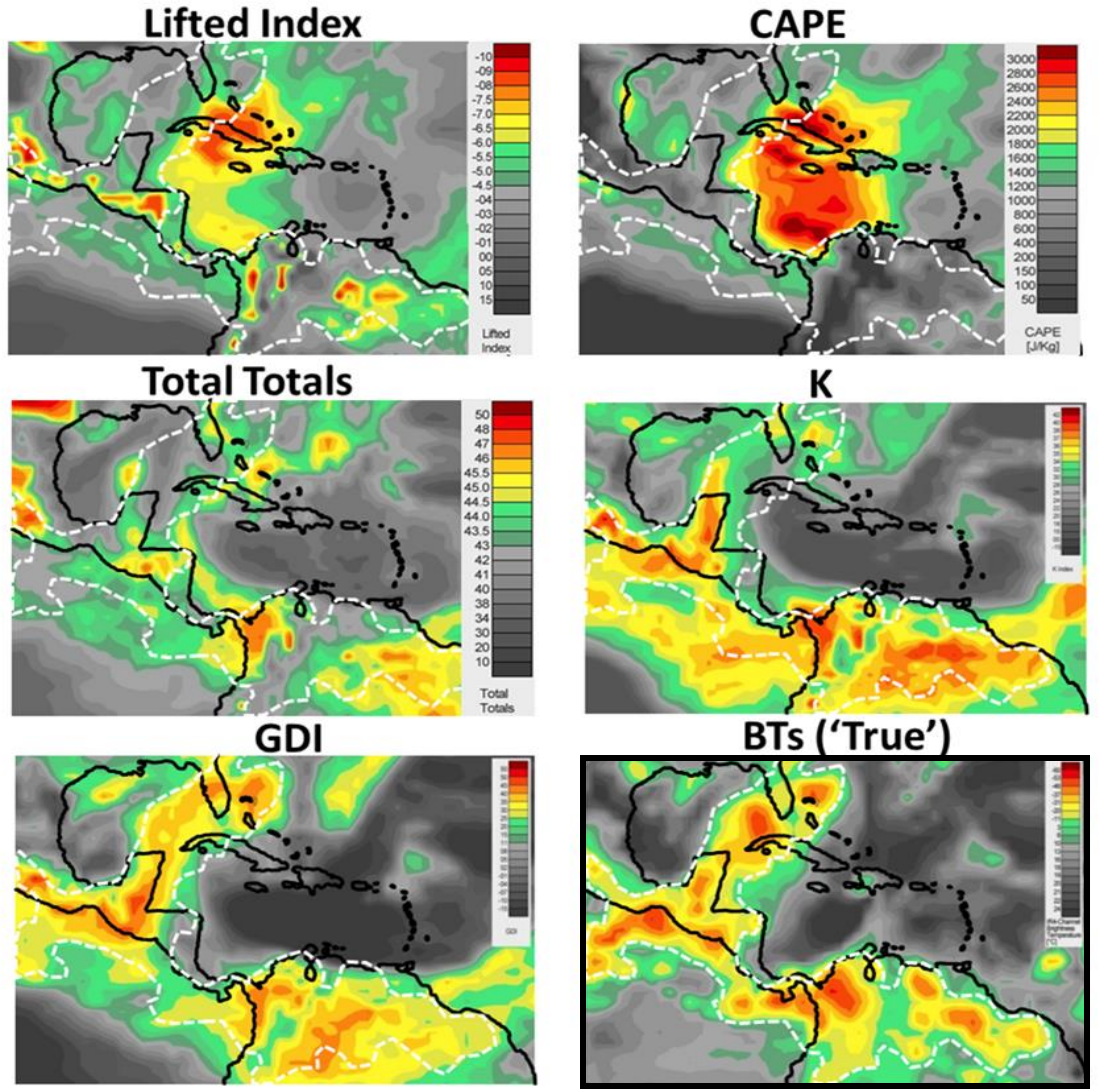
GFS GDI: Tropical Cyclone Mindulle and feeder band

September 30, 2021, 00 UTC

# Why develop the GDI?

- By 2013, no stability index could properly detect environments suitable for tropical convection.
- The K-index (George, 1960) was often the best tool. Yet it had a tendency to overestimate the size of areas where convection was possible.




12-hr averages of five stability indices versus 12-hr averages of GOES-13 IR4 brigntness temperature (BT). Period: 16 Aug 2013, 00-12 UTC. BT is used to represent regions with the coldest and/or highest frequency of cold cloud tops, or with the strongest and/or most frequent deep convection. The GDI is the index that matches BT the most.

# Processes the GDI considers

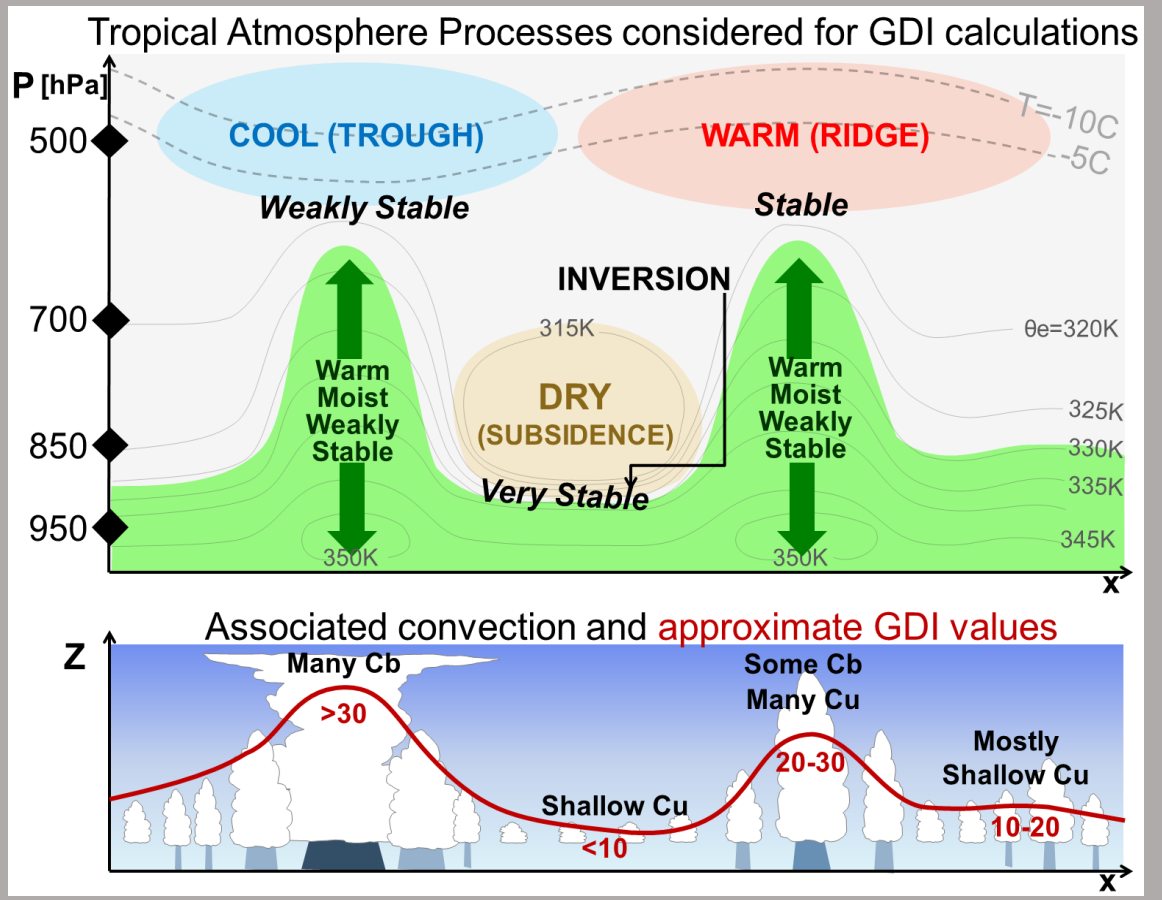
1) Availability of heat and moisture between 950 and 500 hPa. Assessed with the **Column Buoyancy Index (CBI).**

2) Stabilizing impacts of warm mid-levels. Assessed with the **Mid-level Warming Index (MWI).**

3) Stabilizing and drying impacts of temperature inversions in trade wind regimes. Assessed with the **Inversion Index (II).**

**GDI Formulation: Algebraic sum of subindices**

| GDI | = | CBI ≥ 0 | + | MWI ≤ 0 | + | II ≤ 0 | + | Terrain Correction ≤ 0 |
|---|---|---|---|---|---|---|---|---|

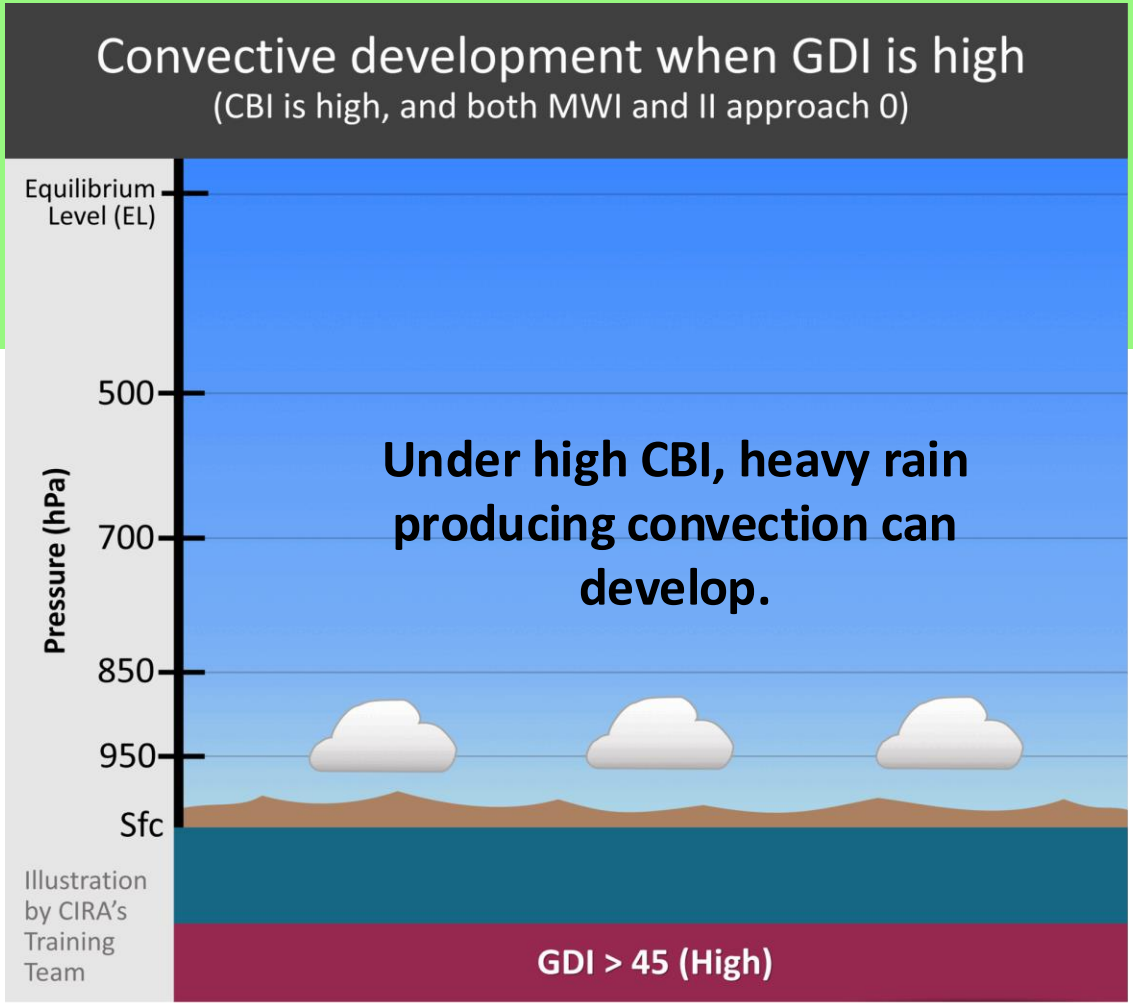


# 1) Column Buoyancy Index (CBI)

- **Describes the amount of heat, moisture and buoyancy in the column.**
- **“Fuel” for the GDI.**
- **Calculated with θe at 950 and 500 hPa.**

**GDI Formulation: Algebraic sum of subindices**

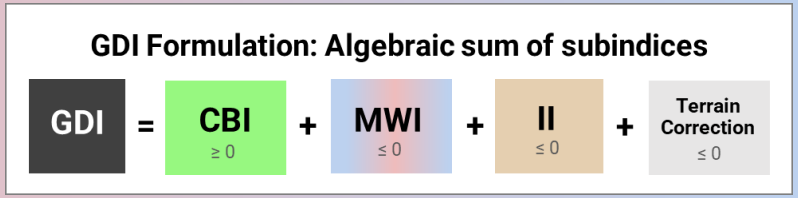
**GDI** = **CBI** ≥ 0 + **MWI** ≤ 0 + **II** ≤ 0 + **Terrain Correction** ≤ 0




- Only GDI sub-index with positive values.
- **<u>High CBI</u> (CBI>45)** describes a warm, moist and buoyant air column, capable of hosting deep convection and heavy rainfall.

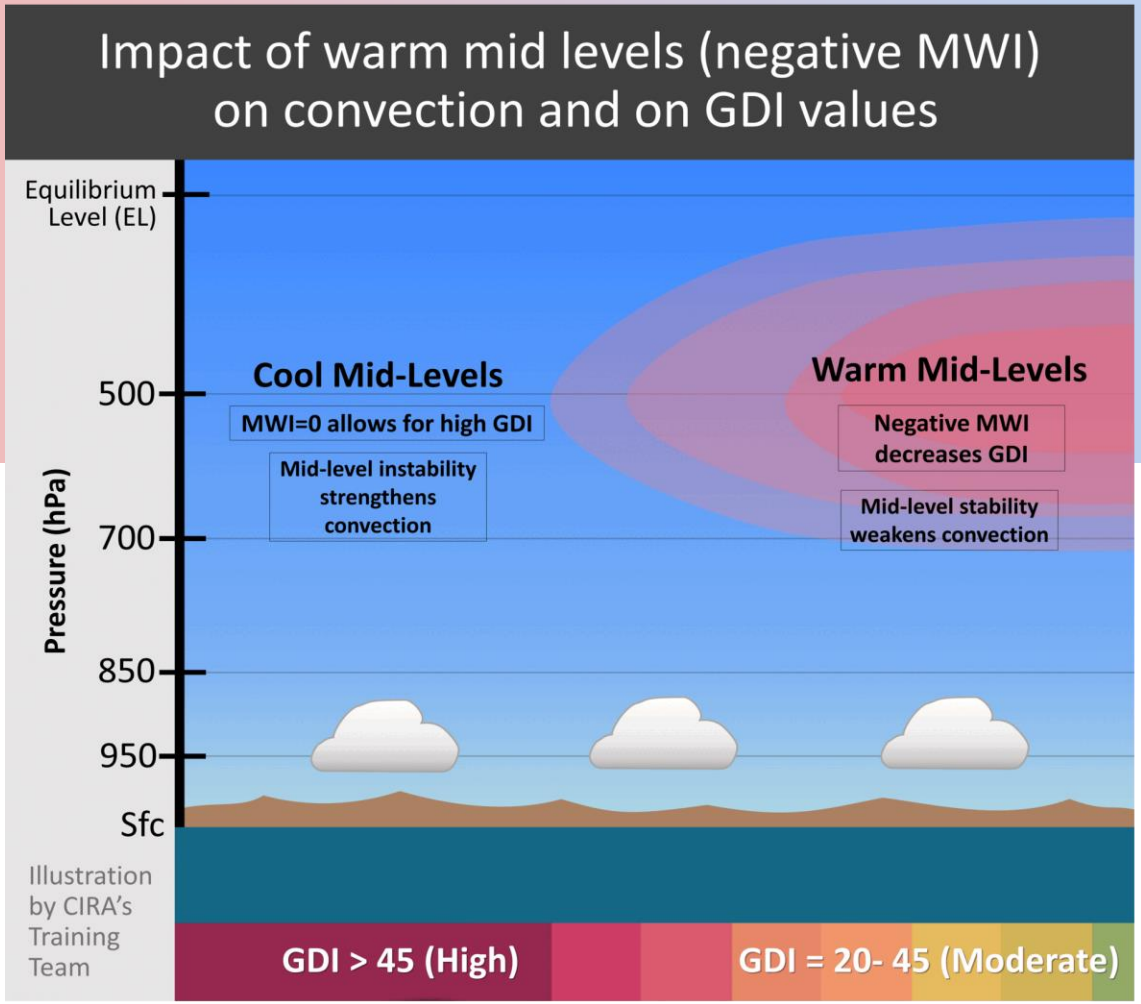
Occurs when θe is high at 950 and 500 hPa. Assumes 850 and 700 hPa also have high θe. If this were not the case, the Inversion Index (II) will account for it.

# 2) Mid-level Warming Index (MWI)




- **Describes the stabilizing impacts of warm air in the mid-troposphere. This limits convective growth, and tends to reduce storm size and the heavy rainfall potential.**

- **Calculated with 500 hPa temperatures.**

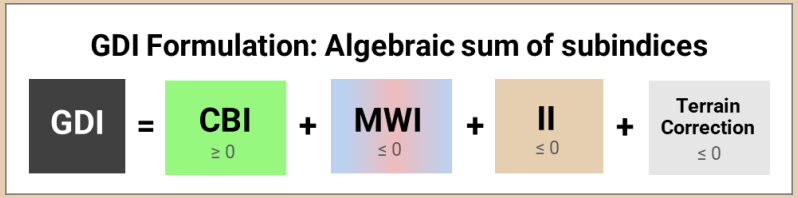


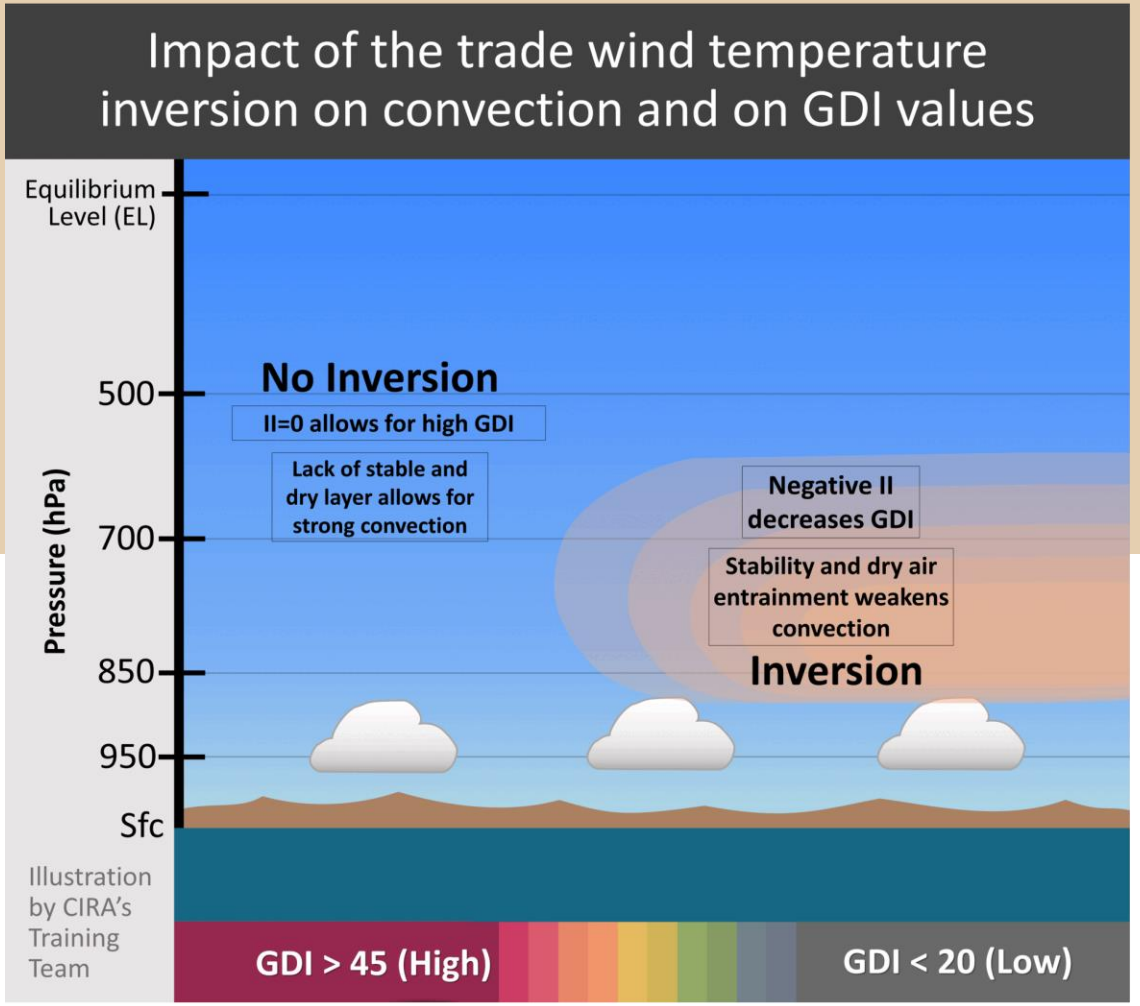

- MWI can only be zero or negative.

- Impacts on the GDI: MWI turns more negative the warmer the mid-troposphere becomes. This lowers the GDI, signaling that convection might not become too strong and/or widespread.

# 3) Inversion Index (II)

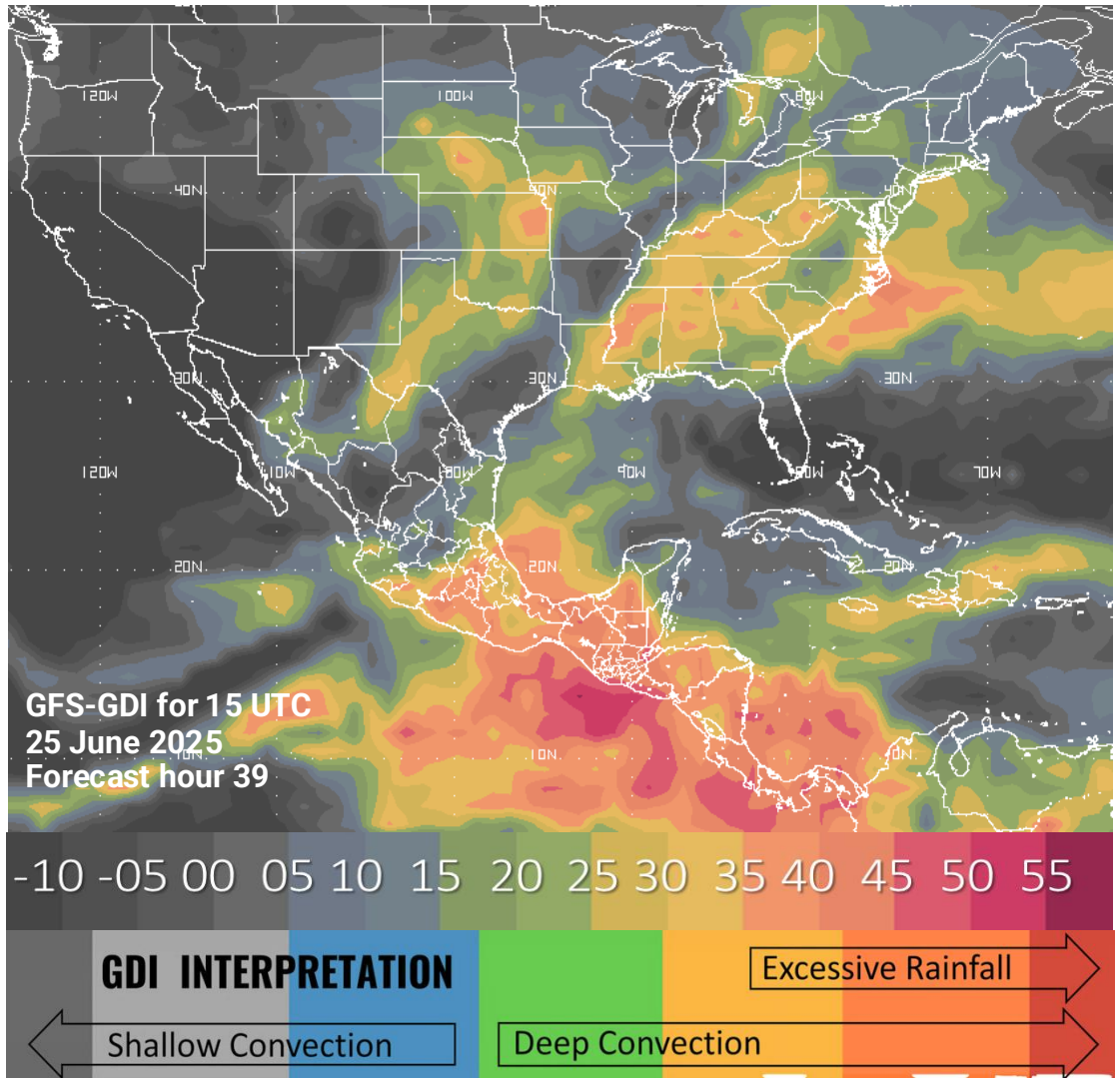
**Describes the impacts of stabilization and dry air entrainment associated with trade wind inversions, which are detrimental to robust convection. The II evaluates 950-700 hPa lapse rates for stability, and θe differences between 950 and the 850-700 hPa layer for dry air.**




- II can only be zero or negative.
- Impacts on the GDI: The more stable and/or dry, the more negative II. This lowers the GDI, signaling that convection that forms might not be strong and deep.

# GDI Value Interpretation




- A general interpretation color scale is commonly used. Yet, interpretation is sensitive to seasonal and diurnal cycles; local climate and atmospheric dynamics.
- GDI<15 generally implies shallow convection with low heavy rain potential.
- GDI>35 implies an increased potential for deep convection and increasing chances for heavy rainfall.
- Once GDI>50, the chances for heavy rainfall increase.

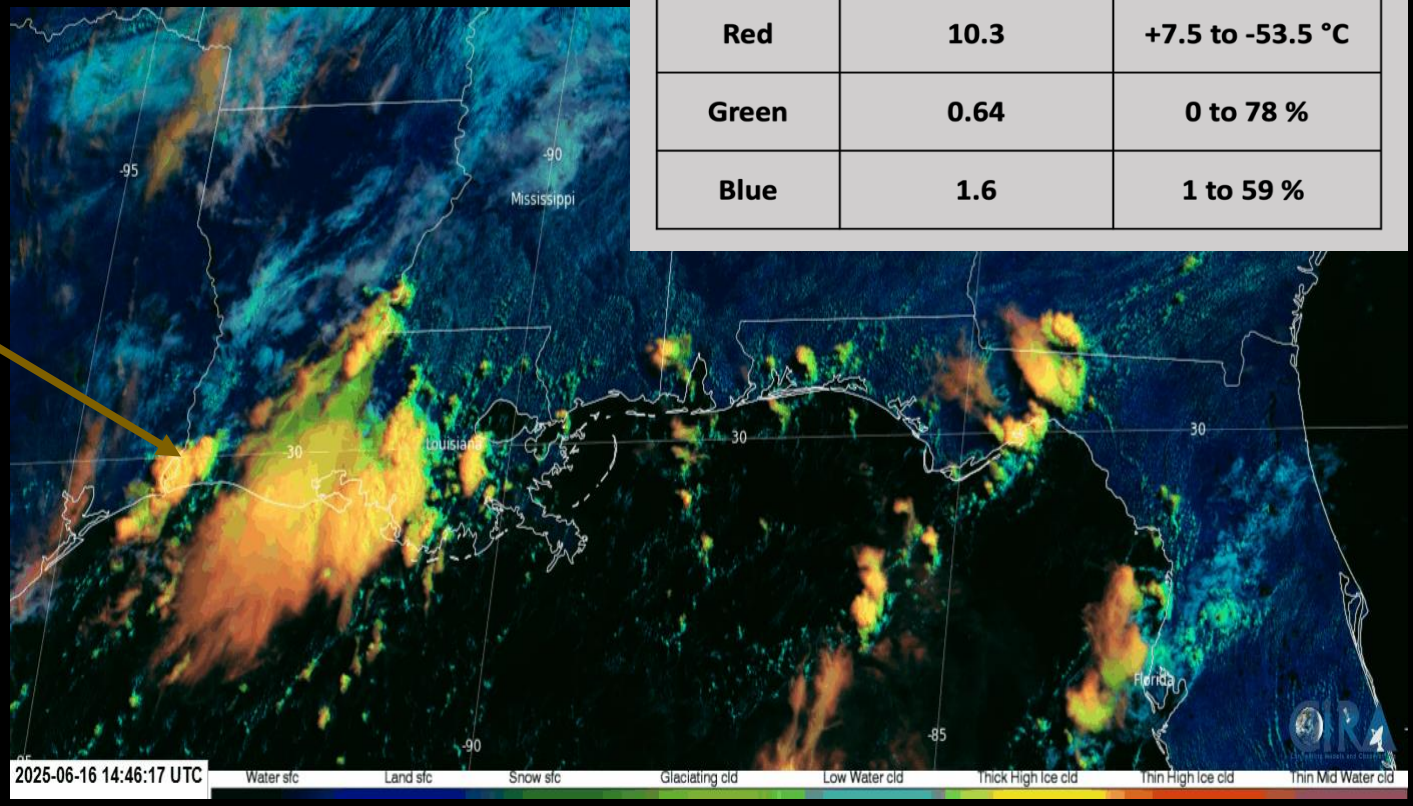
# GDI Verification with Satellite Products

## Day Cloud Phase Distinction RGB

- Detects water clouds (greens/blues) vs ice clouds (yellows/reds).
- Deep convection looks like round yellow features often growing with time.
- Yellow = thick ice clouds. When dense convective clouds develop vertically and reach subfreezing temperatures, they develop ice and appear yellow in this RGB.
- This is why this RGB is a great tool to evaluate “convective initiation”, and we will use it to evaluate the GDI.

Day Cloud Phase Distinction RGB Recipe

| Color | Band (µm) | Min to Max |
|---|---|---|
| Red | 10.3 | +7.5 to -53.5 °C |
| Green | 0.64 | 0 to 78 % |
| Blue | 1.6 | 1 to 59 % |



# GDI Verification with Satellite Products

## Day Cloud Phase Distinction RGB

- As nighttime sets in, the green and blue features disappear. This is because they depend upon reflective bands.
- The red component of the RGB, however, contains the 10.3um or long wave IR band, which does not depend on sunlight.
- So at nighttime, only cold cloud tops can be seen, and they appear red.

Day Cloud Phase Distinction RGB Recipe

| Color | Band (µm) | Min to Max |
|---|---|---|
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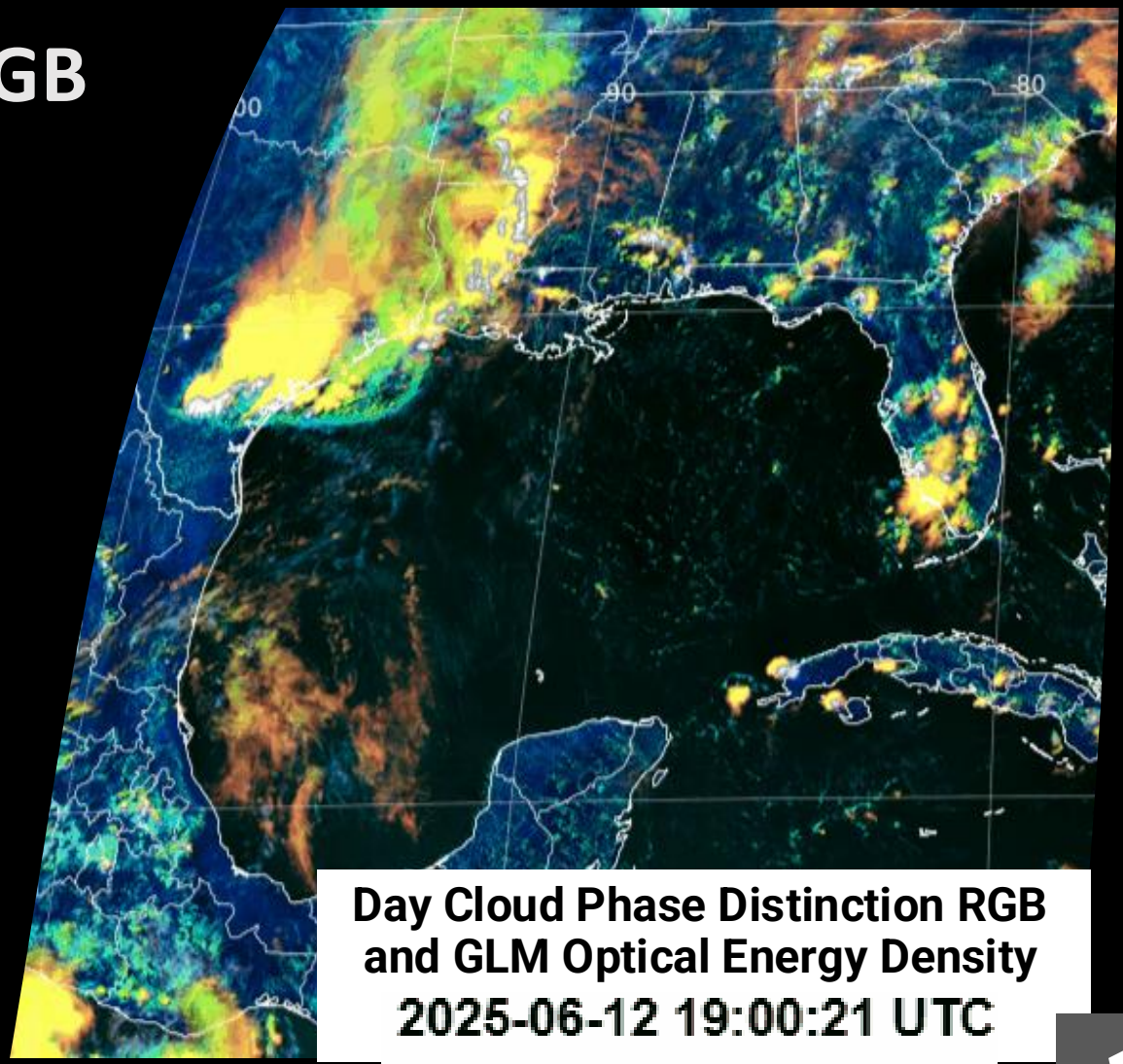
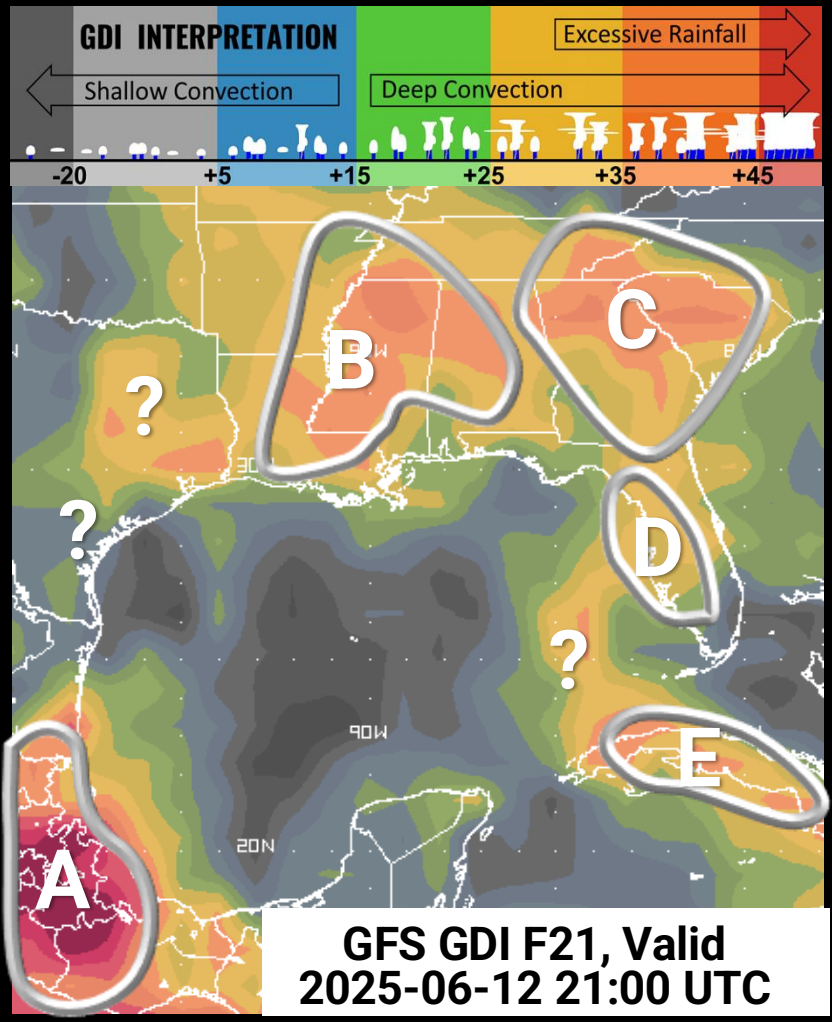
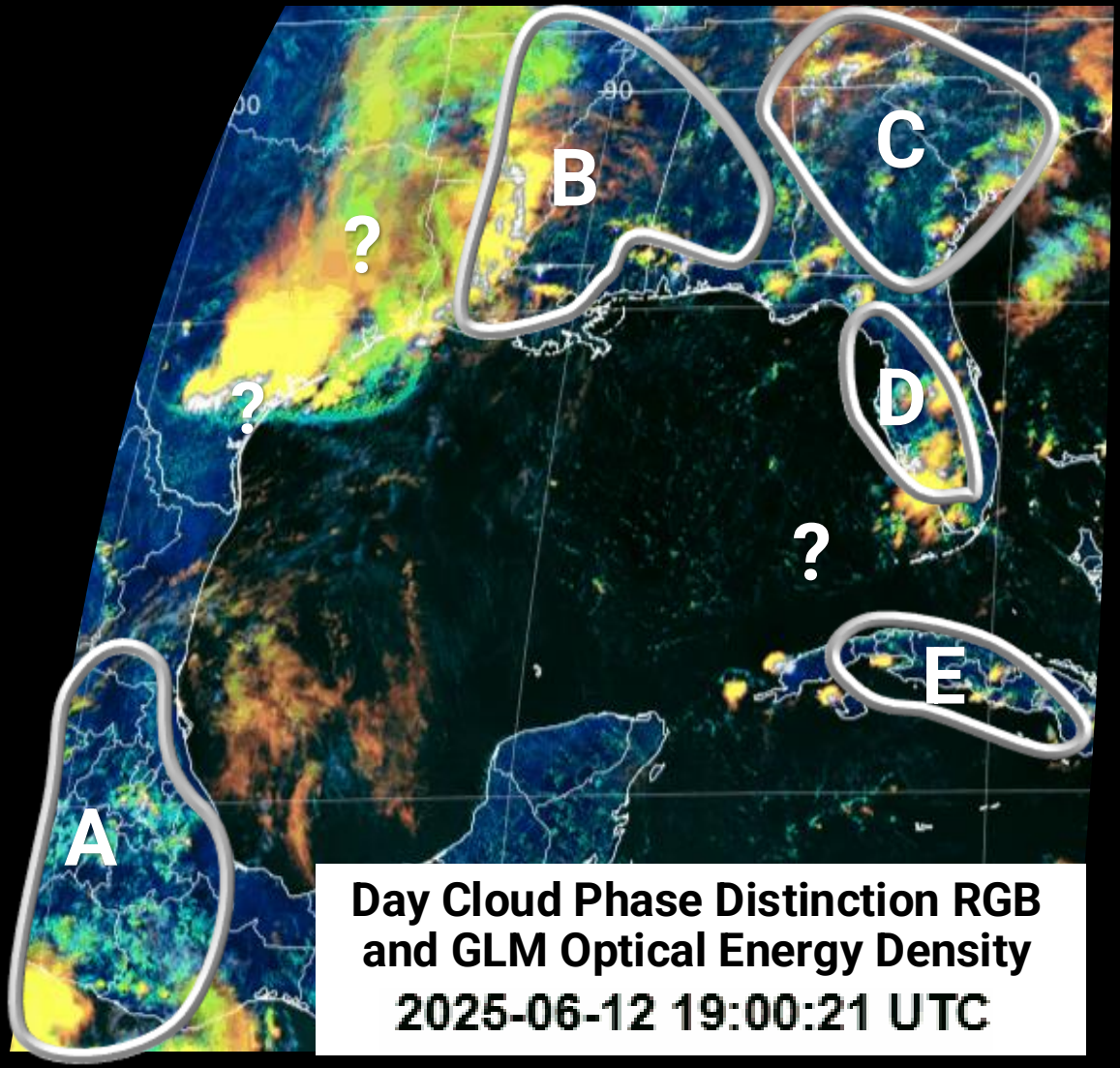


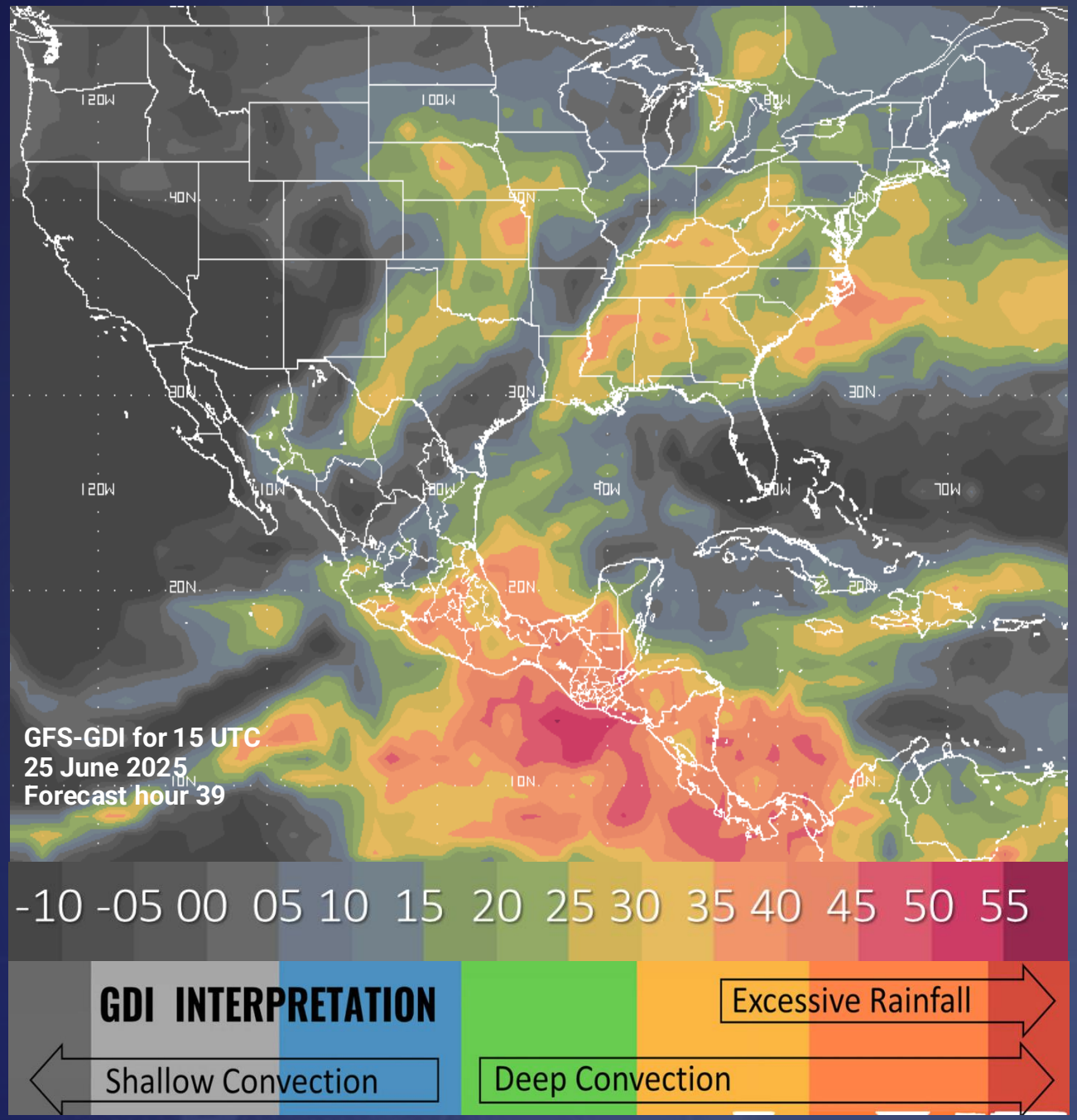
# Did the GDI capture all areas with deep convection?




GFS GDI F21, Valid
2025-06-12 21:00 UTC




Day Cloud Phase Distinction RGB
and GLM Optical Energy Density
2025-06-12 19:00:21 UTC

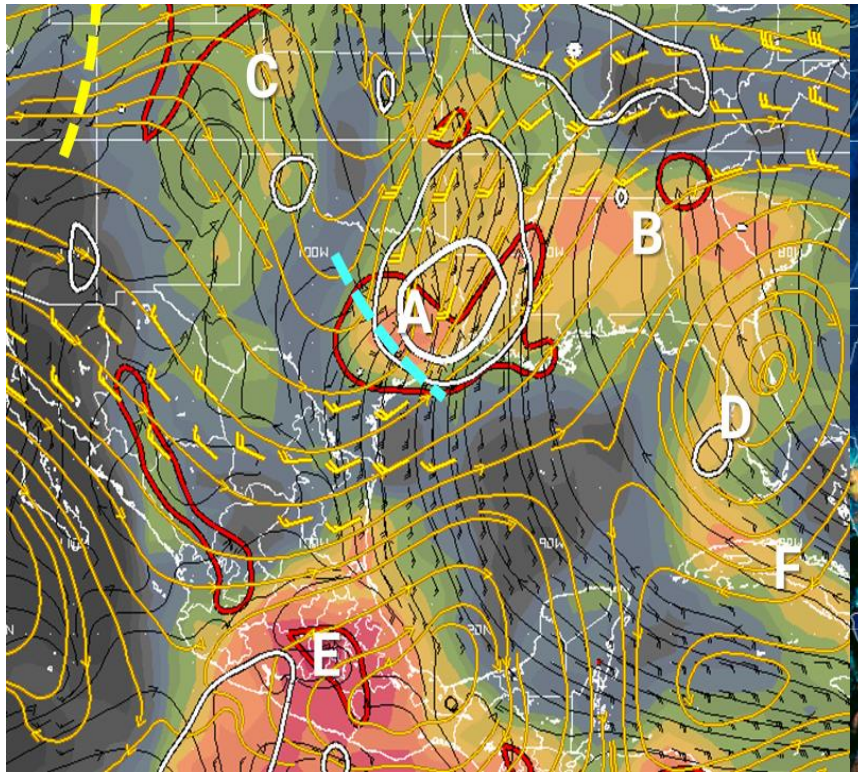



# Let's pause and analyze satellite imagery vs the GDI

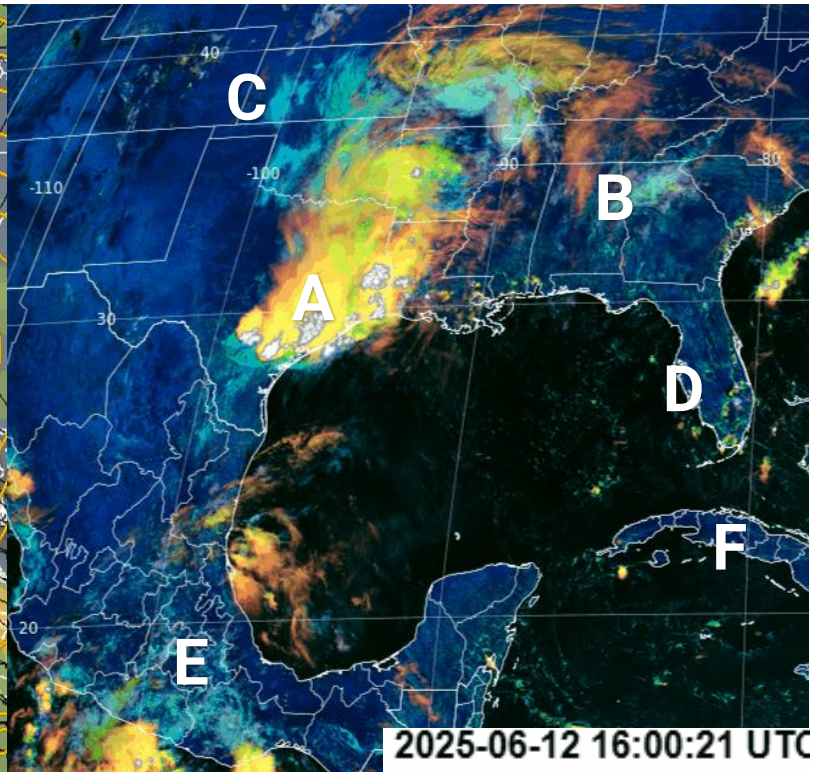
# Importance of considering the dynamics and moisture products

# Why considering dynamics when using the GDI as a forecasting tool?

- Because the GDI does not consider winds, so it does not assess triggering mechanisms.
- An analysis of the dynamics suggests the location of atmospheric motions that could trigger convection and stimulate the use of GDI (point A), or those that could favor descent and limit the ability of parcels to use GDI to create convection (point C).
- The diurnal cycle also matters. In points B, E and F, convection is only starting.




Galvez-Davison Index (GDI)
Including 1000-850 hPa averaged windsin kt (black), 400-200 hPa averaged winds in kt (yellow), 1000-850 hPa moisture convergence > (red contours) and 300-200 hPa upper divergence (white contours)




Day Cloud Phase Distinction RGB

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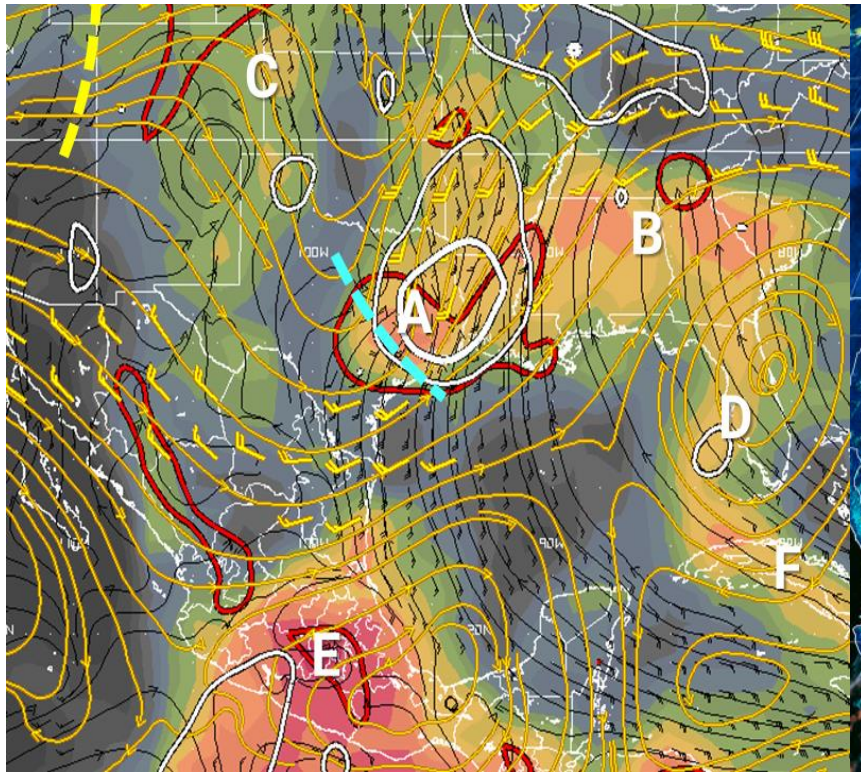


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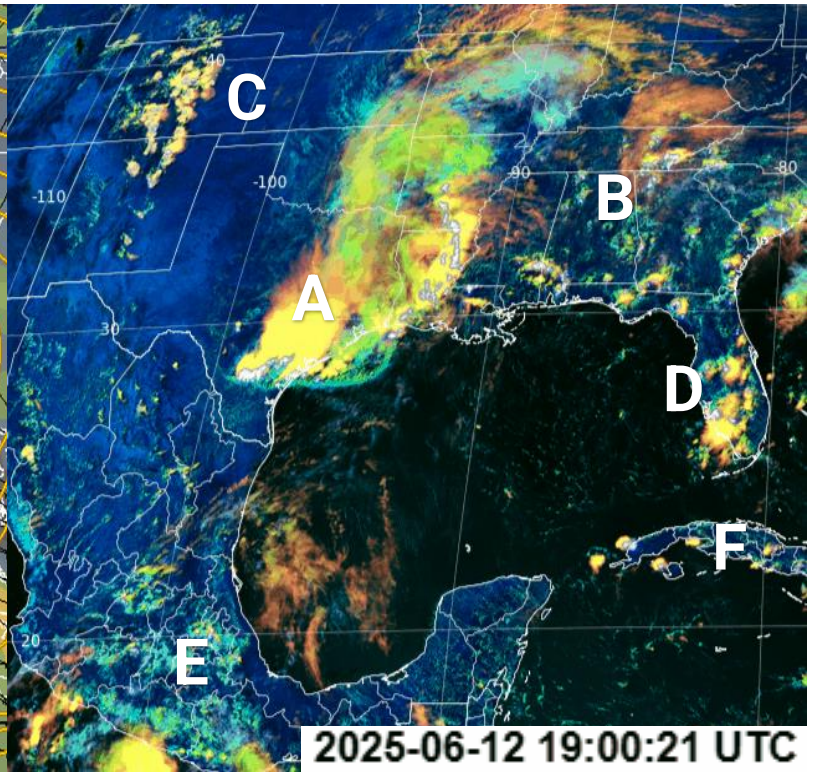
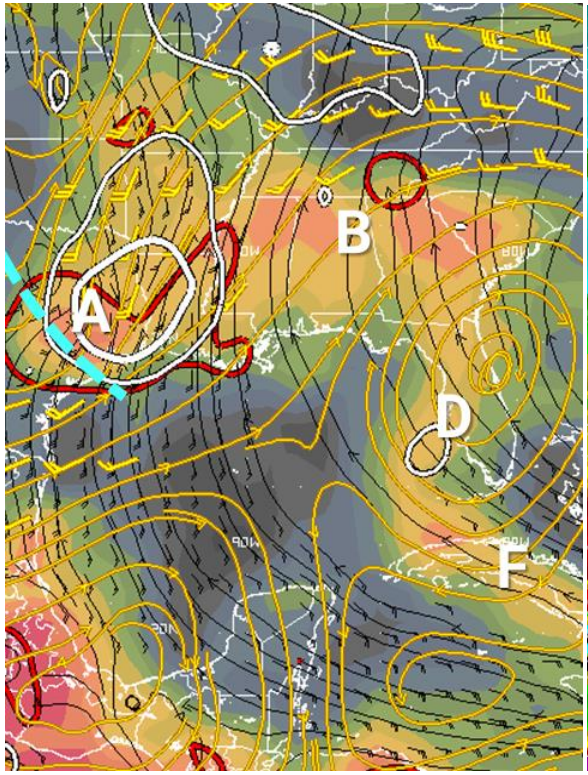


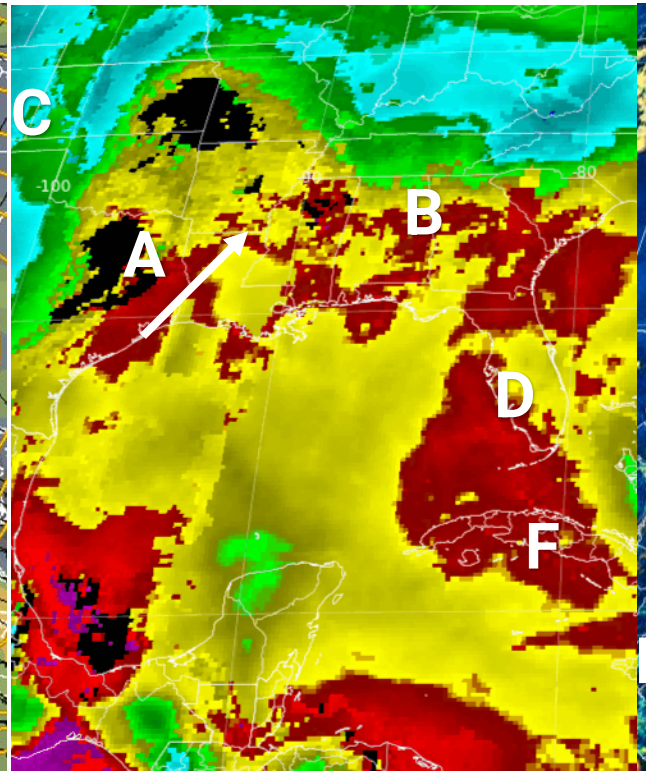

Day Cloud Phase Distinction RGB

# Precipitable Water Products

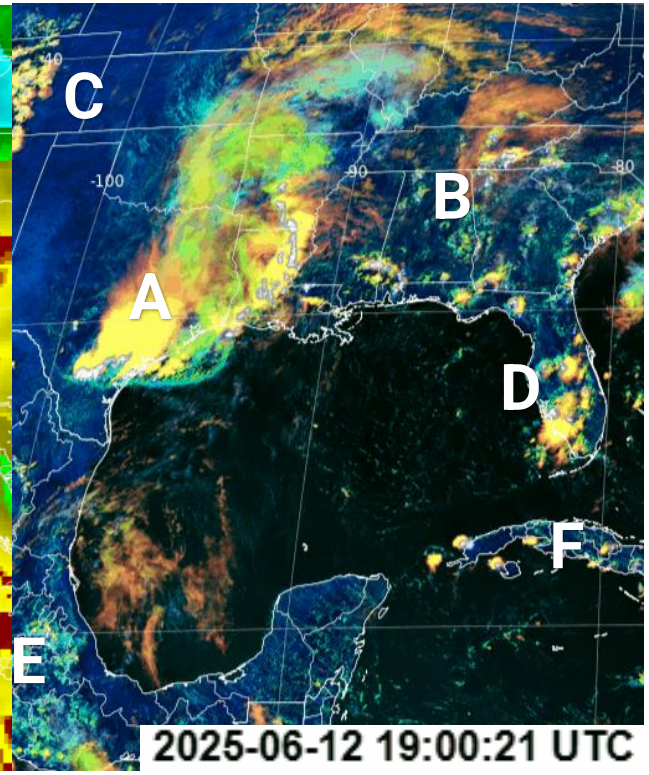
- The arrival of a plume of high precipitable water values can enhance the ability of the atmosphere to generate convection and use GDI.
- Low-level moist plumes are particularly important, so the ALPW SFC-850 hPa product is important.



GDI and Flow



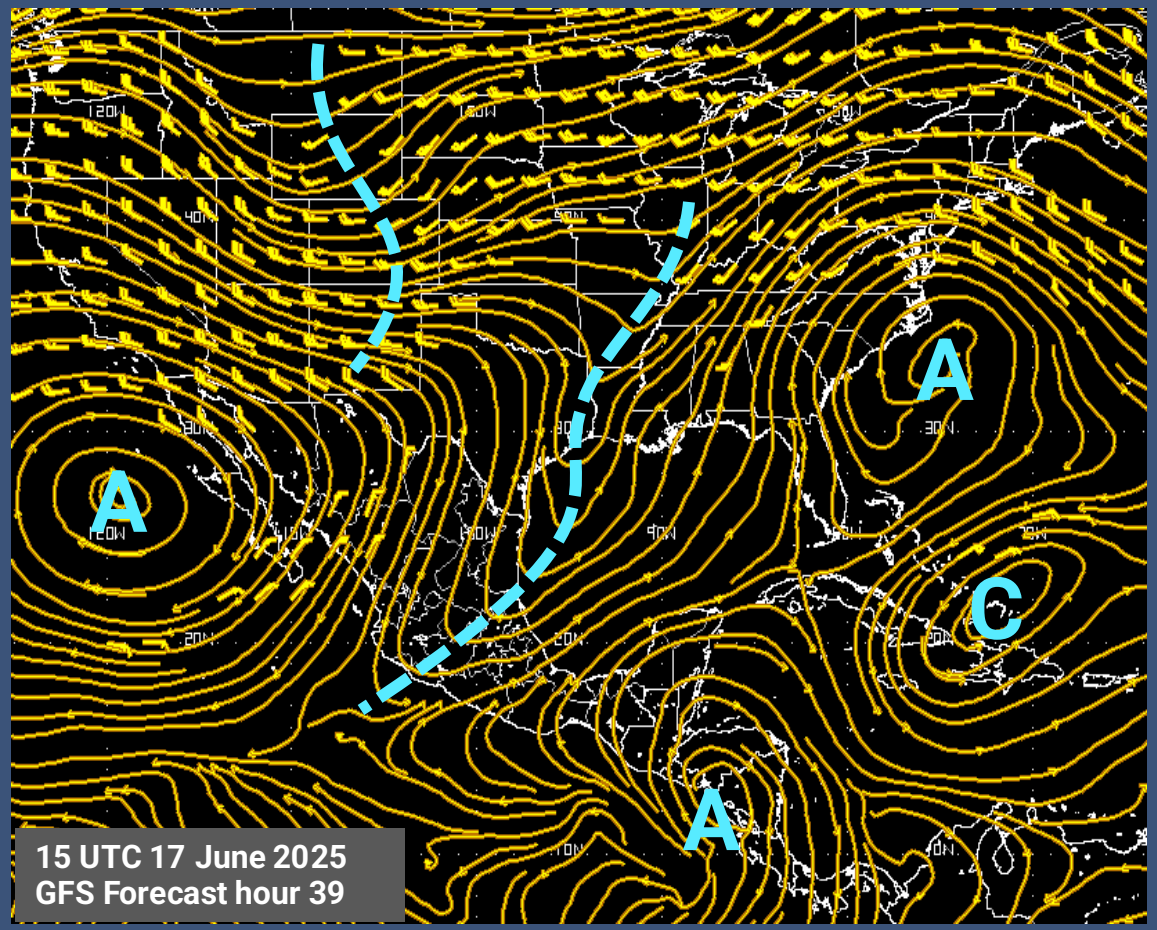
Total Precipitable Water



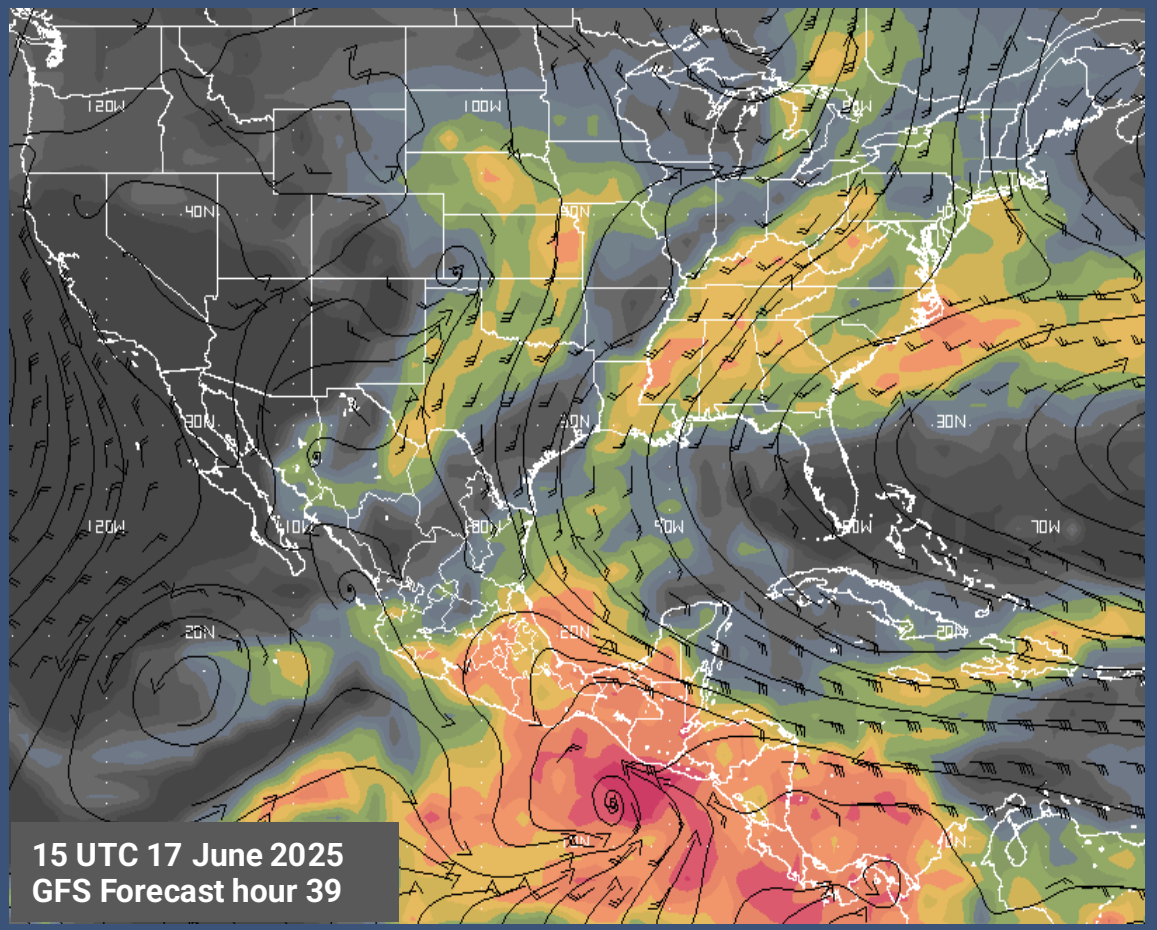
Day Cloud Phase Distinction RGB

# Let’s analyze current conditions

# Upper Flow vs GDI and Low-Level Flow

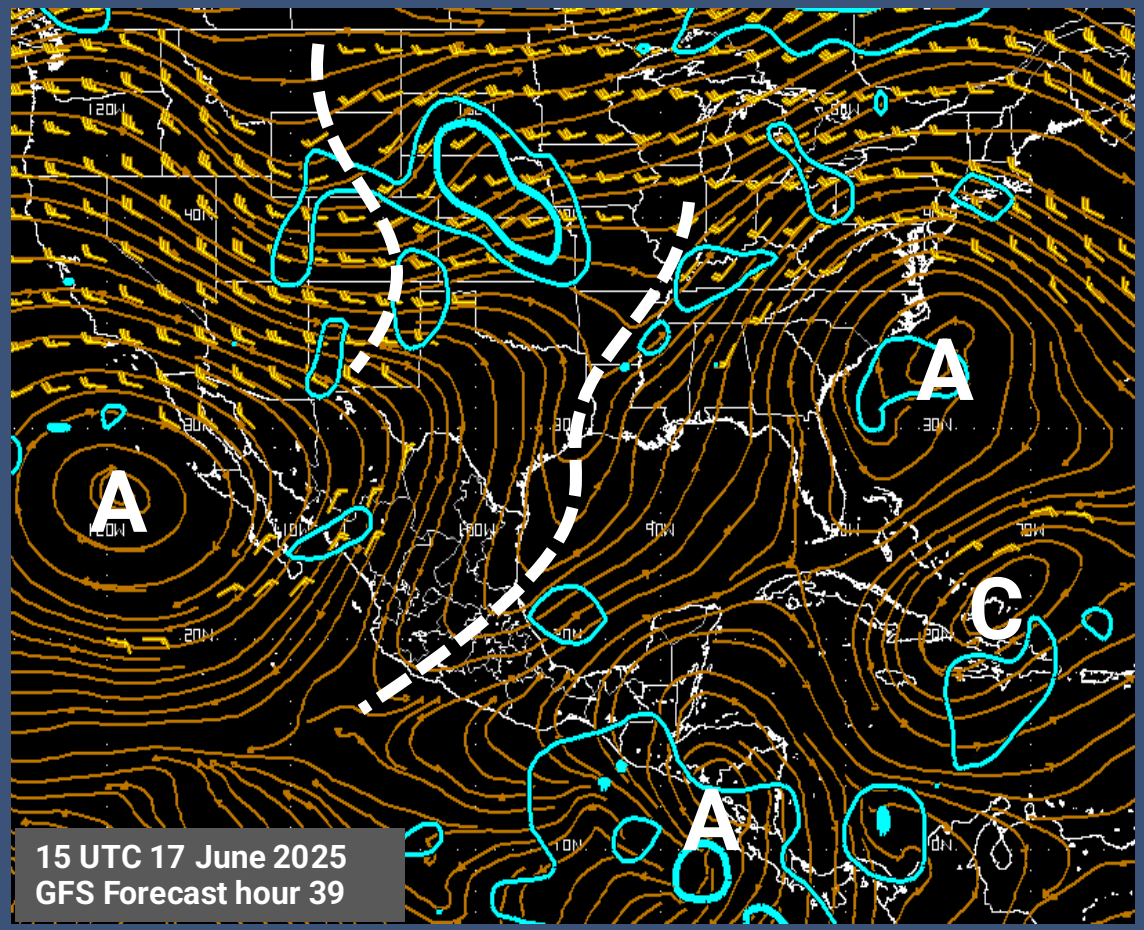



400-200 hPa averaged winds in kt (yellow)

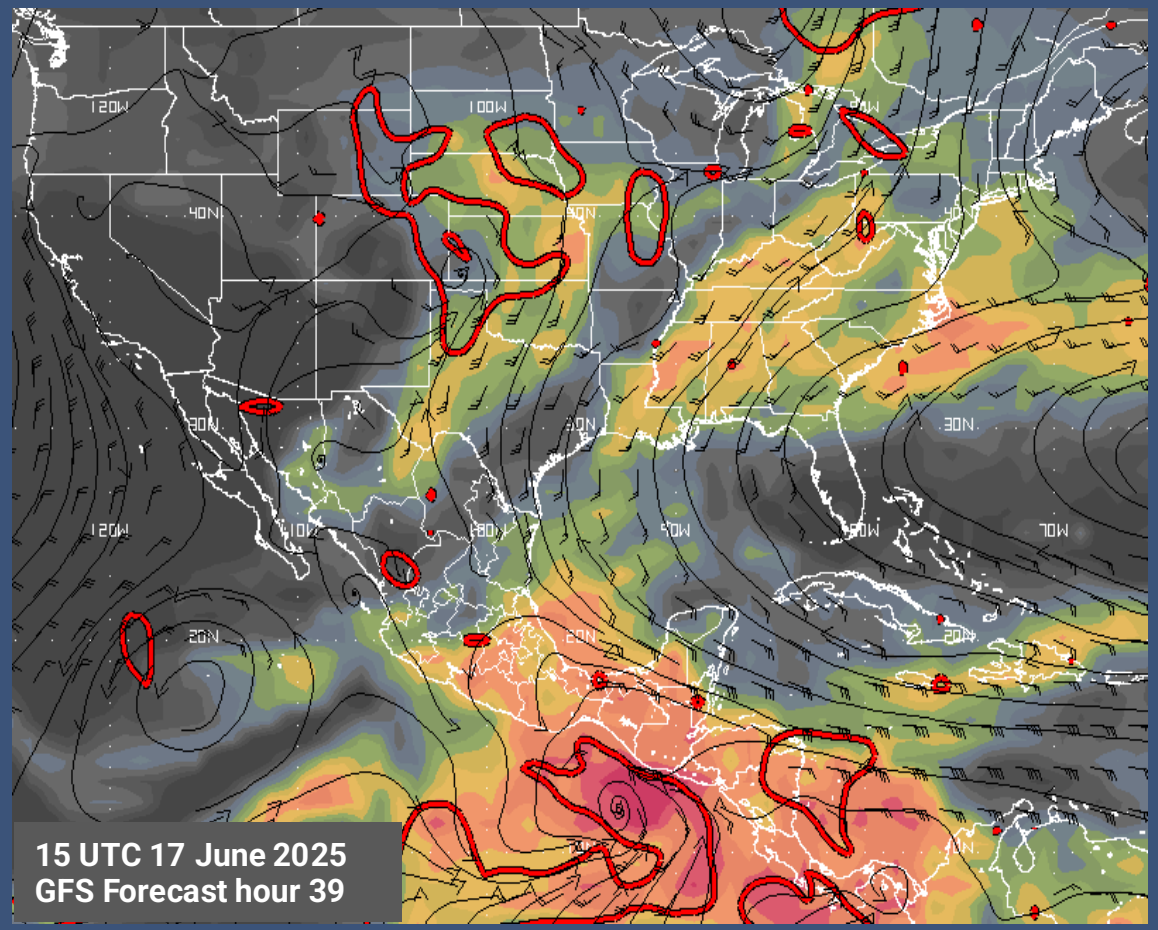



GDI and 1000-850 hPa averaged winds in kt (black)

# Upper Flow vs GDI and Low-Level Flow

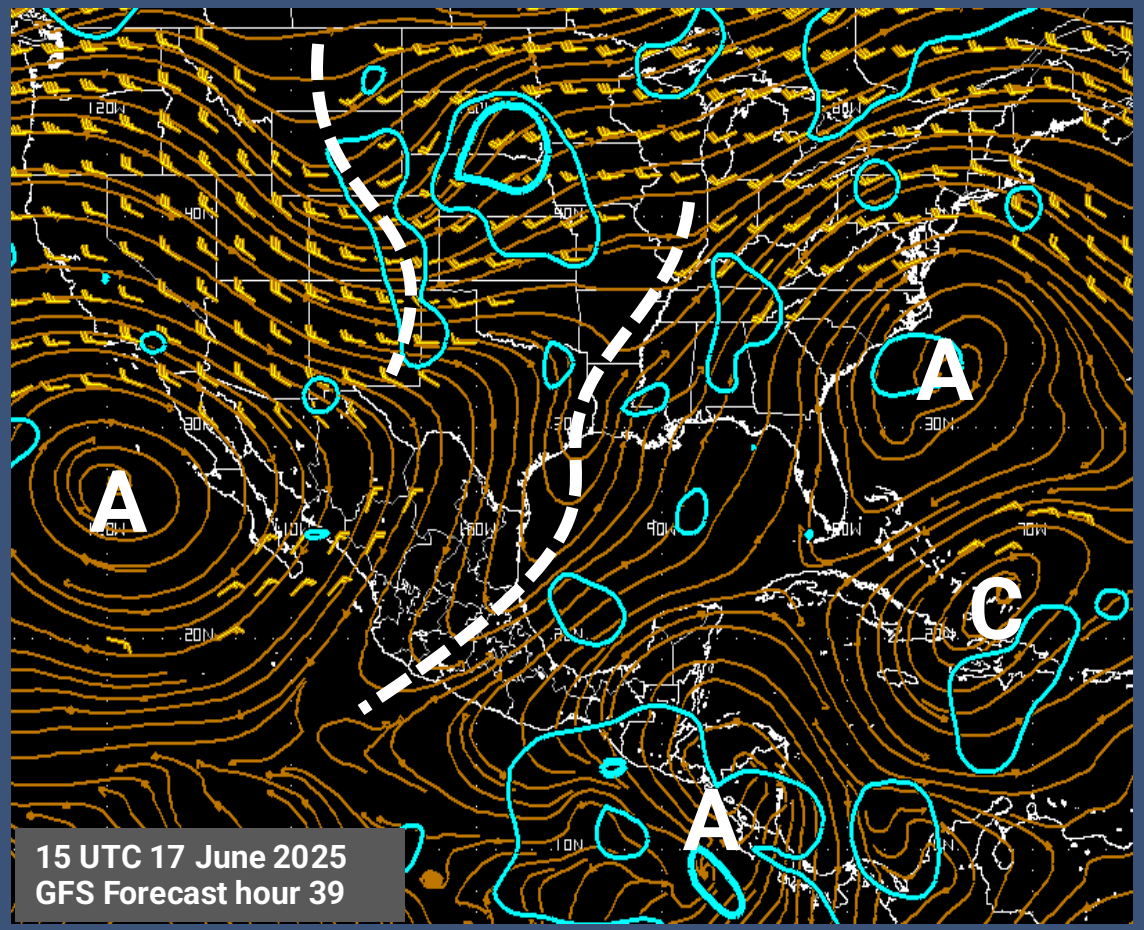



400-200 hPa averaged winds in kt (yellow)

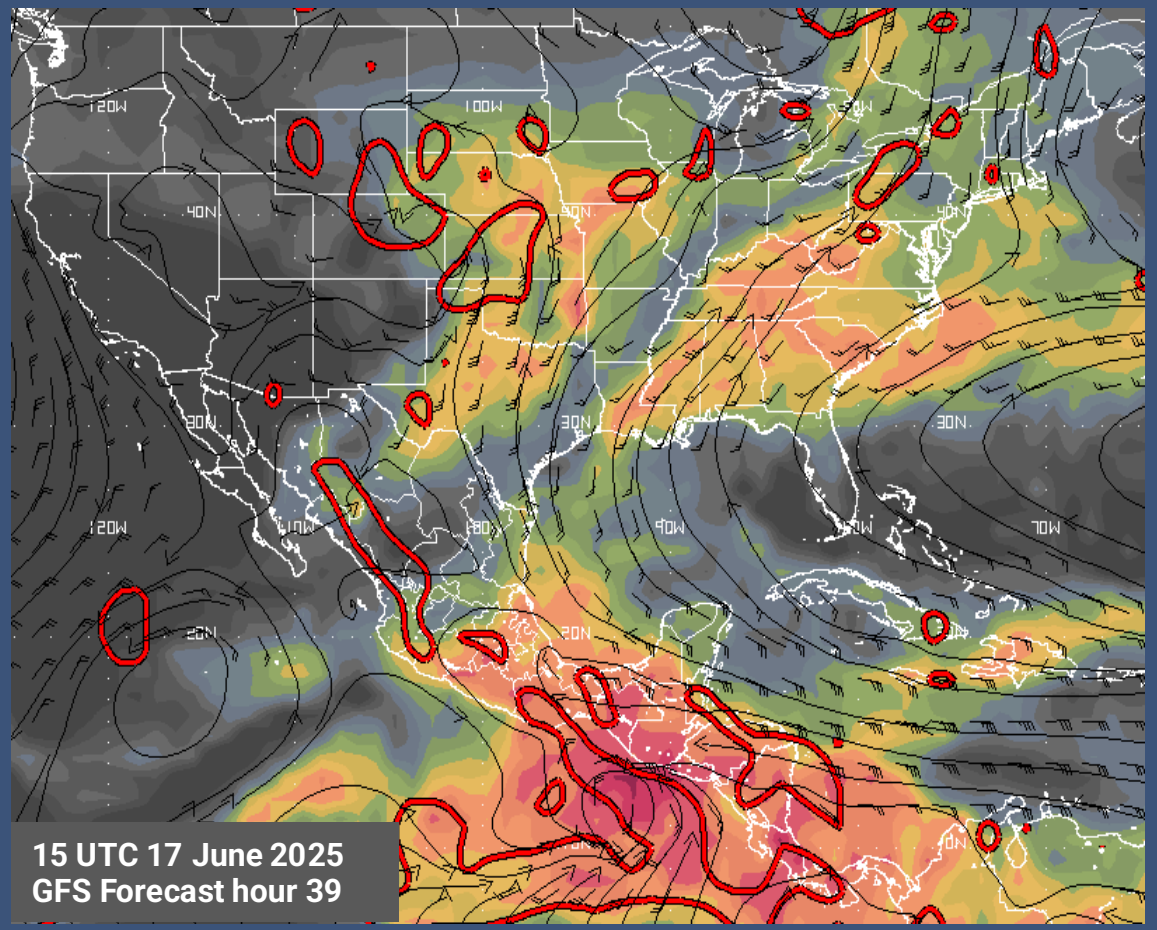



GDI and 1000-850 hPa averaged winds in kt (black)

# Upper Flow vs GDI and Low-Level Flow




400-200 hPa averaged winds in kt (yellow)




GDI and 1000-850 hPa averaged winds in kt (black)

# Thank you!

# Additional Slides

# The Galvez-Davison Index (GDI)

This special session on the Galvez-Davison Index (GDI) will explore the science behind its calculation and demonstrate its application in forecasting various types of convection and rainfall occurring during the session. The session will emphasize the importance of integrating complementary tools into the analysis, to provide a more comprehensive understanding of atmospheric conditions and their response to GDI values. Particular attention will be given to the use of satellite-based diagnostics for assessing moisture availability, and numerical model guidance to assess atmospheric dynamics.