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

We maintain our forecast for an above-average 2023 Atlantic hurricane season. While a robust El Niño has developed and is likely to persist for the peak of the Atlantic hurricane season, most of the tropical and subtropical Atlantic has record warm sea surface temperatures for this time of year. El Niño increases vertical wind shear in the Caribbean and tropical Atlantic, but the extreme anomalous warmth in the tropical and subtropical Atlantic is anticipated to 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 3 August 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

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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	Issue Date 3 August 2023	Observed Thru 2 August 2023	Remainder of Season Forecast
Named Storms (NS) (14.4)	13	15	18	18*	5	13
Named Storm Days (NSD) (69.4)	55	60	90	90	19.50	70.50
Hurricanes (H) (7.2)	6	7	9	9	1	8
Hurricane Days (HD) (27.0)	25	30	35	35	0.5	34.50
Major Hurricanes (MH) (3.2)	2	3	4	4	0	4
Major Hurricane Days (MHD) (7.4)	5	7	9	9	0	9
Accumulated Cyclone Energy (ACE) (123)	100	125	160	160	16	144
ACE West of 60°W (73)	55	70	82	82	4	78
Net Tropical Cyclone Activity (NTC) (135%)	105	135	170	170	18	152

*Total forecast includes an unnamed subtropical storm in January as well as Arlene, Bret and Cindy in June and Don in July.

PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING COASTAL AREAS (AFTER 2 AUGUST):

1) Entire continental U.S. coastline - 48% (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 - 31% (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) (AFTER 2 AUGUST):

1) 53% (full-season average from 1880–2020 is 47%)

ABSTRACT

Information obtained through July 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 five storms that have formed already this year (January subtropical storm, Arlene, Bret, Cindy and Don). The probability of U.S. major hurricane landfall is 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 130 percent of their 1991–2020 average. We are forecasting the same seasonal numbers with our August forecast that we predicted in early July.

This forecast is based on two early August statistical models that were developed using ~40 years of past data. Analog predictors are also utilized. We are also including statistical/dynamical models based on ~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. The statistical/dynamical models unanimously agrees that the 2023 Atlantic hurricane season should be hyperactive, while statistical model guidance is calling for an above-average remainder of the Atlantic hurricane season. We stress that there is considerable uncertainty with this season's outlook given the large spread in model guidance, as well as uncertainty with exactly how El Niño will interact with the extremely warm Atlantic.

The tropical Pacific is currently characterized by El Niño conditions. 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.

Sea surface temperatures across most of the tropical and subtropical Atlantic remain at record levels, so despite the potential for a moderate/strong El Niño, the impacts on tropical Atlantic/Caribbean vertical wind shear are likely to not be as strong as is typically experienced given the extremely warm Atlantic.

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 August forecast has good long-term skill when evaluated in hindcast mode. The skill of CSU's forecast updates typically increases as the peak of the Atlantic hurricane season approaches.

Starting today and issued every two weeks following (e.g., August 3, August 17, August 31, etc.), we will issue two-week forecasts for Atlantic TC activity during the peak of the Atlantic hurricane season from August-October.

Why issue forecasts for seasonal hurricane activity?

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

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early August. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged as regards the probability of an active or inactive hurricane season for the coming year. Our early August 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 improved quantification 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. However, regardless of seasonal outlooks, it only takes one hurricane making landfall near you to make it an active season for you.

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 several 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 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.

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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 based on maximum wind speed 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 August forecast is based on two statistical models 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 August Forecast Methodology

2.1 August Statistical Forecast Scheme using July Data

We developed a 1 August statistical seasonal forecast scheme for the prediction of Accumulated Cyclone Energy (ACE) that has been utilized operationally since 2012. The model was updated last year to use ERA5 data. We developed the model over 1979–2020 and have then applied the model to the 2021–2023 seasons.

The pool of three predictors for the early August statistical forecast scheme is given and defined in Table 1. The location of each of these predictors are shown in Figure 1. Skillful forecasts can be issued for post-31 July ACE based upon cross-validated hindcasts from 1979-2022. When these three predictors are combined, they correlate at 0.81 with observed ACE using cross-validated hindcasts from 1979-2022 (Figure 2). Predictor 1 (Caribbean trade wind strength) calls for near-average activity, Predictor 2 (Subtropical northeastern Atlantic SST) calls for an extremely active season, while Predictor 3 (tropical Africa upper-level winds) calls for below-average activity. The combination of the three predictors yields a slightly above-average remainder of the season forecast.

Table 1: Listing of 1 August 2023 predictors for this year's hurricane activity. A plus (+) means that positive deviations of the parameter indicate increased hurricane activity this year, and a minus (-) means that positive deviations of the parameter indicate decreased hurricane activity this year.

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) July 10 m U (7.5-17.5°N, 85-60°W) (+)	0.0 SD	Neutral
2) July SST (20-40°N, 35-15°W) (+)	+3.0 SD	Significantly Enhance
3) July 200 hPa U (10-20°N, 30°W-30°E) (-)	+1.4 SD	Significantly Suppress

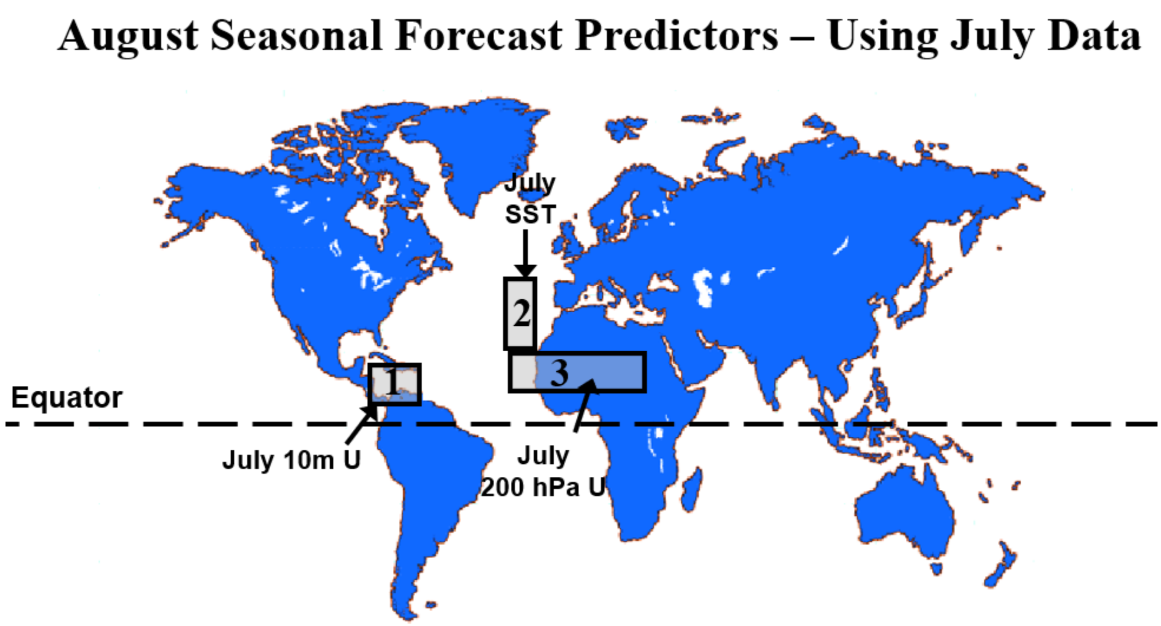

Figure 1: Location of predictors for the post-31 July forecast for the 2023 hurricane season from the July-averaged statistical model.

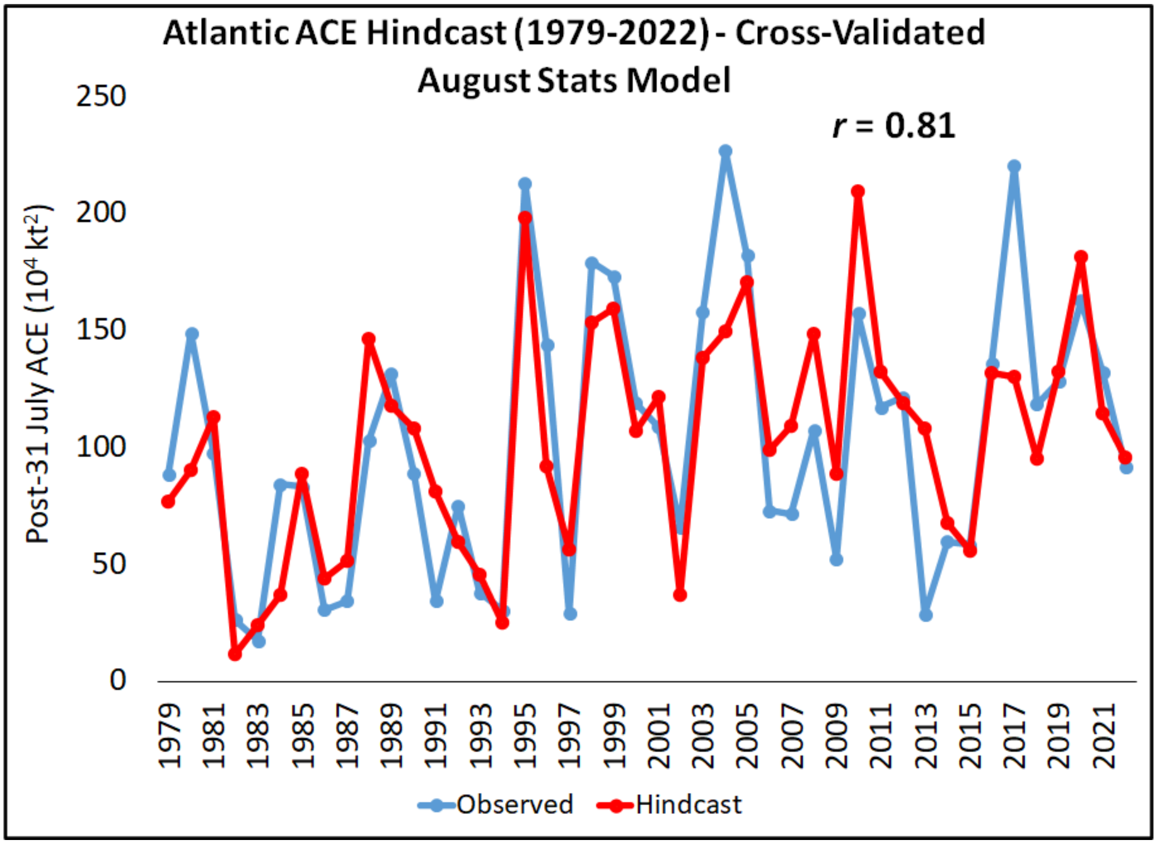

Figure 2: Observed versus hindcast values of post-31 July ACE for 1979-2022 using our statistical scheme that uses July averages.

Table 2 shows our forecast for the 2023 hurricane season from the July-averaged statistical model and the comparison of this forecast with the 1991-2020 average. The statistical forecast is calling for an above-average remainder of the season.

Table 2: Post-31 July statistical forecast for 2023 from the July-averaged statistical model.

Predictands and Climatology (1991-2020 Post-31 July Average)	Post-31 July Statistical Forecast	Full Season Statistical Forecast (Activity Thru 2 August Added In)
Named Storms (NS) – 11.6	15.5	20.5
Named Storm Days (NSD) – 61.3	76.7	96.2
Hurricanes (H) – 6.5	7.9	8.9
Hurricane Days (HD) – 25.6	31.0	31.5
Major Hurricanes (MH) – 3.1	3.7	3.7
Major Hurricane Days (MHD) – 7.1	8.8	8.8
Accumulated Cyclone Energy (ACE) – 113	140	156
Net Tropical Cyclone Activity (NTC) – 123	152	168

2.1a Physical Associations among Predictors Listed in Table 2

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

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

(7.5-17.5°N, 85-60°W)

Low-level trade wind flow has been utilized as a predictor in seasonal forecasting systems for the Atlantic basin (Saunders and Lea 2008). When the trades are weaker-than-normal, SSTs across the tropical Atlantic tend to be elevated, and consequently a larger-than-normal Atlantic Warm Pool (AWP) is typically observed (Wang and Lee 2007) (Figure 3). A larger AWP also correlates with reduced vertical shear across the tropical Atlantic. Weaker trade winds are typically associated with higher pressure in the tropical eastern Pacific (a La Niña signal) and lower pressure in the Caribbean and tropical Atlantic. Both of these conditions generally occur when active hurricane seasons are observed. Predictor 1 also has a strong negative correlation with August-October-averaged 200-850-hPa zonal shear.

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

(20°-40°N, 35-15°W)

A similar predictor was utilized in earlier August seasonal forecast models (Klotzbach 2007, Klotzbach 2011). Anomalously warm SSTs in the subtropical North Atlantic are associated with a positive phase of the Atlantic Meridional Mode (AMM), a northward-shifted Intertropical Convergence Zone, and consequently, reduced trade wind strength (Kossin and Vimont 2007). Weaker trade winds are associated with less surface evaporative cooling and less mixing and upwelling. This results in warmer tropical Atlantic SSTs during the August-October period (Figure 4).

Predictor 3. July 200 hPa U over the Tropical Eastern Atlantic and Northern Tropical Africa (-)

(10-20°N, 30°W-30°E)

Anomalous easterly flow at upper levels over the eastern Atlantic and northern tropical Africa provides an environment that is more favorable for easterly wave development into TCs. This anomalous easterly flow tends to persist through August-October, which reduces shear over the Main Development Region (MDR). This predictor also correlates with SLP and SST anomalies over the tropical eastern Pacific that are typically associated with cool ENSO conditions (Figure 5).

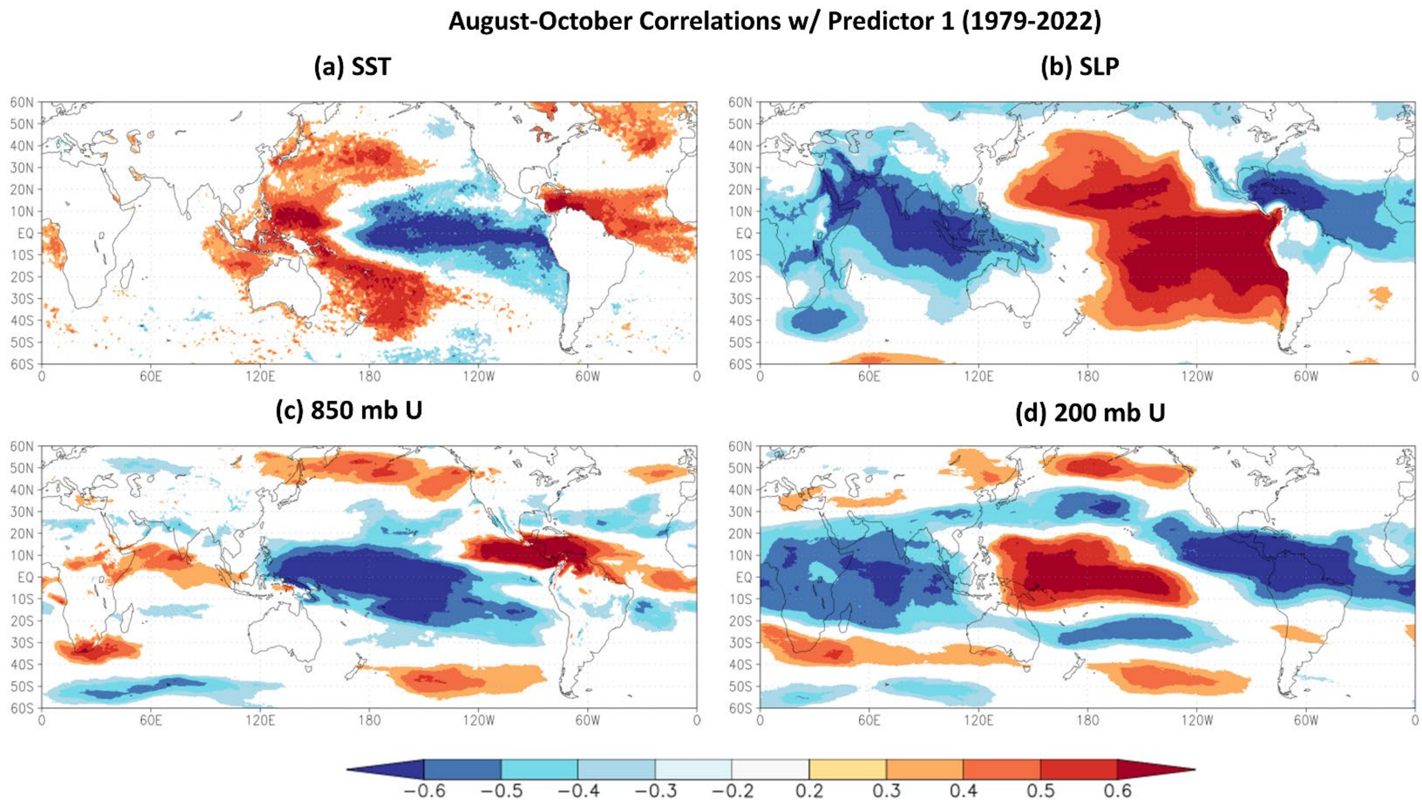

Figure 3: Rank correlations between July 10 meter U in the Caribbean (Predictor 1) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 850 hPa zonal wind (panel c) and August-October 200 hPa zonal wind (panel d) over the period from 1979-2022.

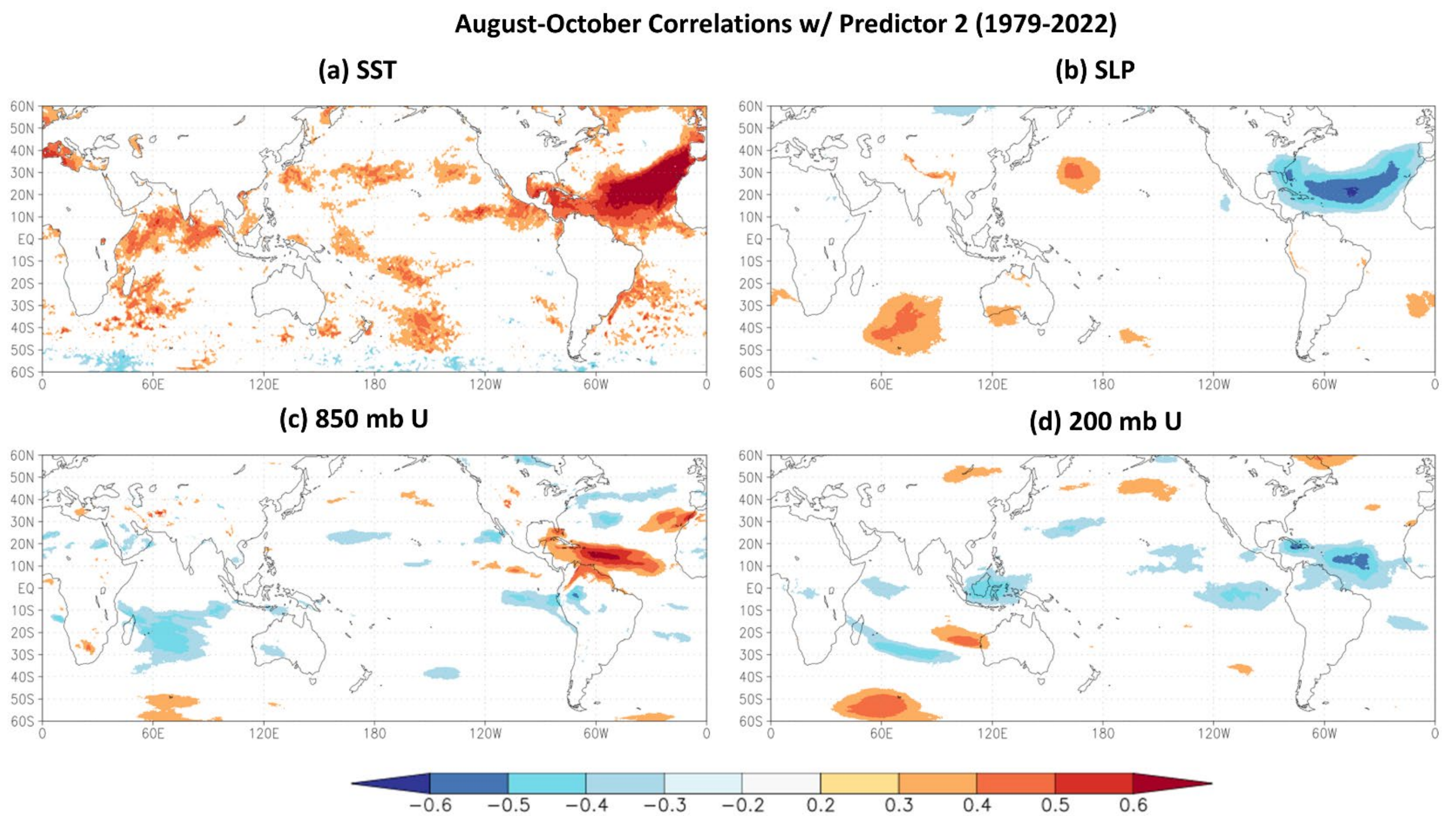

Figure 4: Rank correlations between July sea surface temperature in the subtropical northeastern Atlantic (Predictor 2) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 850 hPa zonal wind (panel c) and August-October 200 hPa zonal wind (panel d) over the period from 1979-2022.

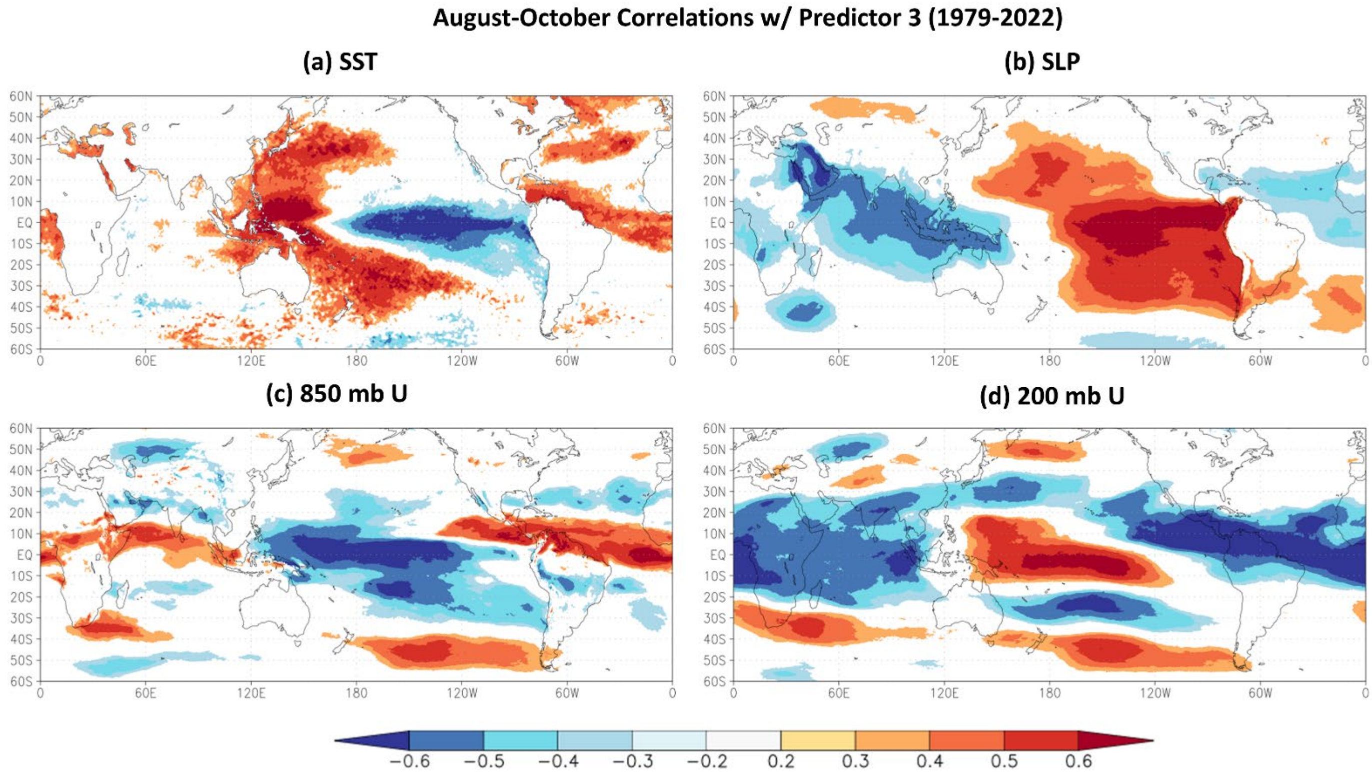

Figure 5: Rank correlations between July 200 hPa zonal wind over tropical north Africa (Predictor 3) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 hPa zonal wind (panel c) and August-October 200 hPa zonal wind (panel d) over the period from 1979-2022. Predictor values have been multiplied by -1 so that the signs of correlations match up with those in Figures 4 and 5.

2.2 August Statistical Forecast Scheme using 50-Day Averages

Last year, we developed a new 1 August statistical seasonal forecast scheme that uses 50-day averages, to complement the scheme that uses July-only data. The reason for using the longer averages is to reduce the impact of sub-seasonal variability, such as the Madden-Julian oscillation, which can impart atmospheric signals on shorter timescales that may not be representative of the longer-term signal that is critical for seasonal forecasting. The new model uses similar predictors to what is used with our model using July averages, with slight tweaks to the predictor boundaries to capture where these predictors showed higher skill in mid- to late June. Given that the boundaries and physical reasonings are similar between our 50-day-averaged and July-averaged statistical model, we do not include a separate discussion of the physical reasoning behind each of the three predictors selected for the 50-day-average model.

This new statistical model also uses ERA5 data. The model was developed on data from 1979-2021 and was issued in real time in 2022.

The pool of three predictors for the 50-day-averaged early August statistical forecast scheme is given and defined in Table 3. The location of each of these predictors is shown in Figure 6. Skillful forecasts can be issued for post-31 July ACE based upon cross-validated hindcasts from 1979-2021 and a forecast in 2022. When these three predictors are combined, they correlate at 0.79 with observed ACE using cross-validated hindcasts from 1979-2022 (Figure 7). Predictor 1 (Caribbean trade wind strength) calls for near-average activity, Predictor 2 (Subtropical northeastern Atlantic SST) calls for an extremely active season, while Predictor 3 (tropical Africa upper-level winds) calls for slightly below-average activity. The combination of the three predictors yields a slightly above-average remainder of the season forecast, slightly more than was forecast by the July-averaged statistical model.

Table 3: Listing of 50-day-averaged statistical model values for the August 2023 hurricane forecast. A plus (+) means that positive deviations of the parameter indicate increased hurricane activity this year, and a minus (-) means that positive deviations of the parameter indicate decreased hurricane activity this year.

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) June 12 – July 31 10 m U (5-20°N, 90-60°W) (+)	-0.4 SD	Slightly Suppress
2) June 12 – July 31 SST (25-50°N, 30-10°W) (+)	+3.2 SD	Significantly Enhance
3) June 12 – July 31 200 hPa U (15°S-15°N, 20°W-40°E) (-)	+0.5 SD	Slightly Suppress

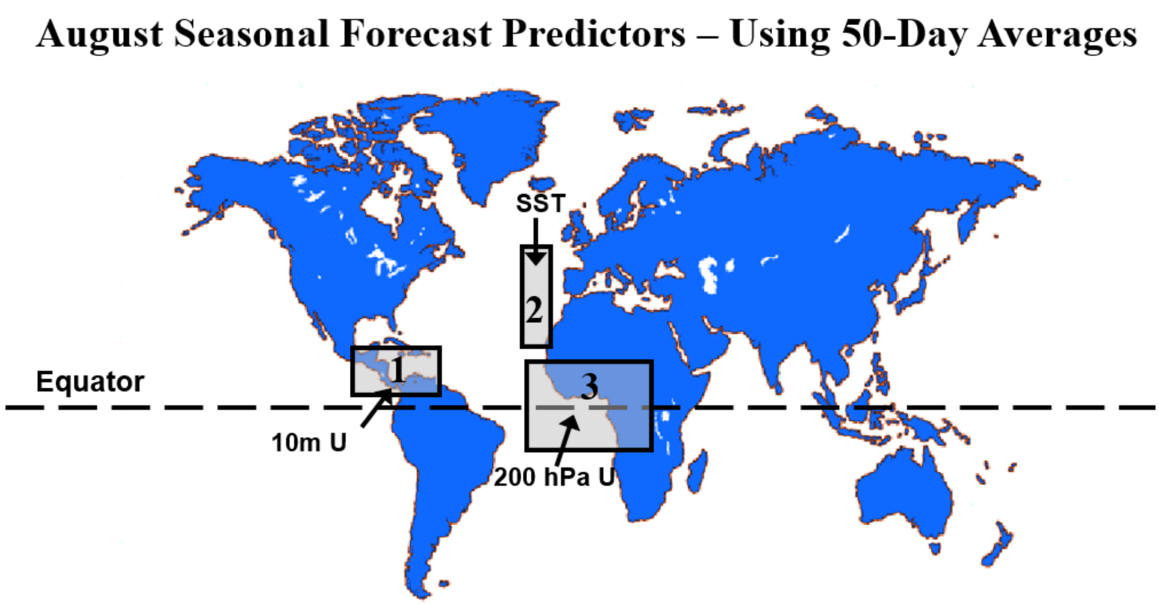

Figure 6: Location of predictors for the post-31 July forecast for the 2023 hurricane season from the 50-day-averaged (e.g., June 12 – July 31) statistical model.

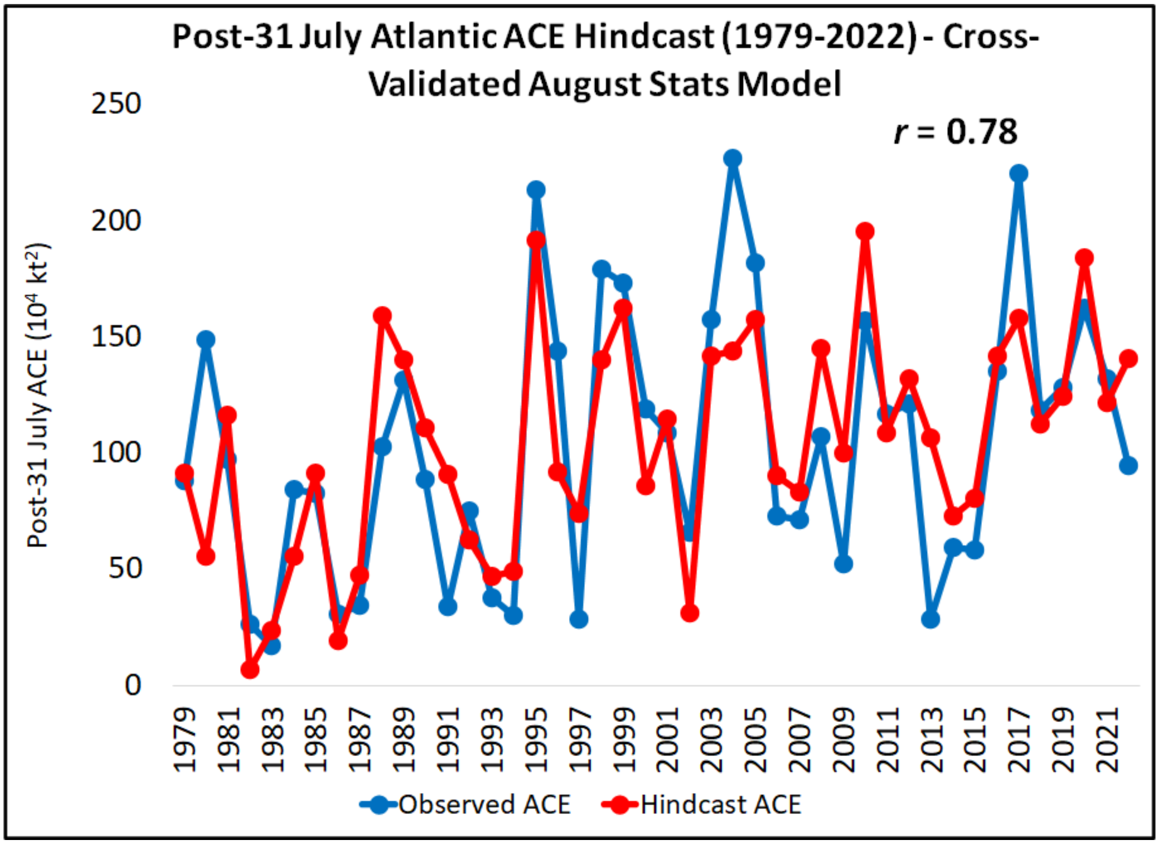

Figure 7: Observed versus hindcast values of post-31 July ACE for 1979-2022 using the 50-day-average statistical model.

Table 4 shows our forecast for the 2023 hurricane season from the statistical model using 50-day averages and the comparison of this forecast with the 1991-2020 average. This statistical forecast calls for an above-average remainder of the season.

Table 4: Post-31 July statistical forecast for 2023 from the 50-day averaged statistical model.

Predictands and Climatology (1991-2020 Post-31 July Average)	Post-31 July Statistical Forecast	Full Season Statistical Forecast (Activity Thru 2 August Added In)
Named Storms (NS) – 11.6	16.4	21.4
Named Storm Days (NSD) – 61.3	83.0	92.5
Hurricanes (H) – 6.5	8.6	9.6
Hurricane Days (HD) – 25.6	34.4	34.9
Major Hurricanes (MH) – 3.1	4.1	4.1
Major Hurricane Days (MHD) – 7.1	10.0	9.5
Accumulated Cyclone Energy (ACE) – 113	155	171
Net Tropical Cyclone Activity (NTC) – 123	167	183

2.3 July Statistical/Dynamical Forecast Schemes

We have modified our statistical/dynamical model this year and now use four different models: ECMWF, UK Met, JMA and CMCC to forecast 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 8 displays the locations of the two forecast parameters, while Table 5 displays ECMWF's forecasts of these parameters for 2023 from a 1 July initialization date. The ECMWF model predicts 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 extremely active seasonal forecast from this model. Figure 9 displays cross-validated hindcasts of ECMWF hindcasts of ACE from 1981–2022, while Table 6 presents the forecast from ECMWF for the 2023 Atlantic hurricane season.

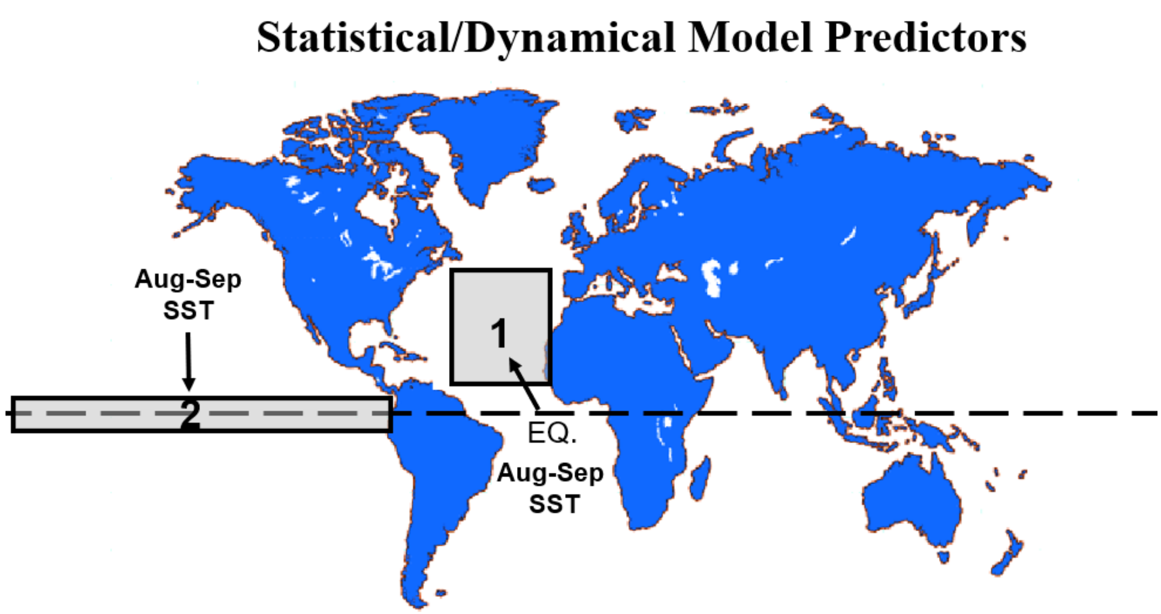

Figure 8: Location of predictors for our early August statistical/dynamical statistical prediction for the 2023 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August-September conditions in the two boxes displayed and uses those predictors to forecast ACE.

Table 5: Listing of predictions of August–September large-scale conditions from ECMWF model output, initialized on 1 July. 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) (+)	+4.3 SD	Strongly Enhance
2) ECMWF Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+2.1 SD	Strongly Suppress

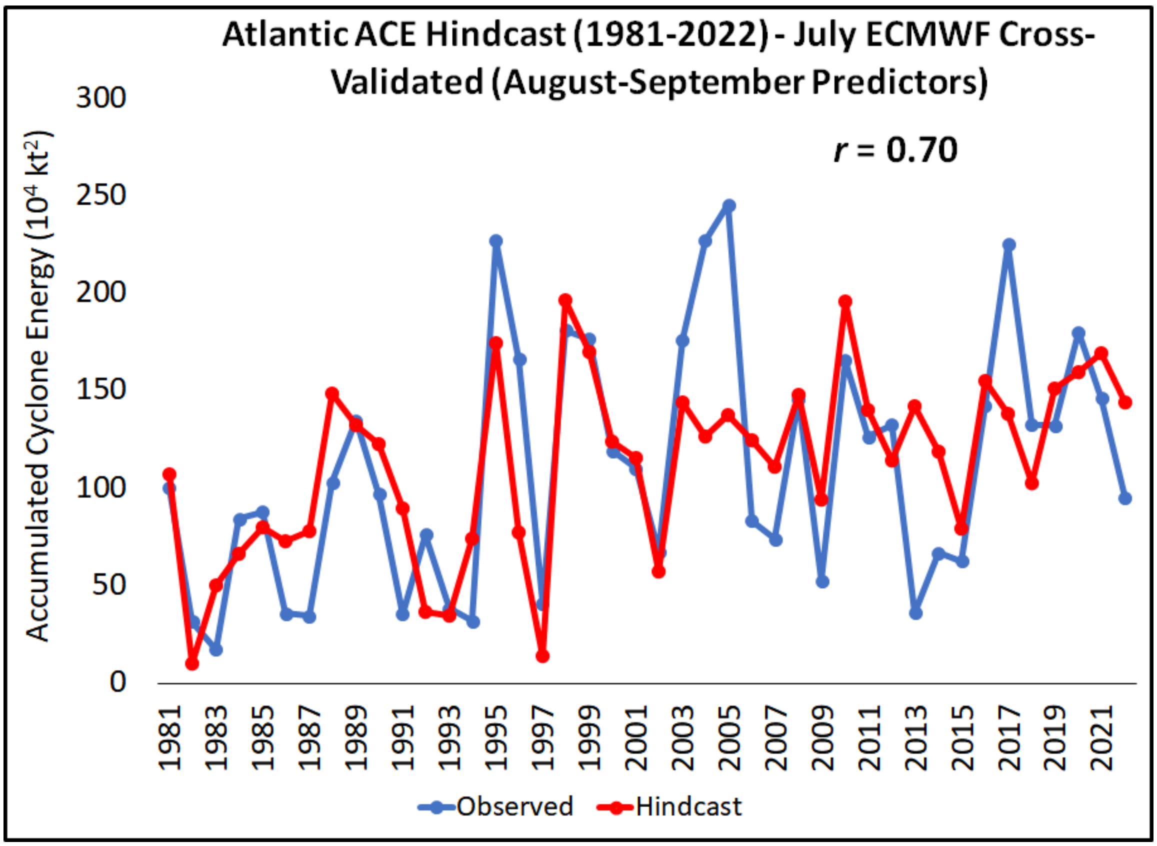

Figure 9: Observed versus cross-validated statistical/dynamical hindcast values of ACE for 1981–2022 from ECMWF.

Table 6: 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)	19.1	18
Named Storm Days (69.4)	101.9	90
Hurricanes (7.2)	10.6	9
Hurricane Days (27.0)	44.7	35
Major Hurricanes (3.2)	5.2	4
Major Hurricane Days (7.4)	13.8	9
Accumulated Cyclone Energy Index (123)	200	160
Net Tropical Cyclone Activity (135%)	212	170

b) UK Met Office Statistical/Dynamical Model Forecast

Table 7 displays the UK Met Office forecast of the August-September parameters for 2023 from a 1 July 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 10 displays hindcasts for the UK Met Office of ACE from 1993–2016, while Table 8 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 an extremely busy season, similar to ECMWF.

Table 7: Listing of predictions of August-September large-scale conditions from UK Met model output, initialized on 1 July. 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) (+)	+4.8 SD	Strongly Enhance
2) UK Met Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+2.0 SD	Strongly Suppress

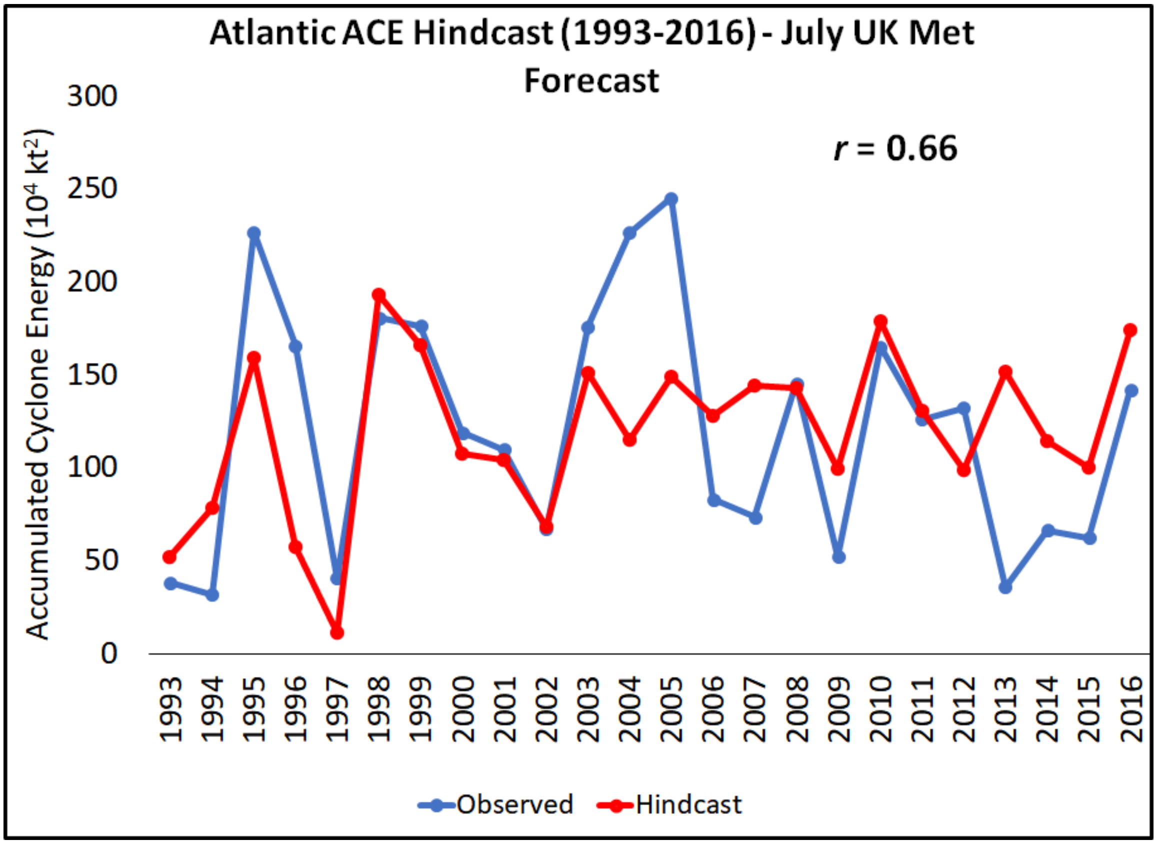

Figure 10: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the UK Met Office.

Table 8: 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)	20.5	18
Named Storm Days (69.4)	111.5	90
Hurricanes (7.2)	11.6	9
Hurricane Days (27.0)	49.9	35
Major Hurricanes (3.2)	5.8	4
Major Hurricane Days (7.4)	15.7	9
Accumulated Cyclone Energy Index (123)	223	160
Net Tropical Cyclone Activity (135%)	235	170

c) JMA Met Office Statistical/Dynamical Model Forecast

Table 9 displays the JMA forecasts of the August-September parameters for 2023 from a 1 July 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 11 displays hindcasts for the JMA of ACE from 1993–2016, while Table 10 presents the forecast from the JMA for the 2023 Atlantic hurricane season. The statistical/dynamical model based off of JMA is also calling for a well above-average 2023 Atlantic hurricane season.

Table 9: Listing of predictions of August-September large-scale conditions from JMA model output, initialized on 1 July. 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) (+)	+3.3 SD	Strongly Enhance
2) JMA Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.9 SD	Strongly Suppress

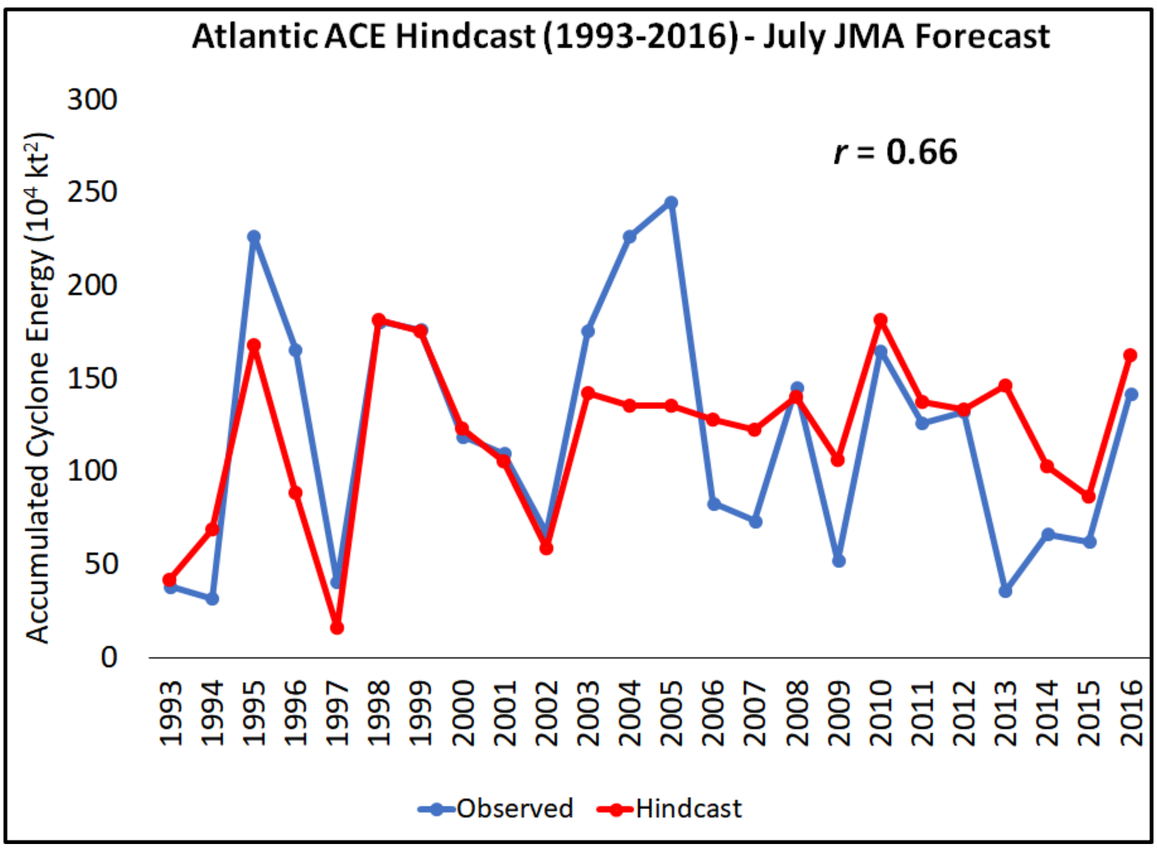

Figure 11: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the JMA.

Table 10: 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)	18.1	18
Named Storm Days (69.4)	94.7	90
Hurricanes (7.2)	9.8	9
Hurricane Days (27.0)	40.8	35
Major Hurricanes (3.2)	4.8	4
Major Hurricane Days (7.4)	12.4	9
Accumulated Cyclone Energy Index (123)	183	160
Net Tropical Cyclone Activity (135%)	195	170

d) CMCC Statistical/Dynamical Model Forecast

Table 11 displays the CMCC forecasts of the August-September parameters for 2023 from a 1 July 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 12 displays CMCC hindcasts of ACE from 1993–2016, while Table 12 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 11: Listing of predictions of August-September large-scale conditions from CMCC model output, initialized on 1 July. 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) (+)	+4.6 SD	Strongly Enhance
2) CMCC Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.4 SD	Strongly Suppress

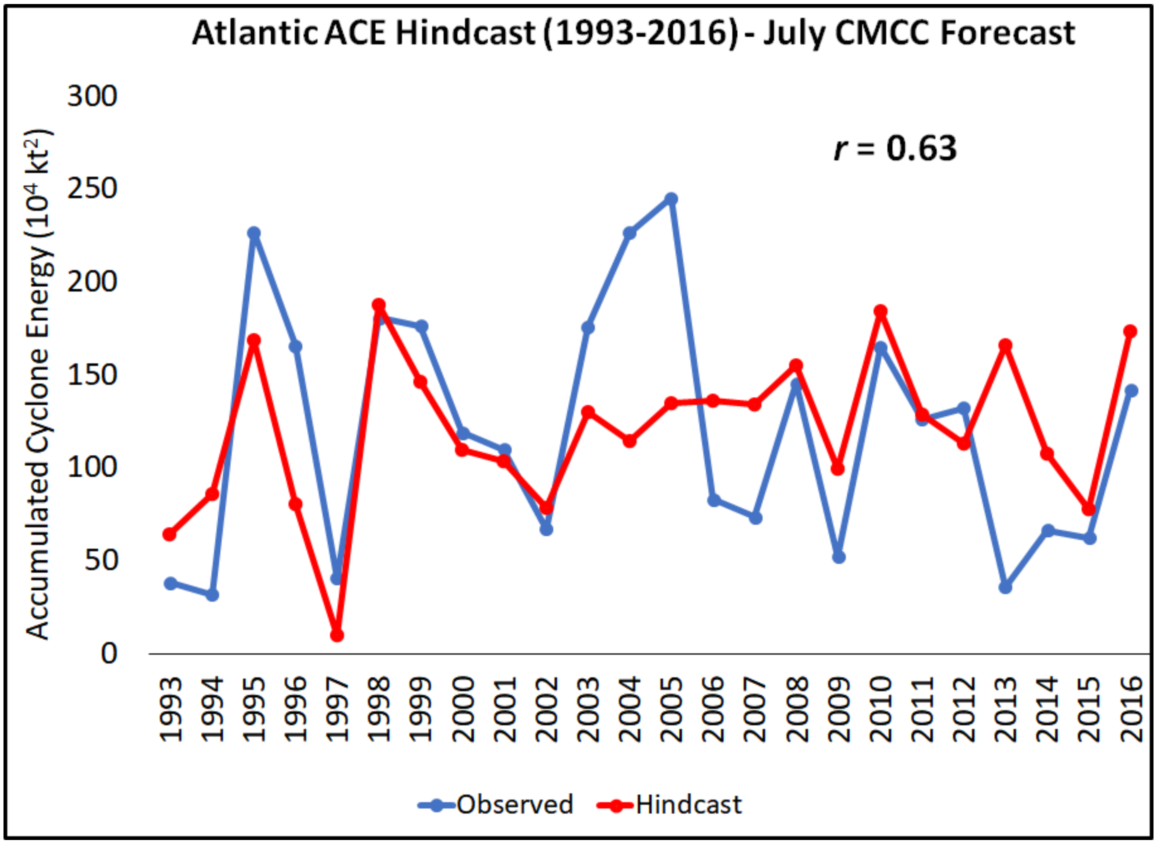

Figure 12: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the CMCC.

Table 12: 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)	19.7	18
Named Storm Days (69.4)	105.6	90
Hurricanes (7.2)	11.0	9
Hurricane Days (27.0)	46.7	35
Major Hurricanes (3.2)	5.5	4
Major Hurricane Days (7.4)	14.5	9
Accumulated Cyclone Energy Index (123)	209	160
Net Tropical Cyclone Activity (135%)	221	170

2.3 August 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 August forecast, we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current July 2023 conditions and, more importantly, projected August-October 2023 conditions. Table 13 lists our analog selections, while Figure 13 shows the composite August–October SST in our six analog years.

As discussed in July, 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. 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. The 2012 Atlantic hurricane season did not quite reach the El Niño threshold but did have a very warm Atlantic and a strongly negative Pacific decadal oscillation, similar to what we have this year. We anticipate that the 2023 hurricane season will have activity slightly above the average of our seven analog years. There is a large spread in Atlantic hurricane activity in the seven analog years that we selected, highlighting the large uncertainty in the potential outcomes for the 2023 season.

Table 13: 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
2012	19	101.25	10	28.50	2	0.50	132.6	131.2
Average	15.6	82.9	8.9	30.8	3.4	7.3	143	150
2023 Forecast	**18**	**90**	**9**	**35**	**4**	**9**	**160**	**170**

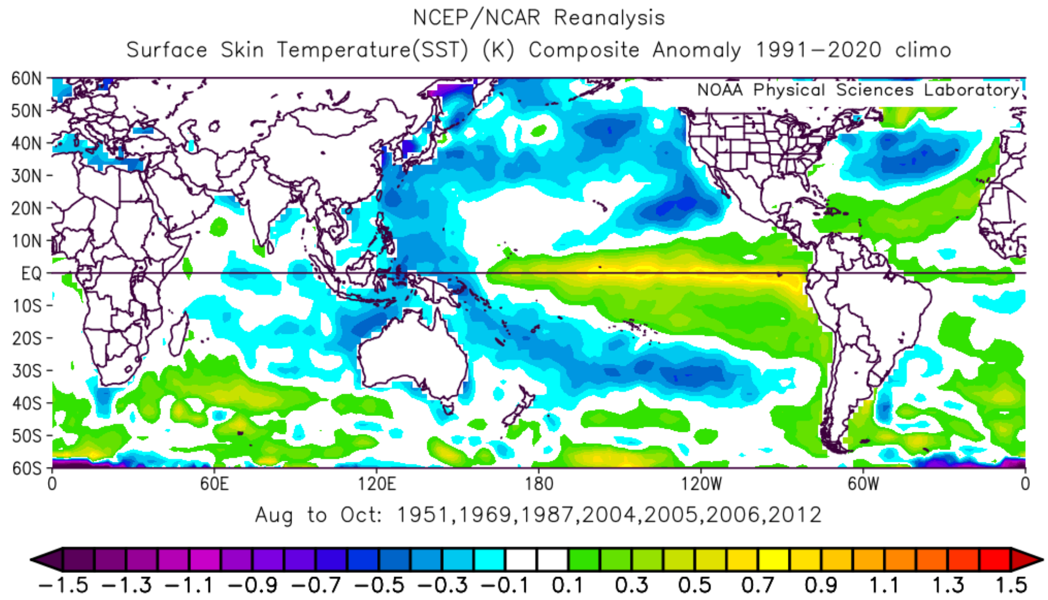

Figure 13: Average August–October SST anomalies in our six analog years.

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 14 and 15).

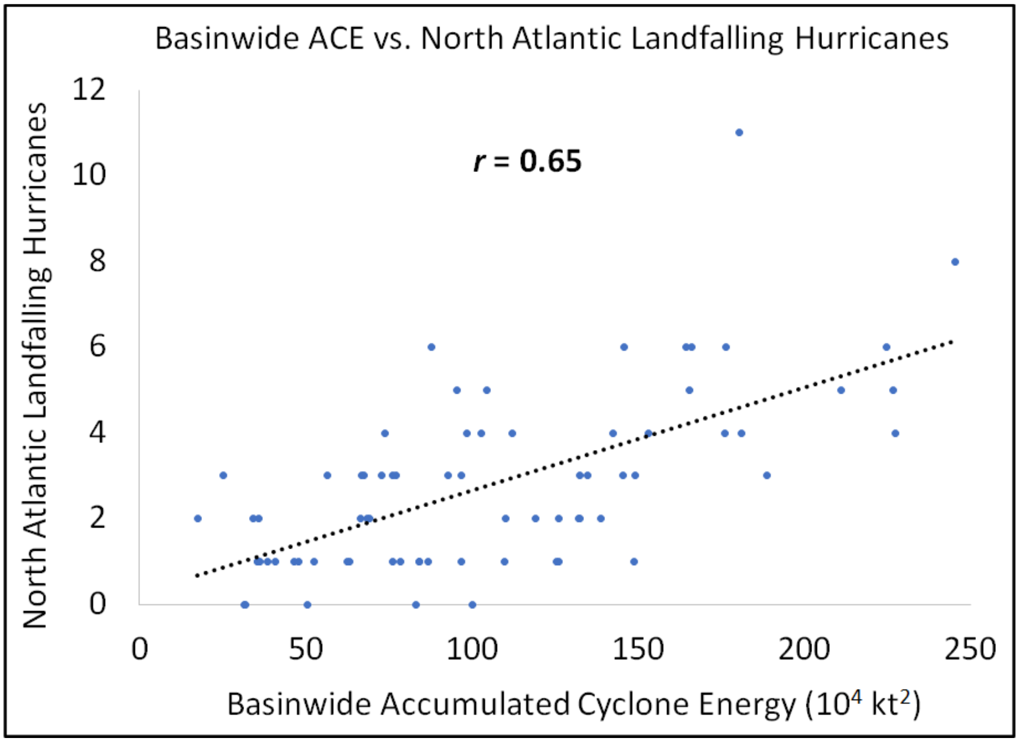

Figure 14: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

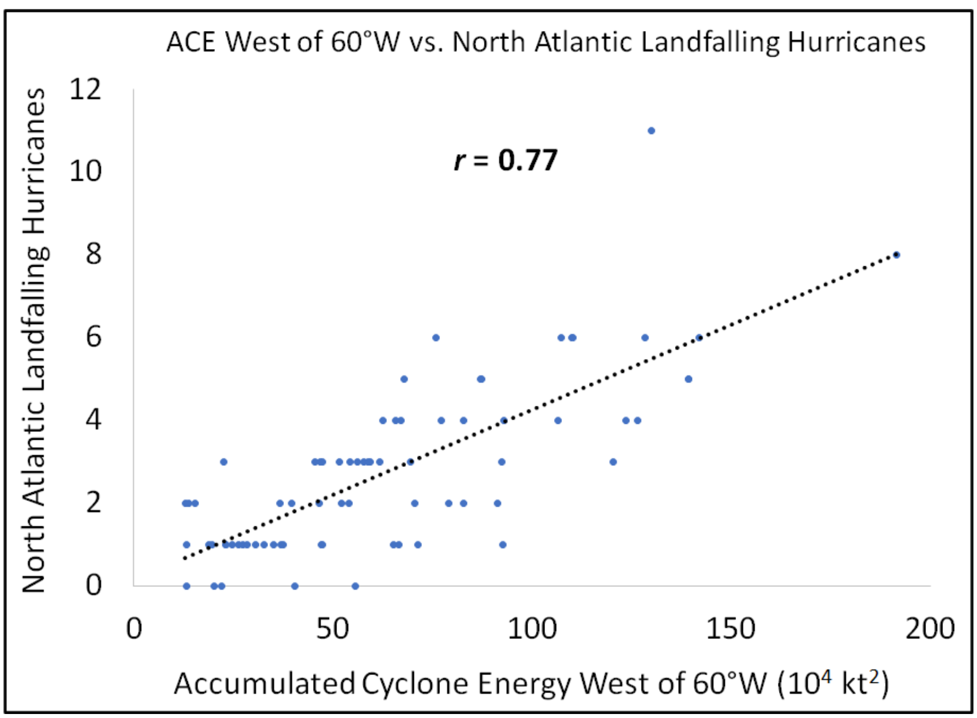

Figure 15: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

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 16). Given that El Niño conditions are already present and are a near certainty 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.

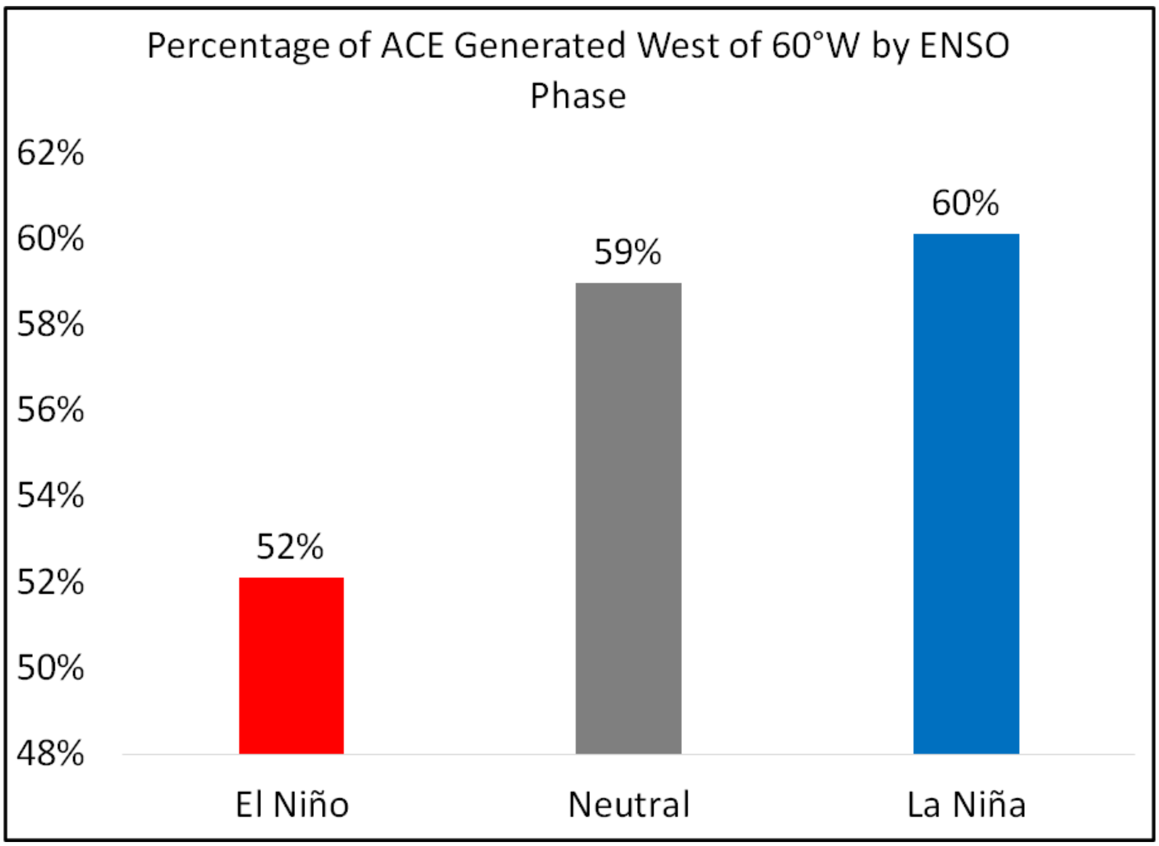

Figure 16: Percentage of ACE generated west of 60°W by ENSO phase.

2.4 August Forecast Summary and Final Adjusted Forecast

Table 14 shows our final adjusted early August forecast for the 2023 season which is a combination of our two statistical schemes, our four statistical/dynamical model schemes, our analog scheme and qualitative adjustments for other factors not explicitly contained in any of these schemes. The model guidance is split between statistical models which favor a somewhat above-normal season to the statistical/dynamical models which favor a hyperactive season. Our final forecast favors the lower statistical guidance but still calls for an above-average season.

Table 14: Summary of our two early August statistical forecasts, our four statistical/dynamical model forecasts, our analog forecast, the average of these schemes and our adjusted final forecast for the 2023 hurricane season. All schemes have TC activity that was observed prior to 3 August included.

Forecast Parameter (1991-2020 Average)	July Statistical Scheme	50-Day Stat. Scheme	ECMWF Scheme	UK Met Scheme	JMA Scheme	CMCC Scheme	Analog Scheme	Average	Adjusted Forecast
Named Storms (14.4)	20.5	21.4	19.1	20.5	18.1	19.7	15.6	19.3	18
Named Storm Days (69.4)	96.2	92.5	101.9	111.5	94.7	105.6	82.9	97.9	90
Hurricanes (7.2)	8.9	9.6	10.6	11.6	9.8	11.0	8.9	10.1	9
Hurricane Days (27.0)	31.5	34.9	44.7	49.9	40.8	46.7	30.8	39.9	35
Major Hurricanes (3.2)	3.7	4.1	5.2	5.8	4.8	5.5	3.4	4.6	4
Major Hurricane Days (7.4)	8.8	9.5	13.8	15.7	12.4	14.5	7.3	11.7	9
ACE Index (123)	156	171	200	223	183	209	143	184	160
NTC Activity (135%)	168	183	212	235	195	221	150	195	170

3 Forecast Uncertainty

This season we continue to use probability of exceedance curves as discussed in Saunders et al. (2020) to better 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 17 and 18), using the error distributions calculated from both normalized cross-validated statistical as well as the cross-validated statistical/dynamical hindcasts from ECMWF. Hurricane numbers are fit to a Poisson distribution, while ACE is fit to a Weibull distribution. Table 15 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 (e.g., named storm days, ACE, etc.) except for major hurricane days. We use a Laplace distribution for major hurricane days.

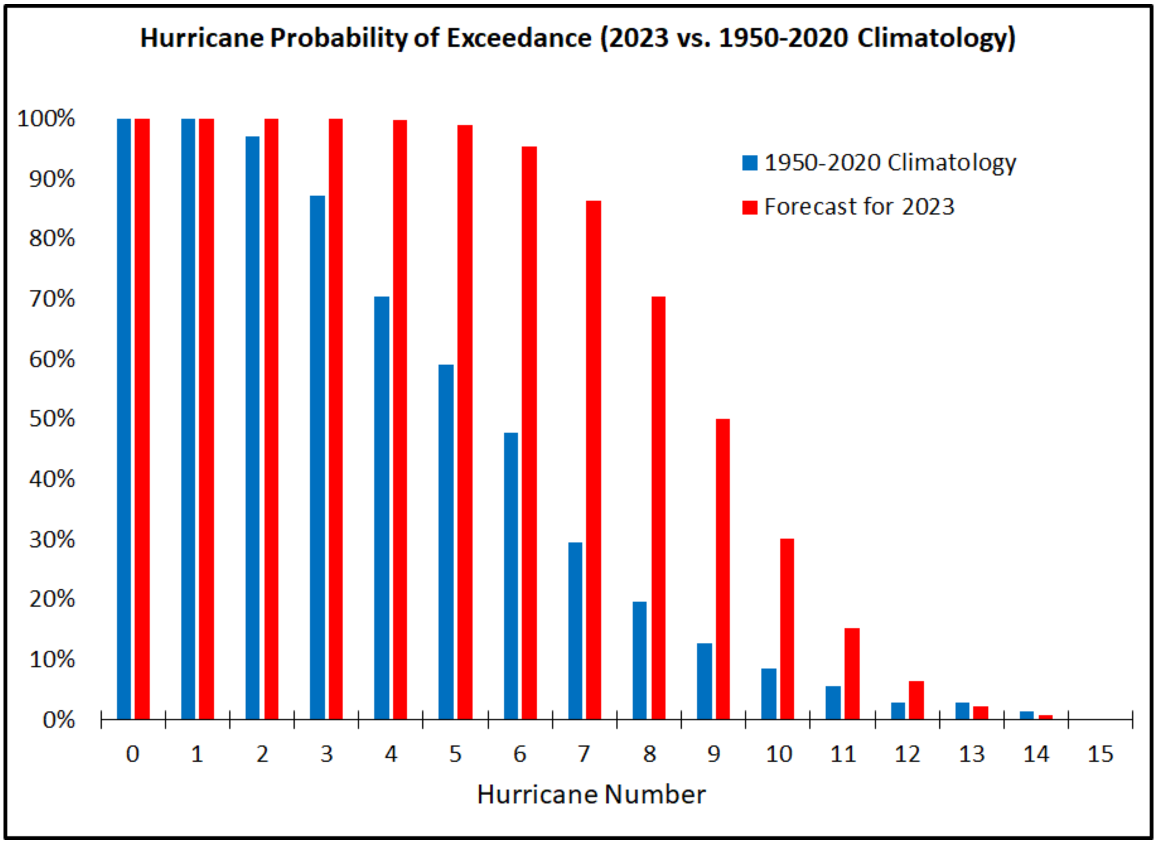

Figure 17: Probability of exceedance plot for hurricane numbers for the 2023 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950-2020 have had more than two hurricanes.

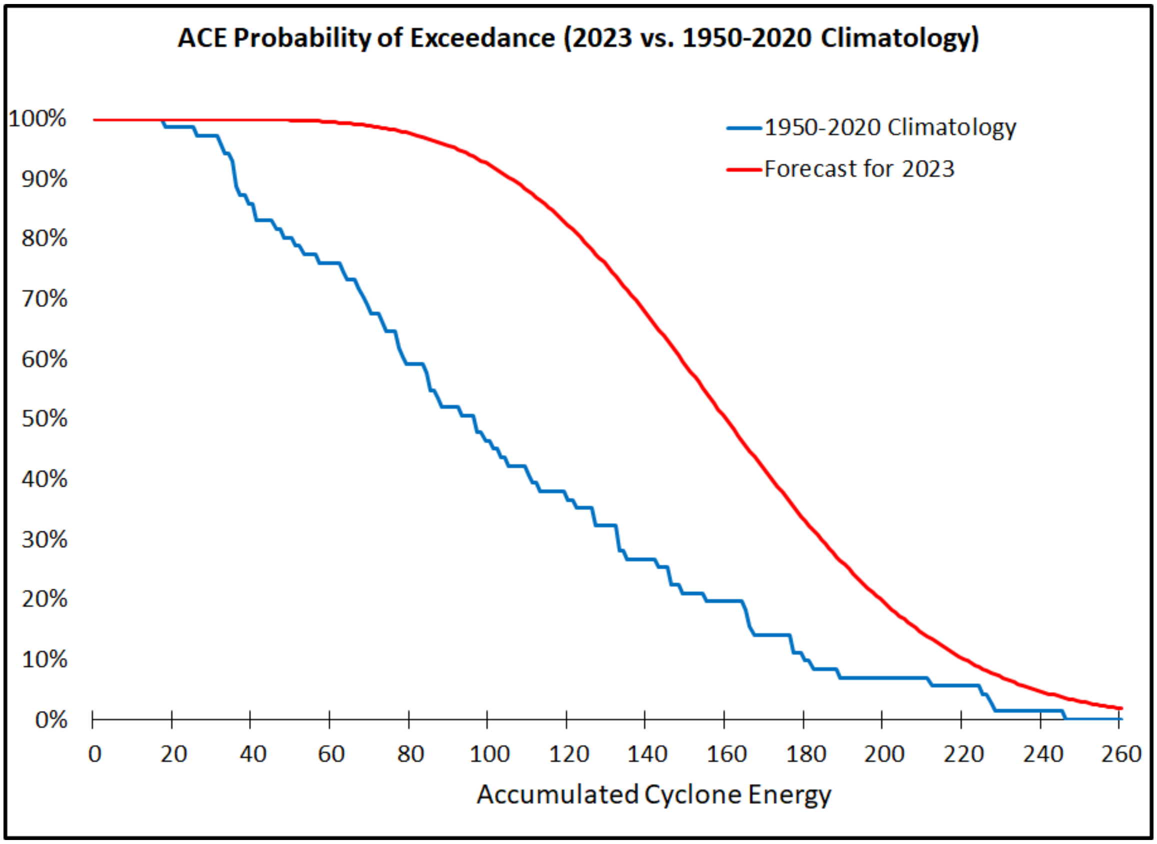

Figure 18: As in Figure 17 but for ACE.

Table 15: 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	71 – 109
Hurricanes (H)	9	7 – 11
Hurricane Days (HD)	35	24 – 47
Major Hurricanes (MH)	4	3 – 5
Major Hurricane Days (MHD)	9	6 – 13
Accumulated Cyclone Energy (ACE)	160	116 – 209
ACE West of 60°W	78	50 – 111
Net Tropical Cyclone (NTC) Activity	170	127 – 216

4 ENSO

The tropical Pacific continues to be characterized by El Niño conditions, with above-average SSTs across the central and eastern tropical Pacific (Figure 19). These SST anomalies are especially warm in the eastern tropical Pacific, where they have exceeded 3°C in recent weeks. 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. When SSTs in the Nino 3.4 region 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. SST anomalies have continued to increase in the Nino 3.4 region over the past few weeks (Figure 20) and are now in the moderate strength category. Anomalously weak trade winds are forecast by the Climate Forecast System (and other global models) to occur across the central tropical Pacific for the next several weeks (Figure 21), likely helping to further increase the strength of the El Niño event. Weaker-than-normal trade winds favor downwelling (warming) Kelvin waves, likely leading to additional anomalous warming in the central and eastern tropical Pacific over the next few weeks.

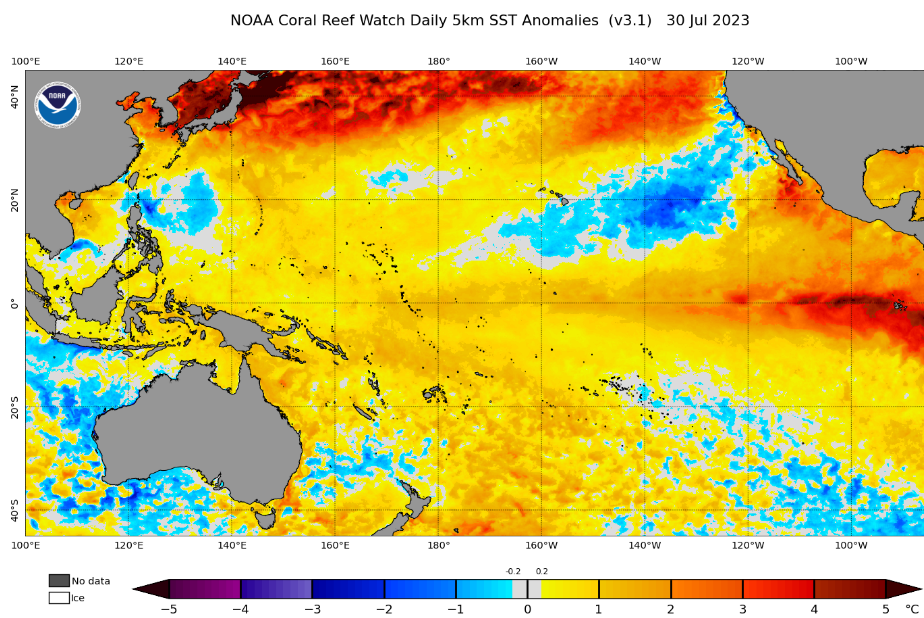

Figure 19: Current SST anomalies across the tropical and subtropical Pacific.

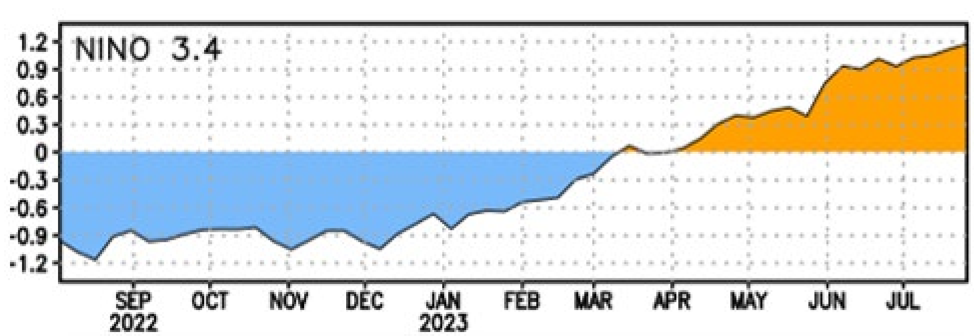

Figure 20: Nino 3.4 SST anomalies from August 2022 through July 2023. Figure courtesy of the Climate Prediction Center.

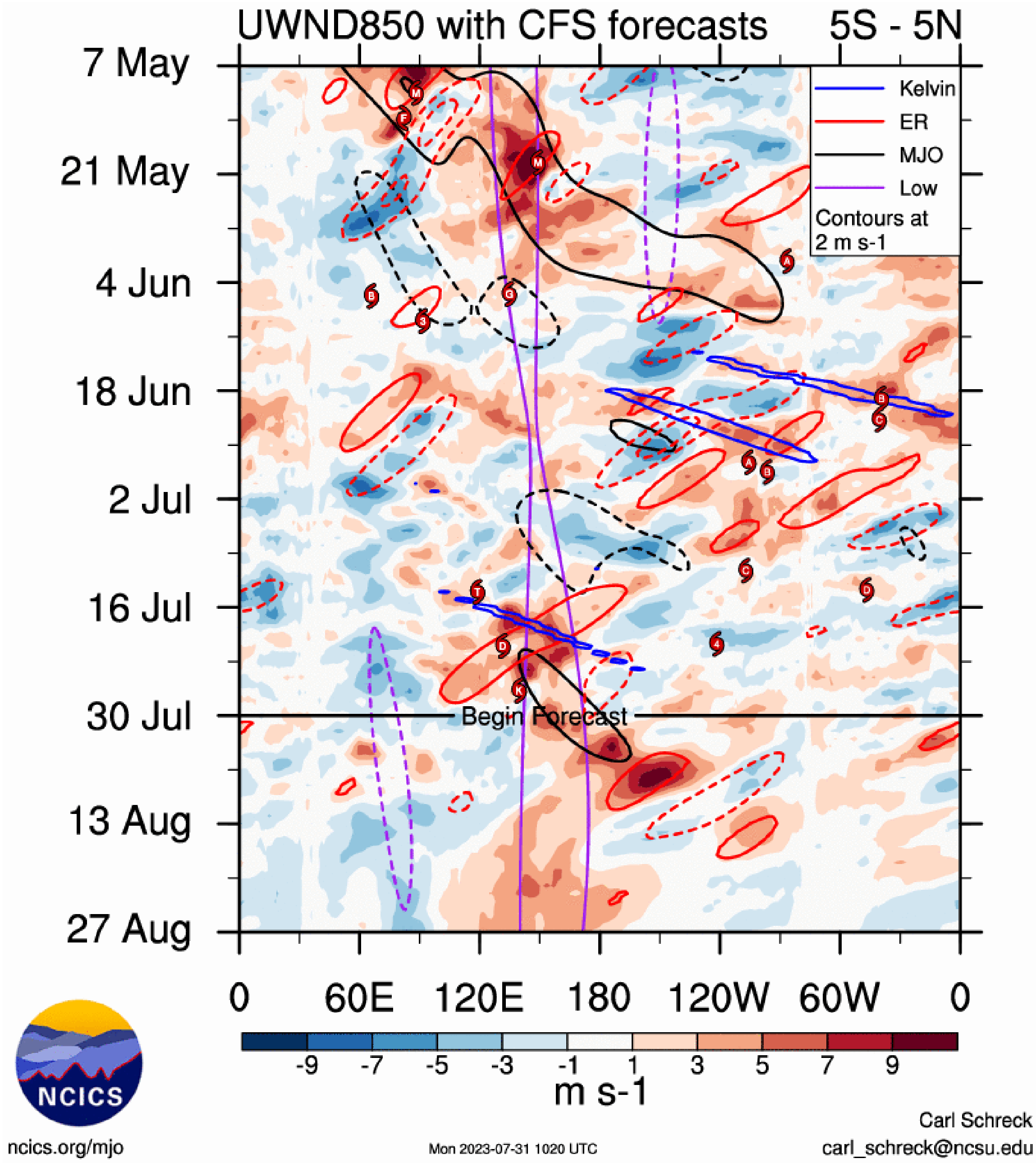

Figure 21: Observed low-level winds across the equatorial region as well as predictions for the next four weeks by the Climate Forecast System. The small TC symbols on the figure indicate TC formations, with the letter denoting the first letter of the storm that formed. Figure courtesy of Carl Schreck.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific were at their coldest during the latter part of last October and increased rapidly through the middle of April (Figure 22). The heat content anomalies decreased over the next few weeks, increased through the early part of June and have since decreased. However, most of the anomalously cold water contributing to the decline in upper-ocean heat content anomalies remains below 150 meters (Figure 23). Given that low-level winds are forecast to be weaker than normal in the next few weeks, we do not anticipate much (if any) anomalous surface cooling in the eastern and central tropical Pacific from these cool sub-surface temperatures.

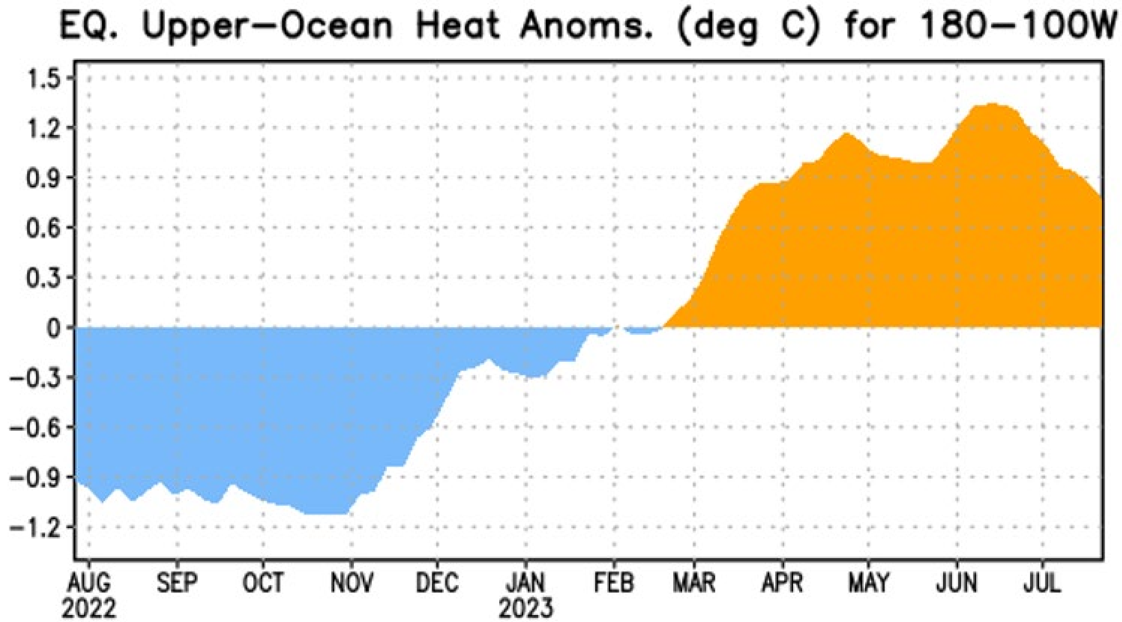

Figure 22: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

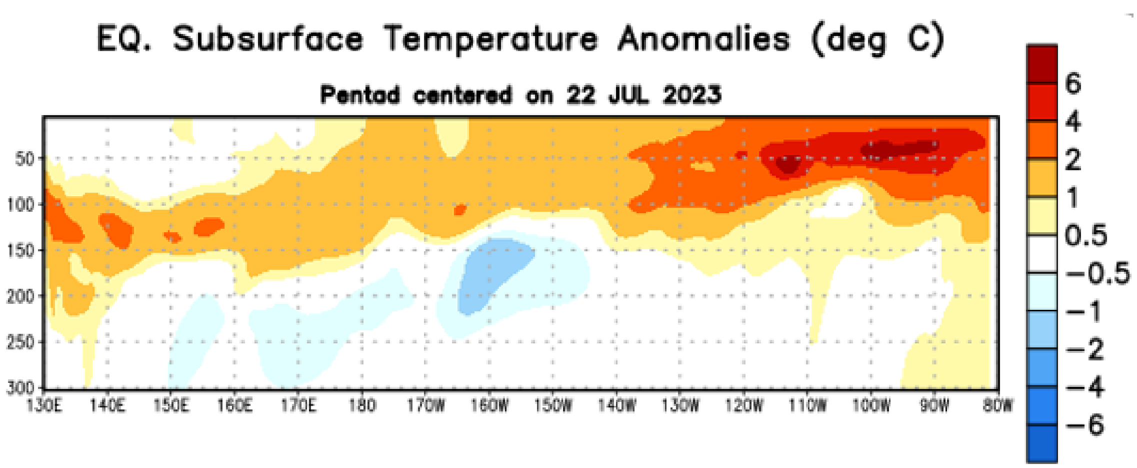

Figure 23: Equatorially-averaged subsurface temperature anomalies. Figure courtesy of Climate Prediction Center.

Table 16 displays June and July SST anomalies for several Nino regions. Anomalies have continued to trend upward across most of the eastern and central tropical Pacific.

Table 16: June and July SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. July minus June SST anomaly differences are also provided.

Region	June SST Anomaly (°C)	July SST Anomaly (°C)	July – June SST Anomaly (°C)
Nino 1+2	+2.6	+3.3	+0.7
Nino 3	+1.2	+1.6	+0.4
Nino 3.4	+0.9	+1.1	+0.2
Nino 4	+0.6	+0.8	+0.2

There is still some uncertainty as to how strong the El Niño will be for the peak of the Atlantic hurricane season. The latest plume of ENSO predictions from several statistical and dynamical models shows a continued spread for August-October (Figure 24), but we currently expect to see either a moderate or strong El Niño for the peak of this year's season.

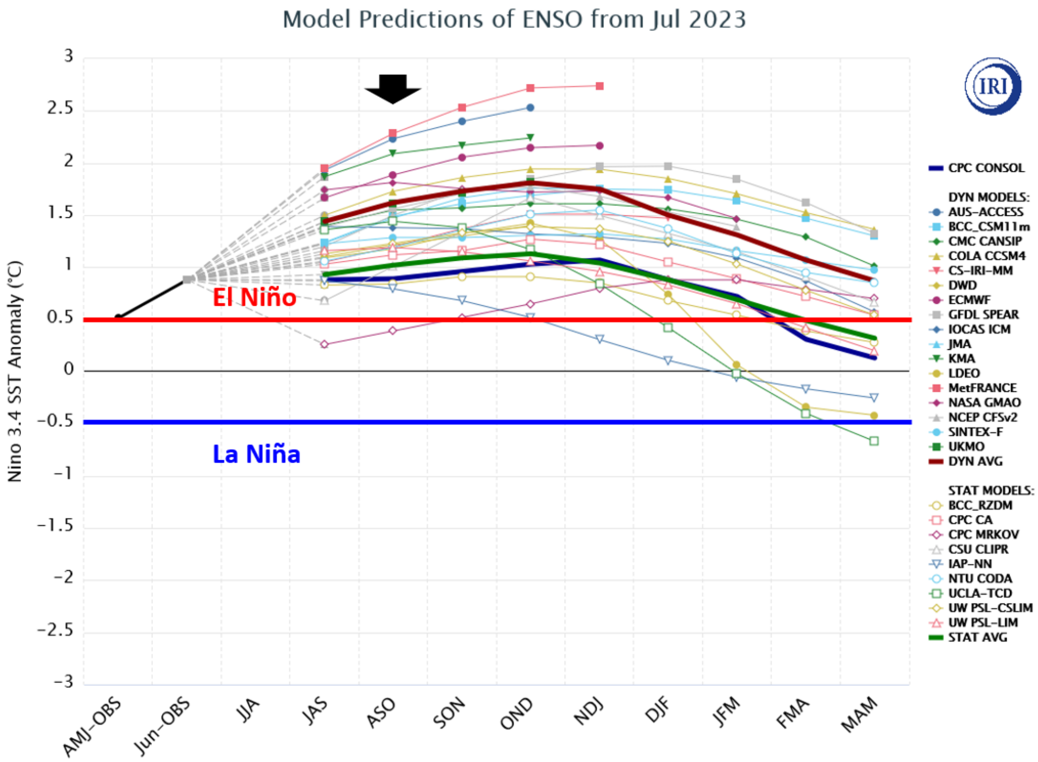

Figure 24: ENSO forecasts from various statistical and dynamical models for the Nino 3.4 SST anomaly based on late June to early July initial conditions. Figure courtesy of the International Research Institute (IRI). The black arrow denotes the peak of the Atlantic hurricane season (August-October).

The latest official forecast from NOAA confirms that the chances of El Niño are extremely high for August-October. NOAA is currently predicting a 96% chance of El Niño and a 4% chance of ENSO neutral conditions for the peak of the Atlantic hurricane season (Figure 25).

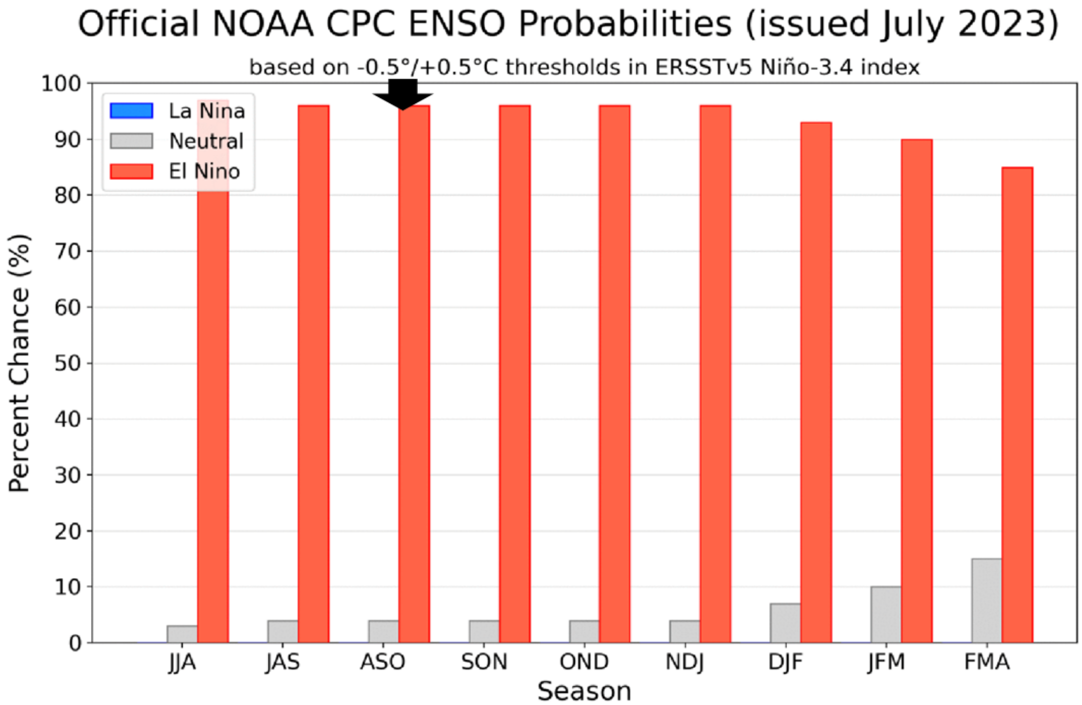

Figure 25: Official NOAA probabilistic forecast for ENSO.

5 Current Atlantic Basin Conditions

The tropical and subtropical Atlantic remain extremely warm, with both the Main Development Region (MDR; 10-20°N, 85-20°W) and subtropical/tropical eastern Atlantic (0-45°N, 45-10°W) having record warm 30-day-averaged sea surface temperatures (Figure 26) through the end of July. Both regions have high correlations with seasonal Atlantic ACE, with 30-day-averaged SSTs ending on 31 July in the MDR correlating at 0.62 with seasonal ACE and 30-day-averaged SSTs in the subtropical/tropical Atlantic correlating at 0.66 with seasonal ACE. The five warmest 30-day-averaged SSTs at the end of July in the MDR after 2023 (in order from warmest) are: 2010, 2005, 1998, 2020 and 2011.All but 2011 ended up hyperactive Atlantic seasons. The five warmest 30-day-averaged SSTs at the end of July in the tropical and subtropical eastern Atlantic after 2023 (in order from warmest) are: 1995, 2010, 2005, 2003 and 1989. All but 1989 ended up hyperactive Atlantic seasons.

The current SST anomaly pattern matches almost identically the historical SST pattern in August that has correlated with active Atlantic hurricane seasons (Figure 27). Current SSTs in the MDR are tracking well above a typical hyperactive season (Figure 28).

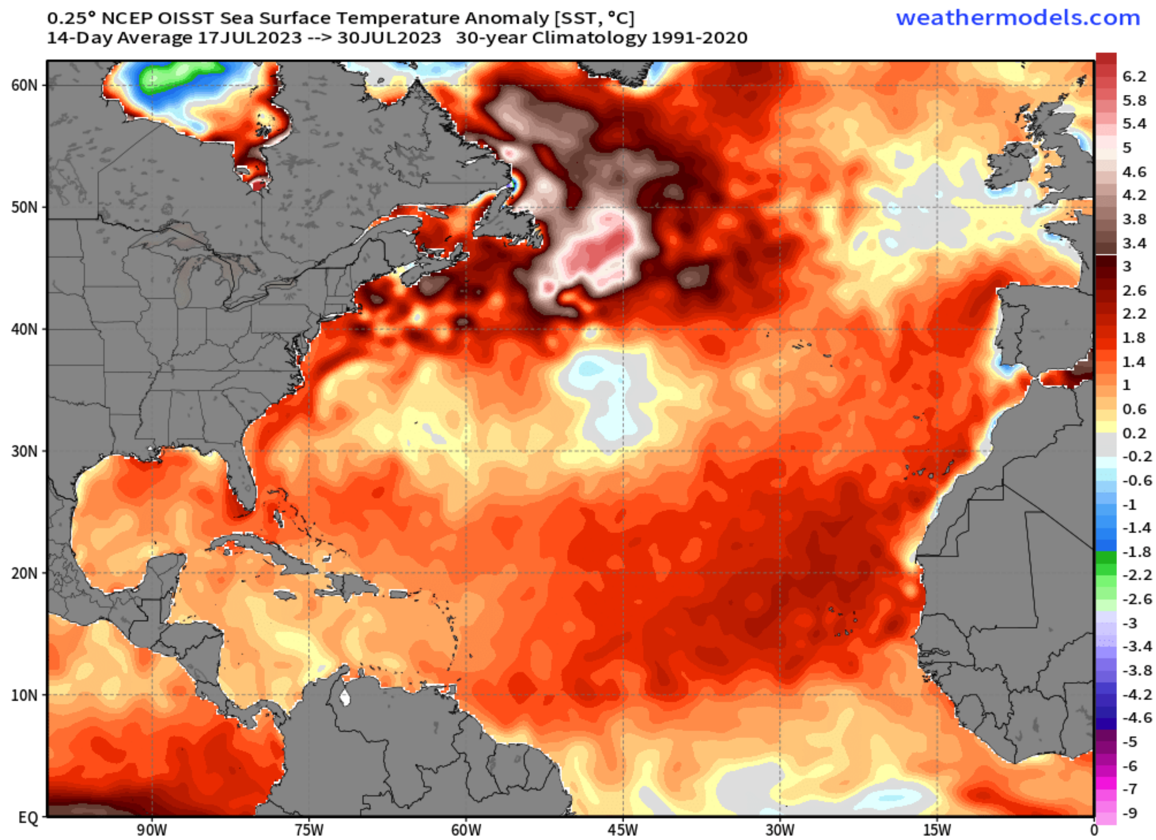

Figure 26: Late July SST anomaly pattern across the North Atlantic Ocean.

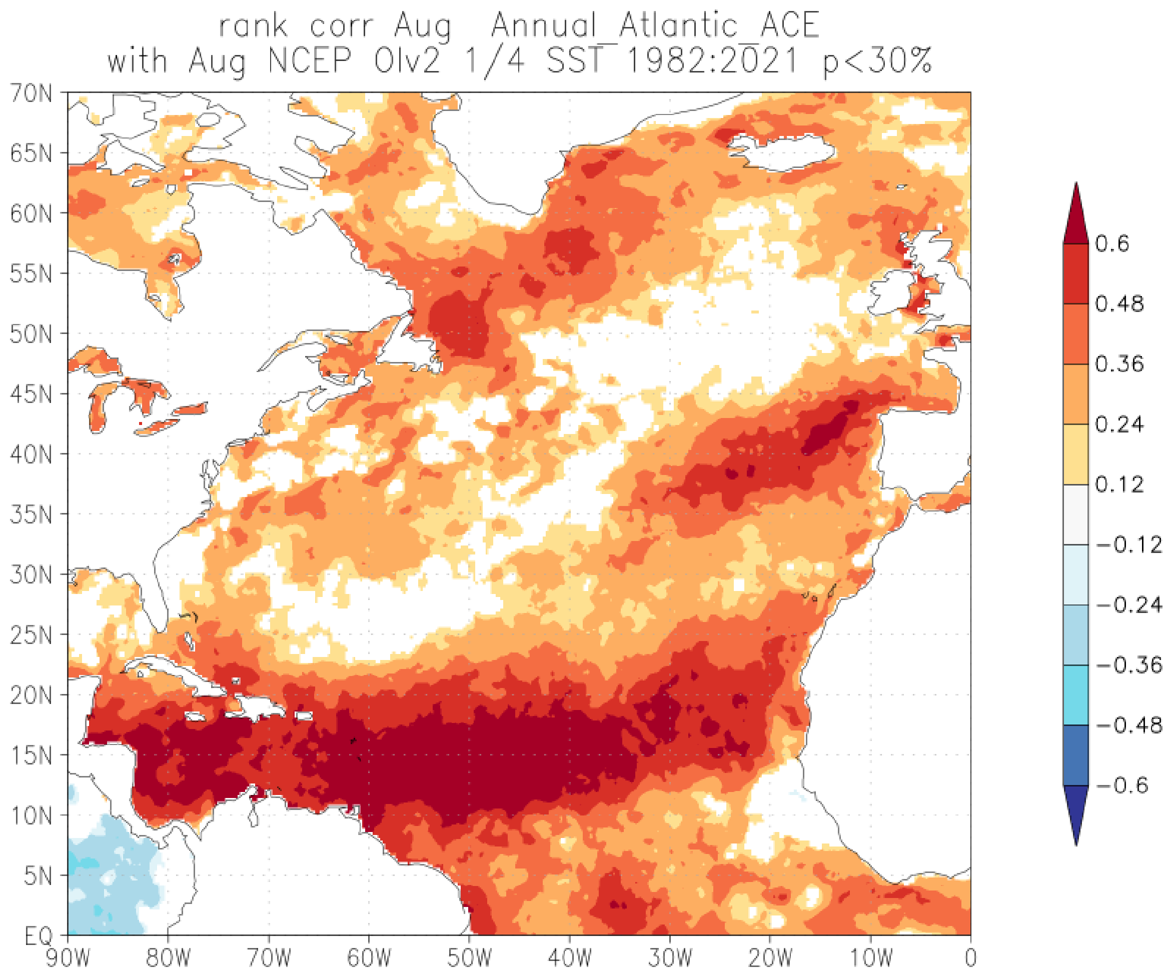

Figure 27: Correlation between August North Atlantic SSTs and seasonal Atlantic ACE from 1982-2021.

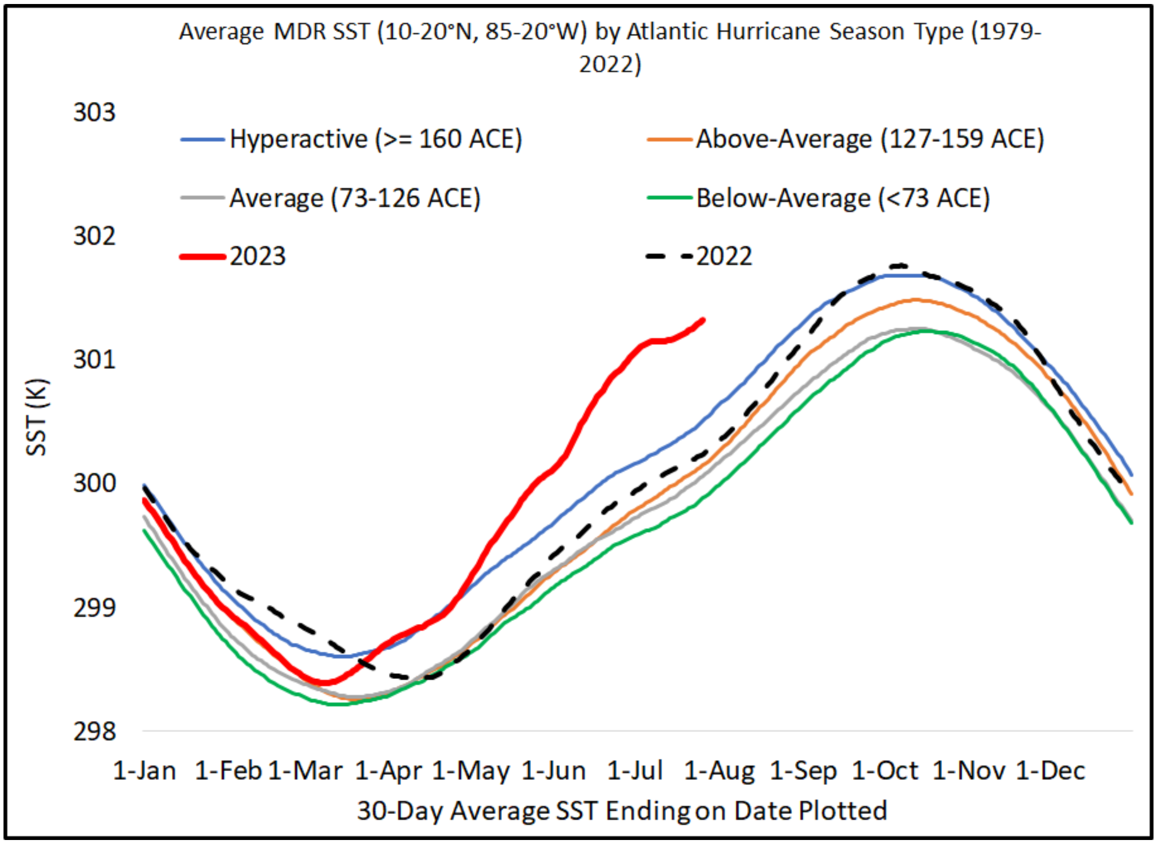

Figure 28: 30-day average SSTs for various Atlantic hurricane season types from 1979-2022 based on the NOAA definition. Also plotted are SSTs for 2022 (for comparison). Sea surface temperature anomalies in the tropical Atlantic in 2023 are currently tracking well above the typical hyperactive Atlantic hurricane season.

30-day-averaged vertical wind shear was below normal for most of June and is now running at near-average levels across most of the MDR (Figure 29). Current 30-day-averaged zonal wind shear across the MDR is tracking slightly above what has been historically experienced in a near-normal season (Figure 30).

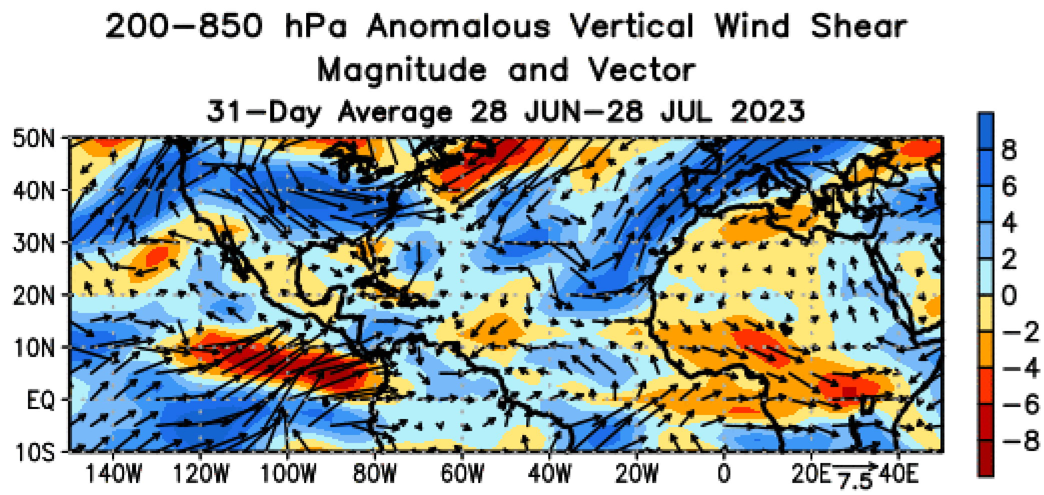

Figure 29: 28 June – 28 July-averaged vertical wind shear across the tropical and subtropical Atlantic differenced from the 1991-2020 climatology.

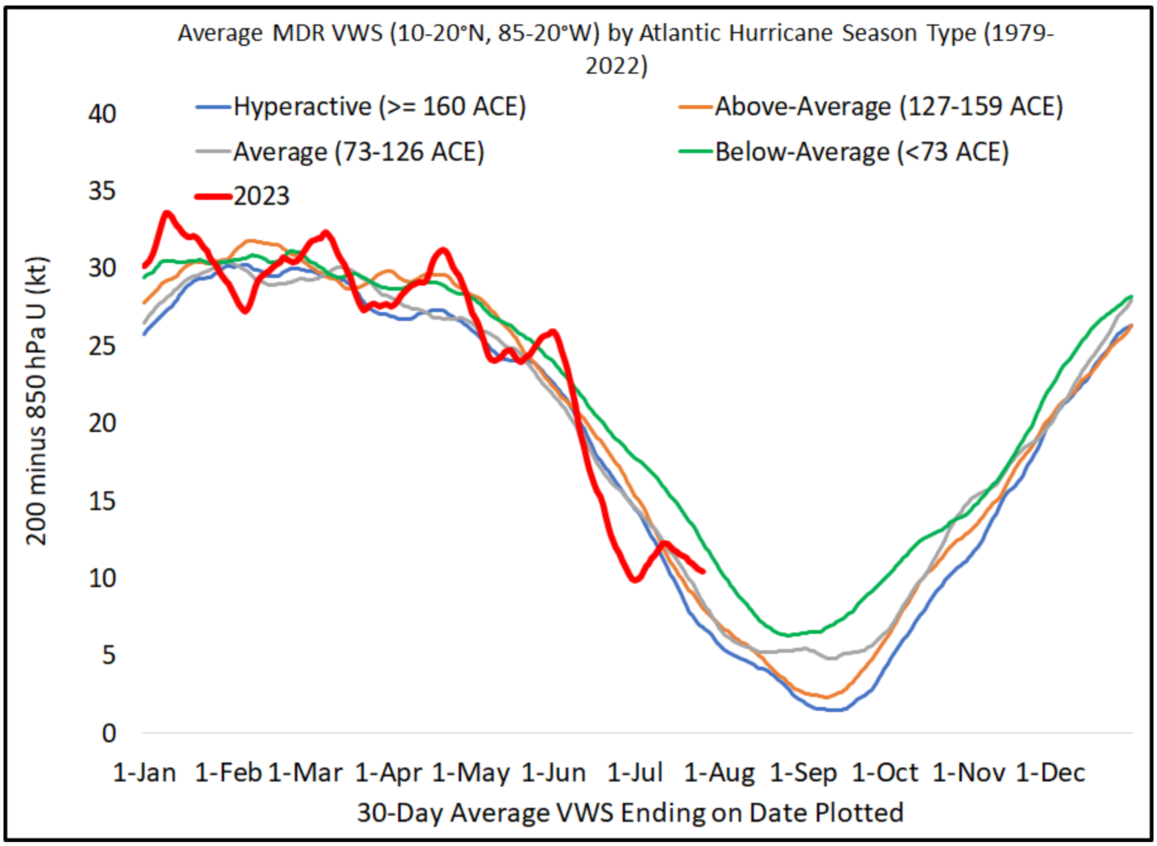

Figure 30: 30-day average zonal wind shear across the MDR for various Atlantic hurricane season types from 1979-2022 based on the NOAA definition. Also plotted is zonal wind shear for 2023.

Sea level pressure anomalies across the MDR (10-20°N, 85-20°W) in July 2023 were generally below normal (Figure 31). When July sea level pressure anomalies are low, typically more active Atlantic hurricane seasons are experienced. Lower pressure is often associated with increased instability, increased mid-level moisture and decreased vertical wind shear.

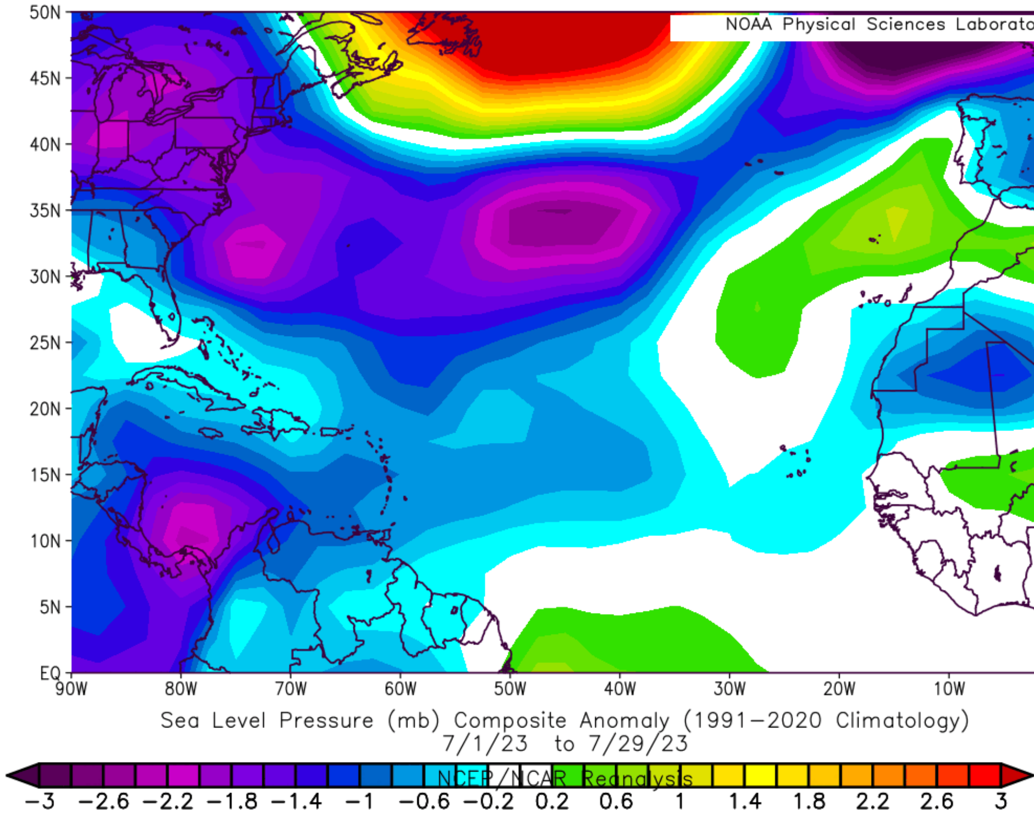

Figure 31: 1 – 29 July-averaged sea level pressure anomalies across the tropical and subtropical North Atlantic.

Below-normal sea level pressure anomalies across the tropical Atlantic are also atypical for El Niño seasons. Normally in El Niño events, there is anomalous subsidence and associated high pressure over the tropical Atlantic associated with the eastward-shifted Walker Circulation (Figure 32). Figure 33 shows the July correlation between the Nino 3.4 index and Atlantic sea level pressures, highlighting the typical high pressure observed in the tropical Atlantic associated with El Niño events. We hypothesize that the extremely warm tropical Atlantic is likely leading to the below-average sea level pressures observed in the MDR.

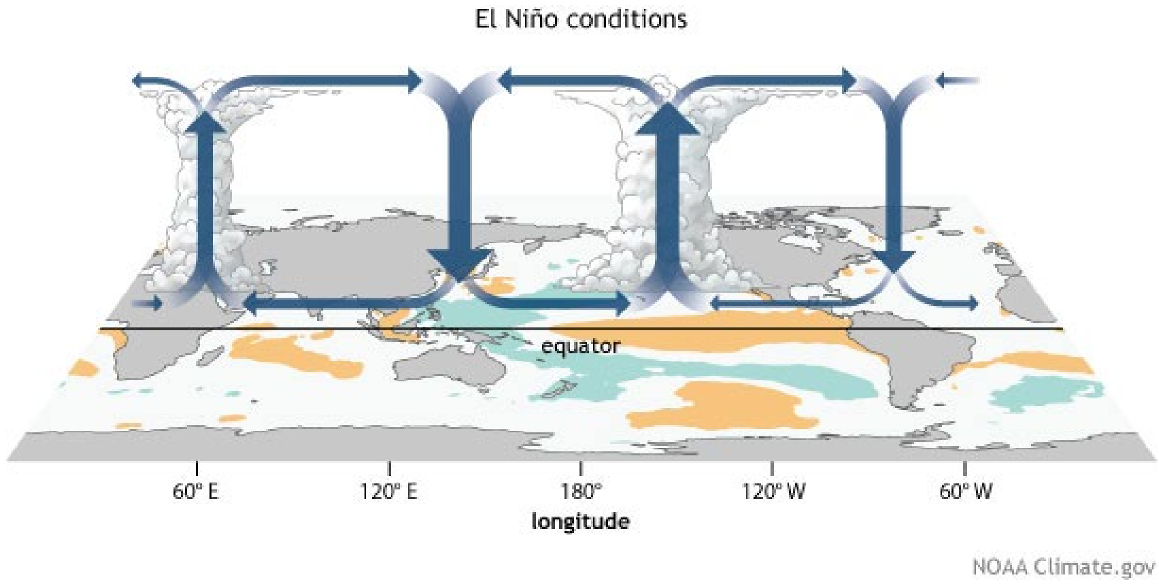

Figure 32: Anomalous tropical circulation associated with El Niño. Figure courtesy of NOAA.

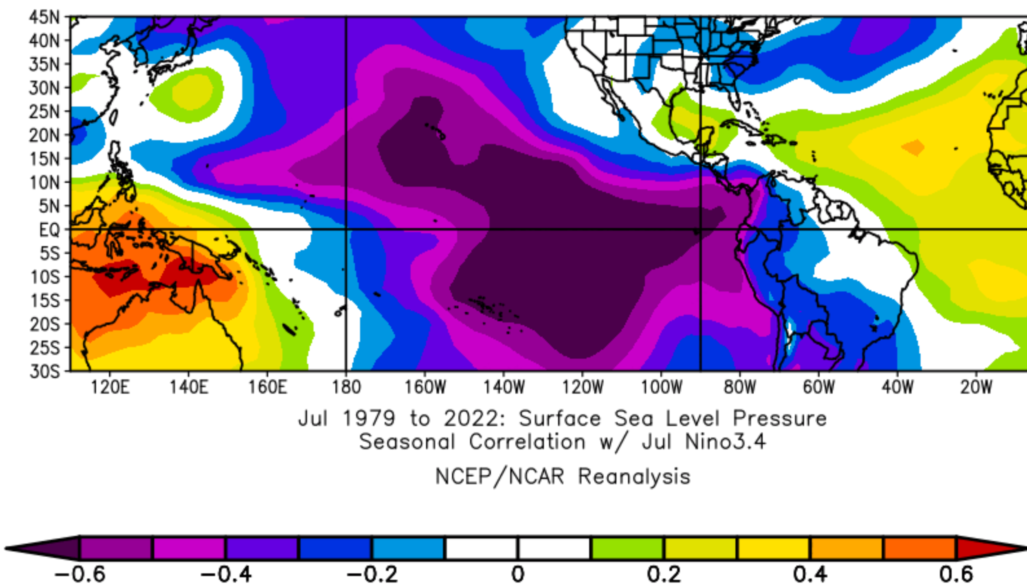

Figure 33: July correlation between the Nino 3.4 index and sea level pressure across the tropical and subtropical Pacific/Atlantic.

6 West Africa Conditions

During July, monsoon rainfall over West Africa has been near average (Figure 34). The latest 45-day forecast from ECMWF indicates that monsoon rainfall across most of West Africa should be above average, although there are indications that rainfall may be lower than normal closer to the coast of West Africa (Figure 35). Overall, we consider observed and projected West African rainfall to be a neutral factor for the 2023 Atlantic hurricane season.

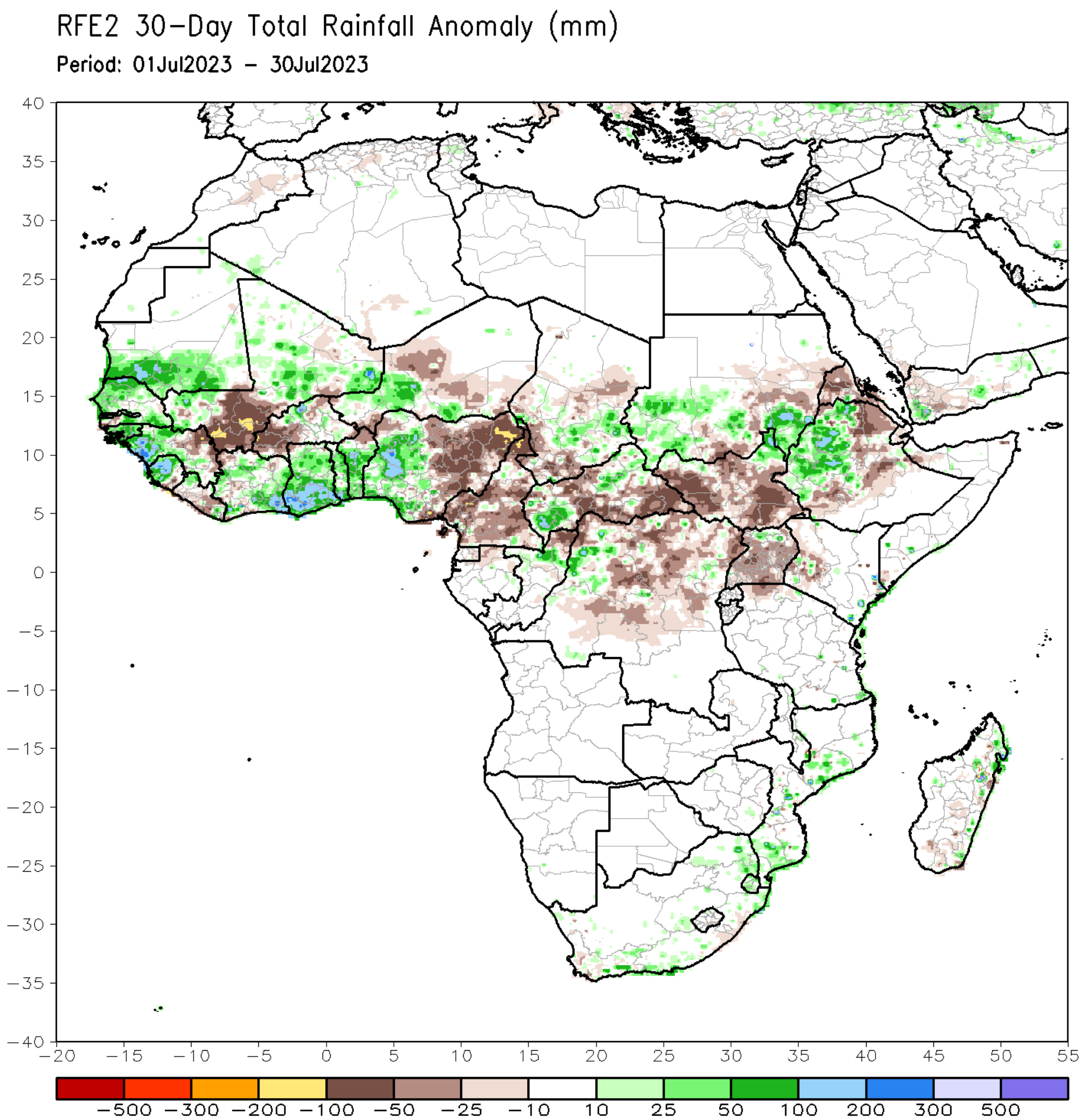

Figure 34: Observed precipitation across Africa from July 1-30, based on the African Rainfall Estimation Algorithm Version 2.

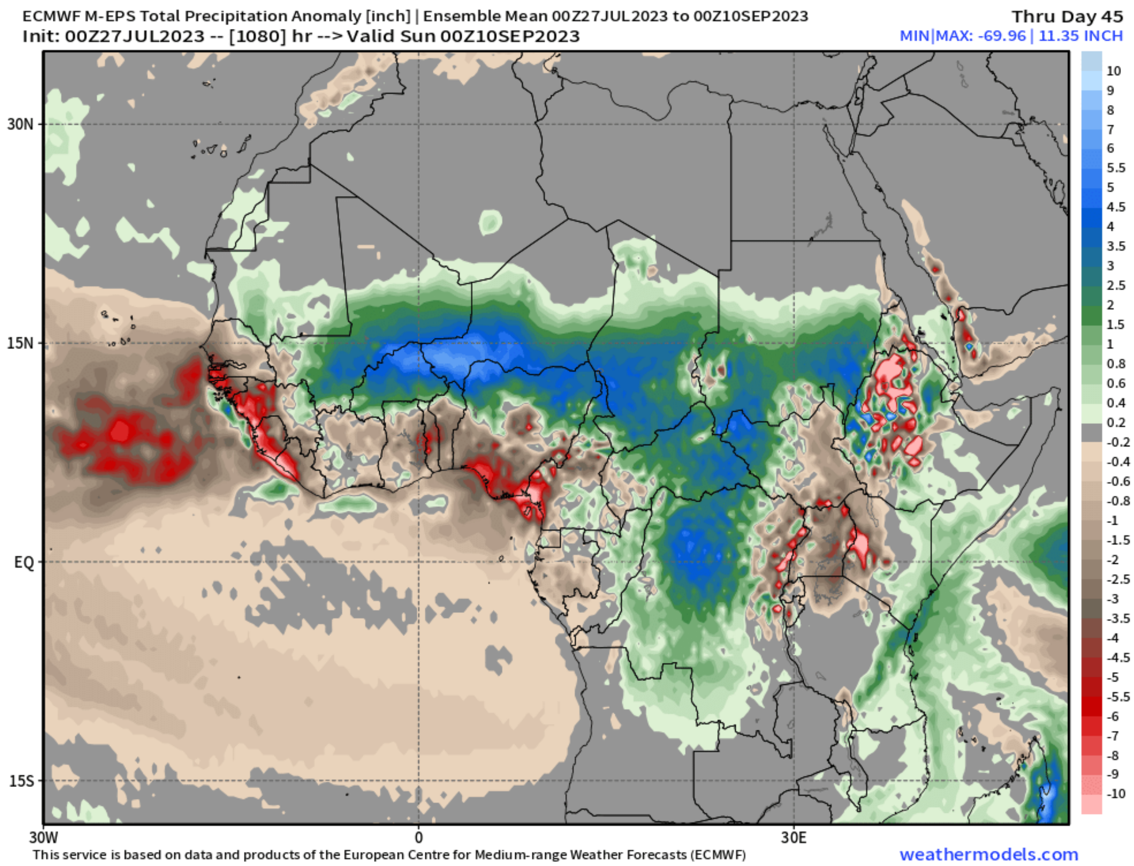

Figure 35: Forecast precipitation across North Africa over the next 45 days from ECMWF.

7 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-2 August 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%

8 Summary

An analysis of a variety of different atmosphere and ocean measurements (through July) which are known to have long-period statistical relationships with the upcoming season's Atlantic tropical cyclone activity, 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.

9 Forthcoming Updated Forecasts of 2023 Hurricane Activity

We will be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August-October, beginning today, Thursday, August 3 and continuing every other Thursday (e.g., August 17, August 31, etc.). A verification and discussion of all 2023 forecasts will be issued in late November 2023. All of these forecasts will be available online.

10 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 36 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

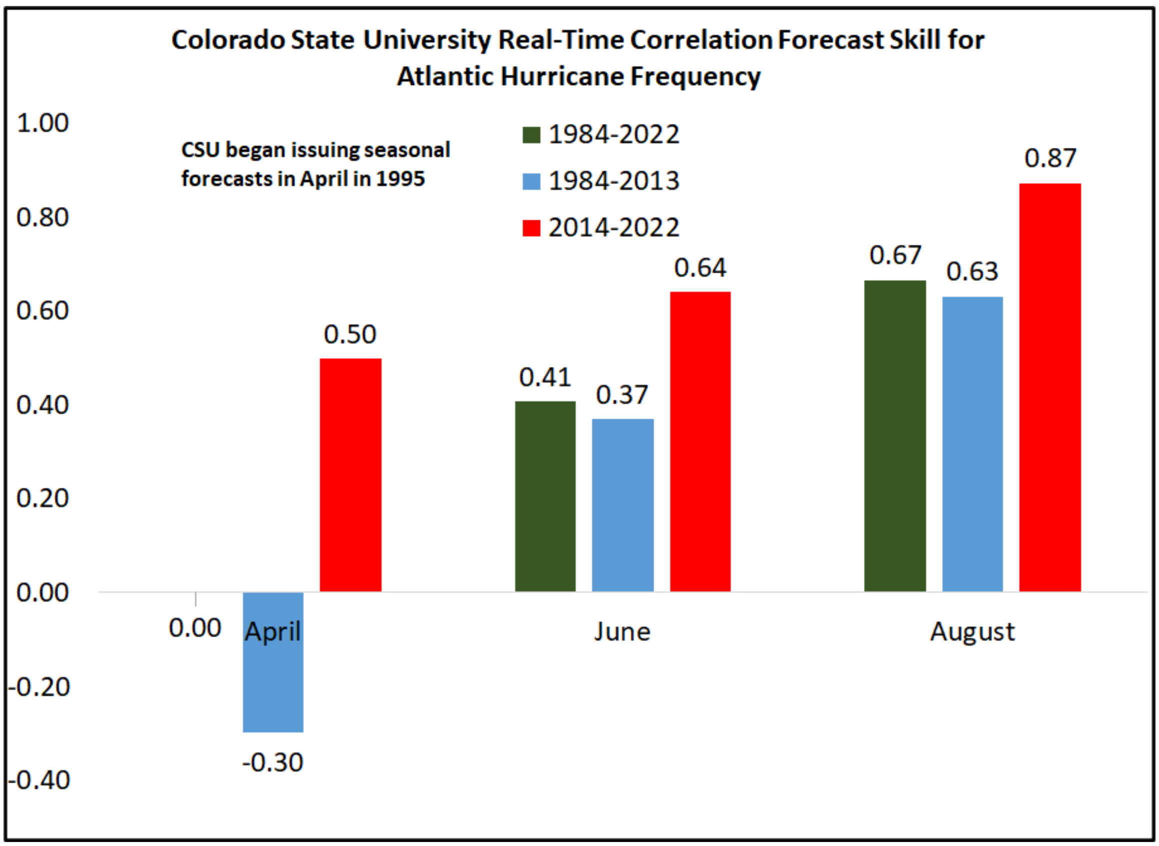

Figure 36: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2022 and 1984–2022, respectively.