FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2023

We have increased our forecast and now call for an above-average Atlantic basin hurricane season in 2023, although uncertainty with this outlook is larger than normal. While we continue to anticipate a robust El Niño for the peak of the Atlantic hurricane season, most of the tropical and subtropical Atlantic now has record warm sea surface temperatures. El Niño increases vertical wind shear in the Caribbean and tropical Atlantic, but the extreme anomalous warmth in the tropical and subtropical Atlantic may counteract some of the typical El Niño-driven increase in vertical wind shear. The probability of U.S. major hurricane landfall is estimated to be above the long-period average. As is the case with all hurricane seasons, coastal residents are reminded that it only takes one hurricane making landfall to make it an active season for them. They should prepare the same for every season, regardless of how much activity is predicted.

(as of 6 July 2023)

By Philip J. Klotzbach[1], Michael M. Bell[2] and Alexander J. DesRosiers[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

Jennifer Dimas, Colorado State University media representative, is coordinating media inquiries into this forecast. She can be reached at 970-491-1543 or Jennifer.Dimas@colostate.edu

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2023

Forecast Parameter and 1991-2020 Average (in parentheses)	Issue Date 13 April 2023	Issue Date 1 June 2023	Issue Date 6 July 2023	Observed Thru 5 July 2023	Remainder of Season Forecast
Named Storms (NS) (14.4)	13	15	18	4	14
Named Storm Days (NSD) (69.4)	55	60	90	11.50	78.50
Hurricanes (H) (7.2)	6	7	9	0	9
Hurricane Days (HD) (27.0)	25	30	35	0	35
Major Hurricanes (MH) (3.2)	2	3	4	0	4
Major Hurricane Days (MHD) (7.4)	5	7	9	0	9
Accumulated Cyclone Energy (ACE) (123)	100	125	160	10	150
ACE West of 60°W (73)	55	70	82	4	78
Net Tropical Cyclone Activity (NTC) (135%)	105	135	170	11	159

*Forecast includes the unnamed subtropical storm in January and Tropical Storms Arlene, Bret and Cindy in June.

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

1) Entire continental U.S. coastline - 50% (full-season average from 1880–2020 is 43%)

2) U.S. East Coast Including Peninsula Florida (south and east of Cedar Key, Florida) - 25% (full-season average from 1880–2020 is 21%)

3) Gulf Coast from the Florida Panhandle (west and north of Cedar Key, Florida) westward to Brownsville - 32% (full-season average from 1880–2020 is 27%)

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

1) 54% (full-season average from 1880–2020 is 47%)

ABSTRACT

Information obtained through June indicates that the 2023 Atlantic hurricane season will have activity above the 1991–2020 average. We estimate that 2023 will have a total of 18 named storms (average is 14.4), 90 named storm days (average is 69.4), 9 hurricanes (average is 7.2), 35 hurricane days (average is 27.0), 4 major (Category 3-4-5) hurricanes (average is 3.2) and 9 major hurricane days (average is 7.4). These numbers include the four named storms that have formed already this year (January subtropical storm, Arlene, Bret and Cindy). The probability of U.S. major hurricane landfall is now estimated to be above the long-period average. We predict Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity in 2023 to be approximately 115 percent of their 1991–2020 average.

This forecast is based on an extended-range early July statistical prediction scheme that was developed using ~40 years of past data. Analog predictors are also utilized. We are also including statistical/dynamical models based off of 25–40 years of past data from the European Centre for Medium Range Weather Forecasts, the UK Met Office, the Japan Meteorological Agency and the Centro Euro-Mediterraneo sui Cambiamenti Climatici model as four additional forecast guidance tools. While there remains considerable spread in our model guidance this year, the model guidance has continued to shift upwards towards a very active season, necessitating a significant increase in the forecast numbers with this update.

The tropical Pacific is currently characterized by El Niño conditions. However, the intensity of the El Niño for the remainder of the hurricane season remains unclear, although a moderate to strong event seems relatively likely. El Niño typically reduces Atlantic hurricane activity through increases in vertical wind shear.

However, sea surface temperatures in the eastern and central tropical Atlantic are now at record levels, so despite the high potential for an El Niño, the impacts on tropical Atlantic/Caribbean vertical wind shear may not be as strong as is typically experienced given the extremely warm Atlantic. The continued anomalous warming of the tropical and subtropical Atlantic is the primary reason for the increase in our forecast numbers with this update.

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

The early July forecast has good 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. We also present probabilities of exceedance for hurricanes and Accumulated Cyclone Energy to give interested readers a better idea of the uncertainty associated with these forecasts.

Why issue extended-range forecasts for seasonal hurricane activity?

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

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early July. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged with regards to the probability of an active or inactive hurricane season for the coming year. Our early July statistical and statistical/dynamical hybrid models show strong evidence on ~25–40 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 on 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 Ironshore Insurance, the Insurance Information Institute, Weatherboy, First Onsite and IAA. We acknowledge a grant from the G. Unger Vetlesen Foundation for additional financial support.

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 also would like to thank Jhordanne Jones, recent Ph.D. graduate in Michael Bell's research group, for model development and forecast assistance over the past several years.

We would also like to acknowledge Tyler Barbero and Angelie Nieves-Jimenez for assistance with preparing these forecasts and handling media inquiries. Thanks also to Angelie for translating our forecast press releases into Spanish.

We thank 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 Louis-Philippe Caron, Dan Chavas, Jason Dunion, Brian McNoldy, Paul Roundy, Carl Schreck, Mike Ventrice and Peng Xian over the past few years.

DEFINITIONS AND ACRONYMS

Accumulated Cyclone Energy (ACE) - A measure of a named storm's potential for wind 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 1991–2020 average value of this parameter is 123 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.

El Niño – Southern Oscillation (ENSO) – A quasi-periodic coupled climate mode of the tropical Pacific Ocean characterized by changes in sea surface temperature, atmospheric pressure and wind patterns.

ENSO Longitude Index – An index defining ENSO that estimates the average longitude of deep convection associated with the Walker Circulation.

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.

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.

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 1991-2020 average value of this parameter is 135.

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. Note that this scale does not take storm surge or other deadly hazards into account.

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) – Differences in sea surface temperature compared to the long-term average.

Thermohaline Circulation – A large-scale circulation in the Atlantic Ocean that is driven by fluctuations in salinity and temperature. When the thermohaline circulation 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 40th year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. Our research team has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. This year's July forecast is based on a statistical model as well as output from statistical/dynamical models from the European Centre for Medium-Range Weather Forecasts (ECMWF), the UK Met Office, the Japan Meteorological Agency (JMA) and the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC). These models show skill at predicting TC activity based on ~25–40 years of historical data. We also select analog seasons, based on currently-observed conditions as well as conditions that 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.

2 July Forecast Methodology

2.1 July Statistical Forecast Scheme

We have modified our July statistical forecast scheme from what has been used during the past few years. The current iteration of the forecast model uses ECMWF Reanalysis 5 (ERA5; Hersbach et al. 2020) for all three parameters. Due to the switch in input sea surface temperature (SST) dataset from NOAA OI SST to ERA5, we now extend the model back to 1979. We developed the model over 1979–2020 and then applied the model to the 2021 and 2022 Atlantic hurricane seasons. This model shows 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 = 0.76) over the period from 1979–2022 (Figure 1).

Figure 2 displays the locations of the three predictors, while Table 1 displays the individual linear correlations between each predictor and ACE over the 1979–2022 hindcast/forecast period. All three predictors correlate significantly at the 5% level using a two-tailed Student's t-test and assuming that each year represents an individual degree of freedom. Table 2 displays the 2023 observed values for the three predictors in the statistical forecast scheme. Table 3 displays the statistical model output for the 2023 hurricane season. All three predictors are much warmer than normal, highlighting both the likely moderate/strong El Niño as well as the extremely warm tropical and subtropical Atlantic. The three predictors in combination call for a well above-average season, due to the extremely warm Atlantic dominating the statistical model signal.

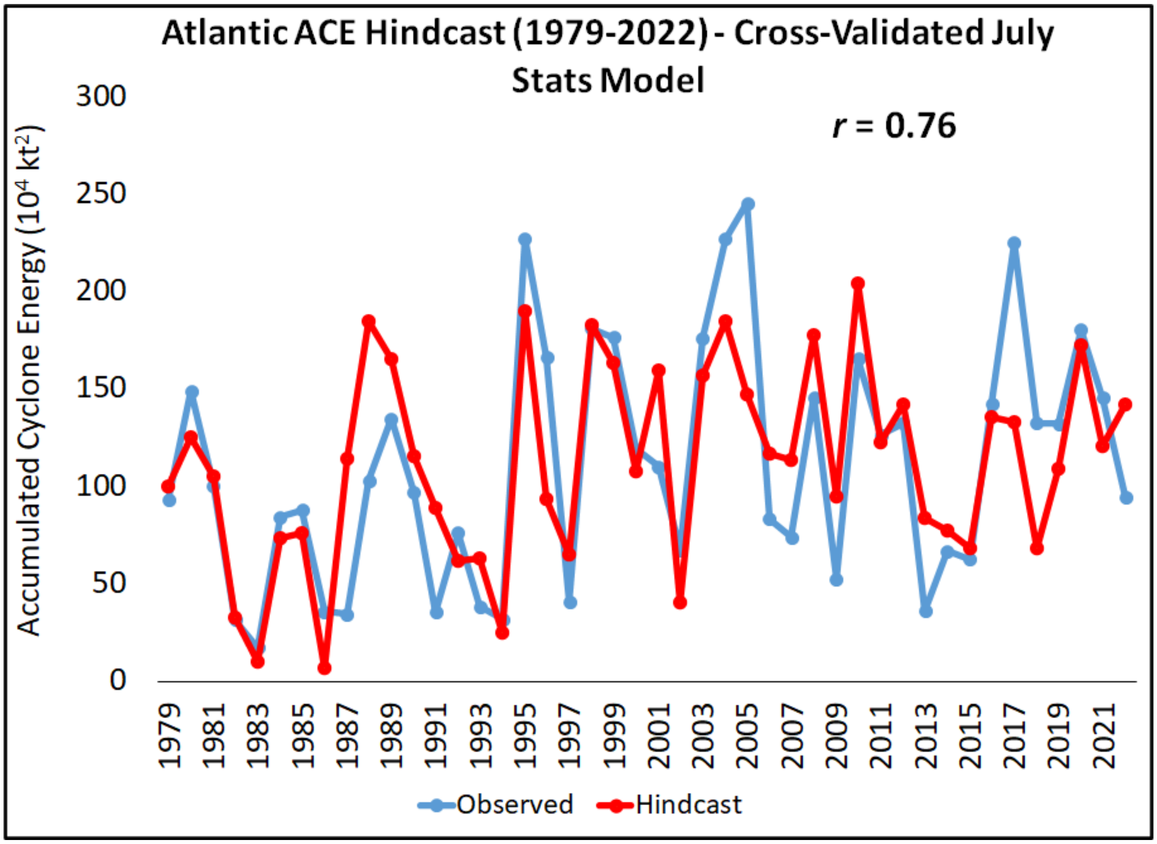

Figure 1: Observed versus early July cross-validated hindcast values of ACE for the statistical model from 1979–2022.

July Forecast Predictors

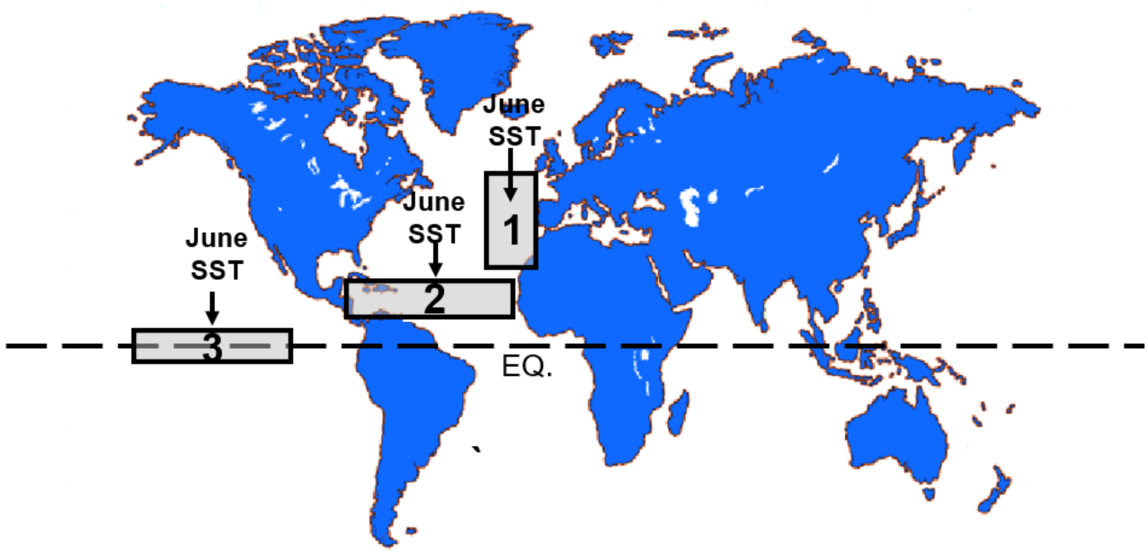

Figure 2: Location of predictors for the early July extended-range statistical prediction for the 2023 hurricane season.

Table 1: Linear correlation between early July predictors and ACE over the period from 1979–2022.

Predictor	Correlation w/ ACE
1) June SST (30°N–50°N, 30°W–10°W) (+)	0.66
2) June SST (10°N–20°N, 85°W–20°W) (+)	0.45
3) June SST (5°S–5°N, 160°W–110°W) (-)	-0.42

Table 2: Listing of early July 2023 predictors for the 2023 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	2023 Forecast Value	Impact on 2023 TC Activity
1) June SST (30°N–50°N, 30°W–10°W) (+)	+3.1 SD	Strongly Enhance
2) June SST (10°N–20°N, 85°W–20°W) (+)	+2.7 SD	Strongly Enhance
3) June SST (5°S–5°N, 160°W–110°W) (-)	+1.8 SD	Strongly Suppress

Table 3: Statistical model output for the 2023 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Forecast	Final Forecast
Named Storms (NS) (14.4)	20.5	18
Named Storm Days (NSD) (69.4)	111.5	90
Hurricanes (H) (7.2)	11.6	9
Hurricane Days (HD) (27.0)	49.9	35
Major Hurricanes (MH) (3.2)	5.8	4
Major Hurricane Days (MHD) (7.4)	15.7	9
Accumulated Cyclone Energy (ACE) (123)	223	160
Net Tropical Cyclone Activity (NTC) (135%)	235	170

The locations and brief descriptions of the predictors for our early July statistical forecast are now discussed. All three 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, 70–20°W as shown in Figure 3.

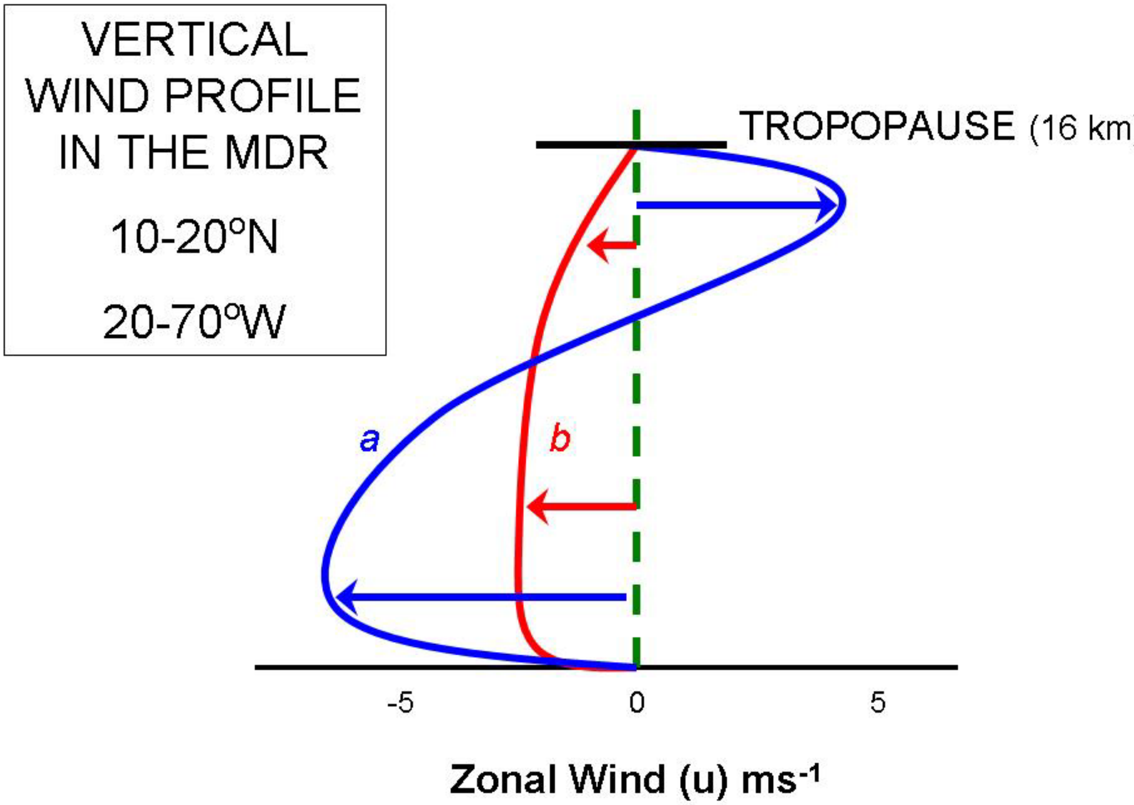

Figure 3: Vertical wind profile typically associated with (a) inactive Atlantic basin hurricane seasons and (b) active Atlantic basin hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

For each of these predictors, we display a four-panel figure showing rank correlations between values of each predictor and August–October values of SST, sea level pressure (SLP), 200 hPa zonal wind, and 850 hPa zonal wind, respectively, during 1979–2022. In general, higher values of tropical Atlantic SSTs, lower values of tropical Atlantic SLP, anomalous tropical Atlantic westerlies at 850 hPa and anomalous tropical Atlantic easterlies at 200 hPa are associated with active Atlantic basin hurricane seasons. All correlations are displayed using ERA5.

<u>Predictor 1. June SSTs in the subtropical eastern Atlantic (+)</u>

(30°N–50°N, 30°W–10°W)

Warmer-than-normal SSTs in the subtropical Atlantic during June are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the boreal summer (Knaff 1997). Positive SSTs in June are correlated with weaker trade winds and weaker upper tropospheric westerly winds, lower-than-normal sea level pressures and above-normal SSTs in the tropical Atlantic during the following August–October period (Figure 4). All of these August–October features are commonly associated with active

Atlantic basin hurricane seasons, through reductions in vertical wind shear, increased vertical instability and increased mid-tropospheric moisture, respectively. Predictor 1 correlates quite strongly (r =0.66) with ACE from 1979–2022. Predictor 1 also strongly correlates (r = 0.72) with August–October values of the SST component of the Atlantic Meridional Mode (AMM) (Kossin and Vimont 2007) from 1979–2022. 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. June SSTs in the Atlantic Main Development Region (+)

(10°N–20°N, 85°W–20°W)

Warmer-than-normal SSTs in the Atlantic Main Development Region (MDR) during June are strongly correlated with warmer-than-normal SSTs in the same region during August-October (r =0.66). A warmer-than-normal MDR during the peak of the Atlantic hurricane season provides a more favorable dynamic and thermodynamic environment for hurricane formation and intensification. Above-normal SSTs in the MDR are also associated with weaker trade winds and weaker upper-tropospheric westerly winds and lower-than-normal sea level pressures (Figure 5).

Predictor 3. June SSTs in the central/eastern tropical Pacific (-)

(5°S–5°N, 160°W–110°W)

Anomalously cool SSTs in the eastern and central tropical Pacific in June correlate strongly with anomalously cool SSTs in the Nino 3.4 region during August-October (r =0.80). The Nino 3.4 region is the region that NOAA uses to assess the strength of ENSO events. As would be expected given this significant correlation, cool values of Predictor 3 are also associated 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).

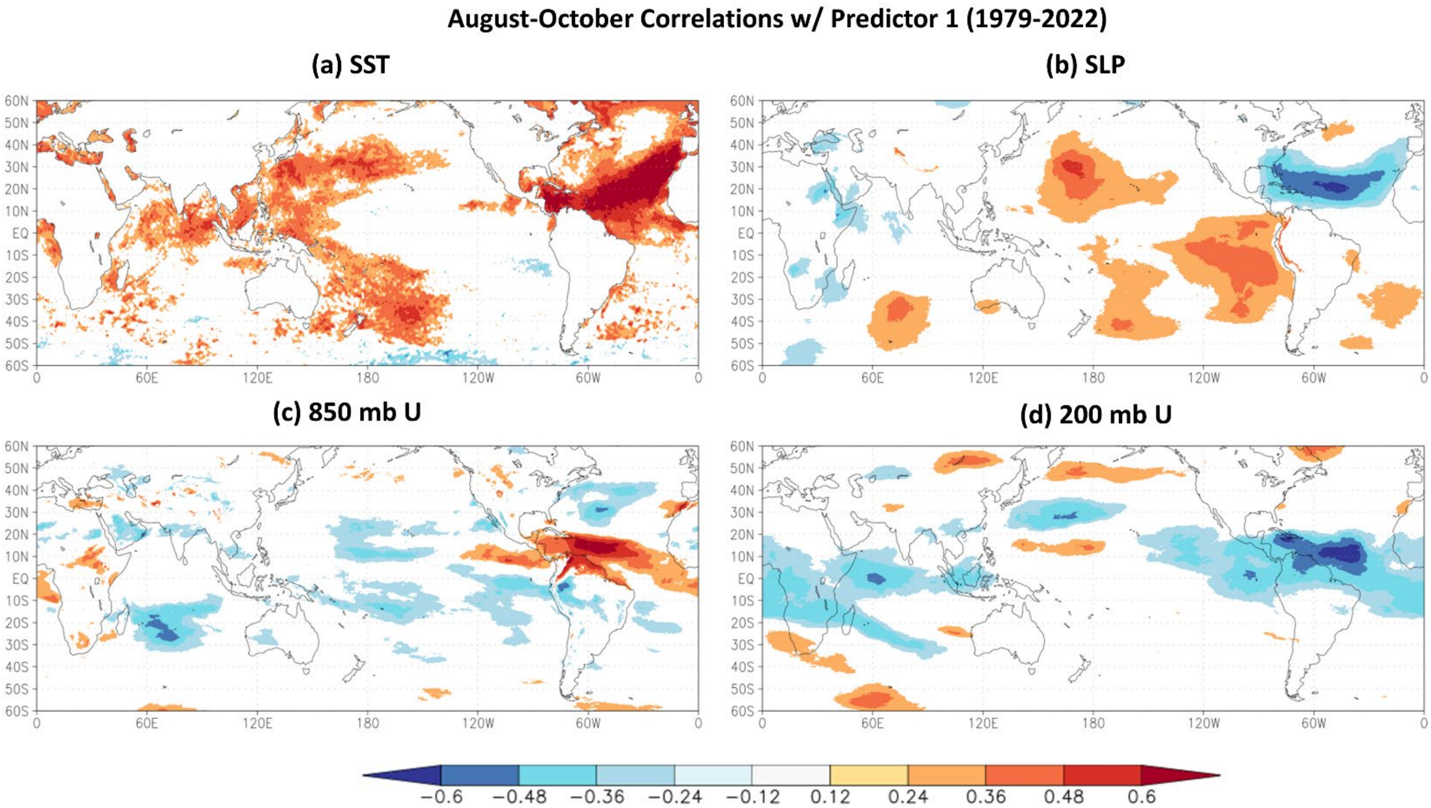

Figure 4: Rank correlations between June SST in the subtropical eastern Atlantic (Predictor 1) and (panel a) August–October sea surface temperature, (panel b) August–October sea level pressure, (panel c) August–October 850 hPa zonal wind and (panel d) August–October 200 hPa zonal wind. All four of these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

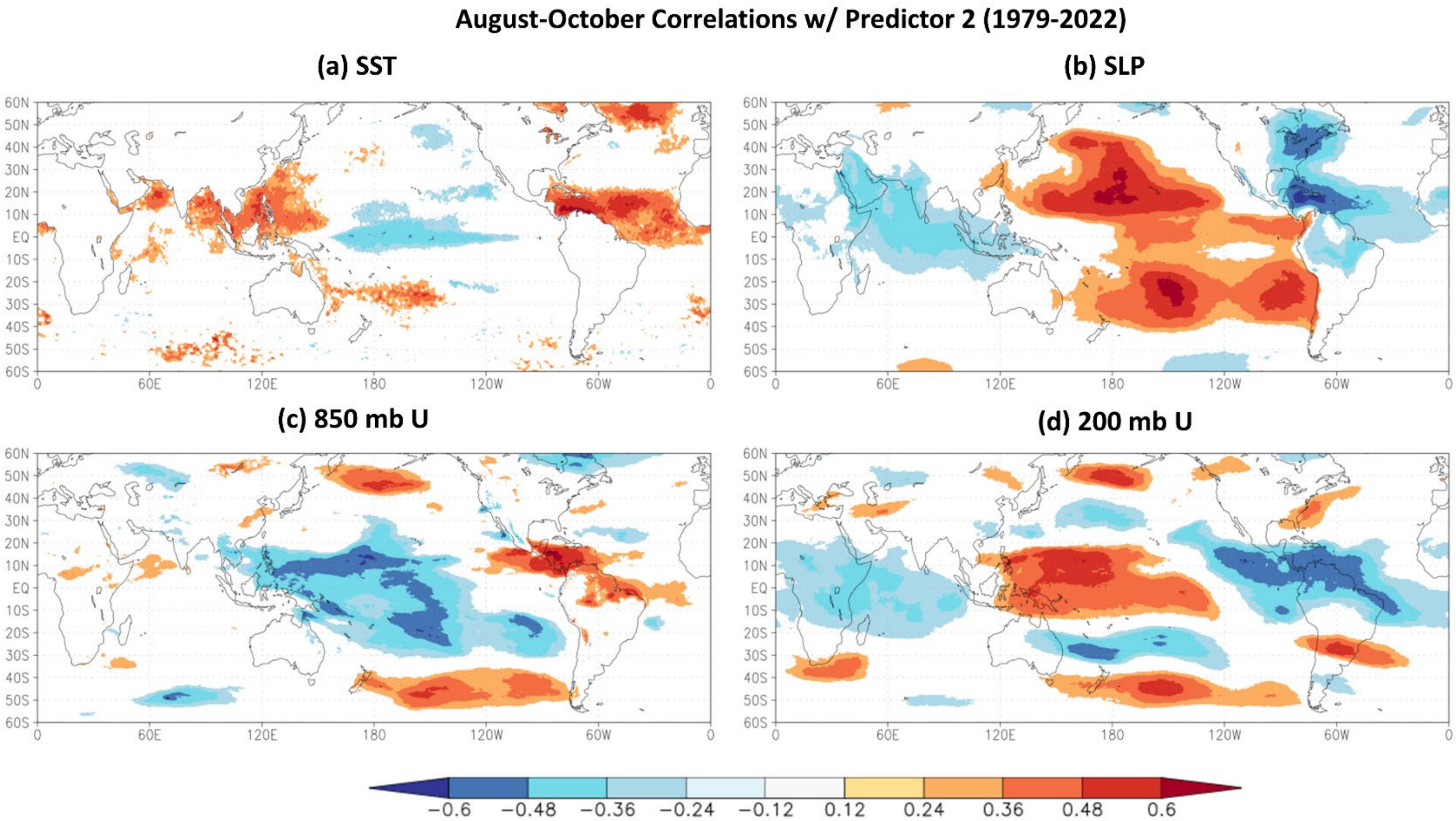

Figure 5: As in Figure 4 but for June SST in the Atlantic Main Development Region.

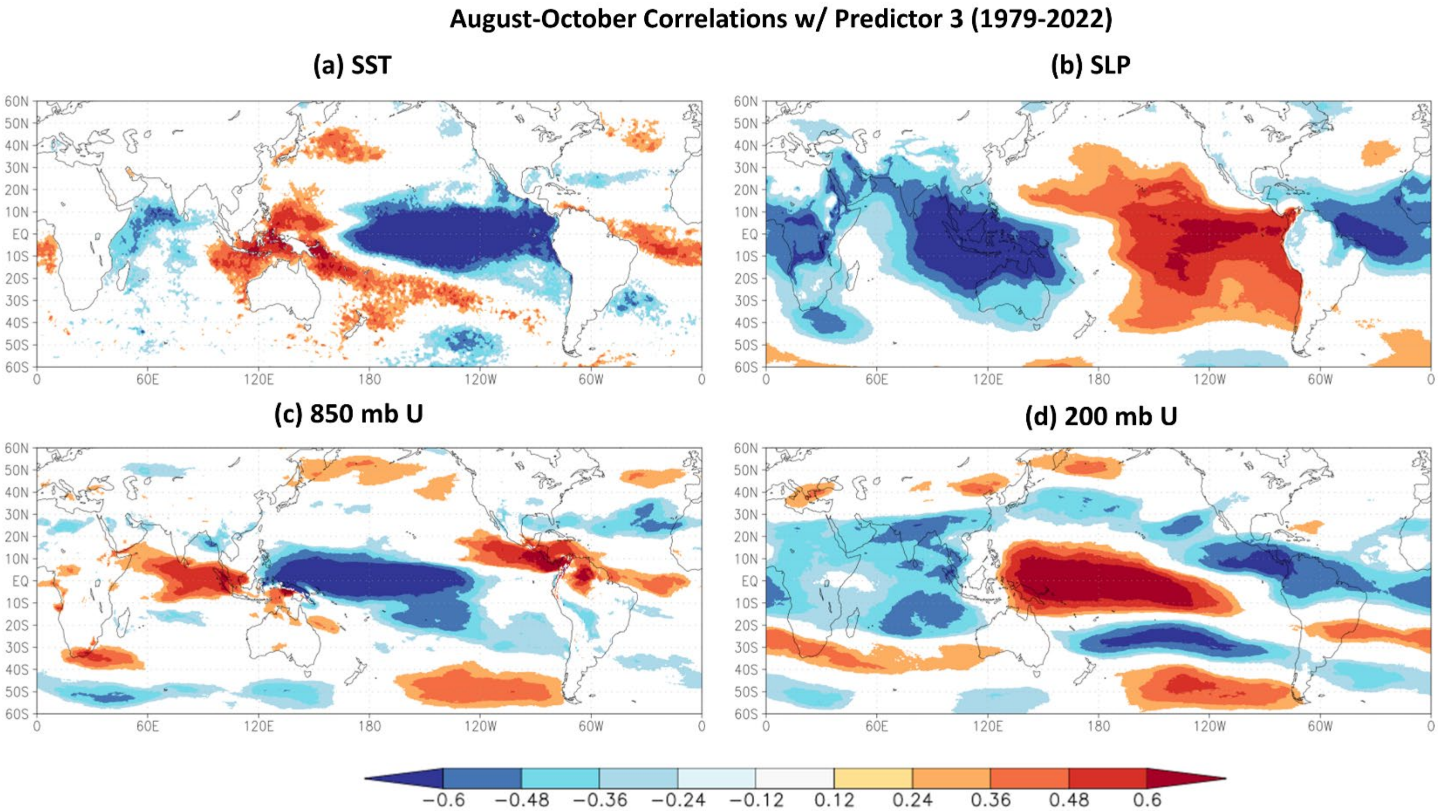

Figure 6: As in Figure 5 but for June SST in the tropical eastern and central Pacific. The sign of the predictor has been reversed for ease of comparison with Figures 4 and 5.

2.2 July Statistical/Dynamical Forecast Schemes

We developed a 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, originally used output from the ECMWF SEAS5 model to forecast the input to our early August statistical forecast model. We have modified our statistical/dynamical model this year and now use four different models: ECMWF, UK Met, JMA and CMCC. We examine model forecasts of August-September SSTs in the eastern/central equatorial Pacific and in the eastern/central North Atlantic. We then use the forecasts of these individual parameters to forecast ACE for the 2023 season. All other predictands (e.g., named storms, major hurricanes) are calculated based on their historical relationships with ACE.

a) ECMWF Statistical/Dynamical Model Forecast

Figure 7 displays the locations of the two forecast parameters, while Table 4 displays ECMWF's forecasts of these parameters for 2023 from a 1 June initialization date. The ECMWF model is predicting the warmest eastern/central North Atlantic on record (since 1981) and the third warmest equatorial eastern/central tropical Pacific on record (trailing 1997 and 2015). Despite the model's forecast for a strong El Niño, the extreme warmth that is predicted for the eastern/central North Atlantic results in an above-average forecast from this model. Figure 8 displays cross-validated hindcasts of ECMWF hindcasts of ACE from 1981–2022, while Table 5 presents the forecast from ECMWF for the 2023 Atlantic hurricane season.

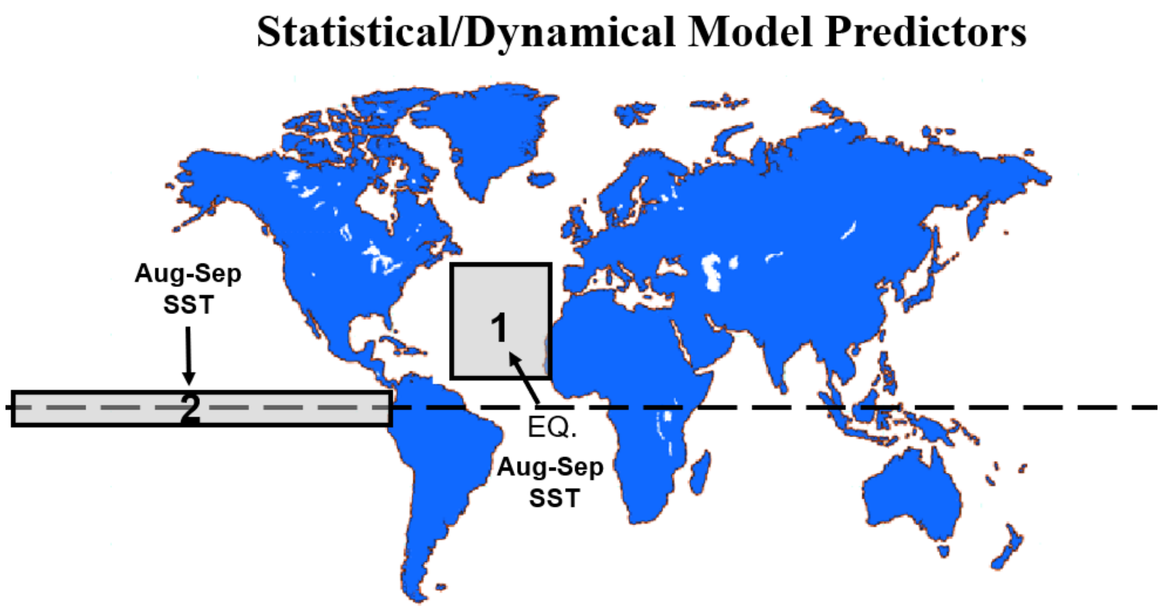

Figure 7: Location of predictors for our early July statistical/dynamical extended-range statistical prediction for the 2023 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August-September conditions in the two boxes displayed and uses those predictors to forecast ACE.

Table 4: Listing of predictions of August–September large-scale conditions from ECMWF model output, initialized on 1 June. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) ECMWF Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+3.8 SD	Strongly Enhance
2) ECMWF Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+2.0 SD	Strongly Suppress

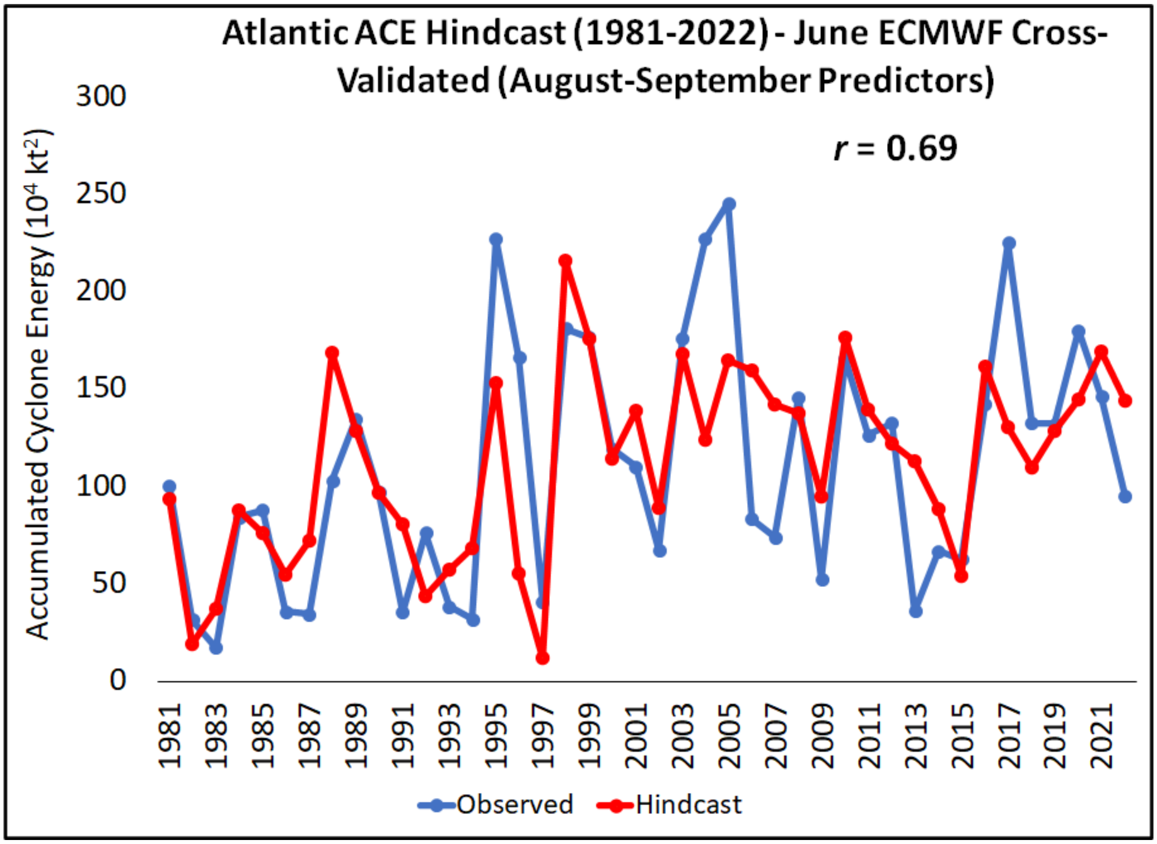

Figure 8: Observed versus cross-validated statistical/dynamical hindcast values of ACE for 1981–2022 from ECMWF.

Table 5: Statistical/dynamical model output from ECMWF for the 2023 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	ECMWF Hybrid Forecast	Final Forecast
Named Storms (14.4)	17.8	18
Named Storm Days (69.4)	93.1	90
Hurricanes (7.2)	9.6	9
Hurricane Days (27.0)	39.9	35
Major Hurricanes (3.2)	4.7	4
Major Hurricane Days (7.4)	12.0	9
Accumulated Cyclone Energy Index (123)	179	160
Net Tropical Cyclone Activity (135%)	191	170

b) UK Met Office Statistical/Dynamical Model Forecast

Table 6 displays the UK Met Office forecast of the August-September parameters for 2023 from a 1 June initialization date. Similar to ECMWF, the UK Met Office is calling for the third strongest El Niño on record (trailing 1997 and 2015) but also the warmest central/eastern North Atlantic on record. Figure 9 displays hindcasts for the UK

Met Office of ACE from 1993–2016, while Table 7 presents the forecast from the UK Met Office for the 2023 Atlantic hurricane season. We note that the UK Met Office, JMA and CPCC have shorter hindcasts available on the Copernicus website (the website where we download our climate model forecasts). The UK Met Office statistical/dynamical model is calling for a very busy season, similar to ECMWF.

Table 6: Listing of predictions of August-September large-scale conditions from UK Met model output, initialized on 1 June. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) UK Met Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+4.9 SD	Strongly Enhance
2) UK Met Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.8 SD	Strongly Suppress

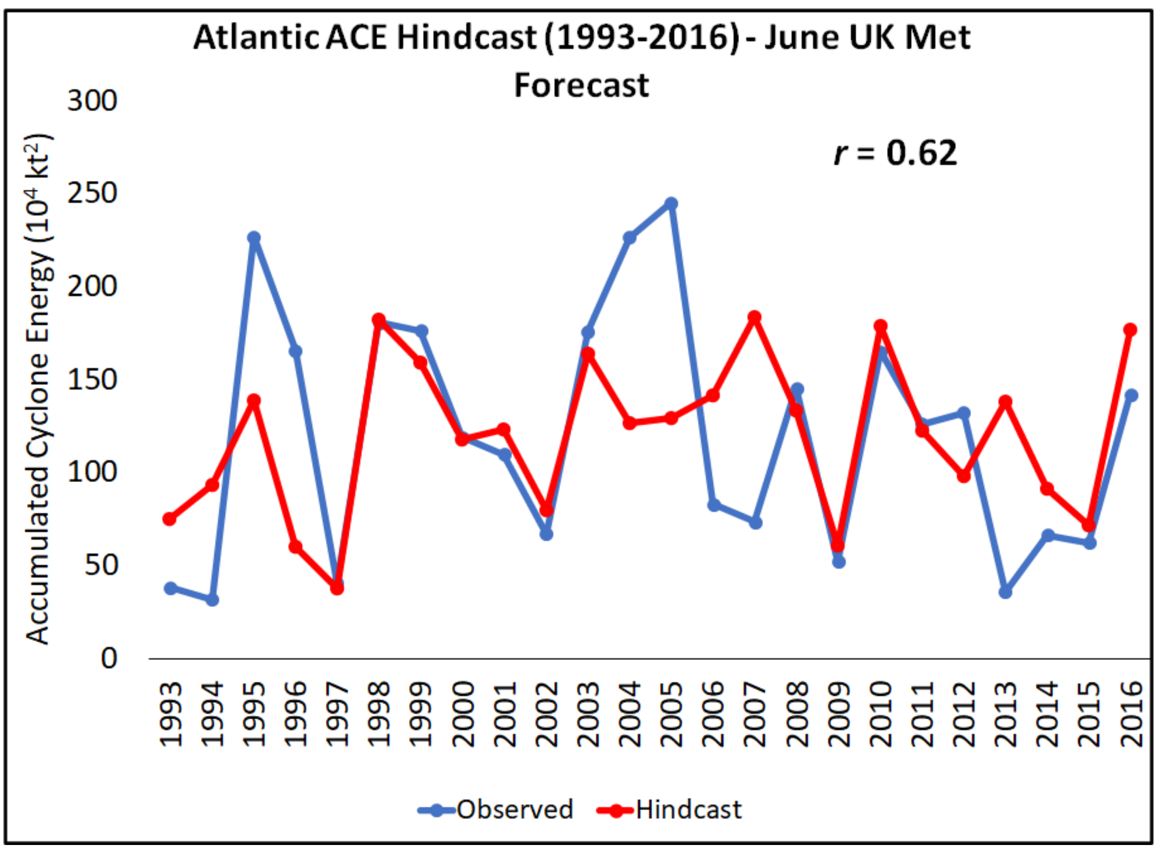

Figure 9: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the UK Met Office.

Table 7: Statistical/dynamical model output from the UK Met Office for the 2023 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	Met Office Hybrid Forecast	Final Forecast
Named Storms (14.4)	17.8	18
Named Storm Days (69.4)	92.6	90
Hurricanes (7.2)	9.6	9
Hurricane Days (27.0)	39.7	35
Major Hurricanes (3.2)	4.7	4
Major Hurricane Days (7.4)	11.9	9
Accumulated Cyclone Energy Index (123)	178	160
Net Tropical Cyclone Activity (135%)	190	170

c) JMA Met Office Statistical/Dynamical Model Forecast

Table 8 displays the JMA forecasts of the August-September parameters for 2023 from a 1 June initialization date. JMA is also calling for the 3rd strongest El Niño on record (trailing 1997 and 2015) and the warmest central/eastern North Atlantic on record. Figure 10 displays hindcasts for the JMA of ACE from 1993–2016, while Table 9 presents the forecast from the JMA for the 2023 Atlantic hurricane season. The statistical/dynamical model based off of JMA is calling for a slightly above-average 2023 Atlantic hurricane season. The JMA forecast is calling for less activity than the other statistical/dynamical models due to stronger weighing of the Pacific SST predictor and lesser weighing of the Atlantic SST predictor.

Table 8: Listing of predictions of August-September large-scale conditions from JMA model output, initialized on 1 June. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) JMA Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+3.1 SD	Strongly Enhance
2) JMA Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.8 SD	Strongly Suppress

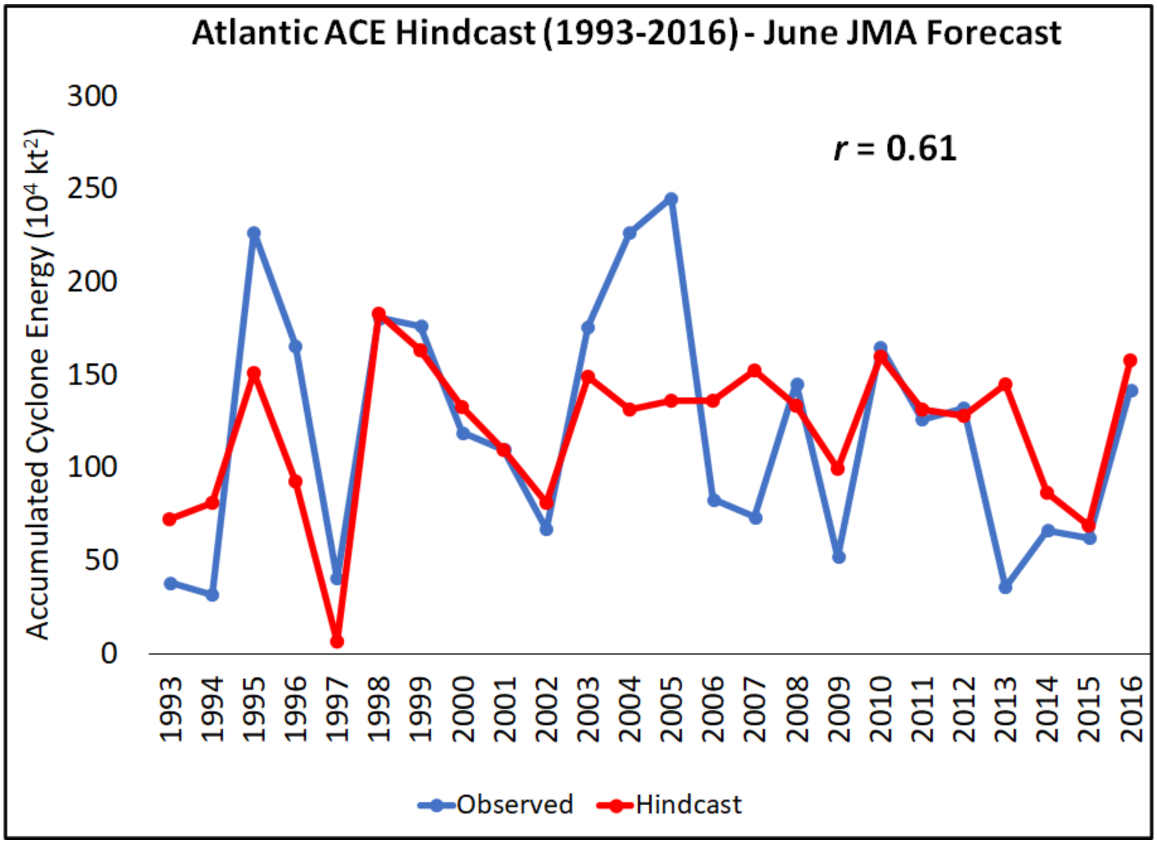

Figure 10: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the JMA.

Table 9: Statistical/dynamical model output from the JMA for the 2023 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	JMA Hybrid Forecast	Final Forecast
Named Storms (14.4)	15.1	18
Named Storm Days (69.4)	74.2	90
Hurricanes (7.2)	7.7	9
Hurricane Days (27.0)	29.6	35
Major Hurricanes (3.2)	3.5	4
Major Hurricane Days (7.4)	8.3	9
Accumulated Cyclone Energy Index (123)	134	160
Net Tropical Cyclone Activity (135%)	146	170

d) CMCC Statistical/Dynamical Model Forecast

Table 10 displays the CMCC forecasts of the August-September parameters for 2023 from a 1 June initialization date. CMCC is also calling for the 3rd strongest El Niño on record (trailing 1997 and 2015) and the warmest central/eastern North Atlantic on record. Figure 11 displays CMCC hindcasts of ACE from 1993–2016, while Table 11 presents the forecast from the CMCC for the 2023 Atlantic hurricane season. The statistical/dynamical model based off of CMCC is calling for an above-average 2023 Atlantic hurricane season.

Table 10: Listing of predictions of August-September large-scale conditions from CMCC model output, initialized on 1 June. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) CMCC Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+4.0 SD	Strongly Enhance
2) CMCC Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.7 SD	Strongly Suppress

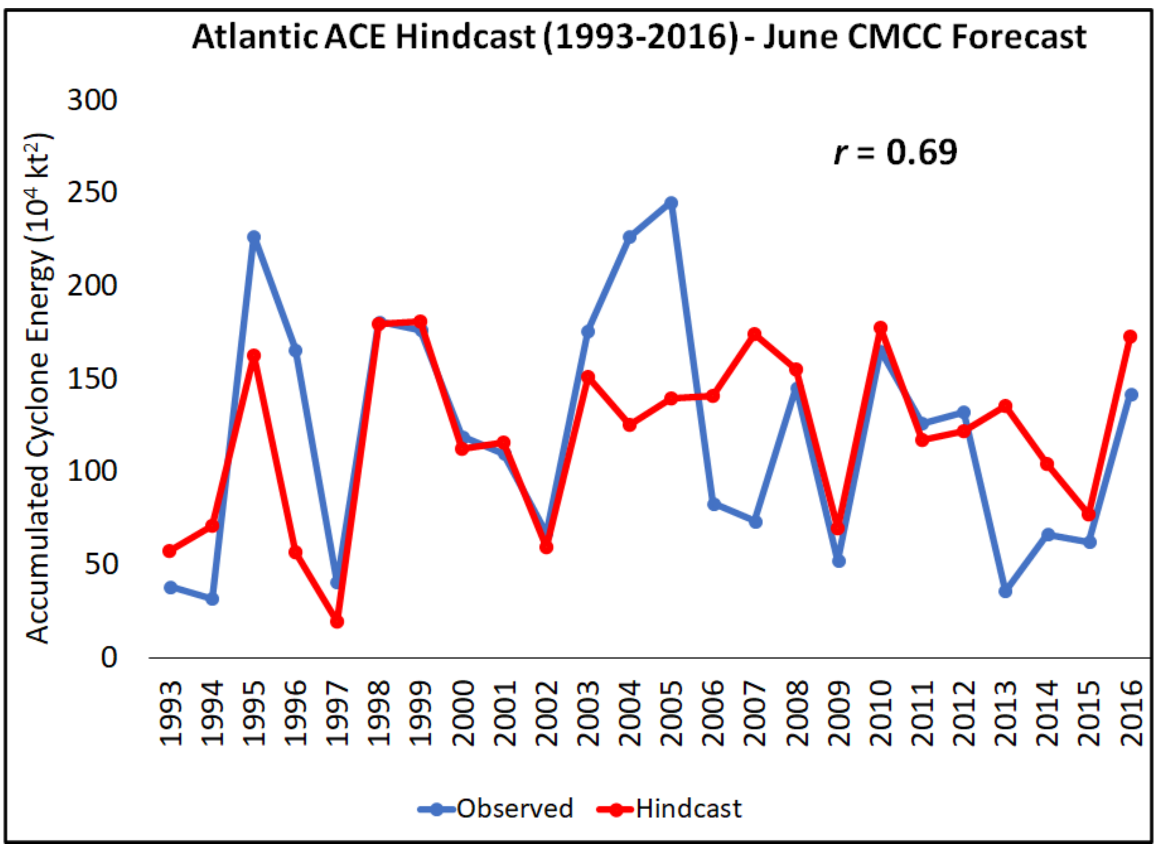

Figure 11: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the CMCC.

Table 11: Statistical/dynamical model output from the CMCC for the 2023 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	CMCC Hybrid Forecast	Final Forecast
Named Storms (14.4)	18.3	18
Named Storm Days (69.4)	96.0	90
Hurricanes (7.2)	10.0	9
Hurricane Days (27.0)	41.5	35
Major Hurricanes (3.2)	4.9	4
Major Hurricane Days (7.4)	12.6	9
Accumulated Cyclone Energy Index (123)	186	160
Net Tropical Cyclone Activity (135%)	198	170

2.3 July Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2023. These years also provide useful clues as to likely levels of activity that the forthcoming 2023 hurricane season may bring. For this early July extended range forecast, we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current June 2023 conditions and, more importantly, projected August–October 2023 conditions. Table 12 lists our analog selections, while Figure 12 shows the composite August–October SST in our six analog years.

We note that there are no great analogs for the current and projected situation of a moderate to strong El Niño combined with a record warm Atlantic. The anomalous state of Atlantic SSTs is underscored by every statistical/dynamical scheme consistently predicting the warmest eastern/central North Atlantic on record. Most other years with a very warm Atlantic either had neutral ENSO or La Niña conditions. The analogs that we selected were generally characterized by El Niño conditions and a relatively warm Atlantic for the peak of the Atlantic hurricane season (August–October). While 2005 was an ENSO neutral year, we included it is an analog since the Atlantic was very warm that year. We anticipate that the 2023 hurricane season will have activity slightly above the average of our six analog years. There is a large spread in Atlantic hurricane activity in the six analog years that we selected, highlighting the large uncertainty in the potential outcomes for the 2023 season.

Table 12: Analog years for 2023 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1951	12	67.00	8	34.25	3	4.50	126.3	126.2
1969	18	92.25	12	40.25	5	6.50	165.7	181.7
1987	7	37.25	3	5.00	1	0.50	34.4	45.6
2004	15	93.00	9	45.50	6	22.25	226.9	231.6
2005	28	126.25	15	49.75	7	17.50	245.3	276.7
2006	10	58.00	5	21.25	2	2.00	83.3	86.8
Average	15.0	79.9	8.7	31.2	3.7	8.4	144	154
2023 Forecast	**18**	**90**	**9**	**35**	**4**	**9**	**160**	**170**

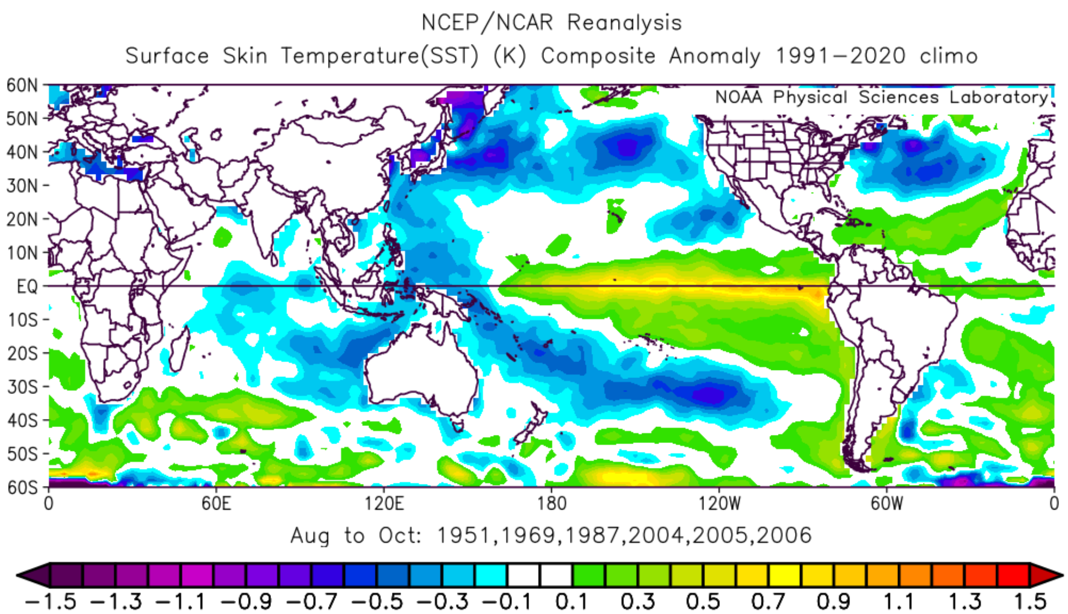

Figure 12: Average August–October SST anomalies in our six analog years.

2.4 ACE West of 60°W Forecast

For the first time this year, we are explicitly forecasting ACE occurring west of 60°W. While there is a relatively robust relationship between basinwide ACE and North Atlantic landfalling hurricanes (defined as hurricanes making landfall west of 60°W) since 1950, there is an improved relationship between North Atlantic landfalling hurricanes and ACE west of 60°W (Figures 13 and 14).

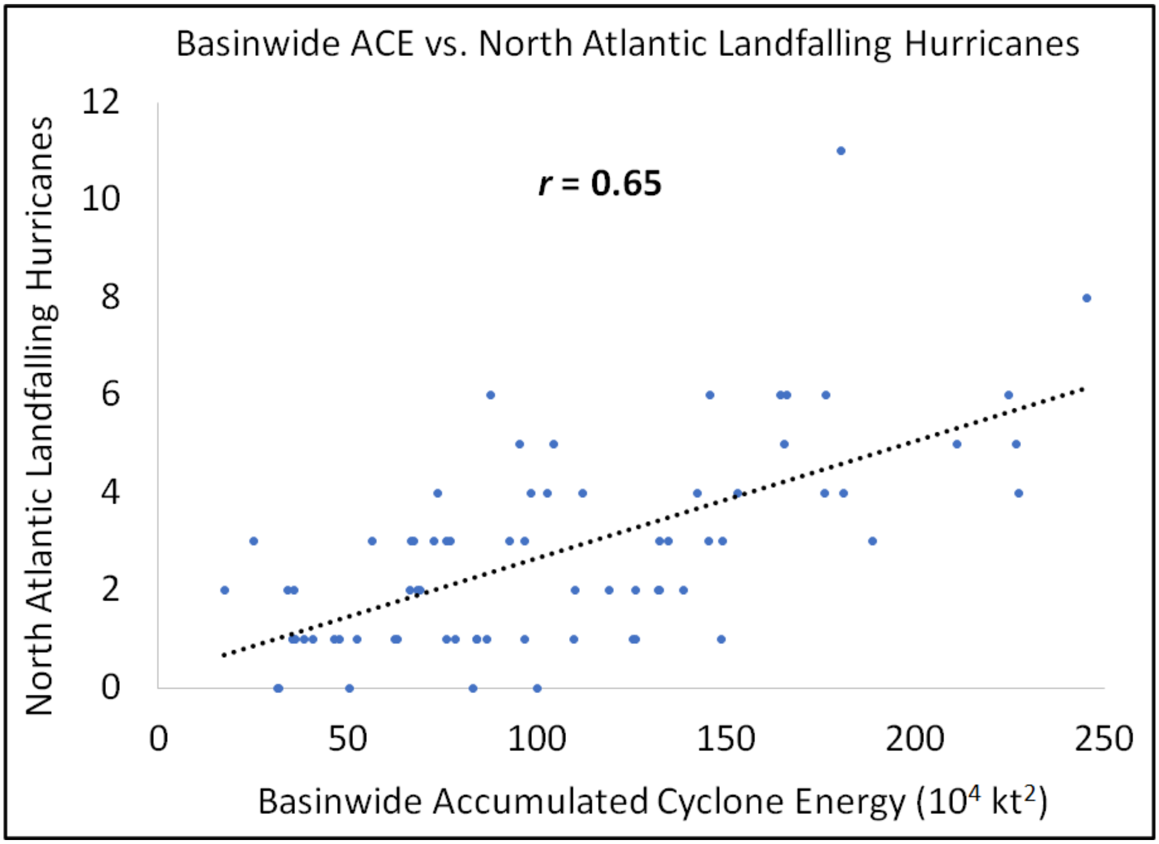

Figure 13: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

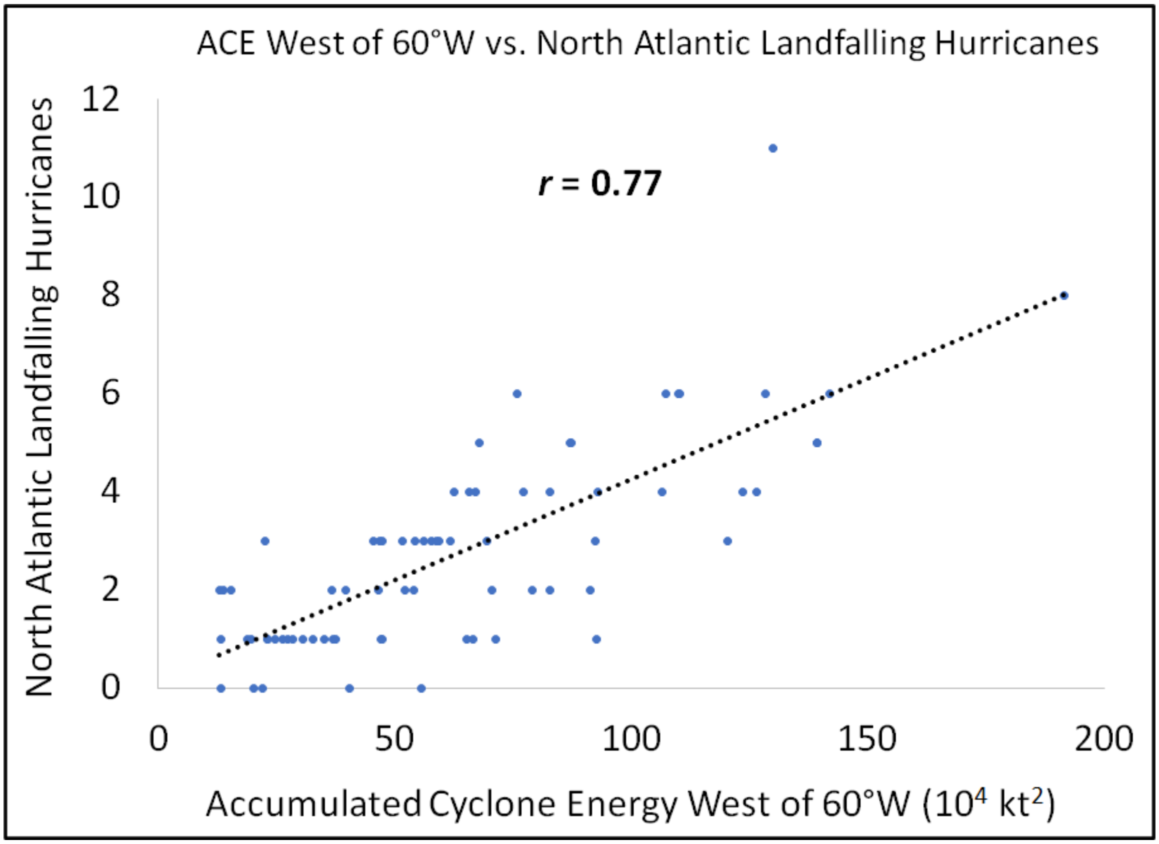

Figure 14: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

In general, years characterized by El Niño conditions tend to have slightly less ACE west of 60°W than La Niña seasons, likely due to both more conducive conditions in the western Atlantic in La Niña seasons, as well as an increased chance of recurvature for TCs in El Niño seasons (Colbert and Soden 2012). We use data from 1979–2022 and base ENSO classifications on the August–October-averaged Oceanic Nino Index (ONI). Years with an ONI >= 0.5°C are classified as El Niño, years with an ONI <= -0.5°C are classified as La Niña, while all other seasons are classified as neutral ENSO.

We find that 52% of basinwide ACE occurs west of 60°W in El Niño years, while 60% of basinwide ACE occurs west of 60°W in La Niña years. In neutral ENSO years, 59% of basinwide ACE occurs west of 60°W (Figure 15). Given that El Niño conditions are already present and are very likely to continue this season, we are estimating 52% of basinwide ACE to occur west of 60°W for the remainder of 2023. More research on additional impact-relevant metrics will be forthcoming in future forecasts.

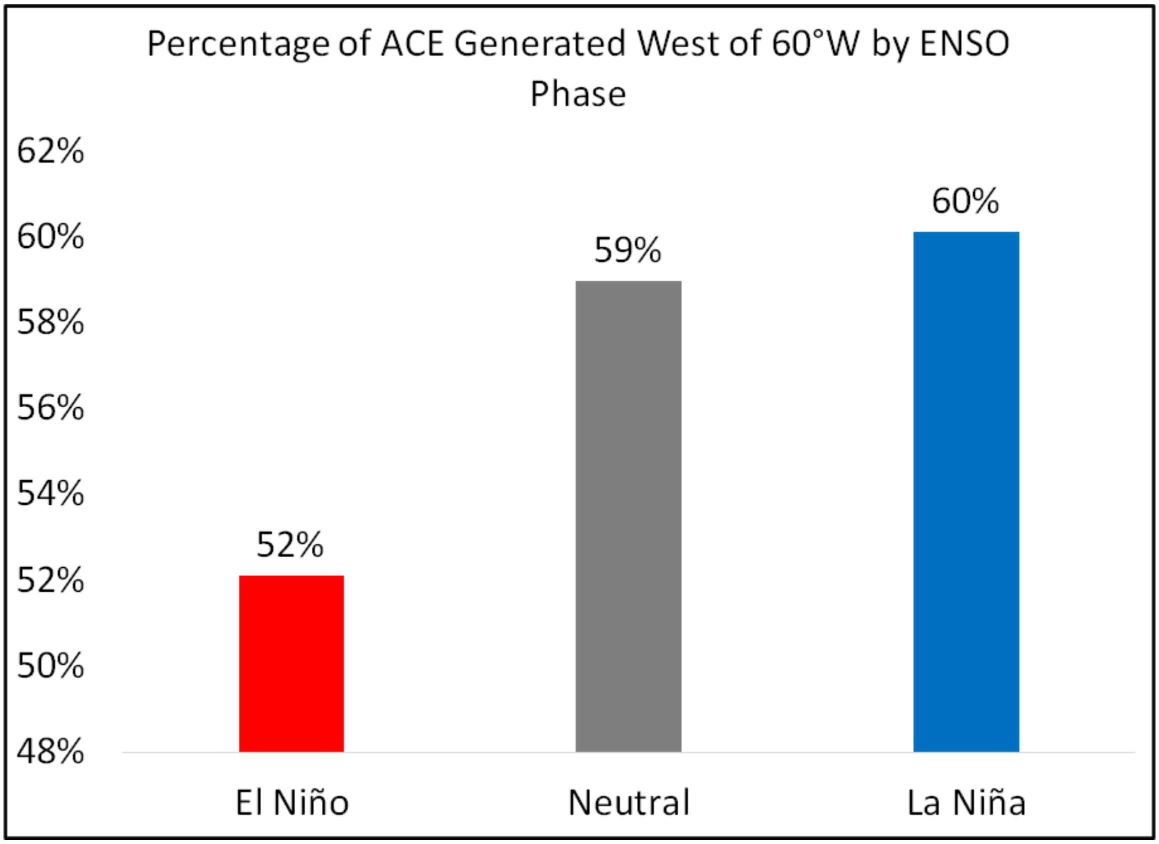

Figure 15: Percentage of ACE generated west of 60°W by ENSO phase.

2.5 July Forecast Summary and Final Adjusted Forecast

Table 13 shows our final adjusted early July forecast for the 2023 season which is a combination of our statistical scheme, our statistical/dynamical schemes, our analog scheme and qualitative adjustments for other factors not explicitly contained in any of these schemes. The various forecast models range from a slightly above-average season to an extremely active season. Our final forecast is slightly below the average of our six forecast schemes due to the potential for a stronger El Niño than we currently anticipate. As noted earlier, there is larger-than-normal uncertainty associated with this forecast.

Table 13: Summary of our early July statistical forecast, our statistical/dynamical forecasts, our analog forecast, the average of these six schemes and our adjusted final forecast for the 2023 hurricane season.

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Scheme	ECMWF Scheme	Met Office Scheme	JMA Scheme	CMCC Scheme	Analog Scheme	6-Scheme Average	Adjusted Final Forecast
Named Storms (14.4)	20.5	17.8	17.8	15.1	18.3	15.0	17.4	18
Named Storm Days (69.4)	111.5	93.1	92.6	74.2	96.0	79.9	91.2	90
Hurricanes (7.2)	11.6	9.6	9.6	7.7	10.0	8.7	9.5	9
Hurricane Days (27.0)	49.9	39.9	39.7	29.6	41.5	31.2	38.6	35
Major Hurricanes (3.2)	5.8	4.7	4.7	3.5	4.9	3.7	4.6	4
Major Hurricane Days (7.4)	15.7	12.0	11.9	8.3	12.6	8.4	11.5	9
Accumulated Cyclone Energy Index (123)	223	179	178	134	186	144	174	160
Net Tropical Cyclone Activity (135%)	235	191	190	146	198	154	186	170

3 Forecast Uncertainty

This season we continue to use probability of exceedance curves as discussed in Saunders et al. (2020) to quantify forecast uncertainty. 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 16 and 17), 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 14 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. As noted earlier, uncertainty is higher than normal with this year’s seasonal hurricane forecast.

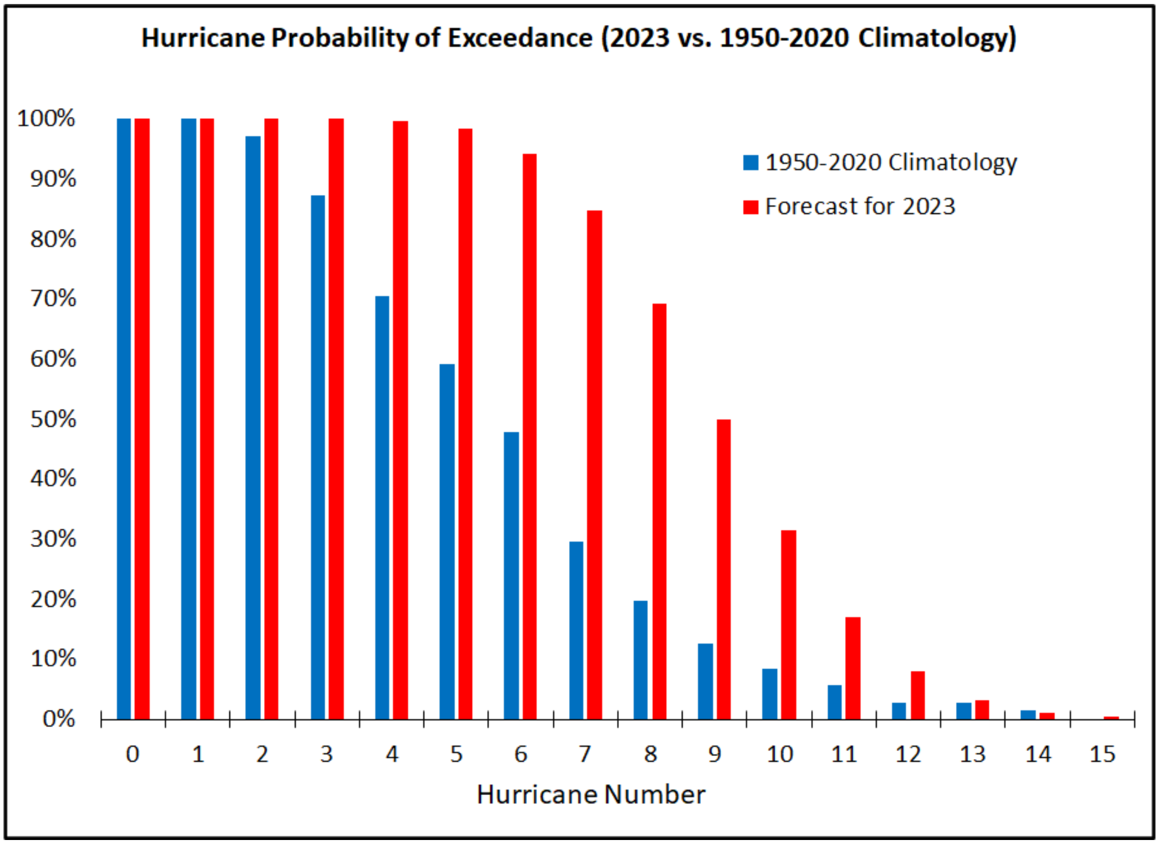

Figure 16: Probability of exceedance plot for hurricane numbers for the 2023 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950–2020 have had more than two hurricanes.

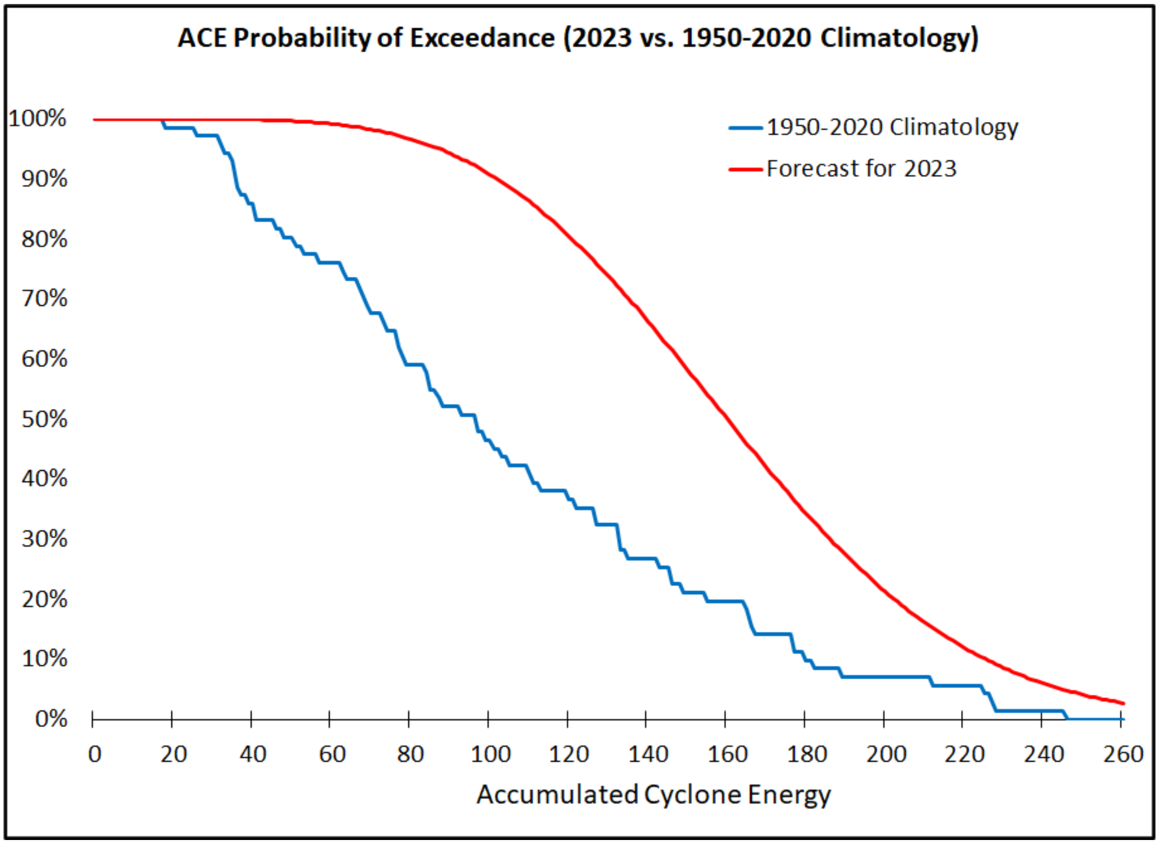

Figure 17: As in Figure 16 but for ACE.

Table 14: 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	2023 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	18	15 – 21
Named Storm Days (NSD)	90	70 – 111
Hurricanes (H)	9	7 – 11
Hurricane Days (HD)	35	23 – 48
Major Hurricanes (MH)	4	3 – 6
Major Hurricane Days (MHD)	9	6 – 14
Accumulated Cyclone Energy (ACE)	160	112 – 212
ACE West of 60°W	78	48 – 113
Net Tropical Cyclone (NTC) Activity	170	124 – 220

4 ENSO

The tropical Pacific has continued to anomalously warm over the past few weeks (Figure 18). NOAA officially declared that El Niño was underway in early June, and since that time, El Niño conditions have intensified somewhat. Broad swaths of the tropical eastern/central Pacific are now >1.0°C warmer than normal, indicating that El

Niño is approaching moderate intensity. When SSTs in the Nino 3.4 region (5°S-5°N, 170-120°W) are between 0.5°C-0.9°C warmer than normal, El Niño is considered to be of weak strength, when SSTs in the Nino 3.4 region are between 1.0°C-1.4°C warmer than normal, El Niño is considered to be of moderate strength, and when SSTs in the Nino 3.4 region are >=1.5°C, El Niño is considered to be strong.

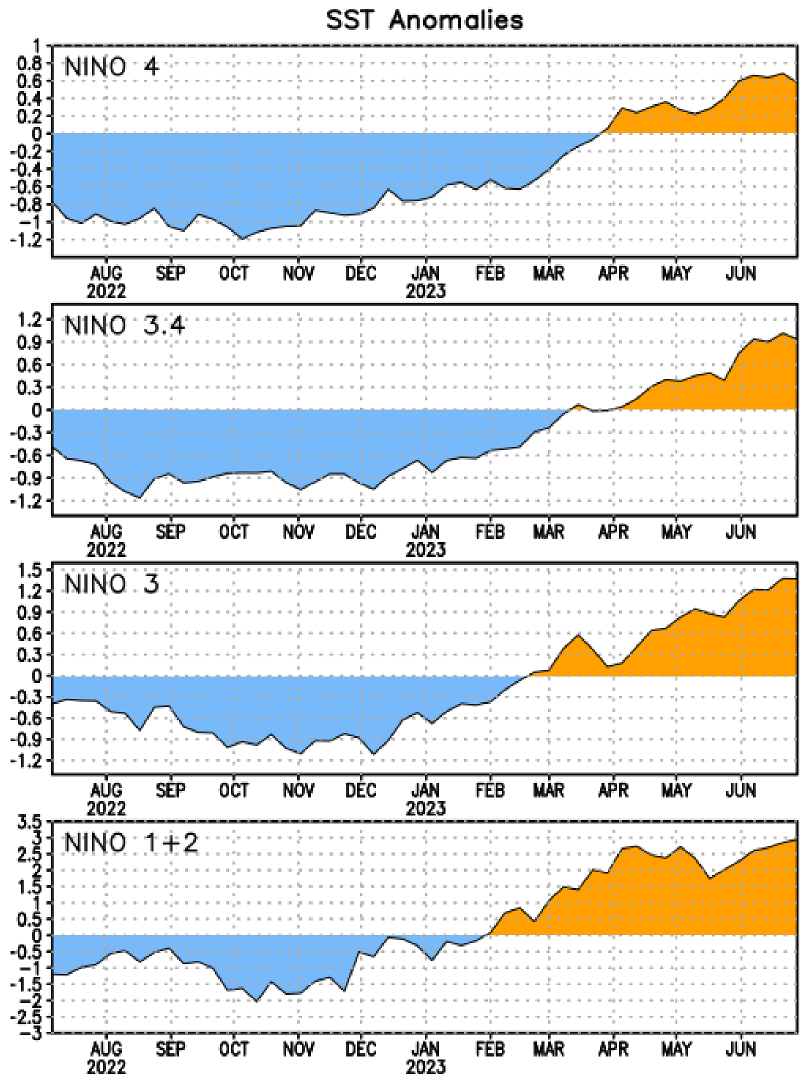

Figure 18: SST anomalies for several ENSO regions over the past year. Figure courtesy of Climate Prediction Center.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific have continued to increase as well (Figure 19). This increase in upper-ocean heat content anomalies is likely tied to a strong westerly wind burst that occurred in May associated with developing tropical cyclone Mawar in the western North Pacific (Figure 20). Over the past few weeks, low-level winds across the tropical Pacific have alternated between easterly and westerly anomalies, likely due to shorter-term variability associated with the Madden-Julian oscillation.

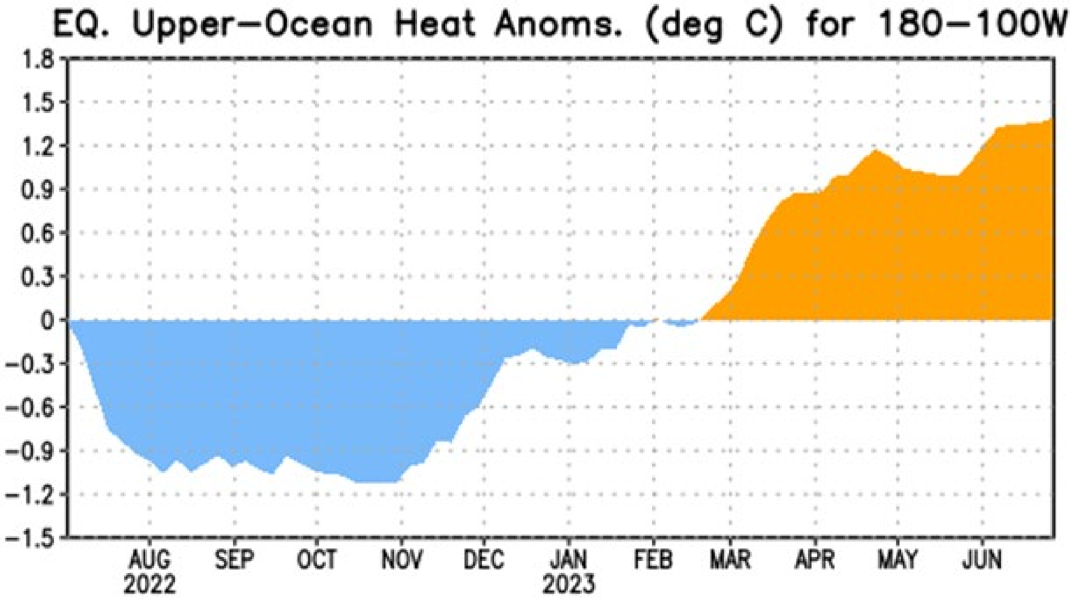

Figure 19: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

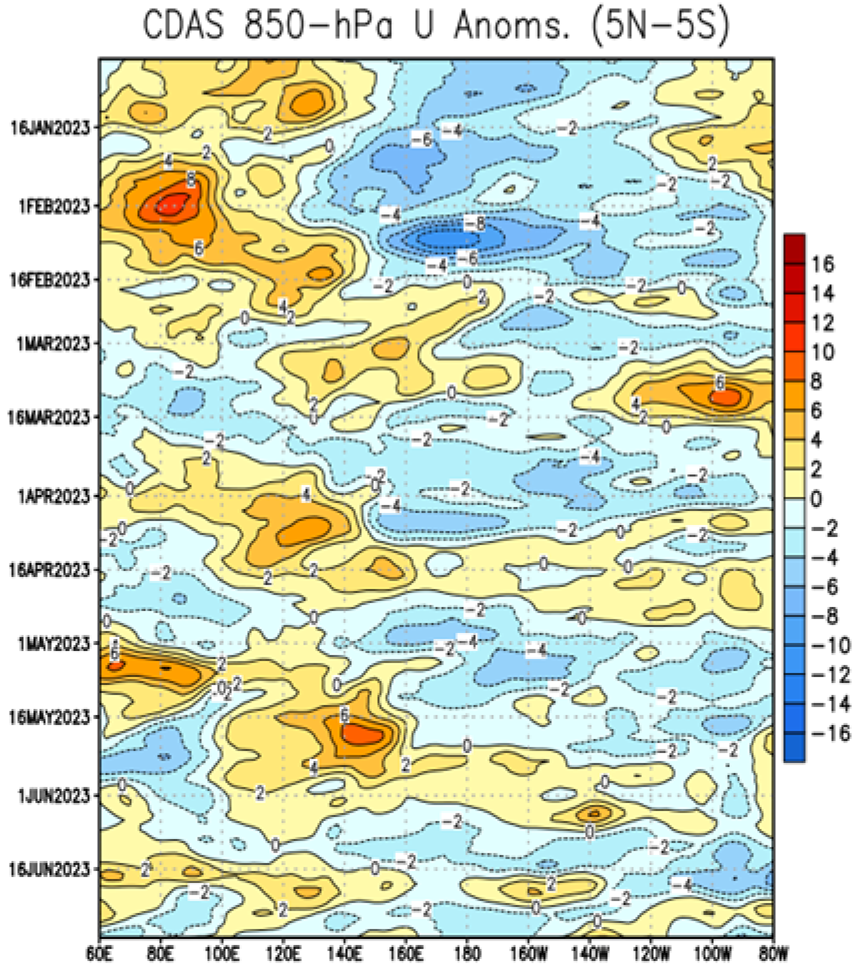

Figure 20: Anomalous equatorial low-level winds spanning from 60°E to 80°W. Figure courtesy of Climate Prediction Center.

SSTs are currently above-normal across the eastern and central tropical Pacific, with the strongest warm anomalies in the far eastern tropical Pacific (Figure 21). The western North Pacific is warmer than normal, while the current spatial pattern of SSTs in the North Pacific (e.g., warm anomalies across most of the North Pacific and cold anomalies off of the west coast of California) are indicative of a continued negative phase of the Pacific Decadal Oscillation. The June value of the Pacific Decadal Oscillation (-2.57) was the most negative June value of the Pacific Decadal Oscillation since 1894. These strong negative anomalies in the eastern subtropical Pacific tend to favor anomalously strong trade winds across the central tropical Pacific, which is one reason why we do not anticipate that El Niño will become as strong as some of the most aggressive model projections indicate.

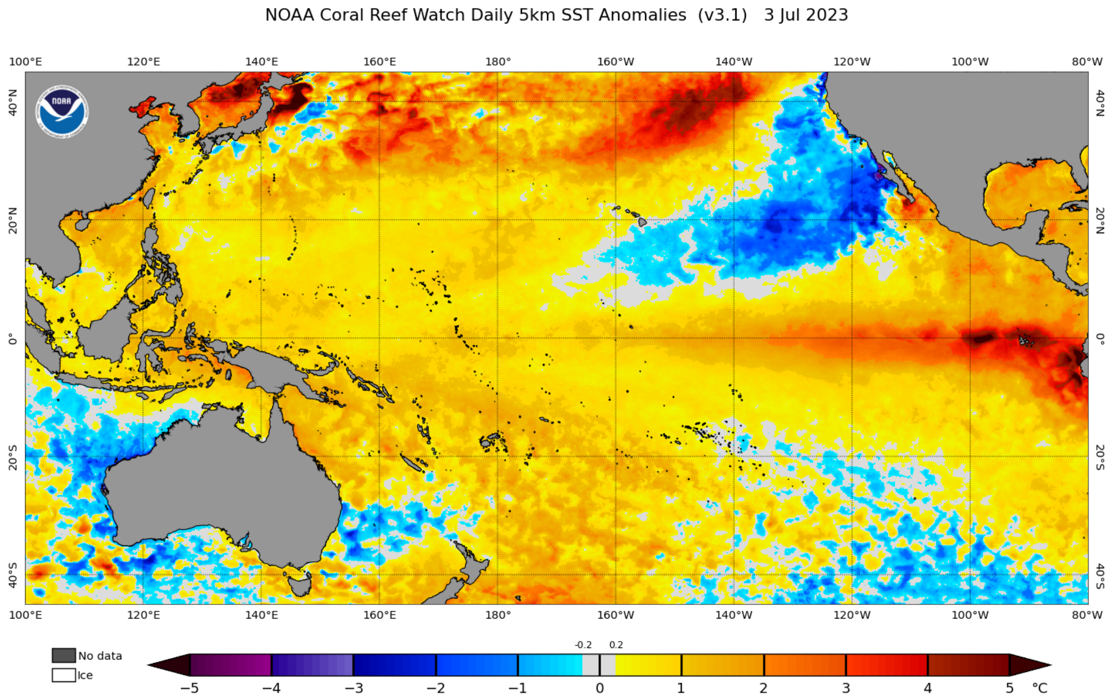

Figure 21: Current SST anomalies across the tropical and subtropical Pacific.

Table 15 displays May and June SST anomalies for several Nino regions. Over the past month, SST anomalies have continued to warm across the tropical Pacific.

Table 15: May and June SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. June-May SST anomaly differences are also provided.

Region	May SST Anomaly (°C)	June SST Anomaly (°C)	June – May SST Anomaly (°C)
Nino 1+2	+2.0	+2.8	+0.8
Nino 3	+0.9	+1.3	+0.4
Nino 3.4	+0.5	+0.9	+0.4
Nino 4	+0.3	+0.6	+0.3

As noted earlier, a downwelling (warming) Kelvin wave, was generated in the western tropical Pacific during the middle of May and is currently propagating eastward, fueling additional anomalous SST warming across the tropical Pacific (Figure 22).

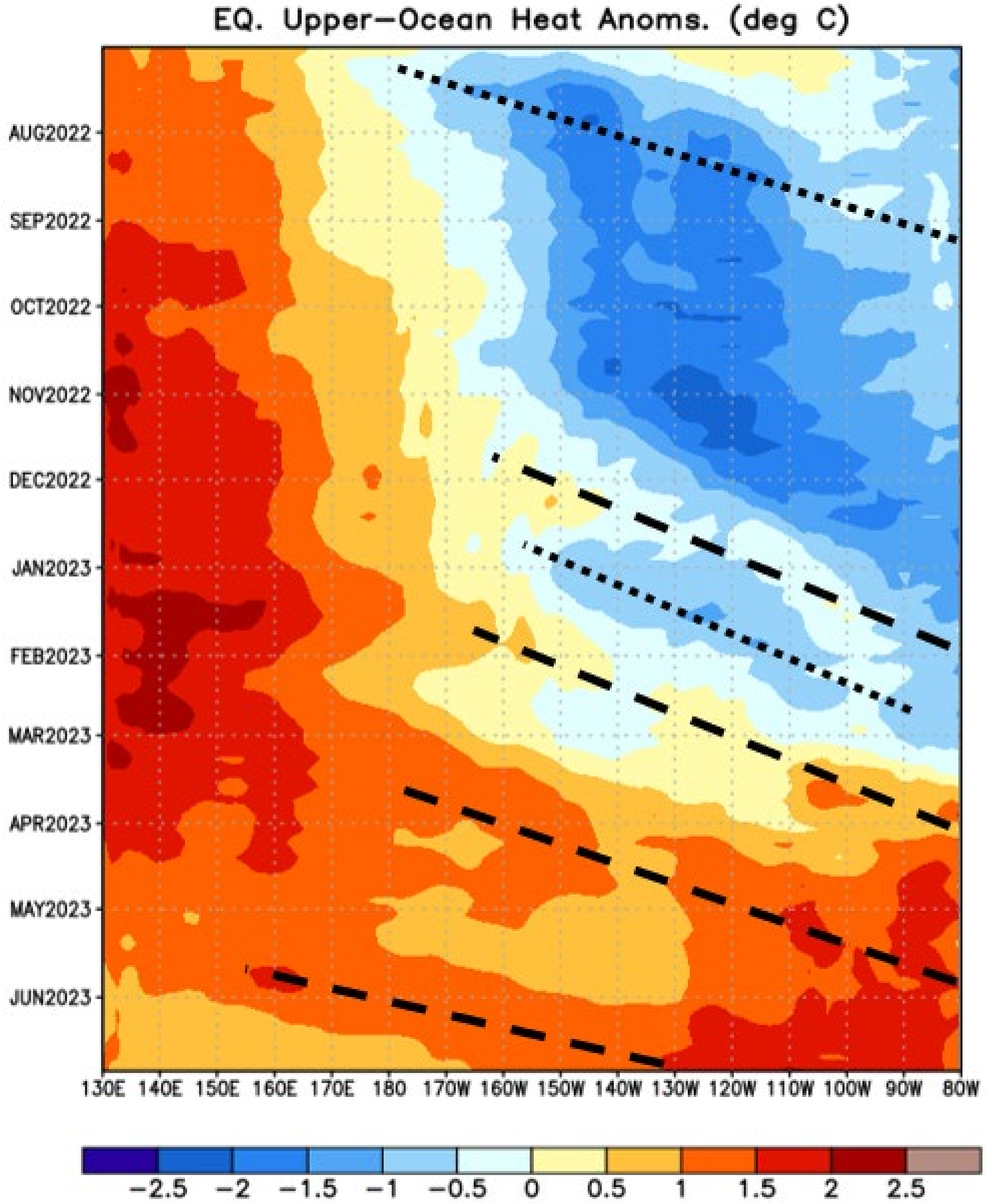

Figure 22: Upper-ocean heat content anomalies in the tropical Pacific since July 2022. Dashed lines indicate downwelling Kelvin waves, while dotted lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases. Figure courtesy of Climate Prediction Center.

Over the next several months, we will be closely monitoring low-level winds over the tropical Pacific, as these winds will play an important role in just how strong the current El Niño will get. Over the next week, low-level winds across the central tropical Pacific are forecast to be stronger than normal, but the low-level winds are then forecast to weaken with another potential westerly wind burst developing west of the International Date Line (Figure 23).

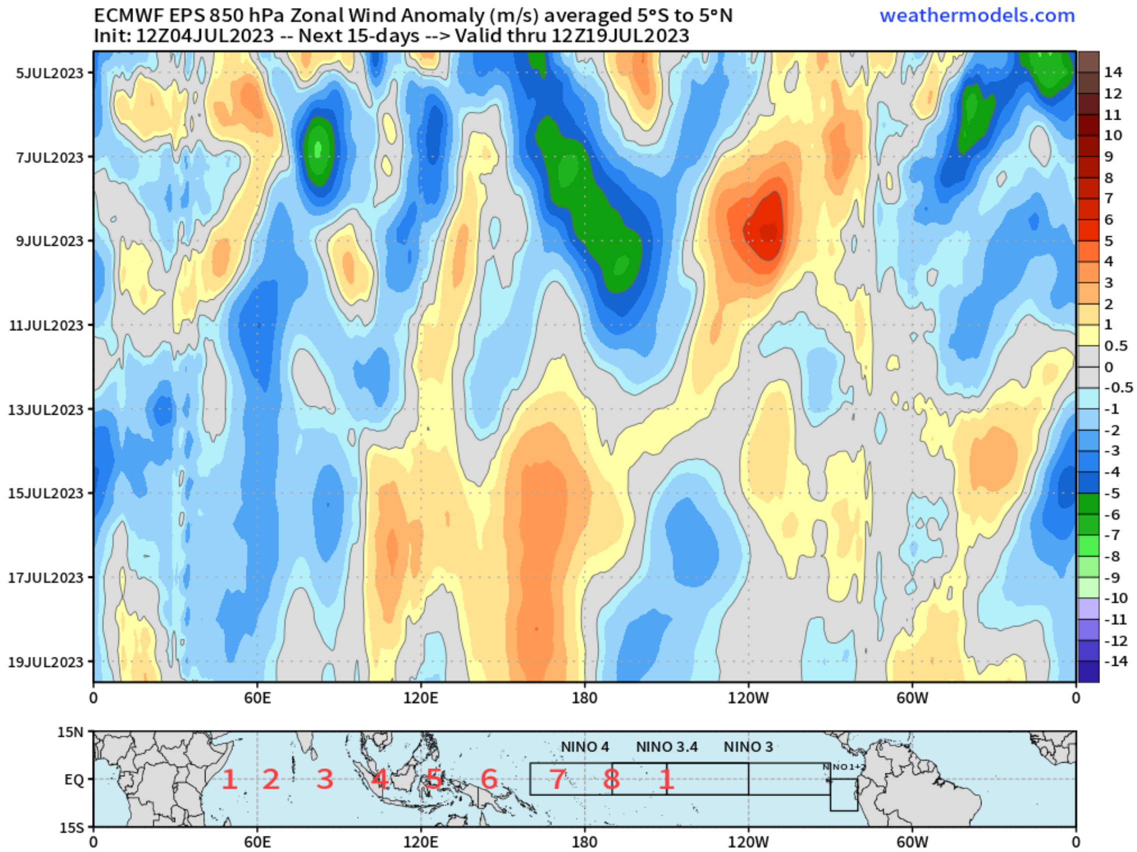

Figure 23: ECMWF forecast 850 hPa zonal equatorial winds for the next 15 days. Figure courtesy of weathermodels.com.

The latest plume of ENSO predictions from several statistical and dynamical models shows considerable spread by the peak of the Atlantic hurricane season in August–October (Figure 24), but the majority of models are favoring a robust El Niño. The dynamical models generally are more aggressive with the intensity of El Niño than are the statistical models.

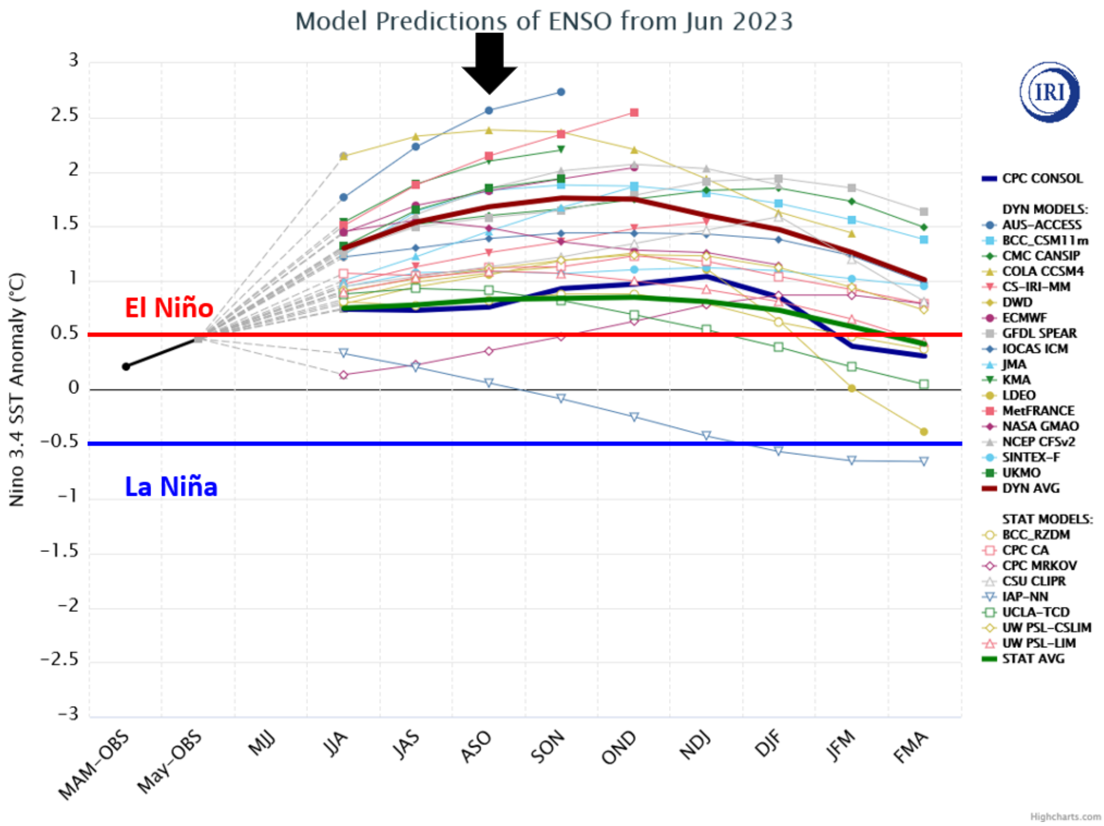

Figure 24: ENSO forecasts from various statistical and dynamical models for Nino 3.4 SST anomalies based on late May to early June initial conditions. Almost all models are calling for El Niño for August–October. Figure courtesy of the International Research Institute (IRI). The black arrow delineates the peak of the Atlantic hurricane season (August–October).

The latest official forecast from NOAA also strongly favors El Niño for August–October. NOAA is currently predicting a 95% chance of El Niño and a 5% chance of ENSO neutral conditions for the peak of the Atlantic hurricane season (Figure 25).

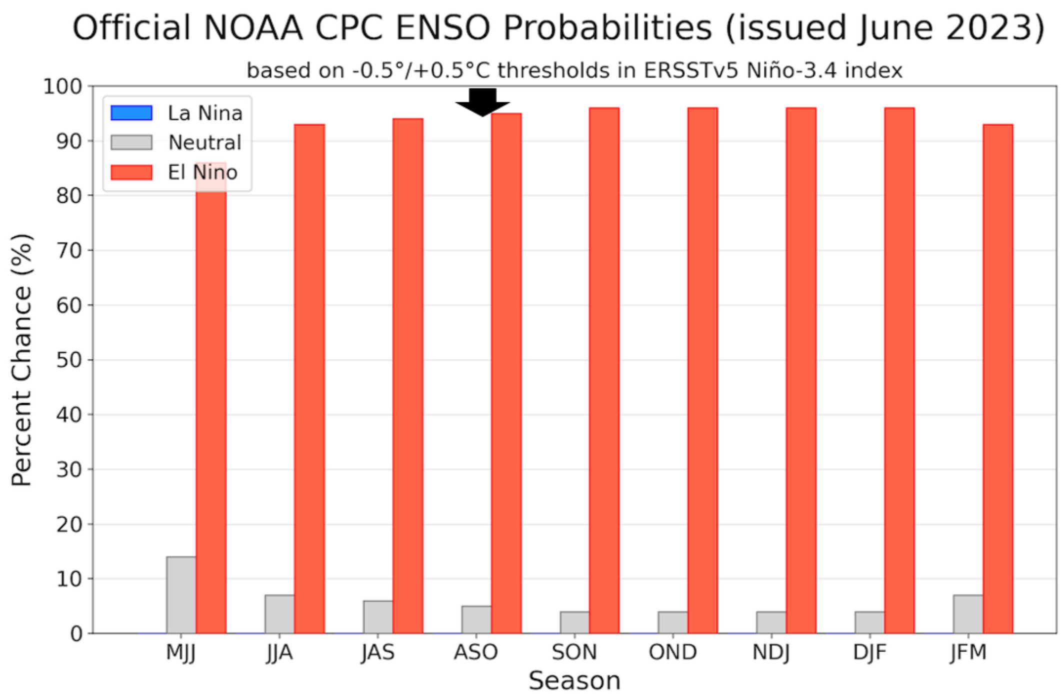

Figure 25: Official probabilistic ENSO forecast from NOAA. The black arrow delineates the peak of the Atlantic hurricane season (August–October).

Based on the above information, we continue to estimate that we will have a moderate to strong El Niño for the peak of the Atlantic hurricane season. The overall strength of the El Niño event is likely critical for this season's Atlantic hurricane outlook, given the record warmth occurring across most of the tropical and subtropical Atlantic right now (discussed in the next section).

5 Current Atlantic Basin Conditions

Currently, SSTs are at record warm levels across most of the North Atlantic (Figure 26). We have been monitoring SSTs in the region from 0-45°N, 45-10°W, as this region in June historically has high correlations (~0.65) with seasonal Atlantic ACE (Figure 27). SSTs are the warmest on record (since 1979) using the most recent 30-day averages. The eastern Atlantic is also currently warmer (using 30-day averages) by ~0.5°C than any other early July on record since 1979, highlighting just how anomalously warm conditions are right now. The five years with the warmest SSTs after 2023 through early July were (in descending order from 2nd warmest): 1995, 2008, 2010, 2020, and 2005. Four out of those five seasons were classified as hyperactive Atlantic hurricane seasons by NOAA, while 2008 was classified as an above-average season.. However, none of those seasons had El Niño conditions.

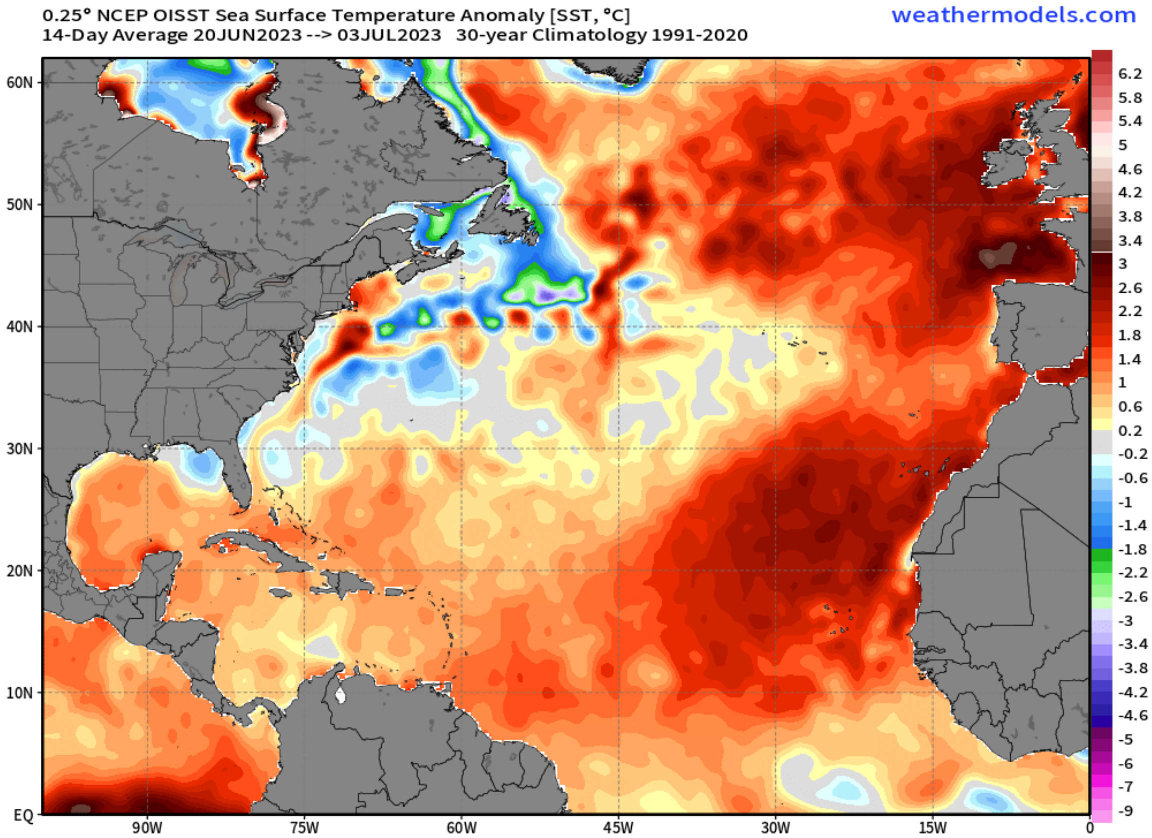

Figure 26: Early July 2023 SST anomaly pattern across the Atlantic Ocean.

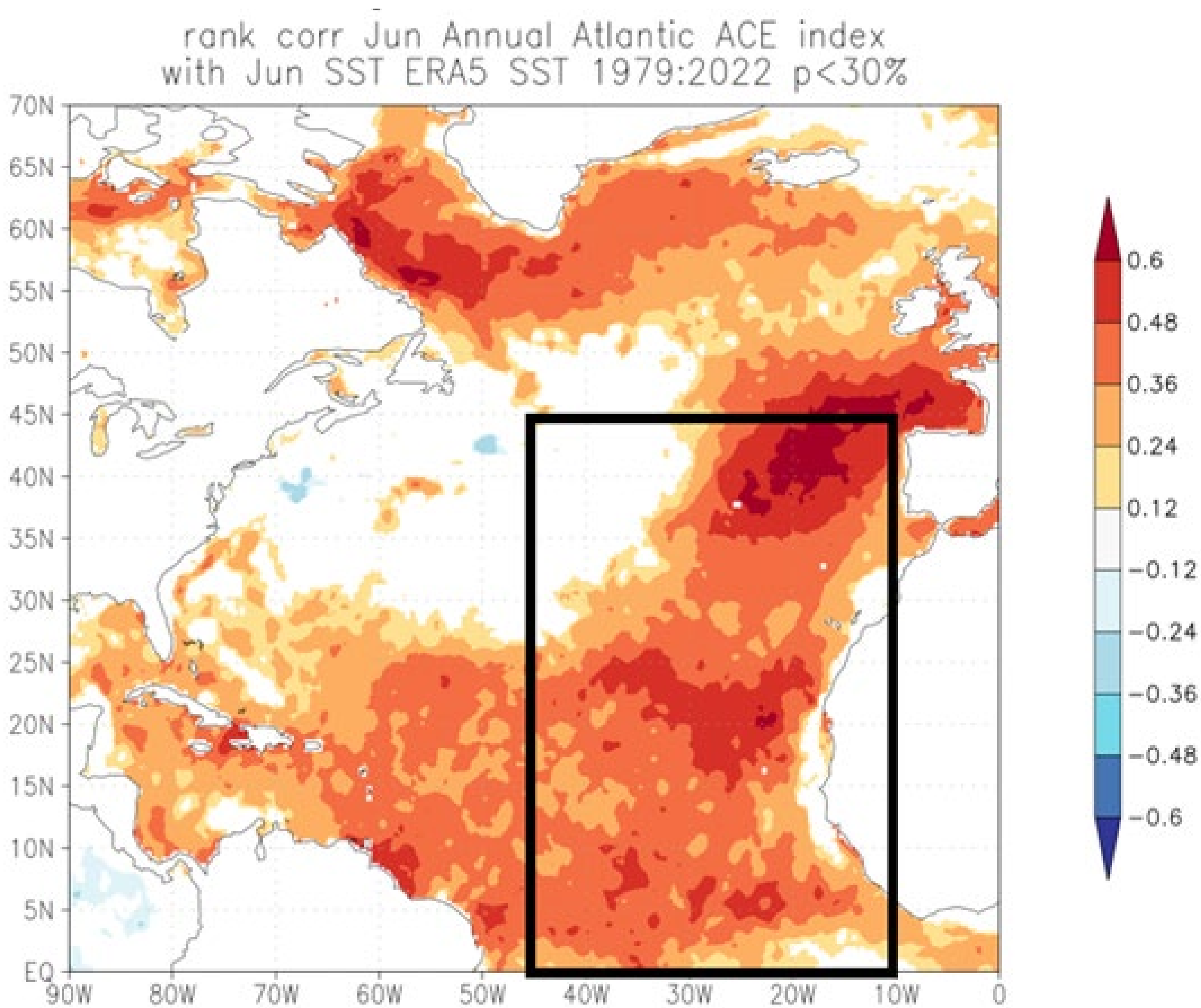

Figure 27: Rank correlations between June sea surface temperatures in the North Atlantic and annual Atlantic ACE from 1979-2022. The black rectangle denotes the region discussed in the previous paragraph (0-45°N, 45-10°W).

The North Atlantic Oscillation was generally in its negative phase from late February through the middle of May (Figure 28), was positive during late May and has since trended predominately negatively through June. Associated with this negative phase has been weaker-than-normal trade winds across most of the tropical and subtropical eastern Atlantic (Figure 29). These weaker trades have led to less evaporation and mixing, leading to considerable anomalous warming across the basin.

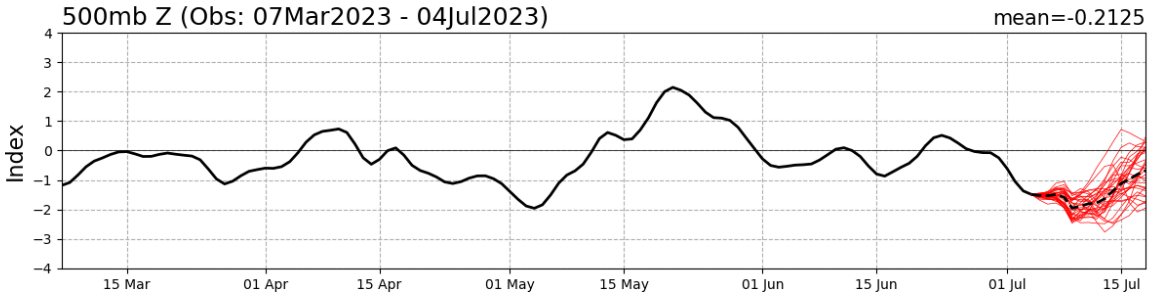

Figure 28: Observed values of the North Atlantic Oscillation since early March and forecasts of the North Atlantic Oscillation from the Global Ensemble Forecast System for the next 15 days.

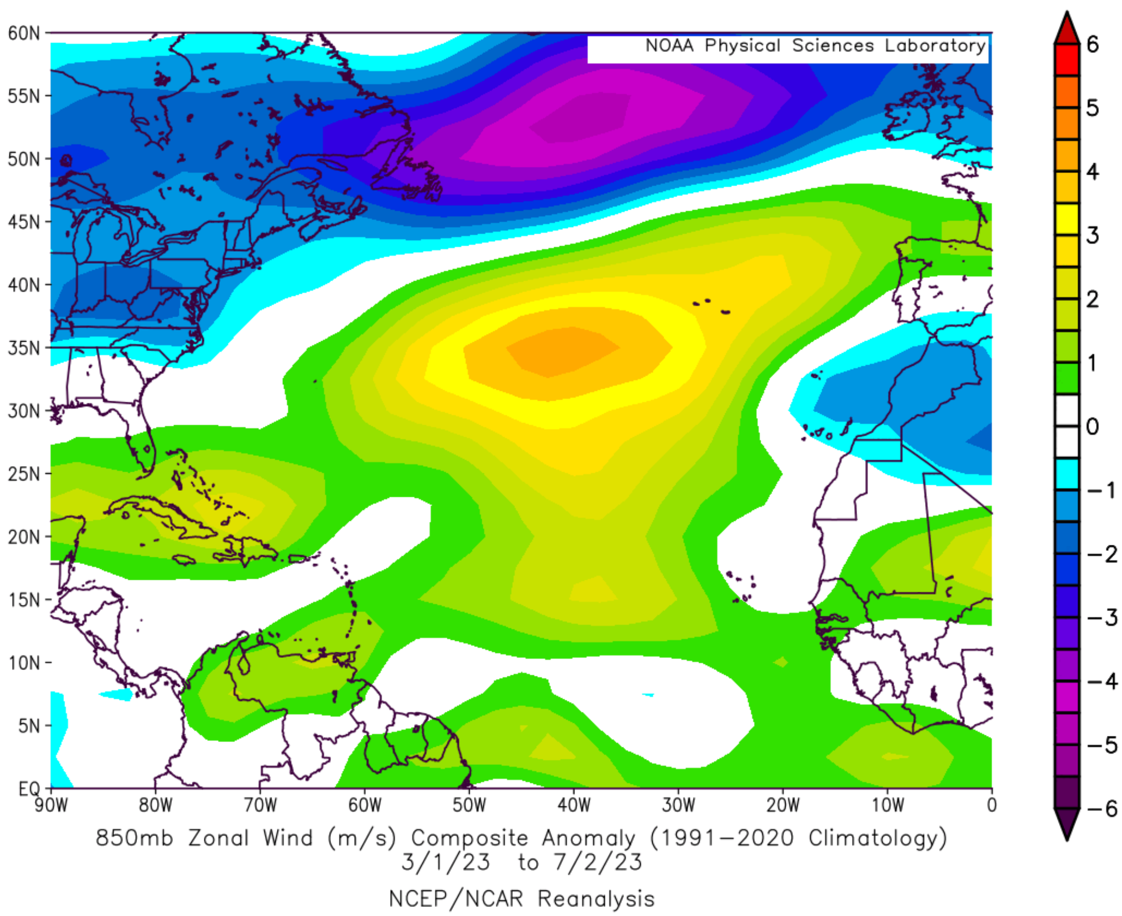

Figure 29: 850 hPa zonal wind anomalies across the North Atlantic Ocean from March 1, 2023 through July 2, 2023.

Figure 30 shows observed low-level winds and the forecast for the next few weeks of low-level winds across the Atlantic from the Climate Forecast System. In general, tropical Atlantic trade winds are forecast to be near average for the next few weeks, indicating that anomalous warming may plateau, however, there are no consistent signs of anomalously strong trades emerging.

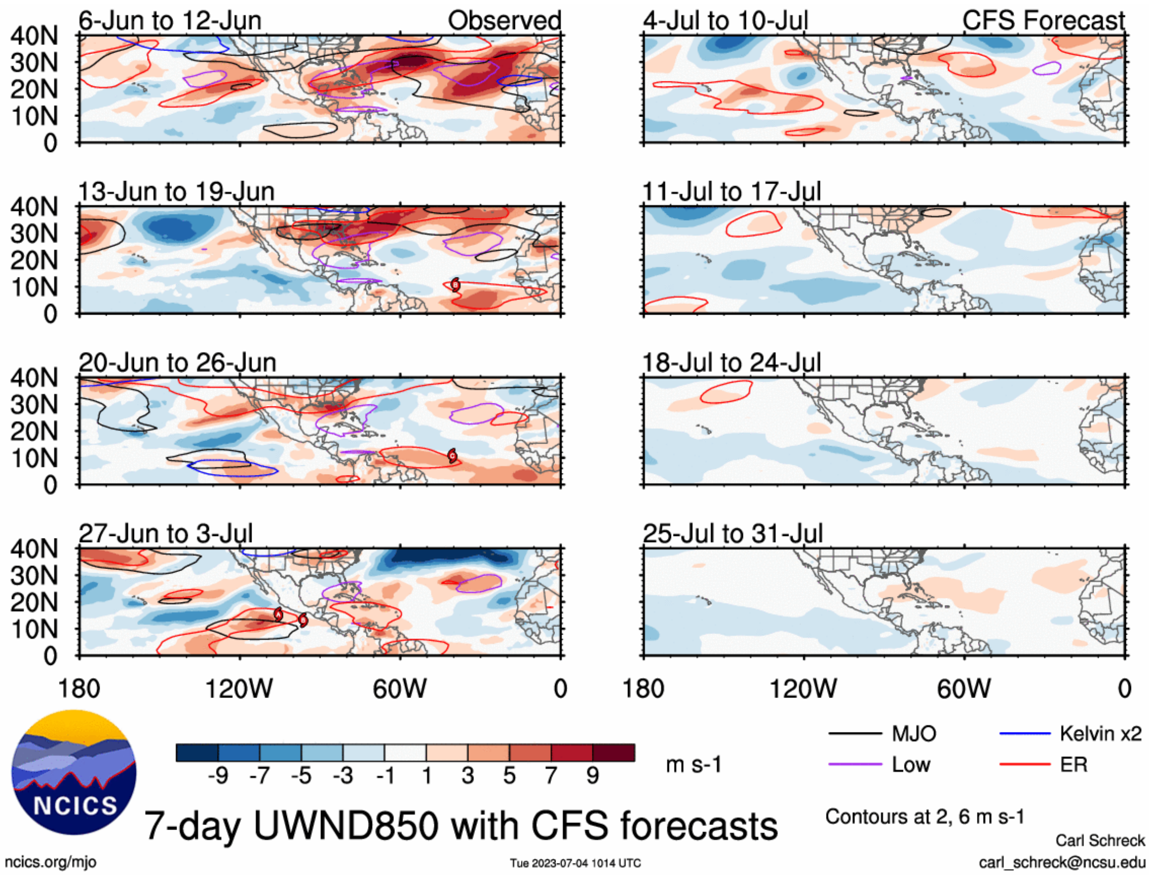

Figure 30: Observed low-level zonal winds across portions of the Western Hemisphere over the past four weeks and predicted low-level zonal winds from the Climate Forecast System for the next four weeks. Figure courtesy of Carl Schreck.

6 West Africa Conditions

The West African monsoon has gotten off to a modestly above-normal start, with precipitation in the Sahel being slightly above normal during June (Figure 31). An active West African monsoon is typically associated with more active Atlantic hurricane seasons.

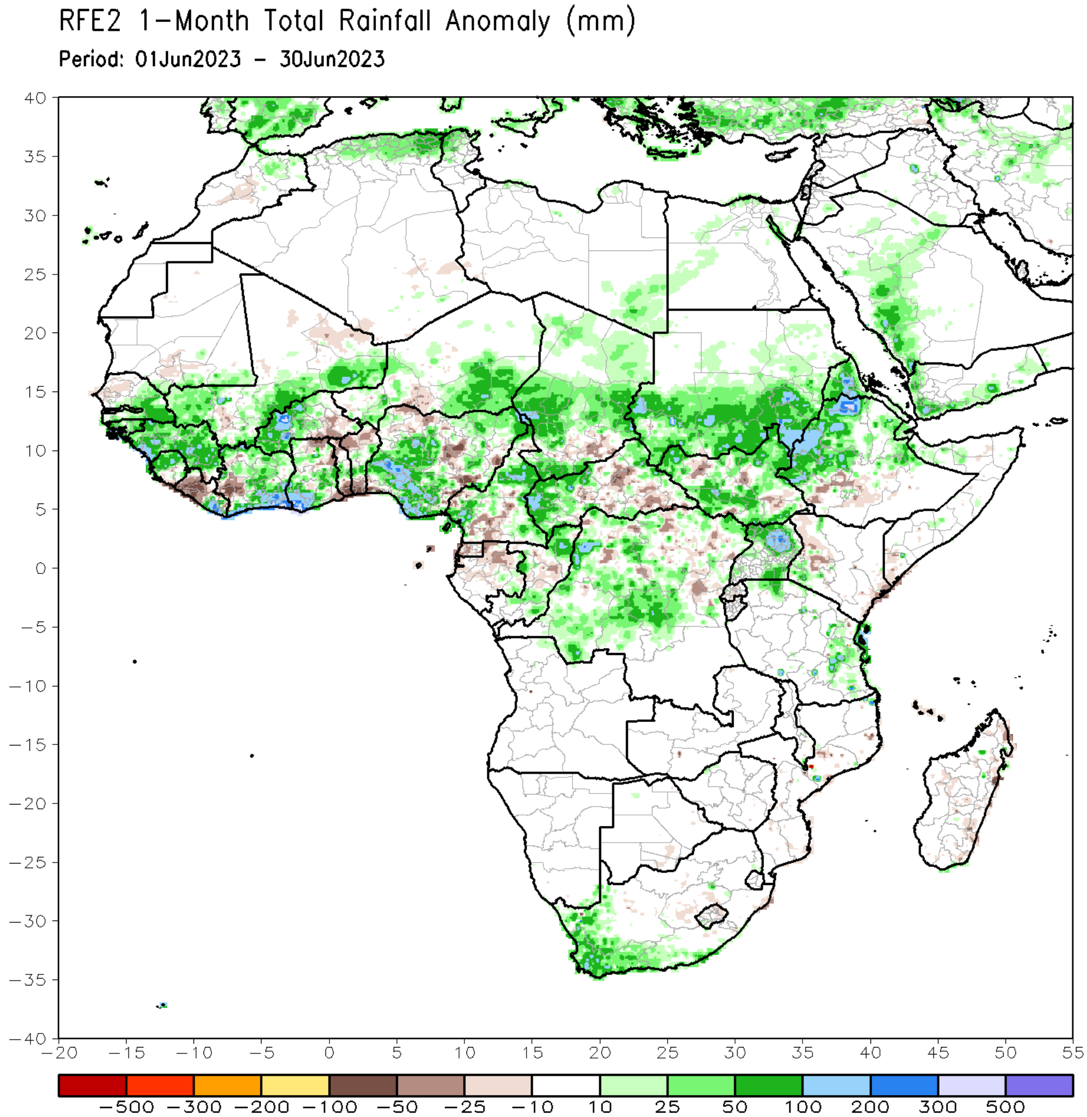

Figure 31: June 2023 rainfall estimates from the African Rainfall Estimation Algorithm, version 2.

7 Tropical Storms Bret and Cindy

In general, early season Atlantic hurricane activity has very little correlation with overall Atlantic hurricane activity. However, when this activity occurs in the tropical Atlantic (south of 23.5°N, east of 70°W), it is often a harbinger of a very active season. 2023 is the first season to have two storms form in the tropical Atlantic in June on record, with the only other years recording one named storm formation in the tropical Atlantic in June being 1933, 1979 and 2017. Both 1933 and 2017 were hyperactive seasons, while 1979 recorded near-normal activity.

The tropical Atlantic has already produced 8 named storm days in the tropical Atlantic. Table 16 displays all seasons on record with 4+ named storm days in the tropical Atlantic in June-July. Most of these seasons had above-average activity, with the notable exception of 2013. ACE values may be underestimated somewhat in seasons prior to the satellite era (mid-1960s).

Table 16: Seasons with 4+ named storm days in June-July in the tropical Atlantic and associated seasonal values of Atlantic ACE.

Year	June-July Tropical Atlantic NSD	Seasonal ACE
1933	7	259
2013	6.5	36
2008	6	146
1901	5.75	99
1966	5	139
1996	4.75	166
2005	4.5	245
2020	4.5	180
1916	4.25	144
1969	4.25	149
1887	4	181
Average		159

8 Tropical Cyclone Impact Probabilities for 2023

This year, we continue to calculate the impacts of tropical cyclones for each state and county/parish along the Gulf and East Coasts, tropical cyclone-prone provinces of Canada, states in Mexico, islands in the Caribbean and countries in Central America. We have used NOAA's Historical Hurricane Tracks website and selected all named storms, hurricanes and major hurricanes that have tracked within 50 miles of each landmass from 1880–2020. This approach allows for tropical cyclones that may have made landfall in an immediately adjacent region to be counted for all regions that were in close proximity to the landfall location of the storm. We then fit the observed frequency of storms within 50 miles of each landmass using a Poisson distribution to calculate the climatological odds of one or more events within 50 miles.

Net landfall probability is shown to be linked to overall Atlantic basin ACE. Long-term statistics show that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of hurricane landfalls for various landmasses in the basin.

Table 17 displays the climatological odds of storms tracking within 50 miles of each state along the Gulf and East Coasts along with the odds for the remainder of 2023. Landfall probabilities are above their long-term averages. Probabilities for other Atlantic basin landmasses are available on our website.

Given that landfall rates between 1880–2020 and 1991–2020 are similar for the continental US, we adjust all landfall rates relative to the 1991–2020 Atlantic basin ACE climatology. We prefer to use 1880–2020 for landfall statistics to increase the robustness of the historical landfall dataset. Also, storms near landfall are likely better observed than those farther east in the basin prior to the satellite era (e.g., mid-1960s). Discrepancies in basinwide ACE between the two periods (123 for 1991–2020 vs. 95 for 1880–2020) are likely mostly due to improved observational technology in the more recent period.

Table 17: Post-5 July probability of >=1 named storm, hurricane and major hurricane tracking within 50 miles of each coastal state from Texas to Maine. Probabilities are provided for both the full season 1880–2020 climatological average as well as the probability for the remainder of 2023, based on the latest CSU seasonal hurricane forecast.

		2023 Probability			Climatological	
	Probability >=1	event within	50 miles	Probability >=1	event within	50 miles
State	Named Storm	Hurricane	Major Hurricane	Named Storm	Hurricane	Major Hurricane
Alabama	65%	33%	10%	58%	28%	8%
Connecticut	26%	9%	2%	22%	8%	1%
Delaware	27%	7%	1%	23%	6%	1%
Florida	91%	63%	34%	86%	56%	29%
Georgia	70%	36%	7%	63%	30%	6%
Louisiana	73%	44%	17%	66%	38%	14%
Maine	25%	8%	2%	21%	7%	1%
Maryland	36%	13%	1%	31%	11%	1%
Massachusetts	38%	17%	3%	33%	14%	3%
Mississippi	60%	33%	9%	53%	28%	8%
New Hampshire	22%	7%	2%	18%	6%	1%
New Jersey	27%	8%	1%	23%	7%	1%
New York	31%	11%	3%	26%	9%	2%
North Carolina	75%	44%	9%	68%	38%	8%
Rhode Island	24%	9%	2%	20%	8%	1%
South Carolina	64%	34%	10%	57%	29%	8%
Texas	68%	43%	19%	61%	36%	16%
Virginia	52%	24%	2%	46%	20%	1%

9 Summary

An analysis of a variety of different atmosphere and ocean measurements (through June) 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 2023 will have above-average activity. The big question marks with this season's predictions revolve around the strength of El Niño and how anomalously warm the tropical and subtropical Atlantic is for the peak of the hurricane season. We stress again that there is greater-than-normal uncertainty associated with this outlook.

10 Forthcoming Updated Forecasts of 2023 Hurricane Activity

We will be issuing a seasonal update of our 2023 Atlantic basin hurricane forecast on **Thursday, 3 August**. We will also be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August–October. The first two-week forecast for 2023 will also be issued on **Thursday, 3 August.** A verification and discussion of all 2023 forecasts will be issued on **Thursday, 30 November**. All of these forecasts will be available on our website.

11 Verification of Previous Forecasts

CSU's seasonal hurricane forecasts have shown considerable improvement in recent years, likely due to a combination of improved physical understanding, adoption of statistical/dynamical models and more reliable reanalysis products. Figure 32 displays correlations between observed and predicted Atlantic hurricanes from 1984–2013, from 2014–2022 and from 1984–2022, respectively. Correlation skill has improved at all lead times in recent years, with the most noticeable improvements at longer lead times. While nine years is a relatively short sample size, improvements in both modeling and physical understanding should continue to result in future improvements in seasonal Atlantic hurricane forecast skill. More detailed verification statistics are also available at: https://tropical.colostate.edu/archive.html#verification

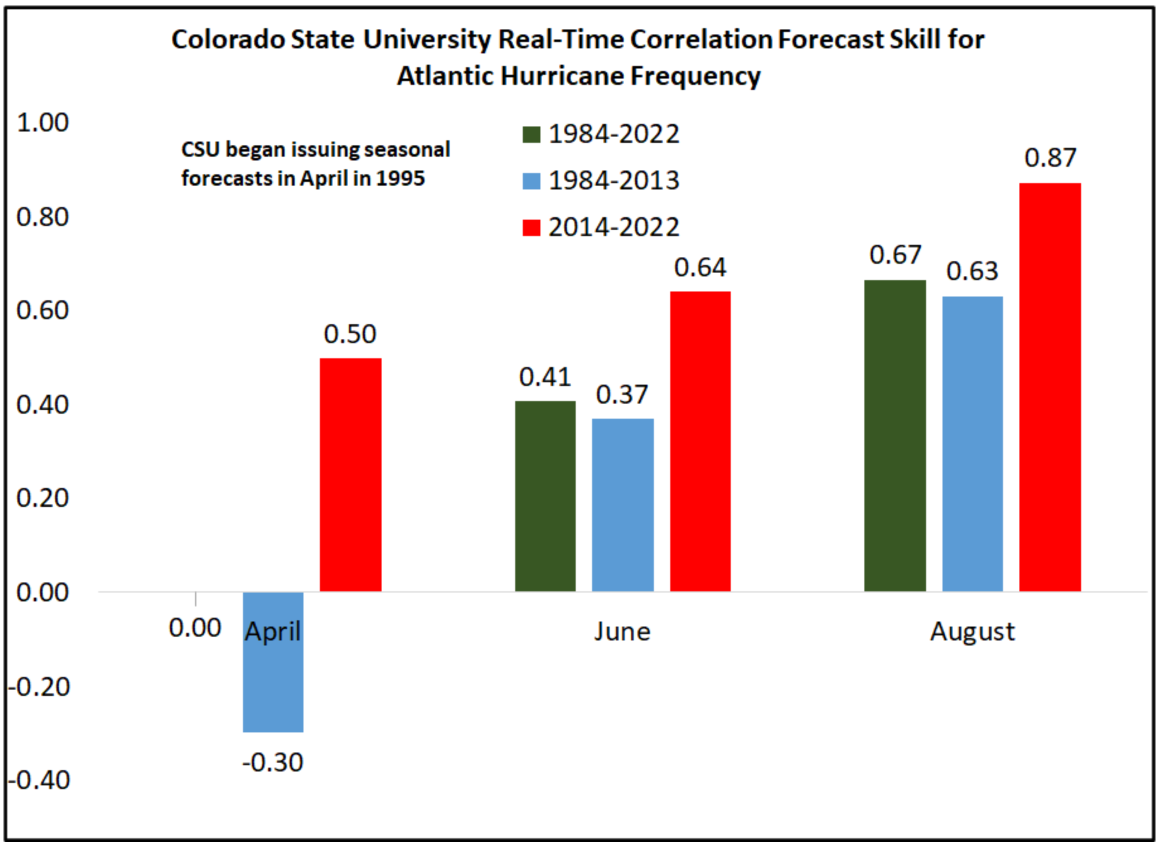

Figure 32: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2022 and 1984–2022, respectively.