Analysis of Kelvin waves during the GRIP Field Campaign

Michael J. Ventrice
Department of Atmospheric and Environmental Science, University at Albany, Albany, NY

Chris D. Thorncroft
Department of Atmospheric and Environmental Science, University at Albany, Albany, NY

May 2012

UNIVERSITY AT ALBANY
State University of New York

This Talk

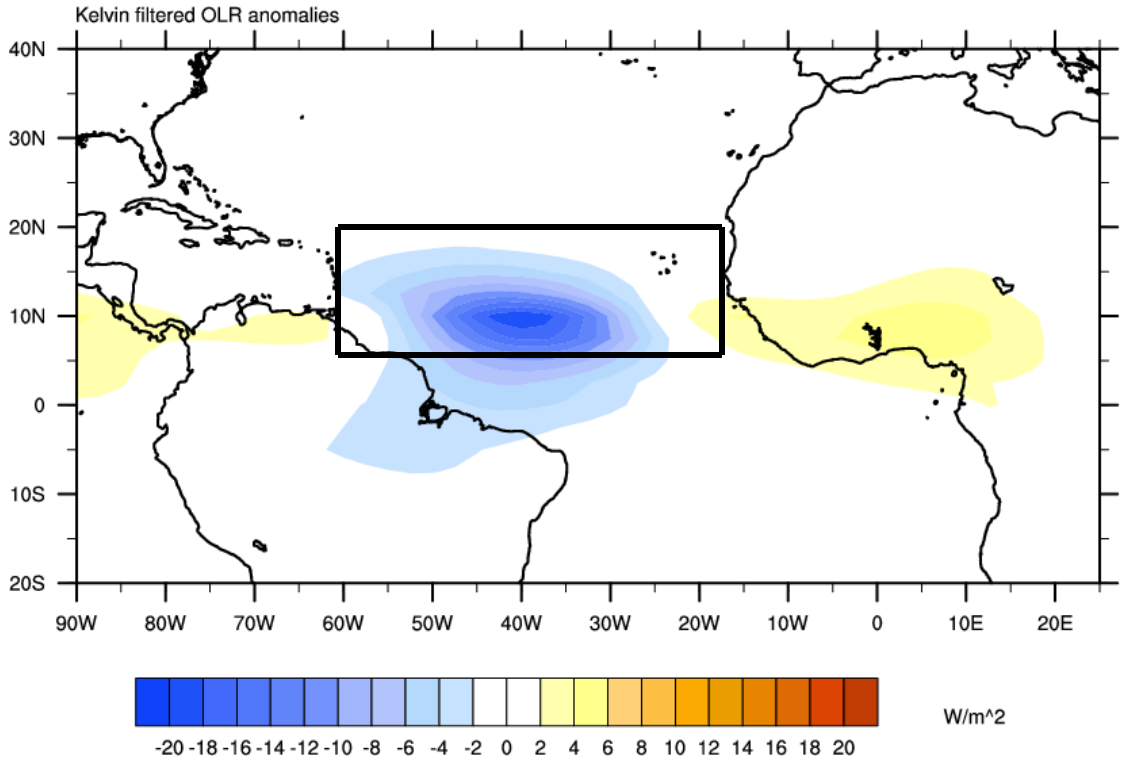
1. Background information regarding convectively-coupled atmospheric equatorial Kelvin waves (henceforth CCKWs)

2. CCKWs and Atlantic tropical cyclones during GRIP

3. Genesis of Karl

4. Intensity of Earl

5. Conclusions and Final Comments

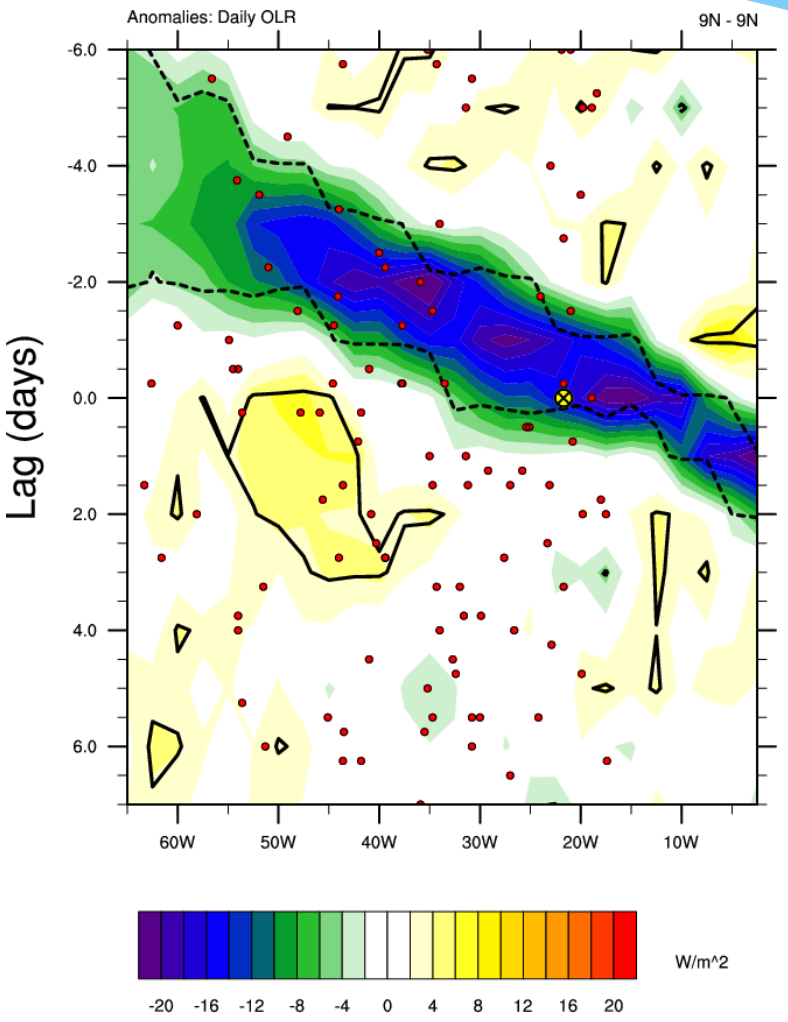


Data Sources

- ECMWF-Interim Dataset (Simmons et al. 2007)
- NOAA's Daily Average OLR Dataset (Liebmann and Smith 1996)
- TRMM 3B42 Rain Rate Product
  - Wheeler and Kiladis (1999) for Kelvin wave filtering [period of 2.5-20 days, with eastward wavenumber 1-14]
- NASA's Merged IR-dataset
- South American Sounding network

Composite Methodology

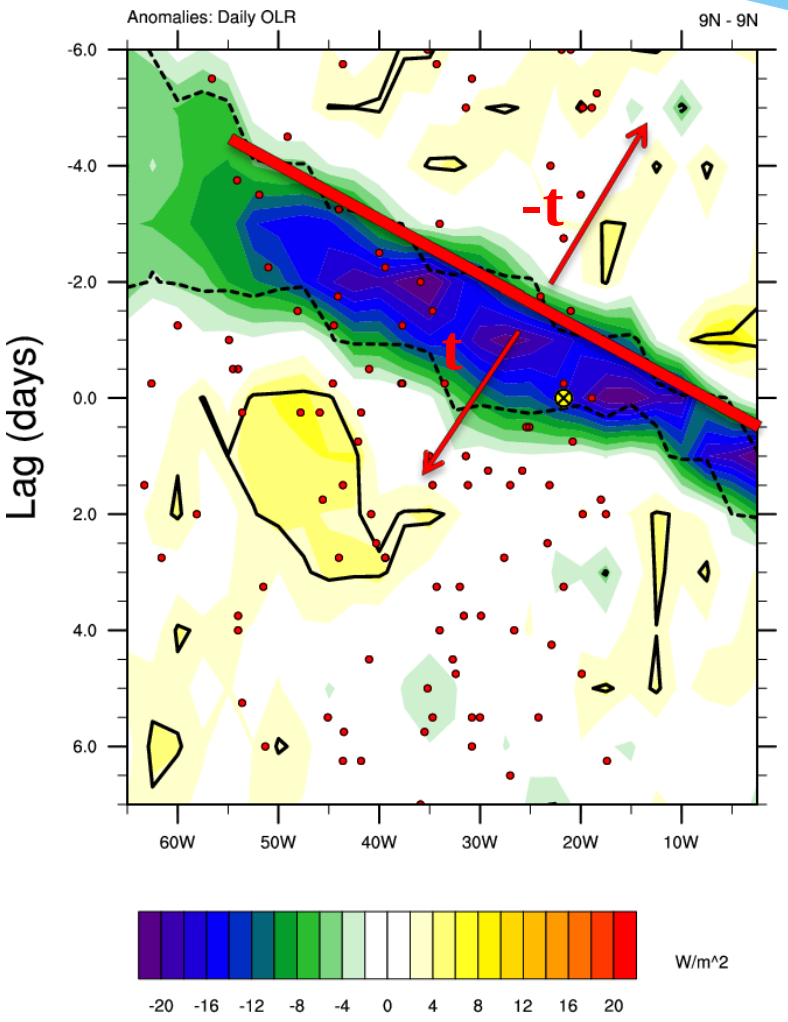
- Developed a time-series using Kelvin filtered OLR anomalies.
  - Selected dates where Kelvin filtered OLR anomaly was a minimum over a selected base point (**DAY 0**)
  - Used a daily lagged approach
  - Threshold was -1.5 standard deviations



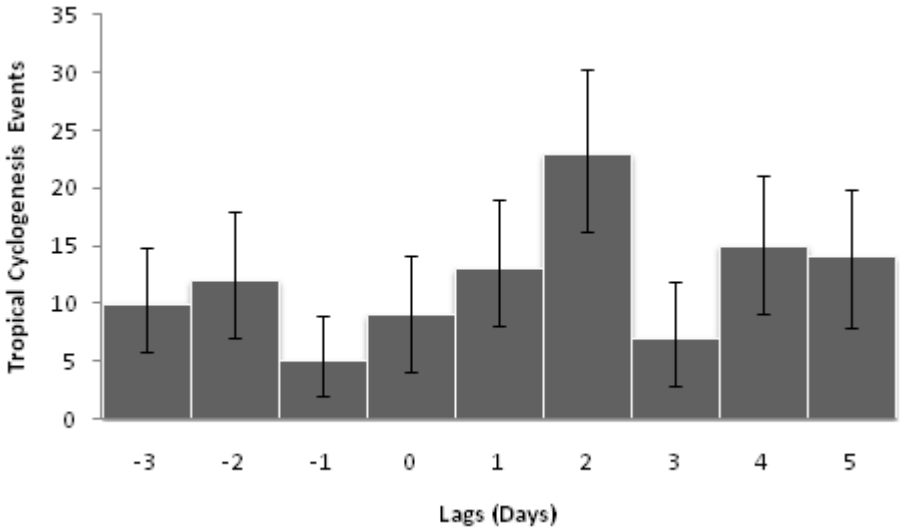
Ventrice et al. 2012a

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.



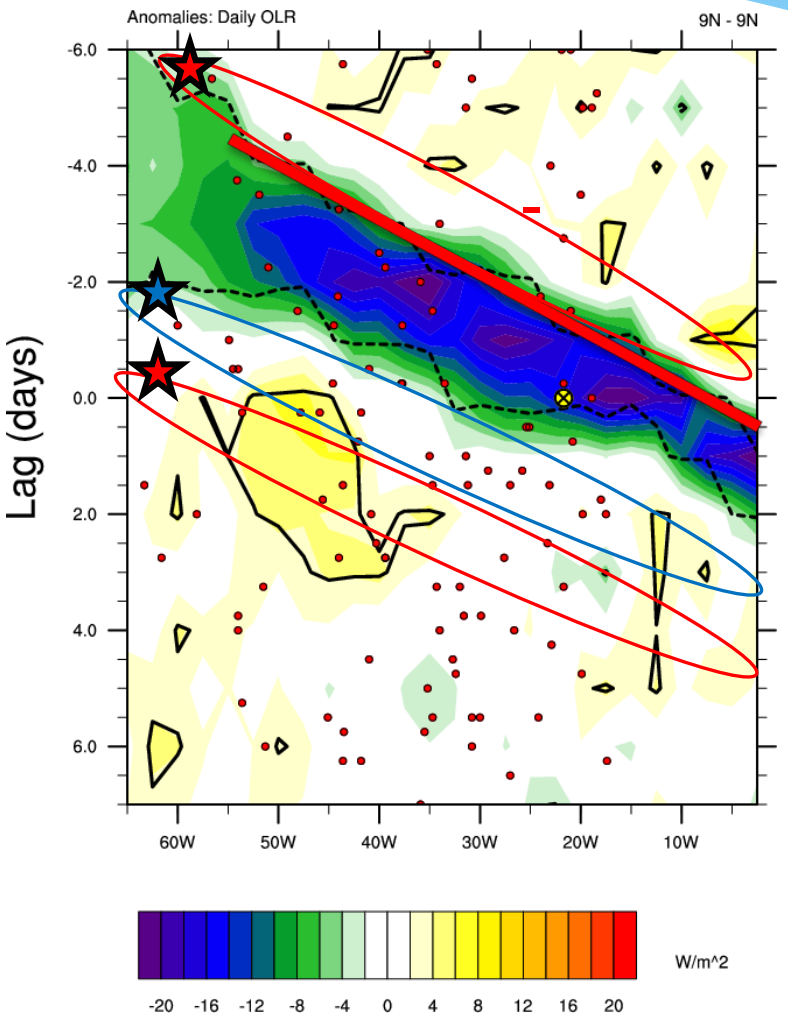
Ventrice et al. 2012a

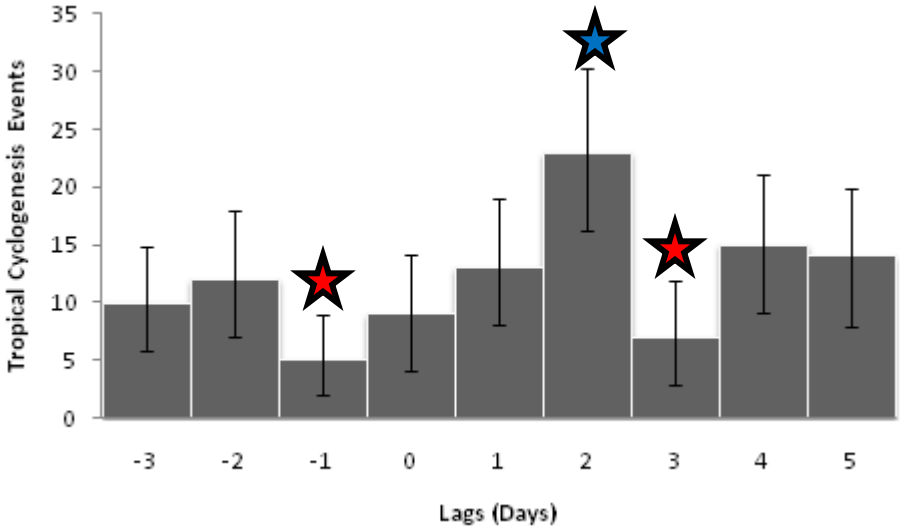


Tropical cyclogenesis events over the MDR (5-25°N, 15-65°W) relative to the CCKW during June-September 1979-2009

- 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

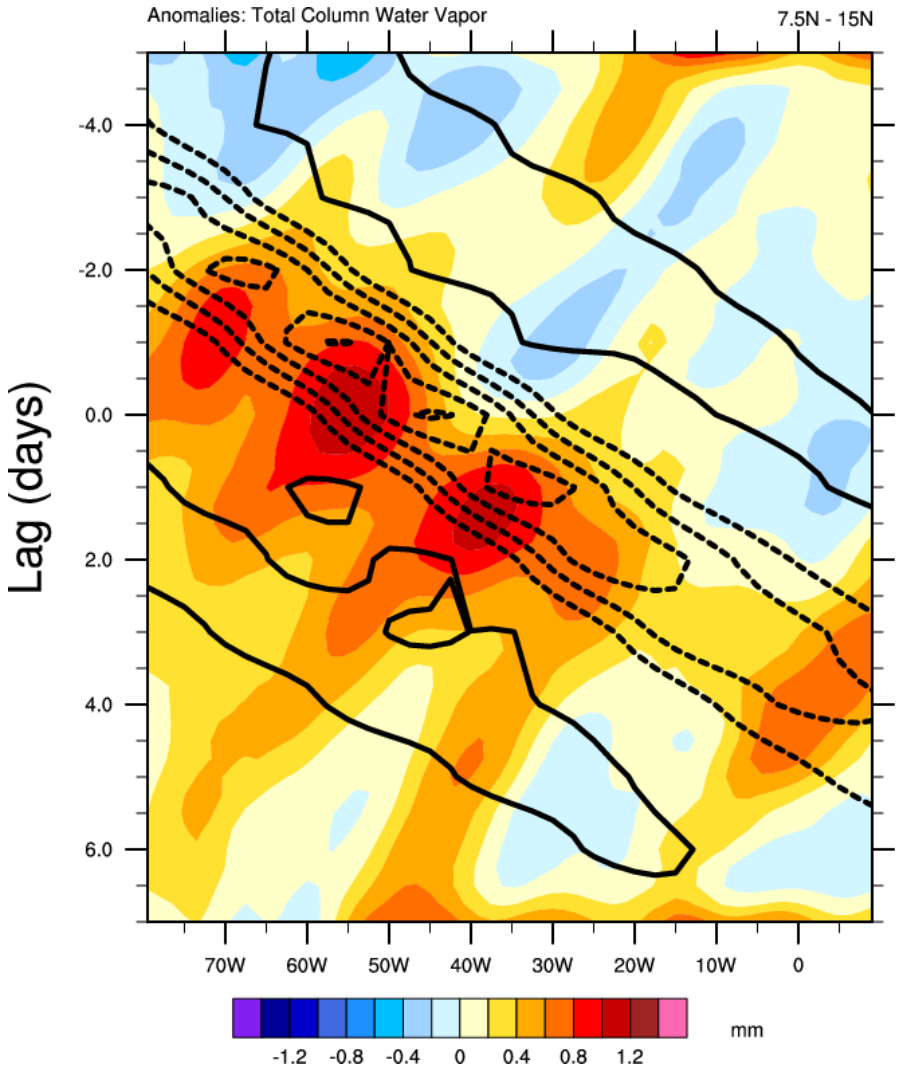




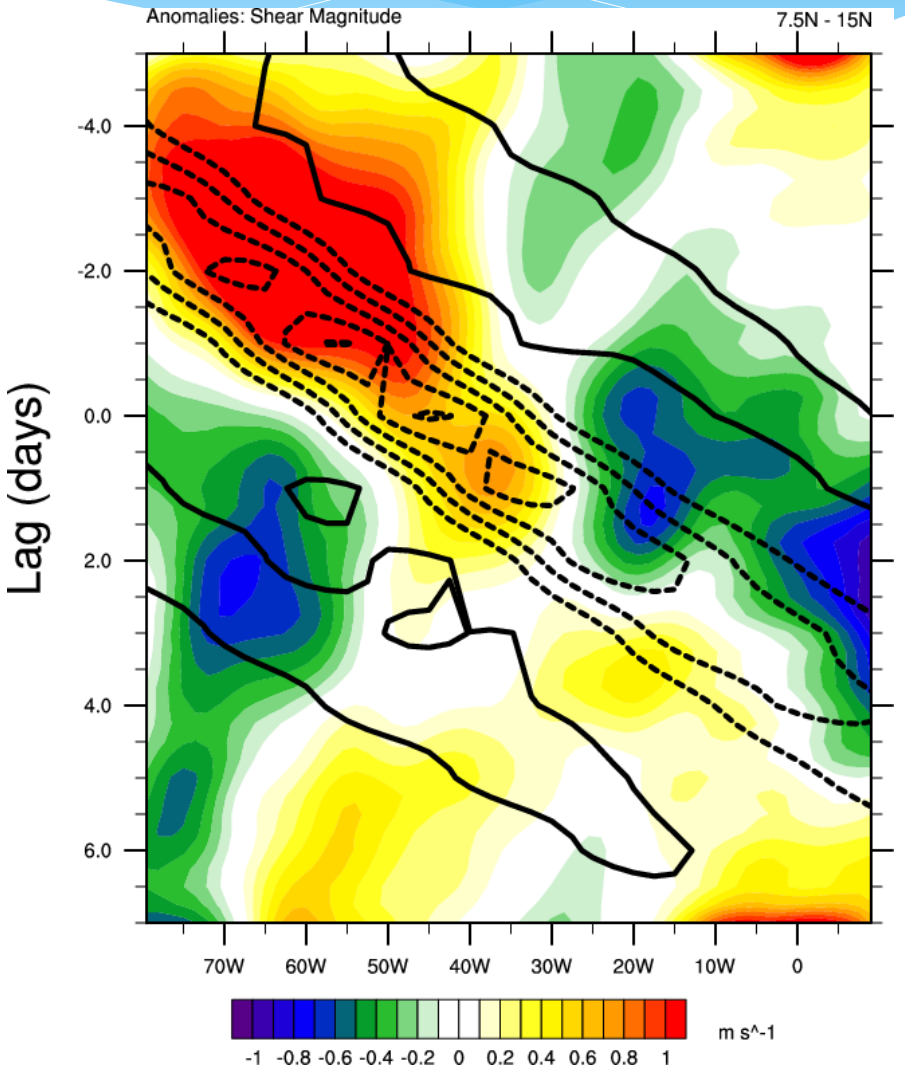
Ventrice et al. 2012a

CCKWs in the Large-Scale Synoptic Environment

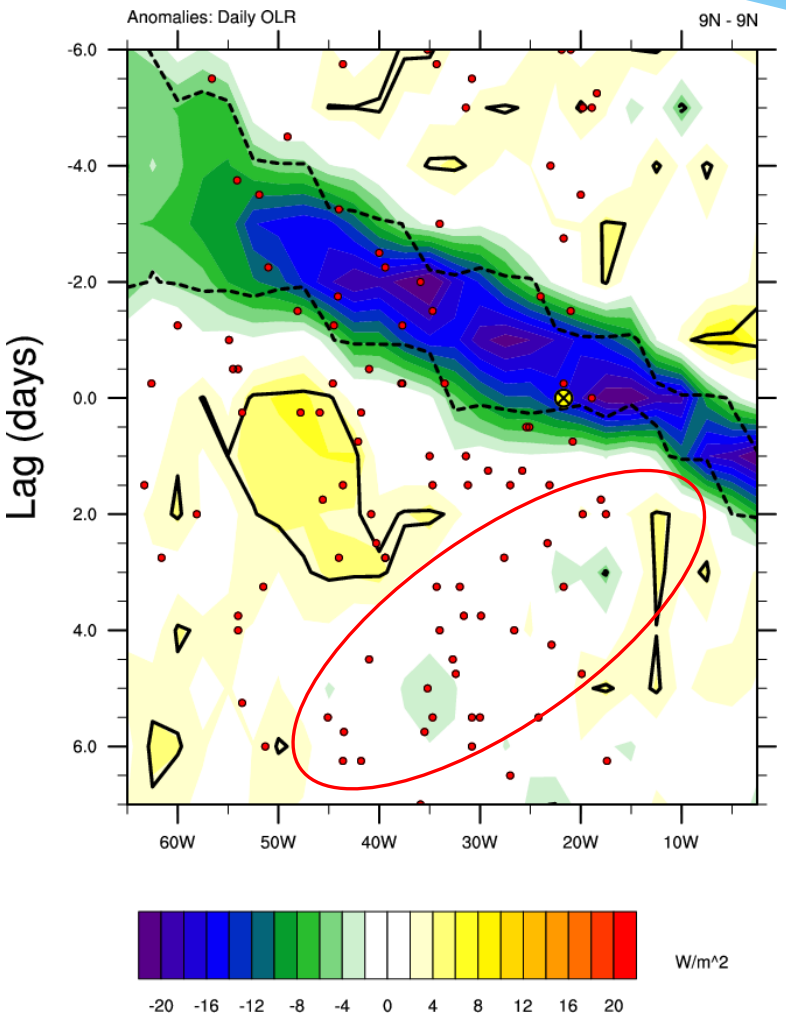
Total Column Water Vapor



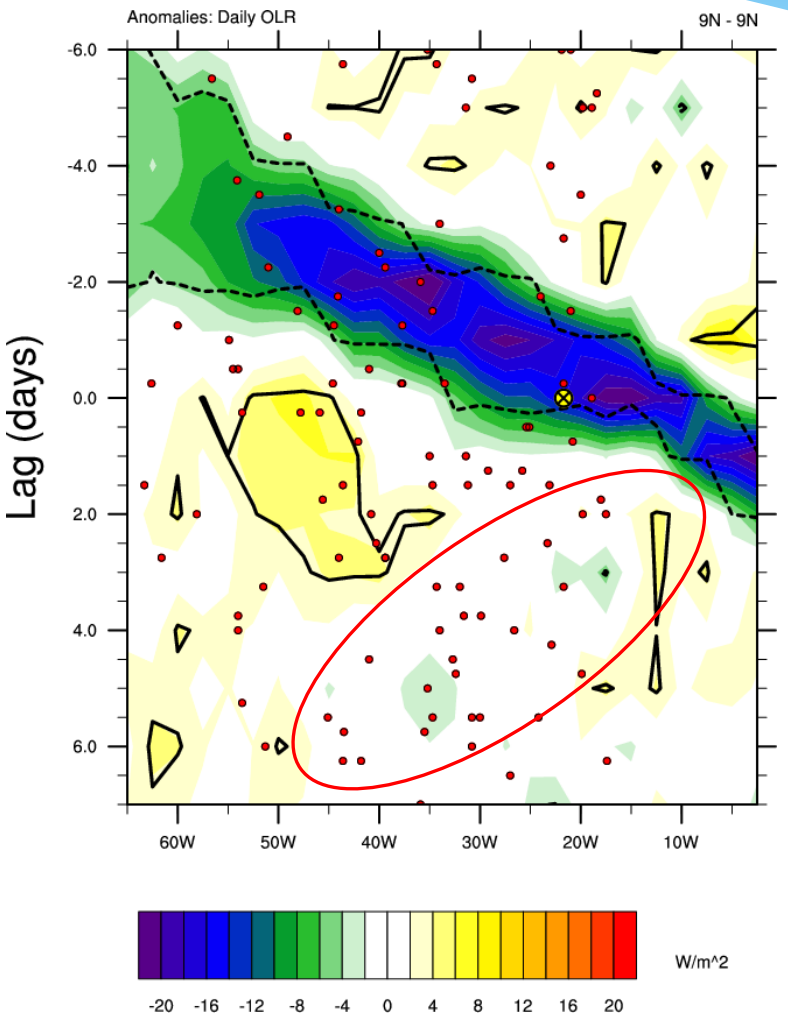
925 – 200 hPa Wind Shear



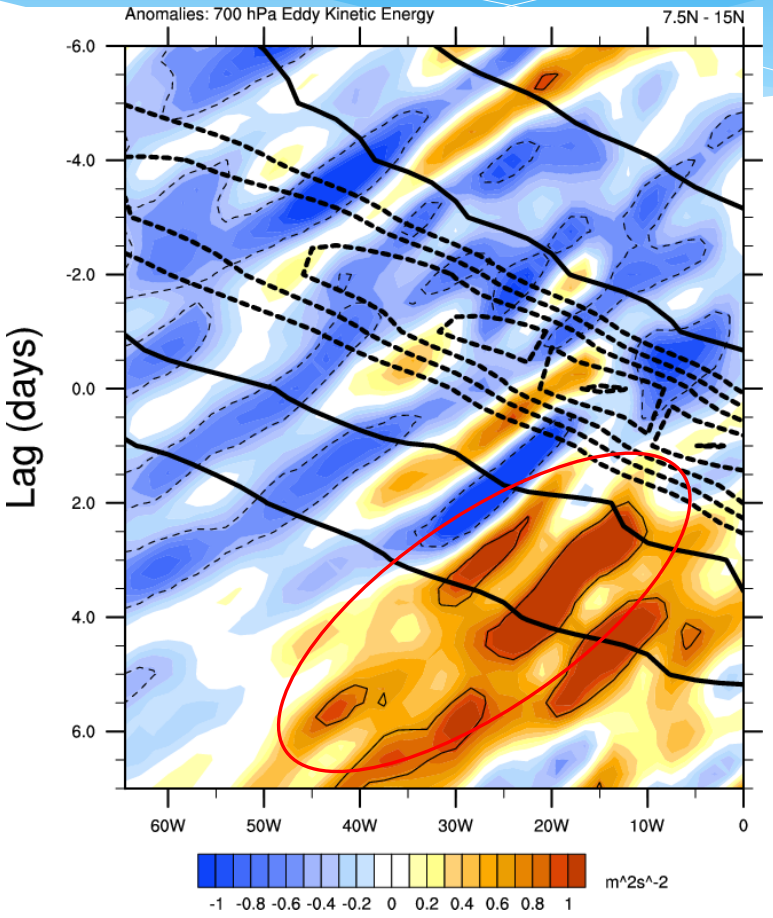
Adapted from Ventrice et al. 2012b



Ventrice et al. 2012a



Ventrice et al. 2012a



Ventrice et al. 2012c

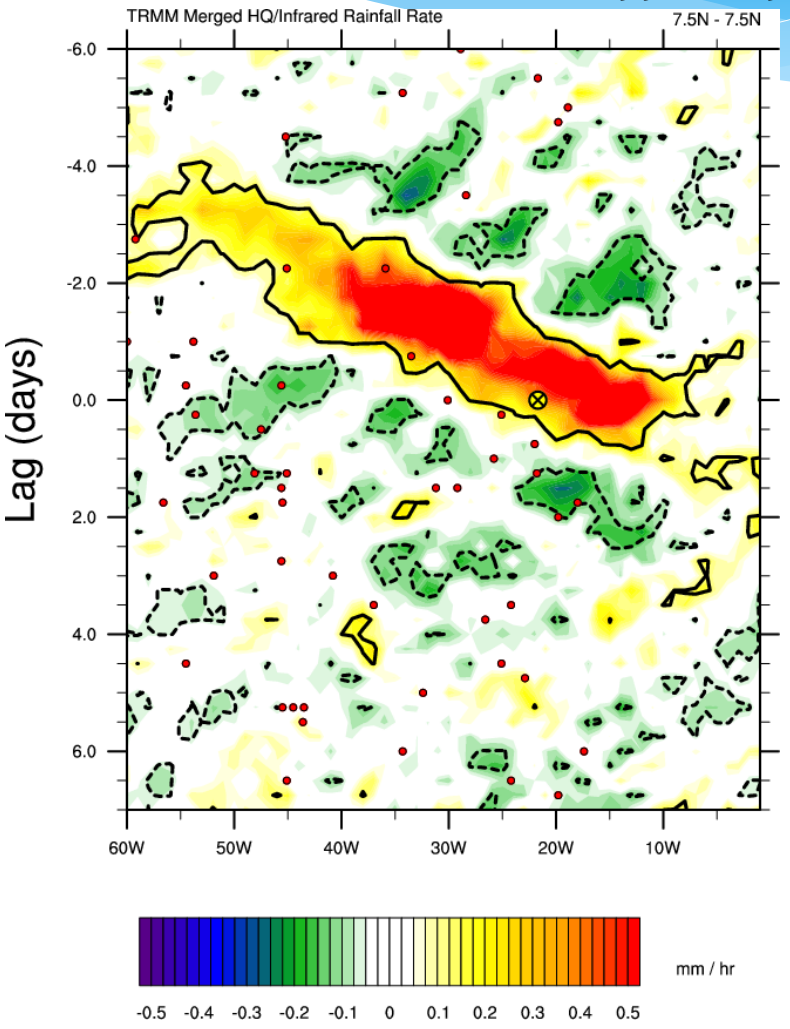
TRMM 3B42 Product

Kelvin waves are easily identified using the TRMM Satellite

Greater than 12 mm/day increase to climatological rain rates over Atlantic ocean during the passage of the active phase of a strong Kelvin wave

TRMM 3B42 real-time product will be heavily used to identify locations of Kelvin waves during the **HS3** Field Campaign

1998-2009

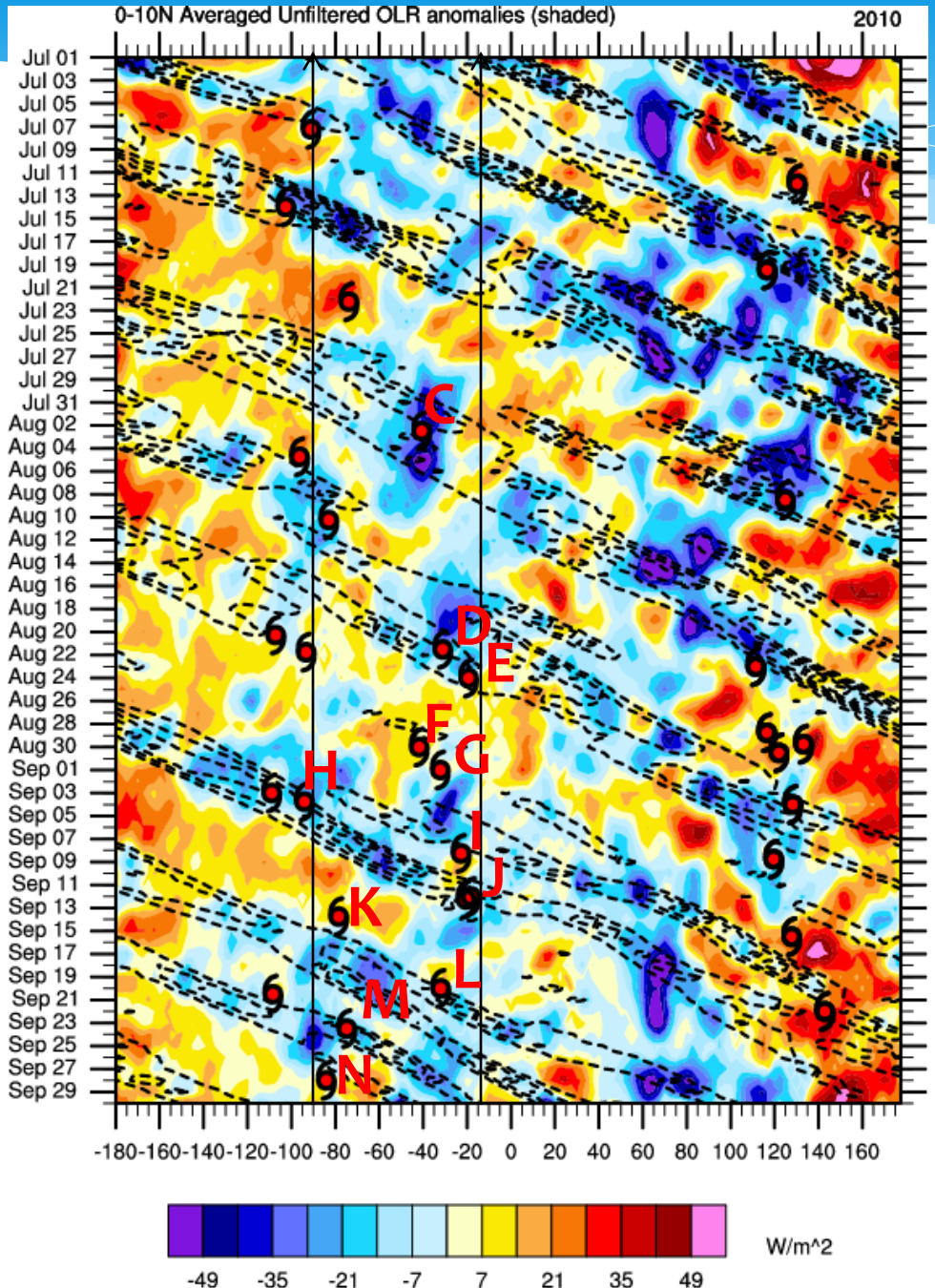


Shading: Unfiltered TRMM 3B42 rain rate anomalies

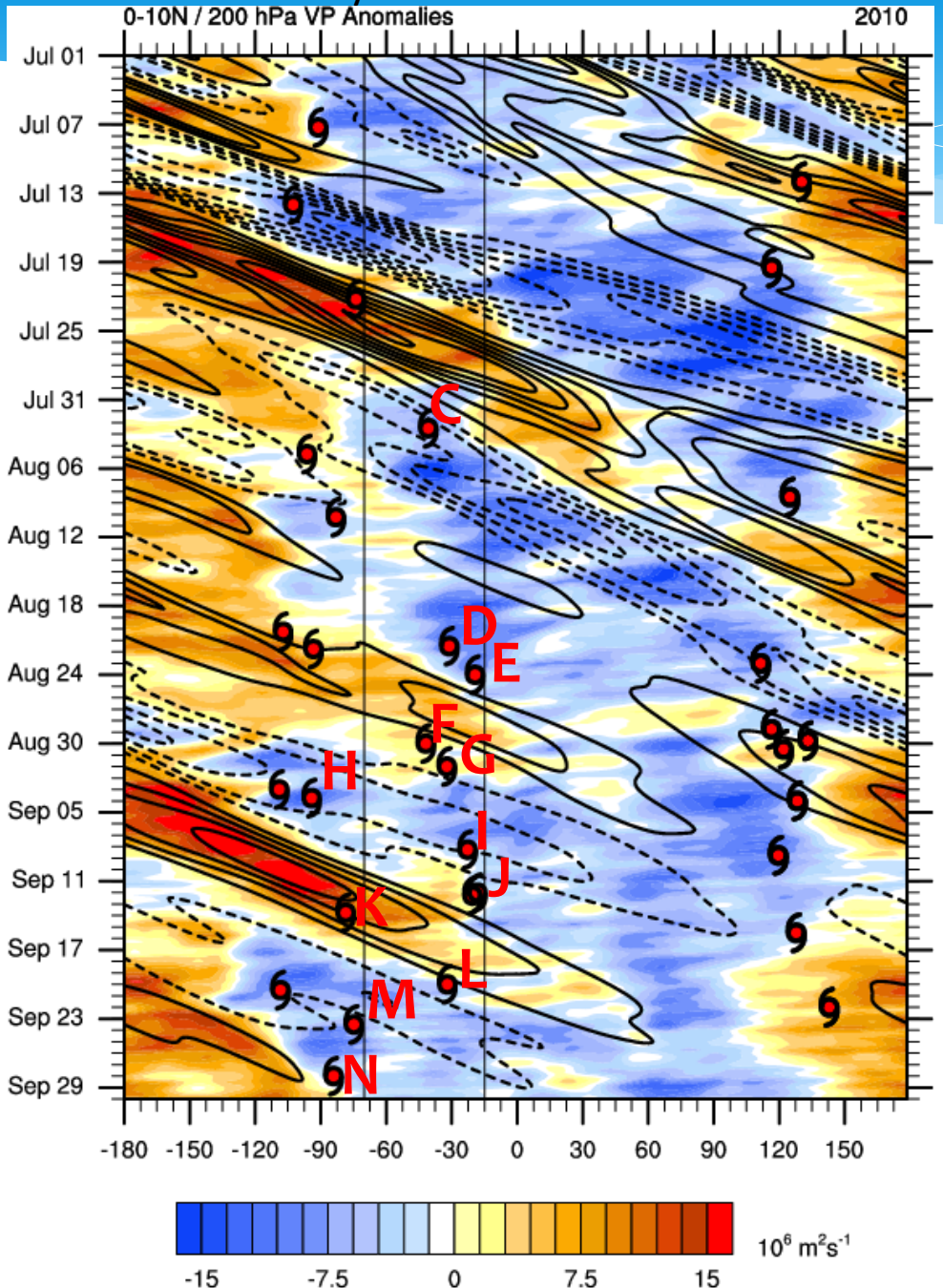
Contours:

GRIP Field Campaign

2010


0-10N Averaged Unfiltered OLR anomalies (shaded)
2010
Jul 01
Jul 03
Jul 05
Jul 07
Jul 09
Jul 11
Jul 13
Jul 15
Jul 17
Jul 19
Jul 21
Jul 23
Jul 25
Jul 27
Jul 29
Jul 31
Aug 02
Aug 04
Aug 06
Aug 08
Aug 10
Aug 12
Aug 14
Aug 16
Aug 18
Aug 20
Aug 22
Aug 24
Aug 26
Aug 28
Aug 30
Sep 01
Sep 03
Sep 05
Sep 07
Sep 09
Sep 11
Sep 13
Sep 15
Sep 17
Sep 19
Sep 21
Sep 23
Sep 25
Sep 27
Sep 29
C
D
E
F
G
H
I
J
K
L
M
N
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160
-49 -35 -21 -7 7 21 35 49
W/m^2

200 hPa Velocity Potential Anomalies

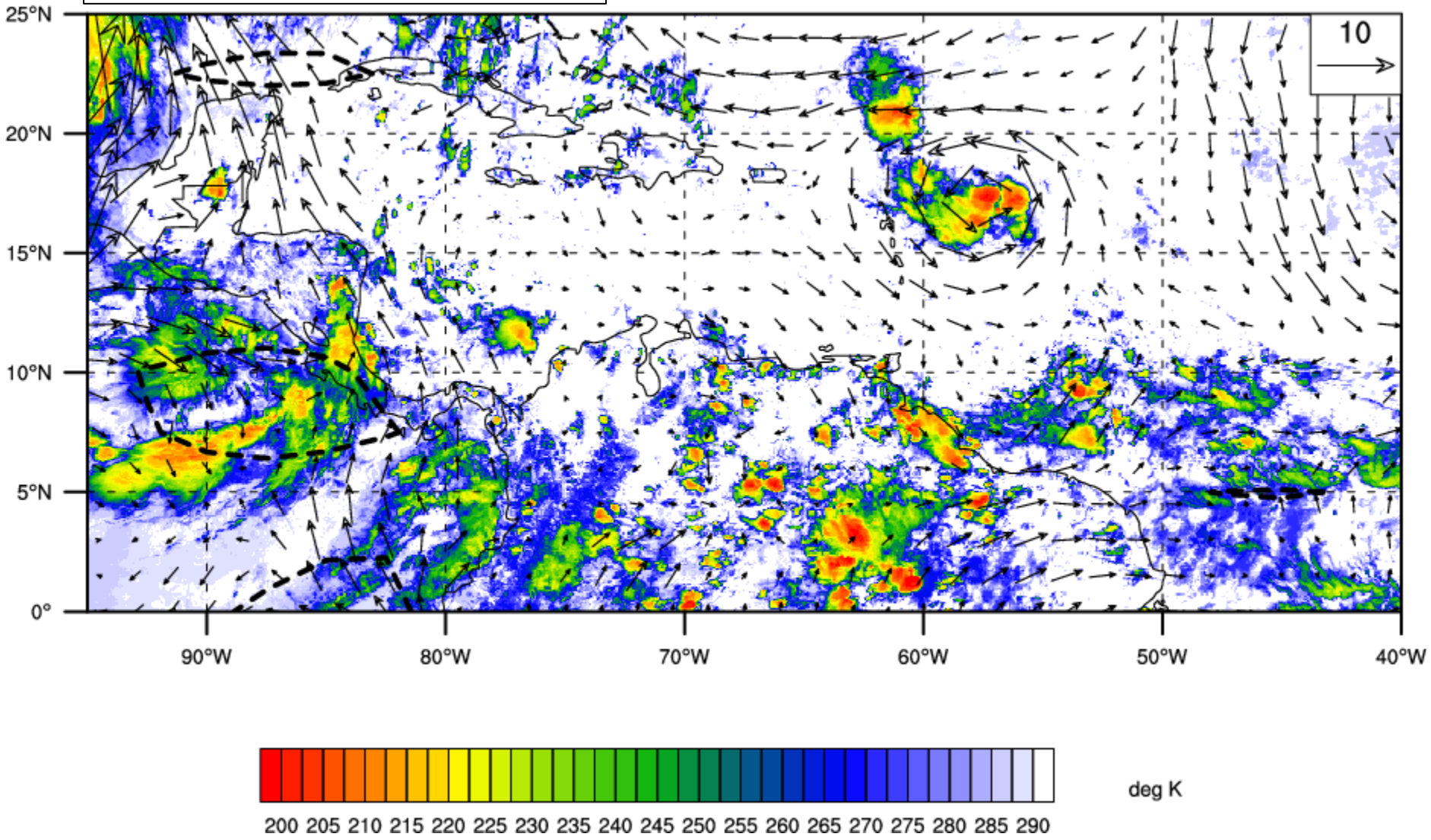


Genesis of Hurricane Karl

Where did the low-level circulation associated with pre-Karl come from?

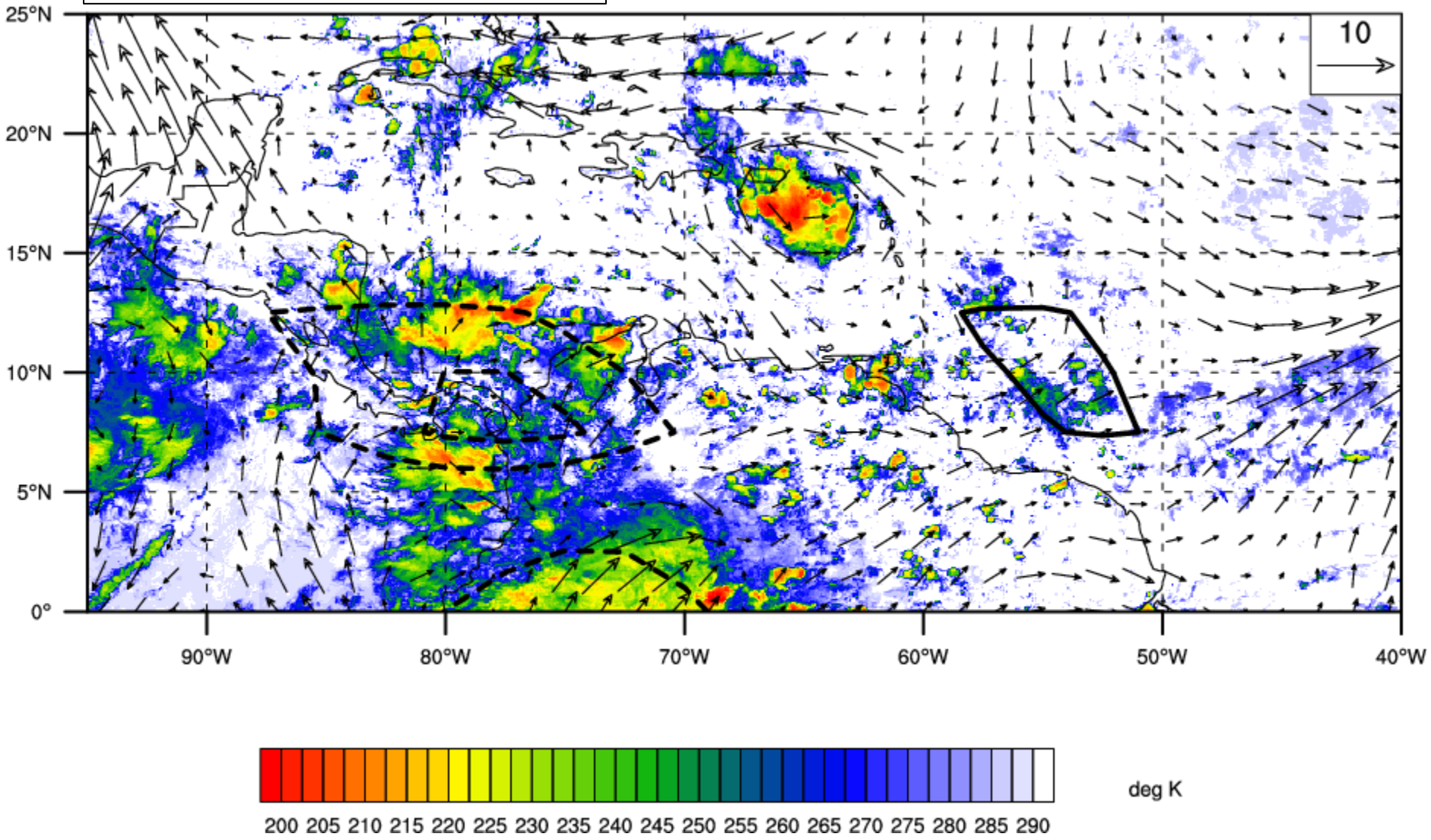
In collaboration with Kyle Griffin and Lance Bosart

1800 UTC 6 Sep



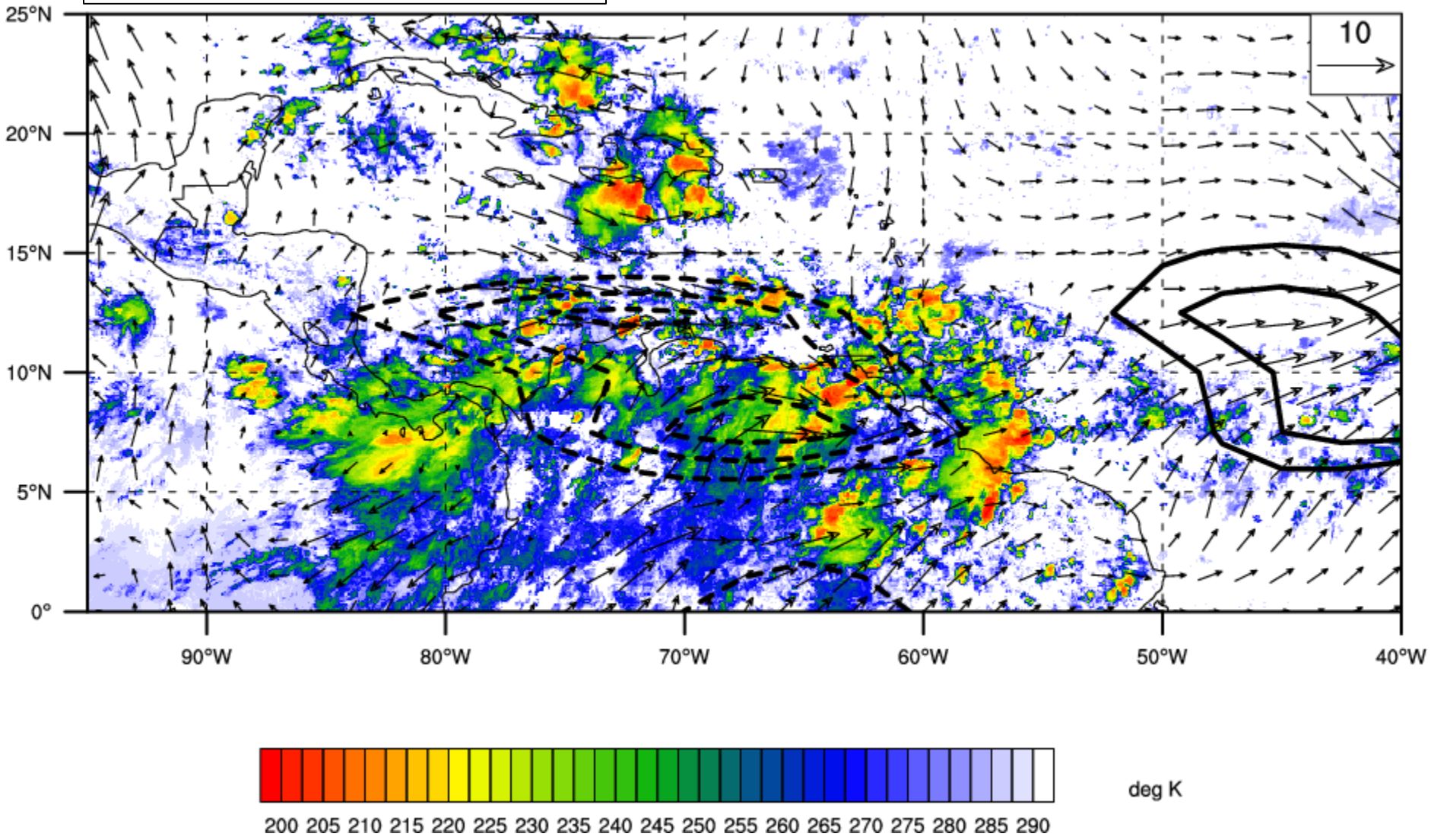
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 7 Sep



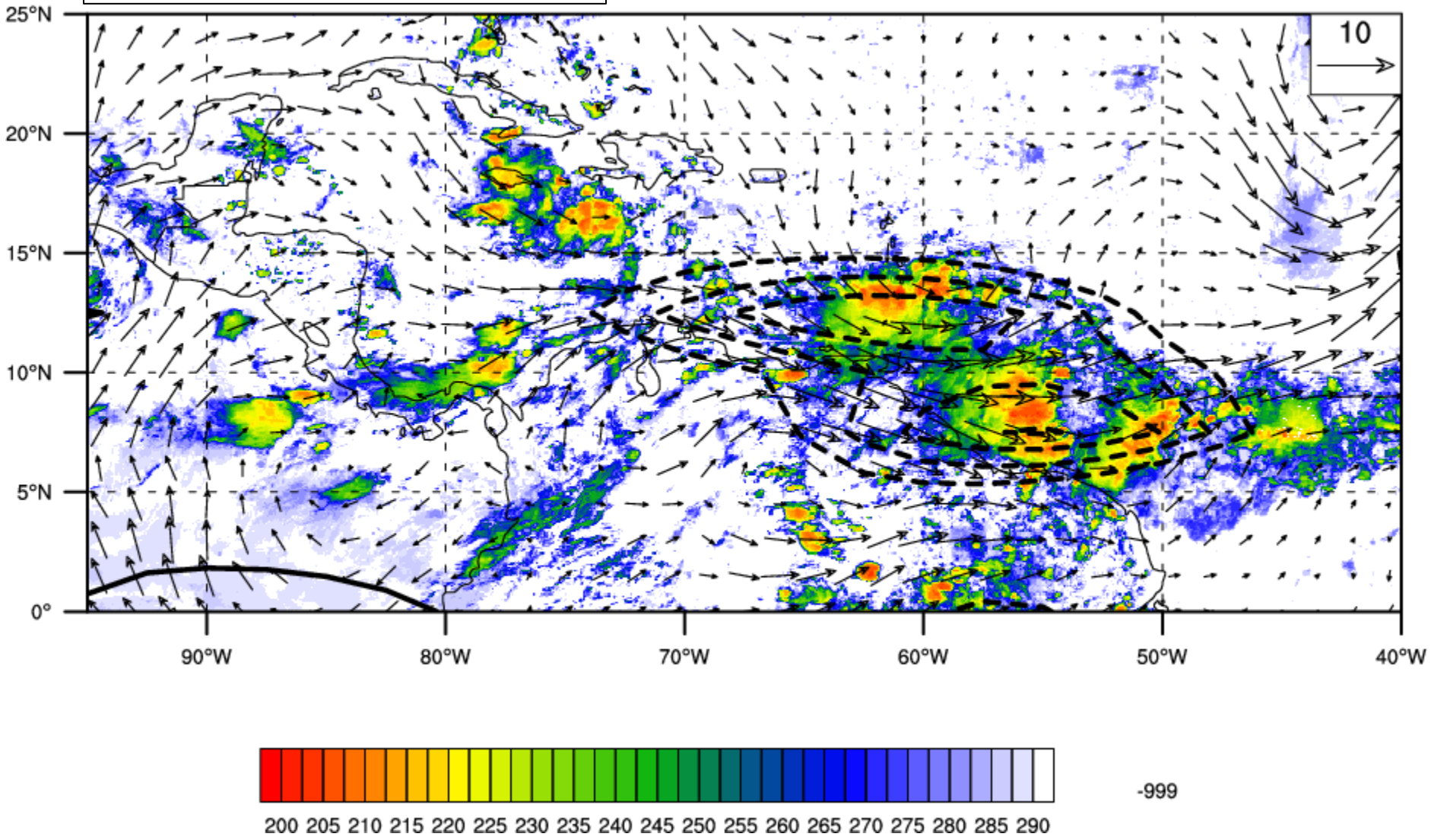
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 8 Sep



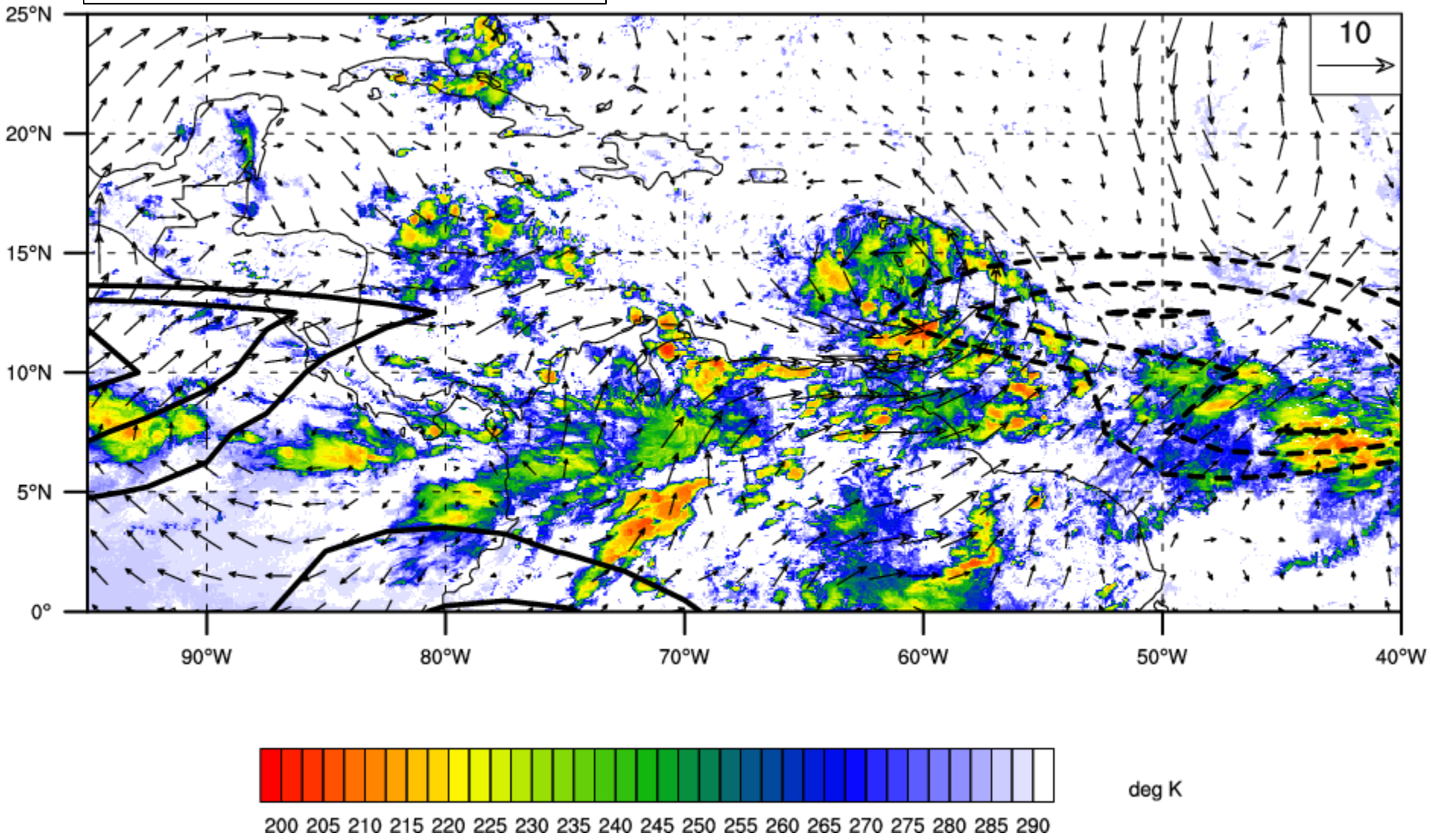
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 9 Sep



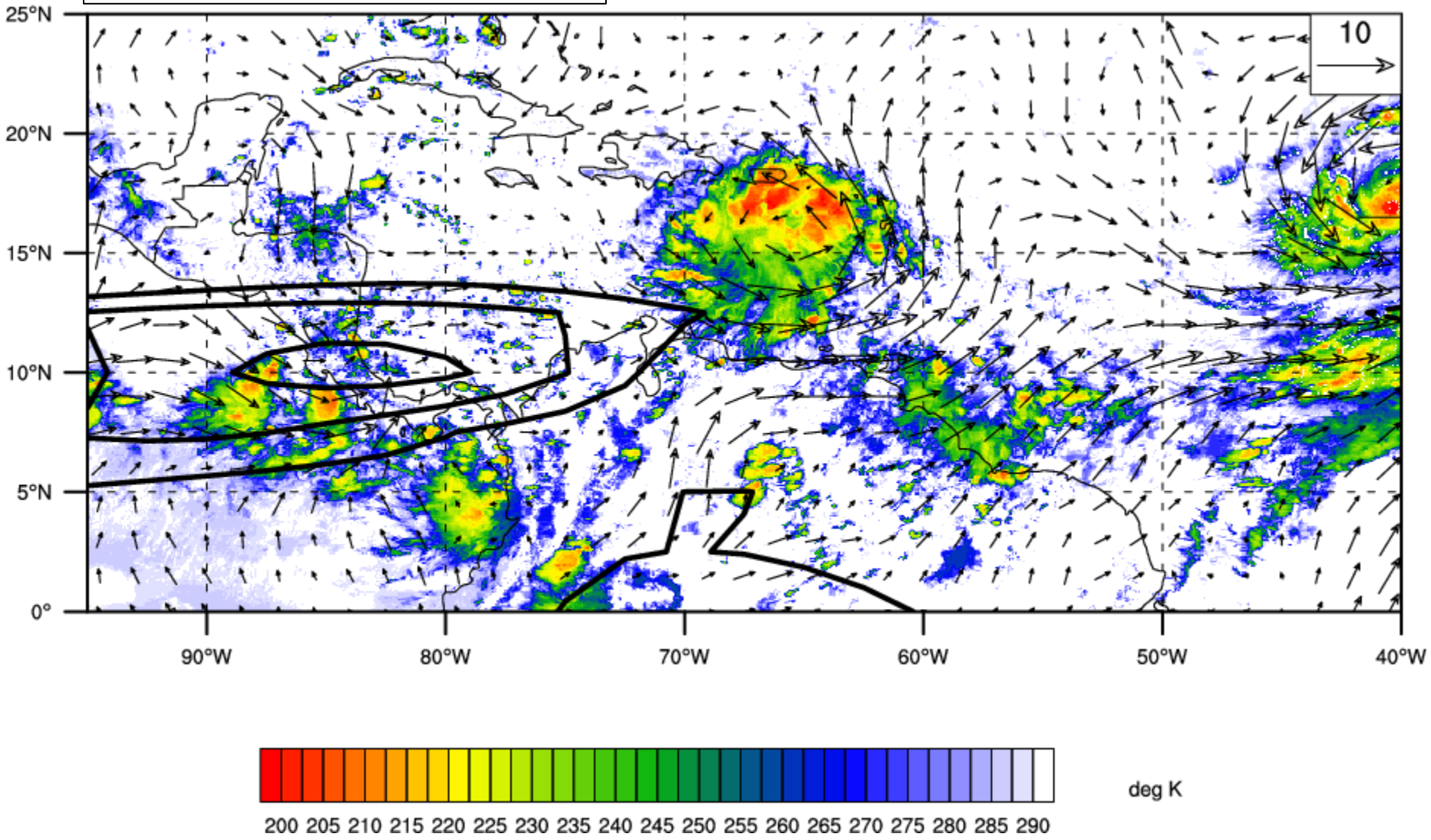
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 10 Sep



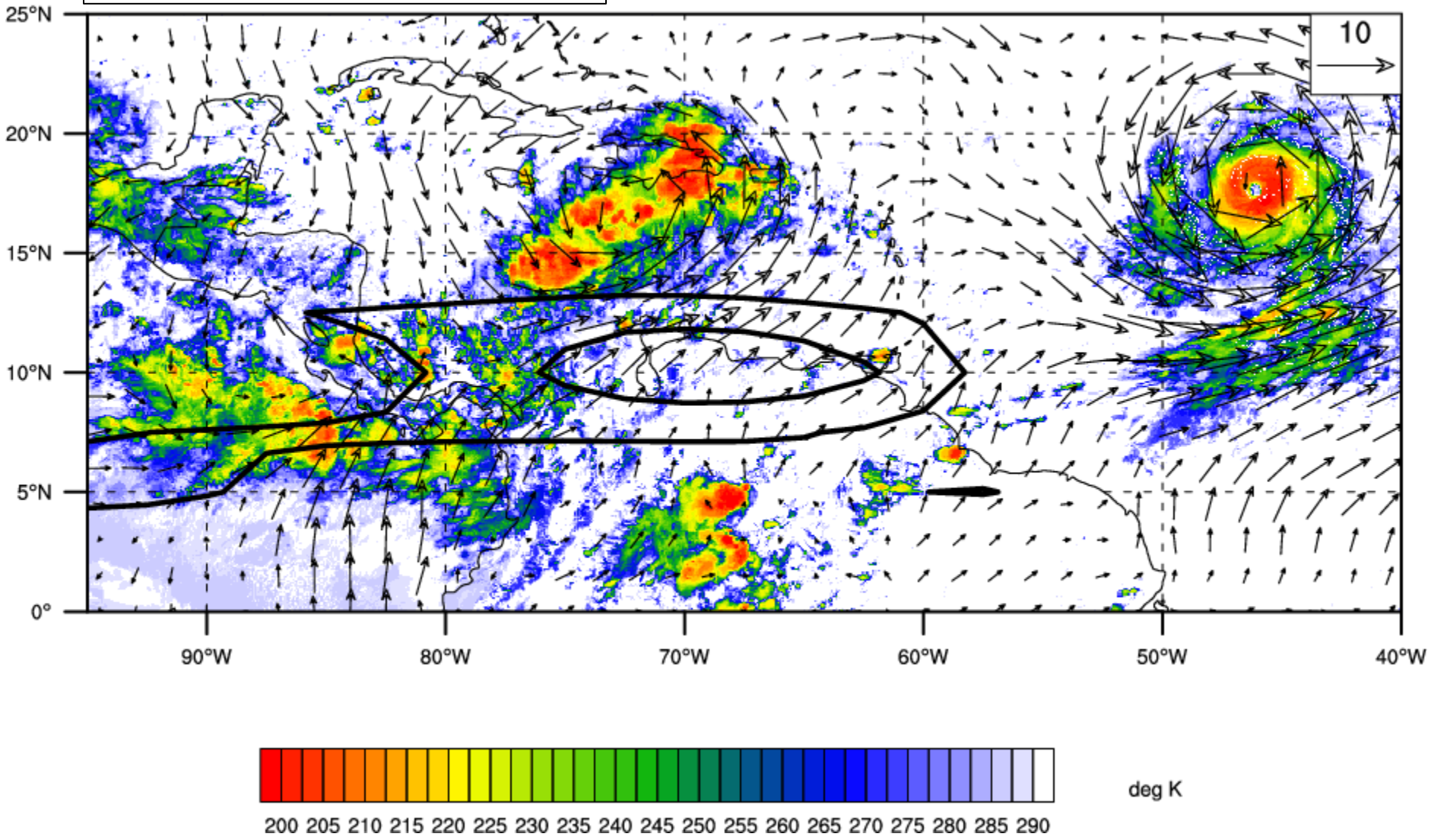
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 11 Sep



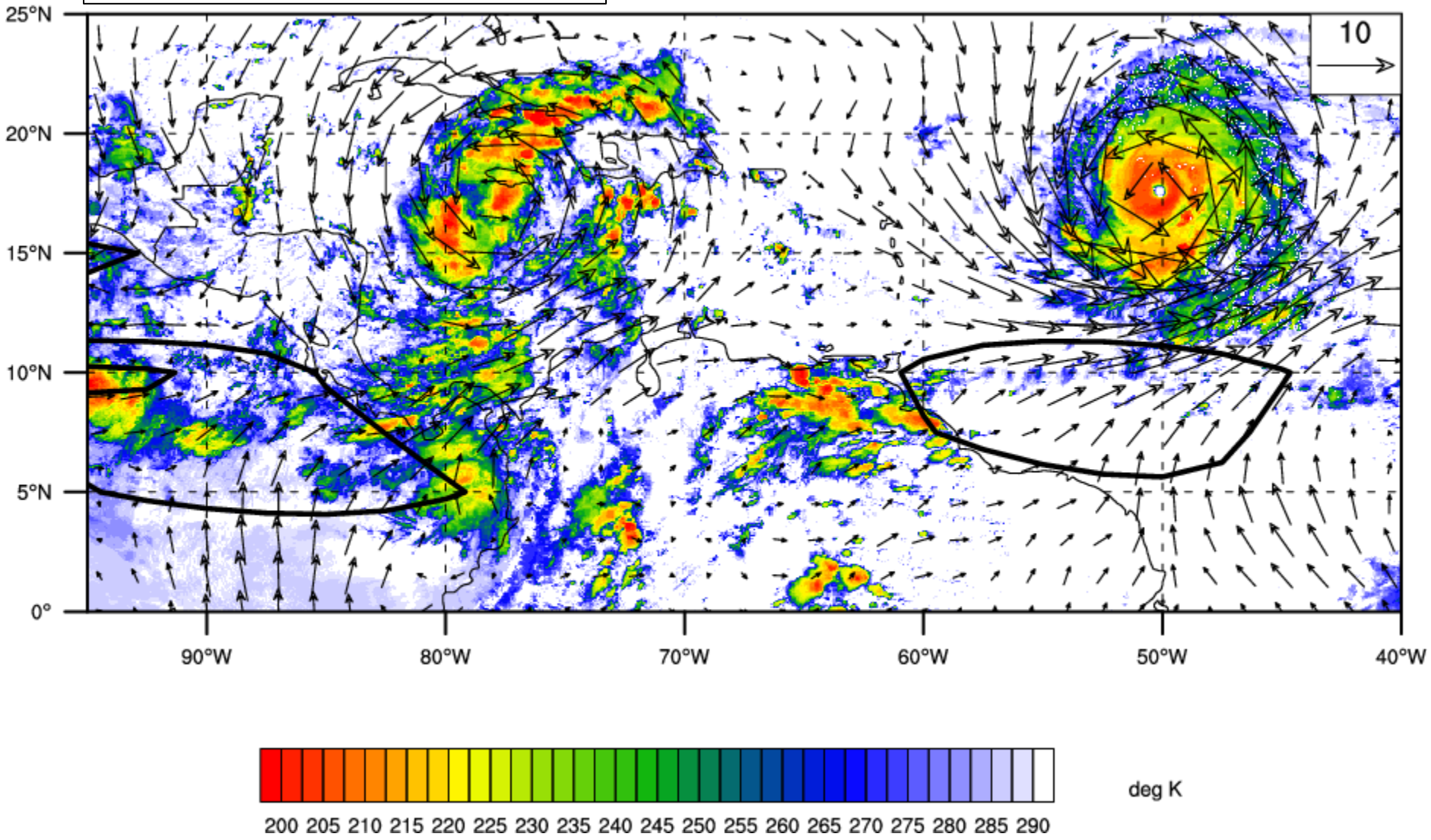
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 12 Sep



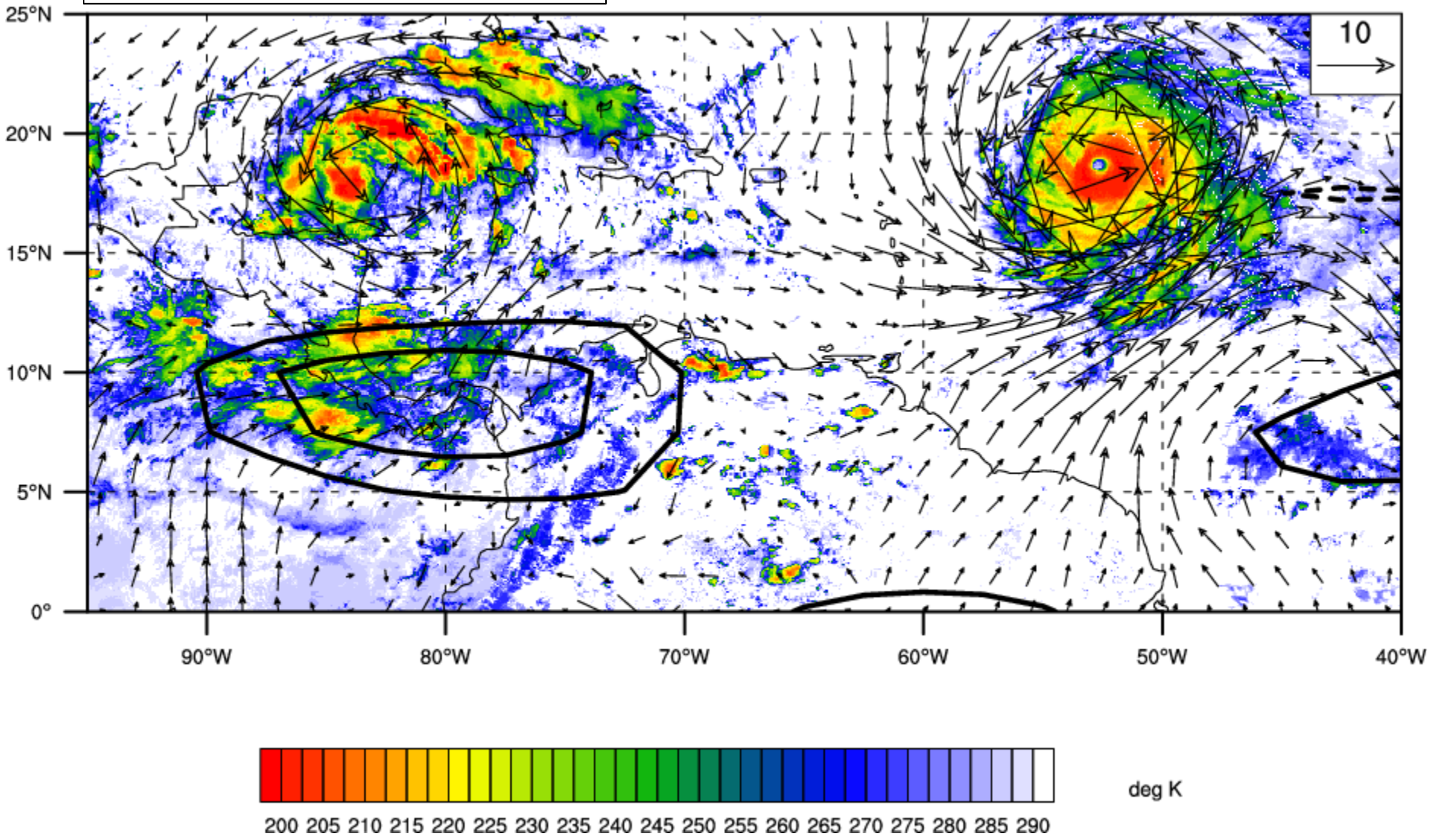
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 13 Sep



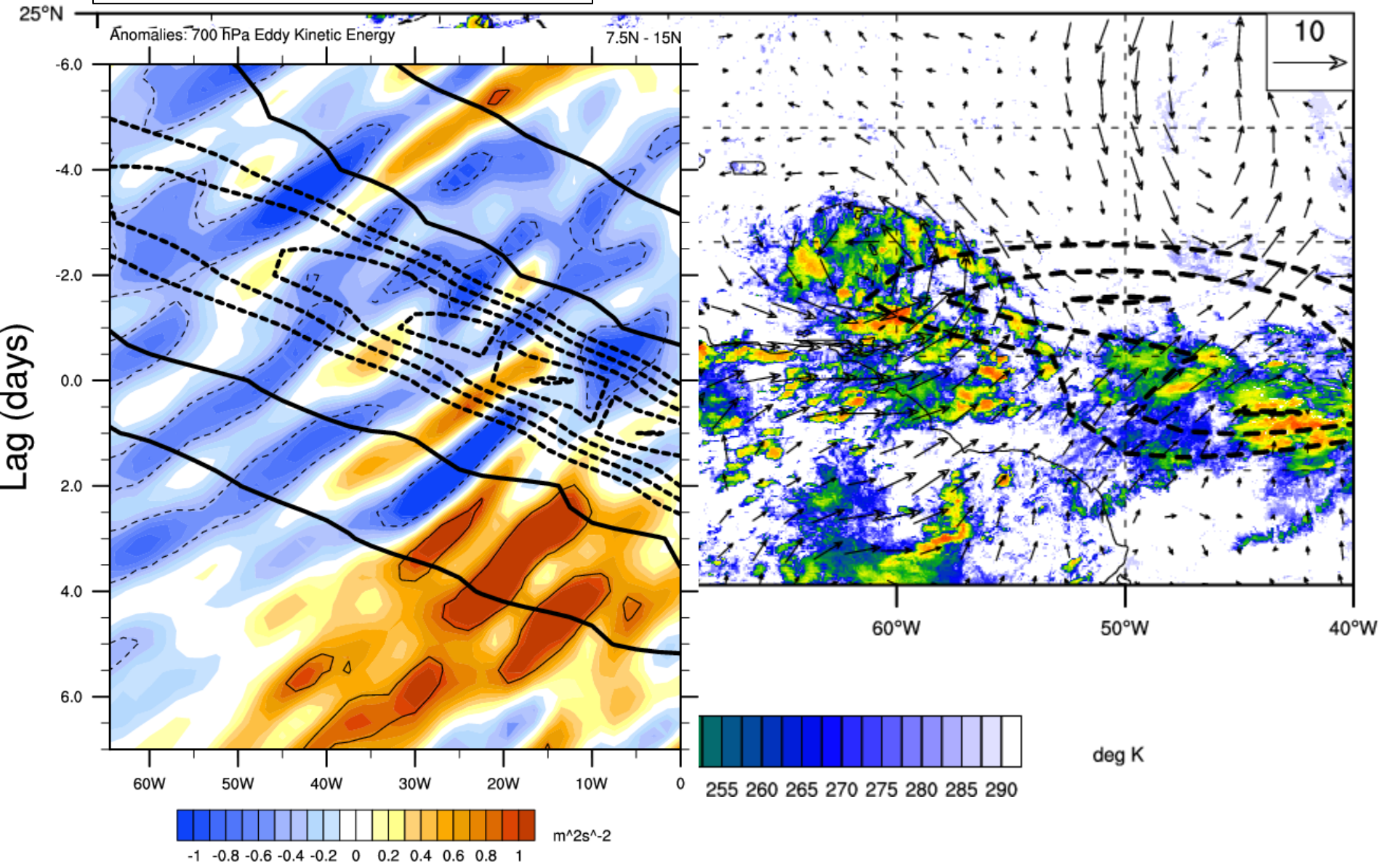
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

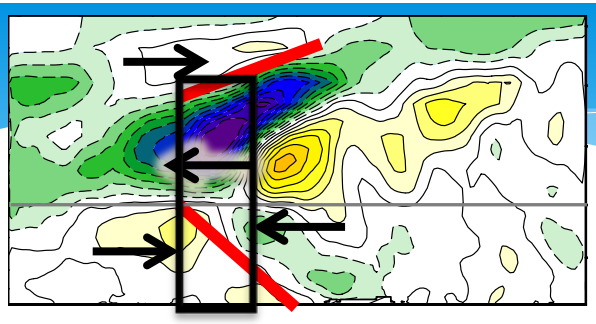
1800 UTC 14 Sep

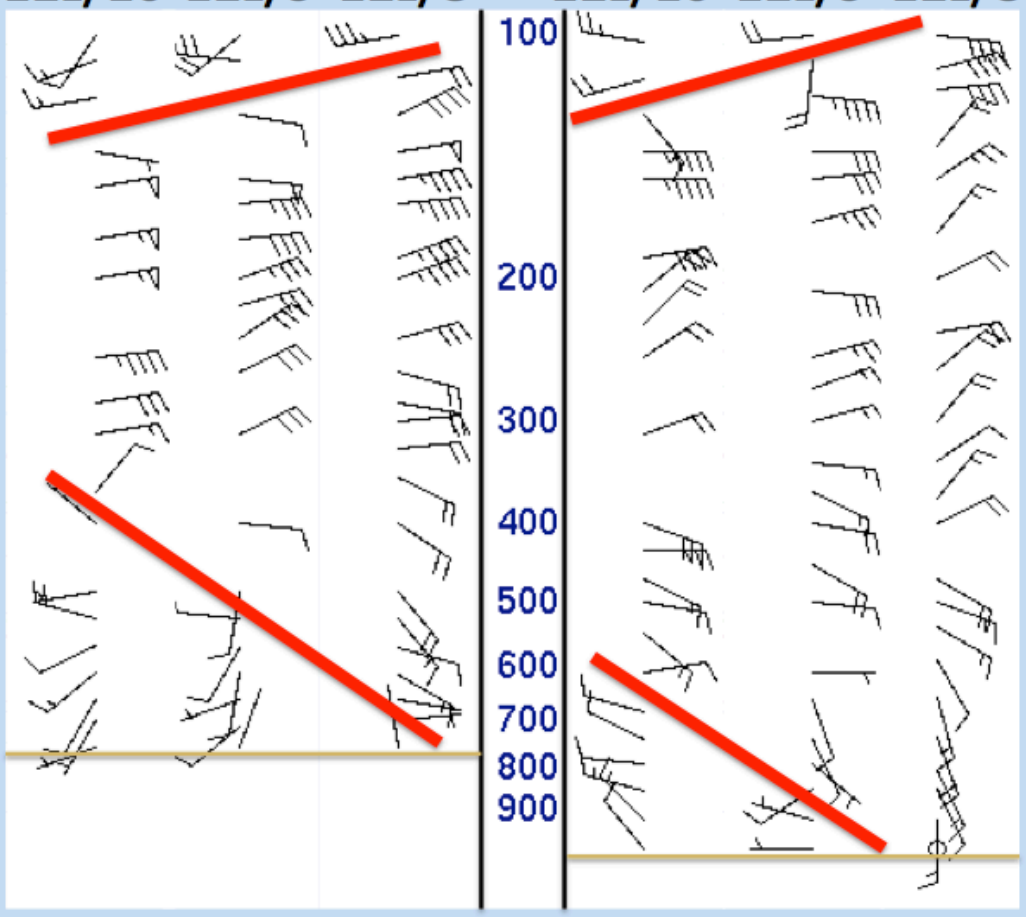


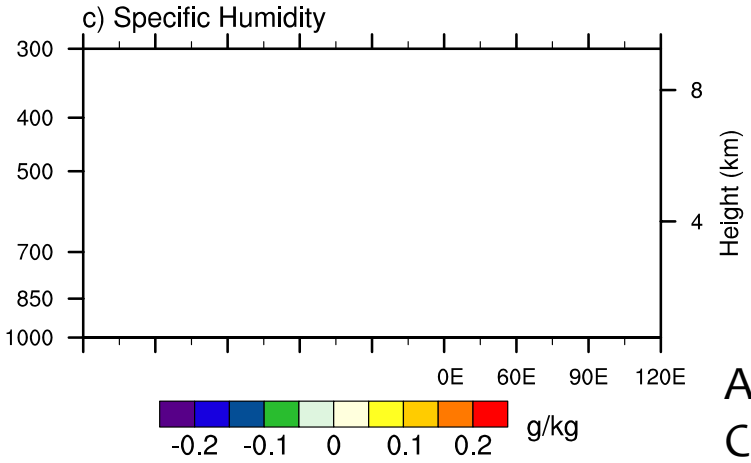
NASA Merged-IR product (shaded) – 850 hPa zonal wind anomalies (vectors)
Kelvin filtered NOAA OLR (contours)

1800 UTC 10 Sep

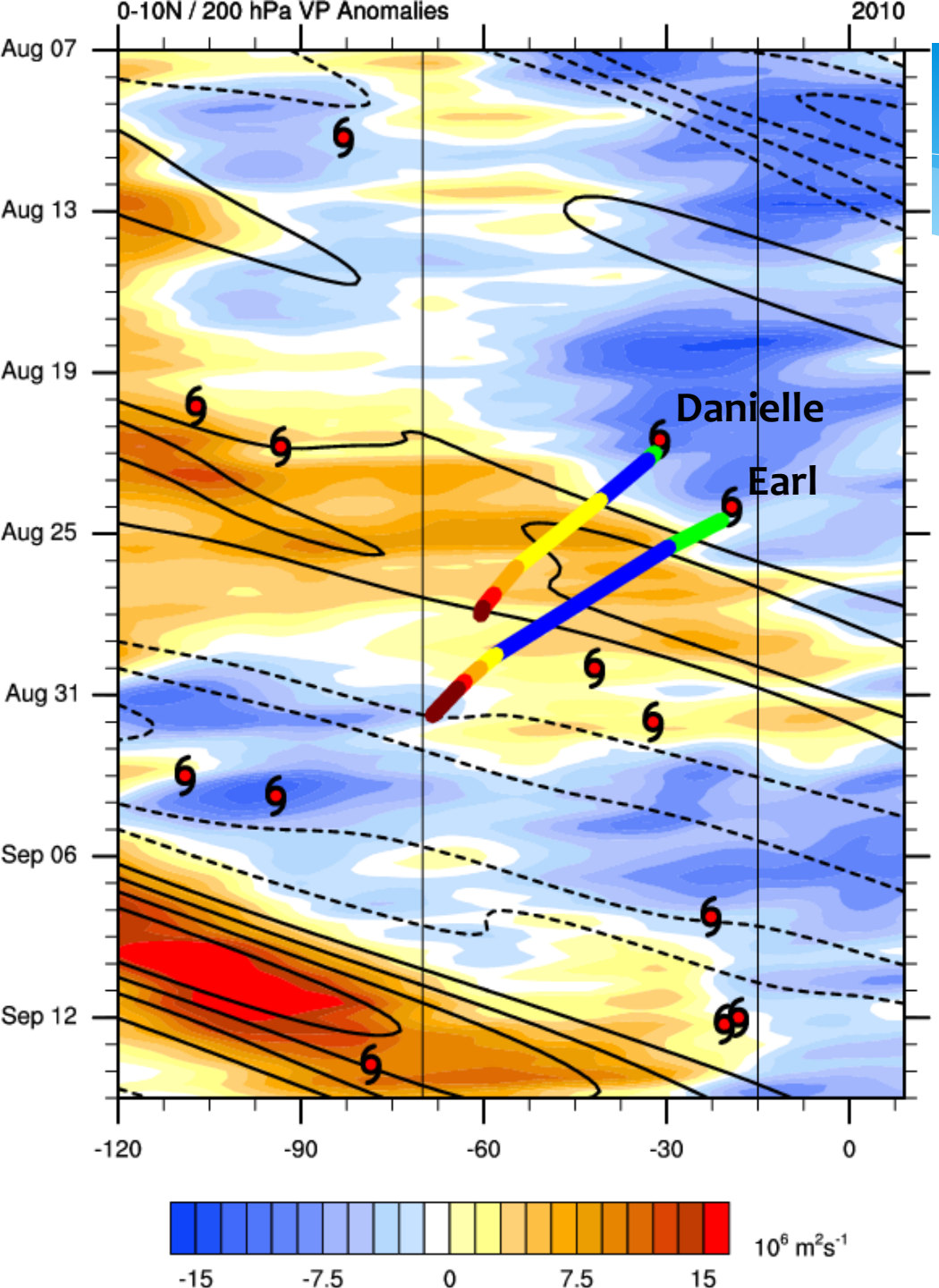








Adapted from Fig. 2, Ventrice et al. 2012b
Consistent with Kiladis et al. 2009



Kelvin waves and TC Intensity

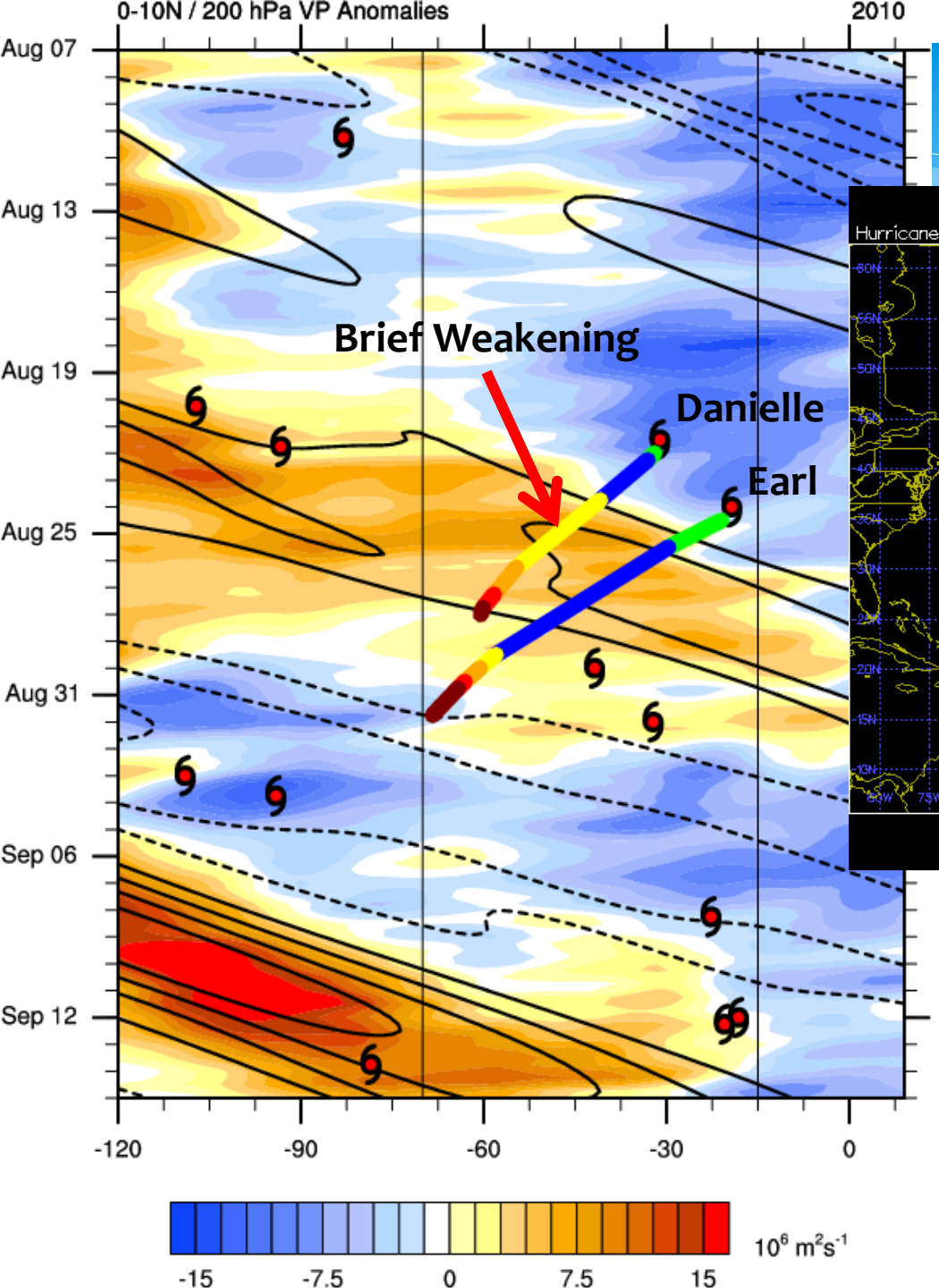
Last GRIP Meeting: Unexpected weakening of Hurricane Danielle

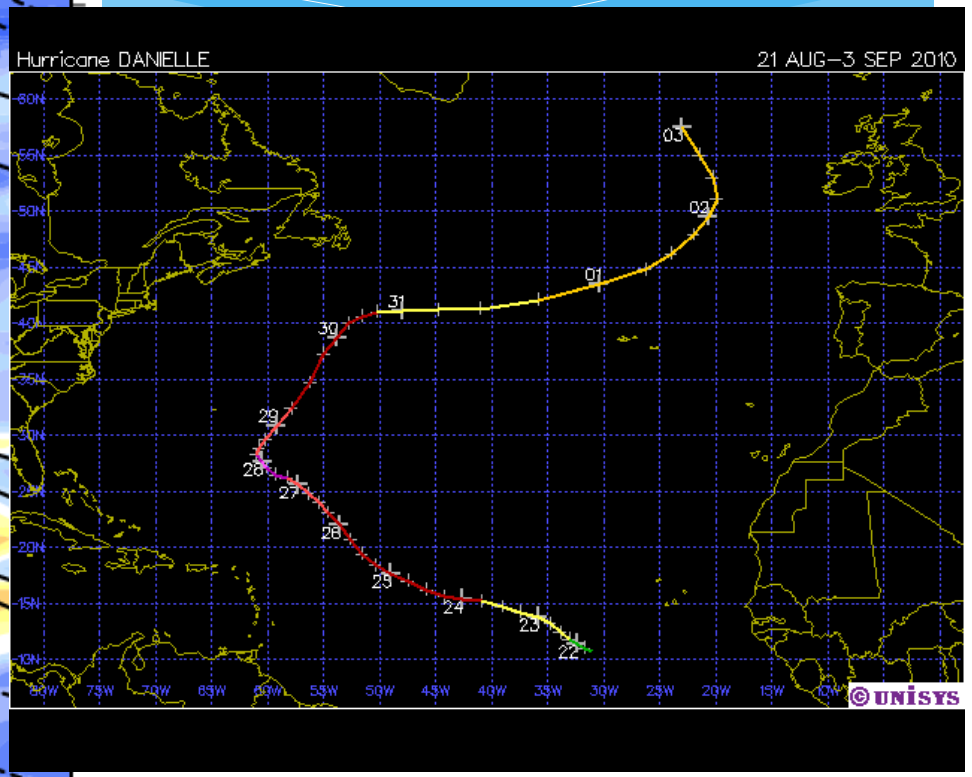
Hurricane Earl remained a Tropical Storm while superimposed with the same convectively suppressed Kelvin wave phase that may have contributed to the unexpected weakening of Danielle

Earl **rapidly intensified** just after the passage of the suppressed Kelvin wave phase

Tropical Depression Tropical Storm
Cat. 1 Cat. 2 Cat. 3 Cat .4

Kelvin waves and TC Intensity



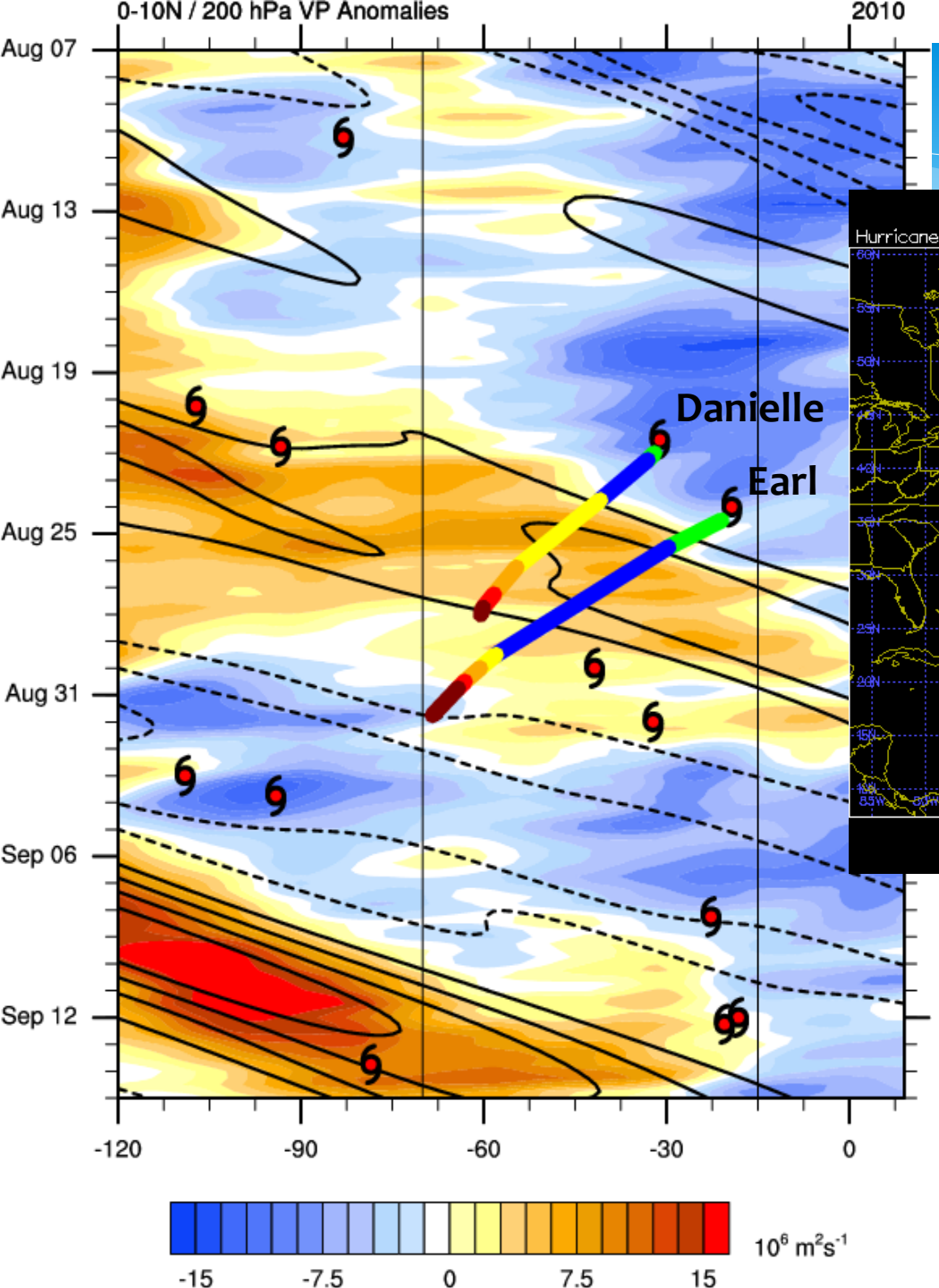


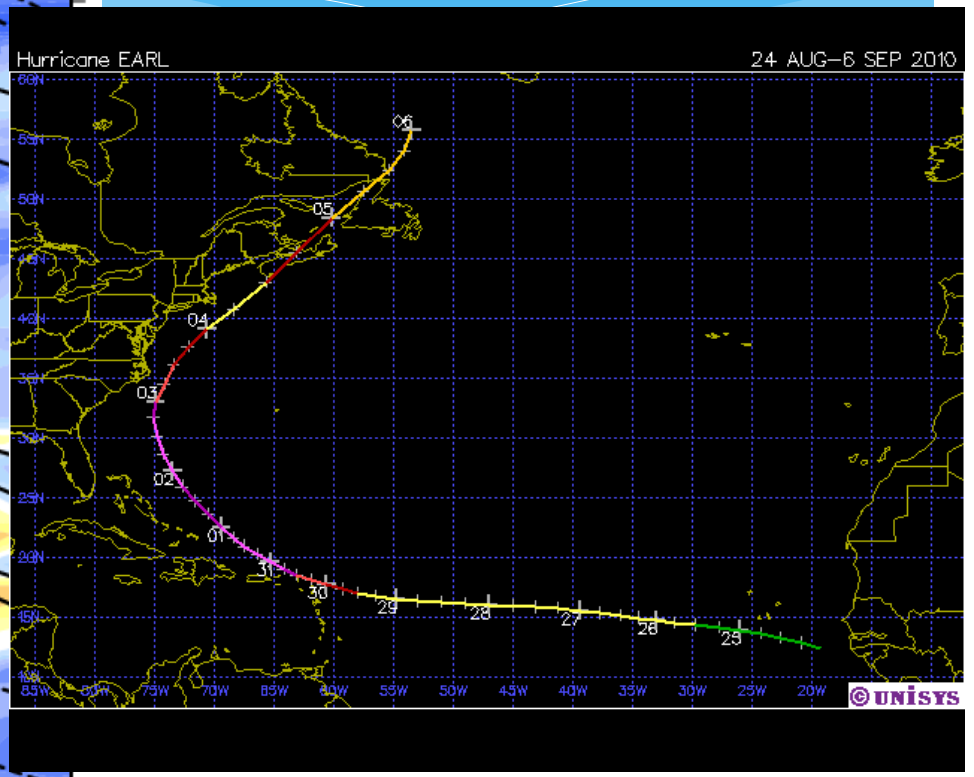
Earl **rapidly intensified** just after the passage of the suppressed Kelvin wave phase

Tropical Depression Tropical Storm

Cat. 1 Cat. 2 Cat. 3 Cat .4

Kelvin waves and TC Intensity





Earl **rapidly intensified** just after the passage of the suppressed Kelvin wave phase

Tropical Depression Tropical Storm

Cat. 1 Cat. 2 Cat. 3 Cat .4

Conclusions – GRIP 2010 Campaign

1) Kelvin waves were active during the 2010 GRIP field campaign

2) The low-level circulation associated with pre-Karl developed after the passage of the convectively active phase of a strong CCKW
   -A "new" mechanism for Kelvin-induced genesis over the Atlantic (e.g., Roundy 2008)

3) Radiosonde data over South America (and Barbados, not shown) observed the dynamical structure of the CCKW

4) In addition to Hurricane Danielle, the intensification of Hurricane Earl was interrupted by the passage of a strong suppressed Kelvin wave phase (200 hPa velocity potential)
   -Hurricane Earl **rapidly intensified** after the passage of the suppressed Kelvin wave phase

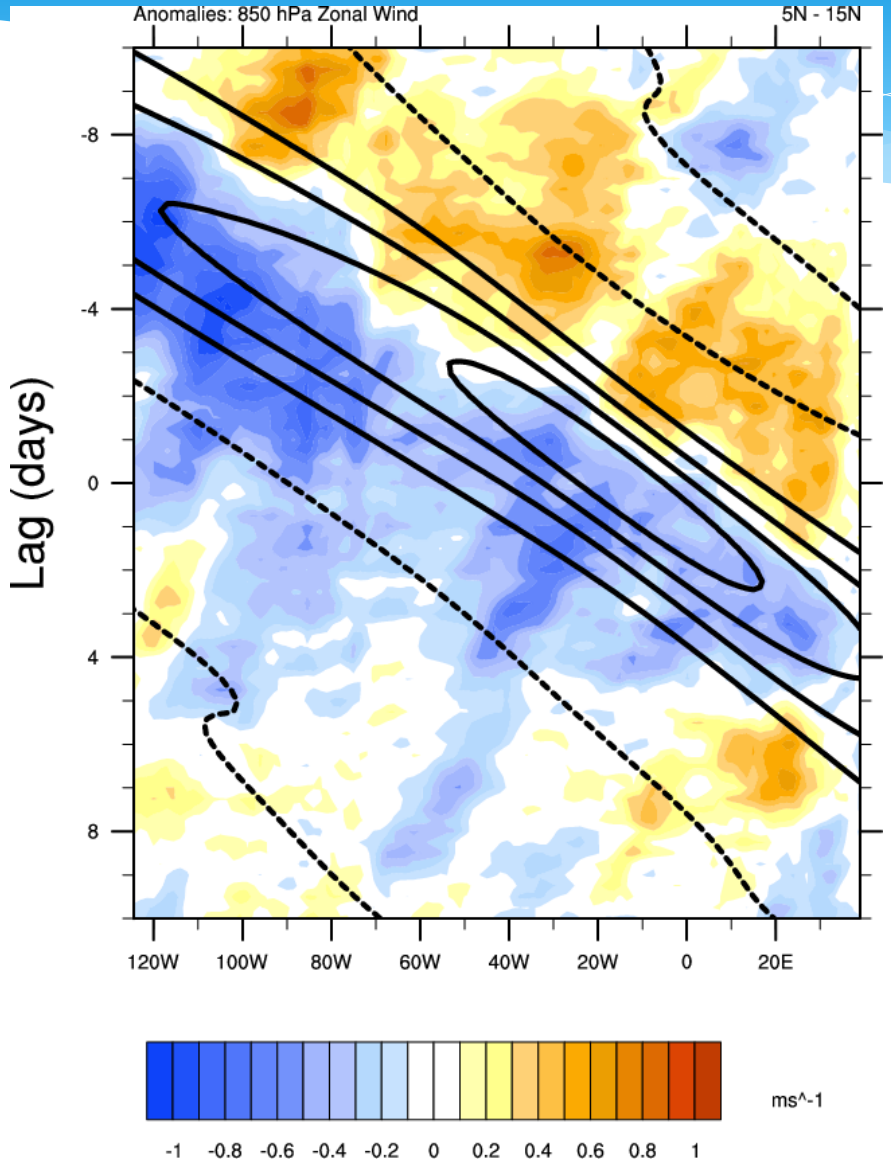
Final Thoughts

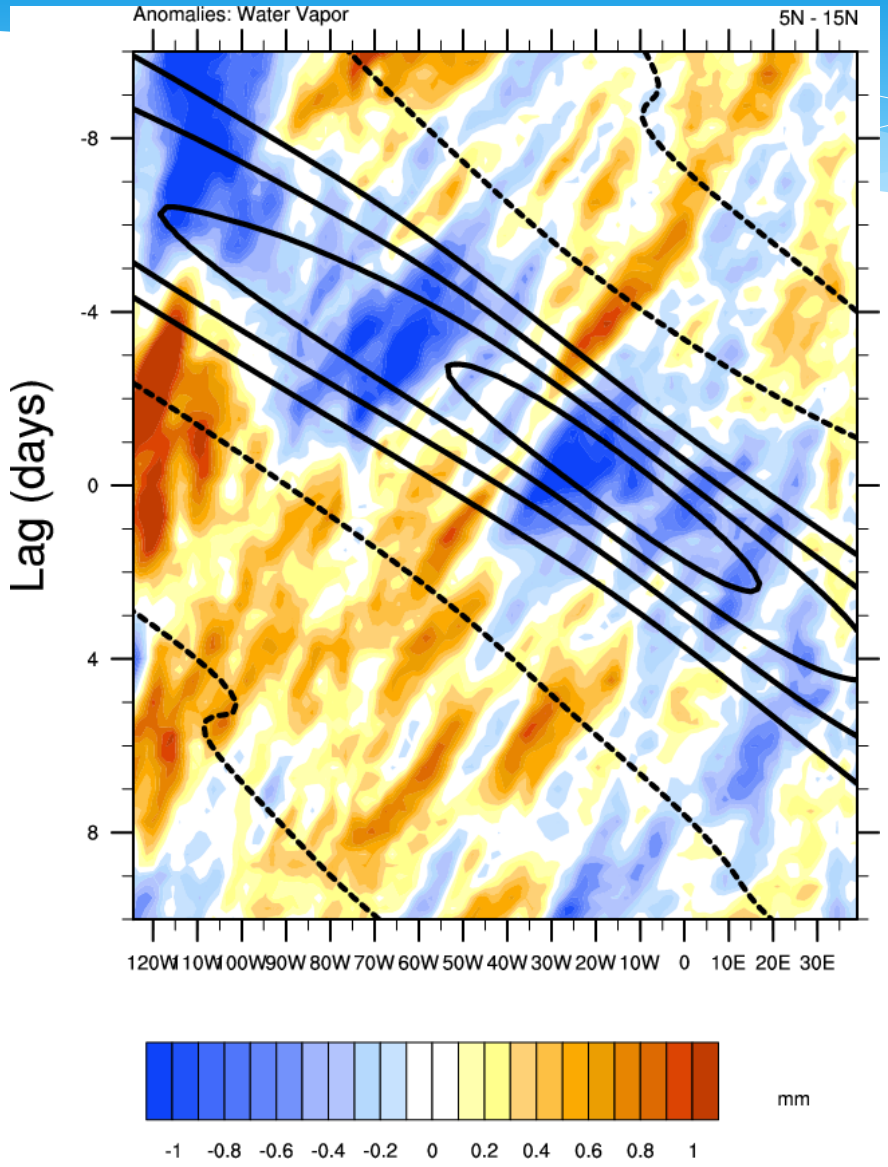
1: Knowledge of the nature and location of CCKWs 3-5 days before they arrive in the tropical Atlantic should be exploited to improve medium range forecast skill of tropical cyclone intensity change including genesis.

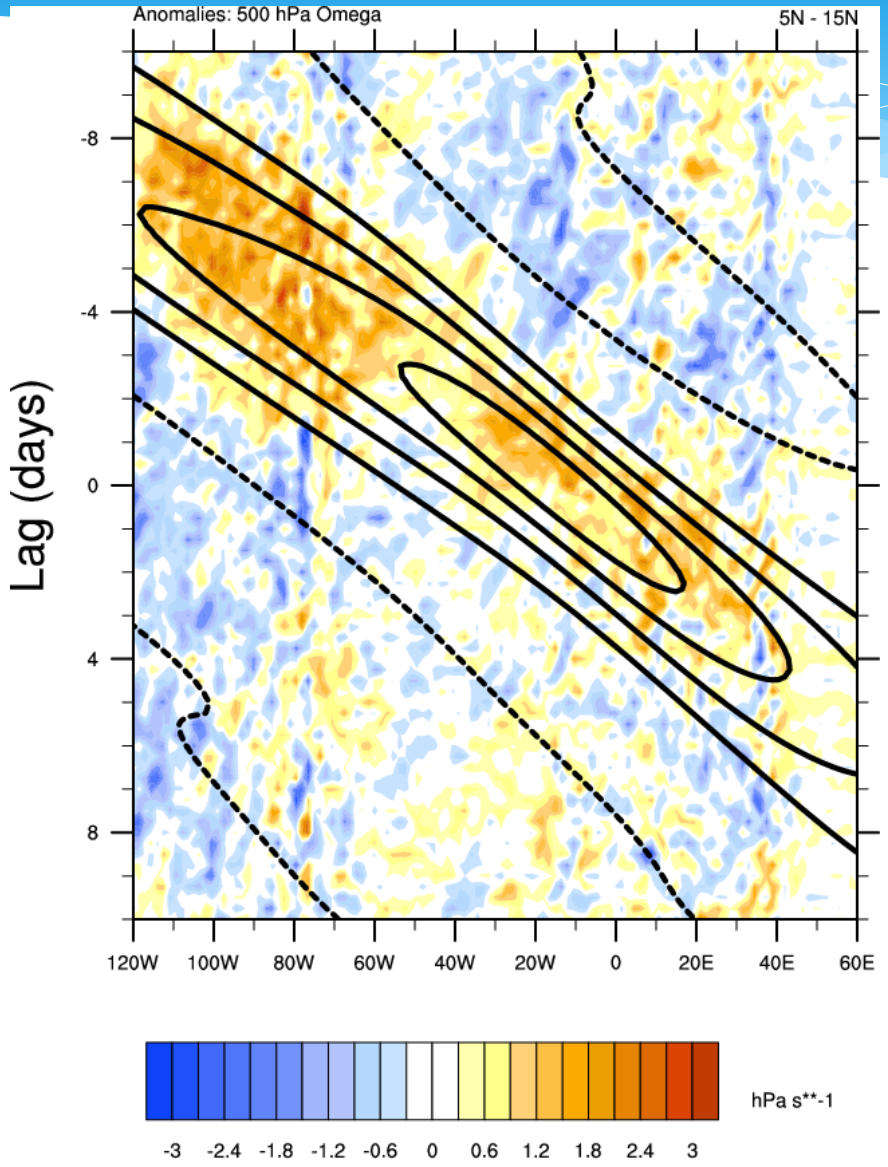
2 : More work is needed to improve our understanding of the processes involved when CCKWs interact with and initiate tropical cyclones and easterly waves.

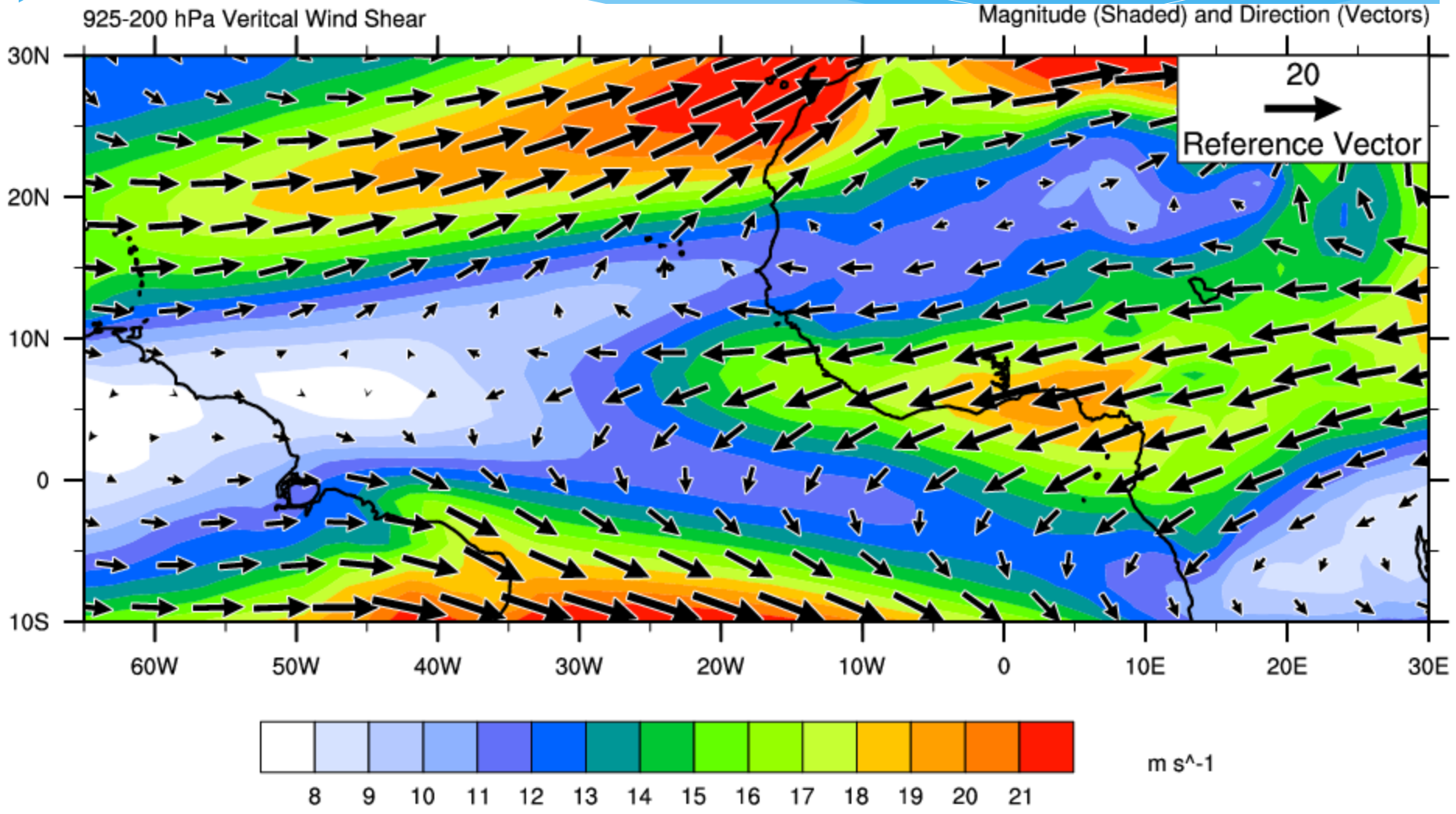
3: More work is needed to evaluate how operational models represent and forecast CCKWs and to establish the key observations needed to improve these predictions (through data assimilation efforts).

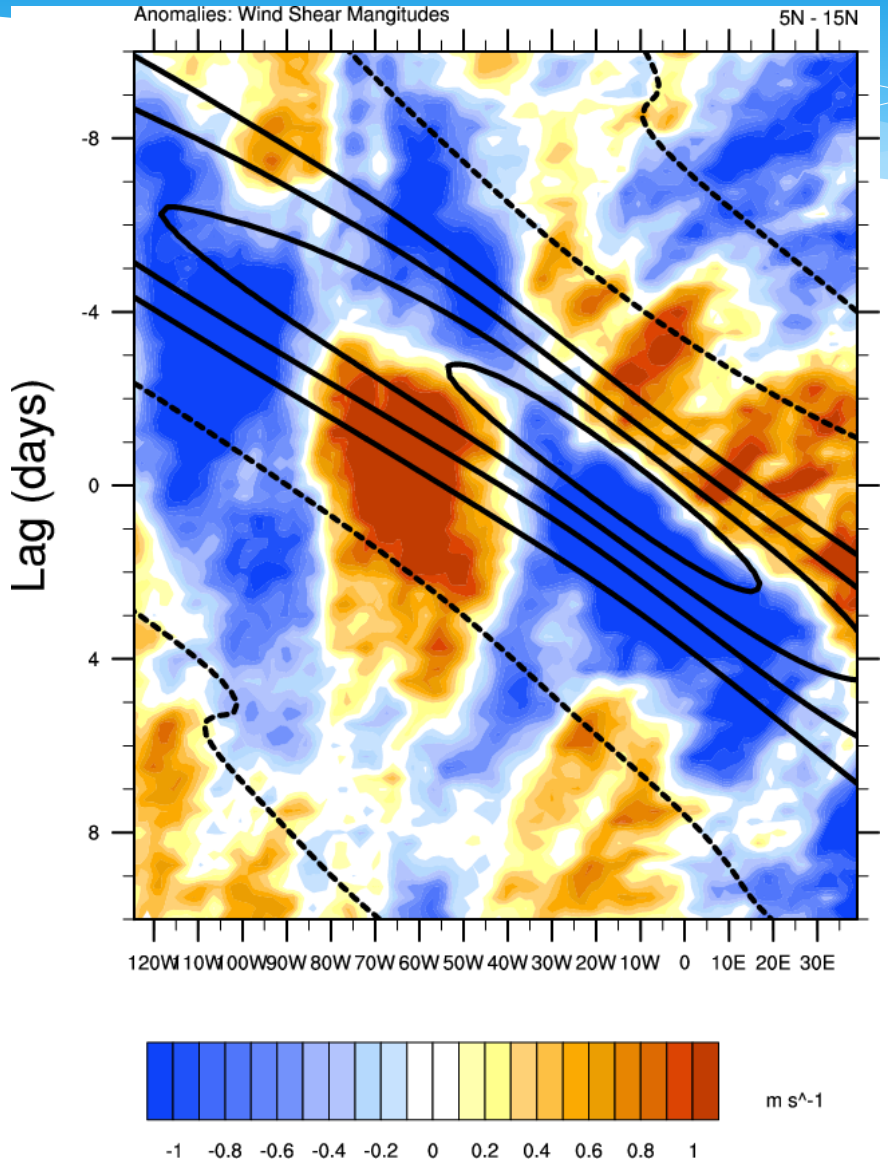
Supplemental Slides


Anomalies: 850 hPa Zonal Wind
5N - 15N
Lag (days)
-8
-4
0
4
8
120W
100W
80W
60W
40W
20W
0
20E
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
ms^-1


Anomalies: Water Vapor
5N - 15N
Lag (days)
-8
-4
0
4
8
120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0 10E 20E 30E
mm
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1


Anomalies: 500 hPa Omega
5N - 15N
Lag (days)
-8
-4
0
4
8
120W
100W
80W
60W
40W
20W
0
20E
40E
60E
-3
-2.4
-1.8
-1.2
-0.6
0
0.6
1.2
1.8
2.4
3
hPa s**-1


925-200 hPa Veritcal Wind Shear
Magnitude (Shaded) and Direction (Vectors)
20
Reference Vector
30N
20N
10N
0
10S
60W
50W
40W
30W
20W
10W
0
10E
20E
30E
8
9
10
11
12
13
14
15
16
17
18
19
20
21
m s^-1


Anomalies: Wind Shear Mangitudes
5N - 15N
Lag (days)
-8
-4
0
4
8
120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0 10E 20E 30E
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
m s^-1