Intraseasonal TC Variability and Seasonal Hurricane Forecasting

2018 WMO Class

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Outline

- Madden-Julian Oscillation (MJO)
- MJO analysis tools
- Kelvin Waves
- Seasonal forecasting
- Exercise
- Brief look at 2018

Question 1

What’s the 3rd busiest month on average in terms of Atlantic ACE?

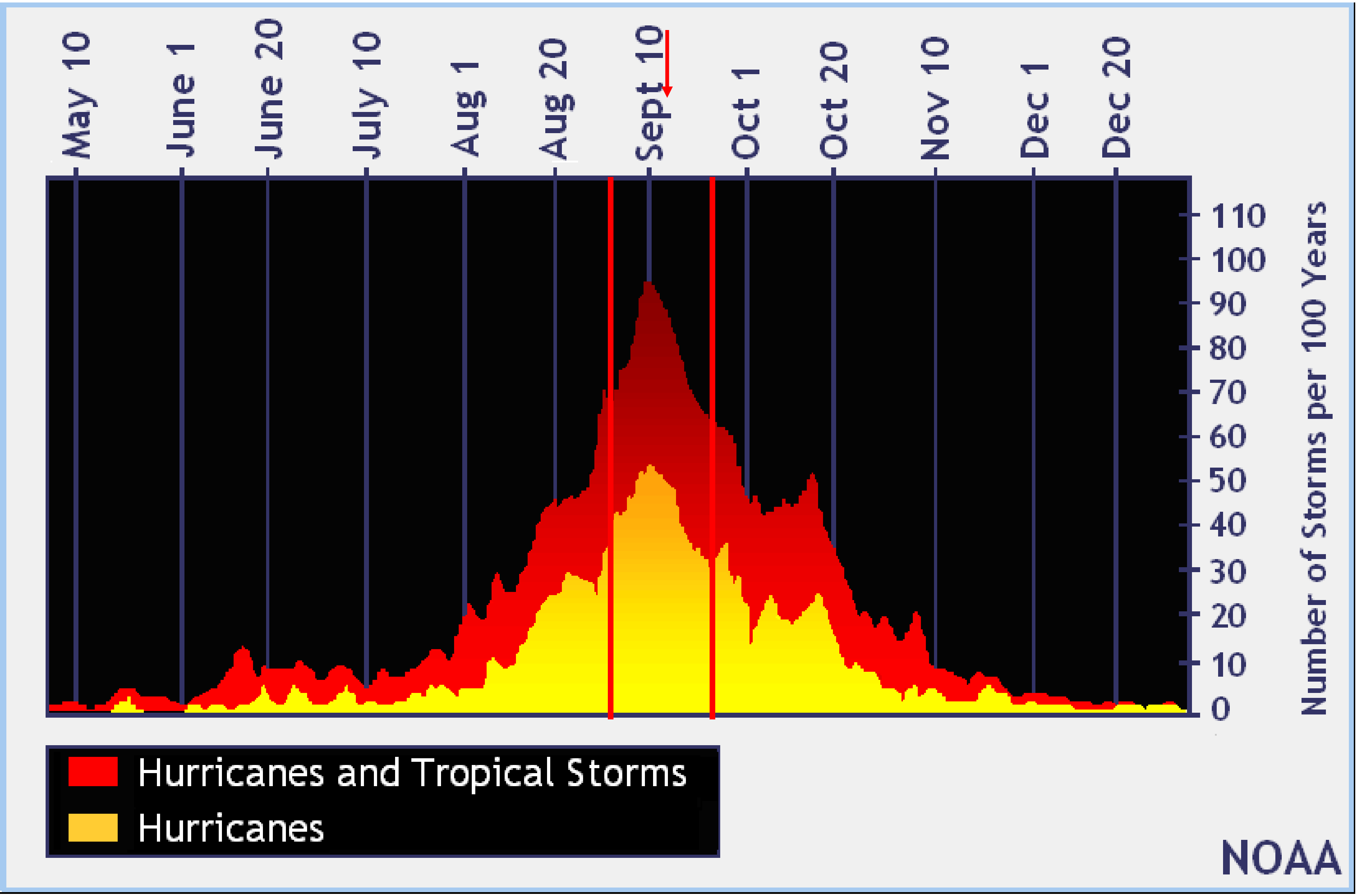
A. July

B. August

C. September

D. October

No Storm
Formations in 2008



Madden-Julian Oscillation

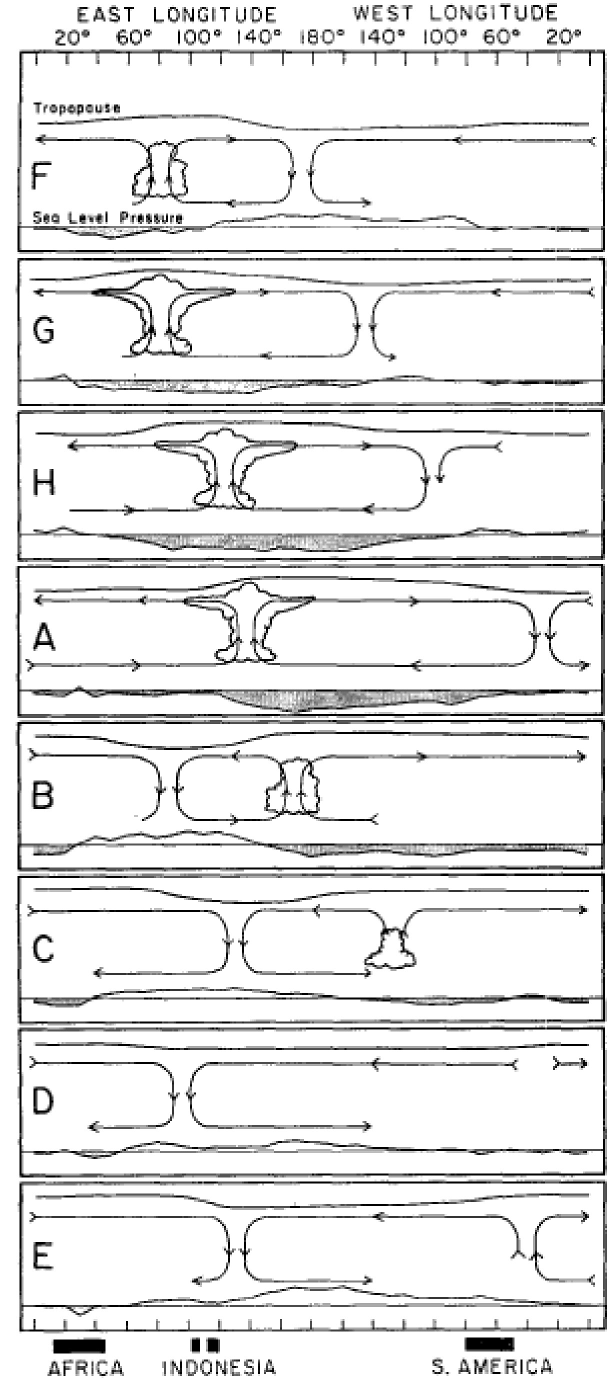
- Discovered in the early 1970s by Roland Madden and Paul Julian.
- An eastward propagating wave that circles the globe in about 40-50 days involving tropical convection.
- Detected in the Outgoing Longwave Radiation (OLR) and wind fields across the tropics.
- Later papers showed that it is an important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

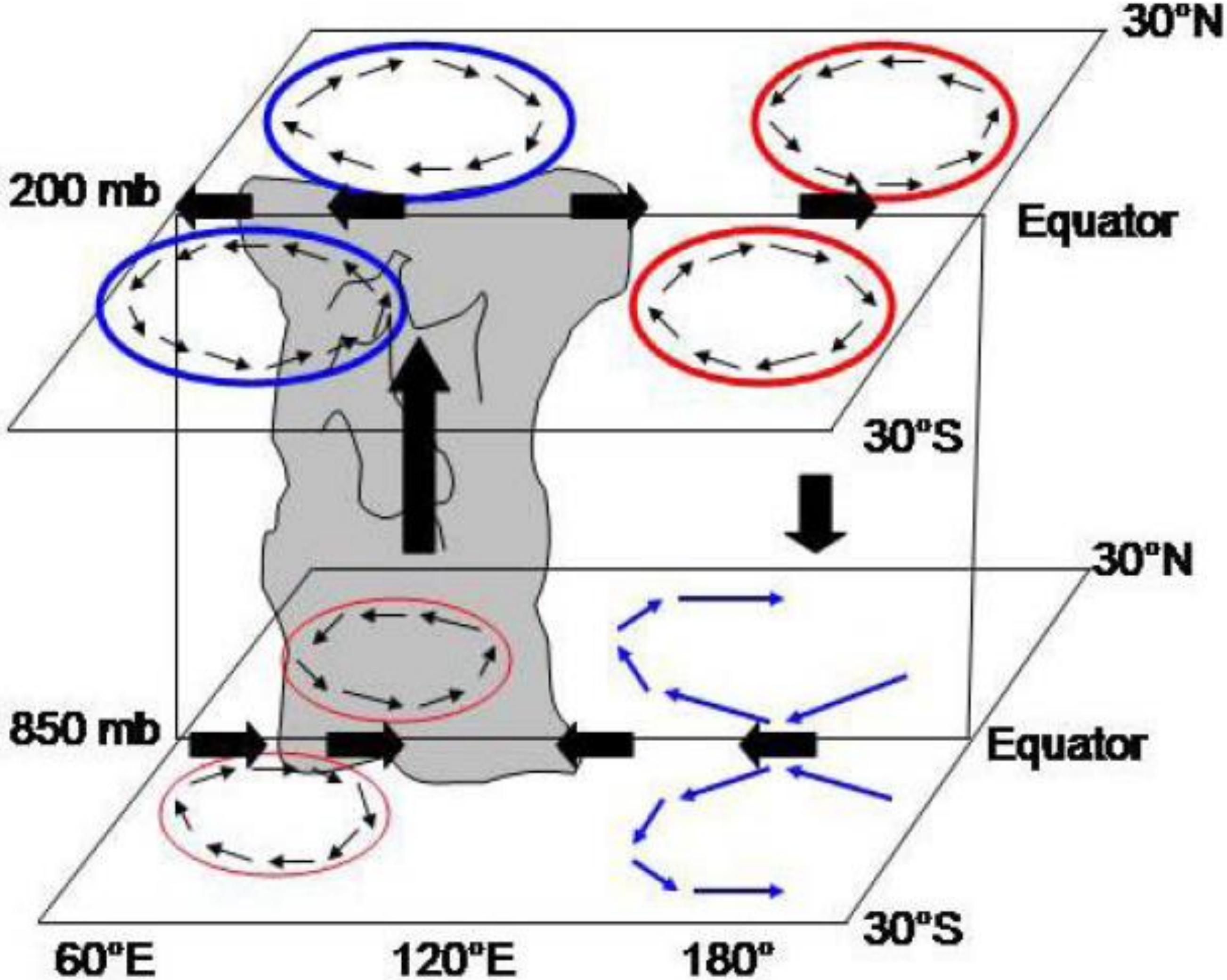
-Idealized Diagram of the 40-50 day Tropical Intraseasonal Oscillation

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

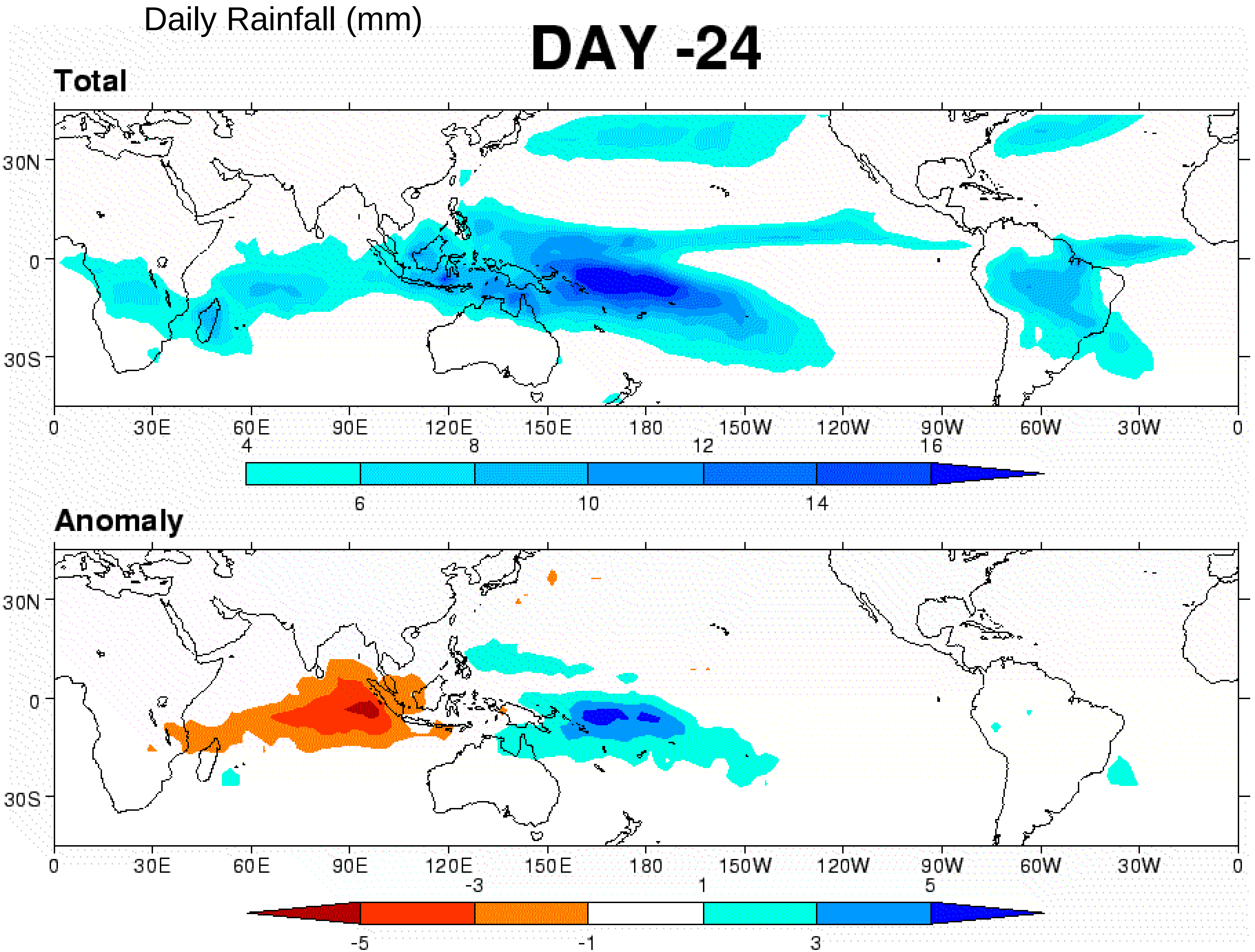
-Generally forms over the Indian Ocean, strengthens over the Pacific Ocean and weakens due to interaction with South America and cooler eastern Pacific SSTs

(Madden and Julian 1972)

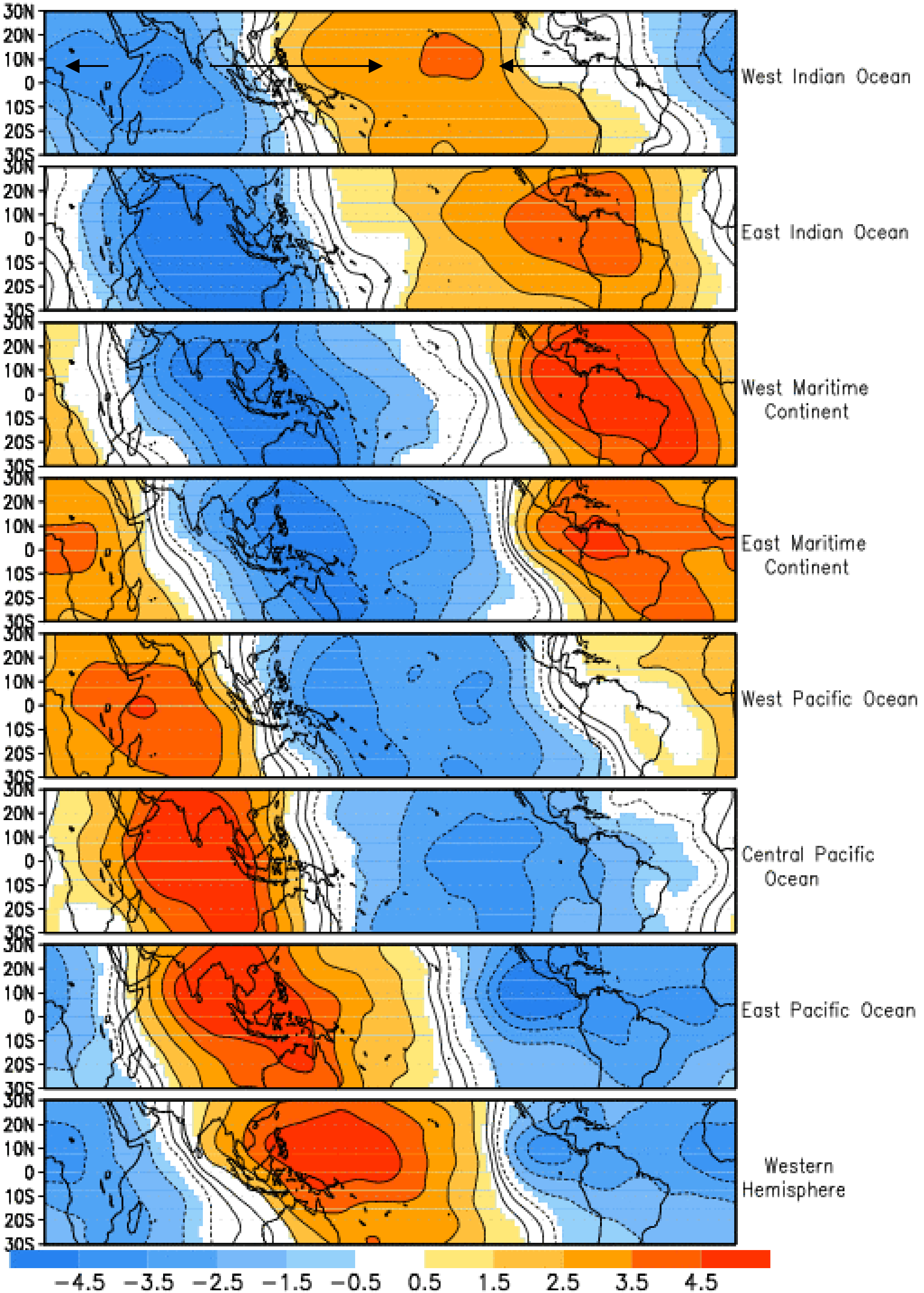




Rui and Wang (1990)



Daily Rainfall (mm)
DAY -24
Total
30N
0
30S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
4
8
12
16
6
10
14
Anomaly
30N
0
30S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
-3
1
5
-5
-1
3

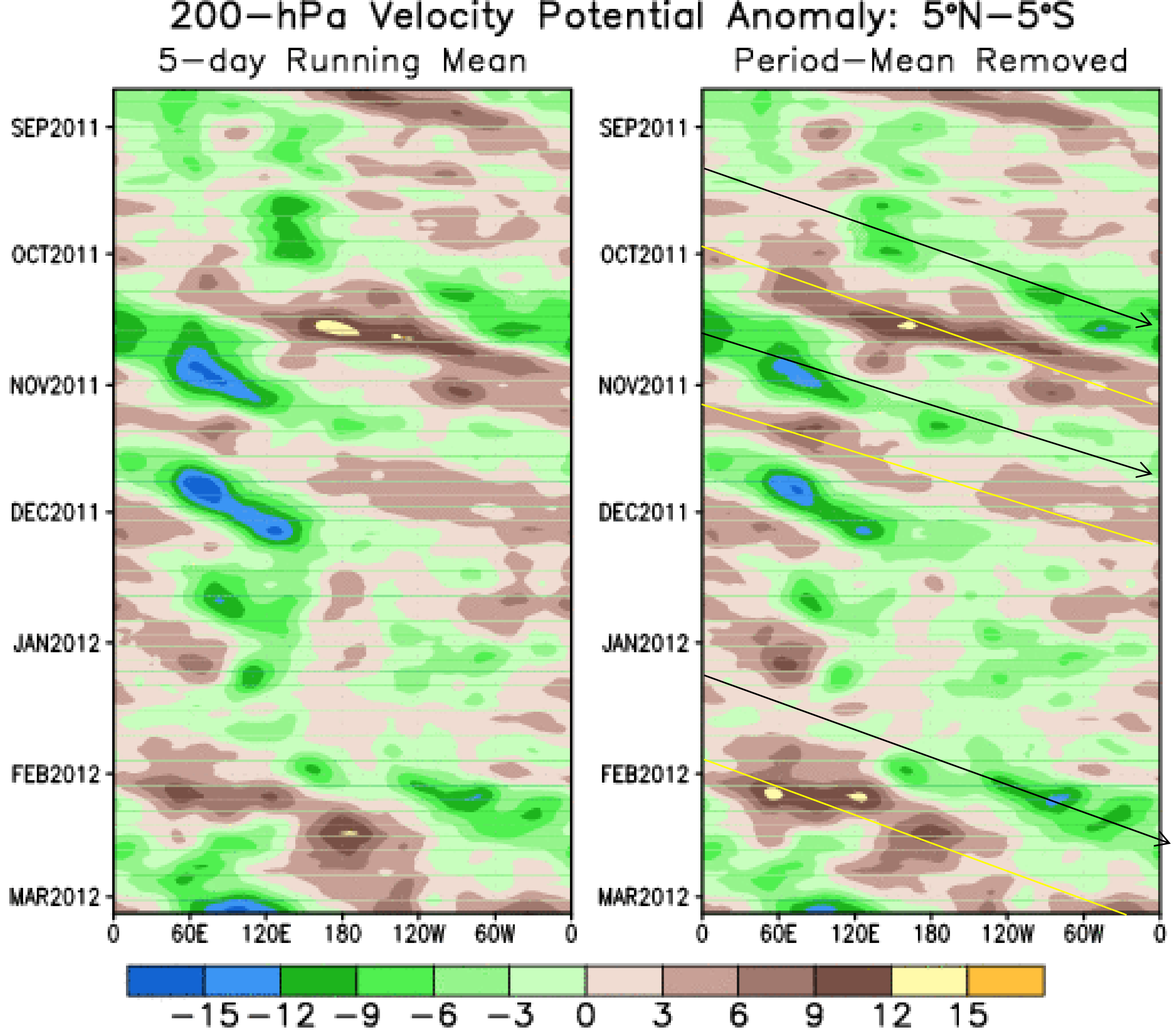


200 mb Velocity Potential fields– one way to track the MJO

Blue= divergence

Red= convergence

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



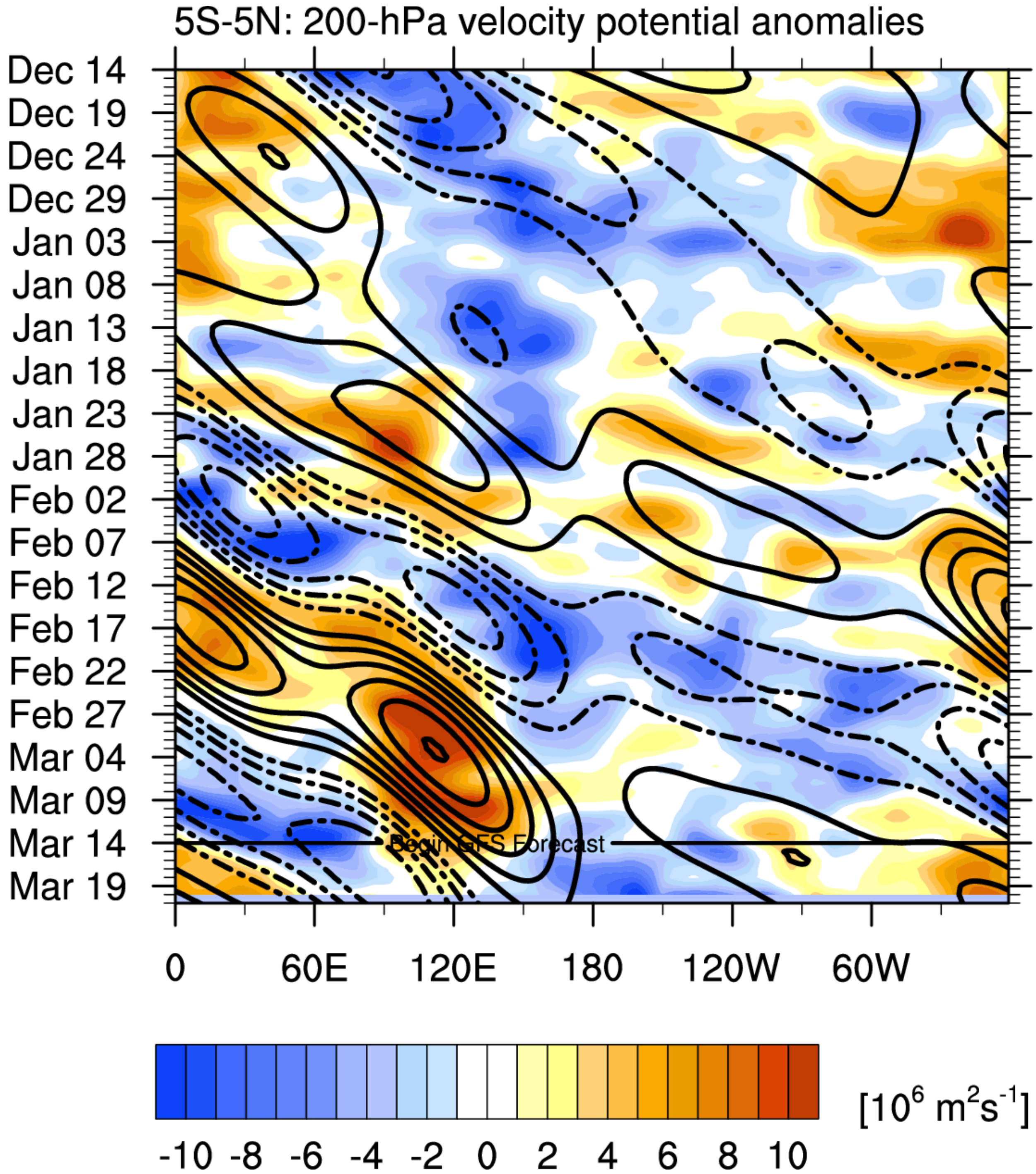
Time−longitude sections of anomalous 200−hPa velocity potential (x 10^6 m^2 s^{-1}) averaged between 5°N−5°S for the last 180 days ending 05 MAR 2012: (Left) 5−day running means and (Right) 5−day running means with period mean removed. Anomalies are departures from the 1981−2010 period daily means. CLIMATE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

MJO characteristics

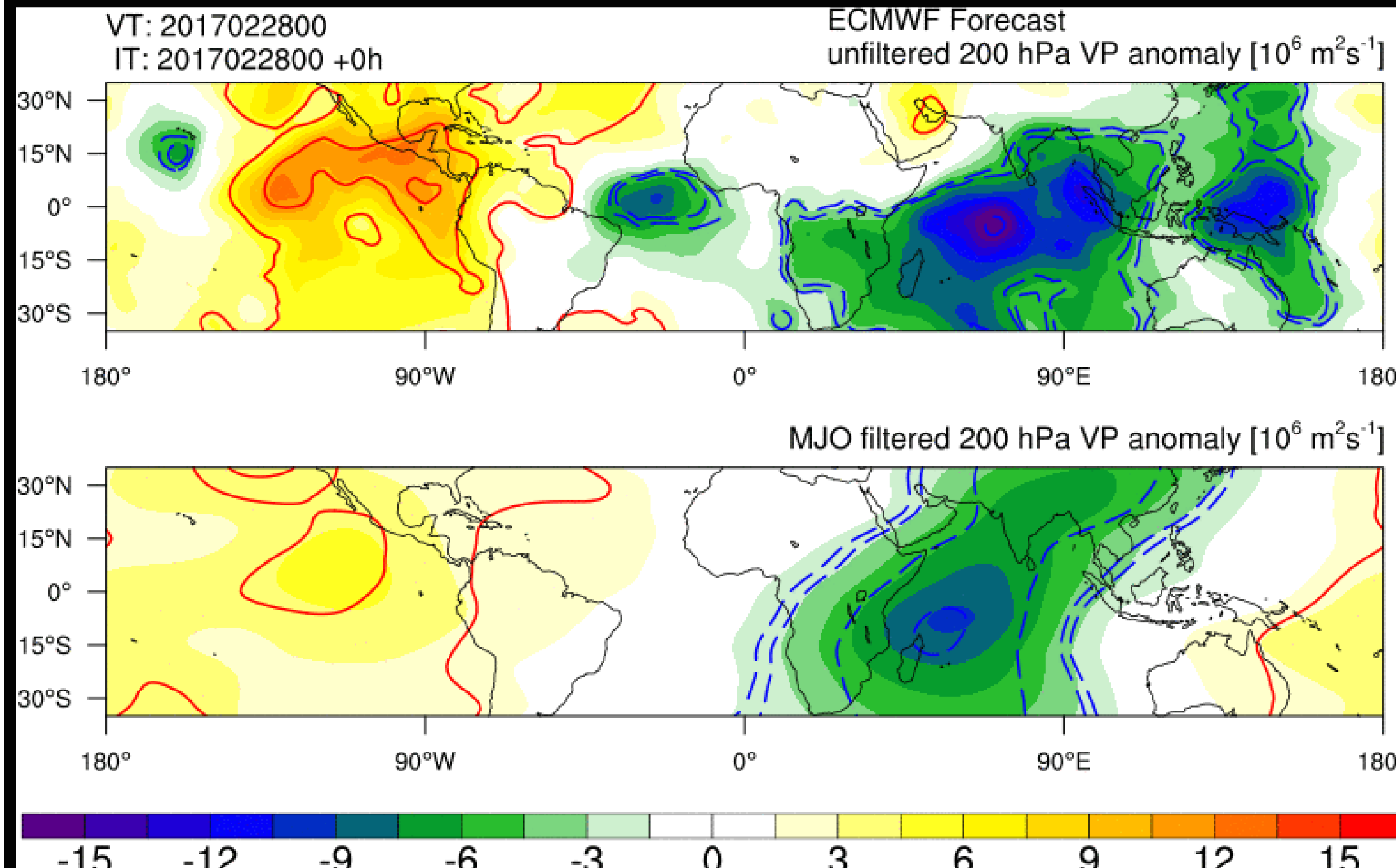
Note signal is much stronger in eastern Hemisphere than western

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



10-day ECMWF MJO Forecast



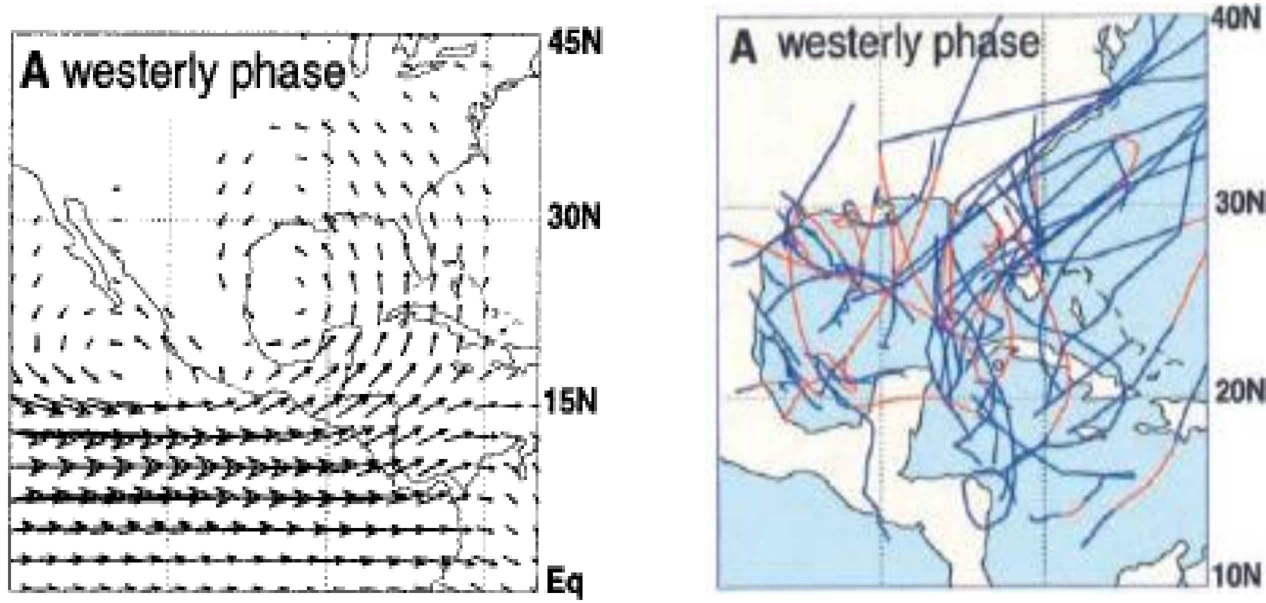
MJO Effects in the Atlantic Basin

- 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).

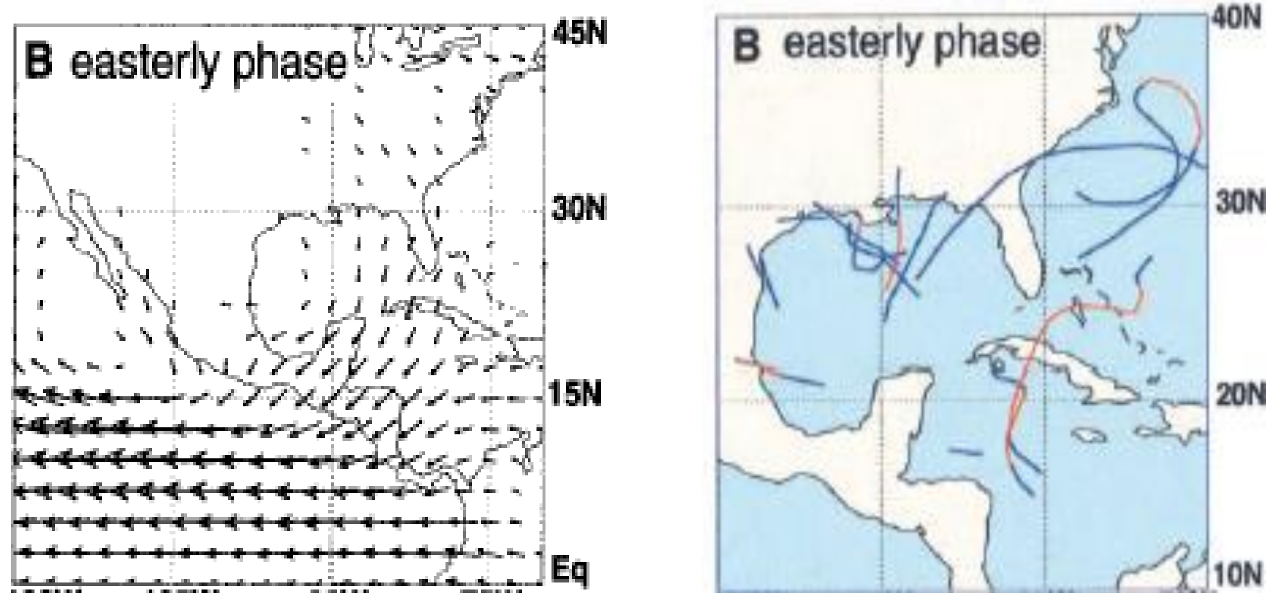
Active MJO in the western Caribbean Sea and Gulf of Mexico produces more storms due to:

- 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

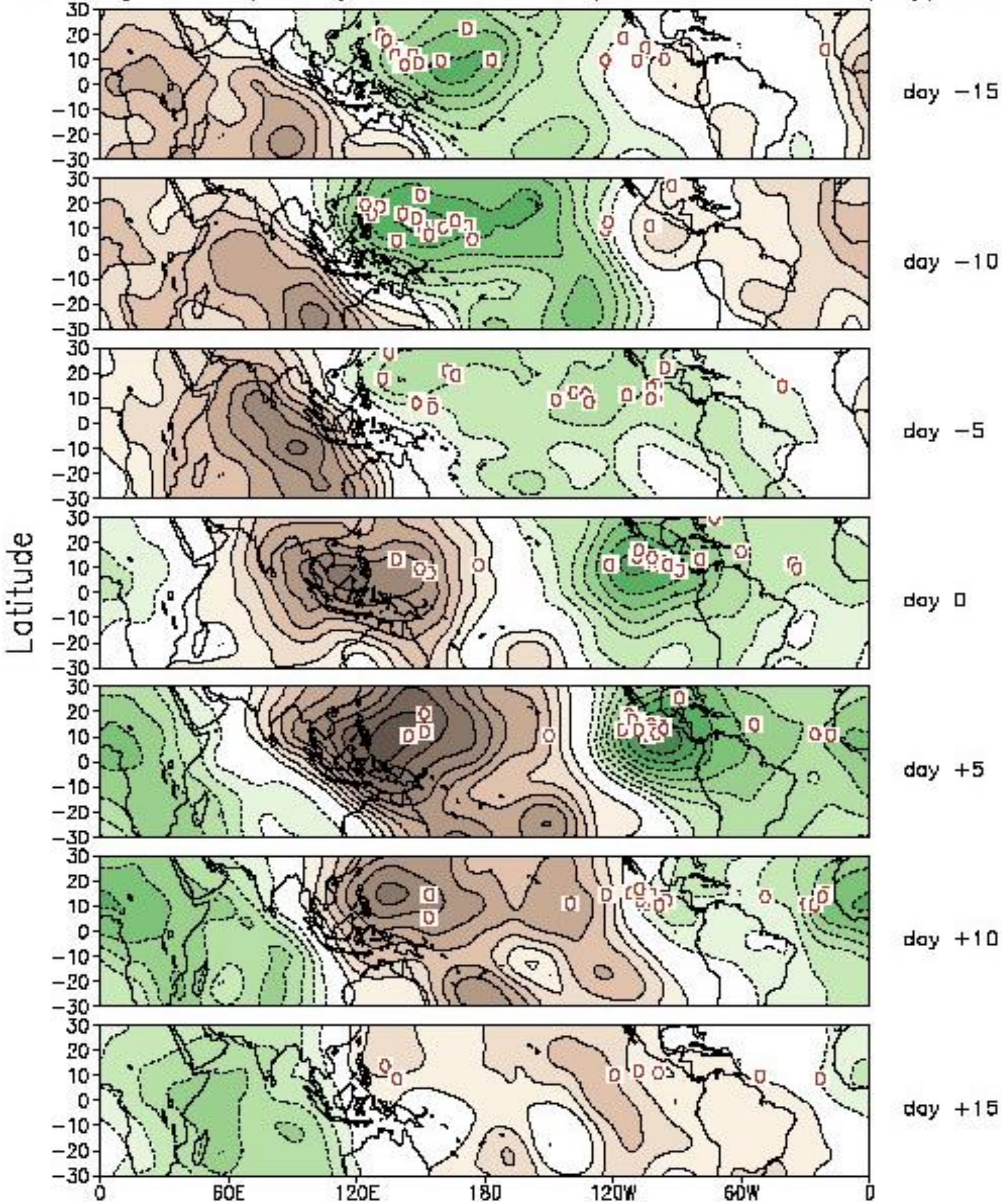
Active MJO EOF and corresponding TS and H tracks



Inactive MJO EOF and corresponding TS and H tracks



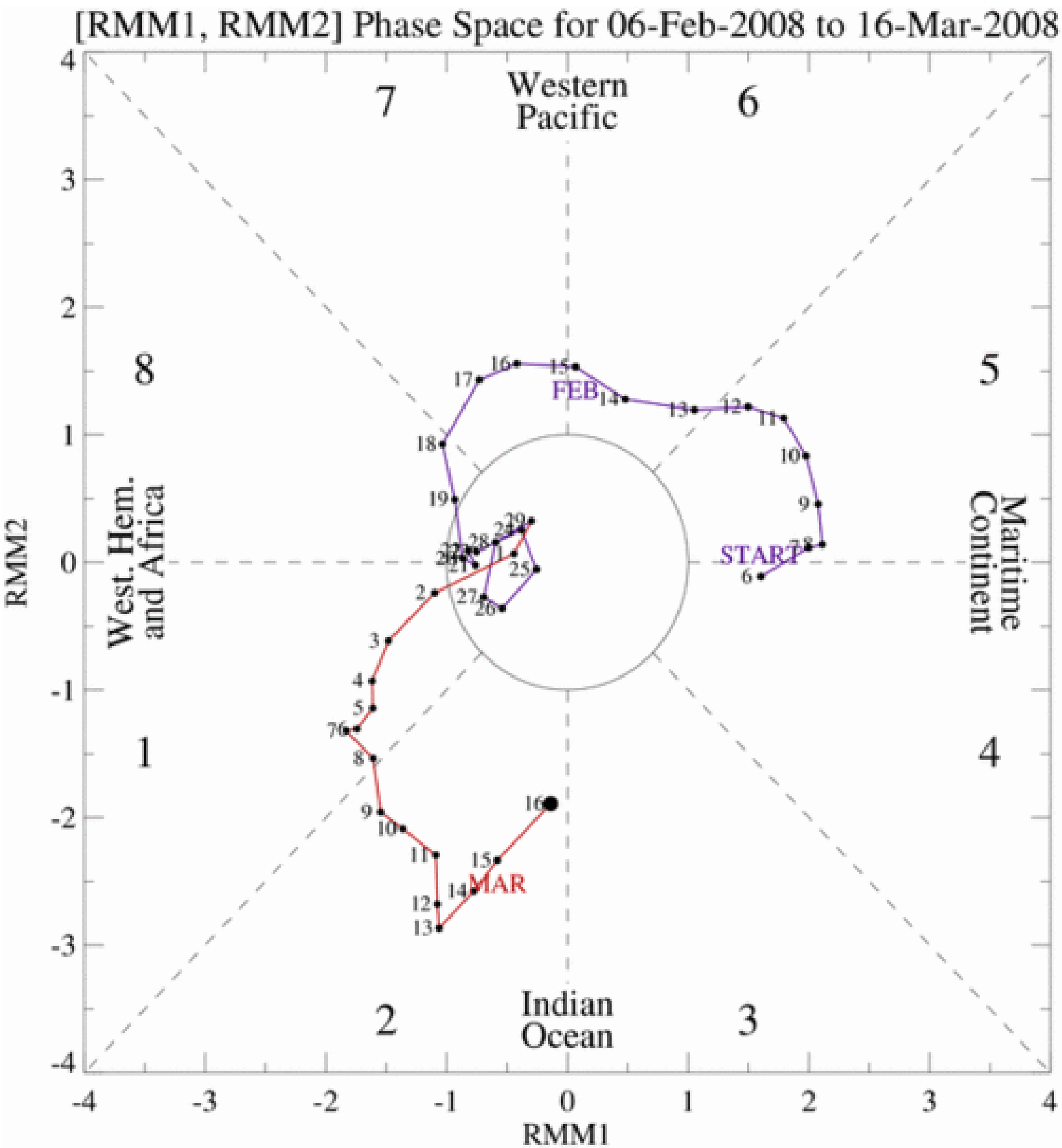
Adapted from Maloney and Hartmann (2000)



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

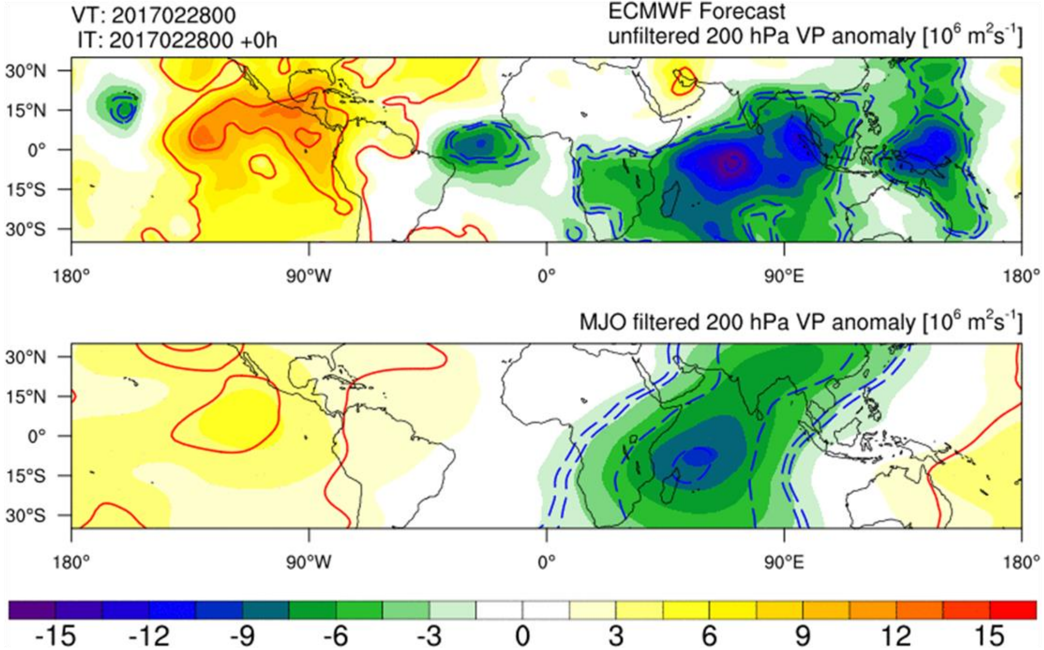
Figure 10: Velocity potential composites for different phases of the MJO cycle with hurricane/typhoon origin locations. Green shading indicates upper level divergence and brow shading indicates upper level convergence. Open circles indicate hurricane/typhoon origin centers.

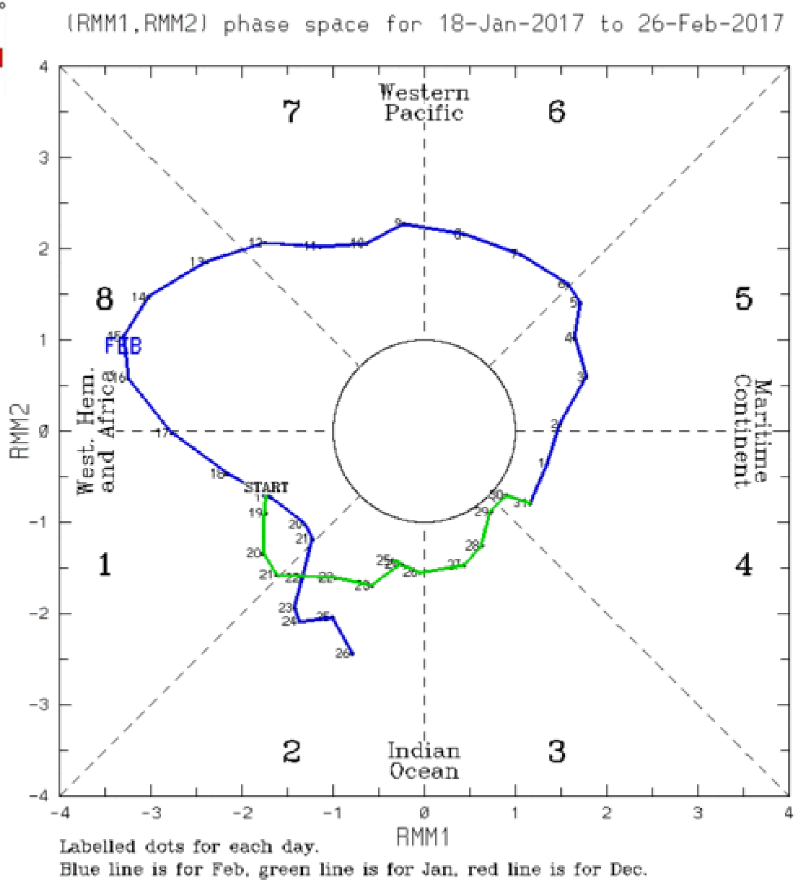
A different way to visualize the MJO

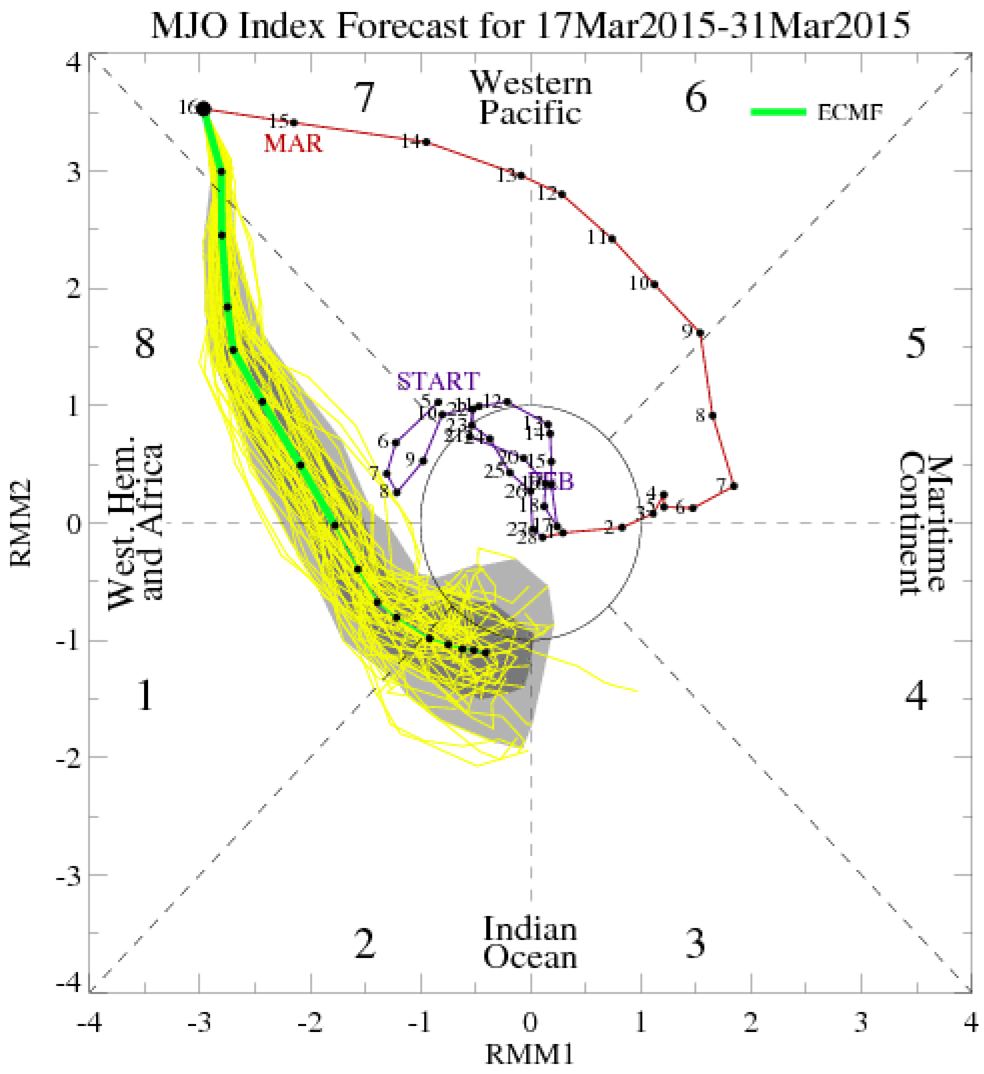


- The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes, following the active convection.
- The triangular areas indicate the location of the enhanced phase of the MJO
- Counter-clockwise motion is indicative of eastward propagation
- Distance from the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

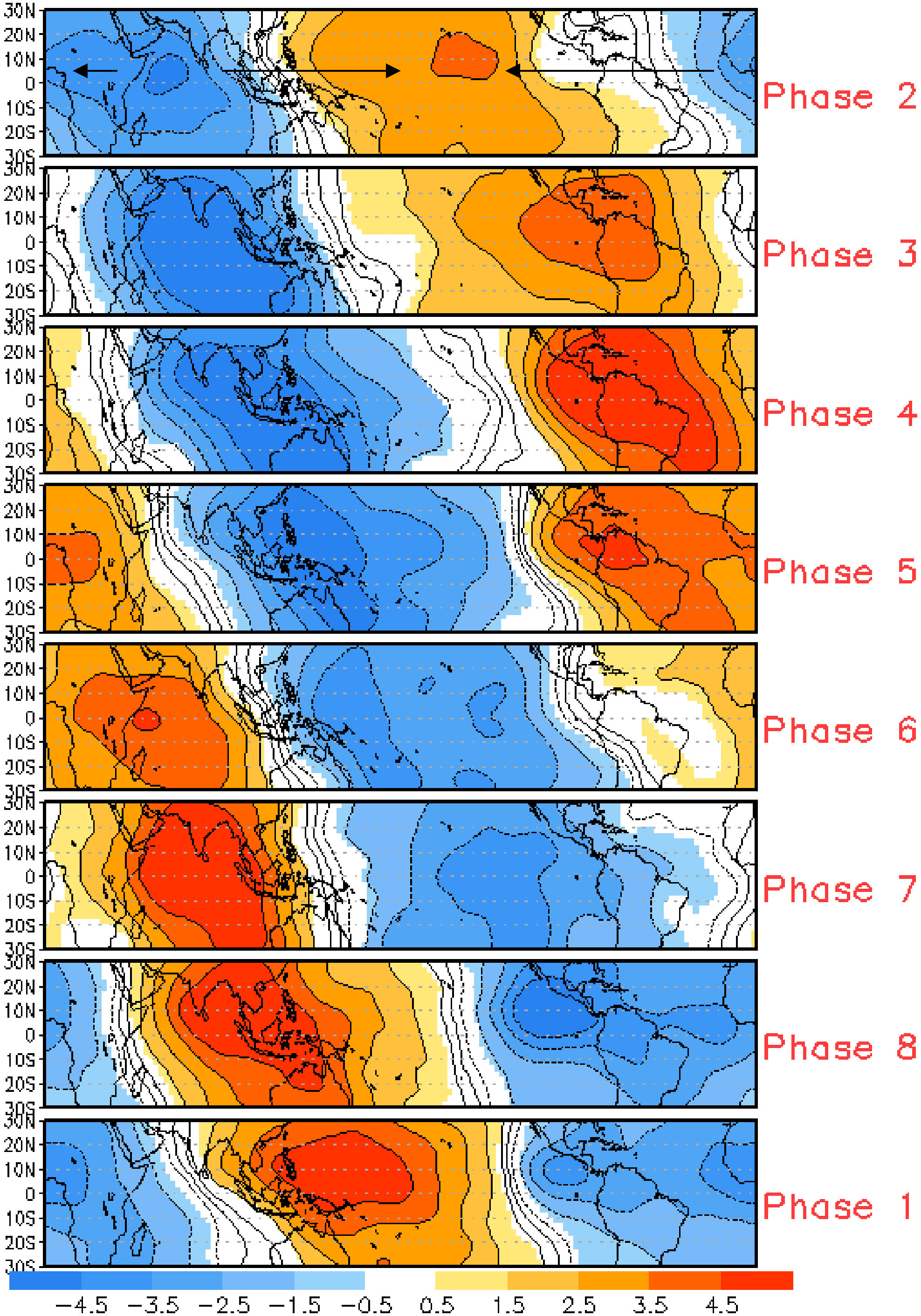
Current MJO: Plan view versus RMM diagram







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



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

Question 2

What phases of the MJO are most favorable for Atlantic TC activity?

A. Phases 3/4

B. Phases 5/6

C. Phases 7/8

D. Phases 1/2

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**

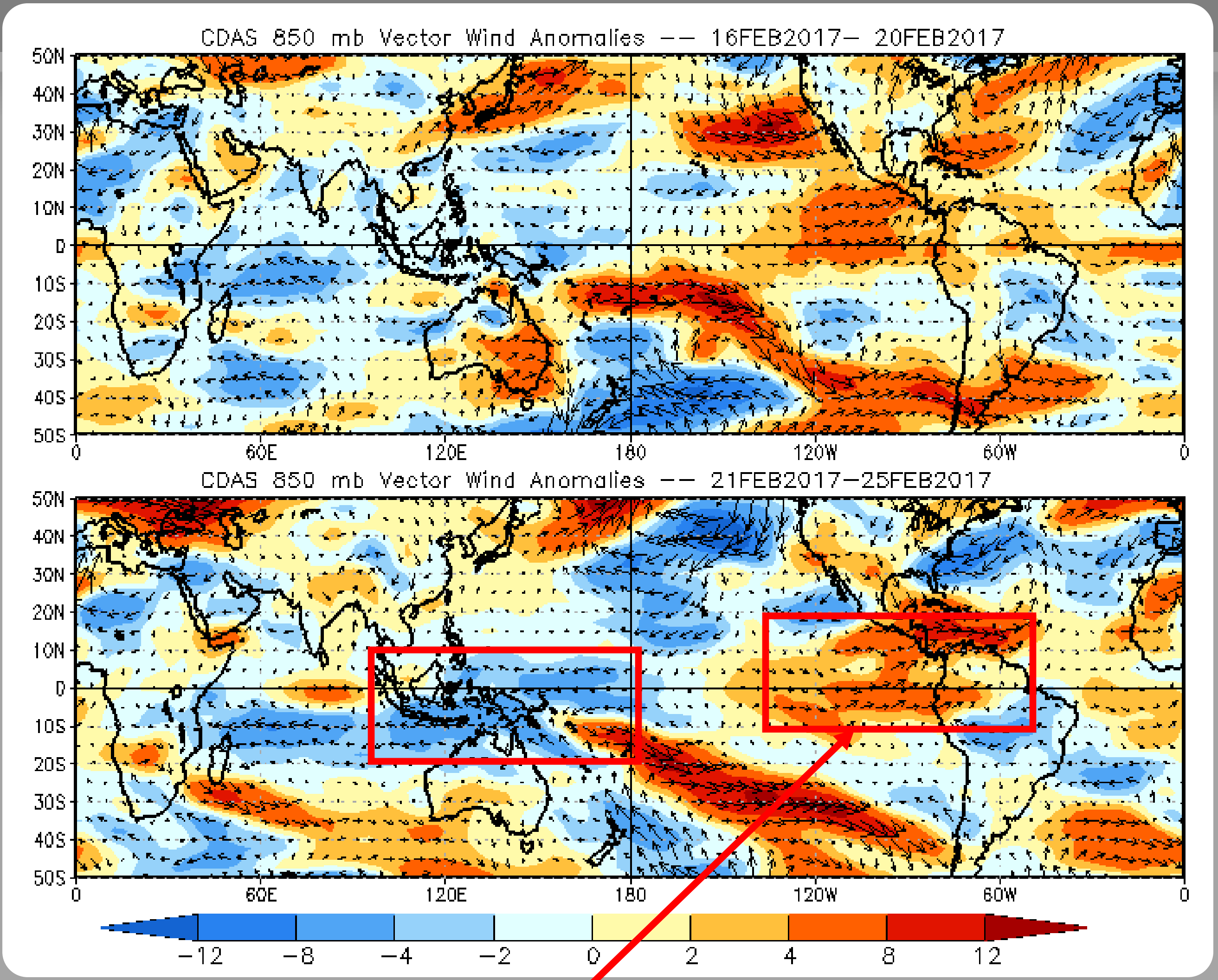
From Klotzbach (2010)

850-hPa Vector Wind Anomalies (m s-1)

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

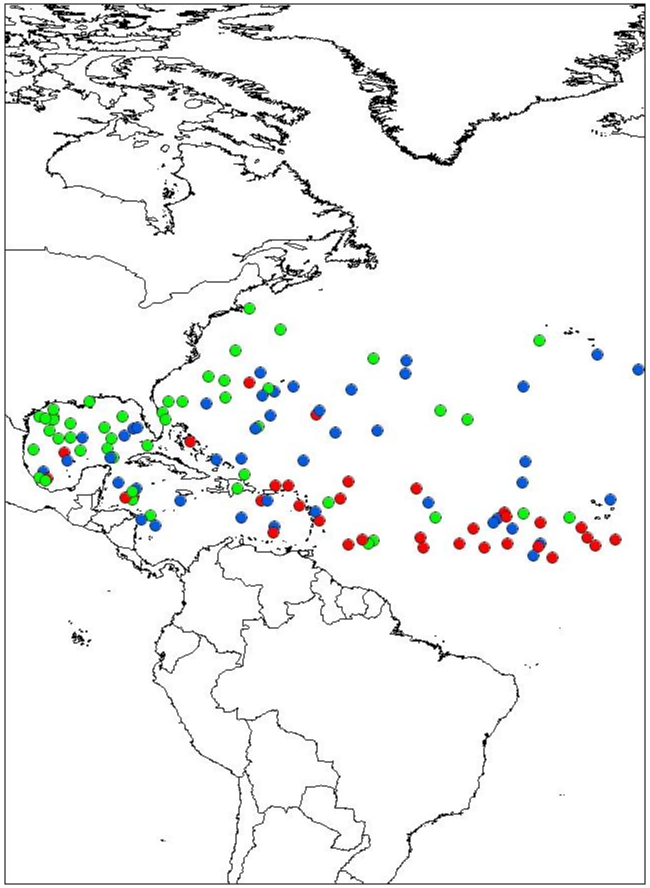
Red shades: Westerly anomalies



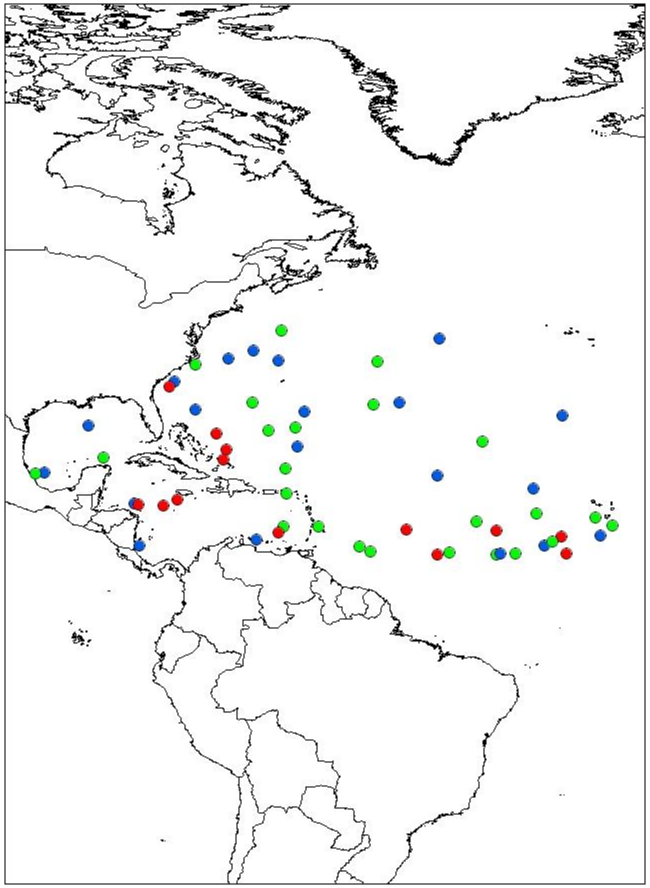
Typical Active Atlantic pattern (if in summer-time)!

All Genesis Points

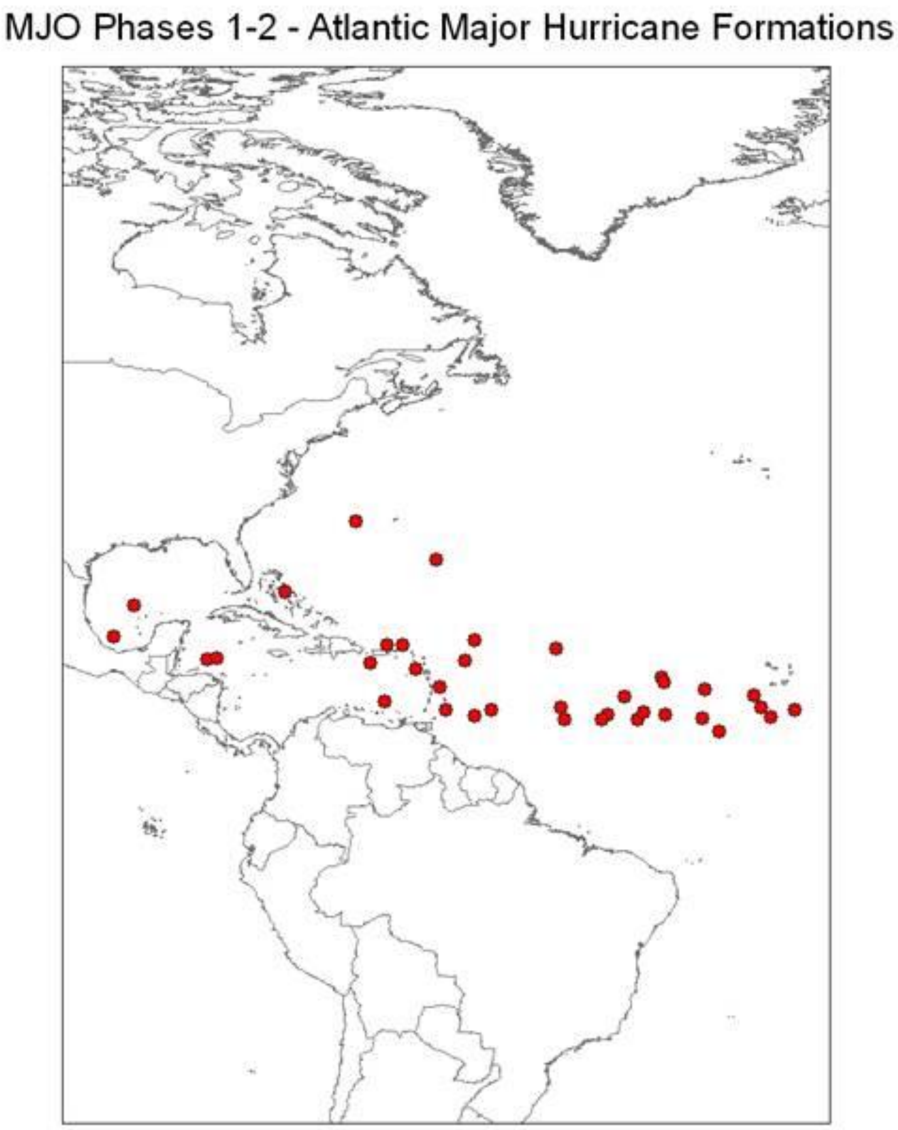
MJO Phases 1+2



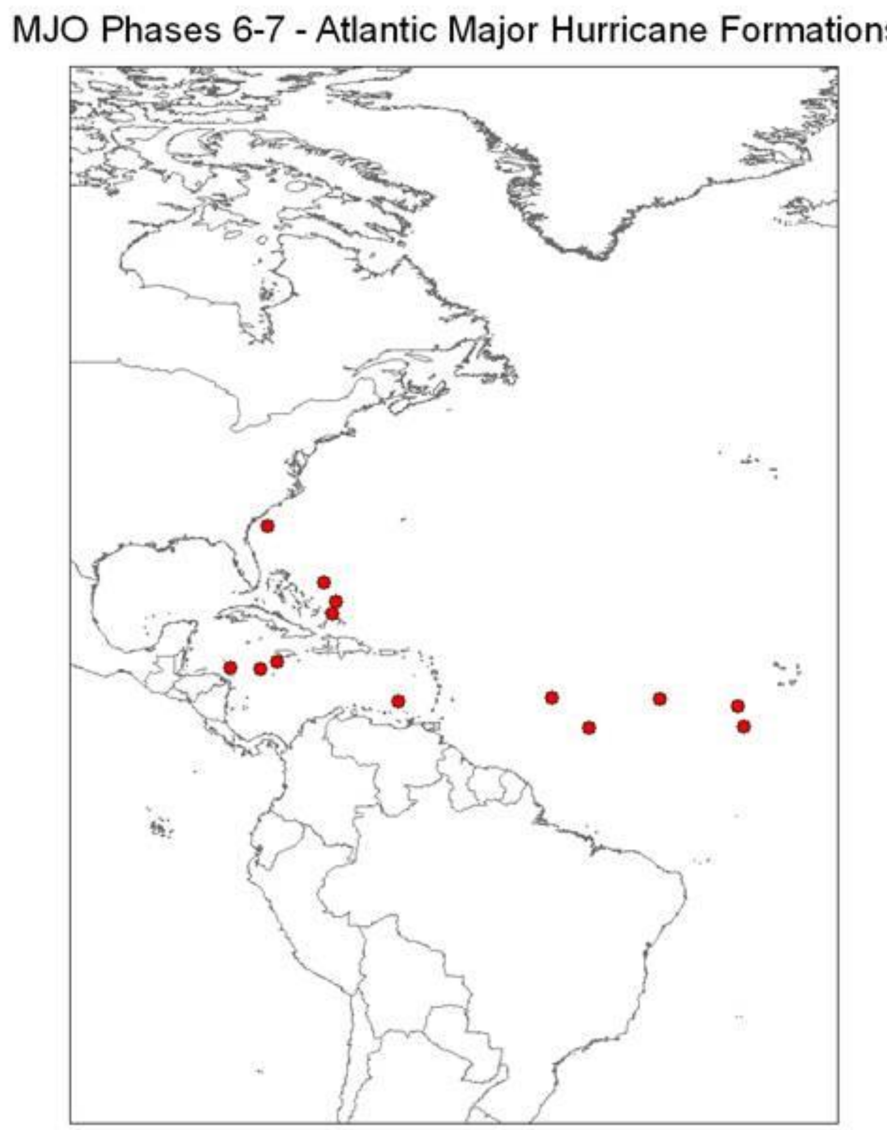
MJO Phases 6+7



36 Major Hurricanes

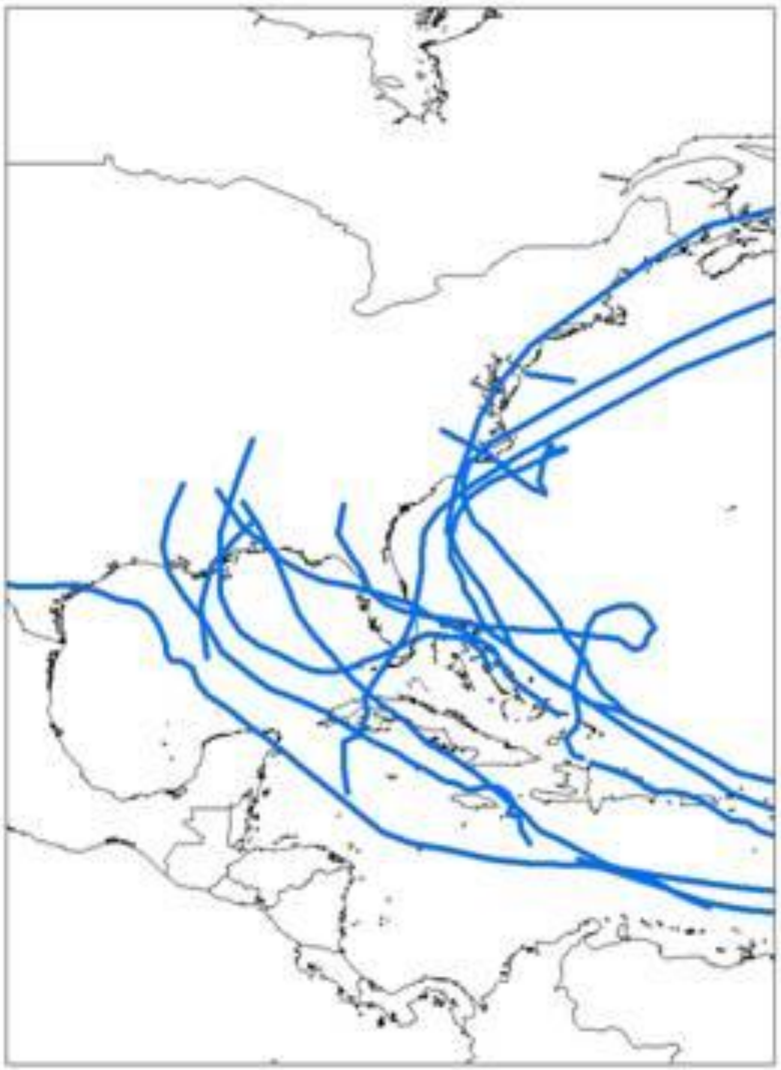


13 Major Hurricanes



10 Hurricane Landfalls

MJO Phase 2

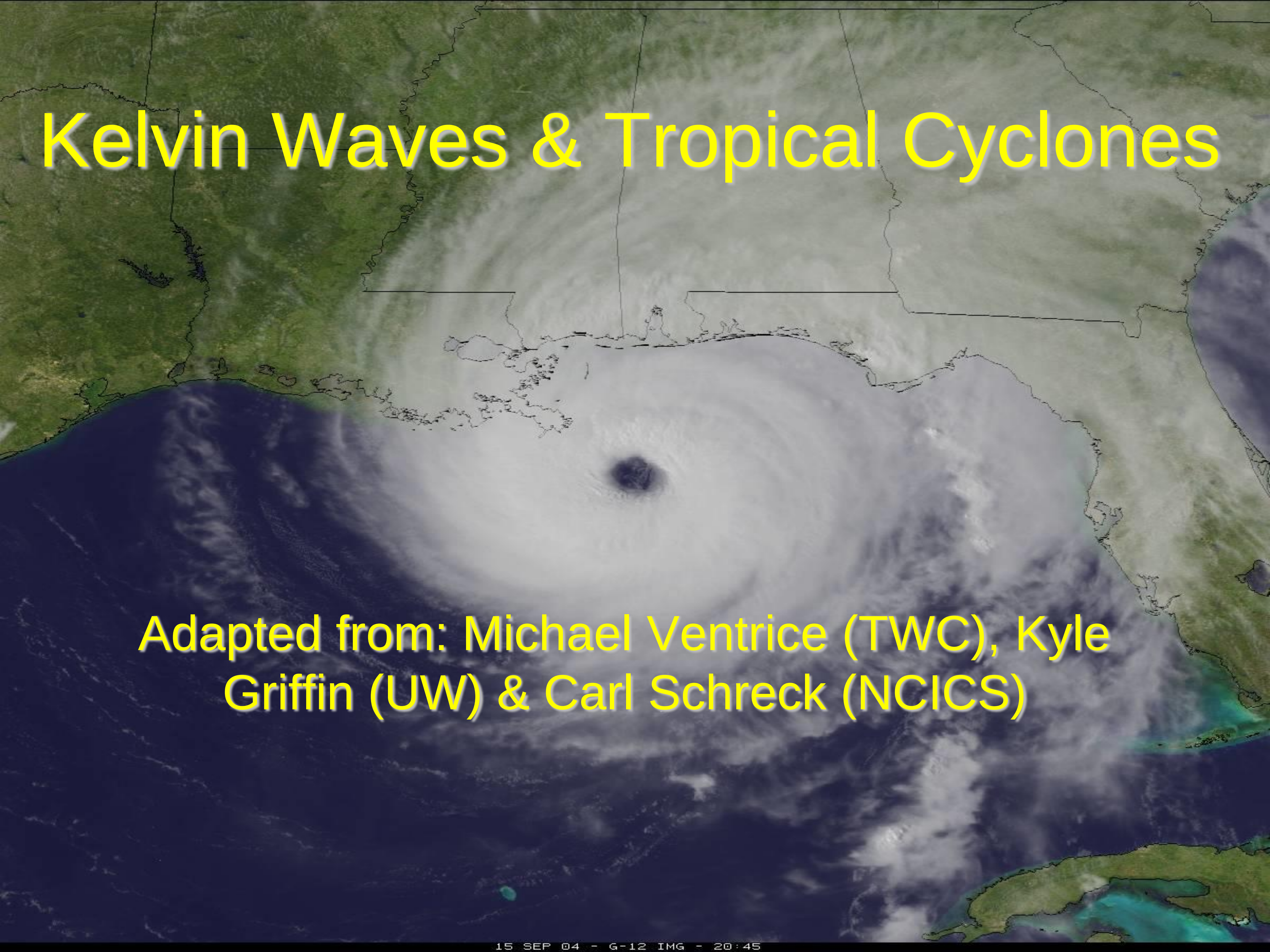


1 Hurricane Landfall

MJO Phase 7

Kelvin Waves & Tropical Cyclones

Adapted from: Michael Ventrice (TWC), Kyle Griffin (UW) & Carl Schreck (NCICS)



Background

The idea of equatorial waves interacting with TCs is relatively new…

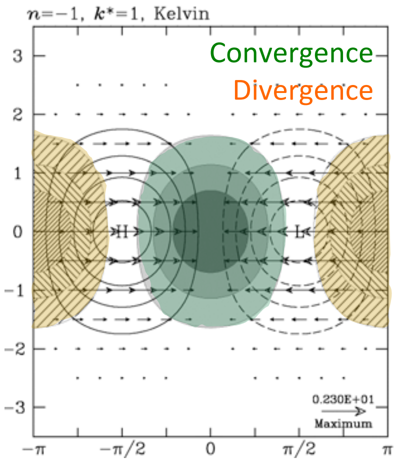
- An objective method of tracking equatorial waves in real-time wasn’t published until 1999

- First AMS papers mentioning (atmospheric) equatorial waves and TCs appeared around 2002

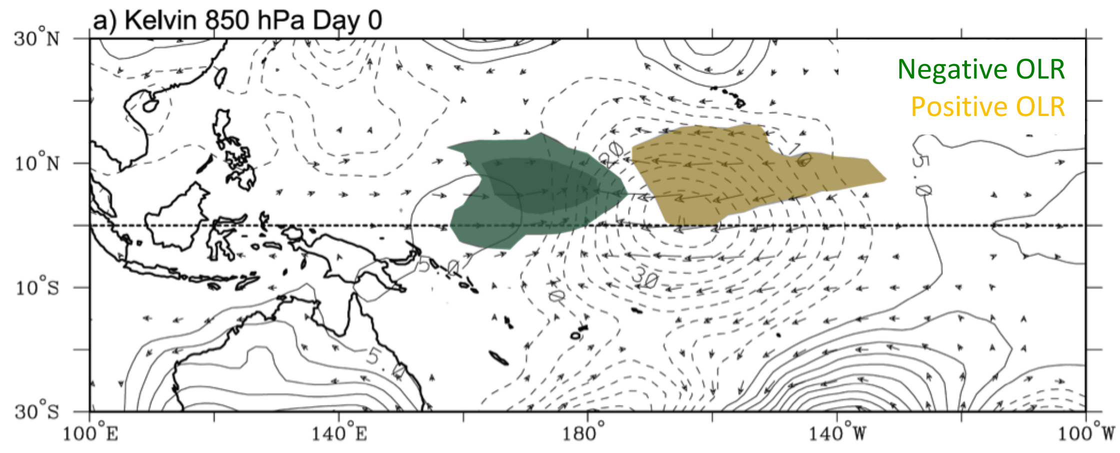
- Number of papers that involve this or similar topics in AMS journals only number in the ~2 dozen range

Equatorial waves aid in *enhanced* predictability of TC genesis several (3-7) days into the future.

Kelvin Waves



Matsuno (1966)



Kiladis et al. (2009)

- Alternating westerlies and easterlies on the equator
- Enhanced convection where low-level winds converge
- Active phase associated with **latent heating** & the generation of **low-level relative vorticity** due to presence of meridional flow
- Modifies ITCZ convection, which causes significant changes to a system's local environment

Propagation:	Eastward
Phase speed:	10–20 m s^{-1}
Period:	3–10 days
Wavelength:	2000–4000 km

Adapted from Carl Schreck 2017

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.

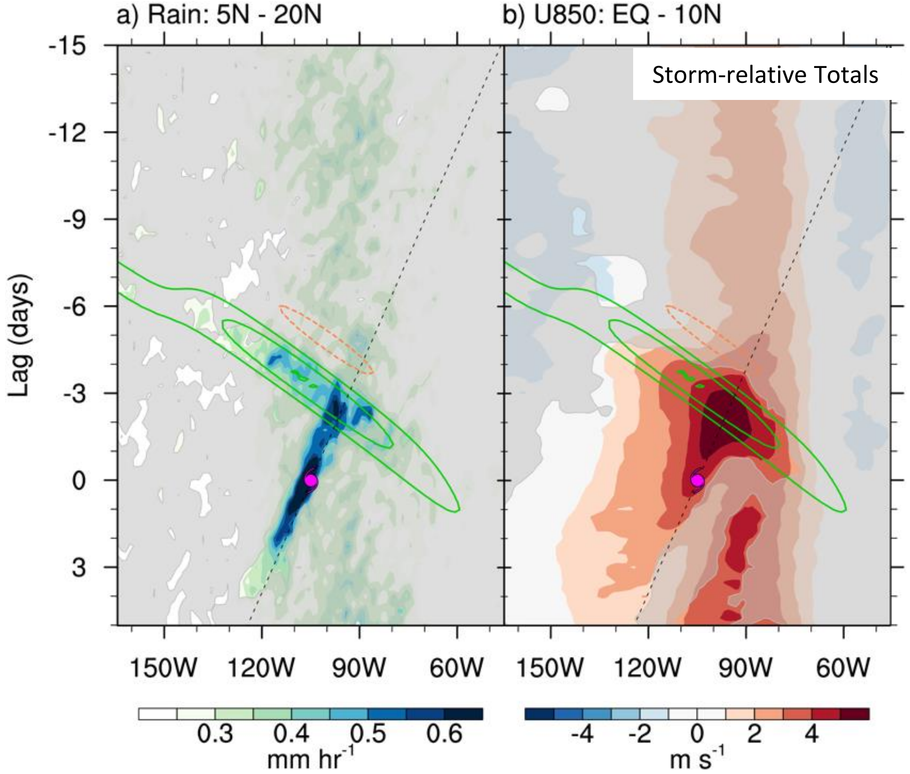
A **Kelvin wave** is spatially very similar to the MJO, but is typically observed at higher zonal wavenumbers and moves eastward at 10 – 20 m s^{-1}.

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

Adapted from Griffin (2014)

Tropical wave + CCKW composite

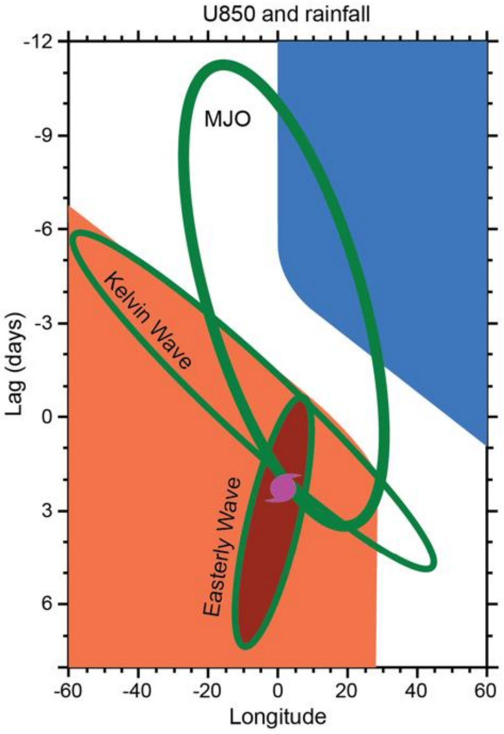
East Pacific: 40 storms



- Composite Hovmöllers of storms forming at the most favorable lags (2-3d) from Kelvin wave crest
- The wave is invigorated with convection/rainfall, leading to genesis.
- CCKW most effective when some westerly flow already present

Kelvin Waves, MJO and Tropical Cyclogenesis

- Storms typically form 0–3 days after the Kelvin wave's convective peak
- Easterly wave amplifies in the Kelvin wave/MJO convective envelope
- Timing of genesis can be strongly influenced by the Kelvin Wave in positive MJO

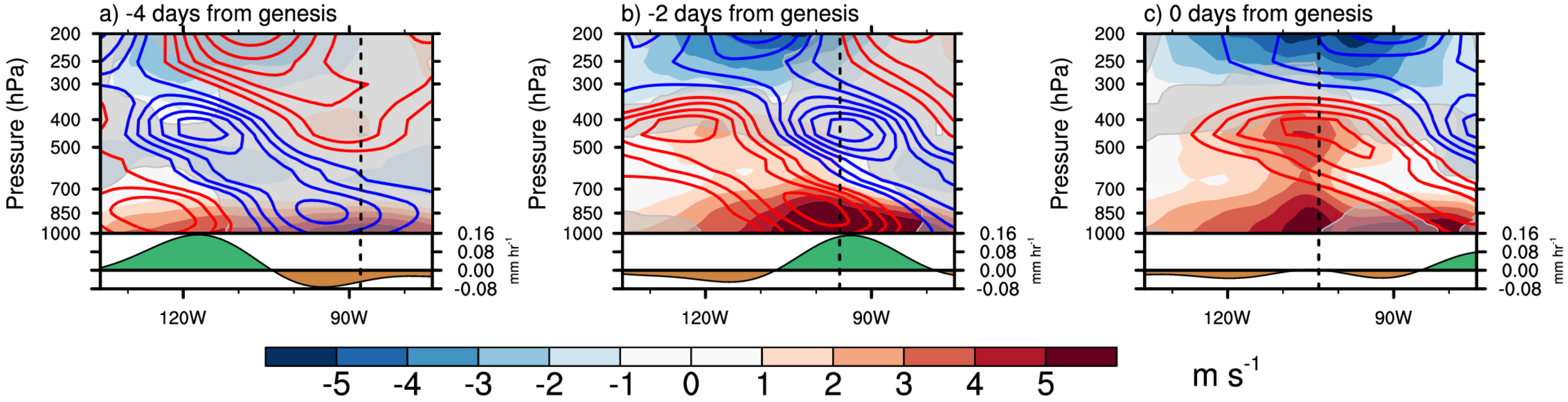


Schreck (2015, MWR)

Background

Vertical Structure

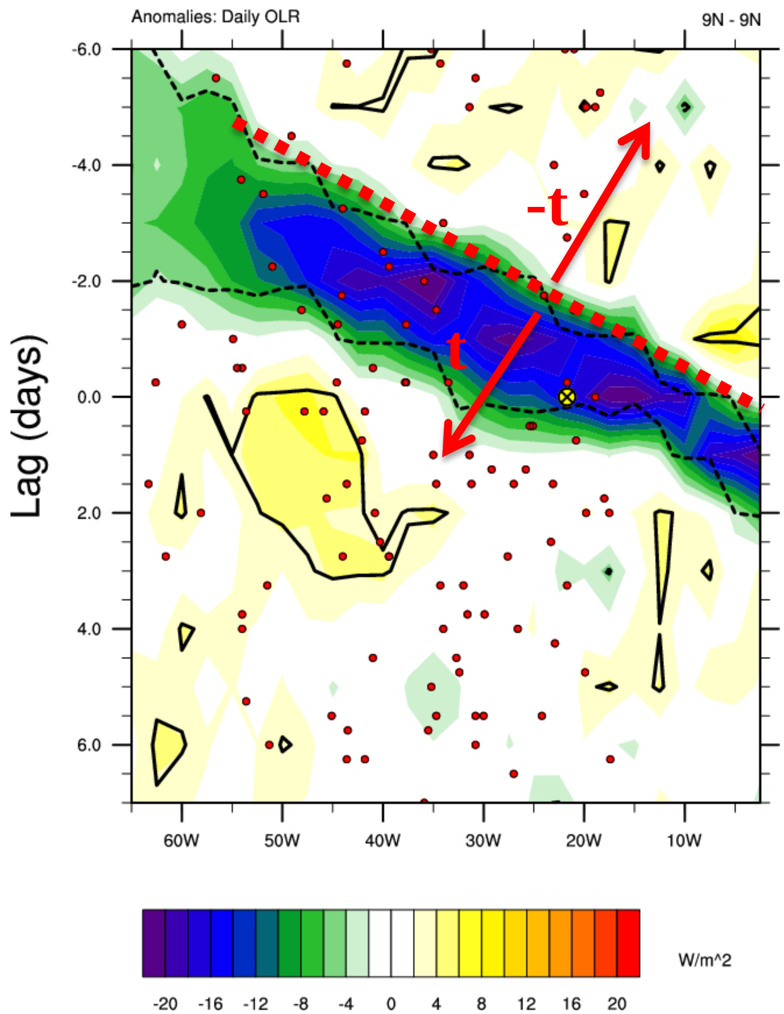
East Pacific Zonal Wind Eq–10°N

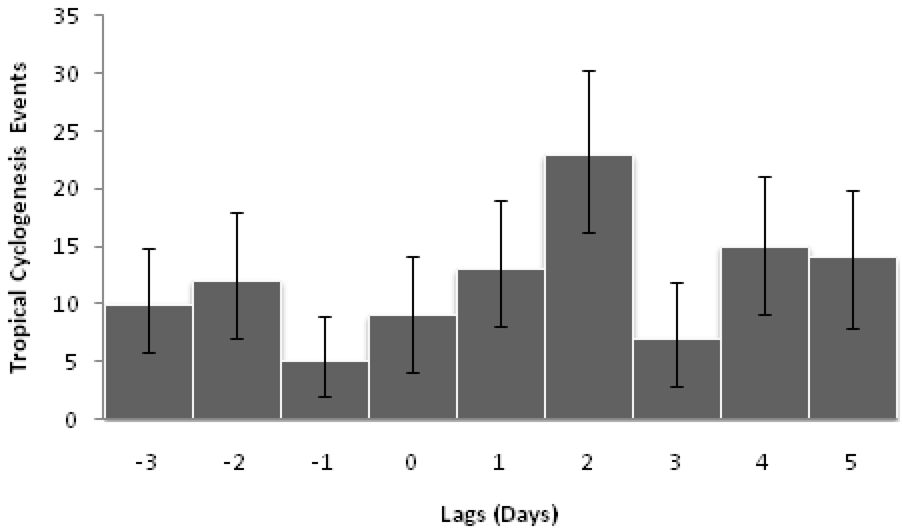


- Convection and storm-relative westerlies intersect easterly wave 2 days before genesis
- Easterly wave circulation builds upward as the Kelvin wave propagates

- Kelvin tilt might explain lag in genesis from convection
  - 400-hPa is 30° longitude behind 850-hPa
  - Kelvin speed of 15 m s^{-1} gives a 2.5-day lag between 850 hPa and 400 hPa

Atlantic CCKWs and genesis

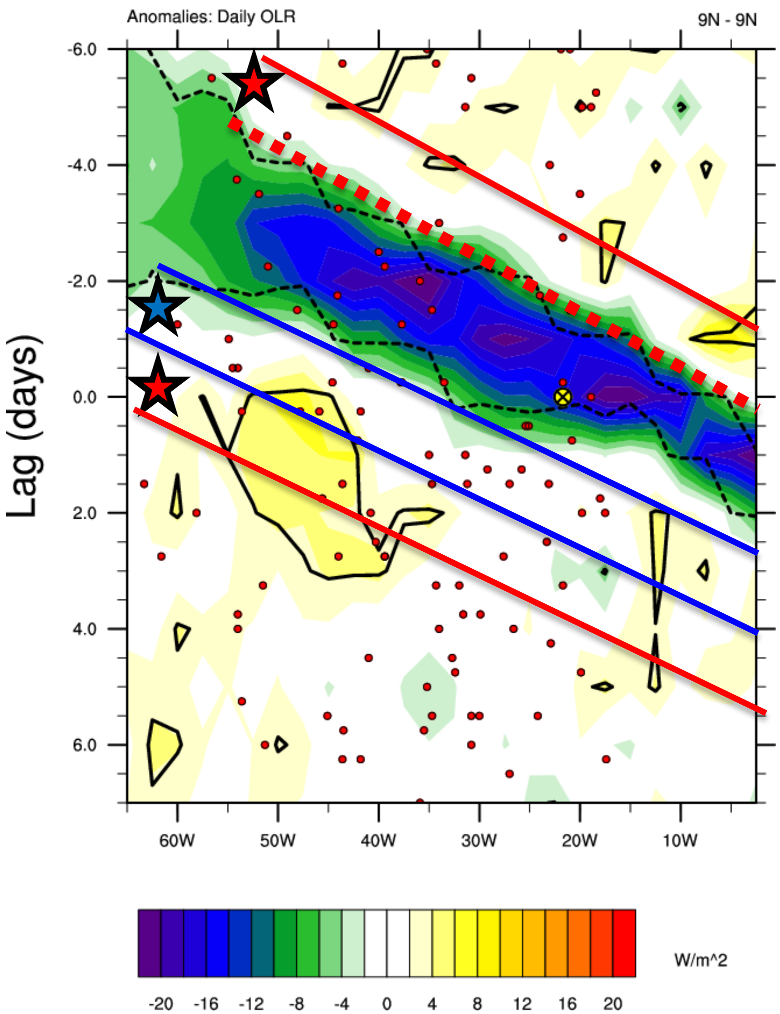


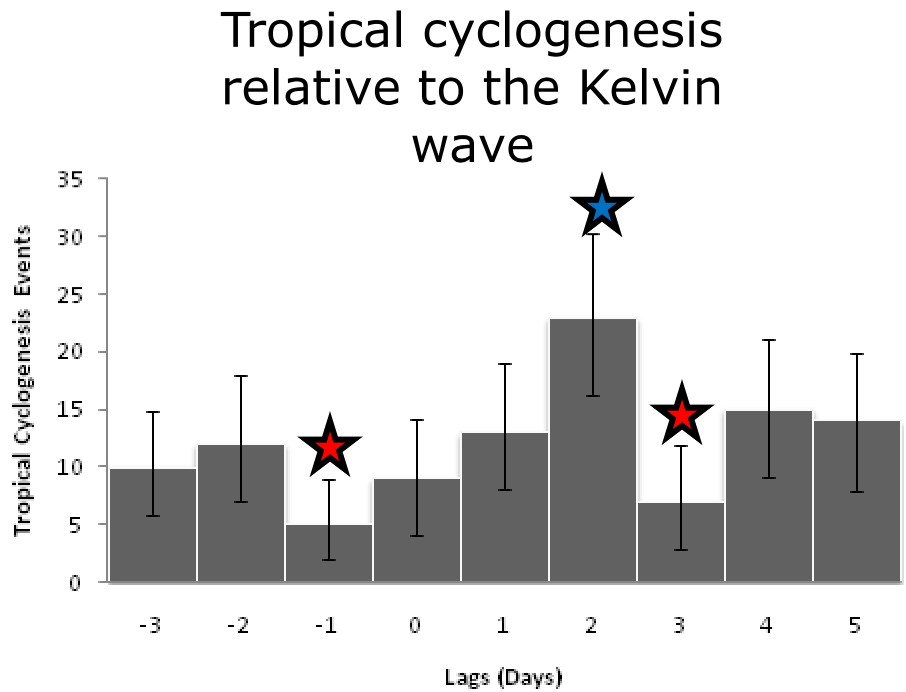


Tropical cyclogenesis events over the MDR (5-25°N, 15-65°W) relative to the CCKW during June-September 1979-2009

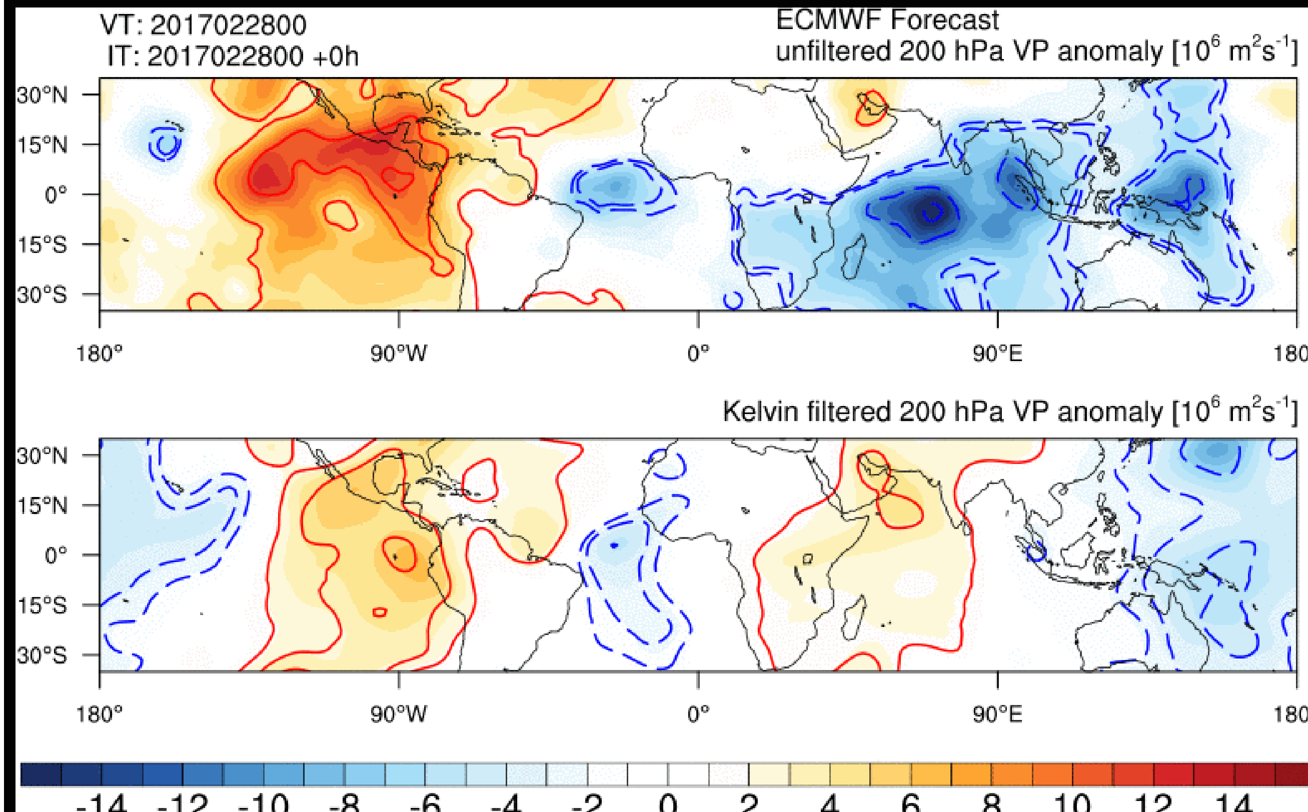
- Day 0 highlights the transition to statistically significant negative unfiltered OLR anomalies, or the eastern-most side of the convectively active phase of the CCKW.
- Error bars indicate the 95% confidence interval.

Atlantic CCKWs and genesis



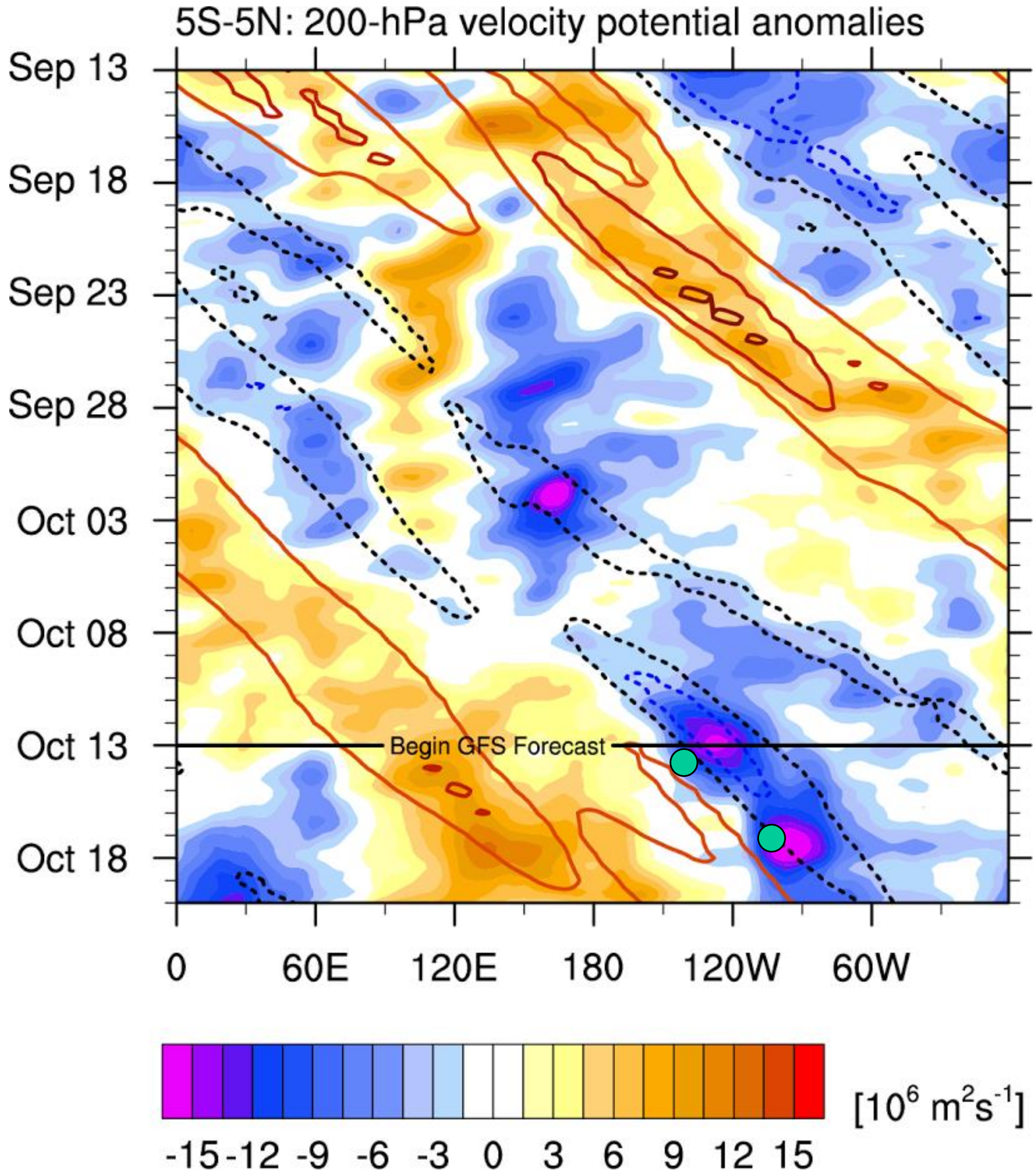


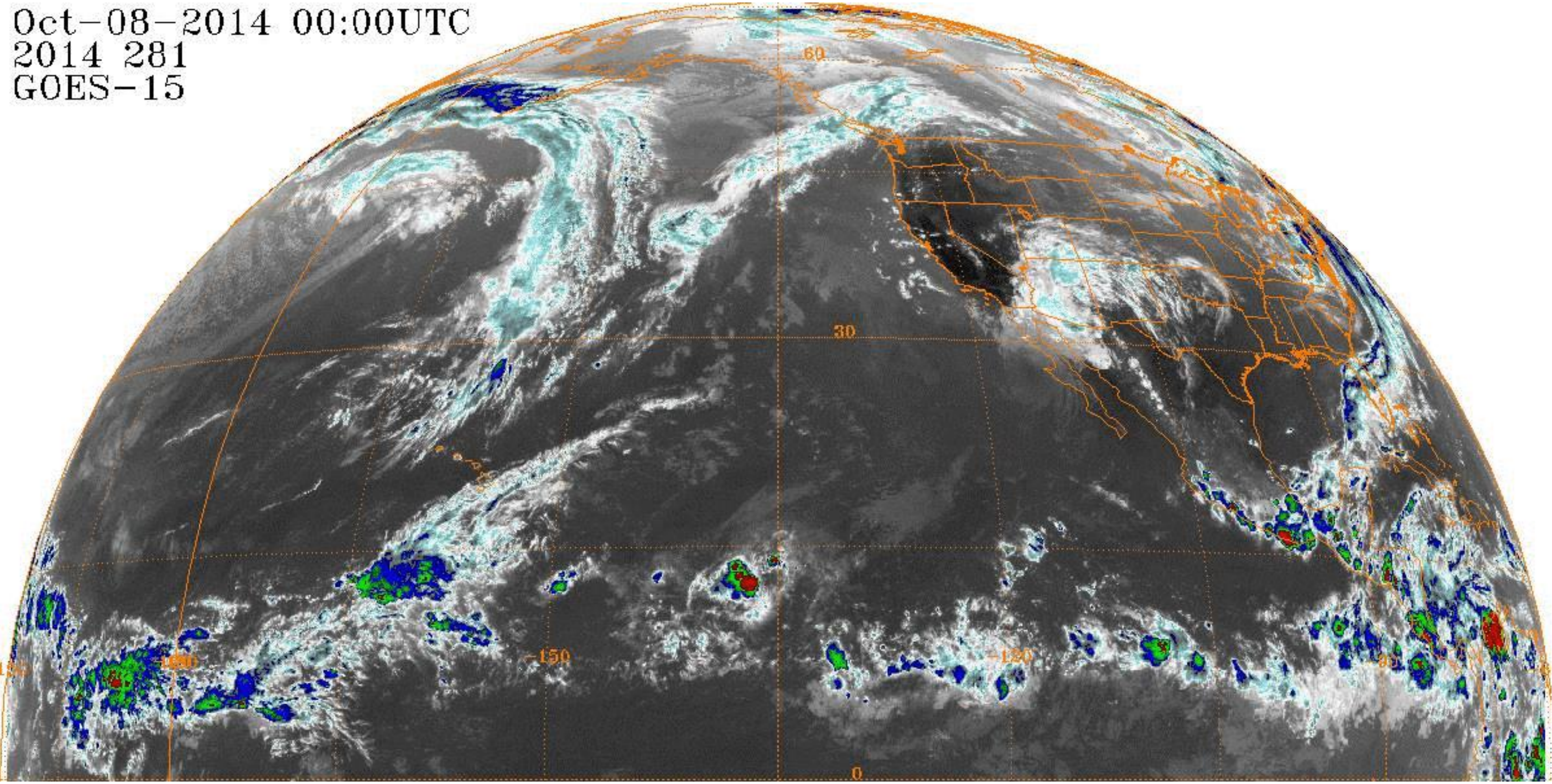
10-[redacted]Ws



"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."

Ana & Trudy form





Ana Trudy

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)

Current NHC practices

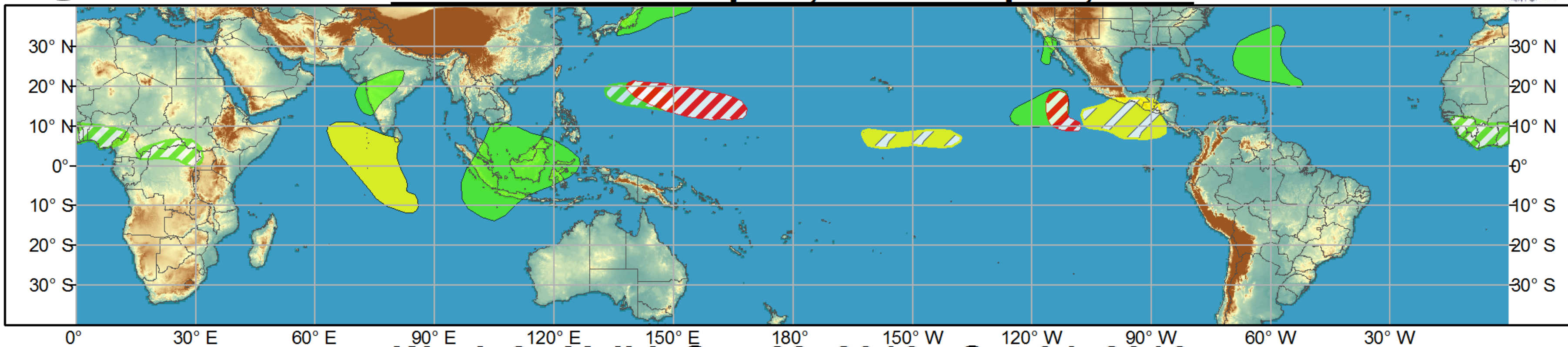
- No operational standard on use of CCKW in genesis forecasts (about half of forecasters use it).
- It is believed that global models handle the MJO much more accurately than individual CCKWs (too much dampening), and thus the forecaster can add value to the deterministic models.
- Any adjustments to 5-day genesis probabilities are small and subjectively determined.
- Also used as a way to increase forecaster confidence in a given situation if conceptual model of CCKWs and genesis matches model solutions.

Operational long-range TC forecasts

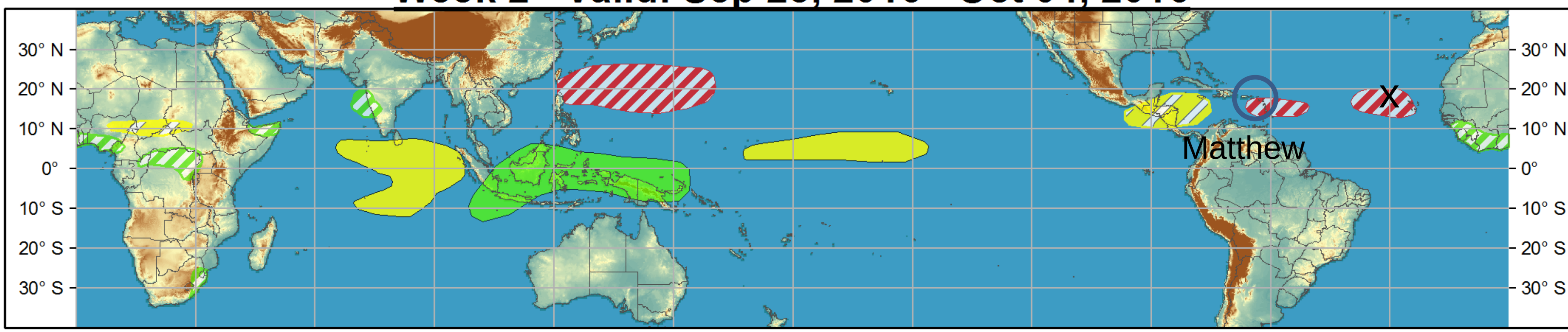
- CPC, in combination with other NOAA/federal/university partners, issues a week 1 and week 2 possible TC risk areas (in addition to other global hazards)
- These global forecasts are released Tuesday afternoons
- The TC-only forecasts are updated on Friday afternoons, if necessary, for the Atlantic/E Pacific only during week 1/2

Global Tropics Hazards and Benefits Outlook - Climate Prediction Center

Week 1 - Valid: Sep 21, 2016 - Sep 27, 2016



Week 2 - Valid: Sep 28, 2016 - Oct 04, 2016



Produced: 09/20/2016

Forecaster: Rosencrans

	Confidence High	Confidence Moderate	
Tropical Cyclone Formation			Development of a tropical cyclone (tropical depression - TD, or greater strength).
Above-average rainfall			Weekly total rainfall in the upper third of the historical range.
Below-average rainfall			Weekly total rainfall in the lower third of the historical range.
Above-normal temperatures			7-day mean temperatures in the upper third of the historical range.
Below-normal temperatures			7-day mean temperatures in the lower third of the historical range.

Product is updated once per week, except from 6/1 - 11/30 for the region from 120E to 0, 0 to 40N. The product targets broad scale conditions integrated over a 7-day period for US interests only. Consult your local responsible forecast agency.

中央氣象局 Central Weather Bureau
UNIVERSITY AT ALBANY State University of New York
EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER ESSIC UNIVERSITY OF MARYLAND
Australian Government Bureau of Meteorology
cics.nc
NPS PRAESTANTIA PER SCIENTIAM

Seasonal Forecasting

Seasonal Forecasting is more than this!

Short history of NOAA seasonal hurricane forecasting

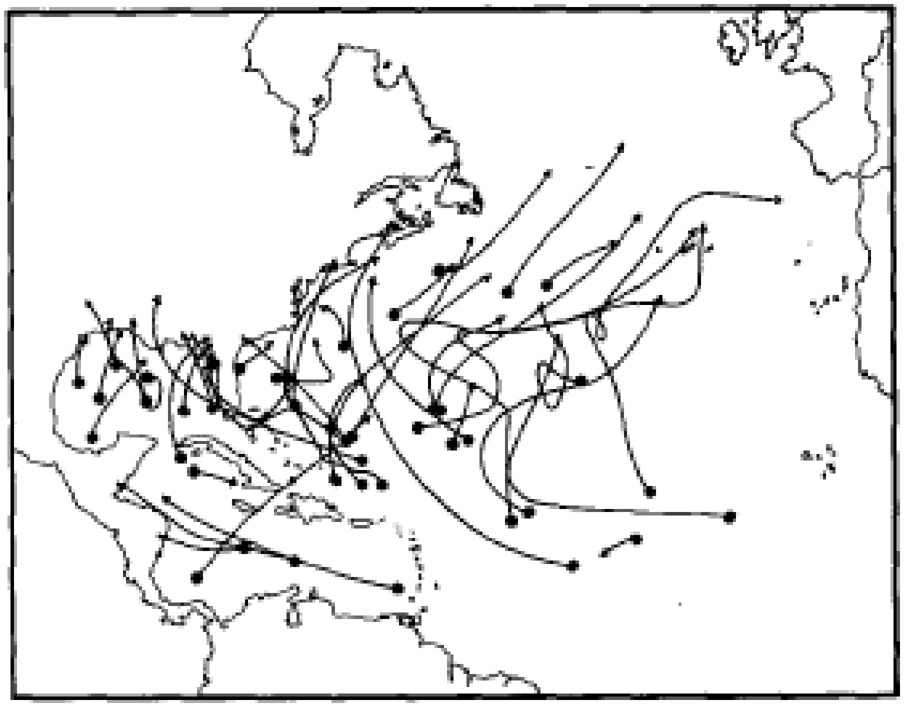
- The Climate Prediction Center (CPC) began issuing Atlantic seasonal hurricane forecasts after the Gray 1997 forecast bust.
- Outlooks issued in late May and early August.
- Collaborative effort between the CPC, National Hurricane Center and Hurricane Research Division.
- Outlooks are a qualitative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

El Niño

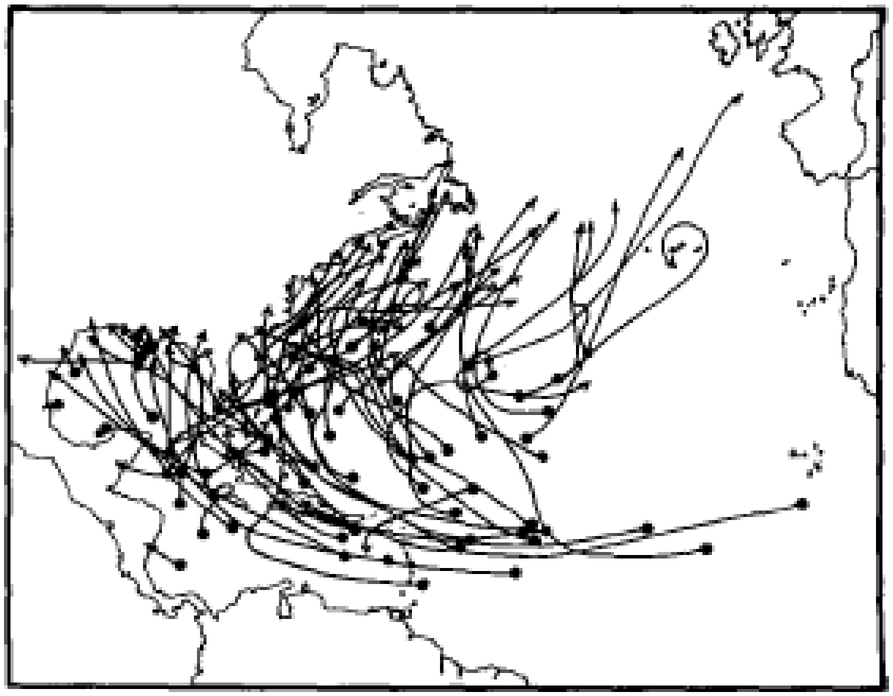
- Warming of the equatorial waters in the central and eastern Pacific every 3-5 years
- Changes global atmospheric circulation by altering low-latitude deep convection.
- Moderate/strong events generally cause a reduced Atlantic season
- Weaker events have little relationship to Atlantic hurricane activity

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

El Niño Years

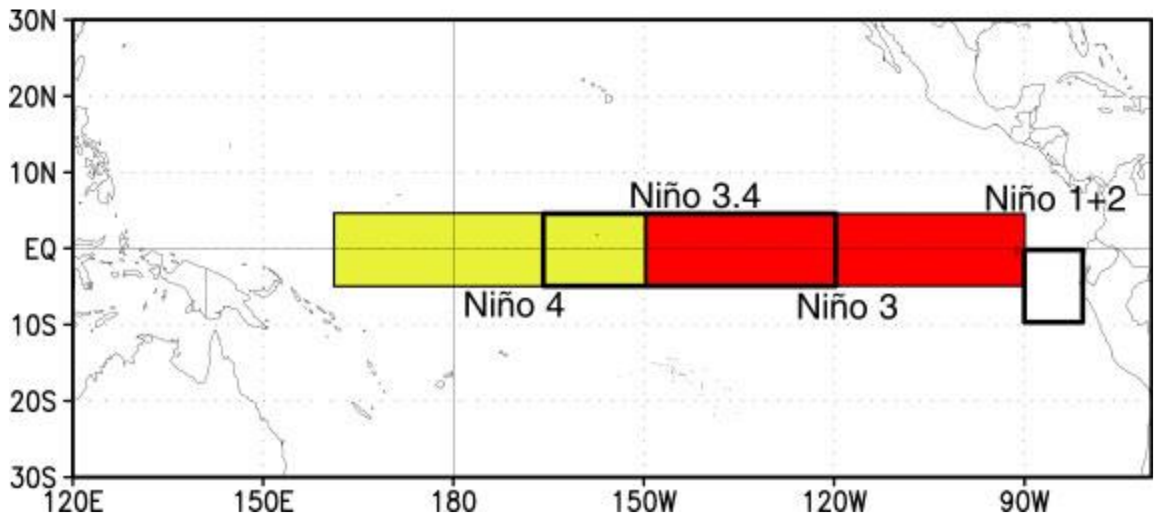


Year after El Niño

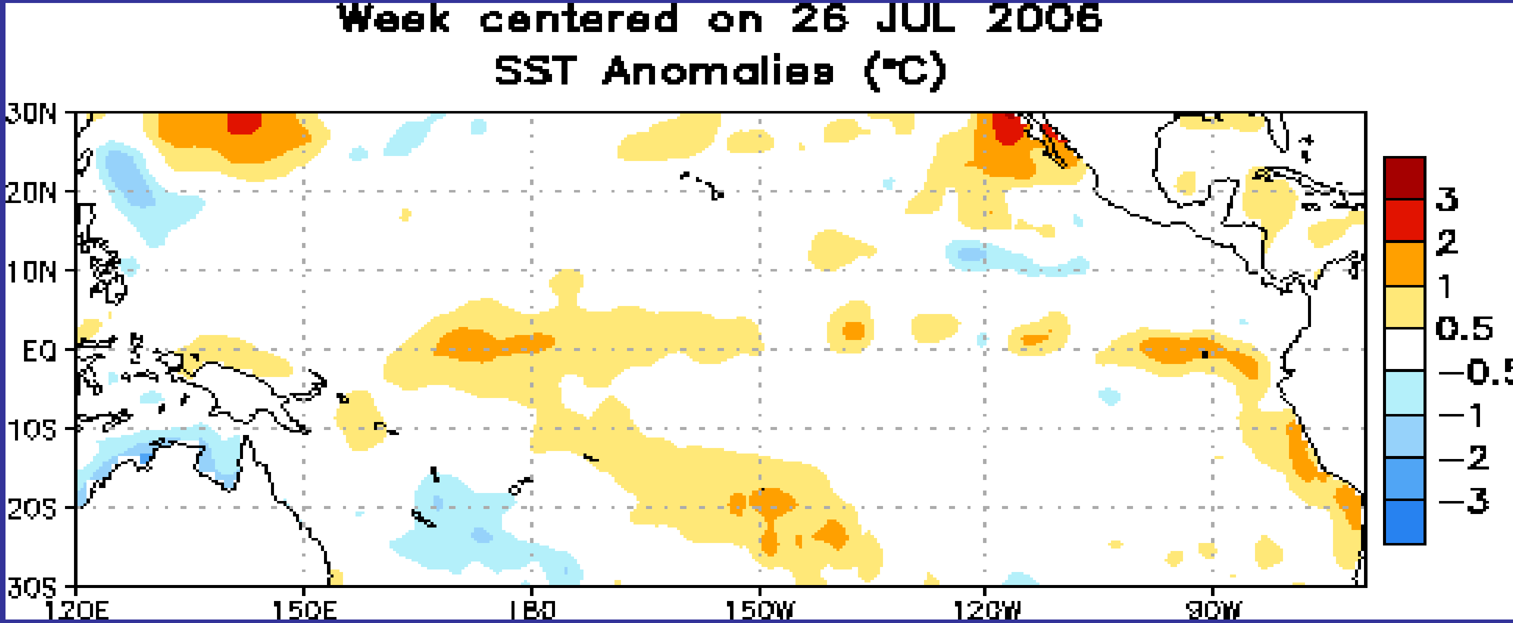


From Gray 1984

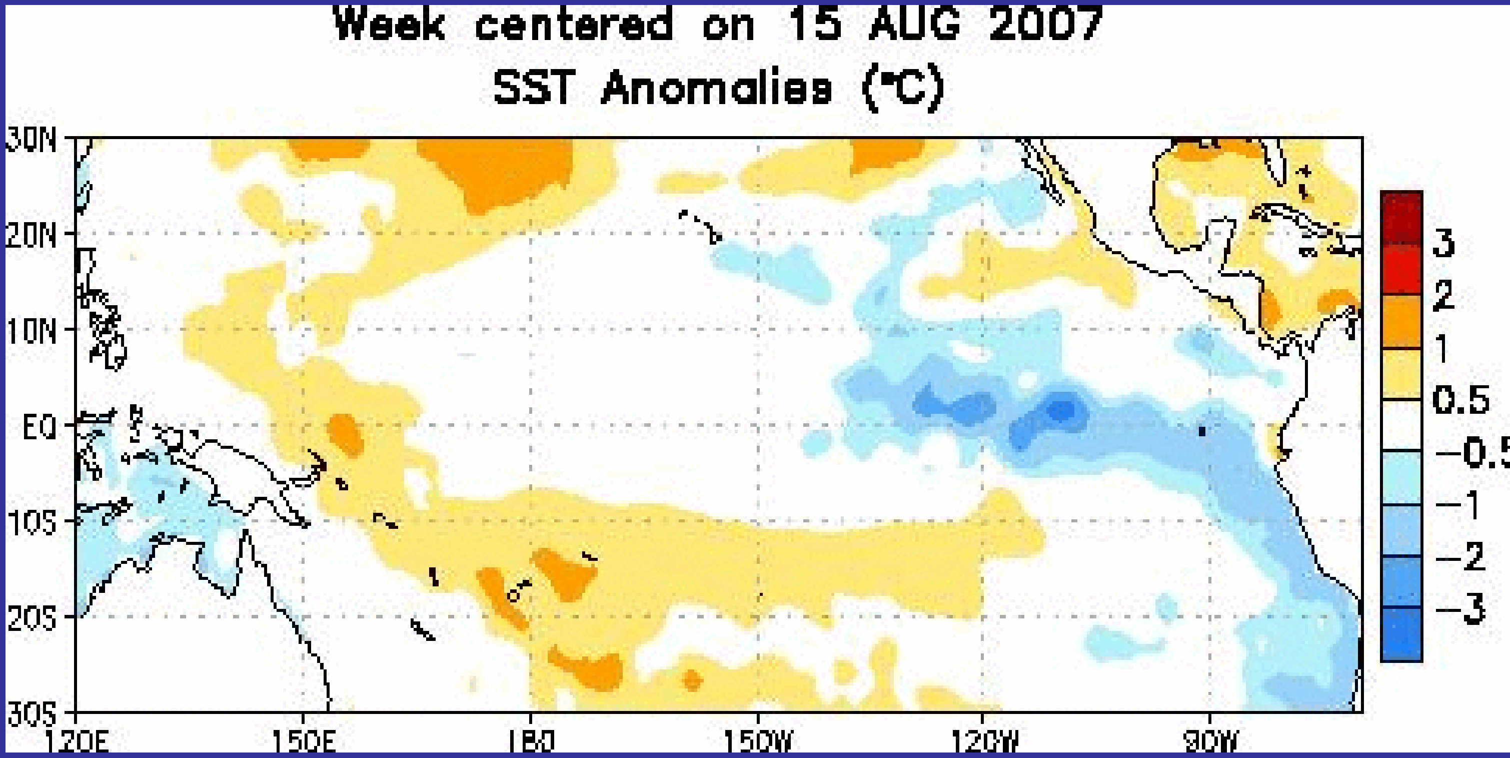
Niño regions



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

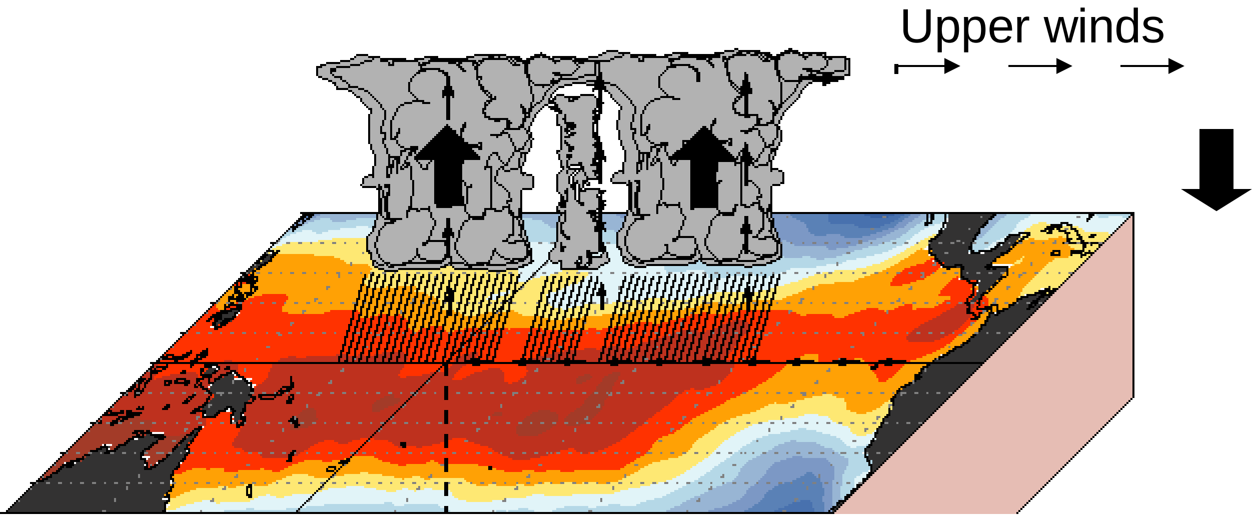


El Niño

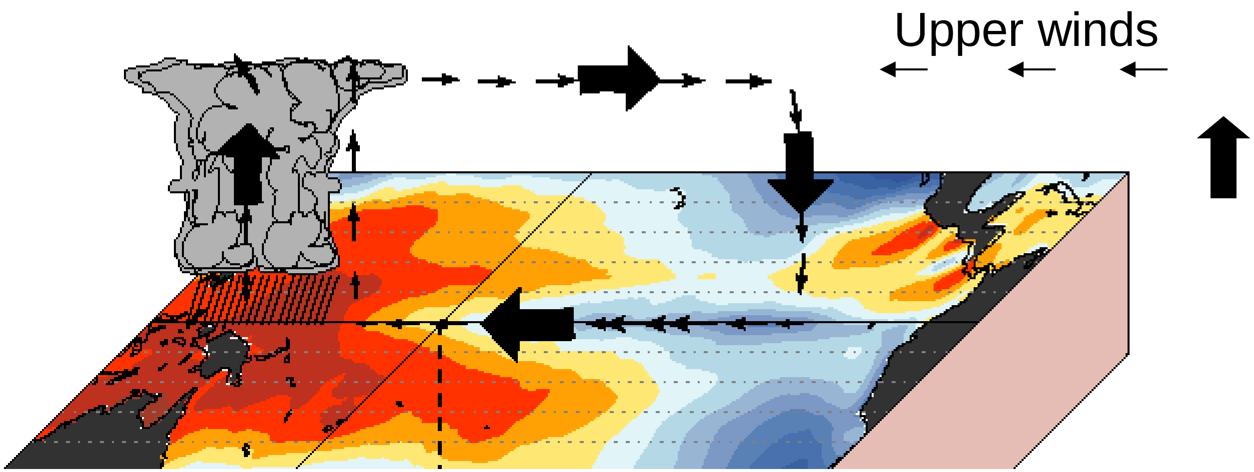


La Niña

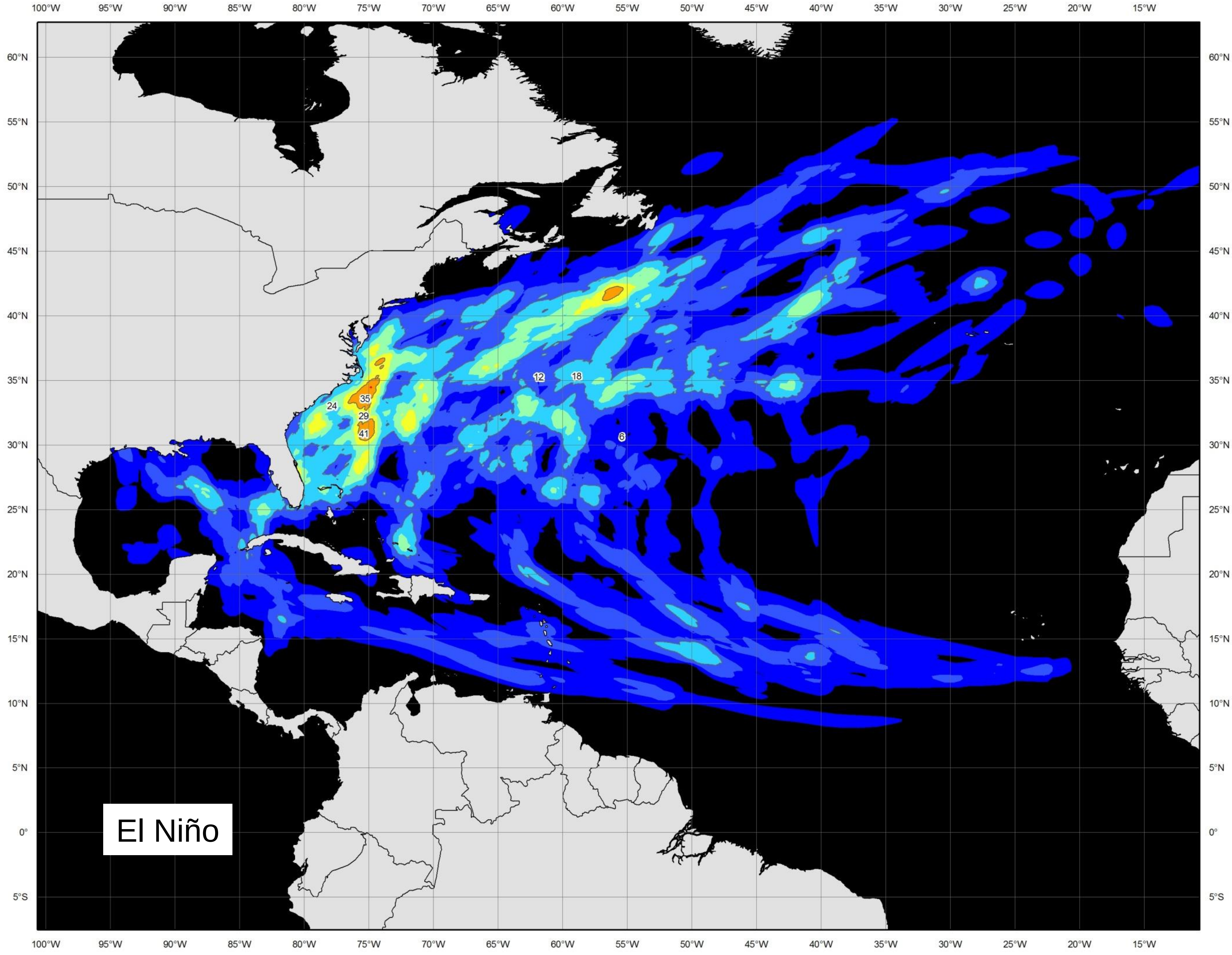
El Niño versus La Niña

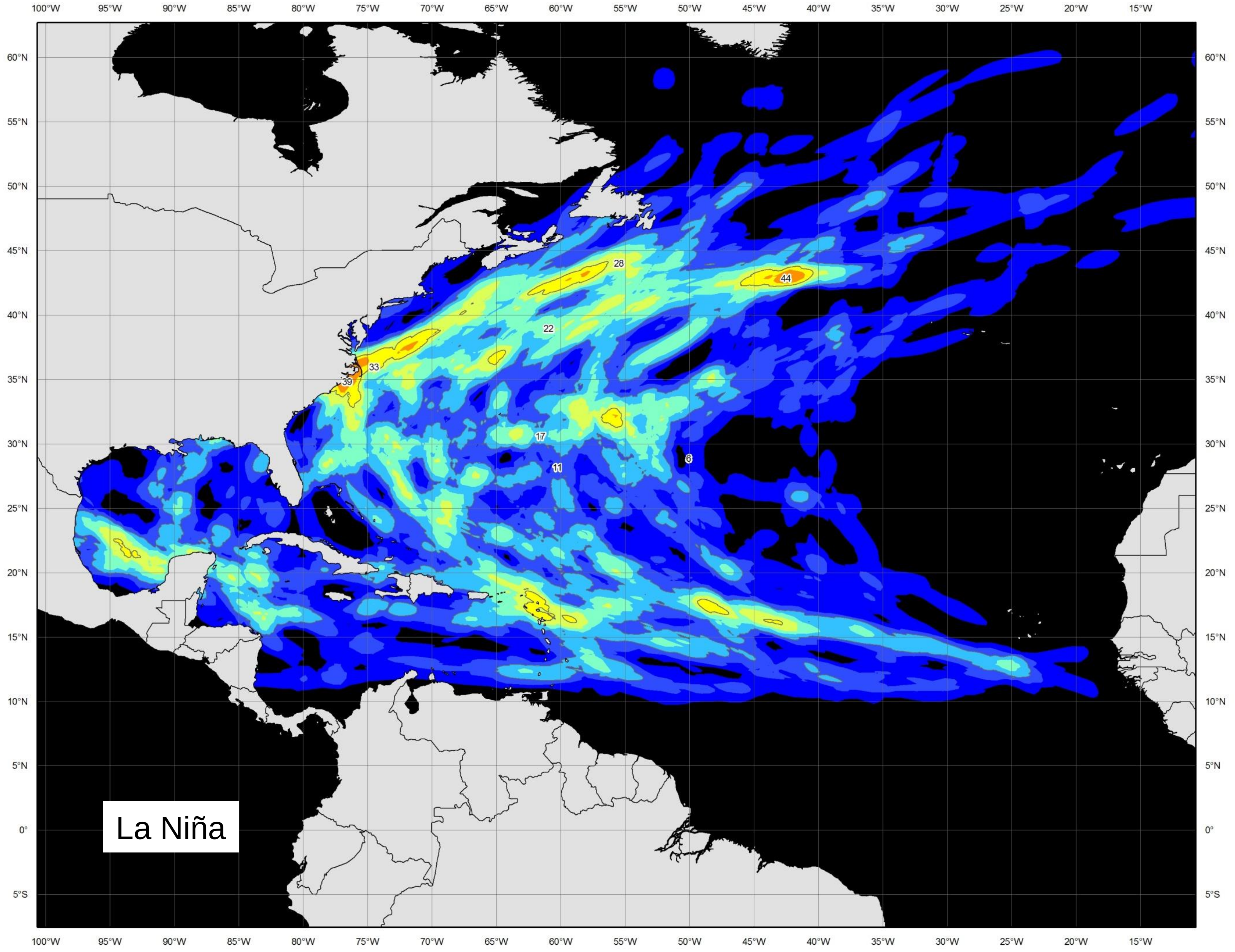


Convection shifted eastward during El Niño causes more shear and sinking air over the Atlantic.



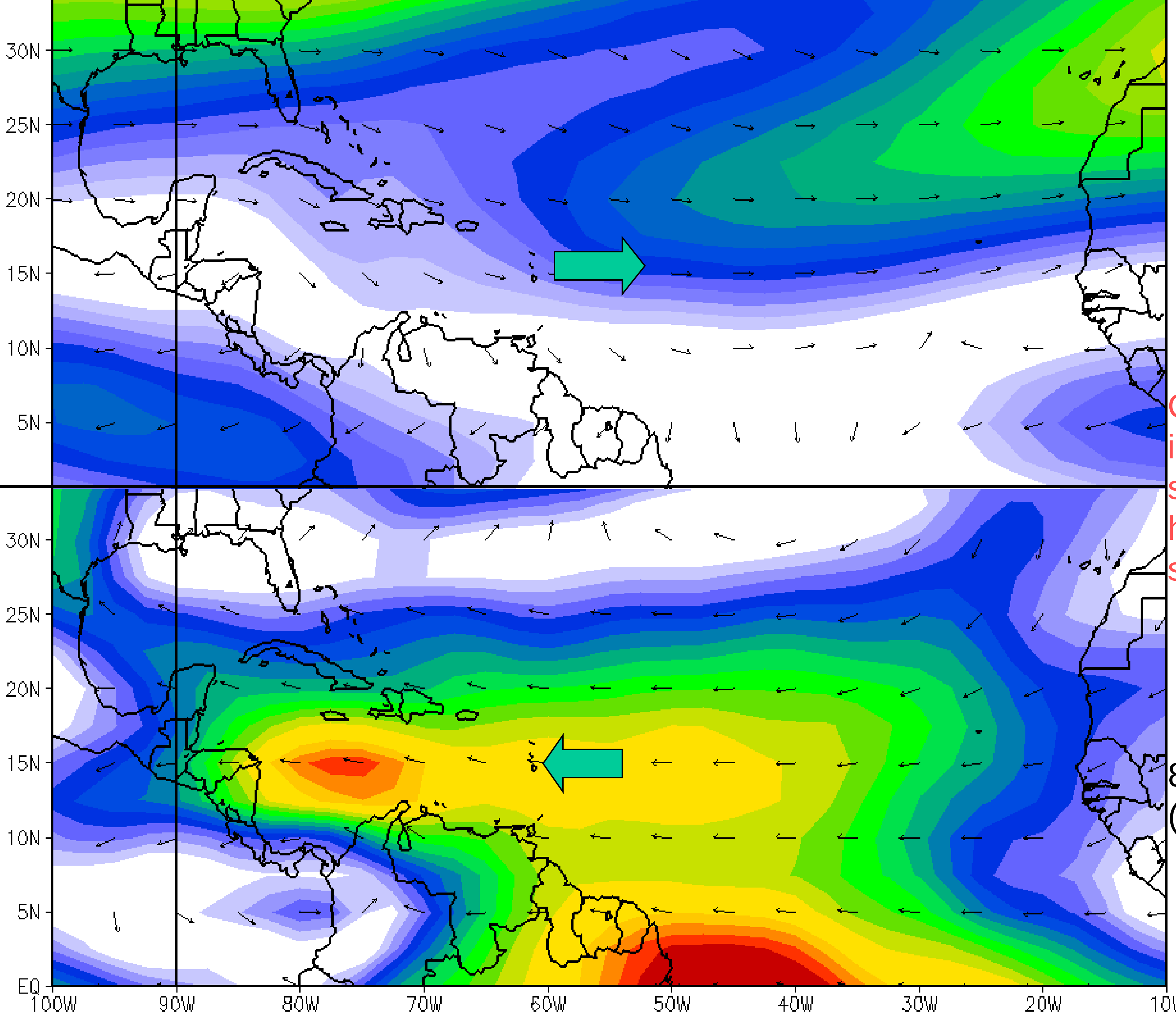
Convection shifted westward during La Niña causes less sinking air and shear over the Atlantic.


El Niño
12
18
24
35
29
41
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


La Niña
28
44
22
33
39
17
11
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

Vertical Wind Shear

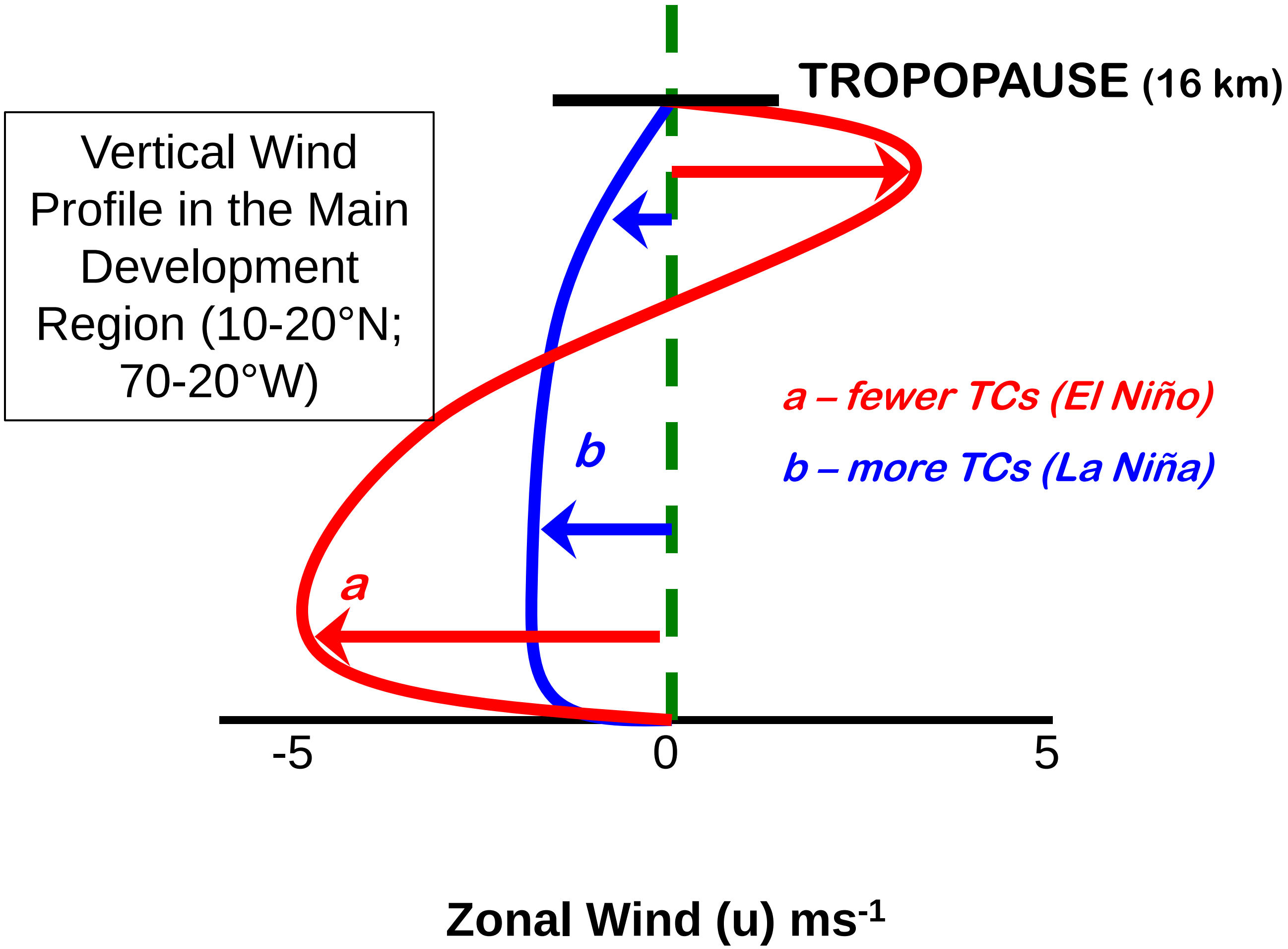
- Tropical cyclones generally require low vertical wind shear to develop, less than about 20 mph.
- Early-season vertical shear (June-July) relates well to August-October shear (peak season).
- Since 90% of the season is usually after 1 August, useful to update then.



200 mb
(~40,000 ft)

Climatology is for lots of shear during hurricane season

850 mb
(~5,000 ft)

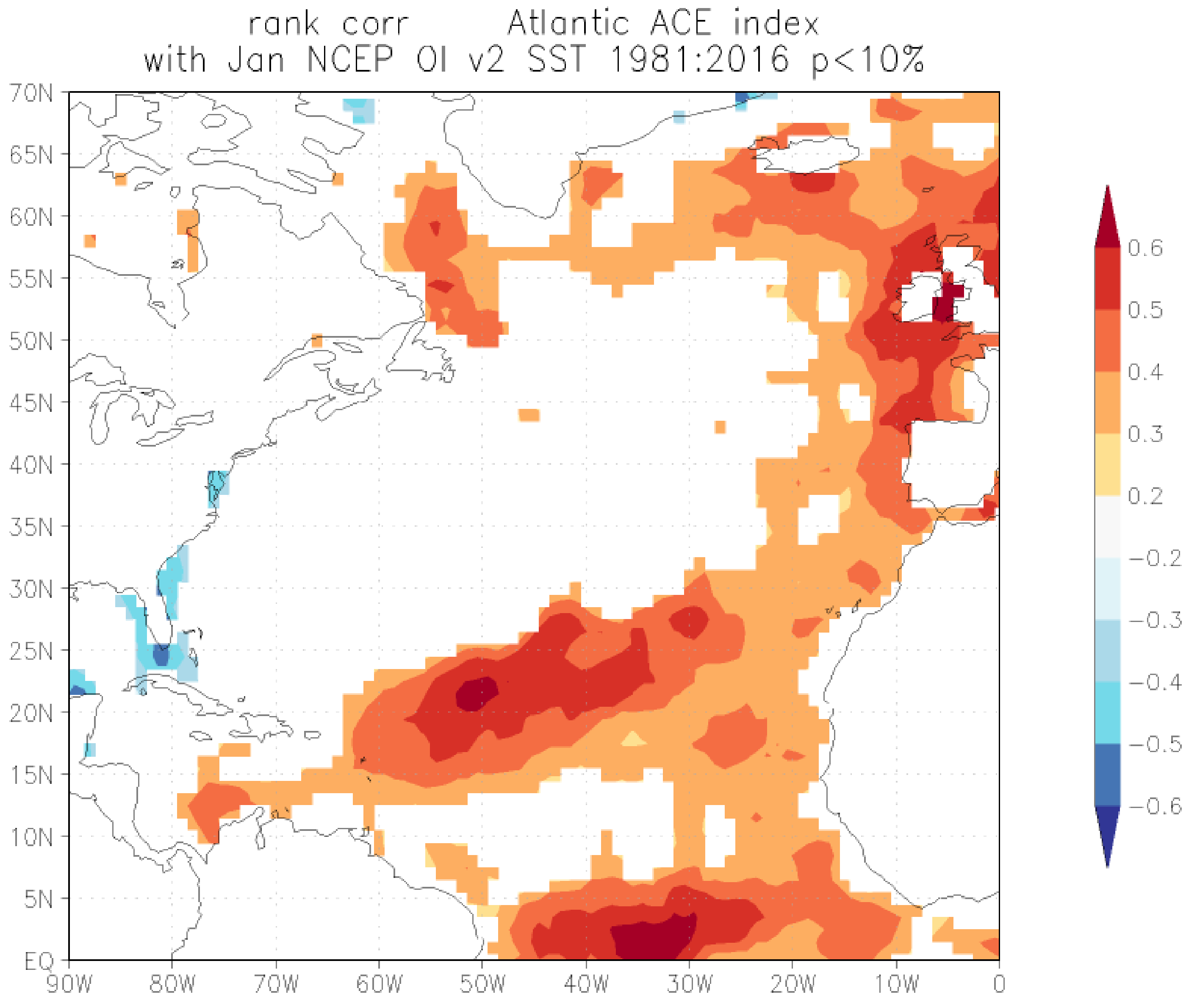


TROPOPAUSE (16 km)
Vertical Wind Profile in the Main Development Region (10-20°N; 70-20°W)
a – fewer TCs (El Niño)
b – more TCs (La Niña)
b
a
-5
0
5
Zonal Wind (u) ms^{-1}

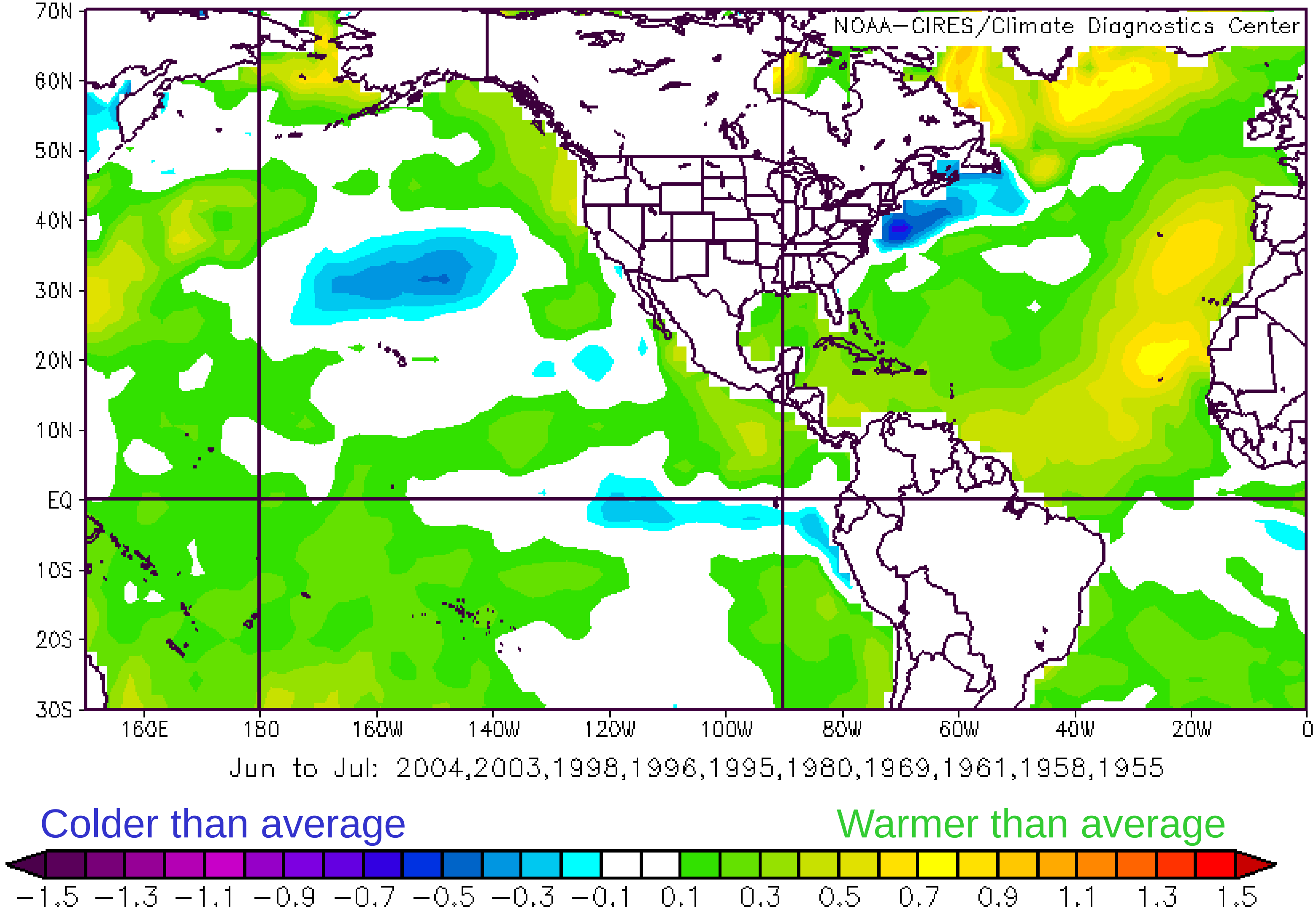
Sea-Surface Temperatures (SSTs)

- Warmer Atlantic 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.
- Atlantic SSTs also atmospheric proxy.
- Cooler waters are linked to higher surface pressures, stronger surface winds (higher shear as a result) and upwelling.

Correlation between Atlantic SST and Atlantic Hurricane Activity



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

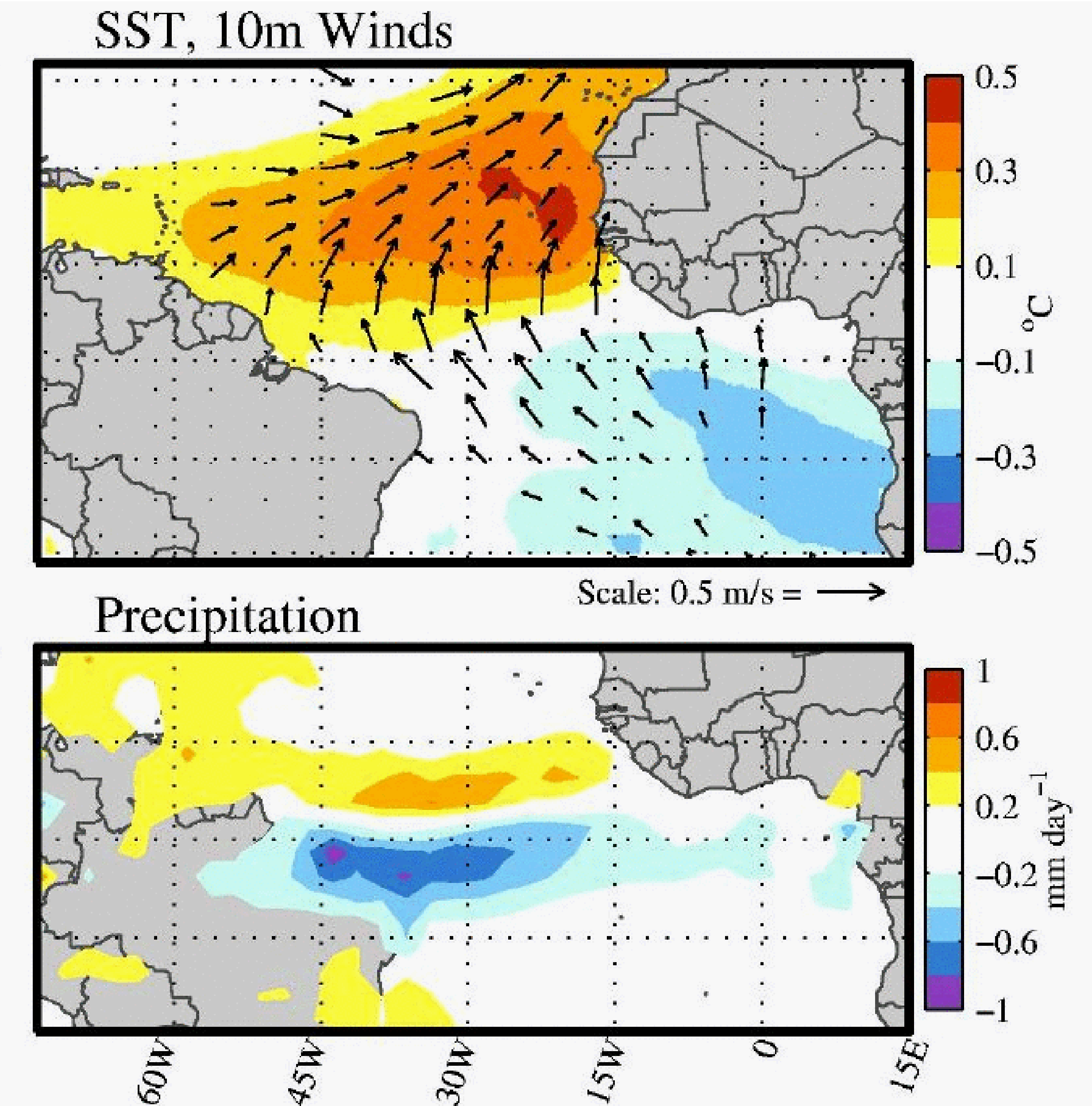


The Atlantic Meridional Mode: SST, wind, and precip anoms

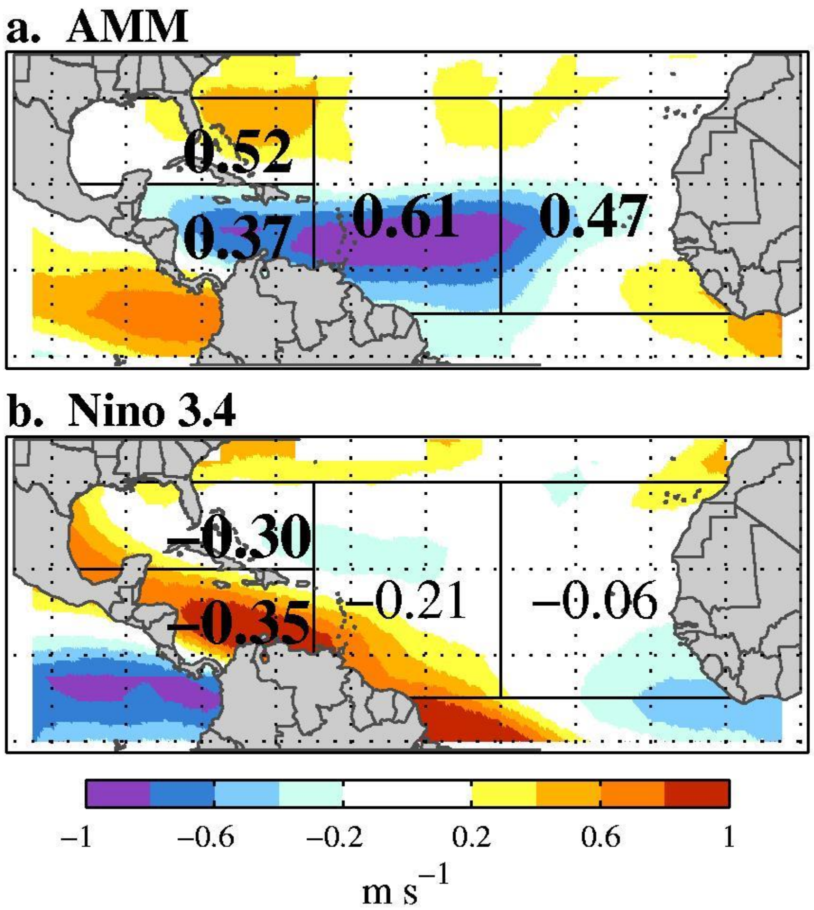
•Leading mode of basin-wide ocean-atmosphere interaction between SST and low-level winds

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

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



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

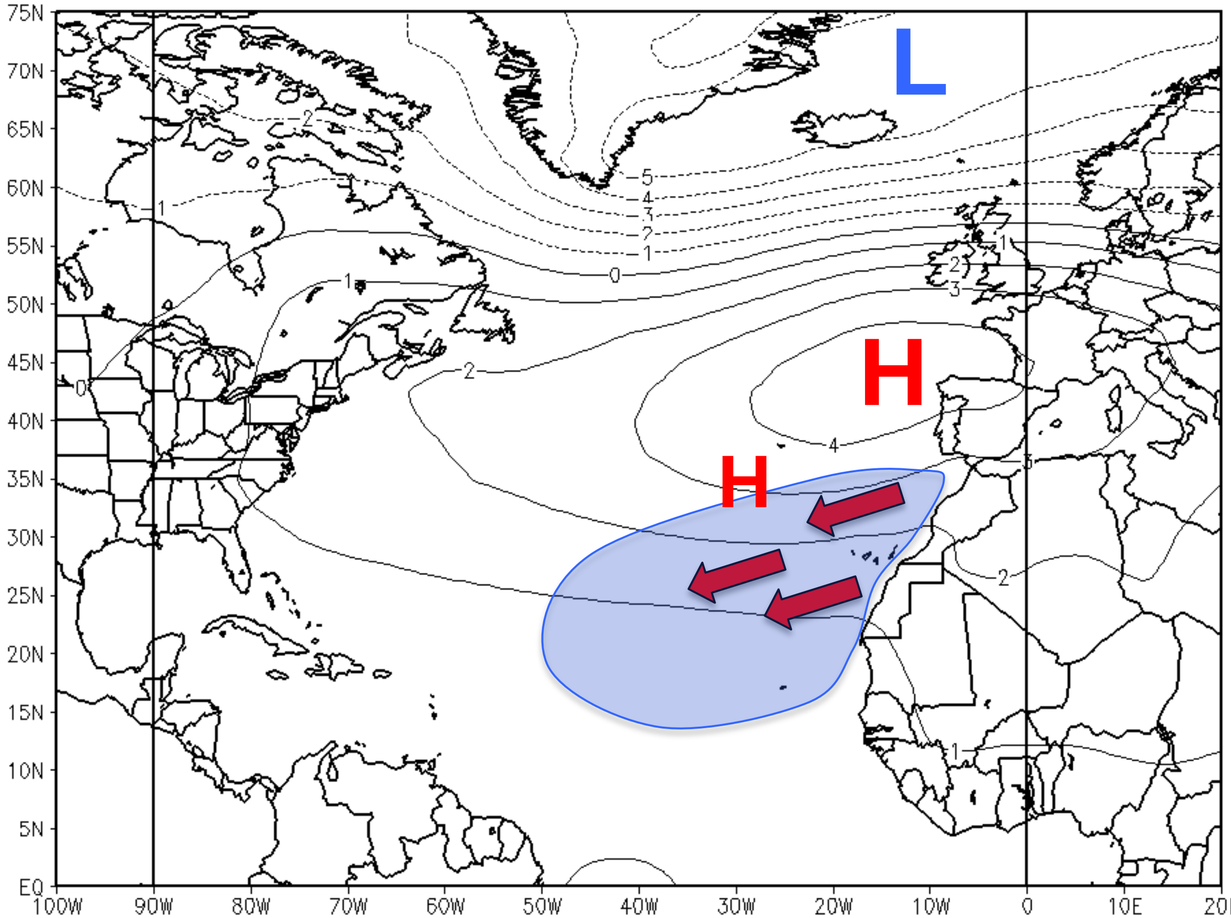


units: m/s per standard deviation

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

Forcing the AMM

SLP anomaly associated with (+) NAO

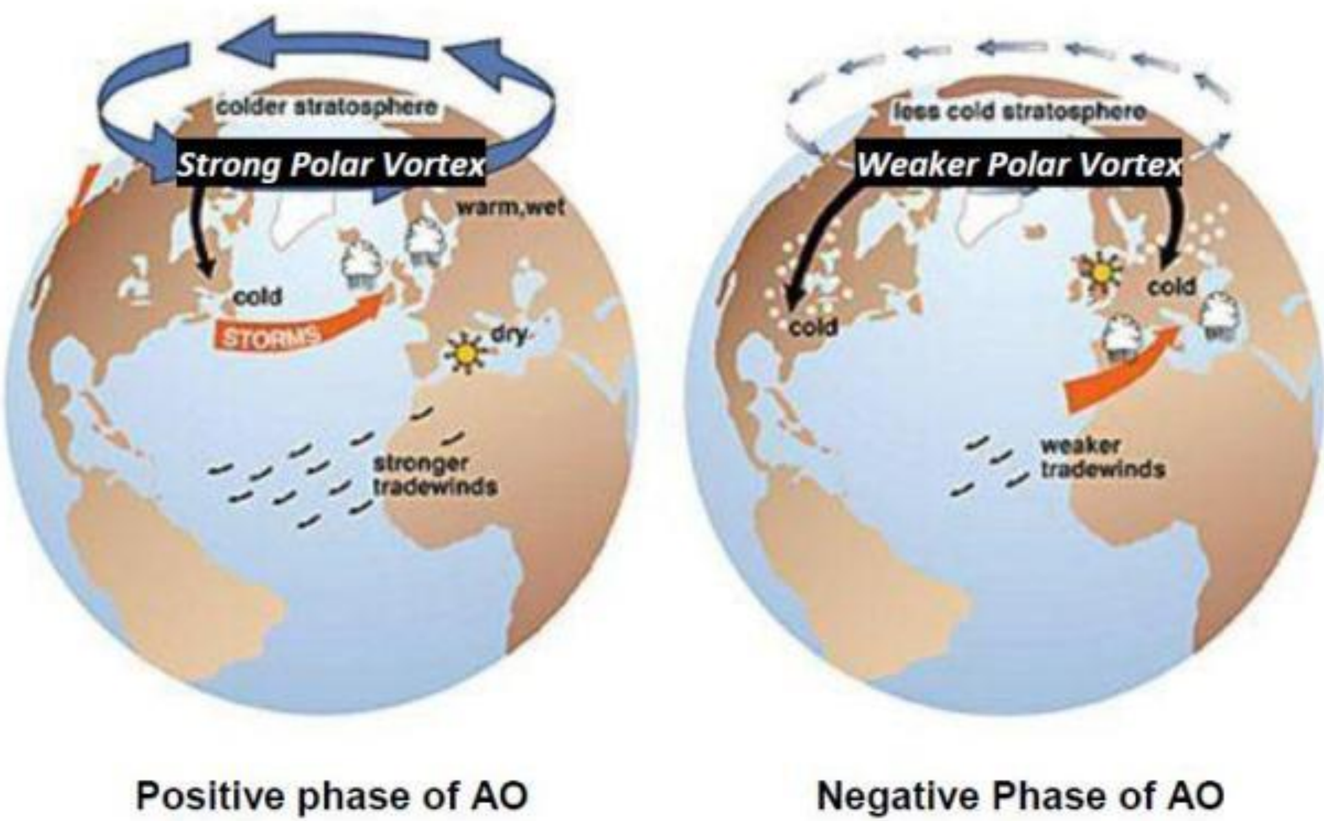


1. Subtropical SLP anomalies associated with NAO
2. Cool SST through enhanced evaporation (stronger easterlies)
3. Atmosphere responds through anticyclonic circulation, reinforcing wind anomalies → (-) AMM
4. Resulting feedback can last for several months, even after NAO forcing subsides

[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.

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

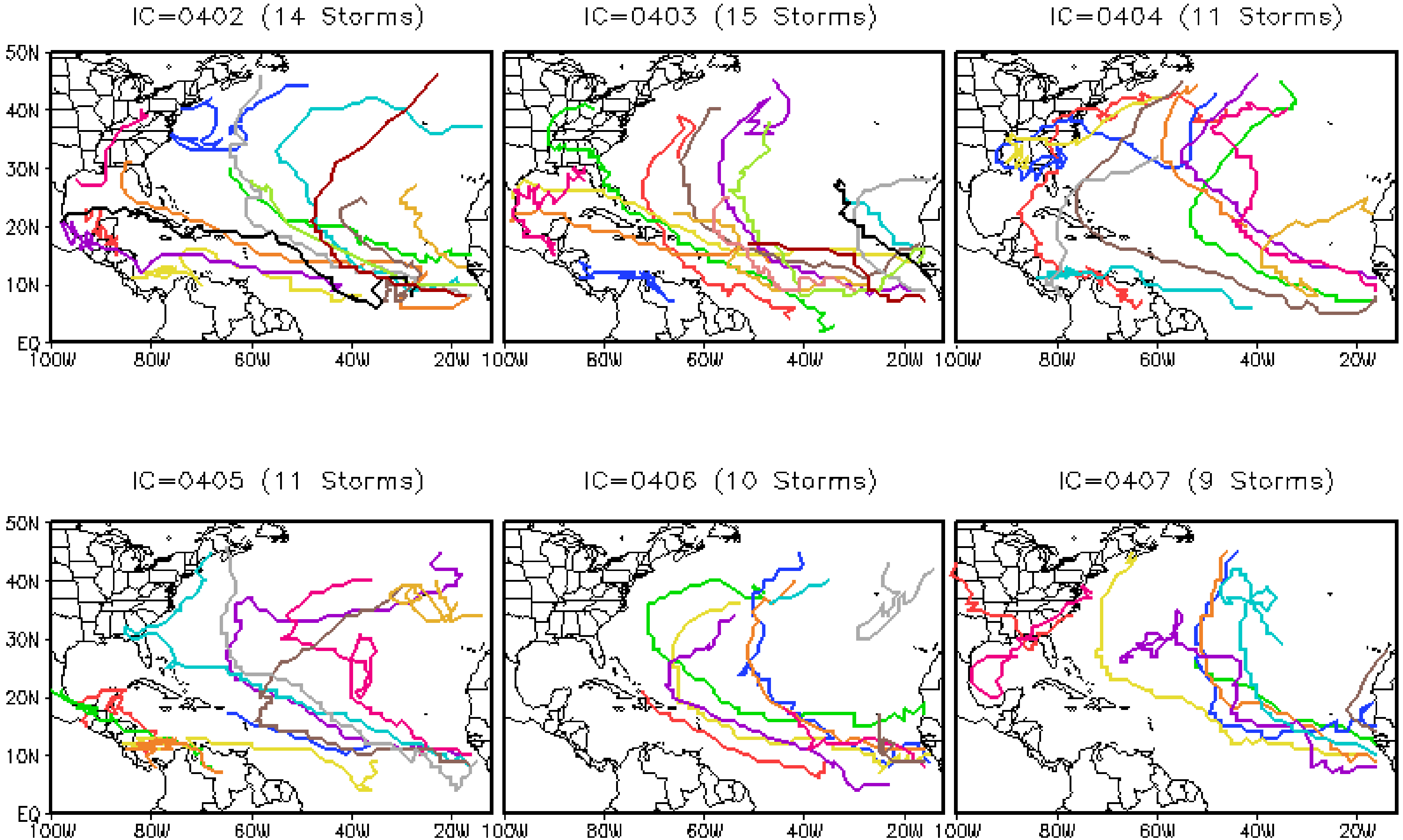
	Tropical Storms	Hurricanes	ACE Index % of Median
402	14	4	132
403	15	5	131
404	11	2	94
405	11	2	132
406	10	3	72
407	9	3	106
408	15	5	131
409	14	2	84
410	11	4	88
411	13	6	184
412	11	0	77
413	14	7	166
414	16	8	185
415			
416			
417			
418			

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 TC activity is explained. This could increase as dynamical model skill grows.

2) This make a 1-category forecast error possible in 1 out of 3 or 4 years, and a 2-category error in 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)
Statistical	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)
Statistical	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	CFS-V2 T126: 1	12-16 (14)	6-9 (7.5)	3-4 (3.5)	112-168 (140)
CFS	CFS-V2 T126: 2	13-17 (15)	7-10 (8.5)	3-4 (3.5)	121-182 (152)
CFS	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)
European	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

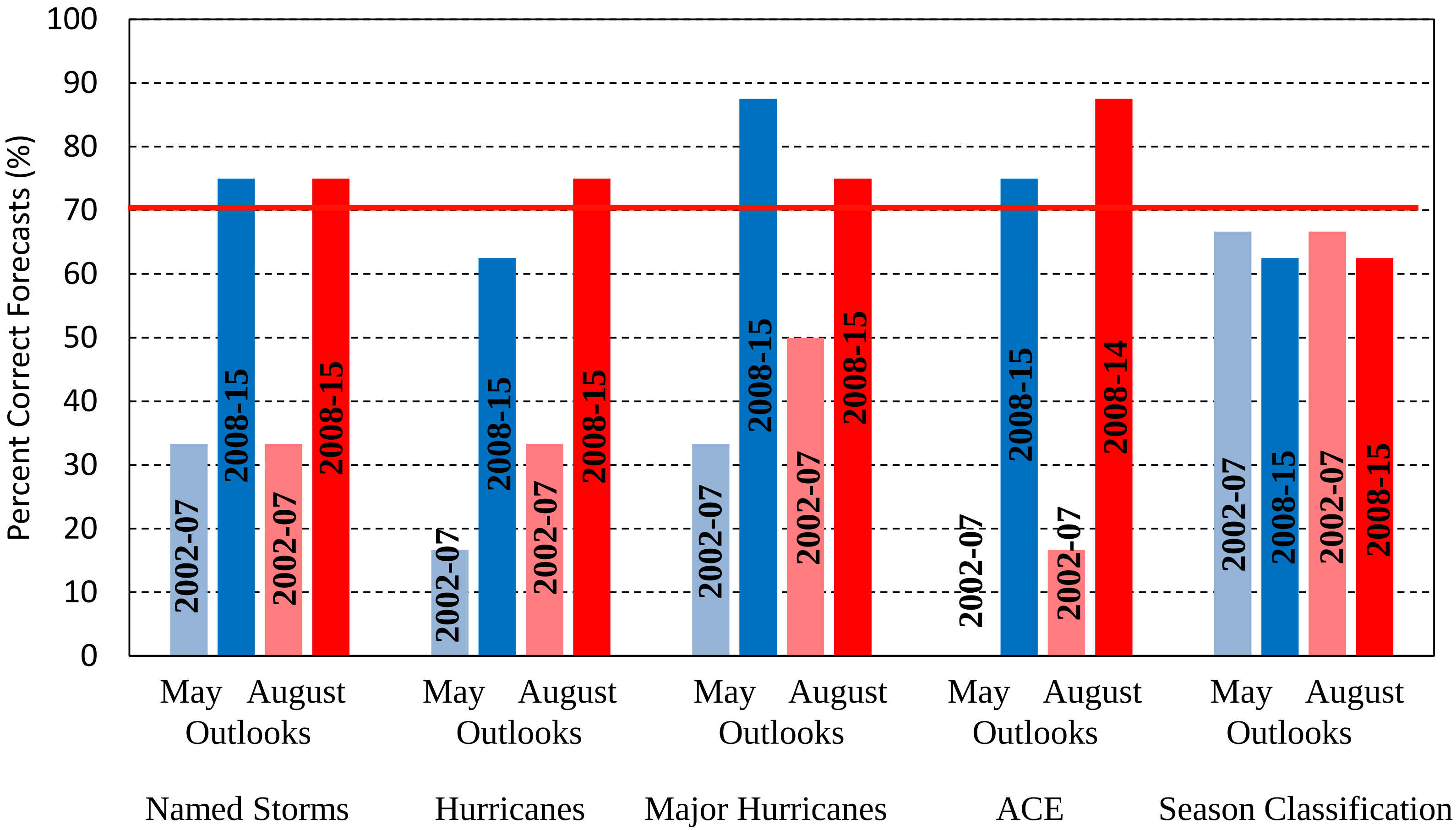
NOAA Forecast Methodology

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.)

Percent of Correctly Forecasted Parameters

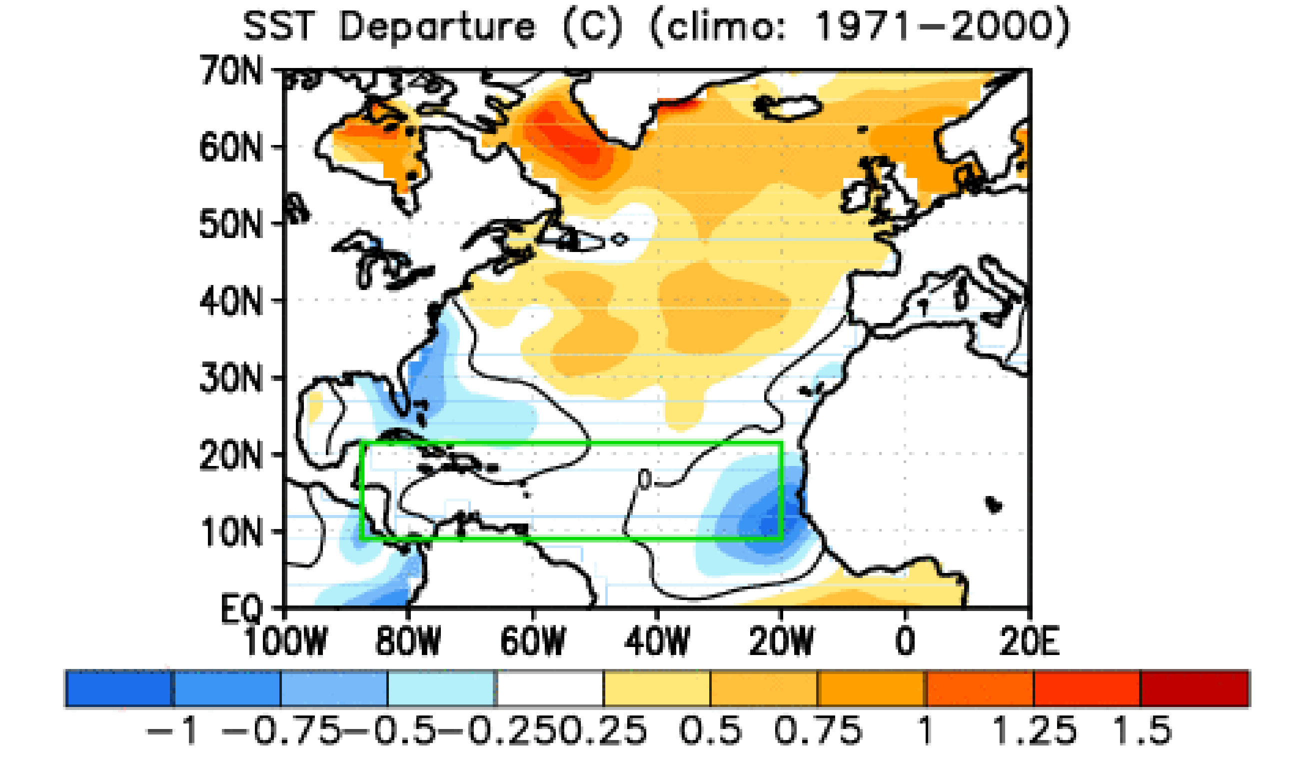


For both the May (Blue) and August (Red) outlooks, large skill improvements are seen since 2008 for all predicted parameters except Season Classification,.

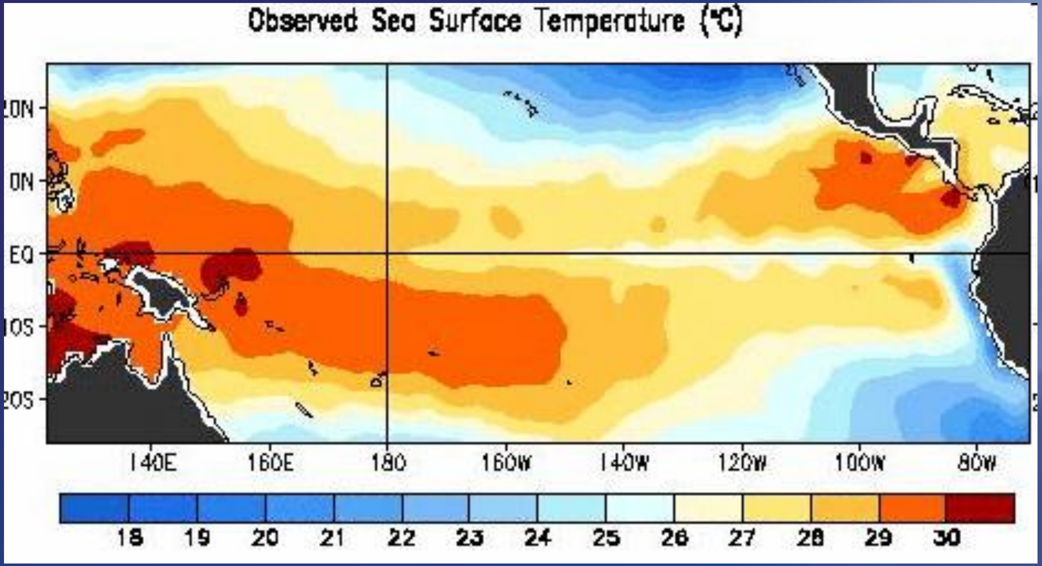
Exercise

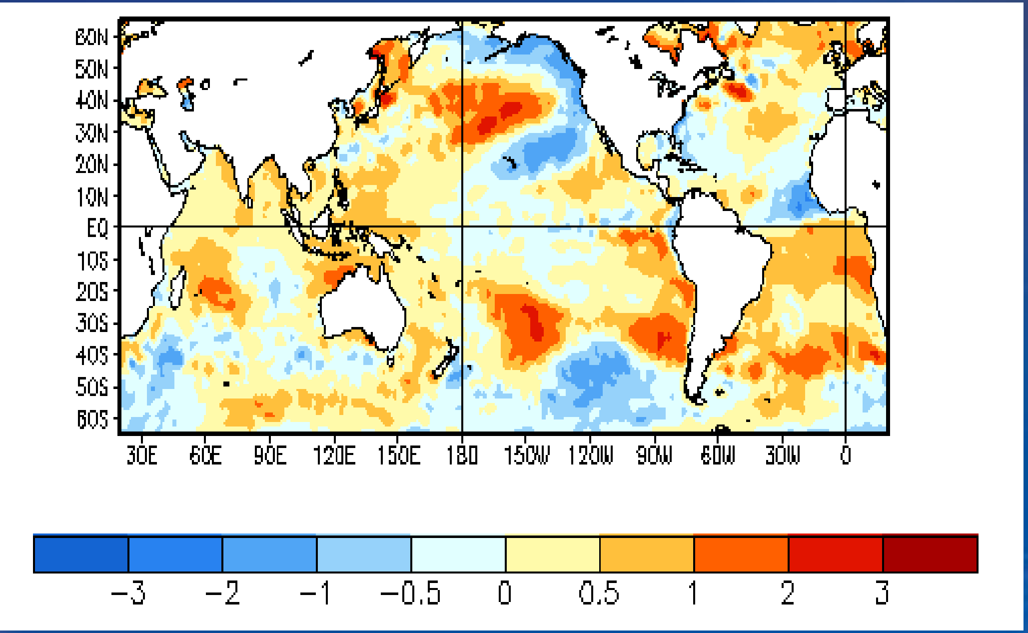
- Using what you have been taught about seasonal forecasting, make a seasonal forecast with the atmospheric and oceanic slides in the following slides.
- Please forecast ranges of activity for tropical storms, hurricanes, major hurricanes and ACE.
- Remember long term averages are 12 TS, 6 H, 3 MH and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

March-April SSTAs

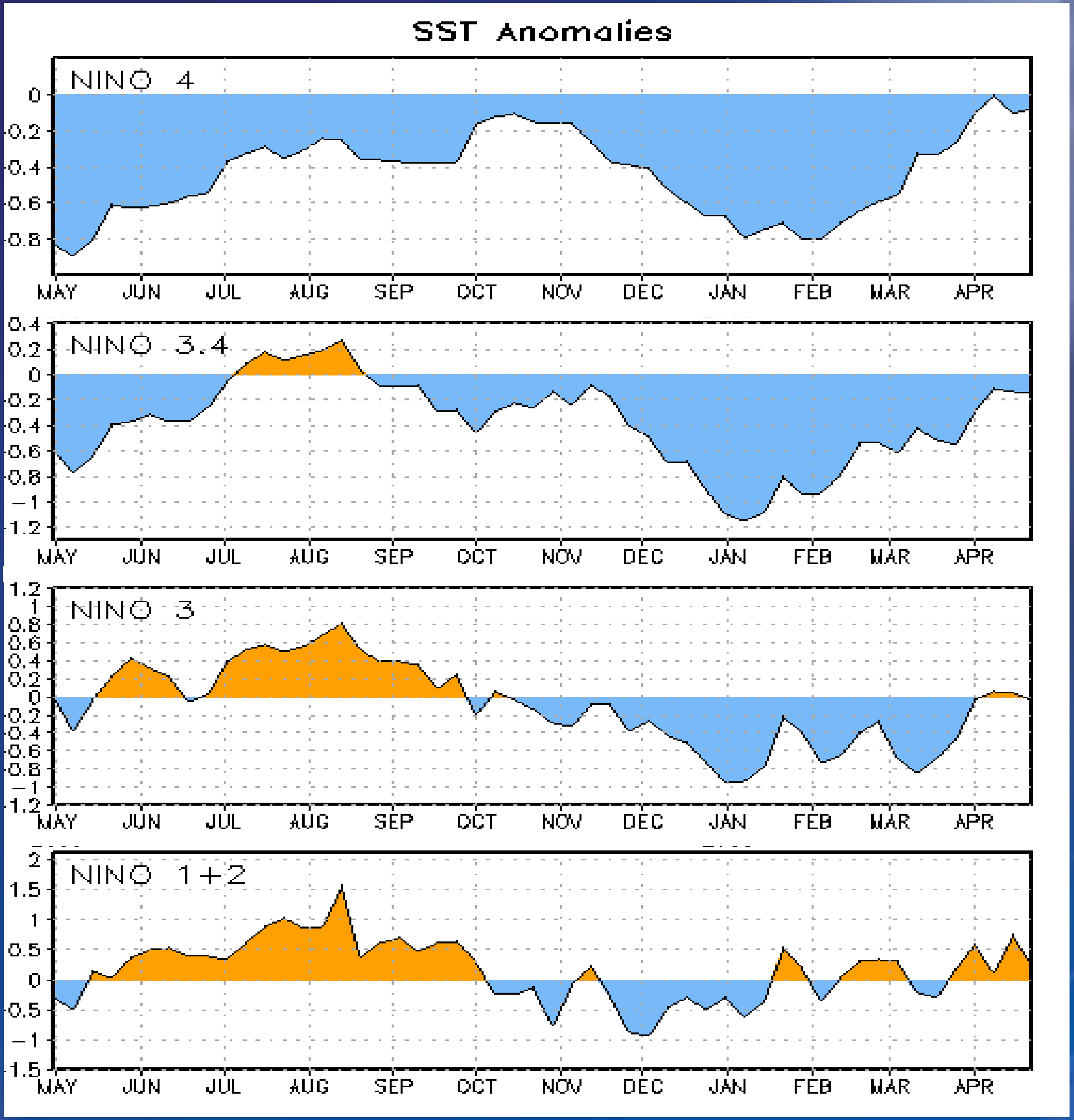


April SST and SSTA

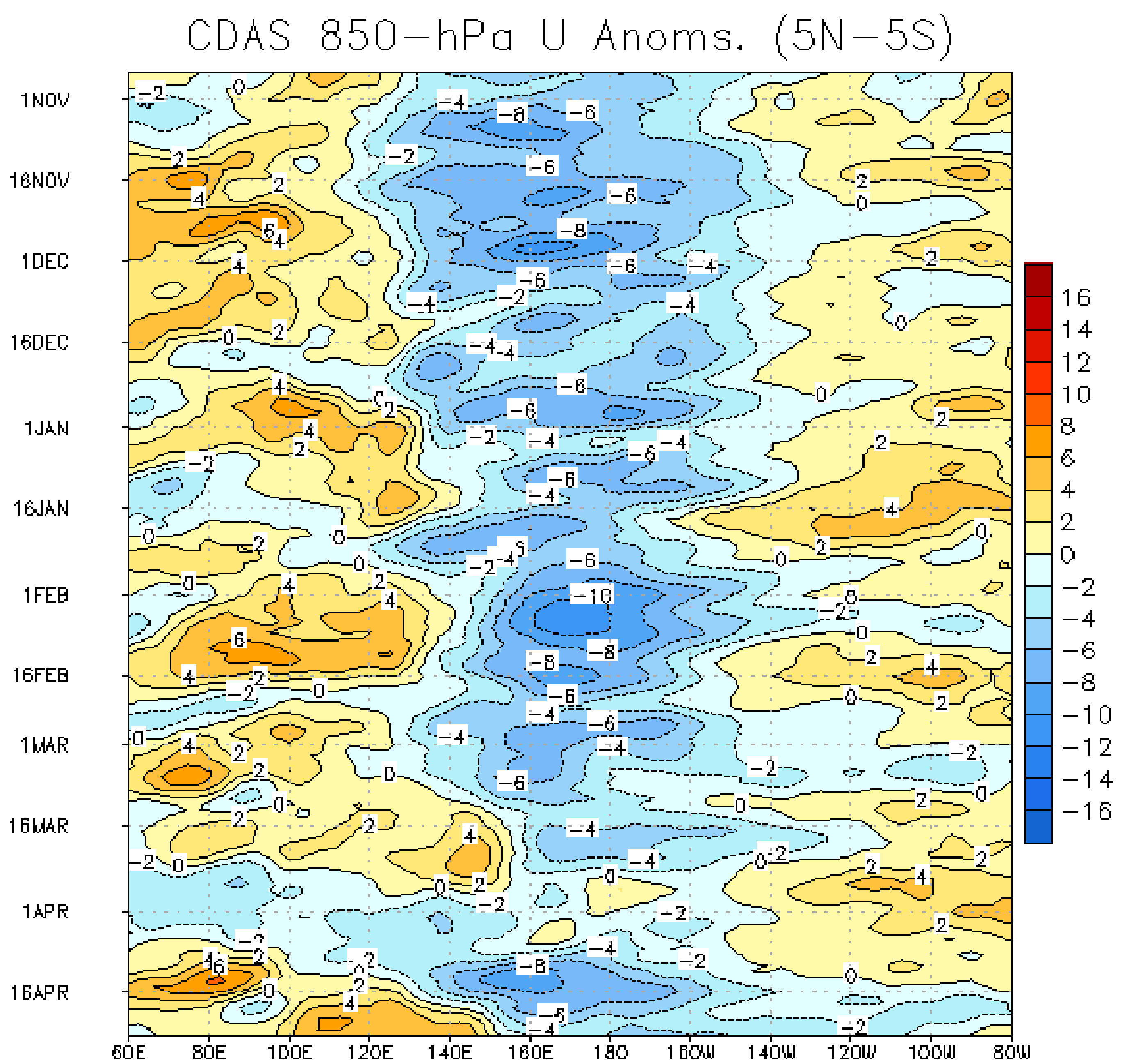




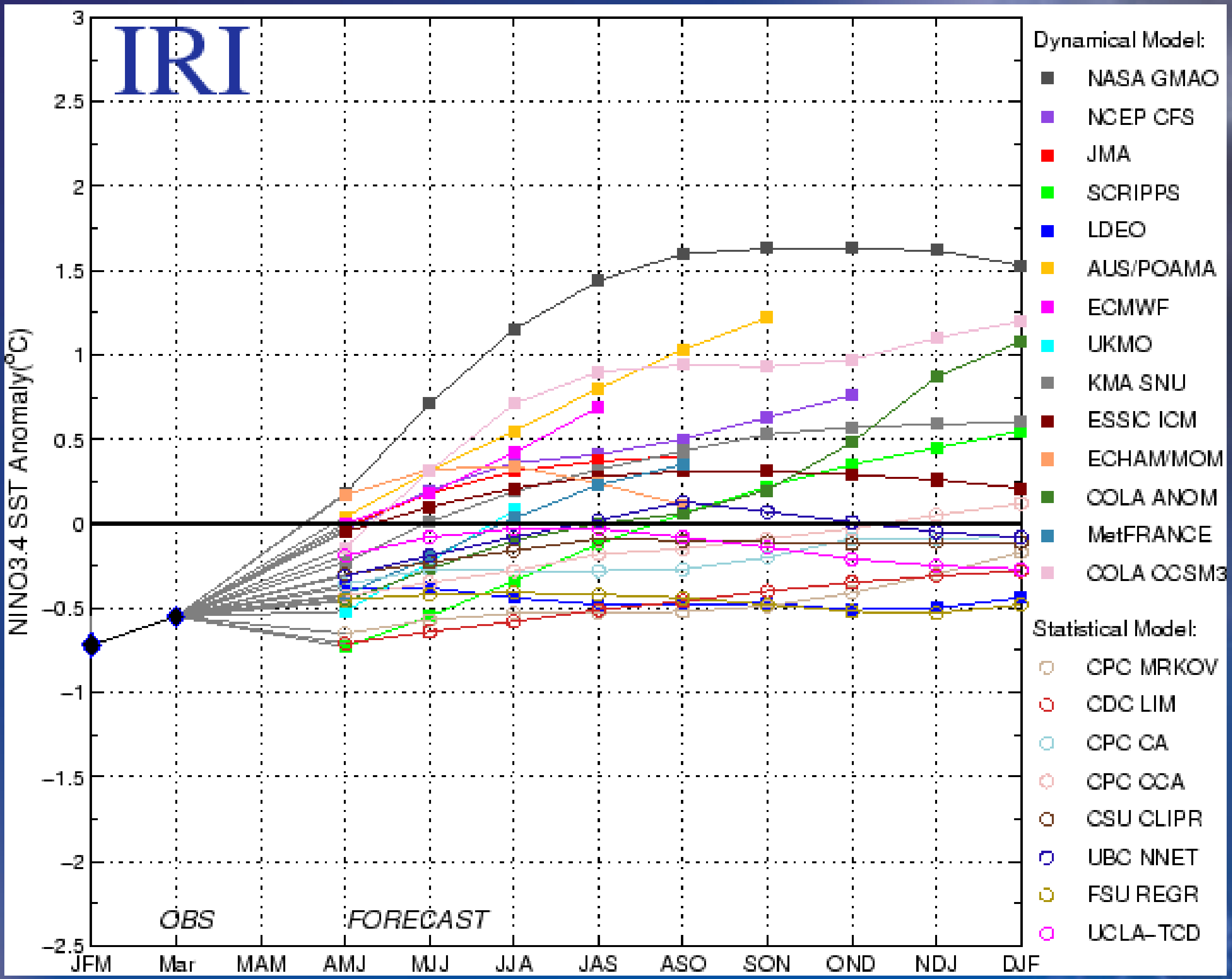
Tropical Pacific SSTA Evolution



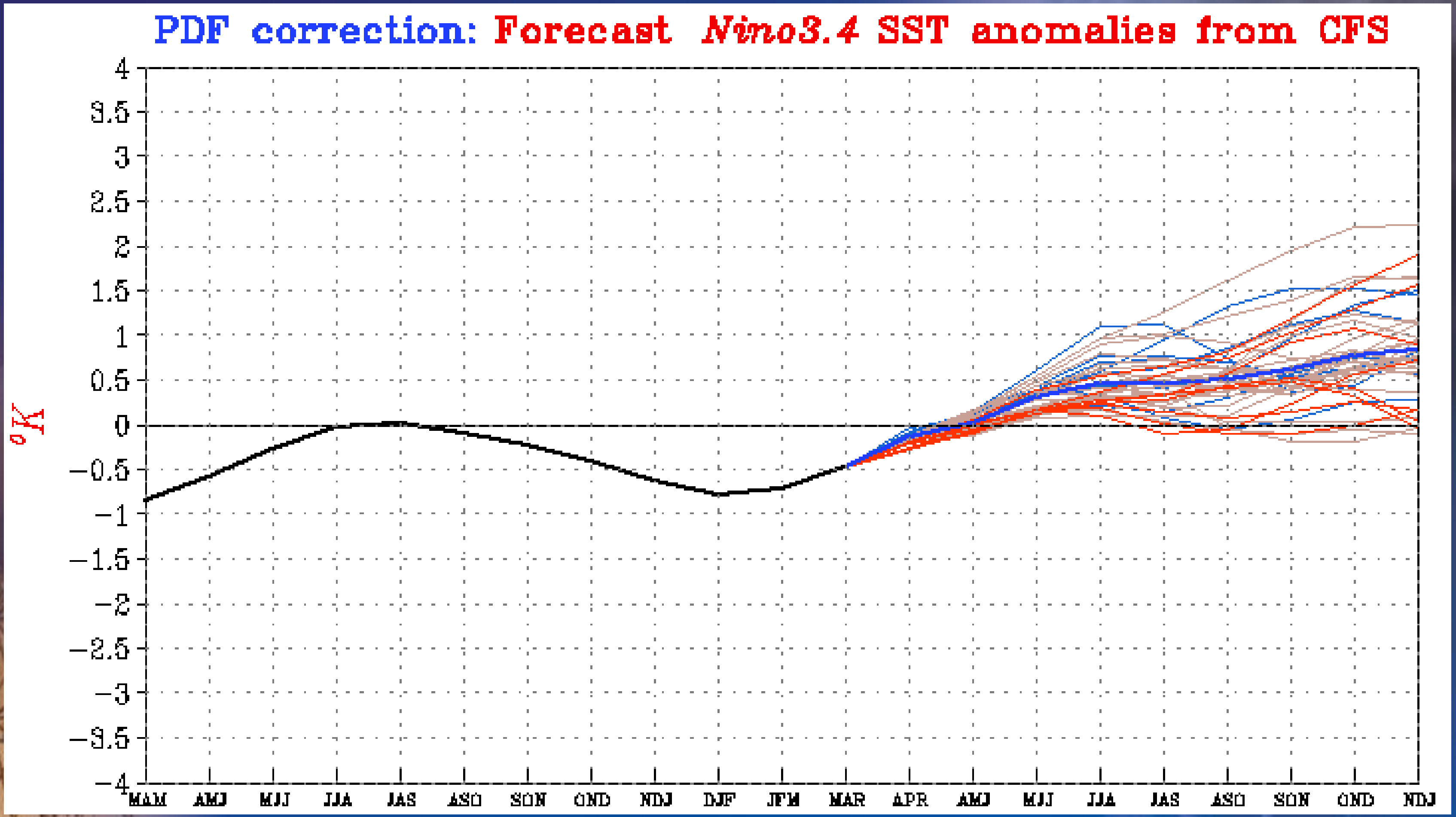
Time-Longitude Section of 850-hPa Zonal Wind Anomalies averaged 5N-5S



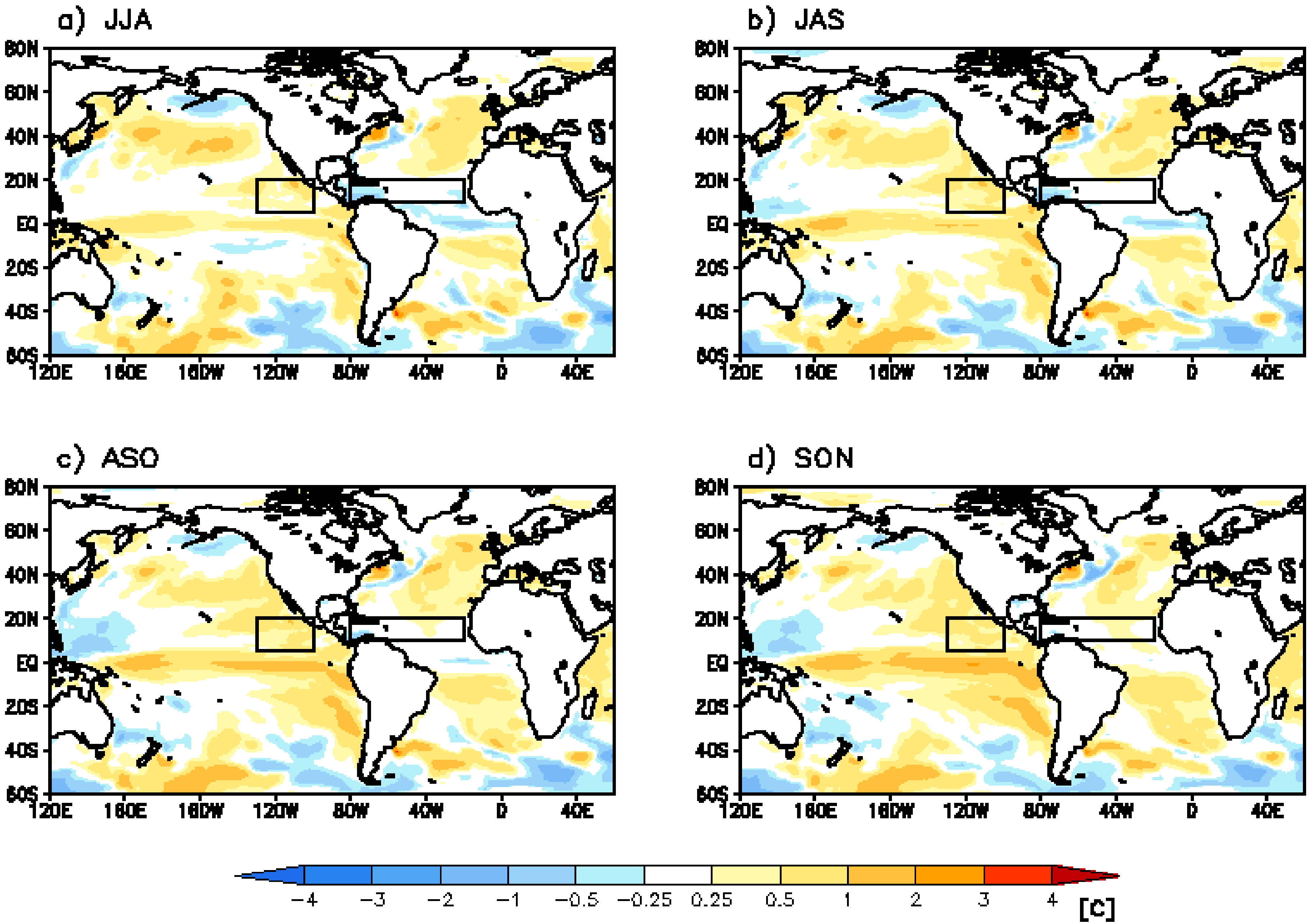
ENSO Forecast Plume



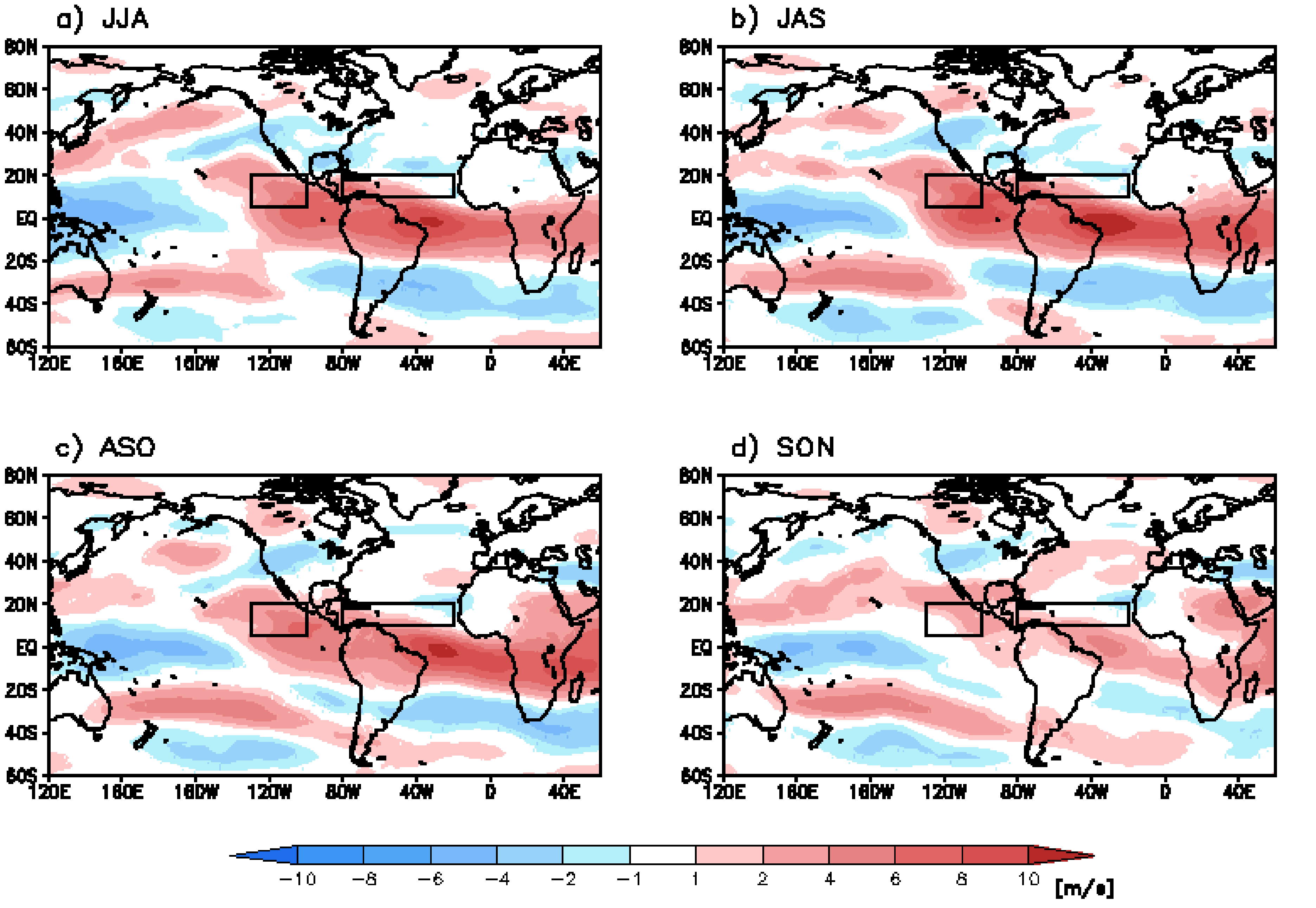
Niño 3.4 region: CFS Forecast



T382 High Resolution SST anomaly forecast:



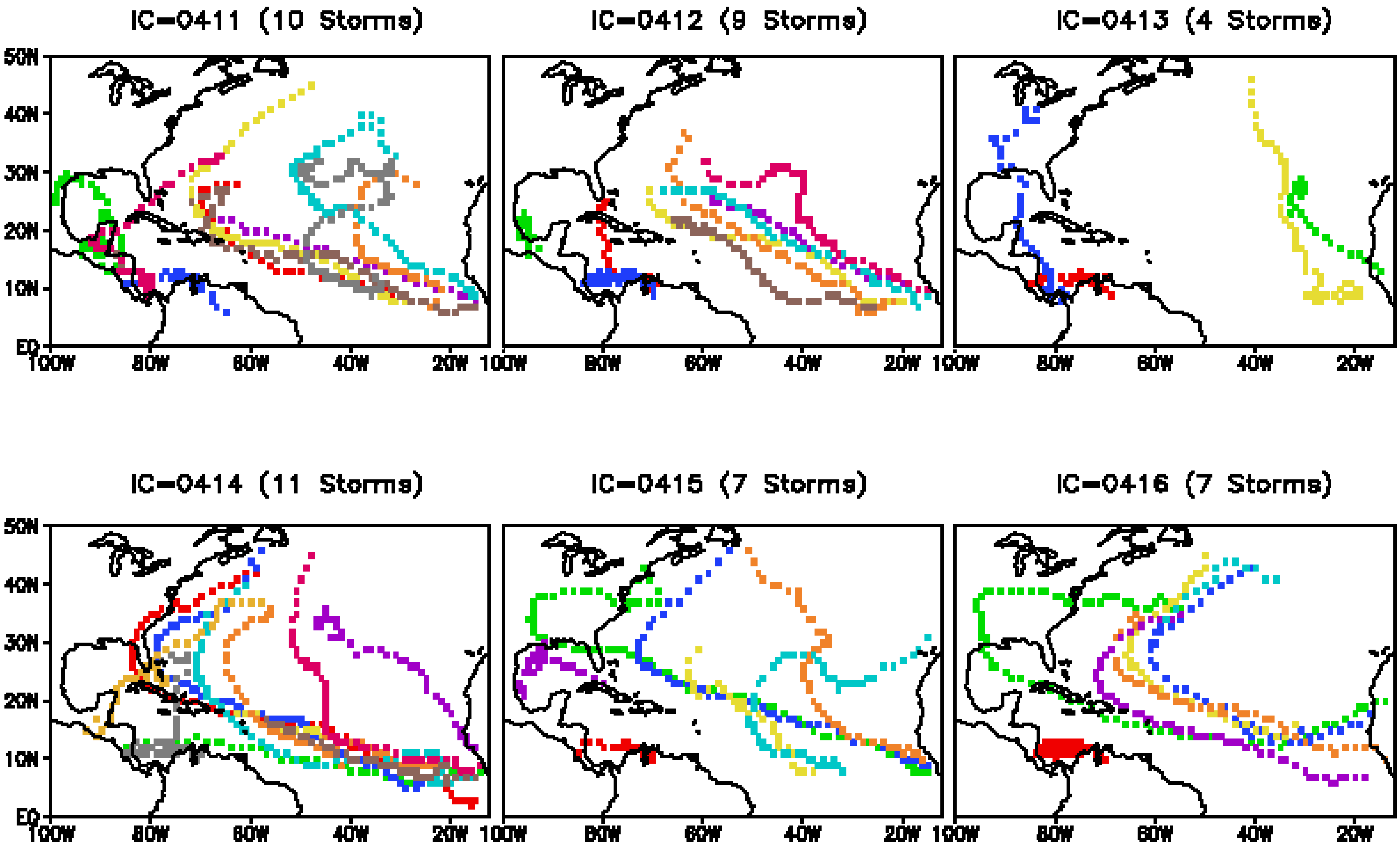
T382 High Resolution shear anomaly forecast:



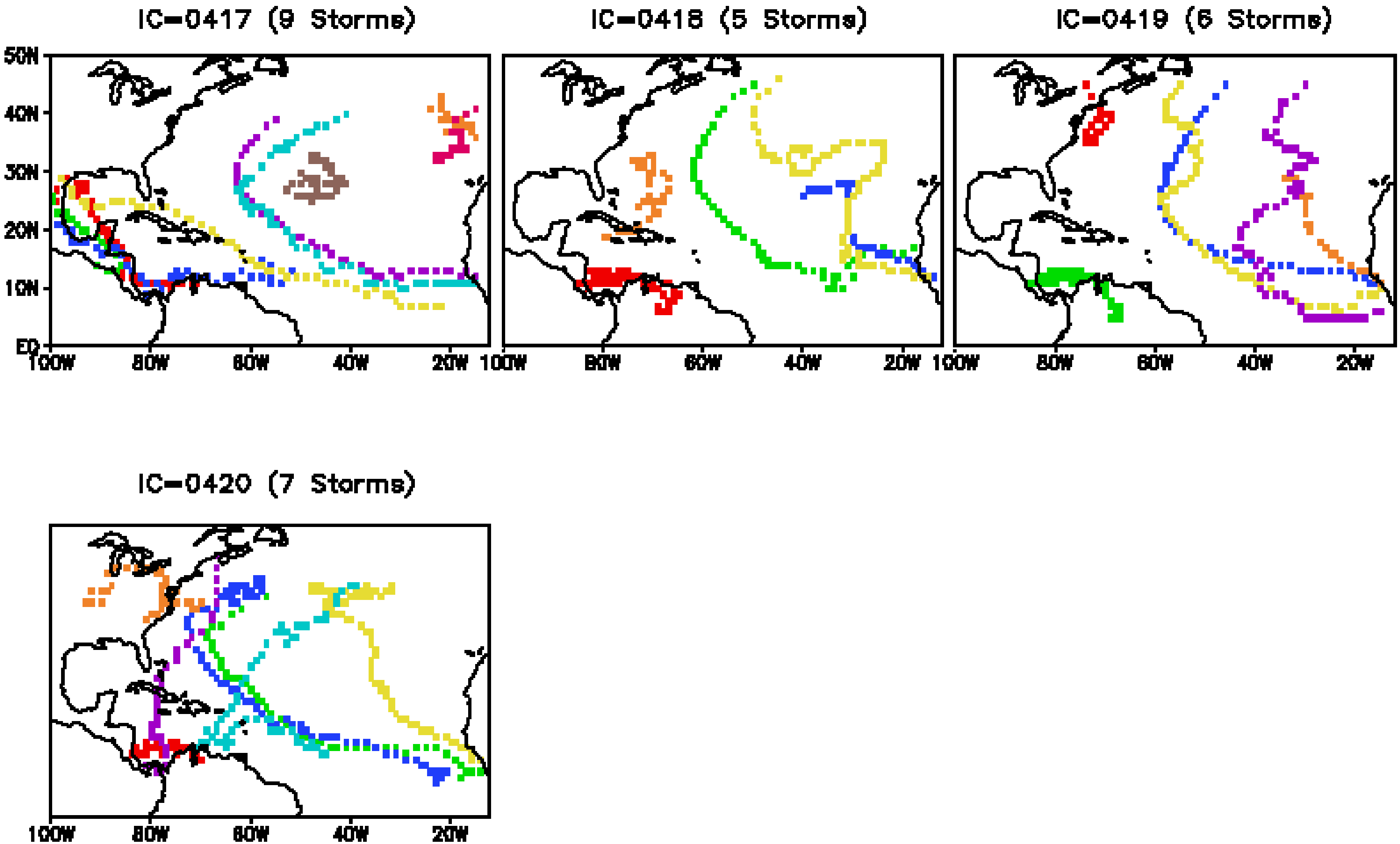
Storm Counts and ACE Index
Atlantic Basin

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

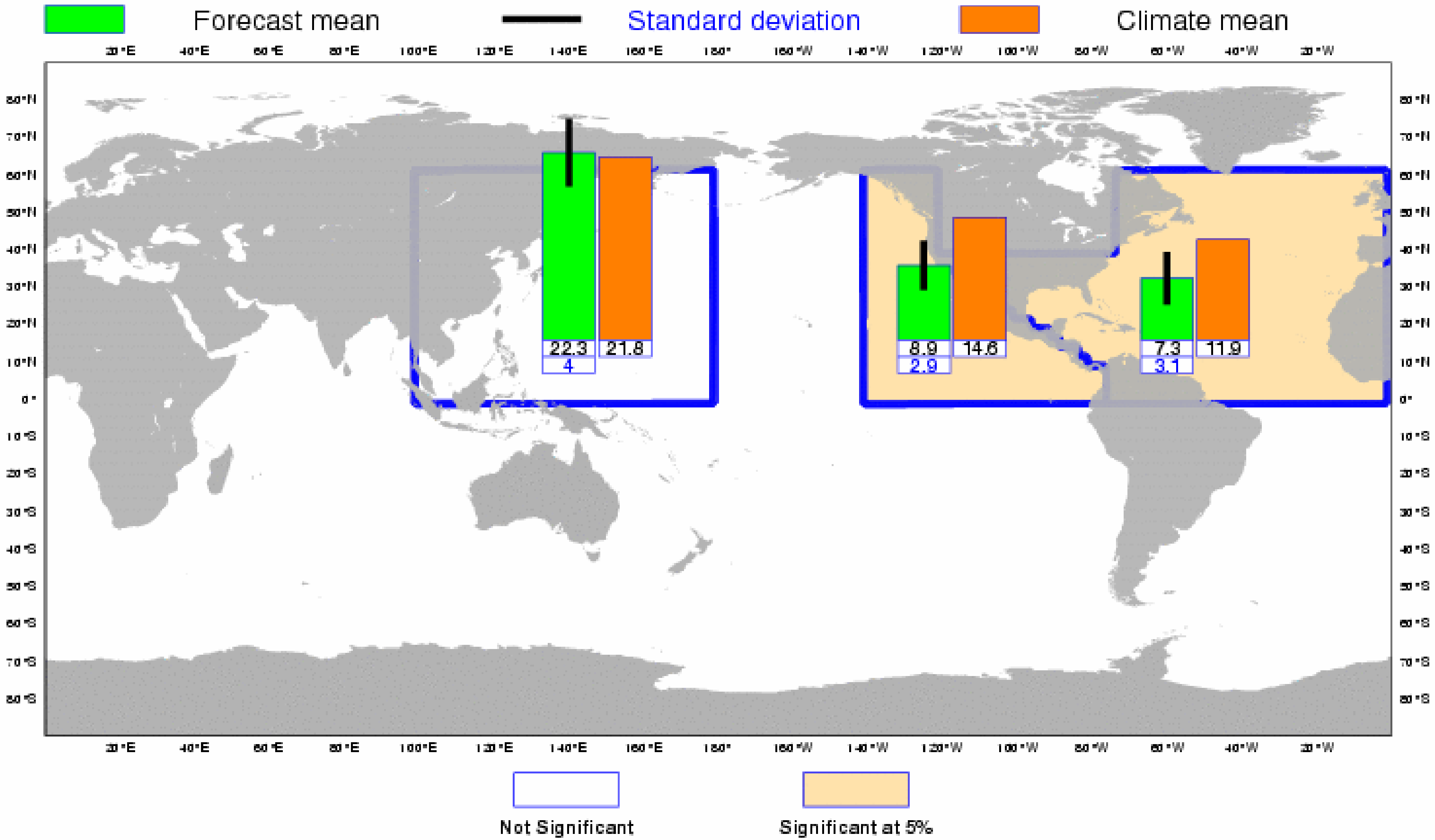
Updated CFS (T-62) NS Forecast: ATLANTIC

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

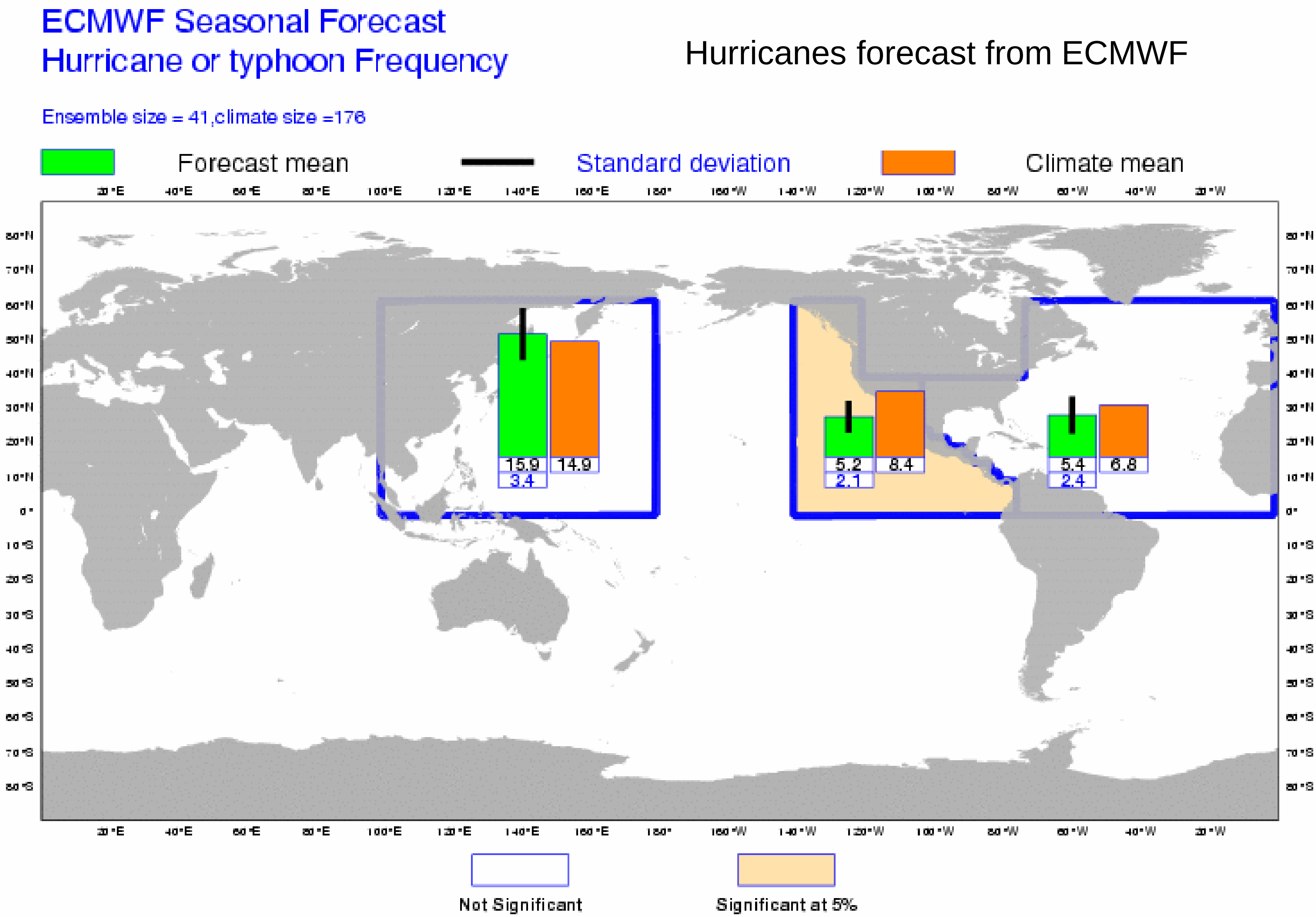
ECMWF Seasonal Forecast
Tropical Storm Frequency

TS forecast from ECMWF

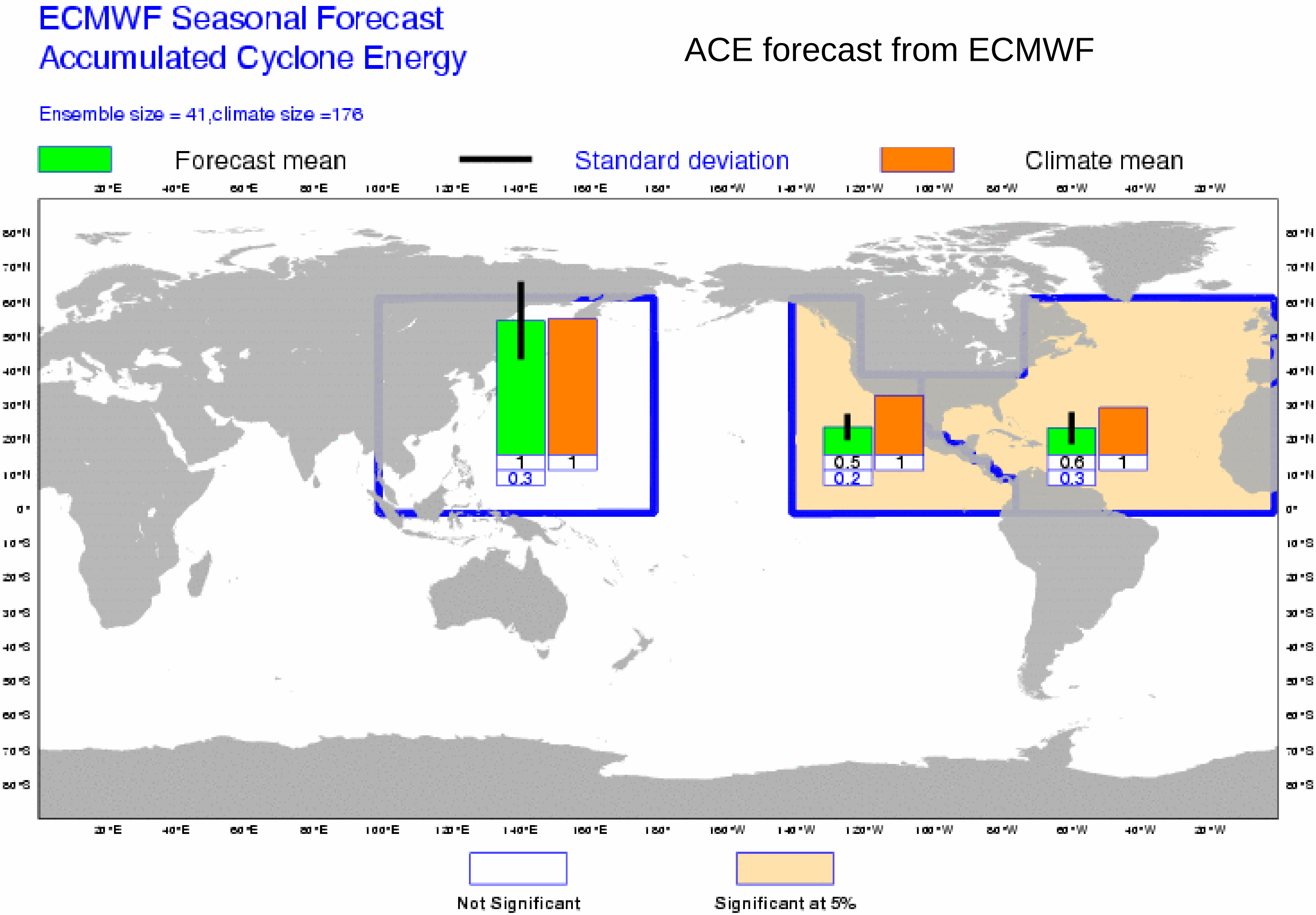
Ensemble size = 41,climate size =176



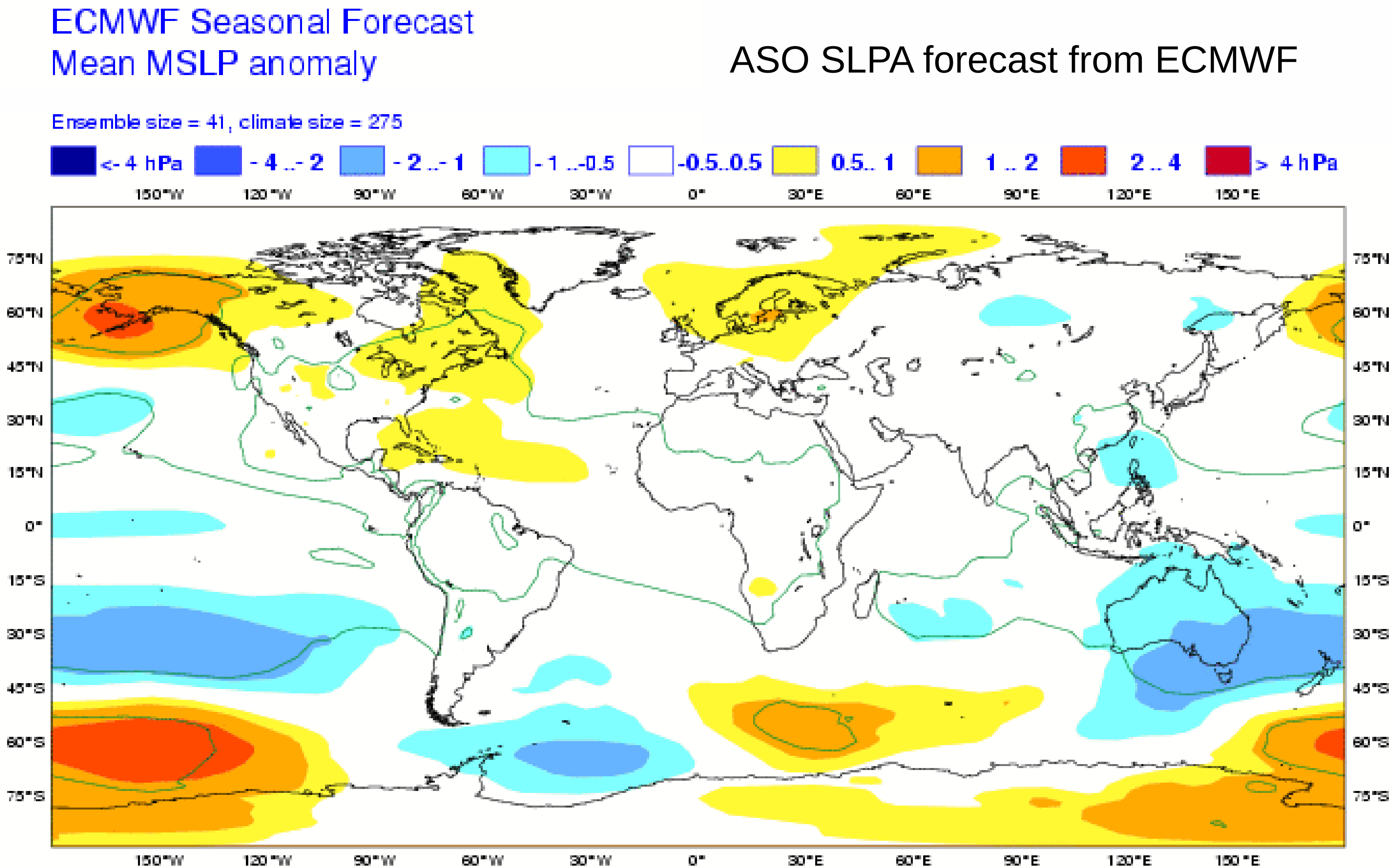
Hurricanes forecast from ECMWF



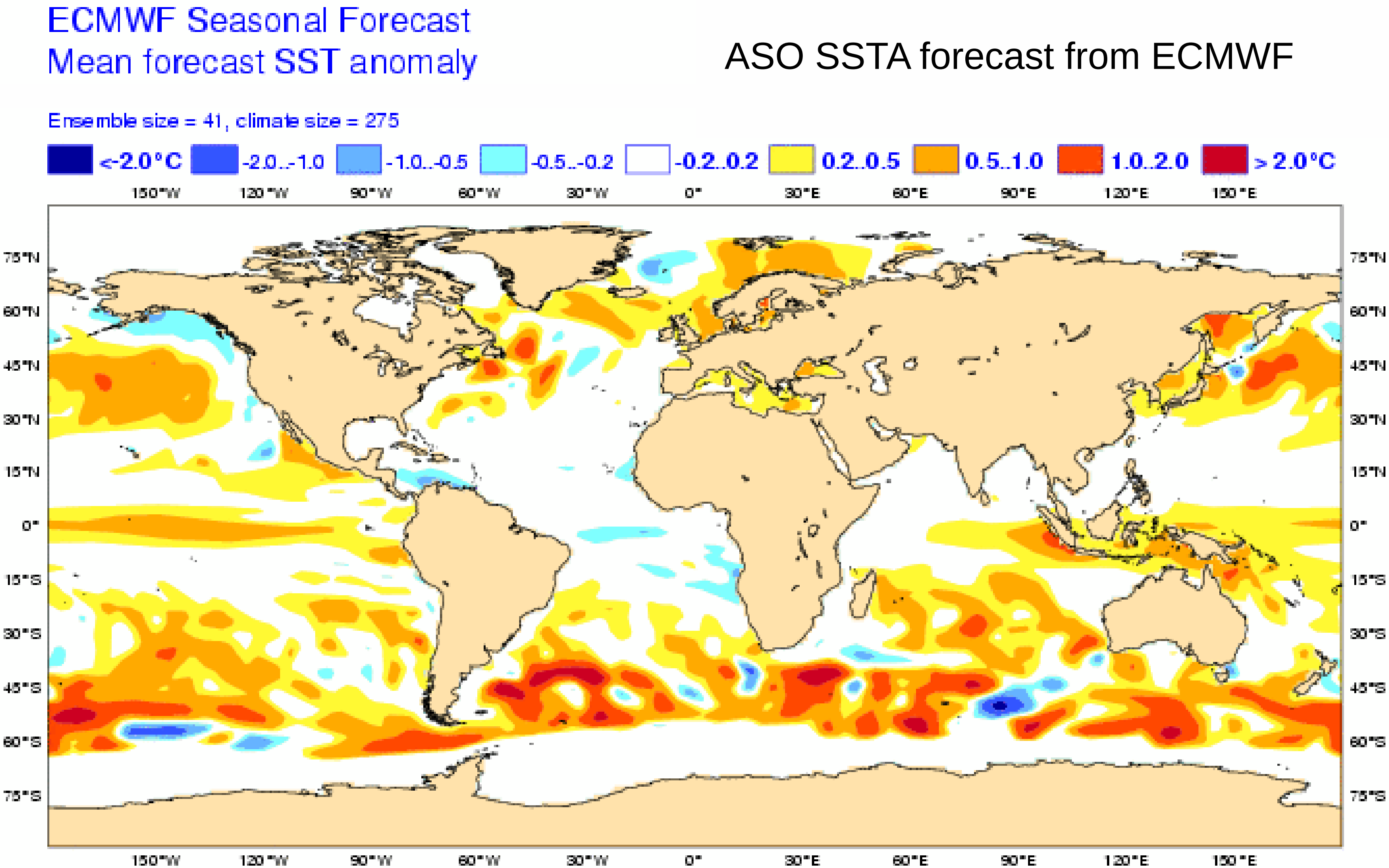
ACE forecast from ECMWF



ASO SLPA forecast from ECMWF



ASO SSTA forecast from ECMWF



Question 3

What ACE did you predict for the exercise?

A. Under 60

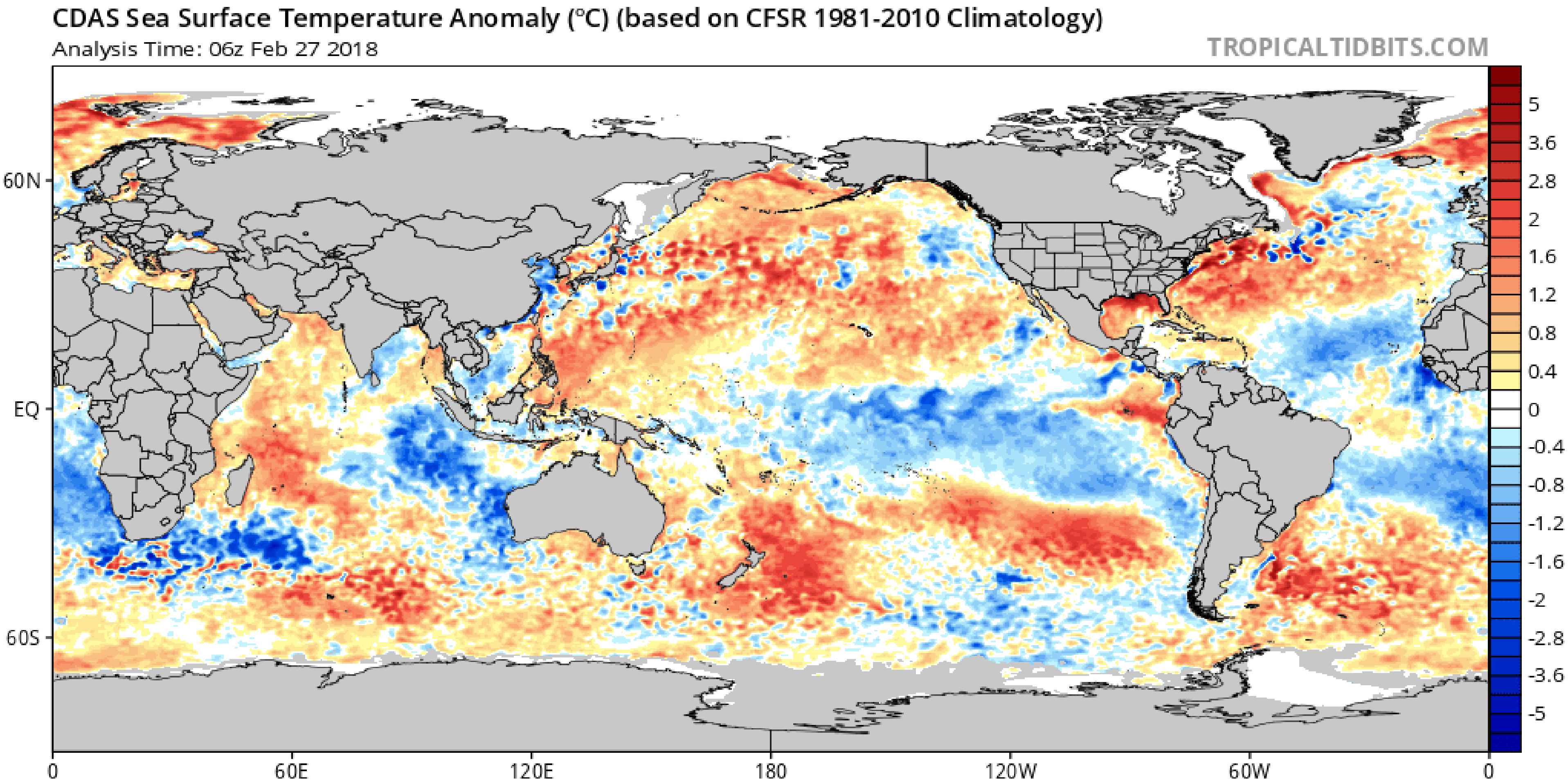
B. 60-89

C. 90-120

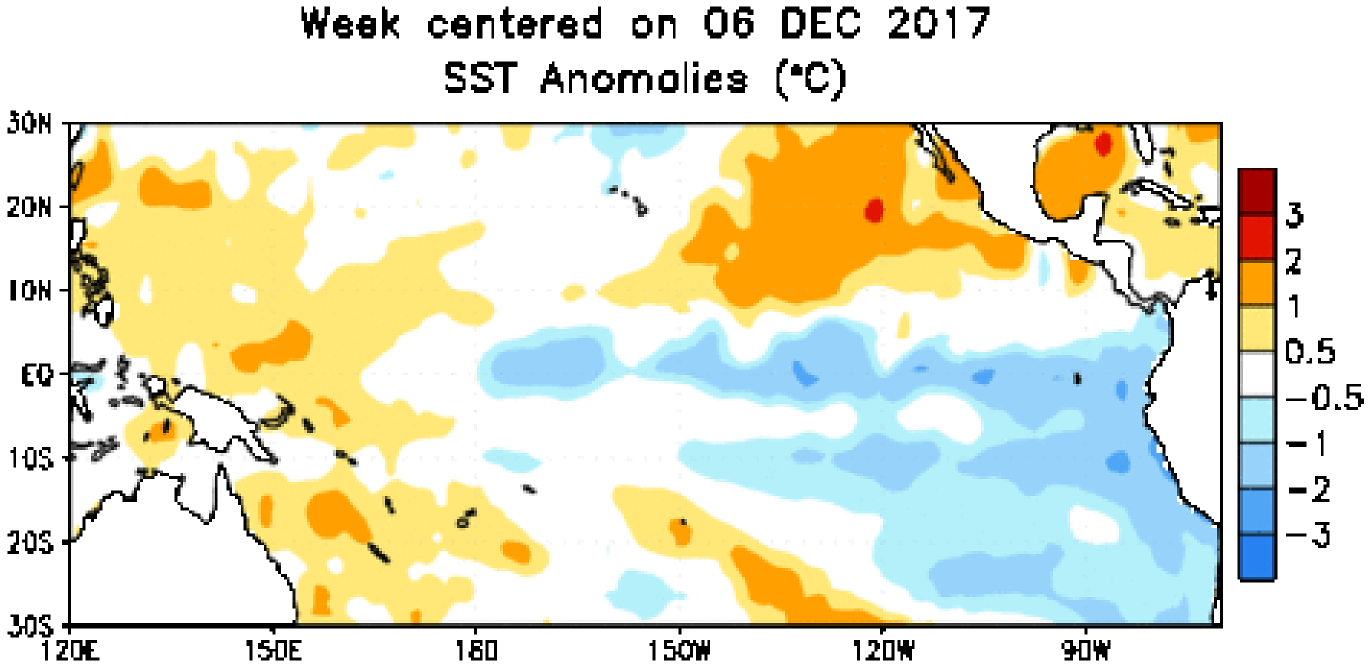
D. Over 120

What about 2018?

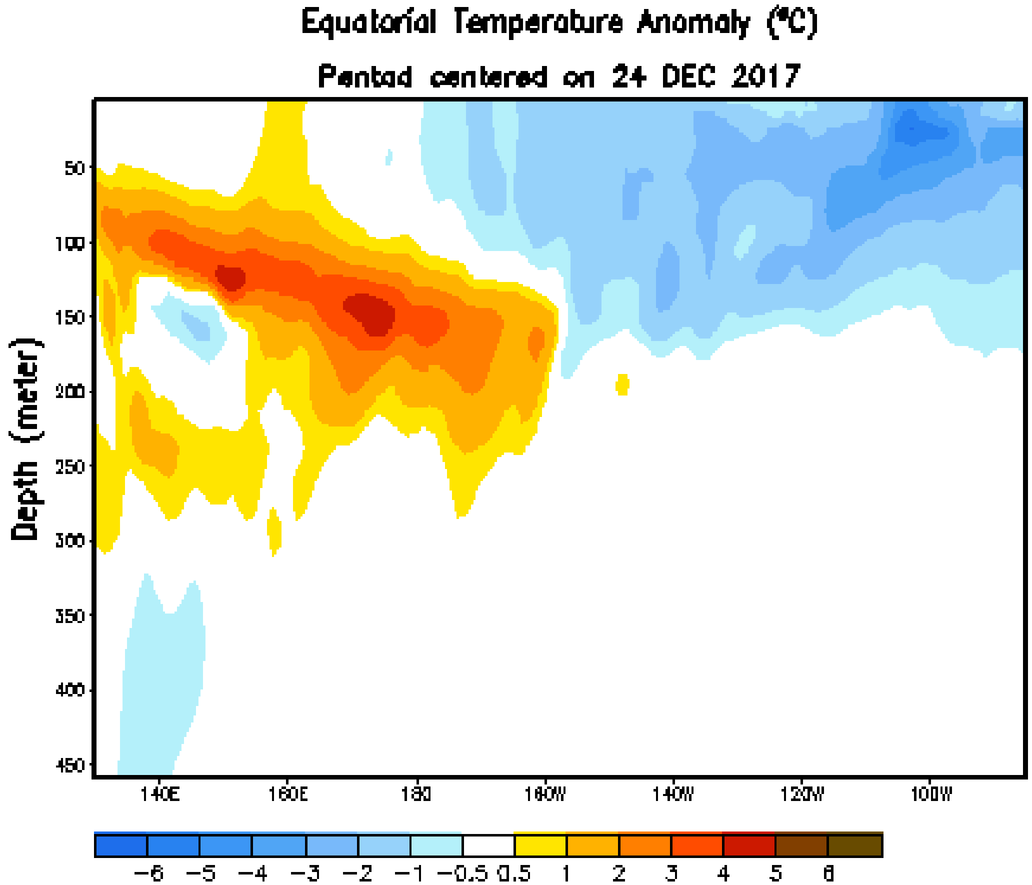
Current Global SST anomalies



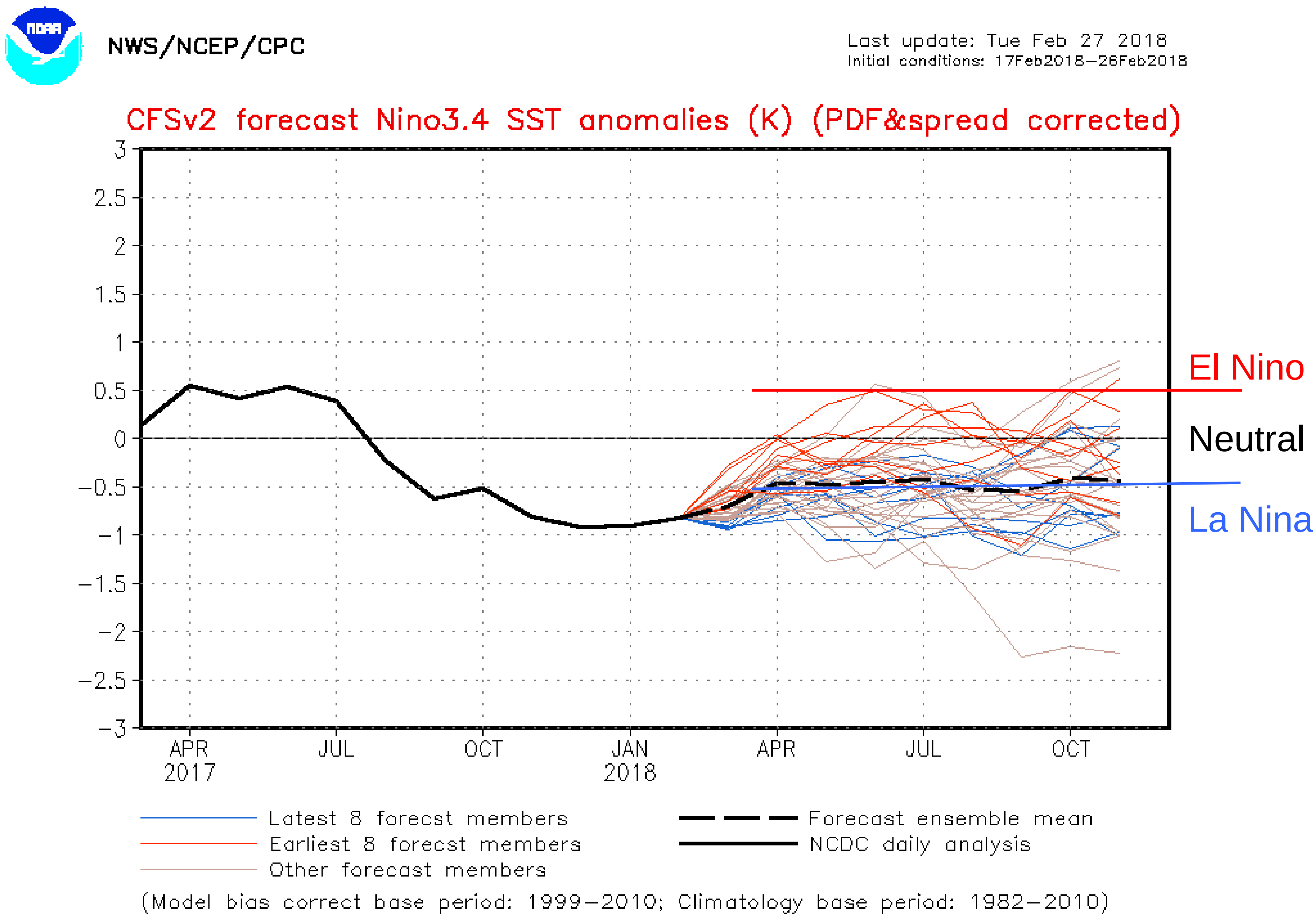
La Niña gradually weakening

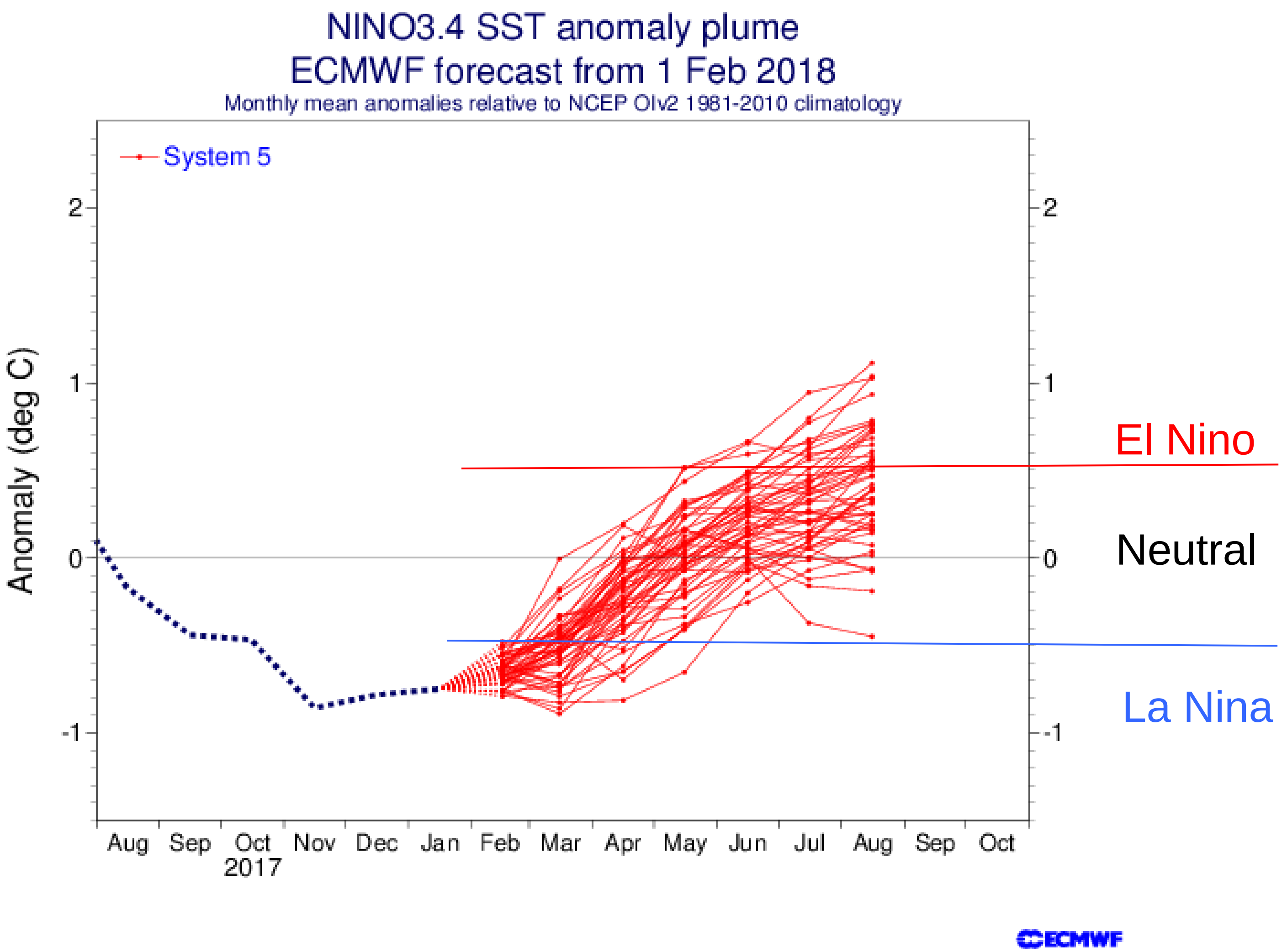


Strong downwelling oceanic Kelvin Wave



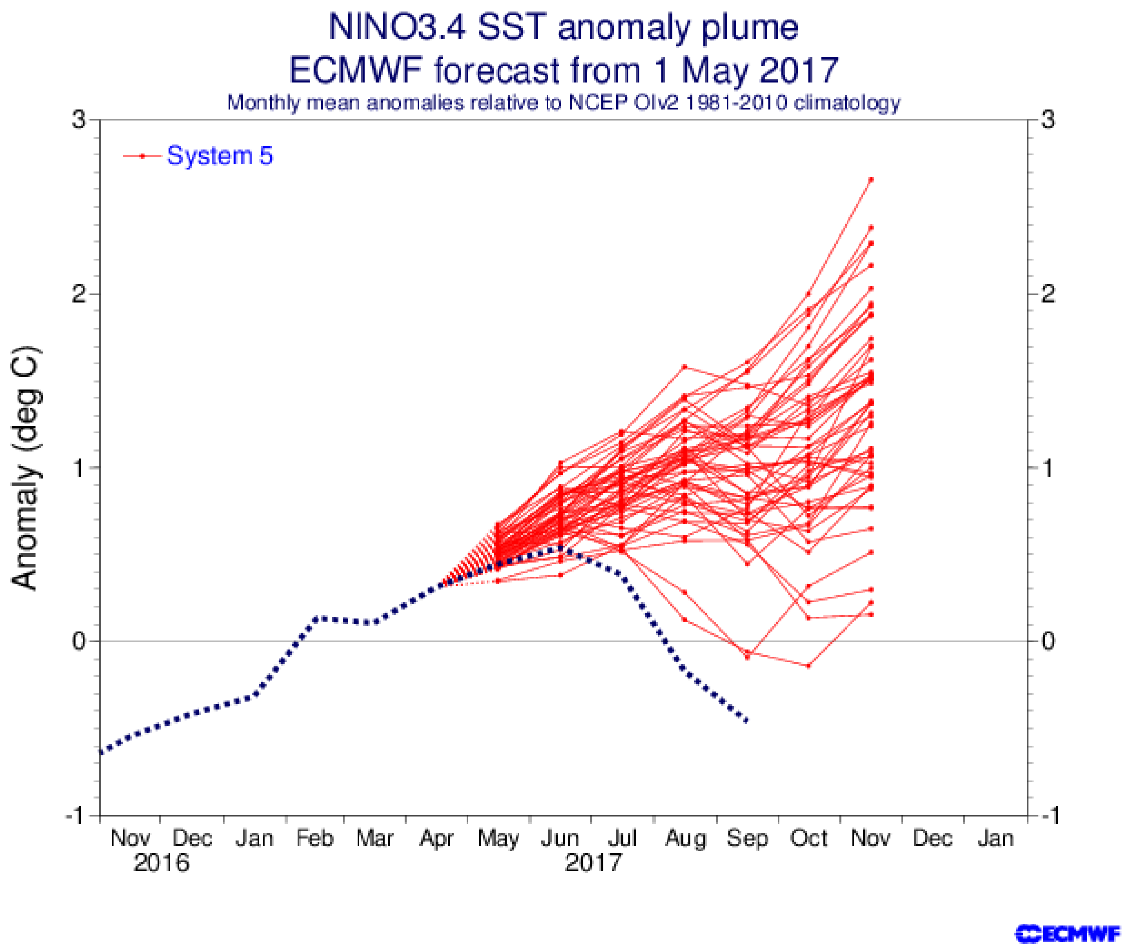
CFS forecasts best chance of neutral for ASO 2018

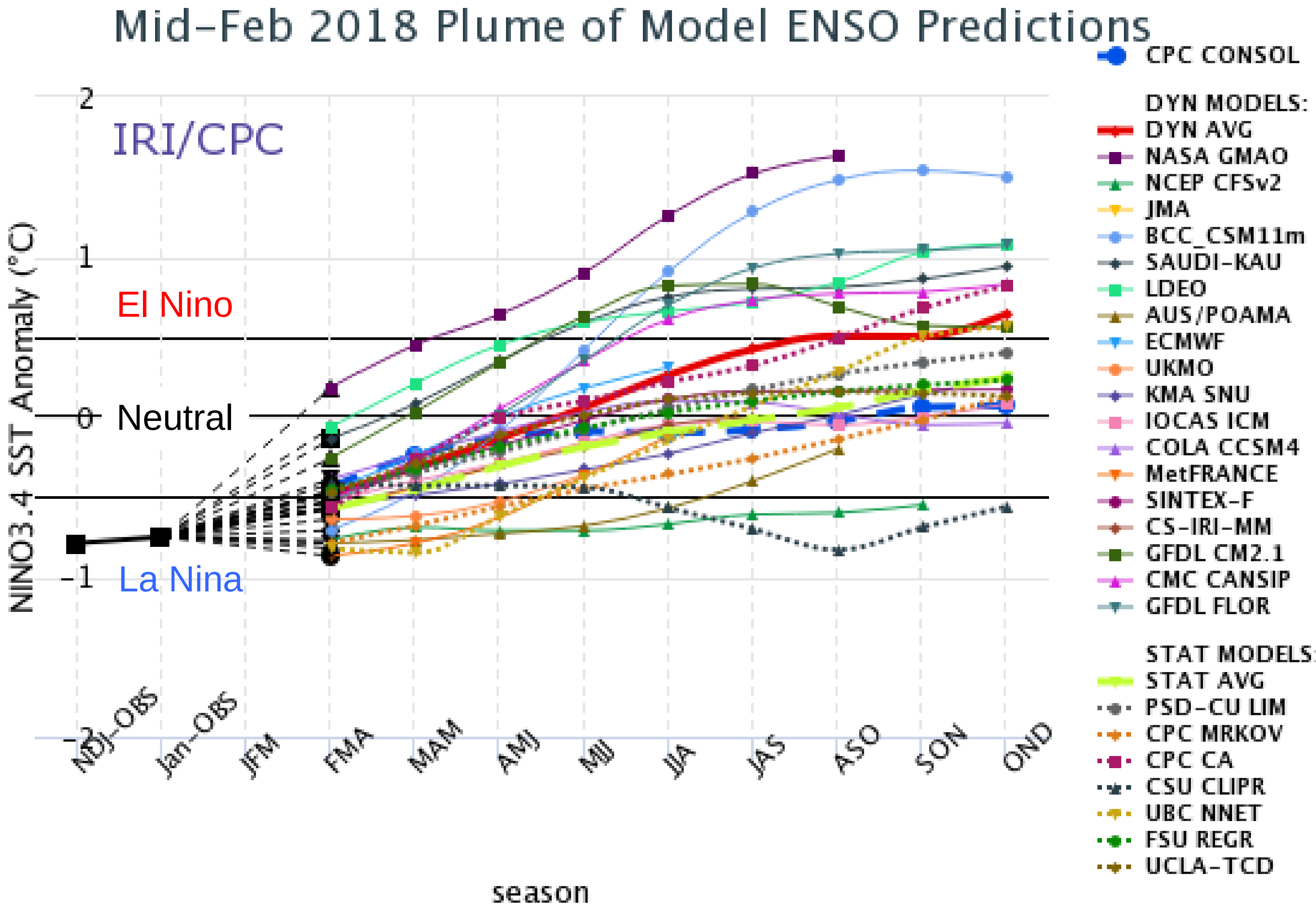




ECMWF warmer than CFS, neutral likely by Spring, El Nino possible by late summer

Nino models aren't very good though!

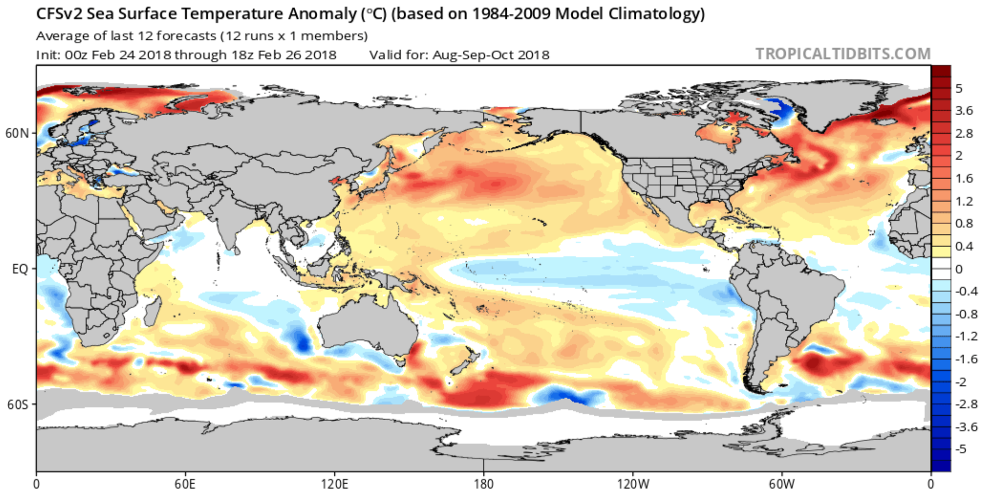


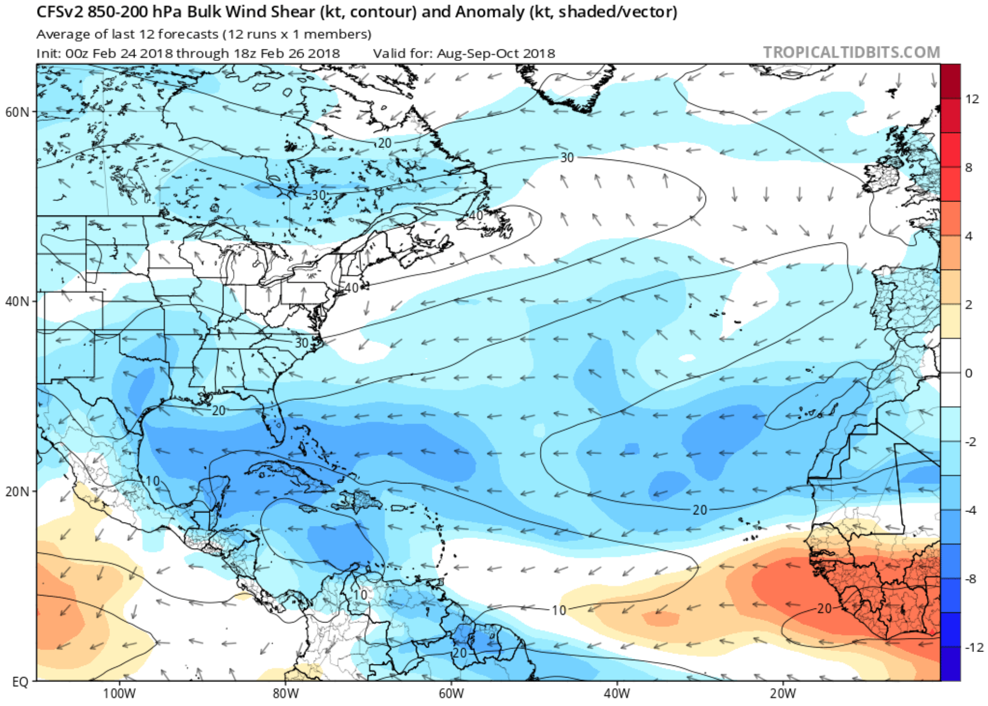


- Huge uncertainty for summer!

CFS ASO Seasonal Forecasts from Feb 26

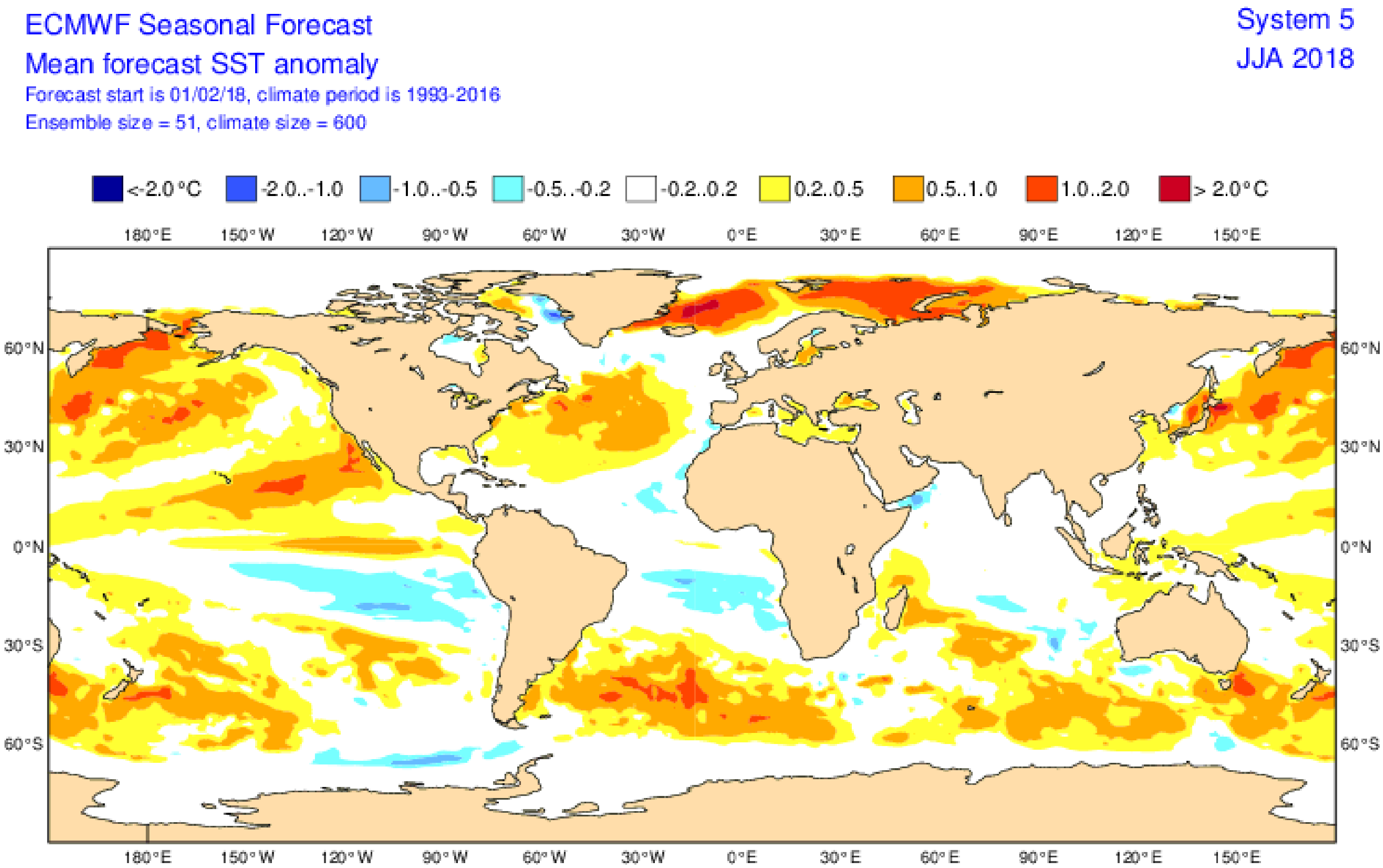
SST (warm Atlantic, neutral ENSO)





Vertical Shear (lower than normal)

ECMWF JJA SST forecast



Both CFS/EC agree on warm high latitude Atlantic, ENSO big unknown

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.
- 2018 appears to be less active than 2017 but how much so is an open question.