Fronts and Shear Lines

Michel Davison and José Gálvez
WPC International Desks
2020
Distribution

• The presentation is available on our ftp server at:
  • **Title**: Fronts and Shearlines_Caribbean
    – You can copy the presentation, or part of it, and you may share it with others as long as you give credit to NOAA.
    – The use of the material for commercial purposes is not allowed

• NOAA retains all copyrights of the material
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.
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**
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!
• 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?

Instructions
1. Find the gradient
2. Analyze the thickness values
3. Find the cold side
4. Find the warm side
What’s required?

(1) Wind Flow $\leftrightarrow$ Vector
(2) Temperature or Thickness $\leftrightarrow$ 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 °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

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

Example: “A”
Westerly flow points from warm to cold.
The advection is: Warm
Coded as: = A:W
Poll Question #1
(Select the correct answer)

• A:W, B:C, C:C, D:W, E:W, F:N


• A:W, B:N, C:W, D:N, E:C, F:N
Poll 1 Answers Review
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
- 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
At low levels, the colder air moving over warmer SSTs incites convective instability, while the stronger winds result in mixing of the boundary layer.
- 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
I. Frontal Wave Forms
II. Frontal Wave
III. Occluding Front
IV. Occluded Front
Surface Front Placement

Fronts are drawn along a **trough**, **parallel** to the isotherms and on the **warm side** 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
- 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?

A is correct, 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

- $\Delta T$
  - Temperature drops following frontal passage
- $\Delta P$
  - Pressure drops as the frontal trough approaches
  - Pressure rises as the polar ridge builds
- $\Delta T_d$
  - Note: Dew point temperature alone not enough to determine air mass changes
  - In polar maritime air masses
    - $T_d > 18^\circ C$ cold front is probably north of the station
    - $T_d \leq 18^\circ C$, 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 isodrosootherms every 2-3 degrees
    • *Td ≤ 18°C* for a polar maritime air mass.
  – **Temperature**
    • Strong contrast in continental/marine polar air masses
    • Slighter difference, 2-4°C, 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
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.
- 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
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.
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.
Front has deep layer support and it is clearly evident in both layers, 1000-850 and 1000-500 hPa
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
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

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?
Analysis Tools
Analysis Tools

• Mean Layer Relative Humidity

• Equivalent Potential Temperature (EPT)

• “FRONT” Macro
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

- Cold
- Warm
- Gradient, Frontal Plume
- No Gradient, Non-Frontal Plume
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

Mean RH

Mean RH & THCK

RH, THCK, PMSL

RH, THCK, PMSL, Wind
Verification of the Forecast

VT: 20200921/00Z
Proxy Visible

20200920-23Z to 20200921-01Z

T.S. Beta

Hurricane Teddy
Poll #6

Mean Layer RH, THCK, PMSL

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

- It is frontal
- It is non-frontal
- Cannot be determined
The moist plume is frontal, as it lies parallel to the thickness gradient.
Poll #7
Mean Layer RH, THCK, PMSL

Is the “A” moist plume frontal or non-frontal?
Is the “B” moist plume frontal or non-frontal?
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
The “A” moist plume is frontal, parallel to the gradient. The “B” moist plume is with a prefrontal trough.
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
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)

Determine if gradient is frontal or non-frontal

- Only EPT Gradient
- Non-frontal
- Weak EPT and THCK Gradient
- Frontal
- EPT and THCK Gradient
- Frontal
- Determine if gradient is frontal or non-frontal
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
What is plotted?

1. Colors: Variable $\alpha =$ represents air mass properties

2. Contours: Variable $\beta =$

3. Complementary Fields
   - 1000-850 hPa Thickness (GPM)
   - Td=18°C at 2m
   - 1000-925 hPa Winds (kt)
Constructing $\alpha$

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

Identification of Surface Fronts

Constructing $\beta$

Combination of
- Magnitude of the gradient of $\alpha$
  - "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 $\theta_e$ 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

**Indirect Circulation:** Tightens the gradient – sustains the front

**Direct Circulation:** Loosens the gradient – weakens the front
Subtropical Jet
Positive Scale Interaction

- Divergence aloft along the jet maxima could enhance development along a weak front/frontal shear line
- More favorable for an echo training event

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

**Required:**
- Post frontal northerlies $\geq 25$KT
- CAA over Warm Waters
- $T_d \geq 20$C
- 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)
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

Most intense convection on the cyclonic side of the low level jet maxima
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

• Impact
  • 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
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 Diffuence in the Caribbean

- Diffuence
- Confluence
- "Polar Ridge"
- Subtropical Ridge
- Trough
- Prefrontal Trough
- Col

GFS 2018/12/18 00 F96
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/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

Diffuence/Confluence
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?

Directional Confluence

Speed Diffluence
Convergent or Divergent?

Objective analysis, divergence in blue: *Speed dominates*
Convergent or Divergent?

Directional Diffluence

Speed Confluence

Directional Diffluence
Convergent or Divergent?

Objective analysis, convergence in red: **Speed dominates**
Poll Question #11

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

850 hPa Winds and Isotachs
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
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)

Along the tail end of the front, winds weaken and become nearly parallel to the thickness gradient.
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
• 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
In weak CAA (white shaded), the tail of the front can degrade to a shear line.
Weak thickness gradient, with low level wind maxima along the warm side to the south.
Weak thickness gradient, with low level wind maxima along the warm side to the south.
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

Cyclonic Shear
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 Thick & 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*
**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
EPT and Winds

Cold Air Advection
Analysis
Geocolor: Front or Shear Line?
1000-850 Thickness and Winds

Polar Ridge

Polar Trough

CAA

STR

Shear Line
Analysis

Shear Line
Geocolor: Front or Shear Line?
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.
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
- Is Td ≤ 18°C?
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
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)

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

- 1999 was a cold ENSO year
Conceptual Model
Low Level Flow Cool ENSO – La Niña
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.
High PWAT content suggests ITCZ north of its climo position, conditions often seen during La Niña.
High PWAT content suggests ITCZ north of its climo position
Mid/upper level ridge building over the Caribbean while a high amplitude trough settles to the east.
In 24 hrs the ridge builds across the central Caribbean and the trough amplifies to the east.
Cold front evident?
Shear Line?
ITCZ?
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

Cold Air Cu

ITCZ
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

Vargas – Venezuela
14 – 16 December 1999