FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2019

We have maintained our forecast for a near-average 2019 Atlantic hurricane season. The tropical Atlantic currently has near-average sea surface temperatures. We believe that the odds of a weak El Niño persisting through August-October have diminished slightly. However, neither ENSO nor tropical Atlantic sea surface temperatures look particularly favorable for an active season. The probability for major hurricanes making landfall along the United States coastline and in the Caribbean remains near its long-term average. As is the case with all hurricane seasons, coastal residents are reminded that it only takes one hurricane making landfall to make it an active season for them. They should prepare the same for every season, regardless of how much activity is predicted.

(as of 9 July 2019)

By Philip J. Klotzbach[1], Michael M. Bell[2], and Jhordanne Jones[3]

In Memory of William M. Gray[4]

This discussion as well as past forecasts and verifications are available online at http://tropical.colostate.edu

Anne Manning, Colorado State University media representative, is coordinating media inquiries into this forecast. She can be reached at 970-491-7099 or anne.manning@colostate.edu.

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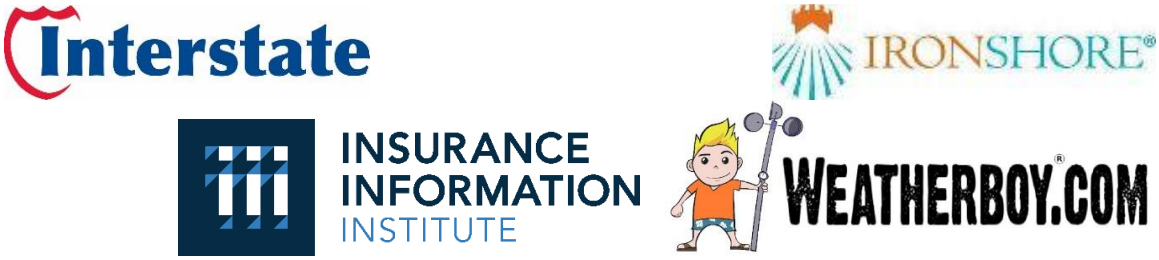

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2019*

Forecast Parameter and 1981-2010 Average (in parentheses)	Issue Date 4 April 2019	Issue Date 4 June 2019	Issue Date 9 July 2019	Observed Activity Through June 2019	9 July Forecast for Remainder of 2019
Named Storms (NS) (12.1)	13	14	14	1	13
Named Storm Days (NSD) (59.4)	50	55	55	0.75	54.25
Hurricanes (H) (6.4)	5	6	6	0	6
Hurricane Days (HD) (24.2)	16	20	20	0	20
Major Hurricanes (MH) (2.7)	2	2	2	0	2
Major Hurricane Days (MHD) (6.2)	4	5	5	0	5
Accumulated Cyclone Energy (ACE) (106)	80	100	100	1	99
Net Tropical Cyclone Activity (NTC) (116%)	90	105	105	3	102

*Seasonal forecast numbers in the first three forecast columns in the above table include tropical cyclones that formed prior to the date of the forecast release (e.g., Andrea in May).

PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING COASTAL AREAS:

1) Entire U.S. coastline - 54% (average for last century is 52%)

2) U.S. East Coast Including Peninsula Florida - 32% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 31% (average for last century is 30%)

PROBABILITY FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE TRACKING INTO THE CARIBBEAN (10-20°N, 60-88°W)

1) 44% (average for last century is 42%)

ABSTRACT

Information obtained through June 2019 indicates that the 2019 Atlantic hurricane season will have activity near the average 1981-2010 season. This revised prediction is the same as our forecast issued in early June. There remains some uncertainty with this forecast which we outline in the following paragraphs.

We estimate that 2019 will have an additional 6 hurricanes (average is 6.4), 13 named storms (average is 12.1), 54.25 named storm days (average is 59.4), 20 hurricane days (average is 24.2), 2 major (Category 3-4-5) hurricanes (average is 2.7) and 5 major hurricane days (average is 6.2). The probability of U.S. major hurricane landfall is estimated to be about 105 percent of the long-period average. We expect Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity for the remainder of the season to be approximately 95 percent of their long-term average values.

This forecast is based on an extended-range early July statistical prediction scheme that was developed utilizing 37 years of past data. Analog predictors are also utilized. We anticipate a near-average Atlantic basin hurricane season. The tropical Atlantic currently has sea surface temperatures near their long-term average. Near-average sea surface temperatures in the tropical Atlantic tend to be associated with near-average Atlantic hurricane seasons.

The odds of the currently-observed weak El Niño persisting for the peak of the Atlantic hurricane season in 2019 have decreased slightly. If El Niño were to persist, it would tend to lead to more vertical wind shear in the Caribbean extending into the tropical Atlantic, tearing apart hurricanes as they are trying to develop and intensify. Neither El Niño nor tropical Atlantic sea surface temperatures look to play either a significantly enhancing or diminishing role on the 2019 season. Consequently, we are forecasting a near-average season.

Coastal residents are reminded that it only takes one hurricane making landfall to make it an active season for them, and they need to prepare the same for every season, regardless of how much activity is predicted.

Acknowledgment

These seasonal forecasts were developed by the late Dr. William Gray, who was lead author on these predictions for over 20 years and continued as a co-author until his death in 2016. In addition to pioneering seasonal Atlantic hurricane prediction, he conducted groundbreaking research in a wide variety of other topics including hurricane genesis, hurricane structure and cumulus convection. His investments in both time and energy to these forecasts cannot be acknowledged enough.

We are grateful for support from Interstate Restoration, Ironshore Insurance, the Insurance Information Institute and Weatherboy that partially support the release of these predictions. We acknowledge a grant from the G. Unger Vetlesen Foundation for additional financial support. We thank the GeoGraphics Laboratory at Bridgewater State University (MA) for their assistance in developing the United States Landfalling Hurricane Probability Webpage (available online at http://www.e-transit.org/hurricane).

Colorado State University's seasonal hurricane forecasts have benefited greatly from a number of individuals that were former graduate students of William Gray. Among these former project members are Chris Landsea, John Knaff and Eric Blake. We have also benefited from meteorological discussions with Carl Schreck, Louis-Philippe Caron, Brian McNoldy, Paul Roundy, Jason Dunion, Peng Xian and Amato Evan over the past few years.

1 Introduction

This is the 37th year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. We have shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology.

2 July Forecast Methodology

2.1 July Statistical Forecast Scheme

Klotzbach (2014) developed a 1 July seasonal forecast model which was utilized for the first time in real time in 2016. This 1 July forecast is now based on 37 years of historical data since 1982 (Figure 1).

The model has been modified since Klotzbach (2014) to substitute daily NOAA Optimum Interpolation (NOAA OI) SST instead of ERA-Interim 2-meter temperature for the East Atlantic predictor. The primary reason why this was done is daily OI SST is available in real-time, while ERA-Interim is not available in real-time. ERA-Interim is generally preferred over the Climate Forecast System Reanalysis (CFSR) for statistical model development, as most geophysical parameters show slightly better correlations with Accumulated Cyclone Energy (ACE) when using ERA-Interim than they do with CFSR. We utilize the CFSR dataset to estimate the real-time values for our 2nd predictor which is surface pressure in the tropical equatorial Pacific. We replaced the 2nd predictor in the forecast model in 2016, as sea level pressure anomalies in the tropical Pacific likely have a stronger physical link with Atlantic hurricane activity than do upper-level winds in the tropical Indian Ocean.

Figure 2 displays the locations of our two 1 July predictors, while Table 1 displays the values of each predictor for the 2019 hurricane season. Table 2 displays the combination of the two predictors as model output for the 2019 Atlantic hurricane season. The May-June SST predictor in the eastern Atlantic is near-average this season, while the surface pressure predictor in the tropical eastern Pacific is below its long-term average value. Lower surface pressure in the eastern tropical equatorial Pacific tends to be associated with a less active Atlantic hurricane season. The two predictors combined call for a slightly below-average season.

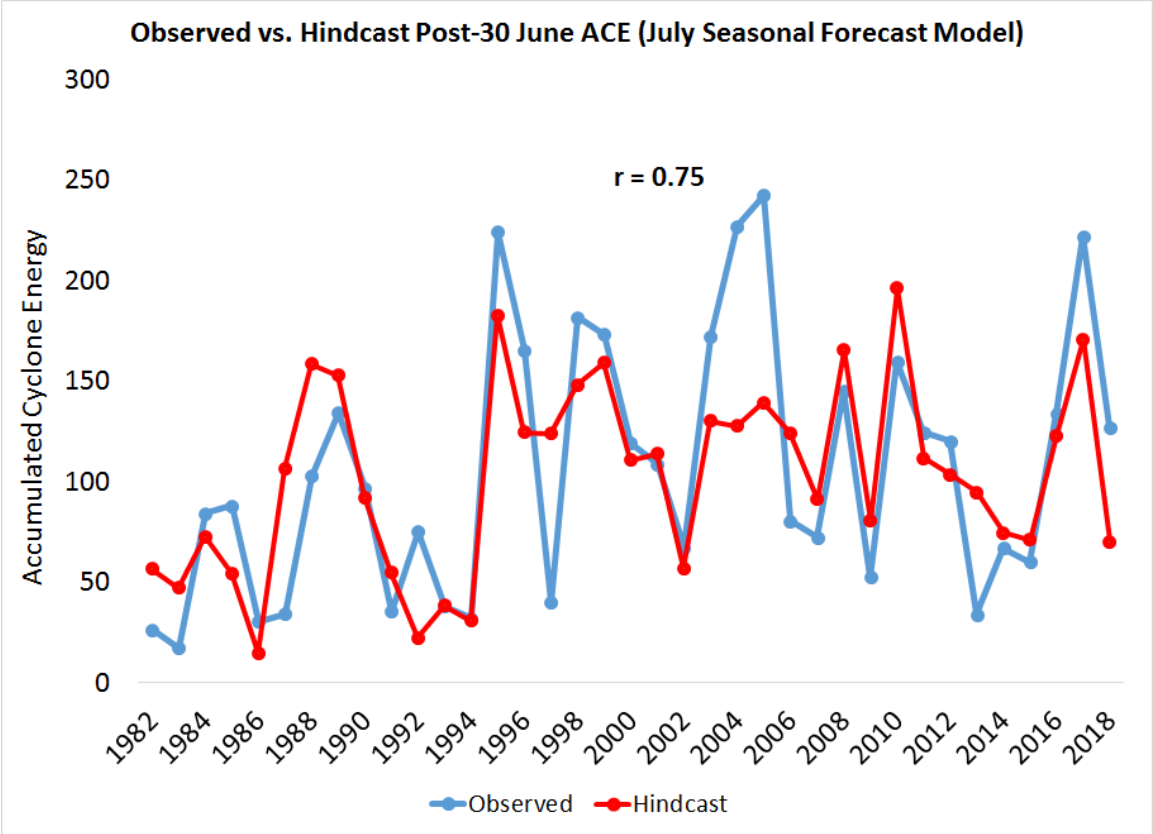

Figure 1: Observed versus early July jackknifed hindcast values of ACE for 1982-2018. The hindcast model explains approximately 55% of the variance from climatology.

July Forecast Predictors

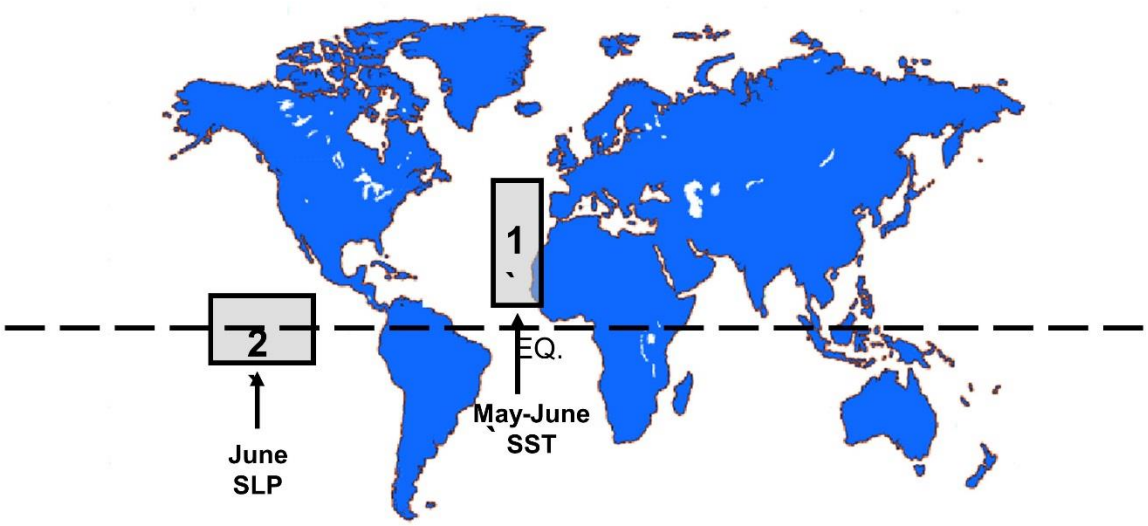

Figure 2: Location of predictors for the early July statistical prediction for the 2019 hurricane season.

Table 1: Listing of 1 July 2019 predictors for the 2019 hurricane season. A plus (+) means that positive values of the parameter indicate increased hurricane activity.

Predictor	2019 Forecast Value	Favorable/Unfavorable for TCs
1) May-June SST (10-50°N, 30-10°W) (+)	+0.2 SD	Neutral
2) June SLP (15°S-15°N, 150-110°W) (+)	-0.8 SD	Unfavorable

Table 2: 1 July statistical model output for the remainder of the 2019 Atlantic hurricane season.

Forecast Parameter and 1981-2010 Average (in parentheses)	Statistical Forecast
Named Storms (12.1)	12.0
Named Storm Days (59.4)	55.6
Hurricanes (6.4)	5.8
Hurricane Days (24.2)	20.1
Major Hurricanes (2.7)	2.2
Major Hurricane Days (6.2)	4.6
Accumulated Cyclone Energy Index (106)	90
Net Tropical Cyclone Activity (116%)	101

2.2 July Statistical/Dynamical Forecast Scheme

We have developed a new statistical/dynamical hybrid forecast model scheme this year. This model, developed in partnership with Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre, uses output from the ECMWF SEA5 model to forecast the input to our early August statistical forecast model. The early August statistical forecast model shows the highest level of skill of any of our statistical models, since it is the model released just before the peak of the Atlantic hurricane season in September. ECMWF SEA5 is able to forecast the large-scale fields that go into the early August statistical forecast model with considerable skill by March. This skill then improves as the peak of the hurricane season approaches. We then use the forecasts of the individual parameters to forecast ACE for the 2019 season. It typically takes about ten days after the initialization date to obtain SEA5 output, so the results displayed below are from the model output from the 1 June forecast.

Figure 3 displays the parameters used in our early August statistical model, while Table 3 displays SEA5's forecasts of these parameters for 2019. SEA5 is calling for above-average trade wind strength, which is typically associated with quieter Atlantic hurricane seasons. However, the model is also calling for above-normal 2-meter temperatures in the eastern subtropical Atlantic and near-normal zonal wind over western tropical Africa. The average of these three predictors yields a near-normal forecast for the 2019 hurricane season. Figure 4 displays hindcast data of the SEA5 forecast of ACE from 1981-2018. Table 4 presents the statistical model output based off of the SEA5 forecast.

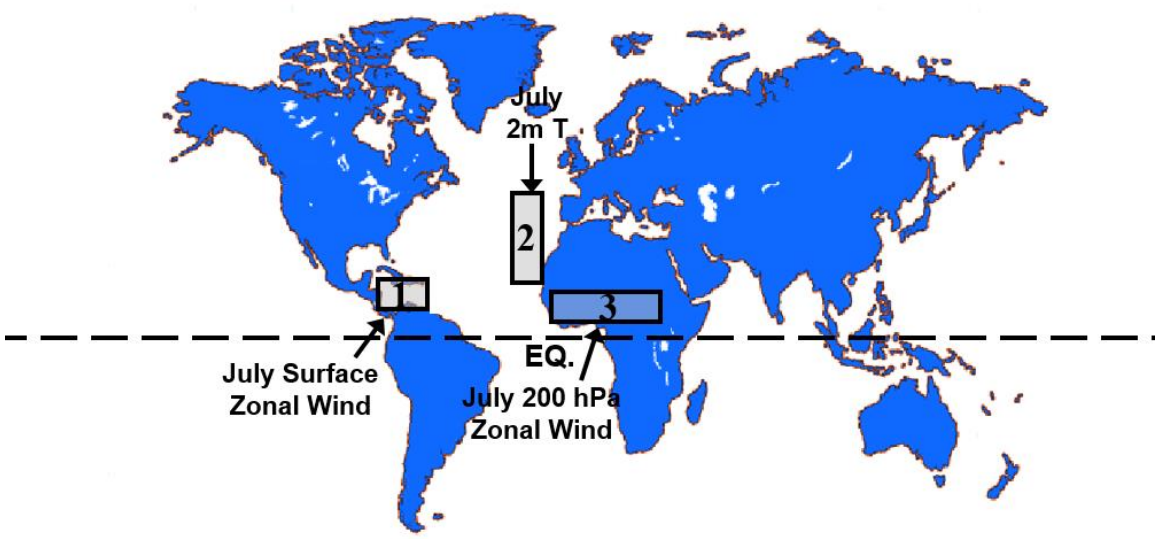

Figure 3: Location of predictors for our August statistical/dynamical extended-range statistical prediction for the 2019 hurricane season. This forecast uses ECMWF SEA5 to predict July conditions in the three boxes displayed and uses those predictors to forecast ACE.

Table 3: Listing of predictions of July large-scale conditions from ECMWF SEA5 output, initialized on 1 June. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2019 Forecast	Effect on 2019 Hurricane Season
1) SEA5 Prediction of July Surface U (10-17.5°N, 60-85°W) (+)	-1.2 SD	Suppress
2) SEA5 Prediction of July 2-Meter Temperature (20-40°N, 15-35°W) (+)	+0.6 SD	Enhance
3) SEA5 Prediction of July 200 mb U (5-15°N, 0-40°E) (-)	+0.2 SD	Neutral

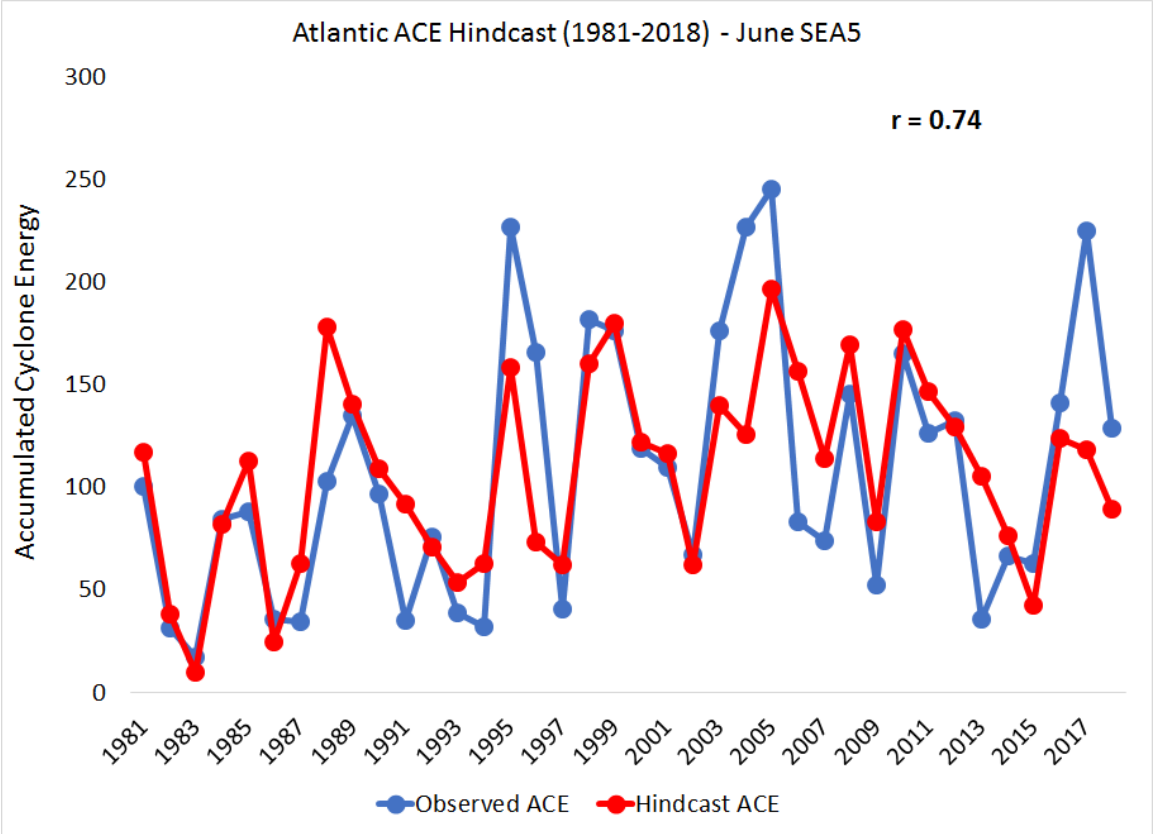

Figure 4: Observed versus hindcast ACE values using the statistical/dynamical hybrid model, initialized on 1 June.

Table 4: Statistical/dynamical model output for the 2019 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1981-2010 Average (in parentheses)	Statistical/Dynamical Hybrid Forecast	Final Forecast
Named Storms (12.1)	12.2	14
Named Storm Days (59.4)	57.3	55
Hurricanes (6.4)	5.9	6
Hurricane Days (24.2)	21.0	20
Major Hurricanes (2.7)	2.3	2
Major Hurricane Days (6.2)	4.9	5
Accumulated Cyclone Energy Index (106)	94	100
Net Tropical Cyclone Activity (116%)	105	105

2.3 July Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2019. These years also provide useful clues as to likely trends in

activity that the forthcoming 2019 hurricane season may bring. For this early July extended range forecast, we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current May-June 2019 conditions as well as what we anticipate will be present during August-October. Table 5 lists our analog selections.

We select prior hurricane seasons since 1950 which have similar atmospheric-oceanic conditions to those currently being experienced. We searched for years that were generally characterized by neutral to weak El Niño conditions and near-average tropical Atlantic SST conditions.

There were five hurricane seasons since 1950 with characteristics most similar to what we expect to see in August-October of 2019. We anticipate that the 2019 hurricane season will have activity slightly above the average of our five analog years. We believe that this season should experience near-average activity.

Table 5: Best analog years for 2019 with the associated full-season hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1990	14	72.25	8	26.75	1	1.00	97	100
1993	8	29.75	4	9.50	1	0.75	38	52
2009	9	30.00	3	12.00	2	3.50	53	70
2014	8	35.00	6	17.75	2	3.75	67	82
2018	15	86.75	8	27.50	2	5.25	133	129
Average	10.8	50.75	5.8	18.7	1.6	2.9	78	87
2019 Forecast	**14**	**55**	**6**	**20**	**2**	**5**	**100**	**105**

2.4 July Forecast Summary and Final Adjusted Forecast

Table 6 shows our final adjusted early June forecast for the 2019 season which is a combination of our statistical scheme, our statistical/dynamical scheme, our analog scheme and qualitative adjustments for other factors not explicitly contained in any of these schemes. All three schemes call for slightly below- to near-average activity. Our forecast is close to the average of the three schemes and also calls for a near-average season, due to what we anticipate will be either neutral ENSO or weak El Niño conditions and near-average tropical Atlantic SST conditions for the peak of the Atlantic hurricane season (August-October).

Table 6: Summary of our early July statistical forecast, our statistical/dynamical forecast, our analog forecast, the average of those three schemes and our adjusted final forecast for the 2019 hurricane season.

Forecast Parameter and 1981-2010 Average (in parentheses)	Statistical Scheme	Statistical/ Dynamical Scheme	Analog Scheme	Average of Three Schemes	Adjusted Final Forecast
Named Storms (12.1)	12.0	12.2	10.8	11.7	14
Named Storm Days (59.4)	55.6	57.3	50.8	54.6	55
Hurricanes (6.4)	5.8	5.9	5.8	5.9	6
Hurricane Days (24.2)	20.1	21.0	18.7	19.9	20
Major Hurricanes (2.7)	2.2	2.3	1.6	2.0	2
Major Hurricane Days (6.2)	4.6	4.9	2.9	4.1	5
Accumulated Cyclone Energy Index (106)	90	94	78	87	100
Net Tropical Cyclone Activity (116%)	101	105	87	98	105

3 Forecast Uncertainty

One of the questions that we are asked regarding our seasonal hurricane predictions is the degree of uncertainty that is involved. Our predictions are our best estimate, but there is with all forecasts an uncertainty as to how well they will verify.

Table 7 provides our early July forecasts, with error bars based on one standard deviation of the 1982-2010 cross-validated hindcast error. We typically expect to see 2/3 of our forecasts verify within one standard deviation of observed values, with 95% of forecasts verifying within two standard deviations of observed values.

Table 7: Model hindcast error and our 2019 hurricane forecast (including Andrea). Uncertainty ranges are given in one standard deviation (SD) increments.

Parameter	Hindcast Error (SD)	2019 Forecast	Uncertainty Range – 1 SD (67% of Forecasts Likely in this Range)
Named Storms (NS)	3	14	11 – 17
Named Storm Days (NSD)	19	55	36 – 74
Hurricanes (H)	2	6	4 – 8
Hurricane Days (HD)	10	20	10 – 30
Major Hurricanes (MH)	1	2	1 – 3
Major Hurricane Days (MHD)	4	5	1 – 9
Accumulated Cyclone Energy (ACE)	42	100	58 – 142
Net Tropical Cyclone (NTC) Activity	41	105	64 – 146

4 ENSO

The tropical Pacific currently is characterized by weak El Niño conditions. There has been a decrease in upper ocean heat content over the past several months, with

current values of upper ocean heat content indicating a potential transition to neutral ENSO (Figure 5).

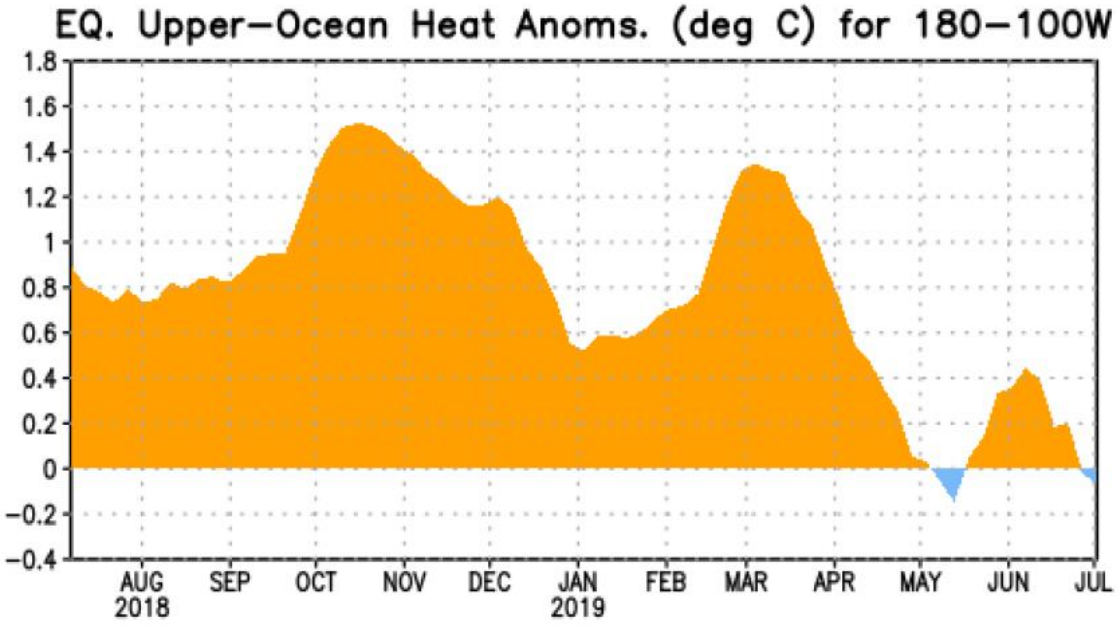

Figure 5: Central and eastern tropical Pacific upper ocean (0-300 meters) heat content anomalies over the past year. After a brief increase in upper ocean heat content anomalies in late May/early June, upper ocean heat content anomalies have recently decreased to slightly below-average levels. Figure courtesy of the Climate Prediction Center.

Currently, SST anomalies are running about 0.5-0.8°C above normal across most of the eastern and central tropical Pacific, with below-average SSTs right along the west coast of South American in the Nino 1+2 region. Table 8 displays the May and June SST anomalies across the tropical Pacific. There has been a slight cooling of SST anomalies in the eastern tropical Pacific, while central tropical Pacific SST anomalies have remained nearly constant.

Table 8: May and June SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. June minus May SST anomaly differences are also provided.

Region	May SST Anomaly (°C)	June SST Anomaly (°C)	June minus May SST Anomaly (°C)
Nino 1+2	+0.1	-0.2	-0.3
Nino 3	+0.6	+0.5	-0.1
Nino 3.4	+0.7	+0.7	0.0
Nino 4	+0.8	+0.8	0.0

The models are about evenly split whether the current weak El Niño event (0.5 - 1°C) will persist or a neutral ENSO event (-0.5 - 0.5°C) will characterize the peak of the

Atlantic hurricane season from August-October (Figure 6). A weak El Niño event could potentially make conditions more detrimental for Atlantic hurricane activity.

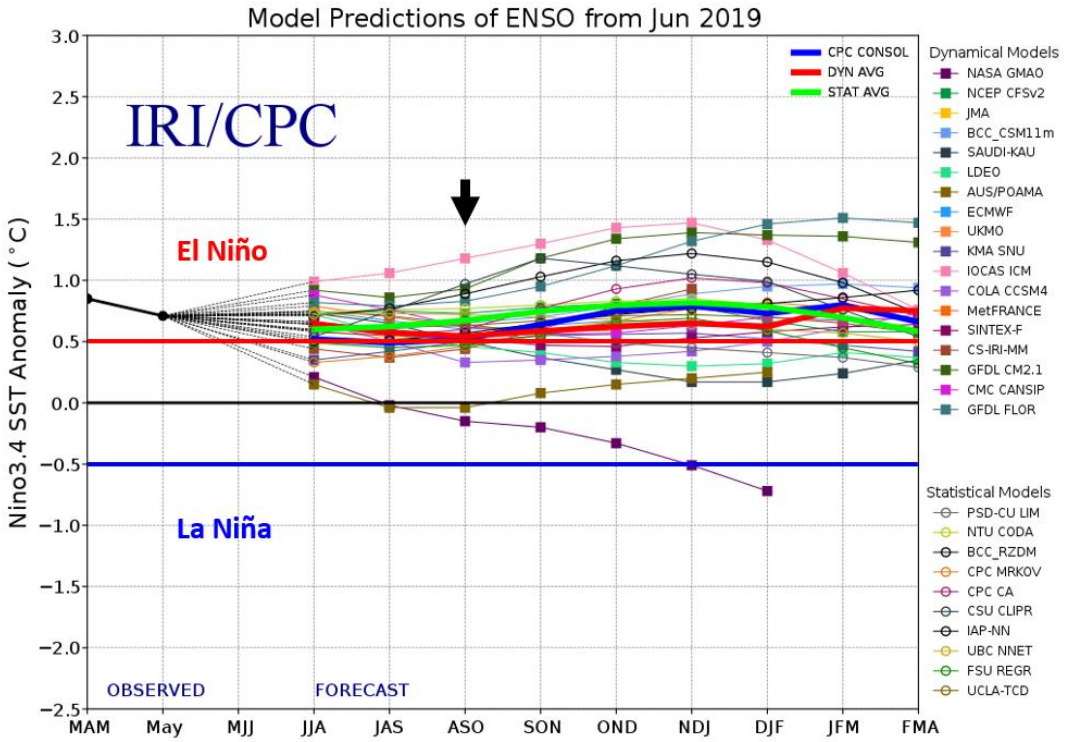

Figure 6: ENSO forecasts from a variety of dynamical and statistical models. Figure courtesy of International Research Institute/Climate Prediction Center. The black arrow highlights the peak of the Atlantic hurricane season (August-October).

Based on the above information, our best estimate is that we will have either warm neutral or weak El Niño conditions in place for the peak of the 2019 Atlantic hurricane season. Additional discussion of ENSO will be included with the 5 August update.

5 Current Atlantic Basin Conditions

Tropical Atlantic SSTs and far North Atlantic SSTs are currently near average when averaged across longitudinal bands (Figure 7). However, the current SST anomaly pattern is also relatively inhomogeneous, with areas of above-normal and below-normal SSTs over fairly small regions. The current SST anomaly pattern in the tropical Atlantic and the far North Atlantic does not correlate strongly with above-normal hurricane seasons (Figure 8).

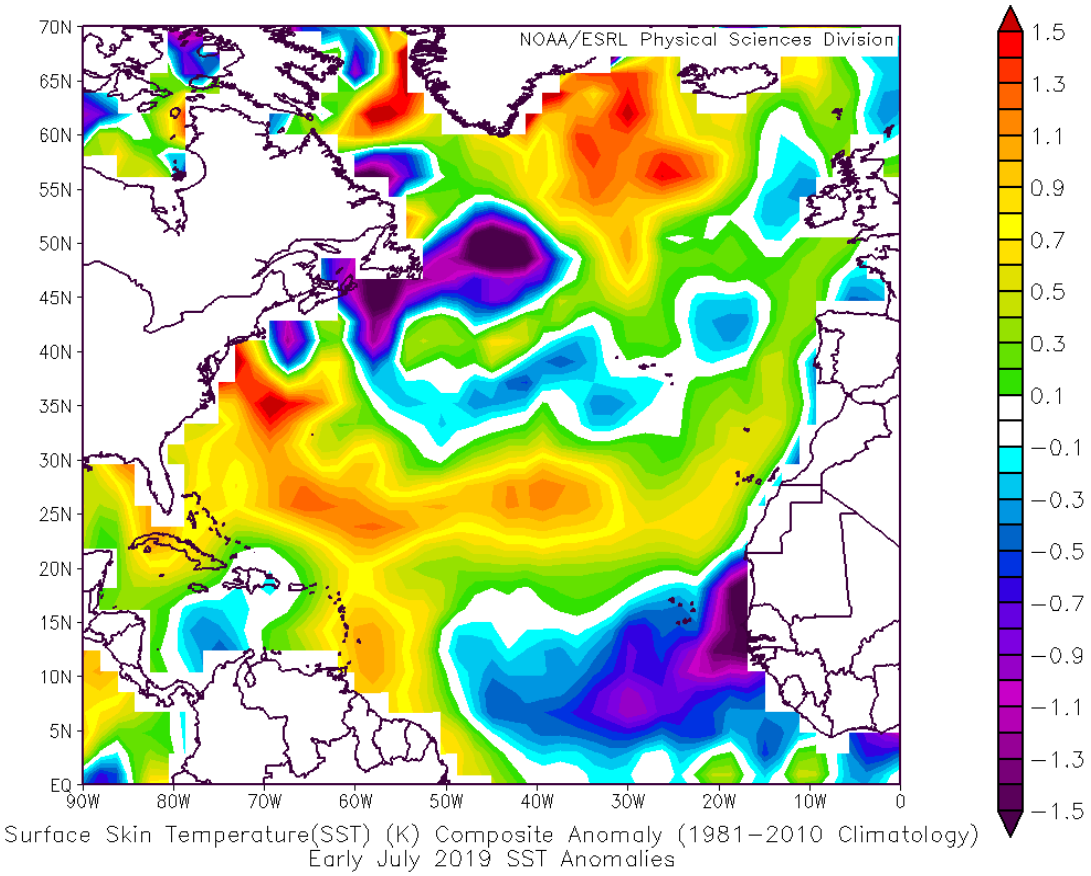

Figure 7: Early July 2019 SST anomalies across the Atlantic.

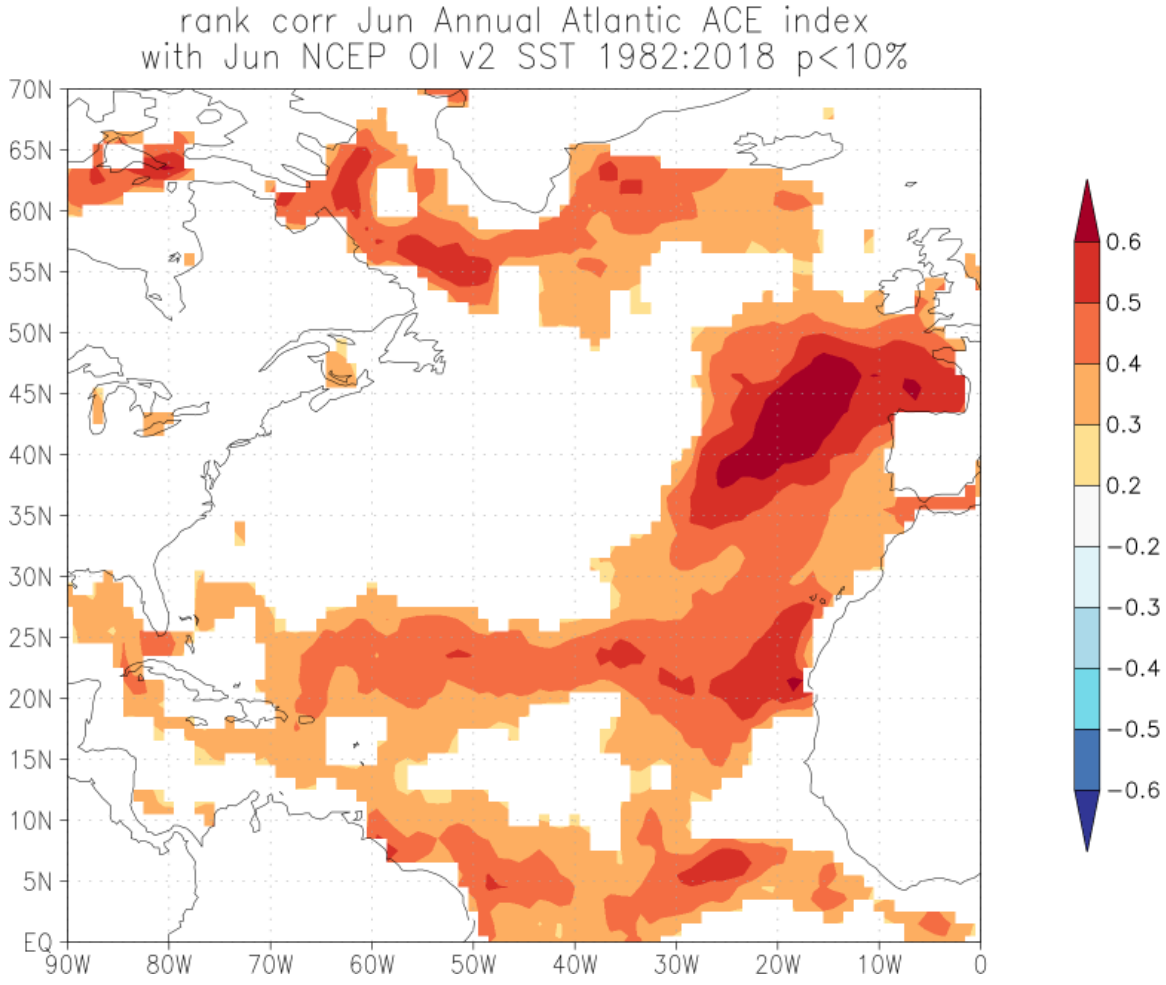

Figure 8: Rank correlation map between June SSTs and annual Atlantic ACE.

A colder-than-normal tropical Atlantic inhibits hurricane formation for several reasons. In addition to colder water providing less fuel for developing tropical cyclones, it also is typically characterized by higher sea level pressure anomalies as well as drier air masses and more subsidence. Drier and more stable air suppresses deep thunderstorm formation which are the building blocks of hurricanes. June sea level pressure anomalies were slightly above-average in the Main Development Region (MDR) (10-20°N, 60-20°W) (Figure 9). The tropical Atlantic has been much more stable than normal, as evidenced by below-average vertical instability (Figure 10).

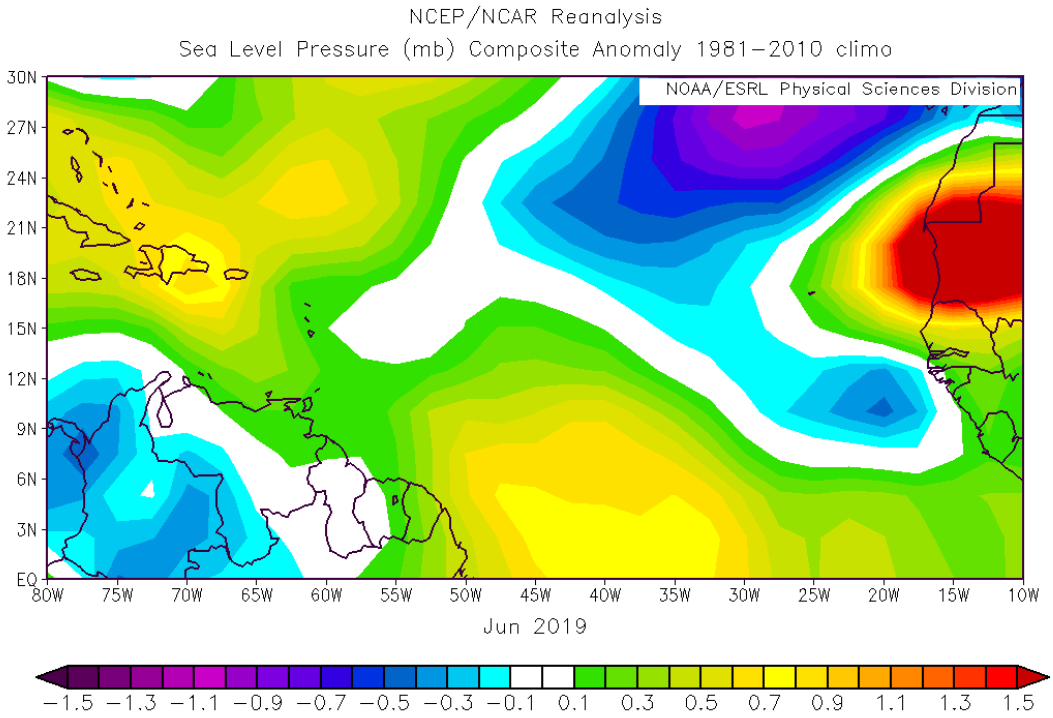

Figure 9: Sea level pressure anomalies across the tropical Atlantic during June 2019. Sea level pressure anomalies were slightly above-average in the MDR during the month.

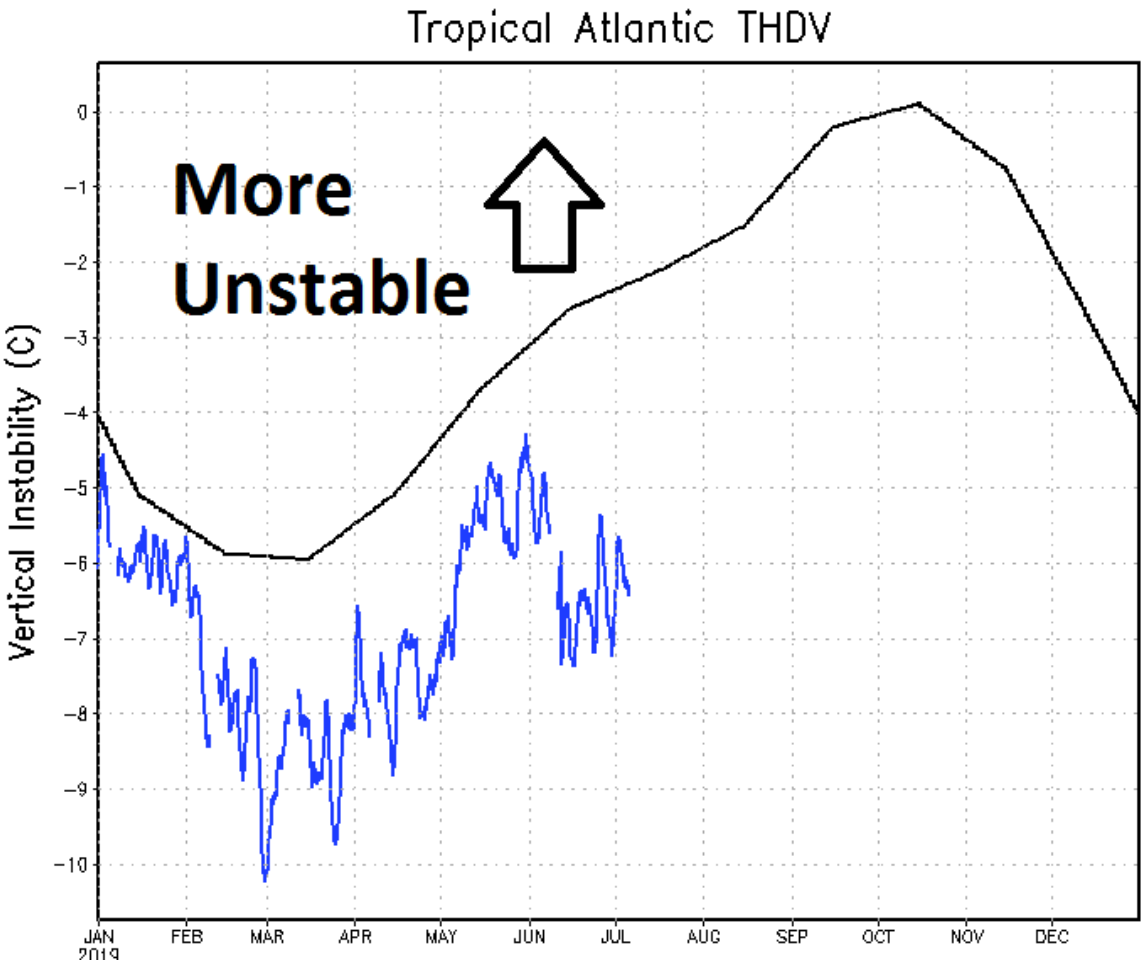

Figure 10: Vertical instability as measured across the tropical Atlantic in 2019. The atmosphere has generally been more stable than normal for the entire year, with the tropical Atlantic being quite stable currently. Figure courtesy of the Cooperative Institute for Research in the Atmosphere (CIRA).

Levels of vertical wind shear across the Caribbean have been well above-average while they have been near normal across the tropical Atlantic over the past 30 days (Figure 11). In general, the correlation between shear and Atlantic ACE is stronger in the Caribbean than it is in the tropical Atlantic. The relationship between shear and Atlantic hurricanes is much stronger in July than it is in June.

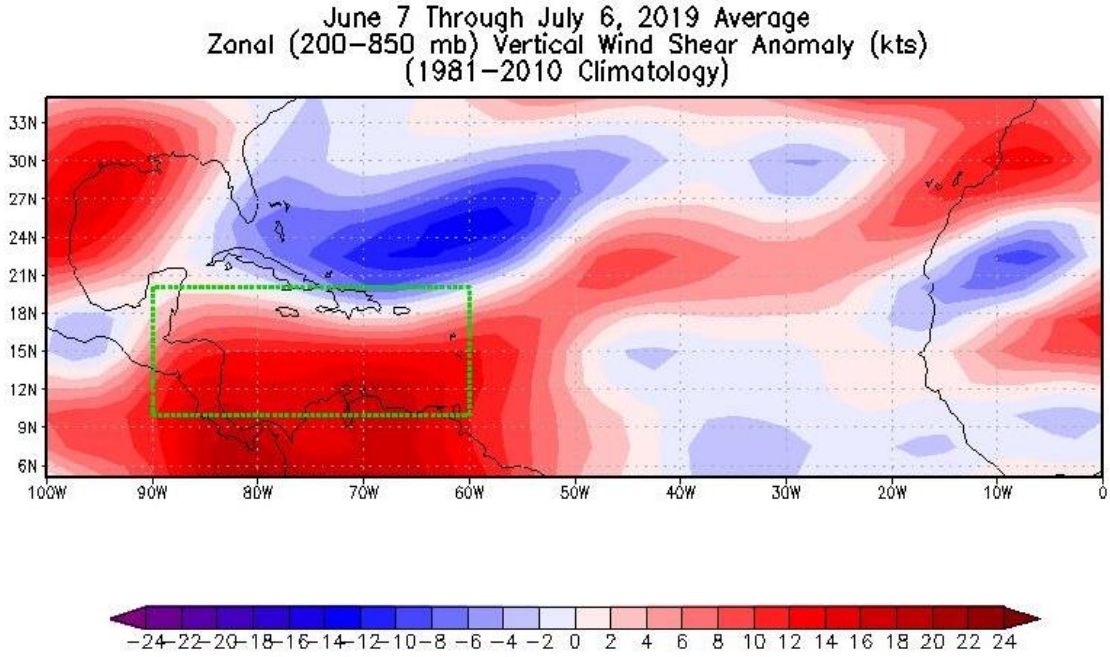

Figure 11: Recent 30-day anomalies of zonal vertical wind shear across the tropical Atlantic and Caribbean differenced from the 1981-2010 climatology.

6 Forthcoming Updated Forecasts of 2019 Hurricane Activity

We will be issuing a final seasonal update of our 2019 Atlantic basin hurricane forecasts on **Monday, 5 August**. We will also be releasing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August-October. A verification and discussion of all 2019 forecasts will be issued in late November 2019. All of these forecasts are available online.