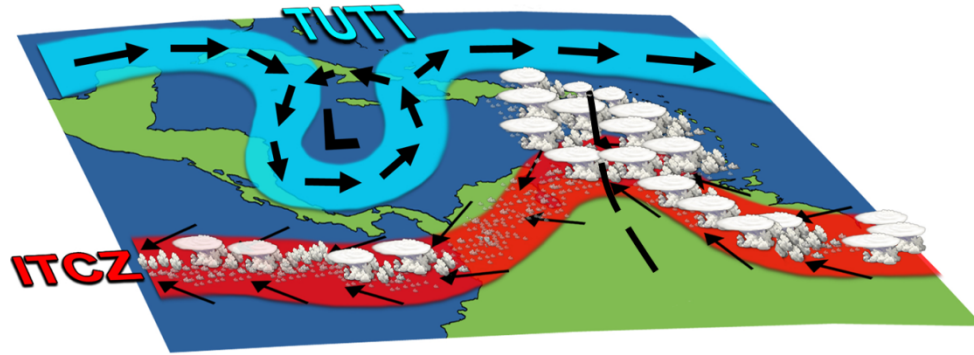


Atlantic/Caribbean Basin Tropical Waves and TUTT Induced Inverted Troughs



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).
<p><u>Movement</u>: Controlled by upper flow.</p>	<p><u>Movement</u>: Controlled by the lower troposphere.</p>
<p><u>Origin</u>: Induced by a trough generally to its northwest</p>	<p><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</p>

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 <u>in-tandem</u> 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 <u>independent</u> 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

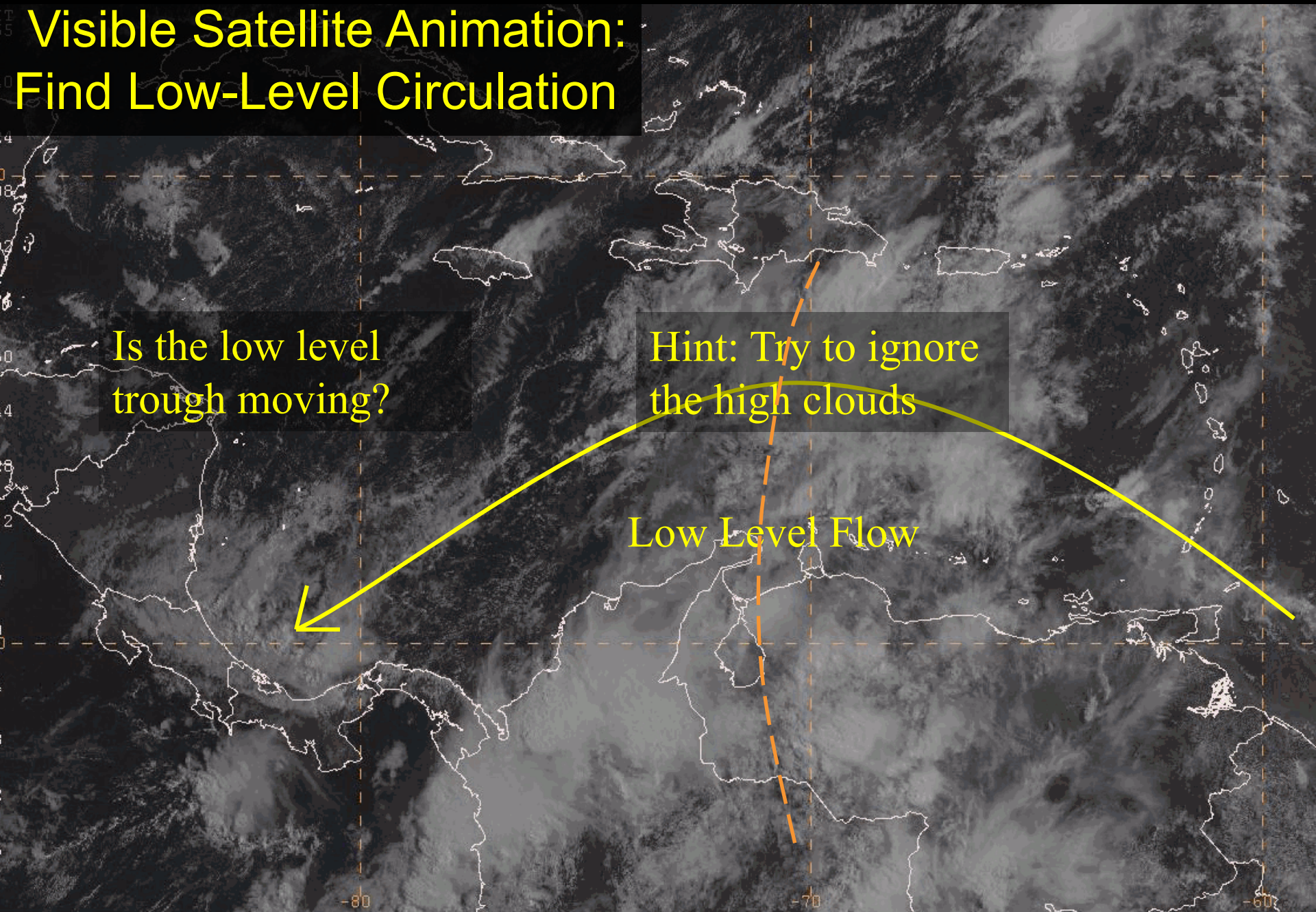
20 April 2004

Visible Satellite Animation: Find Low-Level Circulation

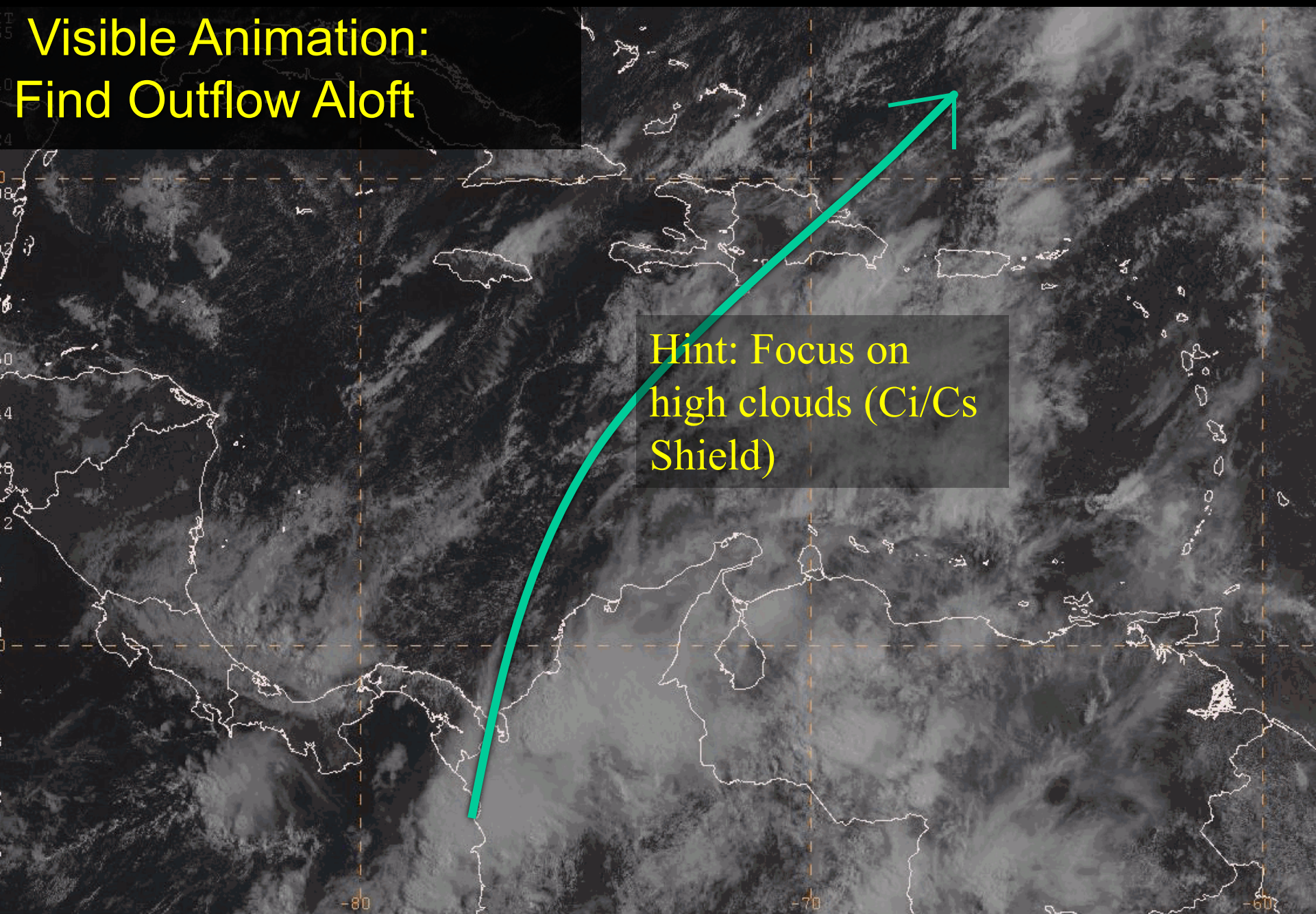
Is the low level
trough moving?

Hint: Try to ignore
the high clouds

Low Level Flow



Visible Animation: Find Outflow Aloft

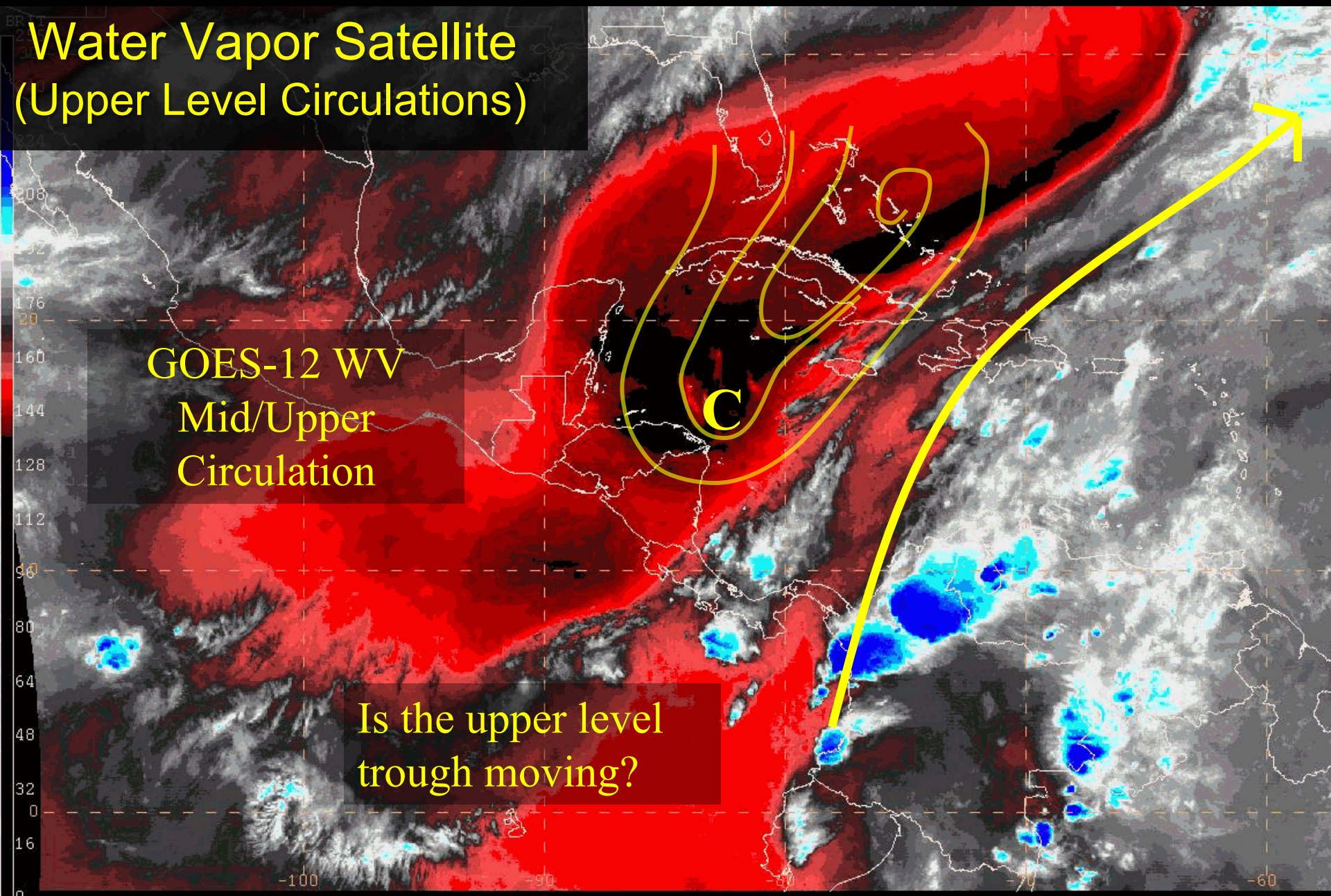


Water Vapor Satellite (Upper Level Circulations)

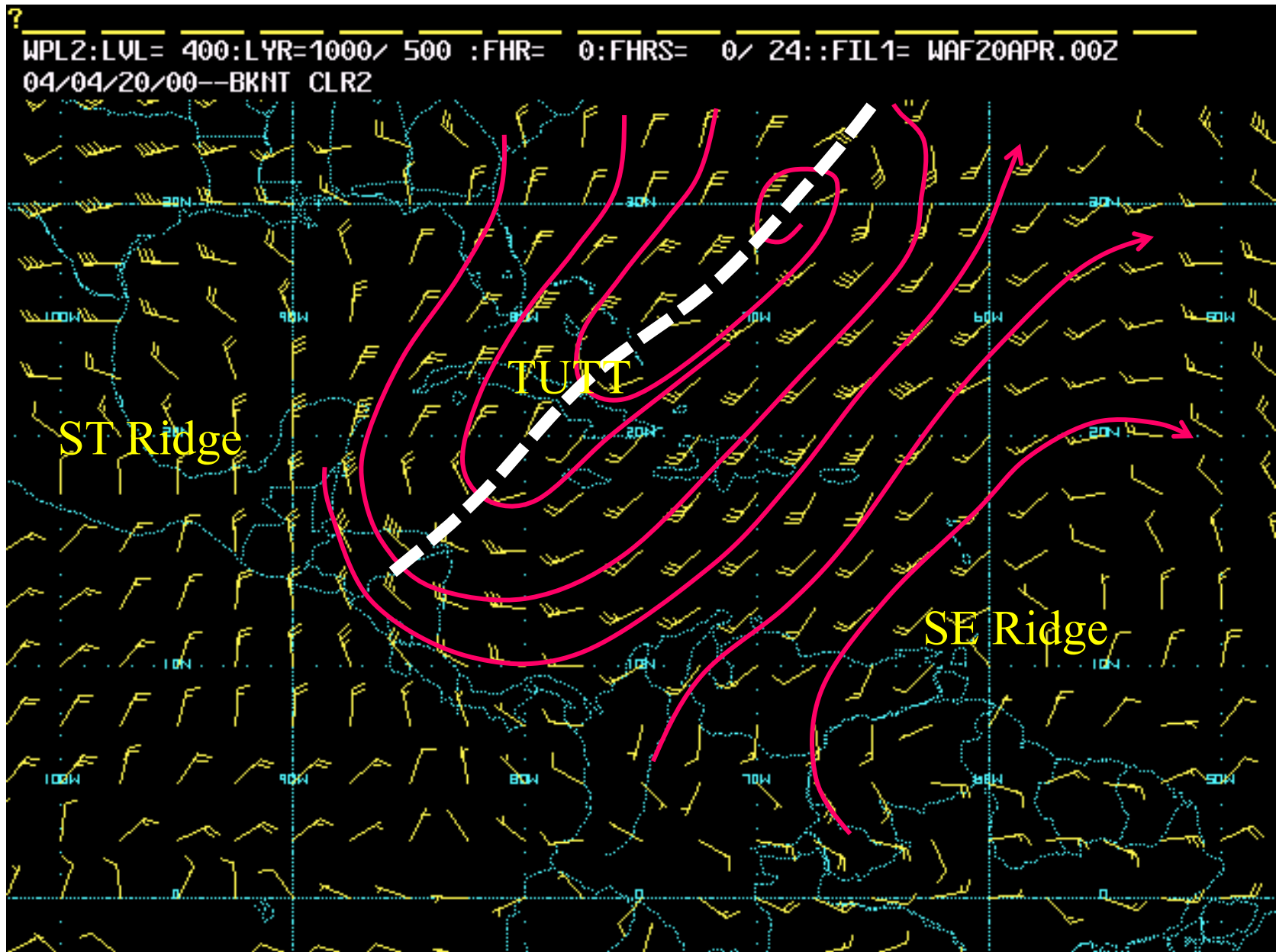
GOES-12 WV
Mid/Upper
Circulation

Is the upper level
trough moving?

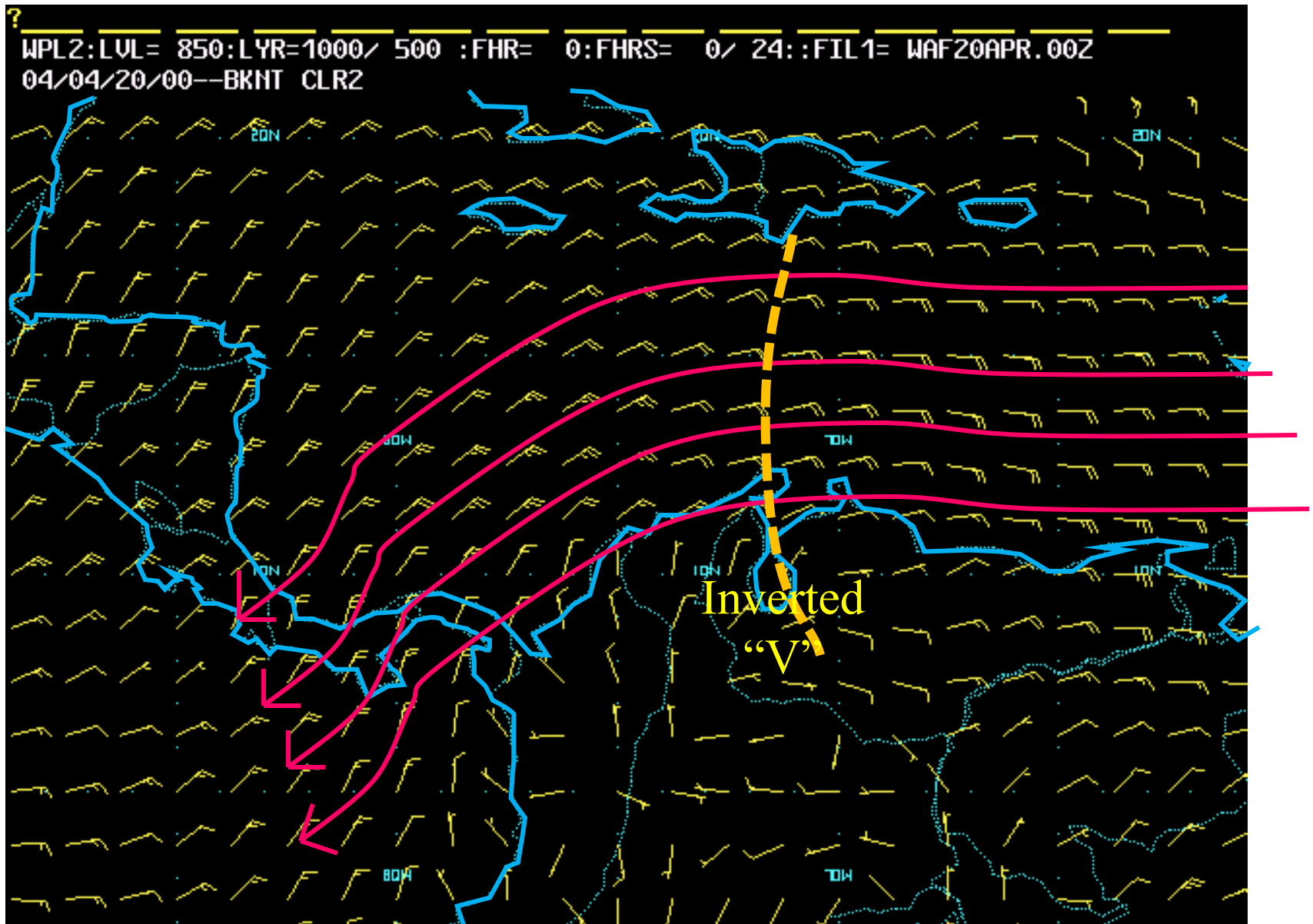
040420/1045 GOES12 IR3



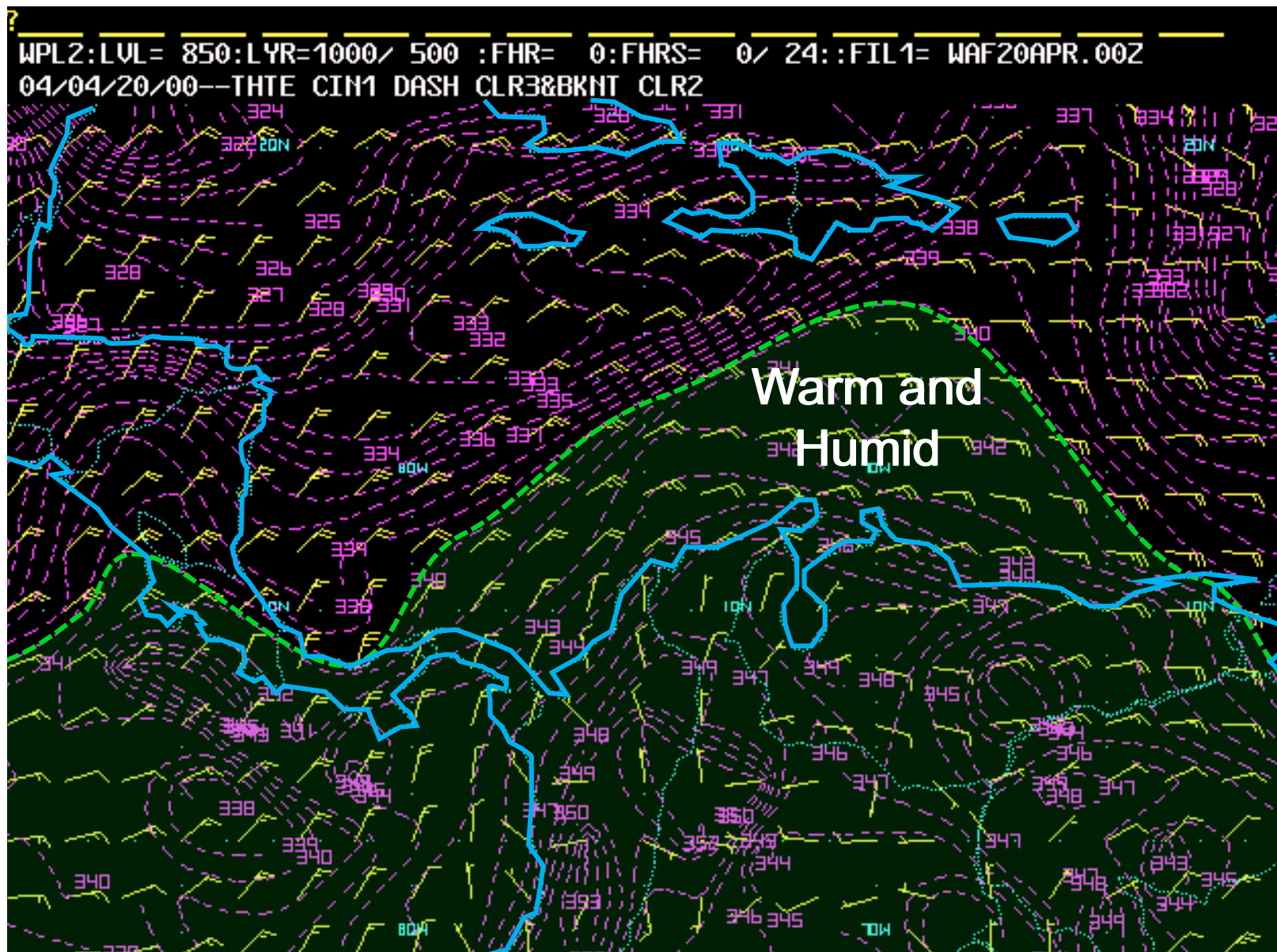
GFS Analysis of Upper (400hPa) Circulation



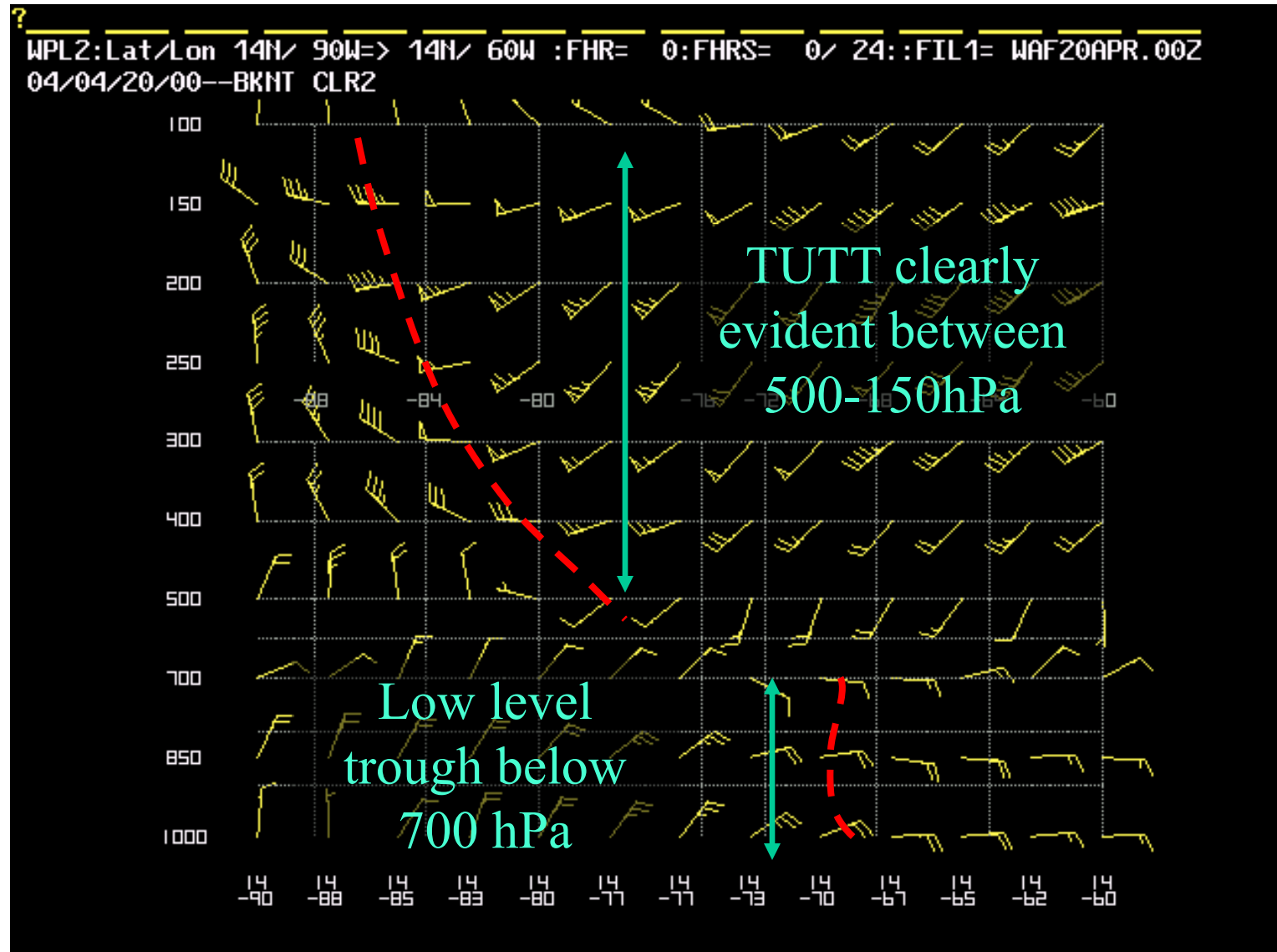
Low-Level Circulations (850 hPa)



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

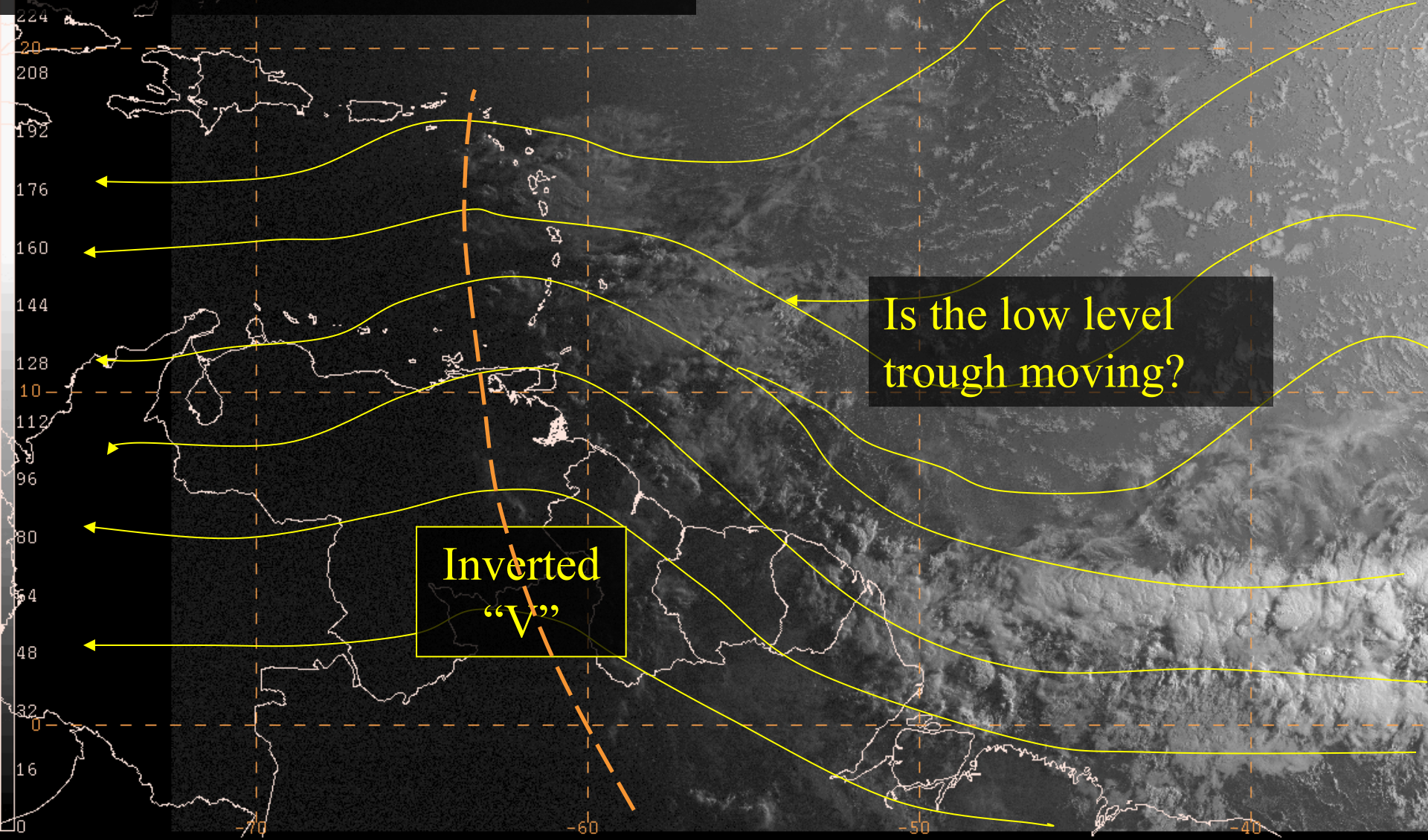
Observations

- **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

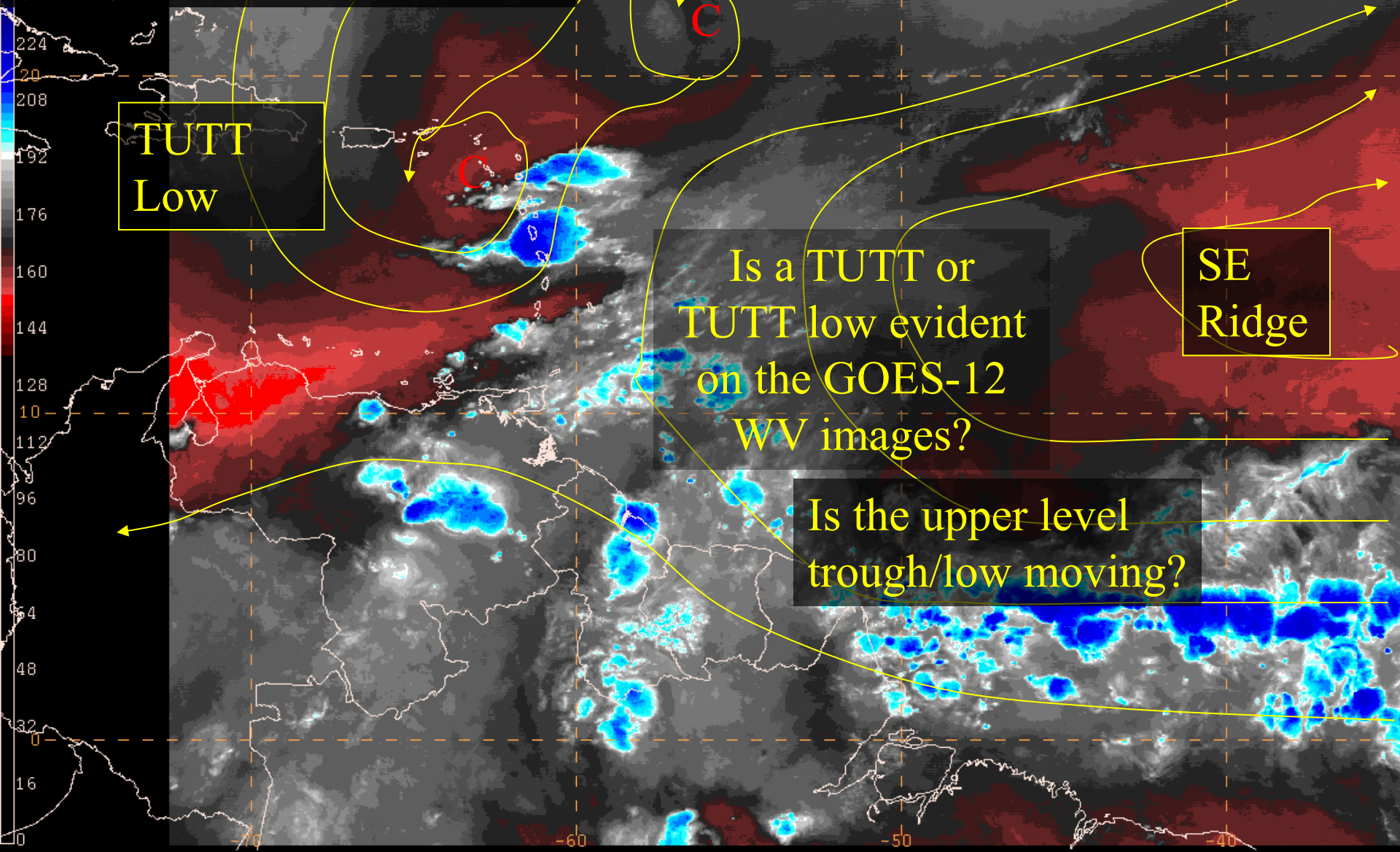
Visible Satellite Animation: Find Low-Level Circulation



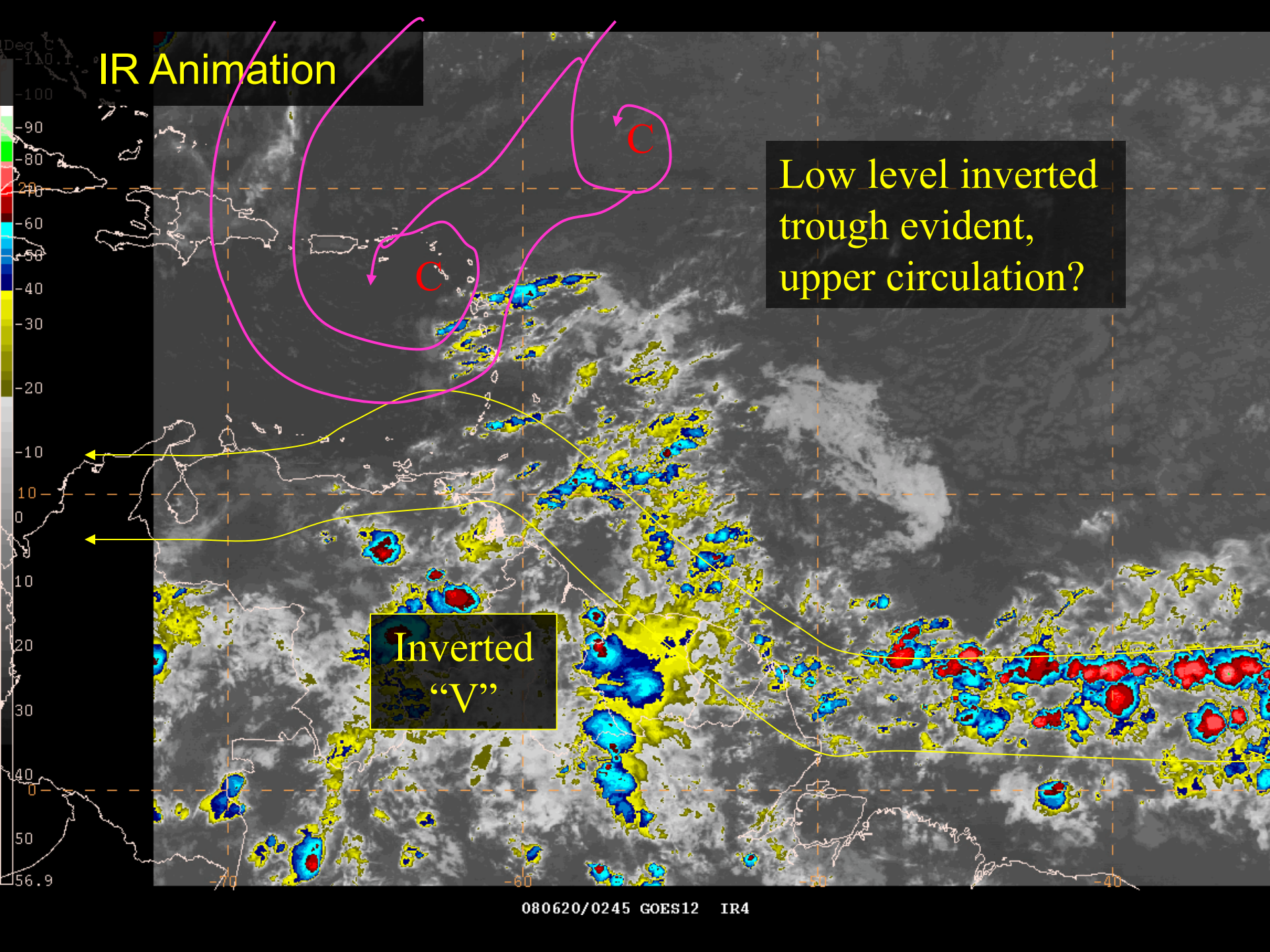
Is the low level
trough moving?

Inverted
"V"

Water Vapor Image Animation (Upper Circulations)



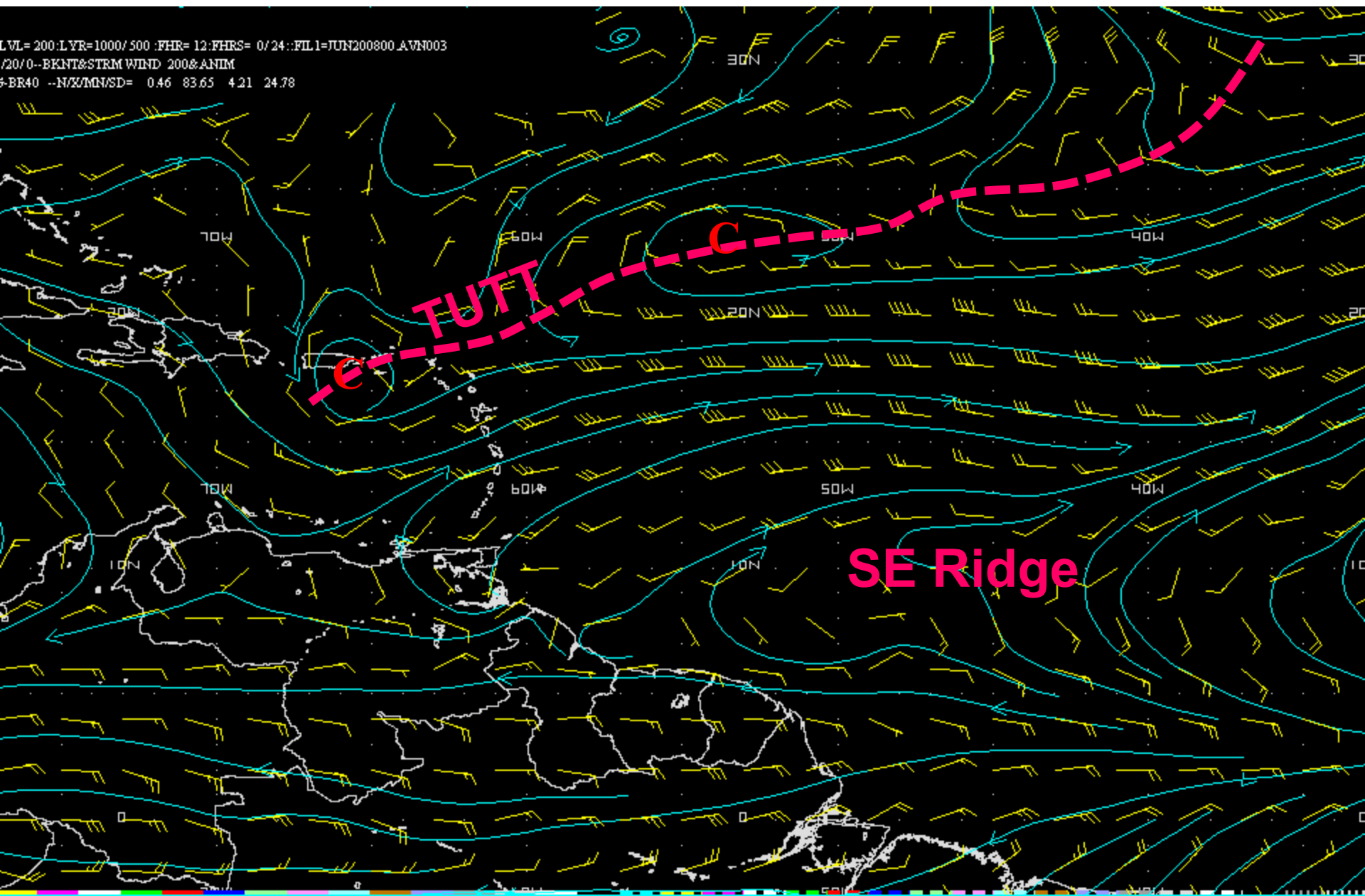
IR Animation



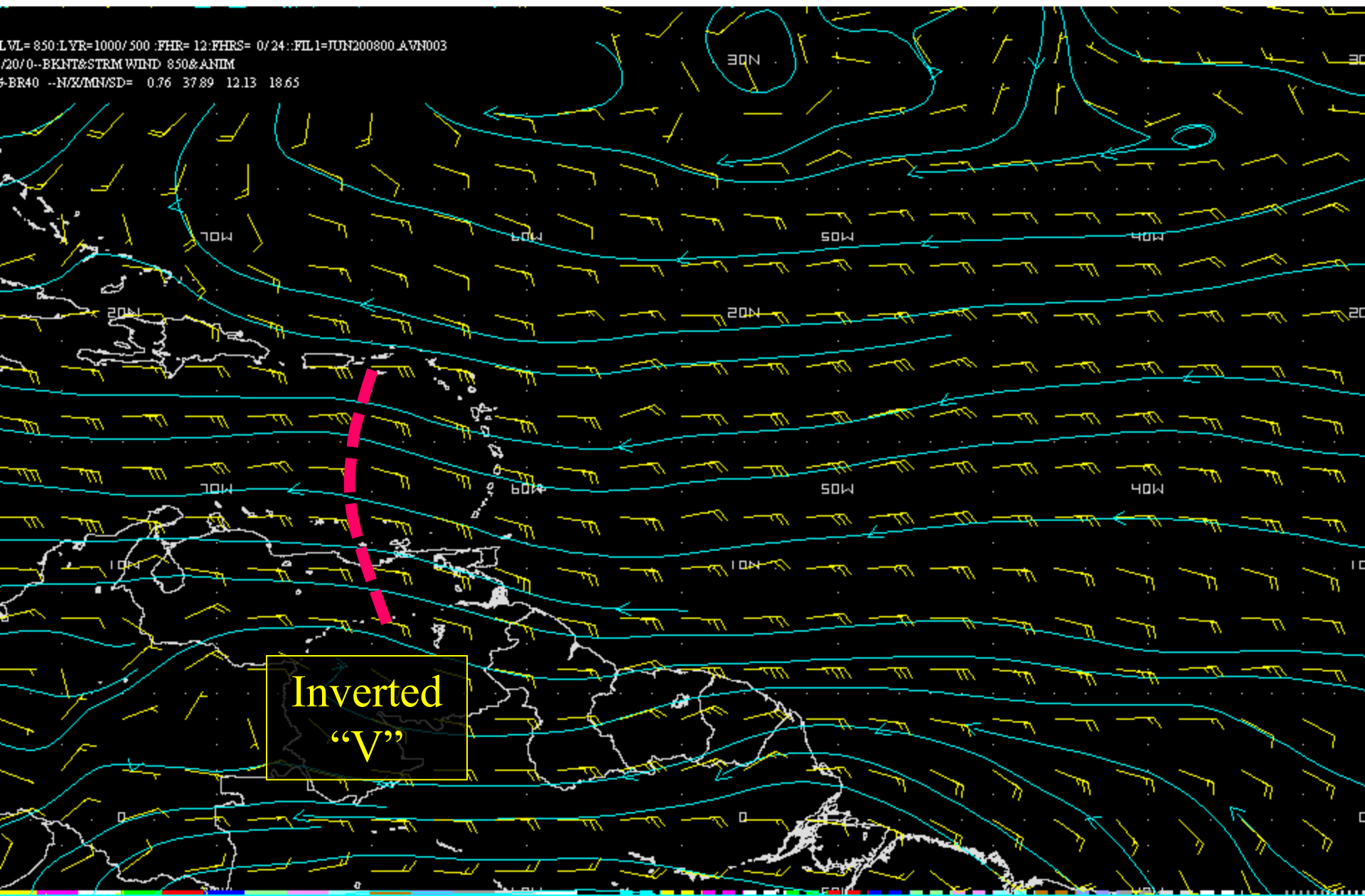
Low level inverted
trough evident,
upper circulation?

Inverted
"V"

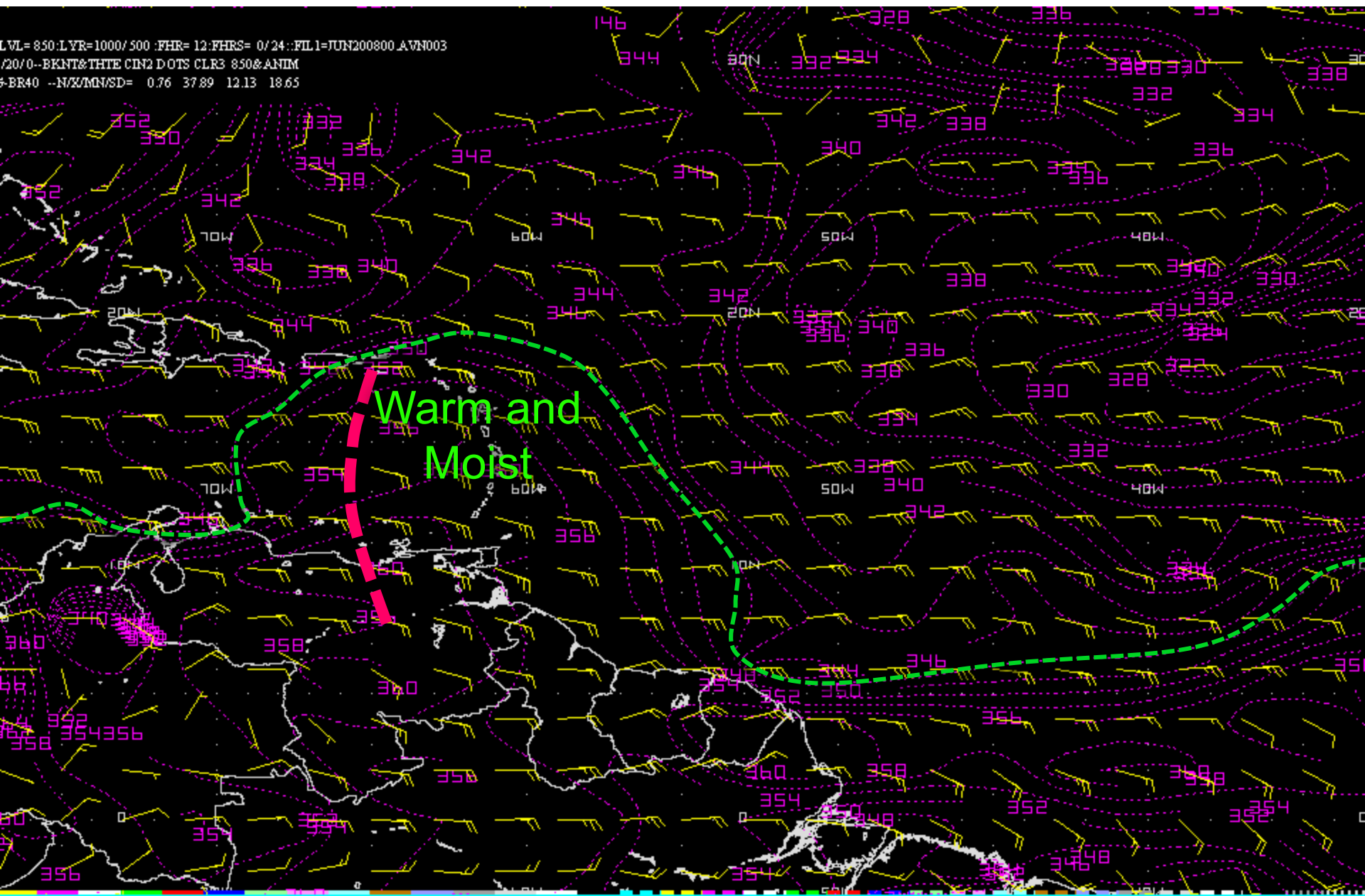
GFS analysis: 200 hPa winds



GFS Analysis: 850 hPa winds



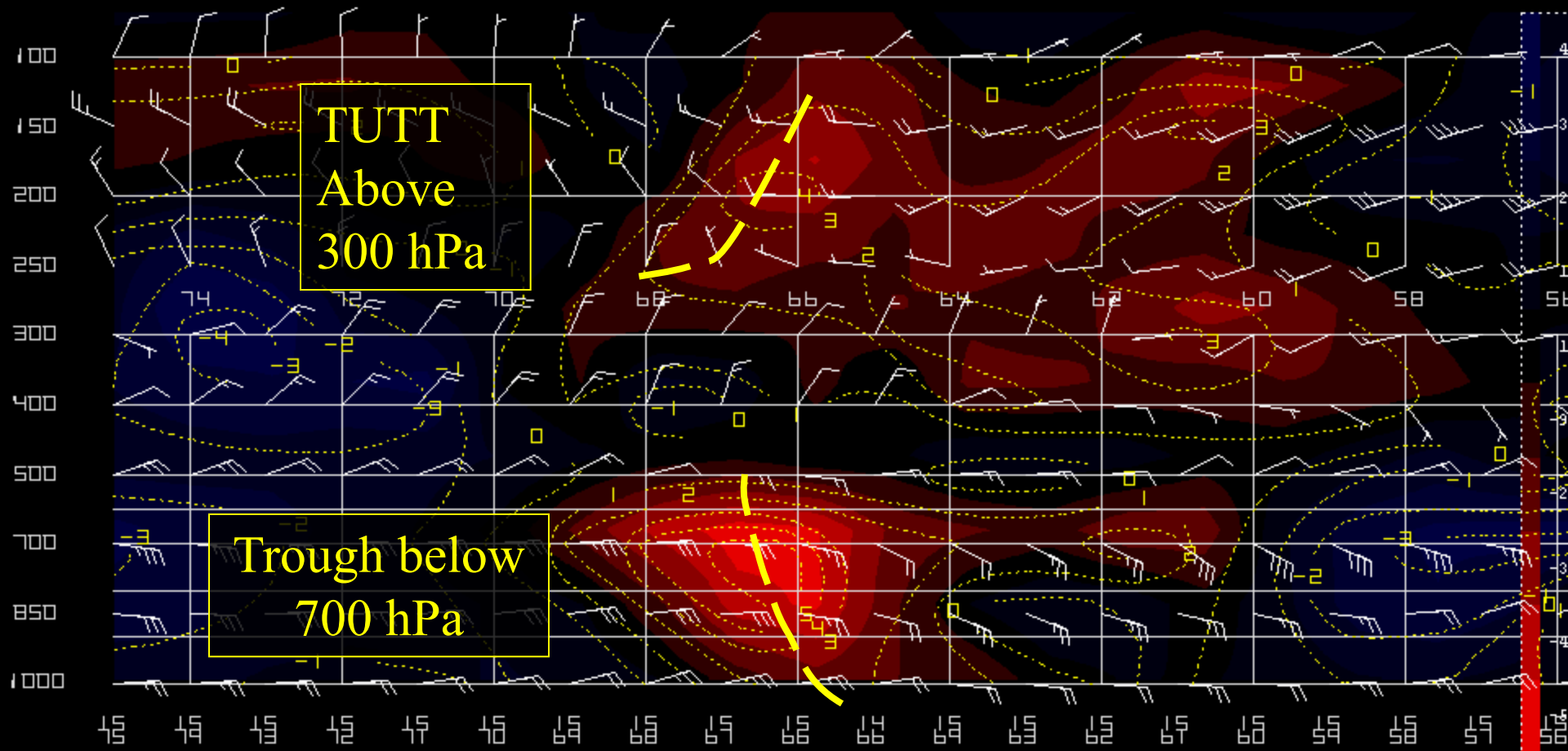
Winds and EPT (θ_e) at 850 hPa



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

AMN3:Lat/Lon 15N/ 75W=> 15N/ 55W :FHR= 12:FHRS= 0/ 24::FIL1=JUN200800.AMN003
2008/ 6/20/ 0--BKNT CLR4&PORT WIND DOTS&SMLC -1 PORT WIND CTFC CFCU&ANIM

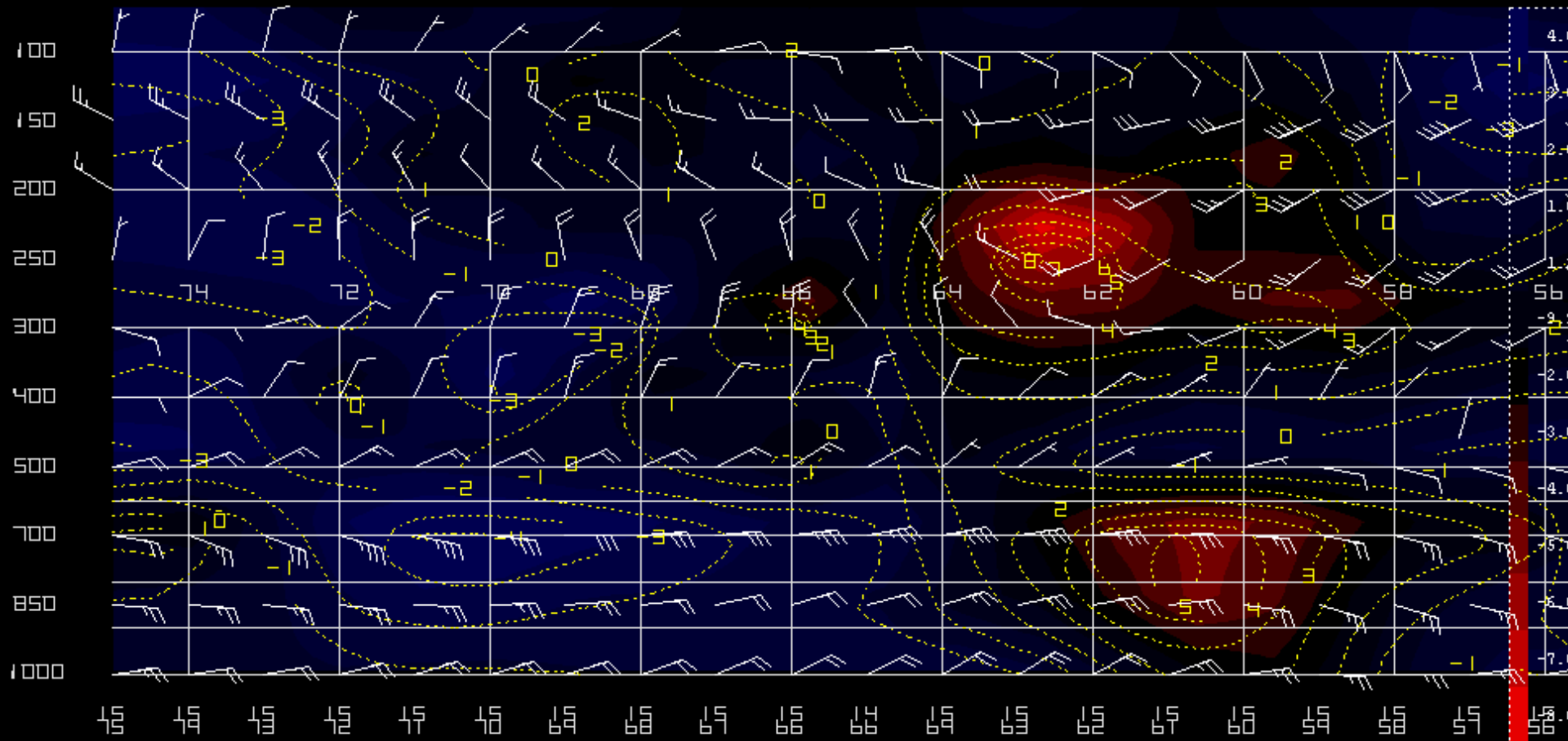
Is the upper level trough deep enough to sustain a perturbation in the easterly trades?



Animation: Winds and relative vorticity

AMN3:Lat/Lon 15N/ 75W=> 15N/ 55W :FHR= 0:FHRS= 0/ 24::FIL1=JUN200800.AMN003
2008/ 6/20/ 0--BKNT CLR4&RVRT WIND DOTS&SMLC -1 RVRT WIND CTFC CFCV&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

BRIT
255

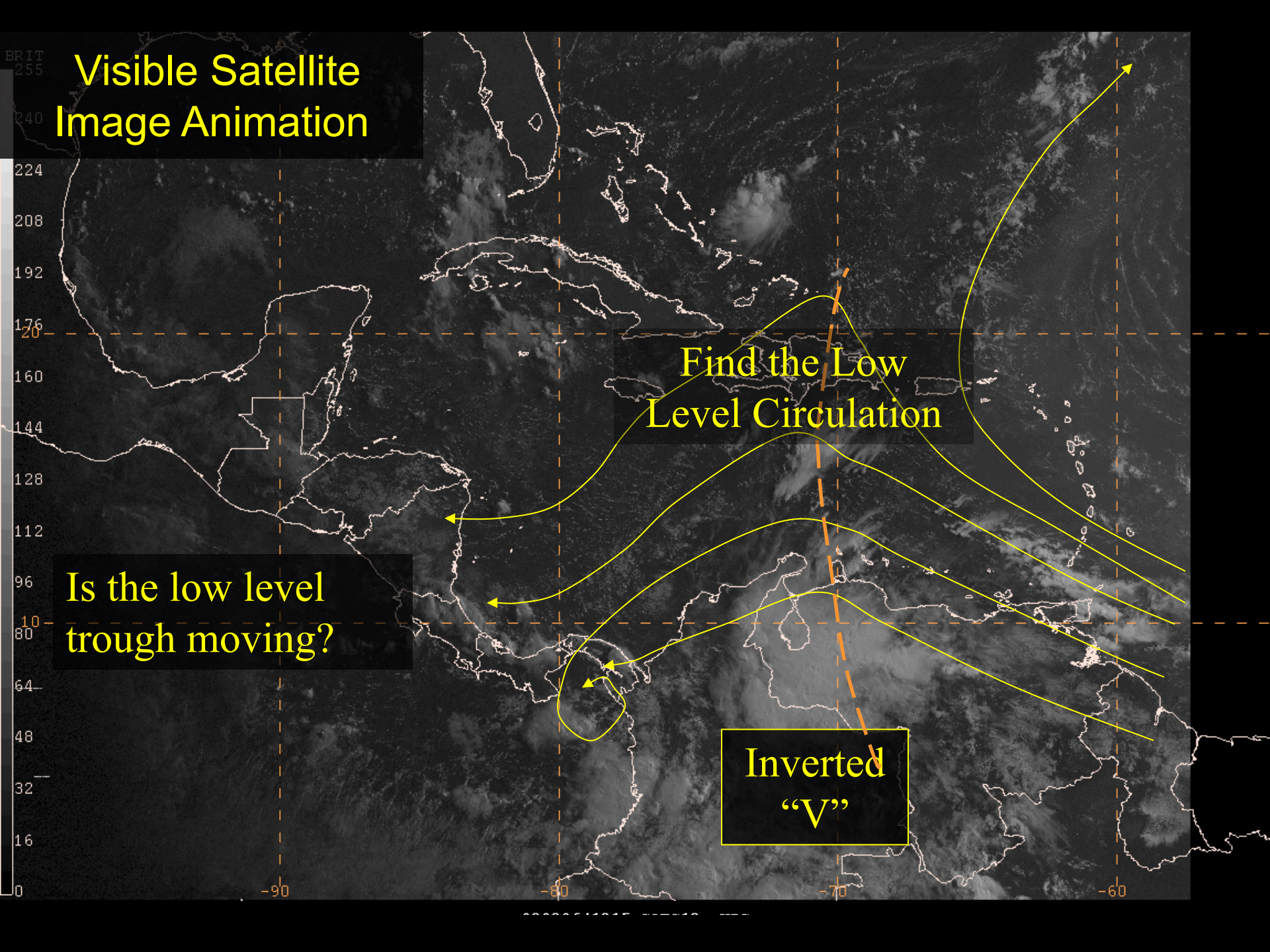
Visible Satellite Image Animation

240
224
208
192
176
160
144
128
112
96
80
64
48
32
16
0

Is the low level trough moving?

Find the Low Level Circulation

Inverted
“V”

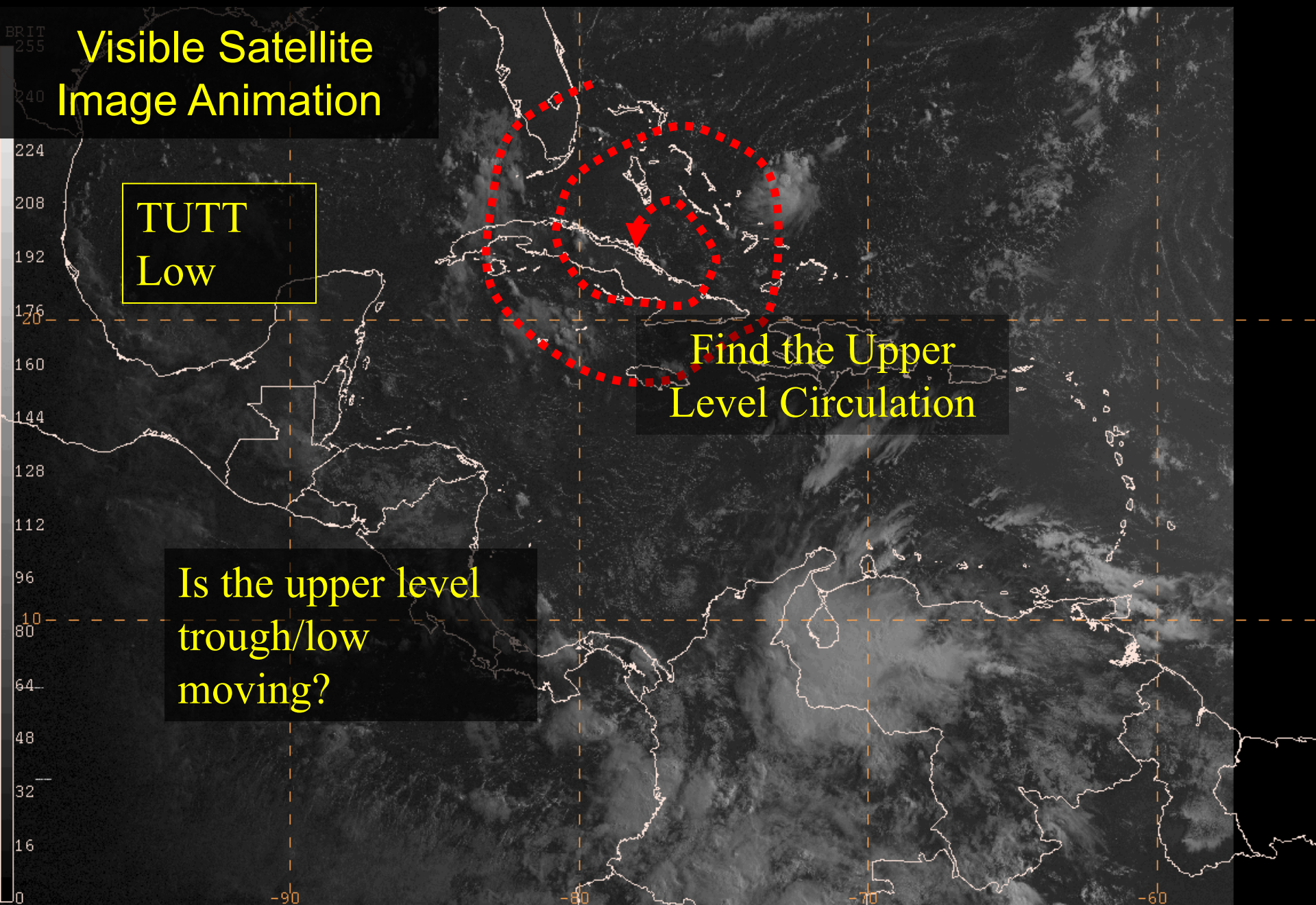


Visible Satellite Image Animation

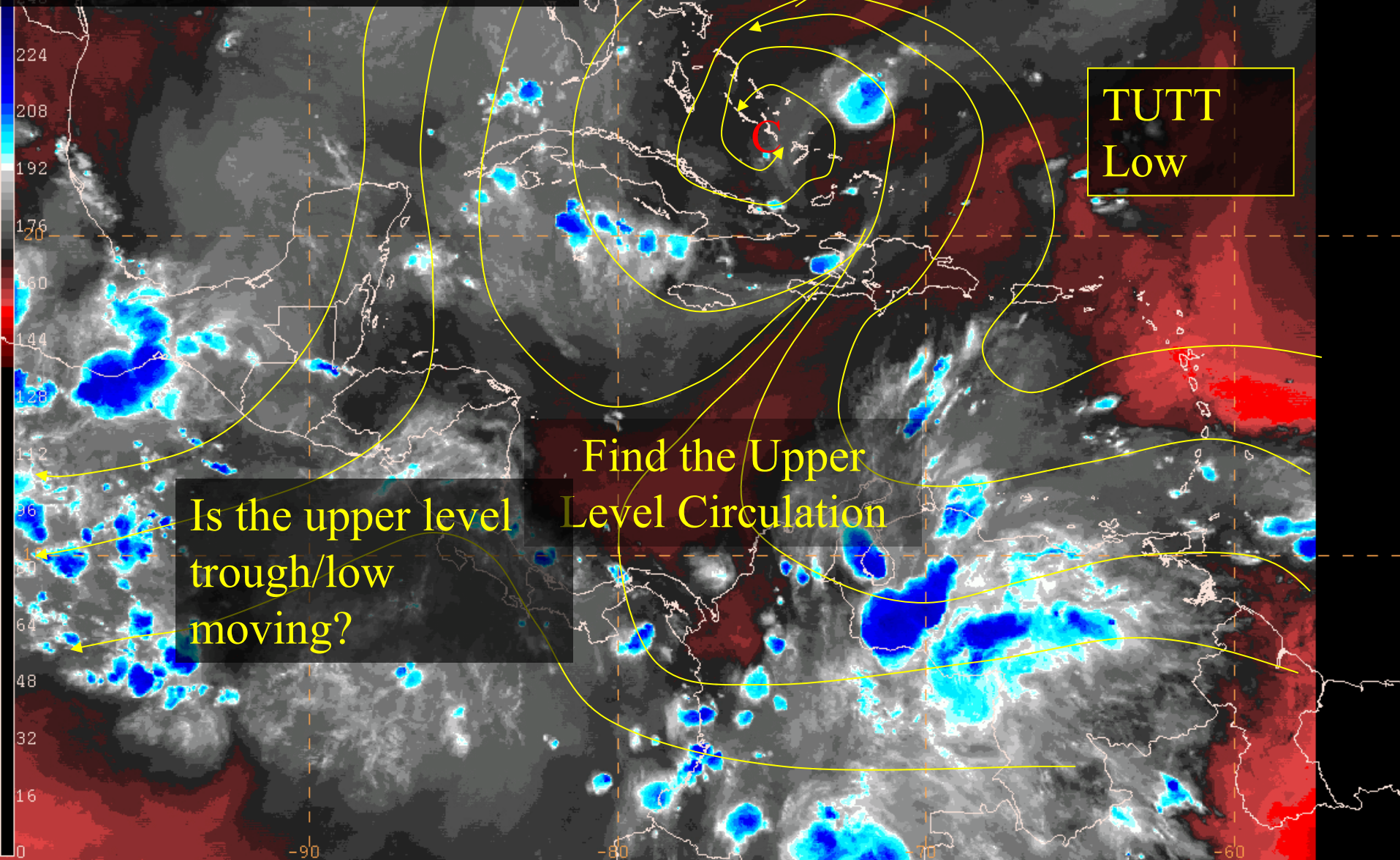
TUTT
Low

Find the Upper
Level Circulation

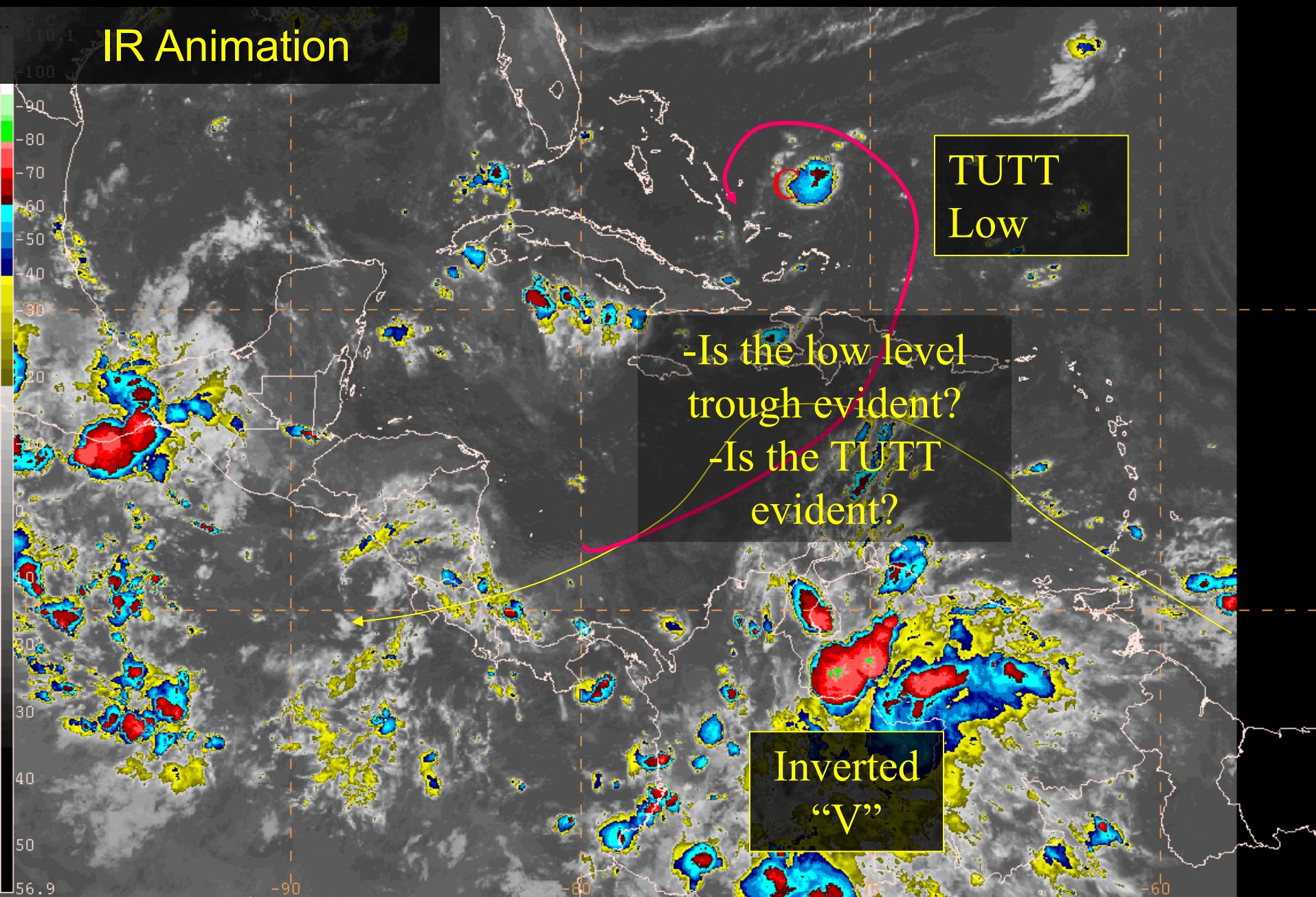
Is the upper level
trough/low
moving?



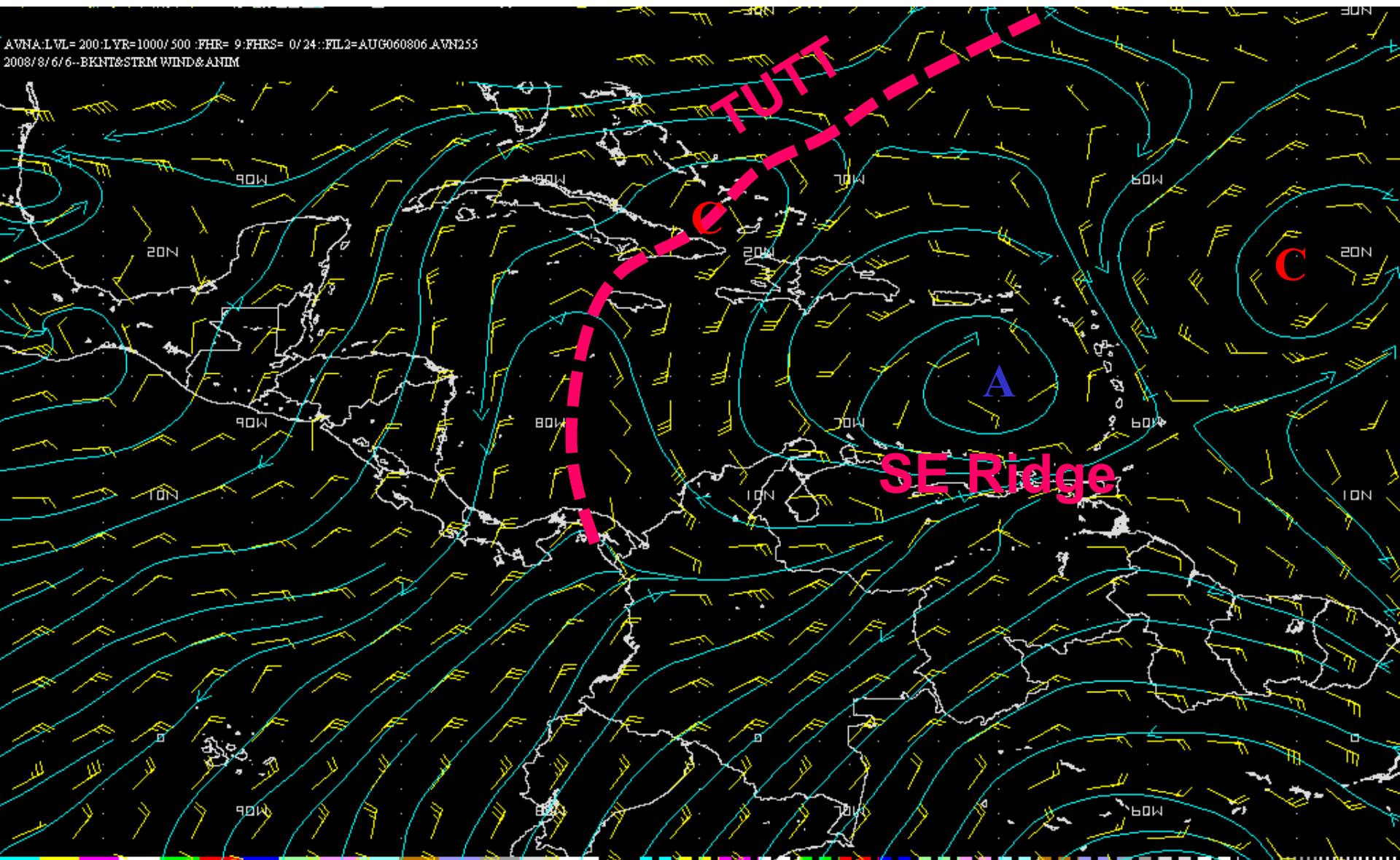
Water Vapor Image Animation (Find Upper Level Circulations)



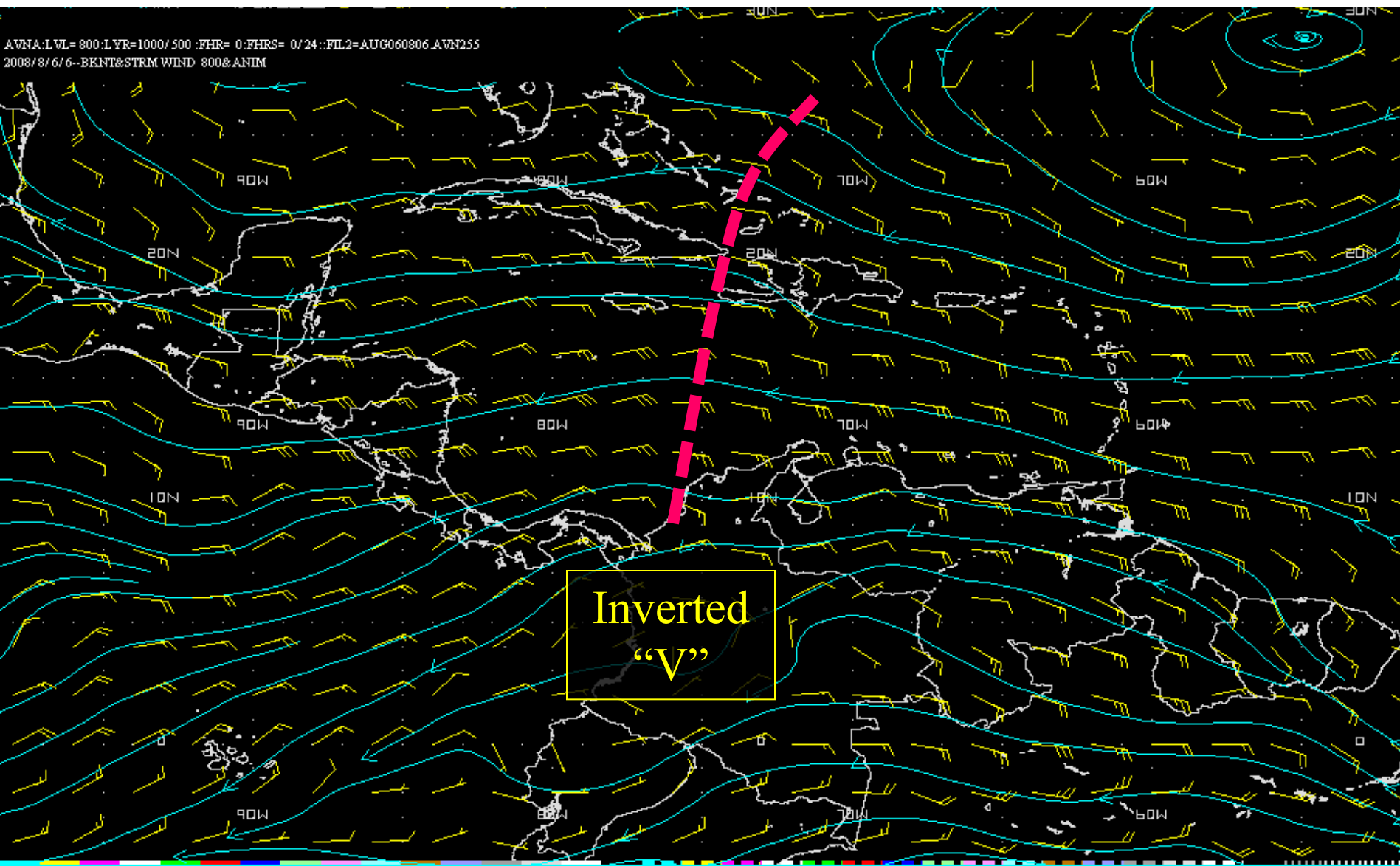
IR Animation



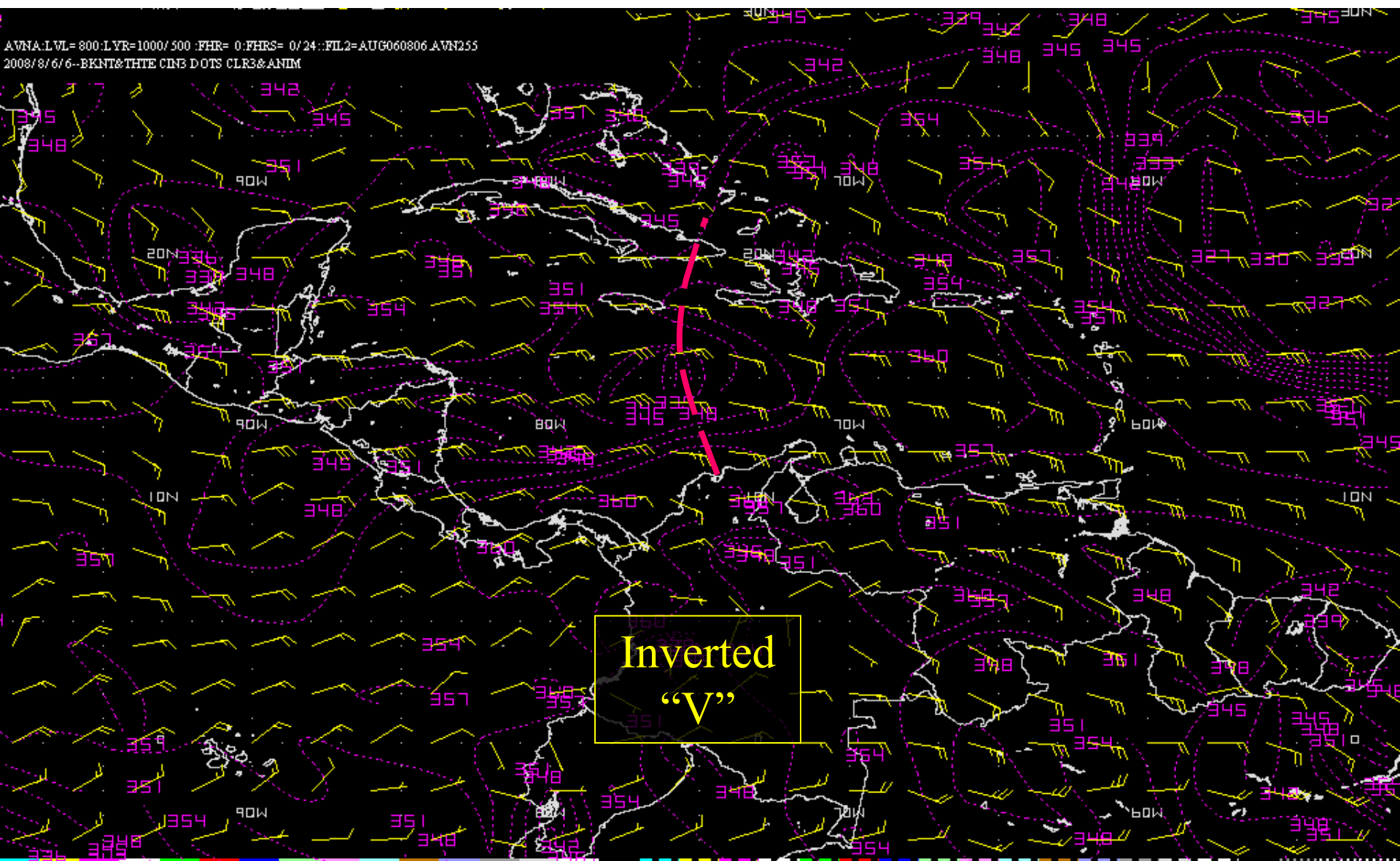
GFS Analysis: 200 hPa Winds



GFS Analysis: 850 hPa winds

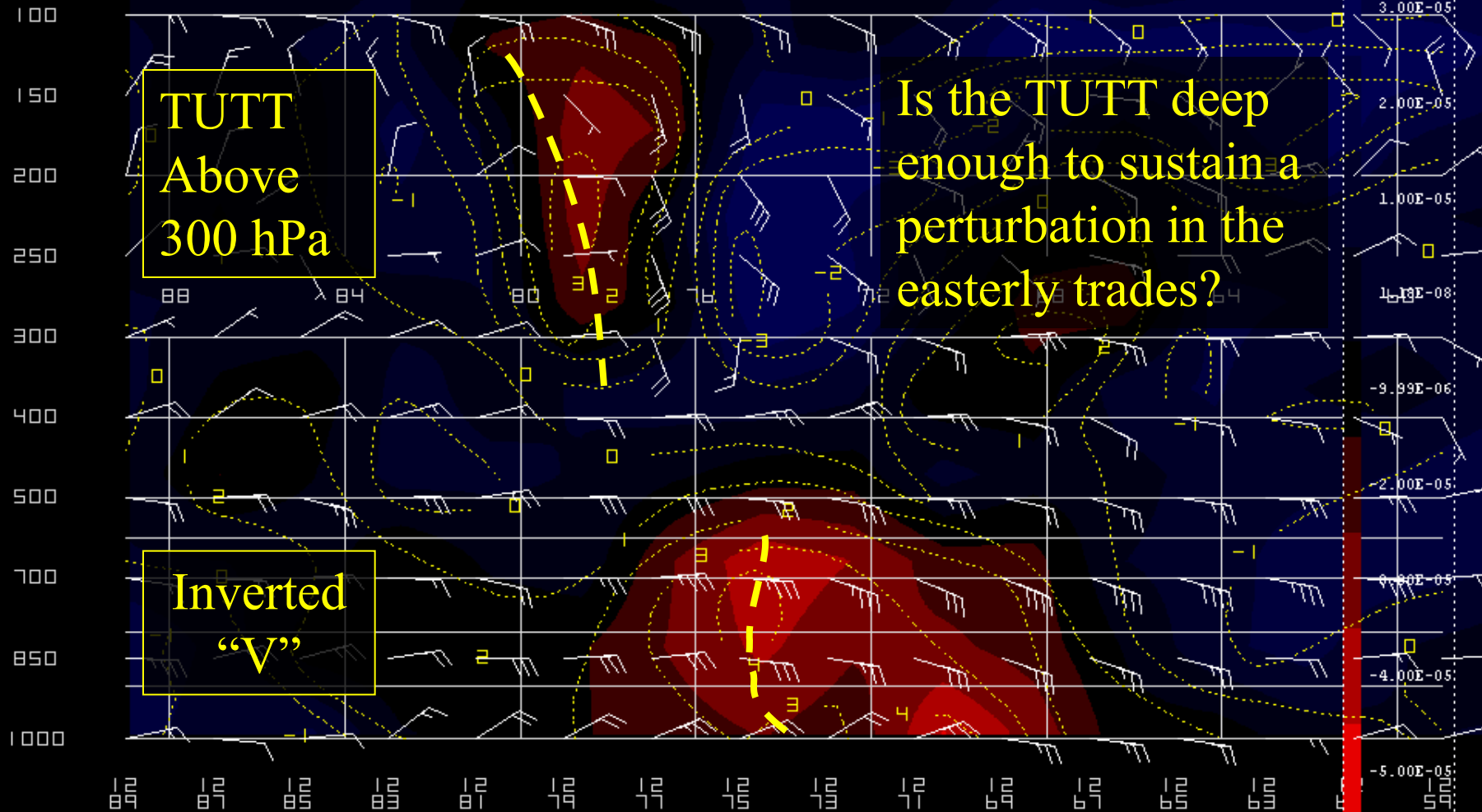


Winds and EPT (θ_e) at 850 hPa



Cross Section: Winds and relative vorticity

ANMA:Lat/Lon 12N/ 90W=> 12N/ 60W :FHR= 15:FHRS= 0/ 24::FIL2=AUG060806.ANM255
2008/ 8/ 6/ 6--BKNT CLR4&RVRT WIND DOTS&SMLC -1 RVRT WIND CTFC CFCU&ANIM

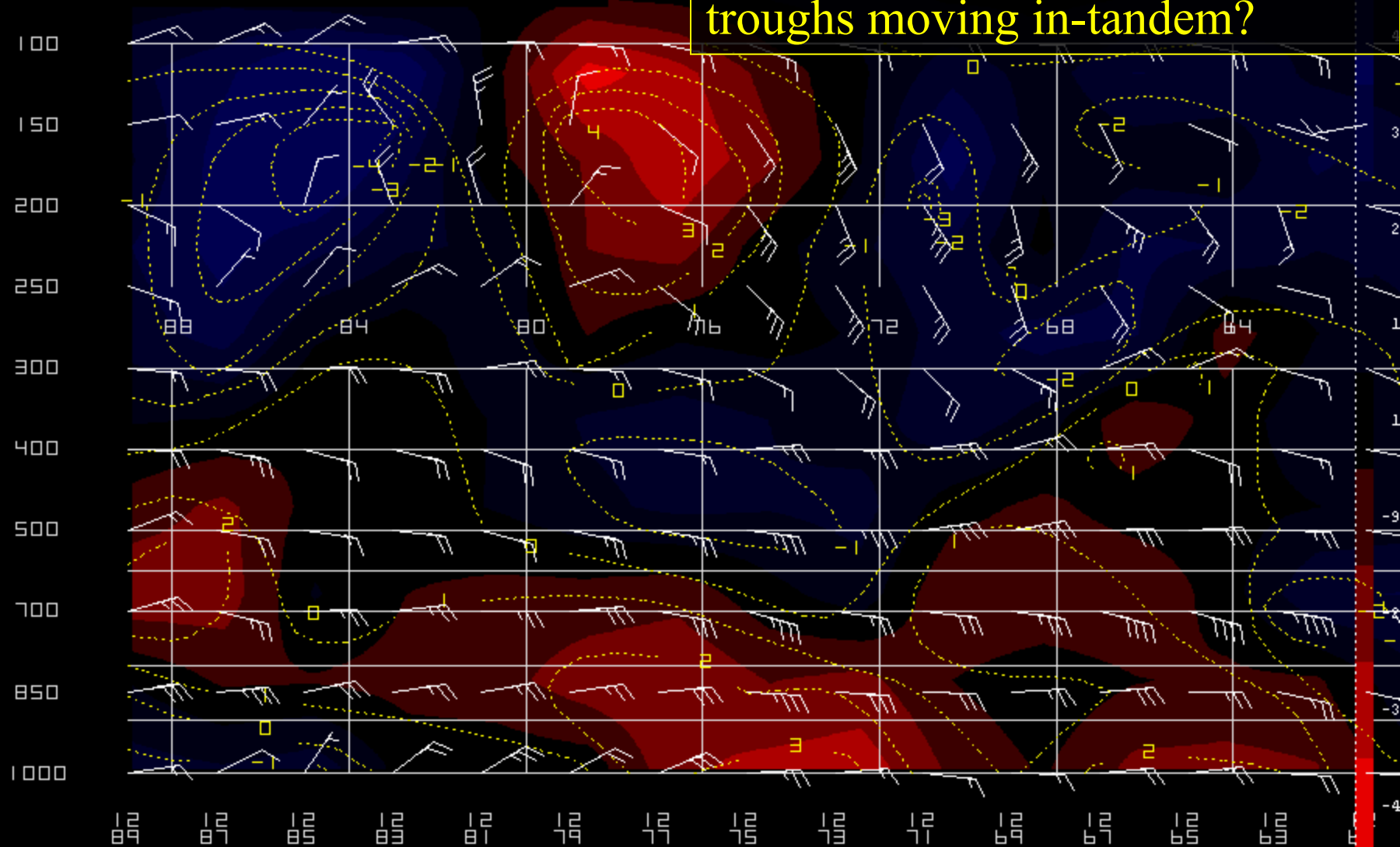


Is the TUTT deep enough to sustain a perturbation in the easterly trades?

Animation: Winds and relative vorticity

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

MM3:Lat/Lon 12N/ 89W=> 12N/ 59W :FHR= 0:FHRS= 0/ 24::FIL1=AUG060806.AW003
2008/ 8/ 6/ 6--BKNT CLR4&RVRT WIND DOTS&SHLC -1 RVRT WIND CTFC CFCU&ANIM



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

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

Jet
Maxima

SE
Ridge

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

GOES-16 Geo Color

Analyze low level flow.
Inverted “V”?
Closed lows?

Are the low level
troughs moving?

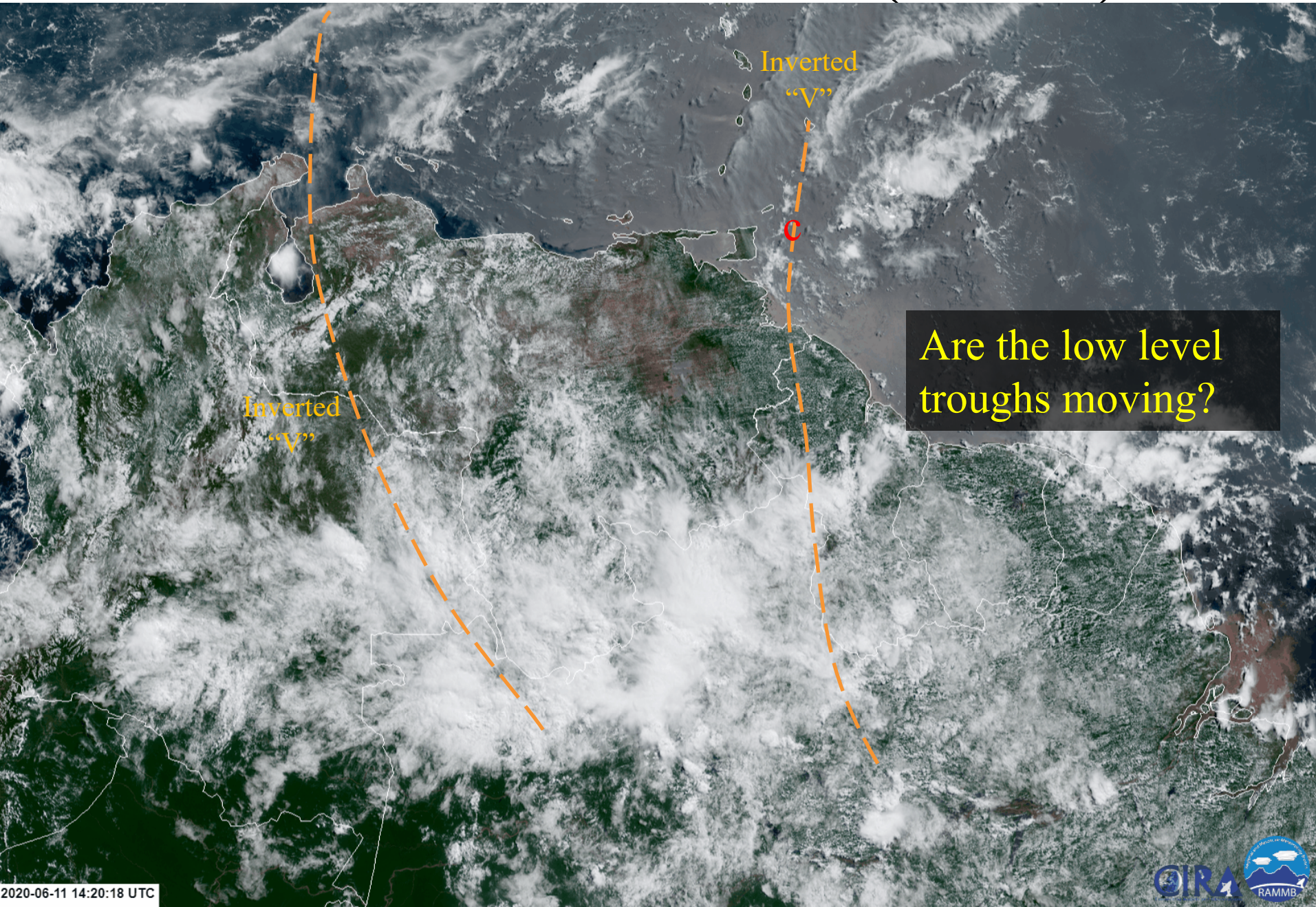
Hint: There are two
waves and two
surface lows south
of 20N.

Inverted
“V”

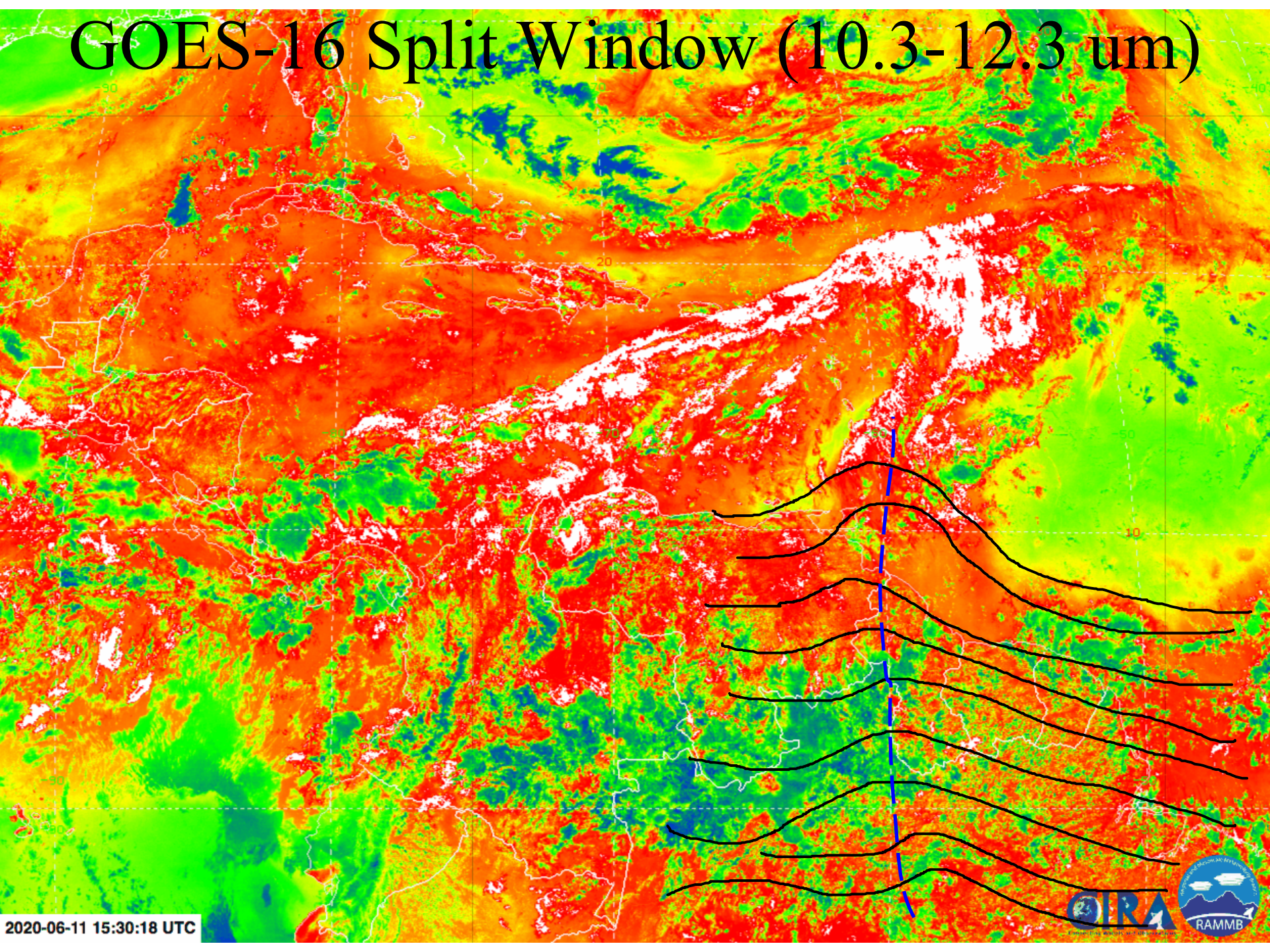
C

C

GOES-16 GeoColor (Zoom)



GOES-16 Split Window (10.3-12.3 um)



2020-06-11 15:30:18 UTC



GOES-16 6.2um

C
TUTT
Low

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

Jet
Maxima

SER



2020-06-11 15:00:18 UTC



GOES-16 7.3um

TUTT
Low

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

SER

SER

GOES-16 10.3um

C
TUTT
Low

Find the Upper
Level Circulation
and inverted "V"

SER

SER

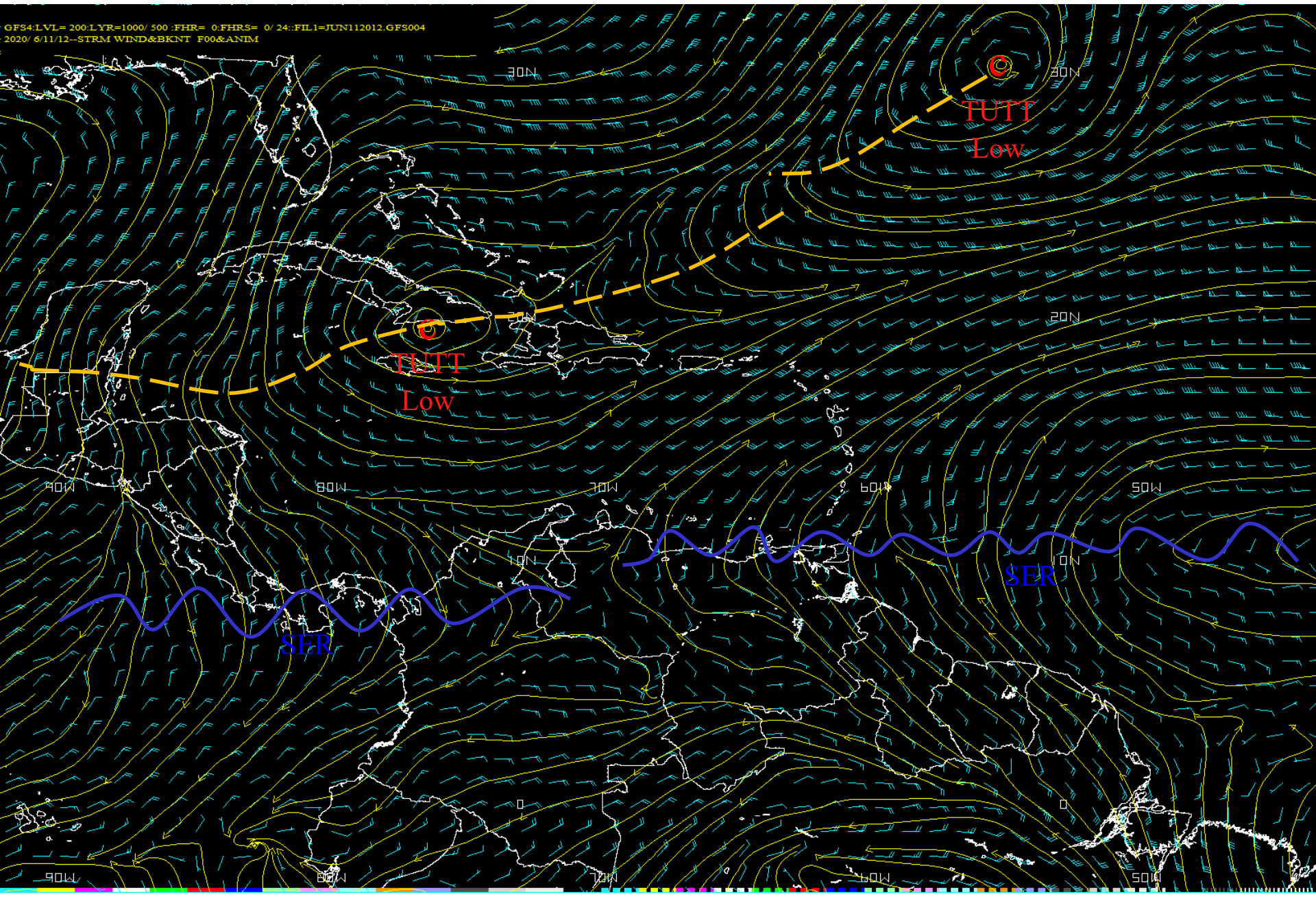


2020-06-11 15:20:18 UTC

Temperature

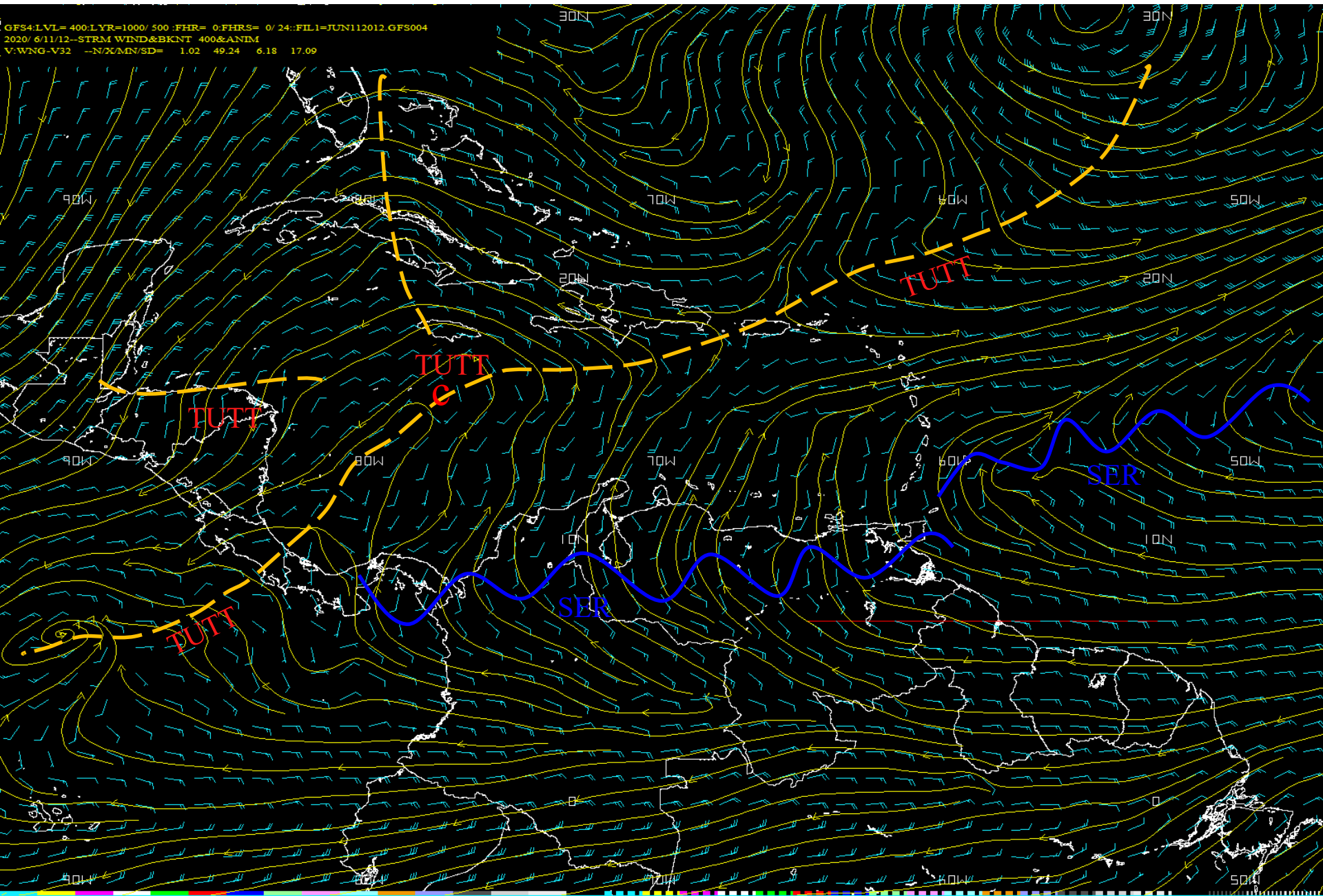
40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90

GFS – 200 hPa

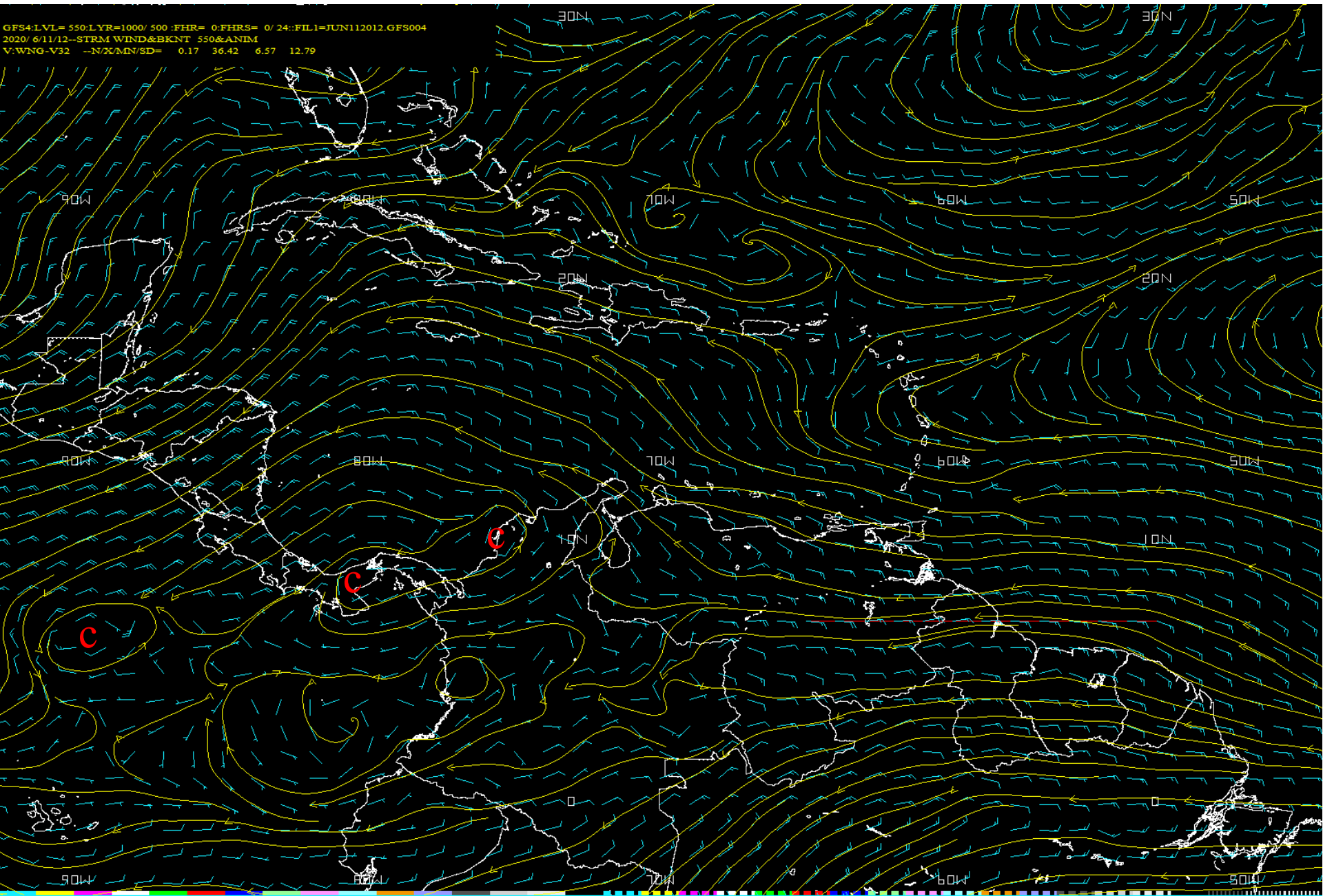


GFS – 400 hPa

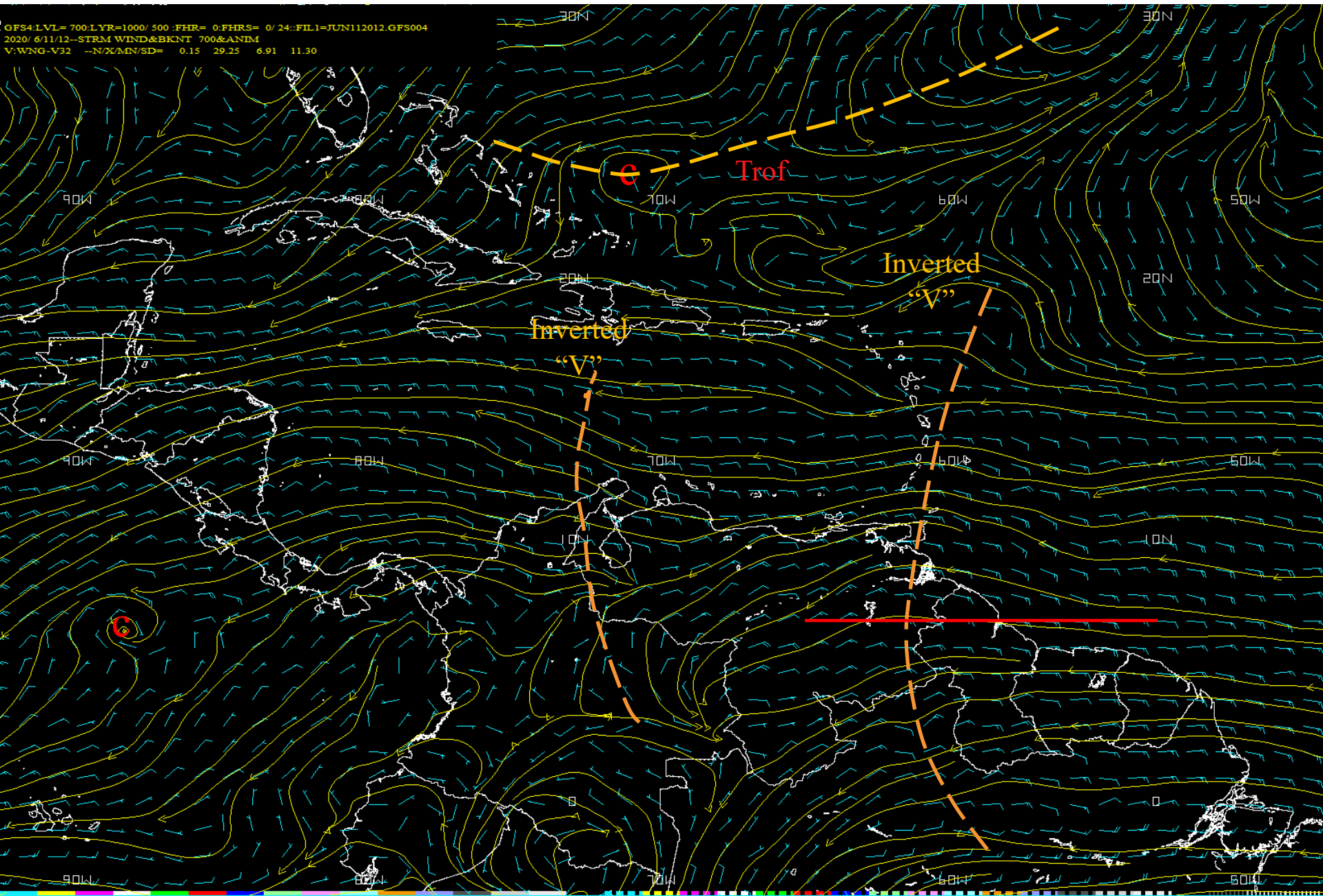
GFS4:LVL= 400:LYR=1000/ 500 :FHR= 0:FHRS= 0/ 24::FIL1=JUN112012.GFS004
2020/ 6/11/12--STRM WIND&BKNT 400&ANIM
V:WNG-V32 --N/X/MN/SD= 1.02 49.24 6.18 17.09



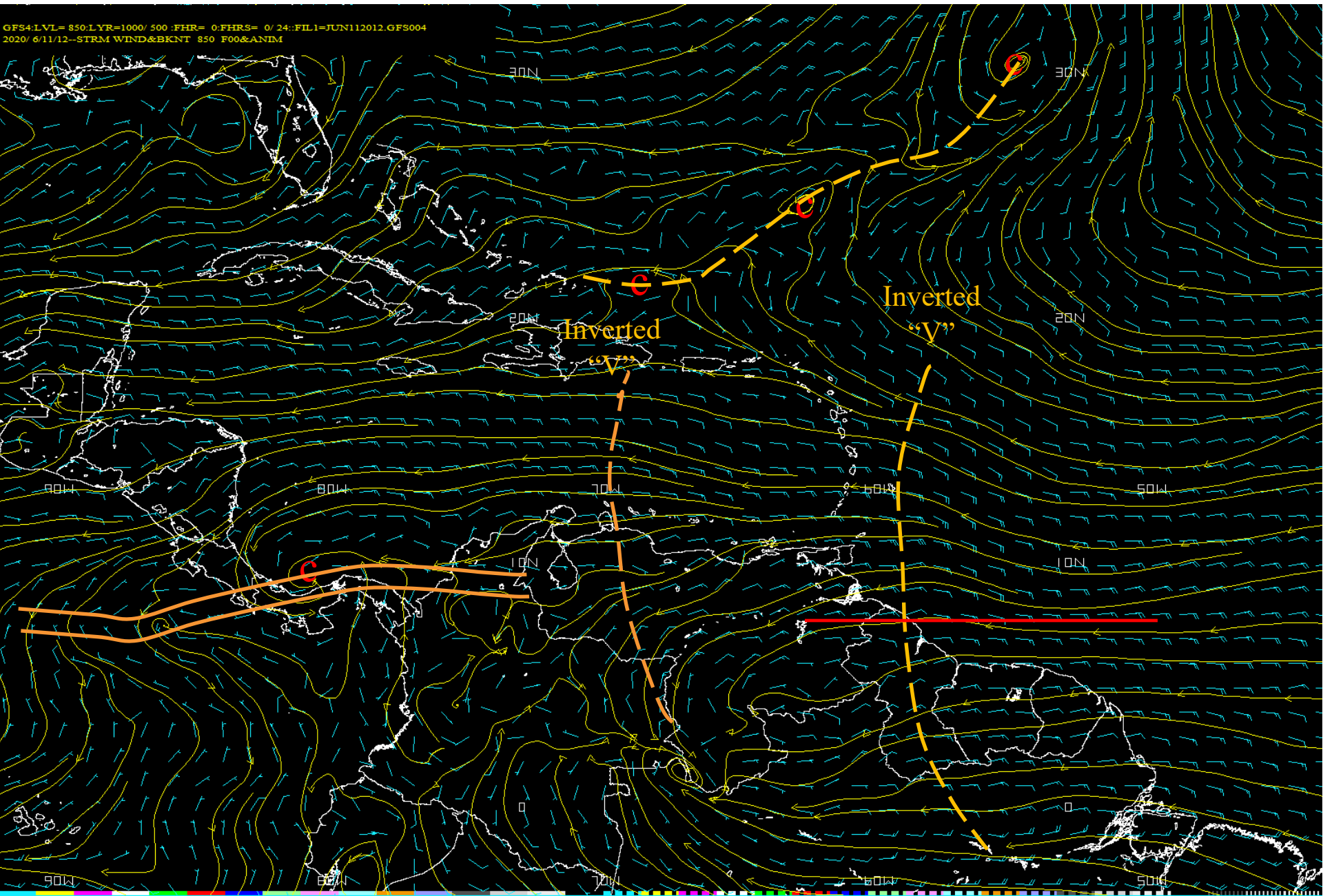
GFS – 550 hPa



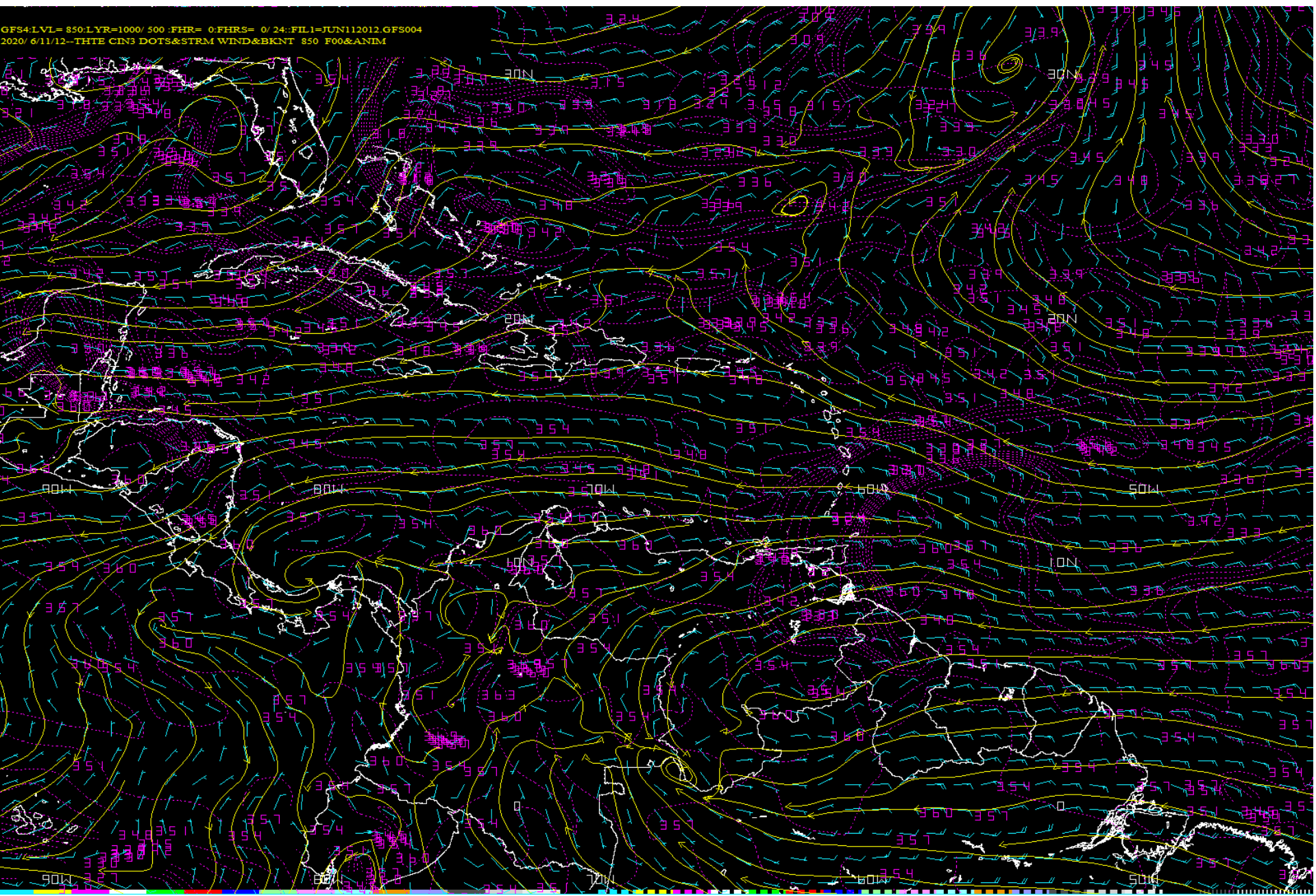
GFS – 700 hPa



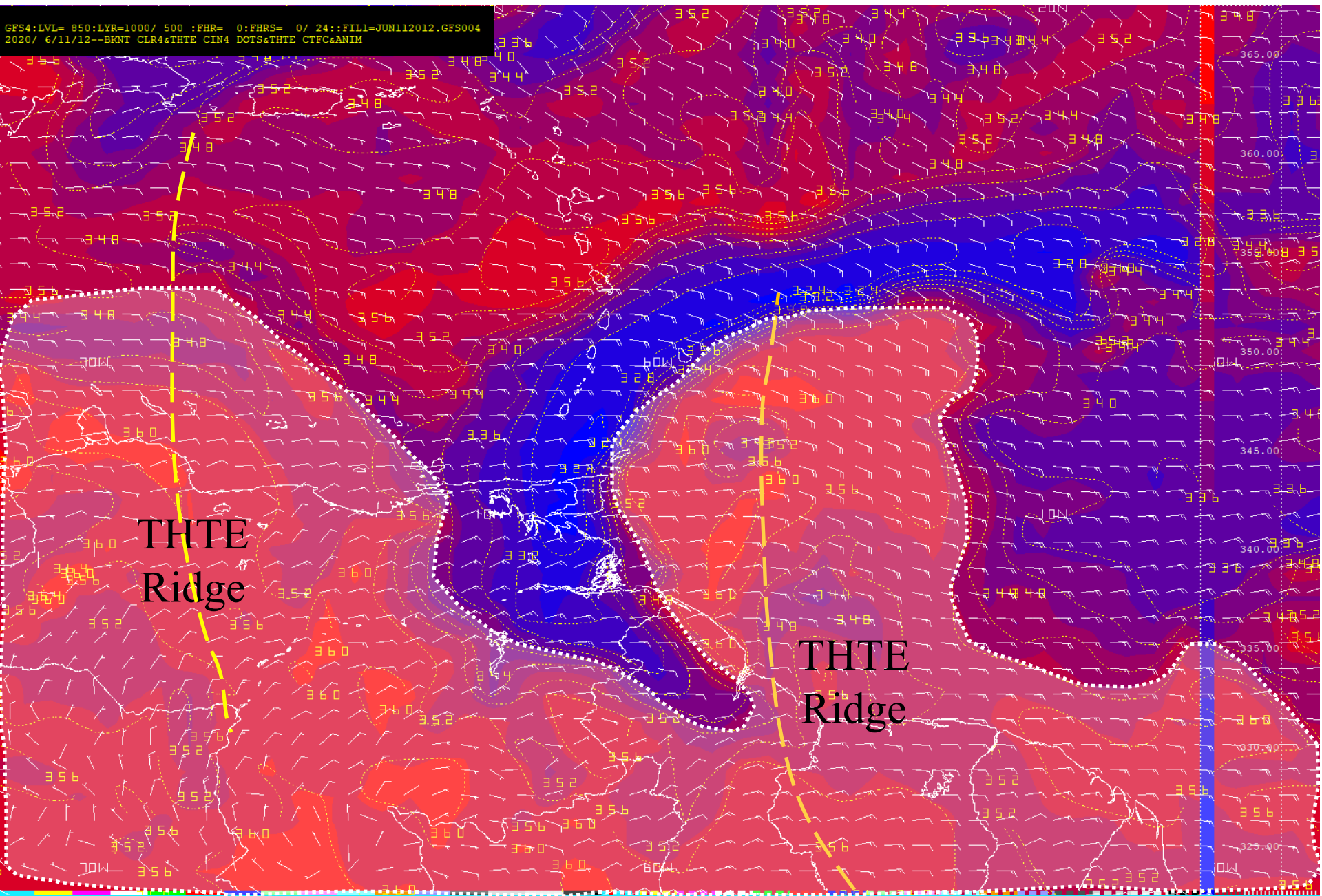
GFS – 850 hPa



GFS – 850 hPa & EPT

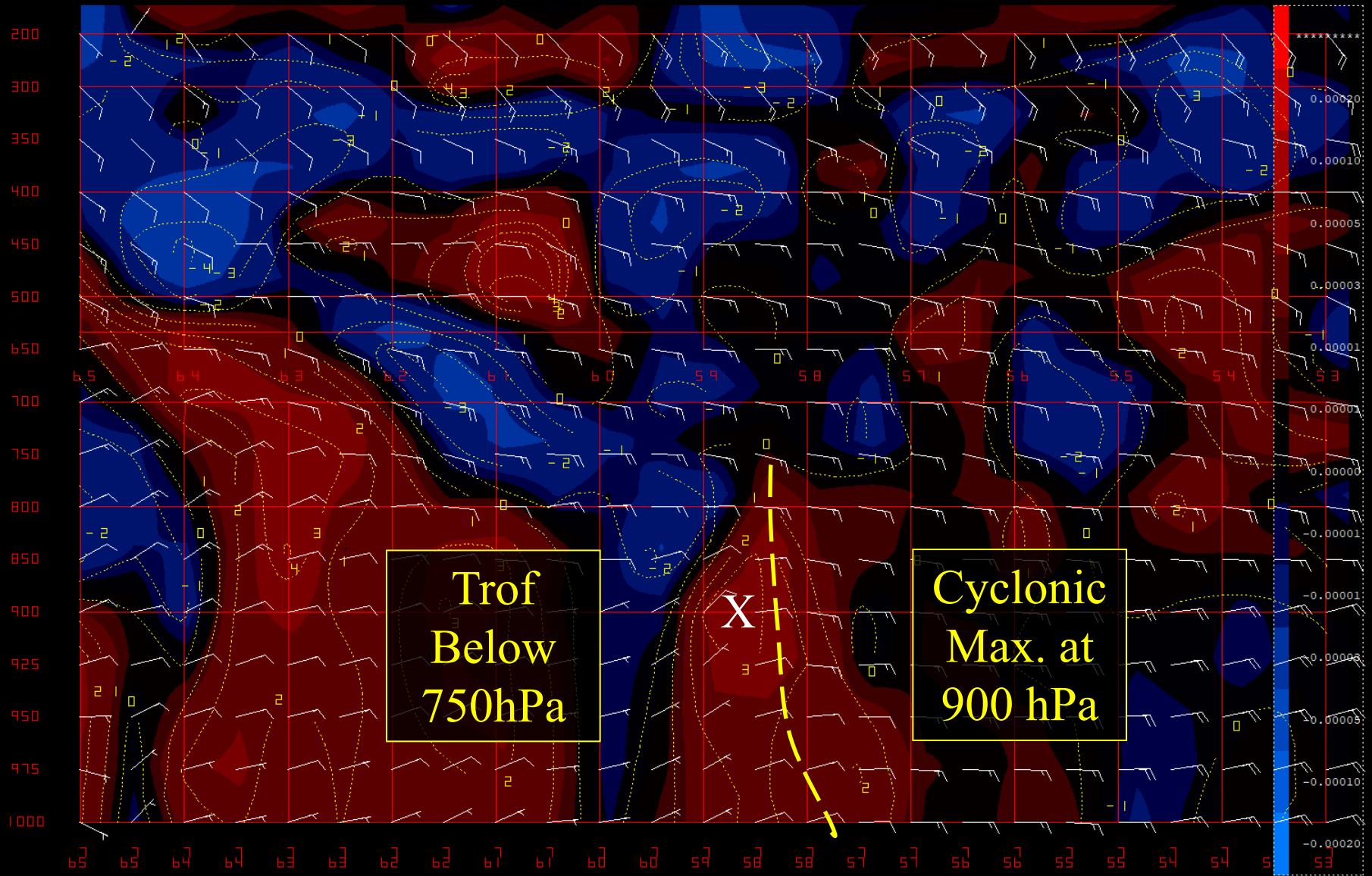


GFS – 850 hPa & EPT



Cross Section – Winds and RVRT

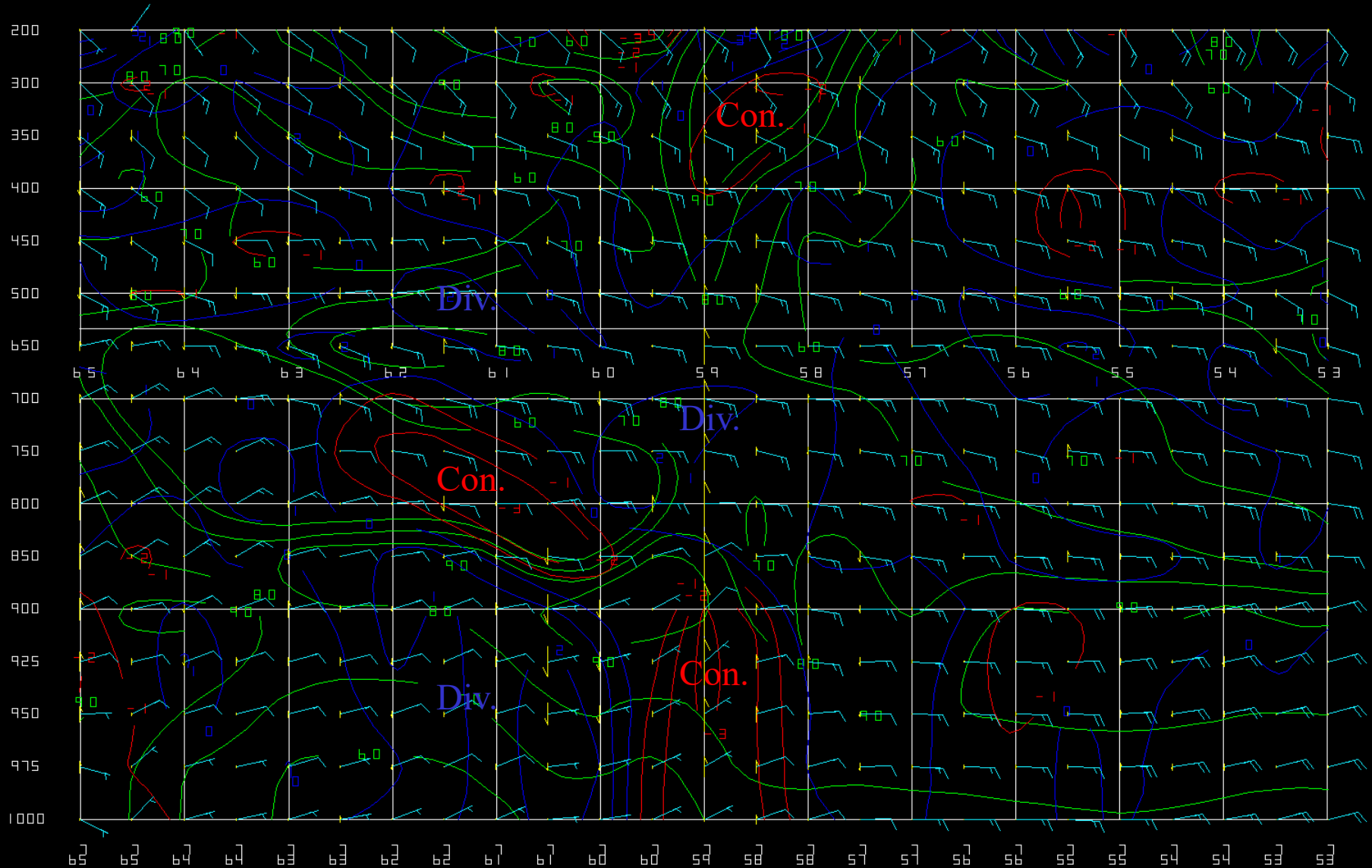
GFS4:Lat/Lon 7N/ 65W=> 7N/ 53W :FHR= 3:FHRS= 0/ 24::FIL1=JUN112012.GFS004
2020/ 6/11/12--BKNT CLR4&RVRT WIND DOT5&RVRT WIND CTFC CFC9&ANIM



Cross Section – Winds & Divergence

GFS4:Lat/Lon 7N/ 65W=> 7N/ 53W :FHR= 3:FHRS= 0/ 24::FIL1=JUN112012.GFS004
2020/ 6/11/12--SMLC -1 OMGA ZERO AROW CLR2&&

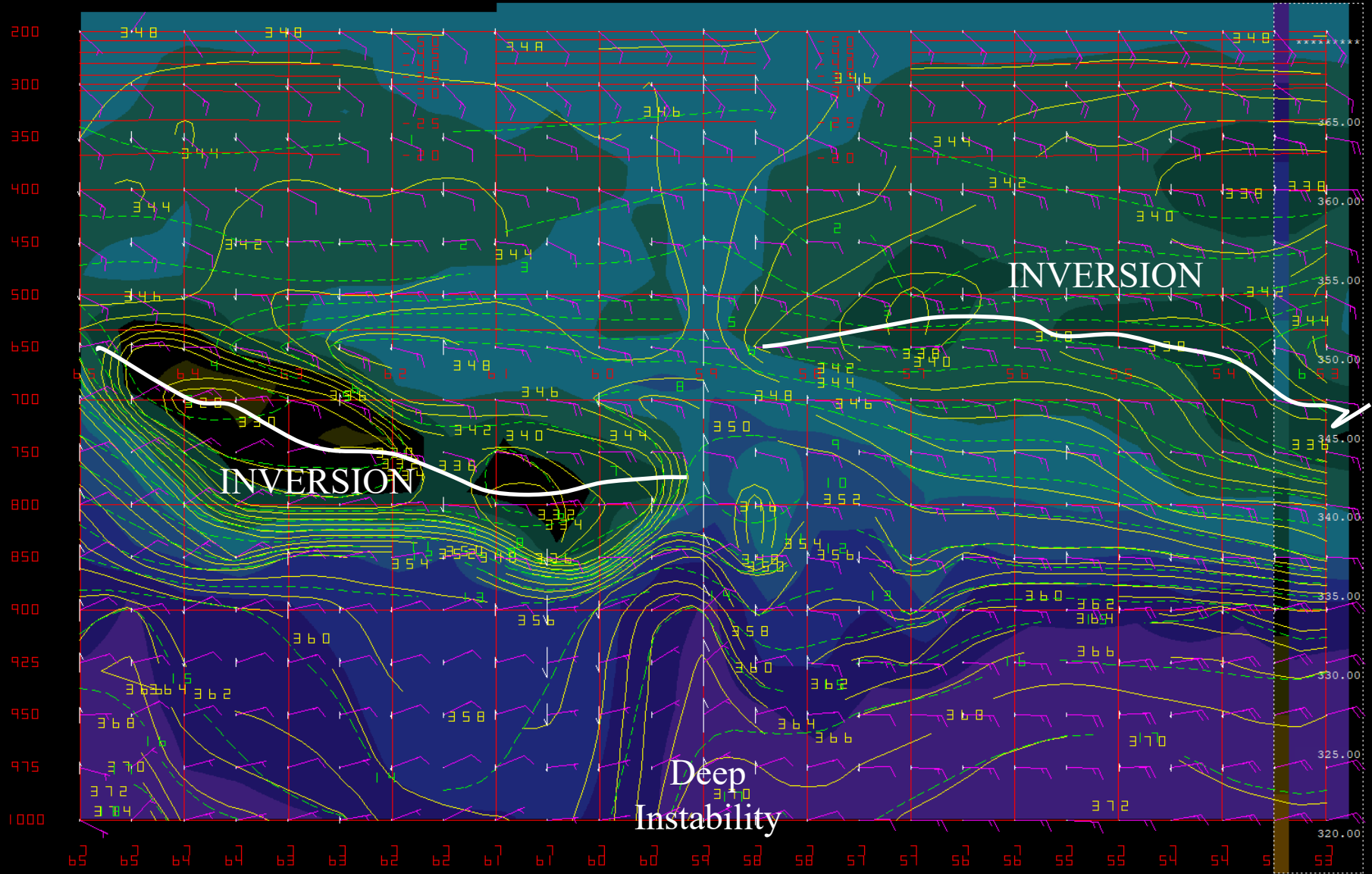
0



Cross Section – EPT, Winds, Omega

GFS4:Lat/Lon 7N/ 65W=> 7N/ 53W :FHR= 3:FHRS= 0/ 24::FIL1=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), AGE0 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

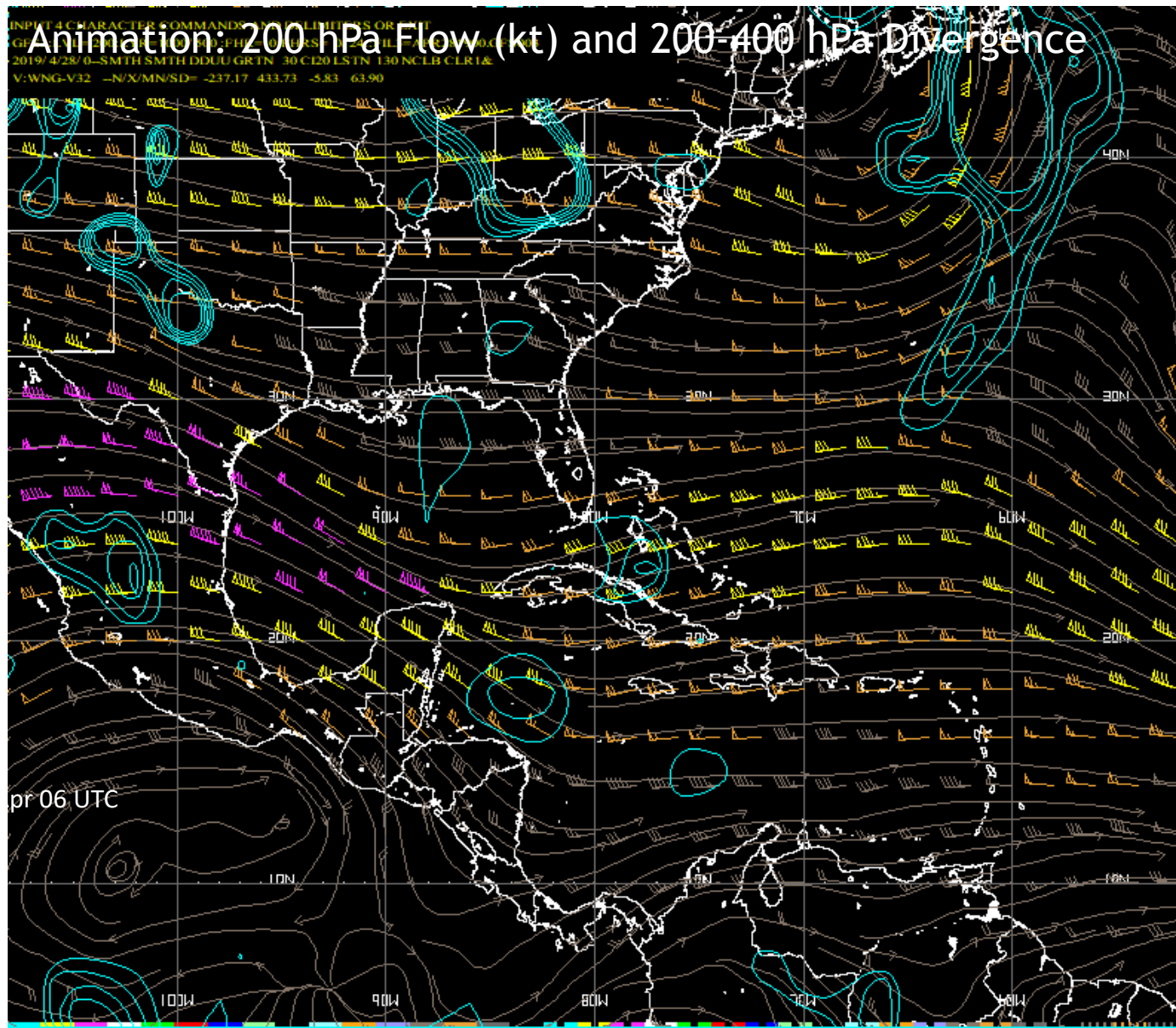
Severe Thunderstorms

April 28-29, 2019

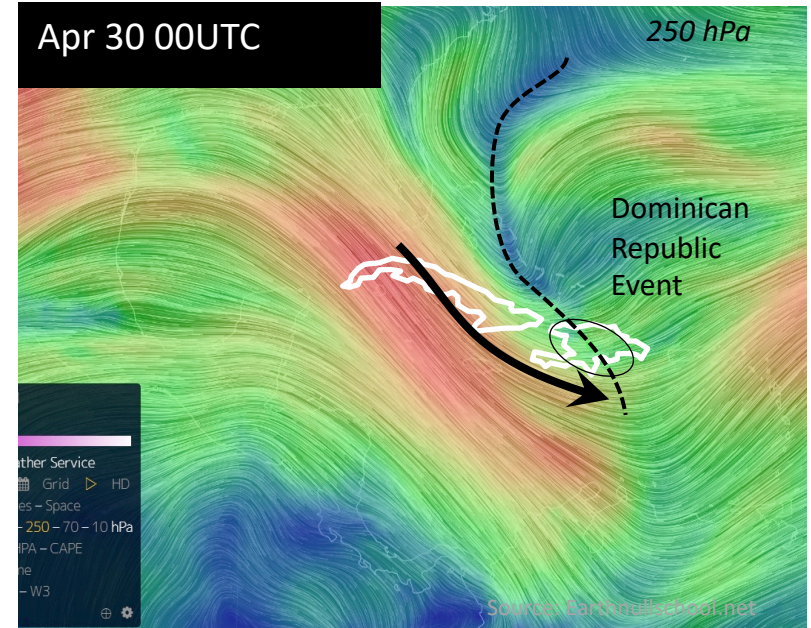
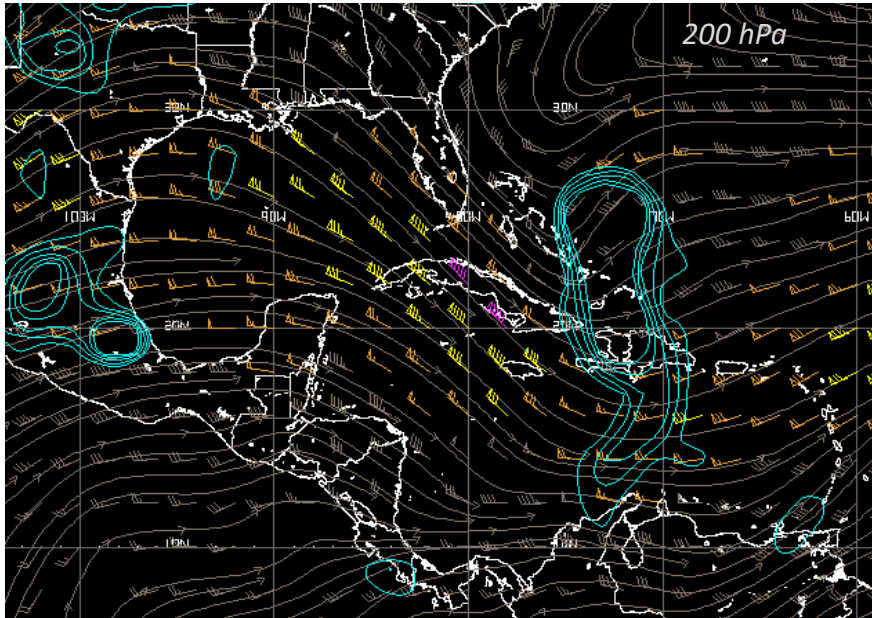
TUTT's Impact on Severe Convection

- 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)

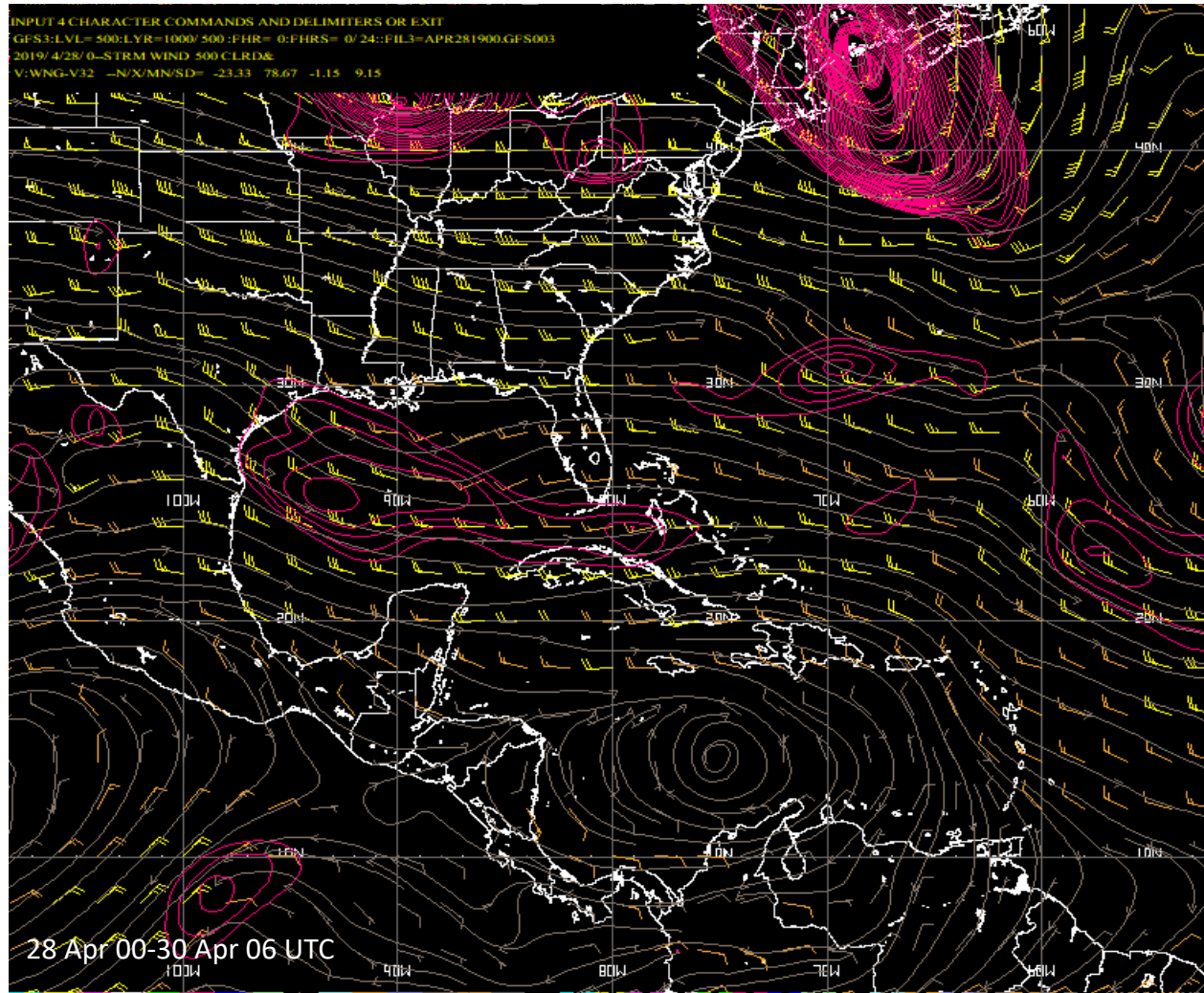
TUTT – Divergence Aloft



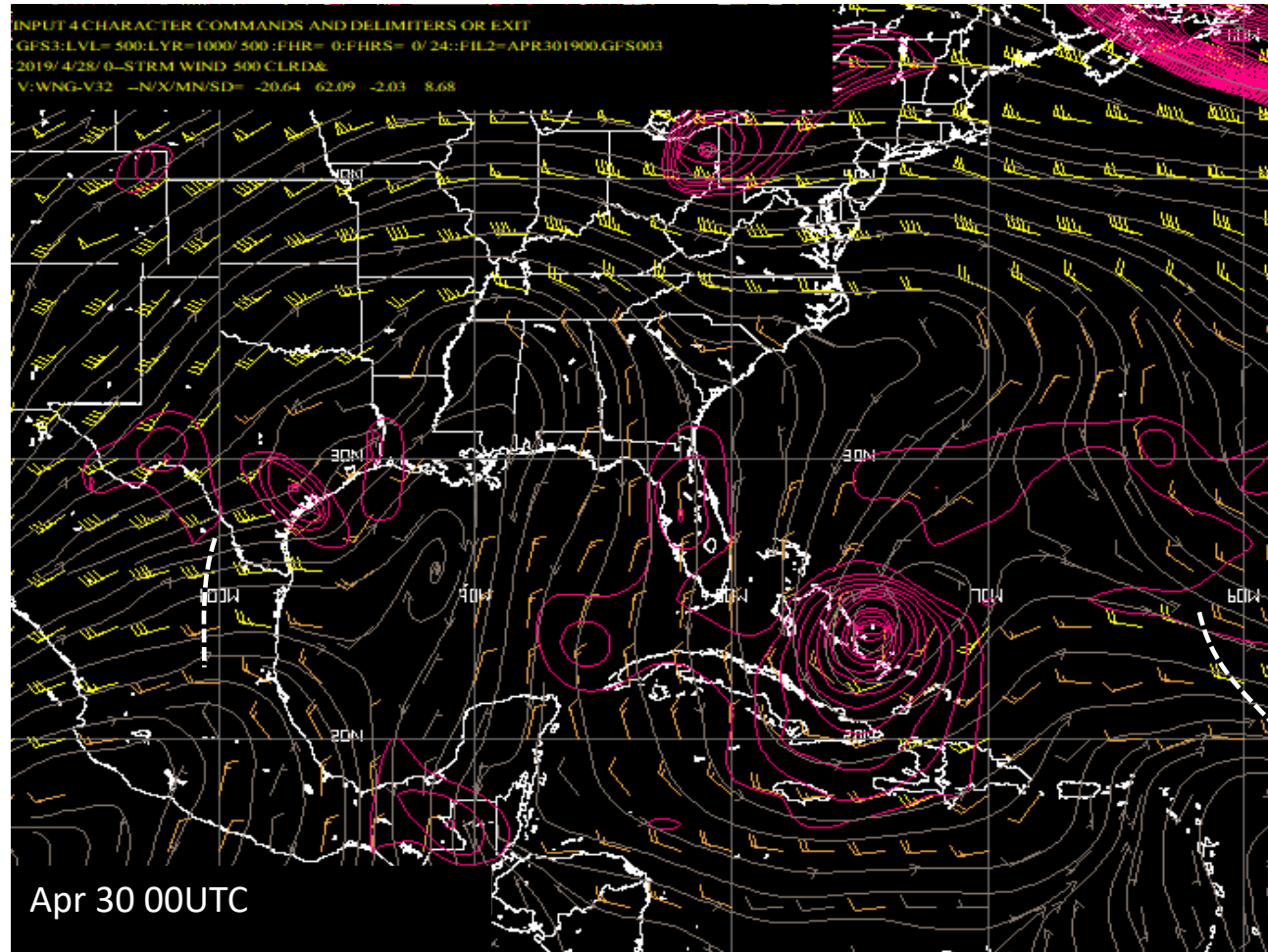
TUTT – Divergence Aloft



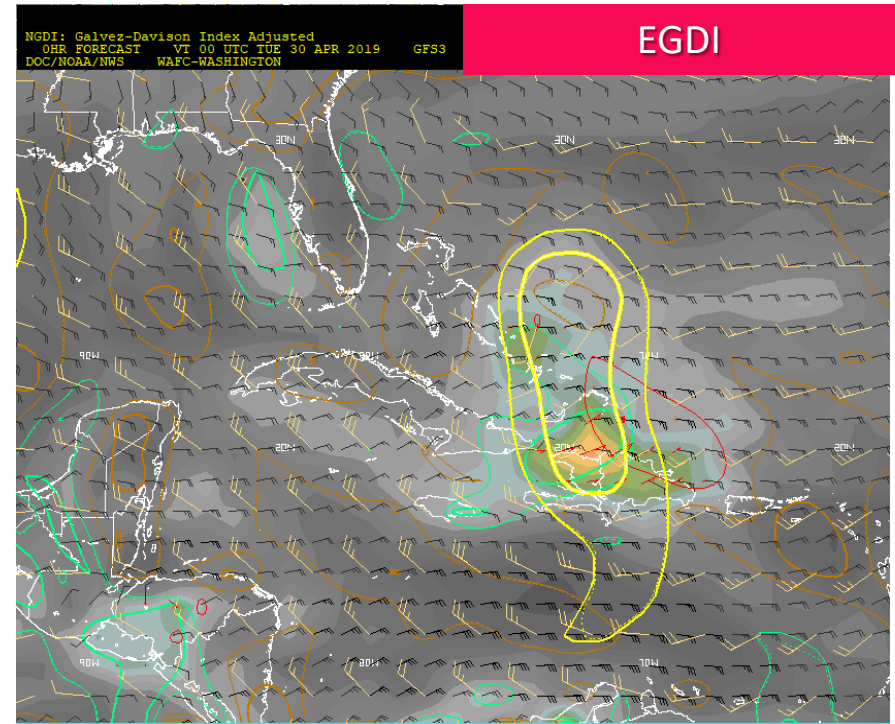
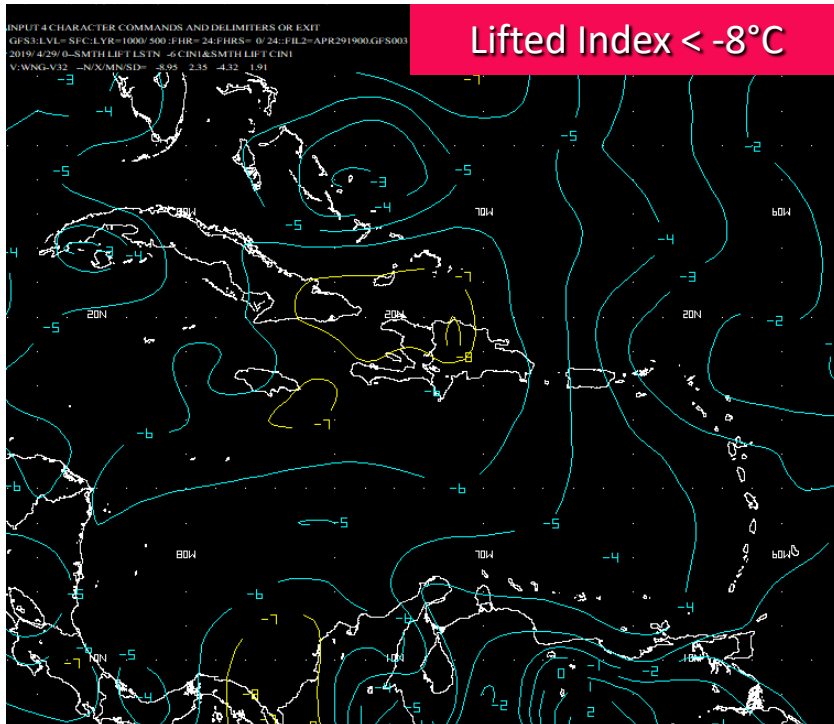
TUTT – Mid Level Cyclonic Vorticity



TUTT – Mid Level Cyclonic Vorticity

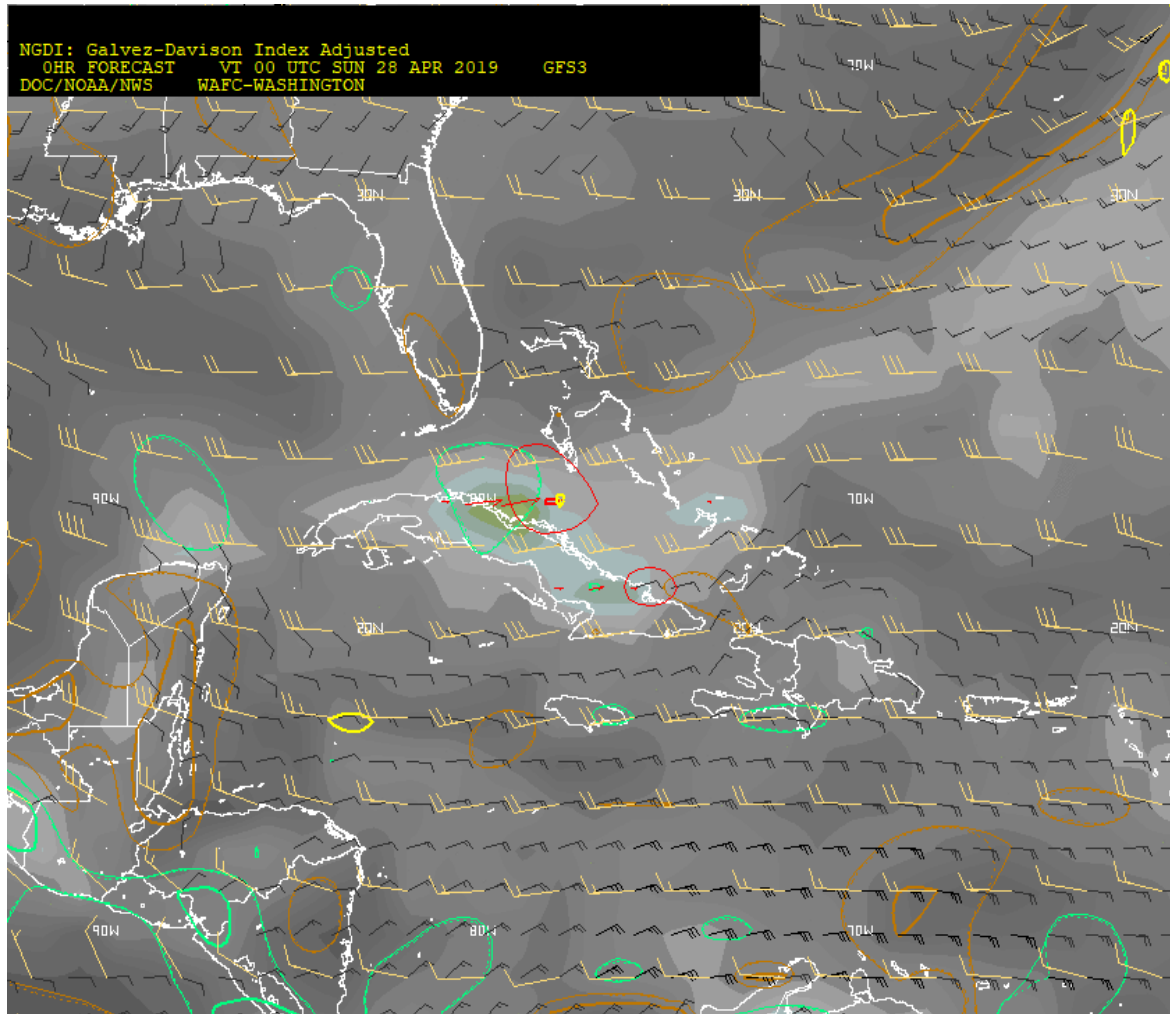


TUTT - Stability

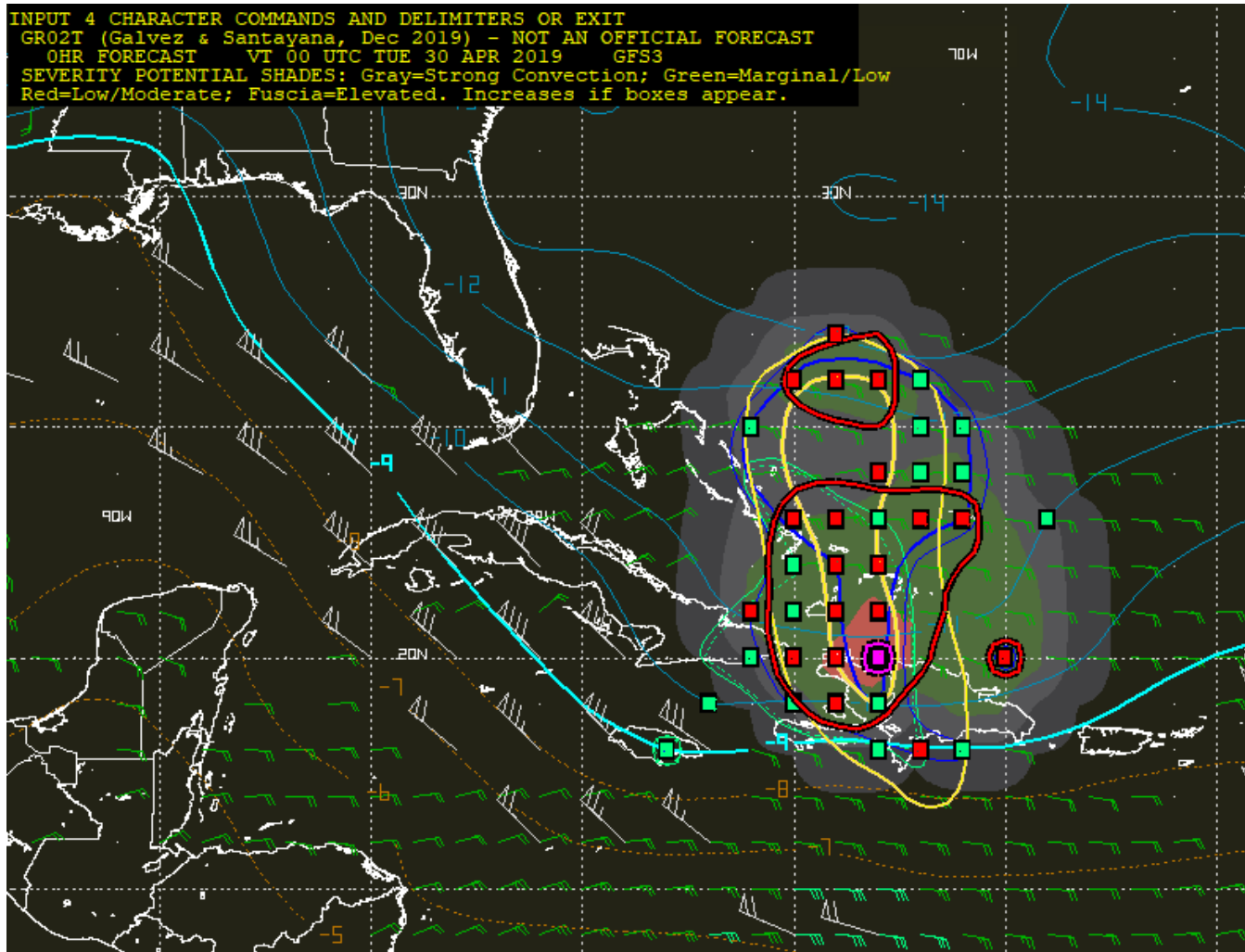


Note: Use the GDI and EGDI to determine potential of deep or shallow convection.

EGDI and Low Level Flow

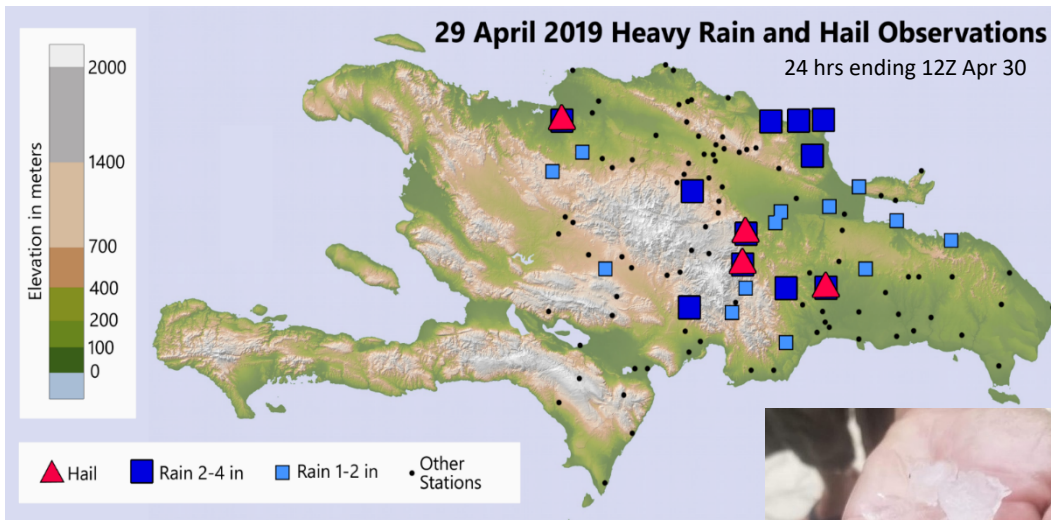


Diagnostic Tools : GR02T



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

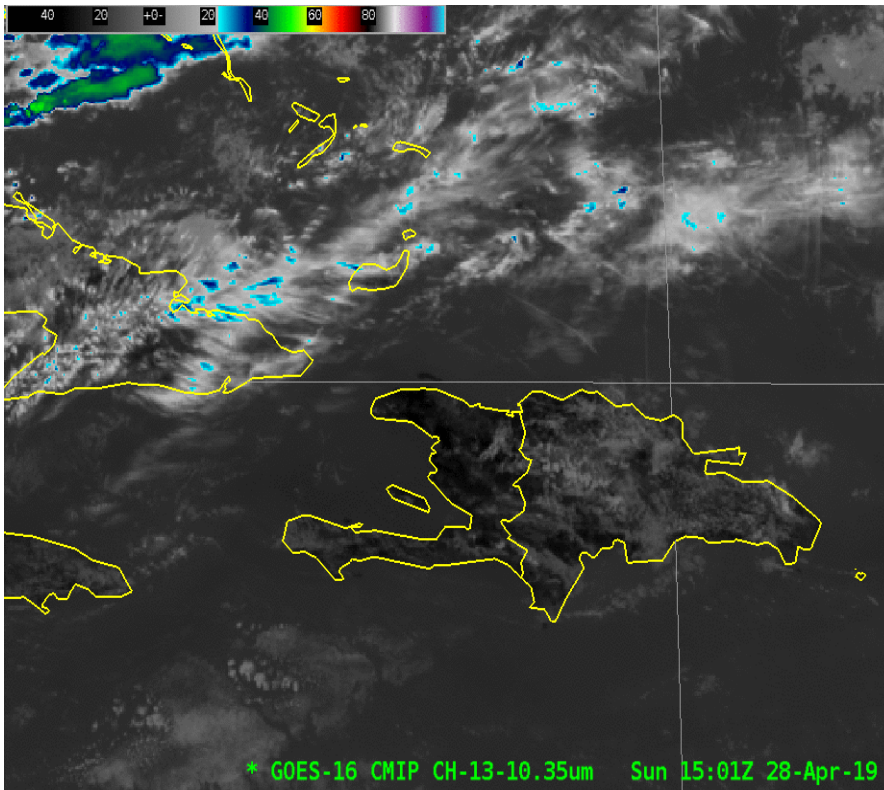
Santa Clara, Cuba - Severe Thunderstorm

- 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.

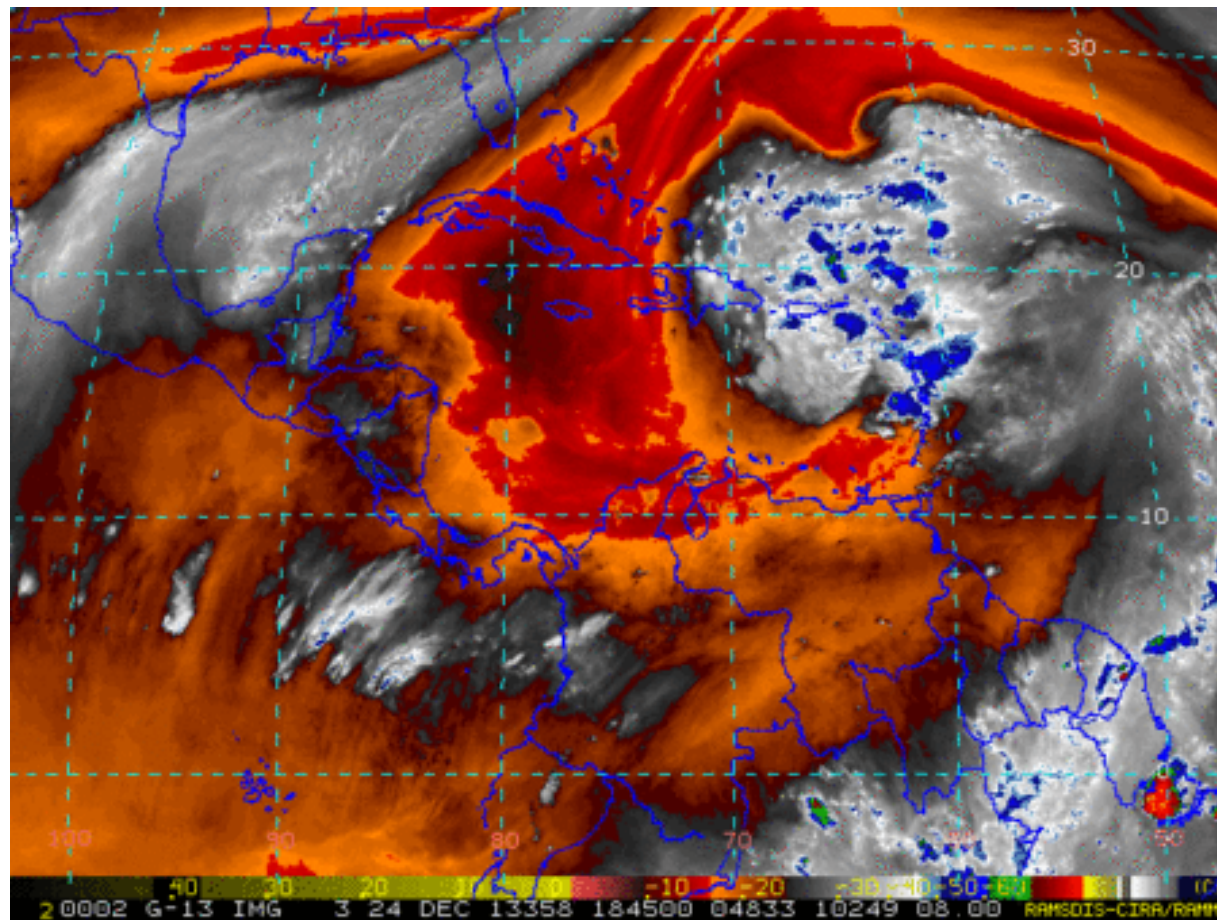
TUTT Enhanced Convection

Flash Flood

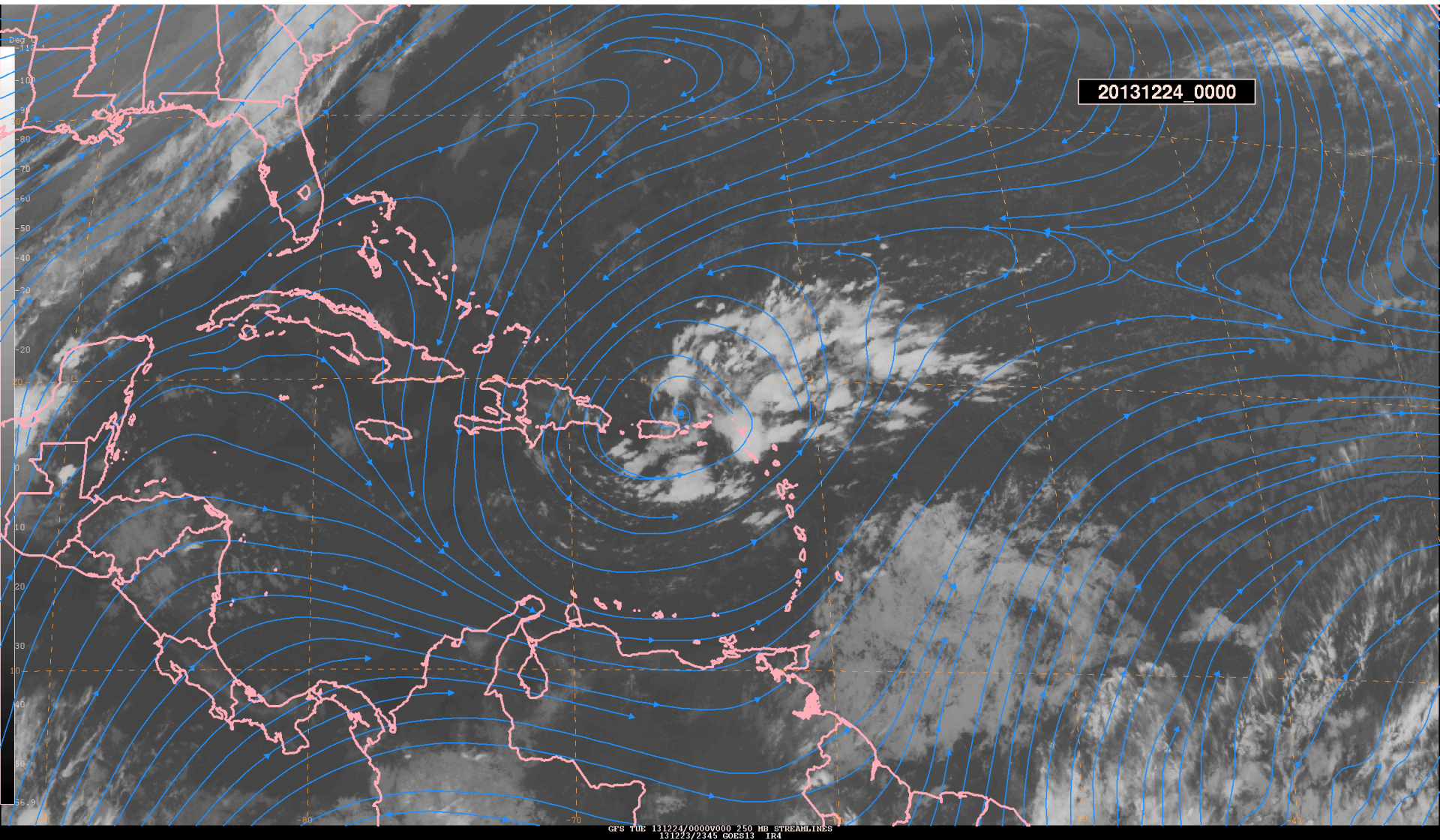
December 24, 2013

Kathy-Ann Caesar, CIMH

WV Animation



IR4 and GFS 250 hPa Streamlines

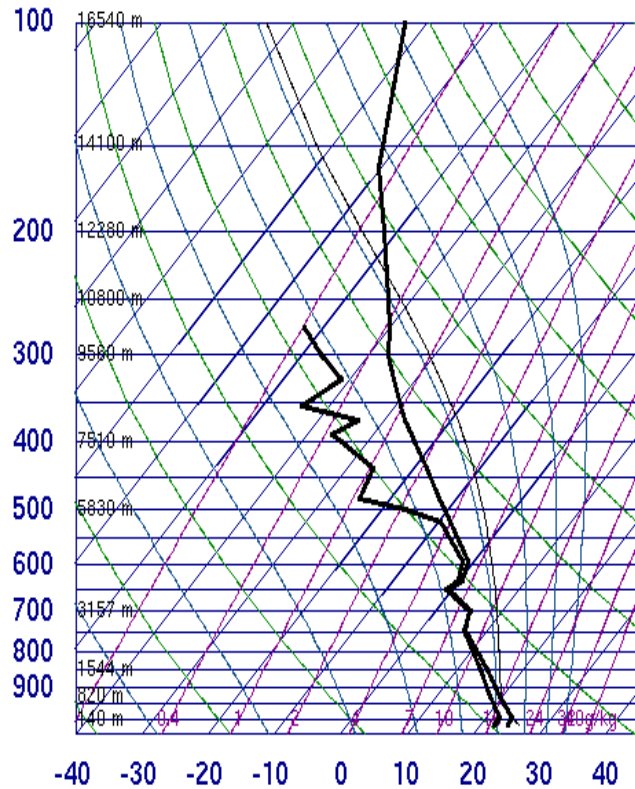


Upper level features and cloudiness

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

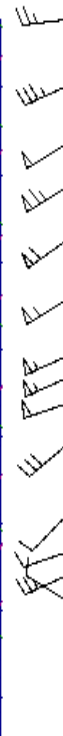
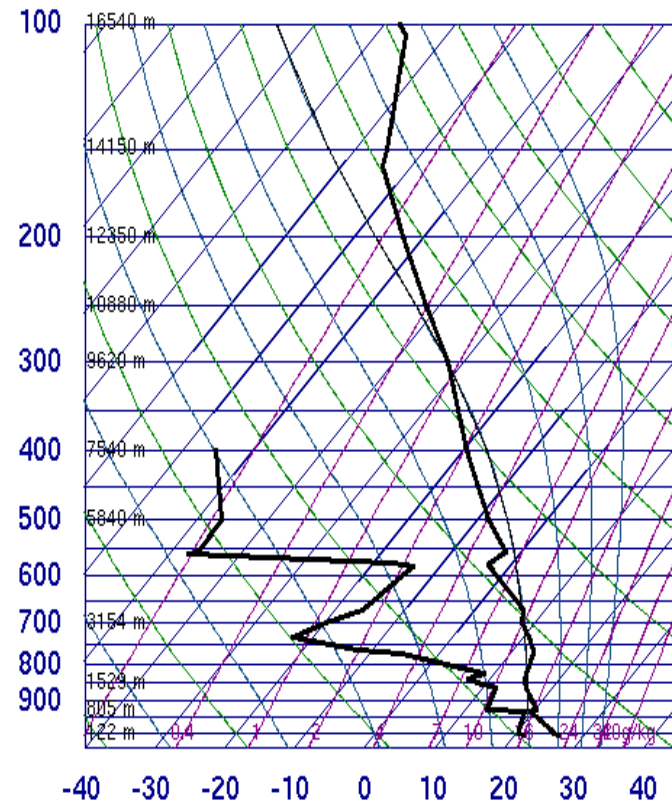


SLAT 16.26
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SELV 11.00
SHOW -1.90
LIFT -5.87
LFTV -6.42
SWET 222.1
KINX 38.60
CTOT 24.10
VTOT 25.10
TOTL 49.20
CAPE 1988
CAPV 2126
CINS -4.16
CINV -2.50
EQLV 230.4
EQTV 230.4
LFCT 926.1
LFCV 934.6
BRCH 316.7
BRCV 338.7
LCLT 294.1
LCLP 960.0
MLTH 297.5
MLMR 16.58
THCK 5680
PWAT 51.21

12Z 23 Dec 2013

University of Wyoming

78954 TBPB Grantley Adams



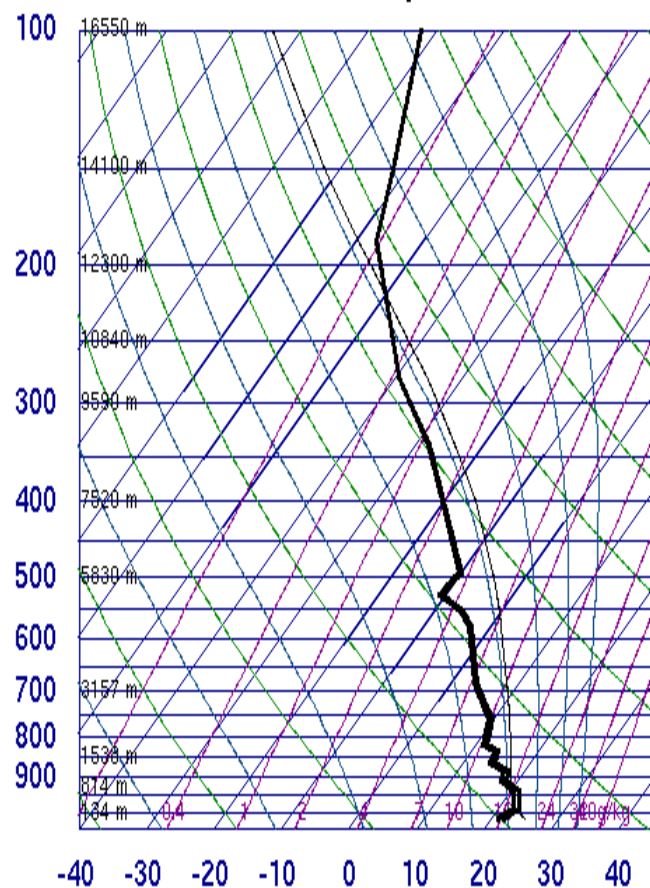
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SHOW 4.05
LIFT -2.84
LFTV -3.64
SWET 144.2
KINX 4.70
CTOT 17.10
VTOT 24.10
TOTL 41.20
CAPE 502.7
CAPV 719.3
CINS -9.27
CINV -0.46
EQLV 300.4
EQTV 300.6
LFCT 873.9
LFCV 912.0
BRCH 46.74
BRCV 66.88
LCLT 292.1
LCLP 925.9
MLTH 298.6
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12Z 23 Dec 2013

University of Wyoming

Soundings 1200 UTC 24-12-2013

78897 TFFR Le Raizet, Guadeloupe

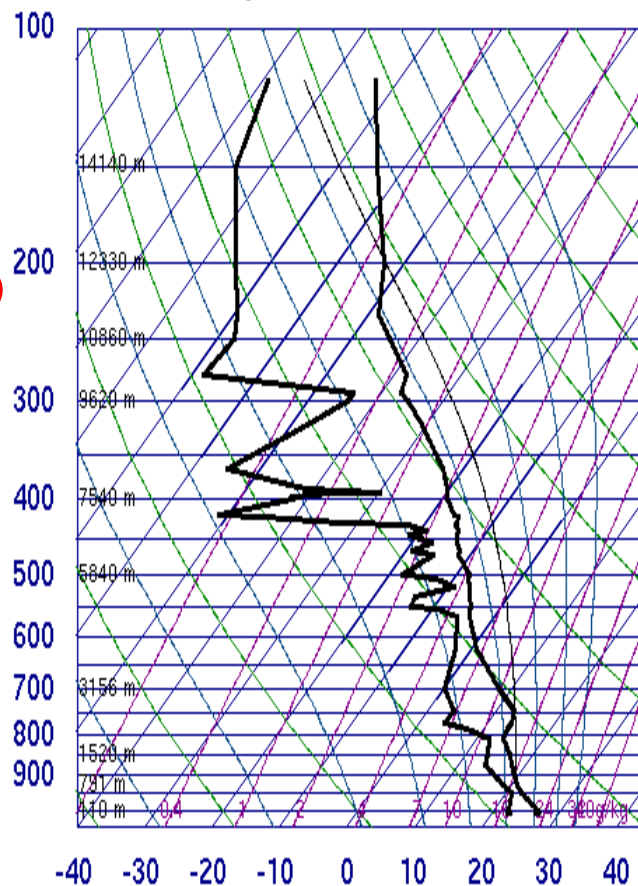


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 LIFT -5.36
 LFTV -5.69
 SWET 206.6
 KINX 37.90
 CTOT 23.90
 VTOT 24.50
 TOTL 48.40
 CAPE 1587.
 CAPV 1684.
 CINS -11.0
 CINV -11.4
 EQLV 219.4
 EQTV 219.2
 LFCT 919.8
 LFCV 921.1
 BRCH 722.2
 BRCV 766.5
 LCLT 294.5
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12Z 24 Dec 2013

University of Wyoming

78954 TBPB Grantley Adams



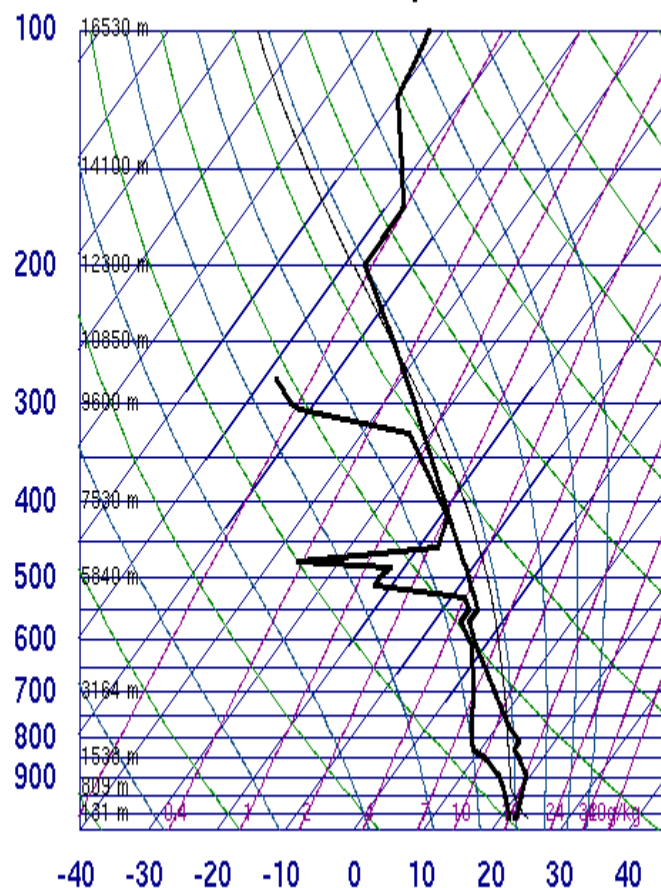
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 SLON -59.48
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 SWET 240.7
 KINX 30.30
 CTOT 21.50
 VTOT 24.90
 TOTL 46.40
 CAPE 1867.
 CAPV 2066.
 CINS -2.73
 CINV -0.72
 EQLV 197.9
 EQTV 197.7
 LFCT 912.1
 LFCV 929.1
 BRCH 67.16
 BRCV 74.31
 LCLT 294.1
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12Z 24 Dec 2013

University of Wyoming

Soundings 1200 UTC 25-12-2013

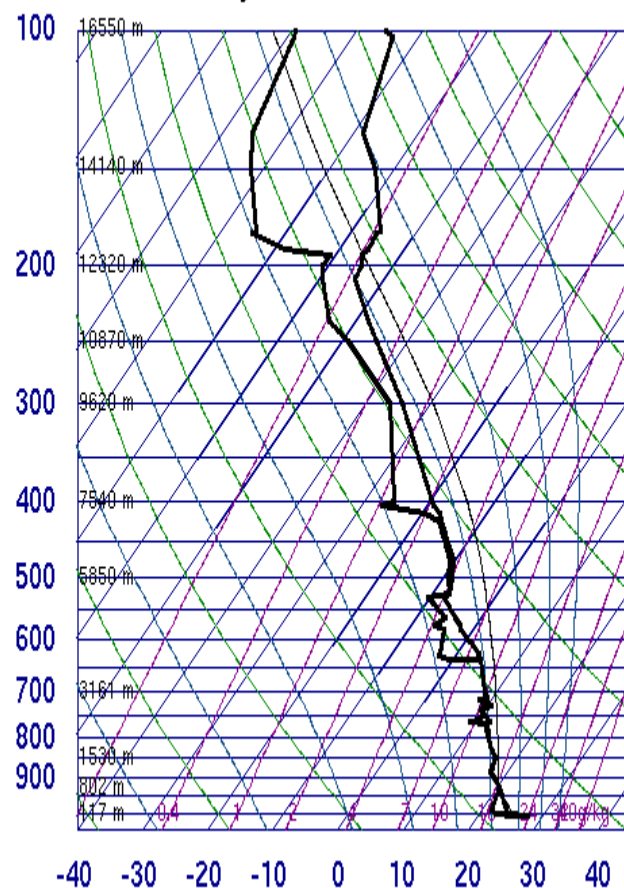
78897 TFFR Le Raizet, Guadeloupe



12Z 25 Dec 2013

University of Wyoming

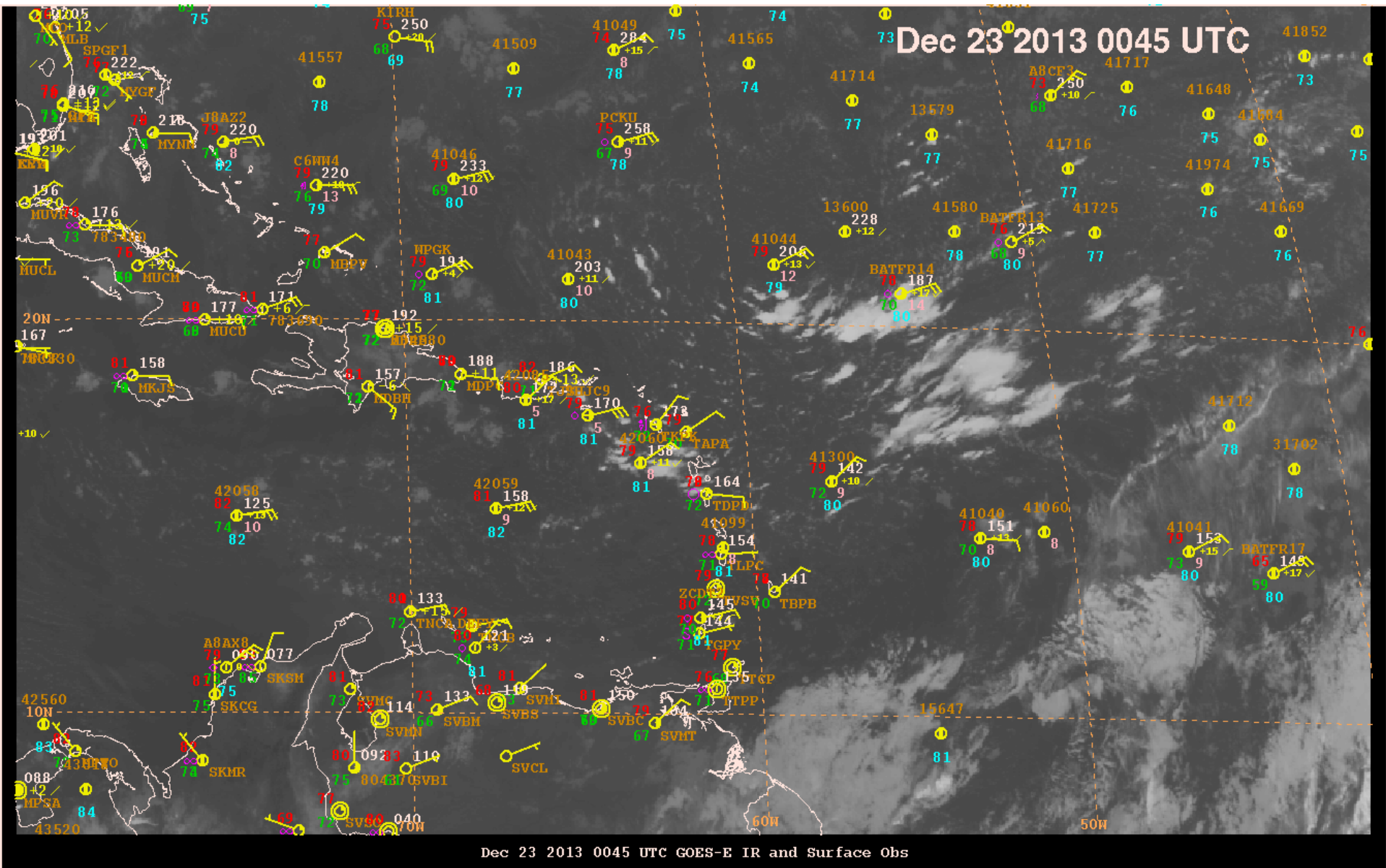
78954 TBPB Grantley Adams



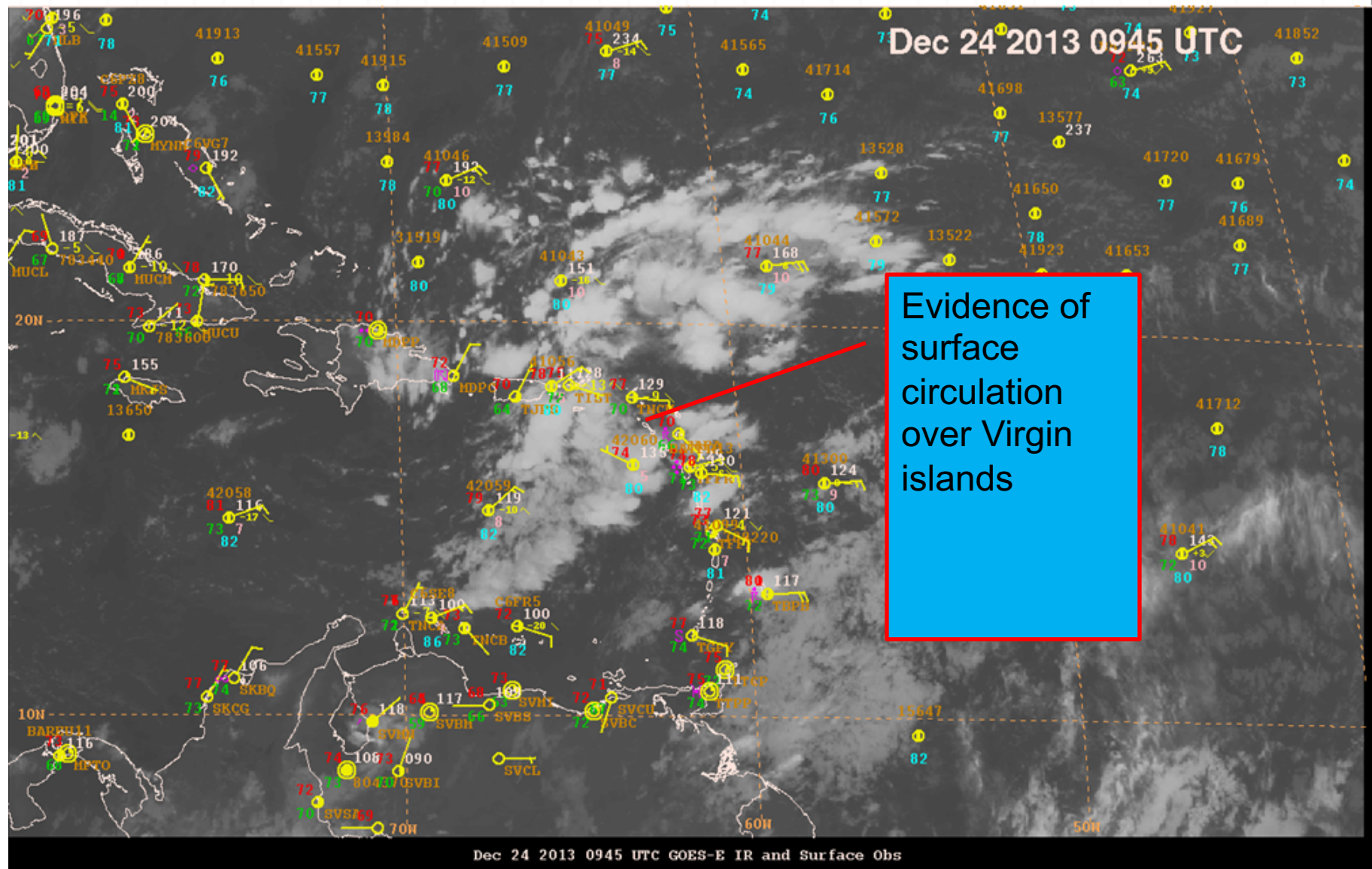
12Z 25 Dec 2013

University of Wyoming

Surface Obs and IR4 Animation

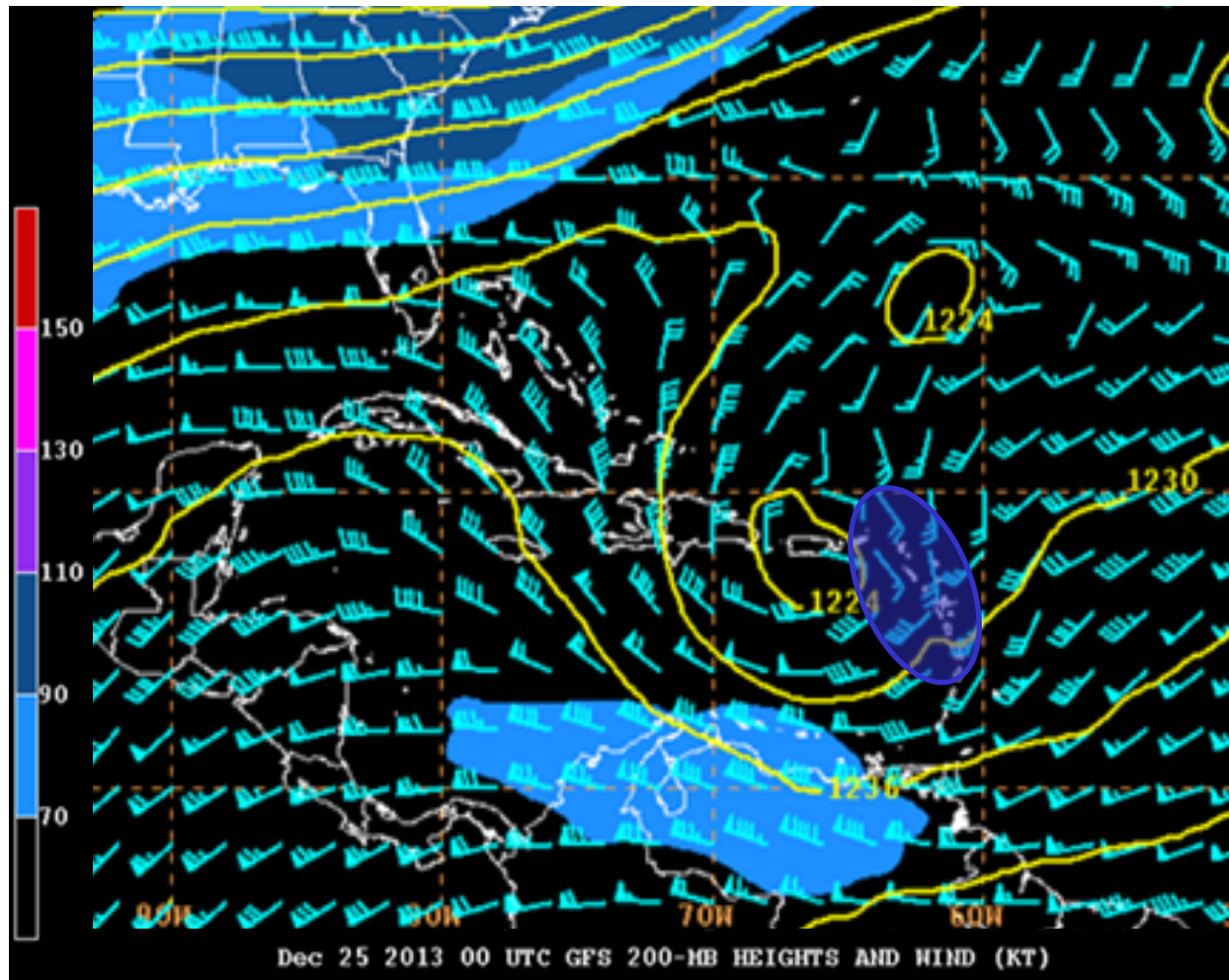


A quick view using GOES-E imagery



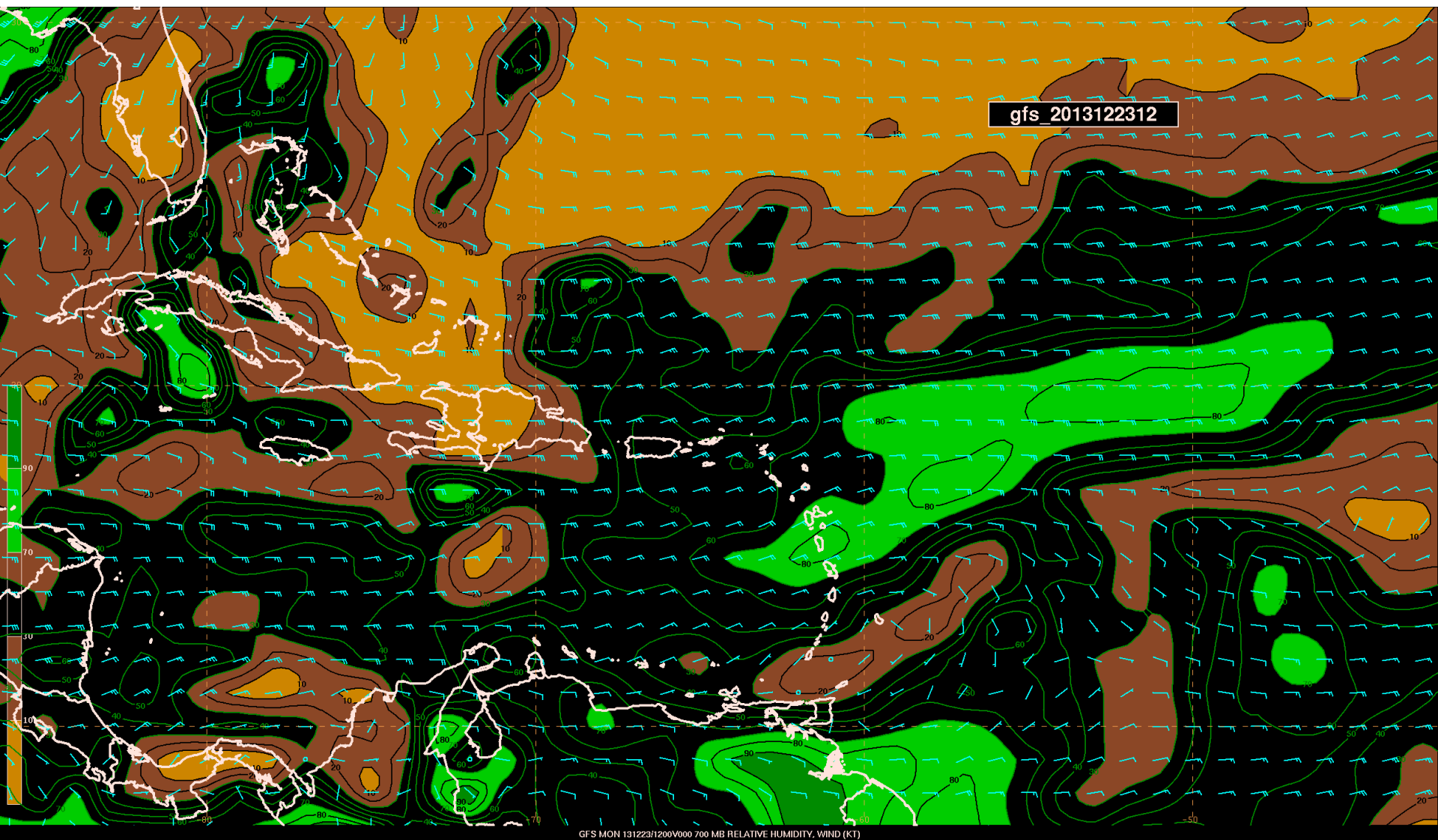
GFS 250 hPa Winds

VT: 20131225/00UTC



Diffluent
pattern aloft
+ Left Exit
Region of Jet
Maxima

Animation 700 hPa RH and Winds

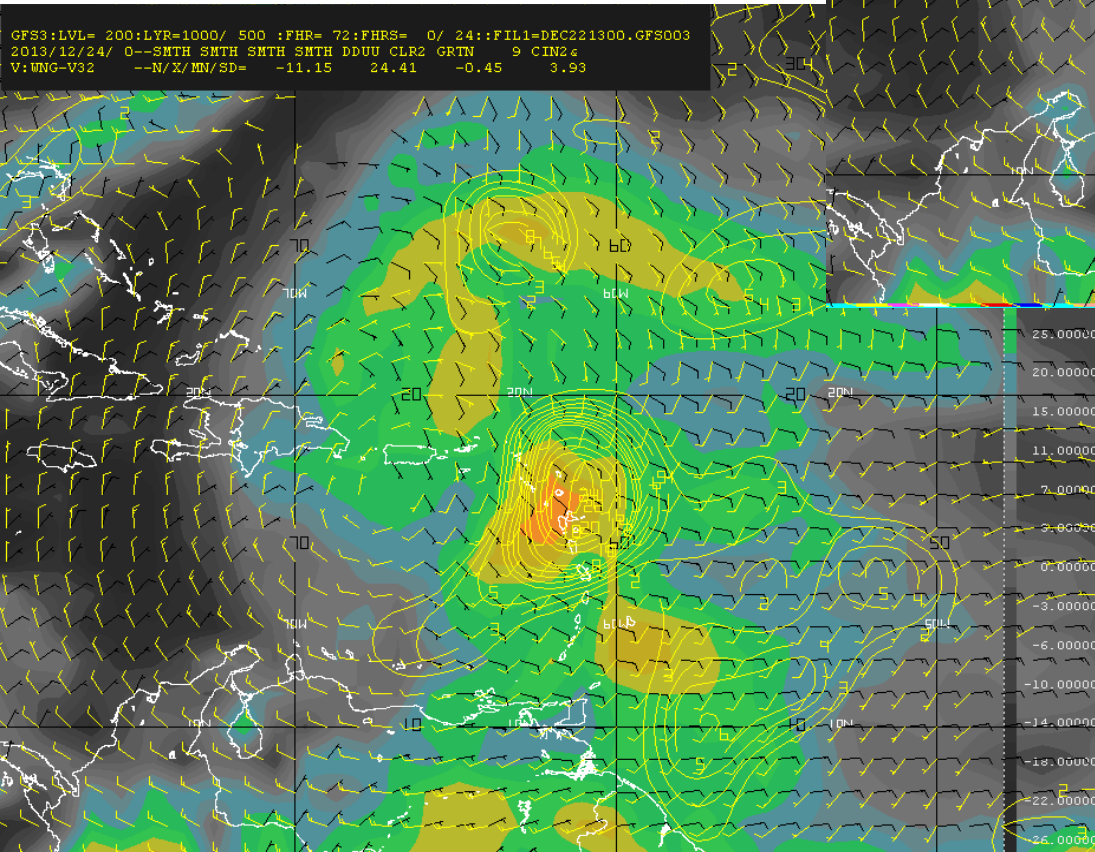
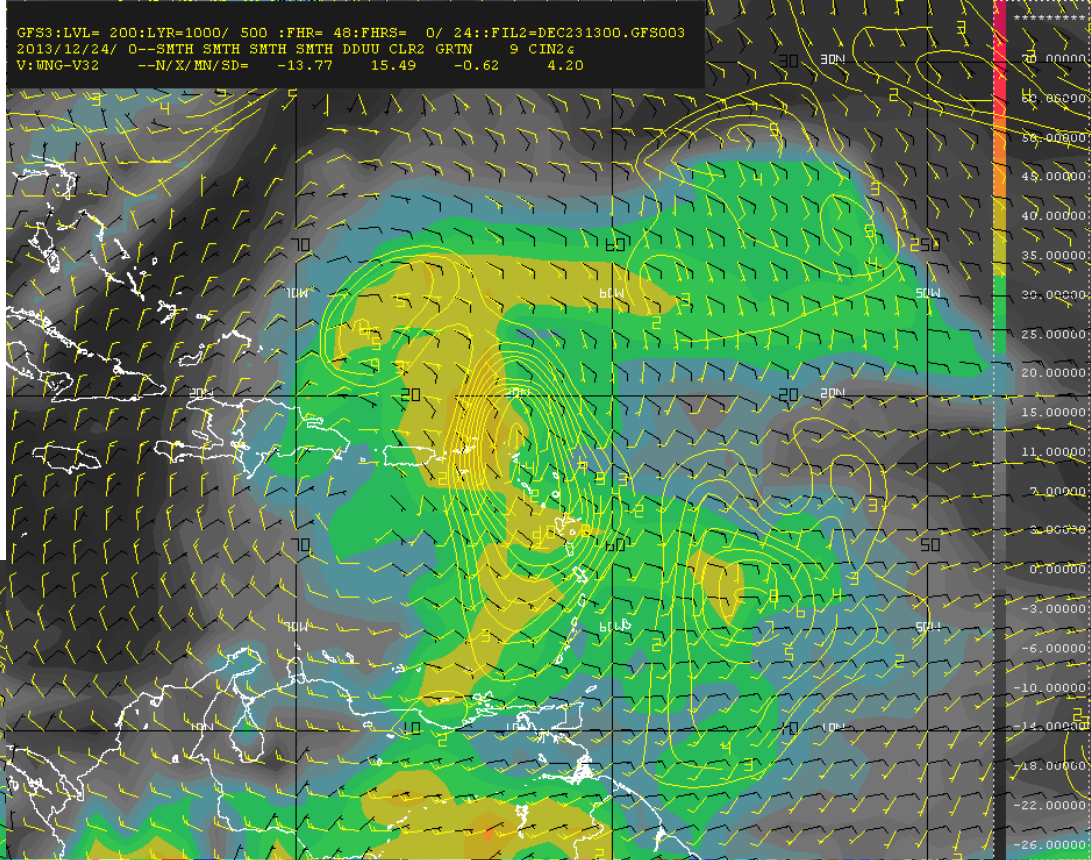


Model data

GFS 850 winds

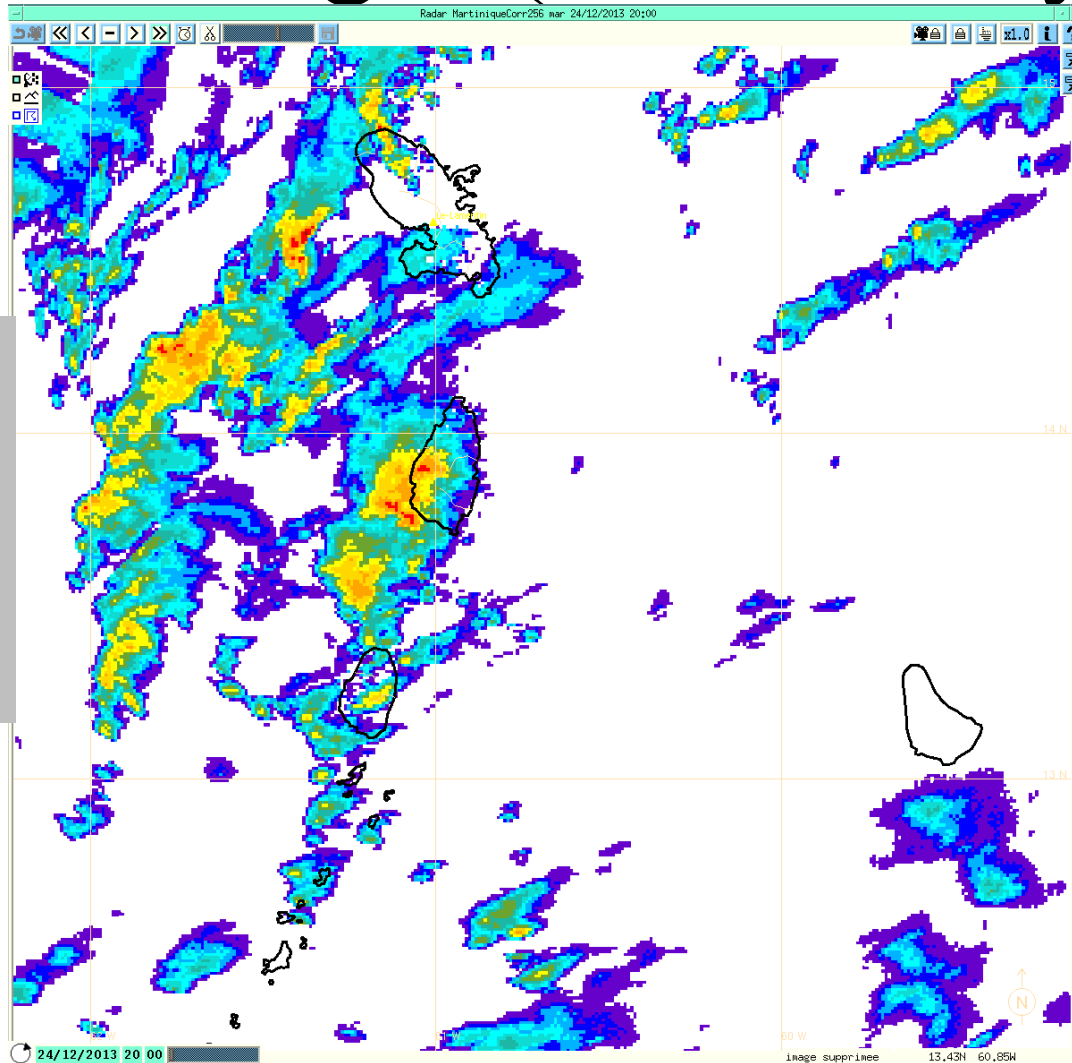
GFS 250 winds

GDI instability



- GFS model run from 22nd and 23rd

Radar Images (Reflectivity)

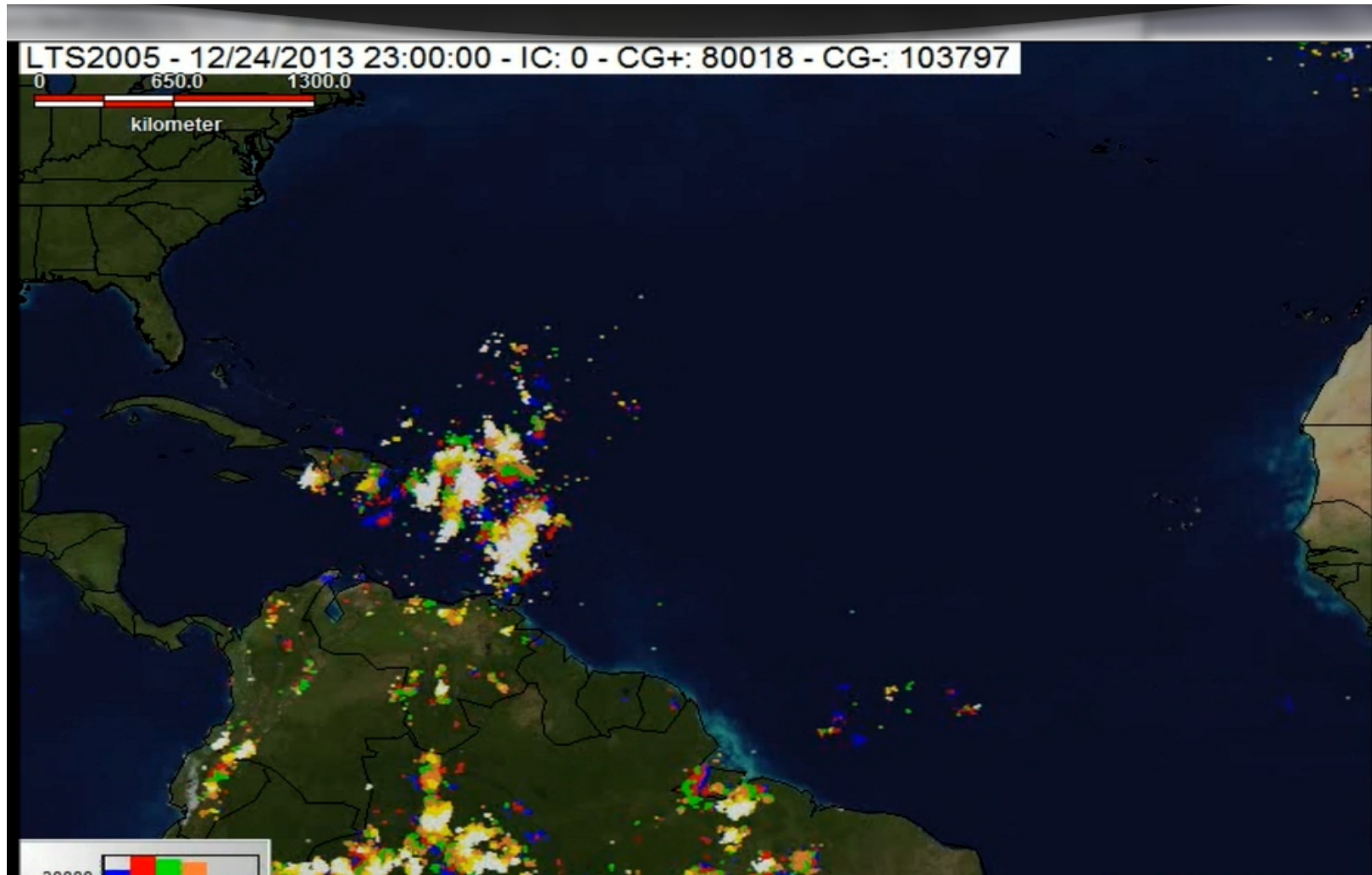


Note the
southwest to
northeast
propagation of
heavier echoes

Radar loop
Courtesy
MeteoFrance

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

Lightning Data



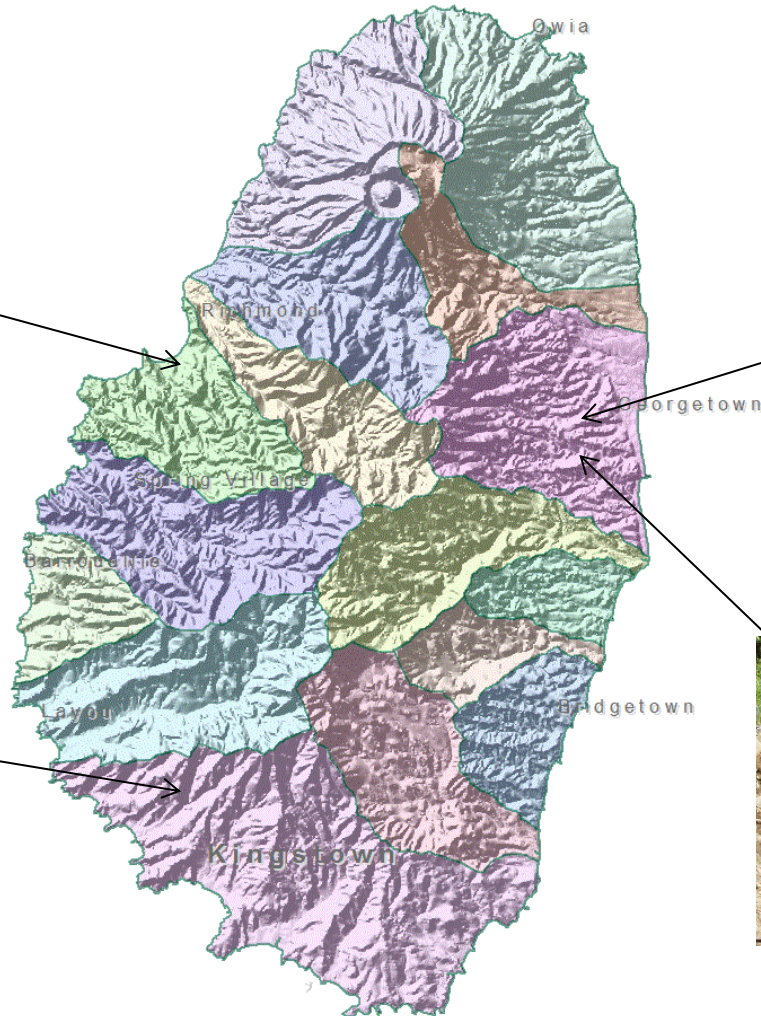
Impact



Chateaubelair



Buccament



World Bank Report



Georgetown



Congo Valley

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

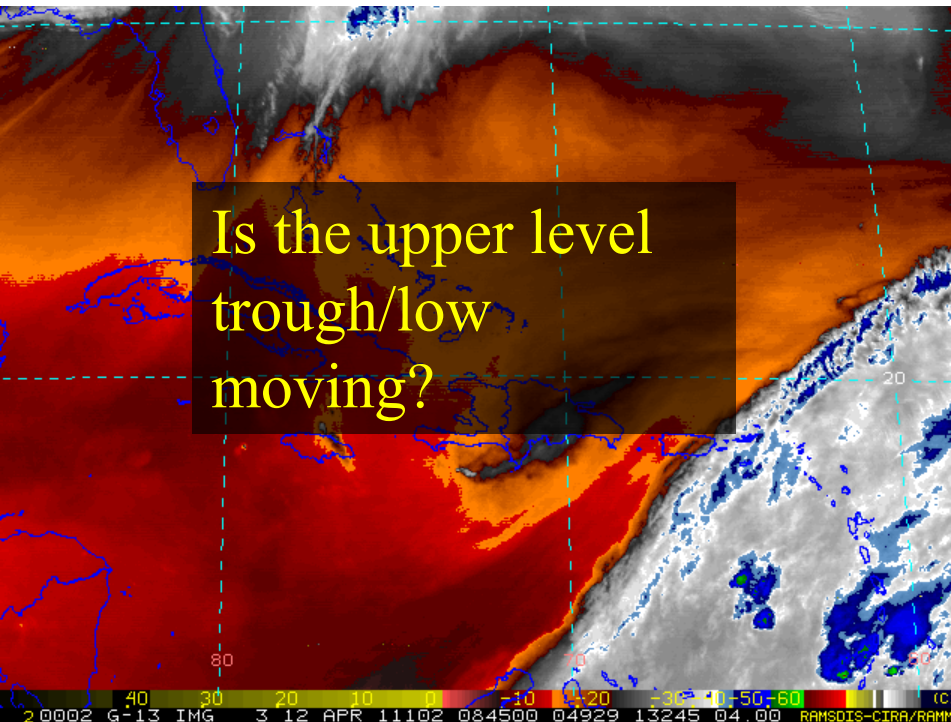
- Is a **cold core tropospheric** trough, with axis from surface to mid/upper levels of the atmosphere, considered a TUTT?
- Can we use the 6.2 micron water vapor images to identify low level circulations?
- Are tropical waves and induced troughs in the low level easterlies the same thing?
- What's the 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

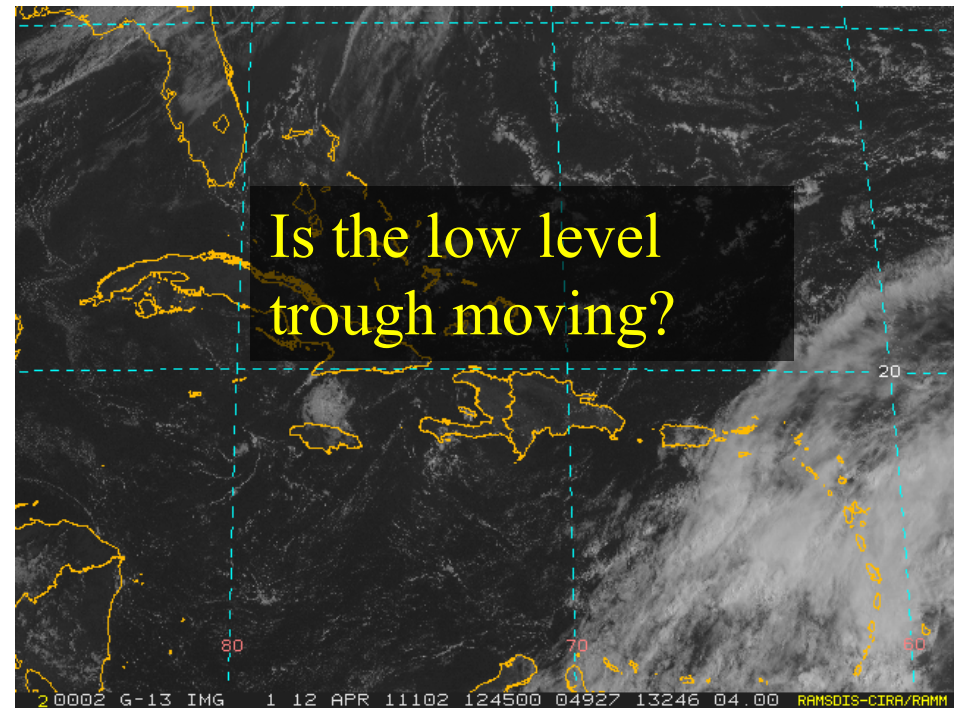
- When the interaction between a tropical wave and a TUTT is considered positive/negative?
- How can we apply the three GOES-16 water vapor images to distinguish between a Tropical Wave and an induced trough?

WV and Visible Images.

Is the perturbation in the low level easterlies a tropical wave or a TUTT induced perturbation?



GOES-12 (WV)



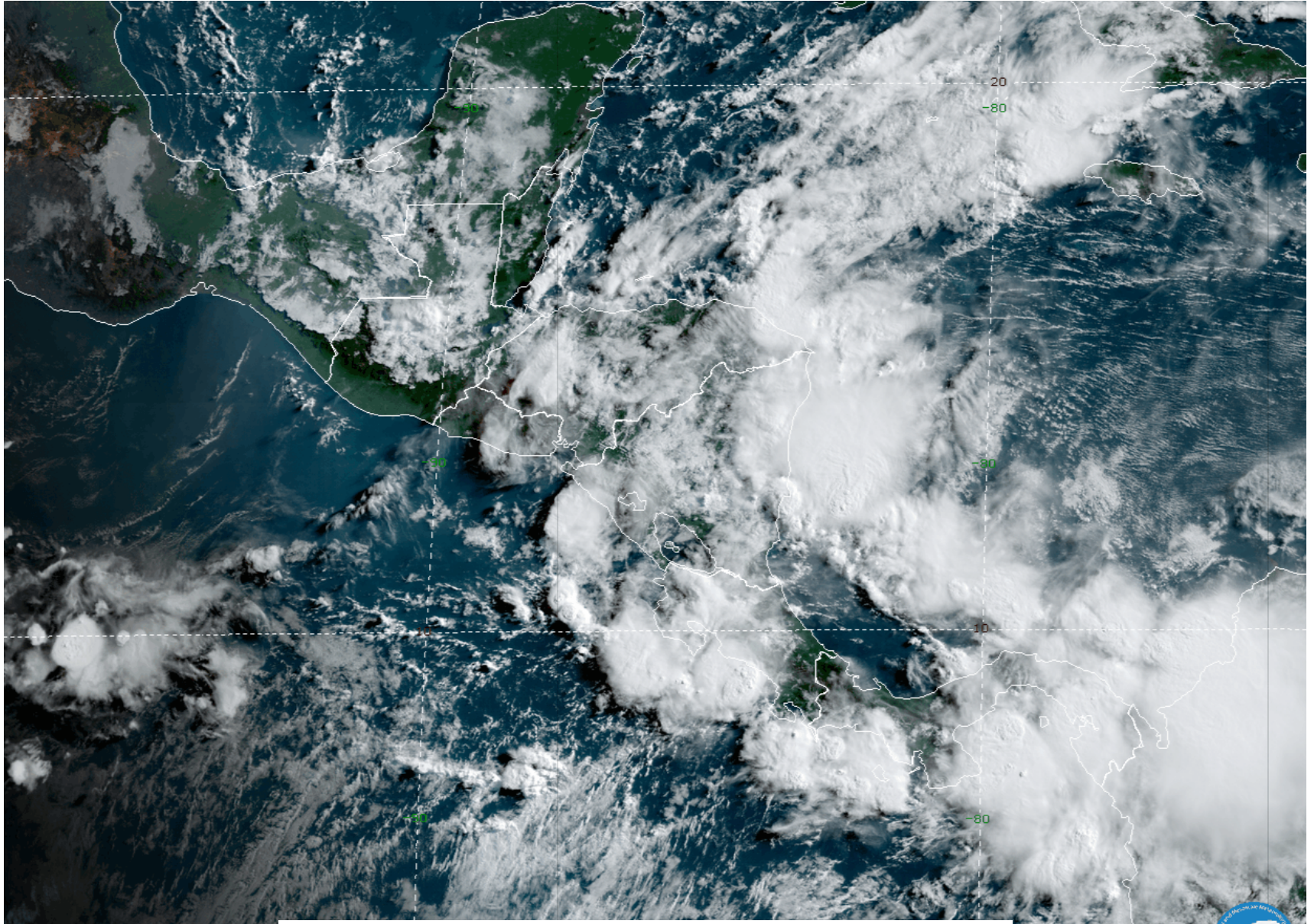
GOES-12 (Vis)

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?



2020-06-15 12:50:18 UTC

Part 2 – Poll Question #6

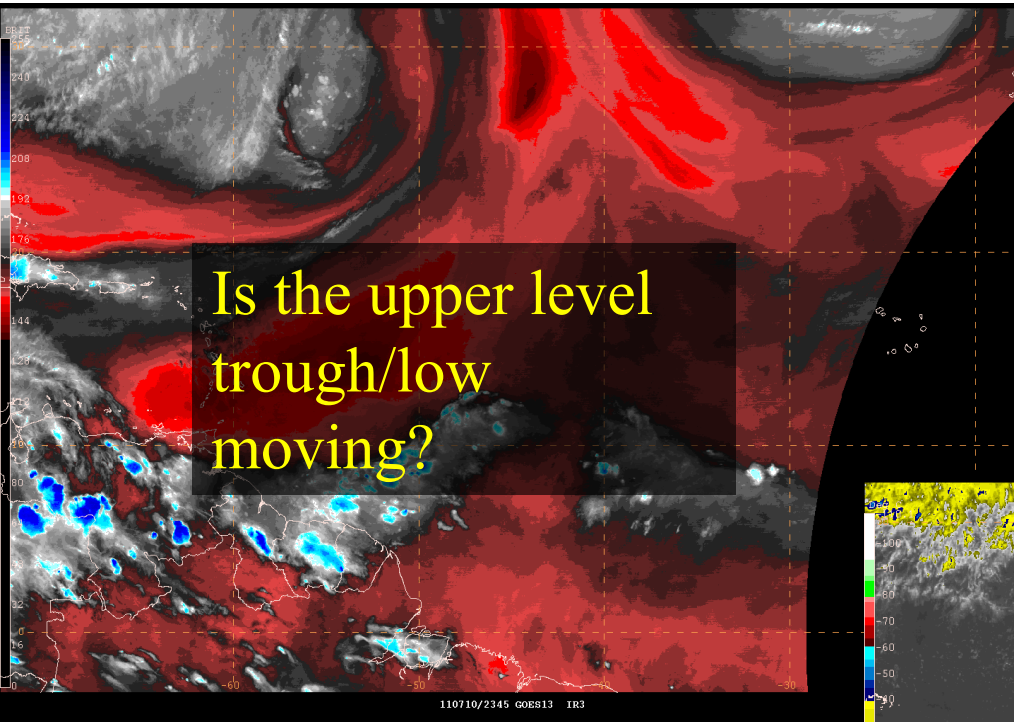


Part 2 – Poll Question #6

(Select all that apply)

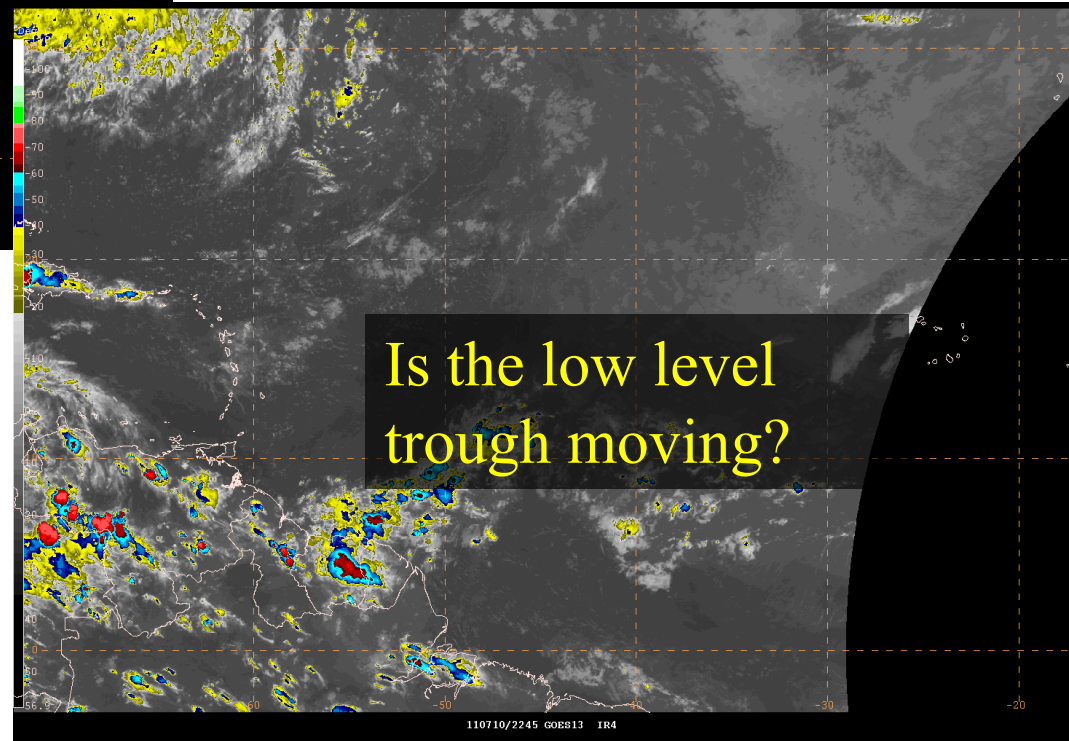
- This is a negatively tilted wave
- Convection precedes (west) the wave
- This is a positively tilted wave
- Convection follows (east) the wave
- None of the above

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



GOES-12 (IR)

GOES-12 (WV)



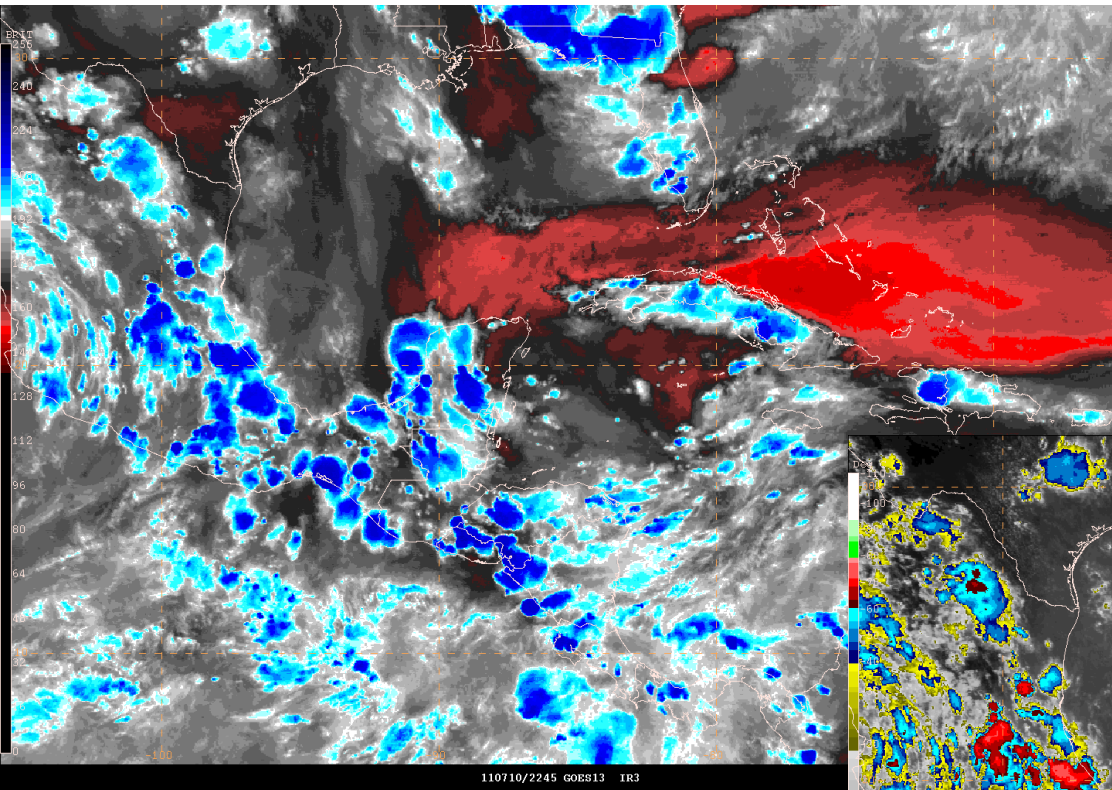
Part 2 – Poll Question #7

Part 2 – Poll Question #7

(Select one)

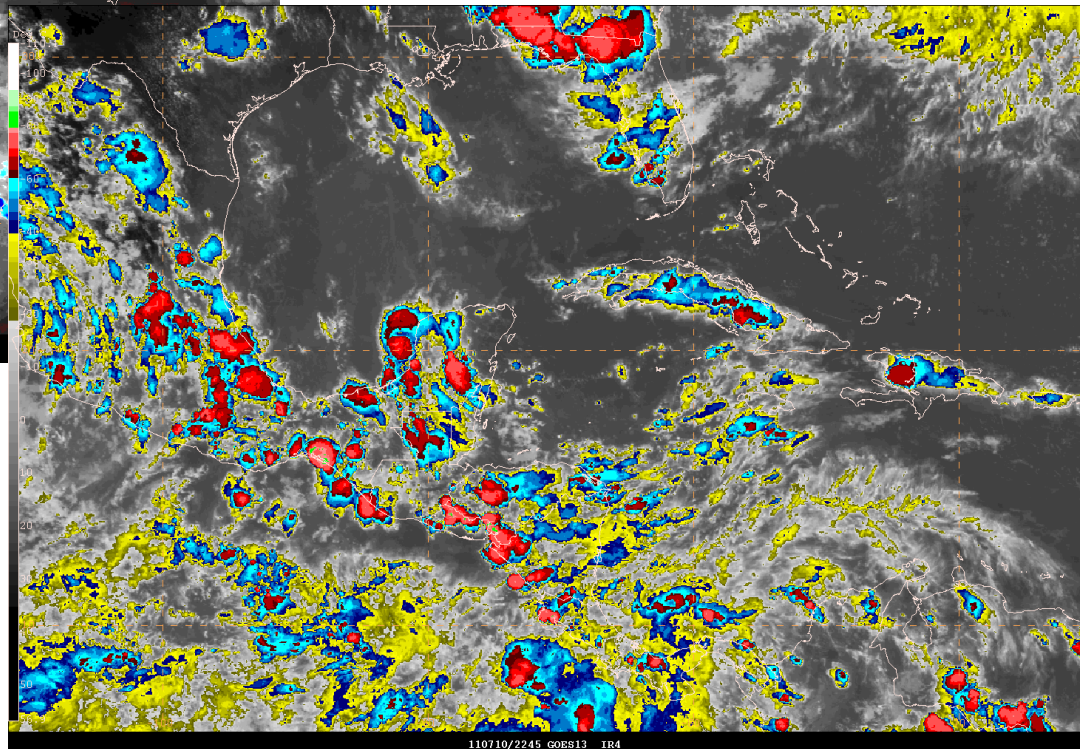
- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above

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



GOES-12 (IR)

GOES-12 (WV)



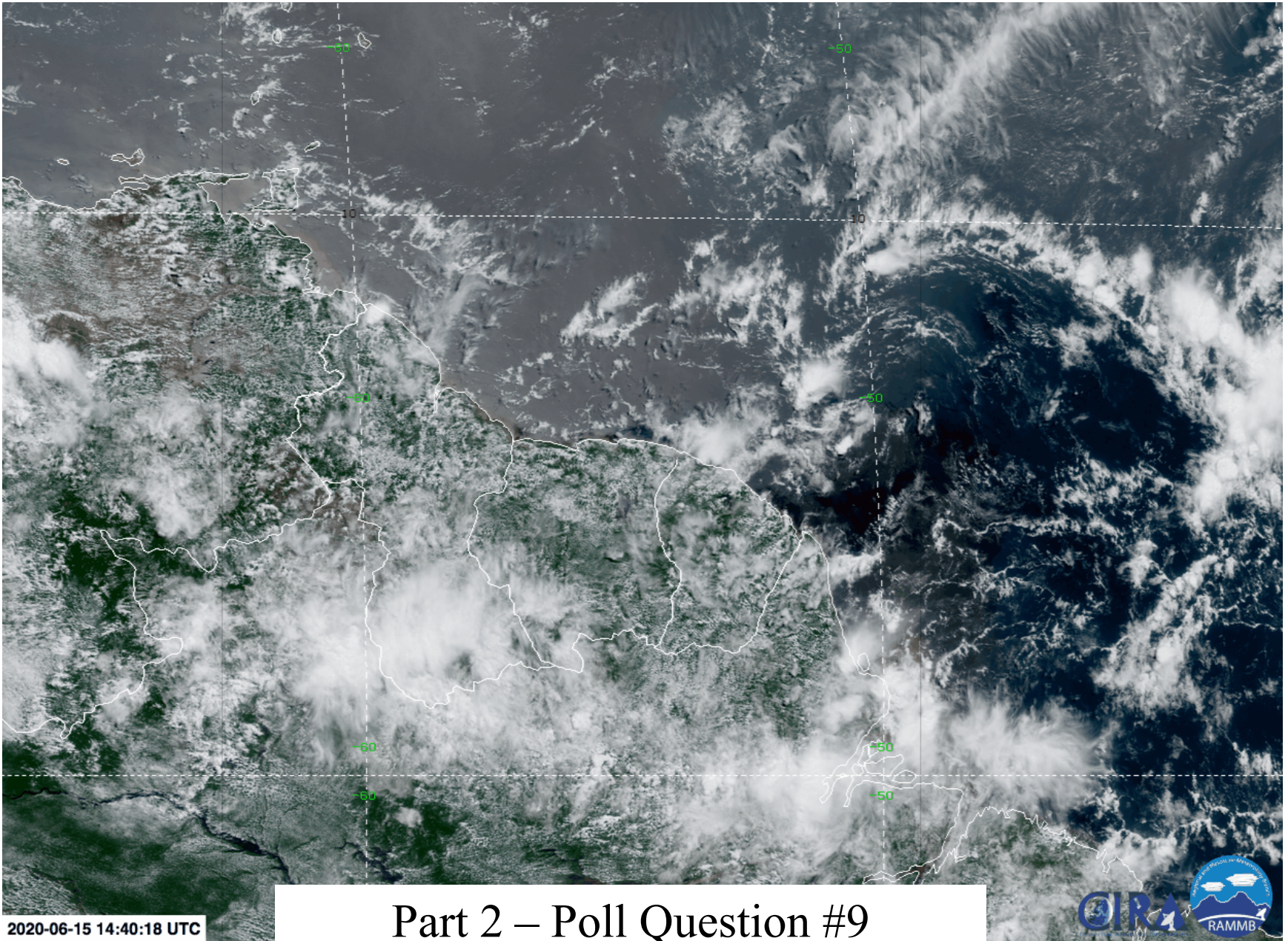
Part 2 – Poll Question #8

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?

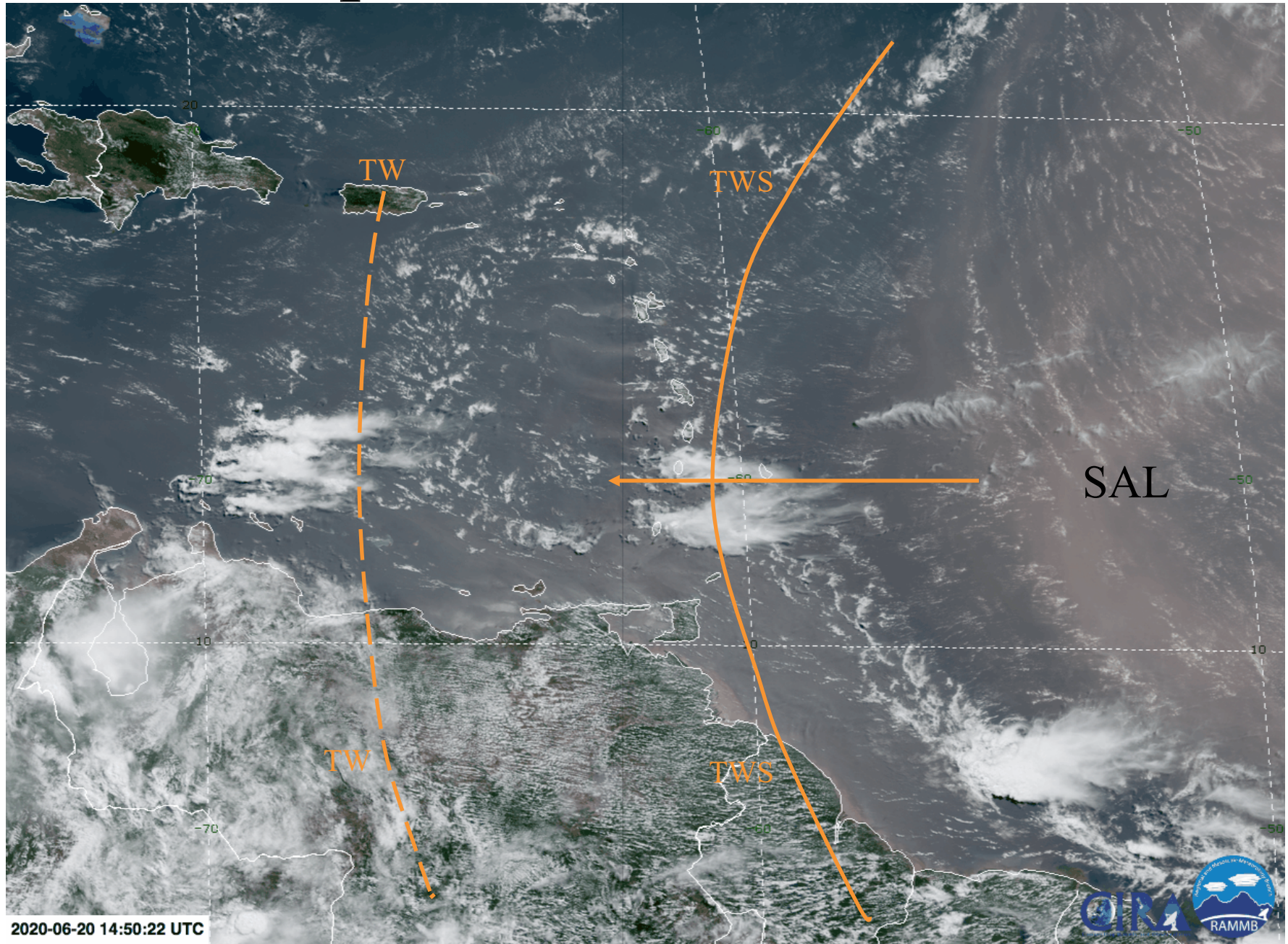


Part 2 – Poll Question #9

(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?



References

- NWS Southern Region Forecaster Notes Number 5, 01 September 1992. Easterly Waves, or TUTT Lows? Sources of Confusion over the Atlantic, Puerto Rico, and along the Gulf Coast in Summer.
- USAFETAC/TN-89/003, *The Caribbean Basin, A Climatological Study*, December 1989
- AFCC Theater Climatic File CD. Volume 4: South America, South of the Amazon River, Ver. 1.0 June 1998.
- Burpee, R.W., 1972: The origin and structure of easterly waves in the lower troposphere of North Africa. J. Atmos. Sci., 29, 77-90.
- Dvorak, V.F., 1975: Tropical cyclone intensity analysis and forecasting from satellite imagery. Mon. Wea. Rev., 180, 1915-1923.
- Riehl, H., 1945: Waves in the easterlies and the polar front in the tropics. Misc. Rep. 17, Dept. Meteor., Univ. Chicago. 79 pp.
- _____, 1954: Tropical Meteorology. McGraw-Hill Book Co., New York, NY. 392 pp.
- Graphics generated using the Wingrids/PcGrids software to display the GFS/AVN global model.
- Satellite images provided by NOAA/NESDIS under permission.