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

We have increased our forecast and now call for an extremely active 2020 Atlantic hurricane season. Sea surface temperatures averaged across the tropical Atlantic are much warmer than normal, and vertical wind shear is well below average. Current cool neutral ENSO conditions may transition to weak La Niña conditions by later this summer. 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 5 August 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	Issue Date 5 August 2020	Observed Thru 4 August 2020	Remainder of Season Forecast
Named Storms (NS) (12.1)	16	19	20	24*	9	15
Named Storm Days (NSD) (59.4)	80	85	85	100	23.75	76.25
Hurricanes (H) (6.4)	8	9	9	12	2	10
Hurricane Days (HD) (24.2)	35	40	40	45	3	42
Major Hurricanes (MH) (2.7)	4	4	4	5	0	5
Major Hurricane Days (MHD) (6.2)	9	9	9	11	0	11
Accumulated Cyclone Energy (ACE) (106)	150	160	160	200	23	177
Net Tropical Cyclone Activity (NTC) (116%)	160	170	170	215	31	184

*Total forecast includes Arthur, Bertha, Cristobal, Dolly, Edouard, Fay, Gonzalo, Hanna and Isaias which have formed in the Atlantic as of August 4th.

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

1) Entire continental U.S. coastline - 74% (full-season average for last century is 52%)

2) U.S. East Coast Including Peninsula Florida - 49% (full-season average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 48% (full-season 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 4 AUGUST):

1) 63% (full-season average for last century is 42%)

ABSTRACT

Information obtained through July 2020 indicates that the 2020 Atlantic hurricane season will be extremely active. The Atlantic has already had 9 named storms and 2 hurricanes through August 4. We estimate that 2020 will have an additional 10 hurricanes (post-31 July average is 5.9), 15 named storms (average is 10.2), 76.25 named storm days (average is 53.2), 42 hurricane days (average is 22.9), 5 major (Category 3-4-5) hurricanes (average is 2.6) and 11 major hurricane days (average is 5.9). The probability of U.S. major hurricane landfall is estimated to be about 140 percent of the long-period full-season average. We expect Atlantic basin Accumulated Cyclone Energy (ACE) to be approximately 190 percent of its long term post-4 August average.

This forecast is based on an extended-range early August statistical prediction scheme that was developed using 38 years of past data. Analog predictors are also utilized.

The tropical Atlantic is much warmer than normal, and vertical wind shear across the tropical Atlantic and Caribbean has been much weaker than normal. Warmer than normal water across the tropical Atlantic provides more fuel for tropical cyclones and also is associated with lower than normal pressure (as was observed in July) and increased instability – all of which favor more hurricane activity. Vertical wind shear in July has been extremely low, and there is typically strong persistence between July vertical wind shear and August-October-averaged vertical wind shear. Lower vertical wind shear allows hurricanes to better vertically couple and also inhibits entrainment of dry air into the circulation. 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 peak of the Atlantic hurricane season. All of these conditions in combination point to a high likelihood of an extremely active hurricane season in 2020.

The early August forecast has 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.

Starting today and issued every two weeks following (e.g., August 5, August 19, September 2, etc.), we will issue two-week forecasts for Atlantic TC activity during the peak of the Atlantic hurricane season from August-October.

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.

Why issue 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 August. 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 August statistical model shows 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 this forecast is based on a statistical model 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, the Insurance Information Institute and Weatherboy. 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 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 August forecast is based on a statistical model which has been updated to use the latest reanalysis product from the European Centre for Medium Range Forecasts – the ERA5 reanalysis. 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 August Forecast Methodology

2.1 August Statistical Forecast Scheme

We developed a 1 August statistical seasonal forecast scheme for the prediction of Accumulated Cyclone Energy (ACE) that has been issued operationally since 2012. This model has recently been re-run with the latest version of the European Centre for Medium Range Weather Forecasts (ECMWF) Reanalysis product – ERA5. We use the daily NOAA Optimum Interpolation SST version 2 product for the SST predictor. Since the NOAA daily SST product is available since September 1981, this model was developed on Atlantic hurricane seasons from 1982-2019.

The pool of three predictors for the early August statistical forecast scheme is given and defined in Table 2. The location of each of these predictors is shown in Figure 2. Skillful forecasts can be issued for post-31 July ACE based upon cross-validated hindcasts from 1982-2019. When these three predictors are combined, they correlate at 0.81 with observed ACE using cross-validated hindcasts from 1982-2019 (Figure 3). All three predictors are calling for a very active Atlantic hurricane season this year.

Table 2: Listing of 1 August 2020 predictors for this year's hurricane activity. A plus (+) means that positive deviations of the parameter indicate increased hurricane activity this year, and a minus (-) means that positive deviations of the parameter indicate decreased hurricane activity this year.

Predictor	Values for 2020 Forecast	Effect on 2020 Hurricane Season
1) July 10 m U (10-17.5°N, 60-85°W) (+)	+1.0 SD	Enhance
2) July SST (20-40°N, 15-35°W) (+)	+0.8 SD	Enhance
3) July 200 hPa U (5-15°N, 0-40°E) (-)	-1.9 SD	Enhance

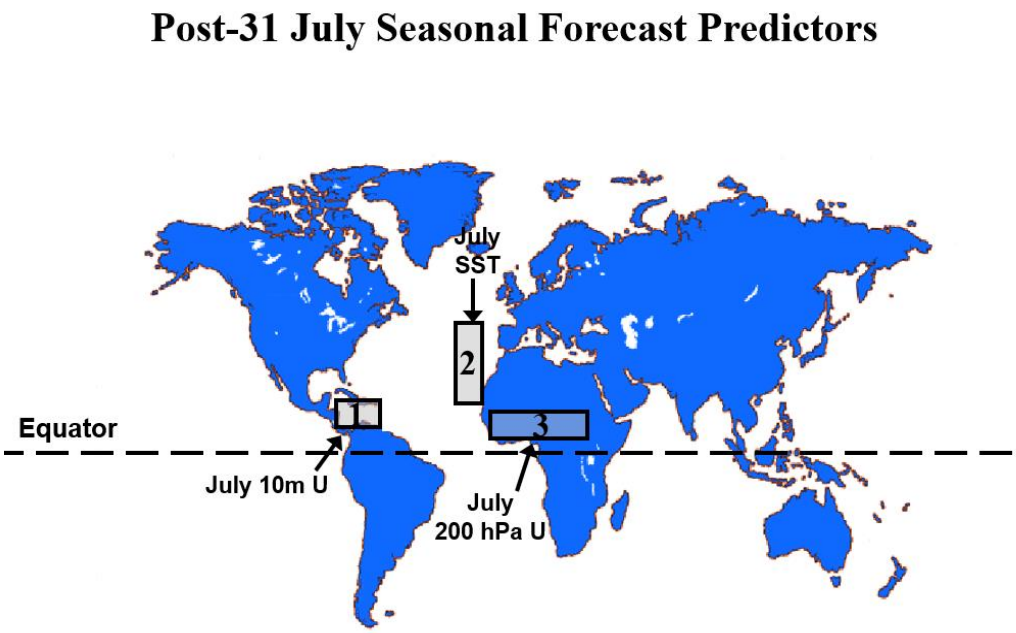

Figure 2: Location of predictors for the post-31 July forecast for the 2020 hurricane season from the statistical model.

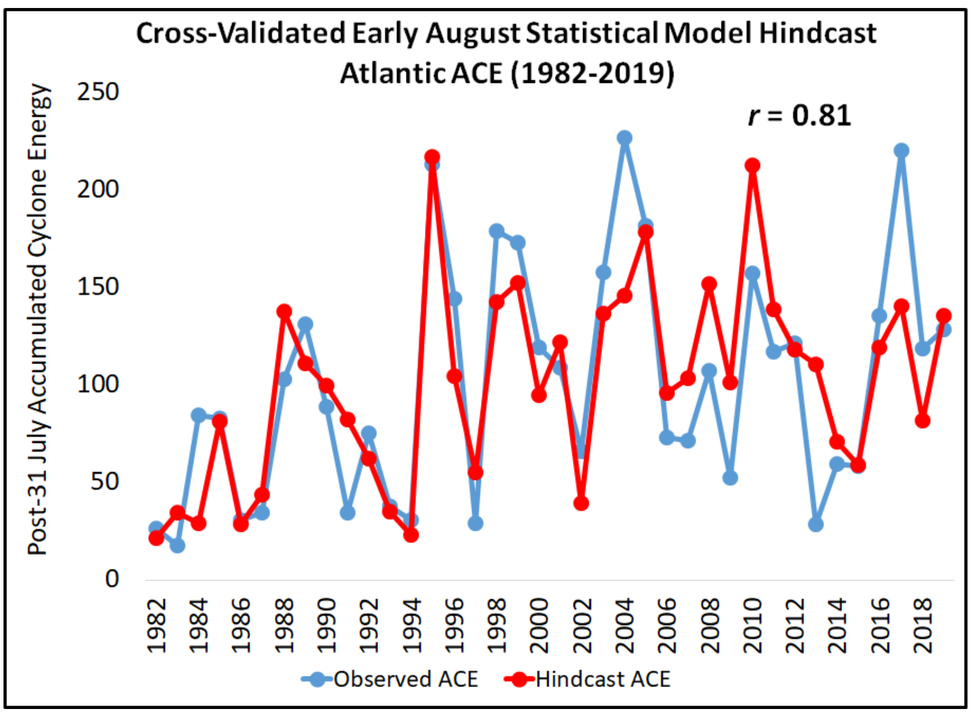

Figure 3: Observed versus hindcast values of post-31 July ACE for 1982-2019 using our current statistical scheme.

Table 3 shows our forecast for the 2020 hurricane season from the statistical model and the comparison of this forecast with the 1981-2010 average. Our statistical forecast is calling for an extremely active remainder of the season.

Table 3: Post-31 July statistical forecast for 2020 from the statistical model.

Predictands and Climatology (1981-2010 Post-31 July Average)	Post-31 July Statistical Forecast	Full Season Statistical Forecast (Activity Thru 31 July Added In)
Named Storms (NS) – 10.2	16.9	24.9
Named Storm Days (NSD) – 53.2	92.0	109.7
Hurricanes (H) – 5.9	9.6	10.6
Hurricane Days (HD) – 22.9	41.0	41.5
Major Hurricanes (MH) – 2.6	4.6	4.6
Major Hurricane Days (MHD) – 5.9	12.2	12.2
Accumulated Cyclone Energy Index (ACE) – 98	180	193
Net Tropical Cyclone Activity (NTC) – 106	189	212

2.2 Physical Associations among Predictors Listed in Table 2

The locations and brief descriptions of the three predictors for our current August statistical forecast are now discussed. It should be noted that all forecast parameters correlate significantly with physical features during August through October that are known to be favorable for elevated levels of TC activity. For each of these predictors, we display a four-panel figure showing rank correlations between values of each predictor and August-October values of SST, sea level pressure (SLP), 850 hPa (~1.5 km altitude) zonal wind (U), and 200 hPa (~12 km altitude) zonal wind (U), respectively.

Predictor 1. July 10 meter U in the Caribbean (+)

(10-17.5°N, 60-85°W)

Low-level trade wind flow has been utilized as a predictor in seasonal forecasting systems for the Atlantic basin (Saunders and Lea 2008). When the trades are weaker-than-normal, SSTs across the tropical Atlantic tend to be elevated, and consequently a larger-than-normal Atlantic Warm Pool (AWP) is typically observed (Wang and Lee 2007) (Figure 4). A larger AWP also correlates with reduced vertical shear across the tropical Atlantic. Weaker trade winds are typically associated with higher pressure in the tropical eastern Pacific (a La Niña signal) and lower pressure in the Caribbean and tropical Atlantic. Both of these conditions generally occur when active hurricane seasons are observed. Predictor 1 also has a strong negative correlation with August-October-averaged 200-850-hPa zonal shear.

Predictor 2. July Surface Temperature in the Northeastern Subtropical Atlantic (+)

(20°-40°N, 15-35°W)

A similar predictor was utilized in earlier August seasonal forecast models (Klotzbach 2007, Klotzbach 2011). Anomalously warm SSTs in the subtropical North Atlantic are associated with a positive phase of the Atlantic Meridional Mode (AMM), a northward-shifted Intertropical Convergence Zone, and consequently, reduced trade wind strength (Kossin and Vimont 2007). Weaker trade winds are associated with less surface evaporative cooling and less mixing and upwelling. This results in warmer tropical Atlantic SSTs during the August-October period (Figure 5).

<u>Predictor 3. July 200 hPa U over Northern Tropical Africa (-)</u>

(5-15°N, 0-40°E)

Anomalous easterly flow at upper levels over northern tropical Africa provides an environment that is more favorable for easterly wave development into TCs. This anomalous easterly flow tends to persist through August-October, which reduces shear over the Main Development Region (MDR). This predictor also correlates with SLP and SST anomalies over the tropical eastern Pacific that are typically associated with cool ENSO conditions (Figure 6).

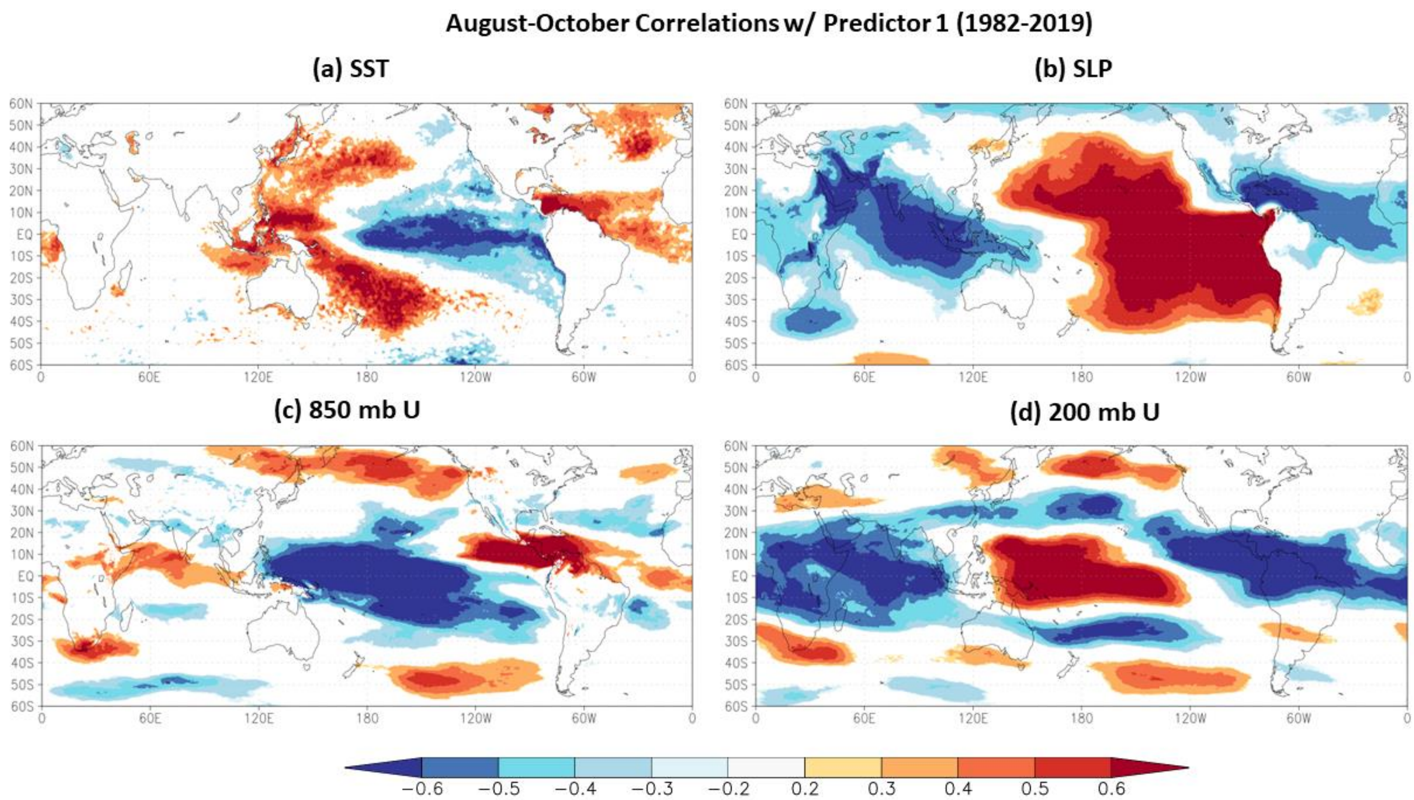

Figure 4: Rank correlations between July 10 meter U in the Caribbean (Predictor 1) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 850 hPa zonal wind (panel c) and August-October 200 hPa zonal wind (panel d) over the period from 1982-2019.

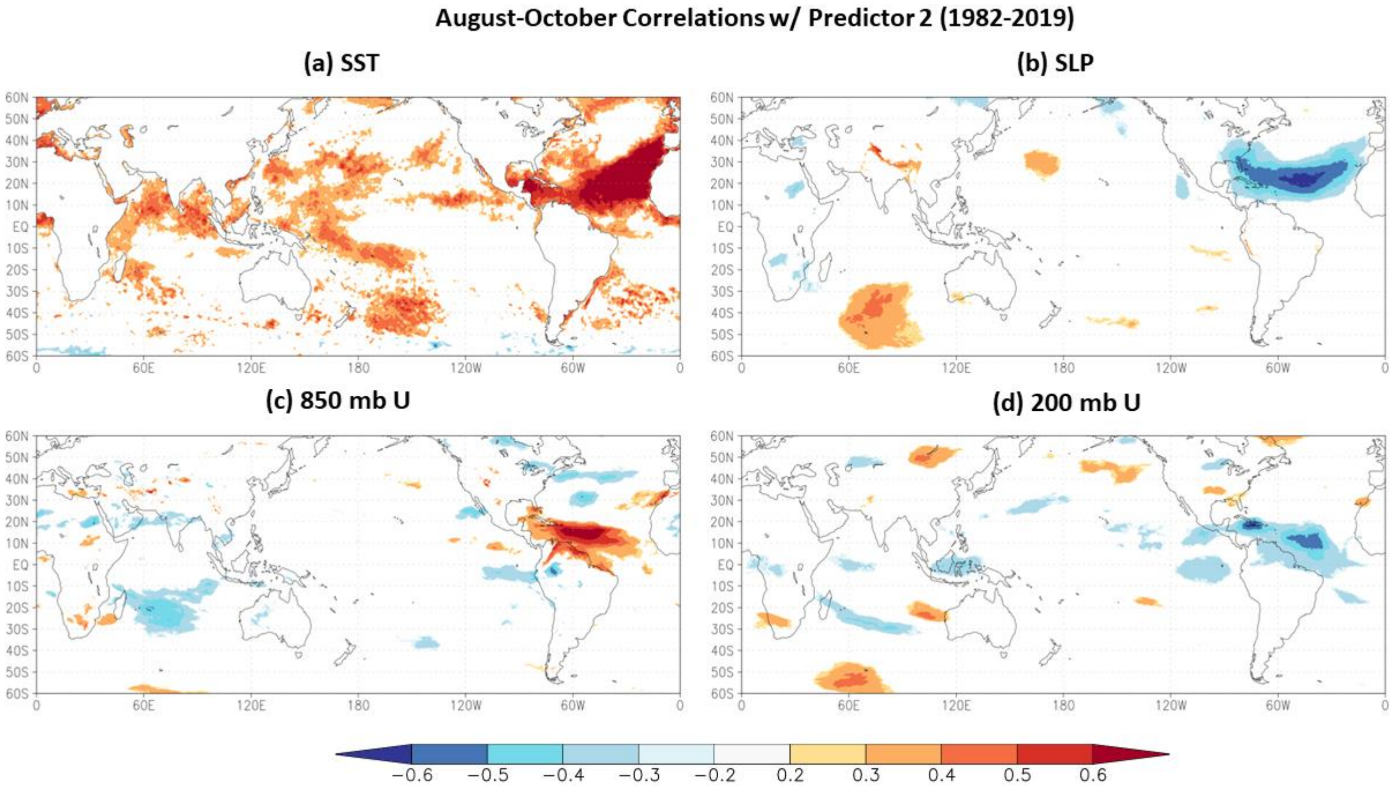

Figure 5: Rank correlations between July sea surface temperature in the subtropical northeastern Atlantic (Predictor 2) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 850 hPa zonal wind (panel c) and August-October 200 hPa zonal wind (panel d) over the period from 1982-2019.

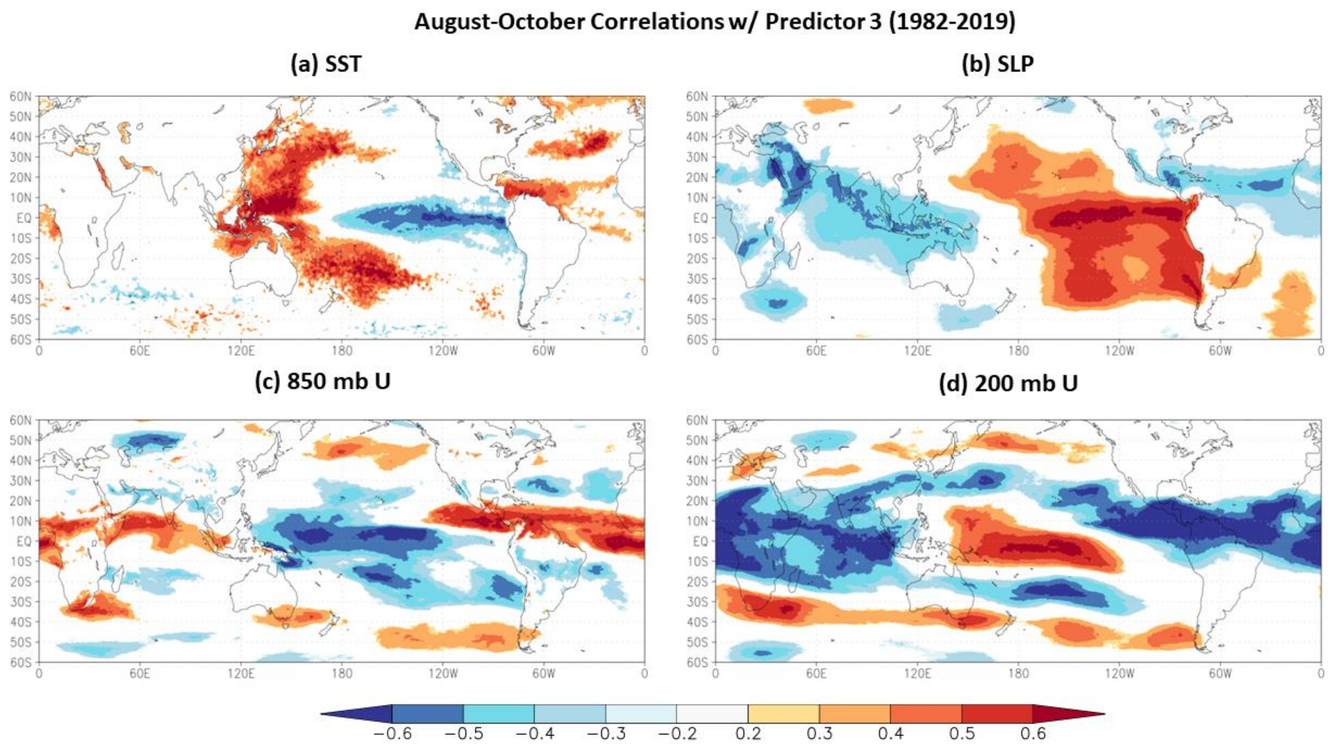

Figure 6: Rank correlations between July 200 hPa zonal wind over tropical north Africa (Predictor 3) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 hPa zonal wind (panel c) and August-October 200 hPa zonal wind (panel d) over the period from 1982-2019. Predictor values have been multiplied by -1 so that the signs of correlations match up with those in Figures 4 and 5.

2.2 August 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 August 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 July 2020 conditions and, more importantly, projected August-October 2020 conditions. Table 4 lists our analog selections.

We searched for years that were generally characterized by cool neutral ENSO to La Niña conditions during August-October. These seasons also had very warm tropical Atlantic SSTs and anomalously weak tropical Atlantic vertical wind shear. We anticipate that the 2020 hurricane season will have activity near the average of our six analog years.

Table 4: 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
2005	28	126.25	15	49.75	7	17.50	245	277
2010	19	89.50	12	38.50	5	11.00	165	196
2017	17	93.00	10	51.75	6	19.25	225	232
Average	*18.3*	*95.9*	*10.3*	*46.0*	*4.8*	*14.1*	*197*	*207*
2020 Forecast	**24**	**100**	**12**	**45**	**5**	**11**	**200**	**215**

2.4 August Forecast Summary and Final Adjusted Forecast

Table 5 shows our final adjusted early August forecast for the 2020 season which is a combination of our statistical scheme, our analog scheme and qualitative adjustments for other factors not explicitly contained in any of these schemes. Both the analog and statistical schemes call for an extremely activity Atlantic hurricane season this year. Our forecast is near the average of the statistical and analog scheme, due to both anticipated cool ENSO-neutral or weak La Niña conditions as well as anticipated anomalously warm SSTs and anomalously weak vertical wind shear in the tropical Atlantic for the peak of the Atlantic hurricane season (August-October).

Table 5: Summary of our early August statistical forecast, our analog forecast, the average of these two schemes and our adjusted final forecast for the 2020 hurricane season.

Forecast Parameter and 1981-2010 Average (in parentheses)	Statistical Scheme (Activity Thru 31 July Added In)	Analog Scheme	2-Scheme Average	Adjusted Final Forecast
Named Storms (12.1)	24.9	18.3	21.6	24
Named Storm Days (59.4)	109.7	95.9	102.8	100
Hurricanes (6.4)	10.6	10.3	10.5	12
Hurricane Days (24.2)	41.5	46.0	43.8	45
Major Hurricanes (2.7)	4.6	4.8	4.7	5
Major Hurricane Days (6.2)	12.2	14.1	13.2	11
Accumulated Cyclone Energy Index (106)	193	197	195	200
Net Tropical Cyclone Activity (116%)	212	207	210	215

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 7 and 8), 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 6 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.

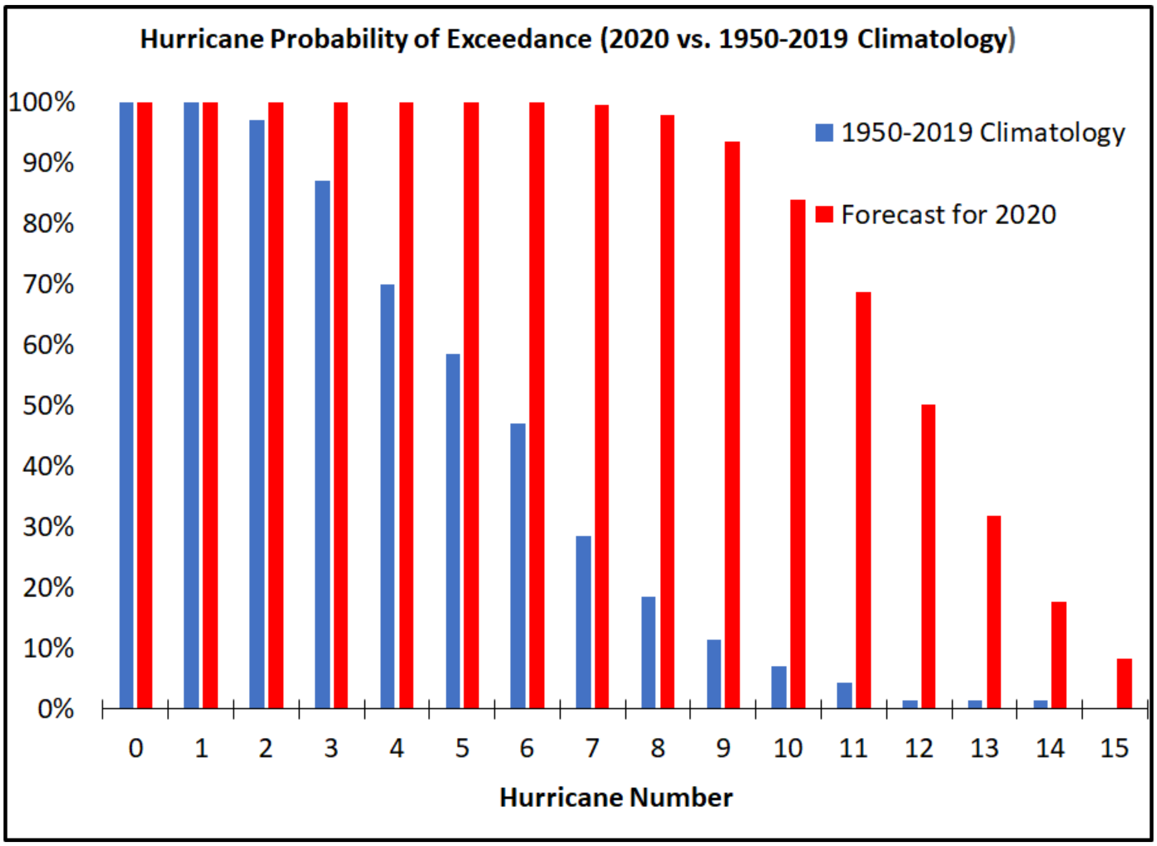

Figure 7: Probability of exceedance plot for hurricane numbers for the 2020 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950-2019 have had more than two hurricanes.

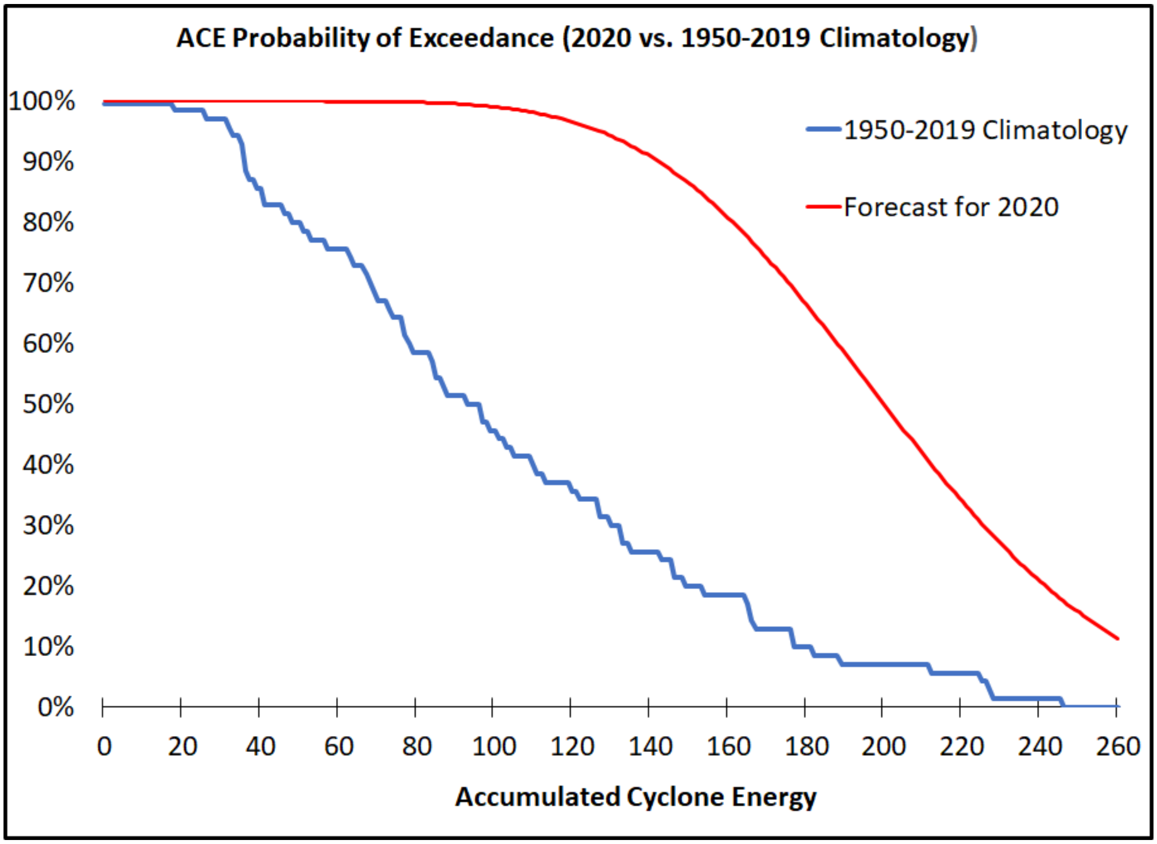

Figure 8: As in Figure 7 but for ACE.

Table 6: 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)	24	21 – 27
Named Storm Days (NSD)	100	79 – 121
Hurricanes (H)	12	10 – 14
Hurricane Days (HD)	45	32 – 59
Major Hurricanes (MH)	5	3 – 7
Major Hurricane Days (MHD)	11	7 – 16
Accumulated Cyclone Energy (ACE)	200	149 – 255
Net Tropical Cyclone (NTC) Activity	215	166 – 266

4 ENSO

The tropical Pacific continues to be characterized by cool neutral ENSO conditions, with SSTs averaging slightly below-normal across most of the central and eastern tropical Pacific (Figure 9). 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. SST anomalies trended upwards in June but have trended downwards in July in the Nino 3.4 region (Figure 10), likely due to a freshening of the trade winds after temporarily weaker trade winds during June (Figure 11).

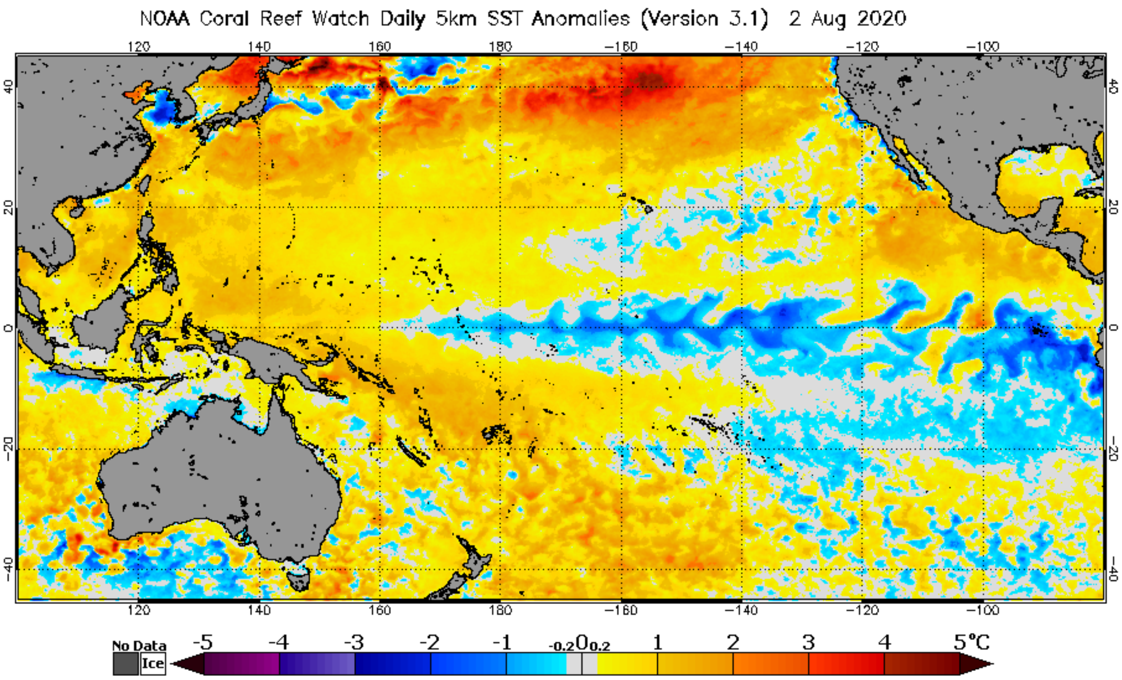

Figure 9: Current SST anomalies across the tropical and subtropical Pacific.

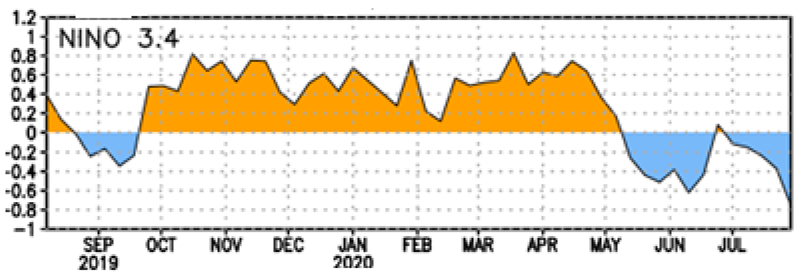

Figure 10: Nino 3.4 SST anomalies from August 2019 through July 2020. Figure courtesy of Climate Prediction Center.

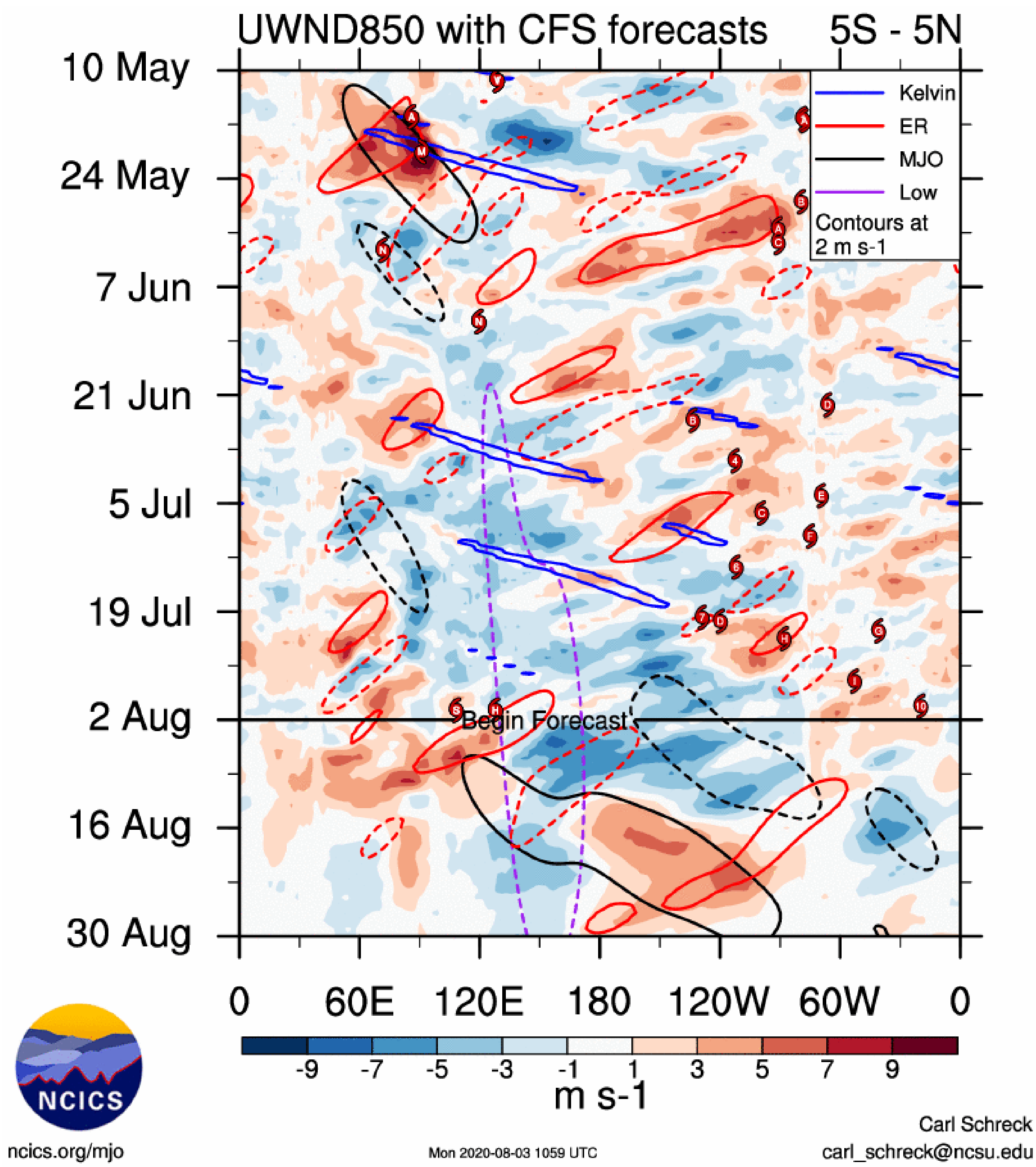

Figure 11: Observed low-level winds across the equatorial region as well as predictions for the next four weeks by the Climate Forecast System. Figure courtesy of Carl Schreck.

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 through mid-May, then increased from mid-May through early July (Figure 12). As noted in the previous paragraph, this was likely due to anomalously weak trade winds which have recently strengthened. As such, upper ocean heat content anomalies have recently started decreasing again.

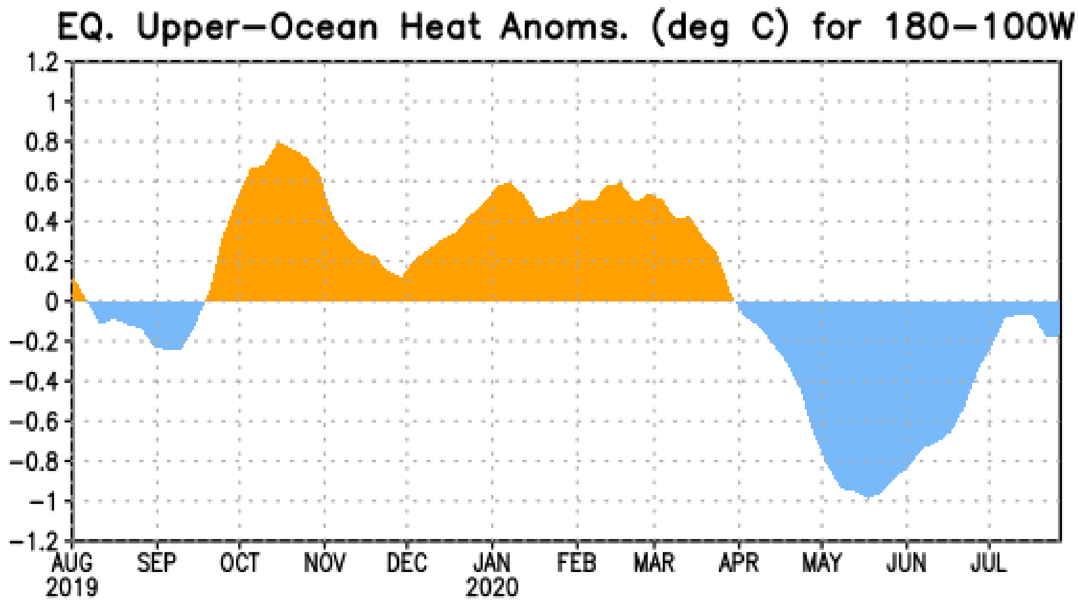

Figure 12: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year.

Table 7 displays June and July SST anomalies for several Nino regions. Anomalies have remained constant or have trended downward slightly over the past few weeks.

Table 7: June and July SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. July minus June SST anomaly differences are also provided.

Region	June SST Anomaly (°C)	July SST Anomaly (°C)	July – June SST Anomaly (°C)
Nino 1+2	-0.7	-1.2	-0.5
Nino 3	-0.7	-0.6	+0.1
Nino 3.4	-0.4	-0.4	0.0
Nino 4	+0.2	-0.1	-0.3

The tropical Pacific experienced an upwelling (cooling) Kelvin wave (denoted by a dotted line) which reached the coast of South America in early July (Figure 13). This anomalous cooling was driven by stronger-than-normal low-level easterly winds in the central tropical Pacific. Over the past few weeks, there has been relatively little change in upper-ocean heat content anomalies across most of the tropical Pacific, although there has been a bit of anomalous cooling over the past week.

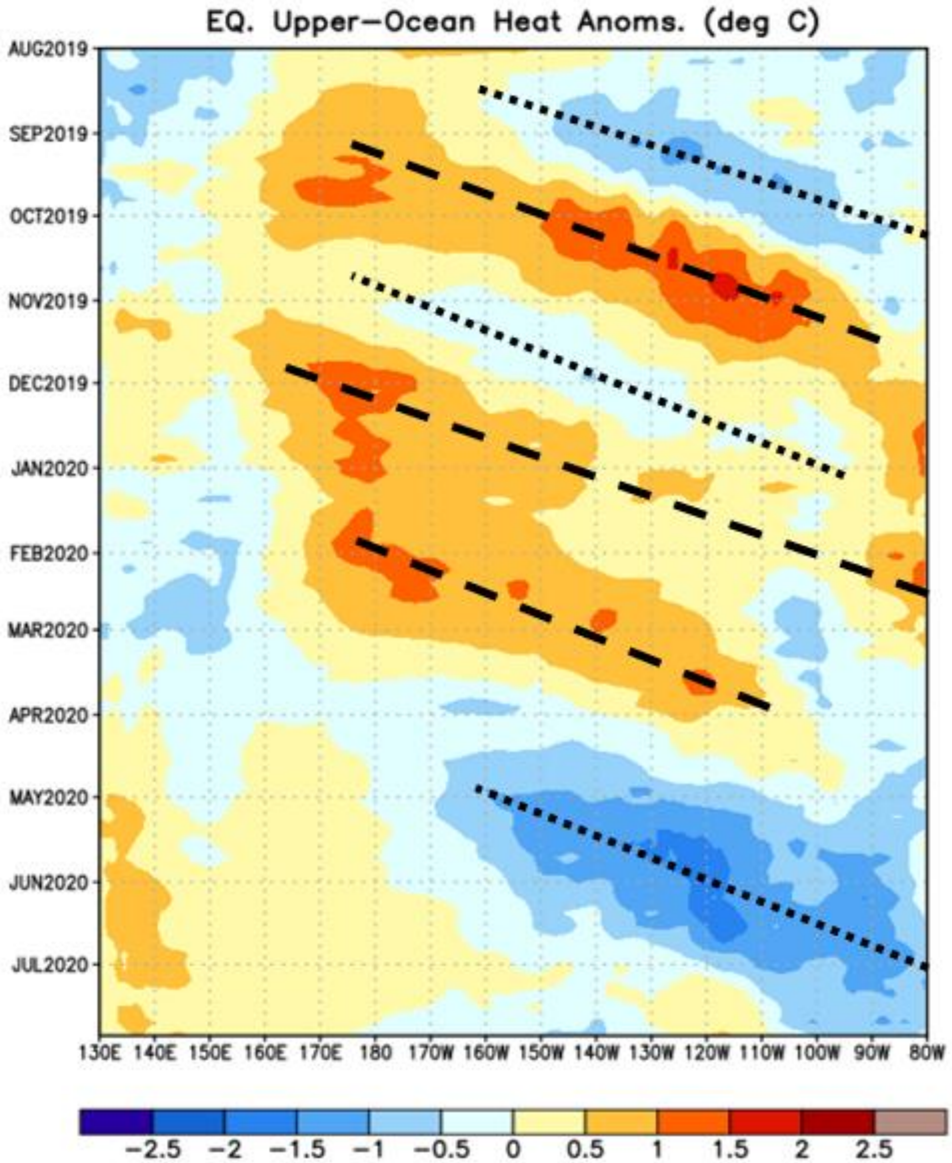

Figure 13: Upper-ocean heat content anomalies in the tropical Pacific since August 2019. Dashed lines indicate downwelling Kelvin waves, while dotted lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases.

We will continue monitoring low-level winds over the tropical Pacific as the peak of the Atlantic hurricane season gets underway. Anomalous easterlies have generally prevailed across the central tropical Pacific for the past couple of weeks, and the Climate Forecast System (CFS) is forecasting a continuation of stronger-than-normal trade winds across the central tropical Pacific for the next two weeks (Figure 11). Consequently, we believe that we will likely have either cool neutral ENSO or weak La Niña for the peak of the Atlantic hurricane season (August-October).

There is still some uncertainty as to what the exact state of ENSO will be 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 14). Most models are calling for either cool neutral ENSO or weak La Niña conditions for August-October. None of the models in the ENSO plume predict El Niño conditions for August-October.

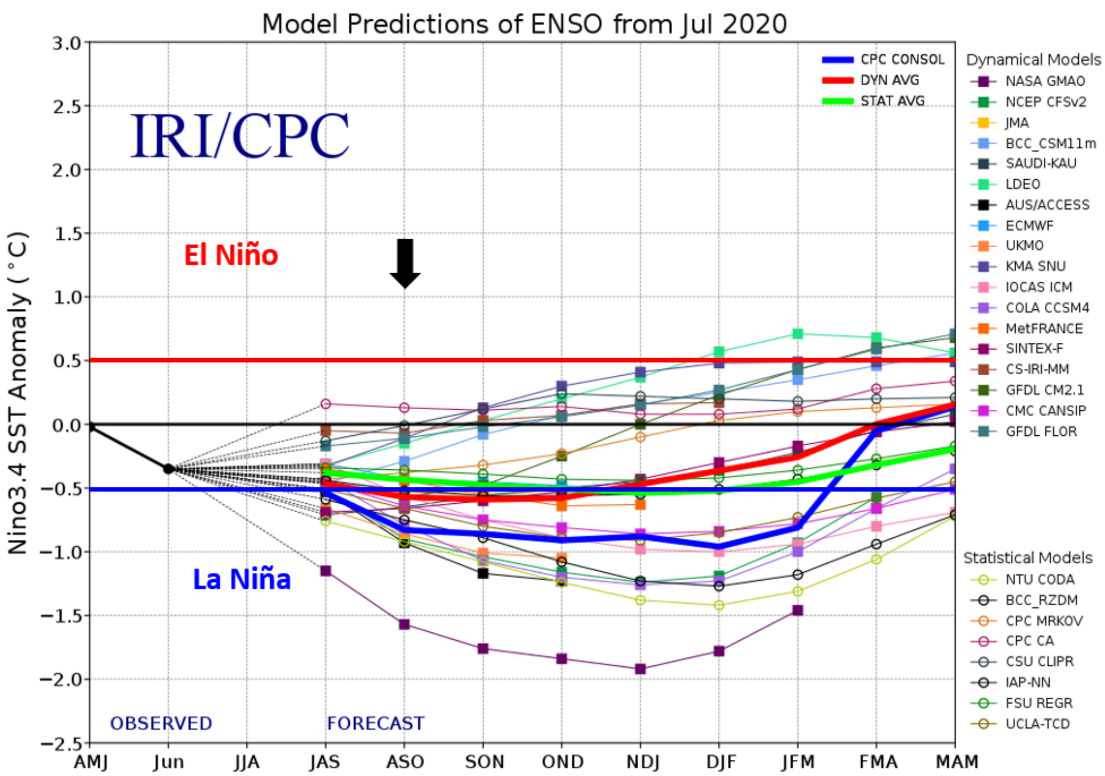

Figure 14: ENSO forecasts from various statistical and dynamical models for the Nino 3.4 SST anomaly based on late May to early June initial conditions. The majority of models are calling for ENSO neutral conditions for August-October. Figure courtesy of the International Research Institute (IRI).

The latest official forecast from NOAA indicates that the chances of El Niño are quite low for August-October. NOAA is currently predicting a 3% chance of El Niño, a 47% chance of ENSO neutral conditions and a 50% chance of La Niña for the peak of the Atlantic hurricane season (Figure 15).

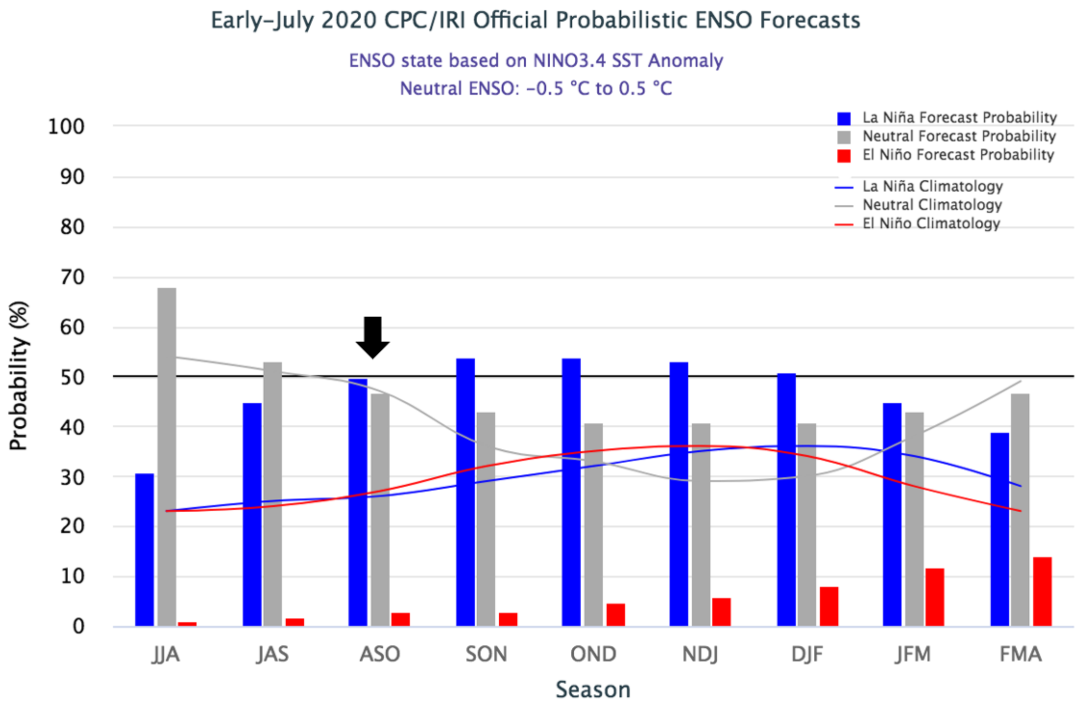

Figure 15: Official NOAA forecast for ENSO.

5 Current Atlantic Basin Conditions

Currently, the tropical Atlantic is much warmer than normal, and most of the subtropical Atlantic is also warmer than normal (Figure 16). The warm SST anomalies in the tropical Atlantic have continued to grow and expand over the past few weeks. 30-day-averaged sea surface temperature anomalies in the tropical Atlantic (10-20°N, 60-20°W) are at their 4th highest levels on record (since 1982) through August 1, trailing only (in descending order from warmest SSTs) 2010, 2005 and 2017. All three of those hurricane seasons were characterized as hyperactive by NOAA (e.g., seasonal ACE >-153). The current SST anomaly pattern is quite similar to the historical SST pattern in August that has correlated with active Atlantic hurricane seasons (Figure 17). The current SST pattern is also tracking warmer than what has typically characterized hyperactive Atlantic hurricane seasons of the past ~40 years (Figure 18).

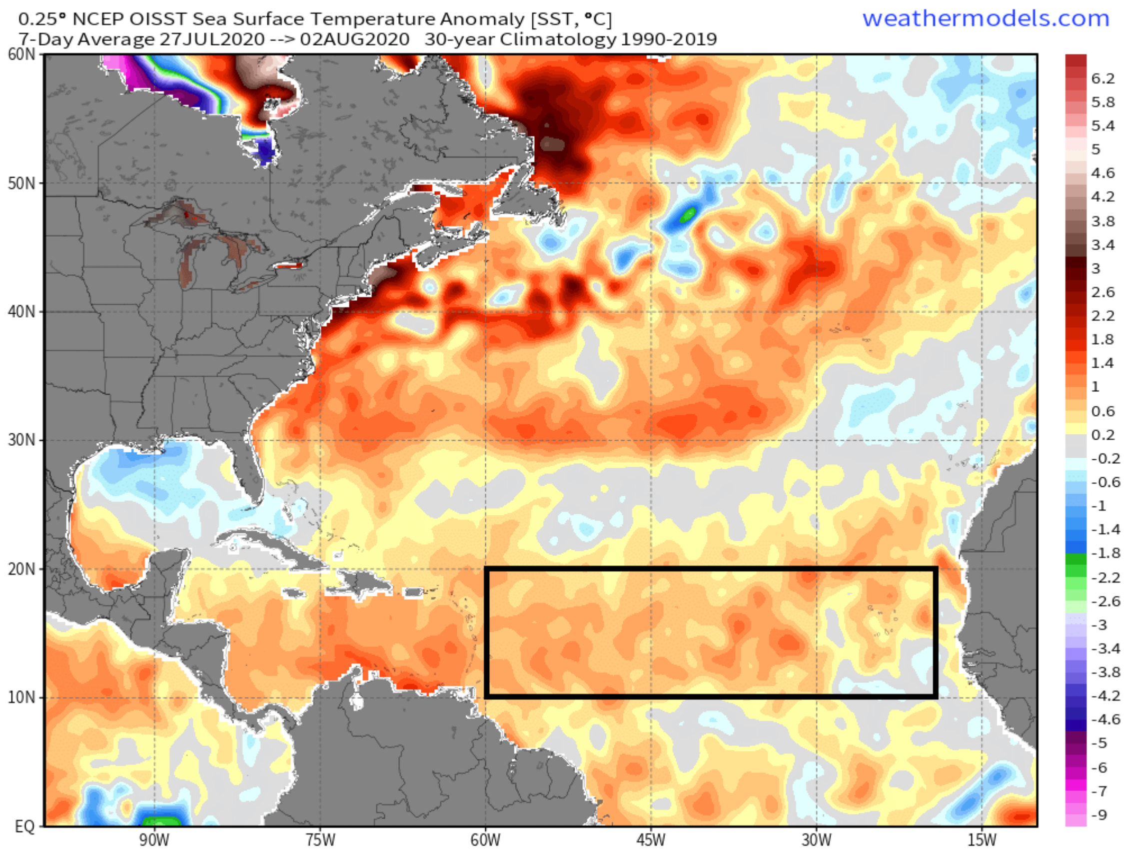

Figure 16: Late July/early August 2020 SST anomaly pattern across the Atlantic Ocean.

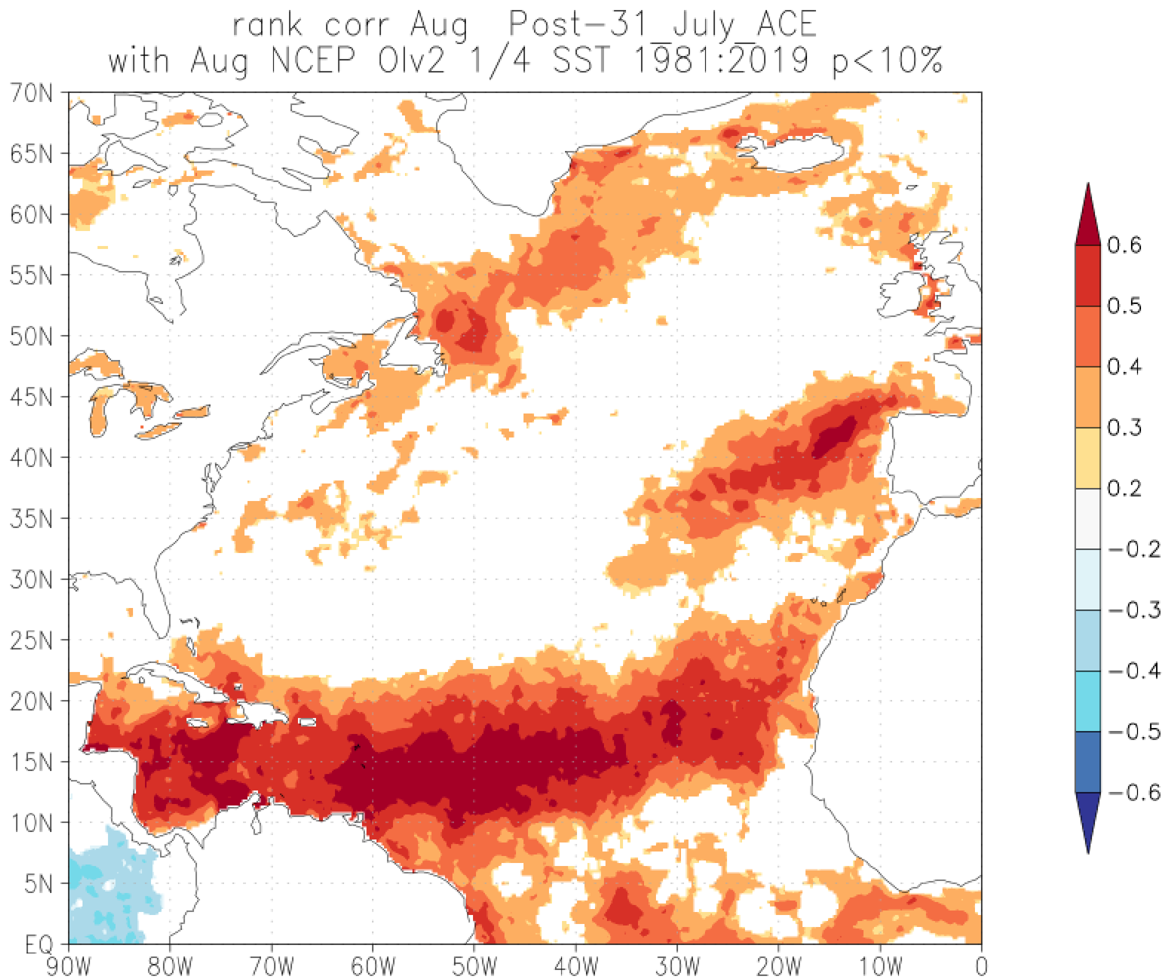

Figure 17: Rank correlation between August North Atlantic SST anomalies and post-31 July Atlantic ACE from 1982-2019.

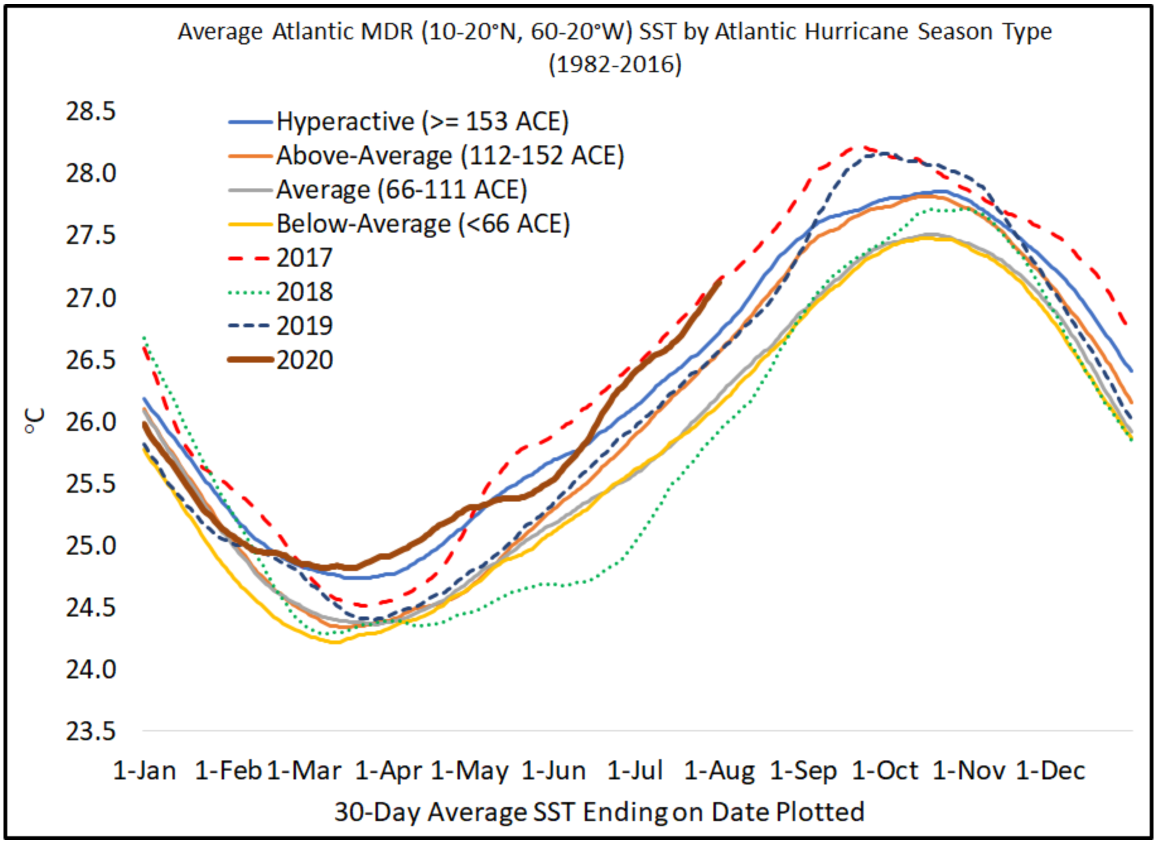

Figure 18: Average sea surface temperatures for various Atlantic hurricane season types from 1982-2016 based on the NOAA definition. Also plotted are SSTs for the past four seasons: 2017, 2018, 2019 and 2020. The 2020 Atlantic hurricane season is now tracking above what has historically been experienced in hyperactive Atlantic hurricane seasons and is just slightly below 2017 for the most recent 30-day averages.

Vertical wind shear over the past several weeks has been much lower than normal across most of the tropical Atlantic and Caribbean (Figure 19). Current 30-day-averaged shear across the central tropical Atlantic and Caribbean (10-20°N, 90-40°W) is the 2nd lowest on record, trailing only 2005. Our analysis is using the ERA5 reanalysis and looks at Atlantic hurricane seasons since 1979. Current vertical wind shear anomalies are weaker than what is observed in the average hyperactive Atlantic hurricane season, indicating extremely conducive upper- and lower-level wind patterns for an active 2020 Atlantic hurricane season (Figure 20).

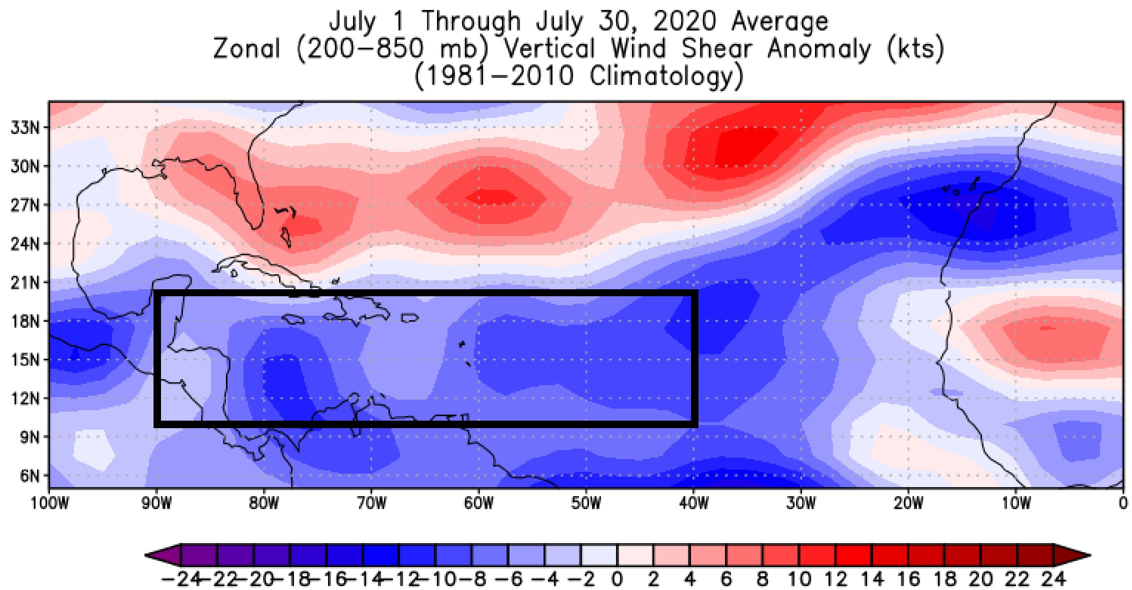

Figure 19: June 30 – July 29, 2020-averaged zonal vertical wind shear across the tropical Atlantic and Caribbean differenced from the 1981-2010 climatology.

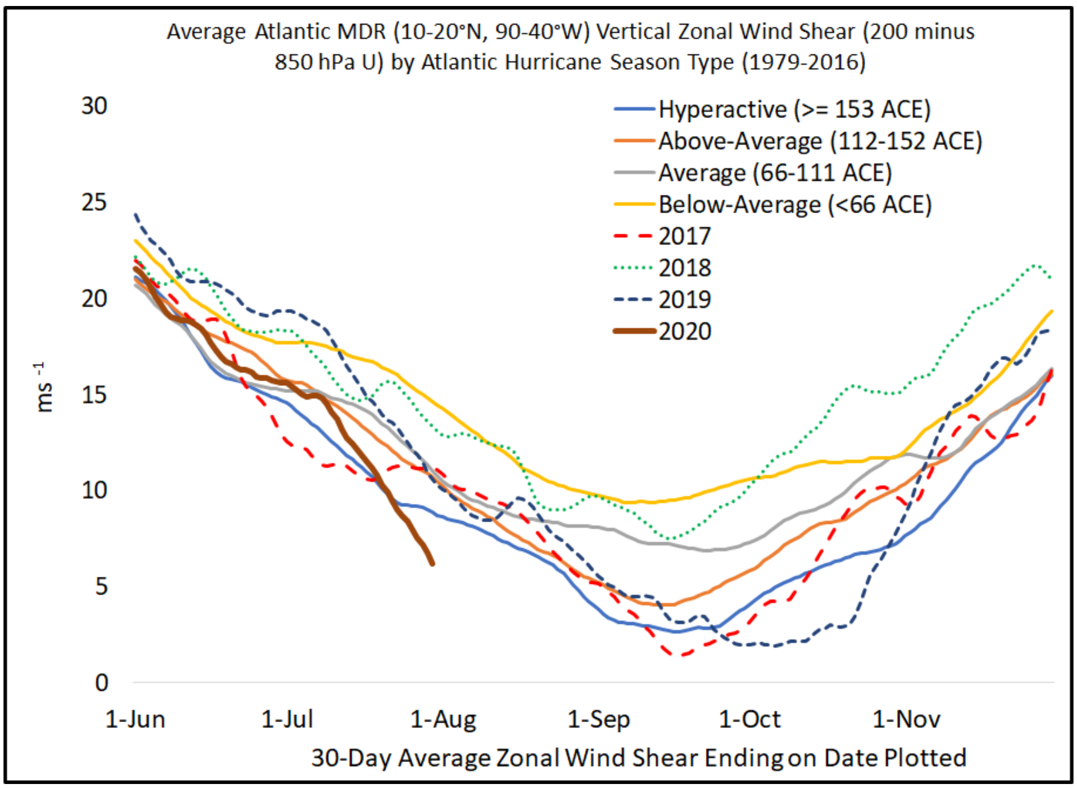

Figure 20: 30-day-averaged 200 minus 850 hPa zonal wind shear for various Atlantic hurricane season types from 1982-2016 based on the NOAA definition. Also plotted is vertical wind shear for the past four seasons: 2017, 2018, 2019 and 2020. The 2020 Atlantic hurricane season now has less vertical wind shear than what has historically been experienced in July during hyperactive Atlantic hurricane seasons.

July sea level pressure anomalies across the tropical Atlantic (10-20°N, 60-20°W) were at their lowest levels on record (since 1948 when the NCEP/NCAR Reanalysis began (Figure 21). Generally, when July sea level pressure anomalies are low, more active Atlantic hurricane seasons are experienced. Lower pressure is typically associated with increased instability, increased mid-level moisture and decreased vertical wind shear.

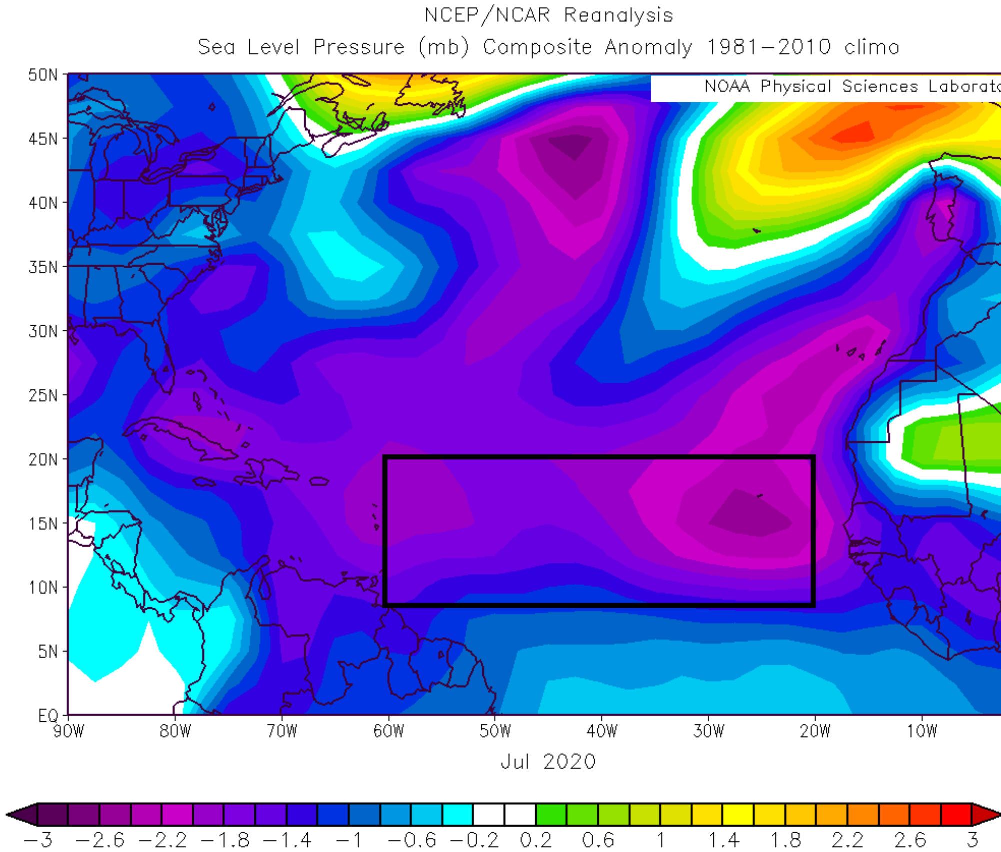

Figure 21: July 2020 sea level pressure anomalies across the tropical and subtropical North Atlantic. The black rectangle highlights the definition of the tropical Atlantic used in the above paragraph.

6 West Africa Conditions

The West African monsoon continues to be very active, with pronounced anomalous upward vertical motion across most of Africa over the past 30 days (Figure 22). Precipitation across most of the Sahel also was well above average in July (Figure 23). Overall, large-scale conditions over West Africa are consistent with our very active Atlantic seasonal hurricane forecast.

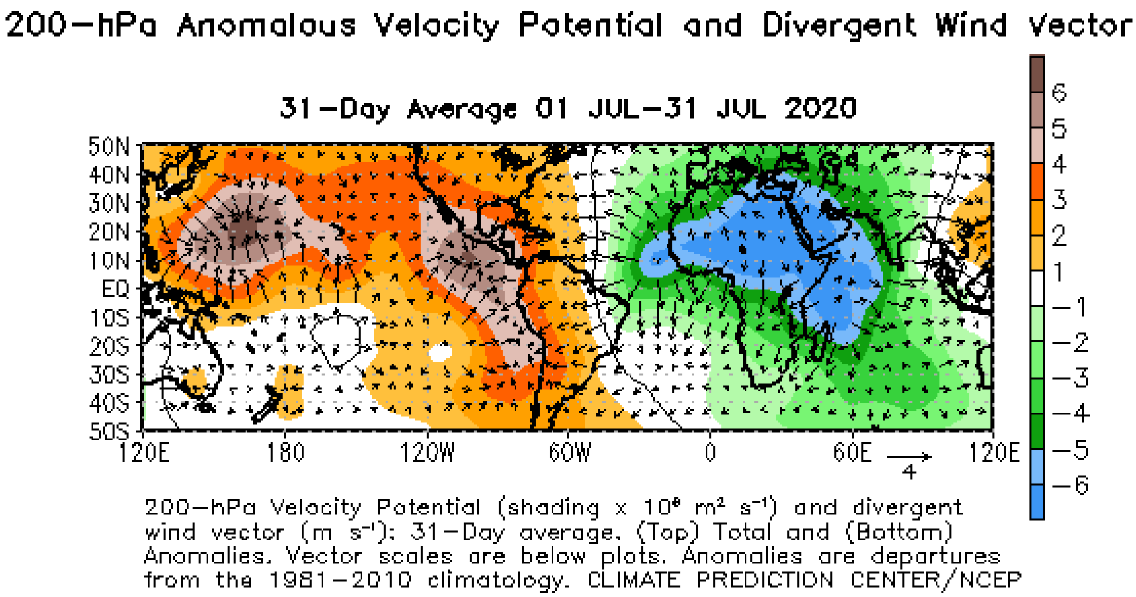

Figure 22: 200 hPa velocity potential anomalies from 50°S – 50°N. Negative velocity potential favors upward vertical motion.

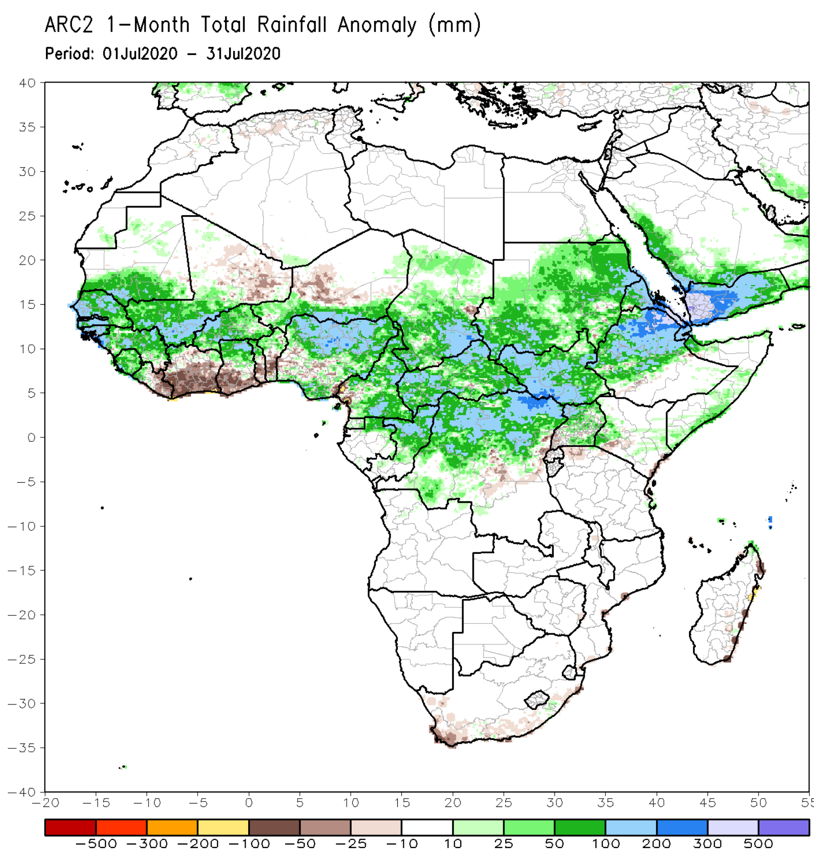

Figure 23: July 2020 rainfall estimates from the African Rainfall Climatology, version 2.

7 Landfall Probabilities for 2020

A significant focus of our recent research involves efforts to develop forecasts of the probability of hurricane landfall along the U.S. coastline and in the Caribbean. Whereas individual hurricane landfall events cannot be forecast months in advance, the total seasonal probability of landfall can be forecast with statistical skill. With the observation that landfall is a function of varying climate conditions, a probability specification has been developed through statistical analyses of all U.S. hurricane and named storm landfall events during the 20th century (1900-1999). Specific landfall probabilities can be given for all tropical cyclone intensity classes for a set of distinct U.S. coastal regions.

Net landfall probability is shown linked to the overall Atlantic basin Net Tropical Cyclone activity (NTC; see Table 8). NTC is a combined measure of the year-to-year mean of six indices of hurricane activity, each expressed as a percentage difference from the long-term average. Long-term statistics show that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of U.S. hurricane landfall.

Table 8: NTC activity in any year consists of the seasonal total of the following six parameters expressed in terms of their long-term averages. A season with 10 NS, 50 NSD, 6 H, 25 HD, 3 MH, and 5 MHD would then be the sum of the following ratios: 10/9.6 = 104, 50/49.1 = 102, 6/5.9 = 102, 25/24.5 = 102, 3/2.3 = 130, 5/5.0 = 100, divided by six, yielding an NTC of 107.

	1950-2000 Average	
1)	Named Storms (NS)	9.6
2)	Named Storm Days (NSD)	49.1
3)	Hurricanes (H)	5.9
4)	Hurricane Days (HD)	24.5
5)	Major Hurricanes (MH)	2.3
6)	Major Hurricane Days (MHD)	5.0

Table 9 lists strike probabilities for the 2020 hurricane season for different TC categories for the entire U.S. coastline, the Gulf Coast and the East Coast including the Florida peninsula. We also issue probabilities for various islands and landmasses in the Caribbean and in Central America. Note that Atlantic basin post-31 July NTC activity in 2020 is expected to well above its long-term average, and therefore, landfall probabilities are well above their long-term average.

Table 9: Estimated probability (expressed in percent) of one or more landfalling tropical storms (TS), category 1-2 hurricanes (HUR), category 3-4-5 hurricanes, total hurricanes and named storms along the entire U.S. coastline, along the Gulf Coast (Regions 1-4), and along the Florida Peninsula and the East Coast (Regions 5-11) for the remainder of the 2020 Atlantic hurricane season. Probabilities of a tropical storm, hurricane and major hurricane tracking into the Caribbean are also provided. The long-term mean annual probability of one or more landfalling systems during the 20th century is given in parentheses.

Region	TS	Category 1-2 HUR	Category 3-4-5 HUR	All HUR	Named Storms
Entire U.S. (Regions 1-11)	94% (79%)	87% (68%)	74% (52%)	97% (84%)	99% (97%)
Gulf Coast (Regions 1-4)	80% (59%)	64% (42%)	48% (30%)	81% (60%)	96% (83%)
Florida plus East Coast (Regions 5-11)	72% (50%)	66% (44%)	49% (31%)	83d% (61%)	95% (81%)
Caribbean (10-20°N, 60-88°W)	96% (82%)	79% (57%)	63% (42%)	92% (75%)	99% (96%)

Please also visit the Landfalling Probability Webpage for landfall probabilities for 11 U.S. coastal regions and 205 coastal and near-coastal counties from Brownsville, Texas to Eastport, Maine as well as probabilities for Caribbean islands.

8 Summary

An analysis of a variety of different atmosphere and ocean measurements (through July) which are known to have long-period statistical relationships with the upcoming season's Atlantic tropical cyclone activity indicate that the remainder of the 2020 Atlantic hurricane season should be extremely active. Tropical Atlantic sea surface temperatures are much warmer than normal, and vertical wind shear is well below normal. Tropical Atlantic sea level pressures are also much lower than normal. The overall tropical circulation pattern (e.g., upward motion over Africa and the Indian Ocean and suppressed motion over the tropical Pacific) is also extremely favorable for an active Atlantic hurricane season.

9 Forthcoming Updated Forecasts of 2020 Hurricane Activity

We will be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August-October, beginning today, Wednesday, August 5 and continuing every other Monday (August 19, September 2, September 16, etc.). A verification and discussion of all 2020 forecasts will be issued in late November 2020. All of these forecasts will be available online.