
ICAO • OACI • ИКАО
ICAO
INTERNATIONAL
CIVIL AVIATION
ORGANIZATION
A UN SPECIALIZED AGENCY

Fronts, Shear Lines and Low-level jets

José Manuel Gálvez

Researcher and Instructor

Axiom for WPC International Desks/NWS/NOAA

ICAO

Overview

01 Fronts and shear lines

02 Frontal Shear Lines

03 Prefrontal Shear Lines

04 Fronts and shear lines in South America

05 Low-level jets

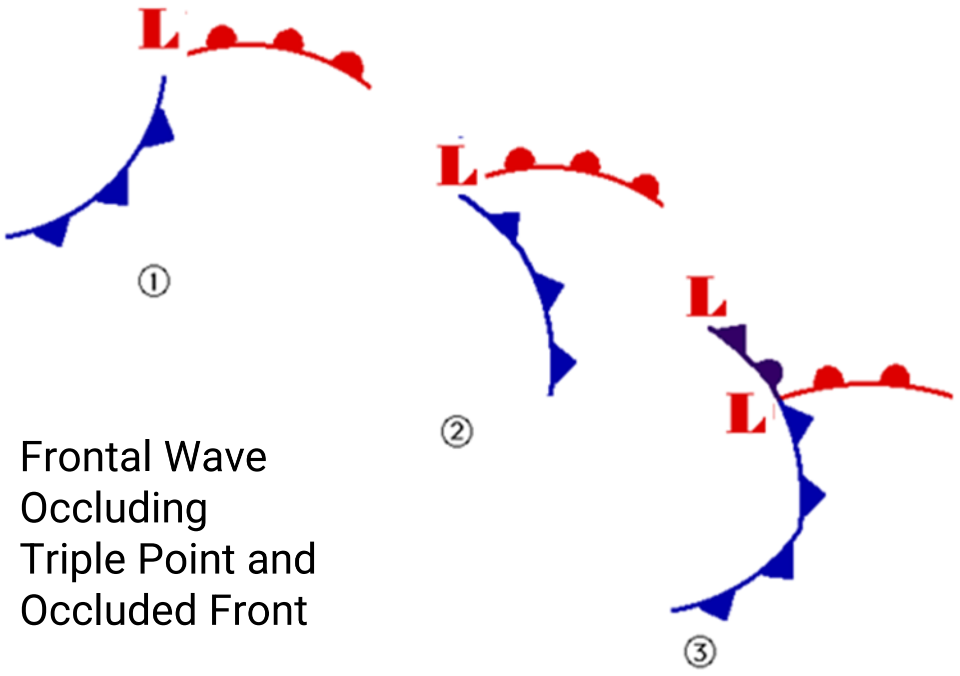
01

Fronts

Fronts

Front: The interface or transition zone between two air masses of different density (baroclinic)

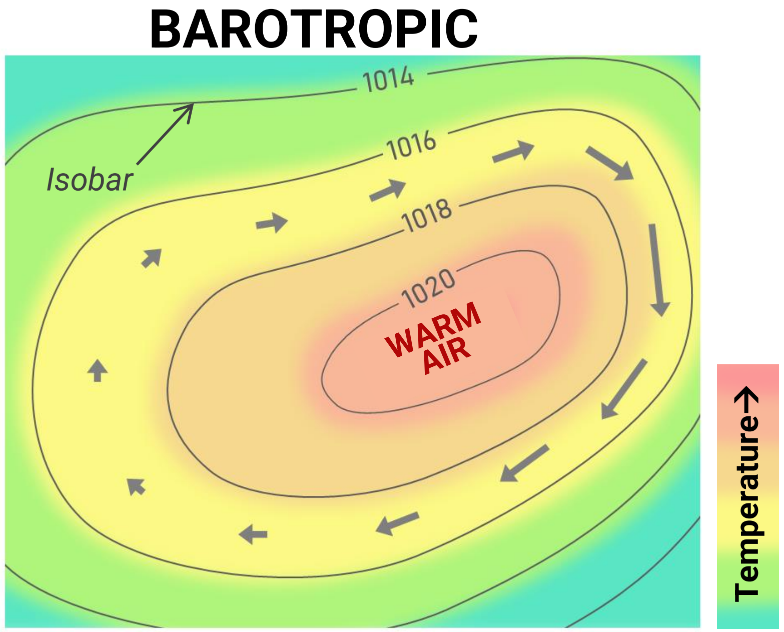
- Density depends on temperature
    - Moisture content affects density, but plays a secondary role
- Clouds and precipitation are not required, dry fronts are possible.

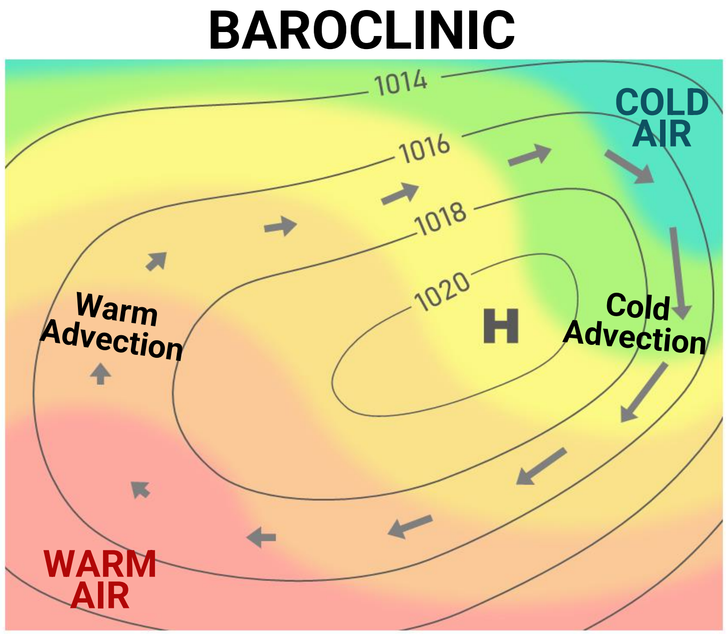


1. Frontal Wave
2. Occluding
3. Triple Point and Occluded Front

Aviation Applications: Fronts can be a source of thunderstorms, turbulence and icing

Baroclinic vs Baroclinic





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

- Advection of temperature.
- Isobars and isotherms are not parallel. They form a cross-contour pattern (solenoid).

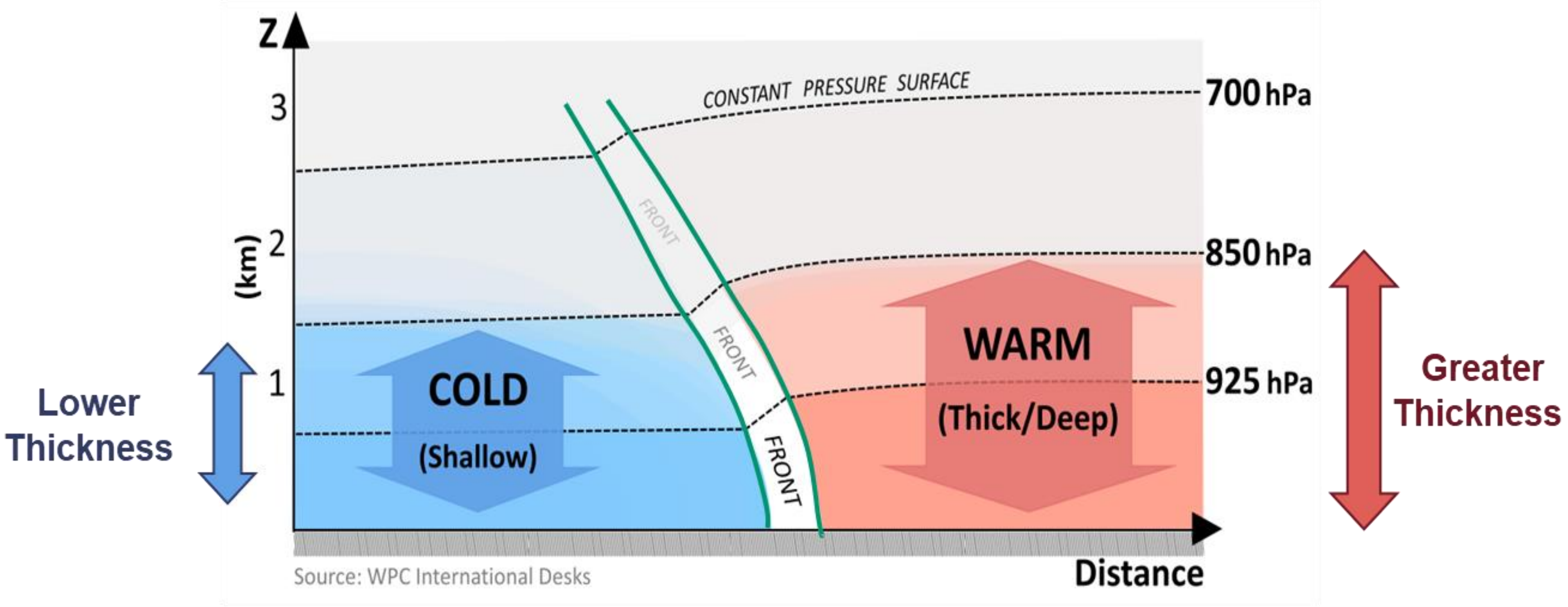
Takeaway: Baroclinicity implies temperature advection.

Temperature and Thickness Relationship

- The thickness of a layer is directly proportional to the mean temperature of that layer, via de hysometric equation:

$$h = z_2 - z_1 = \frac{R \cdot \overline{T_v}}{g} \ln\left(\frac{p_2}{p_1}\right),$$

- Thus, we can analyze air masses by evaluating the layer thickness rather than the temperature at a particular level.



Thickness ~ Mean Temperature of a Layer

Why use thickness instead of temperature?

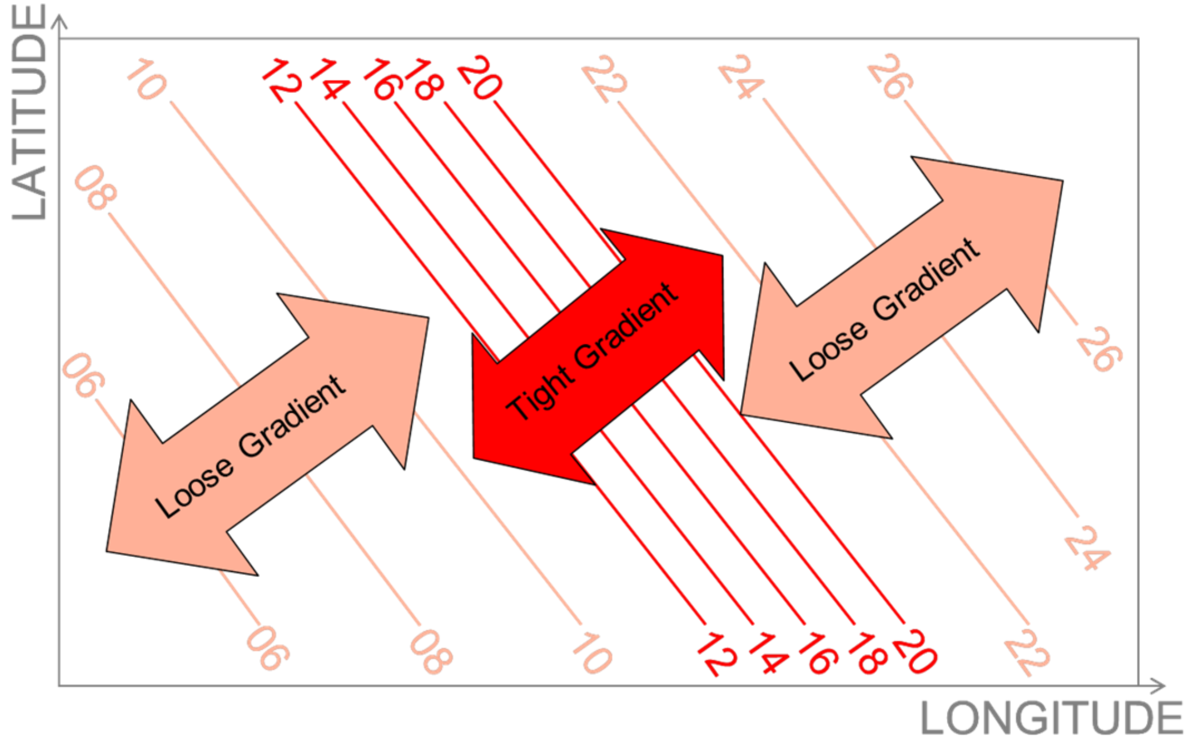
- Provides a feel for vertical structure (depth of the layer)
- Reduces the diurnal/nocturnal temperature variability due to heating/cooling in the boundary layer
- Captures the air mass better, smoothing the thermal effect of surface features.

Gradients

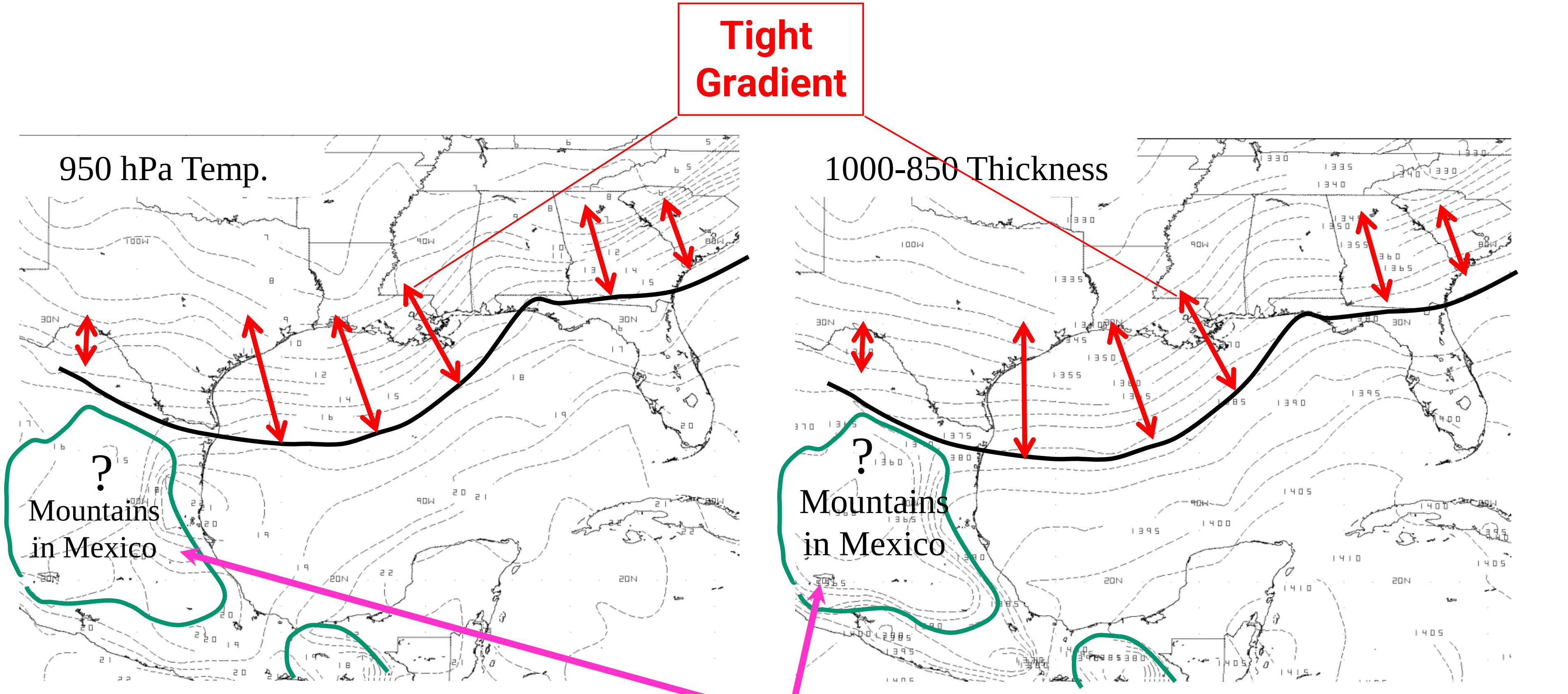
- A gradient is the measure of how much a given variable changes over a distance.

- The rate of change determines the tightness of the gradient and strength of the boundary.

- Tighter gradients relate to
  - More baroclinicity
  - Stronger temperature advection if winds develop, resulting in more violent changes.



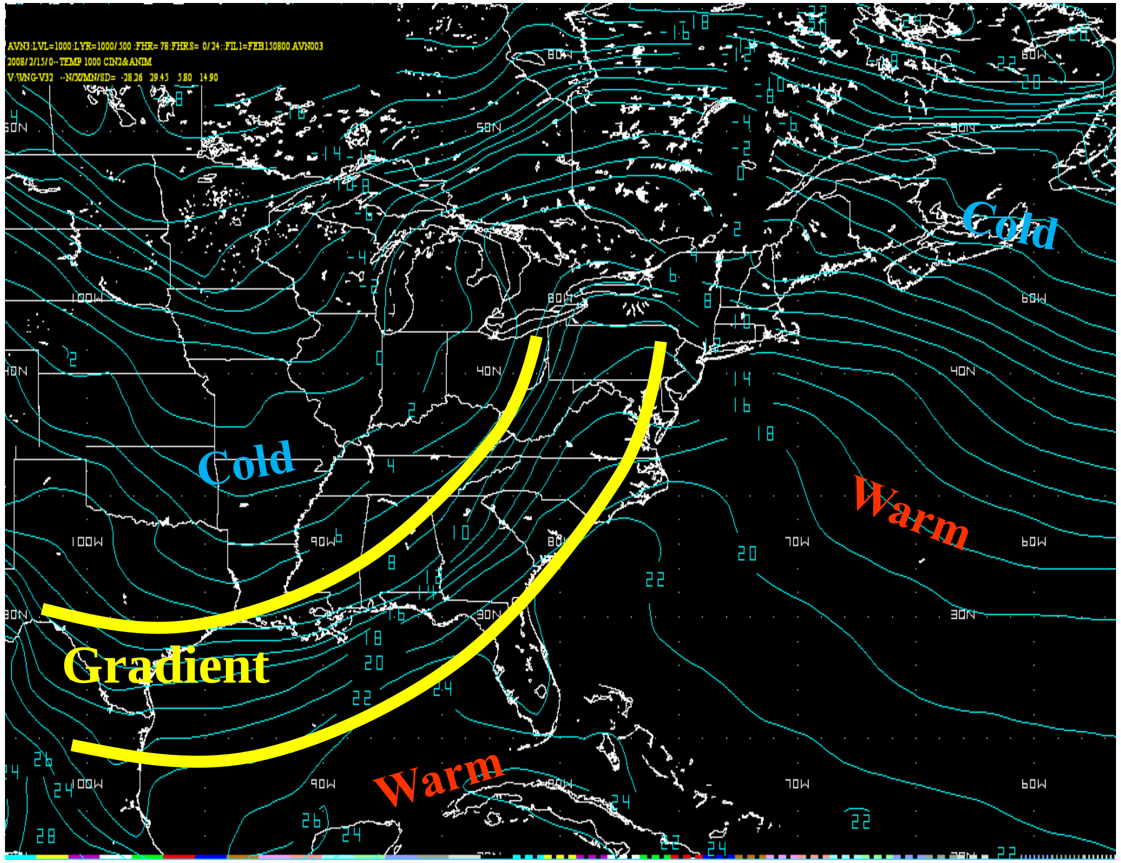
Example: 950 hPa Temp vs. 1000-850 hPa Thickness



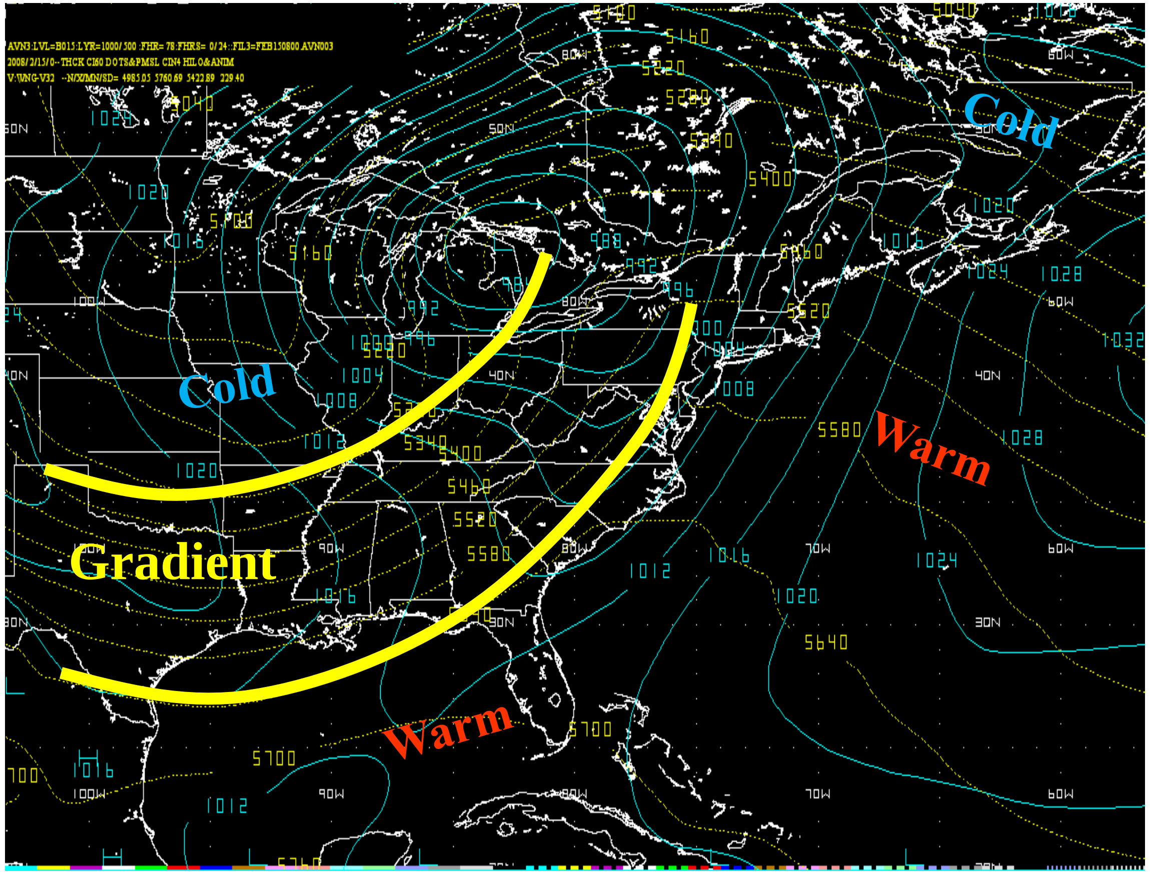
Non frontal, topographically induced gradients.
Very important to know the terrain!

Example: 1000 hPa Temp. vs 1000-500 hPa Thickness

1000 hPa Temperature

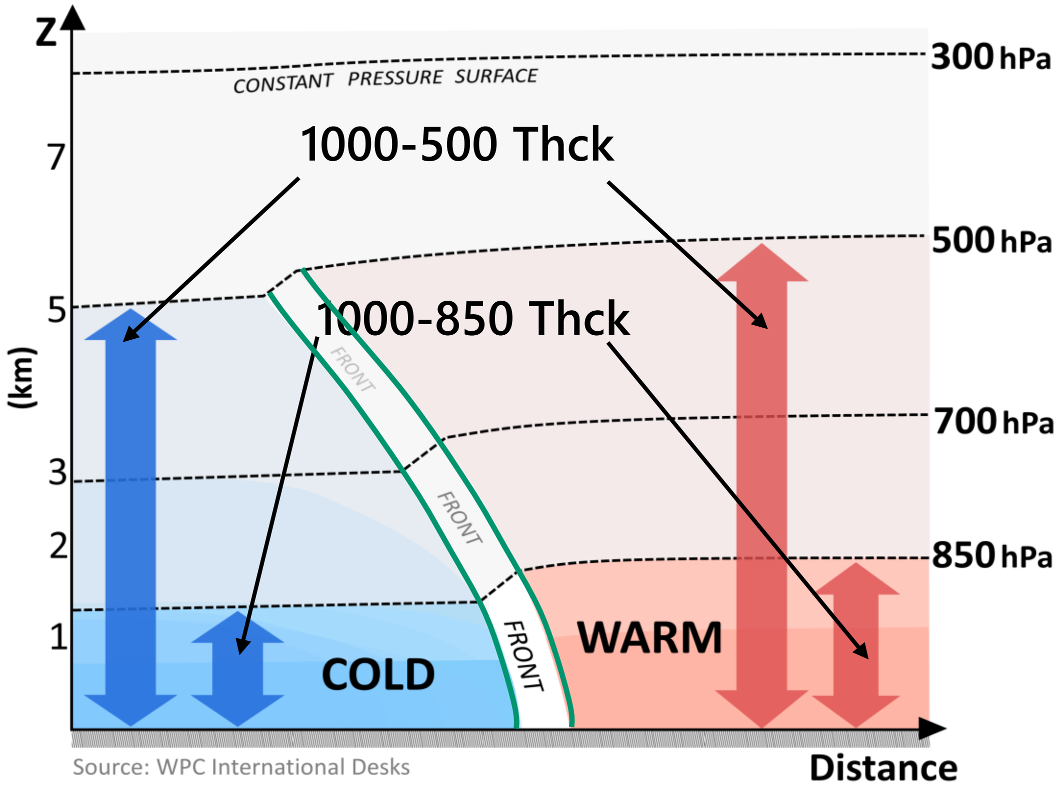


1000-500 hPa Thickness



1000 – 500 vs. 1000 – 850 hPa Thickness

- **1000-500 hPa:** Works in mid latitudes, where cold surges typically span the troposphere.
- **1000-850 hPa:** Works better for the tropics, as fronts become shallow and loose their signature above 850 hPa.
- 1000-925 hPa thickness can also be useful, for tropical latitudes. We use it in WPC International Desks' Front detection algorithm.



Evaluating the Thermal Advection

Required:

1) Wind flow. Recommended wind flow options:

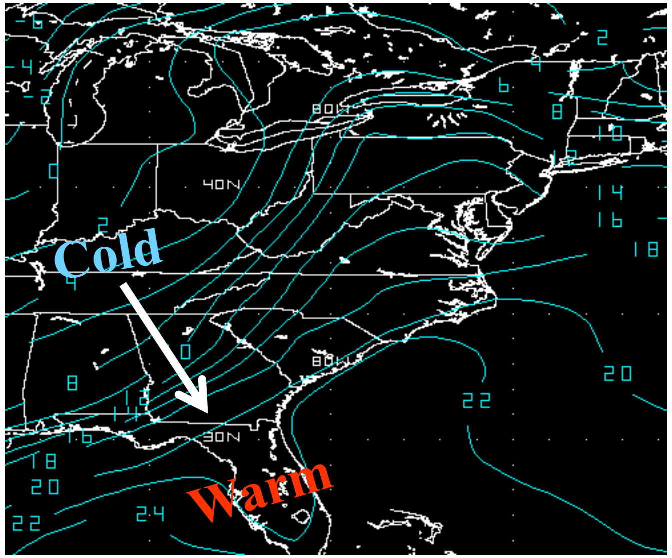
- Total Wind Vectors, barbs or streamlines
- Pressure or Geopotential Heights
  - Assuming geostrophic, wind vectors will lie “parallel” to the pressure contours, and their intensity will be a function on how tight the pressure gradient is.
  - Not too useful in the tropics.

2) A scalar field representing temperature/density. Recommendations:

- Temperature
- Thickness (mean layer temperature)
- Others: Equivalent potential temperature, potential temperature, dewpoint

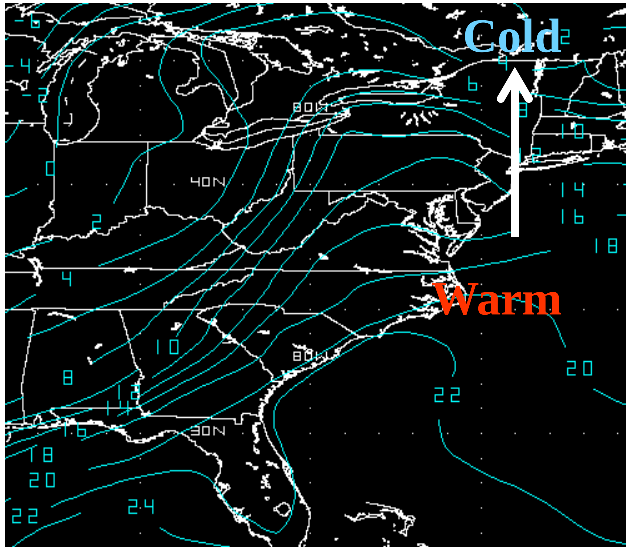
Cold , Warm and Neutral Advection

Cold Advection



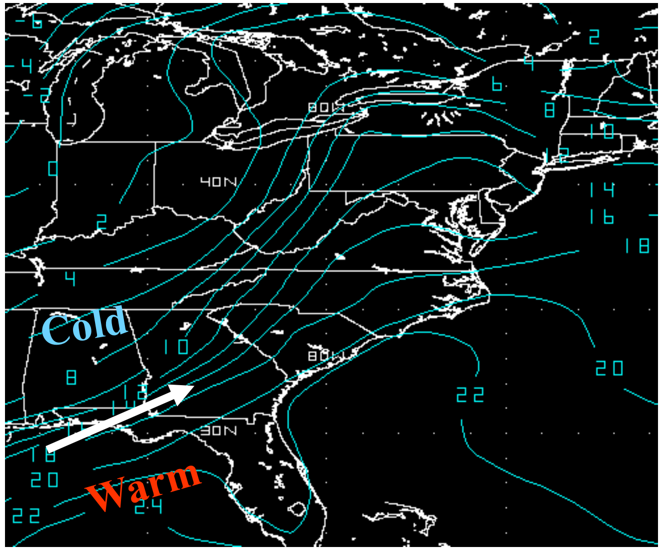
When the flow across the thermal gradients points from cold to warm.

Warm Advection



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

Neutral Advection



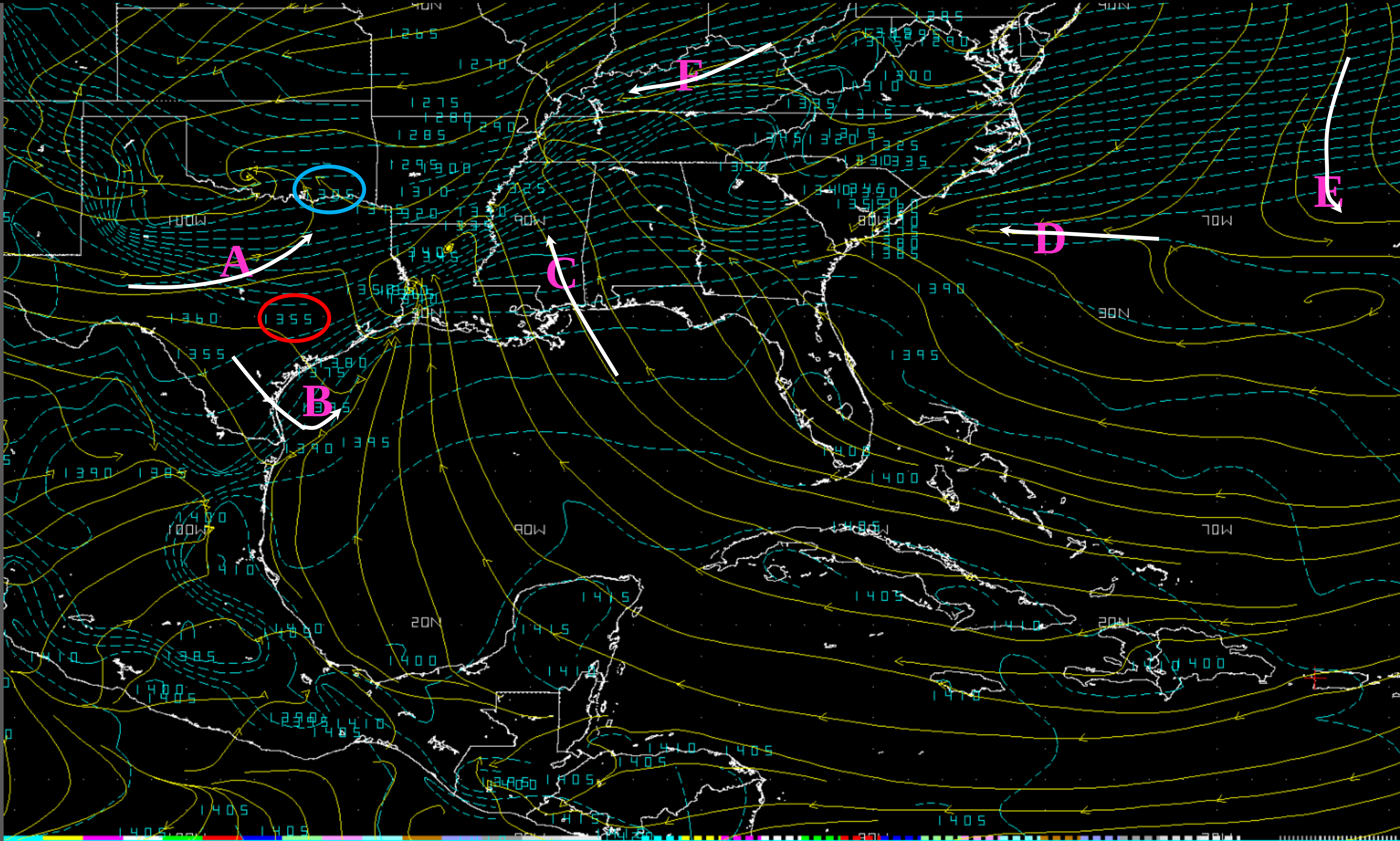
The flow is parallel to the gradient and the front lies stationary.

Temperature Advection Analysis Exercise

Instructions:

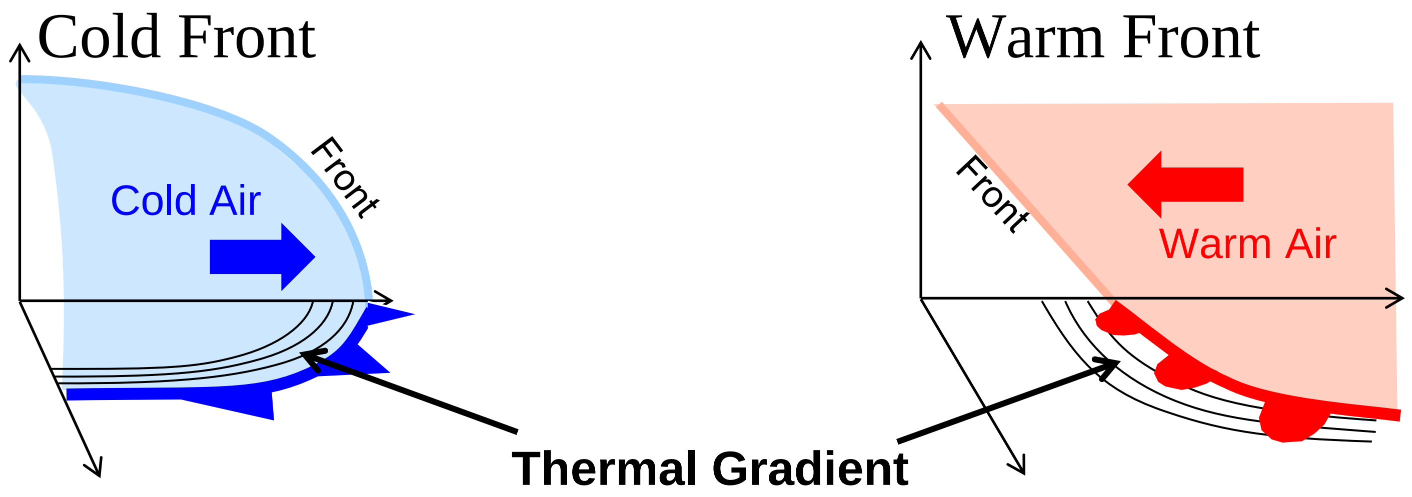
Where indicated, using the flow with respect to the thickness gradient determine if the advection is:

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

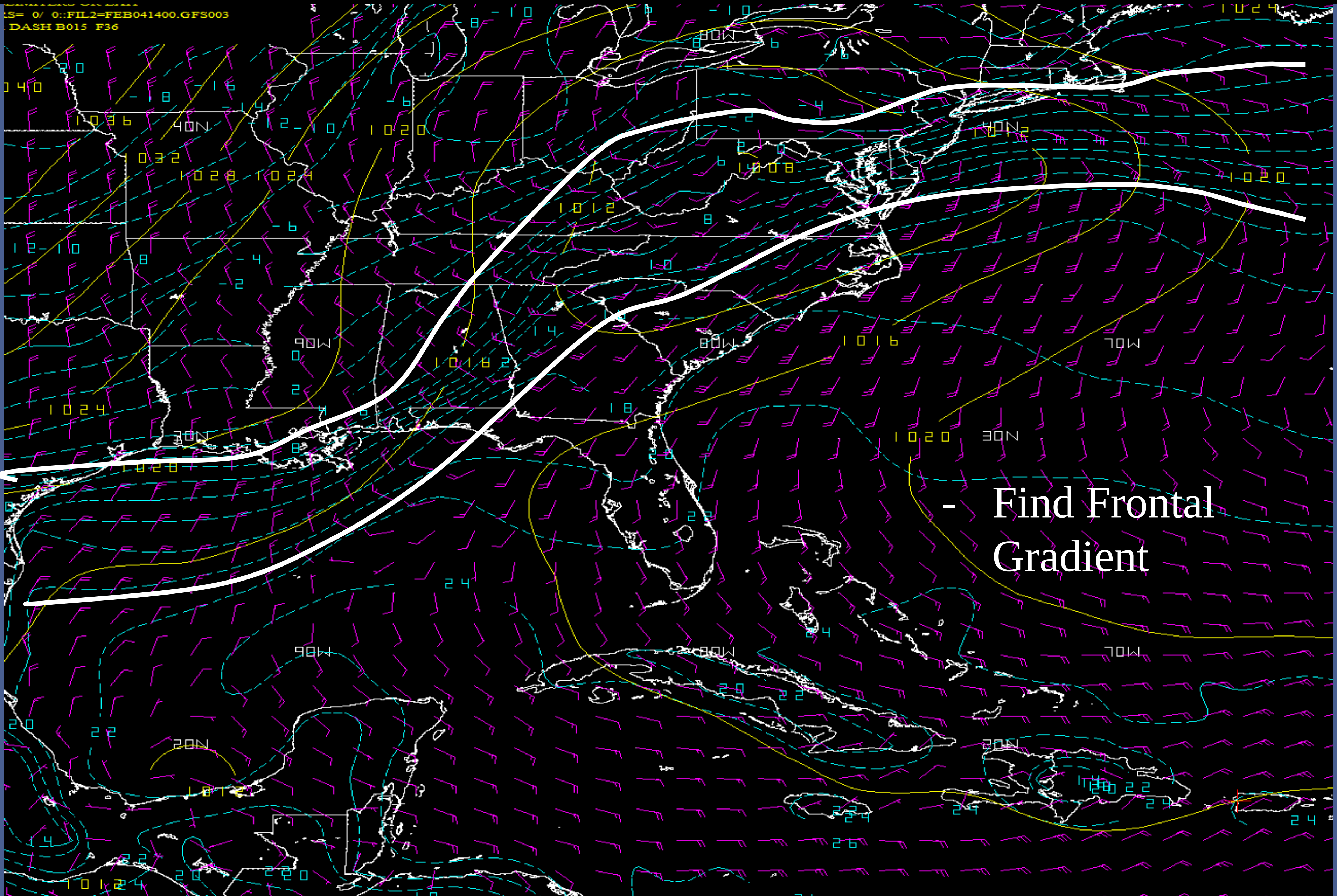


Proper Placement of Surface Front

- Surface Fronts are **<u>always drawn on the warm side</u>** of the tighter thermal gradient and along a trough. The trough is not always well defined.

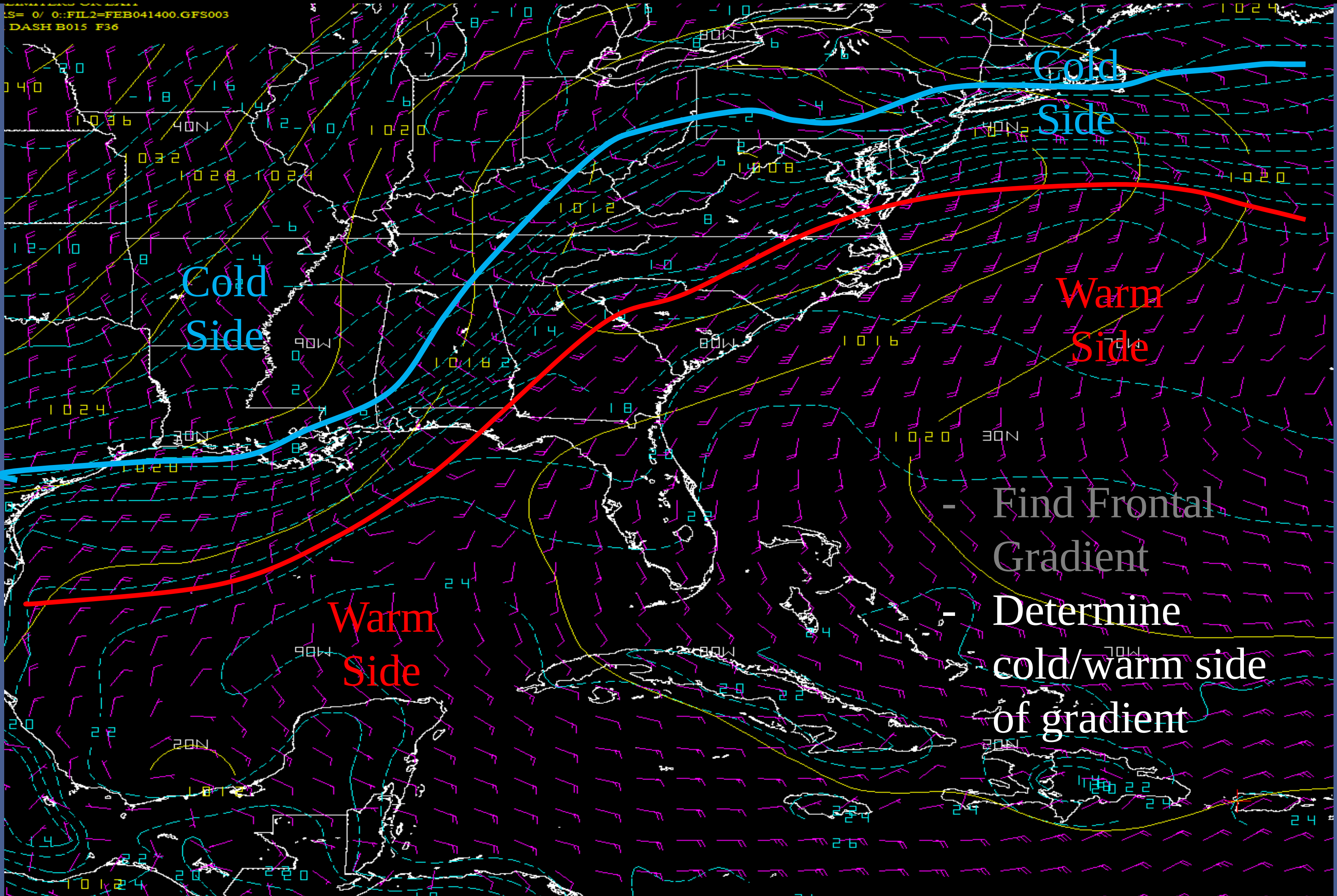


Drawing the Surface Front: PMSL and BL Temps



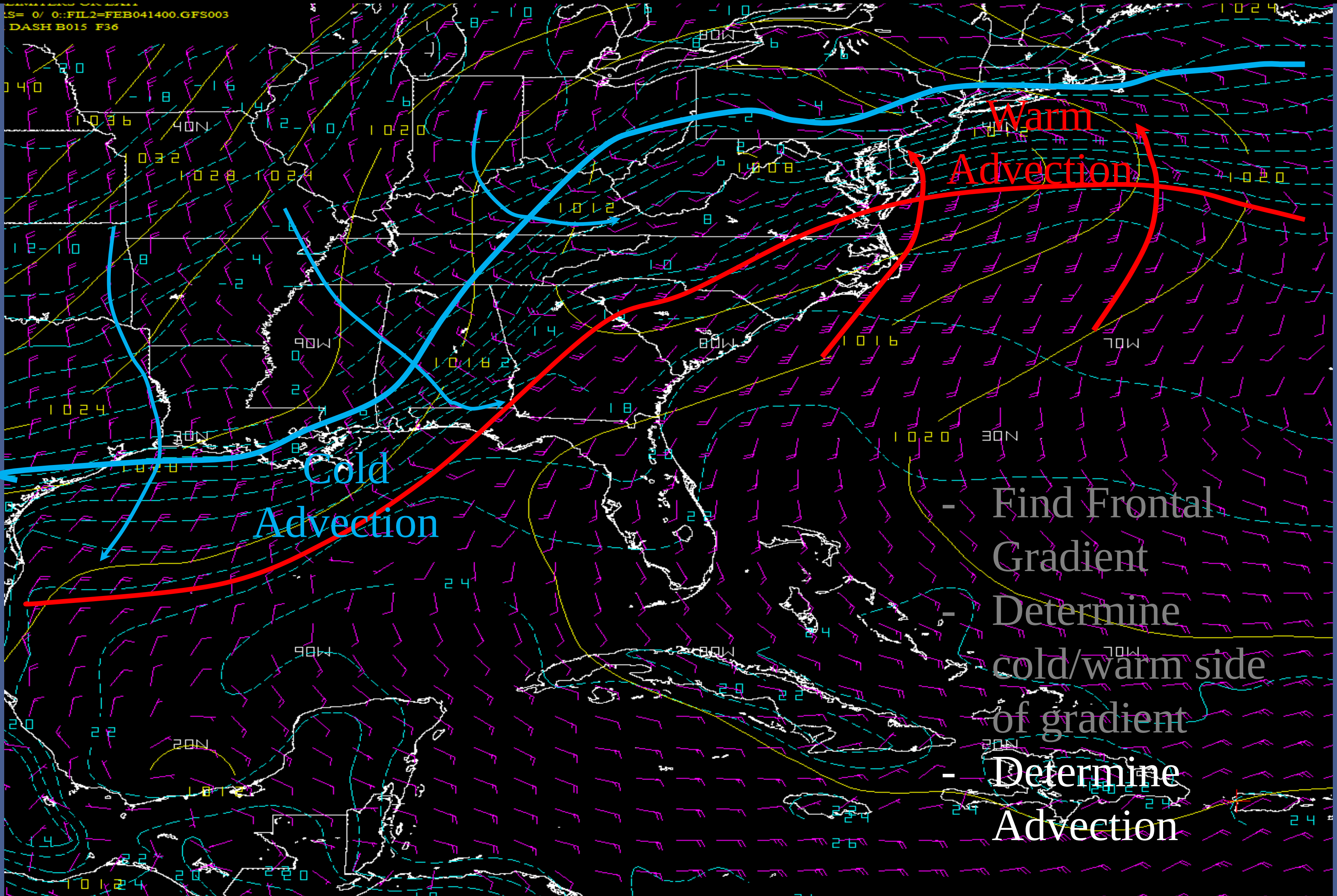
- Find Frontal Gradient

Drawing the Surface Front: PMSL and BL Temps



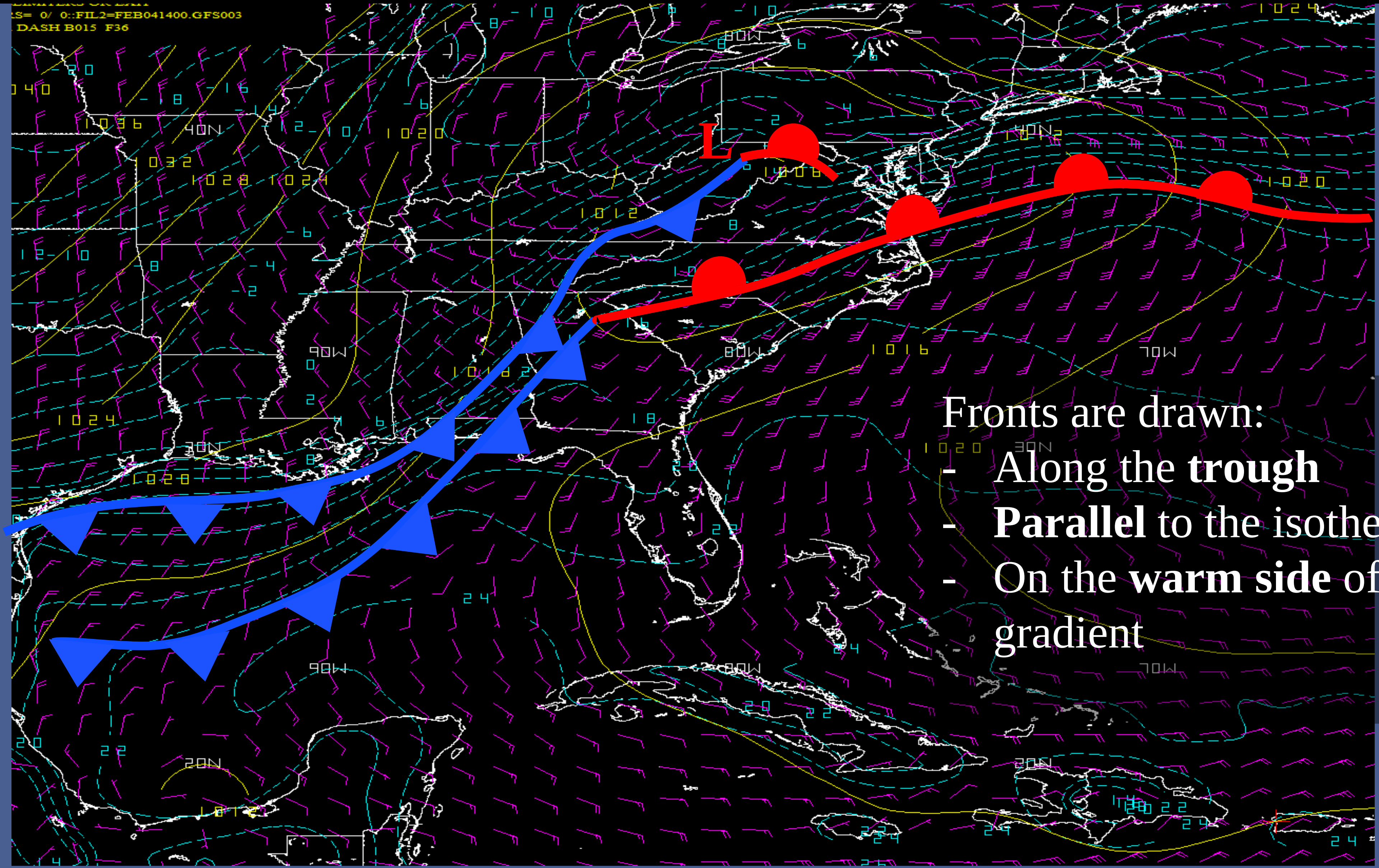
- Find Frontal Gradient
- Determine cold/warm side of gradient

Drawing the Surface Front: PMSL and BL Temps



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

Drawing the Surface Front: PMSL and BL Temps

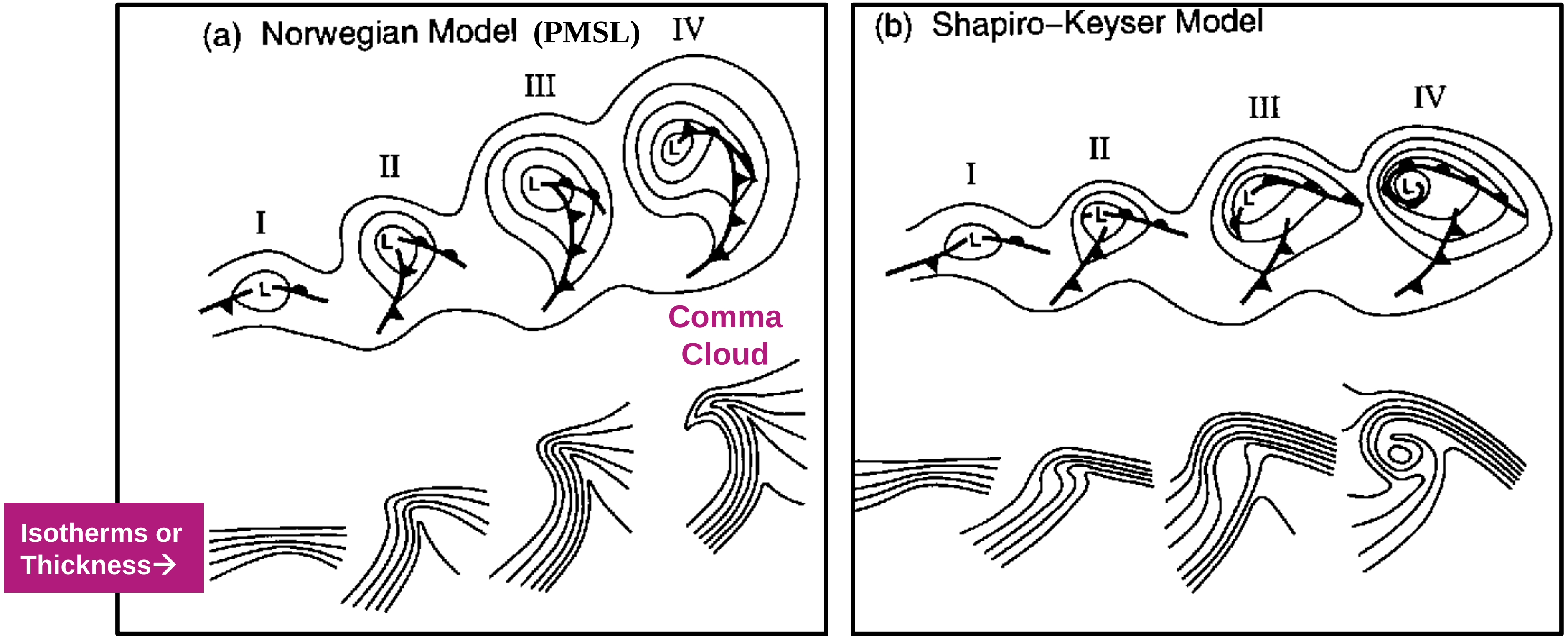


Fronts are drawn:

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

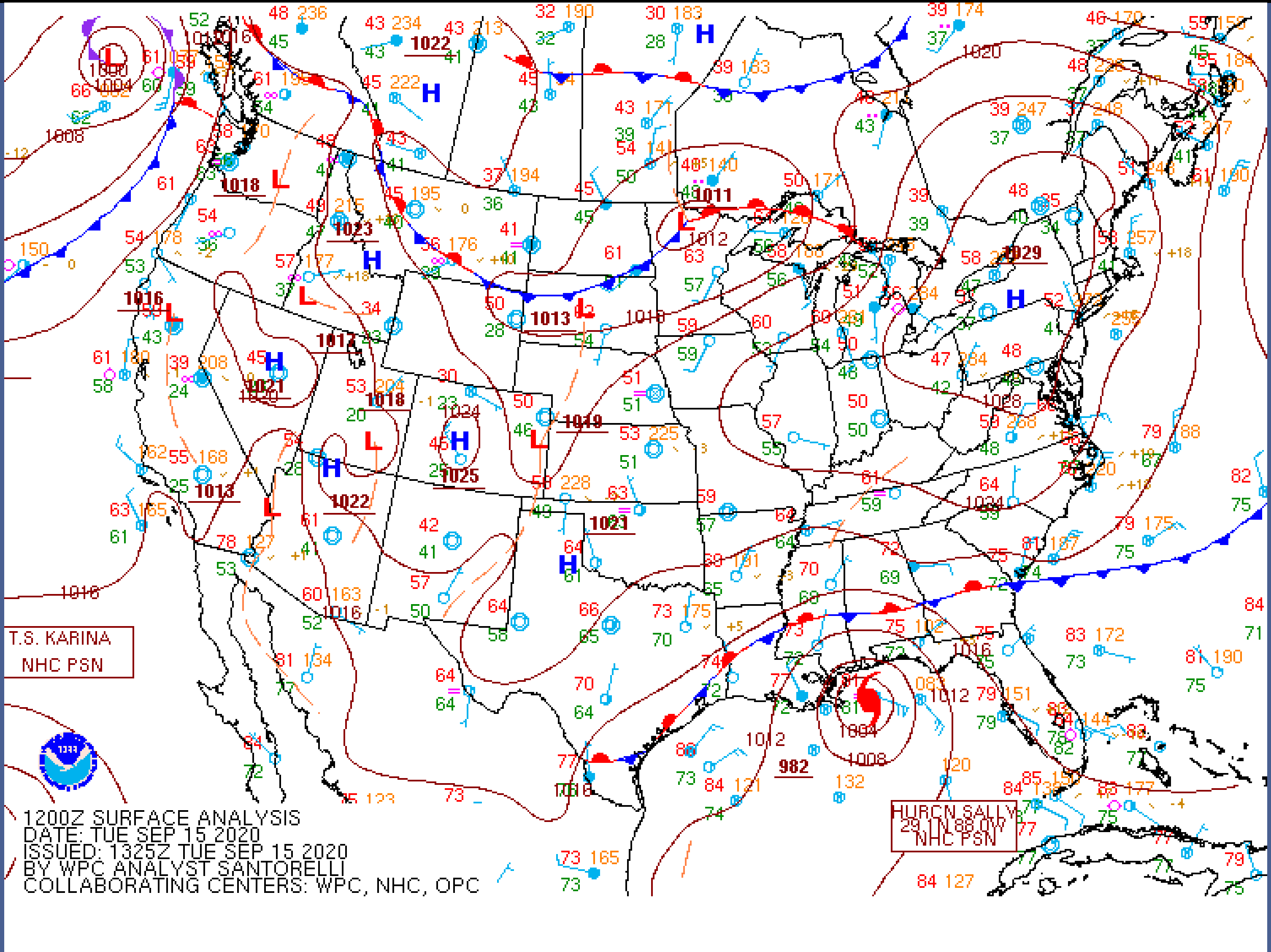
Conceptual Model of Extratropical Cyclones Northern Hemisphere

- Fronts associate with extratropical cyclones. There are different models for analysis:



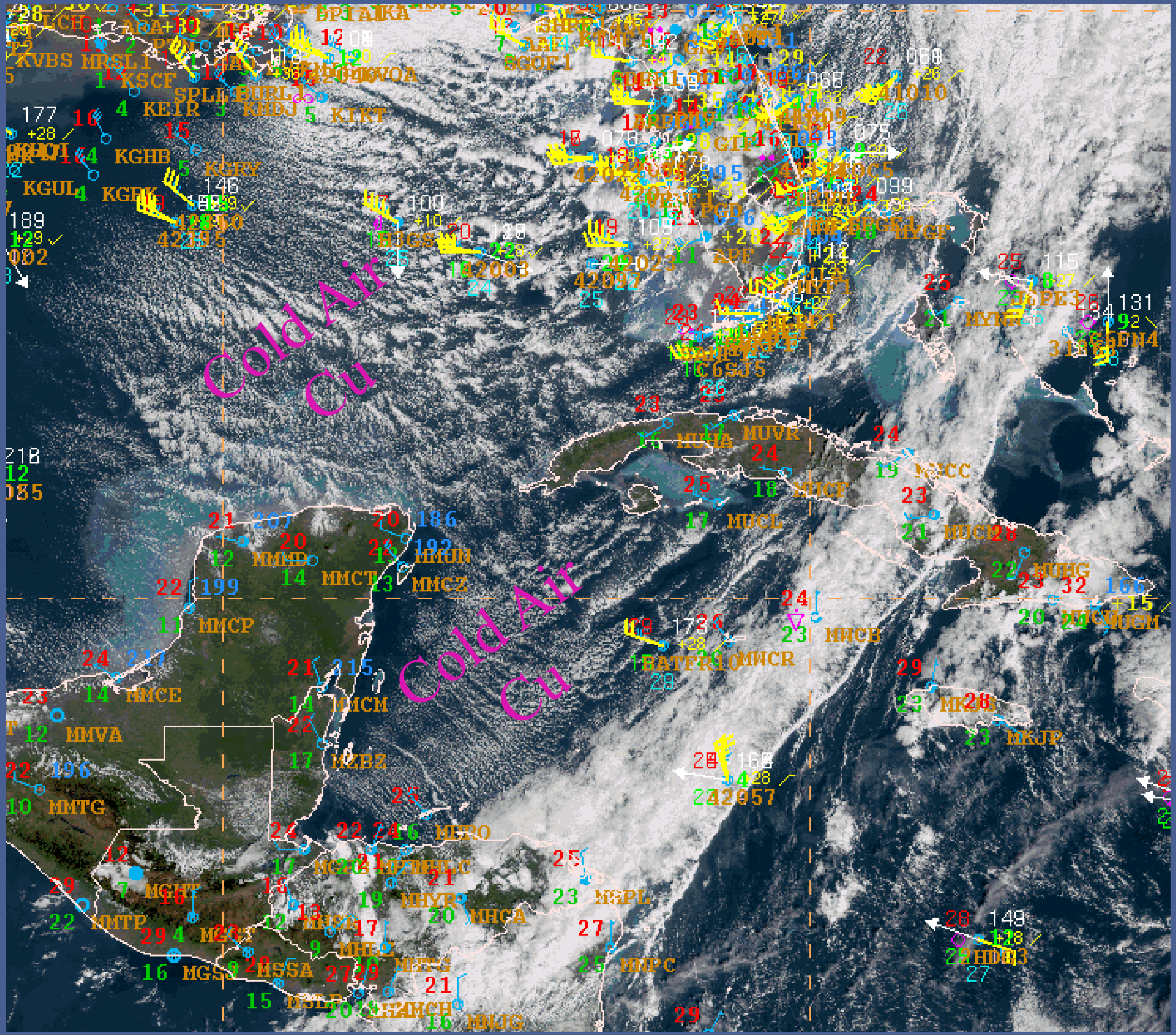
I. Frontal Wave Forms
II. Frontal Wave
III. Occluding Front
IV. Occluded Front

Application Conceptual Model – CONUS

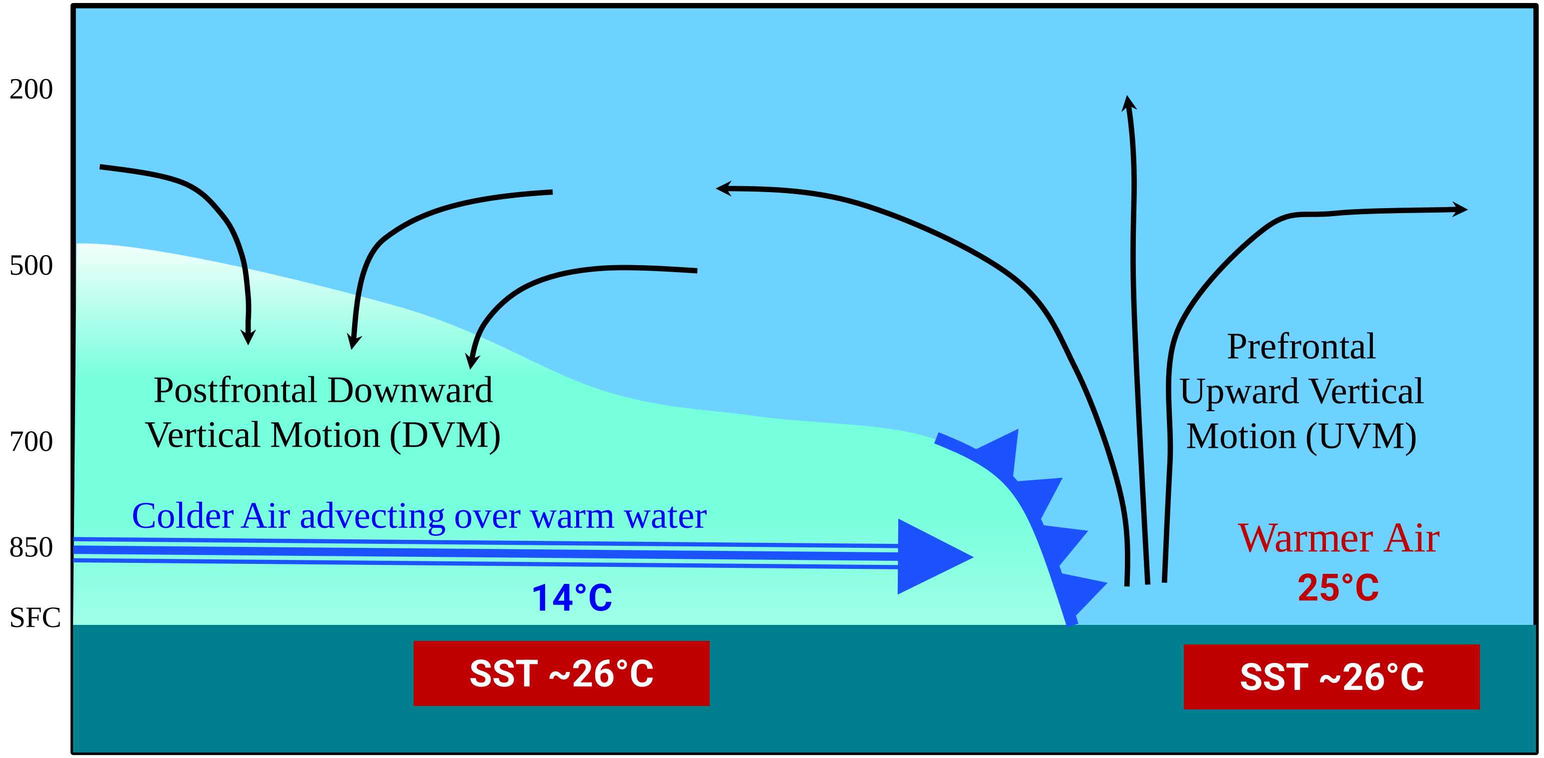


Cold Advection over Warmer Waters
Post Frontal-Cold Air Cu

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

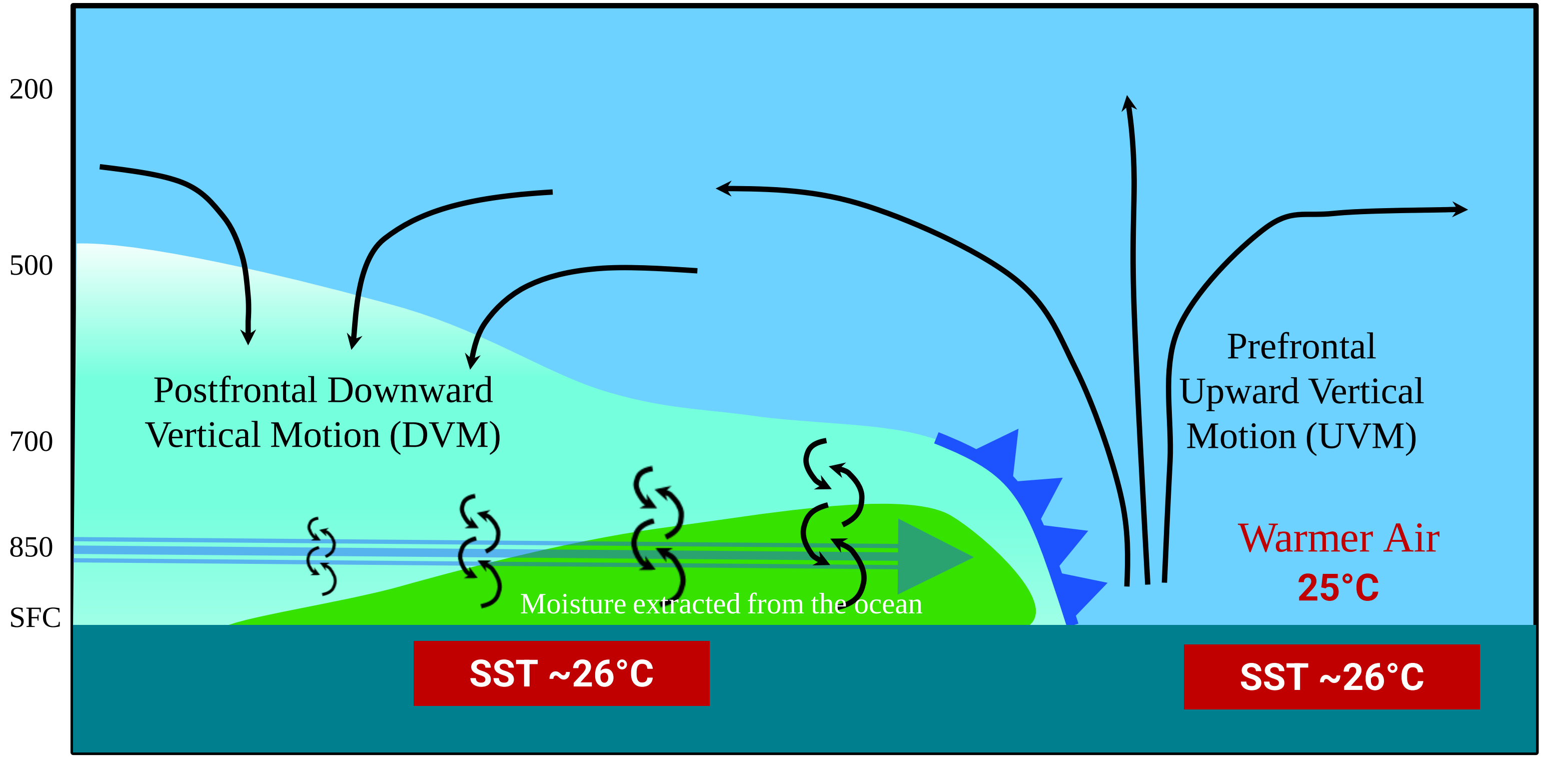


Mechanism Leading to the Formation of Post Frontal Cold Air Cu



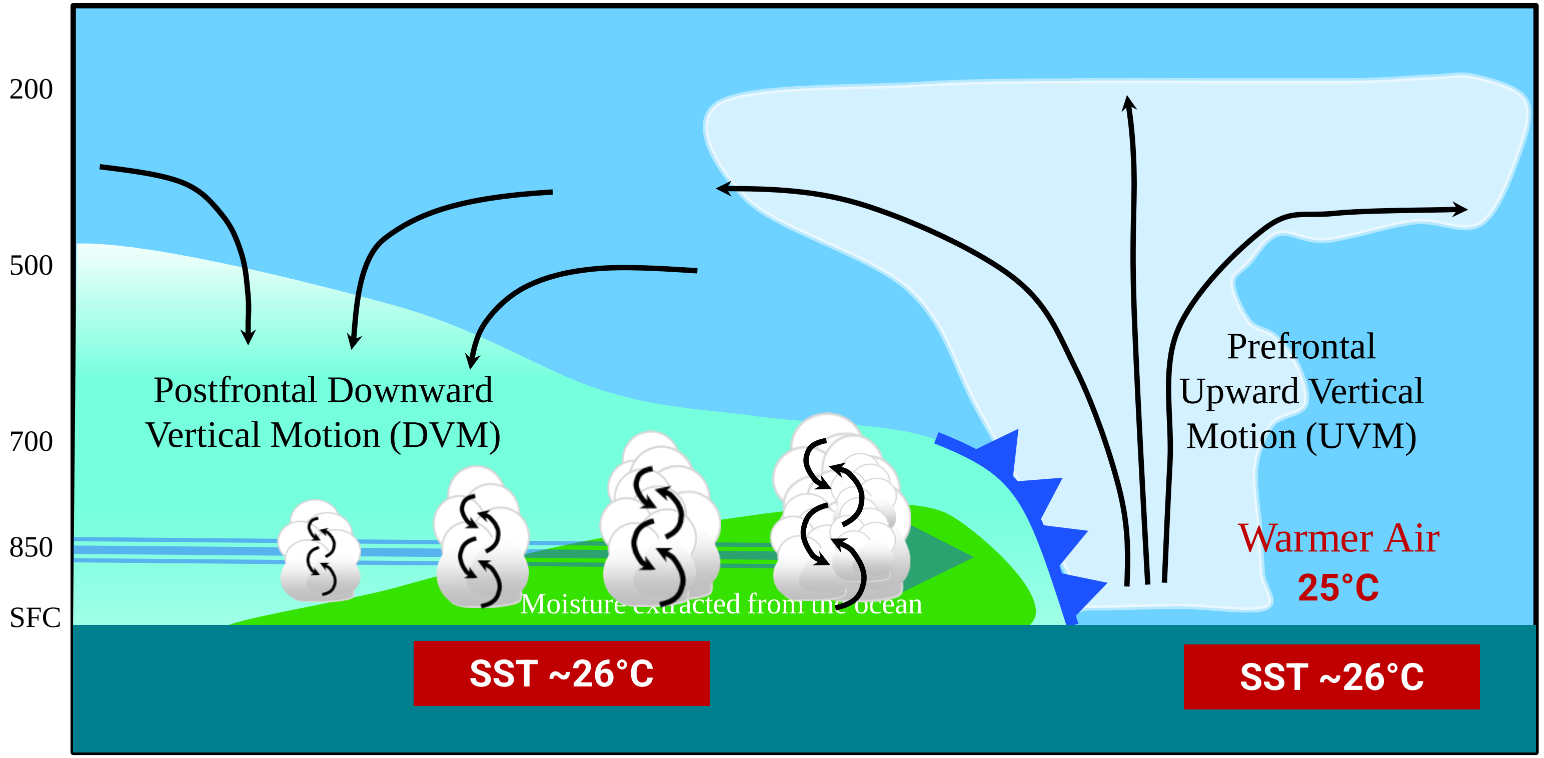
- Contrast between air masses and low level convergence results in upward vertical motion (UVM) ahead of the surface front.
- In an upper convergent pattern, the colder post frontal air sinks

Mechanism Leading to the Formation of Post Frontal Cold Air Cu



At low levels, the stronger winds extract moisture from the ocean and favor enhanced mixing inside the boundary layer. Vertical mixing is enhanced by instability, produced by the colder air moving over warmer SST.

Mechanism Leading to the Formation of Post Frontal Cold Air Cu

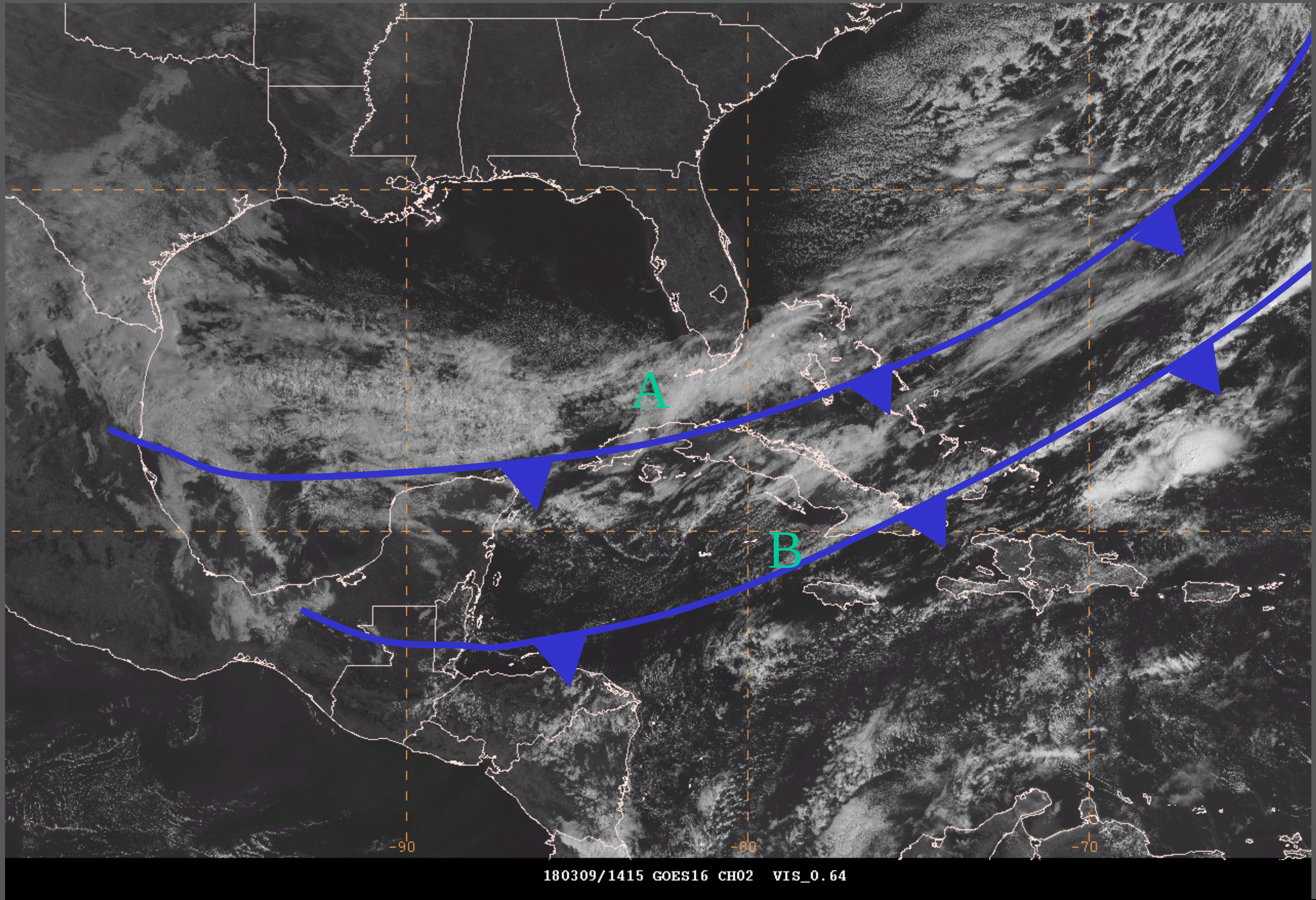


- The deep UVM motion ahead of the front results in deep cloud cover
- Post frontal convection, facing DVM, caps at mid levels. This process continues as long as cold air advects over the warmer ocean waters.

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

Is there a front in A or B… or both?



Front Analysis Tools

Tools for Front Detection and Analysis

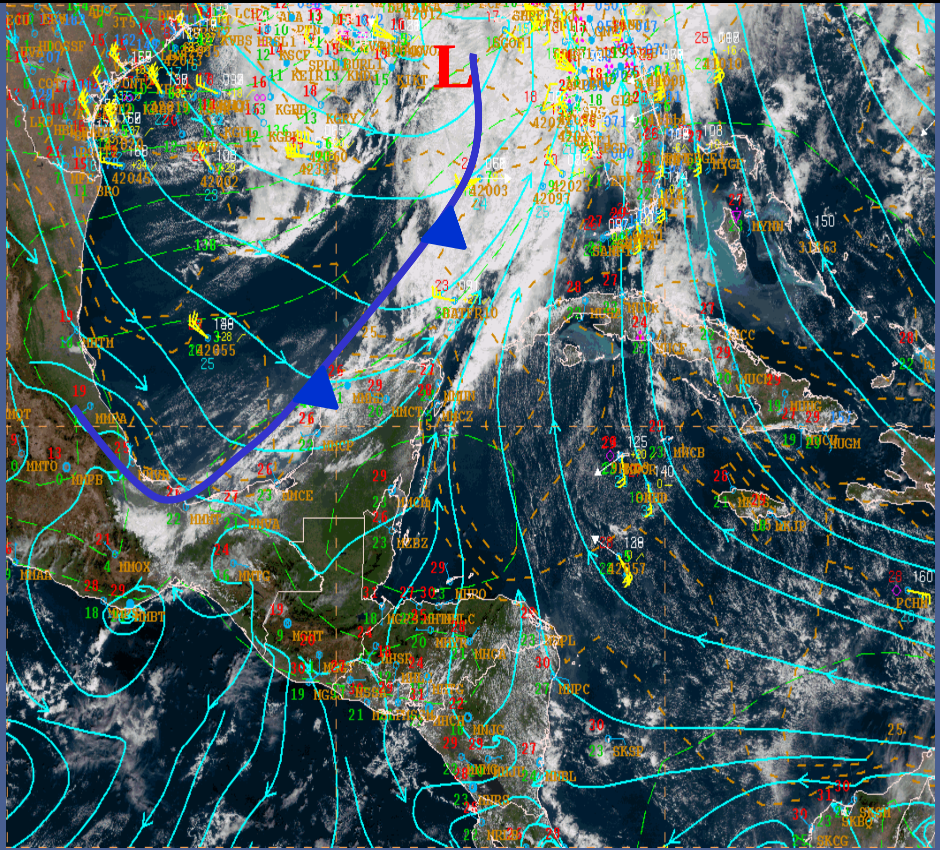
- Temperature / Thickness gradients (for baroclinicity)
- Winds and surface pressure (for the detection of the surface trough, position of the front and advection)
- Relative humidity (for rapid detection of a potential boundary, vigen that high relative humidity in the column usually peaks near fronts)
- Equivalent potential temperature (for detection of gradients between warm/moist and cool/dry air masses)
- Precipitable water and dewpoint (they often relate to differences in air mass moisture)

Some specific for the Caribbean

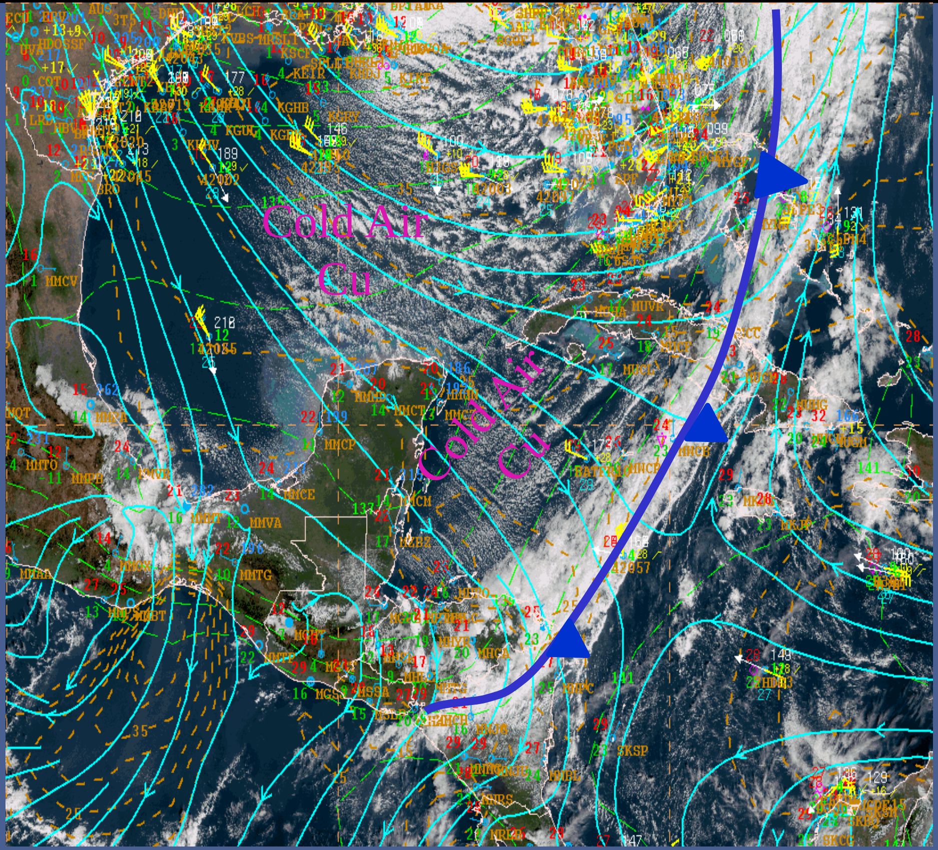
- ΔT
  - Temperature drops following frontal passage. Tropical air masses: 2-4°C
- Pressure Tendency ($\Delta P/\Delta t$)
  - Pressure drops as the frontal trough approaches, rises after passage (polar ridge building)
- Dewpoint (Td)
  - Td alone cannot determine baroclinicity, but complements the analysis by describing moisture decreases associated with post frontal air masses.
  - Td ~ 18°C is often a good parameter to evaluate the southern boundary of polar air masses.
- Clouds
  - Ceiling drops as the front arrives.

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



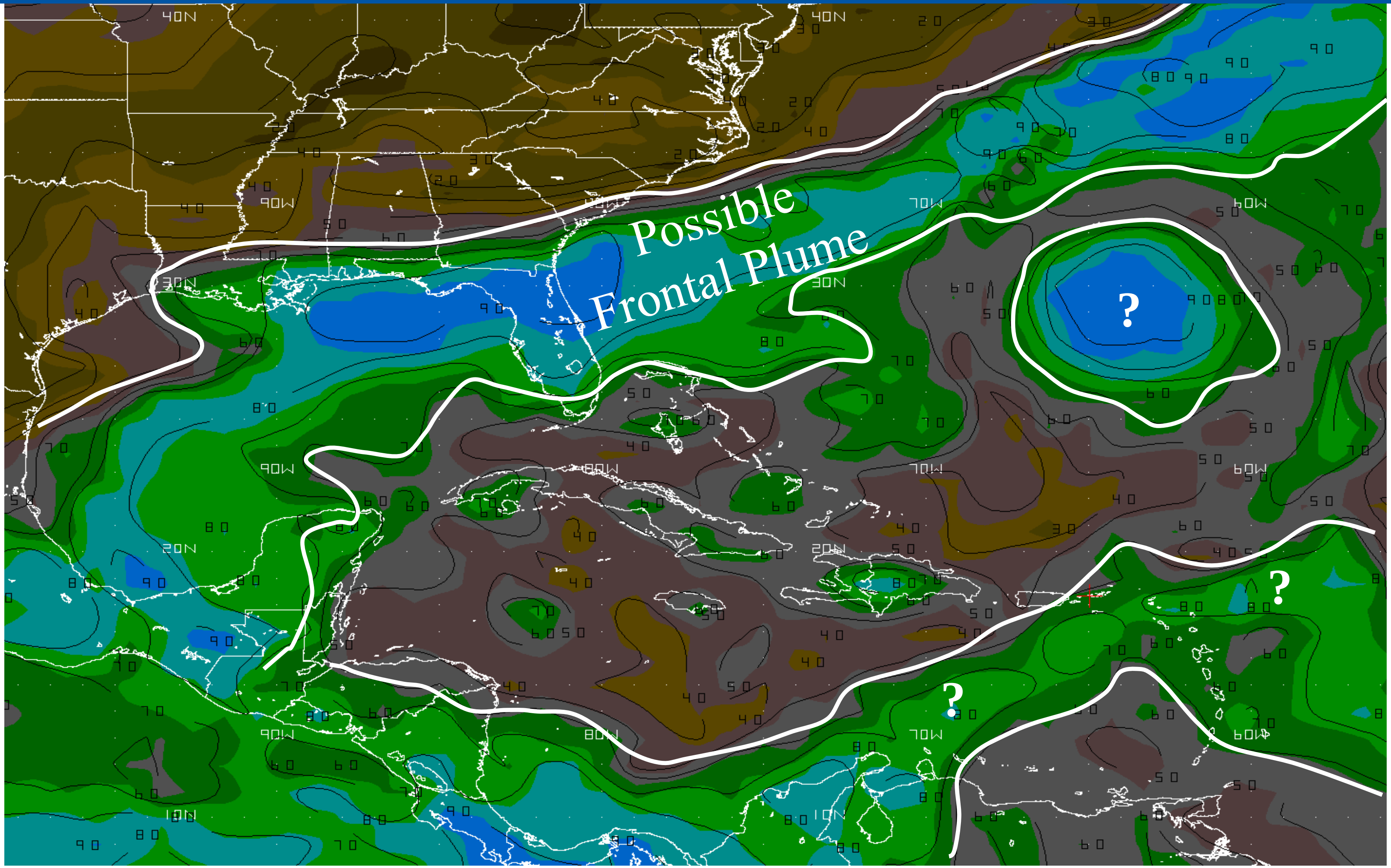
Postfrontal Over the Yucatan
T=21-22C, Td= 12-14C
20181221_15:15Z

Mean Layer Relative Humidity

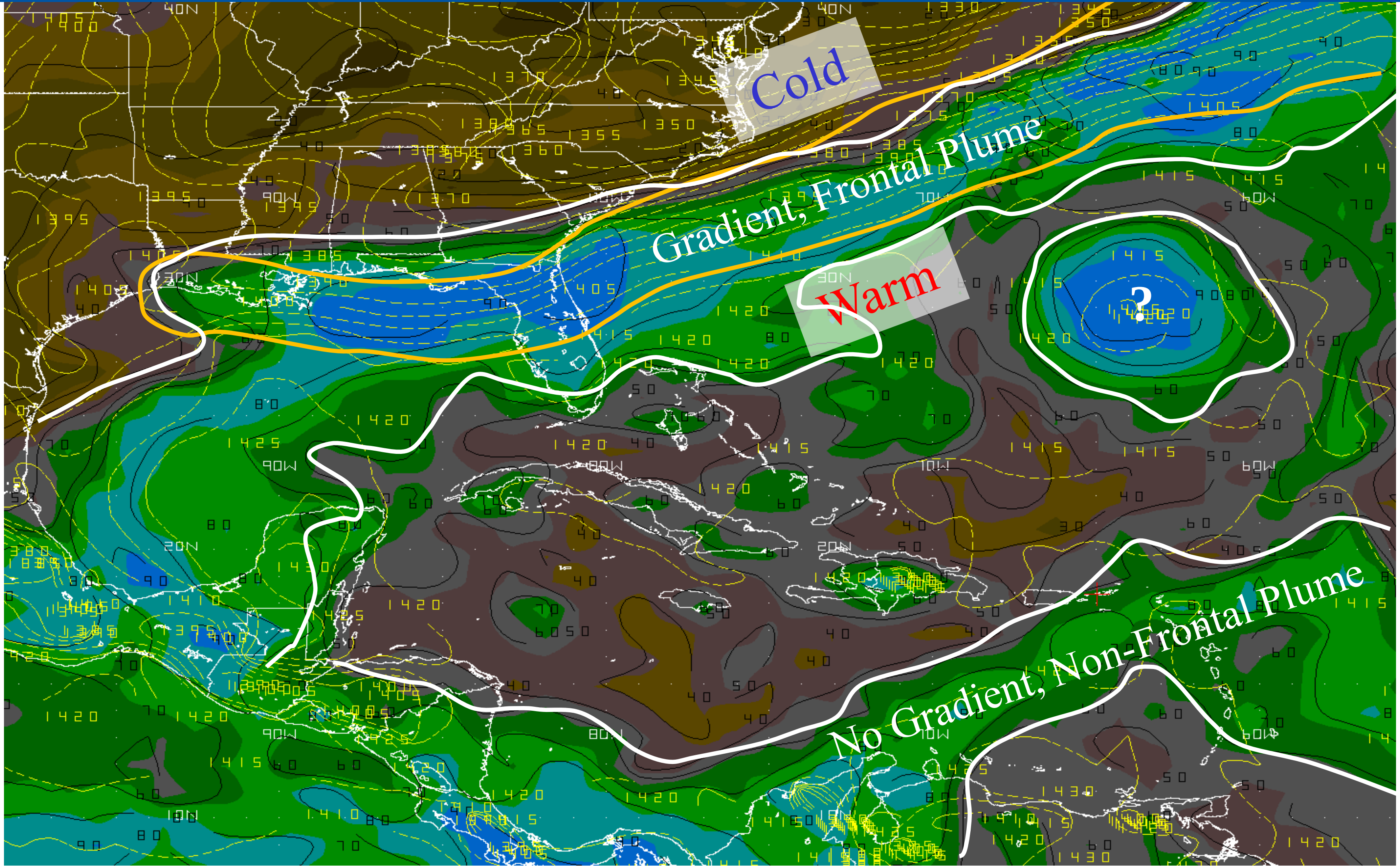
- **Mean Layer Relative Humidity**
  - The mean layer relative humidity between the surface and 500 hPa
  - RH tells us how close to saturation
    - Does not quantify moisture content
  - Typically, RH 60% or greater for significant cloud cover
  - Quasi-conservative property
    - As the front propagates,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

Mean Layer RH

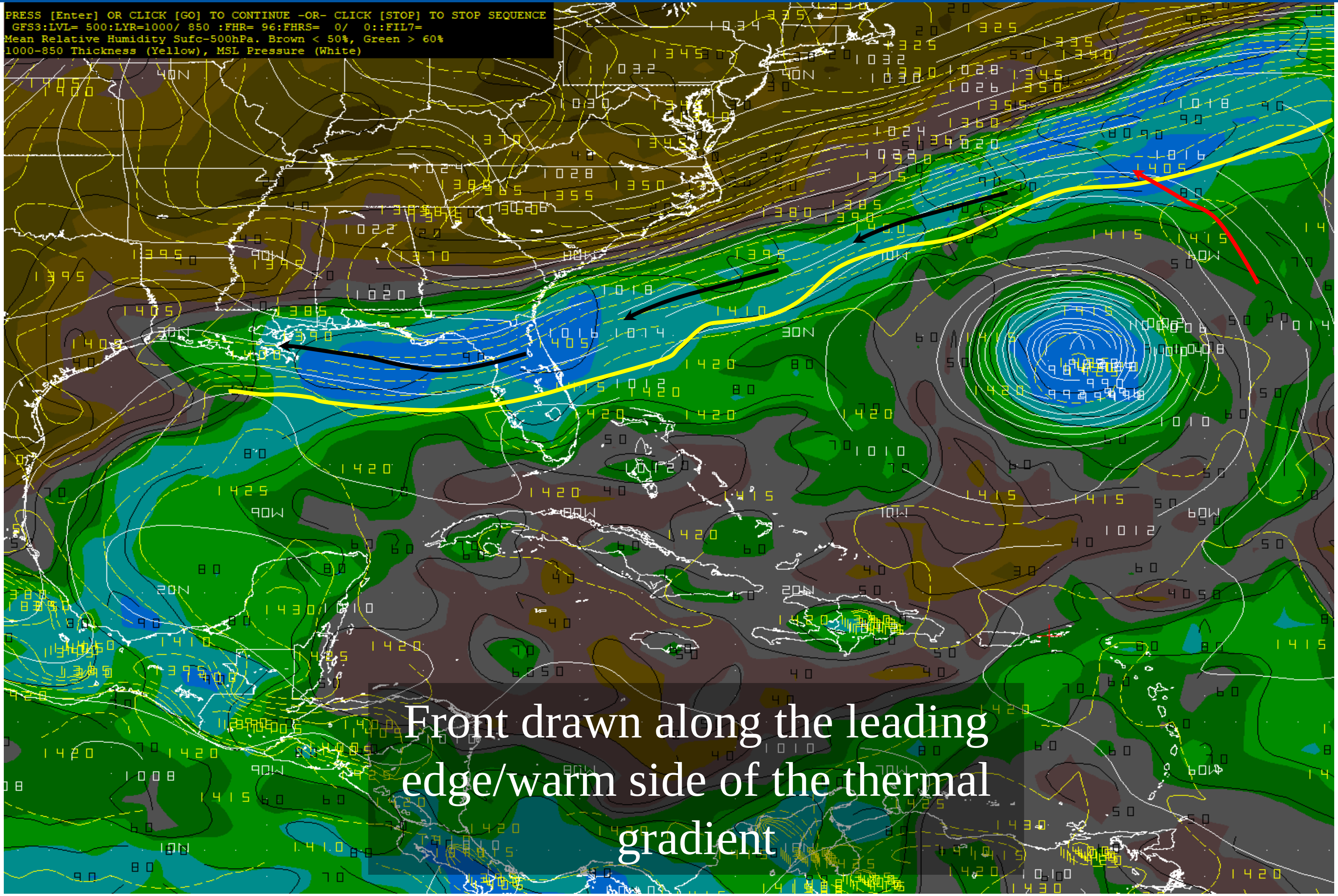
From GFS, 20200917_00, F96



Mean Layer RH / 1000-850 THCK

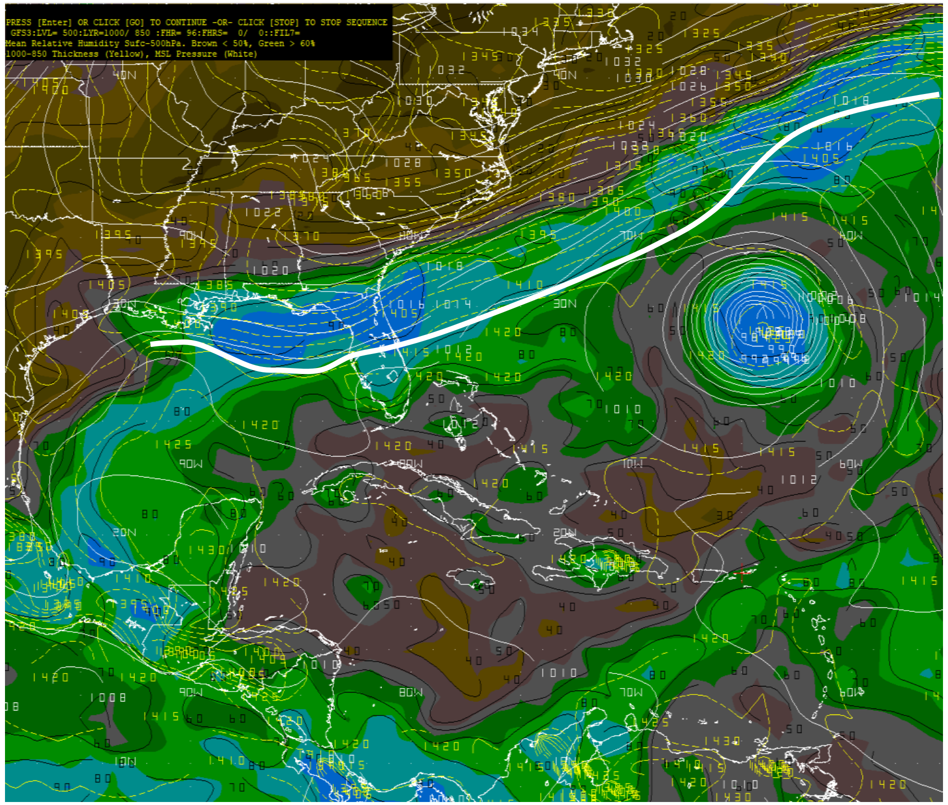


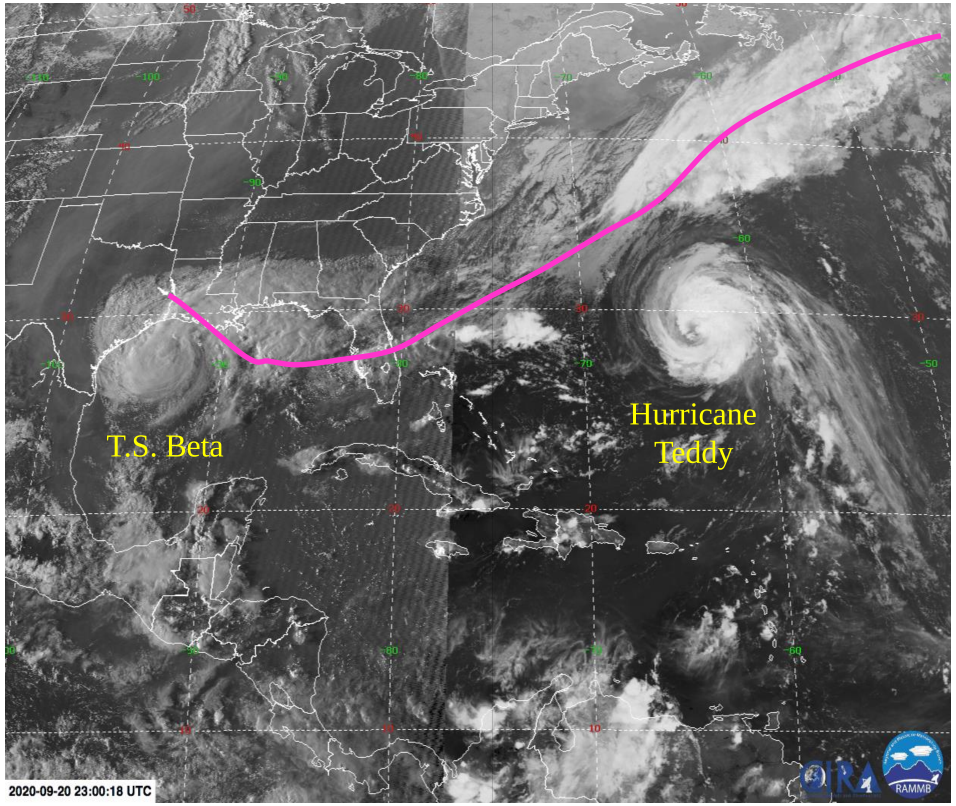
Mean Layer RH, THCK, PMSL



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

Verification of the Forecast





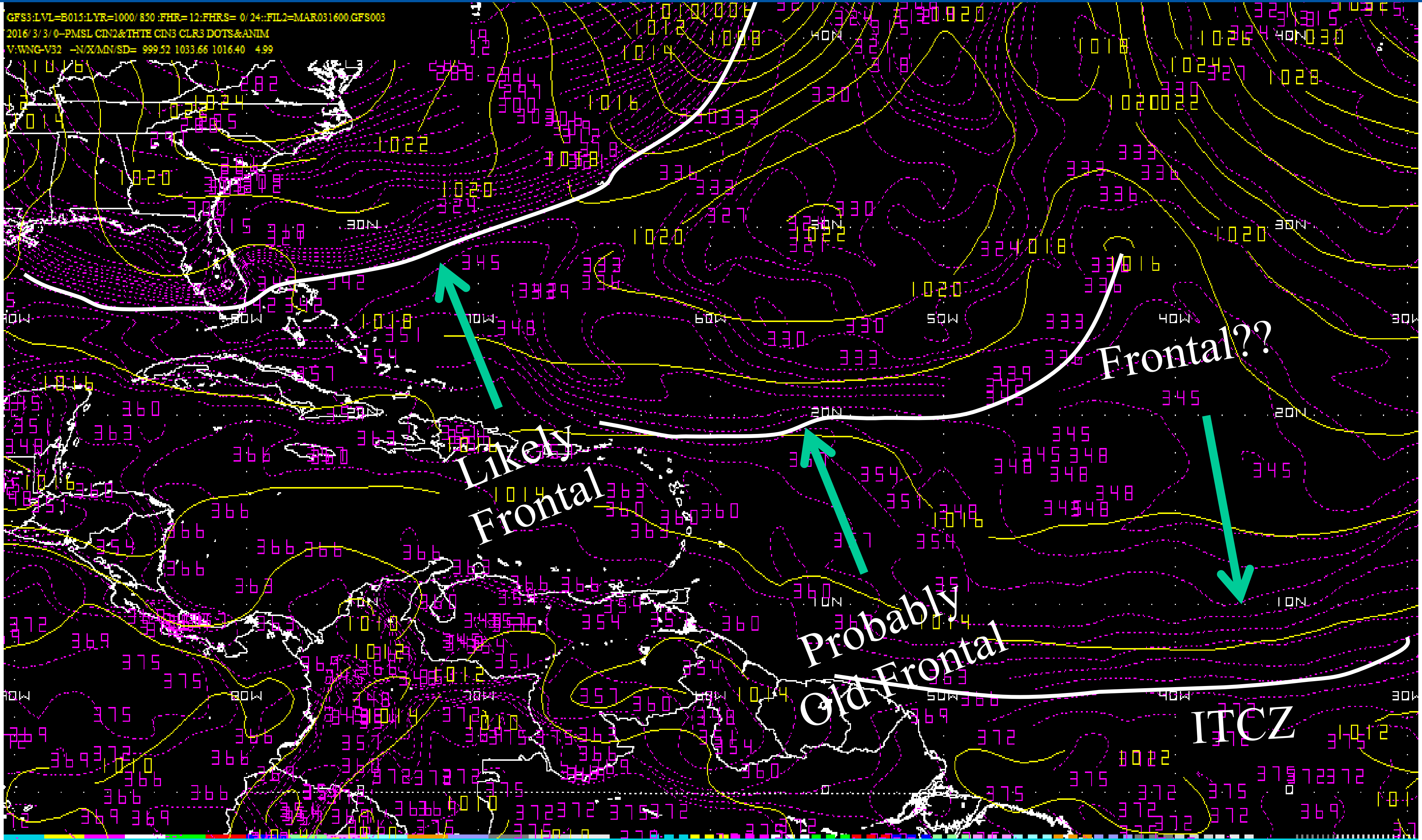
VT: 20200921/00Z

Equivalent Potential Temperature (EPT)

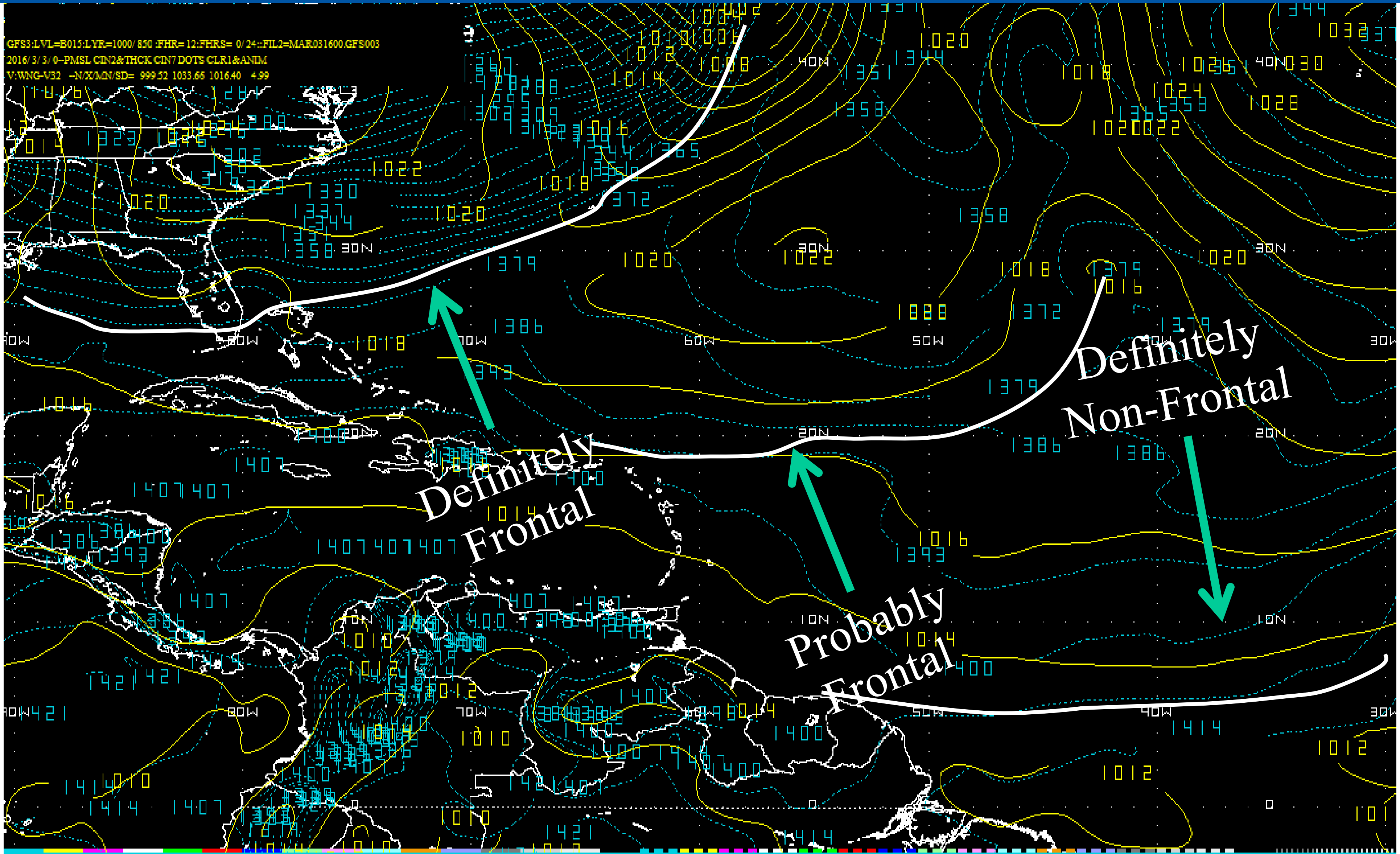
- Temperature of a parcel of air when you add the latent heat released during condensation to the sensible temperature of the parcel at constant pressure (1000 hPa)
  - It depends on the moisture content and actual temperature of the parcel

- **If T held constant, EPT then varies as a function of the moisture content of the parcels**

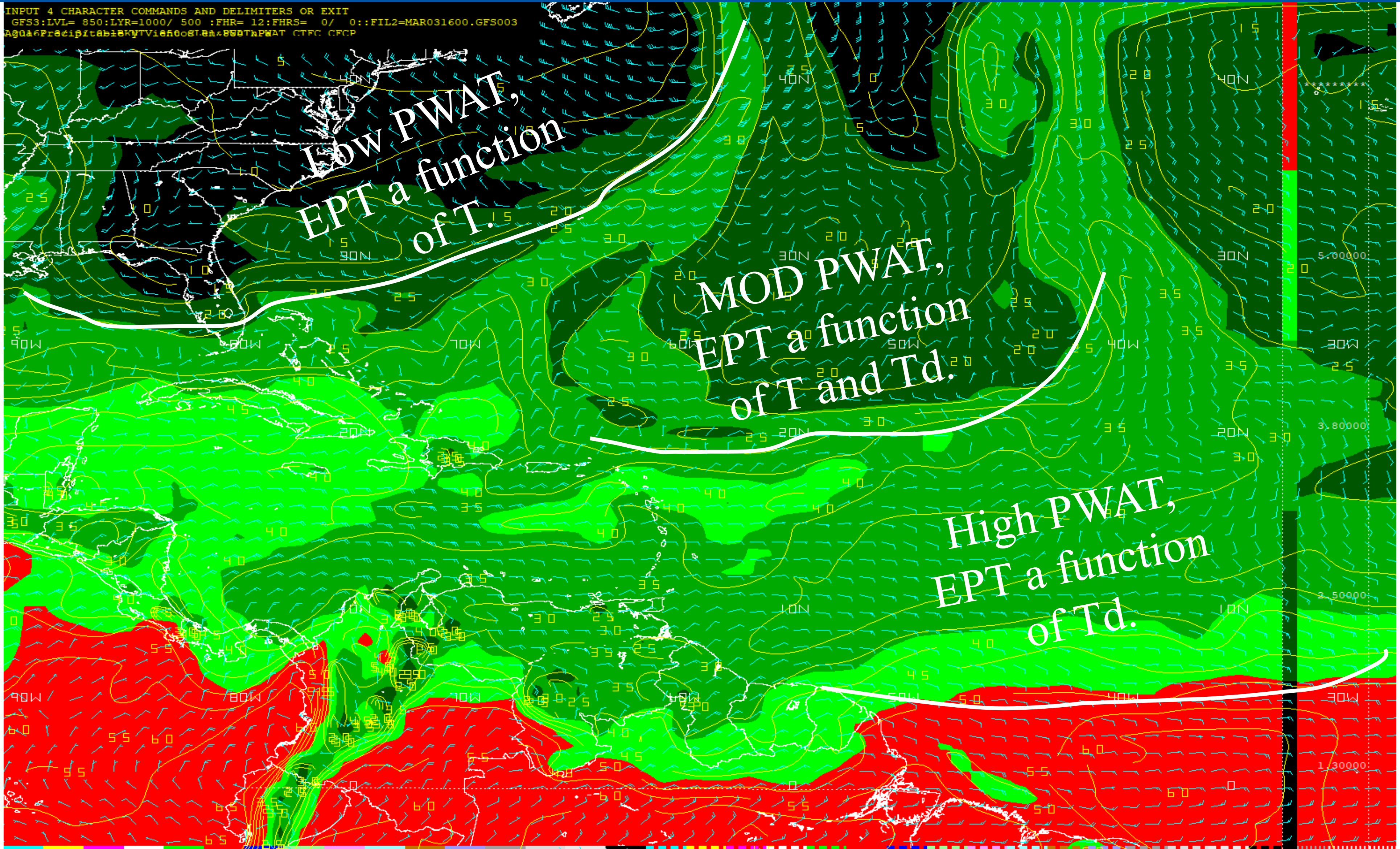
EPT and MSLP
Evaluate Frontal Gradients



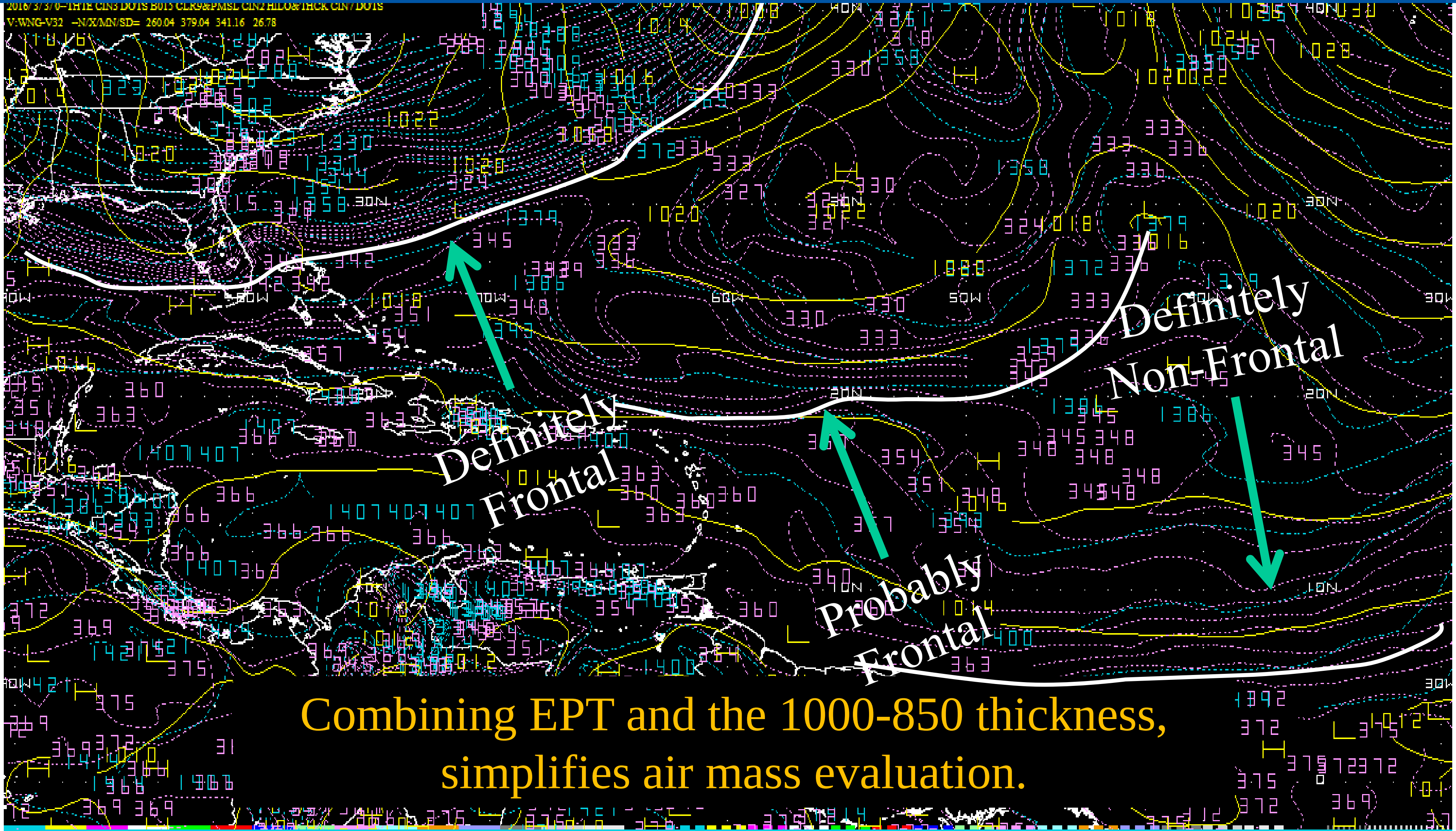
1000-850 Thickness and MSLP
Evaluate Frontal Gradients



EPT as a function of Moisture Content (PWAT)



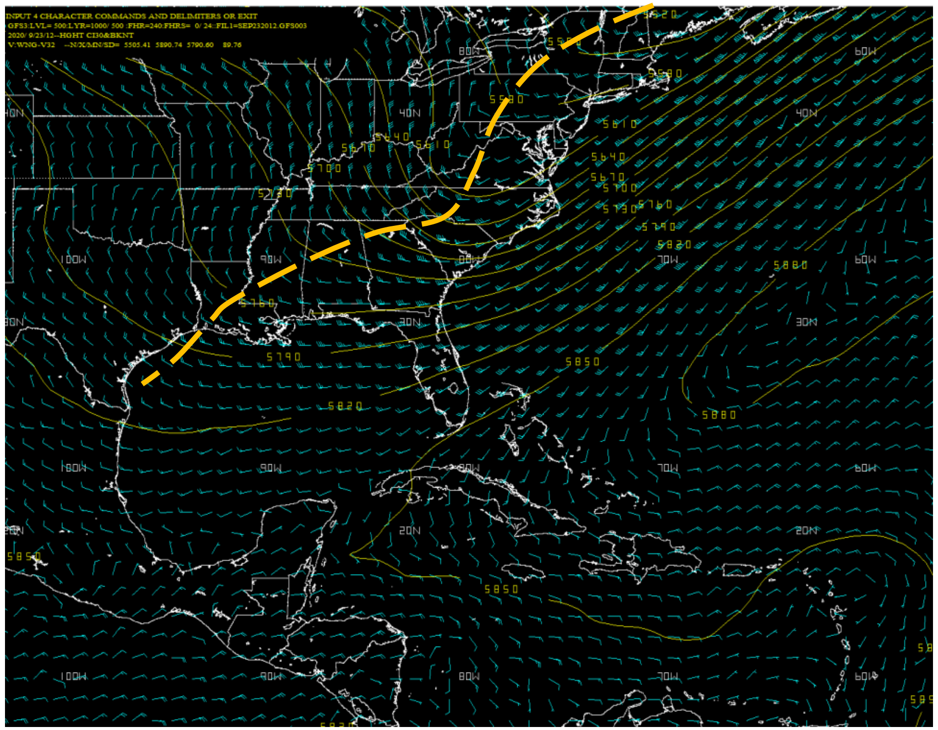
EPT (Magenta), 1000-850 Thickness (Cyan) and MSLP (Yellow)



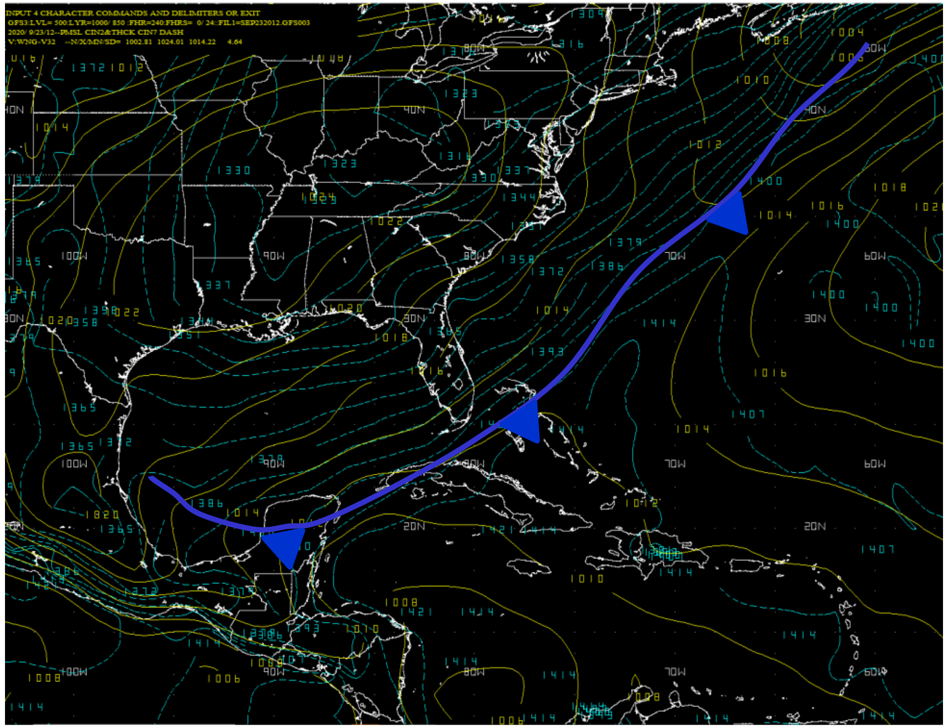
Combining EPT and the 1000-850 thickness, simplifies air mass evaluation.

Frontal Slope

Deep Polar Trough: 1000-850hPa Thickness



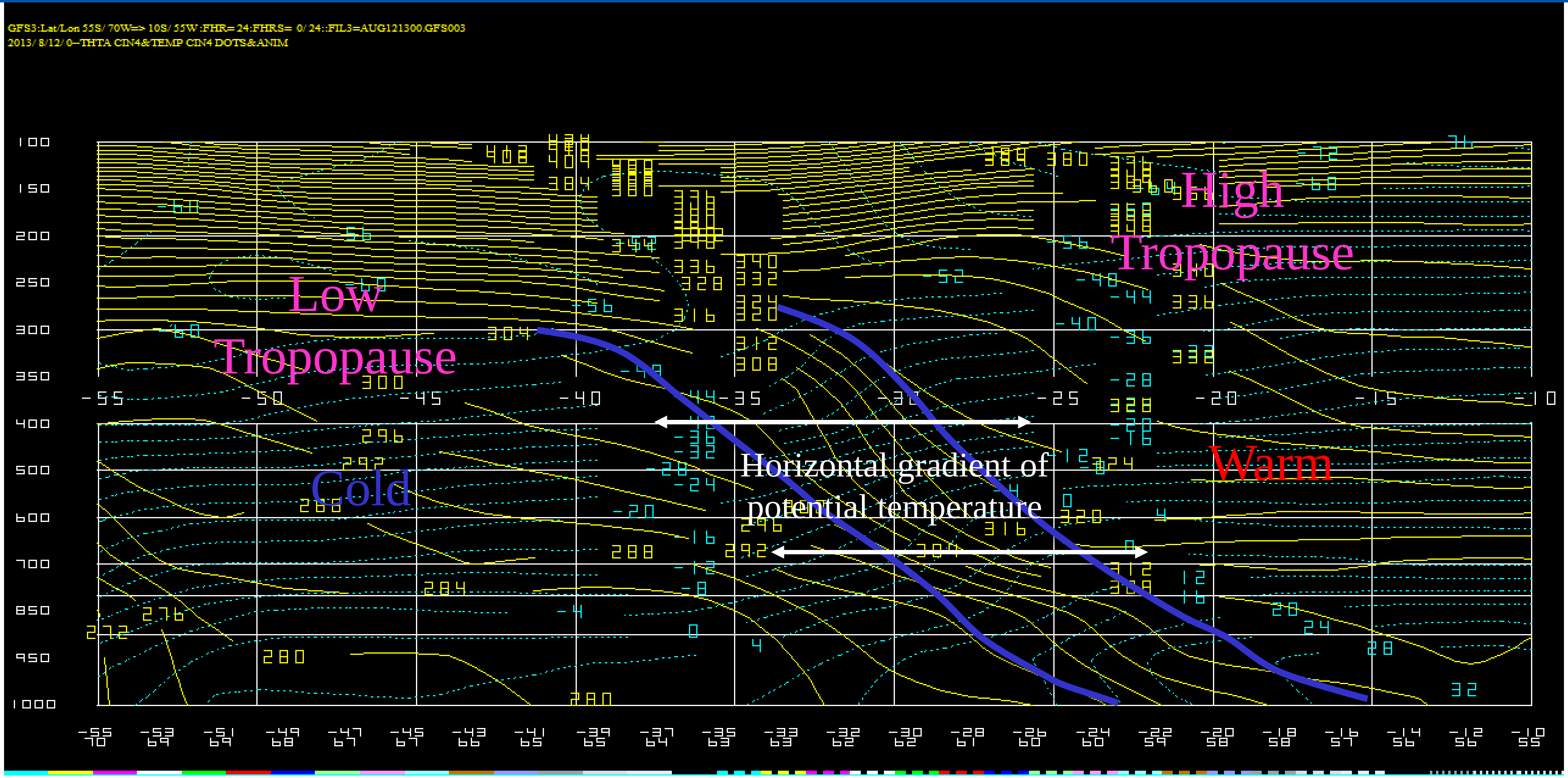
500 hPa Height & Winds



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



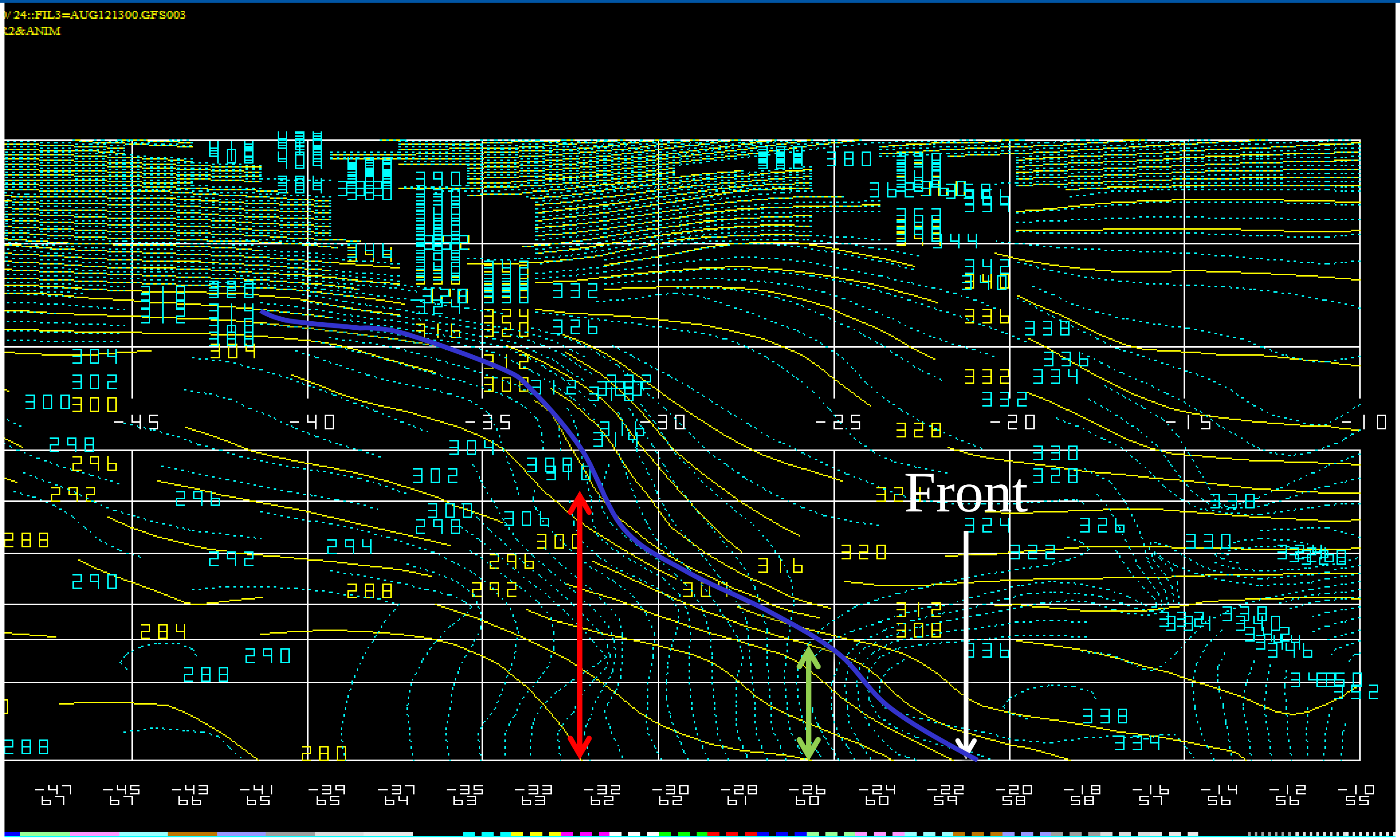
Analyzing fronts in a cross section: Evaluate the horizontal gradient of Temperature or Potential Temperature

Vertical Cross Section
Equivalent Pot. Temperature and Potential Temperature

1. Analyze the horizontal gradient of potential temperature (THTA).

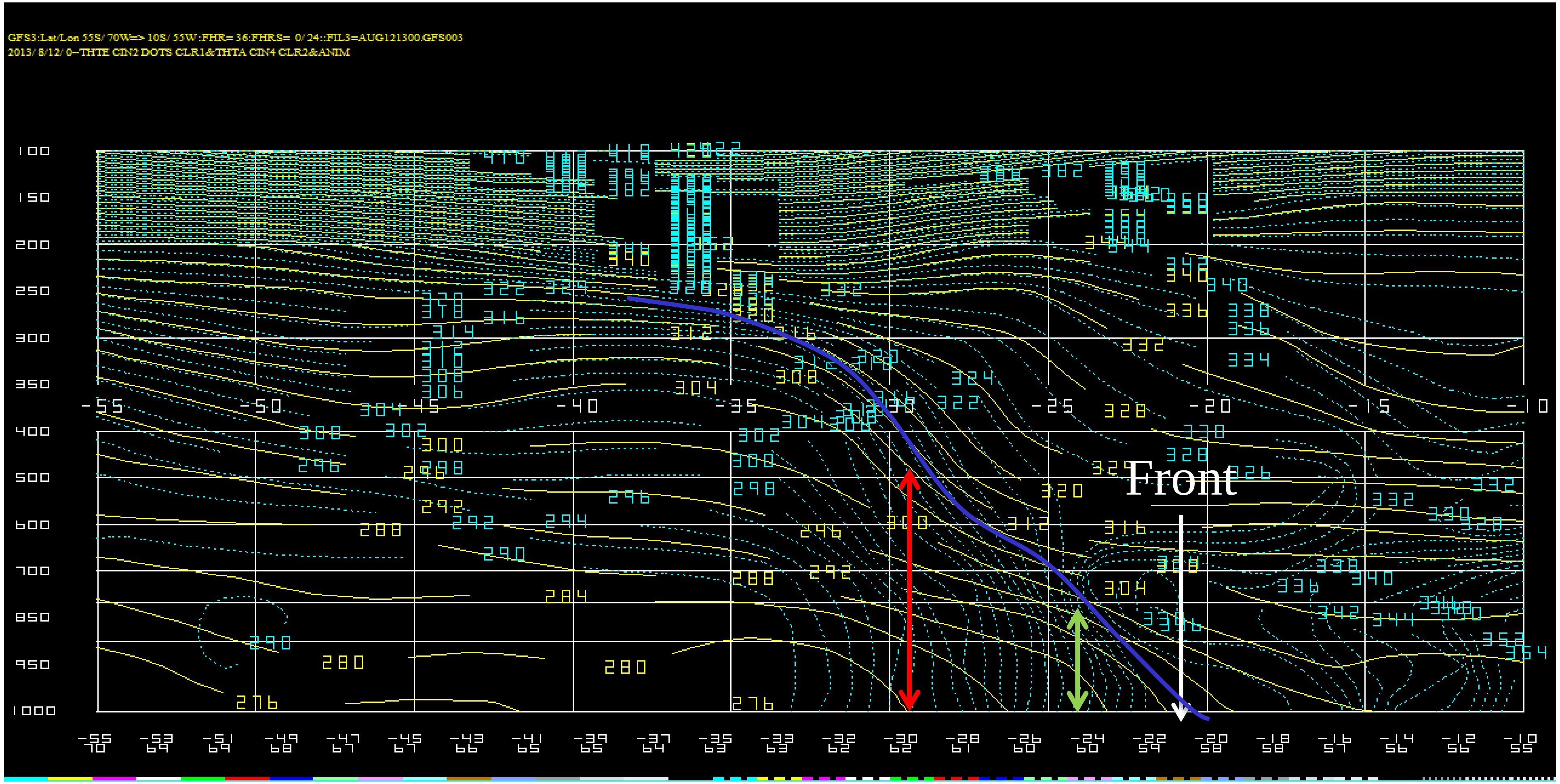
2. Determine which side is the cold/warm one

3. The cold front lies on the warm side of the gradient



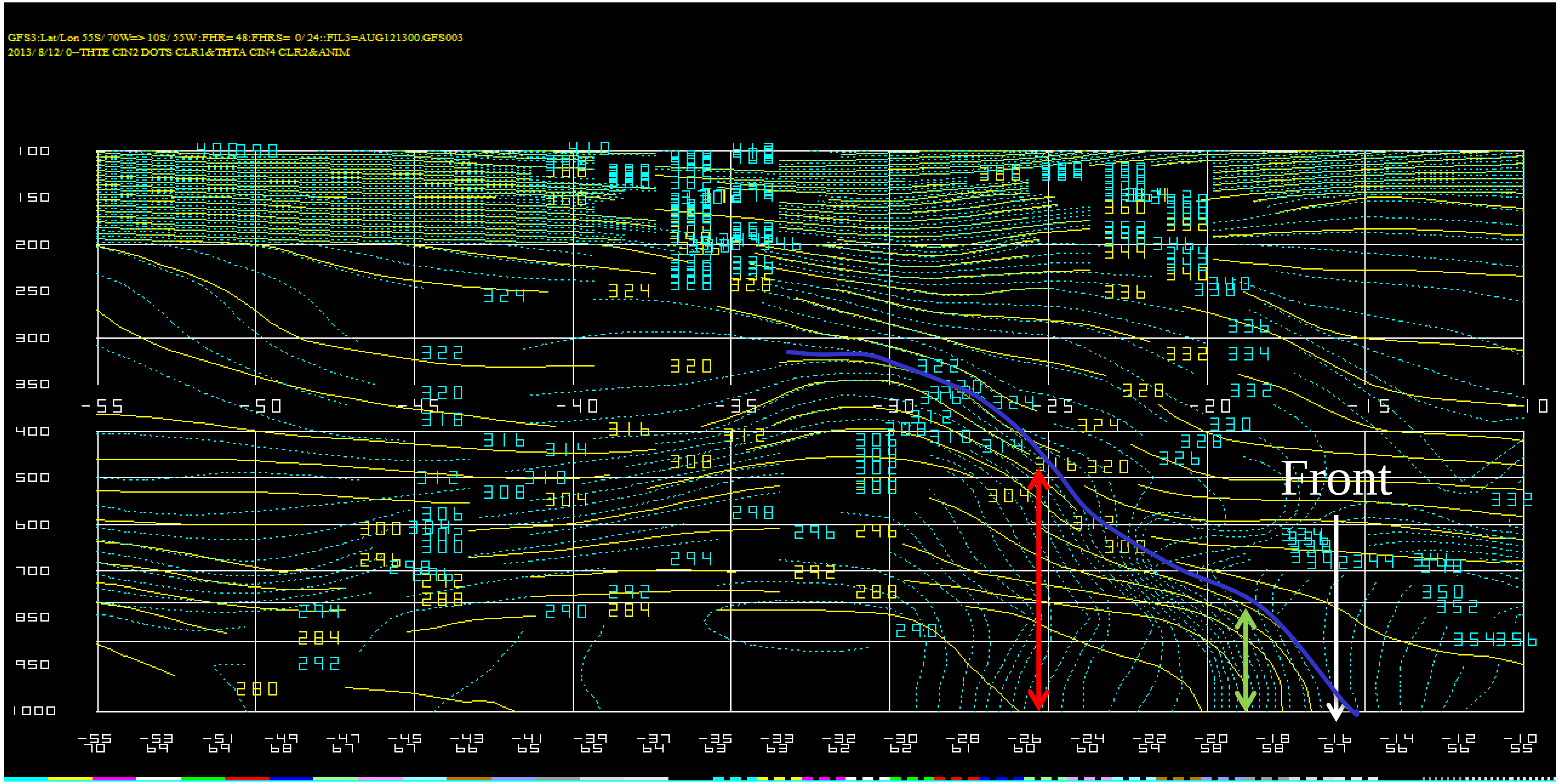
Front has deep layer support and it is clearly evident in both layers, **1000-850** and 1000-500 hPa

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



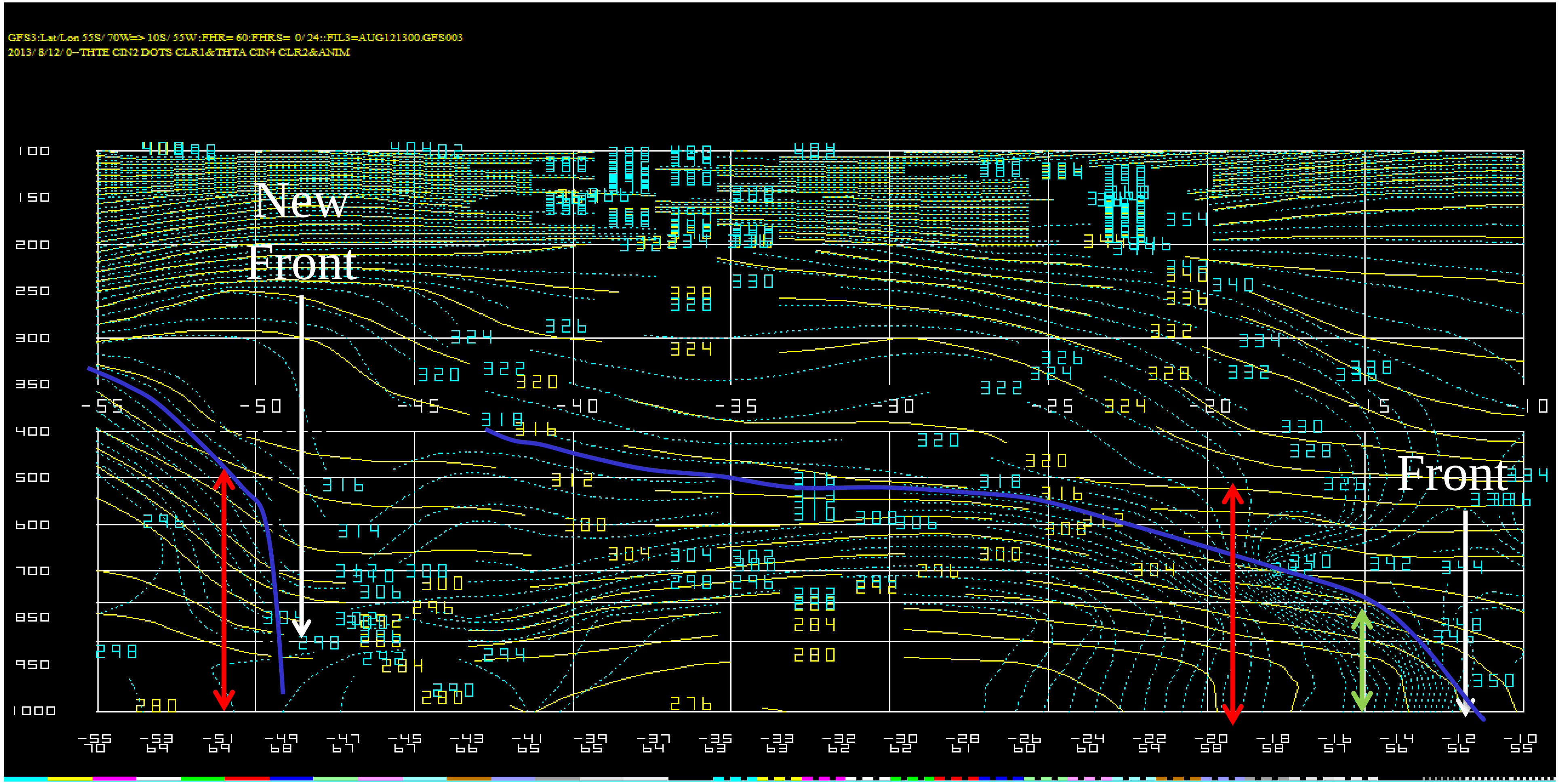
Front has deep layer support and it is clearly evident in both layers, 1000-850 and 1000-500 hPa

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



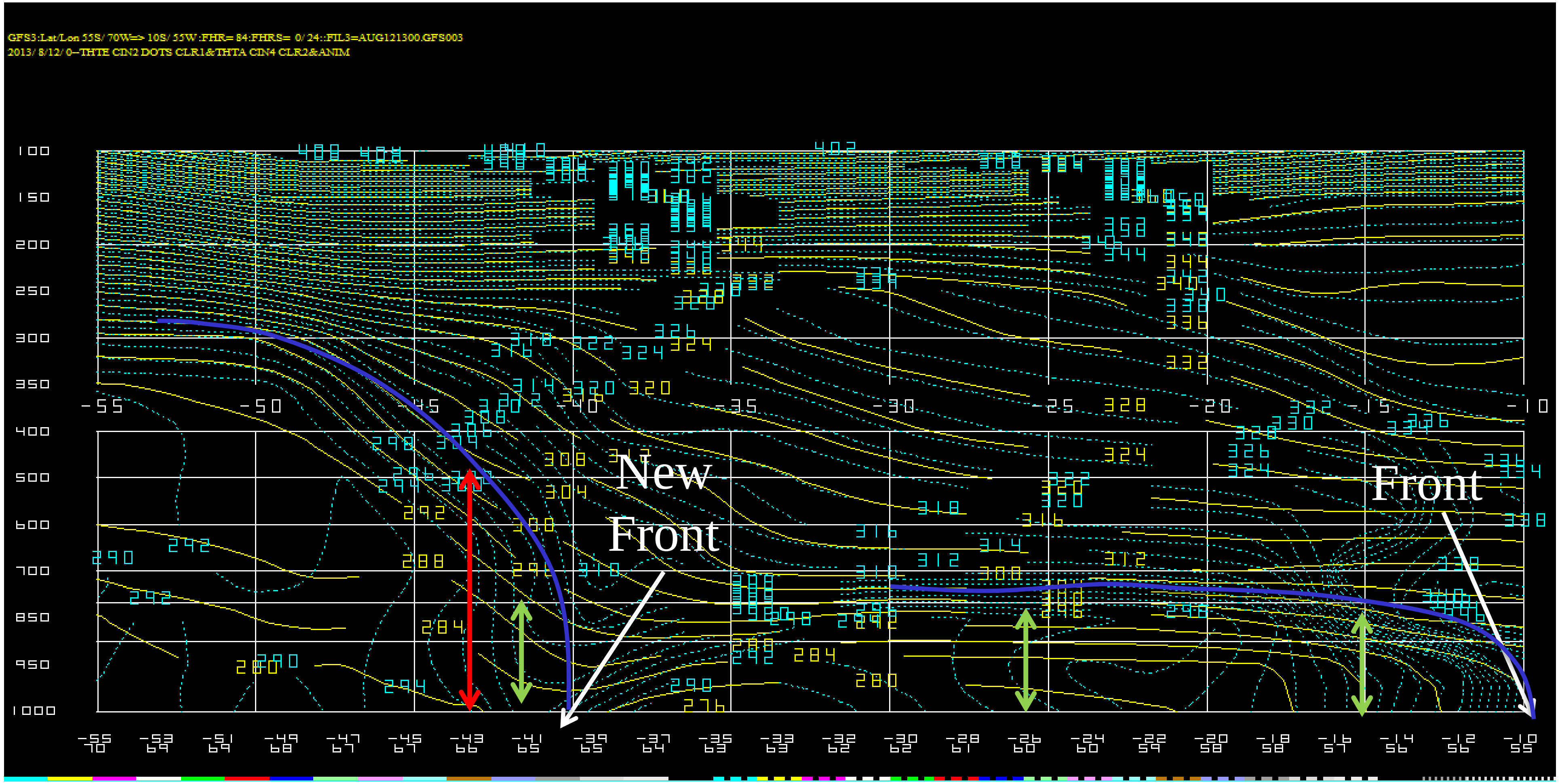
Front has deep layer support and it is clearly evident in both layers, 1000-850 and 1000-500 hPa

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



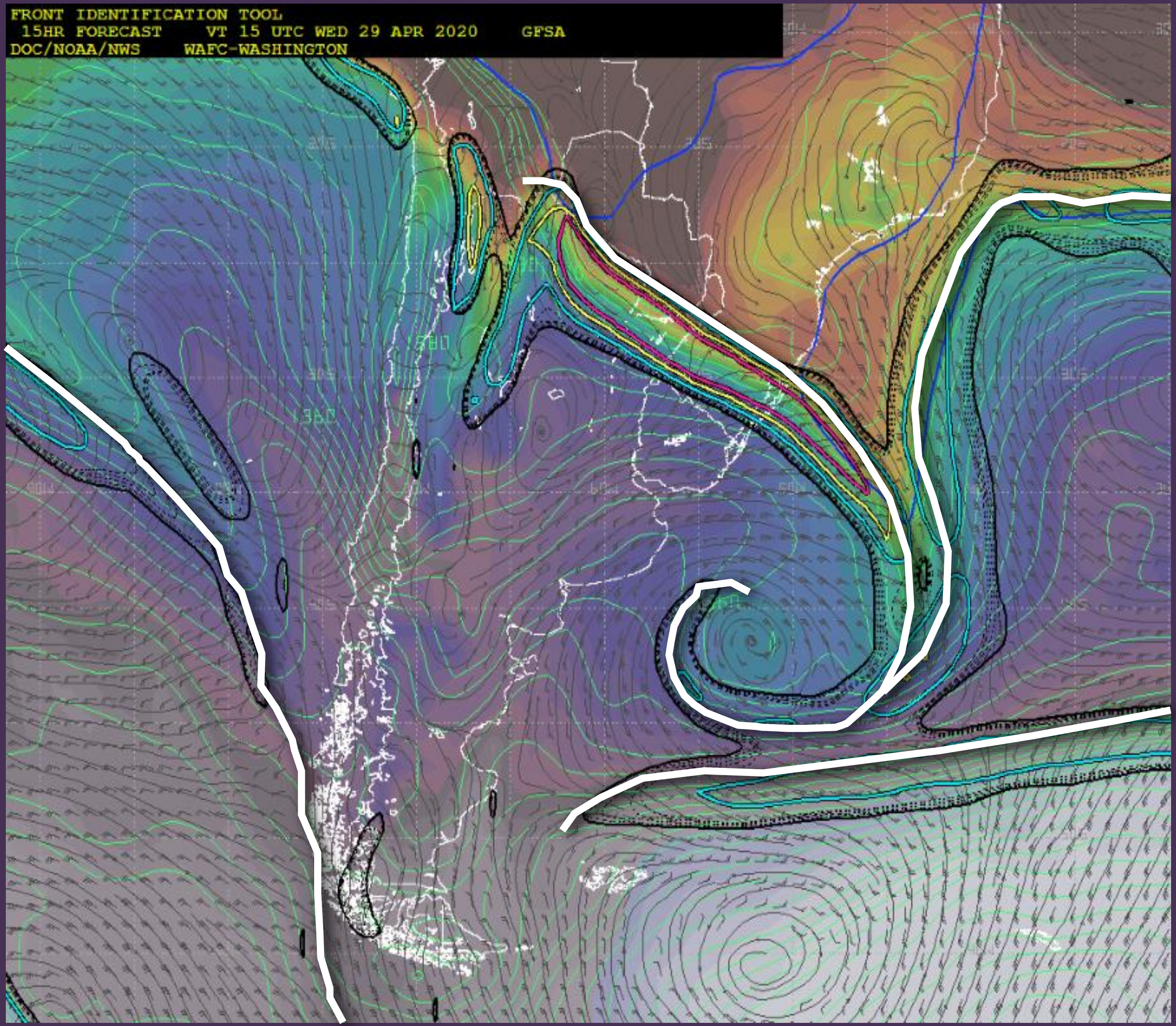
Front well defined in the **1000-850** hPa layer, but no longer between 1000-500 hPa

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

FRONT Algorithm



WinGridDS FRONT Algorithm

Developed at the WPC International Desks to help with the identification of fronts in the Americas. Available online at: **https://www.wpc.ncep.noaa.gov/international/wng/**

What is plotted?

(1) Colors: Variable α = represents air mass properties

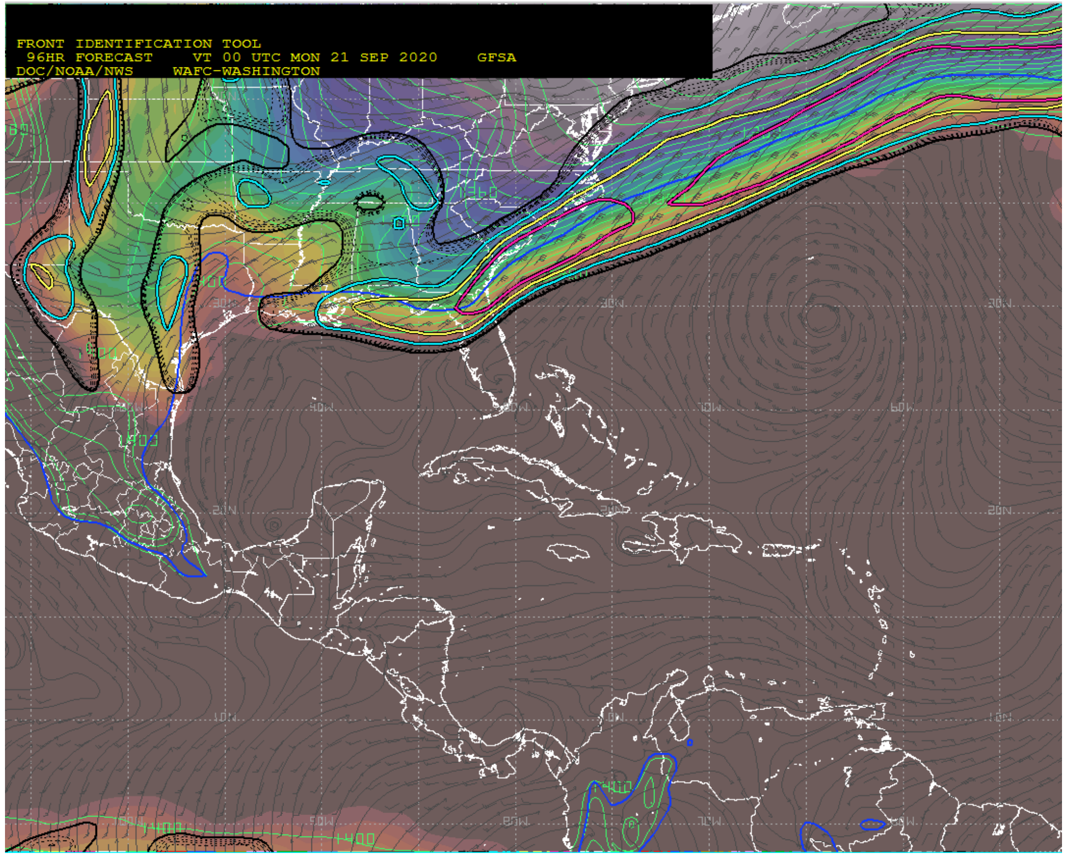
Cool/dry to warm/humid

(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 Algorithm

Constructing α

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

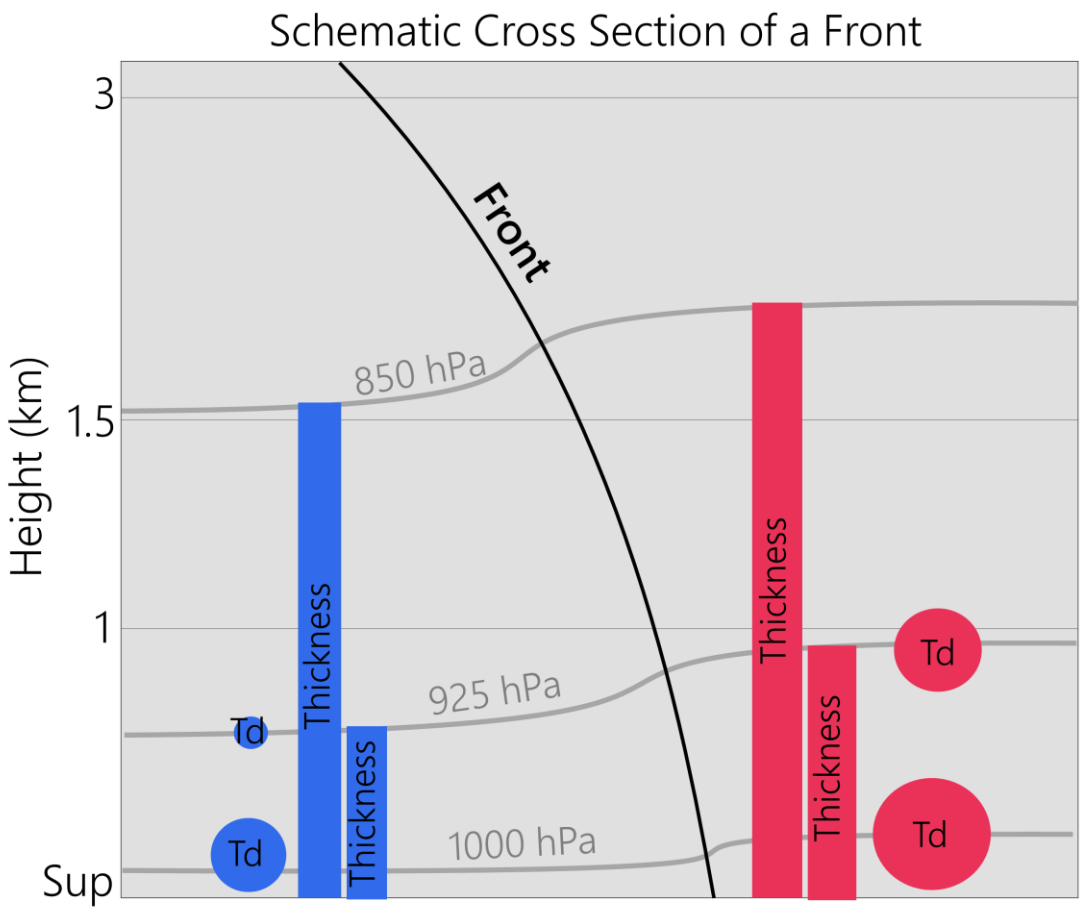
  Thermal Aspects

  - Td 1000 hPa
  - Td 925 hPa

  Moisture Aspects

- Quantities are **<u>multiplied</u>** to enhance gradients for forecasters to see them rapidly.

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



WinGridDS FRONT Algorithm

Constructing β

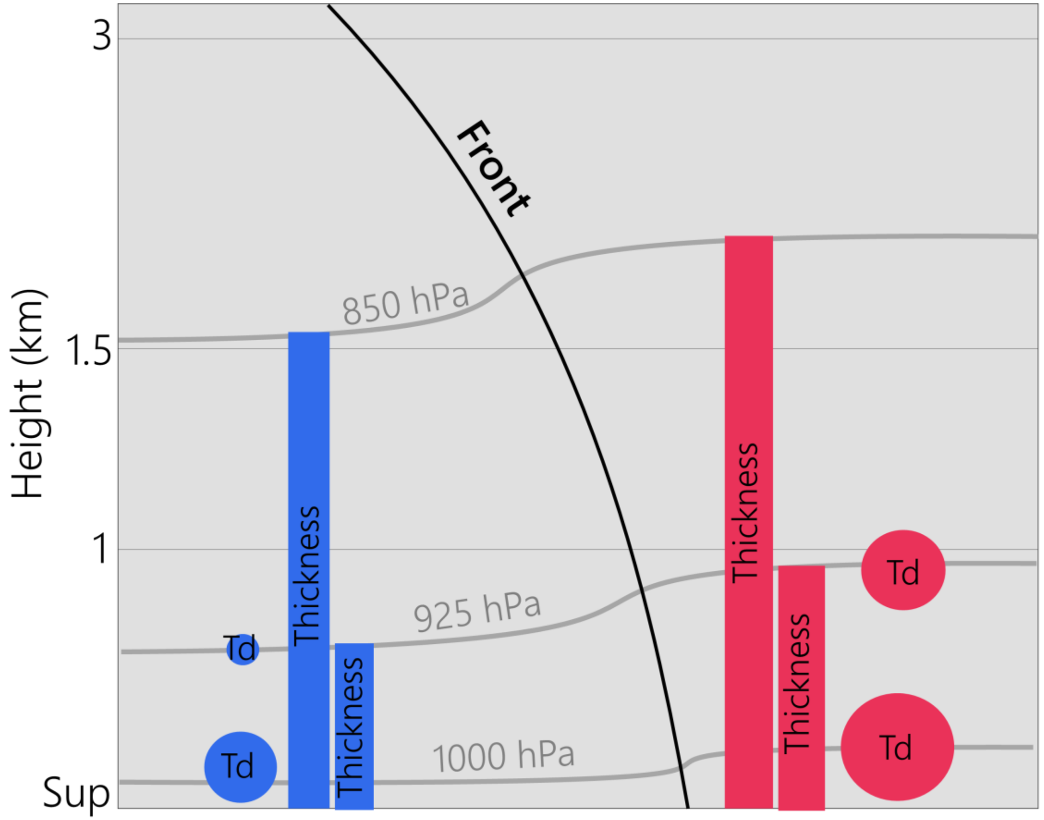
Combination of

- 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.

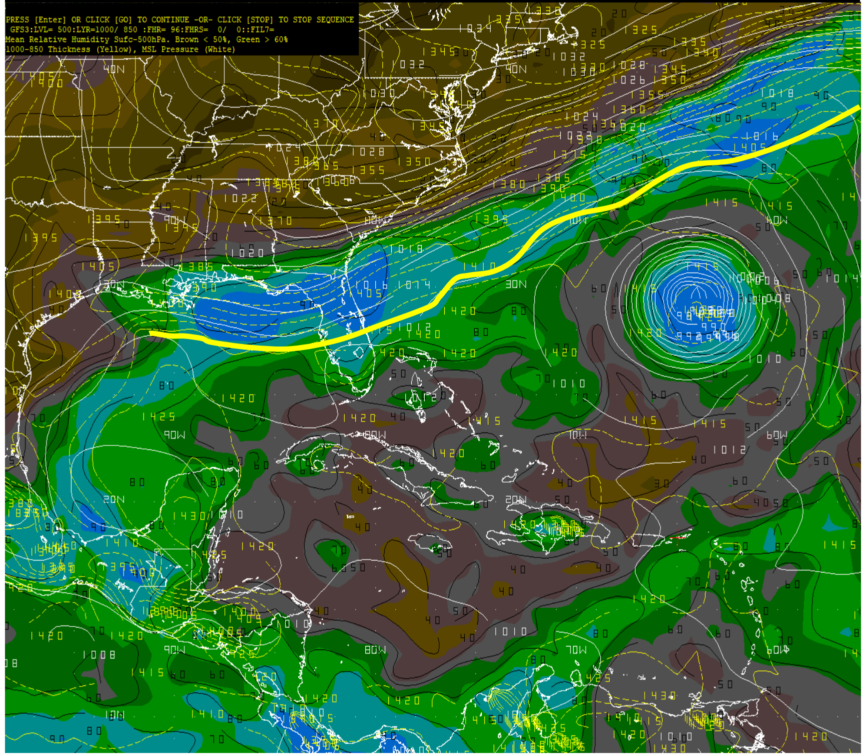
    -Enhances boundaries with strong moisture signals.
- Magnitude of the gradient of θe at 1000 hPa
  - Enhances signature of the front near the surface.

Schematic Cross Section of a Front

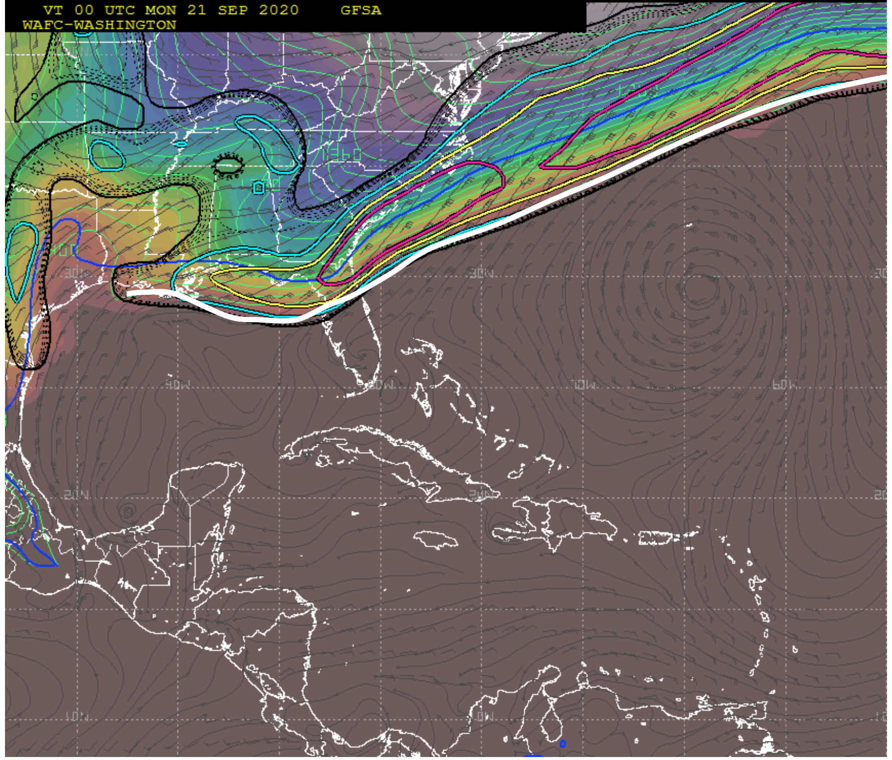


Hand Drawn Analysis vs. Objective Analysis

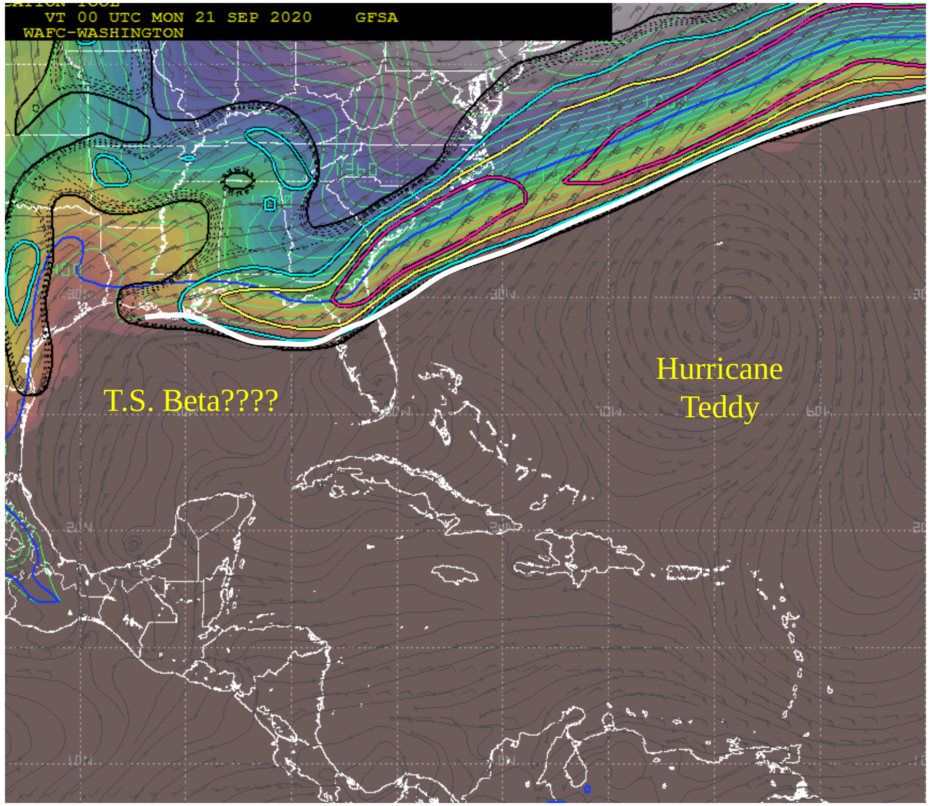
Mean Layer RH, THCK, PMSL

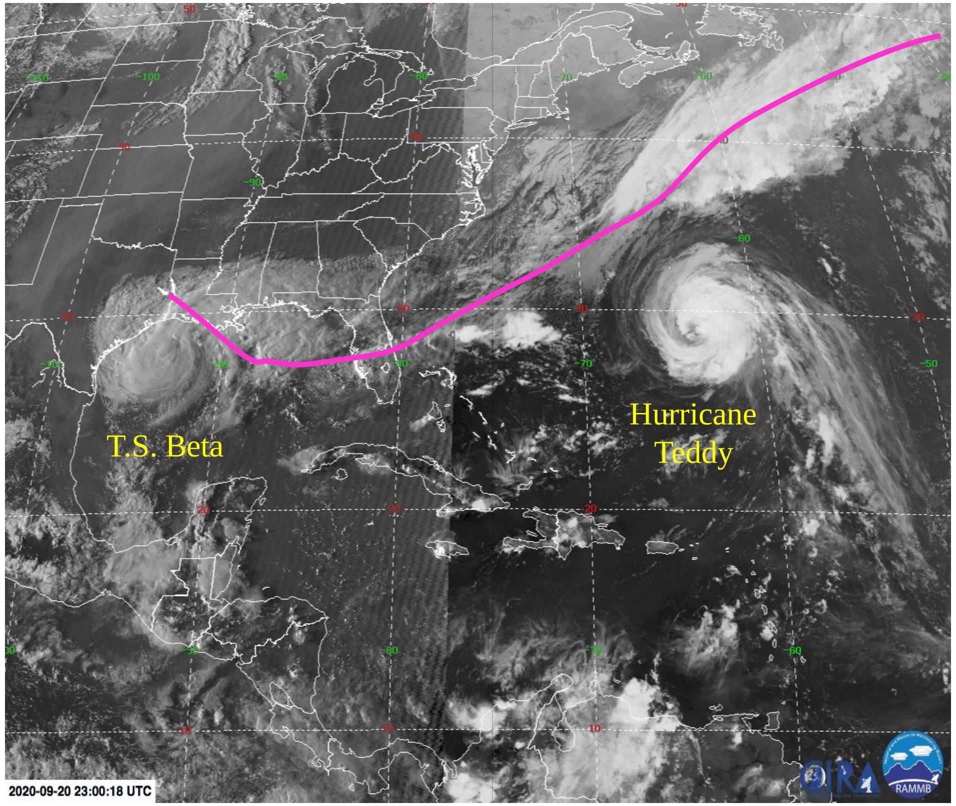


Algorithm FRONT



Verification of the Forecast





VT: 20200921/00Z

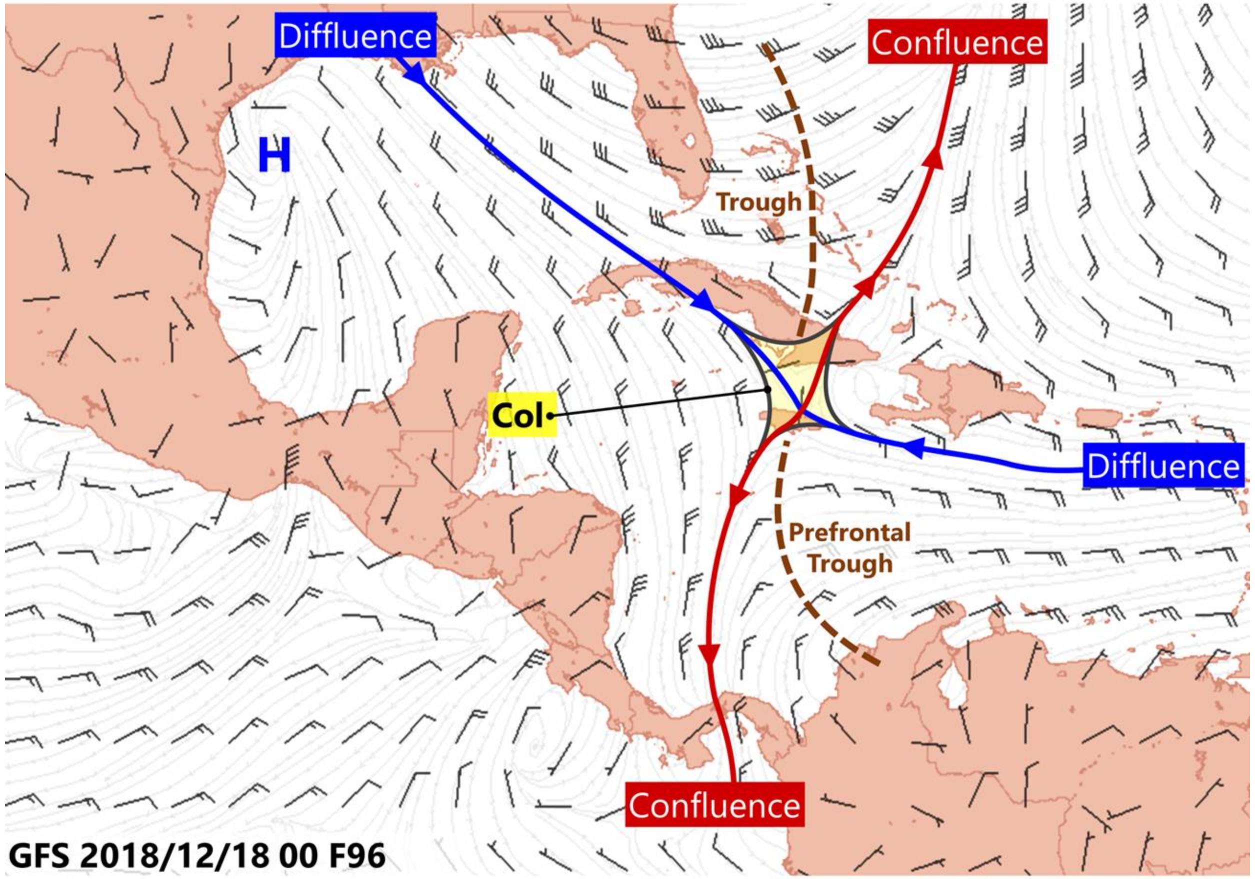
Shear Lines

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:** Transition zone determined by a windshift (horizontal wind shear), without a significant change in density (baroclinicity)
    - A line of maximum horizontal wind shear (10kt shear).
    - Could be directional, speed shear or both.
    - Lacks the **baroclinicity/density** discontinuity of surface fronts.

Evaluation of a Shear Line

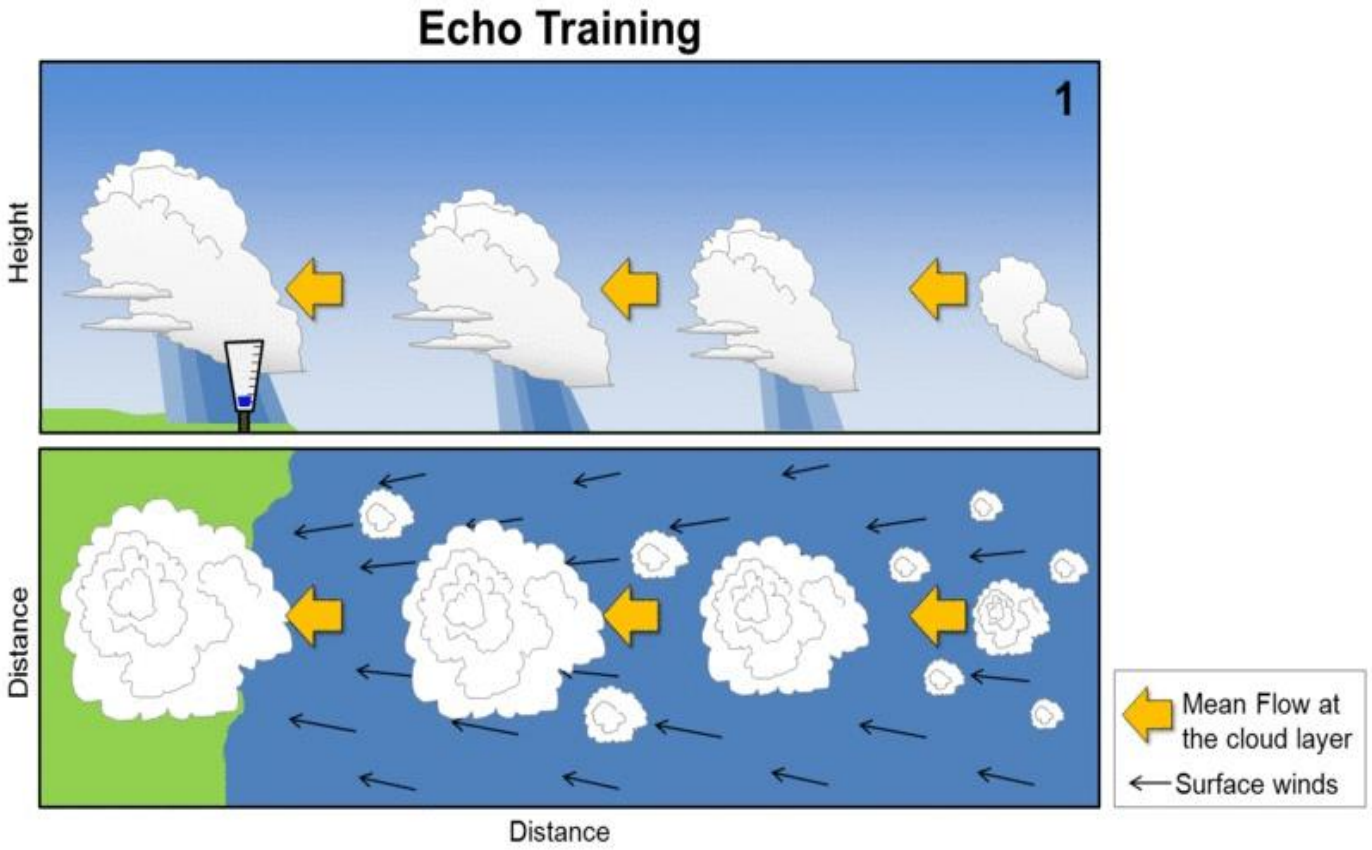
- Area of wind **confluence** that extends outward from a **col**
  - Near surface feature
- Shear line can be found:
  - **Along or trailing a surface front**
    - When parallel, only show the front
  - **Ahead of the surface front**
    - Show both
  - **Never behind!**



Shear Line Types

- **Frontal Shear Line**: When a cold front weakens along the confluent asymptote
- **Prefrontal Shear Line**: Driven by a broad polar ridge, the confluent asymptote often accelerates ahead of the surface front as it nears the Caribbean basin.

Impacts: Echo Training

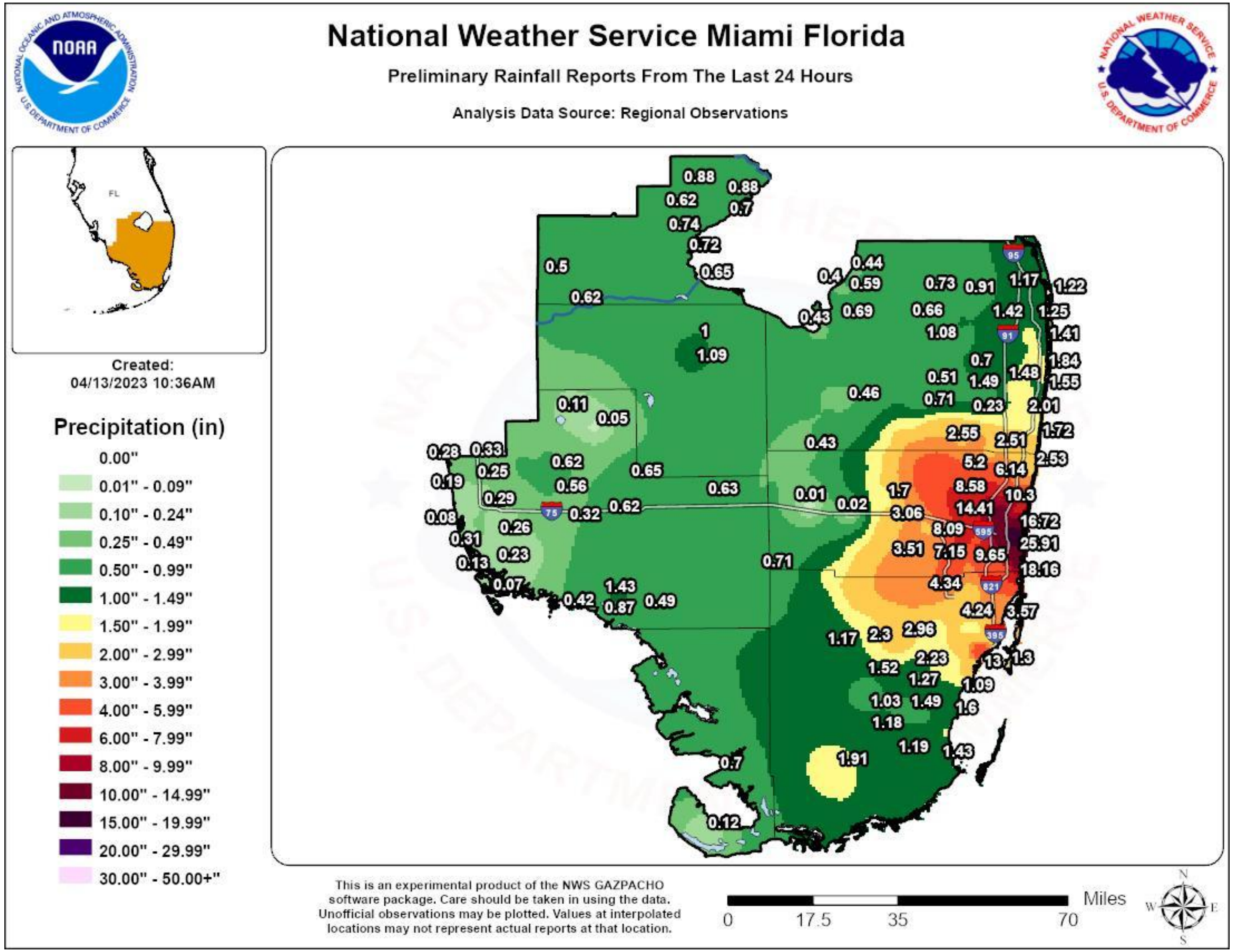


- Shear lines, as they tend to linger, present a higher risk of an echo training event forming.

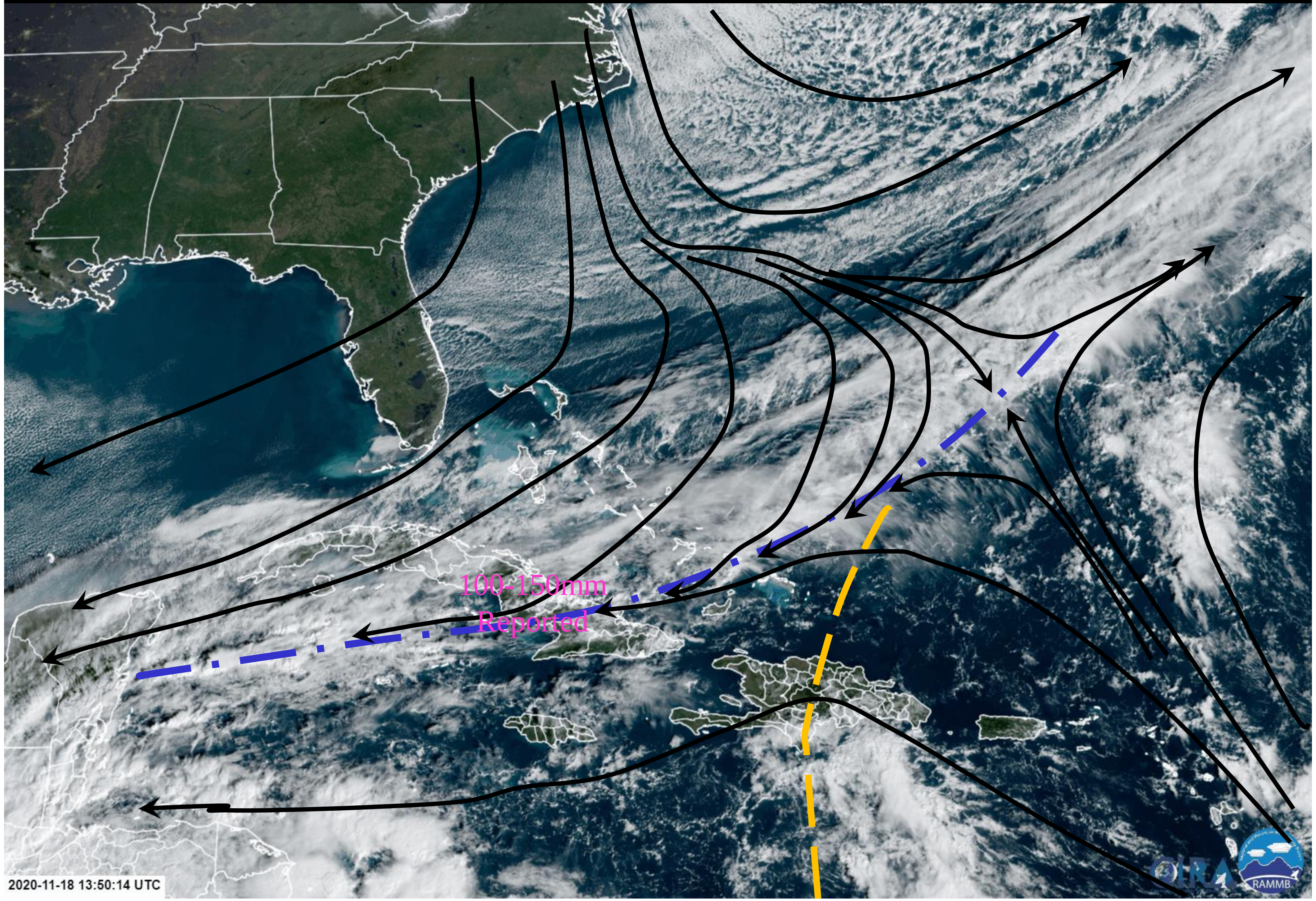
- But echo training can also form along a front.

Shear Lines and Echo Training

- Echo training event in South Florida (April 2023) produced 25 inches of rain (625mm) in less than 24 hrs.



Echo Training – SE Bahamas

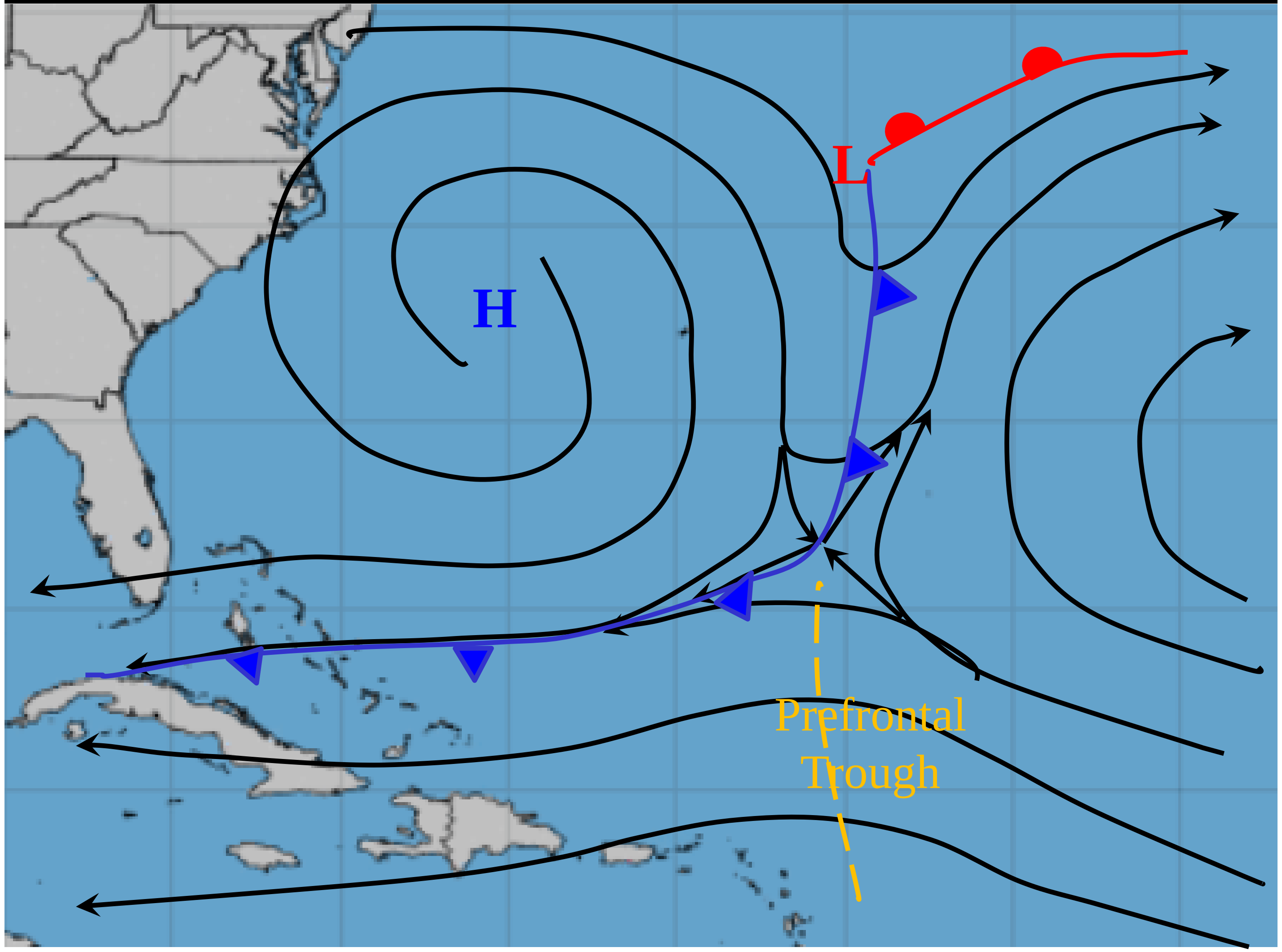


02

Frontal Shear Line

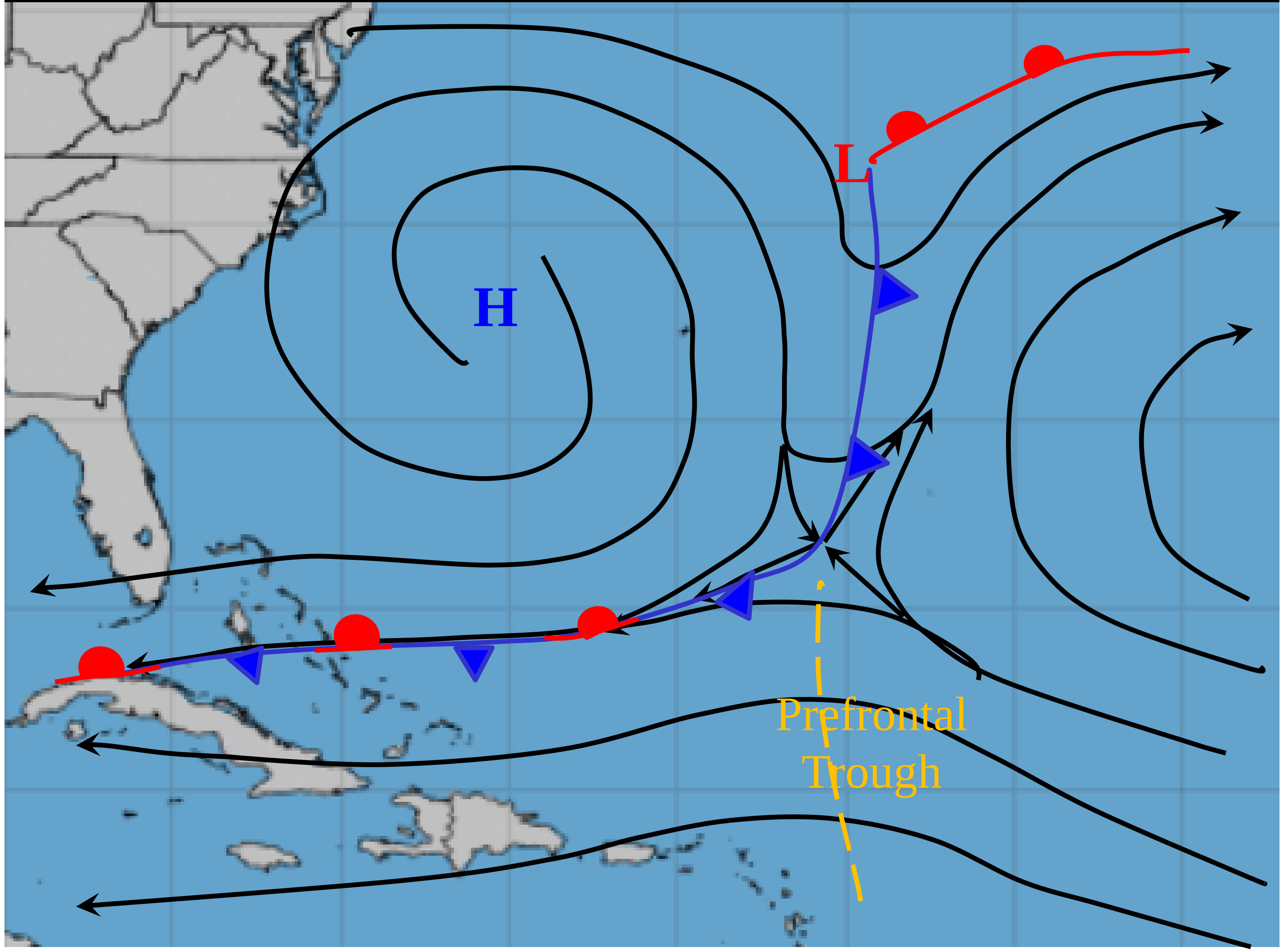
Evolution of a Frontal Shear Line

Front parallel to confluent asymptote



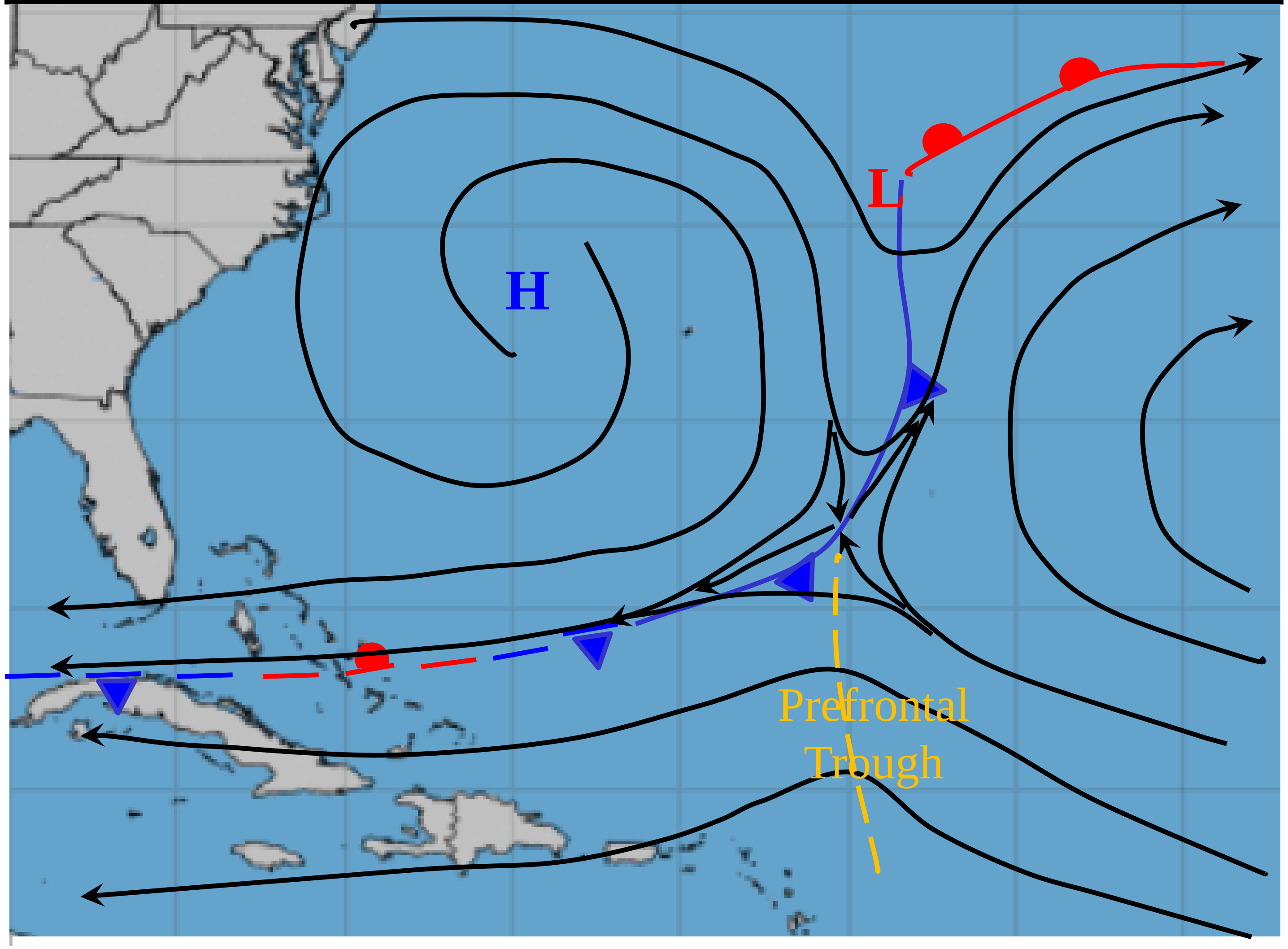
Evolution of a Frontal Shear Line

Front stalls, remains parallel to confluent asymptote



Frontal Shear Line

Frontolysis, stationary front starts to dissipate



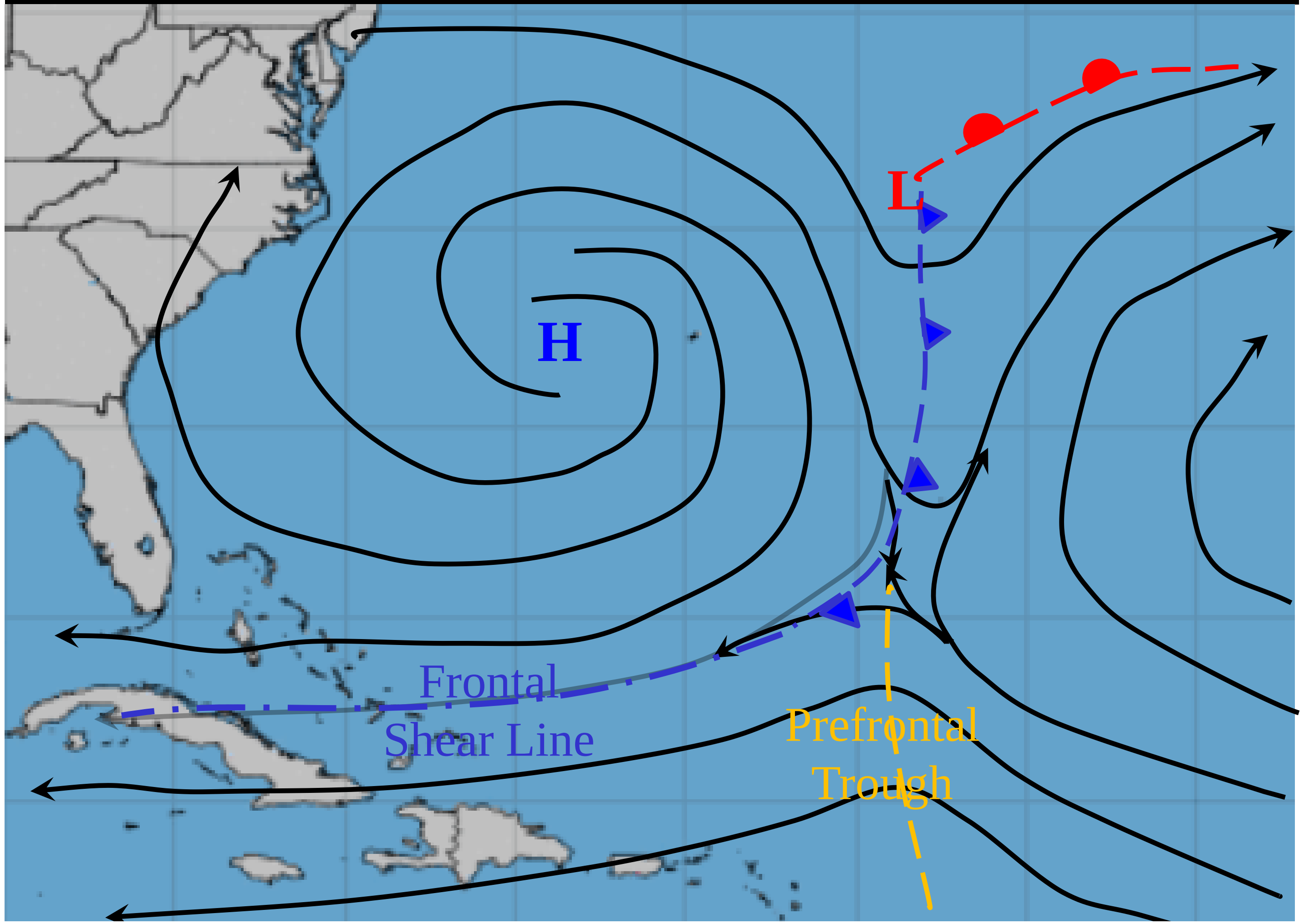
Surface front parallel to confluent asymptote

Frontal Shear Line

Front dissipates, shear line remains

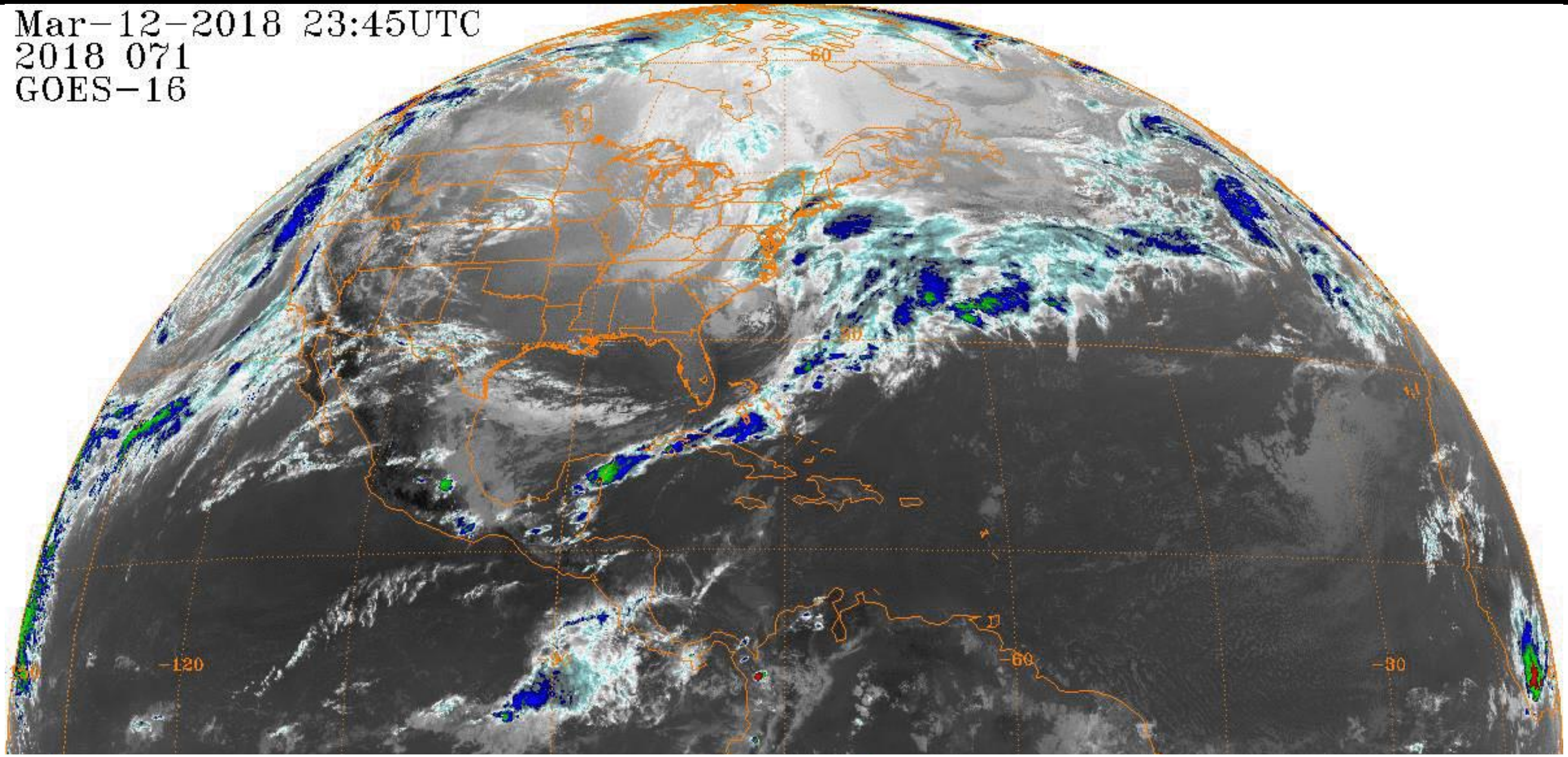
- Broad ridge to the north favors a cool advective pattern that contributes to convective instability

- Convergence along the shear line, when present, provides the low level forcing.



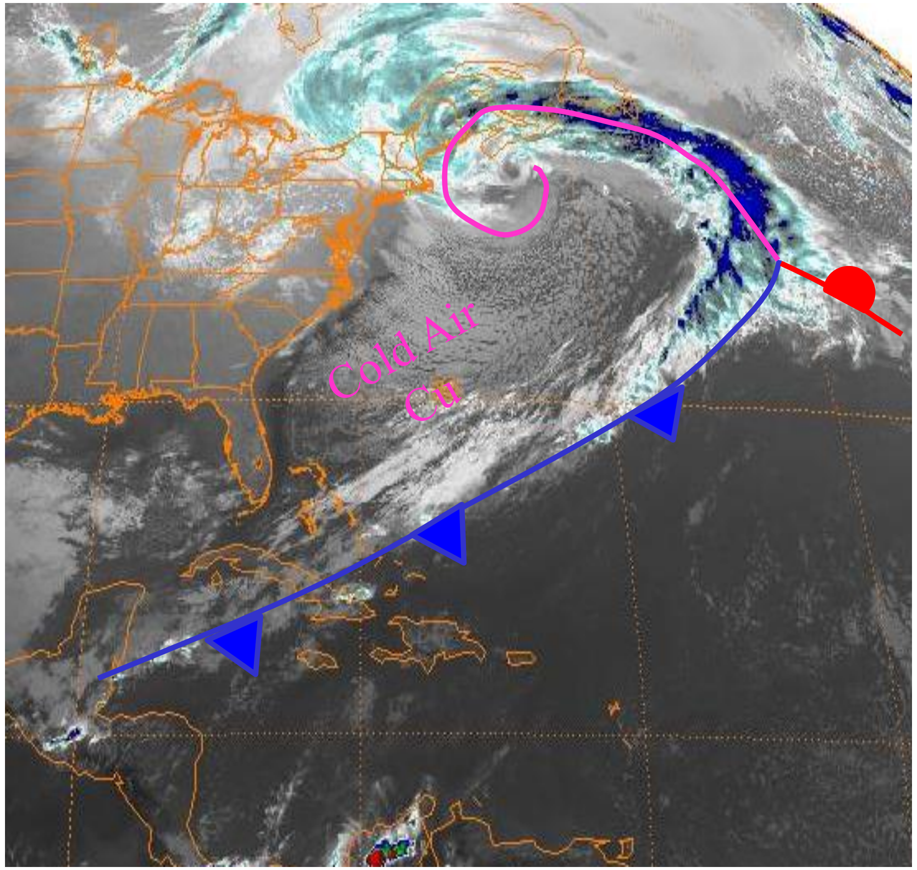
Surface front dissipates, confluent asymptote remains

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

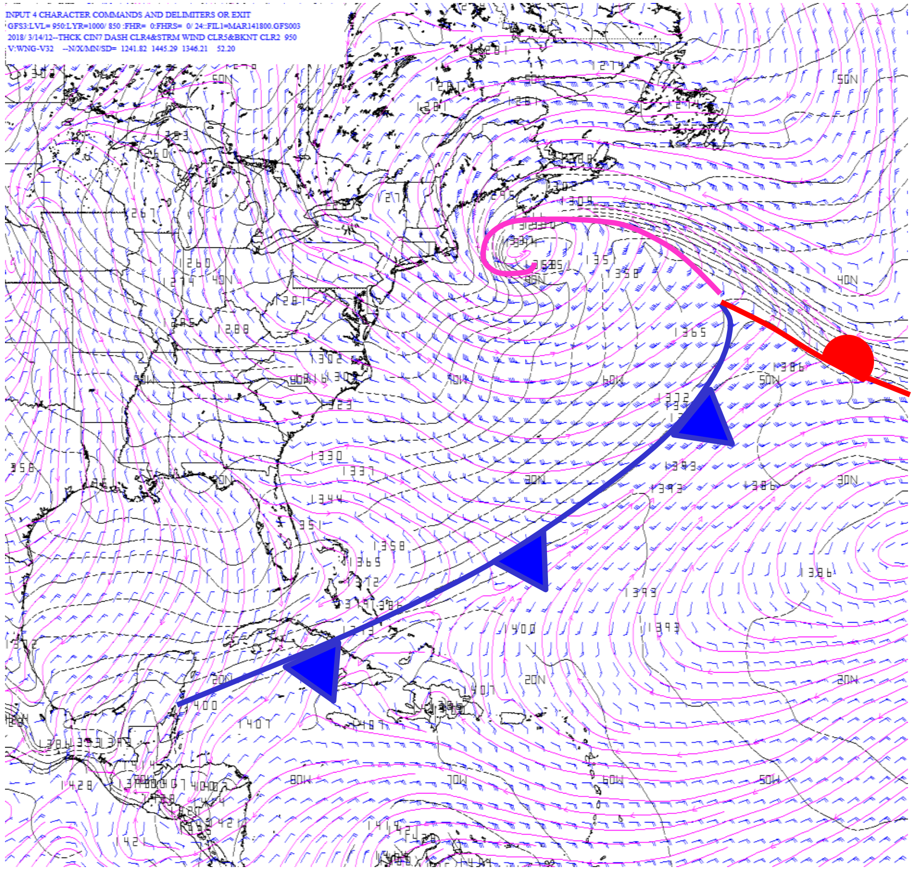


Frontal system streaming across the Bahamas briefly decays to a frontal shear line as it loses its upper level support and stalls to the southeast.

IR 10.3um vs. GDAS: 20180314_00Z



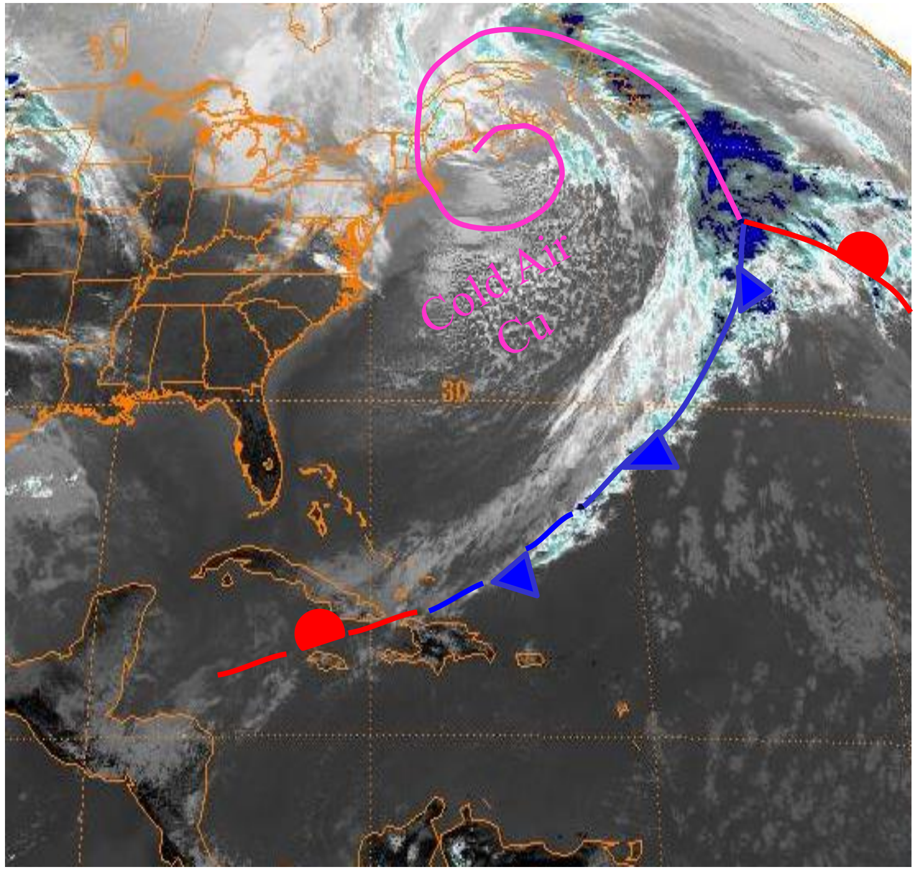
IR 10.3um



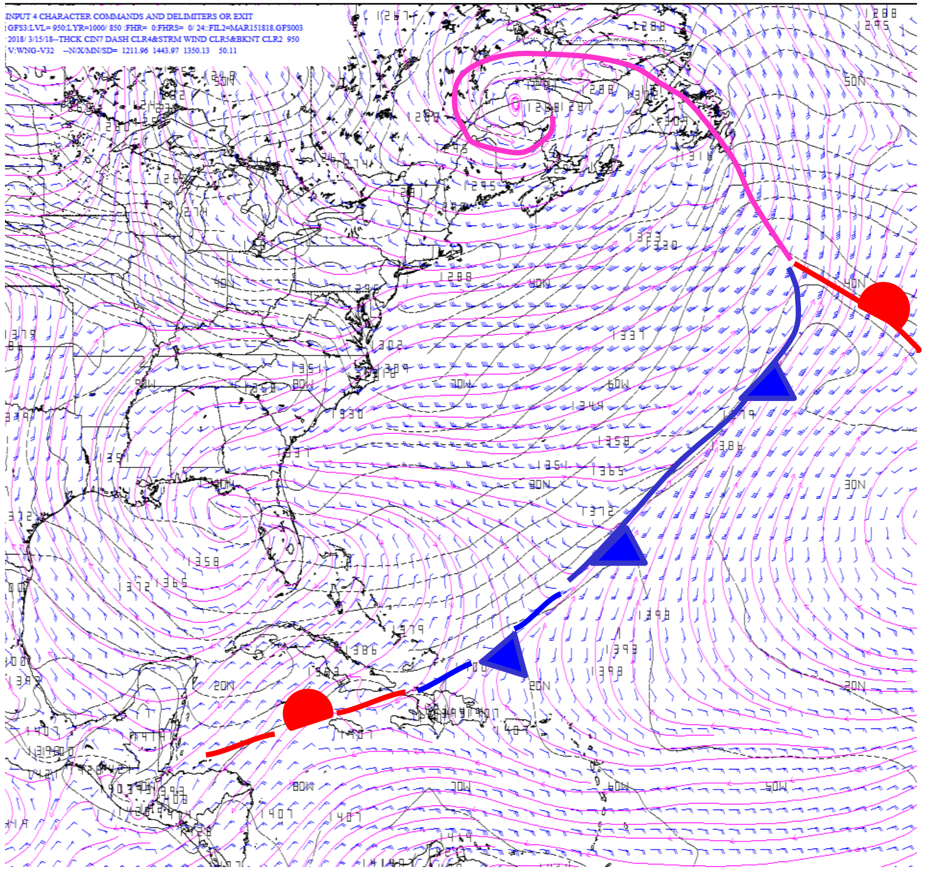
GDAS

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

IR 10.3um vs. GDAS : 20180315_18Z



IR 10.3um

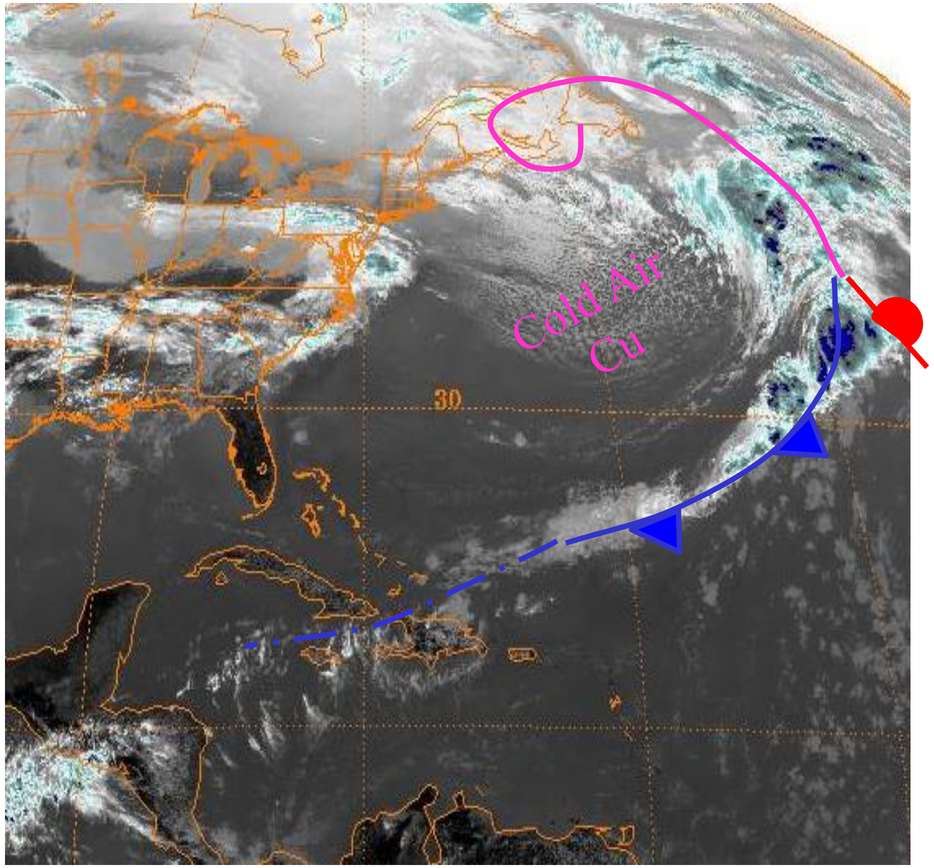


GDAS

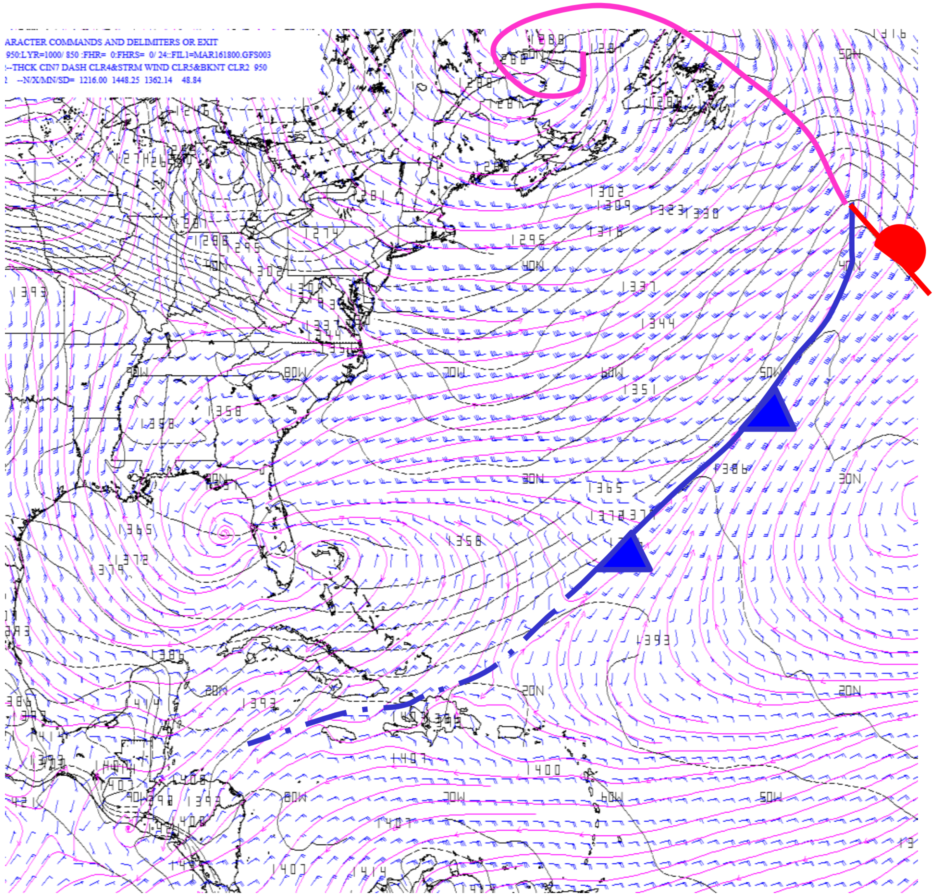
950 hPa Winds, Streamlines, and

1000-850 Thickness

IR 10.3um vs. GDAS : 20180316_18Z



IR 10.3um

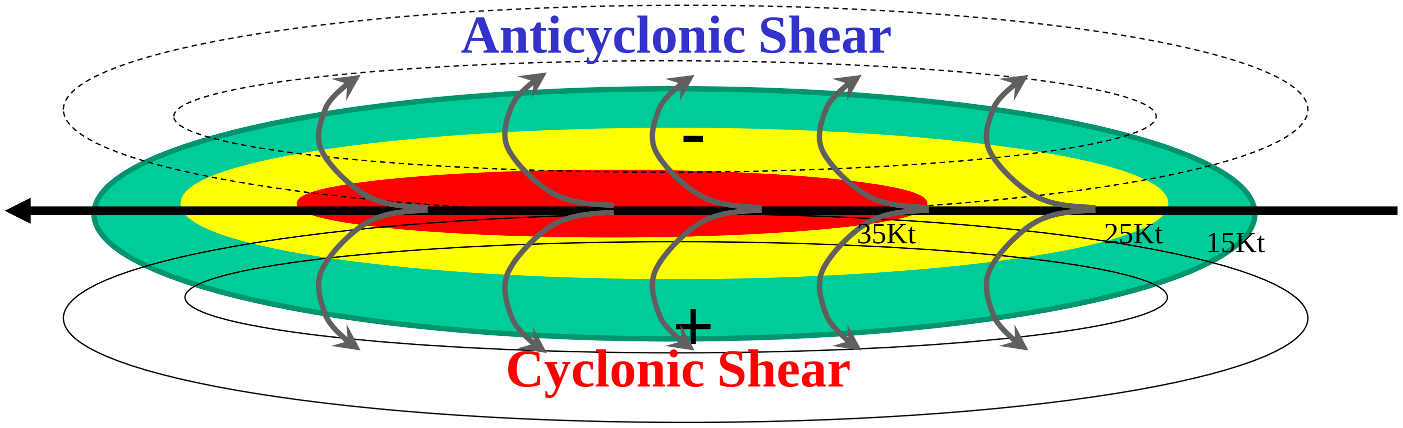


GDAS

950 hPa Winds, Streamlines, and 1000-850 Thickness

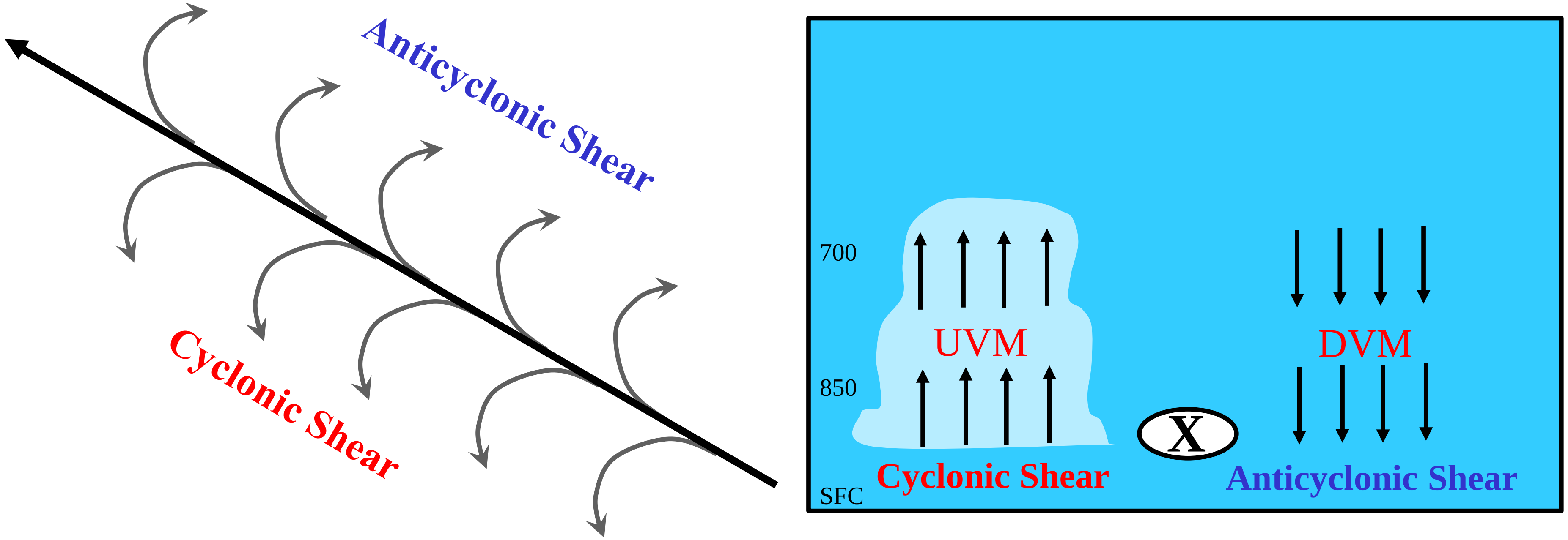
Speed Shear

- As the low level winds increase/decrease along a wind maxima, horizontal wind shear us produced
  - These results in areas of cyclonic/anticyclonic shear, with intensities being a function of the gradient and intensity of the winds.
  - Cyclonic/anticyclonic vorticity and ascent/descent also develops.



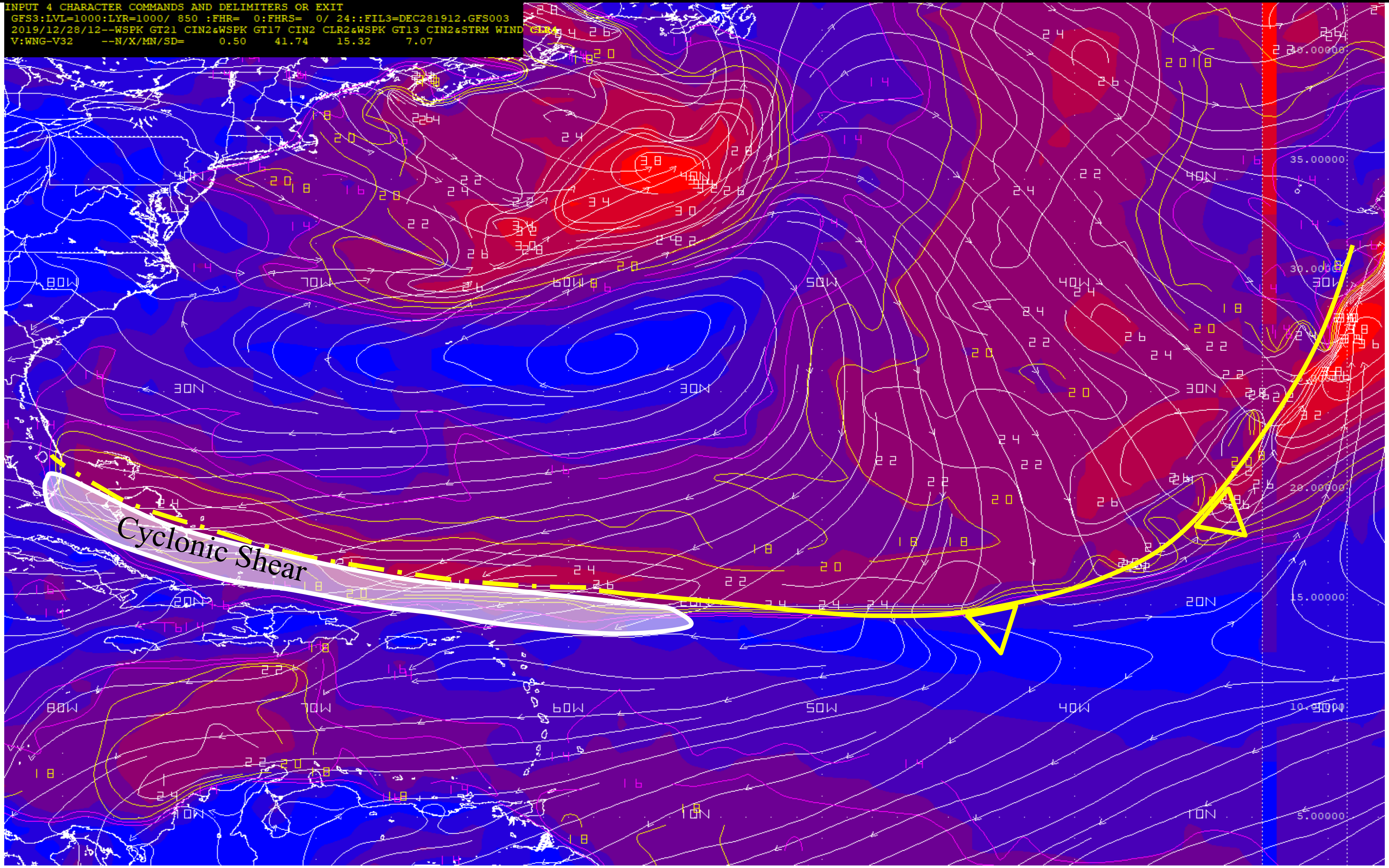
Shear Induced Upward and Downward Vertical Motion

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

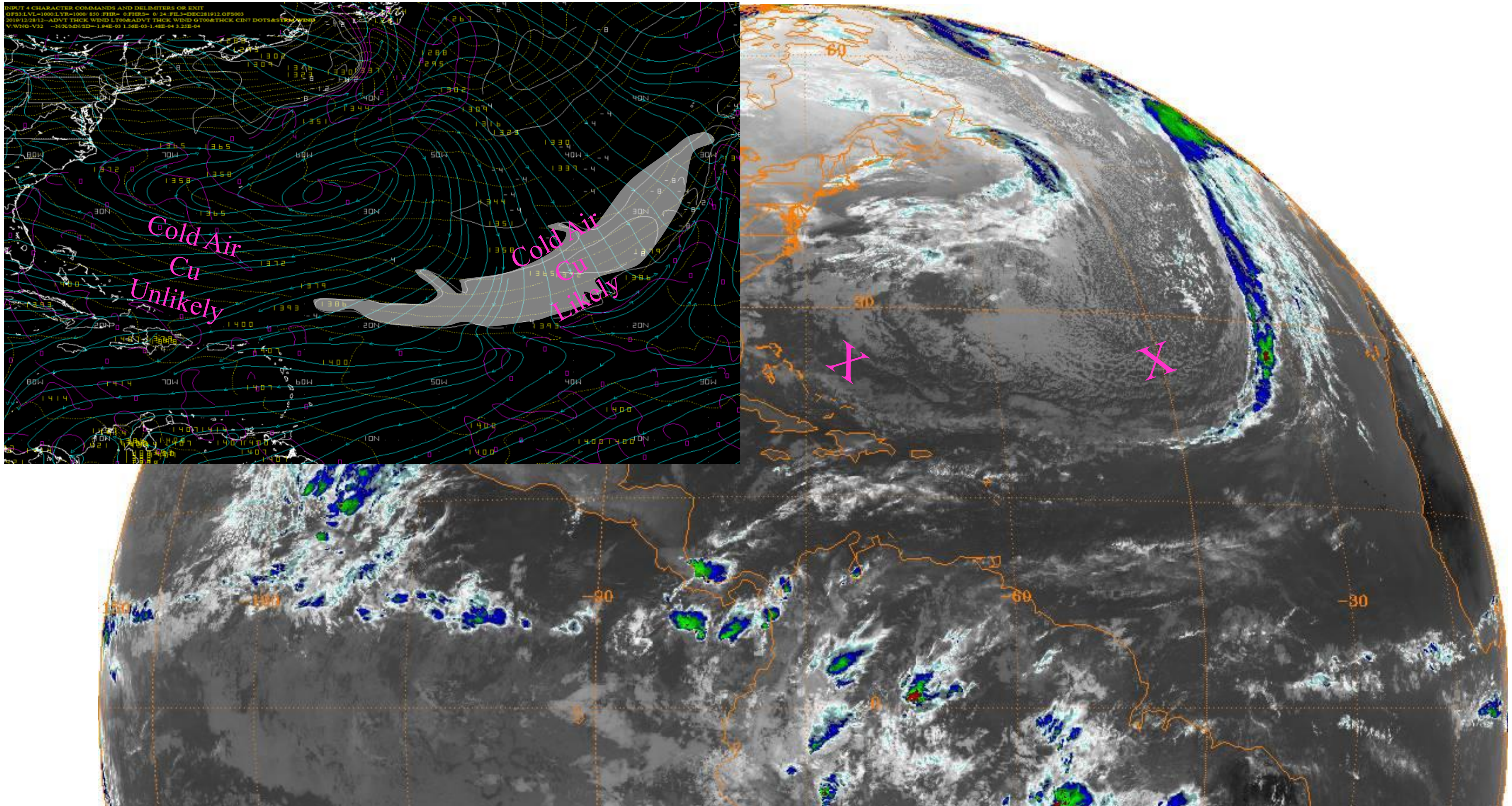


Speed Shear Induced Shear Line

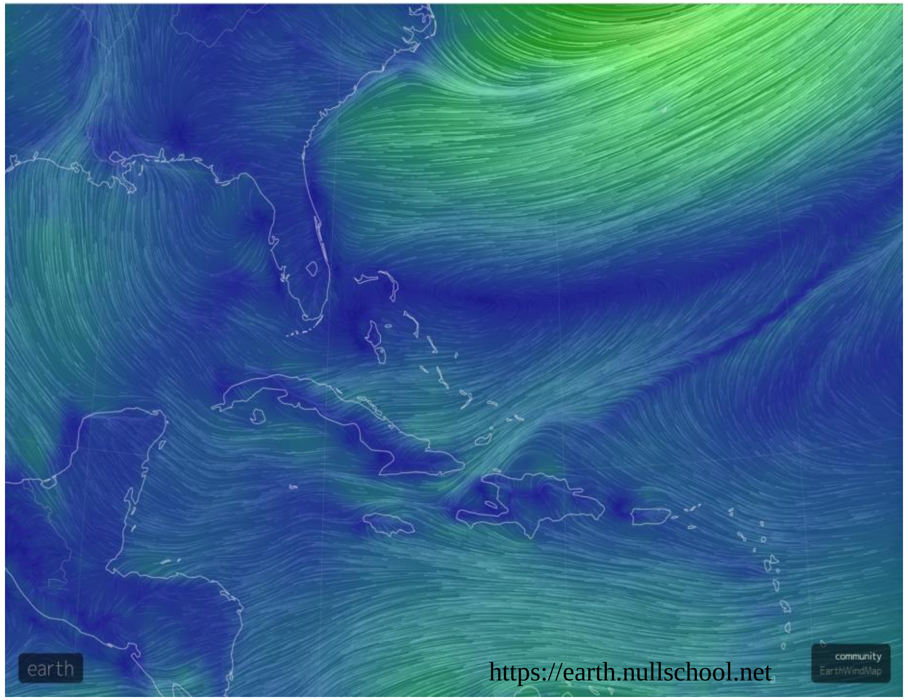
1000 hPa Isotachs and Streamlines



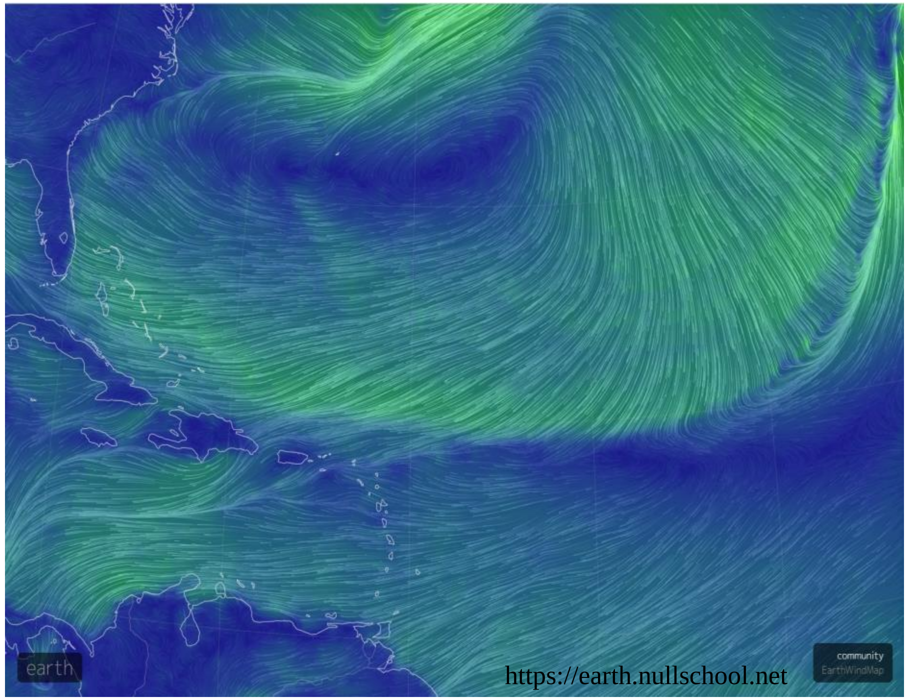
Shear Line Due to Speed Shear



Frontal Shear Line
Directional vs. Speed Shear



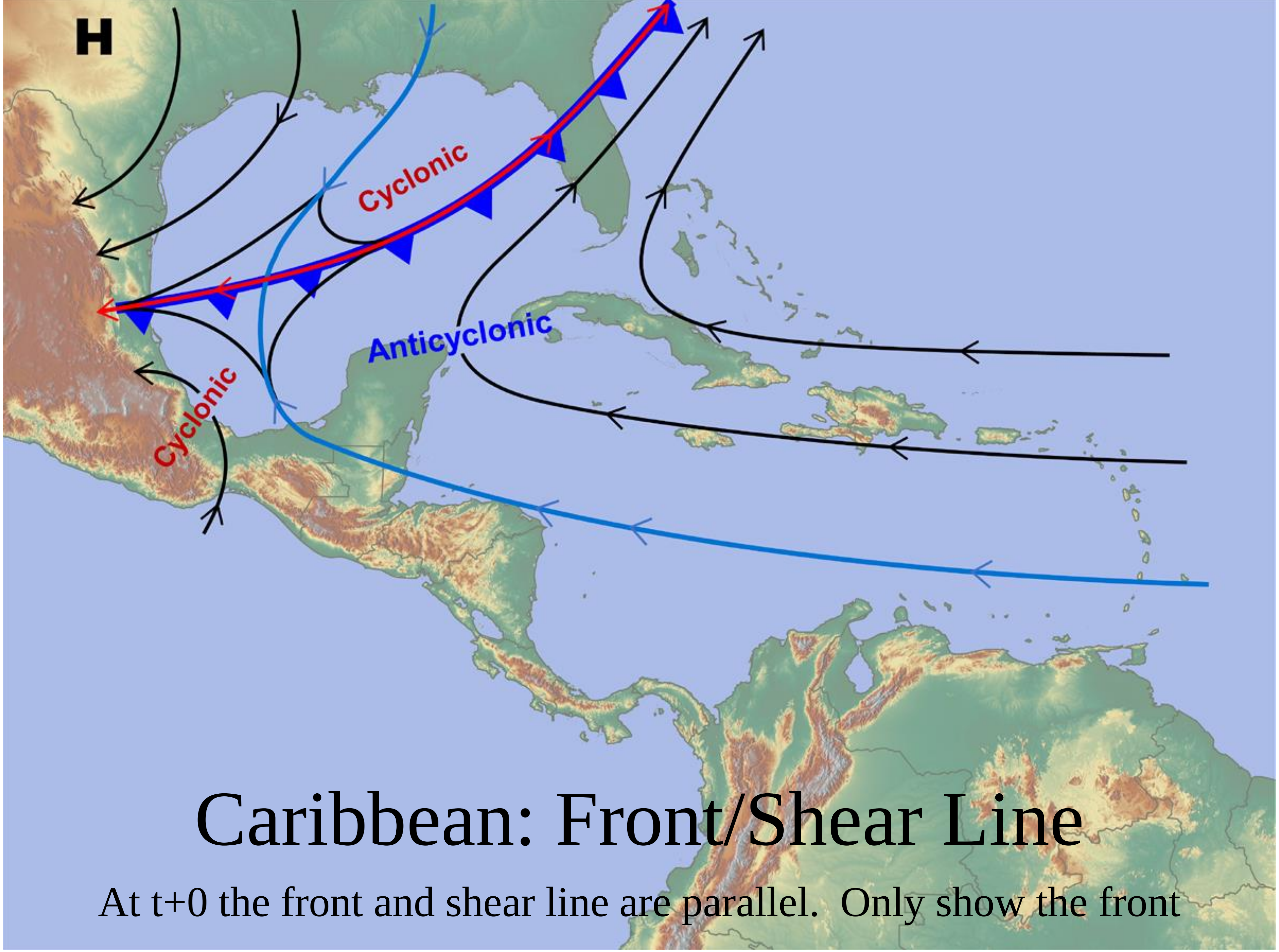
Directional Shear 20180316_18Z



Speed Shear 20191228_12Z

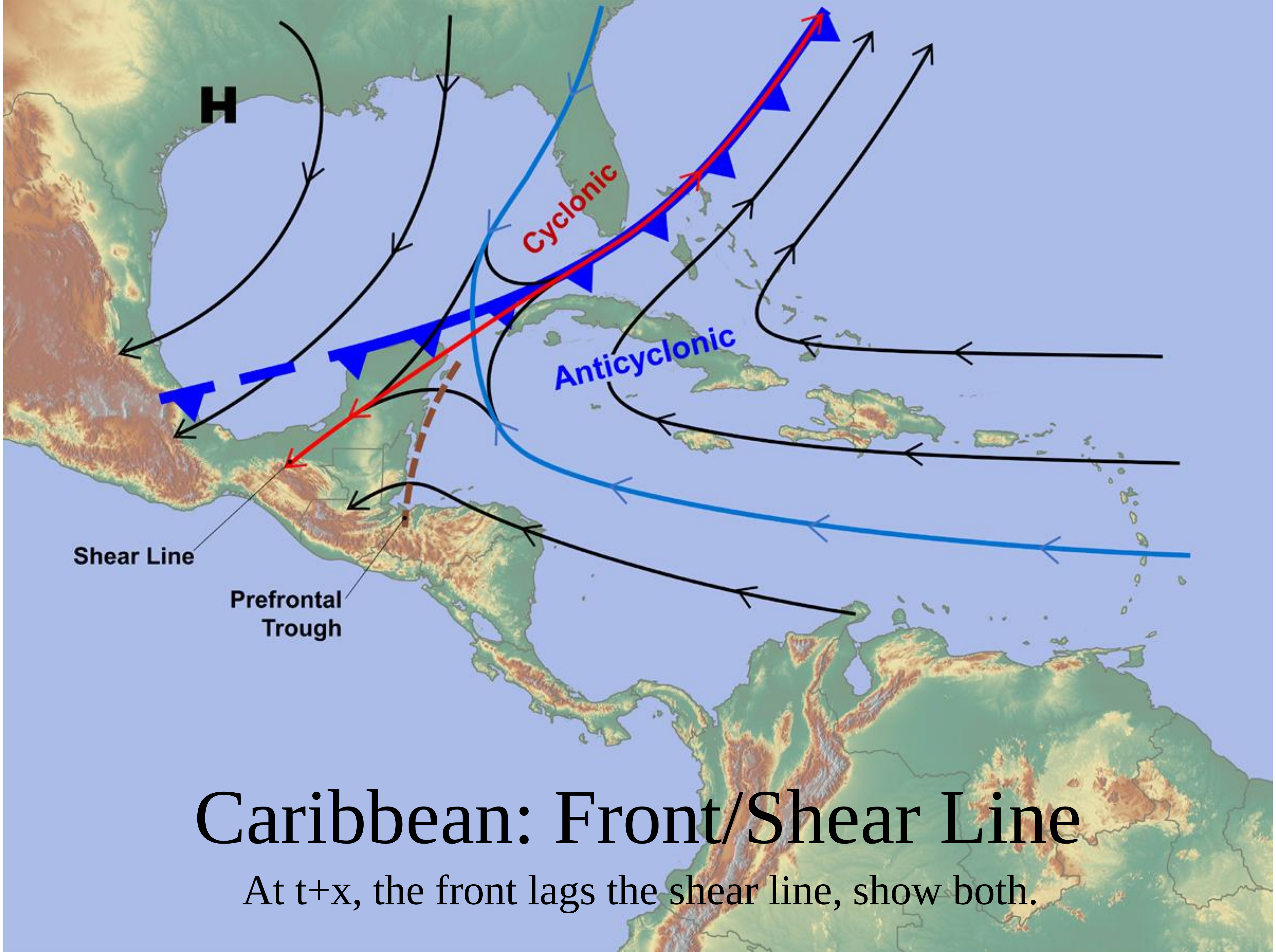
03

Prefrontal Shear Line



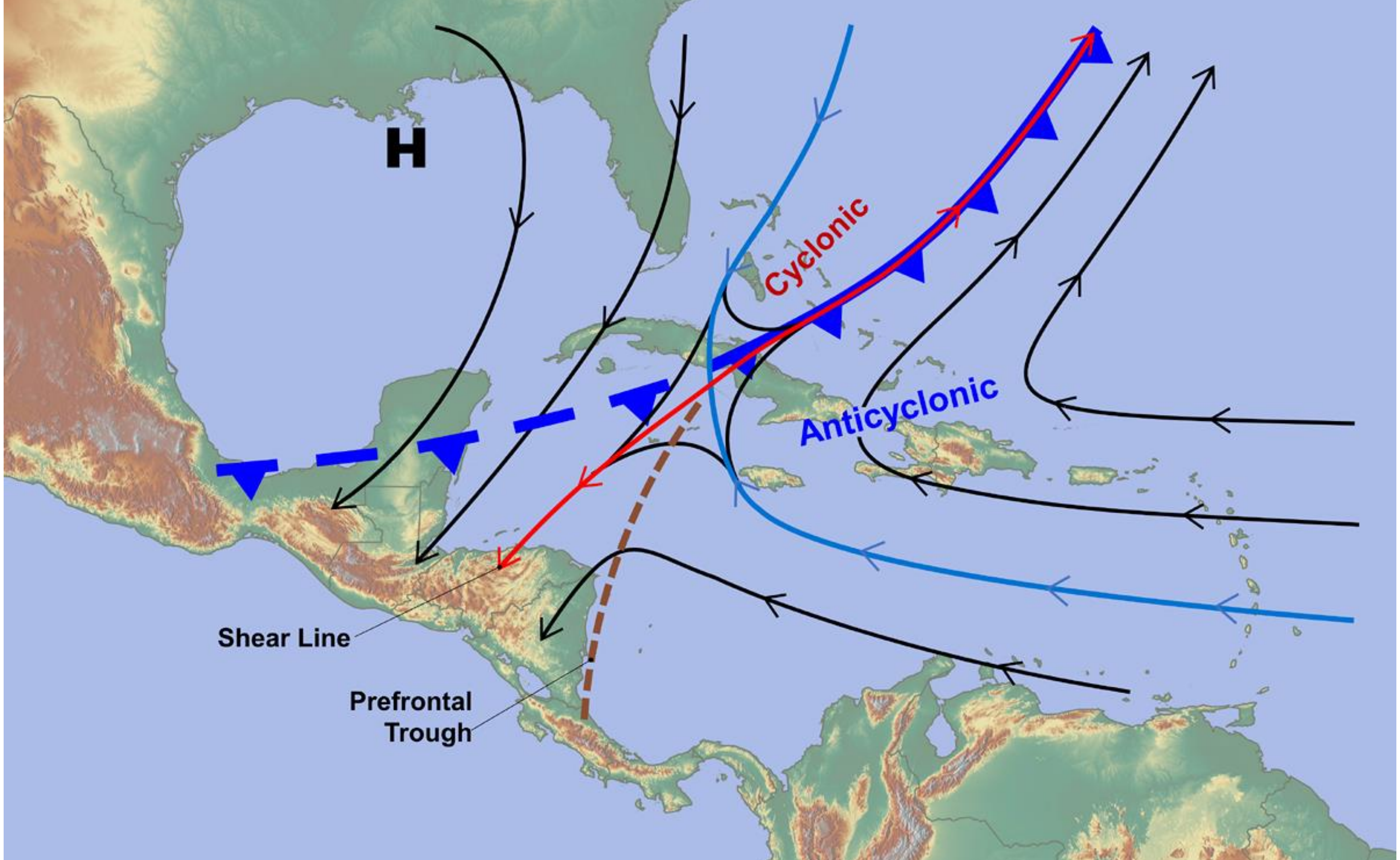
Caribbean: Front/Shear Line

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



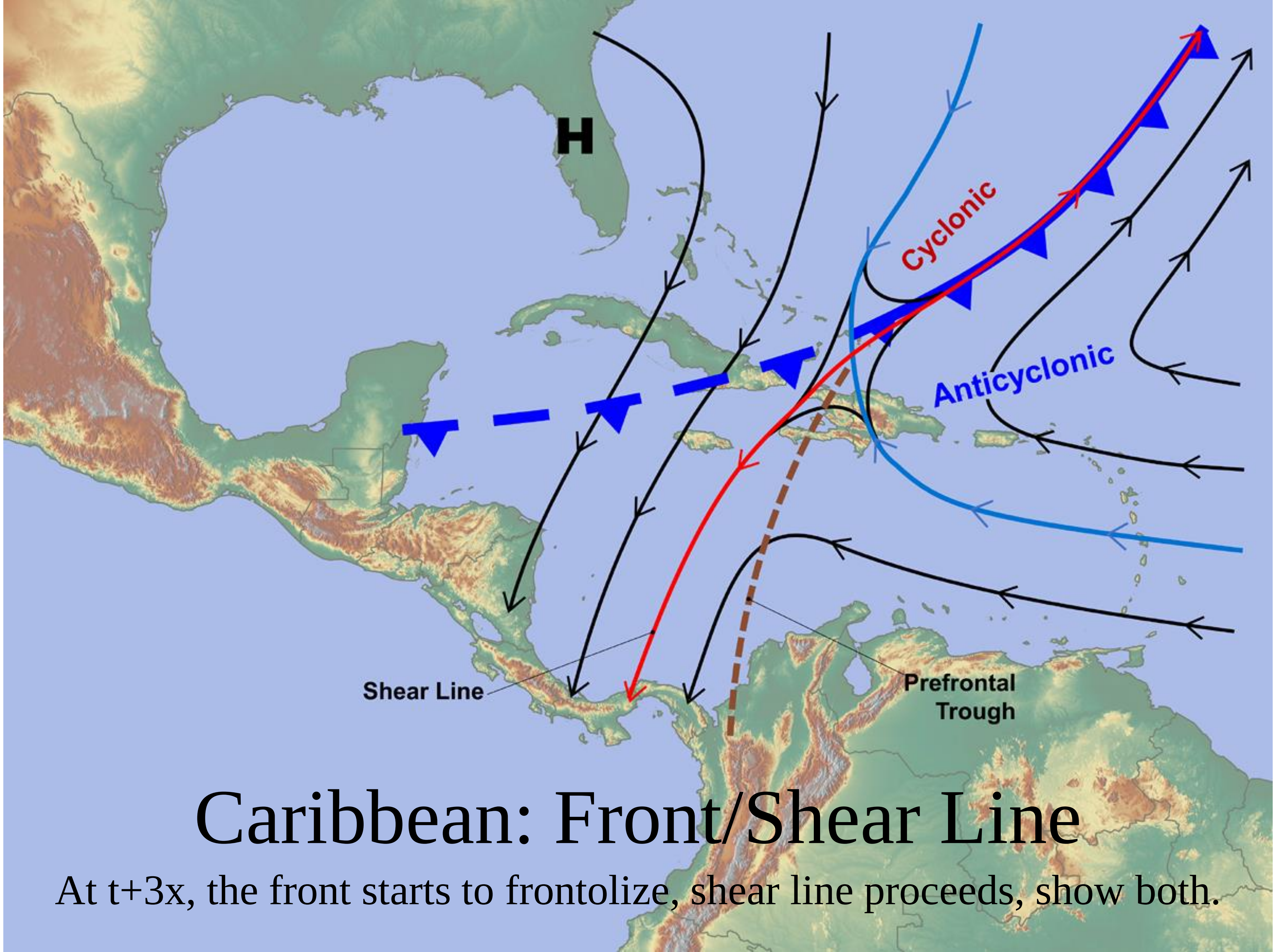
Caribbean: Front/Shear Line

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



Caribbean: Front/Shear Line

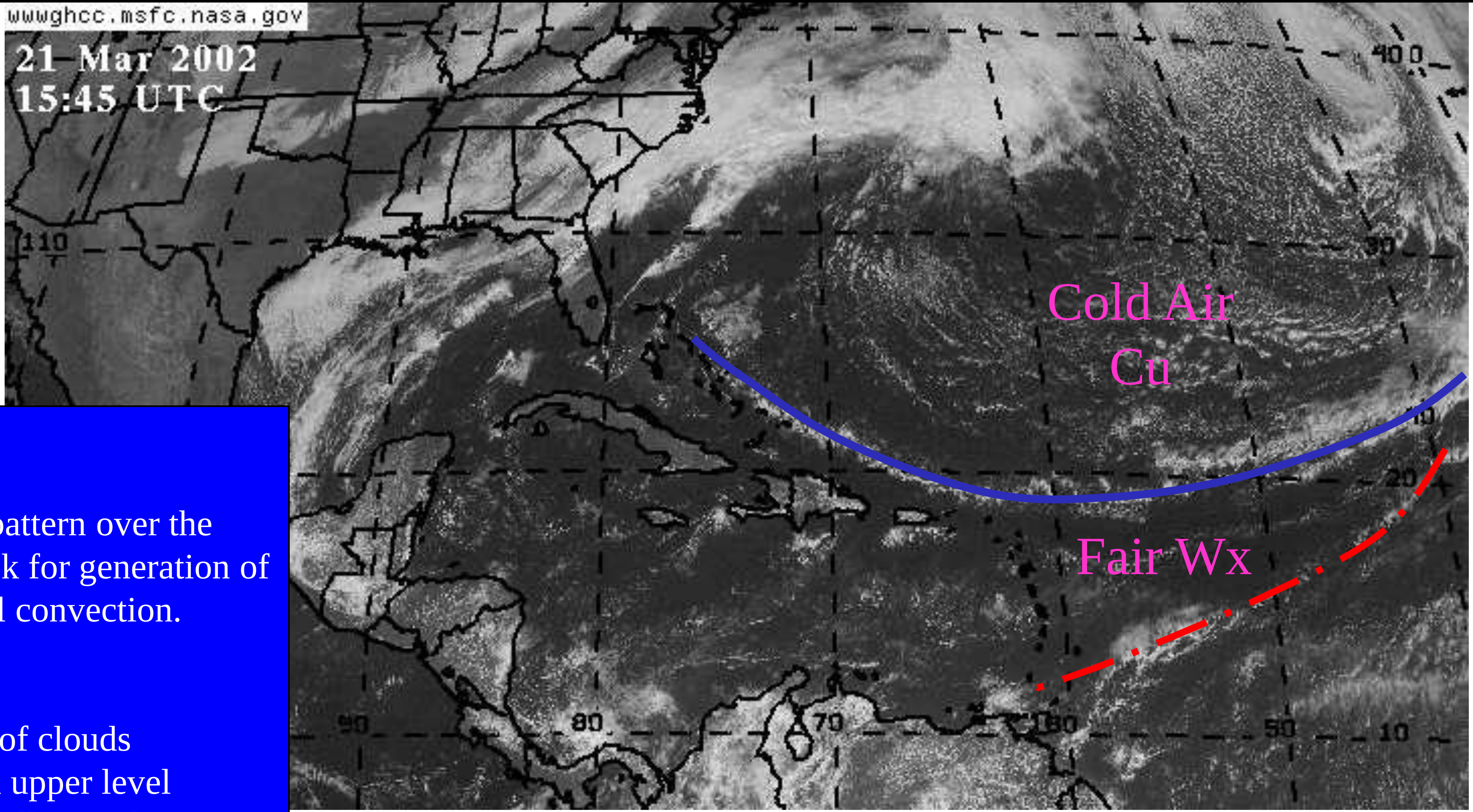
At t+2x, the front falls farther behind, show both.



Caribbean: Front/Shear Line

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

IR Image: Front or Shear Line?



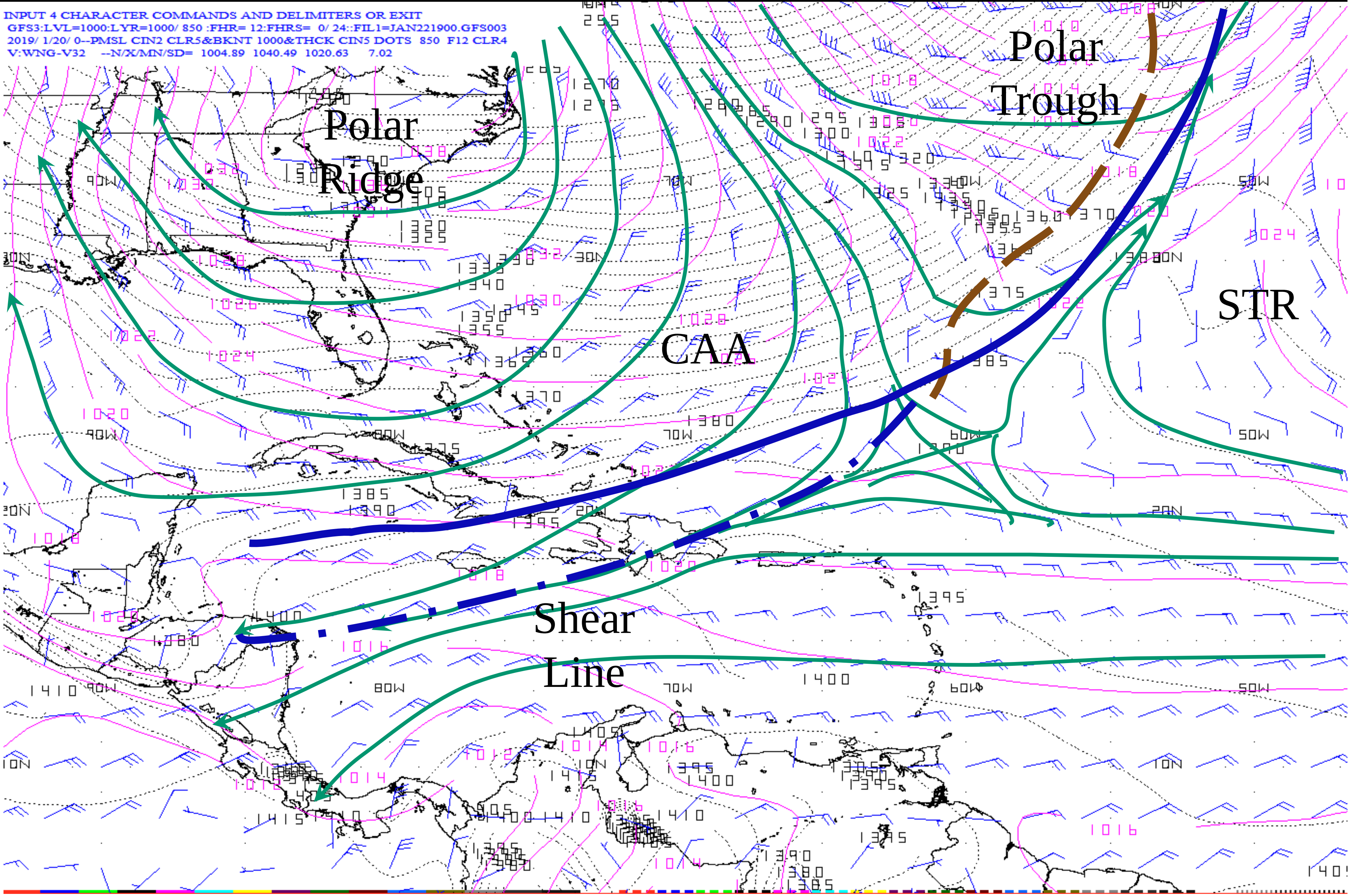
Instructions:

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

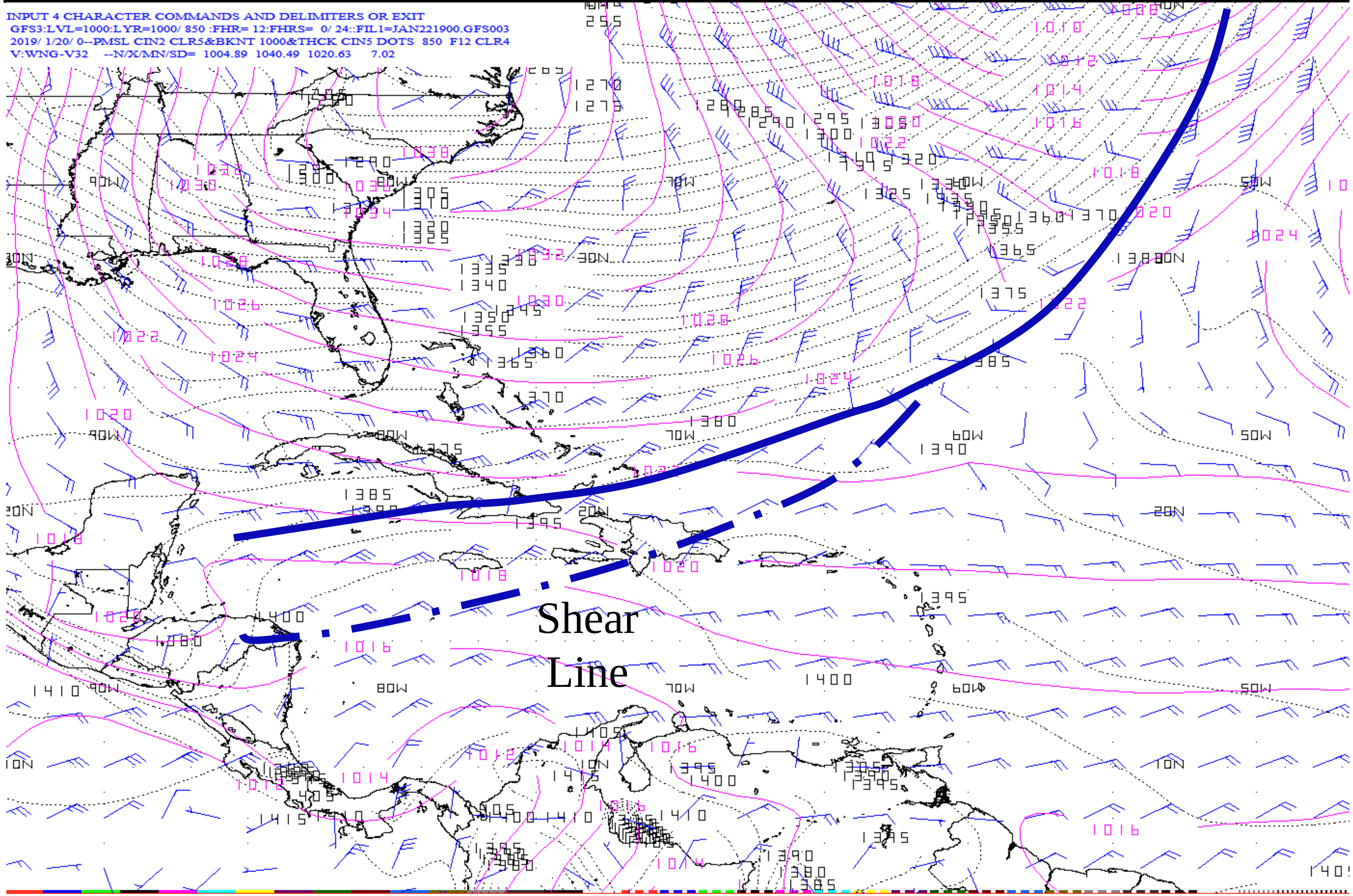
Shear Line:
1. Narrow band of clouds
2. Dependent on upper level support, normally see deeper convective development than with the surface front

Geocolor: Front or Shear Line?

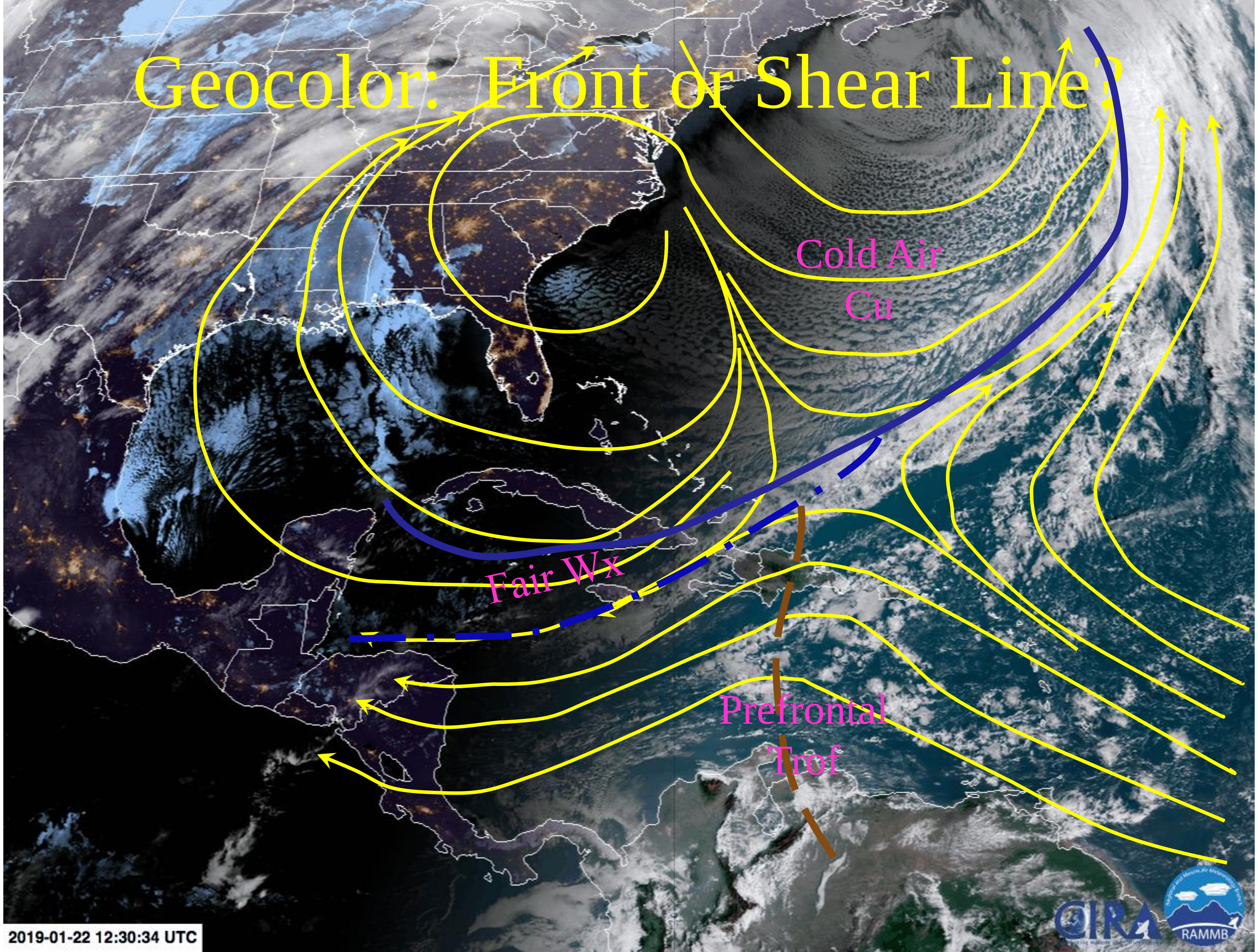
1000-850 Thickness and Winds



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

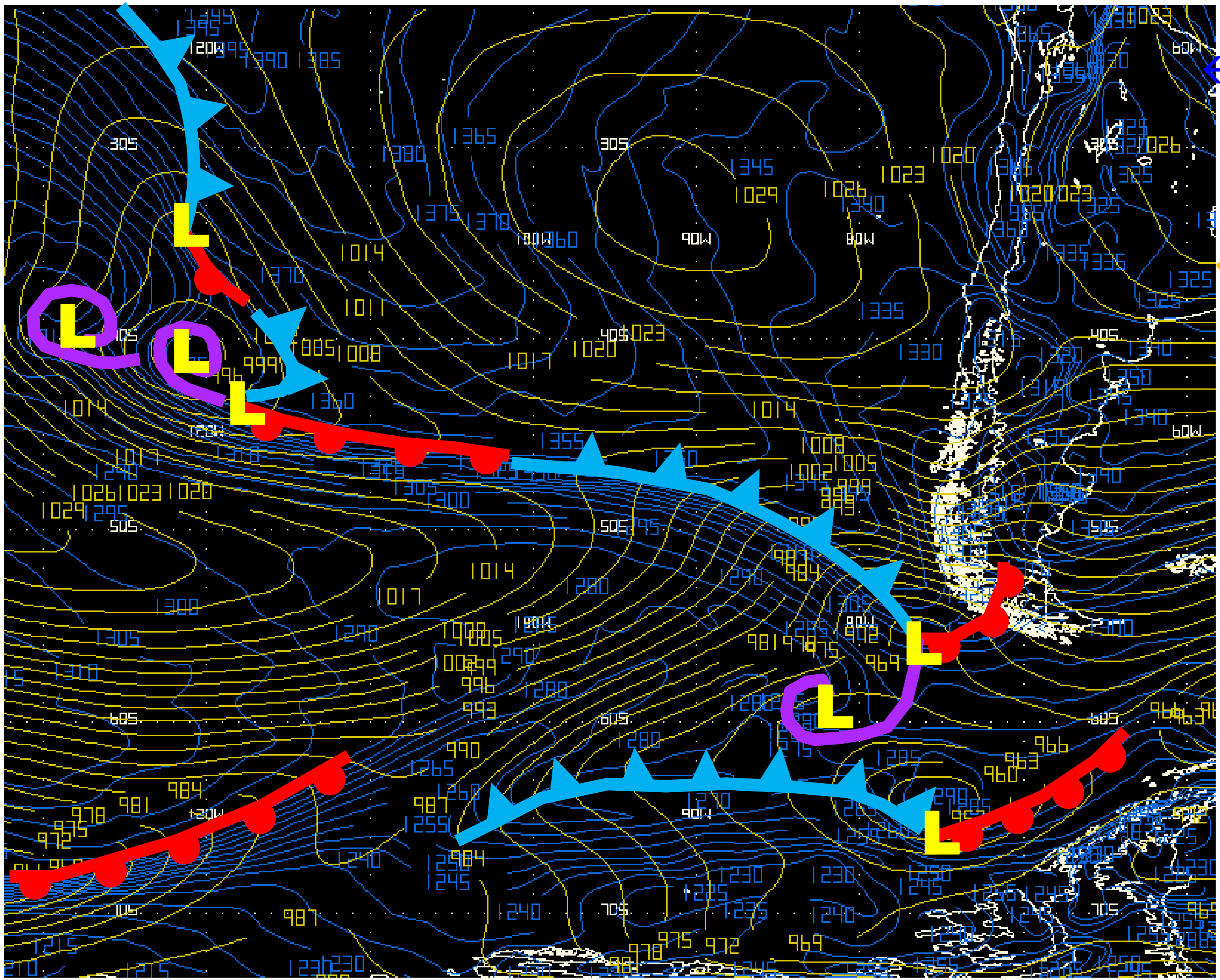
Geocolor: Front or Shear Line?



04

Fronts and Shear Lines in South America

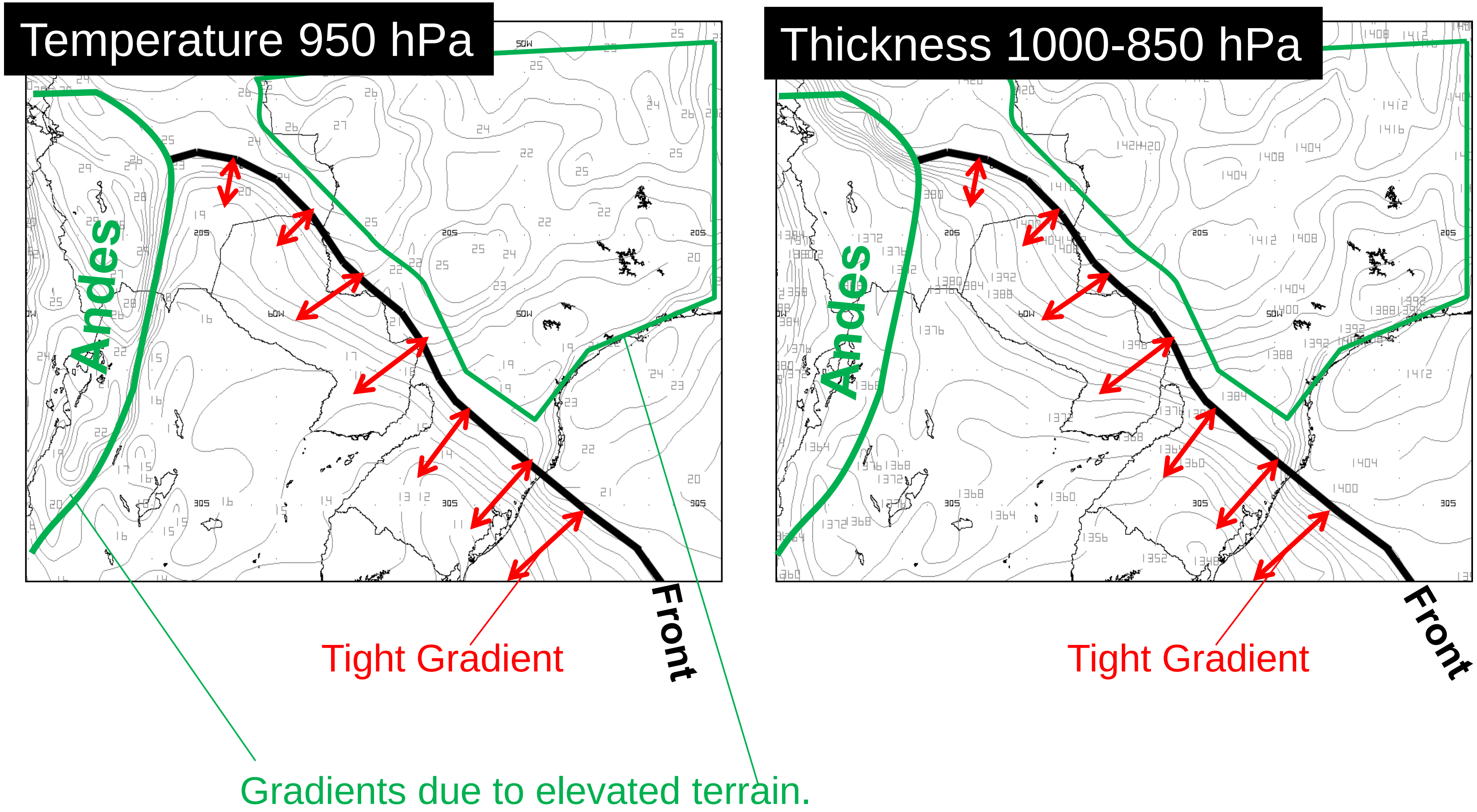
Application of the Conceptual Model



←Espesores

←Isóbaras

Temperature vs Thickness Gradients

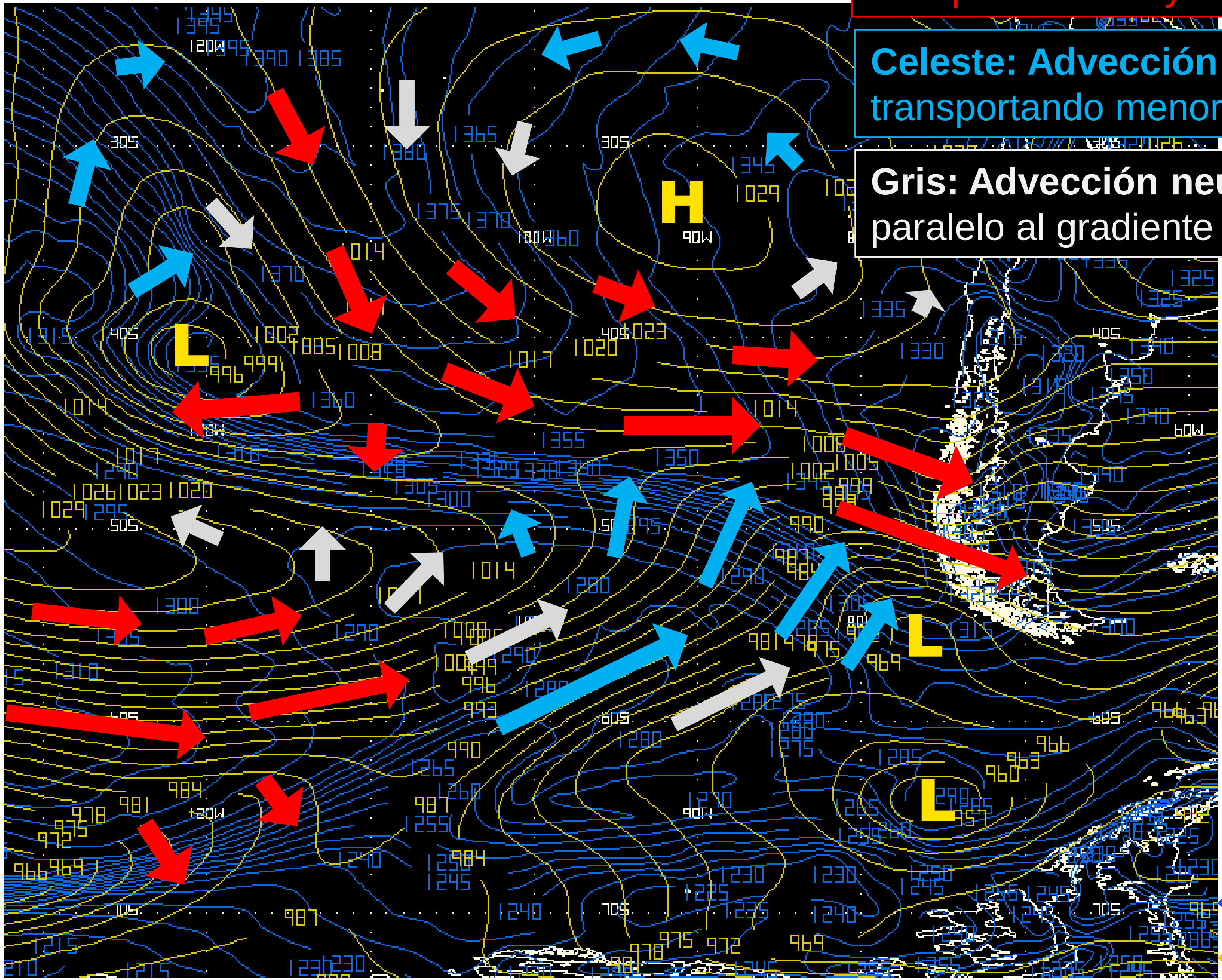


Evaluating Advection: Thickness 1000-850 hPa and sea level pressure

Rojo: Advección cálida. Viento transportando mayores espesores

Celeste: Advección fría. Viento transportando menores espesores

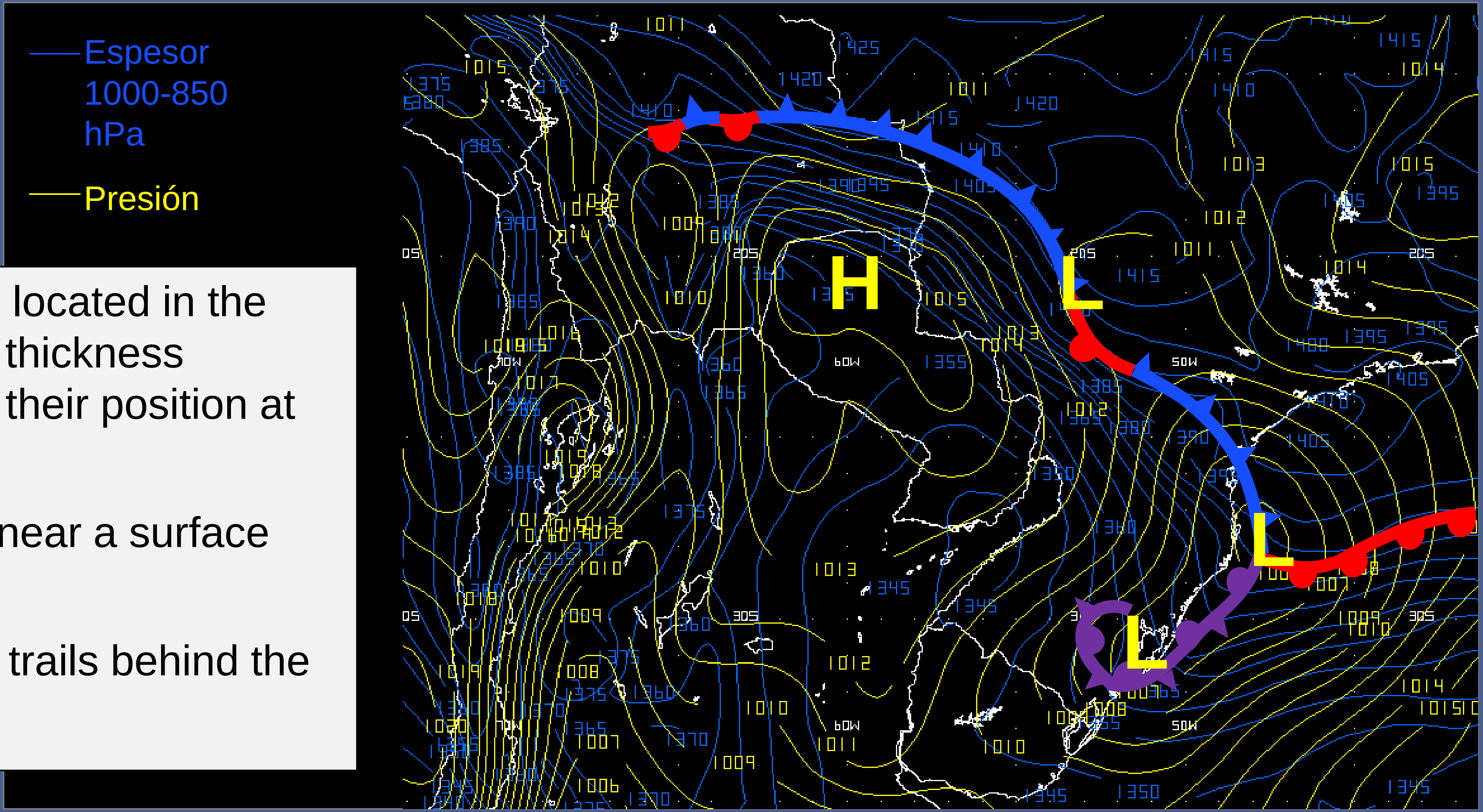
Gris: Advección neutra. Viento paralelo al gradiente de espesor



←Espesores

←Isóbaras

Where should we place the fronts?



- Fronts are always located in the warm edge of the thickness gradient, which is their position at the surface.
- They go along or near a surface trough.
- The occluded low trails behind the triple point low.

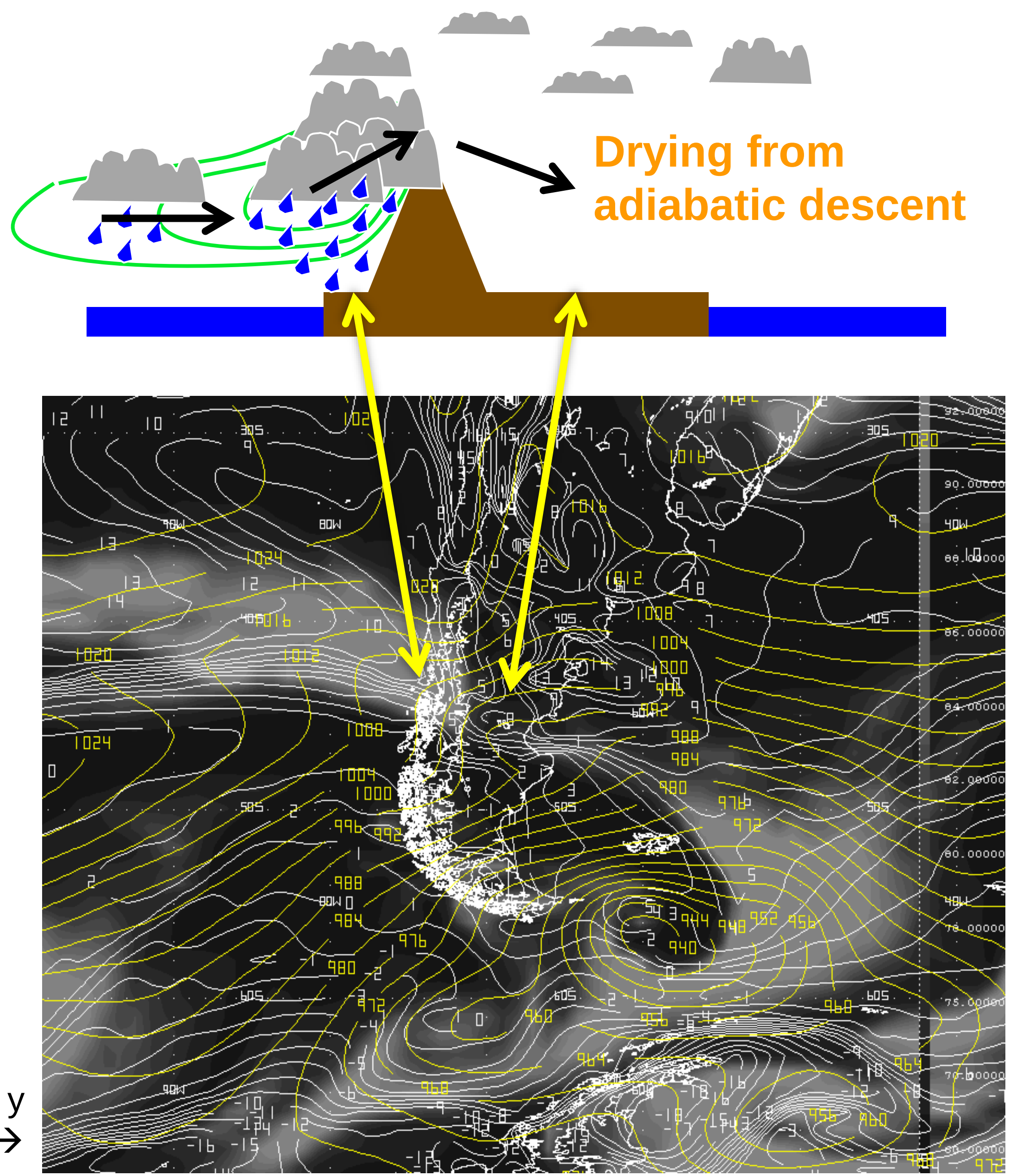
Drying in Patagonia

Sharp decrease in relative humidity once accelerated westerly Flow crosses the cordillera. This is due to:

(1) Adiabatic descent, which warms the air mass rising the temperature.

(2) Loss of water vapor from condensation and then precipitation in the windward side (Pacific Basin)

This difficults the usage of relative humidity to find the fronts. It is important to loop for the termal gradient, troughs and evaluate the movement of the whole system.



(Temperatura, isóbaras y
humedad relativa integrada >70% en sombreado)→

Shear Line in South America

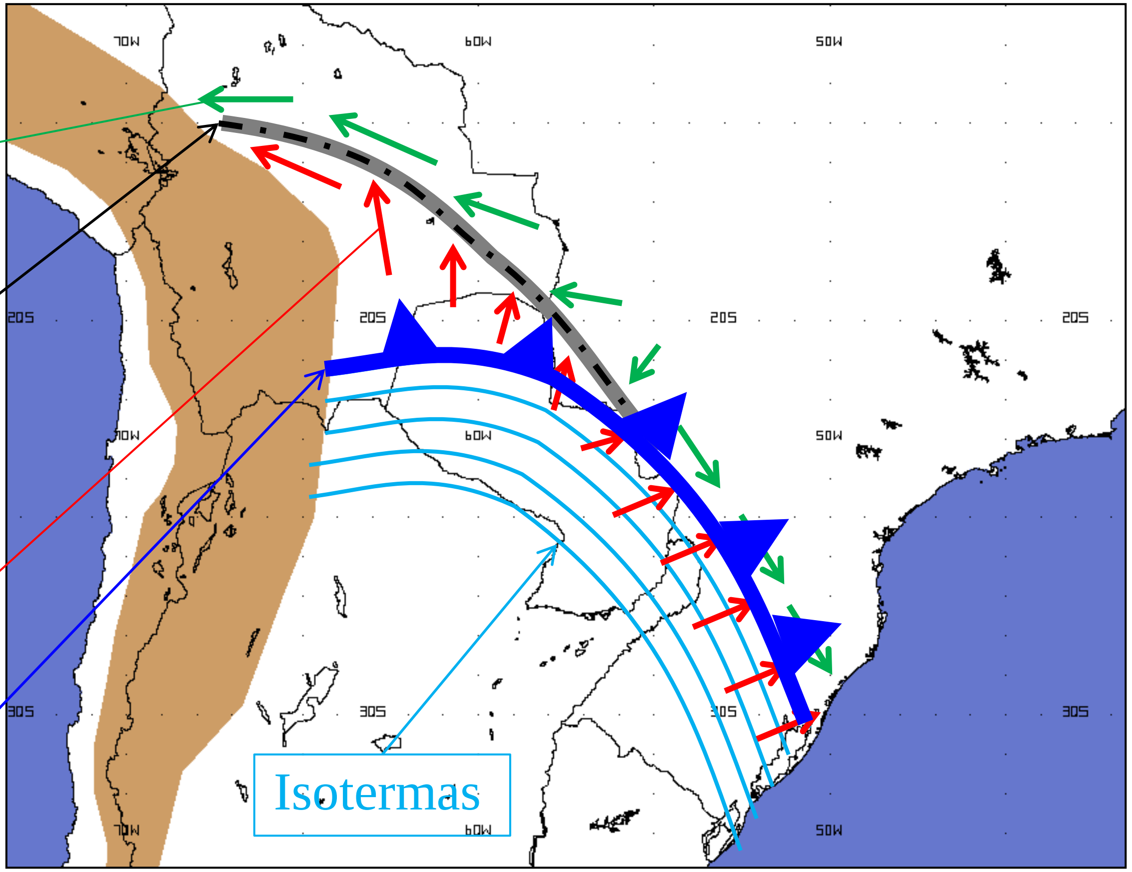
Ejemplo:

Wind ahead of the shear line

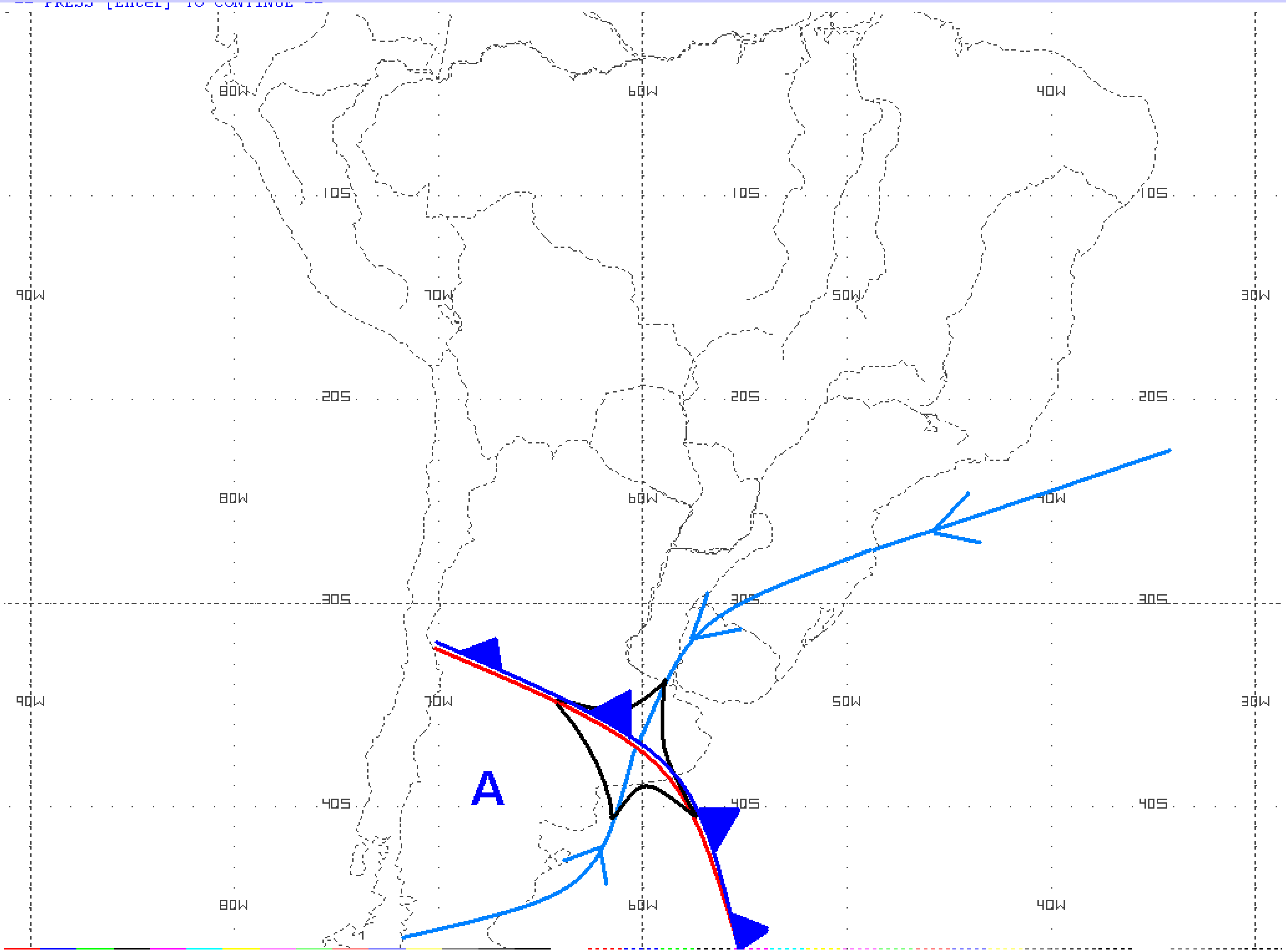
Shear Line: Confluent asymptote. Change in the wind direction/speed but not in the properties of the air mass

Winds behind the shear line.

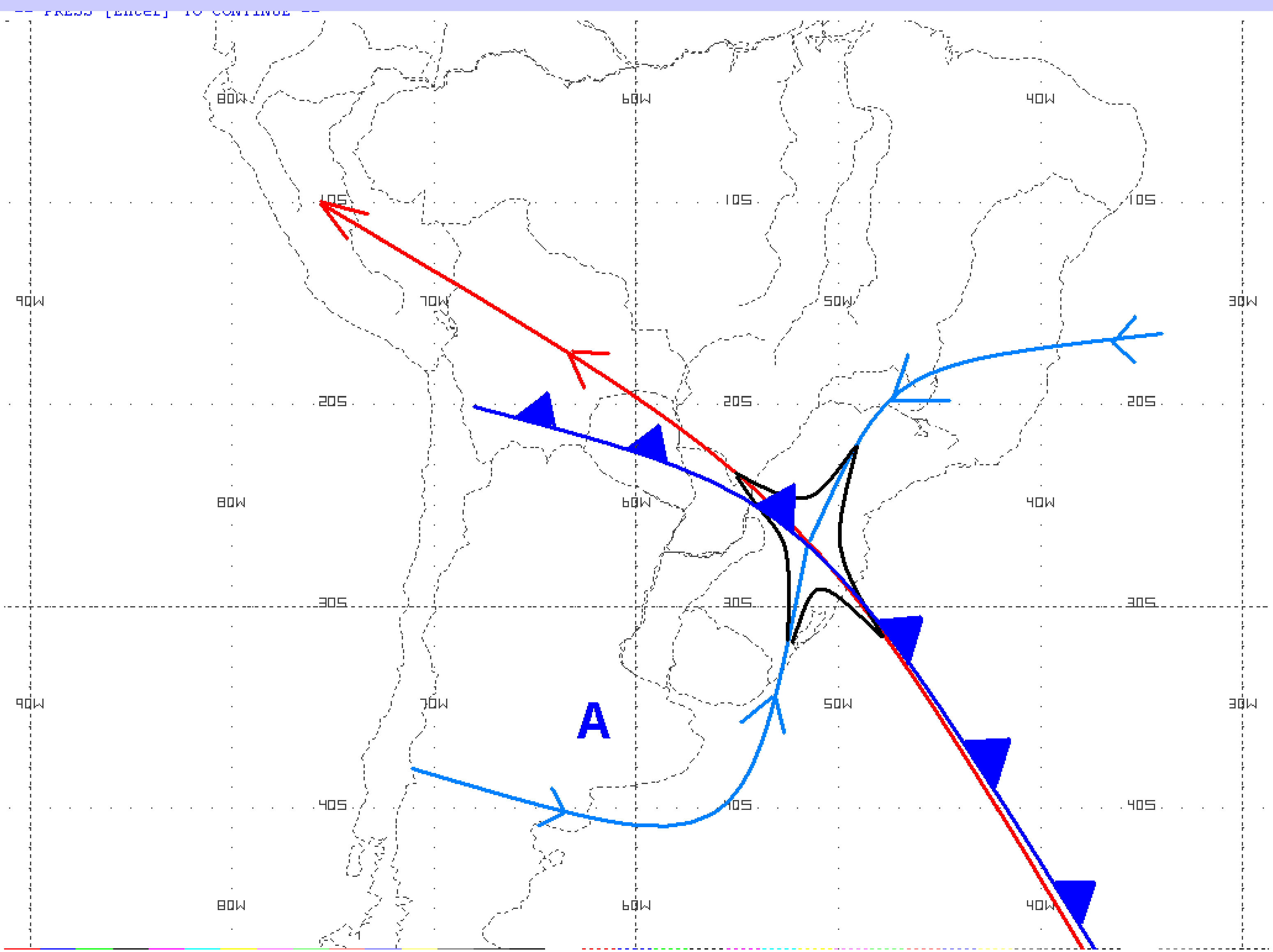
Front, warm edge of the cooler air mass.



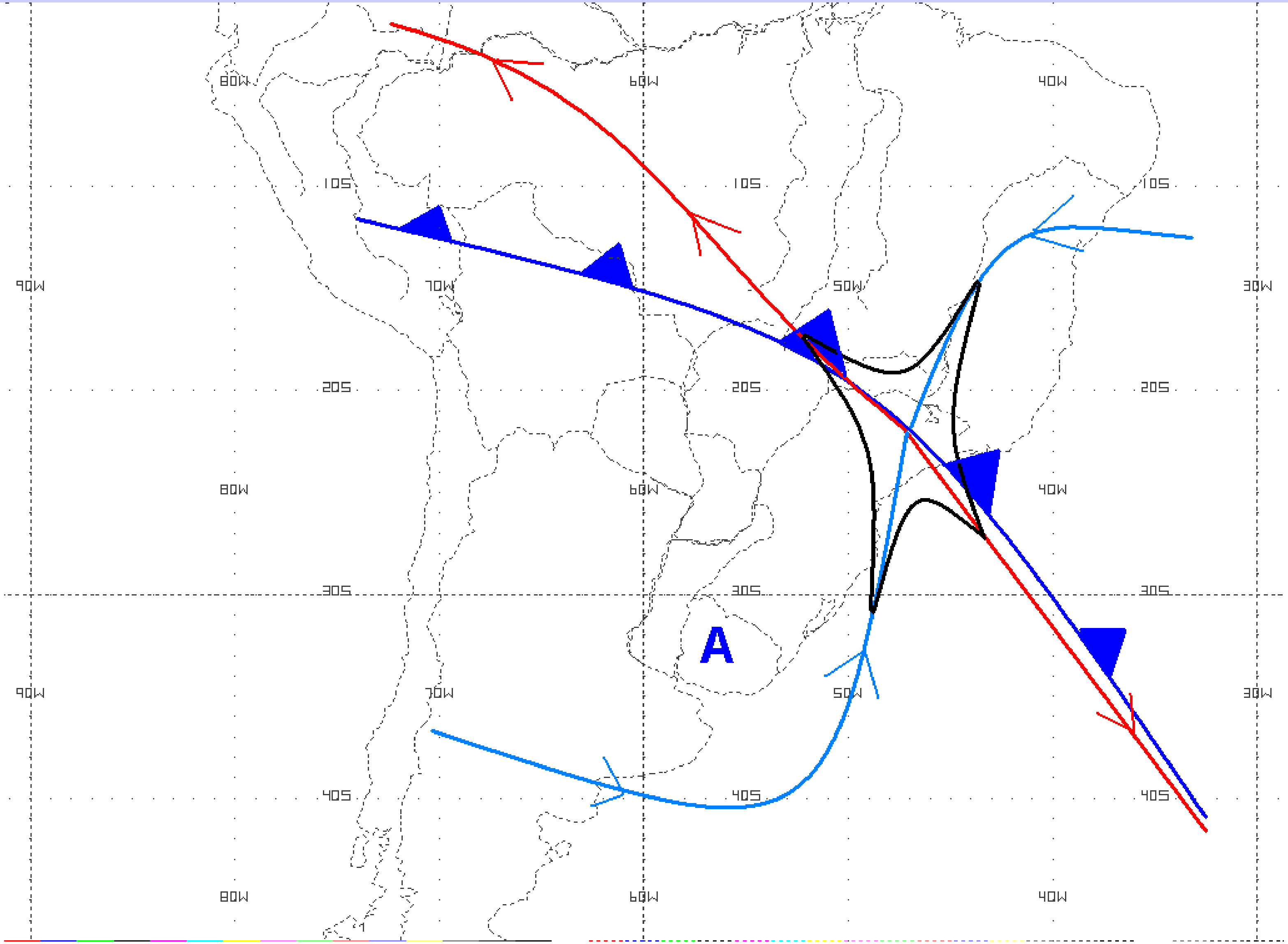
Natural progression of a front and shear line in South America



Natural progression of a front and shear line in South America



Natural progression of a front and shear line in South America



05

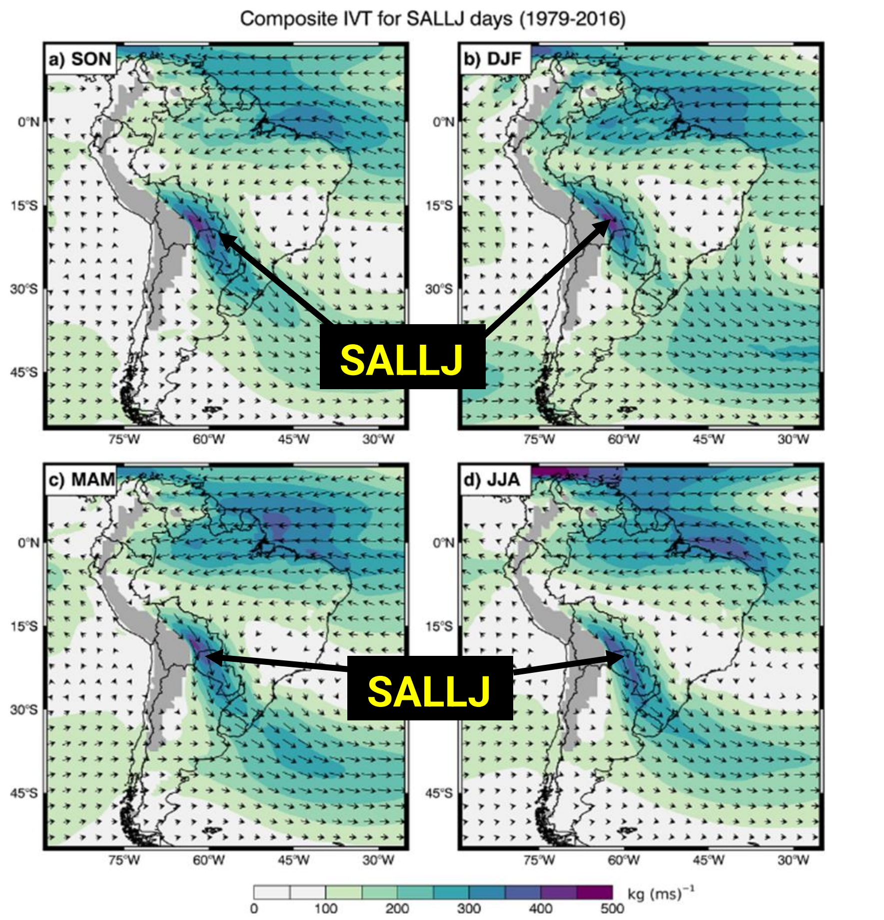
Low-Level Jets

Low-Level Jets

An elongated region of relatively strong winds in the lower part of the atmosphere.

Bonner criteria (for the South American Low-level Jet):
(1) northerly winds (850 hPa) with speeds ≥12 m/s,
(2) vertical wind shear between 850 and 700 hPa ≥ 6 m/s,
(3) meridional component larger than the zonal component,
(4) winds from the north

Bonner criteria generalized:
(1) Winds at 850 hPa > 25kt
(2) Vertical wind shear between 850 and 700 hPa ≥ 6 m/s
(3) Along-jet component larger than the cross-jet component



Seasonal composites of integrated vapor transport (IVT, kg · m^{-1} · s^{-1}) for South American low-level jet (SALLJ) days identified at Santa Cruz/Mariscal (SC/MA) based on ERA-I for 1979–2016.

Source: AMS Glossary of Meteorology, Tessa L. Montini, Charles Jones, Leila M. V. Carvalho, 2019: The South American Low-Level Jet: A New Climatology, Variability, and Changes

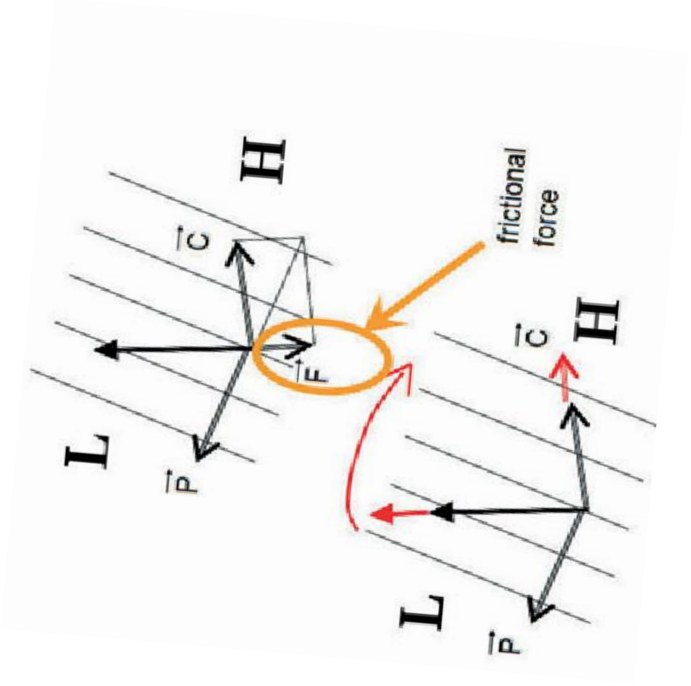
Balance of forces that drive LLJ

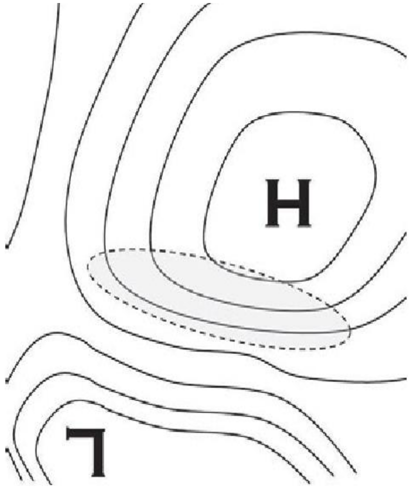
Balance of forces from a LLJ in Germanuy, rotates to simulate an easterly LLJ in the North Henisphere.

They flow close to parallel to the pressure gradient but towards the low. In lower latitudes (e.g. Caribbean), the component towards the low is larger.

In the Caribbean, topography also plays a role funnelling the jets.

They accelerate overnight over land, due to a decrease in thermal friction (no diurnal heating-induced thermals)

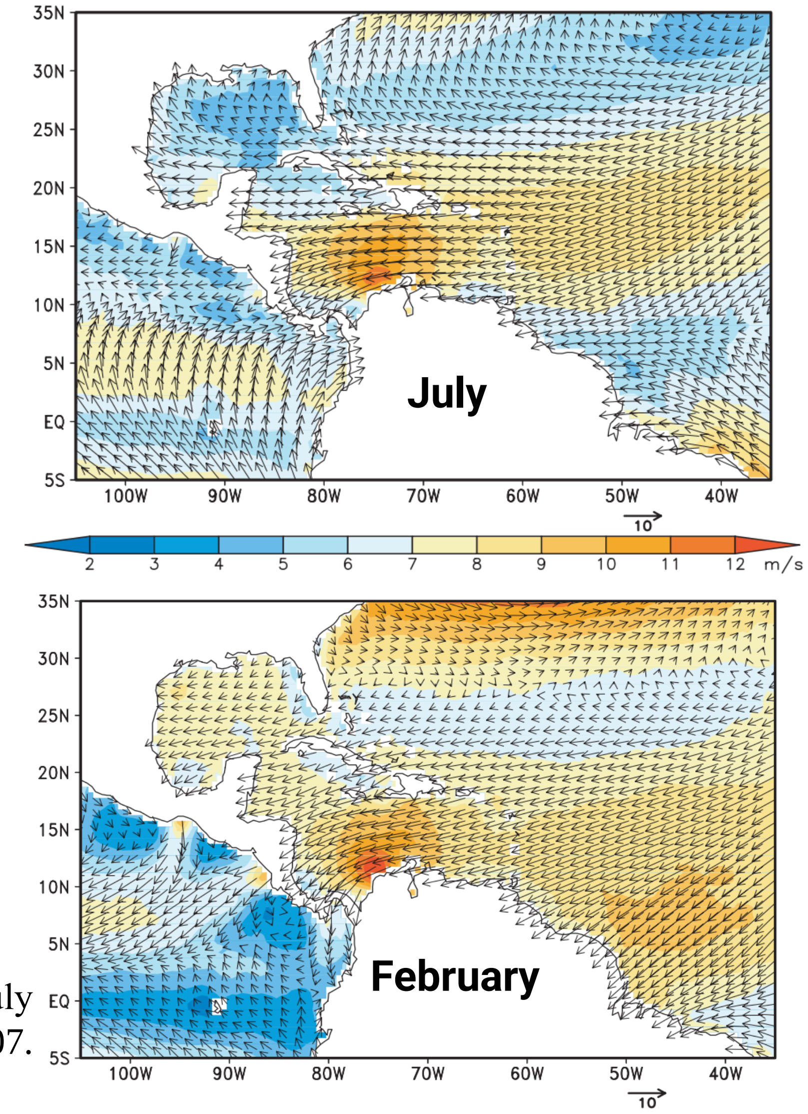




The Caribbean Low-Level Jet

Easterly Jet, peaking between 925 and 850 hPa, that forms in the southern Caribbean during most of the year.

- It peaks in February (Jan-Mar dry season) and July (mid-summer drought).
- Maximum forms in the southern Caribbean.
- It is an important source of low-level wind shear, especially near the coast of northern Colombia and northwest Venezuela.



Mean QuikSCAT winds (m s−1) for (A) July and (B) February for the period 2000–2007.

Source: Amador, 1998: The Intra-Americas Low-level Jet.

Wind shear along the Caribbean Low-Level Jet

Wind shear is stimulated in regions of enhanced wind speed gradients.

In the Caribbean, February LLJ tend to favor more wind shear between 900 and 750 hPa, and down to the surface downstream from the LLJ (reaching eastern Central America).

July LLJ tend to favor stronger shear but closer to the surface, up to 850 hPa. Being a deeper LLJ, another region of wind shear is facored between 650 and 550 hPa.

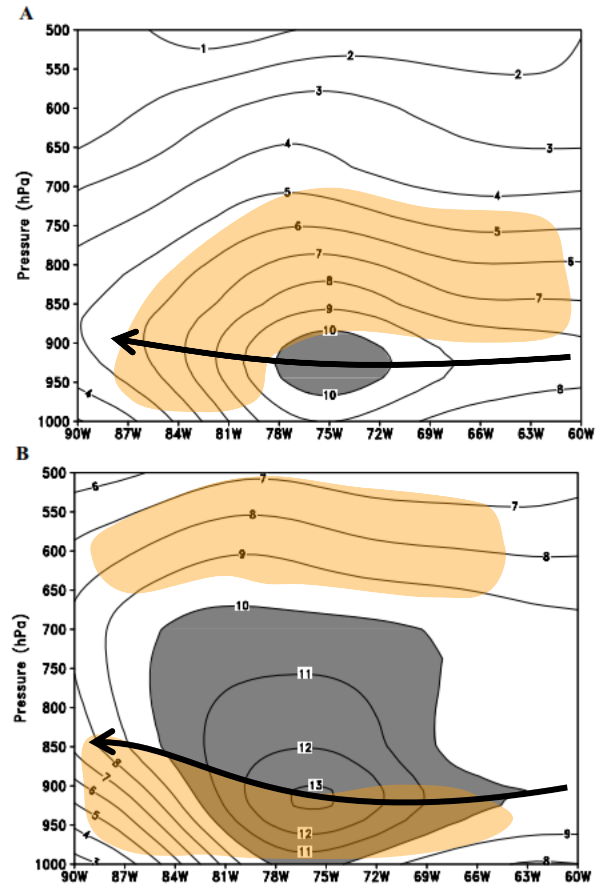
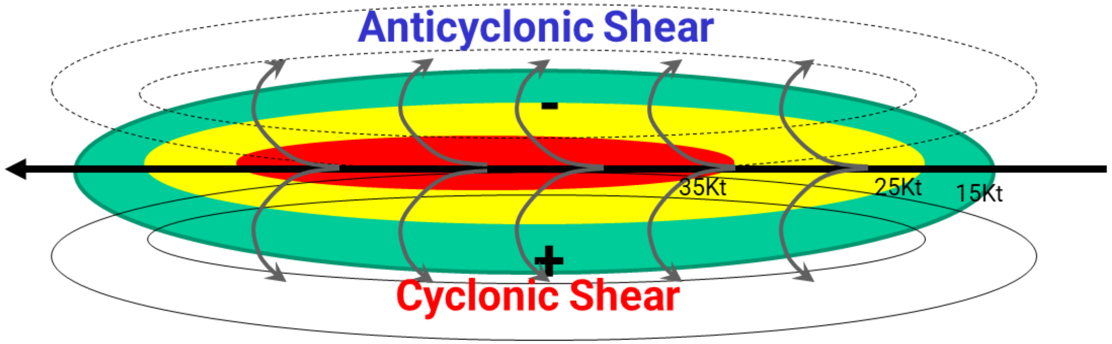


Figure 5. Vertical profile of monthly mean wind speed (m s^{-1}) averaged from 12.5 to 17.5 °N from reanalysis for **(A)** February and **(B)** as in (A) but for July.[68]

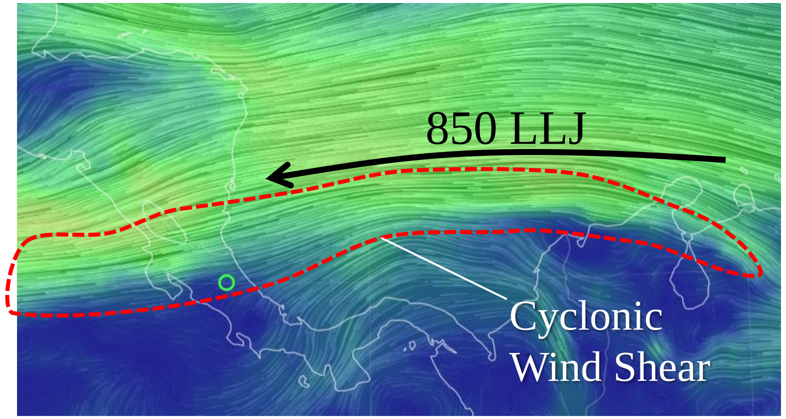
Source: Amador, 1998: The Intra-Americas Low-level Jet.

Horizontal Wind Shear

- Develops where the largest horizontal wind gradients occur.
- This is a region where large values of turbulence develop.
- Generates vorticity. Cyclonic vorticity (NH: left of the jet maxima and SH: right of the jet maxima) favors ascent.
- Regions of cyclonic shear in LLJ can add the vertical motion/convection hazard to the existing turbulence hazard.



850 hPa Winds, 22 Jul 2021 18Z



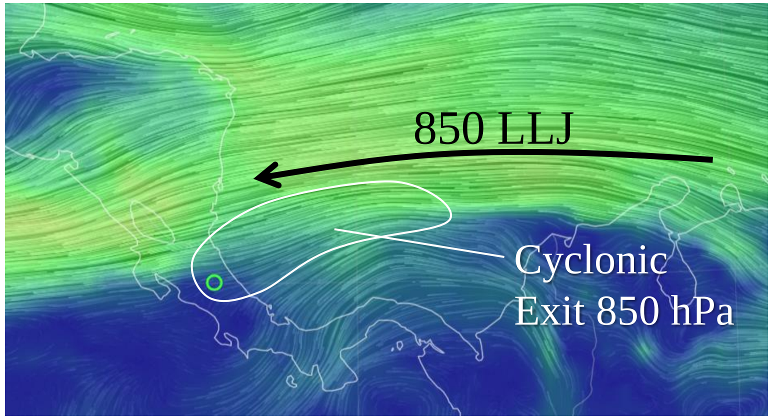
Where do LLJ favor ascent and extreme rainfall?

LLJ enhance ascent along their cyclonic convergent side.

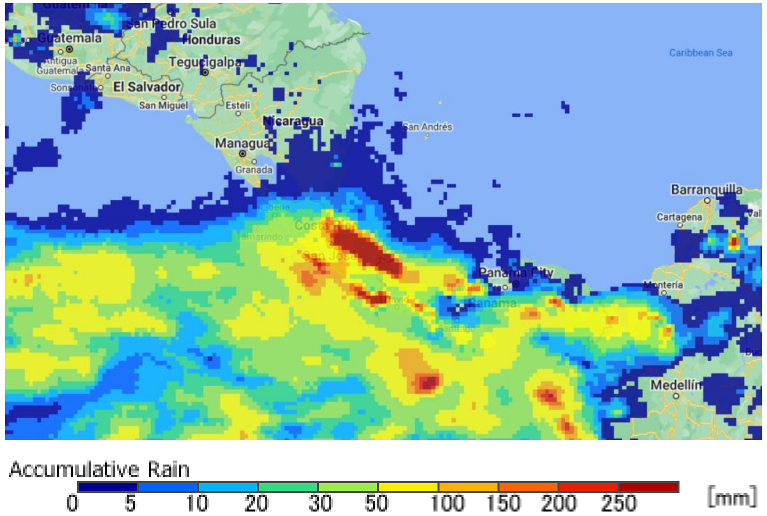
Ascent in the cyclonic exit of the Caribbean LLJ entering eastern Nicaragua often favors convection (T storms) and heavy rain in SE Nicaragua and E Costa Rica.

The 22-23 July 2021 event produced excessive rainfall and flooding in eastern Costa Rica.

850 hPa Winds, 22 Jul 2021 18Z

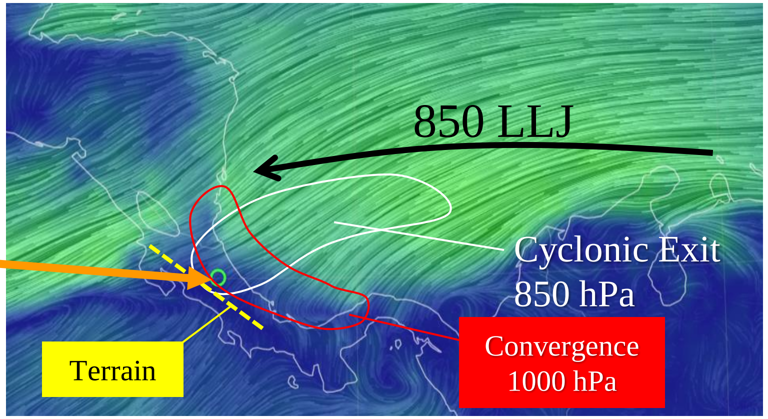


Estimated 24-hr Rainfall > 250mm



1000 hPa Winds, 22 Jul 2021 18Z

Interception of areas in a region of orographic enhancement



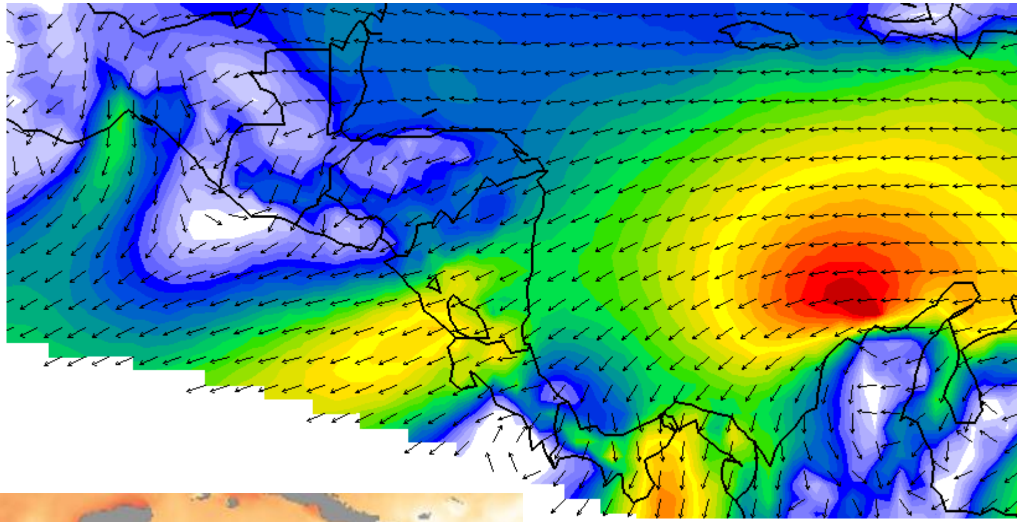
Central American Gap Flows

Low-level jets that form along and downstream from Central American gaps in the terrain, when surface pressures in the Caribbean basin increase.

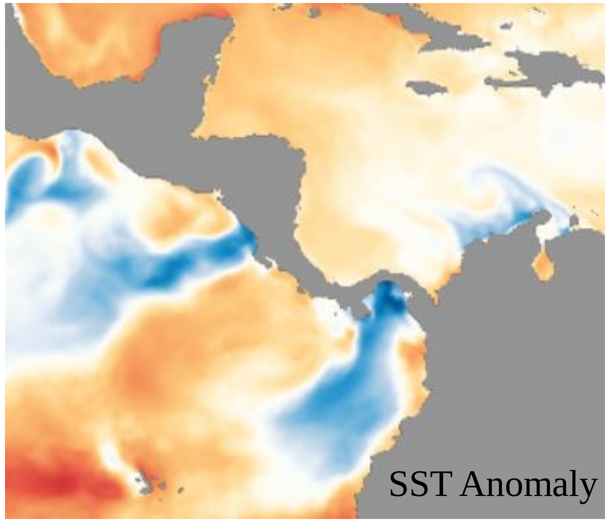
a) Tehuantepecer
b) Papagayo / Nicaragua
c) Panama

They produce low-level wind shear affecting even some airports (e.g. David, Panama).

They affect thunderstorms development and also cool the ocean by inducing upwelling.

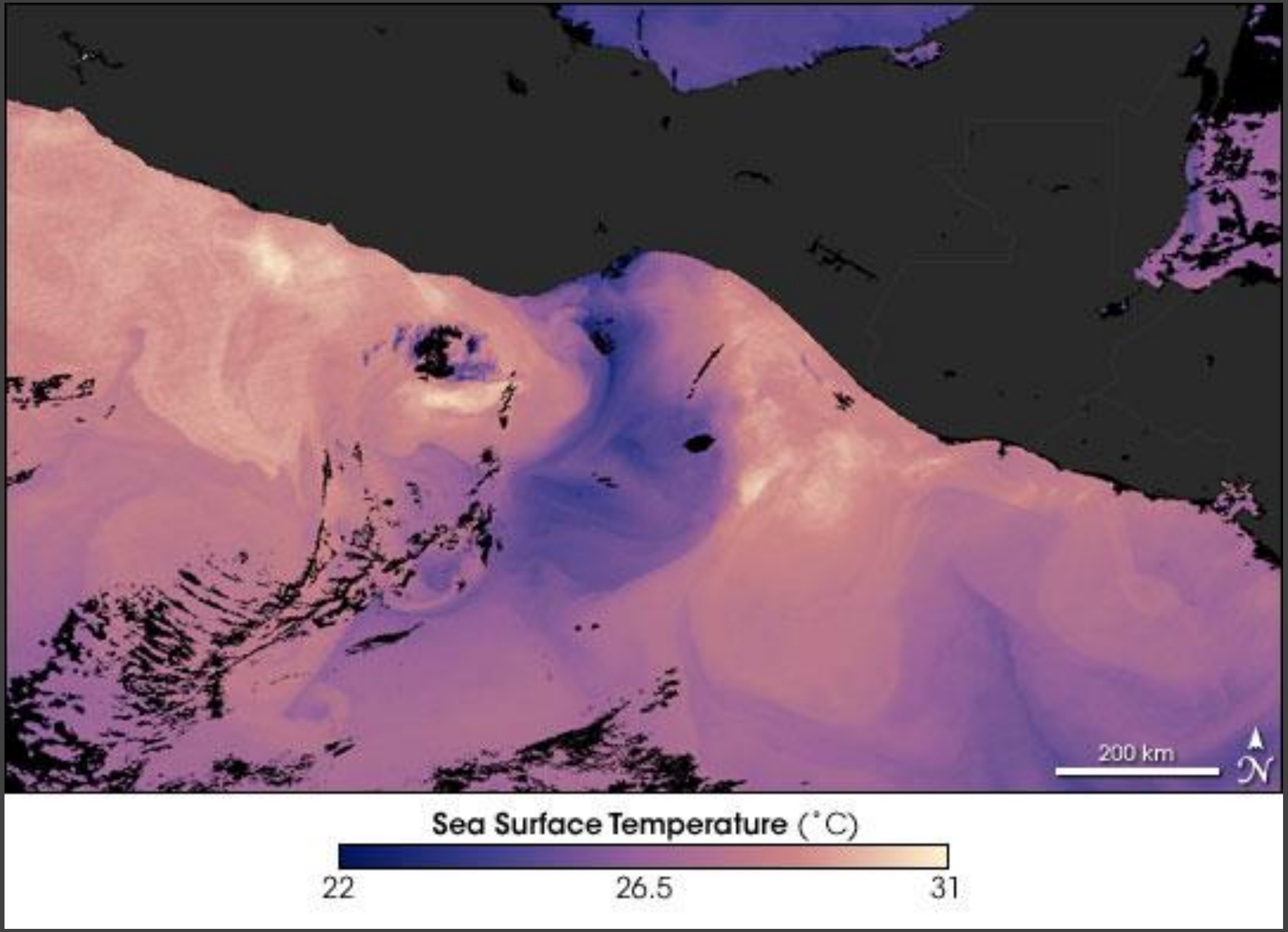


Mean 925 hPa winds for February (NARR)

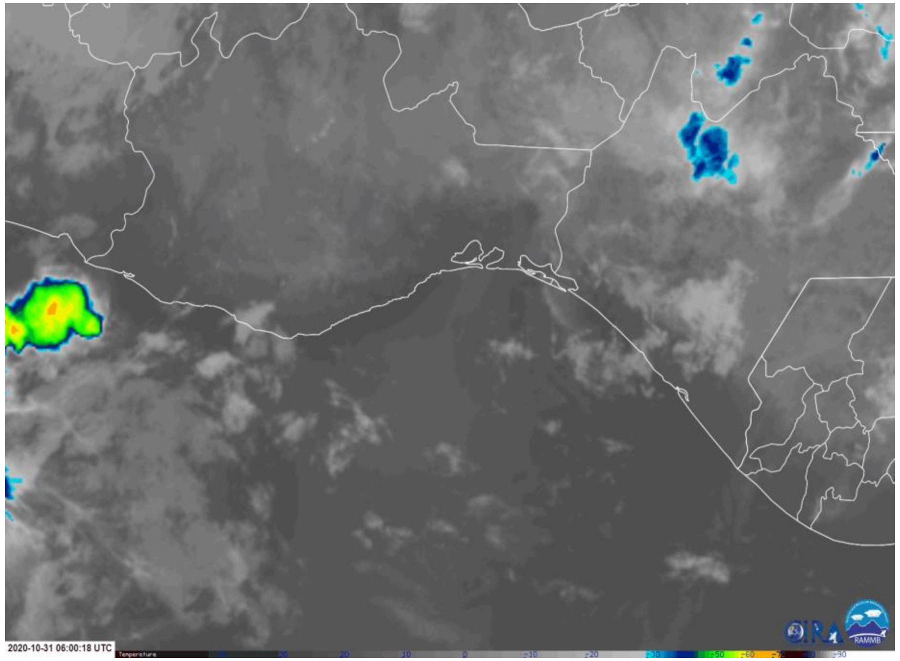


Low-level jet induced upwelling (blue) after a period of intense gap flows, in NOAA NVVL's SST Anomaly OISST Database.

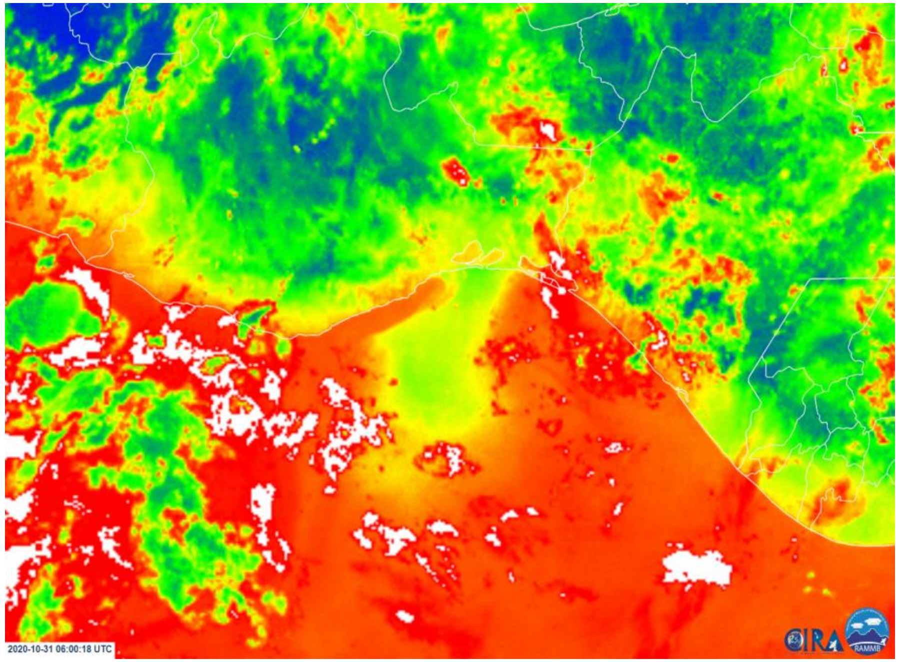
Cold Water Upwelling Gulf of Tehuantepec



Cold Water Upwelling
Gulf of Tehuantepec

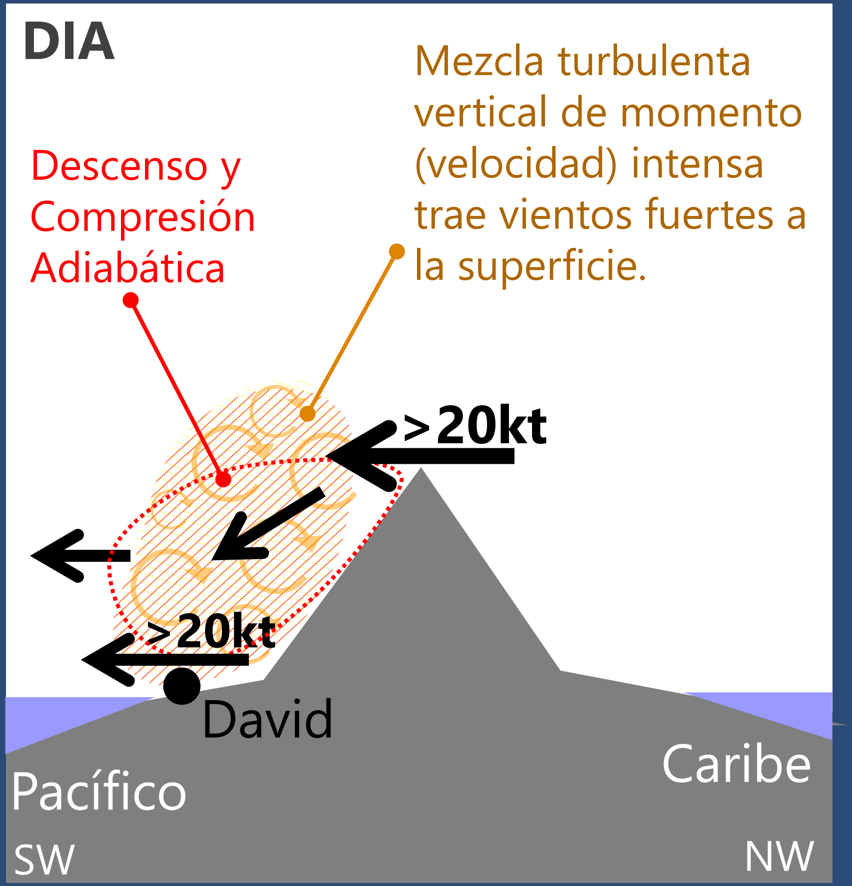


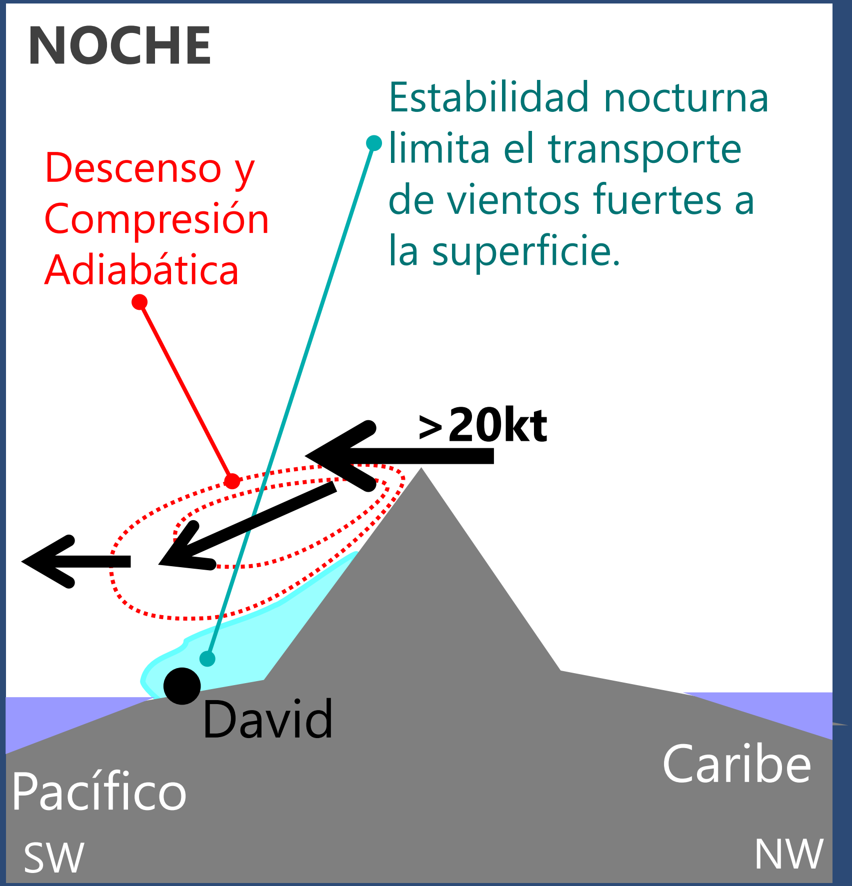
10.3 um



Split Window
10-3 – 12.3um

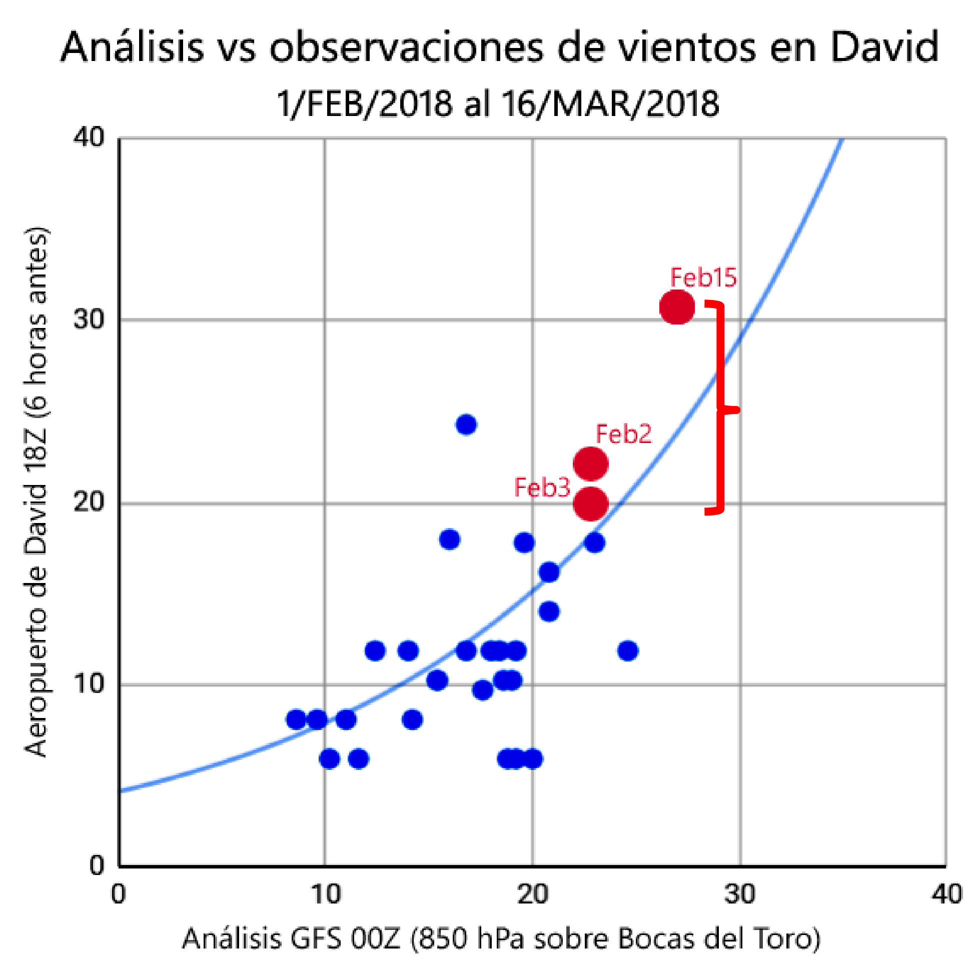
The terrain in Central America can favor strong winds in populated areas, such as David, Panama





Severe Winds in David, Panama (MPDA)

¿Can they be forecasted with the GFS?



- 850hPa GFS Winds (00Z) vs station winds (18Z or 6 hours prior).
- Direct relationship
- Red: Events >20kt in MPDA when GFS winds exceded 20kt in Bocas del Toro (upstream).


ICAO Headquarters
Montréal
European and North Atlantic (EUR/NAT) Office
Paris
Asia and Pacific (APAC) Sub-office
Beijing
Middle East (MID) Office
Cairo
Western and Central African (WACAF) Office
Dakar
North American Central American and Caribbean (NACC) Office
Mexico City
Asia and Pacific (APAC) Office
Bangkok
Eastern and Southern African (ESAF) Office
Nairobi
South American (SAM) Office
Lima

Thank You!