EXTENDED RANGE FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2020

We have maintained our above-average seasonal hurricane forecast for the 2020 Atlantic season. Current cool neutral ENSO conditions may transition to weak La Niña conditions by later this summer. Sea surface temperatures averaged across most of the tropical Atlantic and subtropical Atlantic are somewhat above normal. We anticipate an above-normal probability for major hurricanes making landfall along the continental United States coastline and in the Caribbean. 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 7 July 2020)

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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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2020

Forecast Parameter and 1981-2010 Average (in parentheses)	Issue Date 2 April 2020	Issue Date 4 June 2020	Issue Date 7 July 2020	Observed Thru 6 July 2020	Remainder of Season Forecast
Named Storms (NS) (12.1)	16	19	20*	5	15
Named Storm Days (NSD) (59.4)	80	85	85	9.50	75.50
Hurricanes (H) (6.4)	8	9	9	0	9
Hurricane Days (HD) (24.2)	35	40	40	0	40
Major Hurricanes (MH) (2.7)	4	4	4	0	4
Major Hurricane Days (MHD) (6.2)	9	9	9	0	9
Accumulated Cyclone Energy (ACE) (106)	150	160	160	7	153
Net Tropical Cyclone Activity (NTC) (116%)	160	170	170	12	158

*Total forecast includes Arthur, Bertha, Cristobal, Dolly and Edouard which have formed in the Atlantic as of July 6th.

PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING COASTAL AREAS (AFTER 7 JULY):

1) Entire continental U.S. coastline - 69% (average for last century is 52%)

2) U.S. East Coast Including Peninsula Florida - 45% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 44% (average for last century is 30%)

PROBABILITY FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE TRACKING INTO THE CARIBBEAN (10-20°N, 88-60°W) (AFTER 7 JULY):

1) 58% (average for last century is 42%)

ABSTRACT

Information obtained through June 2020 indicates that the 2020 Atlantic hurricane season will have activity above the 1981-2010 average. Tropical Storms Arthur, Bertha Cristobal, Dolly and Edouard have formed in the Atlantic as of July 6th. We estimate that 2020 will have an additional 9 hurricanes (full season average is 6.4), 15 named storms (average is 12.1), 75.50 named storm days (average is 59.4), 40 hurricane days (average is 24.2), 4 major (Category 3-4-5) hurricanes (average is 2.7) and 9 major hurricane days (average is 6.2). The probability of U.S. major hurricane landfall is estimated to be about 135 percent of the long-period average. We expect Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity in 2020 to be approximately 150 percent of their long-term averages.

This forecast is based on a new extended-range early July statistical prediction scheme that was developed using 38 years of past data. Analog predictors are also utilized. We are also including statistical/dynamical models based off data from both the ECMWF SEAS5 model and the Met Office GloSea5 model as two additional forecast guidance tools.

Sea surface temperatures averaged across the eastern and central tropical Pacific are slightly cooler than average, and it appears likely that there will be either cool neutral ENSO or weak La Niña conditions during the remainder of the summer extending into the fall. The tropical Atlantic is somewhat warmer than normal, while the subtropical Atlantic is quite warm. Most of the eastern Atlantic is warmer than normal, and anomalously warm temperatures in this region in June have been typically associated with more active Atlantic hurricane seasons.

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.

The early July forecast has relatively good long-term skill when evaluated in hindcast mode. The skill of CSU's forecast updates typically increases as the peak of the Atlantic hurricane season approaches. For the first time this year, we are also presenting probabilities of exceedance for hurricanes and Accumulated Cyclone Energy to give interested readers a better idea of the uncertainty associated with these forecasts.

Why issue extended-range forecasts for seasonal hurricane activity?

We are frequently asked this question. Our answer is that it is possible to say something about the probability of the coming year's hurricane activity which is superior to climatology. The Atlantic basin has the largest year-to-year variability of any of the global tropical cyclone basins. People are curious to know how active the upcoming season is likely to be, particularly if you can show hindcast skill improvement over climatology for many past years.

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early July. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged as regards to the probability of an active or inactive hurricane season for the coming year. Our early July statistical and statistical/dynamical hybrid models show strong evidence on nearly 40 years of data that significant improvement over a climatological forecast can be attained. We would never issue a seasonal hurricane forecast unless we had models developed over a long hindcast period which showed skill. We also now include probabilities of exceedance to provide a visualization of the uncertainty associated with these predictions.

We issue these forecasts to satisfy the curiosity of the general public and to bring attention to the hurricane problem. There is a general interest in knowing what the odds are for an active or inactive season. One must remember that our forecasts are based on the premise that those global oceanic and atmospheric conditions which preceded comparatively active or inactive hurricane seasons in the past provide meaningful information about similar trends in future seasons.

It is also important that the reader appreciate that these seasonal forecasts are based on statistical and dynamical models which will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin these storms will strike. The probability of landfall for any one location along the coast is very low and reflects the fact that, in any one season, most U.S. coastal areas will not feel the effects of a hurricane no matter how active the individual season is.

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, and the Insurance Information Institute. 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 would like to acknowledge assistance from Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre for providing data and insight on the statistical/dynamical models. 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.

DEFINITIONS AND ACRONYMS

Accumulated Cyclone Energy (ACE) - A measure of a named storm's potential for wind and storm surge destruction defined as the sum of the square of a named storm's maximum wind speed (in 10^4 knots^2) for each 6-hour period of its existence. The 1981-2010 average value of this parameter is 106 for the Atlantic basin.

Atlantic Multi-Decadal Oscillation (AMO) – A mode of natural variability that occurs in the North Atlantic Ocean and evidencing itself in fluctuations in sea surface temperature and sea level pressure fields. The AMO is likely related to fluctuations in the strength of the oceanic thermohaline circulation. Although several definitions of the AMO are currently used in the literature, we define the AMO based on North Atlantic sea surface temperatures from 50-60°N, 50-10°W and sea level pressure from 0-50°N, 70-10°W.

Atlantic Basin – The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño – A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years on average.

Hurricane (H) - A tropical cyclone with sustained low-level winds of 74 miles per hour (33 ms^{-1} or 64 knots) or greater.

Hurricane Day (HD) - A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or is estimated to have hurricane-force winds.

Indian Ocean Dipole (IOD) - An irregular oscillation of sea surface temperatures between the western and eastern tropical Indian Ocean. A positive phase of the IOD occurs when the western Indian Ocean is anomalously warm compared with the eastern Indian Ocean.

Madden Julian Oscillation (MJO) – A globally propagating mode of tropical atmospheric intra-seasonal variability. The wave tends to propagate eastward at approximately 5 ms^{-1}, circling the globe in roughly 30-60 days.

Main Development Region (MDR) – An area in the tropical Atlantic where a majority of major hurricanes form, which we define as 7.5-22.5°N, 75-20°W.

Major Hurricane (MH) - A hurricane which reaches a sustained low-level wind of at least 111 mph (96 knots or 50 ms^{-1}) at some point in its lifetime. This constitutes a category 3 or higher on the Saffir/Simpson scale.

Major Hurricane Day (MHD) - Four 6-hour periods during which a hurricane has an intensity of Saffir/Simpson category 3 or higher.

Multivariate ENSO Index (MEI) – An index defining ENSO that takes into account tropical Pacific sea surface temperatures, sea level pressures, zonal and meridional winds and cloudiness.

Named Storm (NS) - A hurricane, a tropical storm or a sub-tropical storm.

Named Storm Day (NSD) - As in HD but for four 6-hour periods during which a tropical or sub-tropical cyclone is observed (or is estimated) to have attained tropical storm-force winds.

Net Tropical Cyclone (NTC) Activity –Average seasonal percentage mean of NS, NSD, H, HD, MH, MHD. Gives overall indication of Atlantic basin seasonal hurricane activity. The 1950-2000 average value of this parameter is 100.

Proxy – An approximation or a substitution for a physical process that cannot be directly measured.

Saffir/Simpson Hurricane Wind Scale – A measurement scale ranging from 1 to 5 of hurricane wind intensity. One is a weak hurricane; whereas, five is the most intense hurricane.

Southern Oscillation Index (SOI) – A normalized measure of the surface pressure difference between Tahiti and Darwin. Low values typically indicate El Niño conditions.

Standard Deviation (SD) – A measure used to quantify the variation in a dataset.

Sea Surface Temperature Anomaly – SSTA

Thermohaline Circulation (THC) – A large-scale circulation in the Atlantic Ocean that is driven by fluctuations in salinity and temperature. When the THC is stronger than normal, the AMO tends to be in its warm (or positive) phase, and more Atlantic hurricanes typically form.

Tropical Cyclone (TC) - A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms and other weaker rotating vortices.

Tropical North Atlantic (TNA) index – A measure of sea surface temperatures in the area from 5.5-23.5°N, 57.5-15°W.

Tropical Storm (TS) - A tropical cyclone with maximum sustained winds between 39 mph (18 ms^{-1} or 34 knots) and 73 mph (32 ms^{-1} or 63 knots).

Vertical Wind Shear – The difference in horizontal wind between 200 hPa (approximately 40000 feet or 12 km) and 850 hPa (approximately 5000 feet or 1.6 km).

1 knot = 1.15 miles per hour = 0.515 meters per second

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. Our research team has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. This year's July forecast is based on a new statistical methodology as well as output from two statistical/dynamical models calculated from the SEAS5 climate model from the European Centre for Medium Range Weather Forecasts (ECMWF) and the GloSea5 model from the UK Met Office. These models show skill on 25-40 years of historical data, depending on the particular forecast technique. We also select analog seasons, based primarily on conditions we anticipate for the peak of the Atlantic hurricane season. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by these analyses. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic basin TC activity and landfall probability. We believe that seasonal forecasts must be based on methods that show significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided that the atmosphere continues to behave in the future as it has in the past.

The best predictors do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain the portion of the variance of seasonal hurricane activity that are not associated with the other forecast variables. It is possible for an important hurricane forecast parameter to show little direct relationship to a predictand by itself but to have an important influence when included with a set of 2-3 other predictors.

A direct correlation of a forecast parameter may not be the best measure of the importance of this predictor to the skill of a 3-4 parameter forecast model. This is the nature of the seasonal or climate forecast problem where one is dealing with a very complicated atmospheric-oceanic system that is highly non-linear. There is a maze of changing physical linkages between the many variables. These linkages can undergo unknown changes from weekly to decadal time scales. It is impossible to understand how all of these processes interact with each other. But, it is still possible to develop a reliable statistical forecast scheme which incorporates a number of the climate system's non-linear interactions. Any seasonal or climate forecast scheme should show significant hindcast skill before it is used in real-time forecasts.

2 July Forecast Methodology

2.1 July Statistical Forecast Scheme

We are debuting a new July statistical forecast scheme this year that has been developed over the period from 1982-2019. The model uses the newly-released ECMWF Reanalysis 5 (ERA5) (https://confluence.ecmwf.int/display/CKB/ERA5%3A+data+documentation) as well as NOAA Optimum Interpolation (OI) SST (Reynolds et al. 2002). The ERA5 reanalysis currently extends from 1979 to present and will be extended back to 1950 in the upcoming months. A benefit of the ERA5 reanalysis is that it is the first reanalysis from ECMWF that provides updates in near real-time, allowing for the same reanalysis product to be used for both hindcast model development as well as real-time analysis. The NOAA OISST (Reynolds et al. 2002) is available from 1982-present. This new model showed significant skill in cross-validated (e.g., leaving the year out of the developmental model that is being predicted) hindcasts of Accumulated Cyclone Energy (ACE) (r = 0.78) over the period from 1982-2019.

Figure 2 displays the locations of each of our predictors, while Table 1 displays the individual linear correlations between each predictor and ACE over the 1982-2019 hindcast period. All predictors correlate significantly at the 5% level using a two-tailed Student's t-test and assuming that each year is independent of the prior year (e.g., the correlation between ACE in two consecutive years is very low). Table 2 displays the 2020 observed values for each of the four predictors in the statistical forecast scheme. Table 3 displays the statistical model output for the 2020 hurricane season. Three of the four predictors call for increased Atlantic hurricane activity in 2020.

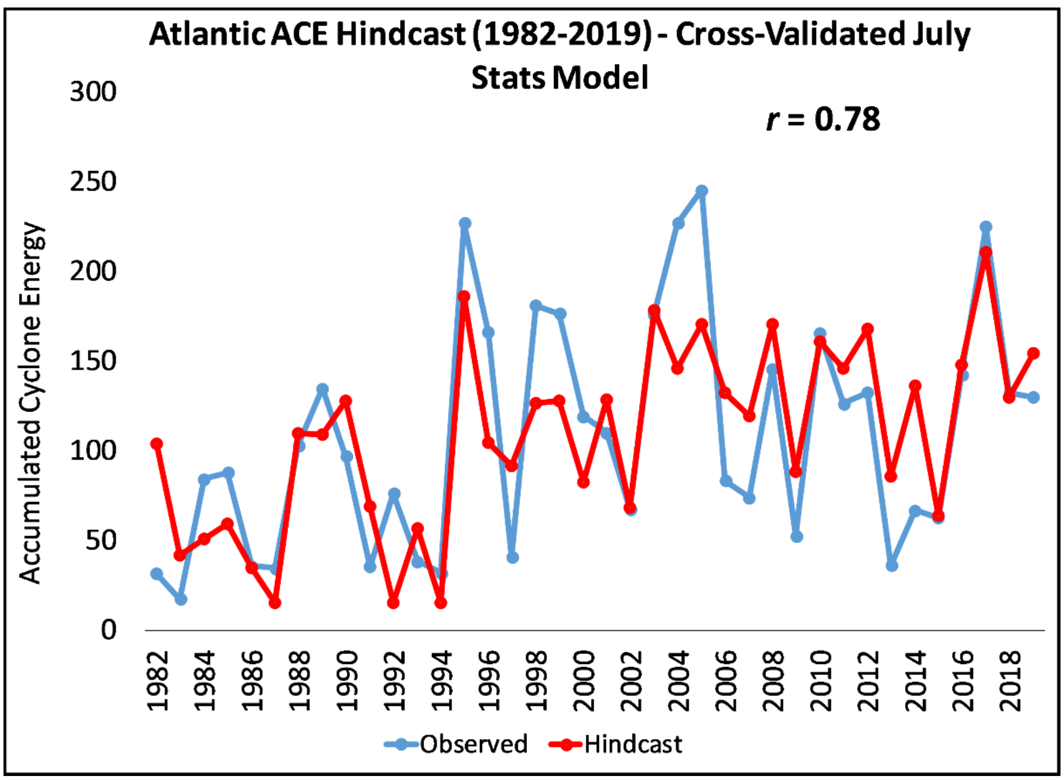

Figure 1: Observed versus early July cross-validated hindcast values of ACE for the statistical model for 1982-2019.

July Forecast Predictors

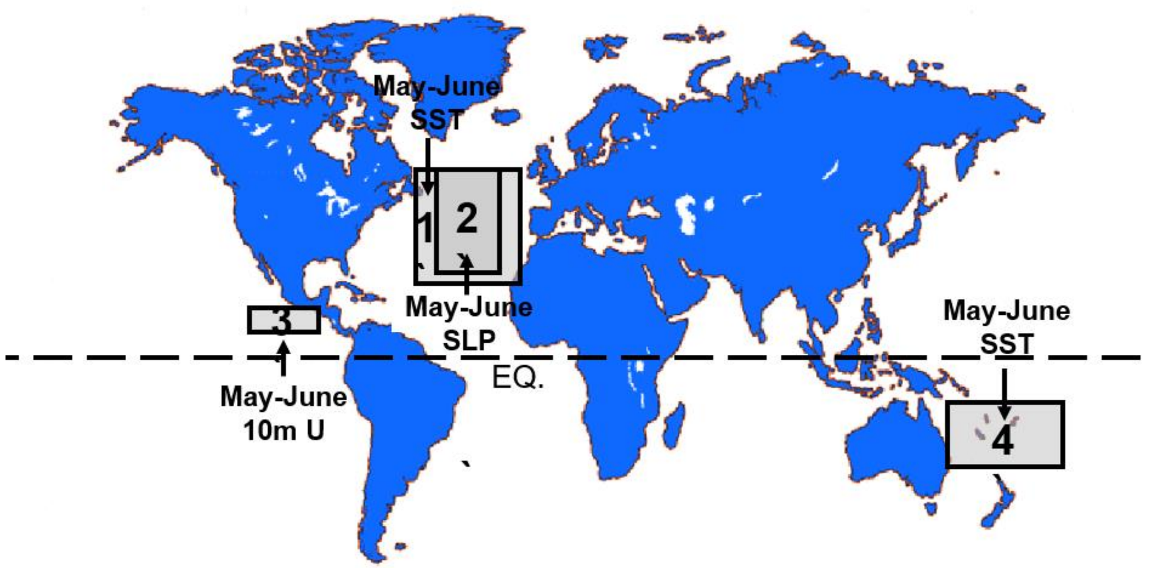

Figure 2: Location of predictors for our early July extended-range statistical prediction for the 2020 hurricane season.

Table 1: Rank correlations between early July predictors and ACE over the period from 1982-2019.

Predictor	Rank Correlation w/ ACE
1) May-June SST (20°N-50°N, 30°W-15°W) (+)	0.64
2) May-June SLP (25°N-50°N, 50°W-30°W) (-)	-0.42
3) May-June 10m U (5°N-10°N, 120°W-90°W) (-)	0.59
4) May-June SST (35°S-15°S, 155°E-180°E) (+)	0.59

Table 2: Listing of early July 2020 predictors for the 2020 hurricane season. 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. SD stands for standard deviation.

Predictor	2020 Forecast Value	Impact on 2020 TC Activity
1) May-June SST (20°N-50°N, 30°W-15°W) (+)	+1.2 SD	Enhance
2) May-June SLP (25°N-50°N, 50°W-30°W) (-)	+1.2 SD	Suppress
3) May-June 10m U (5°N-10°N, 120°W-90°W) (+)	+0.9 SD	Enhance
4) May-June SST (35°S-15°S, 155°E-180°E) (+)	+1.2 SD	Enhance

Table 3: Statistical model output for the 2020 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1981-2010 Average (in parentheses)	Statistical Forecast	Final Forecast
Named Storms (NS) (12.1)	15.5	20
Named Storm Days (NSD) (59.4)	81.5	85
Hurricanes (H) (6.4)	8.5	9
Hurricane Days (HD) (24.2)	35.0	40
Major Hurricanes (MH) (2.7)	3.9	4
Major Hurricane Days (MHD) (6.2)	10.0	9
Accumulated Cyclone Energy (ACE) (106)	154	160
Net Tropical Cyclone Activity (NTC) (116%)	164	170

The locations and brief descriptions of the predictors for our early July statistical forecast are now discussed. It should be noted that all predictors correlate with physical features during August through October that are known to be favorable for elevated levels of hurricane activity. These factors are all generally related to August-October vertical wind shear in the Atlantic Main Development Region (MDR) from 10-20°N, 85-20°W as shown in Figure 3.

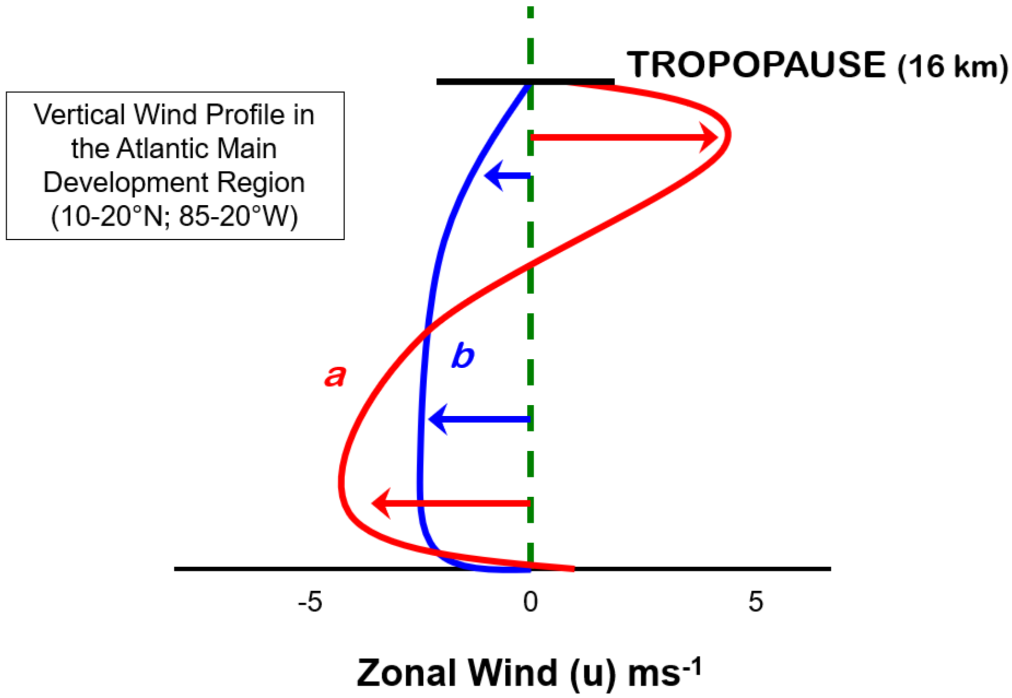

Figure 3: Vertical wind profile typically associated with (a) inactive Atlantic basin hurricane seasons and (b) active Atlantic basin hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

For each of these predictors, we display a four-panel figure showing rank correlations between values of each predictor and August-October values of sea surface temperature (SST), sea level pressure (SLP), 200 hPa zonal wind, and 850 hPa zonal wind, respectively, during 1982-2019. In general, higher values of SST, lower values of SLP, anomalous westerlies at 850 hPa and anomalous easterlies at 200 hPa are associated with active Atlantic basin hurricane seasons.   SST correlations are displayed using the NOAA OISST, while atmospheric field correlations are displayed using ERA5.

<u>Predictor 1. May-June SST in the Subtropical and Mid-latitude eastern North Atlantic (+)</u>

(20°N-50°N, 40°W-15°W)

Warmer-than-normal SSTs in the subtropical and mid-latitude eastern North Atlantic during the May-June time period are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the late boreal spring and early boreal summer (Knaff 1997). These warmer-than-normal SSTs in May-June are also correlated with weaker trade winds and weaker upper tropospheric westerly winds, lower-than-normal sea level pressure and above-normal SSTs in the tropical Atlantic during the following August-October period (Figure 4). All four of these August-October features are commonly associated with active Atlantic basin hurricane seasons, through reductions in vertical wind shear, increased vertical instability and increased mid-tropospheric moisture, respectively. Predictor 1 correlates quite strongly (r_{rank} =0.64) with ACE from 1982-2019. Predictor 1 also strongly correlates (r_{rank} = 0.60) with August-October values of the SST component of the Atlantic Meridional Mode (AMM) (Kossin and Vimont 2007) over the period from 1982-2019. The AMM has been shown to impact Atlantic hurricane activity through alterations in the position and intensity of the Atlantic Inter-Tropical Convergence Zone (ITCZ). Changes in the Atlantic ITCZ bring about changes in tropical Atlantic vertical and horizontal wind shear patterns and in tropical Atlantic SST patterns.

Predictor 2. May-June SLP in the Subtropical and Mid-Latitude North Atlantic (-)

(25°N-50°N, 50°W-30°W)

Anomalously low pressure in the subtropical and mid-latitude North Atlantic during May and June is associated with weaker trade winds and anomalous warming of the central and eastern tropical Atlantic during the boreal summer. While the anomalous warming signal in the tropical Atlantic SST decays somewhat by the peak of the Atlantic hurricane season (Figure 5), there remains a significant correlation in SST, sea level pressure and vertical wind shear, as evidenced by the anomalous westerlies at 850 hPa and the anomalous easterlies at 200 hPa in the Caribbean and western tropical Atlantic during August-October. Consequently, we observe that when the subtropical and mid-latitude North Atlantic is characterized by lower pressure in May and June, the peak of the Atlantic hurricane season typically has more conducive dynamic and thermodynamic conditions across the Main Development Region.

Predictor 3. May-June 10m U in the eastern tropical Pacific (+)

(5°N-10°N, 120°W-90°W)

Weaker-than-normal low-level winds during May-June in the eastern tropical Pacific are typically associated with a La Niña event and warmer SSTs in the Caribbean and tropical Atlantic. This SST gradient pattern drives higher pressure in the eastern tropical Pacific and lower pressure in the Caribbean and tropical Atlantic. This SST and sea level pressure pattern persists through August-October (Figure 6). The August-October-averaged Walker Circulation Index rank correlates with Predictor 3 at 0.51. There is also a significant negative correlation between Predictor 3 and the August-October-averaged Oceanic Nino Index (r_{rank} = -0.39). As would be expected given the negative relationship between Predictor 3 and the Oceanic Nino Index and the positive relationship between Predictor 3 and the Walker Circulation Index, Predictor 3 also correlates with reduced vertical wind shear during the peak of the Atlantic hurricane season, especially in the Caribbean and western tropical Atlantic, where ENSO typically has its strongest impacts (Figure 6).

Predictor 4. May-June SST in the Tropical and Subtropical Western South Pacific (+)

(35°S-15°S, 155°E-180°E)

Anomalous warmth in the tropical and subtropical western South Pacific is associated with higher-than-normal pressure in the eastern tropical Pacific during the boreal spring and early summer. This anomalous pressure pattern results in a positive Southern Oscillation Index (SOI), both in May-June and in August-October. The correlation between the SOI in May-June and Predictor 4 is 0.30, while the correlation increases to 0.40 between Predictor 4 and the August-October-averaged SOI. In addition, the rank correlation between Predictor 4 and the August-October averaged Walker Circulation Index is 0.41. A stronger Walker Circulation Index is associated with decreased vertical wind shear across the Caribbean and tropical Atlantic (Figure 7).

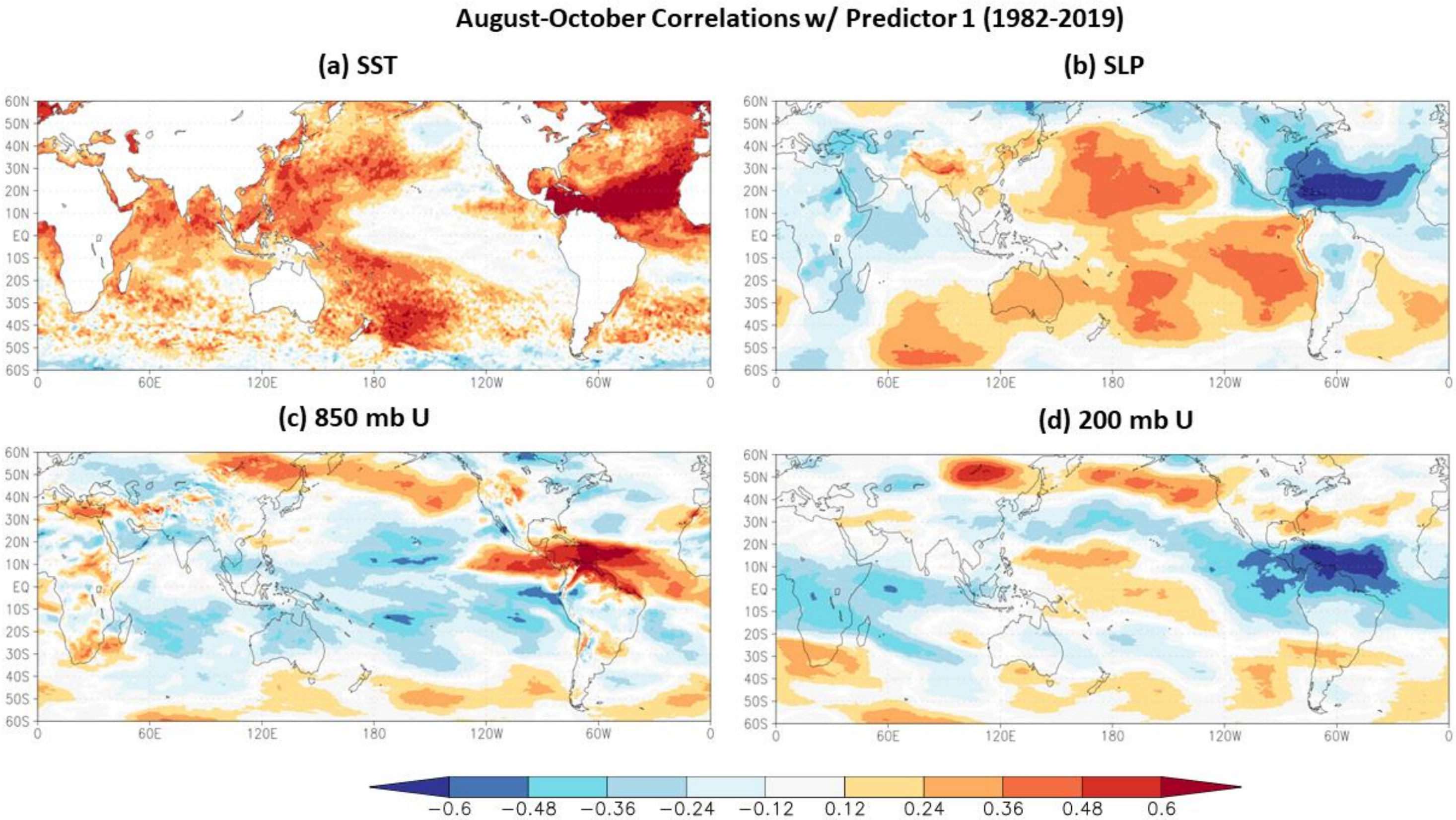

Figure 4: Rank correlations between May-June SST in the subtropical and mid-latitude eastern North Atlantic (Predictor 1) and (panel a) August-October sea surface temperature, (panel b) August-October sea level pressure, (panel c) August-October 850 hPa zonal wind and (panel d) August-October 200 hPa zonal wind. All four of these parameter deviations in the tropical Atlantic are known to be favorable for enhanced hurricane activity.

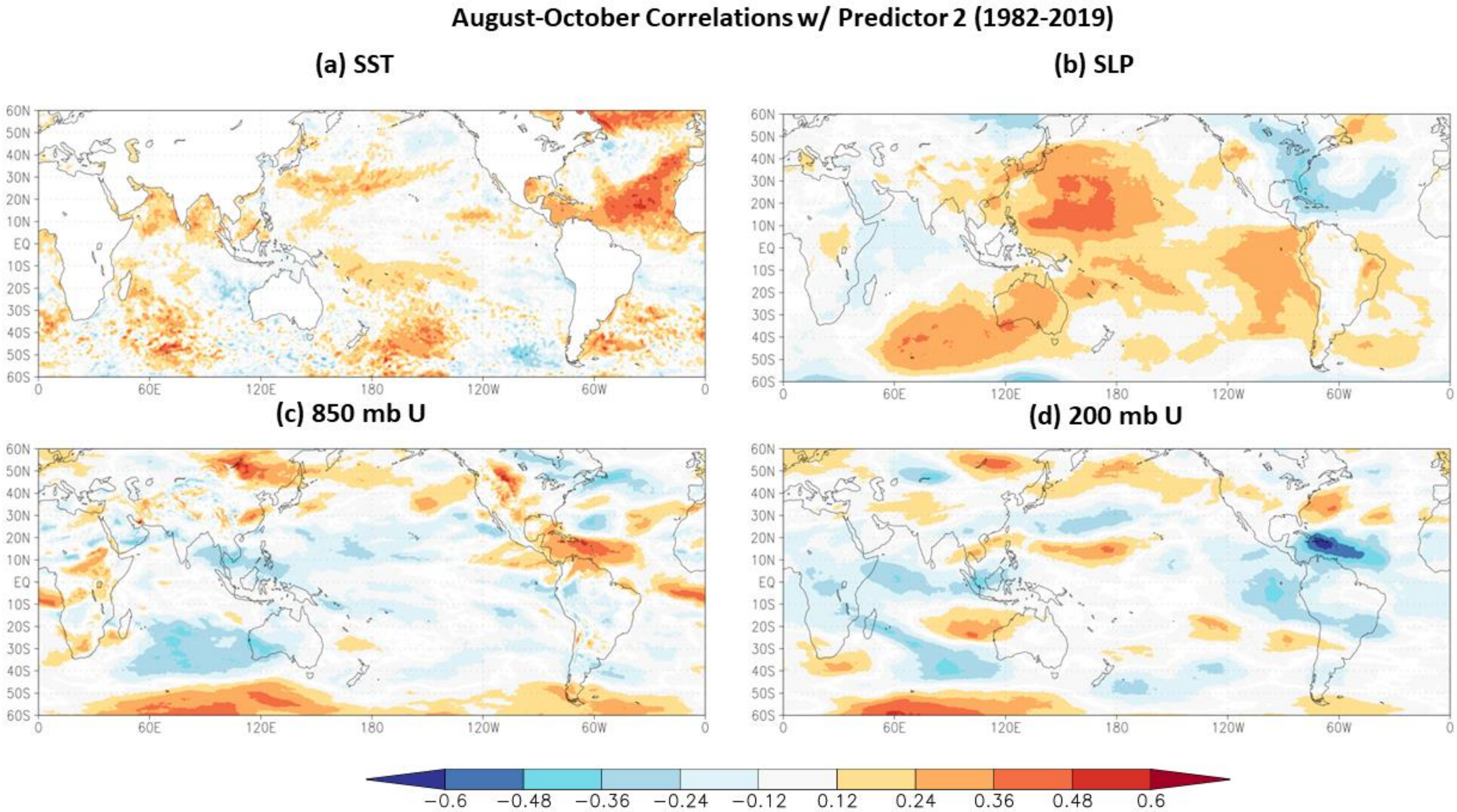

Figure 5: As in Figure 4 but for May-June SLP in the subtropical and mid-latitude North Atlantic. The sign of Predictor 2 has been flipped for easy comparison with Figure 4.

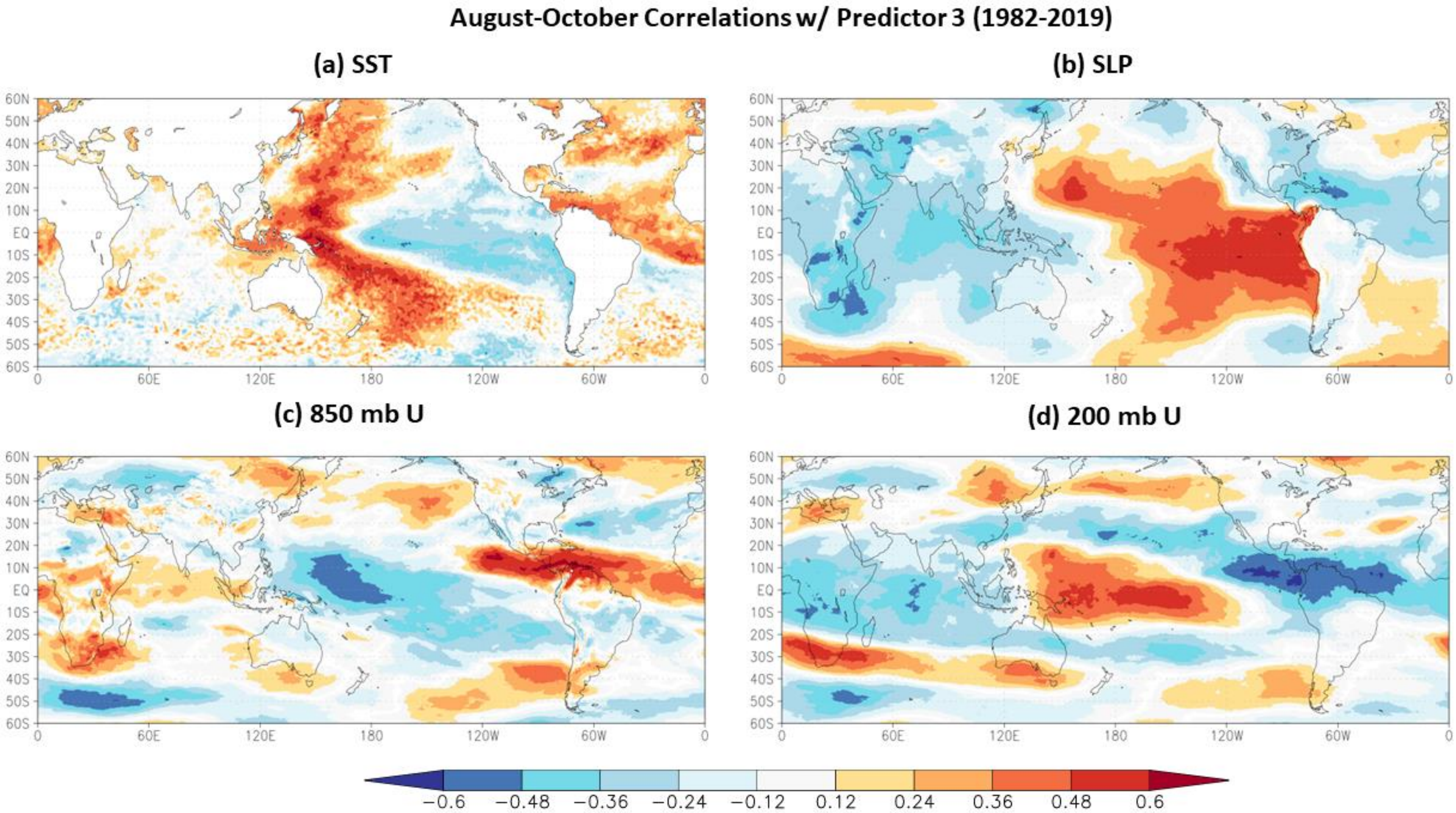

Figure 6: As in Figure 4 but for May-June 10 meter zonal wind in the eastern tropical Pacific Ocean.

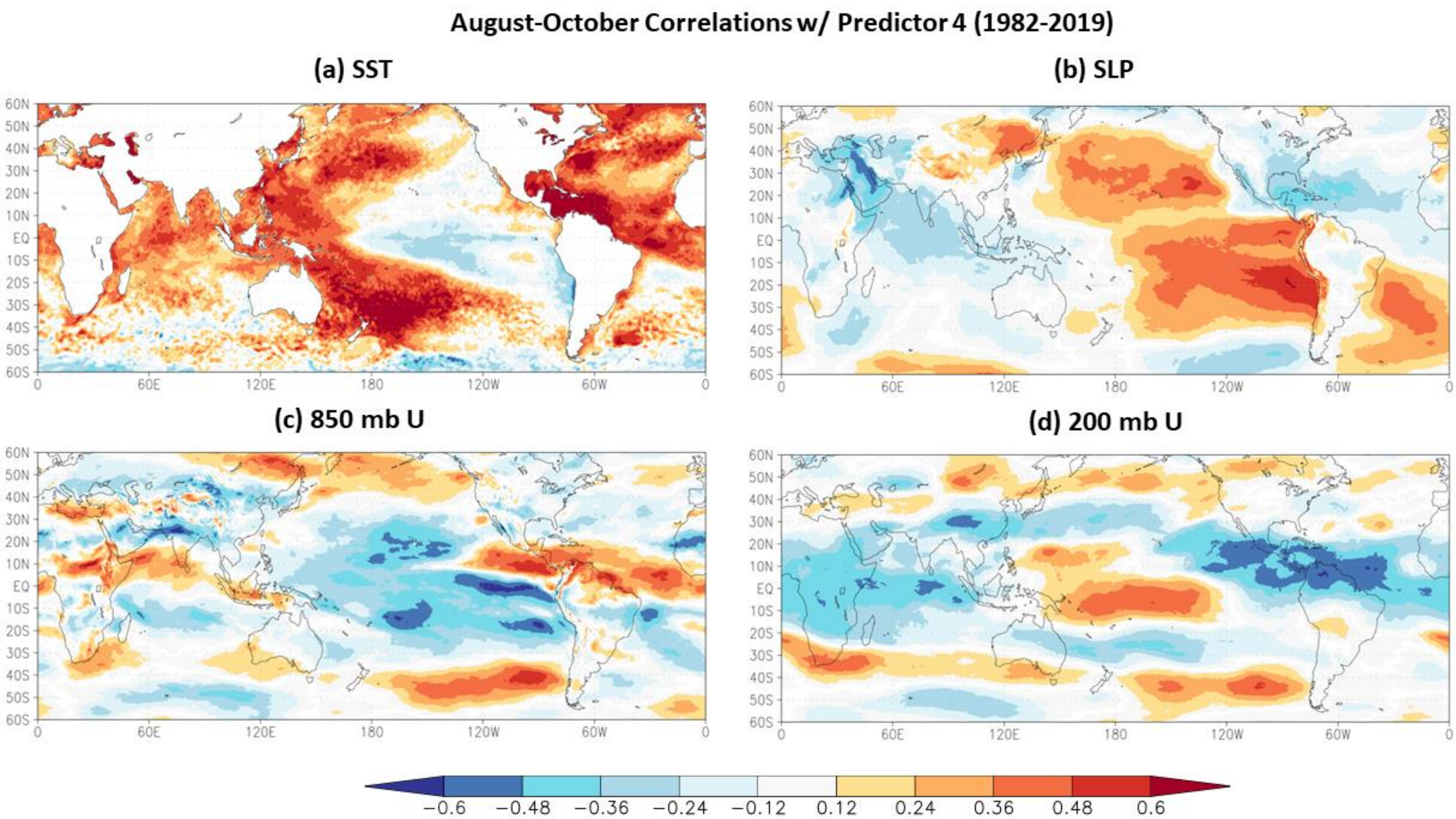

Figure 7: As in Figure 4 but for May-June SST in the tropical and subtropical western South Pacific.

2.2 July Statistical/Dynamical Forecast Scheme

We developed a new statistical/dynamical hybrid forecast model scheme that we used for the first time in 2019. This model, developed in partnership with Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre, uses output from the ECMWF SEAS5 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 SEAS5 is able to forecast the large-scale fields that go into the early August statistical forecast model with considerable skill by March. We then use the forecasts of the individual parameters to forecast ACE for the 2020 season. All of the other predictands (e.g., named storms, major hurricanes) are calculated based on their historical relationships with ACE. It typically takes about two weeks after the initialization date to obtain SEAS5 output, so the results displayed here are from the model output from the 1 June forecast.

Figure 8 displays the parameters used in our early August statistical model, while Table 4 displays SEAS5's forecasts of these parameters for 2020 from a 1 June initialization date. Two of the three parameters call for above-normal activity, while the trade wind predictor in the Caribbean/tropical Atlantic indicates slightly below-normal activity. The trade wind predictor has more weight in the linear regression scheme than it had in earlier forecasts (when the trade winds were also forecast to be stronger than normal), which is why the SEAS5 prediction was reduced from 187 in early June to 140 in early July. Figure 9 displays cross-validated hindcasts for SEAS5 forecast of ACE from 1981-2019, while Table 5 presents the forecast from SEAS5 for the 2020 Atlantic hurricane season.

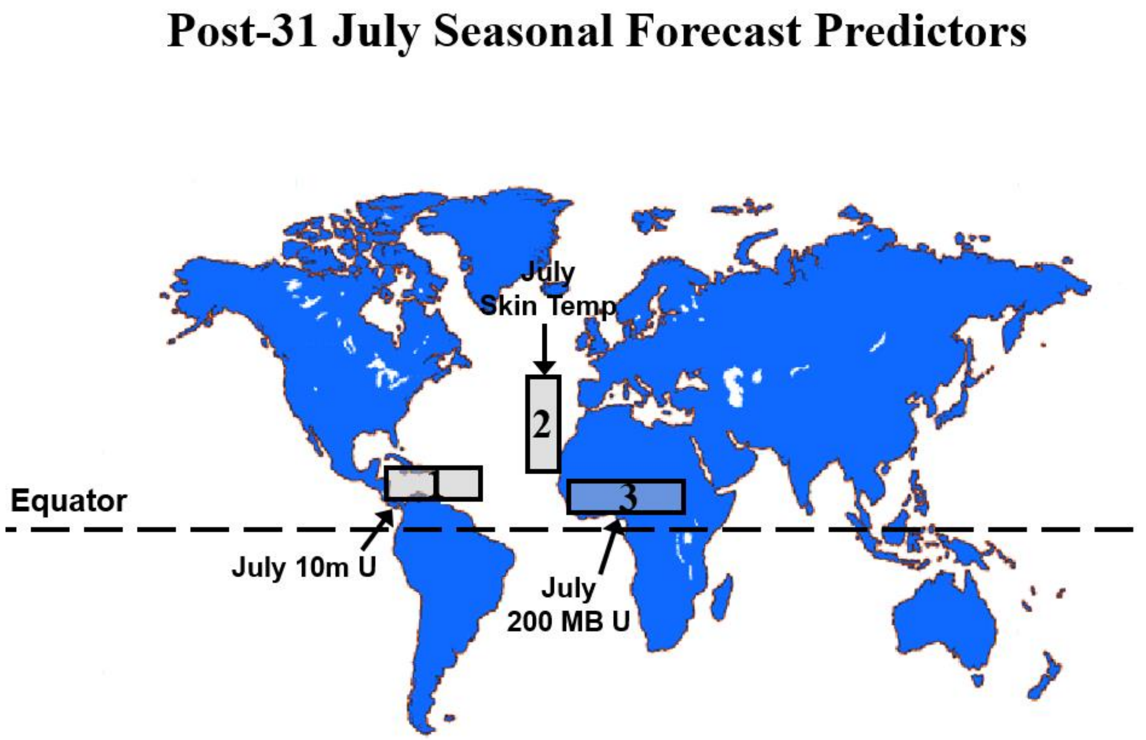

Figure 8: Location of predictors for our early July statistical/dynamical extended-range statistical prediction for the 2020 hurricane season. This forecast uses either the ECMWF SEAS5 model or the UK Met Office GloSea5 model to predict July conditions in the three boxes displayed and uses those predictors to forecast ACE.

Table 4: Listing of predictions of July large-scale conditions from ECMWF SEAS5 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 2020 Forecast	Effect on 2020 Hurricane Season
1) ECMWF Prediction of July Surface U (10-20°N, 90-40°W) (+)	-0.5 SD	Suppress
2) ECMWF Prediction of July Skin Temperature (20-40°N, 35-15°W) (+)	+0.5 SD	Enhance
3) ECMWF Prediction of July 200 hPa U (5-15°N, 0-40°E) (-)	-1.5 SD	Enhance

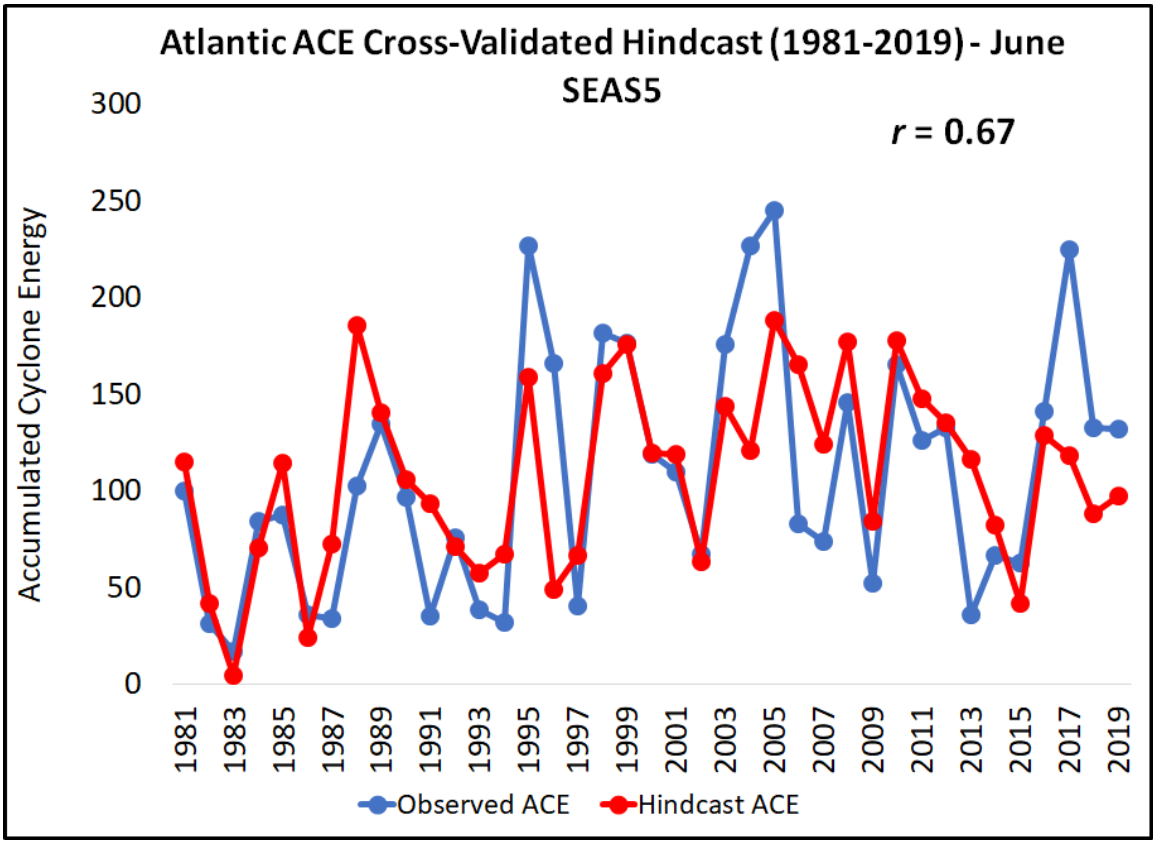

Figure 9: Observed versus early June cross-validated statistical/dynamical hindcast values of ACE for 1981-2019 from SEAS5.

Table 5: Statistical/dynamical model output from SEAS5 for the 2020 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)	14.7	20
Named Storm Days (59.4)	75.9	85
Hurricanes (6.4)	7.9	9
Hurricane Days (24.2)	31.7	40
Major Hurricanes (2.7)	3.5	4
Major Hurricane Days (6.2)	8.8	9
Accumulated Cyclone Energy Index (106)	140	160
Net Tropical Cyclone Activity (116%)	150	170

In addition to forecasts from ECMWF SEAS5, we are incorporating a similar forecast from the UK Met Office's GloSea5 model this year. The GloSea5 model shows comparable levels of skill to ECMWF SEAS5 at predicting the large-scale fields going into the early August statistical forecast model based on GloSea5 hindcast data from 1993-2016. For example, Figure 10 displays the correlation between July low-level winds in the tropical Atlantic and Caribbean with both SEAS5 and GloSea5 model forecasts as well as the average of the two models (e.g., ensemble average) issued at various lead times from 1 March to 1 July.

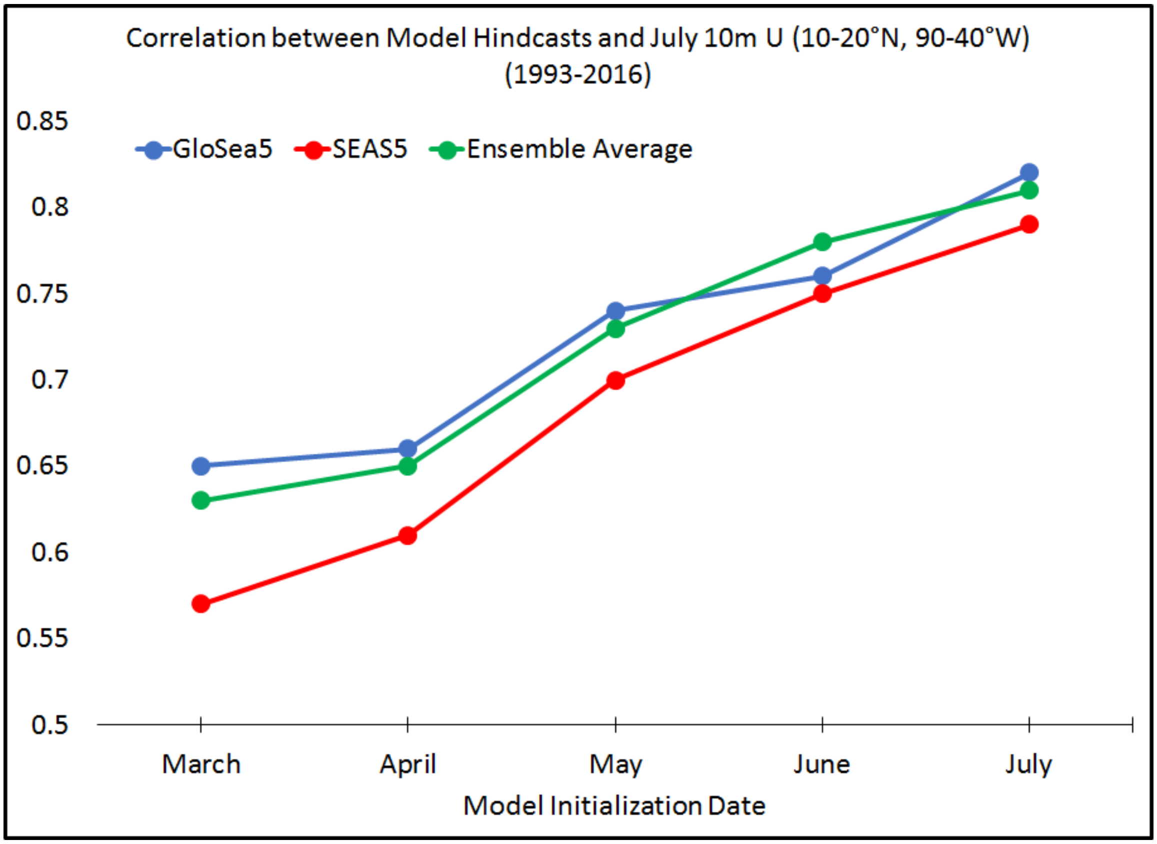

Figure 10: Correlation between model hindcasts issued at various lead times and July low-level wind in the tropical Atlantic and Caribbean based on data from 1993-2016.

The output from the GloSea5 model also calls for an above-average Atlantic hurricane season in 2020. Table 6 displays the forecasts of the three individual parameters comprising the early August statistical/dynamical hybrid forecast, while Table 7 displays the final forecast from the GloSea5 model.

Table 6: Listing of predictions of July large-scale conditions from the Met Office's GloSea5 model 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 2020 Forecast	Effect on 2020 Hurricane Season
1) GloSea5 Prediction of July Surface U (10-20°N, 90-40°W) (+)	+0.1 SD	Neutral
2) GloSea5 Prediction of July Skin Temperature (20-40°N, 35-15°W) (+)	+1.0 SD	Enhance
3) GloSea5 Prediction of July 200 hPa U (5-15°N, 0-40°E) (-)	-1.0 SD	Enhance

Table 7: Statistical/dynamical model output from GloSea5 for the 2020 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)	14.8	20
Named Storm Days (59.4)	76.3	85
Hurricanes (6.4)	7.9	9
Hurricane Days (24.2)	31.9	40
Major Hurricanes (2.7)	3.5	4
Major Hurricane Days (6.2)	8.9	9
Accumulated Cyclone Energy Index (106)	141	160
Net Tropical Cyclone Activity (116%)	151	170

2.3 July Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2020. These years also provide useful clues as to likely levels of activity that the forthcoming 2020 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 June 2020 conditions and, more importantly, projected August-October 2020 conditions. Table 8 lists our analog selections.

We searched for years that were generally characterized by cool neutral ENSO to weak La Niña conditions during August-October. We selected years that had above-average SSTs in the tropical Atlantic. We anticipate that the 2020 hurricane season will have activity near the average of our six analog years.

Table 8: Analog years for 2020 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1966	11	64.00	7	41.75	3	8.75	145	140
1995	19	121.25	11	61.50	5	11.50	227	222
2003	16	81.50	7	32.75	3	16.75	176	175
2008	16	88.25	8	30.50	5	7.50	146	162
2011	19	89.75	7	26.00	4	4.50	126	145
2016	15	81.00	7	27.75	4	10.25	141	155
Average	16.0	87.6	7.8	36.7	4.0	9.9	160	167
2020 Forecast	**20**	**85**	**9**	**40**	**4**	**9**	**160**	**170**

2.4 July Forecast Summary and Final Adjusted Forecast

Table 9 shows our final adjusted early July forecast for the 2020 season which is a combination of our statistical scheme, our two statistical/dynamical schemes, our analog scheme and qualitative adjustments for other factors not explicitly contained in any of these schemes. All four of our schemes call for above-average Atlantic hurricane activity this year. Our forecast is near the average of the four schemes and calls for an above-normal season, due to both anticipated cool ENSO-neutral or weak La Niña conditions as well as anomalously warm SSTs in the tropical Atlantic for the peak of the Atlantic hurricane season (August-October).

Table 9: Summary of our early July statistical forecast, our statistical/dynamical forecast, our analog forecast, the average of those four schemes and our adjusted final forecast for the 2020 hurricane season.

Forecast Parameter and 1981-2010 Average (in parentheses)	Statistical Scheme	SEAS5 Scheme	GloSea5 Scheme	Analog Scheme	4-Scheme Average	Adjusted Final Forecast
Named Storms (12.1)	15.5	14.7	14.8	16.0	15.3	20
Named Storm Days (59.4)	81.5	75.9	76.3	87.6	80.4	85
Hurricanes (6.4)	8.5	7.9	7.9	7.8	8.0	9
Hurricane Days (24.2)	35.0	31.7	31.9	36.7	33.8	40
Major Hurricanes (2.7)	3.9	3.5	3.5	4.0	3.7	4
Major Hurricane Days (6.2)	10.0	8.8	8.9	9.9	9.4	9
Accumulated Cyclone Energy Index (106)	154	140	141	160	149	160
Net Tropical Cyclone Activity (116%)	164	150	151	167	158	170

3 Forecast Uncertainty

One of the questions that we are asked regarding our seasonal hurricane predictions is the degree of uncertainty that is involved. This season we are unveiling probability of exceedance curves using the methodology outlined in Saunders et al. (2020). In that paper, we outlined an approach that uses statistical modeling and historical skill of various forecast models to arrive at a probability that particular values for hurricane numbers and ACE would be exceeded. Here we display probability of exceedance curves for hurricanes and ACE (Figures 11 and 12), using the error distributions calculated from both normalized cross-validated statistical as well as the cross-validated statistical/dynamical hindcasts from SEAS5. Hurricane numbers are fit to a Poisson distribution, while ACE is fit to a Weibull distribution. Table 10 displays one standard deviation uncertainty ranges (~68% of all forecasts within this range). This uncertainty estimate is also very similar to the 70% uncertainty range that NOAA provides with its forecasts. We use Poisson distributions for all storm parameters (e.g., named storms, hurricanes and major hurricanes) while we use a Weibull distribution for all integrated parameters except for major hurricane days (e.g., named storm days, ACE, etc.). We use a Laplace distribution for major hurricane days.

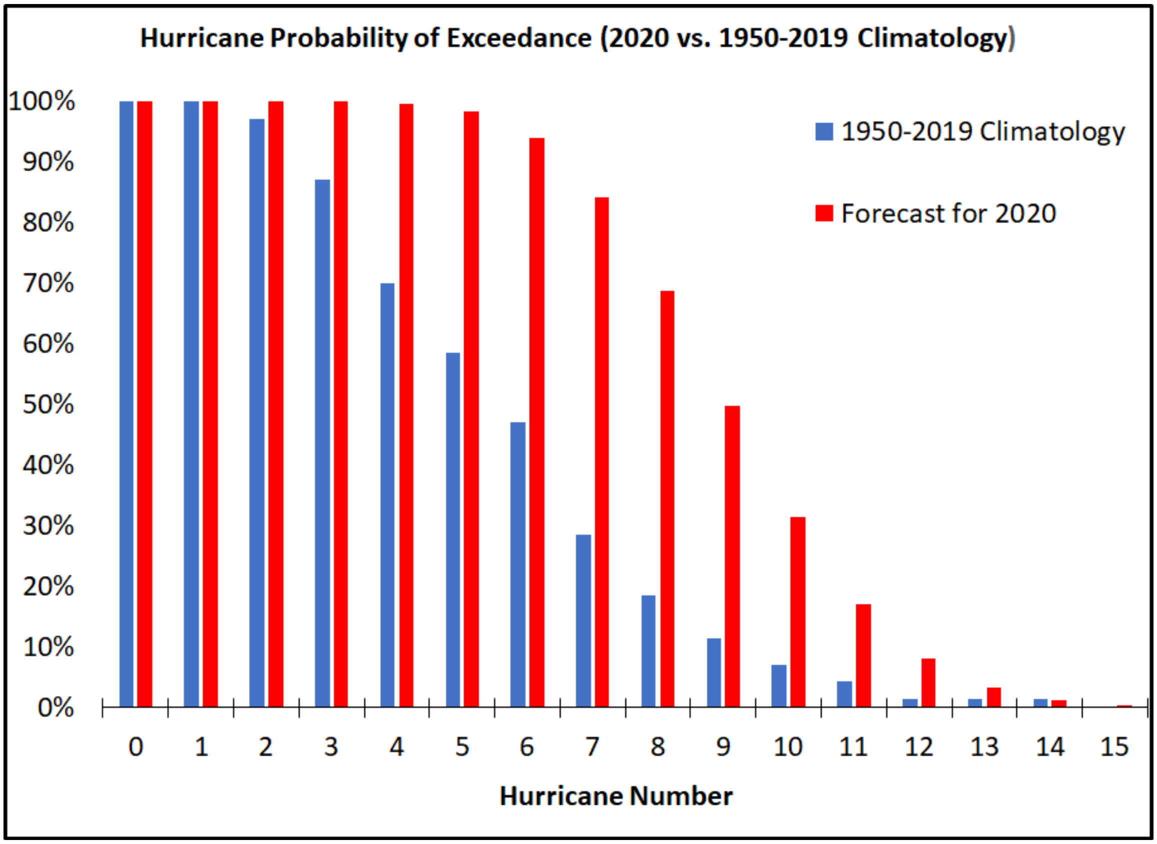

Figure 11: Probability of exceedance plot for hurricane numbers for the 2020 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950-2019 have had more than two hurricanes.

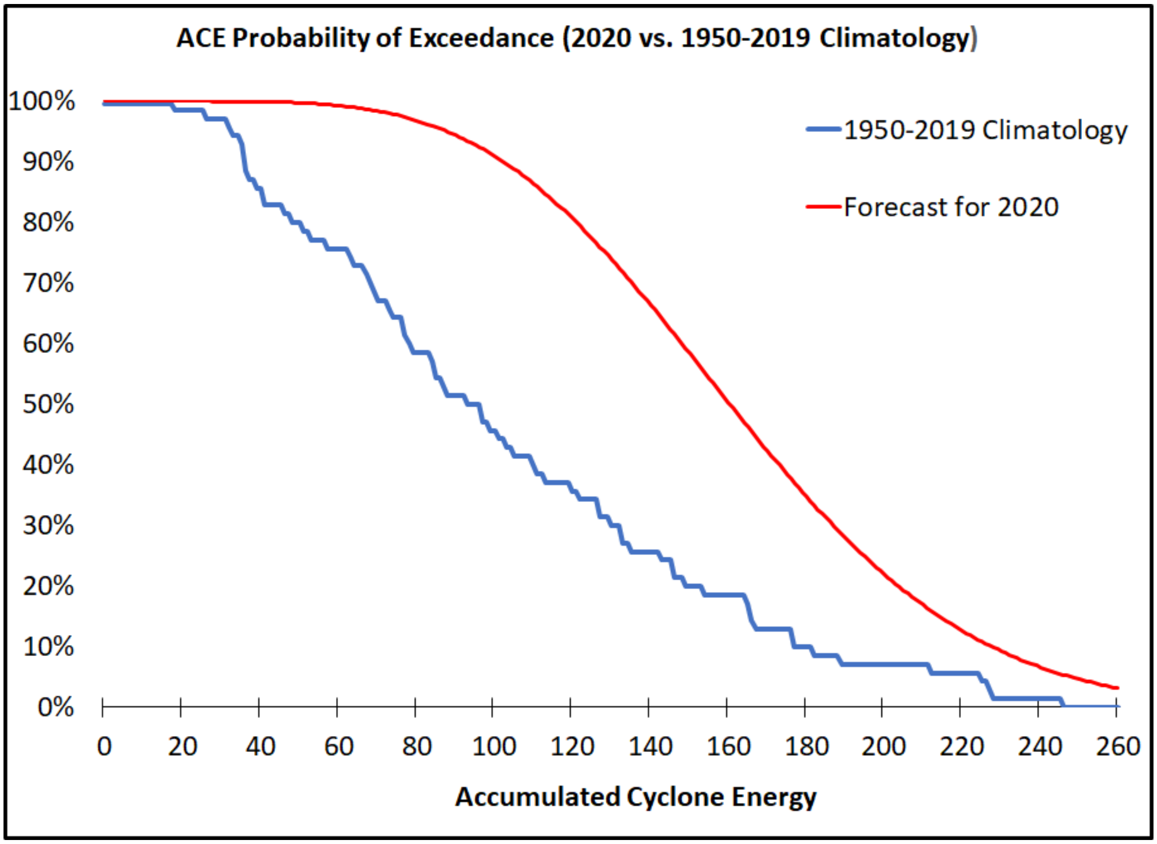

Figure 12: As in Figure 11 but for ACE.

Table 10: Forecast ranges for each parameter. Note that the forecast spread may not be symmetric around the mean value, given the historical distribution of tropical cyclone activity.

Parameter	2020 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	20	17 – 23
Named Storm Days (NSD)	85	65 – 106
Hurricanes (H)	9	7 – 11
Hurricane Days (HD)	40	28 – 54
Major Hurricanes (MH)	4	3 – 6
Major Hurricane Days (MHD)	9	6 – 14
Accumulated Cyclone Energy (ACE)	160	112 – 212
Net Tropical Cyclone (NTC) Activity	170	124 – 220

4 ENSO

The tropical Pacific is currently characterized by cool neutral ENSO conditions, with SSTs averaging slightly below-normal across most of the central and eastern tropical Pacific (Figure 13). ENSO events are partially defined by NOAA based on SST anomalies in the Nino 3.4 region, which is defined as 5°S-5°N, 170-120°W. Cool neutral ENSO conditions are defined by anomalies in the Nino 3.4 region between -0.5°C – 0°C.

Over the past month, SSTs have trended upward in the Nino 3.4 region, due in large part to localized wind forcing which has inhibited upwelling (Figure 14).

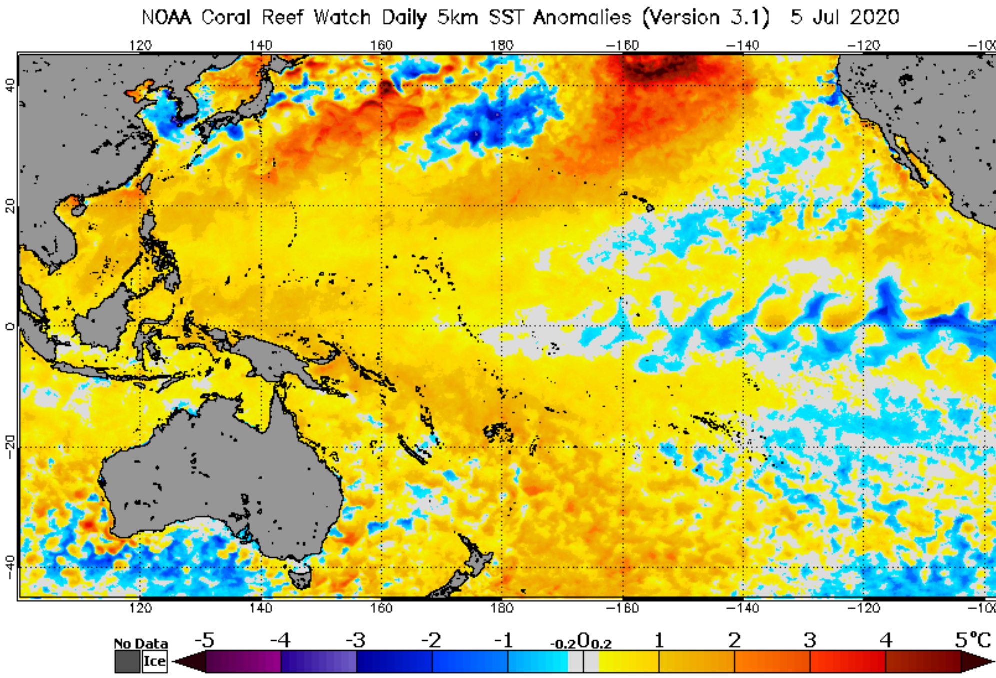

Figure 13: Current SST anomalies across the tropical and subtropical Pacific.

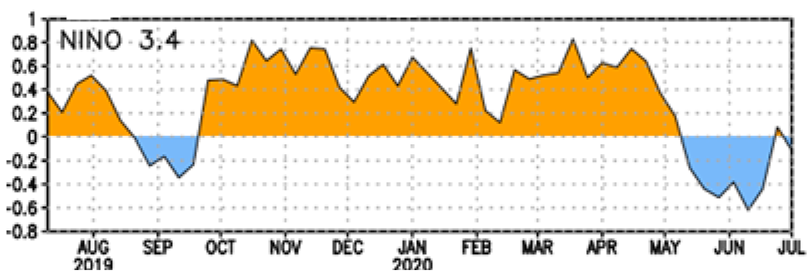

Figure 14: Nino 3.4 SST anomalies from July 2019 through June 2020. Figure courtesy of Climate Prediction Center.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific were at above-normal levels from October 2019 through March 2020, decreased rapidly in April and May but have recently increased (Figure 15). As noted in the previous paragraph, we believe that this is likely due to localized wind forcing which is not forecast to persist.

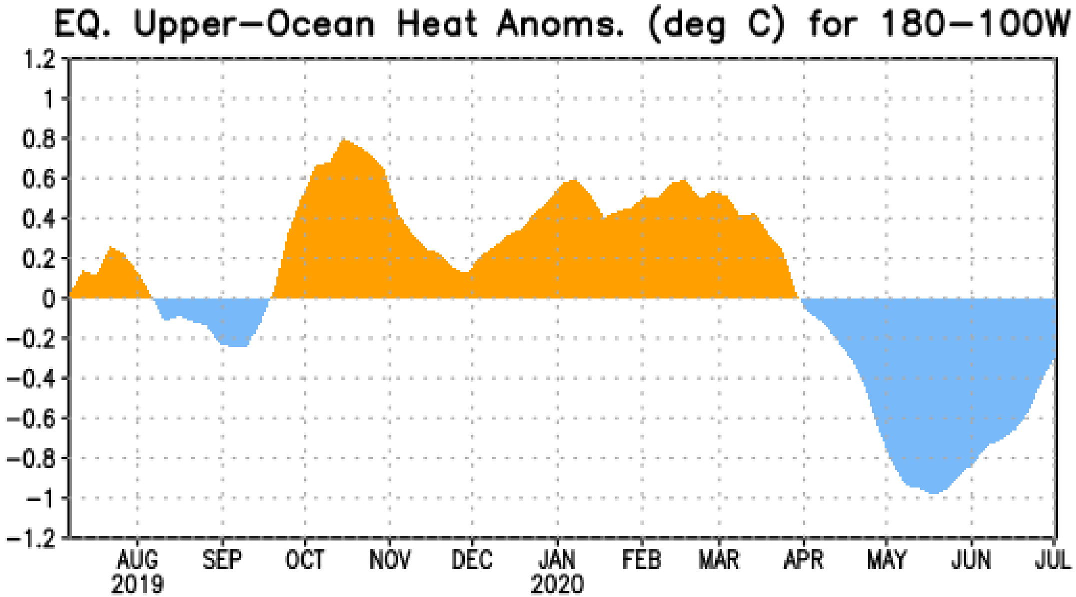

Figure 15: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Upper ocean heat content anomalies have dropped precipitously over the past few weeks.

Table 11 displays May and June SST anomalies for several Nino regions. Anomalies have trended downward in the eastern tropical Pacific and have not changed significantly in the central tropical Pacific.

Table 11: 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 – May SST Anomaly (°C)
Nino 1+2	+0.1	-0.8	-0.9
Nino 3	-0.2	-0.6	-0.4
Nino 3.4	-0.2	-0.3	-0.1
Nino 4	+0.2	+0.3	+0.1

The tropical Pacific experienced an upwelling (cooling) Kelvin wave (denoted by a dotted line) which has recently reached the coast of South America (Figure 16). This anomalous cooling was driven by stronger-than-normal low-level easterly winds in the central tropical Pacific.

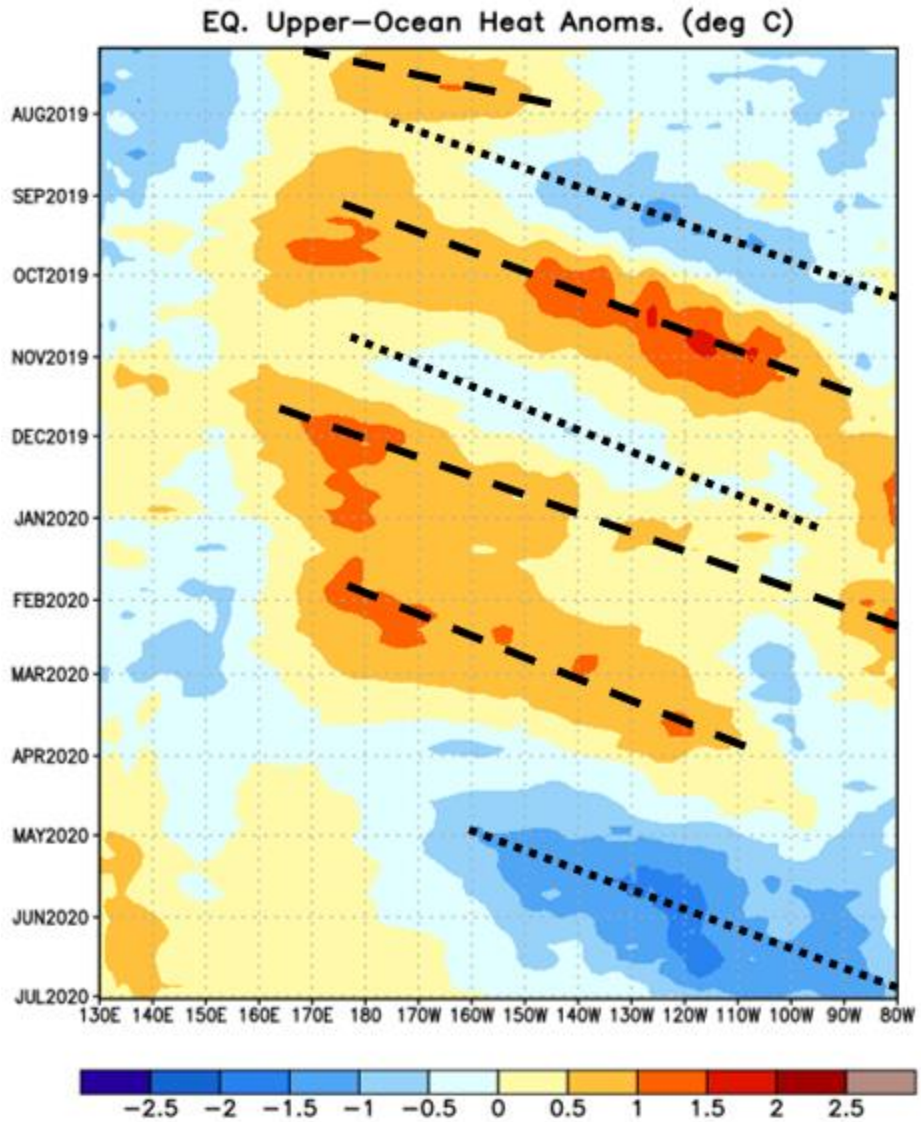

Figure 16: Upper-ocean heat content anomalies in the tropical Pacific since July 2019. Dashed lines indicate downwelling Kelvin waves, while dotted lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases.

We will continue monitoring low-level winds over the tropical Pacific as the peak of the Atlantic hurricane season approaches. Anomalous easterlies have recently developed just west of the International Date Line, and the Climate Forecast System (CFS) is forecasting a continuation of stronger-than-normal trade winds across the central tropical Pacific (Figure 17). Consequently, we believe that the brief anomalous warming that we have witnessed over the past couple of weeks is likely to be short-lived. We believe that there is the potential for a weak La Niña for the peak of the Atlantic hurricane season (August-October).

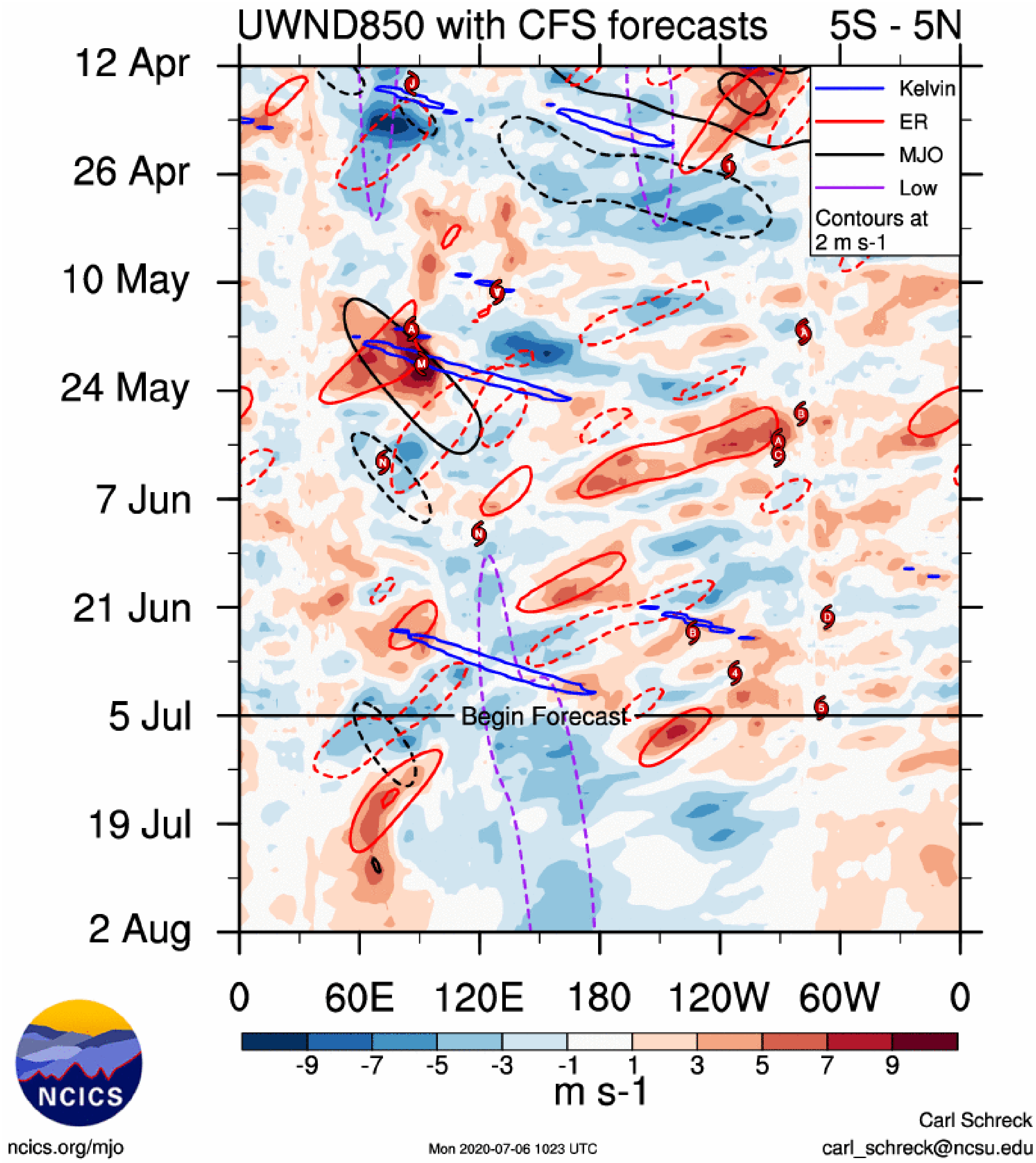

Figure 17: Observed low-level winds across the equatorial region as well as predictions for the next four weeks by the Climate Forecast System. Figure courtesy of Carl Schreck.

There remains considerable uncertainty with the future state of ENSO for the peak of the Atlantic hurricane season. The latest plume of ENSO predictions from several statistical and dynamical models shows a continued spread for August-October (Figure 18). Most models indicate some continued anomalous cooling between now and the peak of the Atlantic hurricane season, however. None of the models in the ENSO prediction plume call for El Niño conditions for August-October.

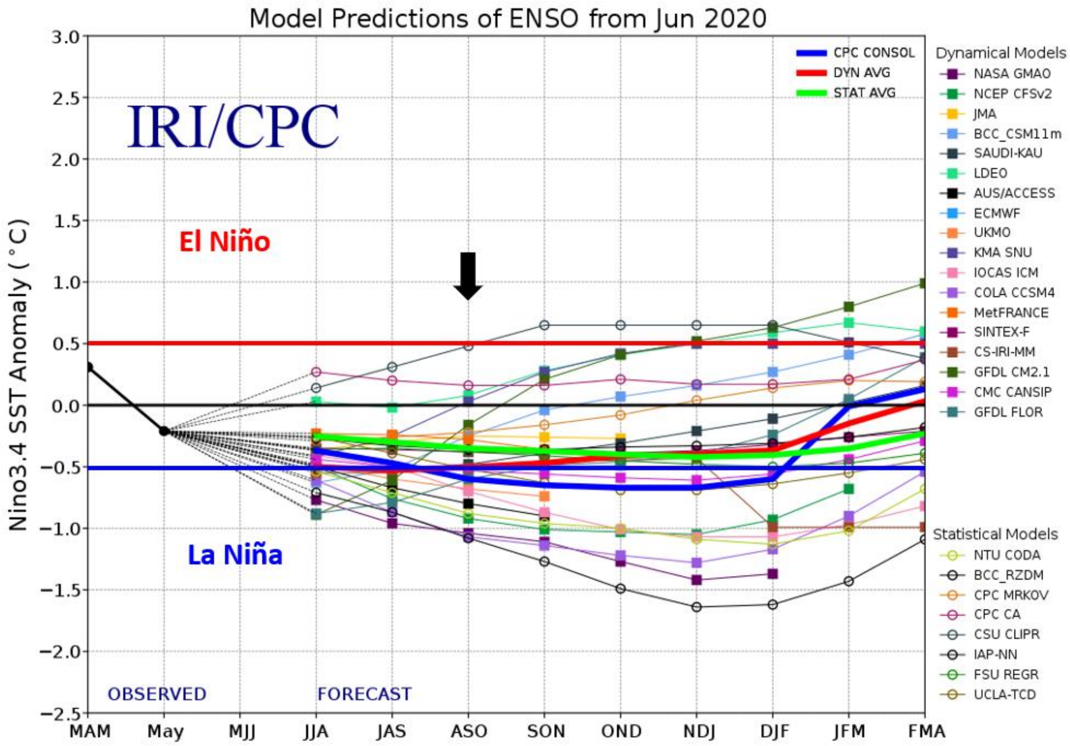

Figure 18: ENSO forecasts from various statistical and dynamical models for the Nino 3.4 SST anomaly based on late May to early June initial conditions. The majority of models are calling for ENSO neutral conditions for August-October. Figure courtesy of the International Research Institute (IRI).

The latest official forecast from NOAA indicates that the chances of El Niño are quite low for August-October. NOAA is currently predicting a 6% chance of El Niño, a 48% chance of ENSO neutral conditions and a 46% chance of La Niña for the peak of the Atlantic hurricane season (Figure 19).

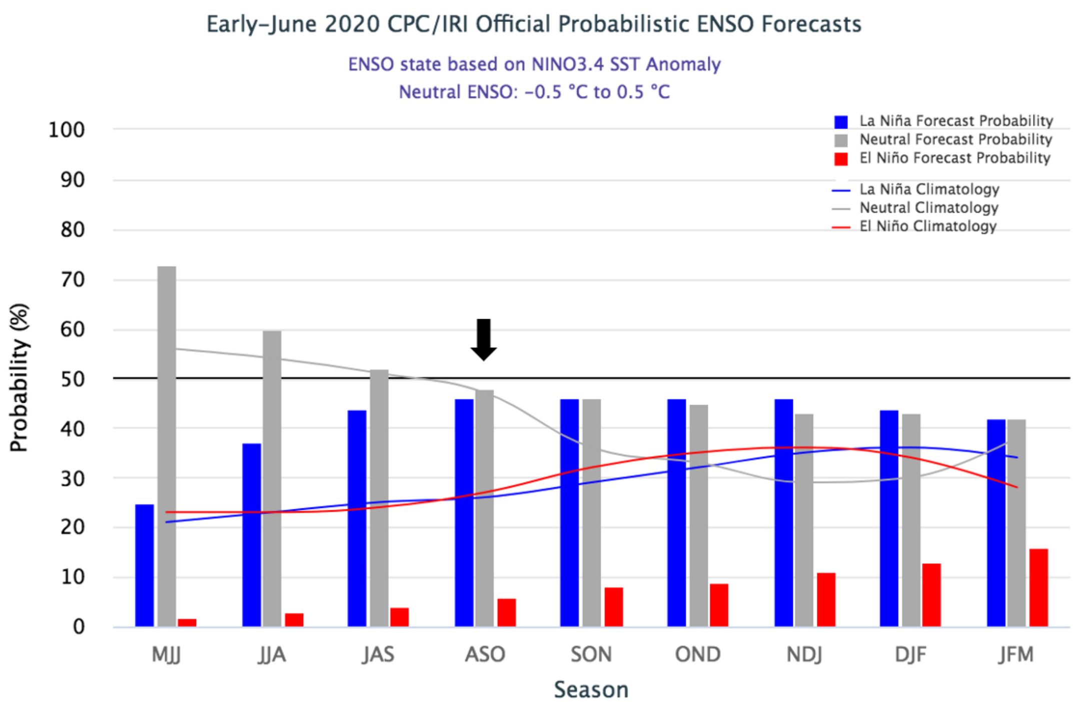

Figure 19: Official NOAA forecast for ENSO.

Based on the above information, our best estimate is that we will likely have either cool neutral ENSO or weak La Niña for the peak of the Atlantic hurricane season.

5 Current Atlantic Basin Conditions

Currently, the tropical Atlantic is warmer than normal, and most of the subtropical Atlantic is also warmer than normal (Figure 20). The warm SST anomalies in the tropical Atlantic have grown and expanded over the past few weeks. The current SST anomaly pattern is quite similar to the historical SST pattern in July that has correlated with active Atlantic hurricane seasons (Figure 21). The Climate Forecast System model is forecasting weaker than normal trades across most of the tropical Atlantic for the next month, which should help to reinforce these warm anomalies for the next several weeks (Figure 22).

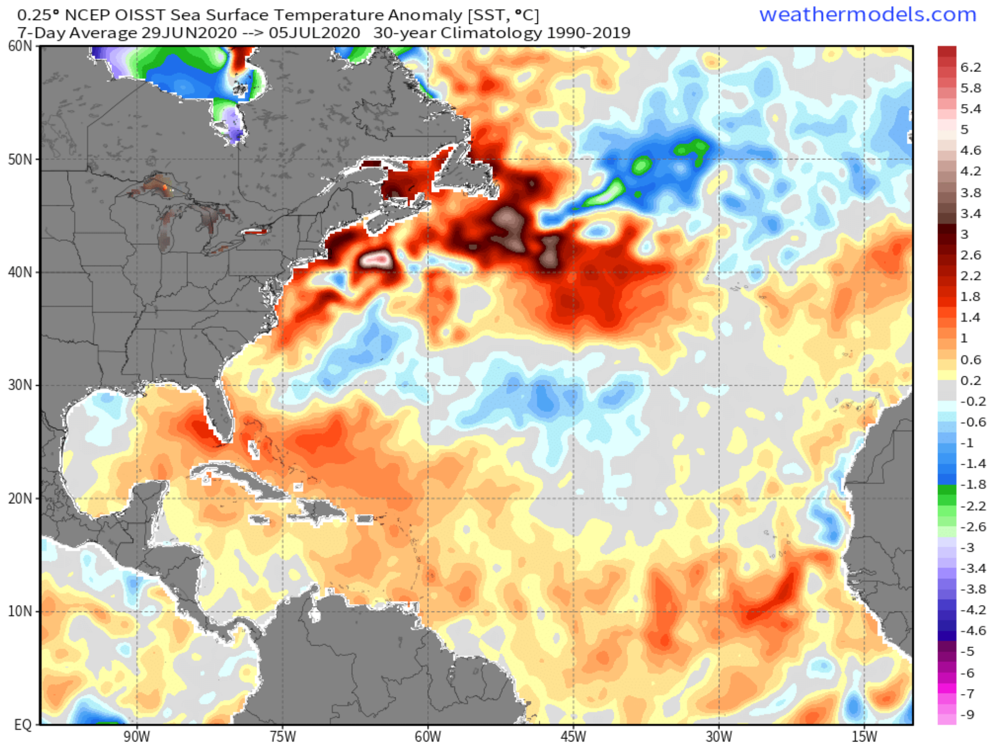

Figure 20: Early July 2020 SST anomaly pattern across the Atlantic Ocean.

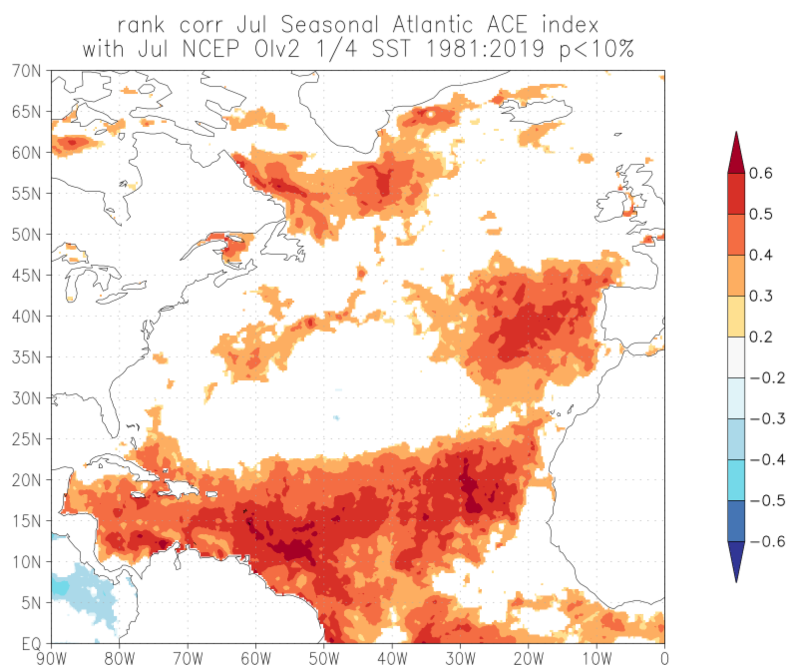

Figure 21: Rank correlation between July North Atlantic SST anomalies and seasonal Atlantic ACE from 1982-2019.

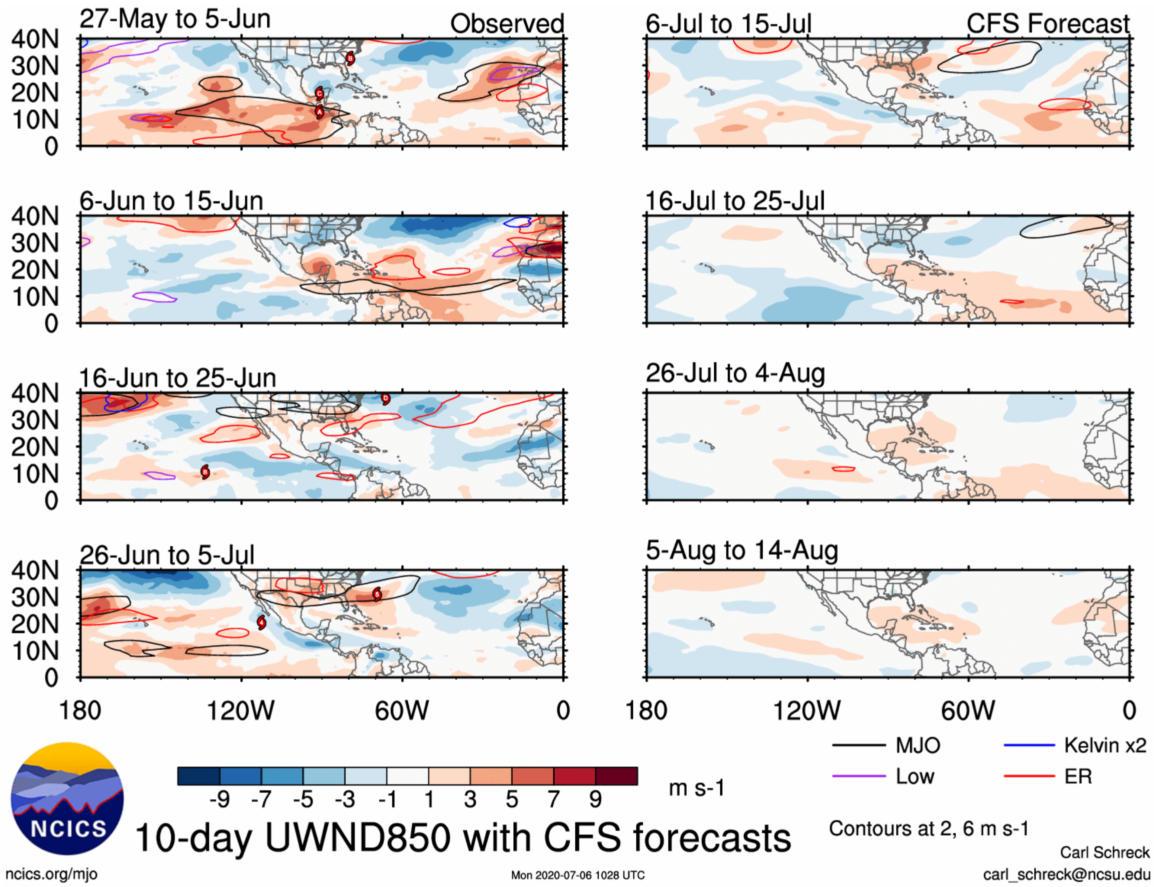

Figure 22: Observed 850 hPa zonal winds and forecast 850 hPa zonal winds from the Climate Forecast System. Winds are generally forecast to be weaker than normal across the tropical Atlantic for the next several weeks.

Vertical wind shear over the past several weeks has generally been lower than normal across most of the Caribbean and the southern part of the tropical Atlantic. 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.

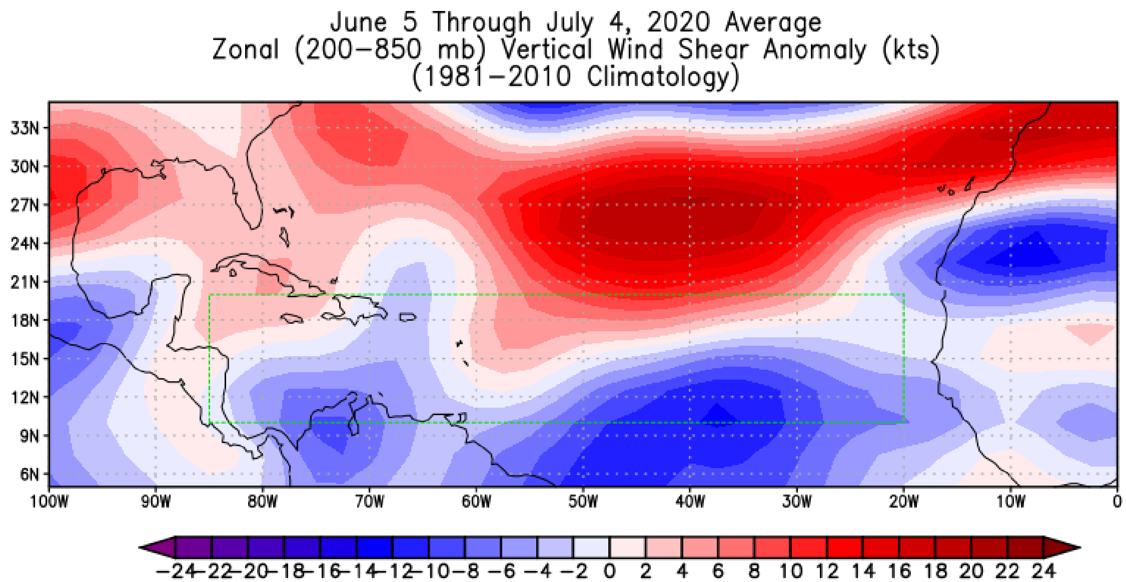

Figure 23: June 5 – July 4, 2020-averaged zonal vertical wind shear across the tropical Atlantic and Caribbean differenced from the 1981-2010 climatology.

6 West Africa Conditions

The West African monsoon has gotten off to a strong start, with pronounced anomalous upward vertical motion across most of Africa over the past 30 days (Figure 24). In addition, precipitation in the Sahel averaged 150-400% of normal during June (Figure 25). Despite the very strong Saharan dust outbreak that occurred during the middle of June, overall, large-scale conditions over West Africa are consistent with an active season.

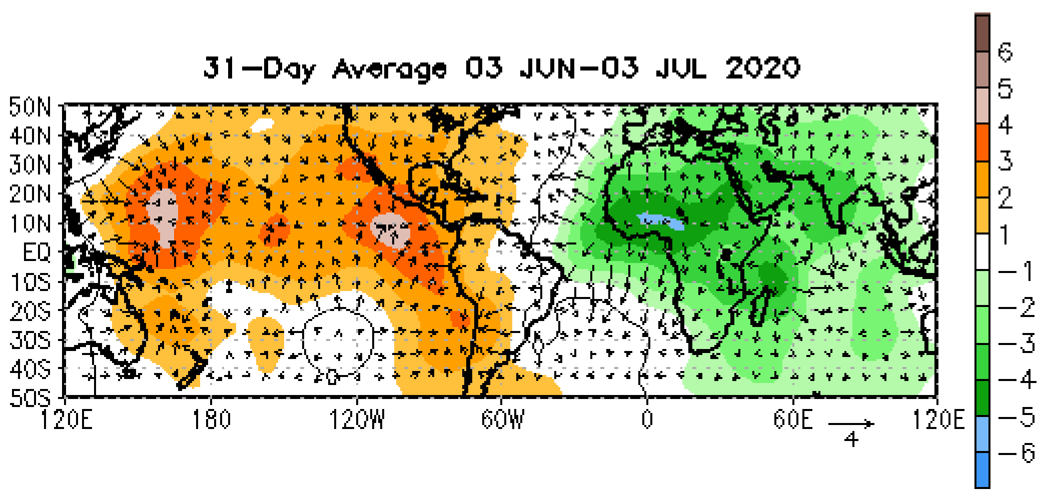

Figure 24: 200 hPa velocity potential anomalies from 50°S – 50°N. Negative velocity potential favors upward vertical motion.

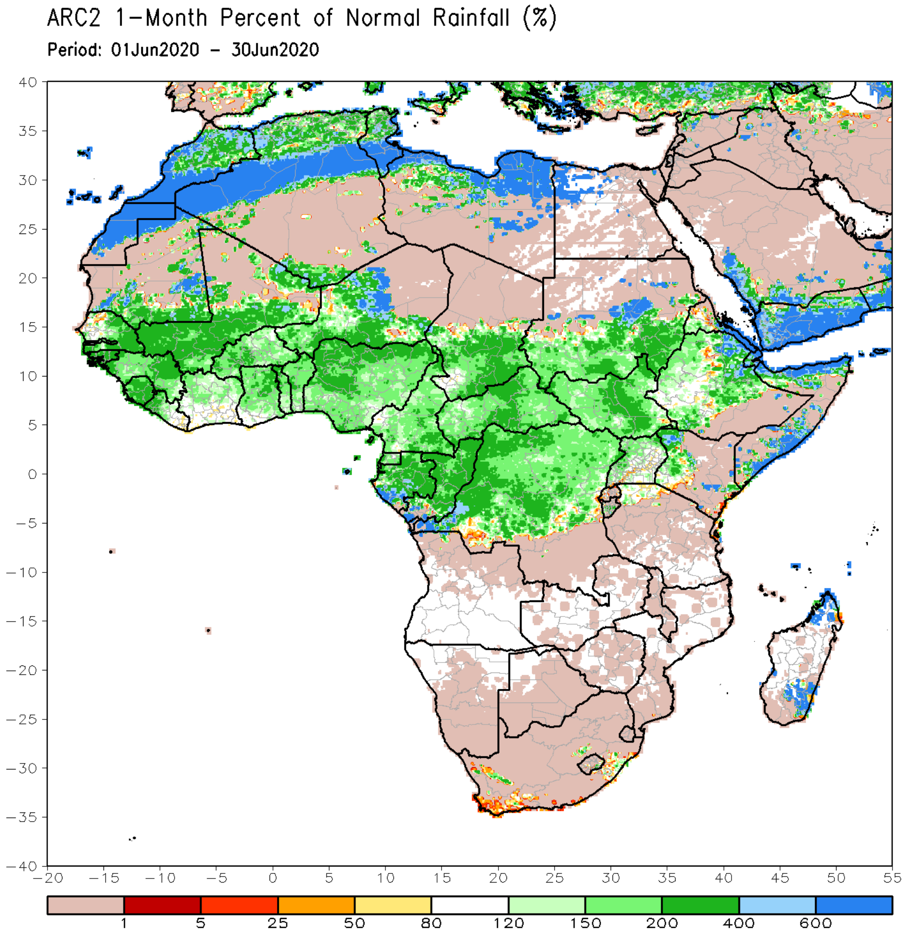

Figure 25: June 2020 rainfall estimates from the African Rainfall Climatology, version 2.

7 Forthcoming Updated Forecasts of 2020 Hurricane Activity

We will be issuing a final seasonal update of our 2020 Atlantic basin hurricane forecast on **Thursday, 6 August**. We will also begin issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season on 6 August. A verification and discussion of all 2020 forecasts will be issued in late November 2020. All of these forecasts will be available on our website.