The role of convectively-coupled atmospheric Kelvin waves during the 2010 Atlantic Hurricane Season

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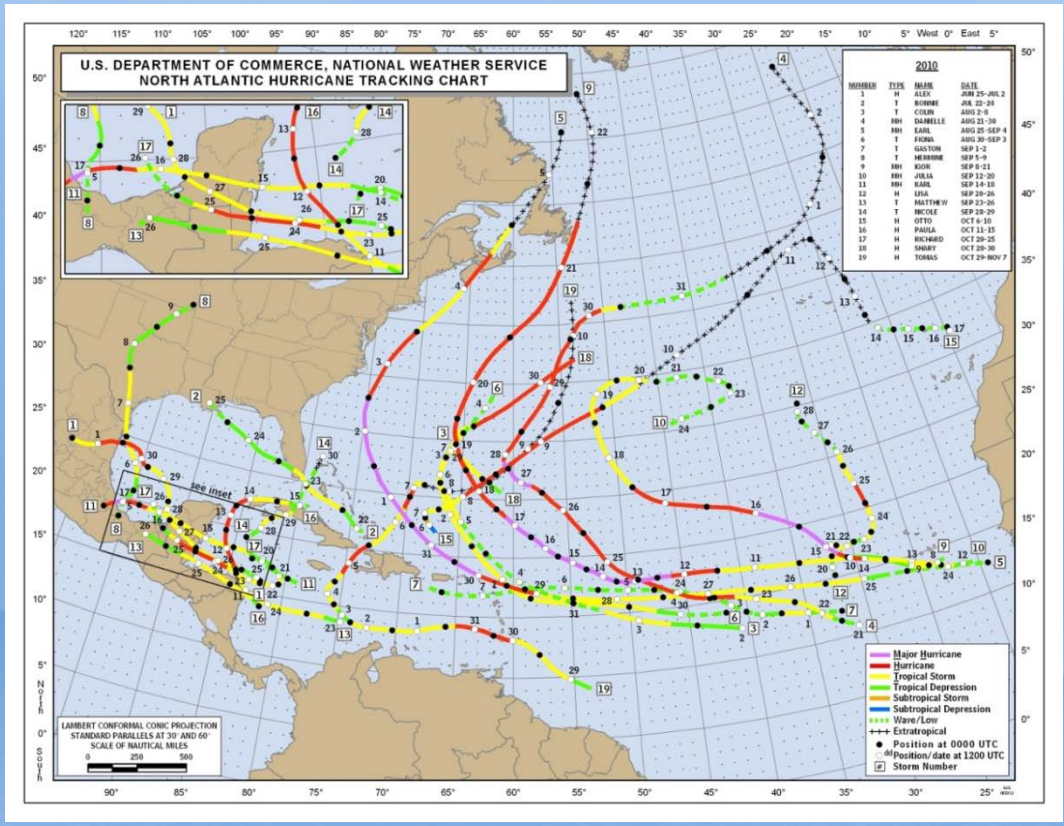
State University of New York

This Talk

1. Background information regarding convectively-coupled atmospheric equatorial Kelvin waves (henceforth CCKWs; Ventrice et al. 2011)
2. The 2010 August-September look on tropical cyclones (TCs) and CCKWs
3. Case Study of the genesis of Julia
4. An unexpected weakening of Hurricane Danielle
5. Conclusions



Data Sources & Methodology

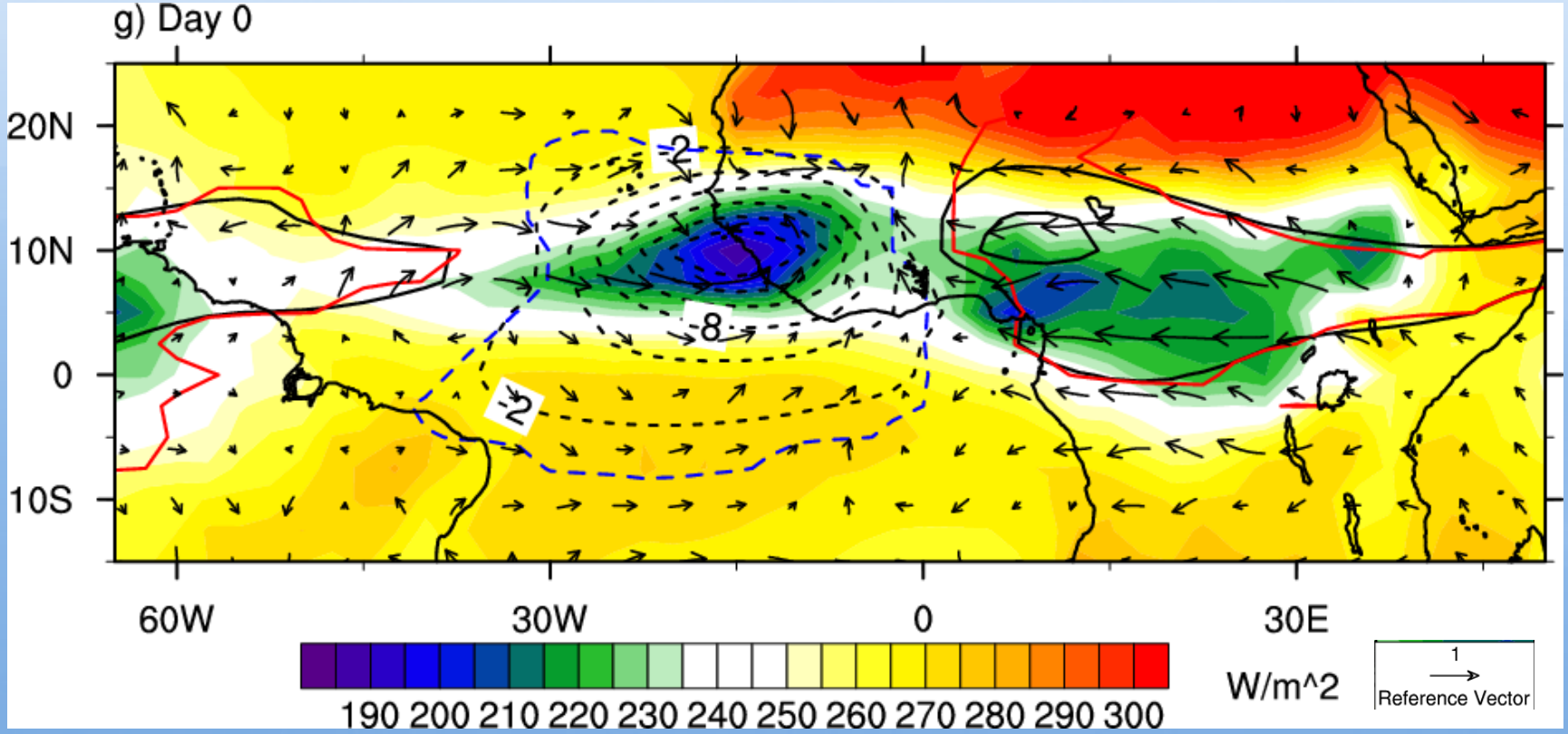
- ECMWF-Interim Dataset (Simmons et al. 2007)
- NOAA's Daily Average OLR Dataset (Liebmann and Smith 1996)
  - Wheeler and Kiladis (1999) for Kelvin wave filtering [period of 2.5-20 days, with eastward wavenumber 1-14]
- NASA's Merged IR-dataset

Data Sources & Methodology

- Developed a time-series using Kelvin filtered OLR anomalies.
  - Selected dates where Kelvin filtered OLR anomaly was a minimum over 7.5°N, 15°W (**DAY 0**)
  - Used a daily lagged approach
  - Threshold was -1.5 standard deviations
    - 215 Kelvin waves (1979-2009)
    - 164 Kelvin waves (1989-2009)

Unfiltered total OLR, Kelvin filtered OLR, and 850 hPa wind anomalies

JJAS



Key:

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- **Kelvin filtered OLR (Contours)**
- **Positive (Negative) Kelvin filtered OLR anomalies statistically different than zero at the 99% level are within the solid (dashed) red (blue) line**
- **850 hPa wind anomalies (Vectors)**

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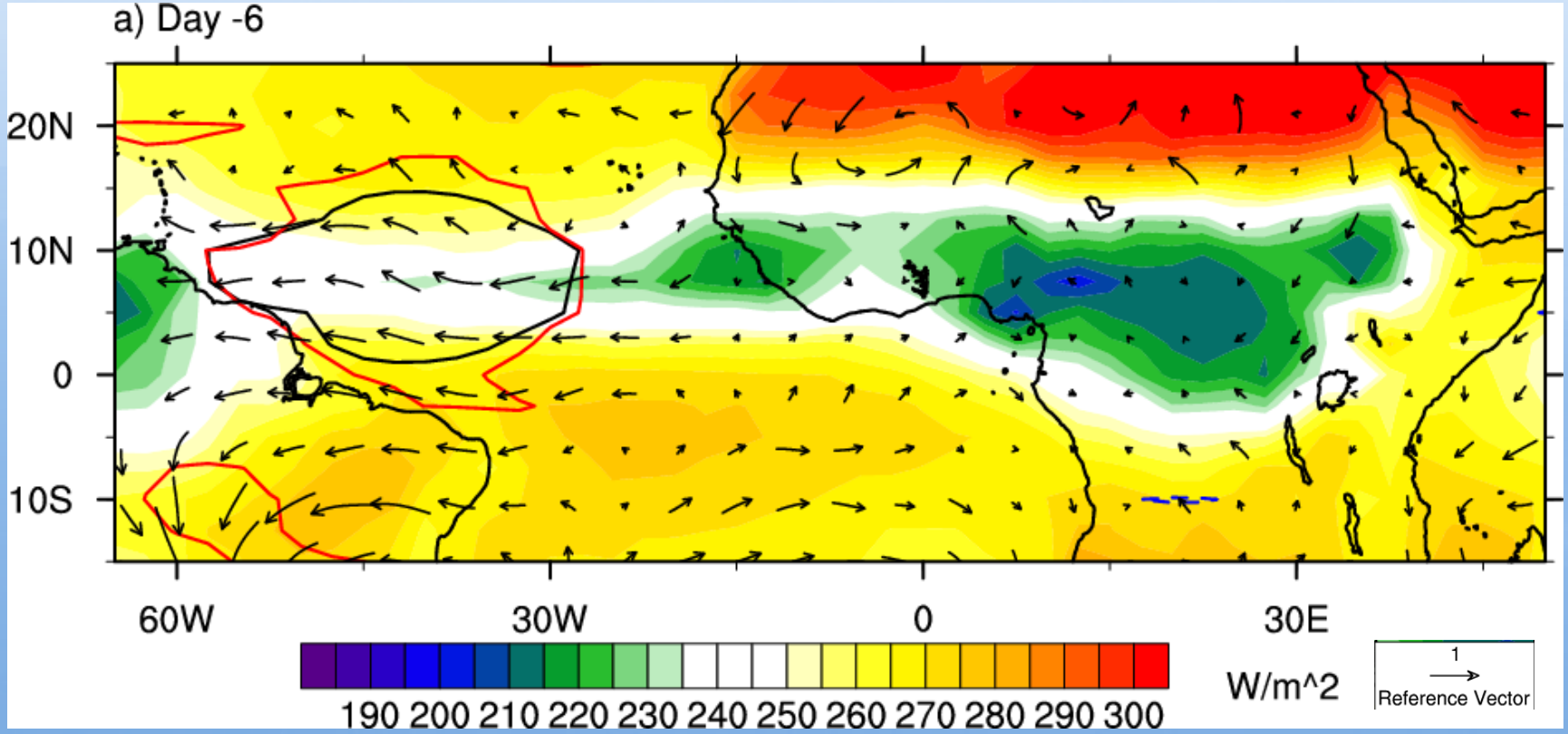

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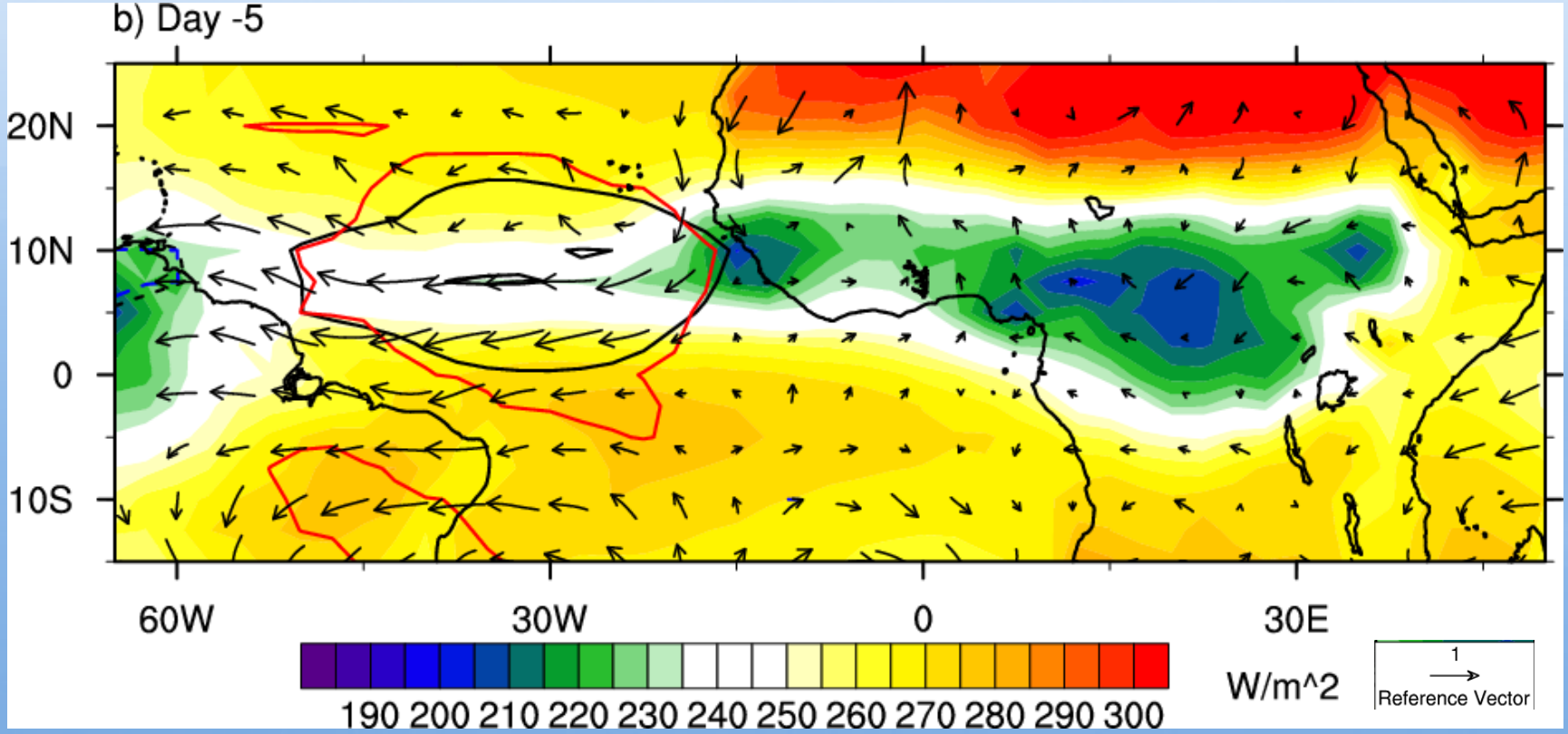

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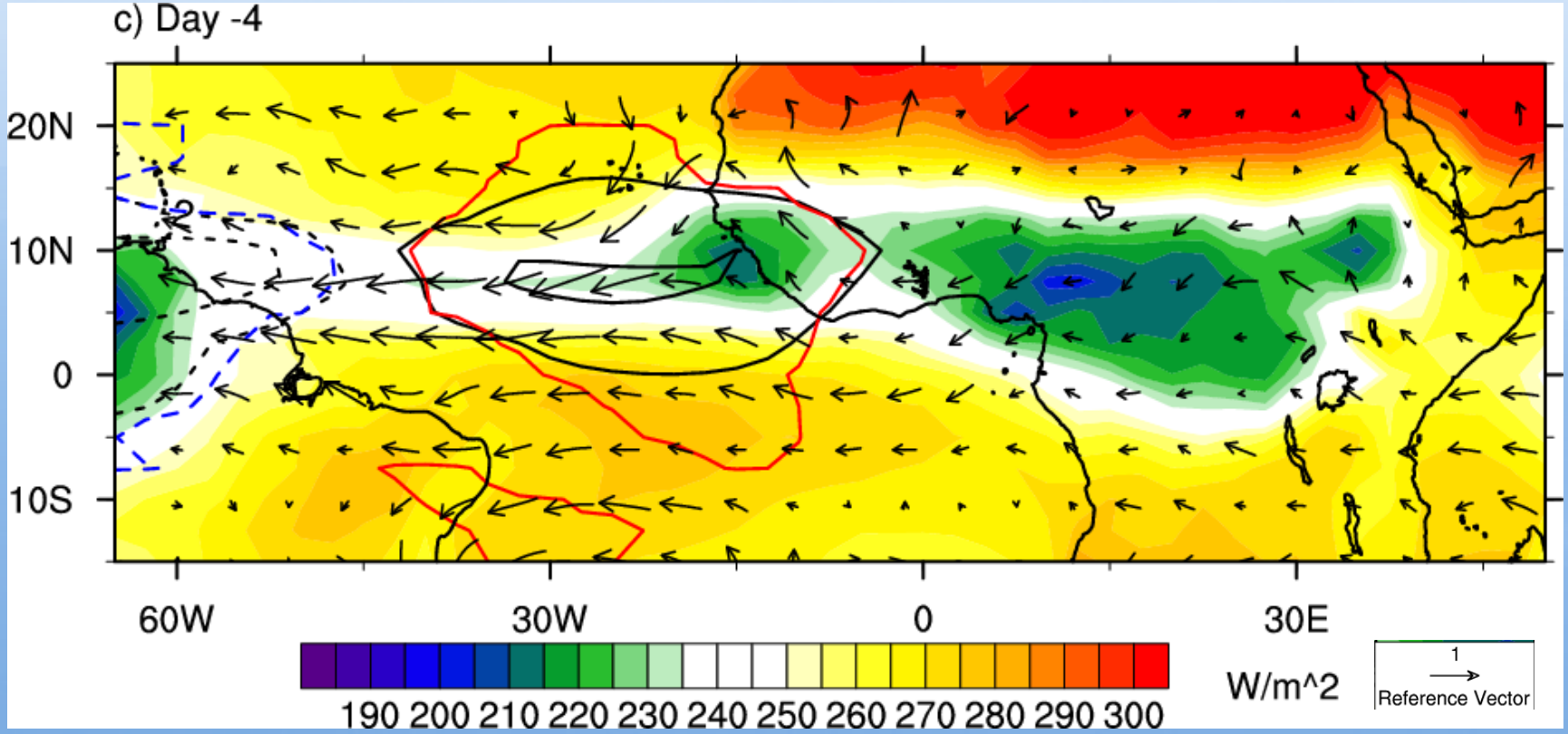

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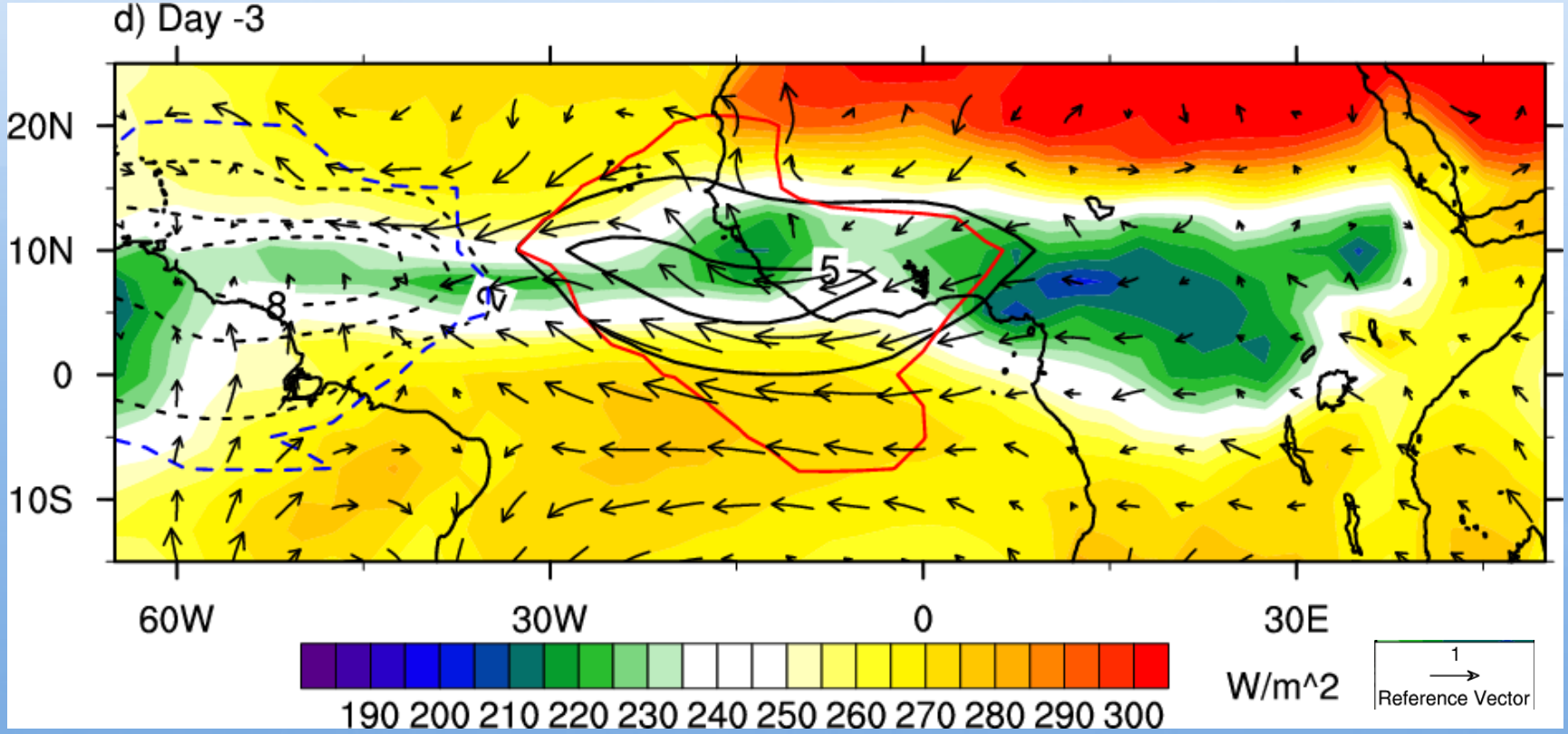

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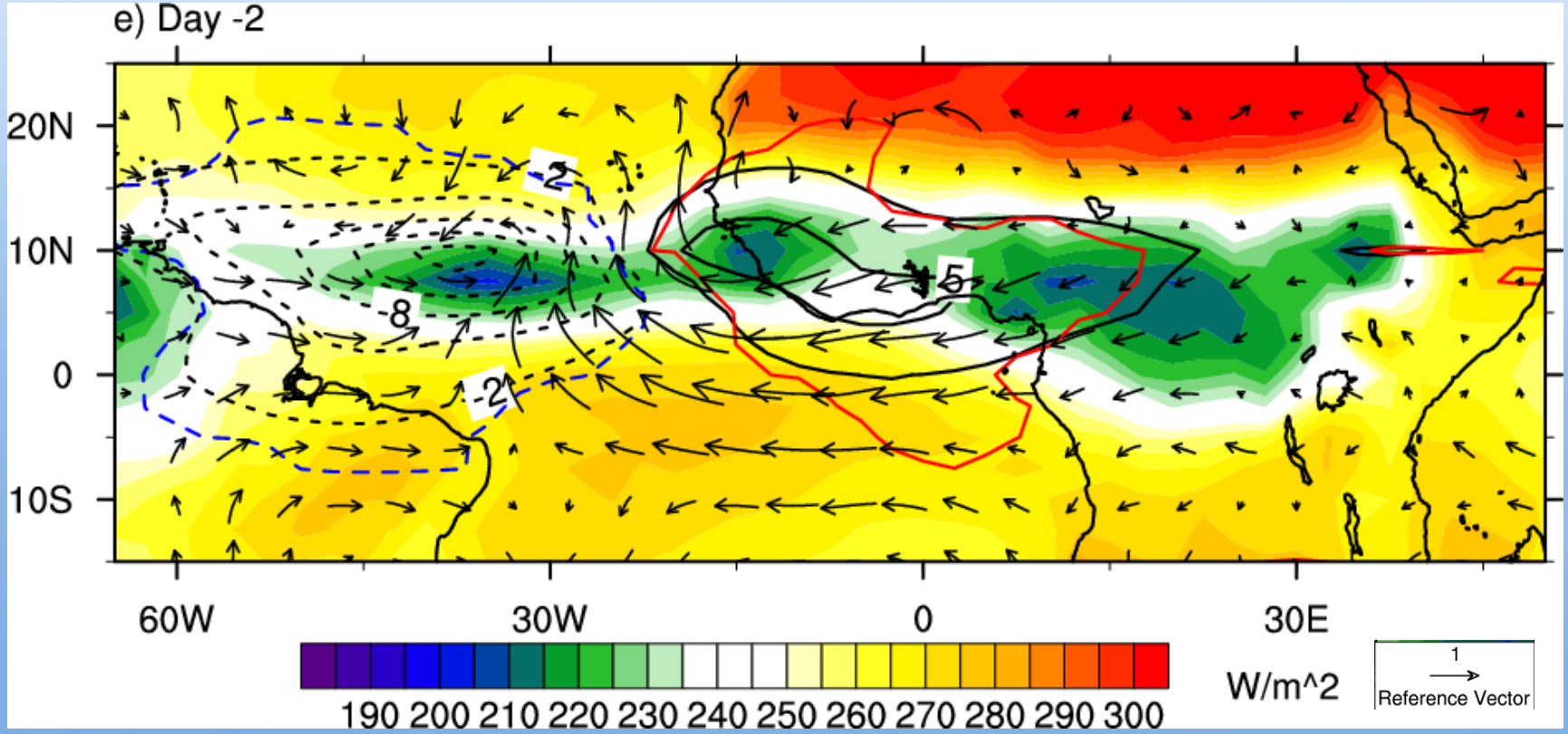

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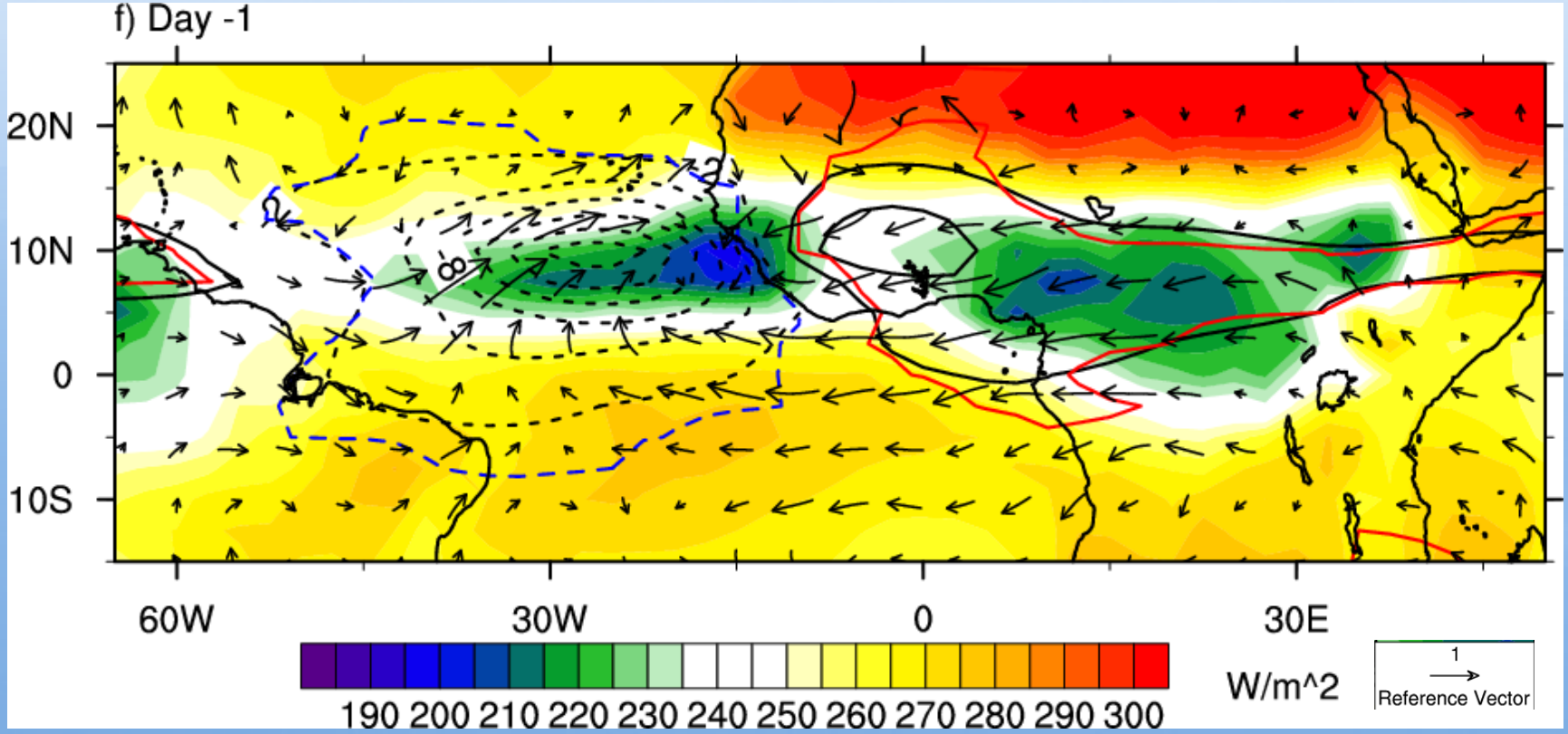

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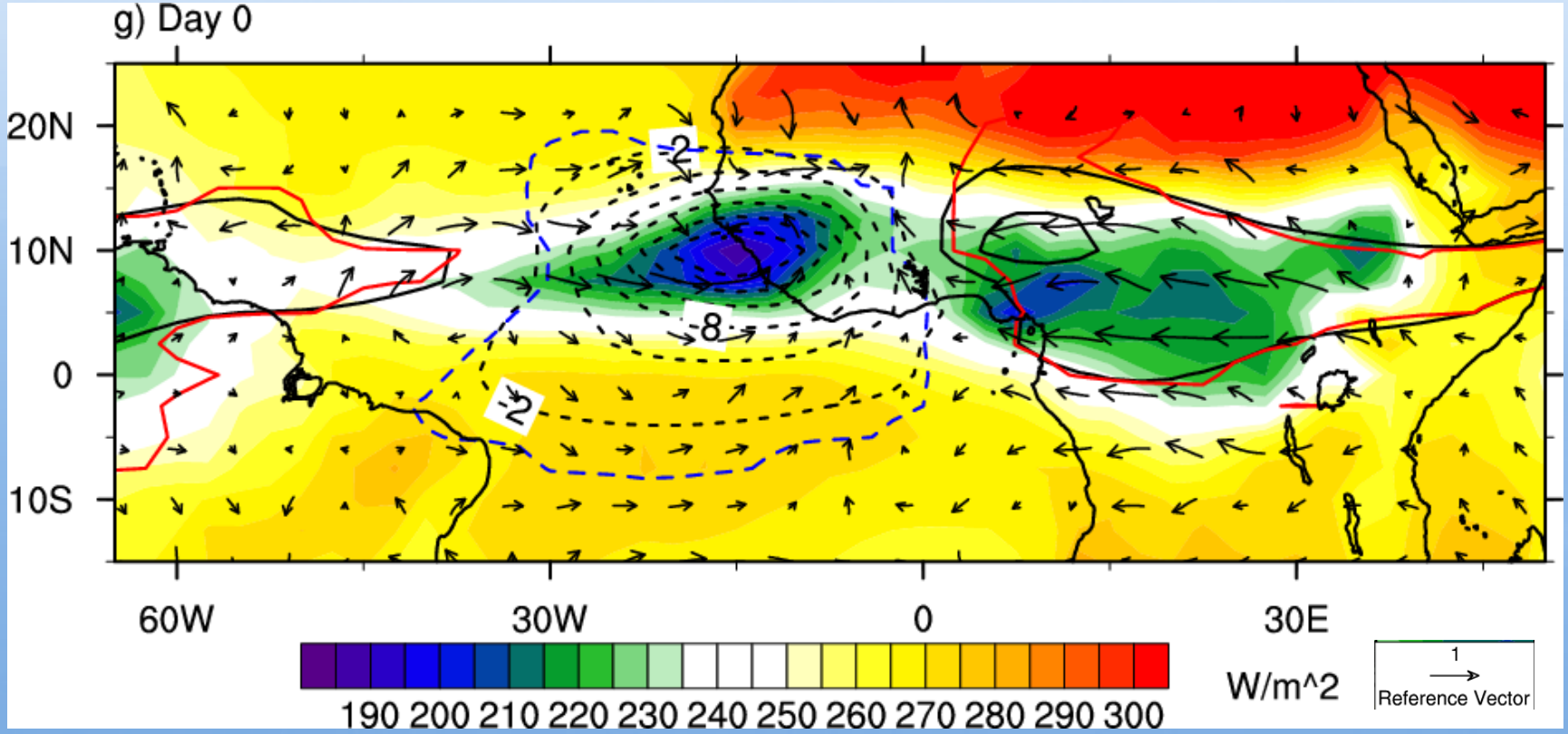

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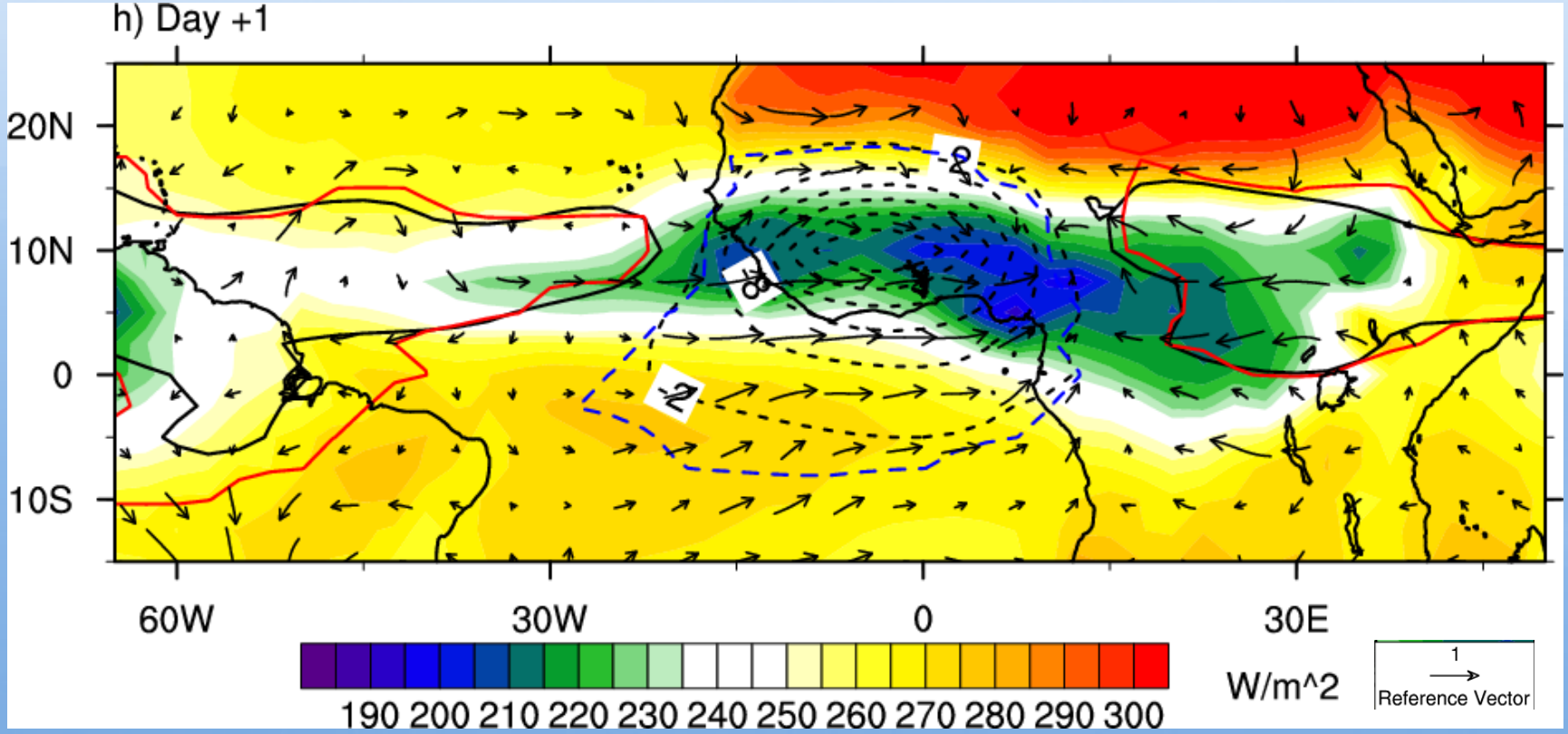

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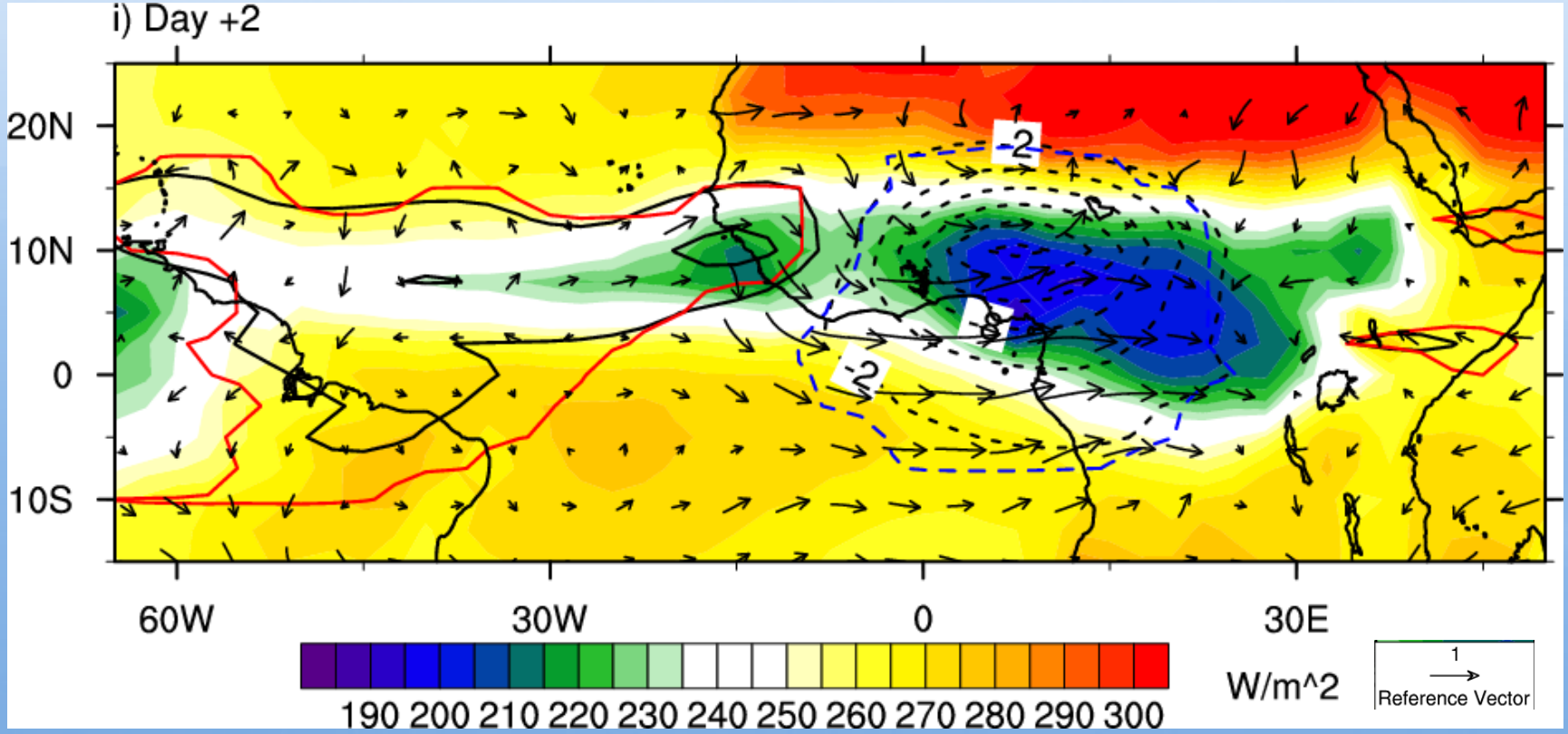

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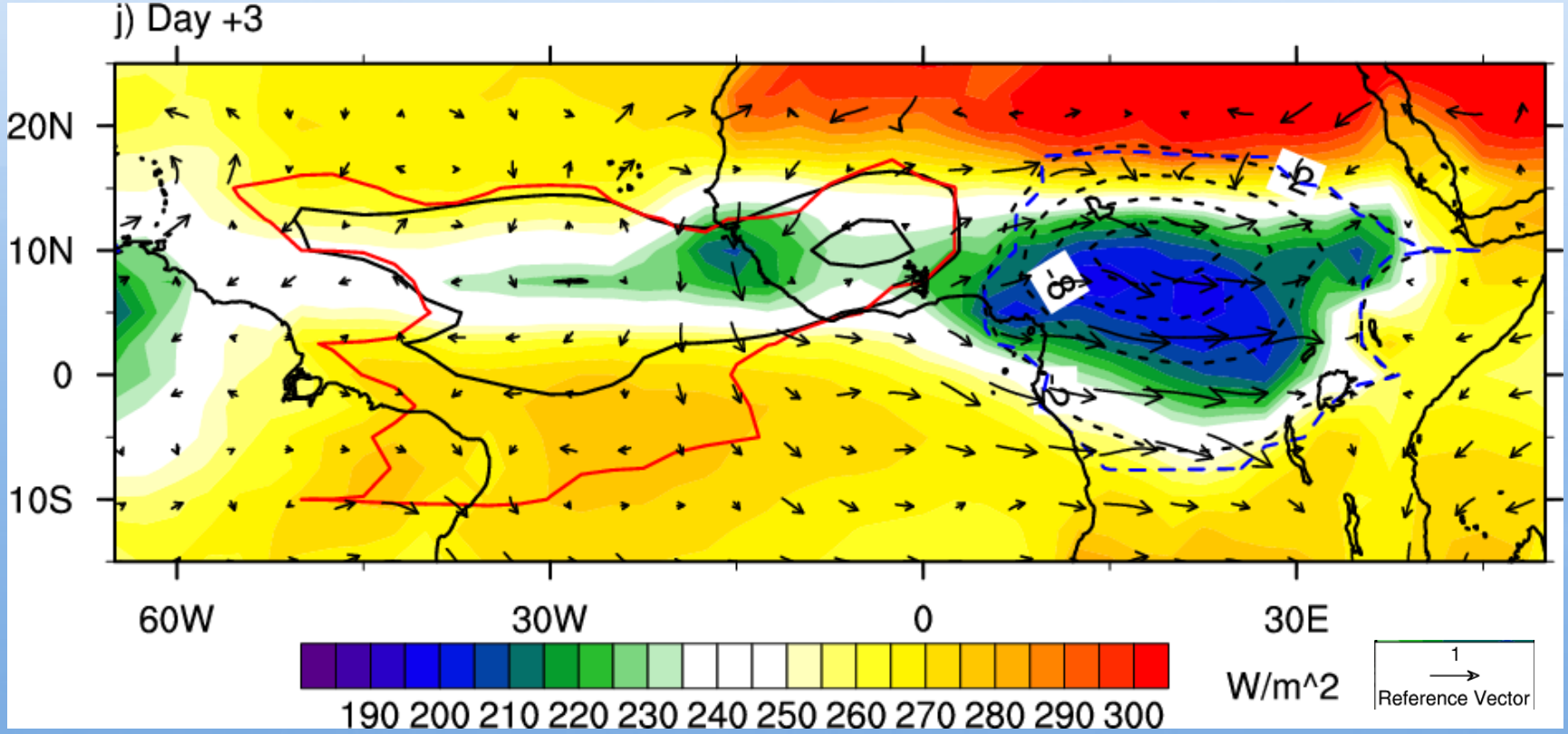

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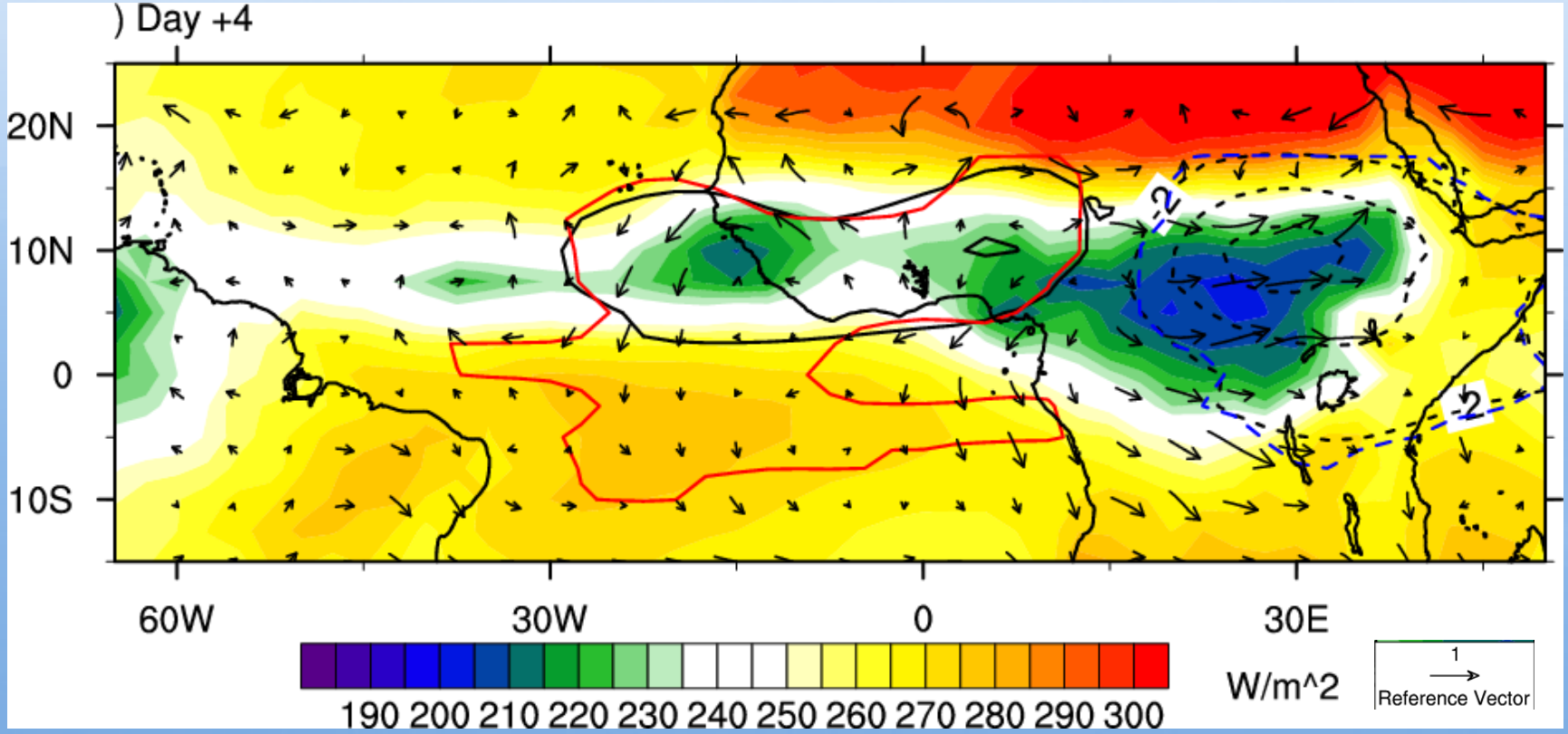

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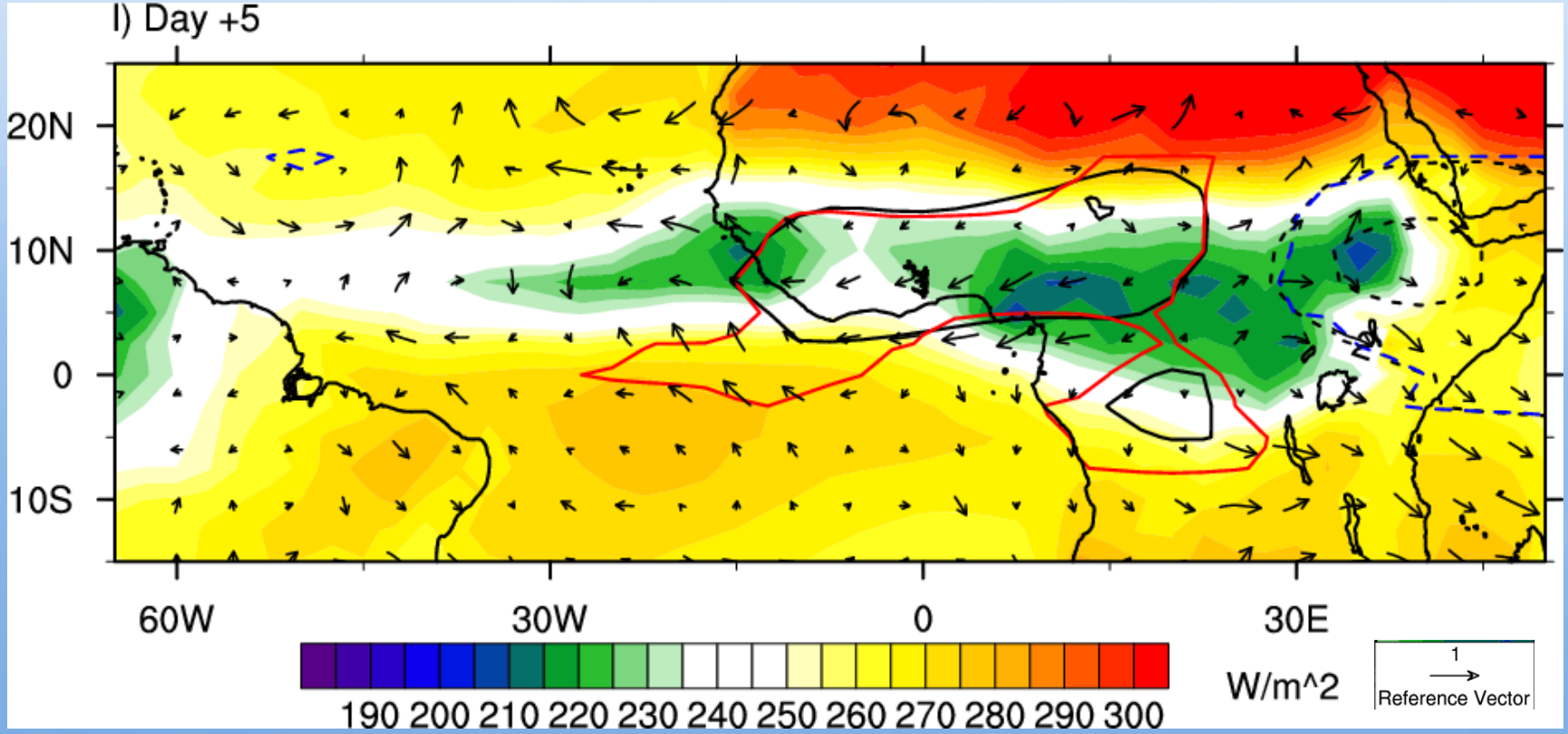

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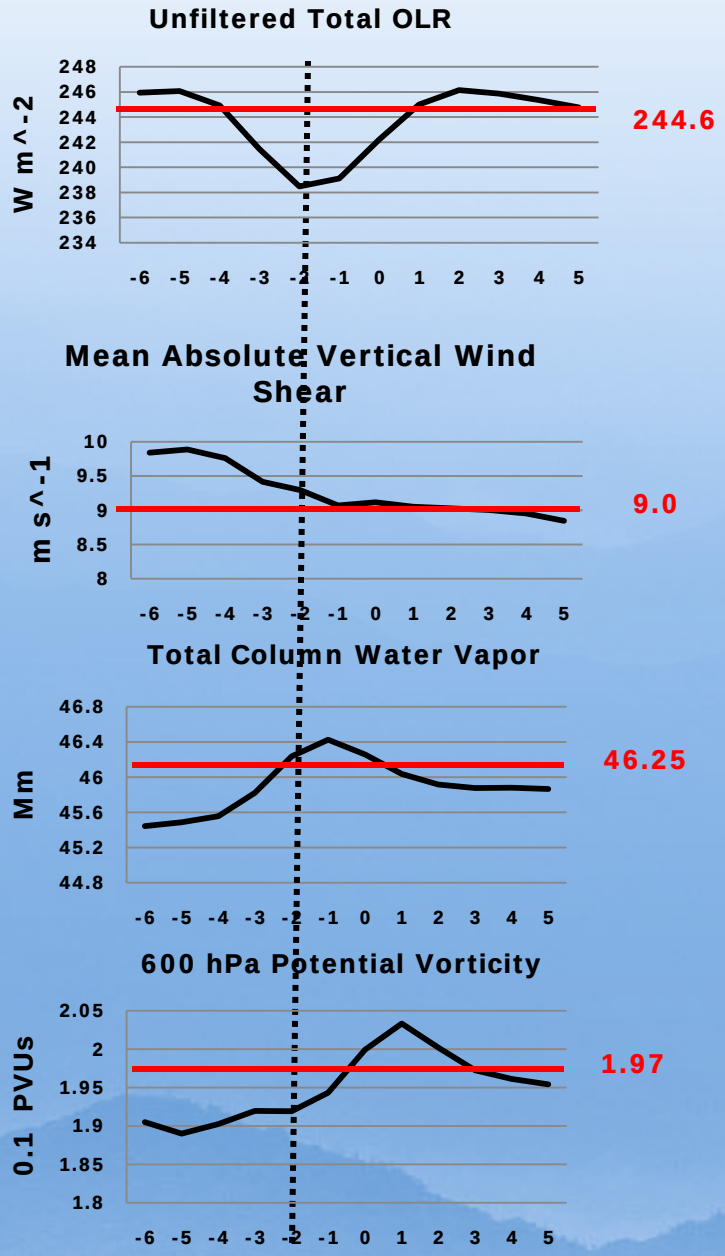
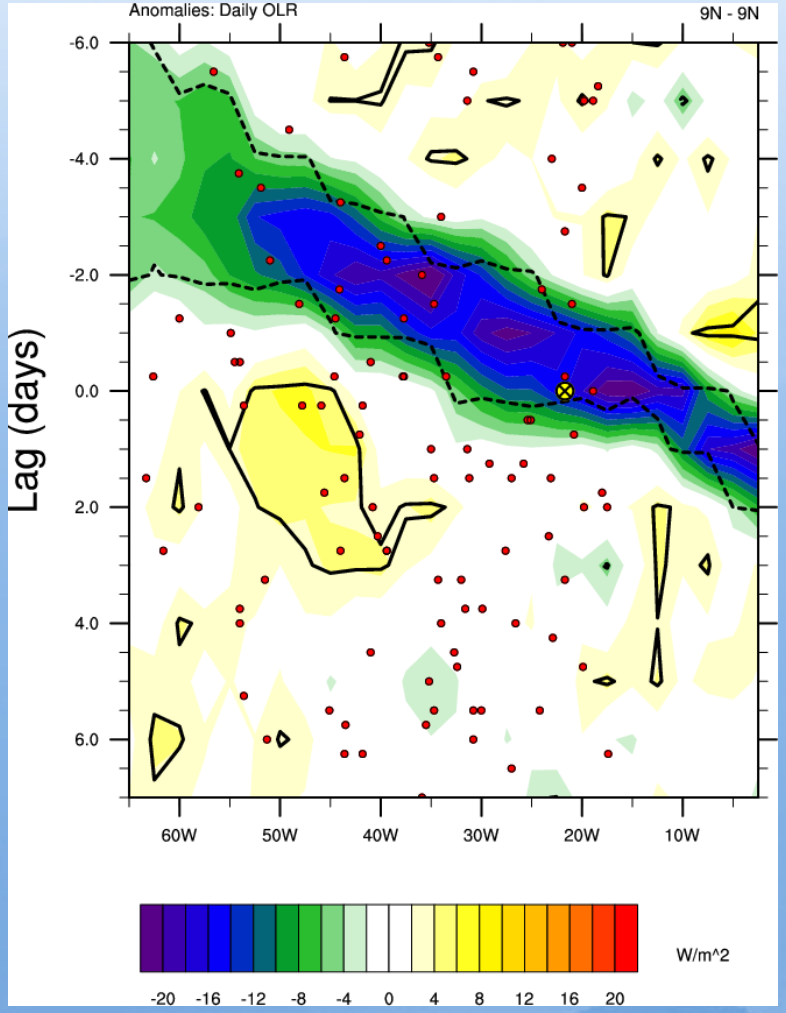


Key:

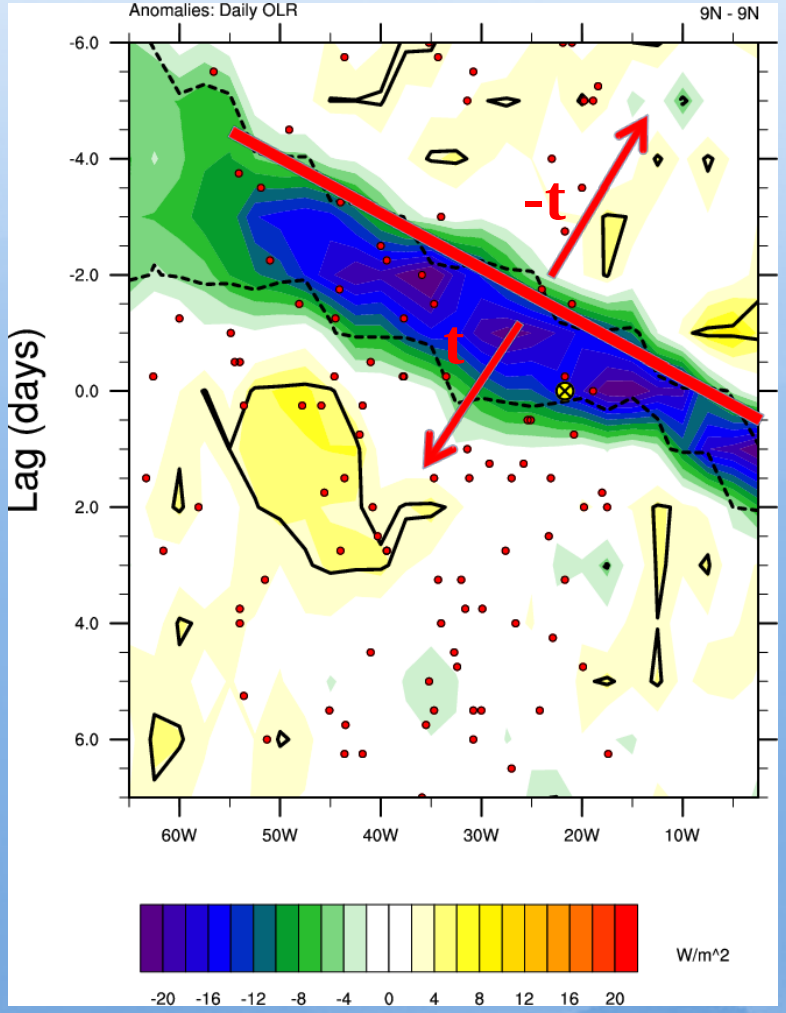
June-September Climatological Value

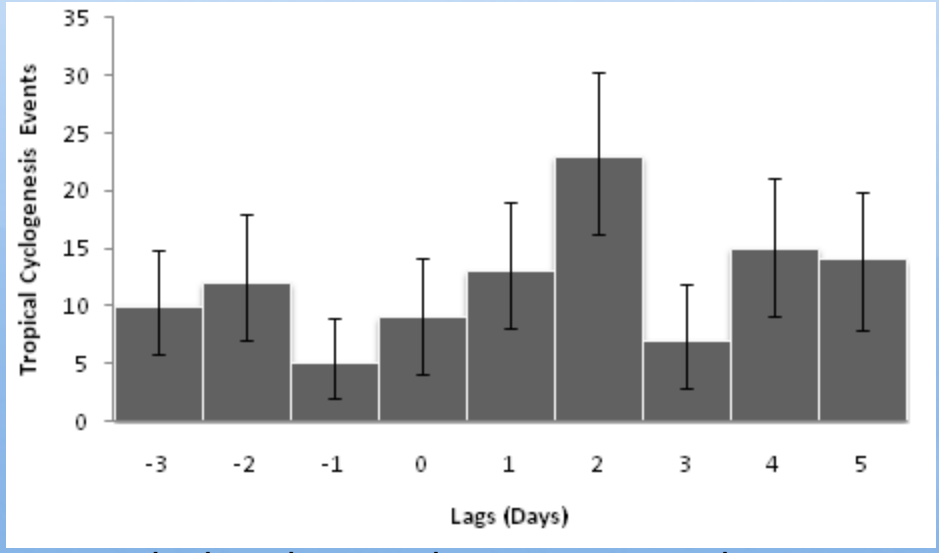
Averaged over 7.5-15°N, 15-60°W



JJAS 1979-2009 Composite

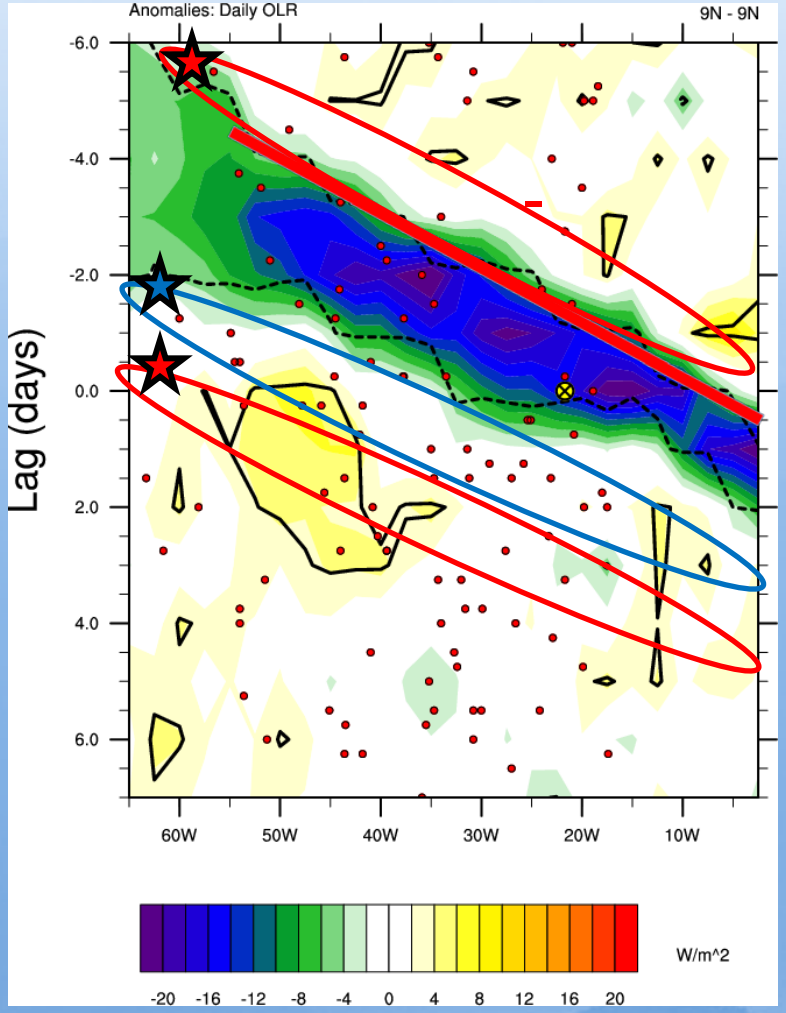
- Unfiltered OLR anomalies (shaded)
- Positive OLR anomalies statistically different than zero at the 95% level are within the solid contour.
- Negative OLR anomalies statistically different than zero at the 95% level are within dashed contour.
- Tropical cyclogenesis within the MDR (5-25°N, 15-65°W) for any given lag is denoted by a red circle.
- The genesis of Tropical Storm Debby is highlighted by the large yellow crossed circle.



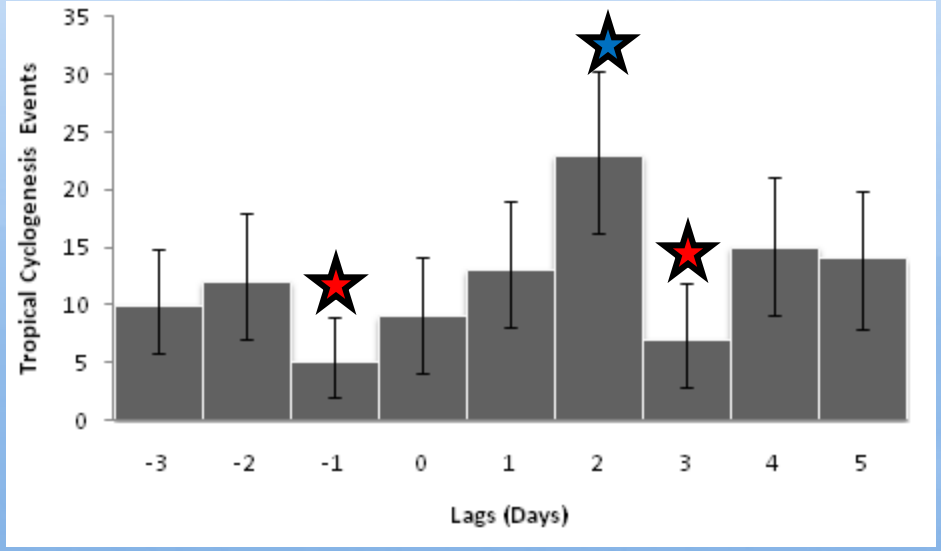


Tropical cyclogenesis events over the MDR (5-25°N, 15-65°W) relative to the CCKW during June-September 1979-2009

- Day 0 highlights the transition to statistically significant negative unfiltered OLR anomalies, or the eastern-most side of the convectively active phase of the CCKW.
- Error bars indicate the 95% confidence interval.

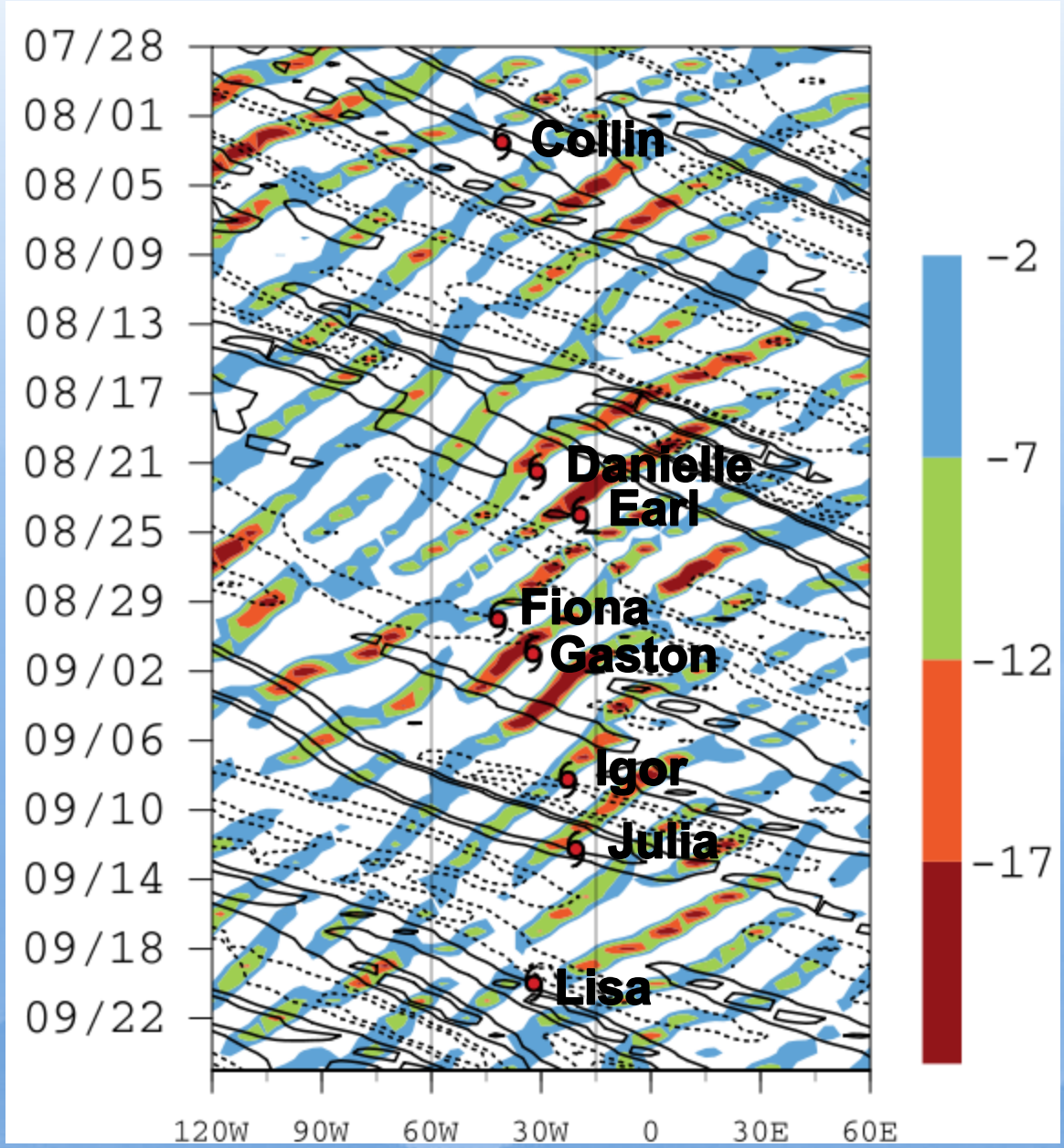


Tropical cyclogenesis relative to the Kelvin wave



August – September 2010

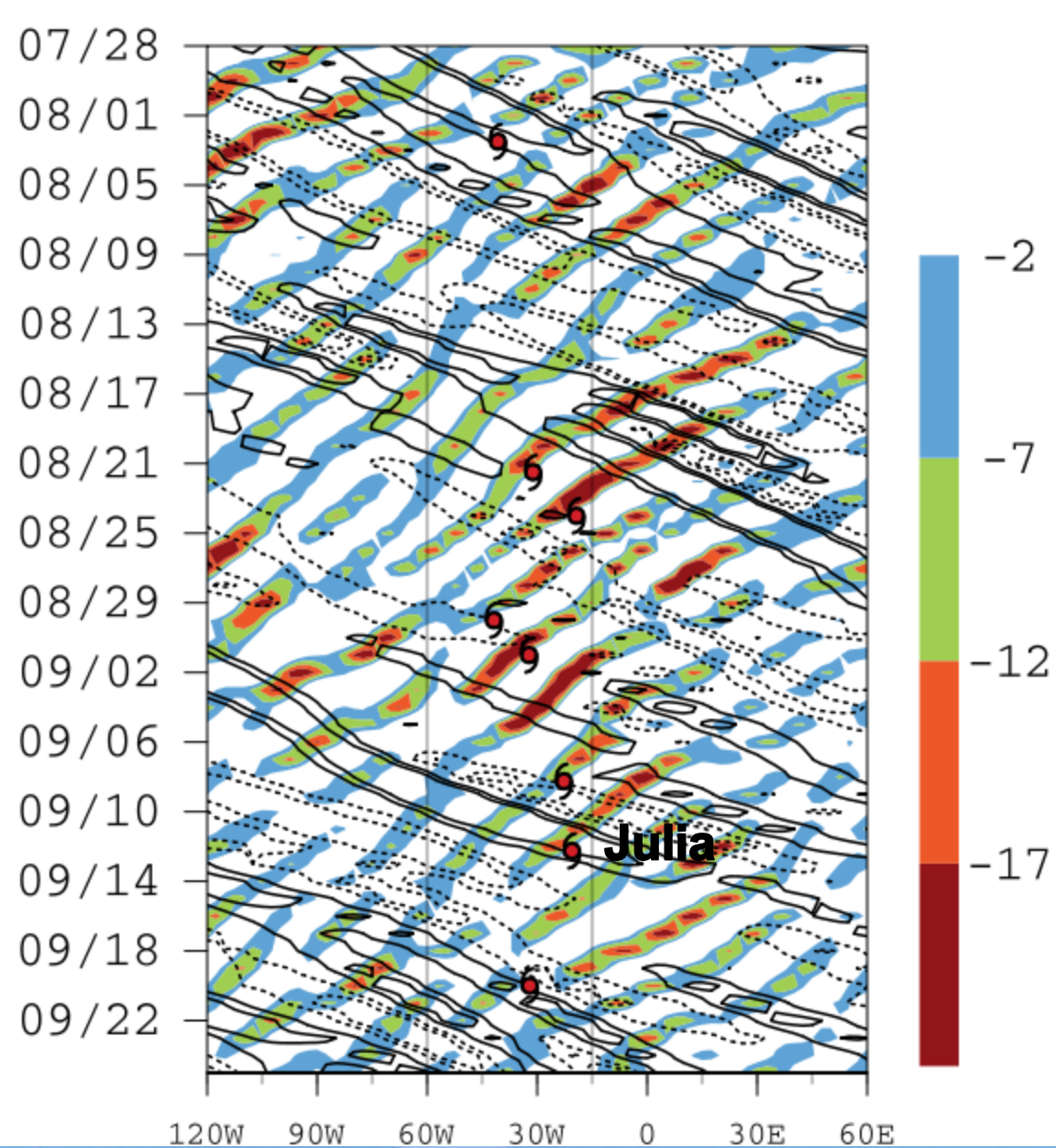
- 8 named TCs inside the MDR
- 3 TCs formed under the convectively active phase of a CCKW
  -Collin, Julia, Lisa
- 7/9 consecutive AEWs developed over the MDR between mid August-September

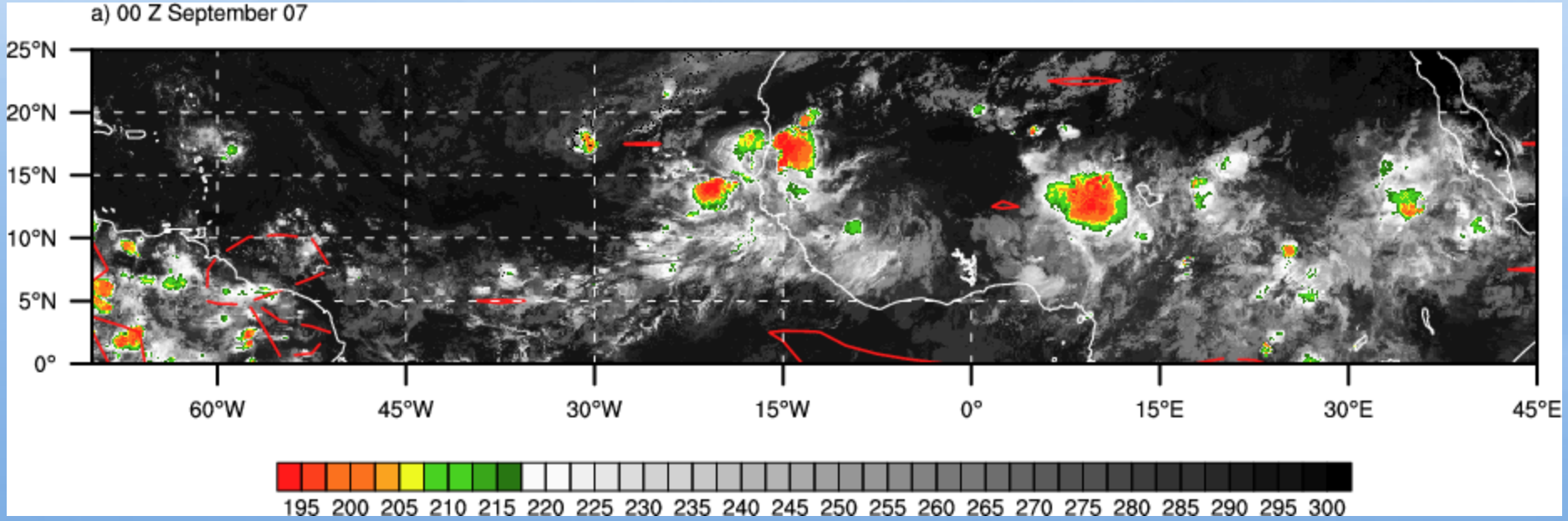


Key:
- TD-type filtered negative OLR anomalies (shaded)
- Kelvin filtered OLR anomalies (contour)
- TC genesis points

Hurricane Julia

- Formed near the coast of West Africa
- Interacted with the convectively-active phase of a CCKW before undergoing tropical cyclogenesis
- Was already a vigorous easterly wave before the interaction with a strong CCKW





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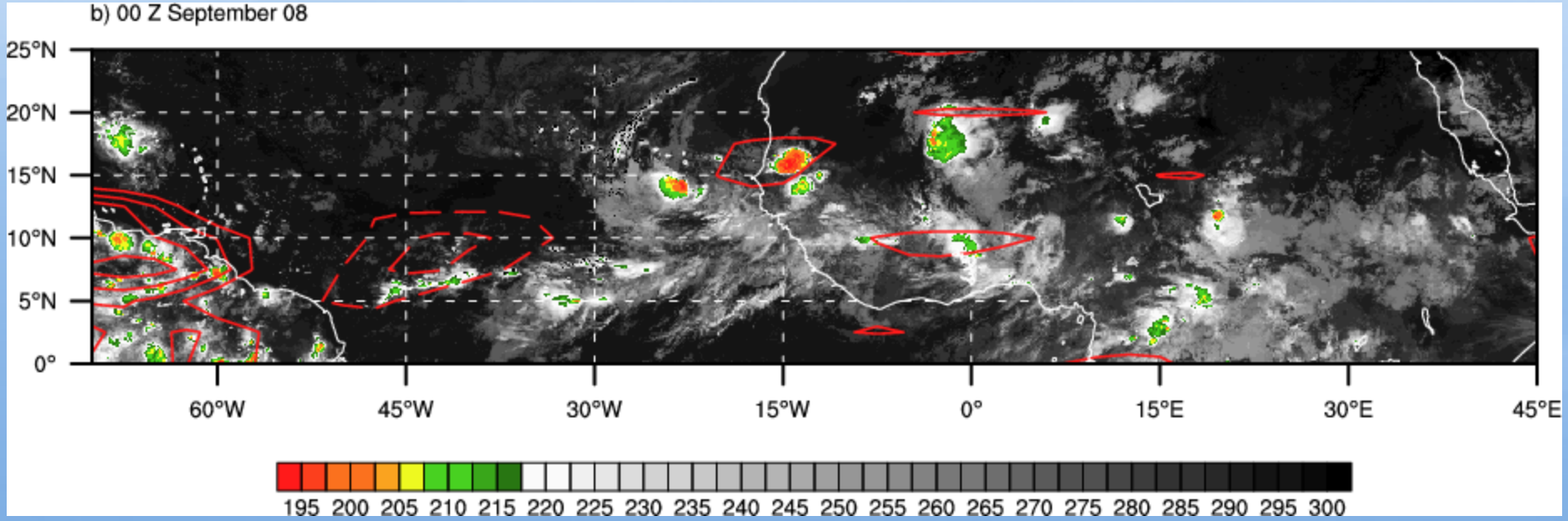

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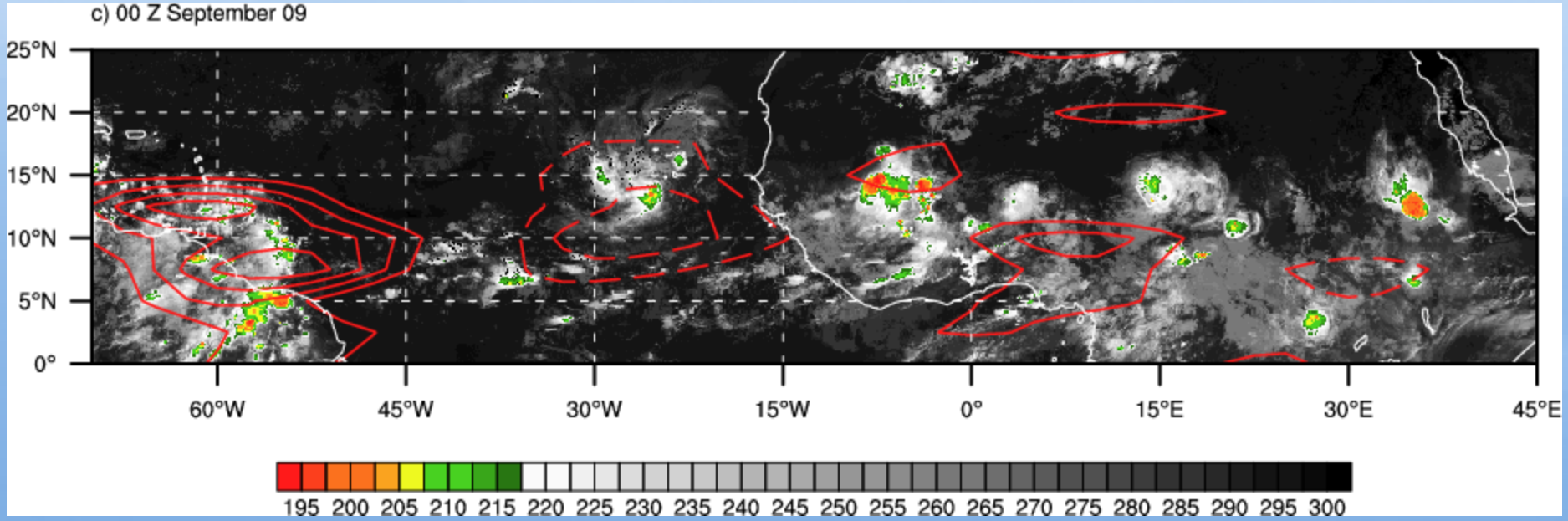

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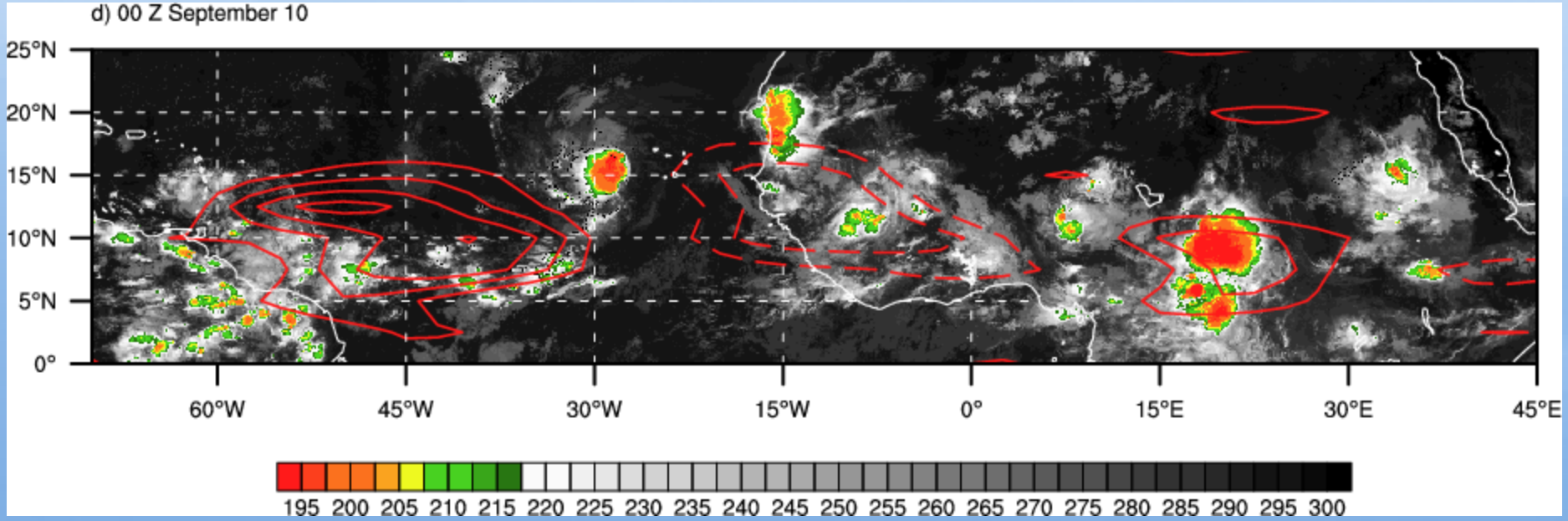

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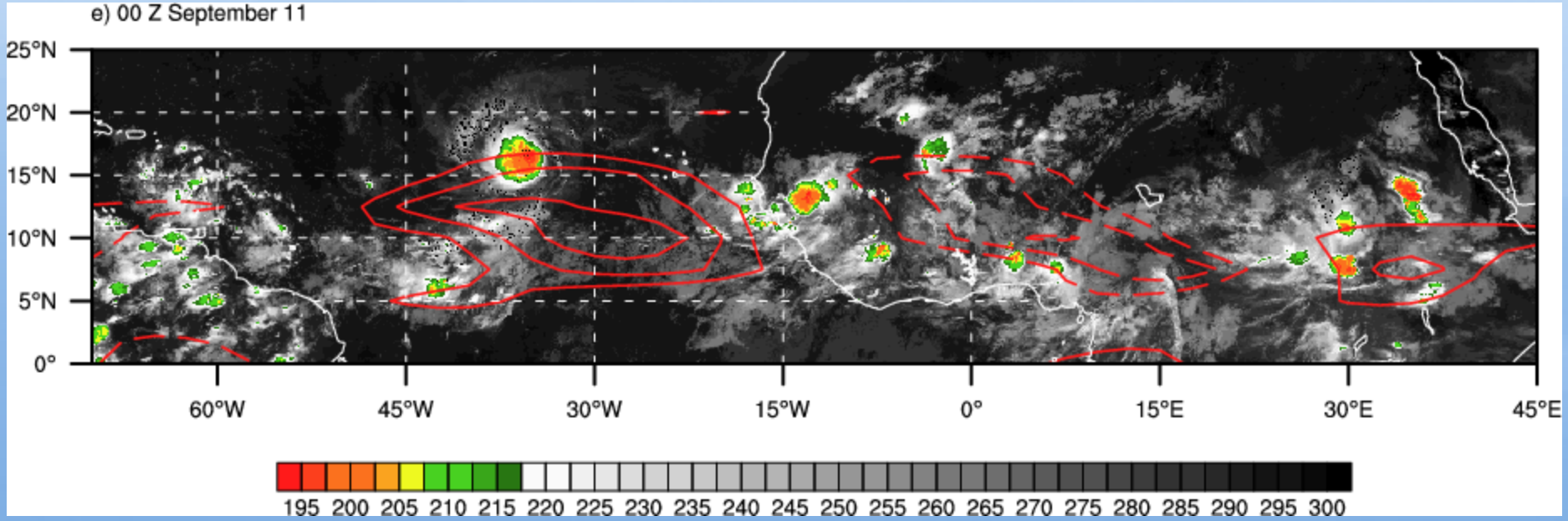

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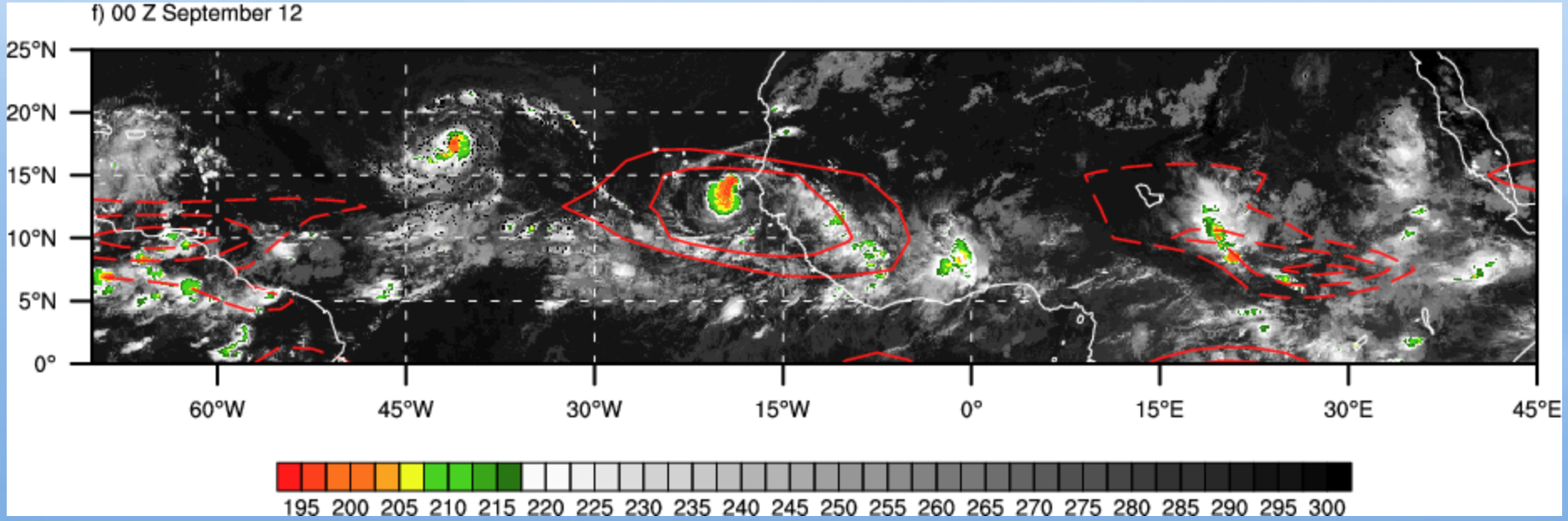
★ Genesis



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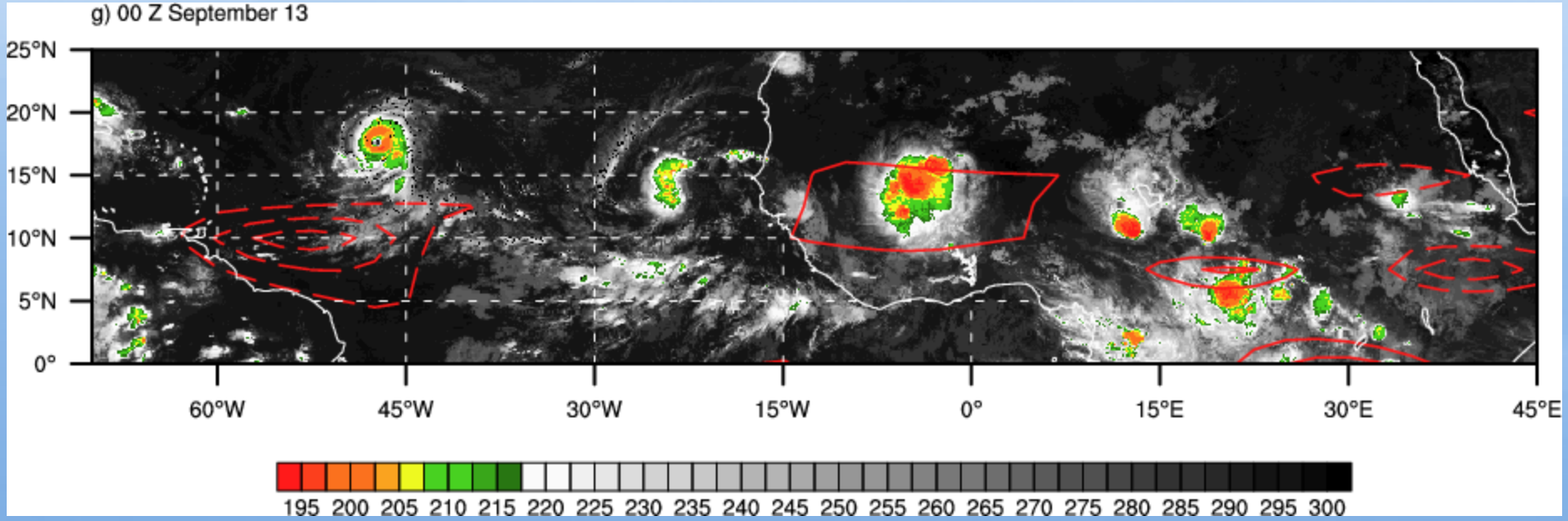

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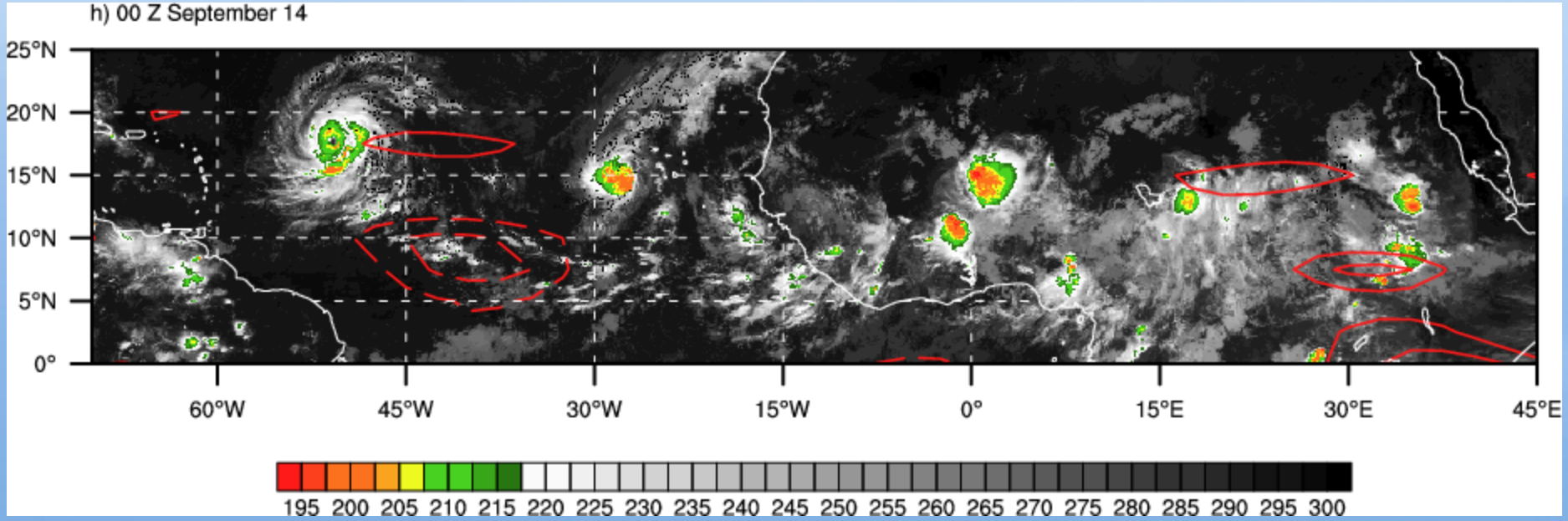

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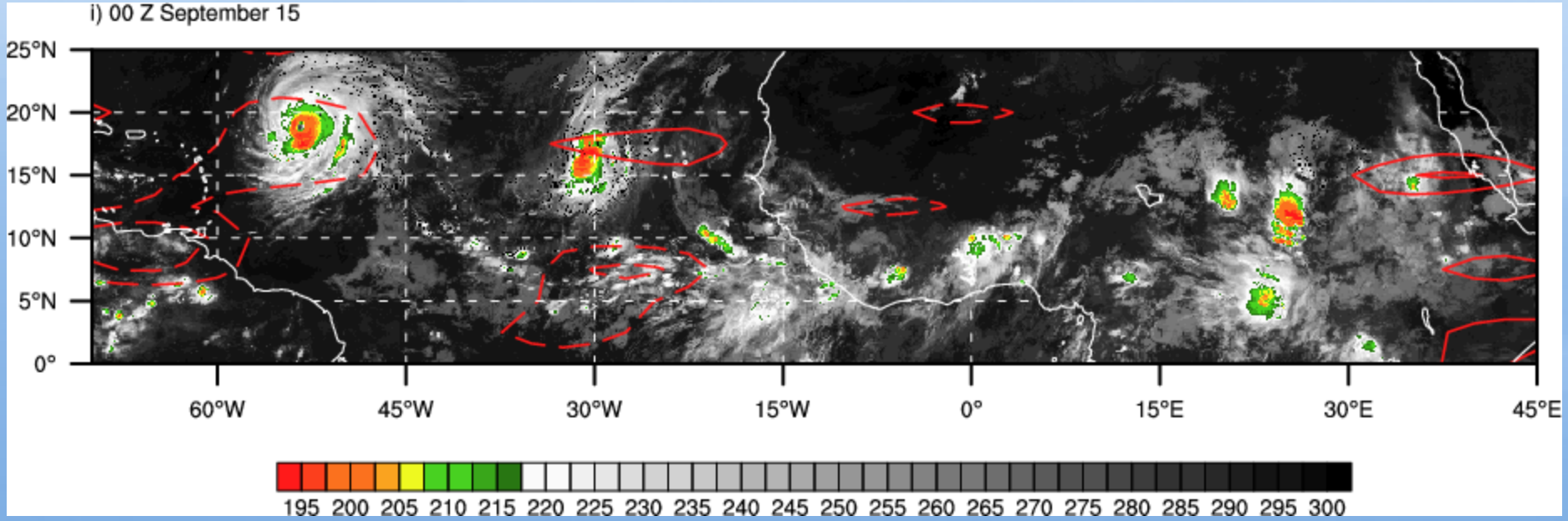

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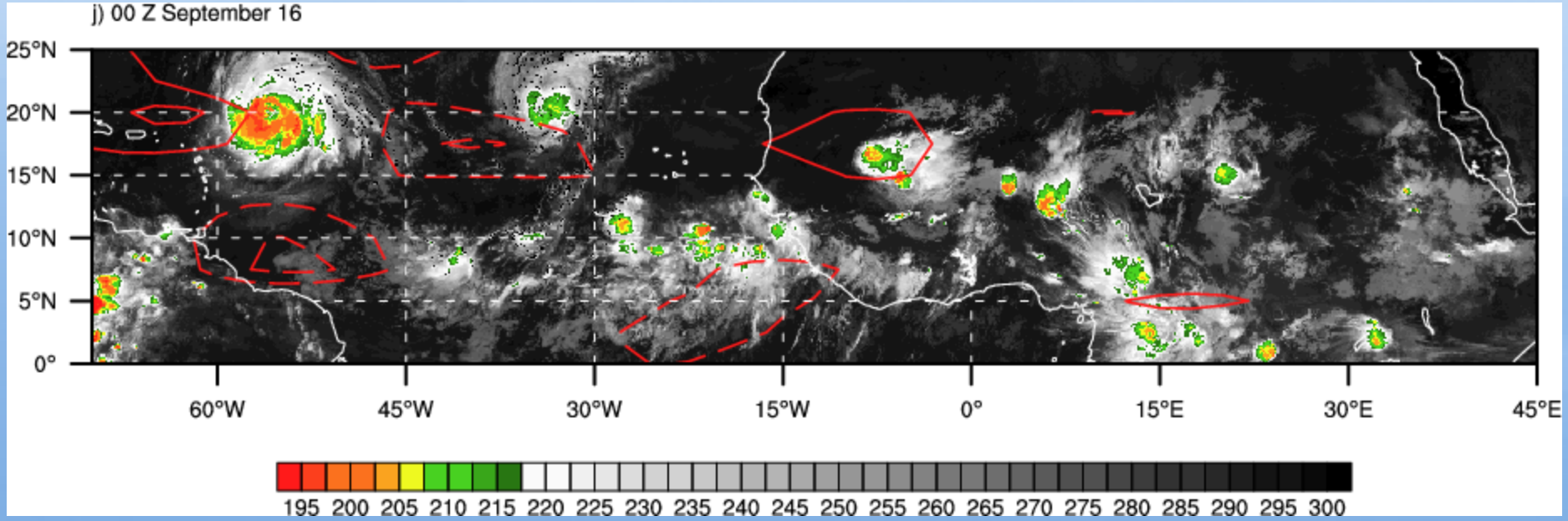

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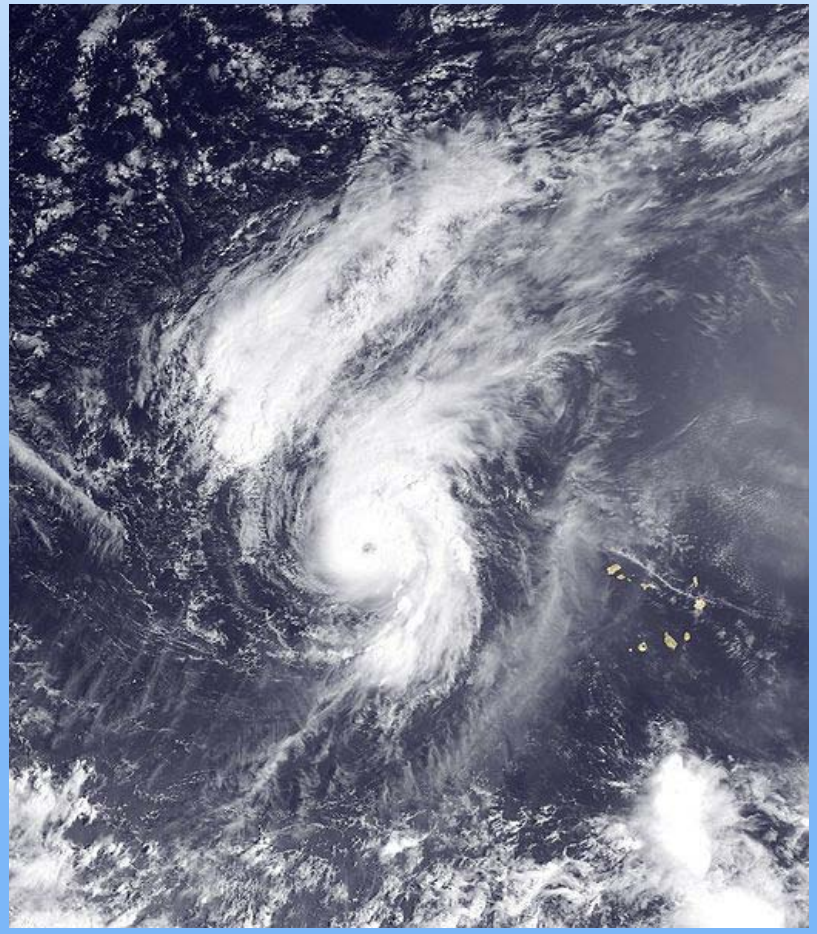
The convectively active phase of a CCKW enhances tropical cyclogenesis over the MDR by:

1) Enhancing westward propagating African easterly waves by providing an environmental suitable for deep convection

2) Enhancing large-scale environmental conditions over the MDR to be favorable for TC genesis for a brief period of time

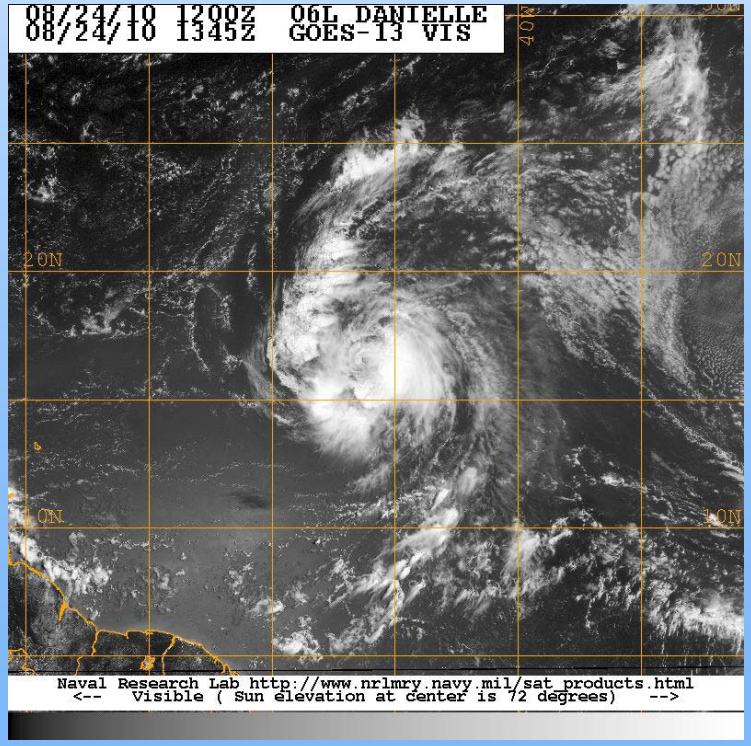
Question:
Can an unfavorable phase of a CCKW be destructive to a TC?



Hurricane Julia (2010)

An Unexpected Weakening of Hurricane Danielle…

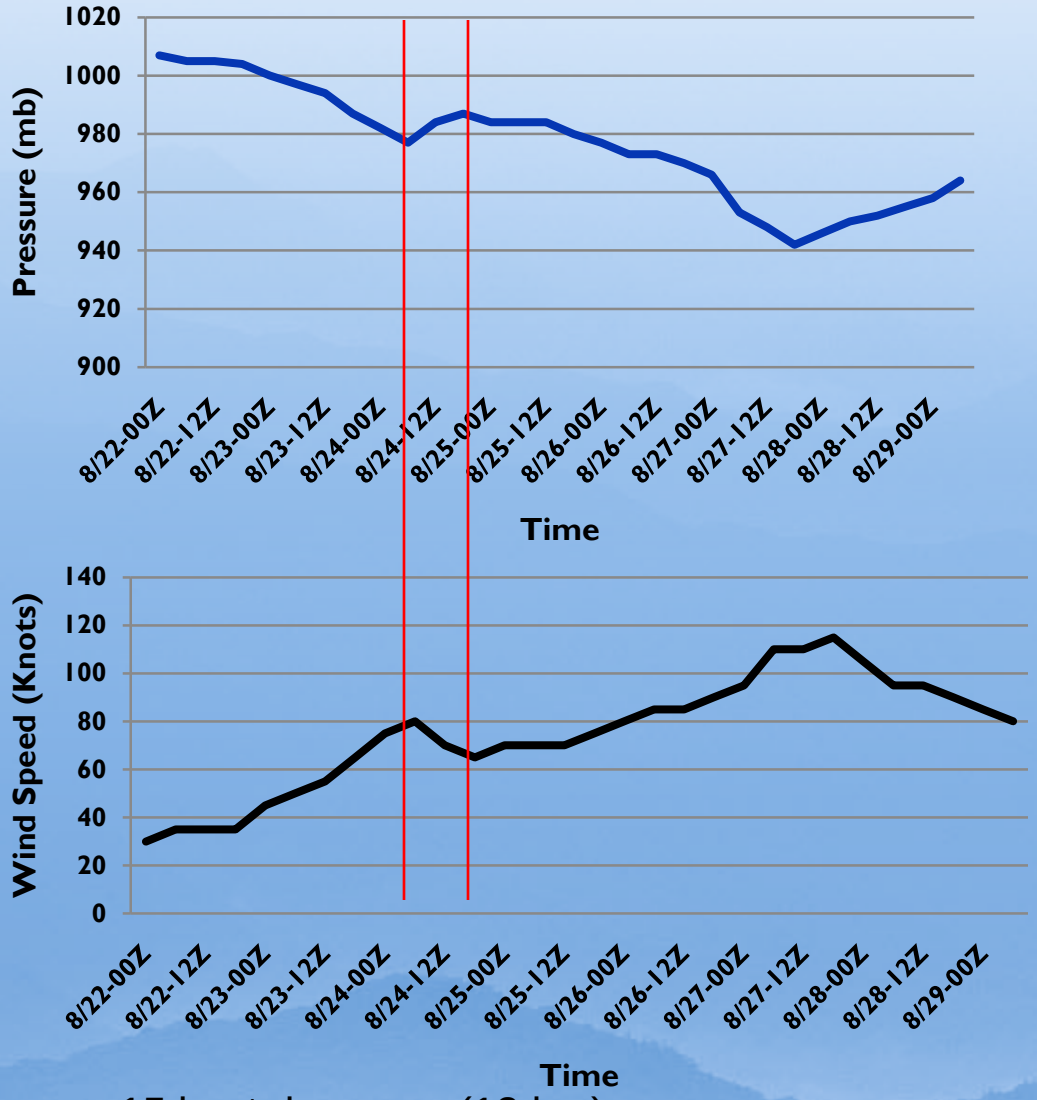
(Reuters) – “Hurricane Danielle unexpectedly weakened in the open Atlantic Ocean on Tuesday and was downgraded to a Category 1 storm on the Saffir-Simpson scale, as winds eased from 100 miles per hour to 80 mph, the U.S. National Hurricane Center said.”



Hurricane Danielle - August 24

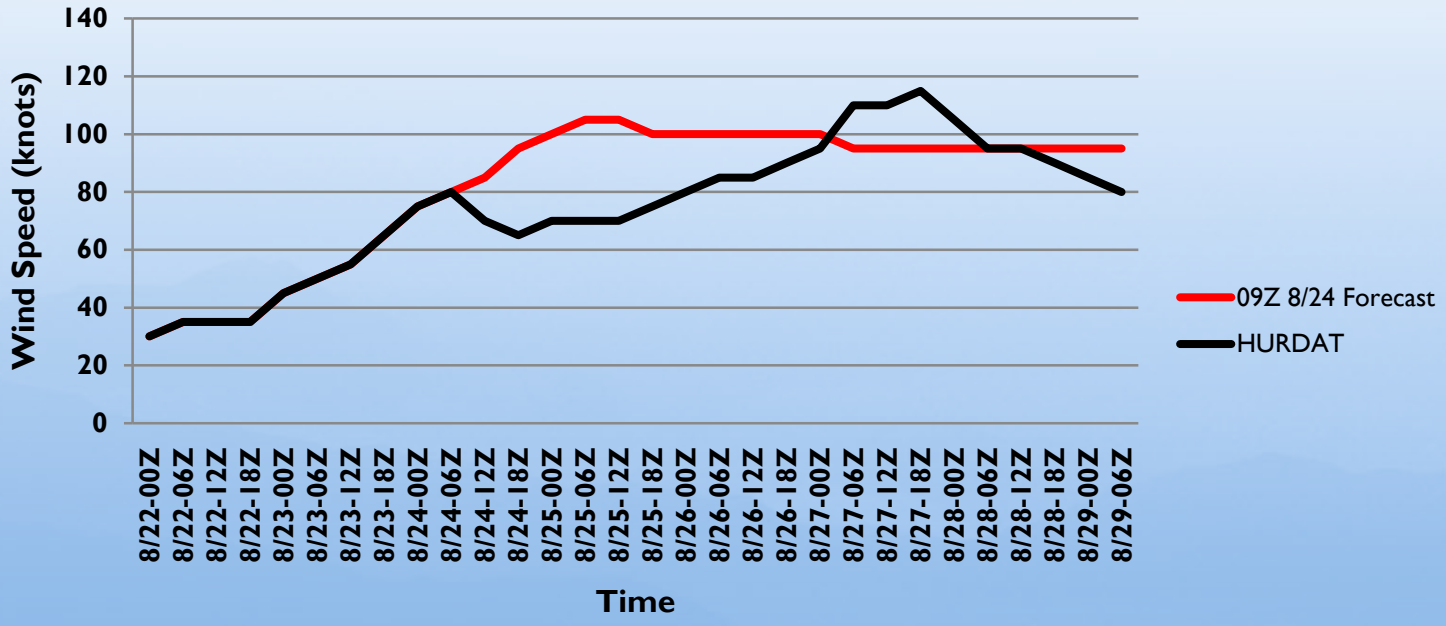
Healthy Category 2 Hurricane → Weak Category 1 Hurricane in only 12 hours!

10 mb pressure rise (12 hrs)



HURDAT

15 knot decrease (12 hrs)


Wind Speed (knots)
140
120
100
80
60
40
20
0
8/22-00Z
8/22-06Z
8/22-12Z
8/22-18Z
8/23-00Z
8/23-06Z
8/23-12Z
8/23-18Z
8/24-00Z
8/24-06Z
8/24-12Z
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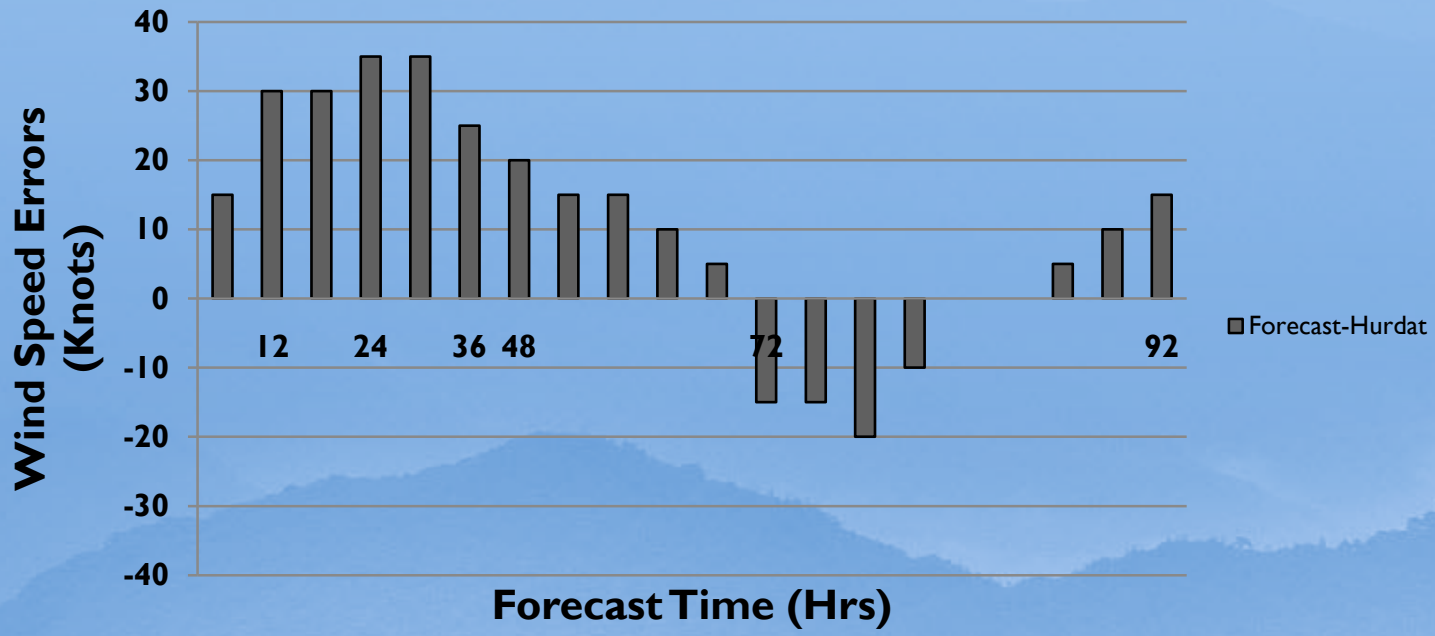
8/27-00Z
8/27-06Z
8/27-12Z
8/27-18Z
8/28-00Z
8/28-06Z
8/28-12Z
8/28-18Z
8/29-00Z
8/29-06Z
Time
09Z 8/24 Forecast
HURDAT

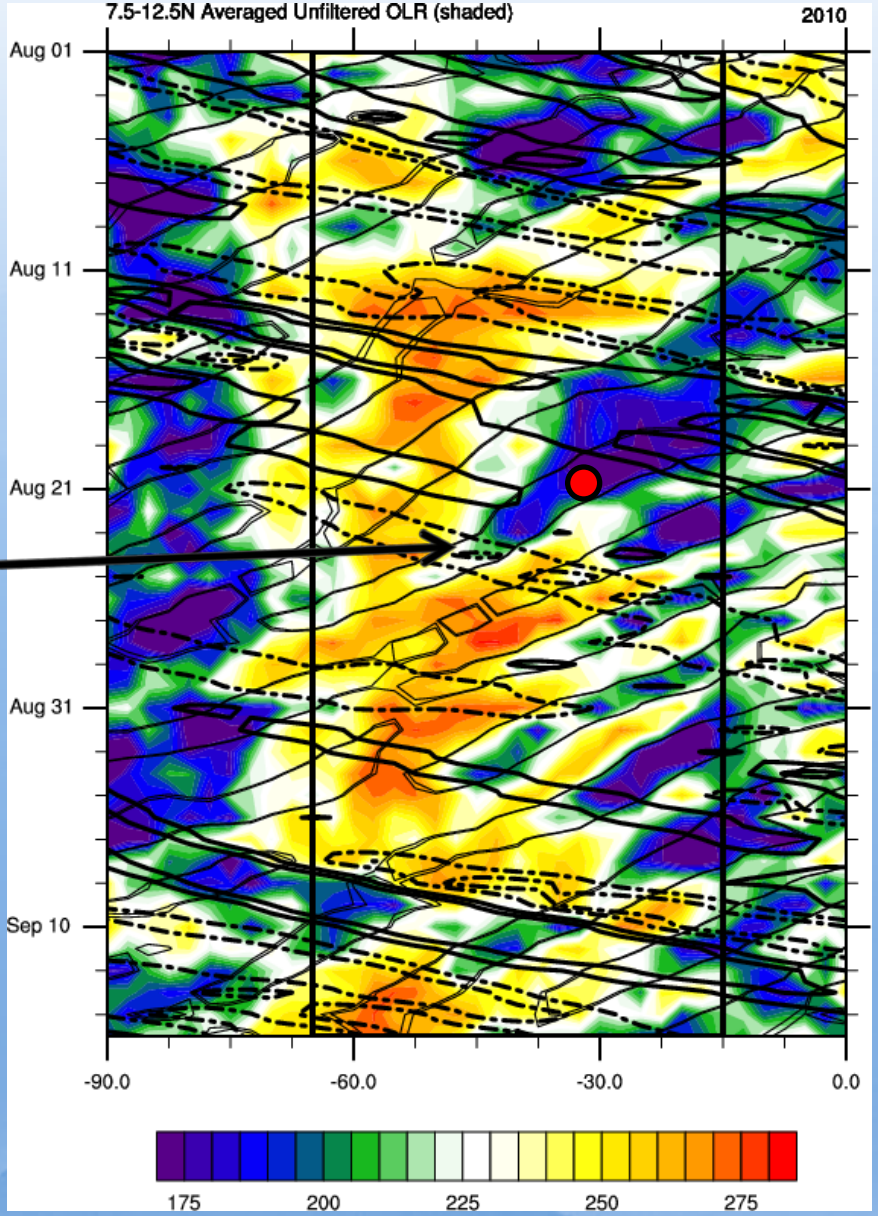

Wind Speed Errors (Knots)
40
30
20
10
0
-10
-20
-30
-40
12
24
36
48
72
92
Forecast Time (Hrs)
Forecast-Hurdat

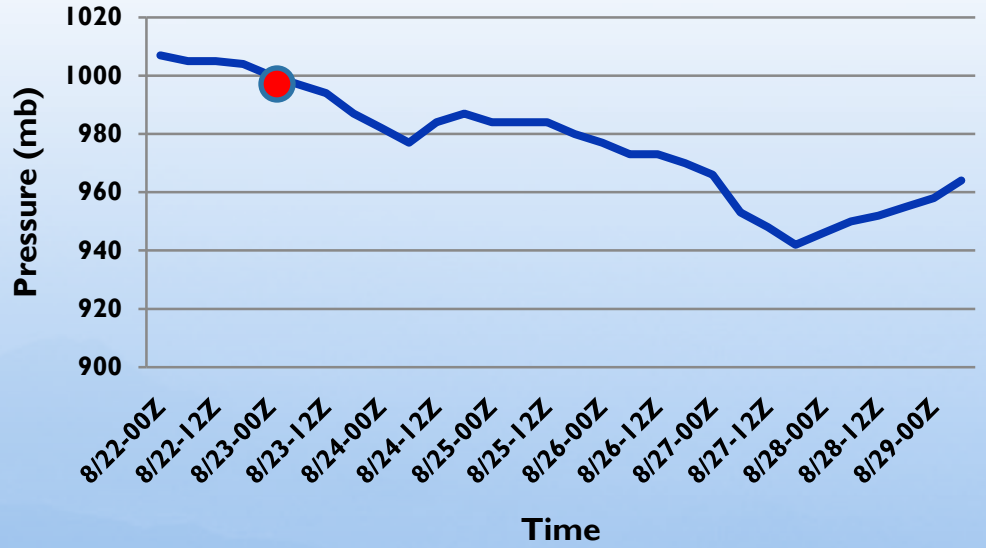
Why the brief rapid decay?

After reaching an intensity of 80 kt around 0600 UTC 24 August, ***southwesterly shear*** associated with a shortwave trough moving southwestward in the subtropical Atlantic between 45-50°W caused Danielle to decrease in strength. The trough also weakened the subtropical ridge that was steering Danielle, which resulted in a turn toward the west-northwest. Despite a continuation of ***moderate southwesterly shear***, Danielle maintained hurricane strength on 24 August and early on 25 August. Late on 25 August the hurricane turned northwestward and its forward speed decreased in response to a new weakness developing in the subtropical ridge over the central Atlantic. A decrease in shear around that time led to a gradual strengthening of the cyclone on 26 August, and the rate of deepening increased early on 27 August.

-National Hurricane Center - 15 December 2010

Sudden
Increase in OLR

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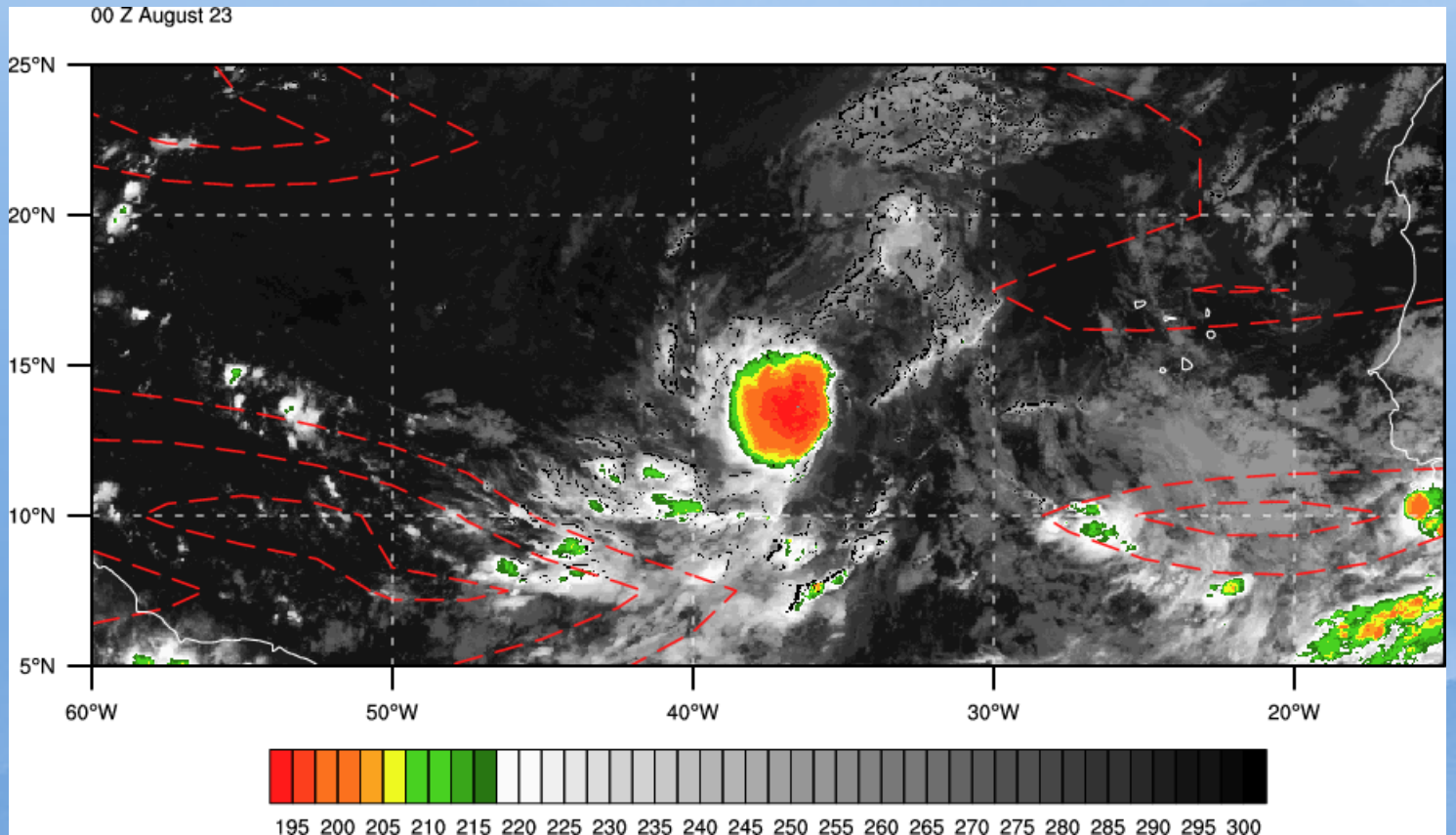
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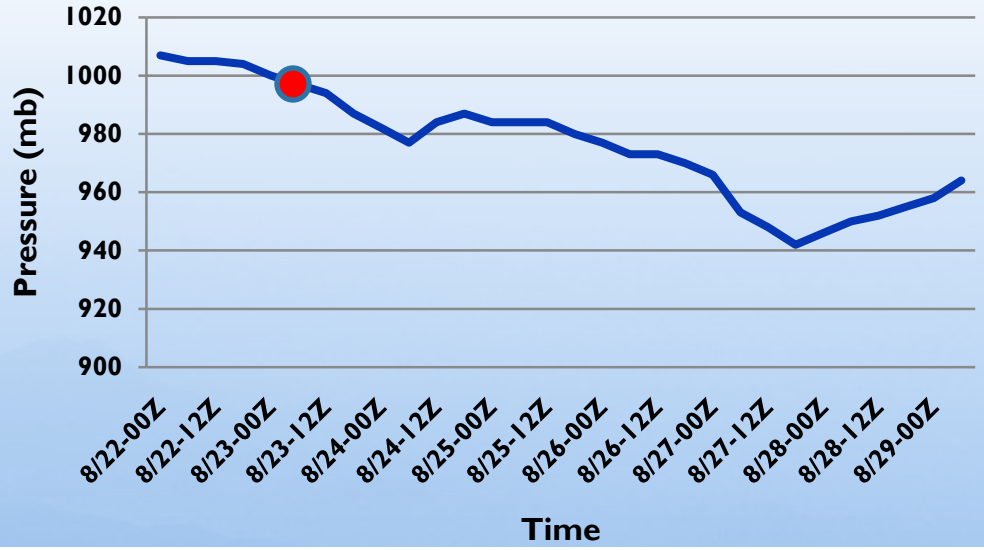
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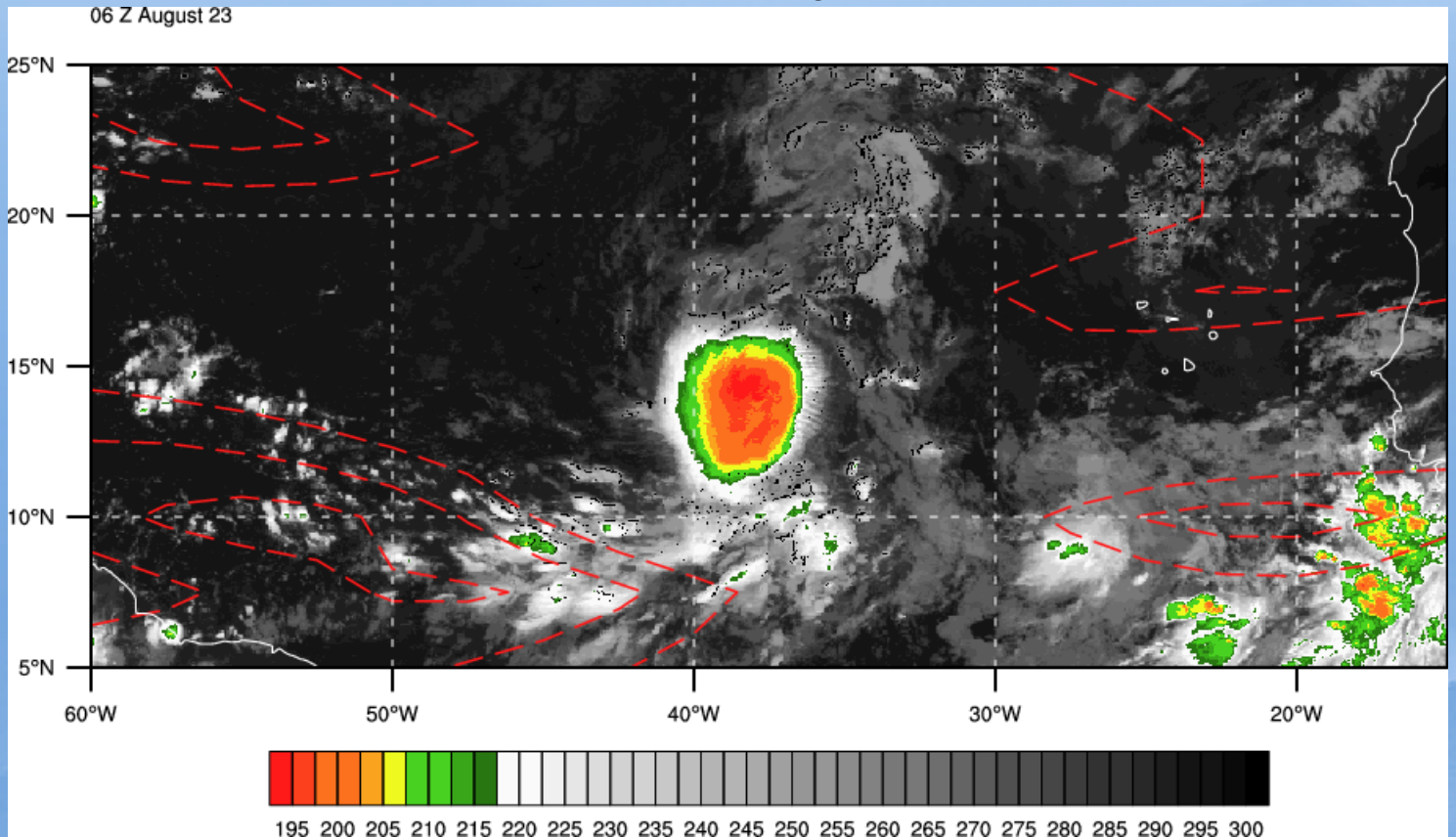
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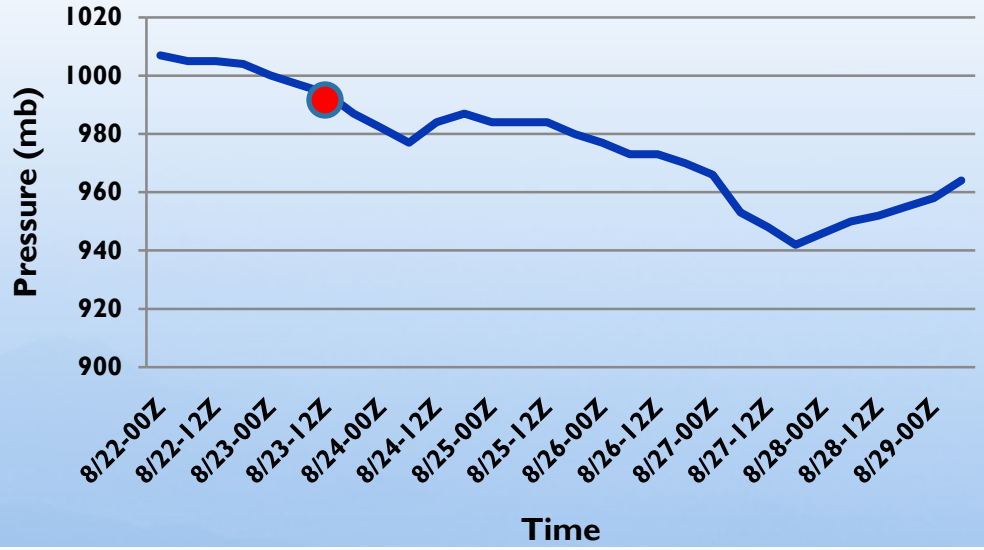
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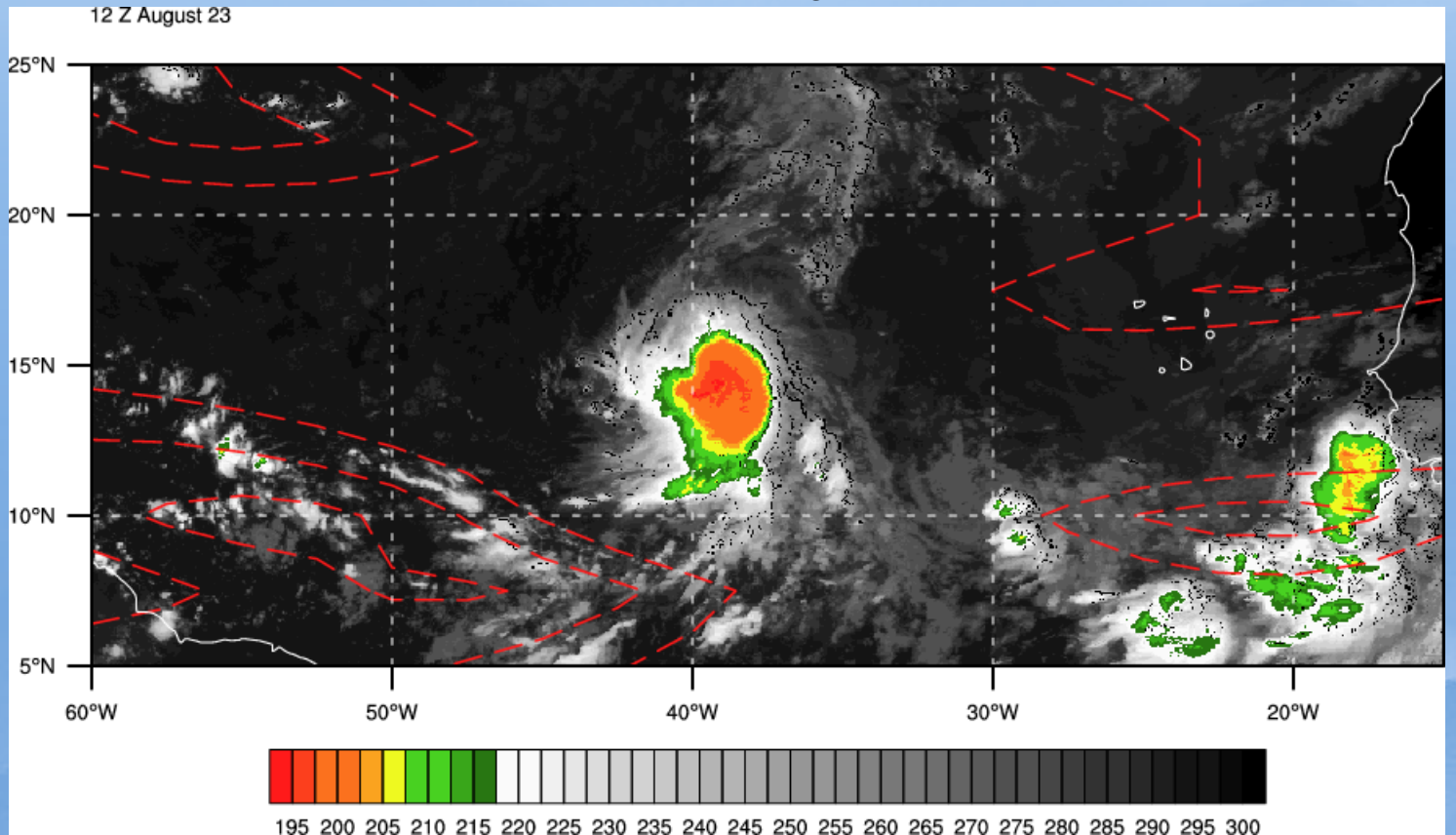
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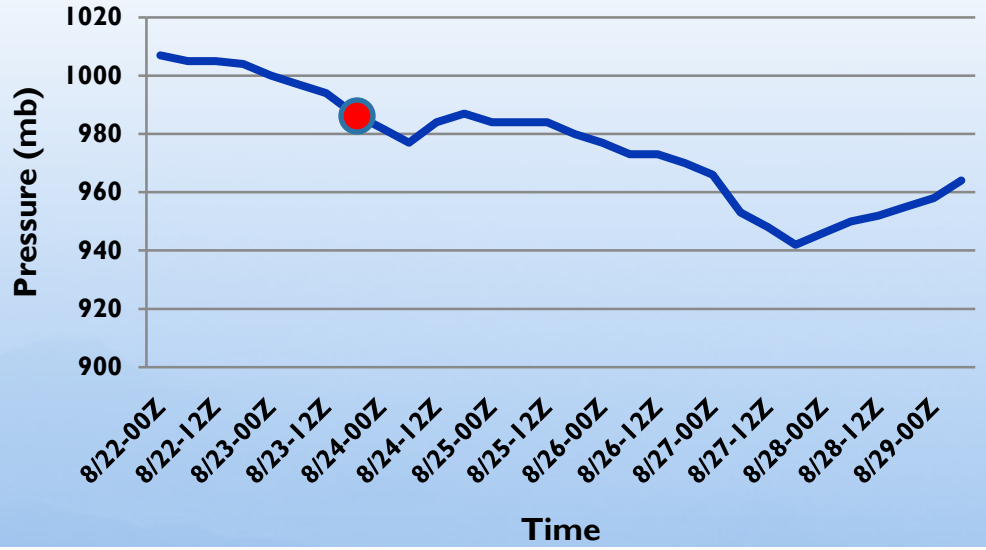
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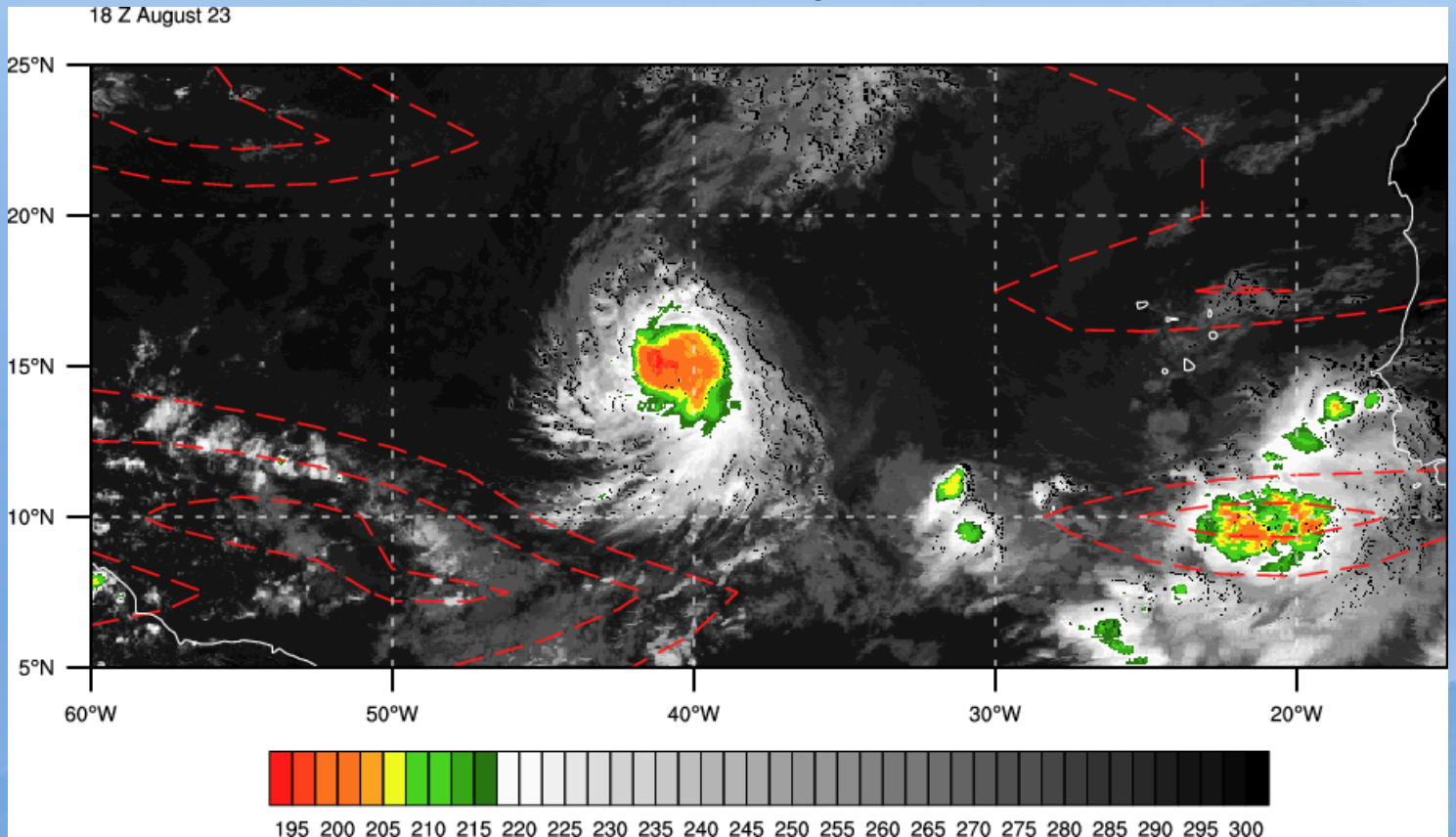
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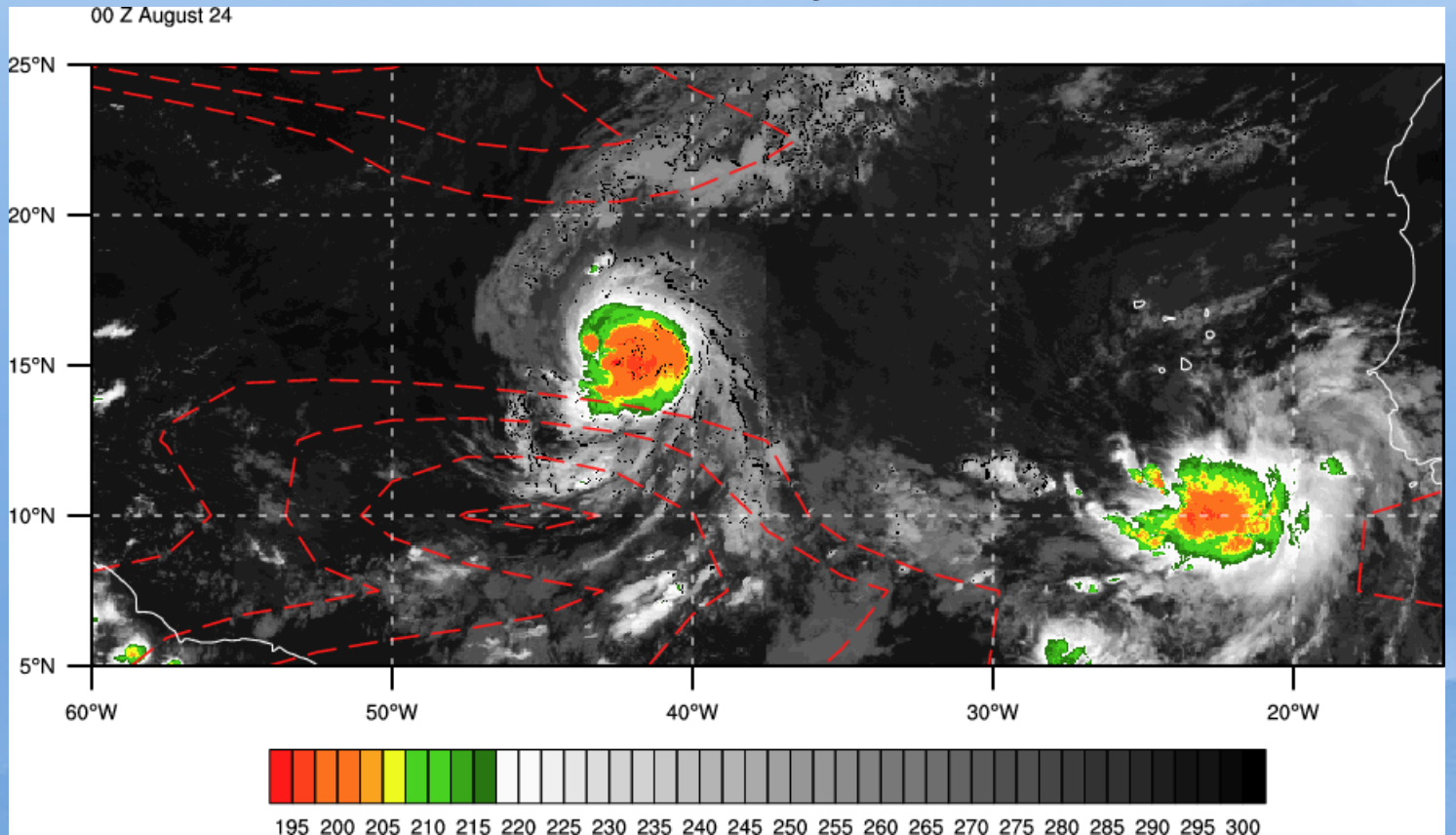
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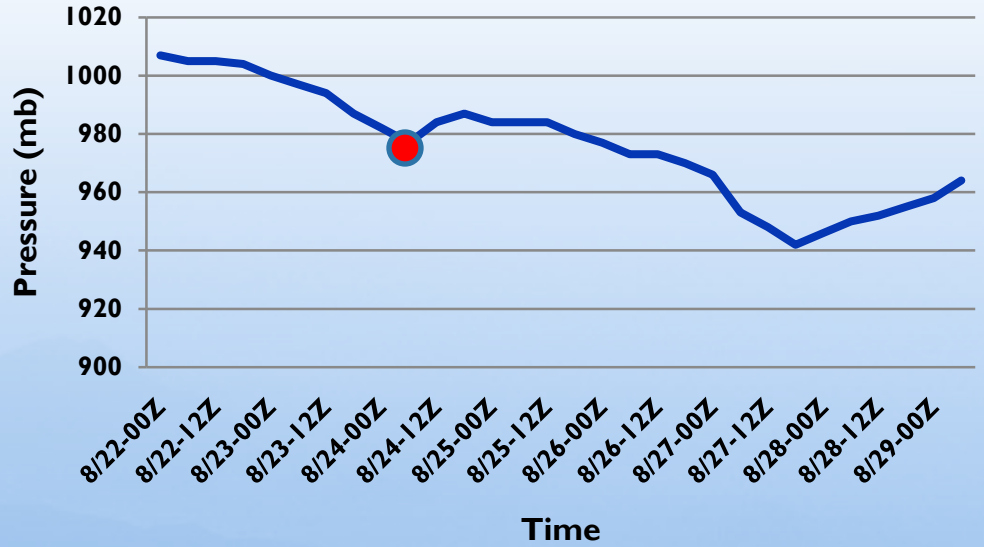
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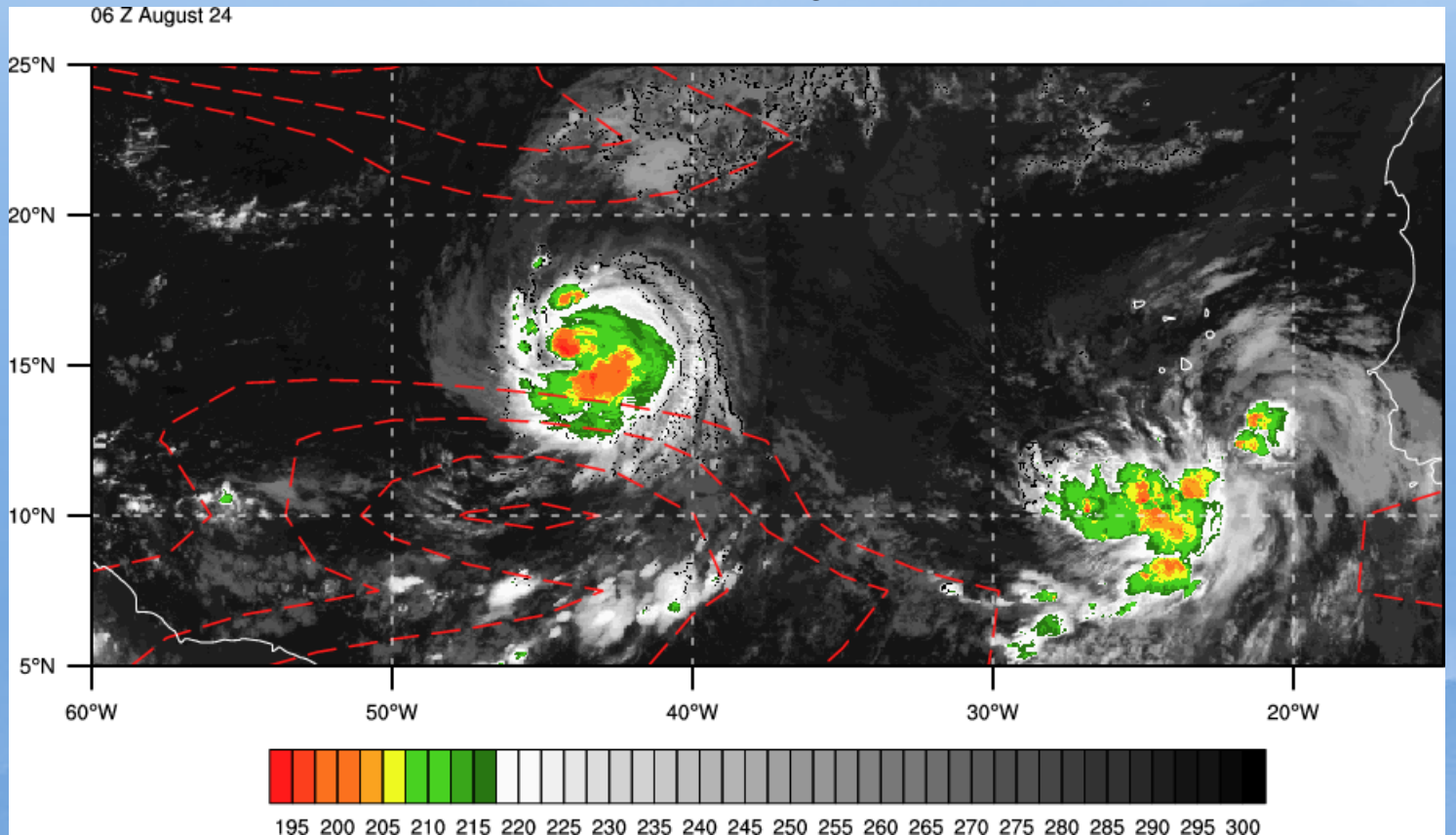
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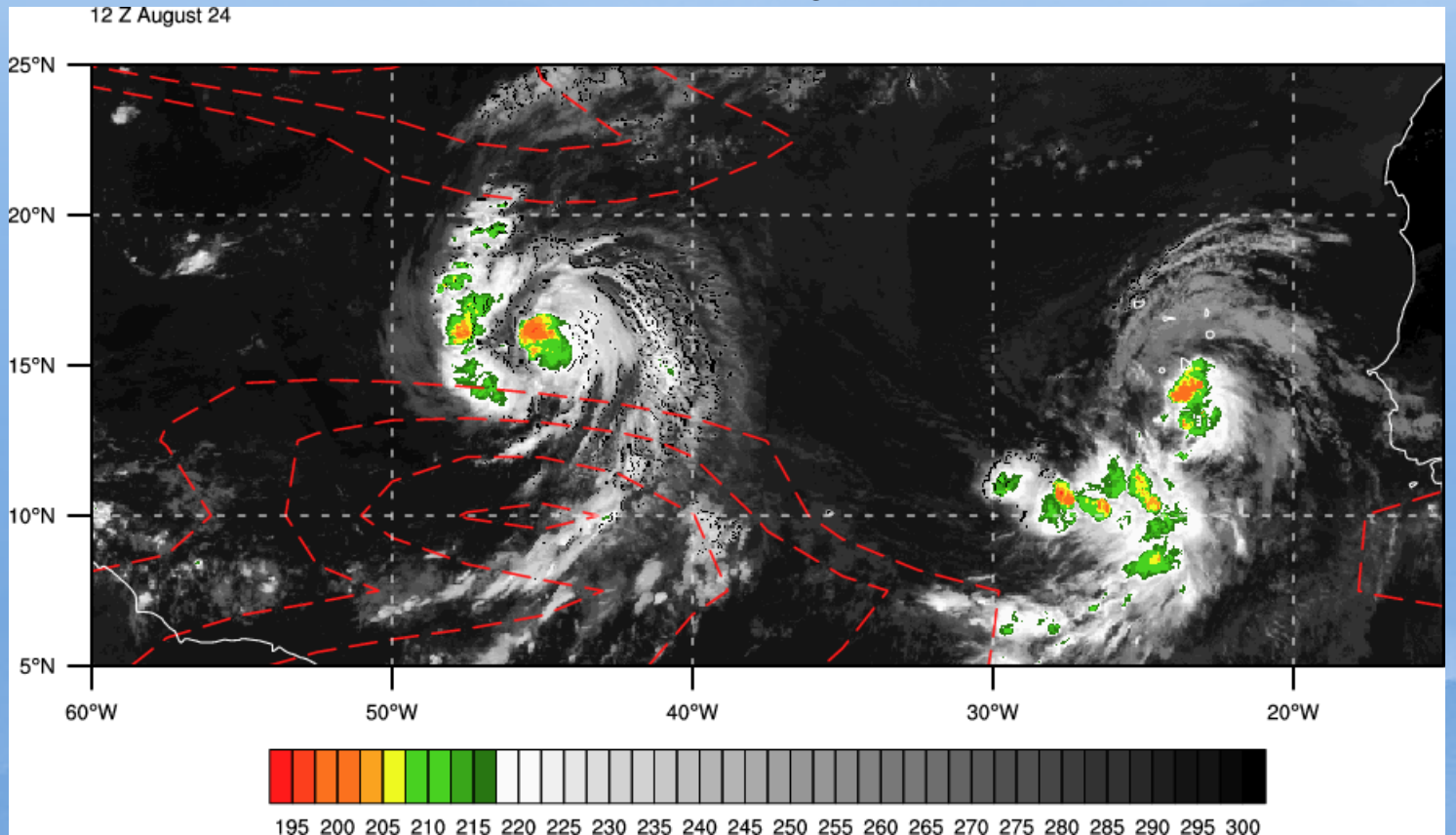
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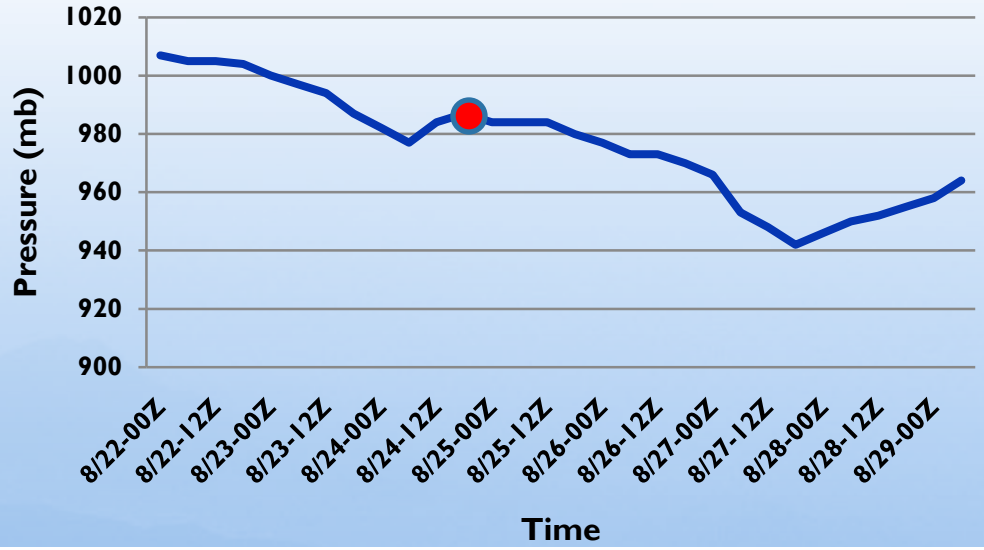
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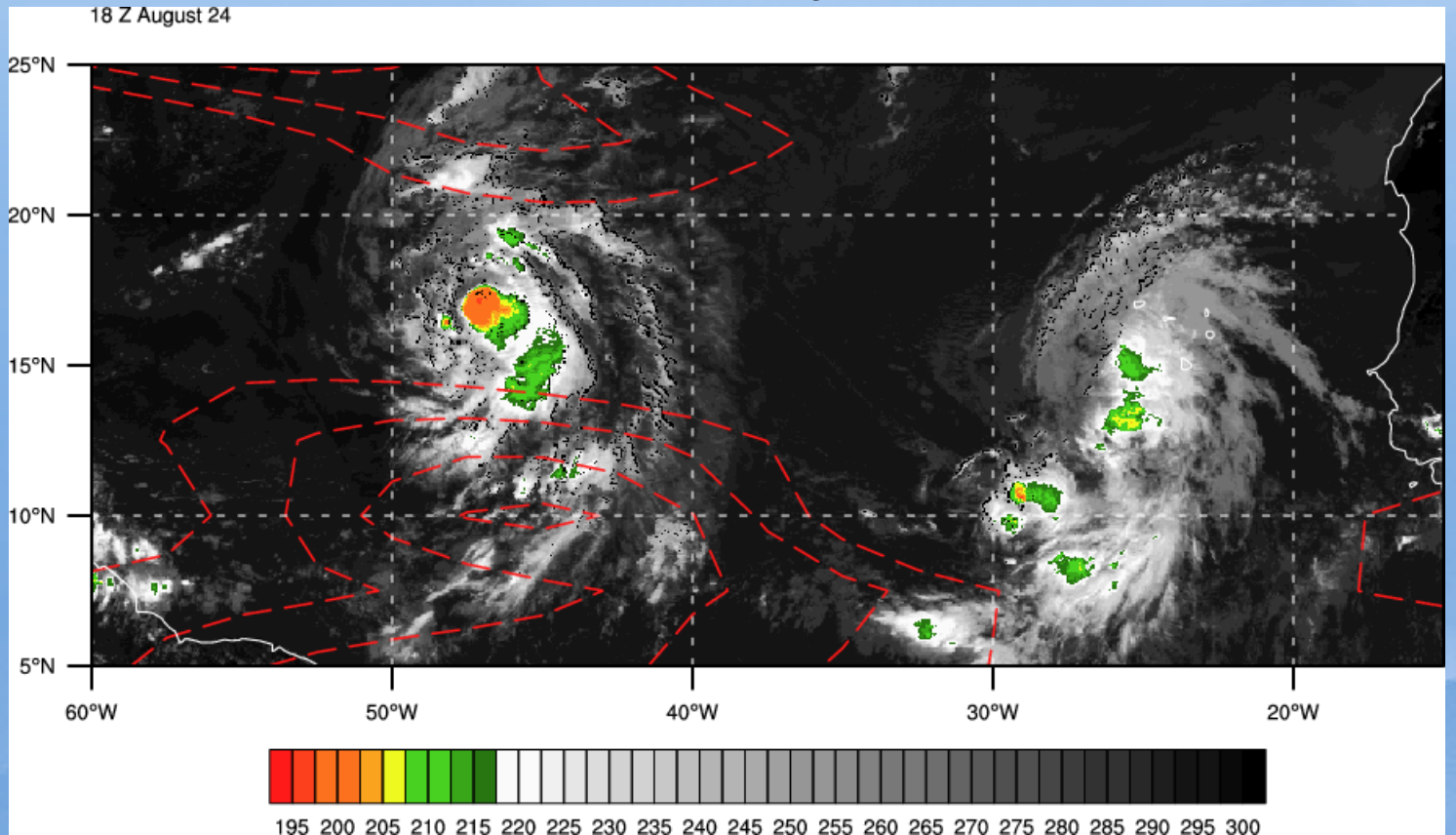
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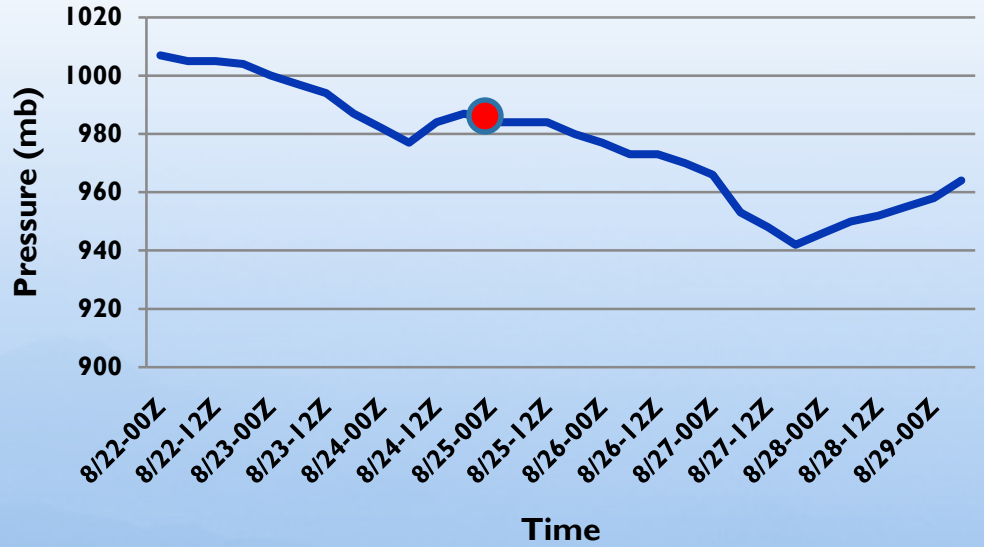
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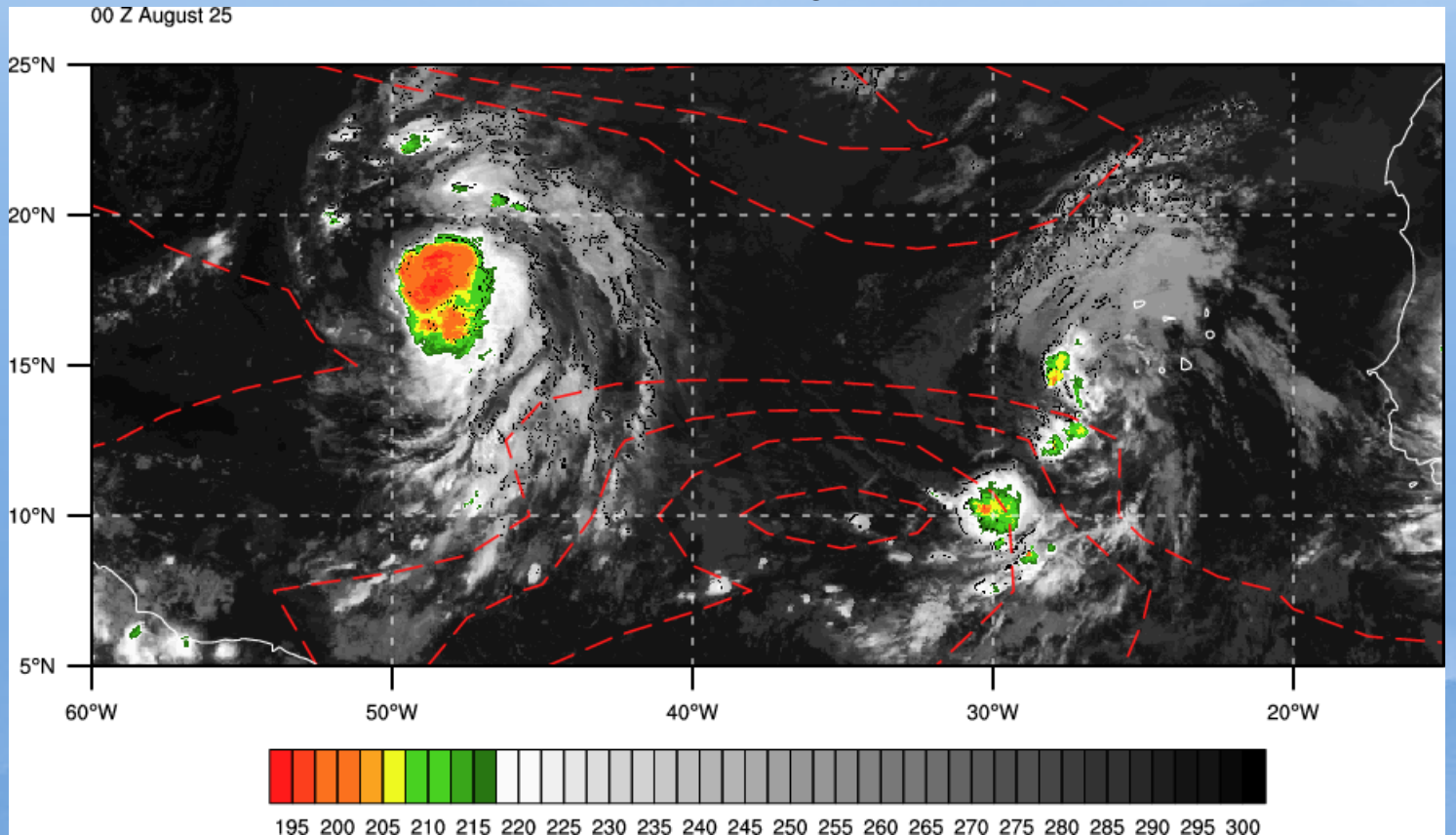
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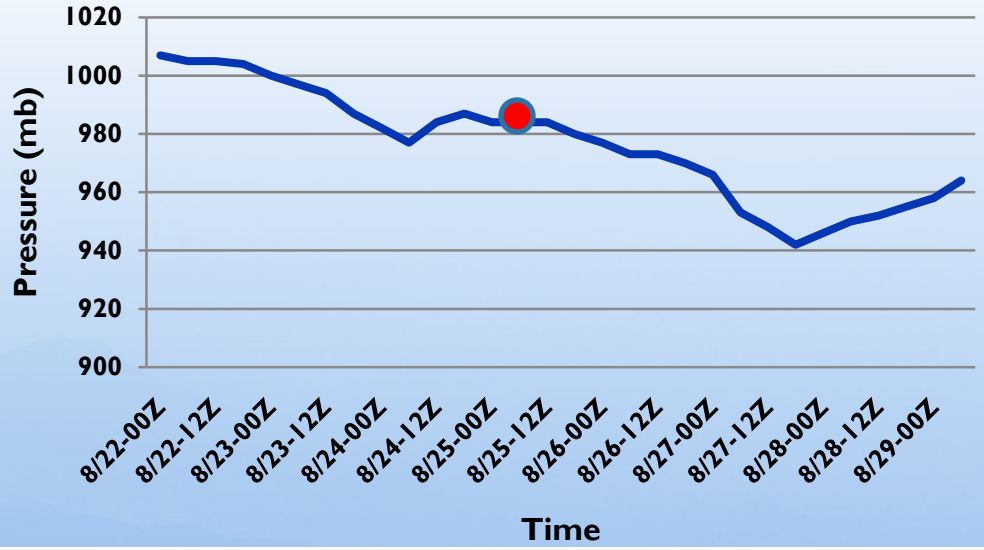
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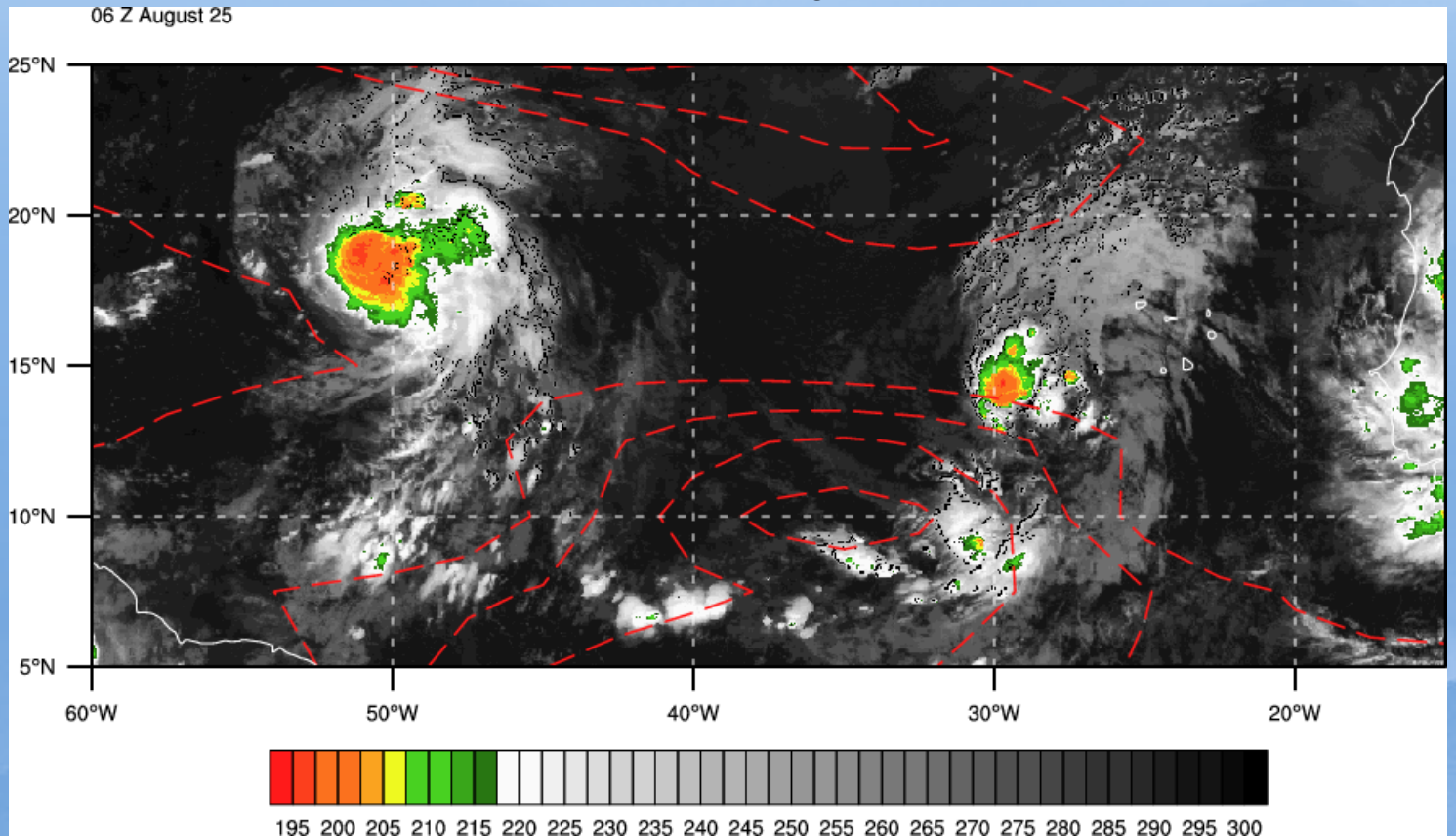
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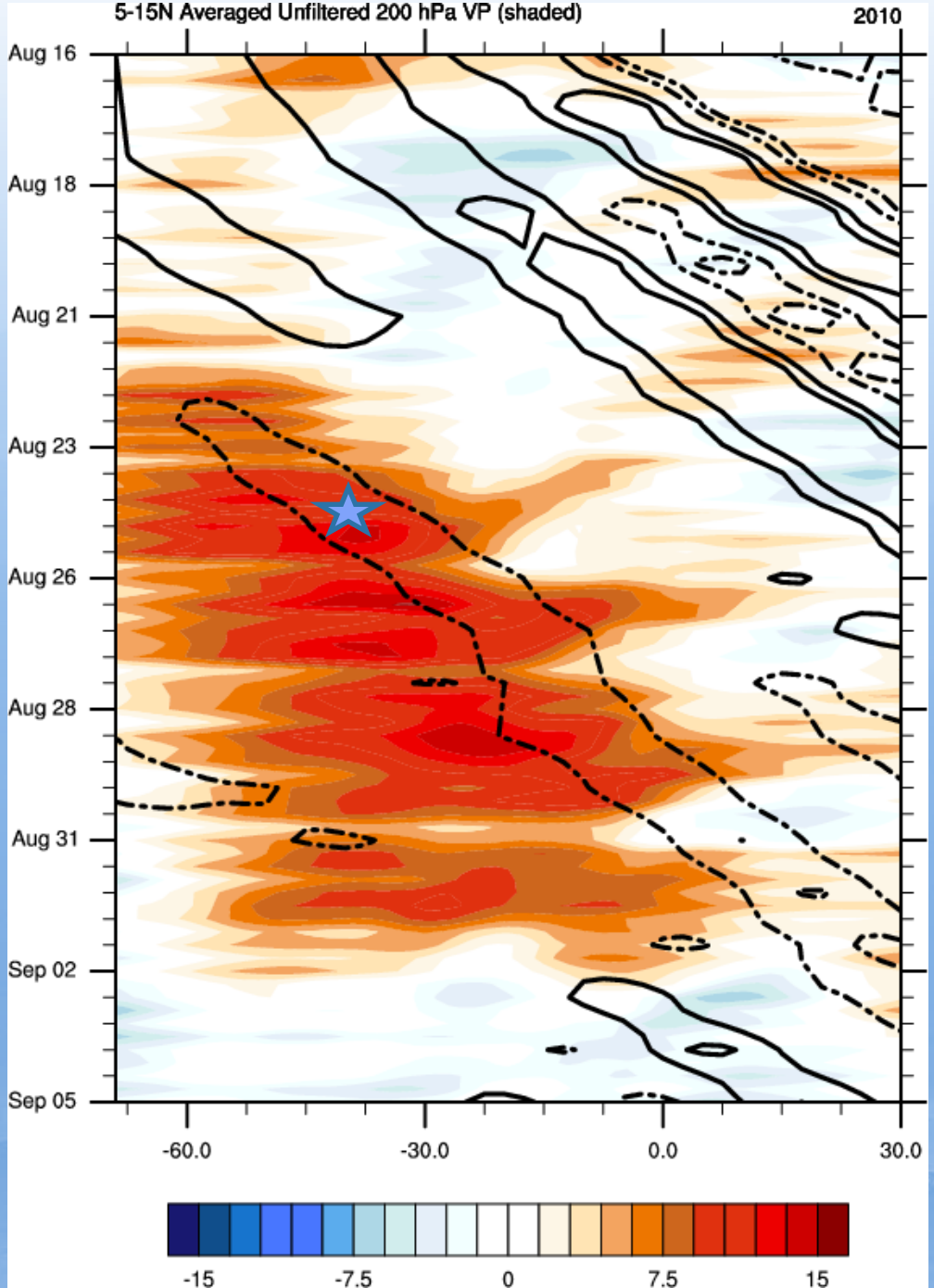
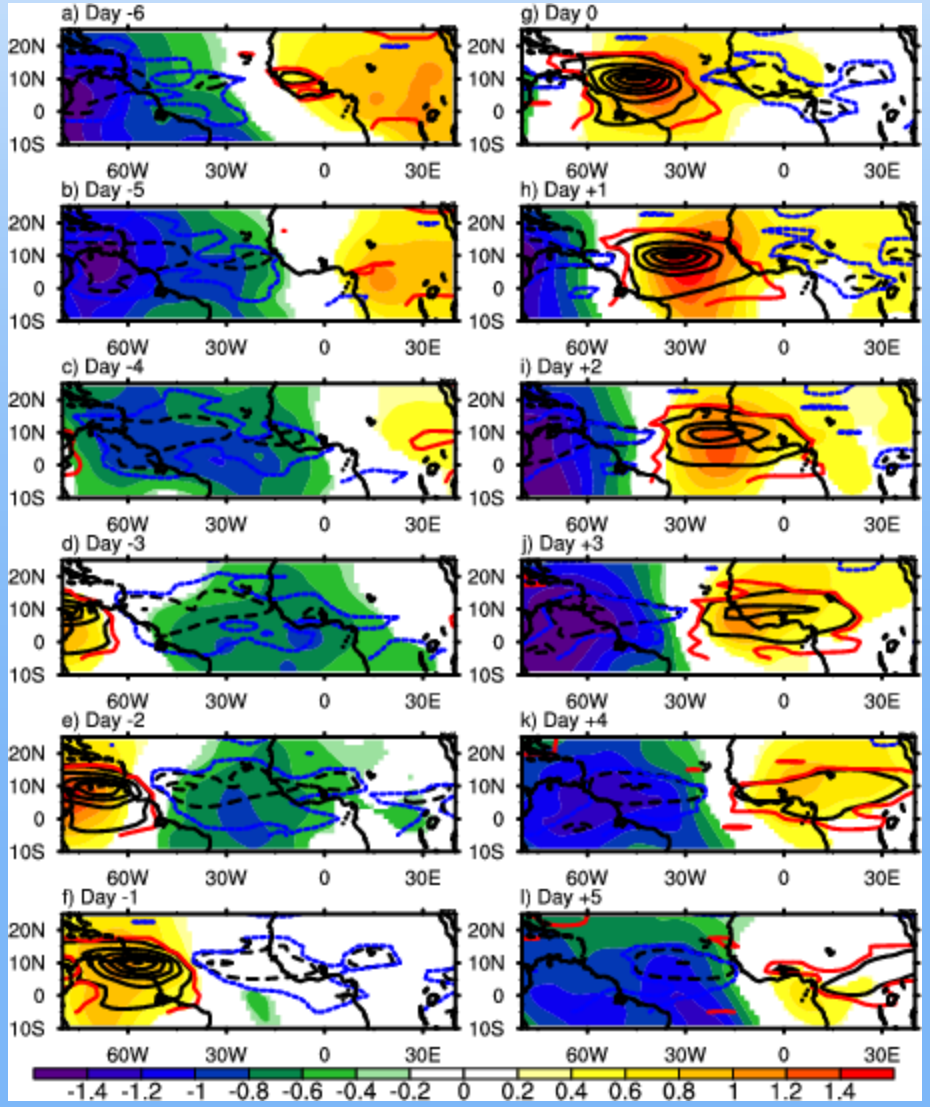
- Location of Danielle when the hurricane experienced a brief weakening



Composite of 200 hPa Velocity Potential Anomalies for a convectively-suppressed phase Kelvin wave index over the MDR

- 119 JAS (1989-2009) Kelvin waves
- +1.5 STDs at 7.5°N, 45°W (Day 0)



Concluding Remarks

•CCKWs are important!

1) Modulate tropical cyclogenesis over the MDR
2) Suppressed phase can weaken developed TCs

•CCKWs were directly associated with the genesis of three TCs over the MDR.

-Collin, Julia, and Lisa

-The formation of the Atlantic ITCZ before the genesis of Danielle was associated with a series of CCKWs.

-Danielle, Earl, Fiona pre-cursor AEWs were enhanced by CCKWs

•A strong suppressed phase of a CCKW interacted with Hurricane Danielle during the time of unexpected weakening.

-Inhibited convection over the southern half of Danielle

-Weakened the moist inflow of the TC

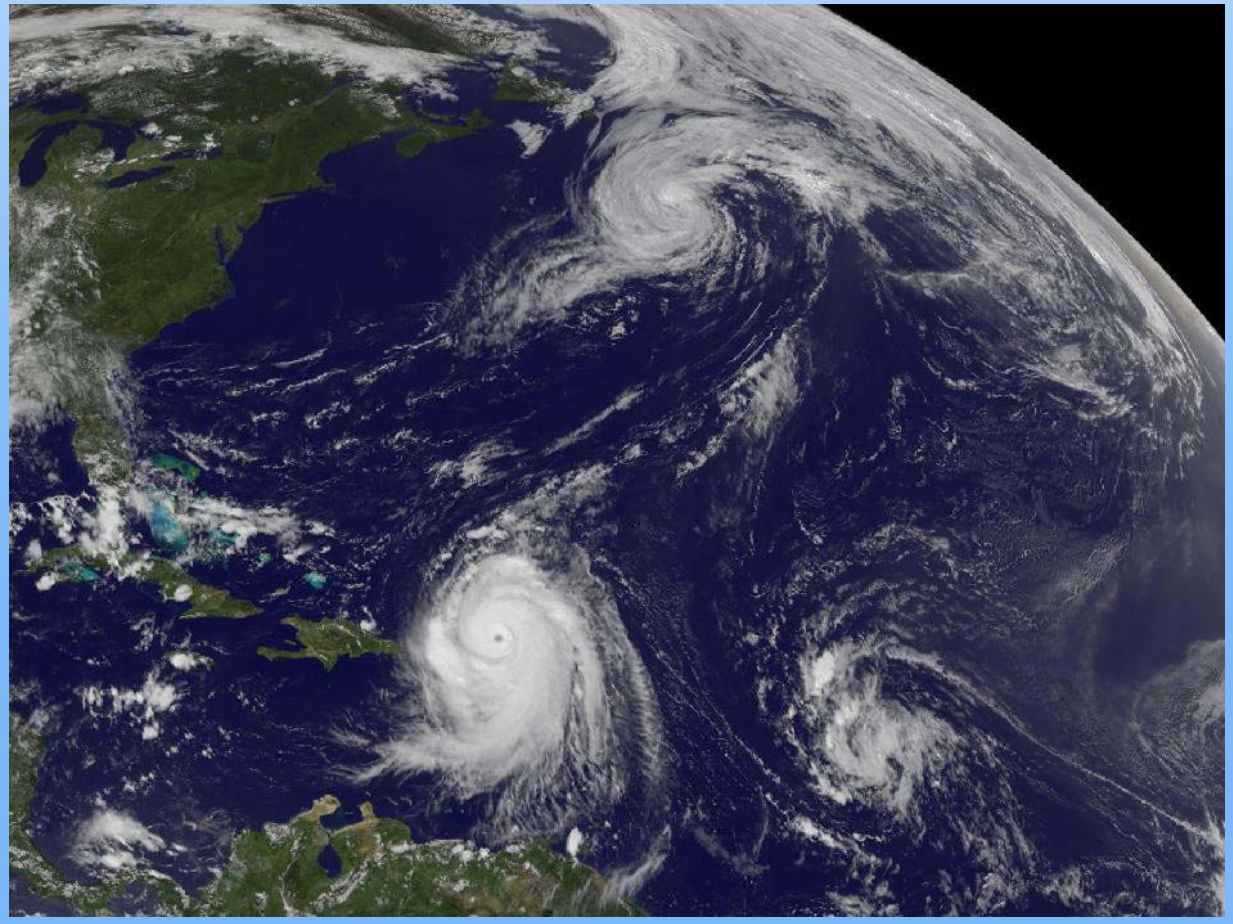
-Large-scale subsidence

Supplemental FIgures

Synoptic Evolution of Danielle-Earl

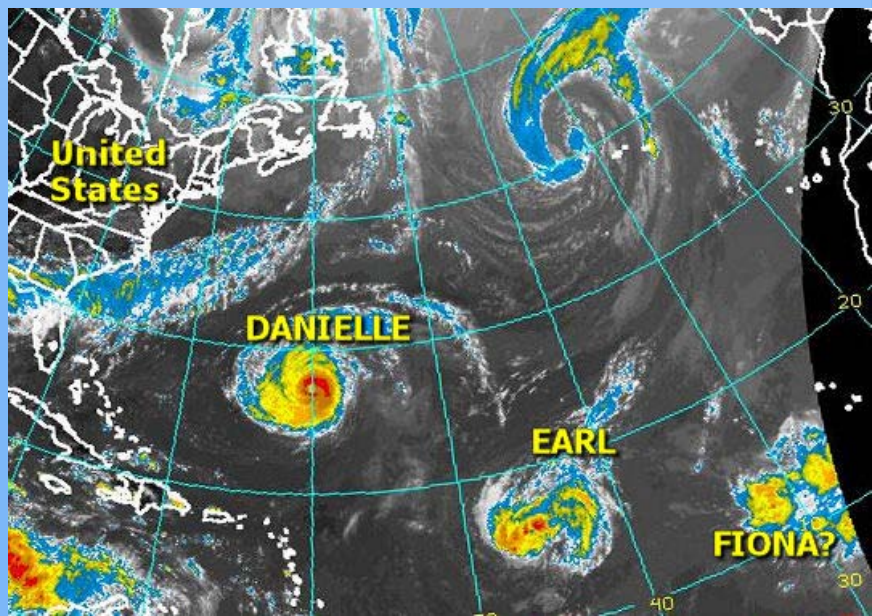
"The origin of Danielle was complex."

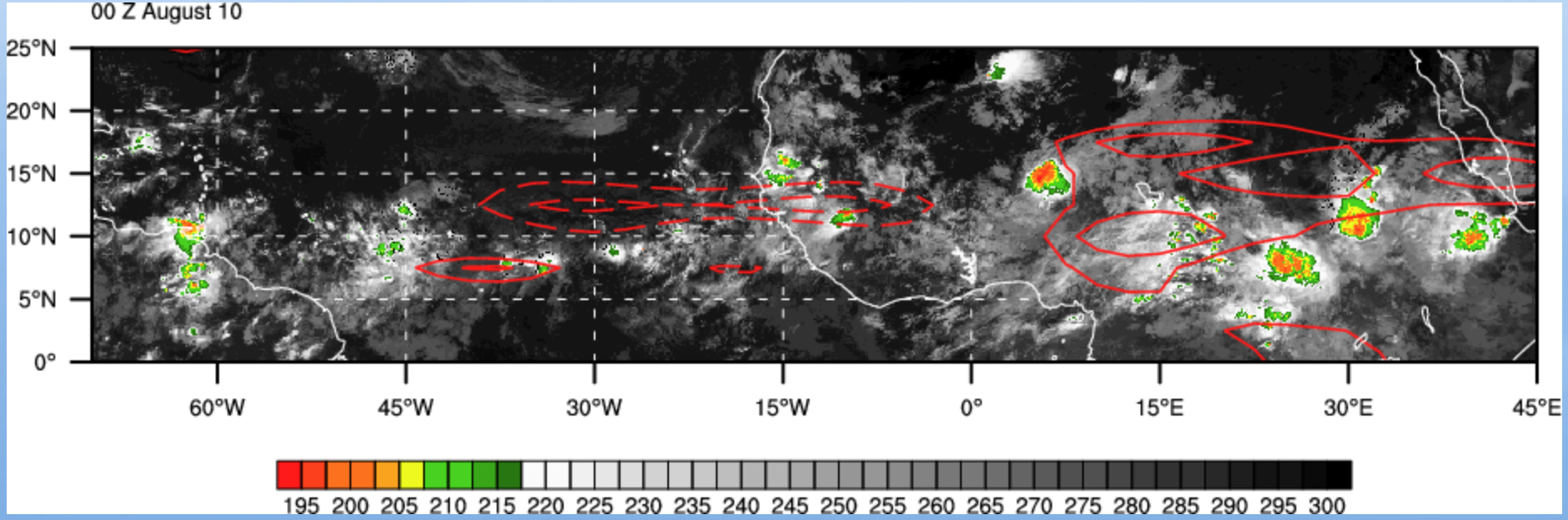
-National Hurricane Center, 15 December 2010



Key Sentences from NHC Discussion

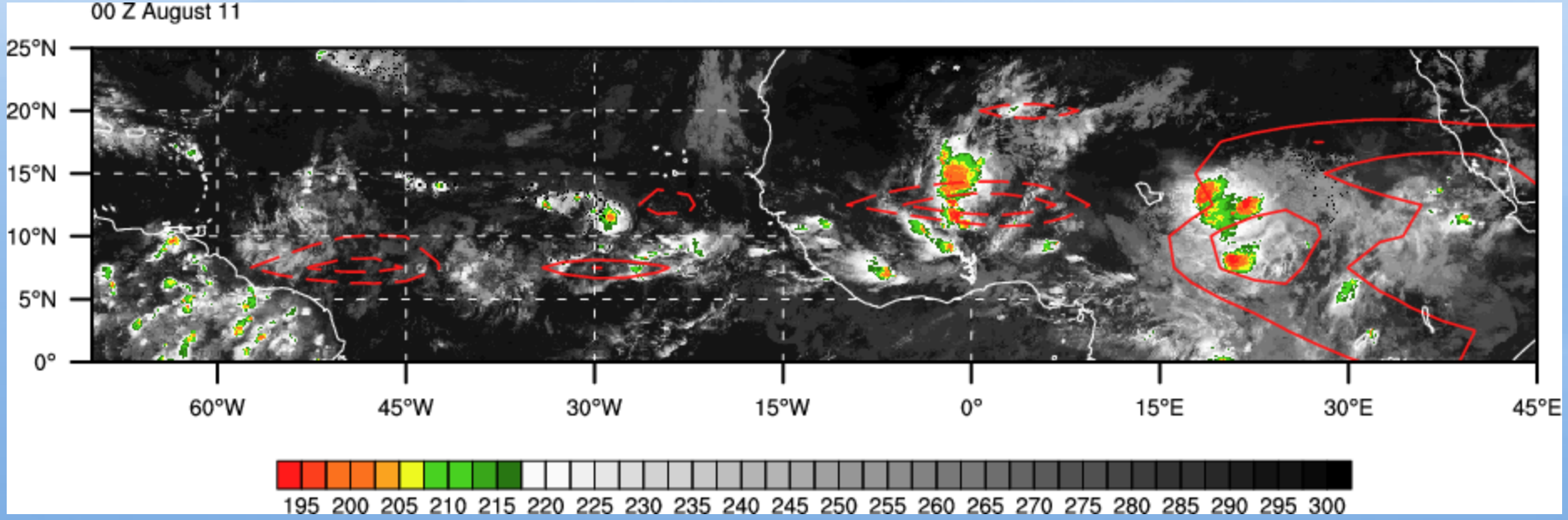
- "…an active Intertropical Convergence Zone (ITCZ) was detected a few hundred nautical miles south-southwest of the Cape Verde Islands."
- "…a smaller-scale circulation formed along the southwestern end of the larger gyre."
- "Embedded within strong low-level westerly flow…"





Key:

- **Unfiltered NASA's merged IR product (Shaded)**
- **Kelvin filtered OLR (Contours)**
- **Negative (Positive) Kelvin filtered OLR anomalies are within the solid (dashed) red line**



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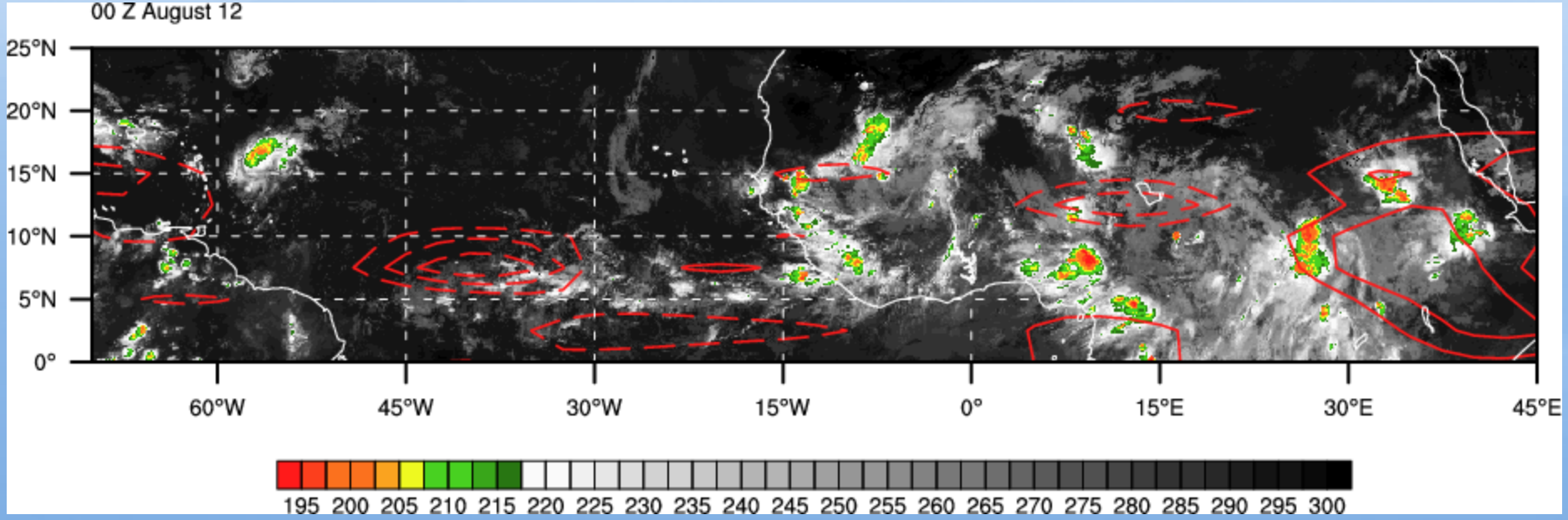

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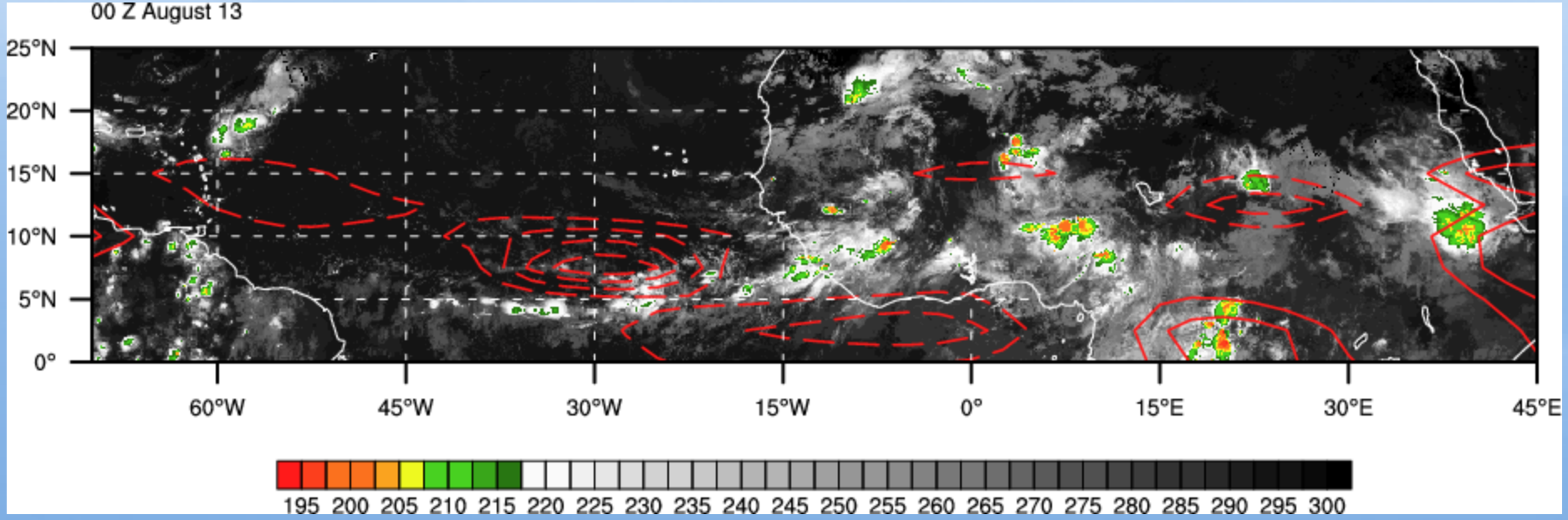

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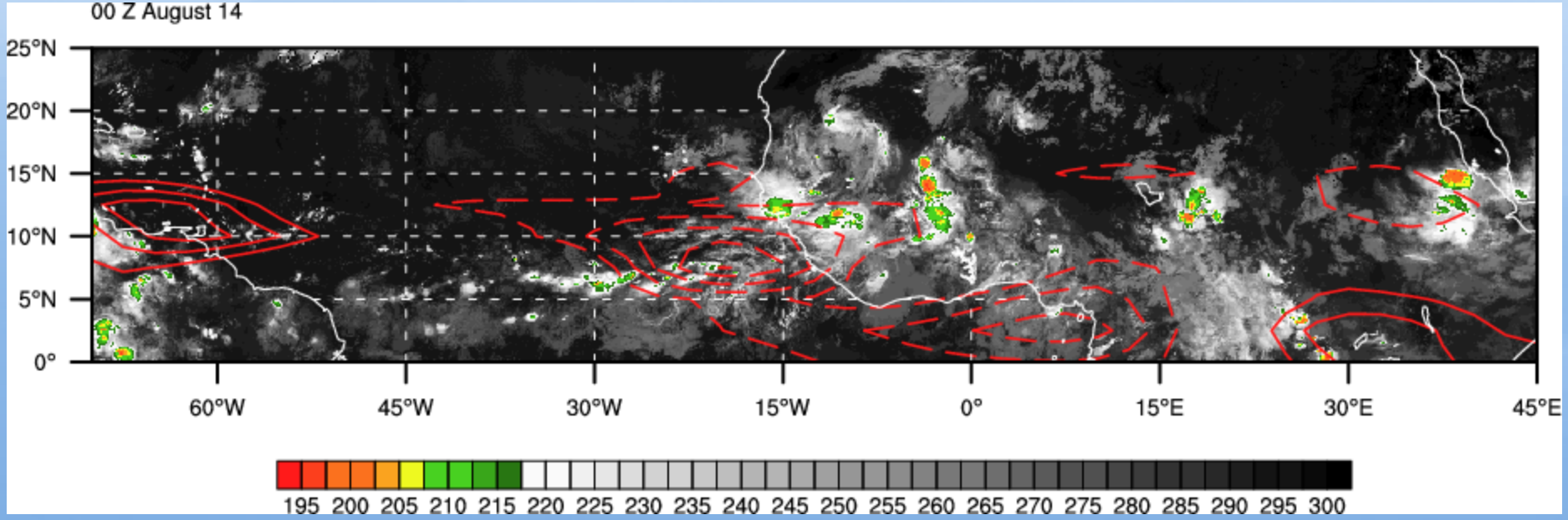

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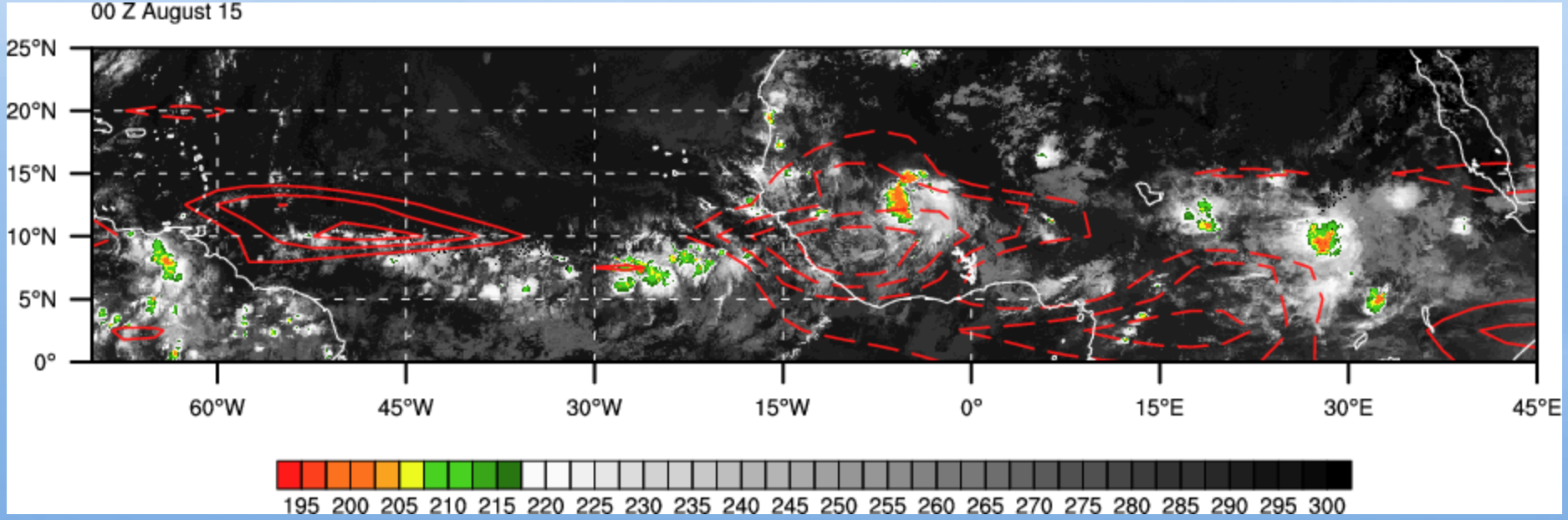

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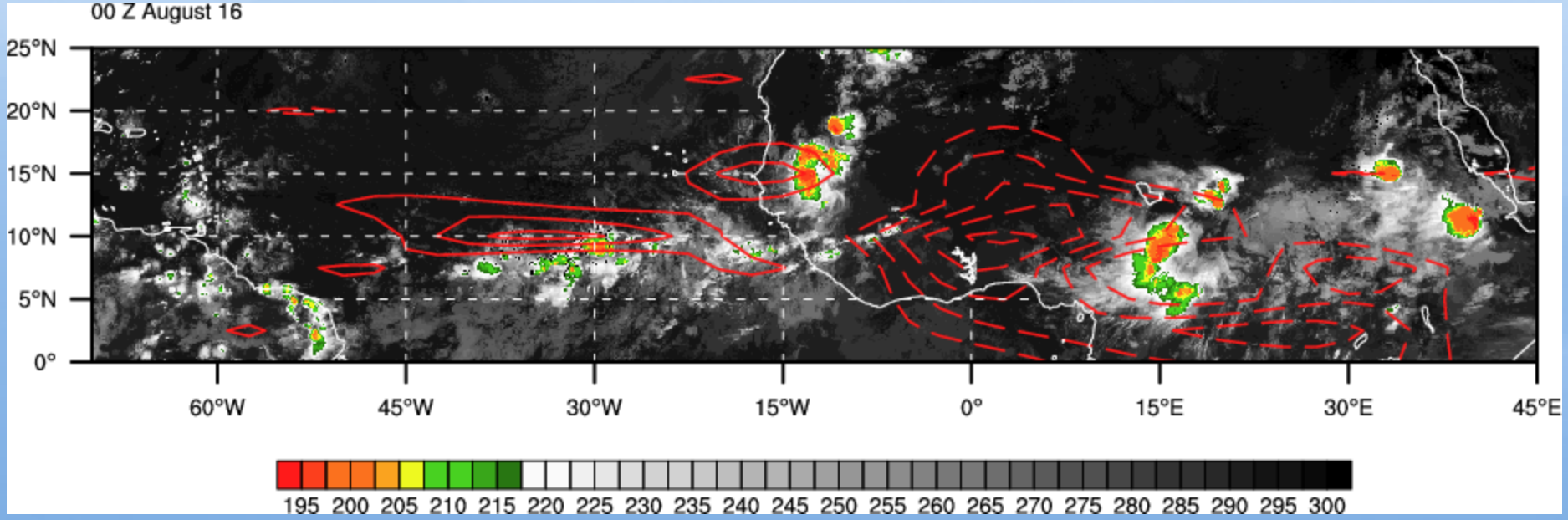

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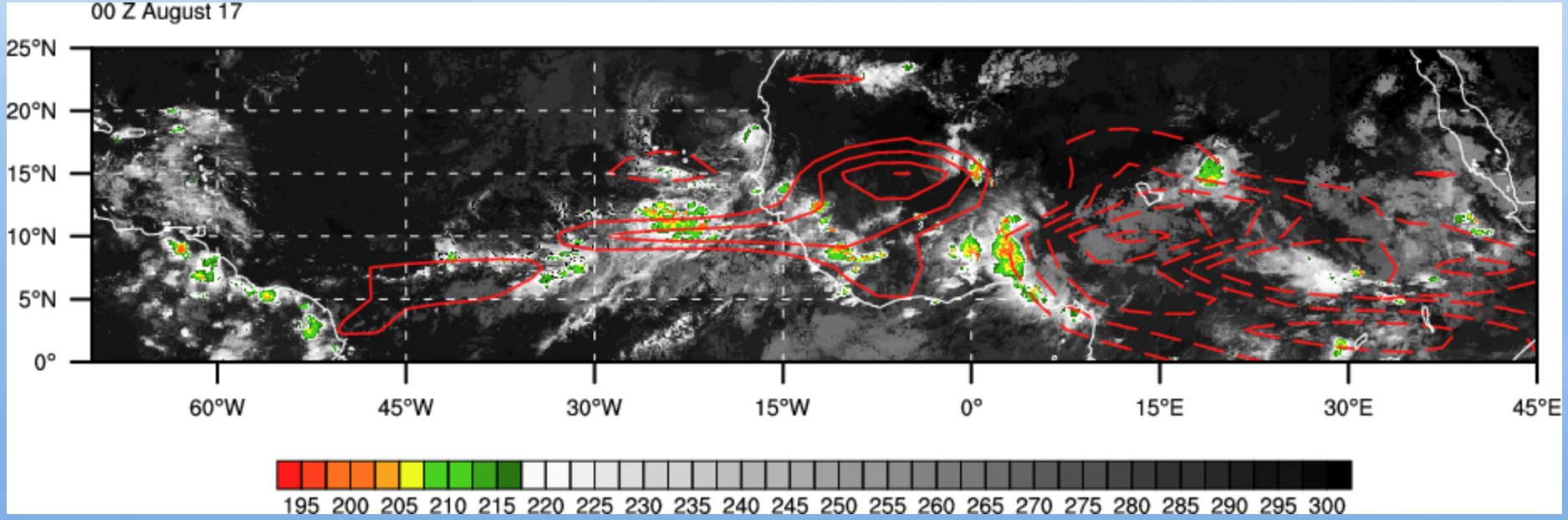

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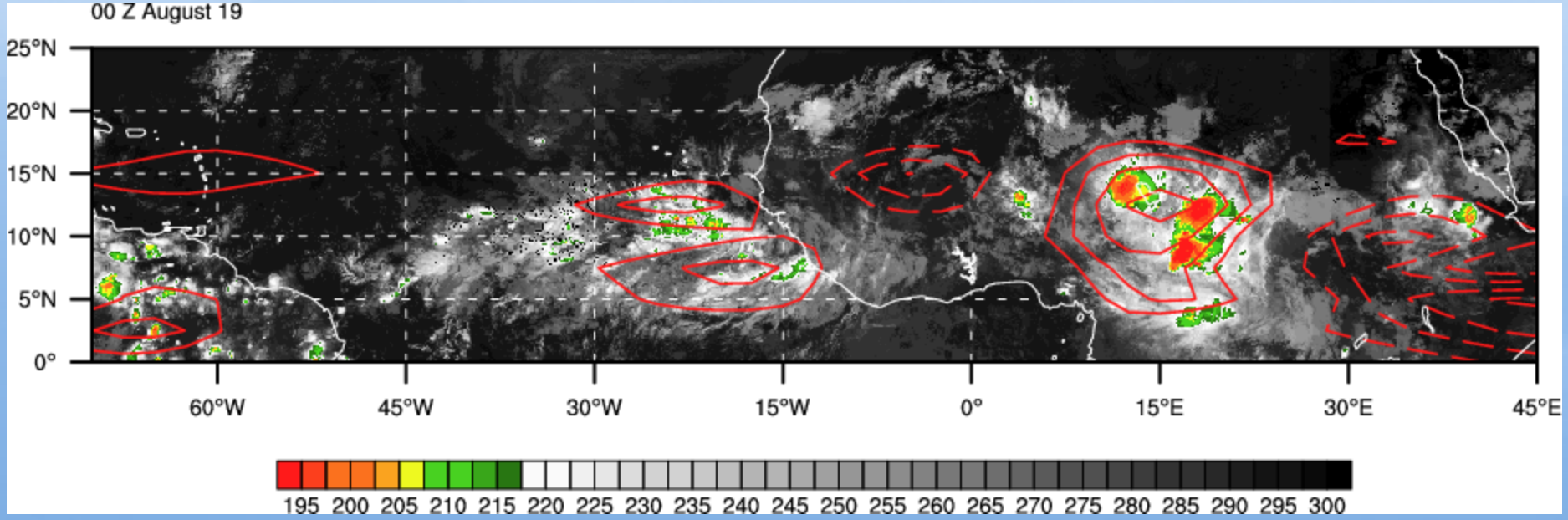

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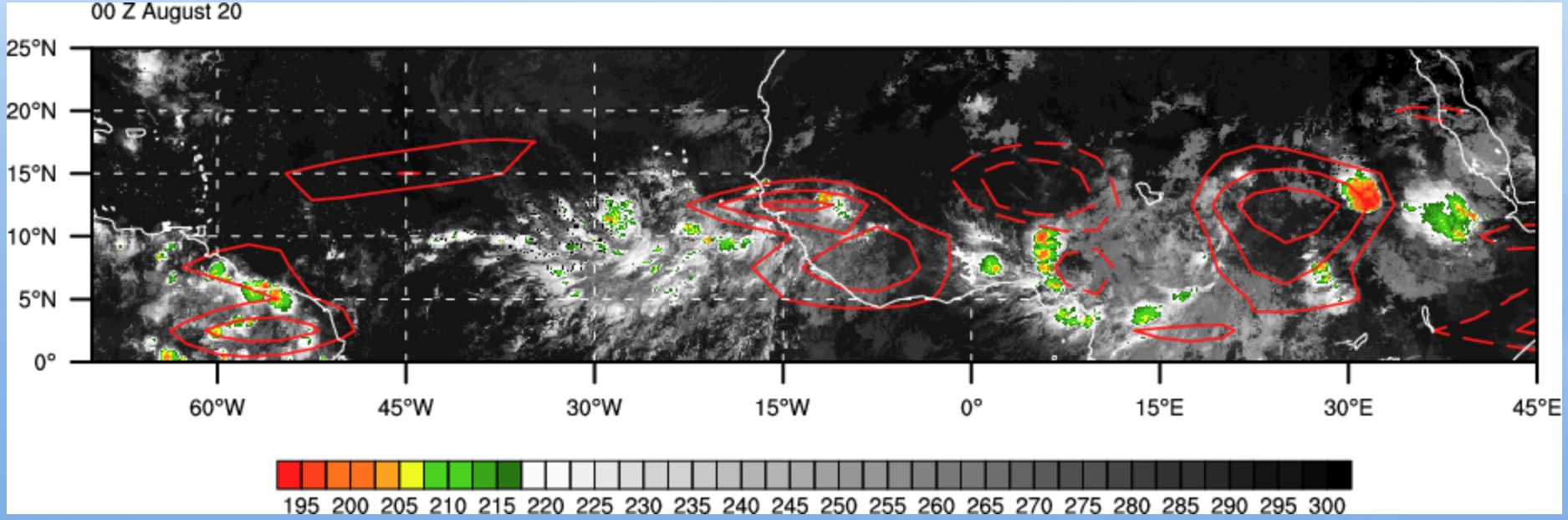

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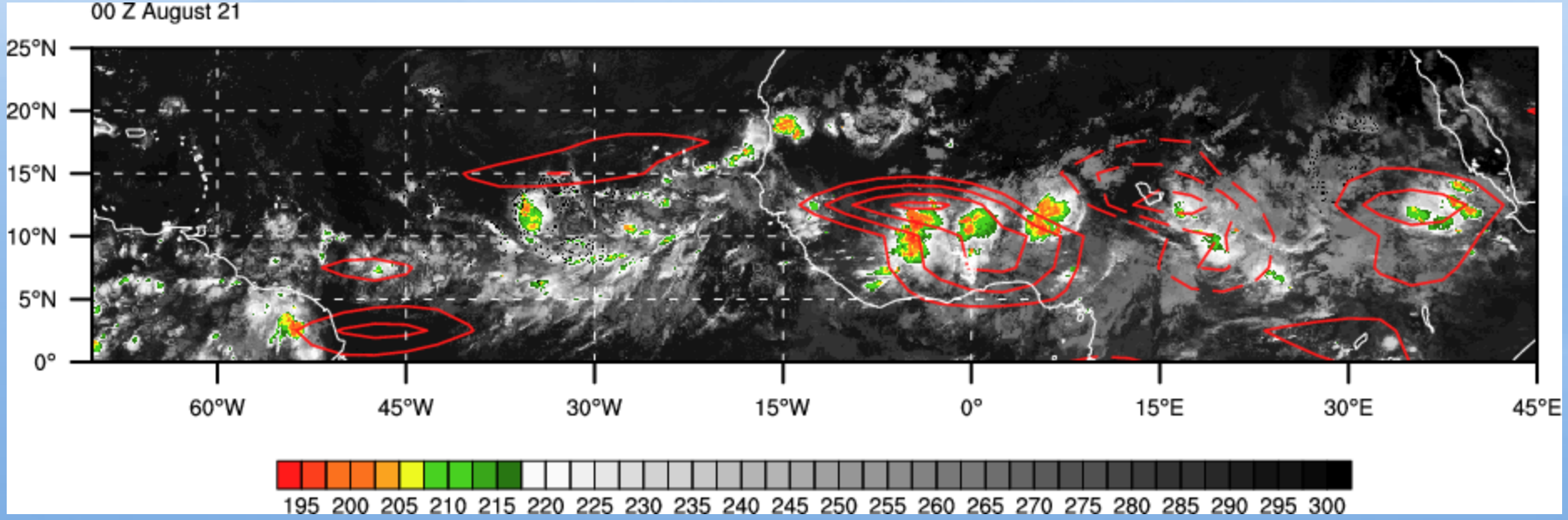

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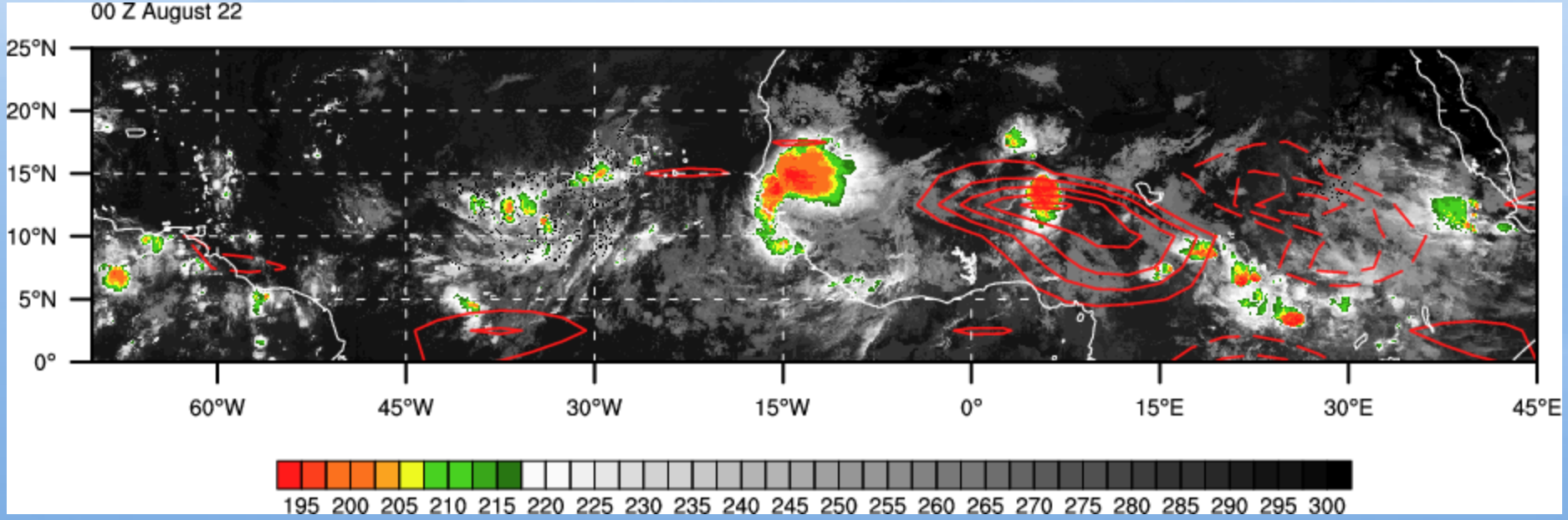

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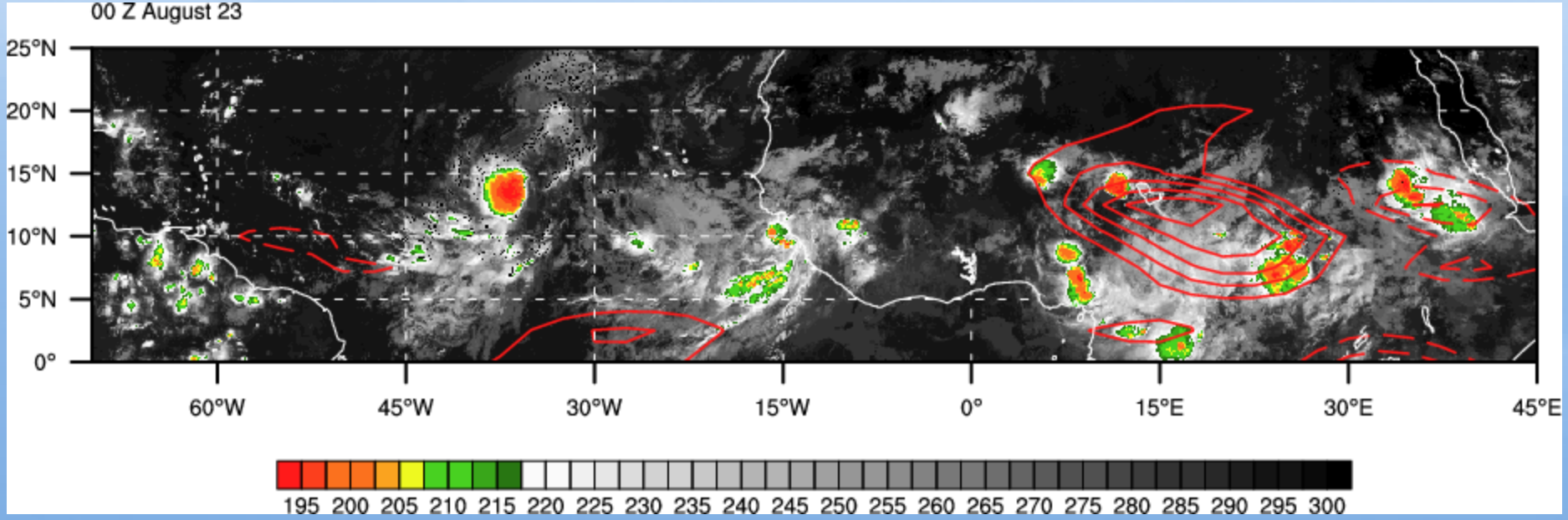
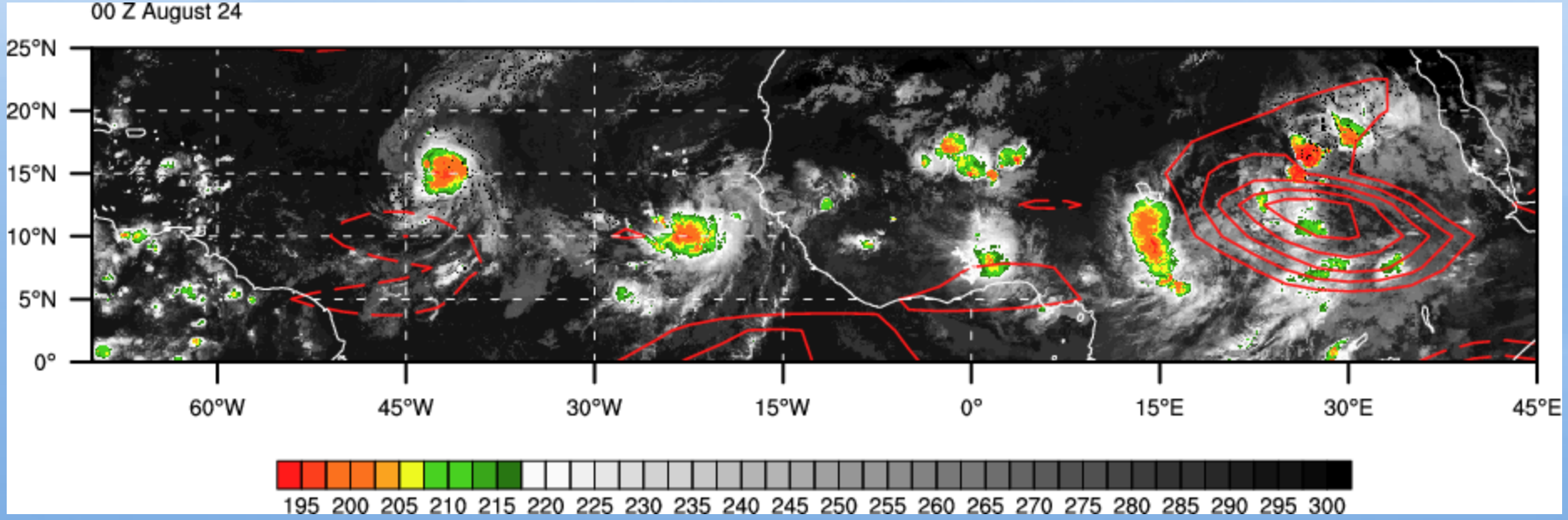


Key:

- **Unfiltered NASA's merged IR product (Shaded)**
- **Kelvin filtered OLR (Contours)**
- **Negative (Positive) Kelvin filtered OLR anomalies are within the solid (dashed) red line**



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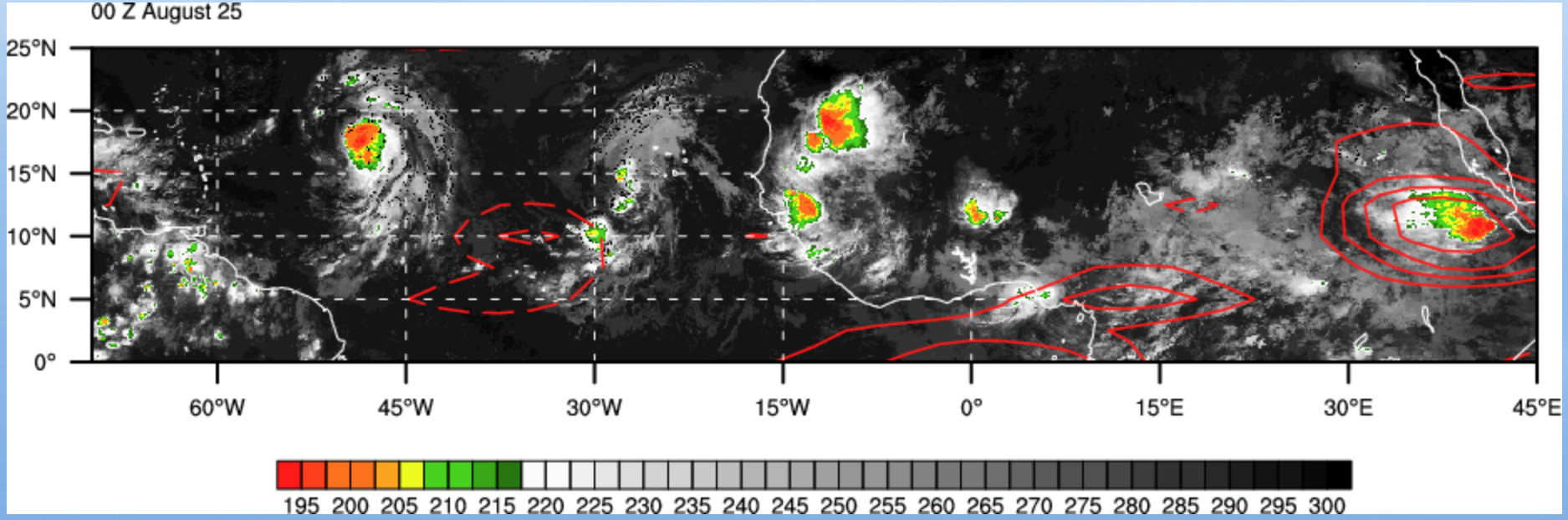

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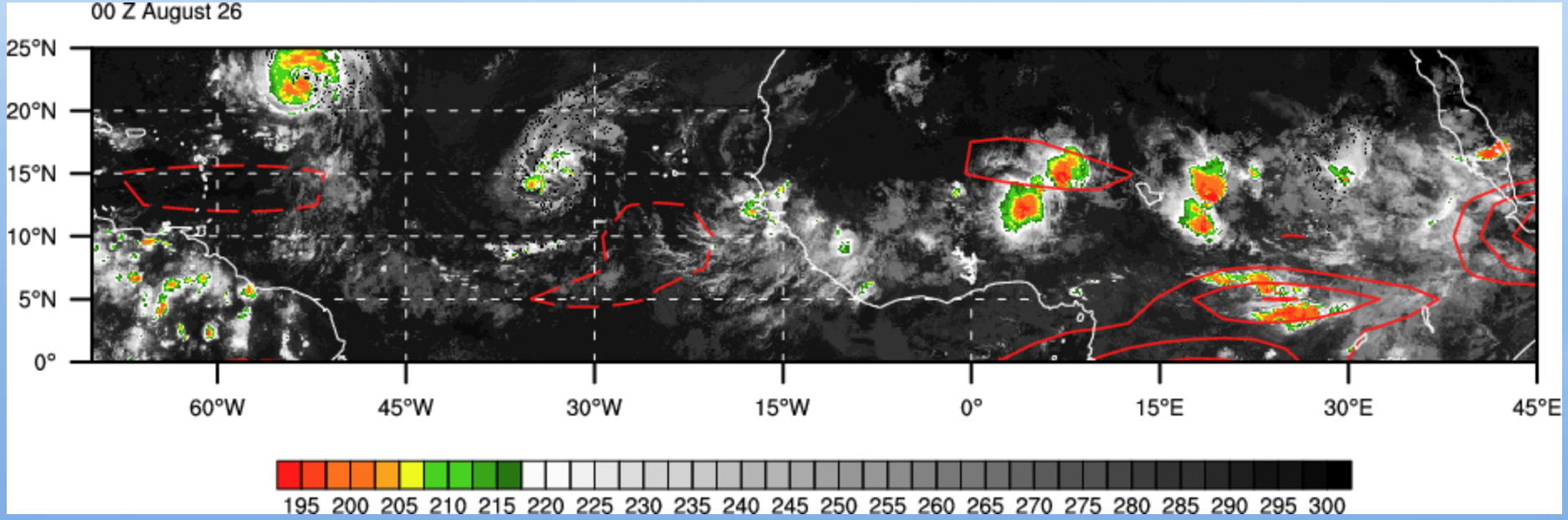

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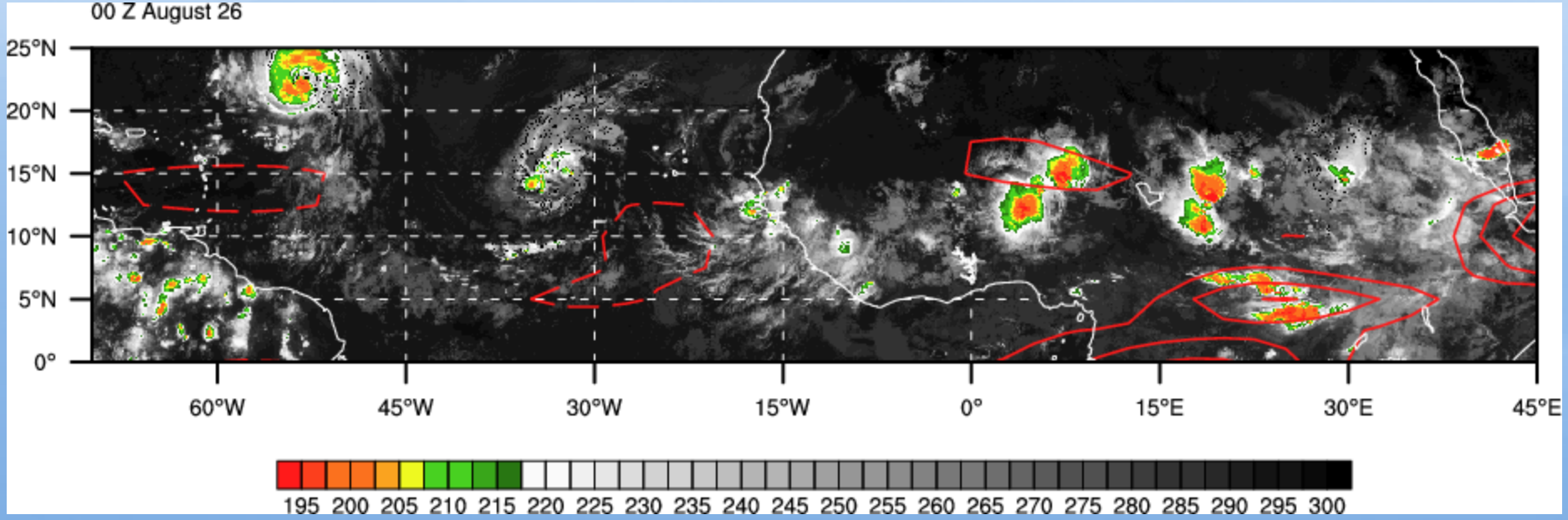

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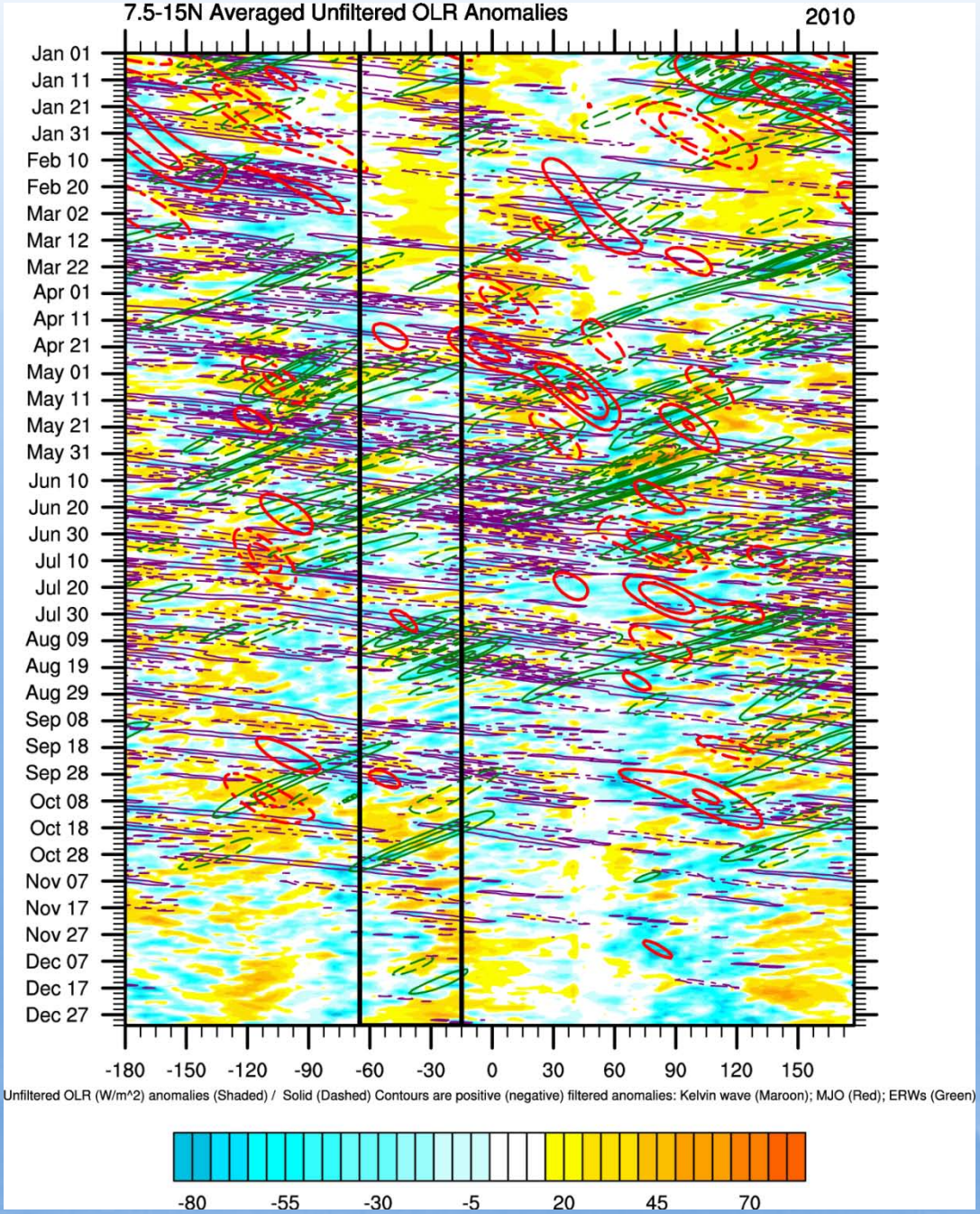
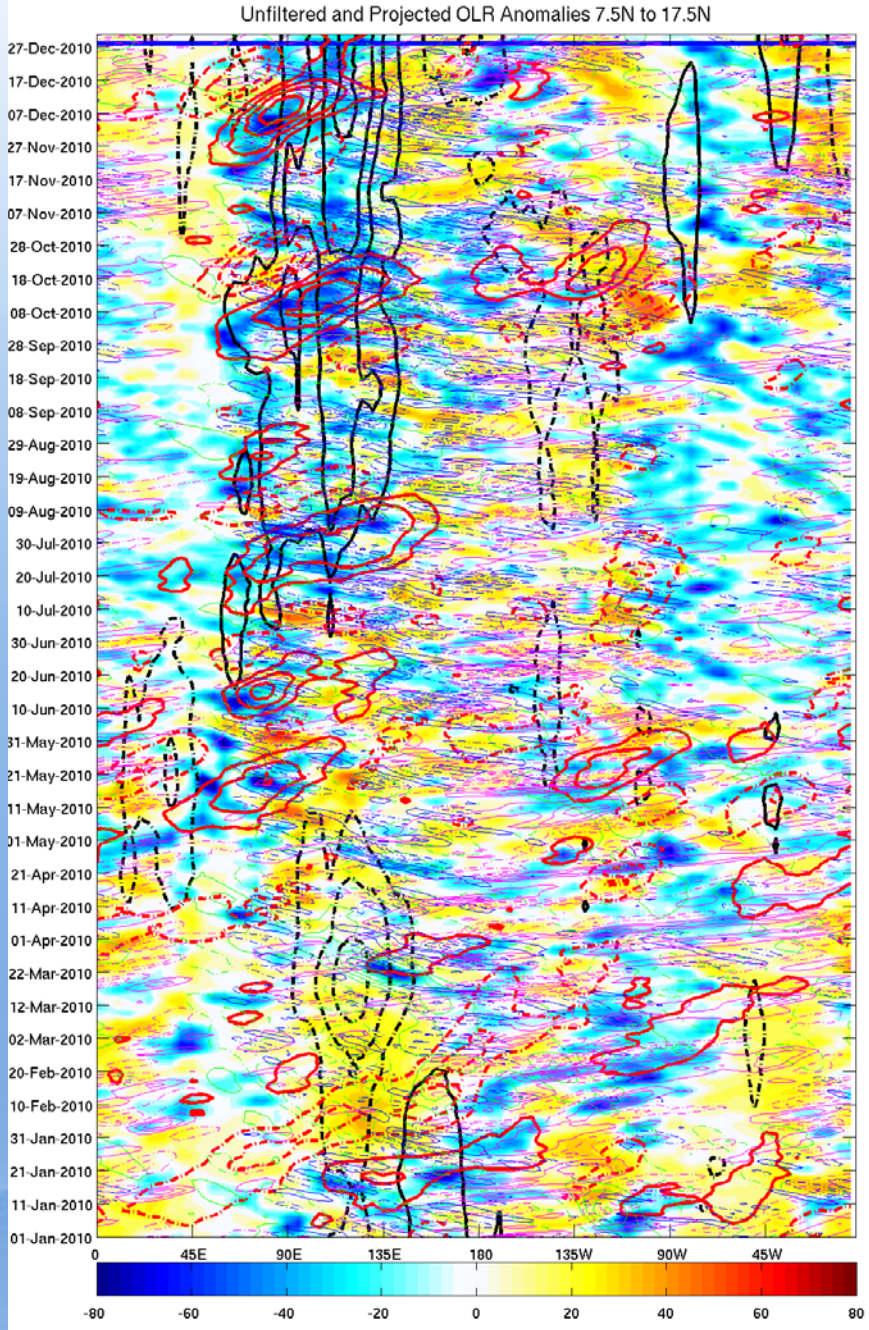
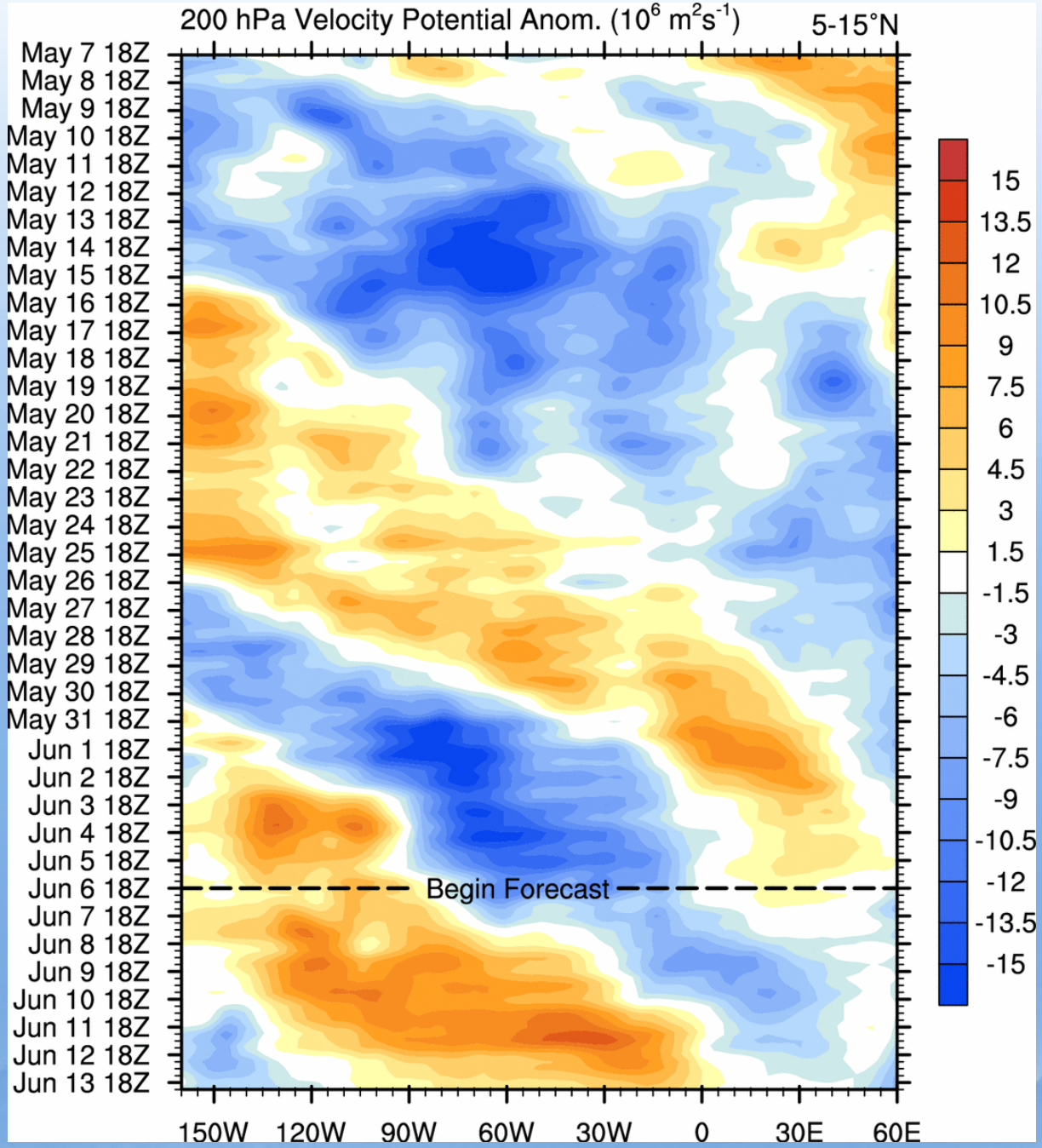

7.5-15N Averaged Unfiltered OLR Anomalies
2010
Jan 01
Jan 11
Jan 21
Jan 31
Feb 10
Feb 20
Mar 02
Mar 12
Mar 22
Apr 01
Apr 11
Apr 21
May 01
May 11
May 21
May 31
Jun 10
Jun 20
Jun 30
Jul 10
Jul 20
Jul 30
Aug 09
Aug 19
Aug 29
Sep 08
Sep 18
Sep 28
Oct 08
Oct 18
Oct 28
Nov 07
Nov 17
Nov 27
Dec 07
Dec 17
Dec 27
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150
Unfiltered OLR (W/m^2) anomalies (Shaded) / Solid (Dashed) Contours are positive (negative) filtered anomalies: Kelvin wave (Maroon); MJO (Red); ERWs (Green)
-80 -55 -30 -5 20 45 70


Unfiltered and Projected OLR Anomalies 7.5N to 17.5N
27-Dec-2010
17-Dec-2010
07-Dec-2010
27-Nov-2010
17-Nov-2010
07-Nov-2010
28-Oct-2010
18-Oct-2010
08-Oct-2010
28-Sep-2010
18-Sep-2010
08-Sep-2010
29-Aug-2010
19-Aug-2010
09-Aug-2010
30-Jul-2010
20-Jul-2010
10-Jul-2010
30-Jun-2010
20-Jun-2010
10-Jun-2010
31-May-2010
21-May-2010
11-May-2010
01-May-2010
21-Apr-2010
11-Apr-2010
01-Apr-2010
22-Mar-2010
12-Mar-2010
02-Mar-2010
20-Feb-2010
10-Feb-2010
31-Jan-2010
21-Jan-2010
11-Jan-2010
01-Jan-2010
0
45E
90E
135E
180
135W
90W
45W
-80
-60
-40
-20
0
20
40
60
80


200 hPa Velocity Potential Anom. (10^6 m^2s^{-1})
5-15°N
May 7 18Z
May 8 18Z
May 9 18Z
May 10 18Z
May 11 18Z
May 12 18Z
May 13 18Z
May 14 18Z
May 15 18Z
May 16 18Z
May 17 18Z
May 18 18Z
May 19 18Z
May 20 18Z
May 21 18Z
May 22 18Z
May 23 18Z
May 24 18Z
May 25 18Z
May 26 18Z
May 27 18Z
May 28 18Z
May 29 18Z
May 30 18Z
May 31 18Z
Jun 1 18Z
Jun 2 18Z
Jun 3 18Z
Jun 4 18Z
Jun 5 18Z
Jun 6 18Z
Jun 7 18Z
Jun 8 18Z
Jun 9 18Z
Jun 10 18Z
Jun 11 18Z
Jun 12 18Z
Jun 13 18Z
Begin Forecast
150W
120W
90W
60W
30W
0
30E
60E
15
13.5
12
10.5
9
7.5
6
4.5
3
1.5
-1.5
-3
-4.5
-6
-7.5
-9
-10.5
-12
-13.5
-15