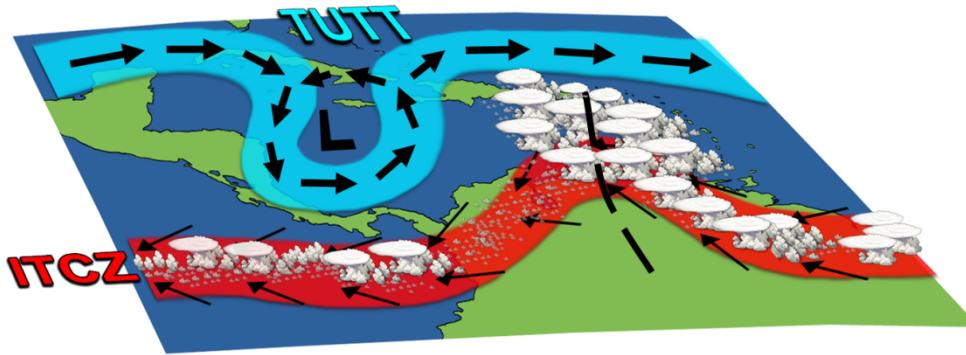


Atlantic/Caribbean Basin Tropical Waves and TUTT Induced Inverted Troughs



Mike Davison, Chief, International Desks
Dr. José Gálvez, International Desks Researcher

June 2020
Part 2: Practical Exercises



NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Summary of Characteristics

TUTT Induced Trough	Tropical Wave
<ul style="list-style-type: none">• Cold core dominates<ul style="list-style-type: none">○ Cannot evolve directly into a Tropical cyclone (warm core system).○ Could first evolve into a subtropical cyclone (hybrid system)	<ul style="list-style-type: none">• Combination of warm/cold core.<ul style="list-style-type: none">○ Could directly evolve into a tropical cyclone (is the seed).
<u>Movement</u> : Controlled by upper flow.	<u>Movement</u> : Controlled by the lower troposphere.
<u>Origin</u> : Induced by a trough generally to its northwest	<u>Origin</u> : Instability along on the African Easterly Jet and latent heat release in organized deep convection and also monsoon trough of Tropical North Africa

Tools to differentiate wave type

	Induced Trough	Tropical Wave
Water Vapor Image	Best tool to assess the presence and depth of an upper cyclone (TUTT).	Determine sources of upper level ventilation, or the lack of.
IR and Visible Images	<ul style="list-style-type: none">• Good to find inverted “V” troughs in low-level cloud fields.• Ci/Cs might hint presence of upper trough..	Good to find inverted “V” troughs in low-level cloud fields.
Flow analysis	500-200 hPa for upper trough, 850-700 hPa for low level trof.	850-700 hPa
Movement of low-level trough	<ul style="list-style-type: none">• It moves in-tandem with upper trough.• Could remain stationary or , if the TUTT is retrogressing, progress at 05-15 kt.	<ul style="list-style-type: none">• Low-level trough moves independent from upper systems.• They move at 10-20 kt.• Negatively tilted tend to be faster.

Part 2 – Poll Questions

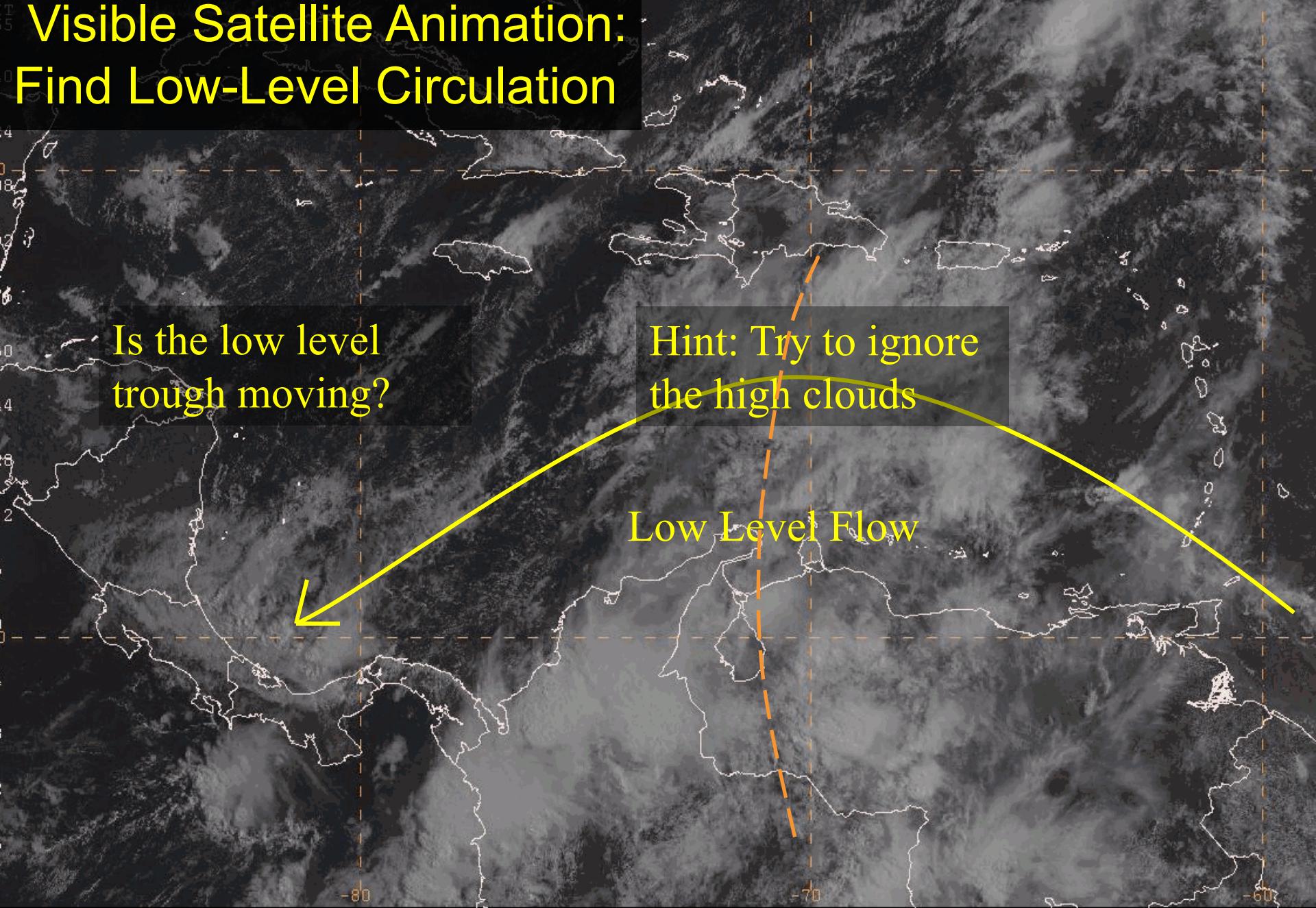
(Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

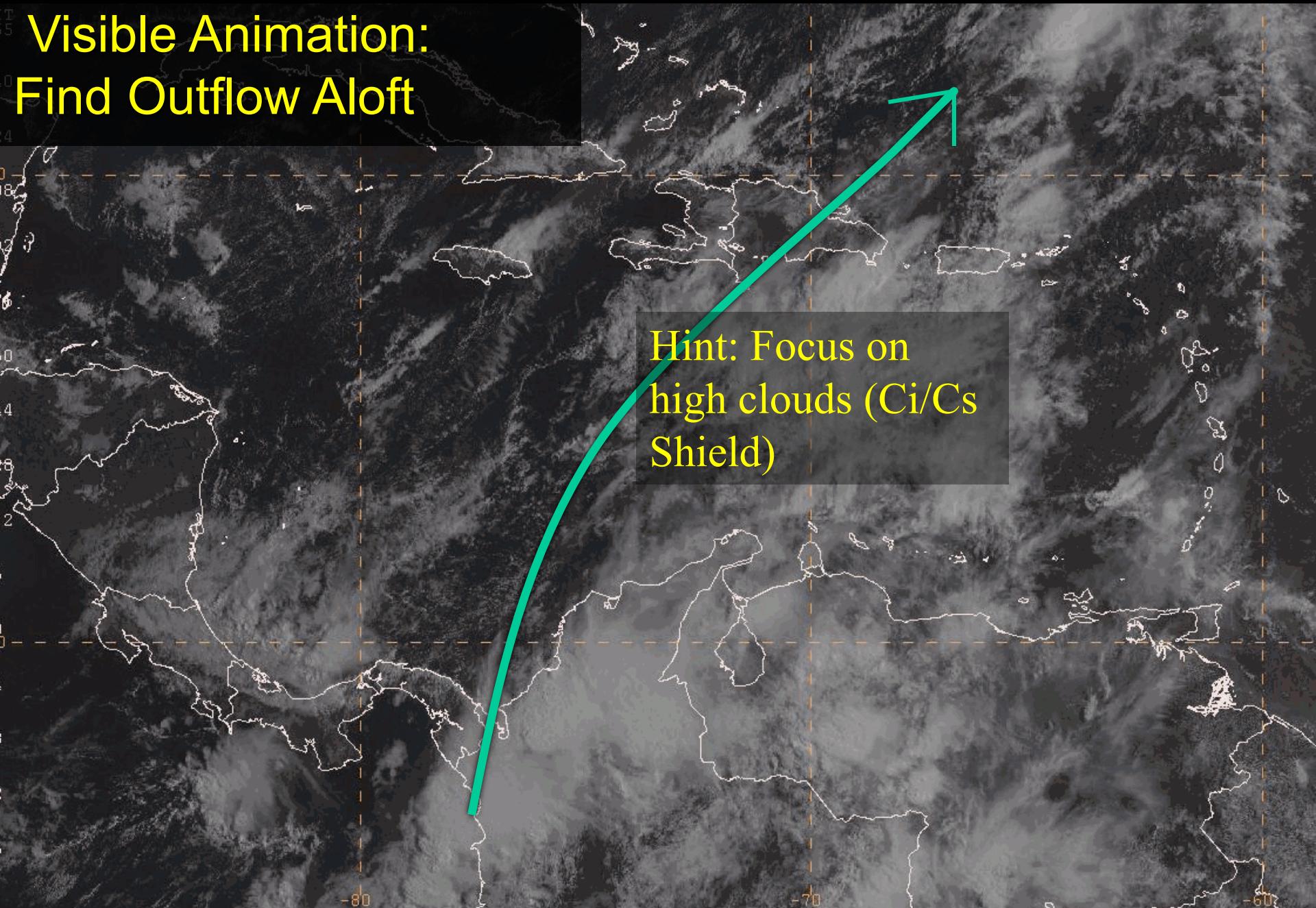
Case Study

20 April 2004

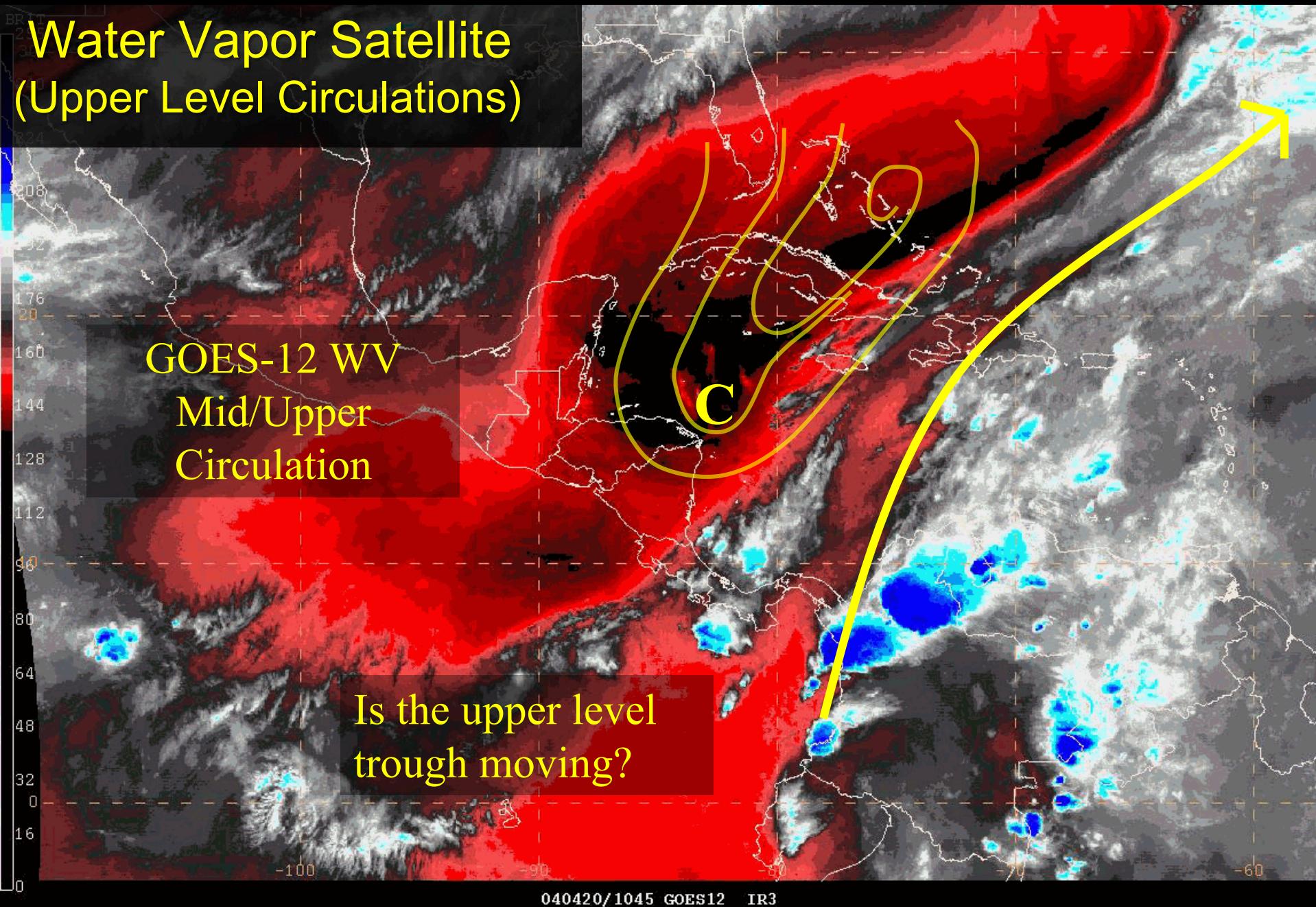
Visible Satellite Animation: Find Low-Level Circulation



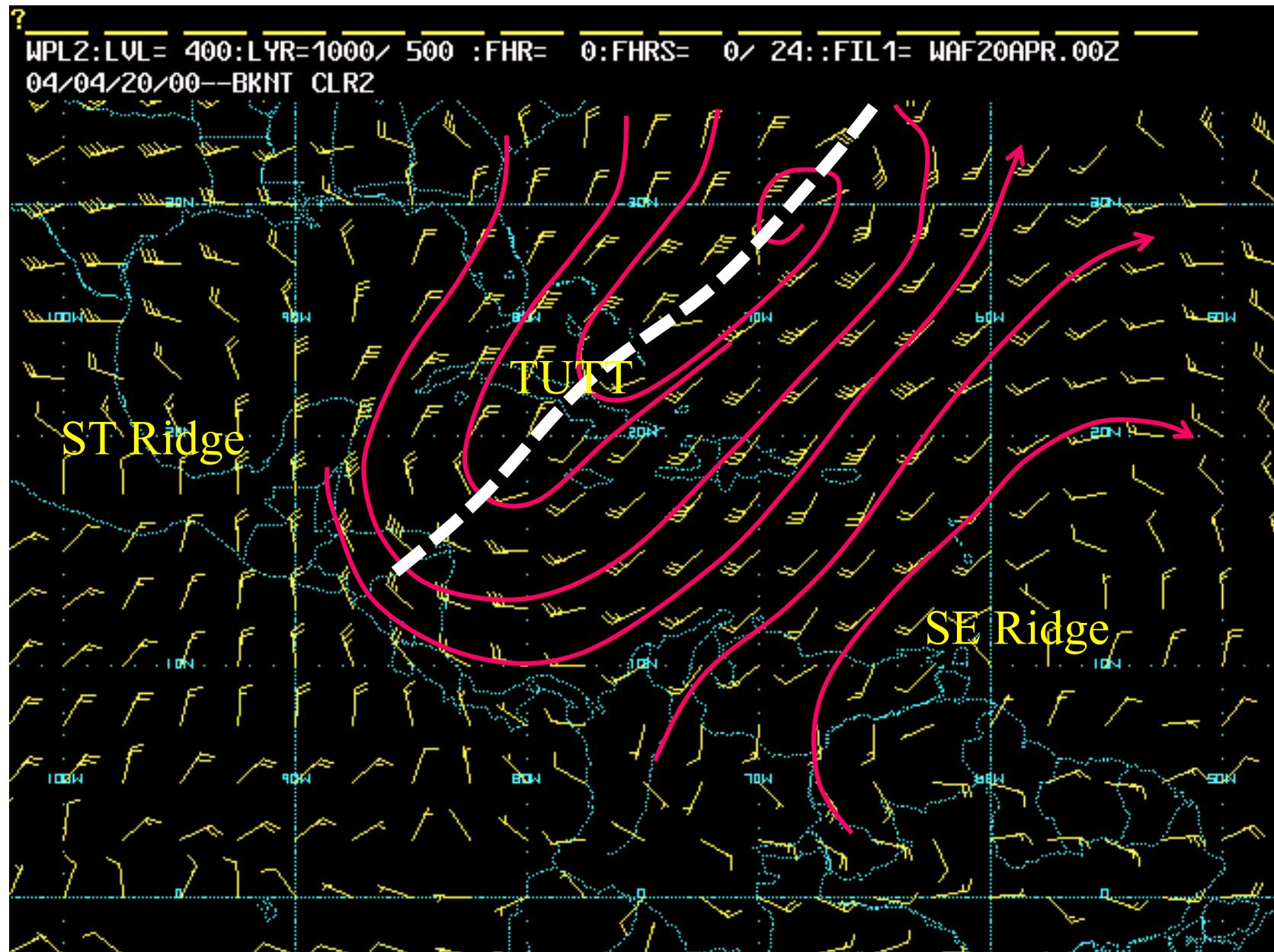
Visible Animation: Find Outflow Aloft



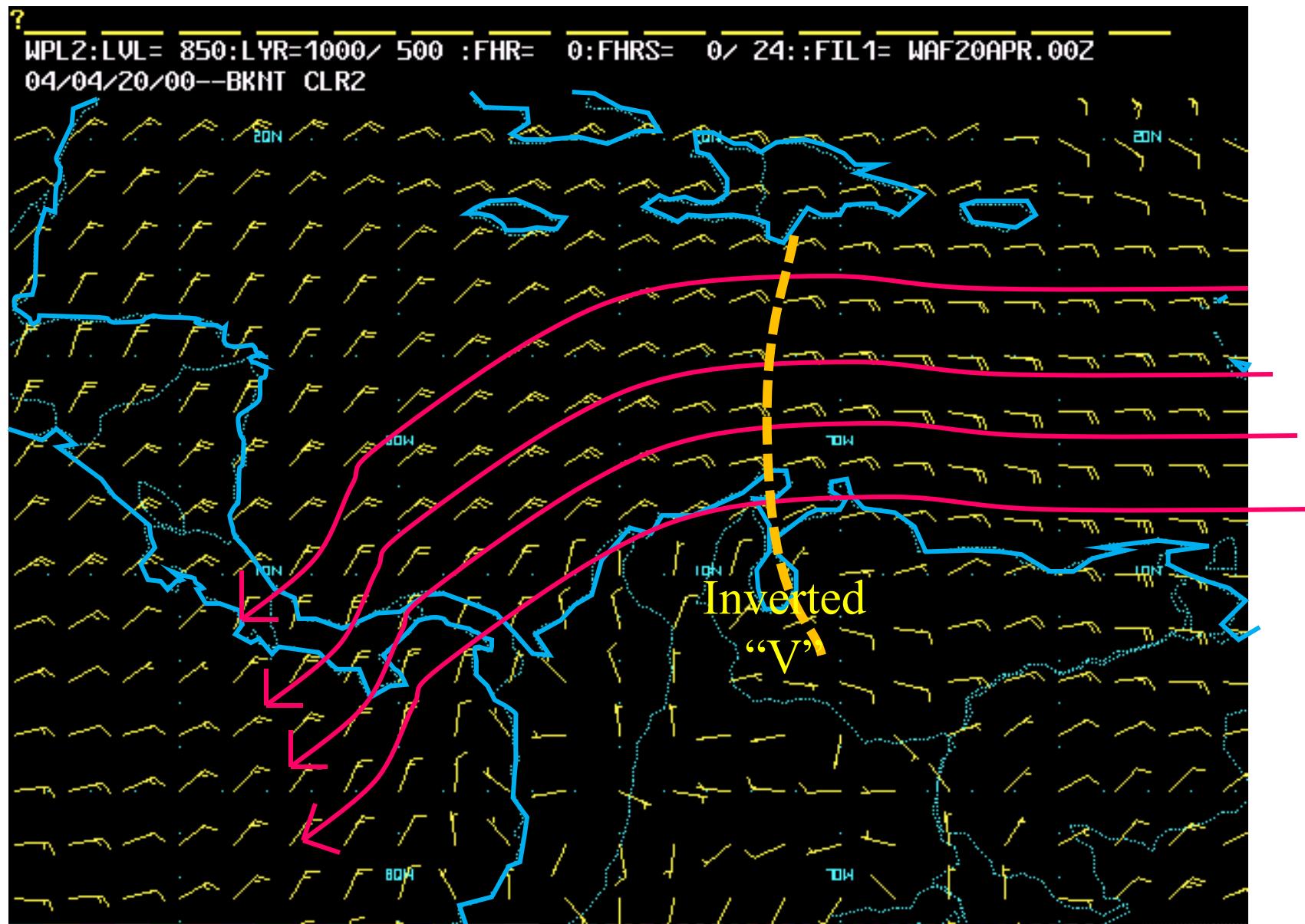
Water Vapor Satellite (Upper Level Circulations)



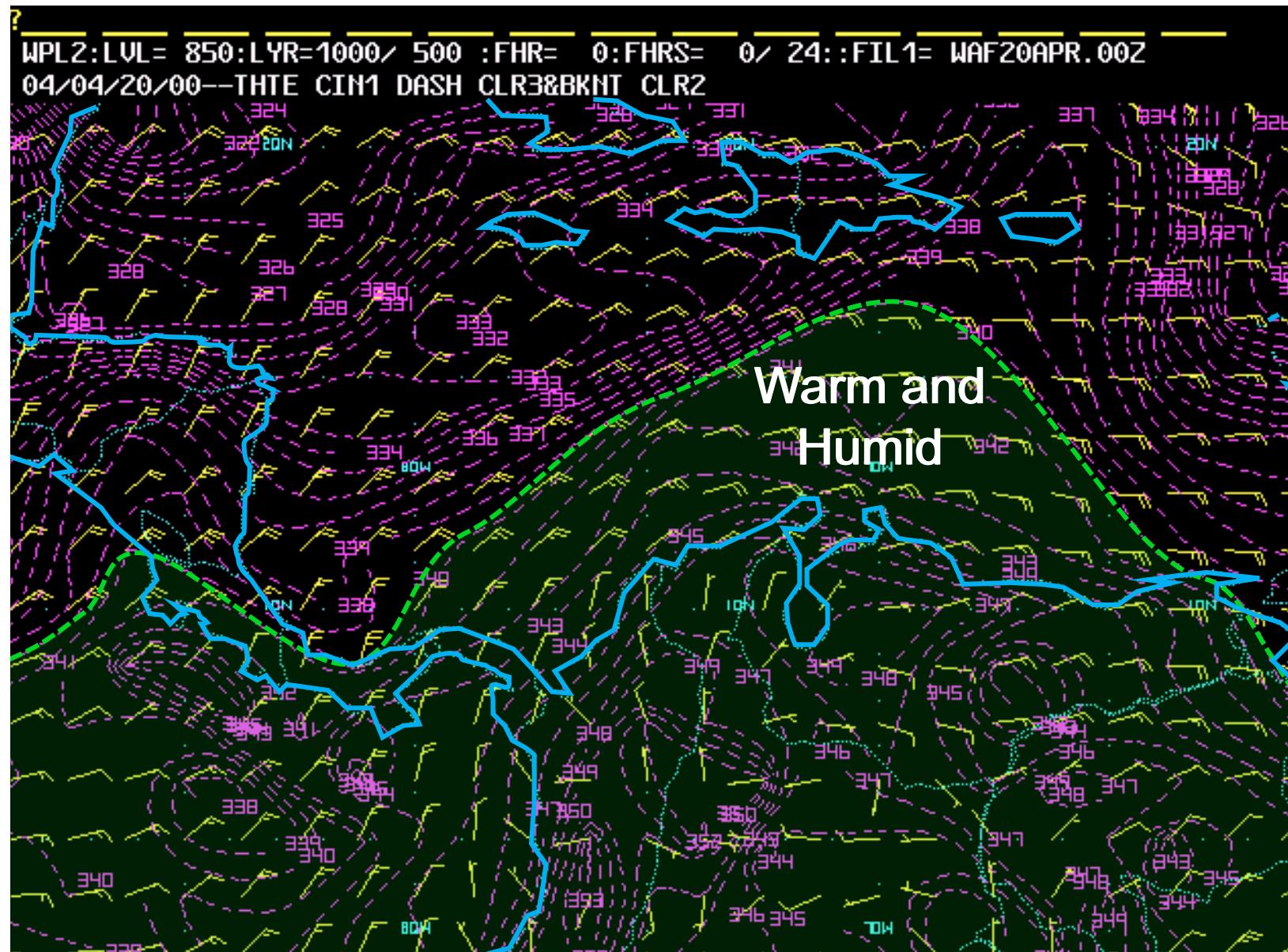
GFS Analysis of Upper (400hPa) Circulation



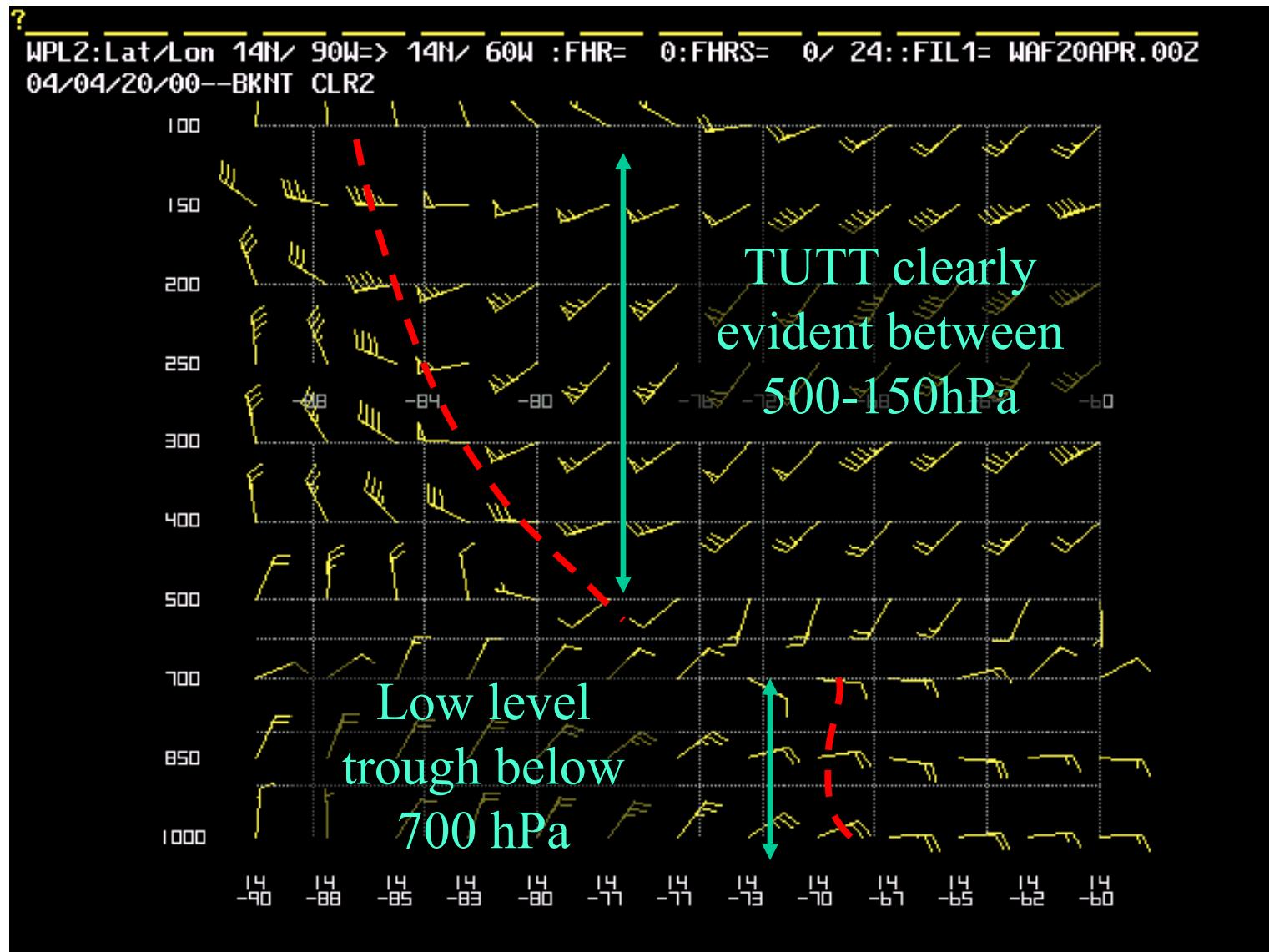
Low-Level Circulations (850 hPa)



Winds and EPT (θ_e) at 850 hPa



Cross Section: Winds



Part 2 – Poll Question #1 (Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

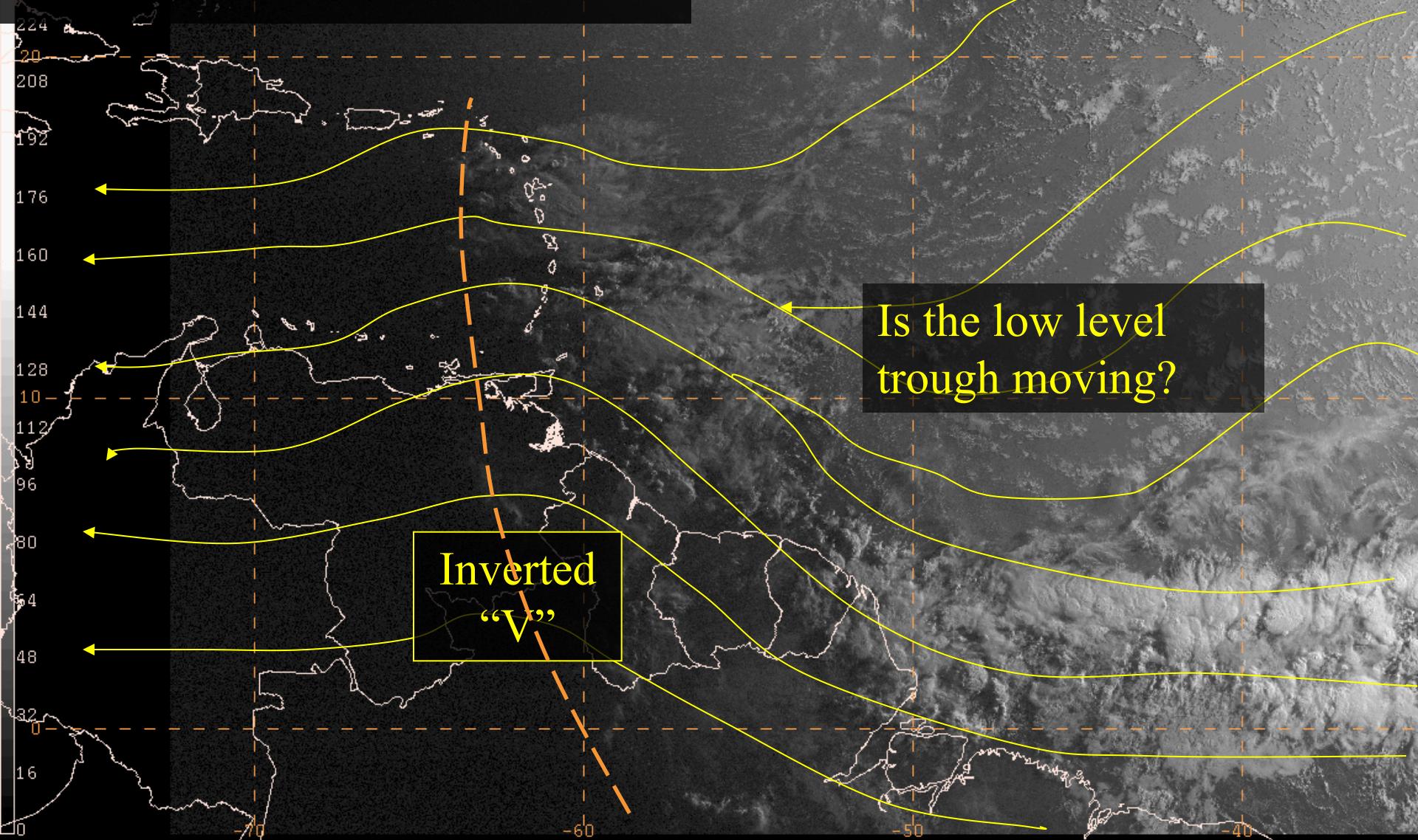
Observations

- **Visible satellite imagery** analysis shows an inverted trough at low levels.
 - Visible imagery clearly shows an inverted trough at low levels. It is yet not clear whether or not it relates to an upper level system.
 - It could easily be confused with a perturbation in the easterlies/tropical wave.
- **Water vapor satellite imagery**, in combination with visible imagery, clearly shows an upper trough with a ridge to its east.
 - This suggests a dependency of the low-level perturbation on the upper level trough..
 - The dependency can be confirmed by the model's vertical cross section of the winds.

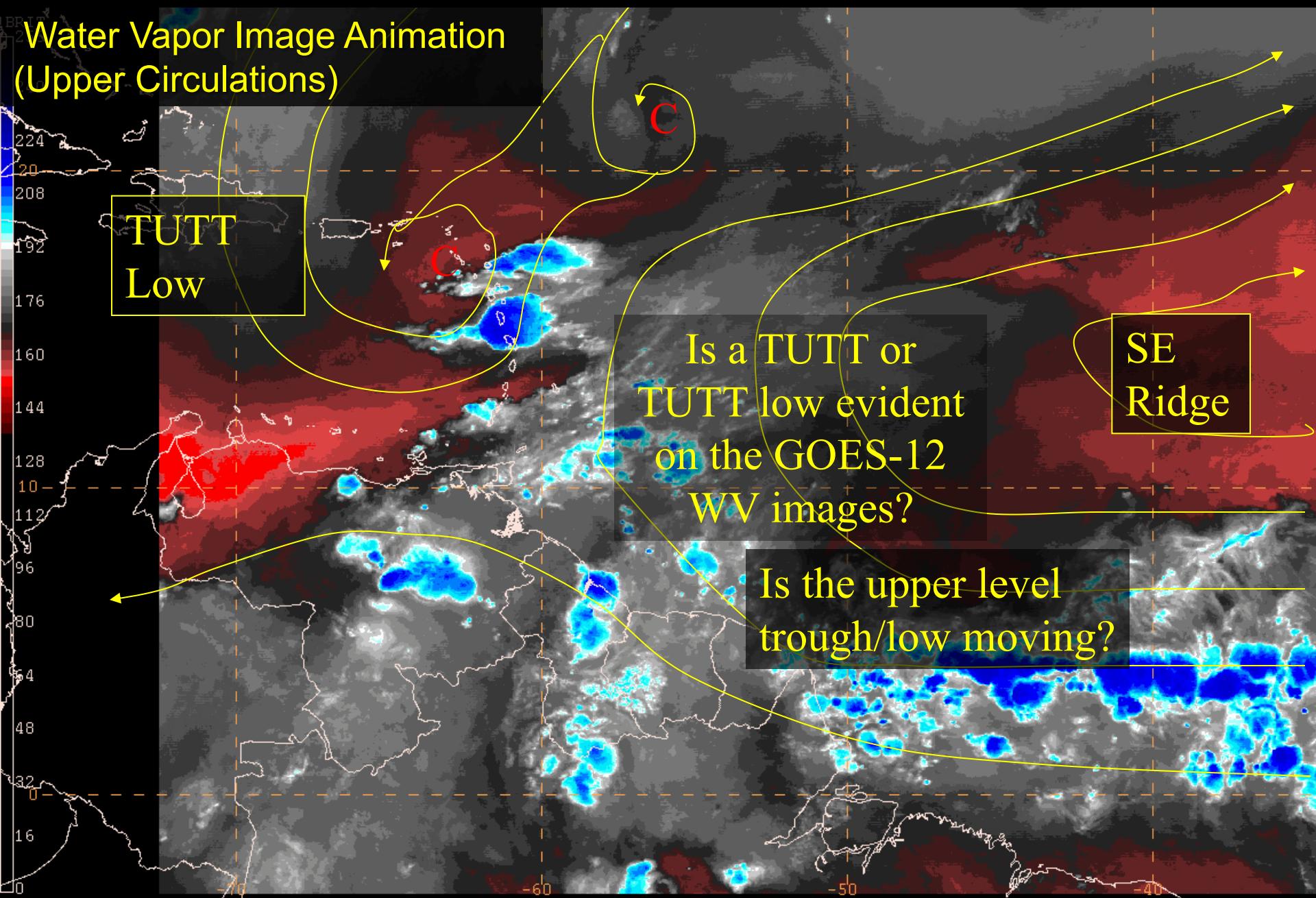
Case Study

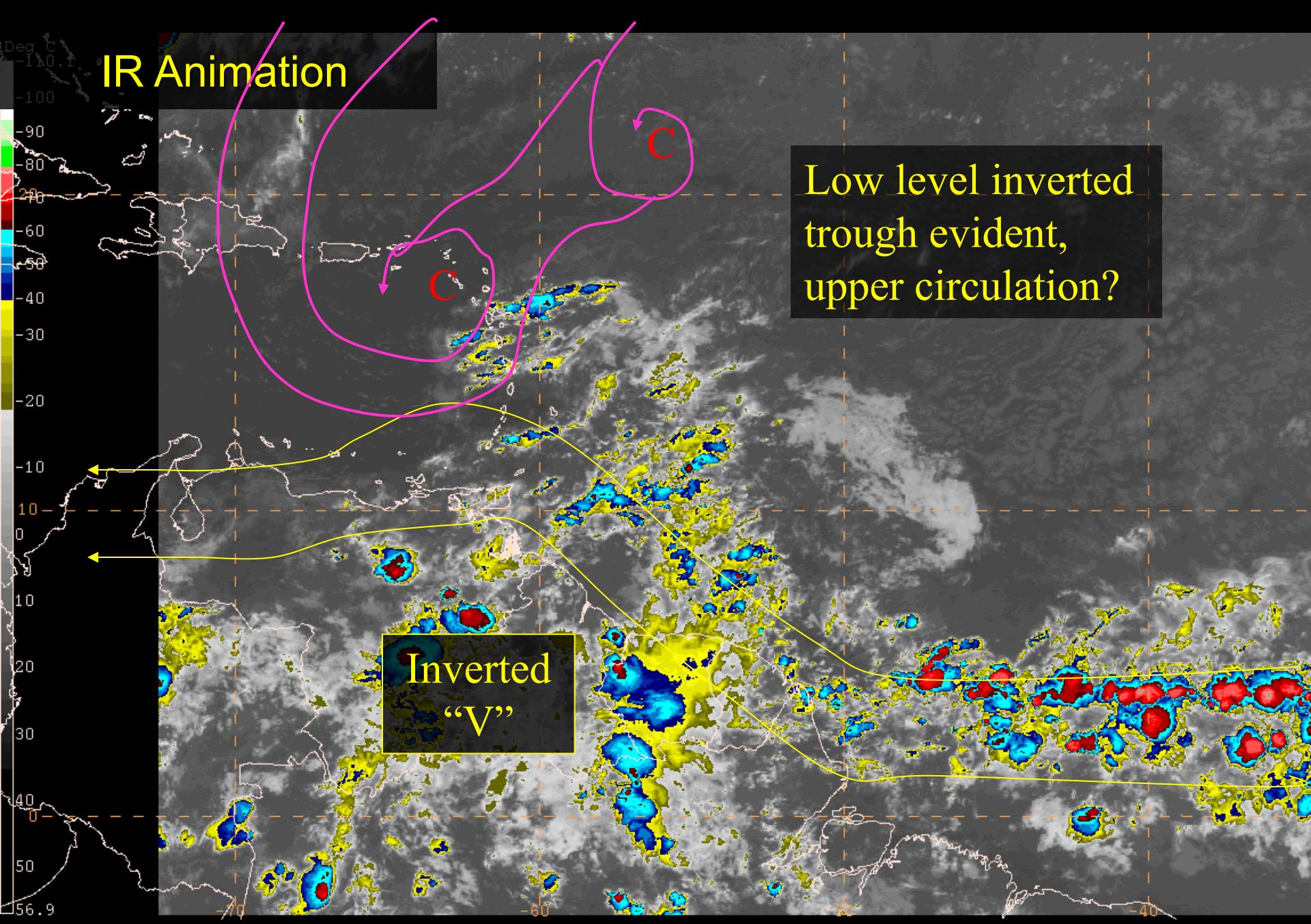
20 June 2008

Visible Satellite Animation: Find Low-Level Circulation



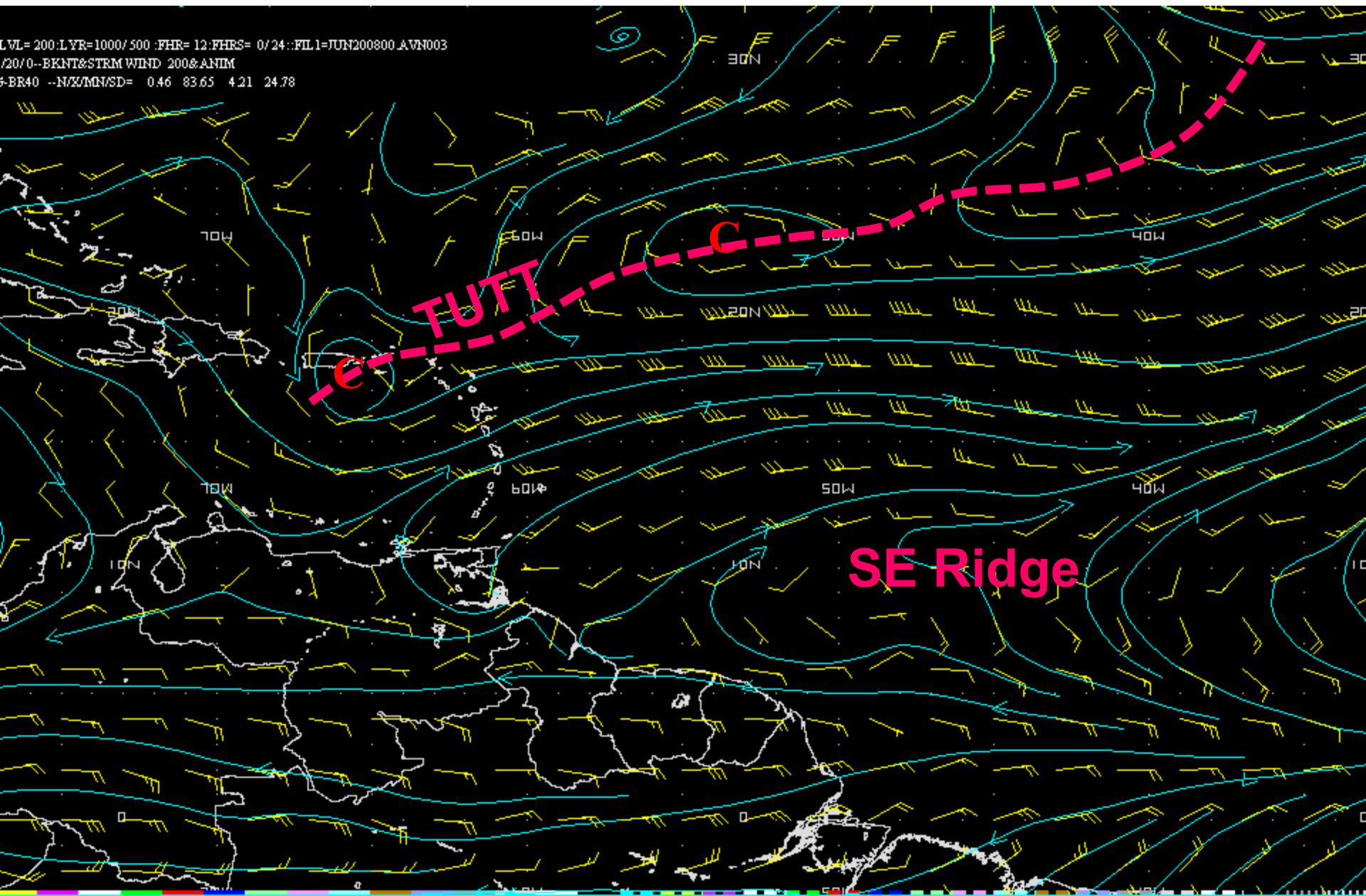
Water Vapor Image Animation (Upper Circulations)



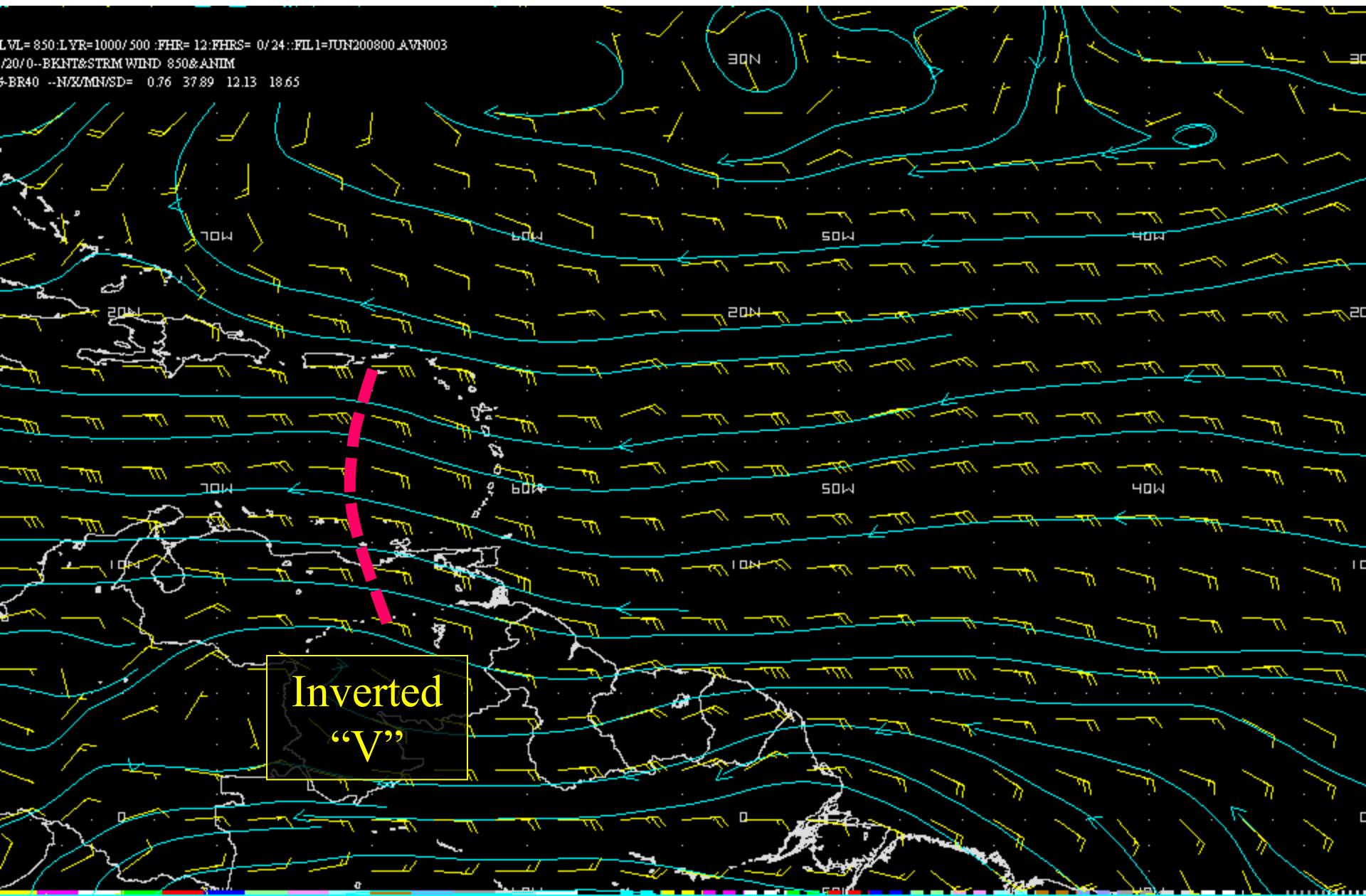


080620/0245 GOES12 IR4

GFS analysis: 200 hPa winds

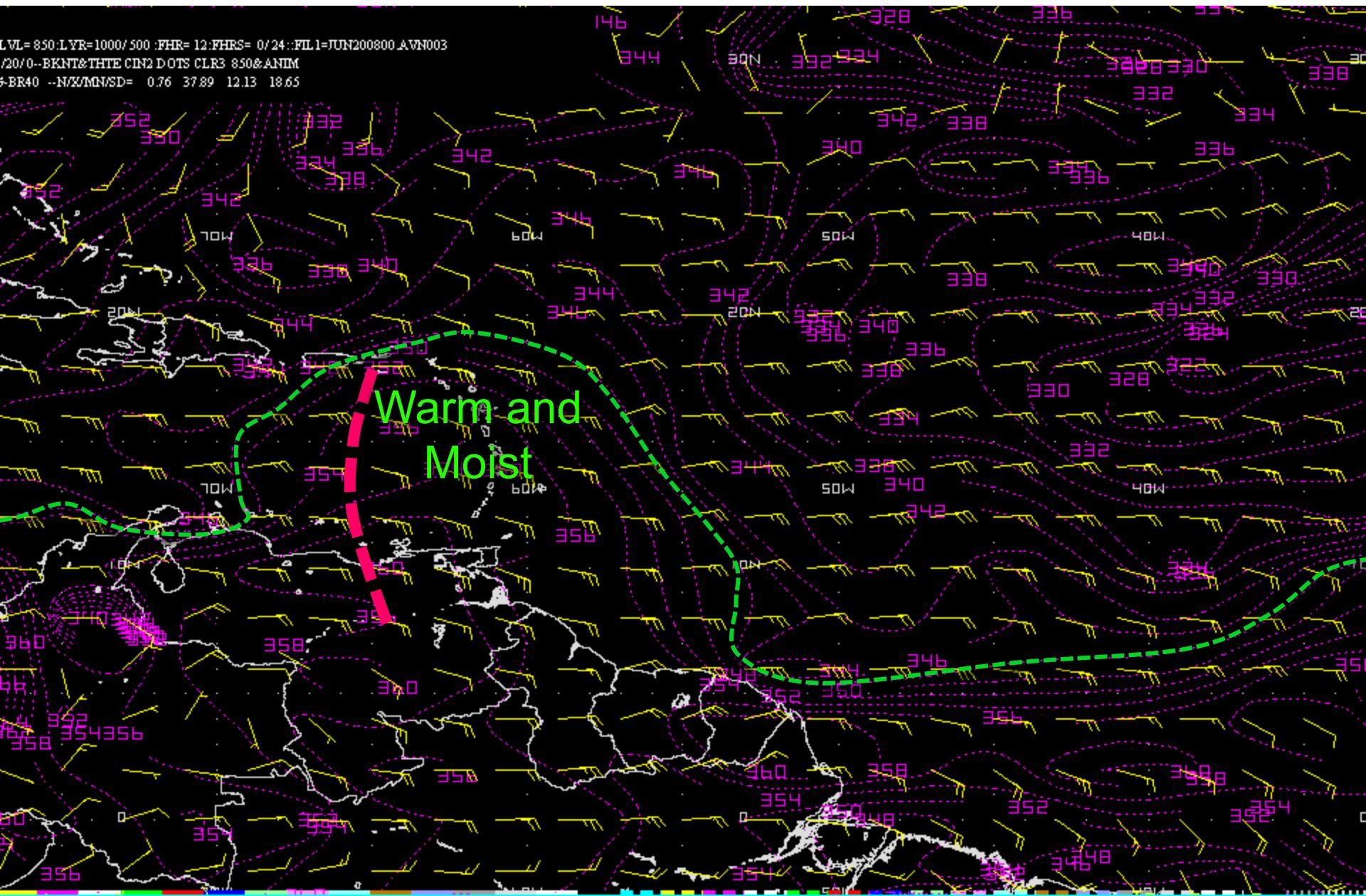


GFS Analysis: 850 hPa winds



Winds and EPT (θe) at 850 hPa

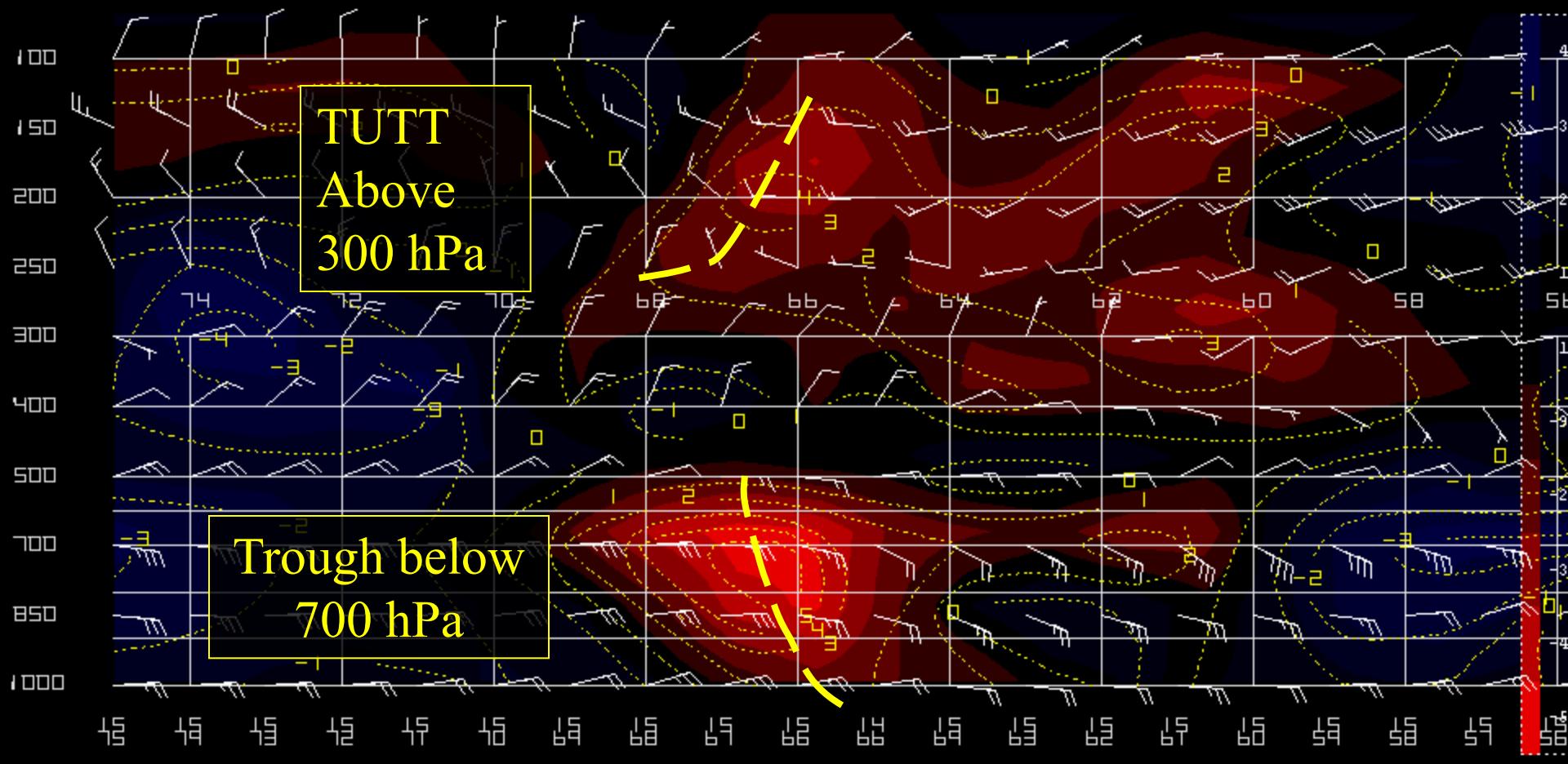
LVL= 850:LYR=1000/500:FLR= 12:FLRS= 0/24::FILE=JUN200800 AVN003
/20/0-BKNT&THE CIN2 DOTS CLR3 850&ANIM
-BR40 --N/X/MNNSD= 0.76 37.89 12.13 18.65



Cross Section: Winds and Relative Vorticity (Cyclonic in Red)

AWN3:Lat/Lon 15N/ 75W=> 15N/ 55W :FHR= 12:FHRS= 0/ 24::FILL=JUN200800.AWN003
2008/ 6/20/ 0--BKNT CLR&RVRT WIND DOTS&SMLC -1 RVRT WIND CTFC CFCU&ANIM

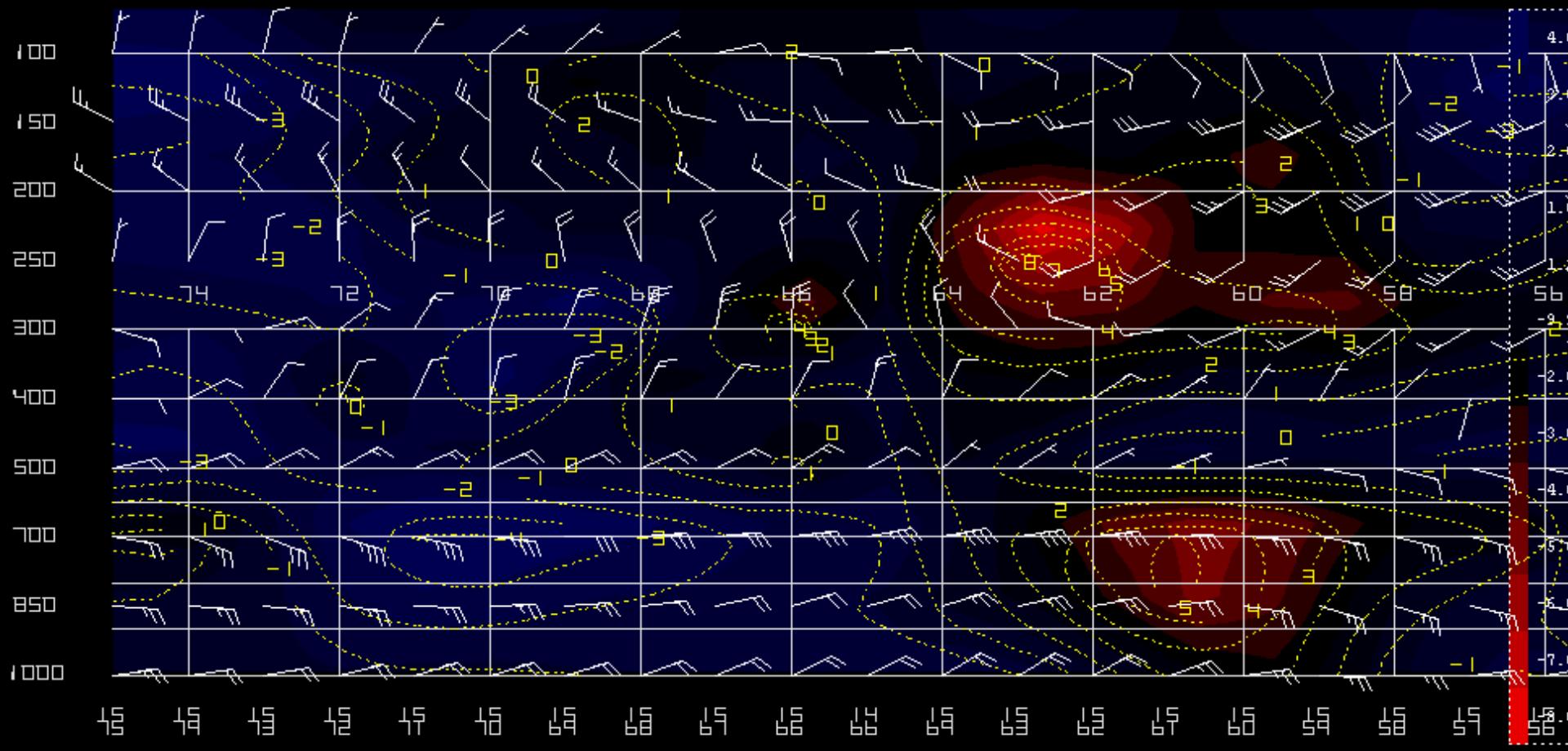
Is the upper level trough deep enough to sustain a perturbation in the easterly trades?



Animation: Winds and relative vorticity

AGM3:Lat/Lon 15N/ 75W=> 15N/ 55W :FHR= 0:FRS= 0/ 24::FIL1=JUN200800:AGM003
2008/ 6/20 0--BKNT CLR4&RWT WIND DOTS&SMLC -1 RURT WIND CTFC CFCU&ANIM

Is the low level perturbation moving in-tandem with the upper level trough?



Part 2 – Poll Question #2 (Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

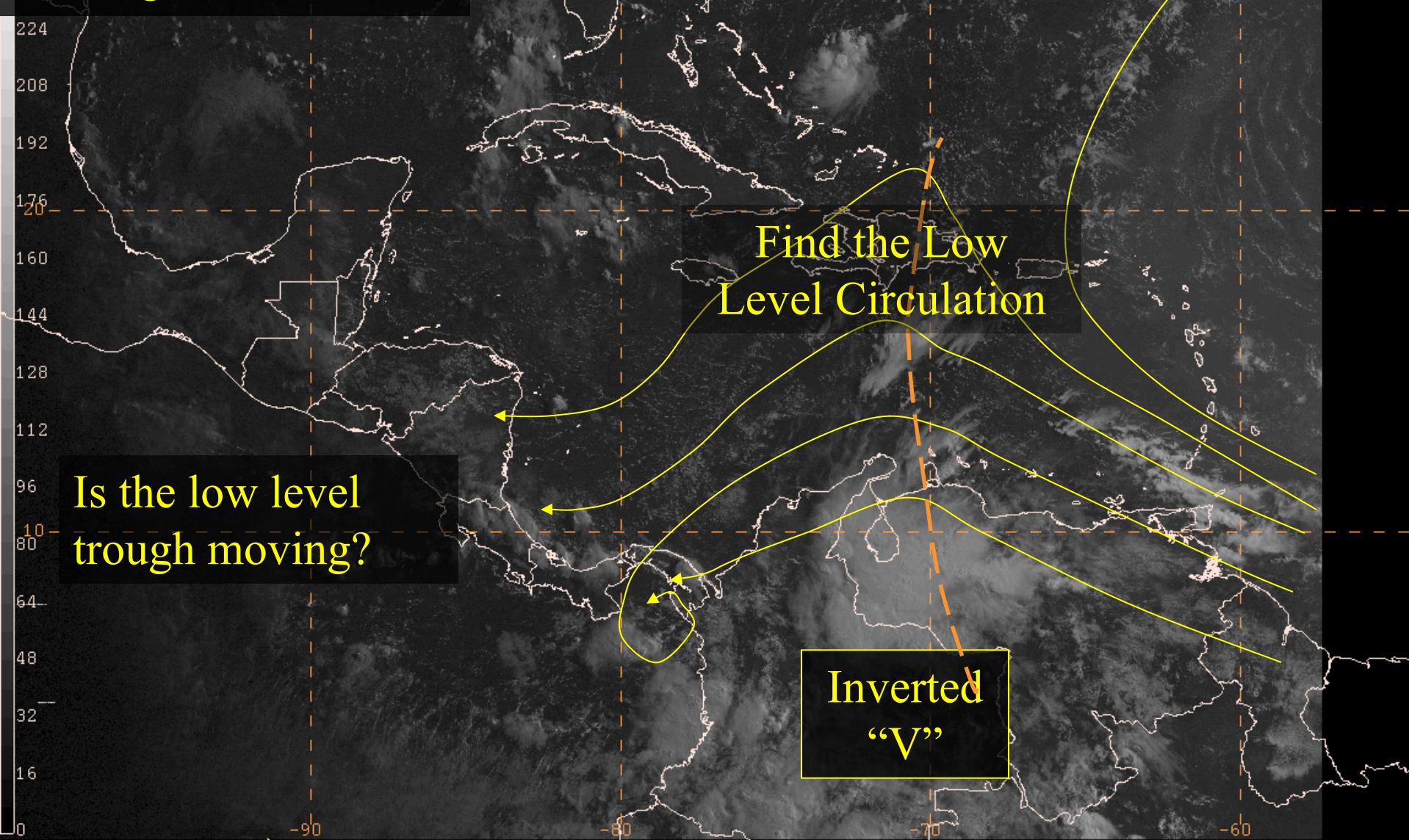
Observations

- Visible and IR imagery show an inverted trough in the low-level trades.
- Water vapor satellite image shows a TUTT/Low.
- Satellite and model data indicates that perturbation in the easterlies propagates independently from that in the upper levels.
 - But there is positive interaction among systems at different scales. This is leading to strong convection across the Leeward Isles.

Case Study

06 August 2008

Visible Satellite Image Animation

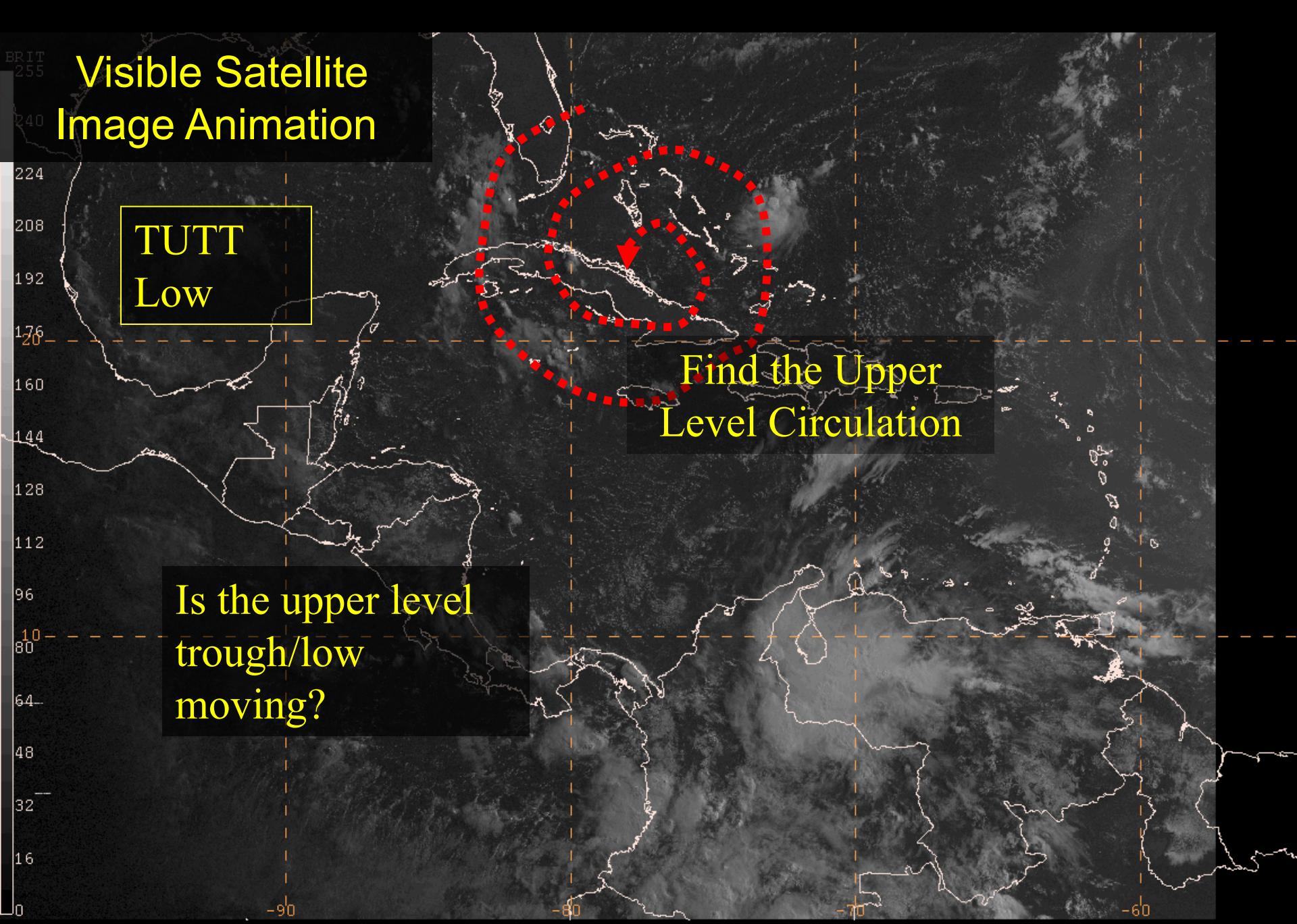


Visible Satellite Image Animation

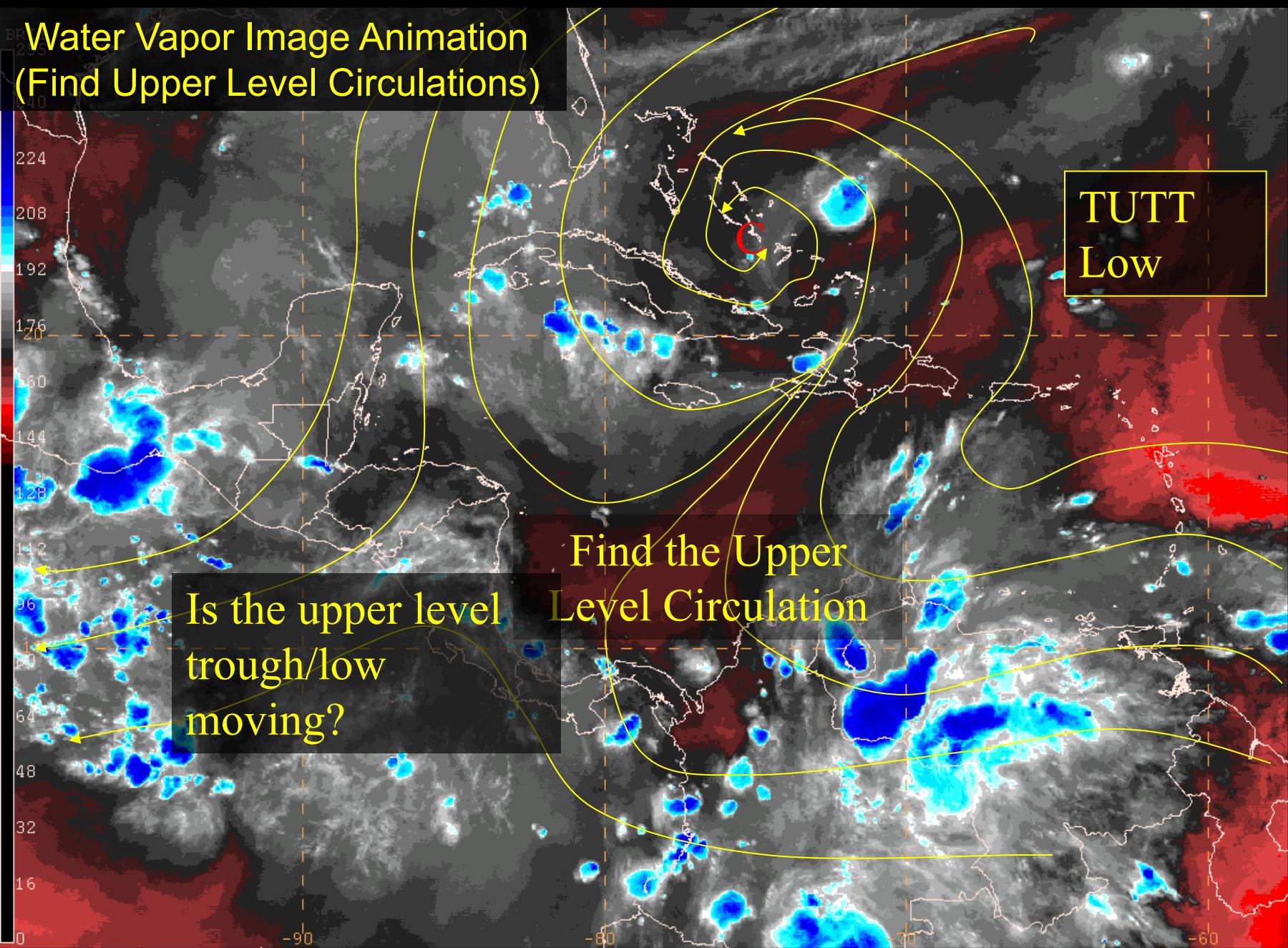
TUTT
Low

Is the upper level
trough/low
moving?

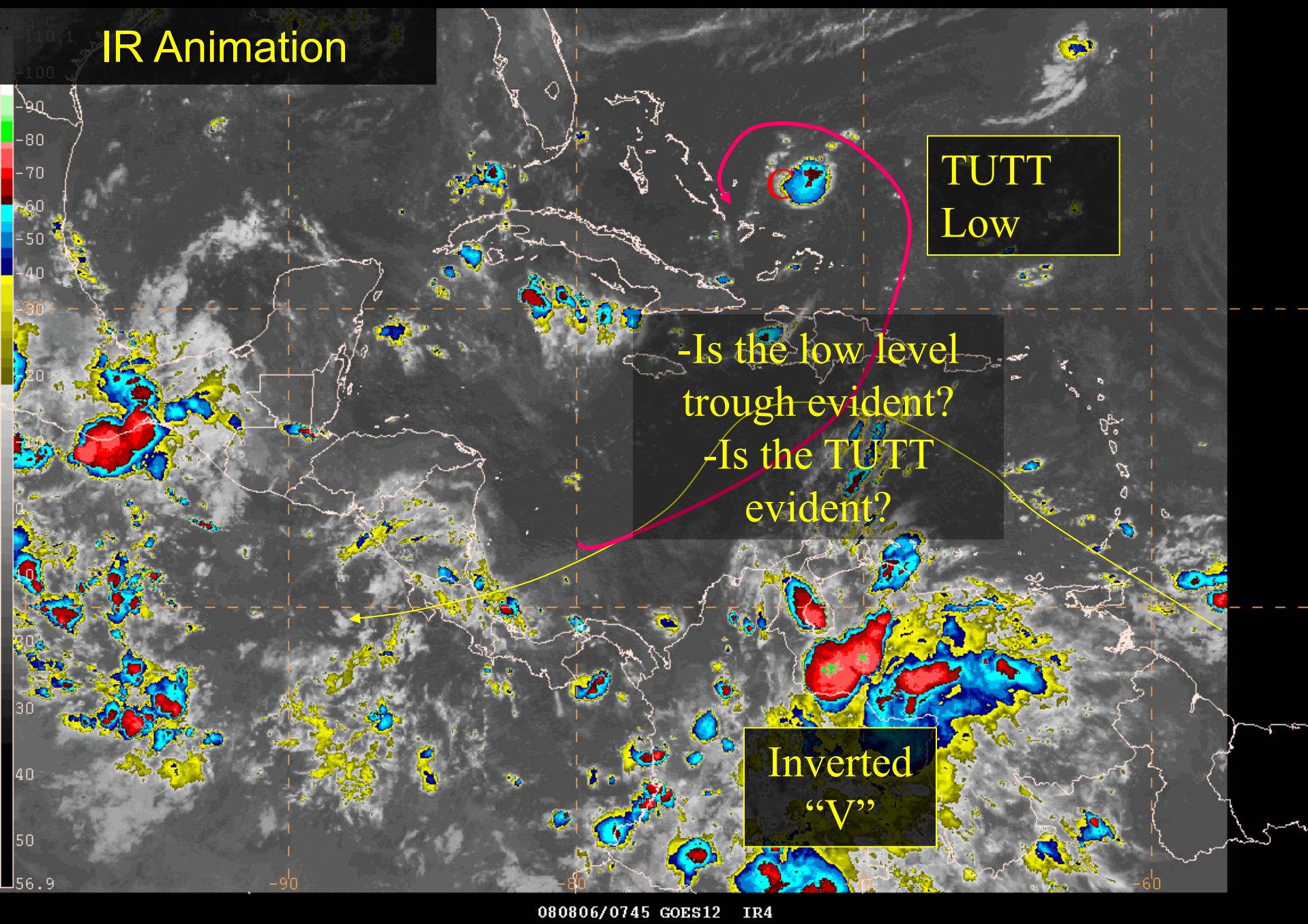
Find the Upper
Level Circulation



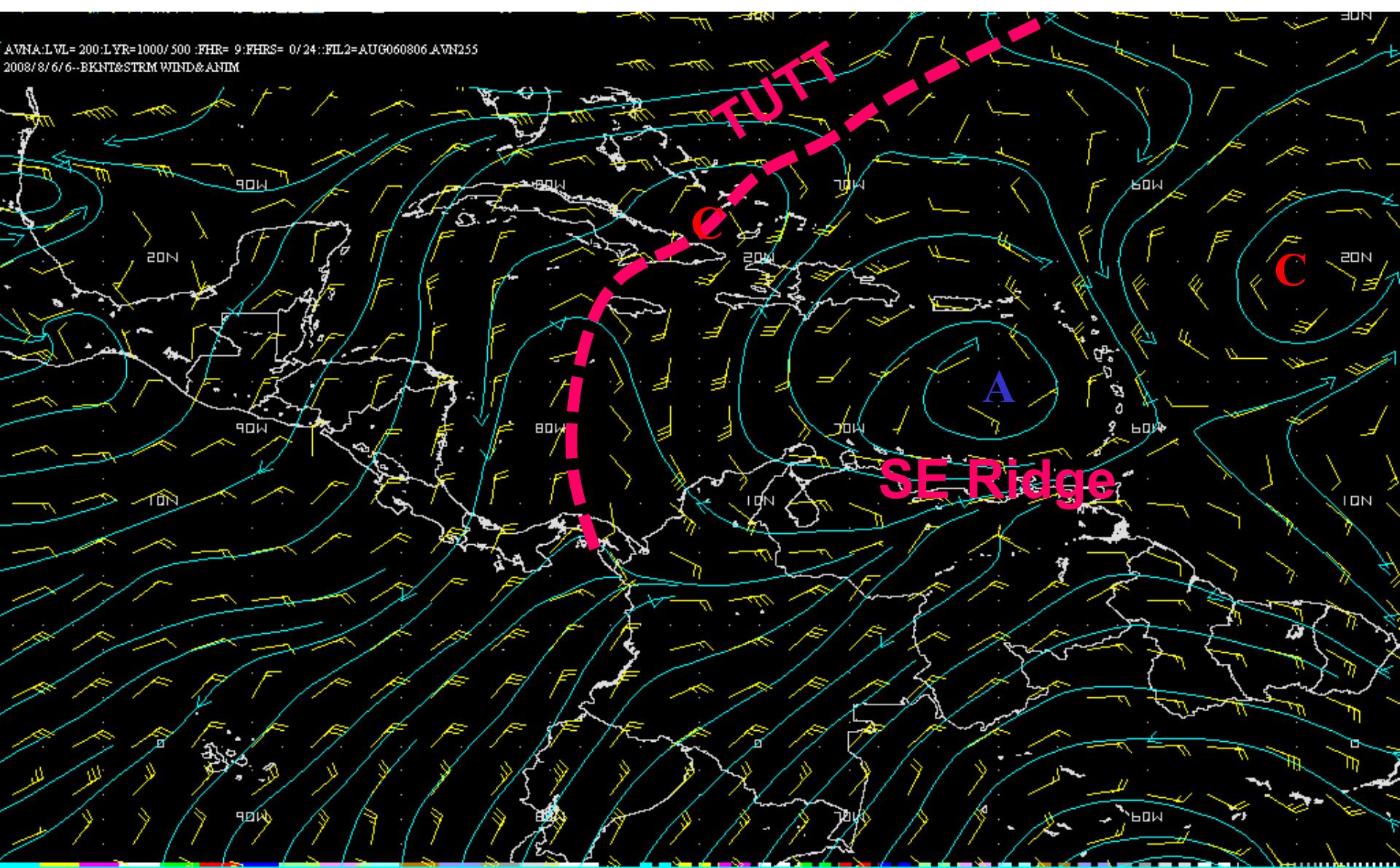
Water Vapor Image Animation (Find Upper Level Circulations)



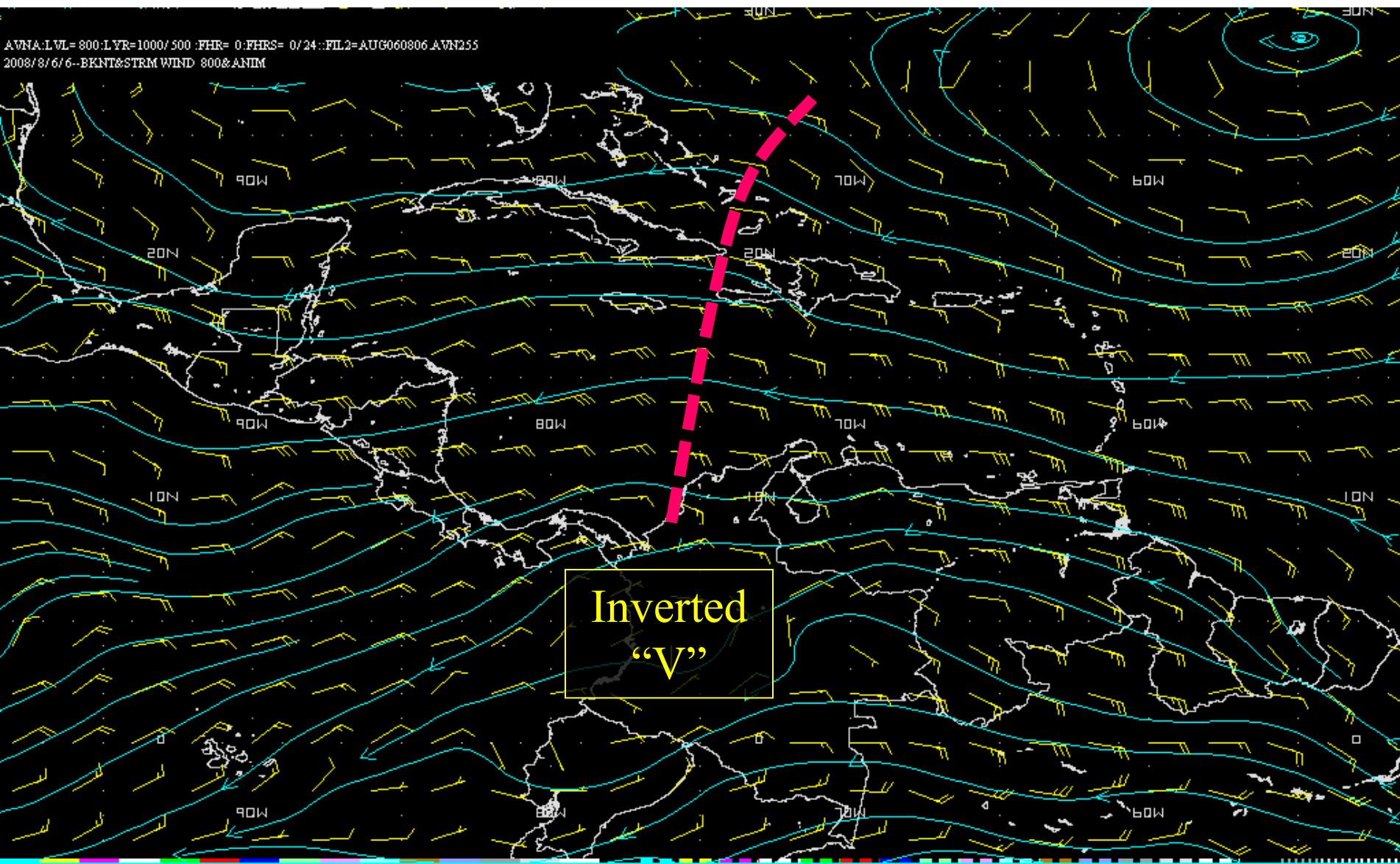
IR Animation



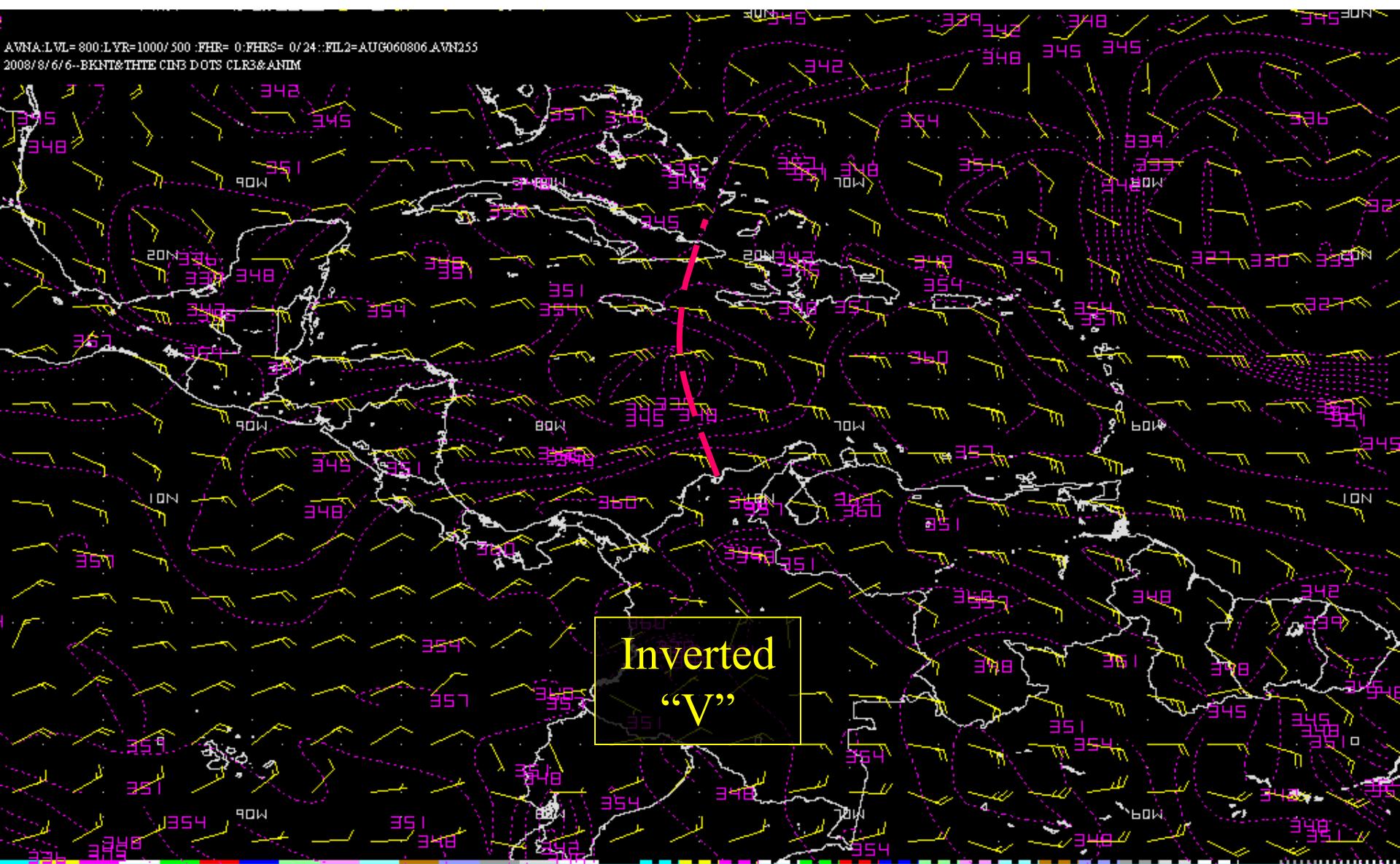
GFS Analysis: 200 hPa Winds



GFS Analysis: 850 hPa winds

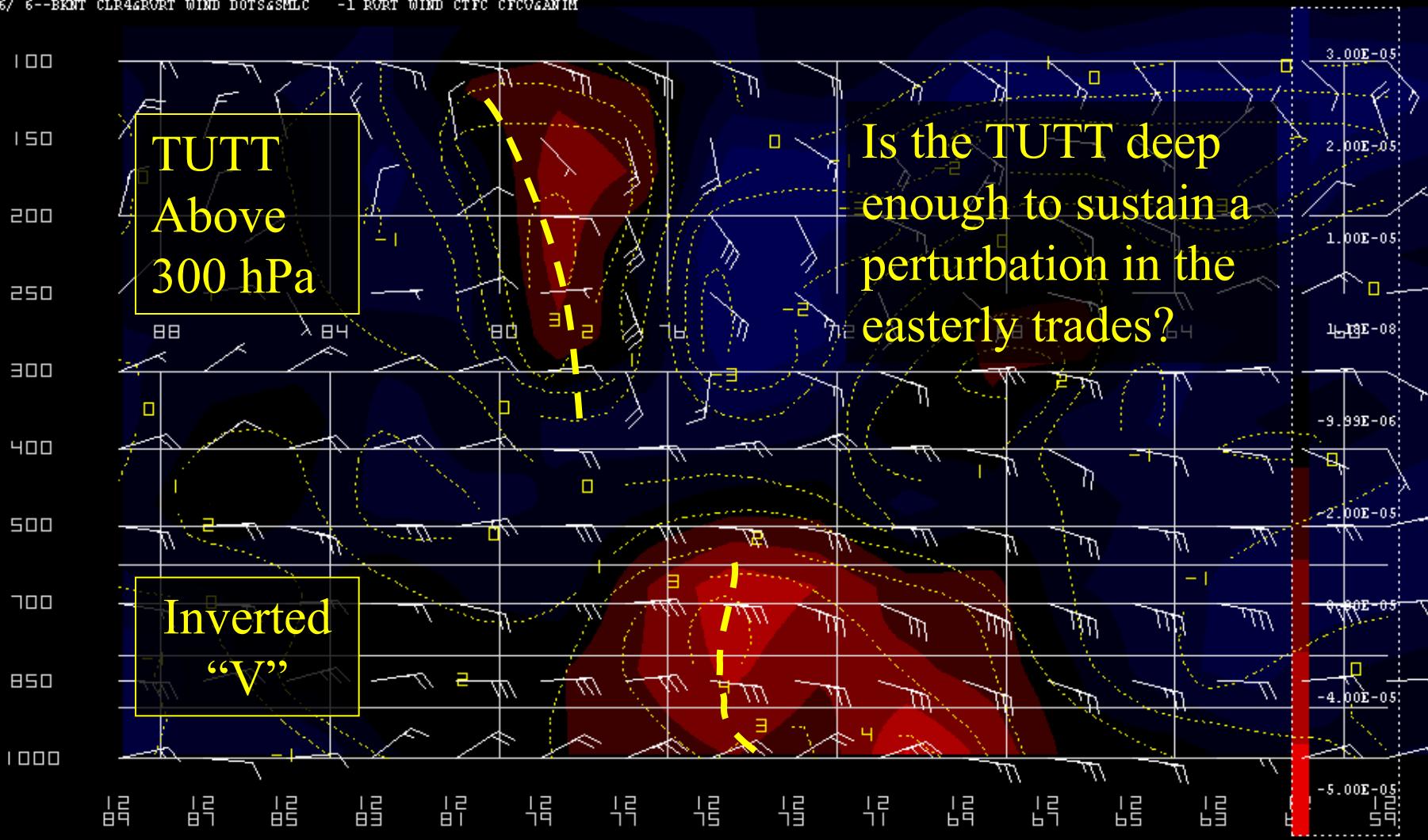


Winds and EPT (θe) at 850 hPa



Cross Section: Winds and relative vorticity

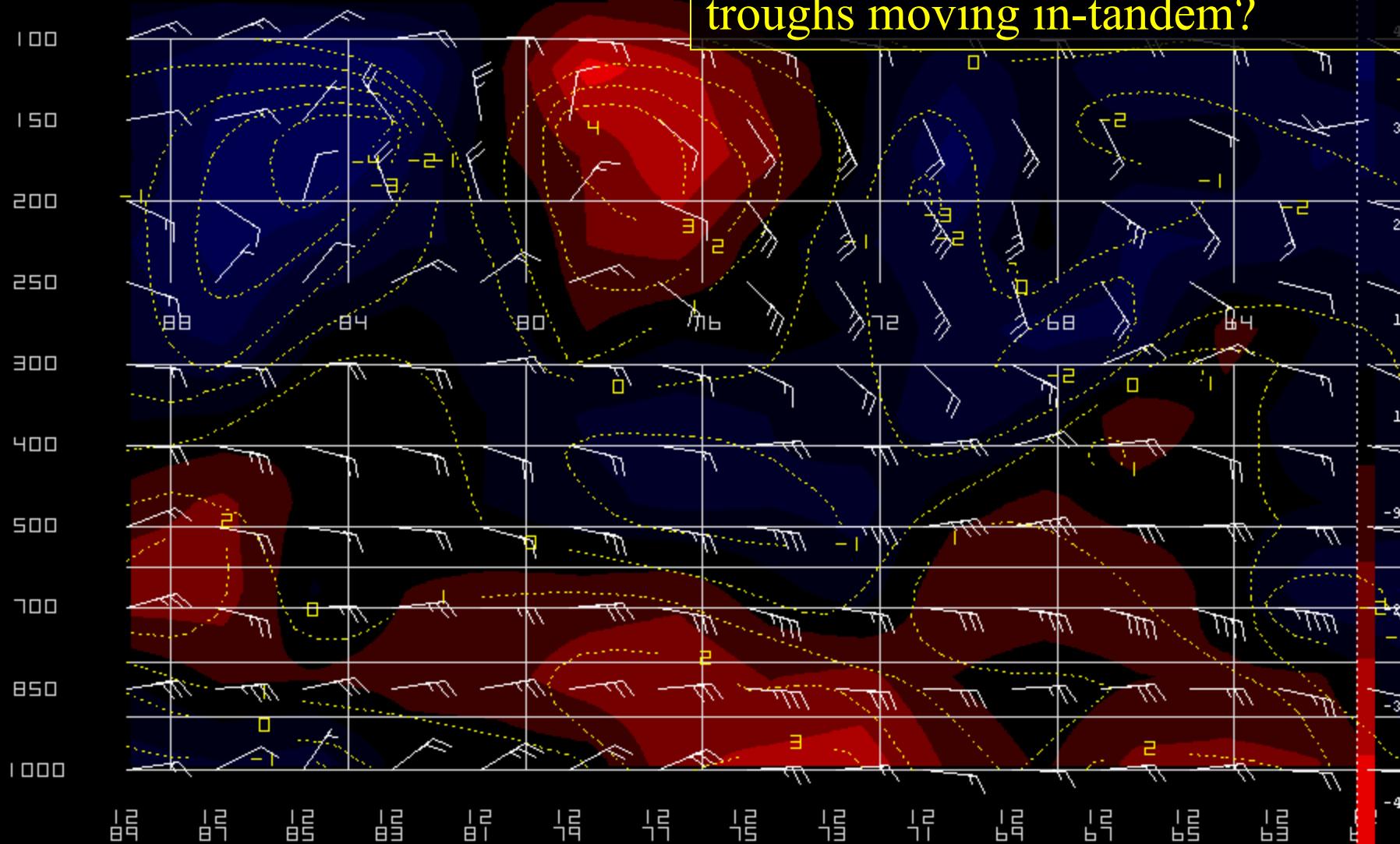
ANAL:Lat/Lon 12N/ 90W=> 12N/ 60W :FHR= 15:FHRS= 0/ 24::FIL2=AUG060806.AVN255
2008/ 8/ 6/ 6--BKNT CLR&RVRT WIND DOT&SMLC -1 RVRT WIND CTFC CFCU&ANIM



Animation: Winds and relative vorticity

AMW3:Lat/Lon 12N/ 89W=> 12N/ 59W :FHR= 0:FHRS= 0/ 24::FILE=AUG060806.AMW003
2008/ 8/ 6/ 6--BKNT CLR46RVRT WIND DOTS&SMLC -1 RVRT WIND CTFC CFCU&ANIM

Are the upper and low level
troughs moving in-tandem?



Part 2 – Poll Question #3

(Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

Observations

- TUTT Low supports deep trough across the Caribbean Basin.
- Visible imagery and wind analysis clearly shows perturbation in the easterlies.
- Low-level perturbations *seems to be in phase* with cyclonic core at upper levels.
- However, the model data show upper trough weakening while low level trough persists.

Case Study

11 June 2020

GOES-16 Geo Color

TUTT
Low

C

Find the Upper
Level Circulation
TUTT/TUTT Low?
SE Ridge?

Hint: Focus on
high clouds (Ci/Cs
Shield)

Jet
Maxima

SE
Ridge

GOES-16 Geo Color

Are the low level troughs moving?

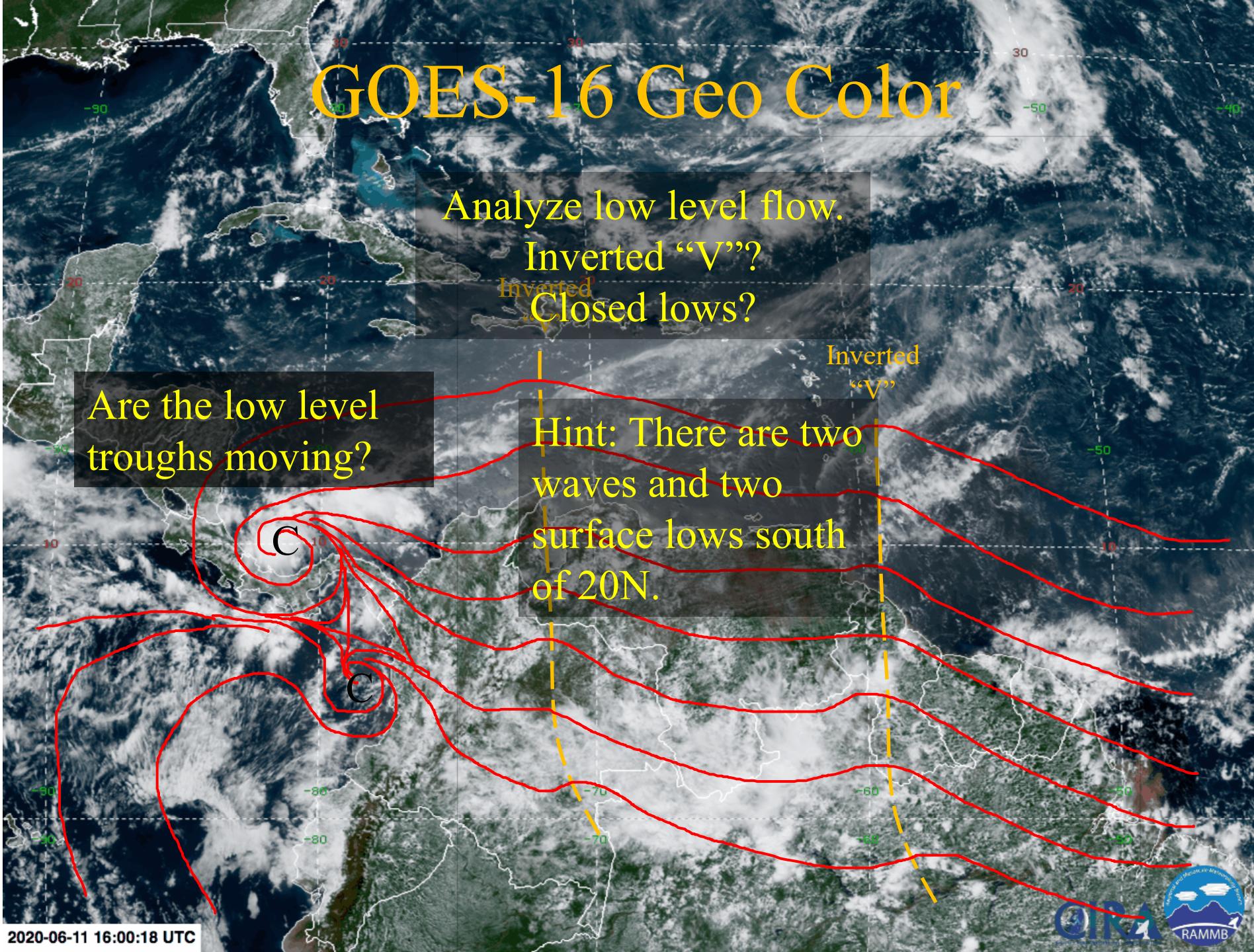
Analyze low level flow.

Inverted “V”?

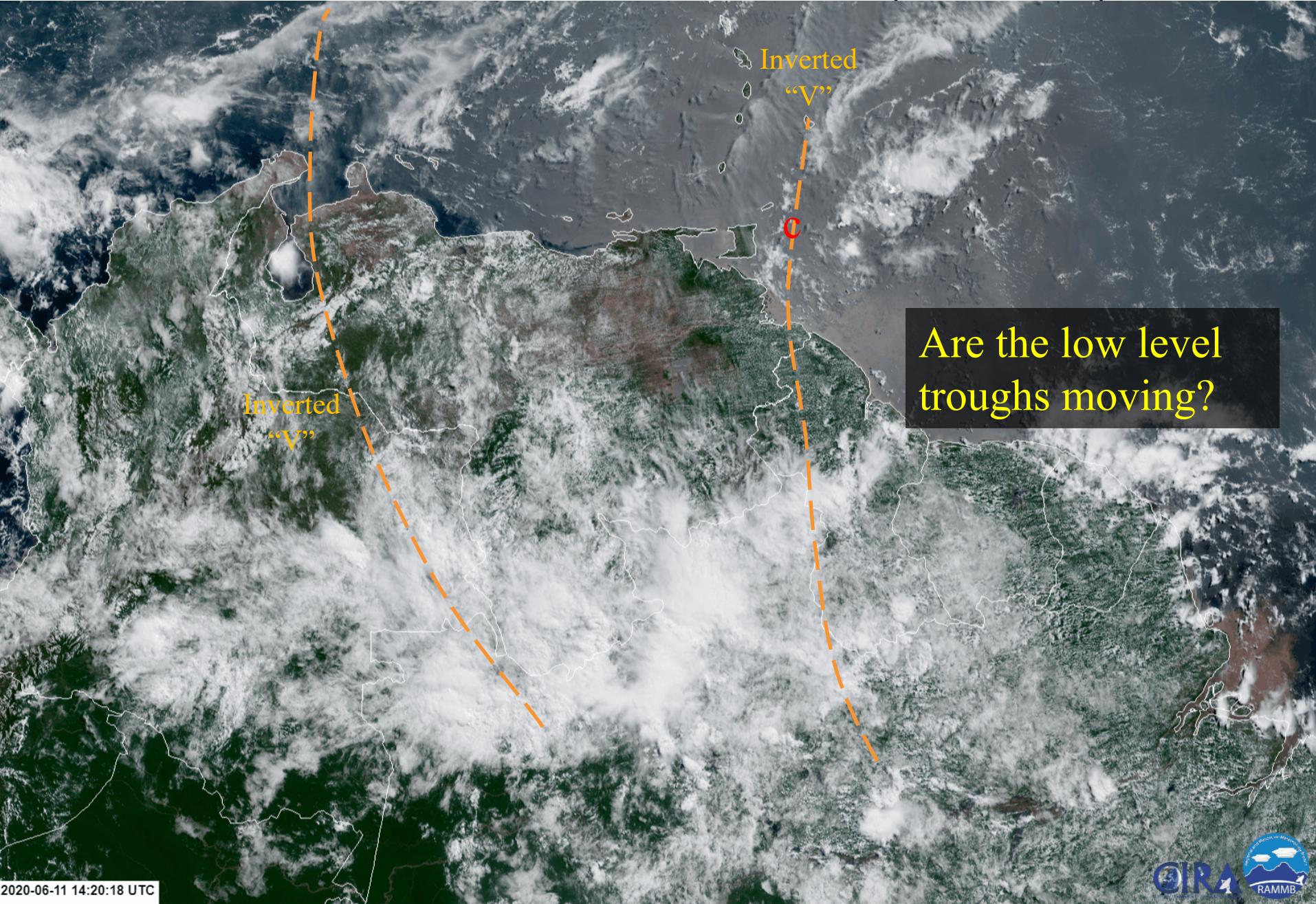
Inverted
“V”?

Inverted
“V”

Hint: There are two waves and two surface lows south of 20N.

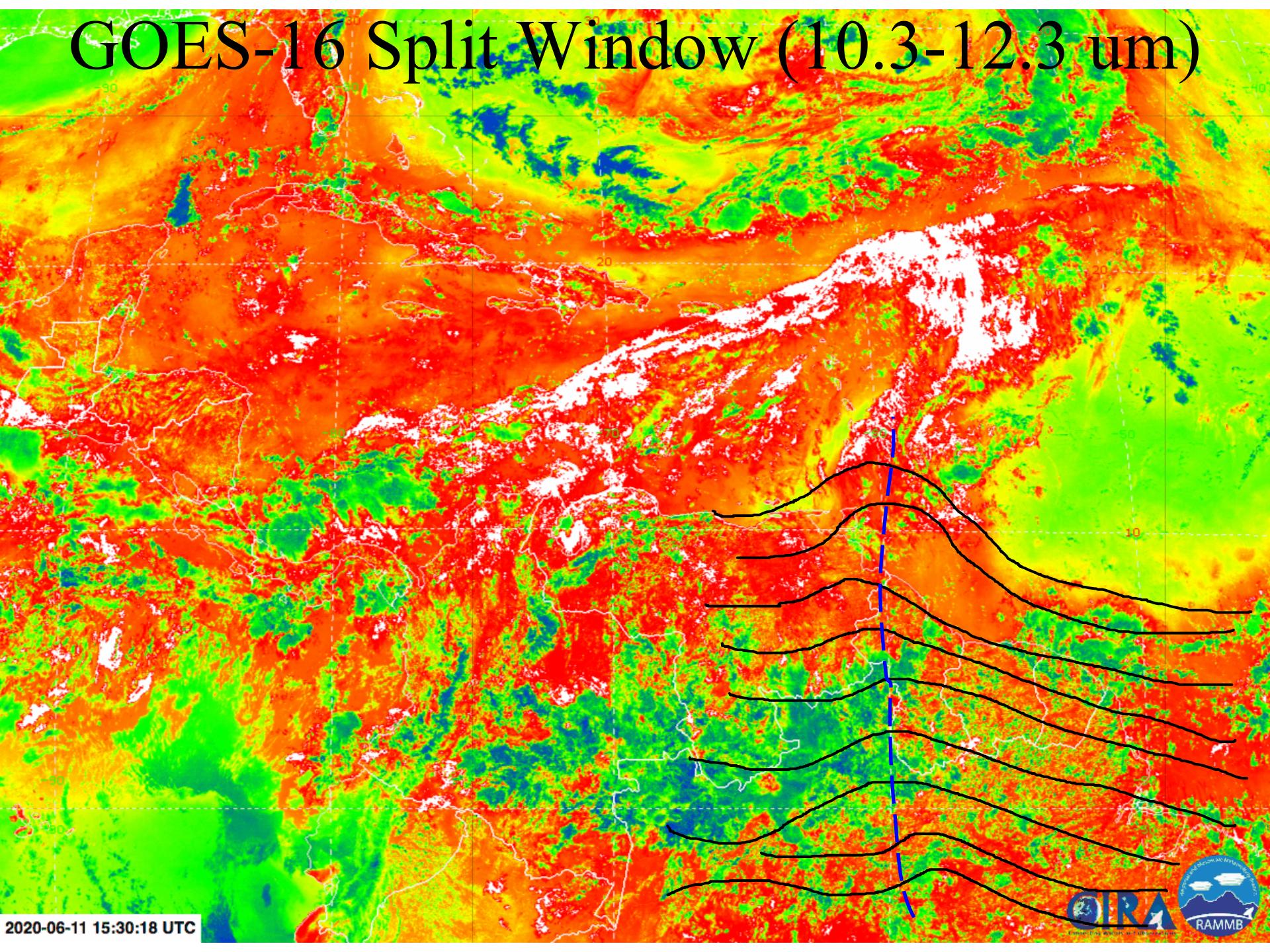


GOES-16 GeoColor (Zoom)



2020-06-11 14:20:18 UTC

GOES-16 Split Window (10.3-12.3 μ m)



2020-06-11 15:30:18 UTC

GOES-16 6.2um

TUTT
Low

C

Jet
Maxima

Find the Upper
Level Circulation
TUTT/TUTT Low?
SER SE Ridge?

SER



GOES-16 7.3um

TUTT
Low

Find the Mid
Level Circulation
TUTT/TUTT Low?
SER SE Ridge?

SER

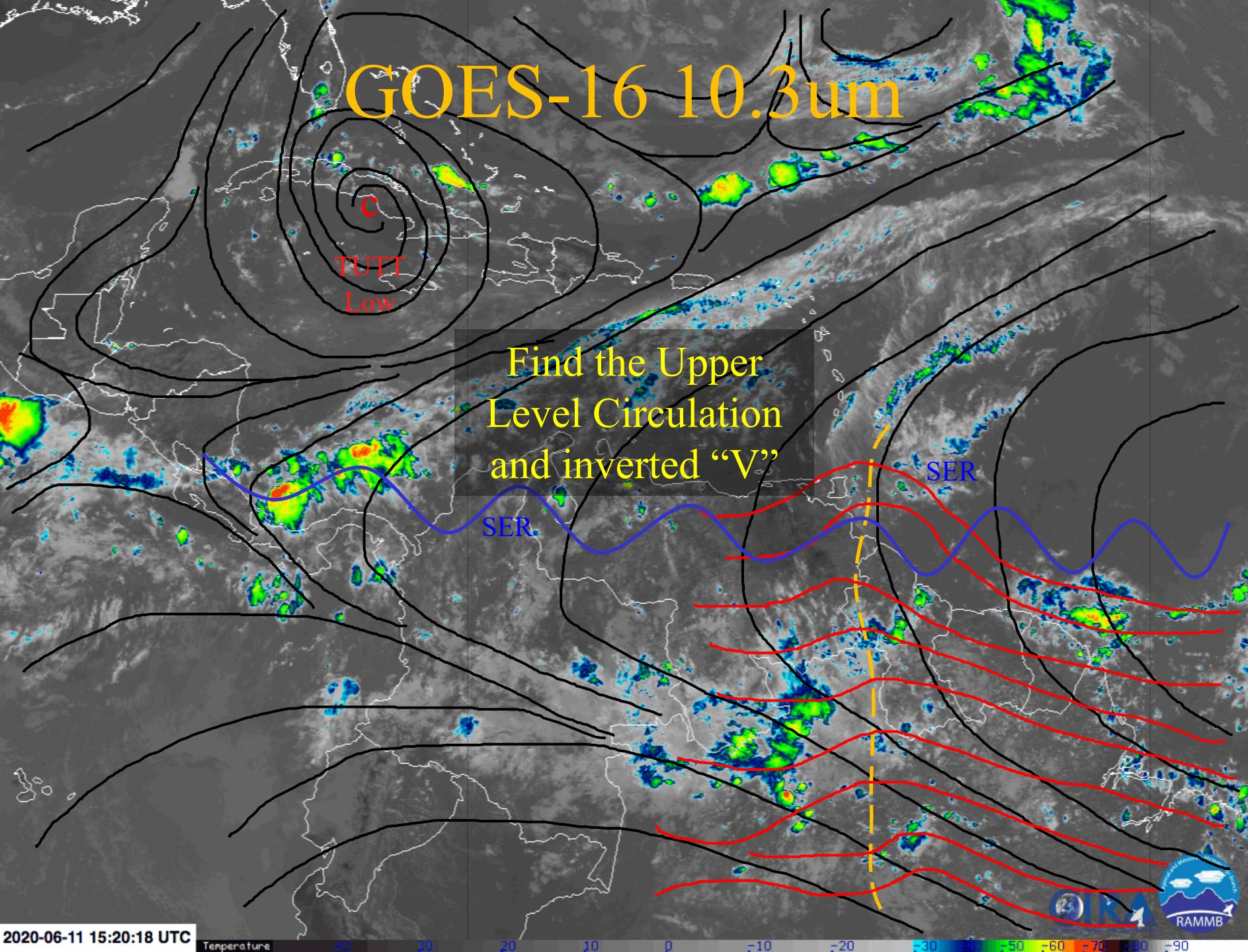


GOES-16 10.3um

Find the Upper
Level Circulation
and inverted “V”

SER.

SER



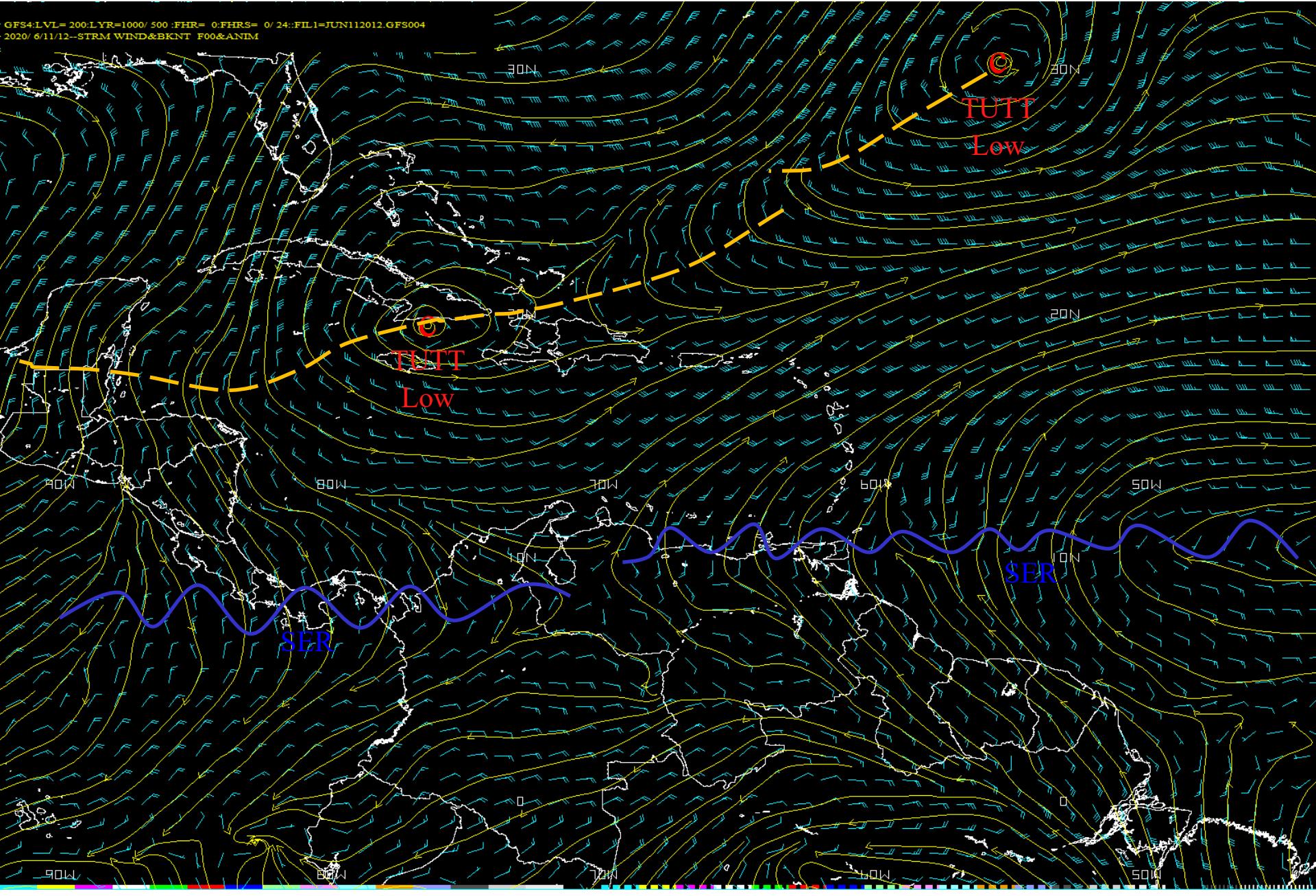
2020-06-11 15:20:18 UTC

Temperature

40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90

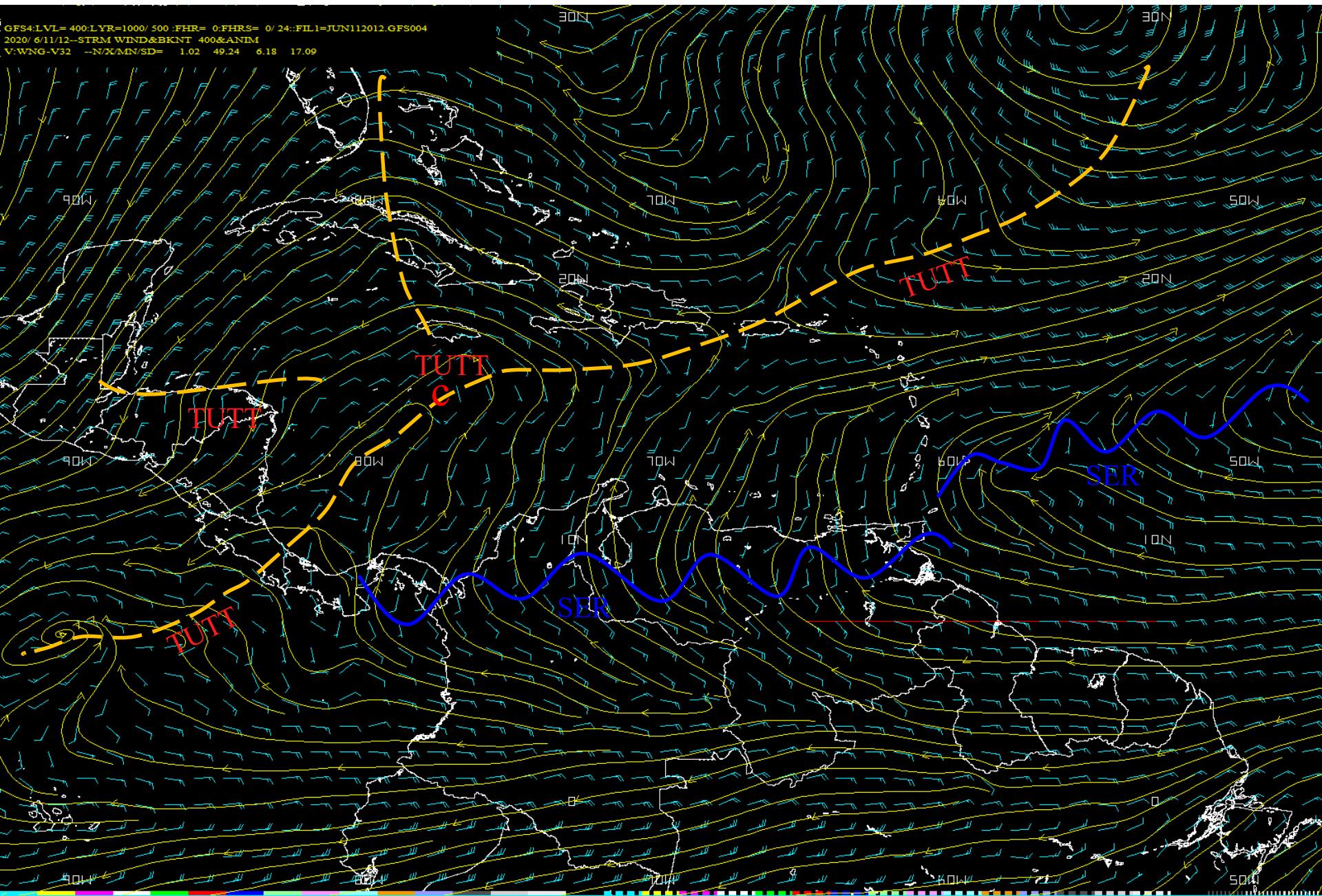


GFS – 200 hPa

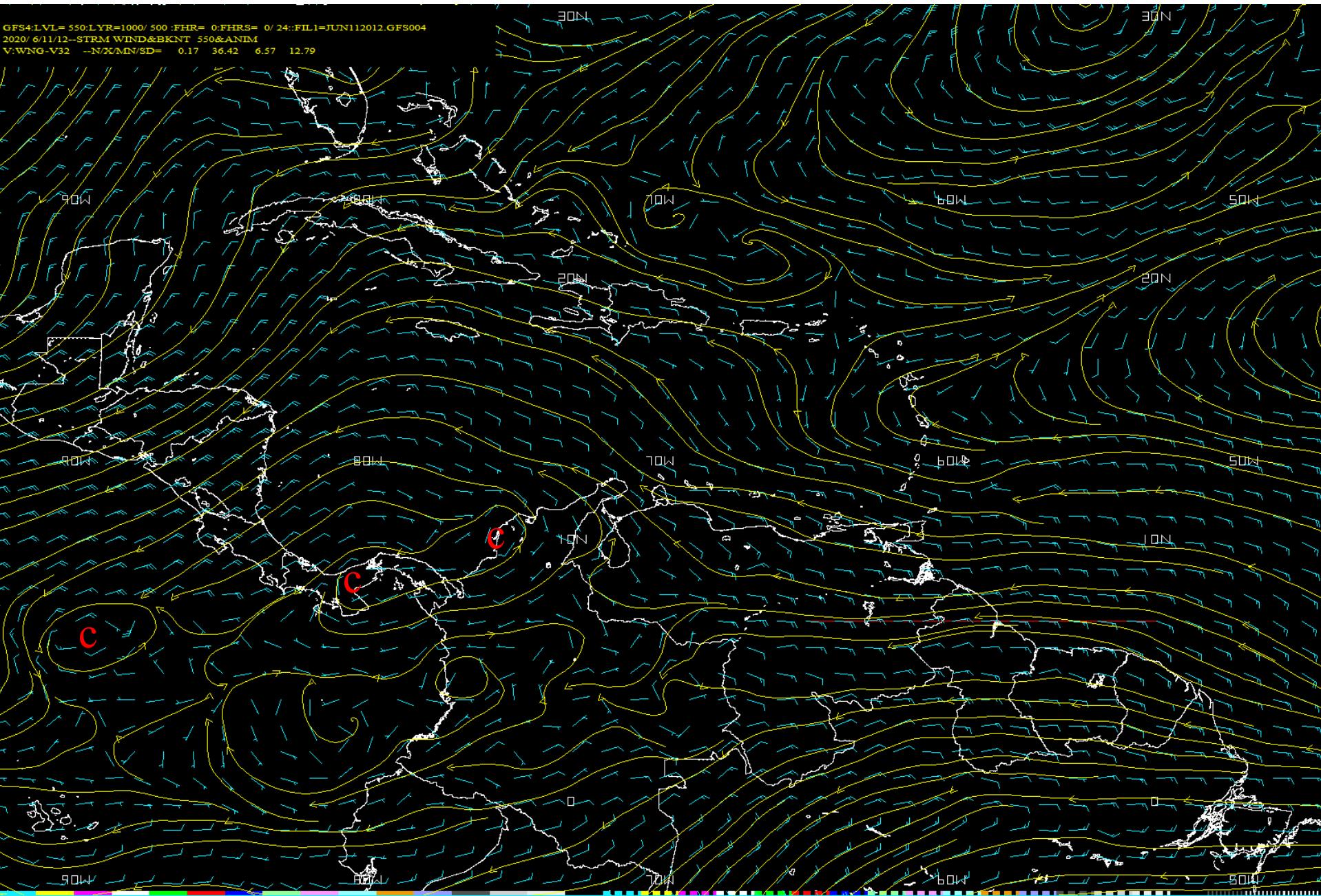


GFS – 400 hPa

GFS4:LVL= 400:LXR=1000/ 500 :FHR= 0:FHRS= 0/ 24::FIL1=JUN112012,GFS004
2020/ 6/11/12-STRM WIND&BKNT 400+ANIM
W:WNG-V32 -N/X/MN/SD= 1.02 49.24 6.18 17.09

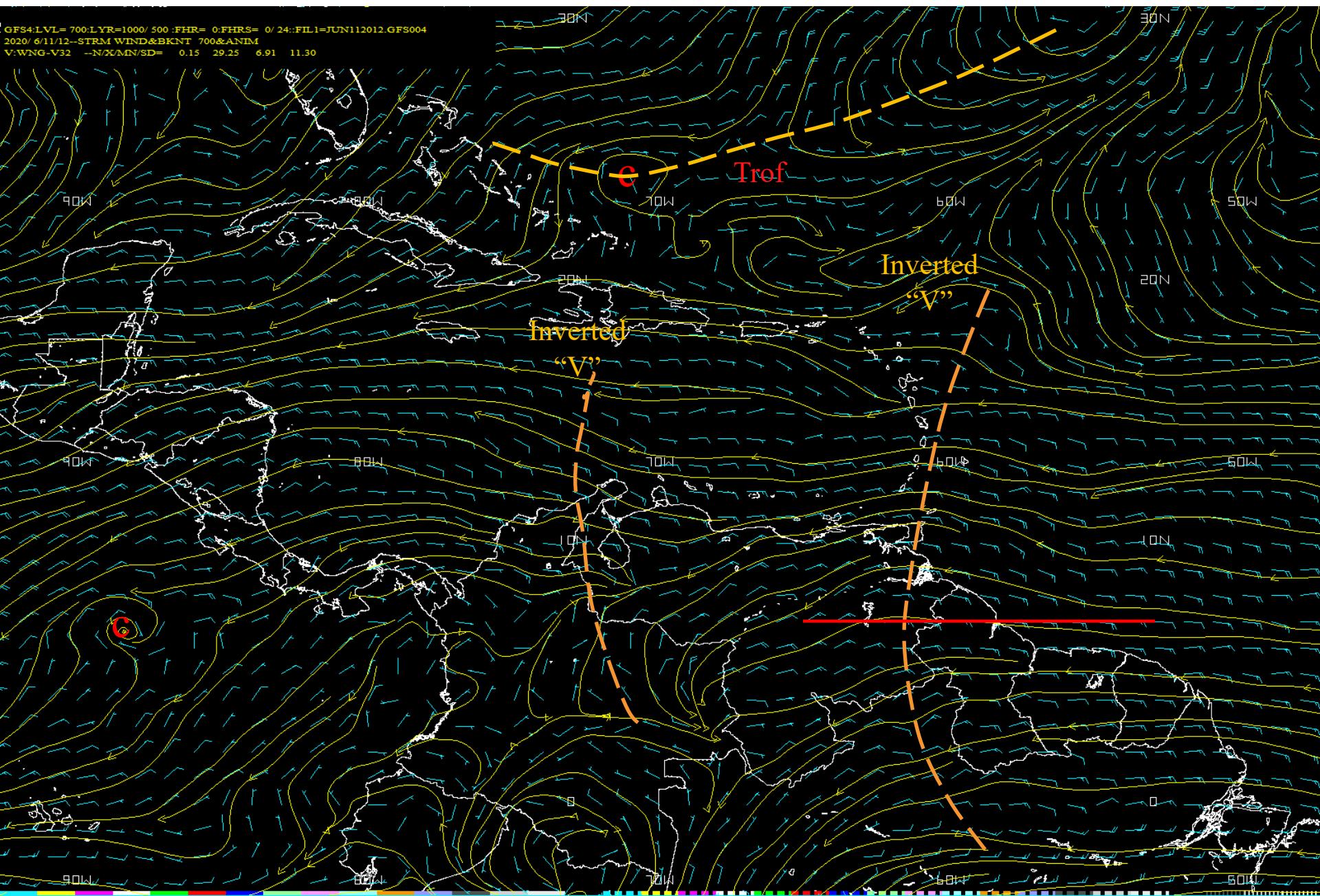


GFS – 550 hPa

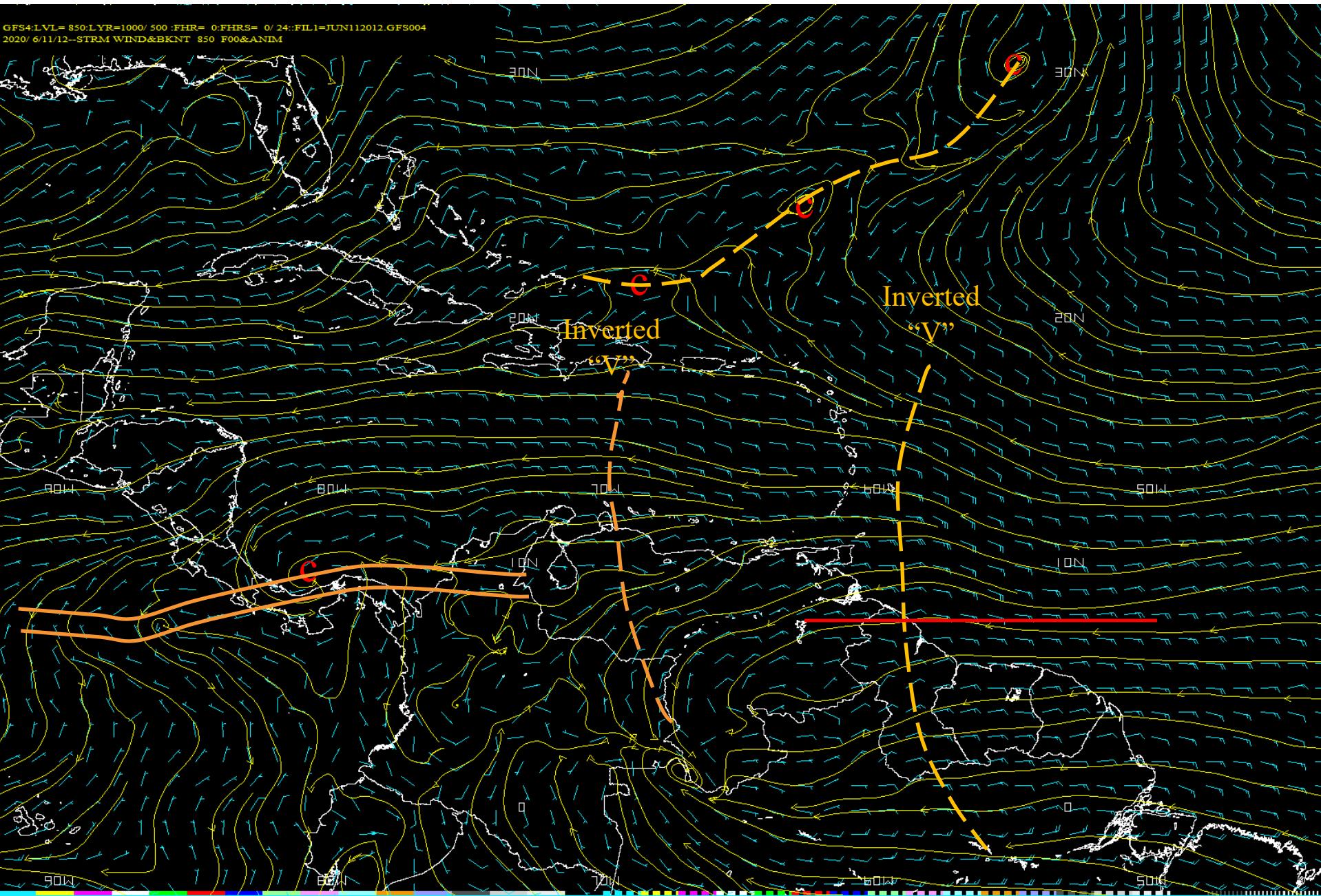


GFS – 700 hPa

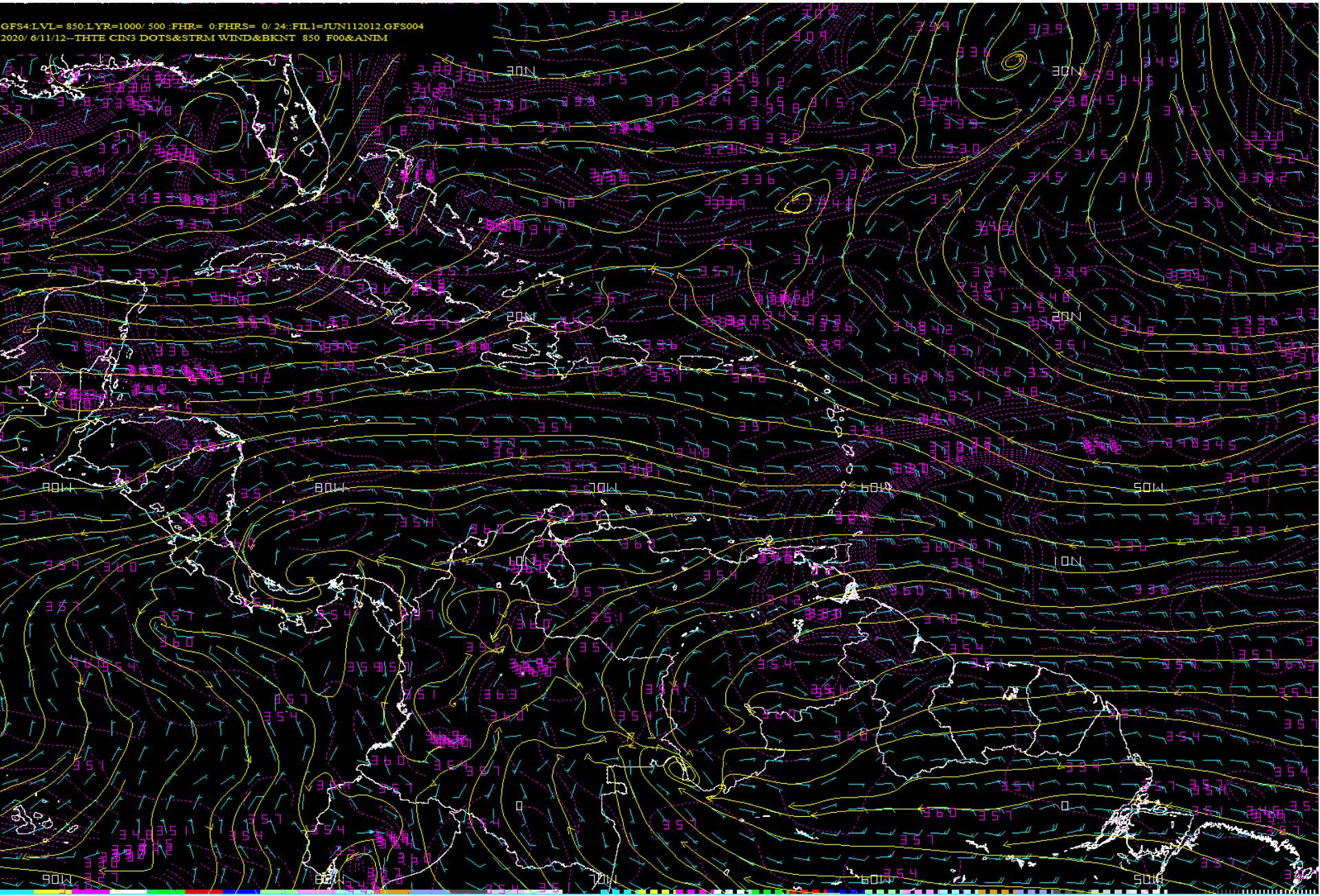
GFS4:LVL= 700:LYR=1000/500 :FHR= 0:FHRS= 0/ 24::FILE=JUN112012.GFS004
2020 6/11/12--STRM WIND&BKNT 700&ANIM
V:WNG-V32 -N/X/MIN/SD= 0.15 29.25 6.91 11.30



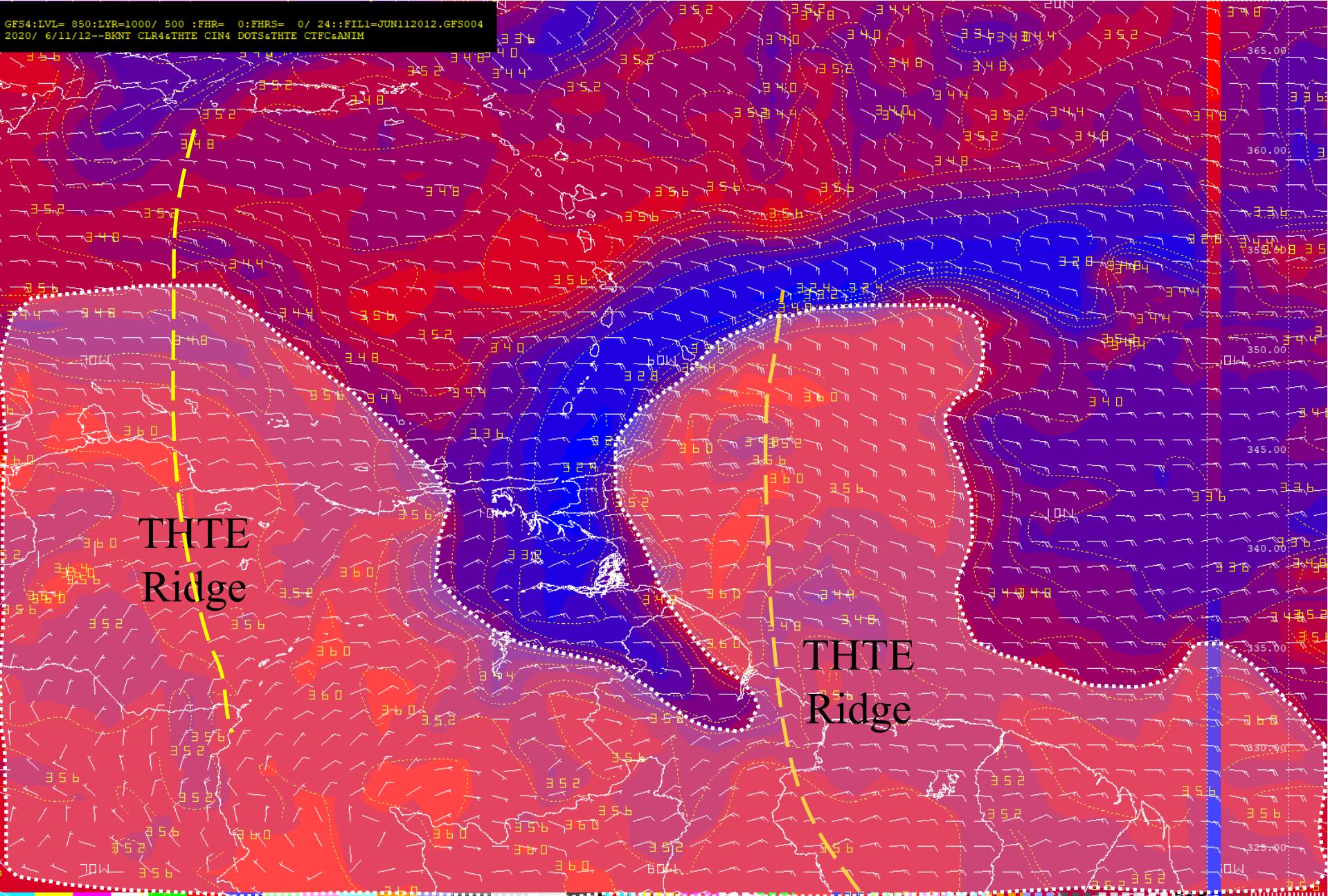
GFS – 850 hPa



GFS – 850 hPa & EPT

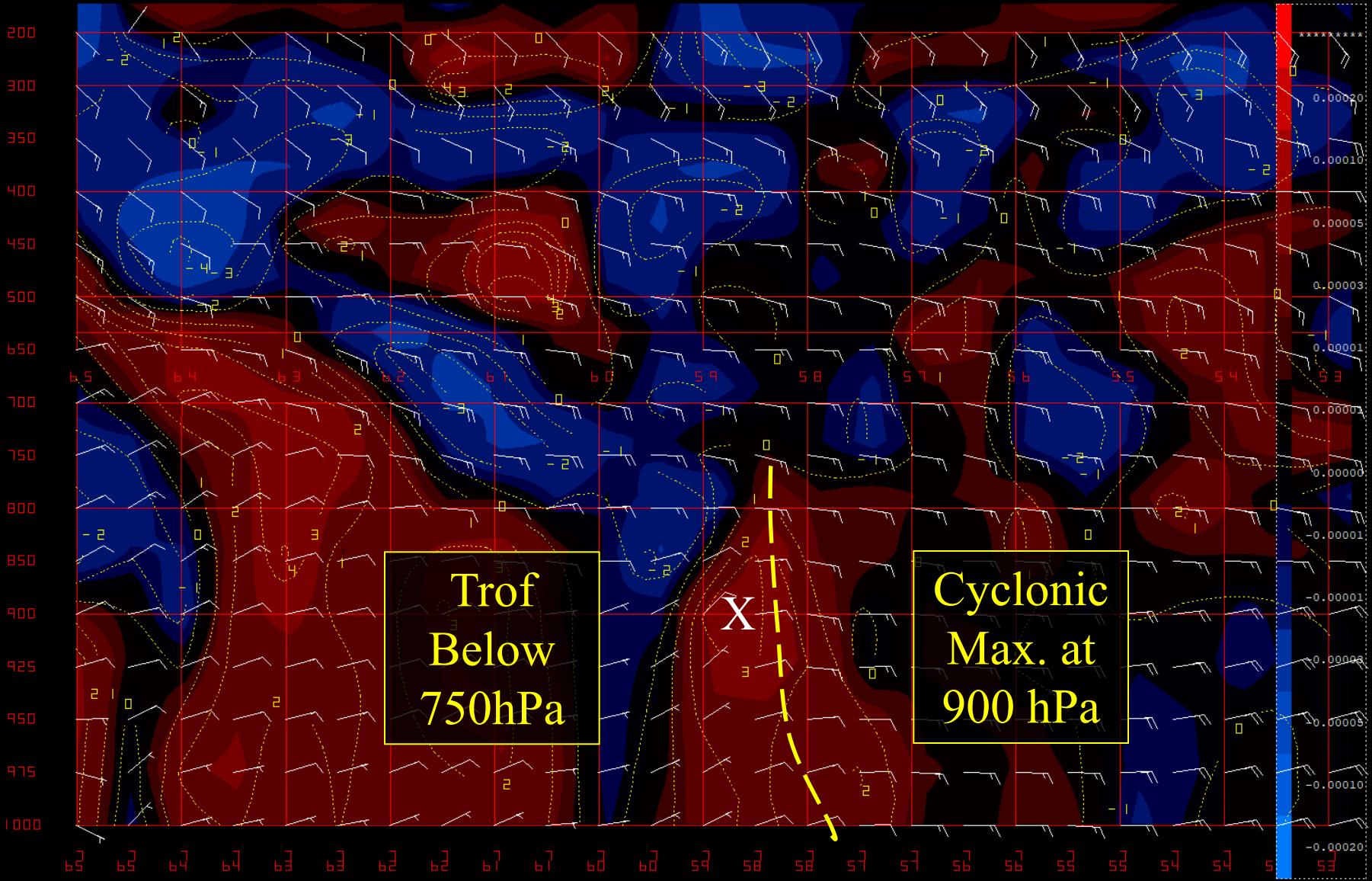


GFS – 850 hPa & EPT

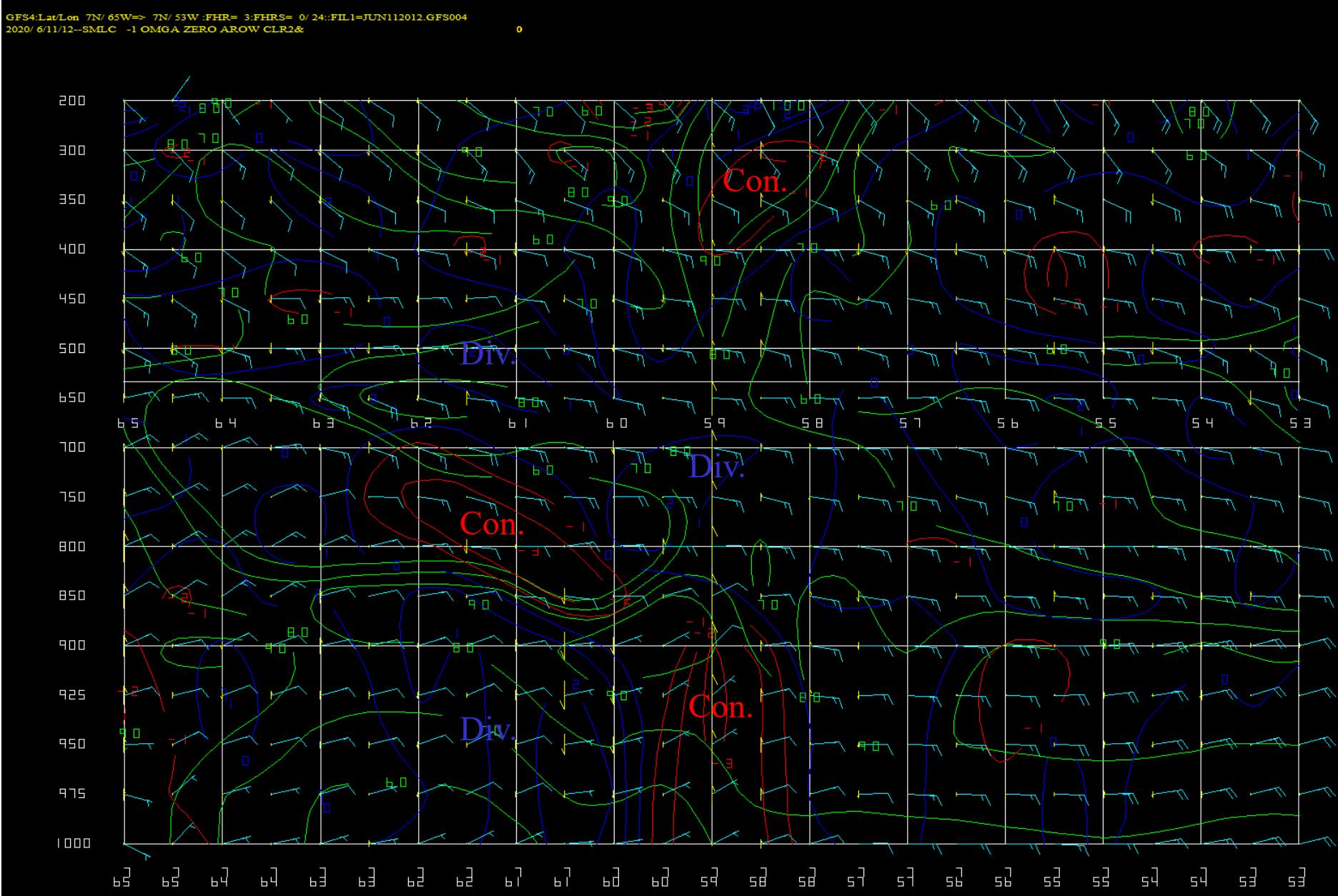


Cross Section – Winds and RVRT

GFS4:Lat/Lon 7N/ 75W=> 7N/ 53W :FHR= 3:FHRS= 0/ 24::FILL=JUN112012.GFS004
2020/ 6/11/12--BKNT CLR4eRVRT WIND DOTSeRVRT WIND CTFC CFC9eANIM



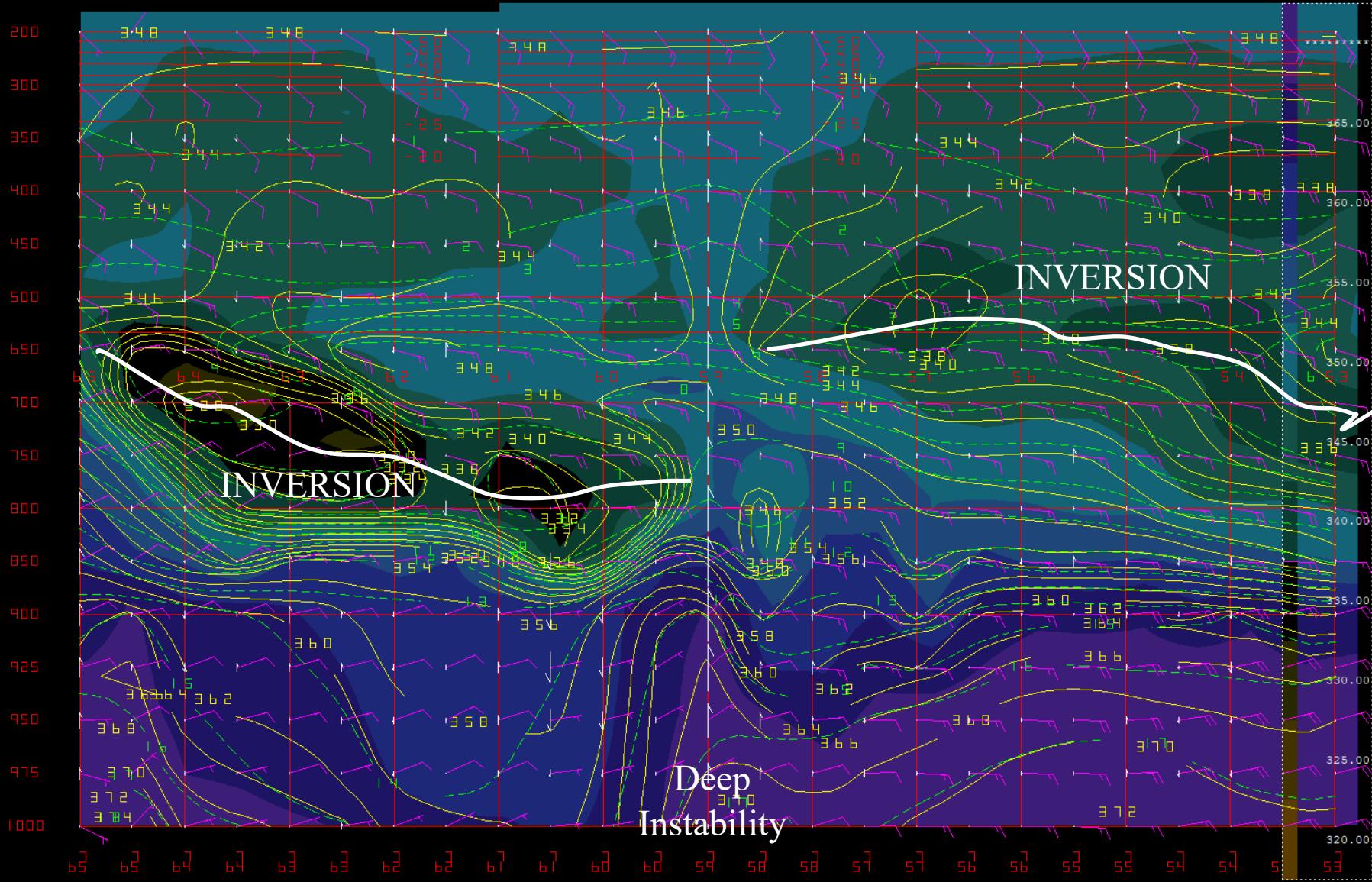
Cross Section – Winds & Divergence



Cross Section – EPT, Winds, Omega

GFS4:Lat/Lon 7N/ 65W=> 7N/ 53W :FHR= 3:FHRS= 0/ 24::FILL=JUN112012.GFS004
2020/ 6/11/12--SMLC -1 OMGA ZERO AROW CLR4&

CB DIAGNOSTIC MACRO, LIFT TO -20 C
TEMP<-20 (RED), EPT (YELLOW), MIX RATIO (GREEN), AGEO CIRC (CYAN)



Part 2 – Poll Question #4 (Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

Observations

- WV Imagery shows the subequatorial ridge branching across the Tropical Atlantic to northern South America, with a TUTT low over Cuba-Western Caribbean
- Visible imagery and wind analysis clearly shows perturbation in the easterlies below 700 hPa.
- Cross sectional analysis confirms that the low level perturbation is not related to upper level feature.

TUTT Enhanced Convection

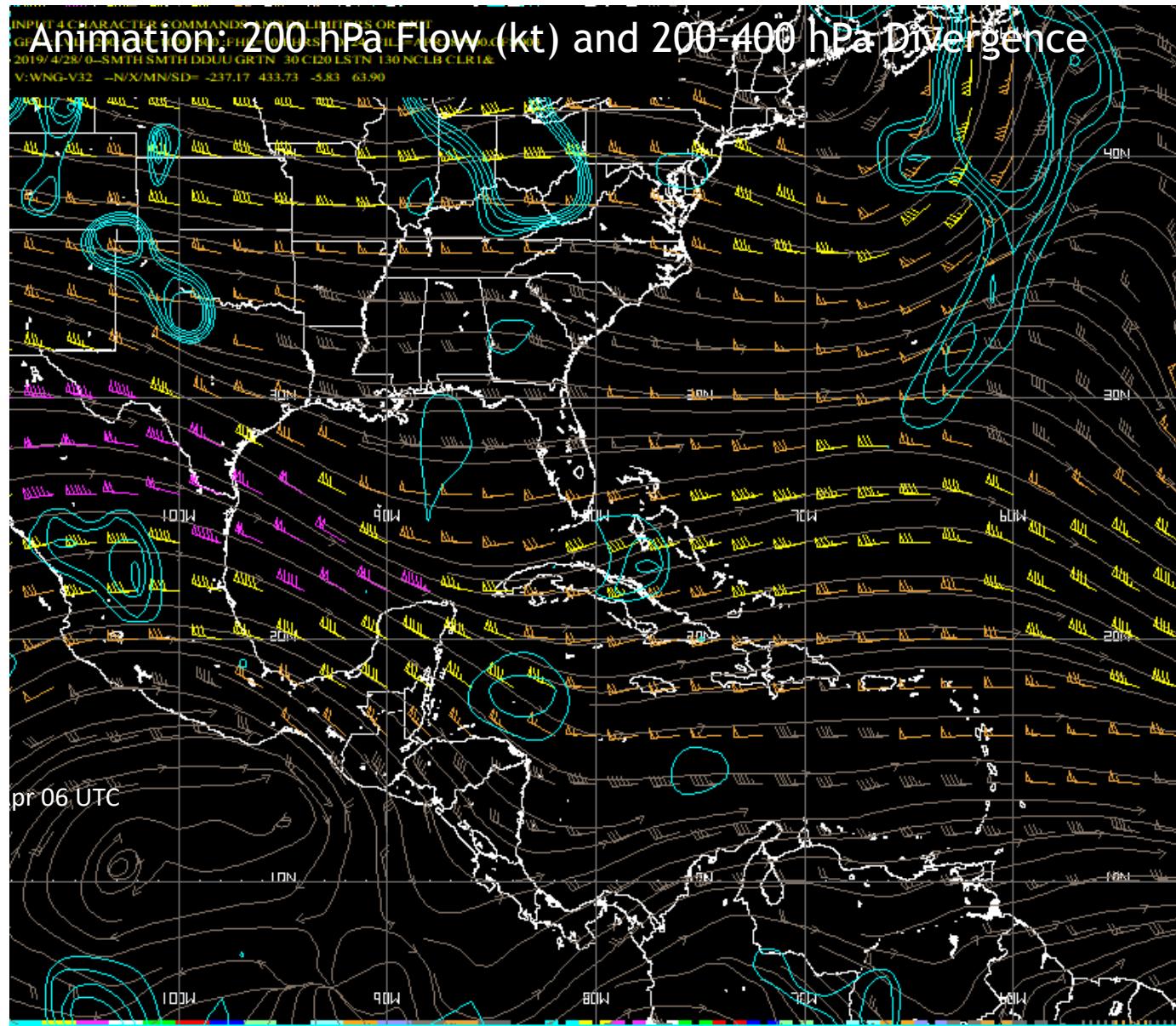
Severe Thunderstorms

April 28-29, 2019

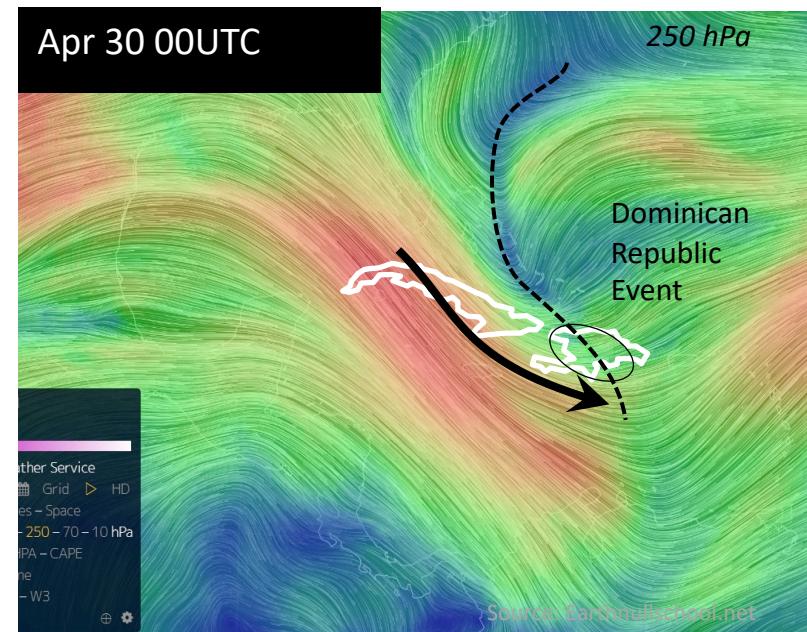
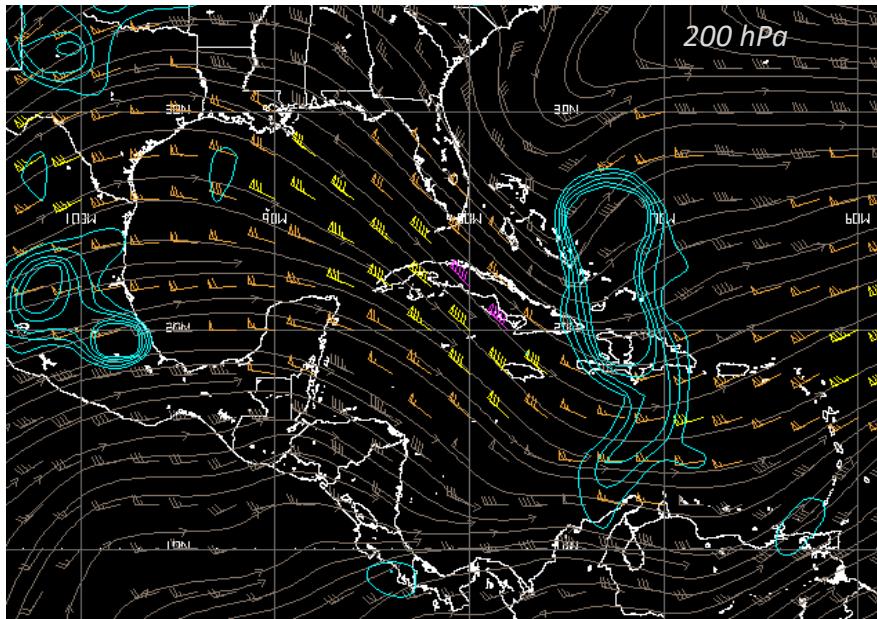
TUTT's Impact on Severe Convection

- Source of upper divergence
 - Vents deep convection
- Cyclonic vorticity advection
 - Enhances upward vertical motion
- Enhances Convective Instability-Cold Core
 - GDI
 - Traditional Indices (LI, SSI, TTI, KI)

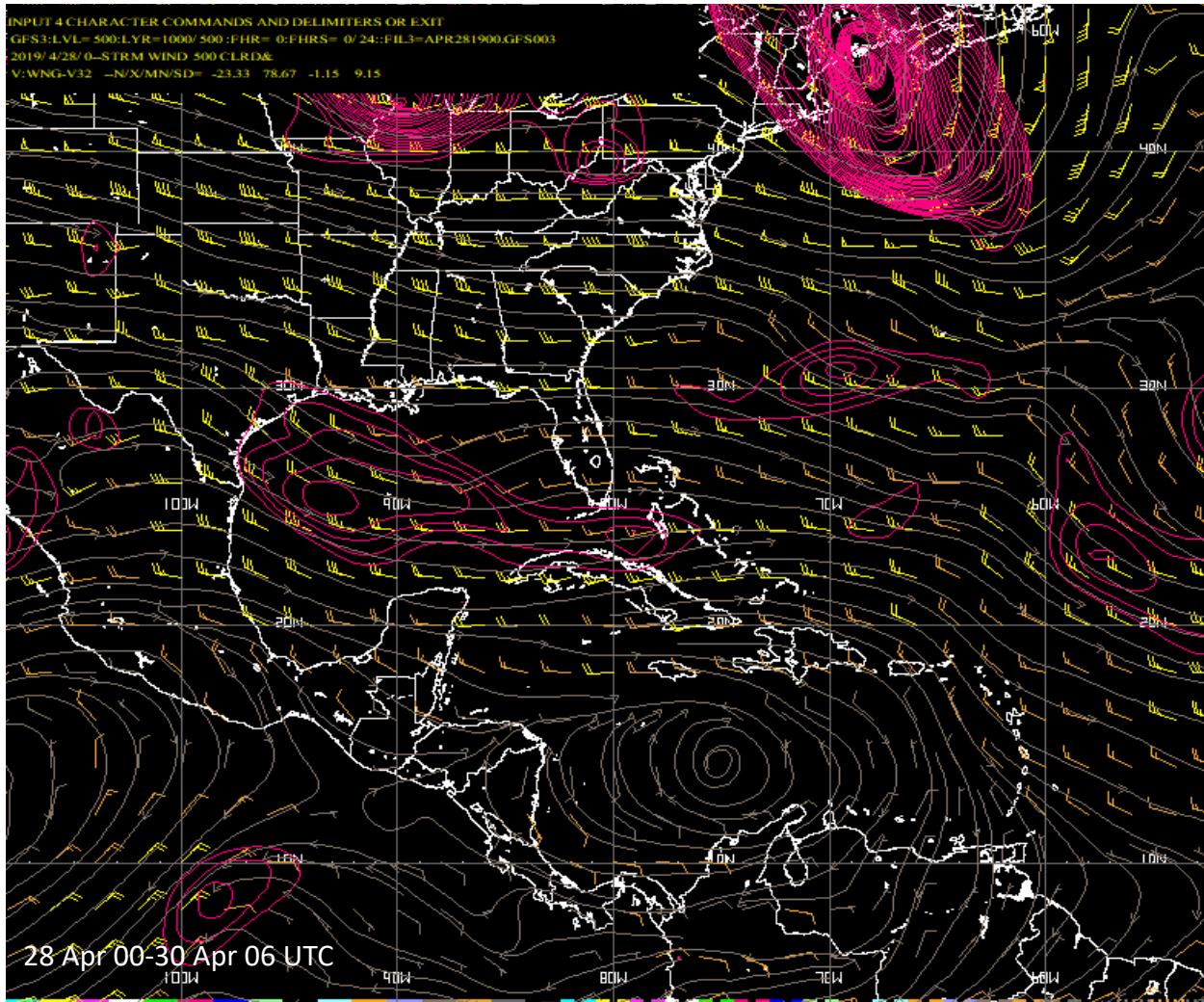
TUTT – Divergence Aloft



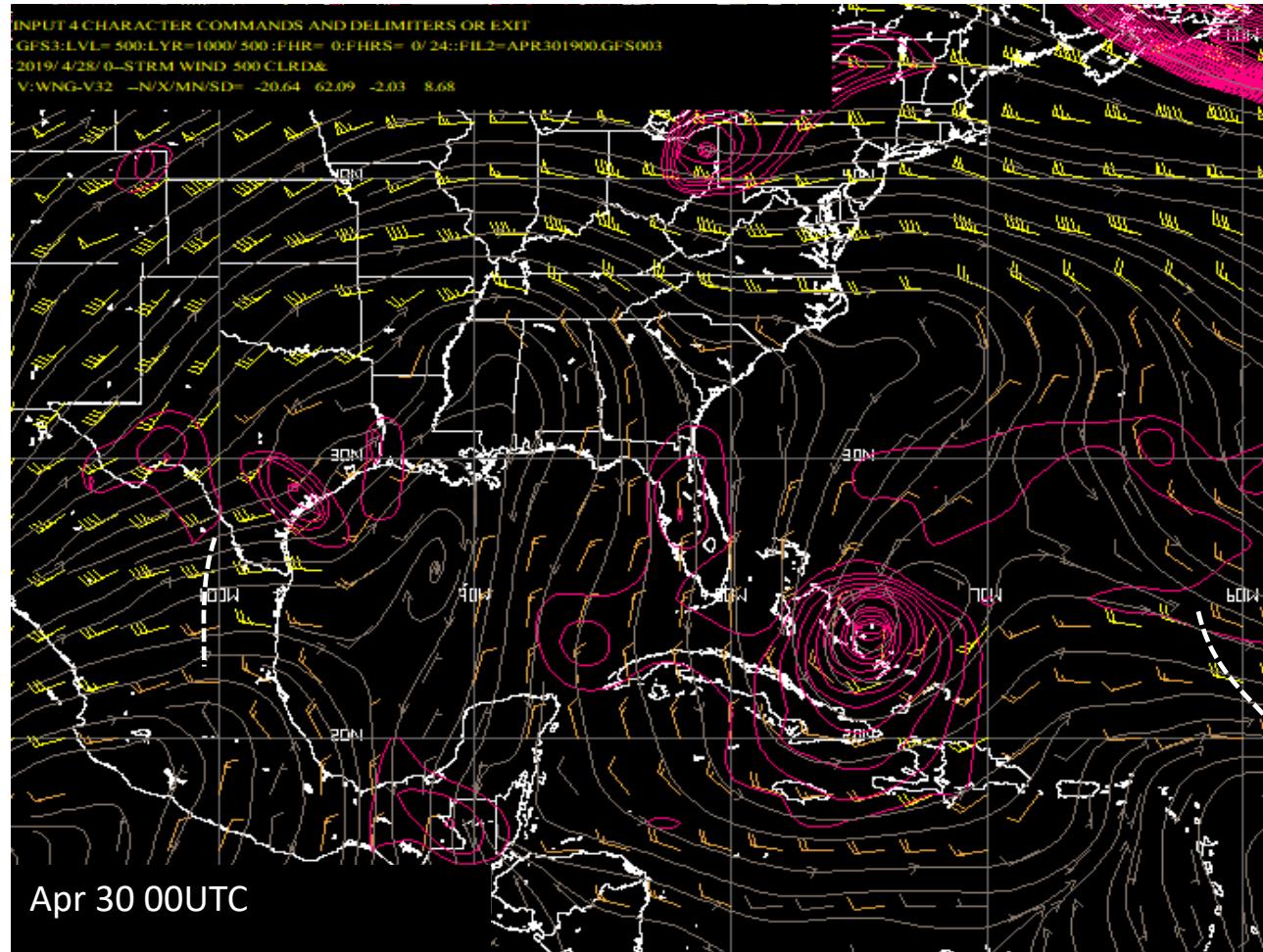
TUTT – Divergence Aloft



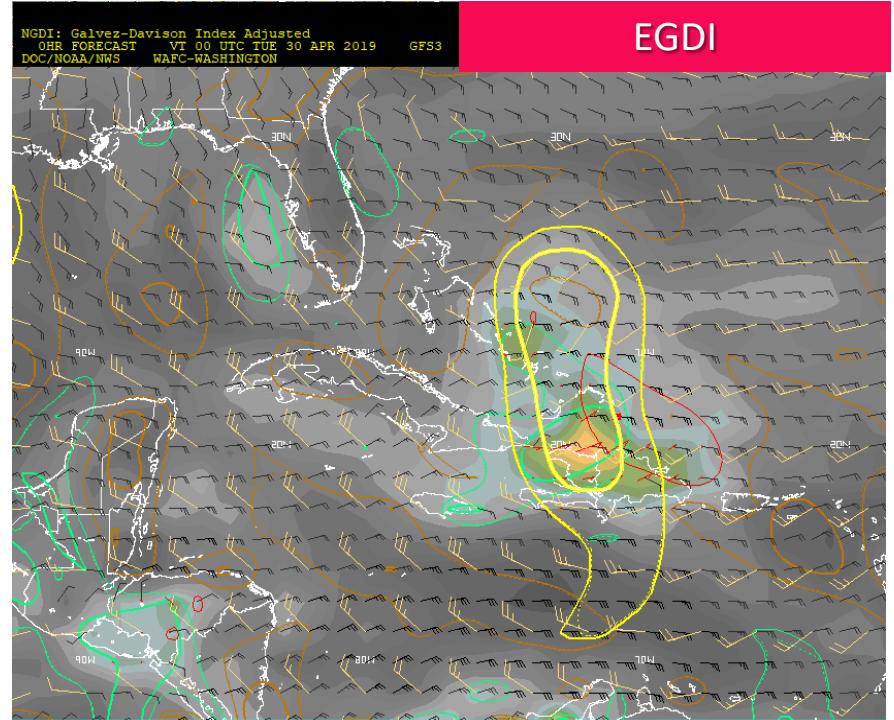
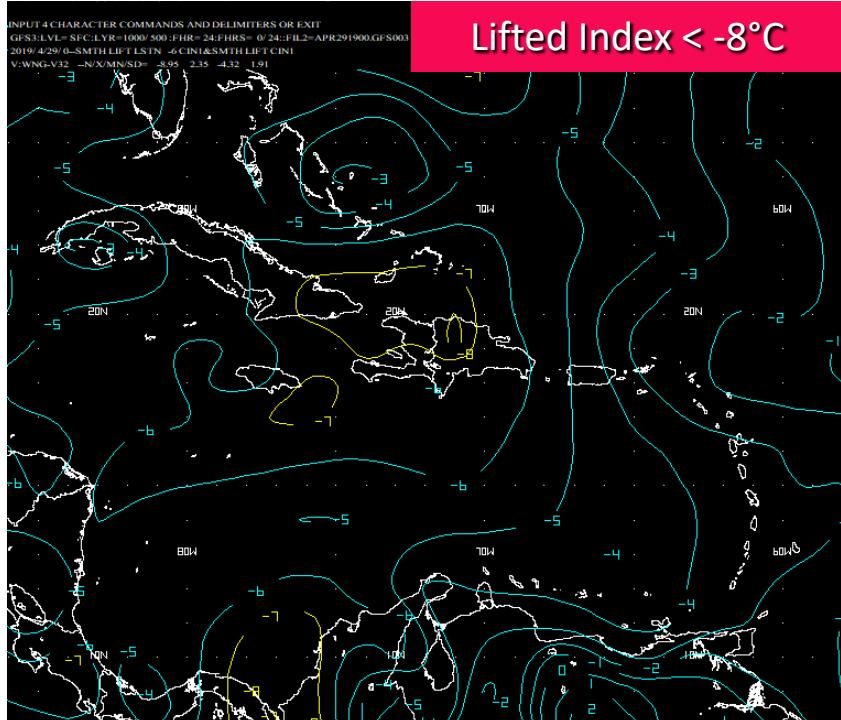
TUTT – Mid Level Cyclonic Vorticity



TUTT – Mid Level Cyclonic Vorticity

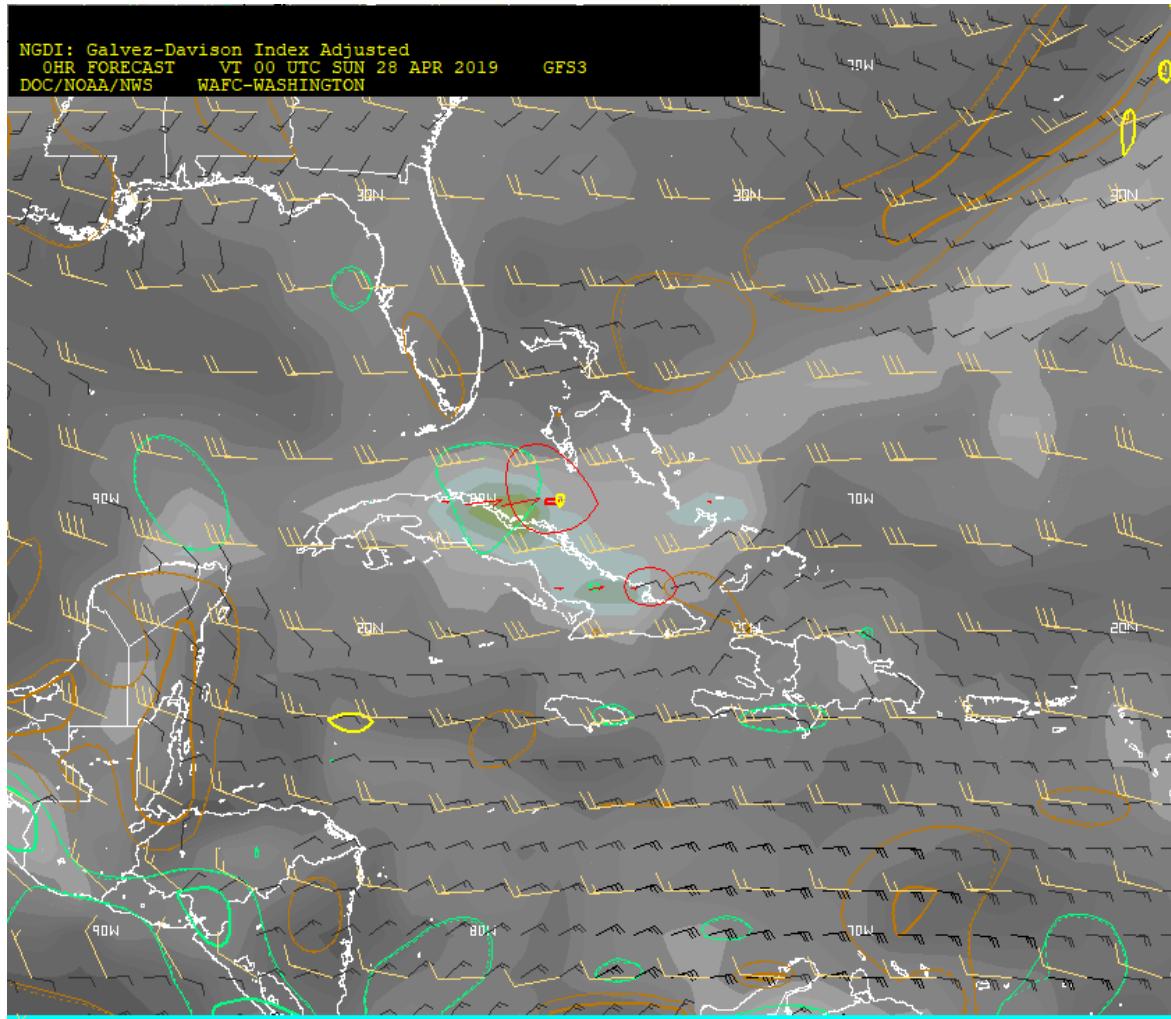


TUTT - Stability

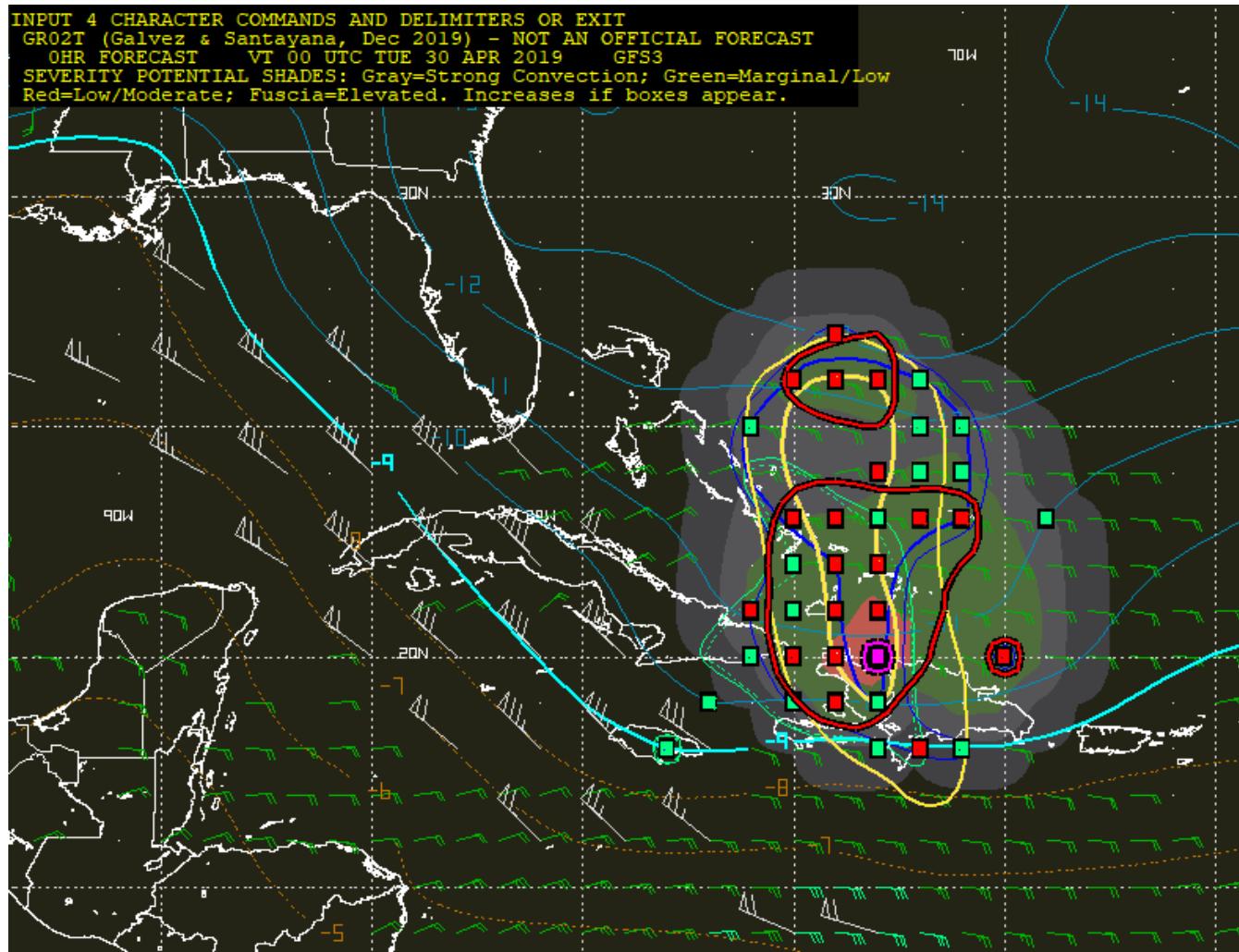


Note: Use the GDI and EGDI to determine potential of deep or shallow convection.

EGDI and Low Level Flow

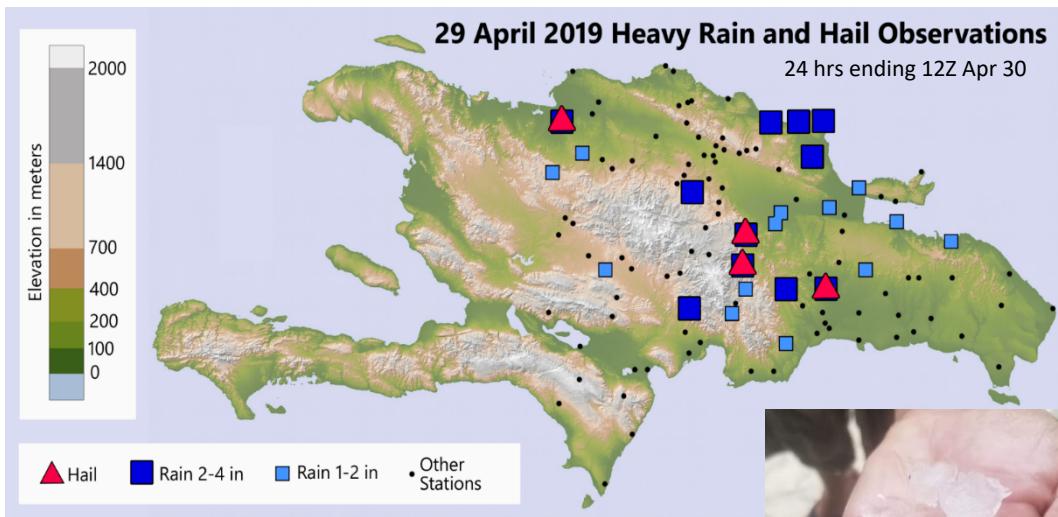


Diagnostic Tools : GR02T



Observations and Impacts

Apr 29: Local Flooding and hail in Hispaniola



HAIL
5% of stations
Heavy rain (>2in)
11% of stations
Moderate rain (1-2in)
13% of stations

Note: Hail reported in lower elevations



Observations and Impacts

Apr 28: Severe Weather in Cuba

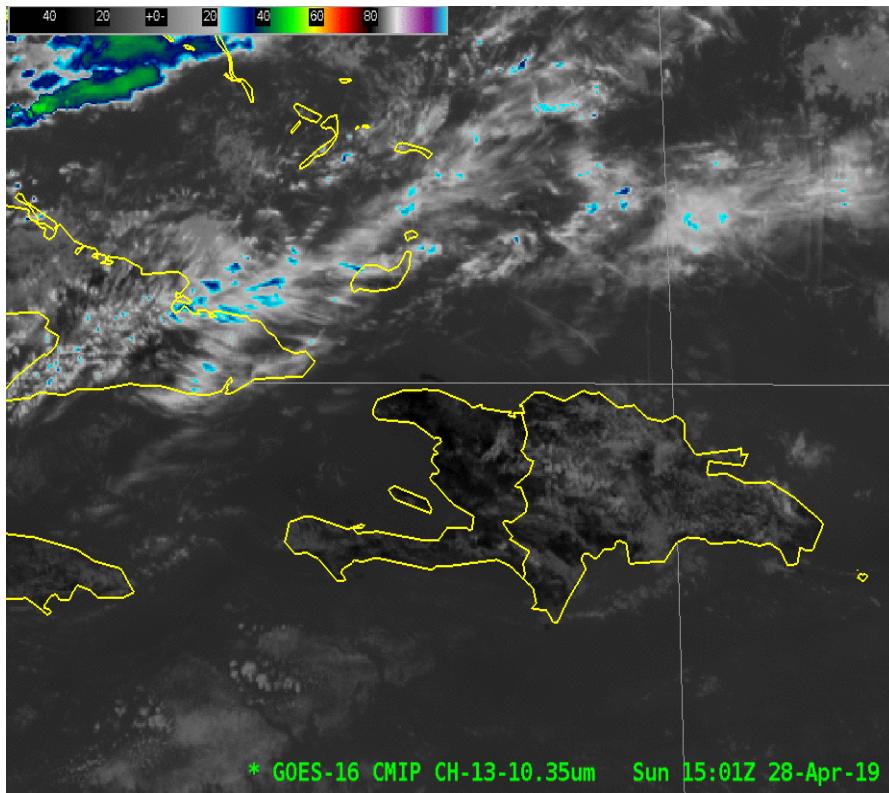
Santa Clara, Cuba - Severe Thunderstorm

- Winds topped near 100 kph
- Nickel-size hail
- Airport and 60 houses affected



Damage in Santa Clara Airport

Satellite Loop over Hispaniola/Cuba on April 28



- April 28: Day of the Cuba event, one day before the Hispaniola event.
- Does not capture Santa Clara in Cuba, but clearly shows
 - Severe convection signatures in Cuba:
 - Long lasting cells
 - Cell propagation in different directions
 - Overshooting tops
 - V-shapes
 - Trough pattern to the west
 - Upper jet (transversal bands)
 - Vertical wind shear.

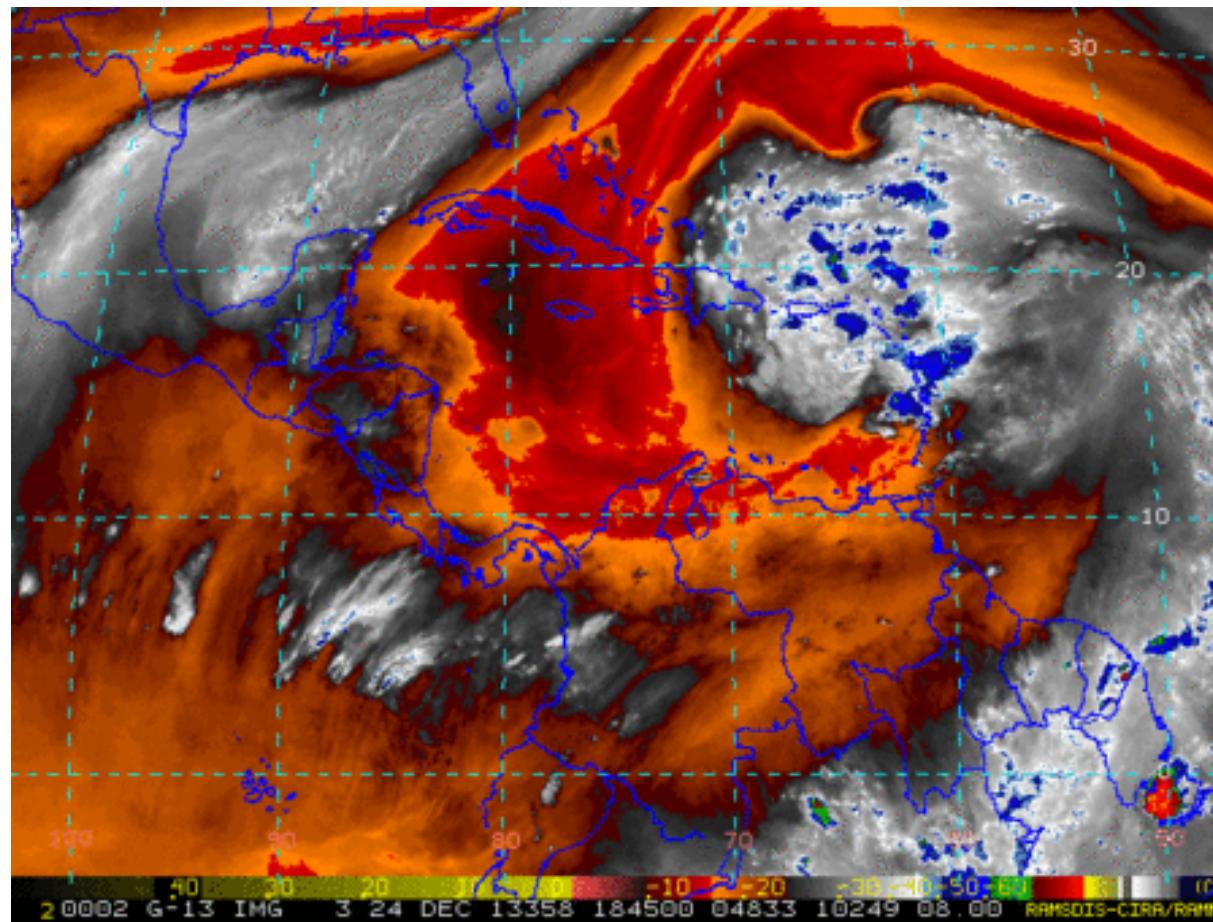
TUTT Enhanced Convection

Flash Flood

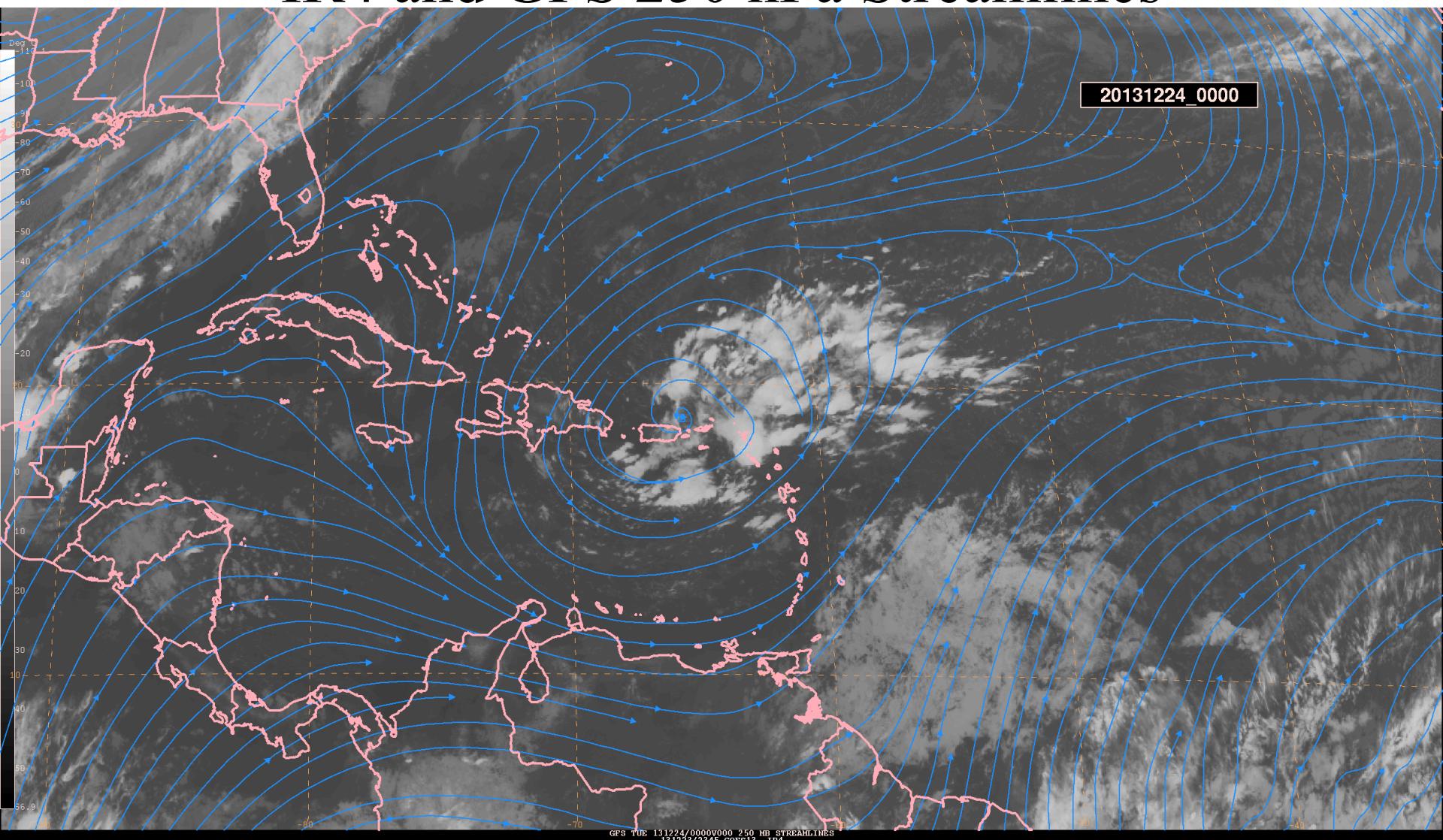
December 24, 2013

Kathy-Ann Caesar, CIMH

WV Animation



IR4 and GFS 250 hPa Streamlines

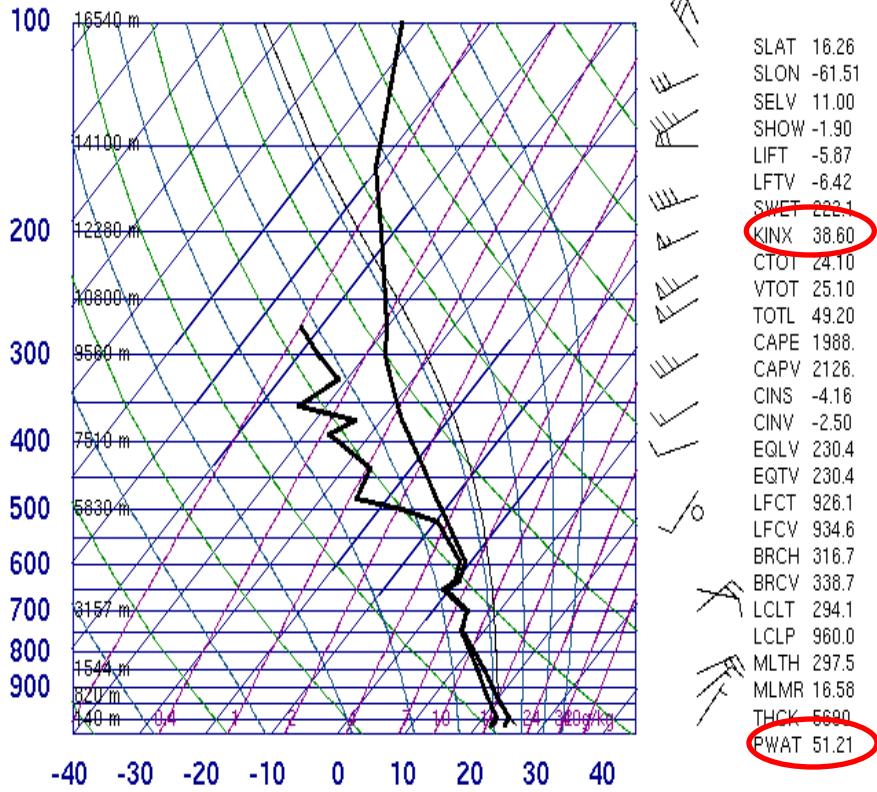


Upper level features and cloudiness

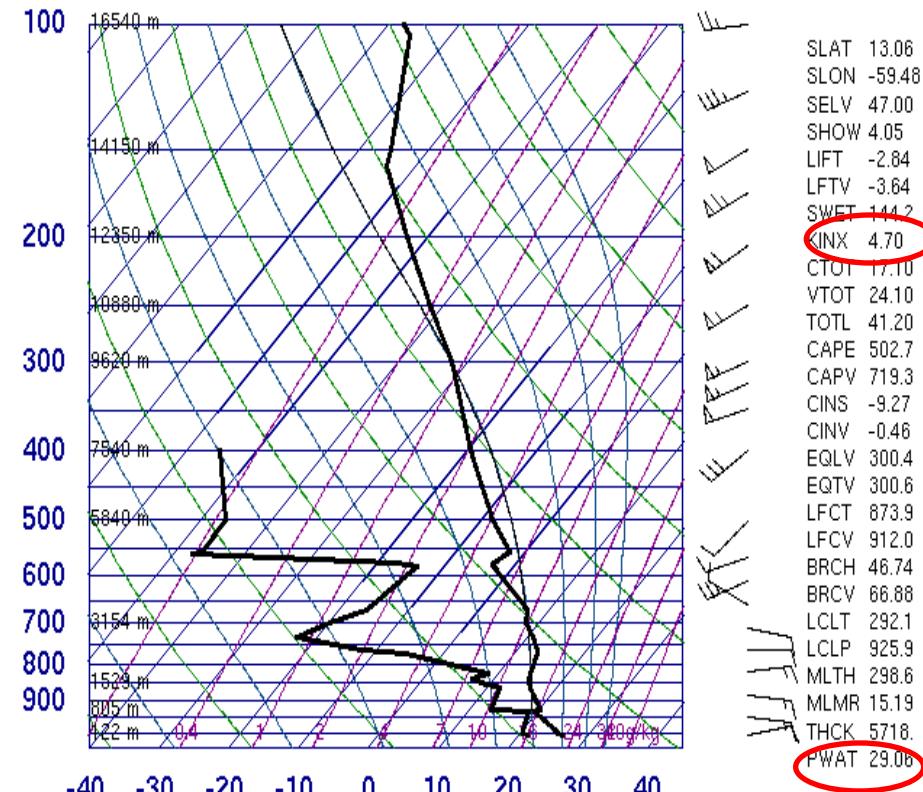
Is the TUTT deep enough to
sustain an induced trough in the
easterly trades?

Soundings 1200 UTC 23-12-2013

78897 TFFR Le Raizet, Guadeloupe

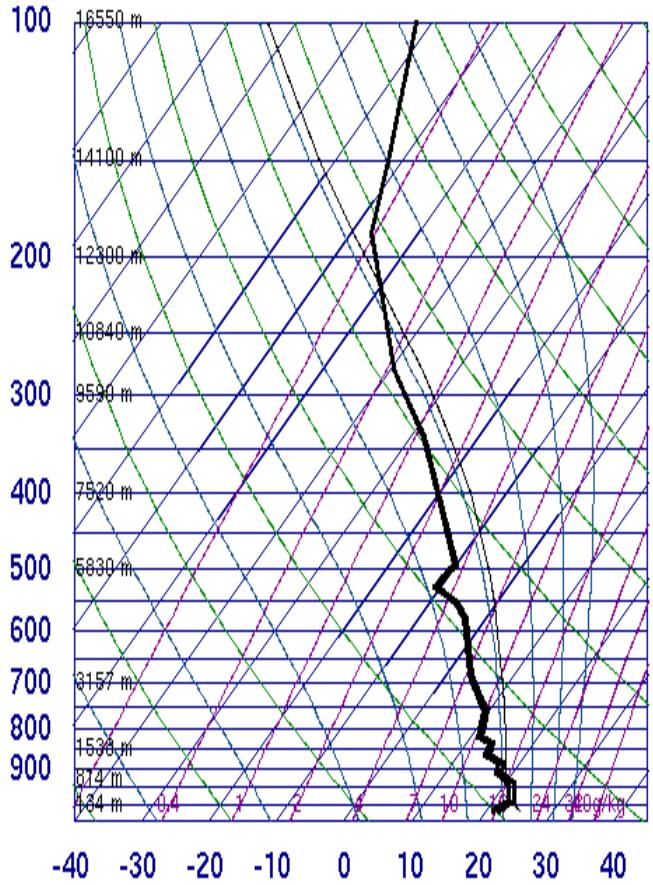


78954 TBPB Grantley Adams



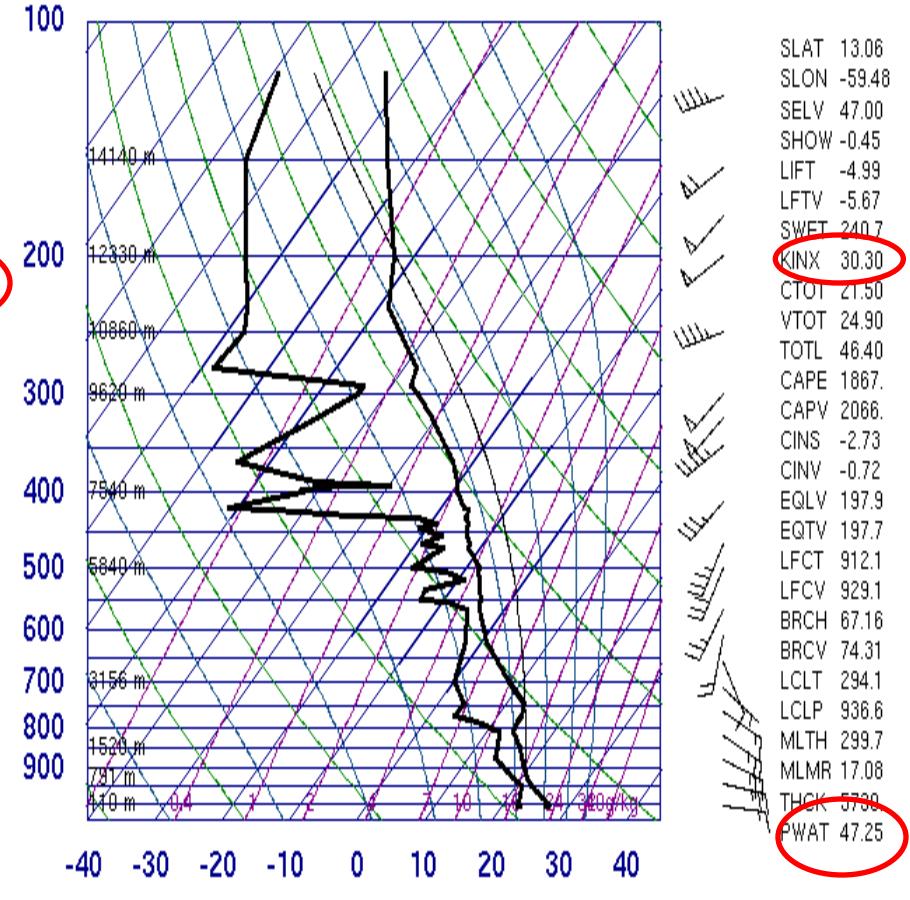
Soundings 1200 UTC 24-12-2013

78897 TFFR Le Raizet, Guadeloupe



University of Wyoming

78954 TBPB Grantley Adams

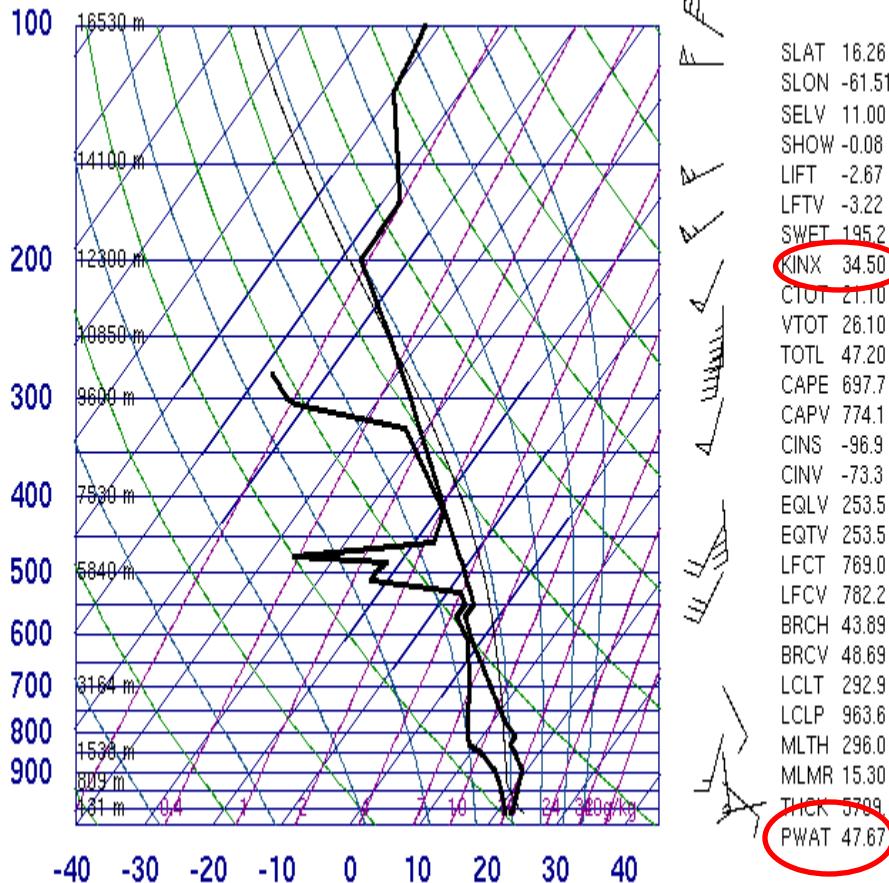


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SLAT 13.06
 SLON -59.48
 SELV 47.00
 SHOW -0.45
 LIFT -4.99
 LFTV -5.67
 SWET 240.7
 KINX 30.30
 CTOT 21.50
 VTOT 24.90
 TOTL 46.40
 CAPE 1867.
 CAPV 2066.
 CINS -2.73
 CINV -0.72
 EQLV 197.9
 EQTV 197.7
 LFCT 912.1
 LFCV 929.1
 BRCH 67.16
 BRCV 74.31
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 LCLP 936.6
 MLTH 299.7
 MLMR 17.08
 THCK 3700.
 PWAT 47.25

Soundings 1200 UTC 25-12-2013

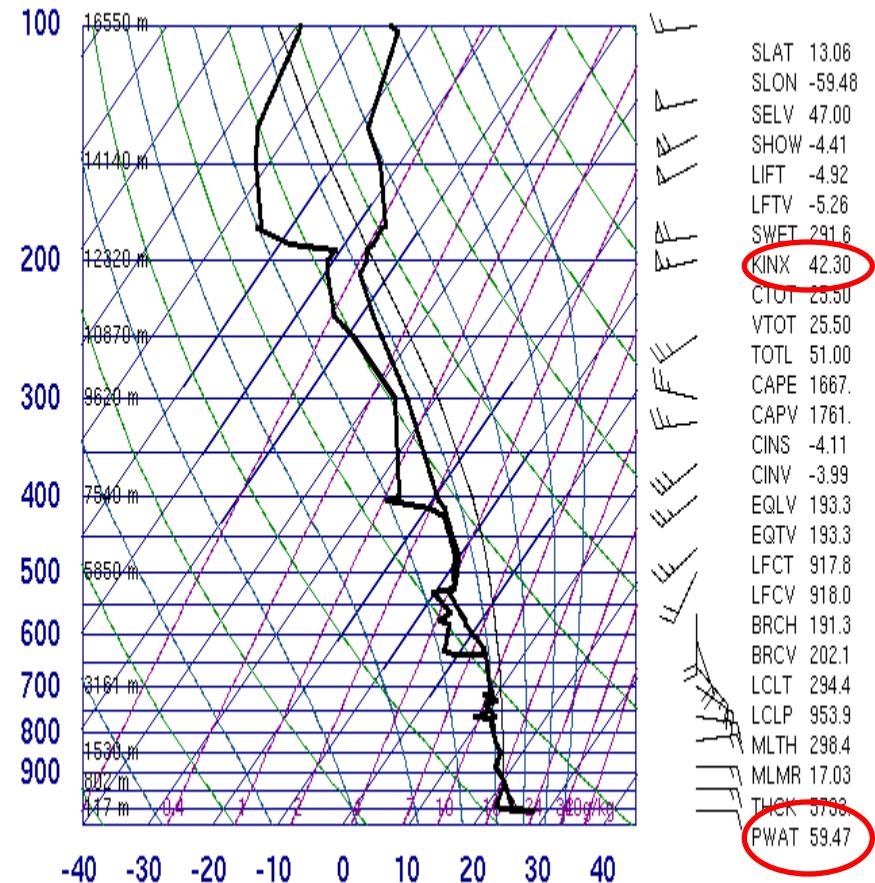
78897 TFFR Le Raizet, Guadeloupe



12Z 25 Dec 2013

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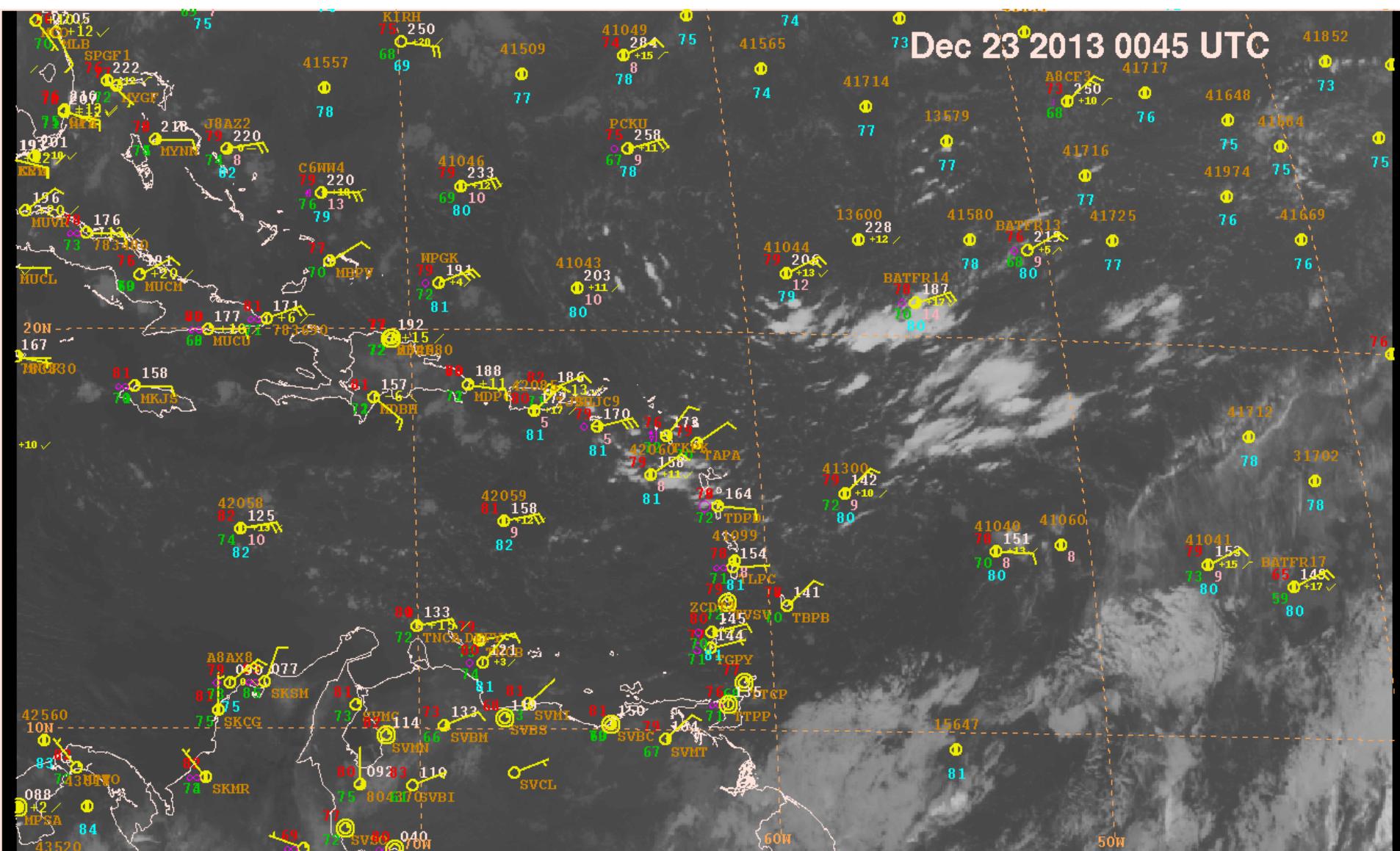
78954 TBPB Grantley Adams



12Z 25 Dec 2013

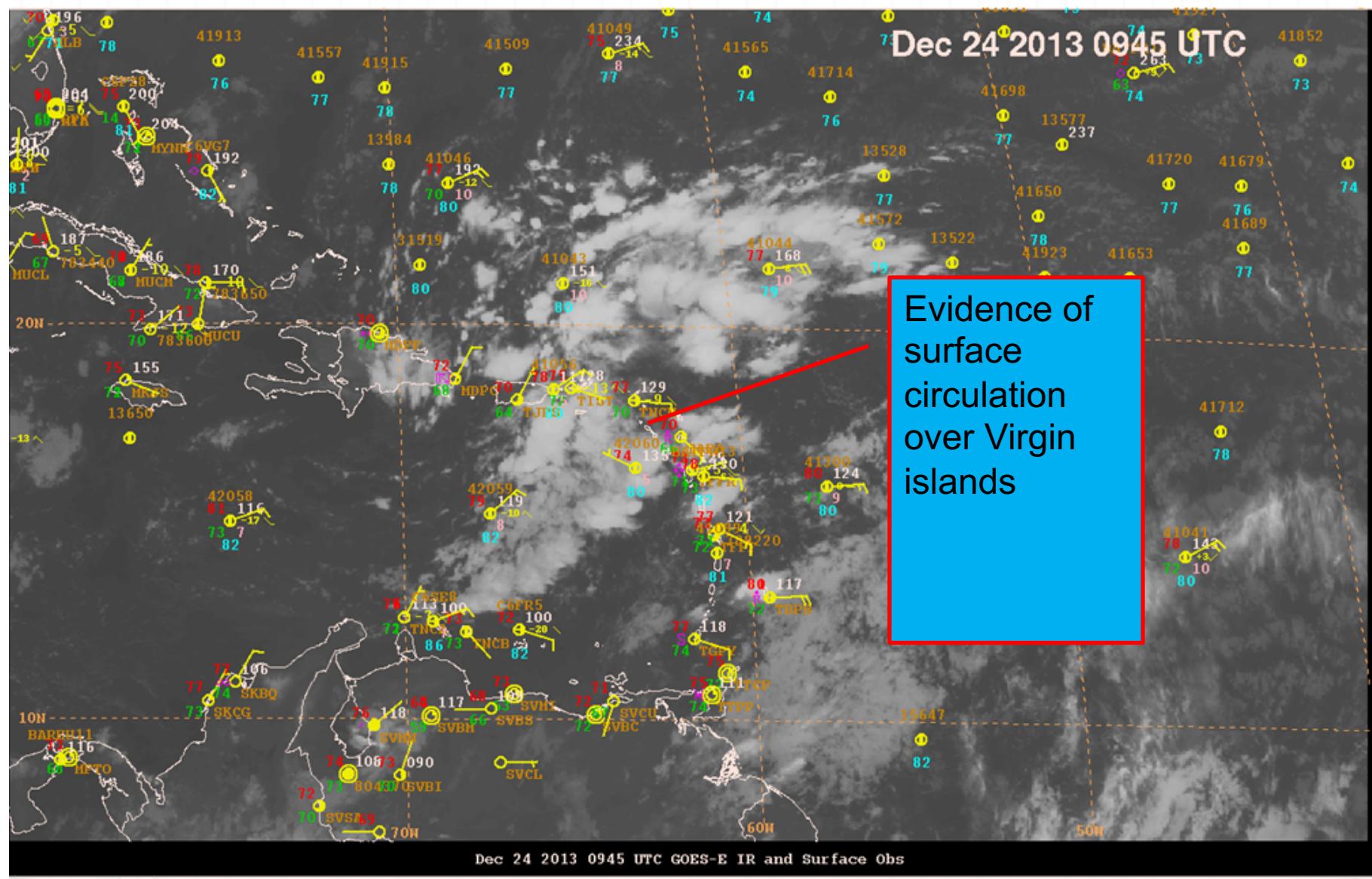
University of Wyoming

Surface Obs and IR4 Animation



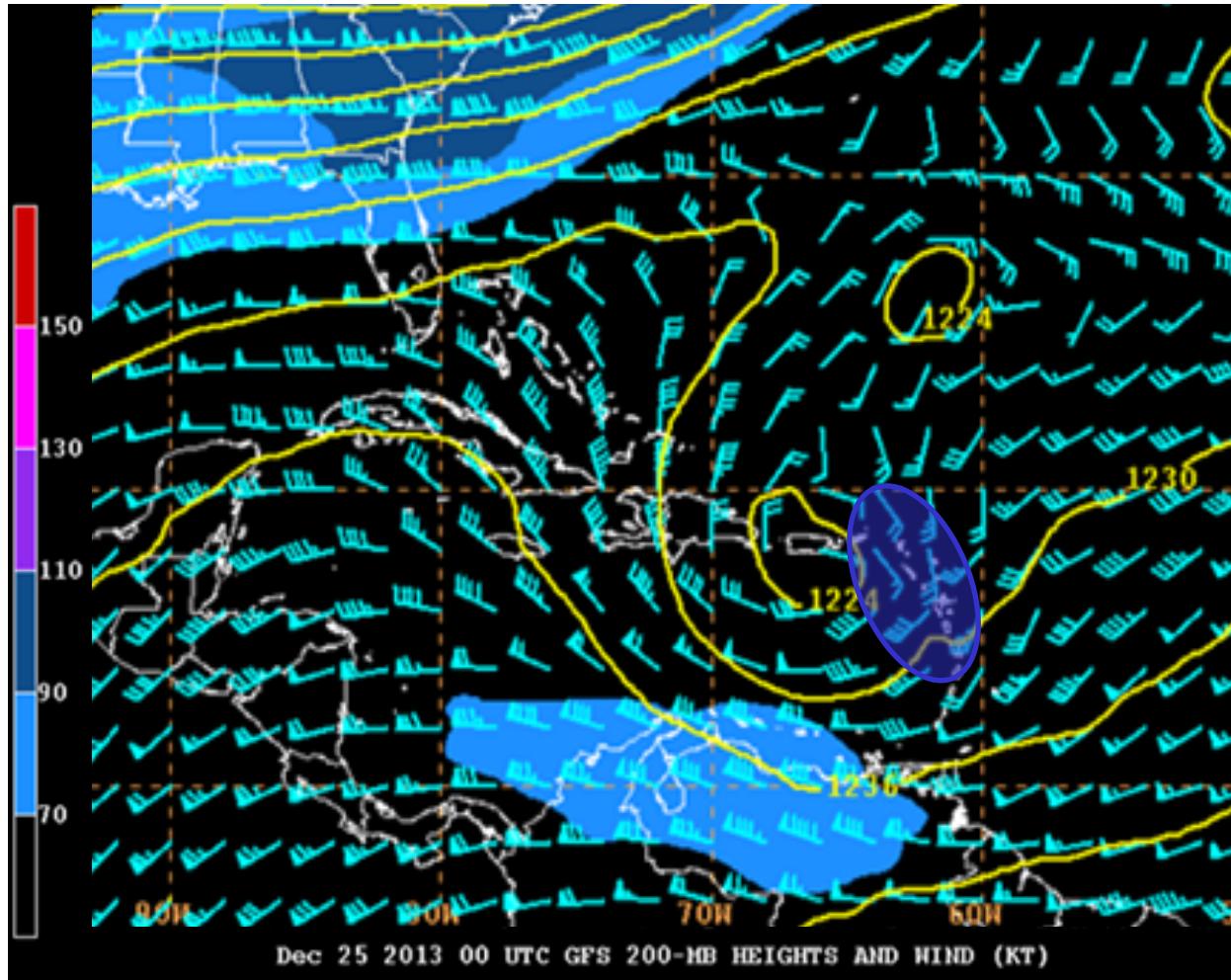
Dec 23 2013 0045 UTC GOES-E IR and Surface Obs

A quick view using GOES-E imagery

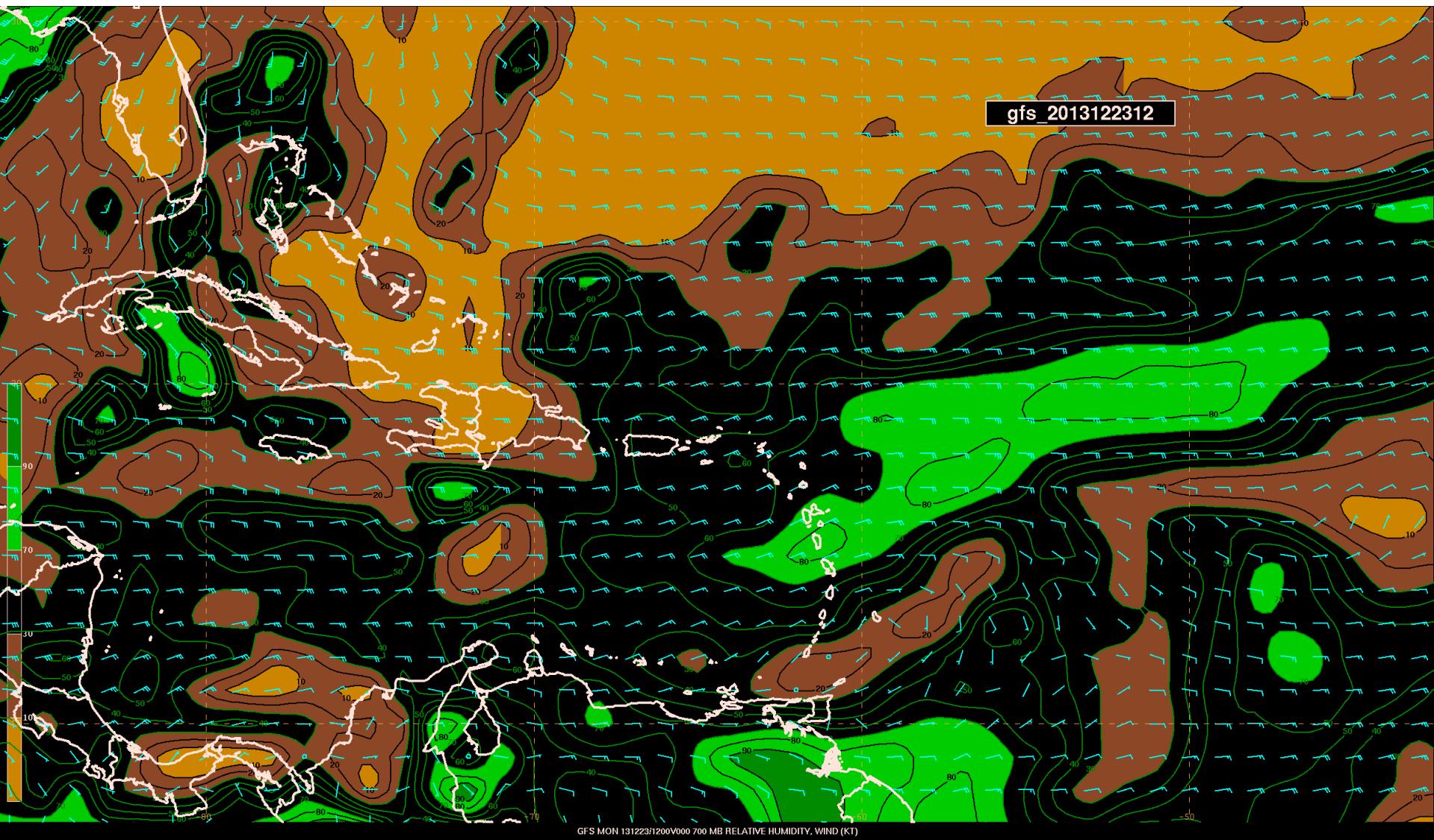


GFS 250 hPa Winds

VT: 20131225/00UTC

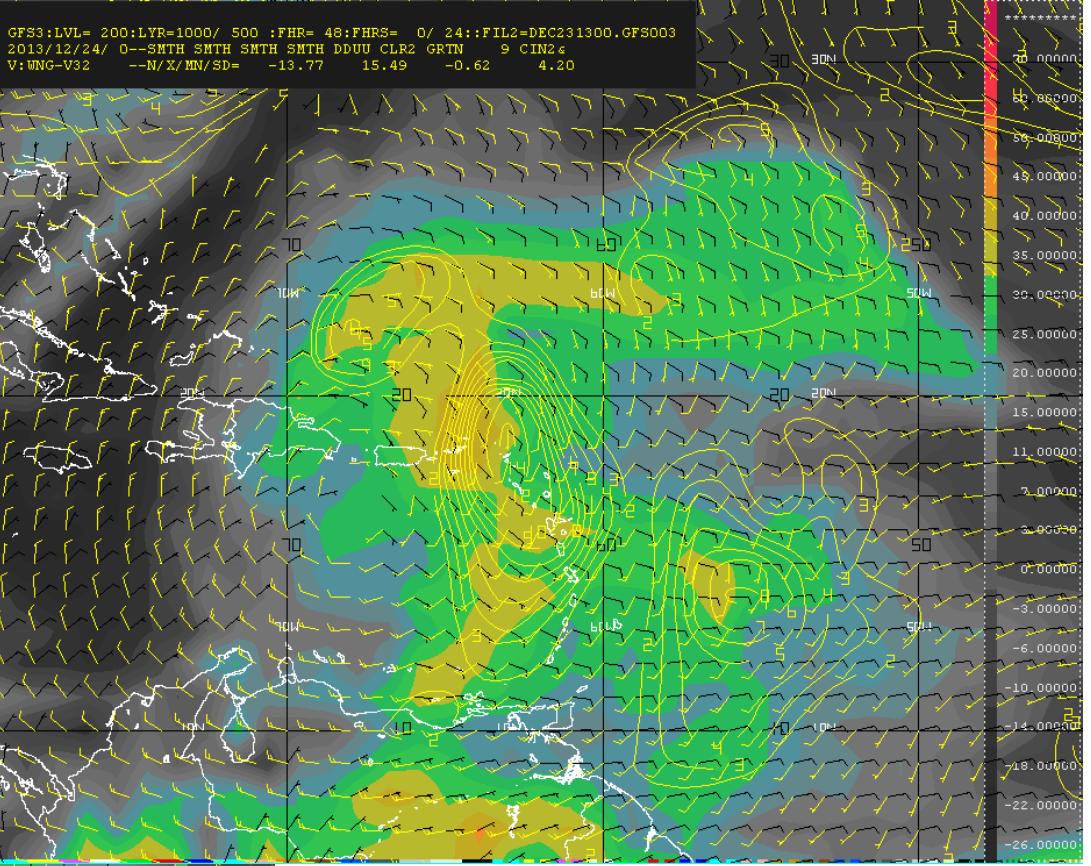
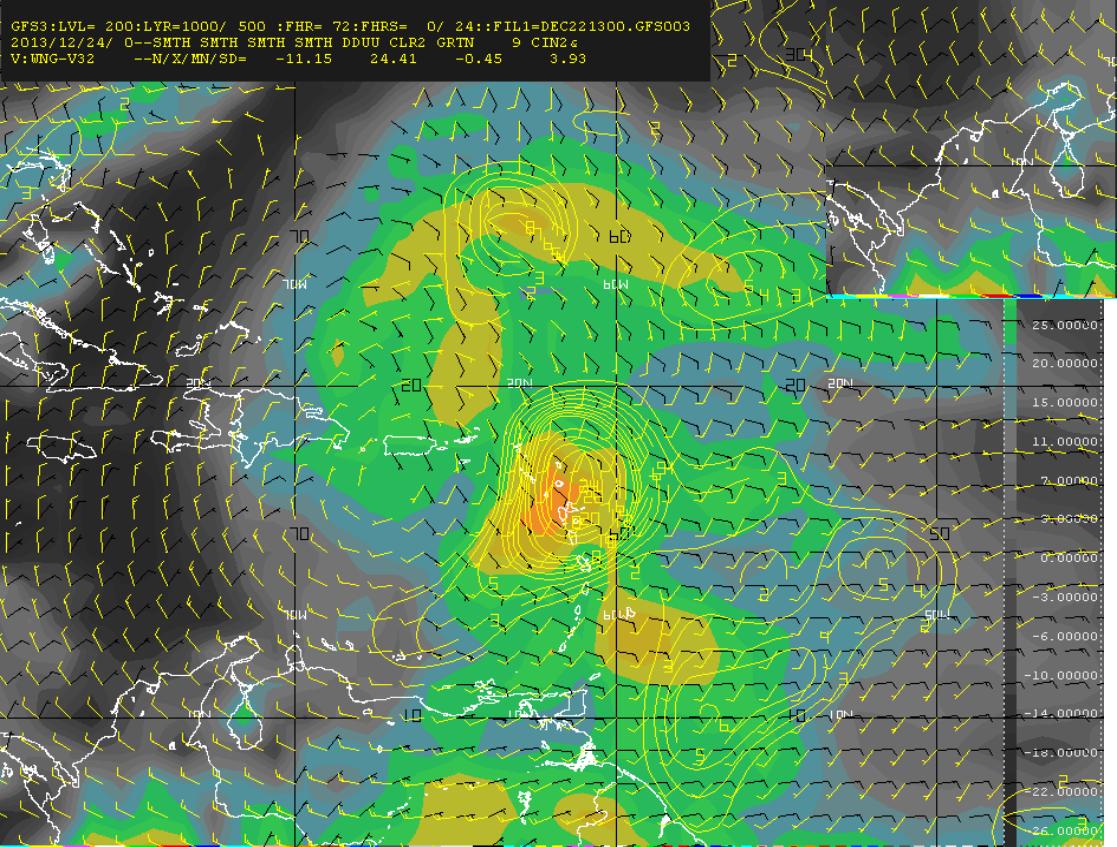


Animation 700 hPa RH and Winds



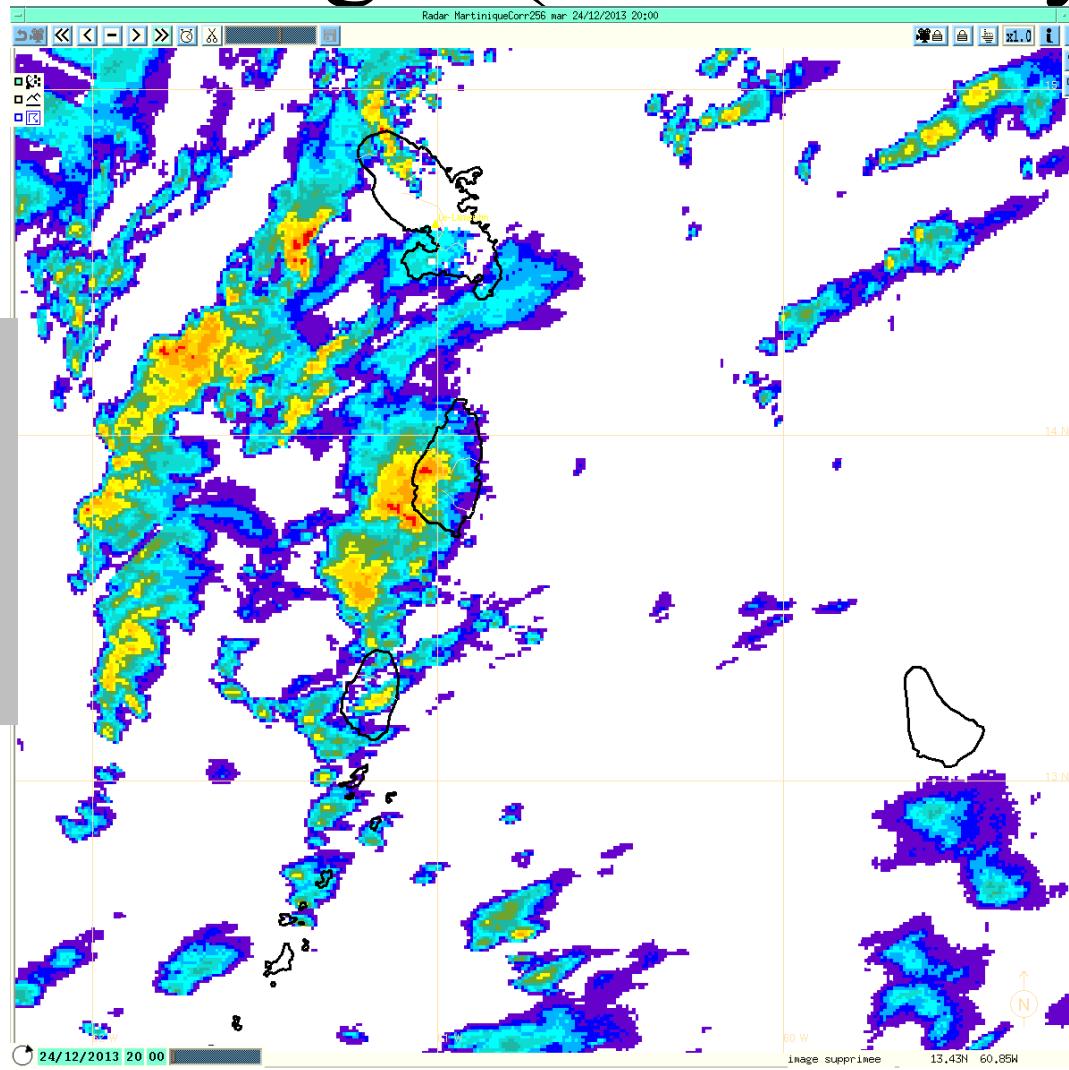
Model data

GFS 850 winds
GFS 250 winds
GDI instability



- GFS model run from 22nd and 23rd

Radar Images (Reflectivity)

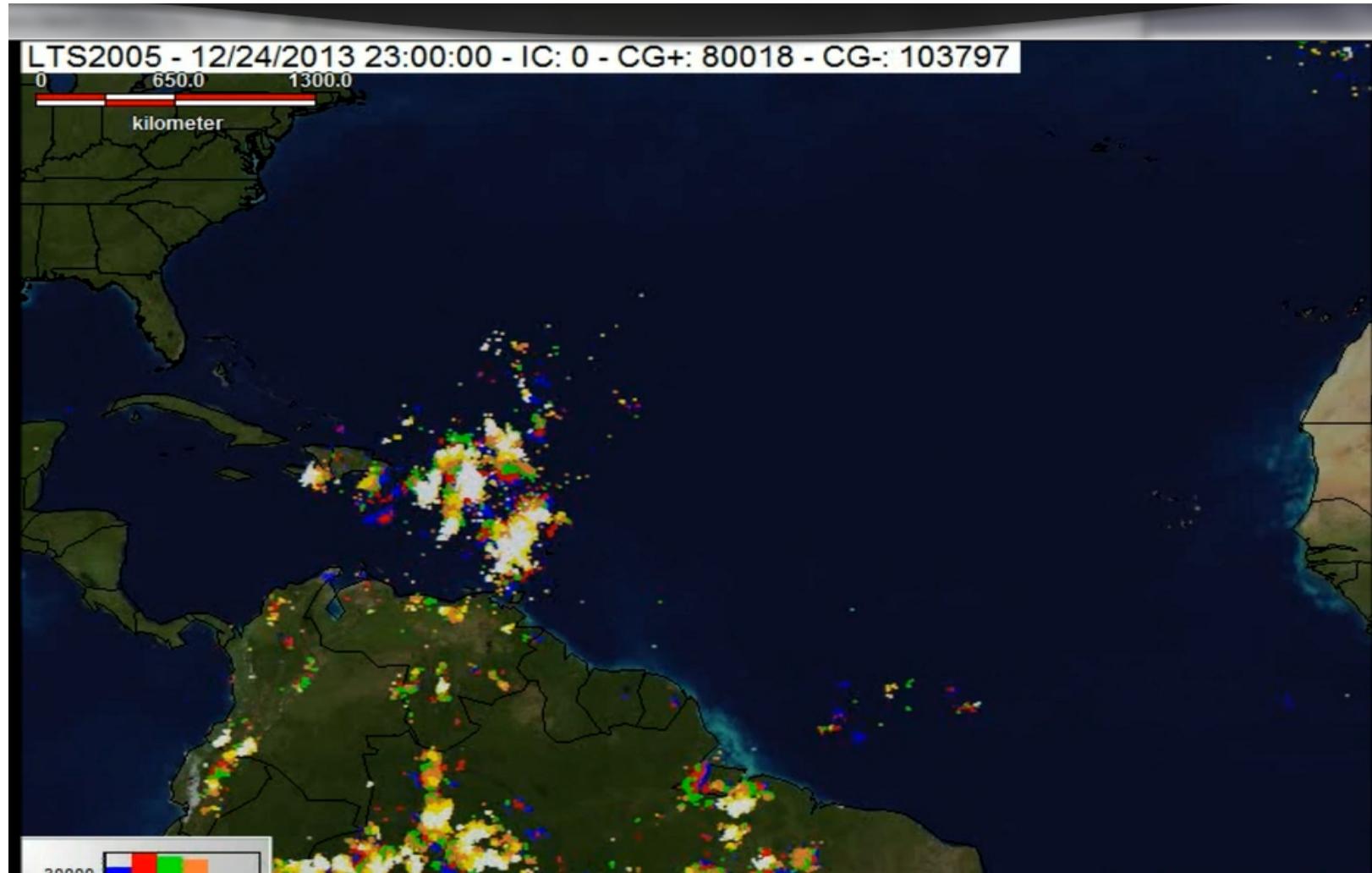


Note the
southwest to
northeast
propagation of
heavier echoes

Radar loop
Courtesy
MeteoFrance

0000 UTC 24-12-2013 to 12 00 UTC on 25-12-2013

Lightning Data



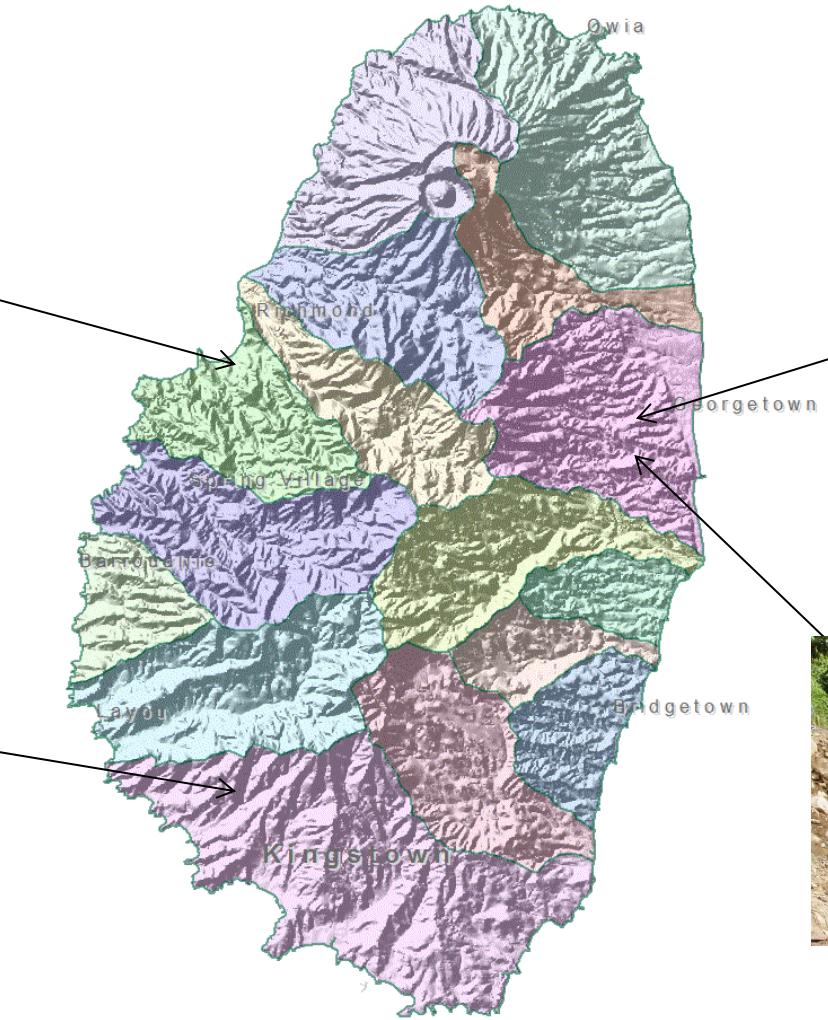
Impact



Chateaubelair



Buccament



Georgetown



Congo Valley

World Bank Report

Summary

Tropical Wave or TUTT-Induced Wave?

- How do we identify a TUTT-induced wave?
 - It develops in situ.
 - If it moves, follows upper air perturbations.
 - Important to see evolution (use previous analyses).
 - Tends to dissipate/weakens if TUTT dissipates.
- How to recognize a tropical wave?
 - It has African origins,
 - TPW Analysis
 - See Hovmöller diagram.
http://www.nhc.noaa.gov/analysis_tools.shtml
 - Propagates independently from upper level systems.

TUTT-Tropical Wave interactions

Can a tropical wave interact/merge with a TUTT induced wave?

- **YES:** But induced circulation at low-levels may end up “masking” tropical wave and end up appearing as an induced wave.
 - Something like this tends to occur across the southern Caribbean due to influence of the Panamanian low.
- **MAYBE:** As tropical wave approaches upper trough, it may encounter vertical wind shear. In some instances the tropical waves loses organization while induced trough persists.
- **NO:** A potent/well organized tropical wave can retain its integrity as it approaches upper trough. This will depend on intensity and depth of upper trough.
 - The deeper the upper trough, the lower the chances the tropical wave survives.

Questions?

Test

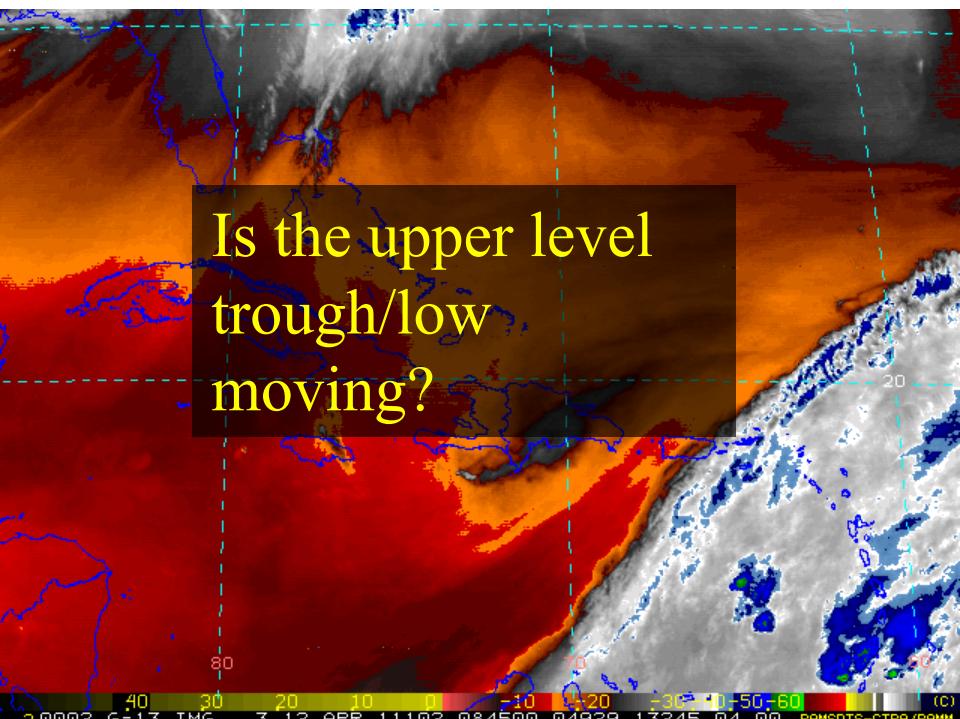
Questions

- Is a **cold core tropospheric** trough, with axis from surface to mid/upper levels of the atmosphere, considered a TUTT?
- Can we use the 6.2 micron water vapor images to identify low level circulations?
- Are tropical waves and induced troughs in the low level easterlies the same thing?
- What's the primary role of the TUTT over the Caribbean Basin?
- Why do we typically see high equivalent potential temperature values in association with tropical waves and induced troughs in the low level easterlies?

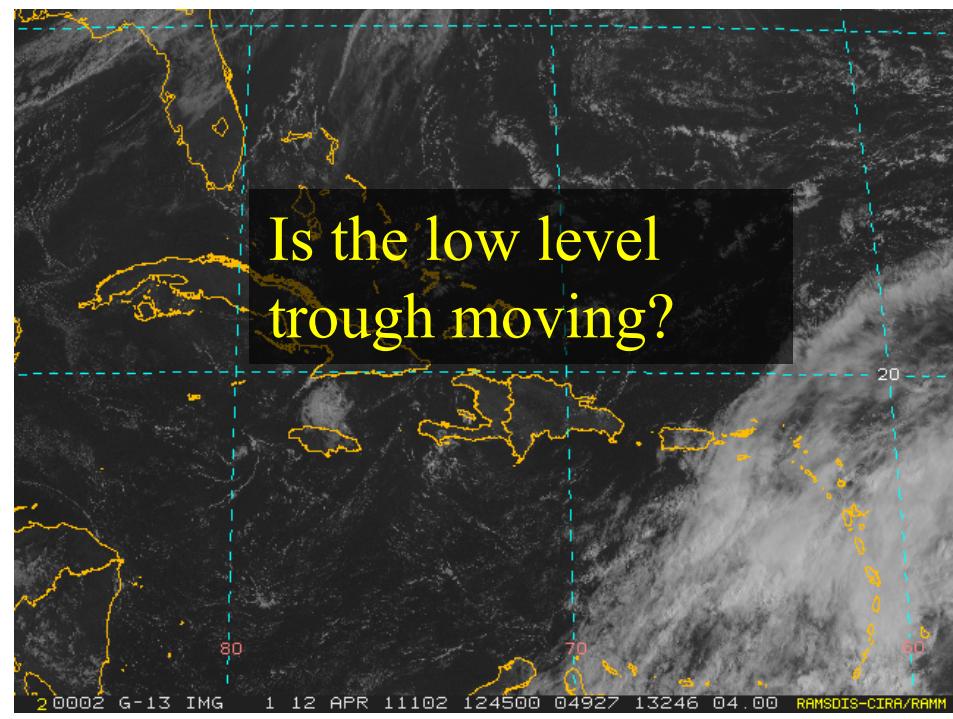
Questions

- When the interaction between a tropical wave and a TUTT is considered positive/negative?
- How can we apply the three GOES-16 water vapor images to distinguish between a Tropical Wave and an induced trough?

WV and Visible Images.
Is the perturbation in the low level easterlies a
tropical wave or a TUTT induced perturbation?



GOES-12 (WV)



GOES-12 (Vis)

Part 2 – Poll Question #5

(Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

Positive or Negatively Tilted Wave?



Part 2 – Poll Question #6

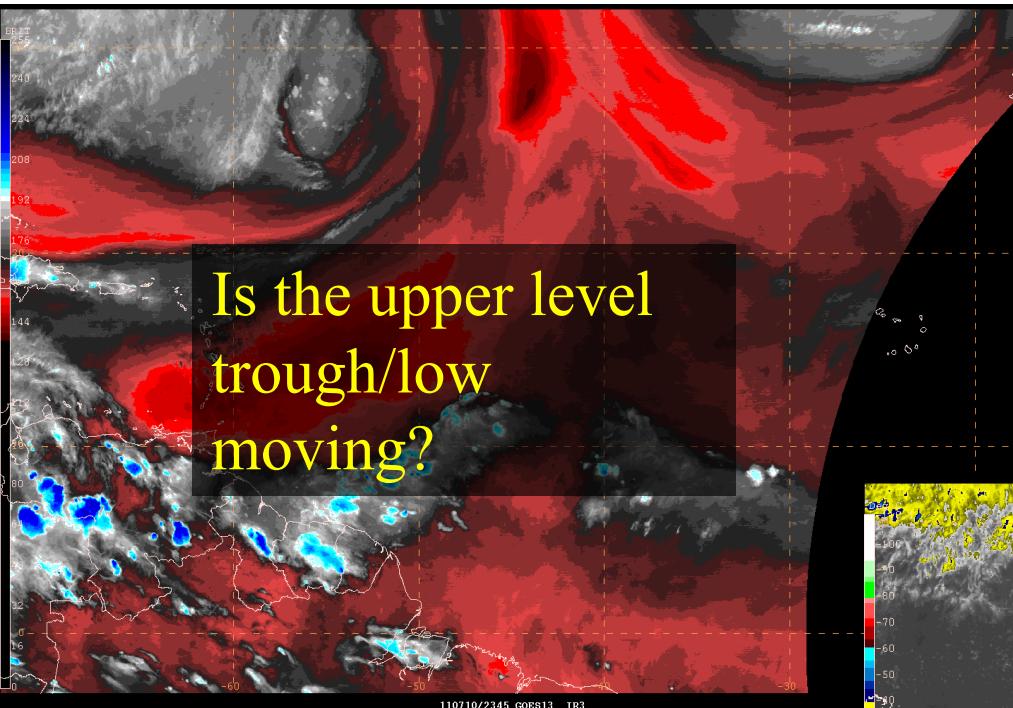
2020-06-15 12:50:18 UTC

Part 2 – Poll Question #6

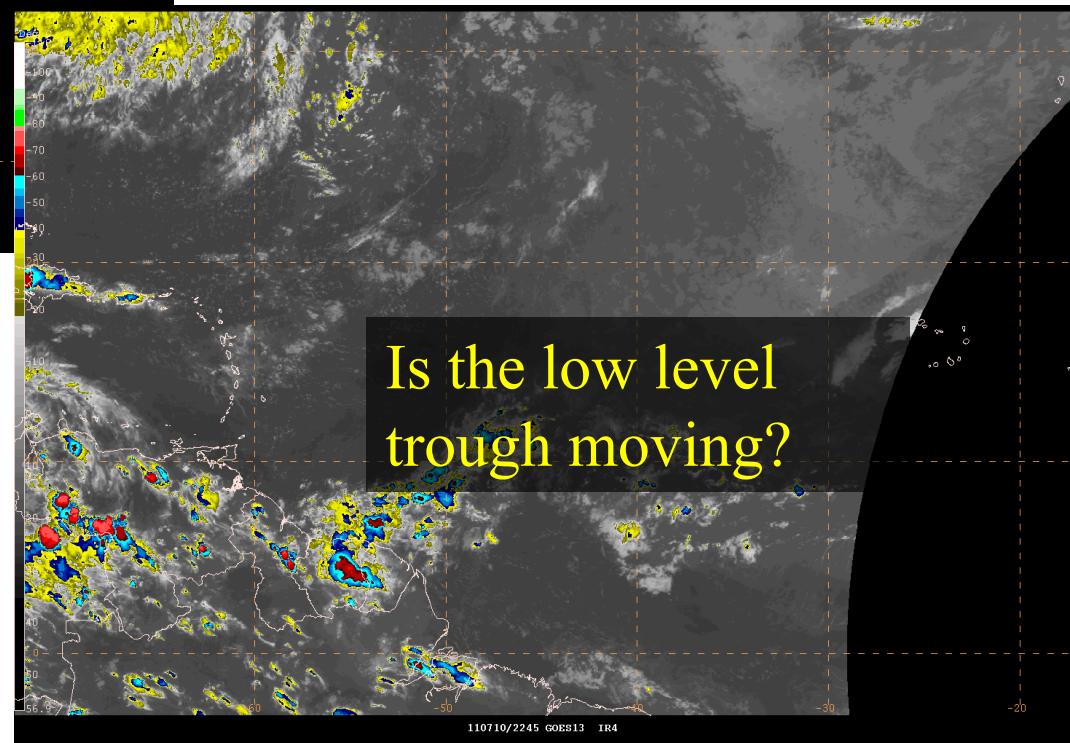
(Select all that apply)

- This is a negatively tilted wave
- Convection precedes (west) the wave
- This is a positively tilted wave
- Convection follows (east) the wave
- None of the above

Perturbation in the Atlantic is a TUTT-induced trough or a tropical wave?



GOES-12 (WV)



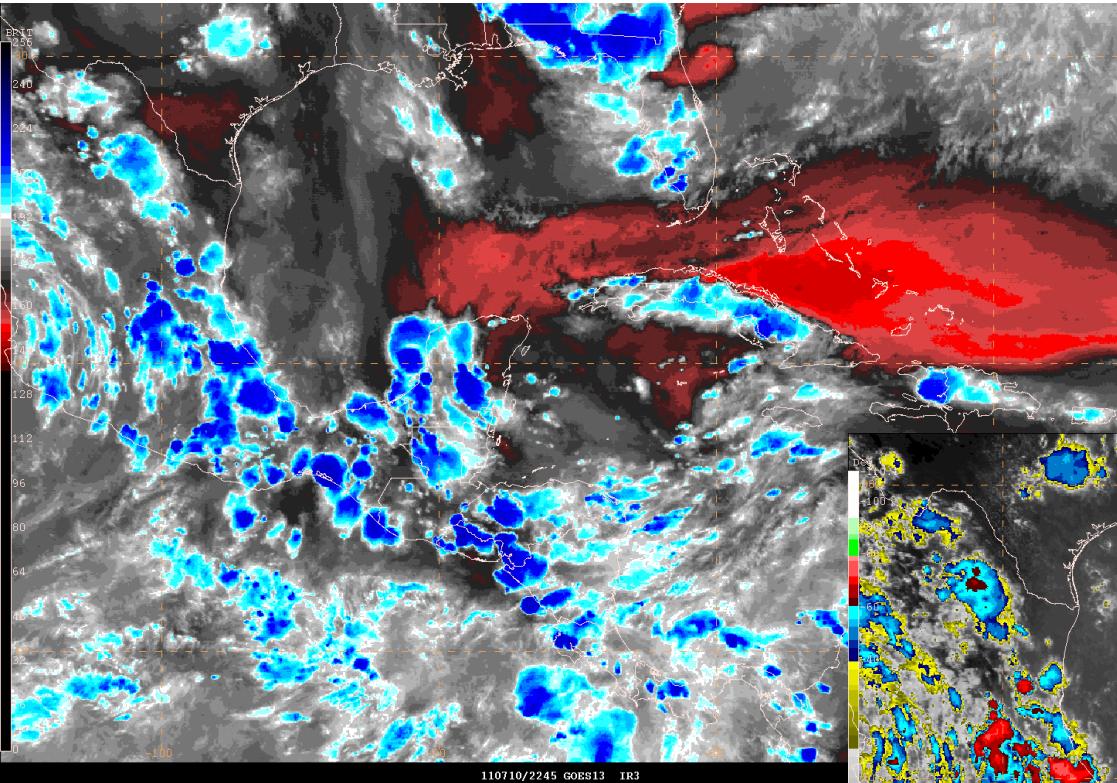
Part 2 – Poll Question #7

Part 2 – Poll Question #7

(Select one)

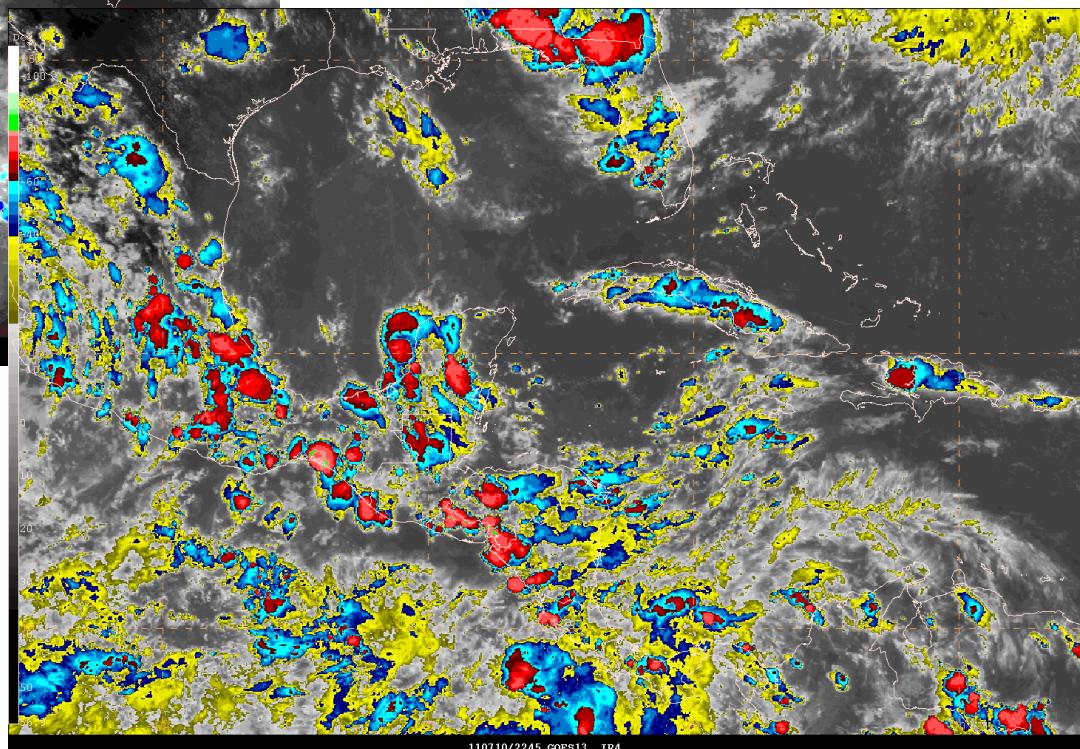
- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

The perturbation in the Caribbean is a TUTT-induced wave or a Tropical Wave?



GOES-12 (IR)

GOES-12 (WV)



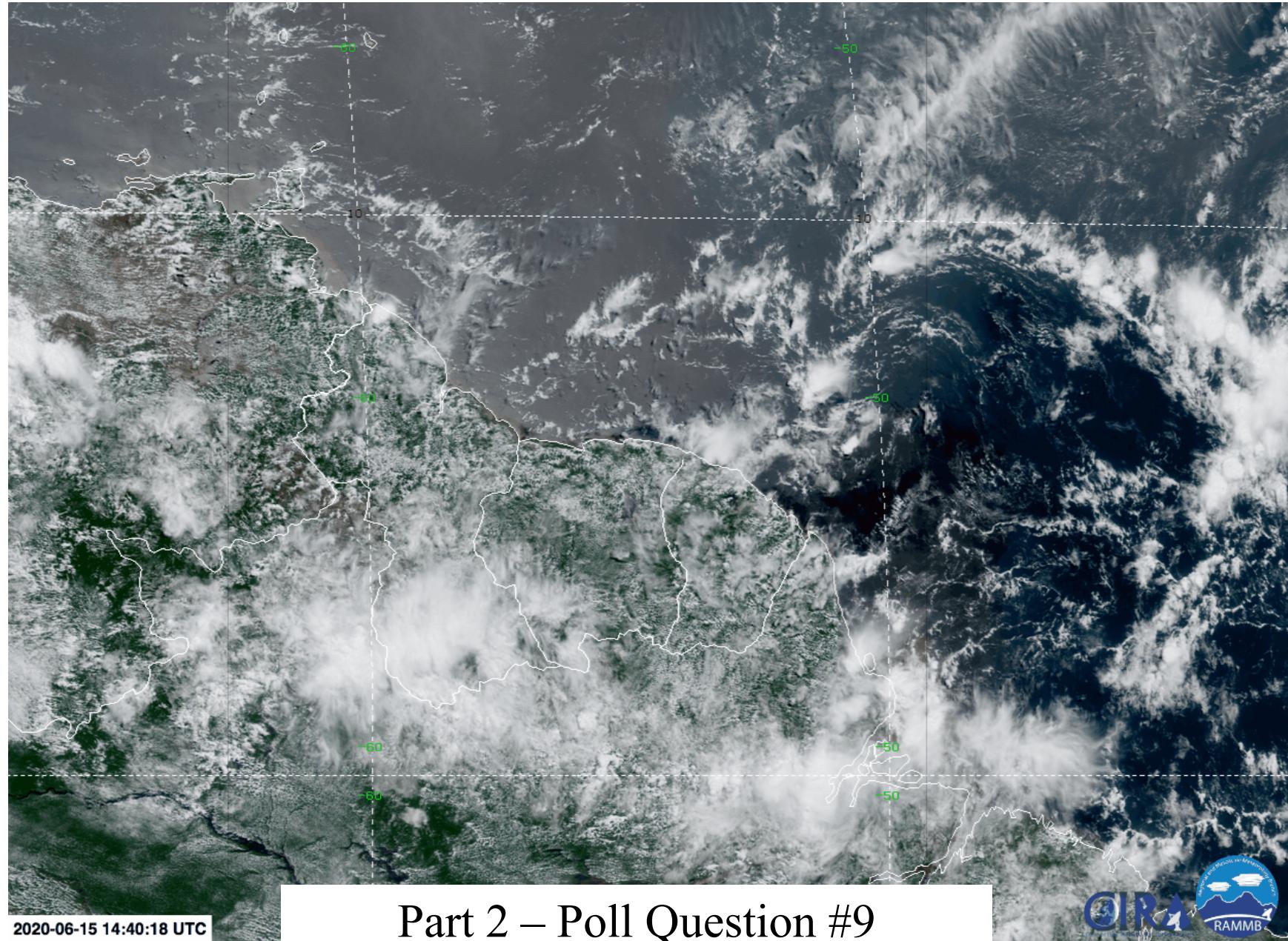
Part 2 – Poll Question #8

Part 2 – Poll Question #8

(Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

Positive or Negatively Tilted Wave?

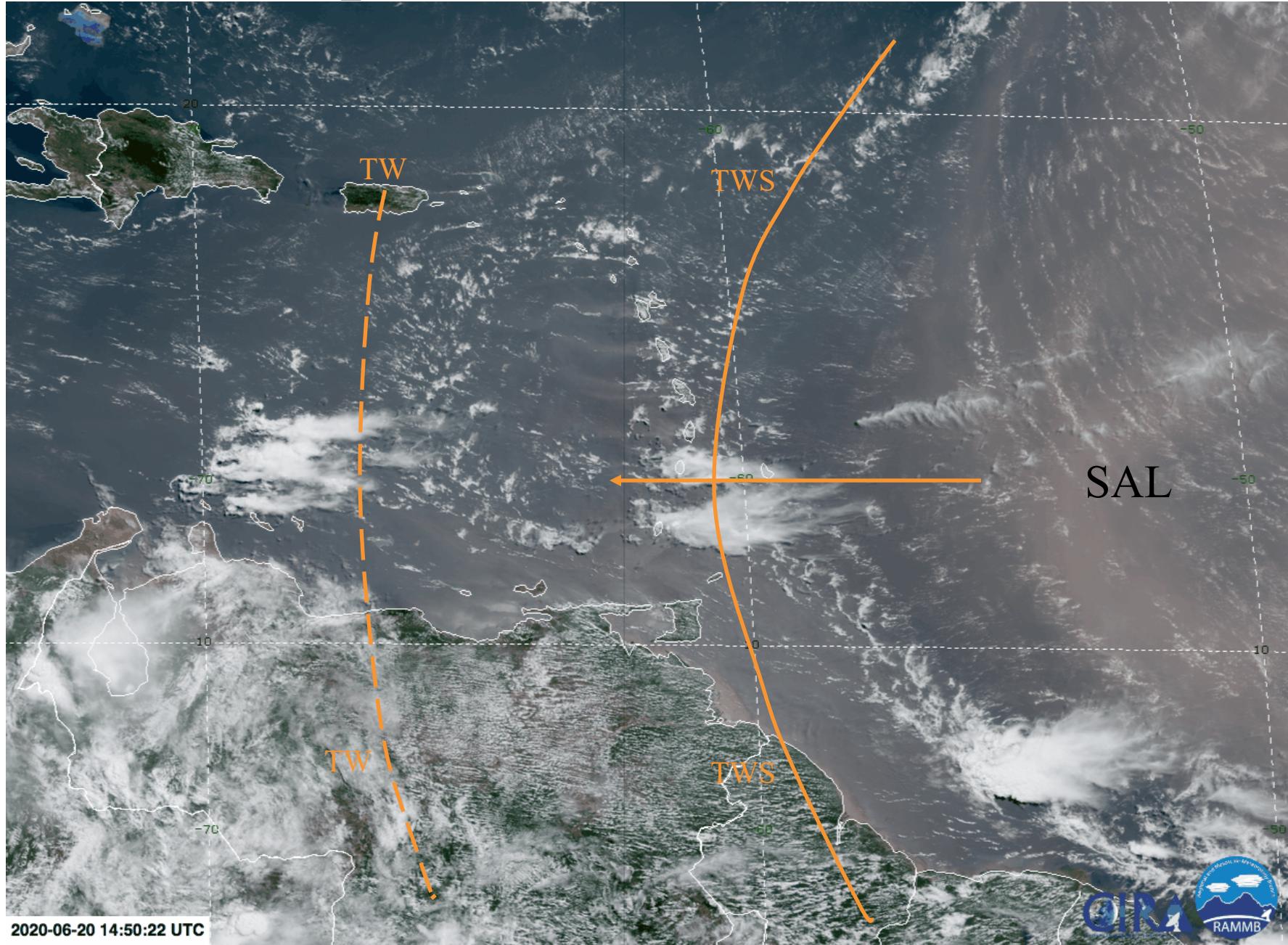


Part 2 – Poll Question #9

(Select all that apply)

- This is a negatively tilted wave
- Convection precedes (west) the wave
- This is a positively tilted wave
- Convection follows (east) the wave
- None of the above

Tropical Wave or TWS?



2020-06-20 14:50:22 UTC

References

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- Graphics generated using the Wingridds/PcGridds software to display the GFS/AVN global model.
- Satellite images provided by NOAA/NESDIS under permission.