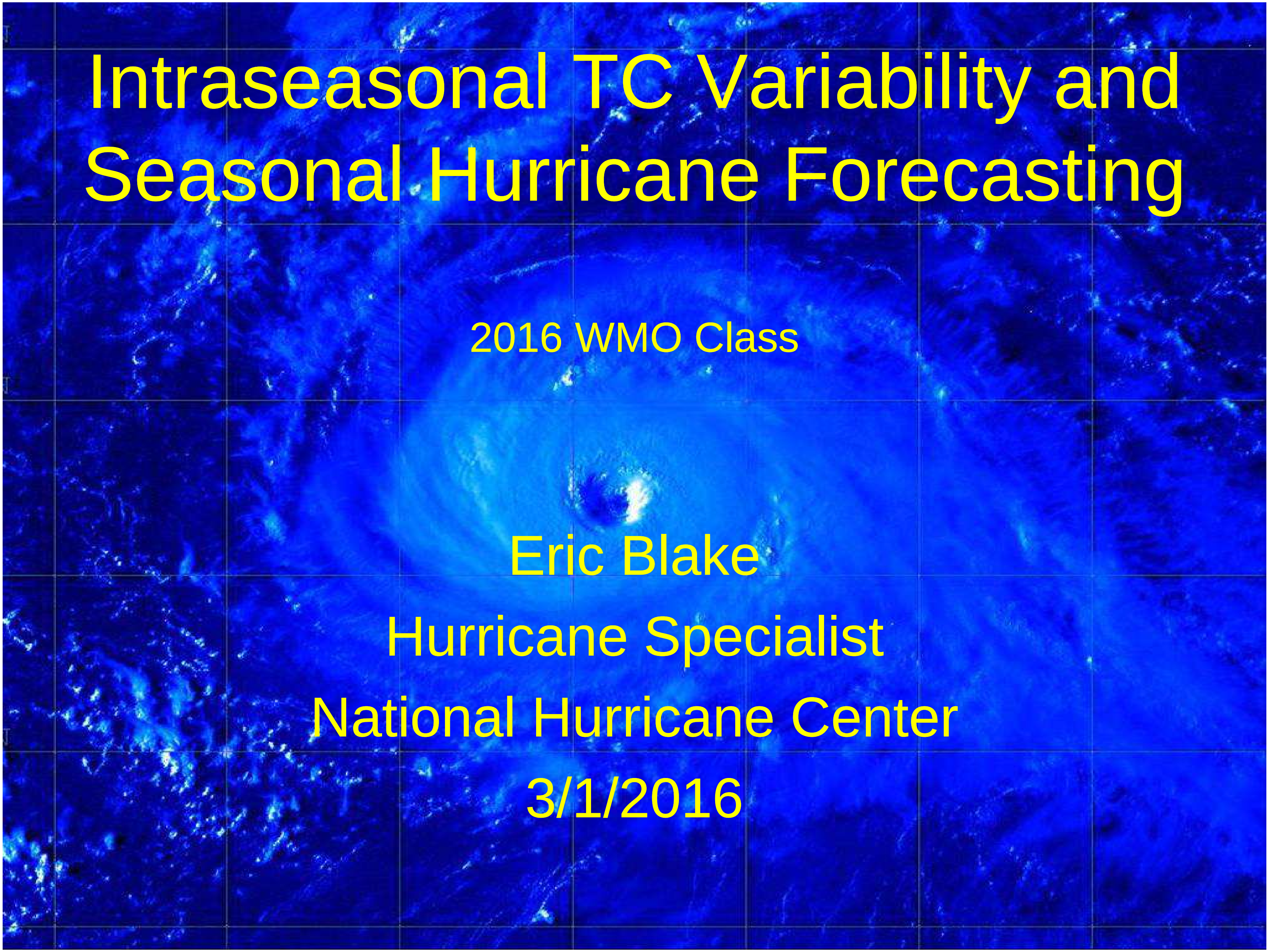

Intraseasonal TC Variability and Seasonal Hurricane Forecasting

2016 WMO Class

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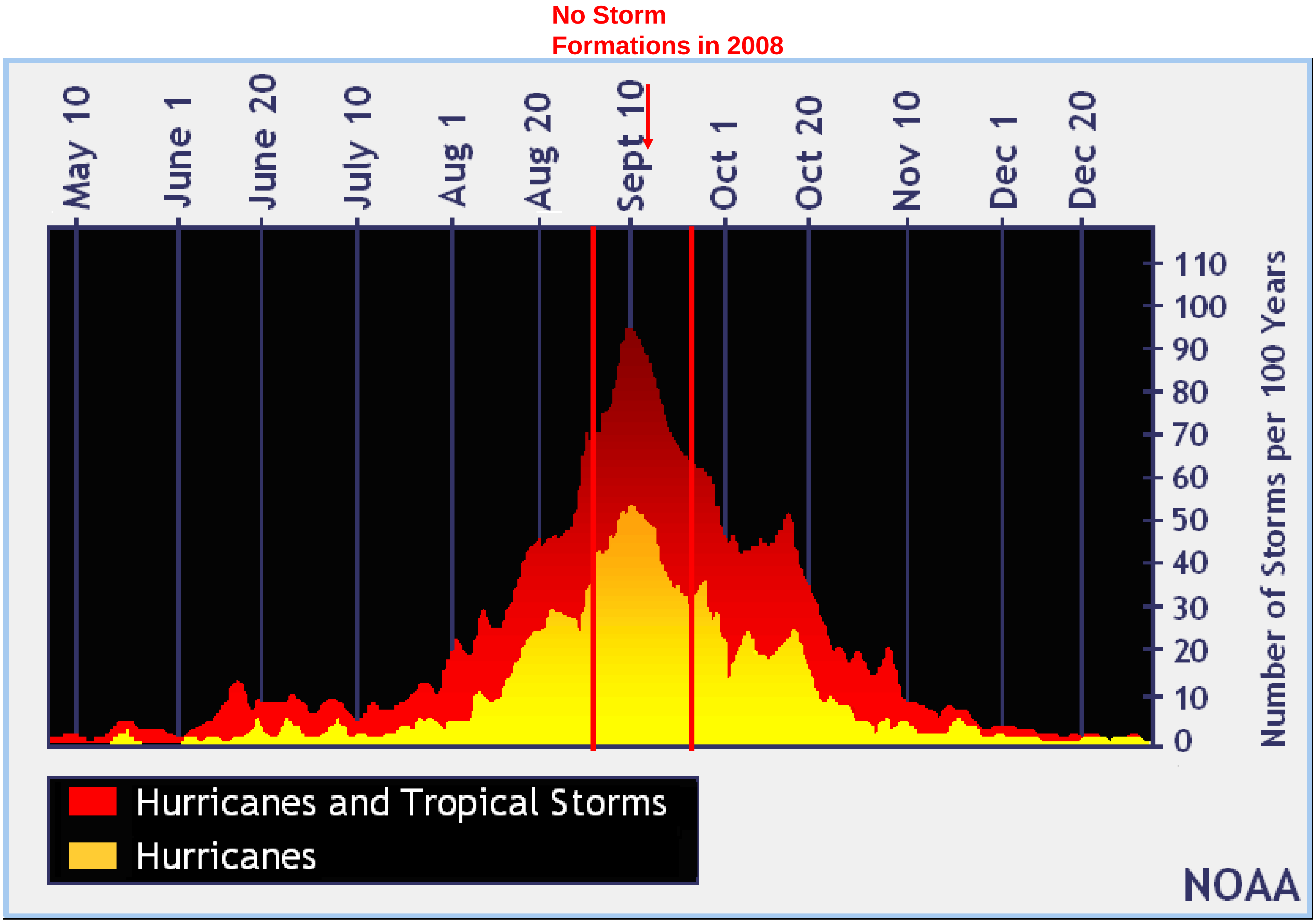
Hurricane Specialist
National Hurricane Center

3/1/2016

Outline

- Madden-Julian Oscillation (MJO)
- MJO analysis tools
- Kelvin Waves
- Seasonal forecasting
- Exercise
- Brief look at 2016


No Storm
Formations in 2008
May 10
June 1
June 20
July 10
Aug 1
Aug 20
Sept 10
Oct 1
Oct 20
Nov 10
Dec 1
Dec 20
110
100
90
80
70
60
50
40
30
20
10
0
Number of Storms per 100 Years
Hurricanes and Tropical Storms
Hurricanes
NOAA

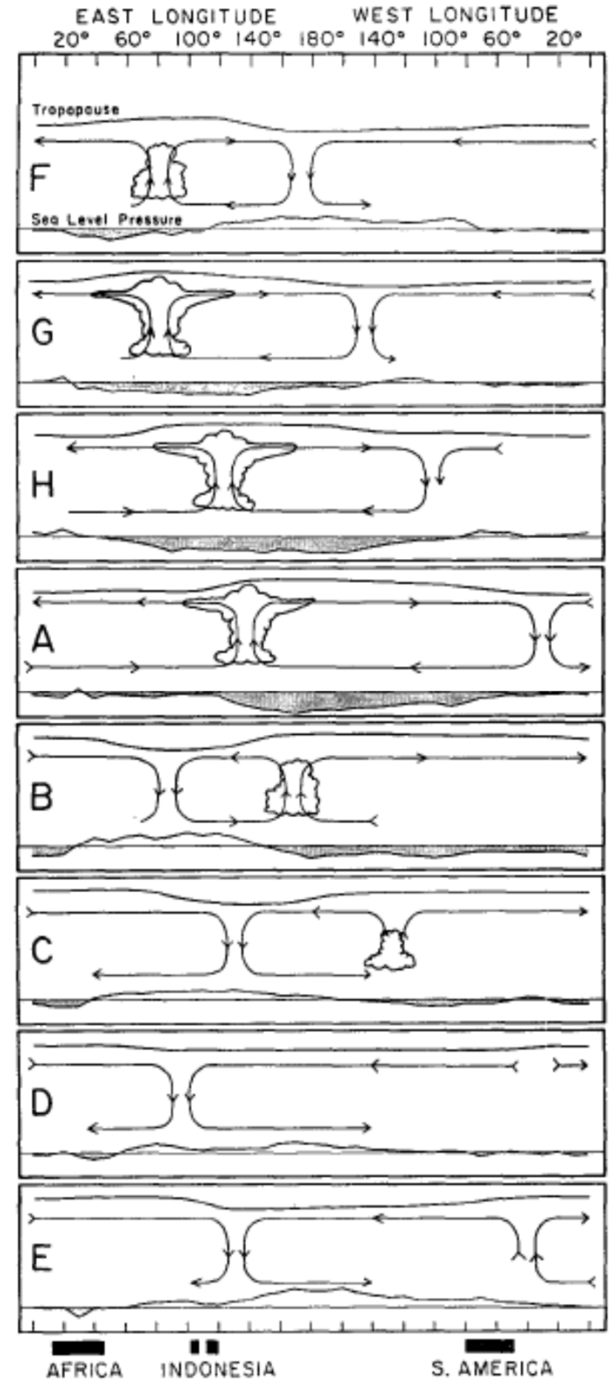
Madden-Julian Oscillation

- Discovered in the early 1970s by Roland Madden and Paul Julian.
- An eastward propagating wave that circles the globe in about 40-50 days involving tropical convection.
- Detected in the Outgoing Longwave Radiation (OLR) and wind fields across the tropics.
- Later papers showed that it is an important modulator of TC activity, especially in the Pacific Ocean.

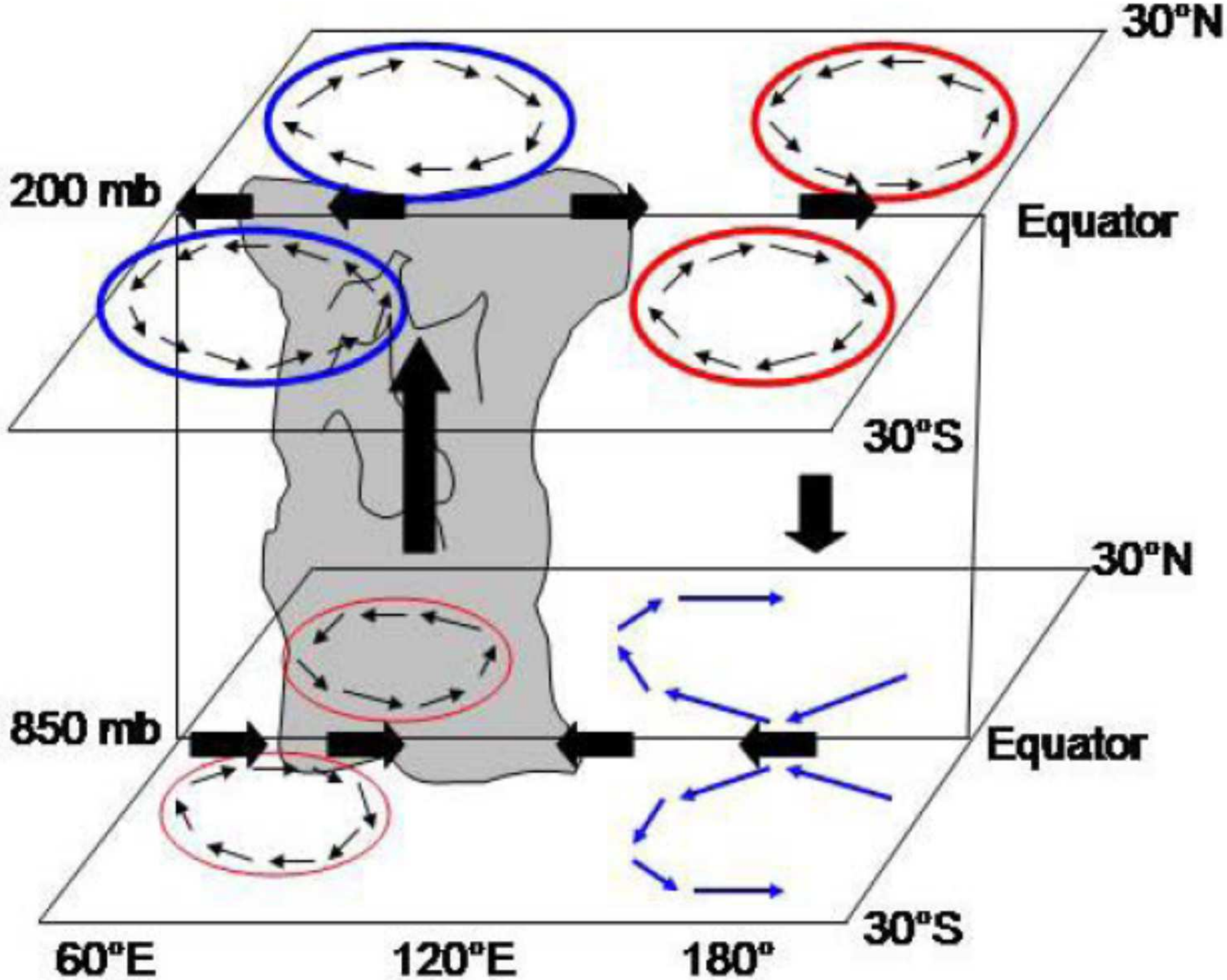
-Idealized Diagram of the 40-50 day Tropical Intraseasonal Oscillation

-Became known as the Madden-Julian Oscillation in the late 1980s

-Generally forms over the Indian Ocean, strengthens over the Pacific Ocean and weakens due to interaction with South America and cooler eastern Pacific SSTs

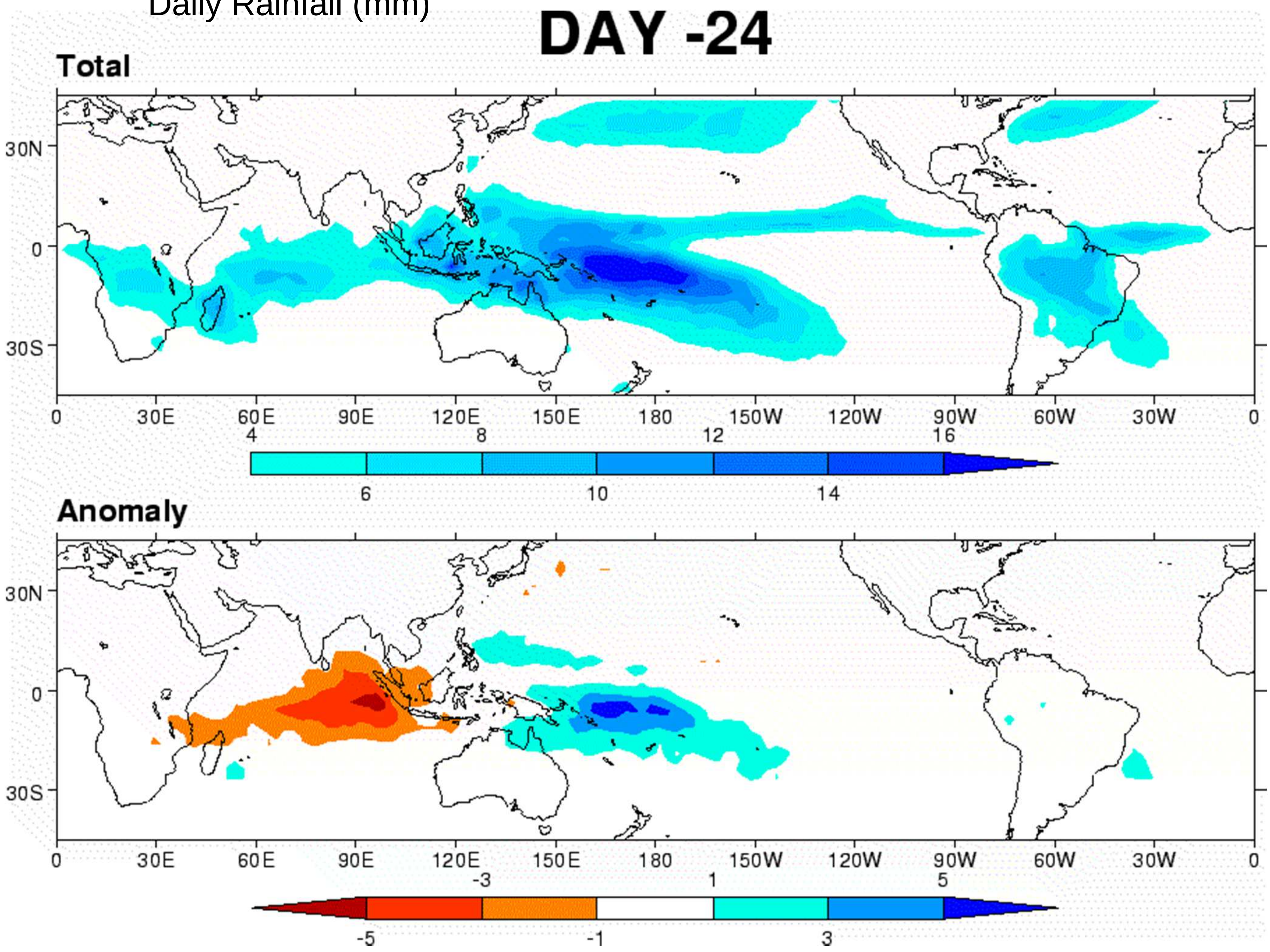


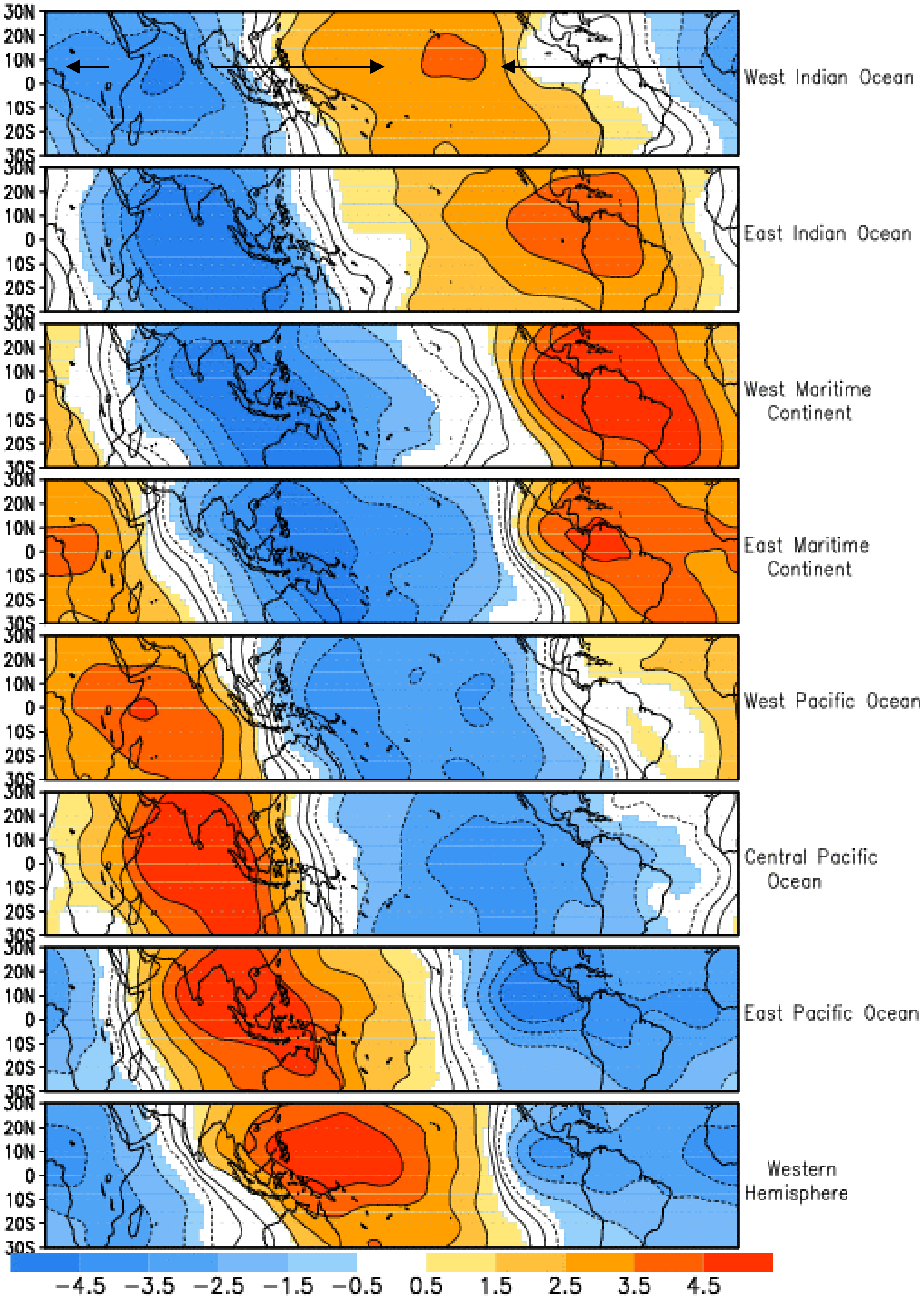
(Madden and Julian 1972)



Rui and Wang (1990)

Daily Rainfall (mm)



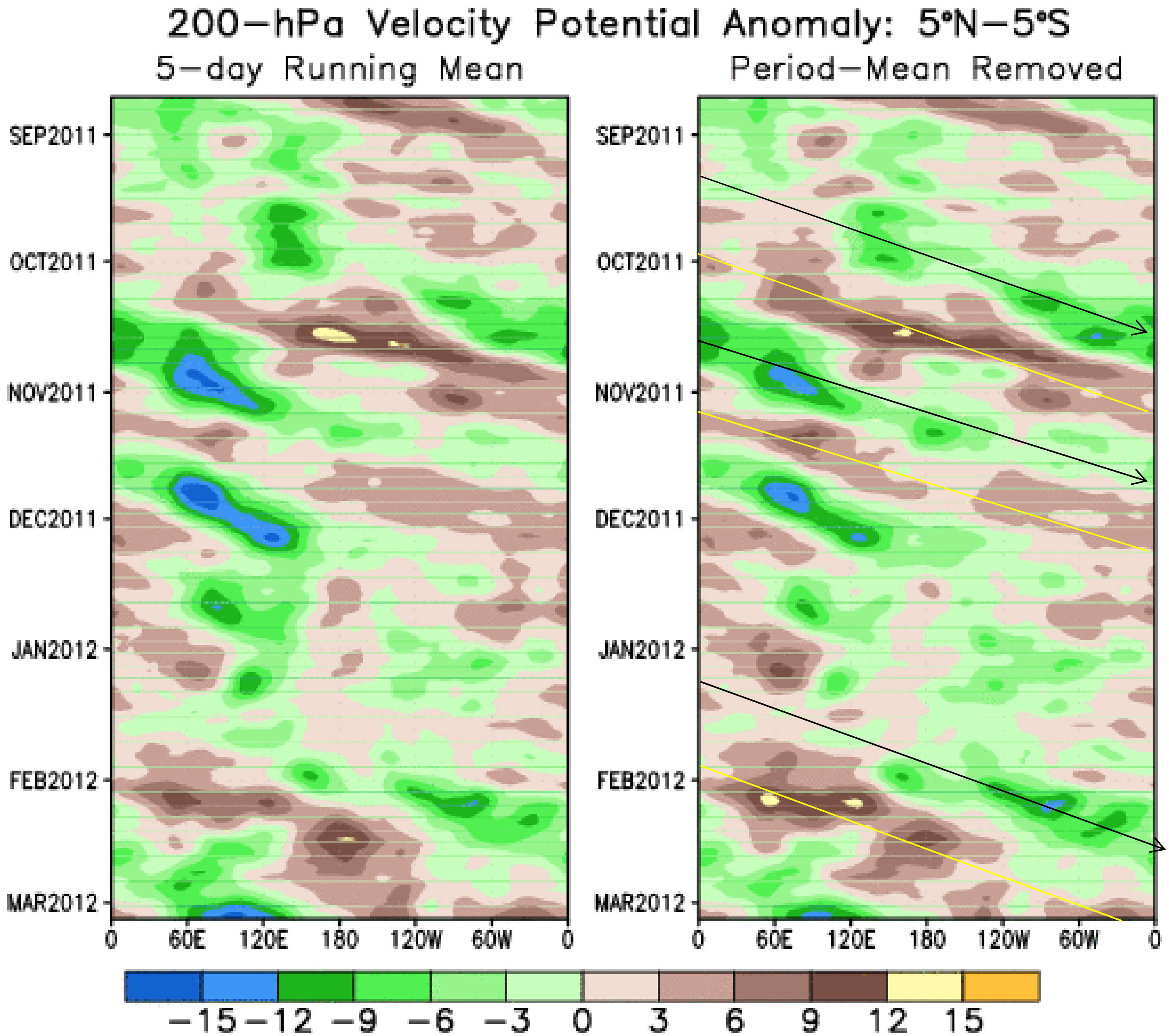


200 mb Velocity Potential fields– one way to track the MJO

Blue= divergence

Red= convergence

Center of the blue area tracks the most upper divergence, which is usually well-linked to thunderstorms



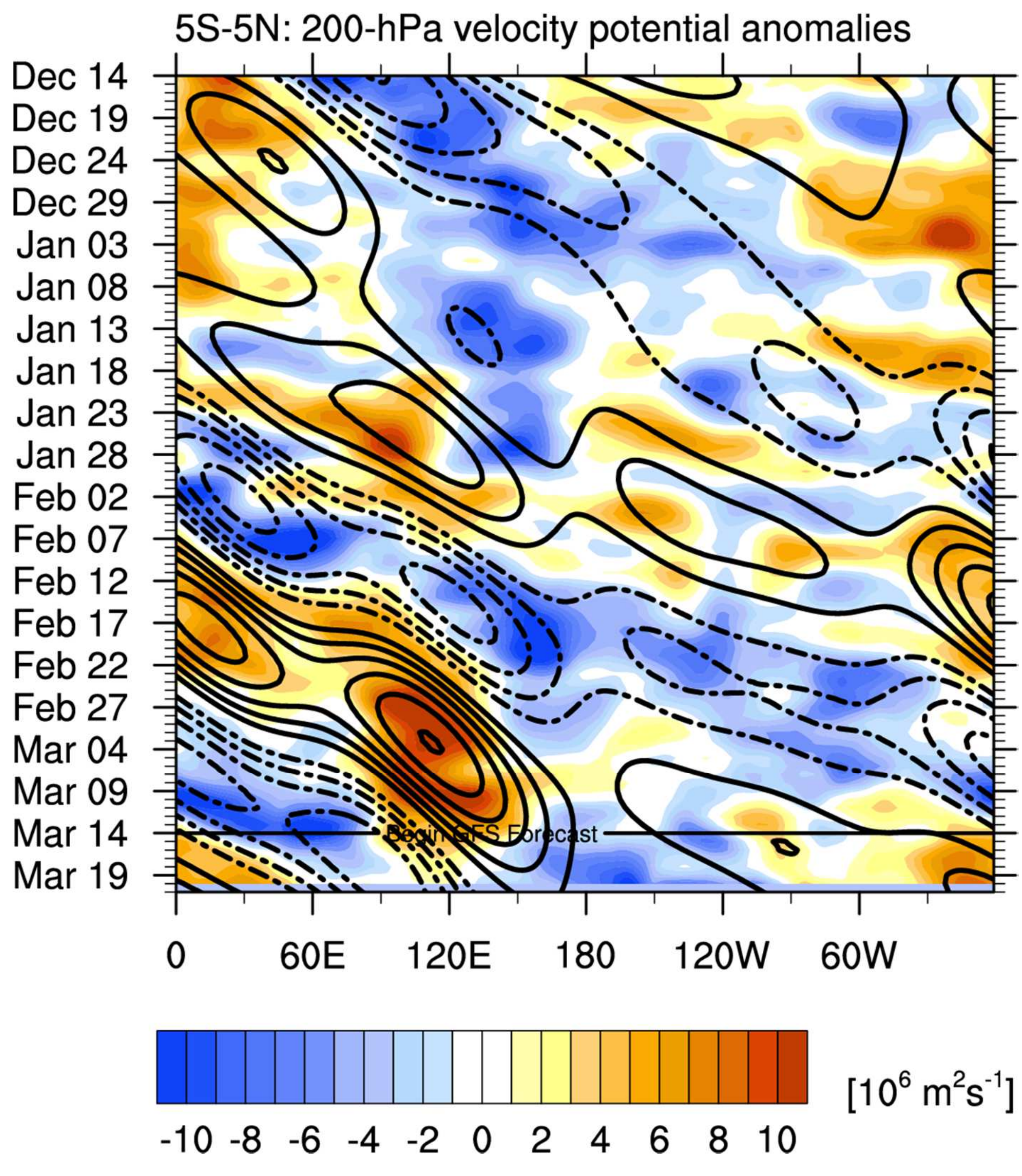
Time-longitude sections of anomalous 200-hPa velocity potential ($x\ 10^6\ m^2\ s^{-1}$) averaged between 5°N-5°S for the last 180 days ending 05 MAR 2012: (Left) 5-day running means and (Right) 5-day running means with period mean removed. Anomalies are departures from the 1981-2010 period daily means. CLIMATE PREDICTION CENTER/NCEP

MJO characteristics

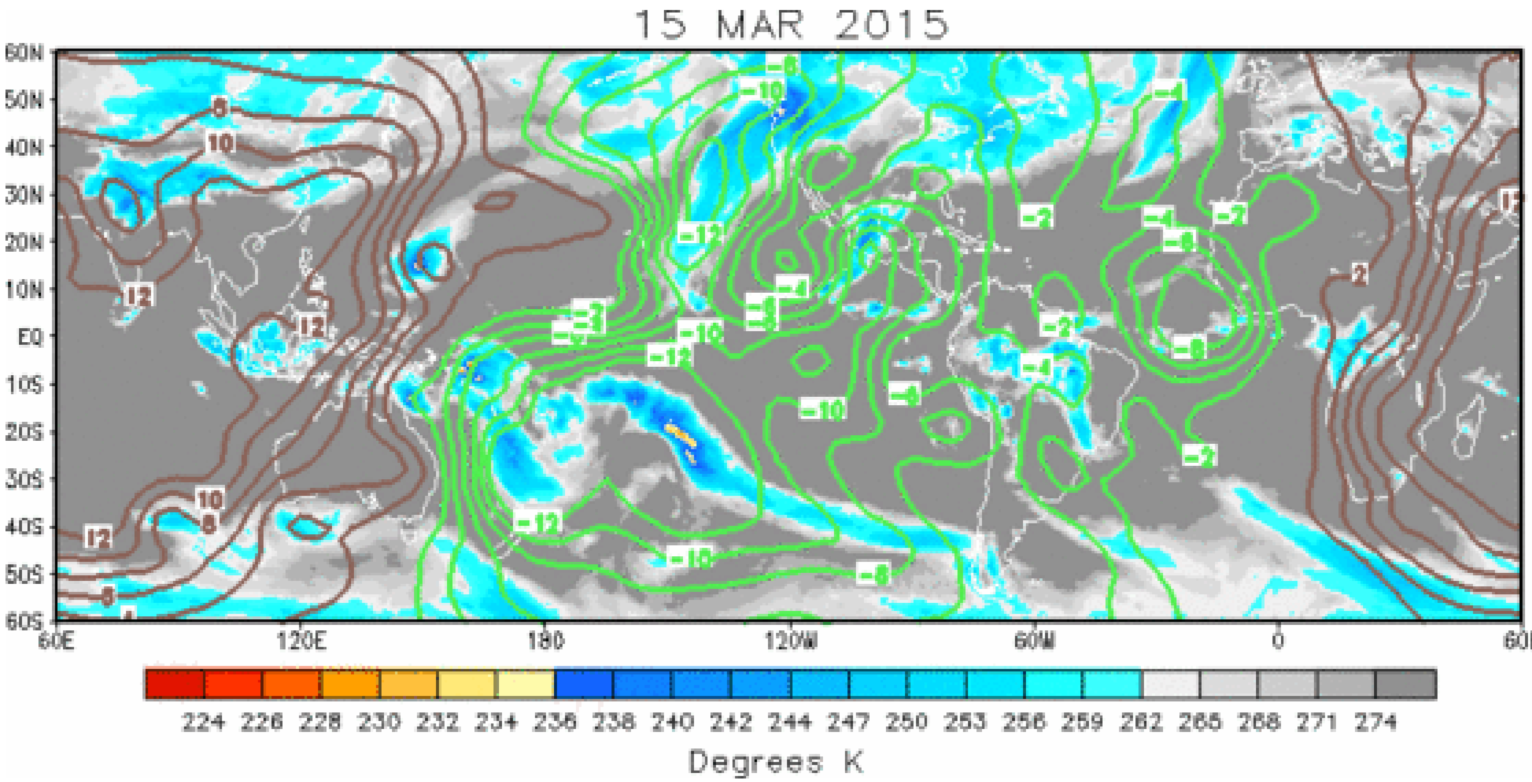
Note signal is much stronger in eastern Hemisphere than western

Eastward phase speed is a lot slower in eastern than western Hemi (convective coupling)

In western hemisphere, upper-level signal usually much easier to track than lower-level



Another way to track the MJO



Animation of daily IR and 200-hPa velocity potential anomalies (base period 1971-2000). Velocity potential anomalies are proportional to divergence with green (brown) contours corresponding to regions in which convection tends to be enhanced (suppressed).

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ir_anim_monthly.shtml

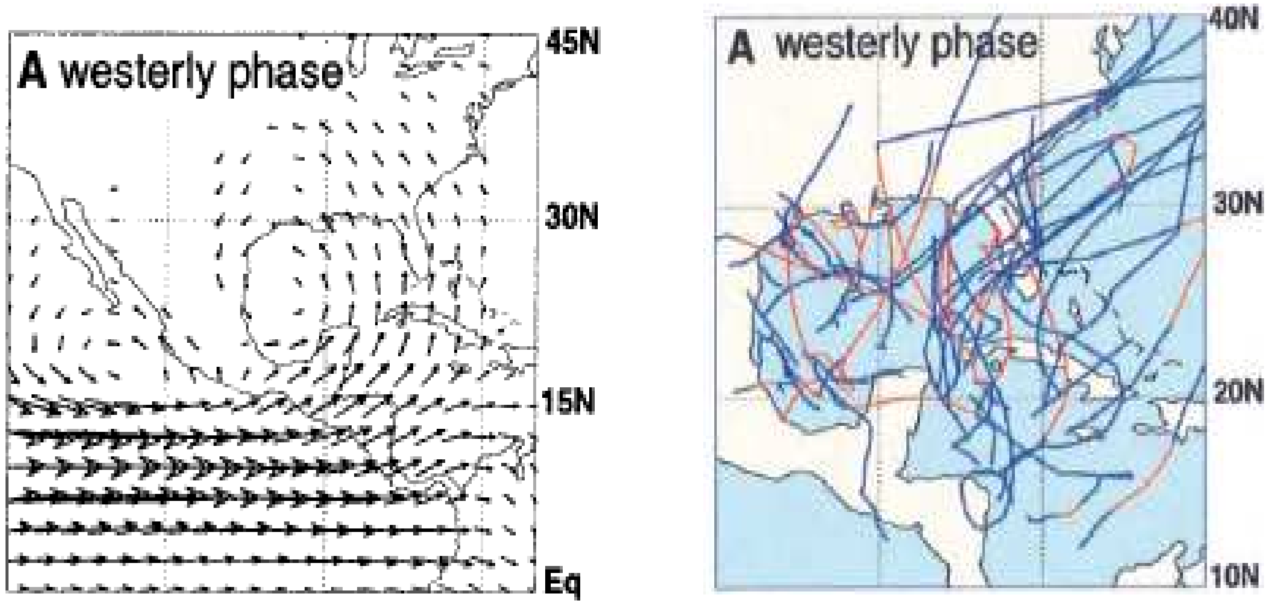
MJO Effects in the Atlantic Basin

- The MJO can lose much of its strength before entering the Atlantic basin.
- In addition, the MJO is weakest during the late summer, near the peak of Atlantic activity.
- Western part of the basin most strongly affected (Maloney and Hartmann 2000).

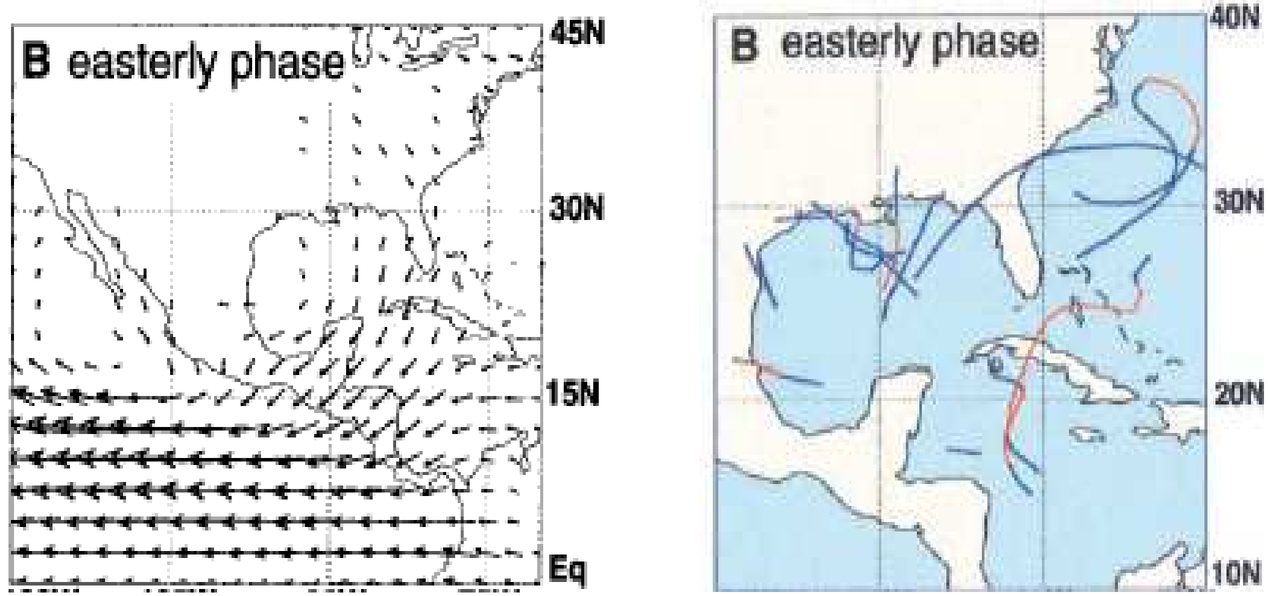
Active MJO in the western Caribbean Sea and Gulf of Mexico produces more storms due to:

- Increase in low-level convergence (ITCZ moves farther north)
- Low-level vorticity is also increased due to westerly low-level flow meeting easterly trades
- Upper divergence is stronger than average during the westerly phase, with a drop in shear as well

Active MJO EOF and corresponding TS and H tracks



Inactive MJO EOF and corresponding TS and H tracks



Adapted from Maloney and Hartmann (2000)

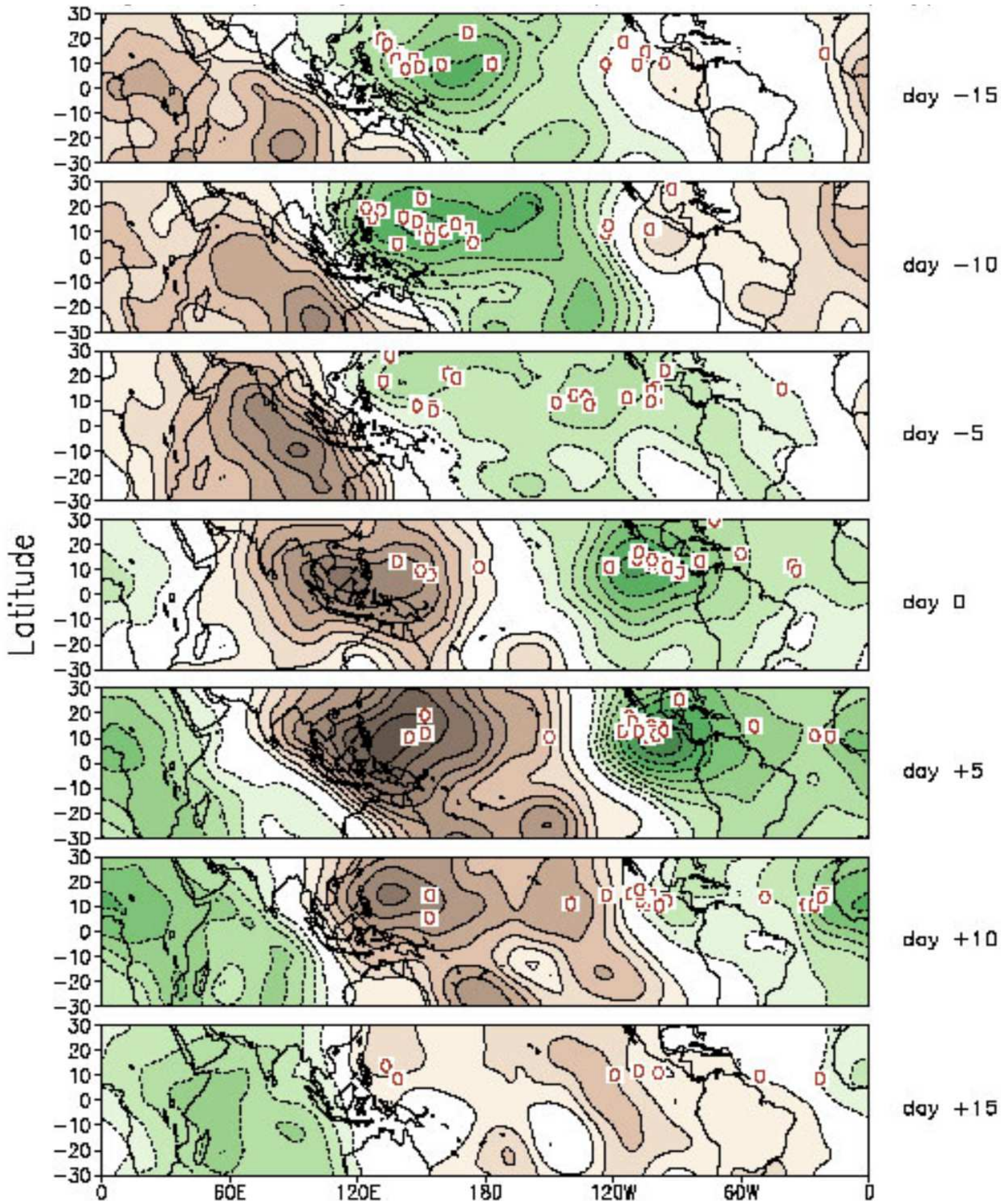
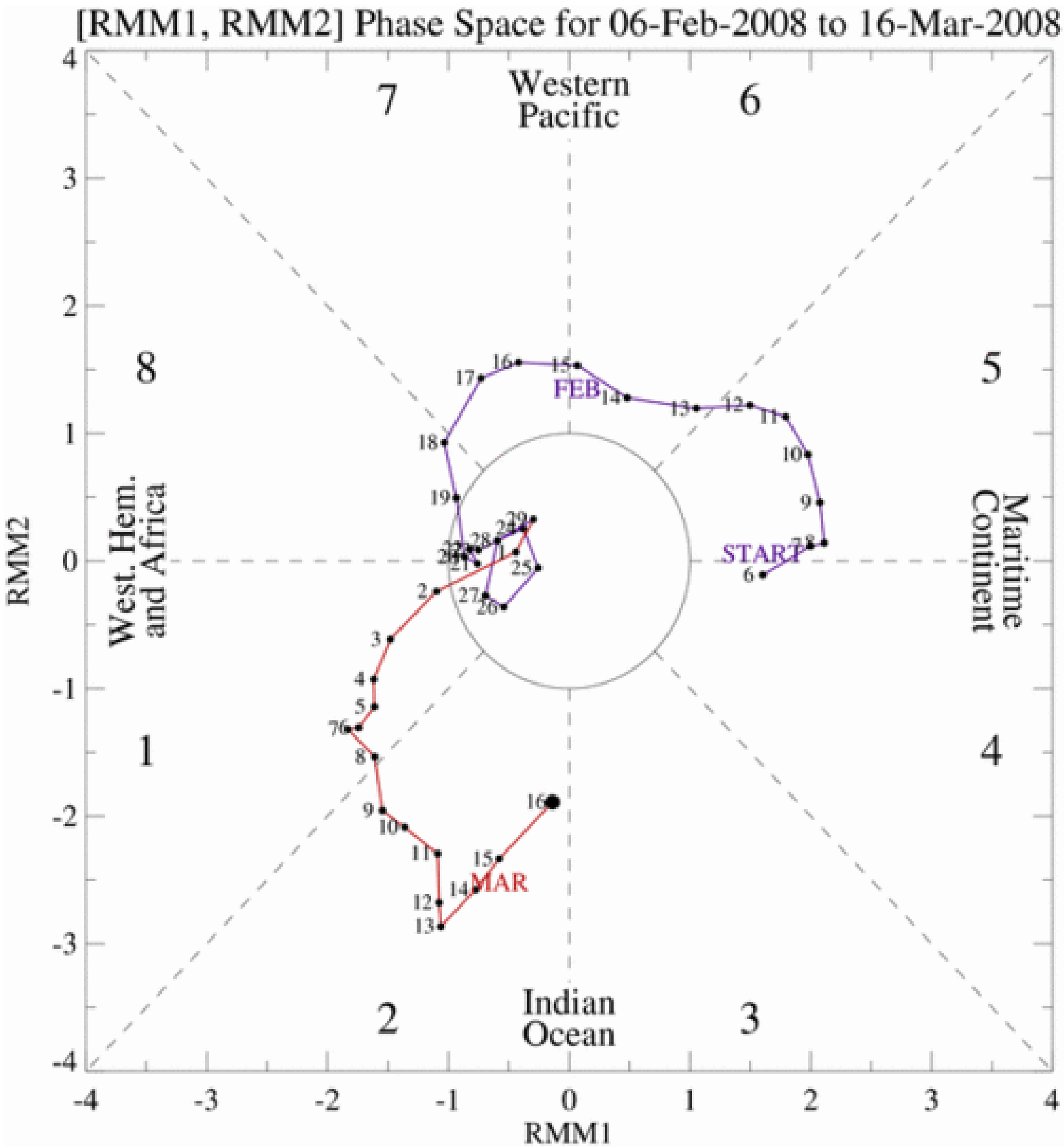


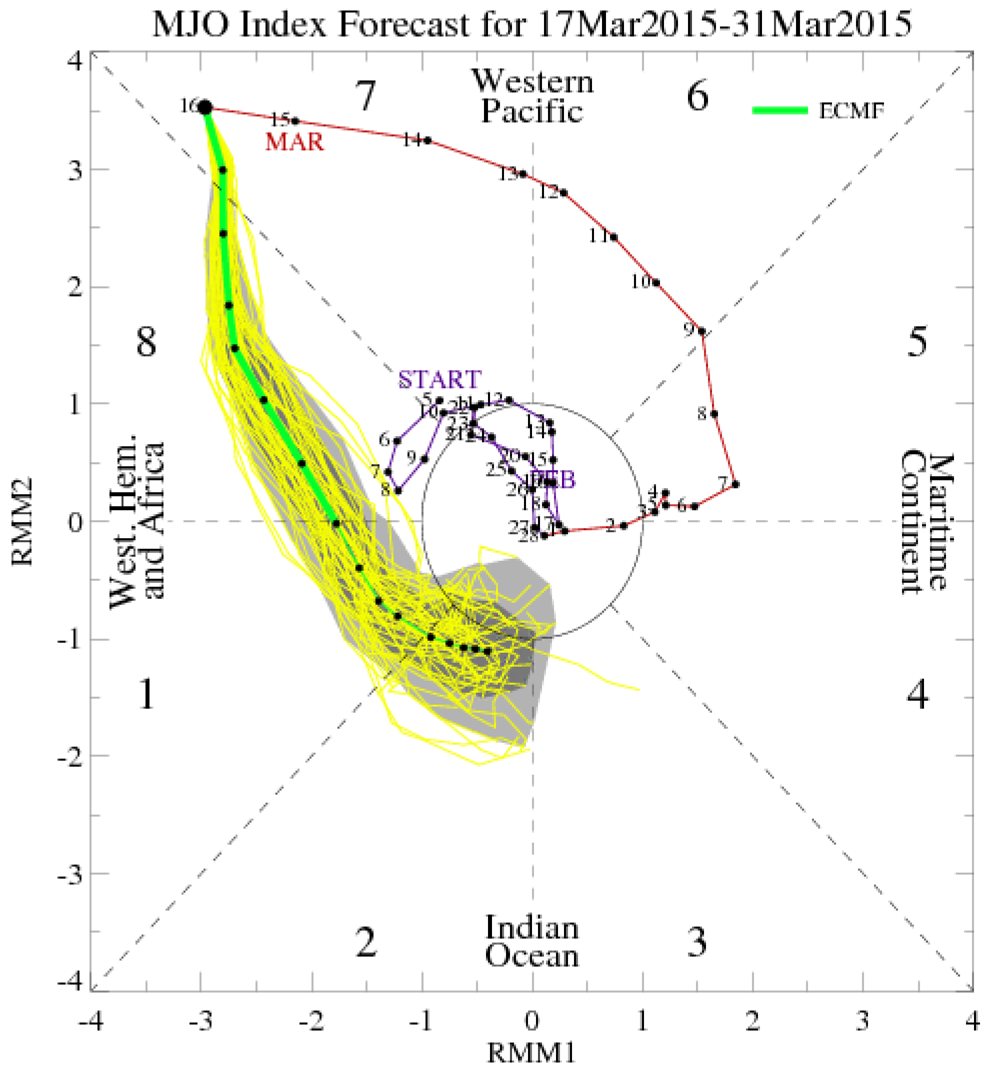
Figure 10: Velocity potential composites for different phases of the MJO cycle with hurricane/typhoon origin locations. Green shading indicates upper level divergence and brow shading indicates upper level convergence. Open circles indicate hurricane/typhoon origin centers.

- Most genesis points are near or behind the upper-level divergence center.

A different way to visualize the MJO



- The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes, following the active convection.
- The triangular areas indicate the location of the enhanced phase of the MJO
- Counter-clockwise motion is indicative of eastward propagation
- Distance from the origin is proportional to MJO strength
- Line colors distinguish different months



http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

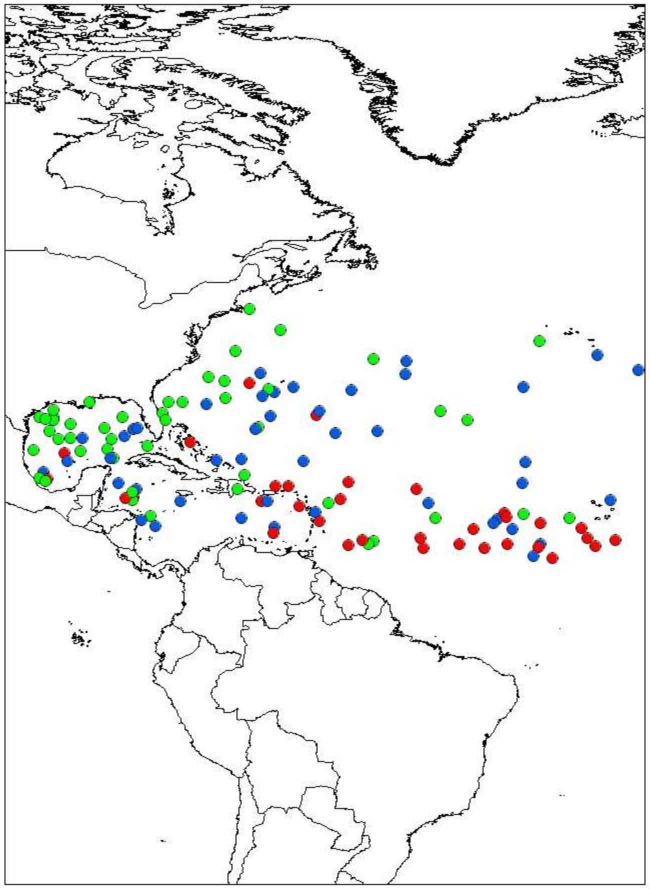
Normalized Activity by MJO Phase (1974-2007)

MJO Phase	NS	NSD	H	HD	MH	MHD	ACE
Phase 1	**2.7**	**22.9**	**2.3**	**13.5**	**1.4**	**4.9**	**57.5**
Phase 2	**3.0**	**24.7**	**2.5**	**13.2**	**1.8**	**4.2**	**53.0**
Phase 3	2.6	19.8	1.7	12.1	0.9	2.1	41.4
Phase 4	1.7	12.1	1.1	8.1	0.7	2.7	32.0
Phase 5	2.7	14.8	1.6	6.3	0.7	1.3	35.7
Phase 6	*2.6*	*13.1*	*1.2*	*3.9*	*0.6*	*0.9*	*20.3*
Phase 7	*1.6*	*9.4*	*0.6*	*3.7*	*0.5*	*1.1*	*17.5*
Phase 8	1.9	12.2	1.1	6.5	0.6	1.9	25.3
Ratio of Phases 1+2 to Phases 6+7	**1.4**	**2.1**	**2.7**	**3.5**	**2.9**	**4.6**	**2.9**

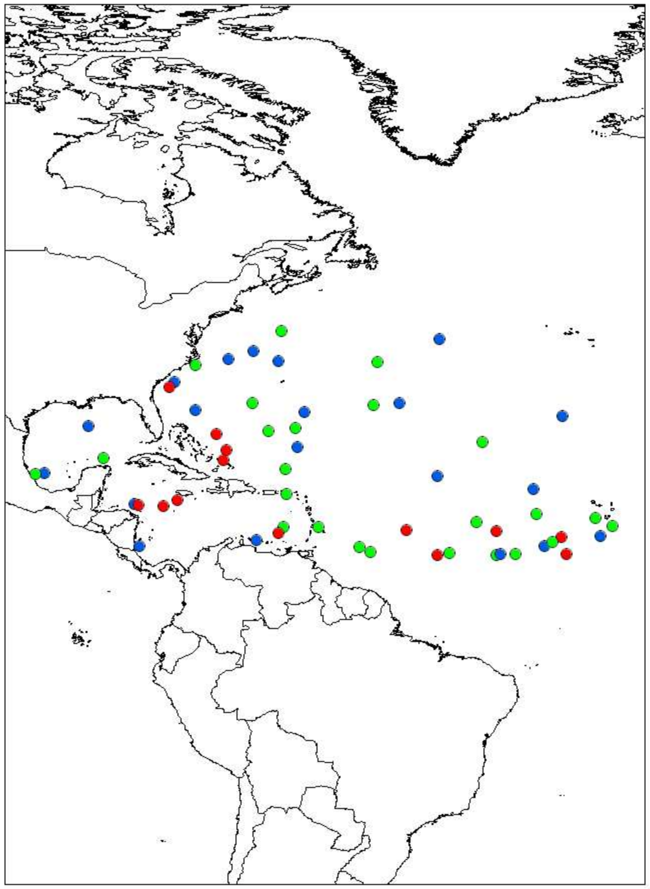
From Klotzbach (2010)

All Genesis Points

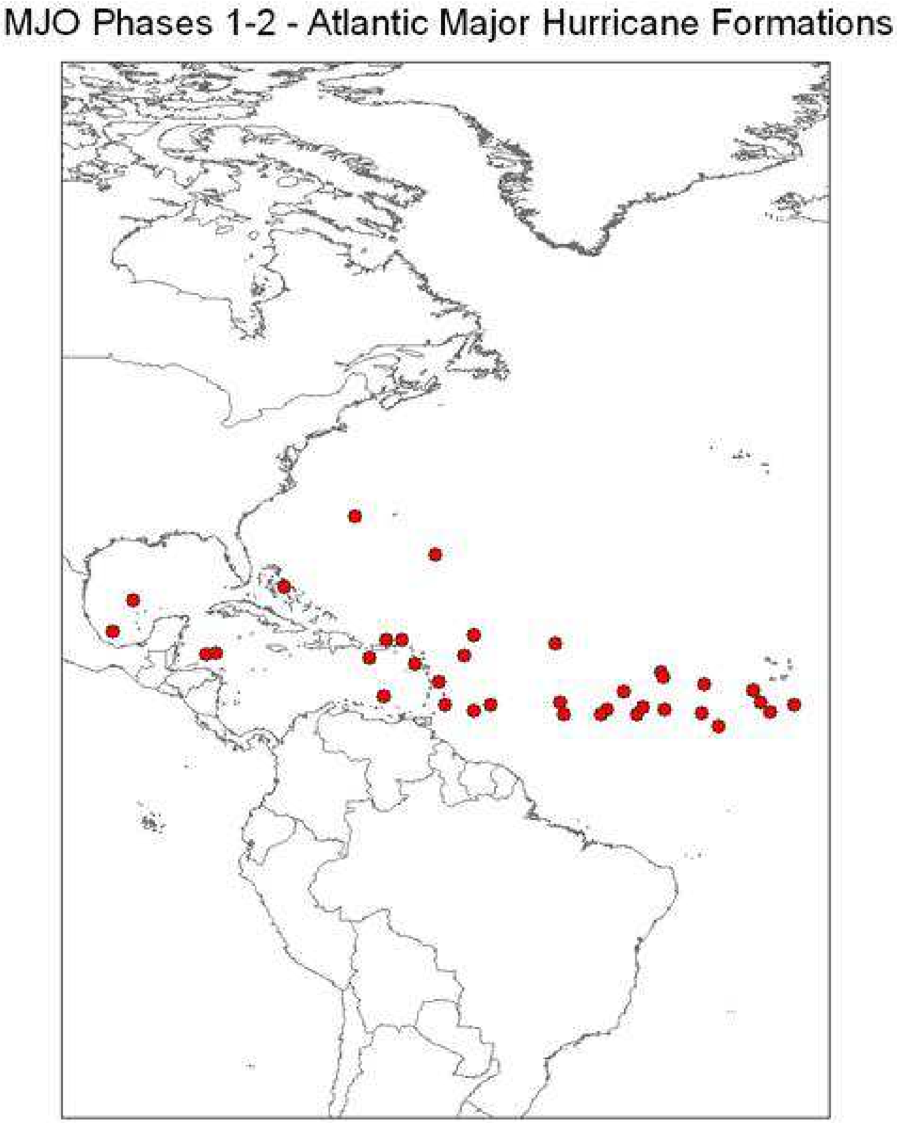
MJO Phases 1+2



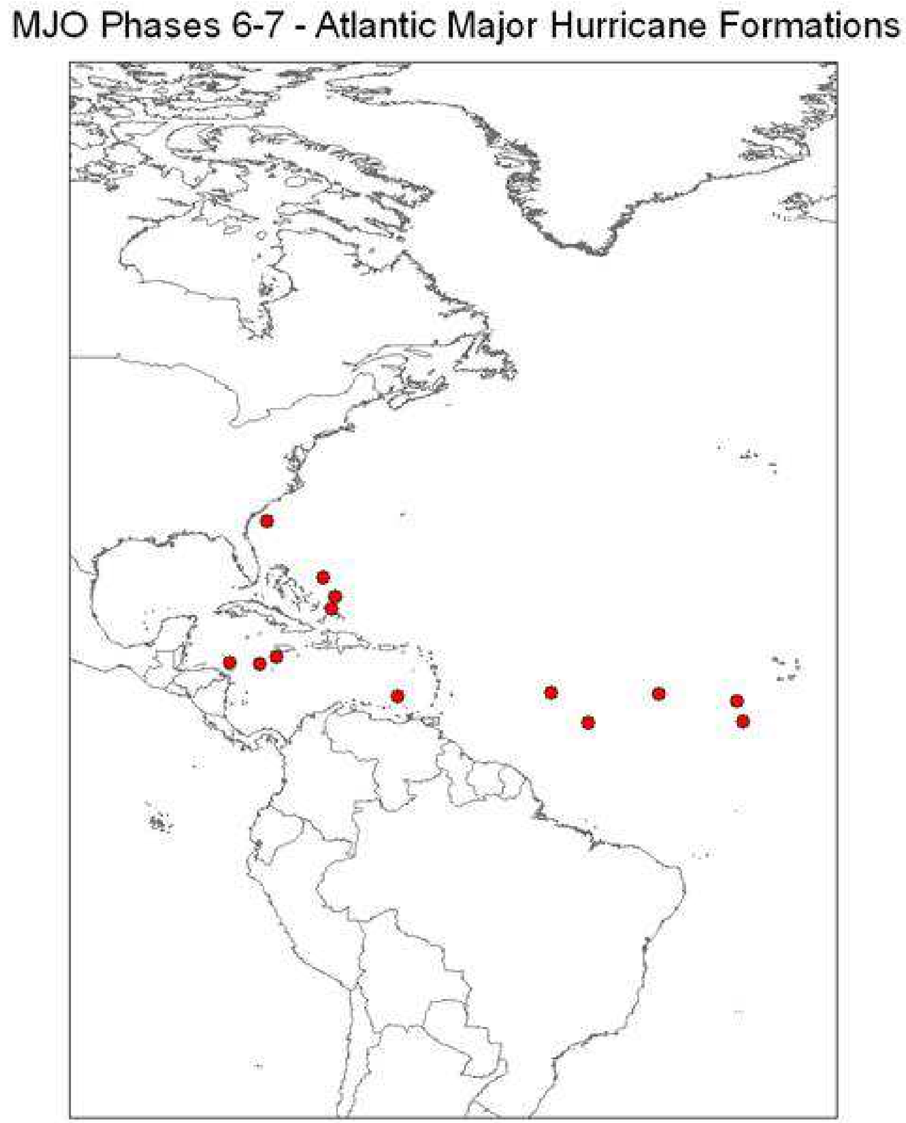
MJO Phases 6+7



36 Major Hurricanes

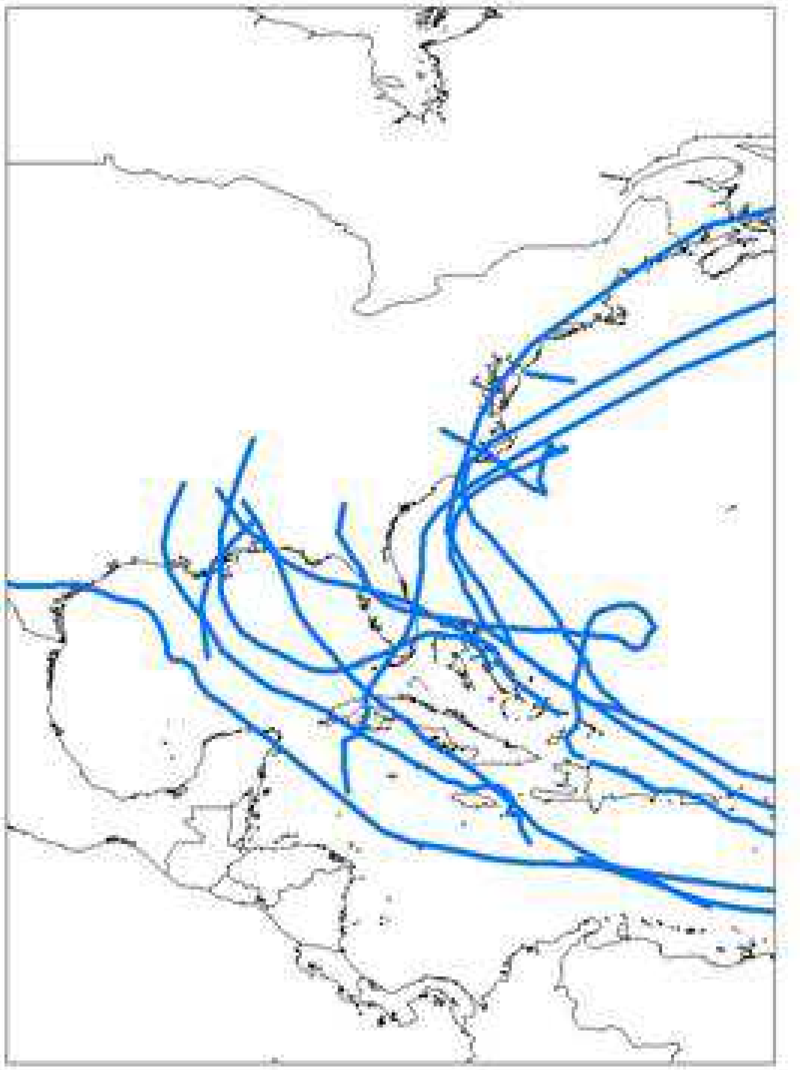


13 Major Hurricanes



10 Hurricane Landfalls

MJO Phase 2



1 Hurricane Landfall

MJO Phase 7

One Last Wave to consider

- Kelvin Waves:
  - Period: 2.5-20 days (much shorter than MJO)
  - Moves eastward at 20-35 kt, roughly 8-12°/Day
  - Trapped equatorially, with the greatest influence in the deep Tropics.
  - Relatively recent use in genesis forecasts
  - When coupled with convection, associated with latent heating and generation of low-level vorticity
  - When Kelvin waves meet tropical waves, under the right conditions they can help cause genesis

Adapted from Ventrice et al. (2012)

MJO vs. KW

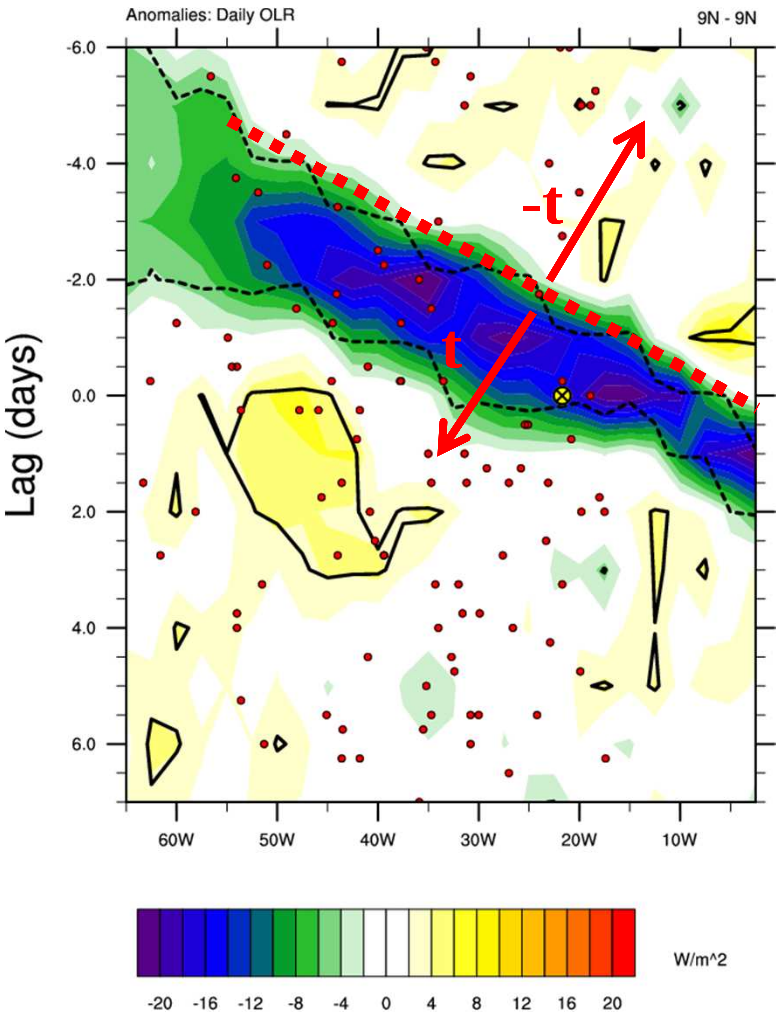
The **Madden-Julian Oscillation** (MJO) consists of an active and suppressed phase, dominated by low-level westerly and easterly anomalies, respectively. Convection is preferred in the active phase.

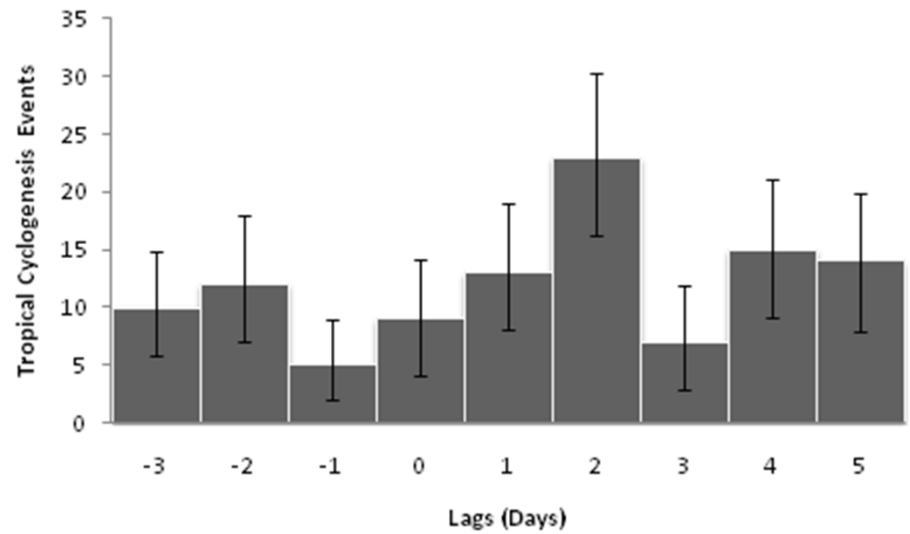
- A typical MJO moves eastward at 4 to 8 m s^{-1} with a zonal extent that spans planetary to synoptic scales.

A **Kelvin wave** is spatially very similar to the MJO, but is typically observed at higher zonal wavenumbers and moves eastward at 10 – 20 m s^{-1}.

- Effects are more constrained within the Tropics and associated wind anomalies are spatially smaller than the MJO.

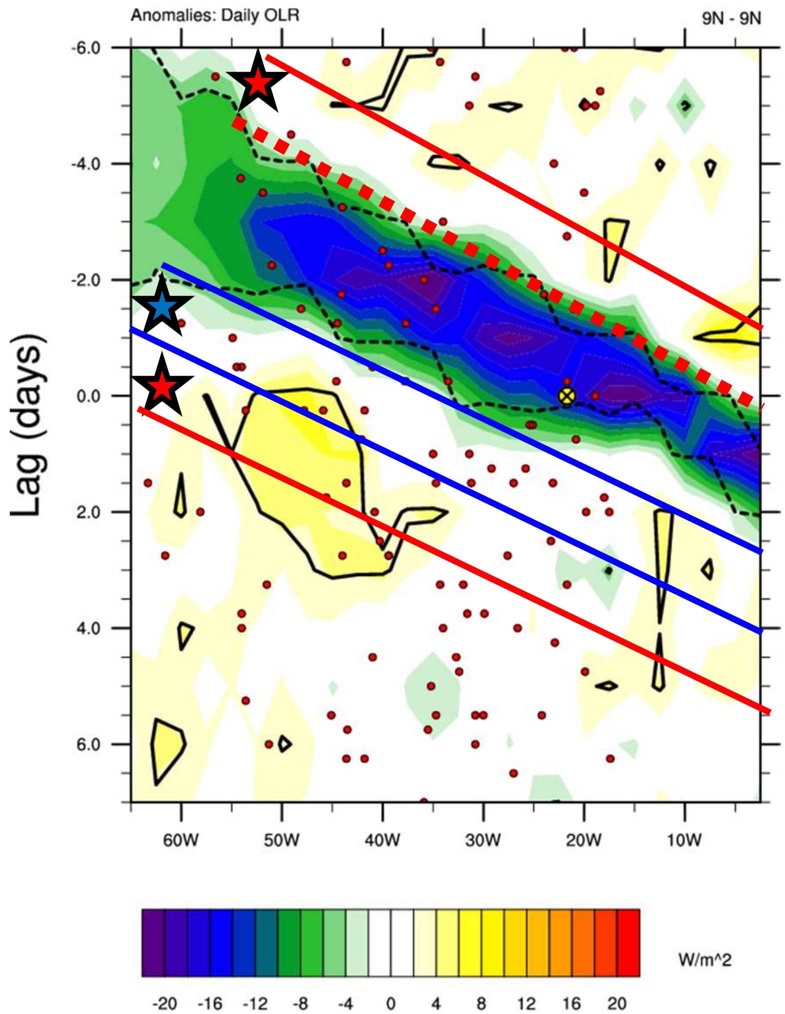
Adapted from Griffin (2014)

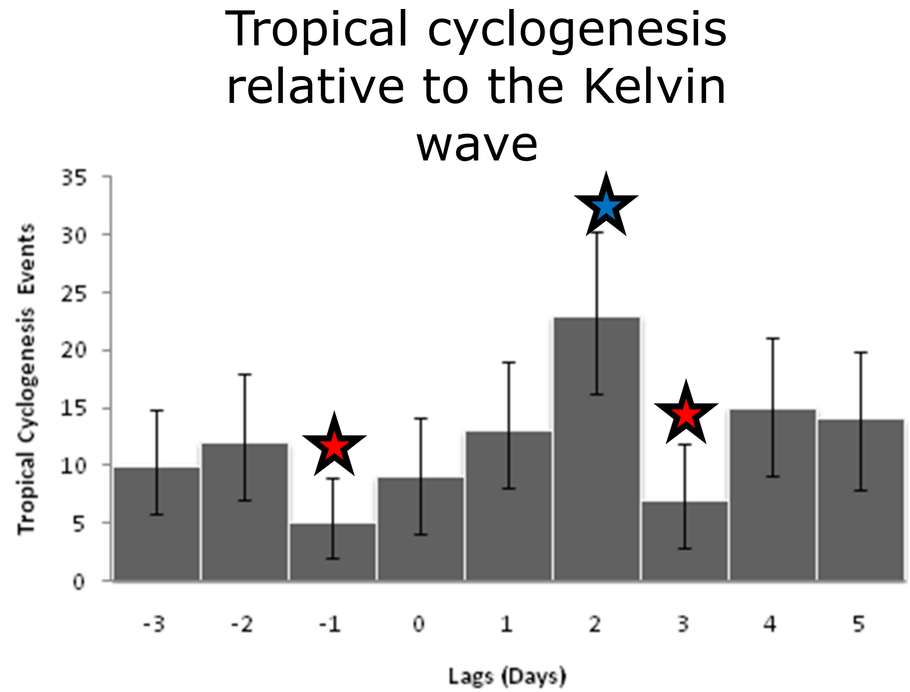




Tropical cyclogenesis events over the MDR (5-25°N, 15-65°W) relative to the CCKW during June-September 1979-2009

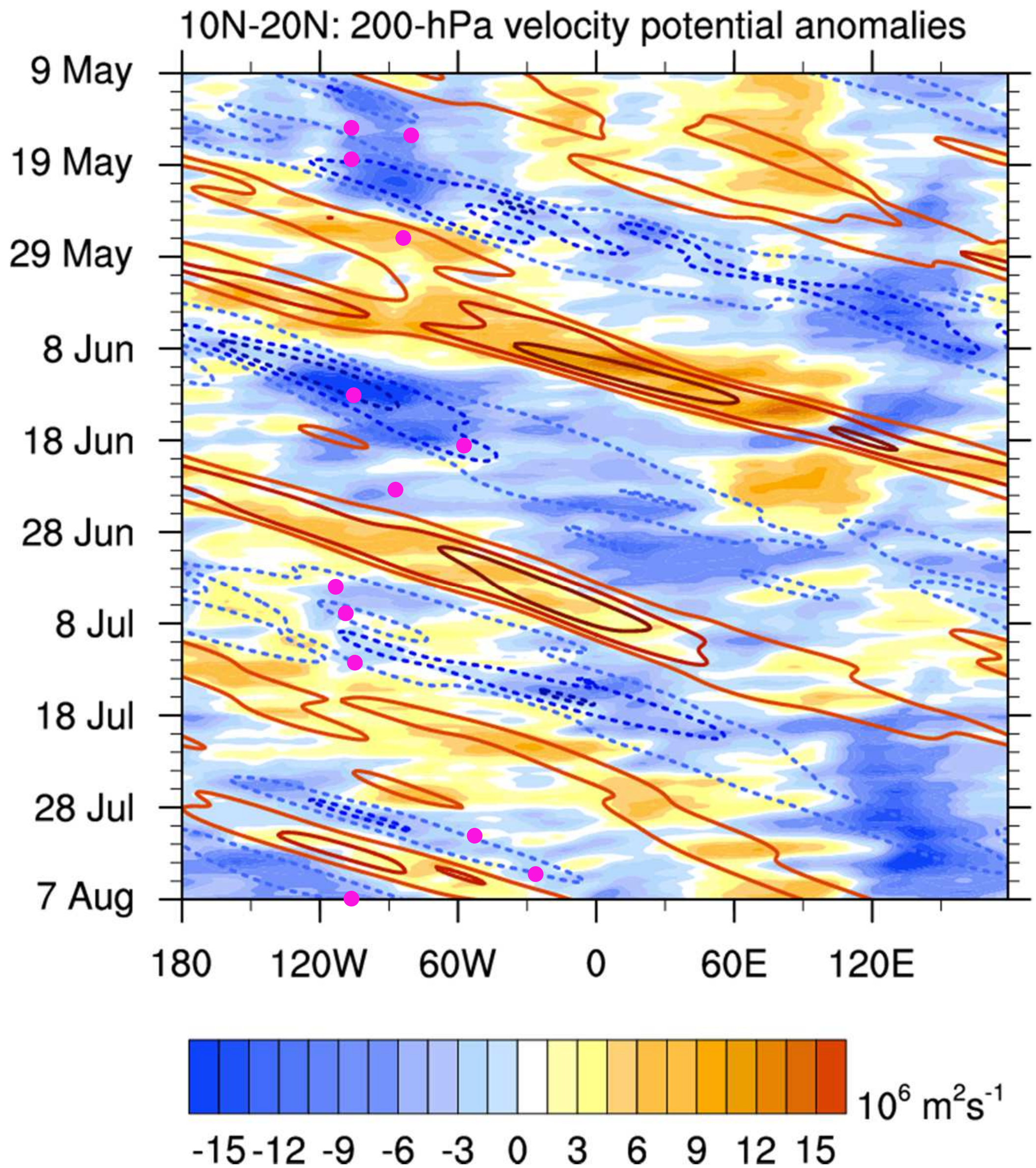
- Day 0 highlights the transition to statistically significant negative unfiltered OLR anomalies, or the eastern-most side of the convectively active phase of the CCKW.
- Error bars indicate the 95% confidence interval.


Anomalies: Daily OLR
9N - 9N
Lag (days)
-6.0
-4.0
-2.0
0.0
2.0
4.0
6.0
60W
50W
40W
30W
20W
10W
W/m^2
-20
-16
-12
-8
-4
0
4
8
12
16
20


Tropical cyclogenesis relative to the Kelvin wave
Tropical Cyclogenesis Events
0
5
10
15
20
25
30
35
-3
-2
-1
0
1
2
3
4
5
Lags (Days)

KW-filtered (blue- favorable) -- magenta dots are Atlc/Epac TC Genesis points in early 2012

Blue–favorable upper-level conditions (lower shear and more unstable)



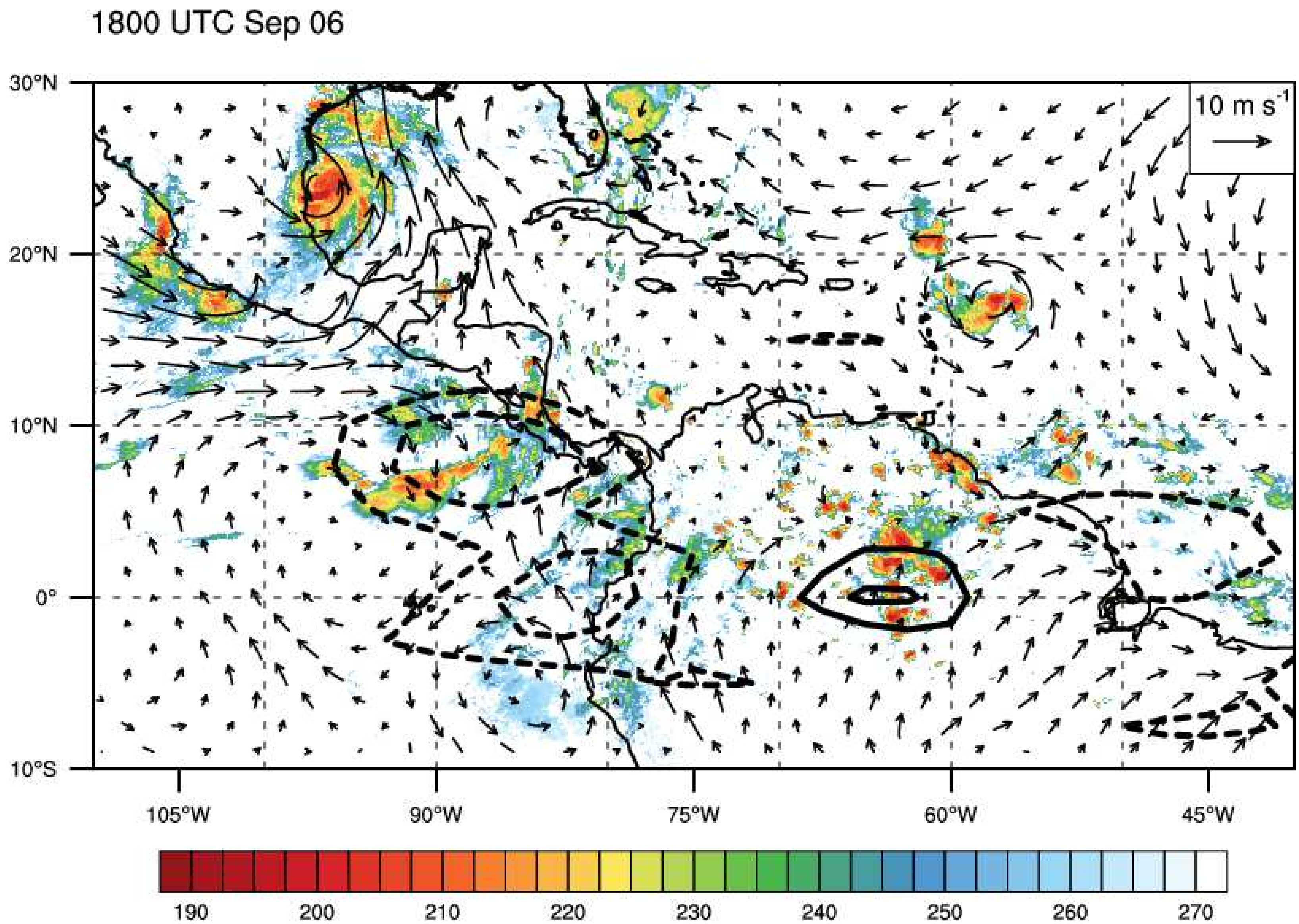
Magenta dots are TC genesis points in early 2012

Unlike conventional tropical waves, this signal moves from west to east

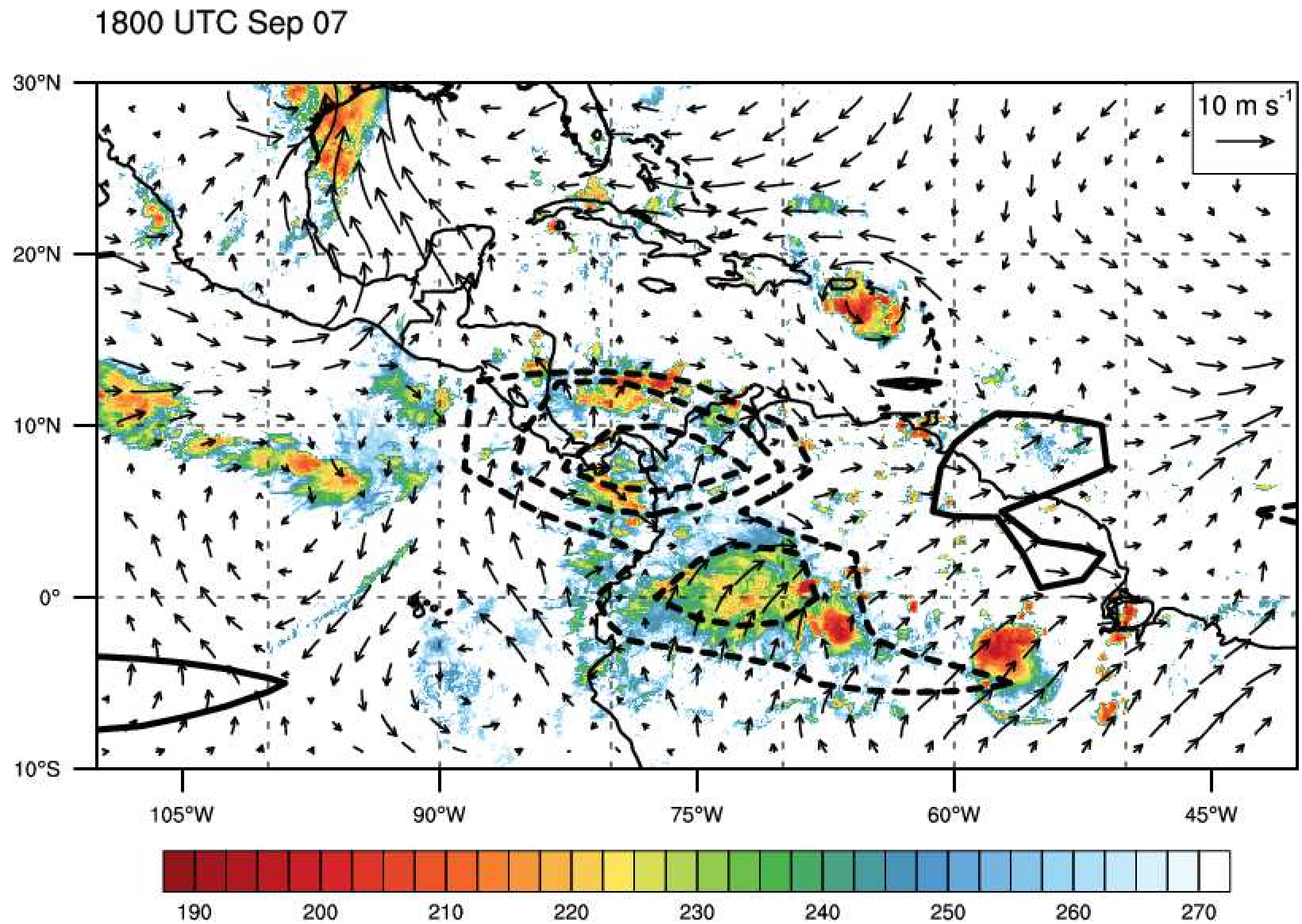
Hurricane Karl’s origins (2010)

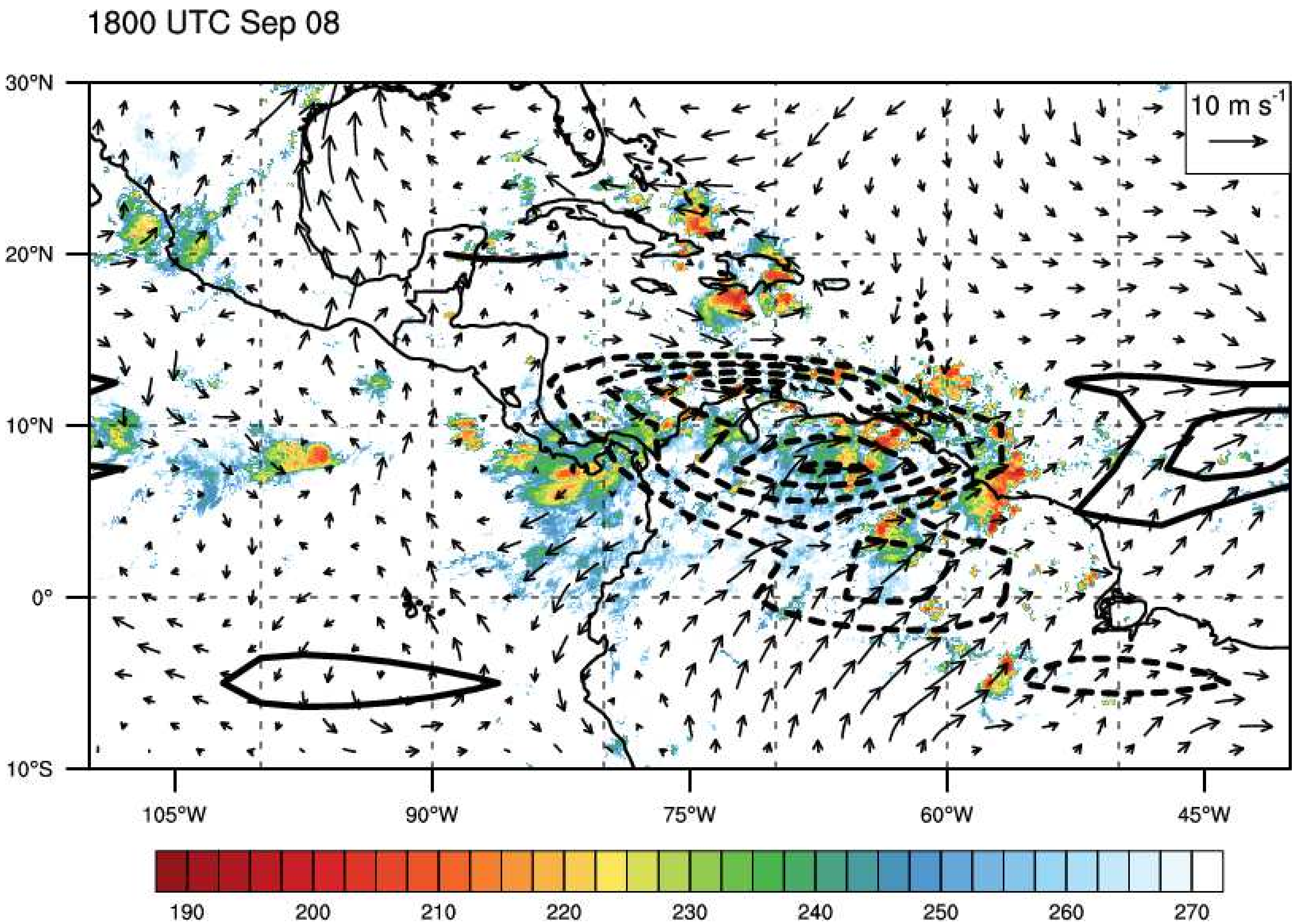
Ventrice, Griffin and Bosart

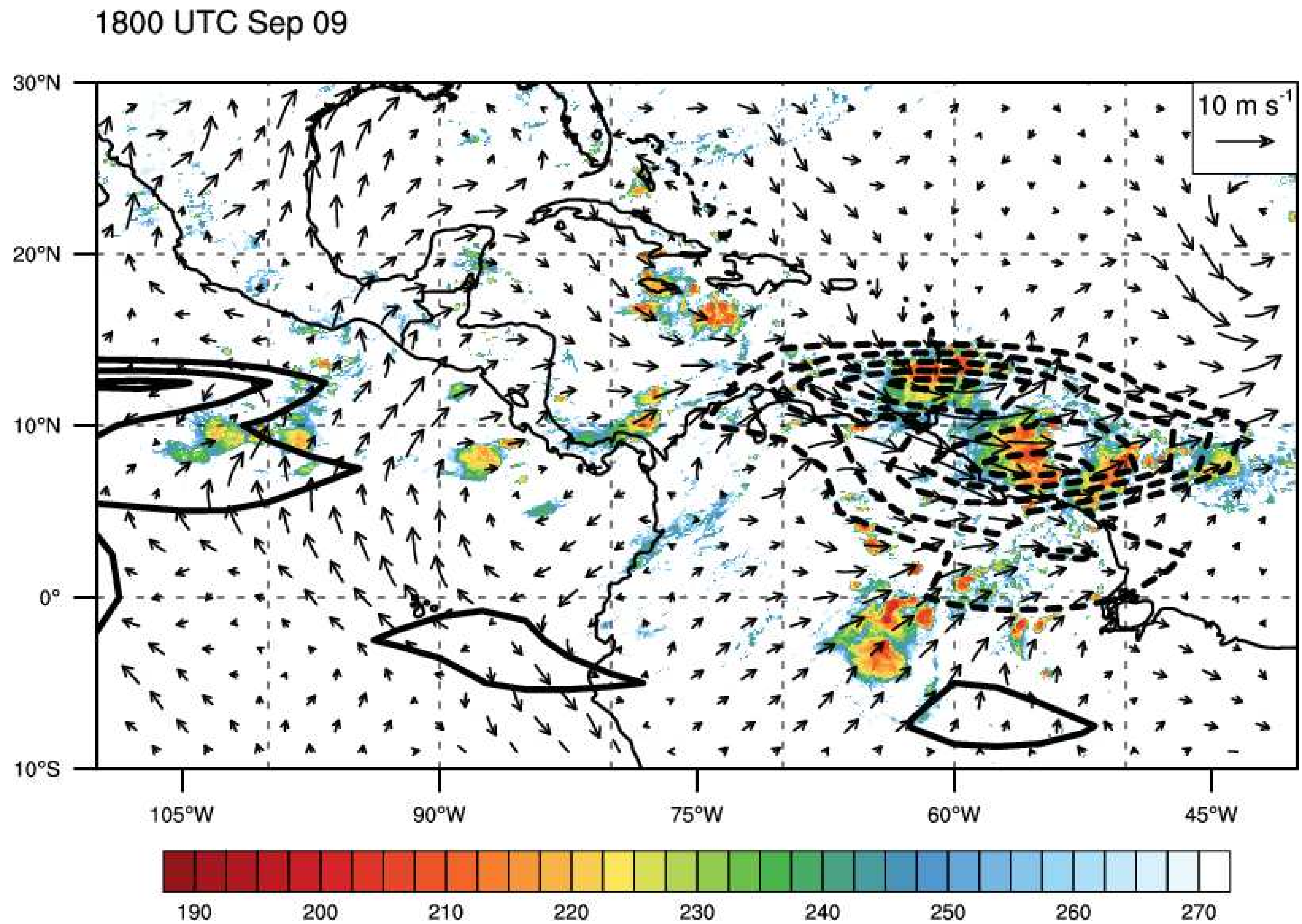
A major question from PREDICT was where did the low-level circulation associated with pre-Karl come from???



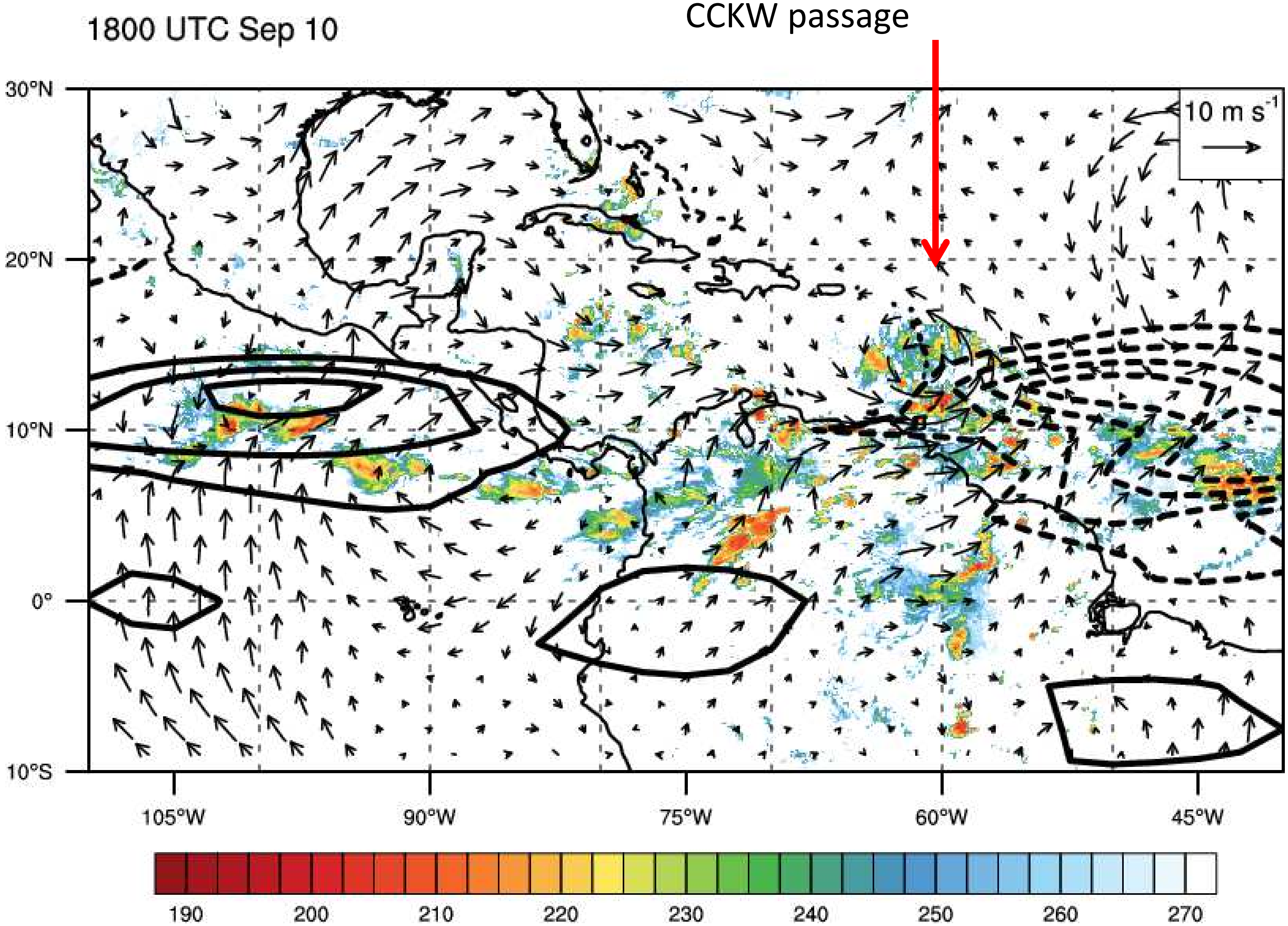
ECMWF-Interim 850 hPa wind anomalies, CPC Merged-IR, NOAA Interpolated Kelvin Filtered OLR anomalies (negative-dashed)

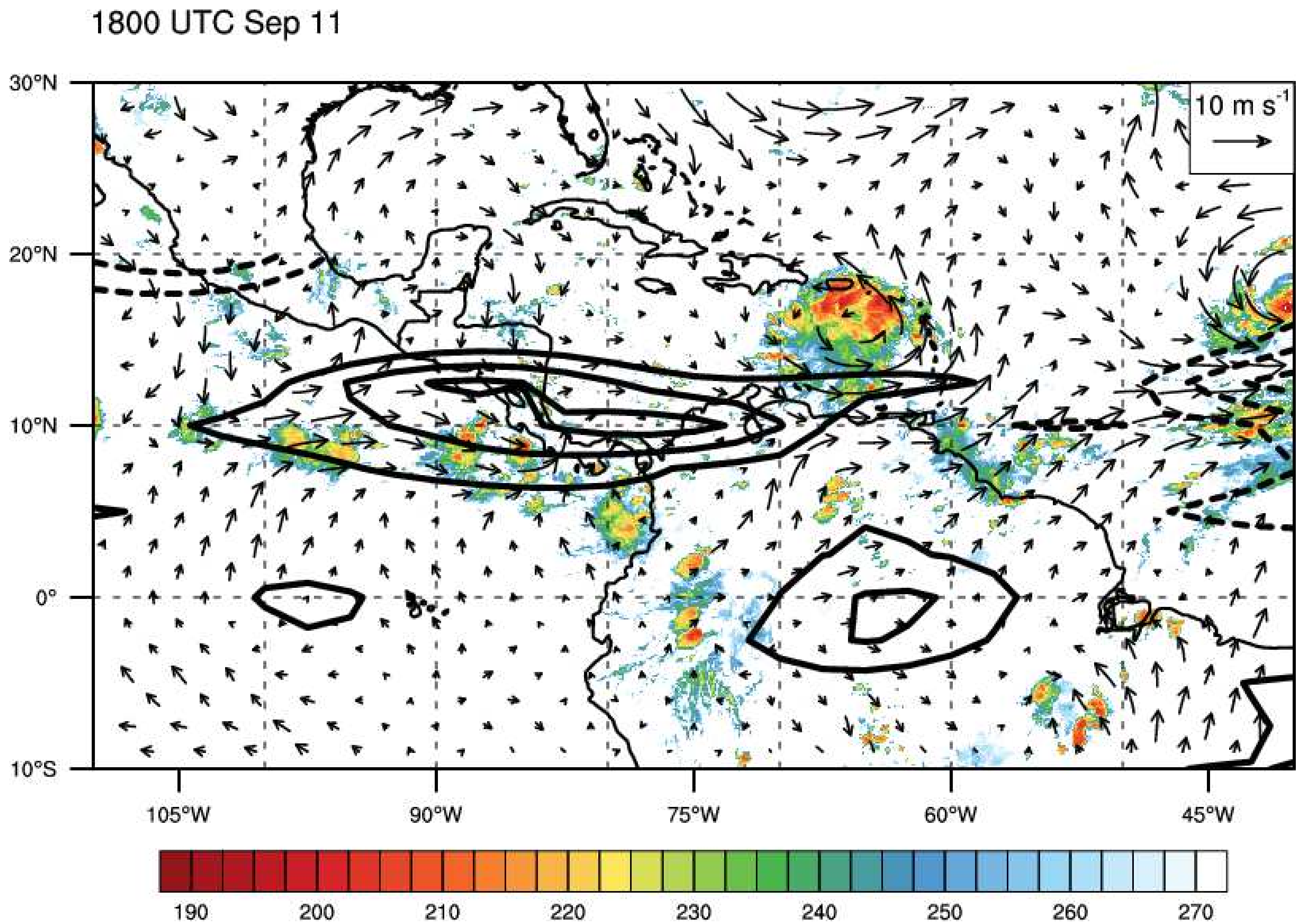

1800 UTC Sep 07
10 m s-1
30°N
20°N
10°N
0°
10°S
105°W
90°W
75°W
60°W
45°W
190
200
210
220
230
240
250
260
270


1800 UTC Sep 08
10 m s-1
30°N
20°N
10°N
0°
10°S
105°W
90°W
75°W
60°W
45°W
190
200
210
220
230
240
250
260
270

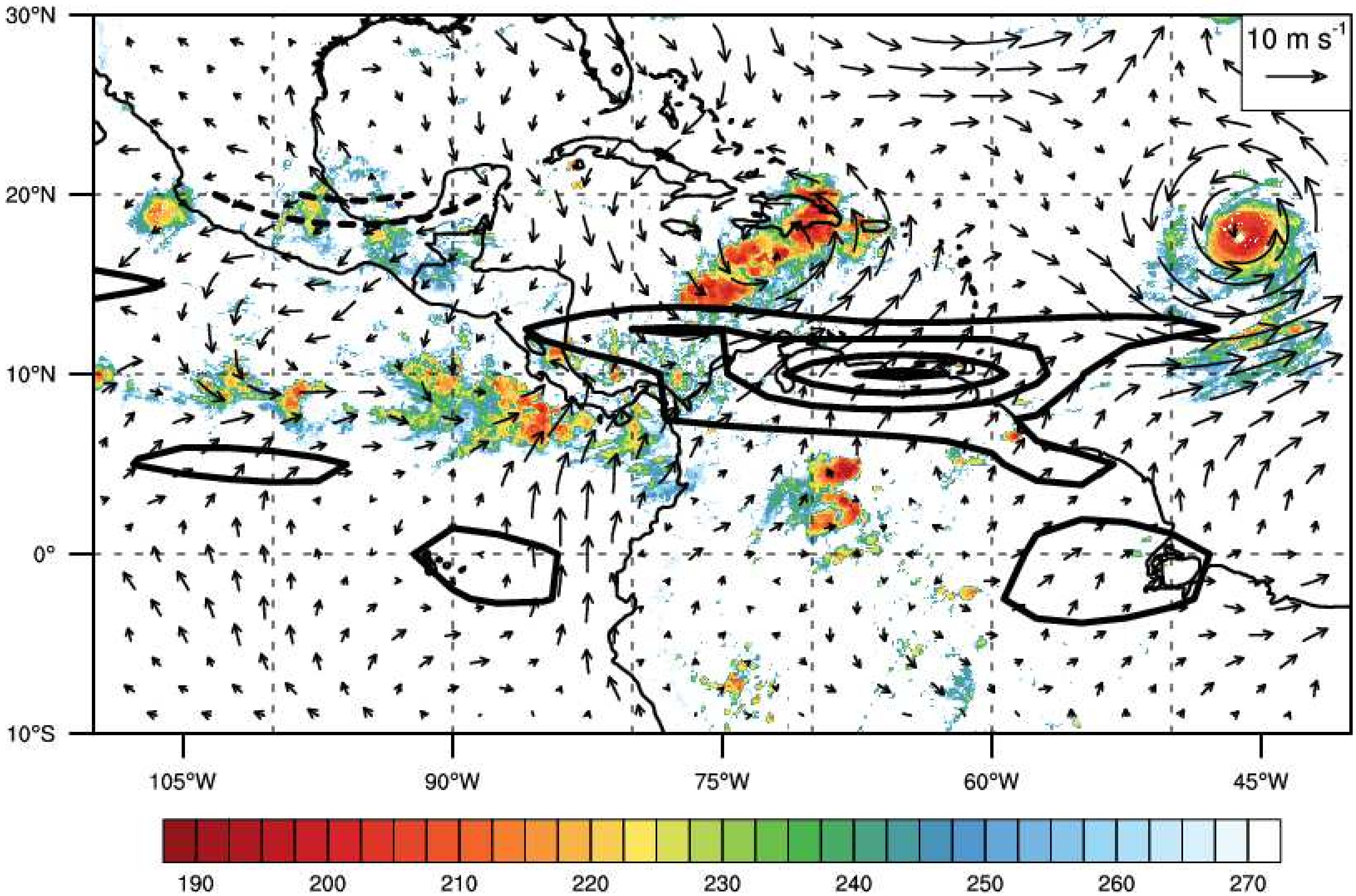

1800 UTC Sep 09
10 m s-1
30°N
20°N
10°N
0°
10°S
105°W
90°W
75°W
60°W
45°W
190
200
210
220
230
240
250
260
270

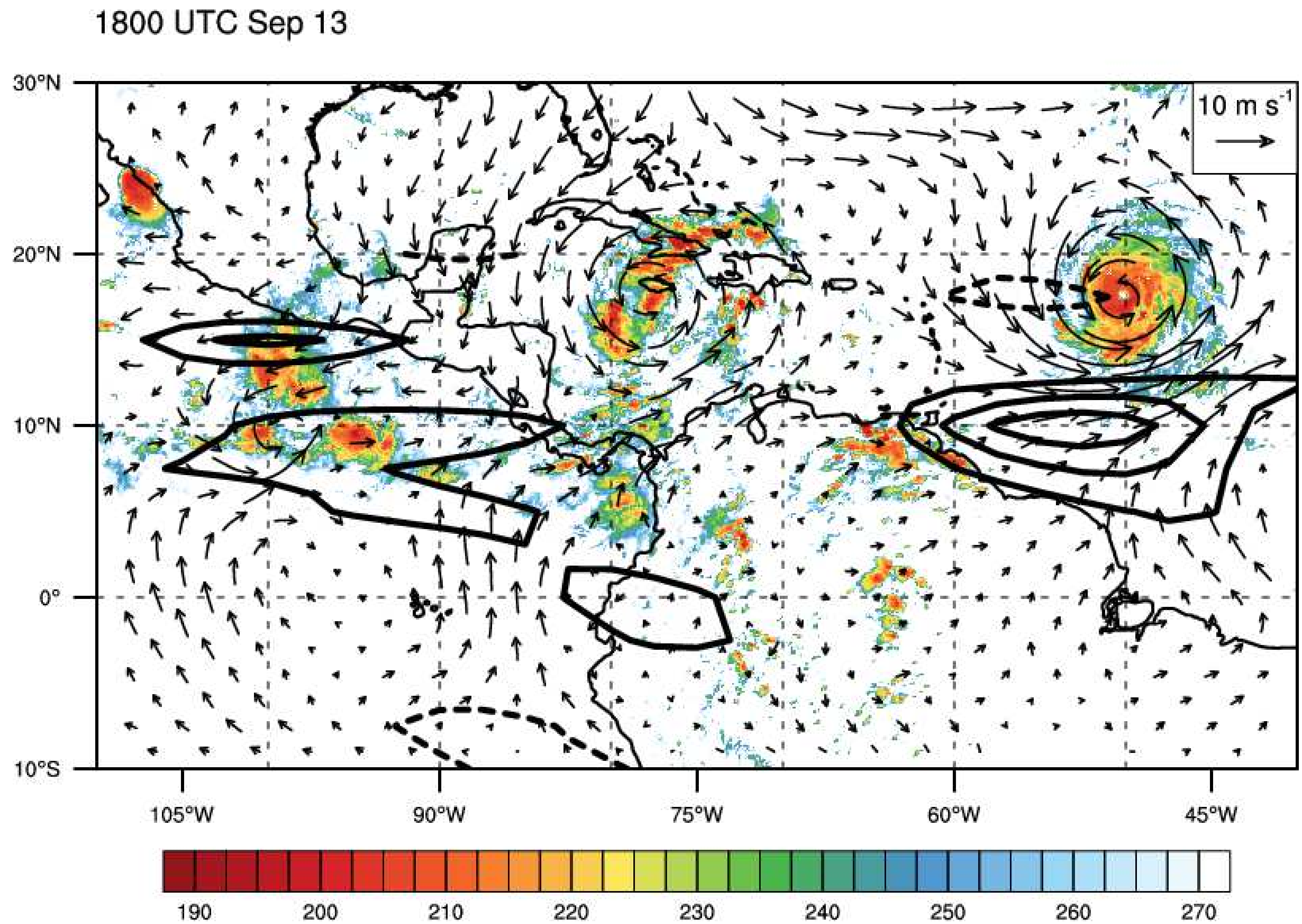
Initial circulation formed after CCKW passage

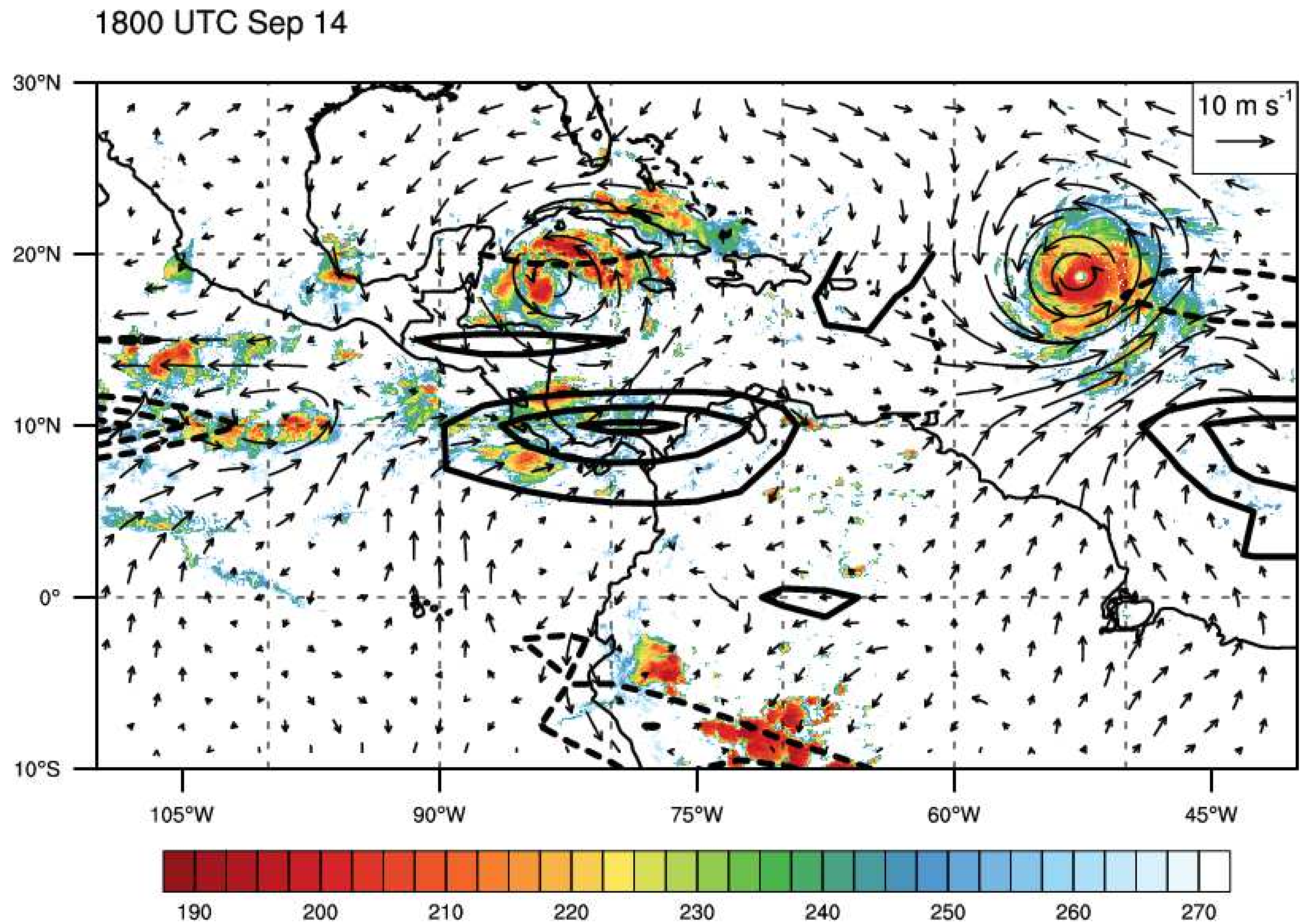



1800 UTC Sep 11
10 m s-1
30°N
20°N
10°N
0°
10°S
105°W
90°W
75°W
60°W
45°W
190
200
210
220
230
240
250
260
270

1800 UTC Sep 12

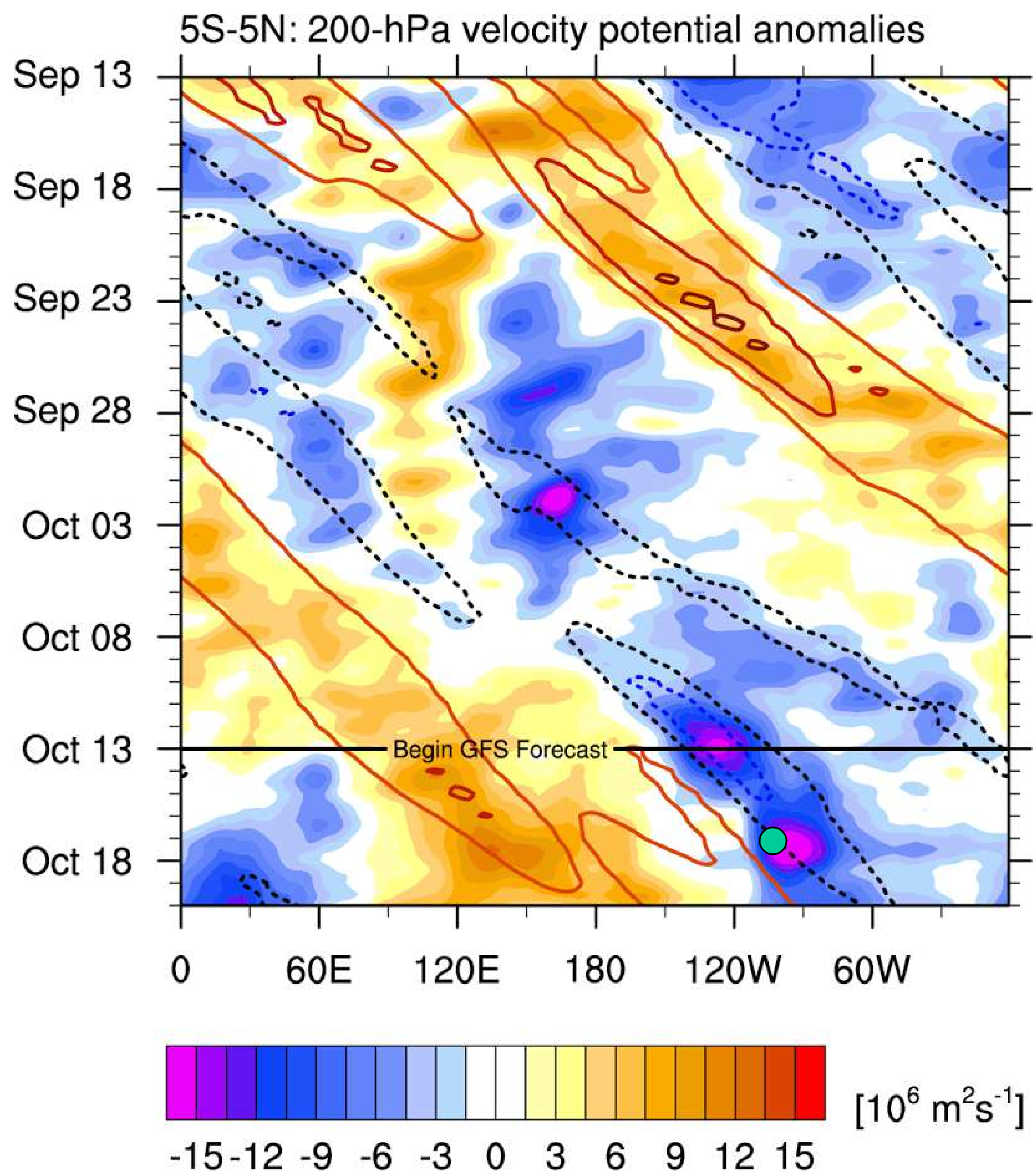



1800 UTC Sep 13
10 m s-1
30°N
20°N
10°N
0°
10°S
105°W
90°W
75°W
60°W
45°W
190
200
210
220
230
240
250
260
270


1800 UTC Sep 14
10 m s-1
30°N
20°N
10°N
0°
10°S
105°W
90°W
75°W
60°W
45°W
190
200
210
220
230
240
250
260
270

"Yet another strong CCKW is moving across the eastern Pacific…This system should move through the eastern Pacific within the next few days, with genesis possible in the far eastern Pacific Days 3-5."

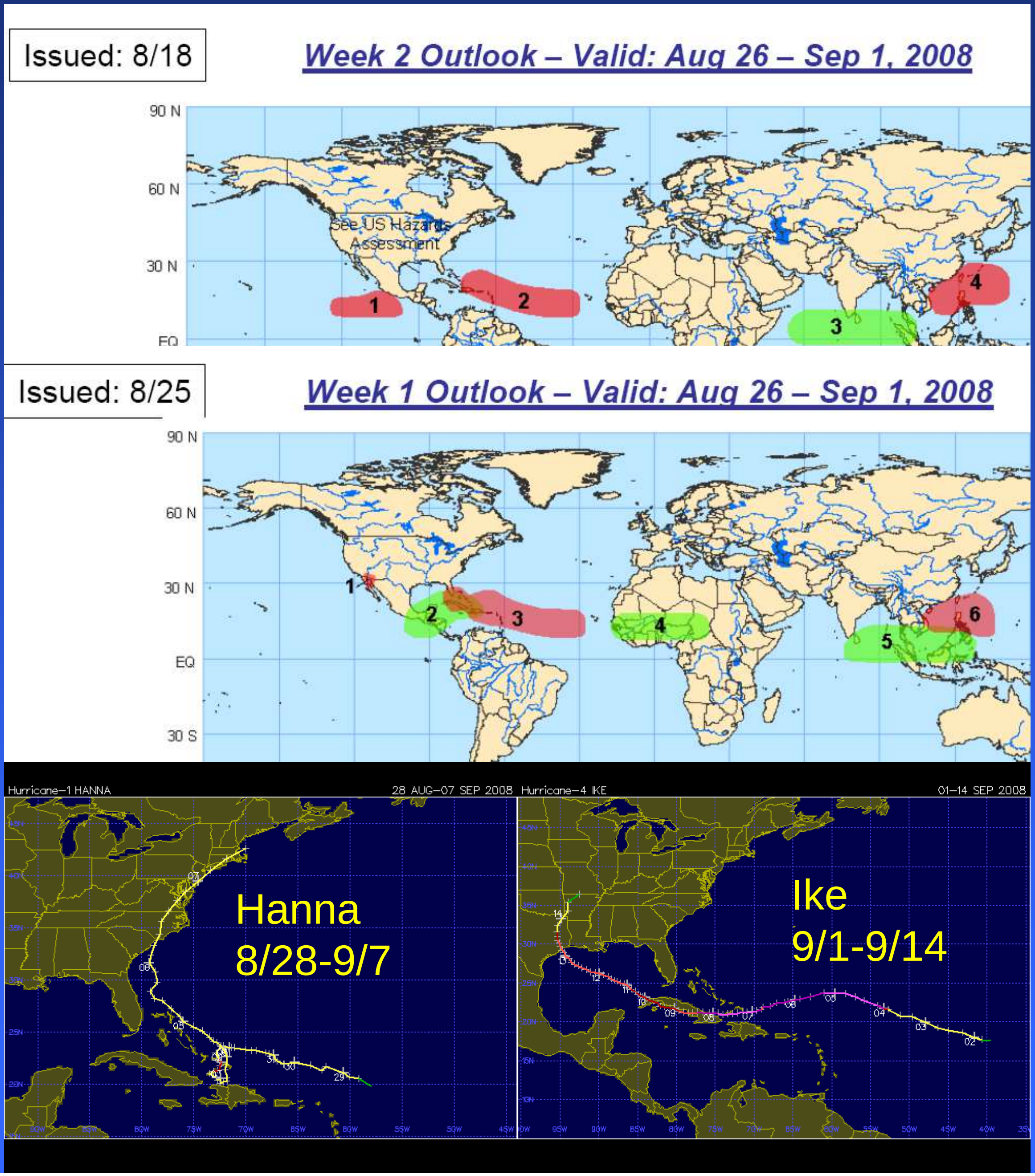
Trudy forms



Operational challenges

- Real-world CCKWs have day-to-day weather patterns overlaid on them, making them harder to recognize.
- When making genesis forecasts for a particular system, any CCKW information must be taken in context with the entire weather situation.
- Knowledge about the base state (~120 d mean or ENSO), MJO phase, climatology and numerical weather models must all be considered in concert with CCKW interactions.
- For example, if the base state is extremely unfavorable, can it overcome other enhancing factors? (e.g. most of the 2014 Atlantic hurricane season, 2015 EPac is the counter example)

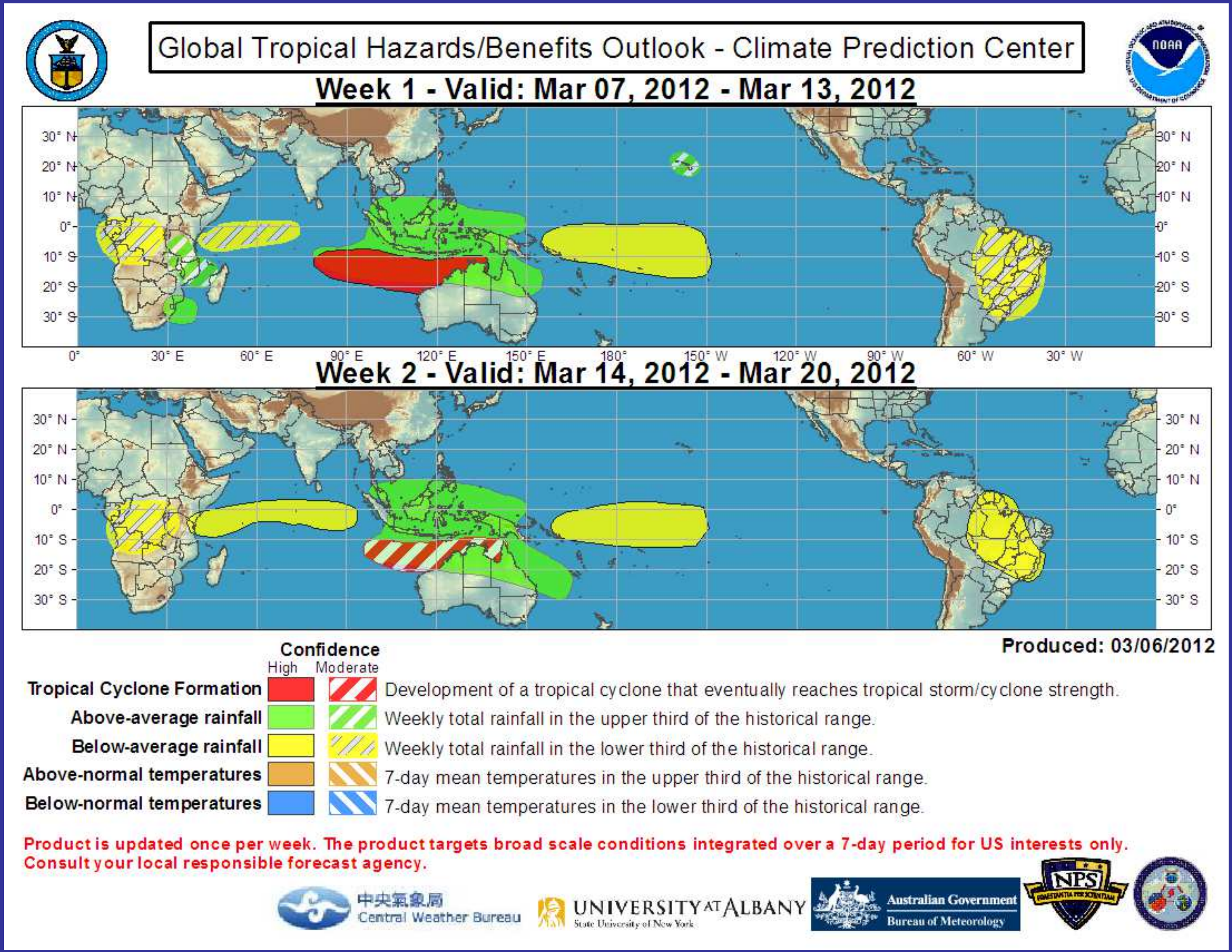
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php



Product Example

Issued 2x per week around noon Tues/Fri.

Current Format



http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php

Seasonal Forecasting

Seasonal Forecasting is more than this!

Short history of NOAA seasonal hurricane forecasting

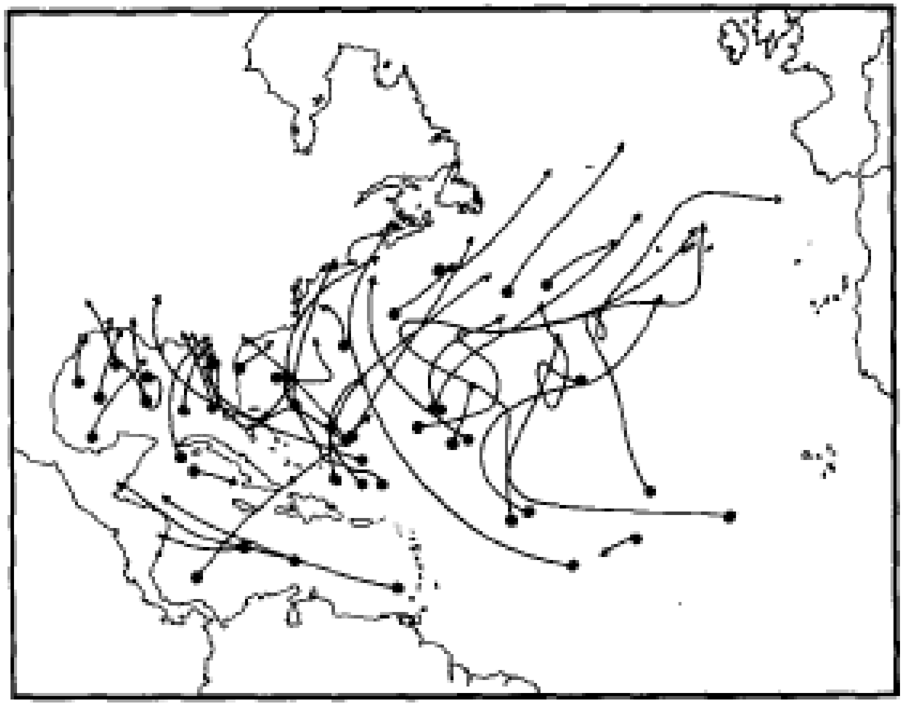
- The Climate Prediction Center (CPC) began issuing Atlantic seasonal hurricane forecasts after the Gray 1997 forecast bust.
- Outlooks issued in late May and early August.
- Collaborative effort between the CPC, National Hurricane Center and Hurricane Research Division.
- Outlooks are a qualitative combination of statistical and dynamical tools, but have become more quantitative over time.

El Niño

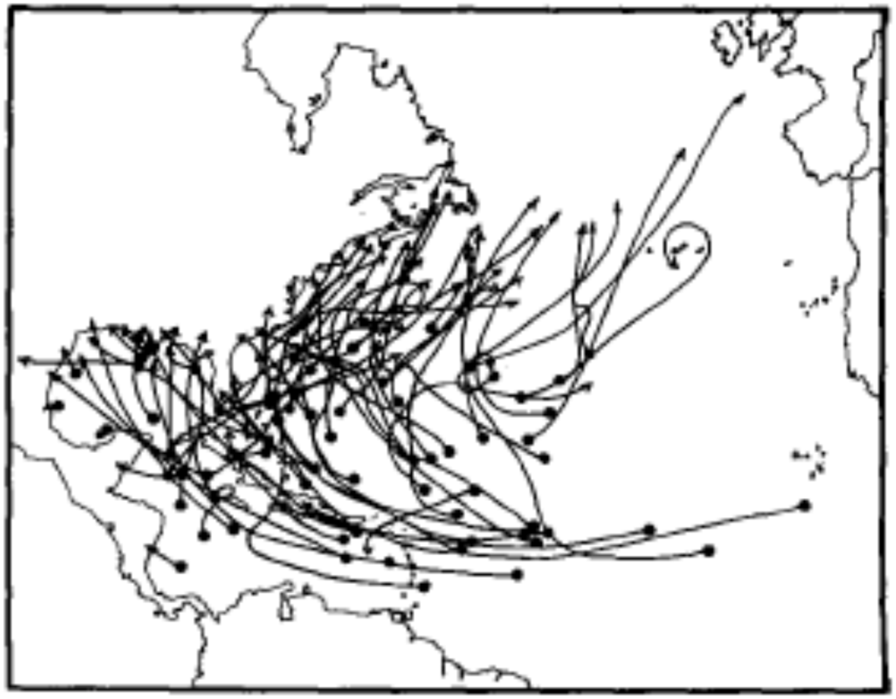
- Natural warming of the equatorial waters in the central and eastern Pacific Ocean every 3 to 5 years
- Affects global atmospheric circulation patterns by altering thunderstorm development in the deep tropics
- Moderate or strong events generally cause a reduced Atlantic hurricane season
- Weaker events have little relationship to Atlantic hurricane activity

Composite of tropical cyclone tracks during 14 moderate to strong El Niño years versus the next year

El Niño Years

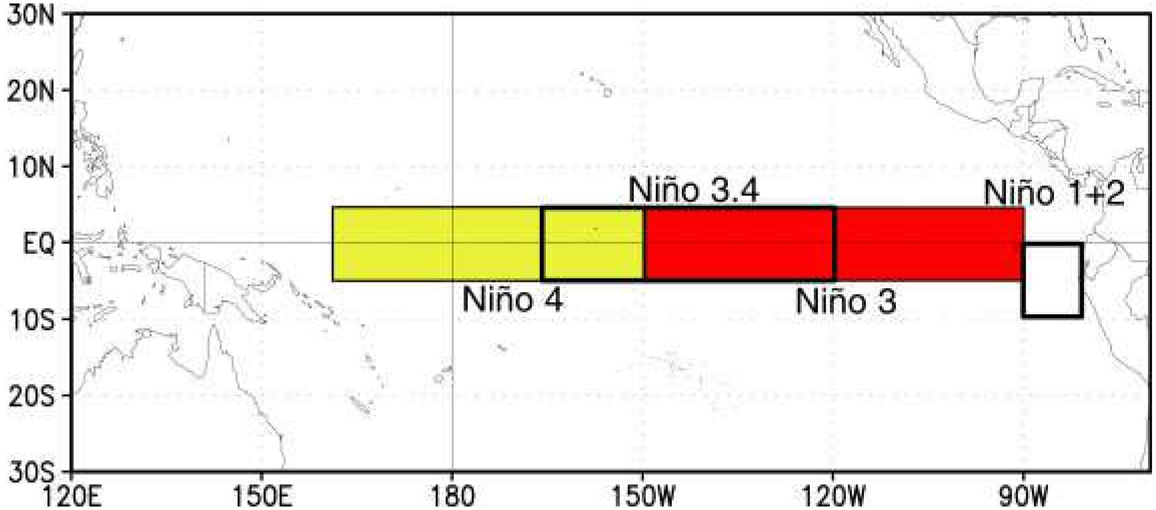


Year after El Niño

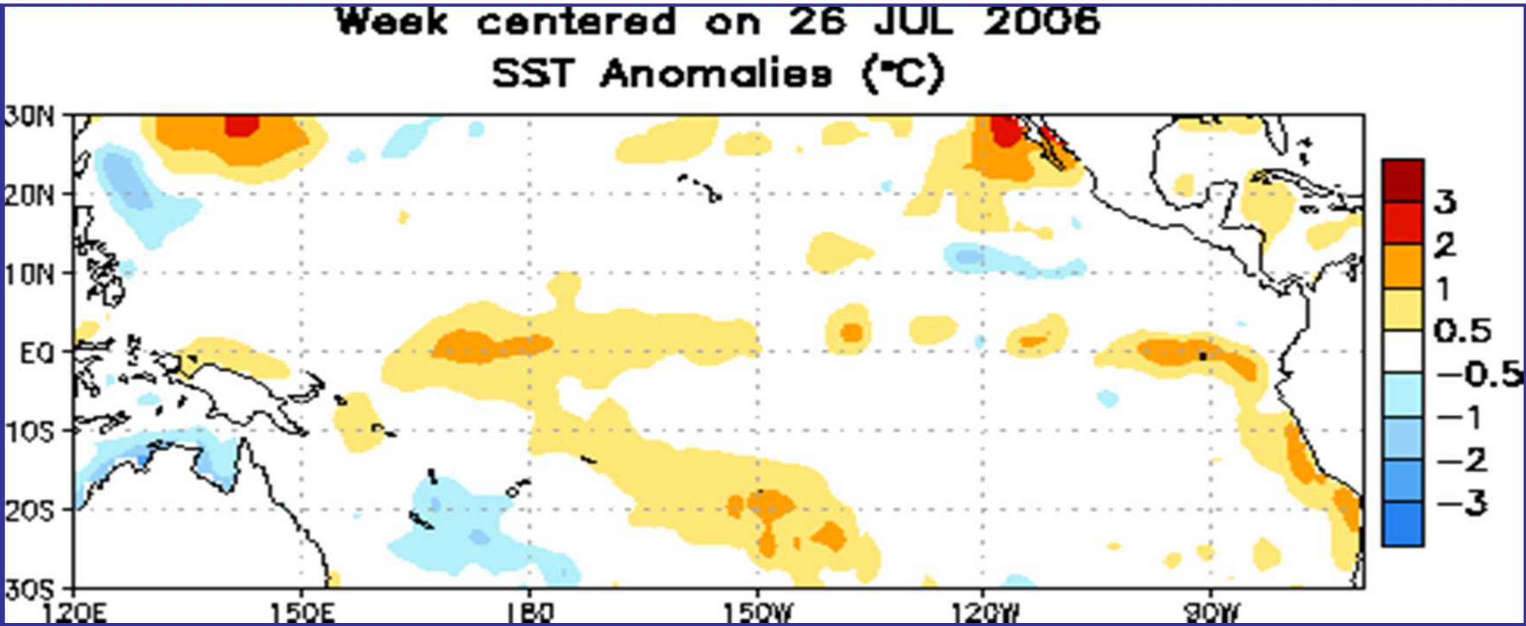


From Gray 1984

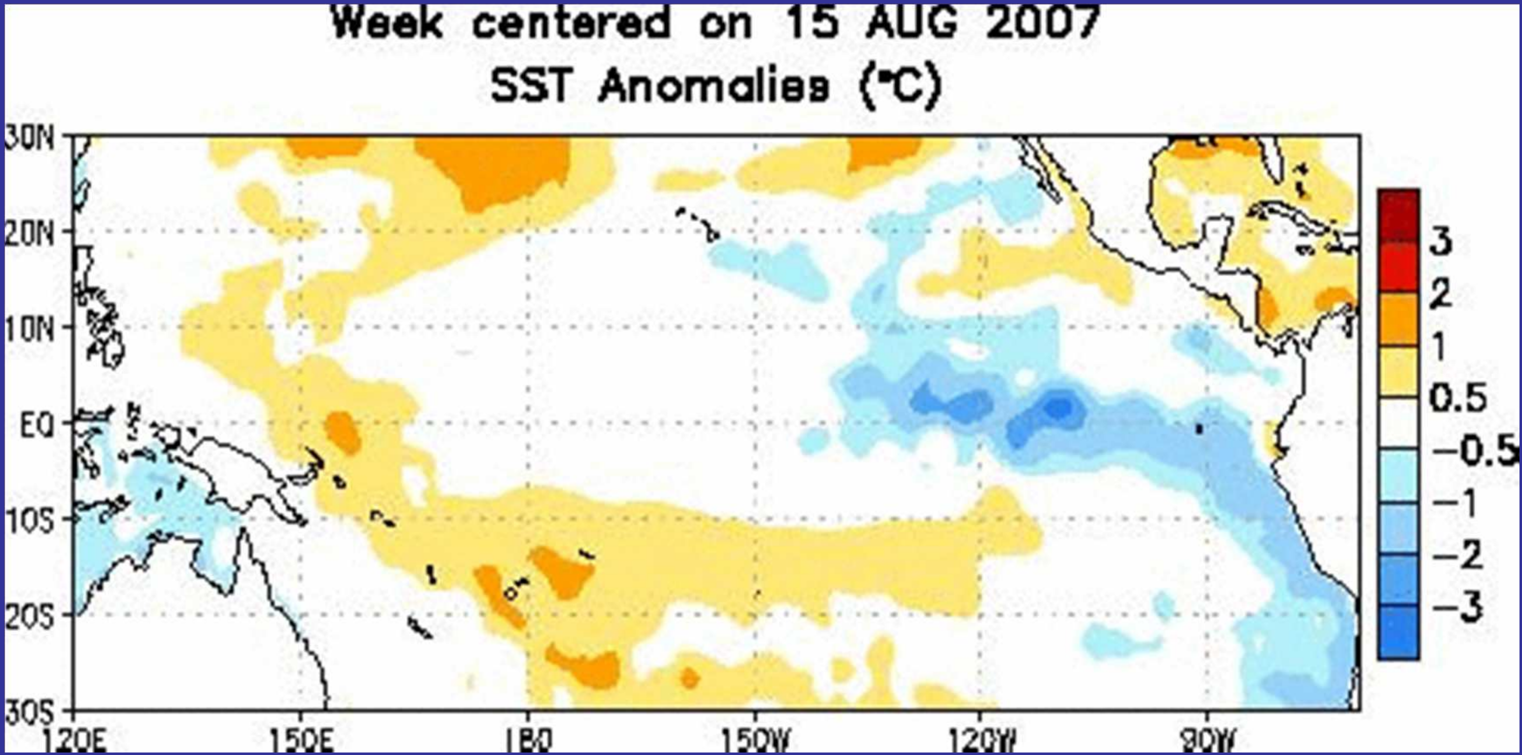
Niño regions



Nino 3.4 region generally has the strongest relationship with Atlantic hurricane activity.

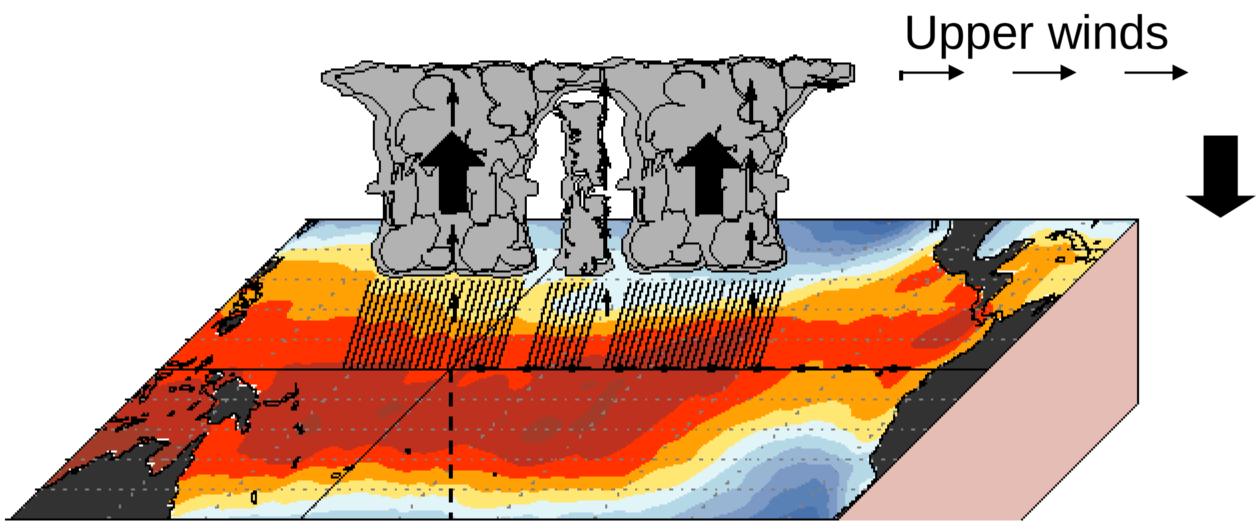


El Niño

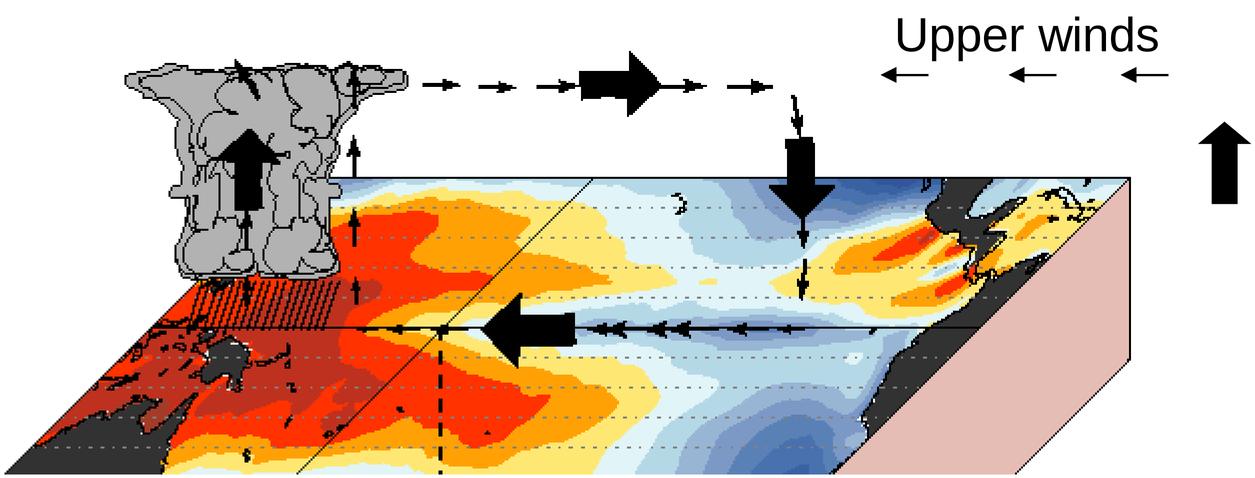


La Niña

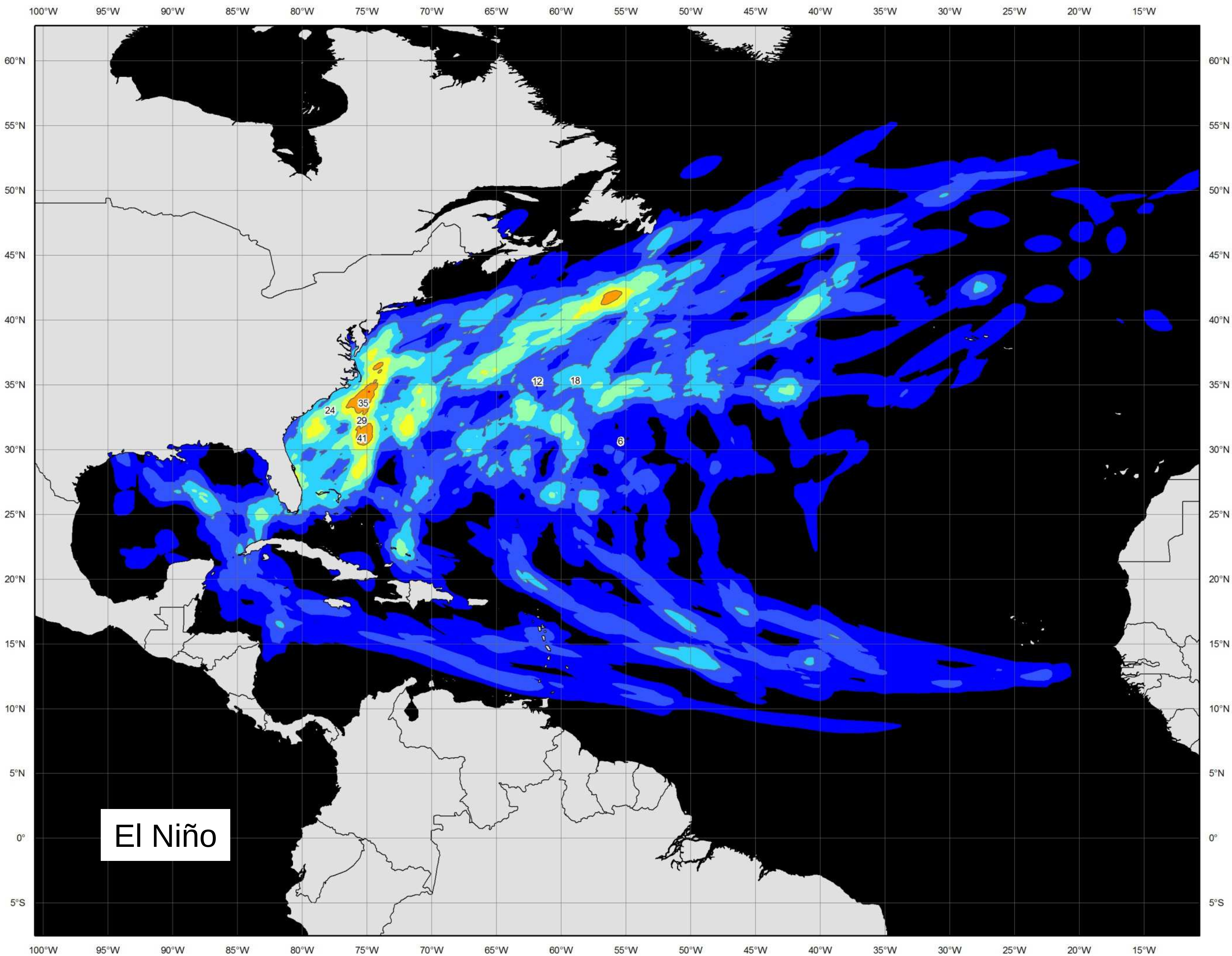
El Niño versus La Niña



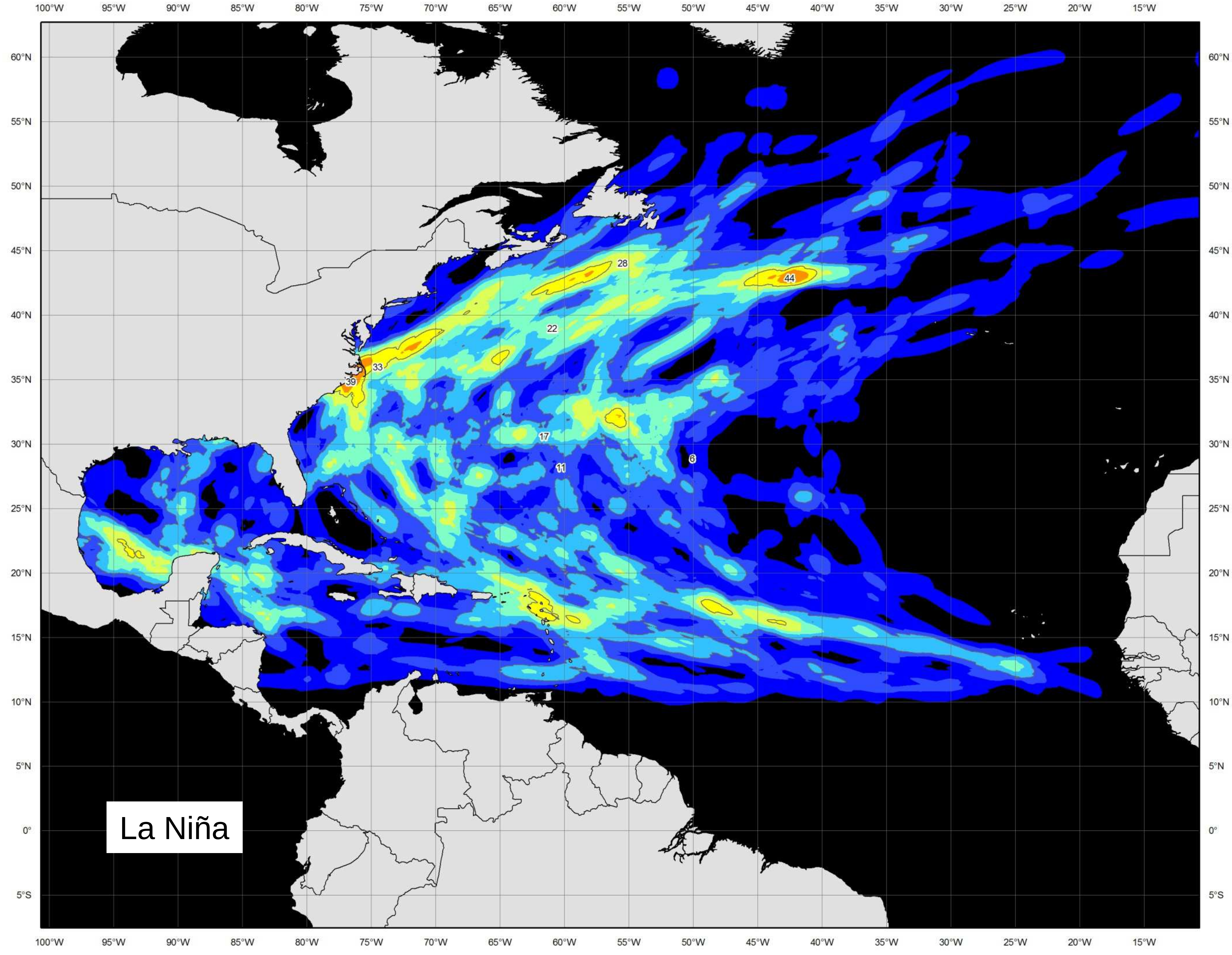
El Niño causes extra thunderstorm development over the central and eastern equatorial Pacific. This causes a response in the atmosphere over the Atlantic basin of increased shear and sinking air, causing a drier and more stable atmosphere.



La Niña causes a reduction and westward shift in thunderstorms. This forces the maximum sinking air to be located over the eastern Pacific and allows air to rise more freely over the Atlantic basin, in addition to less shear.



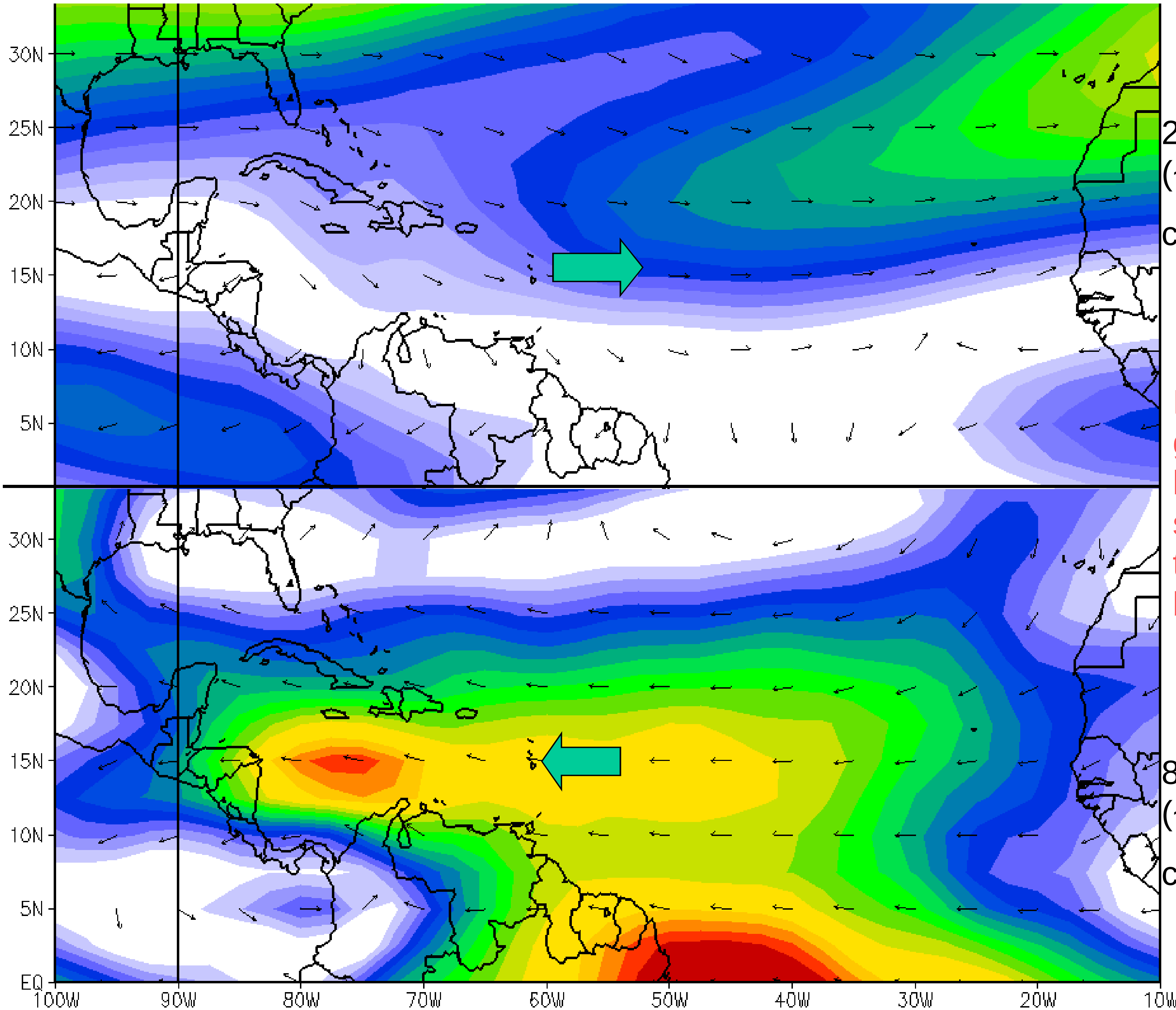
El Niño
35
24
29
41
12
18
6
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
50°W
45°W
40°W
35°W
30°W
25°W
20°W
15°W
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
15°N
10°N
5°N
0°
5°S



100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
50°W
45°W
40°W
35°W
30°W
25°W
20°W
15°W
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
15°N
10°N
5°N
0°
5°S
28
44
22
33
39
17
11
6
La Niña

Vertical Wind Shear

- Tropical cyclones generally require a low vertical wind shear environment to develop, less than about 10-15 mph.
- Vertical shear displaces energy away from the center of a tropical system and slows development.
- By monitoring early season vertical shear (June-July), you can gain knowledge about the peak of hurricane season from August-October (when 90% of all major hurricanes strike).



200 mb
(~40,000 ft)

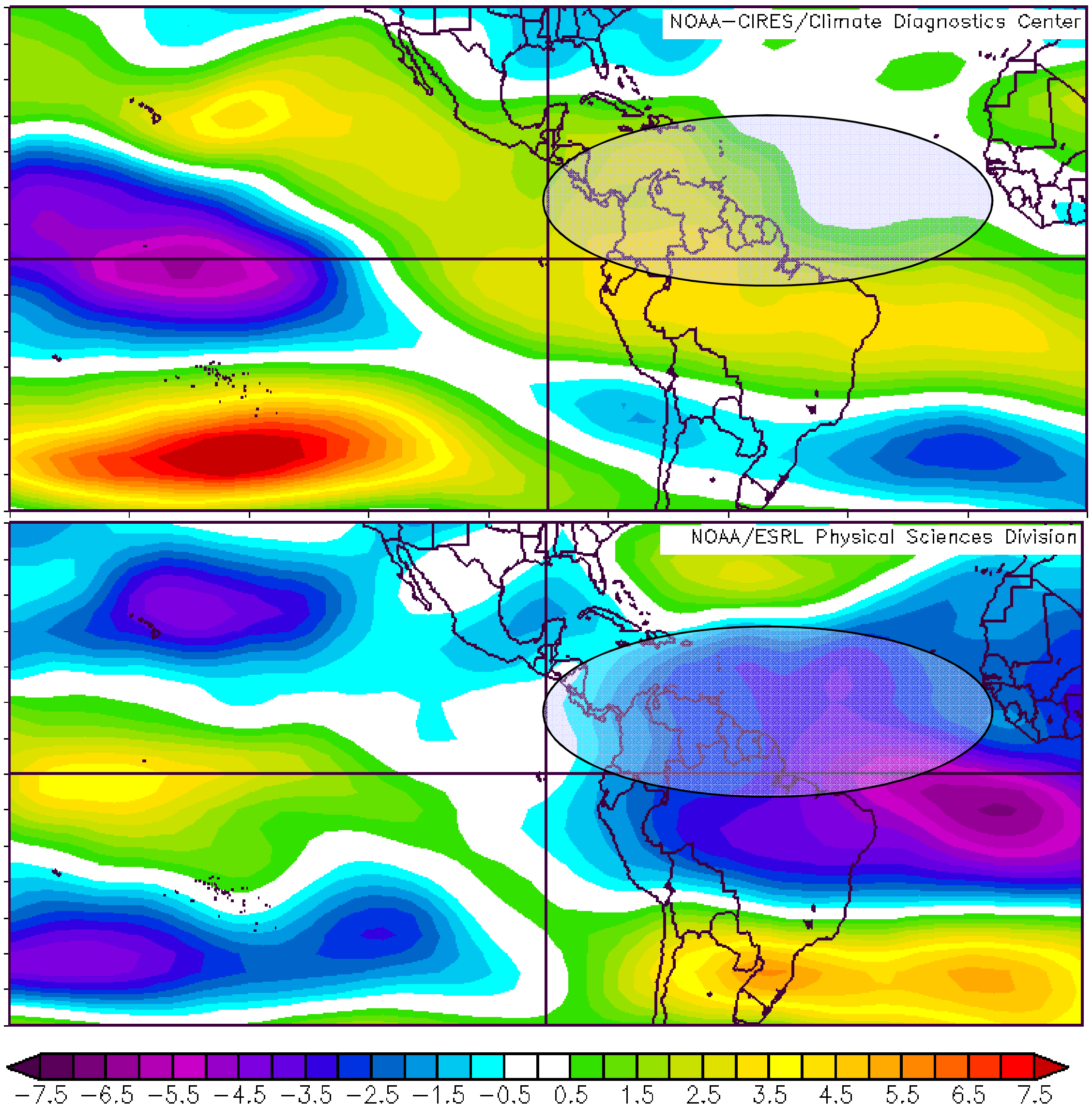
climatology

In general, lots of shear in the basin

850 mb
(~5,000 ft)

climatology

200mb zonal wind anomalies (m/s) during June-July of 10 ENSO events.

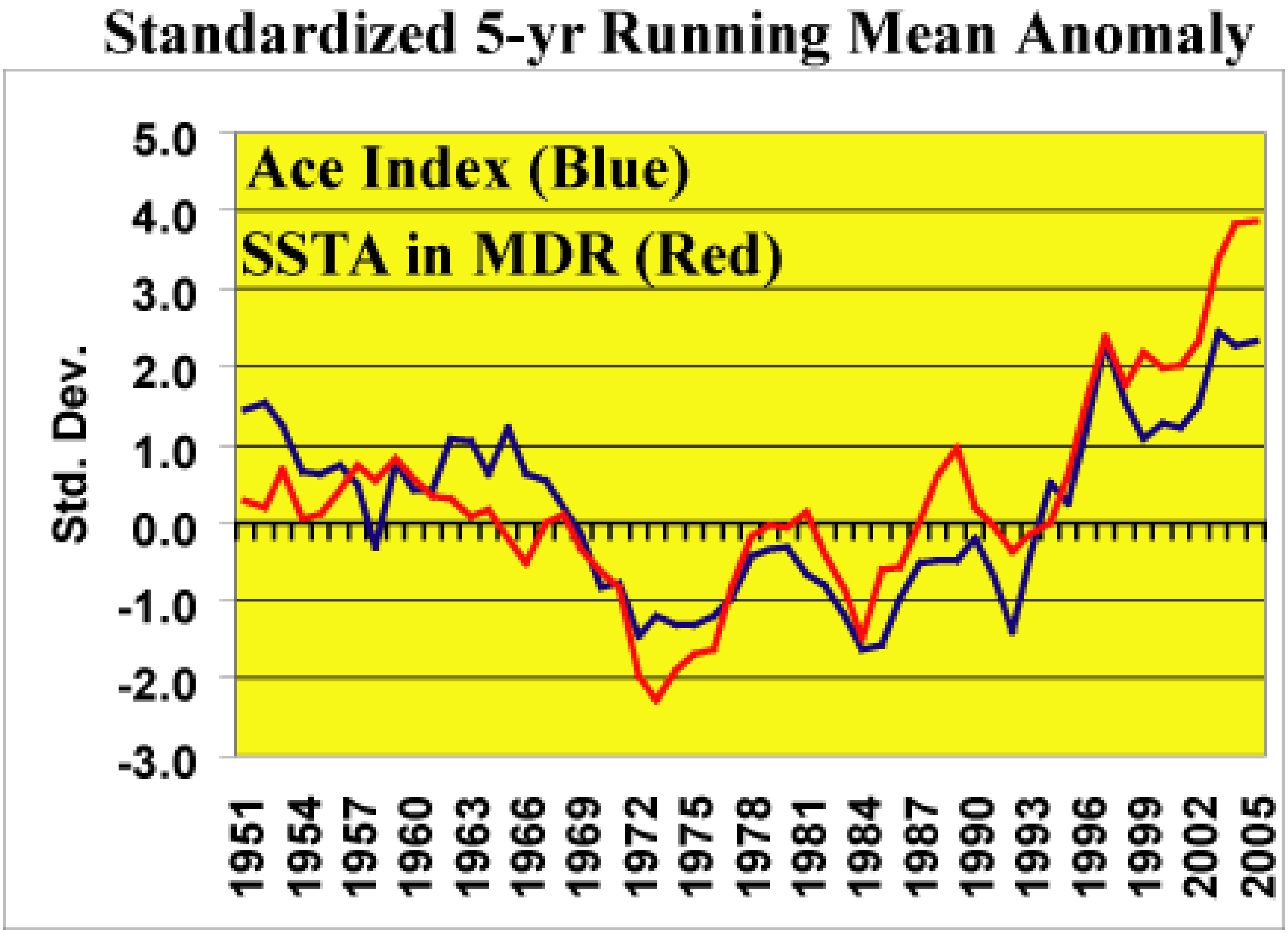


El Niño

La Niña

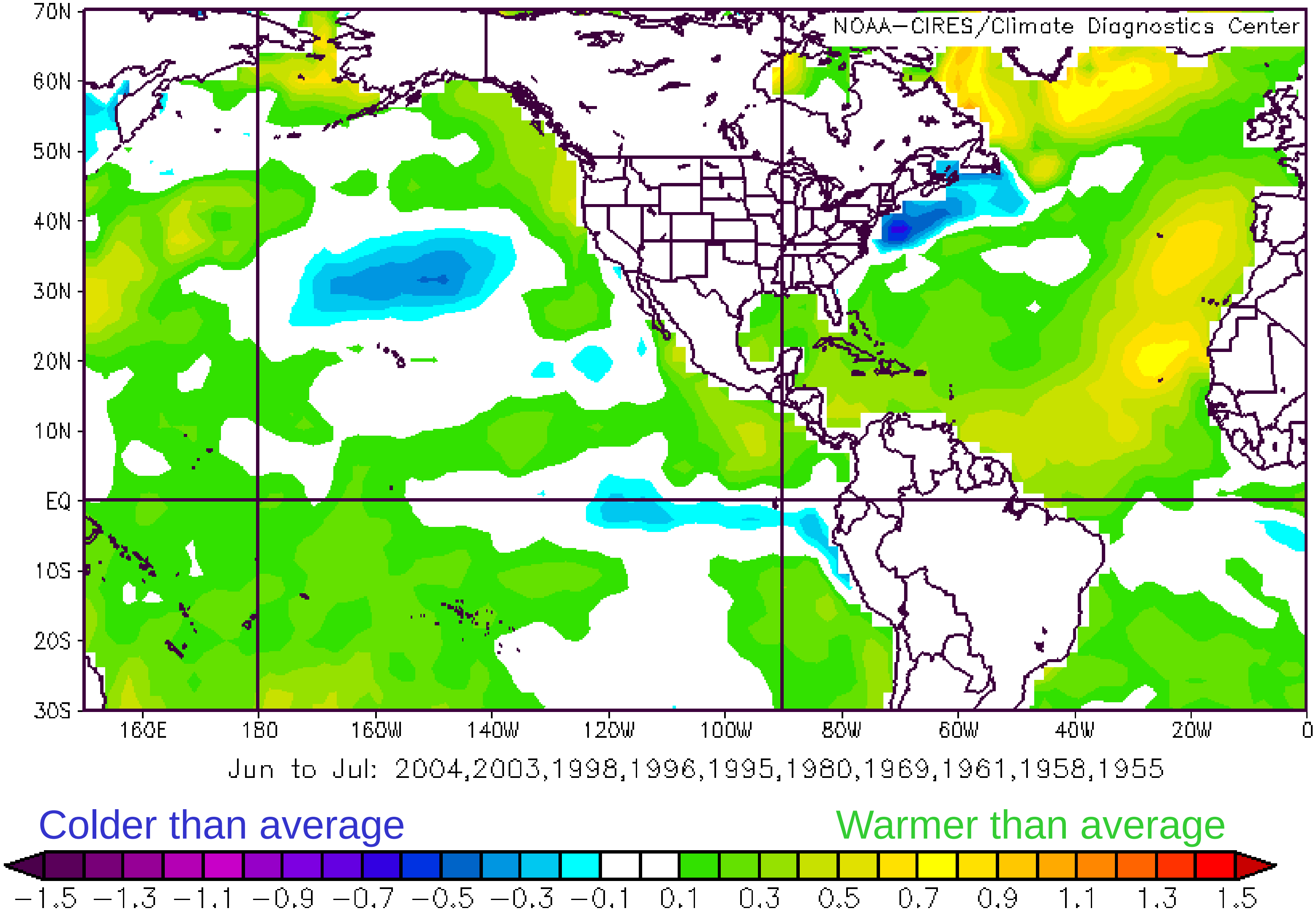
Sea-Surface Temperatures (SSTs)

- In the Atlantic basin, warmer waters generally mean a more active hurricane season.
- Relative warmth of Atlantic to global tropics also important.
- Higher SSTs lead to more instability in the boundary layer of the atmosphere.
- Changes in SST gradients modulates regional circulation patterns.
- Atlantic SSTs also atmospheric proxy.
- Cooler waters are linked to higher surface pressures, stronger surface winds (higher shear as a result) and upwelling.



Note how the SSTs are closely related to total activity (ACE). SST in the Atlantic alone on a 5 year running mean accounts for over 70% of the variability in ACE.

Composite map of June-July SST anomalies during 10 active hurricane seasons

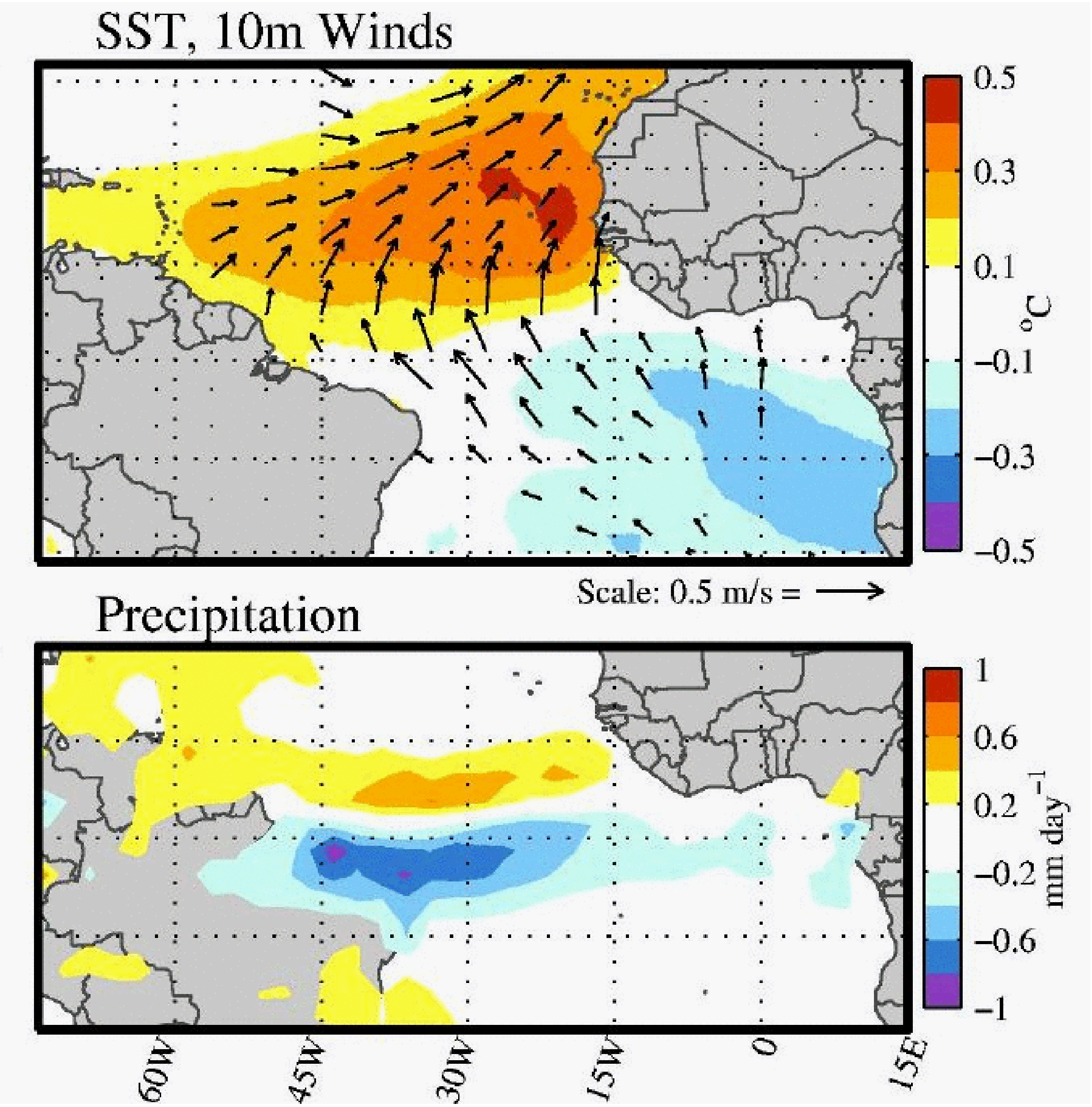


The Atlantic Meridional Mode: SST, wind, and precip anoms

- Leading mode of basin-wide ocean-atmosphere interaction between SST and low-level winds

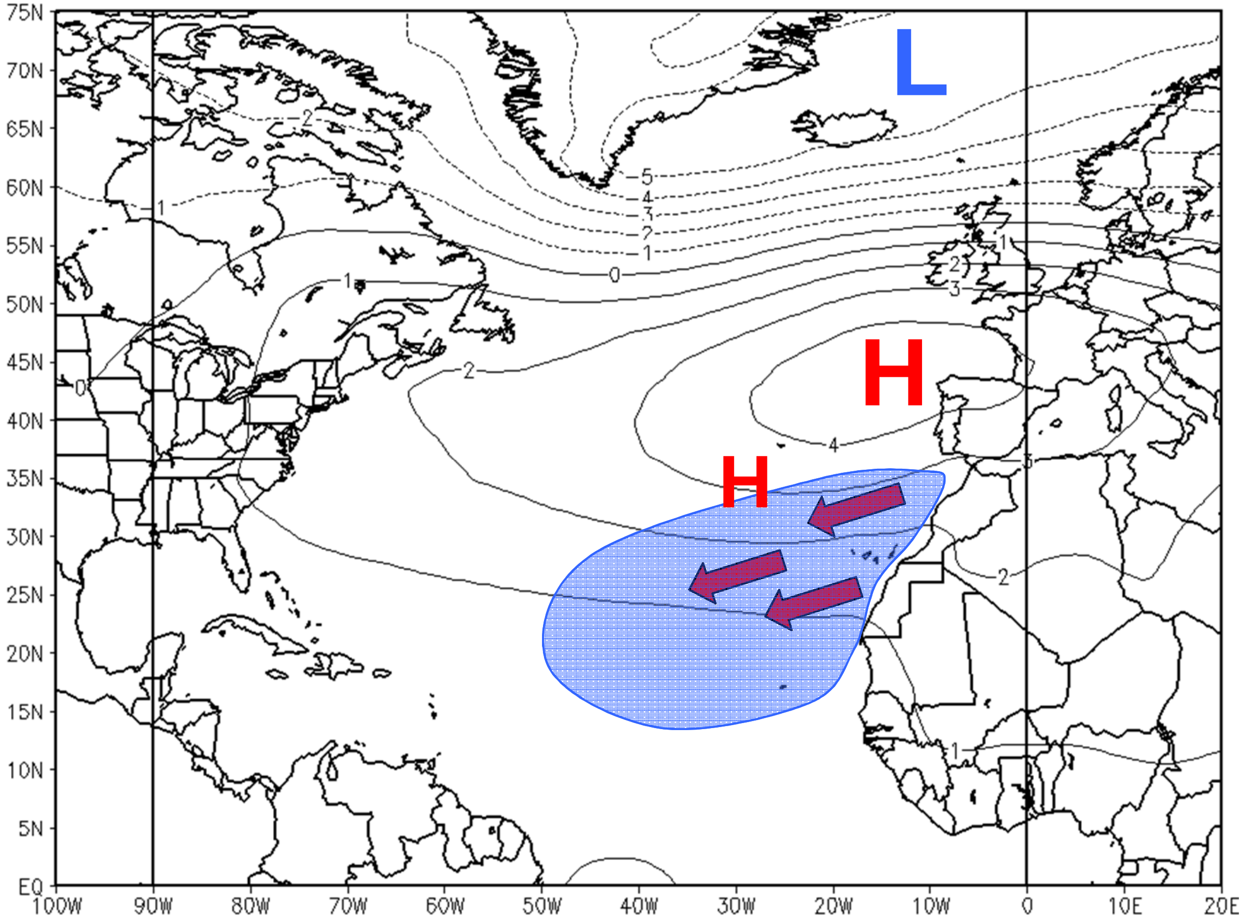
- Amplifies via the **wind-evaporation-SST (WES)** feedback mechanism

- Strongest signal during the spring, but persists into hurricane season



Forcing the AMM

SLP anomaly associated with (+) NAO

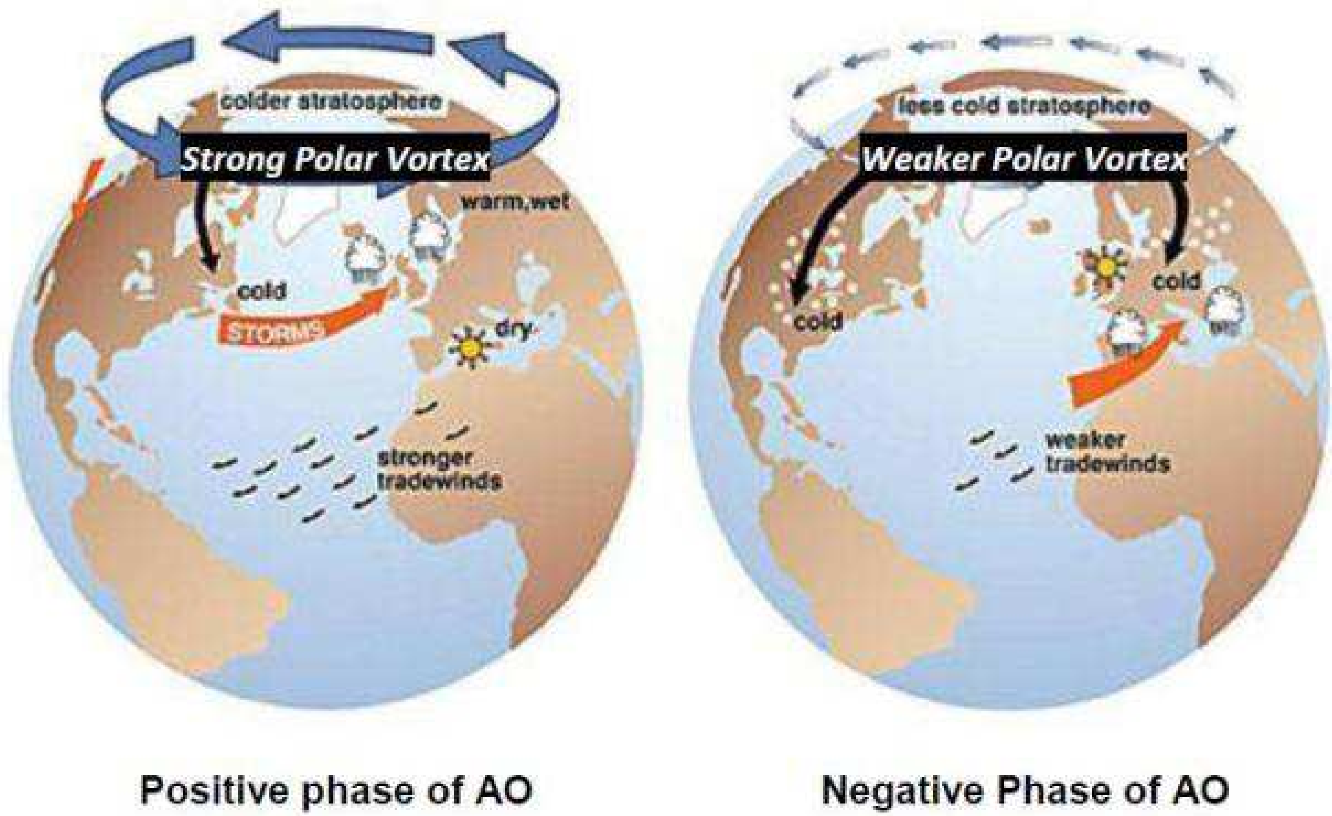


1. Subtropical SLP anomalies associated with NAO
2. Cool SST through enhanced evaporation (stronger easterlies)
3. Atmosphere responds through anticyclonic circulation, reinforcing wind anomalies → (-) AMM
4. Resulting feedback can last for several months, even after NAO forcing subsides

[FLIP sign for (-) NAO]

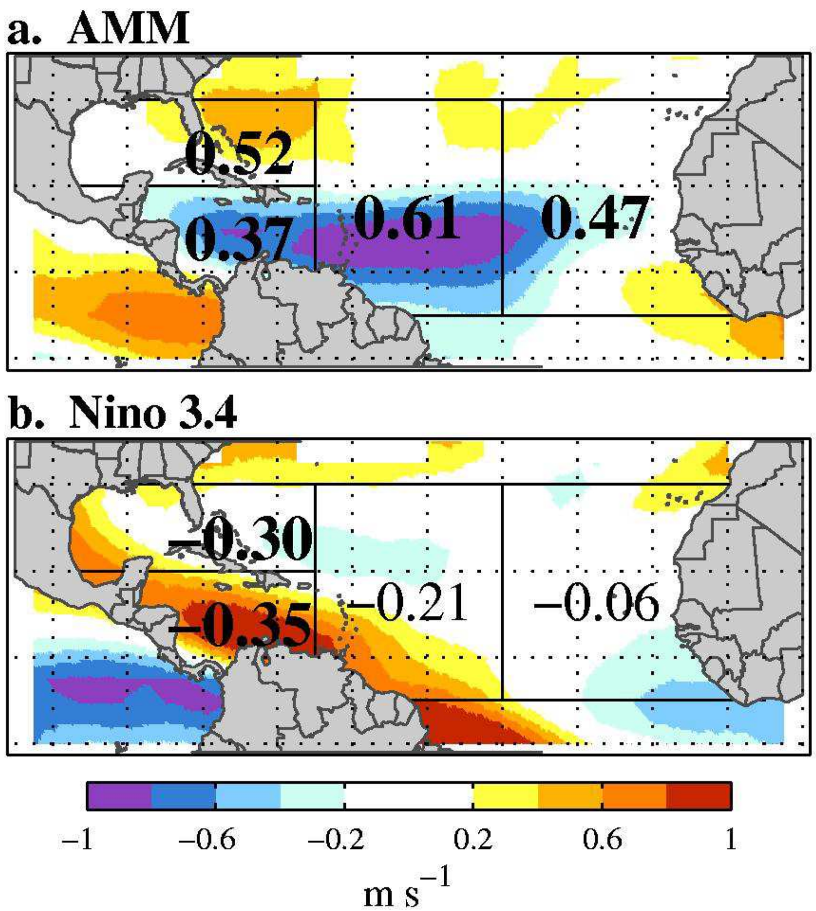
Courtesy Dima Smirnov ESRL

Mid-latitudes in winter/spring can have an impact on the next hurricane season



1) Negative NAO/AO in winter/spring (could be preceded by a stratospheric warming event), leads to weak Atlantic trade winds.
2) Weak trades excite a positive AMM for the summer, leading to warmer-than-average waters and favorable low-level winds for genesis.

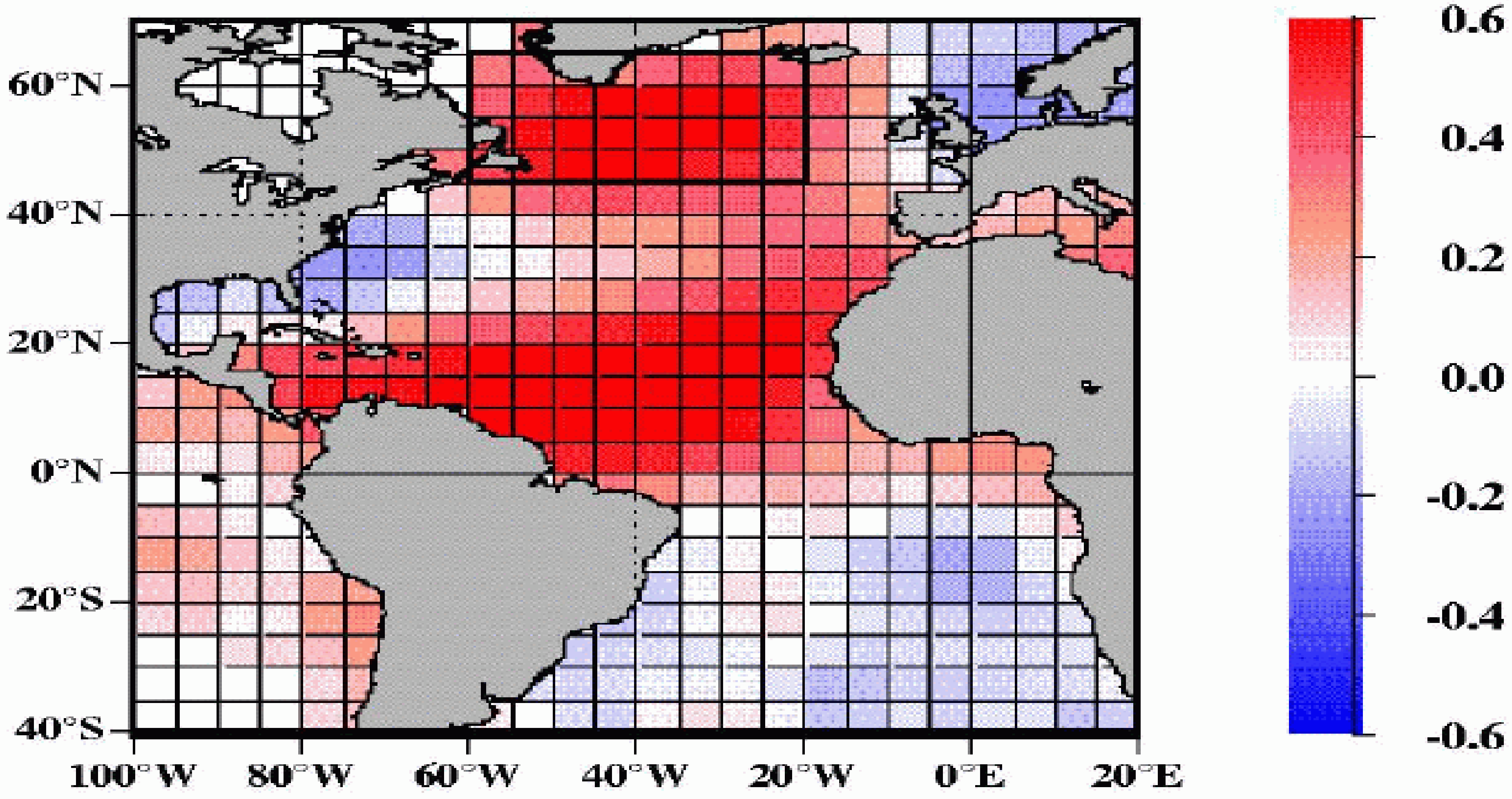
Comparative effects of the AMM (local) and ENSO (remote) on vertical wind shear in the Atlantic



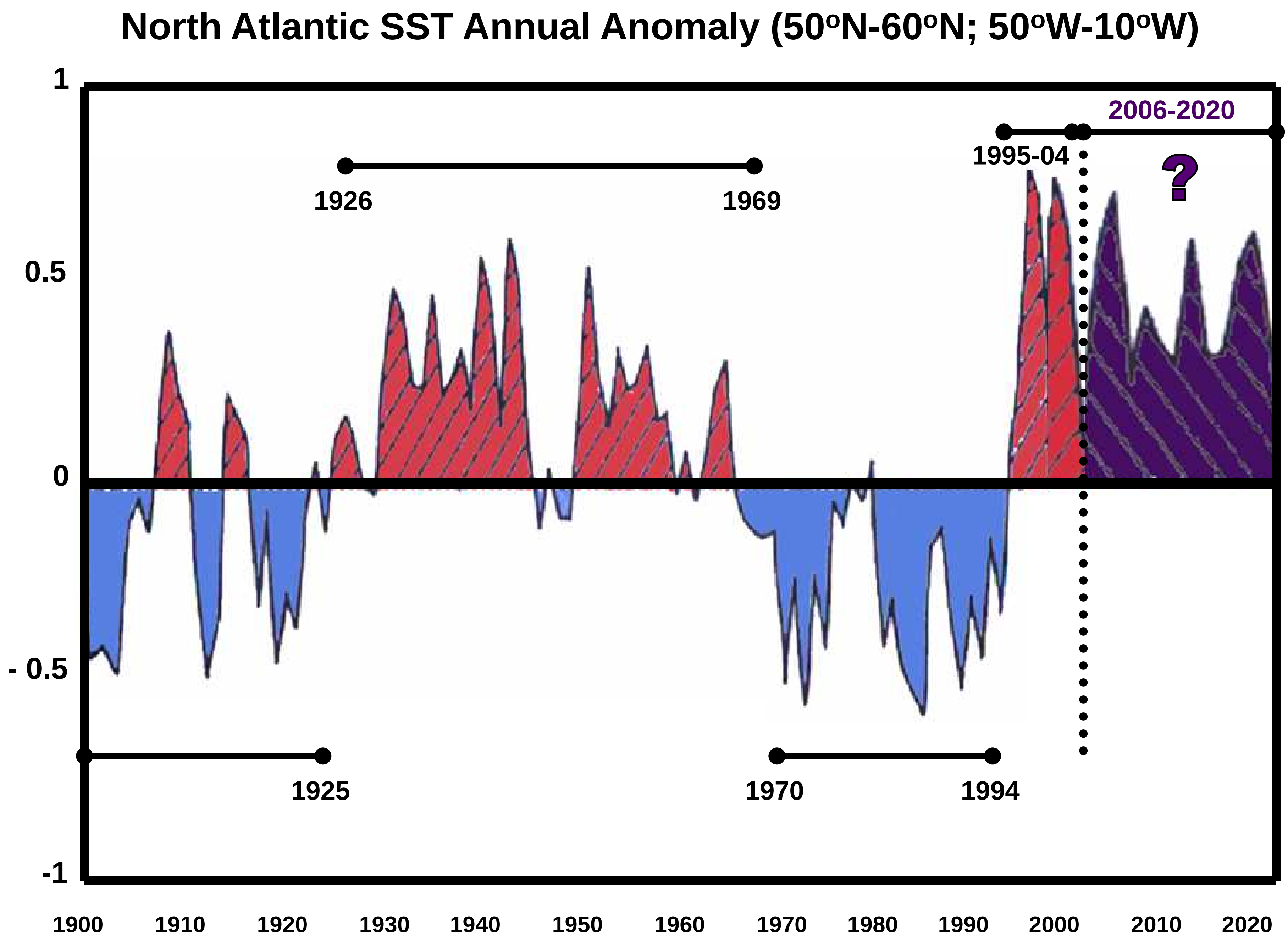
units: m/s per standard deviation

Shear regressed onto AMM and N34 indices, and correlations between the indices and storm activity.

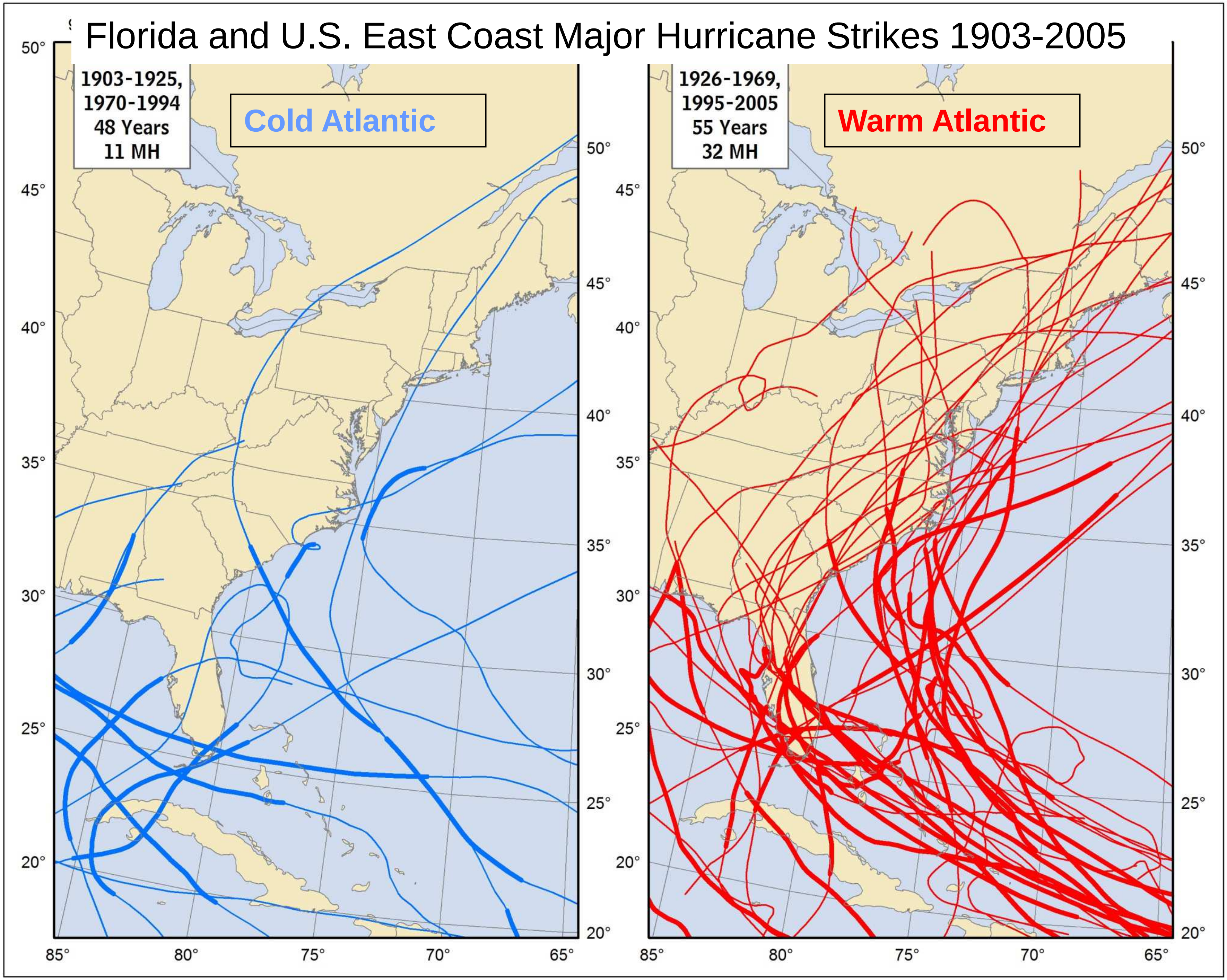
Atlantic Multidecadal Mode (Ocean Temperature)



Mestas-Nunez and Enfield (1999)


North Atlantic SST Annual Anomaly (50ºN-60ºN; 50ºW-10ºW)
1
0.5
0
- 0.5
-1
2006-2020
1995-04
?
1926
1969
1925
1970
1994
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

Florida and U.S. East Coast Major Hurricane Strikes 1903-2005



CFS version 2

1. An atmosphere at high horizontal resolution (spectral T574, ~27 km) and high vertical resolution (64 sigma-pressure hybrid levels) for the real time analysis
2. An atmosphere of T126L64 for the real time forecasts
3. An interactive ocean with 40 levels in the vertical, to a depth of 4737 m, and horizontal resolution of 0.25 degree at the tropics, tapering to a global resolution of 0.5 degree northwards and southwards of 10N and 10S respectively
4. An interactive 3 layer sea-ice model
5. An interactive land model with 4 soil levels

CFS-based TS, Hurricanes and ACE Index Forecast
Atlantic Basin– May forecast

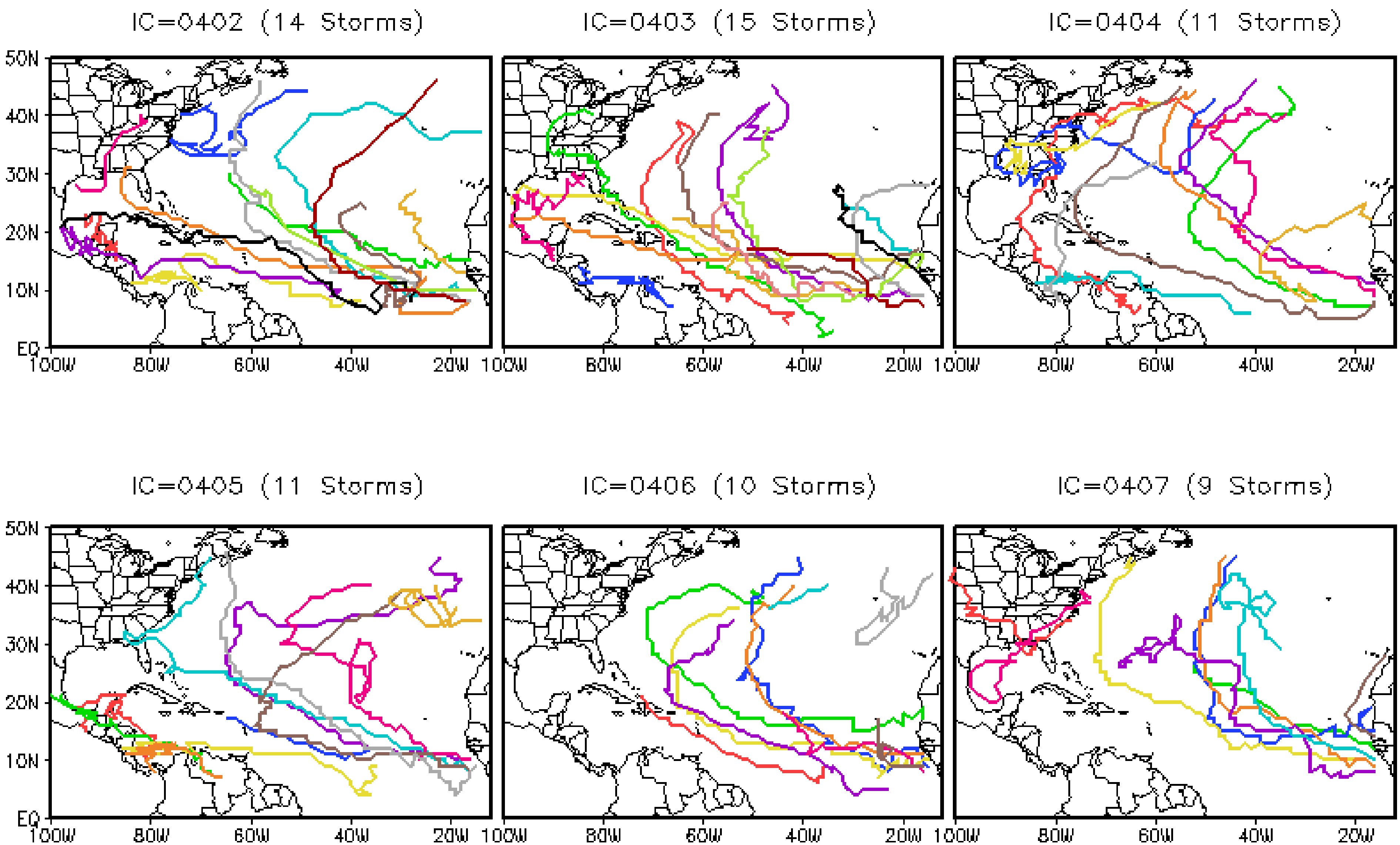
	Tropical Storms	Hurricanes	ACE Index % of Median
402	14	4	132
403	15	5	131
404	11	2	94
405	11	2	132
406	10	3	72
407	9	3	106
408	15	5	131
409	14	2	84
410	11	4	88
411	13	6	184
412	11	0	77
413	14	7	166
414	16	8	185
415			
416			
417			
418			

2012
Slightly Above Normal Year

	Tropical Storms	Hurricanes	ACE Index % of Median
Ensemble	**12.6**	**3.9**	**121.6**
Standard Deviation	**2.2**	**2.3**	**39.0**
Range	**10-15**	**2-6**	**83-161**
Model Clim	**10.6**	**3.8**	**85.4**

Tropical Cyclone Storm Tracks in the Atlantic Region

CFS_07 T382, 2012



Seasonal Forecast Caveats:

1) Even with perfect knowledge of all predictors – only 50-60% of the variance in overall TC activity is explained. This could be increasing as the skill in dynamical models grows, but for now that is a reasonable estimate.

2) This make a one-category forecast error possible in one out of 3 or 4 years, and a two-category error in about 1 in 7 years.

3) In seasonal forecasting, you will be flat wrong some years despite your best efforts. 2013 is a prime example.

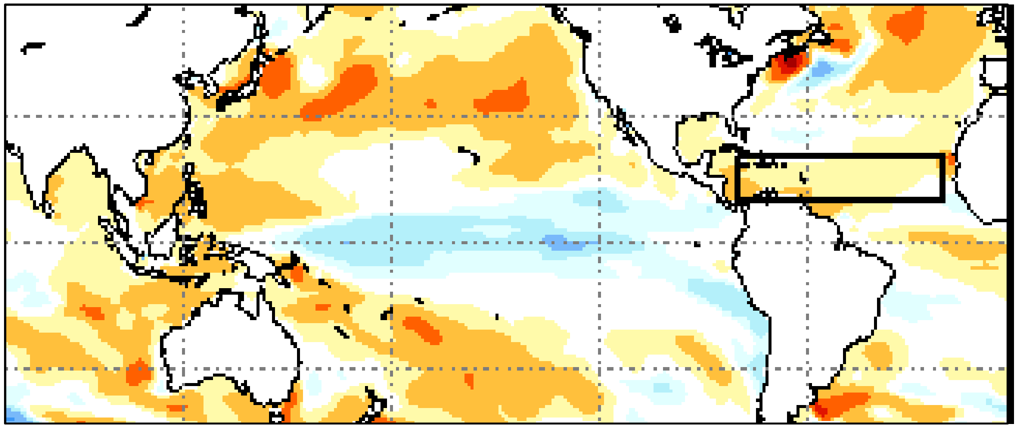
Model Forecast Summary: 2013 Atlantic Outlook

Model predicted ranges (± 1 σ) and mean activity (in parenthesis). The model averages (yellow) and NOAA's outlook (Red) are shown at bottom.

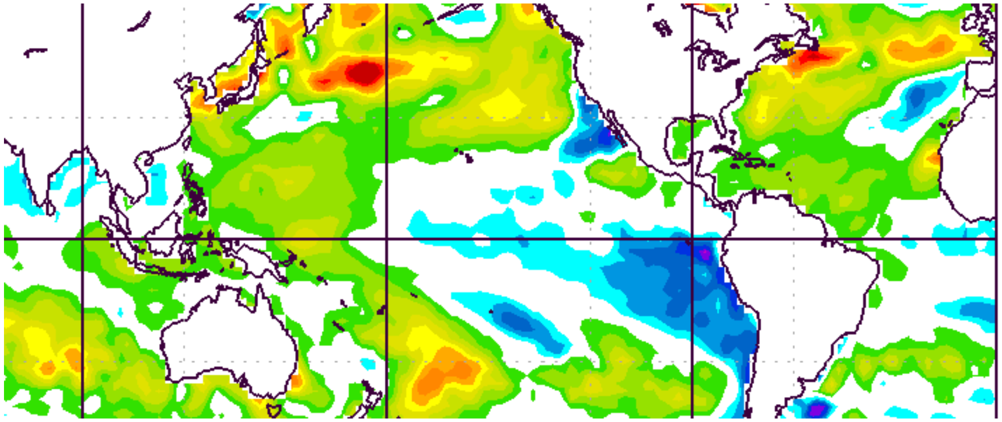
	Model	Named Storms	Hurricanes	Major Hurricanes	ACE (% Median)
Statistical	**CPC Regression:**	14-18 (16)	7-9 (8)	3-4.5 (3.75)	140-170 (155)
	CPC Binning : Nino 3.4+SSTA	7.9-21.5 (14.7)	4.2-11.5 (7.85)	2.1-5.9 (4)	69-217 (143)
	CPC Binning ENSO+SSTA	10.1-21 (15.55)	5.2-11.7 (8.45)	2.8-5.9 (4.35)	106-229 (167)
CFS	**CFS: Hi-Res T-382**	13.4-19.4 (16.4)	5.2-11.2 (8.2)		111-199 (155)
	CFS-V2 T126: 1	12-16 (14)	6-9 (7.5)	3-4 (3.5)	112-168 (140)
	CFS-V2 T126: 2	13-17 (15)	7-10 (8.5)	3-4 (3.5)	121-182 (152)
	CFS-V2 T126: 3	13-17 (15)	6-10 (8)	3-4 (3.5)	119-184 (152)
European	**ECMWF:**	8.9-16.3 (12.6)	5.5-10.5 (8)		90-167 (128)
	EUROSIP:	7.6-14.4 (11)			
	Guidance Mean	**11.1-17.8 (14.5)**	**5.8-10.4 (8.1)**	**2.8-4.7 (3.8)**	**108-190 (149)**
	NOAA Outlook	**13-20 (16.5)**	**6-11 (8.5)**	**3-6 (4.5)**	**120-205 (163)**
	Actual:	14	2	0	39

Pretty good SST prediction!

1 May CFSv3 ASO SST forecast

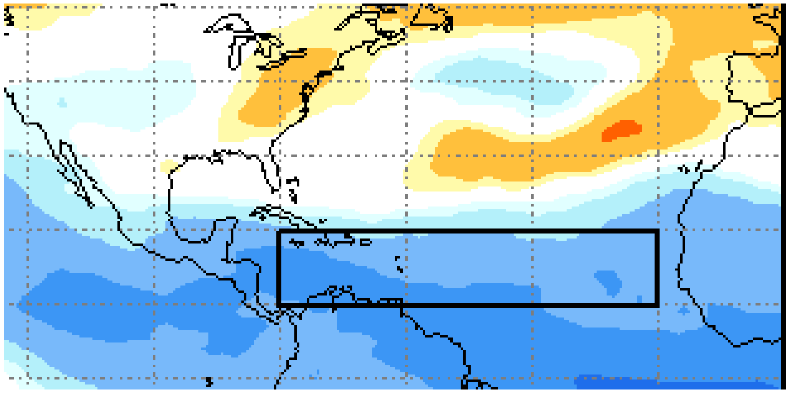


Actual ASO 2013

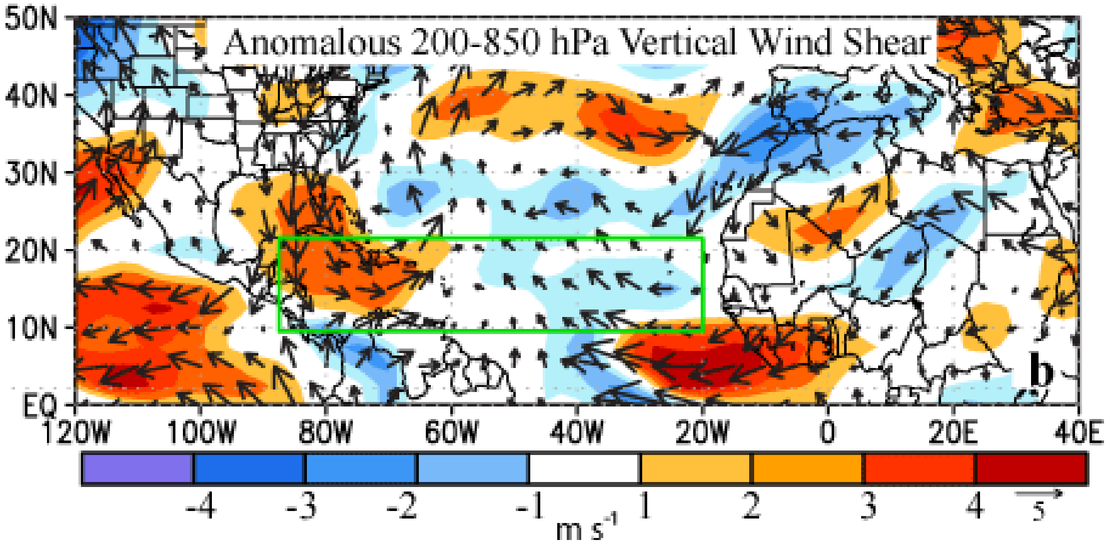


Poor shear forecast in western part of basin

1 May CFSv3 ASO shear forecast



Actual ASO 2013



Total failure with sinking/drying over tropical Atlc

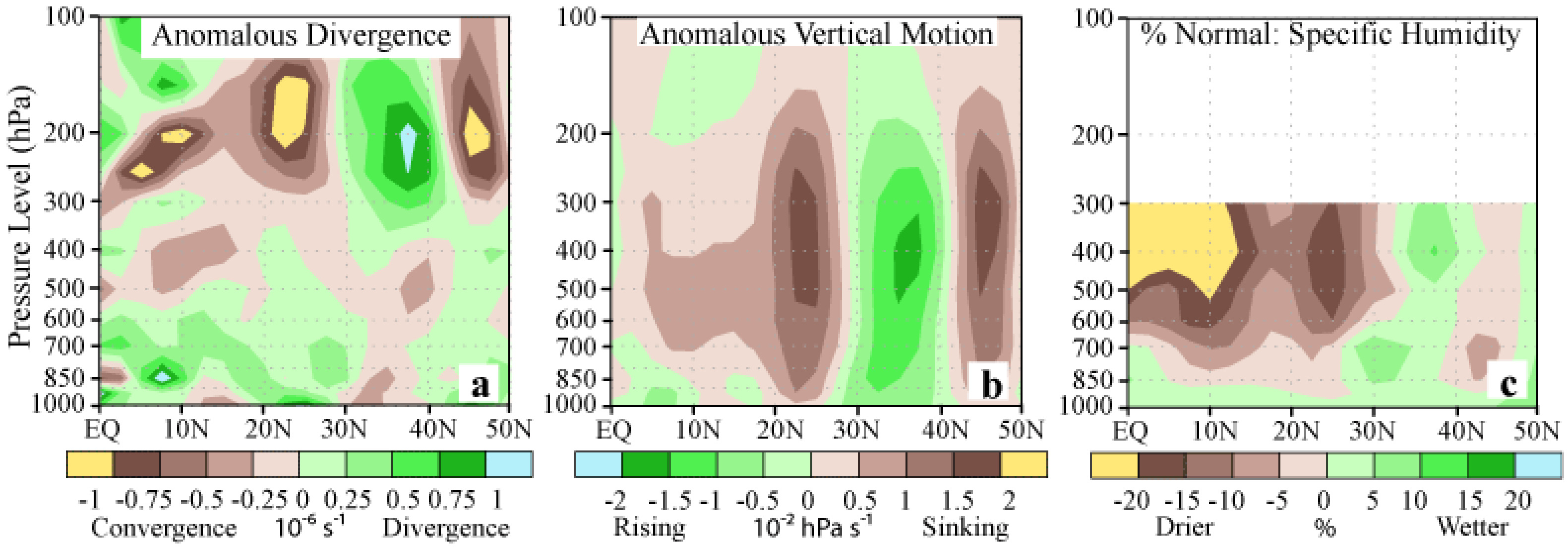


Fig. 5. August-October 2013 height-latitude sections averaged between 40ºW-60ºW of (a) anomalous divergence (x 10^{6} s^{-1}), (b) anomalous vertical velocity (x 10^{-2} Pa s^{-1}), and (c) percent of normal specific humidity. Green shading indicates anomalous divergence, anomalous rising motion, and increased moisture, respectively. Brown shading indicates anomalous convergence, anomalous sinking motion, and decreased moisture. Climatology and anomalies are with respect to the 1981-2010 period monthly means.

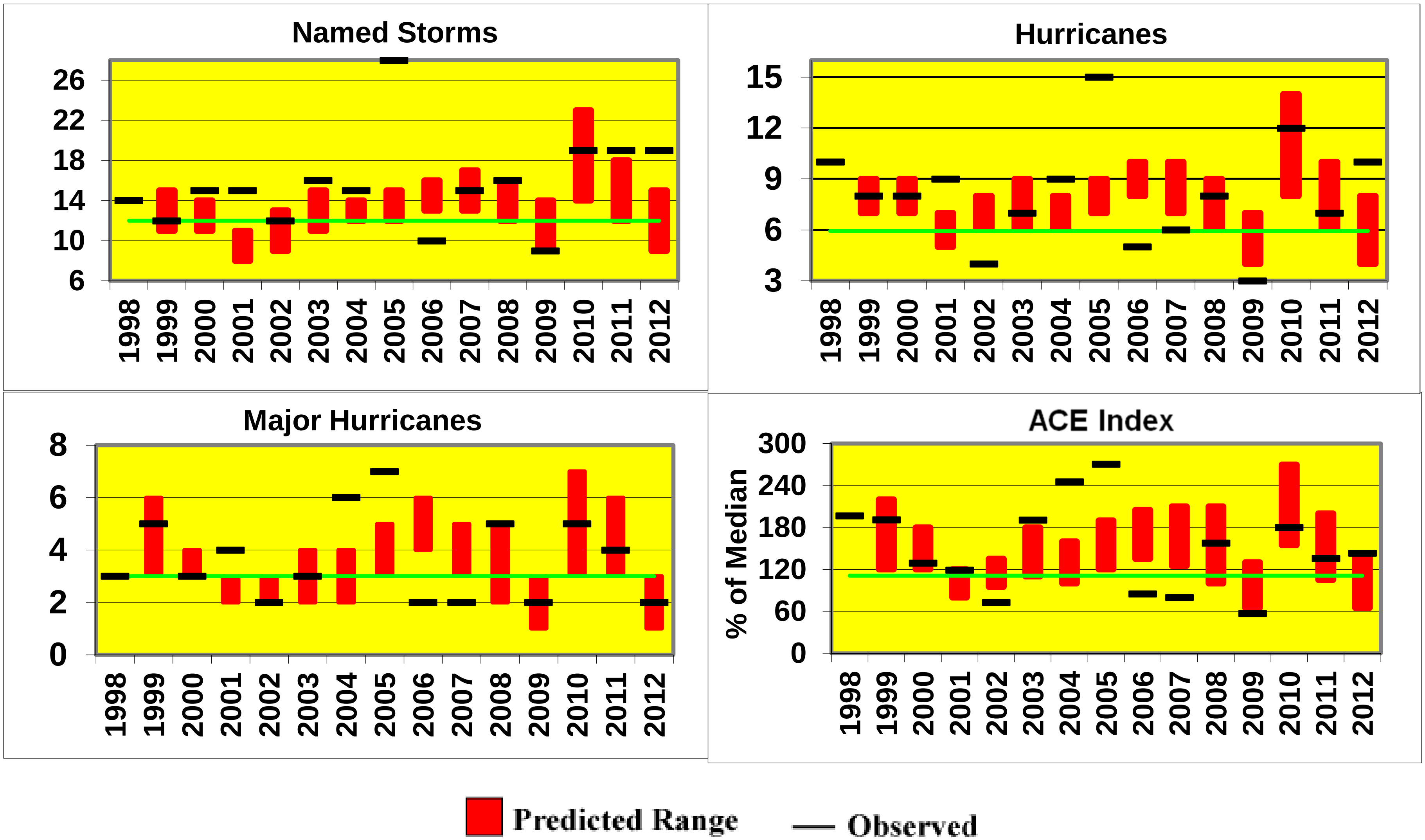
NOAA Forecast Methodology

1) Assess states of the ocean and atmosphere.
2) Use model forecasts for El Niño/Atlantic SSTs and incorporate any analog techniques and dynamical model forecasts of TCs.
3) Predict range of overall activity and probabilities of above-, near-, and below-average seasons.
4) Qualitative/Quantitative process.
5) **No forecast of hurricane landfalls, just the total seasonal activity for the entire basin.**

Why issue a seasonal hurricane outlook then?

- One of the top questions NOAA gets in the offseason is “What’s the season going to be like?”
- Large amount of media coverage makes it ideal to get the preparedness/awareness message out, even if most people can’t use the forecast.
- Gets people thinking about the upcoming hurricane season/activity.
- Specialized users (reinsurance companies, offshore interests etc.)

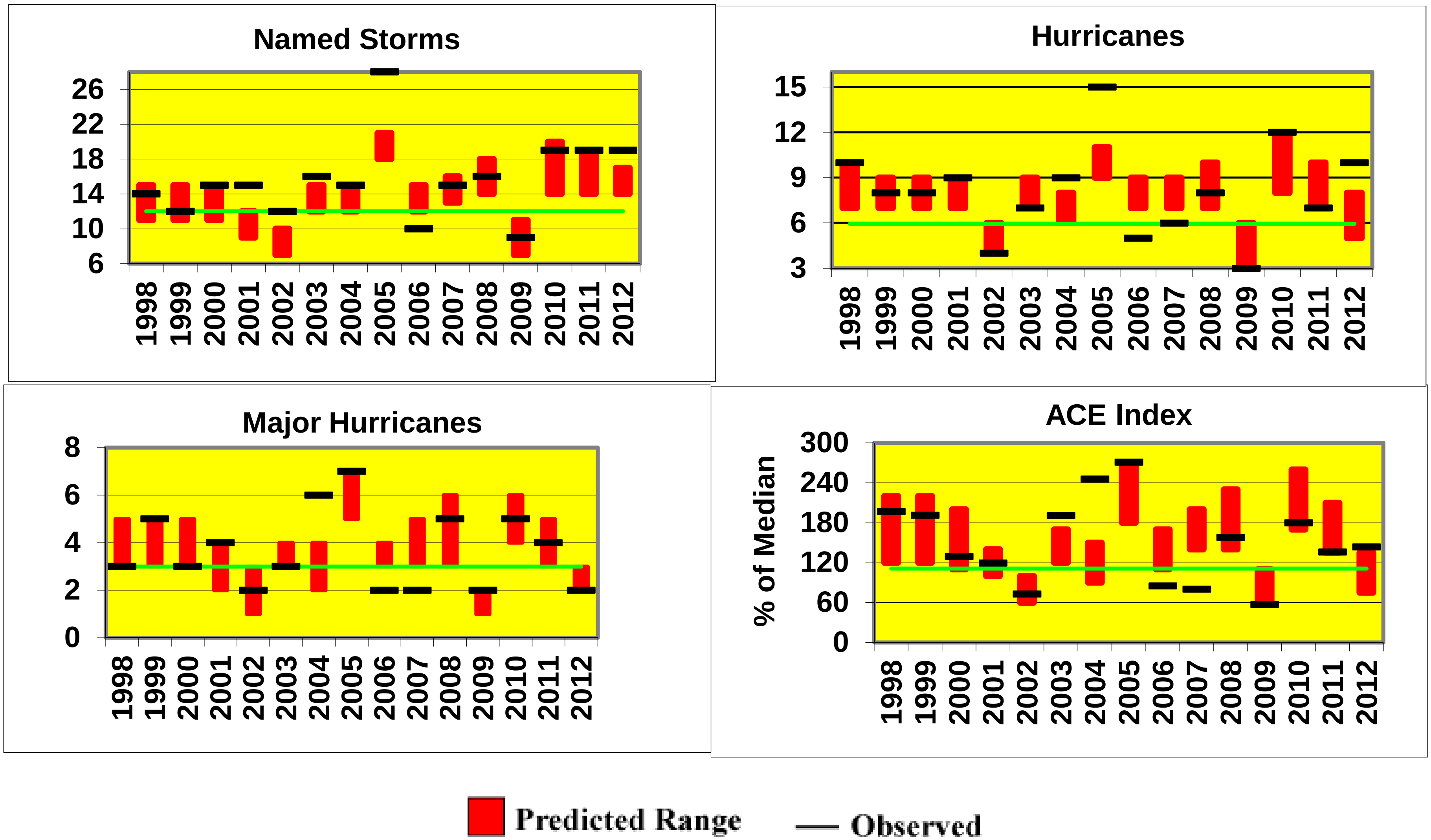
NOAA Atlantic Hurricane Season Outlook Verification
For Outlooks Issued in May



Green Bars for TS, H, MH denote the climatological means

Green bar in ACE plot shows lower boundary for above-normal seasons

NOAA Atlantic Hurricane Season Outlook Verification
For Outlooks Issued in August



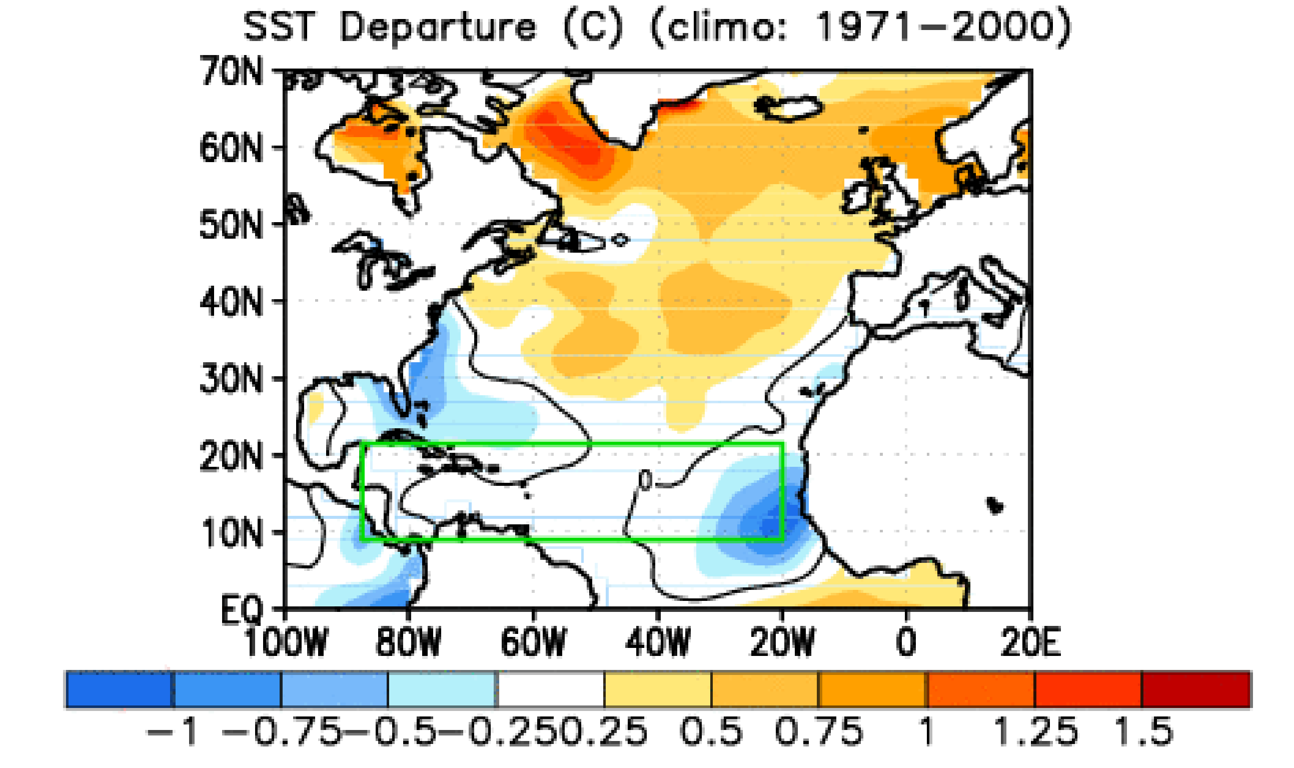
Green Bars for TS, H, MH denote the climatological means

Green bar in ACE plot shows lower boundary for above-normal seasons

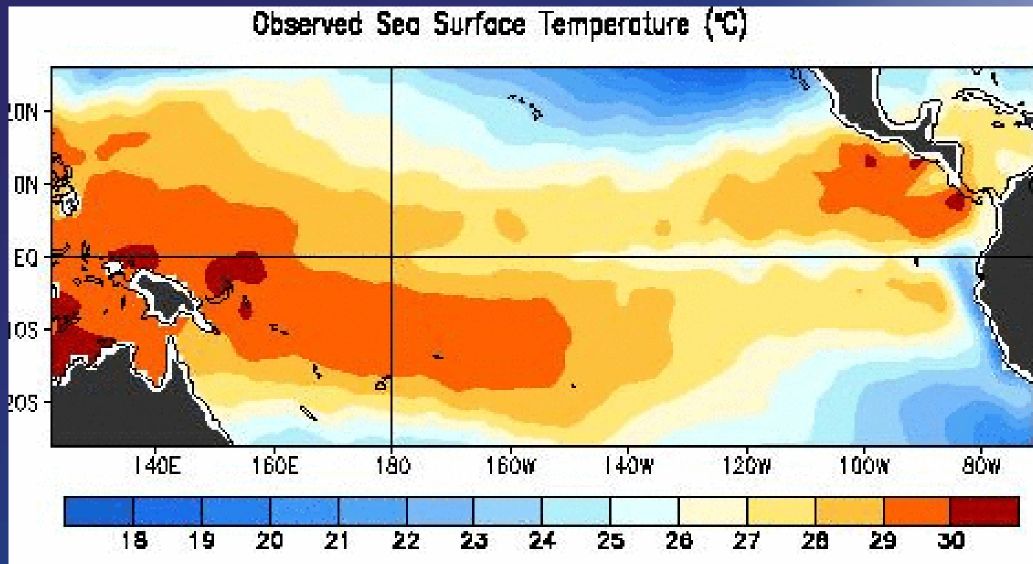
Exercise

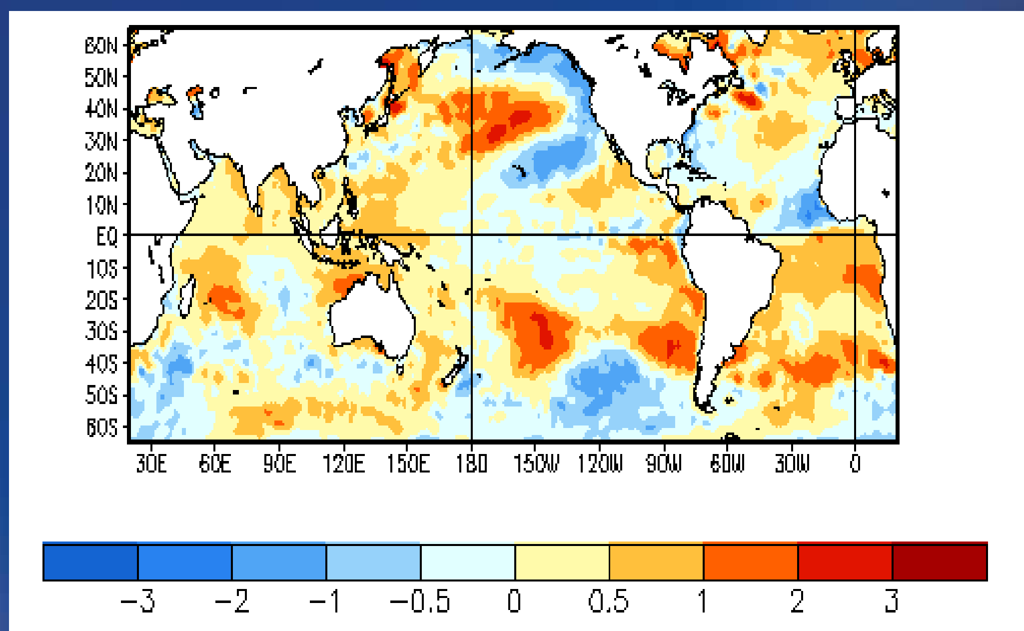
- Using what you have been taught about seasonal forecasting, make a seasonal forecast with the atmospheric and oceanic slides in the following slides.
- Please forecast ranges of activity for tropical storms, hurricanes, major hurricanes and ACE.
- Remember long term averages are 12 TS, 6 H, 3 MH and ACE ~ 100
- What are the expected climate conditions for hurricane season? How will these conditions affect your forecast?

March-April SSTAs

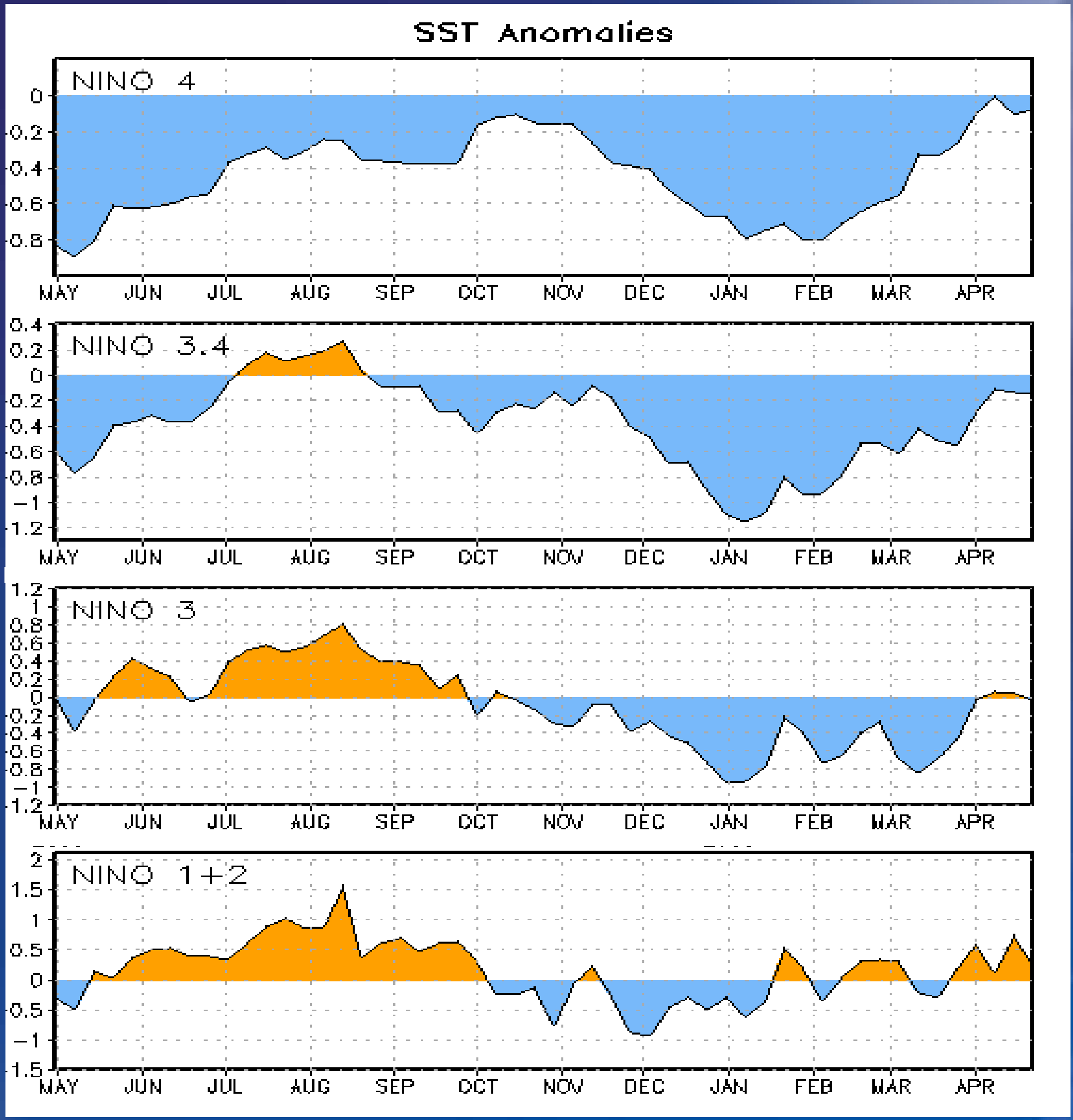


April SST and SSTA

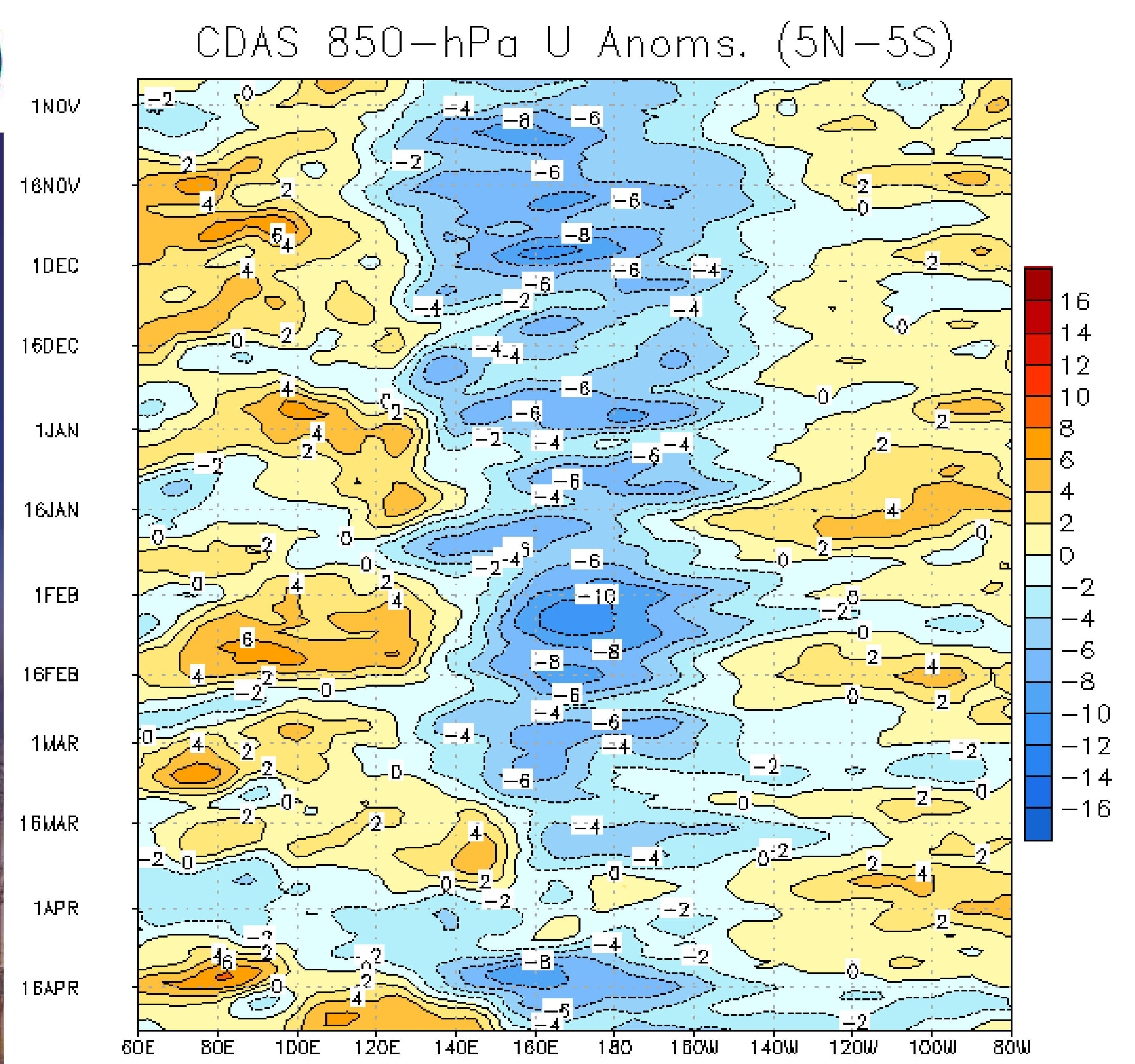




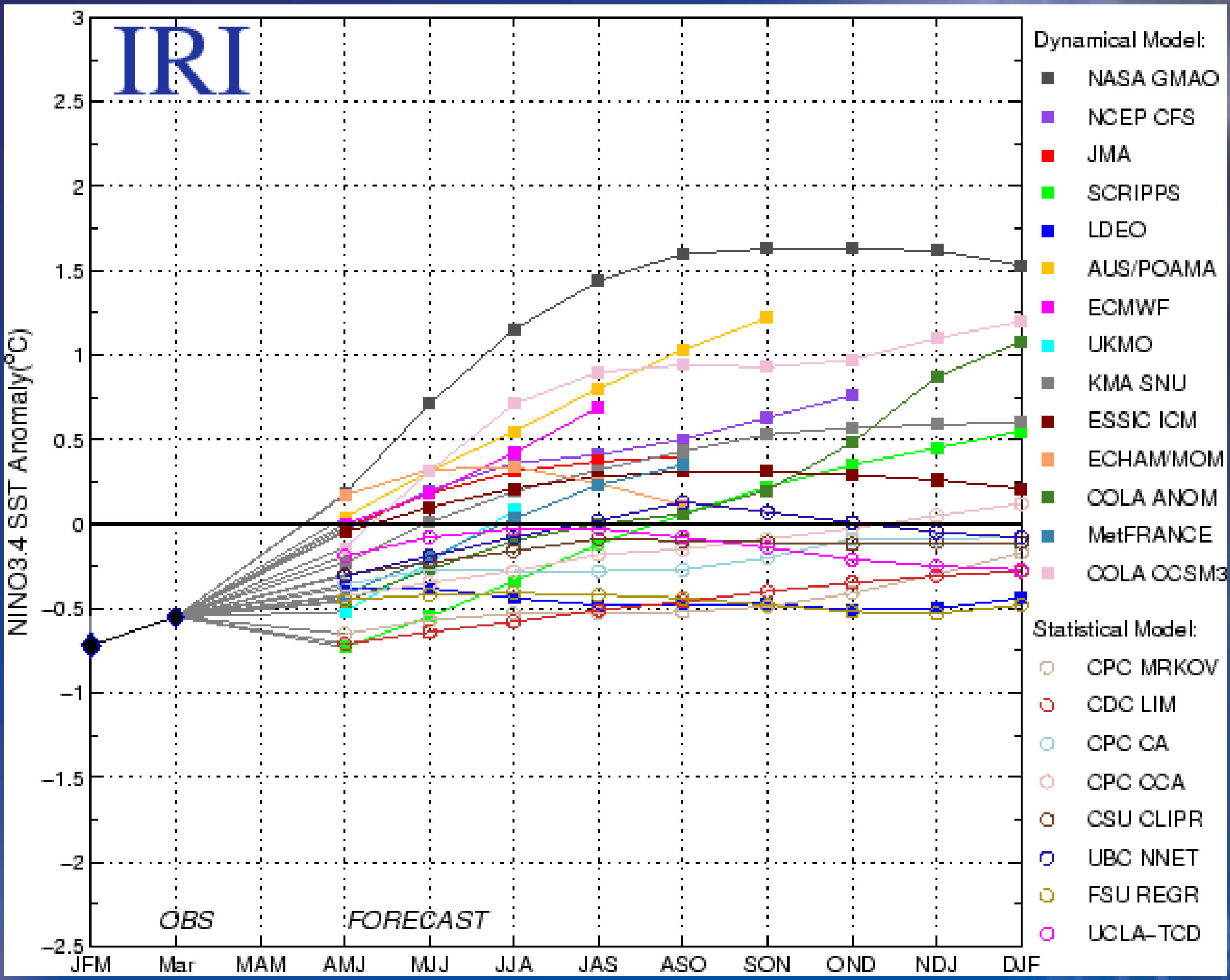
Tropical Pacific SSTA Evolution



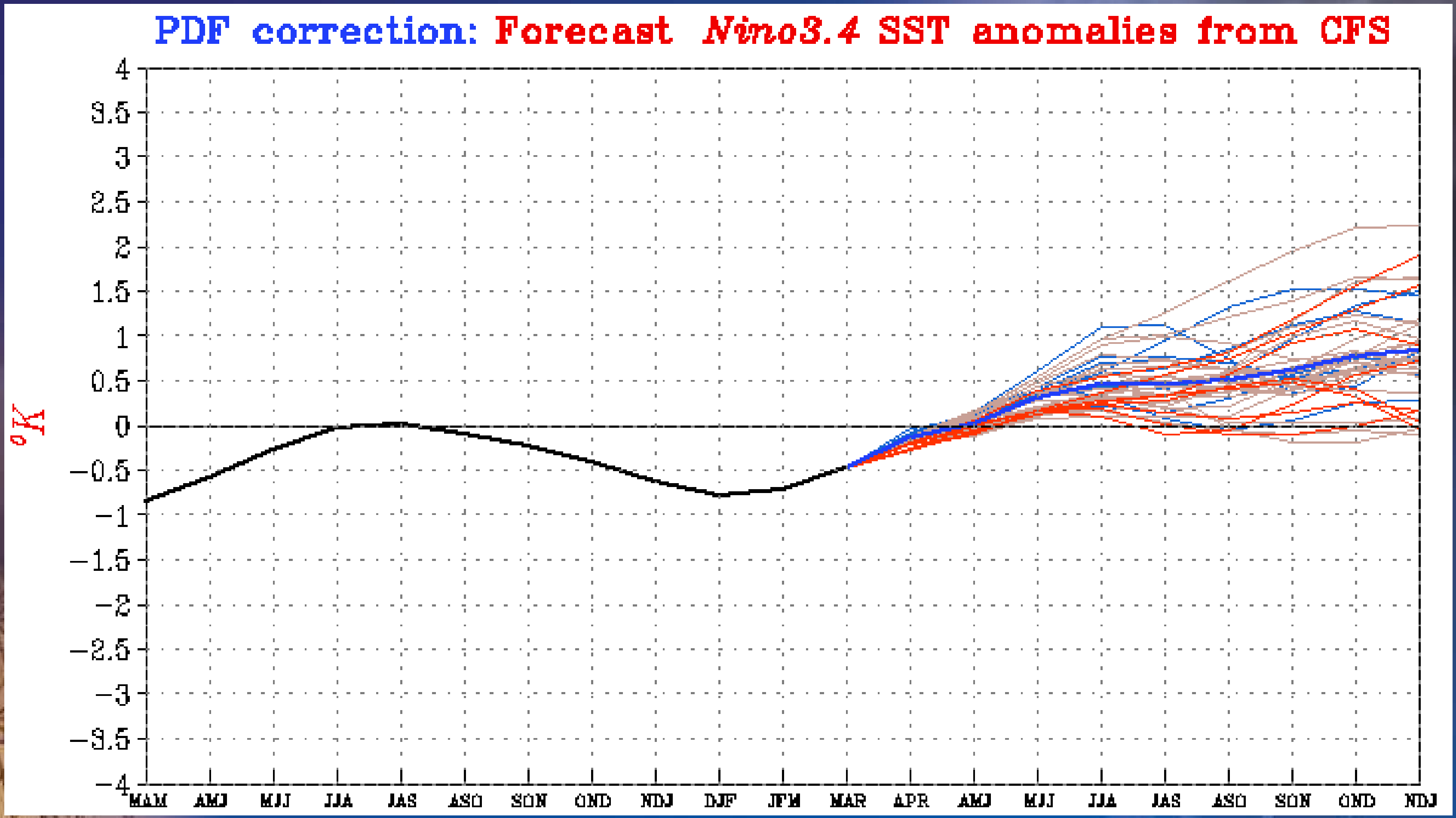
Time-Longitude Section of 850-hPa Zonal Wind Anomalies averaged 5N-5S



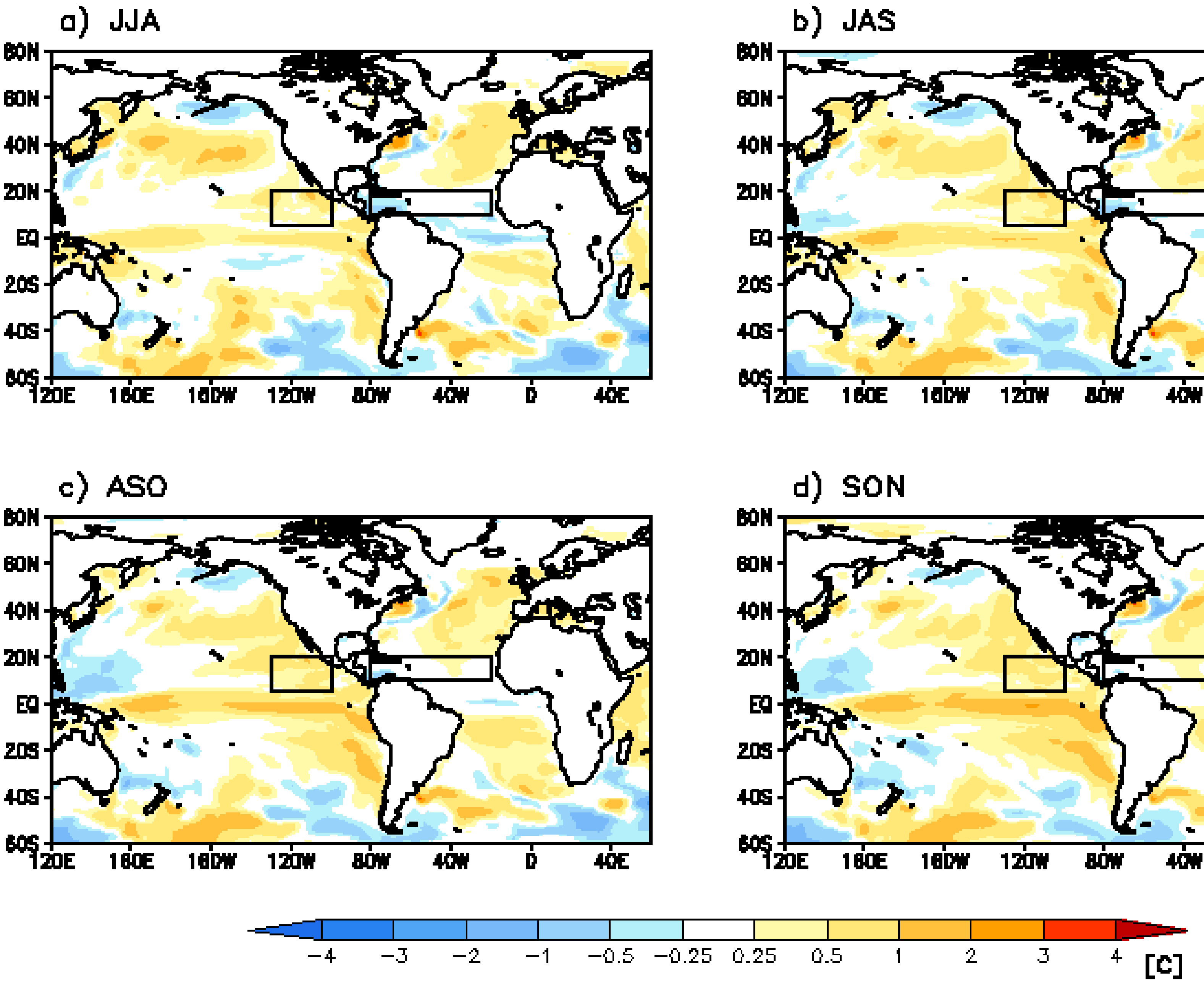
ENSO Forecast Plume



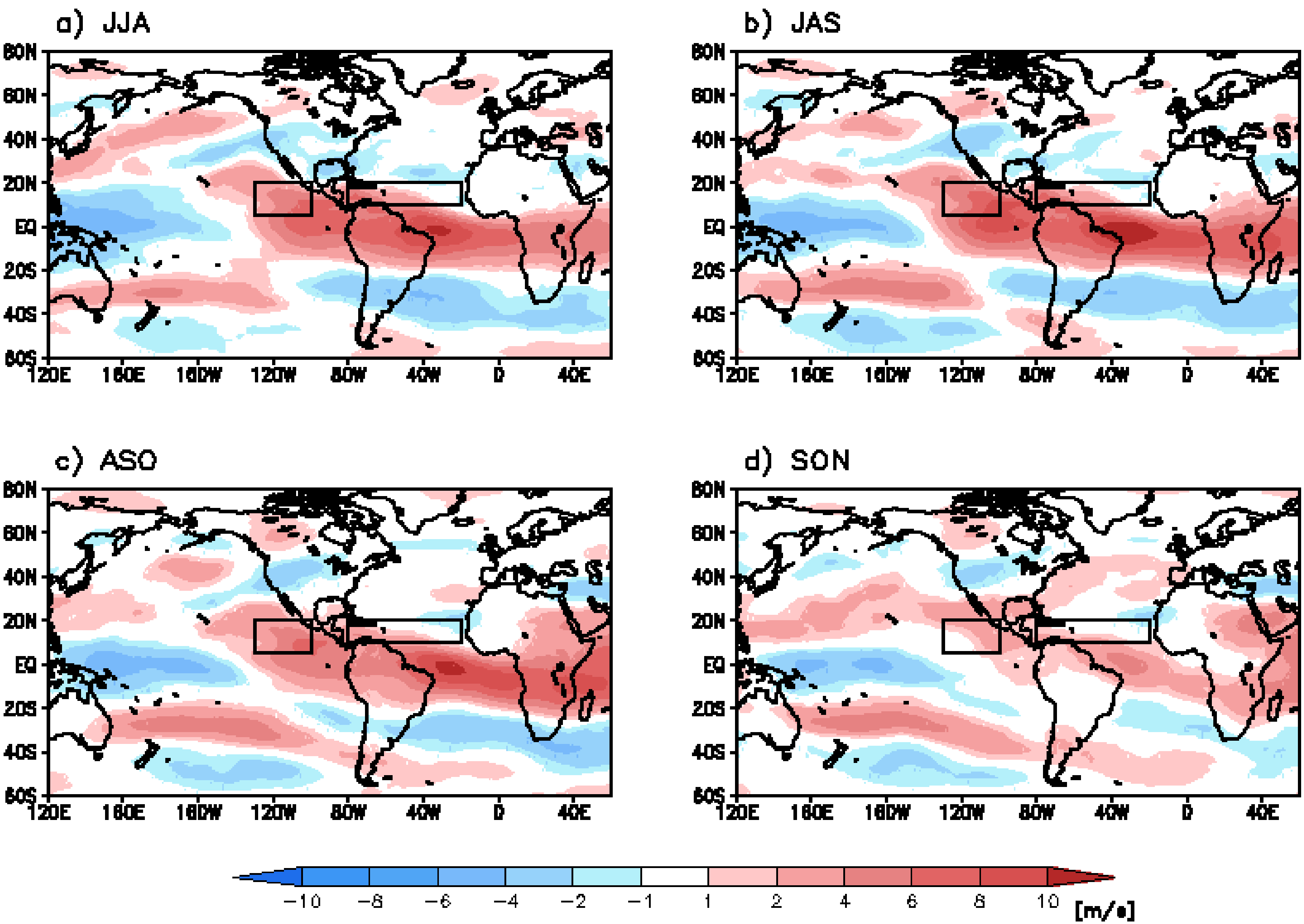
Niño 3.4 region: CFS Forecast



T382 High Resolution SST anomaly forecast:



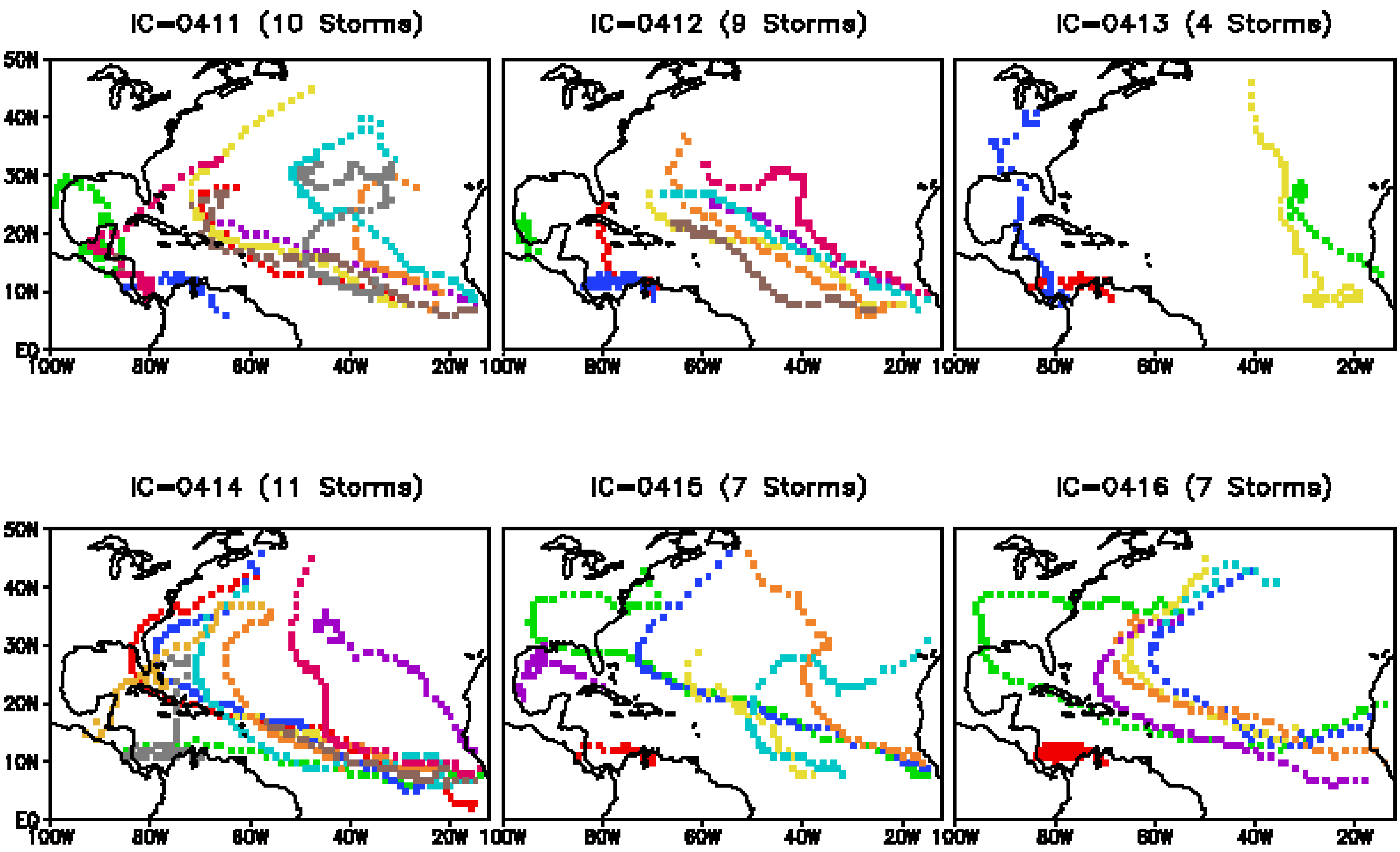
T382 High Resolution shear anomaly forecast:



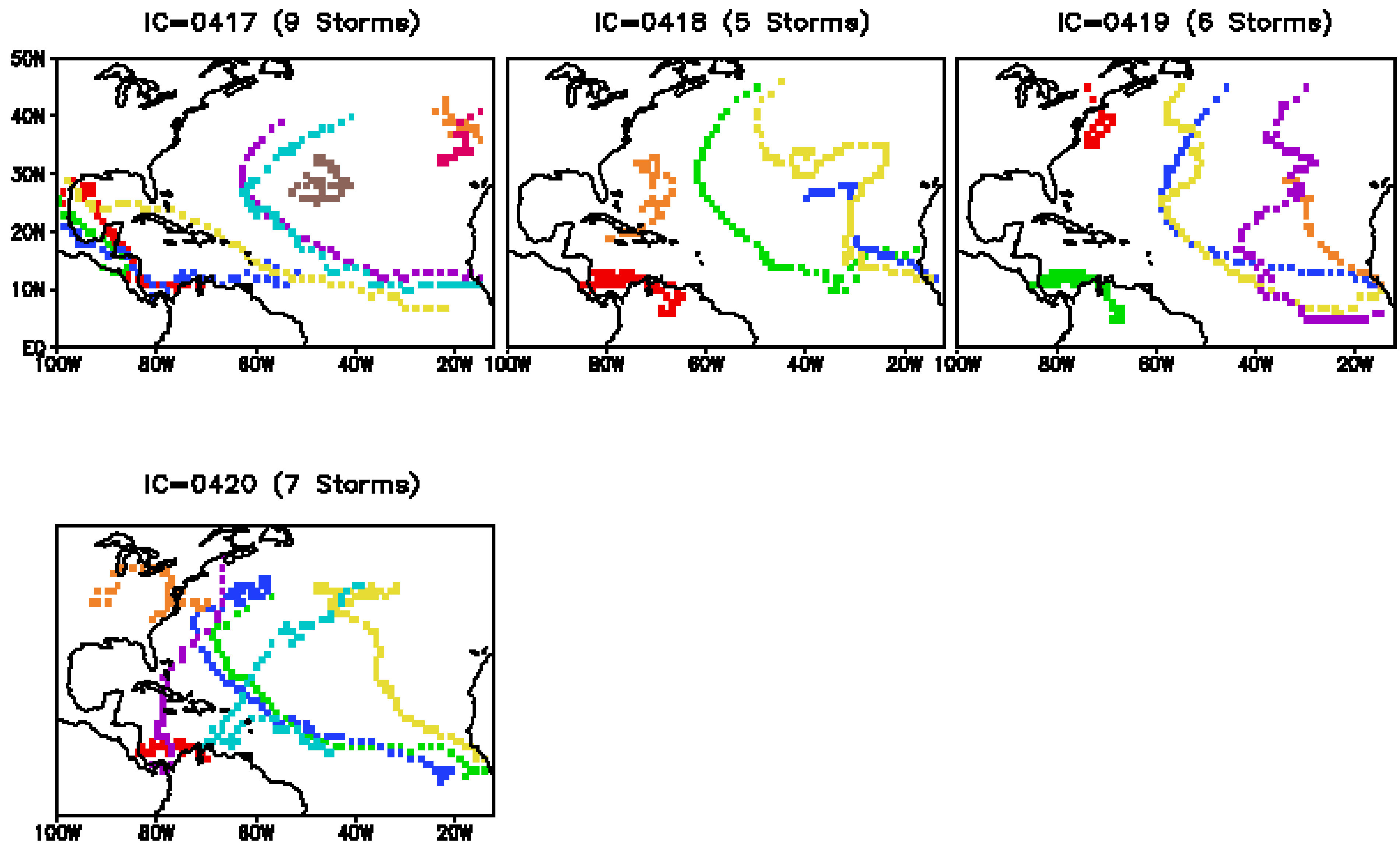
Storm Counts and ACE Index
Atlantic Basin

CFS T382 ATL										
	May	June	July	Aug	Sept	Oct	Nov	**Total**		**% of Normal ACE Index**
411		2	1		4	3		10		95.83
412	1	1	1		6			9		70.77
413			1		2	1		4		32.61
414		1	1	3	4	2		11		113.53
415			2	1	4			7		67.97
416			1	3	3			7		80.00
417		2	4	1	1		1	9		53.98
418				2	2		1	5		73.94
419	1		1	1	3			6		79.91
420			1	1	3	1	1	7	**Clim**	79.89
Ensemble	0.2	0.6	1.3	1.2	3.2	0.7	0.3	7.5	10.9	74.84

CFS is predicting **7.5** storms versus a **10.9** storm climatology.
ACE Index is only **75% of Normal**



IC=0411 (10 Storms)
IC=0412 (9 Storms)
IC=0413 (4 Storms)
IC=0414 (11 Storms)
IC=0415 (7 Storms)
IC=0416 (7 Storms)
50N
40N
30N
20N
10N
EQ
100W
80W
60W
40W
20W


IC=0417 (9 Storms)
IC=0418 (5 Storms)
IC=0419 (6 Storms)
IC=0420 (7 Storms)
50N
40N
30N
20N
10N
EQ
100W
80W
60W
40W
20W

Updated CFS (T-62) ACE Forecast : ATLANTIC

ACE	ICs	Method 1	Method 2	Method 3
Forecast	03/31 – 04/14 04/07 – 04/21 04/13 – 04/27	86 71 64	104 91 85	93 76 68
Range (Forecast ± one standard deviation of inter-member spreads)	03/31 – 04/14 04/07 – 04/21 04/13 – 04/27	39 – 133 30 – 112 27 – 101	64 – 145 56 – 127 53 – 118	40 – 145 29 – 122 26 – 110

Updated CFS (T-62) MH Forecast : ATLANTIC

Major Hurricanes	ICs	Method 1	Method 2	Method 3
Forecast	03/31 – 04/14 04/07 – 04/21 04/13 – 04/27 –	2 2 2	3 3 3	3 3 2
Range (Forecast ± one standard deviation of inter-member spreads)	03/31 – 04/14 04/07 – 04/21 04/13 – 04/27 –	1 – 3 1 – 3 1 – 3	2 – 4 2 – 3 2 – 3	2 – 4 2 – 3 2 – 3

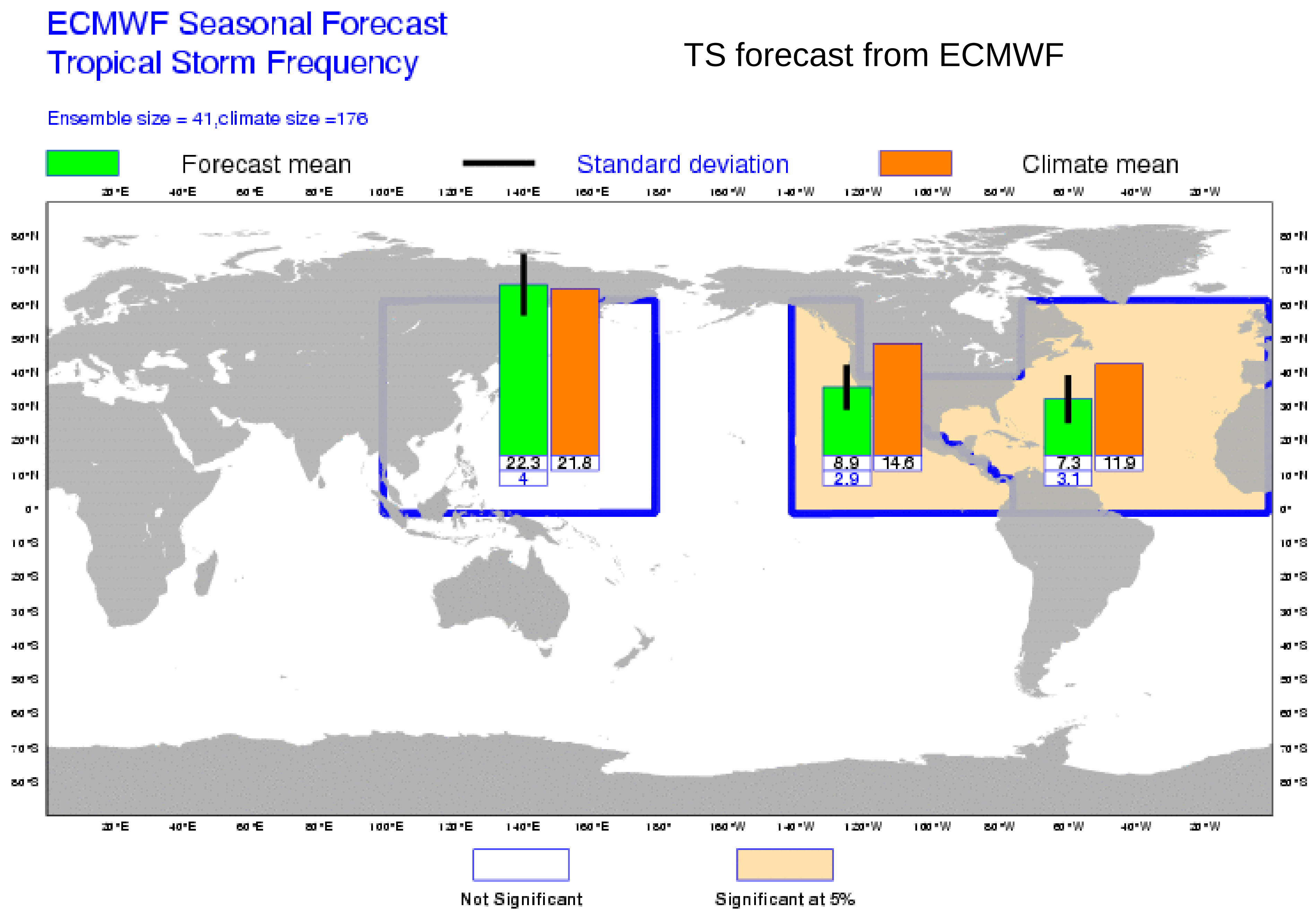
Updated CFS (T-62) Hurricane Forecast: ATLANTIC

Hurricanes	ICs	Method 1	Method 2	Method 3
Forecast	03/31 – 04/14 04/07 – 04/21 04/13 – 04/27	5 5 5	6 6 6	6 5 5
Range (Forecast ± one standard deviation of inter-member spreads)	03/31 – 04/14 04/07 – 04/21 04/13 – 04/27	3 – 7 3 – 7 3 – 6	5 – 8 5 – 7 5 – 7	3 – 8 3 – 7 3 – 6

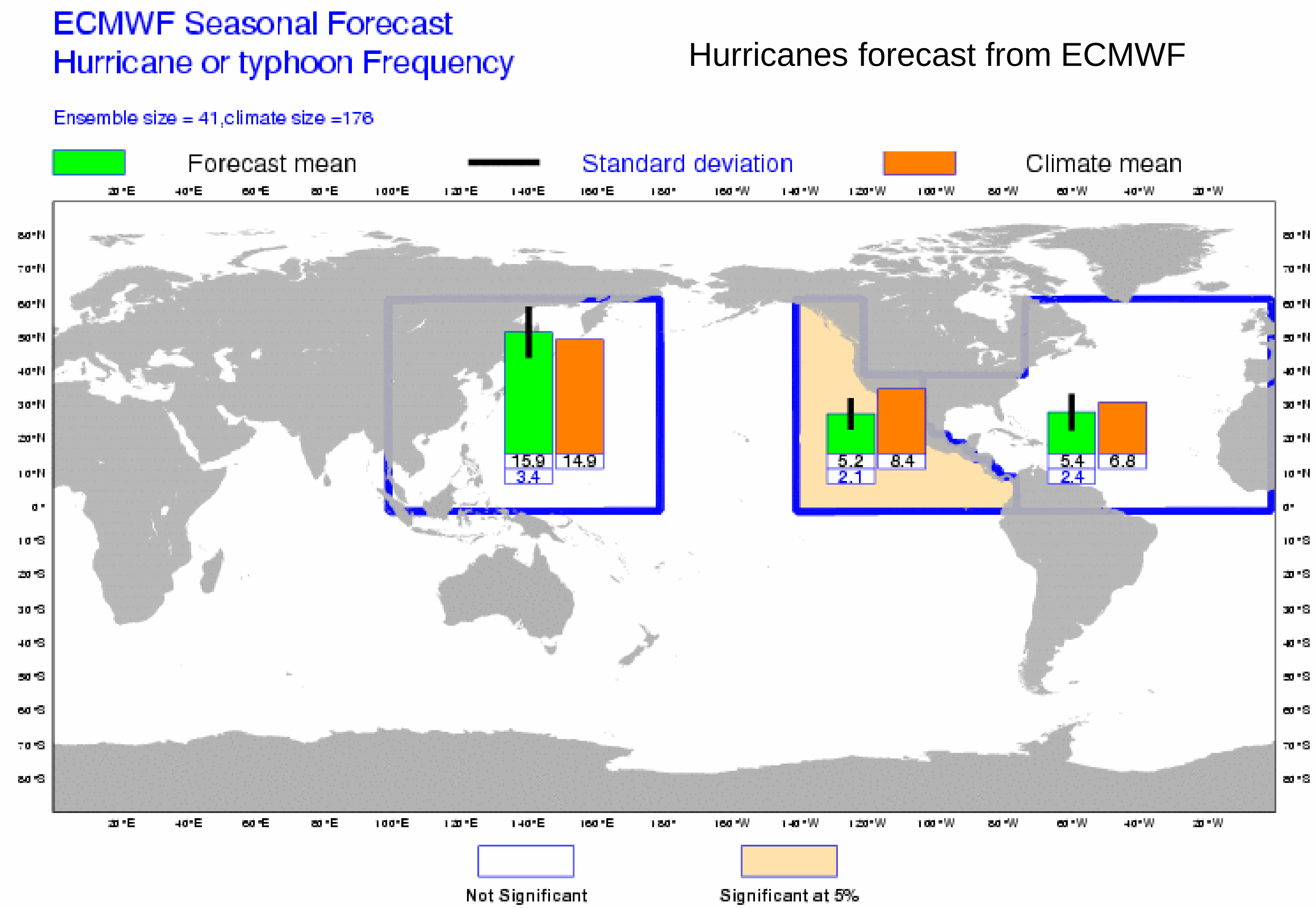
Updated CFS (T-62) NS Forecast: ATLANTIC

Named Storms	ICs	Method 1	Method 2	Method 3
Forecast	03/31 – 04/14	**10**	**11**	**11**
	04/07 – 04/21	**9**	**10**	**10**
	04/13 – 04/27	**8**	**10**	**10**
Range (Forecast ± one standard deviation of inter-member spreads)	03/31 – 04/14	**6 – 13**	**9 – 14**	**8 – 14**
	04/07 – 04/21	**5 – 12**	**8 – 13**	**7 – 13**
	04/13 – 04/27	**5 – 11**	**8 – 12**	**7 – 12**

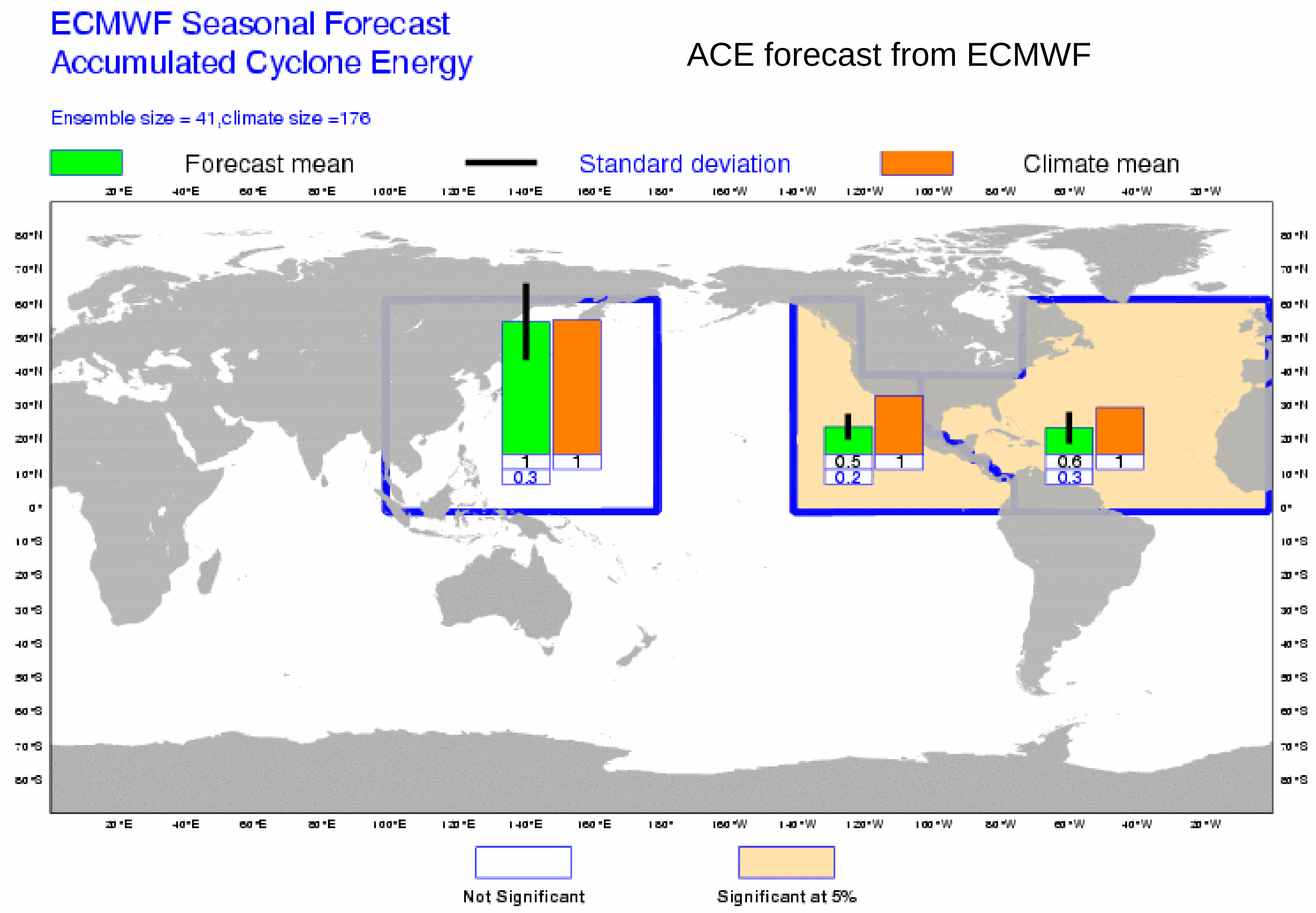
TS forecast from ECMWF



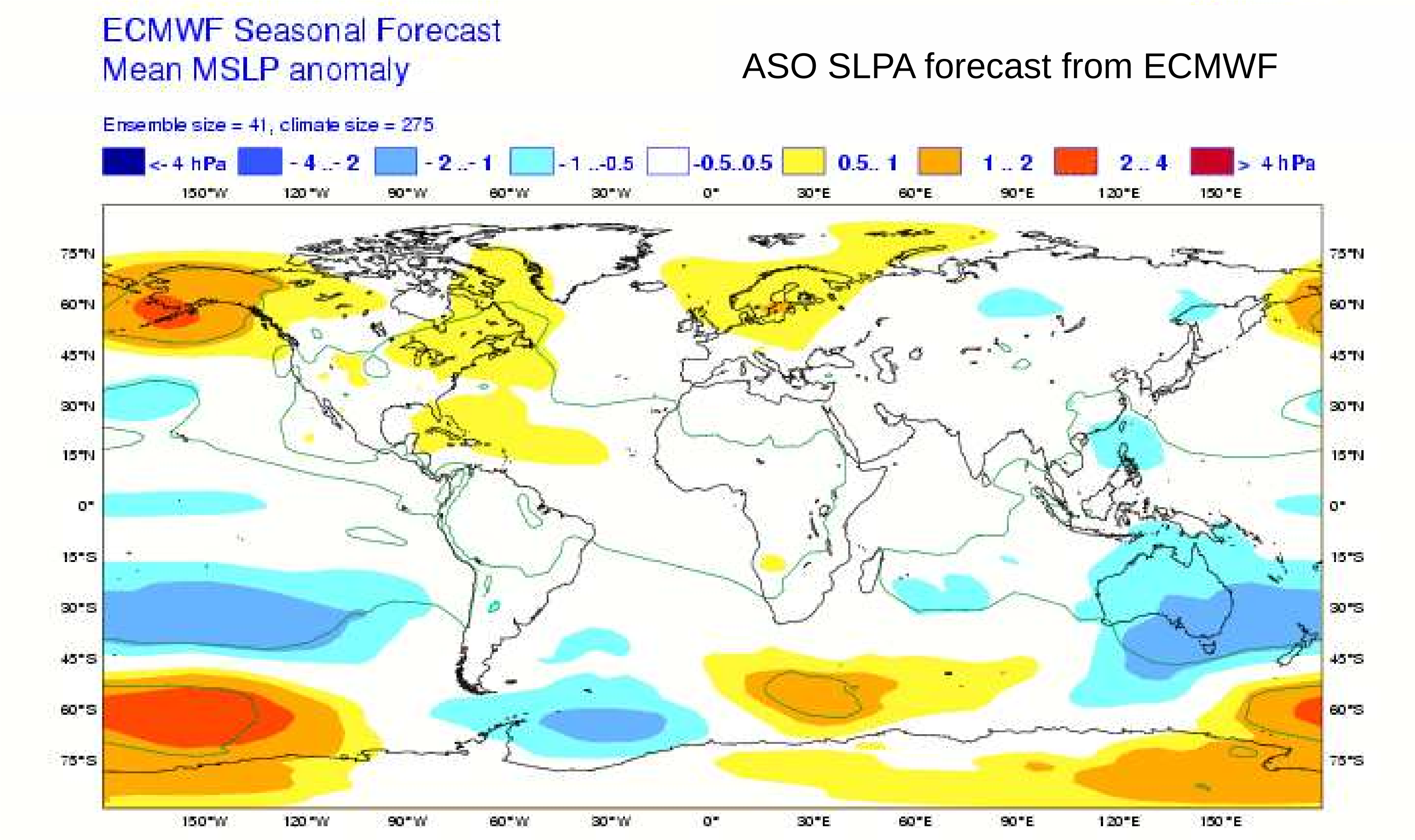
Hurricanes forecast from ECMWF



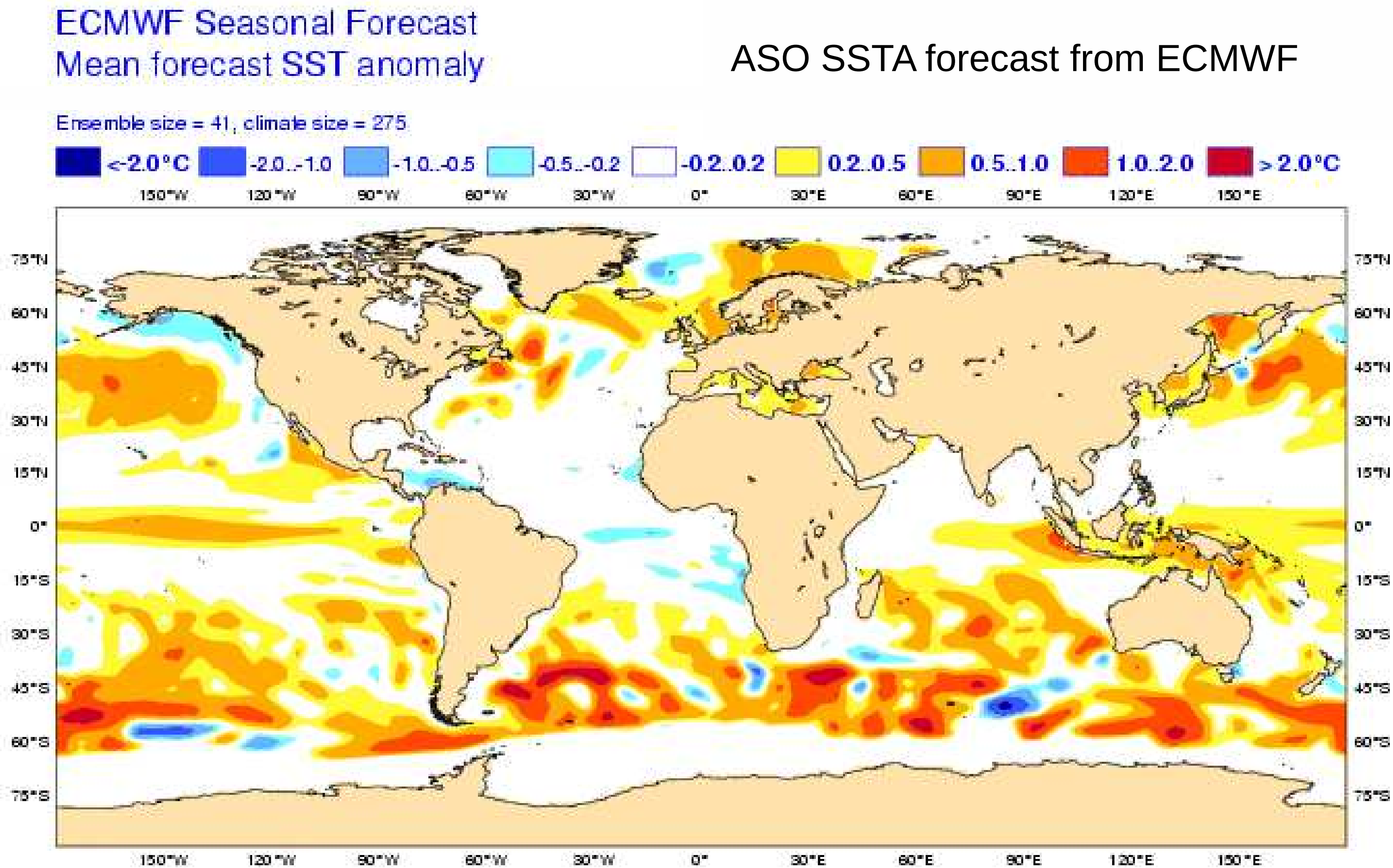
ACE forecast from ECMWF



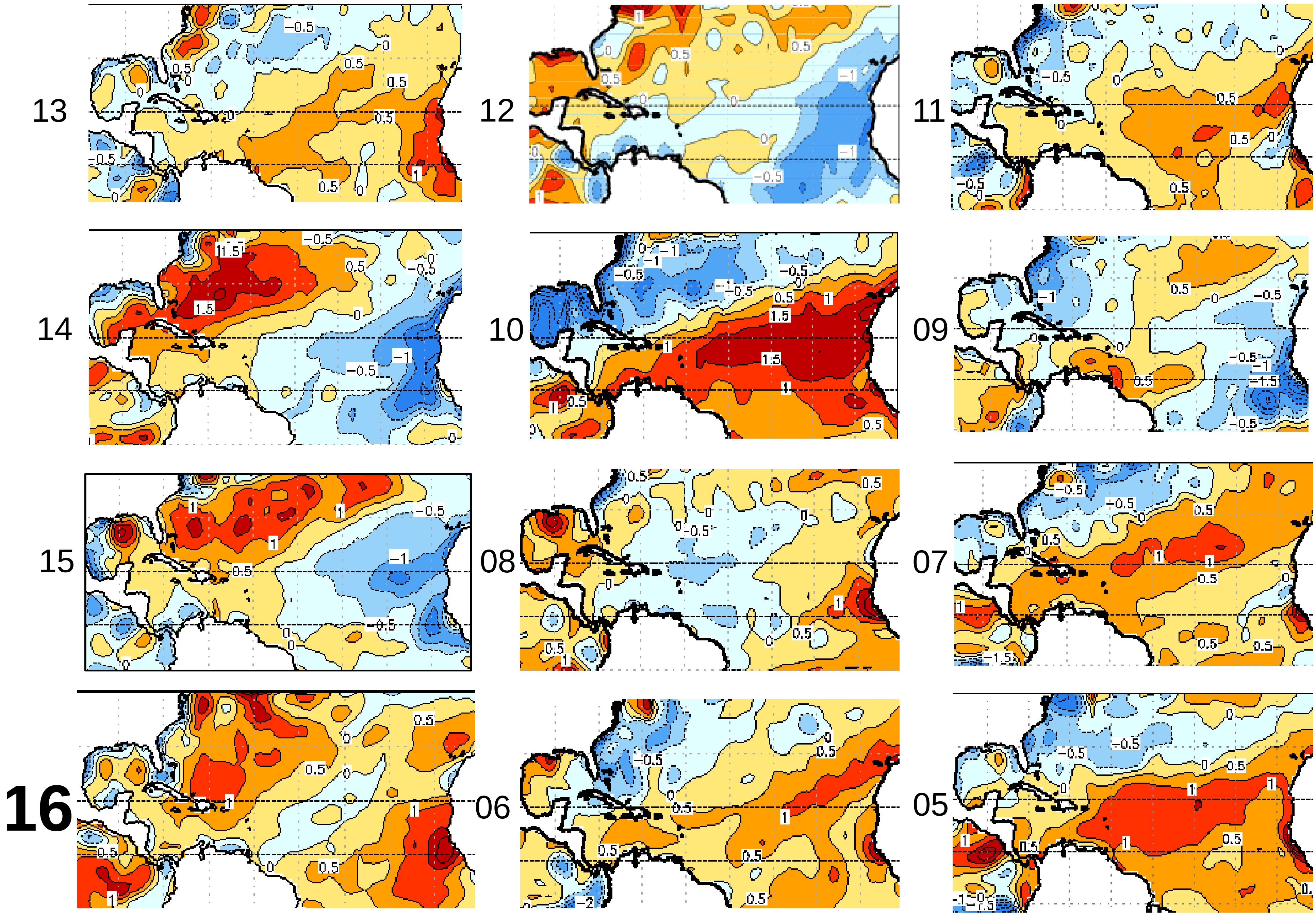
ASO SLPA forecast from ECMWF



ASO SSTA forecast from ECMWF



What about 2016?


13
12
11
14
10
09
15
08
07
16
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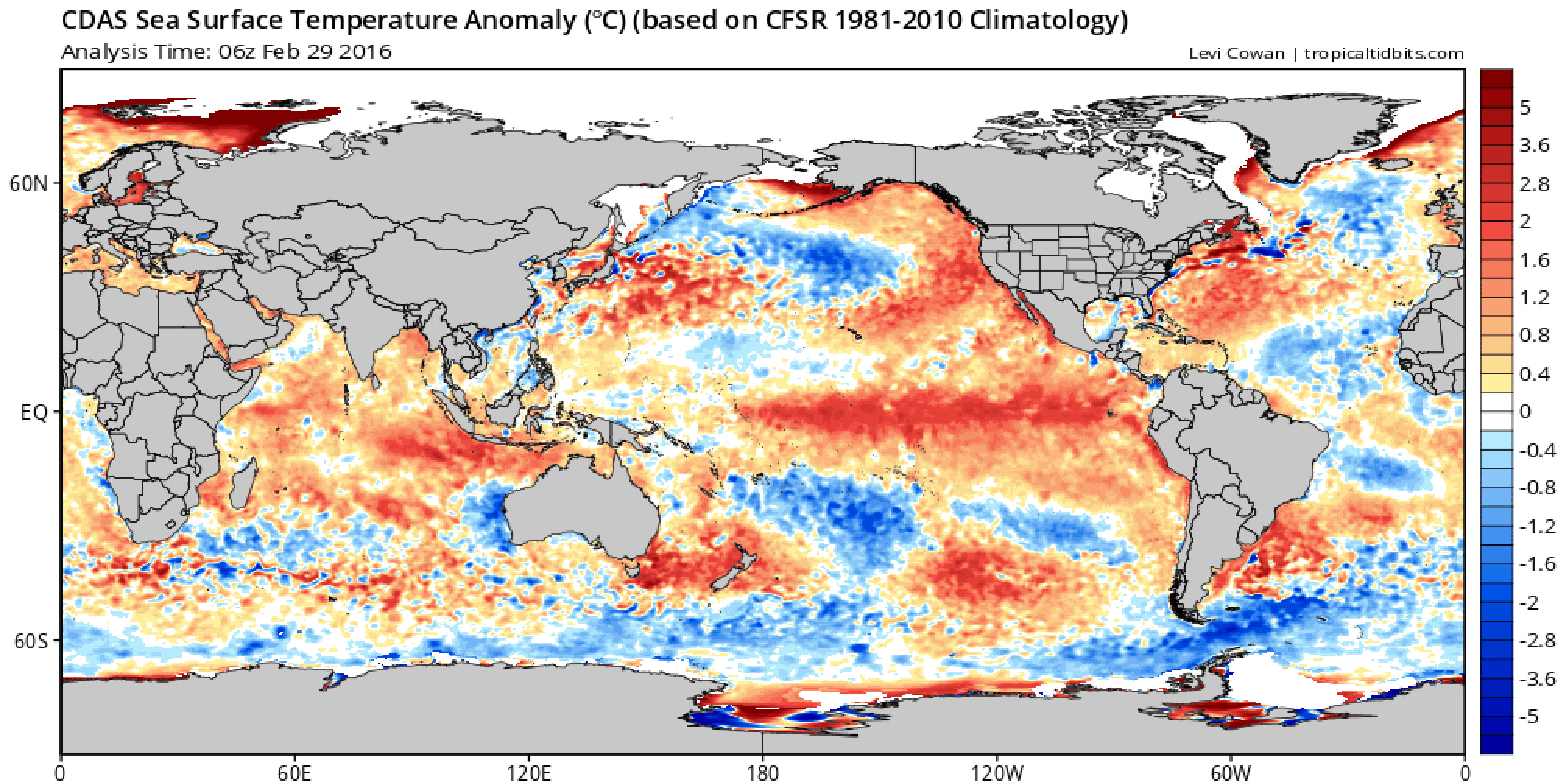
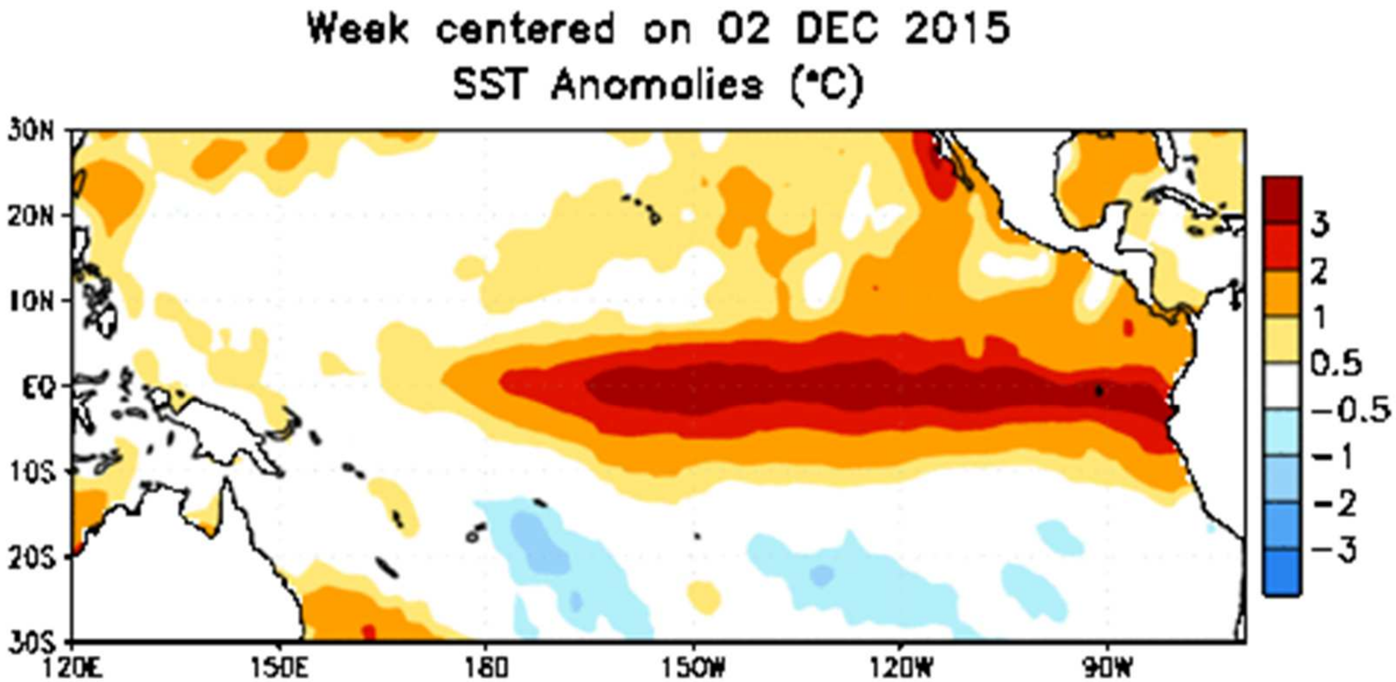
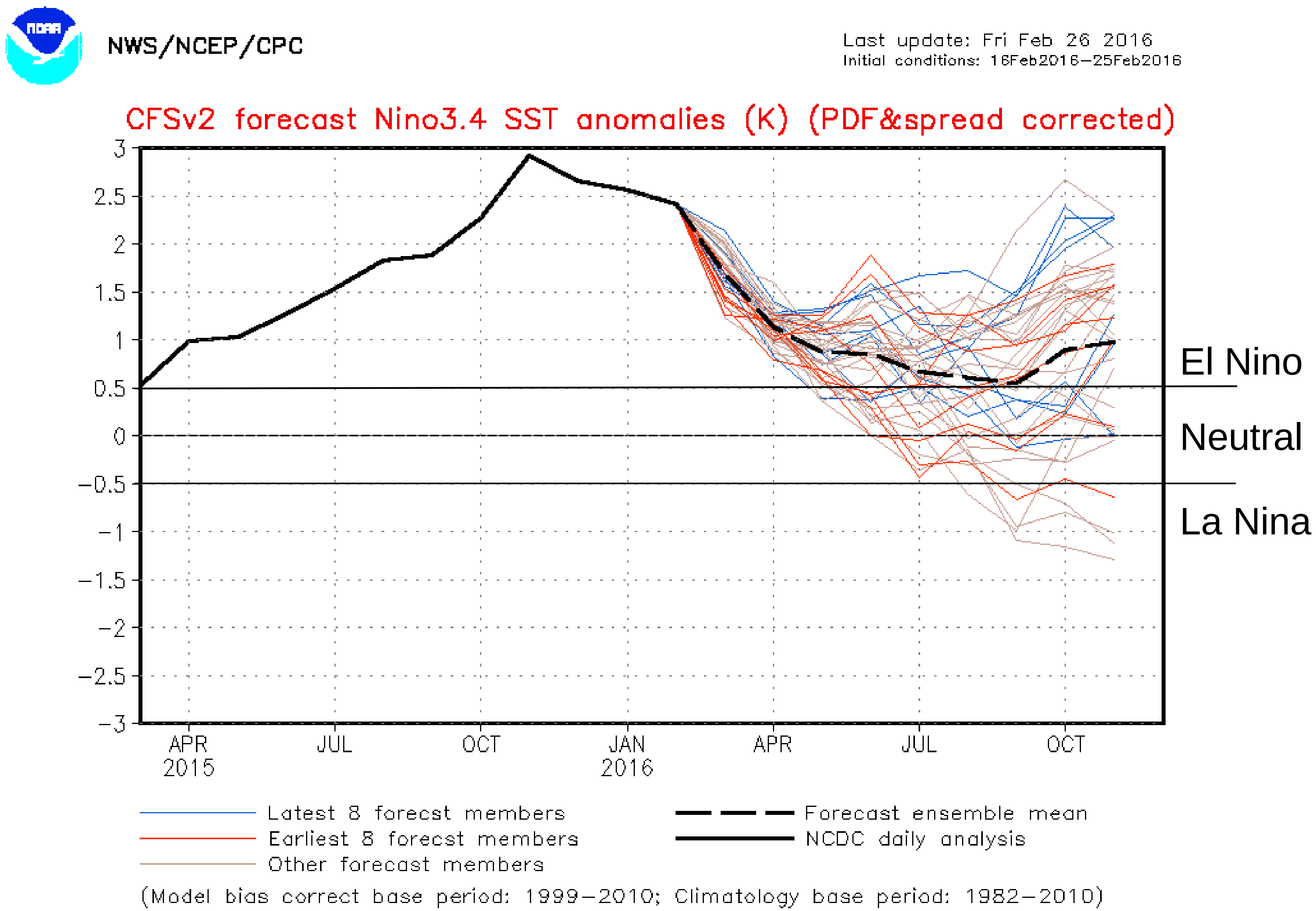
05

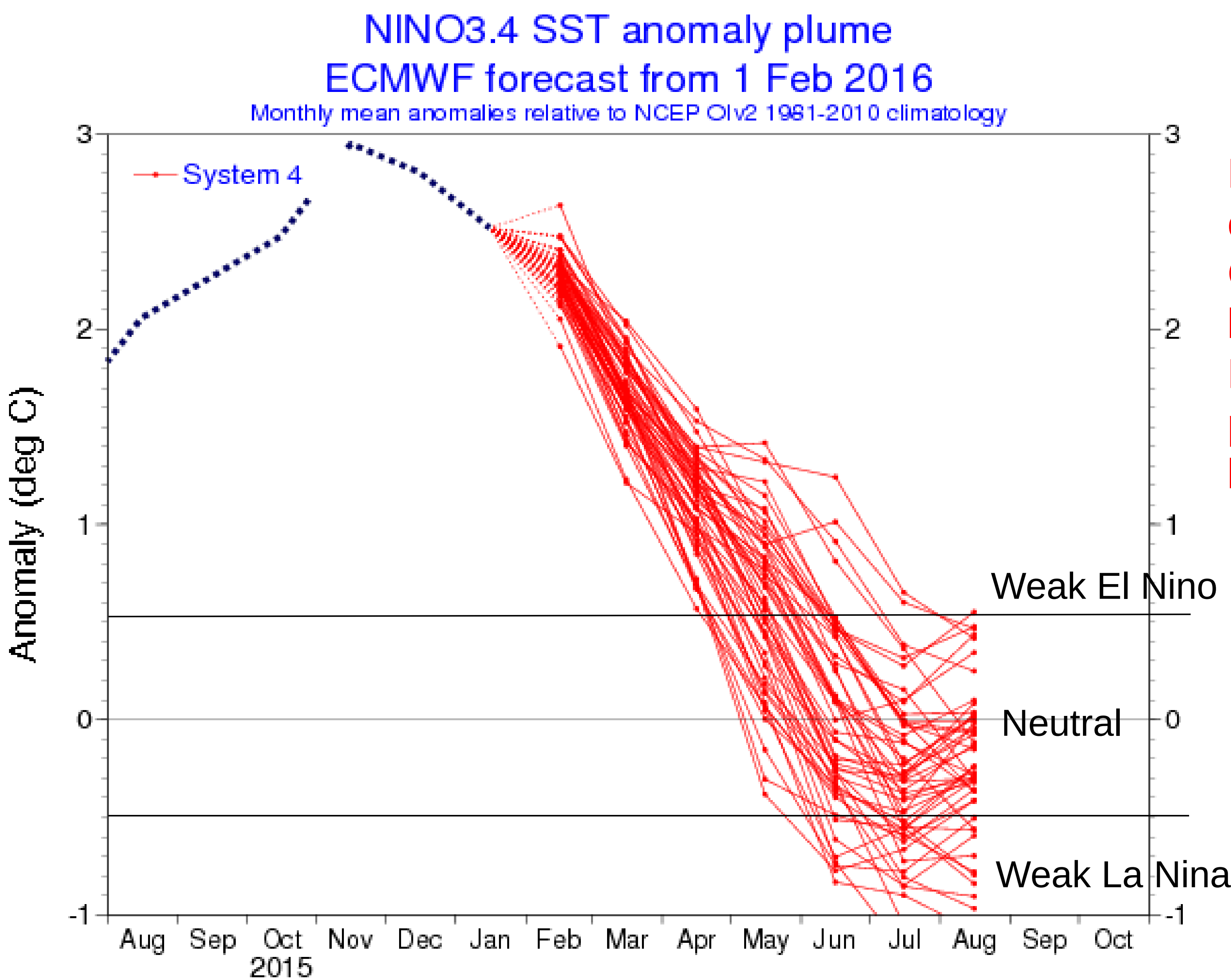

CDAS Sea Surface Temperature Anomaly (°C) (based on CFSR 1981-2010 Climatology)
Analysis Time: 06z Feb 29 2016
Levi Cowan | tropicaltidbits.com
60N
EQ
60S
0
60E
120E
180
120W
60W
0
5
3.6
2.8
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
-2.8
-3.6
-5

Strong El Niño but gradually weakening

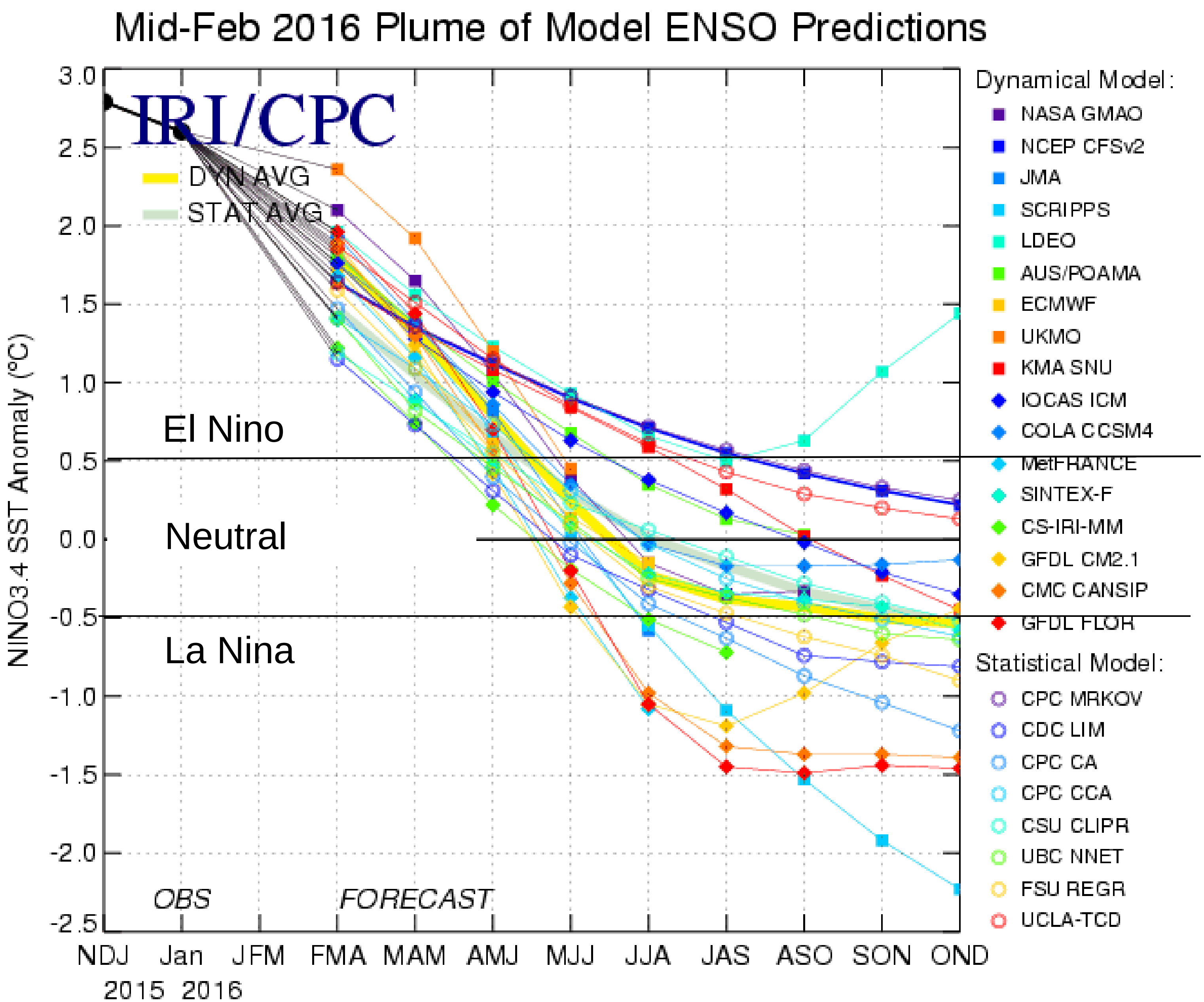


CFS forecasts ~weak El Niño for ASO 2016





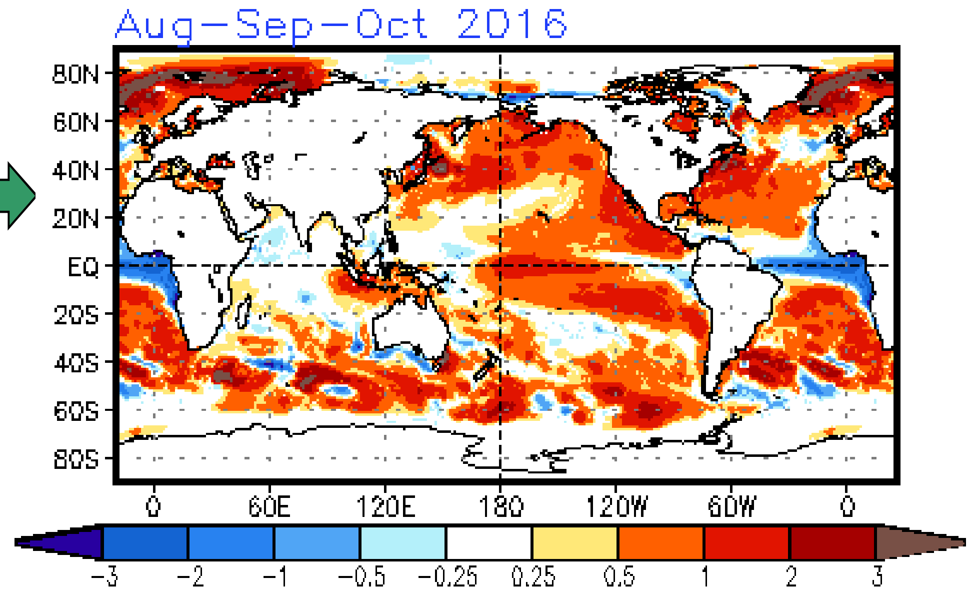
ECMWF much cooler than CFS, neutral likely by June, La Nina possible by late summer

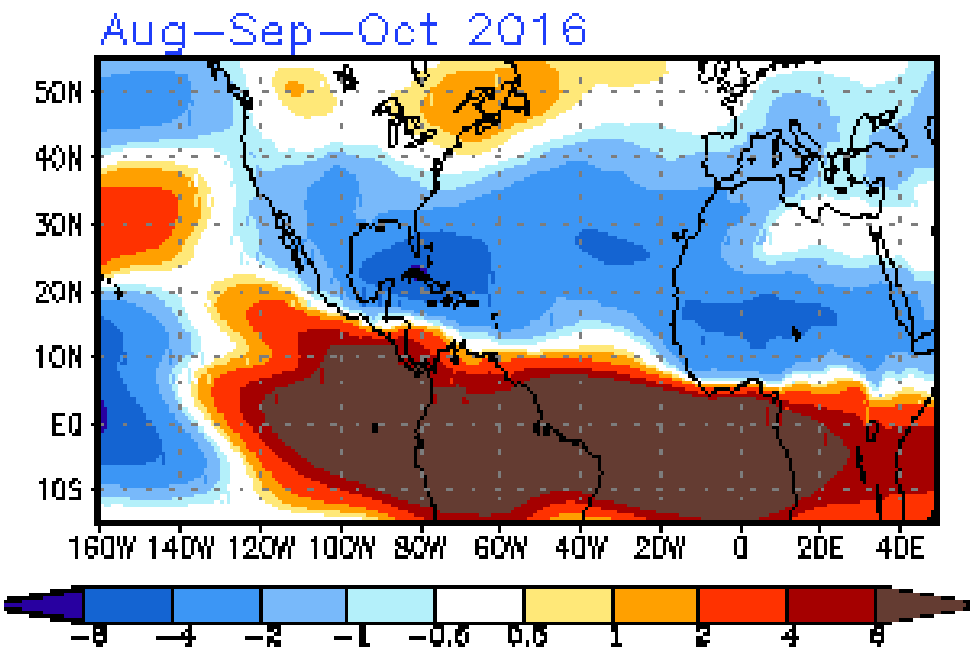


- Huge uncertainty for summer!

CFS ASO Seasonal Forecasts from Feb 26

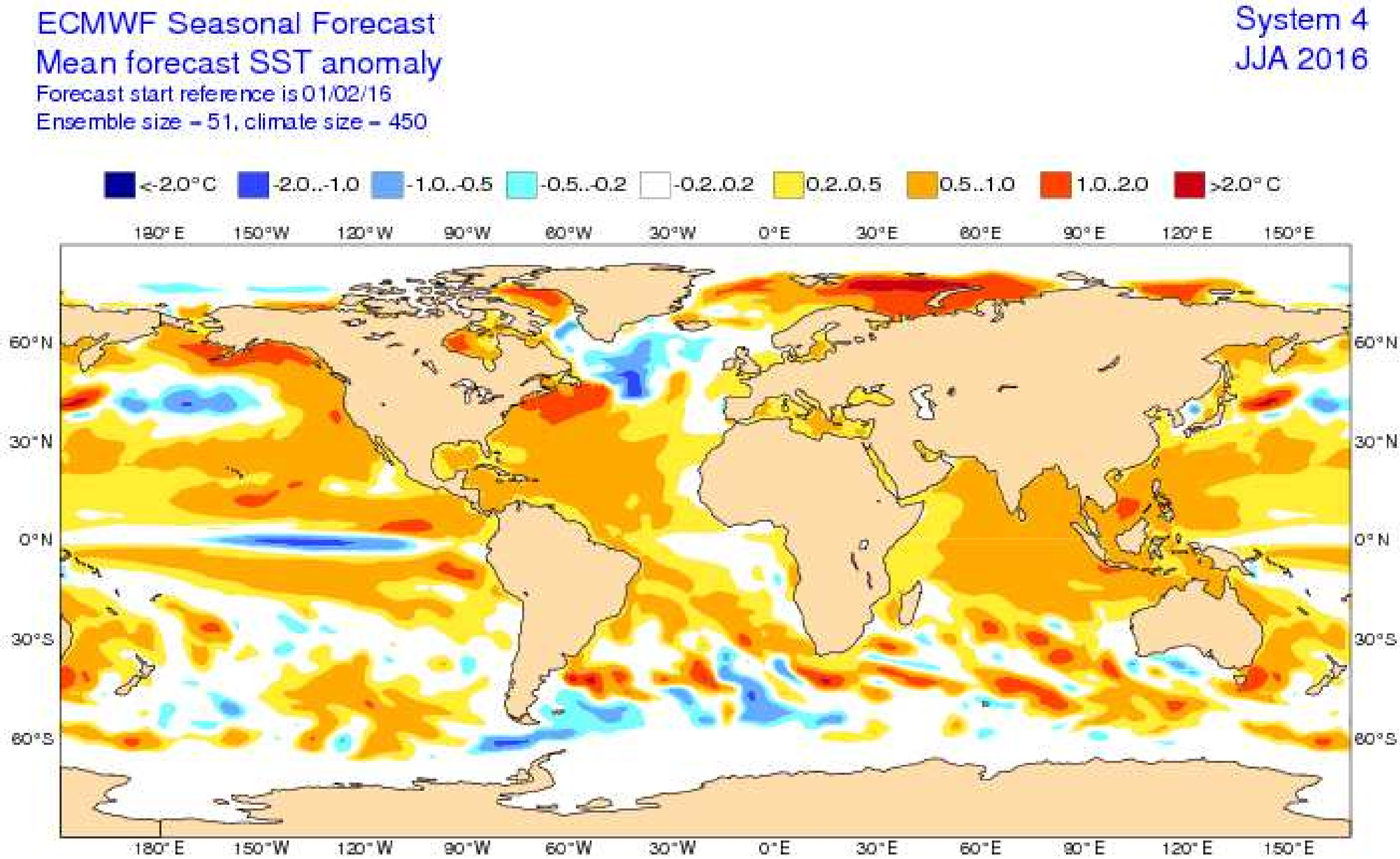
SST (warm Atlantic, weak El Nino)





Vertical Shear (generally lower than normal)

ECMWF JJA SST forecast



Both agree on warm Atlantic, substantial difference in Indian Ocean

Conclusions

- The MJO and Kelvin waves modulate TC activity around the globe.
- El Niño/La Niña conditions are probably the most important factor in a seasonal forecast.
- Tropical Atlantic Ocean water temperatures and multi-decadal cycles are also very important.
- There are also year-to-year differences in vertical wind shear, sea-level pressures, and global circulation changes during the early part of the season that may give clues to how the rest of the season may turn out.
- 2016 appears to be more active than 2015 but Atlantic could be in a quieter mode now.