Kelvin waves and Tropical Cyclones

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Outline

1. Convectively Coupled Kelvin Waves during the HS3 dry run 2011 and open questions

   (i) Genesis

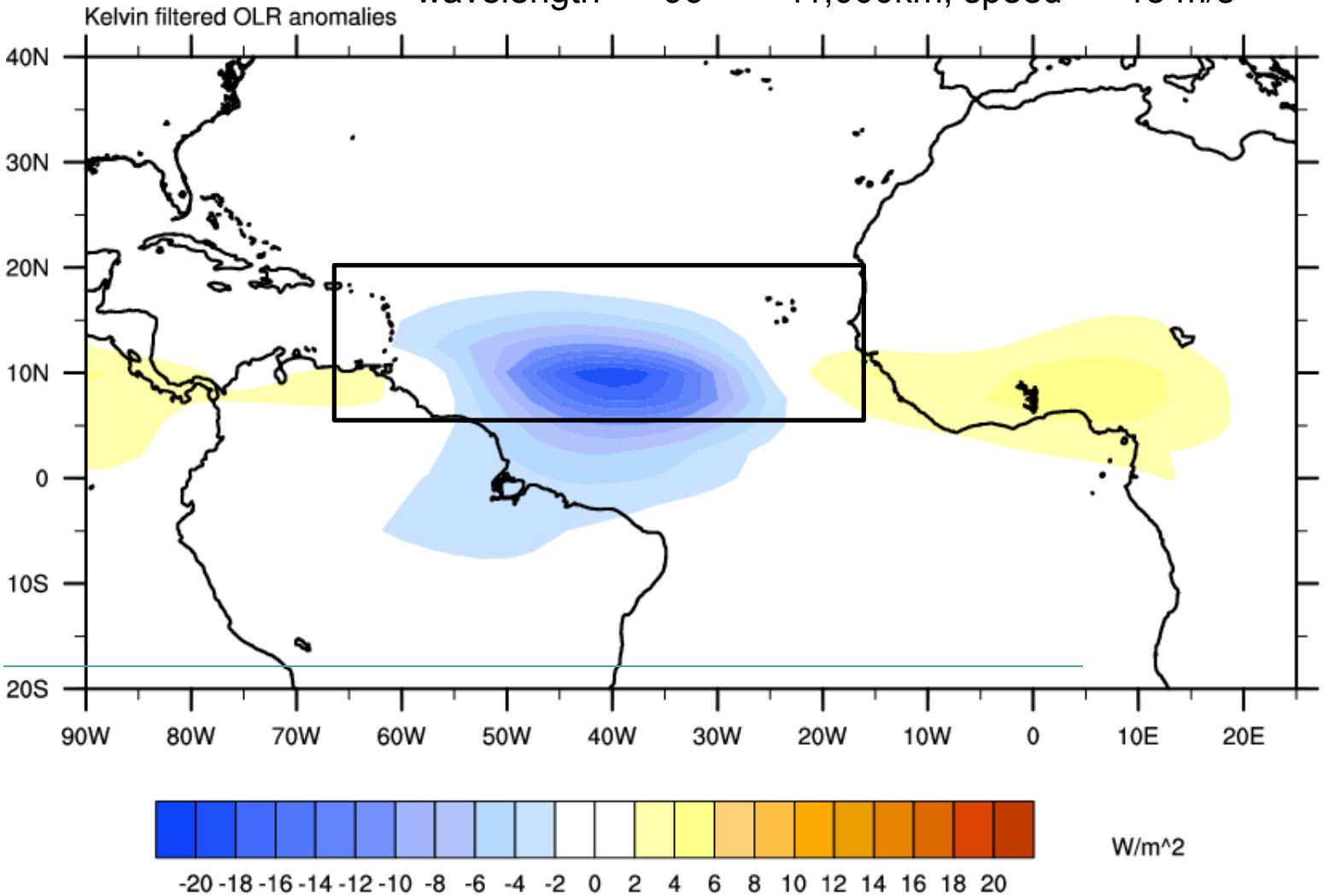
   (ii) Intensity Change

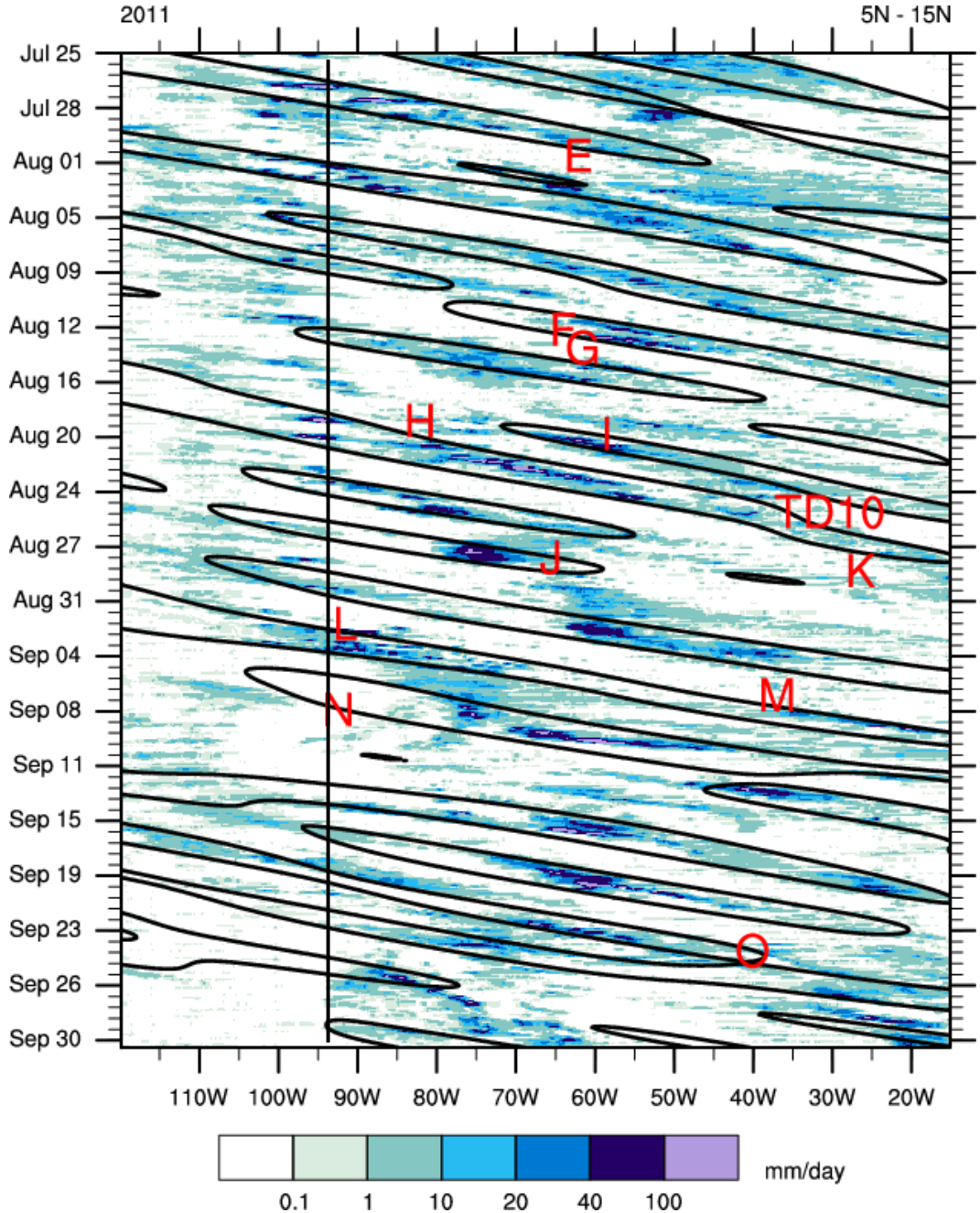
2. Forecasting tools for HS3

Scale!

Composite Convectively Coupled Kelvin Wave

wavelength = ~96° = ~11,000km, speed = ~15 m/s

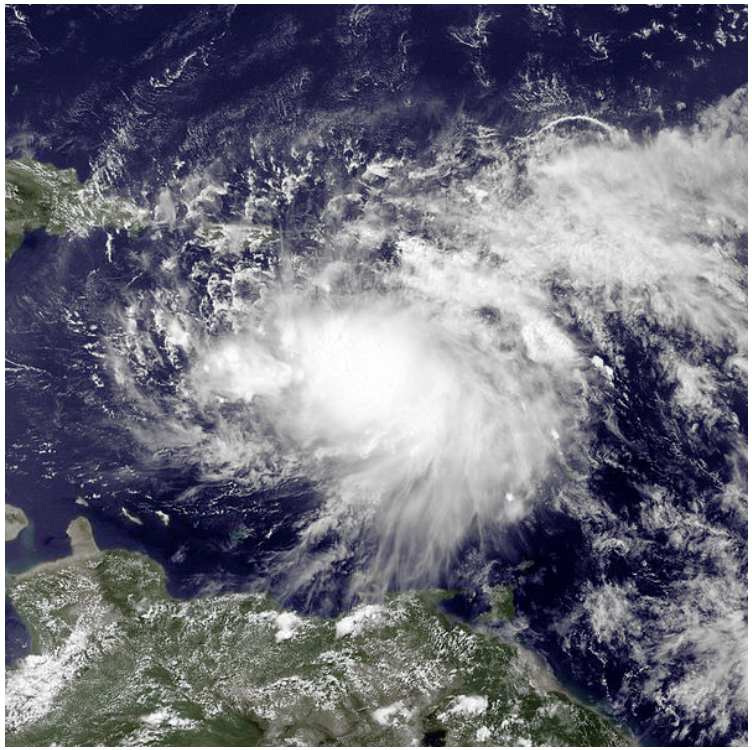




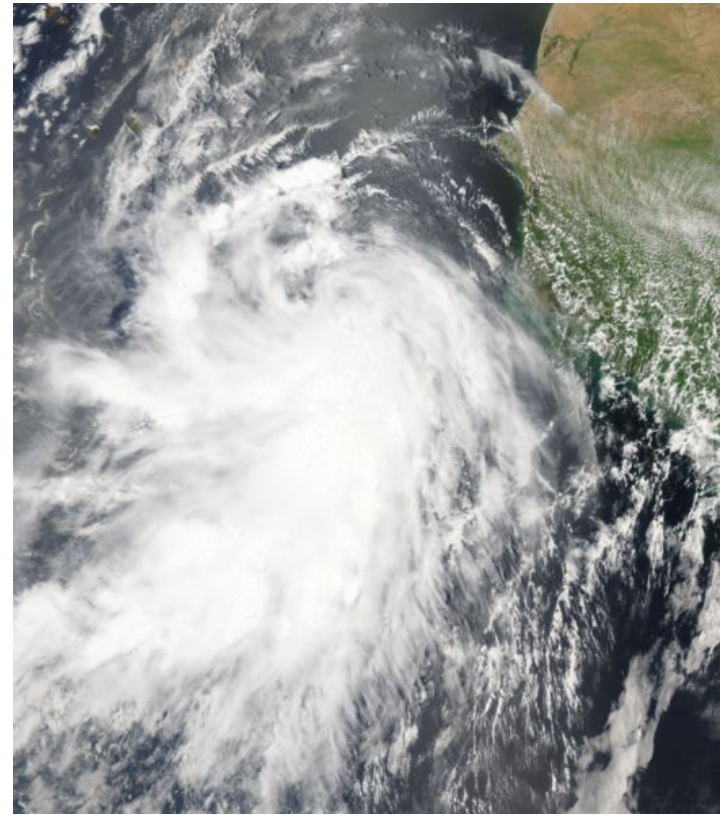
Shaded: Unfiltered positive TRMM 3B42 rain rate anomalies

Contours: Positive Kelvin filtered TRMM 3B42 rain rate anomalies – 2 mm/day contour

CCKWs and Atlantic Tropical Cyclogenesis



Tropical Storm Emily (2011)



Tropical Storm Debby (2006)

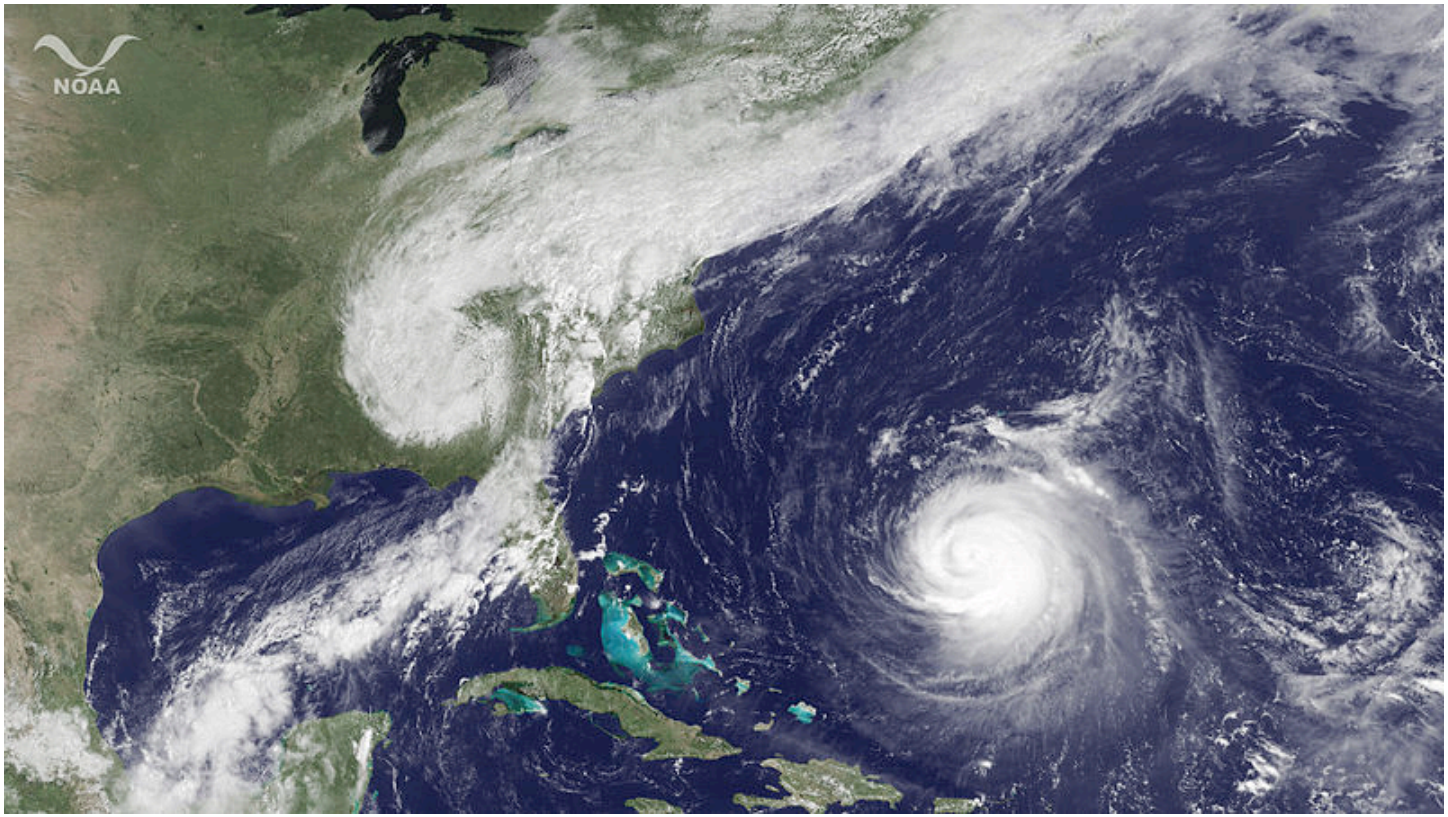
What are the different mechanisms that can explain genesis?

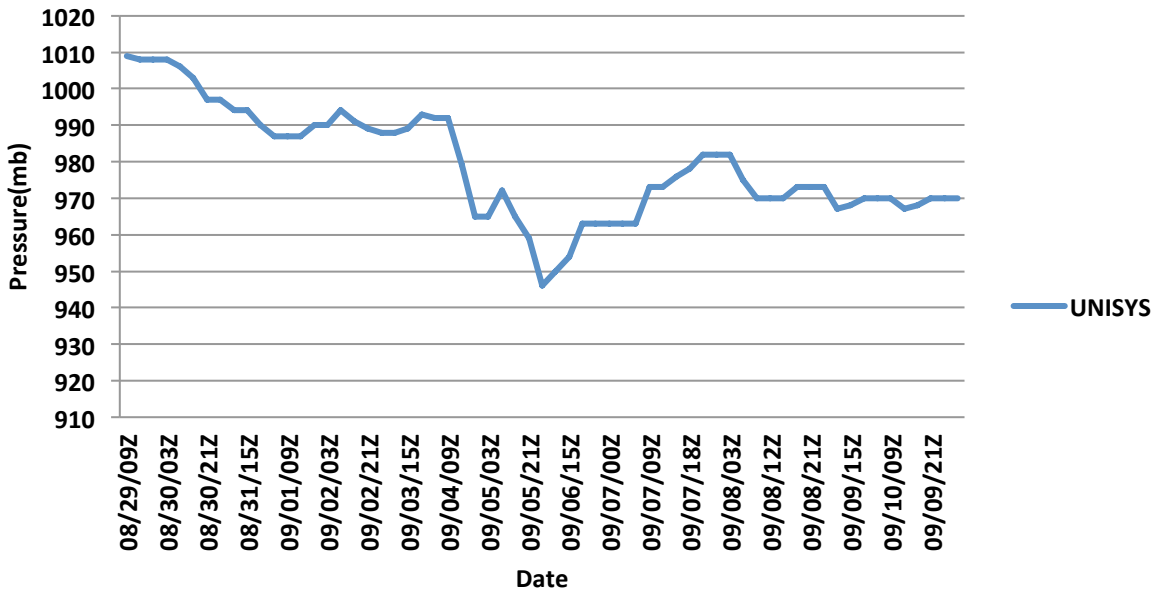
We know that CCKWs modulate the large-scale environment favorable for genesis (Ventrice et al. 2012)

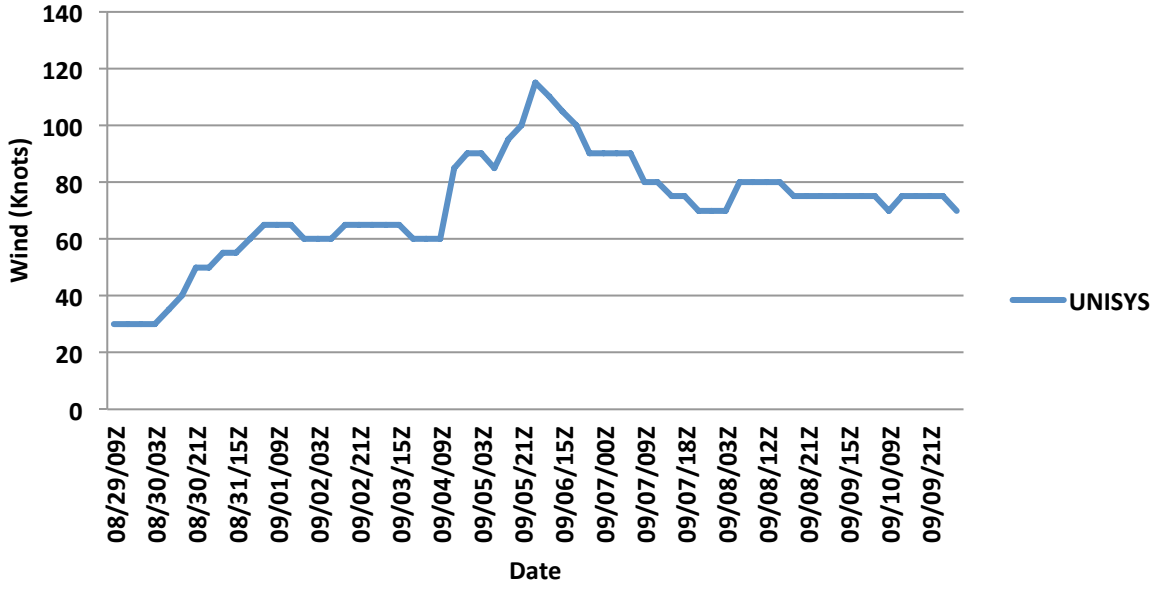
Can CCKWs trigger seedlings that later becomes TCs?

Hurricane Katia:

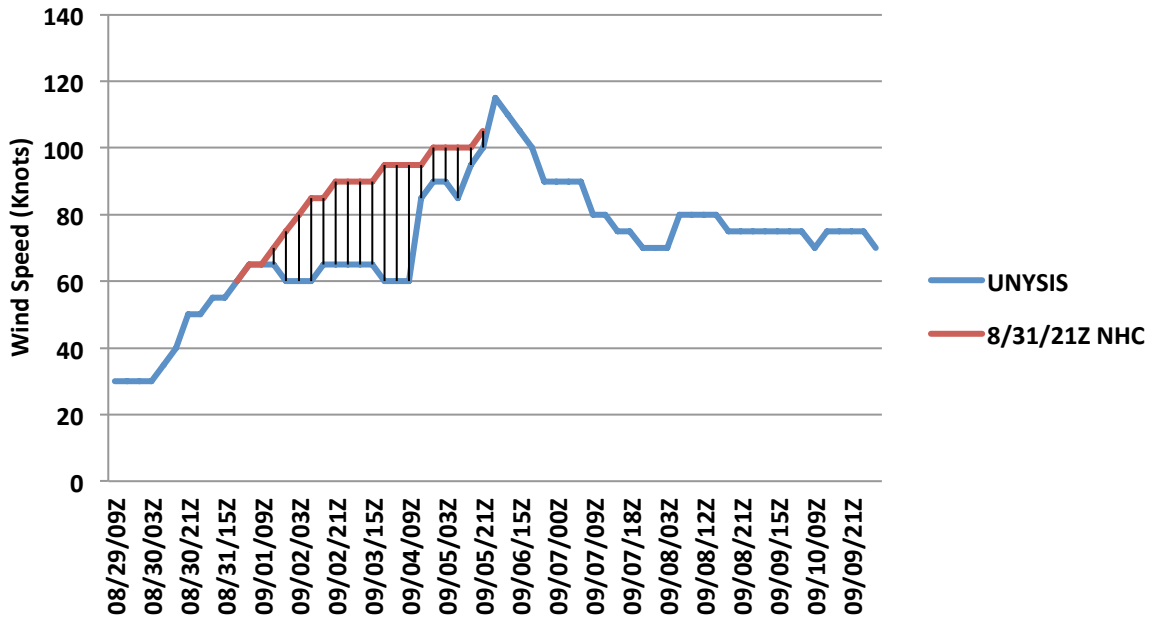
Evidence for the influence of a CCKW on intensity




1020
1010
1000
990
980
970
960
950
940
930
920
910
Pressure(mb)
08/29/09Z
08/30/03Z
08/30/21Z
08/31/15Z
09/01/09Z
09/02/03Z
09/02/21Z
09/03/15Z
09/04/09Z
09/05/03Z
09/05/21Z
09/06/15Z
09/07/00Z
09/07/09Z
09/07/18Z
09/08/03Z
09/08/12Z
09/08/21Z
09/09/15Z
09/10/09Z
09/09/21Z
Date
UNISYS

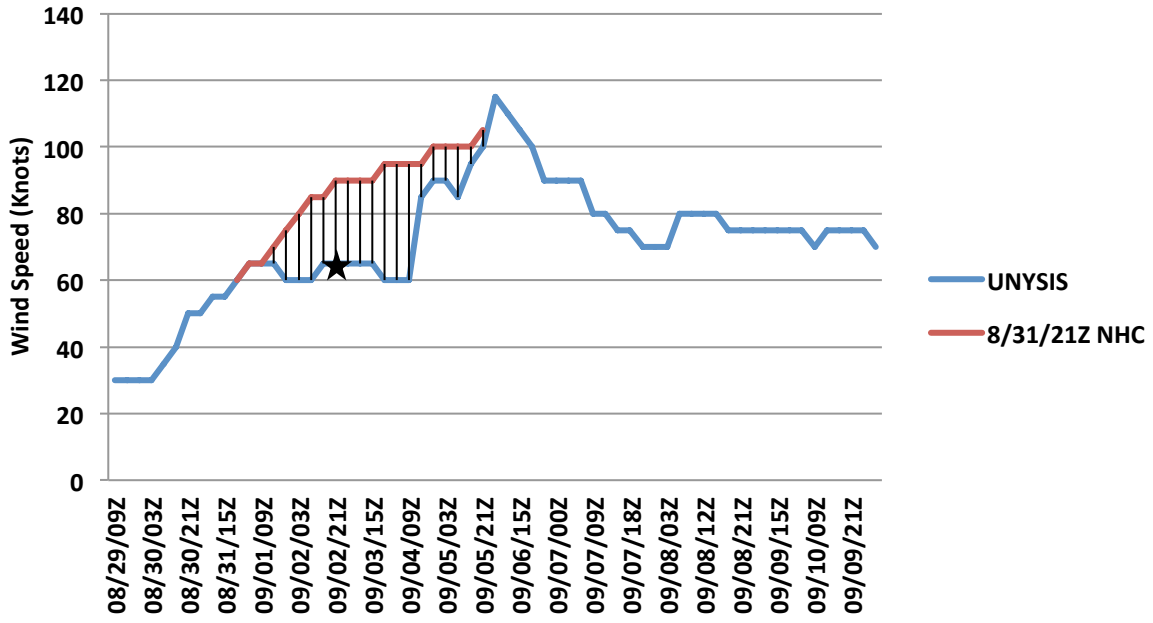

140
120
100
80
60
40
20
0
Wind (Knots)
08/29/09Z
08/30/03Z
08/30/21Z
08/31/15Z
09/01/09Z
09/02/03Z
09/02/21Z
09/03/15Z
09/04/09Z
09/05/03Z
09/05/21Z
09/06/15Z
09/07/00Z
09/07/09Z
09/07/18Z
09/08/03Z
09/08/12Z
09/08/21Z
09/09/15Z
09/10/09Z
09/09/21Z
Date
UNISYS

WEAK VERTICAL SHEAR AND MODESTLY WARM WATERS ARE LIKELY TO PREVAIL OVER THE NEXT FEW DAYS...SO CONTINUED INTENSIFICATION IS FORECAST. A LARGE UPPER-LEVEL LOW TO THE NORTHWEST OF KATIA COULD CAUSE AN INCREASE IN SHEAR...AND INHIBIT INTENSIFICATION...LATE IN THE FORECAST PERIOD.

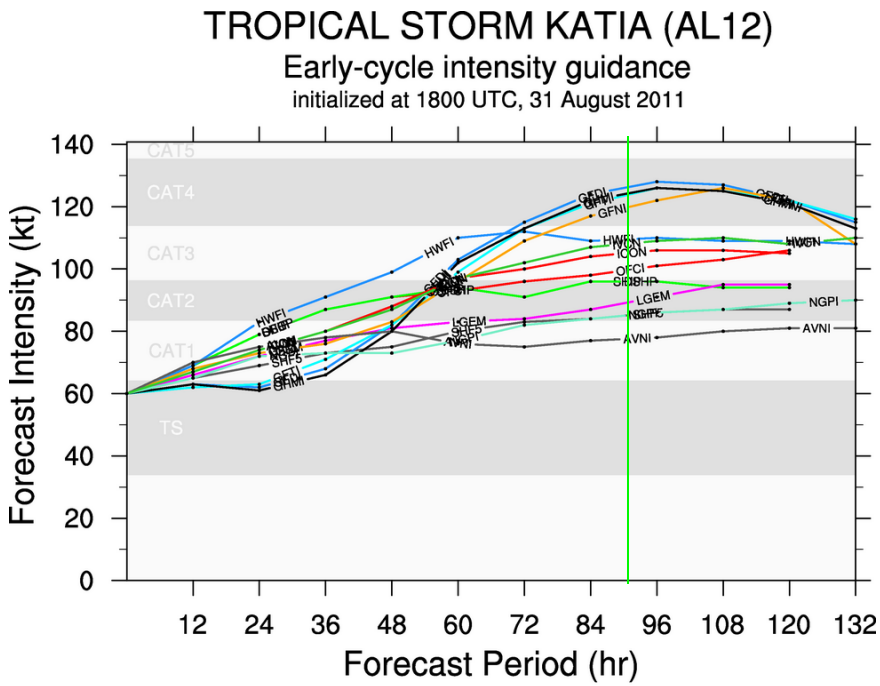


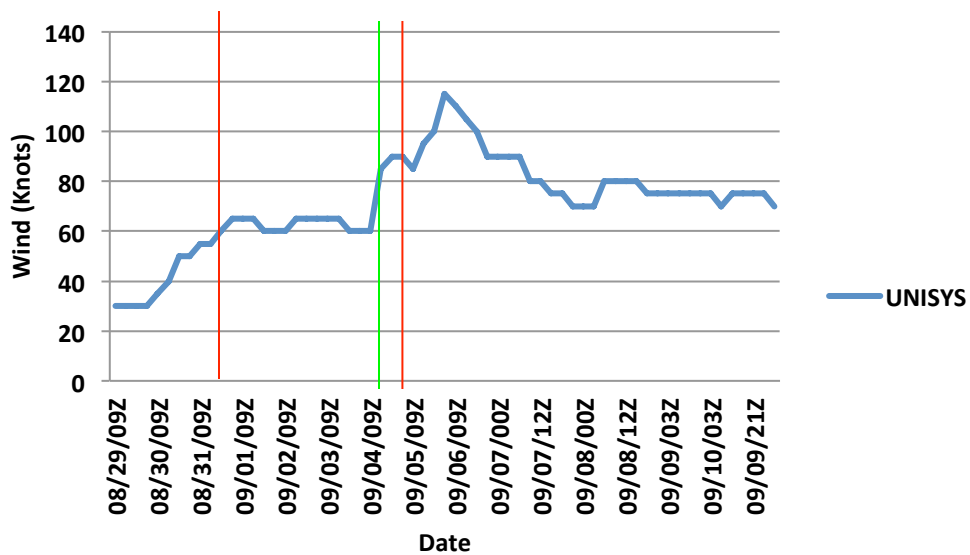
Two days later…

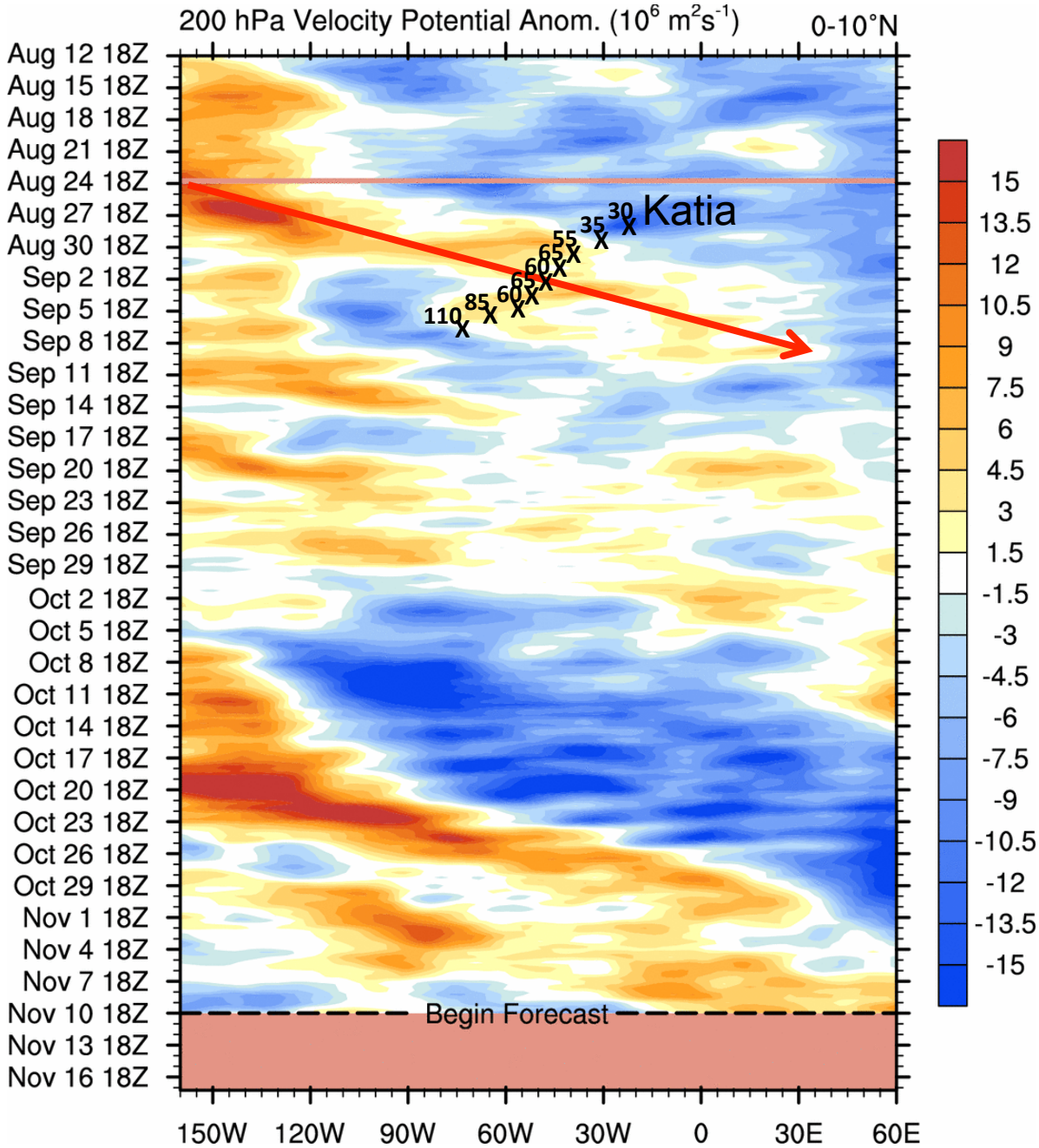
NEEDLESS TO SAY…THE INTENSITY FORECAST IS … COMPLEX.

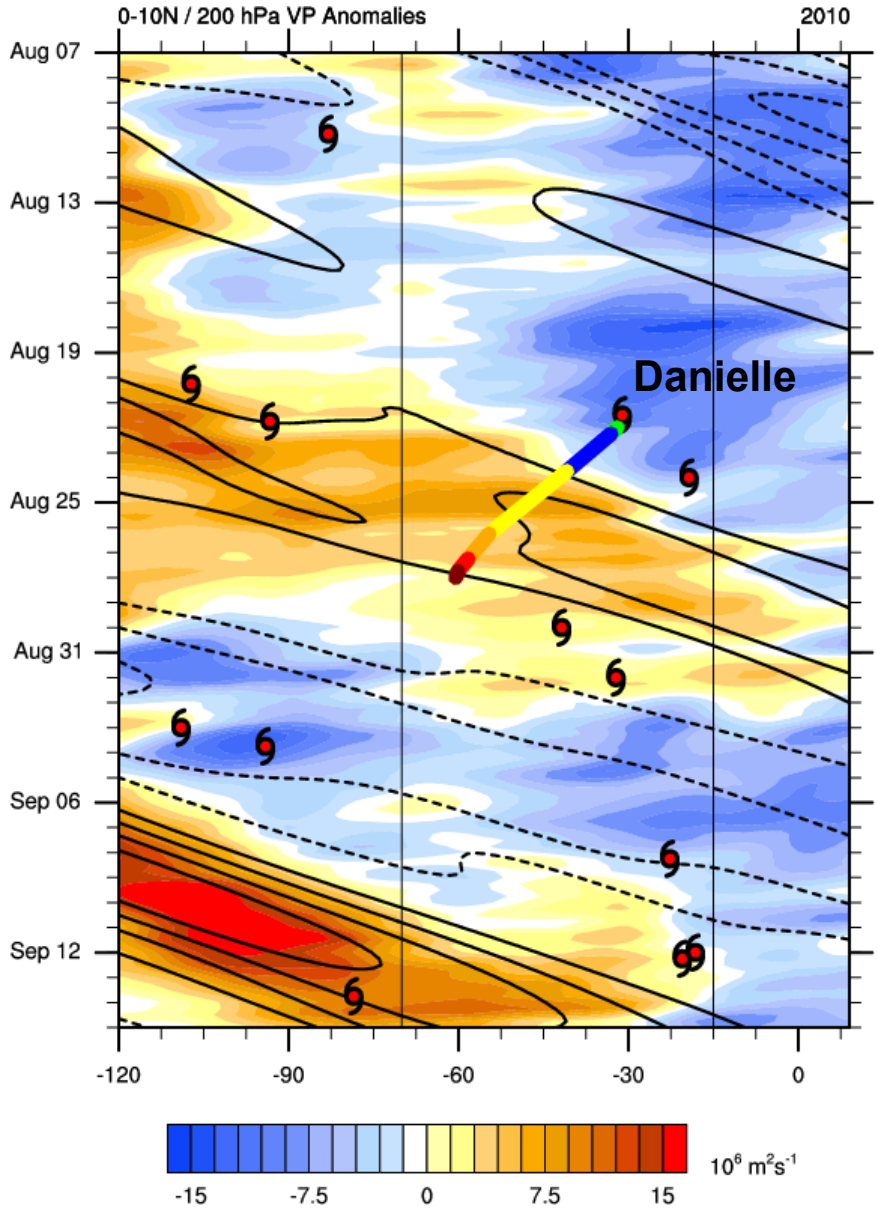


Model Forecasts






200 hPa Velocity Potential Anom. (10^6 m^2s^{-1})
0-10°N
Aug 12 18Z
Aug 15 18Z
Aug 18 18Z
Aug 21 18Z
Aug 24 18Z
Aug 27 18Z
Aug 30 18Z
Sep 2 18Z
Sep 5 18Z
Sep 8 18Z
Sep 11 18Z
Sep 14 18Z
Sep 17 18Z
Sep 20 18Z
Sep 23 18Z
Sep 26 18Z
Sep 29 18Z
Oct 2 18Z
Oct 5 18Z
Oct 8 18Z
Oct 11 18Z
Oct 14 18Z
Oct 17 18Z
Oct 20 18Z
Oct 23 18Z
Oct 26 18Z
Oct 29 18Z
Nov 1 18Z
Nov 4 18Z
Nov 7 18Z
Nov 10 18Z
Nov 13 18Z
Nov 16 18Z
Katia
30
35
55
65
60
65
60
85
110
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

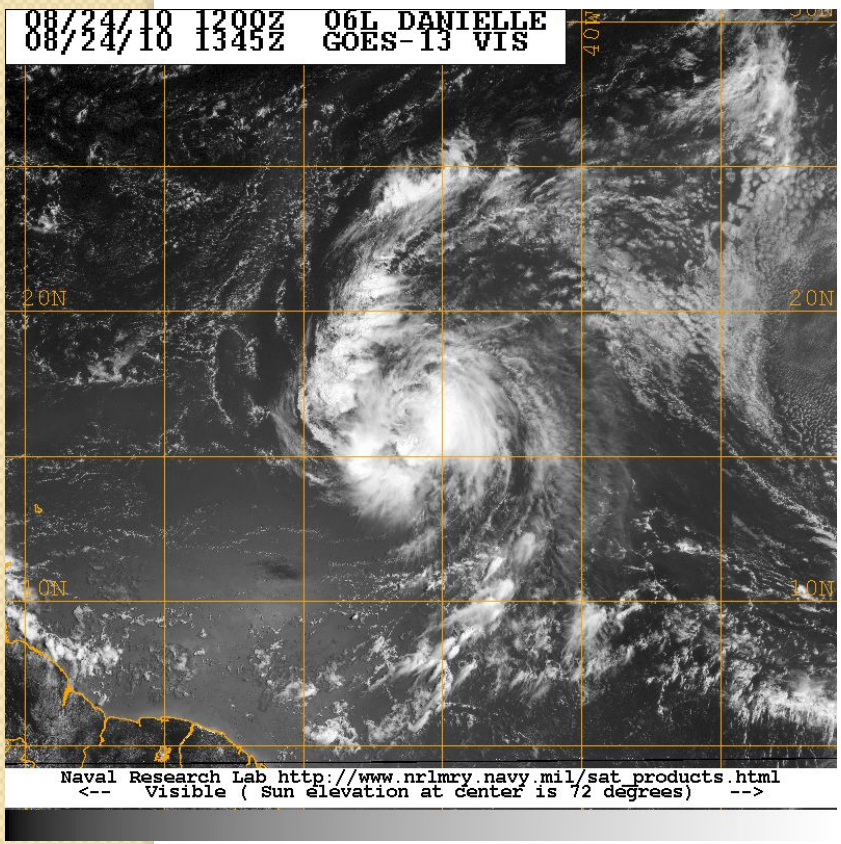


Tropical Depression **Tropical Storm**
Cat. 1 **Cat. 2** **Cat. 3** **Cat. 4**

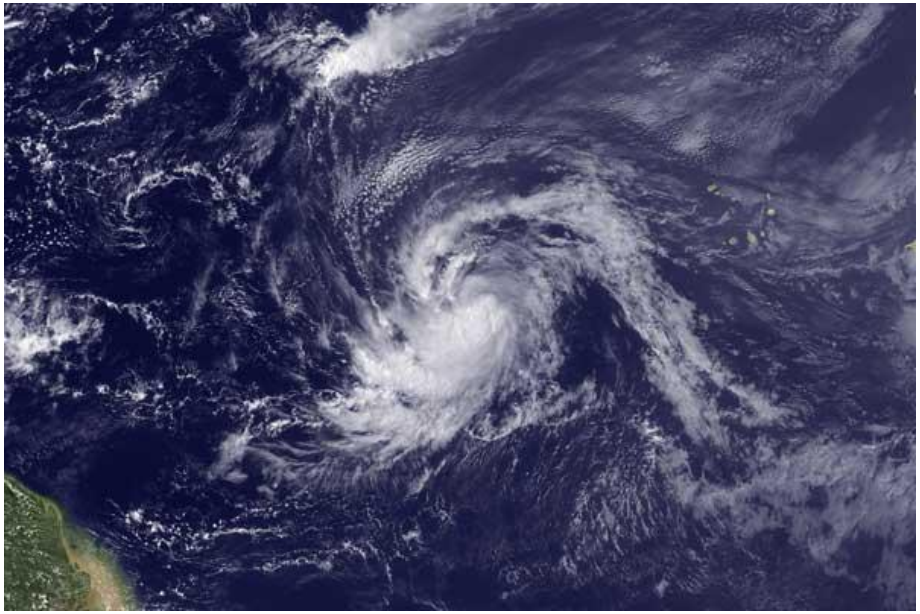
Recall that Danielle (2010) weakened during the superposition of a suppressed Kelvin wave phase.

-Preliminary evidence shows that Earl also struggled to intensify in the unfavorable environment associated with the suppressed Kelvin wave phase – GRIP talk

Comparison of Danielle (2010) and Katia (2011) during their unexpected weakening/stalling phase



9/4/2011 Katia

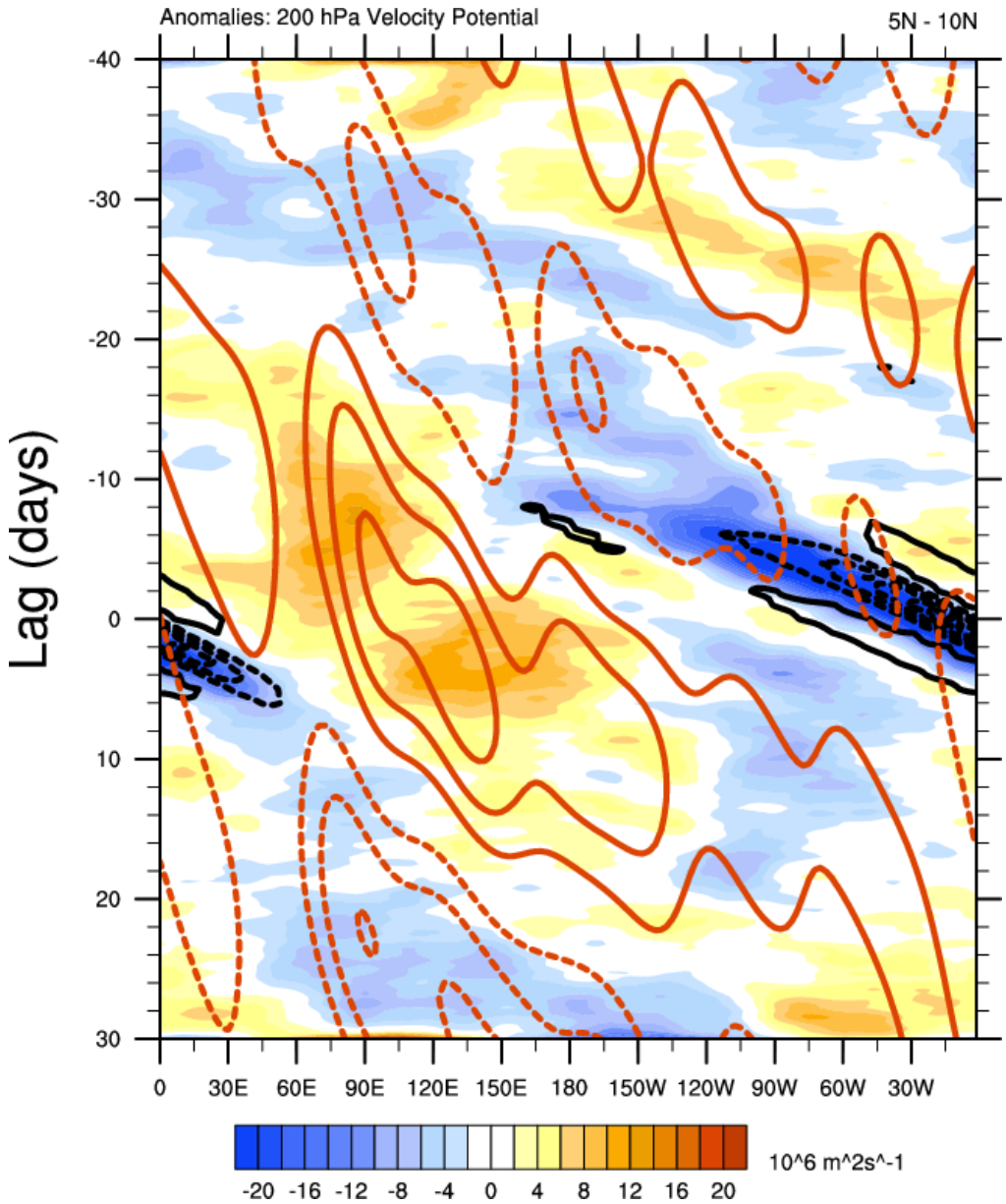


What mechanisms can explain this?

Do CCKWs provide favorable shear for penetration of dry air?

Do CCKWs more simply suppress convection through subsidence?

Predictability?



Apparent Phasing with MJO over Western Hemisphere

Ventrice et al. 2012

Tools for Monitoring and Predicting CCKWs and the MJO

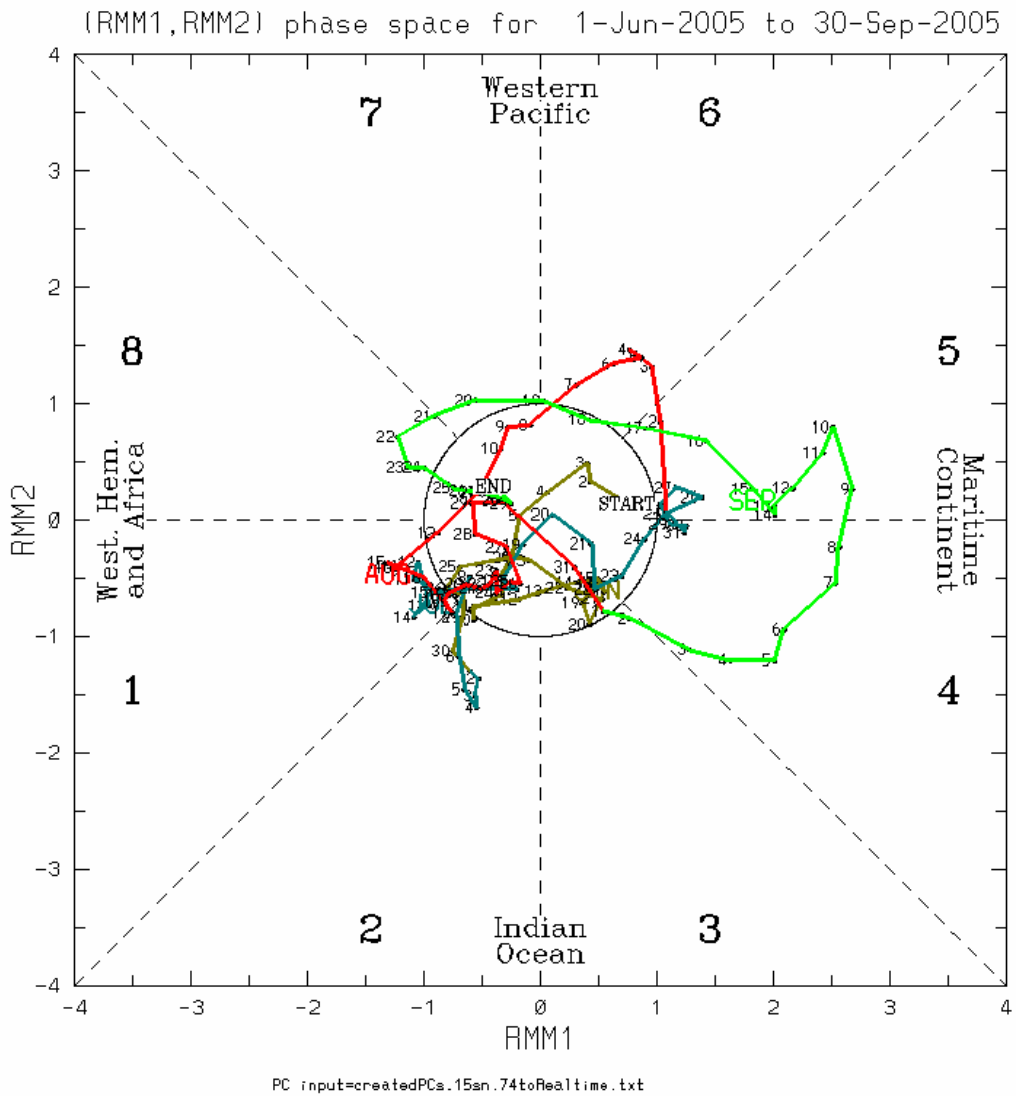
In addition to monitoring and predicting CCKWs during HS3, it is essential to do the same for the MJO

The MJO itself is important for intraseasonal variability of Atlantic tropical cyclogenesis (e.g., Maloney and Shaman 2008; Klotzbach 2010; Ventrice et al. 2011)

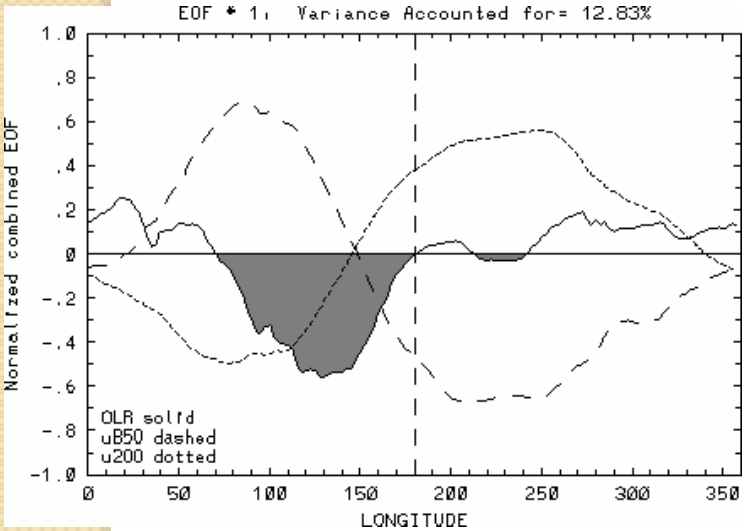
CCKWs are stronger within the convectively active phase of the MJO

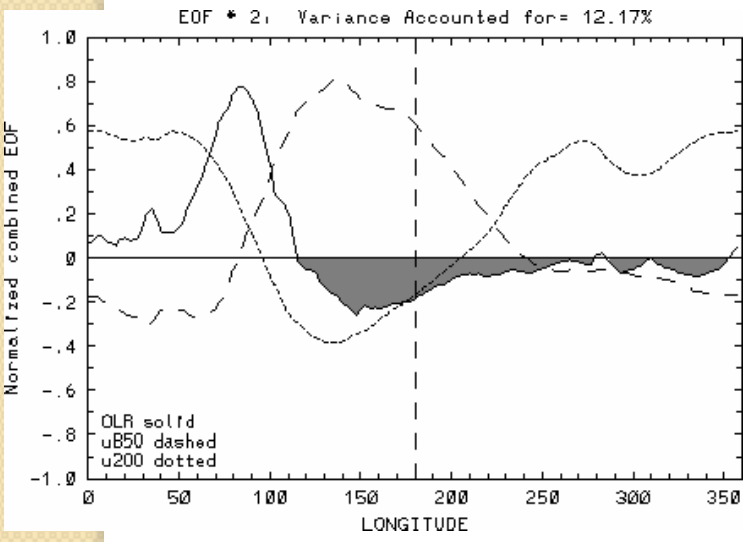
MJO monitoring provides long-term outlook, whereas CCKWs are more of a medium-short term outlook

Wheeler and Hendon (2004)
RMM Phase Space



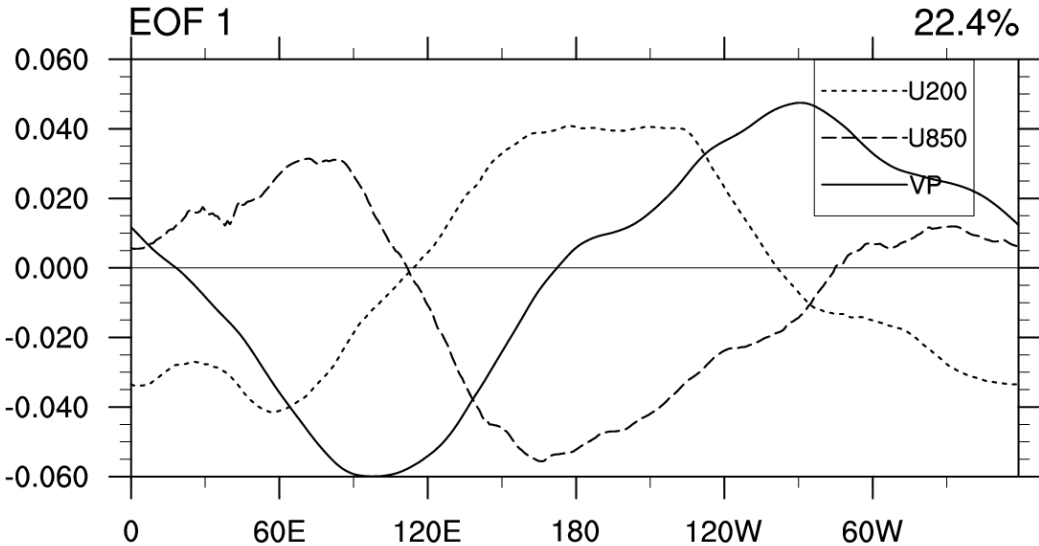
OLR

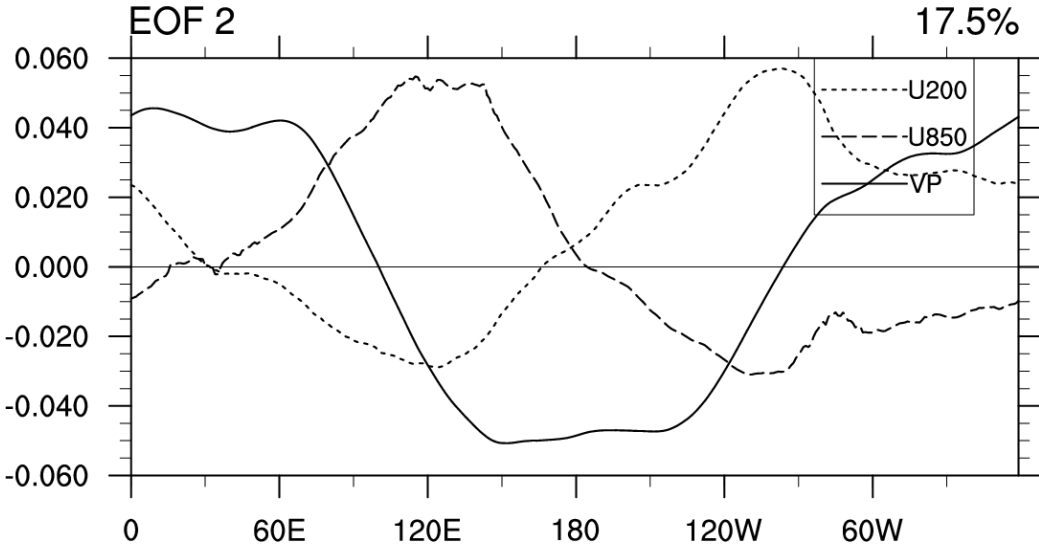




200 hPa VP

Multivariate EOF: 15S-15N

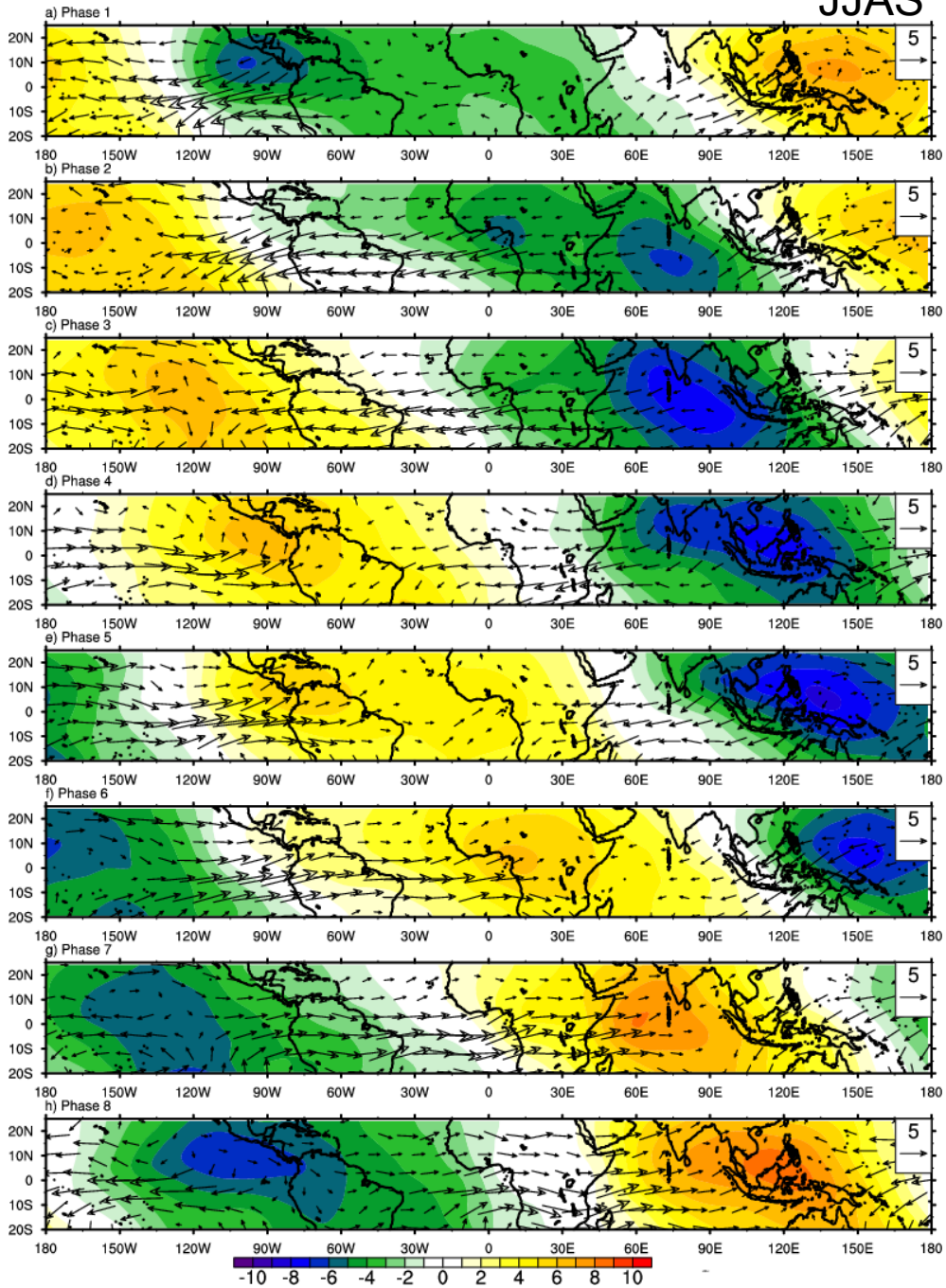




JJAS

Shaded: 200 hPa VP anomalies

Vectors: 200 hPa wind



N=155

N=261

N=224

N=116

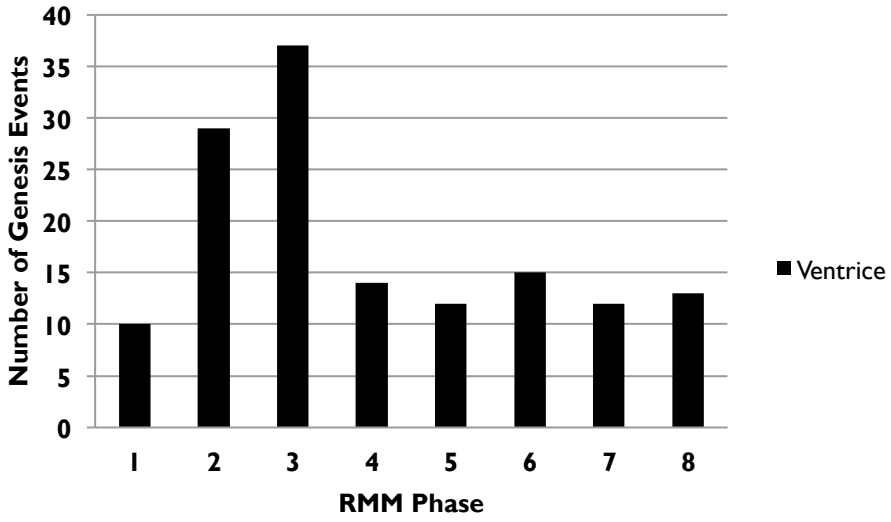
N=187

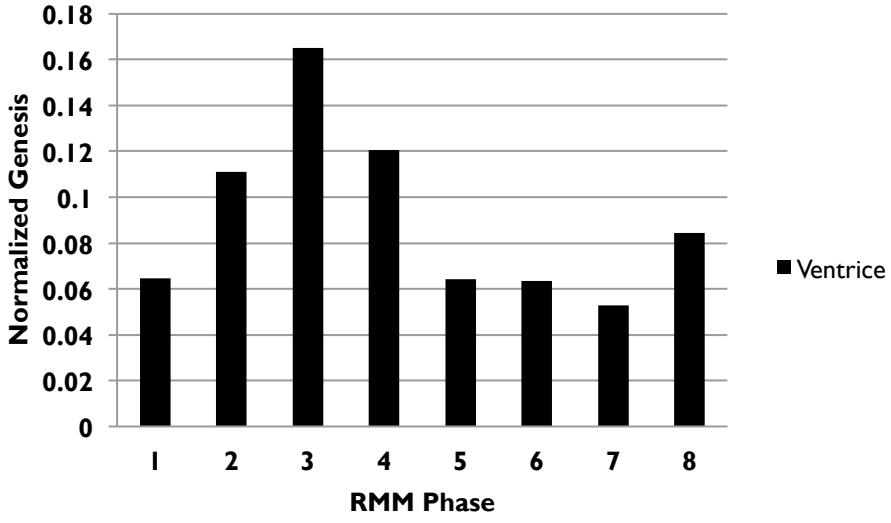
N=236

N=227

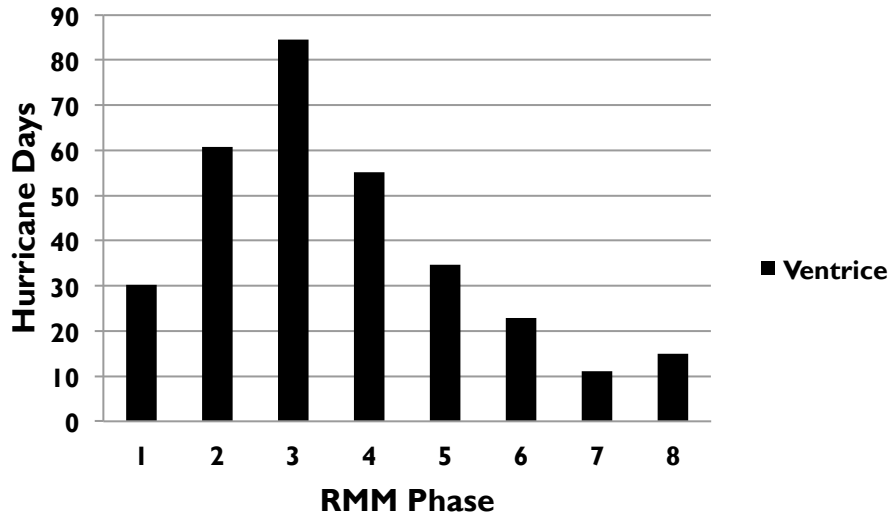
N=154

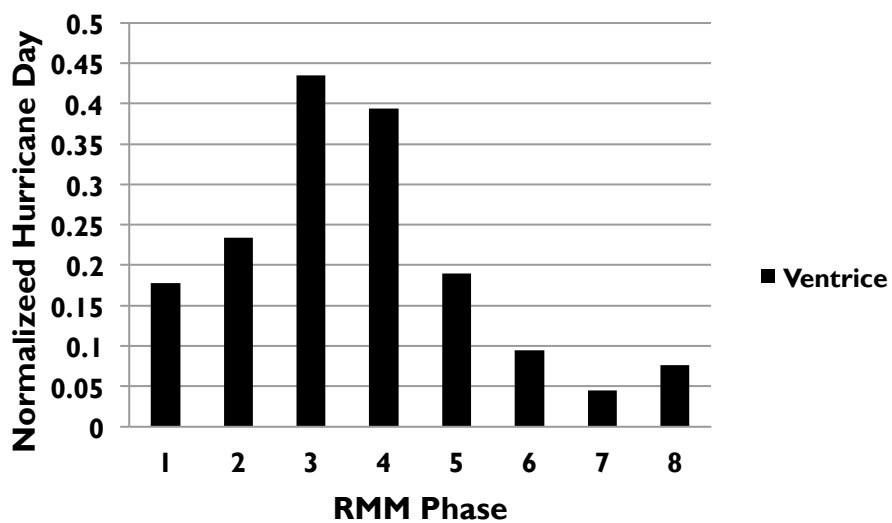
JJAS Atlantic TC Genesis





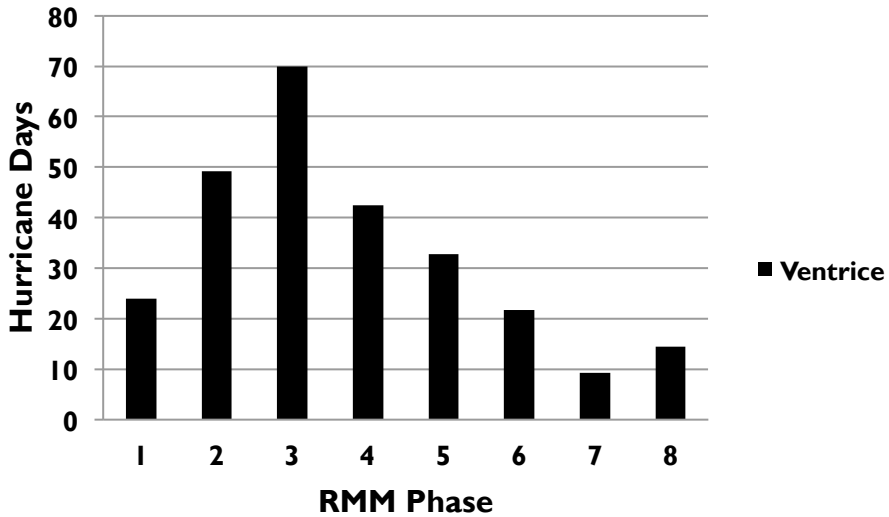
JASO Atlantic Hurricane Days
1989-2010

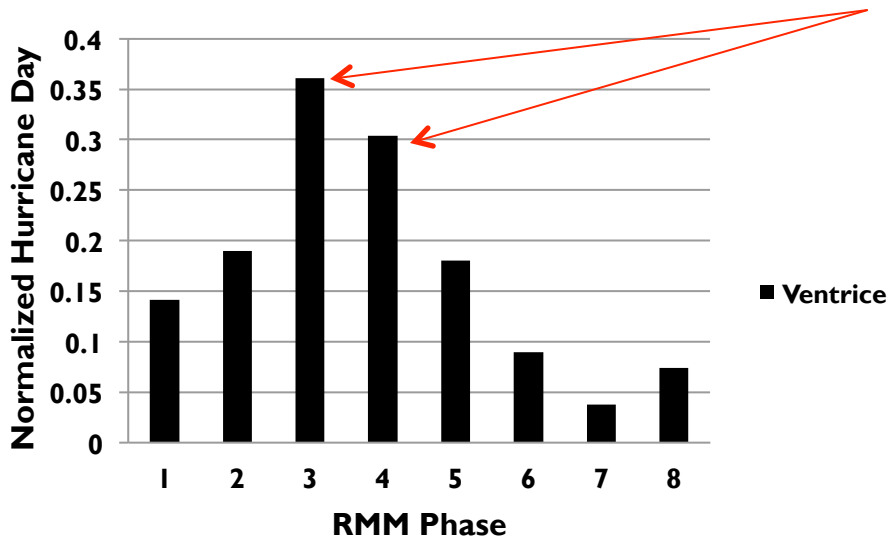




With a 5 day running average, multiple TCs on a given day count as multiple hurricane days

JASO Atlantic Hurricane Days
1989-2010





Greater than a 30% of a hurricane being active in the Atlantic Basin during RMM Phases 3 and 4 when amplitudes > 1sigma

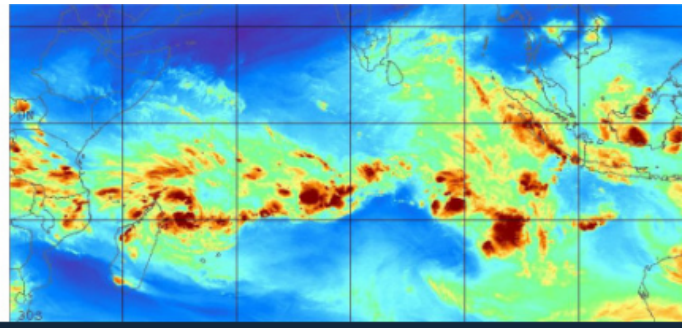
No 5 day running average and counts one storm only per day

Real-Time Monitoring Web Page

http://mikeventrice.weebly.com/index.html

College of Arts and Sciences
University at Albany

NASA Hurricane and Severe Storm Sentinel HS3



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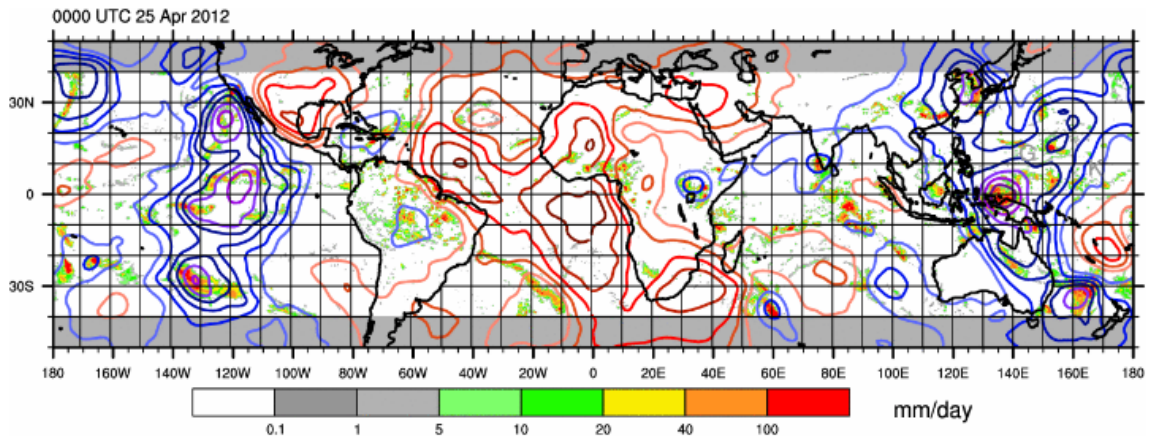
Albany Radar | Tropical Atlantic WV | Anomalous Global TRMM Rain Rates and 200 hPa Velocity Potential | Albany Webmail

Updates: 1) Added RMM phase space archive.

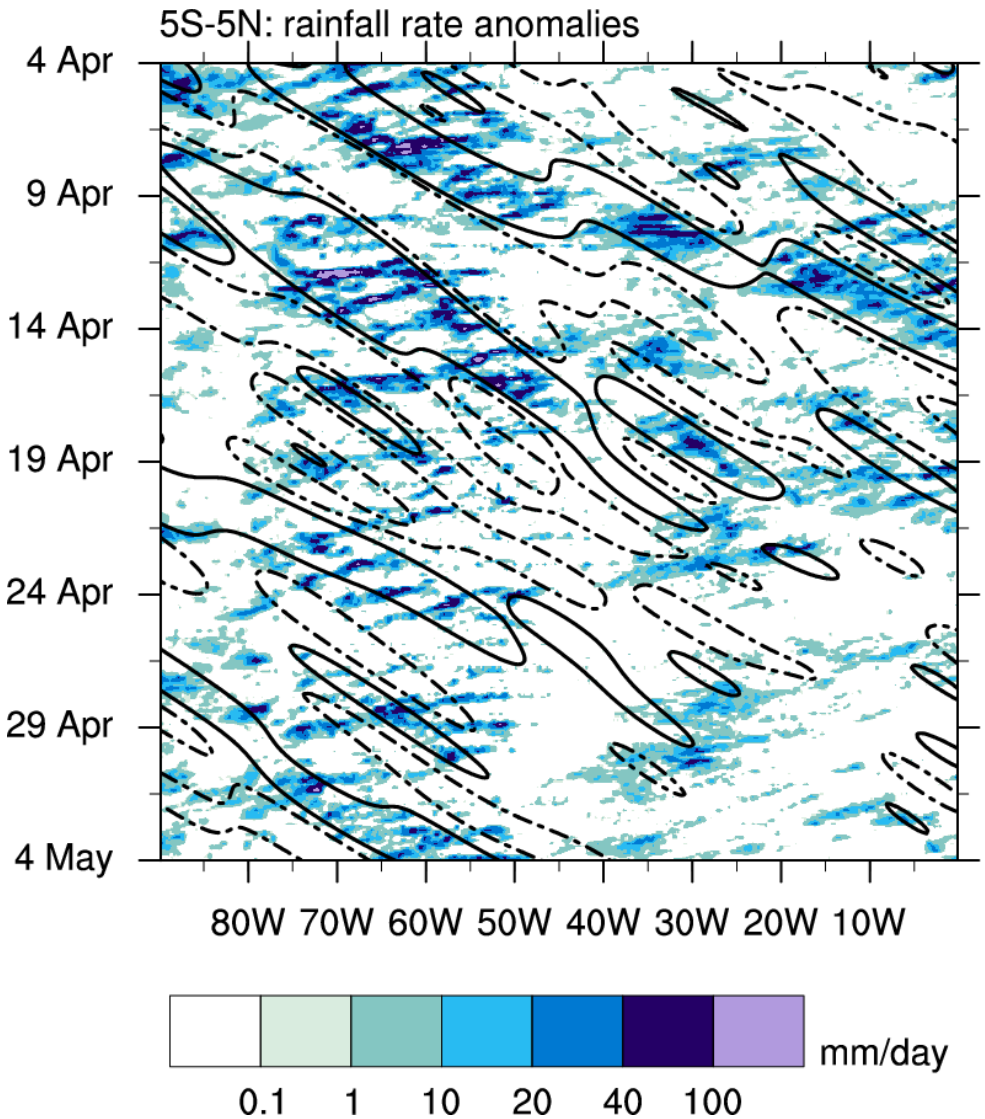


TRMM 3B42 Rain Rates (shaded) overlaid with 200 hPa Velocity Potential Anomalies (contoured)

Negative 200 hPa Velocity Potential Anomalies (Divergence) are cool-colored contours

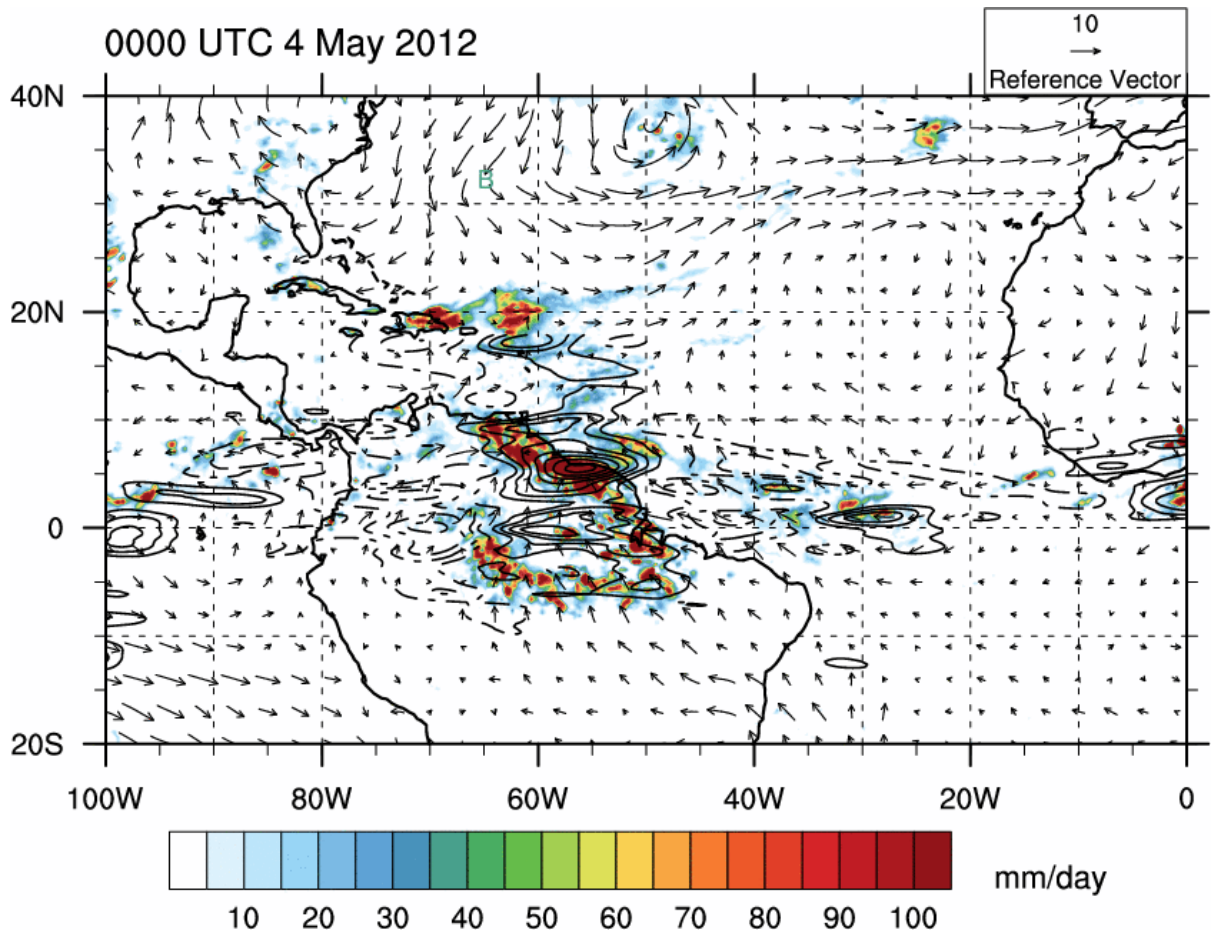
Positive 200 hPa Velocity Potential Anomalies (Convergence) are warm-colored contours

TRMM 3B42 Kelvin wave filtered rain rate Product

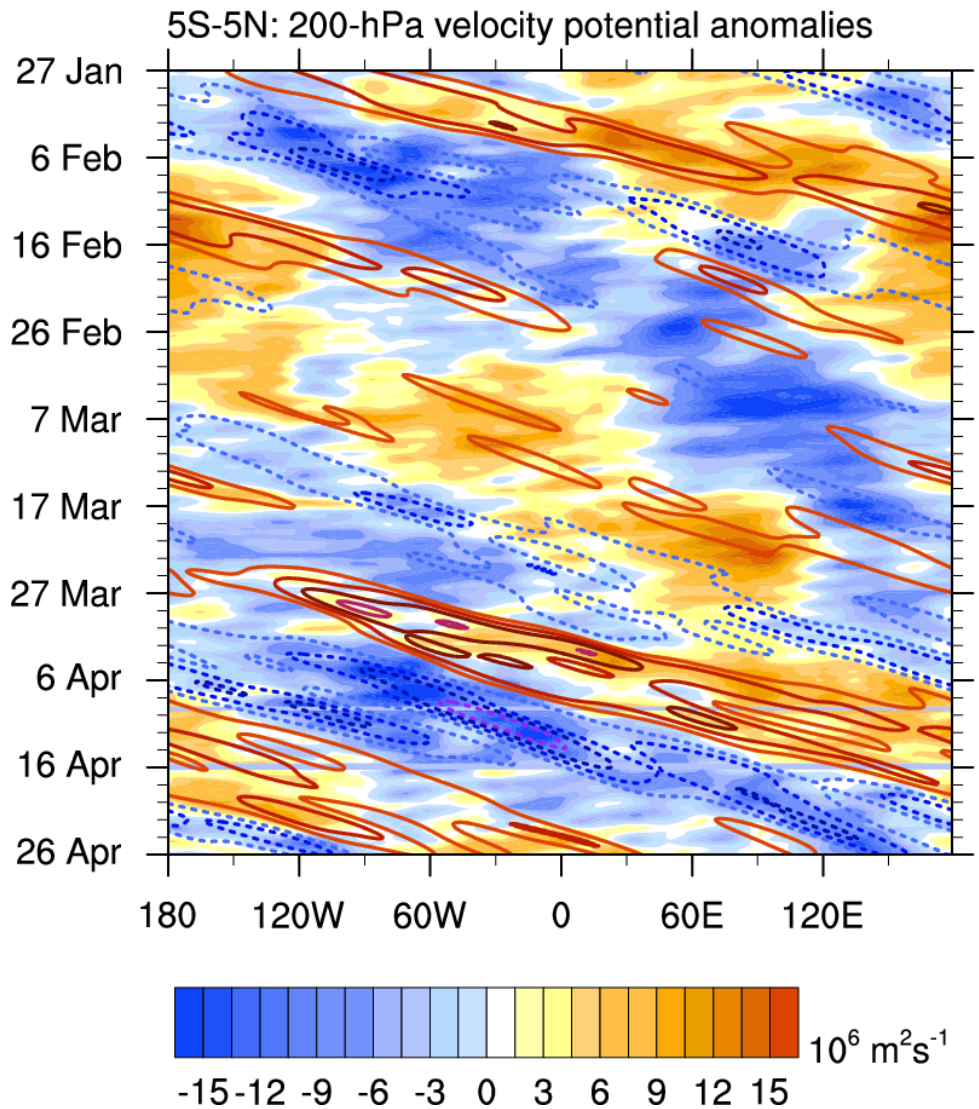


Shaded: Unfiltered TRMM 3B42 positive rain rate anomalies

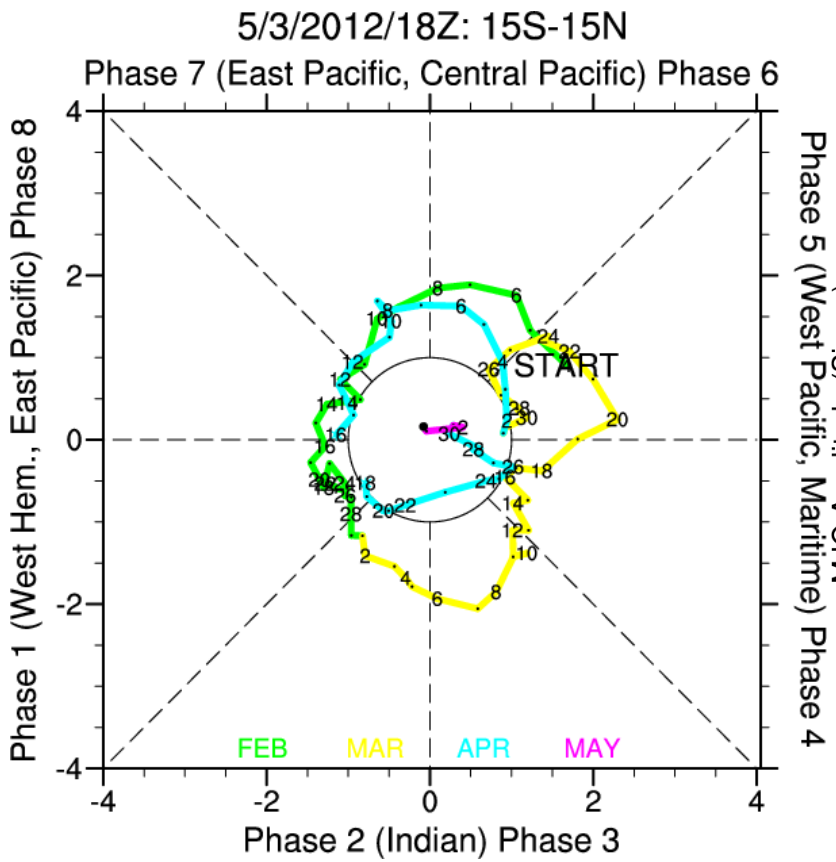
Contours: +/- 2mm per day Kelvin filtered rain rate anomaly contoured



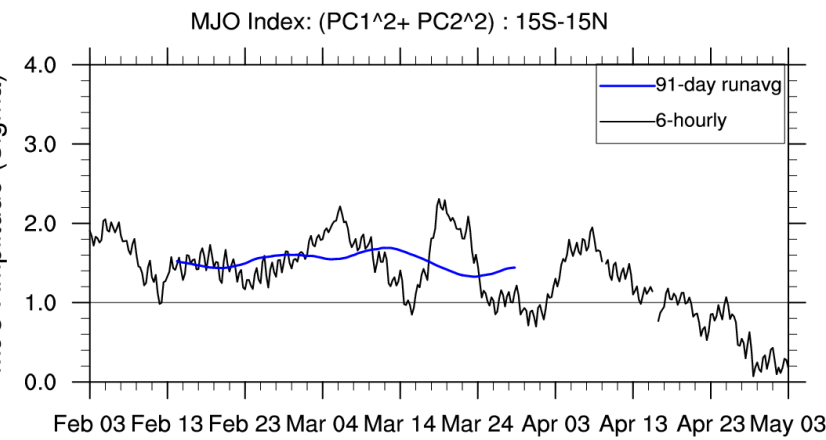
Shading: Total unfiltered TRMM 3B42 rain rates
Contours: Kelvin filtered TRMM 3B42 rain rate anomalies
Vectors: GFS 850 hPa wind anomalies



Shading: Unfiltered 200 hPa GFSV Velocity Potential anomalies
Contours: Kelvin filtered 200 hPa Velocity Potential anomalies

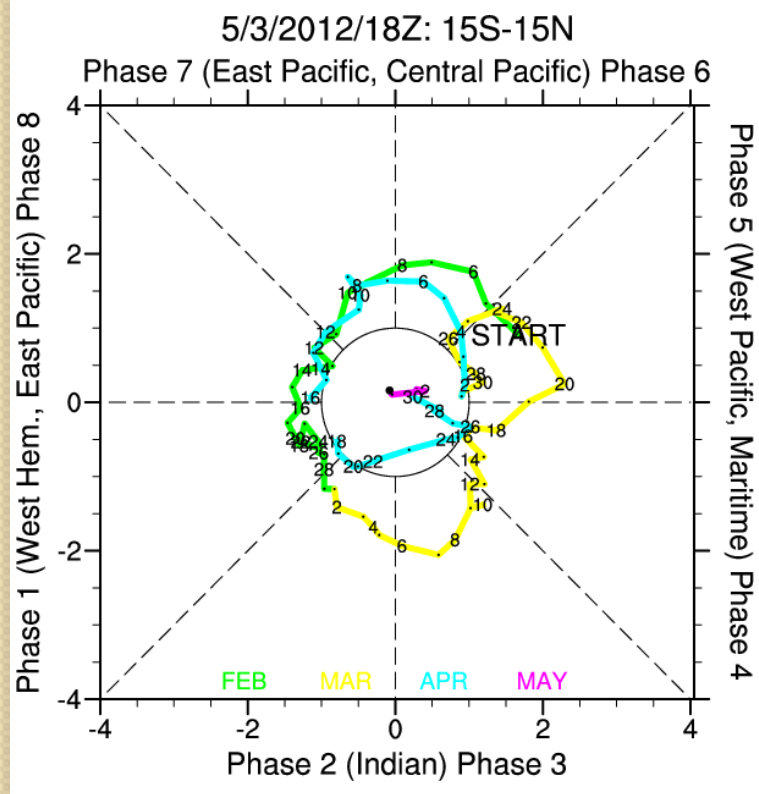


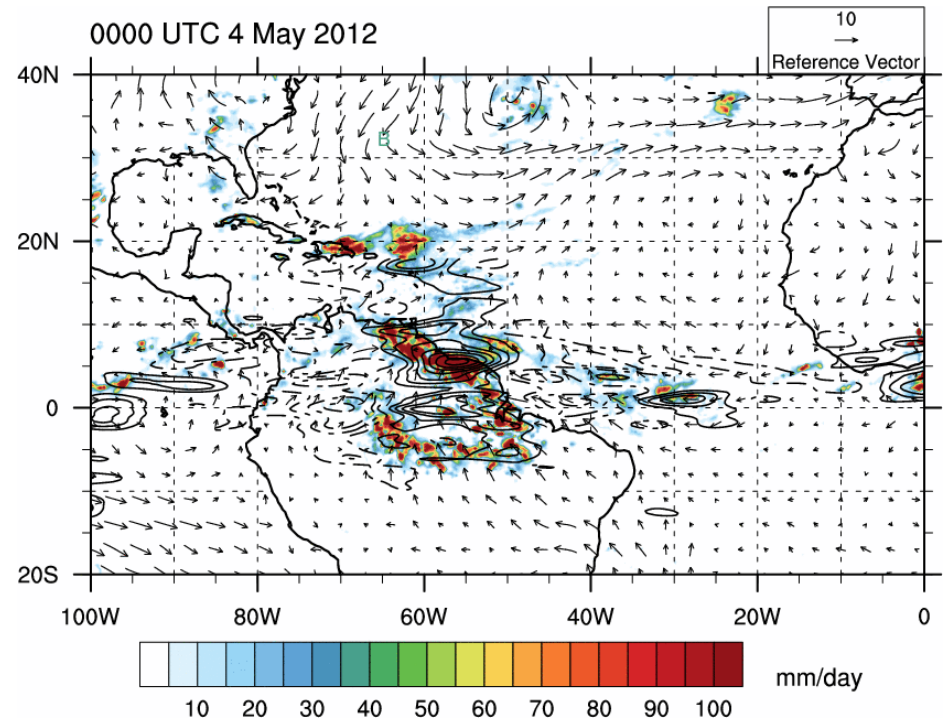
RMM Phase Space Diagram



RMM Amplitude Plot

Example Narrative of HS3 Forecast using Webpage:





For hypothetical purposes, assume it is Atlantic Hurricane Season:
"The current state of the MJO is weak.
Strong CCKW propagating eastward over South America. There is low-medium potential for the genesis of a tropical cyclone over the tropical Atlantic during the next 2-4 days."

Final Comments

CCKWs should clearly be monitored during HS3 to provide context for the short-medium range timing of genesis and possibly the intensification of tropical cyclones

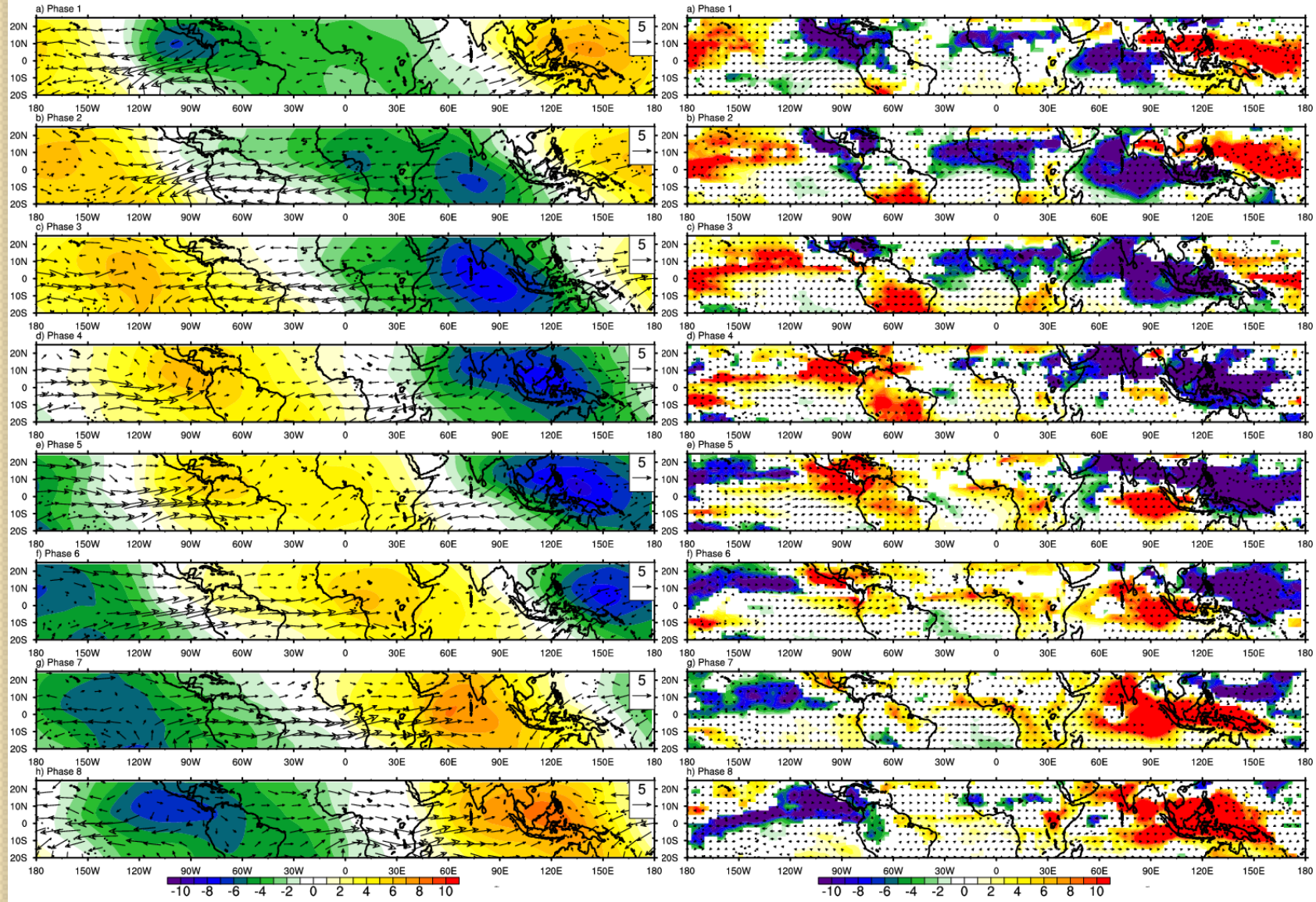
In addition to CCKWs, the MJO should be monitored for long-range predictability of the genesis and the intensification of tropical cyclones

HS3 field observations will be useful to address large-scale environmental changes over the Atlantic associated with individual CCKW and/or MJO passages

Supplemental Slides

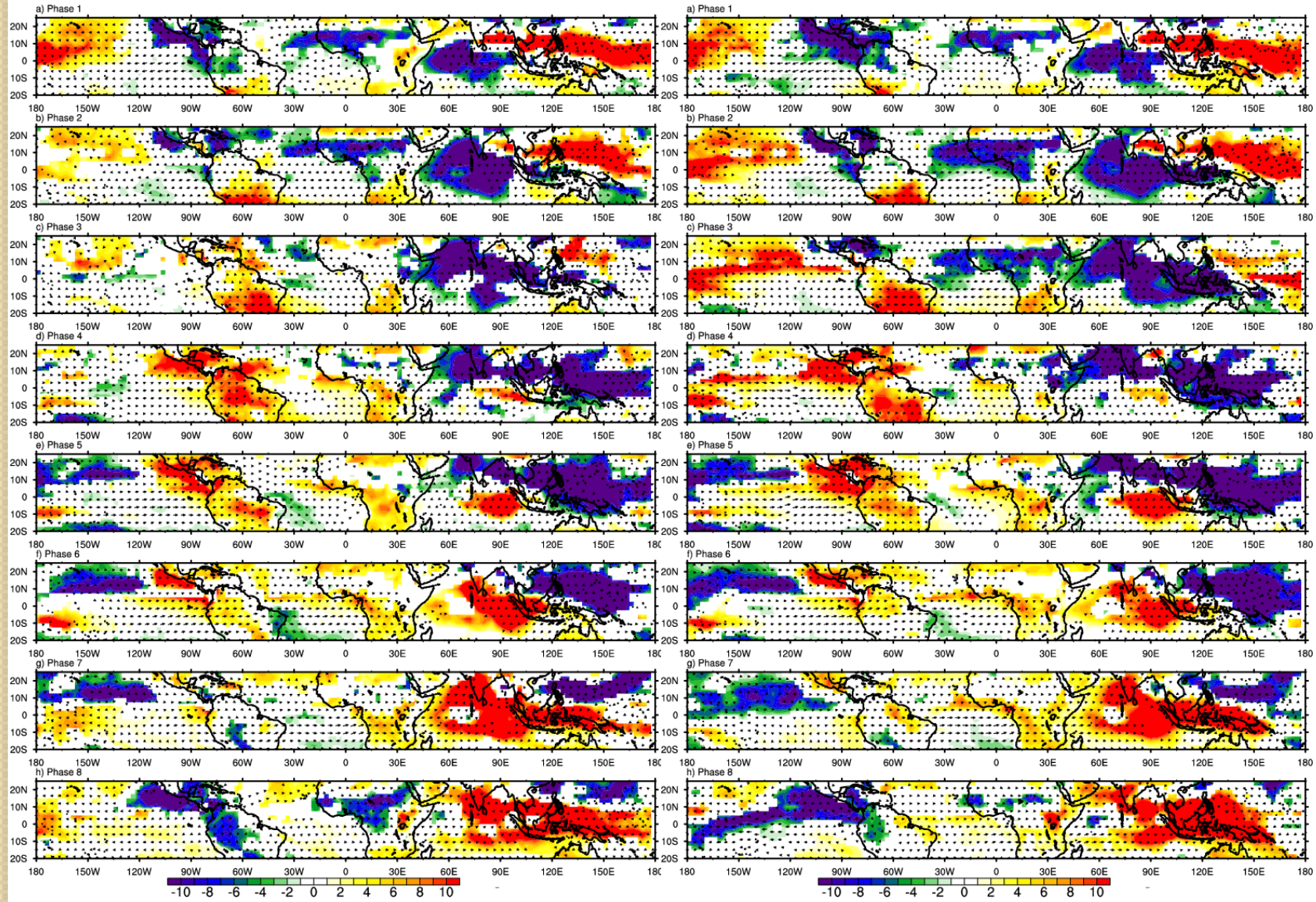
200 hPa VP

OLR

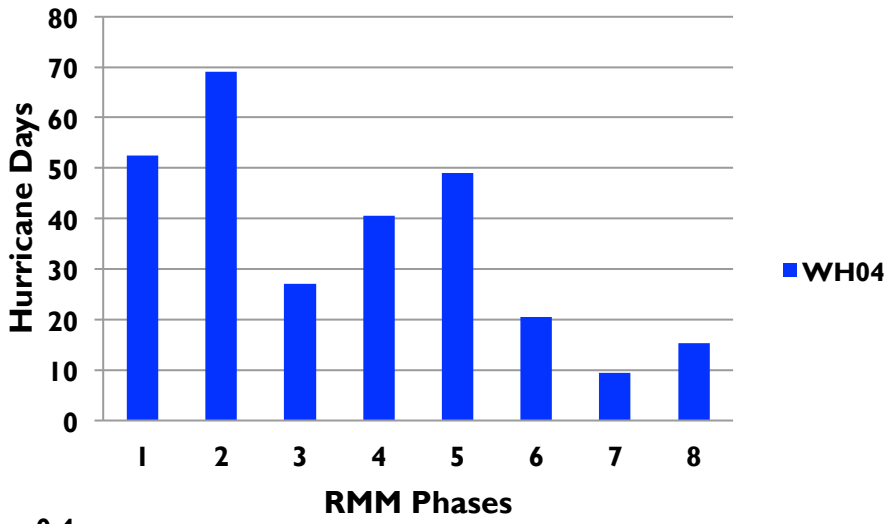


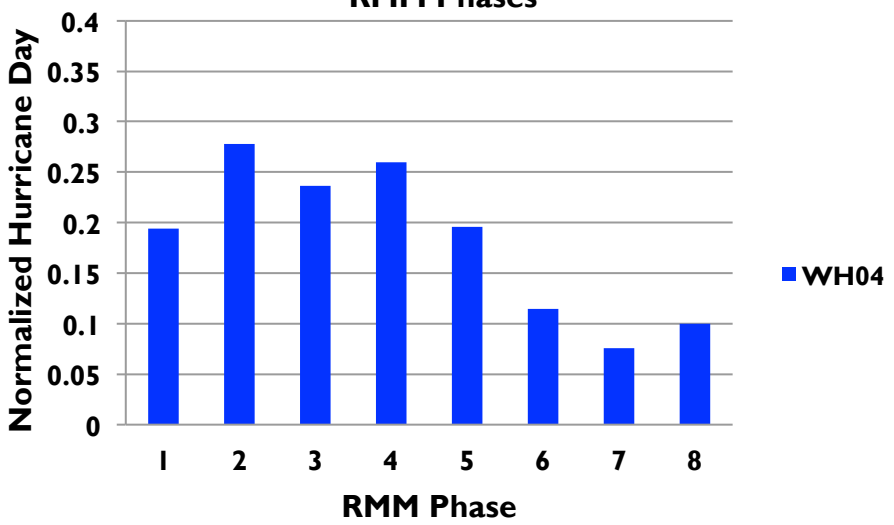
JJAS Season

WH04 | Ventrice



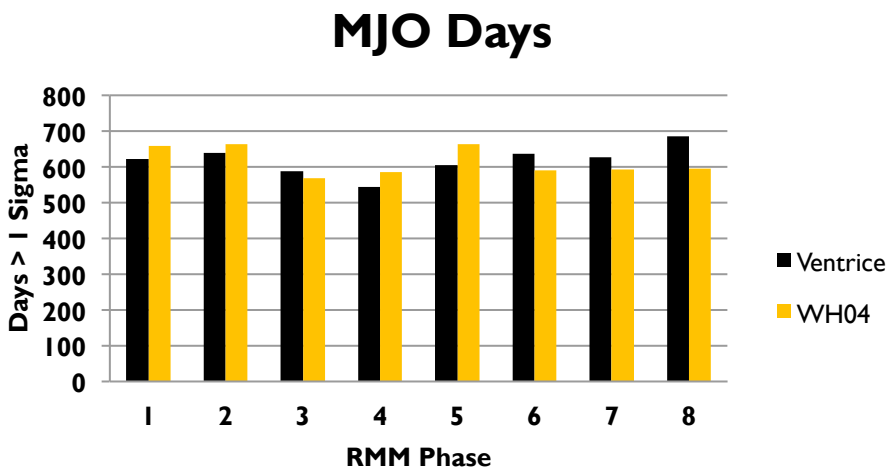
JASON Atlantic Hurricane Days
1989-2010





No 5 day running average and counts one storm only per day

1989-2010



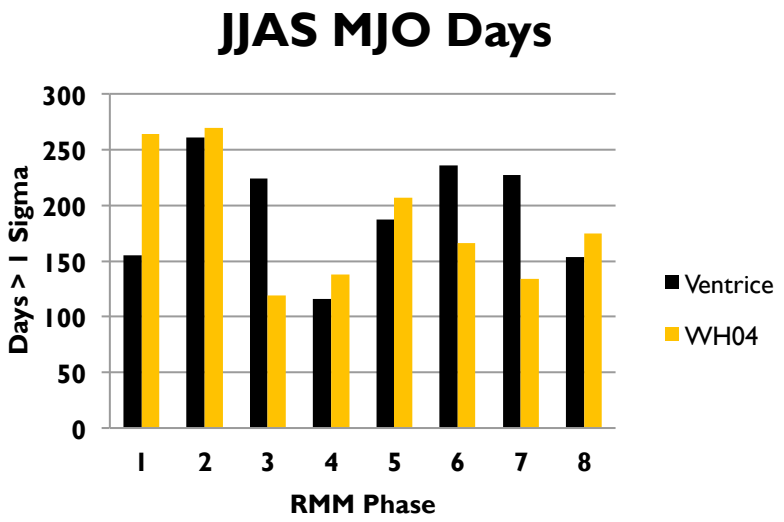
$N_{ventrice}$ = 4950d

N_{wh04} = 4923d

$N_{ventrice} - N_{wh04}$ = 27d

	Correlate
Phase	0.581451
Amplitude	0.630627

1989-2010



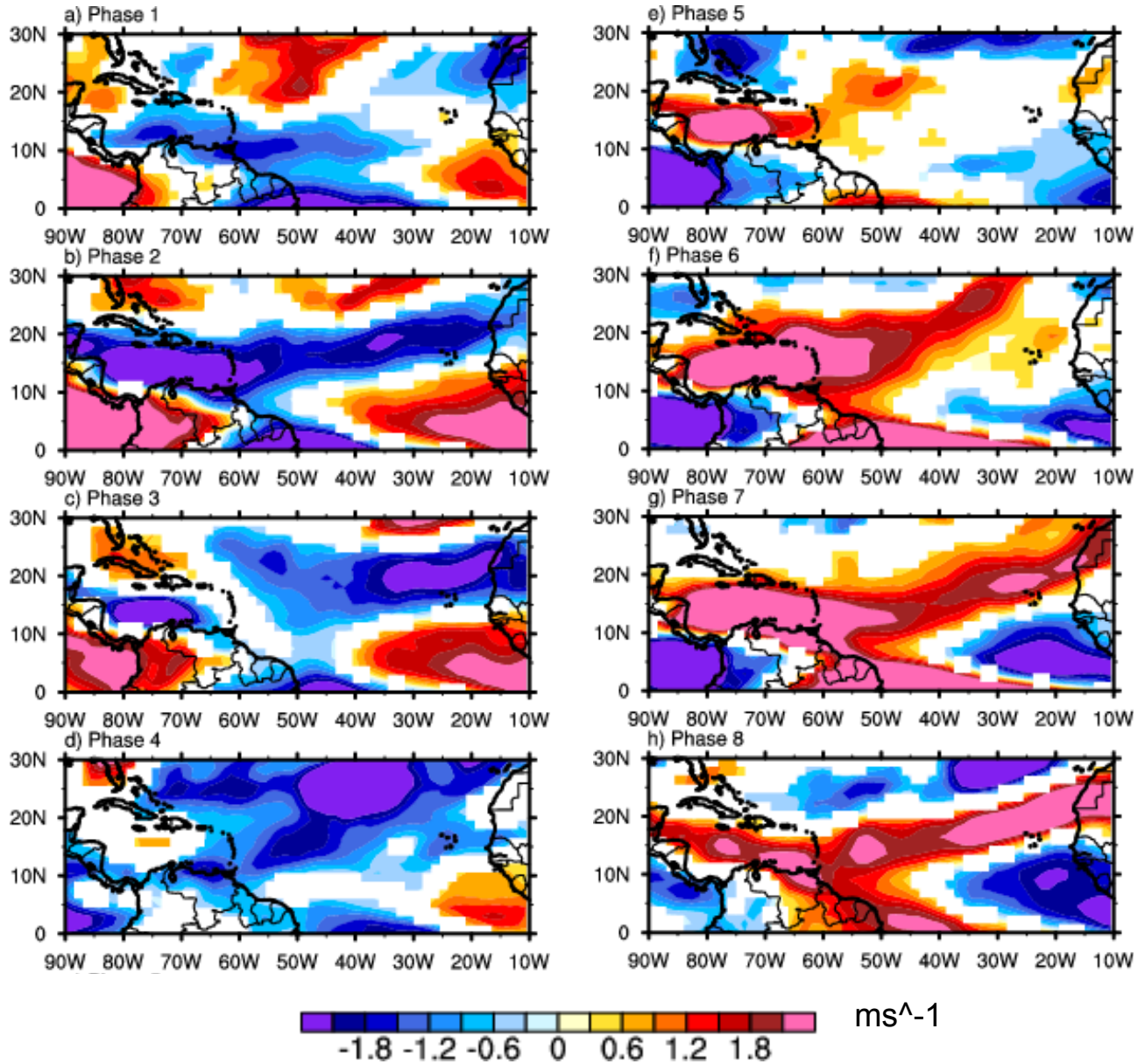
$N_{ventrice}$ = 1560d

N_{wh04} = 1473d

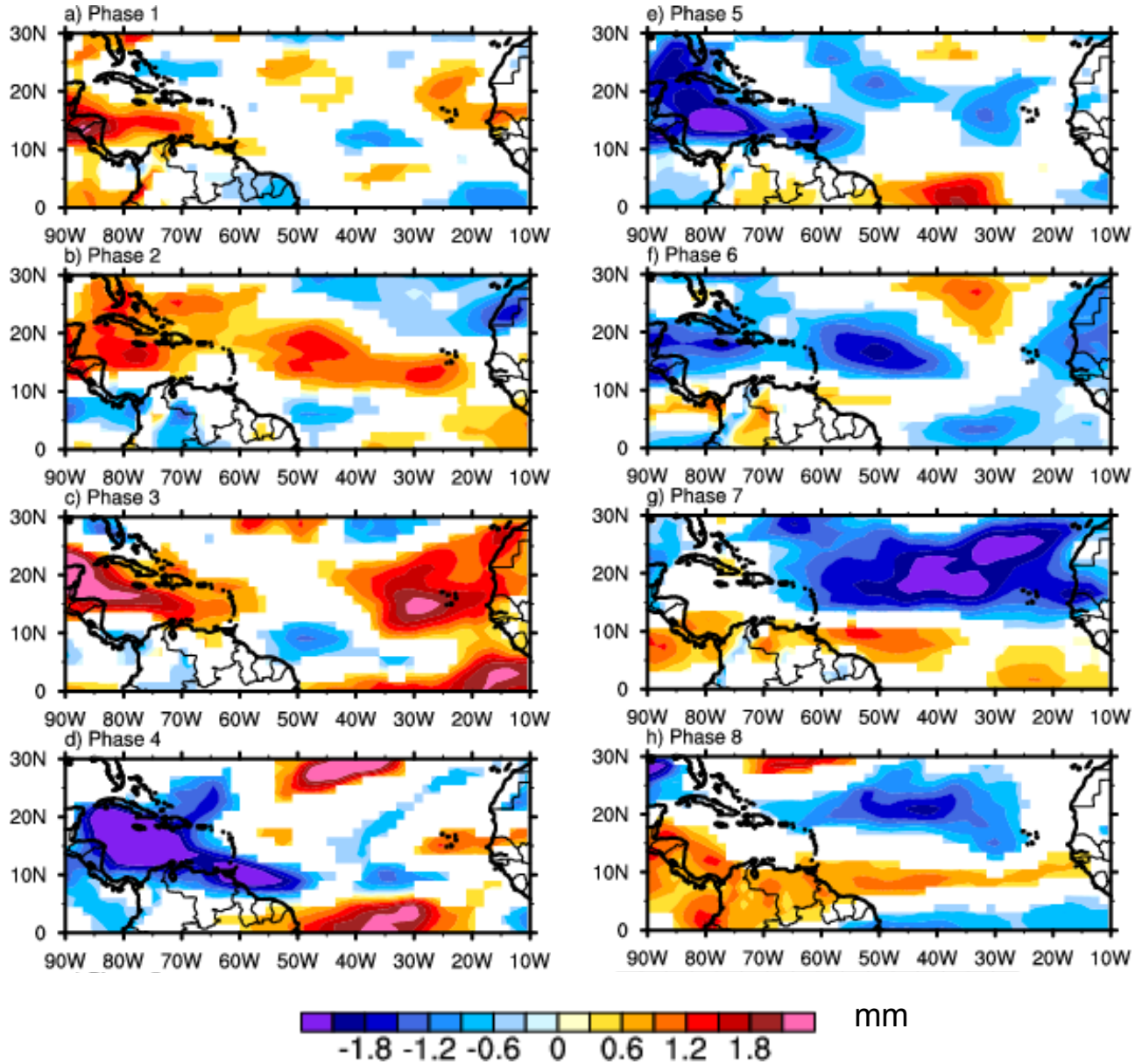
$N_{ventrice} - N_{wh04}$ = 87d

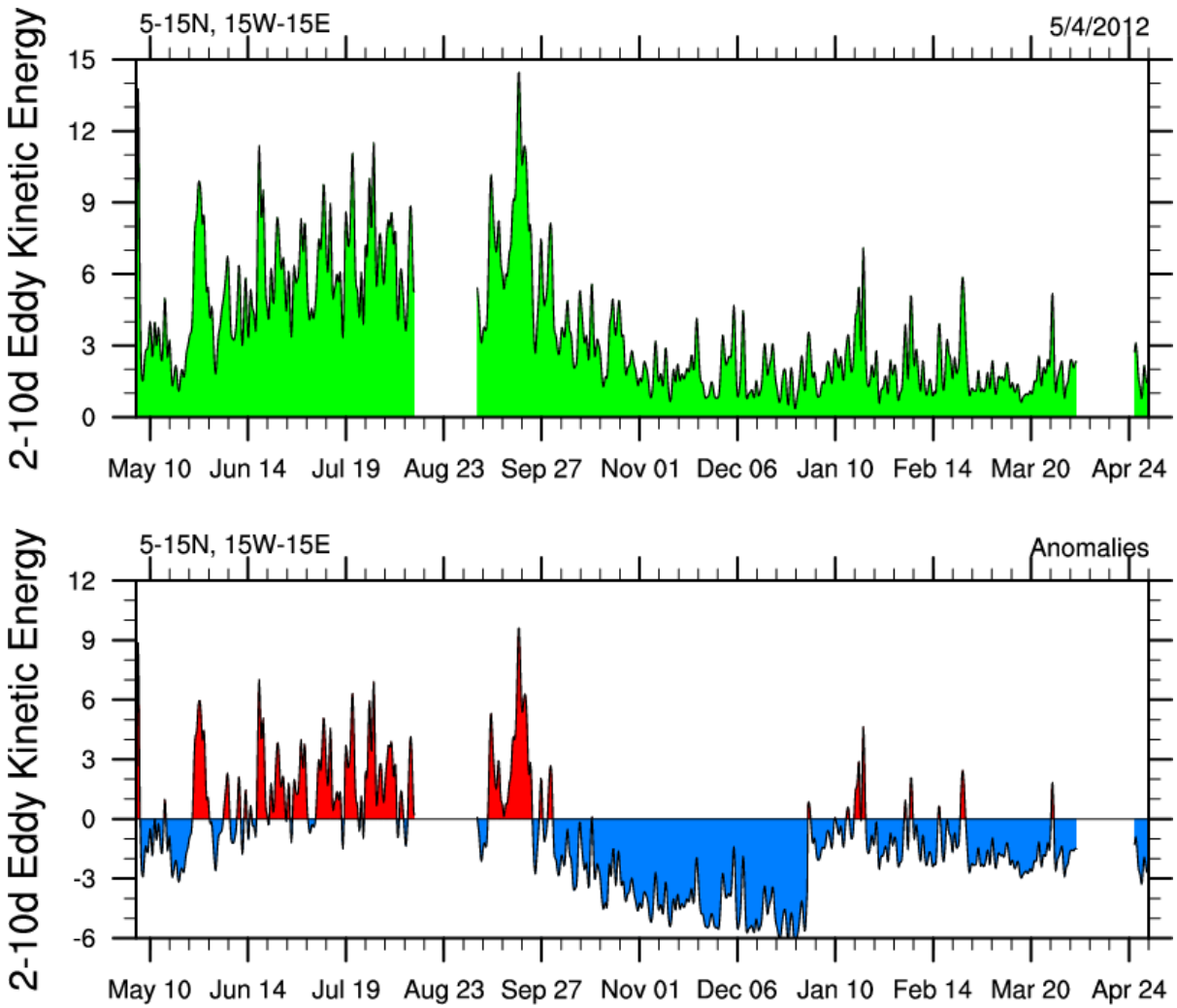
	Correlate
Phase	0.528432
Amplitude	0.568996

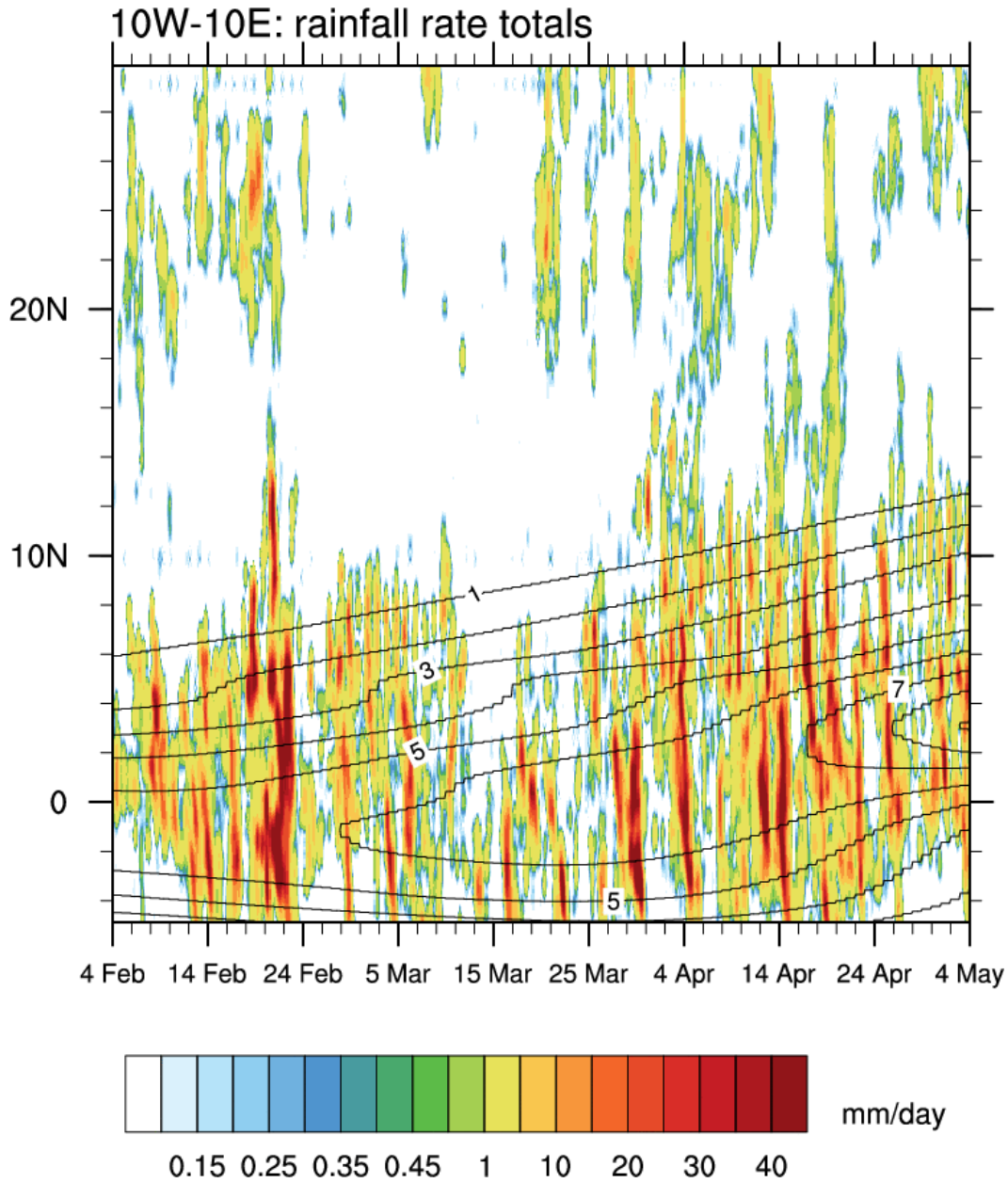
Anomalous 200-925 hPa Shear Magnitude

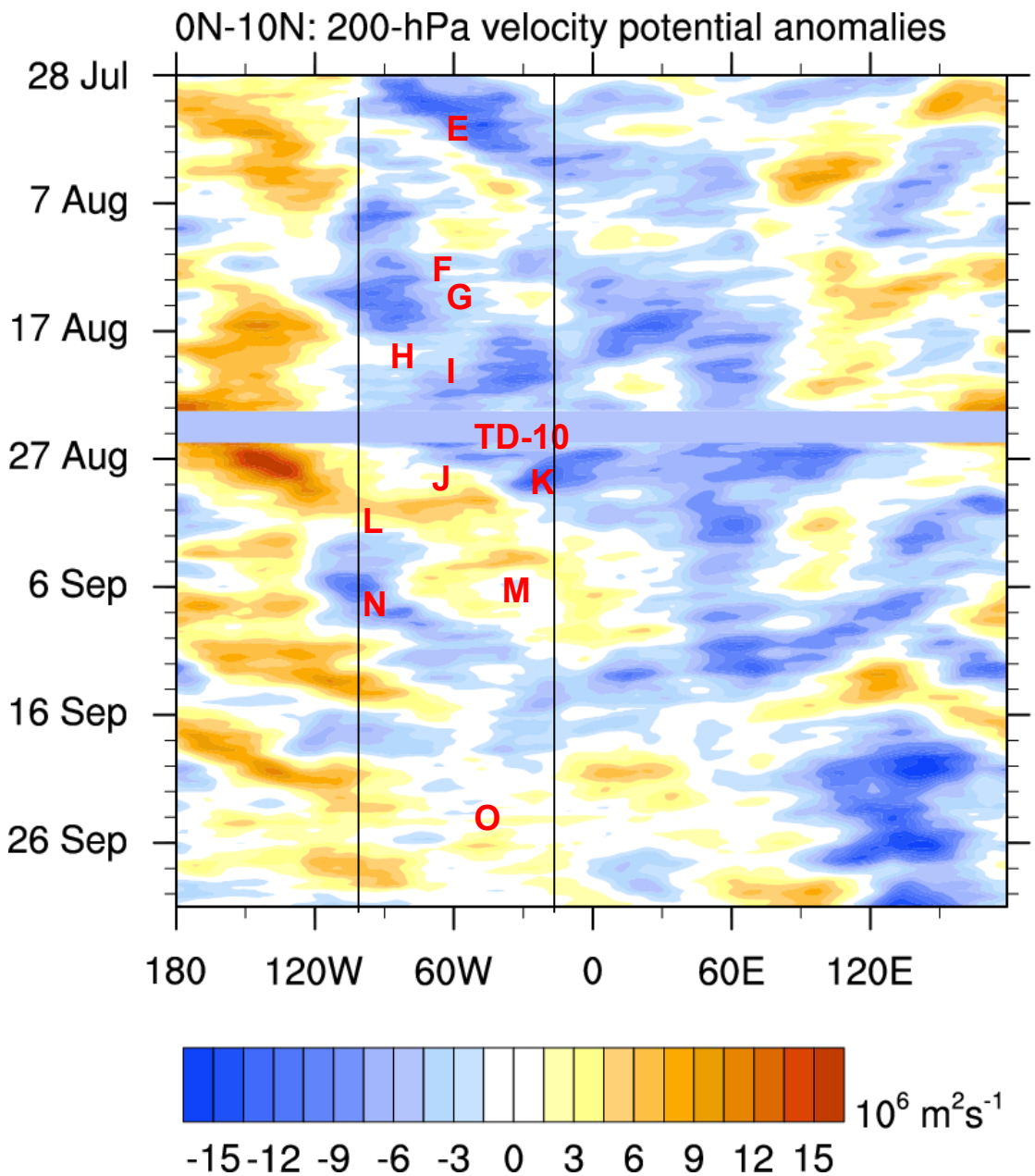


Anomalous Total Column Water Vapor




5-15N, 15W-15E
5/4/2012
2-10d Eddy Kinetic Energy
15
12
9
6
3
0
May 10
Jun 14
Jul 19
Aug 23
Sep 27
Nov 01
Dec 06
Jan 10
Feb 14
Mar 20
Apr 24
5-15N, 15W-15E
Anomalies
2-10d Eddy Kinetic Energy
12
9
6
3
0
-3
-6
May 10
Jun 14
Jul 19
Aug 23
Sep 27
Nov 01
Dec 06
Jan 10
Feb 14
Mar 20
Apr 24


10W-10E: rainfall rate totals
20N
10N
0
1
3
5
7
5
4 Feb
14 Feb
24 Feb
5 Mar
15 Mar
25 Mar
4 Apr
14 Apr
24 Apr
4 May
0.15
0.25
0.35
0.45
1
10
20
30
40
mm/day



Shaded: Unfiltered 200 hPa GFS Velocity Potential Anomalies

Contours: Positive Kelvin filtered TRMM 3B42 rain rate anomalies – 2 mm/day contour