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

We have slightly increased our forecast for the 2020 Atlantic basin hurricane season and believe that the season will have well above-average activity. Current neutral ENSO conditions may transition to weak La Niña conditions by later this summer. Sea surface temperatures averaged across portions of the tropical Atlantic are somewhat above normal, while the subtropical Atlantic is much warmer than average. Our Atlantic Multi-decadal Oscillation index remains somewhat below its long-term average. 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 4 June 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	Observed Activity Through June 2 2020	Total Seasonal Forecast (Includes Arthur, Bertha & Cristobal*)
Named Storms (NS) (12.1)	16	16	3	19
Named Storm Days (NSD) (59.4)	80	81.75	3.25	85
Hurricanes (H) (6.4)	8	9	0	9
Hurricane Days (HD) (24.2)	35	40	0	40
Major Hurricanes (MH) (2.7)	4	4	0	4
Major Hurricane Days (MHD) (6.2)	9	9	0	9
Accumulated Cyclone Energy (ACE) (106)	150	158	2	160
Net Tropical Cyclone Activity (NTC) (116%)	160	164	6	170

*Arthur, Bertha and Cristobal have formed in the Atlantic as of June 2nd.

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

1) Entire continental U.S. coastline - 70% (average for last century is 52%)

2) U.S. East Coast Including Peninsula Florida - 46% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 45% (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)

1) 59% (average for last century is 42%)

ABSTRACT

Information obtained through May 2020 indicates that the 2020 Atlantic hurricane season will have activity above the 1981-2010 average. Tropical Storms Arthur, Bertha and Cristobal have formed in the Atlantic as of June 2nd. We estimate that 2020 will have an additional 9 hurricanes (average is 6.4), 16 named storms (average is 12.1), 81.5 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 June 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 in the eastern and central tropical Pacific have anomalously cooled over the past two months, and it appears likely that there will be either cool neutral ENSO or weak La Niña conditions during the summer/fall. The tropical Atlantic is slightly warmer than normal, while the subtropical Atlantic is quite warm, and the far North Atlantic is anomalously cool. Most of the eastern Atlantic is warmer than normal, and anomalously warm temperatures in this region in May are 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 June forecast has moderate long-term skill when evaluated in hindcast mode. The skill of CSU’s forecast updates 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 June. 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 June 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 June 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 June Forecast Methodology

2.1 June Statistical Forecast Scheme

We are debuting a new June 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 = 0.72) 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.

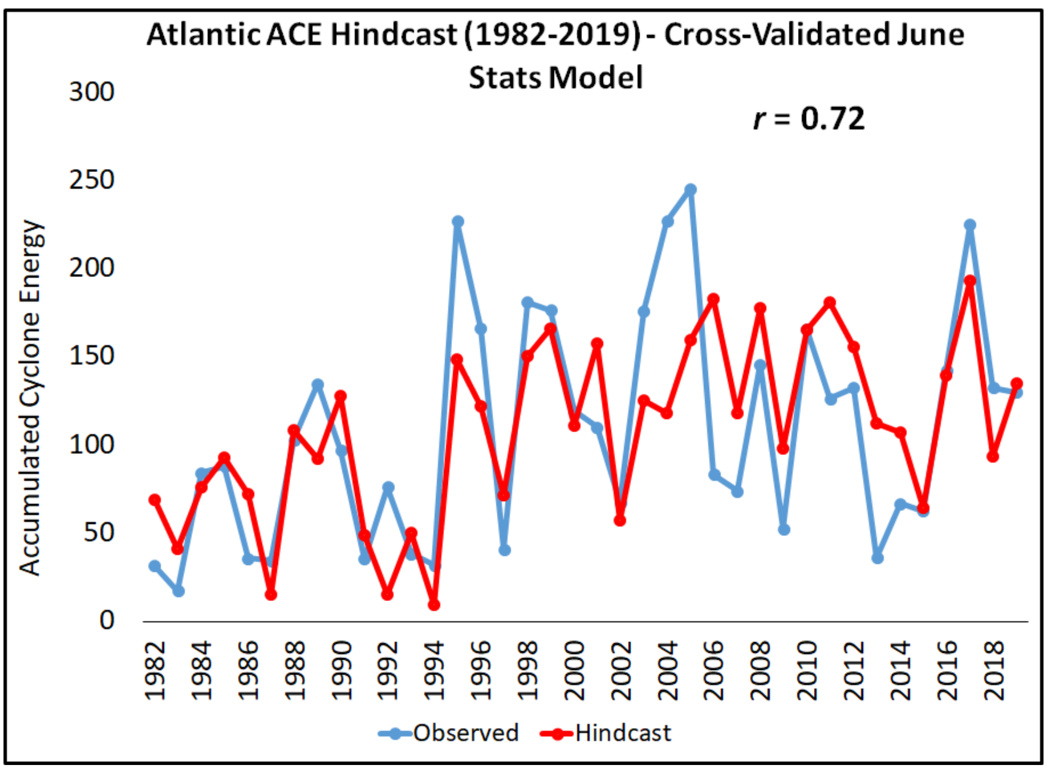

Figure 1: Observed versus early June cross-validated hindcast values of ACE for the statistical model for 1982-2019.

June Forecast Predictors

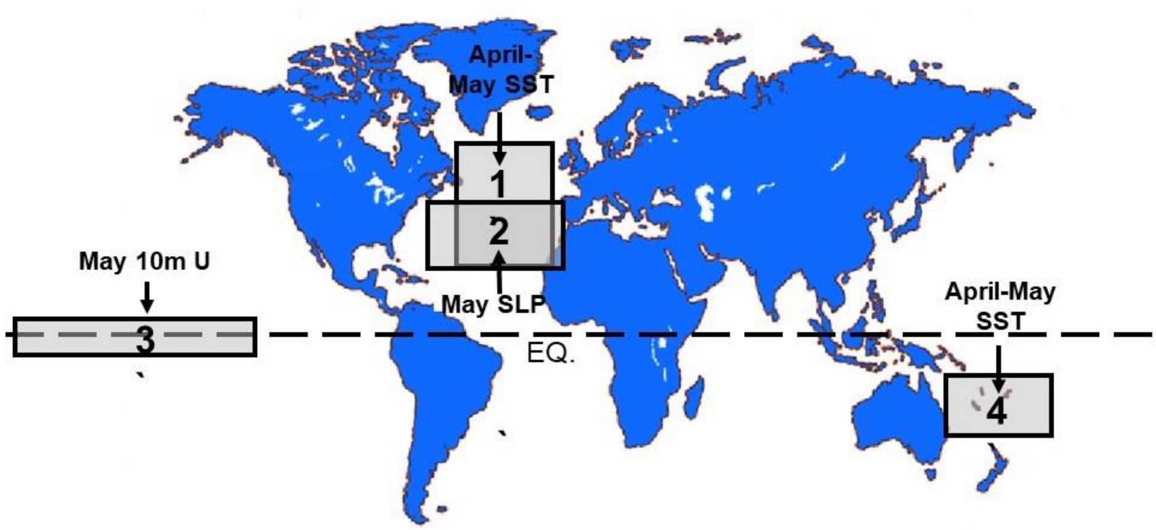

Figure 2: Location of predictors for our early June extended-range statistical prediction for the 2020 hurricane season.

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

Predictor	Correlation w/ ACE
1) April-May SST (20°N-60°N, 40°W-15°W) (+)	0.58
2) May SLP (20°N-40°N, 60°W-10°W) (-)	-0.32
3) May 10m U (5°S-5°N, 180°W-130°W) (-)	-0.54
4) April-May SST (35°S-15°S, 155°E-180°E) (+)	0.64

Table 2: Listing of early June 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) April-May SST (20°N-60°N, 40°W-15°W) (+)	+1.3 SD	Enhance
2) May SLP (20°N-40°N, 60°W-10°W) (-)	+0.9 SD	Suppress
3) May 10m U (5°S-5°N, 180°W-130°W) (-)	-1.0 SD	Enhance
4) April-May SST (35°S-15°S, 155°E-180°E) (+)	+1.0 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)	15.3	19
Named Storm Days (NSD) (59.4)	80.3	85
Hurricanes (H) (6.4)	8.3	9
Hurricane Days (HD) (24.2)	34.3	40
Major Hurricanes (MH) (2.7)	3.8	4
Major Hurricane Days (MHD) (6.2)	9.7	9
Accumulated Cyclone Energy (ACE) (106)	151	160
Net Tropical Cyclone Activity (NTC) (116%)	161	170

The locations and brief descriptions of the predictors for our early June 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.

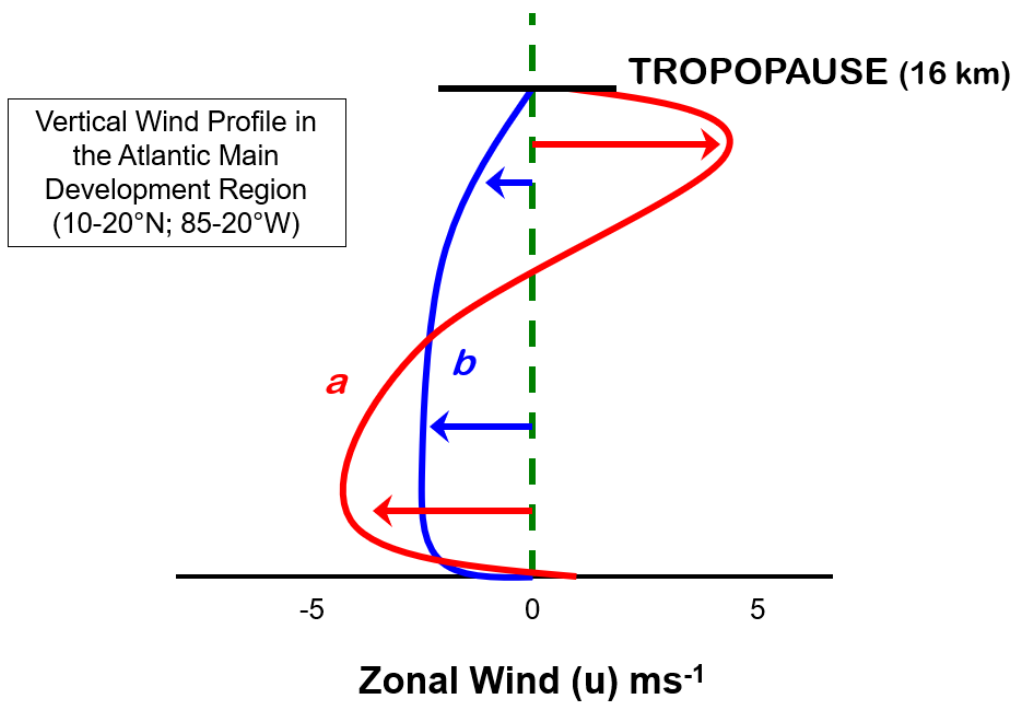

Figure 3: Vertical wind profile typically associated with (a) inactive Atlantic basin hurricane seasons and (b) active Atlantic basin hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

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.

Predictor 1. April-May SST in the Subtropical and Mid-latitude eastern North Atlantic (+)

(20°N-60°N, 40°W-15°W)

Warmer-than-normal SSTs in the subtropical and mid-latitude eastern North Atlantic during the April-May time period are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the boreal spring (Knaff 1997). These warmer-than-normal SSTs in April-May 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 three 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 rank correlates quite strongly (r =0.58) with ACE from 1982-2019. Predictor 1 also strongly correlates (r = 0.66) with August-October values 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 SLP in the Subtropical North Atlantic (-)

(20°N-40°N, 60°W-10°W)

Anomalously low pressure in the subtropical North Atlantic during May is associated with weaker trade winds and anomalous warming of the central and eastern tropical Atlantic during the boreal spring. While the anomalous warming signal in the tropical Atlantic SST decays by the peak of the Atlantic hurricane season (Figure 5), there remains a significant signal in 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 North Atlantic is characterized by lower pressure in May, the peak of the Atlantic hurricane season typically has reduced levels of vertical wind shear across the Main Development Region.

Predictor 3. May 10m U in the central and eastern tropical Pacific (-)

(5°S-5°N, 180°W-130°W)

Stronger-than-normal low-level winds during May in the central and eastern tropical Pacific are associated with enhanced upwelling which drives anomalous cooling in the central and eastern tropical Pacific, inhibiting the development of El Niño conditions. This relationship can be clearly demonstrated by a significant negative correlation between Predictor 3 with the August-October-averaged Oceanic Nino Index (r = -0.49). As would be expected given this significant negative correlation, 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. April-May 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. This anomalous pressure pattern results in a positive Southern Oscillation Index (SOI), both in April-May and in August-October. The correlation between the SOI in April-May and Predictor 4 is 0.31, while the correlation increases to 0.40 between Predictor 4 and the August-October-averaged SOI. In addition, the correlation between Predictor 4 and the August-October averaged Walker Circulation Index is 0.48. A stronger Walker Circulation Index is associated with decreased vertical wind shear across the Caribbean and tropical Atlantic (Figure 7).

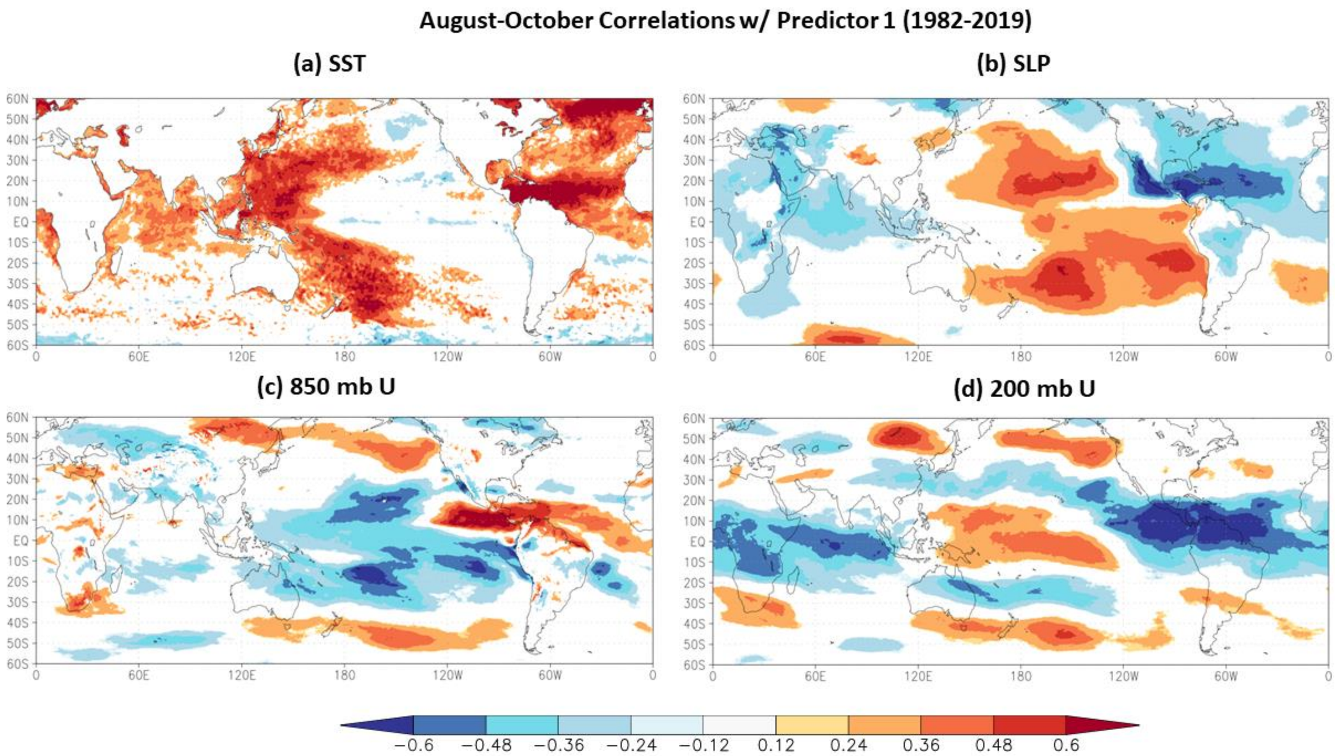

Figure 4: Rank correlations between April-May SST in the subtropical and mid-latitude eastern North Atlantic (Predictor 1) and (panel a) August-October sea surface temperature, (panel b) August-October sea level pressure, (panel c) August-October 850 hPa zonal wind and (panel d) August-October 200 hPa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

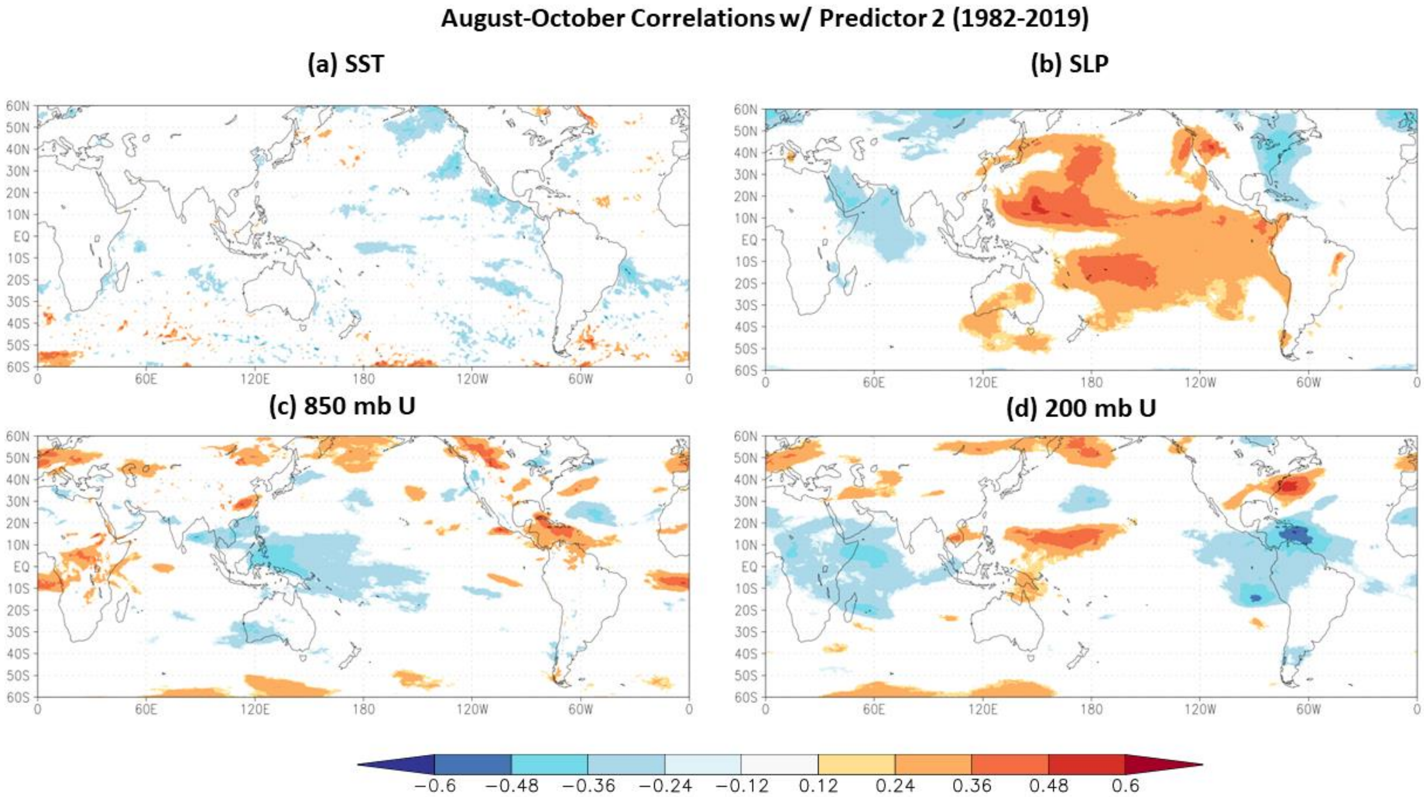

Figure 5: As in Figure 4 but for May SLP in the subtropical North Atlantic. The sign of Predictor 2 has been flipped for easy comparison with Figure 4.

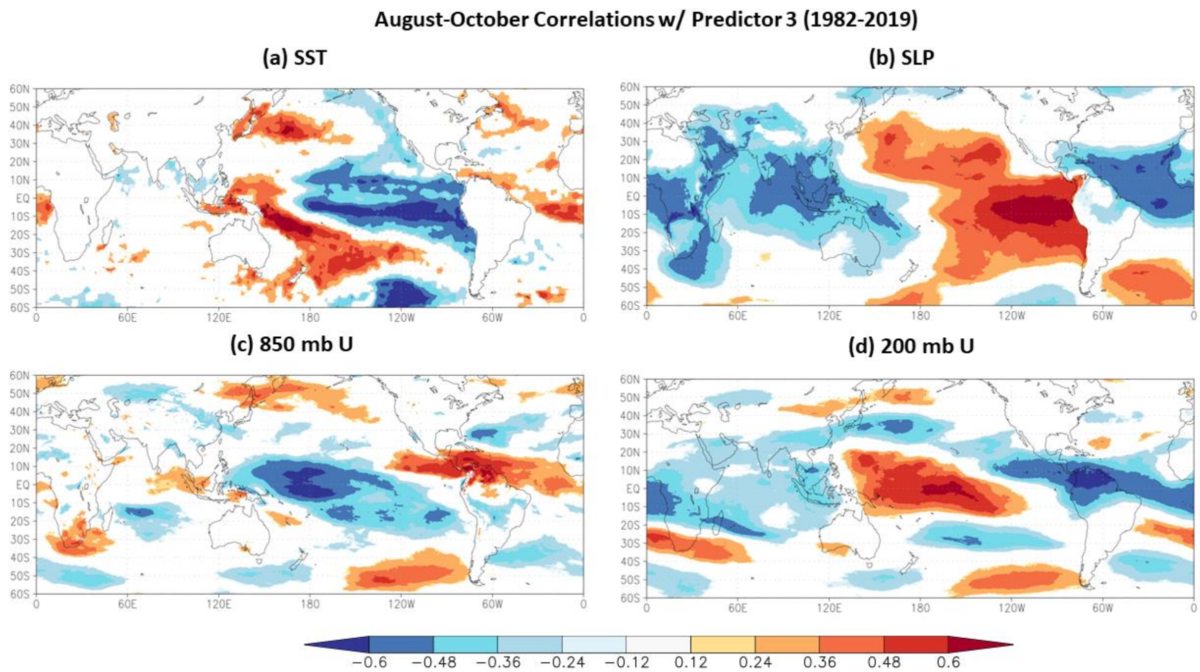

Figure 6: As in Figure 4 but for 10 meter zonal wind in the central and eastern equatorial Pacific Ocean. The sign of Predictor 2 has been flipped for easy comparison with Figure 4.

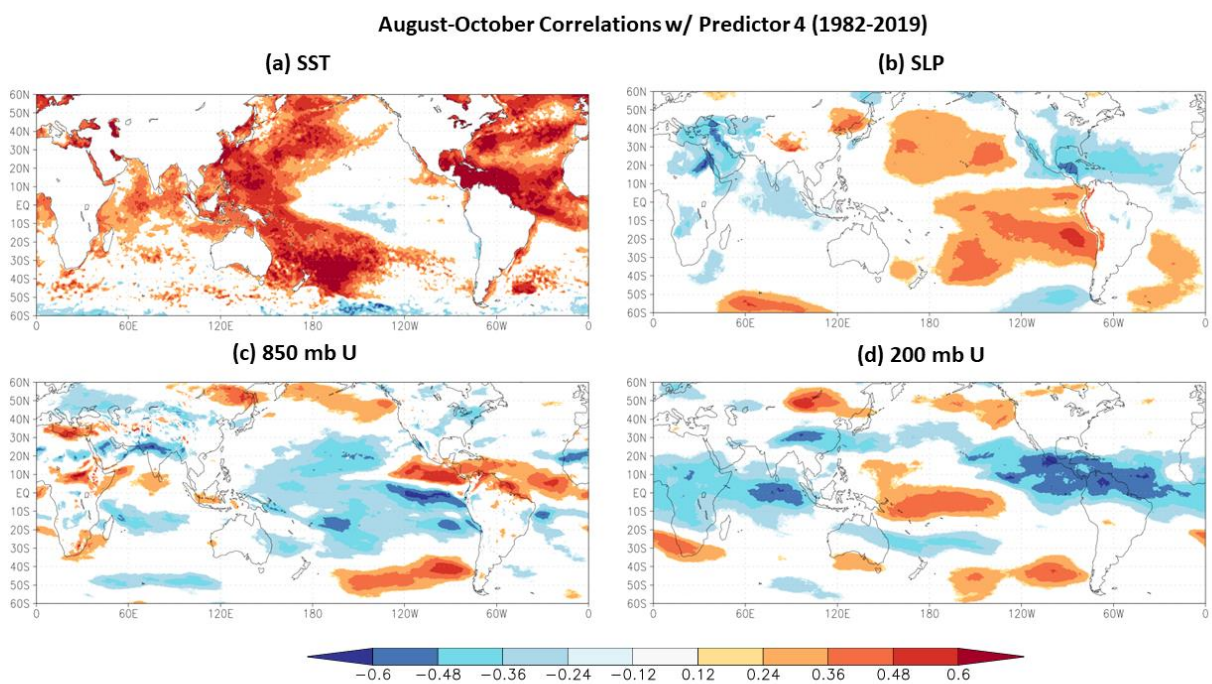

Figure 7: As in Figure 4 but for April-May SST in the tropical and subtropical western South Pacific.

2.2 June 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 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 May 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 May 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. However, the trade wind predictor has relatively less weight at the 1 May initialization time than the other two predictors, and consequently, the SEAS5 statistical/dynamical model is calling for a very active season. 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.

Post-31 July Seasonal Forecast Predictors

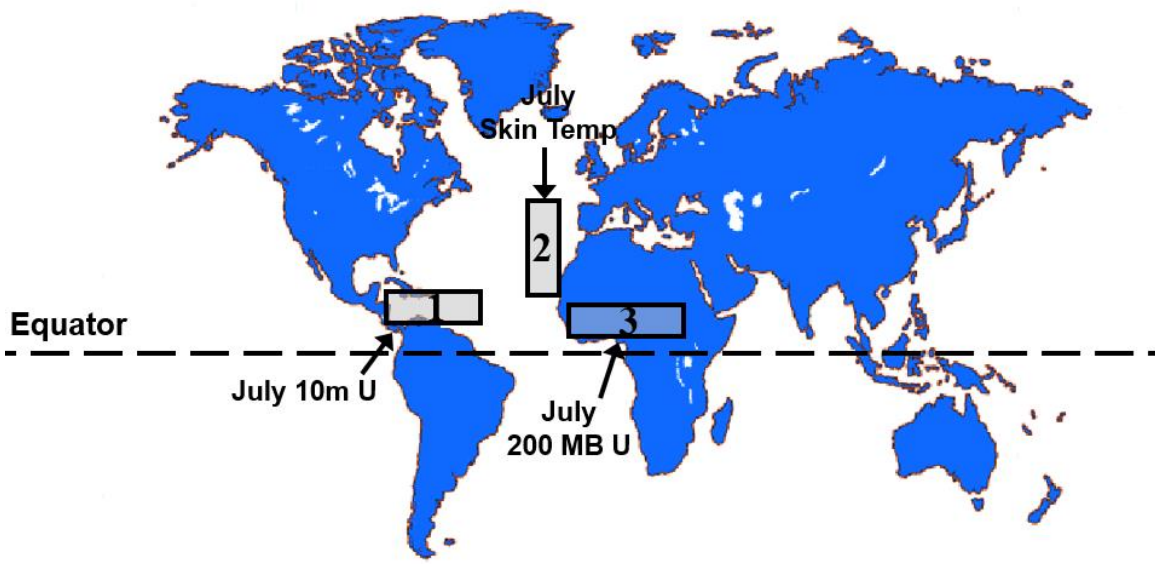

Figure 8: Location of predictors for our early June statistical/dynamical extended-range statistical prediction for the 2020 hurricane season. This forecast uses either the ECMWF SEAS5 model or the UK Met Office GloSea5 model to predict July conditions in the three boxes displayed and uses those predictors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

Table 4: Listing of predictions of July large-scale conditions from ECMWF SEAS5 output, initialized on 1 May. 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) (+)	-0.3 SD	Suppress
2) ECMWF Prediction of July Skin Temperature (20-40°N, 35-15°W) (+)	+1.1 SD	Enhance
3) ECMWF Prediction of July 200 hPa U (5-15°N, 0-40°E) (-)	-1.6 SD	Enhance

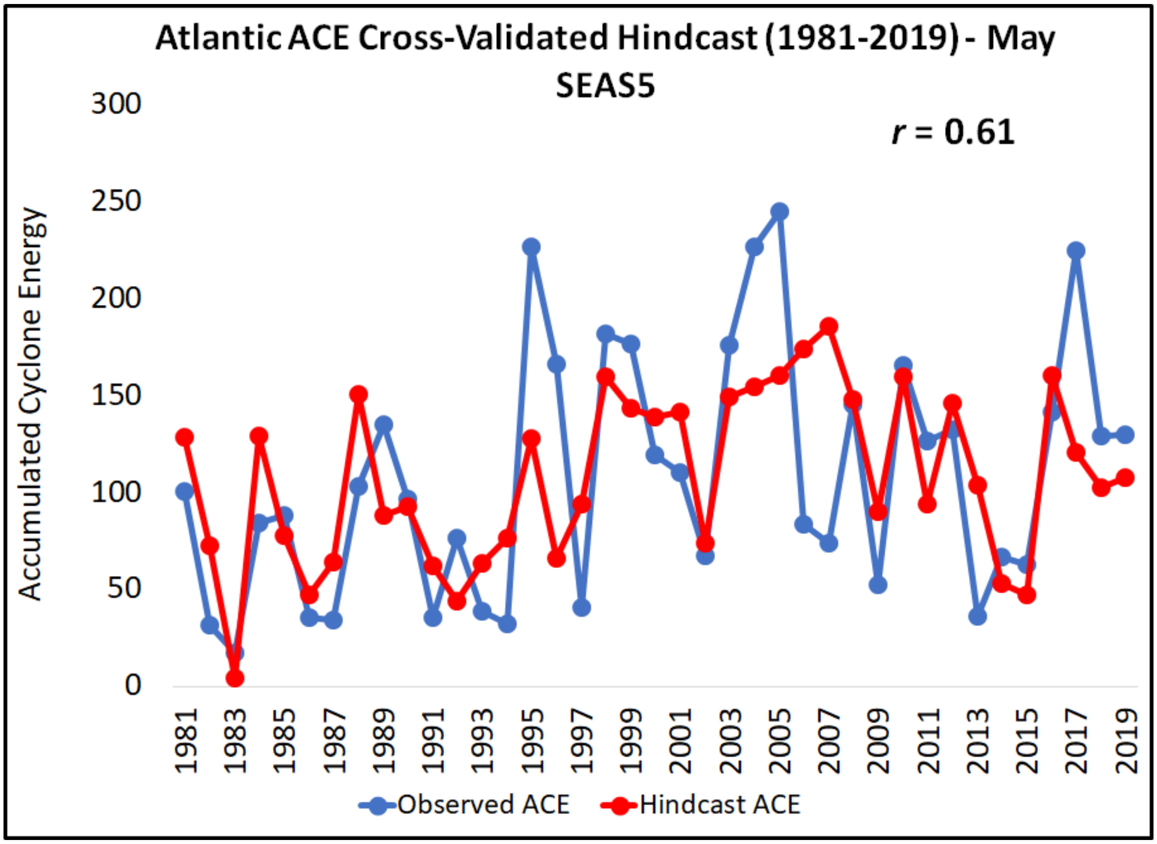

Figure 9: Observed versus early June cross-validated statistical/dynamical hindcast values of ACE for 1981-2019 from SEAS5.

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)	17.2	19
Named Storm Days (59.4)	94.9	85
Hurricanes (6.4)	9.9	9
Hurricane Days (24.2)	42.6	40
Major Hurricanes (2.7)	4.7	4
Major Hurricane Days (6.2)	12.8	9
Accumulated Cyclone Energy Index (106)	187	160
Net Tropical Cyclone Activity (116%)	196	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.

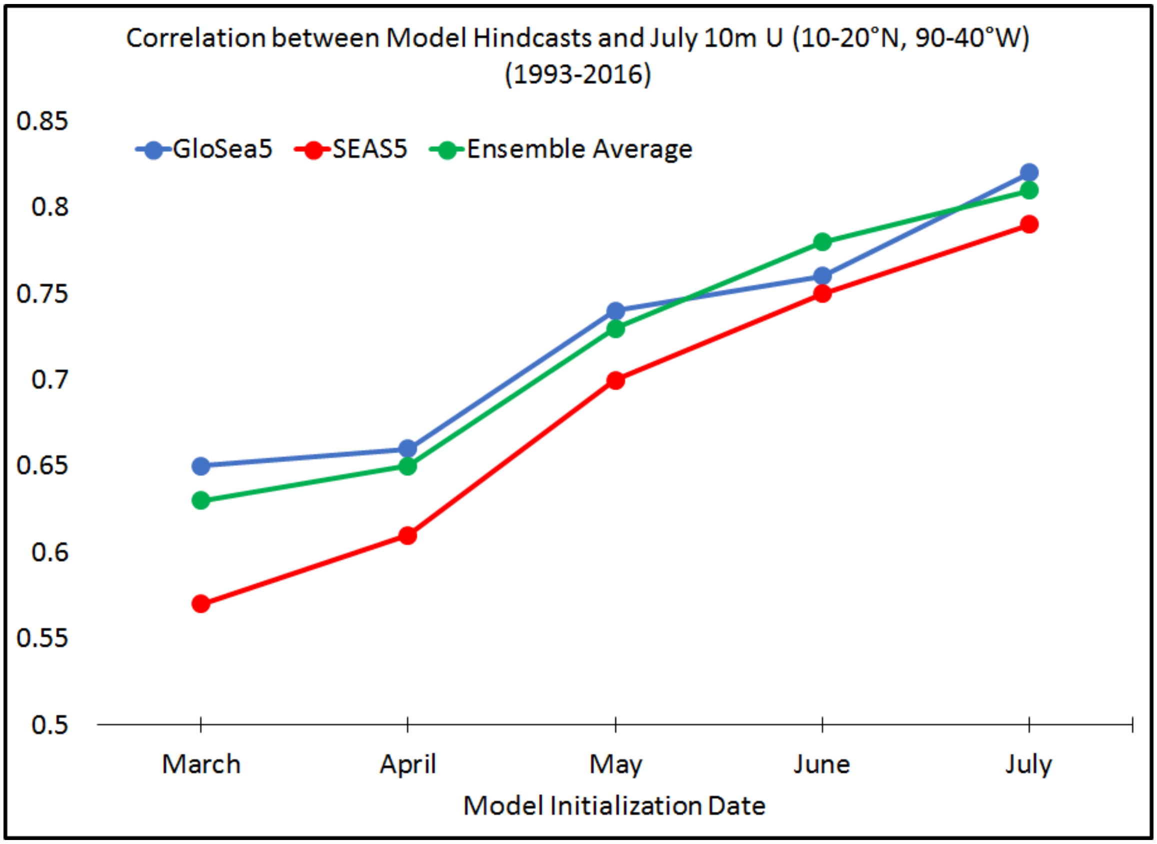

Figure 10: Correlation between model hindcasts issued at various lead times and July low-level wind in the tropical Atlantic and Caribbean based on data from 1993-2016.

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. The reason that the GloSea5 forecast is considerably different from SEAS5 is due to the different weight that each of the three predictors is given in the linear regression.

Table 6: Listing of predictions of July large-scale conditions from the Met Office's GloSea5 model output, initialized on 1 May. 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) (+)	-0.3 SD	Suppress
2) GloSea5 Prediction of July Skin Temperature (20-40°N, 35-15°W) (+)	+1.7 SD	Enhance
3) GloSea5 Prediction of July 200 hPa U (5-15°N, 0-40°E) (-)	-0.6 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)	14.1	19
Named Storm Days (59.4)	71.4	85
Hurricanes (6.4)	7.4	9
Hurricane Days (24.2)	29.2	40
Major Hurricanes (2.7)	3.2	4
Major Hurricane Days (6.2)	7.9	9
Accumulated Cyclone Energy Index (106)	129	160
Net Tropical Cyclone Activity (116%)	139	170

2.3 June 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 June extended range forecast, we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current May 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 slightly- to somewhat above-average SSTs in the tropical Atlantic. We anticipate that the 2020 hurricane season will have activity slightly above 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
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
2013	14	42.25	2	3.25	0	0.00	36	47
2016	15	81.00	7	27.75	4	10.25	141	155
Average	16.5	84.0	7.0	30.3	3.5	8.4	142	151
2020 Forecast	**19**	**85**	**9**	**40**	**4**	**9**	**160**	**170**

2.4 June Forecast Summary and Final Adjusted Forecast

Table 9 shows our final adjusted early June 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 June 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)	15.3	17.2	14.1	16.5	15.8	19
Named Storm Days (59.4)	80.3	94.9	71.4	84.0	83.2	85
Hurricanes (6.4)	8.3	9.9	7.4	7.0	8.2	9
Hurricane Days (24.2)	34.3	42.6	29.2	30.3	34.1	40
Major Hurricanes (2.7)	3.8	4.7	3.2	3.5	3.8	4
Major Hurricane Days (6.2)	9.7	12.8	7.9	8.4	9.7	9
Accumulated Cyclone Energy Index (106)	151	187	129	142	152	160
Net Tropical Cyclone Activity (116%)	161	196	139	151	162	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.

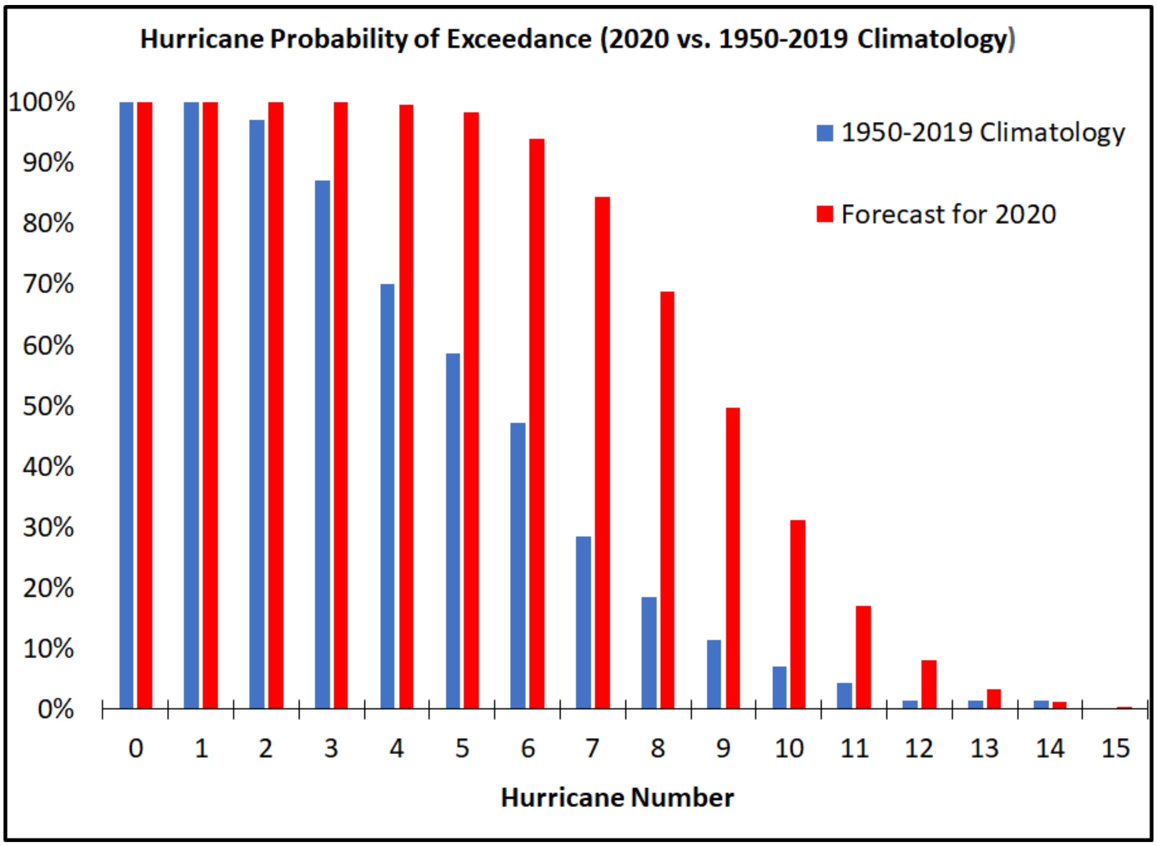

Figure 11: Probability of exceedance plot for hurricane numbers for the 2020 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950-2019 have had more than two hurricanes.

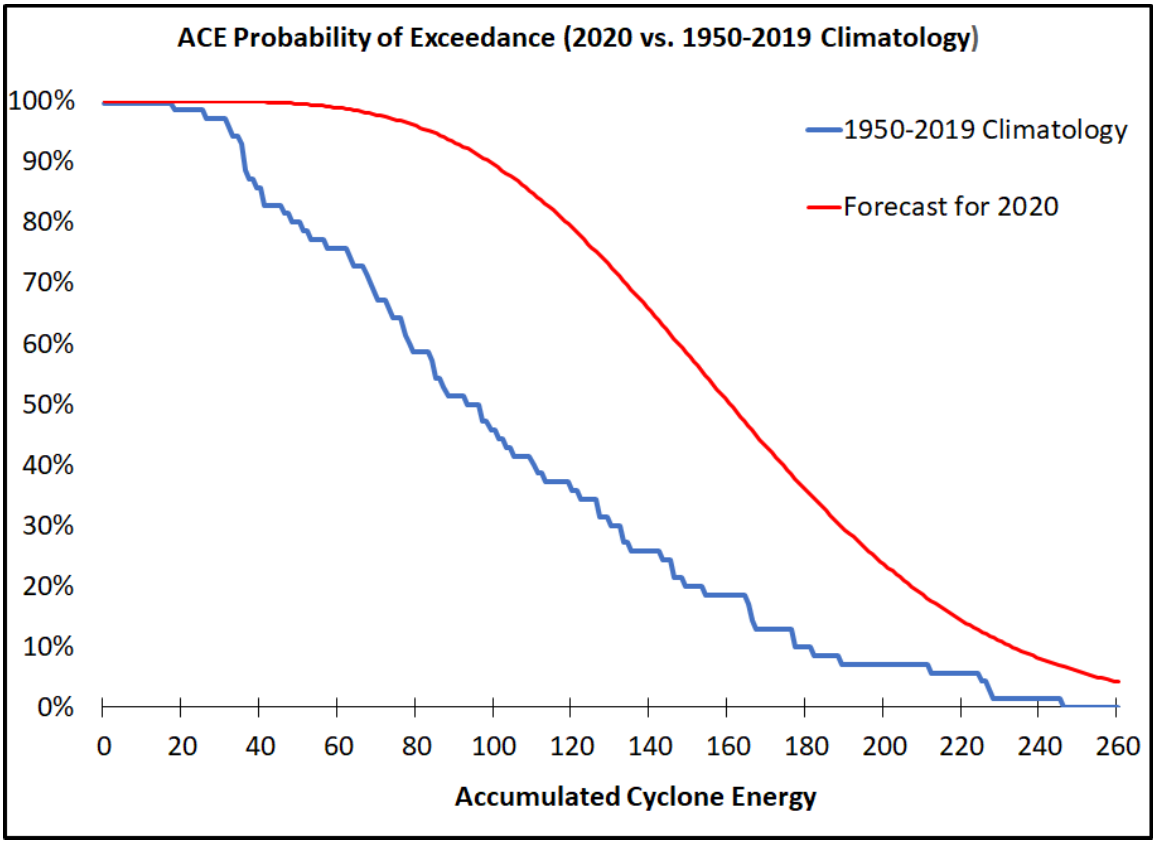

Figure 12: As in Figure 10 but for ACE.

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)	19	16 – 22
Named Storm Days (NSD)	85	63 – 107
Hurricanes (H)	9	7 – 11
Hurricane Days (HD)	40	27 – 55
Major Hurricanes (MH)	4	2 – 6
Major Hurricane Days (MHD)	9	6 – 14
Accumulated Cyclone Energy (ACE)	160	109 – 216
Net Tropical Cyclone (NTC) Activity	170	120 – 223

4 ENSO

The tropical Pacific was broadly characterized by warm neutral ENSO conditions from last summer through the early portion of this spring (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. Warm neutral ENSO conditions are defined by anomalies between 0°C – 0.5°C. Over the past two months, SST anomalies have trended downward, with significant anomalous cooling over most of the central and eastern tropical Pacific in recent weeks.

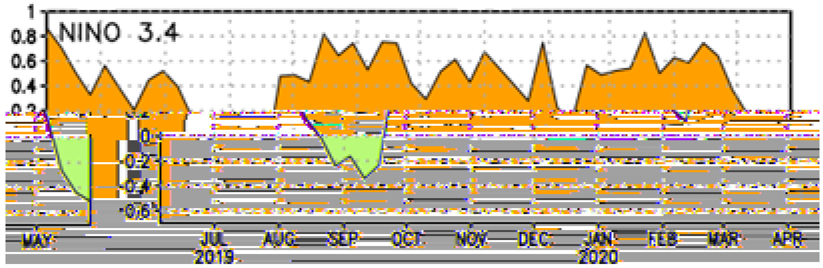

Figure 13: Nino 3.4 SST anomalies from June 2019 through May 2020. Figure courtesy of Climate Prediction Center.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific were at above-normal levels from October 2019 through March 2020 but have recently decreased rapidly (Figure 14). This is another indication that the tropical Pacific may be headed towards La Niña conditions.

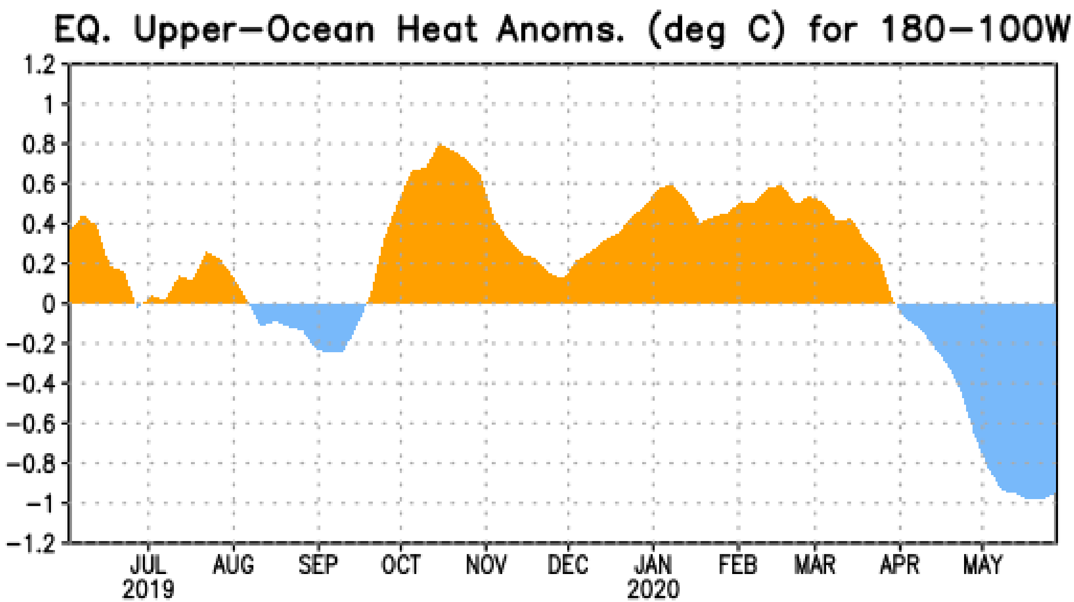

Figure 14: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Upper ocean heat content anomalies have dropped precipitously over the past few weeks.

Anomalously cool water has started to emerge in the central and eastern tropical Pacific (Figure 15). The coldest anomalies are currently located near the equator between 120°W and 140°W.

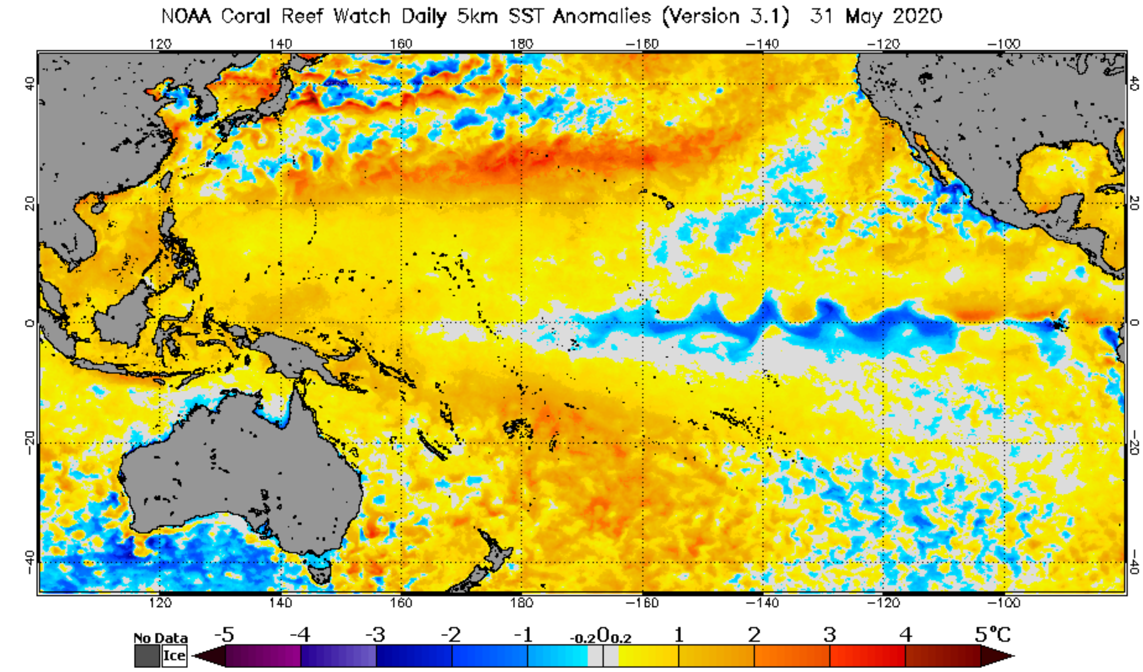

Figure 15: Current SST anomalies across the tropical and subtropical Pacific.

Table 11 displays March and May SST anomalies for several Nino regions. Anomalies have trended considerably downward over all four regions in the past two months.

Table 11: March and May SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. May minus March SST anomaly differences are also provided.

Region	March SST Anomaly (°C)	May SST Anomaly (°C)	May – March SST Anomaly (°C)
Nino 1+2	+0.5	-0.1	-0.6
Nino 3	+0.3	-0.3	-0.6
Nino 3.4	+0.6	-0.3	-0.9
Nino 4	+1.0	+0.2	-0.8

The tropical Pacific has experienced an upwelling (cooling) Kelvin wave (denoted by a dotted line) over the past several weeks (Figure 16). This anomalous cooling has been aided by stronger-than-normal low-level easterly winds in the central tropical Pacific.

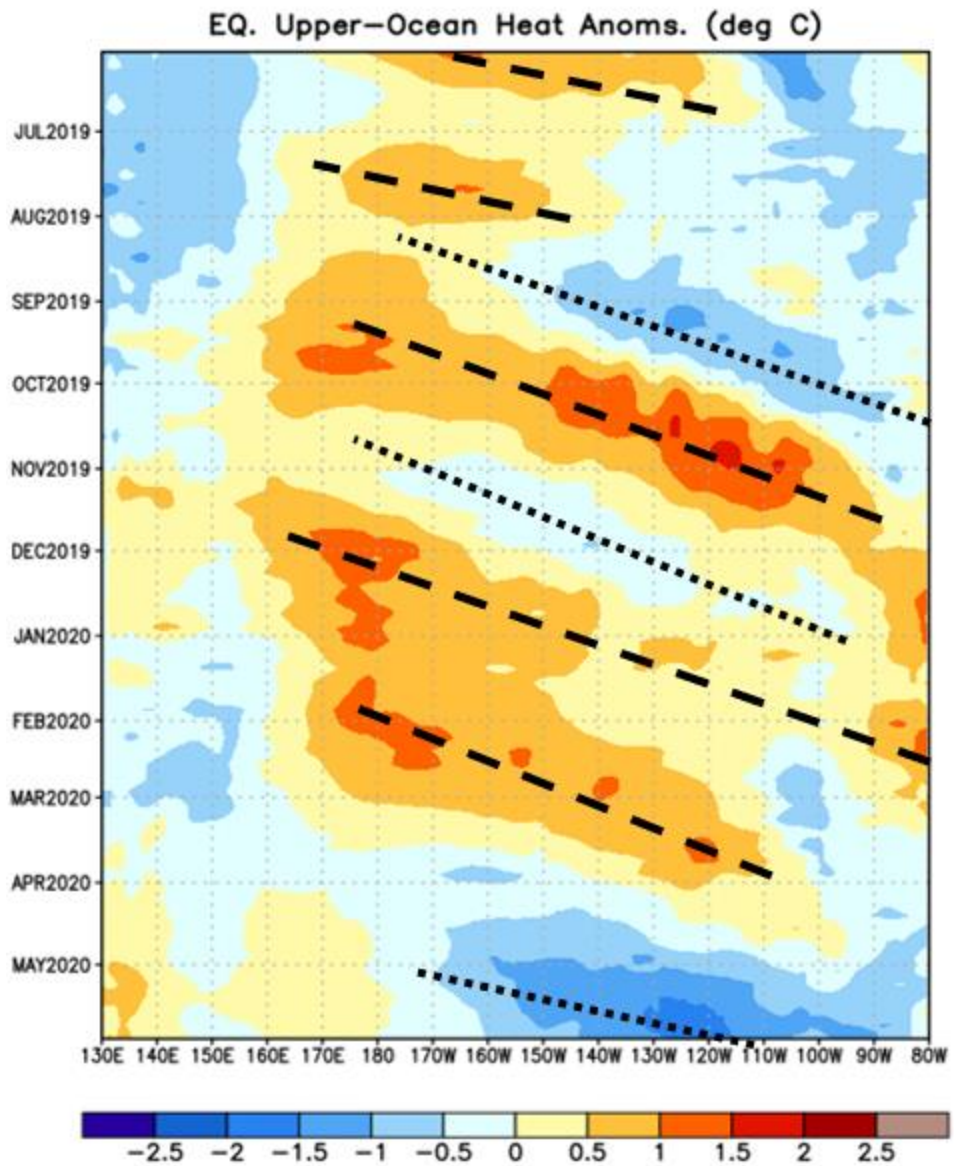

Figure 16: Upper-ocean heat content anomalies in the tropical Pacific since June 2019. Dashed lines indicate downwelling Kelvin waves, while dotted lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean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

Over the next several months, we will be closely monitoring low-level winds over the tropical Pacific. Anomalous easterlies are currently observed across the central tropical Pacific, and the Climate Forecast System (CFS) is forecasting a continuation of stronger-than-normal trade winds across the tropical Pacific (Figure 17). Consequently, we believe that there is likely to be some continued anomalous cooling in the tropical Pacific over the next several weeks, with the potential of a weak La Niña for the peak of the Atlantic hurricane season (August-October).

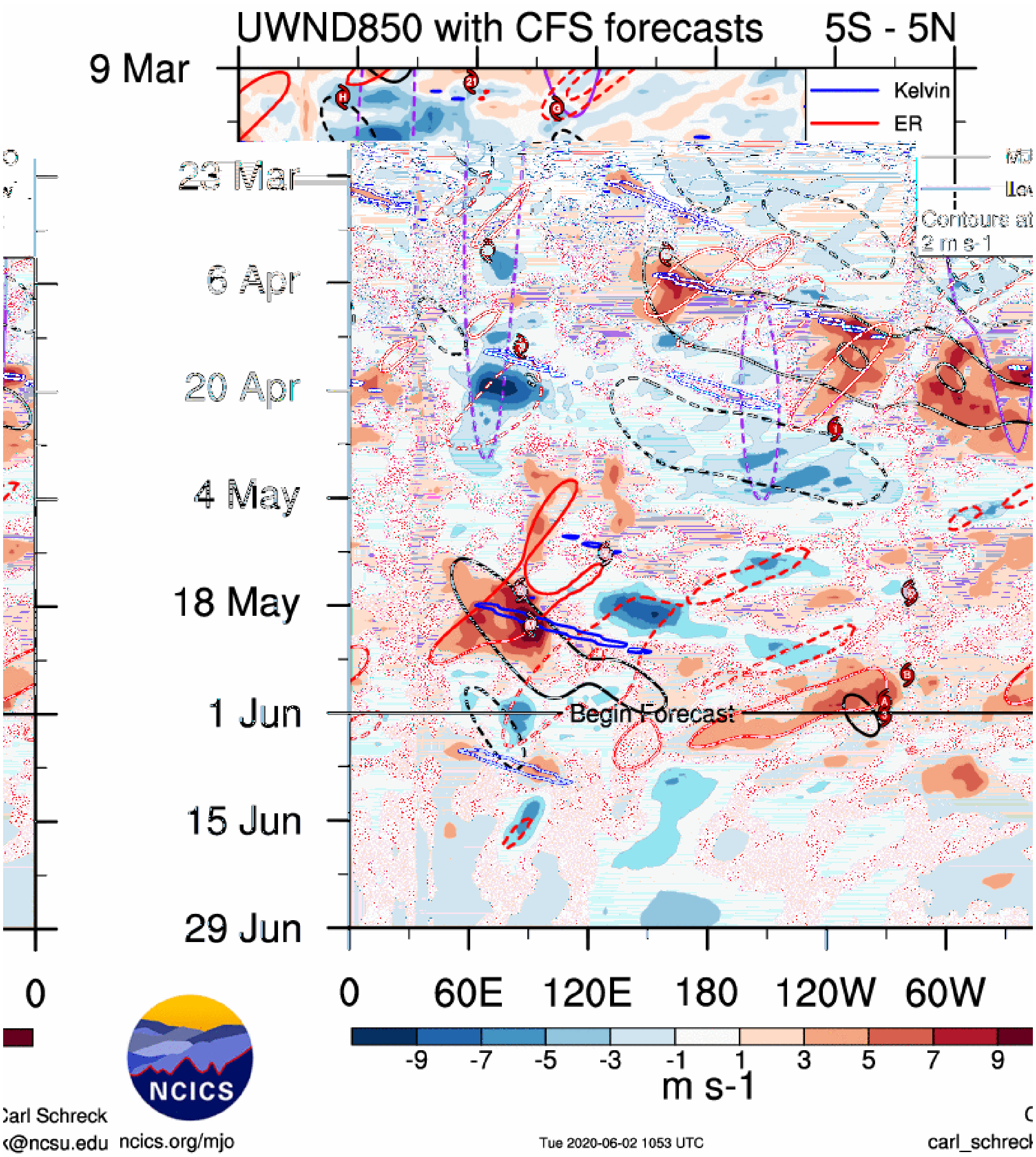

Figure 17: Observed low-level winds across the equatorial region as well as predictions for the next four weeks by the Climate Forecast System. Figure courtesy of Carl Schreck.

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.

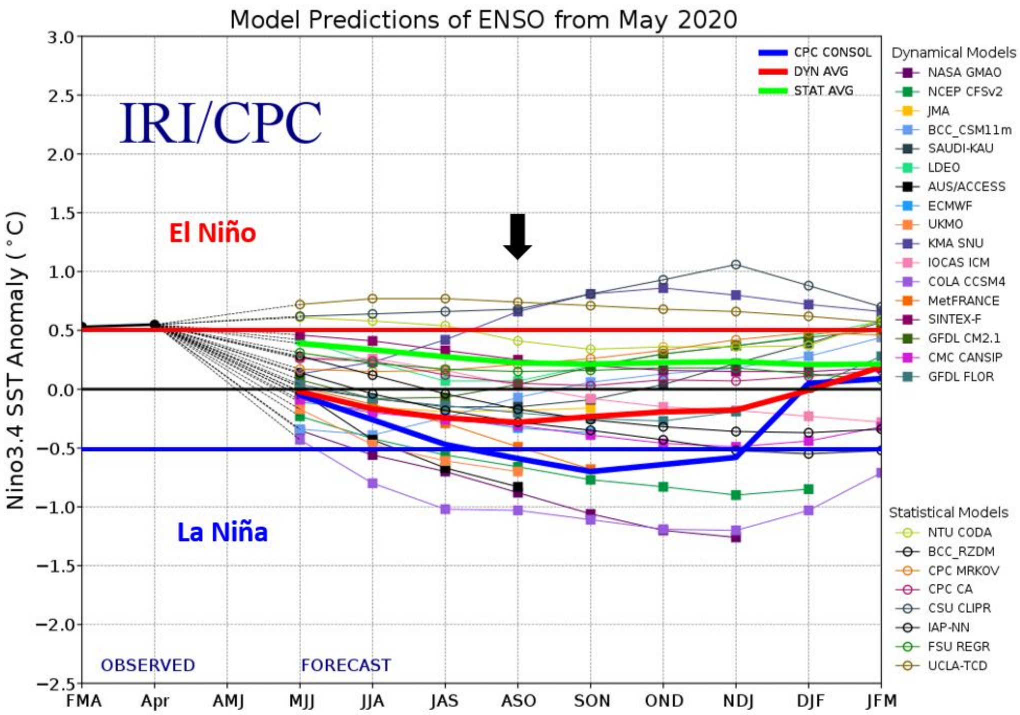

Figure 18: ENSO forecasts from various statistical and dynamical models for the Nino 3.4 SST anomaly based on late April to early May initial conditions. The majority of models are calling for ENSO neutral conditions for August-October. Figure courtesy of the International Research Institute (IRI).

The latest official forecast from NOAA indicates that the chances of El Niño are quite low for August-October. NOAA is currently predicting a 10% chance of El Niño, a 52% chance of ENSO neutral conditions and a 38% chance of La Niña for the peak of the Atlantic hurricane season (Figure 19).

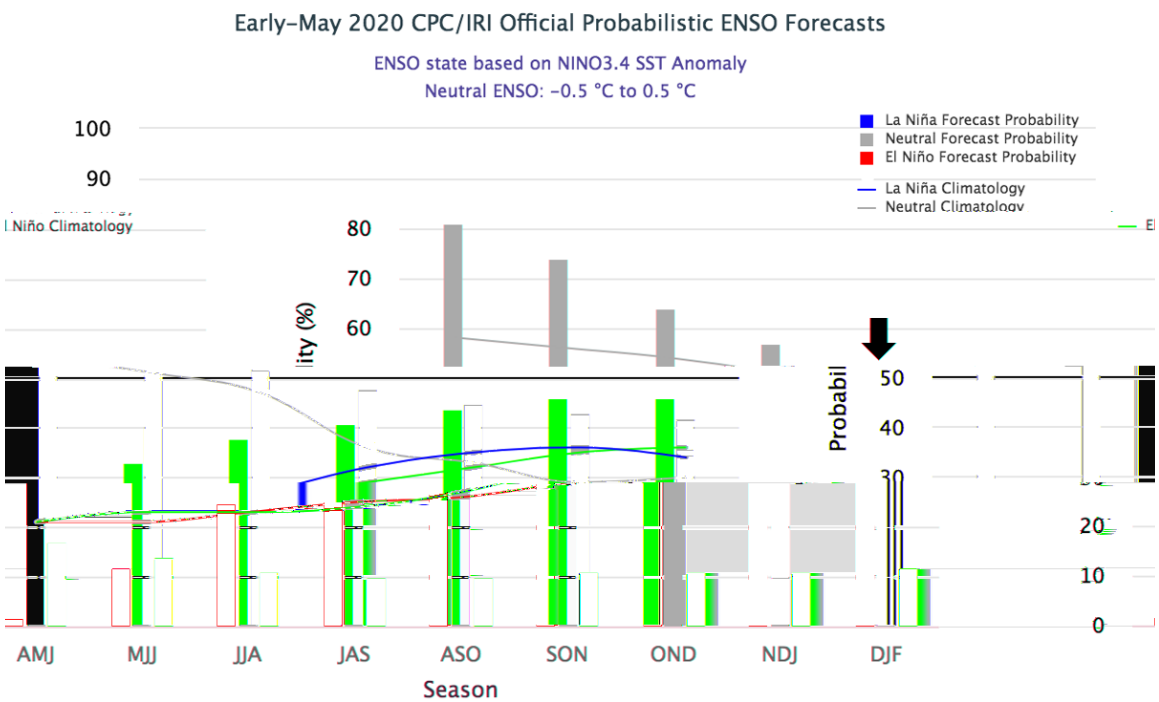

Figure 19: Official NOAA forecast for ENSO.

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

The current SST pattern across the North Atlantic basin is characterized by cold SSTs in the far North Atlantic with warm SST anomalies off of most of the East Coast. The subtropical Atlantic and Caribbean are much warmer than normal, while portions of the central and eastern tropical Atlantic have near-average SSTs. While the cold SSTs in the far North Atlantic are characteristic of the negative phase of the Atlantic Multi-decadal Oscillation (AMO), the anomalous warmth across portions of the tropical Atlantic and Caribbean are not characteristic of a typical negative AMO phase (Figure 20).

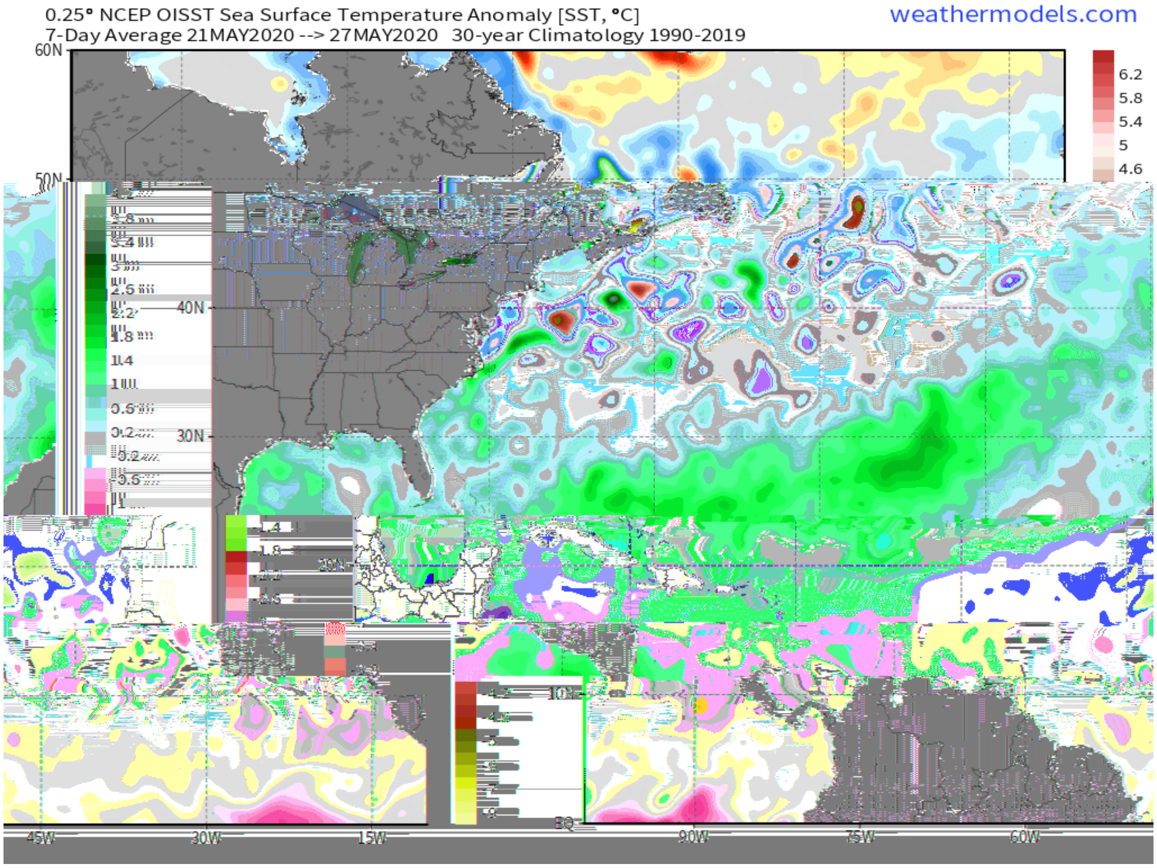

Figure 20: Late May 2020 SST anomaly pattern across the Atlantic Ocean.

The Atlantic had a relatively similar SST pattern in late March, although there are also some significant differences (Figure 21). Over the past two months, the Atlantic has been characterized by considerable anomalous cooling in the Gulf of Mexico, with weak anomalous cooling in the tropical Atlantic. The subtropical Atlantic and far North Atlantic have anomalously warmed (Figure 22). The Atlantic was generally characterized by a positive North Atlantic Oscillation (NAO) during the winter of 2019/20, but in the past few weeks, the NAO has trended more neutral, which has favored anomalous warming in portions of the subtropical Atlantic and anomalous cooling off of the US East Coast (Figure 23). Overall, the current SST anomaly pattern correlates relatively well with what is typically seen in active Atlantic hurricane seasons (Figure 24). Anomalous warmth in the eastern Atlantic in May is typically associated with more active seasons.

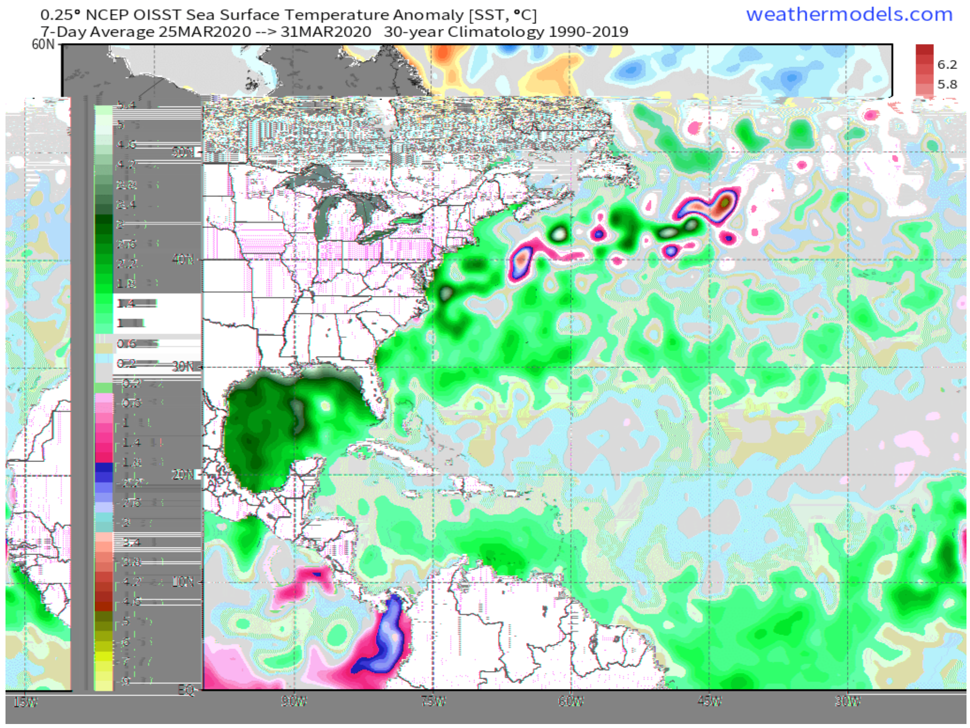

Figure 21: Late March 2020 North Atlantic SST anomalies.

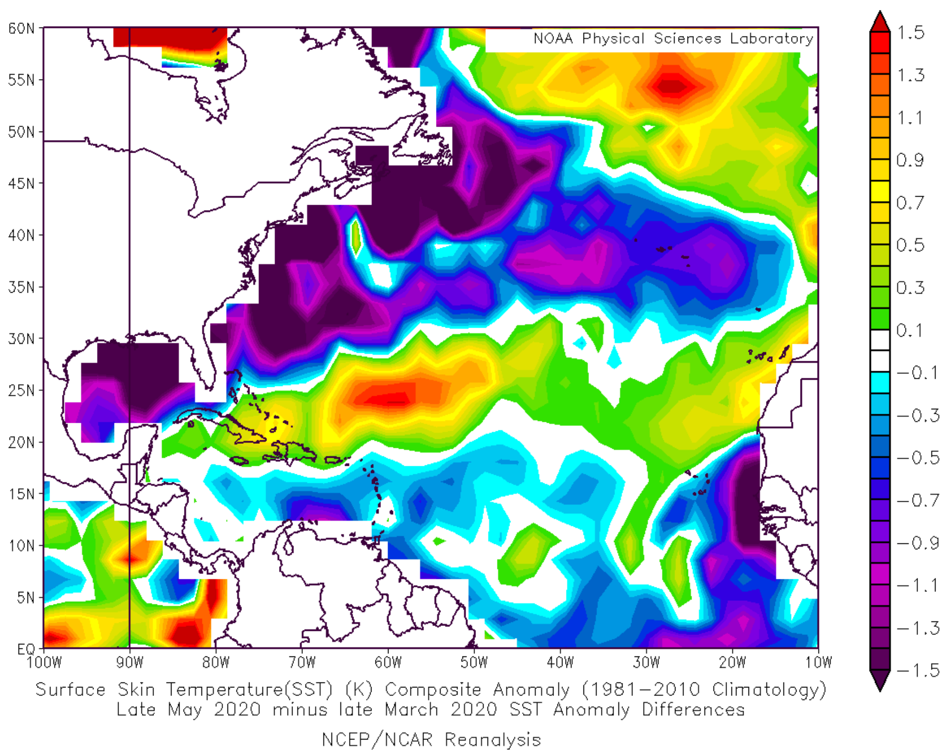

Figure 22: Late May 2020 minus late March 2020 SST anomaly changes.

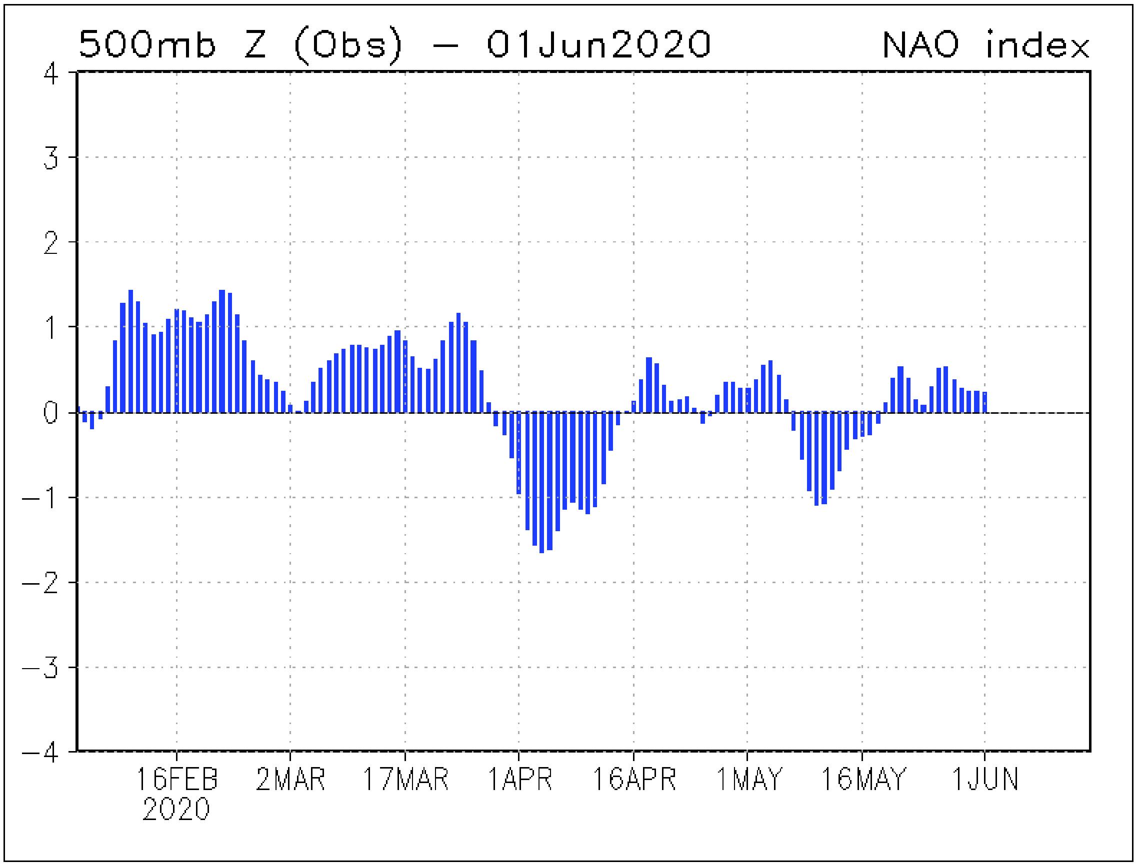

Figure 23: Observed standardized values of the daily NAO since February. The NAO was positive through February and March and has been near average over the past few weeks.

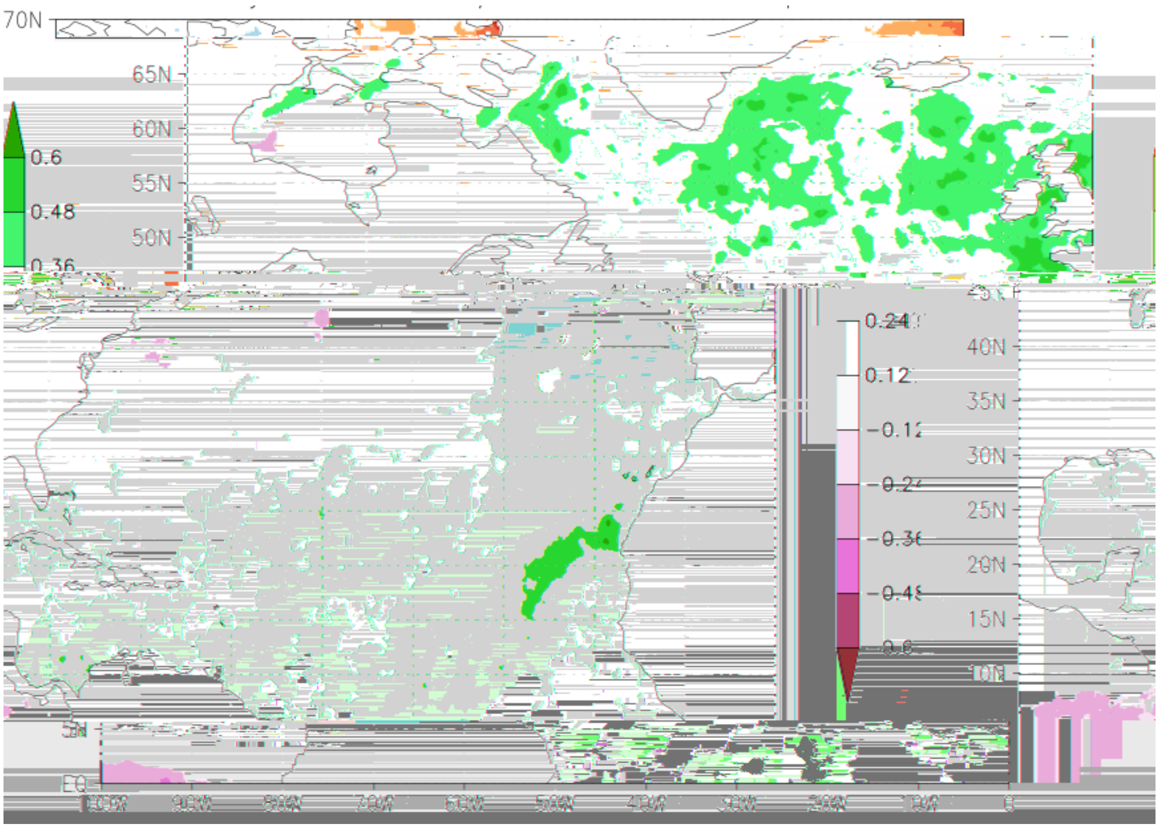

Figure 24: Rank correlation between May North Atlantic SST anomalies and seasonal Atlantic ACE from 1982-2019.

6 Landfall Probabilities for 2020

A significant focus of our research involves efforts to develop forecasts of the probability of hurricane landfall along the continental U.S. coastline and in the Caribbean. Whereas individual hurricane landfall events cannot be accurately 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 to be linked to the overall Atlantic basin Net Tropical Cyclone activity (NTC; see Table 12). 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 1950-2000 climatological 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 12: 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 13 lists landfall 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 NTC activity in 2020 is expected to be well above its long-term average of 100, and therefore, landfall probabilities are also above their long-term average.

Please 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. The probability of each U.S. coastal state being impacted by hurricanes and major hurricanes is also included. In addition, we include probabilities of named storms, hurricanes and major hurricanes tracking within 50 and 100 miles of various islands and landmasses in the Caribbean and Central America.

Table 13: 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 2020. 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 last 100 years 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)	92% (79%)	85% (68%)	70% (52%)	95% (84%)	99% (97%)
Gulf Coast (Regions 1-4)	77% (59%)	60% (42%)	45% (30%)	78% (60%)	95% (83%)
Florida plus East Coast (Regions 5-11)	68% (50%)	62% (44%)	46% (31%)	79% (61%)	93% (81%)
Caribbean (10-20°N, 60-88°W)	94% (82%)	75% (57%)	59% (42%)	90% (75%)	99% (96%)

7 Summary

An analysis of a variety of different atmosphere and ocean measurements (through May) which are known to have long-period statistical relationships with the upcoming season's Atlantic tropical cyclone activity, as well as output from dynamical models, indicate that 2020 should have well above-normal activity. The big question marks with this season's predictions revolve around whether ENSO remains neutral or transitions to La Niña conditions, as well as what the configuration of SSTs will look like in the Atlantic Ocean during the peak of the Atlantic hurricane season.

8 Forthcoming Updated Forecasts of 2020 Hurricane Activity

We will be issuing seasonal updates of our 2020 Atlantic basin hurricane forecasts on **Tuesday 7 July, and Thursday 6 August**. We will also be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August-October. 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.

9 Verification of Previous Forecasts

Table 14: Summary verification of the authors' five previous years of seasonal forecasts for Atlantic TC activity from 2015-2019.

2015	9 April	Update 1 June	Update 1 July	Update 4 August	Obs.
Hurricanes	3	3	3	2	4
Named Storms	7	8	8	8	11
Hurricane Days	10	10	10	8	11.50
Named Storm Days	30	30	30	25	43.75
Major Hurricanes	1	1	1	1	2
Major Hurricane Days	0.5	0.5	0.5	0.5	4
Accumulated Cyclone Energy	40	40	40	35	60
Net Tropical Cyclone Activity	45	45	45	40	81

2016	12 April	Update 1 June	Update 1 July	Update 4 August	Obs.
Hurricanes	6	6	6	6	7
Named Storms	13	14	15	15	15
Hurricane Days	21	21	21	22	27.75
Named Storm Days	52	53	55	55	81.00
Major Hurricanes	2	2	2	2	4
Major Hurricane Days	4	4	4	5	10.25
Accumulated Cyclone Energy	93	94	95	100	141
Net Tropical Cyclone Activity	101	103	105	110	155

2017	6 April	Update 1 June	Update 5 July	Update 4 August	Obs.
Hurricanes	4	6	8	8	10
Named Storms	11	14	15	16	17
Hurricane Days	16	25	35	35	51.25
Named Storm Days	50	60	70	70	91.25
Major Hurricanes	2	2	3	3	6
Major Hurricane Days	4	5	7	7	19.25
Accumulated Cyclone Energy	75	100	135	135	226
Net Tropical Cyclone Activity	85	110	140	140	231

2018	5 April	Update 31 May	Update 2 July	Update 2 August	Obs.
Hurricanes	7	6	4	5	8
Named Storms	14	14	11	12	15
Hurricane Days	30	20	15	15	26.75
Named Storm Days	70	55	45	53	87.25
Major Hurricanes	3	2	1	1	2
Major Hurricane Days	7	4	2	2	5.00
Accumulated Cyclone Energy	130	90	60	64	129
Net Tropical Cyclone Activity	135	100	70	78	128

2019	4 April	Update 4 June	Update 9 July	Update 5 August	Obs.
Hurricanes	5	6	6	7	6
Named Storms	13	14	14	14	18
Hurricane Days	16	20	20	20	23.50
Named Storm Days	50	55	55	55	70
Major Hurricanes	2	2	2	2	3
Major Hurricane Days	4	5	5	5	9.50
Accumulated Cyclone Energy	80	100	100	105	132
Net Tropical Cyclone Activity	90	105	105	110	141