FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2024

We have maintained our forecast for an extremely active Atlantic hurricane season in 2024. We have reduced our forecast number of named storms slightly but have maintained all other numbers from our July update. Sea surface temperatures averaged across the hurricane Main Development Region of the tropical Atlantic and Caribbean remain near record warm levels. Extremely warm sea surface temperatures provide a much more conducive dynamic and thermodynamic environment for hurricane formation and intensification. We continue to anticipate cool neutral ENSO or La Niña during the peak of the Atlantic hurricane season, resulting in reduced levels of tropical Atlantic vertical wind shear. This forecast is of above-normal confidence. We anticipate a well above-average probability for major hurricane landfalls along the continental United States coastline and in the Caribbean. As with all hurricane seasons, coastal residents are reminded that it only takes one hurricane making landfall to make it an active season. Thorough preparations should be made every season, regardless of predicted activity.

(as of 6 August 2024)

By Philip J. Klotzbach[1], Michael M. Bell[2], Alexander J. DesRosiers[3], and Levi G. Silvers[4]
With Special Assistance from Carl J. Schreck III[5]
In Memory of William M. Gray[6]

Allison Sylte, Colorado State University media representative, is coordinating media inquiries in English and Spanish. She can be reached at Allison.Sylte@colostate.edu or 720-849-1907.

Department of Atmospheric Science, Colorado State University, Fort Collins CO 80523

Project Sponsors:

INSURANCE INFORMATION INSTITUTE
IRONSHORE A Liberty Mutual Company
CWG
WEATHERBOY.COM
AA
Gallagher Re

[1] Senior Research Scientist
[2] Professor
[3] Graduate Research Assistant
[4] Research Scientist
[5] Research Scholar at NC State University
[6] Professor Emeritus

ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2024

Forecast Parameter and 1991-2020 Average (in parentheses)	Issue Date 4 April 2024	Issue Date 11 June 2024	Issue Date 9 July 2024	Issue Date 6 August 2024	Observed Thru 5 August 2024	Remainder of Season Forecast
Named Storms (NS) (14.4)	23	23	25	23*	4	19
Named Storm Days (NSD) (69.4)	115	115	120	120	14	106
Hurricanes (H) (7.2)	11	11	12	12	2	10
Hurricane Days (HD) (27.0)	45	45	50	50	6.75	43.25
Major Hurricanes (MH) (3.2)	5	5	6	6	1	5
Major Hurricane Days (MHD) (7.4)	13	13	16	16	4.50	11.50
Accumulated Cyclone Energy (ACE) (123)	210	210	230	230	39	191
ACE West of 60°W (73)	125	125	140	140	32	108
Net Tropical Cyclone Activity (NTC) (135%)	220	220	240	240	43	197

*Total forecast includes Alberto, Beryl, Chris and Debby.

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

1) Entire continental U.S. coastline - 56% (full-season average from 1880–2020 is 43%)

2) U.S. East Coast Including Peninsula Florida (south and east of Cedar Key, Florida) - 30% (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 - 38% (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 5 AUGUST):

1) 61% (full-season average from 1880–2020 is 47%)

ABSTRACT

Information obtained through early August indicates that the 2024 Atlantic hurricane season will have activity well above the 1991–2020 average. We estimate that 2024 will have 23 named storms (average is 14.4), 120 named storm days (average is 69.4), 12 hurricanes (average is 7.2), 50 hurricane days (average is 27.0), 6 major (Category 3-4-5) hurricanes (average is 3.2) and 16 major hurricane days (average is 7.4). These numbers include Alberto, Beryl, Chris and Debby. The probability of U.S. major hurricane landfall is estimated to be well above its long-period average. We predict Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity in 2024 to be ~185% of their 1991–2020 average. We have reduced our forecast number of named storms slightly due to a paucity of storm formations between Chris (formed on 1 July) and Debby (formed on 4 August) but have maintained all other forecast numbers.

Coastal residents are reminded that it only takes one hurricane making landfall to make it an active season for them. Thorough preparations should be made for every season, regardless of how much activity is predicted.

We anticipate that cool neutral ENSO or La Niña conditions are likely at the peak of the Atlantic hurricane season. Cool neutral ENSO or La Niña typically increases Atlantic hurricane activity through decreases in vertical wind shear. This year's sea surface temperatures across the tropical Atlantic and Caribbean are much warmer than normal, with temperatures averaged across the Main Development Region currently measuring ~1.1°C above the 1991–2020 average. This warmth favors an active Atlantic hurricane season via dynamic and thermodynamic conditions that are conducive for developing hurricanes. While early season storm activity in the western Atlantic typically has little relationship with overall basinwide activity, deep tropical hurricane activity in the tropical Atlantic and eastern Caribbean (such as we saw with Beryl) is often associated with hyperactive seasons.

Our confidence this year is higher than normal for an August forecast based on the strength and persistence of the current hurricane-favorable large-scale environmental conditions. We present probabilities of exceedance for hurricanes and Accumulated Cyclone Energy to give interested readers a better idea of the uncertainty associated with these forecasts. The skill of CSU's forecast updates increases as the peak of the Atlantic hurricane season approaches. Our early August forecast has the highest skill of any of our seasonal forecasts based on real-time forecasts as well as hindcasts.

In addition to current observations, this forecast is based on two August statistical prediction schemes that were developed using ~40 years of past data. Analog predictors are utilized as well. We also include statistical/dynamical models based off 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. This model guidance continues to unanimously point towards a hyperactive season.

Starting today and issued every two weeks following (e.g., 6 August, 20 August, 3 September, 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, curiosity as to how global ocean and atmosphere features are presently arranged with respect to the probability of an active or inactive hurricane season for the coming year. Our early August statistical and statistical/dynamical hybrid models show evidence on ~25–45 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 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 Commodity Weather Group, Gallagher Re, the Insurance Information Institute, Ironshore Insurance, IAA, and Weatherboy. 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. Thanks also extend to several current members of Michael Bell's research group who have provided valuable comments and feedback throughout the forecast preparation process. These members include: Tyler Barbero, Delián Cólon Burgos, Jen DeHart, Nick Mesa, Angelie Nieves-Jiménez and Isaac Schluesche.

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. ACE is often calculated over a season to reflect overall storm activity that year. 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.

ENSO Longitude Index (ELI) – 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.

Oceanic Nino Index (ONI) – Three-month running mean of SST anomalies in the Nino 3.4 region (5°S–5°N, 170–120°W) based on centered 30-year base periods.

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

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

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

Sea Surface Temperature Anomaly (SSTA) – Observed sea surface temperature differenced from a long-period average, typically 1991–2020 which is the current NOAA climate baseline.

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 41st 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 less of a relationship with 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.

The pool of three predictors for the early August statistical forecast scheme is given 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 1979–2023. When these three predictors are combined, they predict an ACE that correlates at 0.81 with observed ACE using cross-validated hindcasts from 1979–2023 (Figure 2). All three predictors favor above-average Atlantic hurricane activity in 2024. The combination of the three predictors yields a well above-average remainder of the season forecast.

Table 1: Listing of 1 August 2024 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 2024 Forecast	Effect on 2024 Hurricane Season
1) July 10 m U (7.5-17.5°N, 85-60°W) (+)	+0.7 SD	Enhance
2) July SST (20-40°N, 35-15°W) (+)	+2.0 SD	Enhance
3) July 200 hPa U (10-20°N, 30°W-30°E) (-)	-0.8 SD	Enhance

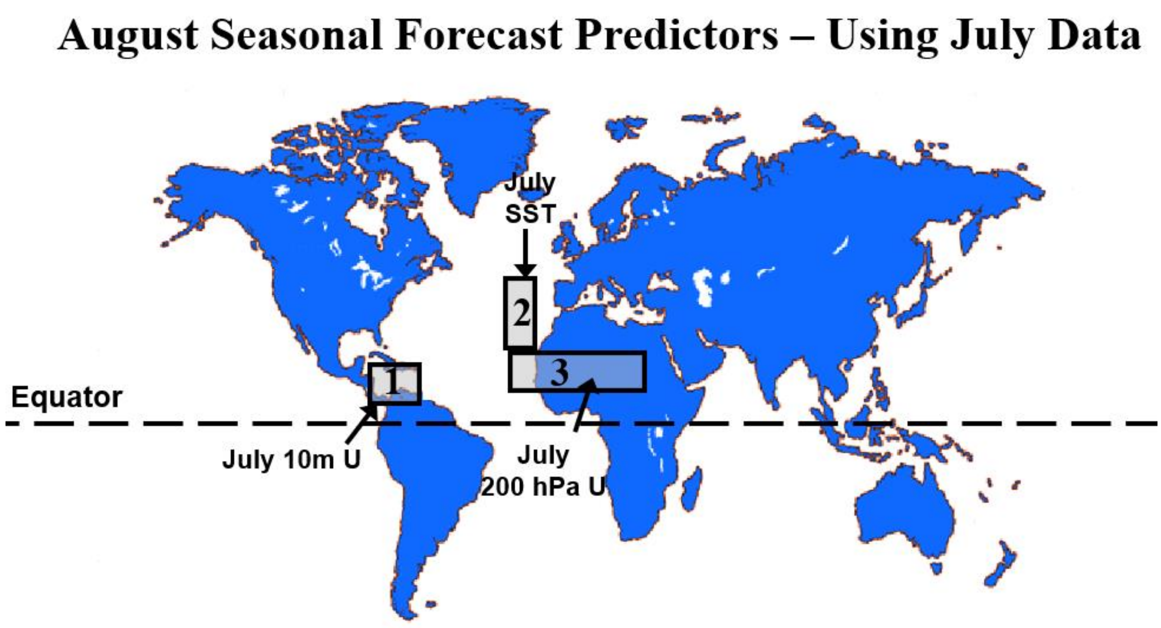

Figure 1: Location of predictors for the post-31 July forecast for the 2024 hurricane season from the July-averaged statistical model.

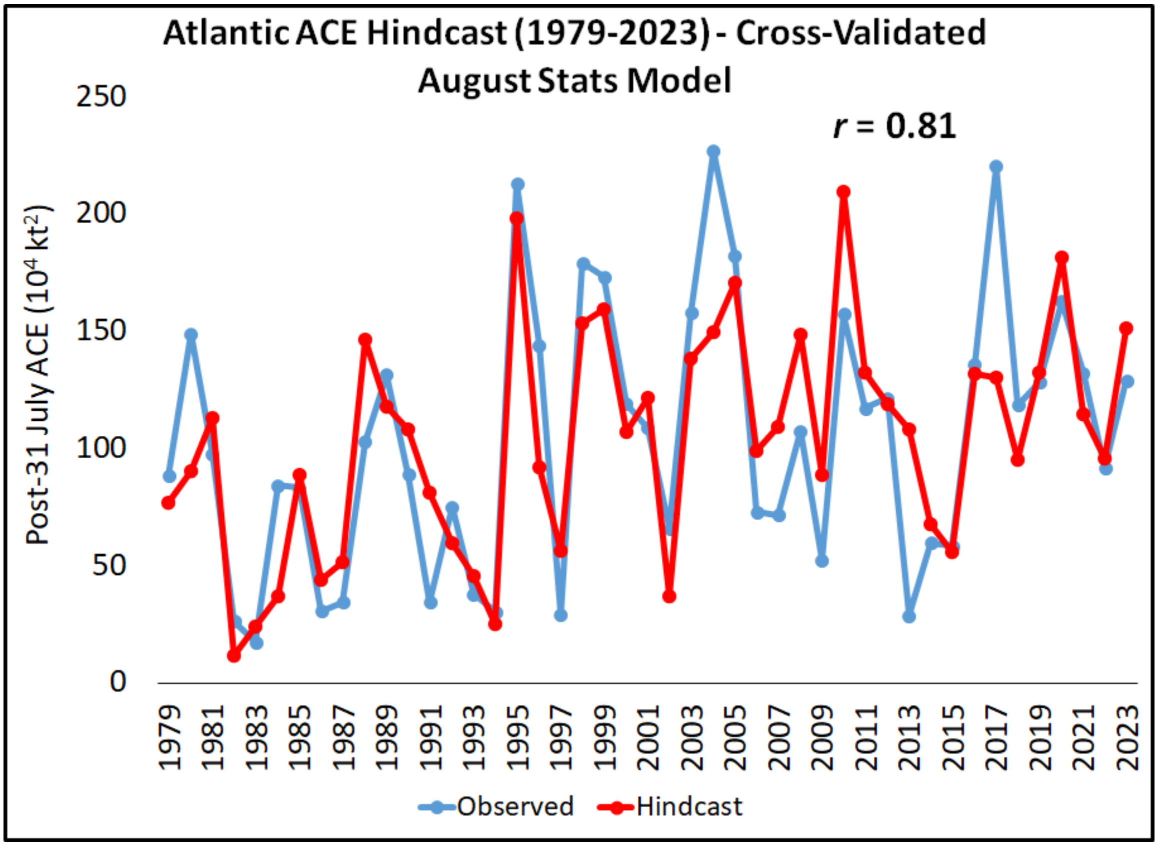

Figure 2: Observed versus hindcast values of post-31 July ACE for 1979–2023 using our statistical scheme that uses July averages.

Table 2 shows our forecast for the 2024 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 a well above-average remainder of the season.

Table 2: Post-31 July statistical forecast for 2024 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 31 July Added In)
Named Storms (NS) – 11.6	19.4	22.4
Named Storm Days (NSD) – 61.3	93.9	105.7
Hurricanes (H) – 6.5	9.7	10.7
Hurricane Days (HD) – 25.6	40.3	46.6
Major Hurricanes (MH) – 3.1	4.7	5.7
Major Hurricane Days (MHD) – 7.1	12.2	16.7
Accumulated Cyclone Energy (ACE) – 113	181	217
Net Tropical Cyclone Activity (NTC) – 123	196	235

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 since 1979 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.

<u>Predictor 1. July 10 meter U in the Caribbean (+)</u>

(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.

<u>Predictor 2. July SST in the Northeastern Subtropical Atlantic (+)</u>

(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).

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

(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).

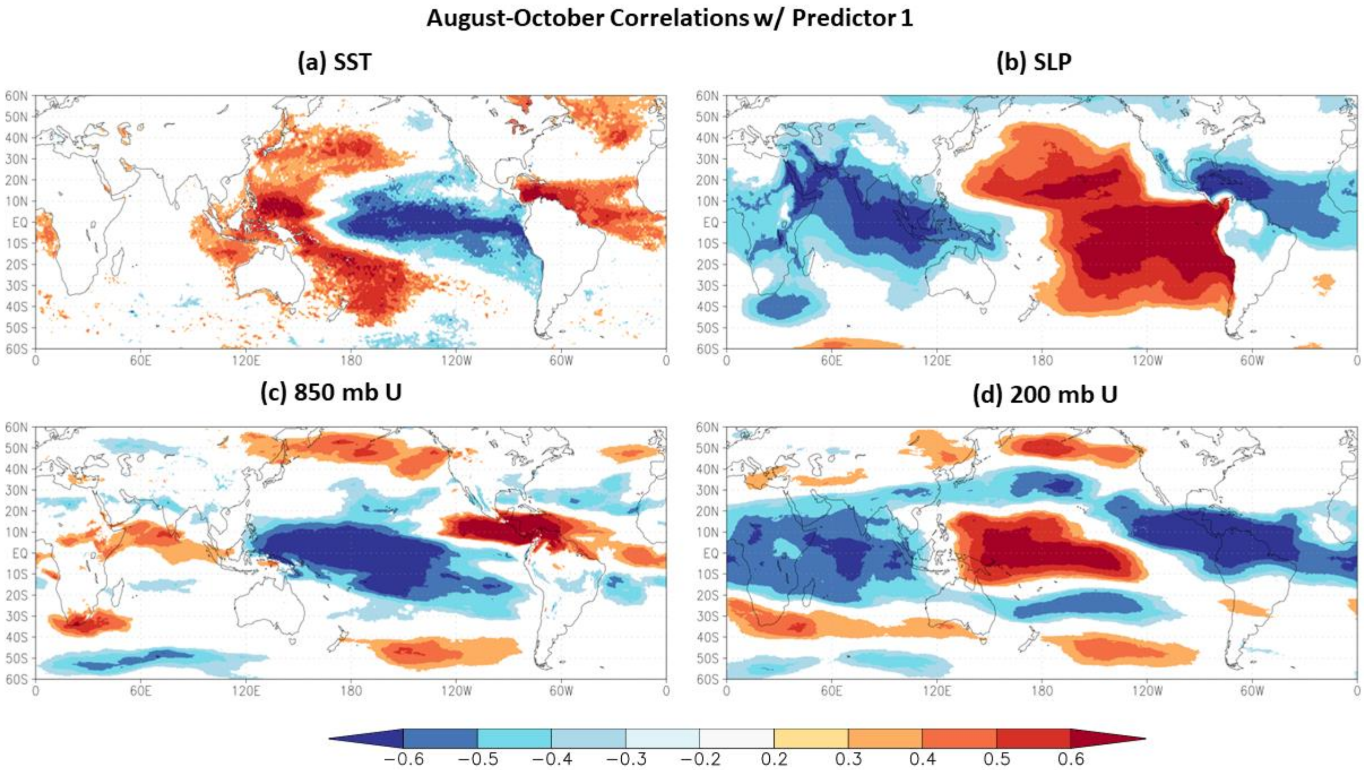

Figure 3: Rank correlations between <u>July 10 meter U</u> in the Caribbean <u>(Predictor 1)</u> and August–October sea surface temperature (panel a), August–October sea level pressure (panel b), August–October 850 hPa zonal wind (panel c) and August–October 200 hPa zonal wind (panel d).

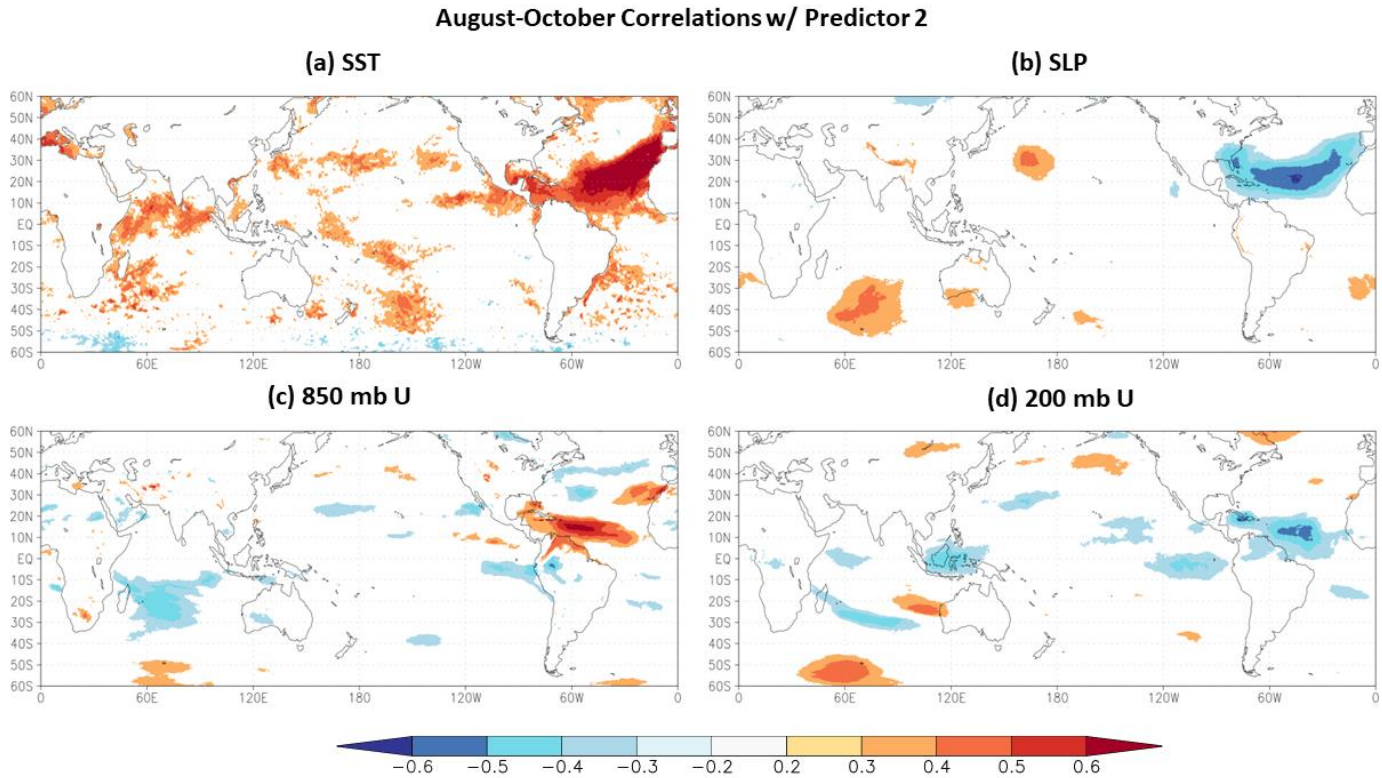

Figure 4: Rank correlations between July sea surface temperature in the subtropical northeastern Atlantic (Predictor 2) and August–October sea surface temperature (panel a), August–October sea level pressure (panel b), August–October 850 hPa zonal wind (panel c) and August–October 200 hPa zonal wind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

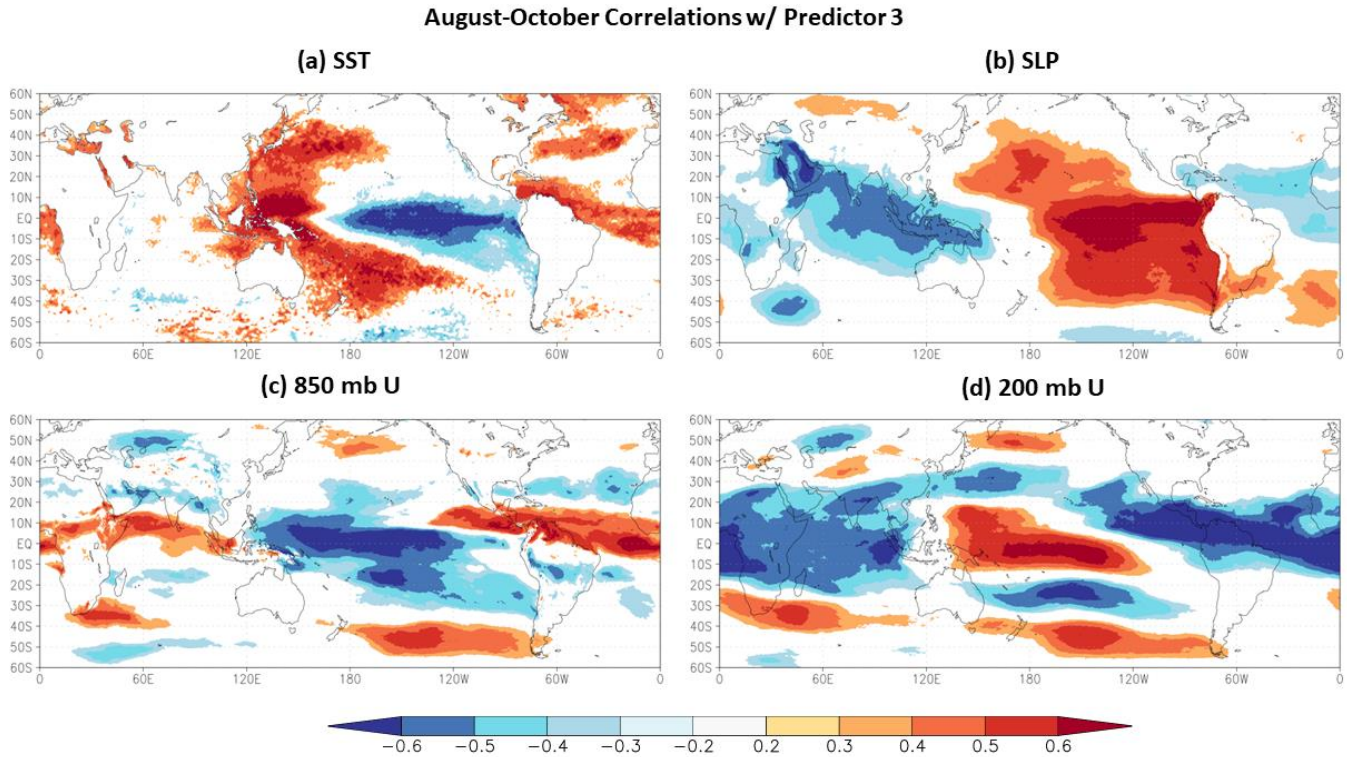

Figure 5: Rank correlations between <u>July 200 hPa zonal wind</u> over tropical north Africa <u>(Predictor 3)</u> and August–October sea surface temperature (panel a), August–October sea level pressure (panel b), August–October 925 hPa zonal wind (panel c) and August–October 200 hPa zonal wind (panel d). 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

We now include a second 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. This 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 has been issued operationally since 2022.

The pool of three predictors for the 50-day-averaged early August statistical forecast scheme is 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 real-time forecasts from 2022–2023. When these three predictors are combined, they correlate at 0.79 with observed ACE using cross-validated hindcasts from 1979–2023 (Figure 7). All three predictors call for a well above-average remainder of the 2024 Atlantic hurricane season.

Table 3: Listing of 50-day-averaged statistical model values for the August 2024 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 2024 Forecast	Effect on 2024 Hurricane Season
1) June 12 – July 31 10 m U (5-20°N, 90-60°W) (+)	+1.0 SD	Enhance
2) June 12 – July 31 SST (25-50°N, 30-10°W) (+)	+1.4 SD	Enhance
3) June 12 – July 31 200 hPa U (15°S-15°N, 20°W-40°E) (-)	-0.8 SD	Enhance

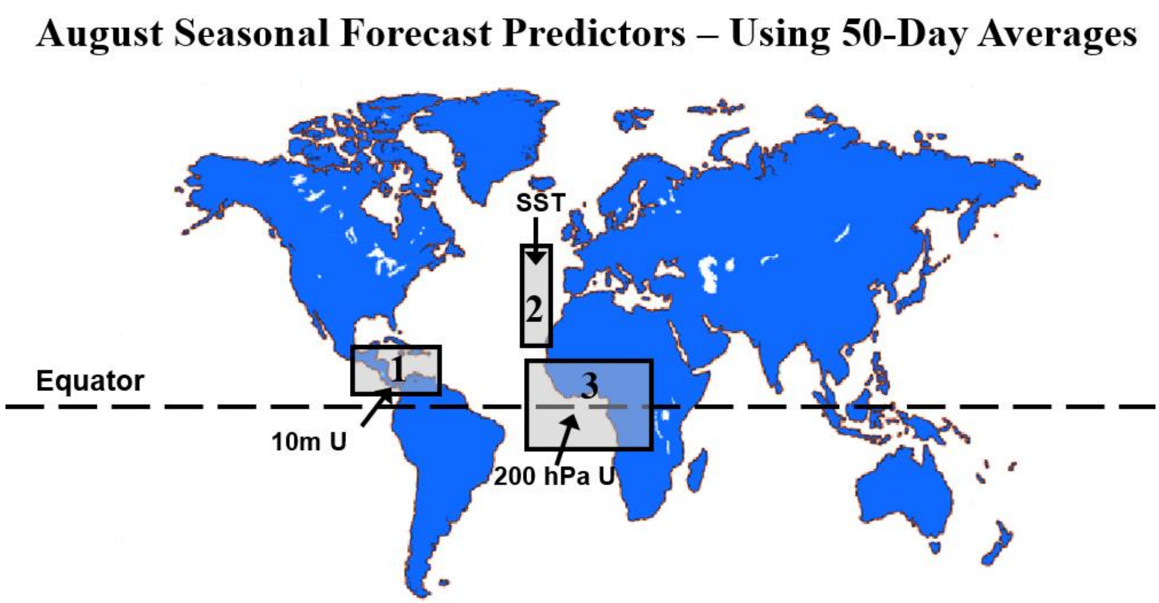

Figure 6: Location of predictors for the post-31 July forecast for the 2024 hurricane season from the 50-day-averaged (e.g., June 12 – July 31) statistical model.

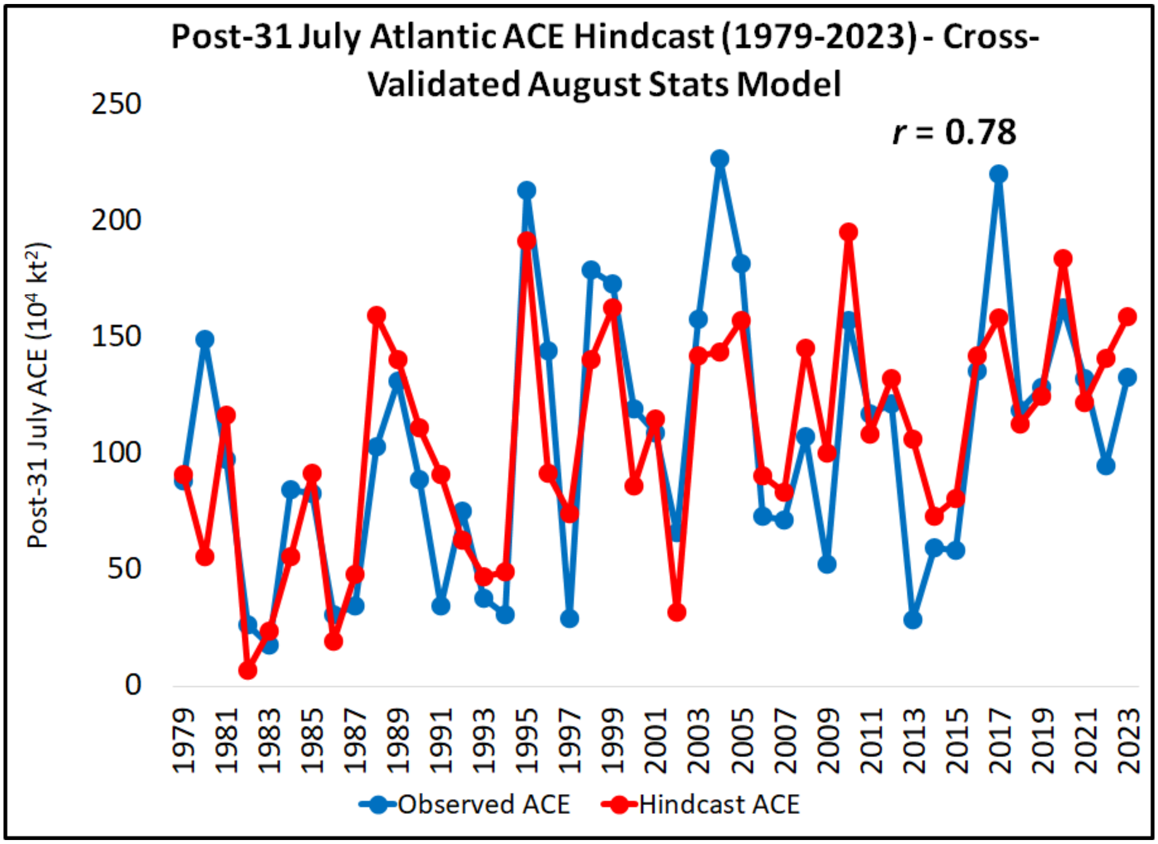

Figure 7: Observed versus hindcast values of post-31 July ACE for 1979–2023 using the 50-day-average statistical model.

Table 4 shows our forecast for the 2024 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 a well above-average remainder of the season.

Table 4: Post-31 July statistical forecast for 2024 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 31 July Added In)
Named Storms (NS) – 11.6	18.9	21.9
Named Storm Days (NSD) – 61.3	90.1	100.9
Hurricanes (H) – 6.5	9.3	10.3
Hurricane Days (HD) – 25.6	38.3	44.6
Major Hurricanes (MH) – 3.1	4.5	5.5
Major Hurricane Days (MHD) – 7.1	11.5	16.0
Accumulated Cyclone Energy (ACE) – 113	172	208
Net Tropical Cyclone Activity (NTC) – 123	187	226

2.3 August Statistical/Dynamical Forecast Schemes

We have developed statistical/dynamical models based on output from the following four modeling systems: 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 2024 season. All other predictands (e.g., named storms, major hurricanes) are calculated based on their historical relationships with ACE. All models are based off a 1 July initialization.

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 2024 from a 1 July initialization date. The ECMWF model is predicting an extremely warm Atlantic and near-average SSTs in the normal eastern/central tropical Pacific. The marked warmth that is predicted for the eastern/central North Atlantic results in a hyperactive seasonal forecast from this model. Figure 9 displays cross-validated hindcasts of ECMWF hindcasts of ACE from 1981–2023, while Table 6 presents the forecast from ECMWF for the 2024 Atlantic hurricane season.

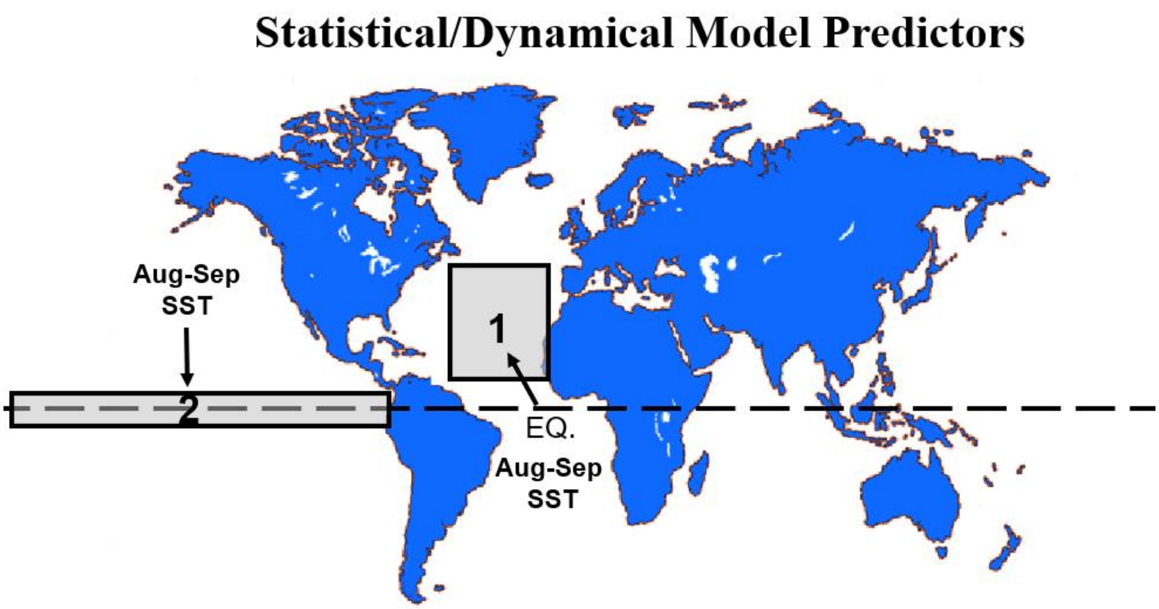

Figure 8: Location of predictors for our early August statistical/dynamical statistical prediction for the 2024 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August–September conditions in the two boxes displayed and uses those 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 2024 Forecast	Effect on 2024 Hurricane Season
1) ECMWF Prediction of Aug–Sep SST (10–45°N, 60–20°W) (+)	+3.9 SD	Strongly Enhance
2) ECMWF Prediction of Aug–Sep SST (5°S–5°N, 180–90°W) (-)	0.0 SD	Neutral

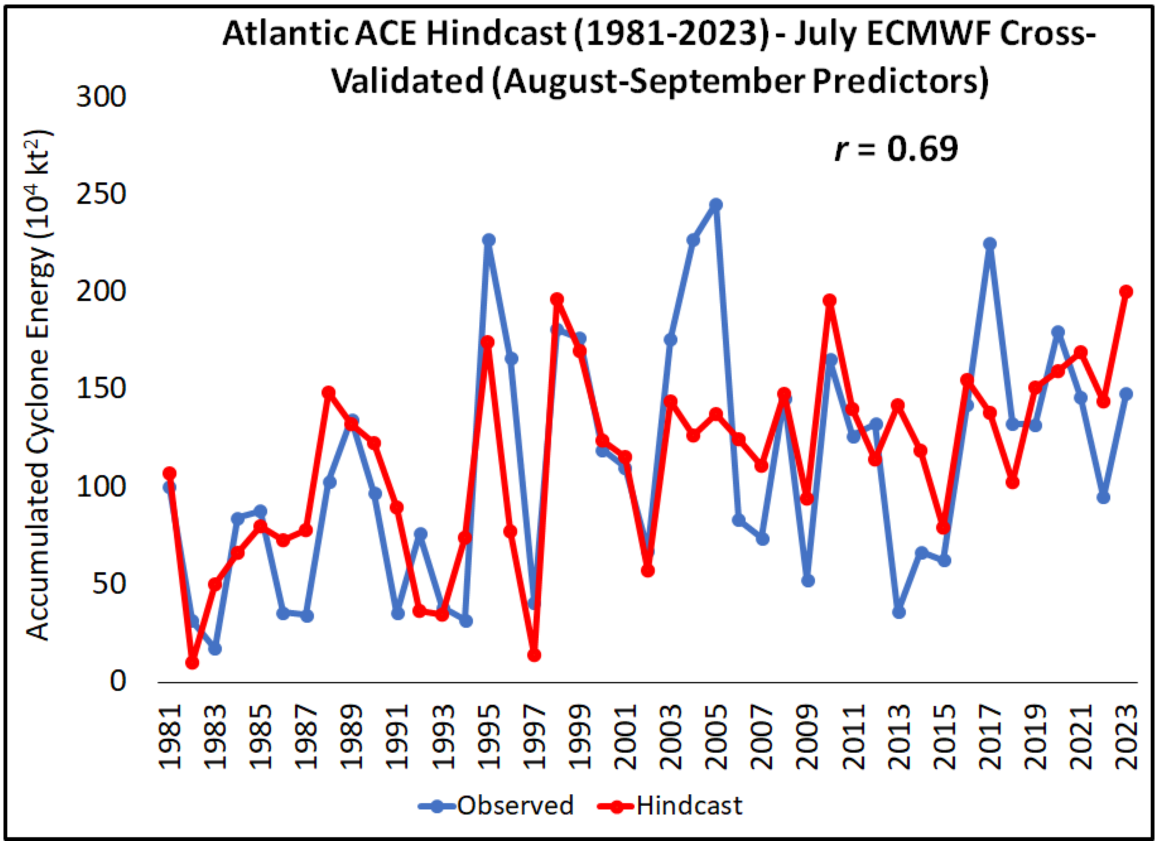

Figure 9: Observed versus cross-validated statistical/dynamical hindcast values of ACE for 1981–2023 from ECMWF.

Table 6: Statistical/dynamical model output from ECMWF for the 2024 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)	23.6	23
Named Storm Days (69.4)	122.0	120
Hurricanes (7.2)	12.7	12
Hurricane Days (27.0)	55.7	50
Major Hurricanes (3.2)	6.5	6
Major Hurricane Days (7.4)	17.7	16
Accumulated Cyclone Energy Index (123)	248	230
Net Tropical Cyclone Activity (135%)	262	240

b) UK Met Office Statistical/Dynamical Model Forecast

Table 7 displays the UK Met Office forecast of the August–September parameters for 2024 from a 1 July initialization date. The UK Met is calling for an extremely warm Atlantic as well as borderline weak La Niña conditions. Figure 10 displays hindcasts for the UK Met Office of ACE from 1993–2016. 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 2024 Forecast	Effect on 2024 Hurricane Season
1) UK Met Prediction of Aug–Sep SST (10–45°N, 60–20°W) (+)	+4.1 SD	Strongly Enhance
2) UK Met Prediction of Aug–Sep SST (5°S–5°N, 180–90°W) (-)	-0.7 SD	Enhance

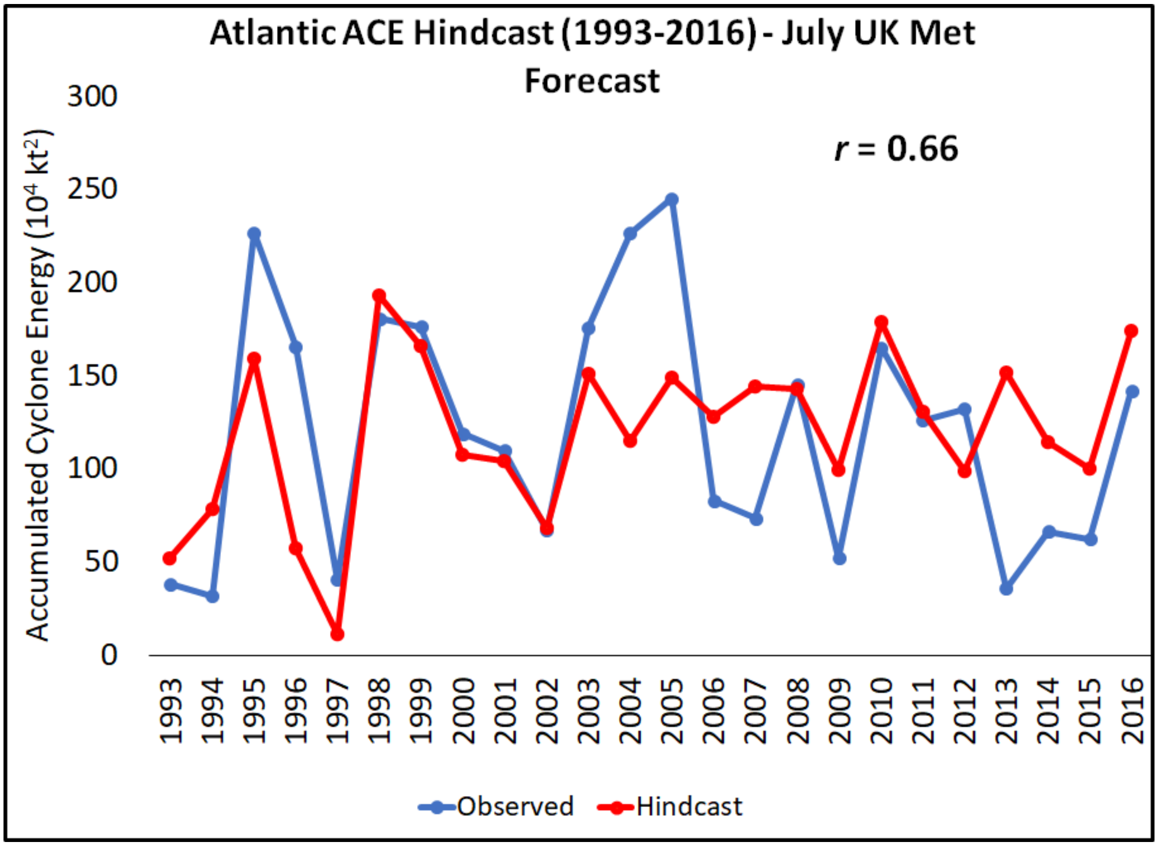

Figure 10: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the UK Met Office.

Table 8: Statistical/dynamical model output from the UK Met Office for the 2024 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)	25.0	23
Named Storm Days (69.4)	131.6	120
Hurricanes (7.2)	13.7	12
Hurricane Days (27.0)	60.9	50
Major Hurricanes (3.2)	7.1	6
Major Hurricane Days (7.4)	19.6	16
Accumulated Cyclone Energy Index (123)	271	230
Net Tropical Cyclone Activity (135%)	285	240

c) JMA Met Office Statistical/Dynamical Model Forecast

Table 9 displays the JMA forecasts of the August–September parameters for 2024 from a 1 July initialization date. JMA is also calling for an extremely warm Atlantic and borderline weak La Niña conditions. Figure 11 displays hindcasts for the JMA of ACE from 1993–2016, while Table 10 presents the forecast from the JMA for the 2024 Atlantic hurricane season. The statistical/dynamical model based off JMA is calling for a hyperactive 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 2024 Forecast	Effect on 2024 Hurricane Season
1) JMA Prediction of Aug–Sep SST (10–45°N, 60–20°W) (+)	+3.8 SD	Strongly Enhance
2) JMA Prediction of Aug–Sep SST (5°S–5°N, 180–90°W) (-)	-0.5 SD	Enhance

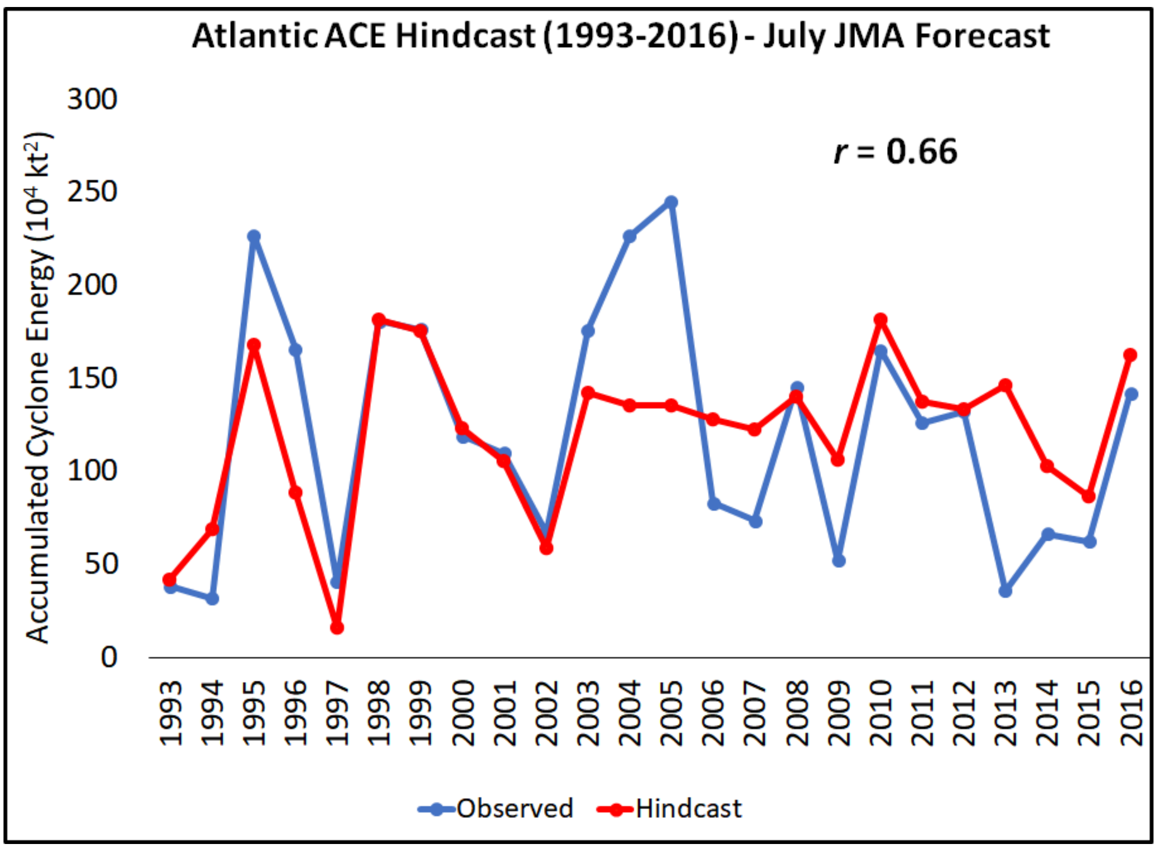

Figure 11: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the JMA.

Table 10: Statistical/dynamical model output from the JMA for the 2024 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)	24.3	23
Named Storm Days (69.4)	126.6	120
Hurricanes (7.2)	13.2	12
Hurricane Days (27.0)	58.2	50
Major Hurricanes (3.2)	6.8	6
Major Hurricane Days (7.4)	18.7	16
Accumulated Cyclone Energy Index (123)	259	230
Net Tropical Cyclone Activity (135%)	273	240

d) CMCC Statistical/Dynamical Model Forecast

Table 11 displays the CMCC forecasts of the August–September parameters for 2024 from a 1 July initialization date. CMCC is also calling for an extremely warm Atlantic and borderline weak La Niña conditions. Figure 12 displays CMCC hindcasts of ACE from 1993–2016, while Table 12 presents the forecast from the CMCC for the 2024 Atlantic hurricane season. The statistical/dynamical model based off CMCC is calling for an extremely active 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 2024 Forecast	Effect on 2024 Hurricane Season
1) CMCC Prediction of Aug–Sep SST (10–45°N, 60–20°W) (+)	+4.4 SD	Strongly Enhance
2) CMCC Prediction of Aug–Sep SST (5°S–5°N, 180–90°W) (-)	-0.8 SD	Enhance

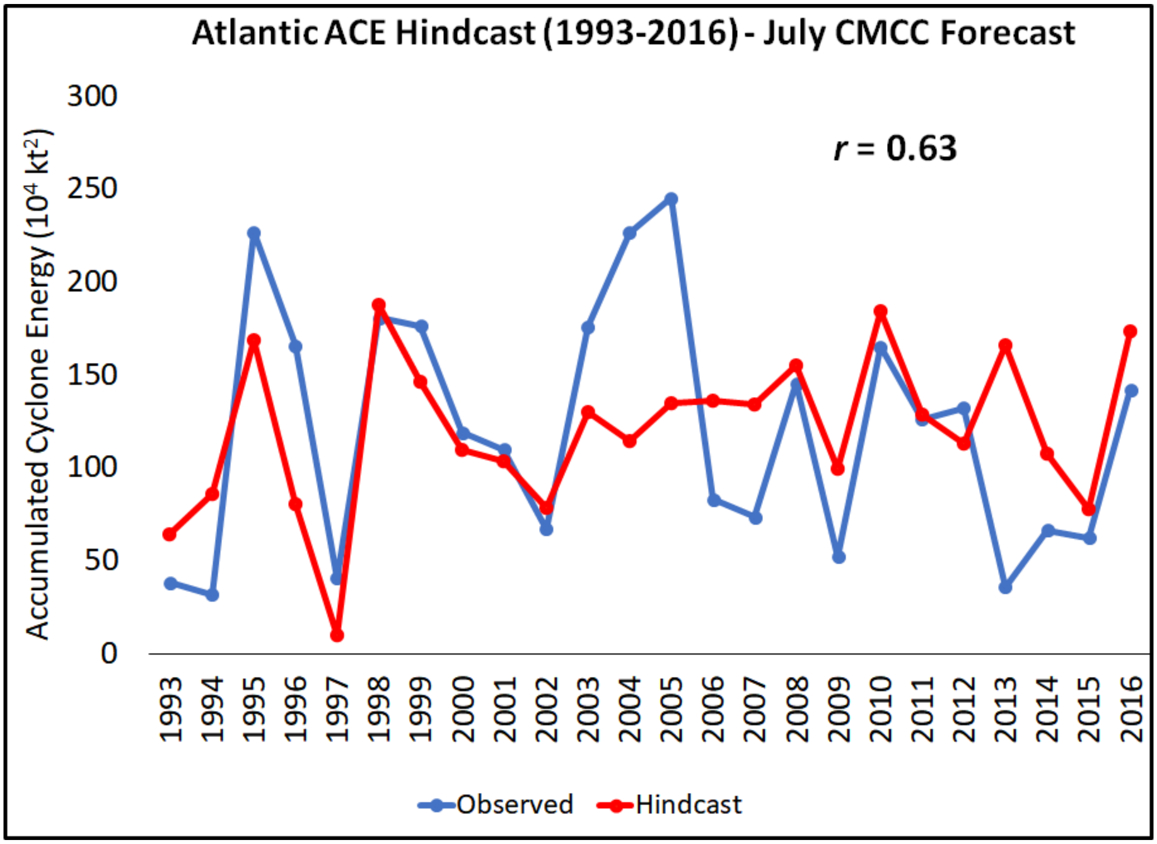

Figure 12: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the CMCC.

Table 12: Statistical/dynamical model output from the CMCC for the 2024 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)	24.4	23
Named Storm Days (69.4)	127.5	120
Hurricanes (7.2)	13.3	12
Hurricane Days (27.0)	58.6	50
Major Hurricanes (3.2)	6.8	6
Major Hurricane Days (7.4)	18.8	16
Accumulated Cyclone Energy Index (123)	261	230
Net Tropical Cyclone Activity (135%)	275	240

2.3 August Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric patterns and trends which resemble 2024. These years also provide useful clues as to likely levels of activity that the forthcoming 2024 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 early August 2024 conditions and, more importantly, projected August–October 2024 conditions. Table 13 lists our analog selections, while Figure 13 shows the composite August–October SST in our seven analog years. Selecting analogs for this season poses an additional challenge in that we have not observed an Atlantic this warm in the historical record without El Niño conditions. Last year had a similarly extremely warm Atlantic but also had a strong El Niño.

We searched for years that were generally characterized by El Niño conditions the previous winter and had cool neutral or La Niña conditions during the peak of the Atlantic hurricane season (August–October). We also selected years that had above-average SSTs relative to their long-term averages in the tropical Atlantic, although none of these years had SSTs in the tropical Atlantic in early August that were as warm as they are now. We also selected several years that were characterized by very busy starts to the season, such as 1886, 1933 and 2005. We anticipate that the 2024 hurricane season will have activity near the average of our seven analog years for most parameters. The busy hurricane seasons in all analog years underscore the higher-than-normal confidence in an active 2024 hurricane season. Named storm activity was likely significantly underestimated in 1886, 1926 and 1933, given the extremely limited observational network available in those years. We have maintained the same analogs that we had for our early July update.

Table 13: Analog years for 2024 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1886	12	84.25	10	49.50	4	4.50	166.2	155.3
1926	11	86.75	8	58.50	6	22.75	229.6	230.3
1933	20	125.25	11	57.00	6	21.75	258.6	263.1
1995	19	120.50	11	60.25	5	11.75	227.4	221.3
2005	28	126.25	15	49.75	7	17.50	245.3	276.7
2010	19	89.50	12	38.50	5	11.00	165.5	196.4
2020	30	122.75	14	35.25	7	8.25	180.4	235.5
Average	19.9	107.9	11.6	49.8	5.7	13.9	217.8	237.2
2024 Forecast	**23**	**120**	**12**	**50**	**6**	**16**	**230**	**240**

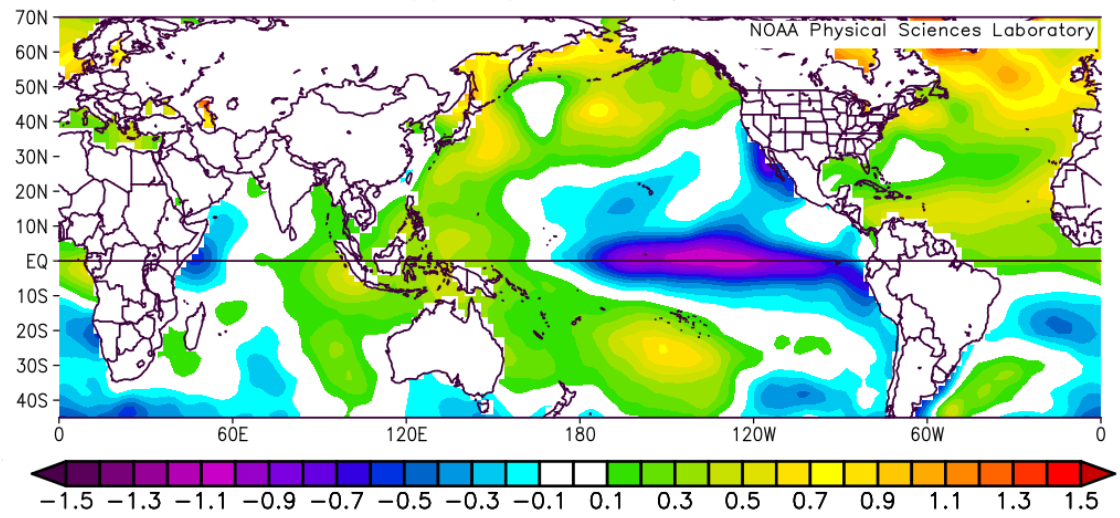

Figure 13: Average August–October SST anomalies in our seven analog years.

2.4 ACE West of 60°W Forecast

We now explicitly forecast 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), there is an improved relationship between North Atlantic landfalling hurricanes and ACE west of 60°W (Figures 14 and 15) since 1950.

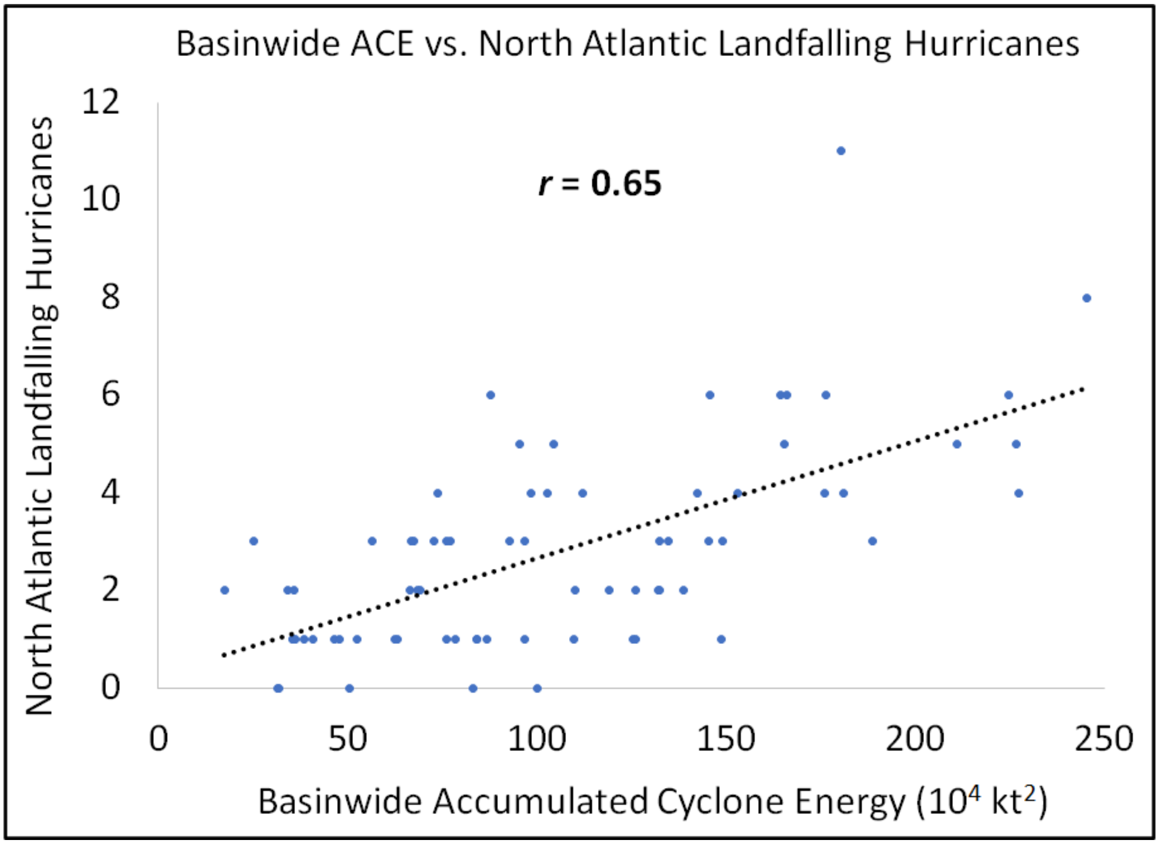

Figure 14: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

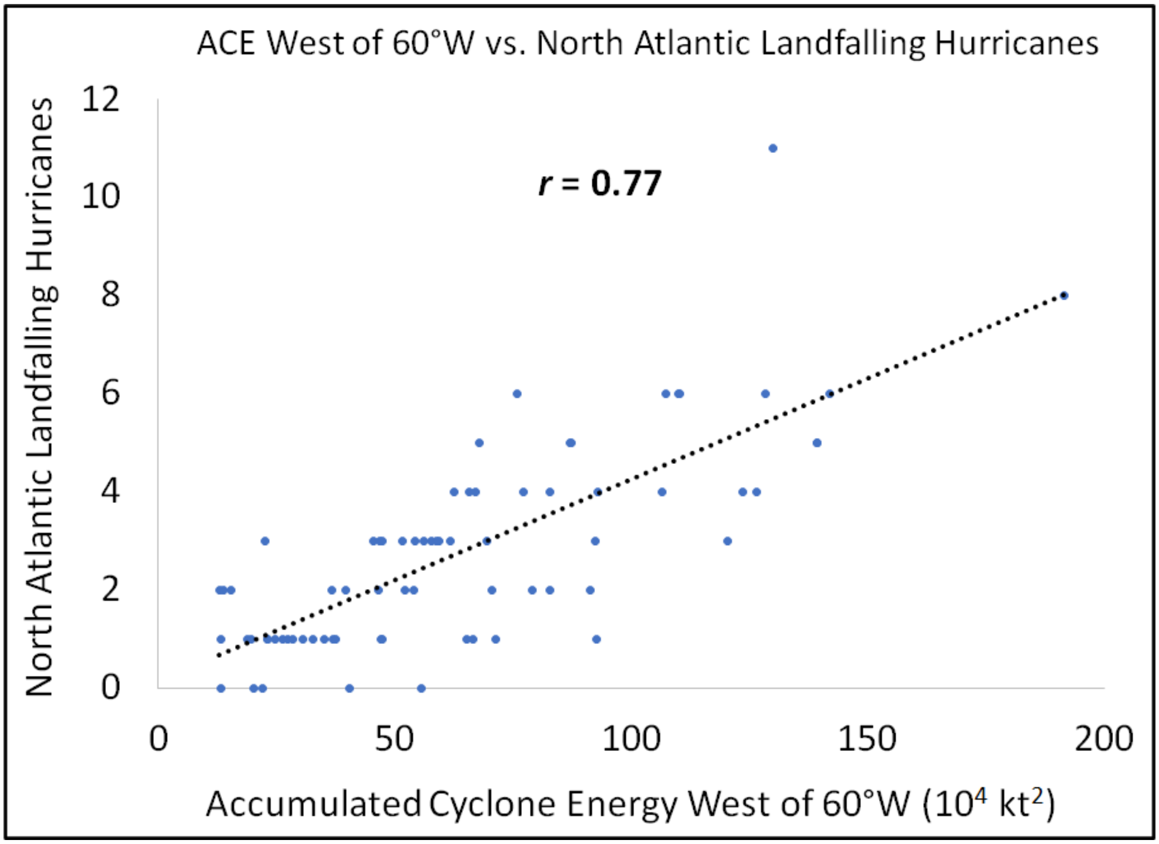

Figure 15: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

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). This was certainly the case in 2023. A strong El Niño occurred, the subtropical high was quite weak, and many of the TCs that occurred recurved east of 60°W. Caribbean TC activity was also suppressed last year.

We use data from 1979–2023 and base ENSO classifications on the August–October-averaged Oceanic Nino Index (ONI). Years with an ONI >= 0.5°C were classified as El Niño, years with an ONI <= -0.5°C were classified as La Niña, while all other seasons were classified as neutral ENSO.

We find that 51% of basinwide ACE occurred west of 60°W in El Niño years, while 60% of basinwide ACE occurred west of 60°W in La Niña years (Figure 16). In neutral ENSO years, 59% of basinwide ACE occurred west of 60°W. Given that we are favoring La Niña with this outlook, we are estimating ~60% of basinwide ACE to occur west of 60°W in 2024.

Hurricane Beryl is an excellent example of why ACE west of 60°W is an important metric. Beryl generated ~28 ACE west of 60°W and caused considerable damage in the Caribbean, Mexico and Texas.

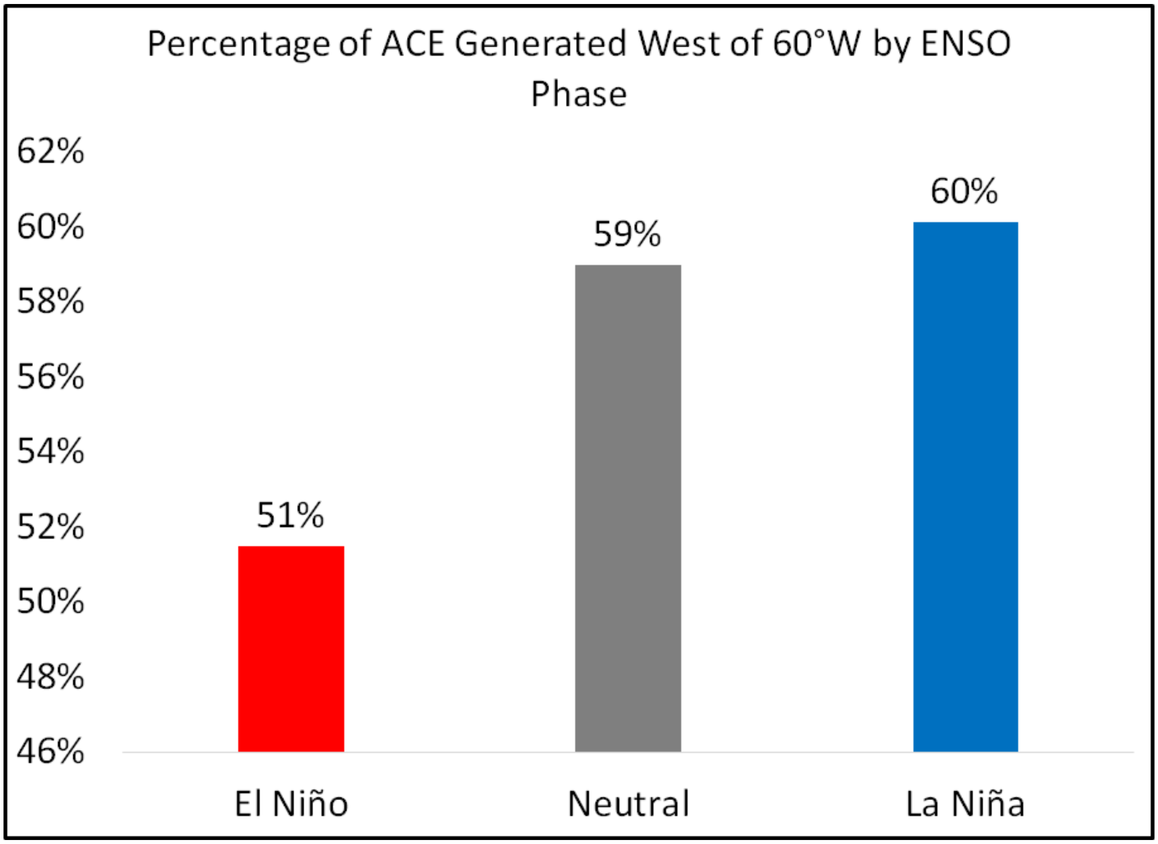

Figure 16: Percentage of ACE generated west of 60°W by ENSO phase.

2.4 August Forecast Summary and Final Adjusted Forecast

Table 14 shows our final adjusted early August forecast for the 2024 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 unanimously favors an extremely active 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 2024 hurricane season. All schemes have TC activity that was observed prior to 1 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)	22.4	21.9	23.6	25.0	24.3	24.4	19.9	23.1	23
Named Storm Days (69.4)	105.7	100.9	122.0	131.6	126.6	127.5	107.9	117.5	120
Hurricanes (7.2)	10.7	10.3	12.7	13.7	13.2	13.3	11.6	12.2	12
Hurricane Days (27.0)	46.6	44.6	55.7	60.9	58.2	58.6	49.8	53.5	50
Major Hurricanes (3.2)	5.7	5.5	6.5	7.1	6.8	6.8	5.7	6.3	6
Major Hurricane Days (7.4)	16.7	16.0	17.7	19.6	18.7	18.8	13.9	17.3	16
ACE Index (123)	217	208	248	271	259	261	218	240	230
NTC Activity (135%)	235	226	262	285	273	275	237	256	240

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 specific 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 SEAS5. 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 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, we are more confident than normal for an August forecast given how robust our primary predictors are (e.g., likely cool neutral ENSO/La Niña, extremely warm Atlantic sea surface temperatures) for an active Atlantic hurricane season.

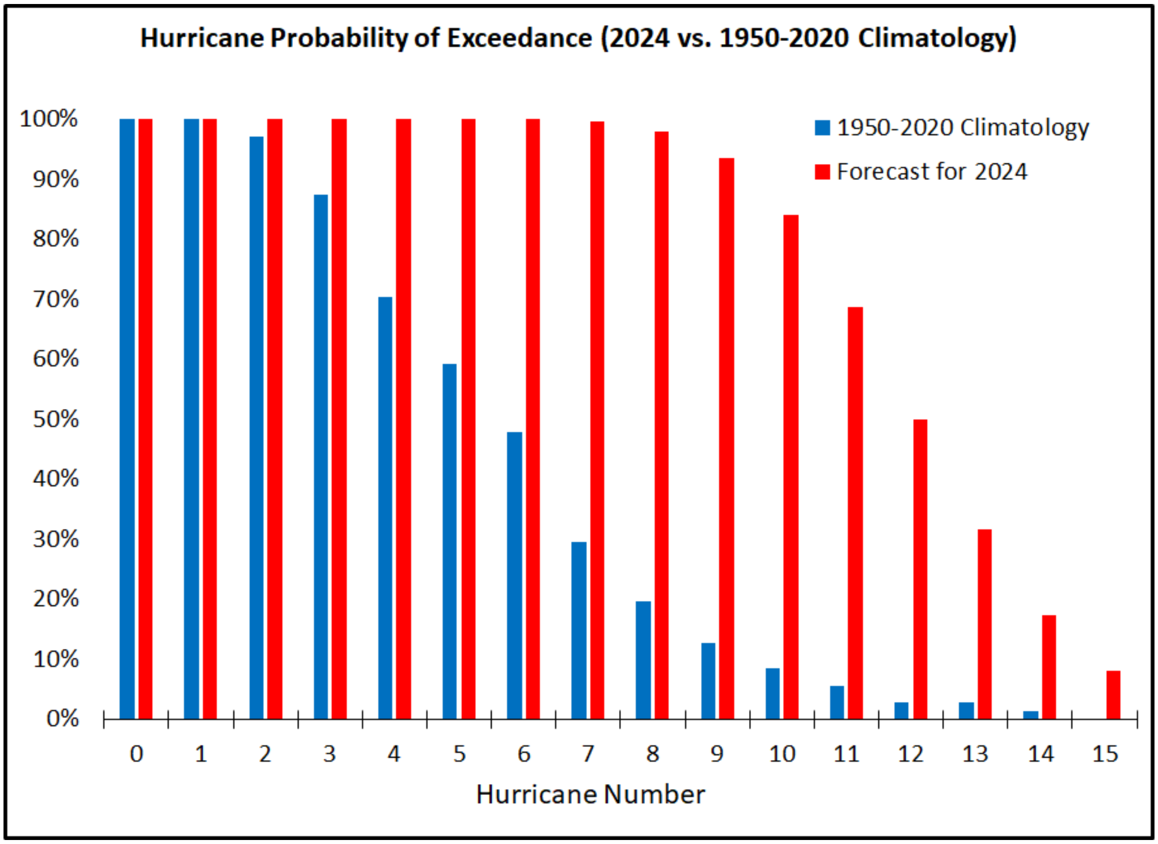

Figure 17: Probability of exceedance plot for hurricane numbers for the 2024 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950–2020 have had more than two hurricanes.

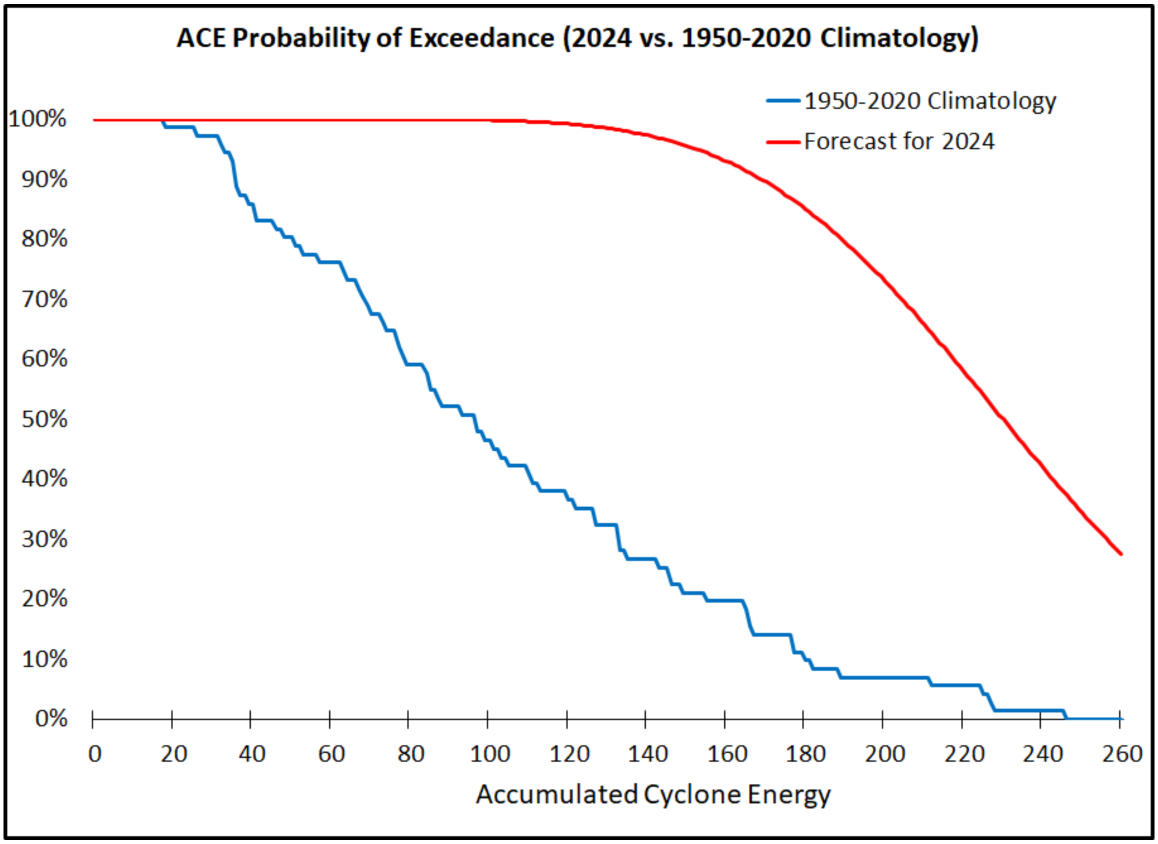

Figure 18: As in Figure 17 but for ACE.

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	2024 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	23	20 – 26
Named Storm Days (NSD)	120	101 – 130
Hurricanes (H)	12	10 – 14
Hurricane Days (HD)	50	37 – 63
Major Hurricanes (MH)	6	4 – 7
Major Hurricane Days (MHD)	16	11 – 22
Accumulated Cyclone Energy (ACE)	230	180 – 260
ACE West of 60°W	140	104 – 180
Net Tropical Cyclone (NTC) Activity	240	193 – 280

4 ENSO

The tropical Pacific is currently characterized by ENSO neutral conditions, with below-average SSTs in the eastern portion of the basin and near-average SSTs in the central portion of the basin (Figure 19). Over the past several weeks, SST anomalies across the eastern and central tropical Pacific have changed little (Table 16), although there has been an anomalous reduction of upper ocean heat content anomalies (Figure 20). This reduction in upper ocean heat content is likely driven by anomalously strong trade winds which have tended to predominate across this portion of the basin (Figure 21). The Climate Forecast System is also calling for these enhanced trade winds to likely continue for the next several weeks, heralding a potential trend towards La Niña conditions.

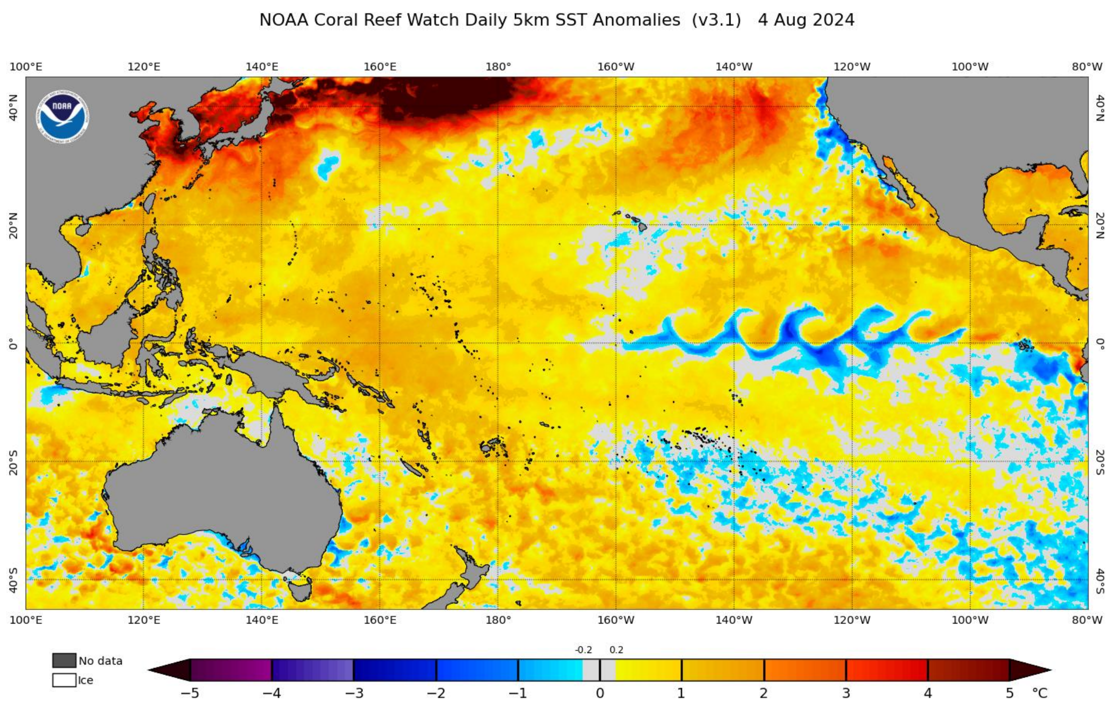

Figure 19: Current SST anomalies across the tropical and subtropical Pacific.

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	-0.7	-0.4	+0.3
Nino 3	-0.1	-0.1	0.0
Nino 3.4	+0.2	+0.2	0.0
Nino 4	+0.7	+0.6	-0.1

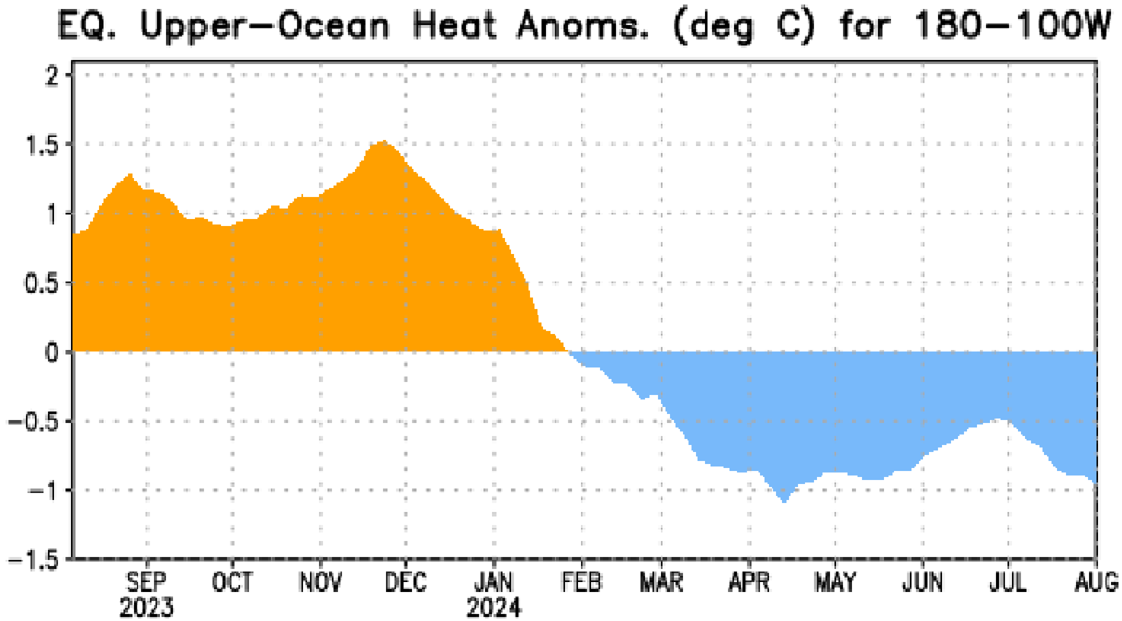

Figure 20: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

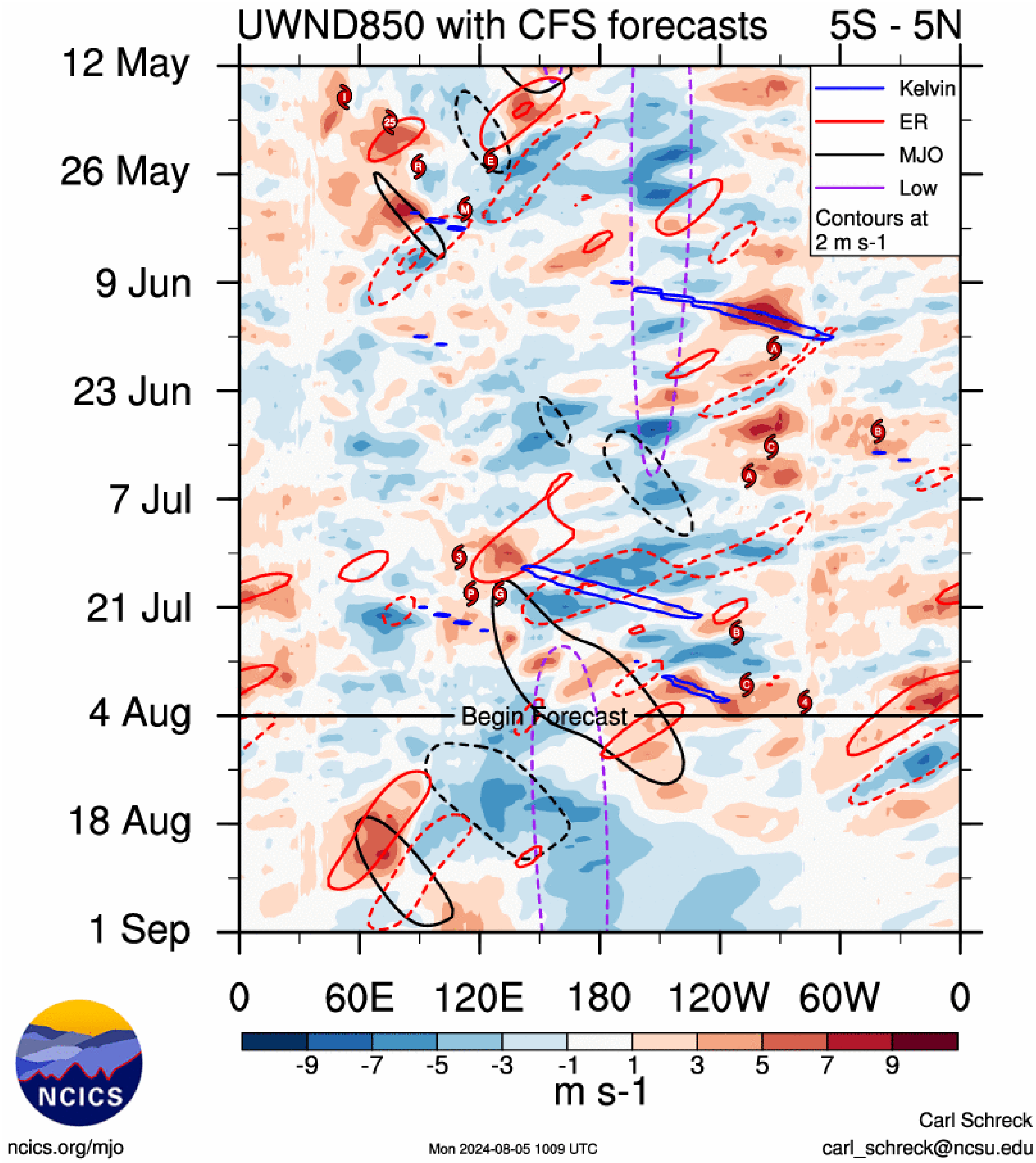

Figure 21: Observed low-level winds across the equatorial region as well as predictions for the next four weeks by the Climate Forecast System. The small TC symbols on the figure indicate TC formations, with the letter denoting the first letter of the storm that formed. Figure courtesy of Carl Schreck.

In addition to the Climate Forecast System, the ECMWF is also calling for heightened trade winds across most of the central tropical Pacific over the next few weeks (Figure 22). These enhanced trades favor a transition towards La Niña conditions over the next several weeks. Even if the official definition of La Niña is not met for the Atlantic hurricane season peak (August–October SSTs in the Nino 3.4 region <= -0.5°C), cool neutral ENSO conditions combined with the extremely warm Atlantic (discussed in the next section) are expected to lead to a hyperactive season.

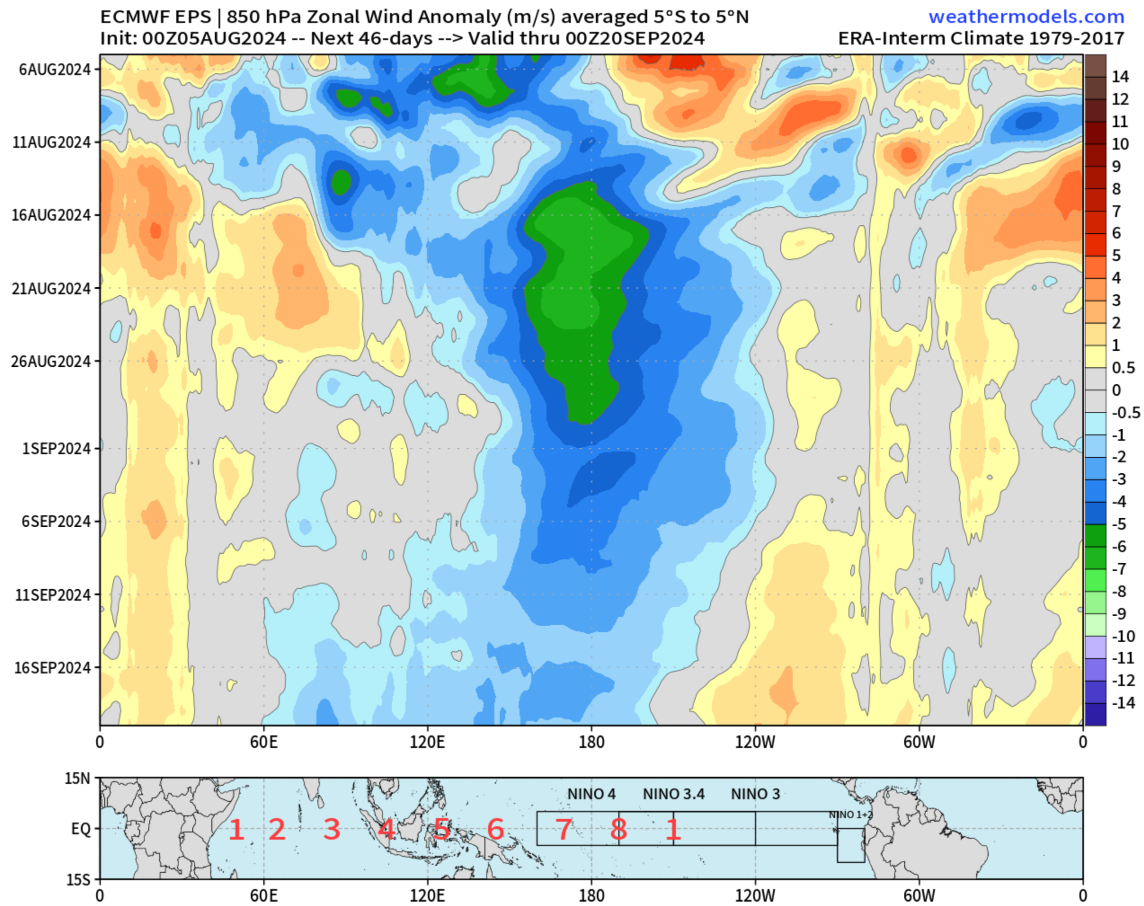

Figure 22: Forecast low-level winds through 19 September from the ECMWF ensemble. Enhanced trade winds are forecast to predominate across the central tropical Pacific. Figure courtesy of weathermodels.com.

We also note that in addition to the Oceanic Nino Index, defined to be three-month averaged Nino 3.4 SST anomalies relative to a 30-year centered base period, a new index known as the Relative Oceanic Nino Index has recently been proposed (L'Heureux et al. 2024). This index examines Nino 3.4 SSTs relative to the rest of the global tropics (20°S–20°N, 0–360°). Given how warm the remainder of the tropics is, the Relative Oceanic Nino Index is quite likely to reach the La Niña threshold by the peak of the season. For example the May–July-averaged Oceanic Nino Index is +0.2°C, while the May–July-averaged relative Oceanic Nino Index is -0.4°C, already approaching the La Niña threshold of -0.5°C. As was shown in Klotzbach et al. (2024) when examining the 2023 Atlantic hurricane season, relative sea surface temperatures are a critical driver of the atmospheric circulation and associated modulations of vertical motion and vertical wind shear.

There is still considerable model spread for the phase of ENSO for August–October, with the spread of the guidance ranging from warm neutral ENSO to La Niña (Figure 23).

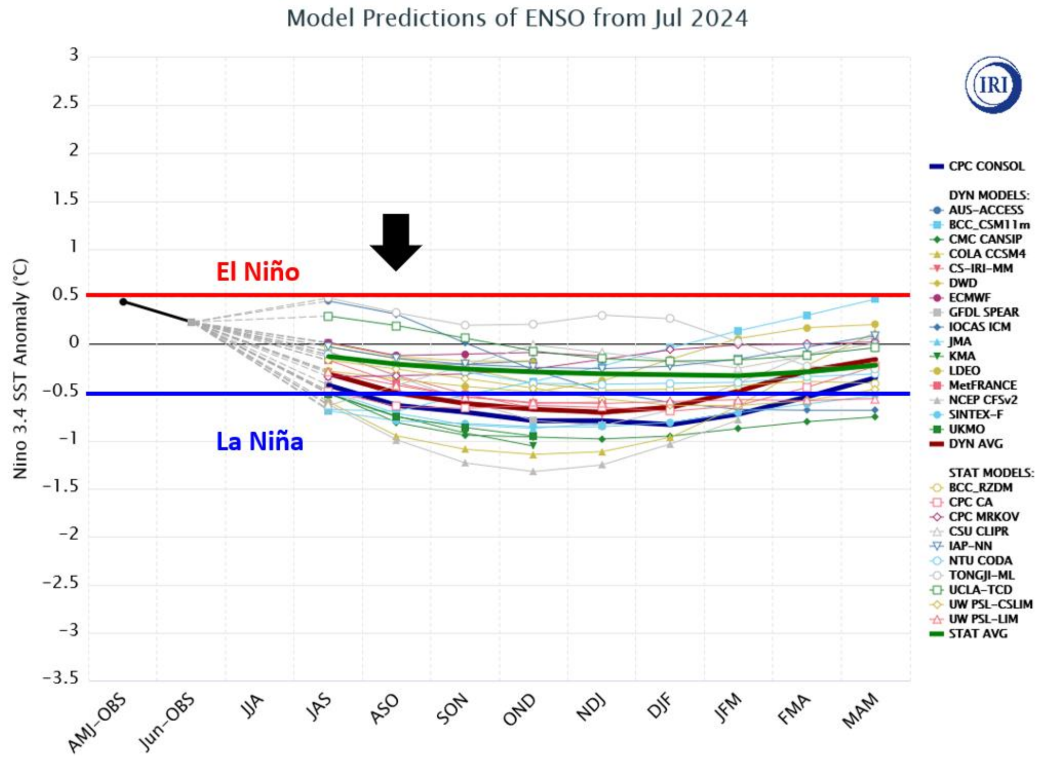

Figure 23: ENSO forecasts from various statistical and dynamical models for the Nino 3.4 SST anomaly based on late June to early July initial conditions. Figure courtesy of the International Research Institute (IRI). The black arrow denotes the peak of the Atlantic hurricane season (August–October).

The latest official forecast from NOAA favors the cooler guidance and calls for a 70% chance of La Niña for August–October (Figure 24). We also tend to think that La Niña is favored given how robust the trade winds look to be coming up across the central Pacific. As noted earlier, even if the official definition of La Niña is not met for the peak of the Atlantic hurricane season, we may exceed the threshold for the Relative Oceanic Nino Index, indicating a La Niña-like oceanic state.

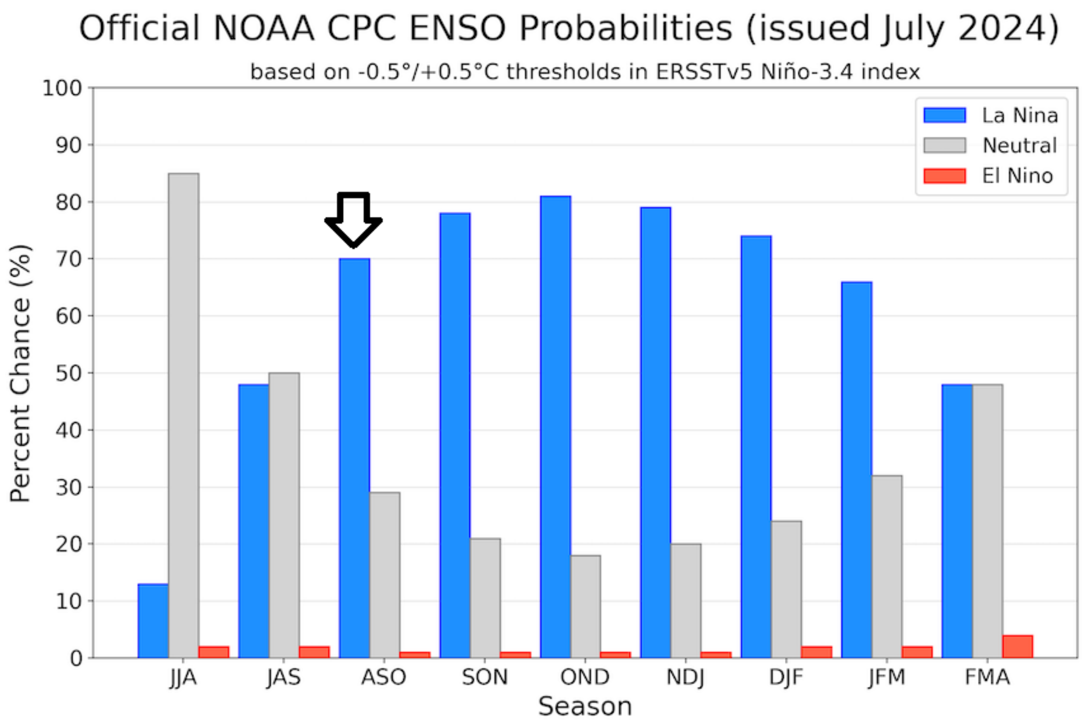

Figure 24: Official NOAA probabilistic forecast for ENSO. The black arrow denotes the peak of the Atlantic hurricane season (August–October).

5 Current Atlantic Basin Conditions

The North Atlantic remains extremely warm, with current Main Development Region (MDR; 10–20°N, 85–20°W) SSTs about 1.1°C warmer than normal. July-averaged MDR SSTs were the second warmest on record (since 1979), trailing only 2023 by <0.1°C) (Figure 25). July MDR SSTs from 1979 to 2023 correlate with seasonal ACE at 0.59. Prior to 2024, the five warmest July-averaged SSTs were: 2023, 2010, 2005, 1998, and 2020. All but 2023 ended up hyperactive Atlantic seasons. The 2023 season still ended up with above-average Atlantic hurricane activity despite strong El Niño conditions.

The recent SST anomaly pattern matches quite well with the historical SST pattern in August that has correlated with active Atlantic hurricane seasons (Figure 26). Current SSTs in the MDR are tracking well above a typical hyperactive season (Figure 27).

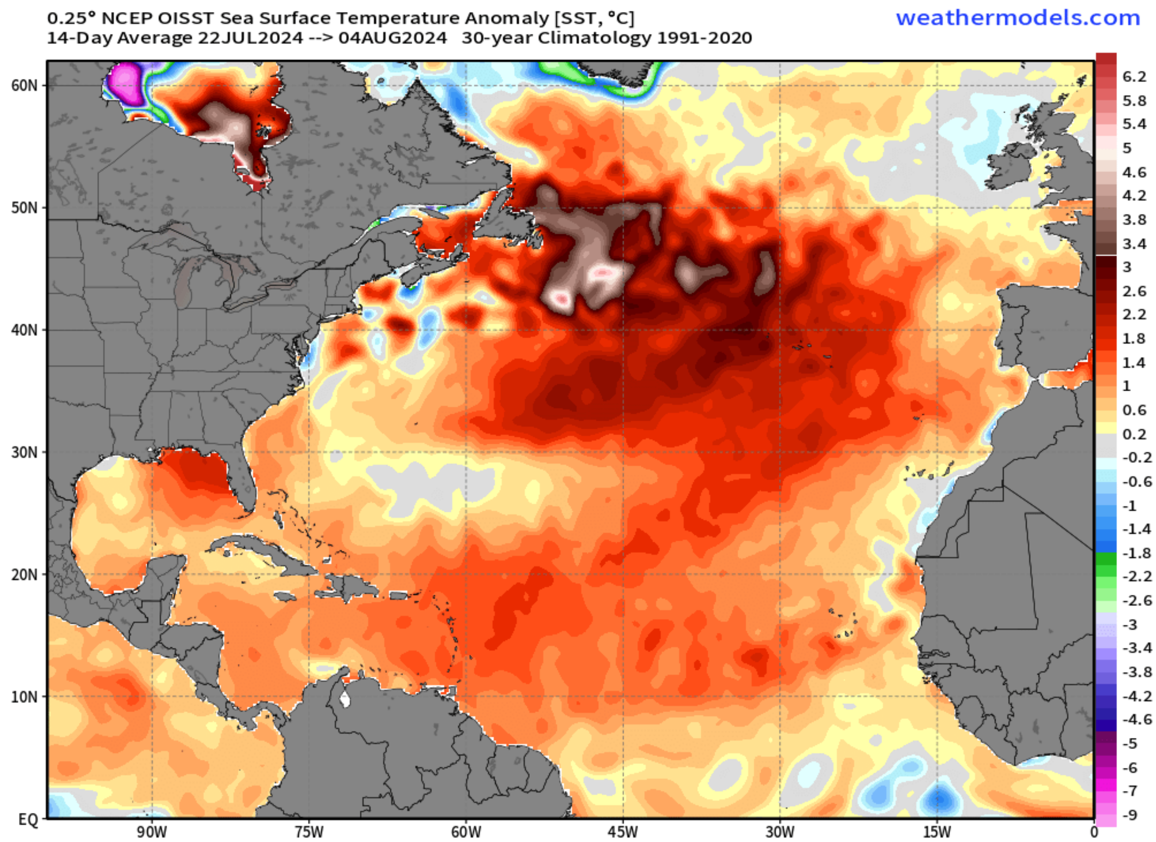

Figure 25: Late July/early August SST anomaly pattern across the North Atlantic Ocean.

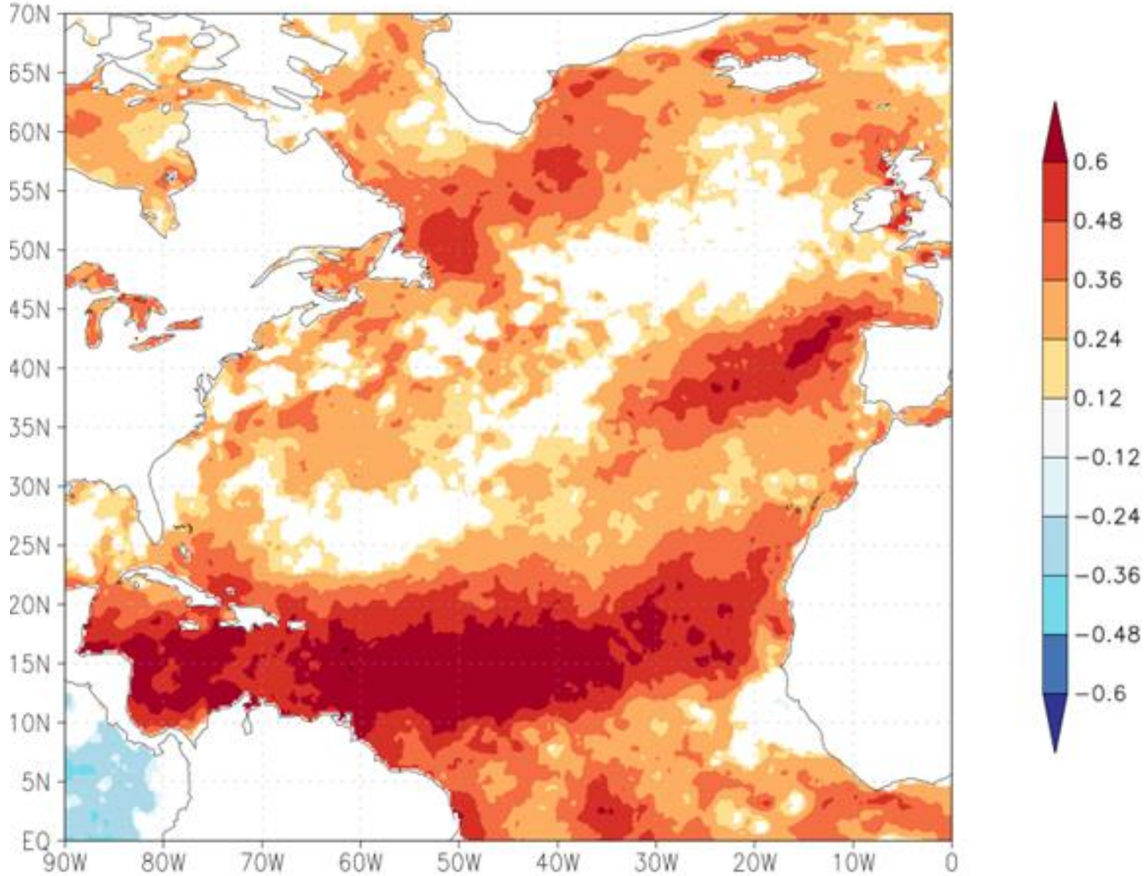

Figure 26: Correlation between August North Atlantic SSTs and seasonal Atlantic ACE.

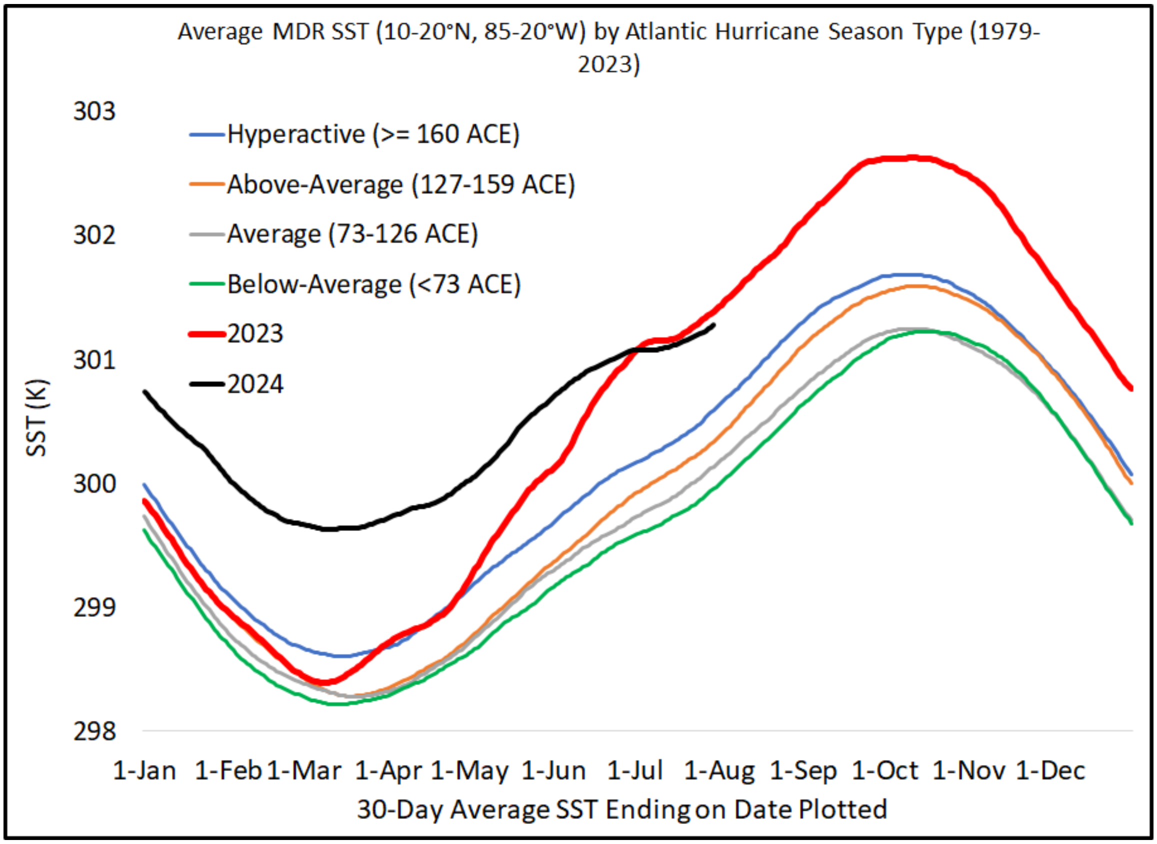

Figure 27: 30-day average SSTs for various Atlantic hurricane season types from 1979–2023 based on the NOAA definition. Also plotted are SSTs for 2023 (for comparison). Sea surface temperature anomalies in the tropical Atlantic in 2024 are currently tracking well above the typical hyperactive Atlantic hurricane season but slightly below 2023.

30-day-averaged vertical wind shear is running at below-average levels across most of the MDR (Figure 28). Current 30-day-averaged zonal wind shear across the MDR is tracking near what is typically experienced in hyperactive seasons (Figure 29).

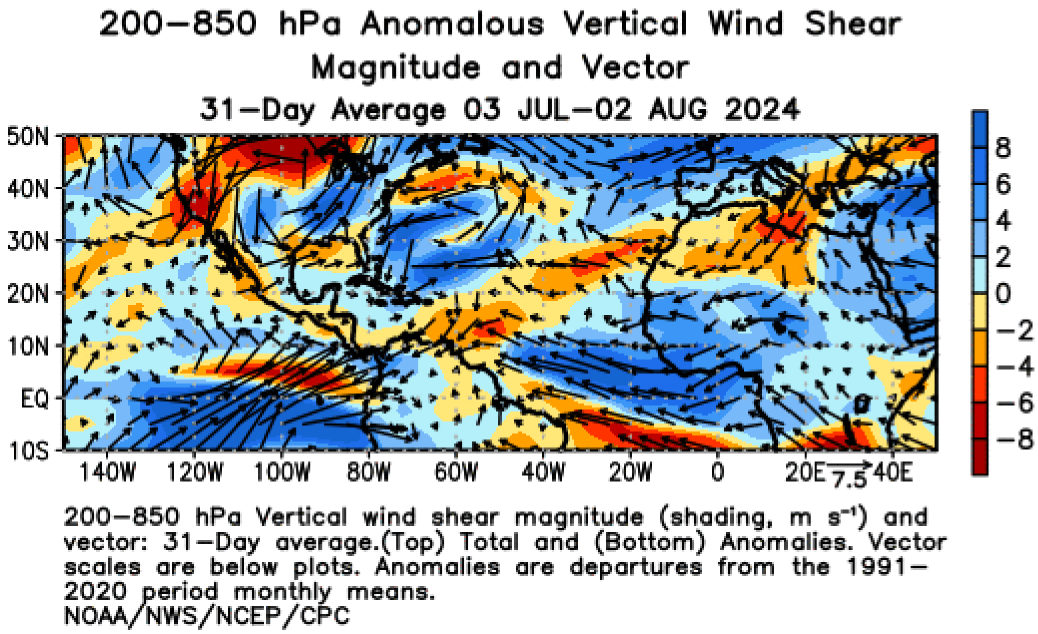

Figure 28: 3 July – 2 August-averaged vertical wind shear across the tropical and subtropical Atlantic differenced from the 1991–2020 climatology.

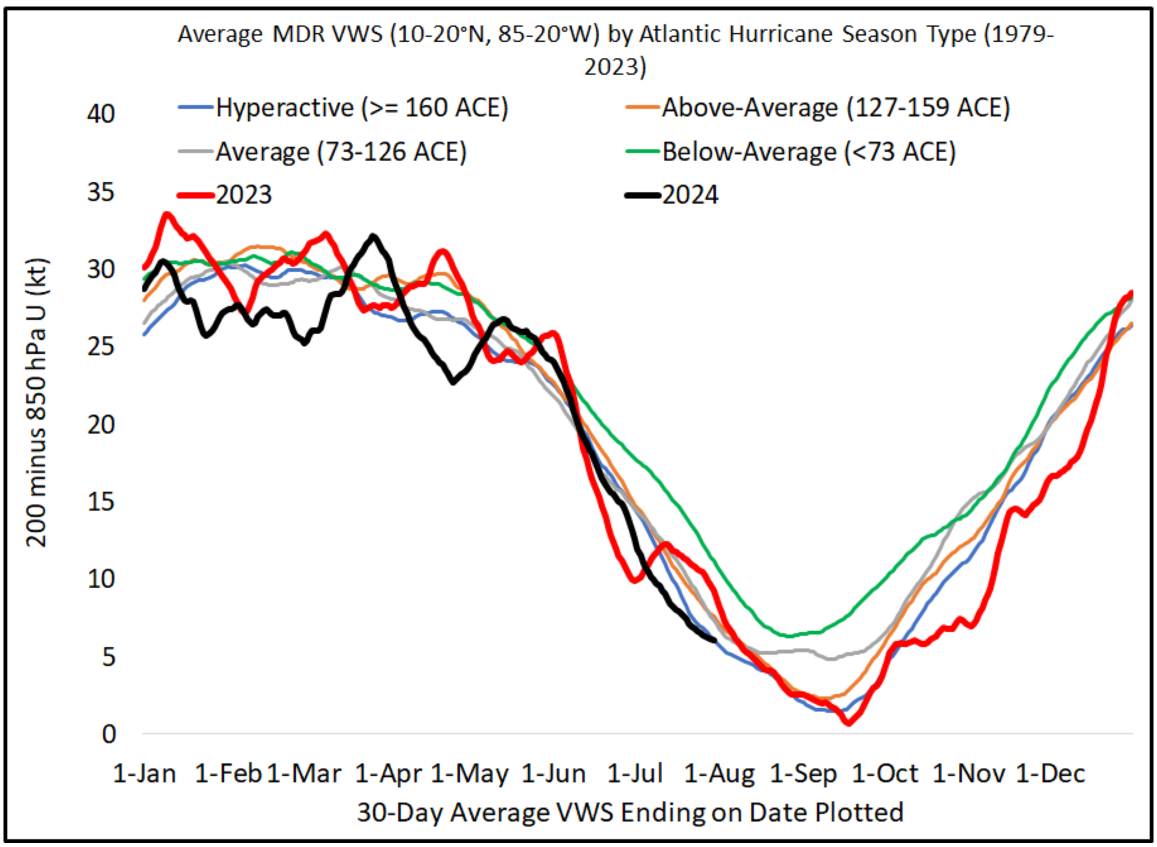

Figure 29: 30-day averaged MDR zonal wind shear in 2024 as well as for various Atlantic hurricane season types from 1979–2023 based on the NOAA definition. Also plotted is zonal wind shear for 2023.

Sea level pressure anomalies across the MDR in July 2024 were below normal (Figure 30). 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.

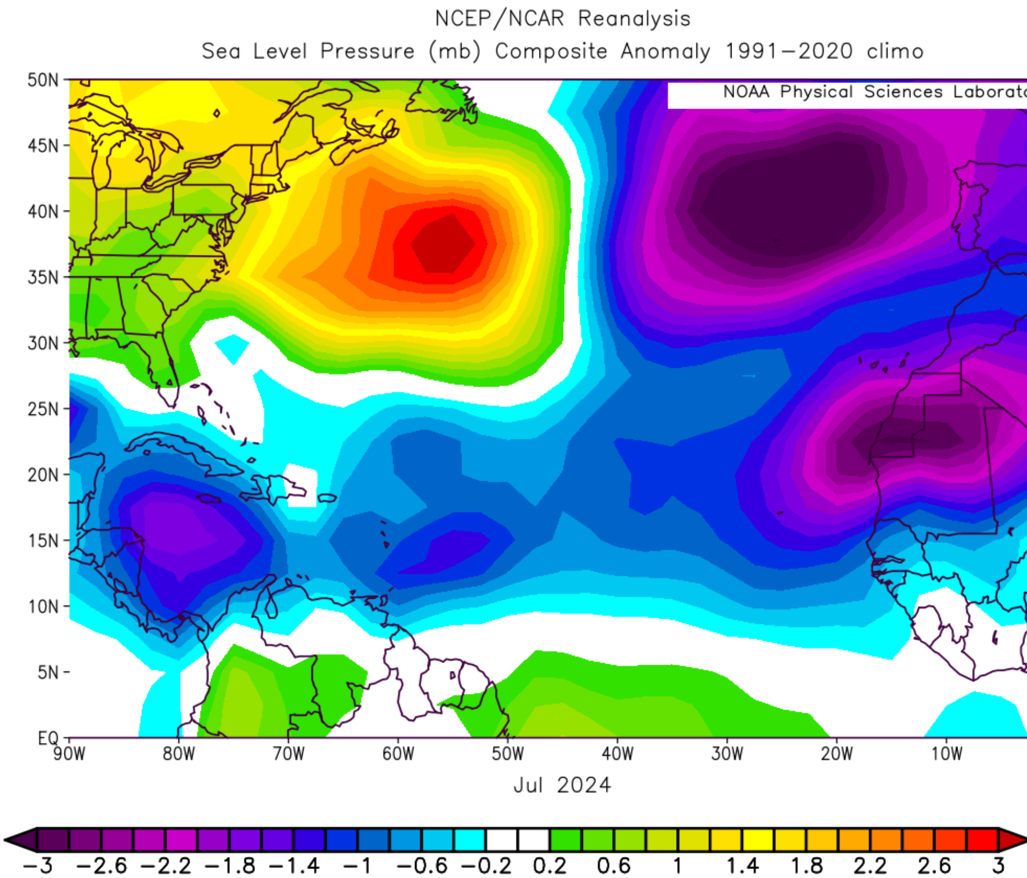

Figure 30: July-averaged sea level pressure anomalies in 2024 across the tropical and subtropical North Atlantic.

While the northern tropical Atlantic remains quite warm, the southern tropical Atlantic has anomalously cooled in recent months, resulting in a strongly positive phase of the Atlantic Meridional Mode (AMM) (Figure 31). Positive phases of the AMM are associated with warm anomalies in the northern tropical Atlantic relative to the southern tropical Atlantic (Figure 32). In response to this SST gradient, an anomalous cross-equatorial pressure gradient develops. This results in anomalous low-level southerly flow across the equator which then veers to westerly wind flow in the northern tropical Atlantic. This wind pattern has predominated over the eastern and central tropical Atlantic in July (Figure 33). These weaker trade winds result in anomalous low-level horizontal vorticity across the MDR, creating a more conducive environment for storm formation across the Atlantic MDR.

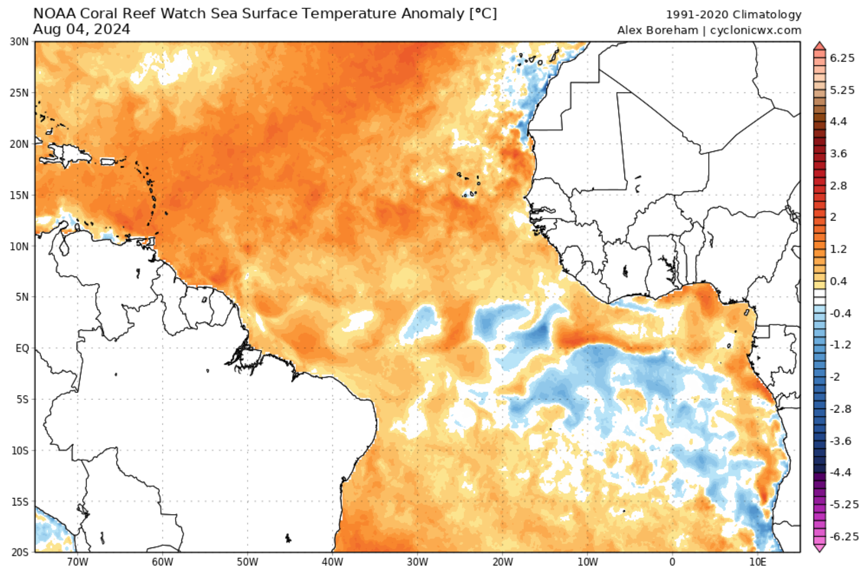

Figure 31: Current SST anomalies in the tropical and subtropical Atlantic.

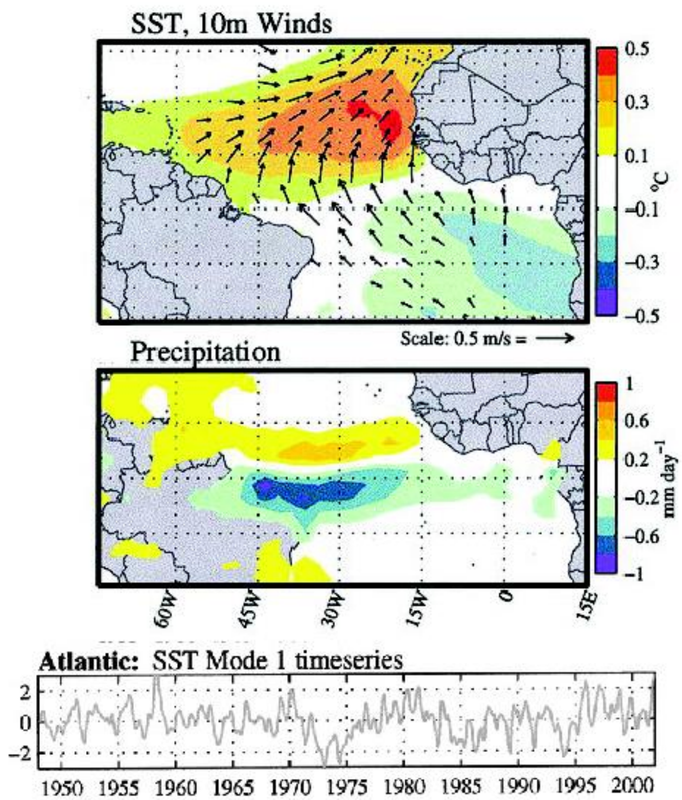

Figure 32: Schematic of the positive phase of the Atlantic Meridional Mode. Figure taken from Chiang and Vimont (2004).

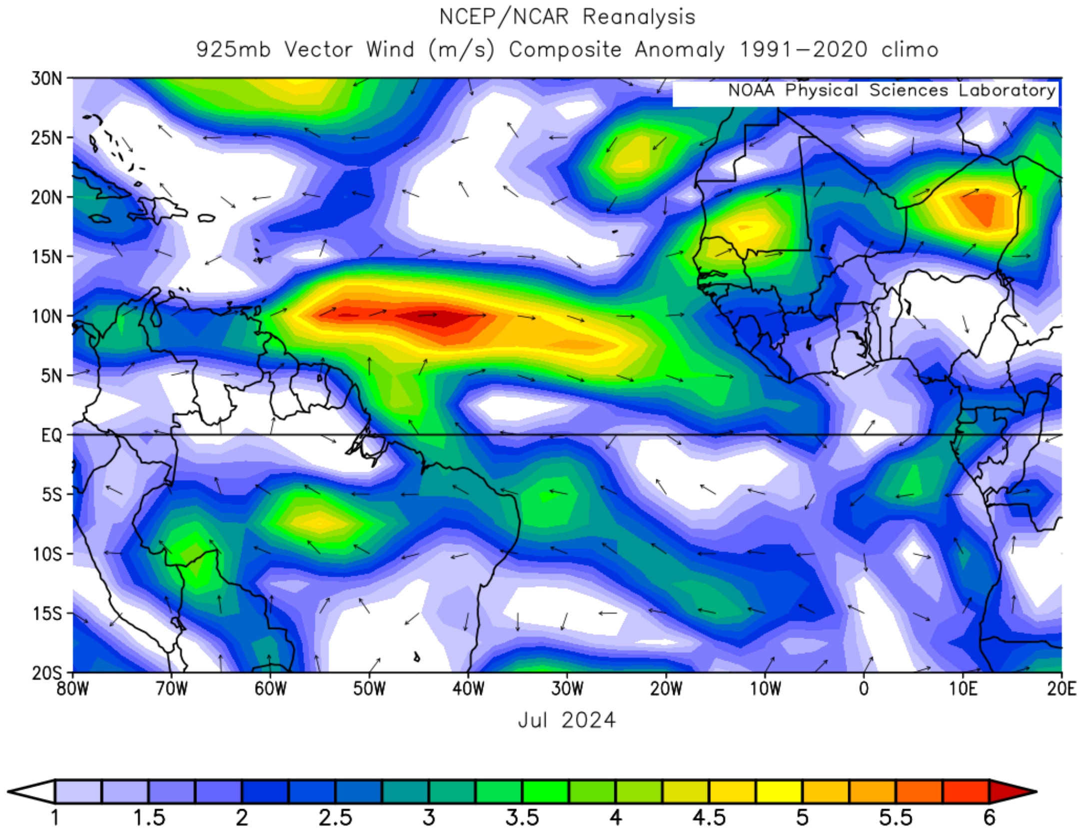

Figure 33: July-averaged 2024 925-hPa vector wind anomalies across the tropical Atlantic.

6 West Africa Conditions

During July, monsoon rainfall over West Africa has been above average (Figure 34). The latest 45-day forecast from ECMWF (Figure 35) indicates that monsoon rainfall across most of West Africa should be well above average, with a pronounced northward shift in the Intertropical Convergence Zone (e.g., above-normal precipitation in the Sahel and below-normal precipitation in the Gulf of Guinea). This anomalous precipitation pattern is associated with more vigorous African easterly waves, likely paving the way for an extremely active hurricane season.

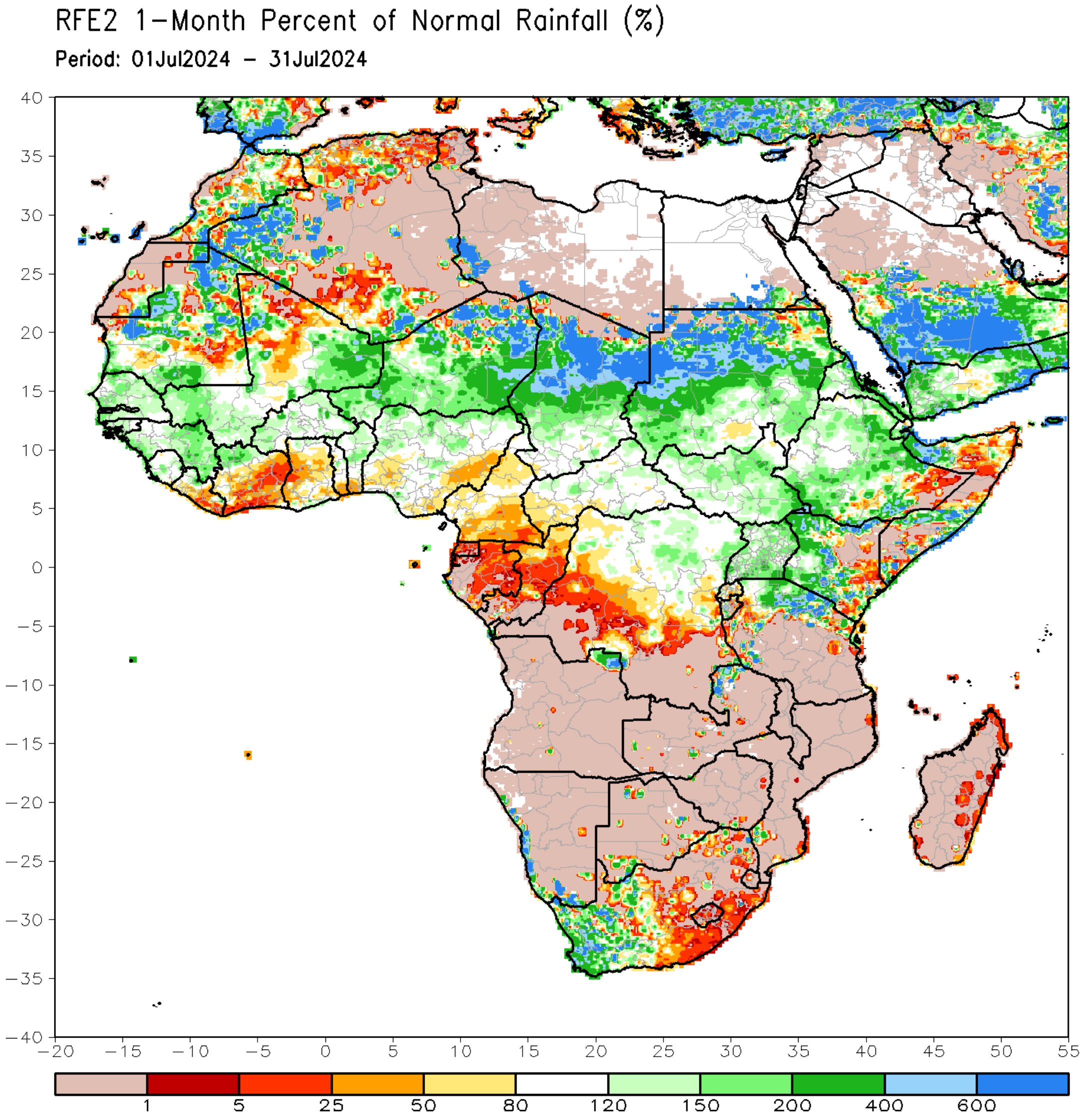

Figure 34: Observed July precipitation across Africa, based on the African Rainfall Estimation Algorithm Version 2.

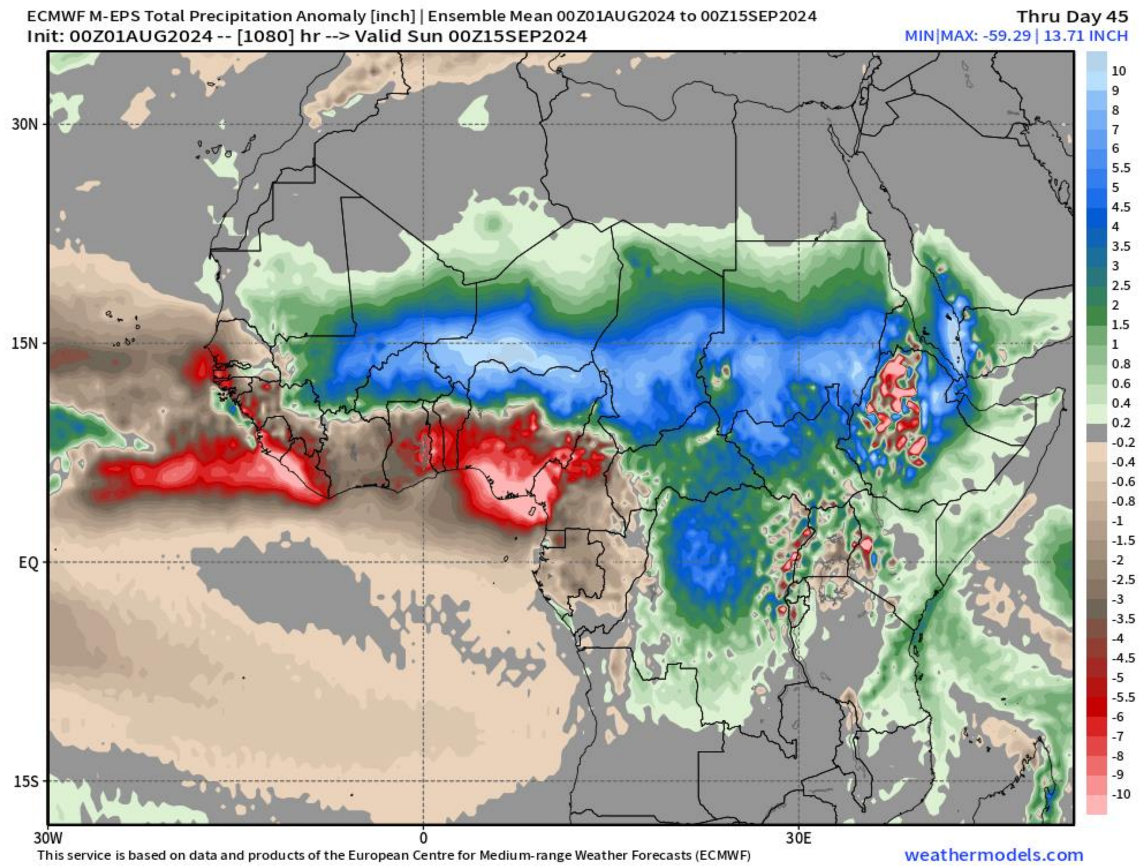

Figure 35: Forecast precipitation across North Africa through 15 September from the ECMWF ensemble.

7 Tropical Cyclone Impact Probabilities for 2024

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 has been 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. Beginning this year, we are adjusting landfall probabilities based on the ratio of predicted ACE west of 60°W to the average ACE west of 60°W, as almost all landmasses that we are issuing probabilities for are west of 60°W.

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 2024. 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 based on a ratio of the forecast ACE relative to the 1991–2020 Atlantic west of 60°W 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). Slight differences in ACE west of 60°W between the two periods (73 for 1991–2020 vs. 66 for 1880–2020) are likely mostly due to improved observational technology in the more recent period.

Table 17: Post-5 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 2024, based on the latest CSU seasonal hurricane forecast.

			2024 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		72%	38%	12%		58%	28%	8%
Connecticut		31%	11%	2%		22%	8%	1%
Delaware		31%	9%	1%		23%	6%	1%
Florida		94%	70%	40%		86%	56%	29%
Georgia		77%	41%	9%		63%	30%	6%
Louisiana		79%	51%	21%		66%	38%	14%
Maine		30%	10%	2%		21%	7%	1%
Maryland		42%	15%	1%		31%	11%	1%
Massachusetts		44%	21%	4%		33%	14%	3%
Mississippi		67%	39%	11%		53%	28%	8%
New Hampshire		25%	8%	2%		18%	6%	1%
New Jersey		31%	10%	1%		23%	7%	1%
New York		36%	14%	3%		26%	9%	2%
North Carolina		81%	51%	11%		68%	38%	8%
Rhode Island		29%	11%	2%		20%	8%	1%
South Carolina		71%	40%	12%		57%	29%	8%
Texas		75%	49%	22%		61%	36%	16%
Virginia		59%	28%	2%		46%	20%	1%

7 Summary

An analysis of a variety of different atmosphere and ocean measurements (through early August) 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 2024 will have well above-average activity. The big question marks with this season's prediction are the persistence of the anomalous warmth in the tropical Atlantic, as well as the potential strength of a La Niña, should it develop.

8 Forthcoming Updated Forecasts of 2024 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, Tuesday, 6 August and continuing every other Tuesday (20 August, 3 September, etc.) A verification and discussion of all 2024 forecasts will be issued on **Tuesday, 26 November**. All forecasts and verifications are available on our website.

9 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 2014–2023 and from 1984–2023 for the June and August forecasts and from 1995–2013, 2014–2023 and from 1995–2023 for the April forecast, respectively. Correlation skill has improved at all lead times in recent years, with the most noticeable improvements at longer lead times. While ten 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:

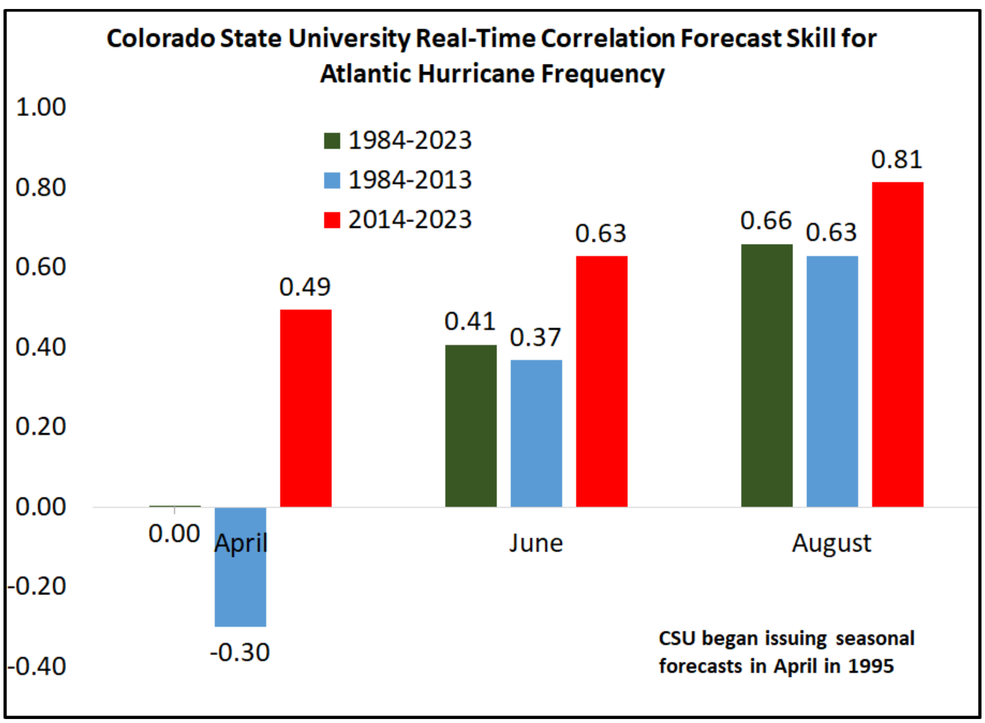

Figure 36: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2023 and 1984–2023 for the June and August forecasts and for 1995–2013, 2014–2023 and 1995–2023 for the April forecast.