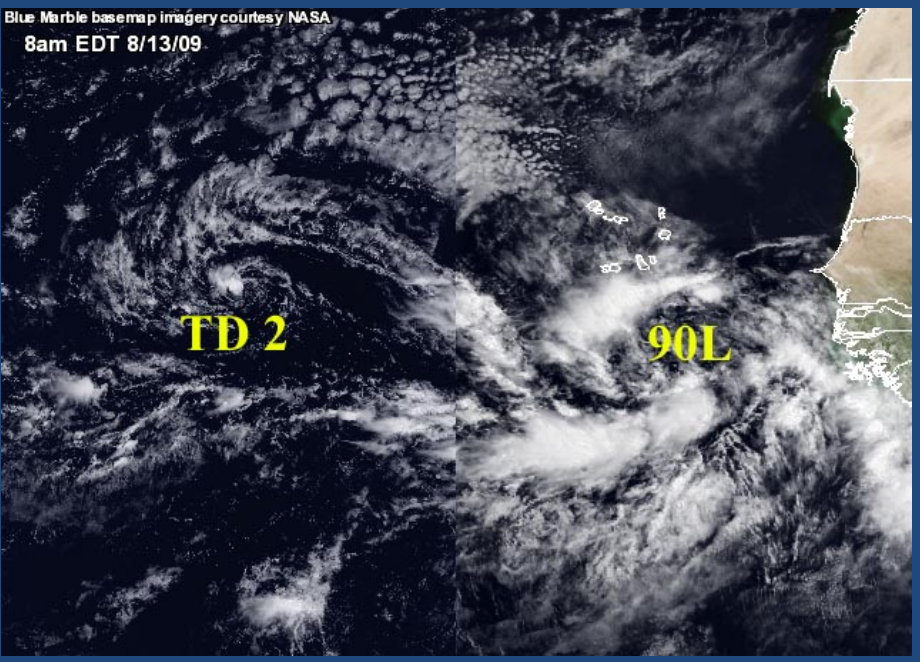
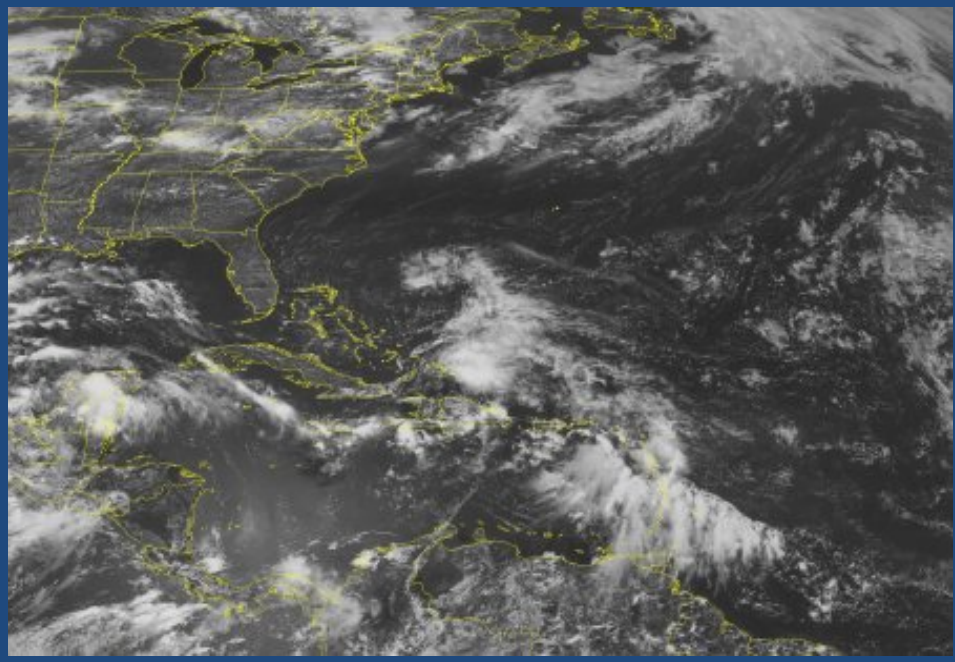
Tropical Waves





John Cangialosi and Andrew Levine
National Hurricane Center

WMO Region IV
Tropical Cyclone Workshop

Outline

- Basic definition/research
- Schematic diagrams/Interactions
- Operational products/forecasts
- Tools for tracking
- Exercise

What are tropical waves?

* Perturbations / disturbances in the tropical easterlies that typically move from east to west.

* Often seen as inverted troughs of low pressure (inverted-V pattern in satellite imagery). Significant rain producers.

* Convection typically on the east side. Subsidence/clearing on the west side.

* Convection highly modulated by atmospheric moisture, upper level features, topography, etc.

* Develop into tropical cyclones.

* Around 60 tracked per year (little annual variability)

Tropical Wave Research

Tropical wave basics

Significance known as far back as 1930s (Piersig, Regula)

Patterns of rain, cloudiness, and windshifts received increased attention during WWII (Riehl, 1945)

With the growth of rawinsonde networks and better surface synoptic data, easterly waves were studied with 3 approaches:

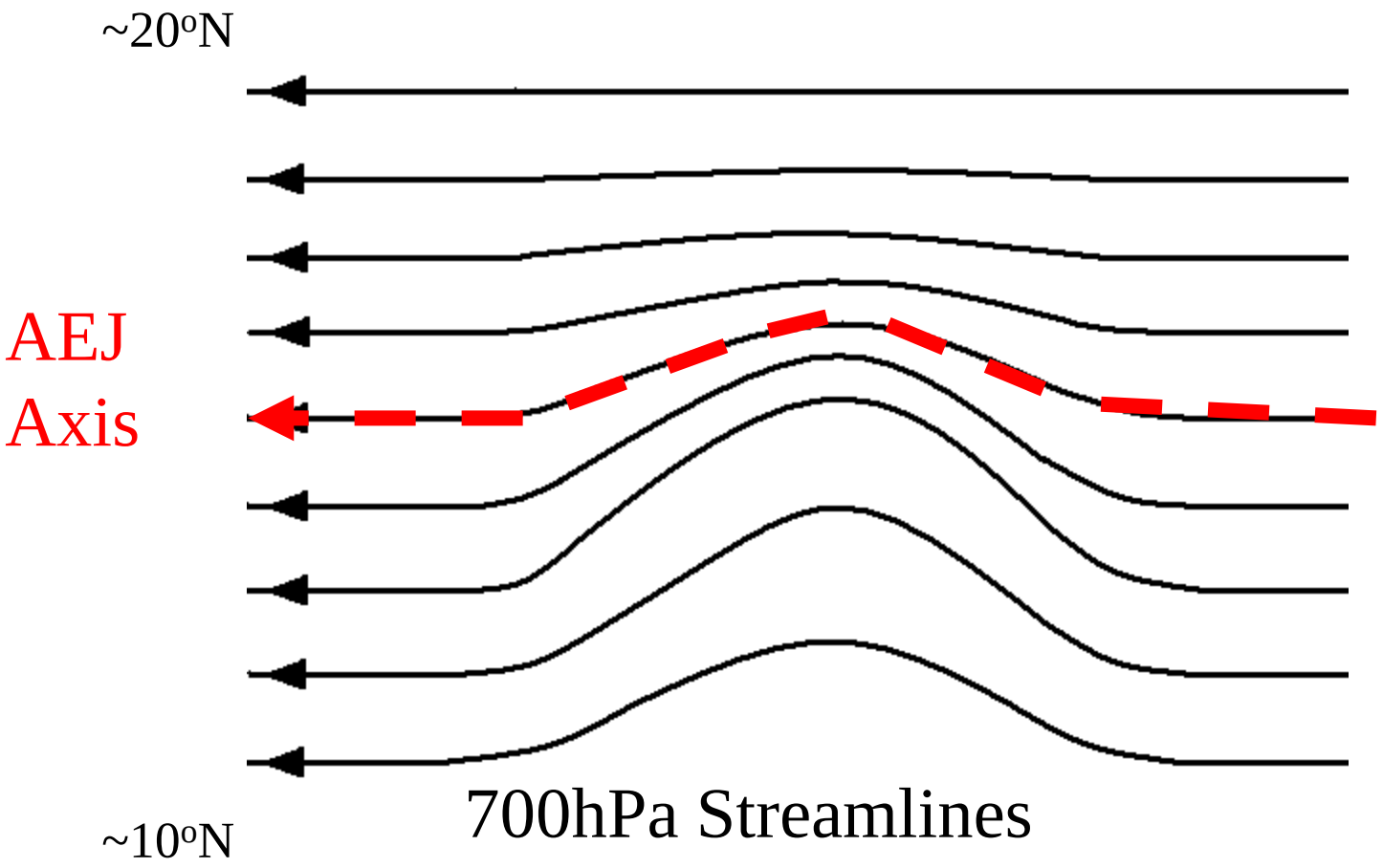
Synoptic (Carlson, 1969)
Spectral analysis (Burpee, 1972)
Compositing (Reed et al. 1971 (Pacific), 1977, 1979 (Atlantic))

The composite from Reed (1977) still serves as the primary 'text book' description of AEWs.

How/where they form

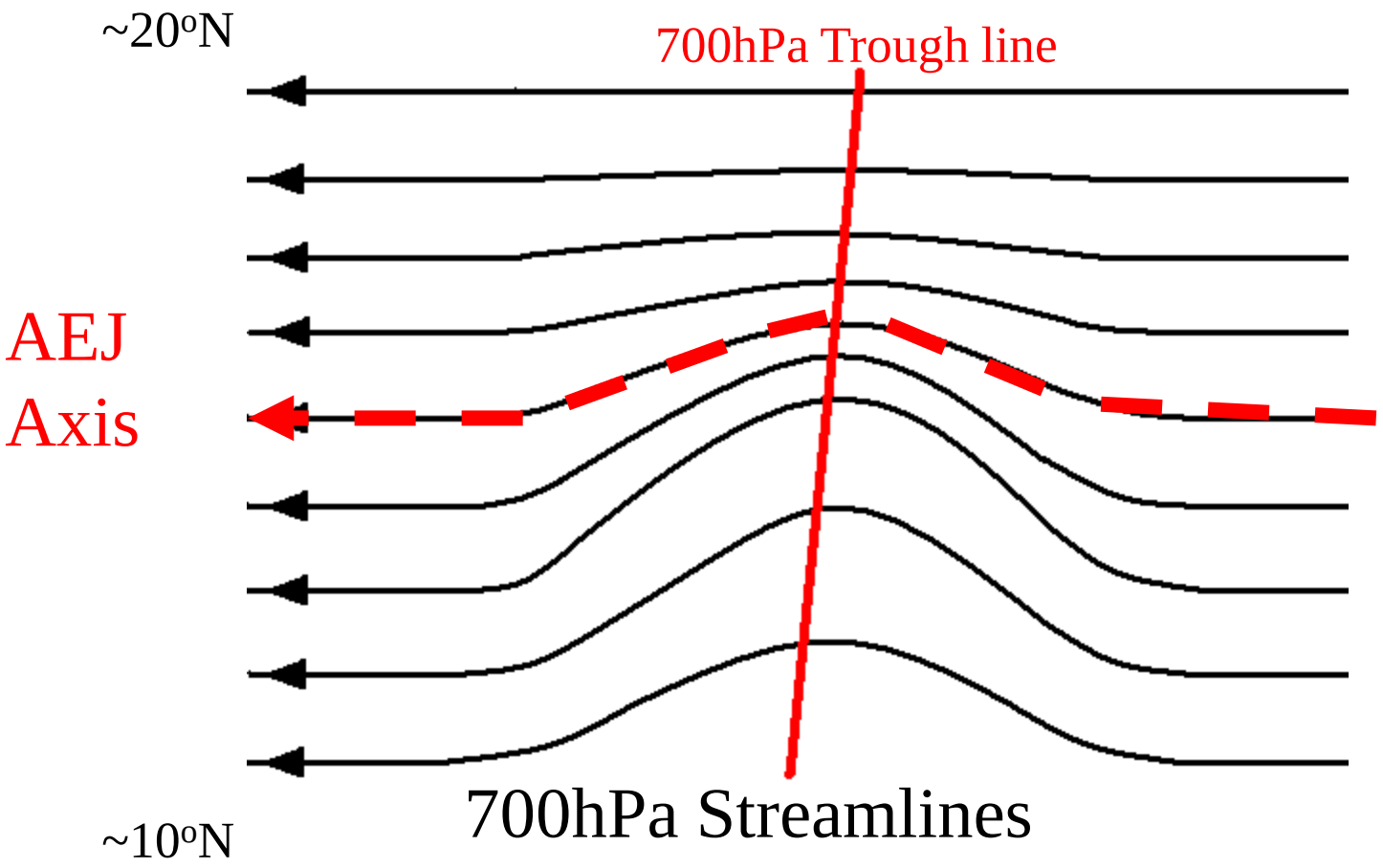
- Generated by an instability (baroclinic-barotropic)of the African easterly jet
- Jet arises as a result of reversed lower tropospheric temperature gradient over west-central north Africa due to extremely warm temperatures over the Sahara Desert and substantially cooler temperatures along the coast of Guinea.

AEW synoptic structure over West Africa.



Synthesis of Carlson (1969a, b), Burpee (1972,1974), Reed et al (1977)

AEW synoptic structure over West Africa.



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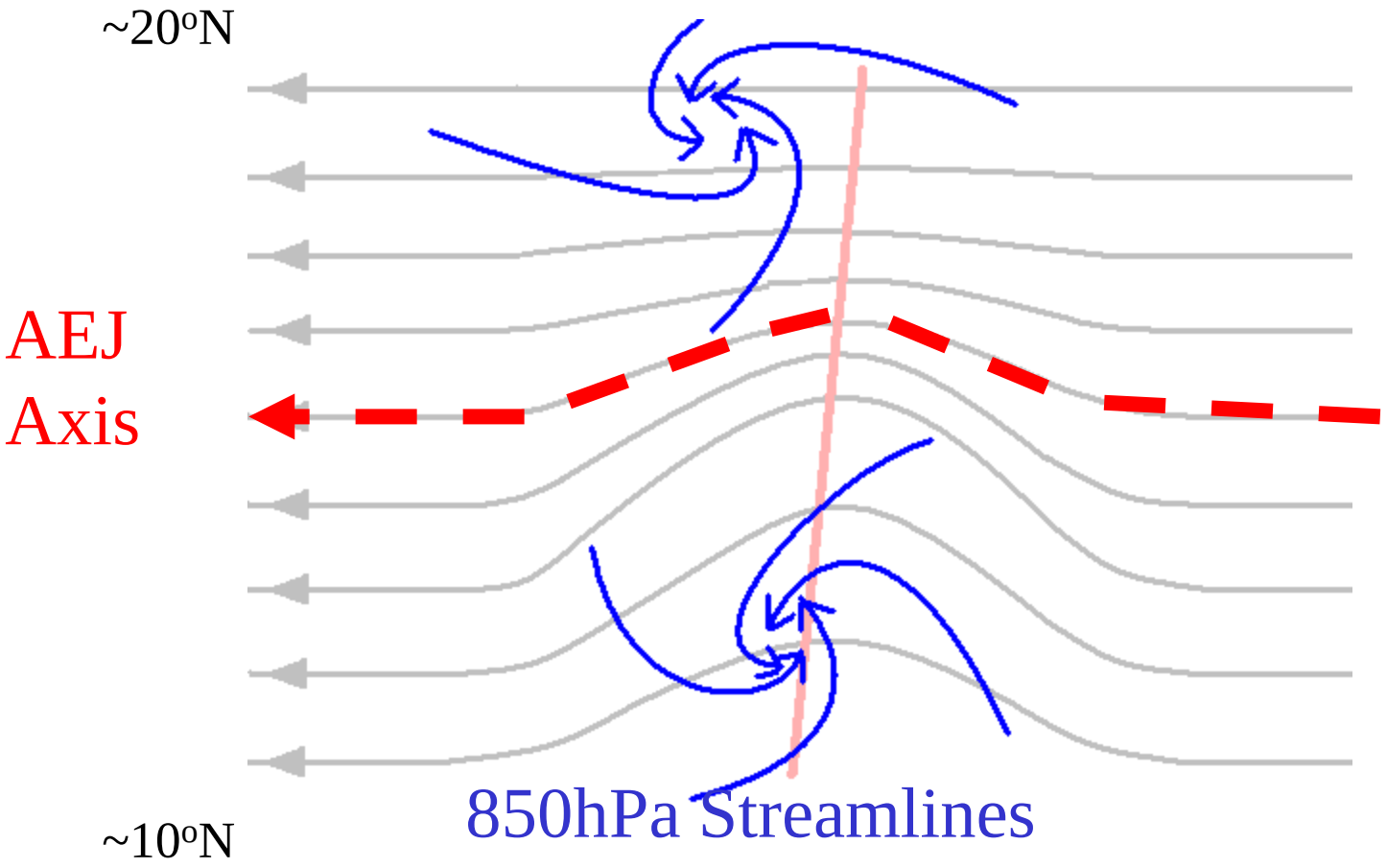

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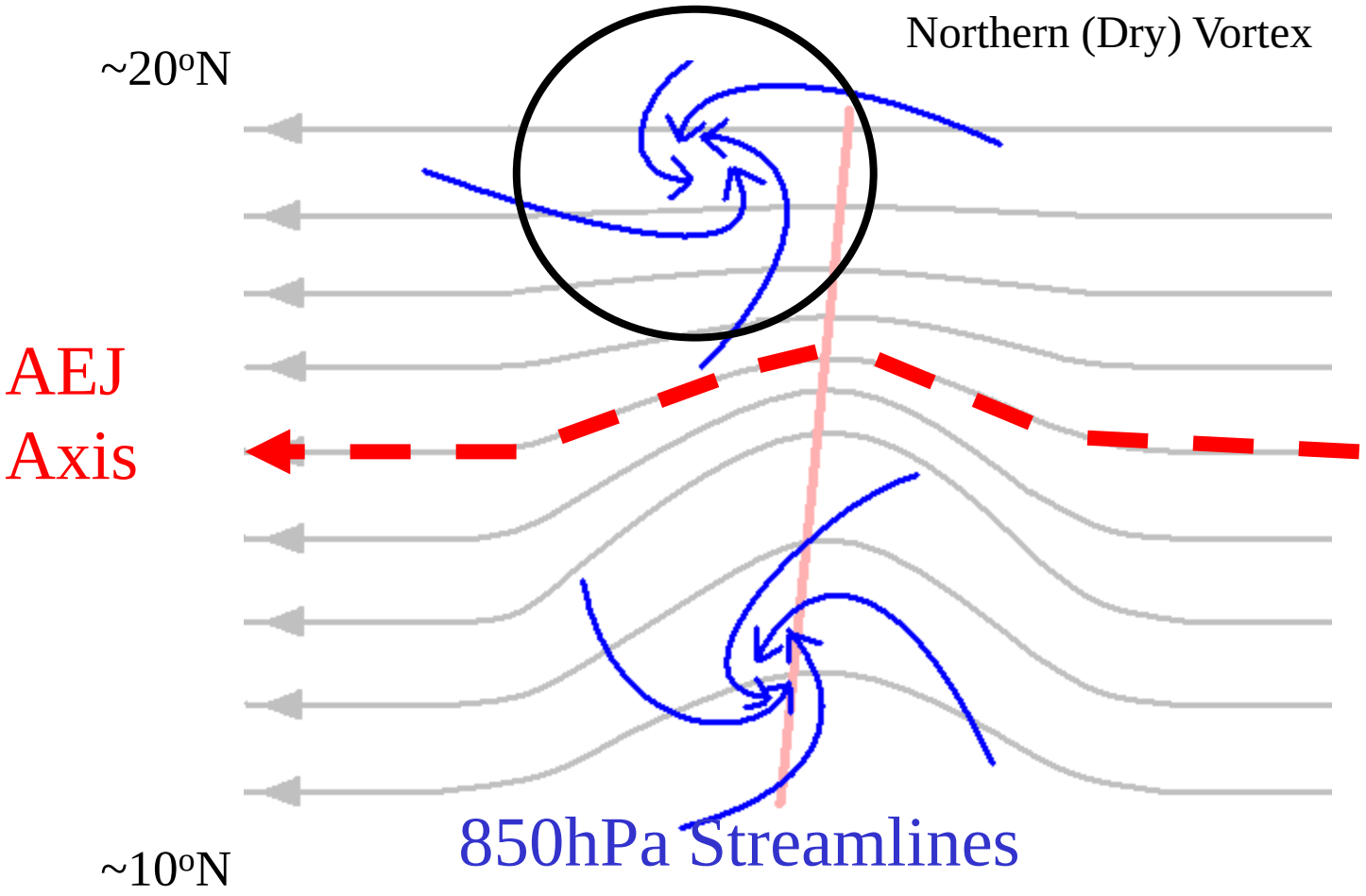

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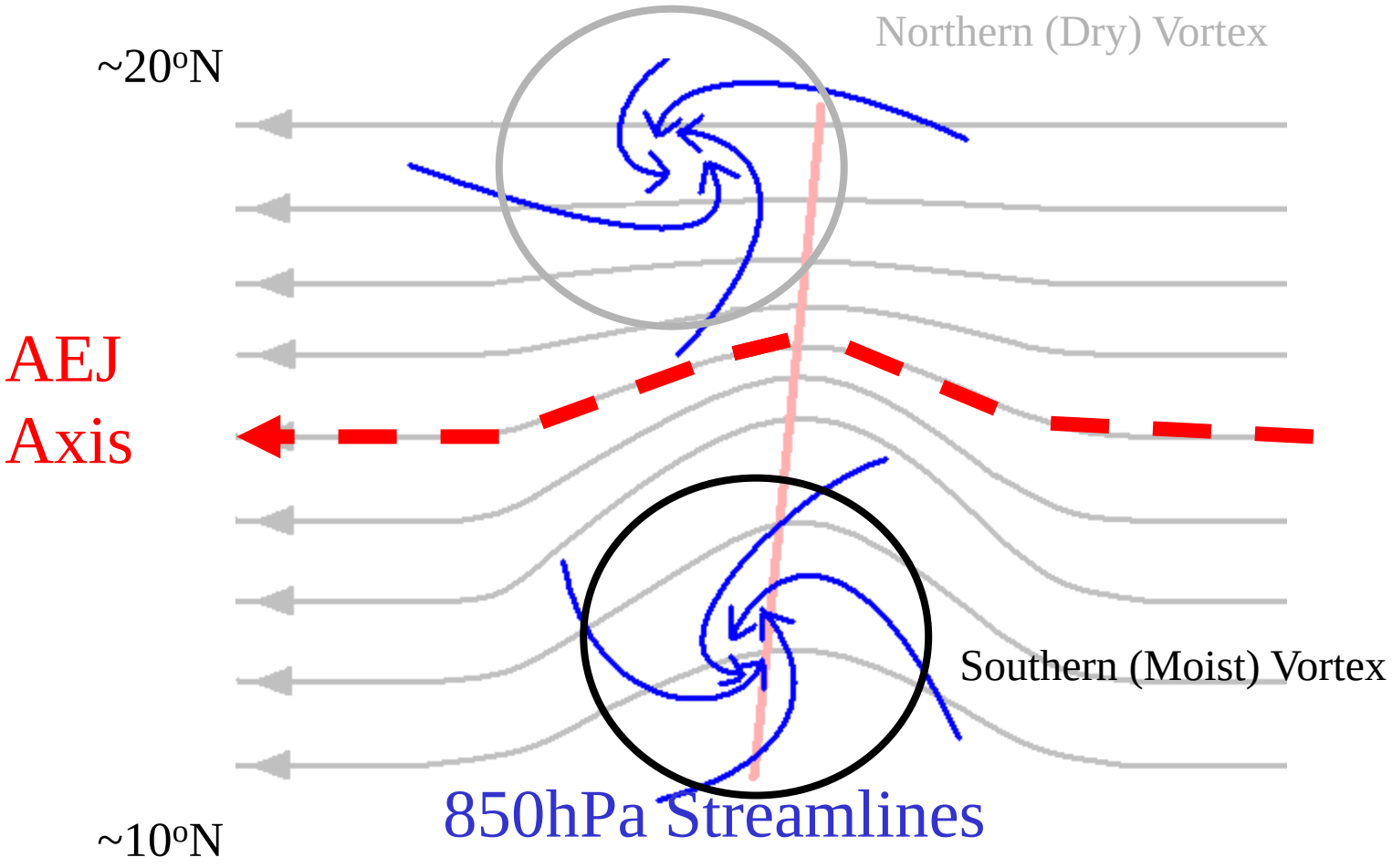

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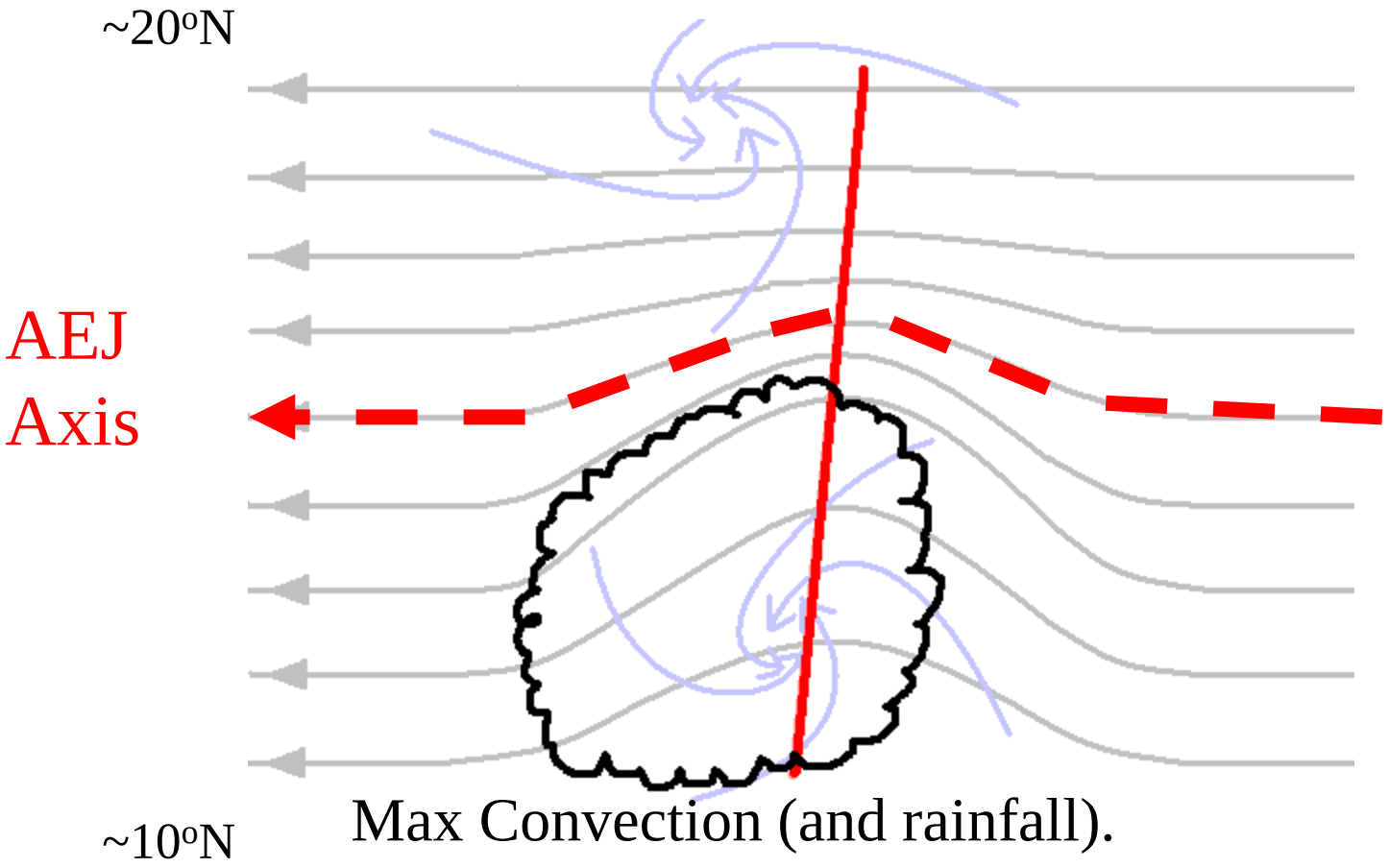
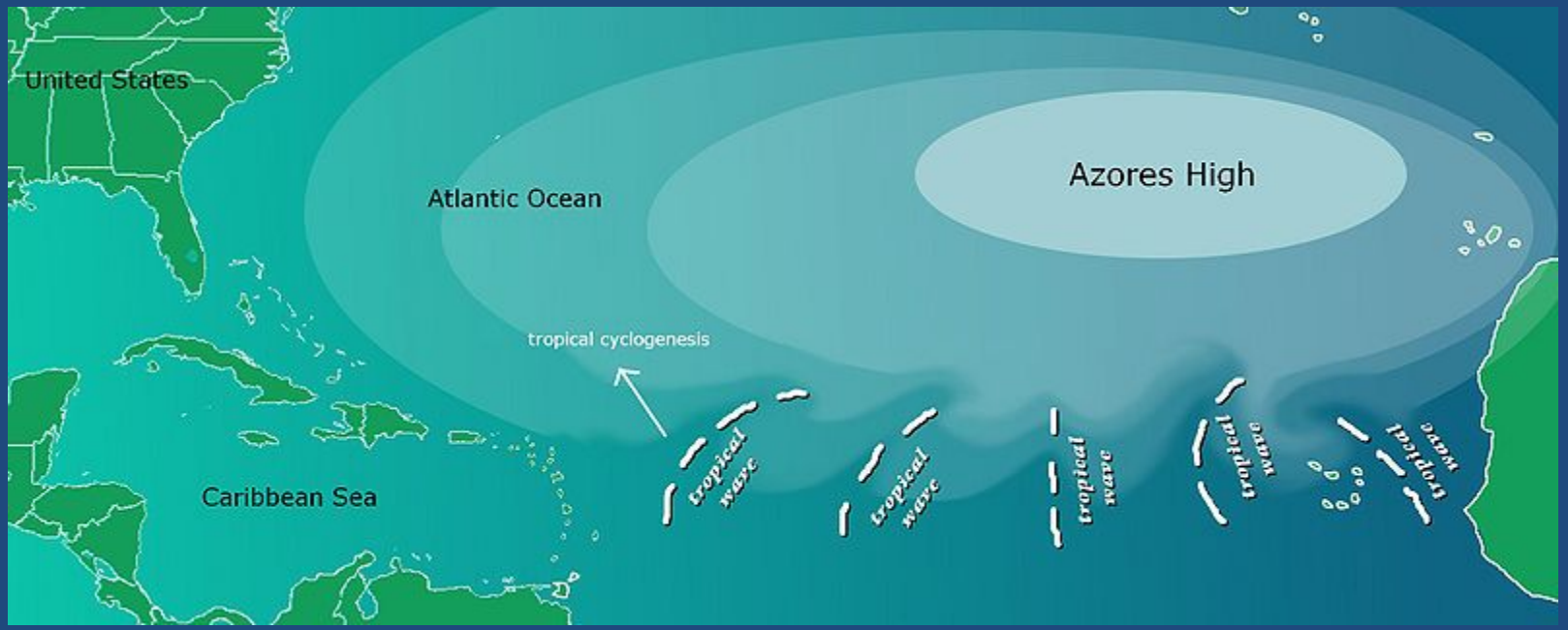


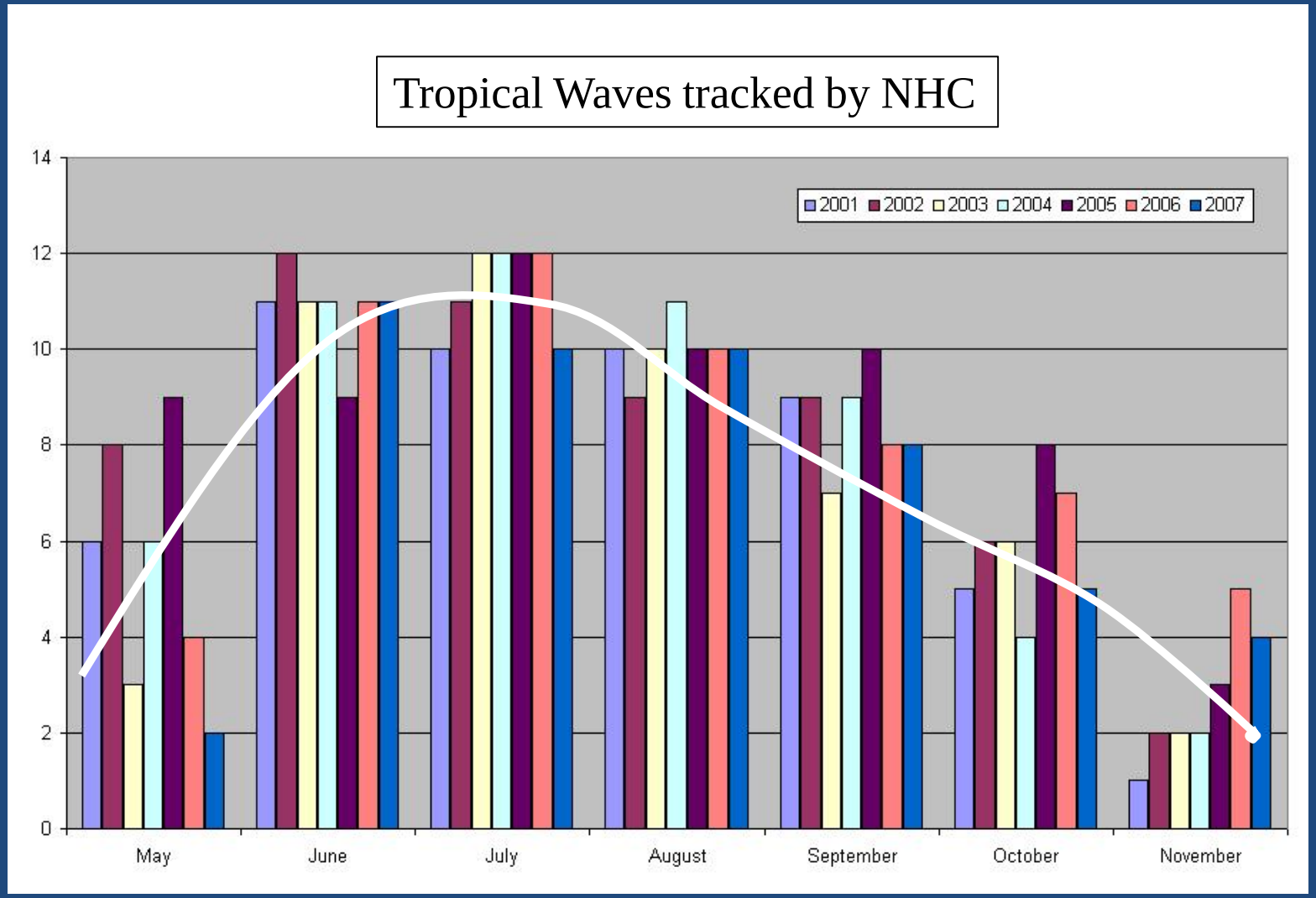
Synthesis of Carlson (1969a, b), Burpee (1972,1974), Reed et al (1977)

Typical Synoptic Setup



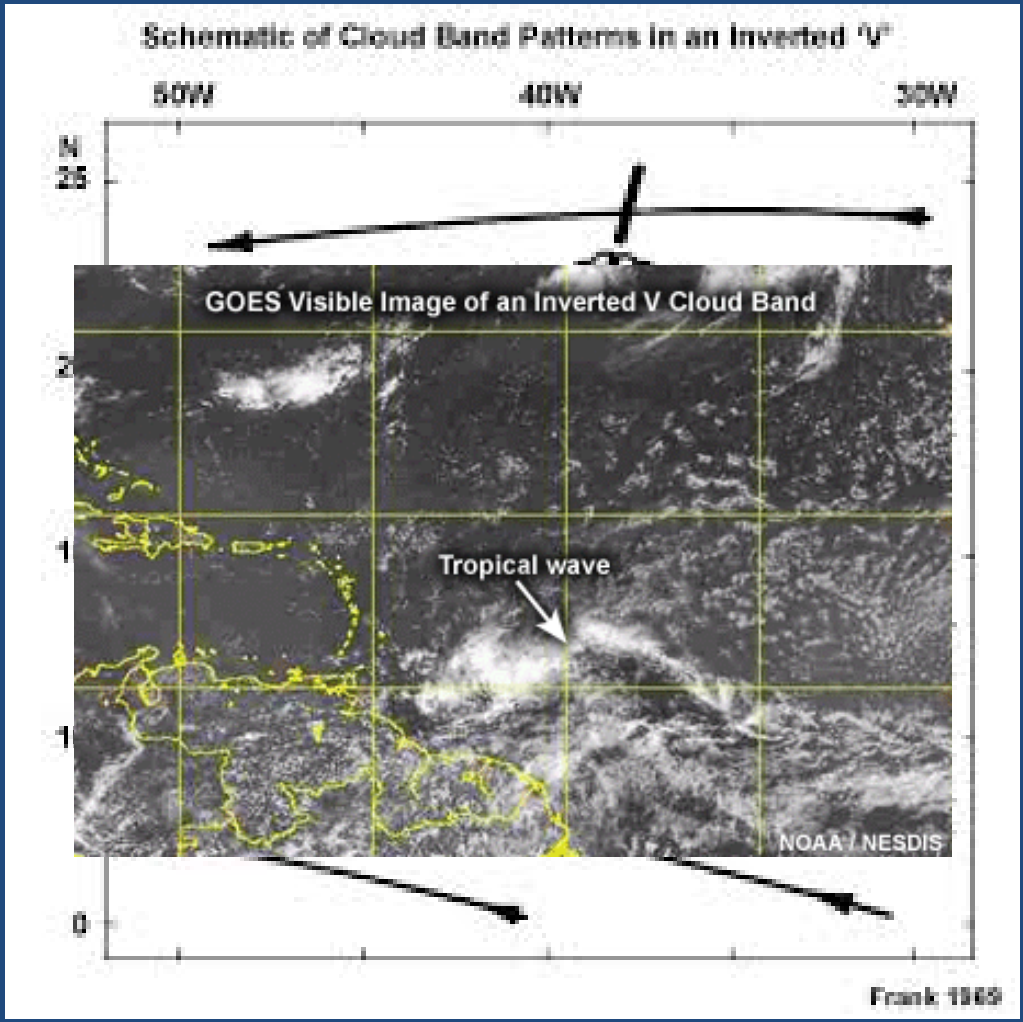
Tropical waves/African easterly waves move westward within the trade wind flow south of the Bermuda-Azores high

Frequency by month



Tropical wave activity in terms of numbers is highest June-August

Schematic diagrams

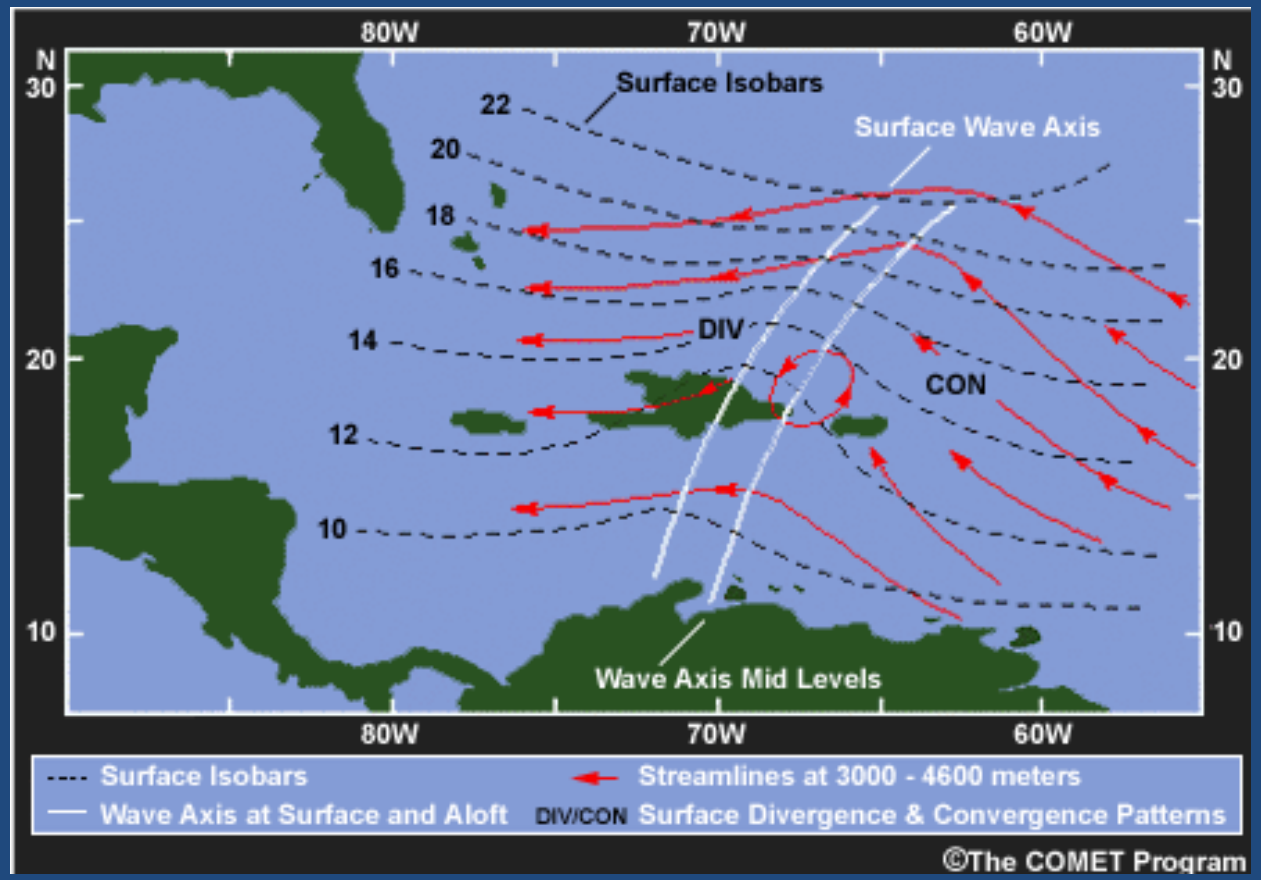


Classic inverted V-shape near the eastern Caribbean

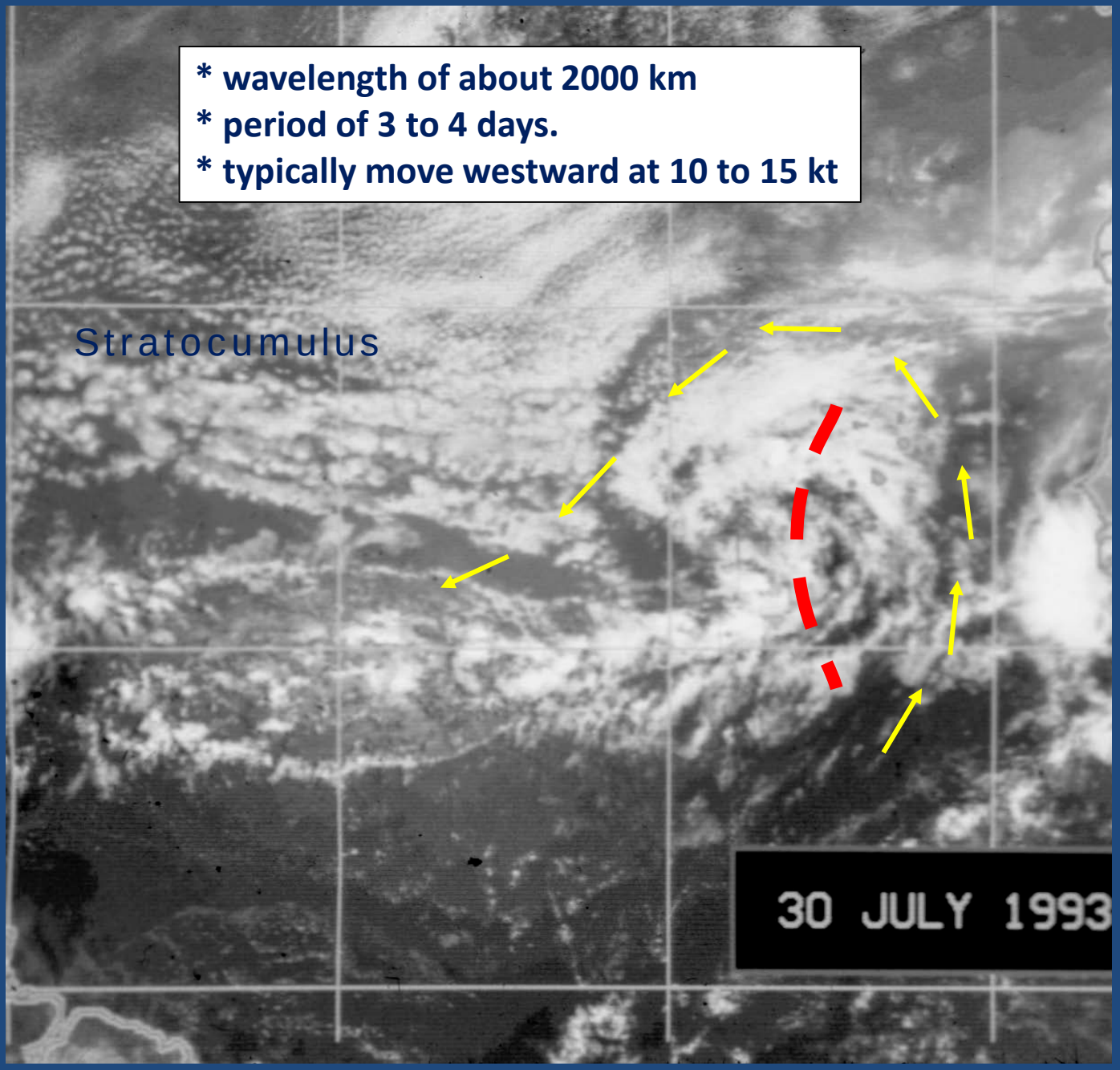
At what pressure level is the maximum amplitude?

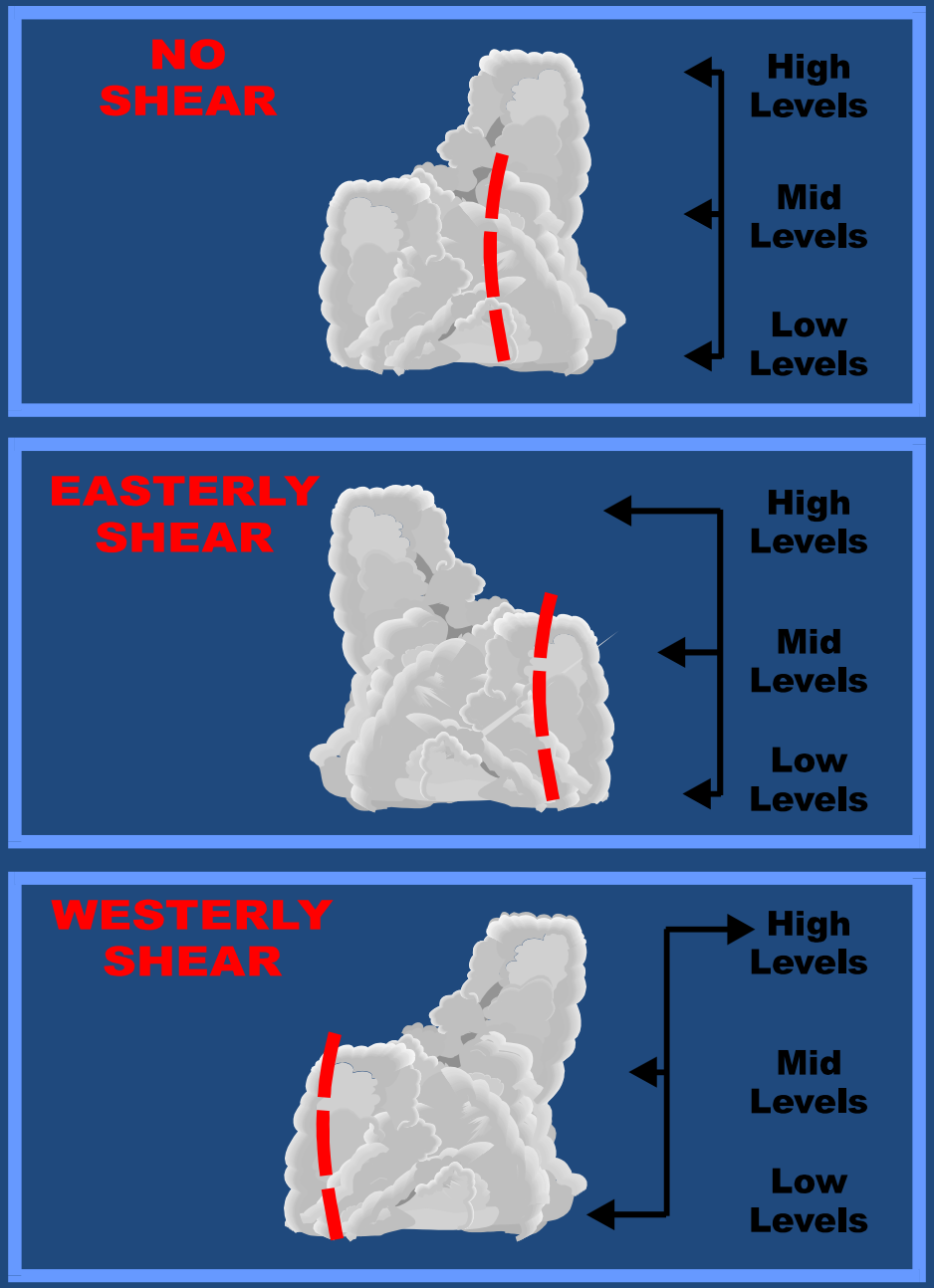
(a) 700 mb
(b) 500 mb
(c) 200 mb
(d) surface

Schematic diagram

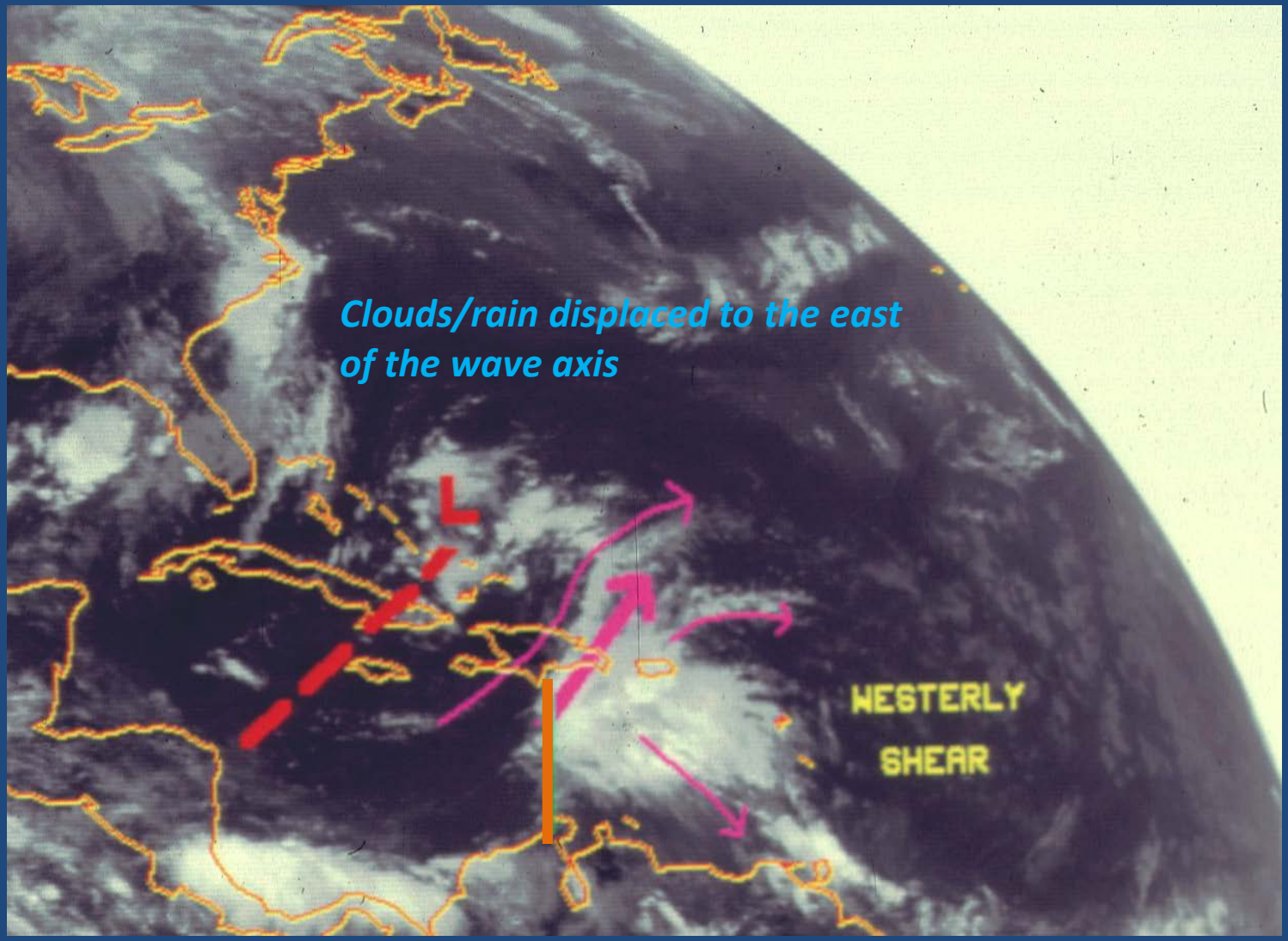


- Notice eastward slope will height
- Maximum amplitude is around 700 mb

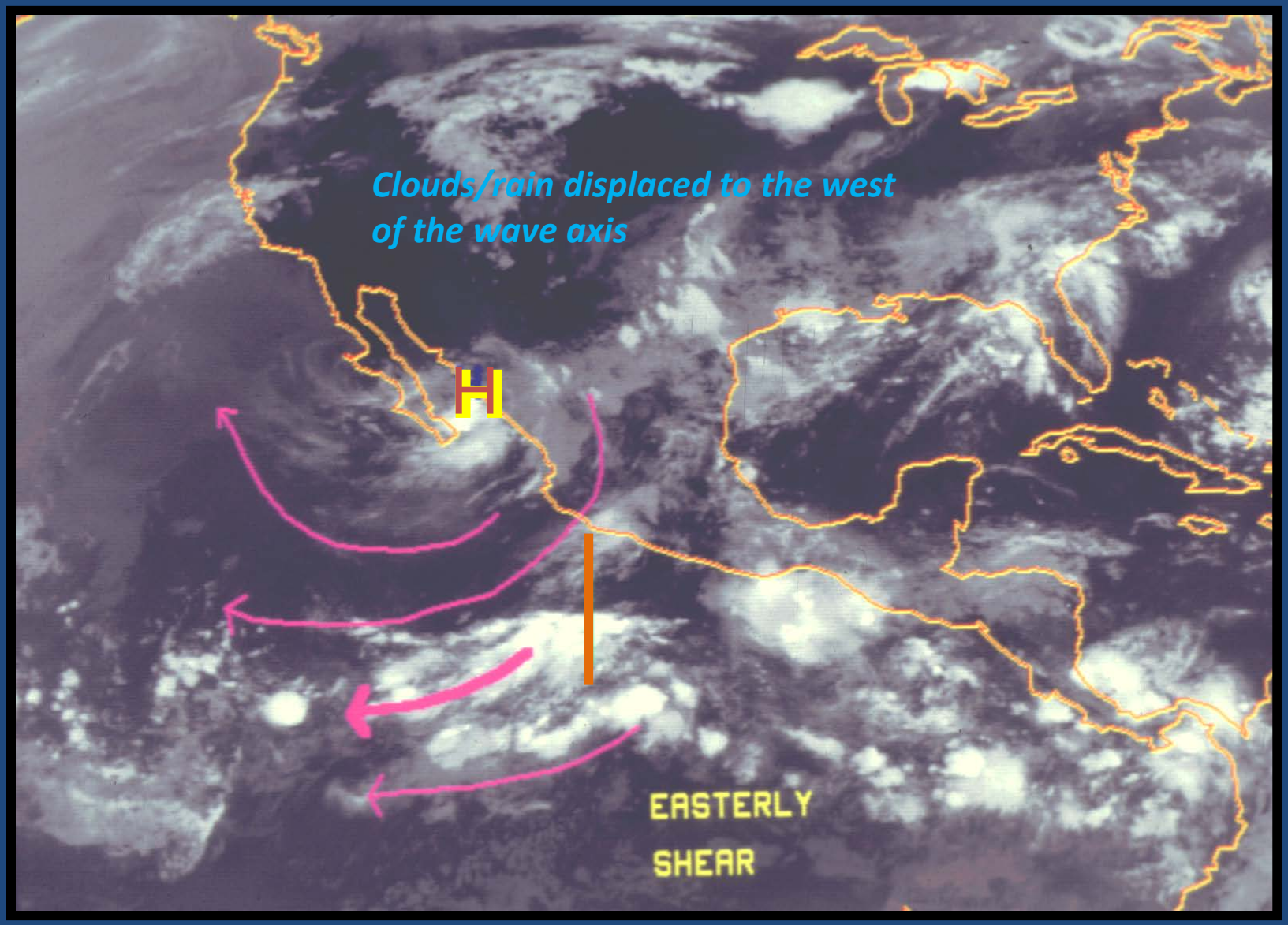

* wavelength of about 2000 km
* period of 3 to 4 days.
* typically move westward at 10 to 15 kt
Stratocumulus
30 JULY 1993


NO SHEAR
High Levels
Mid Levels
Low Levels
EASTERLY SHEAR
High Levels
Mid Levels
Low Levels
WESTERLY SHEAR
High Levels
Mid Levels
Low Levels

Waves in Westerly Shear

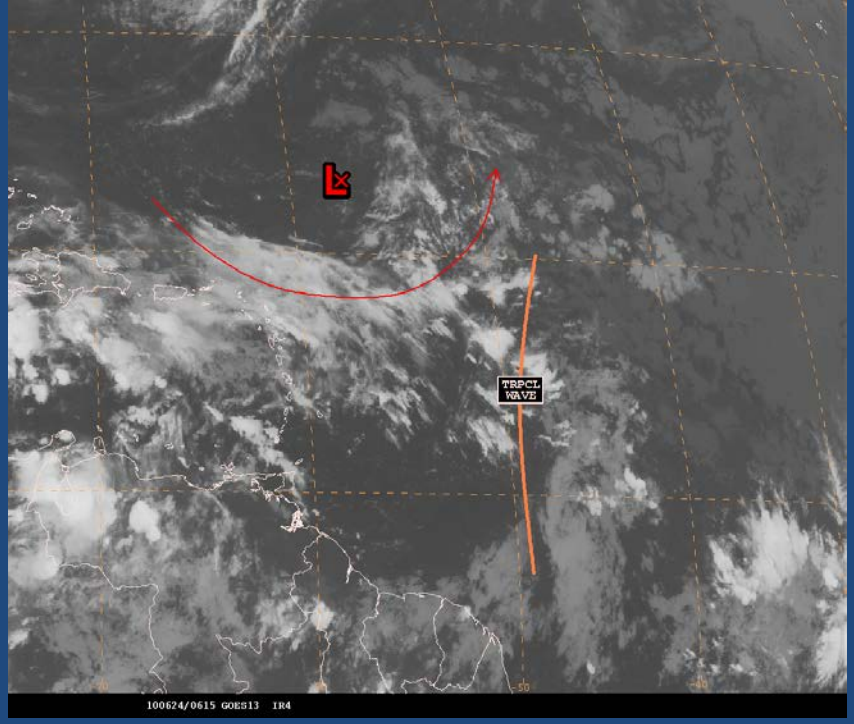


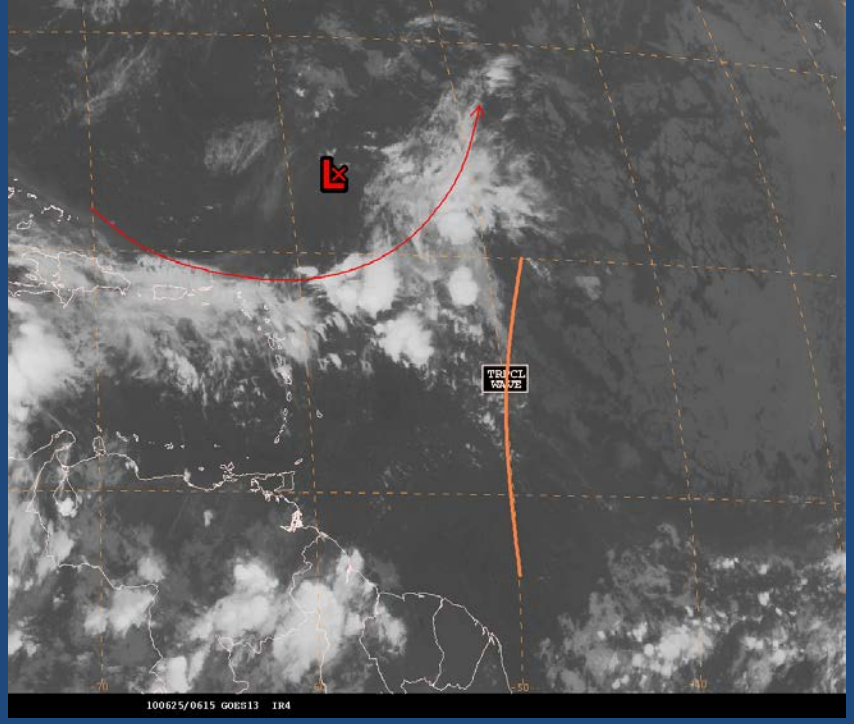
Waves in Easterly Shear

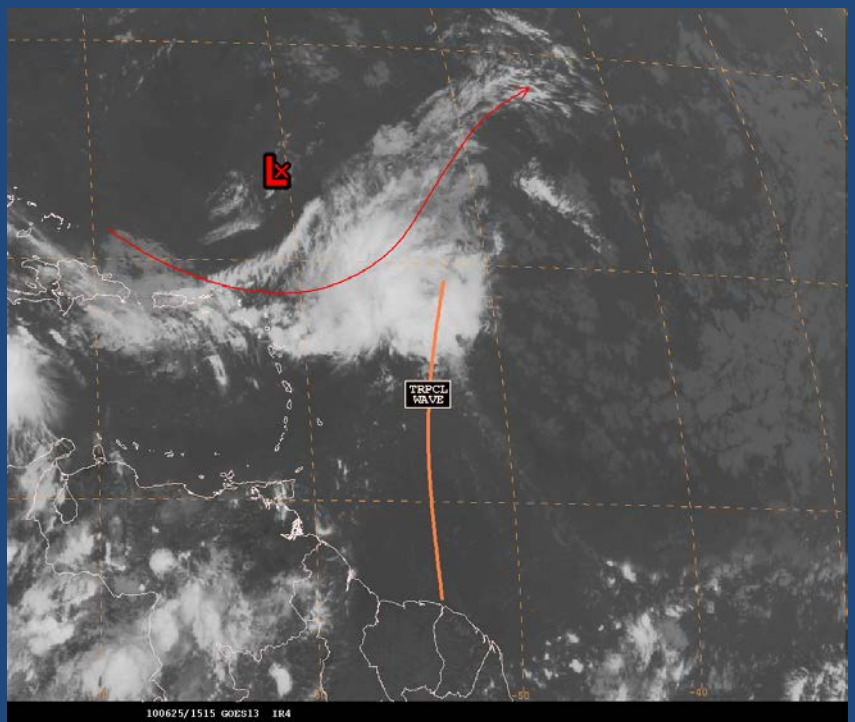


What happens when tropical waves interact with upper-level lows and troughs?

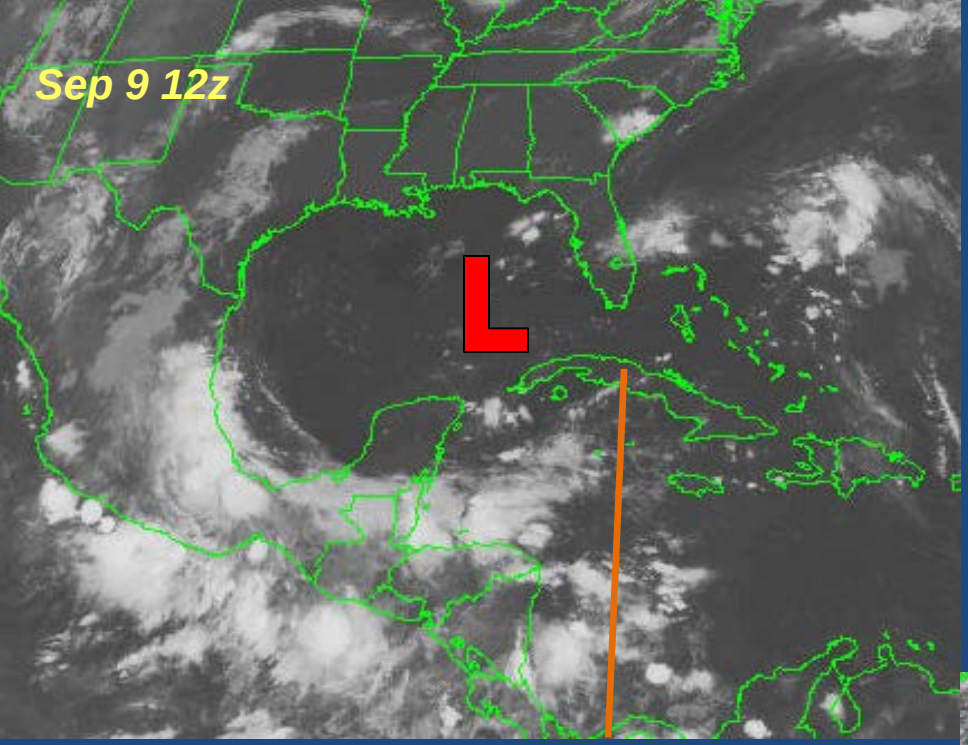
(a) Convection decreases
(b) Convection increases
(c) A tropical cyclone forms



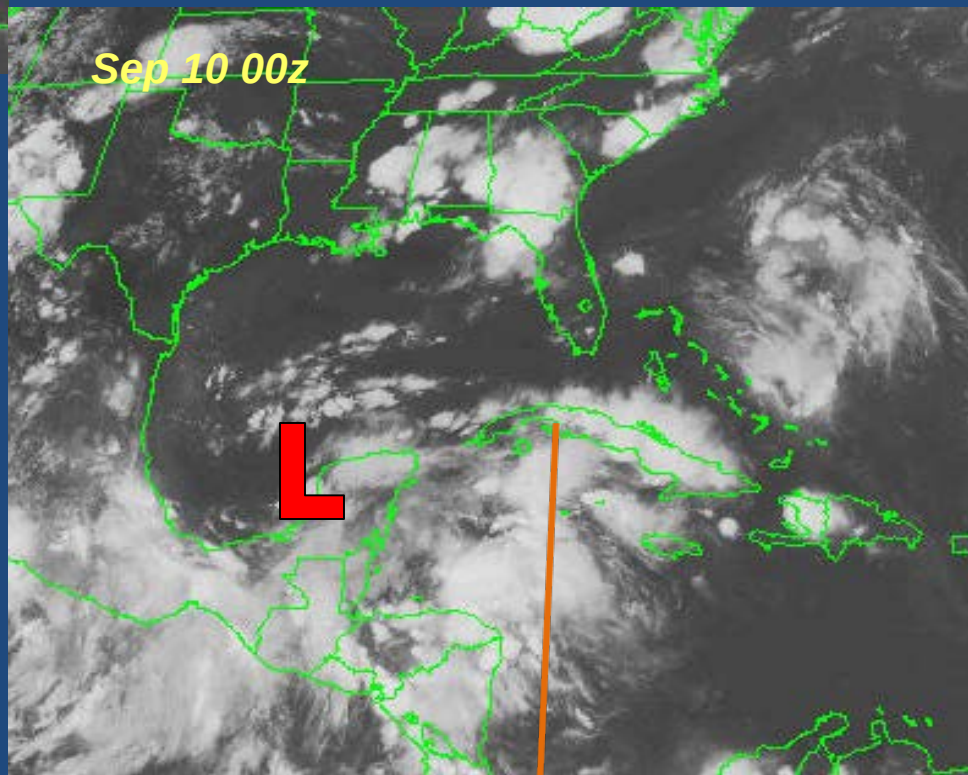




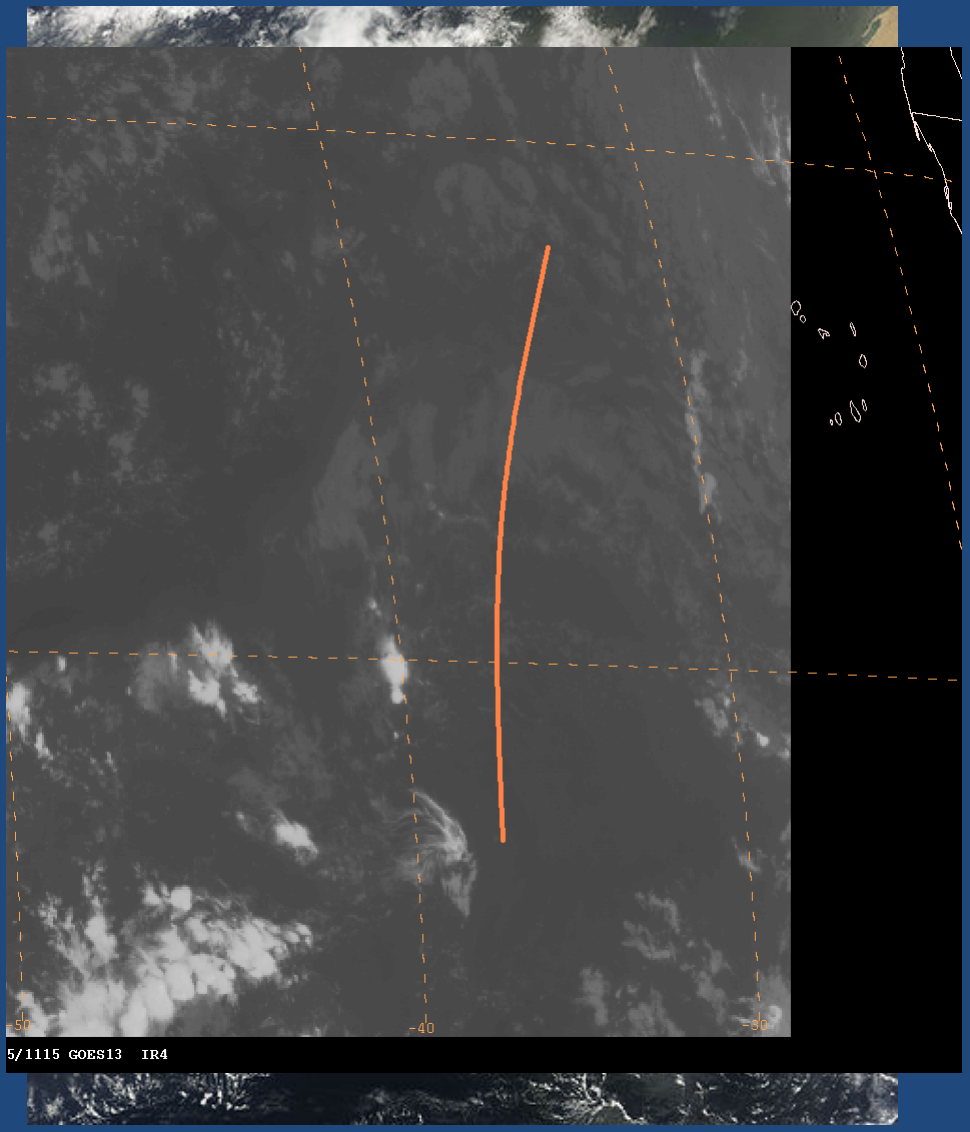
Although interaction with upper-level lows are unfavorable for tropical cyclogenesis, it can often induce heavy rainfall.



Sea-breeze convergence, upslope flows, and afternoon heating can cause convection to become chaotic and difficult to predict.

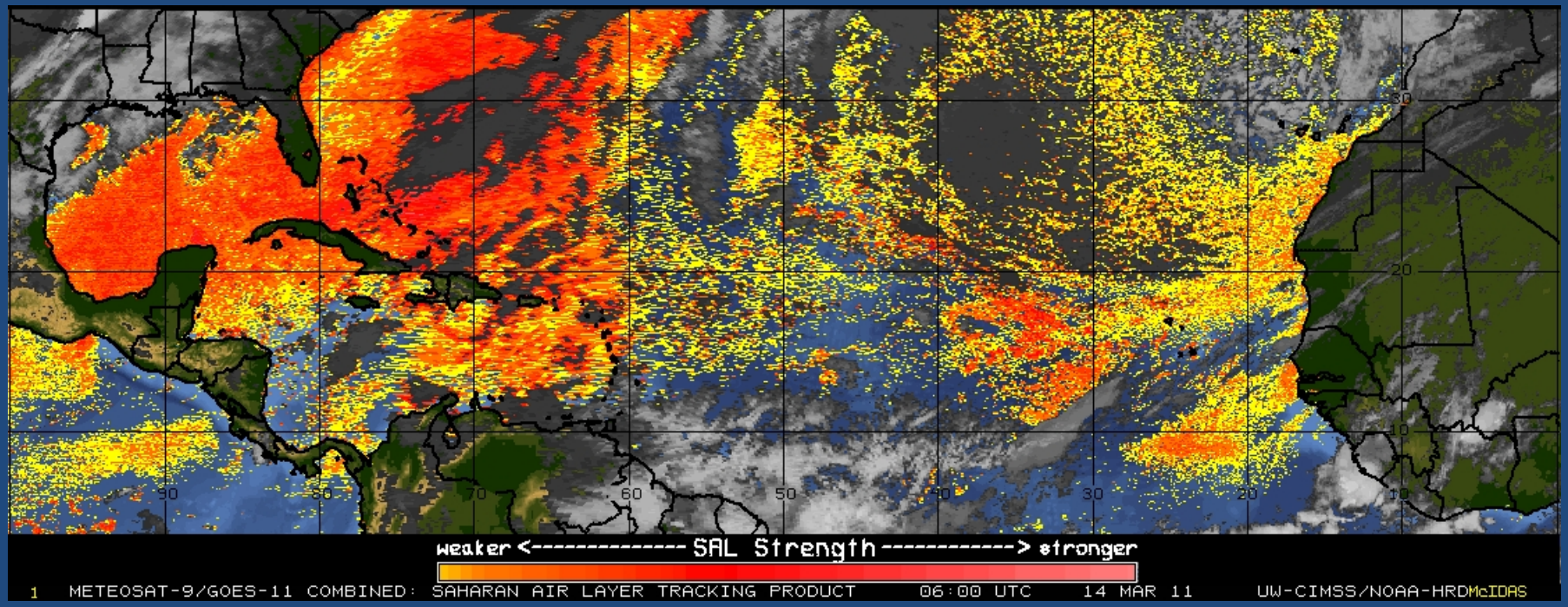


Saharan Air Layer



Very dry/warm air in the low-mid levels of the atmosphere limits convection.

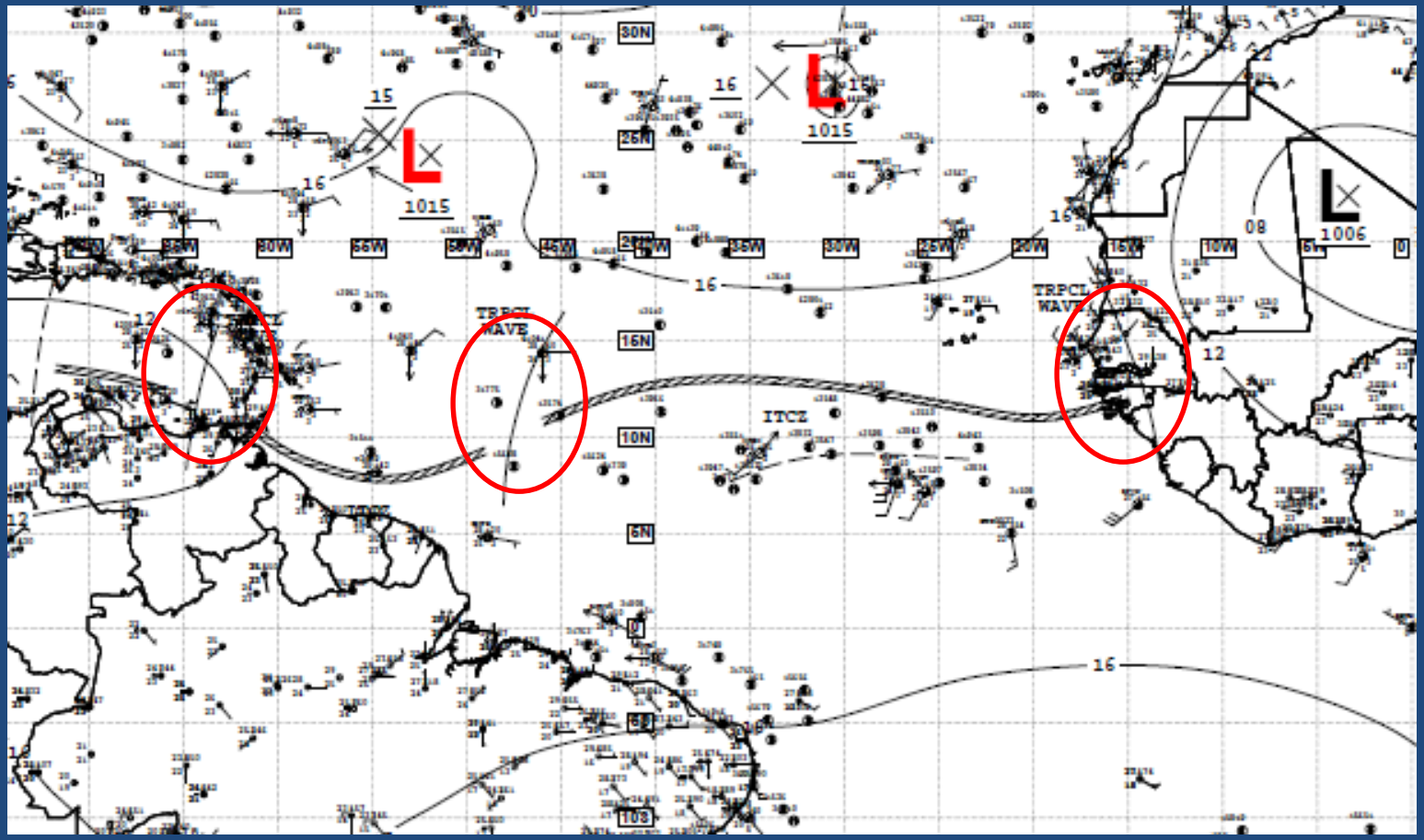
Saharan Air Layer



Tool to help track the strength and position of the SAL

NHC Products

TAFB products: Surface Analysis



Analyze current positions

TAFB products: Tropical Weather Discussion

TROPICAL WEATHER DISCUSSION FOR NORTH AMERICA...CENTRAL
AMERICA...GULF OF MEXICO...CARIBBEAN SEA...NORTHERN SECTIONS
OF SOUTH AMERICA...AND ATLANTIC OCEAN TO THE AFRICAN COAST
FROM THE EQUATOR TO 32N. THE FOLLOWING INFORMATION IS BASED
ON SATELLITE IMAGERY...METEOROLOGICAL ANALYSIS...WEATHER
OBSERVATIONS...AND RADAR.

BASED ON 1800 UTC SURFACE ANALYSIS AND SATELLITE IMAGERY THROUGH
2315 UTC.

...TROPICAL WAVES...

A TROPICAL WAVE IS ALONG 32W S OF 17N MOVING W NEAR 13 KT. THIS
WAVE COINCIDES WITH A DEEP LAYER MOISTURE MAXIMUM OBSERVED IN
TOTAL PRECIPITABLE WATER IMAGERY. ISOLATED MODERATE CONVECTION
IS FROM 13N-15N BETWEEN 30W-34W.

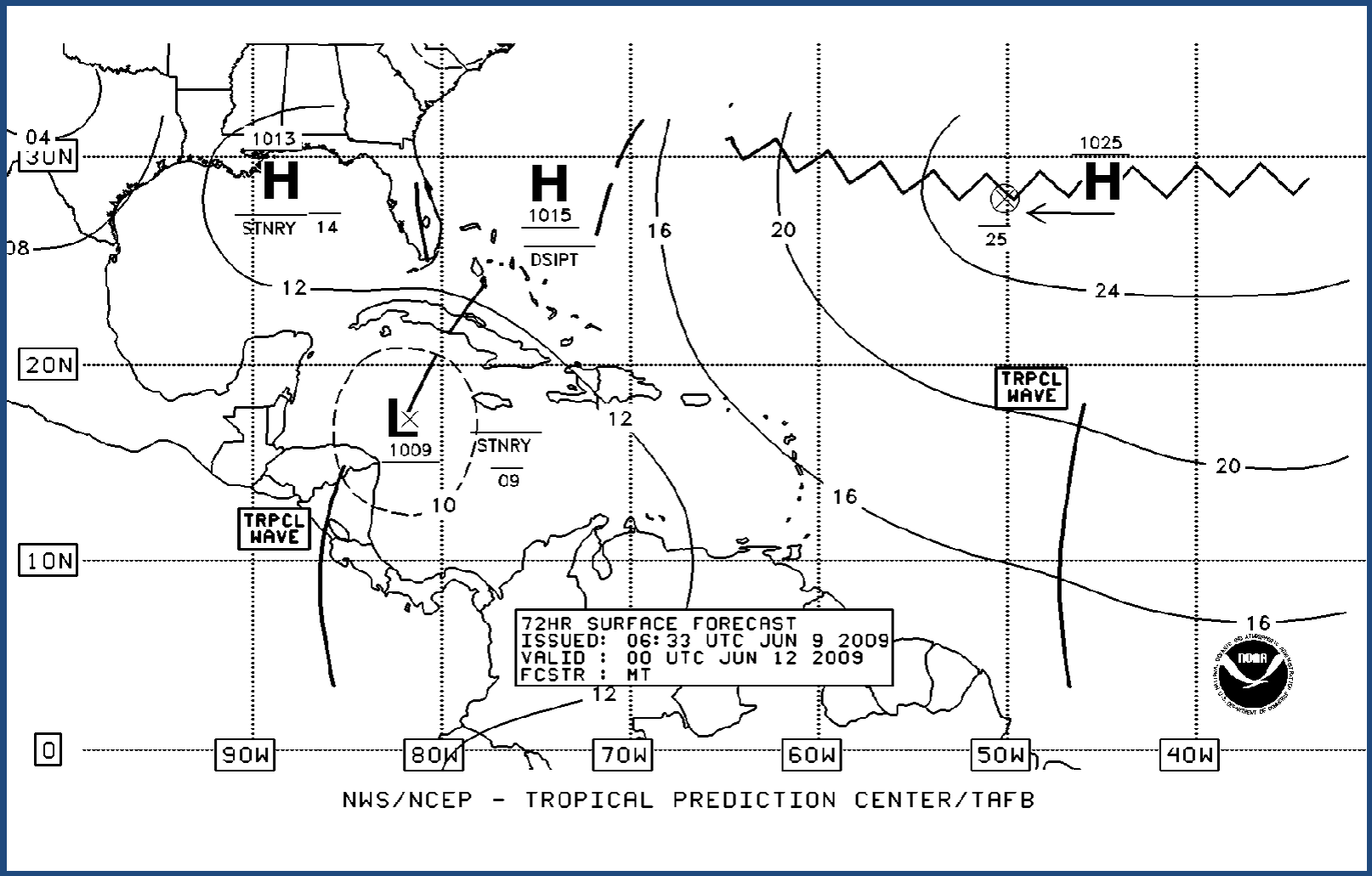
A TROPICAL WAVE IS ALONG 49W S OF 14N MOVING W NEAR 18 KT. THIS
WAVE REMAINS ON THE LEADING EDGE OF DRY SAHARAN AIR AND DUST
INHIBITING DEEP CONVECTION ALONG THE WAVE AXIS. HOWEVER...
SCATTERED SHOWERS ARE FROM 10N-12N BETWEEN 46W-50W.

A TROPICAL WAVE IS ALONG 66W S OF 18N MOVING W NEAR 15 KT. THIS
WAVE COINCIDES WITH A DEEP LAYER MOISTURE MAXIMUM THAT STRETCHES
NWD INTO THE SW NORTH ATLC DUE TO AN UPPER LEVEL LOW CENTERED
NEAR 23N67W. INTERACTIONS BETWEEN THE TROPICAL WAVE AND UPPER
LEVEL LOW ARE PRODUCING SCATTERED SHOWERS AND ISOLATED MODERATE
CONVECTION FROM 10N-19N BETWEEN 60W-70W.

A TROPICAL WAVE IS ALONG 82W S OF 21N MOVING W NEAR 15 KT. THIS
WAVE LIES IN A BROAD AREA OF DEEP LAYER MOISTURE OBSERVED IN
TOTAL PRECIPITABLE WATER IMAGERY. THIS WAVE CONTINUES MOVING
BENEATH A DIFFLUENT PATTERN ALOFT ENHANCING SCATTERED MODERATE
CONVECTION OVER THE SW CARIBBEAN S OF 12N AND ACROSS PANAMA AND
COSTA RICA. ALSO SCATTERED MODERATE/ISOLATED STRONG CONVECTION
IS OVER THE NW CARIBBEAN N OF 18N BETWEEN 80W-89W...INCLUDING
PORTIONS OF WRN CUBA AND THE YUCATAN PENINSULA.

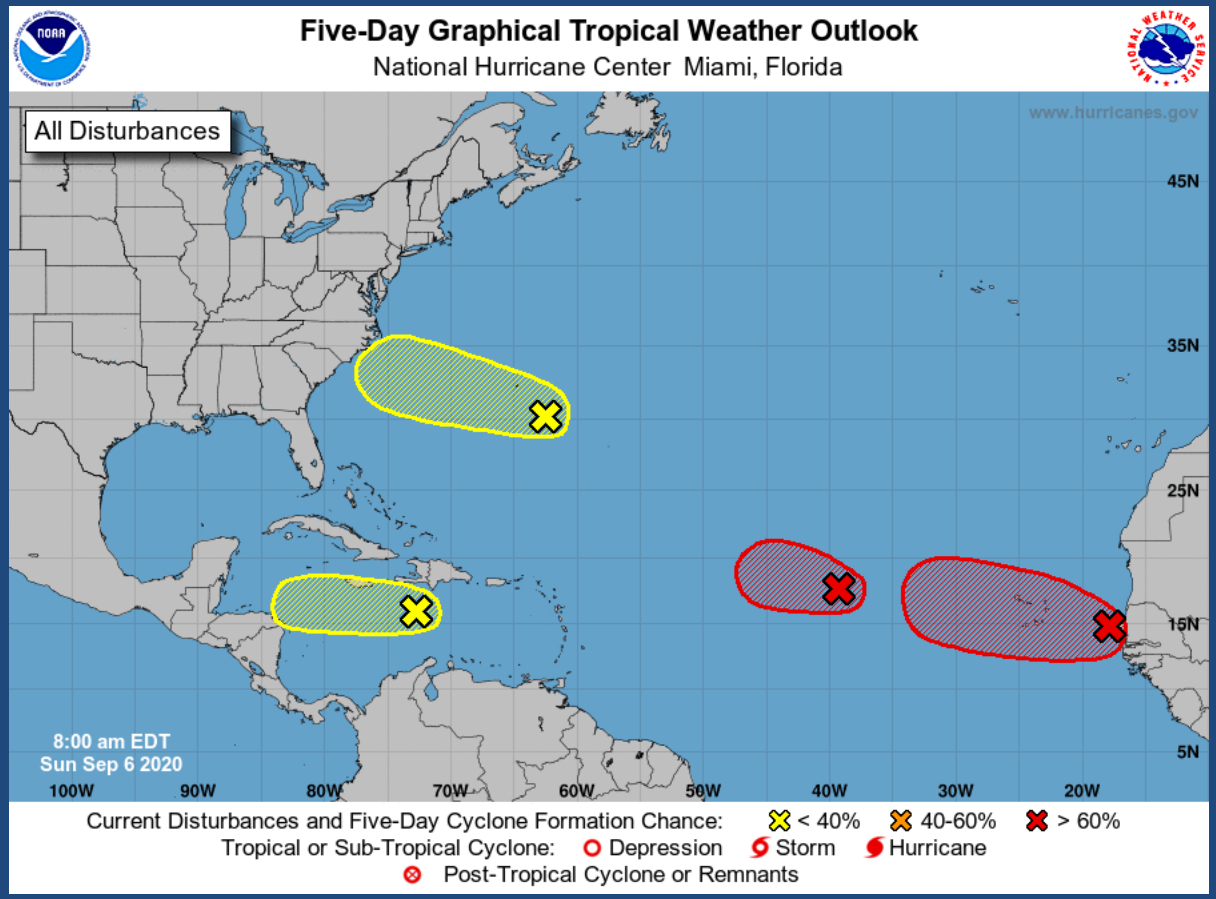
Discussion of tropical waves

TAFB products: graphical forecast



Predict future positions: 24h, 48h, and 72h

Tropical Weather Outlook



Approximately 60 % of Atlantic tropical cyclones and 85 % of major hurricanes originate from tropical waves

What is more important for tropical cyclogenesis?

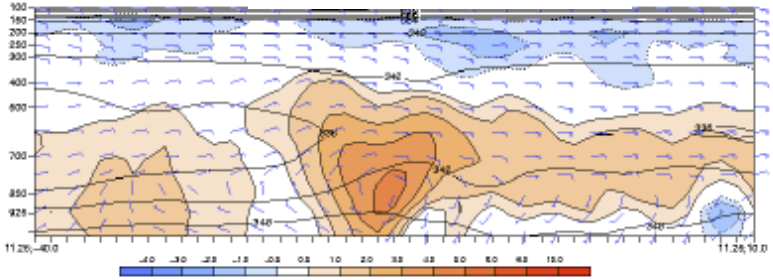
(a) the wave structure

(b) the environment

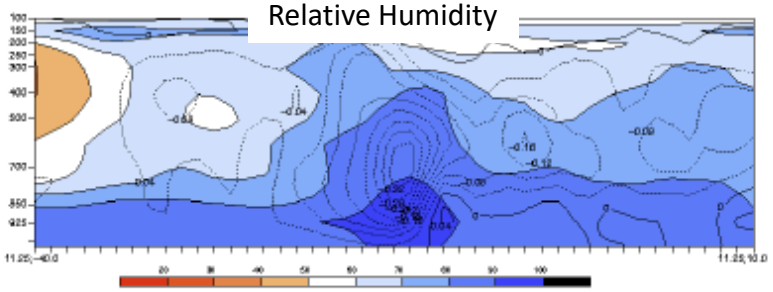
Developing vs. Non-developing

Developing (33)

Relative Vorticity

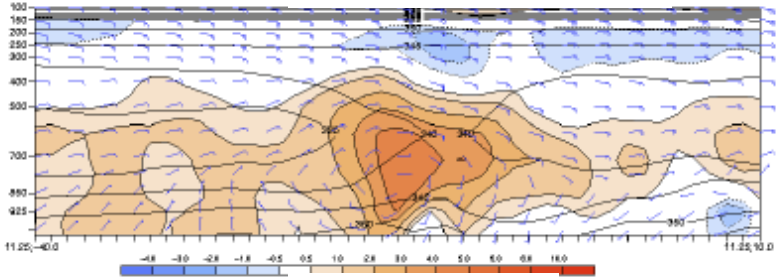


Relative Humidity

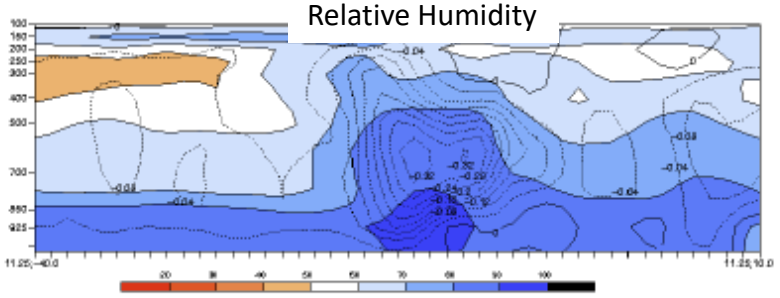


Non-Developing (33 most intense)

Relative Vorticity



Relative Humidity

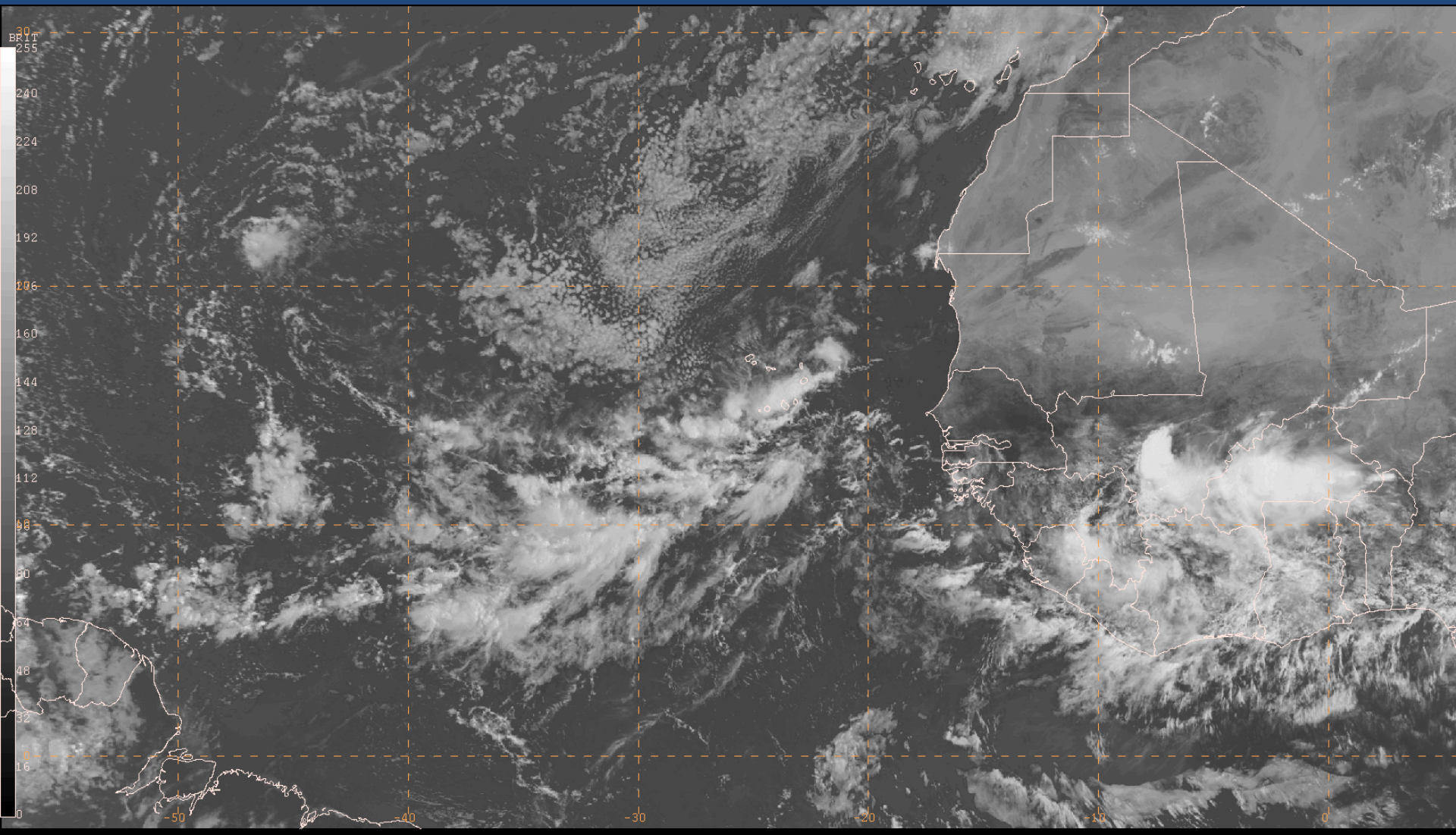


Hopsch, Thorncroft, and Tyle (2009)

Very little different in structure between developing and non-developing waves

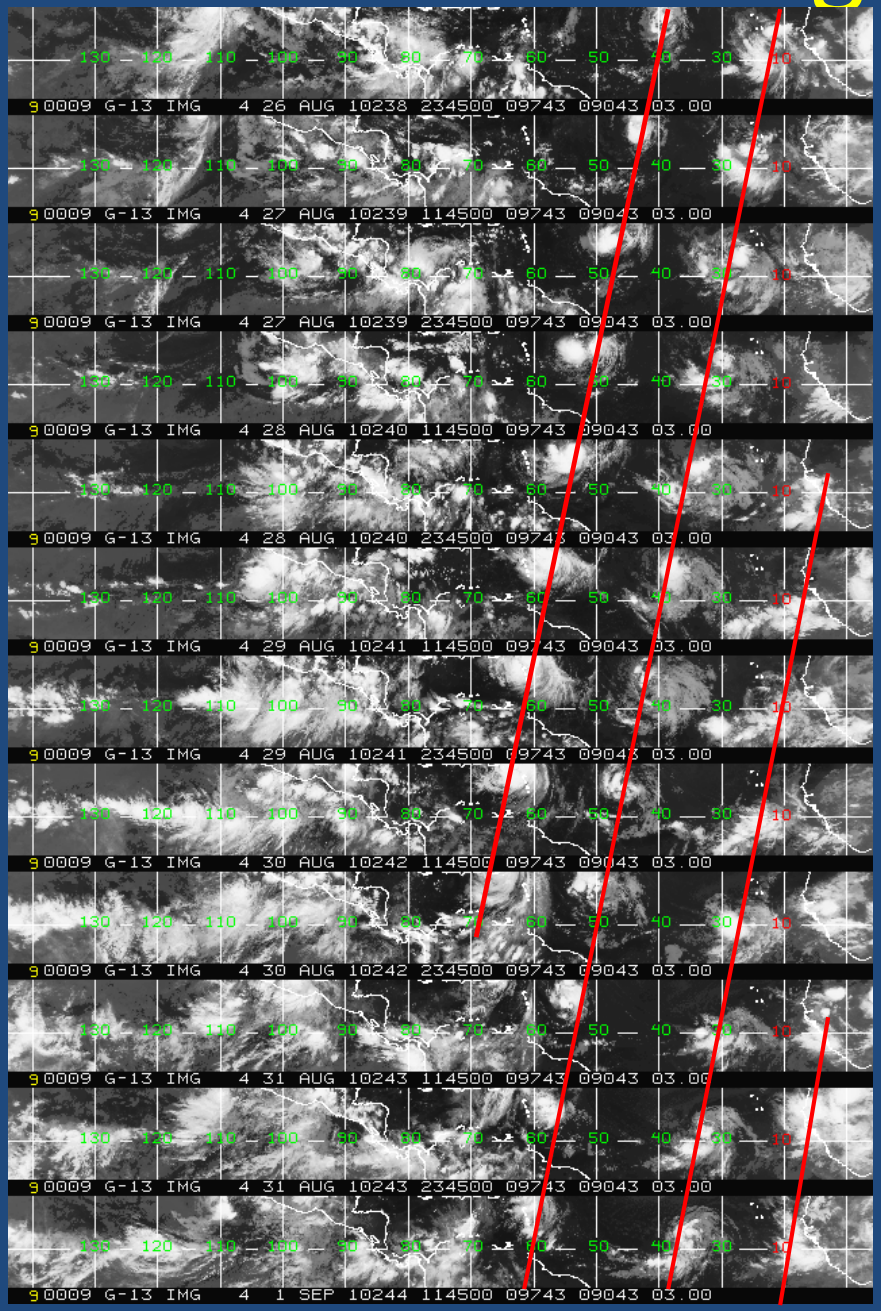
Tools to track tropical waves

Satellite Imagery



Satellite Hovmoller Diagrams

Time



Aug 26

Aug 27

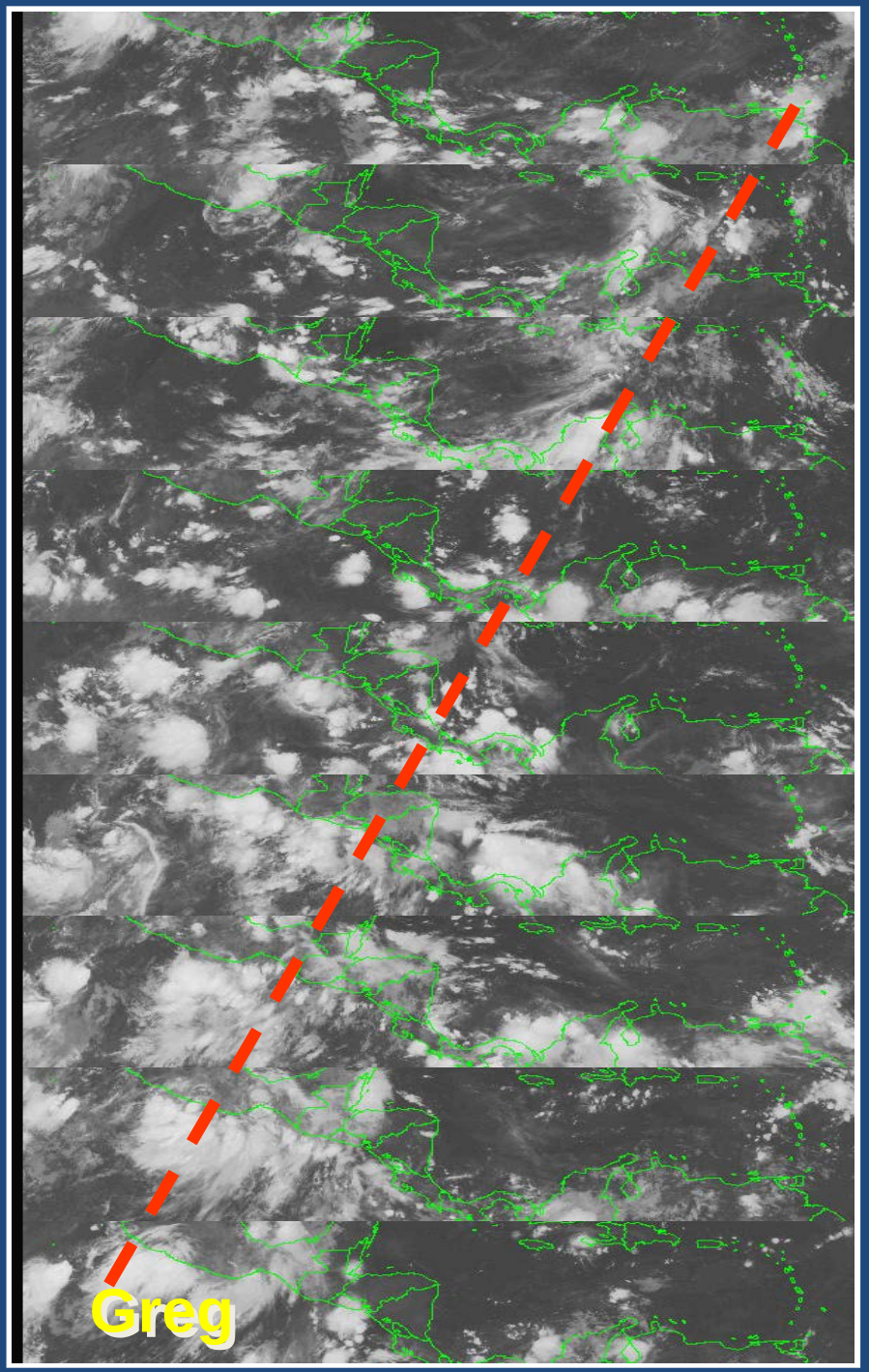
Aug 28

Aug 29

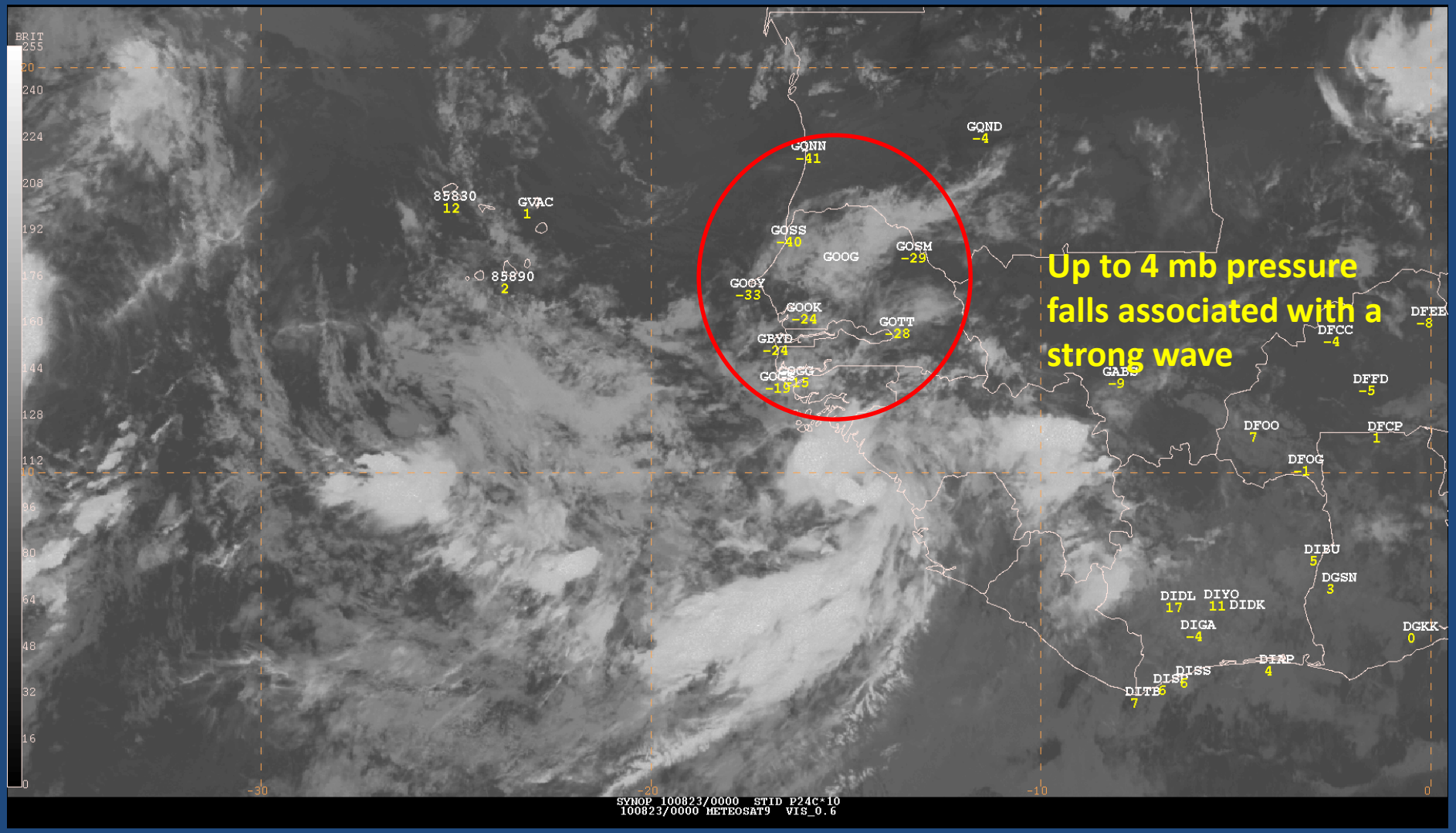
Aug 30

Aug 31

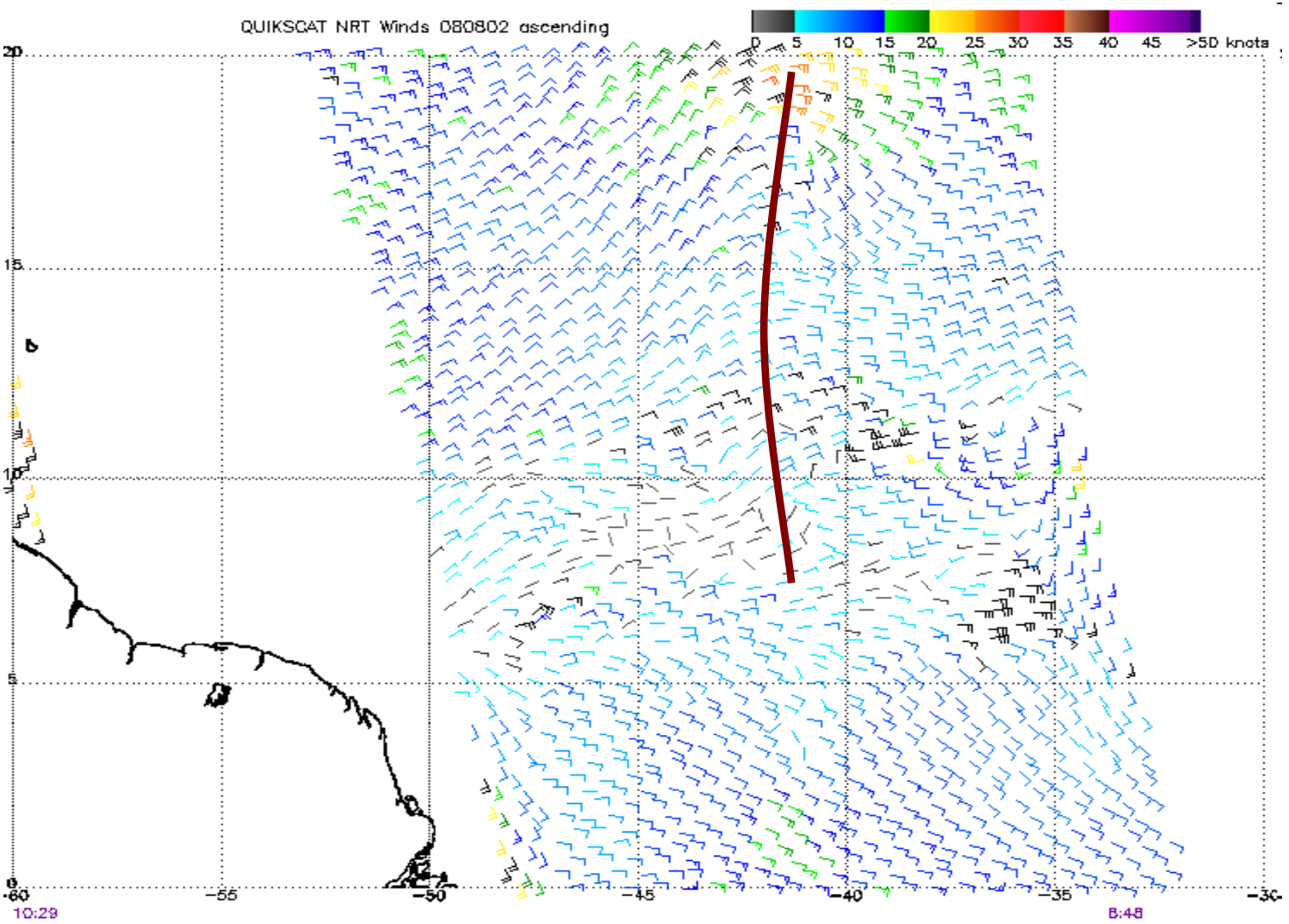
Sep 1


Greg
27
28
29
30
31
1
2
3
4

Surface Observations



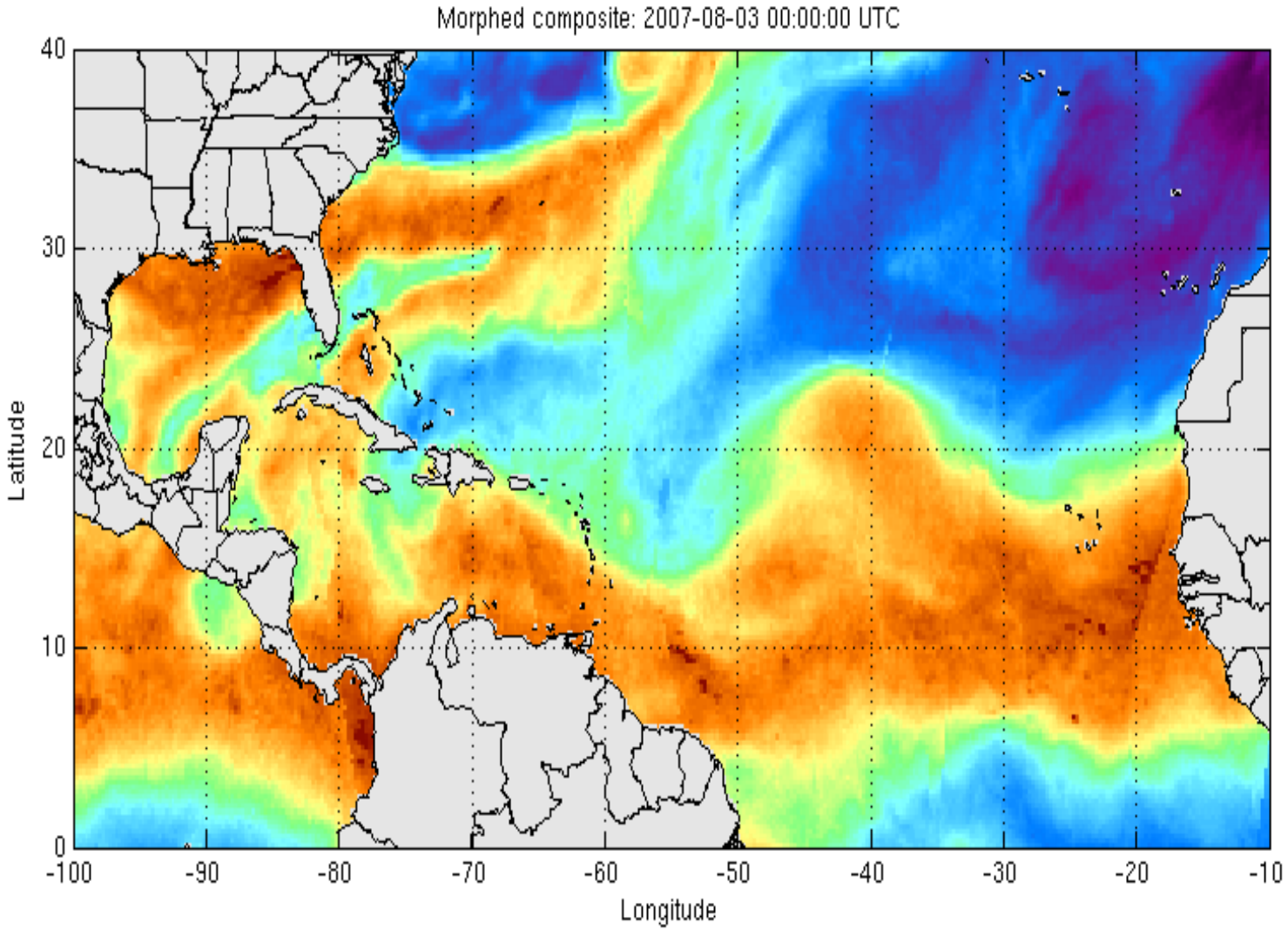
Scatterometer



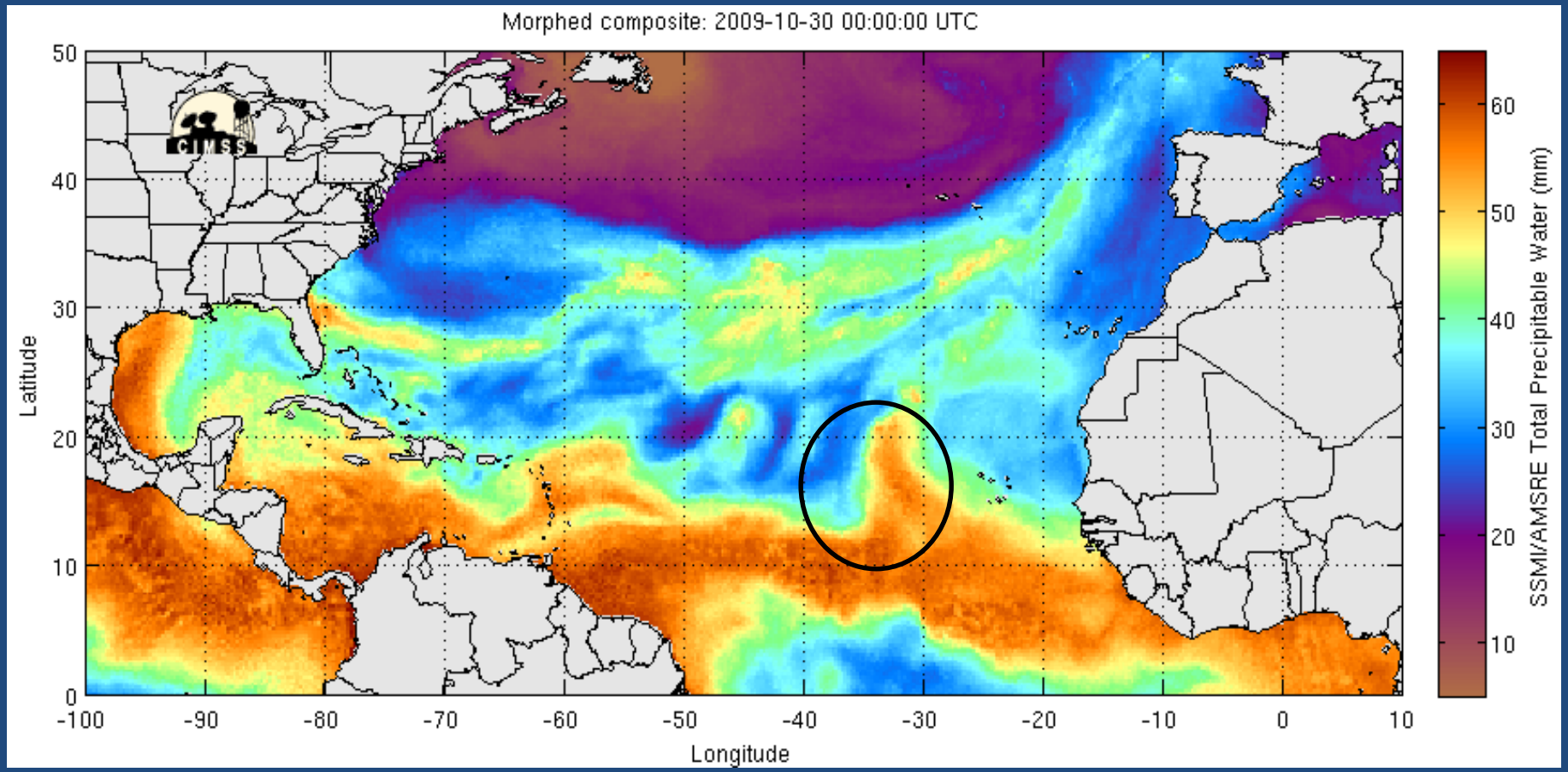
Note: 1) Times are GMT 2)Times correspond to 10N at right swath edge – time is right swath for overlapping swaths at 10N
3)Data buffer is 24 hrs for 080802 4)Black barbs indicate possible rain contamination

NOAA/NESDIS/Office of Research and Applications

Total Precipitable Water



Wave Splitting

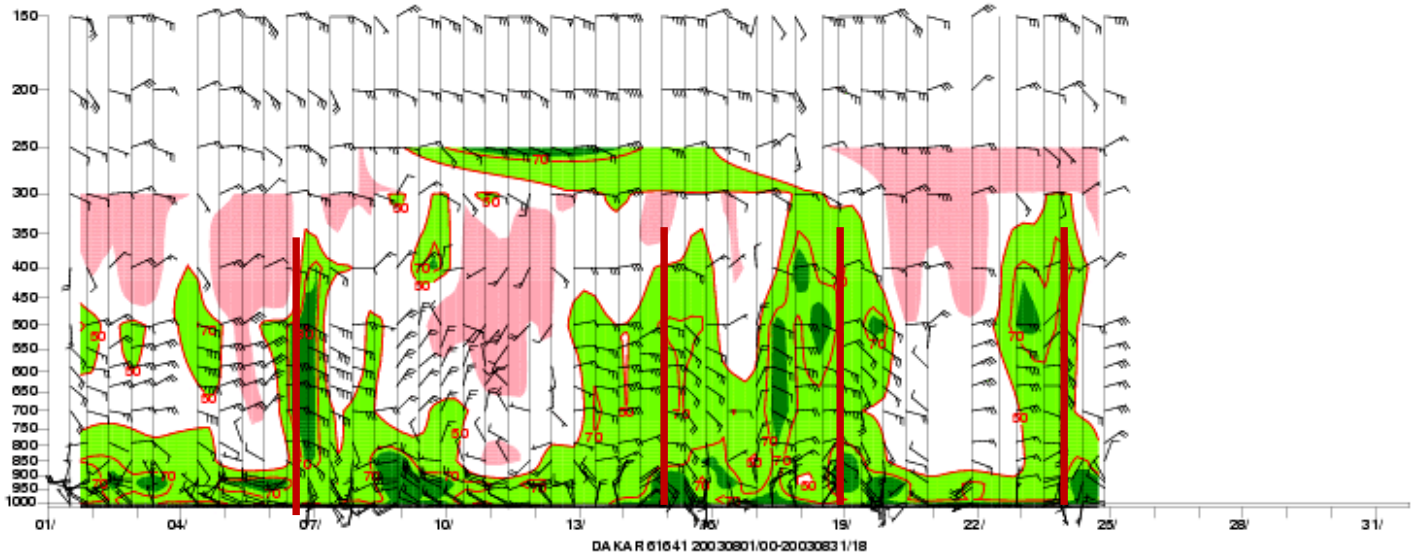


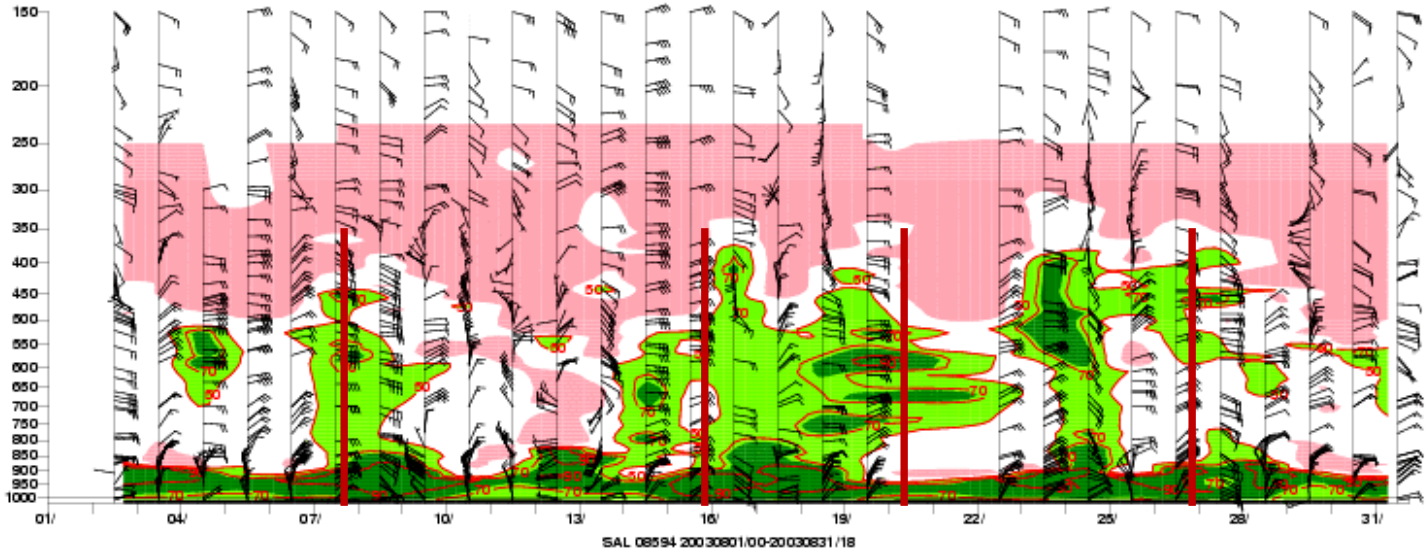
The northern portion of the wave often fractures but the southern extension continues moving westward

Upper-Air Time Sections

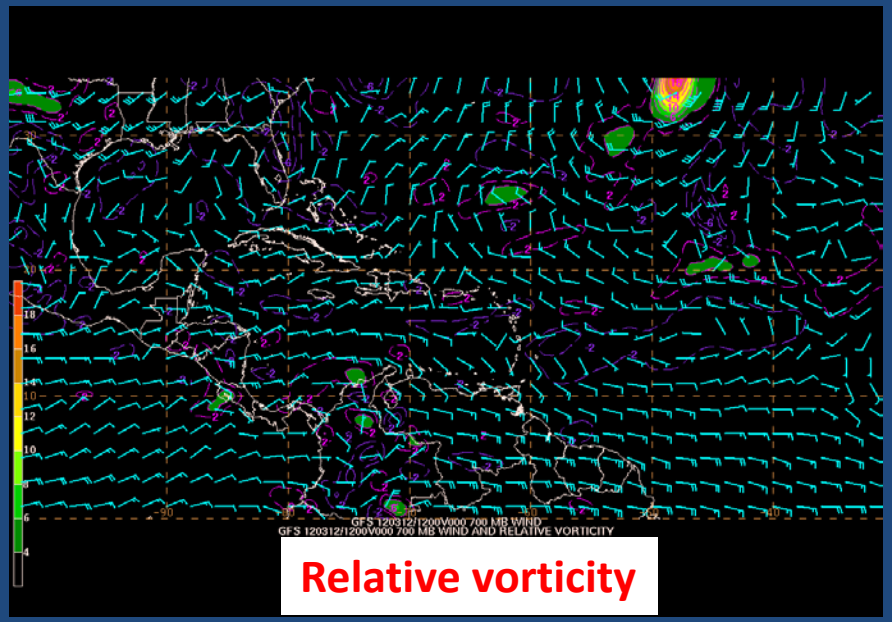
Dakar

Sal

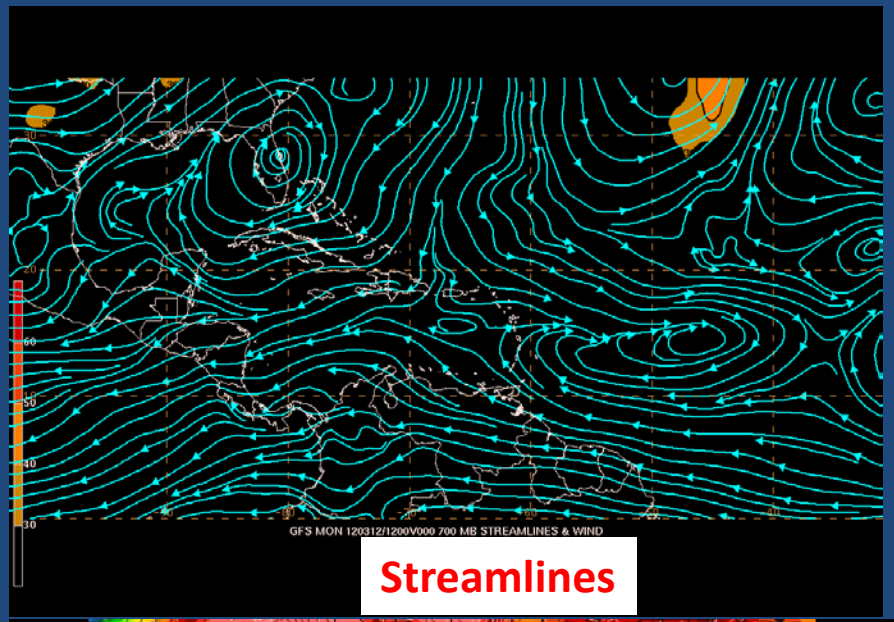




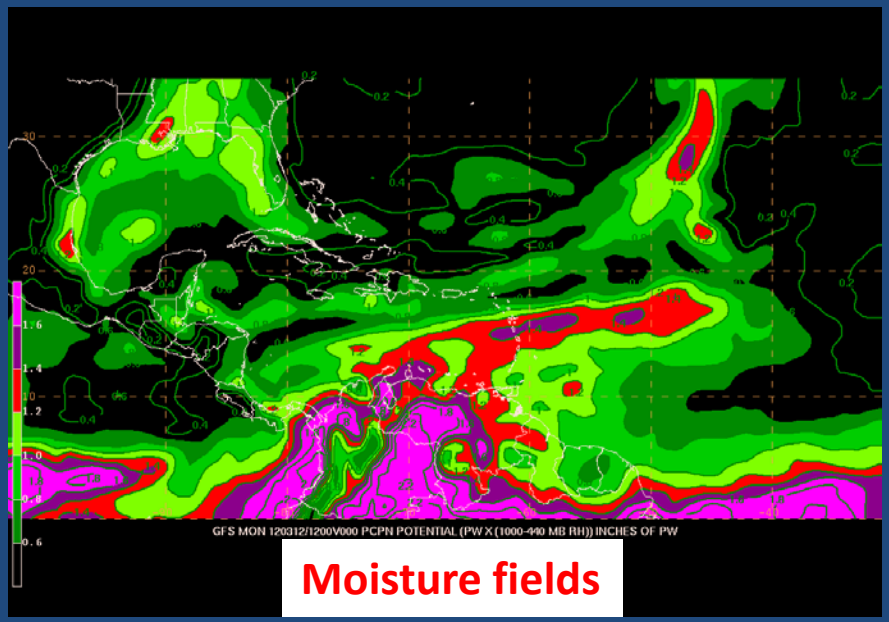
Models



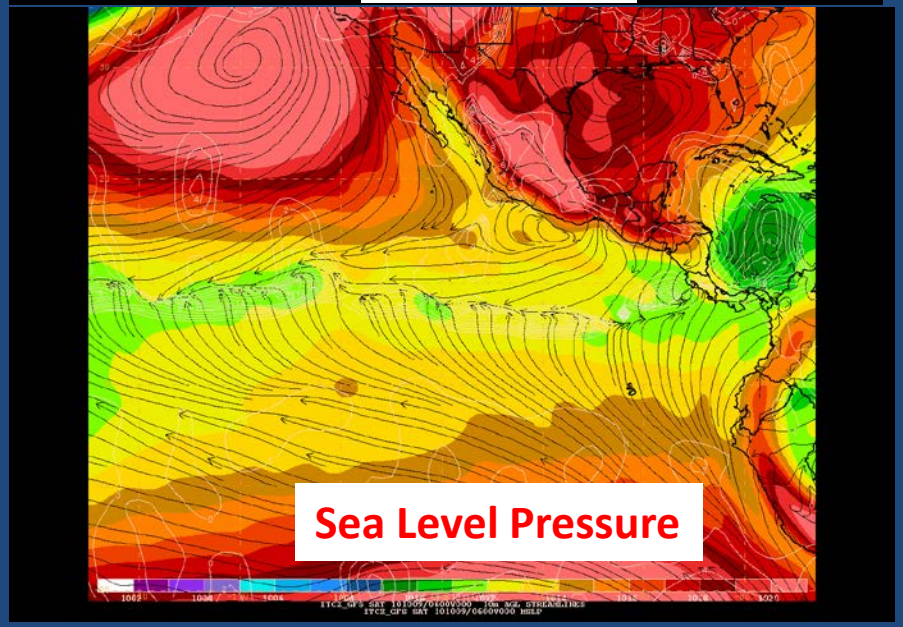
Relative vorticity



Streamlines

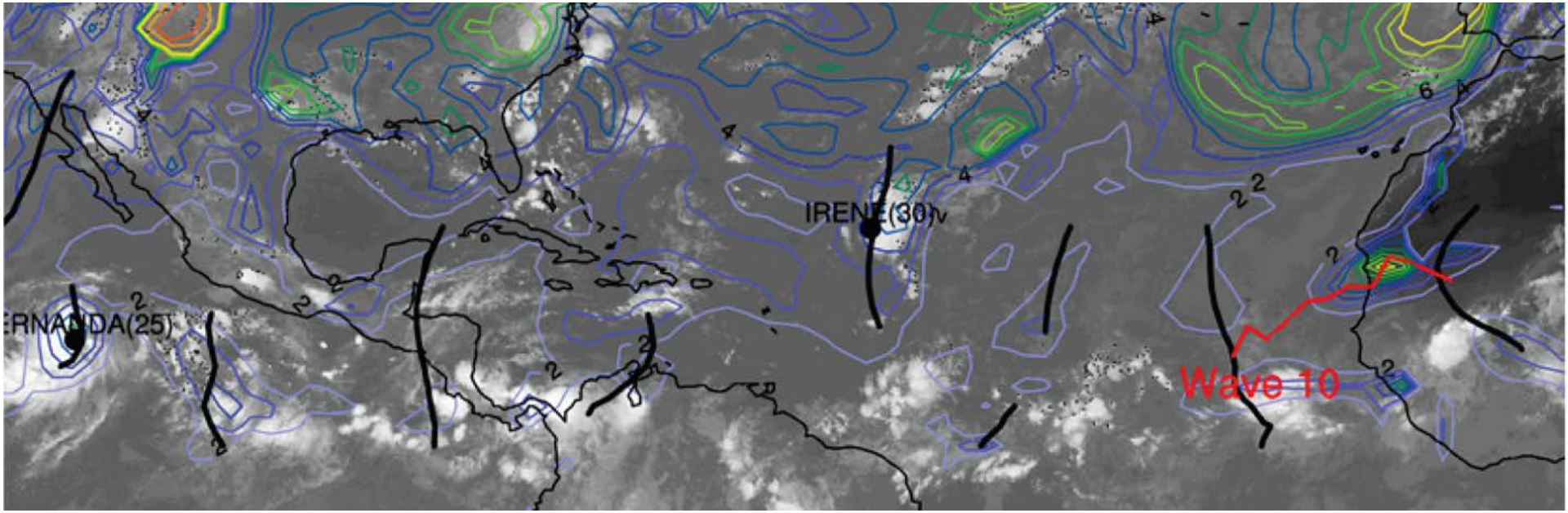


Moisture fields



Sea Level Pressure

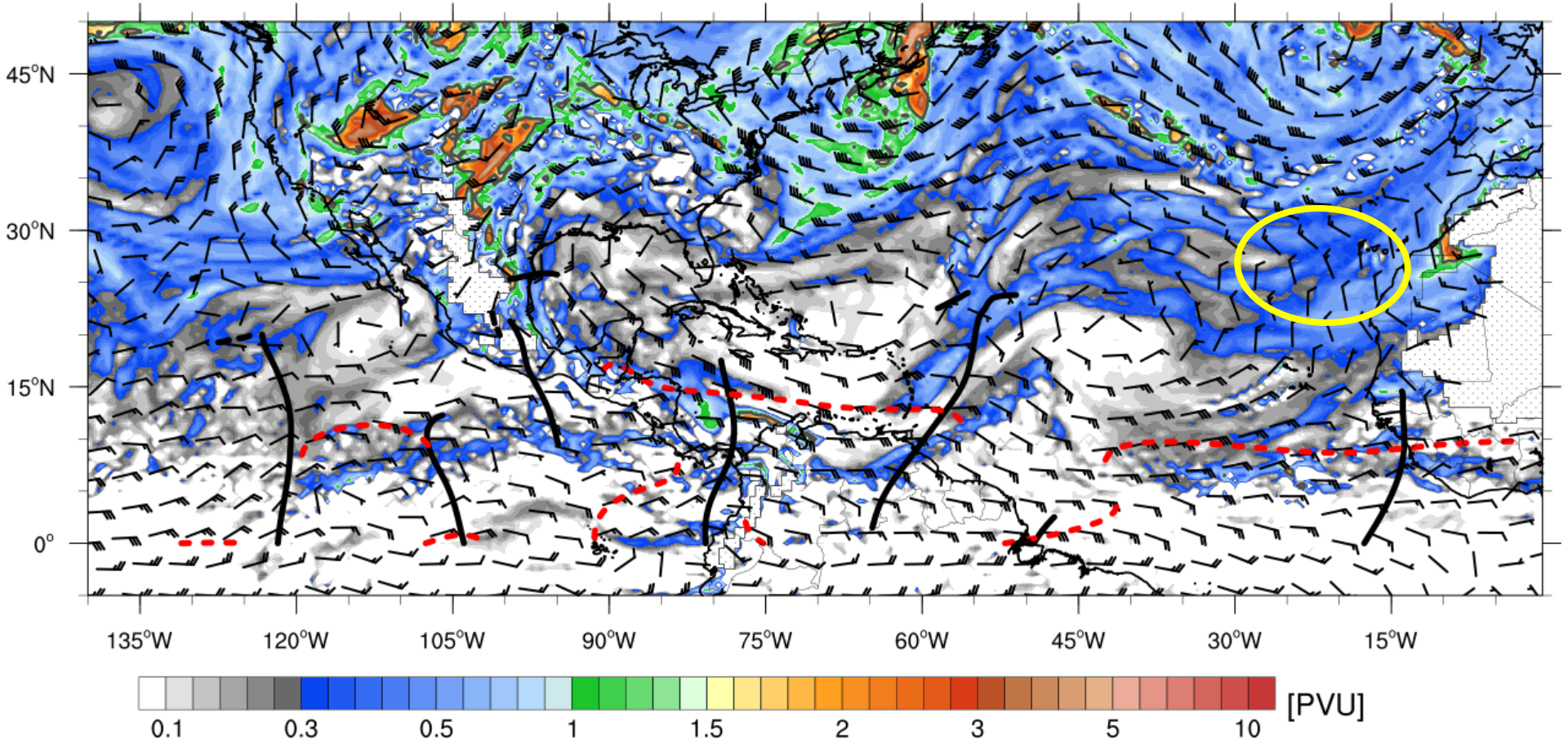
Tools to track easterly waves:
Tropical Wave Diagnostics



GFS 310K Potential Vorticity and Wind

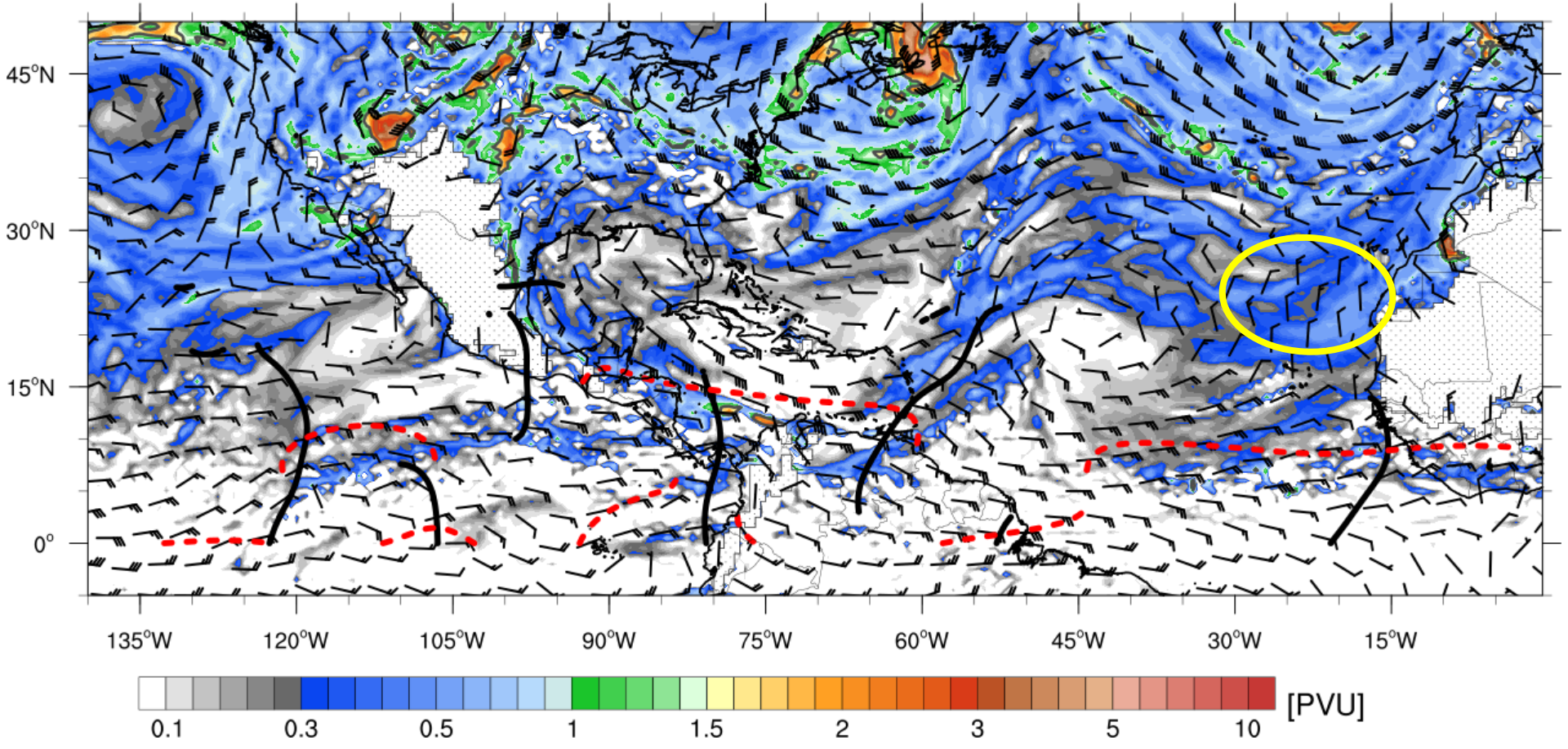
PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 22 Jun 12Z, Forecast: 0 hr, Valid: 22 Jun 12Z



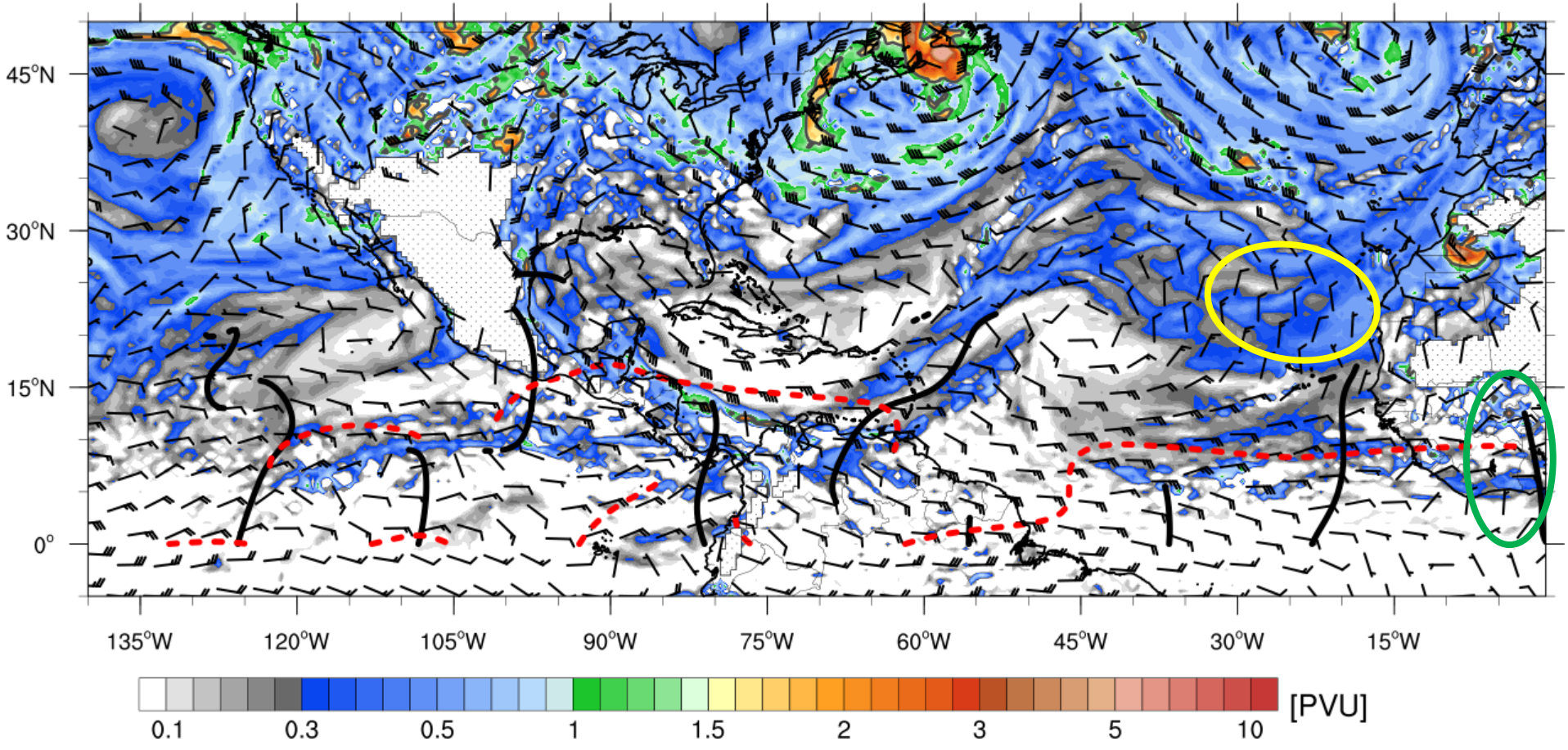
GFS 310K Potential Vorticity and Wind

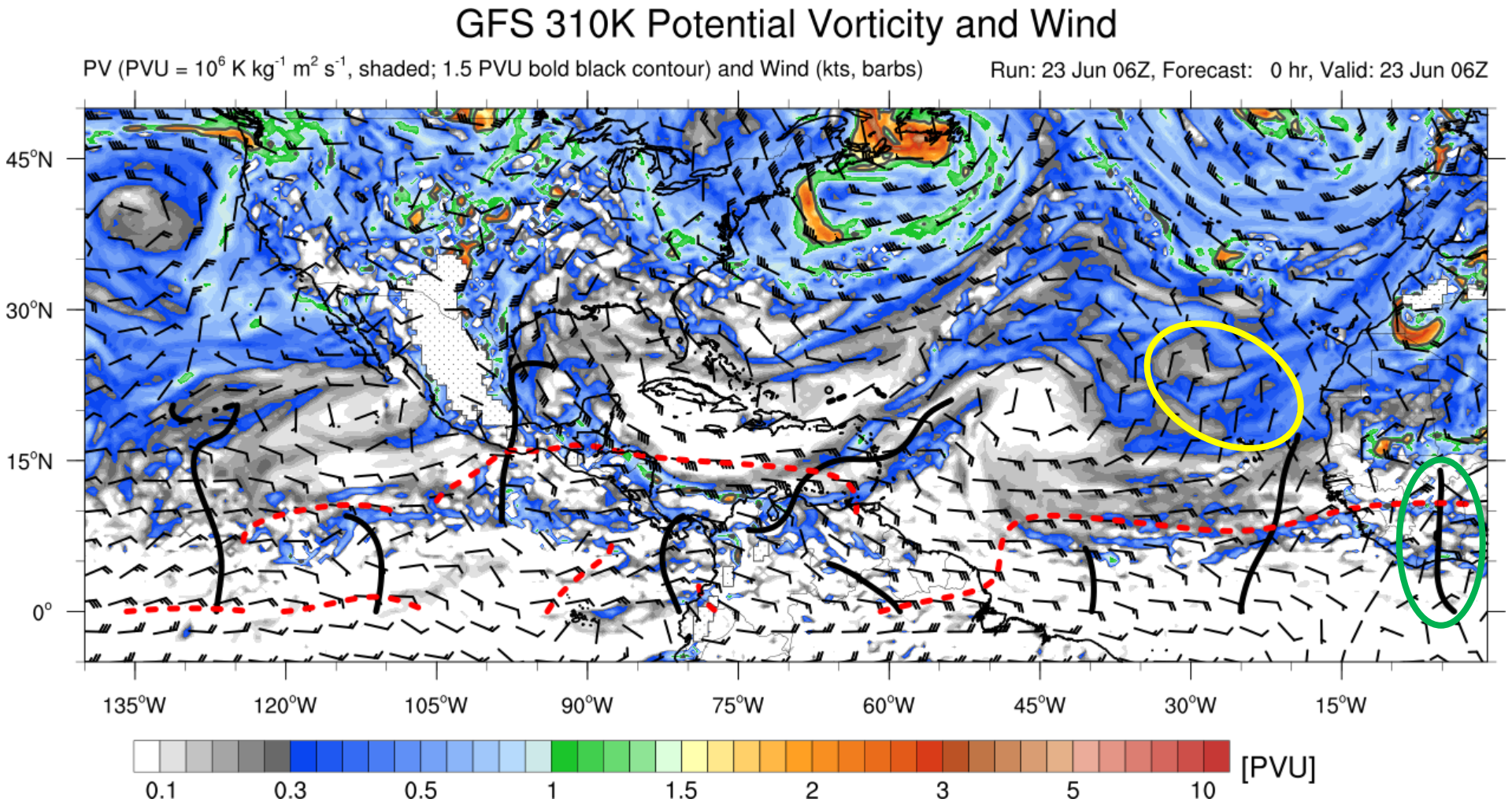
PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 22 Jun 18Z, Forecast: 0 hr, Valid: 22 Jun 18Z



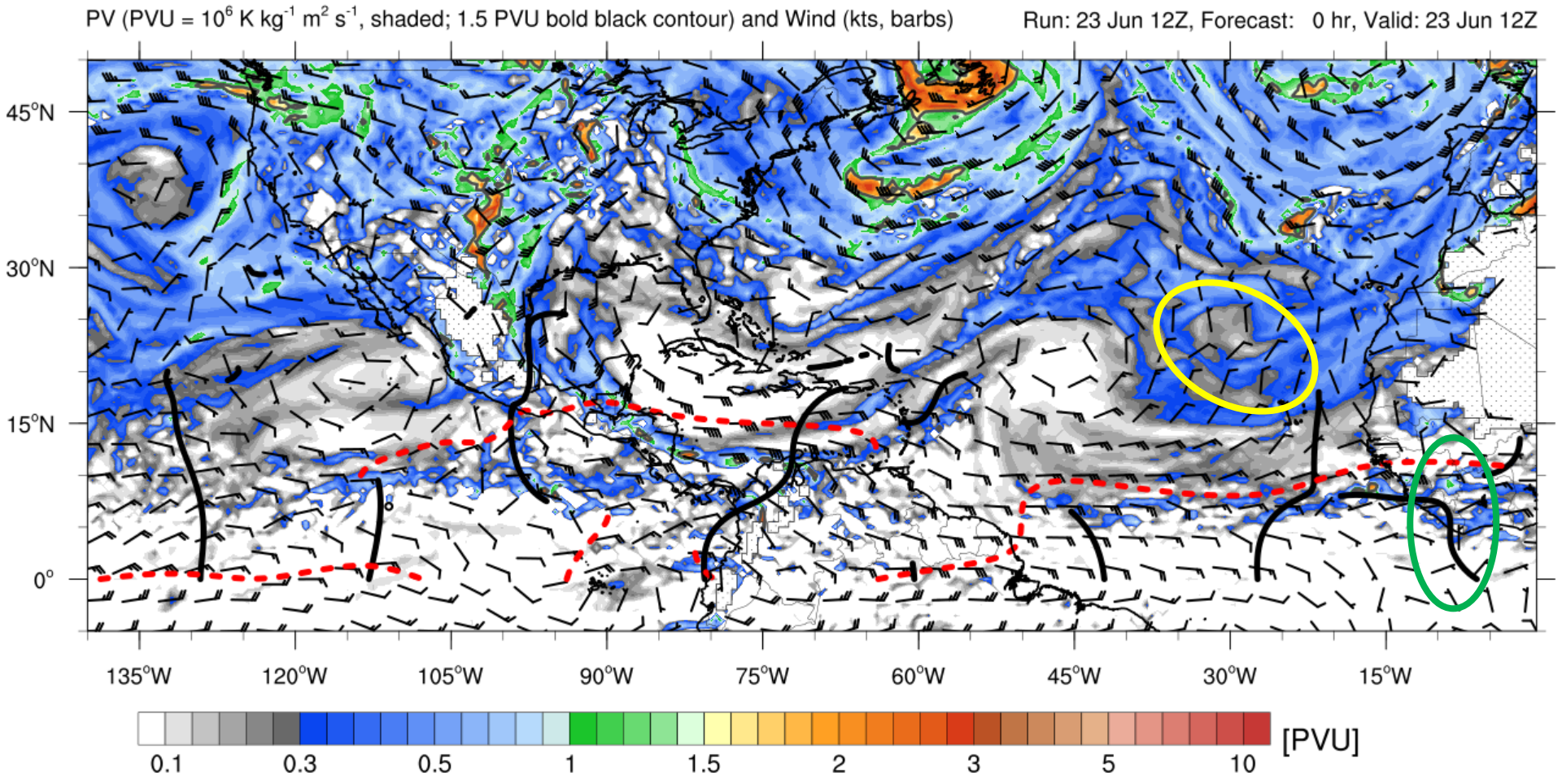
GFS 310K Potential Vorticity and Wind

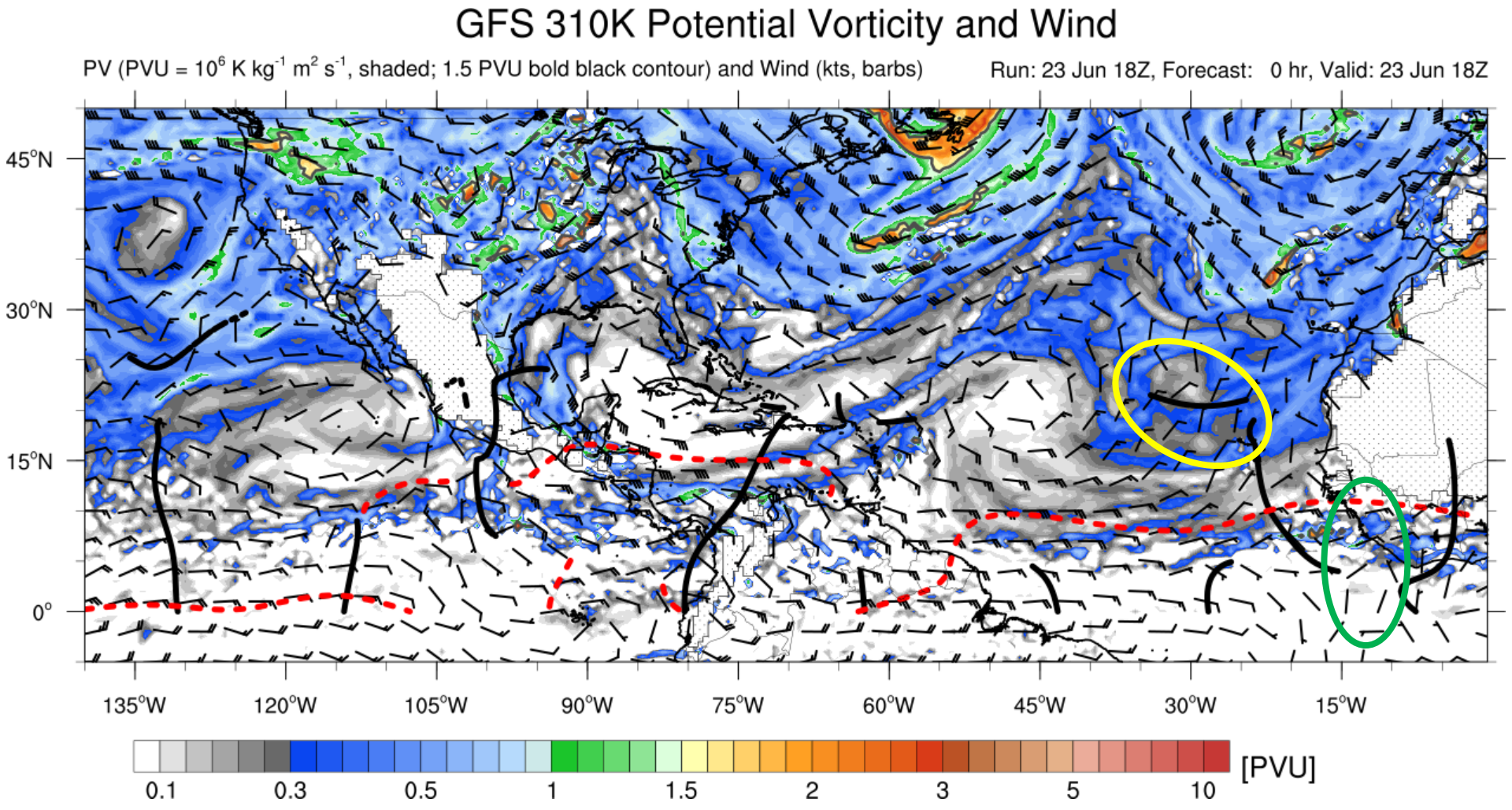
PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 23 Jun 00Z, Forecast: 0 hr, Valid: 23 Jun 00Z



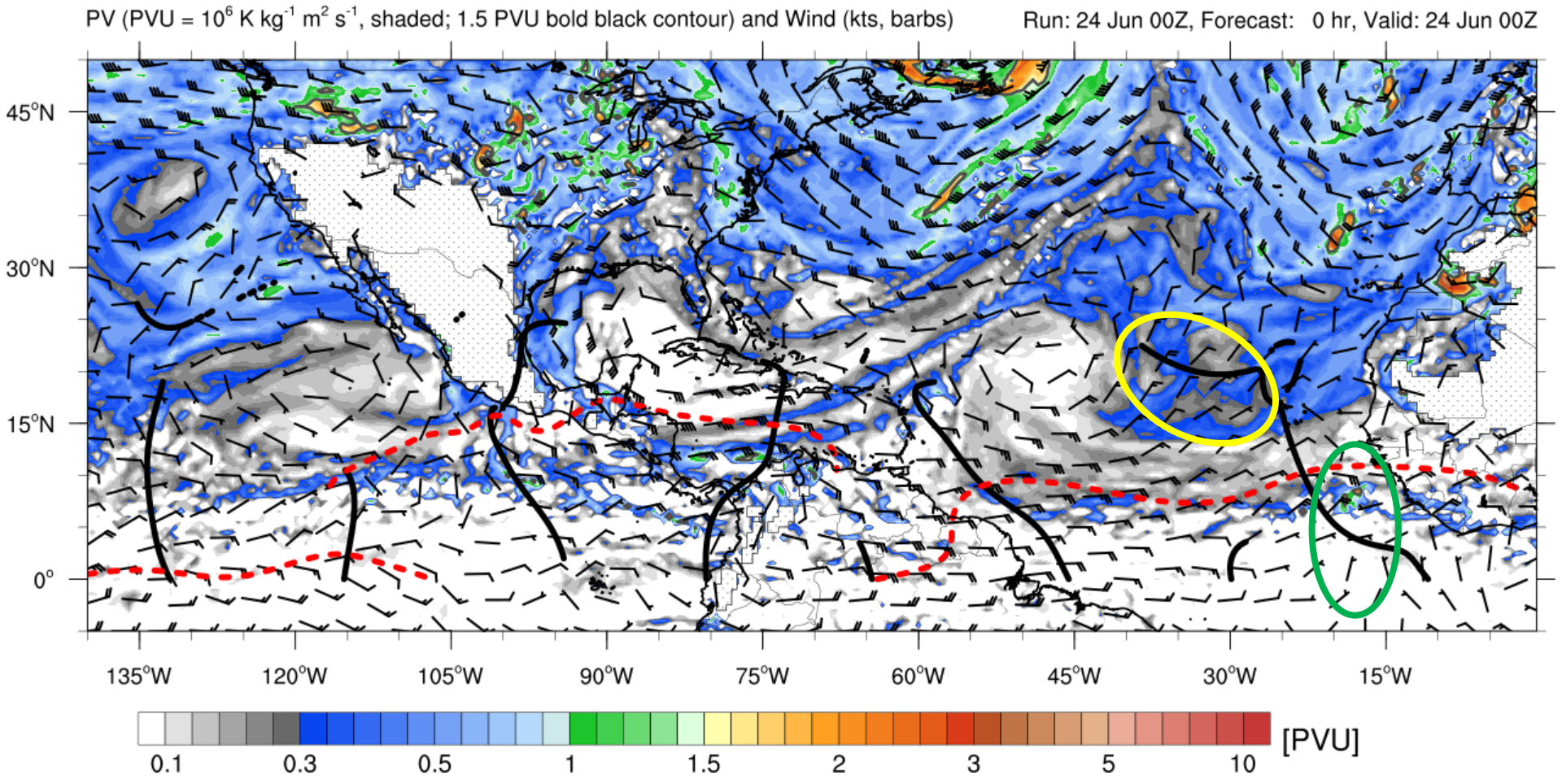

GFS 310K Potential Vorticity and Wind
PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)
Run: 23 Jun 06Z, Forecast: 0 hr, Valid: 23 Jun 06Z
45°N
30°N
15°N
0°
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0.1
0.3
0.5
1
1.5
2
3
5
10
[PVU]

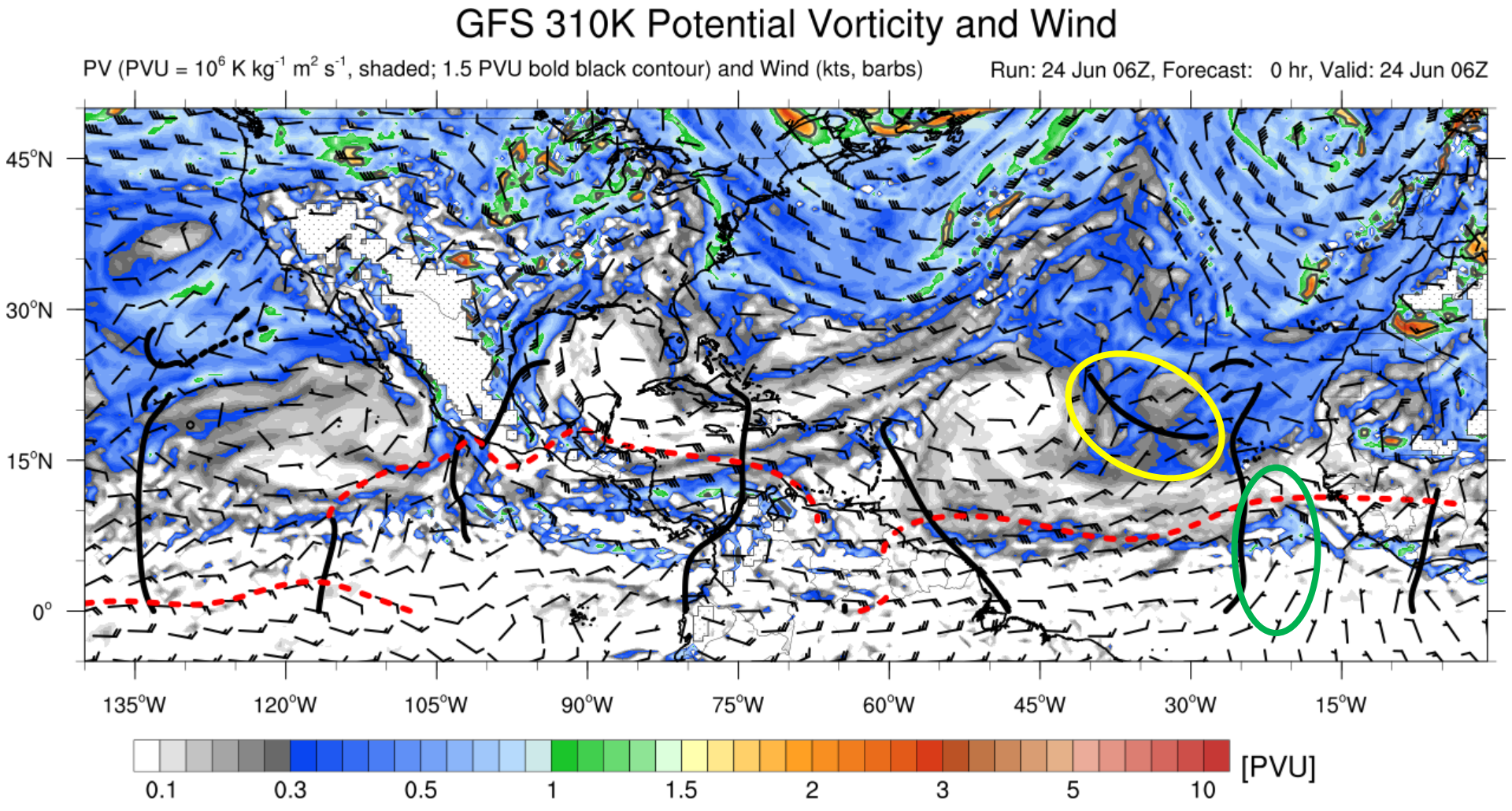
GFS 310K Potential Vorticity and Wind



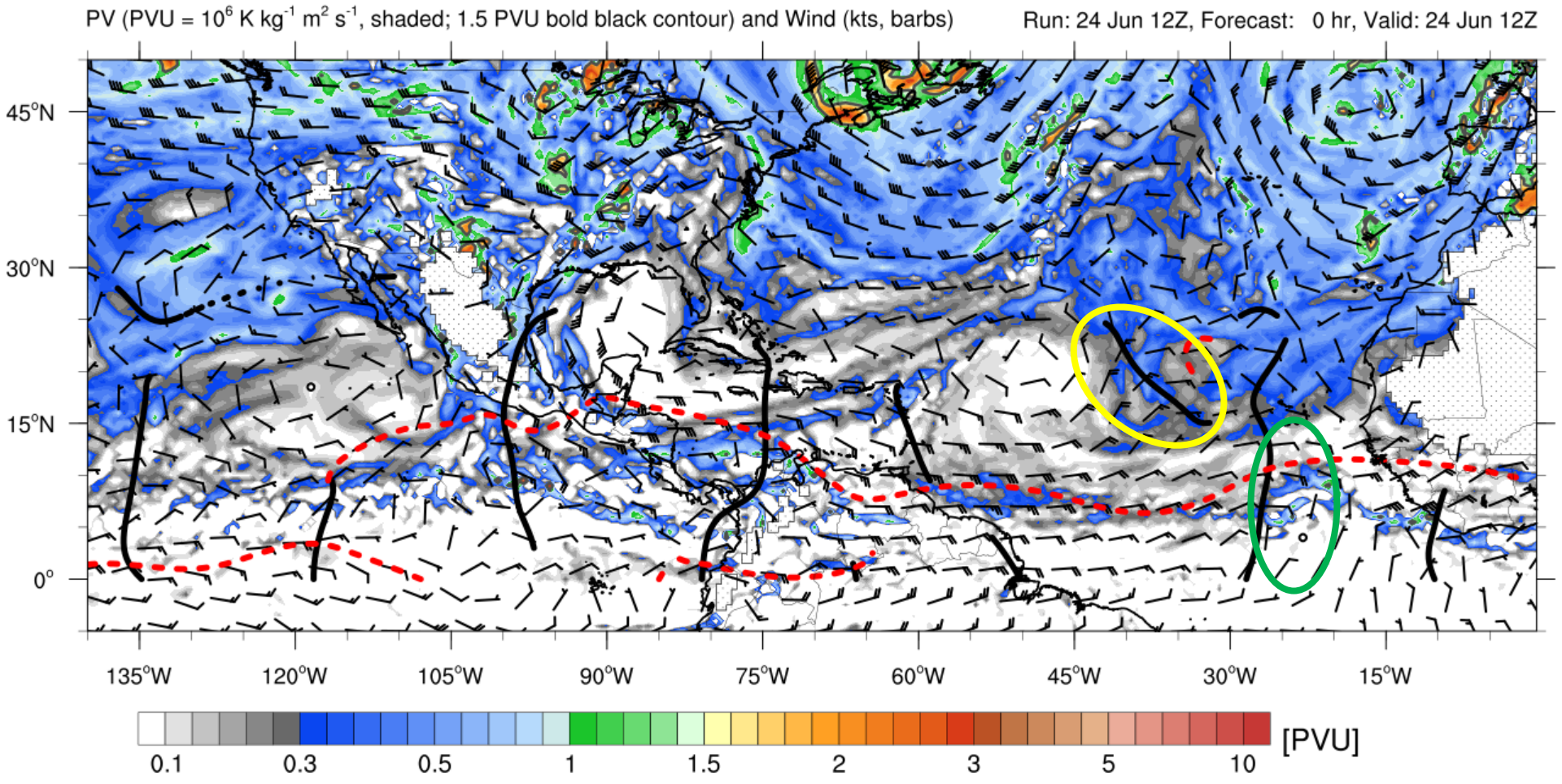

GFS 310K Potential Vorticity and Wind
PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)
Run: 23 Jun 18Z, Forecast: 0 hr, Valid: 23 Jun 18Z
45°N
30°N
15°N
0°
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0.1
0.3
0.5
1
1.5
2
3
5
10
[PVU]

GFS 310K Potential Vorticity and Wind

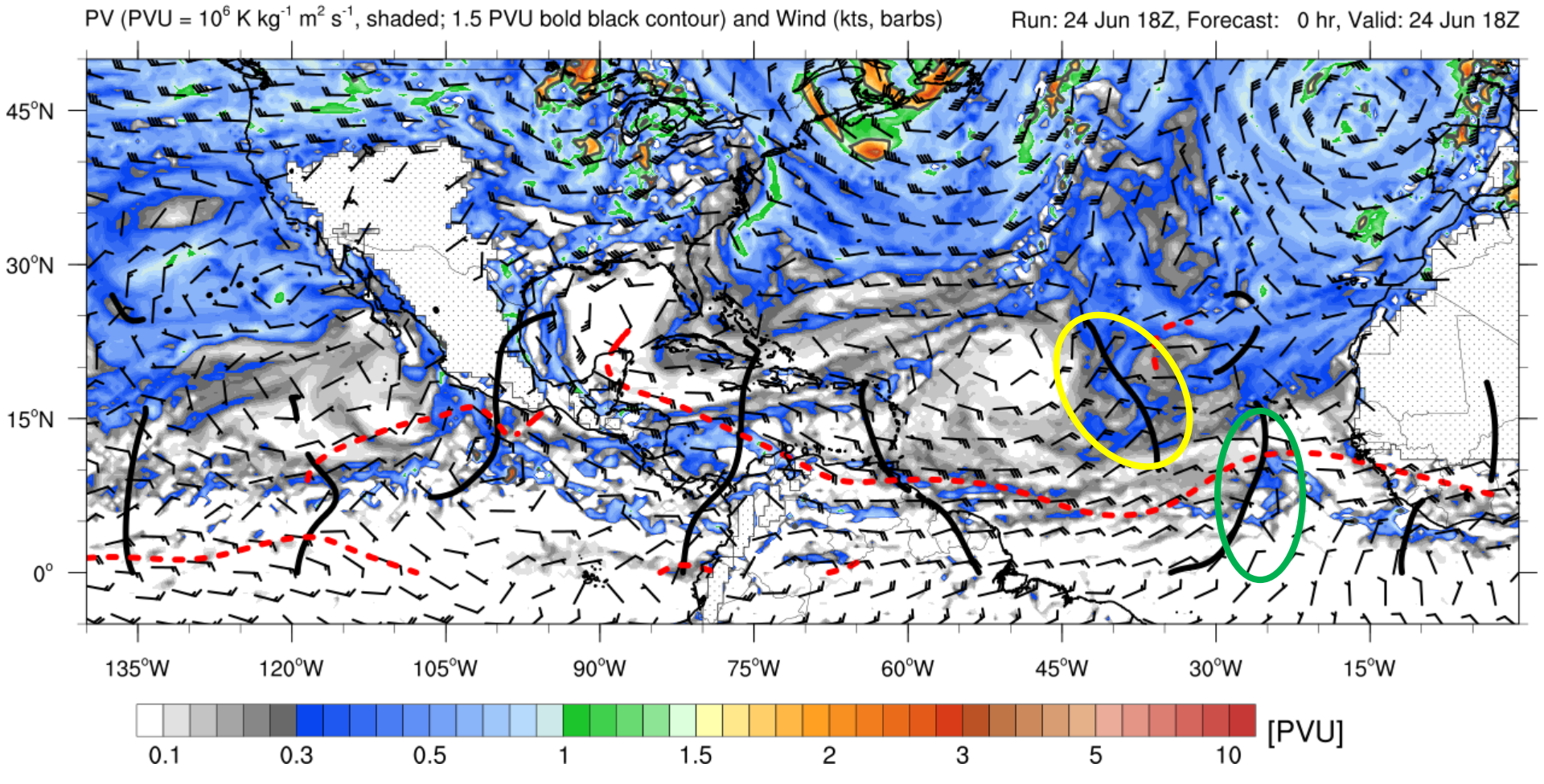



GFS 310K Potential Vorticity and Wind
PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)
Run: 24 Jun 06Z, Forecast: 0 hr, Valid: 24 Jun 06Z
45°N
30°N
15°N
0°
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0.1
0.3
0.5
1
1.5
2
3
5
10
[PVU]

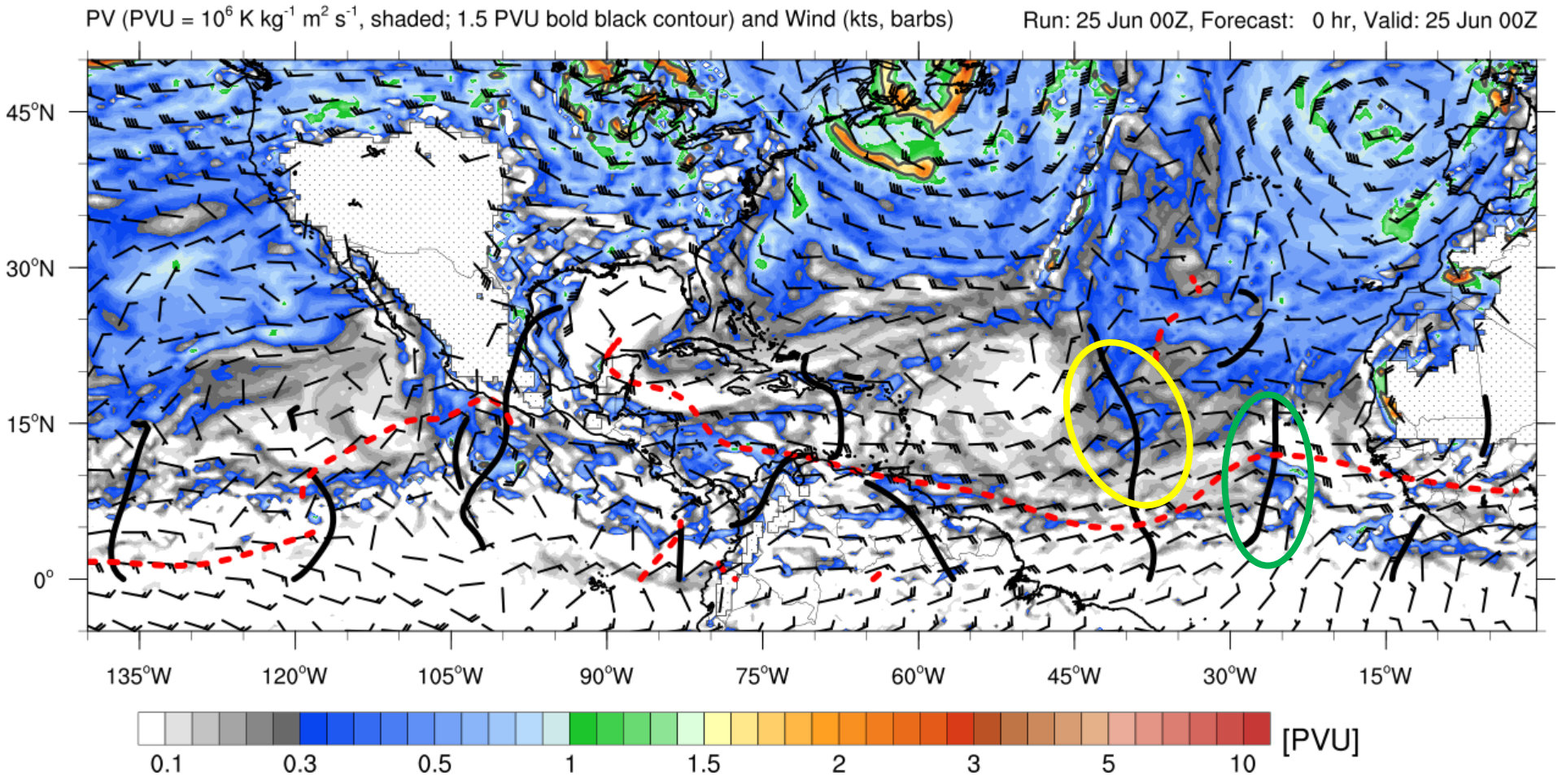
GFS 310K Potential Vorticity and Wind



GFS 310K Potential Vorticity and Wind

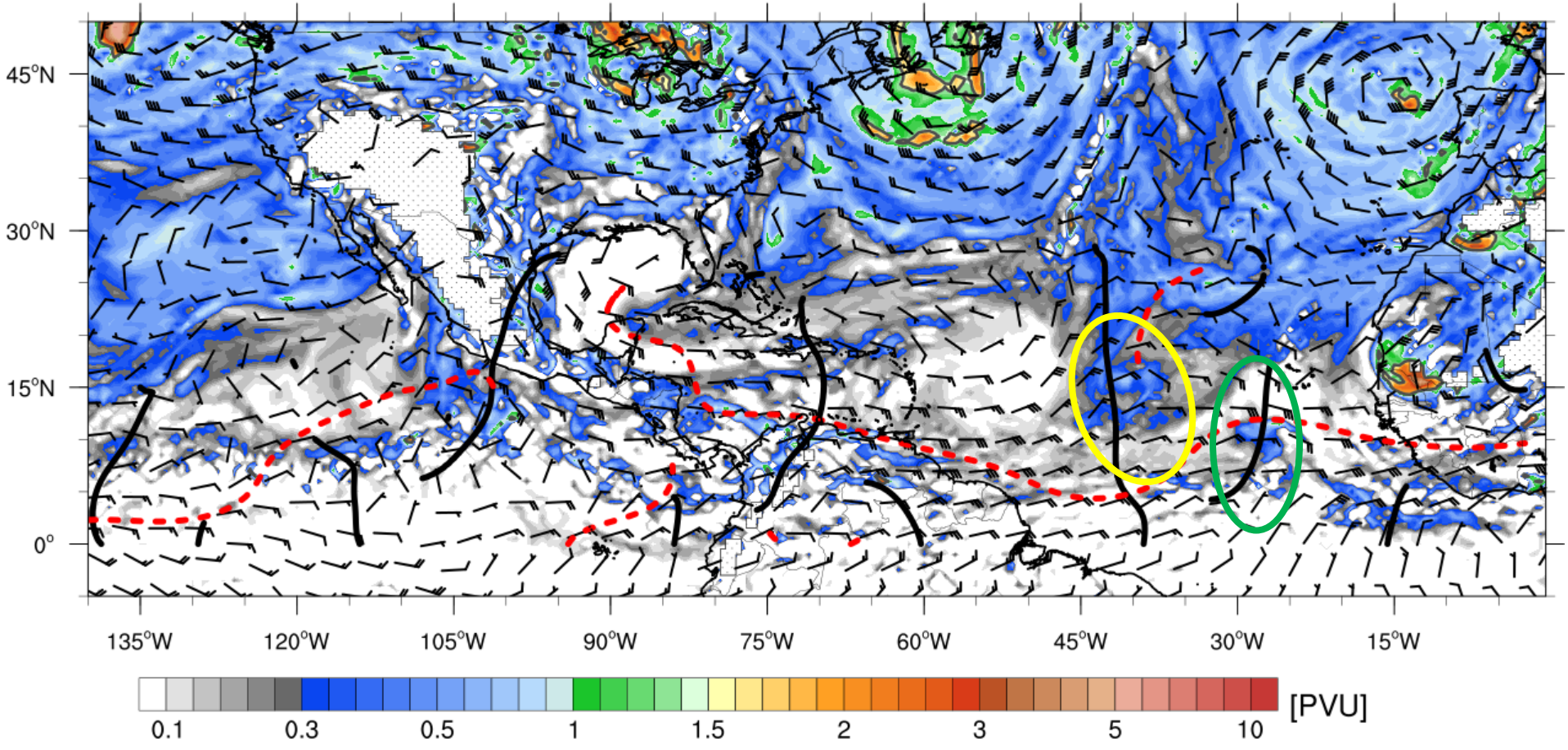


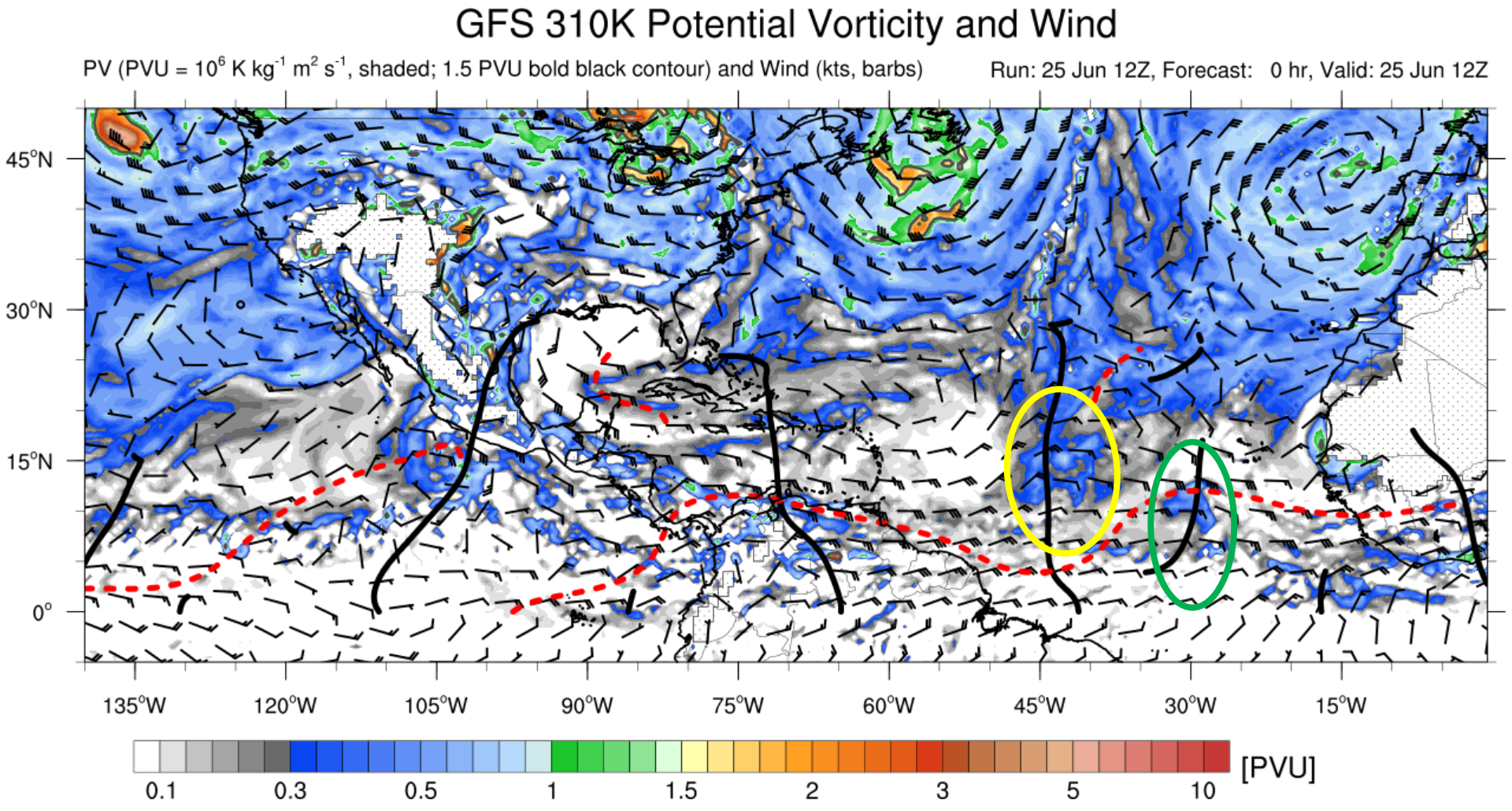
GFS 310K Potential Vorticity and Wind



GFS 310K Potential Vorticity and Wind

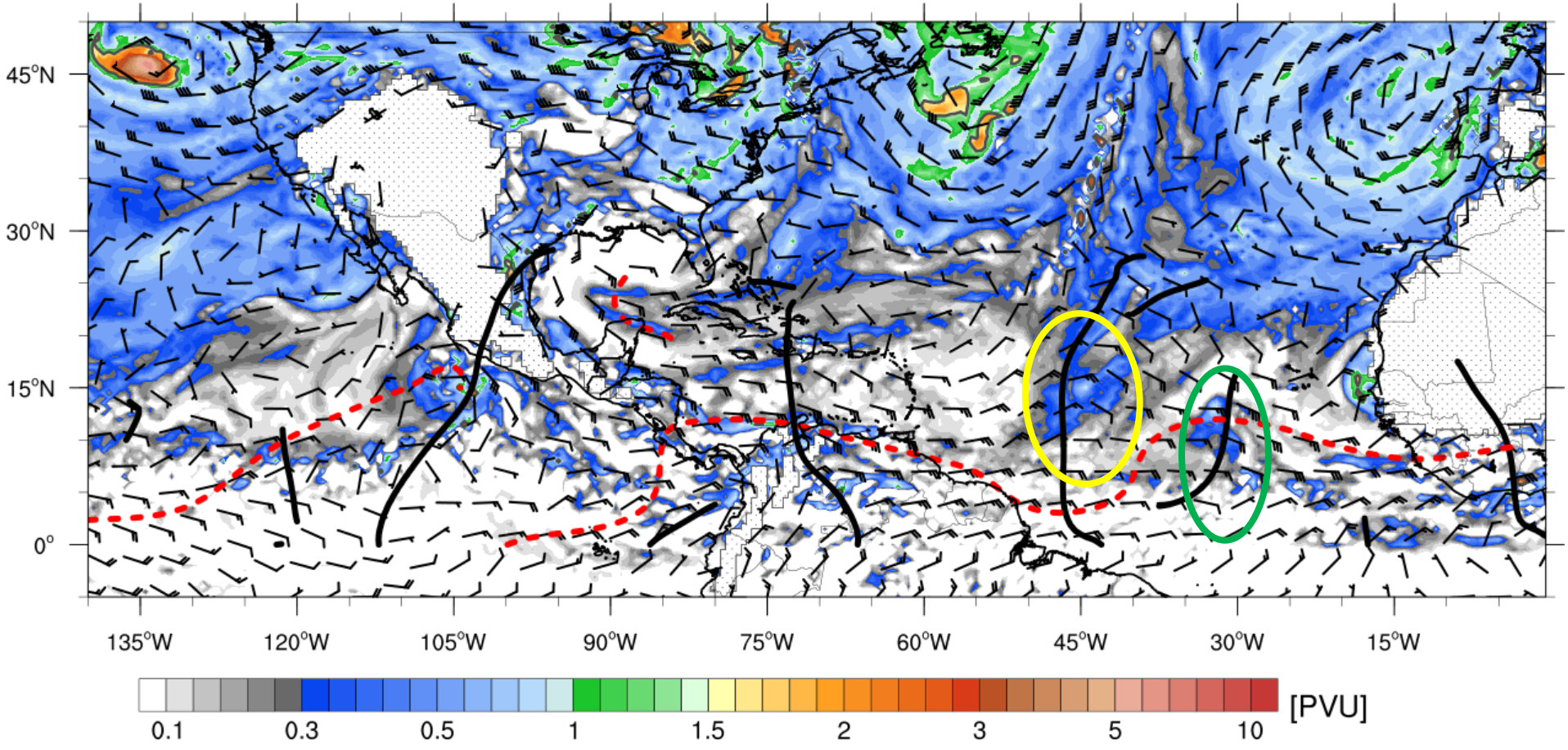
PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 25 Jun 06Z, Forecast: 0 hr, Valid: 25 Jun 06Z



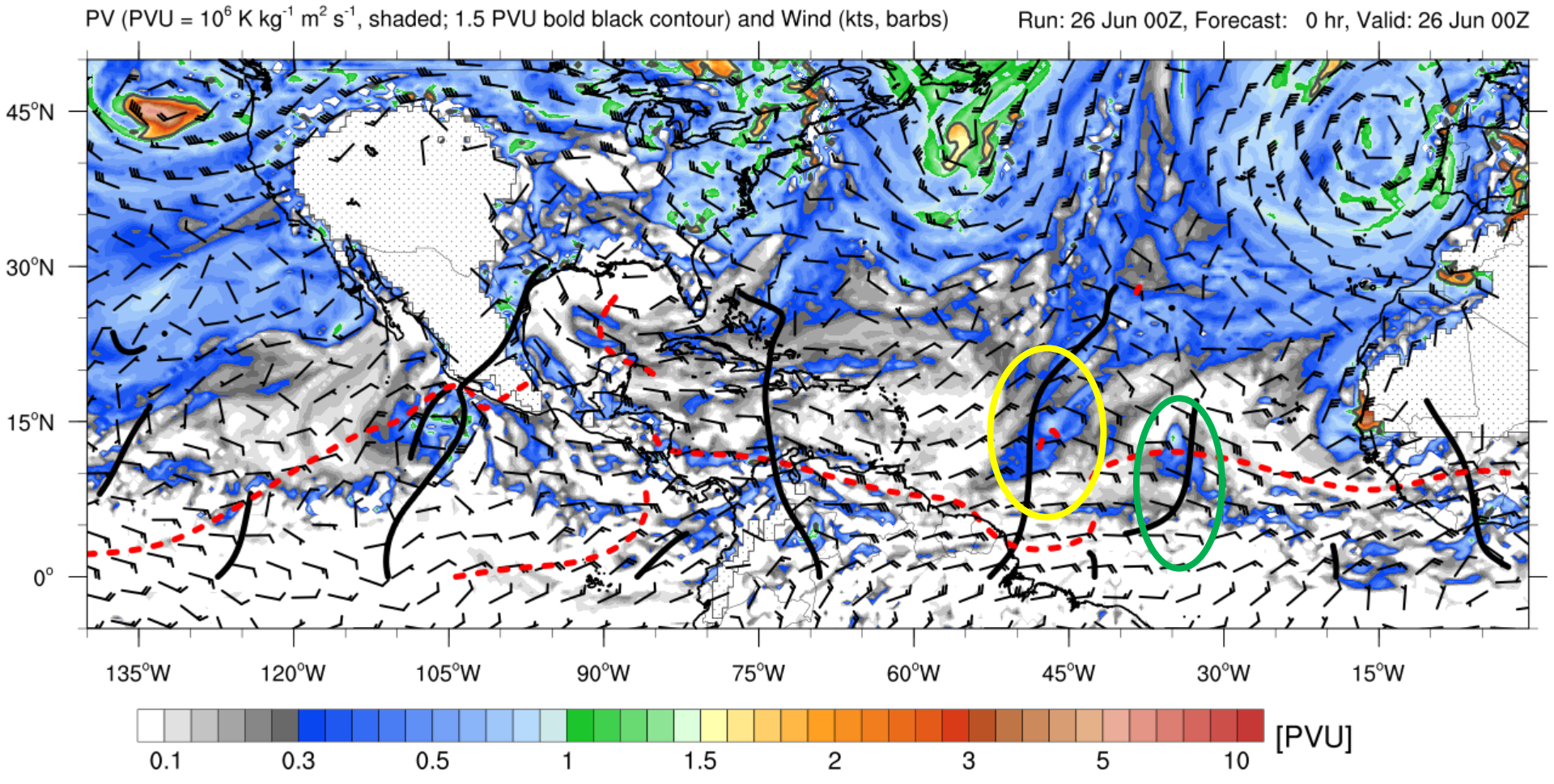

GFS 310K Potential Vorticity and Wind
PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)
Run: 25 Jun 12Z, Forecast: 0 hr, Valid: 25 Jun 12Z
45°N
30°N
15°N
0°
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0.1
0.3
0.5
1
1.5
2
3
5
10
[PVU]

GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 25 Jun 18Z, Forecast: 0 hr, Valid: 25 Jun 18Z

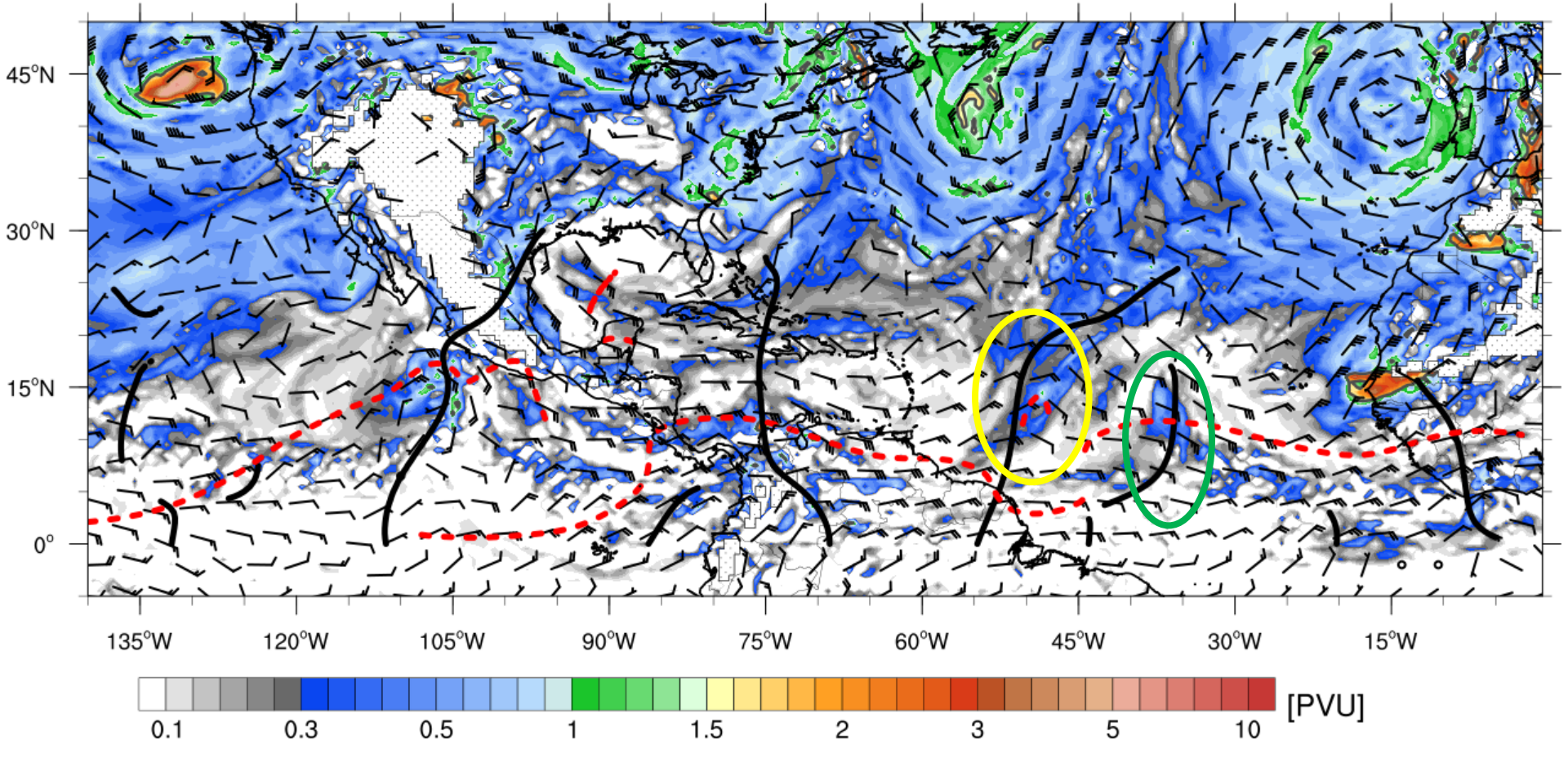


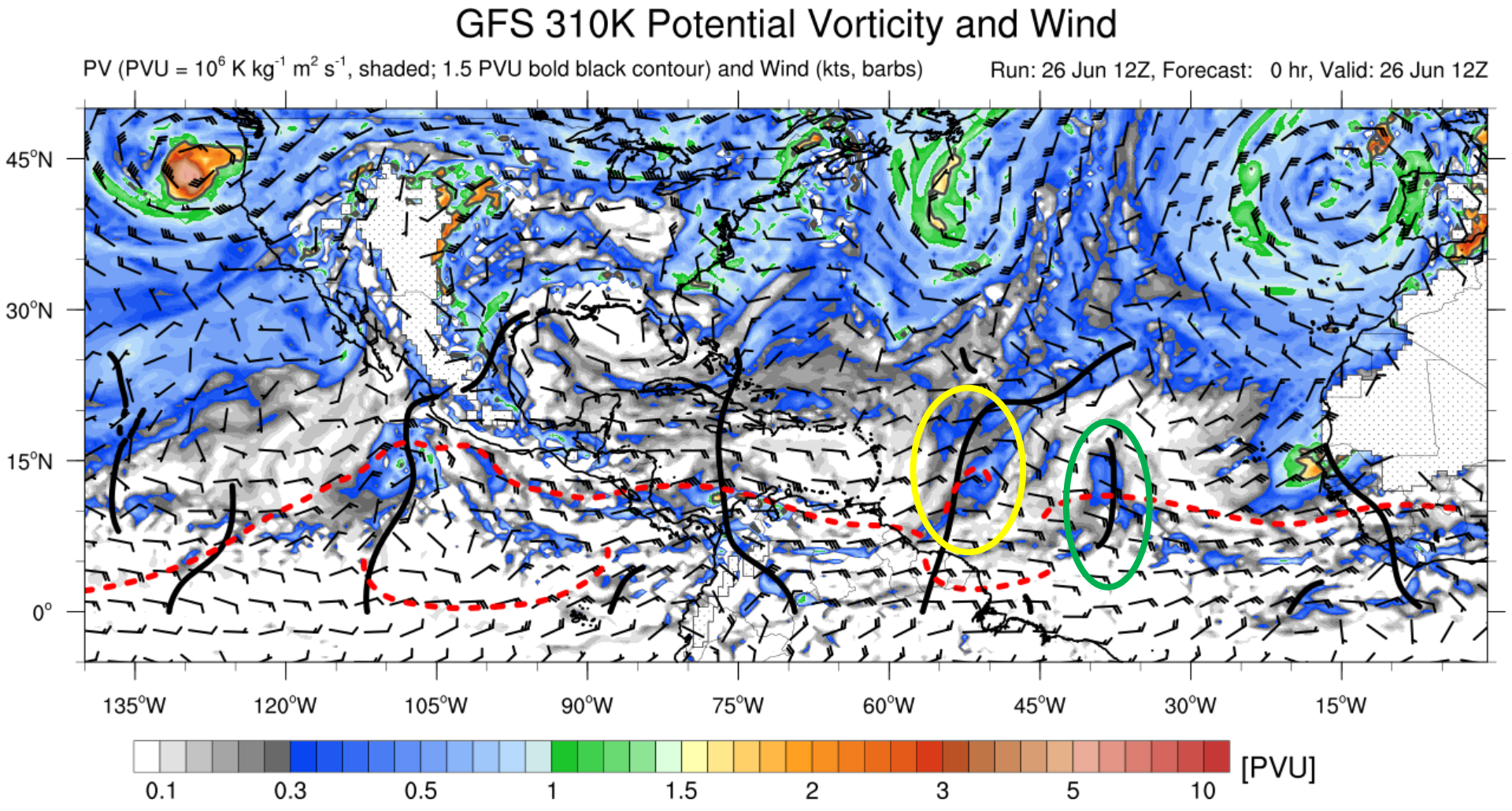
GFS 310K Potential Vorticity and Wind

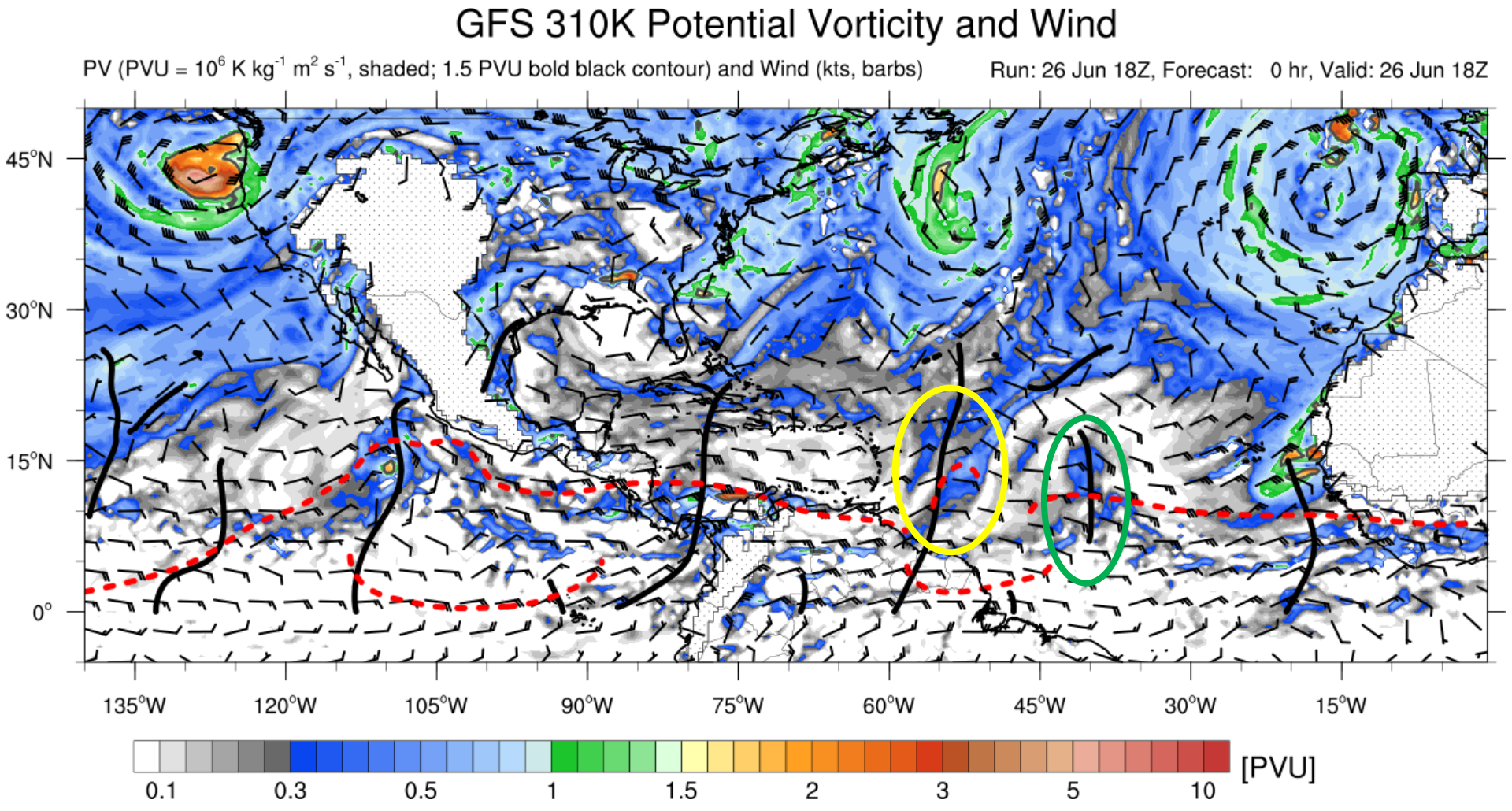


GFS 310K Potential Vorticity and Wind

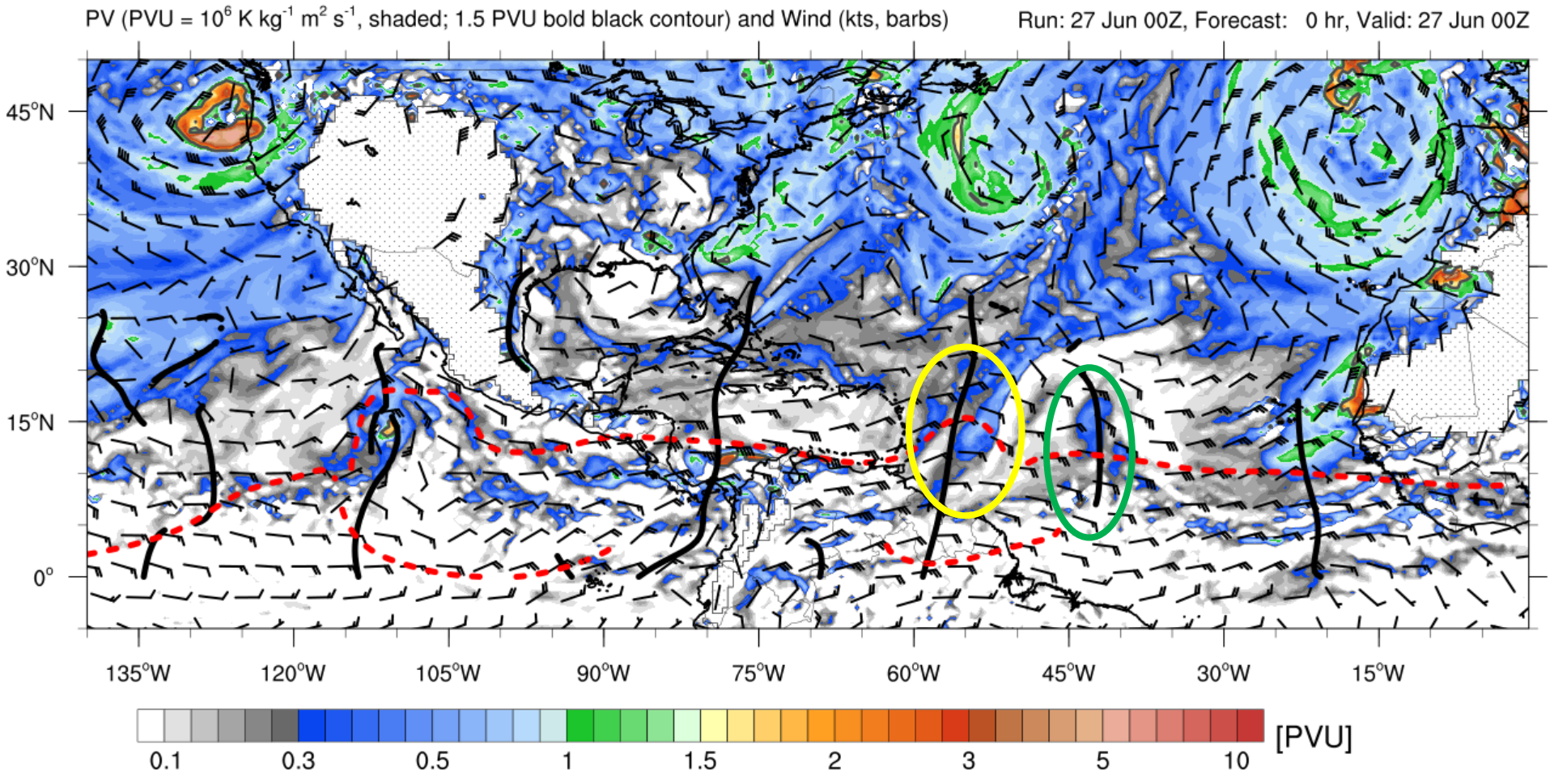
PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 26 Jun 06Z, Forecast: 0 hr, Valid: 26 Jun 06Z




GFS 310K Potential Vorticity and Wind
PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)
Run: 26 Jun 12Z, Forecast: 0 hr, Valid: 26 Jun 12Z
45°N
30°N
15°N
0°
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0.1
0.3
0.5
1
1.5
2
3
5
10
[PVU]

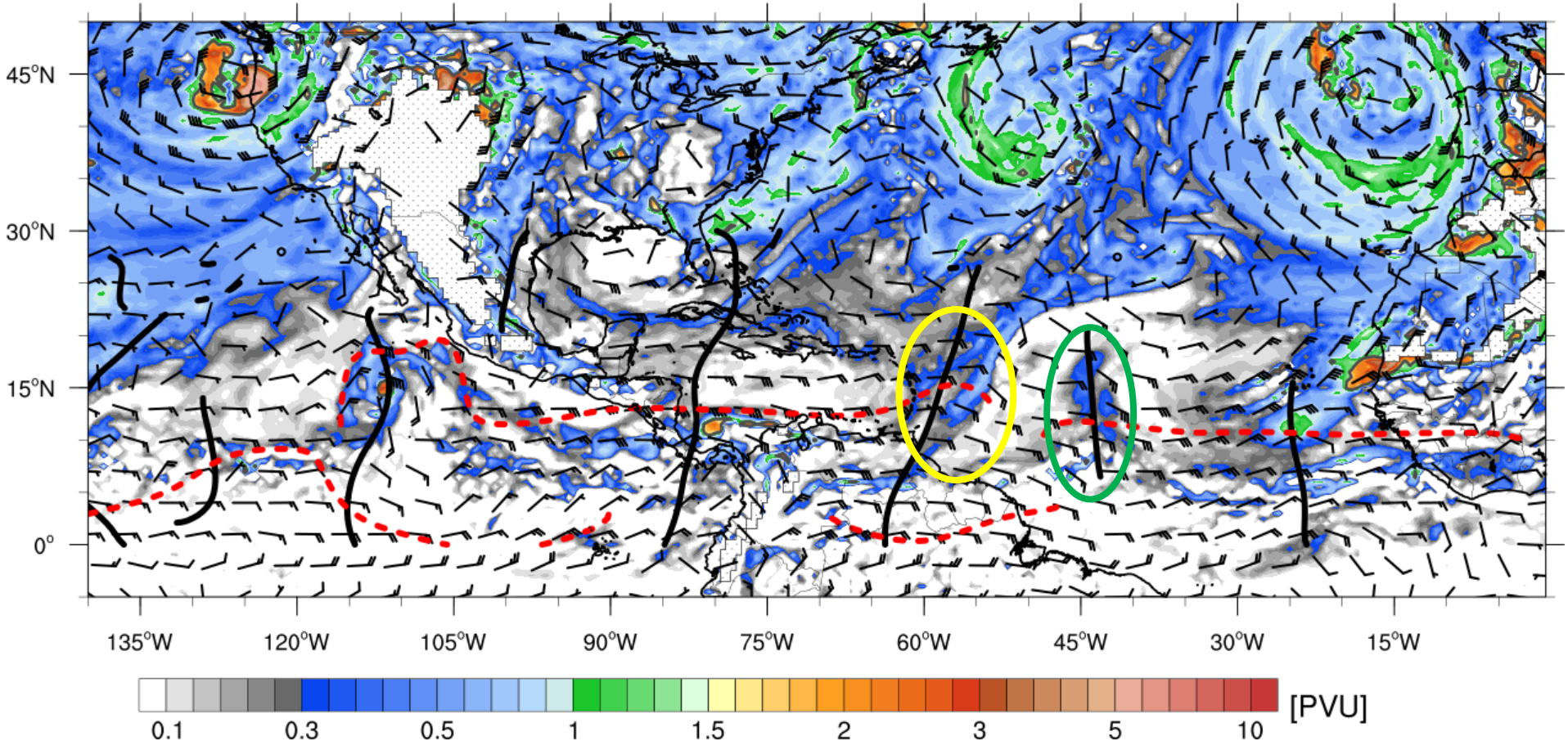

GFS 310K Potential Vorticity and Wind
PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)
Run: 26 Jun 18Z, Forecast: 0 hr, Valid: 26 Jun 18Z
45°N
30°N
15°N
0°
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0.1
0.3
0.5
1
1.5
2
3
5
10
[PVU]

GFS 310K Potential Vorticity and Wind



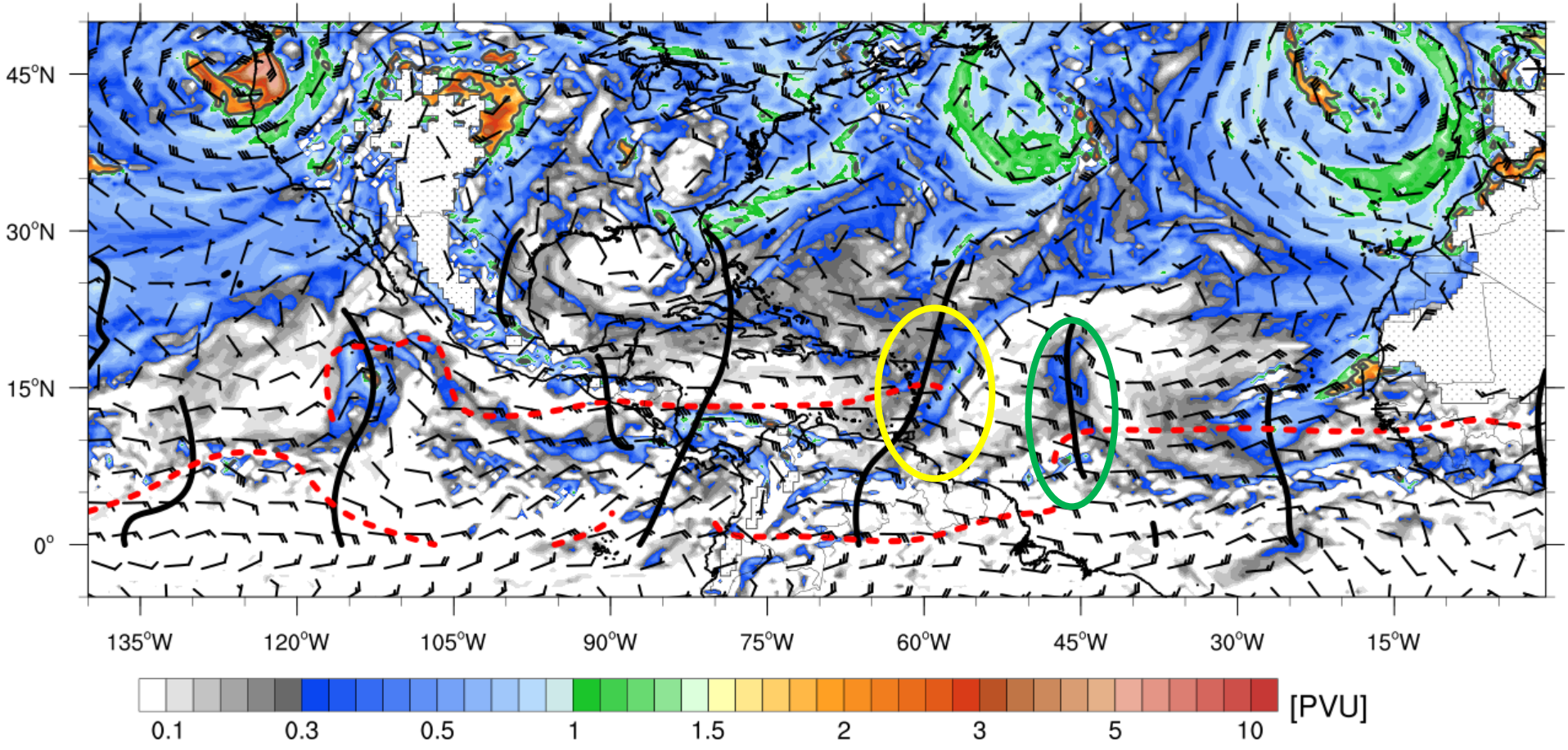
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 27 Jun 06Z, Forecast: 0 hr, Valid: 27 Jun 06Z



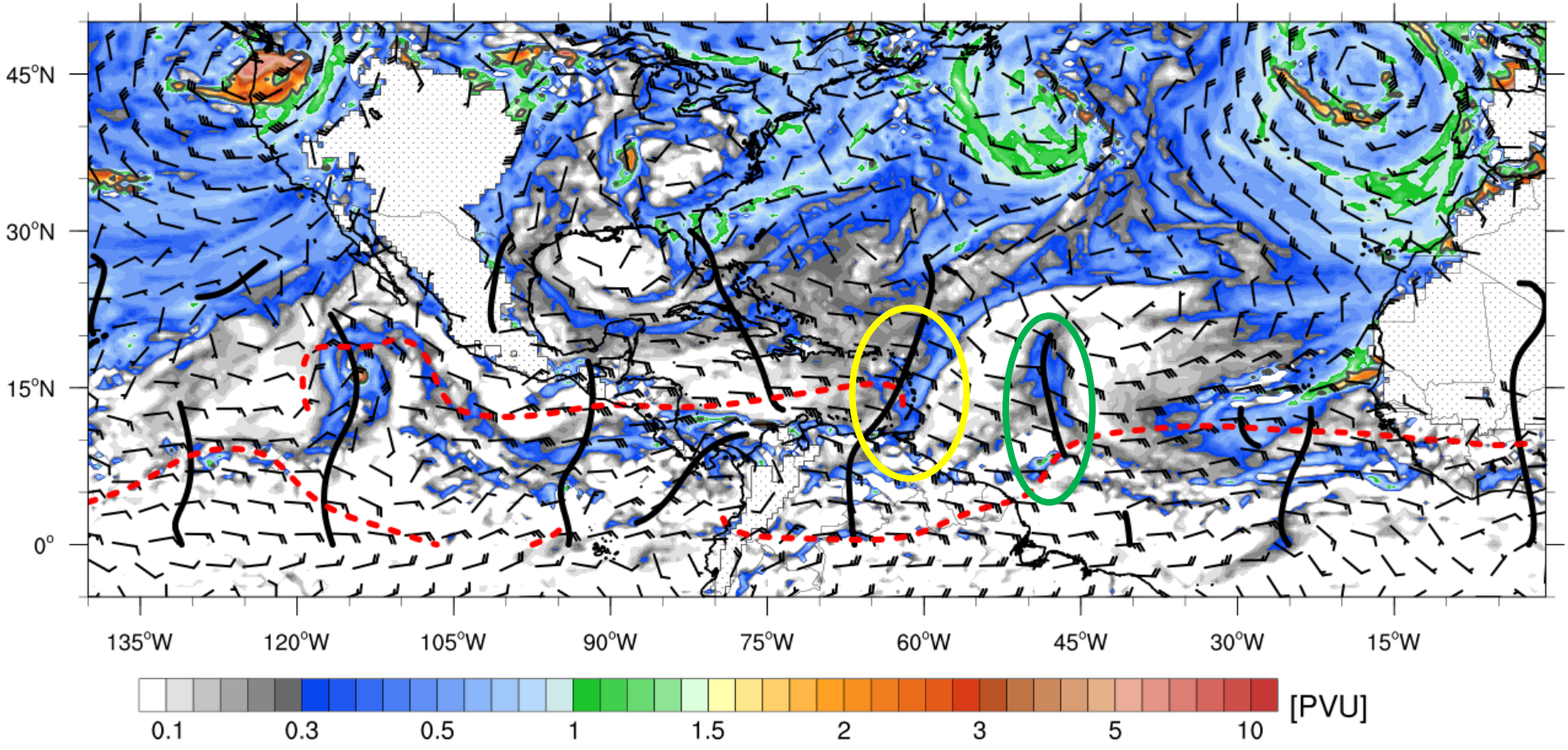
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 27 Jun 12Z, Forecast: 0 hr, Valid: 27 Jun 12Z



GFS 310K Potential Vorticity and Wind

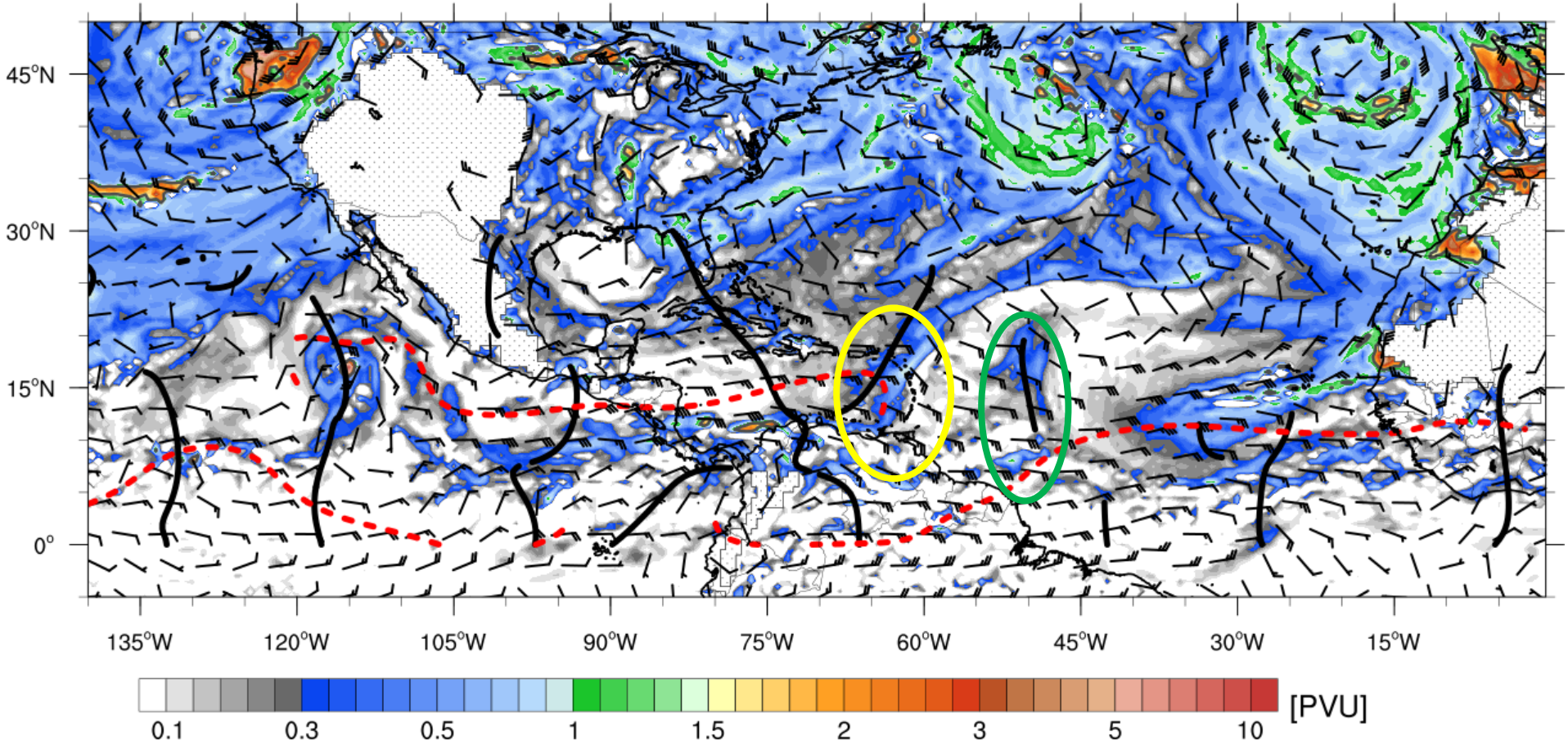
PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 27 Jun 18Z, Forecast: 0 hr, Valid: 27 Jun 18Z

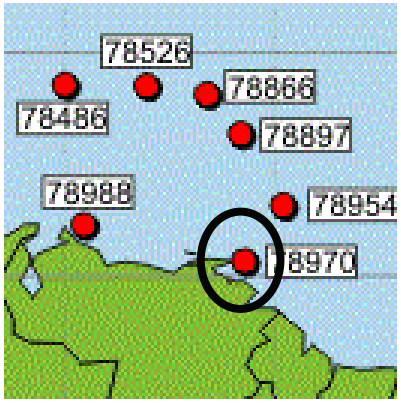


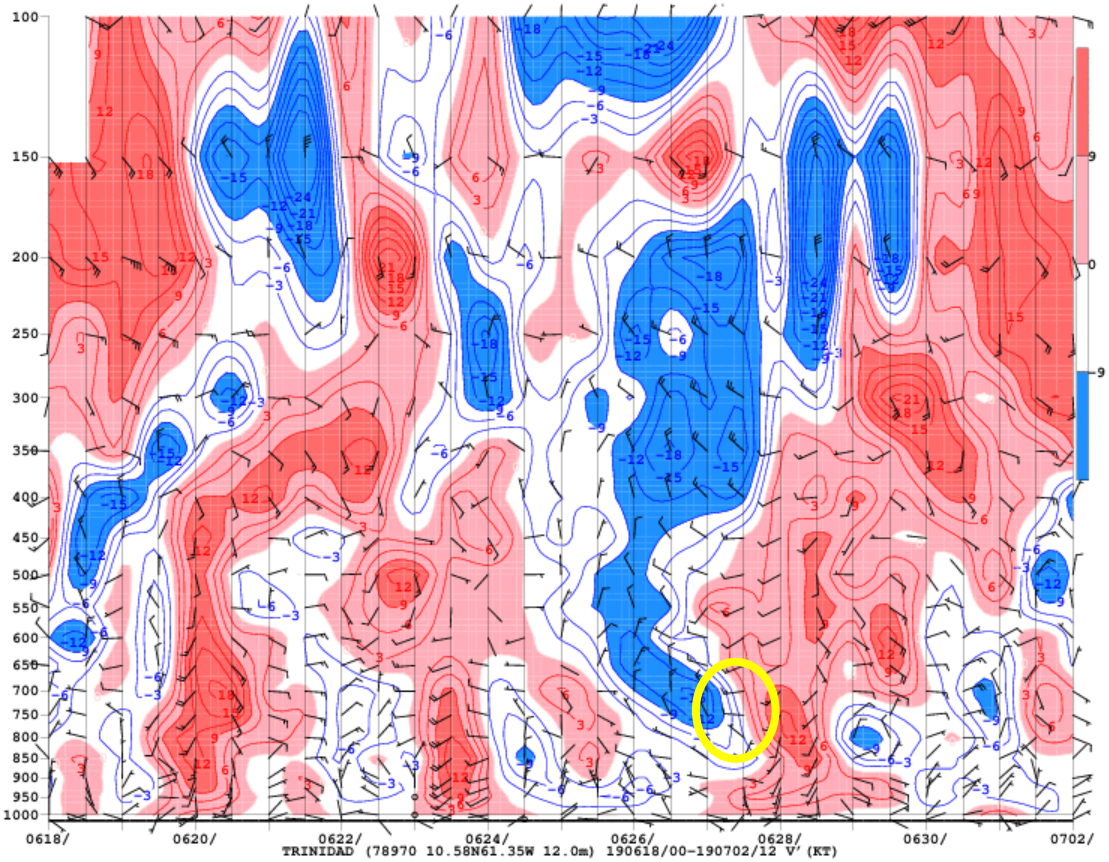
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 28 Jun 00Z, Forecast: 0 hr, Valid: 28 Jun 00Z



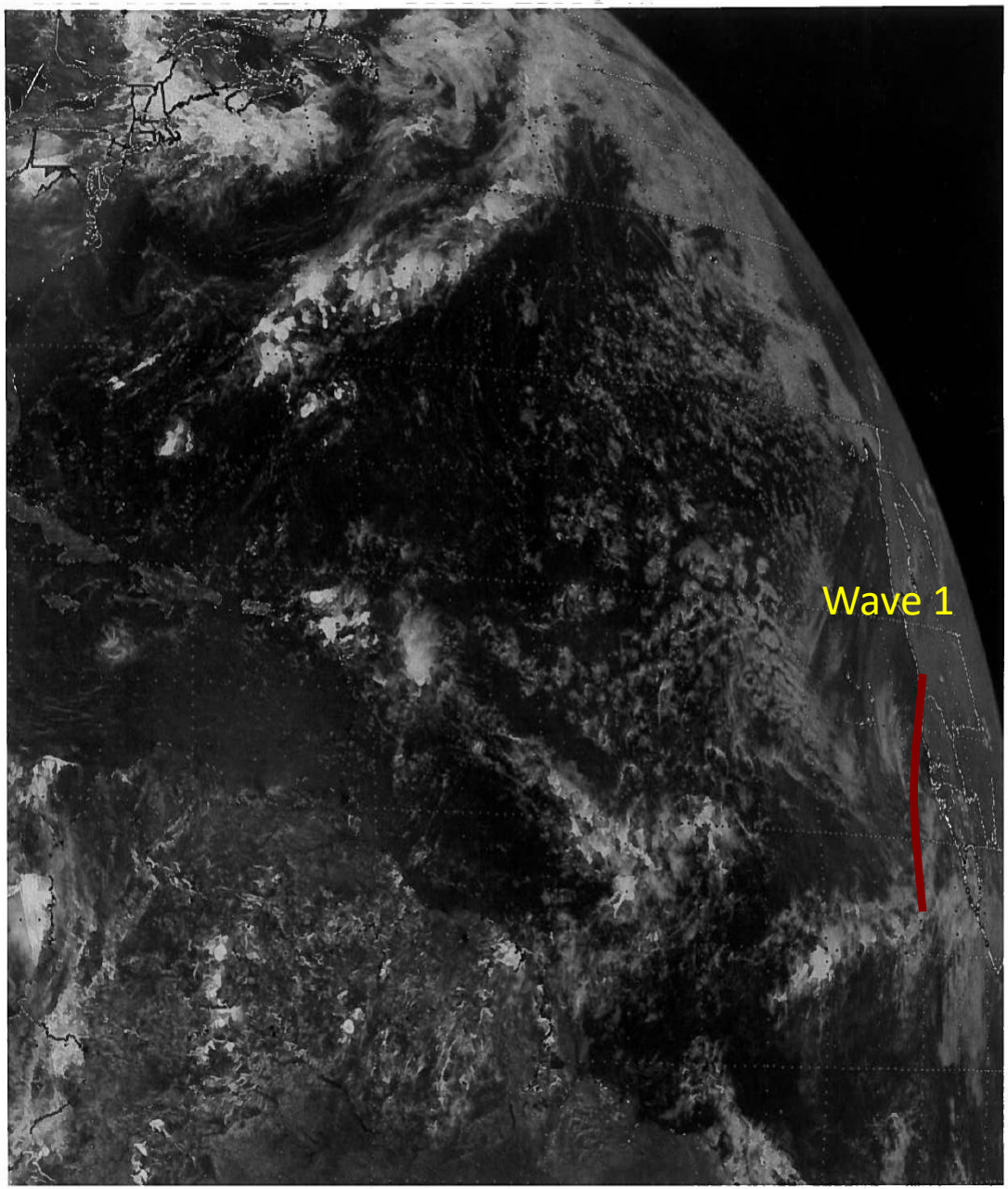




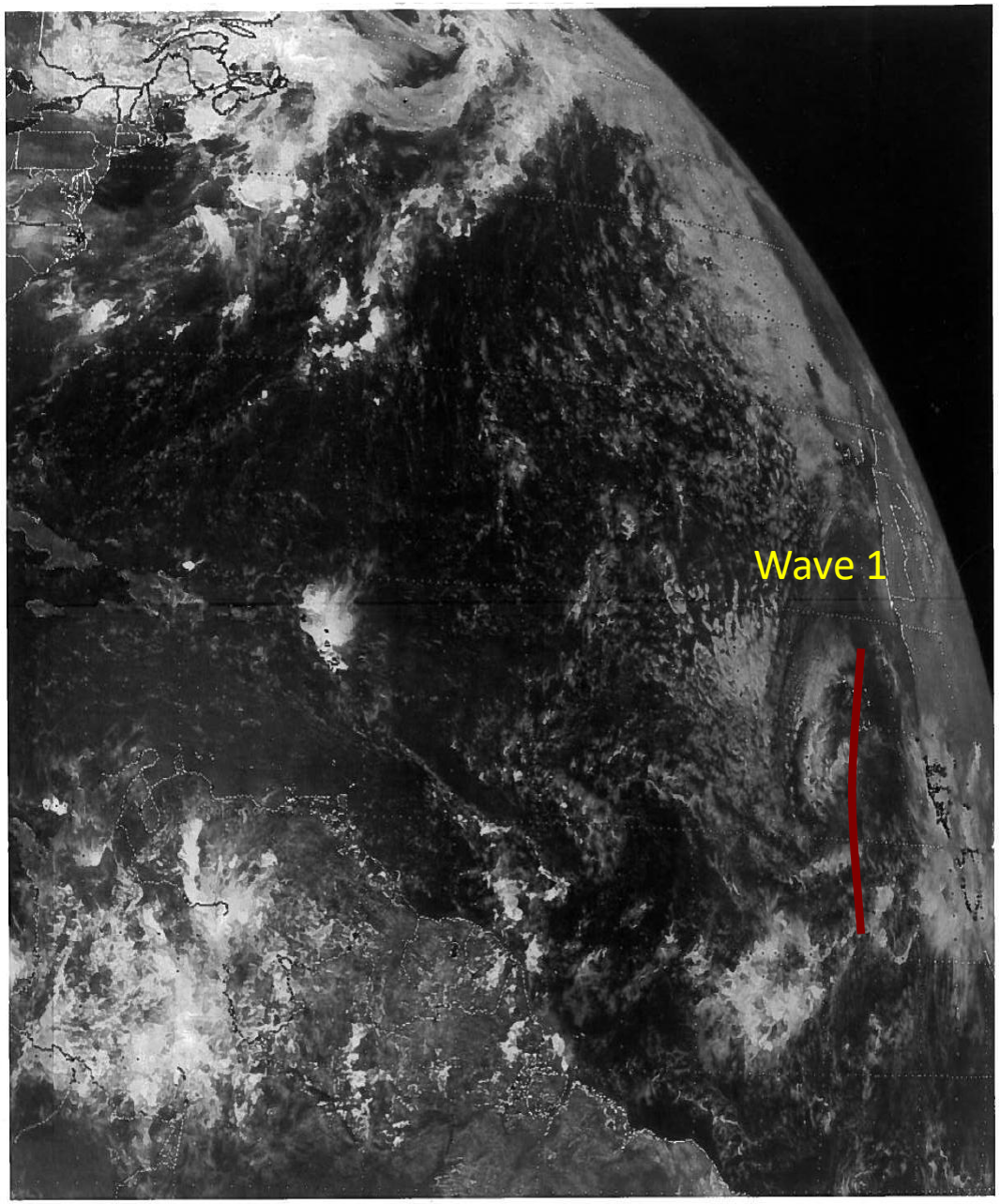
Trinidad upper air sounding v anomaly. The PV streamer passed Trinidad June 27 (yellow oval).

EXERCISE

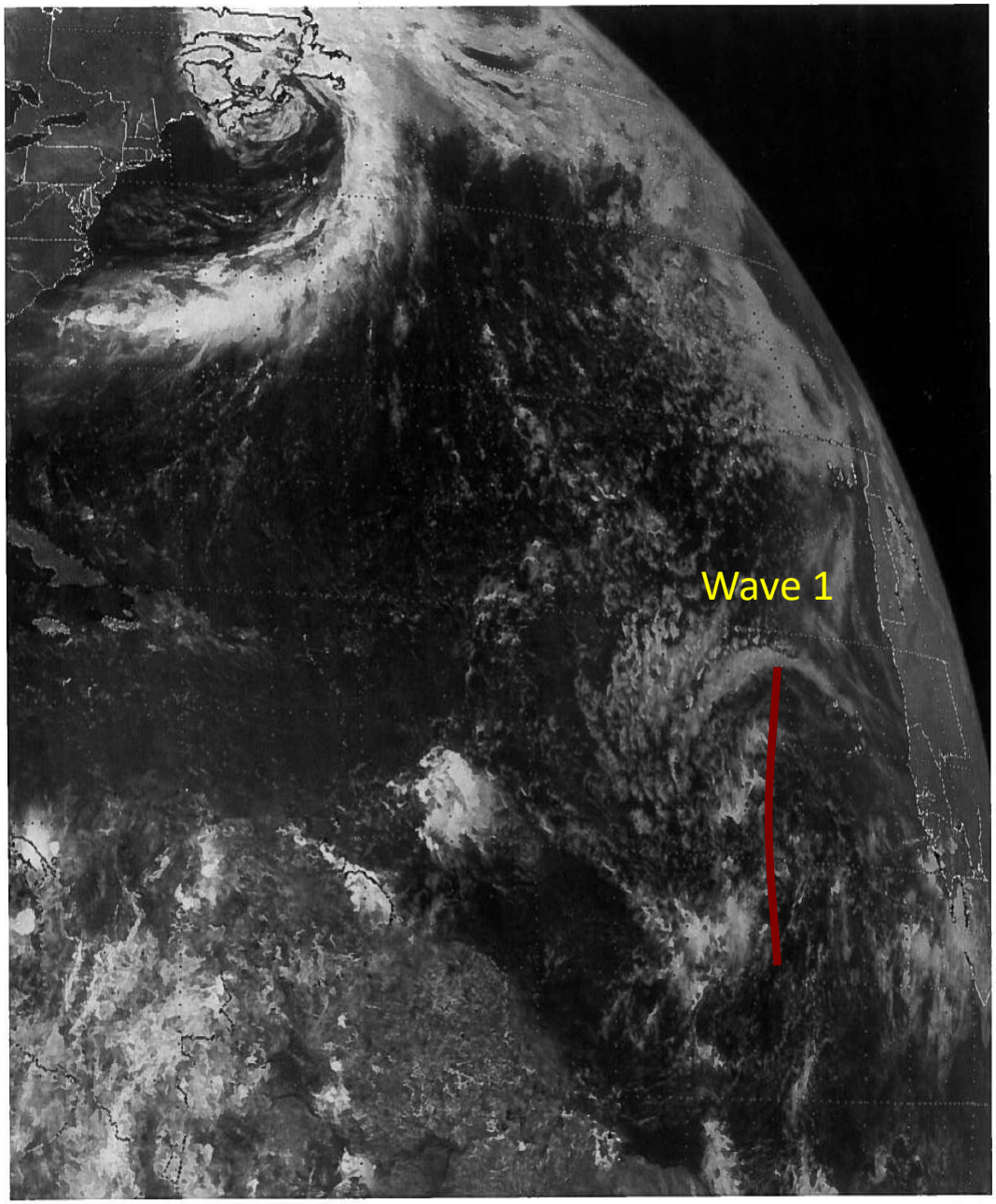
July 13



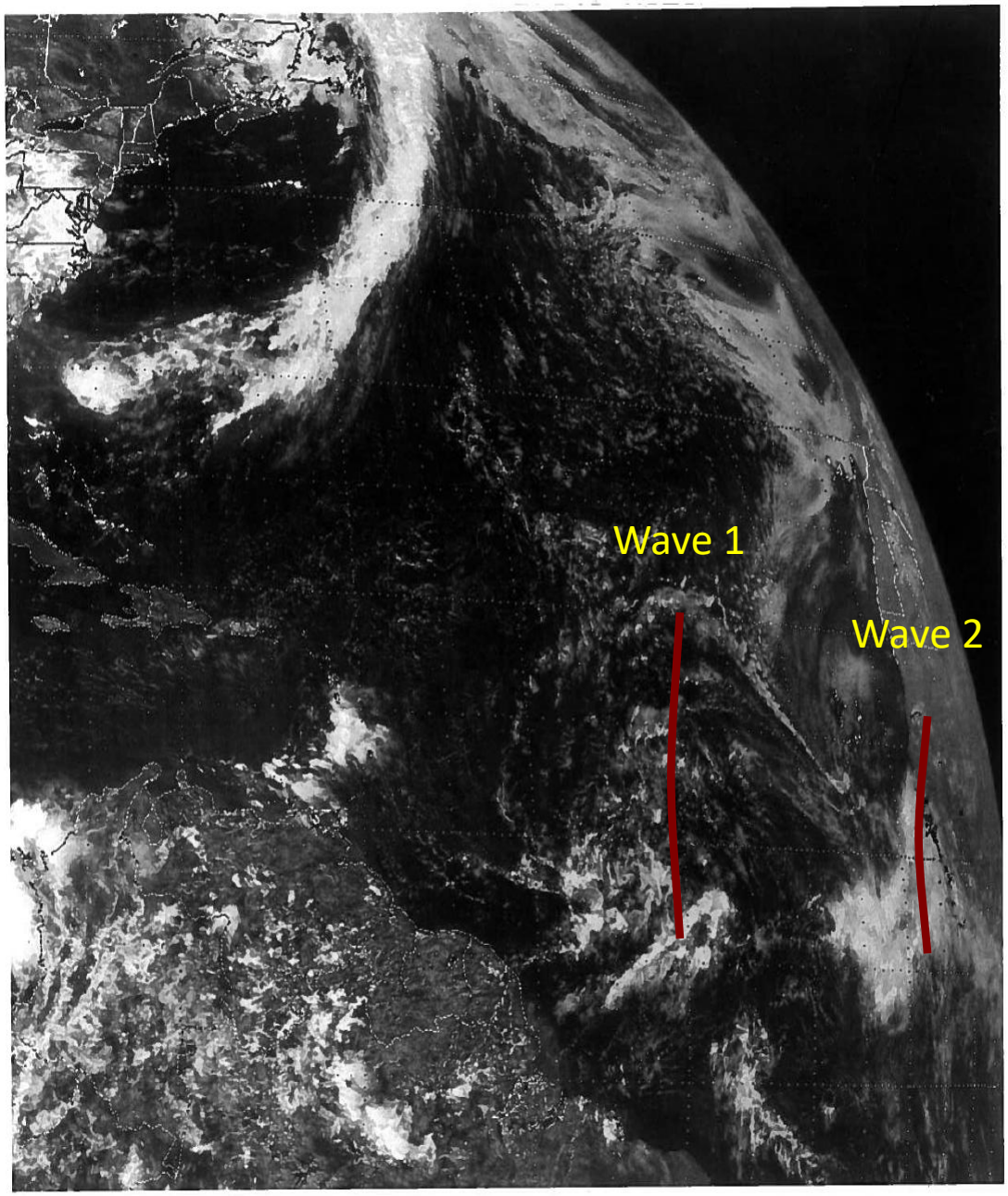
July 14



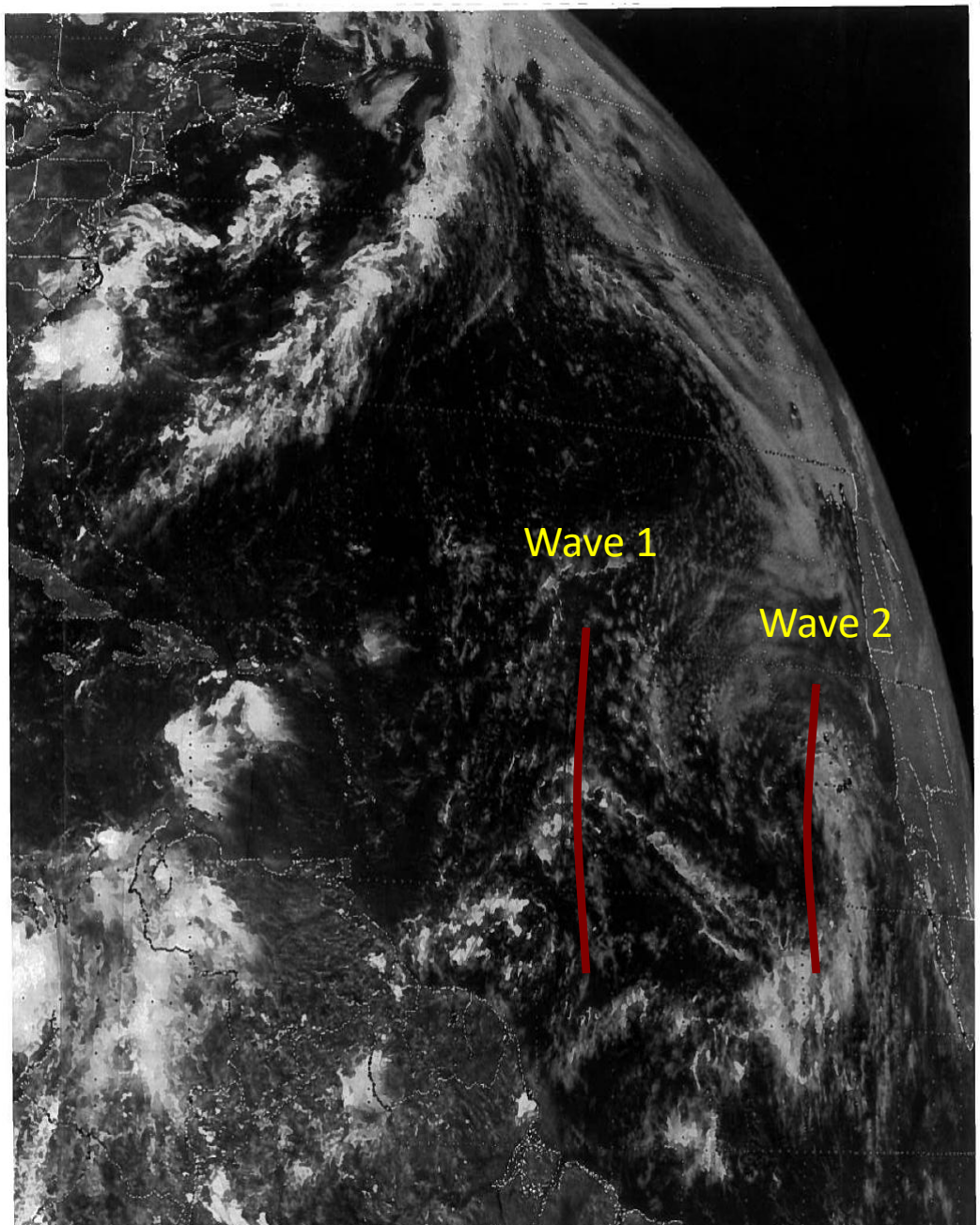
July 15



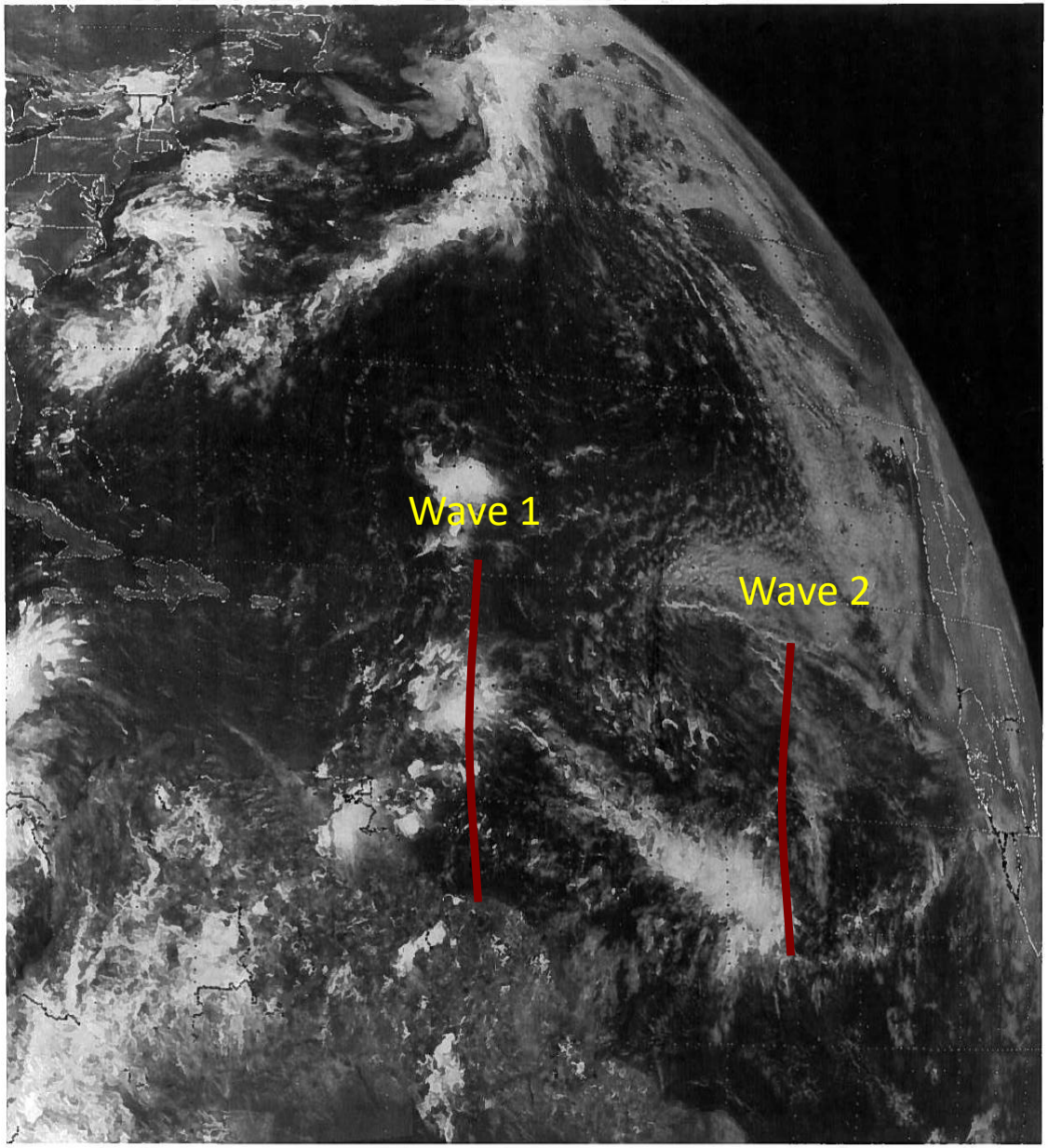
July 16



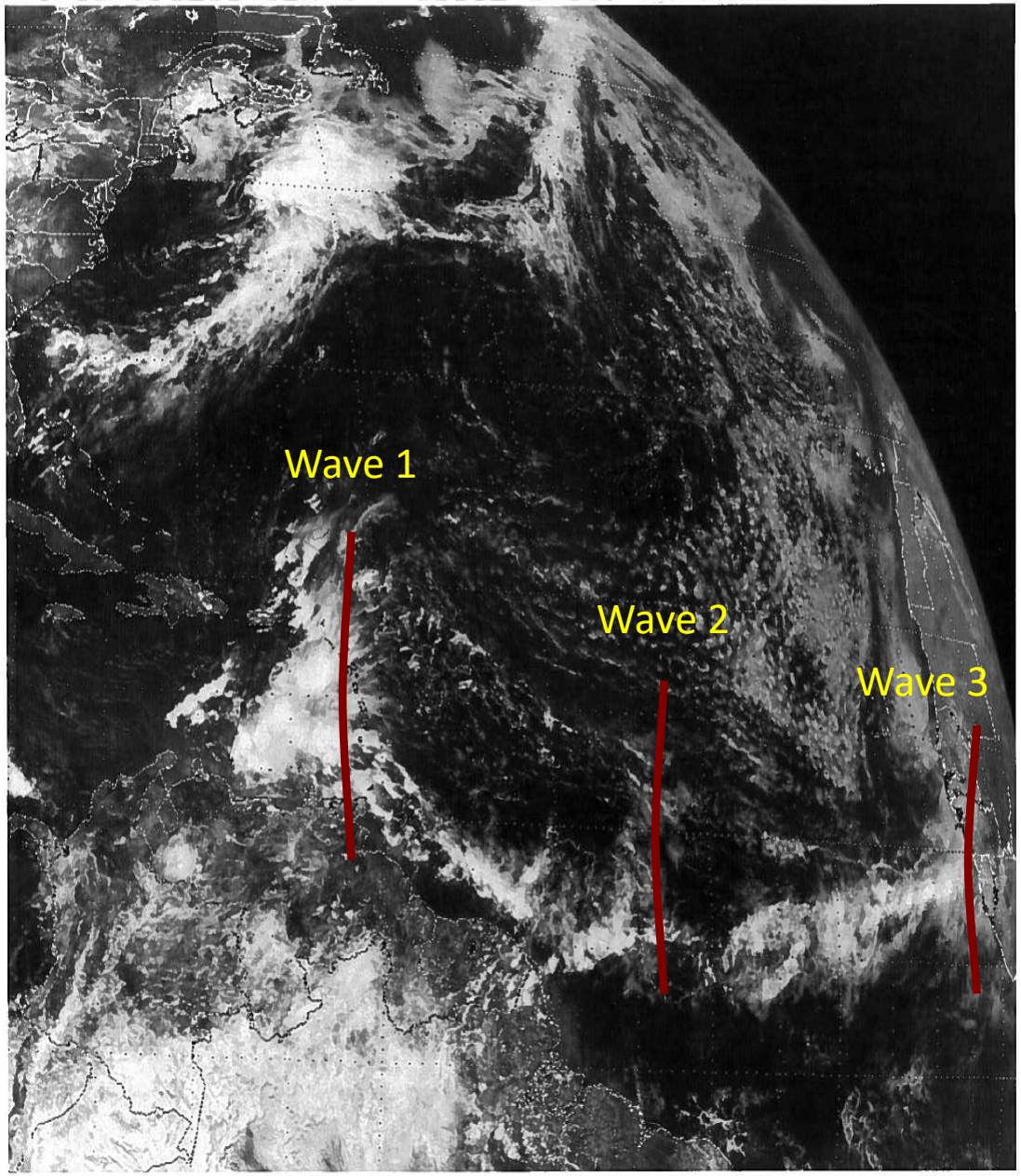
July 17



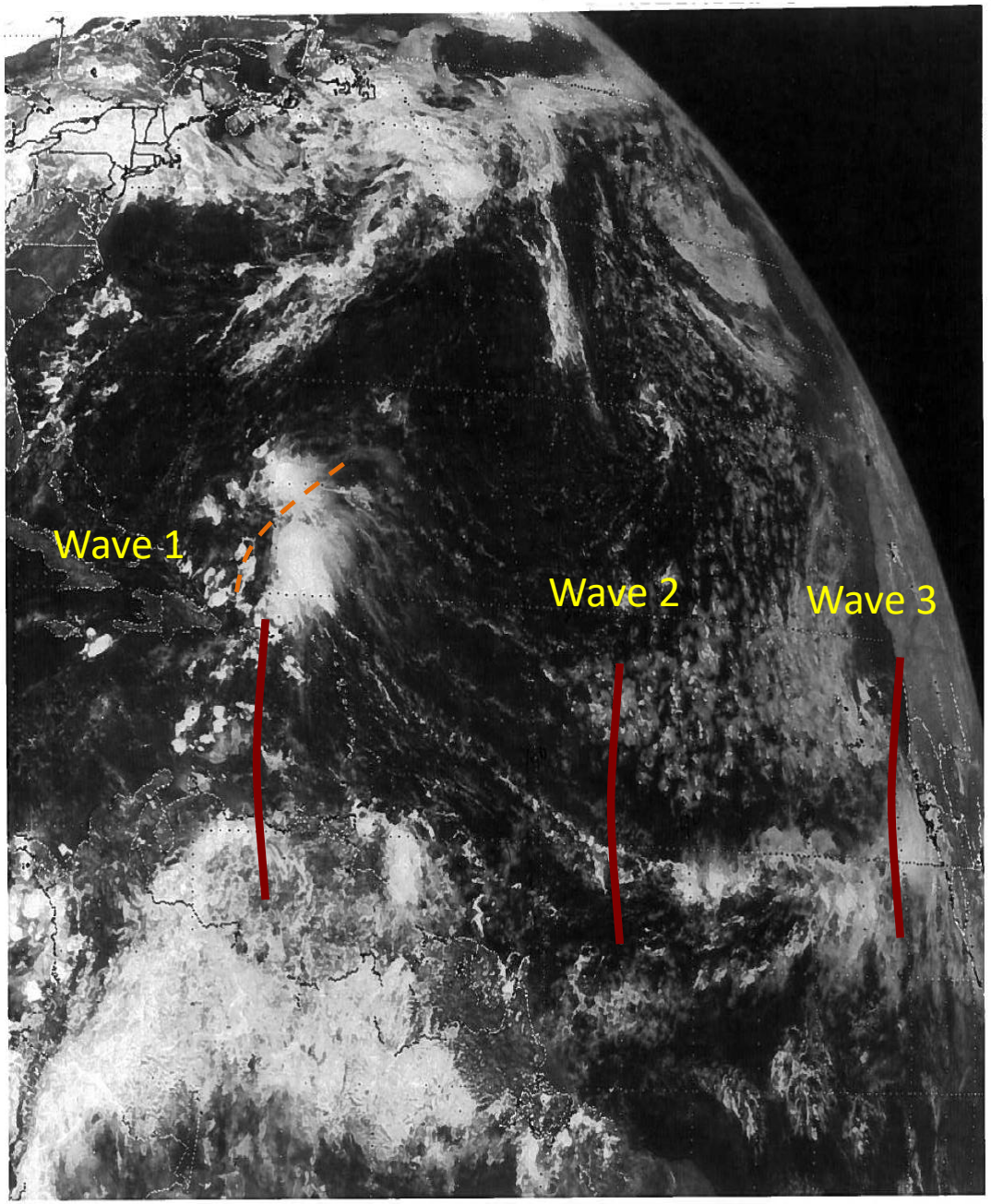
July 18



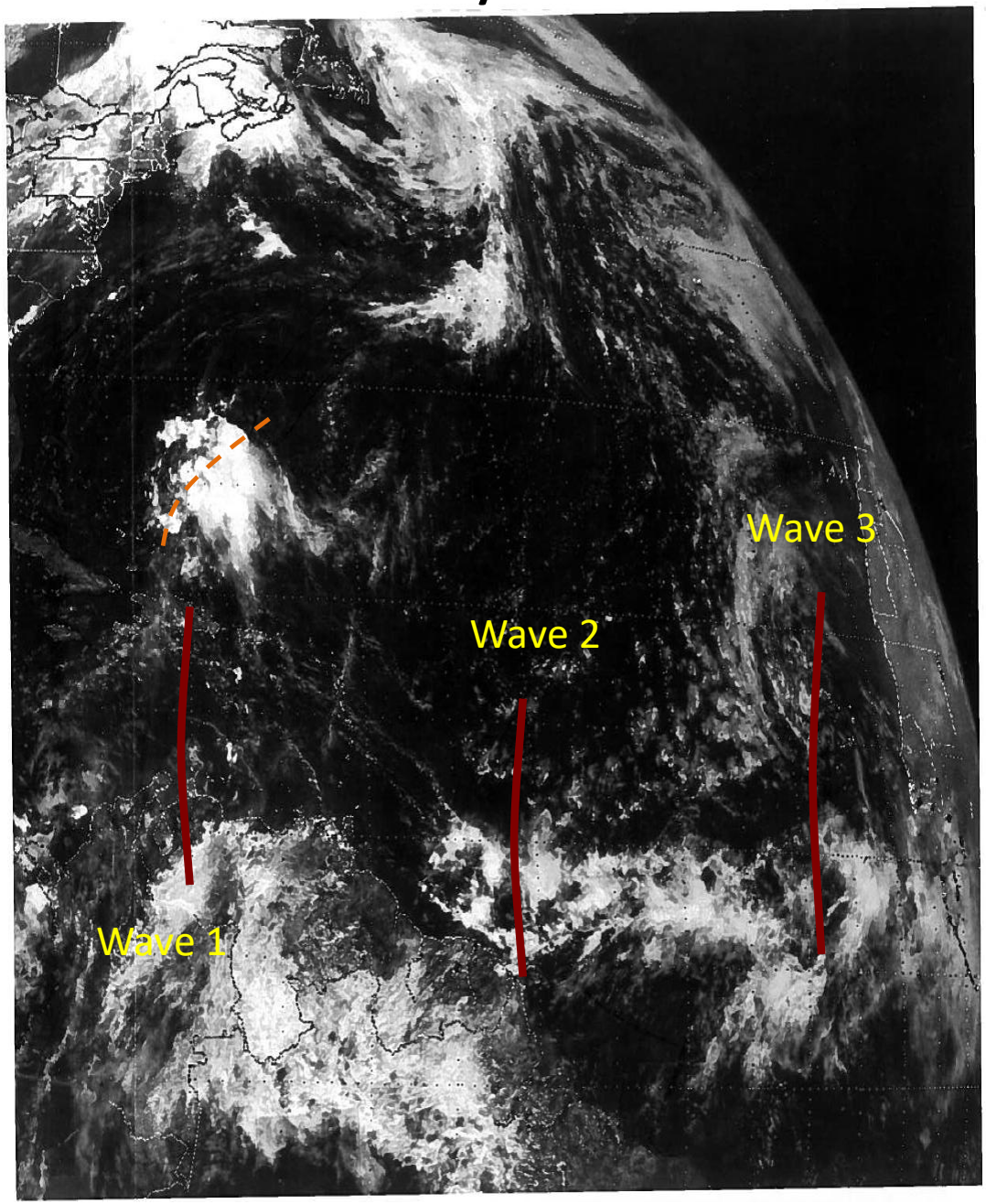
July 19



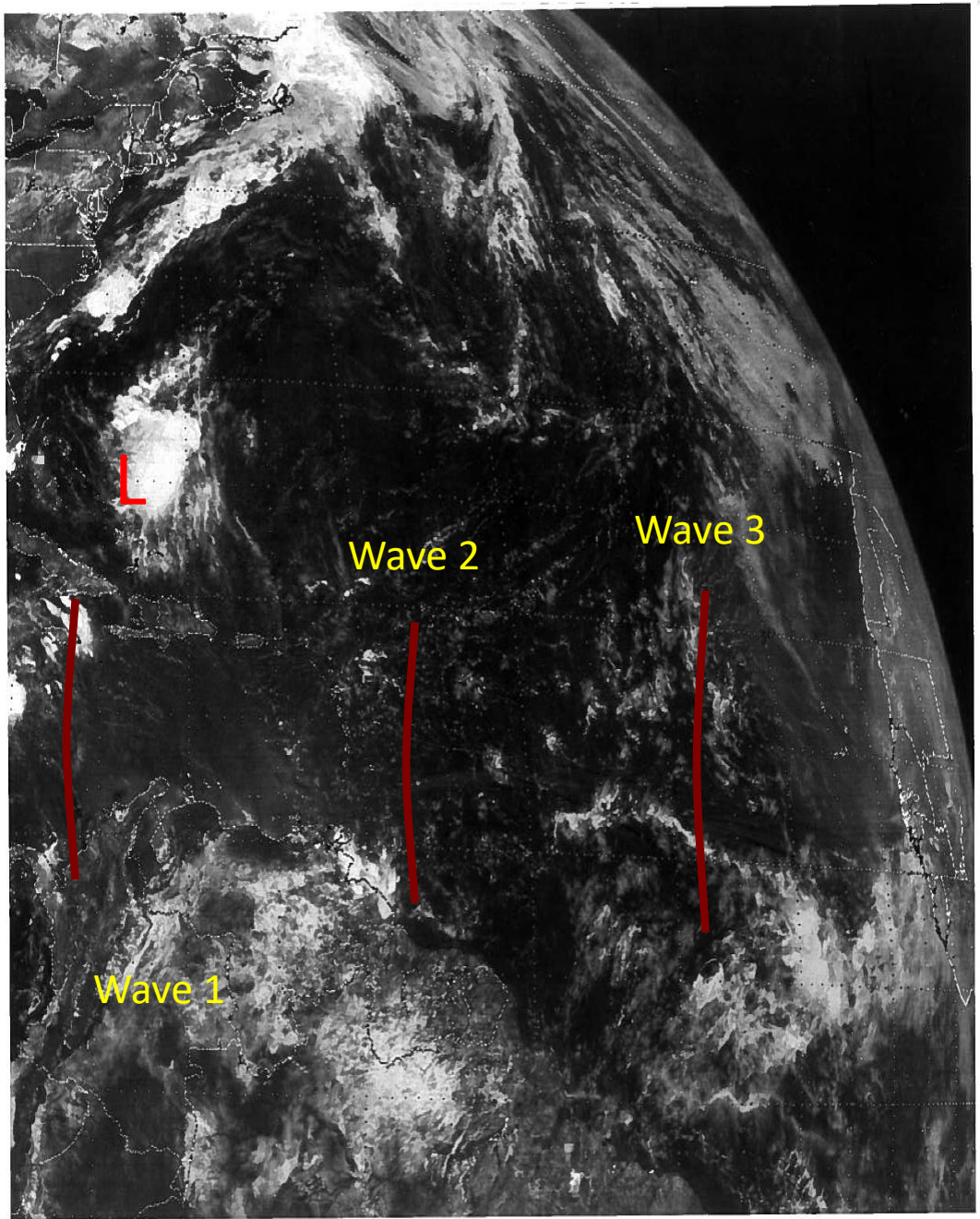
July 20



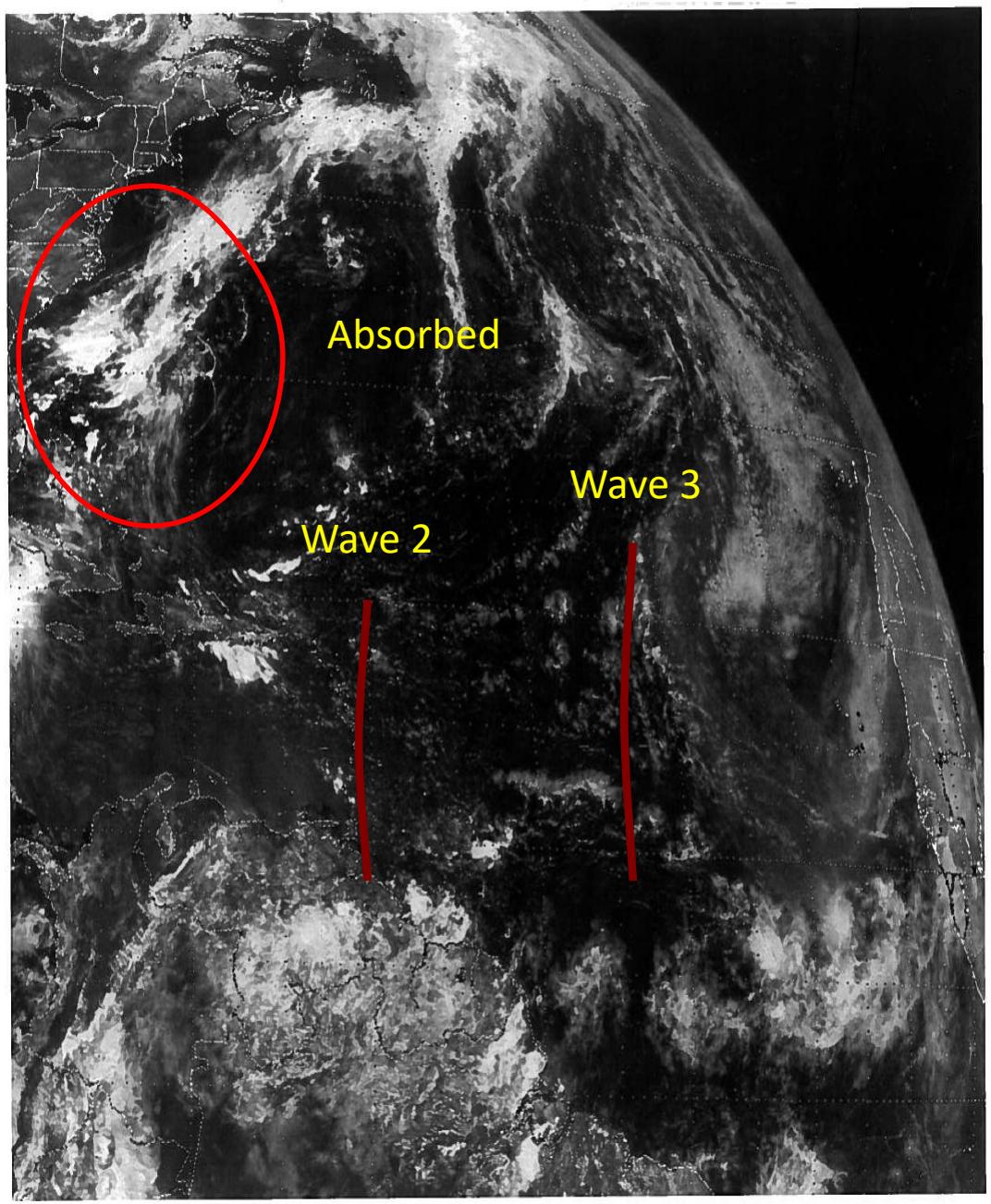
July 21



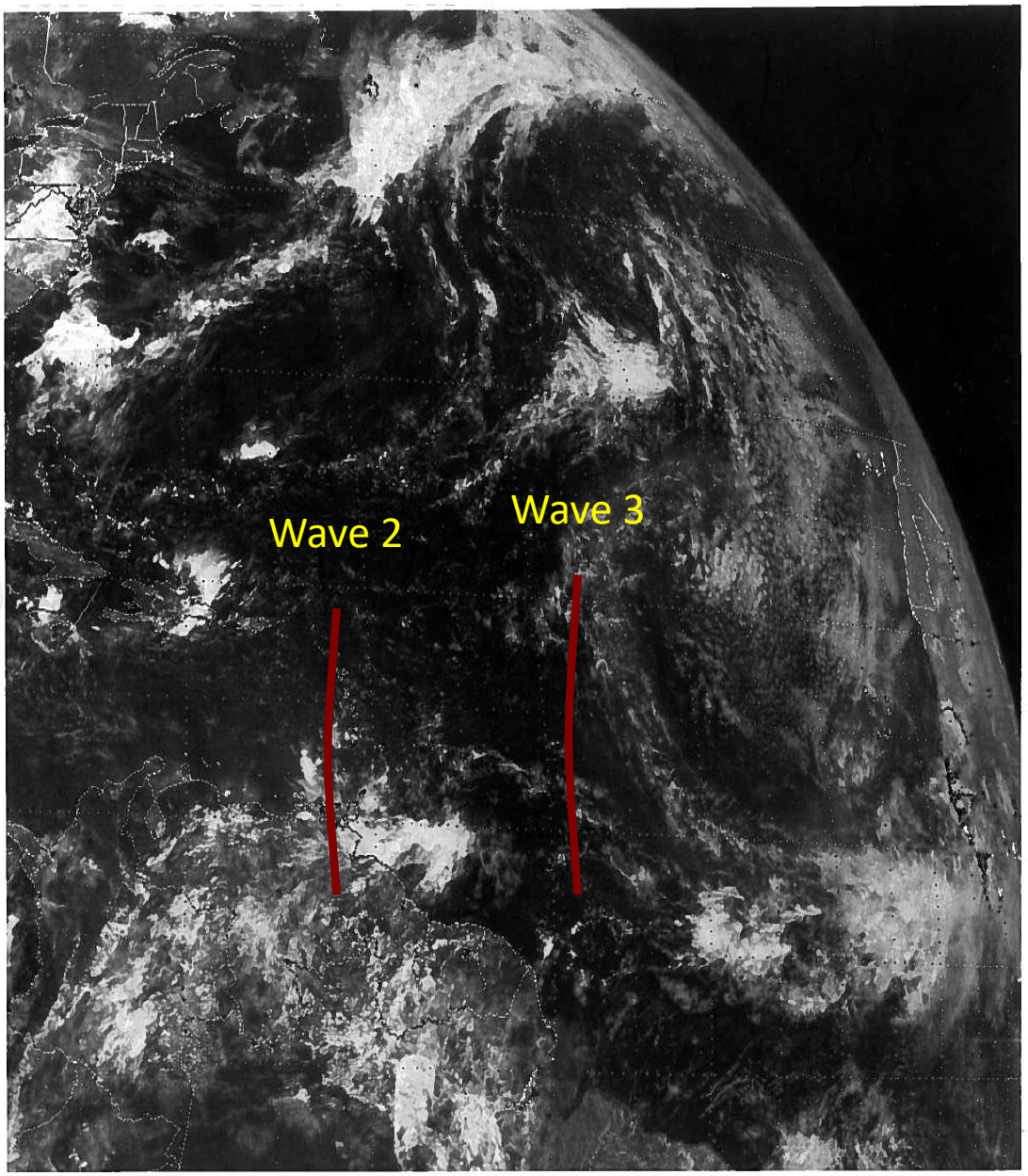
July 22



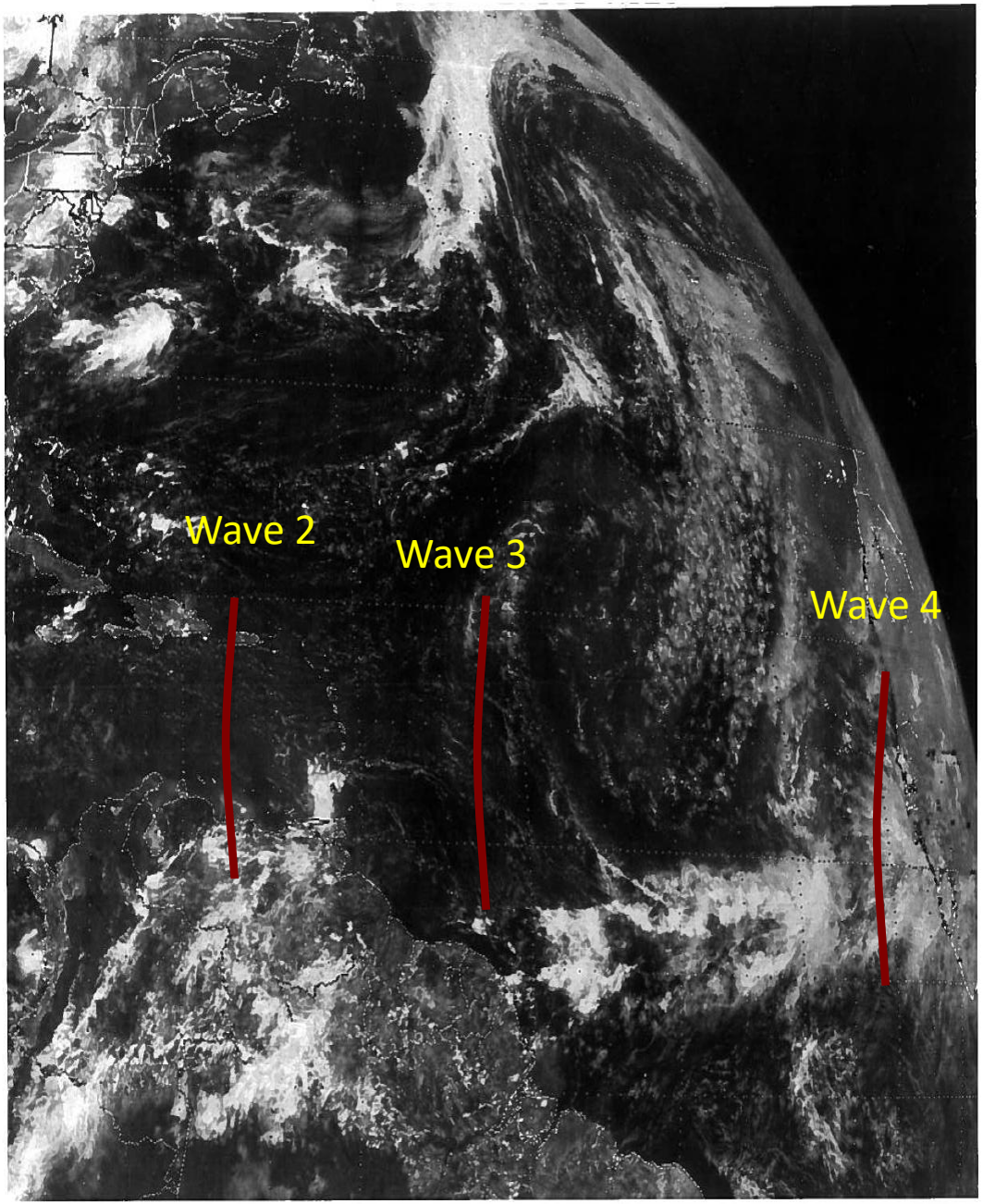
July 23



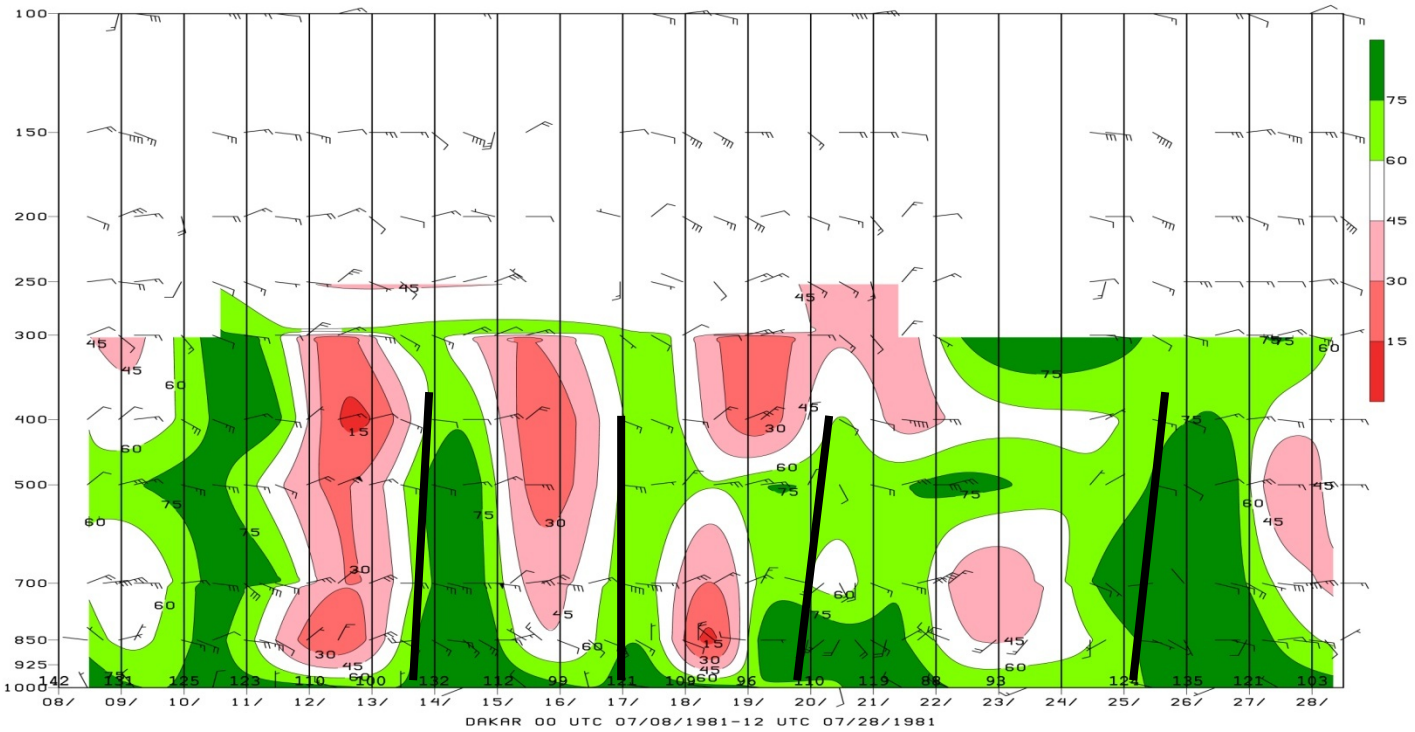
July 24



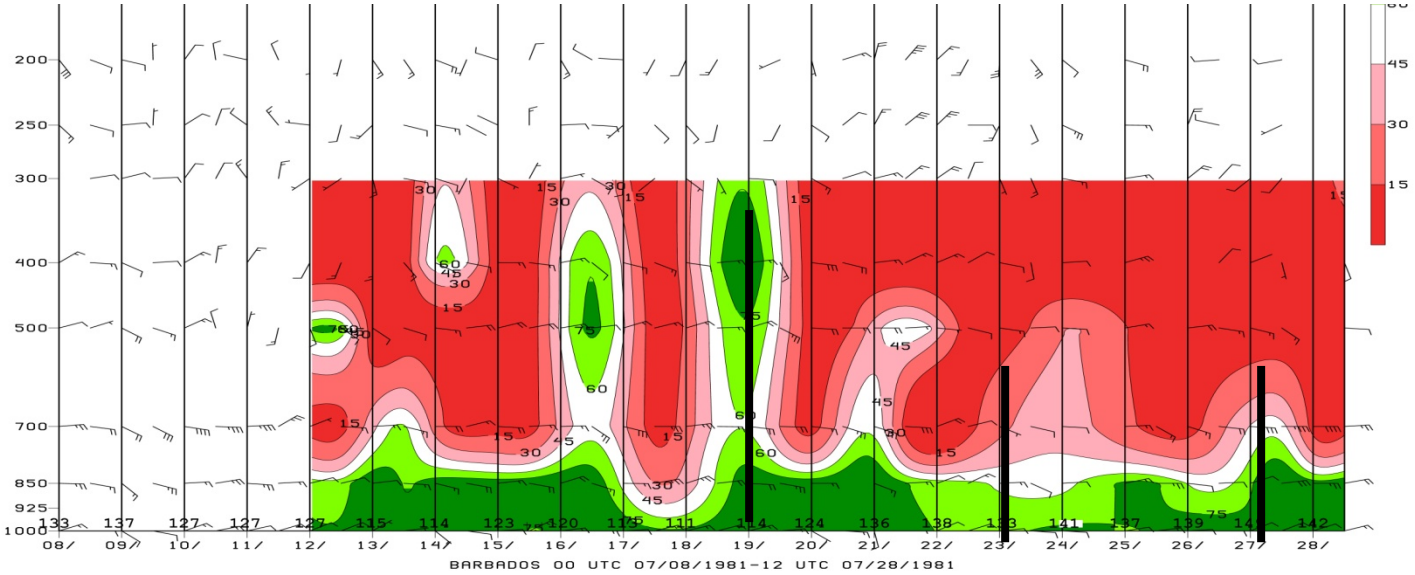
July 25



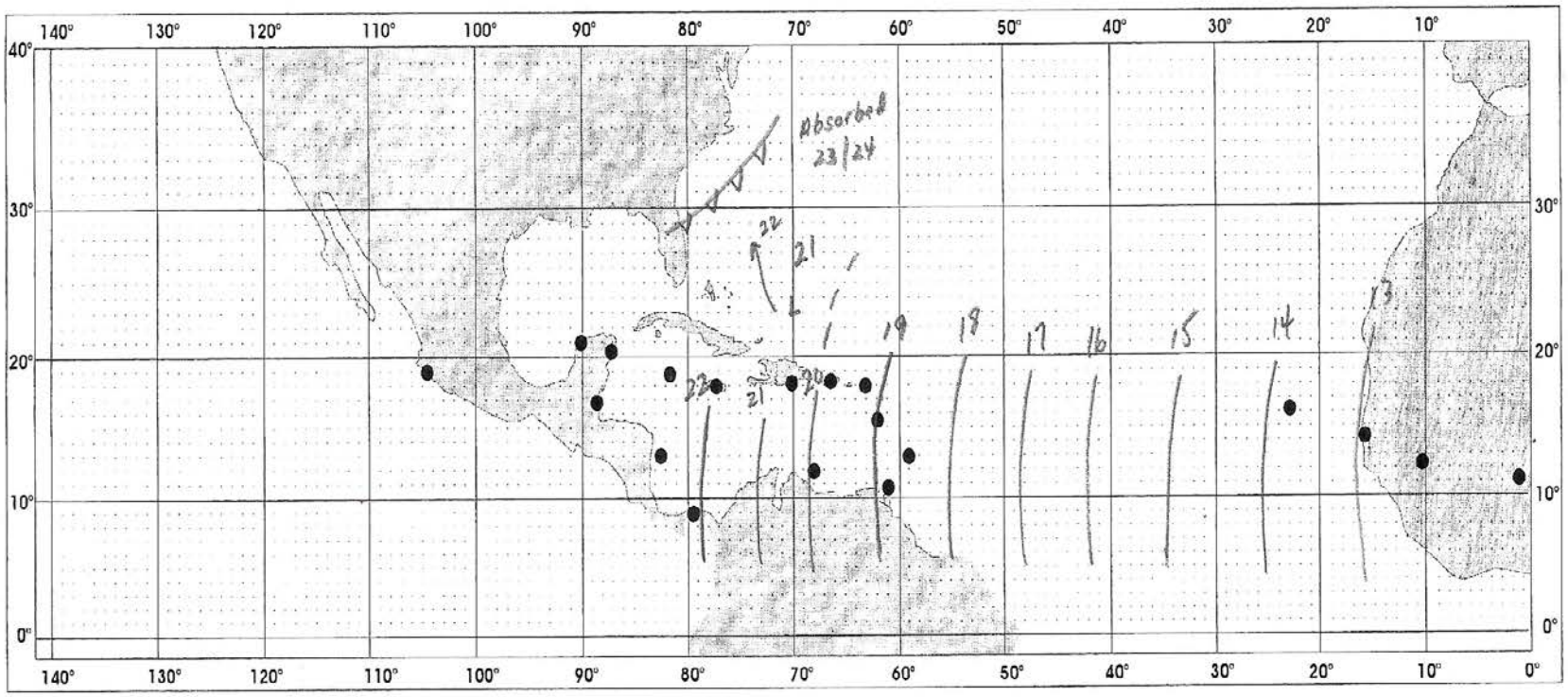
Dakar



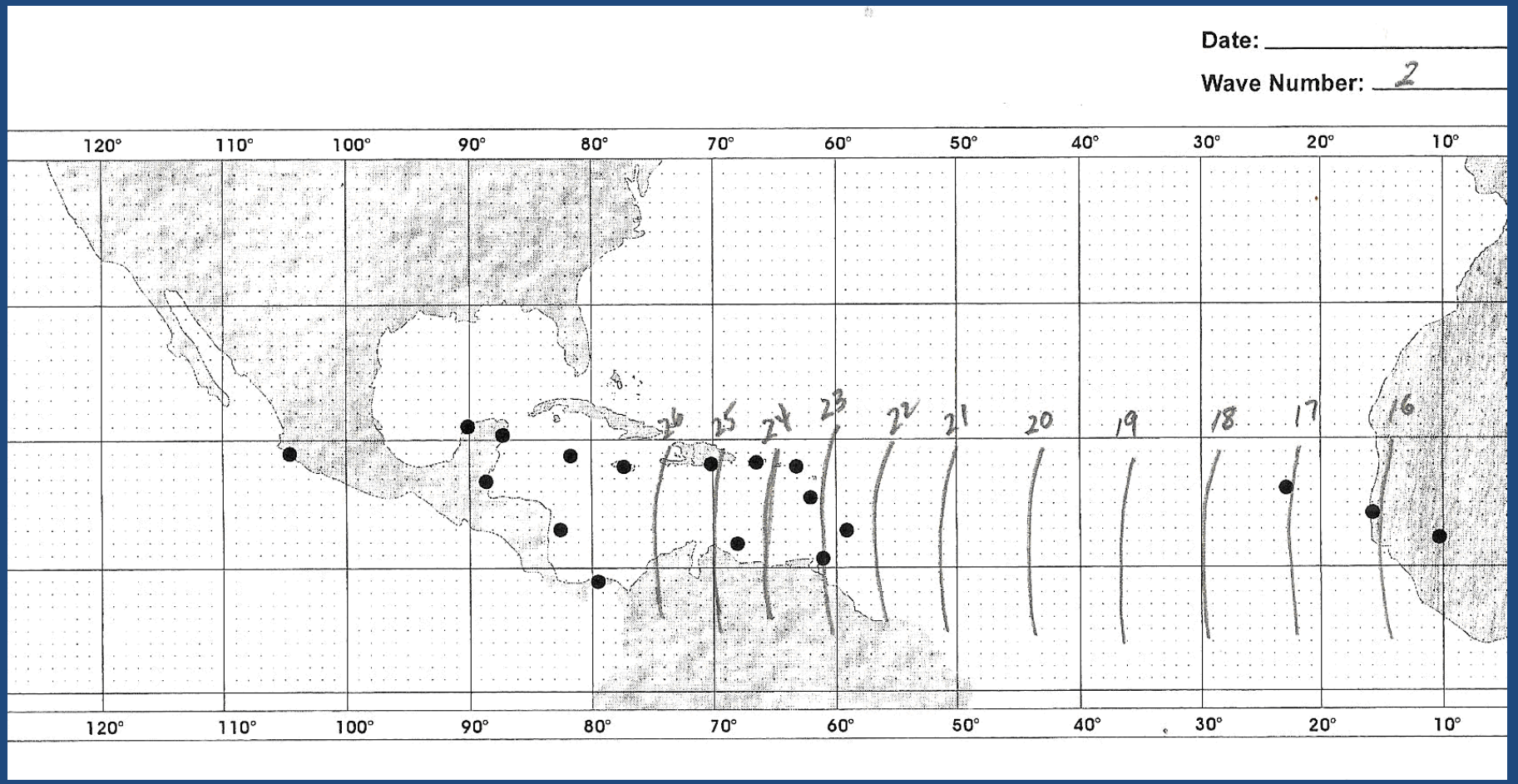
Barbados



Tropical Wave 1



Tropical Wave 2



Tropical Wave 3