Fronts and Shear Lines

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NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Topics

1st Part

- Fronts
  - Baroclinicity
  - Temp Advection
  - Vertical Structure
- Tools
  - Relative Humidity
  - Equiv. Potential Temp
  - FRONT. Macro
- Jets' Interaction
  - Frontogenesis
  - Frontolysis

2nd Part

- Shear Lines
  - Divergence vs. Diffluence
  - Frontal and Prefrontal
    - Concepts
  - Analysis
  - Satellite Applications

Rules

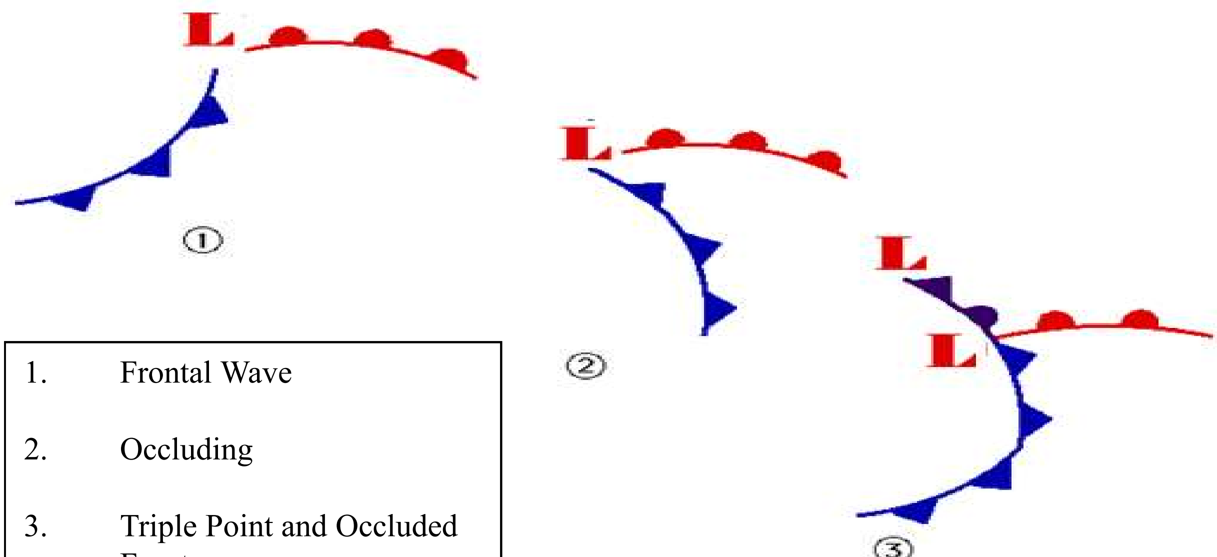
- Your participation is required
  - Partake of the poll questions to assess your understanding of the material

- Questions??
  - Use the chat box to send a text message(s)
  - Bernie, Jose and Kathy will be monitoring
    - They will answer and/or identify questions of common interest.

Surface Fronts

Fronts

- **Fronts**: The interface or transition zone between two air masses of different **density** (baroclinic)
  - Density depends on **temperature**
    - Moisture content plays a secondary role
  - ***Present weather not a requirement***.



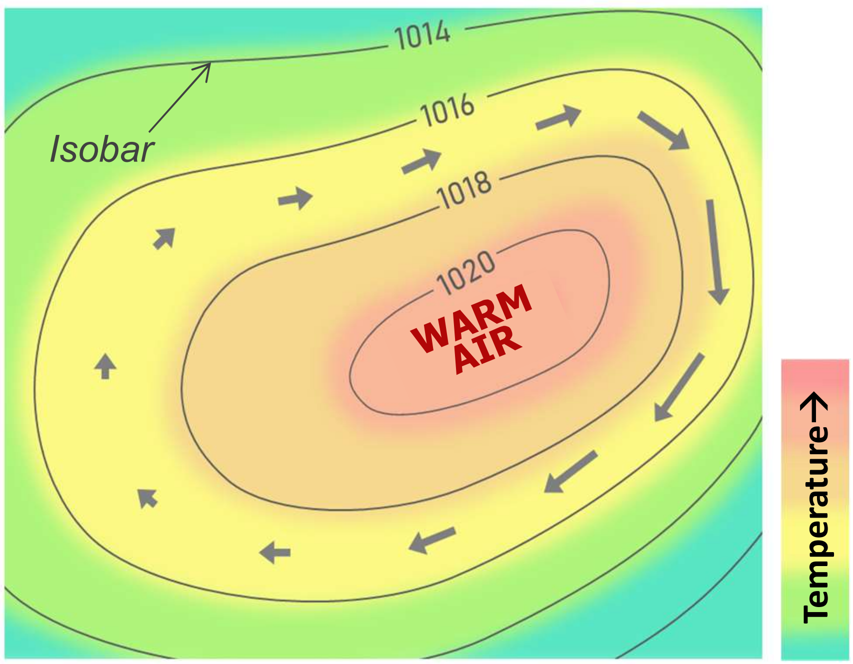
1. Frontal Wave
2. Occluding
3. Triple Point and Occluded Front

Baroclinic Boundaries

Baroclinic

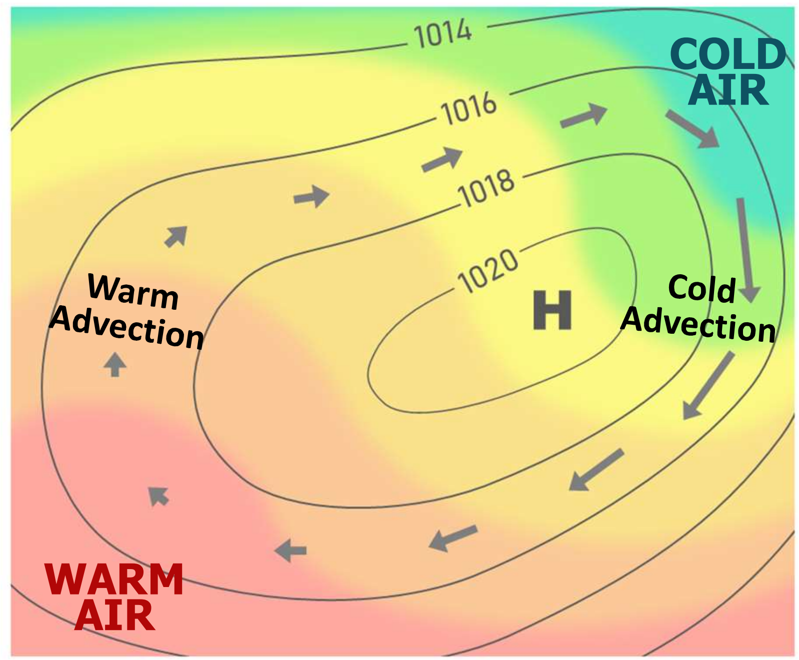
Note: Baroclinic implies temperature advection.

BAROTROPIC SYSTEM



-**NO** temperature advection.
-Isobars and isotherms are parallel

BAROCLINIC SYSTEM



-Isobars and isotherms are not parallel, in a cross-contour pattern
-Advection of temperature.

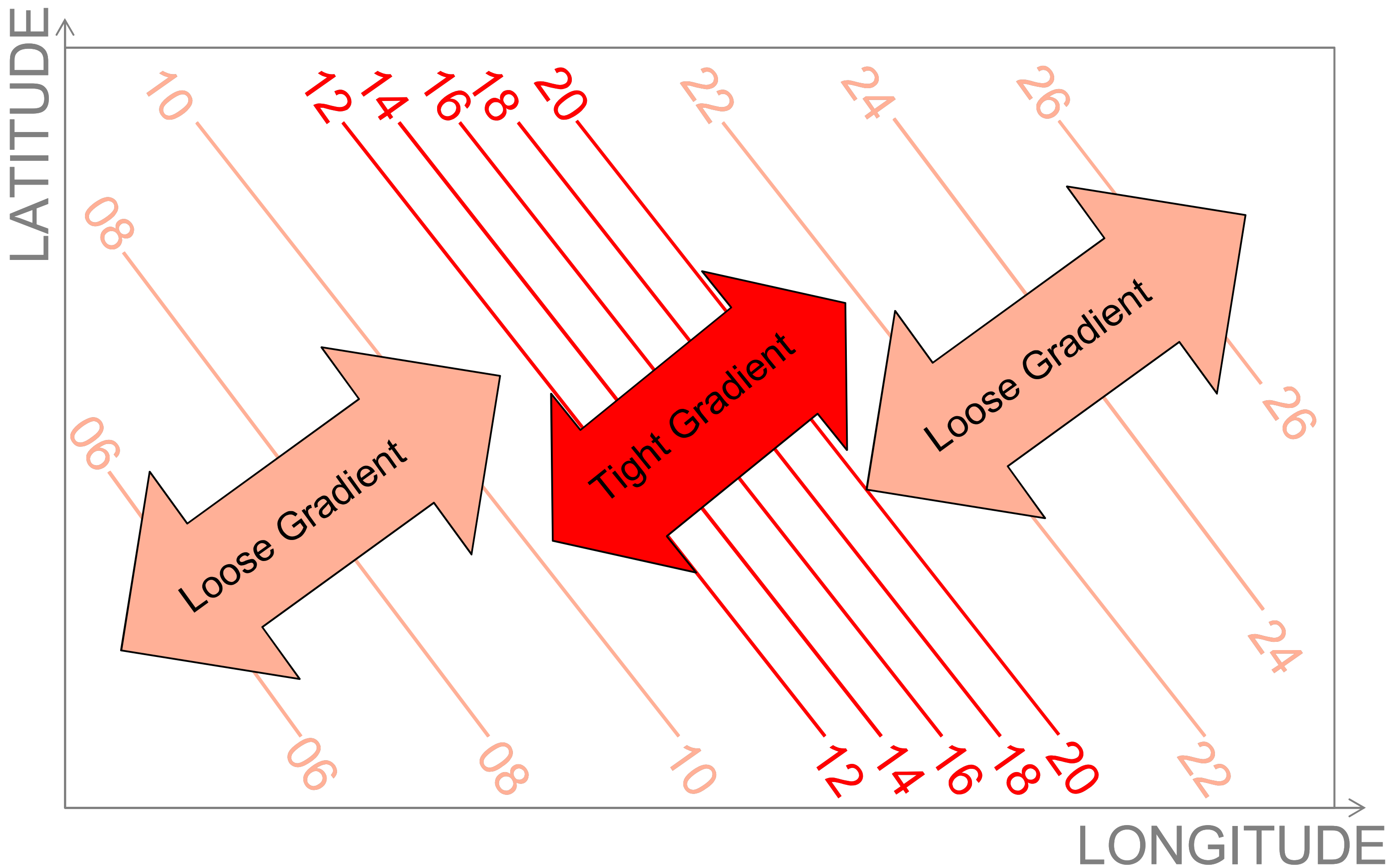
Defining Baroclinicity (Cont.)

- Since baroclinic implies advection of temperature, we can analyze for baroclinicity through gradients of temperature and/or thickness.

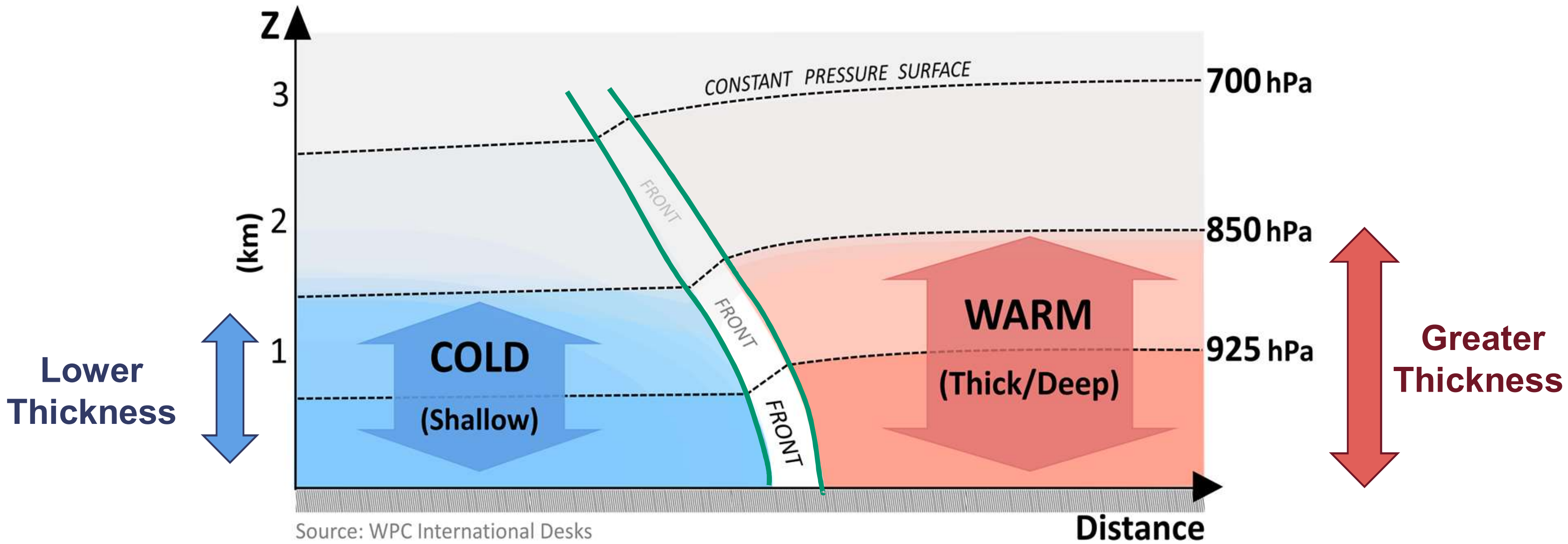
- Gradient measures how much a given variable changes over a set distance, in this case temperature. The rate of change determines the tightness of the gradient and strength of the boundary.
  - Without a thermal (density) gradient there is no front
  - First we need to identify the thermal gradients:
    - Thickness, like the isotherms, allow us to quickly determine warm vs. cold air masses.
      - Low thickness values implies cooler air
      - High thickness values implies warmer air

Gradients

- **What's a gradient?** An increase, or decrease, in the magnitude of a property over a given distance.
- **Example: Temperature** Gradient



Temperature and Thickness Relationship



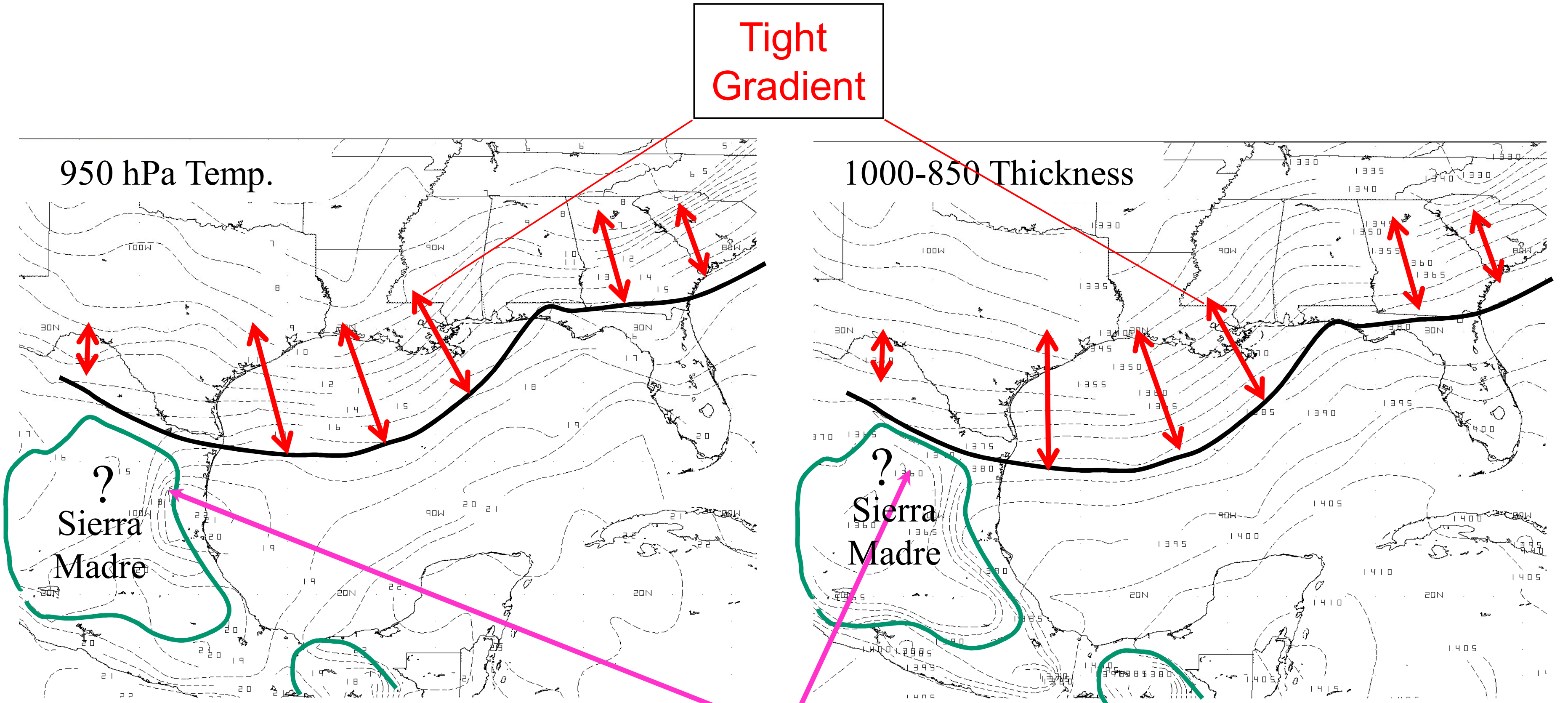
- The thickness of a layer is directly proportional to the mean temperature of that layer.
- Thus, we can analyze air masses by evaluating the layer difference rather than the temperature at a particular level.

Thickness ~ Mean Temperature of a Layer

Why use thickness instead of temperature?

- Provides a feel for vertical structure
  - Depth of the layer
- Reduces the diurnal/nocturnal temperature variability due to heating/cooling in the boundary layer
  - Acts as an “equalizer”

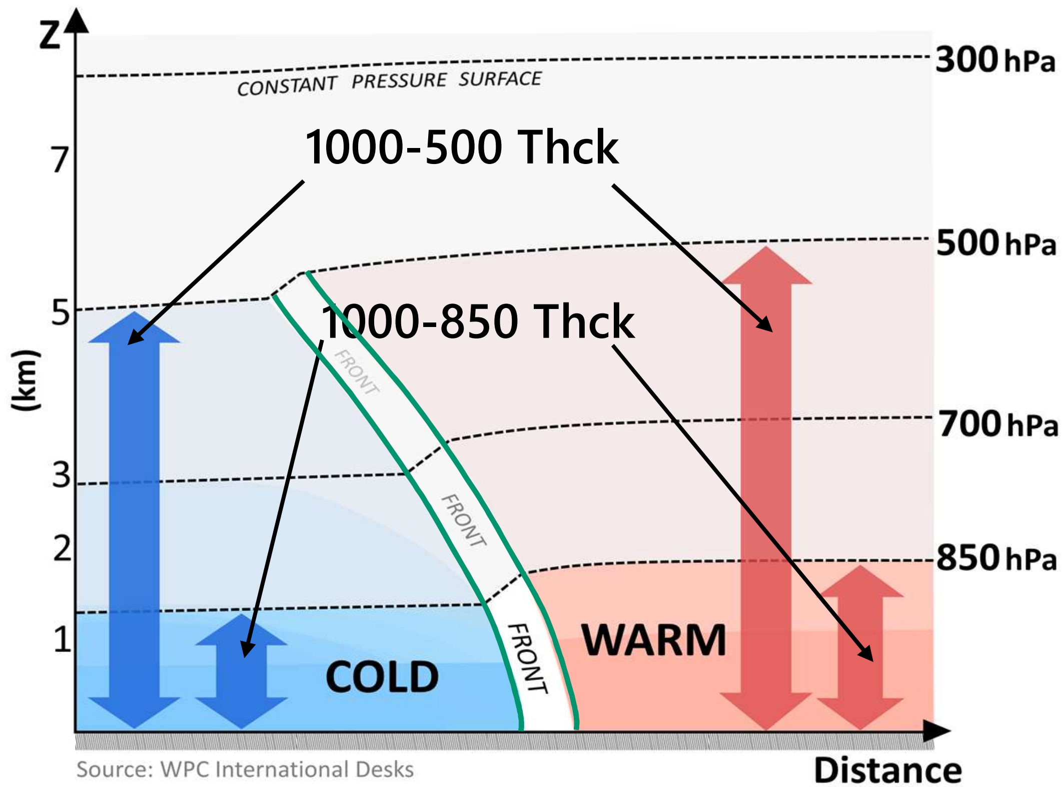
Example: 950 hPa Temp vs. 1000-850 hPa Thickness



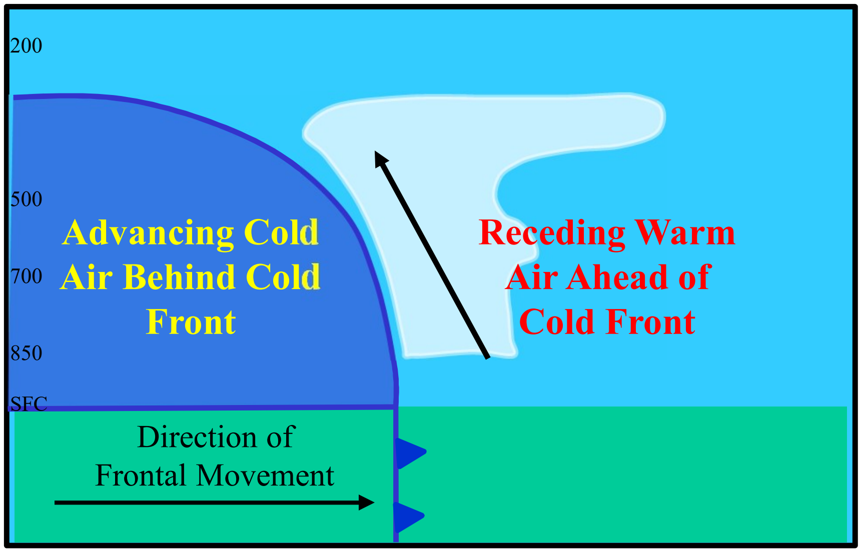
Non frontal, topographically induced gradients.
Very important to know the terrain!

1000 – 500 vs. 1000 – 850 hPa Thickness

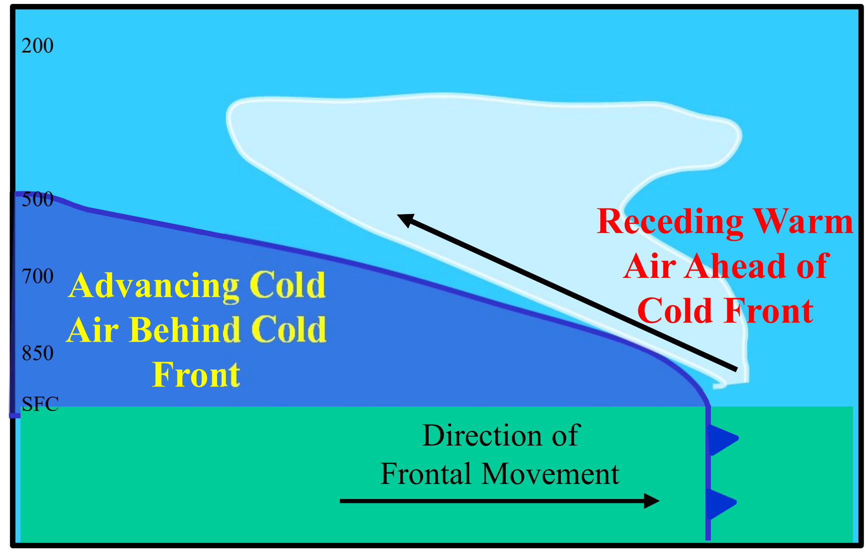
- In mid latitudes, where cold surges typically span the troposphere, the 1000-500 hPa thickness works well.
- Fronts entering the tropics are shallow and tend to confine to the lower atmosphere. Thus, it is better to use the 1000-850 hPa thickness.



Frontal Slope



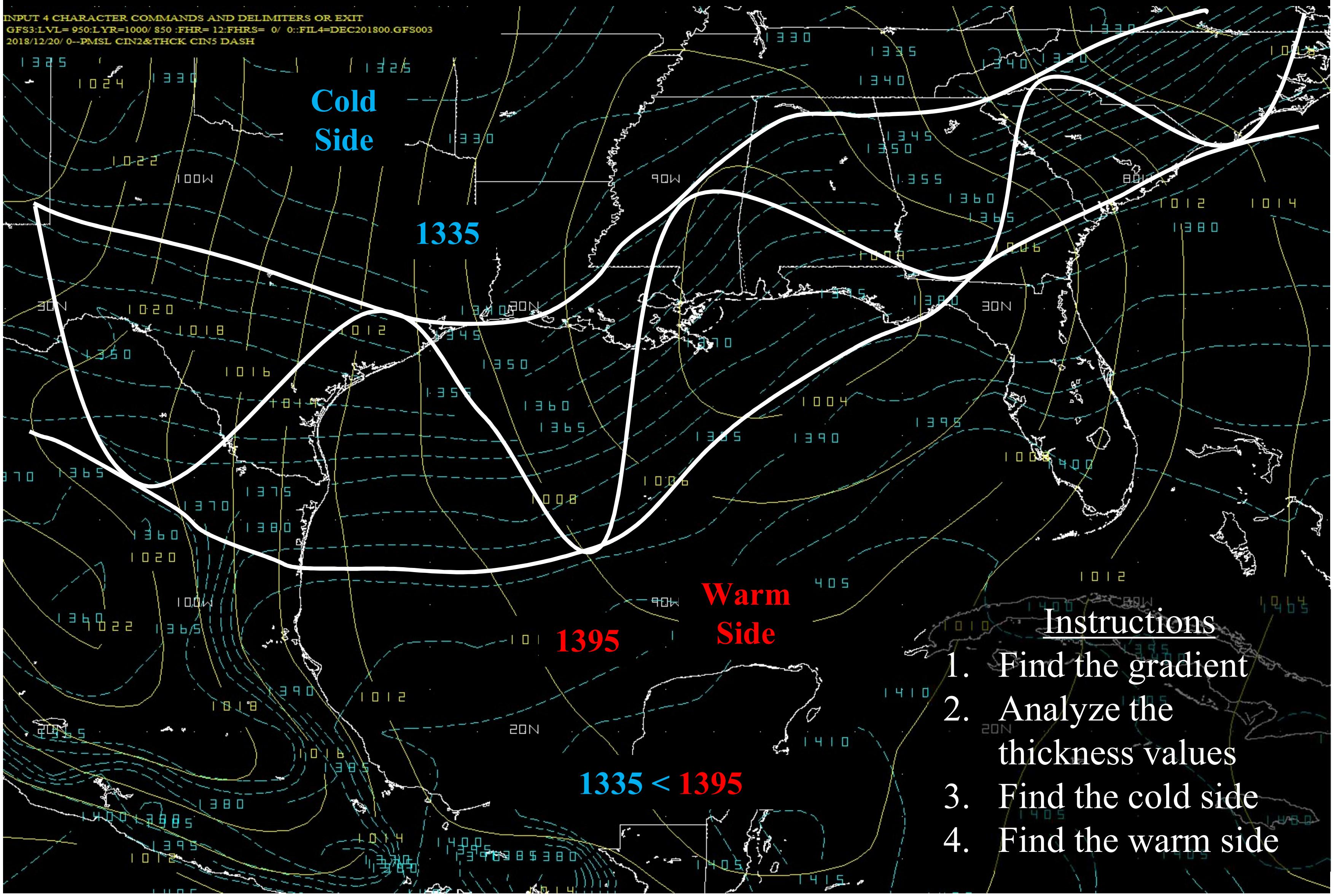
Steep frontal slope
Typical of a continental polar with upper level support.
1000-500 Thickness



Gradual/Gentler frontal slope
Typical of tropical polar maritime, lacks upper support.
1000-850 Thickness

1000 – 850 hPa Thickness

Which is the cold side?



Evaluating the Thermal Advection

What's required?

(1) Wind Flow ←Vector

(2) Temperature or Thickness ←Scalar Field

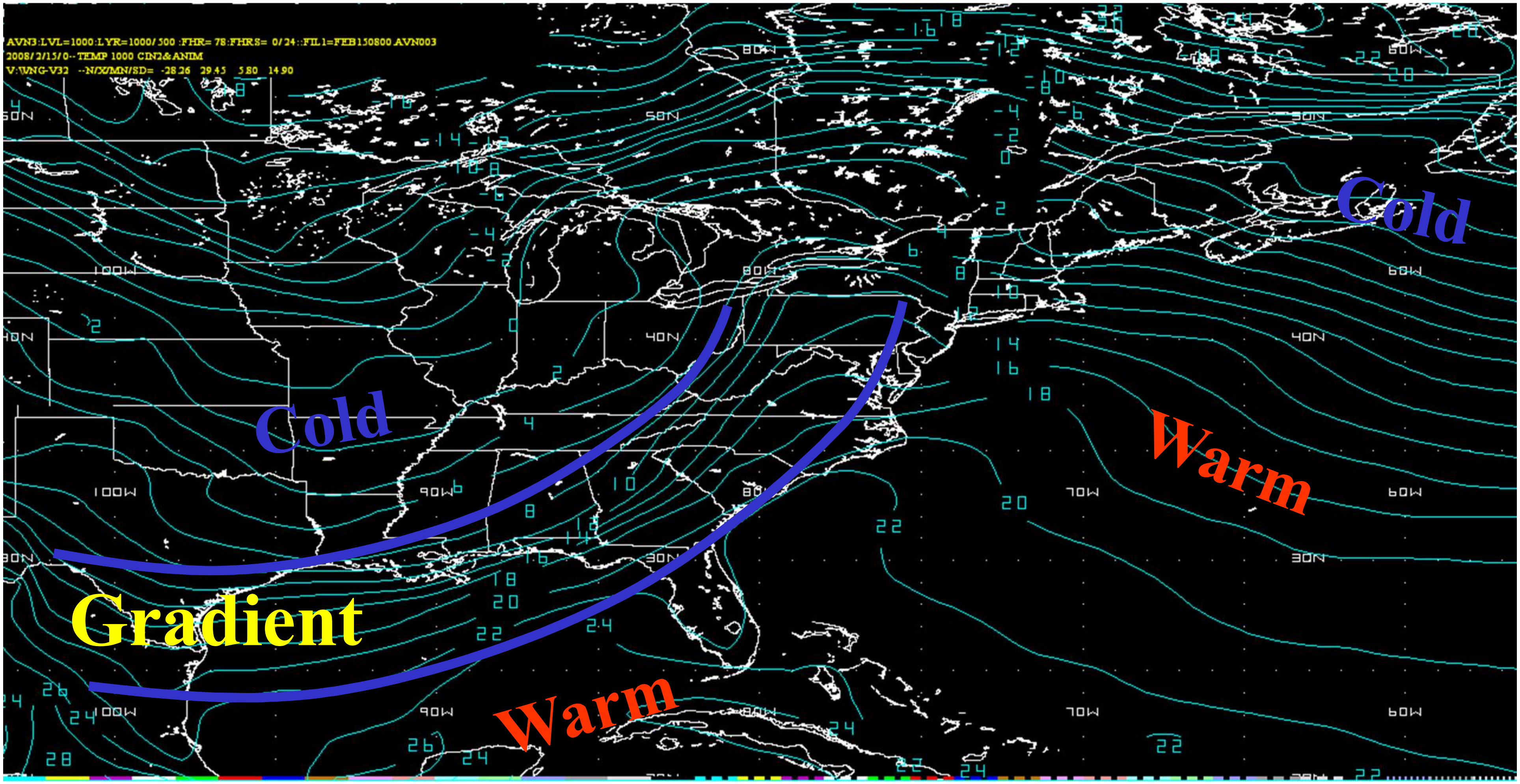
Wind Flow (Options)

- **Total Wind Vectors, barbs or streamlines**
- **Pressure or Geopotential Heights**
  - **Assuming geostrophic, wind vectors will lie "parallel" to the pressure contours, and their intensity will be a function on how tight the pressure gradient is.**

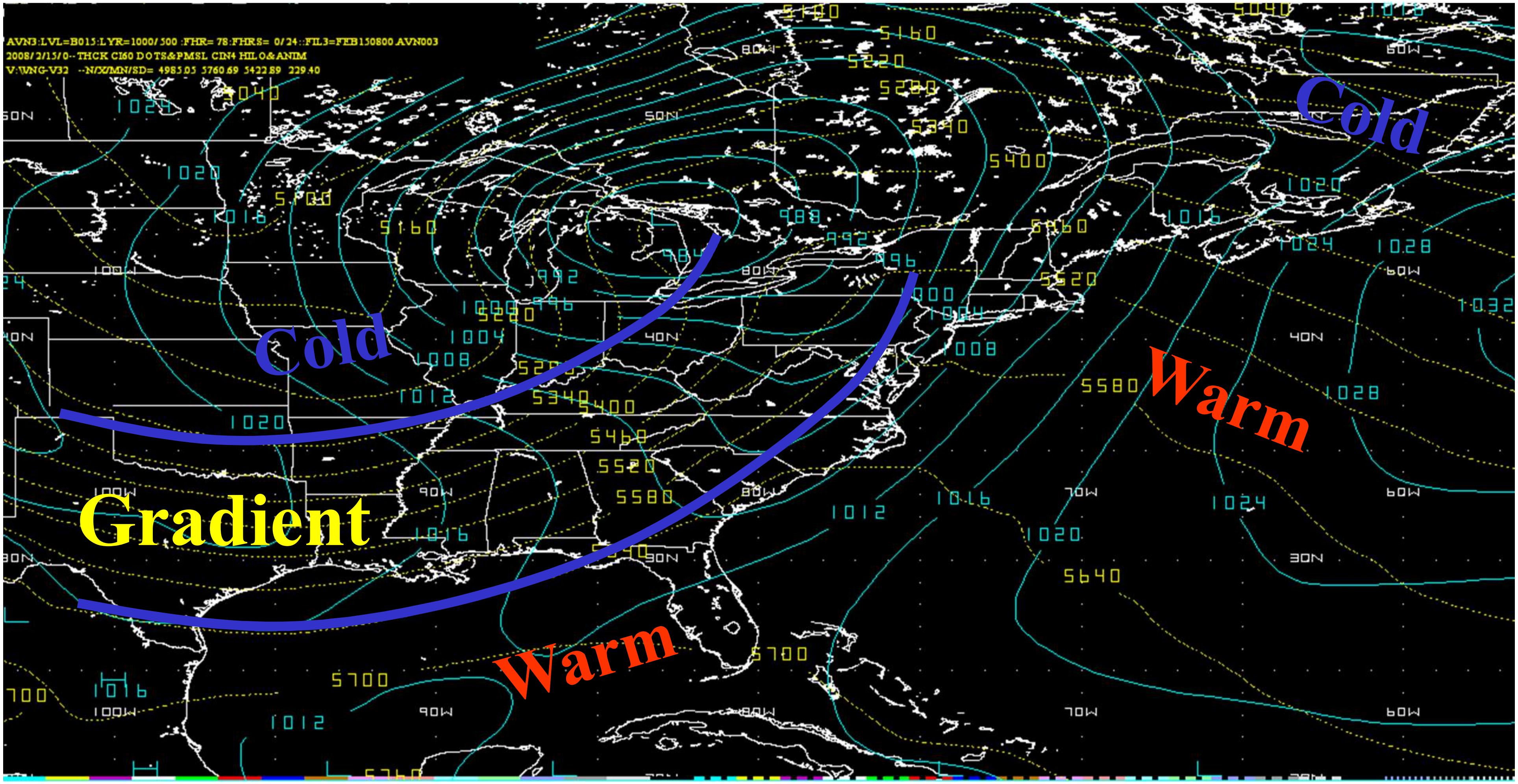
Scalar Field

- **Temperature**
- **Thickness (mean layer temperature)**

1000 hPa Temperature ^{o}C



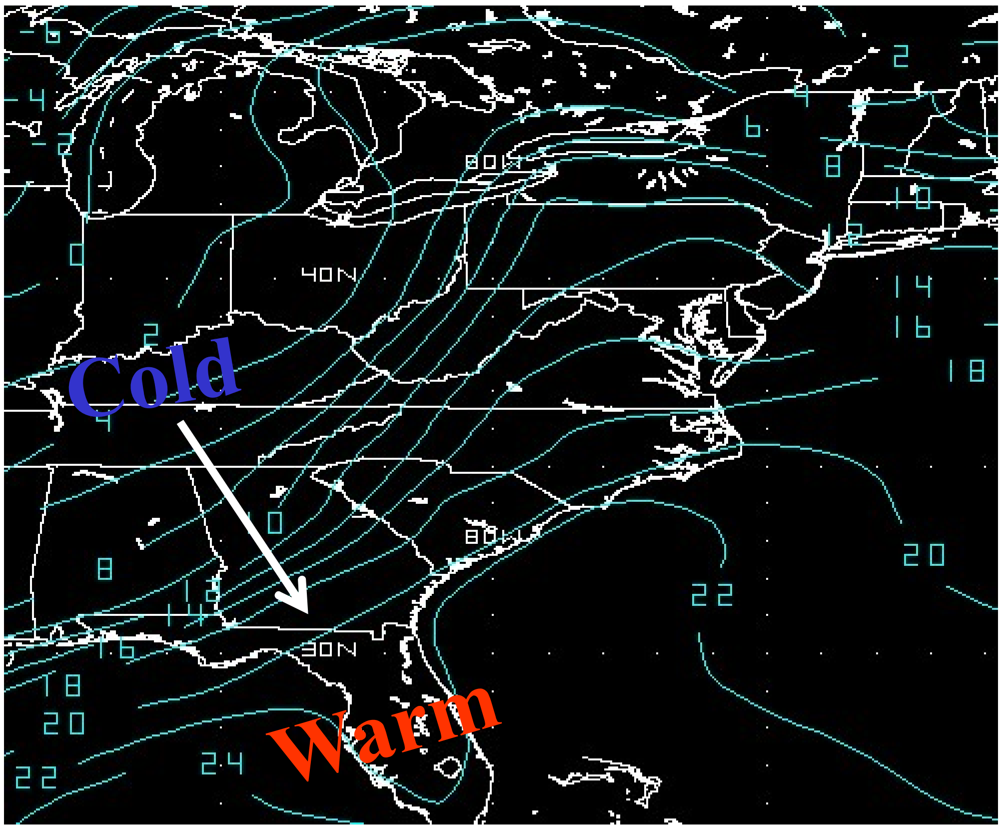
1000 – 500hPa Thickness



Proper Placement of Surface Front

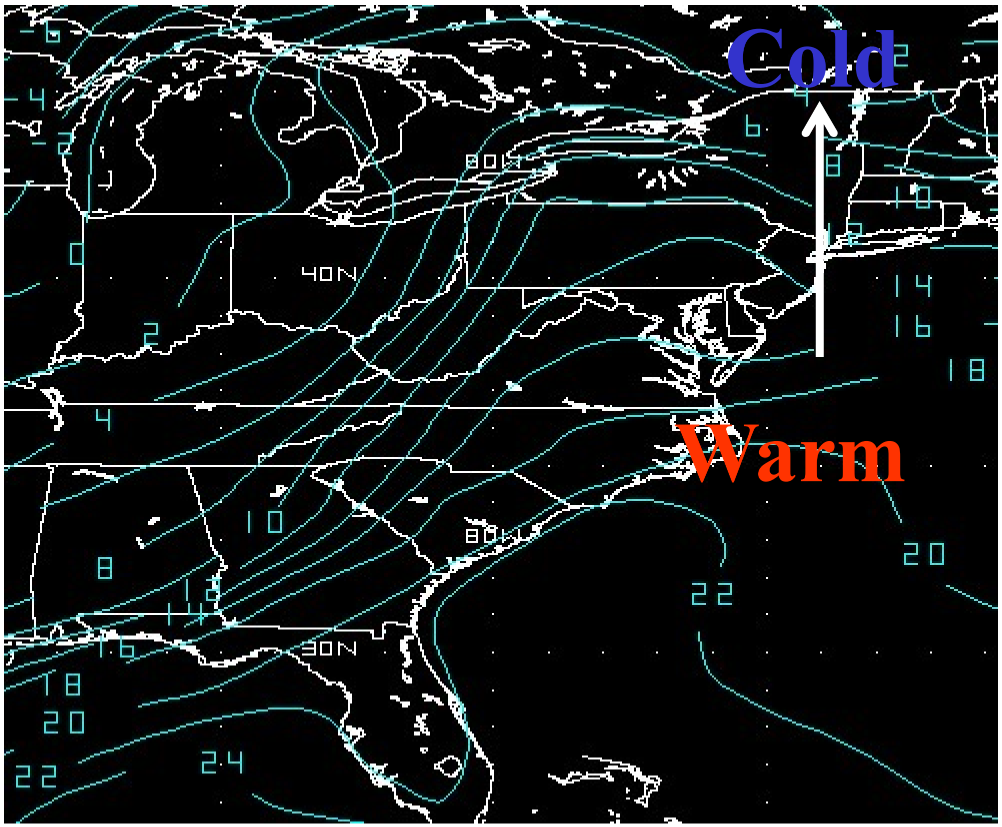
- Fronts are drawn on the ***warm side*** of the thermal gradient.
  - Cold advection equates **cold front**.
  - Warm advection equates **warm front**.
  - Neutral advection, **stationary front.**

Cold Advection



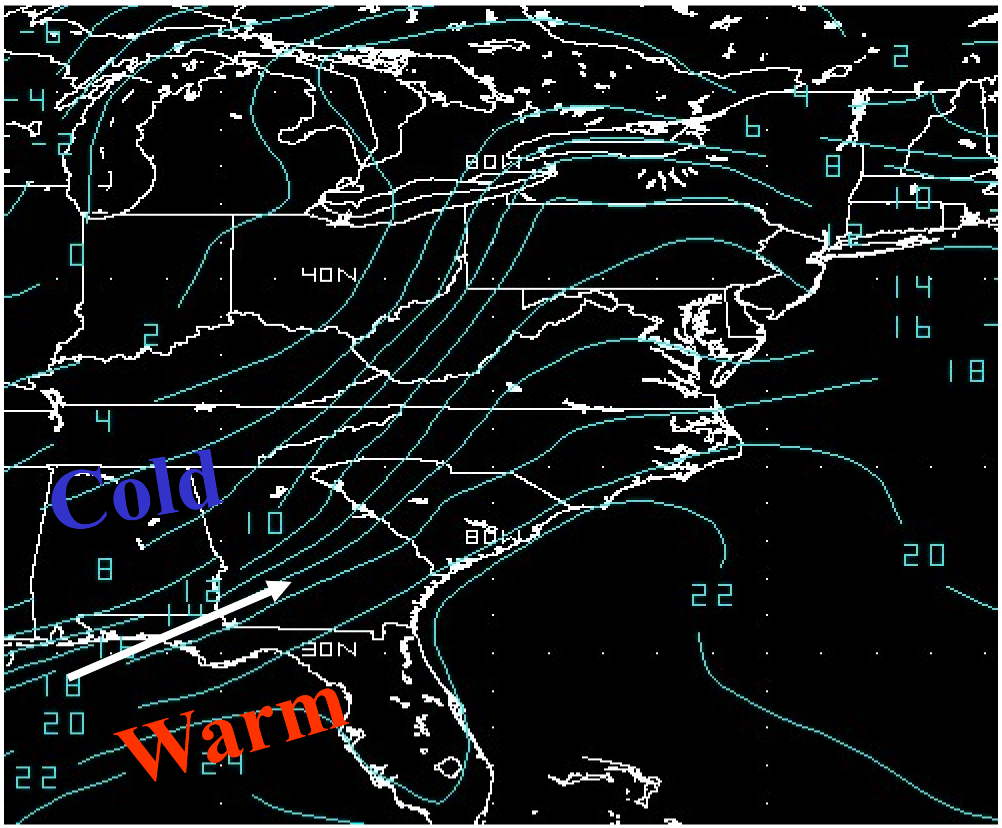
- When the flow across the thermal gradients points from cold to warm.

Warm Advection



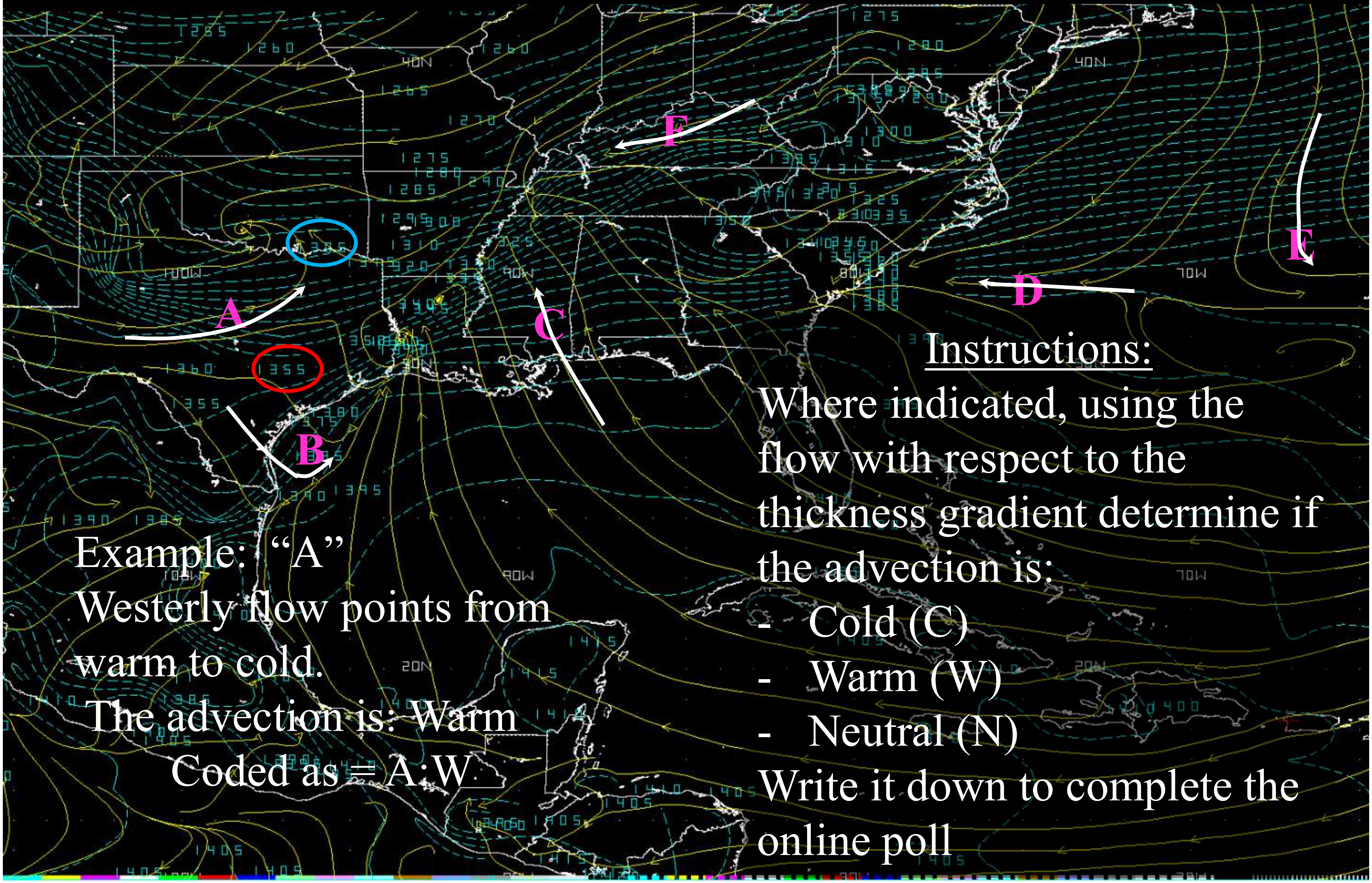
- When the flow across the thermal gradients points from warm to cold.

Neutral Advection



- The flow is parallel to the gradient and the front lies stationary.

Thickness and Streamlines: Temperature Advection Poll 1



Example: "A"
Westerly flow points from warm to cold.
The advection is: Warm
Coded as = A:W

Instructions:

Where indicated, using the flow with respect to the thickness gradient determine if the advection is:

- Cold (C)
- Warm (W)
- Neutral (N)

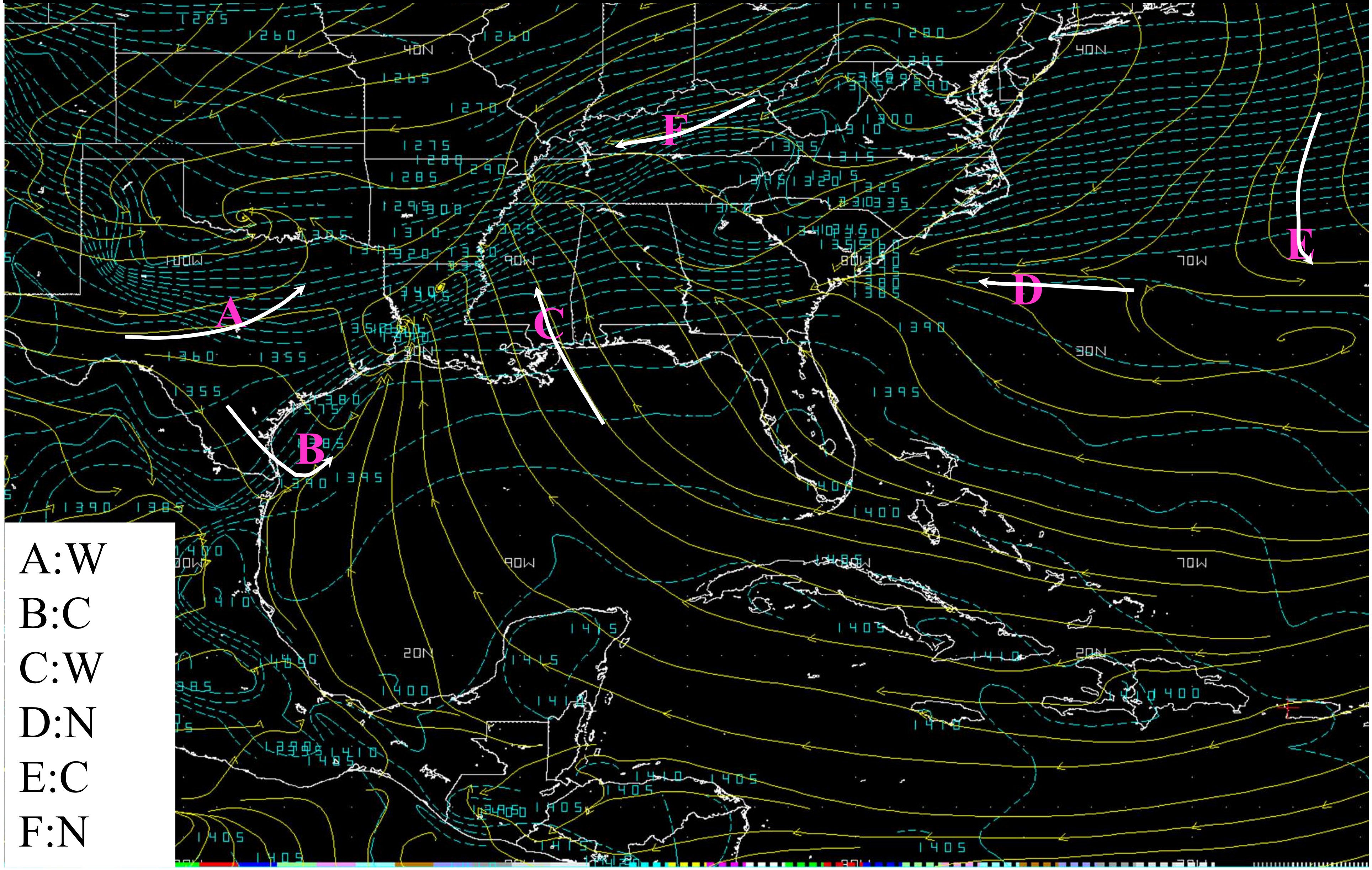
Write it down to complete the online poll

Poll Question #1

(Select the correct answer)

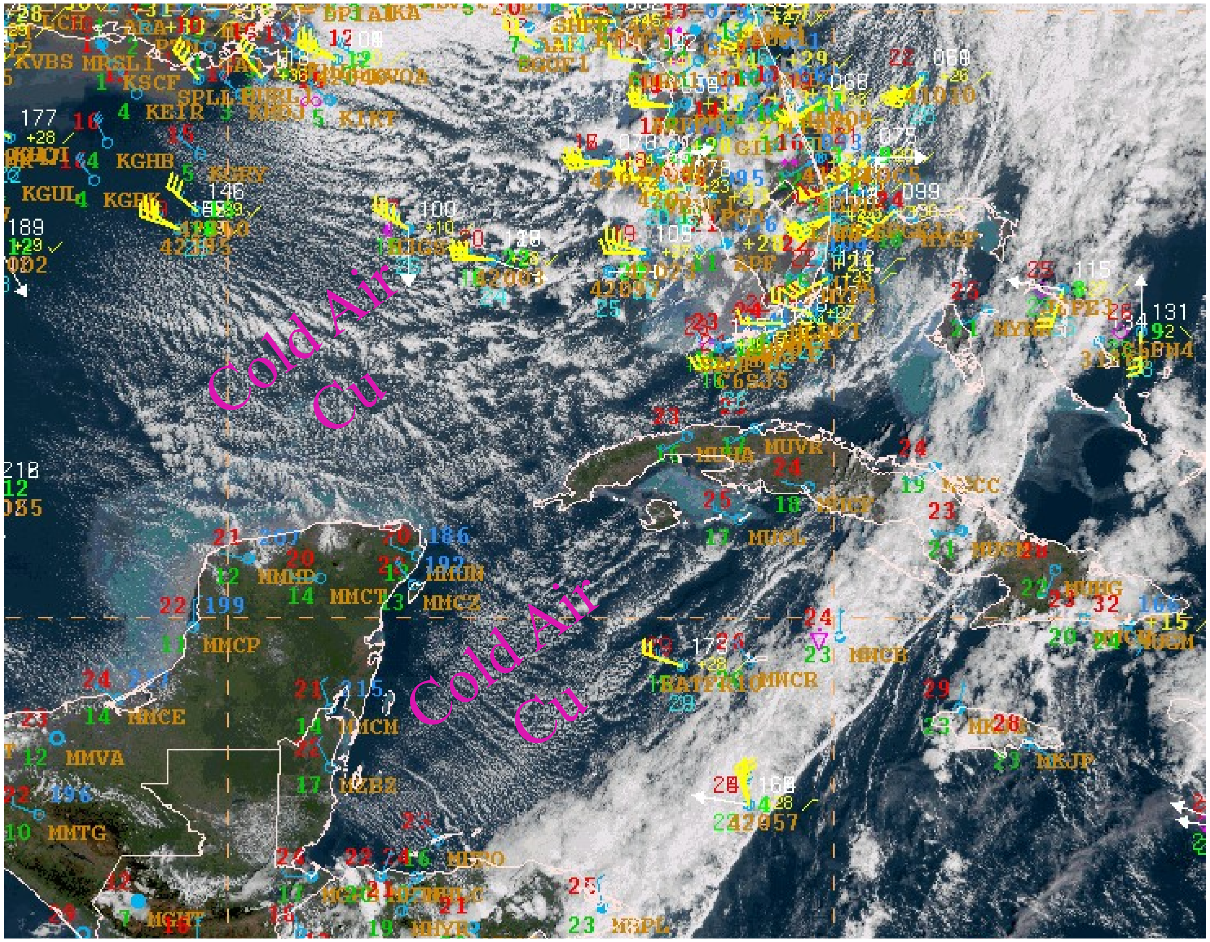
- A:W, B:C, C:C, D:W, E:W, F:N
- A:W, B:C, C:W, D:N, E:C, F:N
- A:W, B:N, C:W, D:N, E:C, F:N

Poll 1 Answers Review



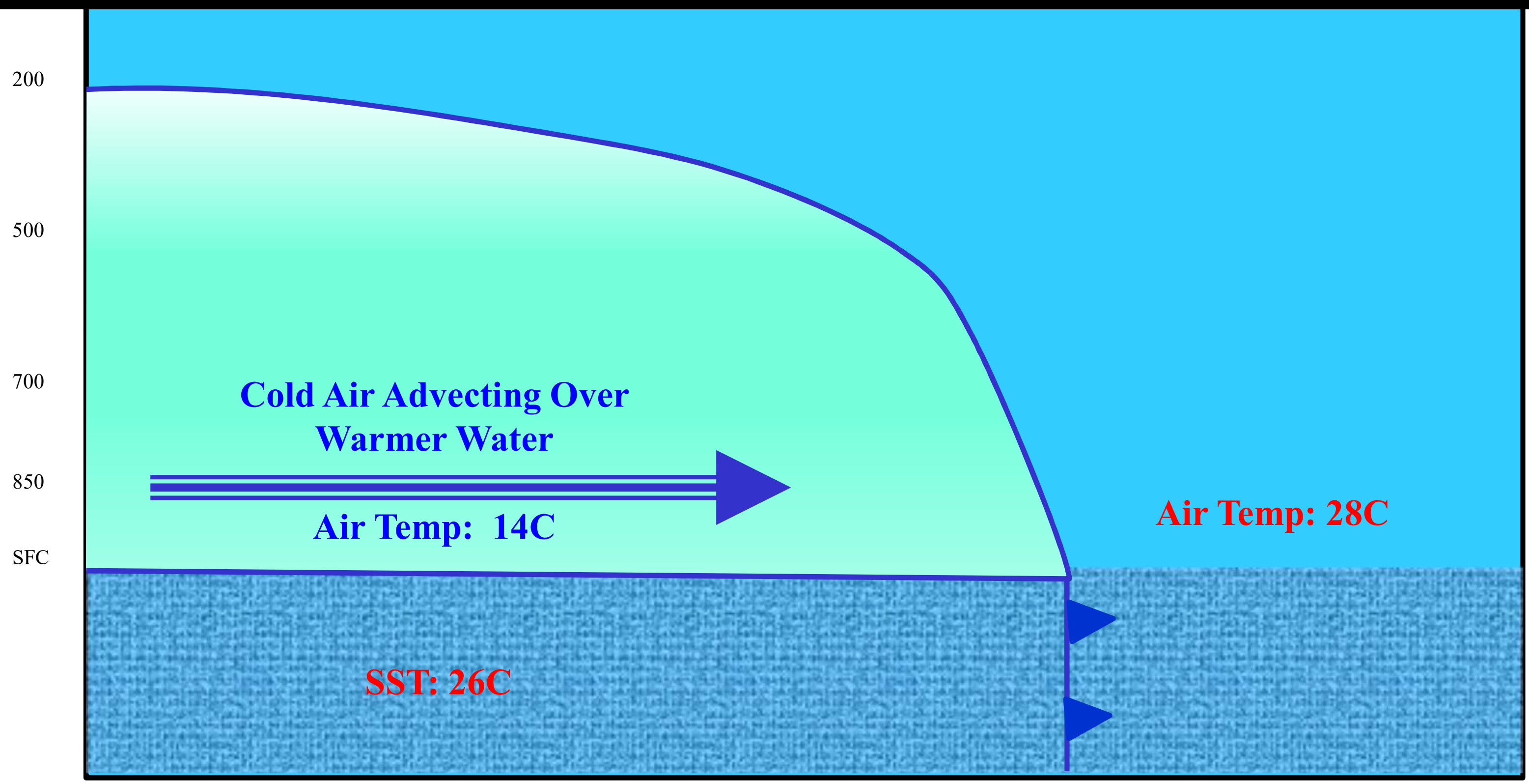
A:W
B:C
C:W
D:N
E:C
F:N

Cold Advection over Warmer Waters
Post Frontal-Cold Air Cu



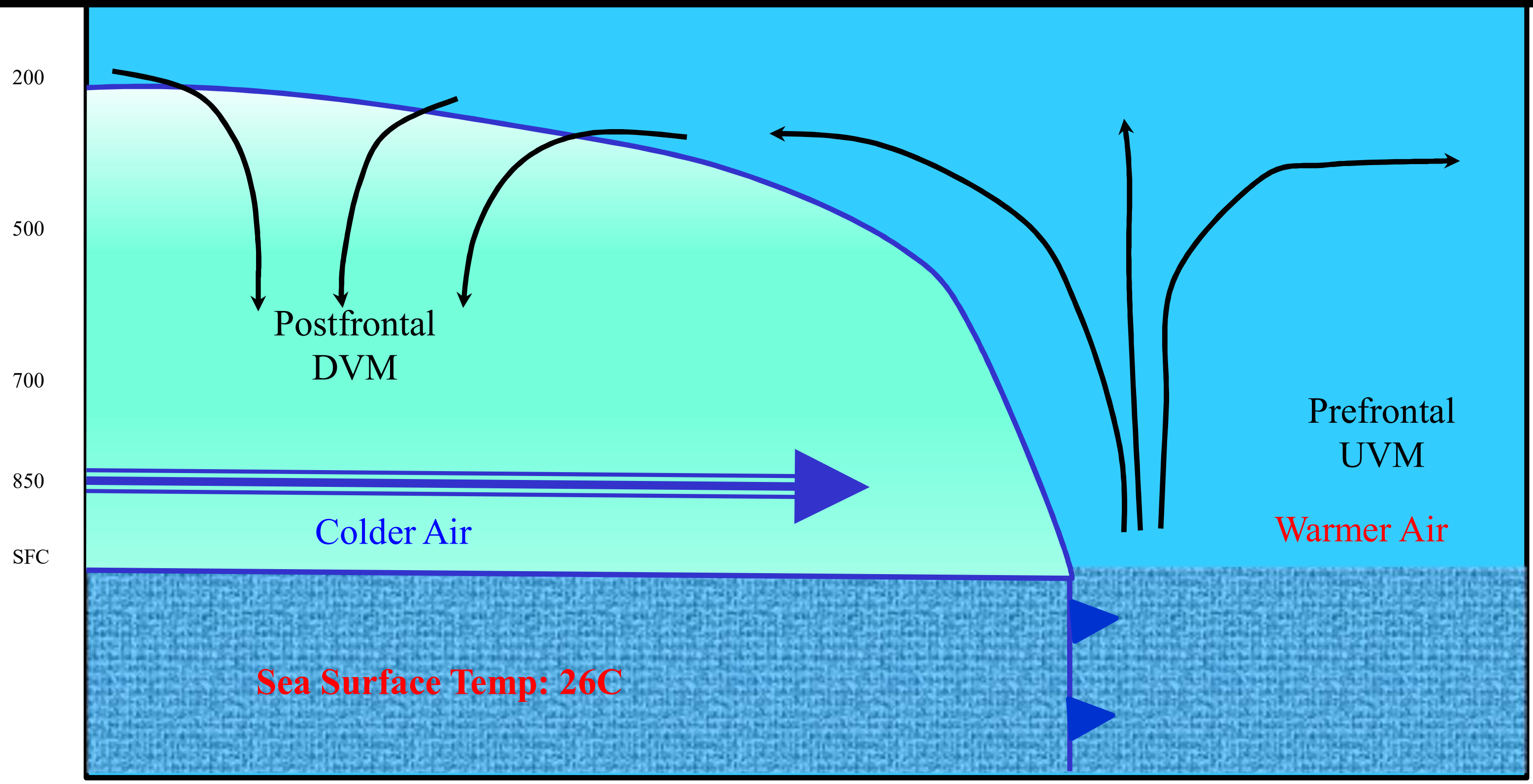
Following frontal passage, cold air advection over warmer waters favors convective instability. This triggers post frontal "cold air cumulus" (Moderate Cu and Cu Congestus)

Mechanism Leading to the Formation of Post Frontal Cold Air Cu



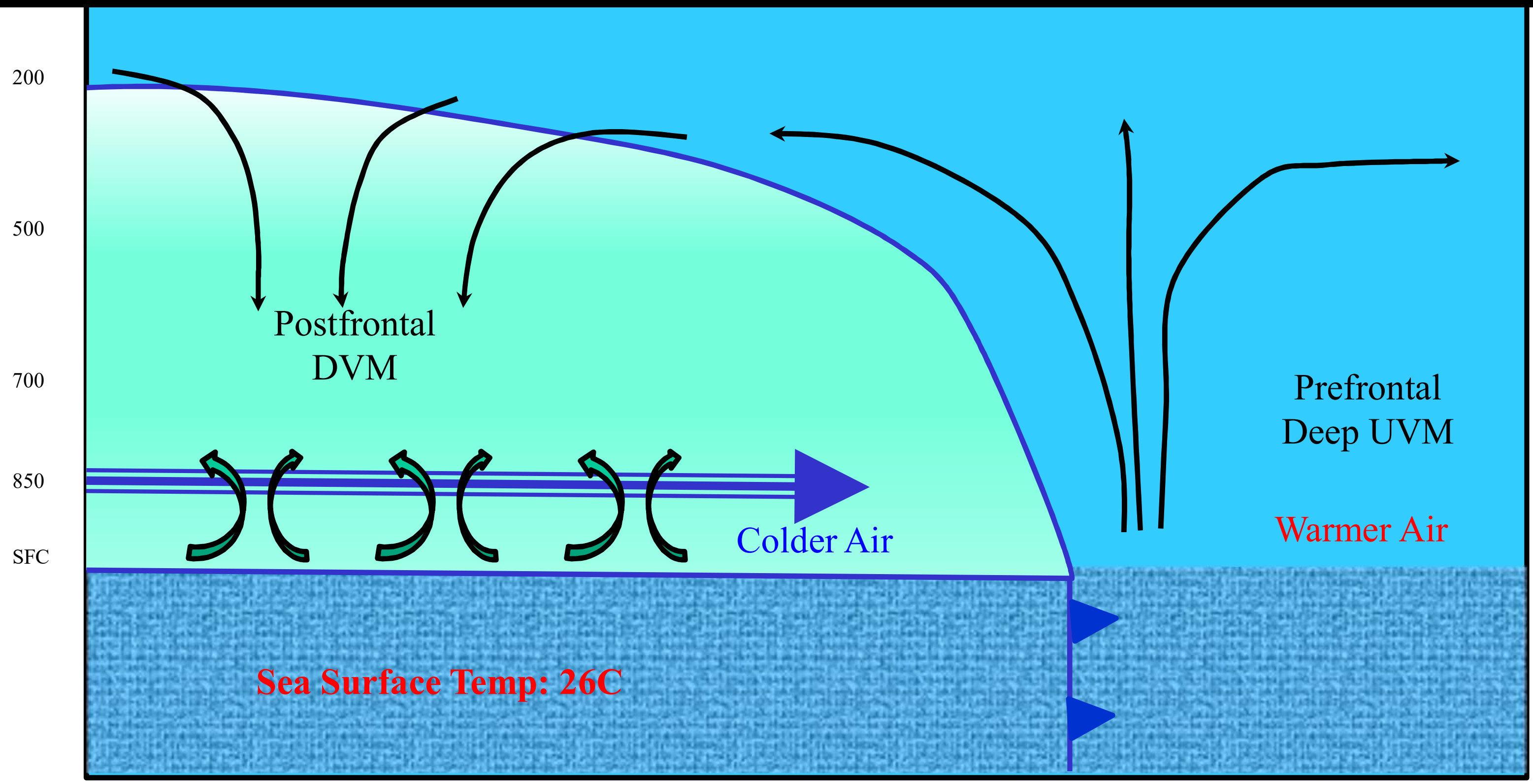
Polar front surges over water, with cold post frontal air advecting over warmer SSTs

Mechanism Leading to the Formation of Post Frontal Cold Air Cu



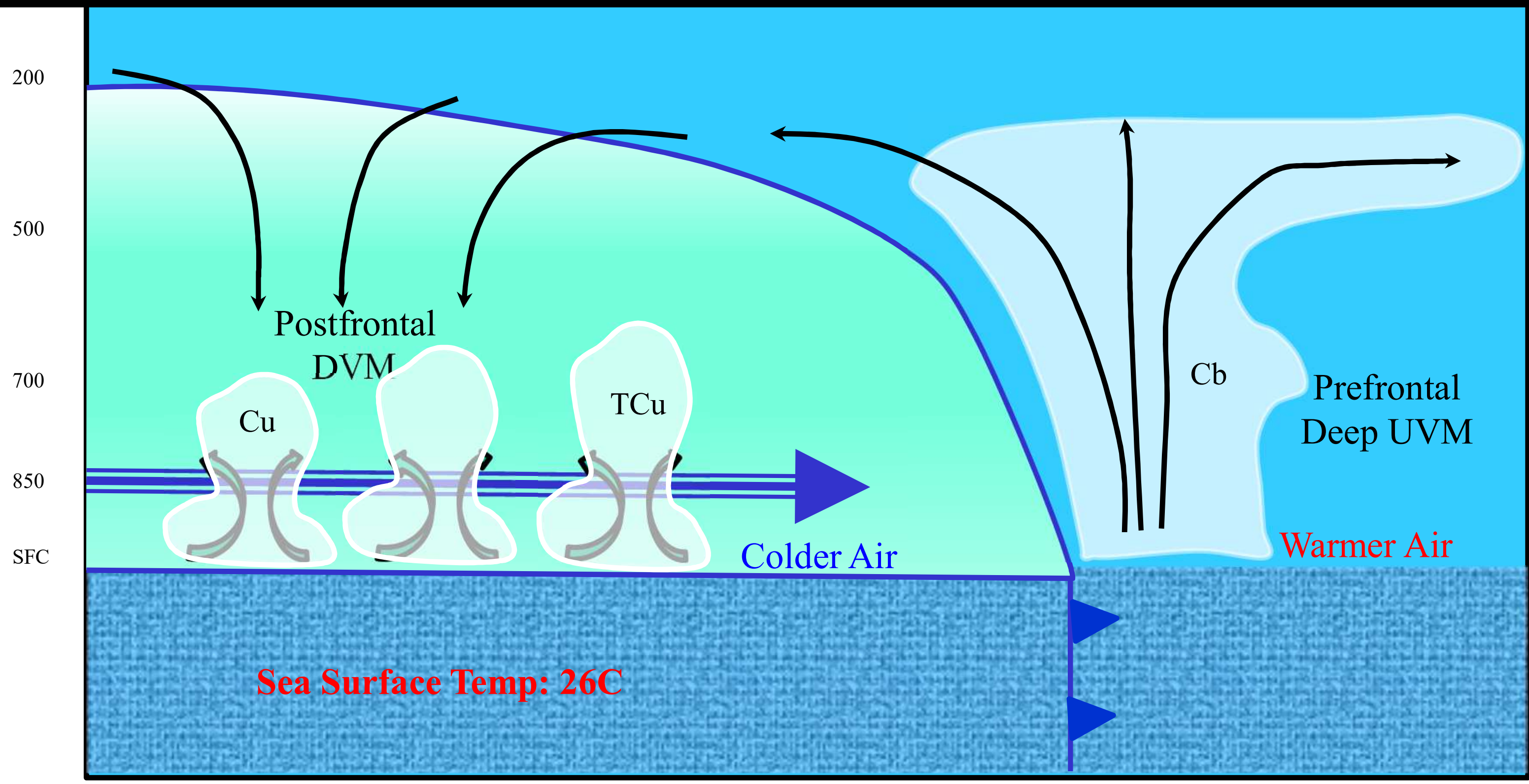
- Contrast between air masses and low level convergence results in upward vertical motion (UVM) ahead of the surface front.
- In an upper convergent pattern, the colder post frontal air sinks

Mechanism Leading to the Formation of Post Frontal Cold Air Cu



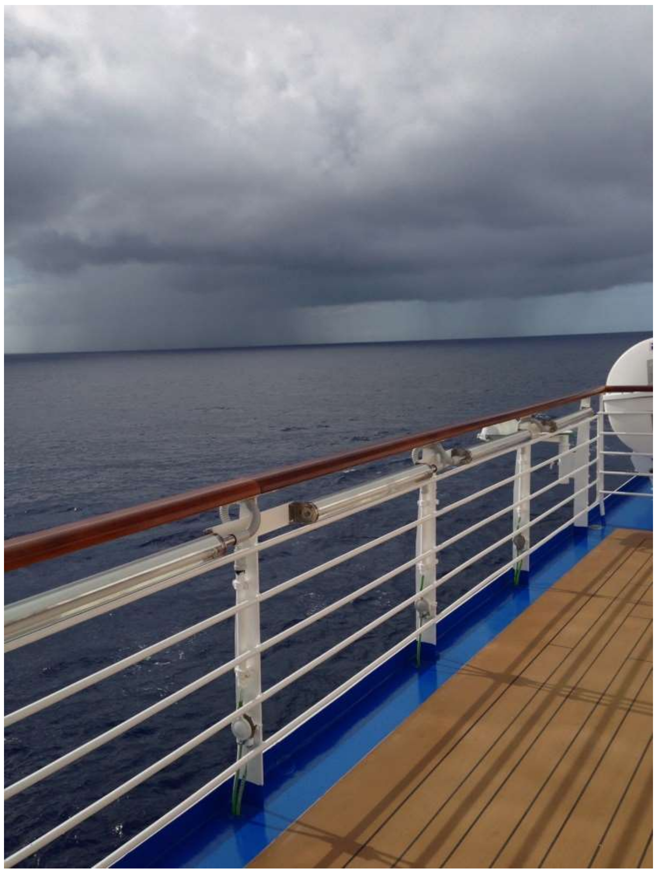
- At low levels, the colder air moving over warmer SSTs incites convective instability, while the stronger winds results in mixing of the boundary layer

Mechanism Leading to the Formation of Post Frontal Cold Air Cu



- The deep UVM motion ahead of the front results in deep cloud cover
- Post frontal convection, facing DVM, caps at mid levels. This process continues as long as cold air advects over the warmer ocean waters.

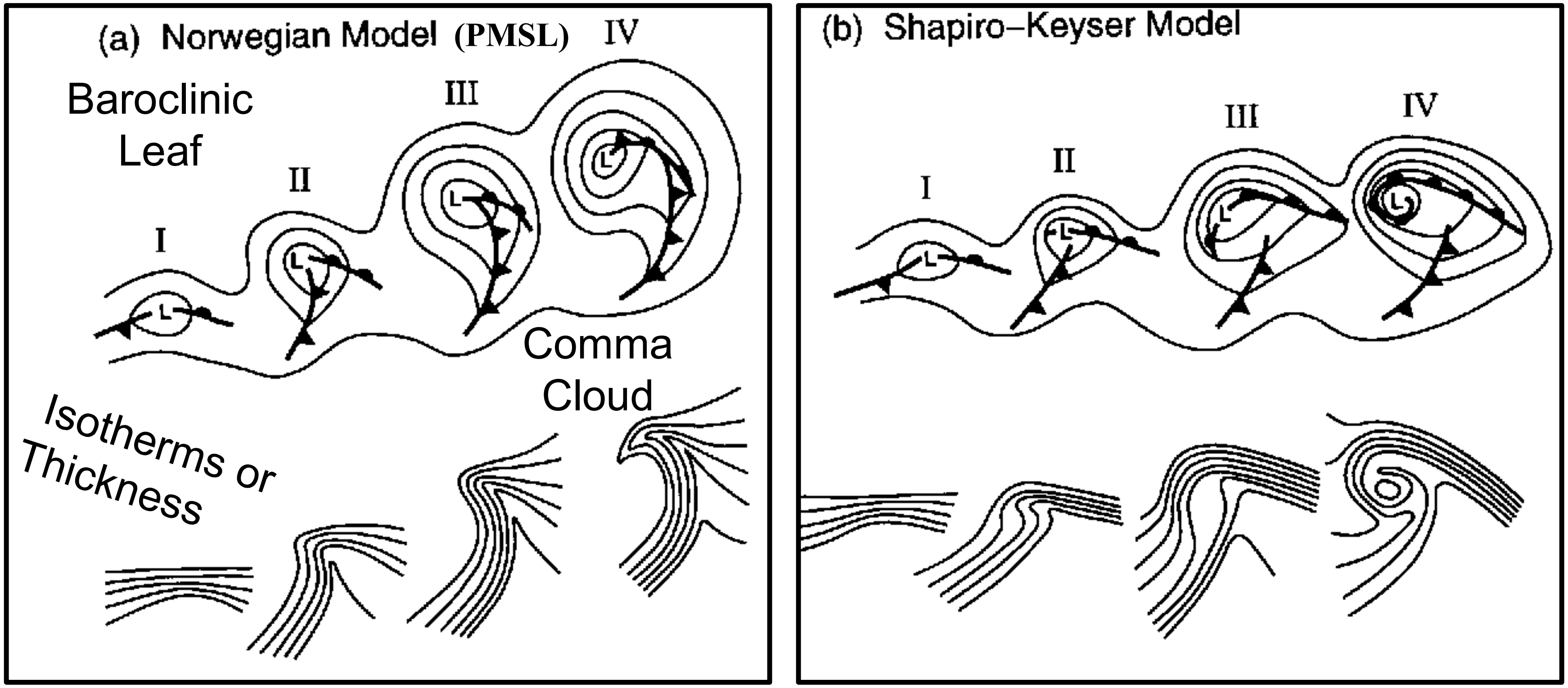
Post Frontal Cu/Shallow Convection over Water



- This often results in shallow post frontal convection.
  - Nocturnal cooling contributes to a higher incidence of rain showers at night
  - Activity typically ebbs during the day as boundary layer warms under radiational heating

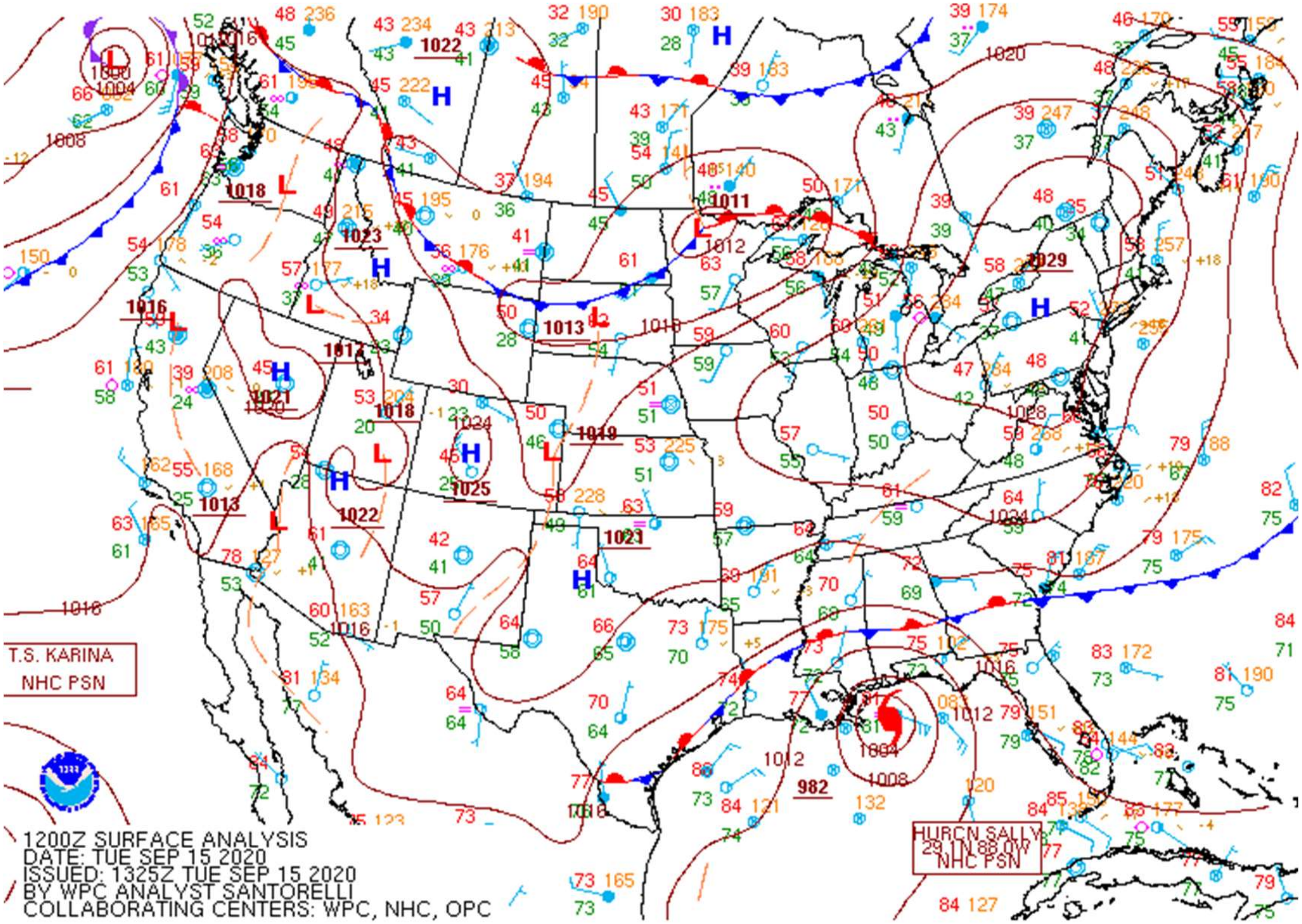
Frontal Analysis

Conceptual Model – Northern Hemisphere

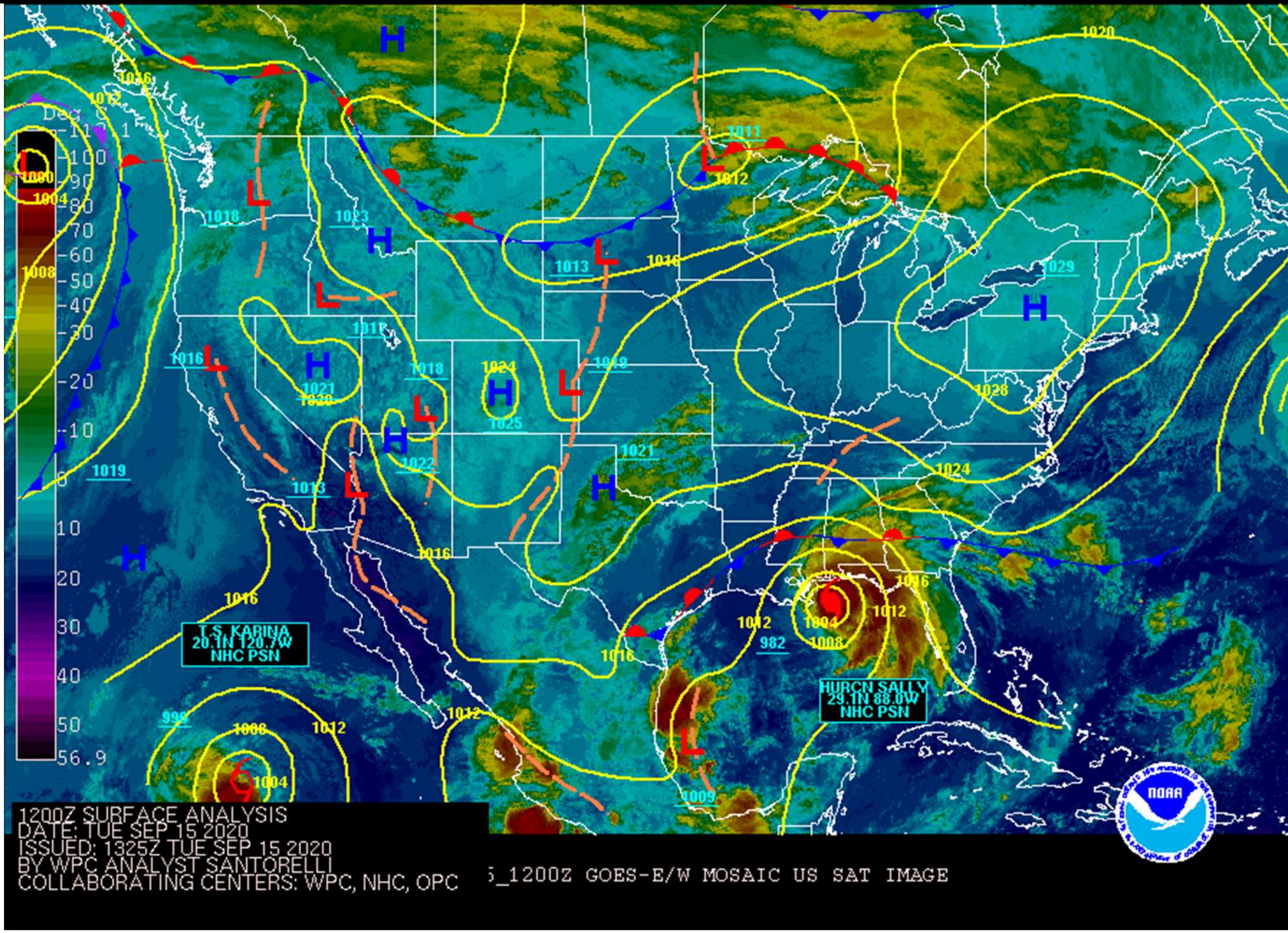


I. Frontal Wave Forms
II. Frontal Wave
III. Occluding Front
IV. Occluded Front

Application Conceptual Model – CONUS

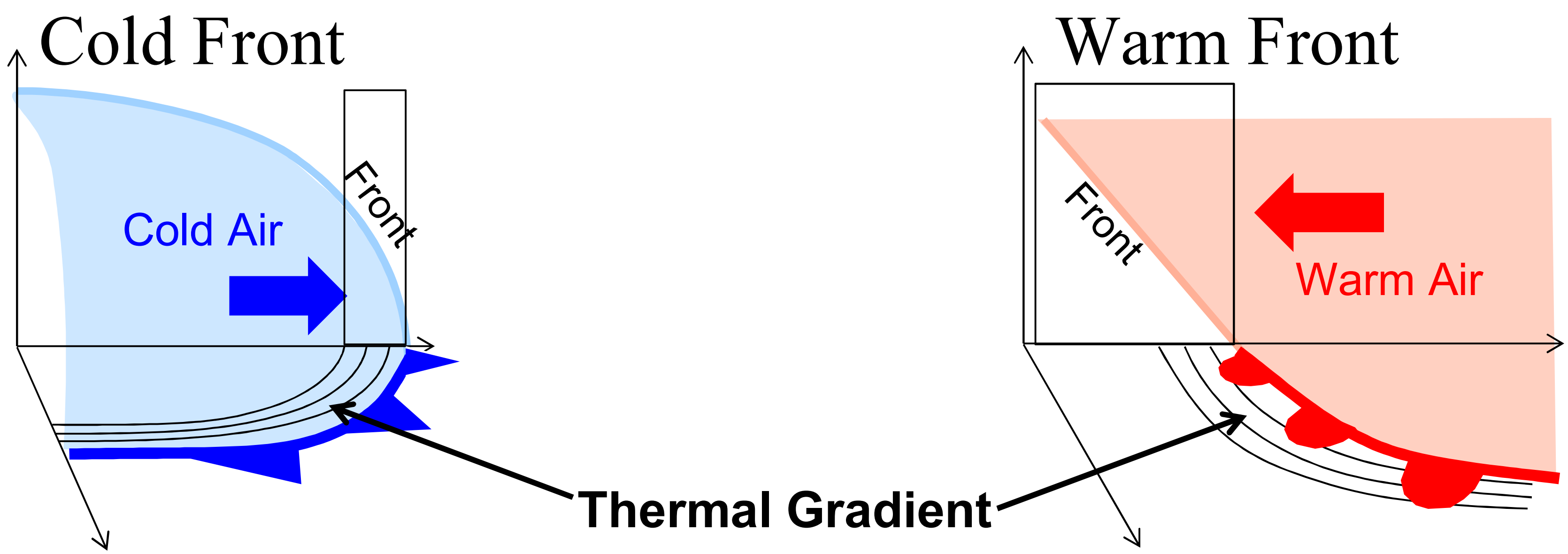


Application Conceptual Model – CONUS



Surface Front Placement

Fronts are drawn along a **<u>trough</u>**, ***<u>parallel</u>*** to the isotherms and on the **<u>warm side</u>** of the gradient



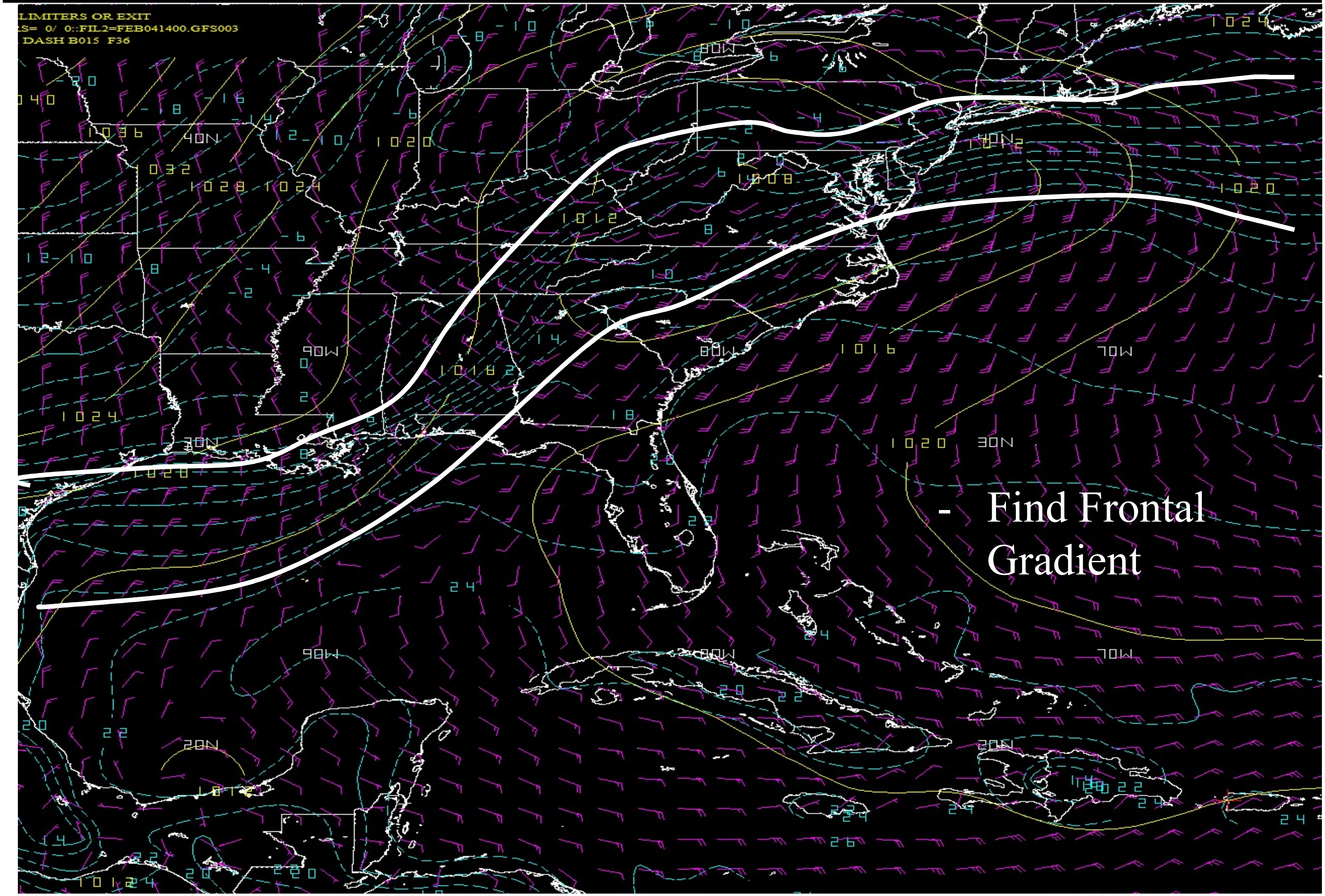
The front type depends on the advection:

-Warm Advection = Warm front

-Cold Advection = Cold front

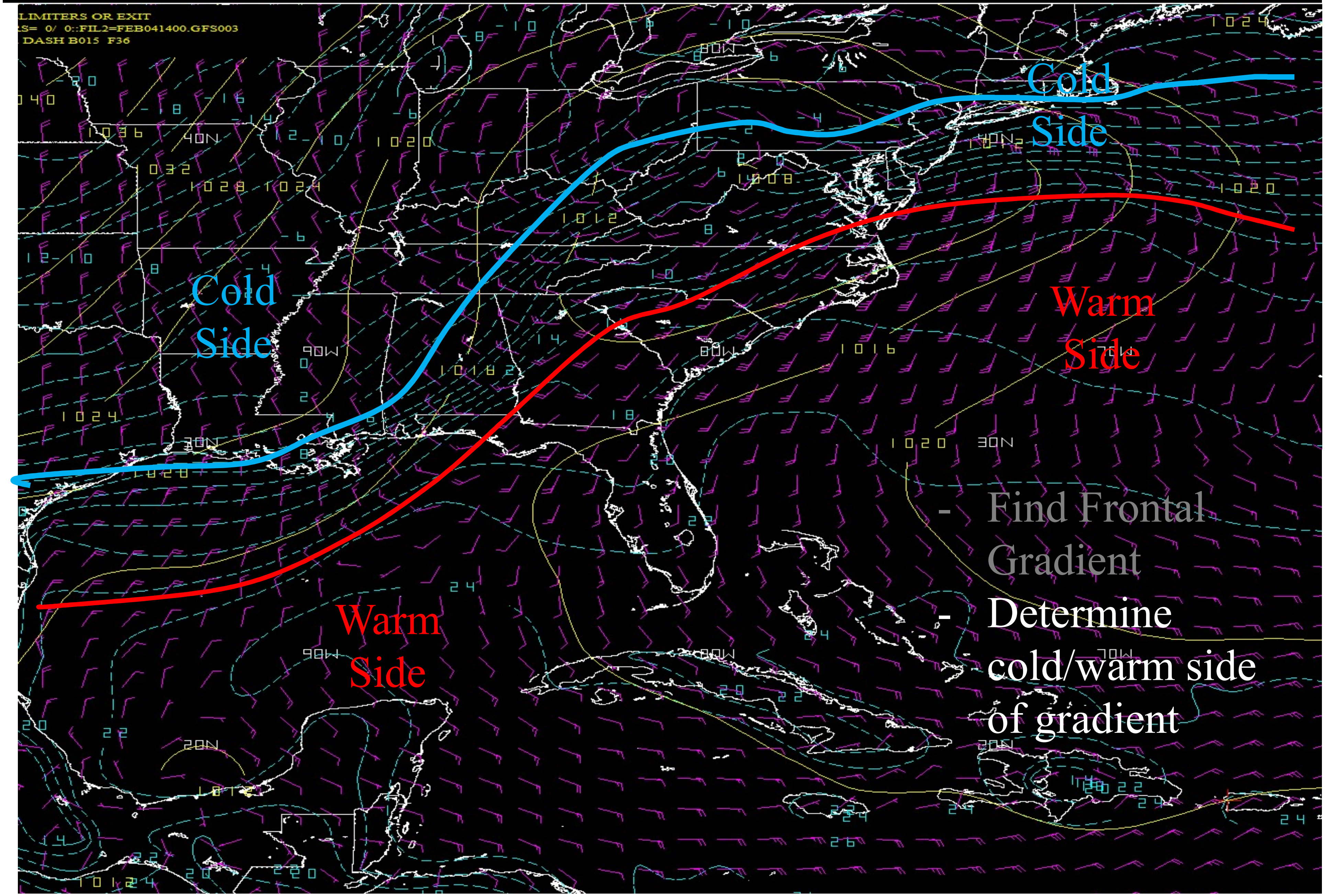
-Neutral = Stationary front

Drawing the Surface Front: PMSL and BL Temps



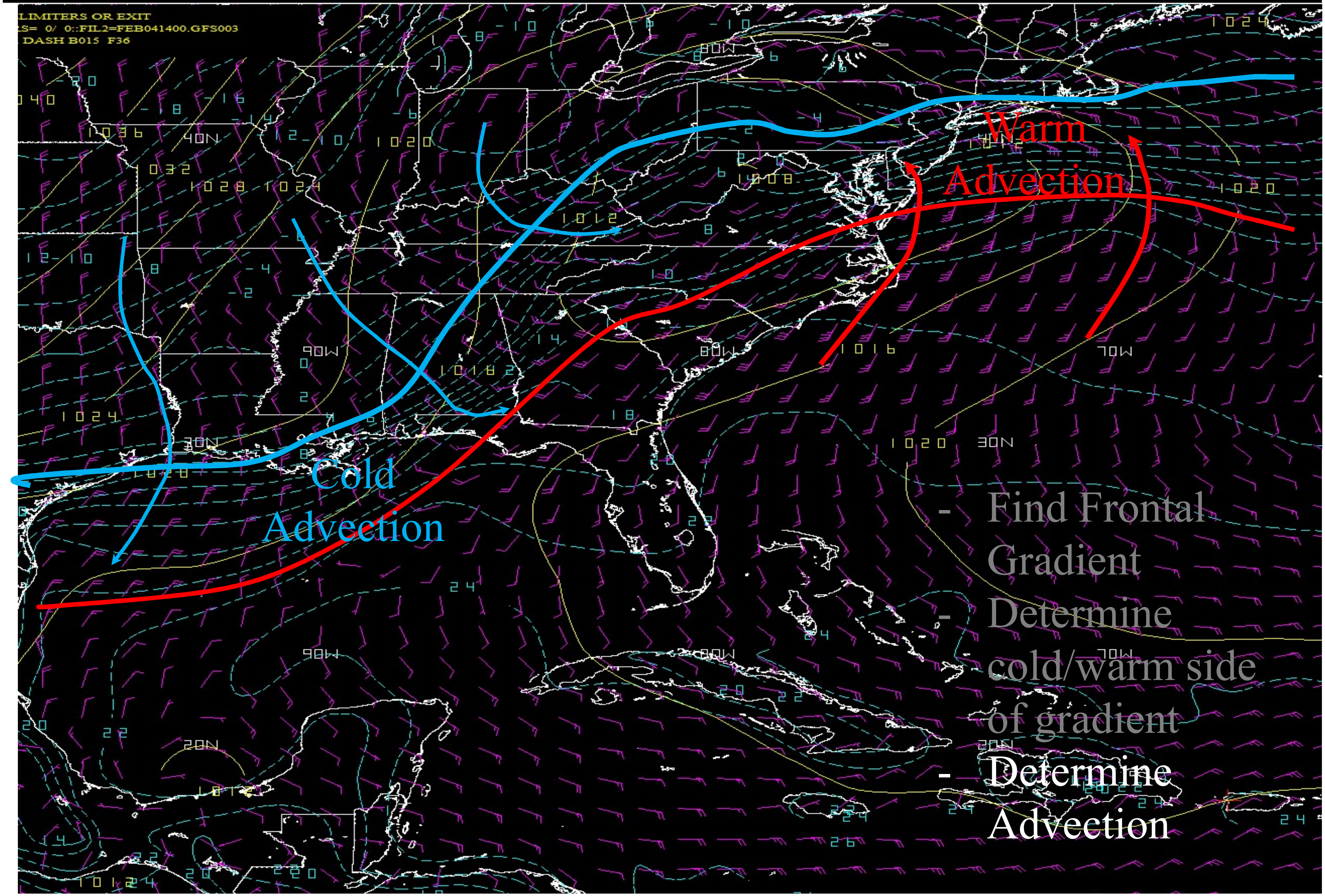
- Find Frontal Gradient

Drawing the Surface Front: PMSL and BL Temp



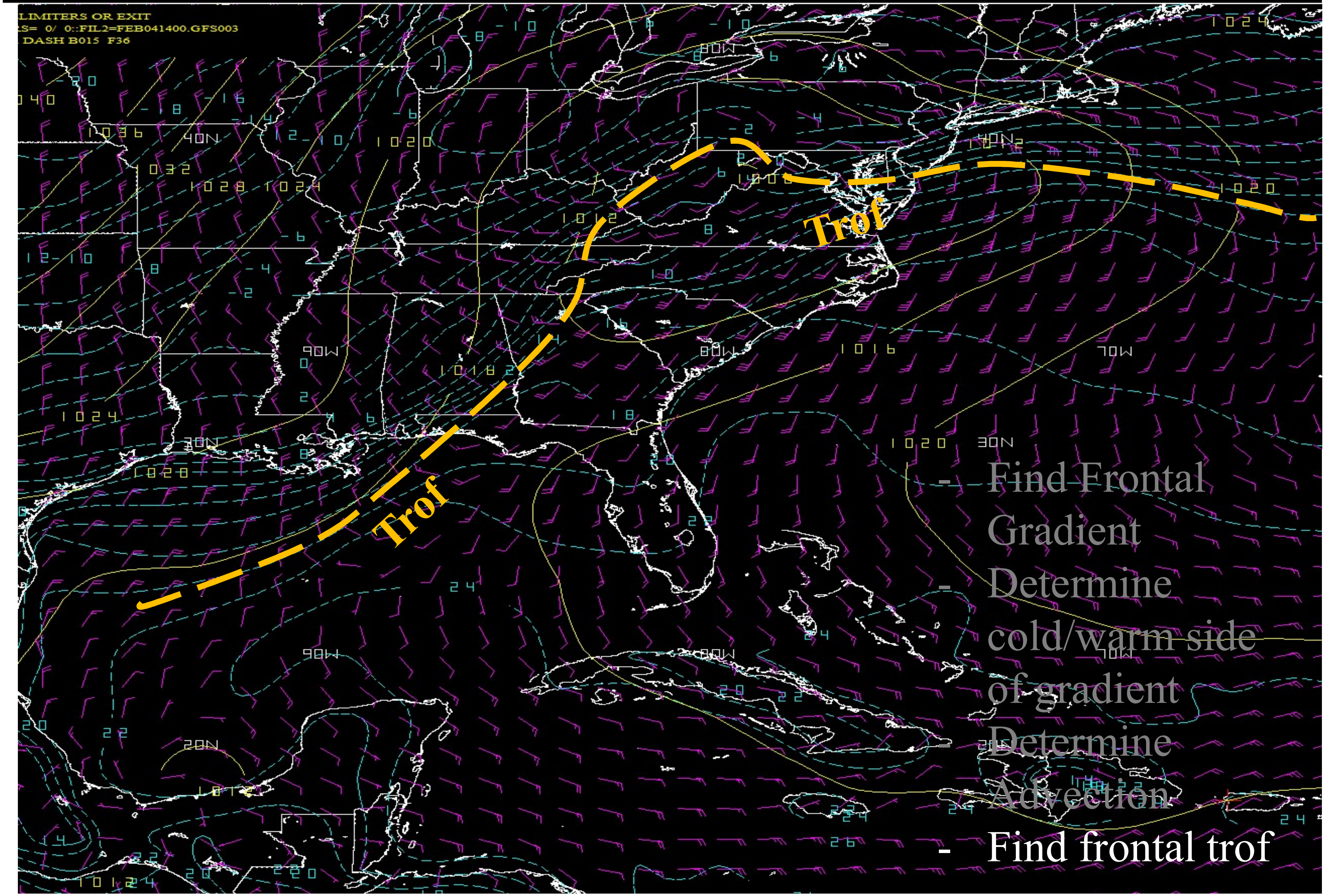
- Find Frontal Gradient
- Determine cold/warm side of gradient

Drawing the Surface Front: PMSL and BL Temp



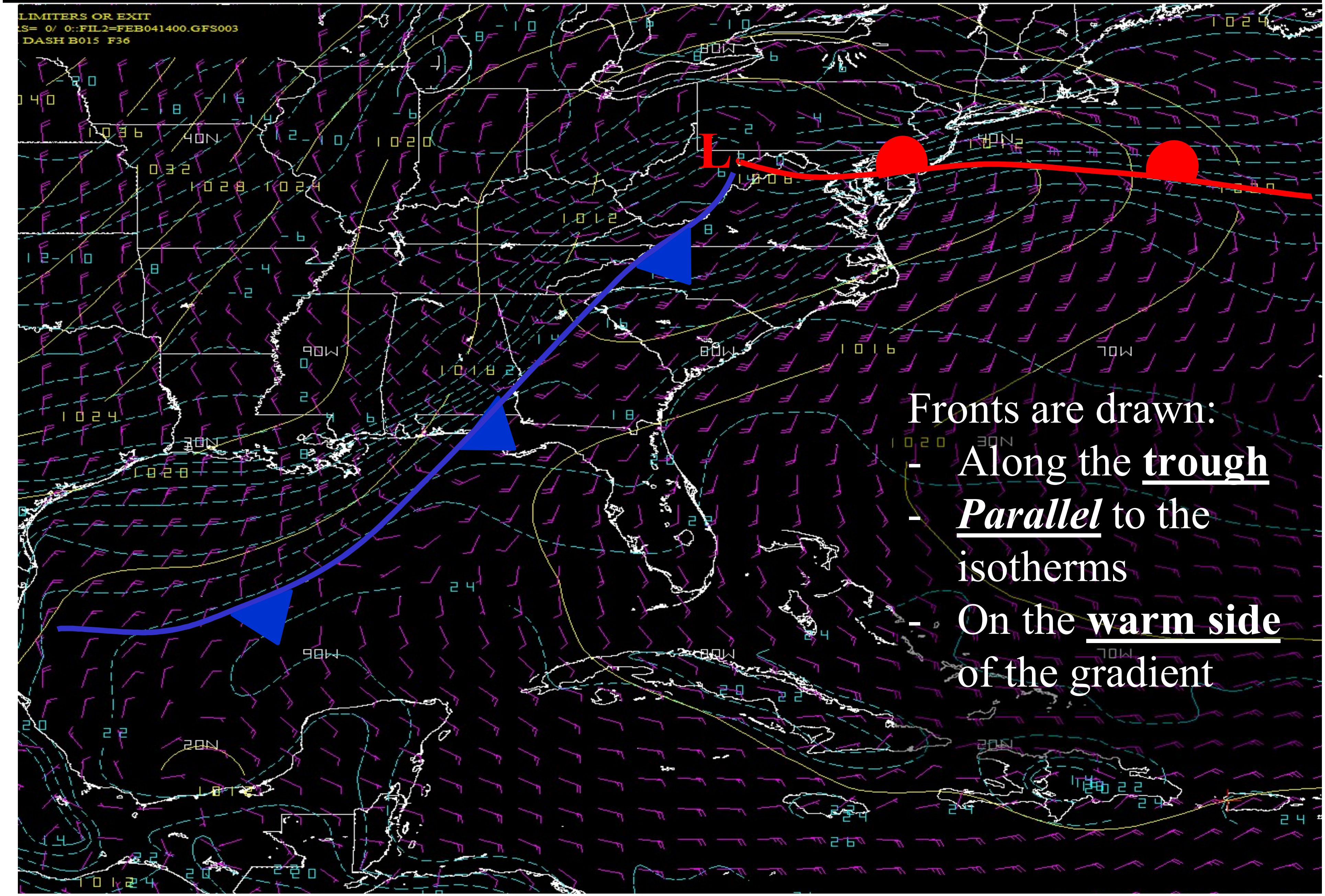
- Find Frontal Gradient
- Determine cold/warm side of gradient
- Determine Advection

Drawing the Surface Front: PMSL and BL Temp



- Find Frontal Gradient
- Determine cold/warm side of gradient
- Determine Advection
- Find frontal trof

Drawing the Surface Front: PMSL and BL Temp



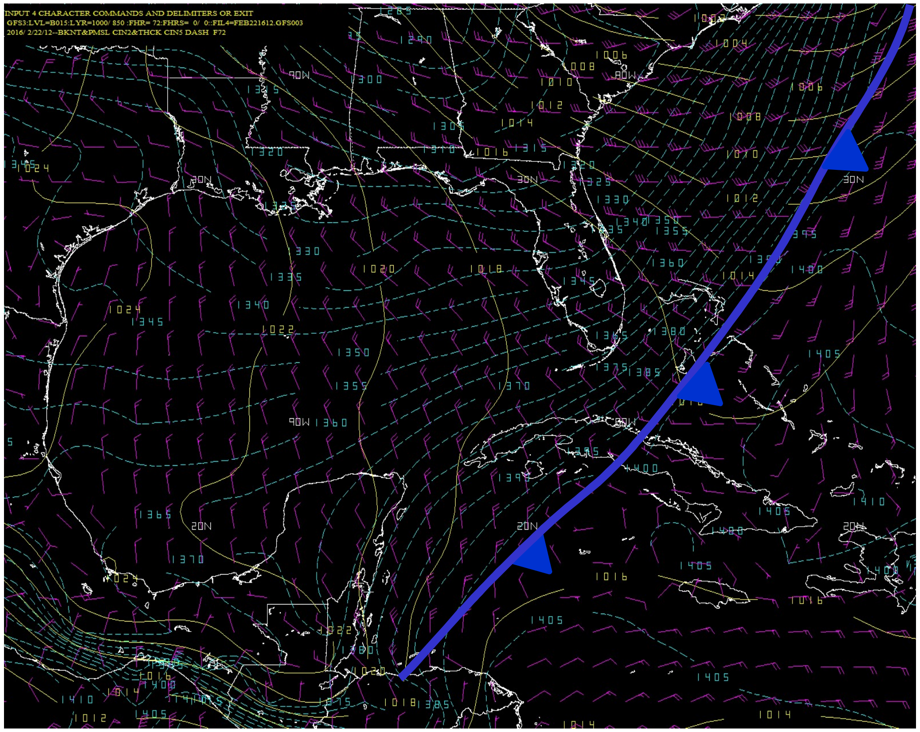
Fronts are drawn:

- Along the **trough**
- ***Parallel*** to the isotherms
- On the **warm side** of the gradient

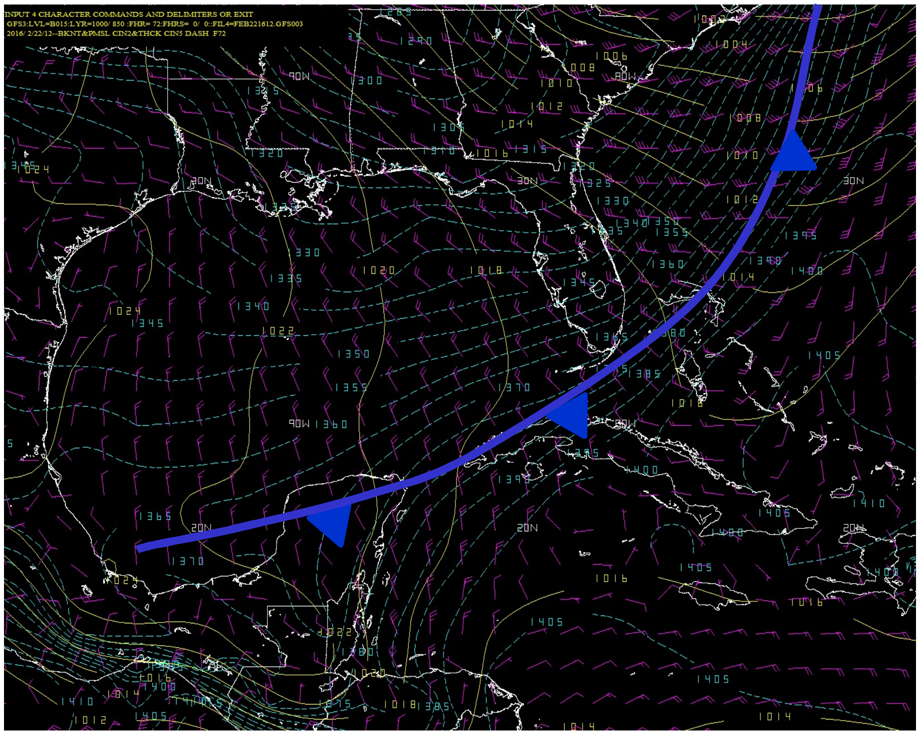
Poll Question #2
(Select all that apply)

- Fronts separate air masses of different density
- Barotropic implies temperature advection
- Baroclinic implies temperature advection
- Shallow boundary in the tropics, use the 1000-850 thickness
- Shallow boundary in the tropics, use the 1000-500 thickness

Poll #3
Which one is correct?



A is correct?

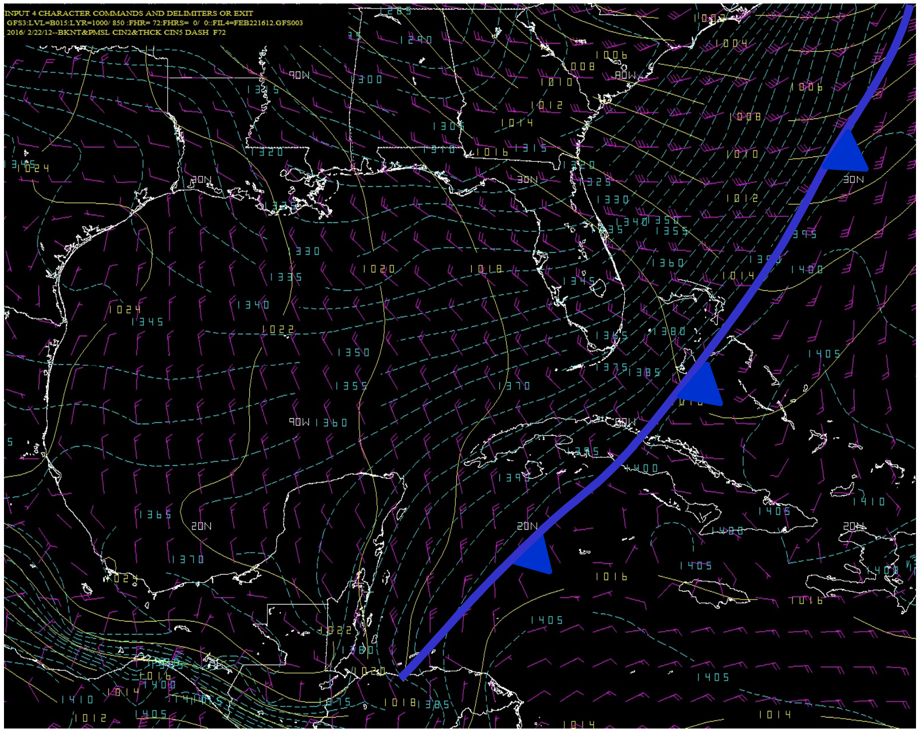


B is correct?

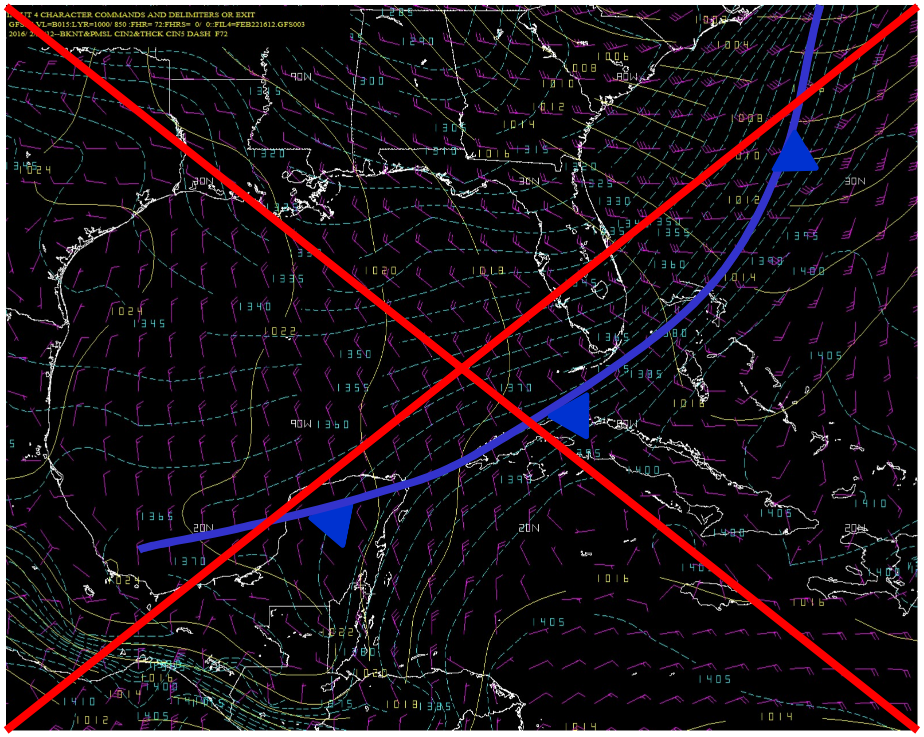
Poll Question #3
(Select one)

- A is correct
- B is correct
- Both are incorrect
- Both are correct
- Not enough information to determine

Poll #3 Review
Which one is correct?



<u>A is correct,</u> along the trough on the warm side of the gradient



B is correct, drawn in the middle of the gradient.

Frontal Analysis in the Caribbean

- ΔT
  - Temperature drops following frontal passage
- ΔP
  - Pressure drops as the frontal trough approaches
  - Pressure rises as the polar ridge builds
- ΔTd
  - Note: Dew point temperature alone not enough to determine air mass changes
  - In polar maritime air masses
    - Td > 18C cold front is probably north of the station
    - Td $\leq$ 18C, cold front is likely south of the station
- Clouds
  - Ceiling drops as the front makes landfall

Frontal Analysis in the Caribbean

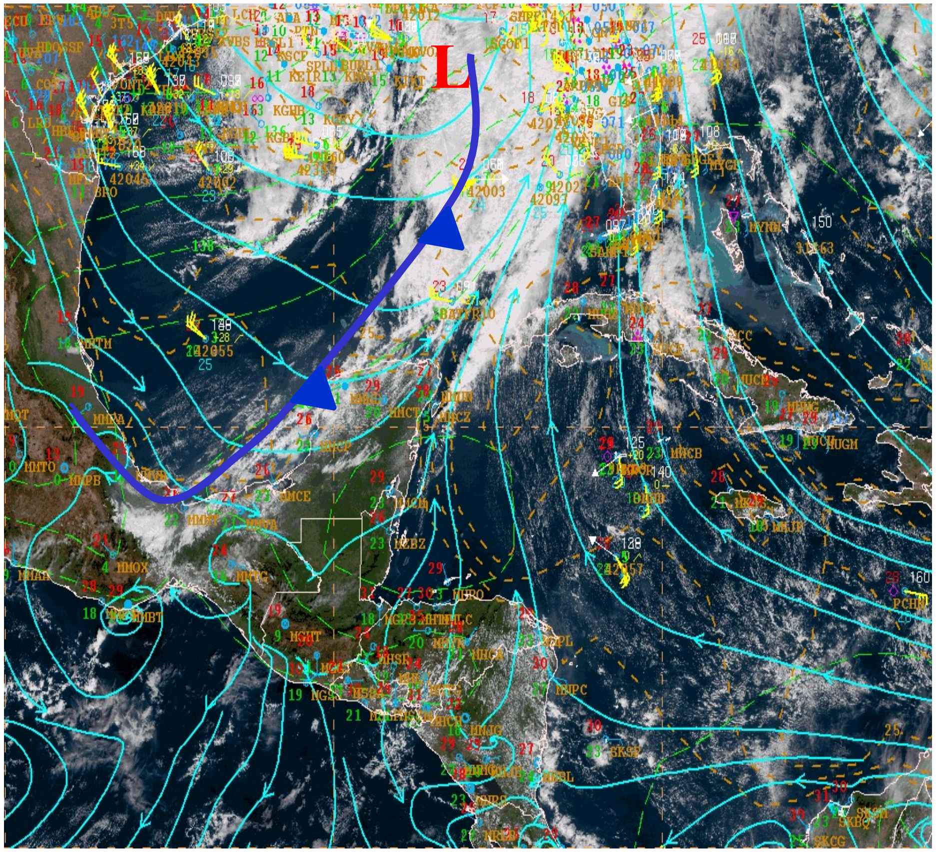
- Pressure/Pressure Tendency

- Air mass density changes (baroclinicity)
  - **Moisture** (**Td**, Mixing Ratio)
    - Analyze isodrosotherms every 2-3 degrees
    - **$Td \leq 18C$ for a polar maritime air mass.**
  - **Temperature**
    - Strong contrast in continental/marine polar air masses
    - Slighter difference, 2-4C, when looking at Tropical air masses
  - ✓ **Combination of T and Td**: Equivalent Potential Temperature (EPT) analyzed every 5-7 degrees

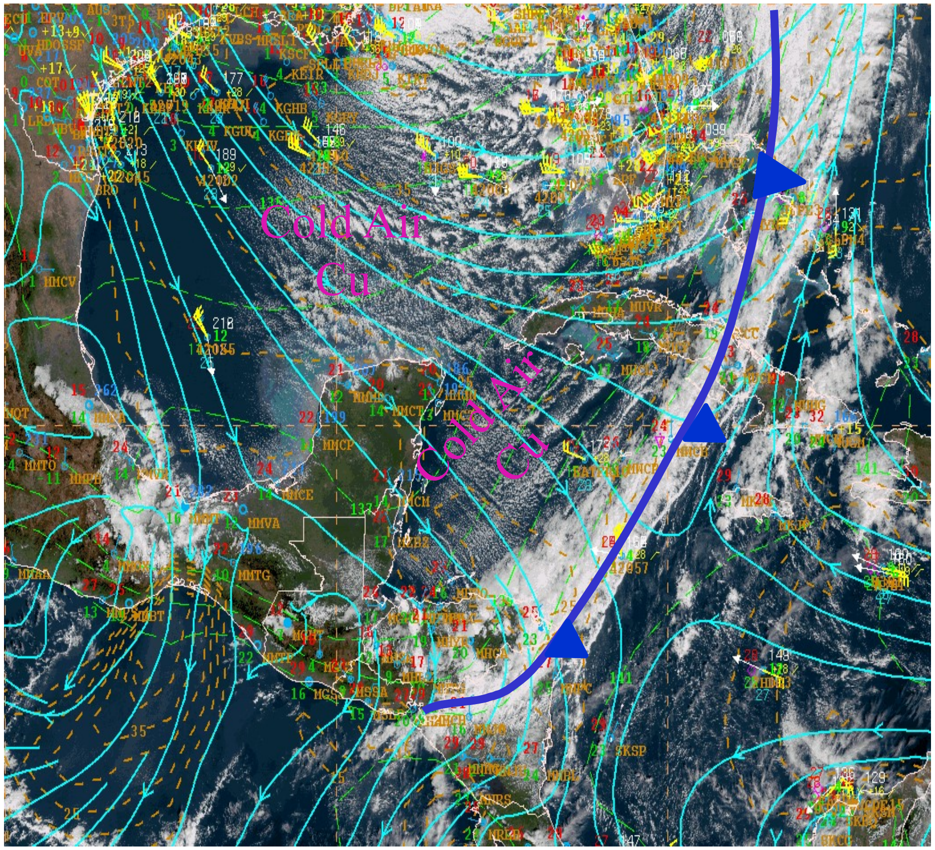
- Wind shift with frontal trough

Analysis of 24 Hours Tendencies

1000 hPa Streamlines, 1000-850 Thickness and Surface Obs



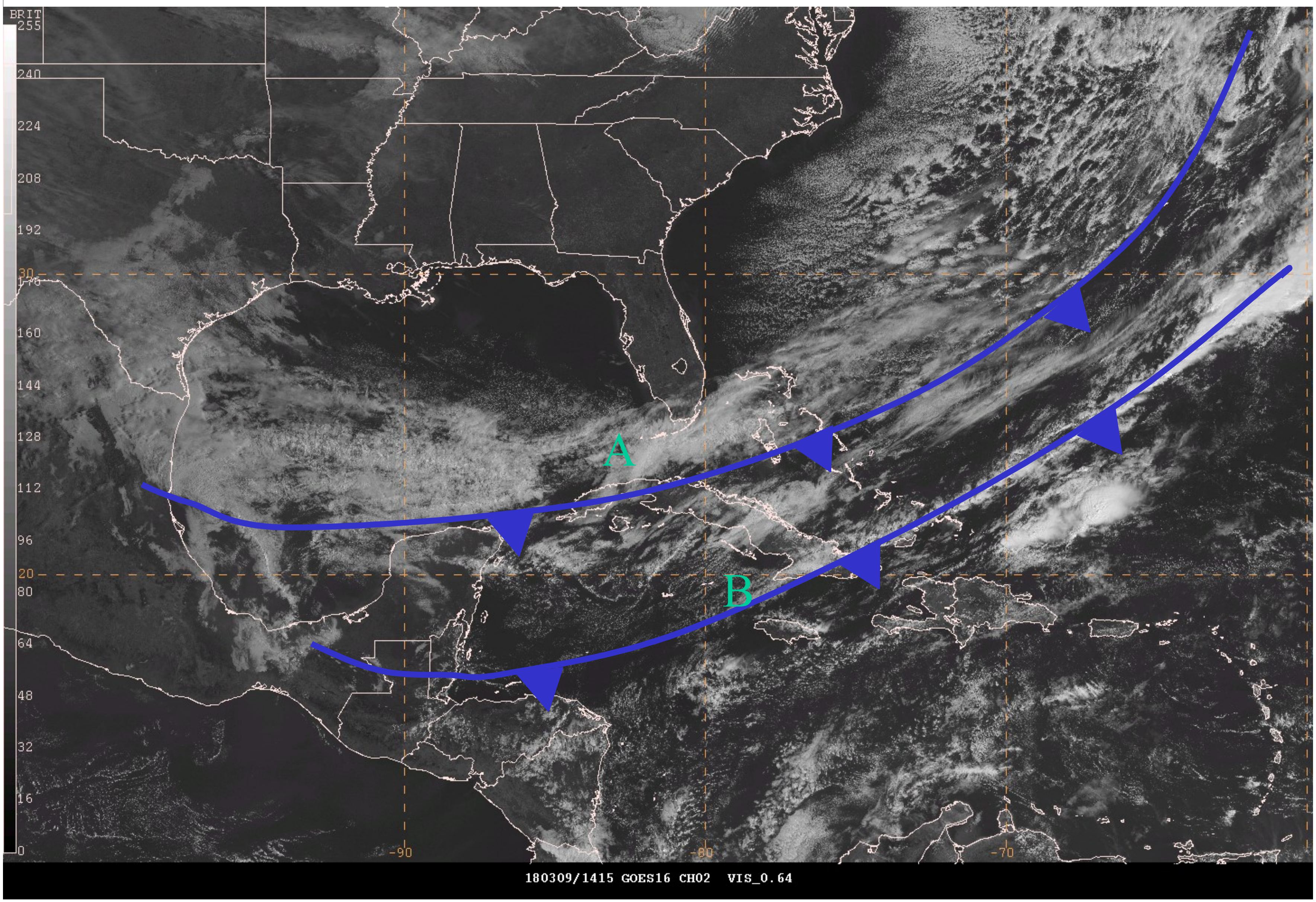
Prefrontal Over the Yucatan
T= 26-29C, Td= 20-23C
20181220_16:15Z



Postfrontal Over the Yucatan
T=21-22C, Td= 12-14C
20181221_15:15Z

Poll Question #4

Which one is correct?



Poll Question 4

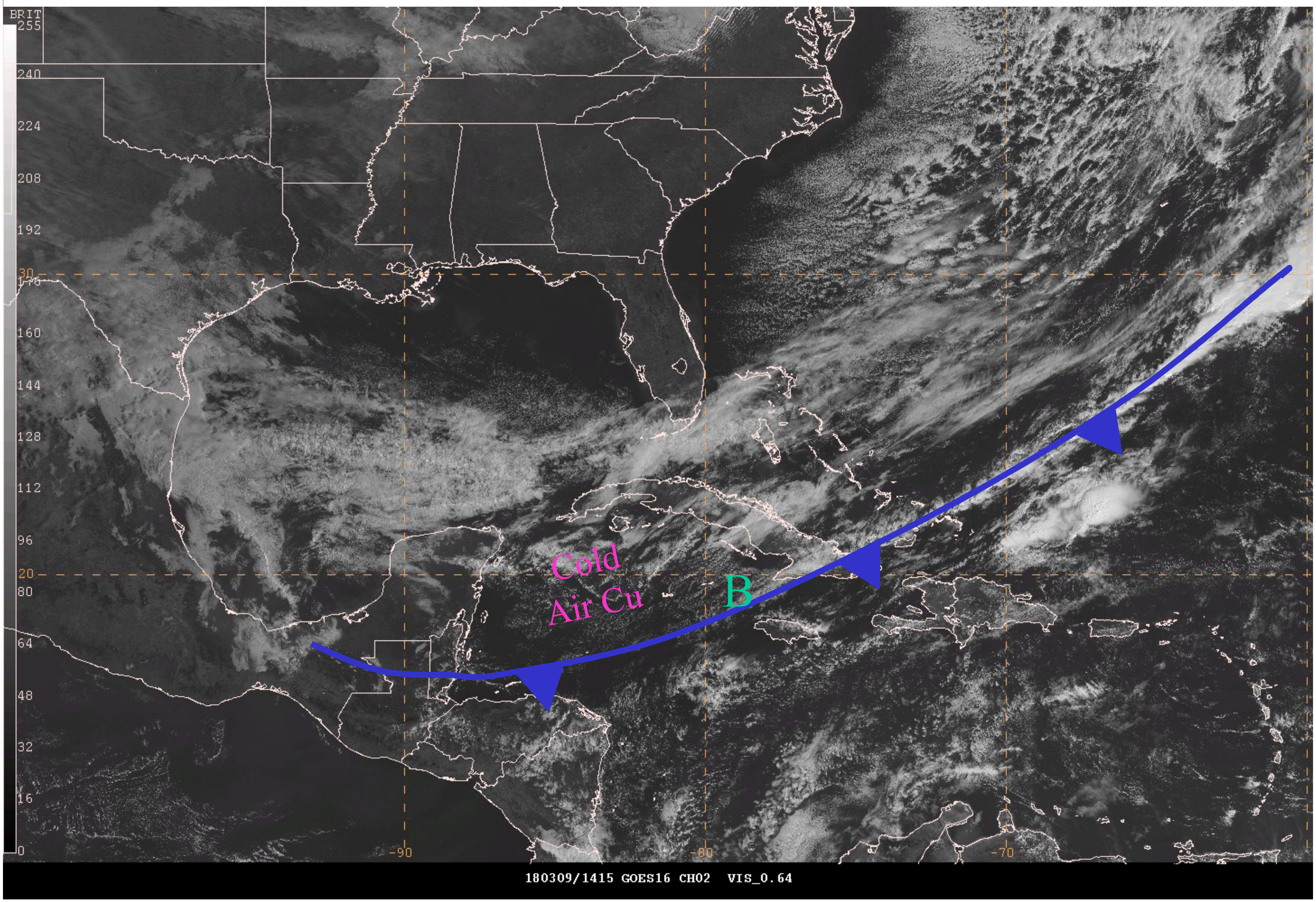
(Select One)

Which one is correct?

- A is correct
- B is correct
- A and B are incorrect
- A and B are correct

Poll Question 4 Review

Which one is correct?



Vertical Structure of a Front

1000-500 hPa Thickness

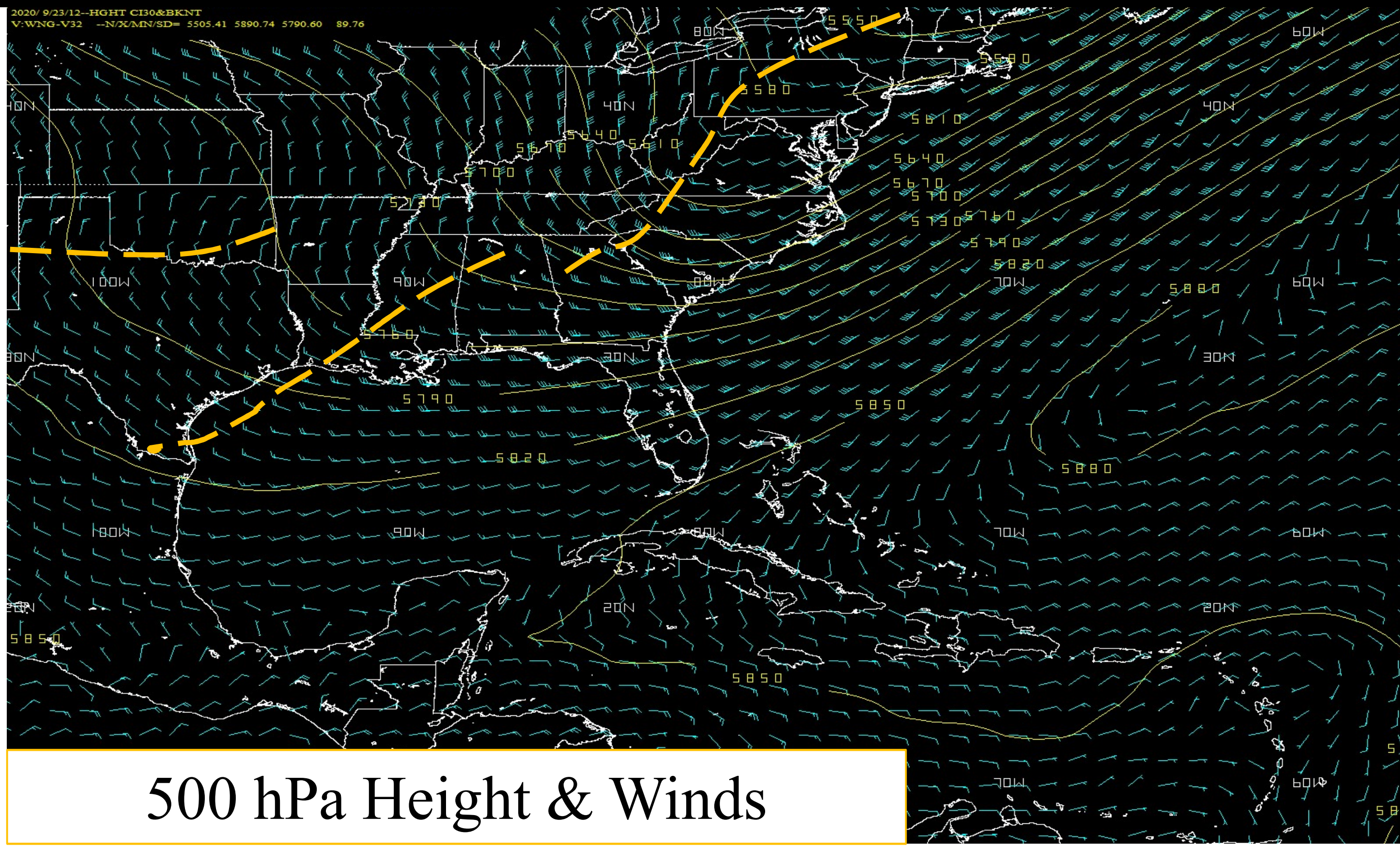
vs.

1000-850 hPa Thickness

Vertical Structure of a Front

- A deep layer/tropospheric polar front is one that **has** strong mid/upper level support
  - 1000-500 hPa Thickness
- A shallow layer polar front is one that **lacks** mid level support
  - 1000-850 hPa Thickness
- ***Fronts entering the tropics typically lack mid level support ⟹ 1000-850 Thck***

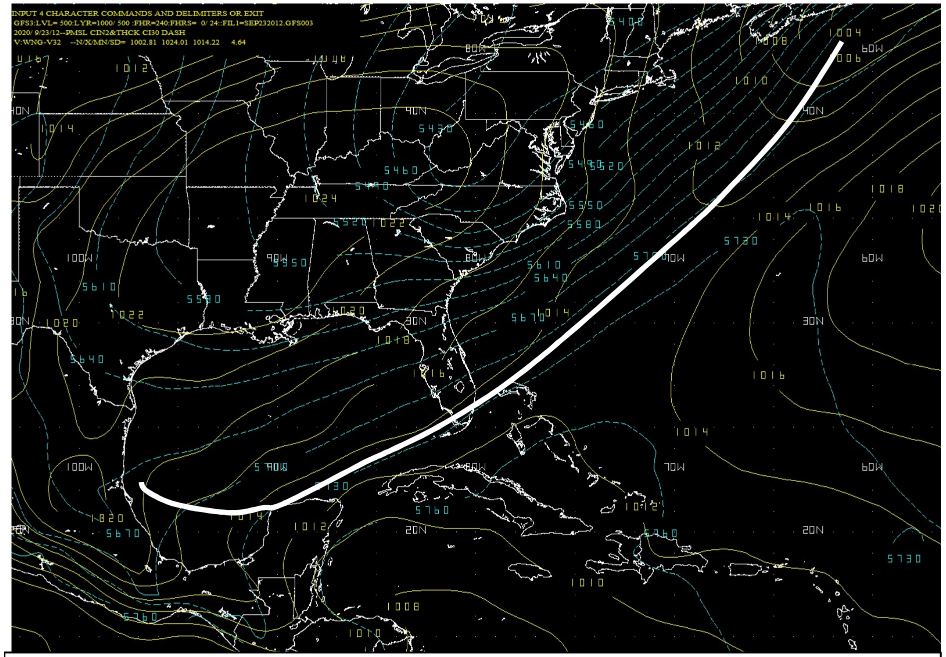
High Amplitude Long Wave Polar Trough



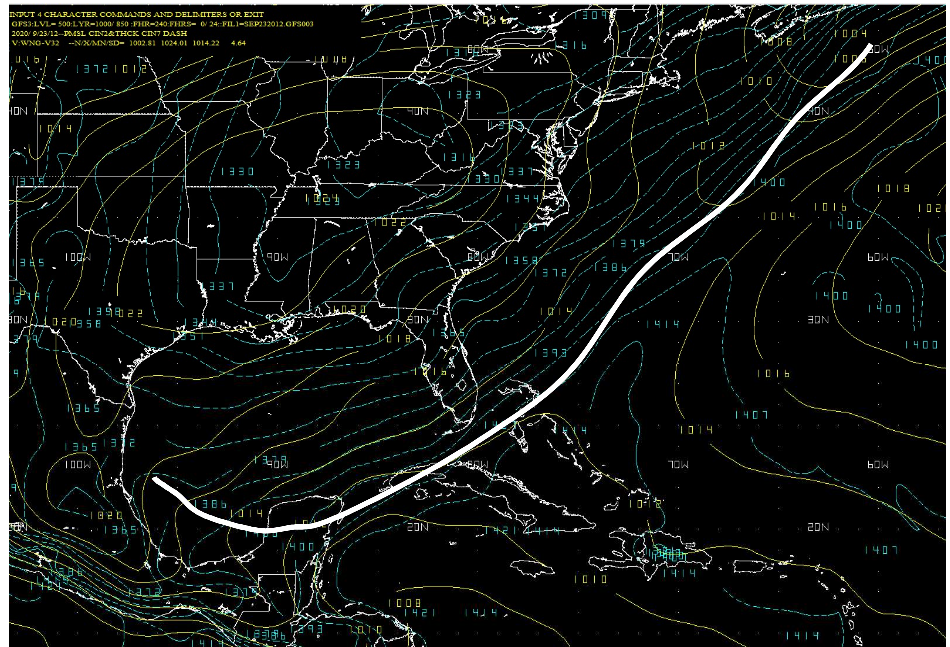
500 hPa Height & Winds

Highly amplified long wave trough over the eastern USA-Gulf of Mexico. The deep cold core is likely to reflect in both, the 1000-500 hPa and the 1000-850 hPa layers.

1000-500 Thickness vs 1000-850 Thickness



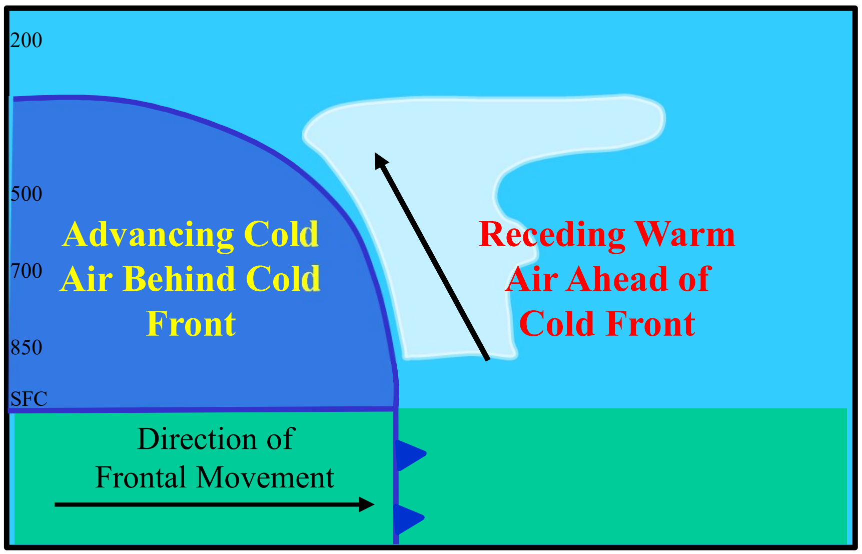
PMSL & 1000-500 Thickness



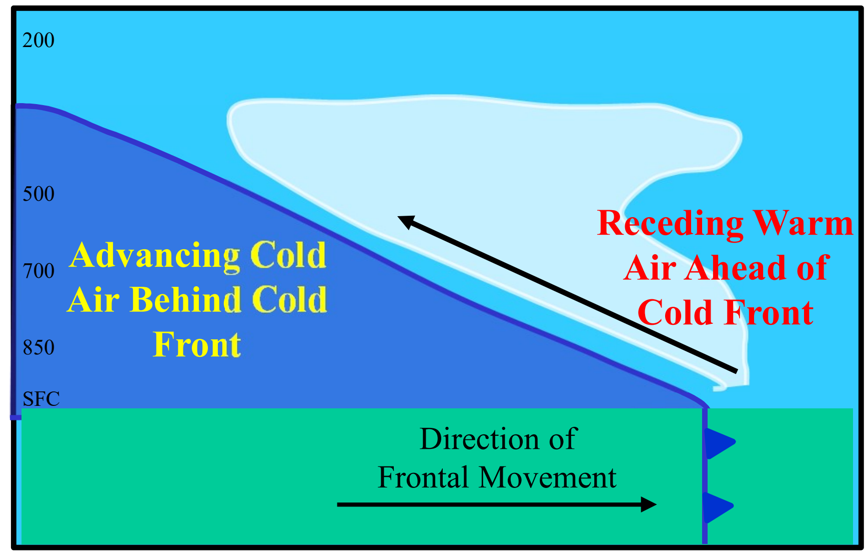
PMSL & 1000-850 Thickness

- Although the 1000-500 hPa thickness gradient clearly shows a front over the Gulf of Mexico, the 1000-850 hPa provides finer detail.
- The difference is due to the slope of the cold front

Frontal Slope



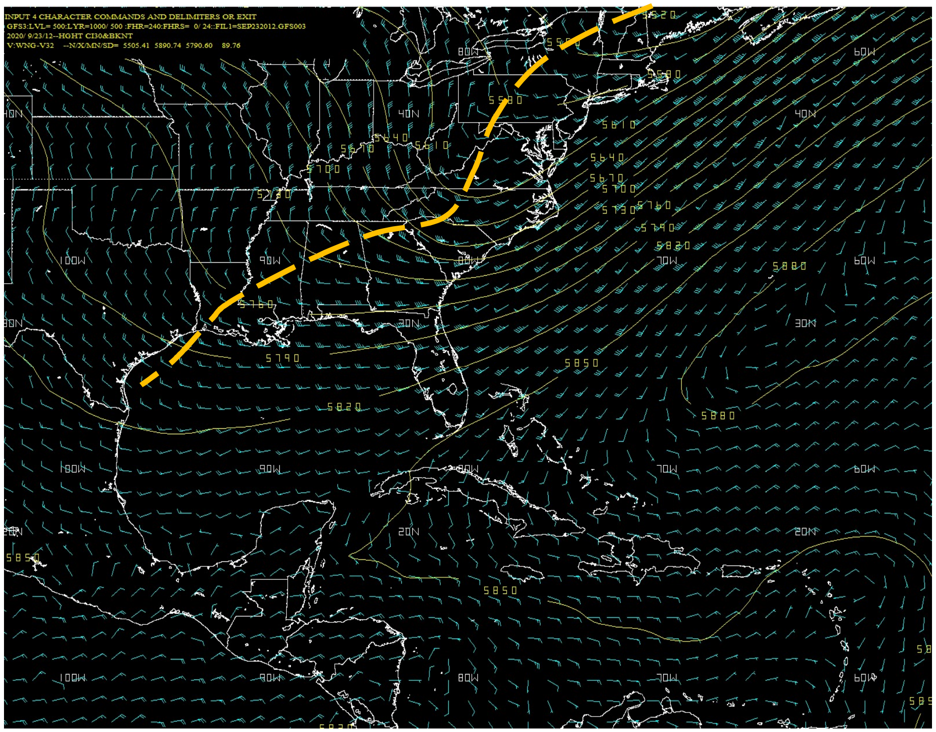
Steep frontal slope

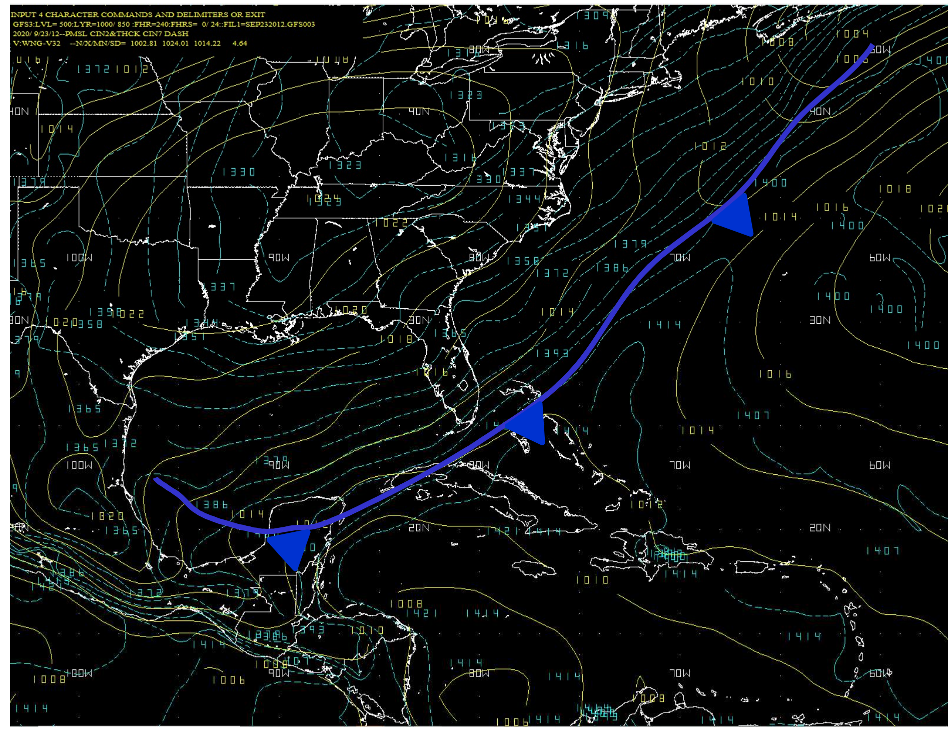


Gradual/Gentle frontal slope

In a shallower boundary with a gentler slope, the 1000-500 hPa thickness would not reflect the proper placement of the surface front as it enters the tropics.

Deep Polar Trough: 1000-850hPa Thickness



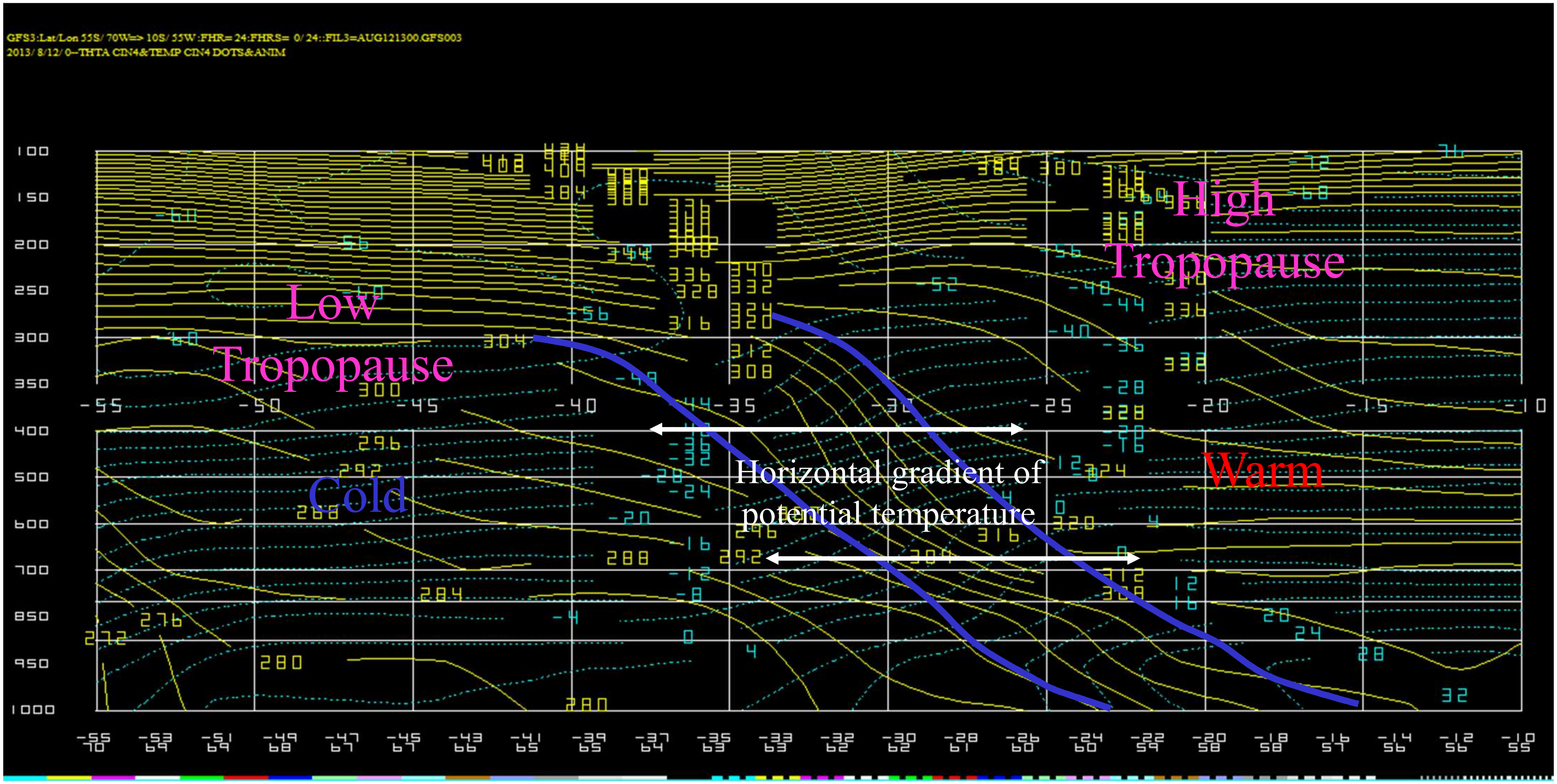


500 hPa Height & Winds

PMSL & 1000-850 Thickness

Deep layer support, with the mid level trough bottoming over the Gulf of Mexico.

Vertical Cross Section
Temperature and Potential Temperature



Analyzing fronts in a cross section: Evaluate the horizontal gradient of Temperature or Potential Temperature

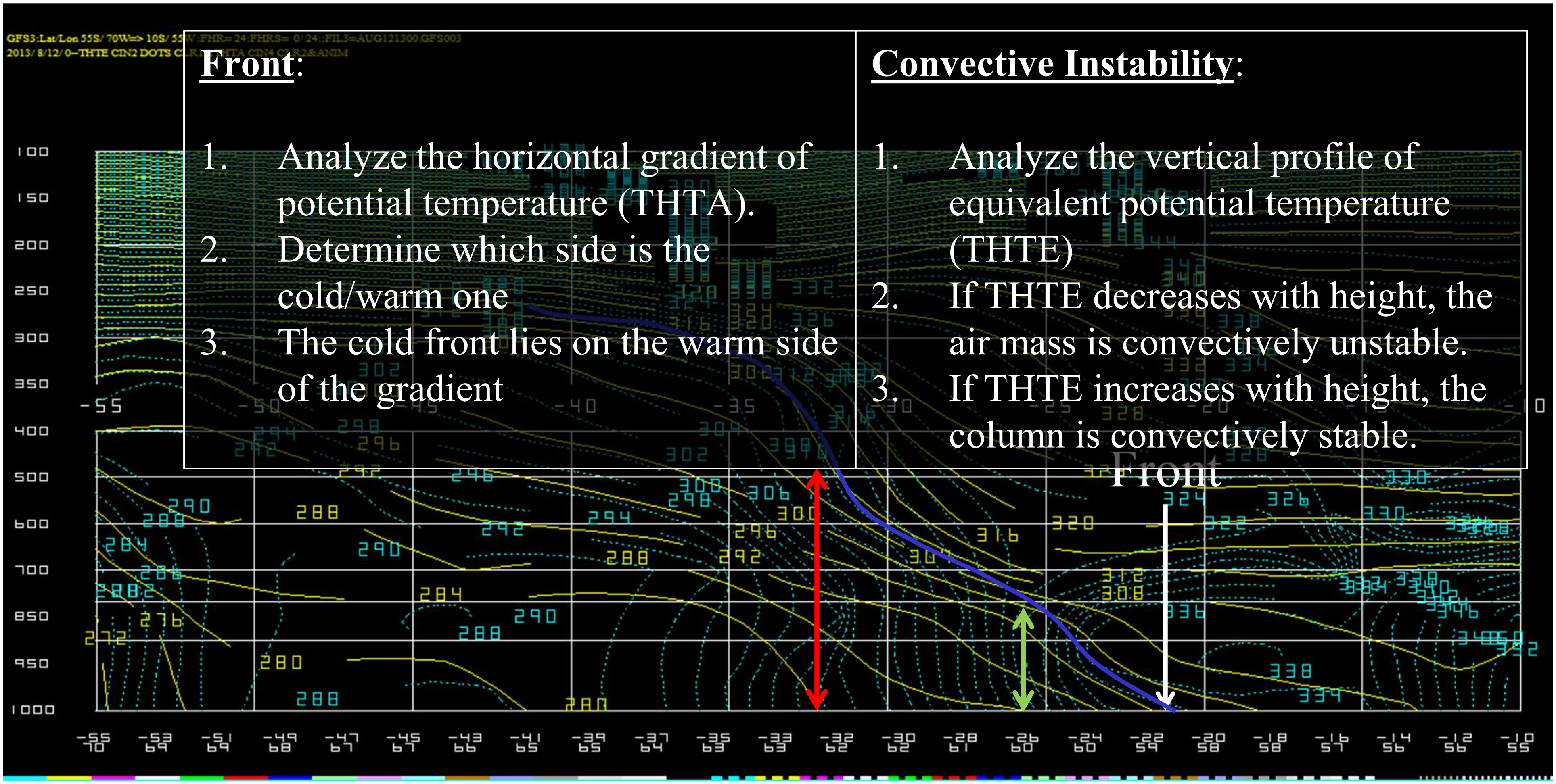
Vertical Cross Section of Potential Temperature and EPT for F24 (Deep Boundary)

Front:

1. Analyze the horizontal gradient of potential temperature (THTA).
2. Determine which side is the cold/warm one
3. The cold front lies on the warm side of the gradient

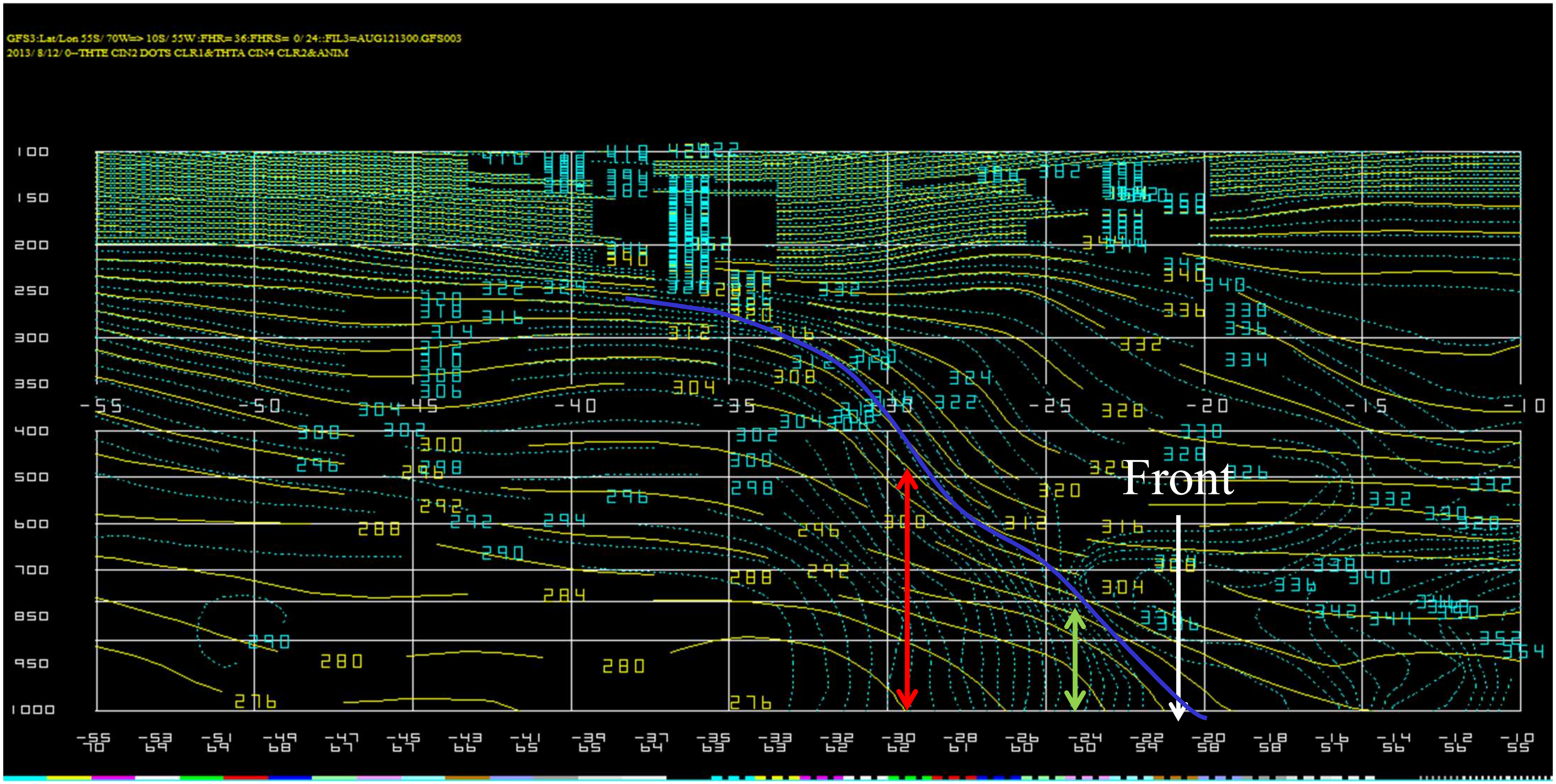
Convective Instability:

1. Analyze the vertical profile of equivalent potential temperature (THTE)
2. If THTE decreases with height, the air mass is convectively unstable.
3. If THTE increases with height, the column is convectively stable.



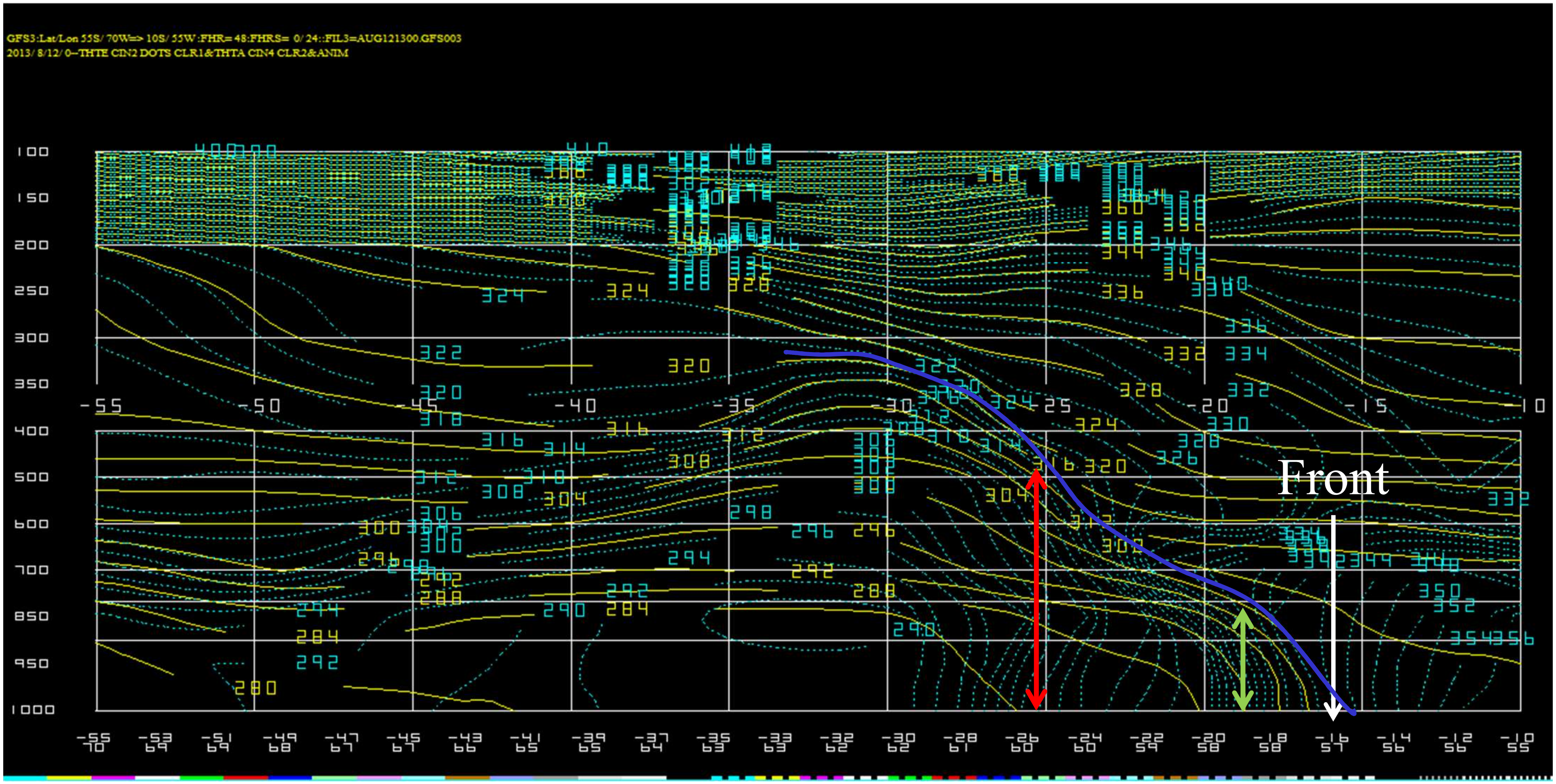
Front has deep layer support and it is clearly evident in both layers, 1000-850 and 1000-500 hPa

Vertical Cross Section of Potential Temperature and EPT for F36 (Deep Boundary/Steep Slope)



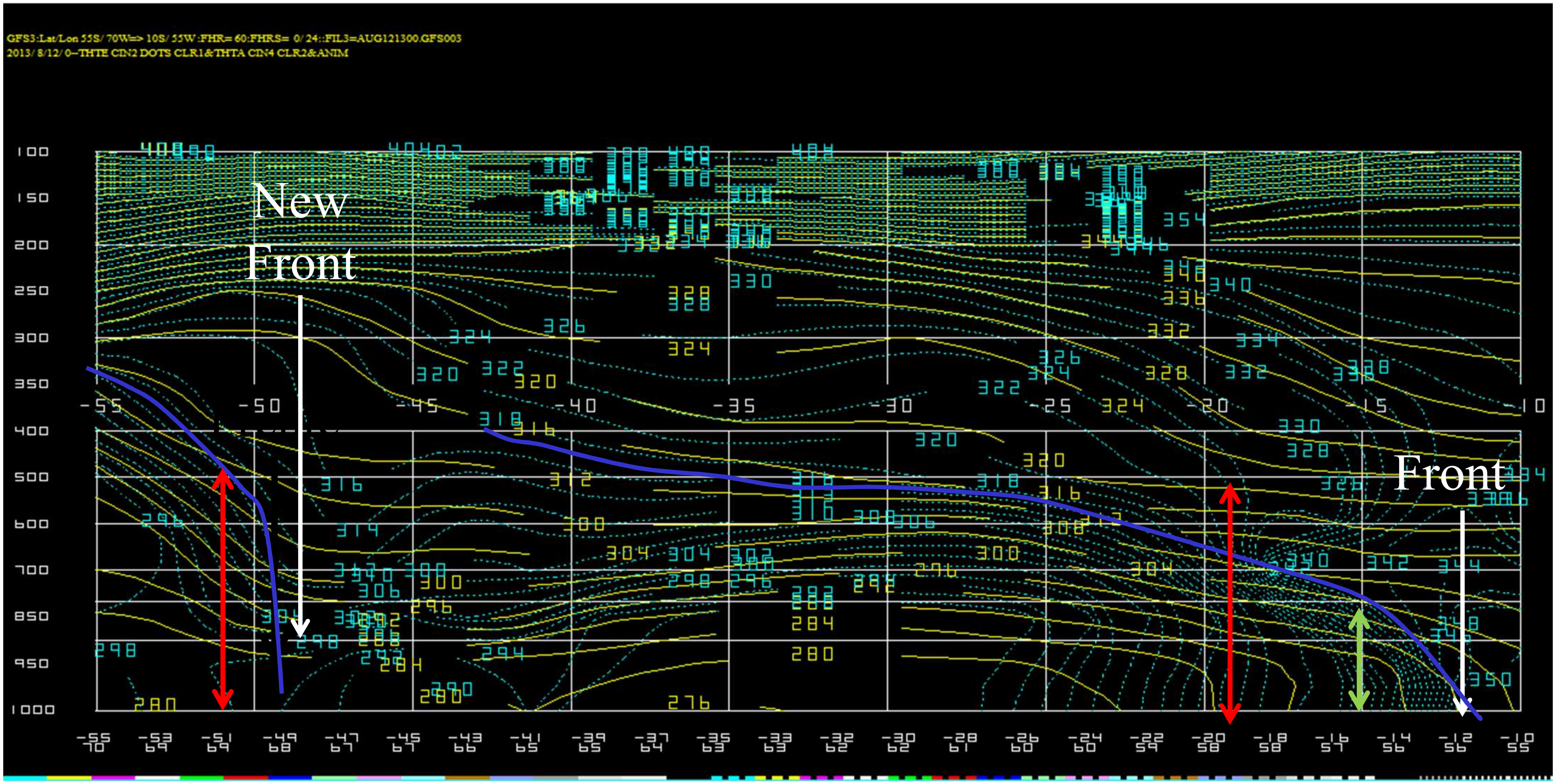
Front has deep layer support and it is clearly evident in both layers, 1000-850 and 1000-500 hPa

Vertical Cross Section of Potential Temperature and EPT for F48 (Deep Boundary/Steep Slope)



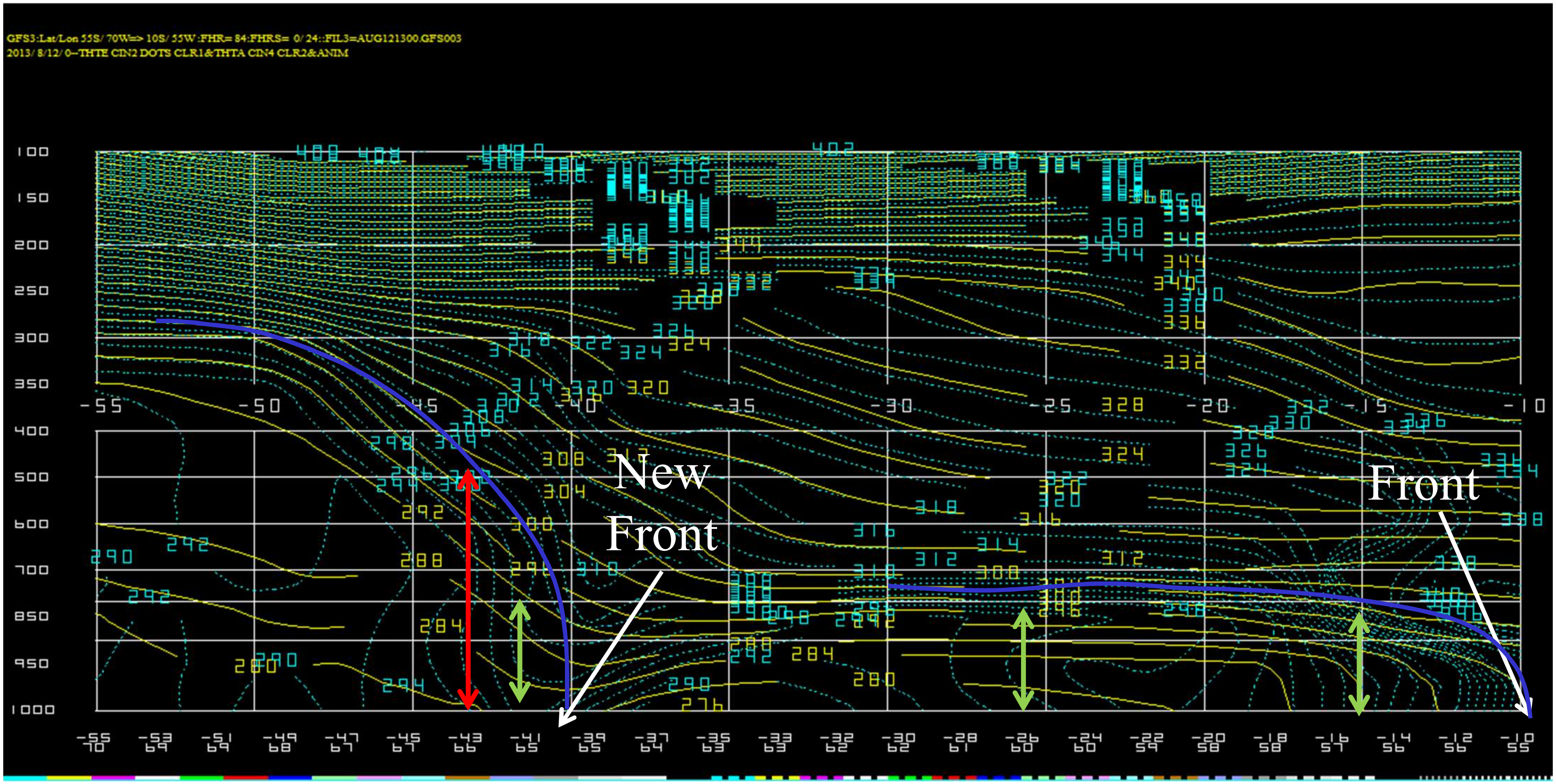
Front has deep layer support and it is clearly evident in both layers, 1000-850 and 1000-500 hPa

Vertical Cross Section of Potential Temperature and EPT for F60. (Shallow boundary/gentler slope)



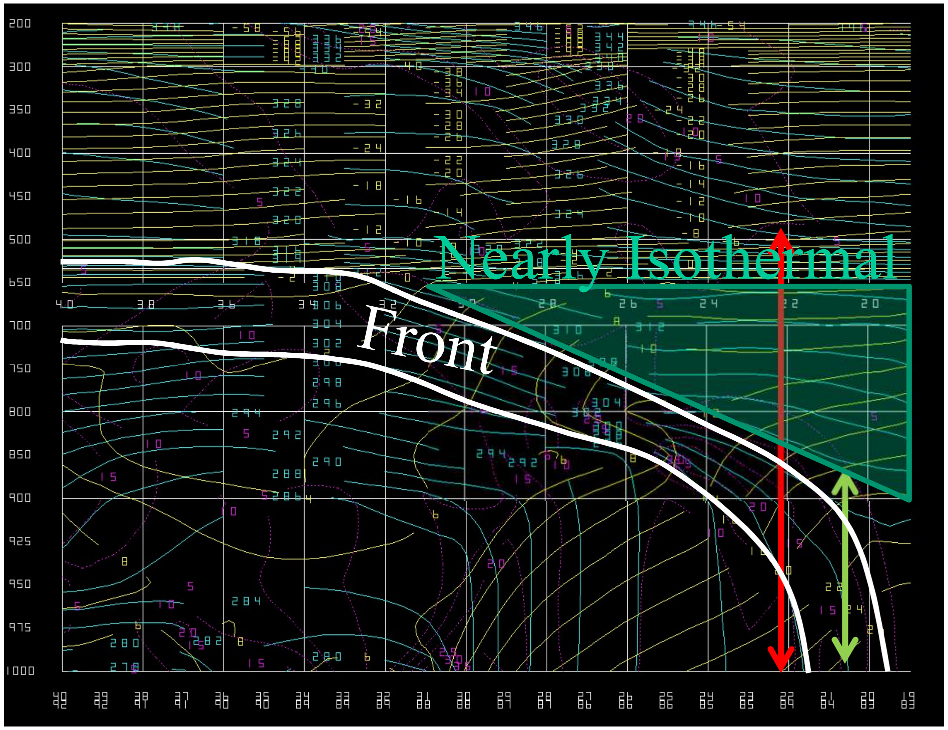
Front well defined in the 1000-850 hPa layer, but no longer between 1000-500 hPa

Vertical Cross Section of Potential Temperature and EPT at F84. Shallow Boundary south into the Tropics

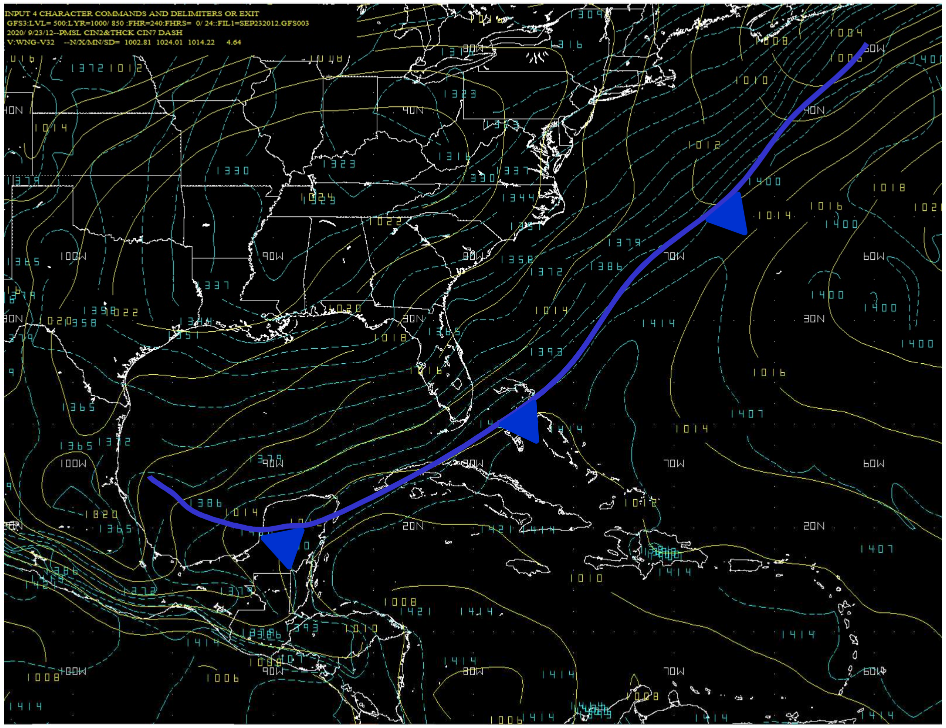


Old front well defined in the 1000-850 hPa layer, but no longer between 1000-500 hPa

Deep Polar Trough: 1000-850 Thickness



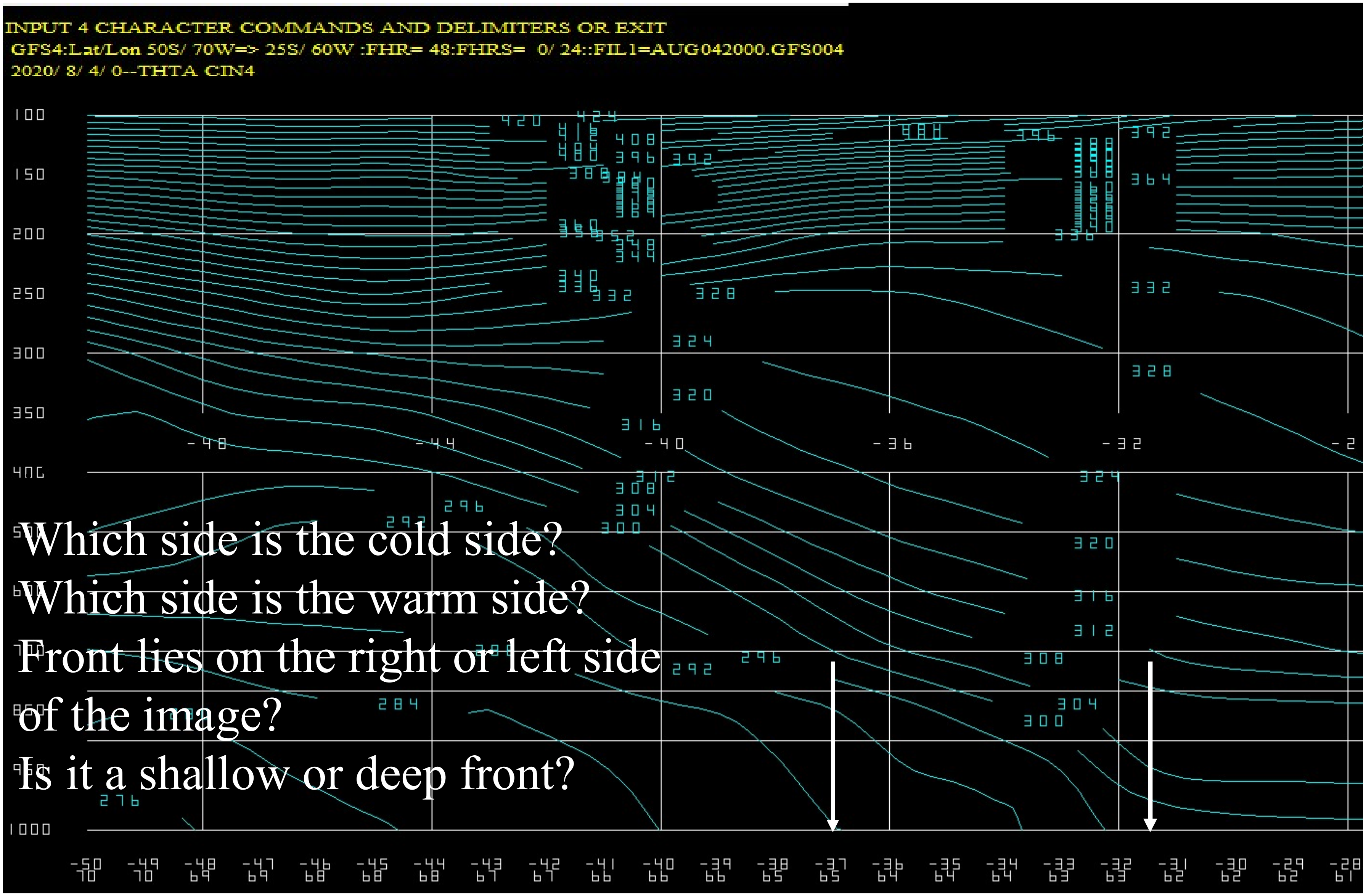
Vertical Cross Section: THTA, TEMP and Gradient



PMSL & 1000-850 Thickness

Layer above 800 hPa nearly isothermal. Lacking contrast, the thickness between the 1000-500 hPa is not as representative as **1000-850** hPa.

Poll #5



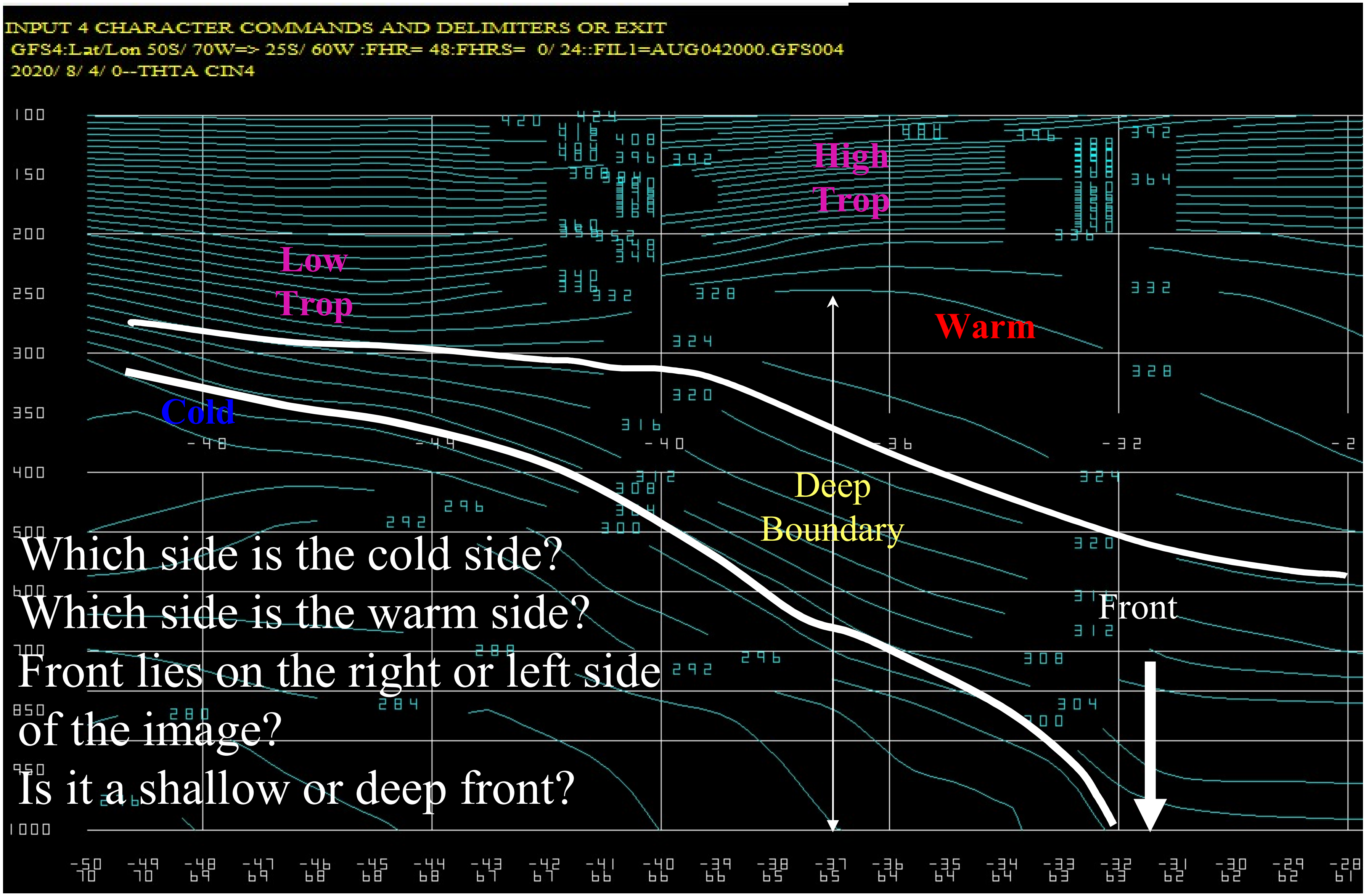
Which side is the cold side?
Which side is the warm side?
Front lies on the right or left side of the image?
Is it a shallow or deep front?

Poll Question #5

(Select all that apply)

- The left side is the cold side
- The tropopause is higher to the left
- The right side is the warm side
- Surface front to the left of the gradient
- This is a shallow front

Poll #5 Review



Analysis Tools

Analysis Tools

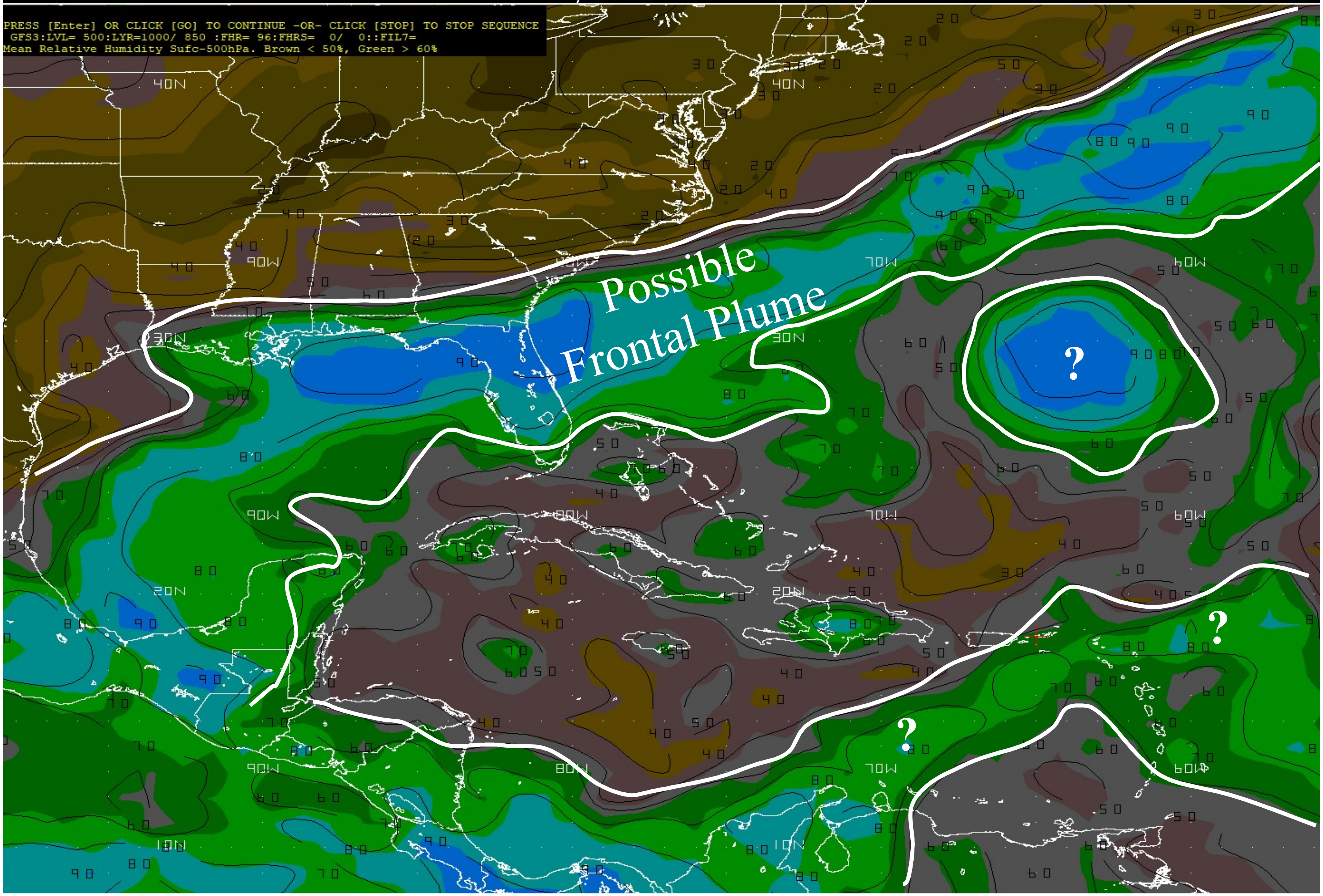
- Mean Layer Relative Humidity
- Equivalent Potential Temperature (EPT)
- “FRONT” Macro

Mean Layer Relative Humidity

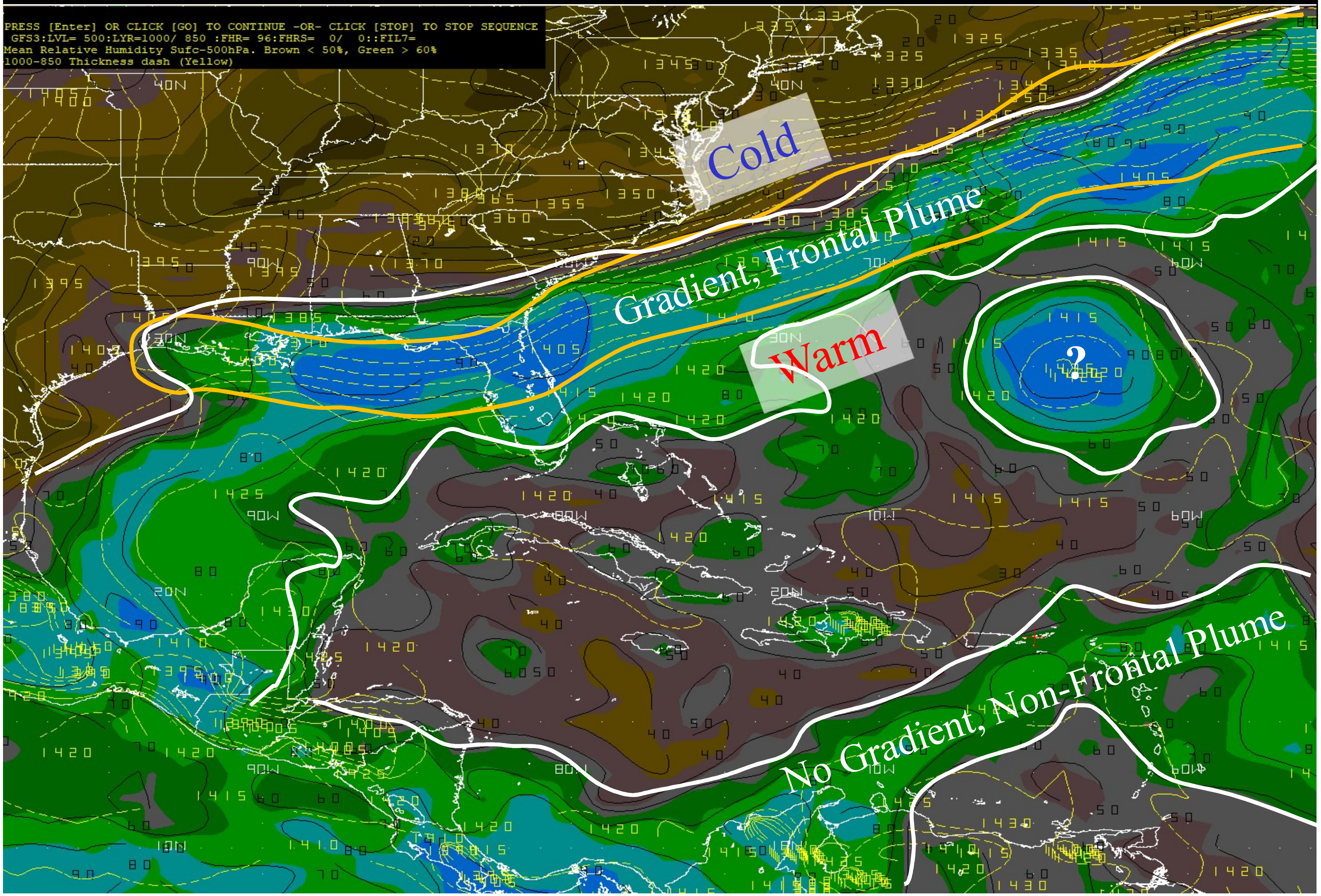
- **<u>Mean Layer Relative Humidity</u>**
  - The mean layer relative humidity between the surface and 500 hPa
  - RH tells us how close to saturation
    - Does not quantify moisture content
  - Typically, RH 60% or greater for significant cloud cover
  - Quasi-conservative property
    - As the front propagates, moisture propagates with it.

Mean Layer RH

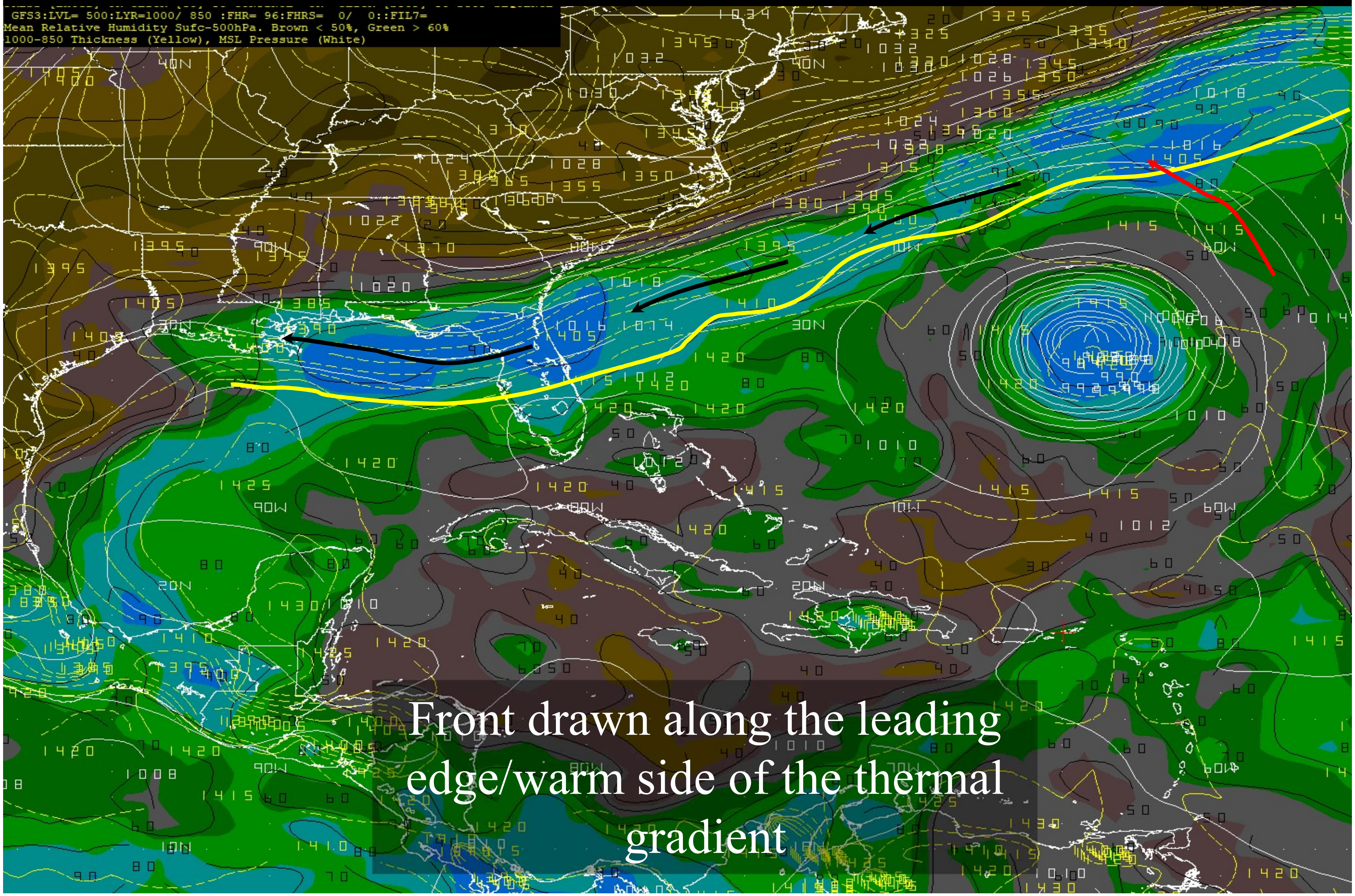
From GFS, 20200917 00, F96



Mean Layer RH / 1000-850 THCK

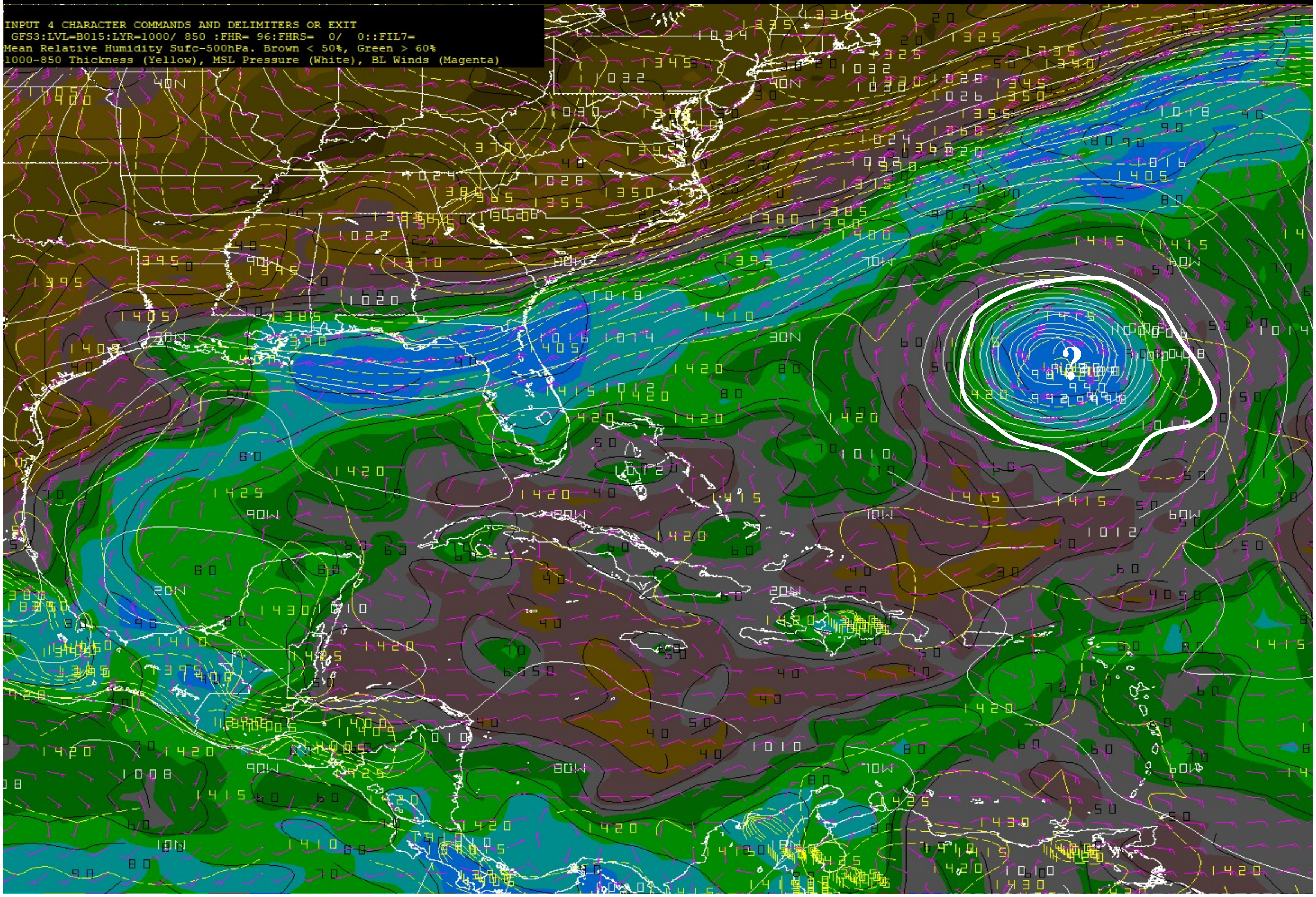


Mean Layer RH, THCK, PMSL

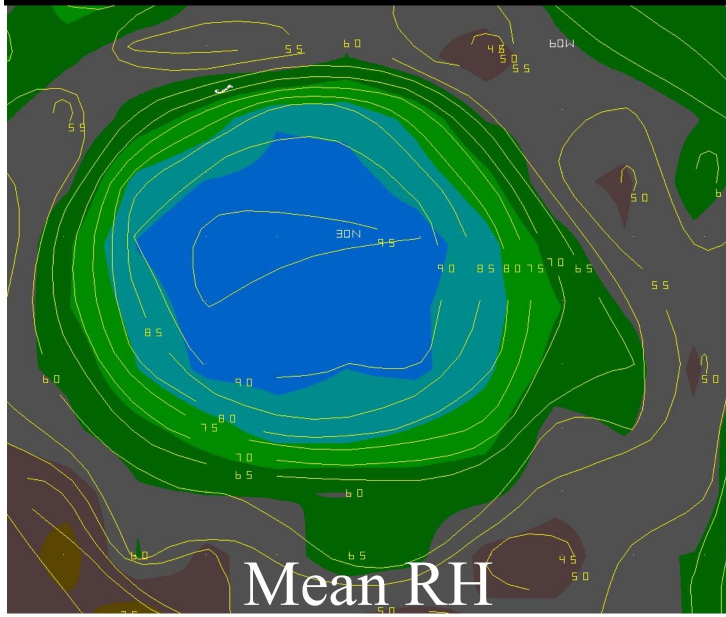


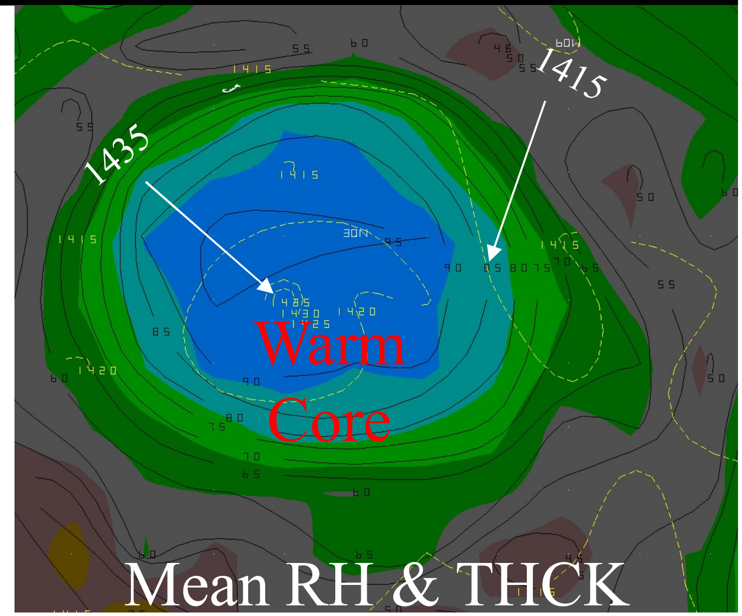
Front drawn along the leading edge/warm side of the thermal gradient

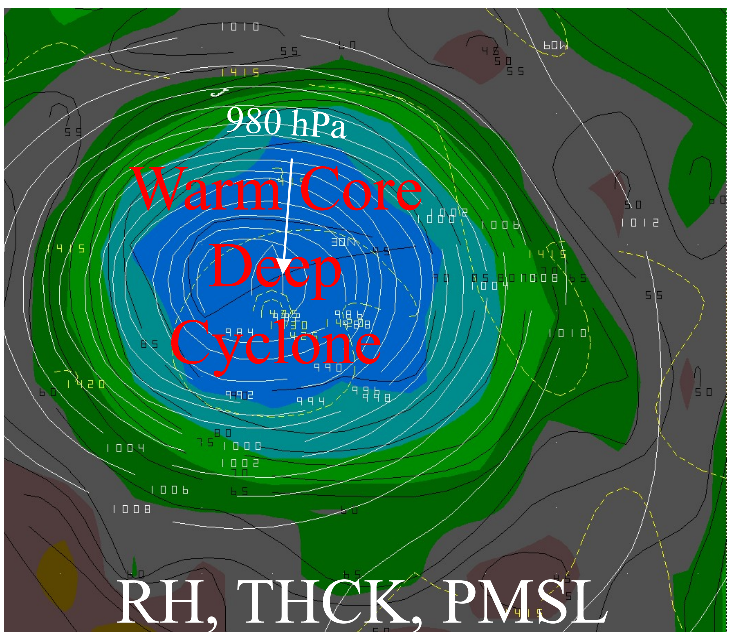
RH, THCK, PMSL, BL Winds

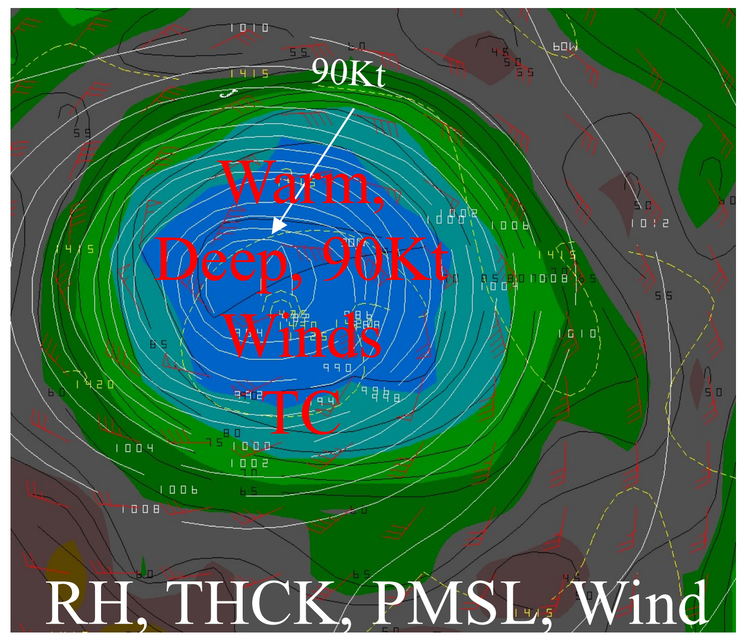


Invest - Moist Pool

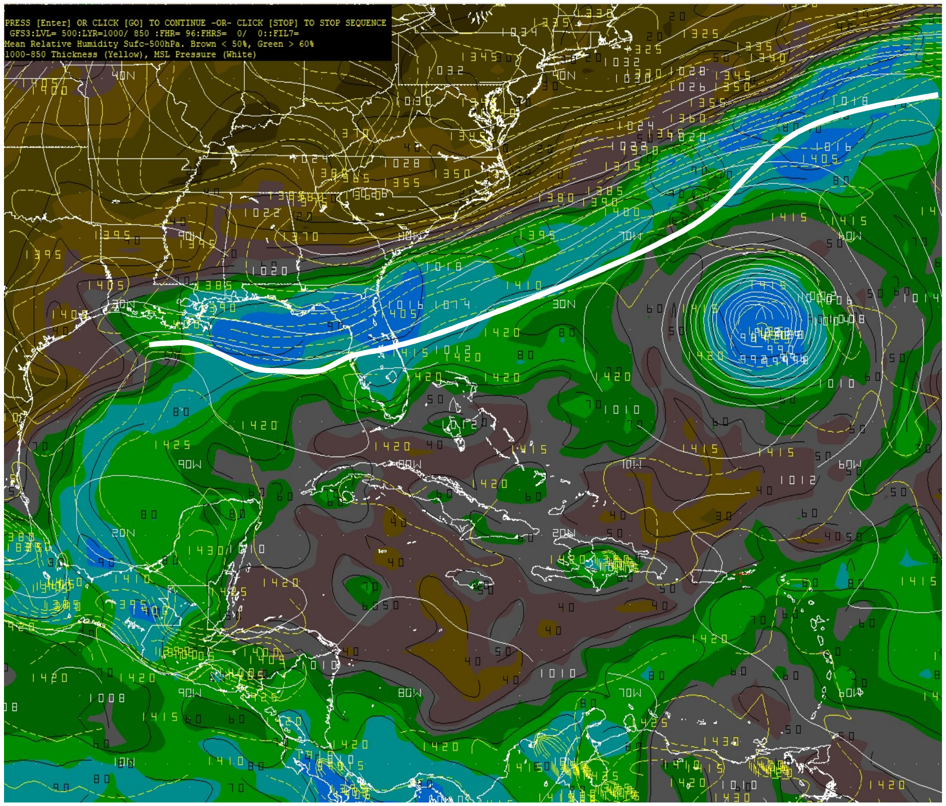


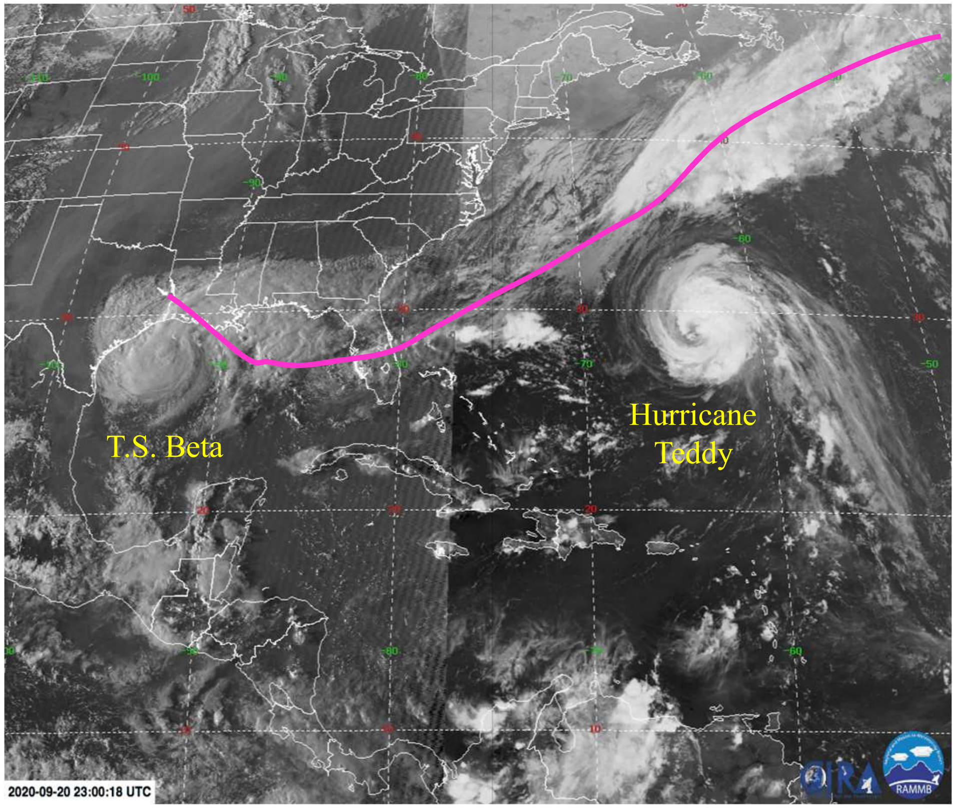






Verification of the Forecast

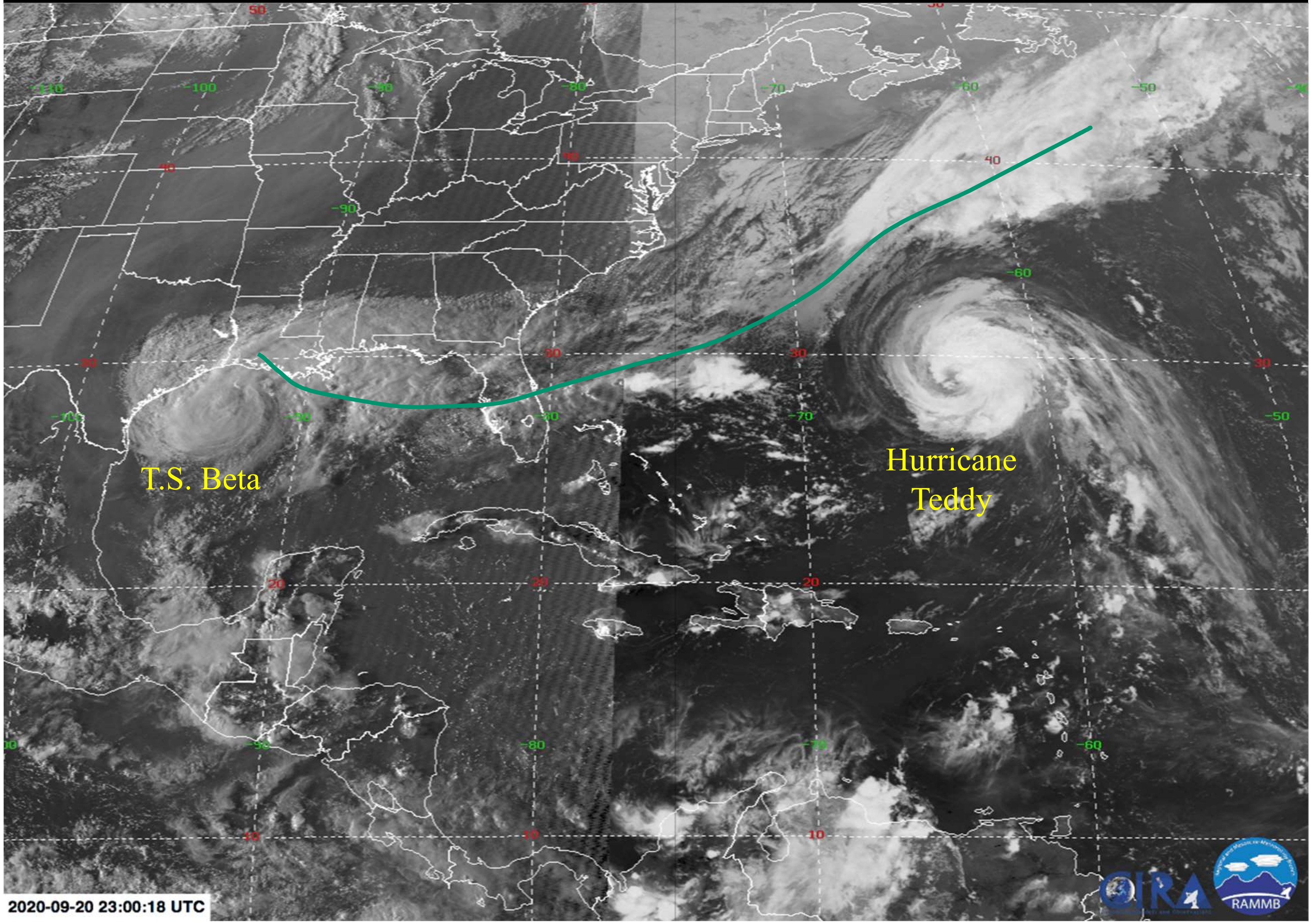




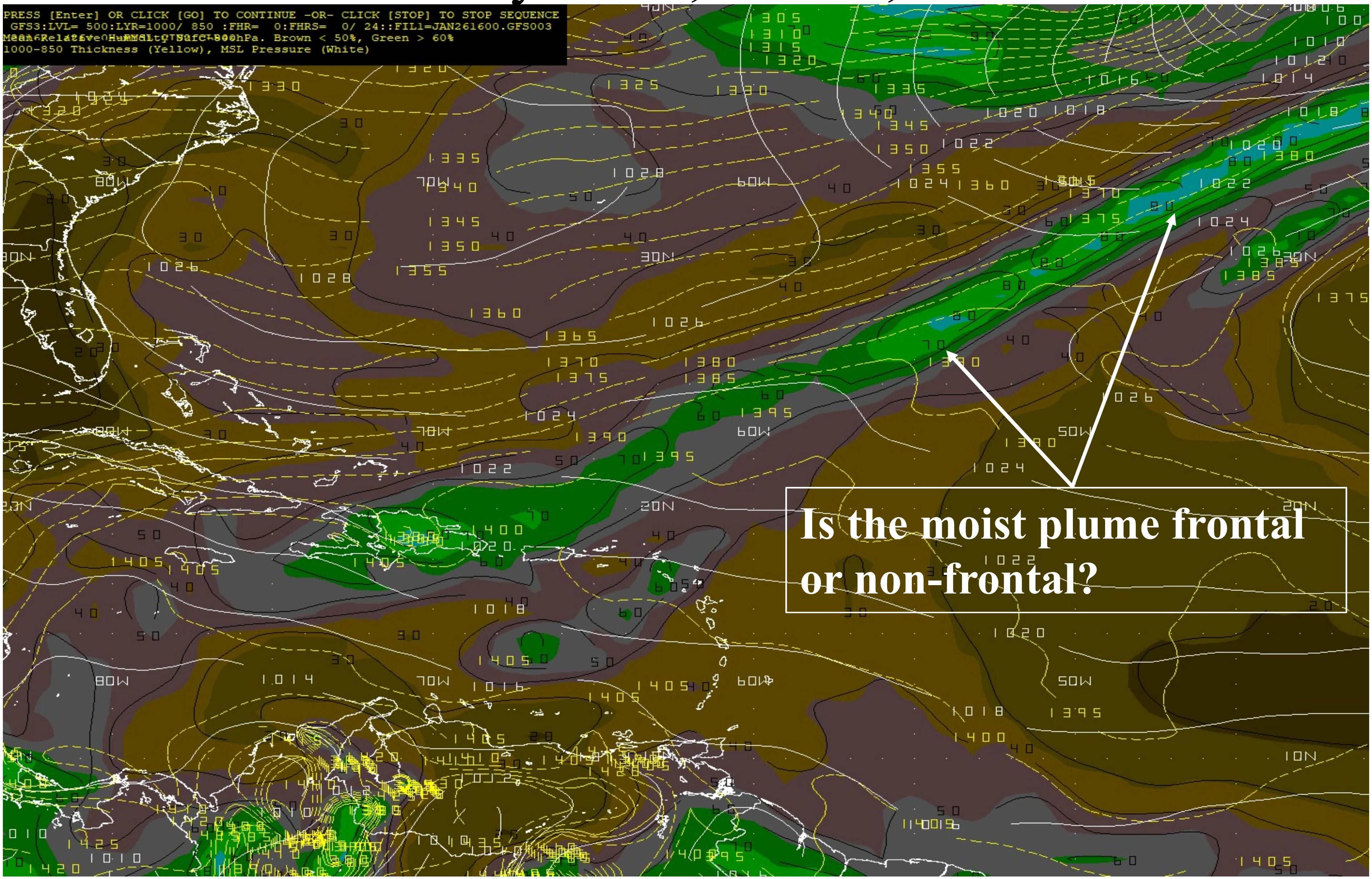
VT: 20200921/00Z

Proxy Visible

20200920-23Z to 20200921-01Z



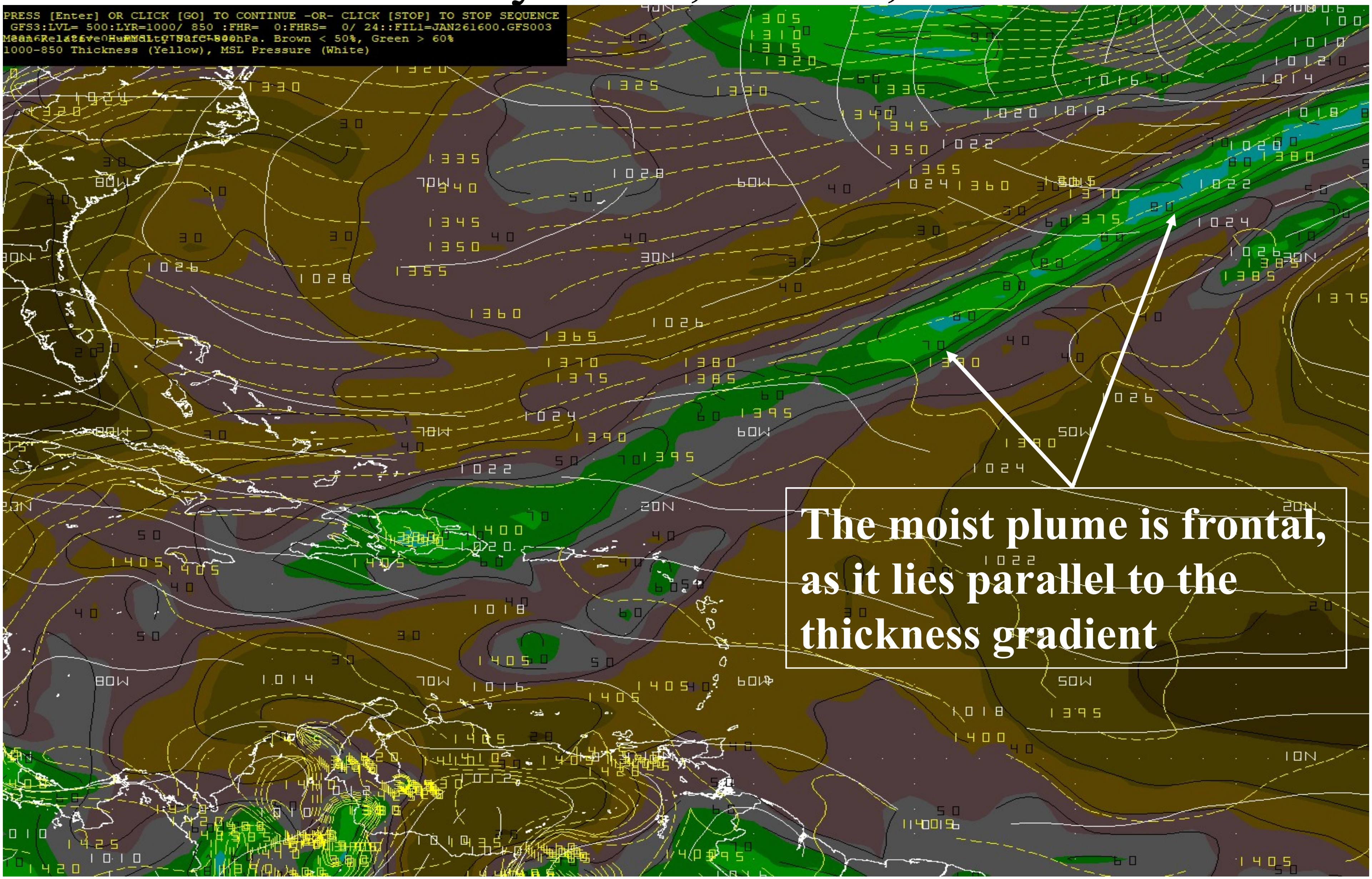
Poll #6
Mean Layer RH, THCK, PMSL



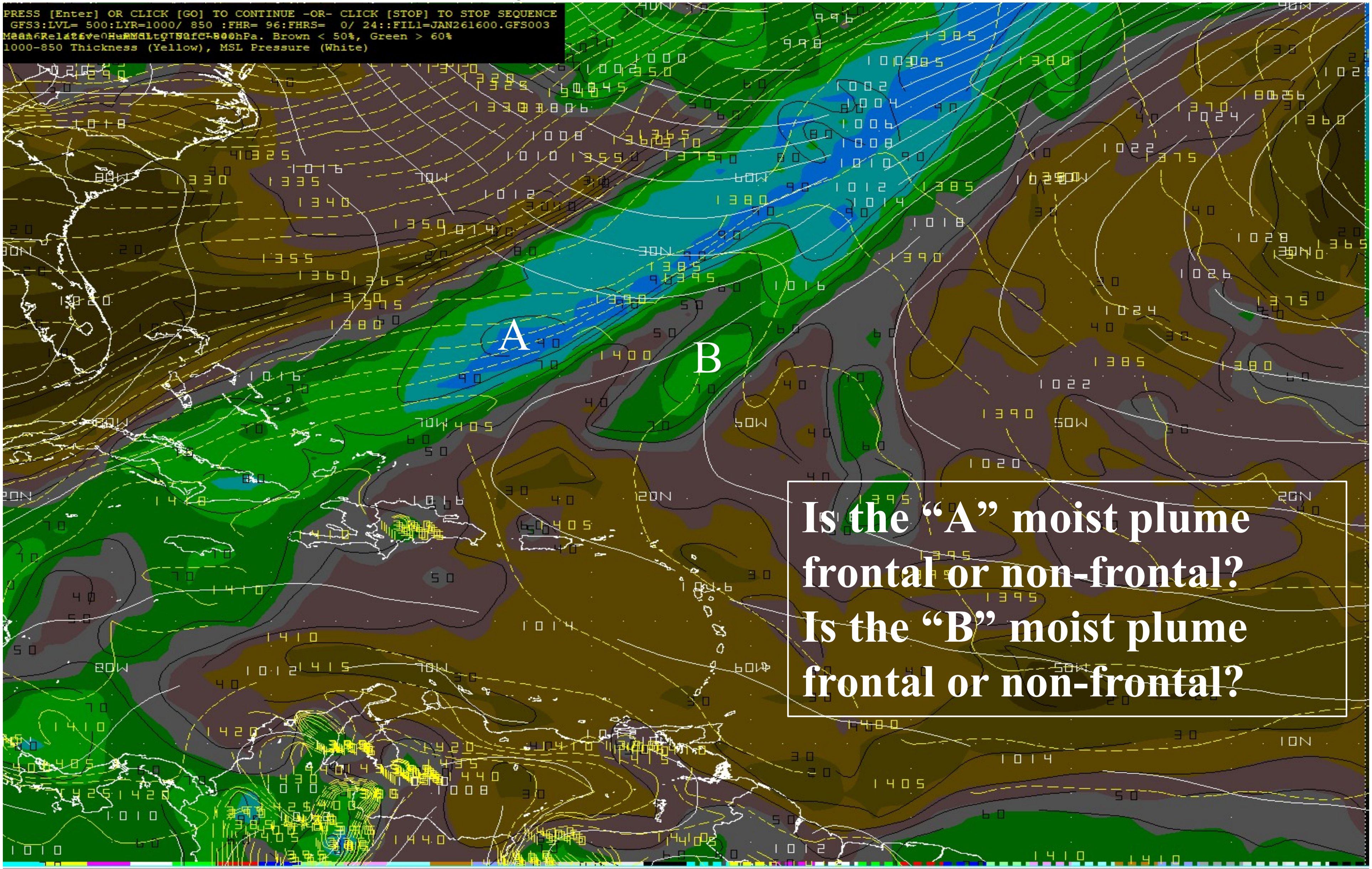
Poll #6
Is the moist plume frontal or non-frontal
(Select one)

- It is frontal
- It is non-frontal
- Cannot be determined

Poll #6 Review
Mean Layer RH, THCK, PMSL



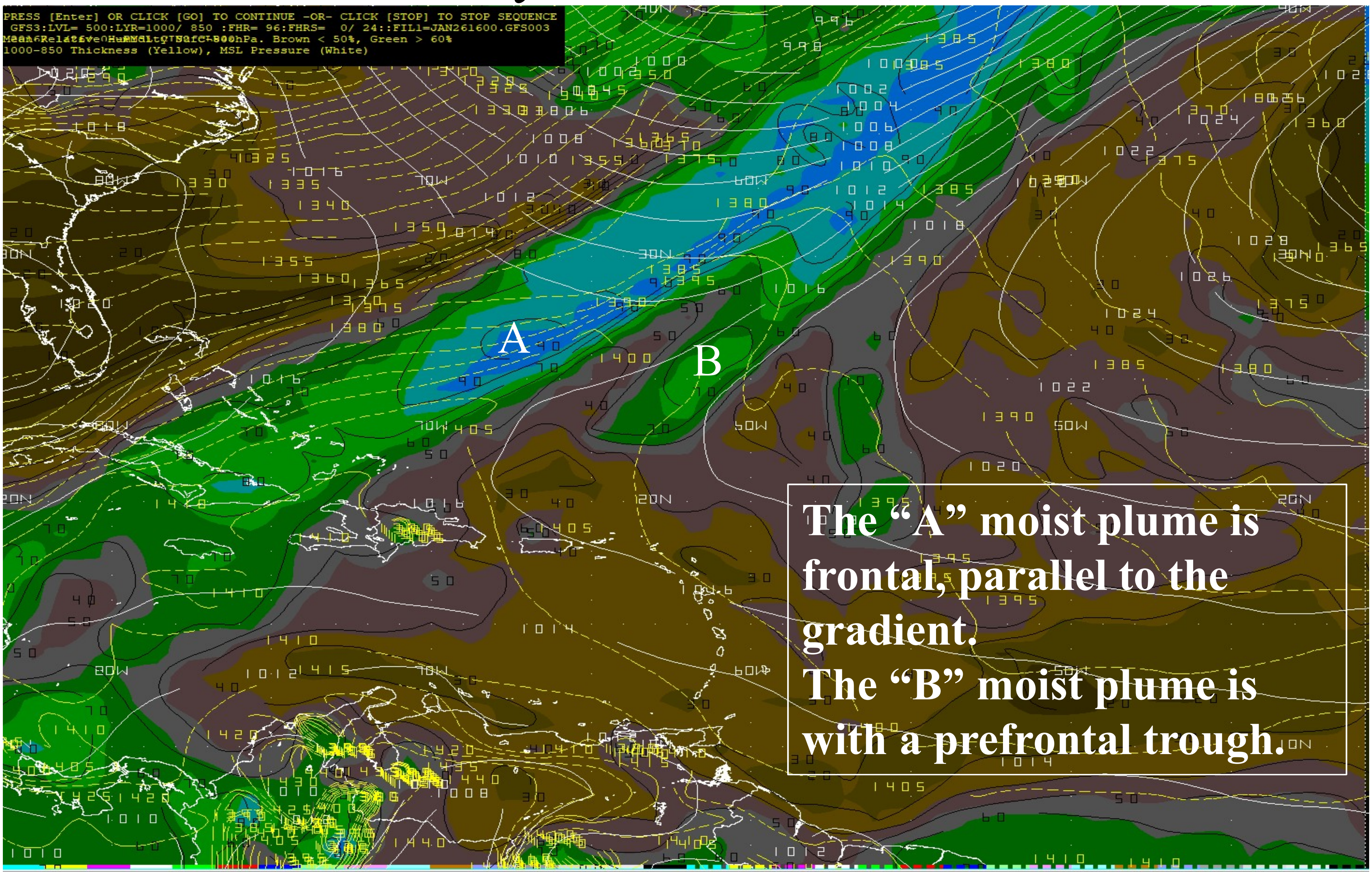
Poll #7
Mean Layer RH, THCK, PMSL



Poll #7
(Select one)

- "A" is frontal, "B" is non-frontal
- "A" is non-frontal, "B" is frontal
- "A" and "B" are frontal
- "A" and "B" are non-frontal

Poll #7 Review
Mean Layer RH, THCK, PMSL



Equivalent Potential Temperature (EPT)

The secret to tropical weather forecasting

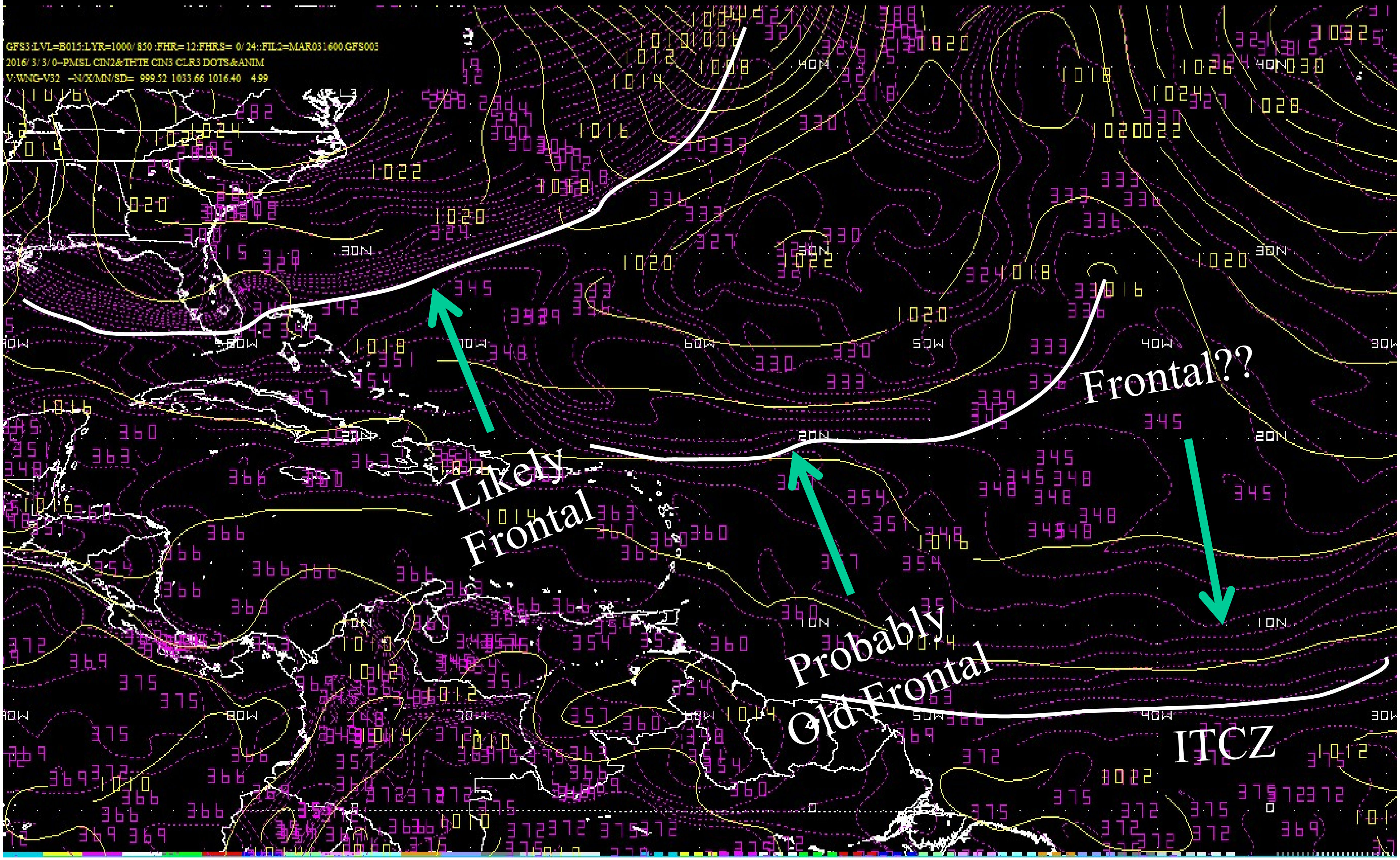
Equivalent Potential Temperature (EPT)

- Temperature of a parcel of air when you add the latent heat released during condensation to the sensible temperature of the parcel at constant pressure (1000 hPa)
  - It depends on the moisture content and actual temperature of the parcel
    - **If T held constant, EPT then varies as a function of the moisture content of the parcels**

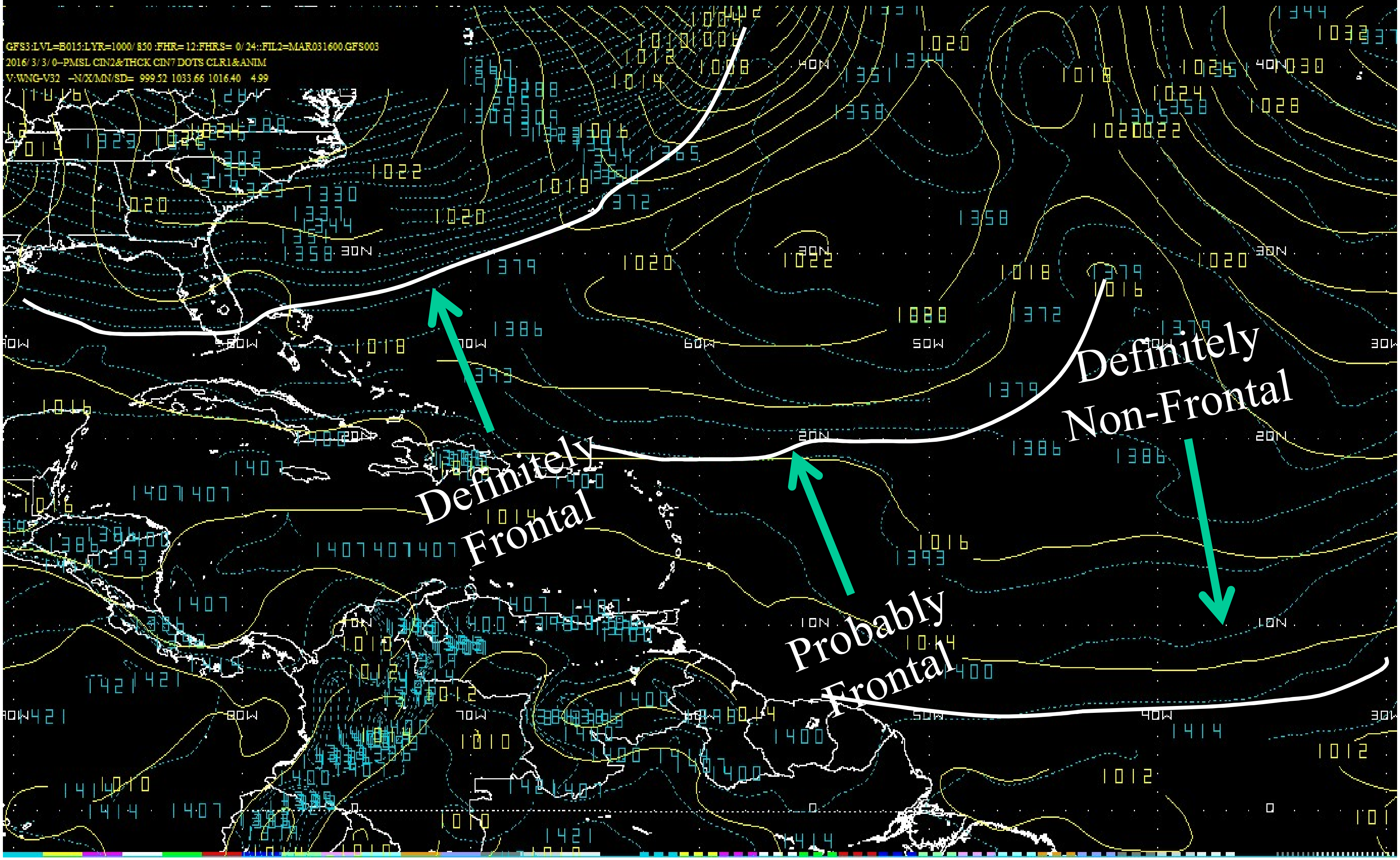
EPT

- Could we use EPT to determine baroclinicity?
  - ***Yes*** **as long as EPT is a function of both T and Td.**
  - ***No*** **if EPT is solely a function of Td, with T held constant**

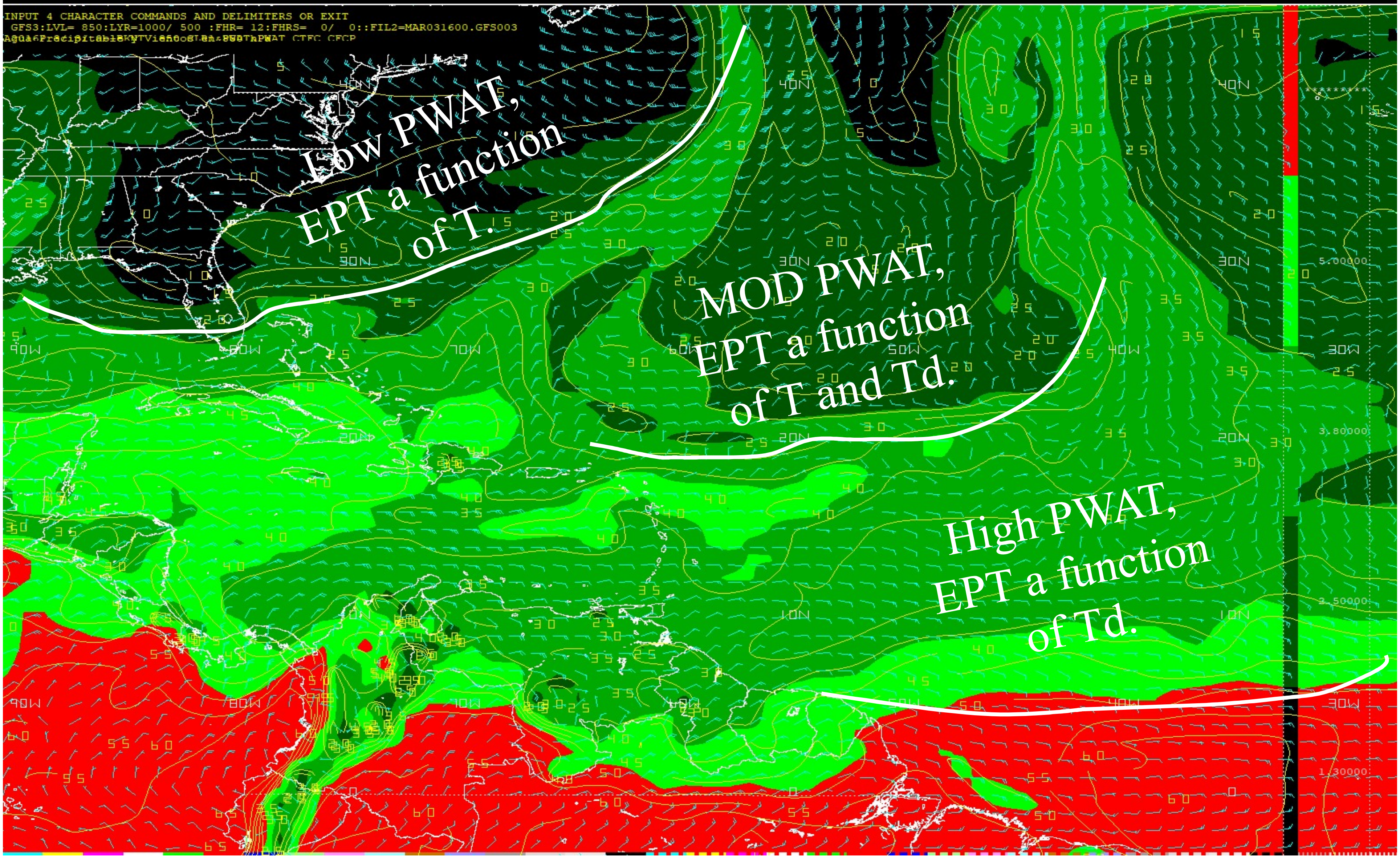
EPT and MSLP
Evaluate Frontal Gradients



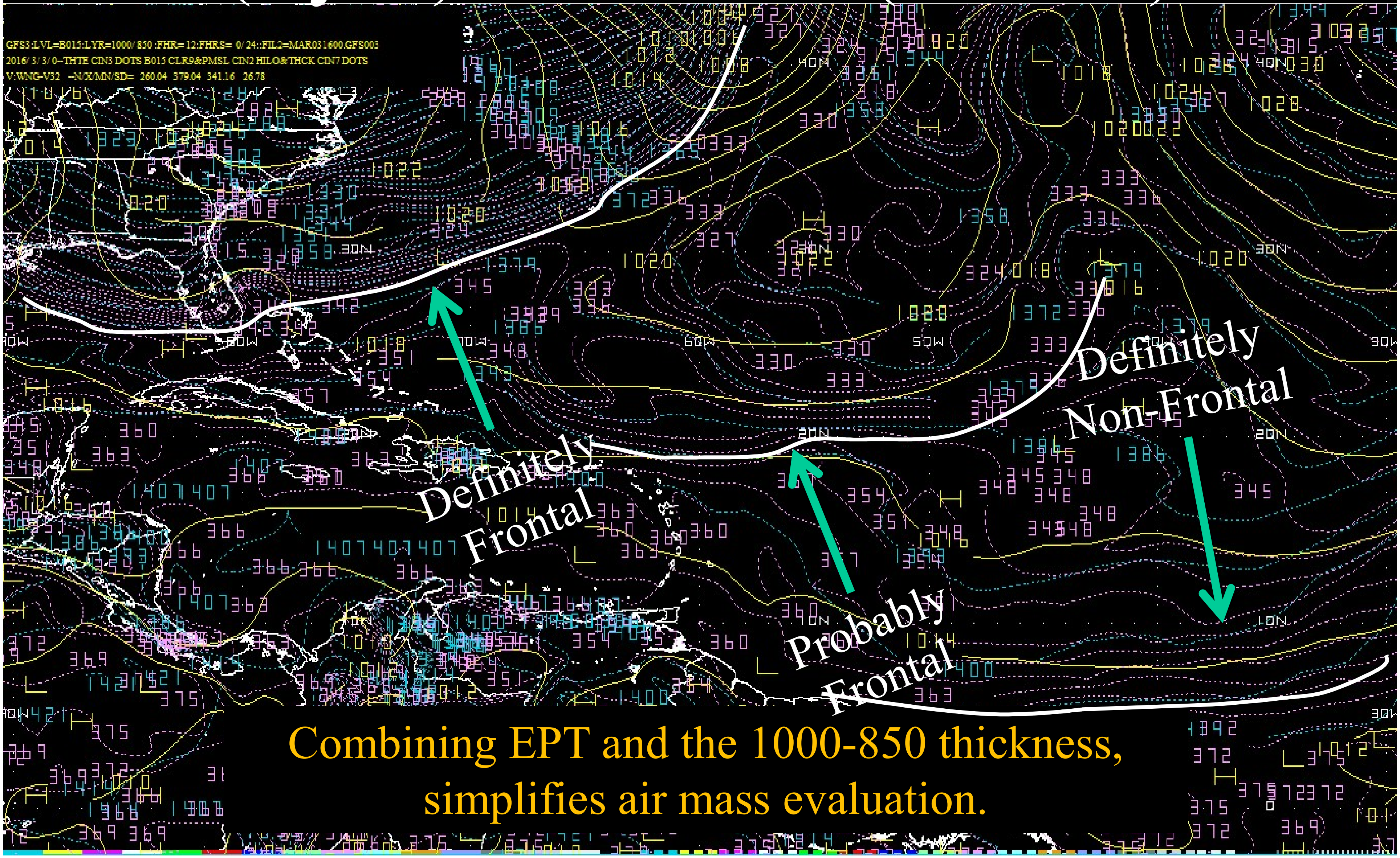
1000-850 Thickness and MSLP Evaluate Frontal Gradients



EPT as a function of Moisture Content (PWAT)



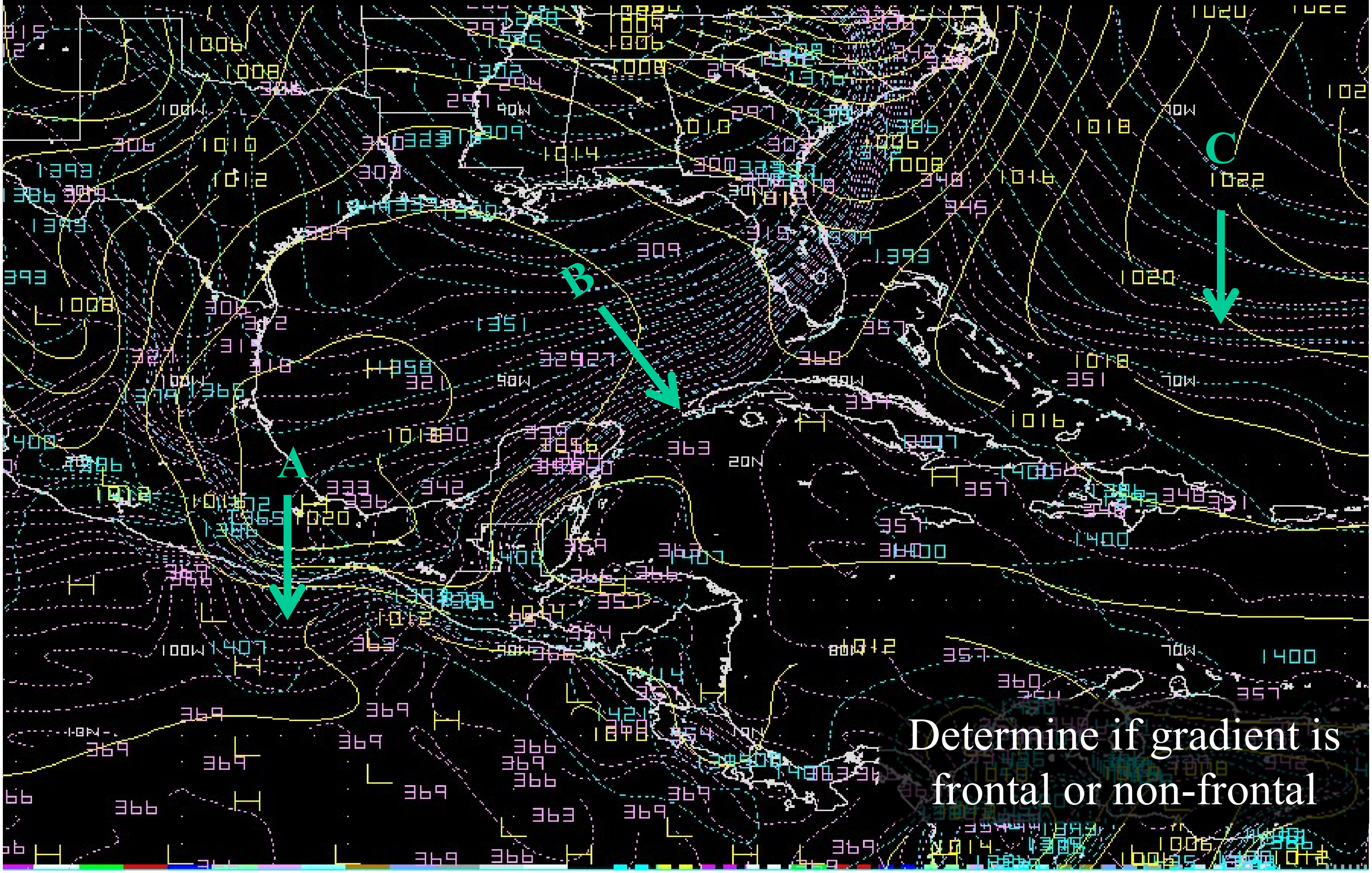
EPT (Magenta), 1000-850 Thickness (Cyan) and MSLP (Yellow)



Combining EPT and the 1000-850 thickness, simplifies air mass evaluation.

Poll Question #8

EPT (Magenta), Thickness (Cyan), PMSL (Yellow)



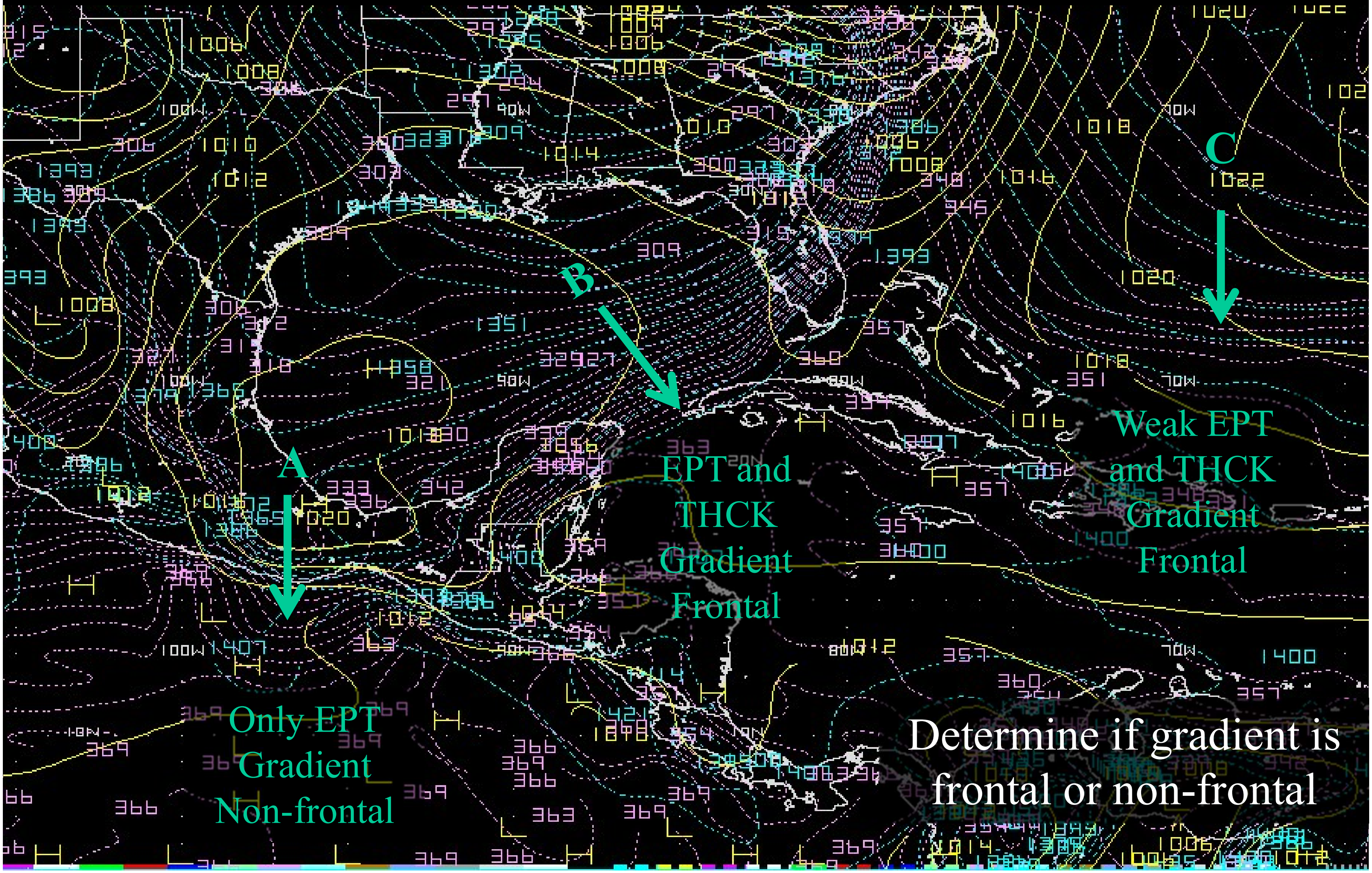
Determine if gradient is frontal or non-frontal

Poll Question #8
(select one)

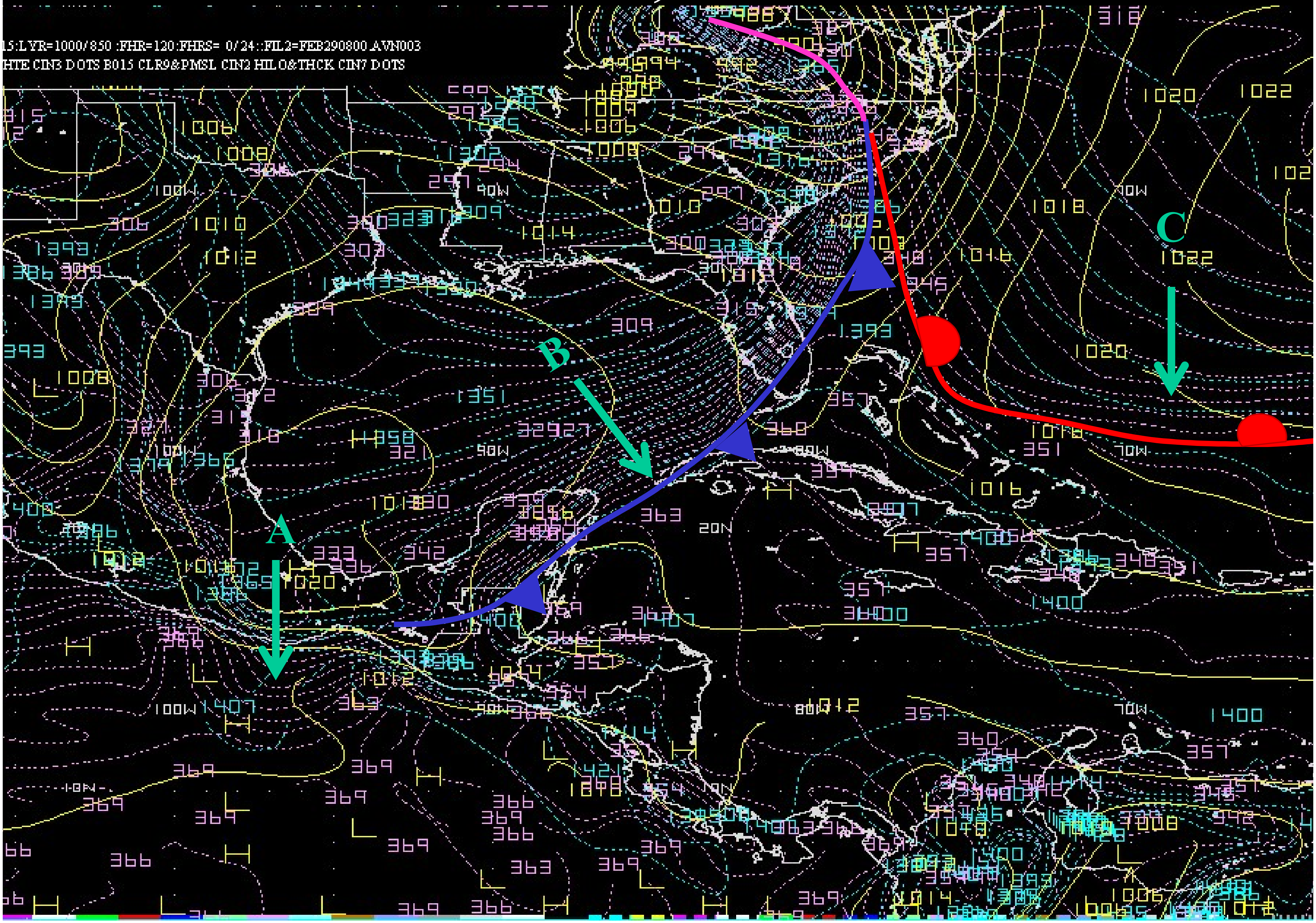
- A: Frontal, B: Frontal, C: Frontal
- A: Non-Frontal, B: Frontal, C: Non-Frontal
- A: Frontal, B: Frontal, C: Non-Frontal
- A: Frontal, B: Non-Frontal, C: Frontal
- A: Non-Frontal, B: Frontal, C: Frontal

Poll Question #8 Review

EPT (Magenta), Thickness (Cyan), PMSL (Yellow)

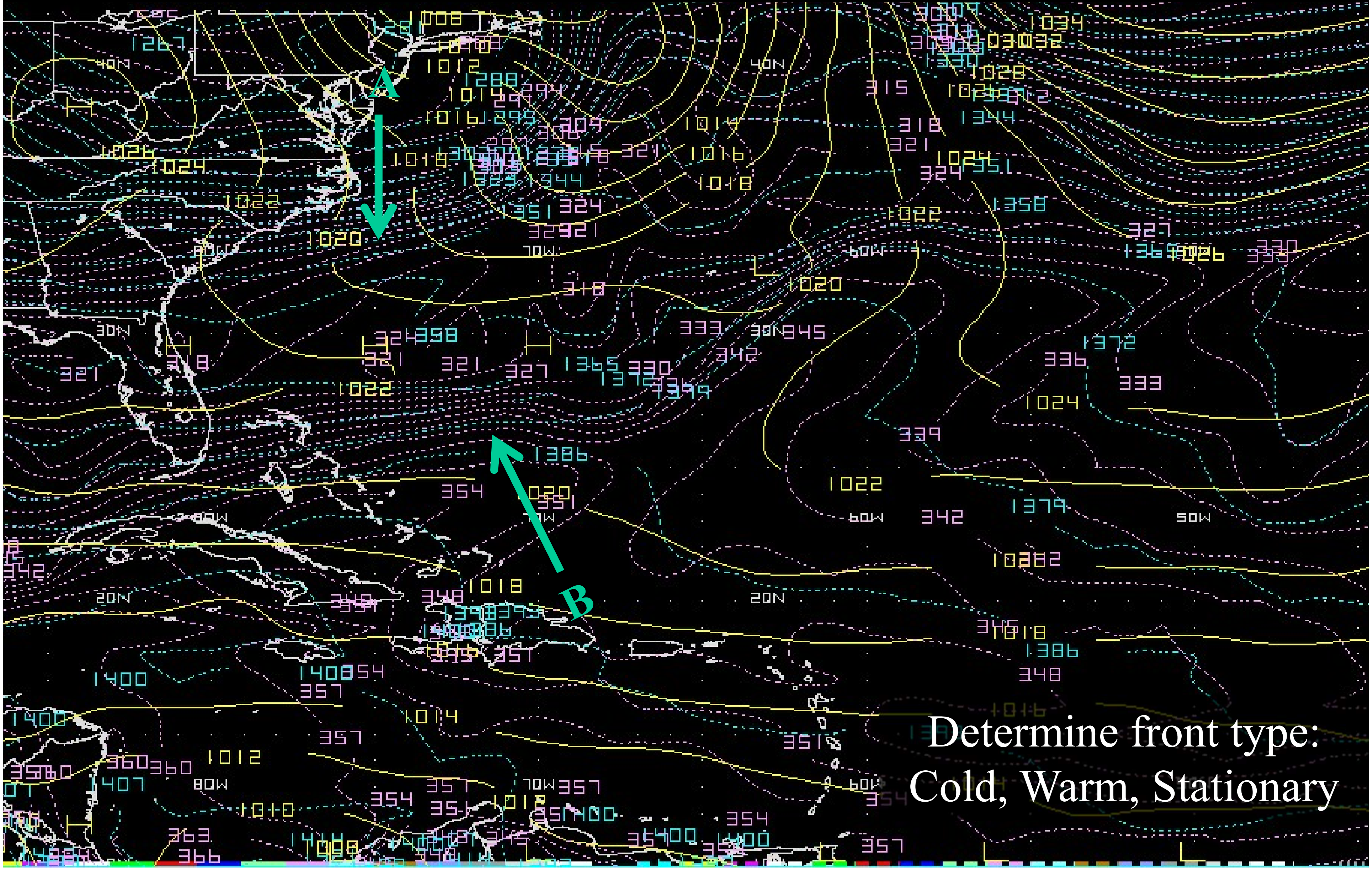


1000-850 Thickness, BL EPT and PMSL



Poll Question #9

EPT (Magenta), Thickness (Cyan), PMSL (Yellow)

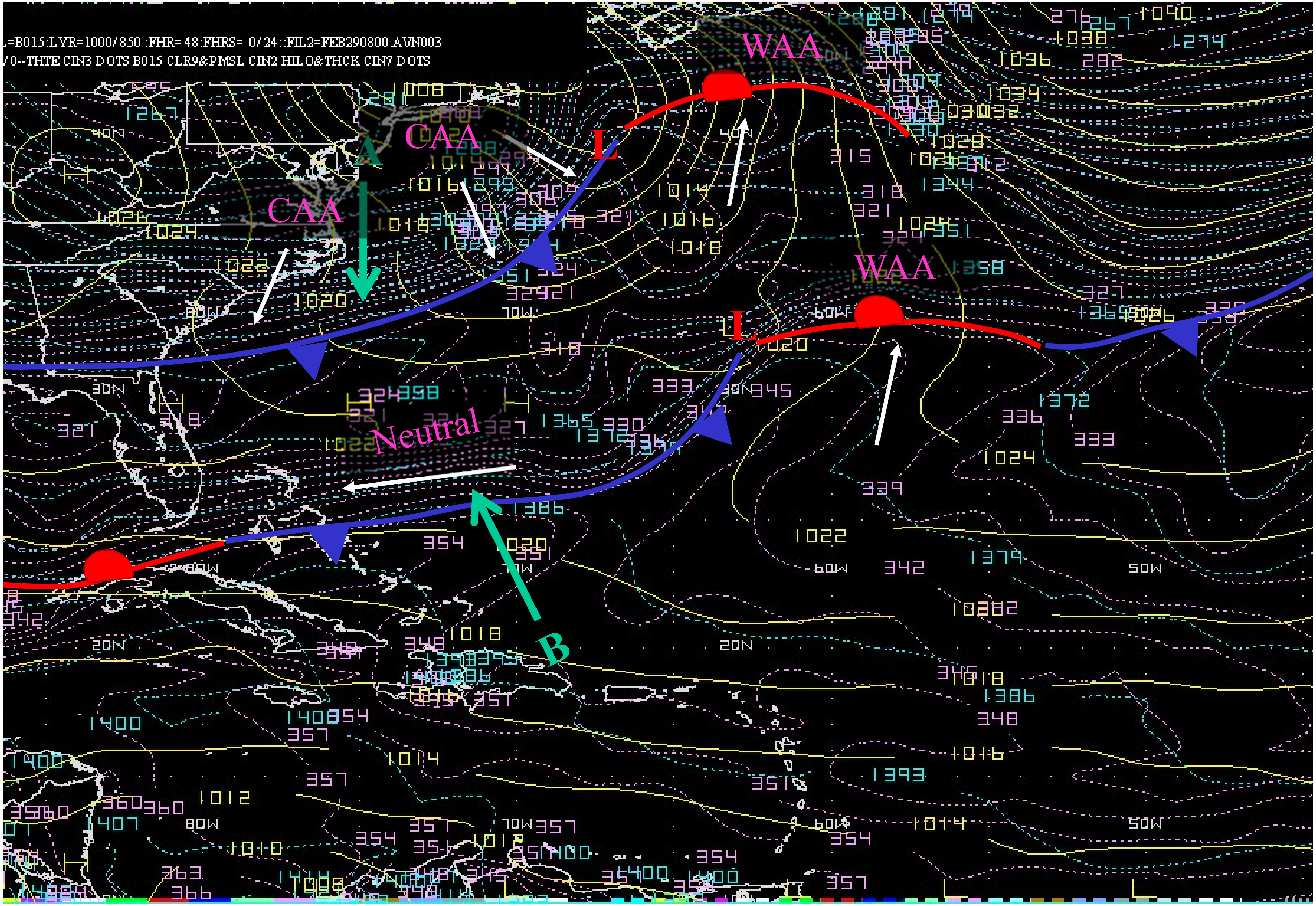


Determine front type:
Cold, Warm, Stationary

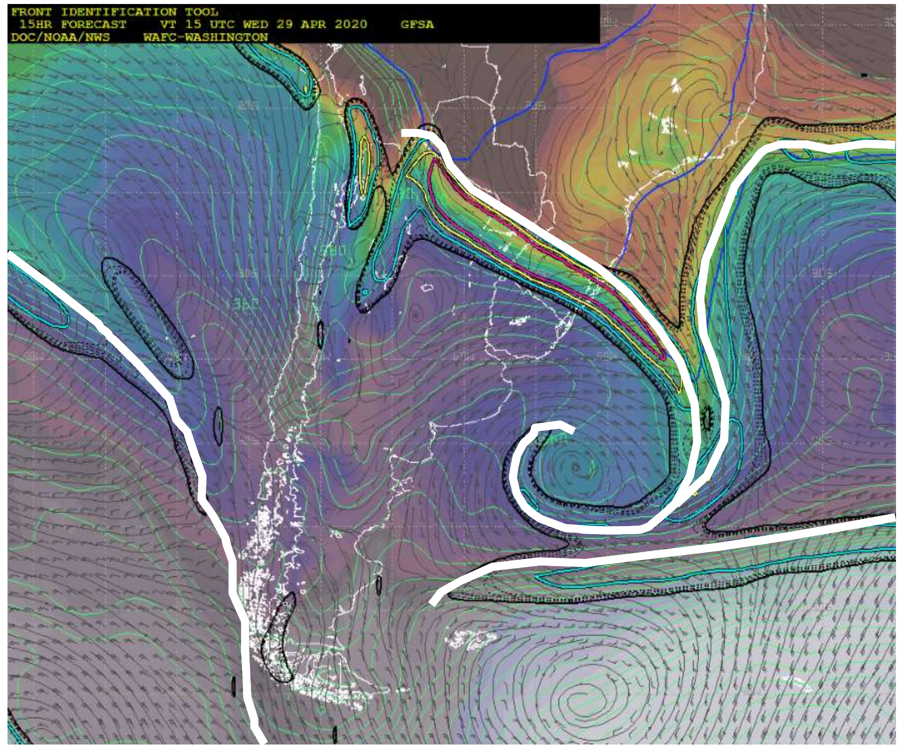
Poll Question 9
(select one)

- A: Cold, B: Cold
- A: Stationary, B: Warm
- A: Warm, B: Cold
- A: Cold, B: Stationary
- A: Stationary, B: Stationary

1000-850 Thickness, BL EPT and PMSL



Front Macro


FRONT IDENTIFICATION TOOL
15HR FORECAST VT 15 UTC WED 29 APR 2020 GFSA
DOC/NOAA/NWS WAFC-WASHINGTON

WinGridDS FRONT Macro

Identification of Surface Fronts

What is plotted?

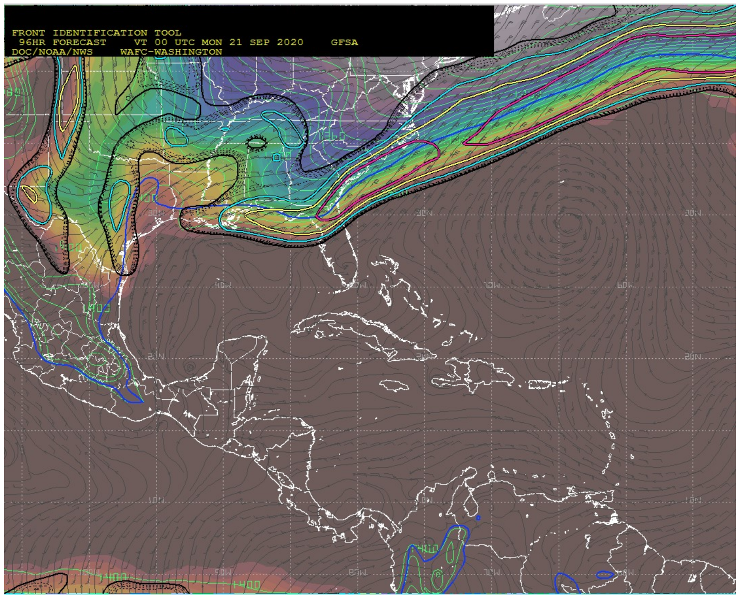
(1) Colors: Variable α = represents air mass properties *Cool/dry to warm/humid*

(2) Contours: Variable β = Magnitude of the gradient of α, enhanced by gradients of PWAT y $\theta_{e\_1000\ hPa}$

Fronts often go here, in the warm side of gradients

(3) Complementary Fields

- 1000-850 hPa Thickness (GPM)
- Td=18°C at 2m
- 1000-925 hPa Winds (kt)



WinGridDS FRONT Macro

Identification of Surface Fronts

Constructing α

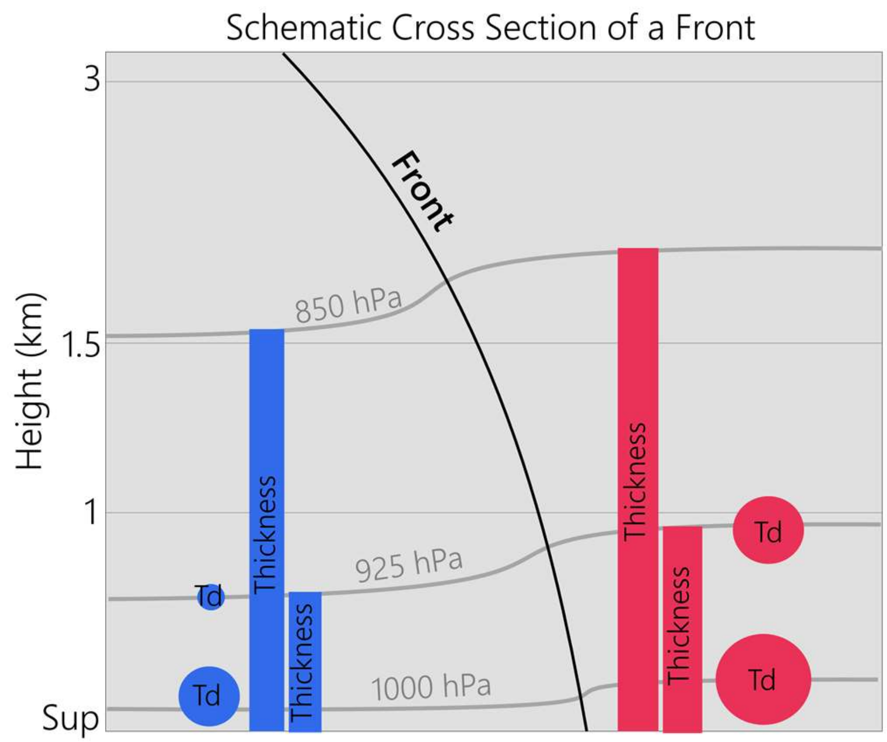
- 4 variables:
  - 1000-850 hPa Thickness
  - 1000-925 hPa Thickness
  - Td 1000 hPa
  - Td 925 hPa

Thermal Aspects (1000-850 hPa and 1000-925 hPa Thickness)

Moisture Aspects (Td 1000 hPa and Td 925 hPa)

- Quantities are **multiplied** to enhance gradients for forecasters to see them rapidly.

- Over terrain, we look a bit higher (e.g. Mexican Plateau/SW US)



WinGridDS FRONT Macro

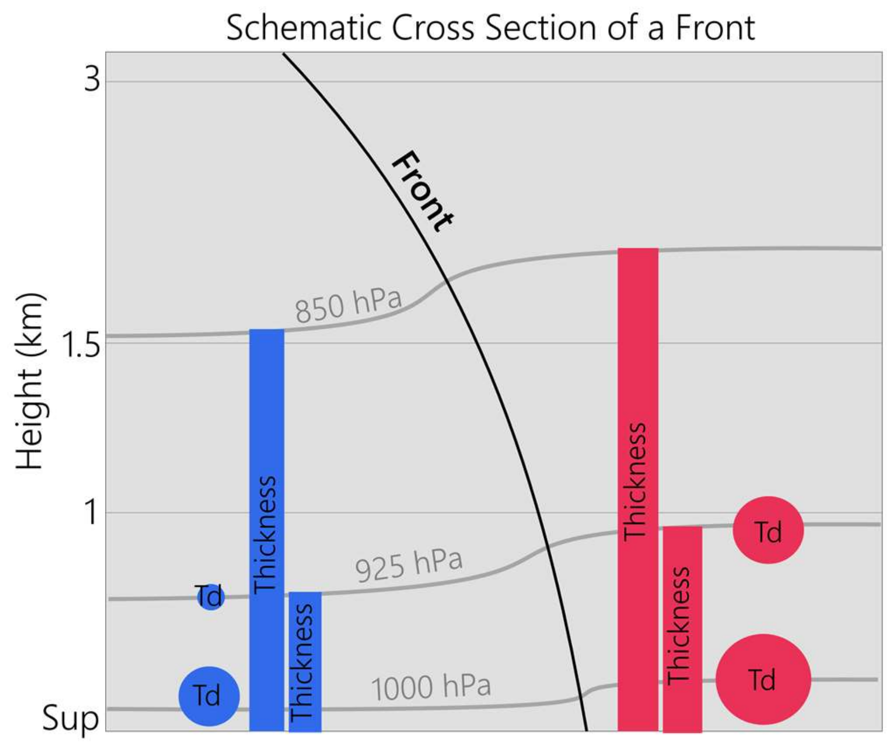
Constructing β

Combination of

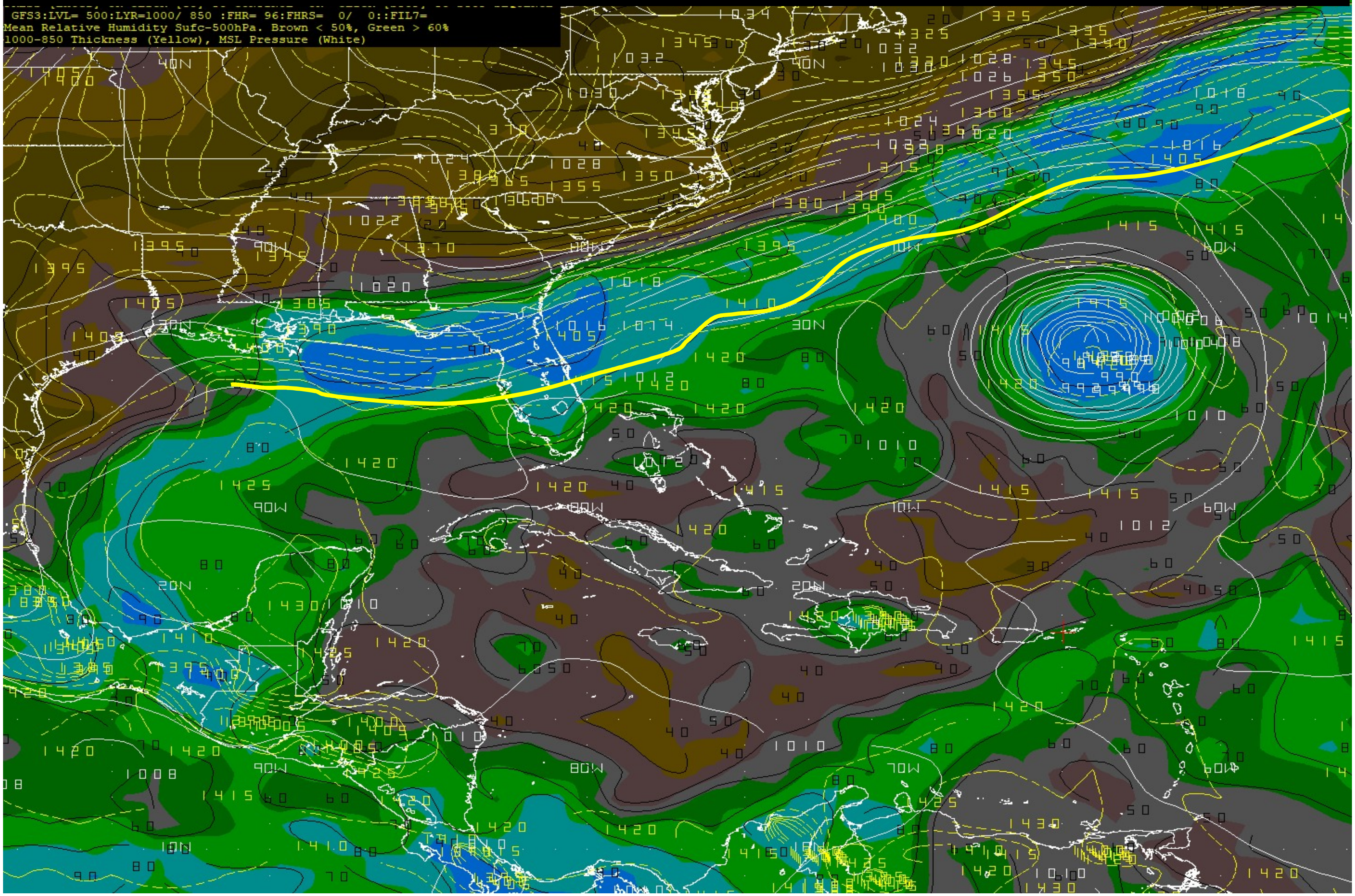
- Magnitude of the gradient of α
  - "Boundaries between air masses"
- Magnitude of the gradient of PWAT
  - Helps over complex terrain/tropics

    -Reduces "noise" from adiabatic compression in lee of mountain ranges.

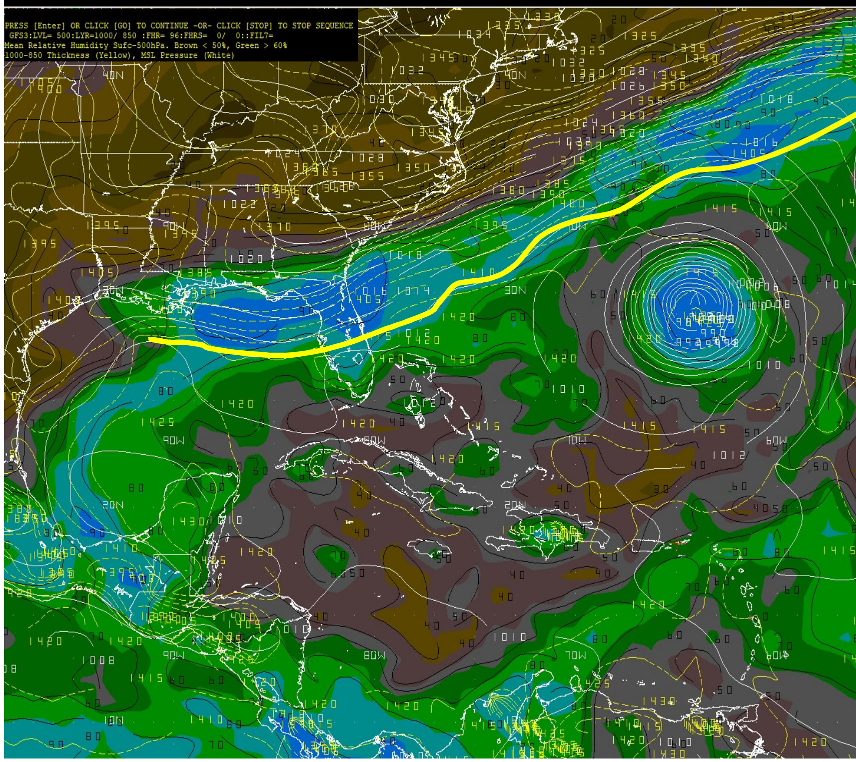
    -Enhances boundaries with strong moisture signals.
- Magnitude of the gradient of θe at 1000 hPa
  - Enhances signature of the front near the surface.

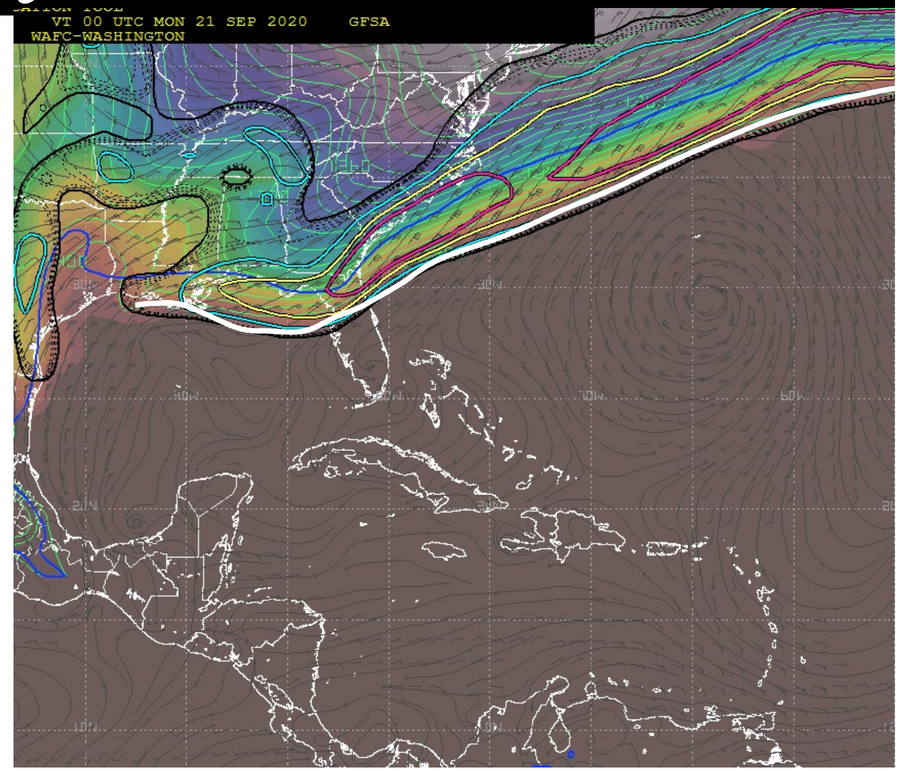


Mean Layer RH, THCK, PMSL

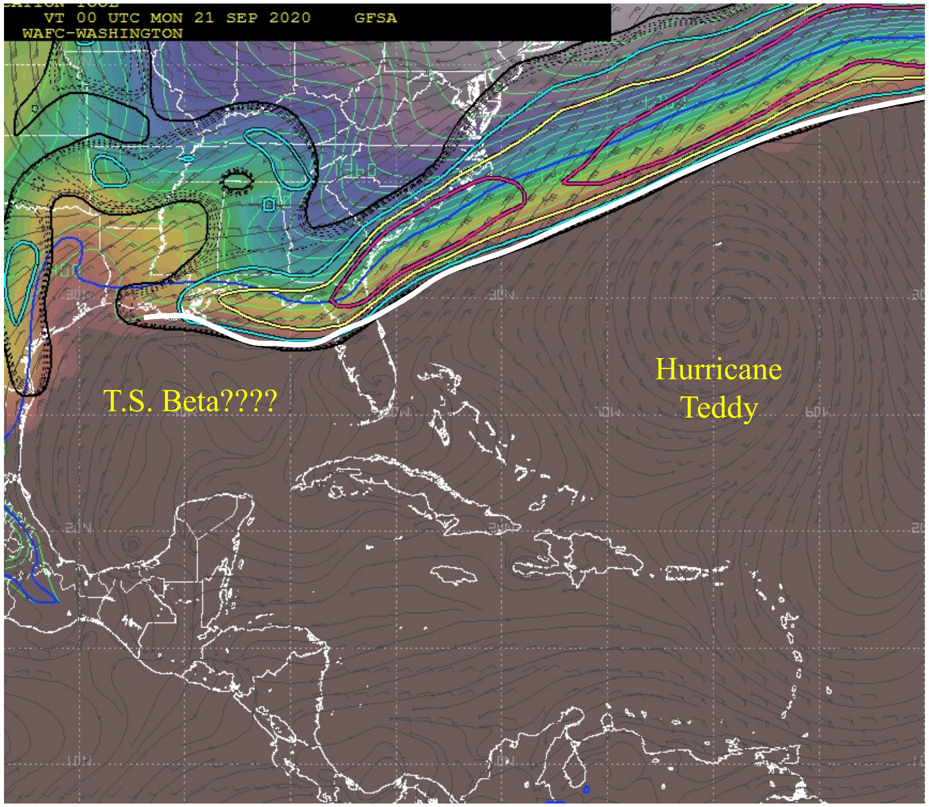


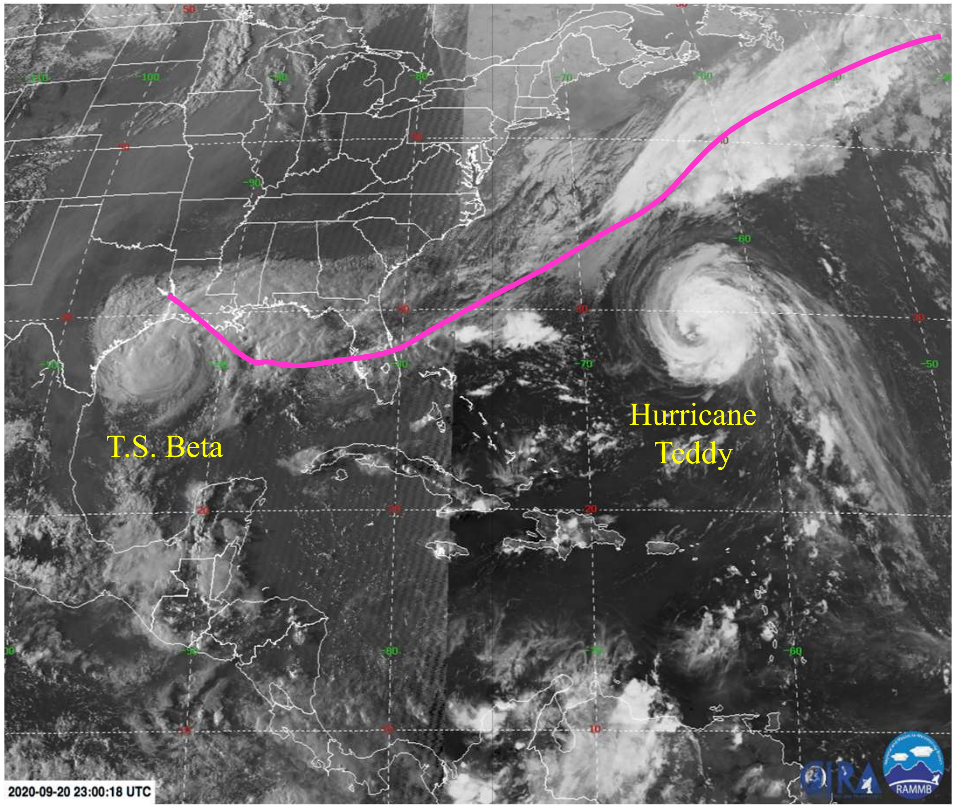
Hand Drawn Analysis vs. Objective Analysis





Verification of the Forecast





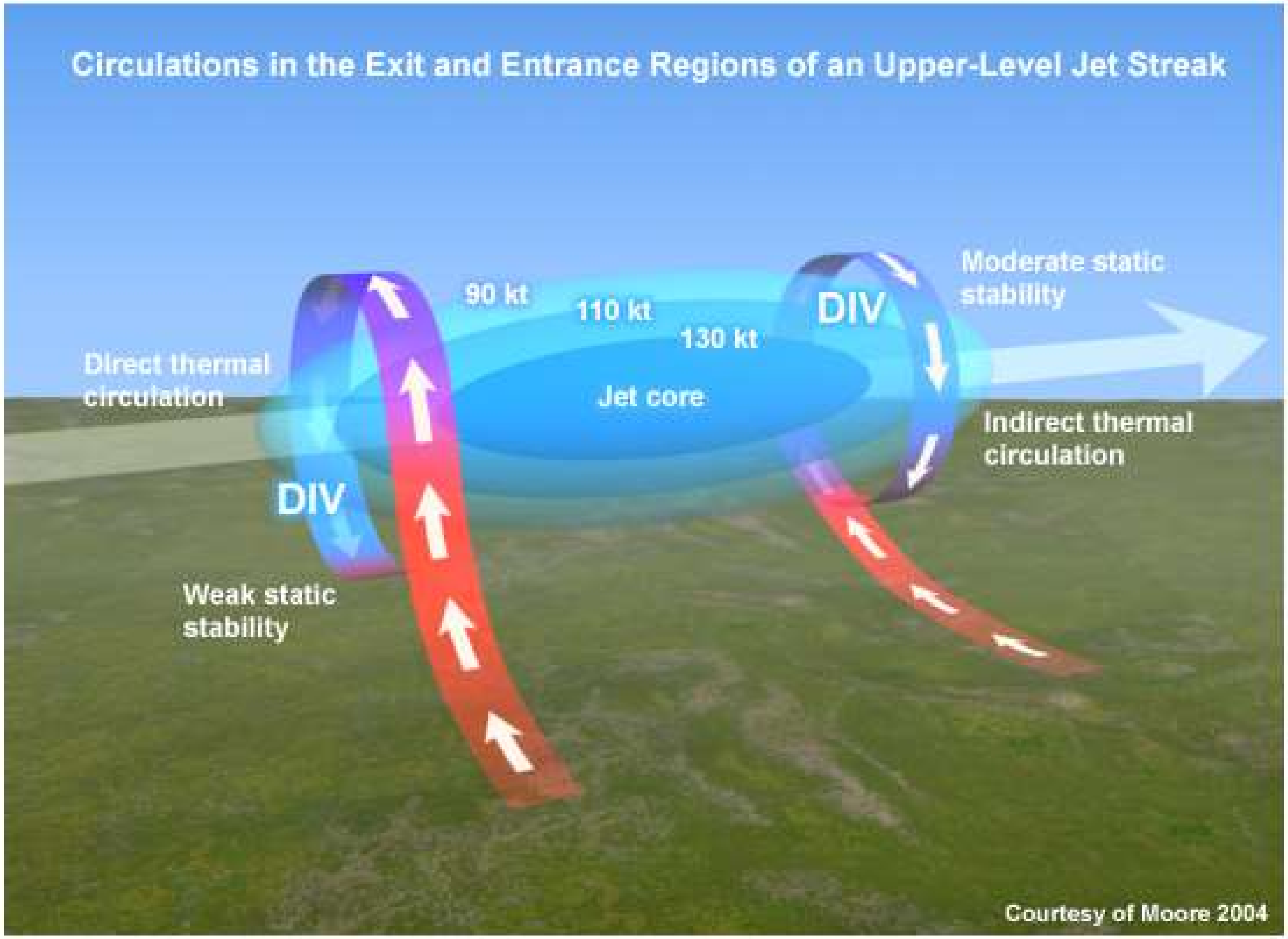
VT: 20200921/00Z

Interaction of Upper Level Jets with Surface Fronts

Subtropical Jet and Polar Front Interaction

- The question is, what interaction, if any, a subtropical jet can have with polar fronts over the Caribbean Basin?
  - Polar fronts are accompanied by polar jets
  - Subtropical Fronts??
    - Only in the marine layer
- ***Ageostrophic circulation*** around an upper level jet can help sustain the baroclinic environment along a polar front as it pushes south into the Basin.
  - The jet aloft, with its indirect ageostrophic circulation, will sustain the temperature gradient
- Although the Polar Front limits to low levels of the atmosphere as it enters the basin, the symbiotic ***interaction with subtropical jet helps sustains this feature.***

Jet Dynamics: Direct/Indirect Ageostrophic Circulation

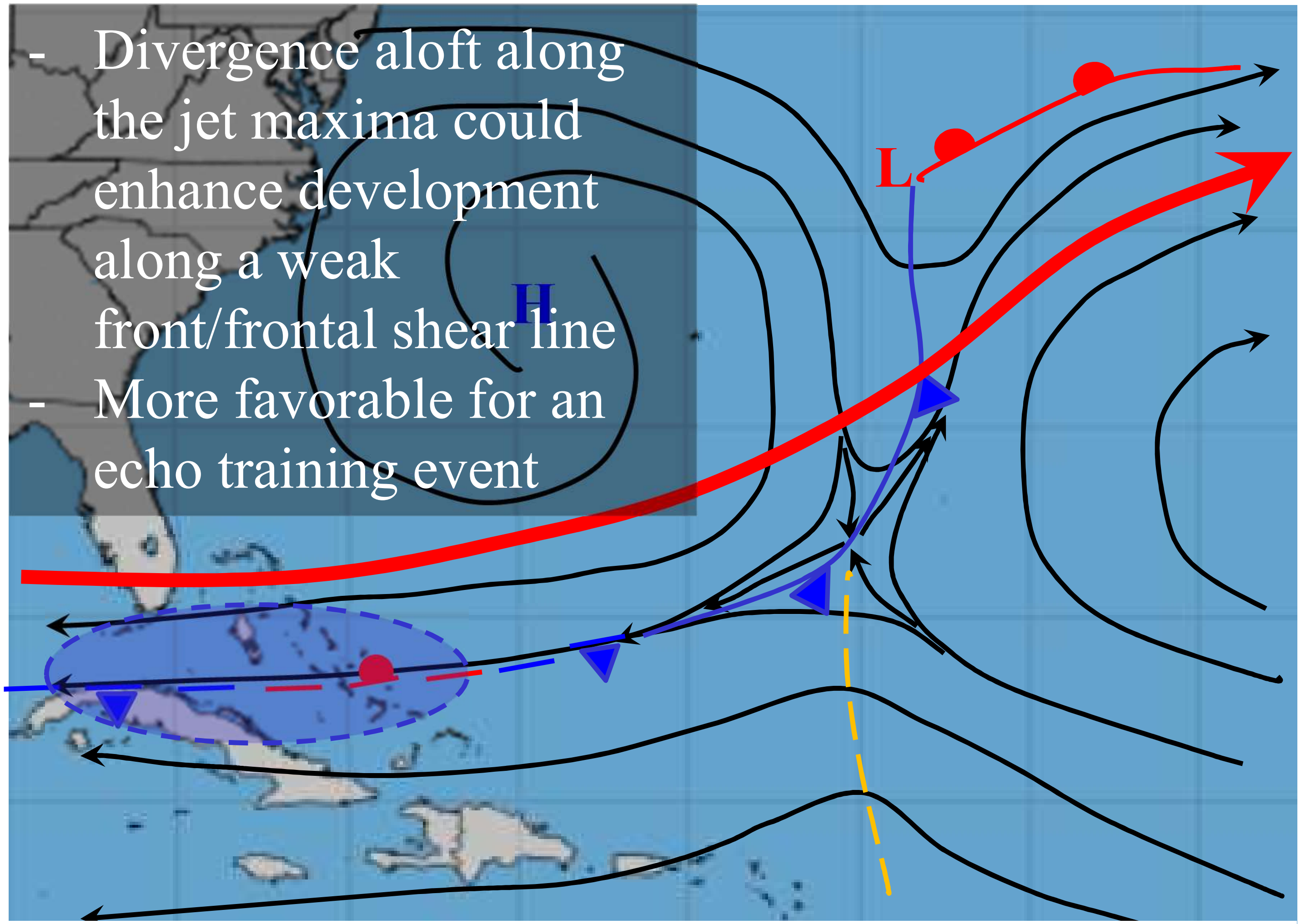


<u>Indirect Circulation</u>: Tightens the gradient – sustains the front

<u>Direct Circulation</u>: Loosens the gradient – weakens the front

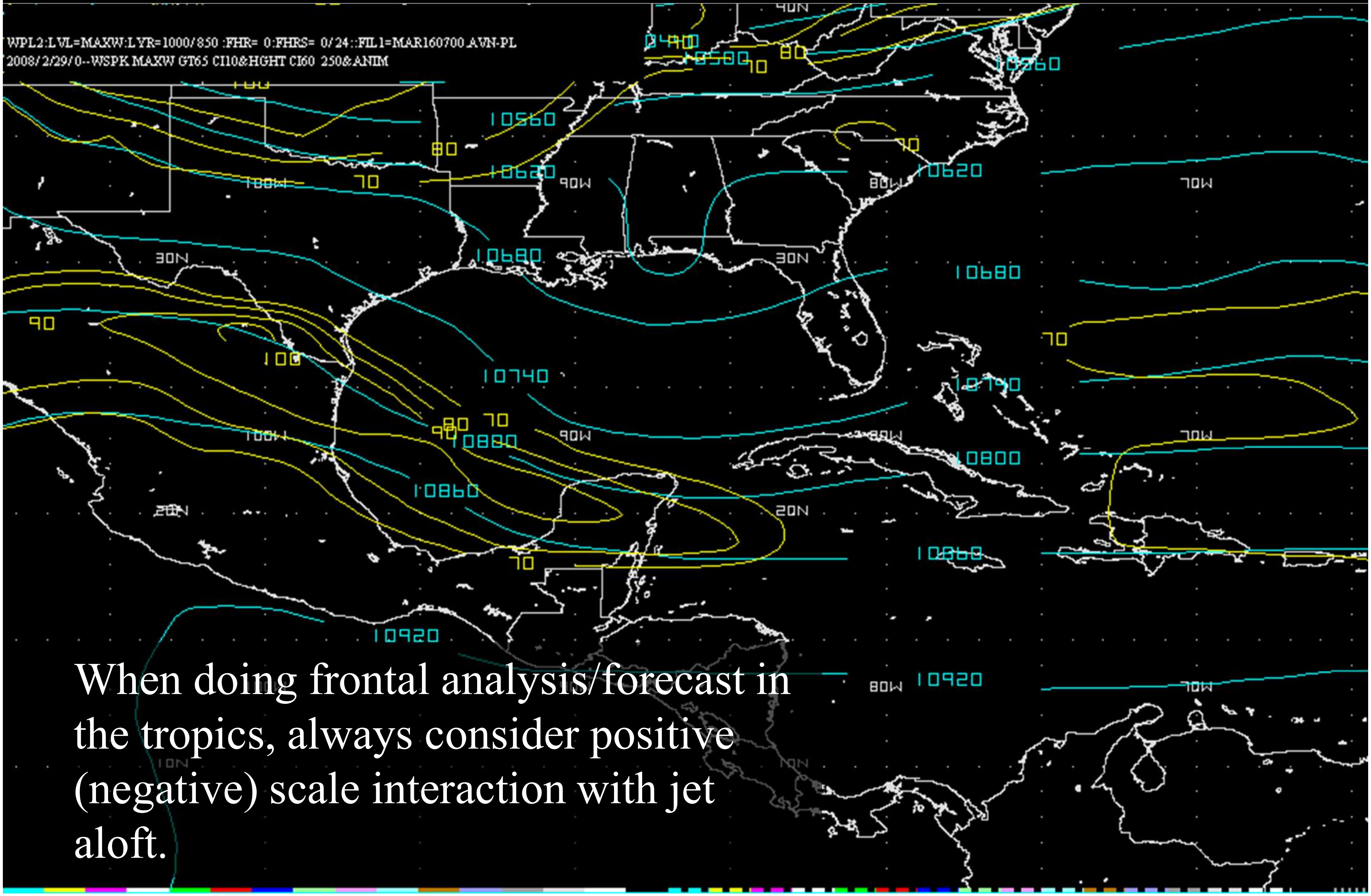
Subtropical Jet

Positive Scale Interaction



Surface front parallel to confluent asymptote

Jet at 250 hPa

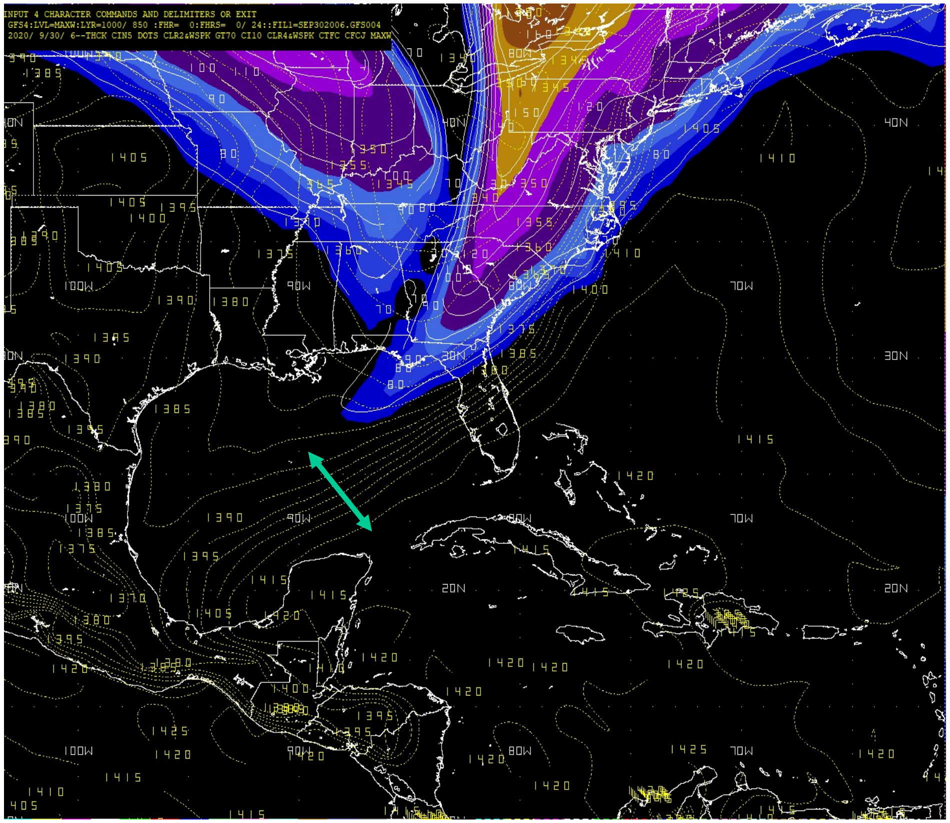


When doing frontal analysis/forecast in the tropics, always consider positive (negative) scale interaction with jet aloft.

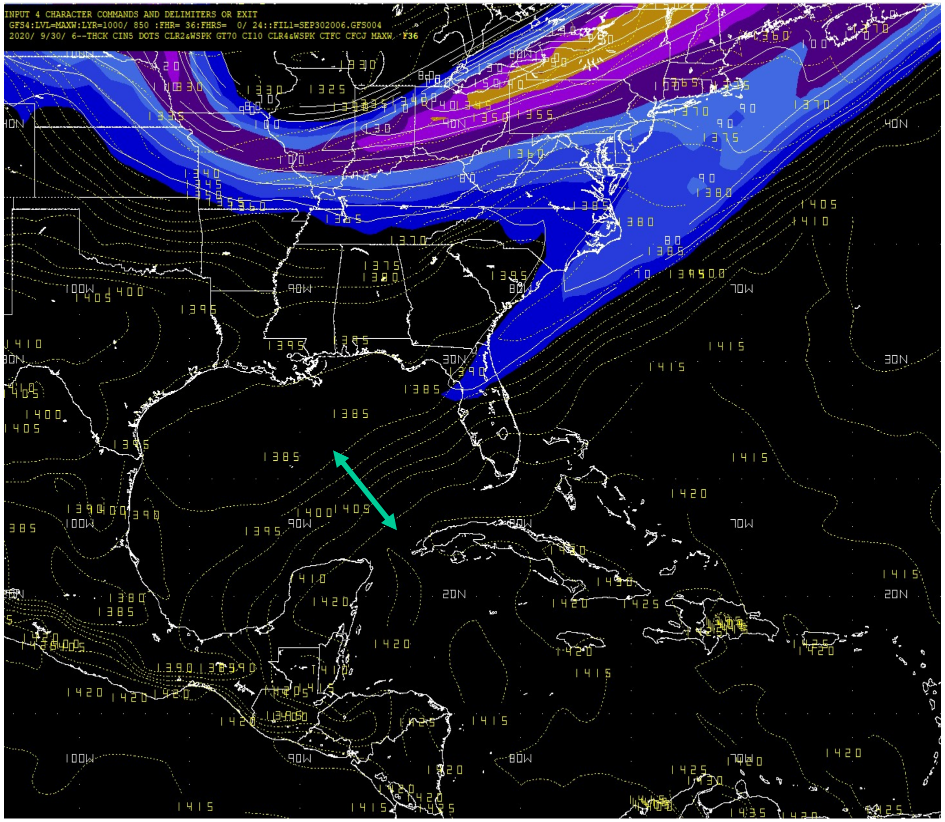
Frontolysis

- As long as the jet aloft remains, the gradient will hold and the surface front will remain
- **Frontolysis**: The gradient will slacken as the jet weakens or pulls away.
- If you have a jet aloft, ***don't kill the front!***

Upper Jet and 1000 – 850hPa Thickness



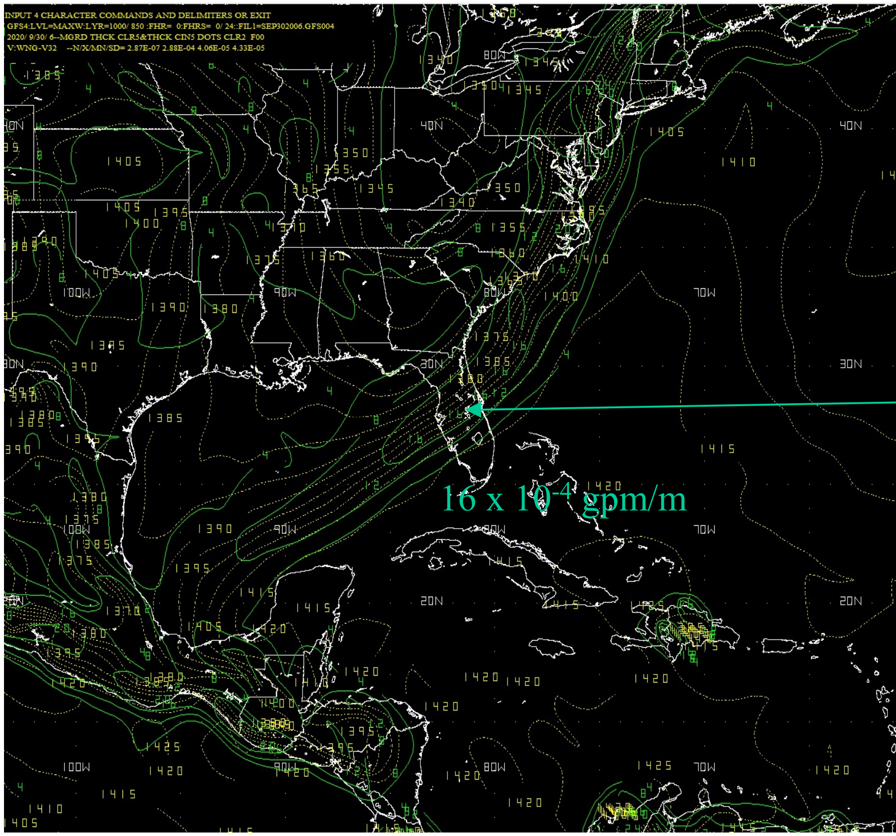
F=00



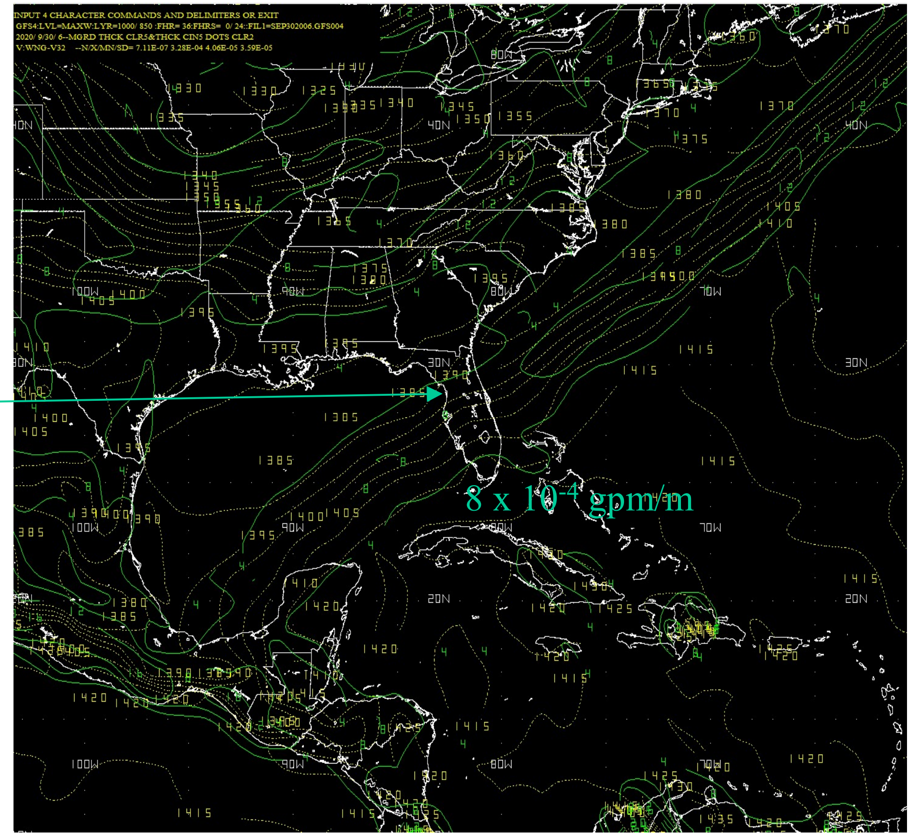
F=36

Model analysis shows gradient slacking as the jet and the trough pulls.

1000 – 850 hPa Thickness/Magnitude of the Gradient



F=00

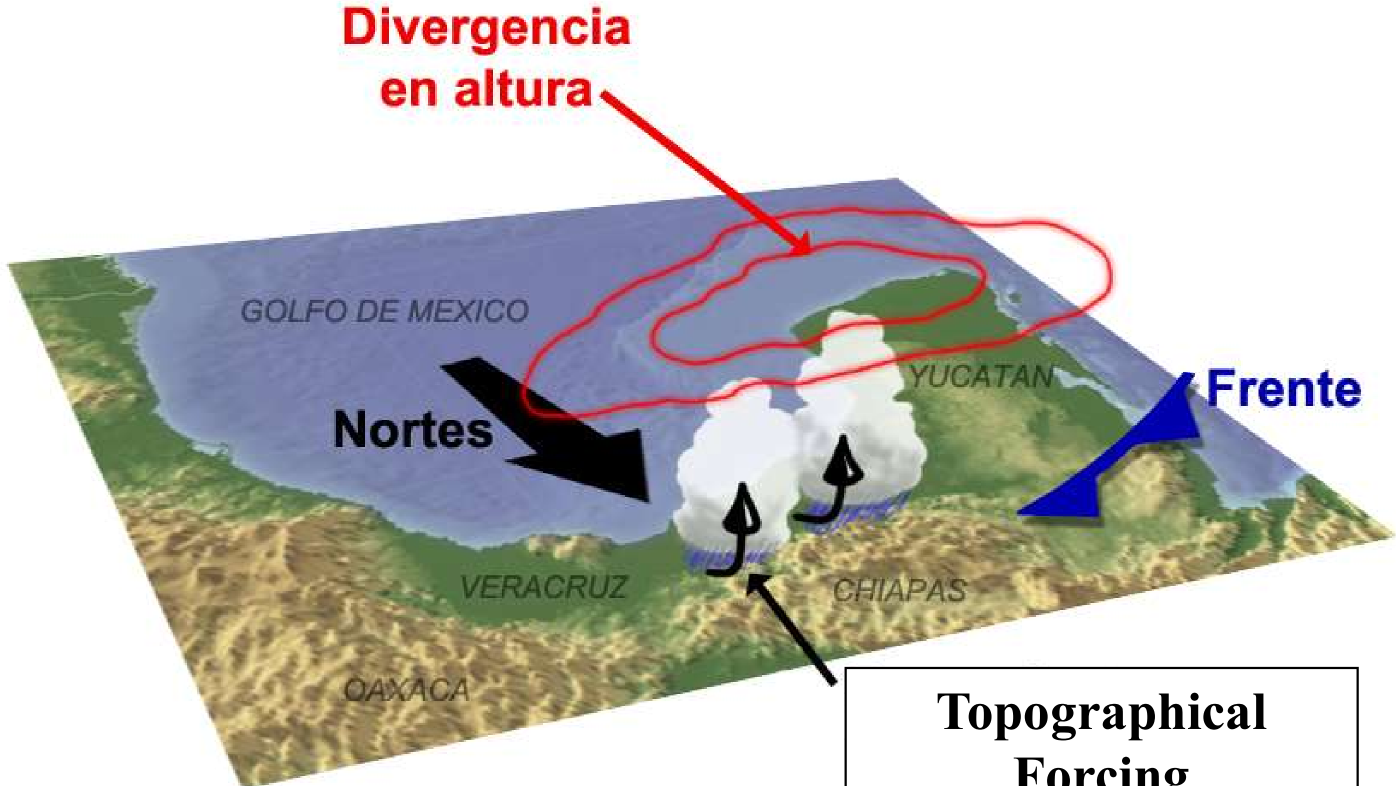


F=36

Objective analysis confirms previous observation, with the magnitude of the gradient decreasing as it slackens.

Cold Air Advection (CAA)

Conceptual Model: Frontal Northerlies and CAA



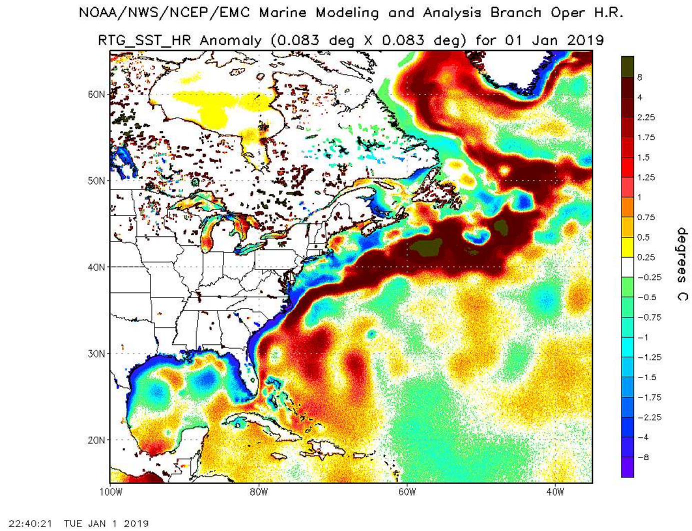
Topographical Forcing

Required: -Post frontal northerlies $\geq$ 25Kt
-CAA over Warm Waters
-Td $\geq$ 20C
-Topographical Forcing
-Mid or upper level divergence

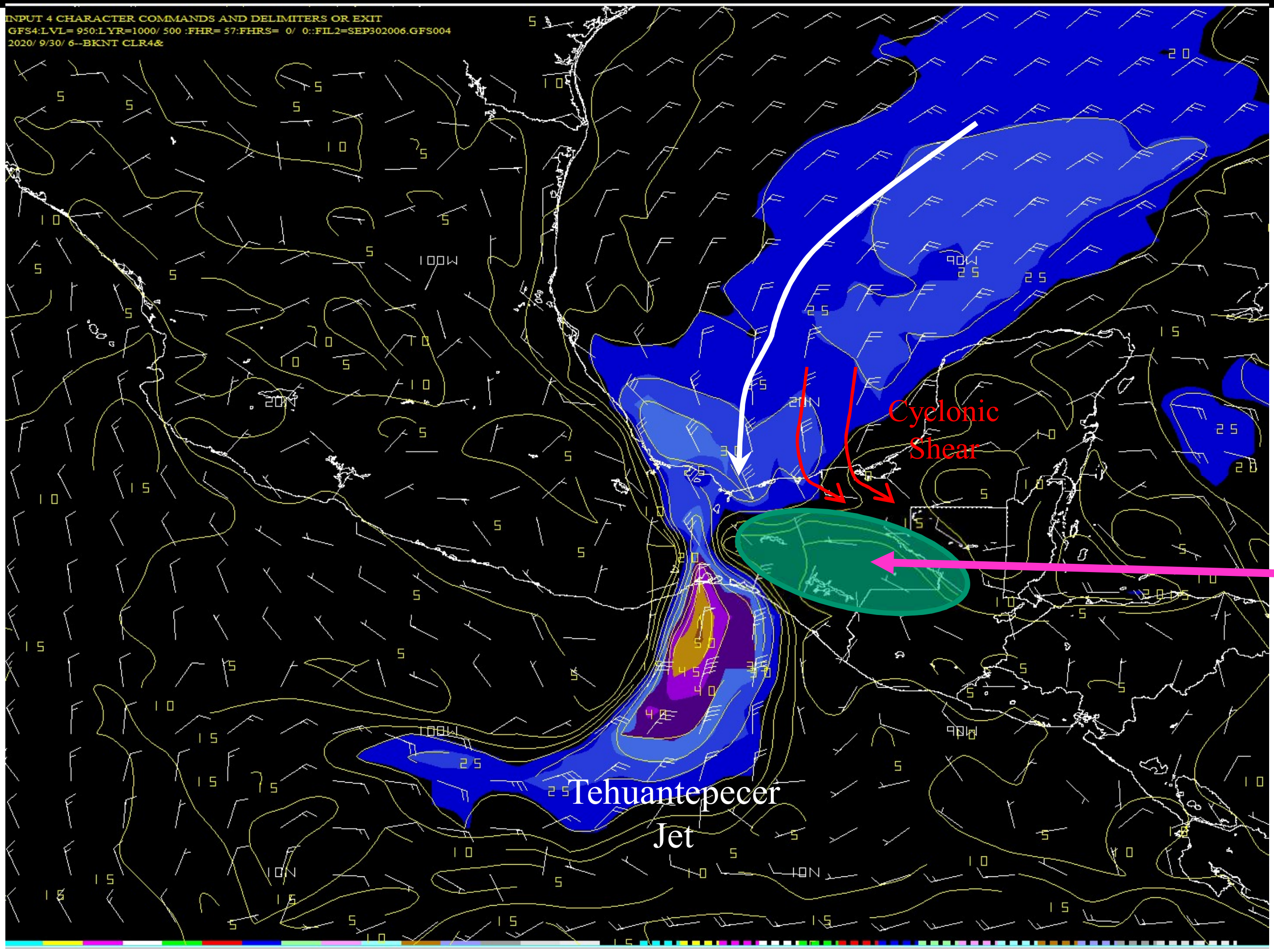
Cold Air Advection

- Consider intensity of the winds
- Cold air advection
  - – ADVT TEMP WIND DPOS
- Sea surface temperature and anomalies

NWP Limitation: GFS is not atmospheric coupled with the ocean. Temperature is assumed to remain constant throughout the forecast cycle (240 hrs)

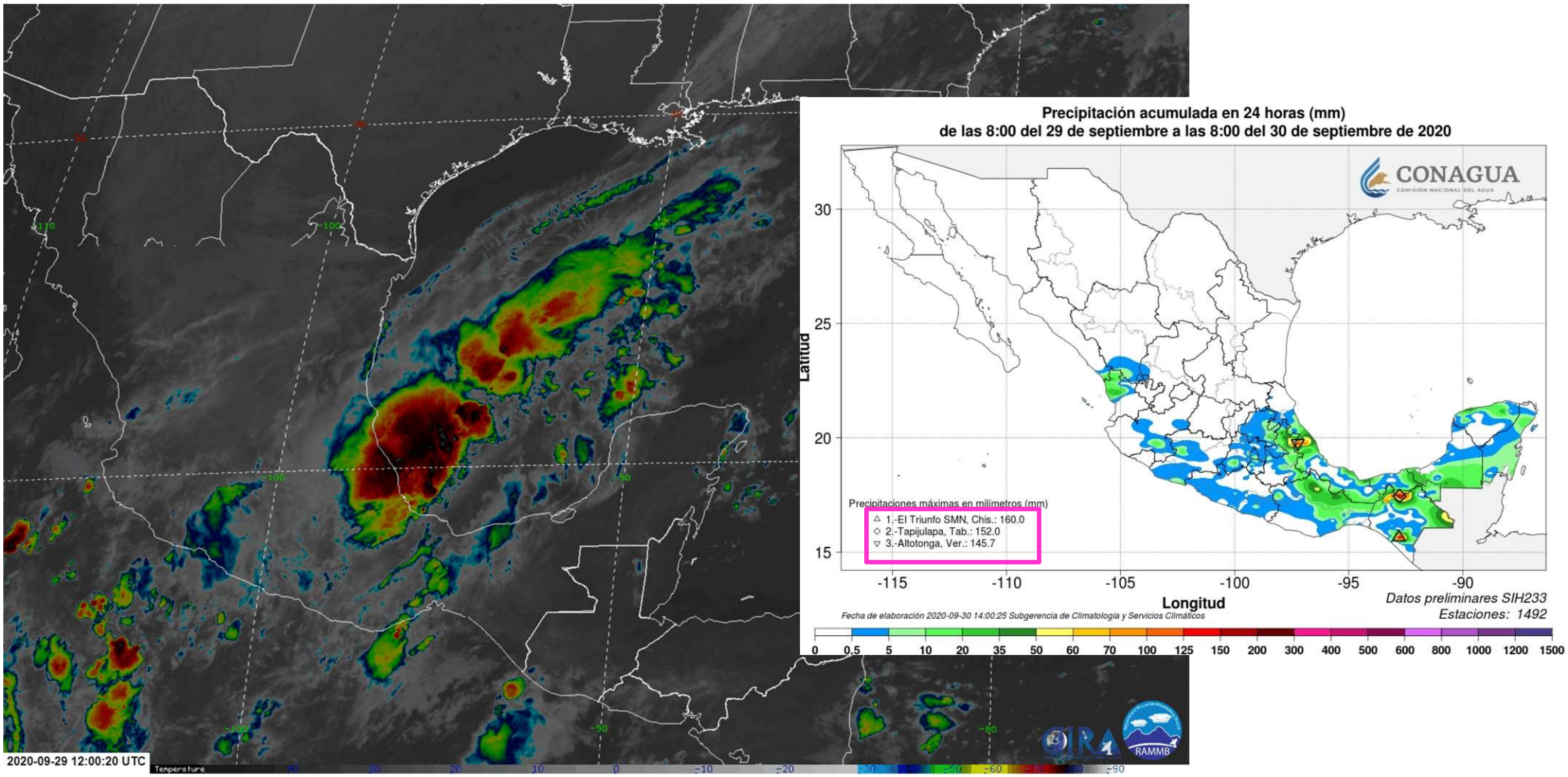


Frontal Northerlies – Tehuantepecer Jet

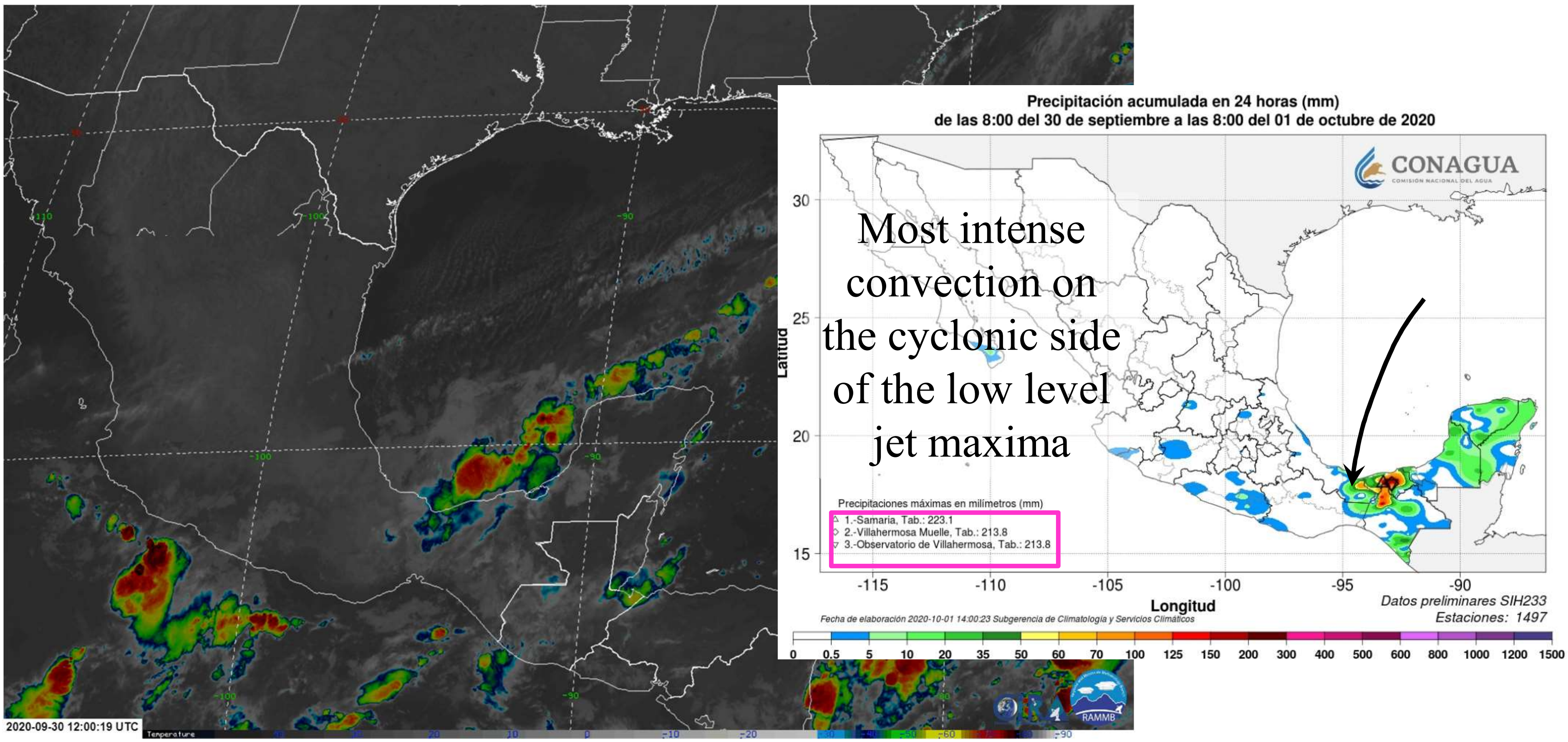


Max rainfall on the cyclonic side of low level jet maxima as enhanced by topographical forcing and CAA over warm waters.

10.3um Sep 29/12z- 30/12z, 2020



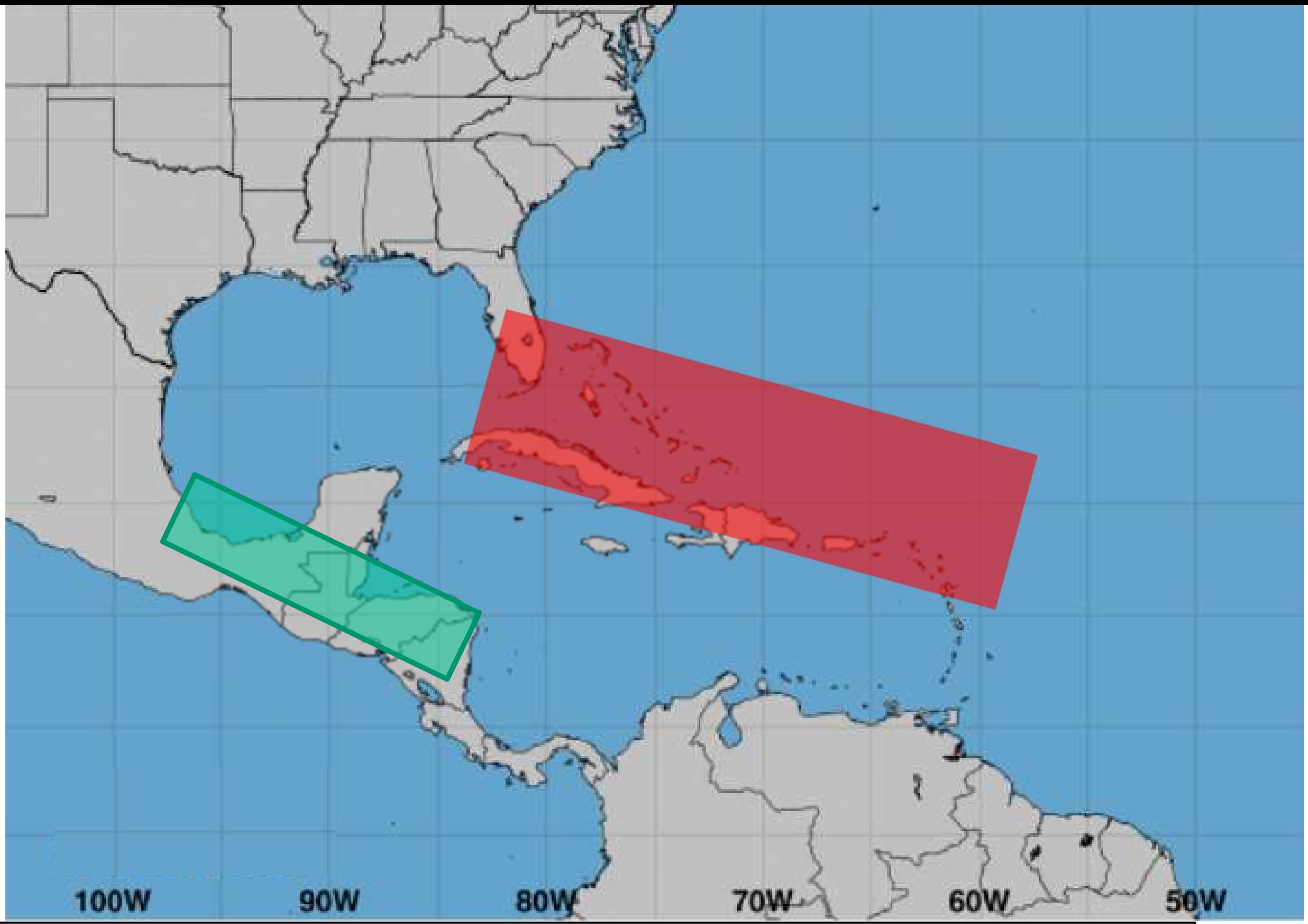
10.3um Sep 30/12z – Oct 1/12Z, 2020



Early and Late Dry Season CAA Events

- Fall and Winter
  - Cuba to Puerto Rico

- Fall
  - Southern Mexico to northern Honduras



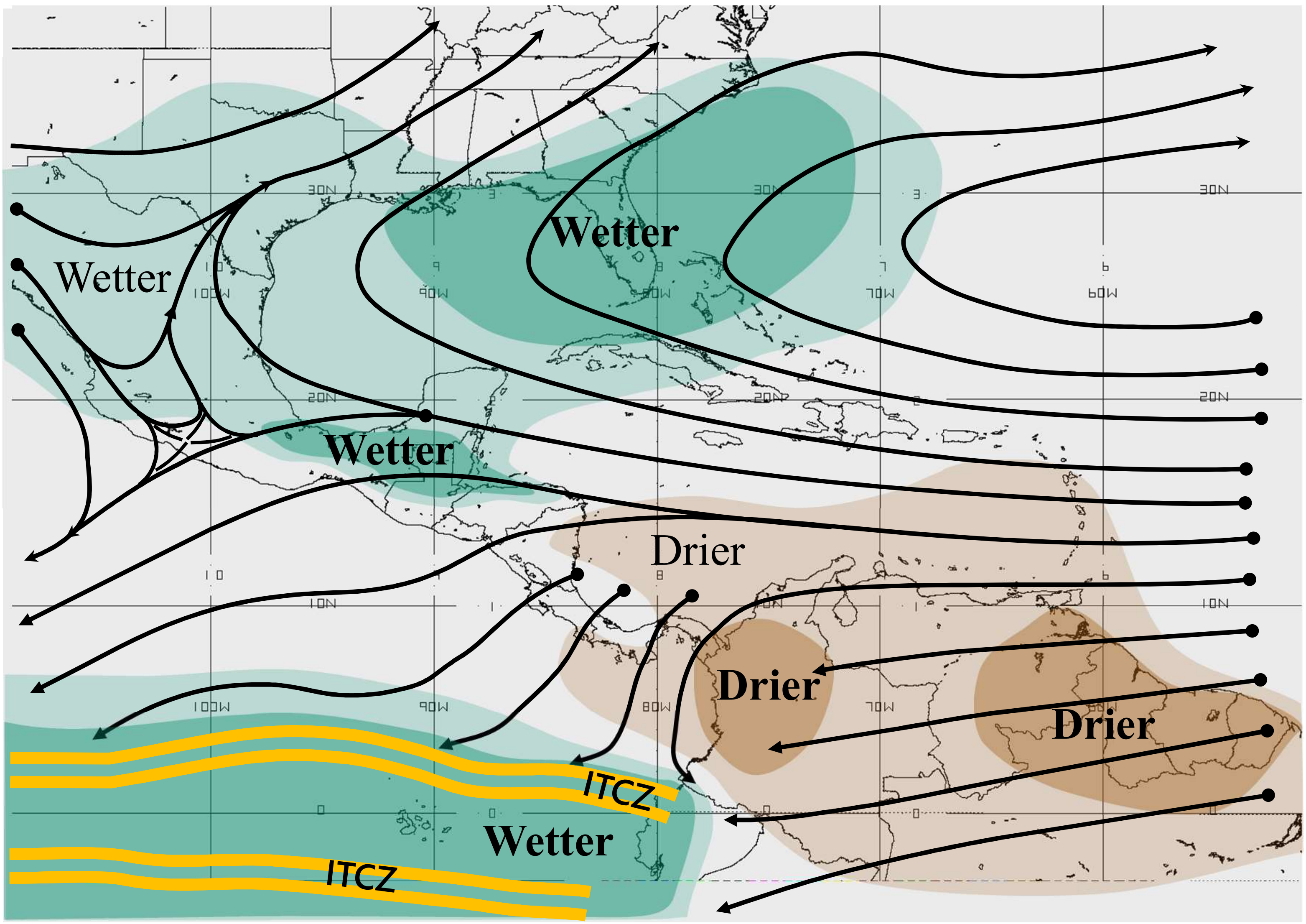
- Mexico-Northern Honduras: 500-1000mm in 3-4 days
- Cuba-Puerto Rico: 250-375mm in 3-4 days

Flooding Mexico – Oct 2007

- Worst event since 1963
  - Some stations got over 12 in/day
  - Storm total amounts of 40” in three days
- Well forecasted
- Forecast issued/coordinated with SMN
  - Cesar Triana, alumni of Tropical Desk at the helm.

Conceptual Model

Low Level Flow Warm ENSO – El Niño

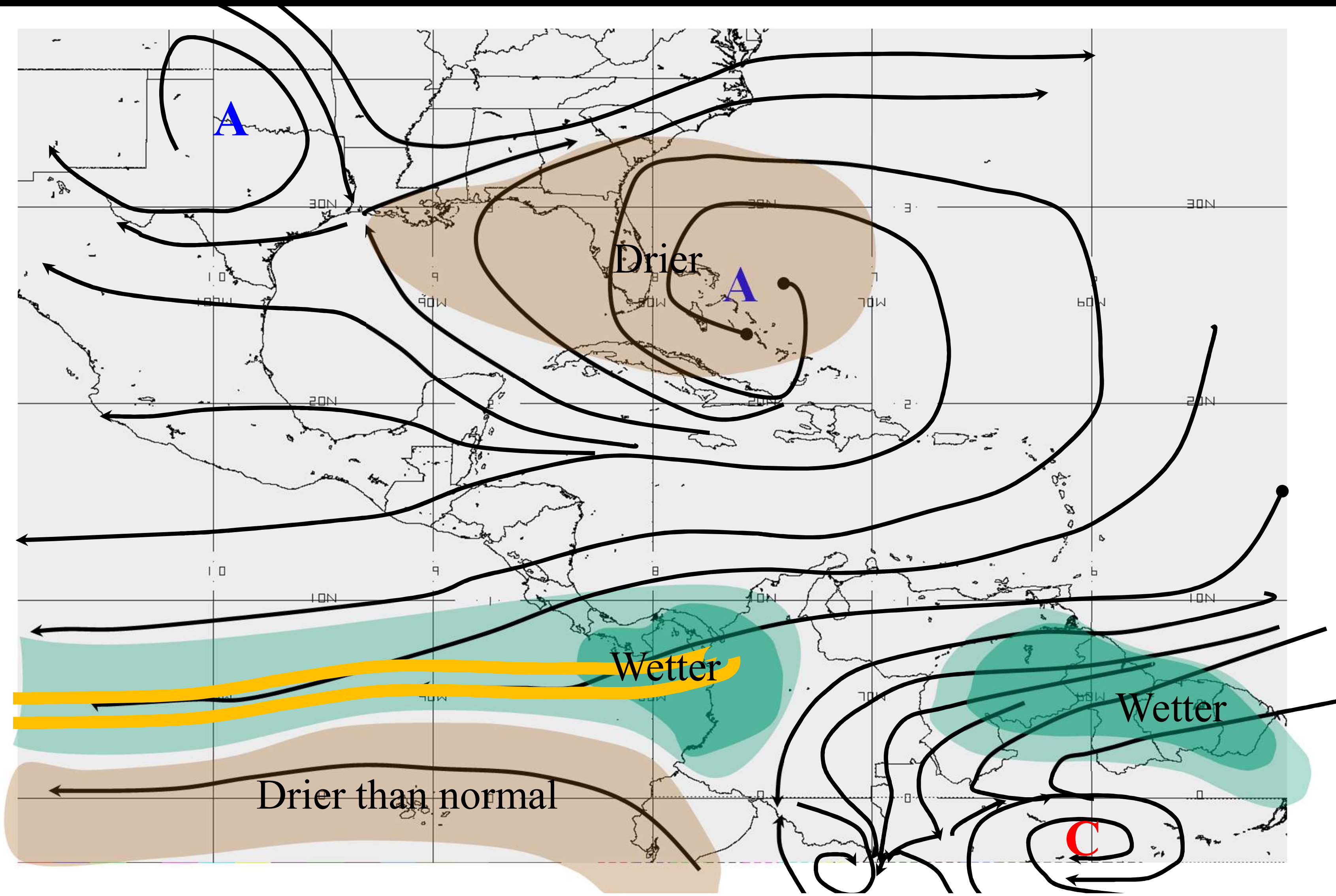


ENSO – La Niña

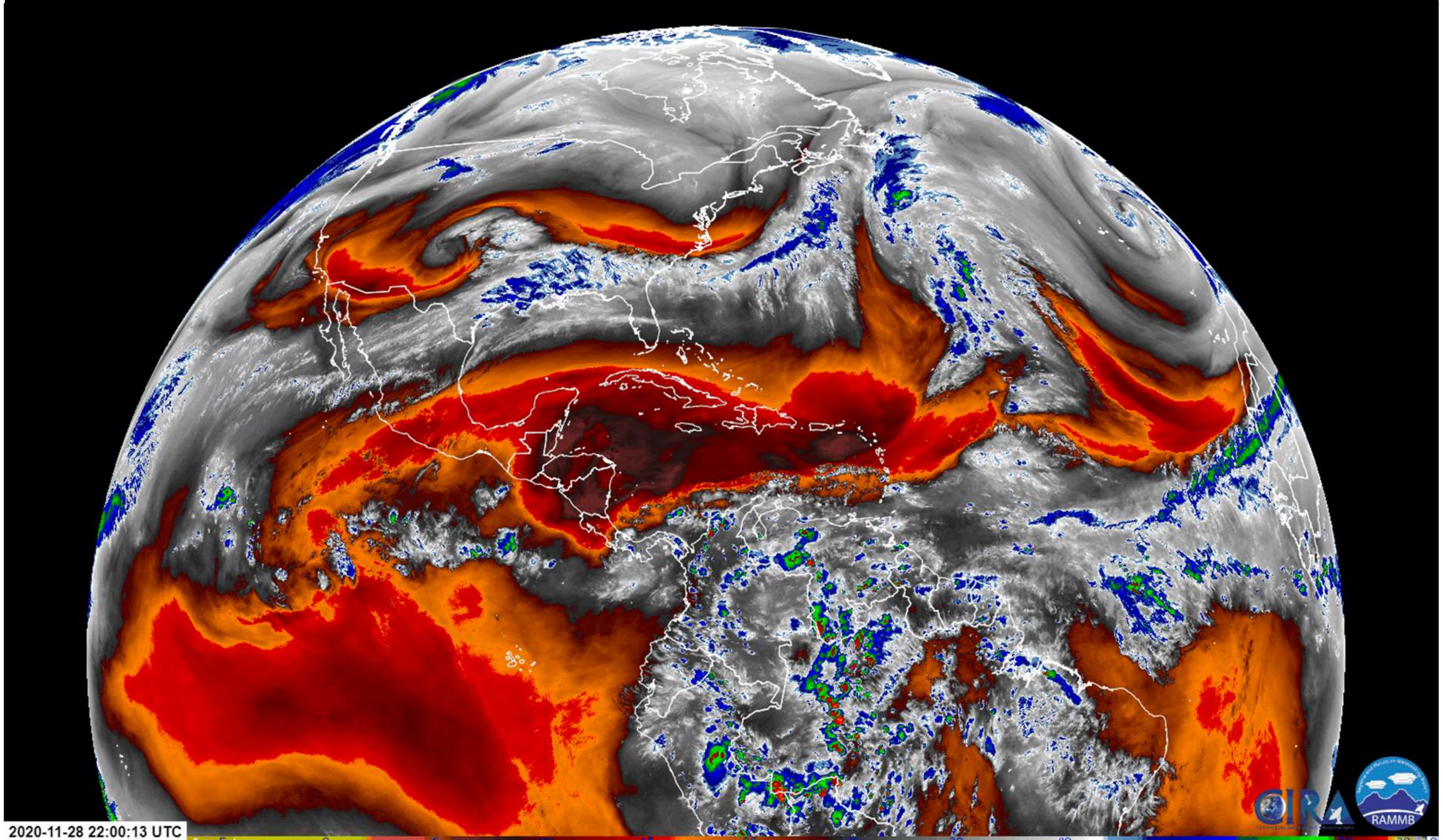
- Warmer than normal SE USA
  - Fronts limit to the Gulf of Mexico
- Weaker than normal northerly trades
  - Eastern Pacific ITCZ remains north of CLIMO
  - Gulf of Panama
    - No upwelling due to weaker northerlies
    - Warm SST Anomalies
- <u>Impact</u>
  - Wrn Colombia/Panama & Guianas: Wetter than normal
  - Ecuador: Dryer than Normal
  - No dual ITCZ over the eastern Pacific

Conceptual Model

Low Level Flow Cool ENSO – La Niña



Upper Level Flow Pattern
2020 Cold ENSO



As expected, ridge builds north from the western Caribbean, with polar perturbations lifting over this axis.

End Part I

Questions?

Shear Lines

Part II

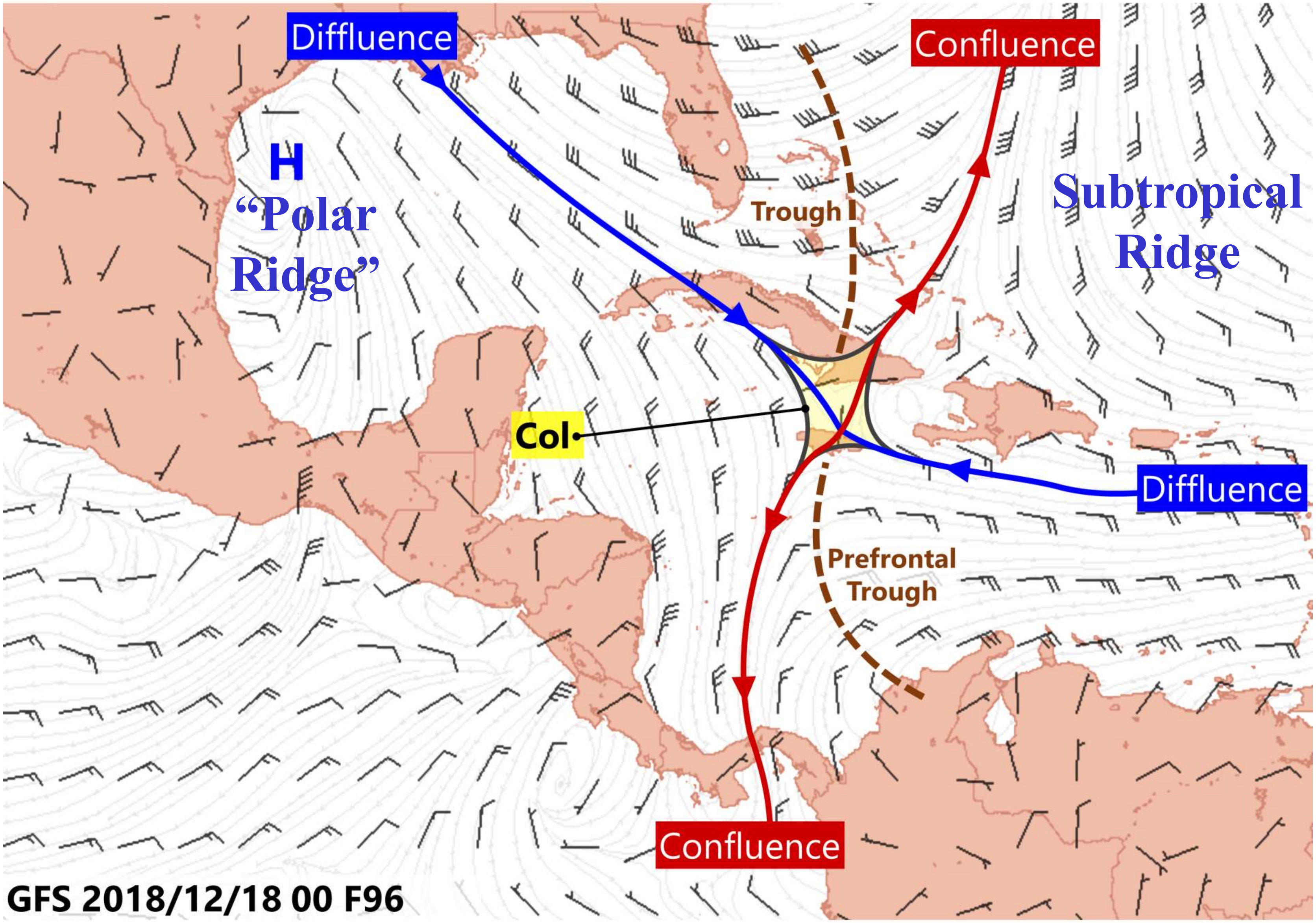
Shear Lines vs. Fronts

- **Fronts**: The transition zone between two air masses of different **density** (baroclinic).
  - Density depends on **temperature** and moisture content
  - Present weather not a requirement.
  - Fronts either lie along shear lines or can lag behind.
- **Shear Lines:** are associated with wind shifts (direction and/or speed).
  - A line or narrow zone across which there is an abrupt change in the **horizontal wind** component parallel to this line
    - A line of maximum horizontal wind shear (10kt shear).
    - An area of directional **wind confluence** along, or preceding, the tail end of a surface front.
    - Lacks the **baroclinicity/density** discontinuity of surface fronts.

Evaluation of a Shear Line

- Area of wind **confluence** that extends outward from a **col**
  - Near surface feature
- Shear line can be found:
  - **Along, or trailing, a surface front**
    - When parallel, only show the front
  - **Ahead of the surface front**
    - Show both
  - ***Never behind!***

Wind Directional Confluence and Diffluence in the Caribbean



Wind Divergence

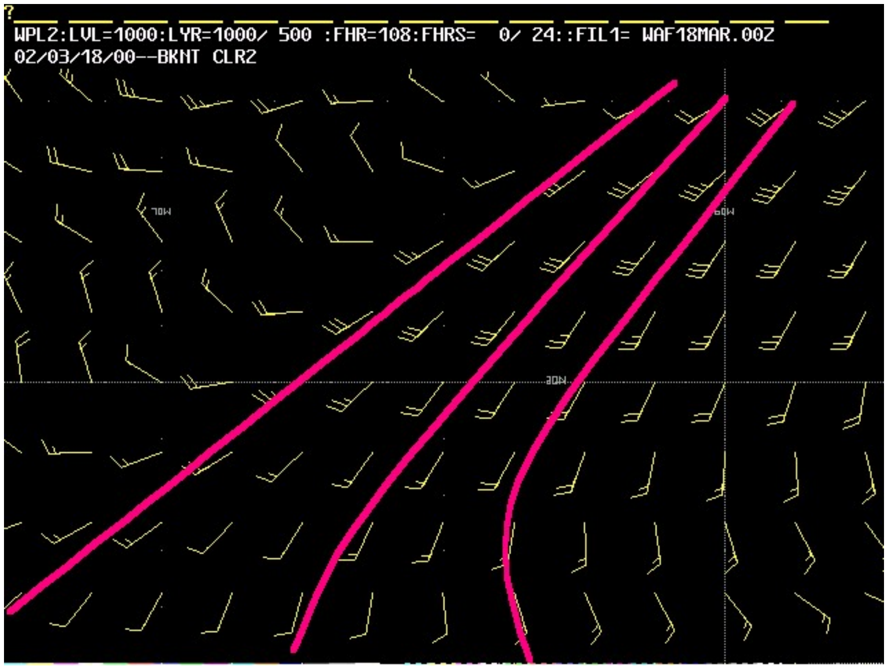
Divergence of the Wind

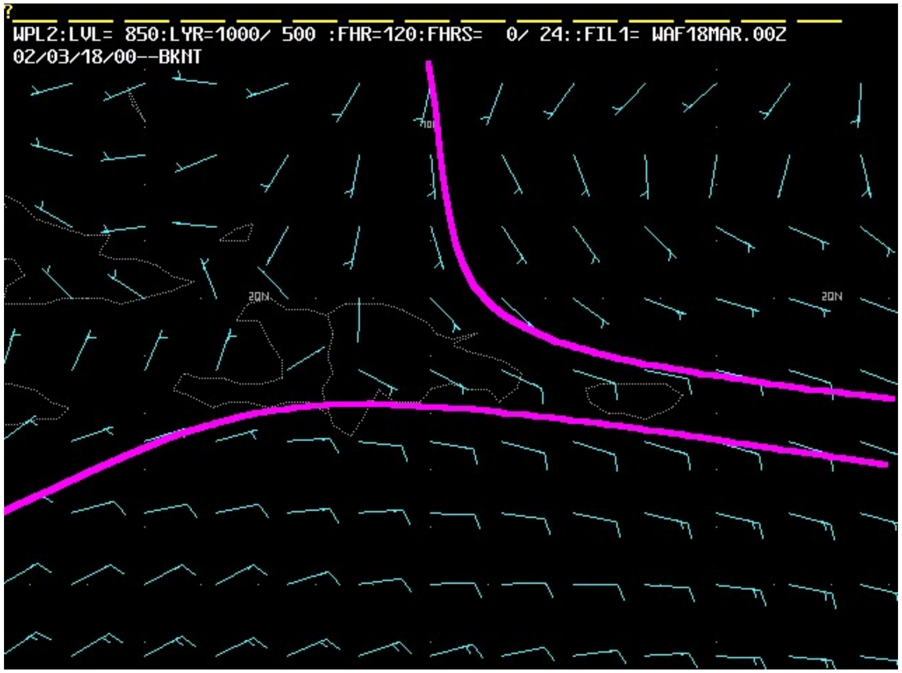
- We can express the divergence equation in a simplified form, with two terms:
  - Direction
  - Speed
- The direction and speed terms, in-turn, can be expressed as directional/speed diffluence and confluence
  - **Confluence** ***is not equal to*** **Convergence**
  - **Diffluence** ***is not equal to*** **Divergence**

Divergence (Cont.)

- Divergence/convergence calculations need to take into account the direction and speed terms.
  - This is done through objective analysis
- ***Streamline analysis*** is a ***subjective*** technique, and it only shows directional diffluence and confluence.
  - It ***does not*** show convergence/divergence

Example Directional Diffluence/Confluence

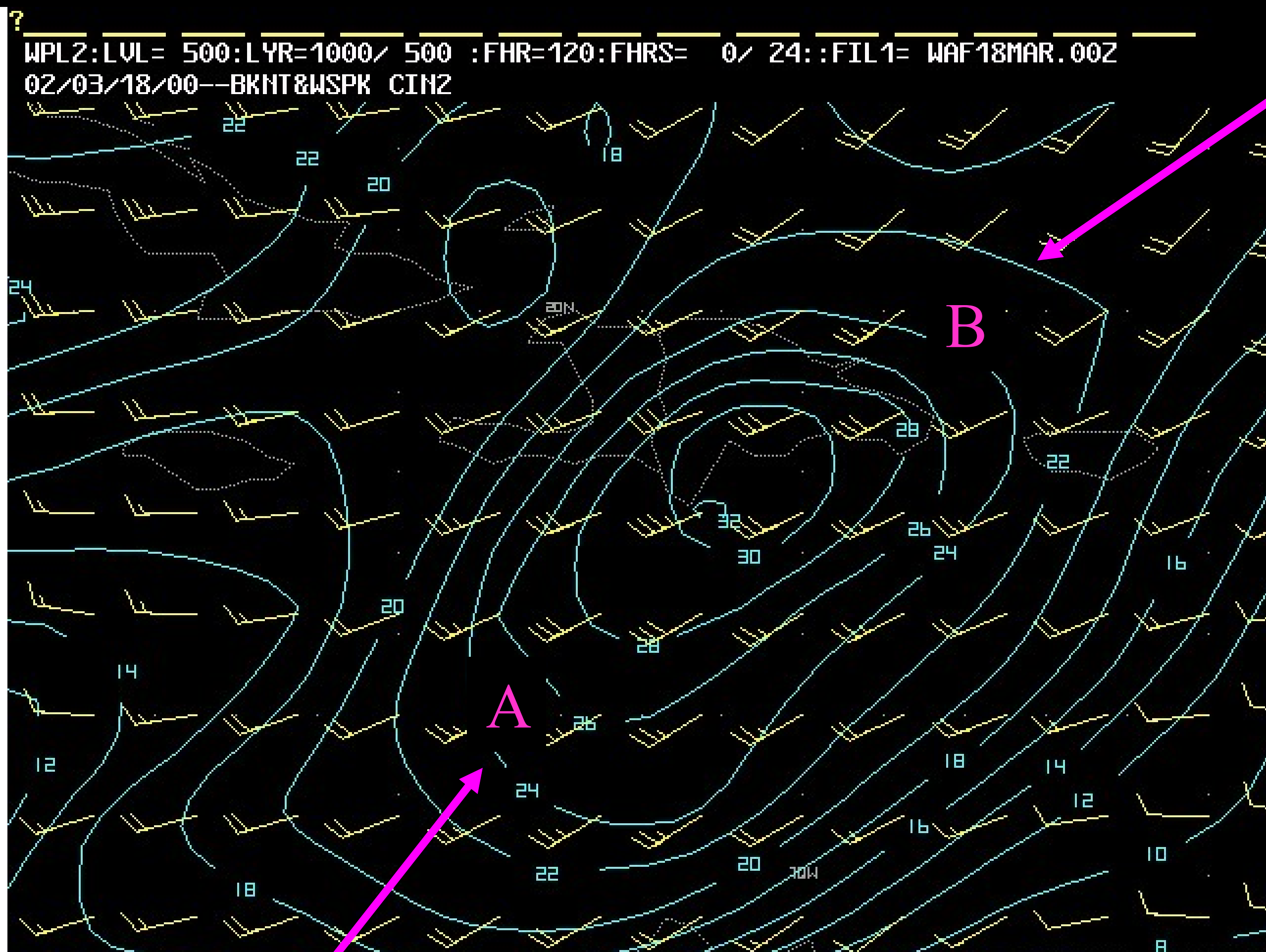




Directional Confluence

Directional Diffluence

Speed Diffluence/Confluence



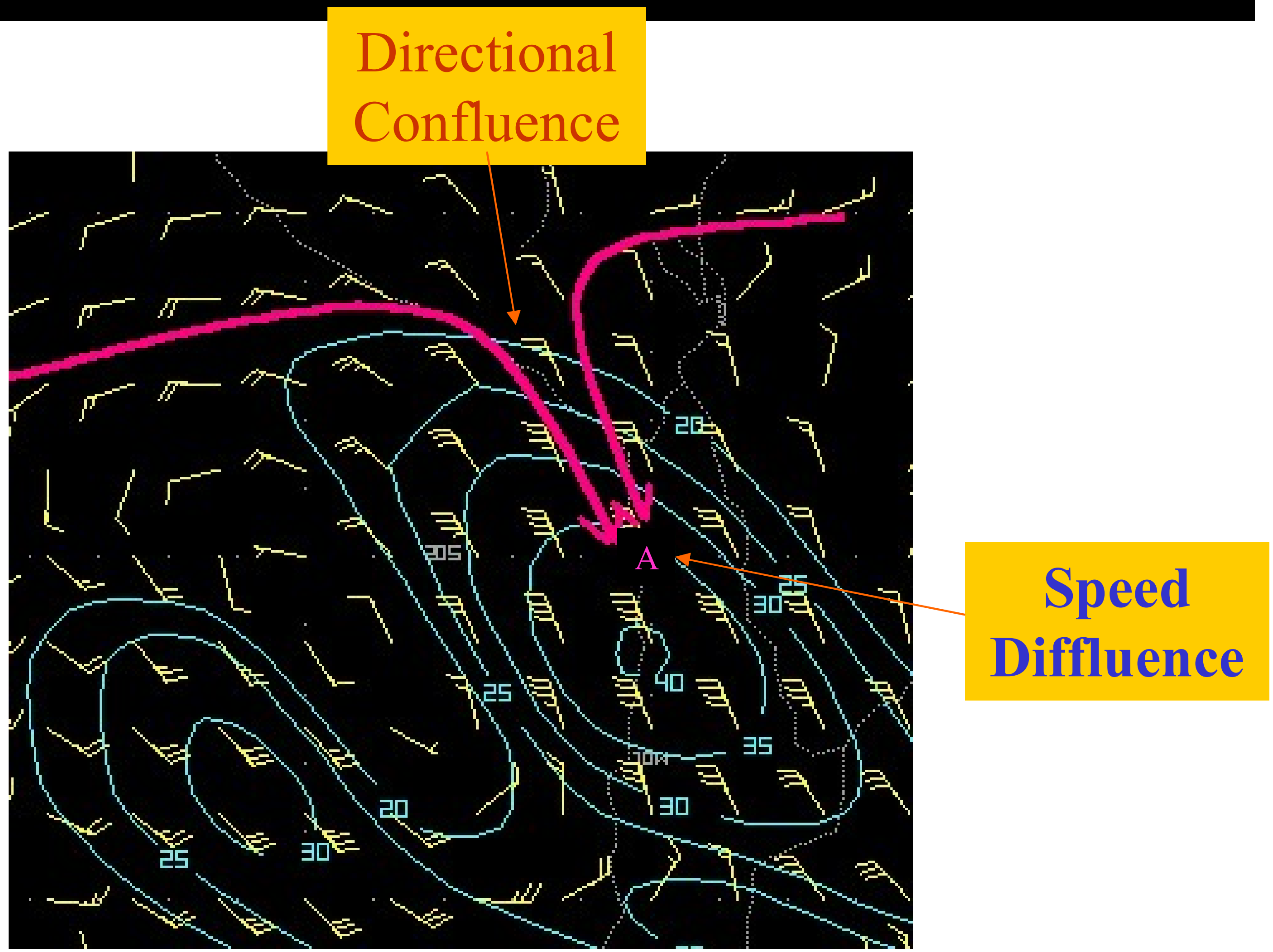
Speed Confluence

Speed Diffluence

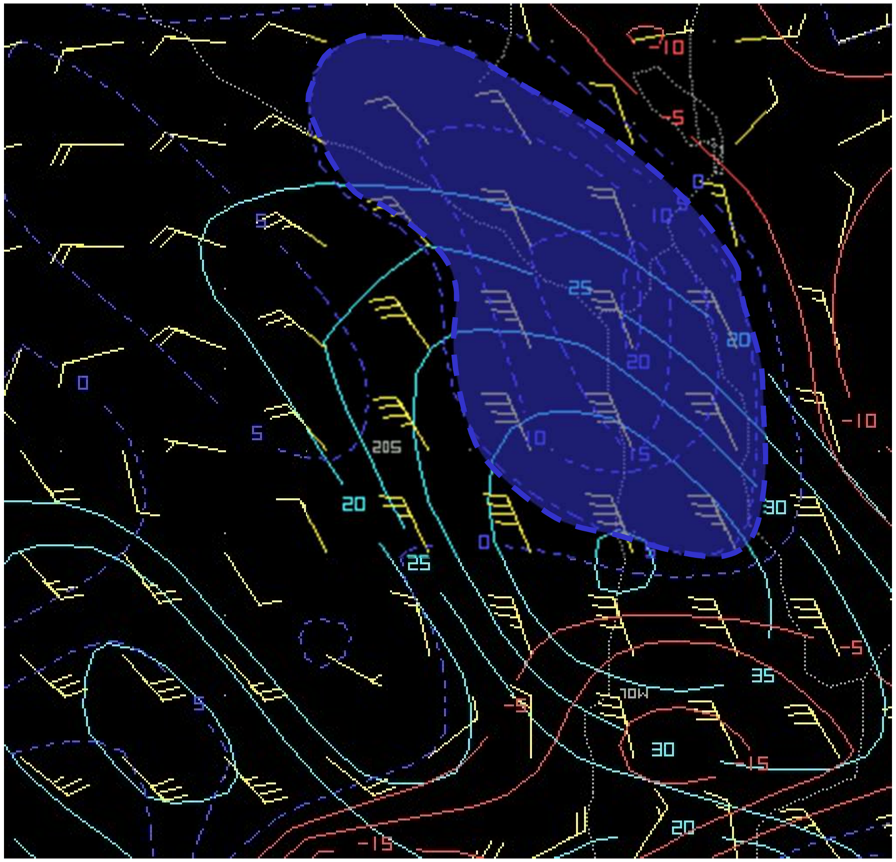
Poll Question #10
(Select all that apply)

- Streamline analysis considers the speed and directional terms
- Streamline analysis only considers the direction
- Diffluence equals divergence
- Diffluence equals convergence

Convergent or Divergent?



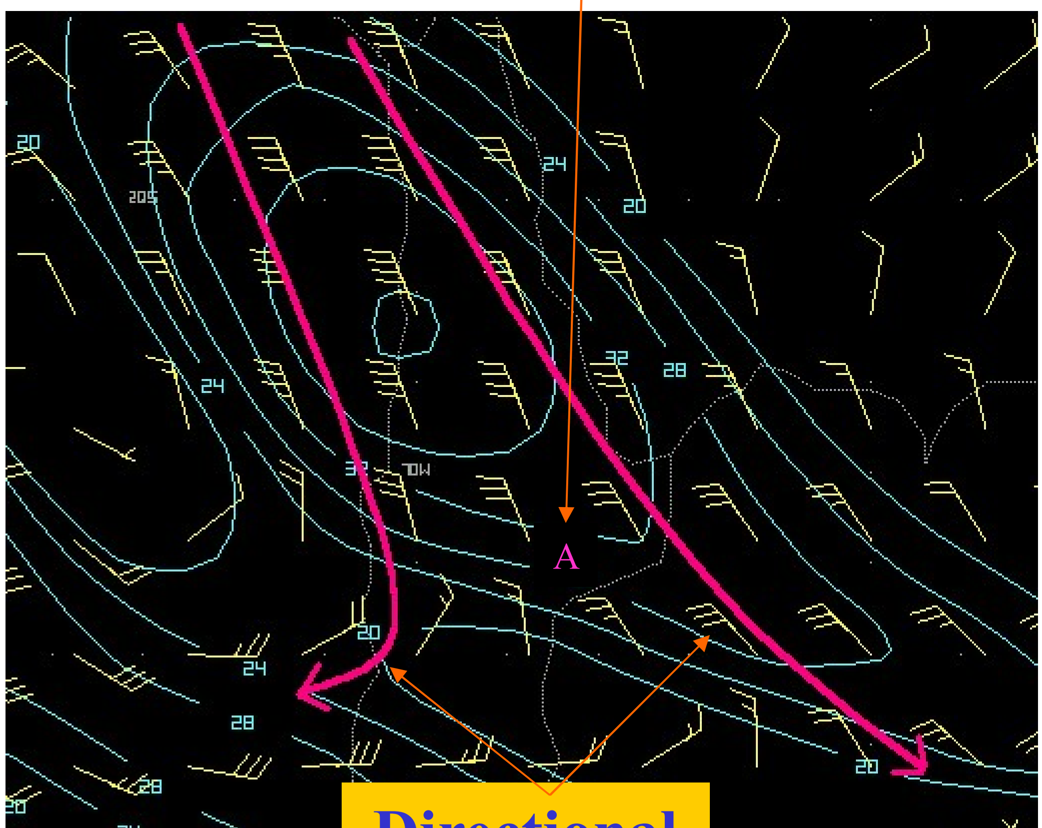
Convergent or Divergent?



Objective analysis, divergence in blue: **Speed dominates**

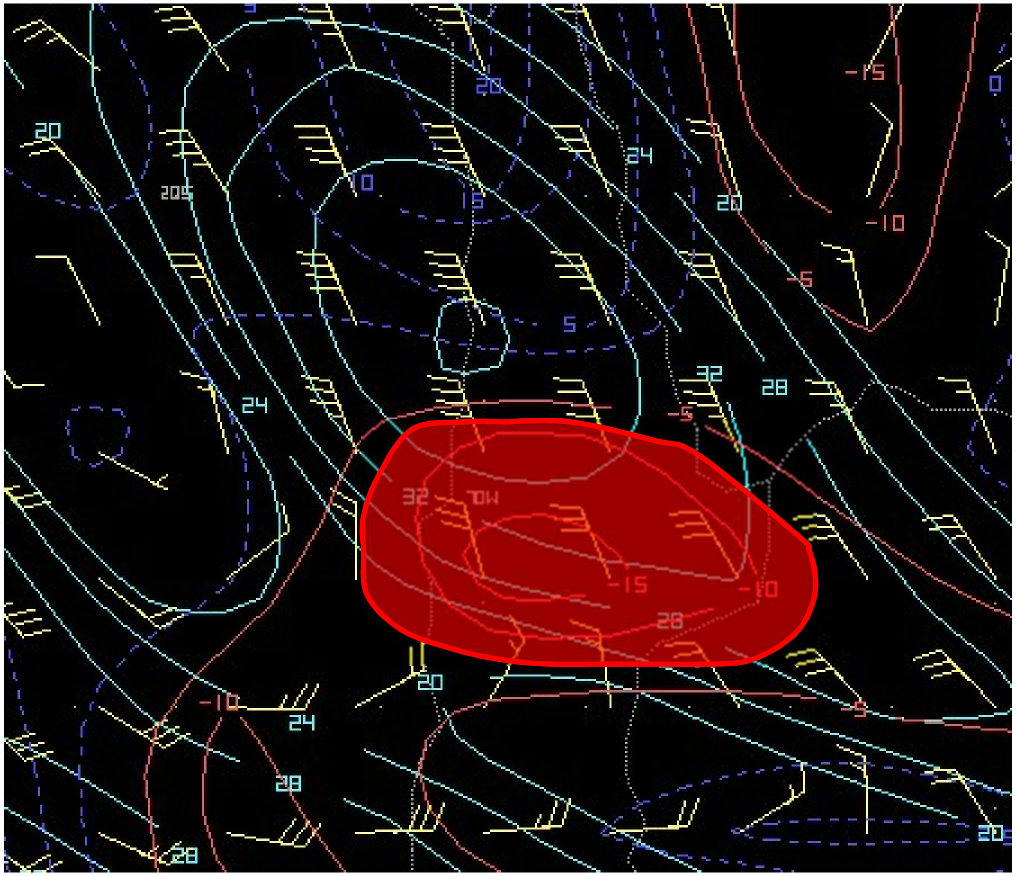
Convergent or Divergent?

Speed Confluence



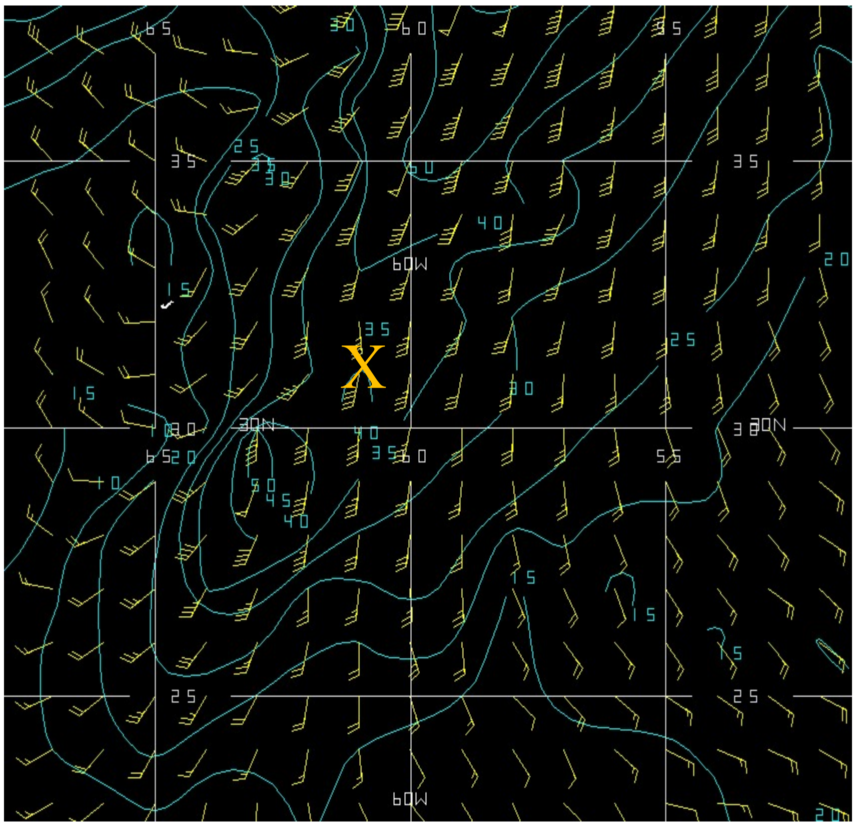
Directional Diffluence

Convergent or Divergent?



Objective analysis, convergence in red: **Speed dominates**

Poll Question #11



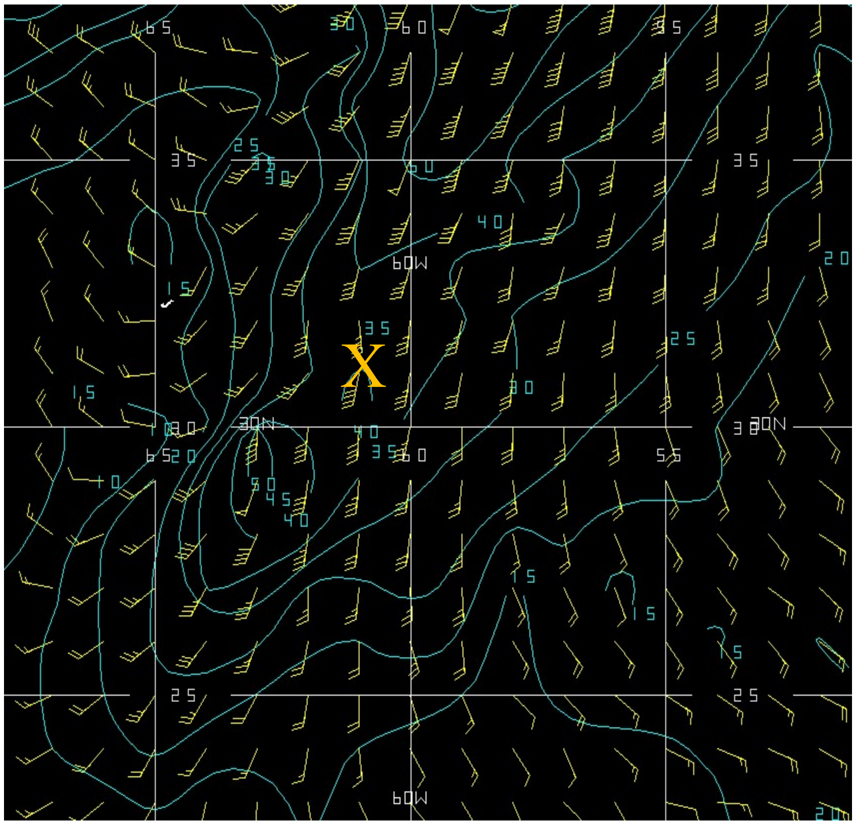
850 hPa Winds and Isotachs

- Is the flow directionally confluent or diffluent?
- Is the flow speed confluent or diffluent?
- ***Subjectively***, will this favor convergence or divergence?

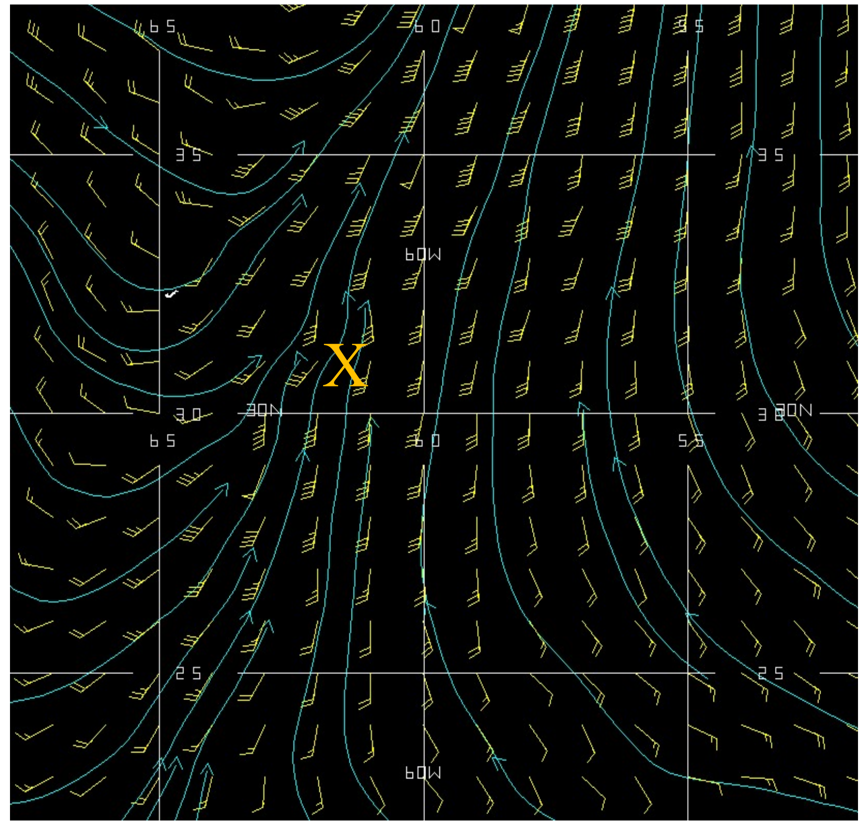
Poll Question #11
(Select one)

- Directionally diffluent, speed confluent, convergent
- Directionally confluent, speed diffluent, divergent
- Directionally diffluent, speed diffluent, divergent
- Directionally confluent, speed confluent, convergent

Poll Question #11 Review

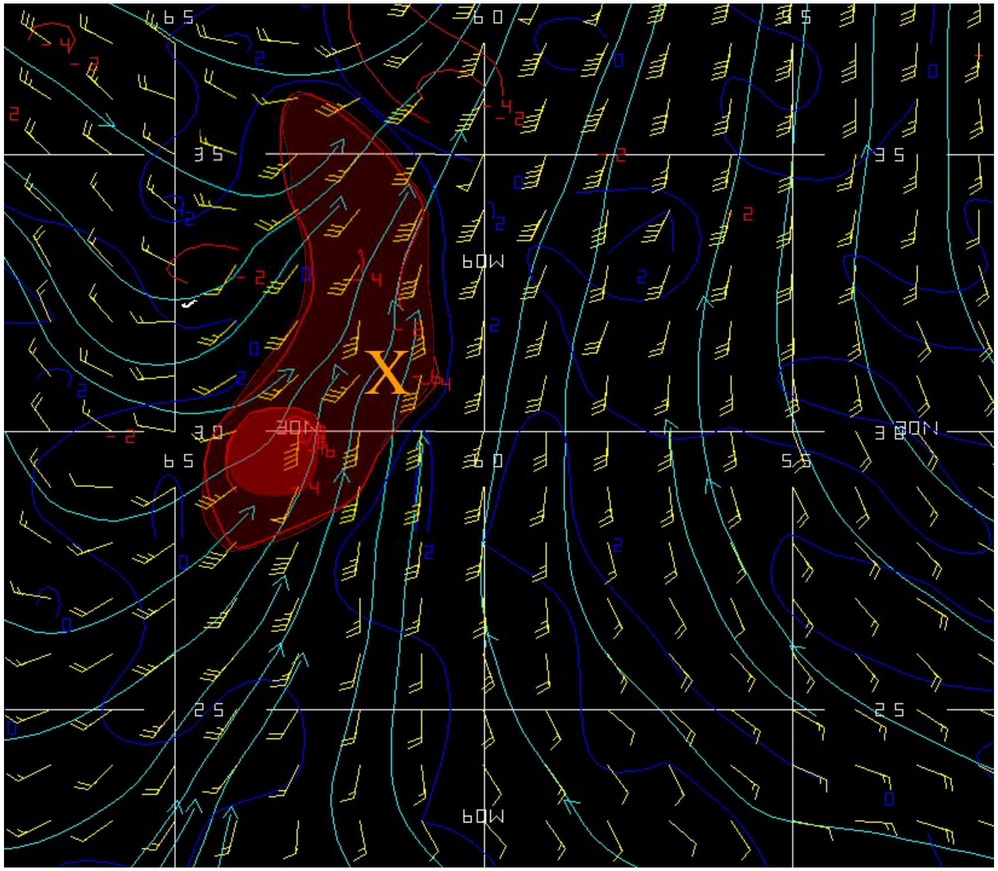


Speed Confluent



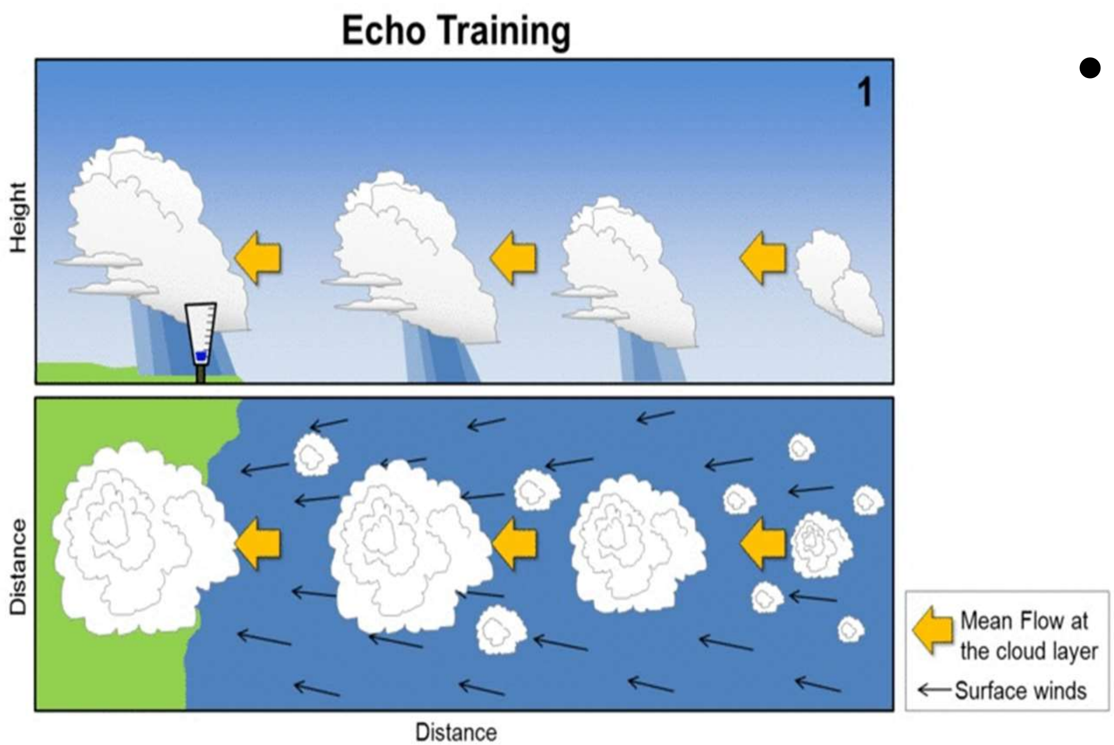
Directionally Confluent

Poll Question #11 Review (convergence in red)



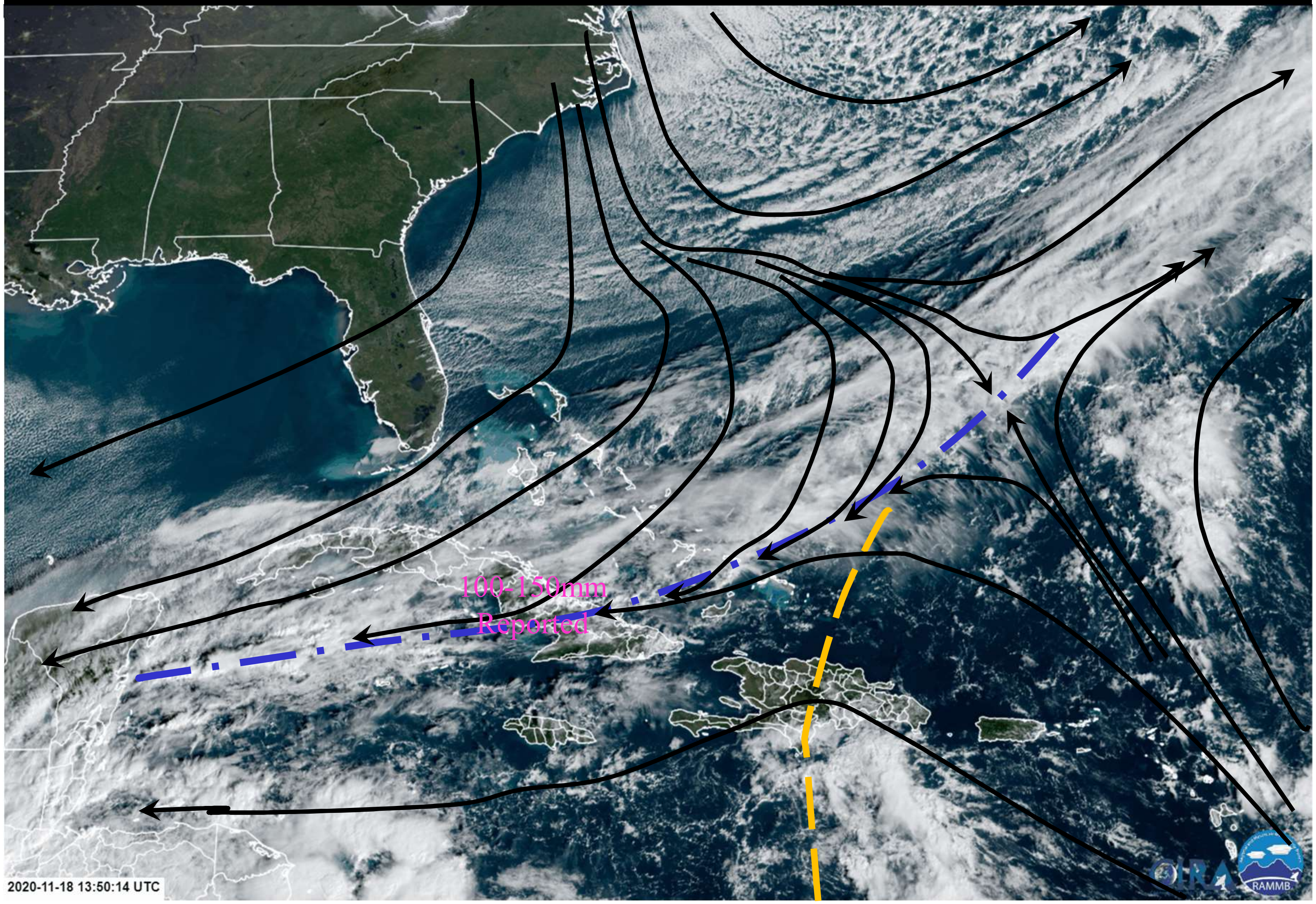
Speed & Directionally Confluent favors convergence

Shear Lines and Echo Training



- Shear lines, as they tend to linger, present a higher risk of an echo training event forming

Echo Training – SE Bahamas



Shear Lines: Types

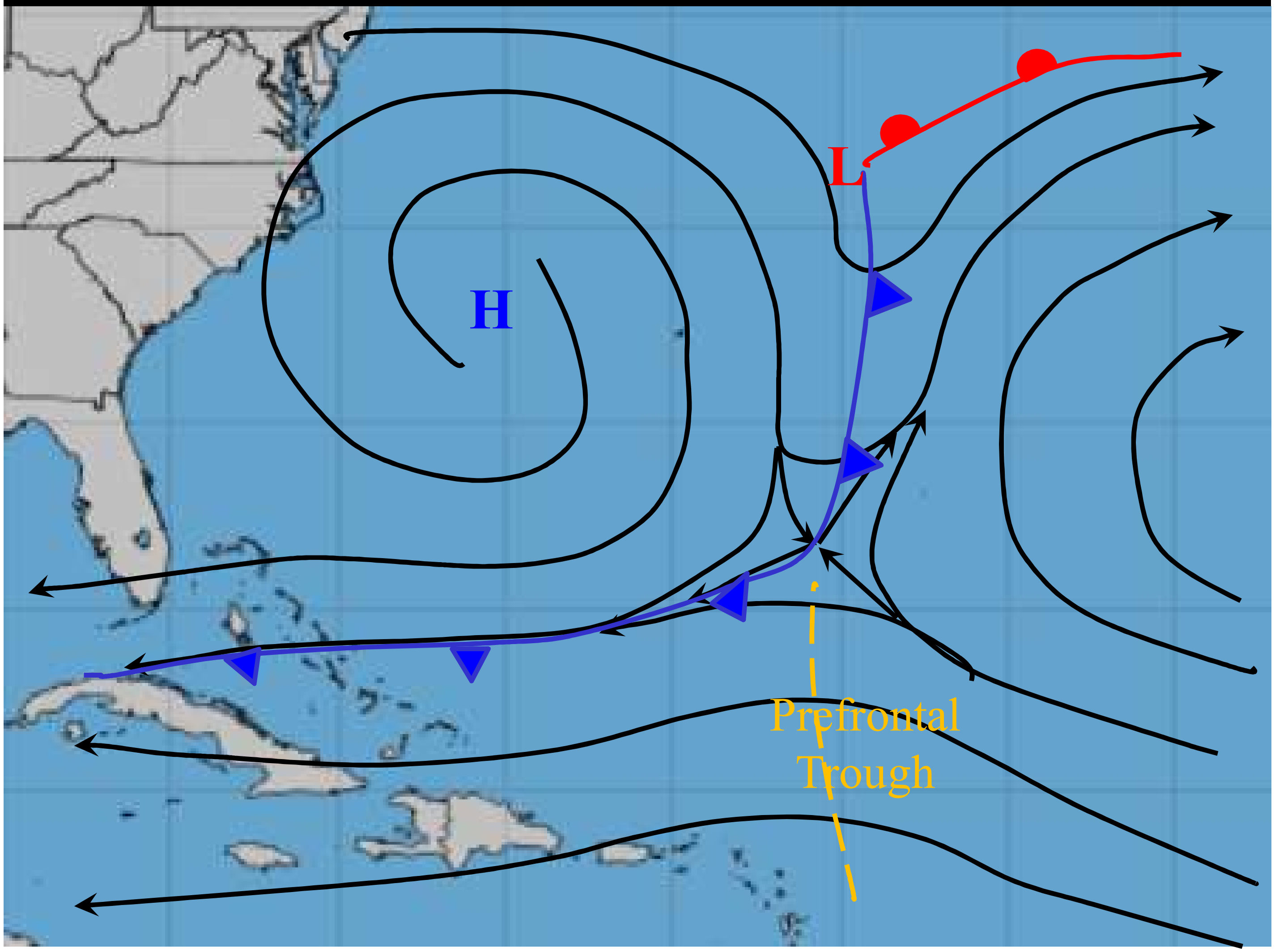
- **Frontal Shear Line**:
  - Cold/Stationary front weakening along the confluent asymptote
  - Speed shear along a waning front
- **Prefrontal Shear Line**: Driven by a broad polar ridge, the confluent asymptote accelerates ahead of the surface front as it nears the Caribbean basin.

Frontal Shear Line

Wind Confluence Induced

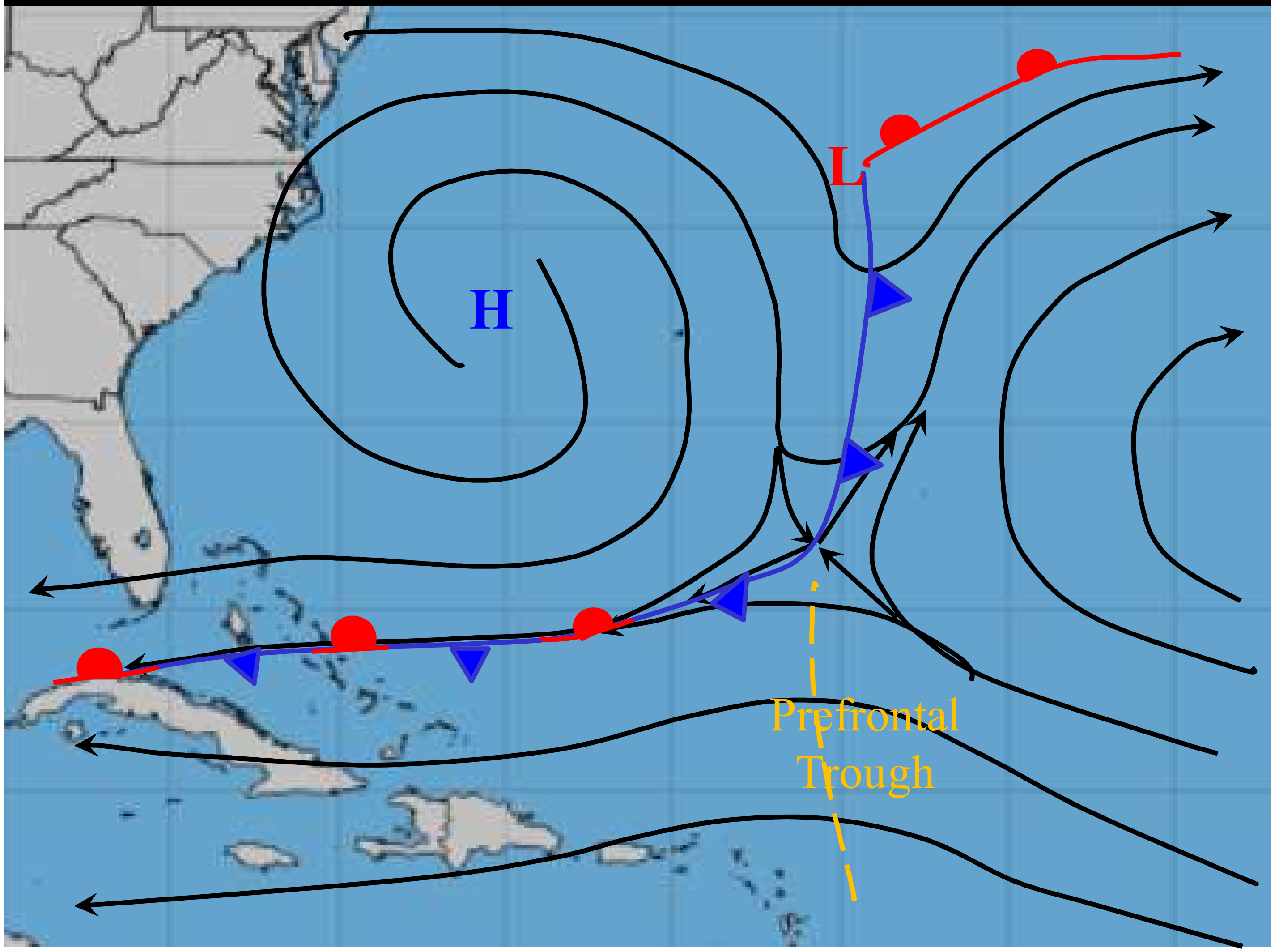
Evolution of a Frontal Shear Line

Front parallel to confluent asymptote



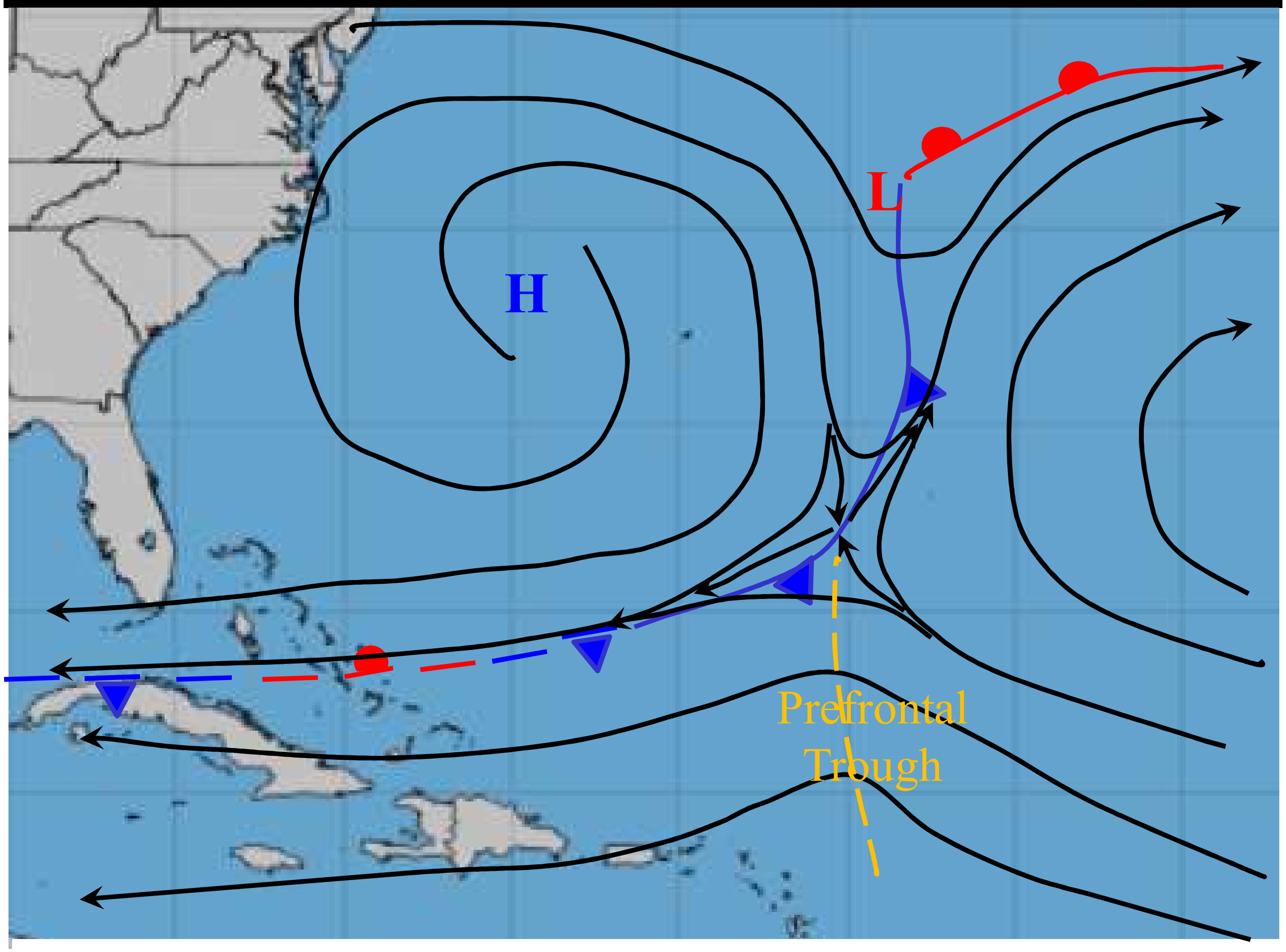
Evolution of a Frontal Shear Line

Front stalls, remains parallel to confluent asymptote



Frontal Shear Line

Frontolysis, stationary front starts to dissipate

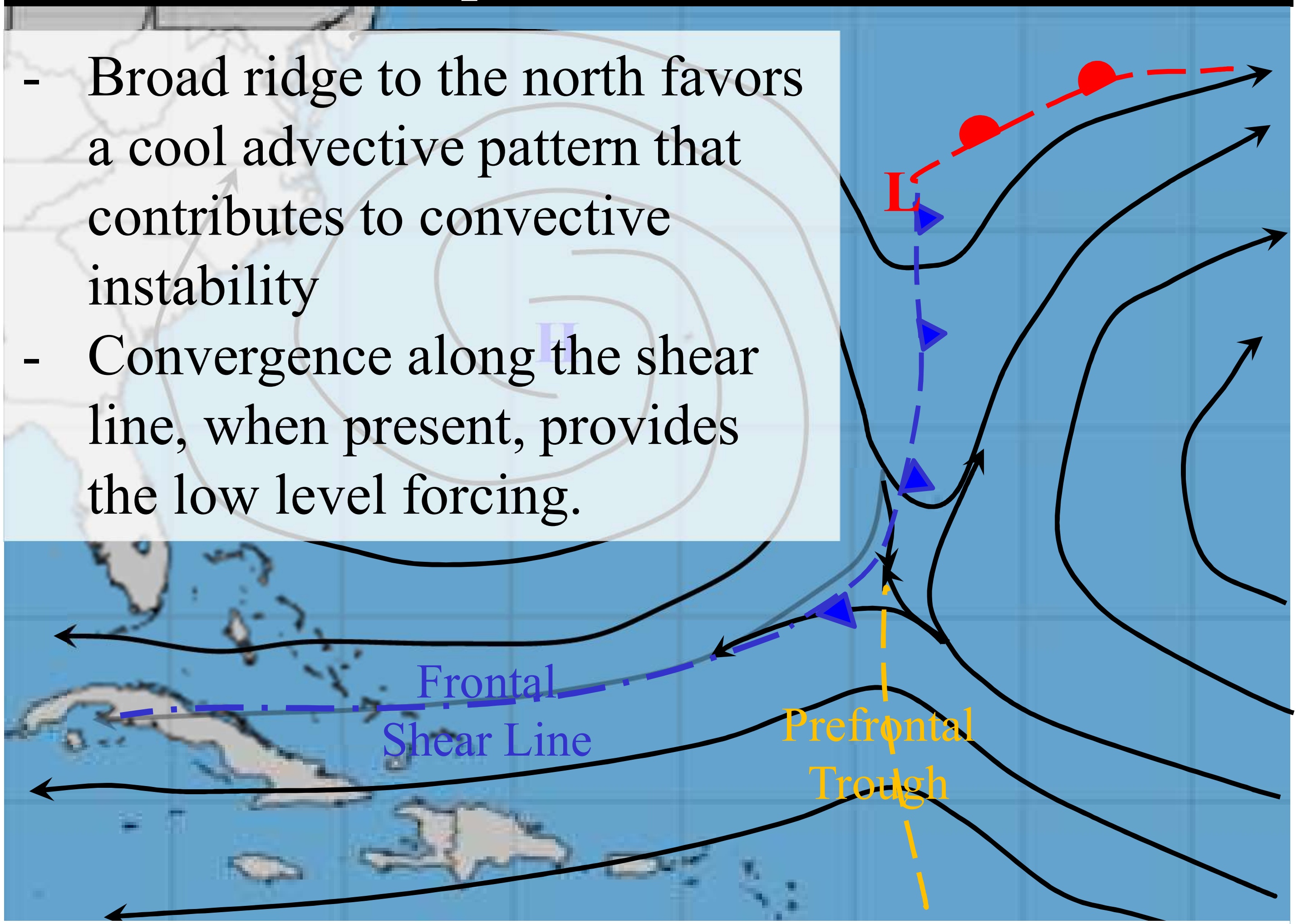


Surface front parallel to confluent asymptote

Frontal Shear Line

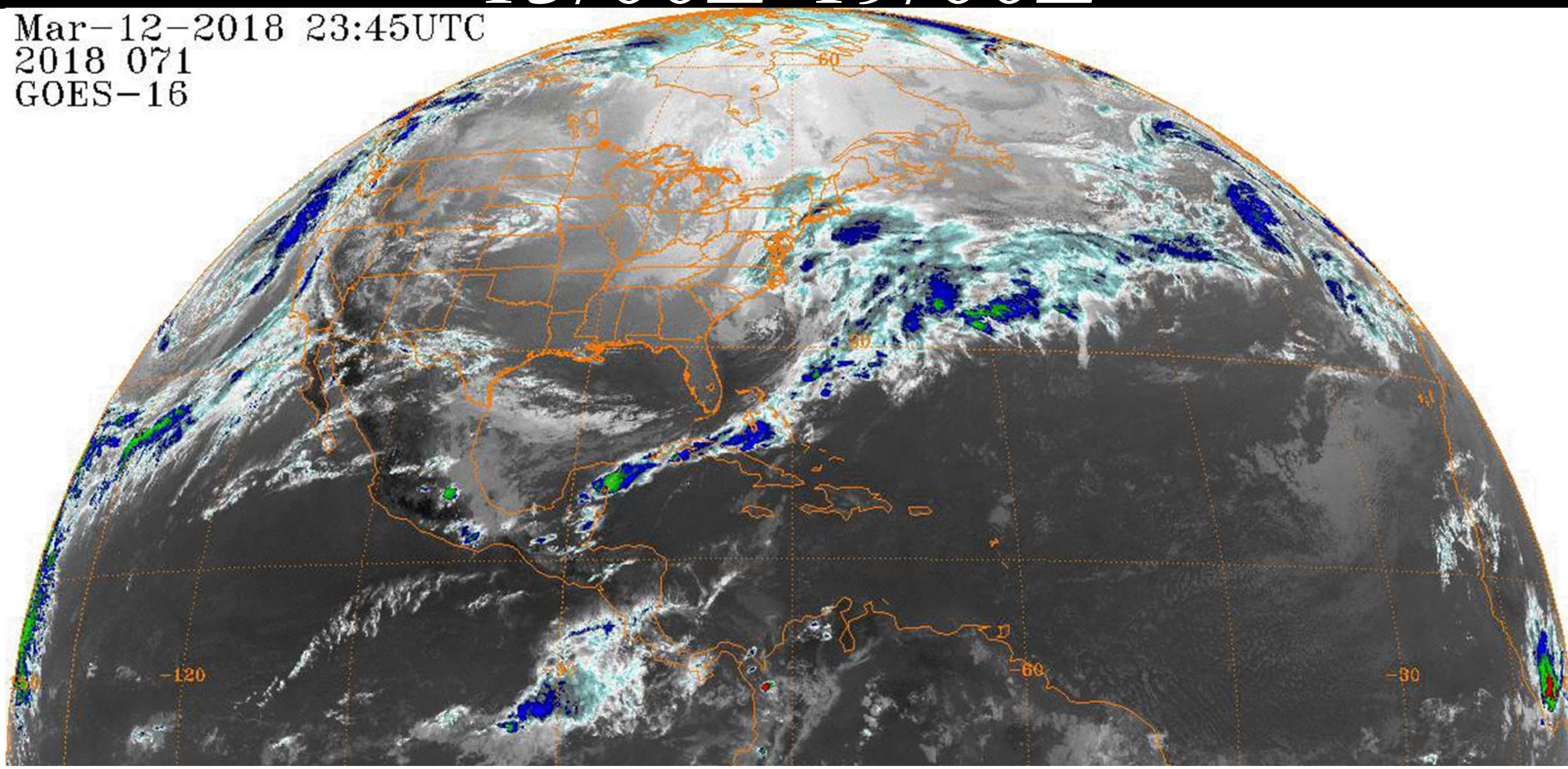
Front dissipates, shear line remains

- Broad ridge to the north favors a cool advective pattern that contributes to convective instability
- Convergence along the shear line, when present, provides the low level forcing.



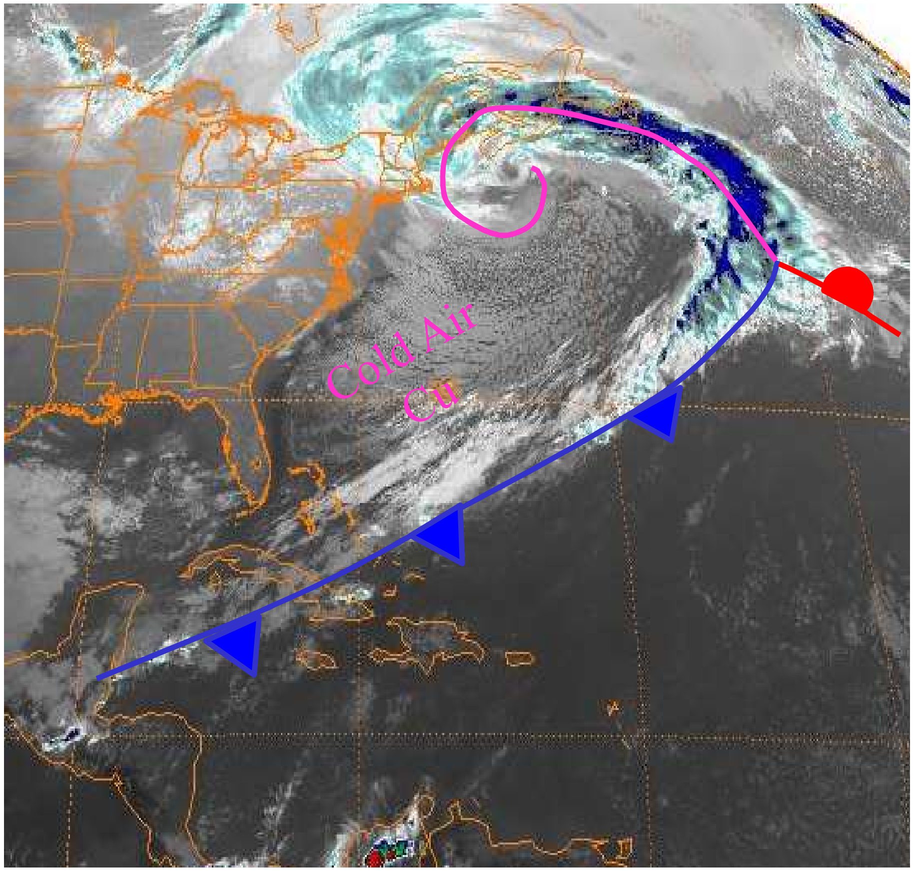
Surface front dissipates, confluent asymptote remains

10.3um Animation – Mar, 2018 13/00Z-19/00Z

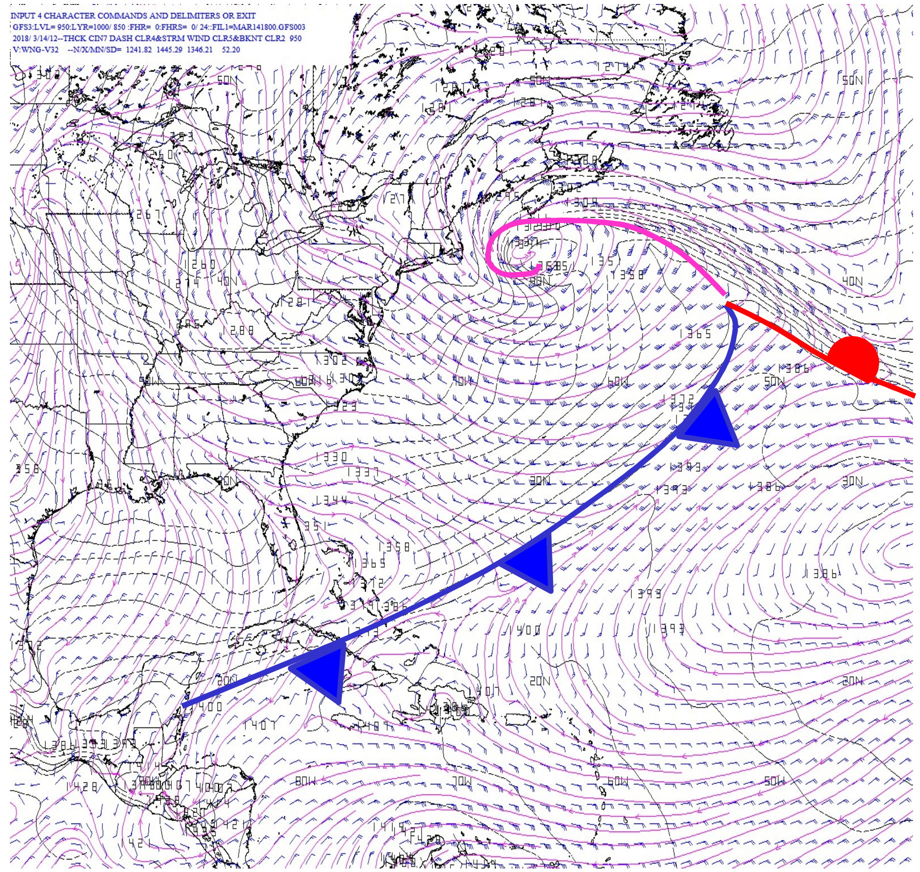


Frontal system streaming across the Bahamas briefly decays to a frontal shear line as it loses its upper level support and stalls to the southeast.

IR 10.3um vs. GDAS: 20180314_00Z



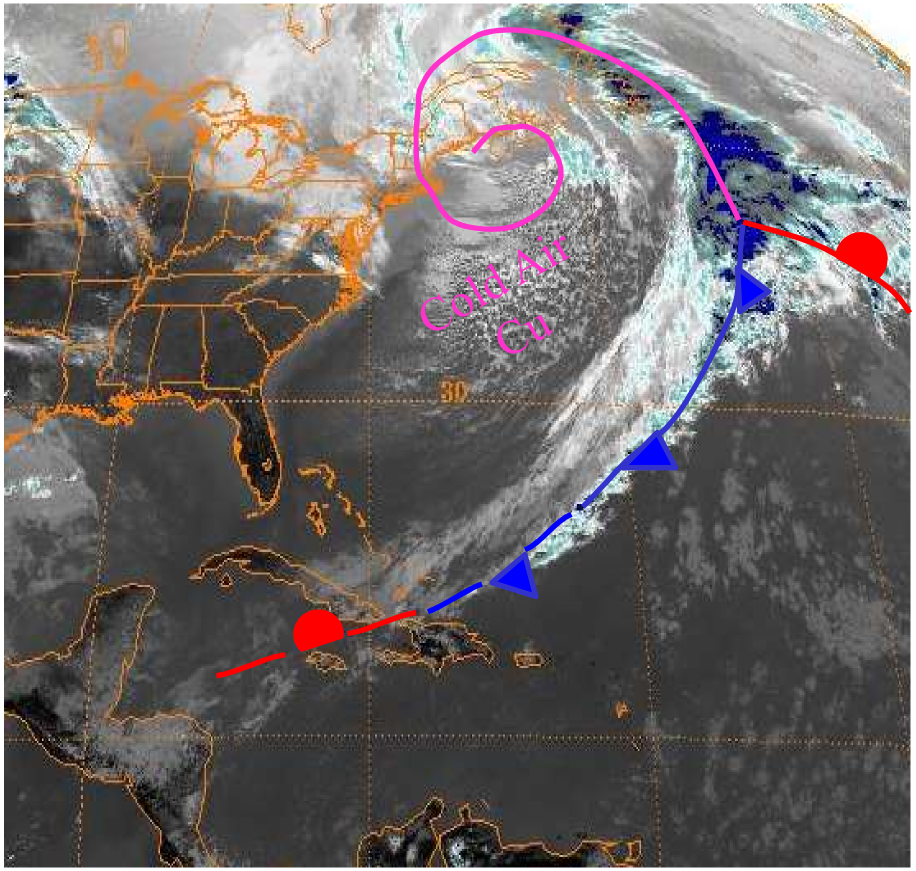
IR 10.3um



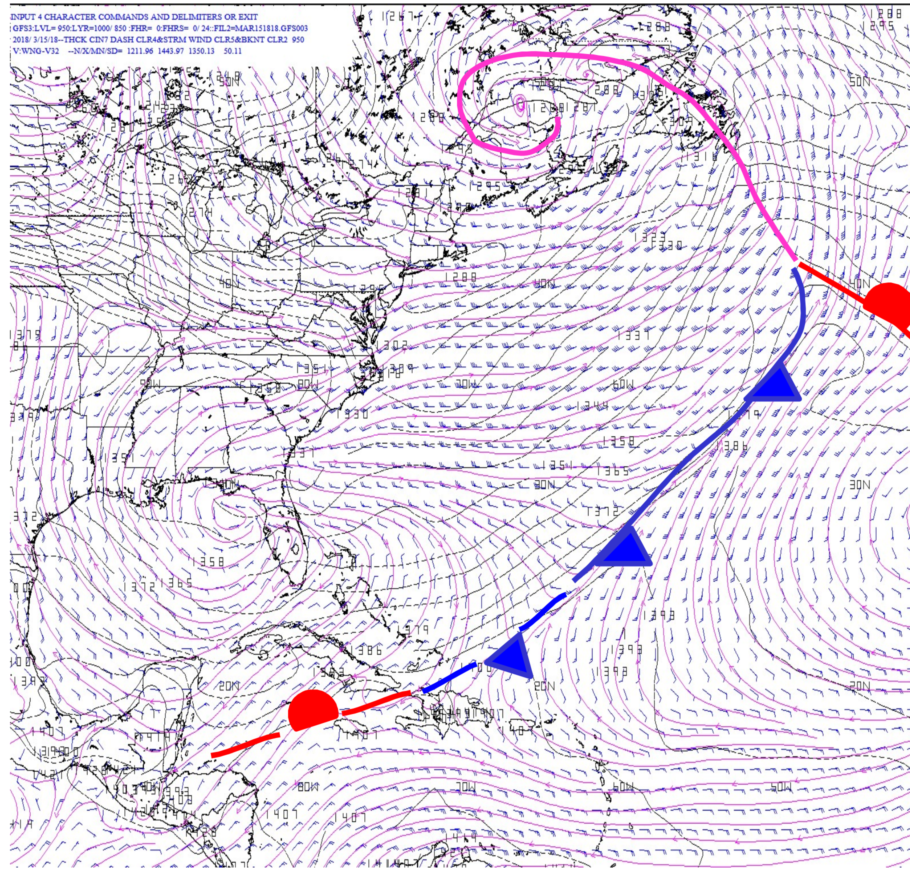
GDAS

950 hPa Winds, Streamlines, and 1000-850 hPa Thickness

IR 10.3um vs. GDAS : 20180315_18Z



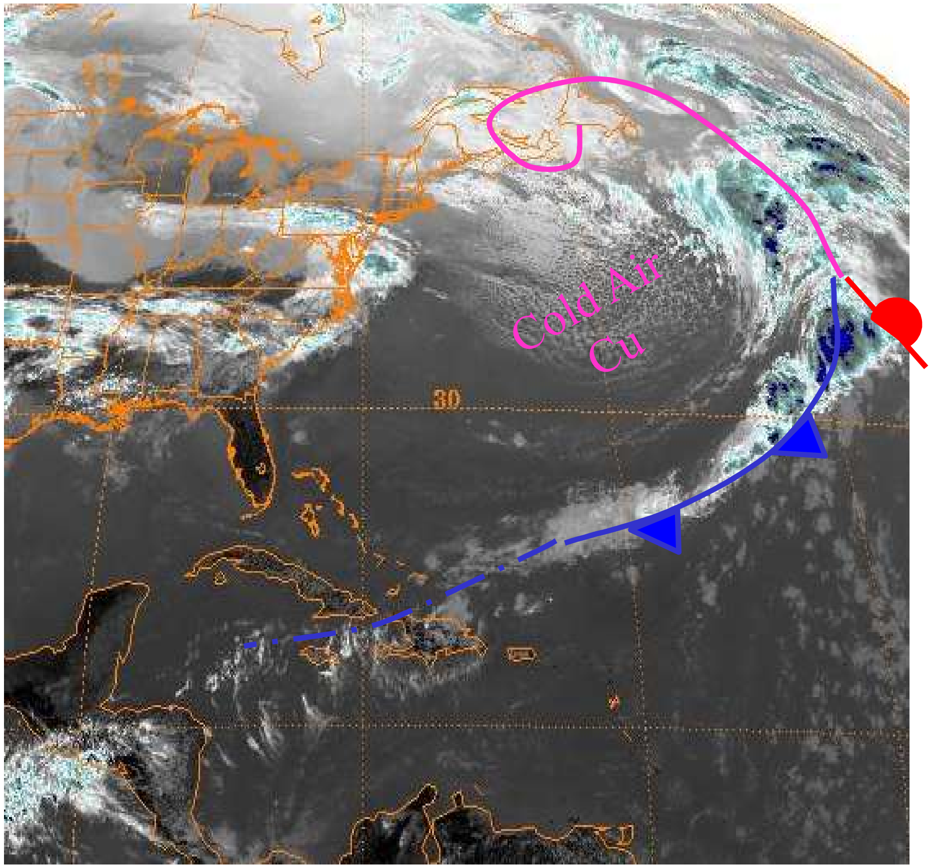
IR 10.3um



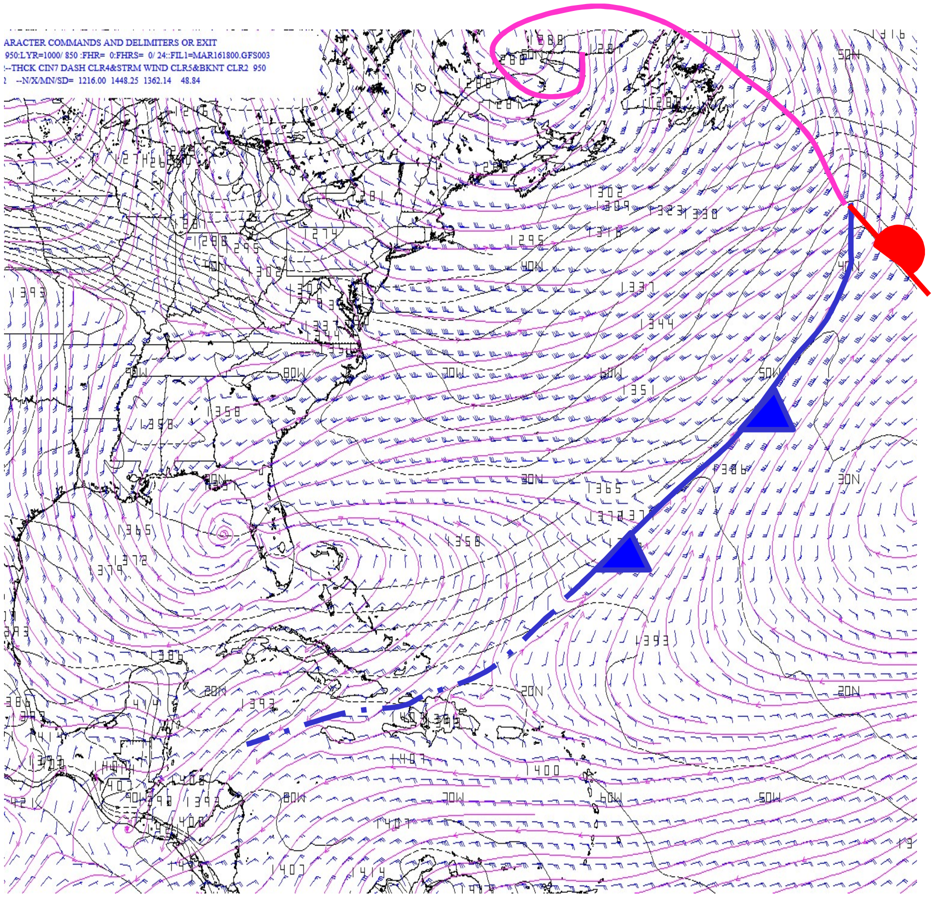
GDAS

950 hPa Winds, Streamlines, and
1000-850 Thickness

IR 10.3um vs. GDAS : 20180316_18Z



IR 10.3um

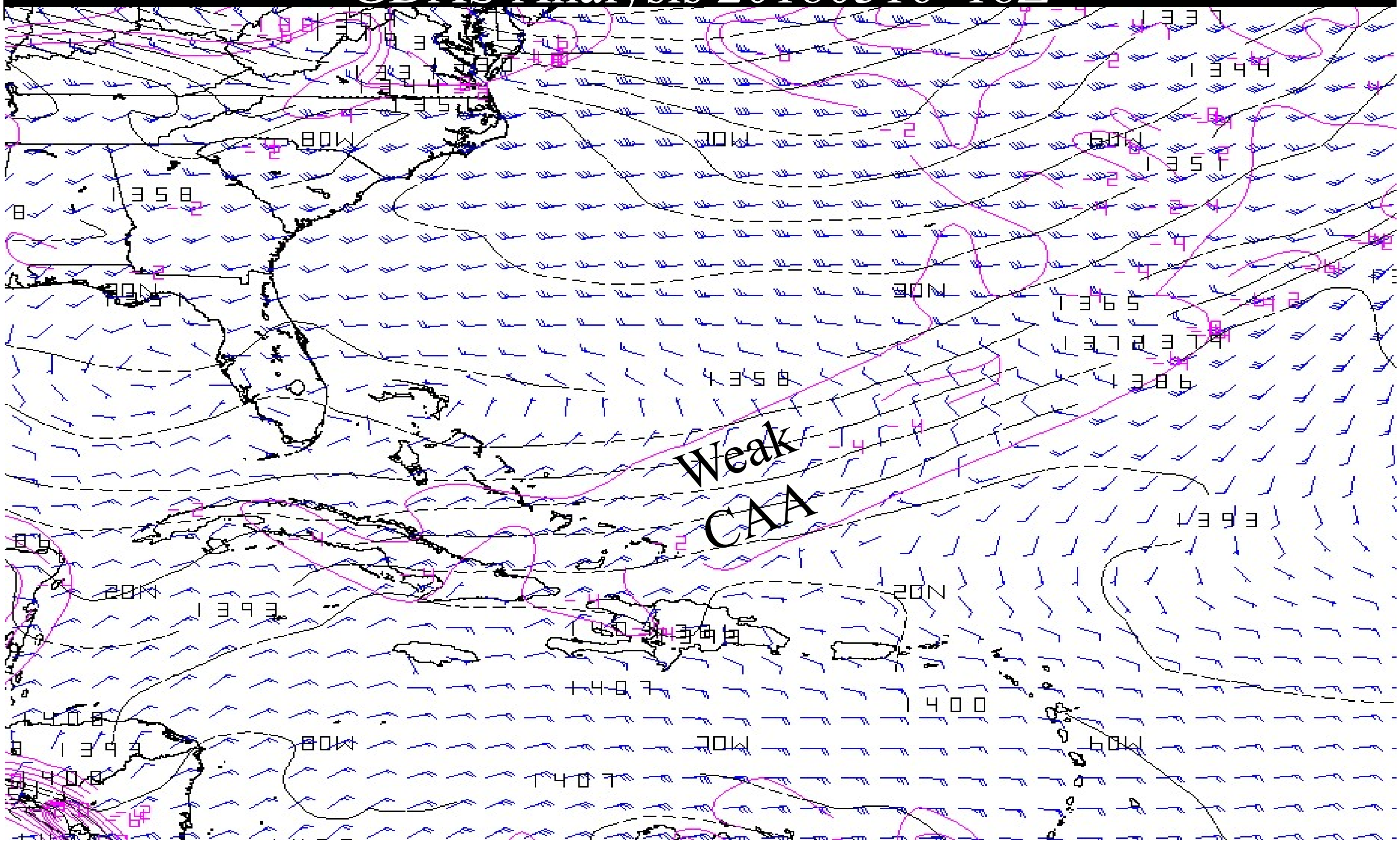


GDAS

950 hPa Winds, Streamlines, and 1000-850 Thickness

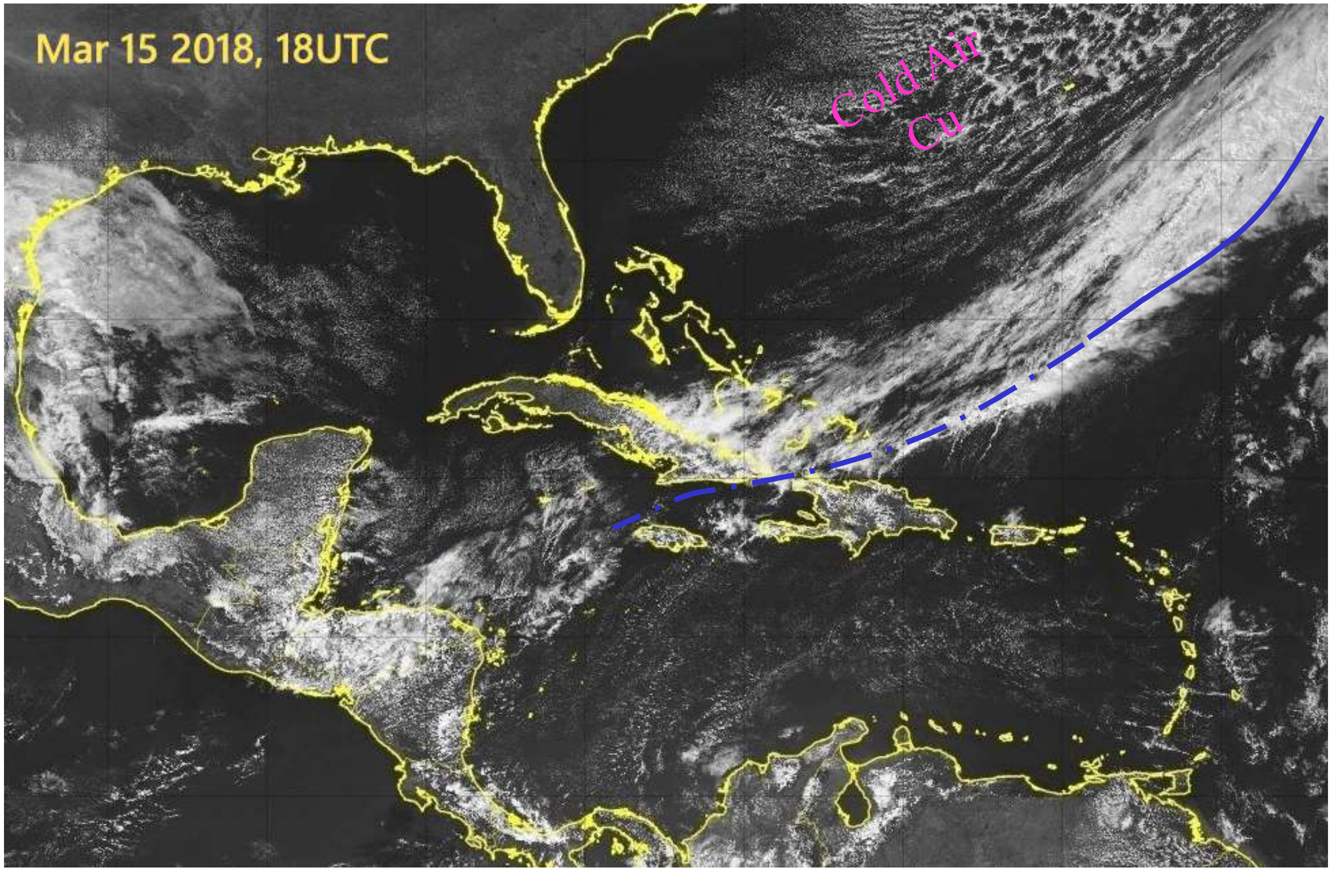
Cold Air Advection (CAA)

GDAS Analysis 20180316 18Z



Along the tail end of the front, winds weaken and become nearly parallel to the thickness gradient.

Vis Image: 20180315_18Z



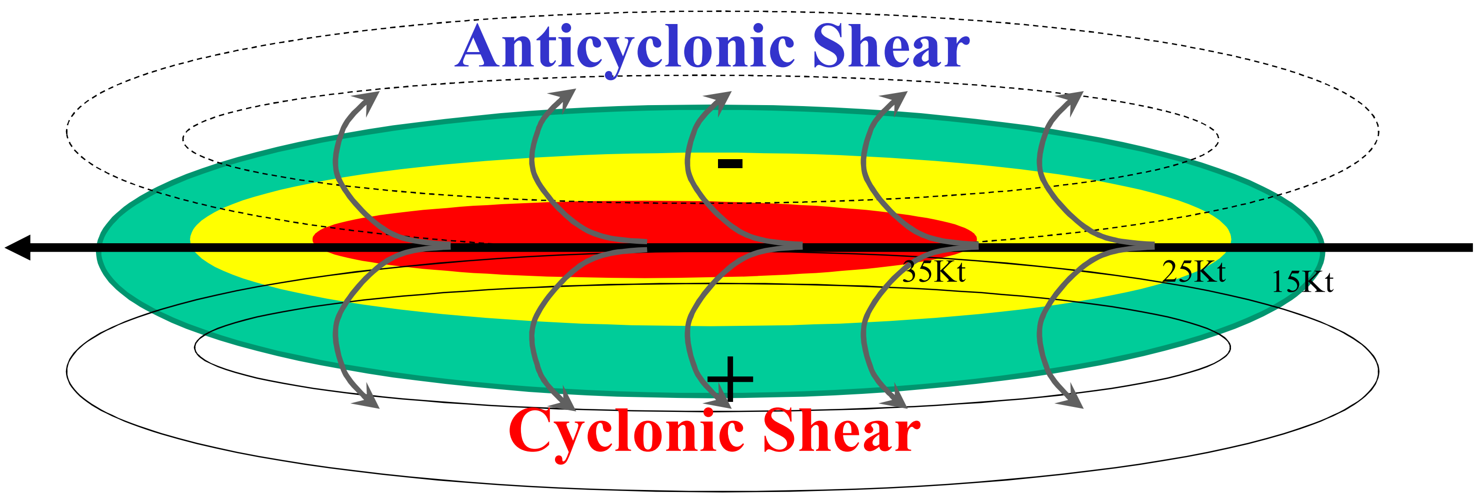
Cold air cumulus is evident far to the north, with fair weather over the northwest Bahamas. Convection clustering along frontal shear line over The Turks and Caicos – Ern Cuba

Frontal Shear Line

Speed Shear Induced

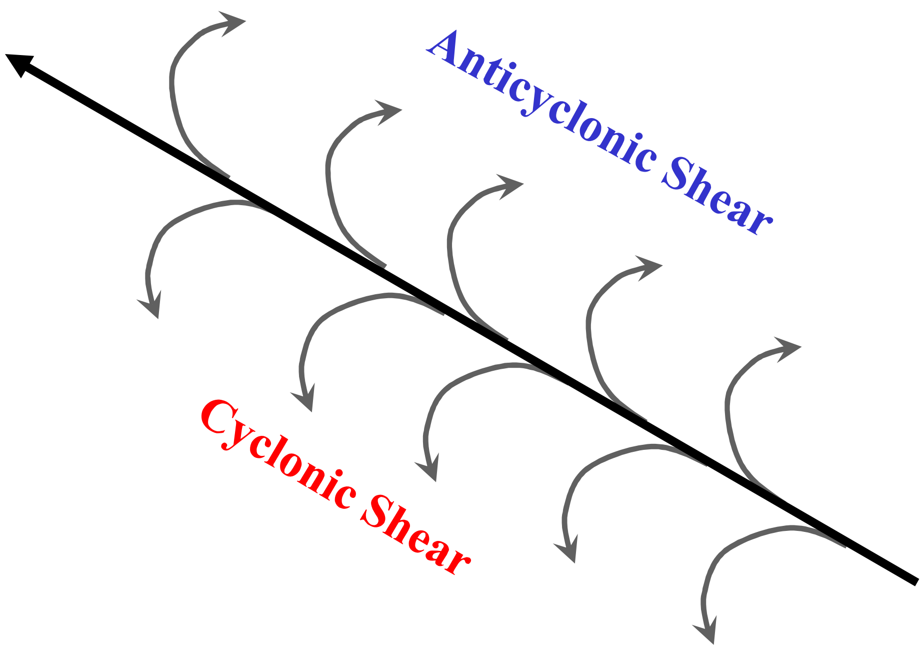
Speed Shear

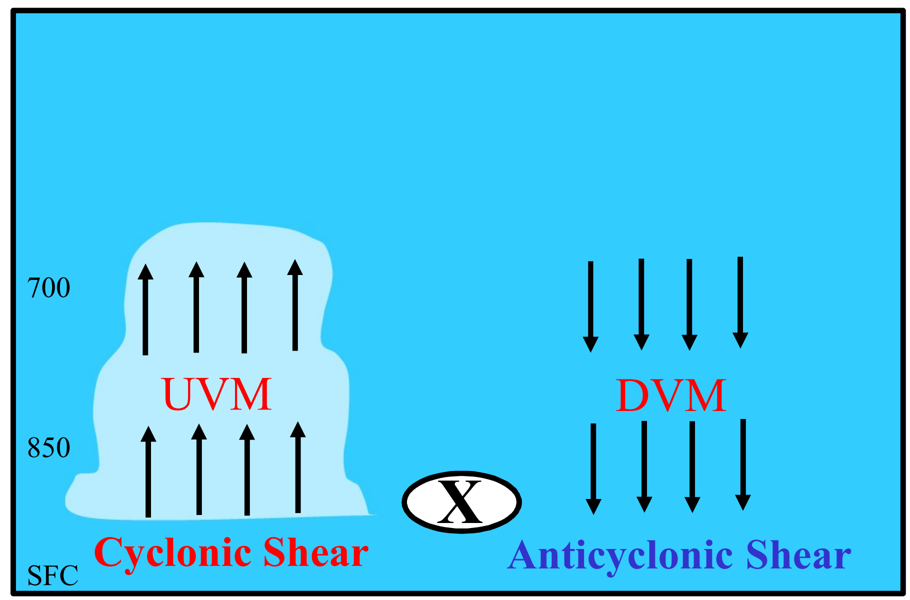
- As the low level winds increase/decrease along a wind maxima, this results in areas of horizontally induced wind shear
  - Ensuing areas of cyclonic/anticyclonic shear are a function of the gradient and intensity of the winds.



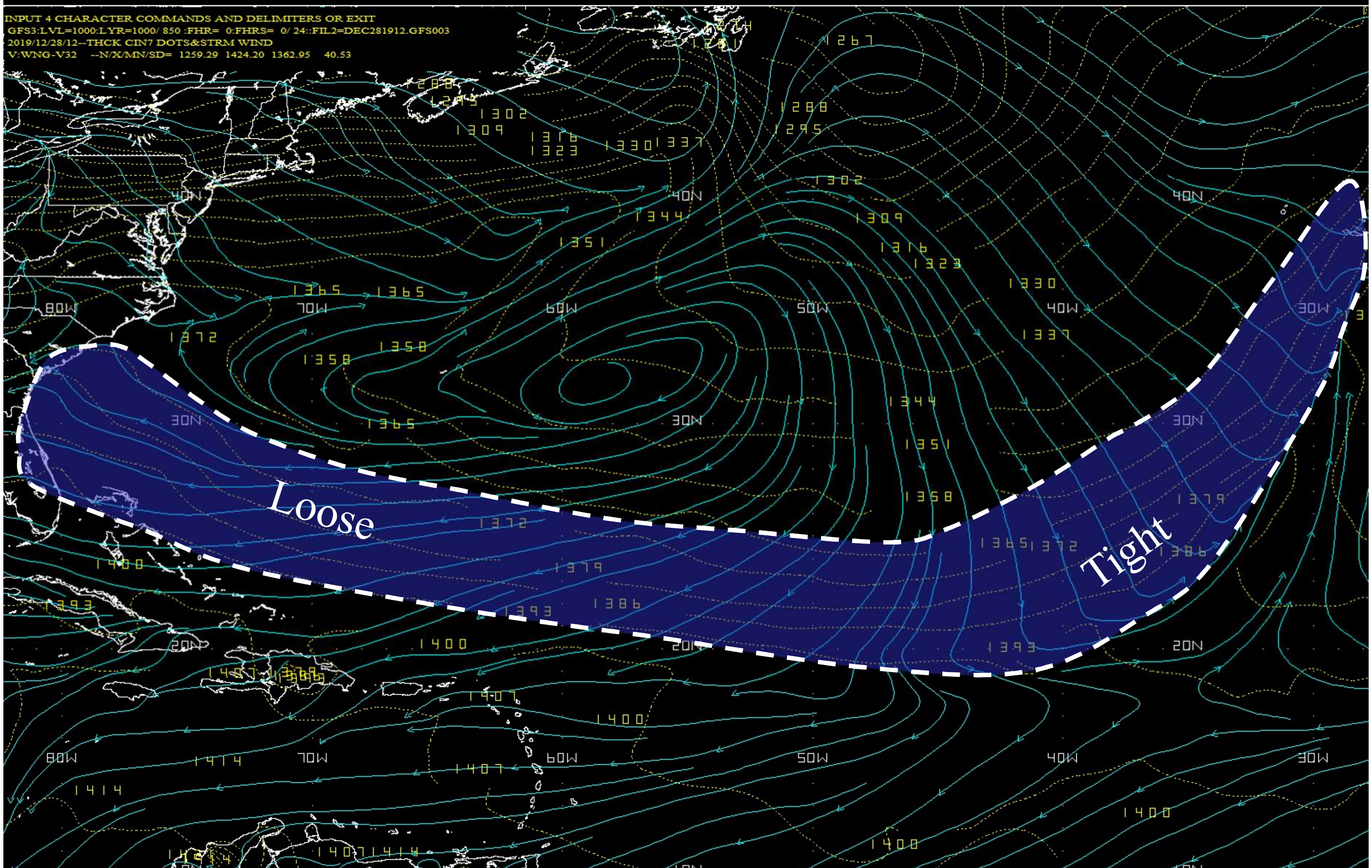
Shear Induced Upward and Downward Vertical Motion

- Cyclonic shear favors upward vertical motion
- Anticyclonic shear favors downward vertical motion



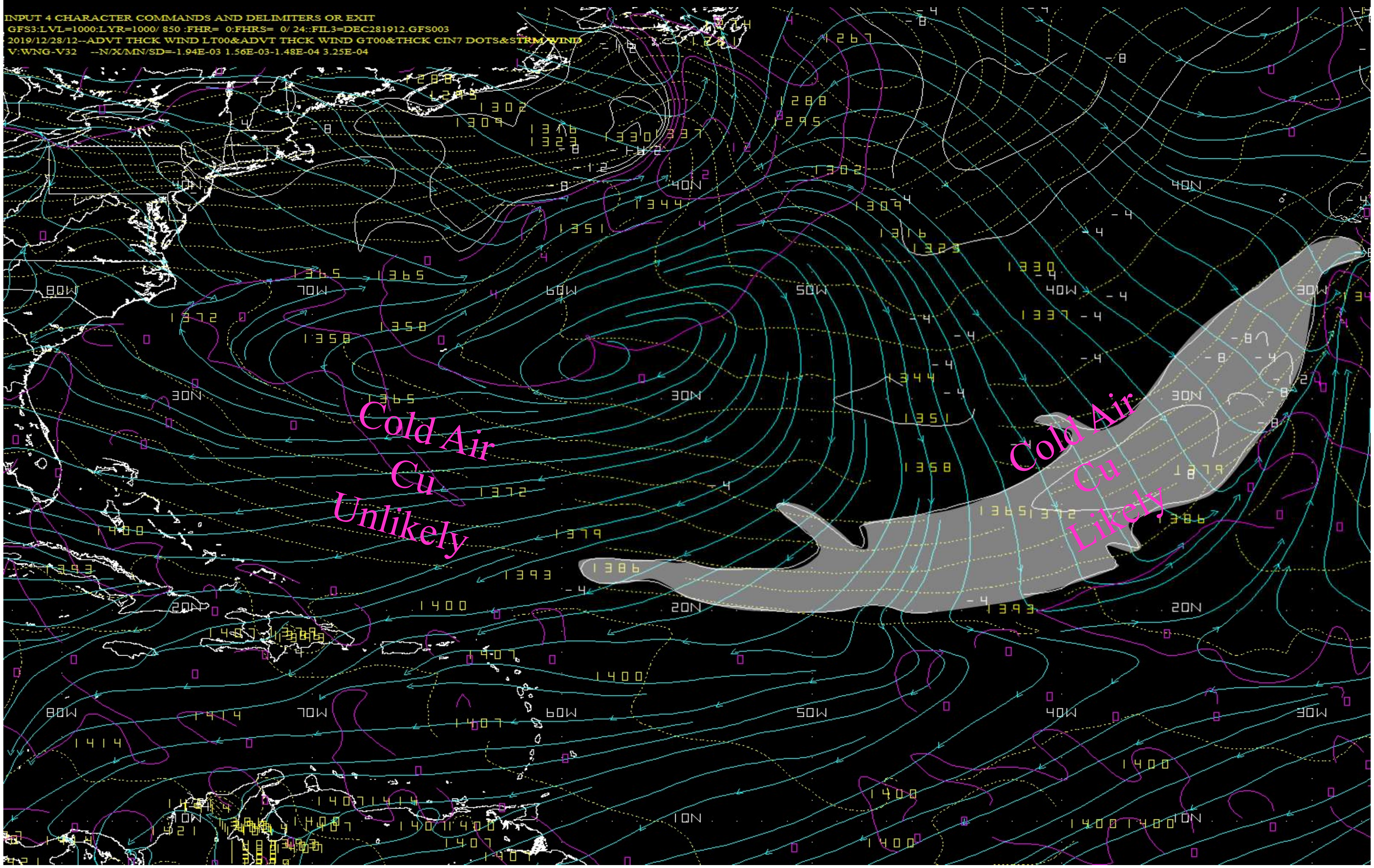


1000 hPa Streamlines & 1000 – 850 hPa Thickness



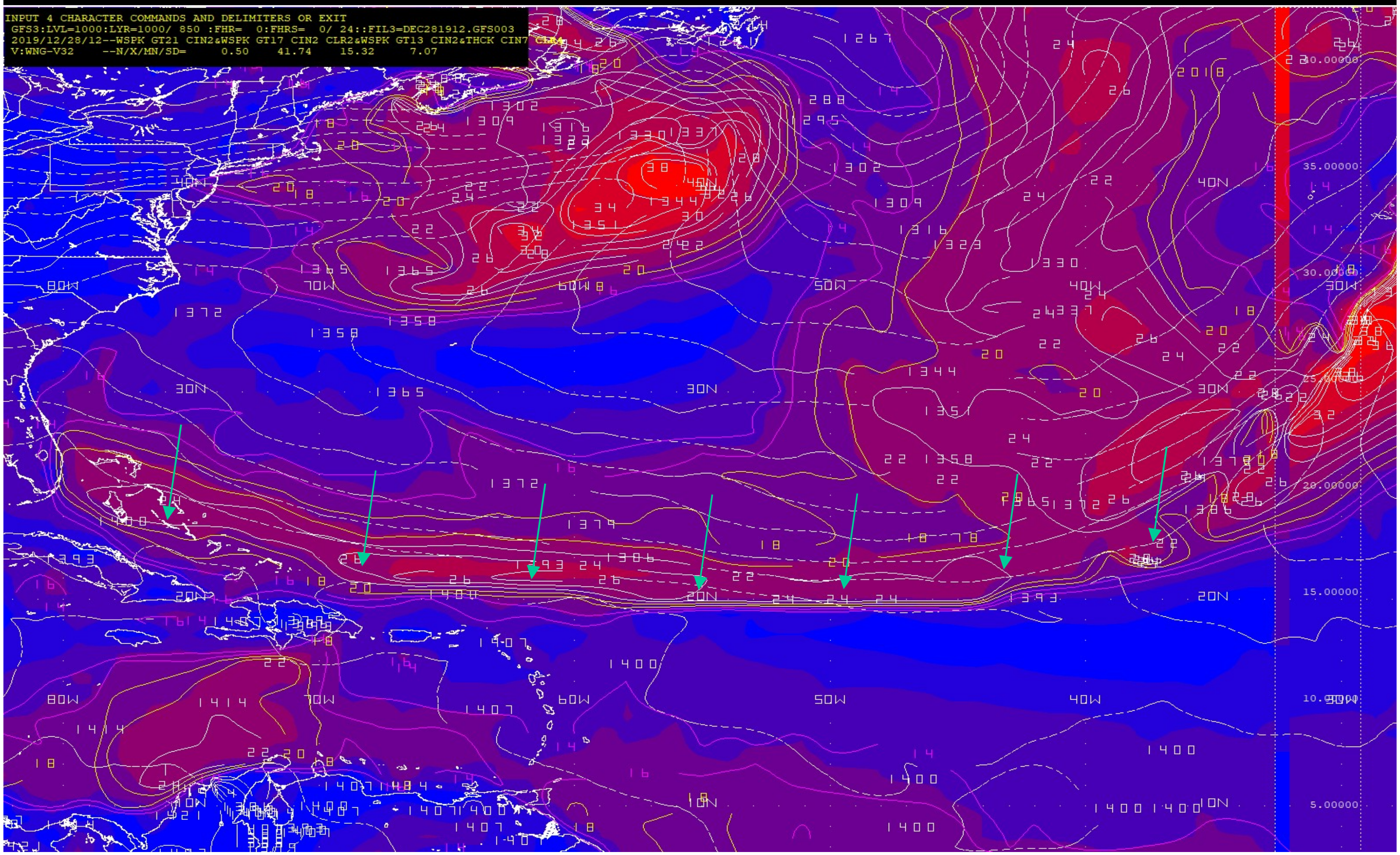
Blue shaded area highlights the thickness gradient

1000 hPa Streamlines, 1000 – 850 hPa Thickness & Thickness Advection



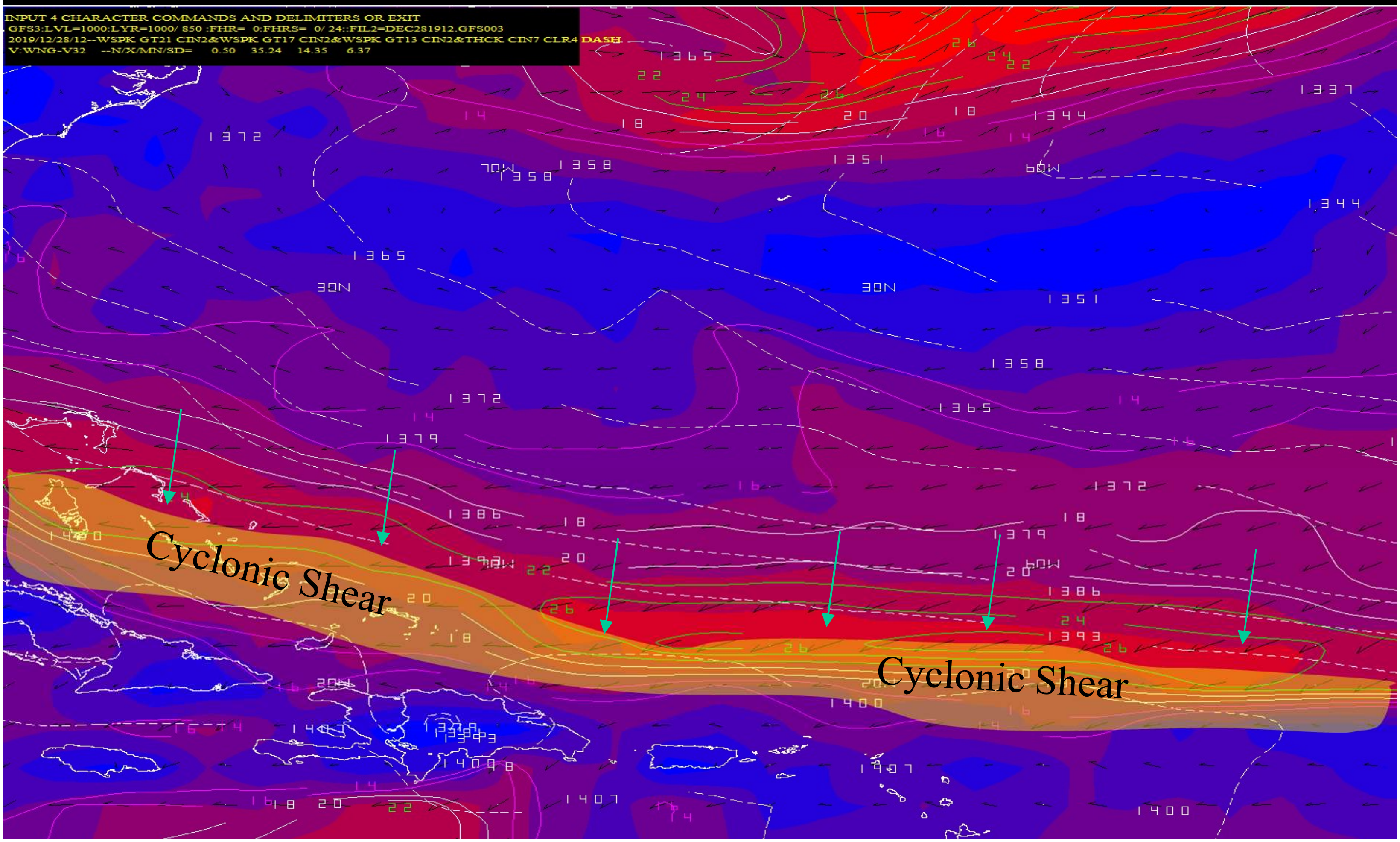
In weak CAA (white shaded), the tail of the front can degrade to a shear line

1000 hPa Isotachs (color filled)
1000 – 850 hPa Thickness (white dashed)



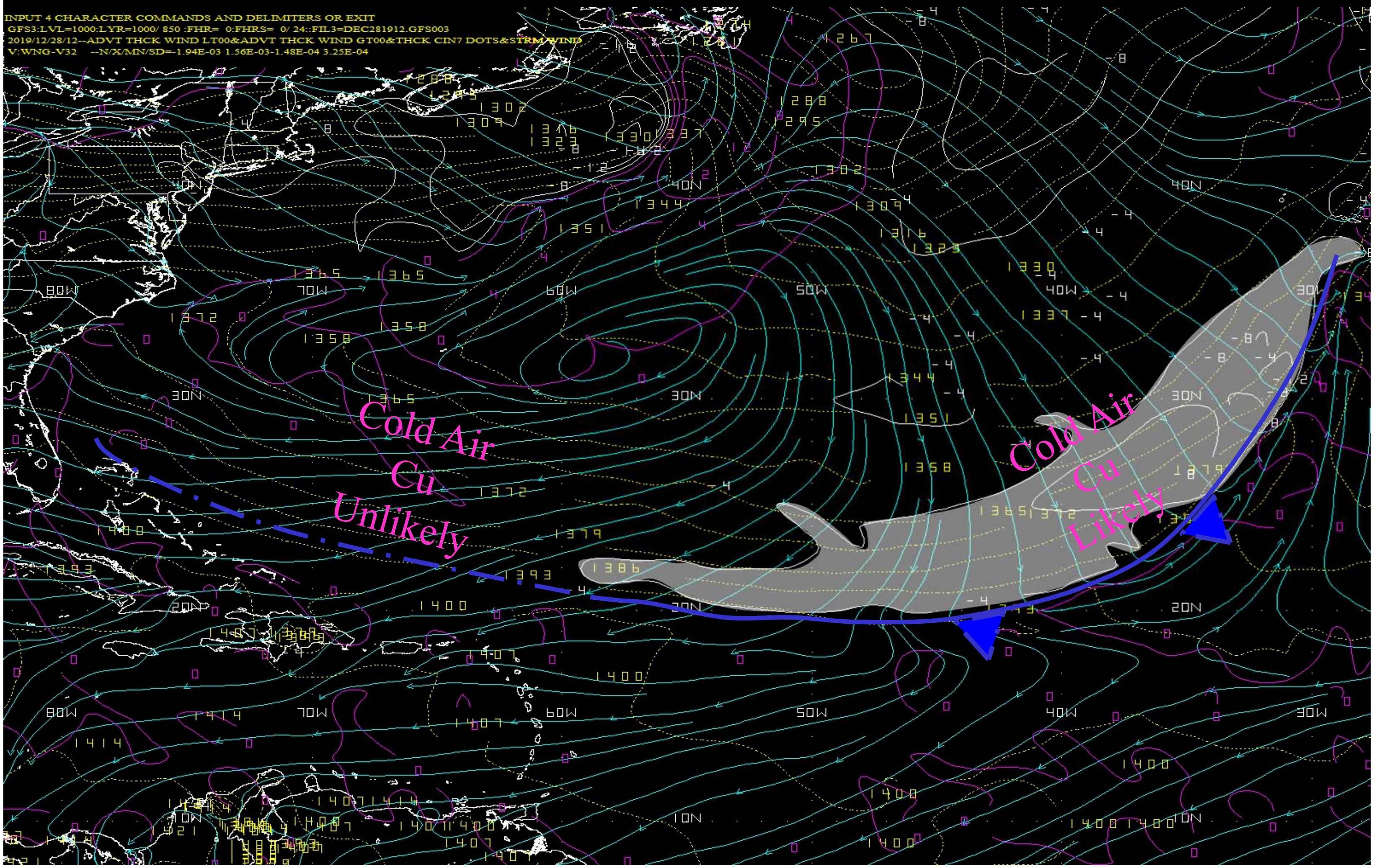
Weak thickness gradient, with low level wind maxima along the warm side to the south.

1000 hPa Isotachs, Wind Vectors , & 1000 – 850 hPa Thickness (Zoom)



Weak thickness gradient, with low level wind maxima along the warm side to the south.

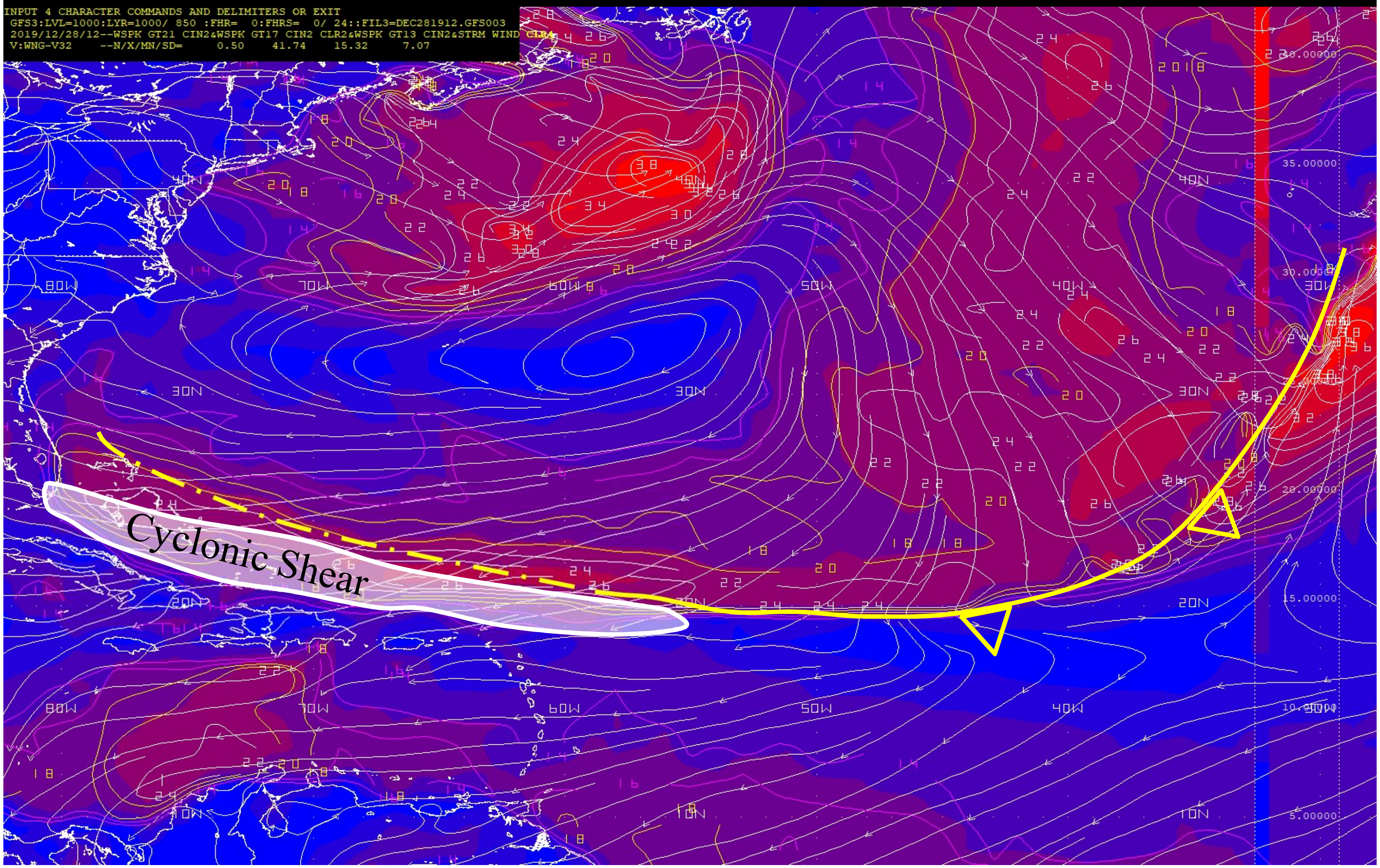
1000 hPa Streamlines, 1000 – 850 hPa Thickness & Thickness Advection



In weak CAA (white shaded), the tail of the front can degrade to a shear line

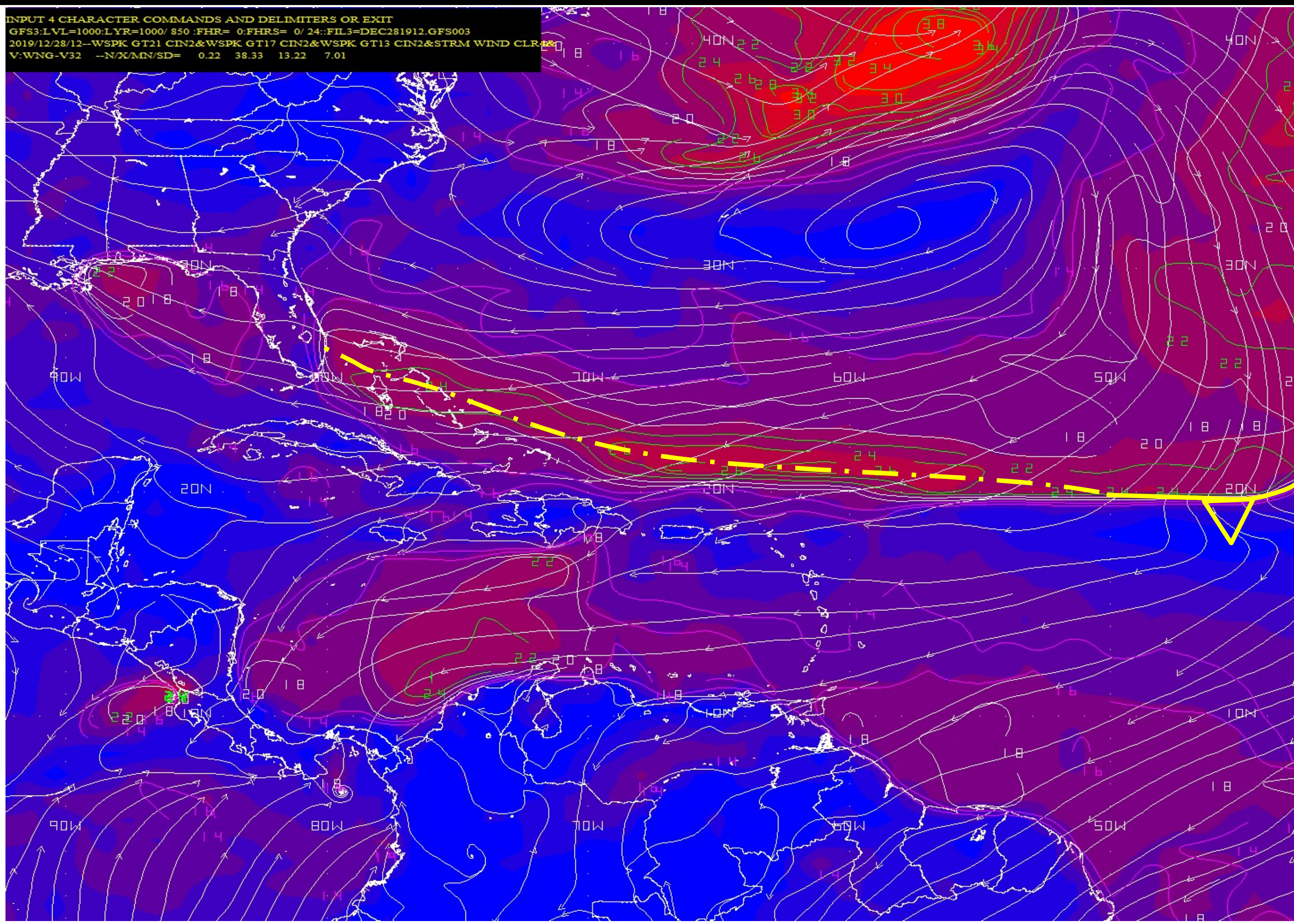
Speed Shear Induced Shear Line

1000 hPa Isotachs and Streamlines

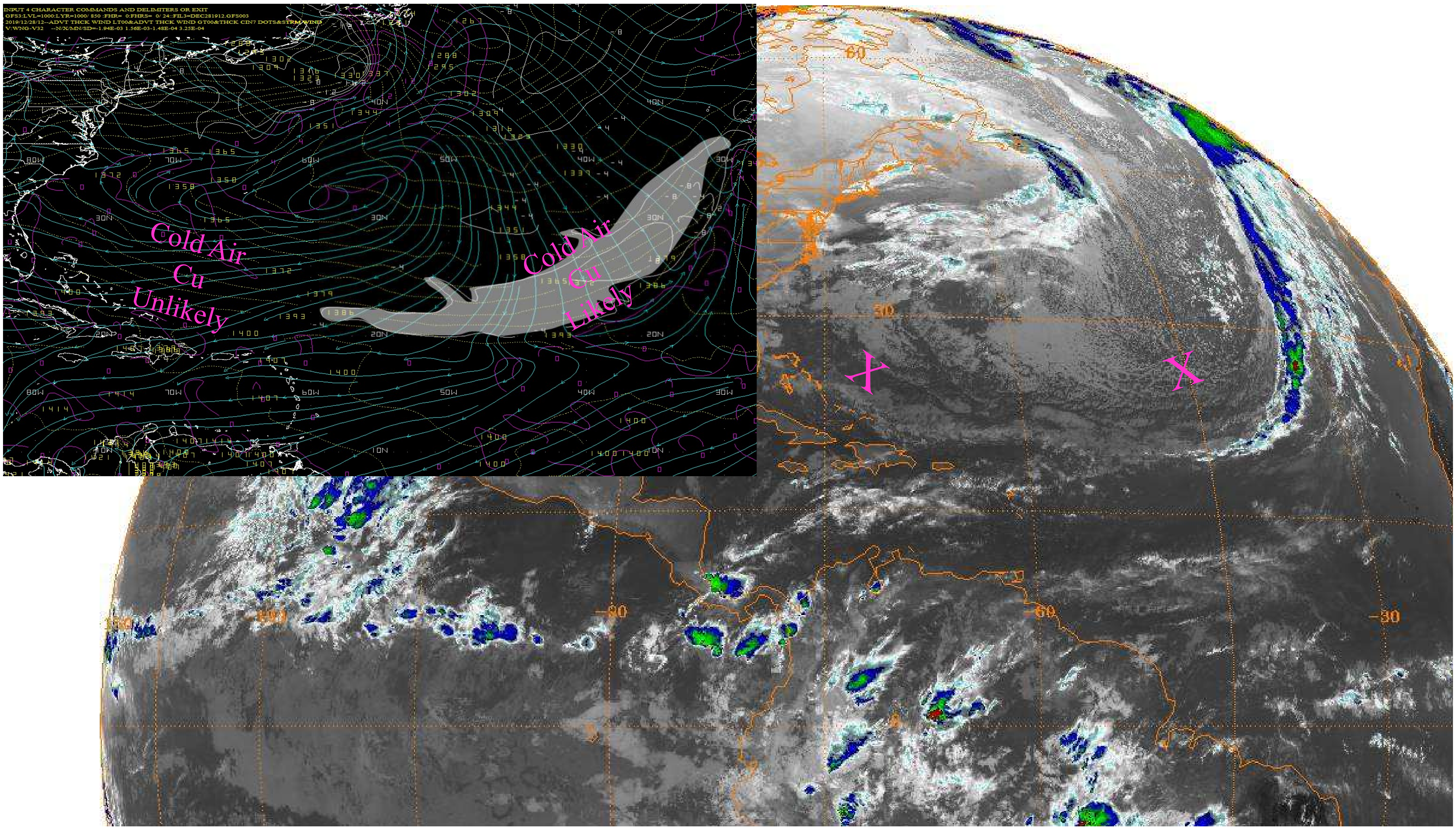


Speed Shear Induced Shear Line

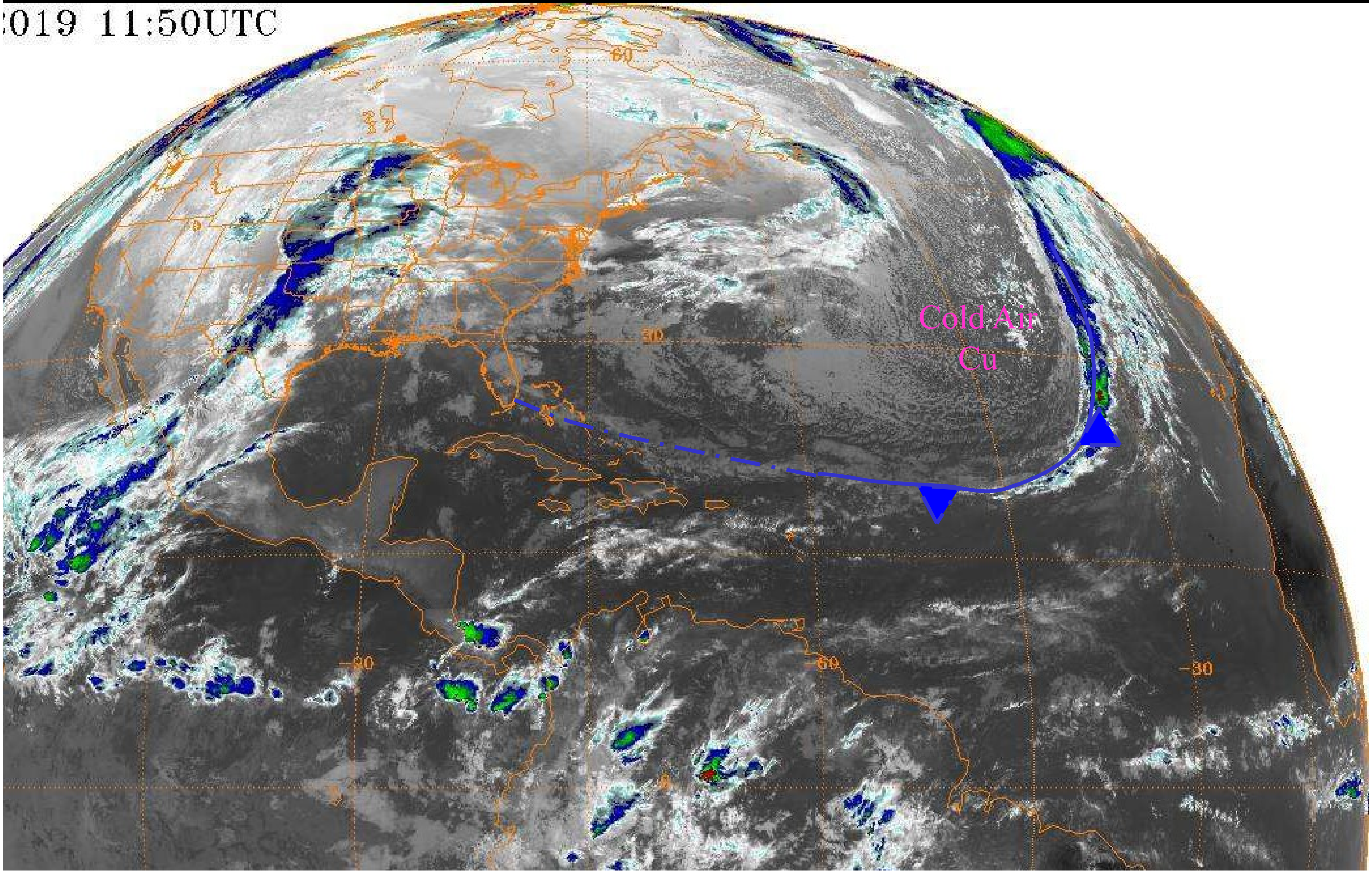
1000 hPa Isotachs and Streamlines



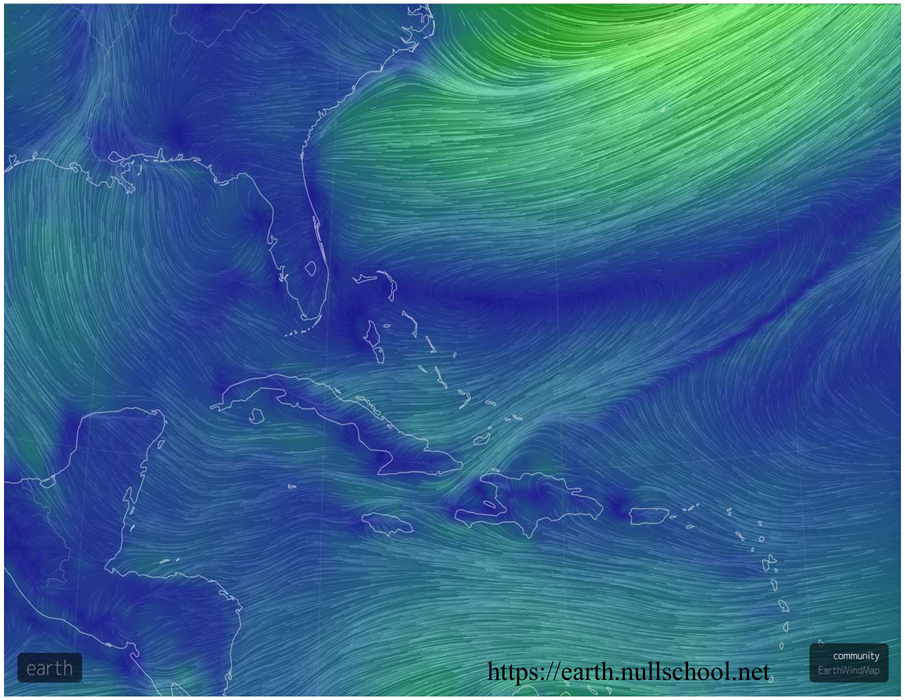
Shear Line Due to Speed Shear



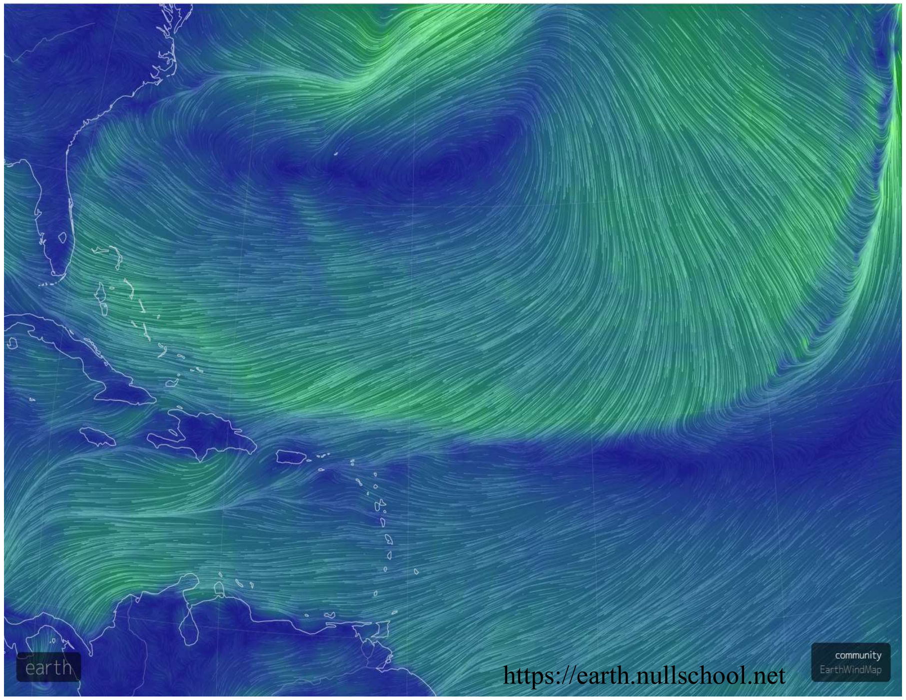
Shear Line Due to Speed Shear



Frontal Shear Line
Directional vs. Speed Shear



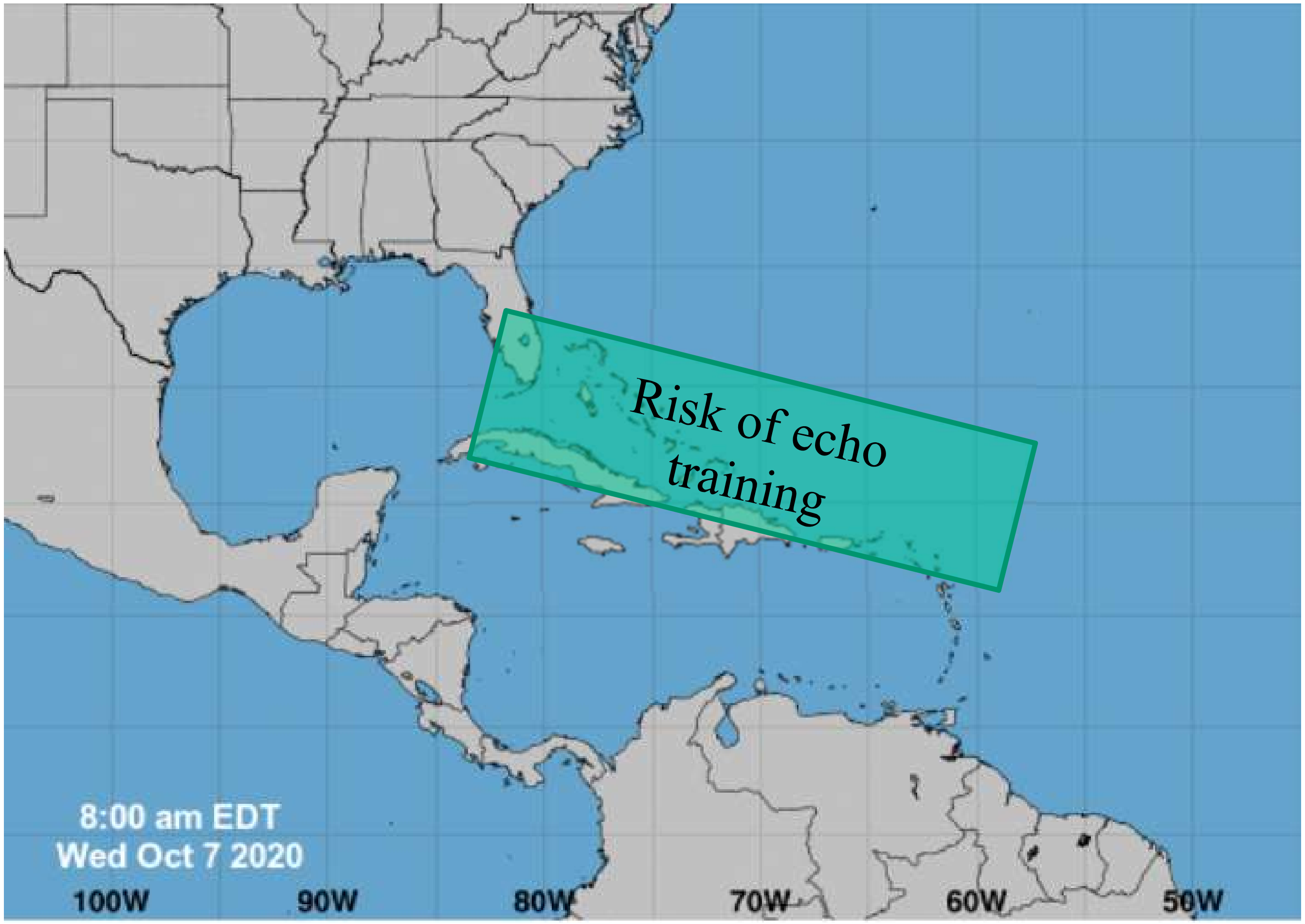
Directional Shear 20180316_18Z



Speed Shear 20191228_12Z

Frontal Shear Lines

Can develop during the fall and through the Winter/early Spring



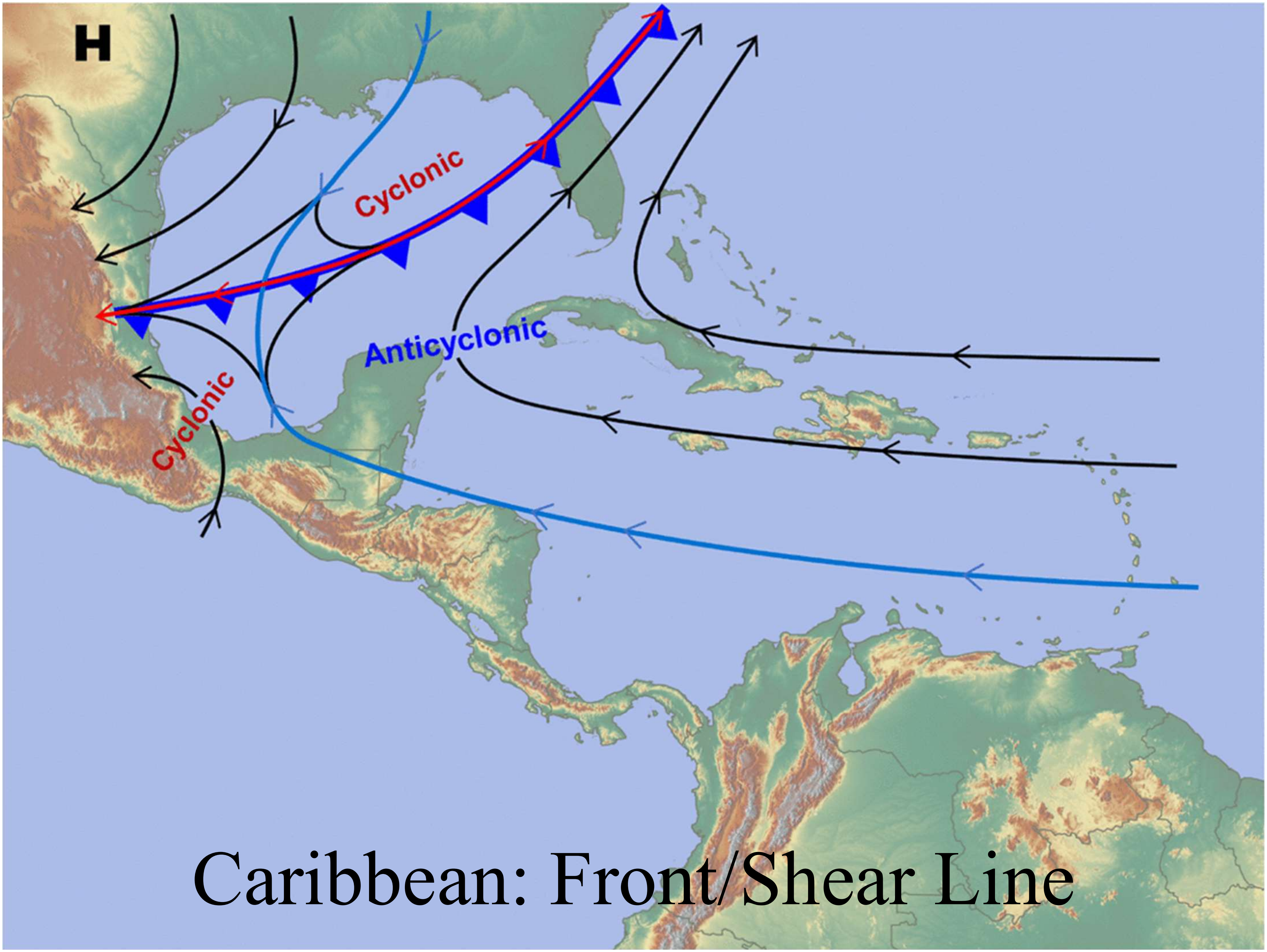
Impact: Storm total rainfall amounts of 250-375mm over several days

Prefrontal Shear Line

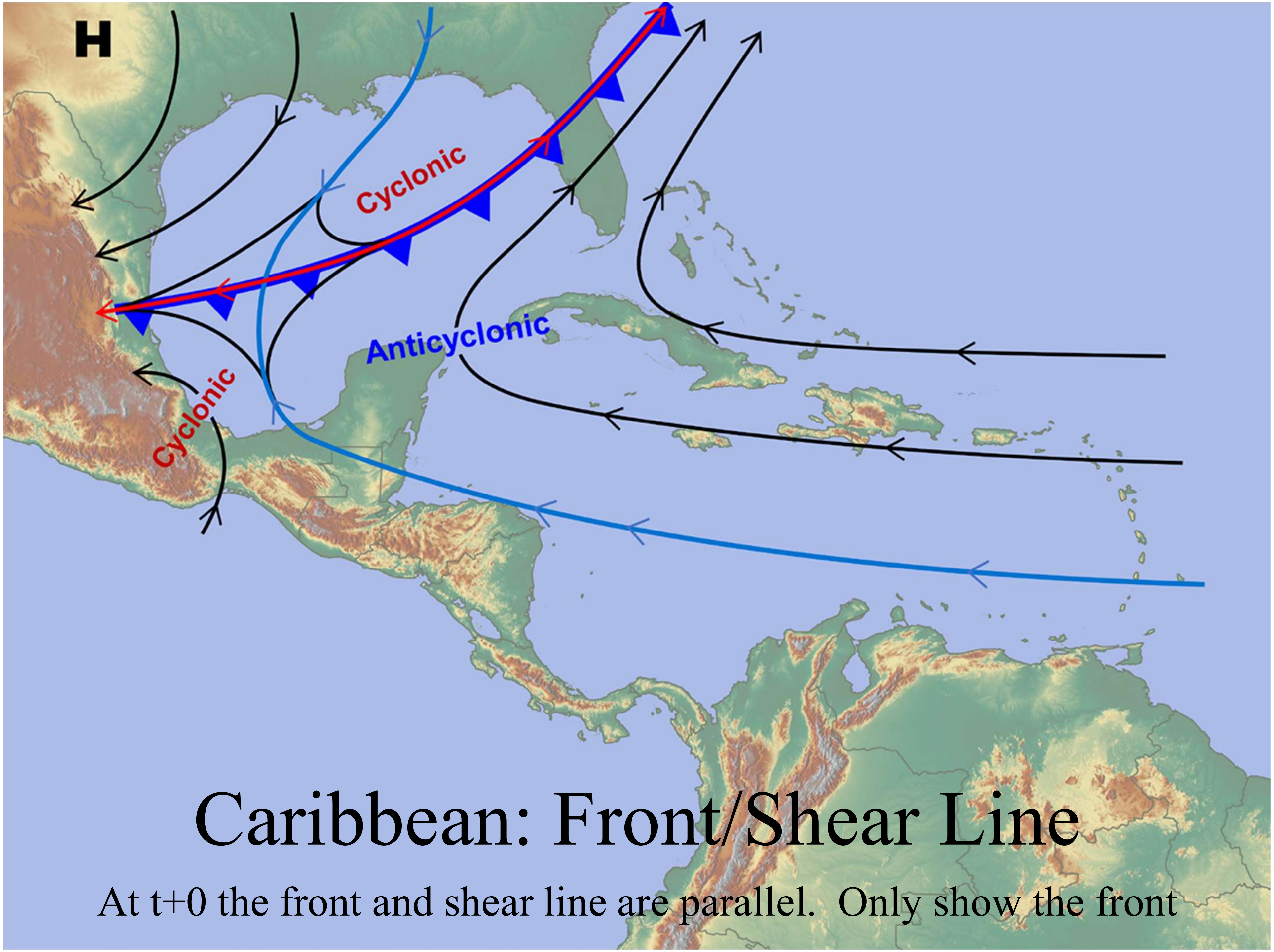
Typical Progression

and

Evolution

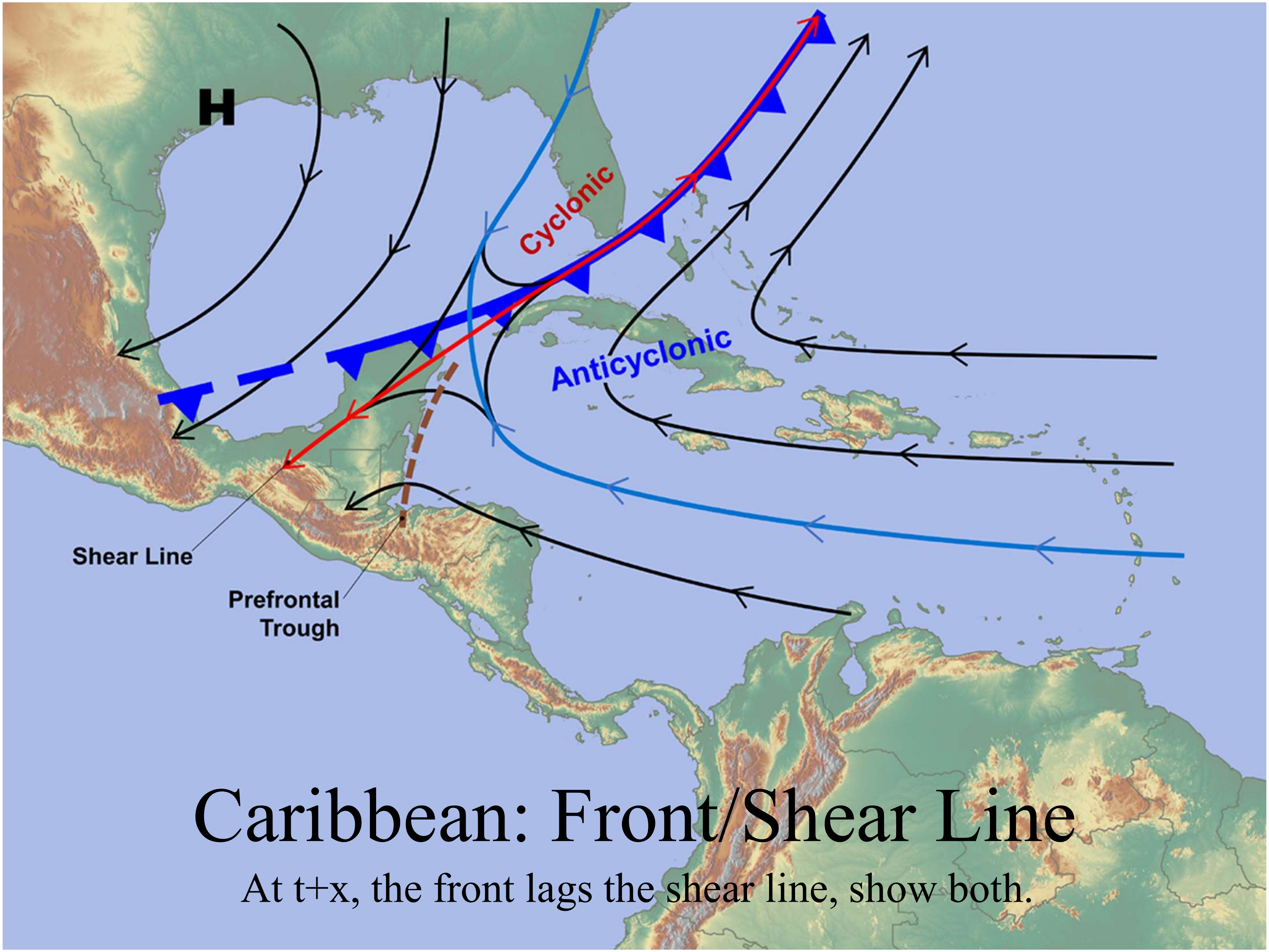


Caribbean: Front/Shear Line



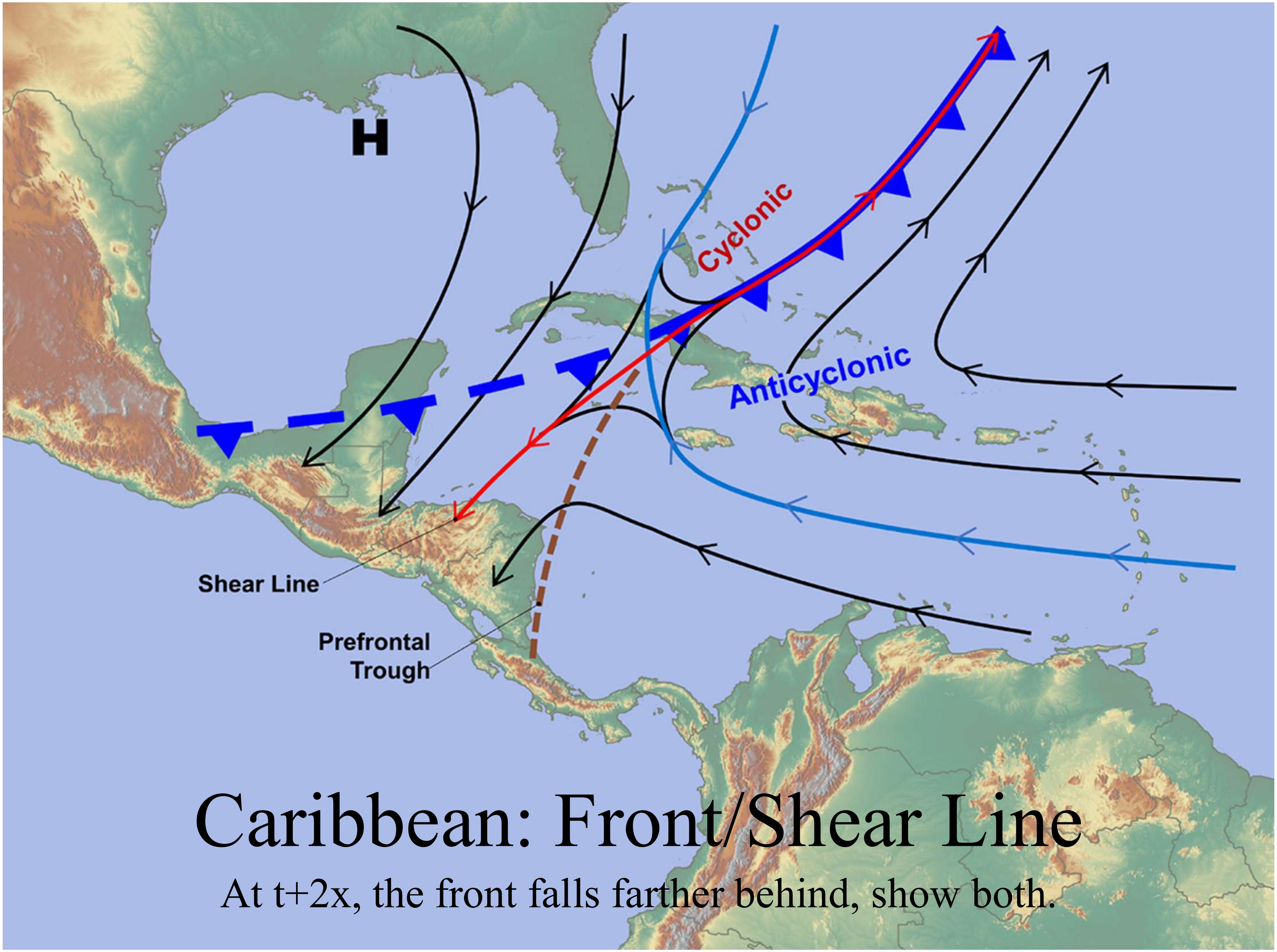
Caribbean: Front/Shear Line

At t+0 the front and shear line are parallel. Only show the front



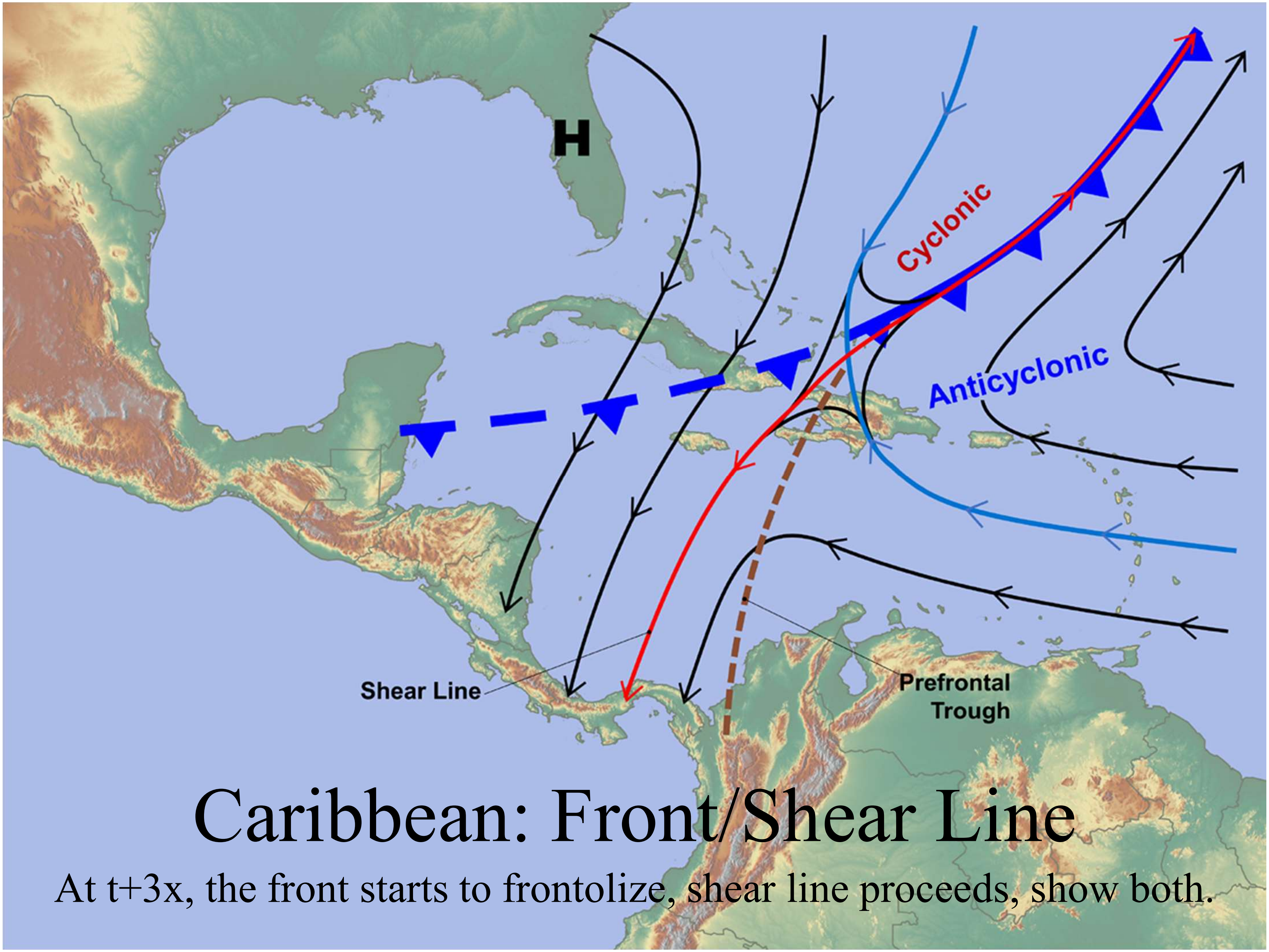
Caribbean: Front/Shear Line

At t+x, the front lags the shear line, show both.



Caribbean: Front/Shear Line

At t+2x, the front falls farther behind, show both.



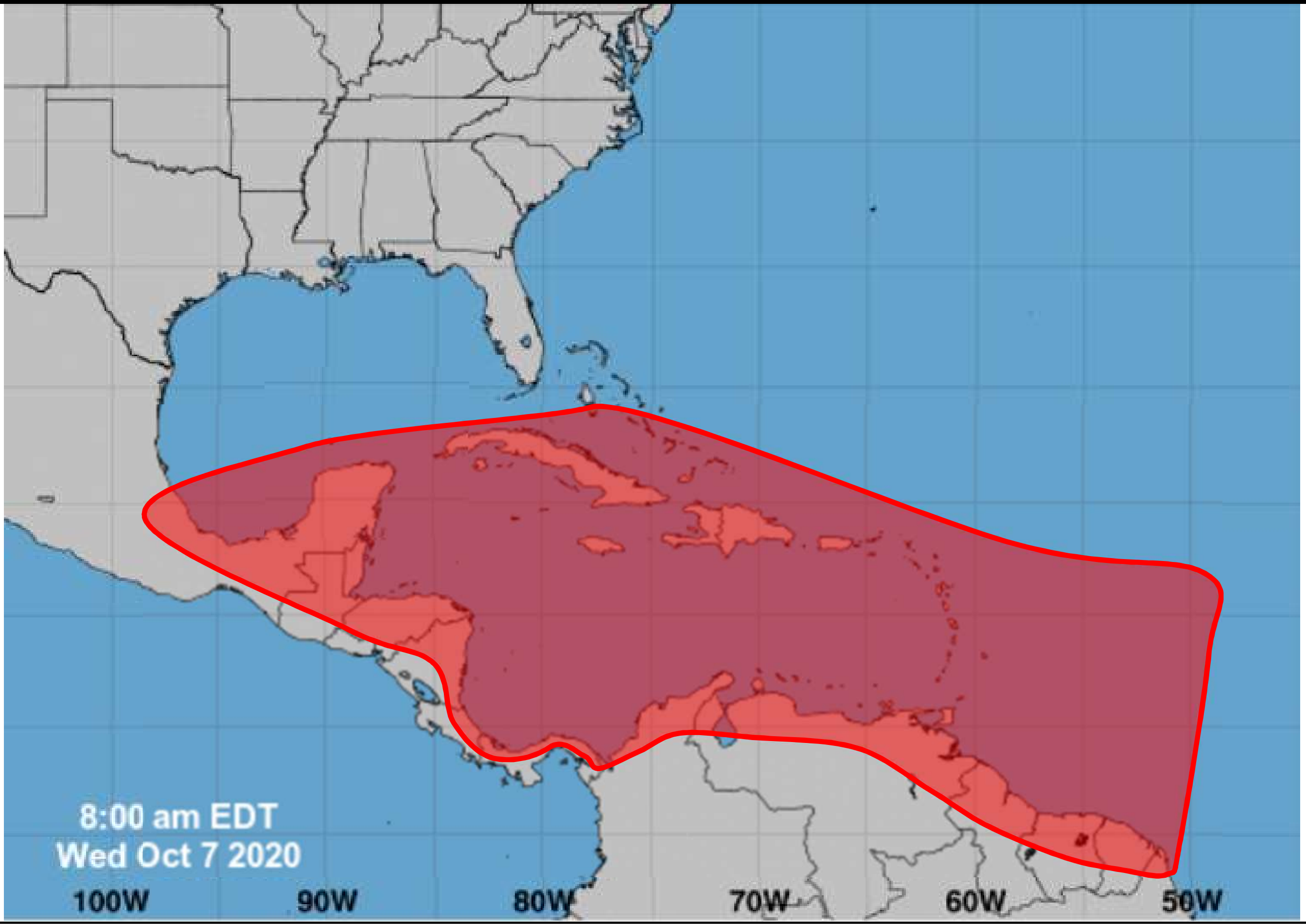
Caribbean: Front/Shear Line

At t+3x, the front starts to frontolize, shear line proceeds, show both.

When to stop showing the front?

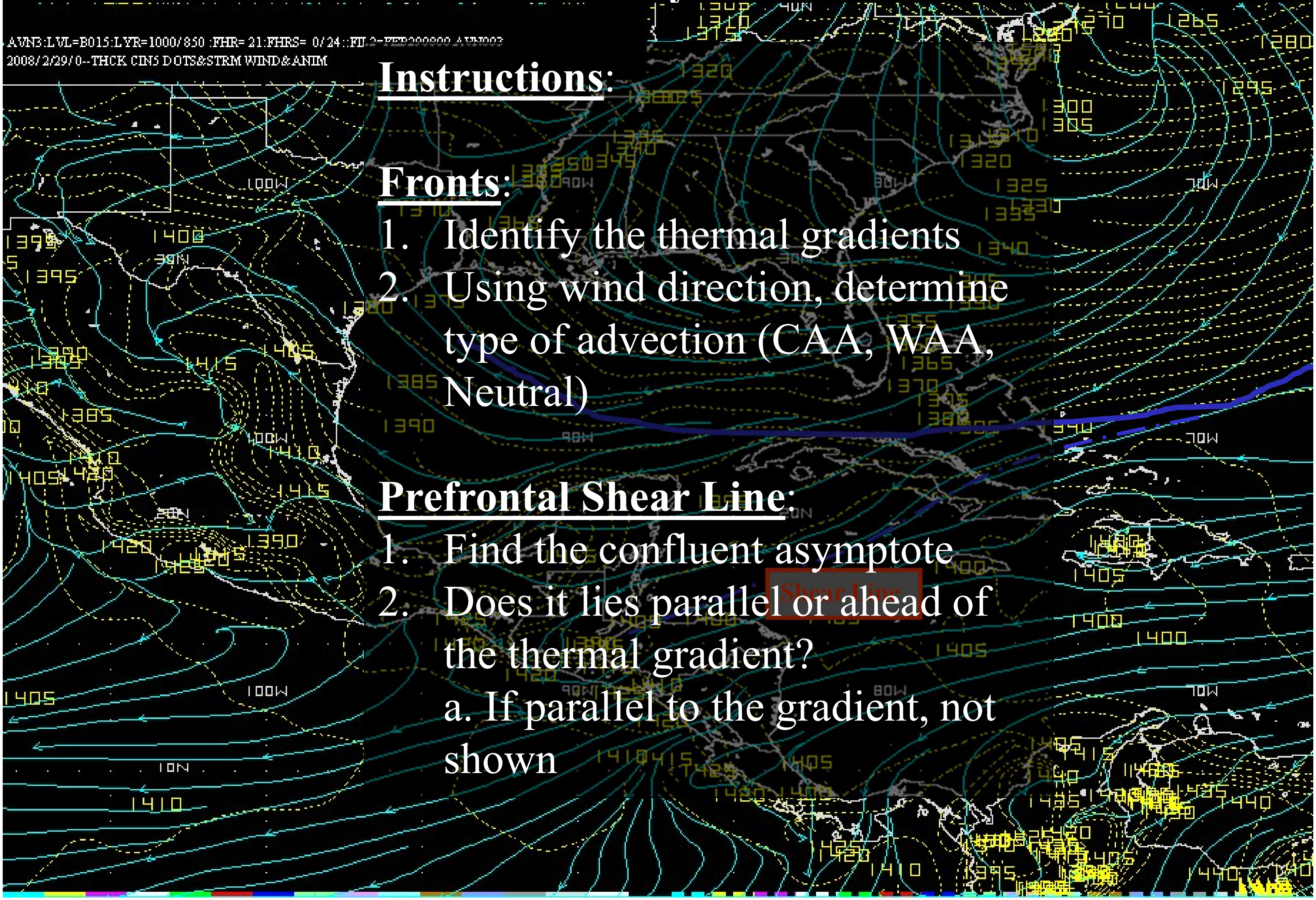
- When the surface observation no longer show density difference across the old boundary.
  - Temperature contrast
  - Td starts to increase
- Consider
  - Upper Jet Support
  - Presence (lack) of cold air cumulus

Prefrontal Shear Line
Basinwide Impact



Impact: Storm total rainfall amounts of 250-500 mm over 36-48 hours (topo forcing and warm SSTs)

1000-850 hPa Thck & Wind: Front and Prefrontal Shear Line Analysis



Instructions:

Fronts:

1. Identify the thermal gradients
2. Using wind direction, determine type of advection (CAA, WAA, Neutral)

Prefrontal Shear Line:

1. Find the confluent asymptote
2. Does it lies parallel or ahead of the thermal gradient?

   a. If parallel to the gradient, not shown

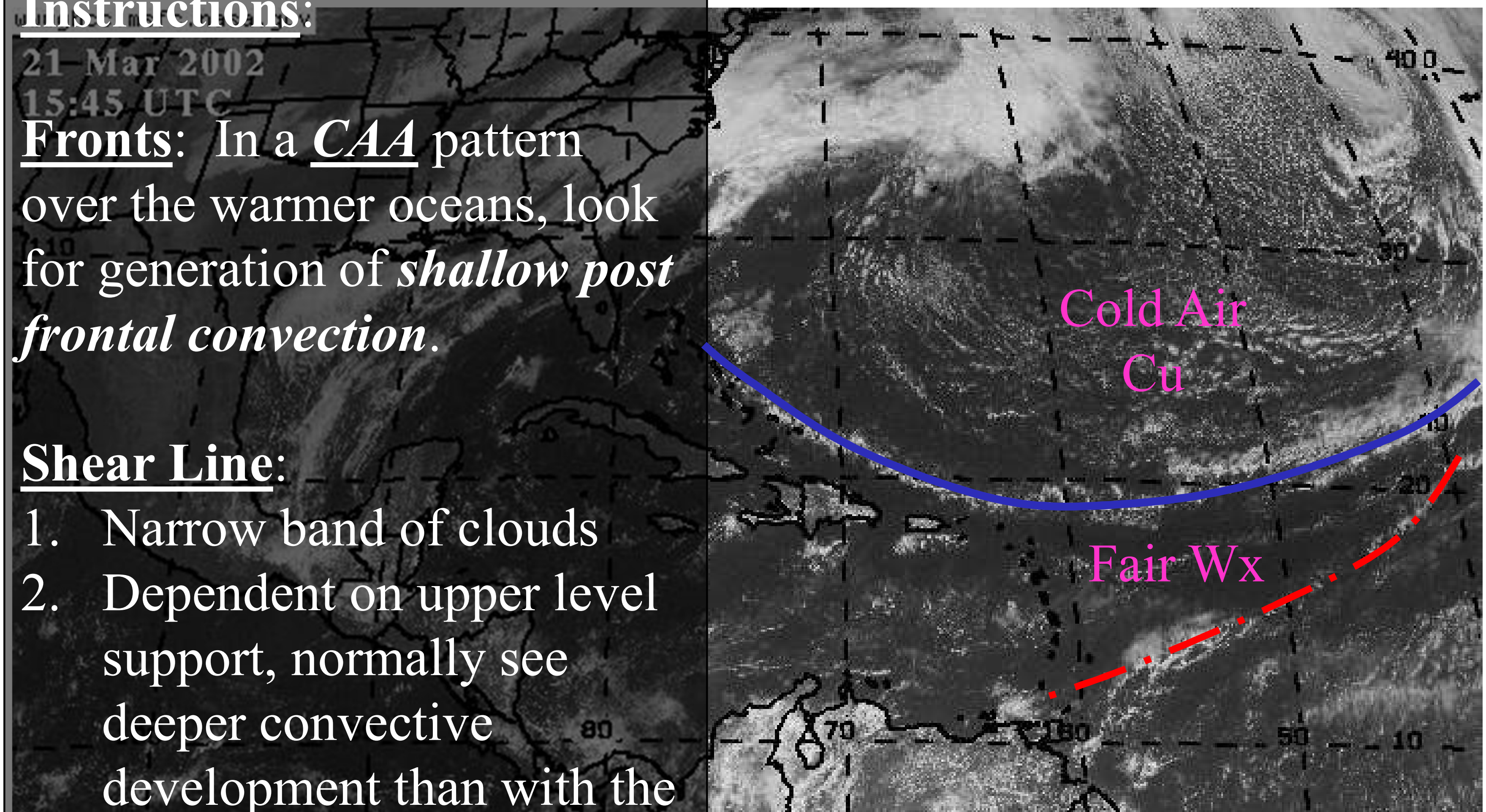
Satellite Applications

Differentiating between a front and a frontal shear line.

Where is the Front?

- Present weather conditions can be a poor indicator of where the front is in the tropics.
  - Weather is a function of moisture convergence and instability
  - Although we often see active convection in association with polar fronts, ***having present weather is not a requirement***

IR Image: Front or Shear Line?



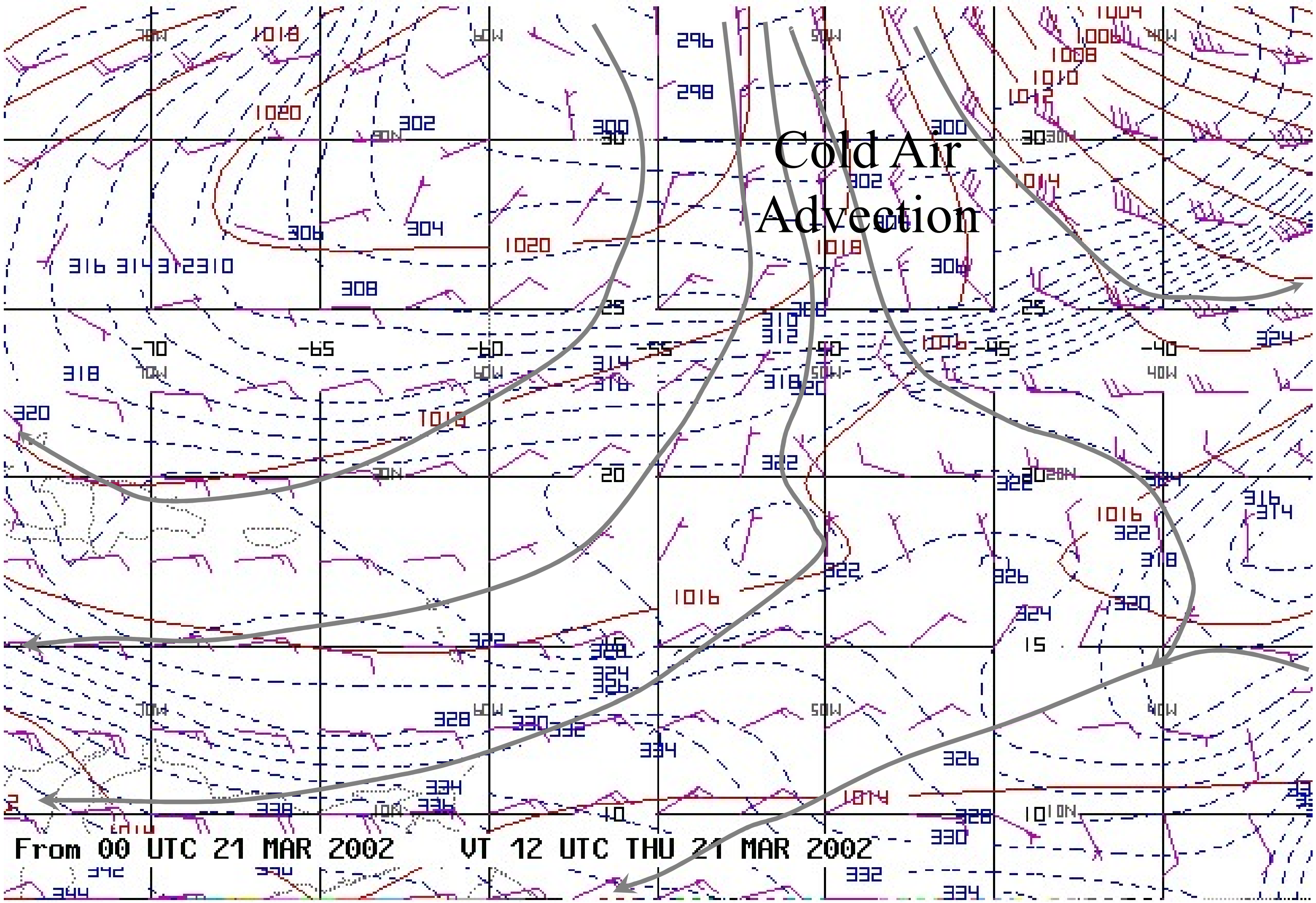
<u>Instructions</u>:

<u>Fronts</u>: In a ***<u>CAA</u>*** pattern over the warmer oceans, look for generation of ***shallow post frontal convection***.

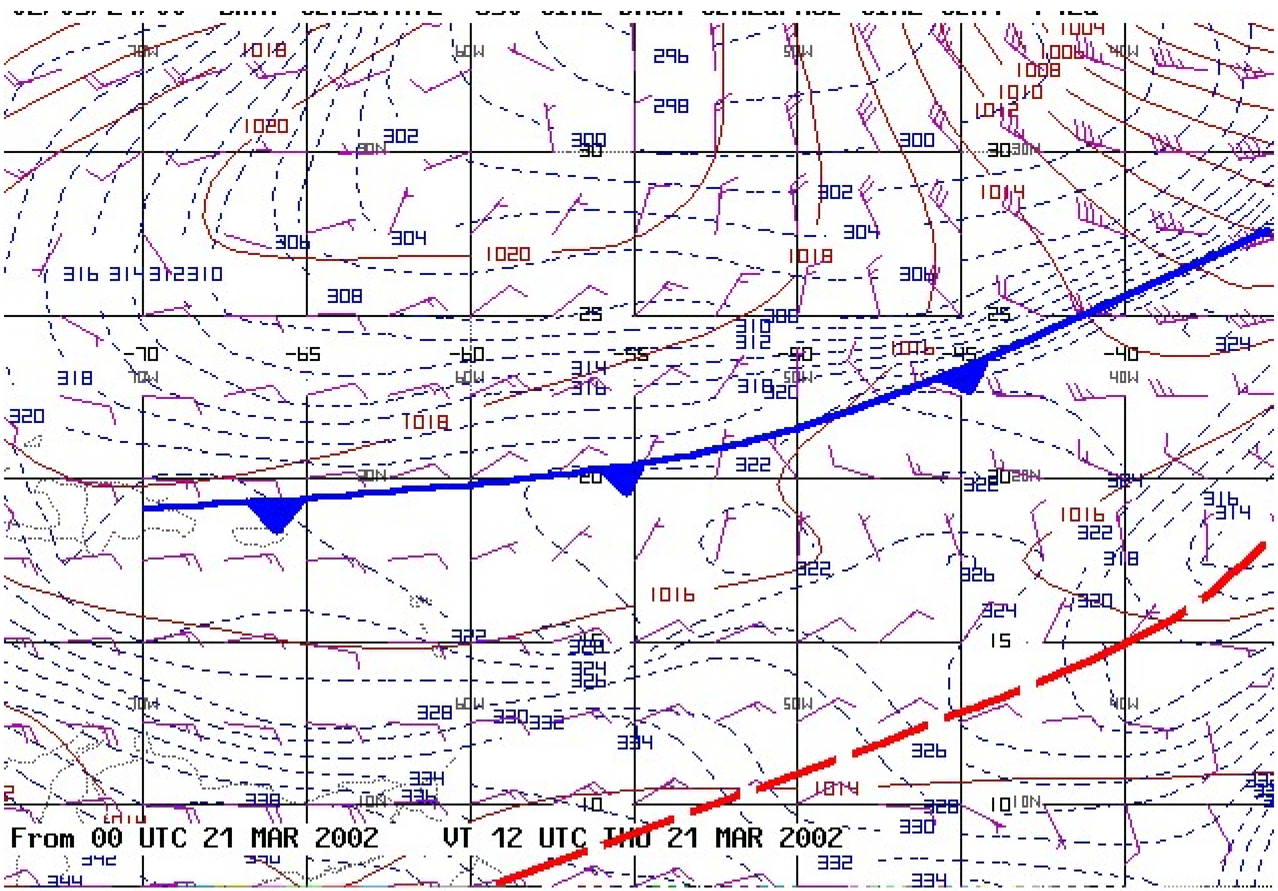
<u>Shear Line</u>:

1. Narrow band of clouds
2. Dependent on upper level support, normally see deeper convective development than with the surface front

EPT and Winds

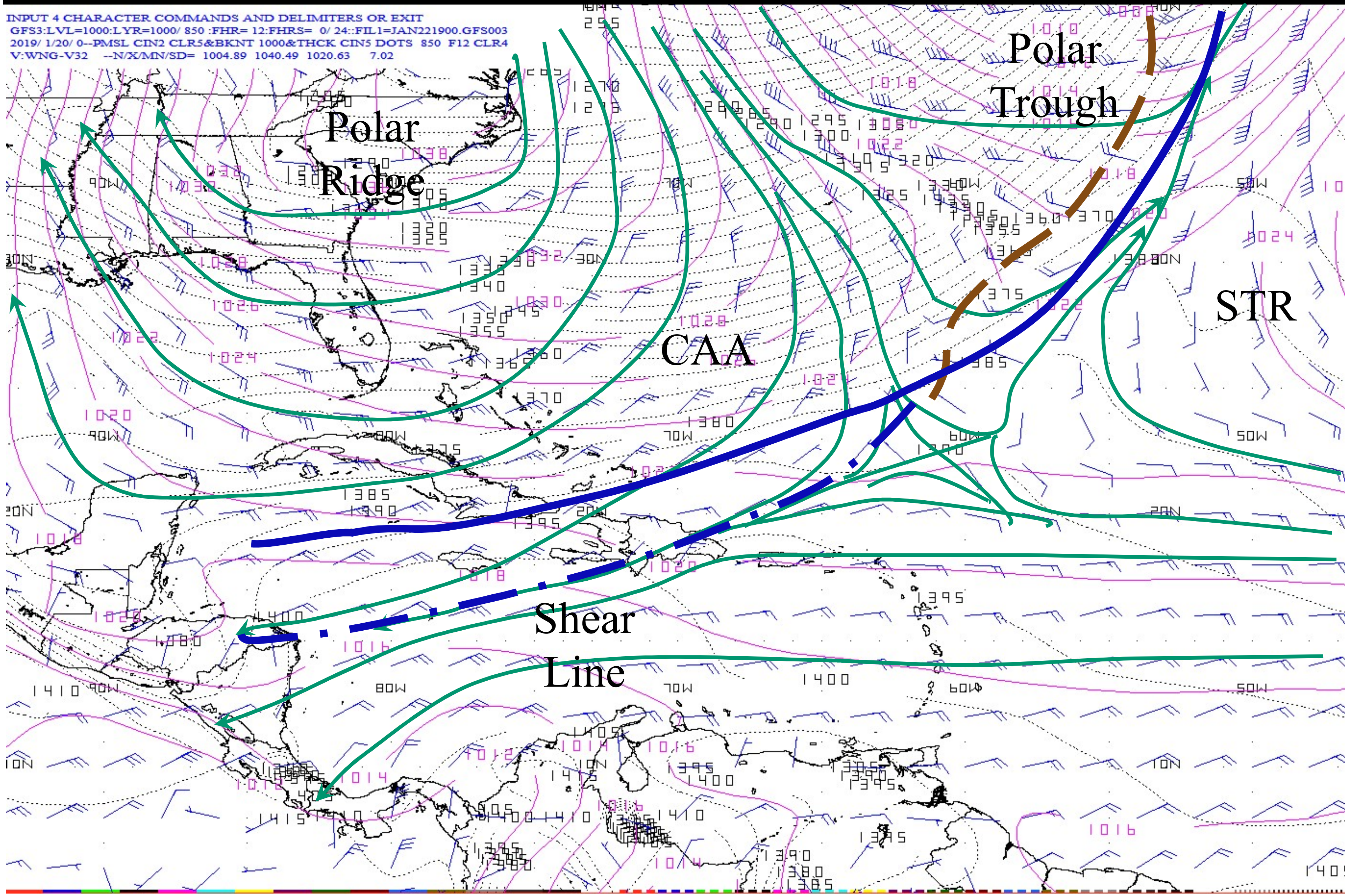


Analysis

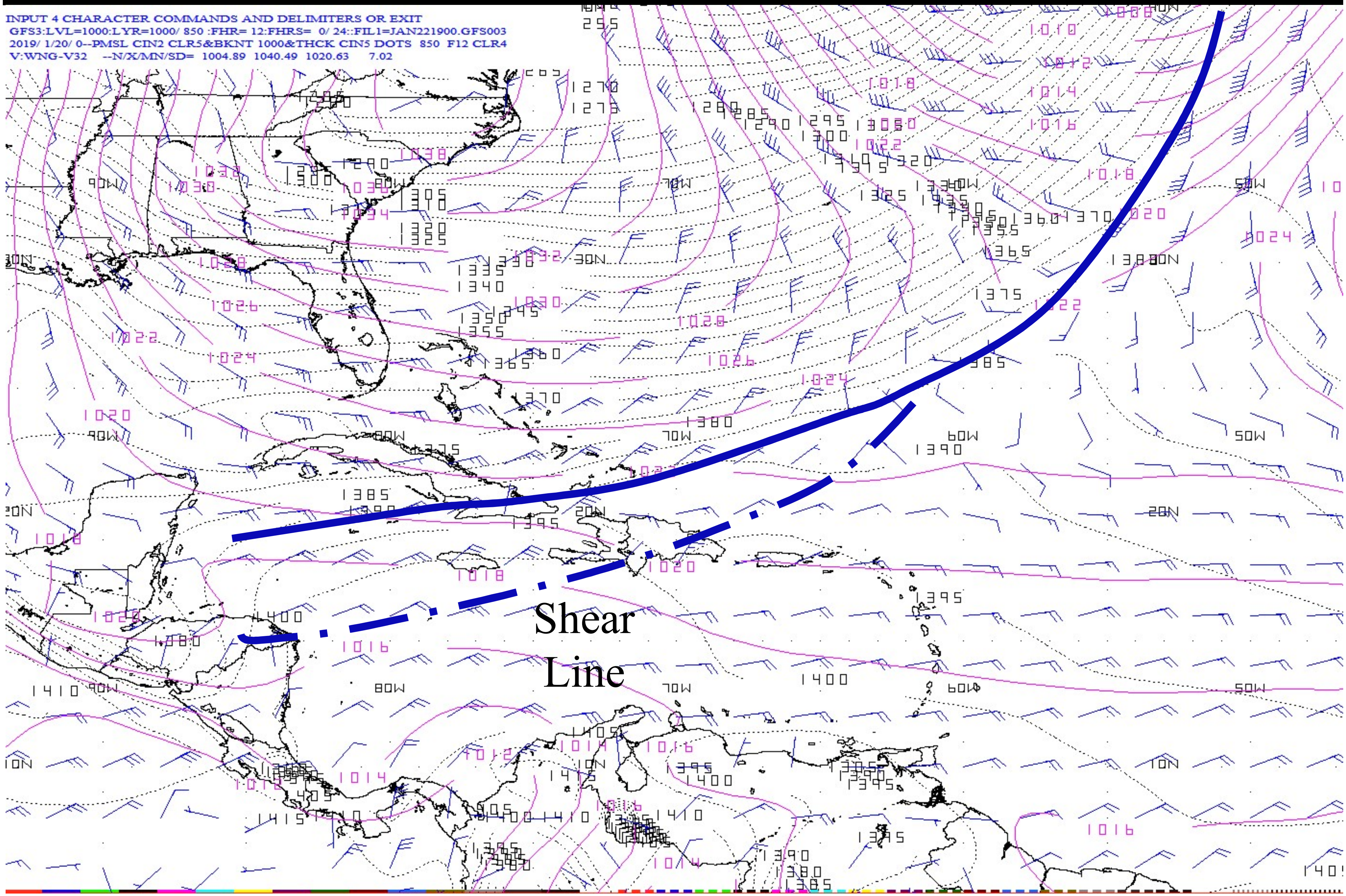


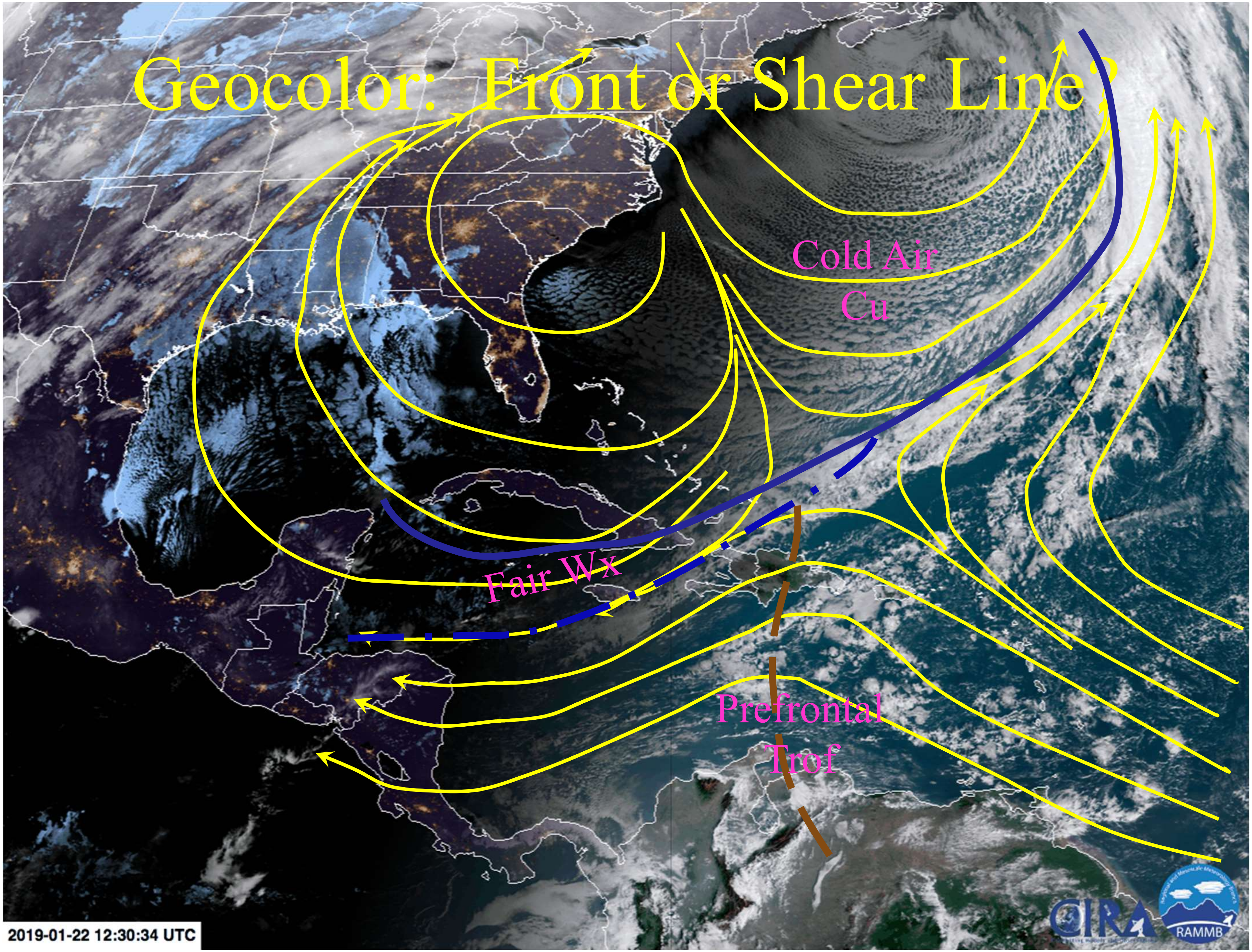
Geocolor: Front or Shear Line?

1000-850 Thickness and Winds



Analysis


INPUT 4 CHARACTER COMMANDS AND DELIMITERS OR EXIT
GFS3:LVL=1000:LYR=1000/ 850 :FHR= 12:FHRS= 0/ 24::FIL1=JAN221900.GFS003
2019/ 1/20/ 0--PMSL CIN2 CLR5&BKNT 1000&THCK CIN5 DOTS 850 F12 CLR4
V:WNG-V32 --N/X/MN/SD= 1004.89 1040.49 1020.63 7.02
Shear
Line


Geocolor: Front or Shear Line?
Cold Air
Cu
Fair Wx
Prefrontal
Trof
2019-01-22 12:30:34 UTC
CIRA
RAMMB

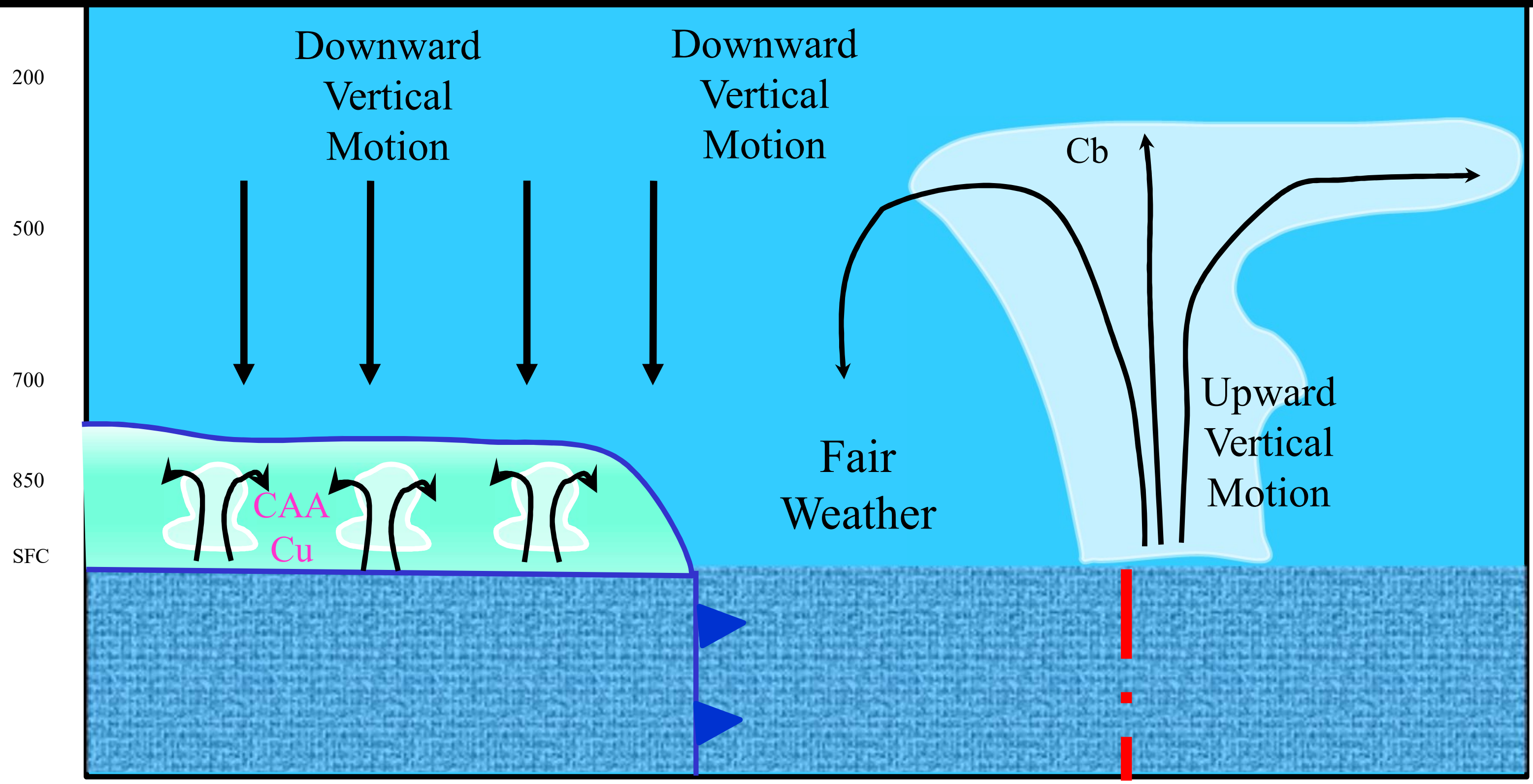
Where is the Weather?

Weather with Fronts and Shear Lines

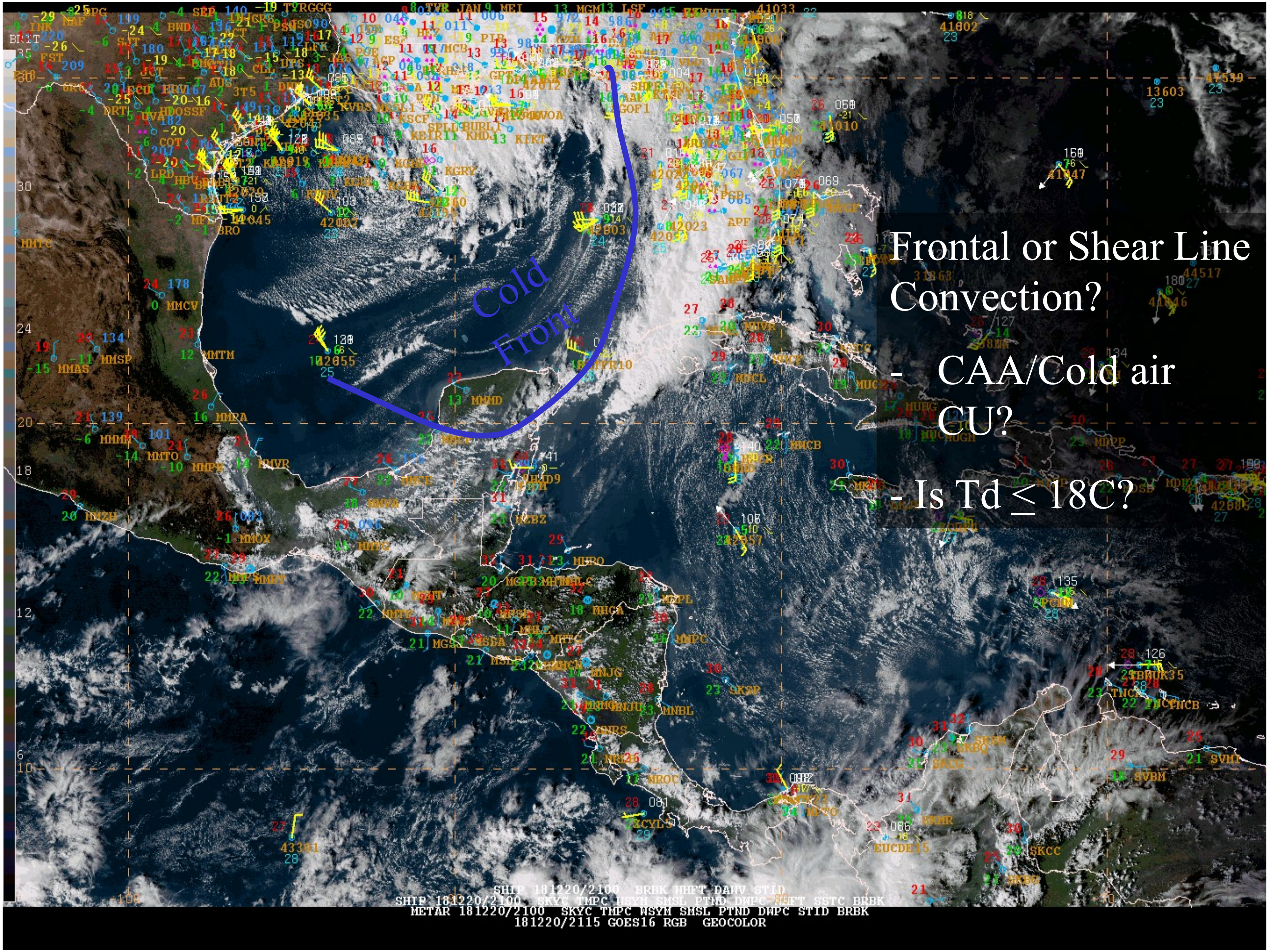
- Where is the weather?
  - Front, Shear Line, Prefrontal Trough?

- The weather is where the moisture converges.
  - ***Typically along the* shear line**
    - **Or between the prefrontal trough and the shear line**
  - Since this is where the weather is most active, some analysts can confuse the shear line with the front.

Conceptual Model – Cloud Cover and Weather with Front and Prefrontal Shear Line

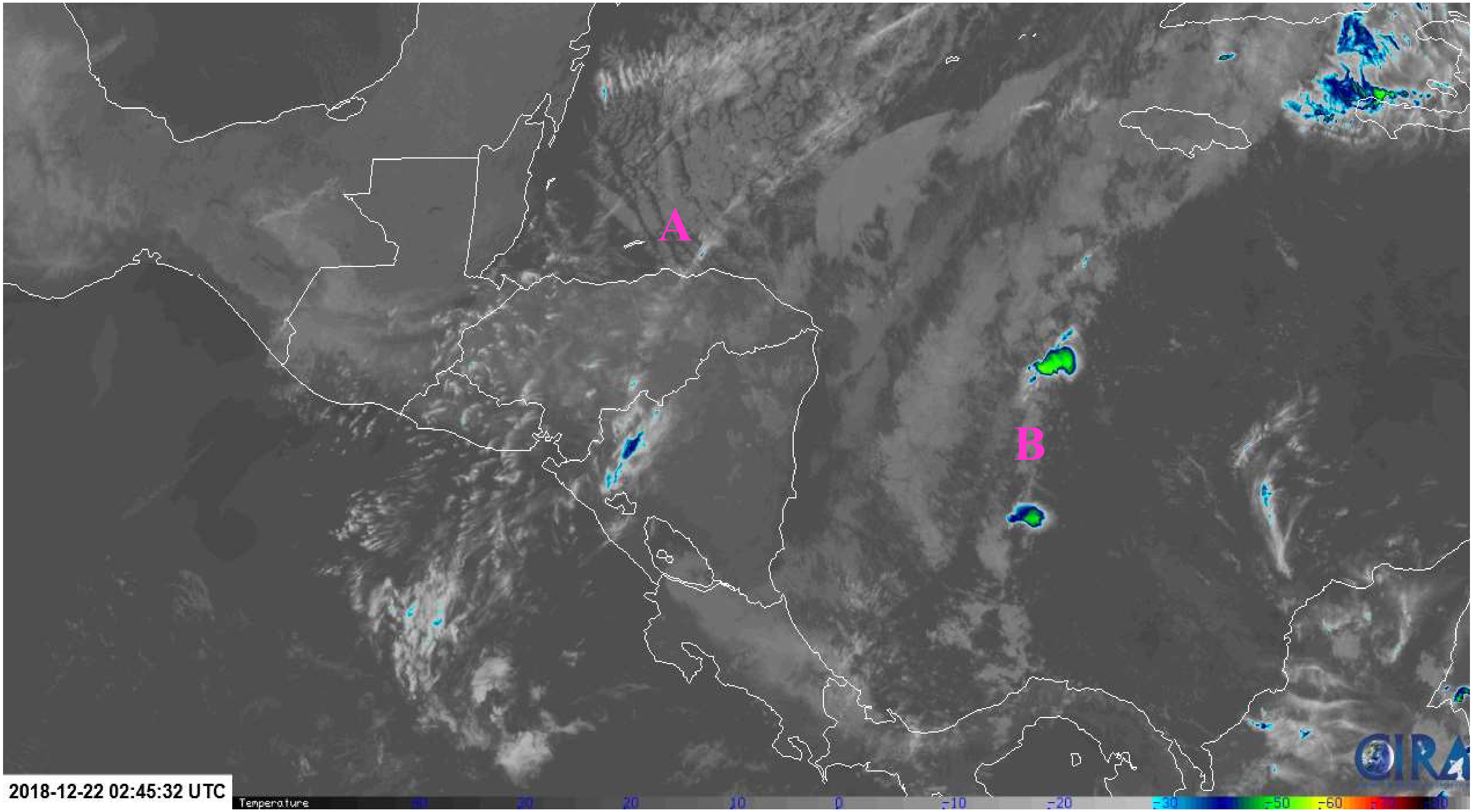


In an upper convergent/subsident pattern, lacking upper support, a shallow front enters the Caribbean, preceded by a shear line


Frontal or Shear Line Convection?
- CAA/Cold air CU?
- Is Td ≤ 18C?
Cold Front
SHIP 181220/2100 BRBK WHFT DAWV STID
SHIP 181220/2100 SKYC TMPC WSYM SMSL PTND DWPC WHFT SSTC BRBK
METAR 181220/2100 SKYC TMPC WSYM SMSL PTND DWPC STID BRBK
181220/2115 GOES16 RGB GEOCOLOR

Poll Question #12

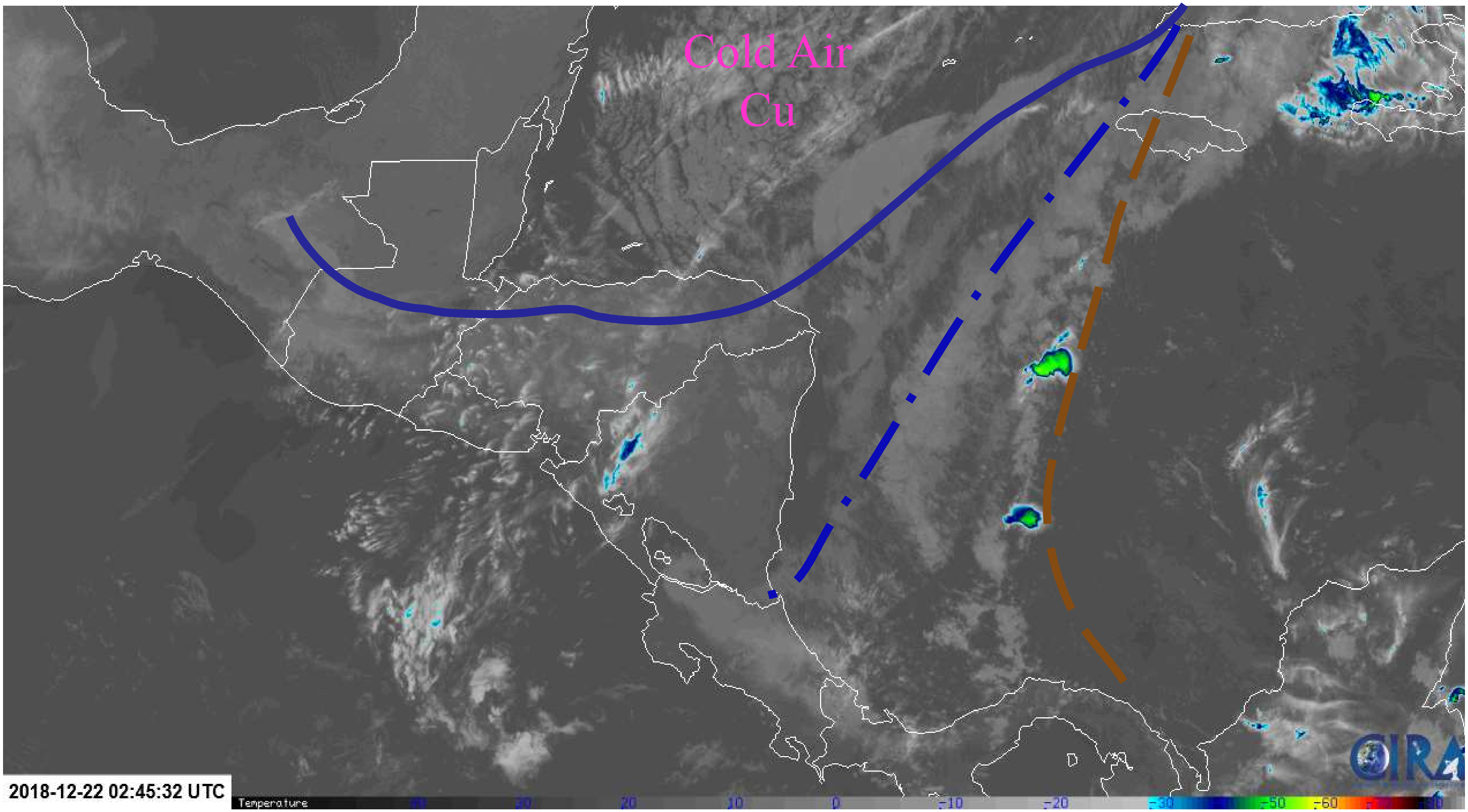
Frontal or Shear Line Convection?



Poll Question #12
(select one)

- A: Frontal, B: Frontal
- A: Shear line, B: Shear Line
- A: Shear Line, B: Frontal
- A: Frontal, B: Shear Line

Poll Question #11
Frontal or Shear Line Convection?



Upwelling

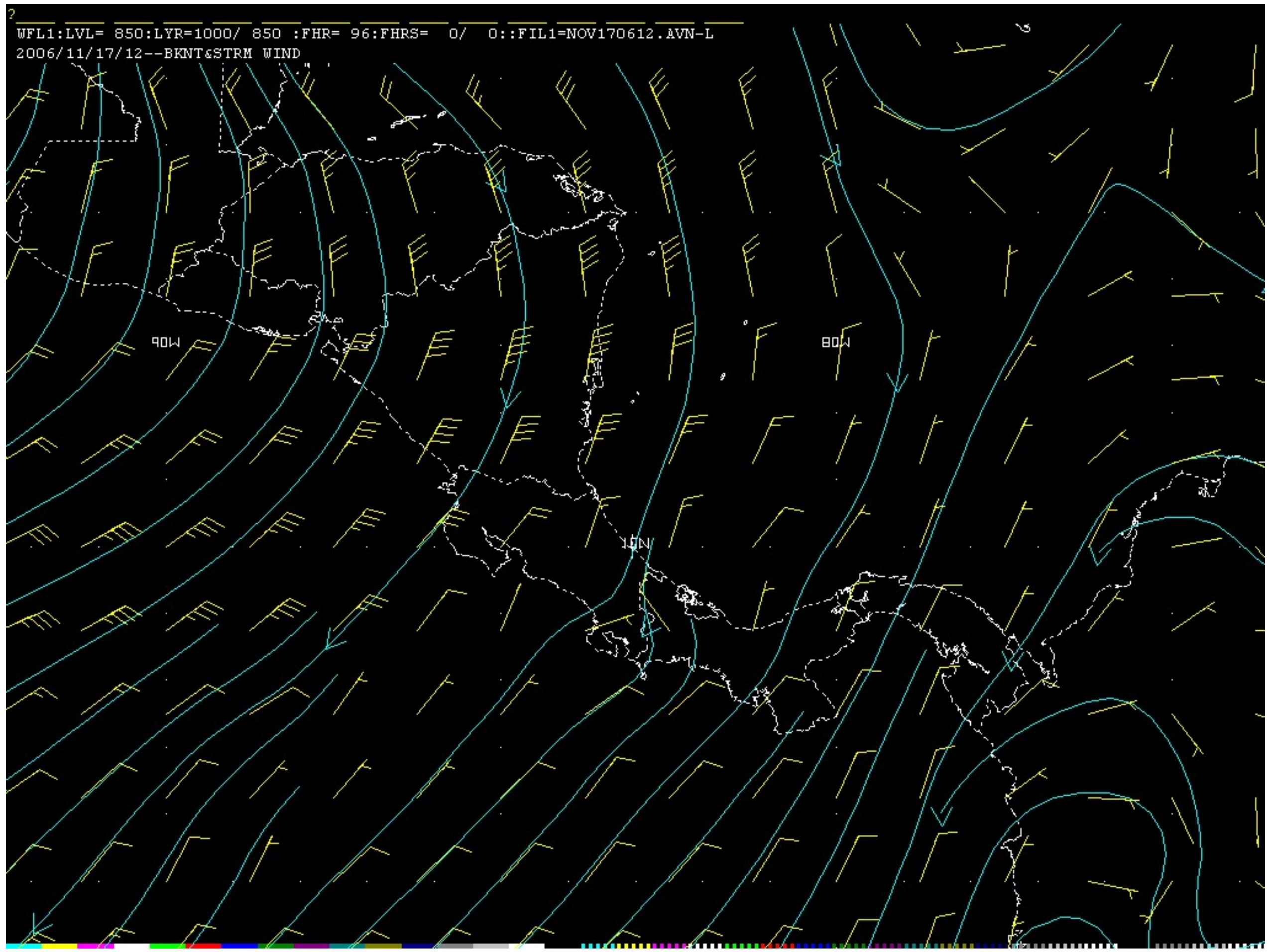
- Strong low level winds accompany the prefrontal shear line
- Strong winds moving off the coast will normally result in cold water upwelling
  - Colder waters = Convectively Stable
- Contrary to what the models forecast, this will lead to decrease in convection the next day following the event.

Dry Season Transition

- During the Fall transition we often see strong surges across the western Caribbean

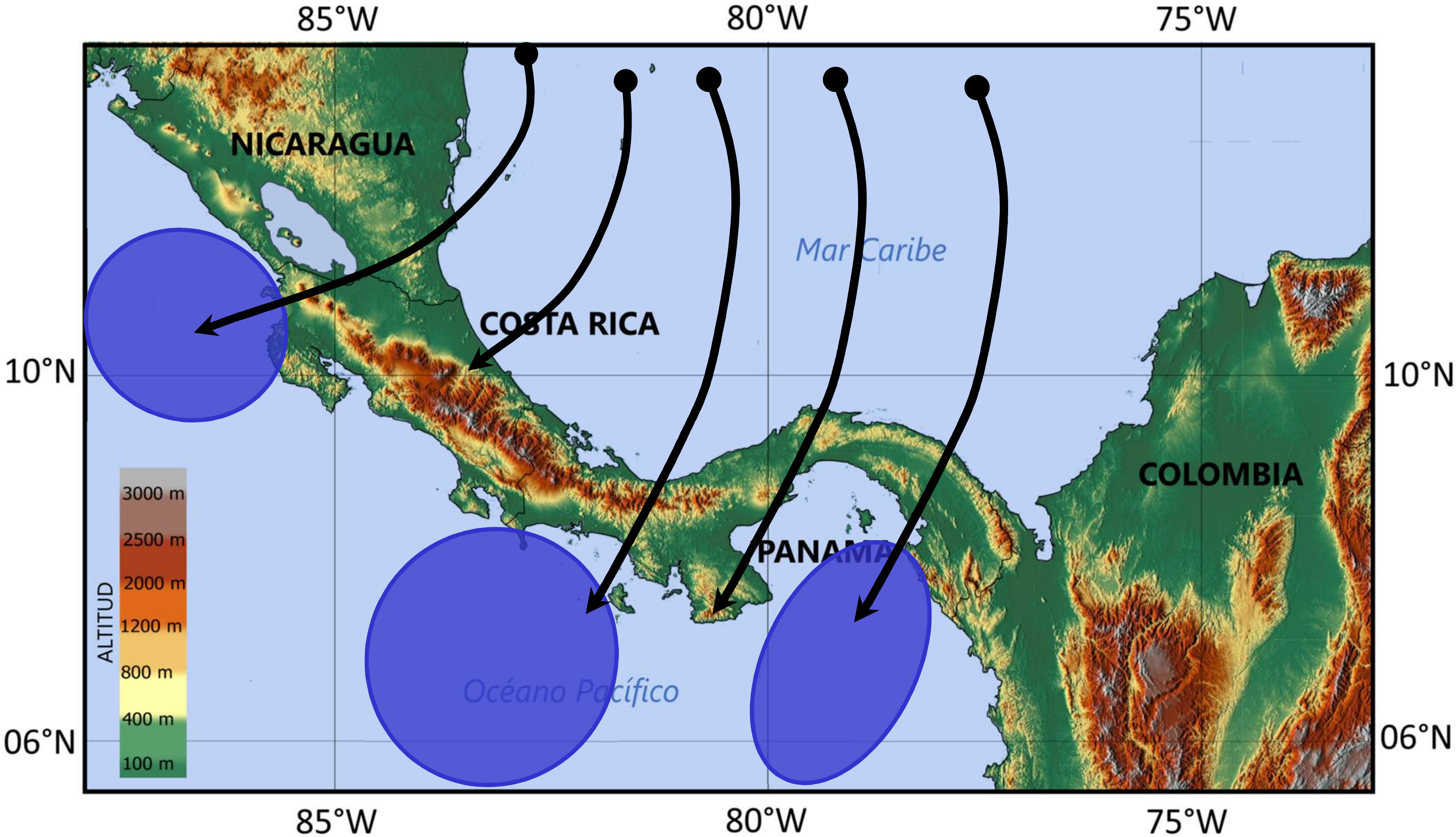
- These can drive the ITCZ south of its climatological position

- These surges often result in cold water upwelling
    - Marine layer becomes convectively stable



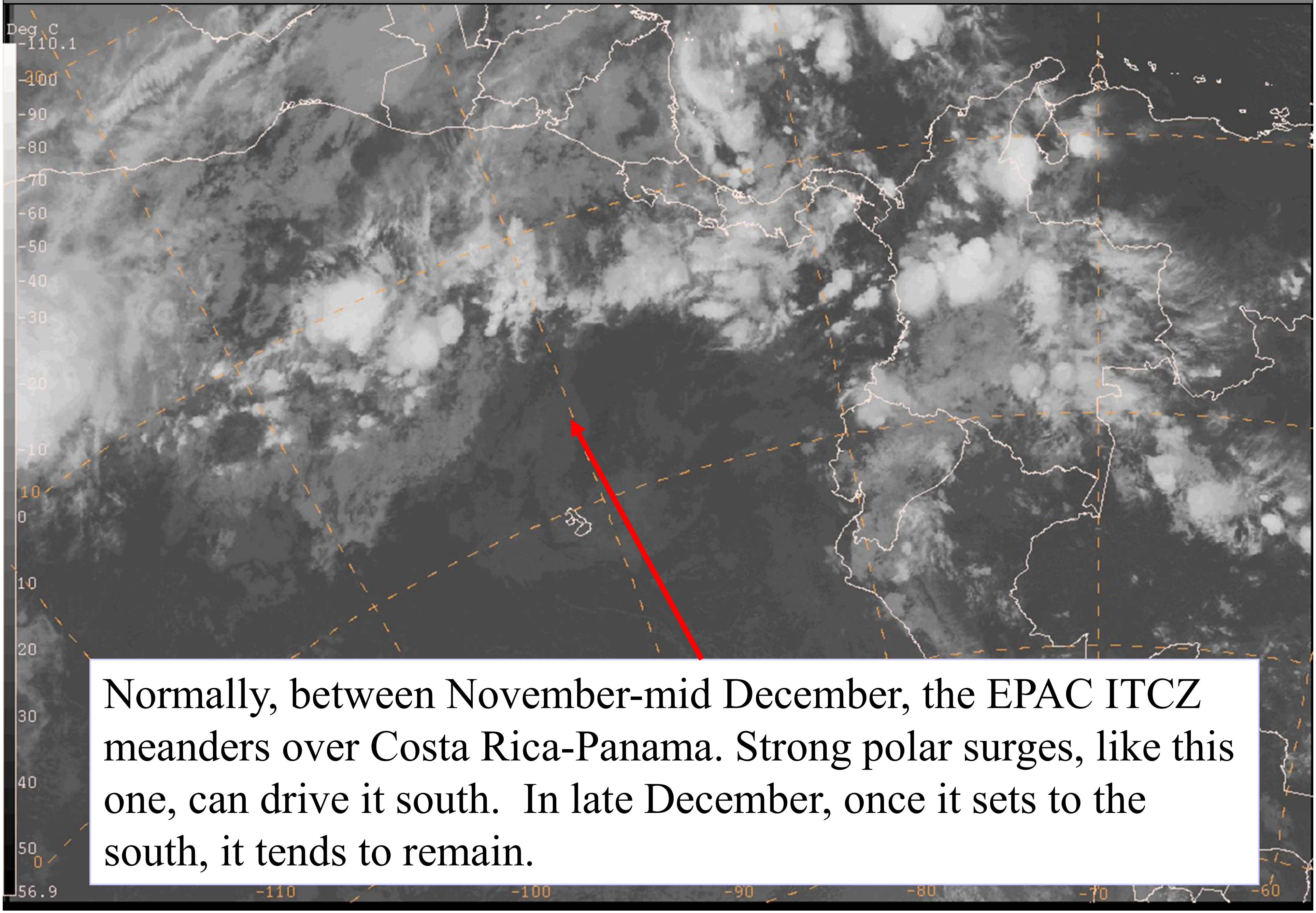
850 hPa Winds (KT)

Upwelling Eastern Pacific



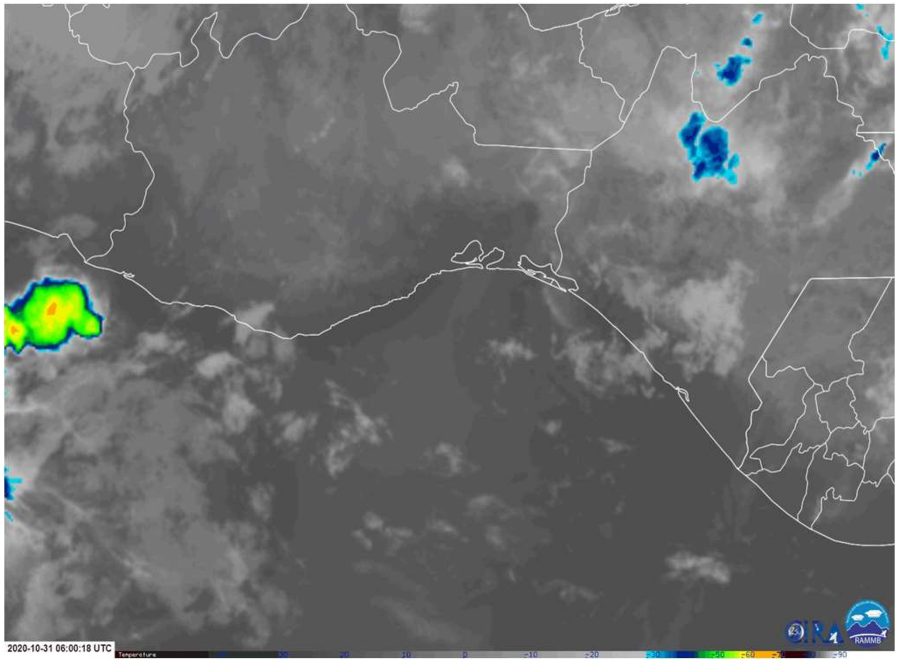
Cold water upwelling leads to marine layer becoming convectively stable

IR Animation Nov 2006, 21/0245Z – 22/1445Z

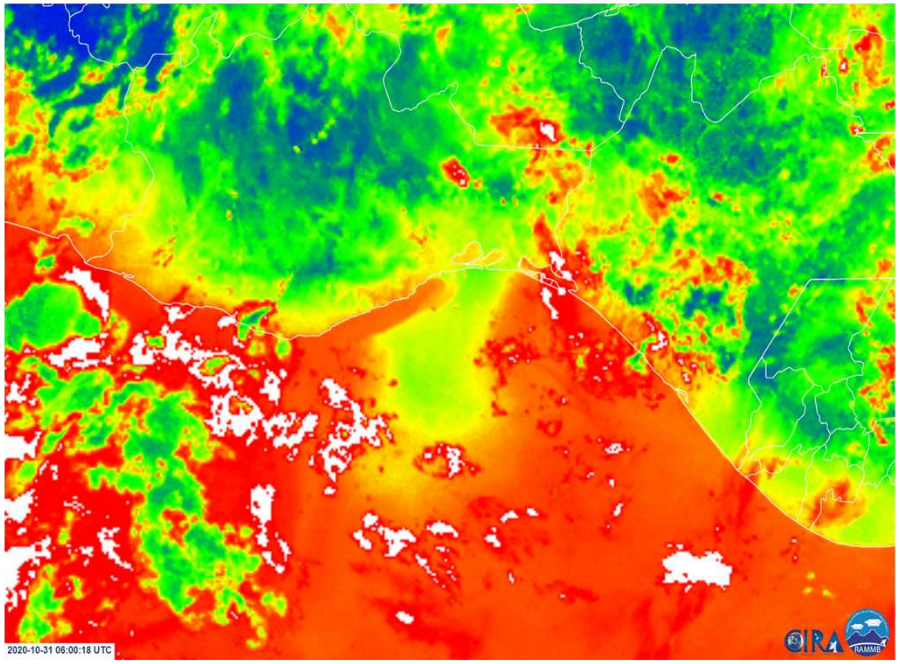


Normally, between November-mid December, the EPAC ITCZ meanders over Costa Rica-Panama. Strong polar surges, like this one, can drive it south. In late December, once it sets to the south, it tends to remain.

Cold Water Upwelling
Gulf of Tehuantepec

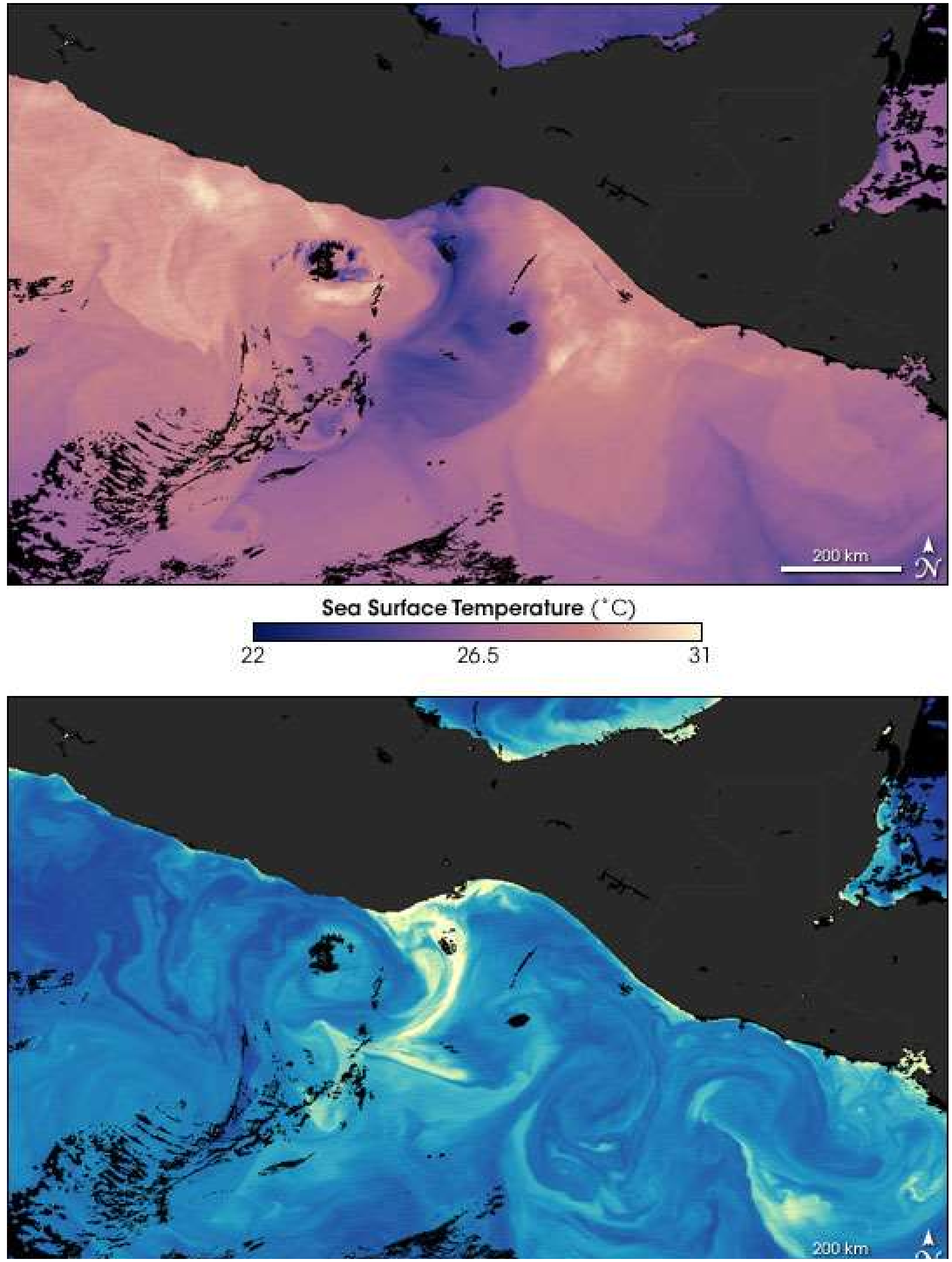


10.3 um



Split Window
10-3 – 12.3um

Cold Water Upwelling Gulf of Tehuantepec



Questions?

Case Study – December 1999

Poll Question #13

Focus of the Analysis SE Caribbean

Poll Question #13

The weather over northern Venezuela is due to:
(select all that apply)

- Frontal Convection
- Shear line / echo training pattern
- ITCZ

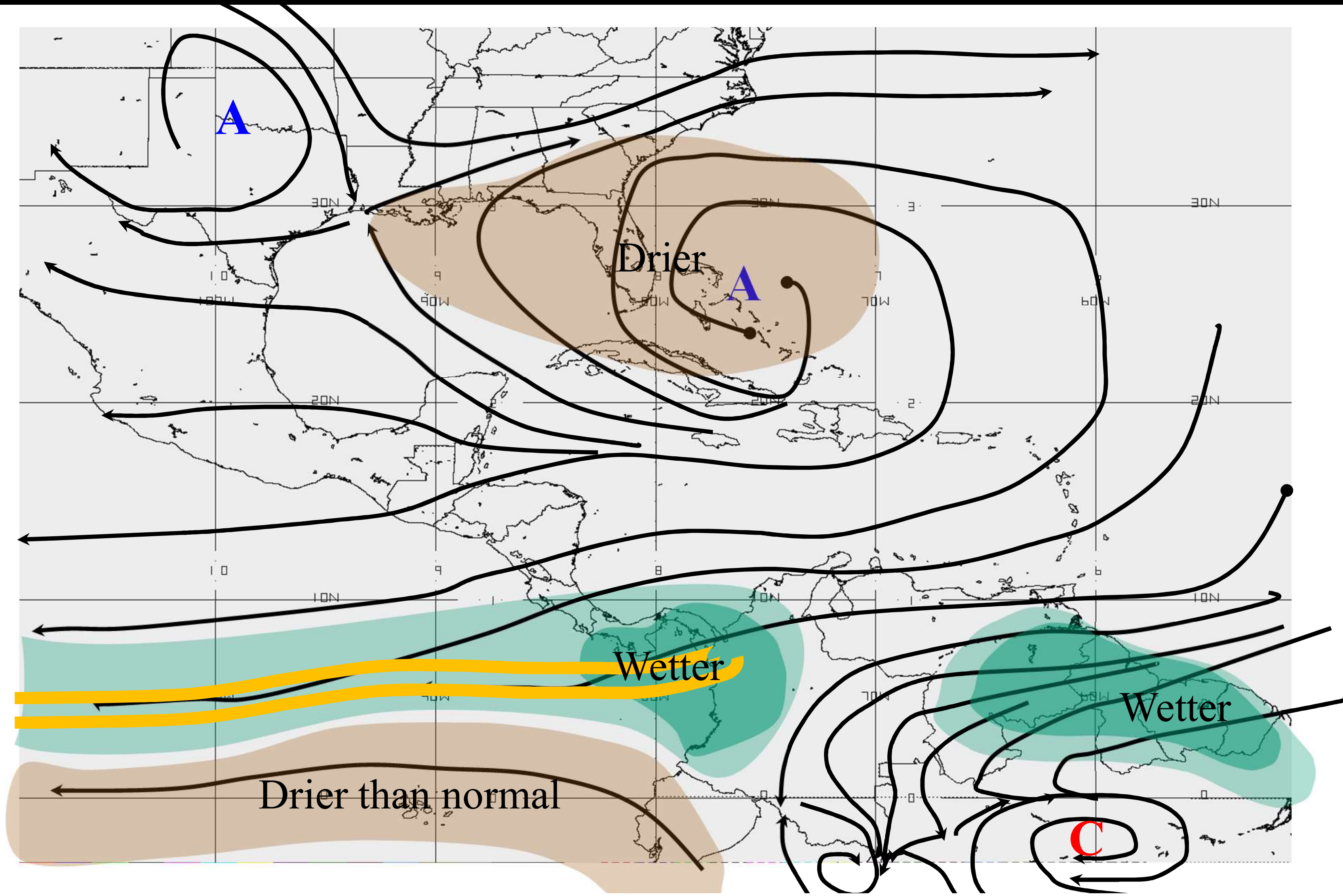
Oceanic Niño Index (ONI)

1998	2.2	1.9	1.4	1.0	0.5	-0.1	-0.8	-1.1	-1.3	-1.4	-1.5	-1.6
1999	-1.5	-1.3	-1.1	-1.0	-1.0	-1.0	-1.1	-1.1	-1.2	-1.3	-1.5	-1.7
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7
2001	-0.7	-0.5	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
2002	-0.1	0.0	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0.0	-0.3	-0.2	0.1	0.2	0.3	0.3	0.4	0.4

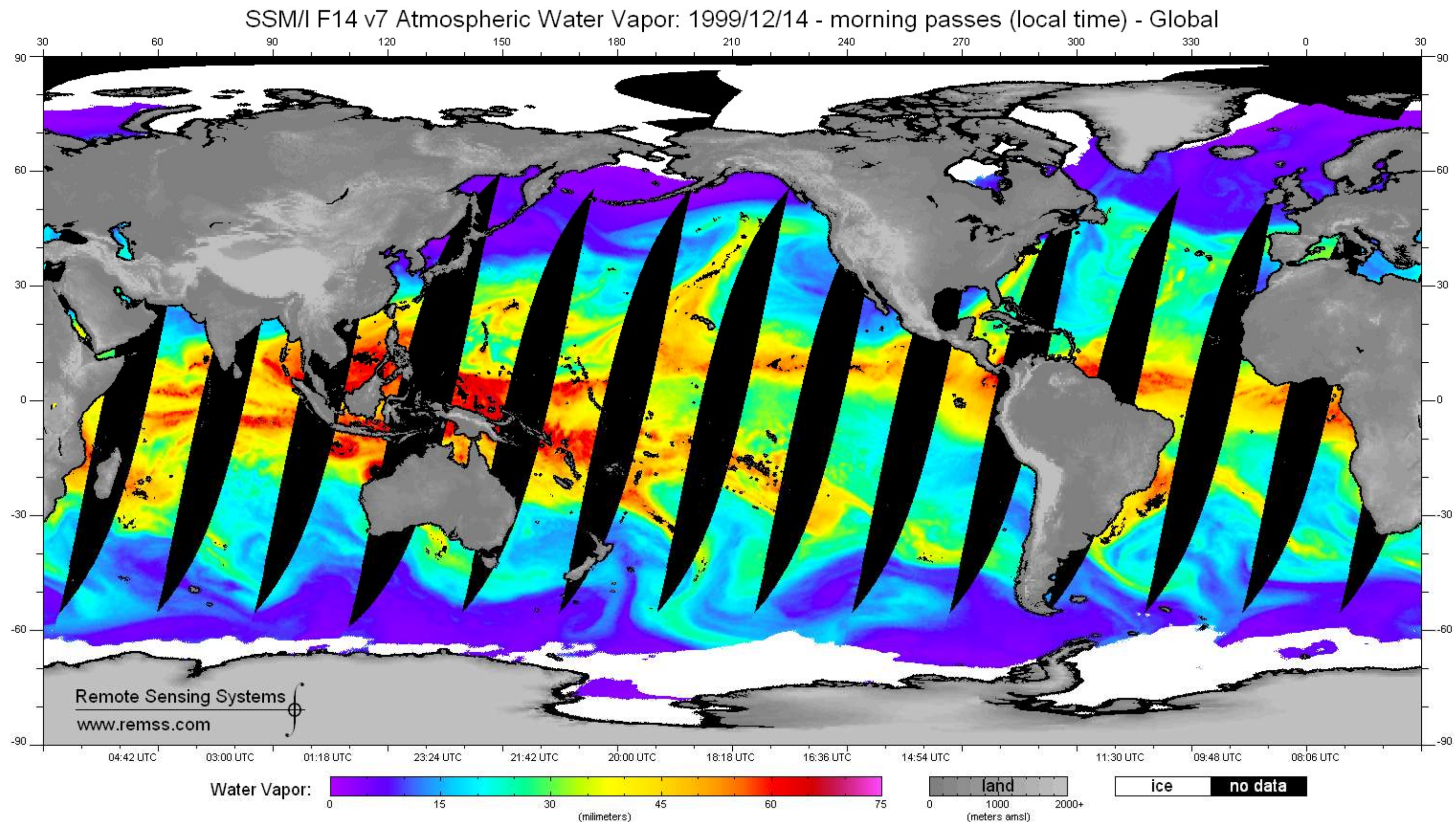
- 1999 was a cold ENSO year

Conceptual Model

Low Level Flow Cool ENSO – La Niña



Atmospheric Water Vapor 1999/12/14

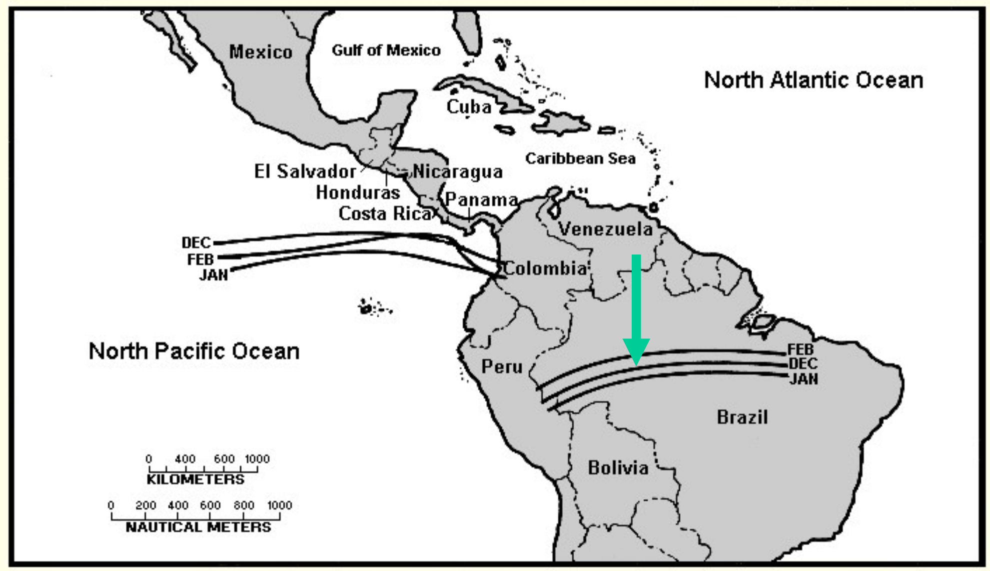


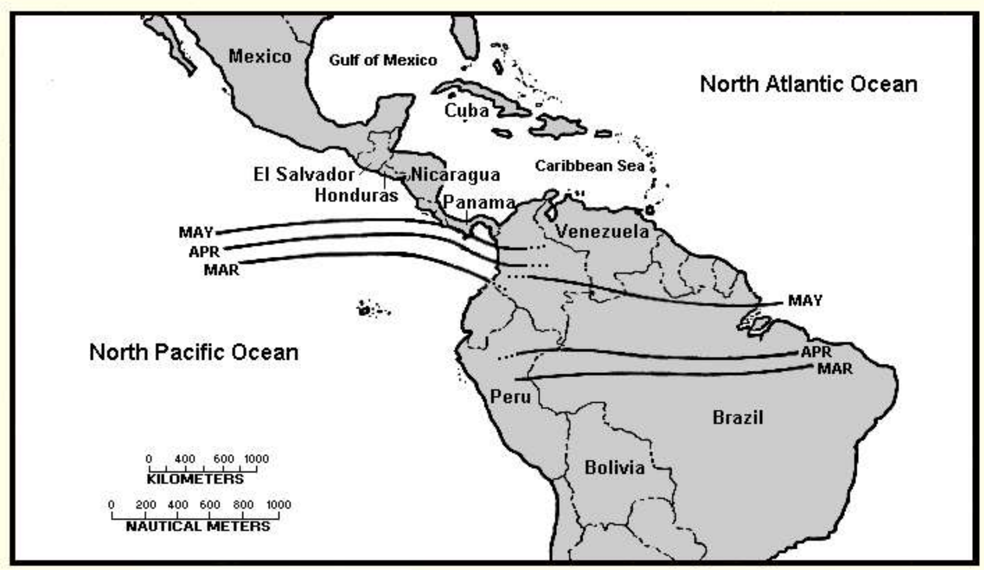
ITCZ – NET During the Dry Season

- The Near Equatorial Trough (NET) migration over the continent is more pronounced than the ITCZ migration over the oceans.

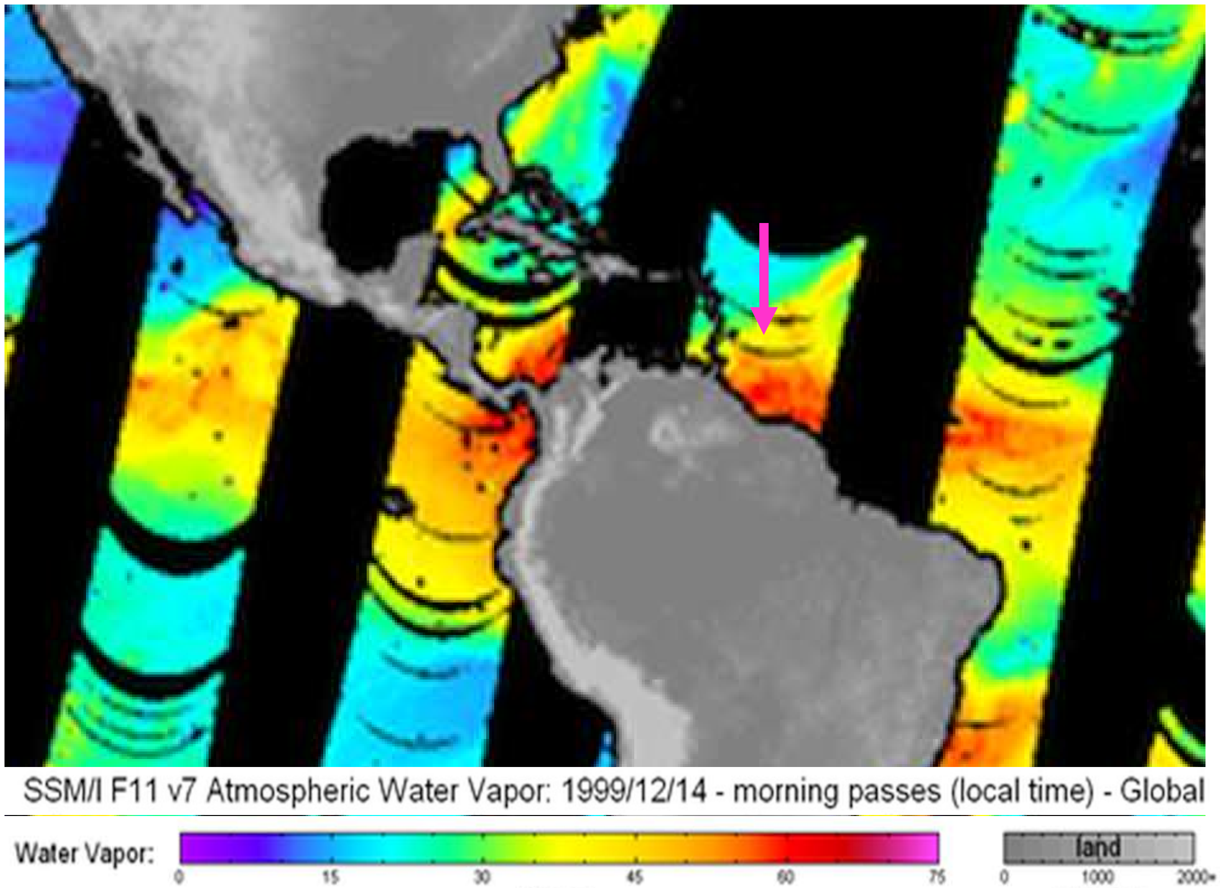
- Following the sun, the NET over the continent moves to northern Brazil-Peruvian Jungle/eastern Ecuador

- Dry season transition over southern CENTAM normally takes place o/a **December 20**



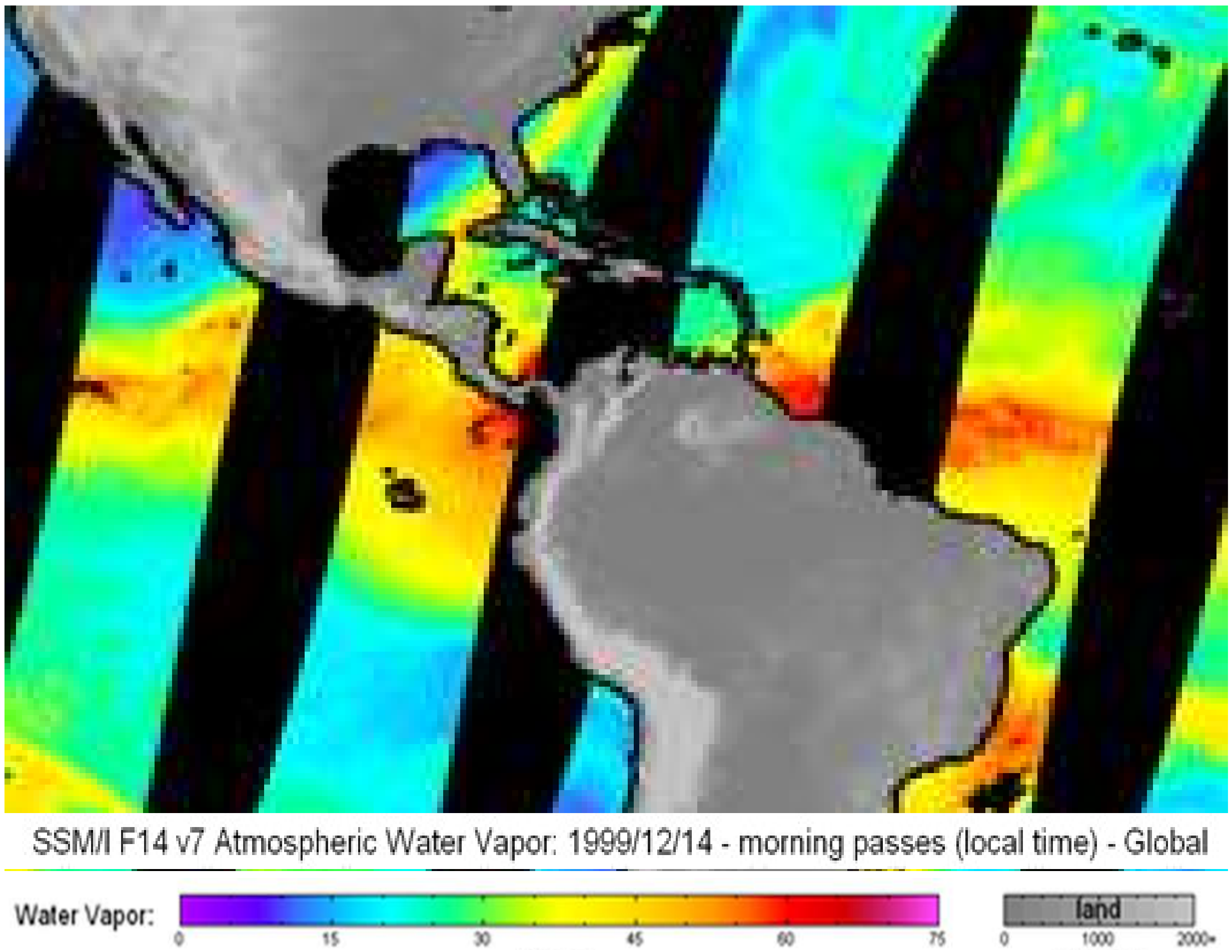


Atmospheric Water Vapor 1999/12/14



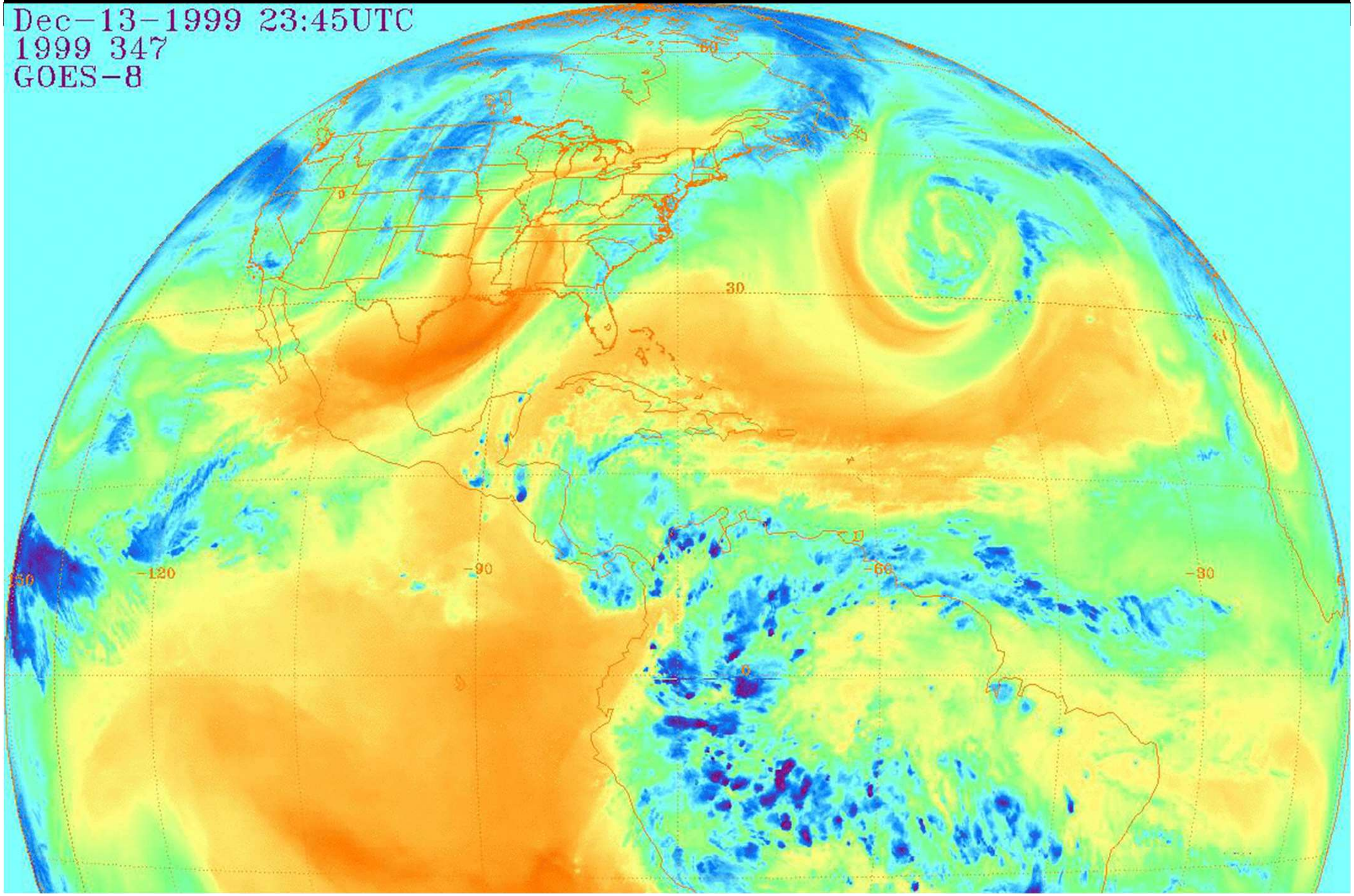
High PWAT content suggests ITCZ north of its climo position, conditions often seen during La Niña.

Atmospheric Water Vapor 1999/12/14

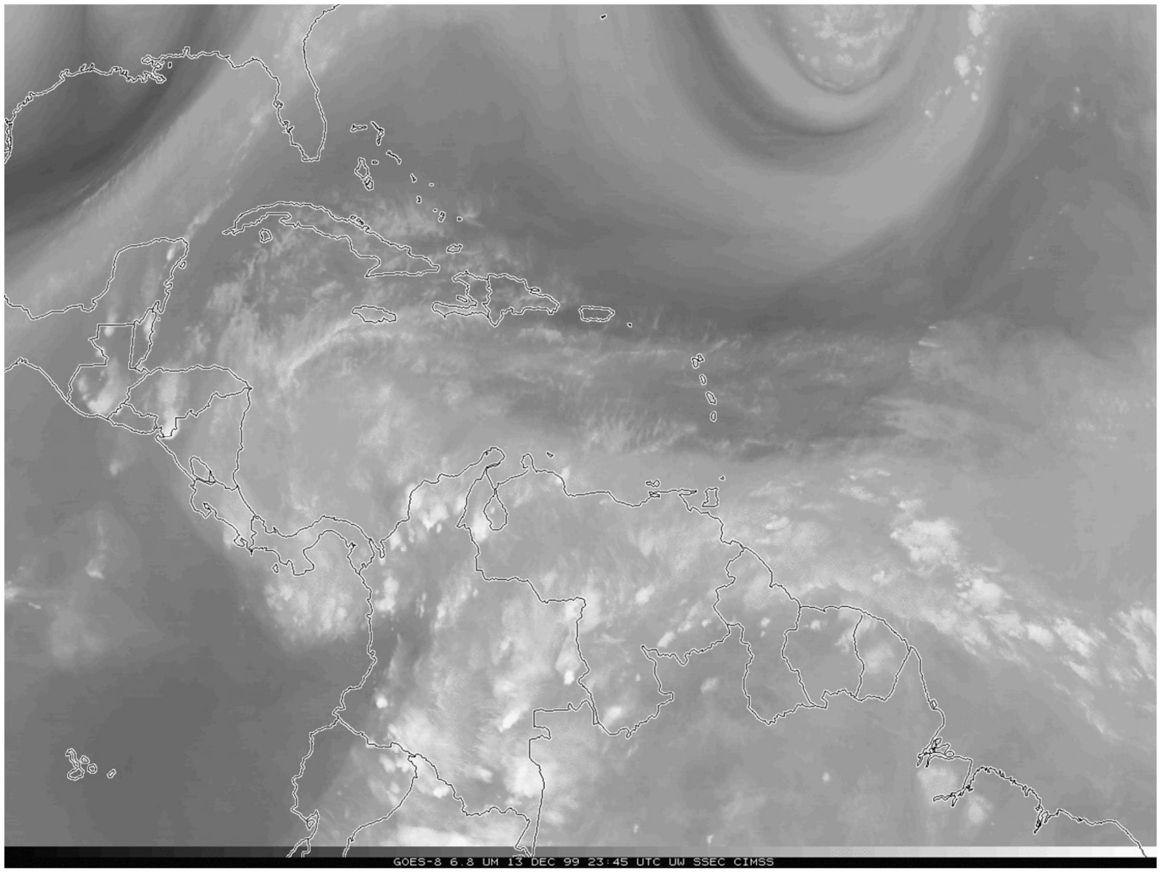


High PWAT content suggests ITCZ north of its climo position

Hemispheric WV 14-16 Dec 1999

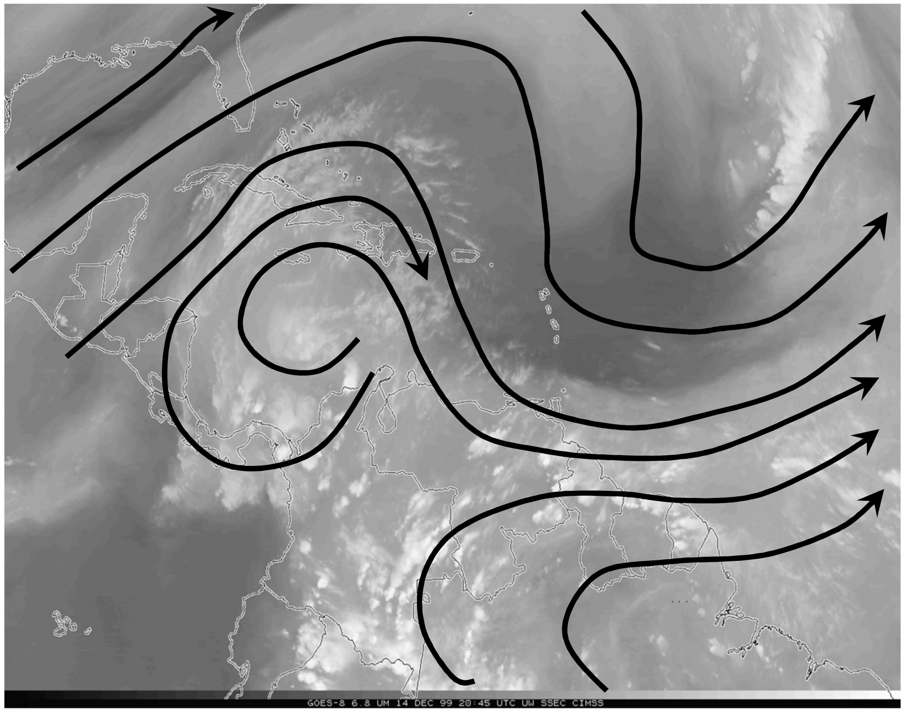


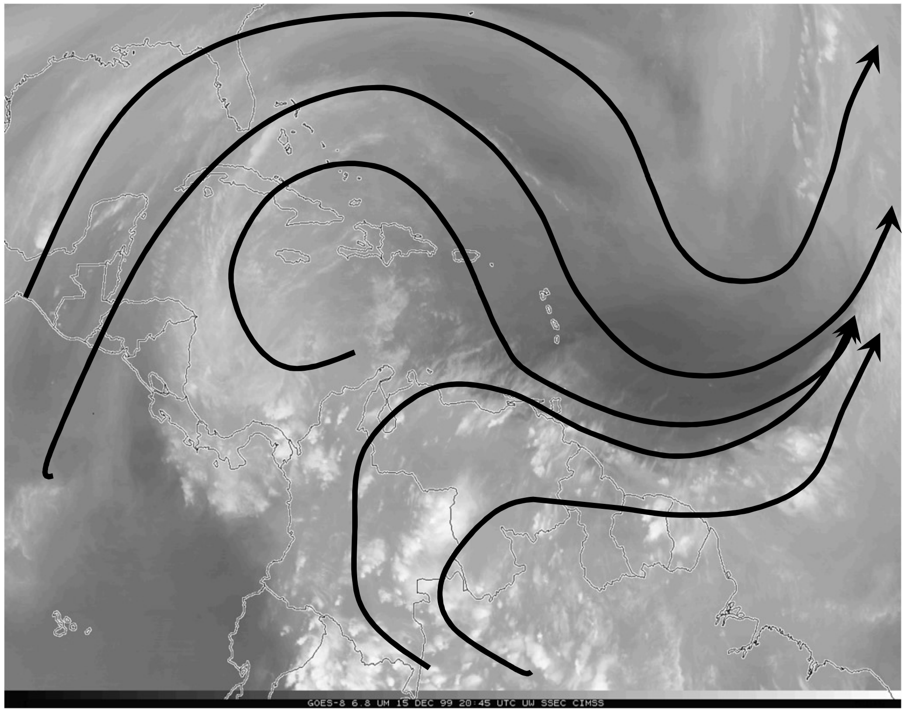
WV Animation 14-16 Dec 1999



Mid/upper level ridge building over the Caribbean while a high amplitude trough settles to the east.

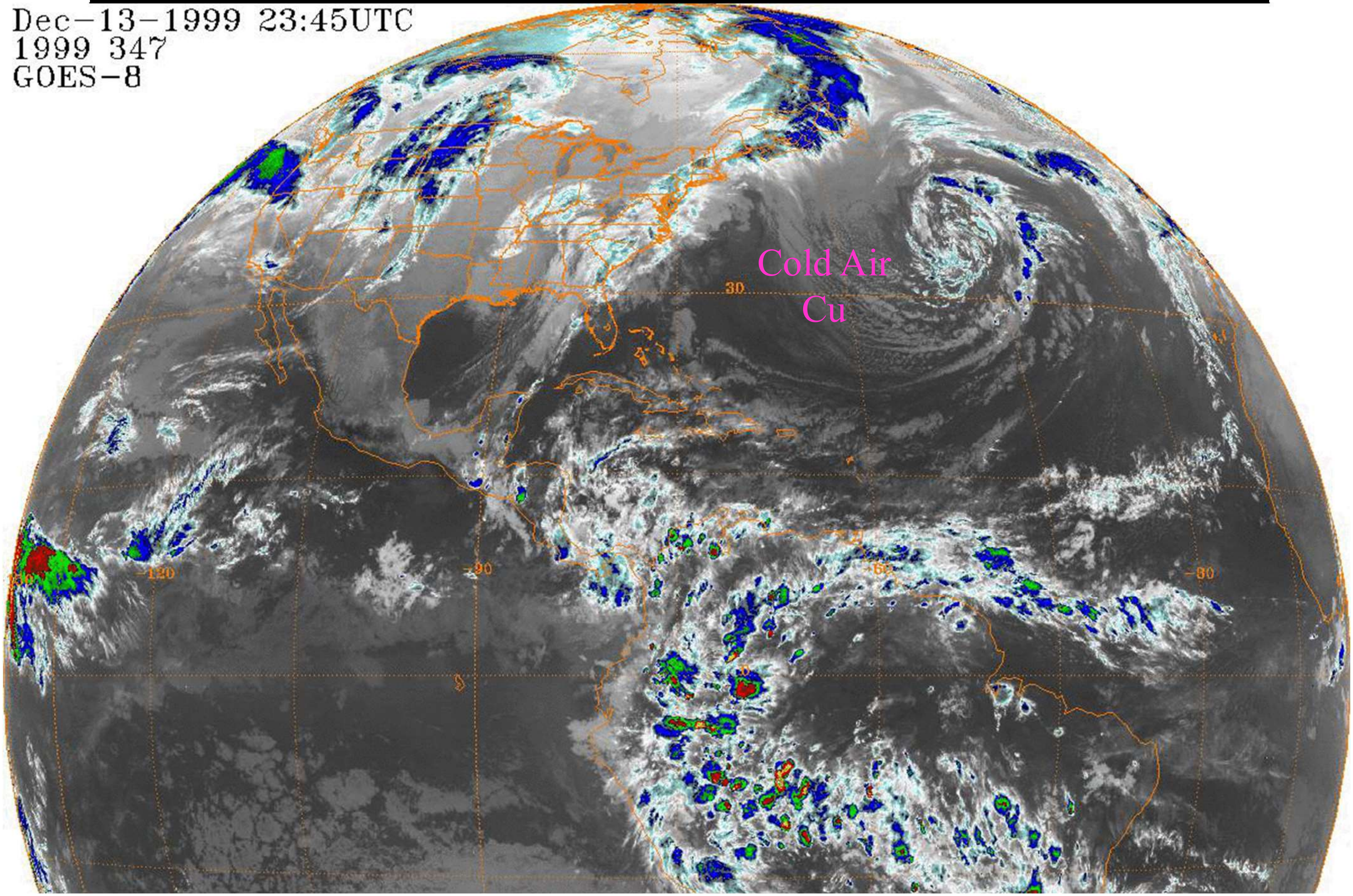
WV Image
Tendency 14 Dec/21Z &15 Dec/21Z



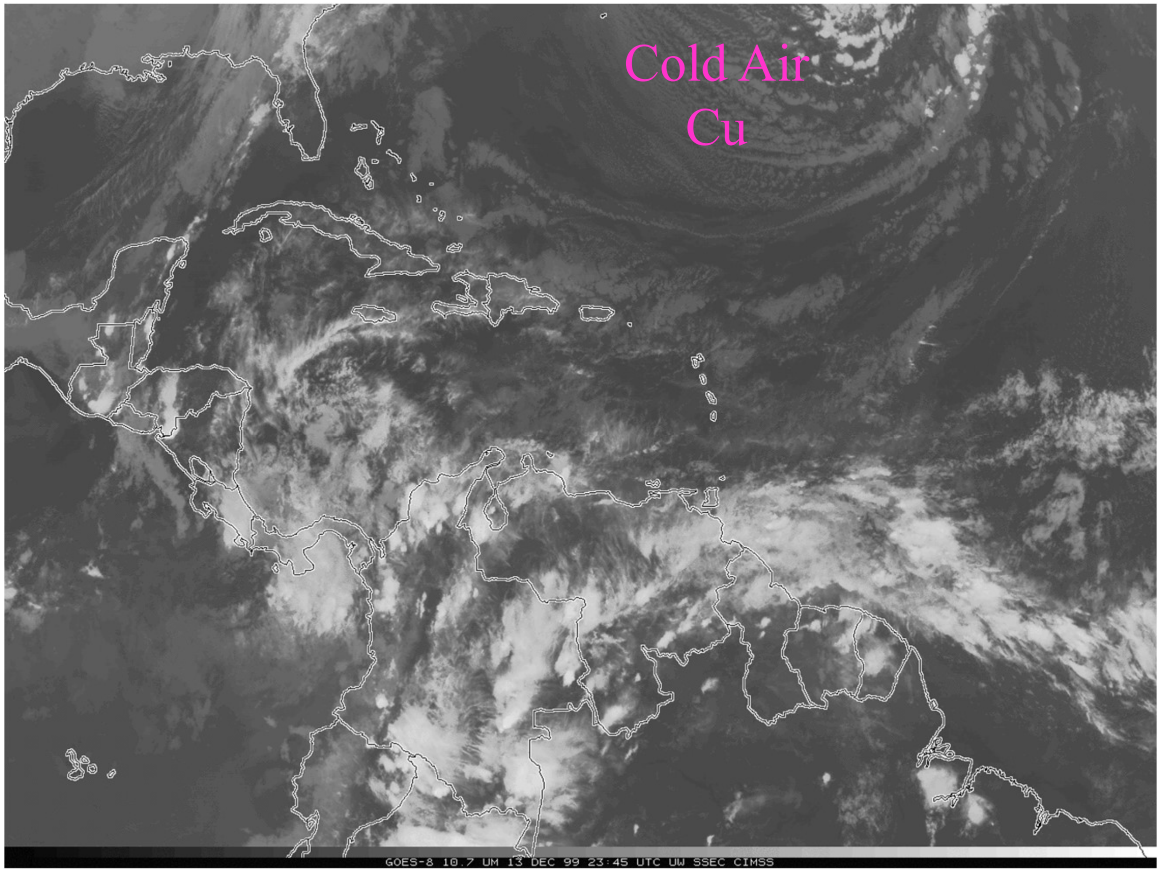


In 24 hrs the ridge builds across the central Caribbean and the trough amplifies to the east.

Hemispheric IR 14-16 Dec 1999

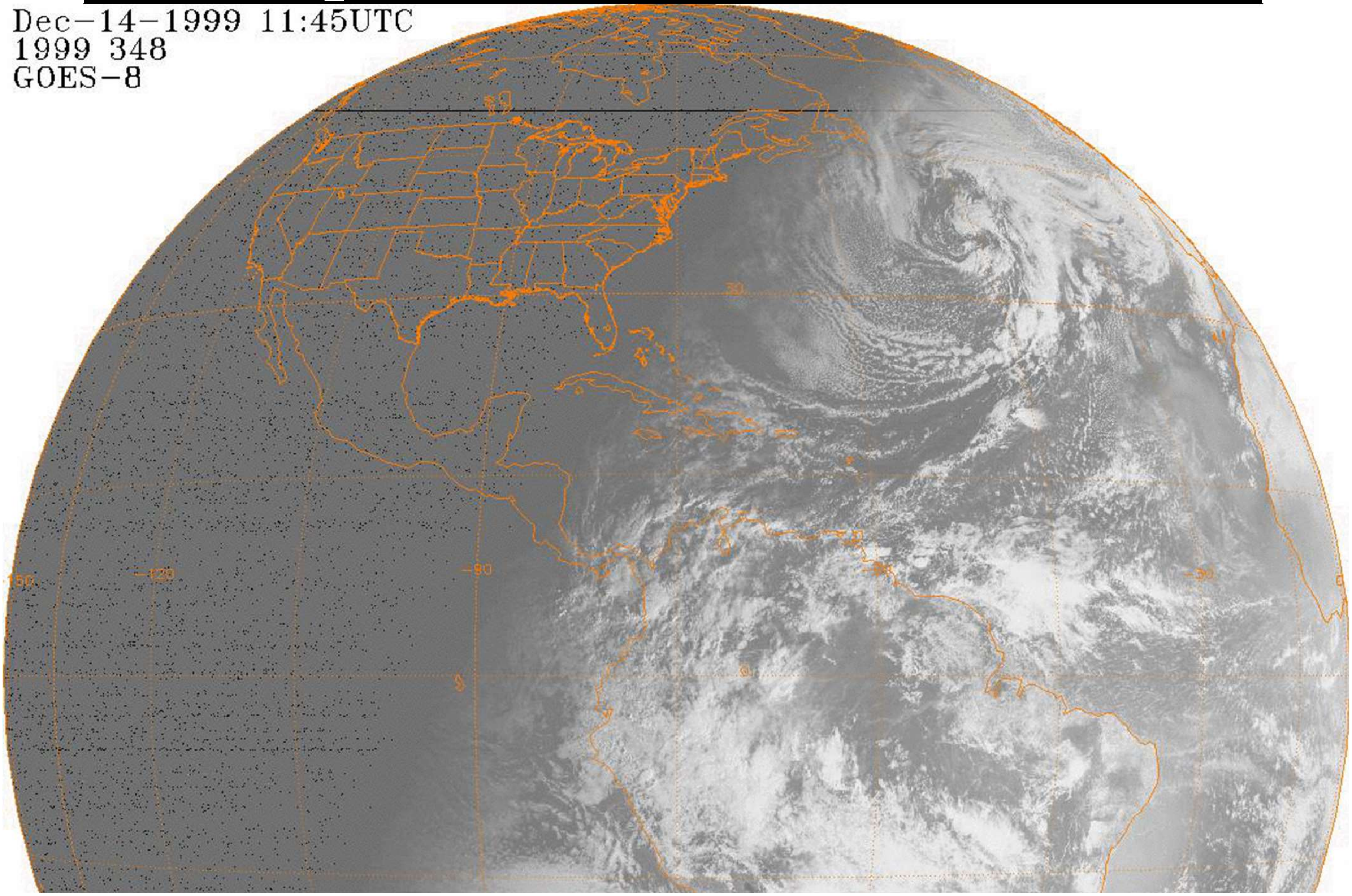


IR Animation 14-16 Dec 1999

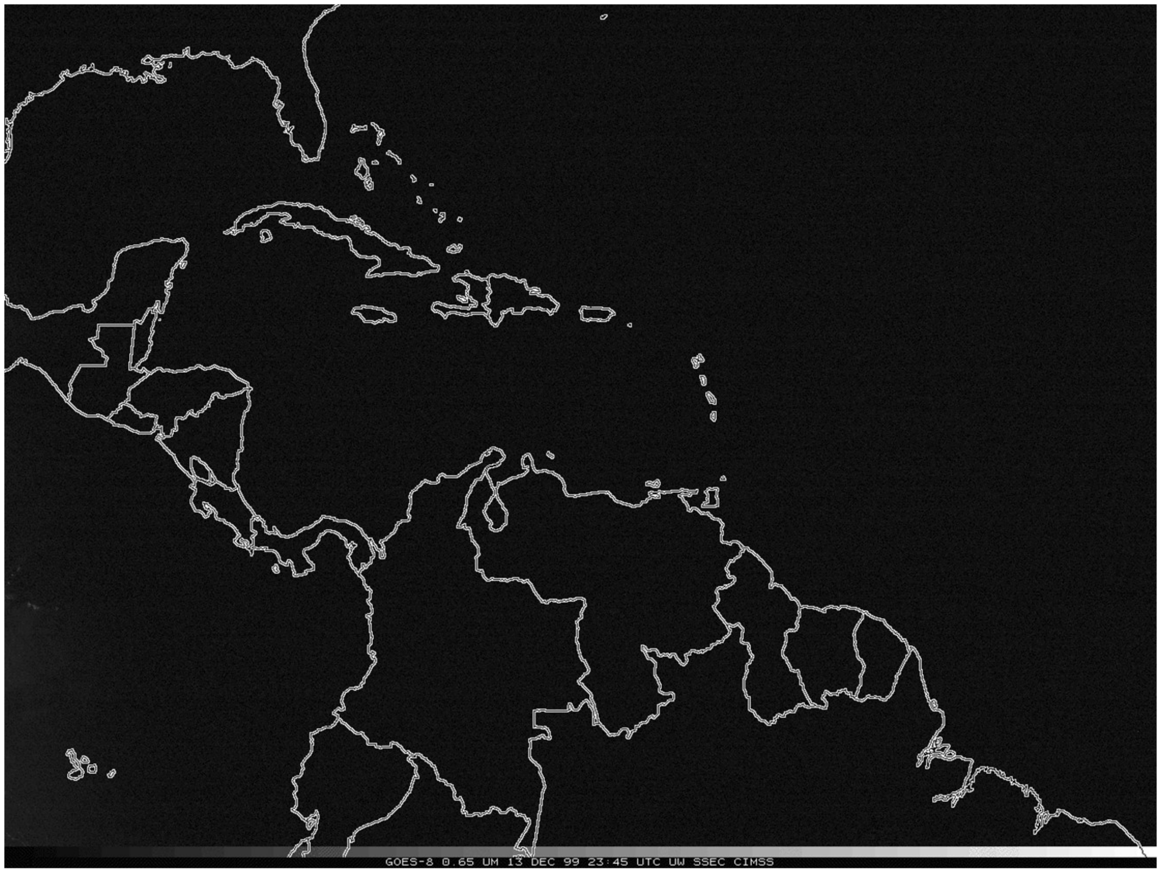


Cold front evident?
Shear Line?
ITCZ?

Hemispheric Vis 14-16 Dec 1999



VIS Animation 14-16 Dec 1999



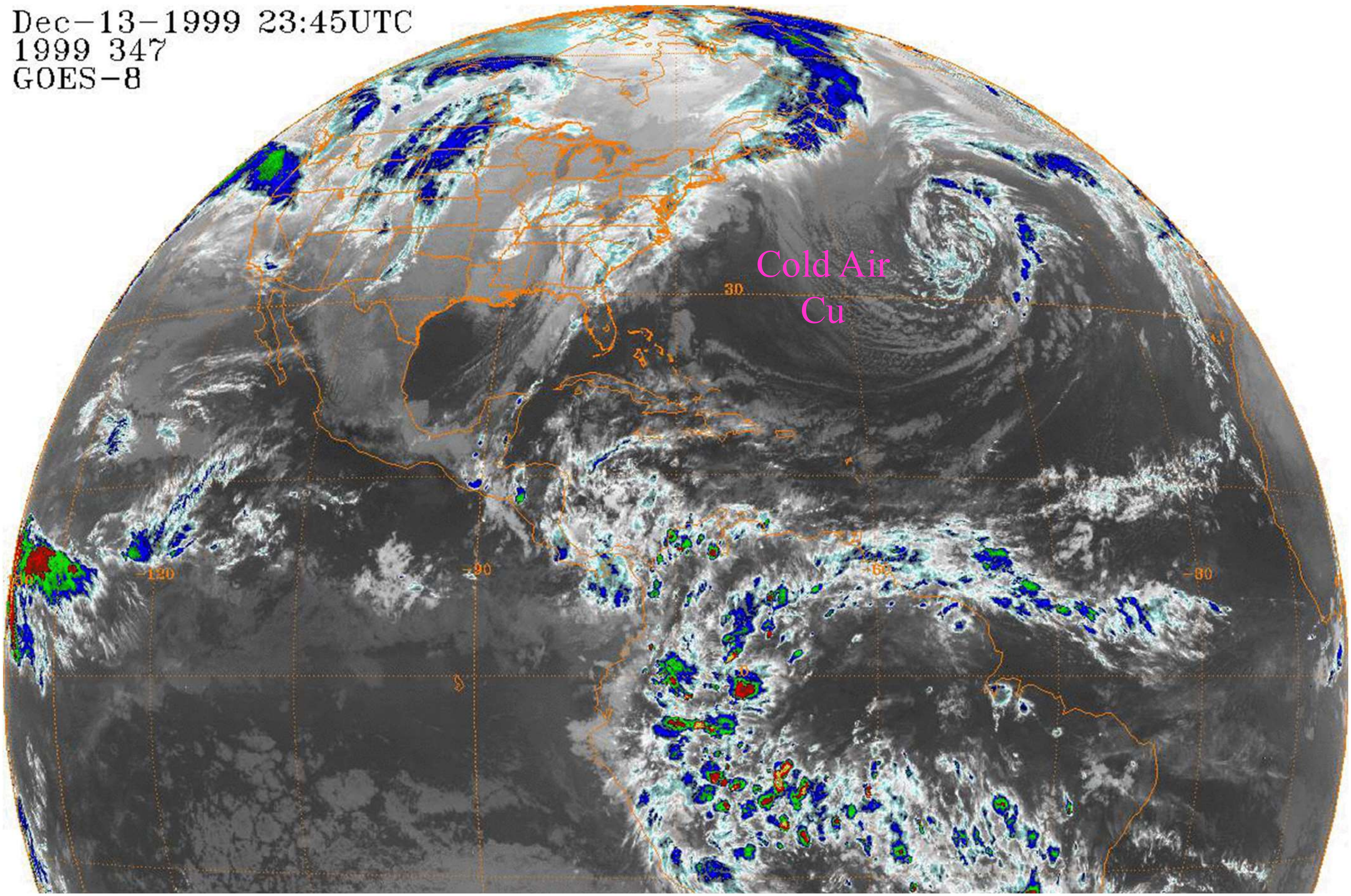
Cold front evident?
Shear Line?
ITCZ?

Poll Question #13

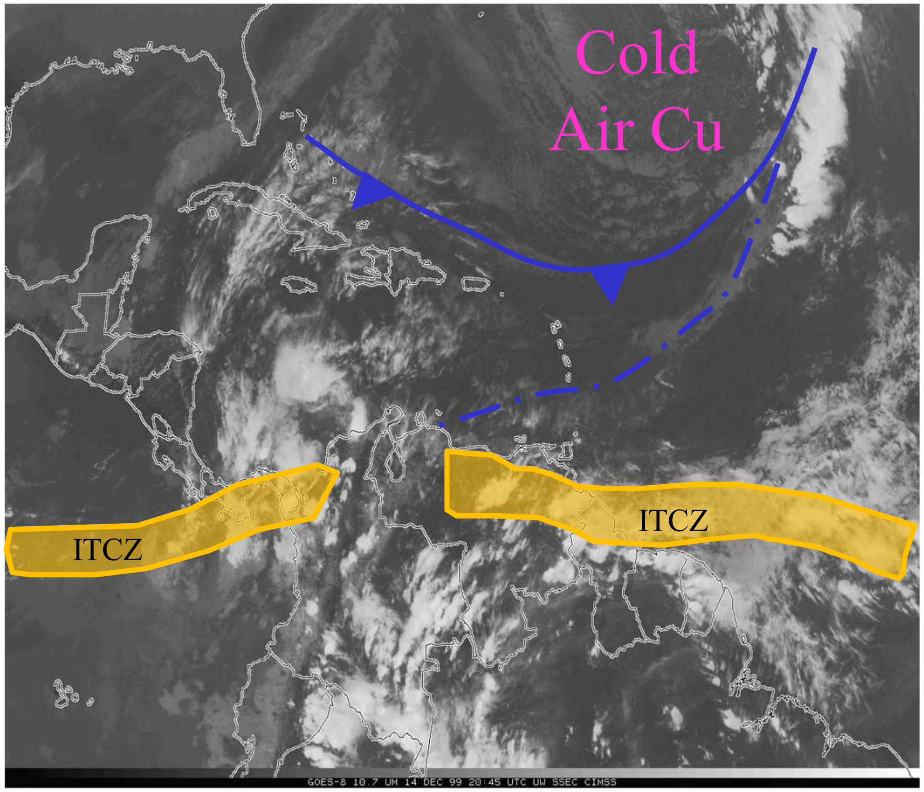
The weather over northern Venezuela is due to:
(select all that apply)

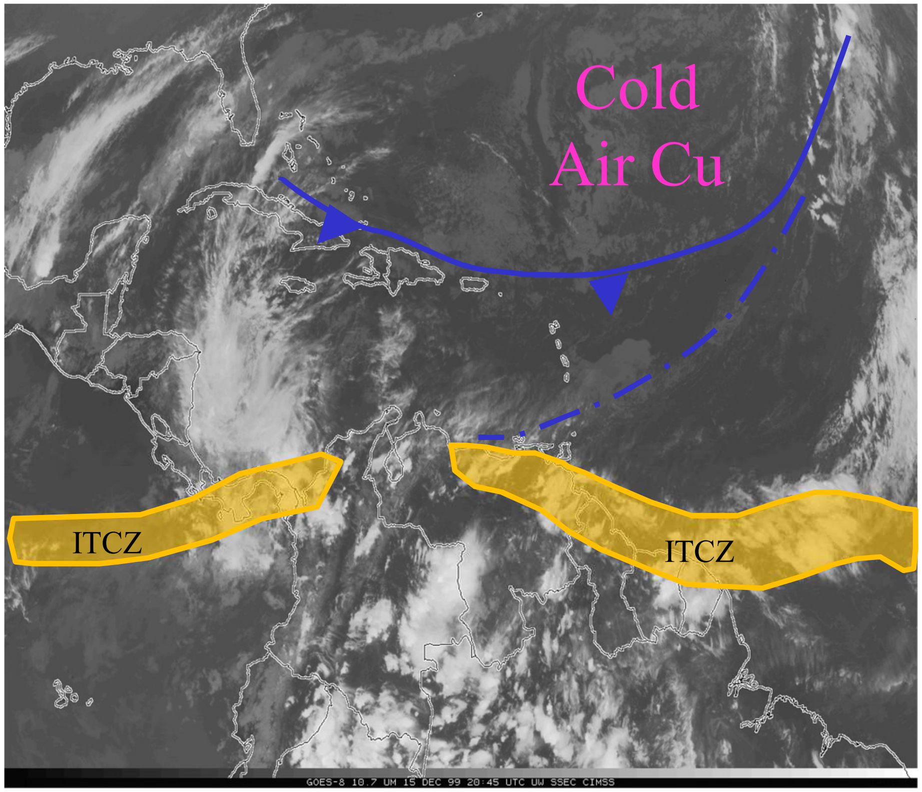
- Frontal Convection
- Shear line / echo training pattern
- ITCZ

Poll #13 Review IR 14-16 Dec 1999

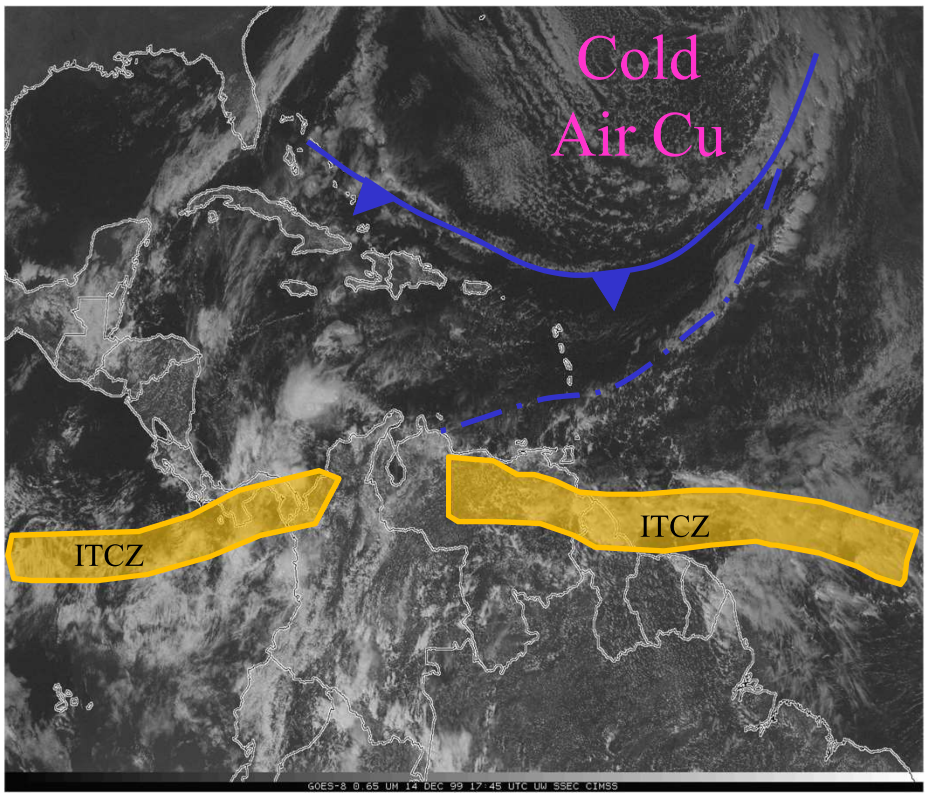


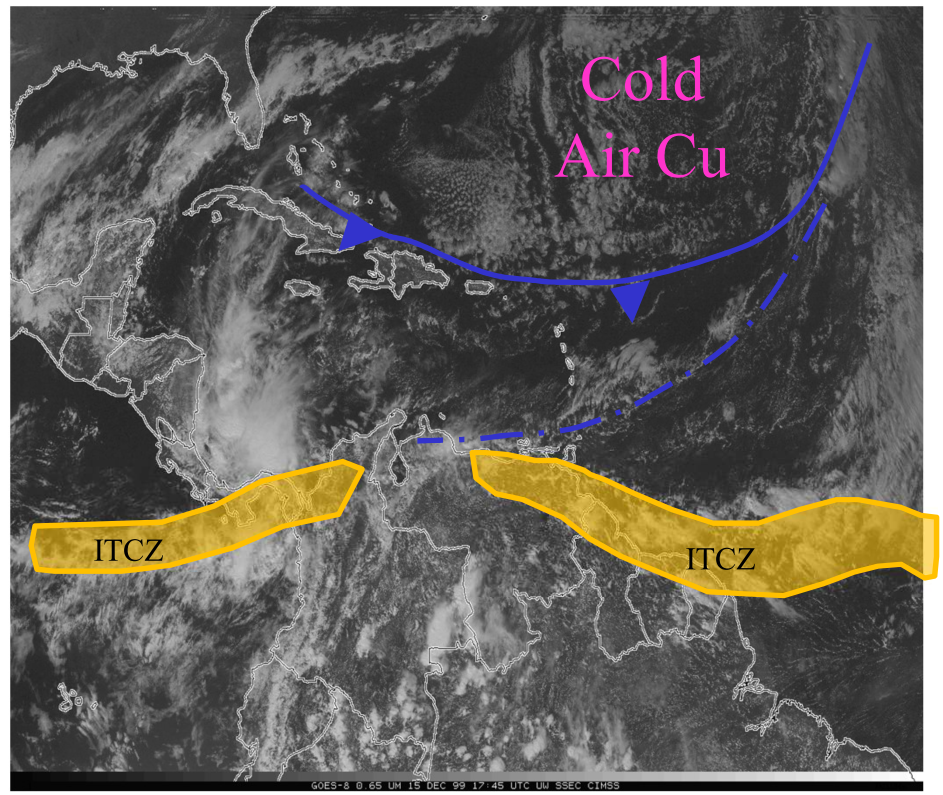
Question 13 Review
IR Image
Tendency 14 Dec/21Z &15 Dec/21Z





Question 13 Review
Vis Image
Tendency 14 Dec/18Z &15 Dec/18Z





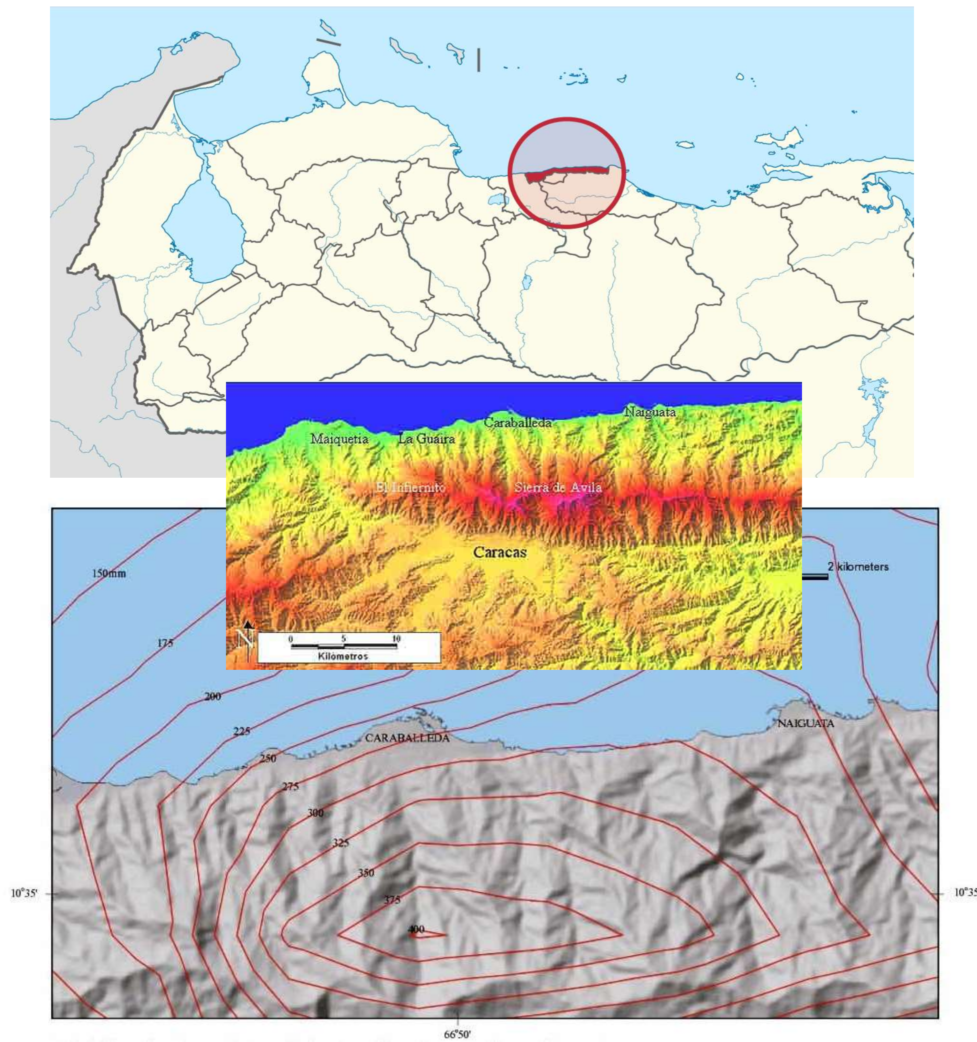
Northern Venezuela

14-16 December 1999

“Tragedia de Vargas”

Vargas – Venezuela
14-16 December 1999

- Echo training pattern over three days
  - ITCZ north of its climatological position
  - Shear line confluence
- Rainfall
  - 1-13 Dec: 293mm
  - 14-16 Dec: 911mm
- Impact:
  - $1.79 Billion in loses
  - Deaths: 30-50K
  - 8,000 houses
  - 700 apartment buildings



United States Geological Survey Open File Report 01-0144.

Vargas – Venezuela
14 – 16 December 1999