FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2025

We have decreased our forecast slightly and now call for a slightly above-normal 2025 Atlantic basin hurricane season. The primary reason for the slight decrease in the outlook is both observed and predicted high levels of Caribbean shear. High levels of Caribbean shear in June/July are typically associated with less active hurricane seasons. However, we also anticipate the tropical Pacific to be characterized by ENSO neutral conditions. Sea surface temperatures across the eastern and central Atlantic are slightly warmer than normal, but not as warm as they were last year at this time. A warmer-than-normal tropical Atlantic combined with likely ENSO neutral conditions typically provides a more conducive dynamic and thermodynamic environment for hurricane formation and intensification. We anticipate a slightly above-average probability for major hurricanes making landfall 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 9 July 2025)

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

Jennifer Dimas and Joshua Rhoten, Colorado State University media representatives, are coordinating media inquiries in English and Spanish. They can be reached at Jennifer.Dimas@colostate.edu and Joshua.Rhoten@colostate.edu, respectively.

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

Project Supporters:

INSURANCE INFORMATION INSTITUTE
Affiliated with The Institutes
IRONSHORE
A Liberty Mutual Company
WEATHERBOY.COM
Gallagher Re

[1] Senior Research Scientist
[2] Professor
[3] Research Scientist
[4] Team members include: Tyler Barbero, Lauren Beard, Delián Cólon Burgos, Jen DeHart, Chandler Jenkins, Nick Mesa, Isaac Schluesche and Meghan Stell.
[5] Research Scholar at NC State University
[6] Professor Emeritus

ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2025

Forecast Parameter and 1991-2020 Average (in parentheses)	Issue Date 3 April 2025	Issue Date 11 June 2025	Issue Date 9 July 2025	Observed Thru 8 July 2025	Remainder of Season Forecast
Named Storms (NS) (14.4)	17	17	16	3	13
Named Storm Days (NSD) (69.4)	85	85	80	2.5	77.5
Hurricanes (H) (7.2)	9	9	8	0	8
Hurricane Days (HD) (27.0)	35	35	30	0	30
Major Hurricanes (MH) (3.2)	4	4	3	0	3
Major Hurricane Days (MHD) (7.4)	9	9	8	0	8
Accumulated Cyclone Energy (ACE) (123)	155	155	140	1	139
ACE West of 60°W (73)	93	93	87	1	86
Net Tropical Cyclone Activity (NTC) (135%)	165	165	145	6	139

PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING COASTAL AREAS (AFTER 8 JULY):

1) Entire continental U.S. coastline – 48% (average from 1880–2020 is 43%)

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

3) Gulf Coast from the Florida Panhandle (west and north of Cedar Key, Florida) westward to Brownsville – 31% (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 8 JULY):

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

ABSTRACT

Information obtained through June indicates that the 2025 Atlantic hurricane season will have activity slightly above the 1991–2020 average. We estimate that 2025 will have 16 named storms (average is 14.4), 80 named storm days (average is 69.4), 8 hurricanes (average is 7.2), 30 hurricane days (average is 27.0), 3 major (Category 3-4-5) hurricanes (average is 3.2) and 8 major hurricane days (average is 7.4). The probability of U.S. and Caribbean major hurricane landfall is estimated to be slightly above its long-period average. We predict Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity in 2025 to be approximately 115 percent of their long-term averages. We have reduced our forecast numbers slightly from our April and June outlooks, due to observed and predicted high levels of Caribbean wind shear.

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.

This forecast is based on an extended-range early July statistical prediction scheme that was developed using ~40 years of past data. Analog predictors are utilized as well. 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 as four additional forecast guidance tools. While all of our quantitative model guidance is pointing towards a very busy season, the aforementioned strong Caribbean shear has caused us to lower our forecast.

The tropical Pacific is currently characterized by ENSO neutral conditions. Our best estimate is that ENSO neutral conditions will likely persist throughout the hurricane season. Sea surface temperatures in the eastern and central tropical Atlantic are slightly warmer than normal, although not as warm as they were last year at this time. A warmer-than-normal Atlantic combined with ENSO neutral conditions typically favors an active Atlantic hurricane season via dynamic and thermodynamic conditions that are conducive for developing hurricanes (e.g., low vertical wind shear, increased upper ocean heat content).

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

Why issue extended-range forecasts for seasonal hurricane activity?

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

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early July. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged with respect to the probability of an active or inactive hurricane season for the coming year. Our early July statistical and statistical/dynamical hybrid models show strong evidence on ~25–40 years of data that significant improvement over a climatological forecast can be attained. We would never issue a seasonal hurricane forecast unless we had models developed over a long hindcast period which showed skill. We also 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 that are discussed in a paper highlighting his research legacy. His investments in both time and energy on 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 and Alex DesRosiers, Ph.D. graduates from 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, Lauren Beard, Delián Cólon Burgos, Jen DeHart, Chandler Jenkins, Nick Mesa, Isaac Schluesche and Meghan Stell.

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, Michael Lowry, Brian McNoldy, Paul Roundy, Carl Schreck, Mike Ventrice, and Peng Xian over the past few years.

DEFINITIONS AND ACRONYMS

Accumulated Cyclone Energy (ACE) - A measure of a named storm's potential for wind destruction defined as the sum of the square of a named storm's maximum wind speed (in 10^4 knots^2) for each 6-hour period of its existence. The 1991–2020 average value of this parameter is 123 for the Atlantic basin.

Atlantic Multi-Decadal Oscillation (AMO) – A mode of natural variability that occurs in the North Atlantic Ocean and evidencing itself in fluctuations in sea surface temperature and sea level pressure fields. The AMO is likely related to fluctuations in the strength of the oceanic thermohaline circulation. Although several definitions of the AMO are currently used in the literature, we define the AMO based on North Atlantic sea surface temperatures from 50–60°N, 50–10°W and sea level pressure from 0–50°N, 70–10°W.

Atlantic Basin – The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño – A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3–7 years on average.

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.

Relative Oceanic Nino Index (RONI) – Three-month running mean of SST anomalies in the Nino 3.4 region (5°S–5°N, 170–120°W) minus tropically-averaged (20°S–20°N) SST anomalies multiplied by a scaling factor.

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.

Thermohaline Circulation (THC) – A large-scale circulation in the Atlantic Ocean that is driven by fluctuations in salinity and temperature. When the THC is stronger than normal, the AMO tends to be in its warm (or positive) phase, and more Atlantic hurricanes typically form.

Tropical Cyclone (TC) - A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms and other weaker rotating vortices.

Tropical Storm (TS) - A tropical cyclone with maximum sustained winds between 39 mph (18 ms^{-1} or 34 knots) and 73 mph (32 ms^{-1} or 63 knots).

Vertical Wind Shear – The difference in horizontal wind between 200 hPa (approximately 40000 feet or 12 km) and 850 hPa (approximately 5000 feet or 1.6 km).

1 knot = 1.15 miles per hour = 0.515 meters per second

1 Introduction

This is the 42nd 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 forecast with skill exceeding climatology. Four components are used to produce our July forecast. These components are a statistical regression model, a combined statistical/dynamical model, a selection of analog seasons, and lastly, qualitative adjustments to accommodate additional processes which may not be explicitly represented by these analyses. The statistical/dynamical models are 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) modeling agencies. All of these models show skill at predicting TC activity based on ~25–40 years of historical data. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic basin TC activity and landfall probability. We believe that seasonal forecasts must be based on methods that show significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided that the atmosphere continues to behave in the future as it has in the past.

The best predictors do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain the portion of the variance of seasonal hurricane activity that are not associated with the other forecast variables. It is possible for an important hurricane forecast parameter to show little direct relationship to a predictand by itself but to have an important influence when included with a set of 2–3 other predictors.

2 July Forecast Methodology

2.1 July Statistical Forecast Scheme

The current iteration of the July statistical forecast model uses ECMWF Reanalysis 5 (ERA5; Hersbach et al. 2020) data for all three predictors. This forecast model was developed over 1979–2020 and then was tested on the 2021 and 2022 Atlantic hurricane seasons (e.g., those years were purposely left out to see how well the model would work at forecasting these omitted years). The model was then used in real-time in 2023 and 2024. The forecast model did somewhat over-forecast Atlantic hurricane activity the past two years. This model shows significant skill in cross-validated (e.g., leaving the year out of the developmental model that is being predicted) hindcasts of Accumulated Cyclone Energy (ACE) (r = 0.75) over the period from 1979–2024 (Figure 1).

Figure 2 displays the locations of the three predictors, while Table 1 displays the individual linear correlations between each predictor and ACE over the 1979–2024 hindcast/forecast period. All three predictors correlate significantly at the 5% level using a two-tailed Student's t-test and assuming that each year represents an individual degree of freedom. Table 2 displays the 2025 observed values for the three predictors in the statistical forecast scheme. Table 3 displays the statistical model output for the 2025 hurricane season. The June Atlantic Main Development Region SST predictor is slightly above its long-term average, while the eastern subtropical Atlantic SST predictor is the 4th warmest since 1979 and is the primary driver of the hyperactive forecast from the statistical model. The tropical Pacific SST predictor is near its long-term average, consistent with the current ENSO neutral conditions. The three predictors in combination call for a well above-average season.

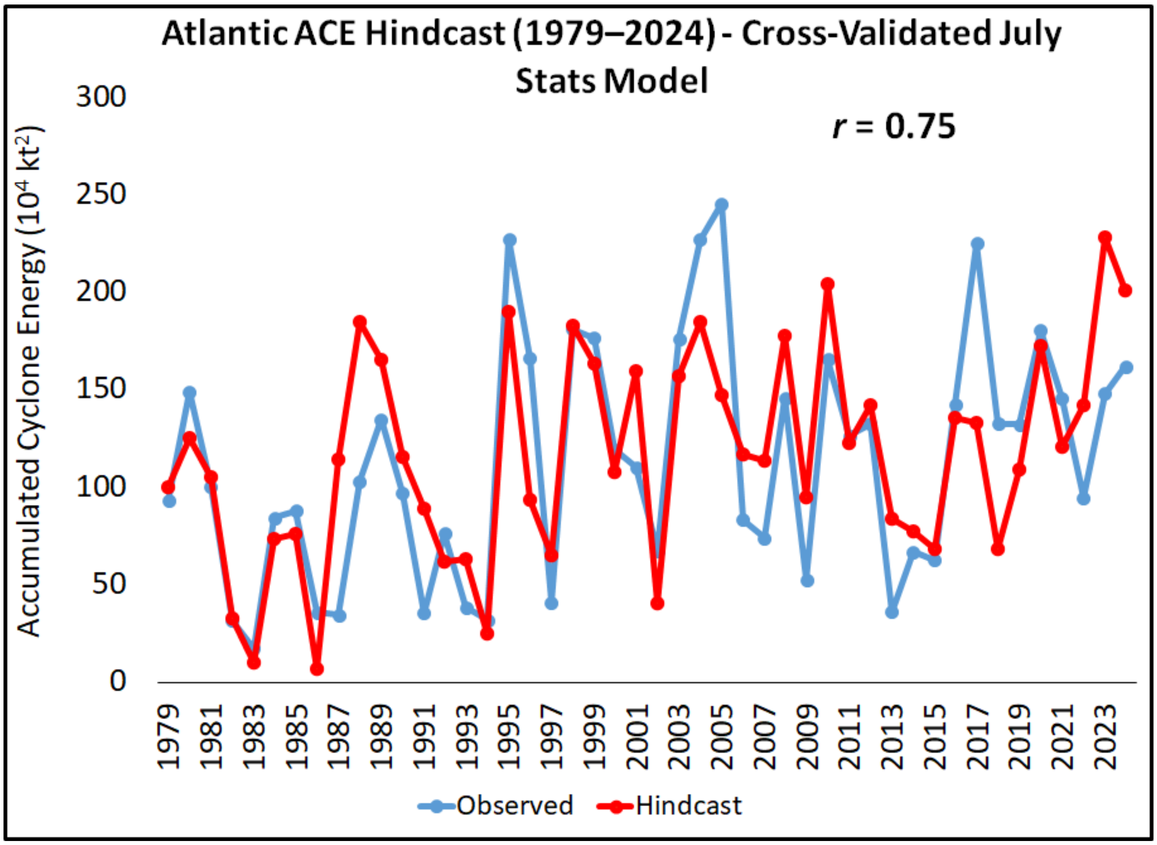


Figure 1: Observed versus early July cross-validated hindcast values of ACE for the statistical model from 1979–2024.

July Forecast Predictors

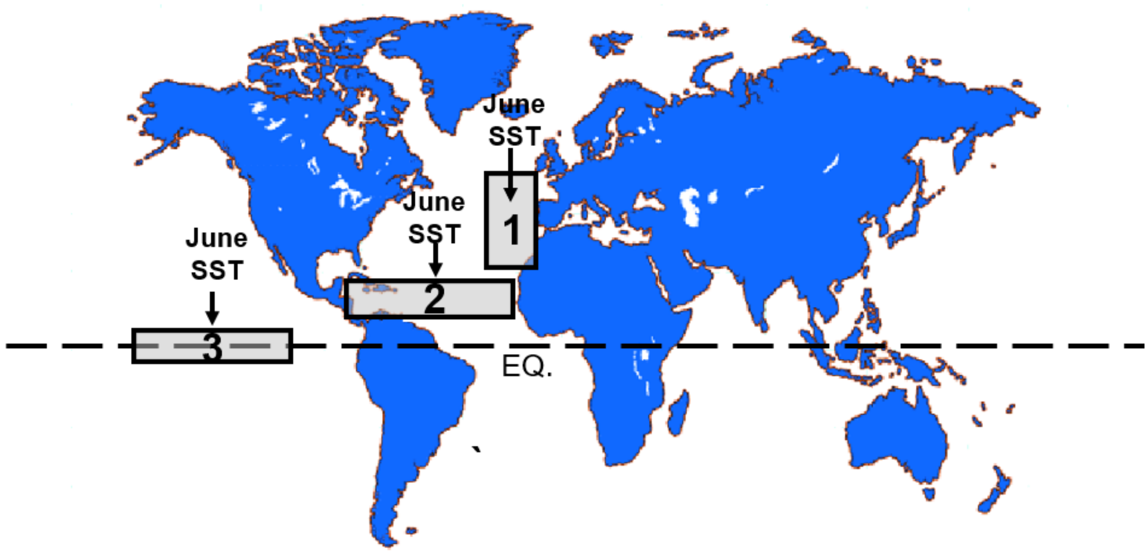


Figure 2: Location of predictors for the early July extended-range statistical prediction for the 2025 hurricane season.

Table 1: Linear correlation between early July predictors and ACE over the period from 1979–2024.

Predictor	Correlation w/ ACE
1) June SST (30°N–50°N, 30°W–10°W) (+)	0.64
2) June SST (10°N–20°N, 85°W–20°W) (+)	0.46
3) June SST (5°S–5°N, 160°W–110°W) (-)	-0.38

Table 2: Listing of early July 2025 predictors for the 2025 hurricane season. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity. SD stands for standard deviation.

Predictor	2025 Forecast Value	Impact on 2025 TC Activity
1) June SST (30°N–50°N, 30°W–10°W) (+)	+1.8 SD	Strongly Enhance
2) June SST (10°N–20°N, 85°W–20°W) (+)	+0.2 SD	Slightly Enhance
3) June SST (5°S–5°N, 160°W–110°W) (-)	-0.2 SD	Slightly Enhance

Table 3: Statistical model output for the 2025 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Forecast	Final Forecast
Named Storms (NS) (14.4)	19.5	16
Named Storm Days (NSD) (69.4)	94.3	80
Hurricanes (H) (7.2)	9.8	8
Hurricane Days (HD) (27.0)	40.6	30
Major Hurricanes (MH) (3.2)	4.8	3
Major Hurricane Days (MHD) (7.4)	12.3	8
Accumulated Cyclone Energy (ACE) (123)	182	140
Net Tropical Cyclone Activity (NTC) (135%)	197	145

The locations and brief descriptions of the predictors for our early July statistical forecast are now discussed. All three predictors correlate with physical features during August through October that are known to be favorable for elevated levels of hurricane activity. These factors are all generally related to August–October vertical wind shear in the Atlantic Main Development Region (MDR) from 10–20°N, 85–20°W as shown in Figure 3.

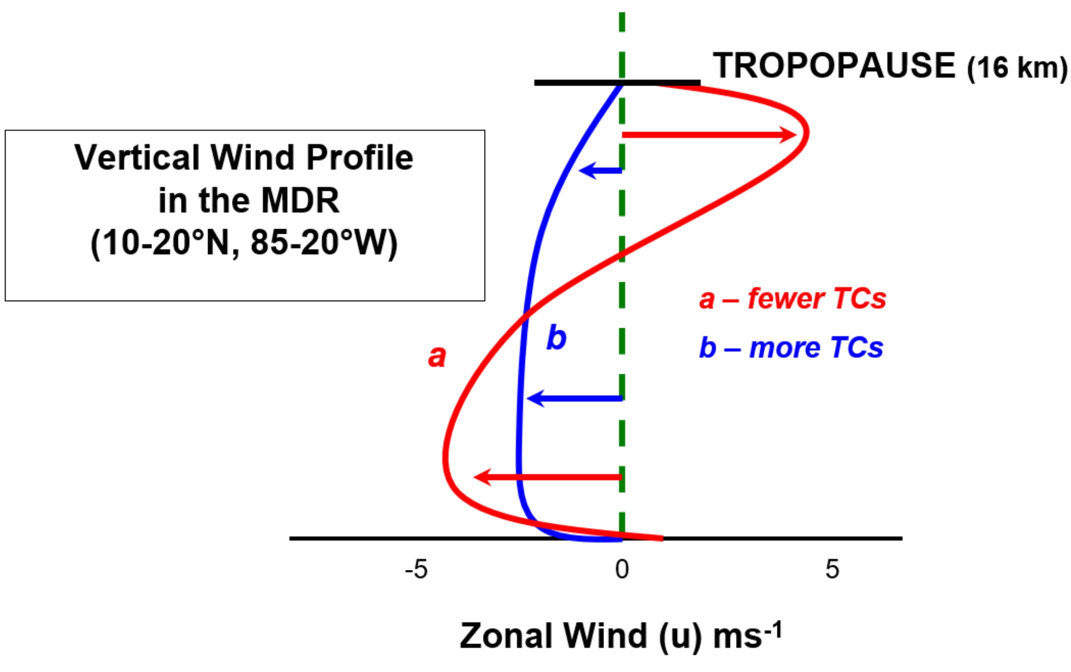


Figure 3: Vertical wind profile typically associated with (a) inactive Atlantic hurricane seasons and (b) active Atlantic hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

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

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

(30°N–50°N, 30°W–10°W)

Warmer-than-normal SSTs in the subtropical Atlantic during June are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the boreal summer (Knaff 1997). Positive SSTs in June are correlated with weaker trade winds and weaker upper tropospheric westerly winds, lower-than-normal sea level pressures and above-normal SSTs in the tropical Atlantic during the following August–October period (Figure 4). All of these August–October features are commonly associated with active Atlantic basin hurricane seasons, through reductions in vertical wind shear, increased vertical instability and increased mid-tropospheric moisture, respectively. Predictor 1 correlates quite strongly (r =0.64) with ACE from 1979–2024. Predictor 1 also significantly correlates (r = 0.76) with August–October values of the SST component of the Atlantic Meridional Mode (AMM) (Kossin and Vimont 2007) from 1979–2024. The AMM has been shown to impact Atlantic hurricane activity through alterations in the position and intensity of the Atlantic Inter-Tropical Convergence Zone (ITCZ). Changes in the Atlantic ITCZ bring about changes in tropical Atlantic vertical and horizontal wind shear patterns and in tropical Atlantic SST patterns.

<u>Predictor 2. June SSTs in the Atlantic Main Development Region (+)</u>

(10°N–20°N, 85°W–20°W)

Warmer-than-normal SSTs in the Atlantic Main Development Region (MDR) during June are strongly correlated with warmer-than-normal SSTs in the same region during August-October (r =0.67). A warmer-than-normal MDR during the peak of the Atlantic hurricane season provides a more favorable dynamic and thermodynamic environment for hurricane formation and intensification. Above-normal SSTs in the MDR are also associated with lower-than-normal sea level pressures, weaker trade winds and weaker upper-tropospheric westerly winds, thereby reducing vertical wind shear (Figure 5).

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

(5°S–5°N, 160°W–110°W)

Anomalously cool SSTs in the eastern and central tropical Pacific in June correlate strongly with anomalously cool SSTs in the Nino 3.4 region during August–October (*r* =0.82). The Nino 3.4 region is the region that NOAA uses to assess the strength of ENSO events. As would be expected given this significant correlation, cool values of Predictor 3 are also associated with reduced vertical wind shear during the peak of the Atlantic hurricane season, especially in the Caribbean and western tropical Atlantic, where ENSO typically has its strongest impacts (Figure 6).

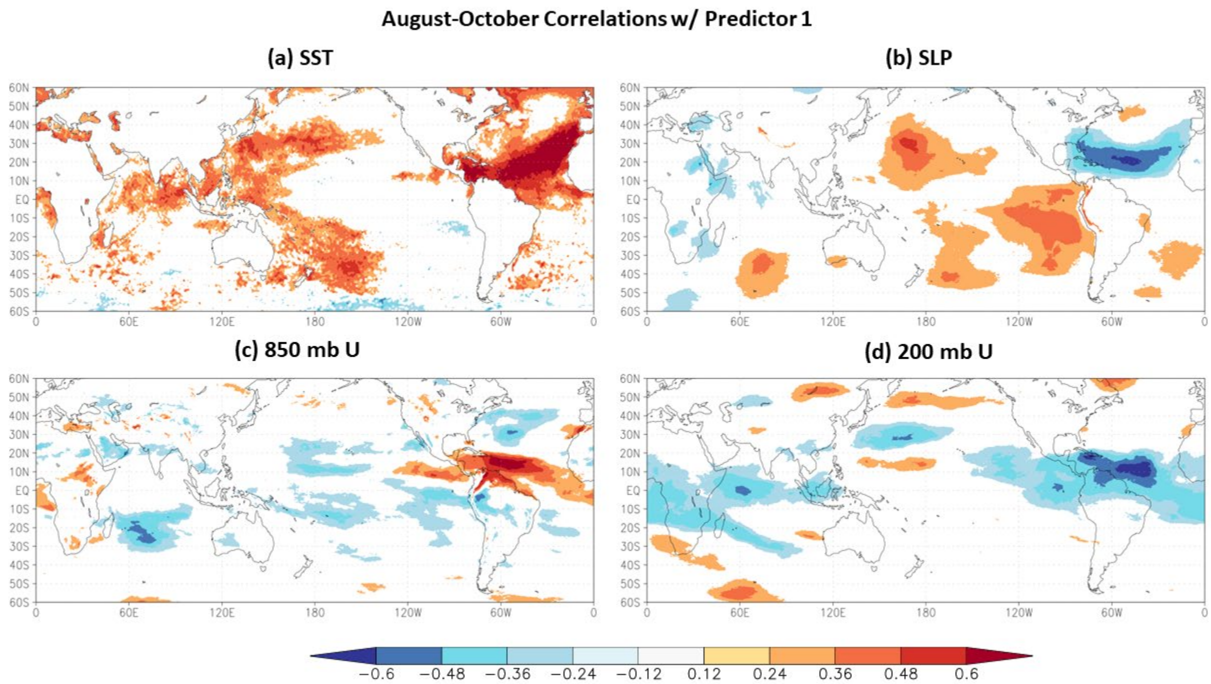


Figure 4: Rank correlations between June SST in the subtropical eastern Atlantic (Predictor 1) and (panel a) August–October sea surface temperature, (panel b) August–October sea level pressure, (panel c) August–October 850 hPa zonal wind and (panel d) August–October 200 hPa zonal wind. All four of these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

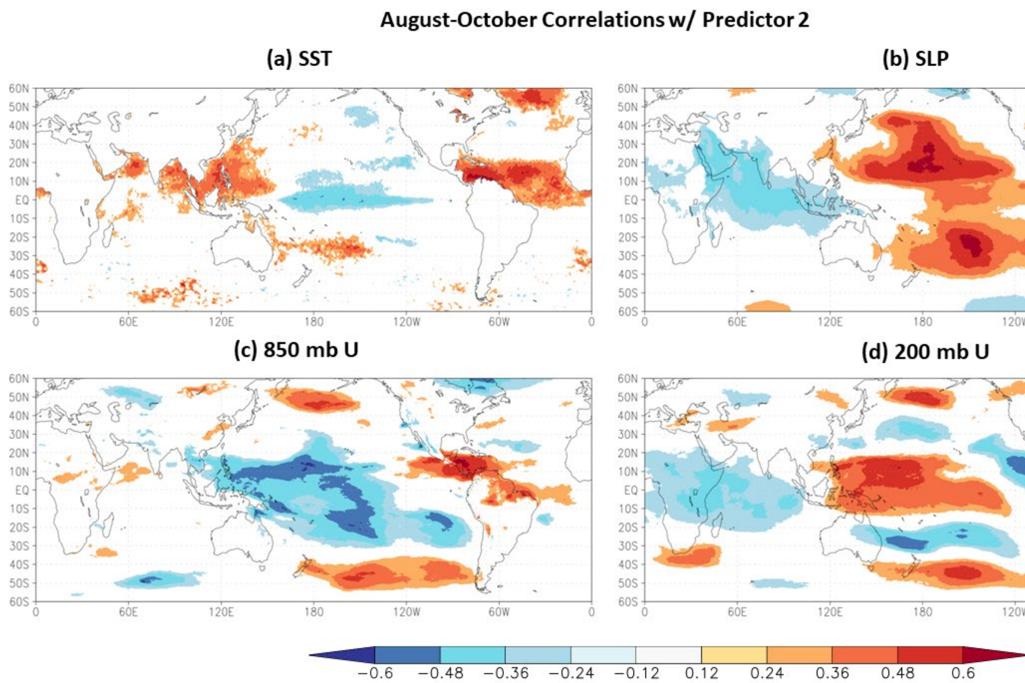


Figure 5: As in Figure 4 but for June SST in the Atlantic Main Development Region.

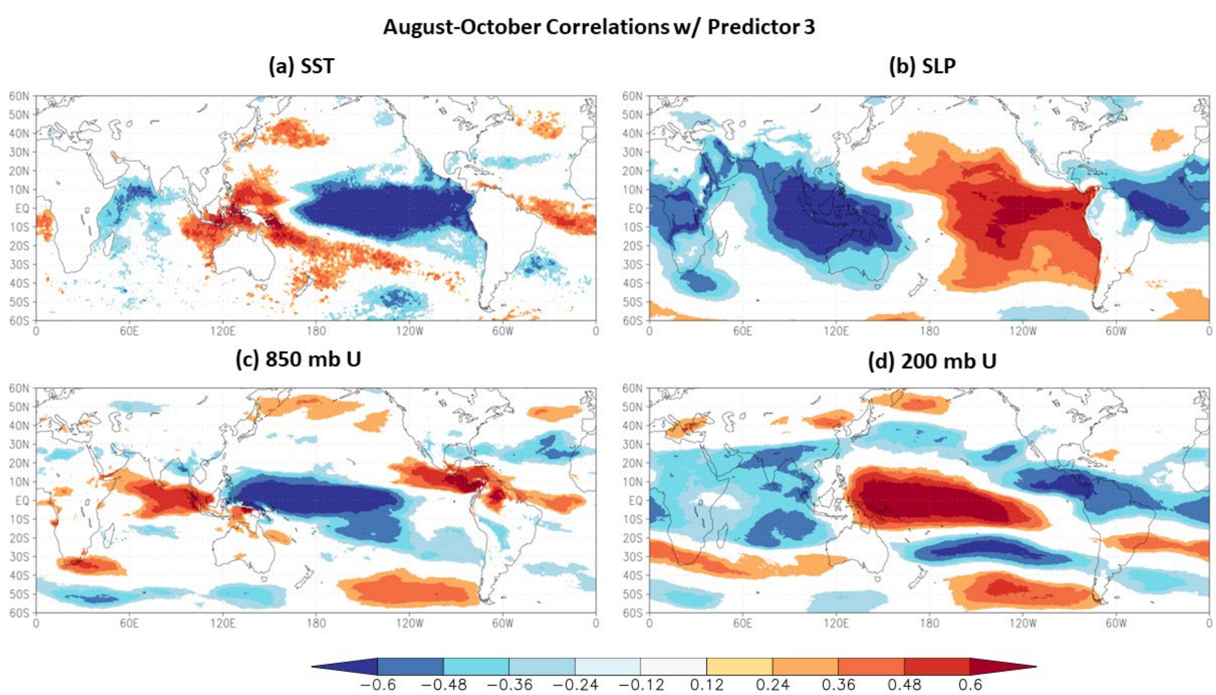
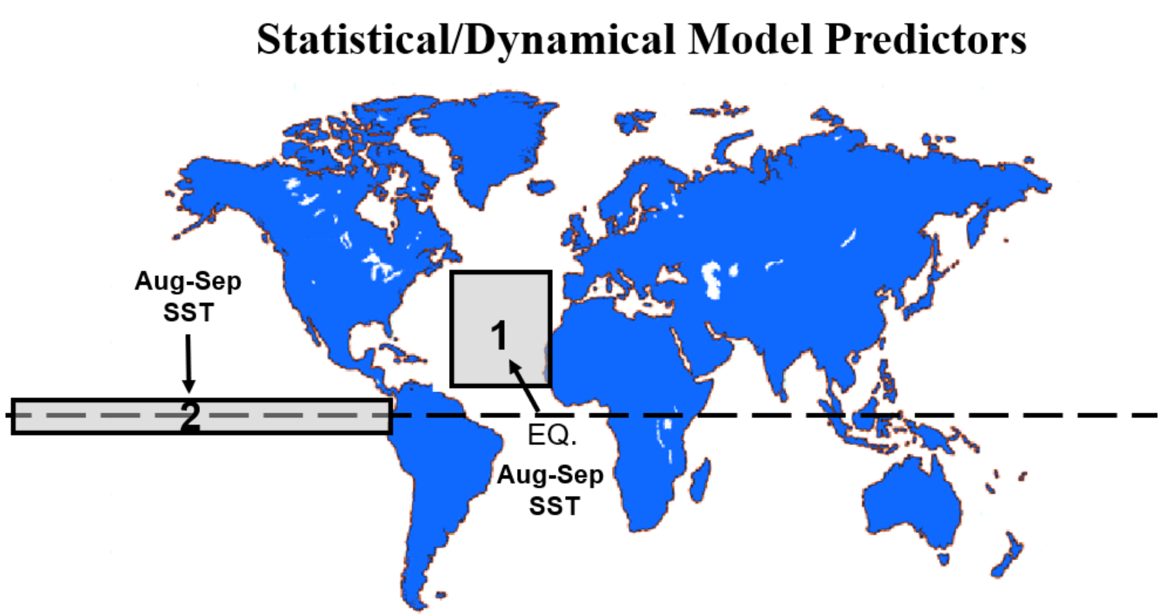


Figure 6: As in Figure 5 but for June SST in the tropical eastern and central Pacific. The sign of the predictor has been reversed for ease of comparison with Figures 4 and 5.

2.2 July Statistical/Dynamical Forecast Schemes

We developed a statistical/dynamical hybrid forecast model scheme that we used for the first time in 2019. This model, developed in partnership with Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre, originally used output from the ECMWF SEAS5 model to forecast the input to our early August statistical forecast model. We now use four different models initialized on 1 June, namely, 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 models to forecast ACE for the 2025 season. ECMWF hindcasts are available from 1981–2024, while all other models have data available spanning the period from 1993–2016. All other predictands (e.g., named storms, major hurricanes) are calculated based on their historical relationships with ACE. All standard deviations are given relative to a 1993–2016 base period – the period for which all four models have hindcasts.

Figure 7 displays the locations of the two forecast parameters, while Table 4 displays the various statistical/dynamical model forecasts for each of these parameters. All models are calling for a very warm eastern and central tropical and subtropical Atlantic and neutral ENSO conditions. Table 5 displays the seasonal TC forecast output for the various statistical/dynamical models. These forecasts all call for a hyperactive[3] 2025 season. Figure 8 displays hindcasts for ECMWF forecasts of ACE from 1981–2024, while Figure 9 displays hindcasts of ACE from all four statistical/dynamical models from 1993–2016 – the joint period where all four models have hindcasts available.



[3] NOAA defines a hyperactive Atlantic hurricane season to have an ACE > 159.6 10^4 kt^2 (https://www.cpc.ncep.noaa.gov/products/outlooks/Background.html)

Figure 7: Location of predictors for our early July statistical/dynamical extended-range statistical prediction for the 2025 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August–September SSTs in the two boxes displayed and then uses those predictors to forecast ACE.

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

Predictor	ECMWF Forecast	UK Met Forecast	JMA Forecast	CMCC Forecast
1) Aug–Sep SST (10–45°N, 60–20°W) (+)	+1.8 SD	+2.9 SD	+1.8 SD	+2.3 SD
2) Aug–Sep SST (5°S–5°N, 180–90°W) (-)	+0.1 SD	-0.7 SD	-0.3 SD	0.0 SD

Table 5: Summary of our statistical/dynamical forecasts.

Forecast Parameter and 1991–2020 Average (in parentheses)	ECMWF Scheme	Met Office Scheme	JMA Scheme	CMCC Scheme	Adjusted Final Forecast
Named Storms (14.4)	18.9	21.6	18.8	19.9	16
Named Storm Days (69.4)	90.5	108.2	89.7	97.3	80
Hurricanes (7.2)	9.4	11.2	9.3	10.1	8
Hurricane Days (27.0)	38.5	48.1	38.1	42.2	30
Major Hurricanes (3.2)	4.5	5.6	4.5	4.9	3
Major Hurricane Days (7.4)	11.5	15	11.4	12.9	8
Accumulated Cyclone Energy Index (123)	173	215	171	189	140
Net Tropical Cyclone Activity (135%)	188	229	186	204	145

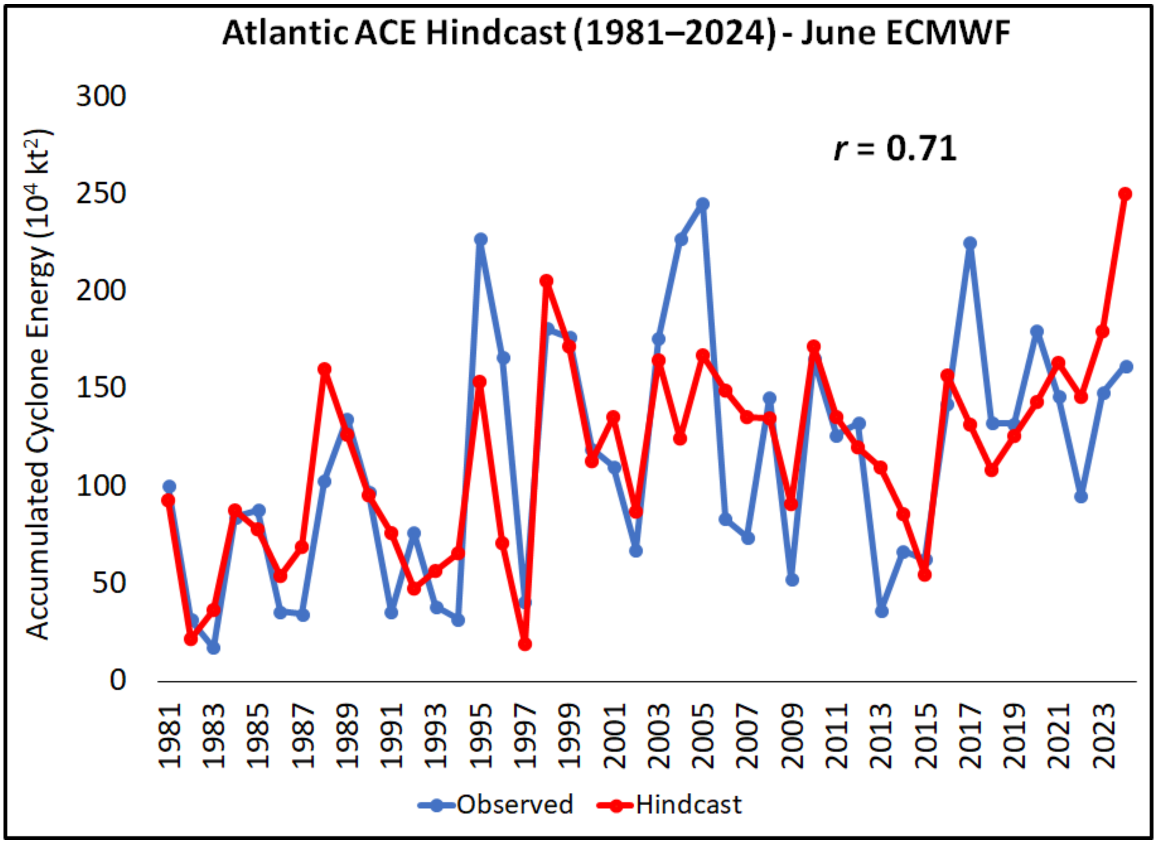


Figure 8: Observed versus statistical/dynamical hindcast values of ACE for 1981–2024 from ECMWF.

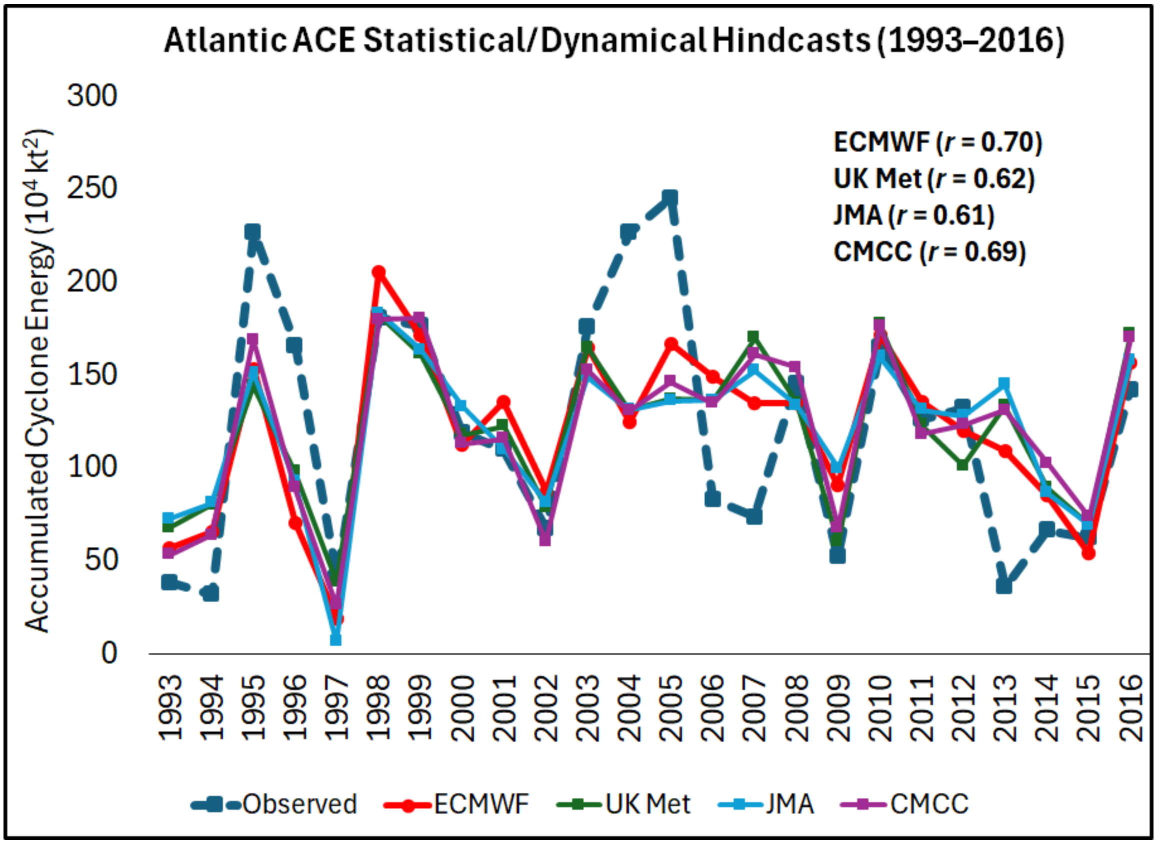


Figure 9: Observed versus statistical/dynamical hindcast values for all four statistical/dynamical models from 1993–2016.

2.3 June Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2025. These years also provide useful clues as to likely levels of activity that the forthcoming 2025 hurricane season may bring. For this early July extended range forecast, we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current conditions and, more importantly, projected August–October 2025 conditions. Table 6 lists our analog selections, while Figure 10 shows the composite August–October SST anomalies in our four analog years.

We searched for years that had either ENSO neutral or weak La Niña conditions. We also selected years that had tropical Atlantic SST anomalies that were higher than eastern and central tropical Pacific SST anomalies. We anticipate that the 2025 hurricane season will have activity near the average of our four analog years for most parameters.

Table 6: Analog years for 2025 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
2001	15	68.75	9	25.50	4	4.25	110.1	135.3
2008	16	88.25	8	30.50	5	7.50	145.7	162.3
2011	19	89.75	7	26.00	4	4.50	126.3	144.9
2021	21	79.75	7	27.75	4	12.75	145.6	173.7
Average	17.8	81.6	7.8	27.4	4.3	7.3	131.9	154.0
2025 Forecast	**16**	**80**	**8**	**30**	**3**	**8**	**140**	**145**

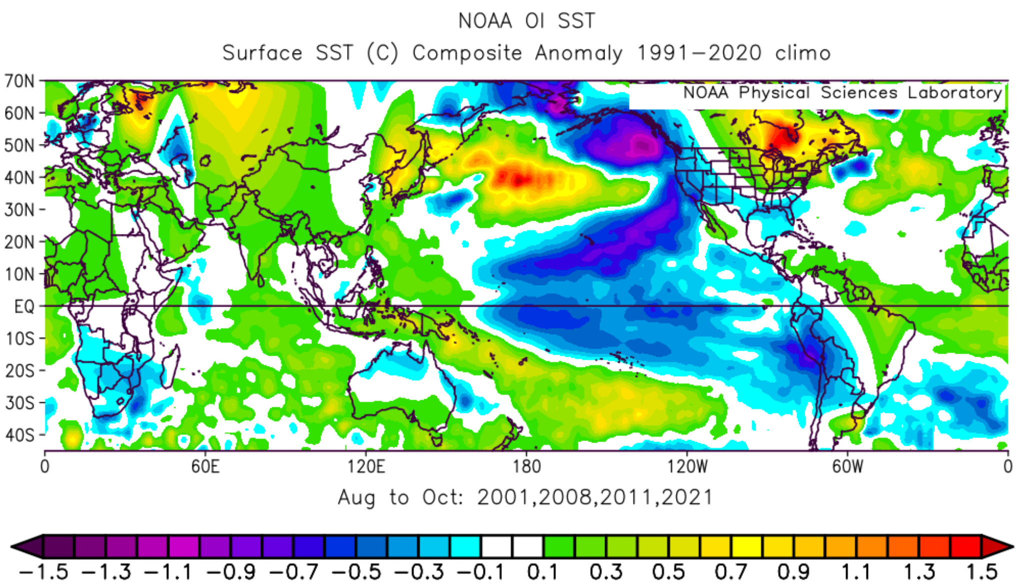


Figure 10: Average August–October SST anomalies in our four analog years.

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 11 and 12) since 1979. In this analysis, we only count one landfall per storm, regardless if the storm made multiple landfalls at hurricane strength (e.g., Irma–2017).

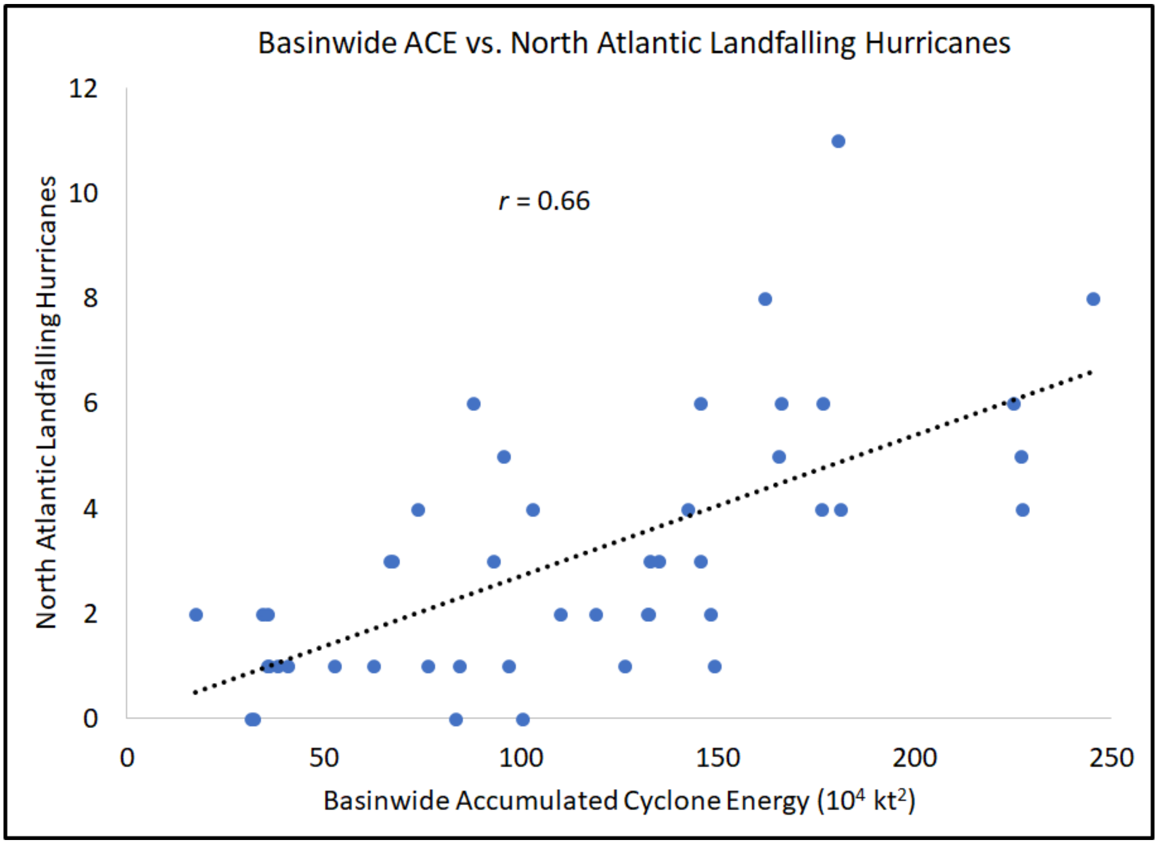


Figure 11: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

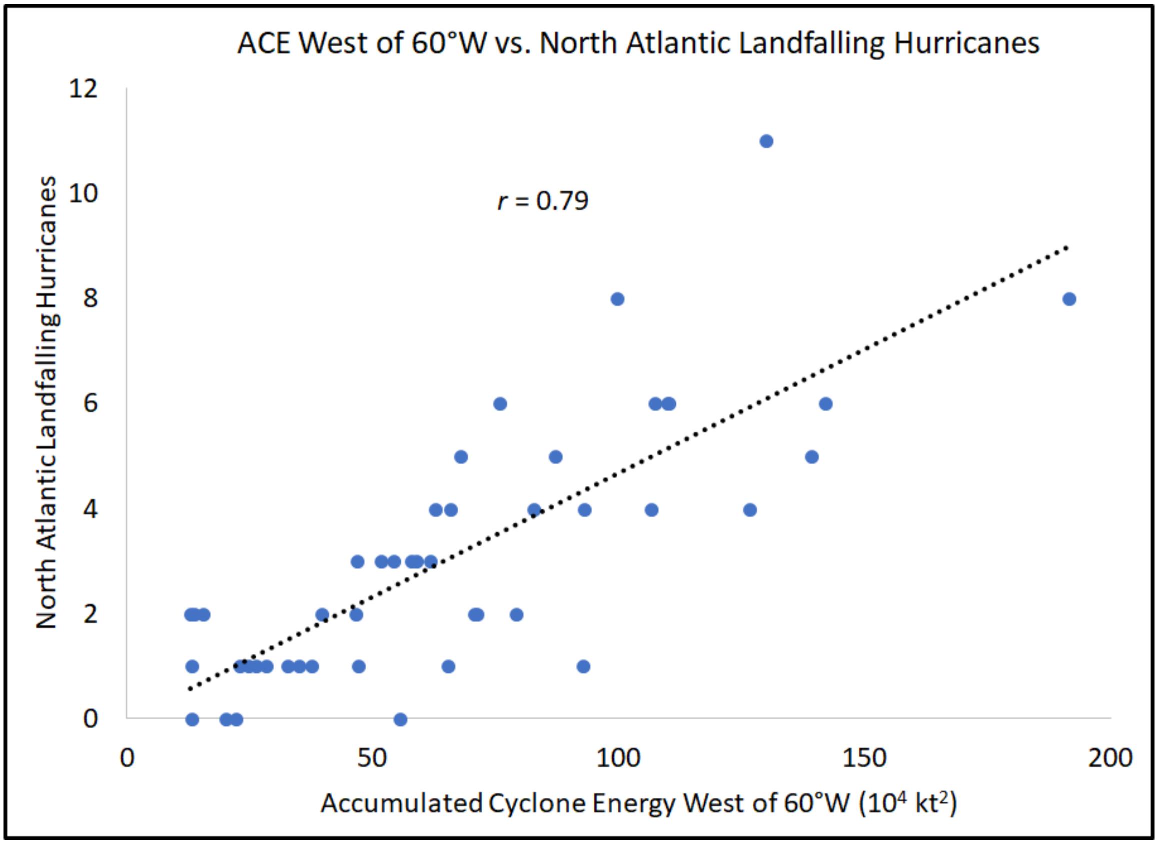


Figure 12: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

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 and 2024. 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. In 2024, the western Atlantic was much busier for TC formations, and 8 of the 11 hurricanes that formed last year made landfall west of 60°W. 48% and 62% of basinwide ACE occurred west of 60°W in 2023 and 2024, respectively.

We use data from 1979–2024 and base ENSO classifications on the August–October-averaged Relative Oceanic Nino Index (RONI). Years with an RONI >= 0.5°C are classified as El Niño, years with an RONI <= -0.5°C are classified as La Niña, while all other seasons are classified as neutral ENSO. The RONI index is calculated by differencing SSTs in the Nino 3.4 region (5°S–5°N, 170–120°W) from tropical mean SST (20°S–20°N, 0°–360°) and scaling the time series to match the variability of the observed SST in the Nino 3.4 region.

We find that 54% of basinwide ACE occurs west of 60°W in El Niño years, while 62% of basinwide ACE occurs west of 60°W in La Niña years. In neutral ENSO years, 58% of basinwide ACE occurs west of 60°W. Given that we believe that the most likely ENSO state are neutral ENSO conditions, with the highest potential for cool neutral ENSO (e.g., Nino 3.4 SST anomaly between -0.5°C and 0.0°C), we are estimating ~60% of basinwide ACE to occur west of 60°W in 2025.

2.5 July Forecast Summary and Final Adjusted Forecast

Table 7 shows our final adjusted early July forecast for the 2025 season which is a combination of our statistical scheme, statistical/dynamical schemes, and analog scheme as well as qualitative adjustments for other factors not explicitly contained in any of these schemes. We favor our analog model guidance over our more aggressive statistical and statistical/dynamical guidance due to strong observed and predicted Caribbean wind shear (discussed in section 5).

Table 7: Summary of our early July statistical forecast, our statistical/dynamical forecasts, our analog forecast, the average of these six schemes and our adjusted final forecast for the 2025 hurricane season.

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Scheme	ECMWF Scheme	Met Office Scheme	JMA Scheme	CMCC Scheme	Analog Scheme	6-Scheme Average	Adjusted Final Forecast
Named Storms (14.4)	19.5	18.9	21.6	18.8	19.9	17.8	19.4	16
Named Storm Days (69.4)	94.3	90.5	108.2	89.7	97.3	81.6	93.6	80
Hurricanes (7.2)	9.8	9.4	11.2	9.3	10.1	7.8	9.6	8
Hurricane Days (27.0)	40.6	38.5	48.1	38.1	42.2	27.4	39.2	30
Major Hurricanes (3.2)	4.8	4.5	5.6	4.5	4.9	4.3	4.8	3
Major Hurricane Days (7.4)	12.3	11.5	15	11.4	12.9	7.3	11.7	8
Accumulated Cyclone Energy Index (123)	182	173	215	171	189	132	177	140
Net Tropical Cyclone Activity (135%)	197	188	229	186	204	154	193	145

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 the particular values of hurricane numbers and ACE would be exceeded. Here we display probability of exceedance curves for hurricanes and ACE (Figures 13 and 14), 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 8 displays one standard deviation uncertainty ranges (~68% of all forecasts within this range). This uncertainty estimate is also very similar to the 70% uncertainty range that NOAA provides with its forecasts. We use Poisson distributions for all storm parameters (e.g., named storms, hurricanes and major hurricanes) while we use a Weibull distribution for all integrated parameters except for major hurricane days (e.g., named storm days, ACE, etc.). We use a Laplace distribution for major hurricane days.

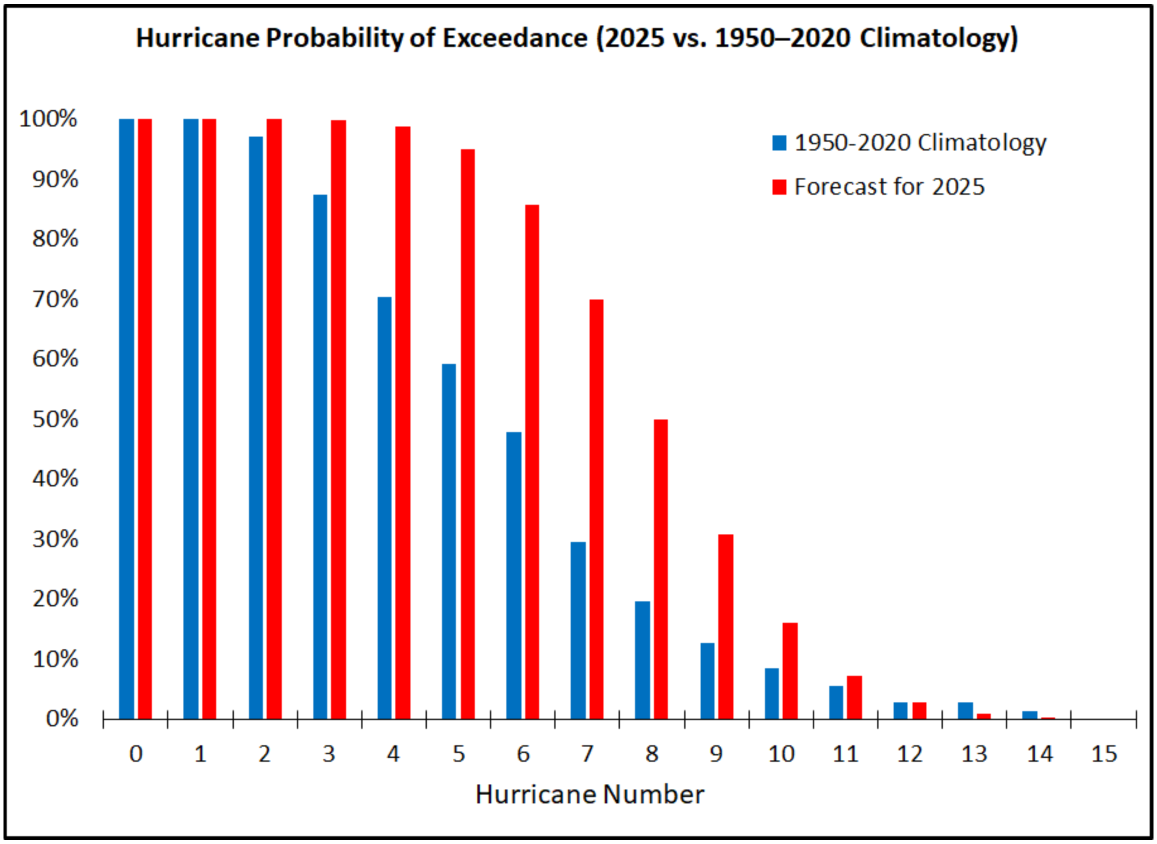


Figure 13: Probability of exceedance plot for hurricane numbers for the 2025 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950–2020 have had more than two hurricanes.

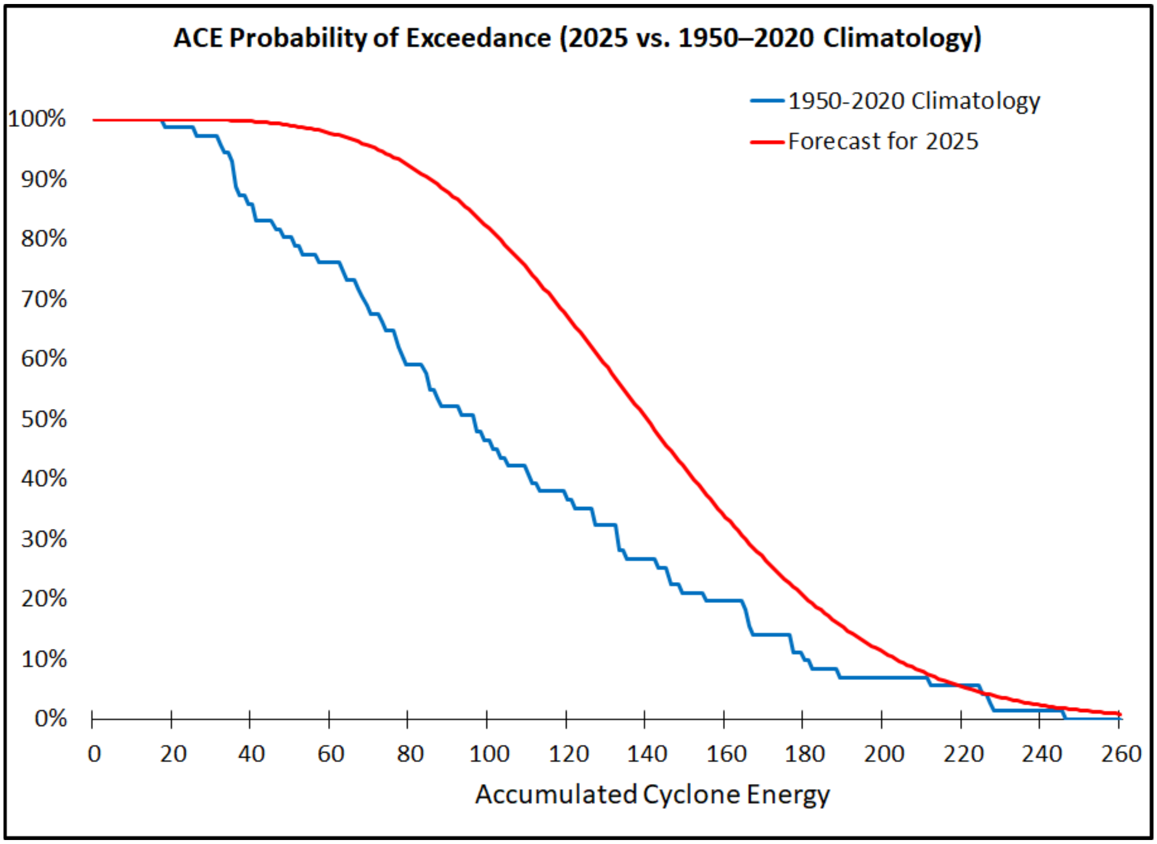


Figure 14: As in Figure 13 but for ACE.

Table 8: 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	2025 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	16	13 – 19
Named Storm Days (NSD)	80	60 – 101
Hurricanes (H)	8	6 – 10
Hurricane Days (HD)	30	19 – 43
Major Hurricanes (MH)	3	2 – 4
Major Hurricane Days (MHD)	8	5 – 12
Accumulated Cyclone Energy (ACE)	140	95 – 191
ACE West of 60°W	87	56 – 124
Net Tropical Cyclone (NTC) Activity	145	101 – 193

4 ENSO

Over the past several weeks, ENSO neutral conditions have prevailed across the tropical Pacific (Figure 15). SST anomalies have increased slightly across the eastern and central tropical Pacific. Figure 16 displays the locations of the various Nino regions displayed in Figure 15.

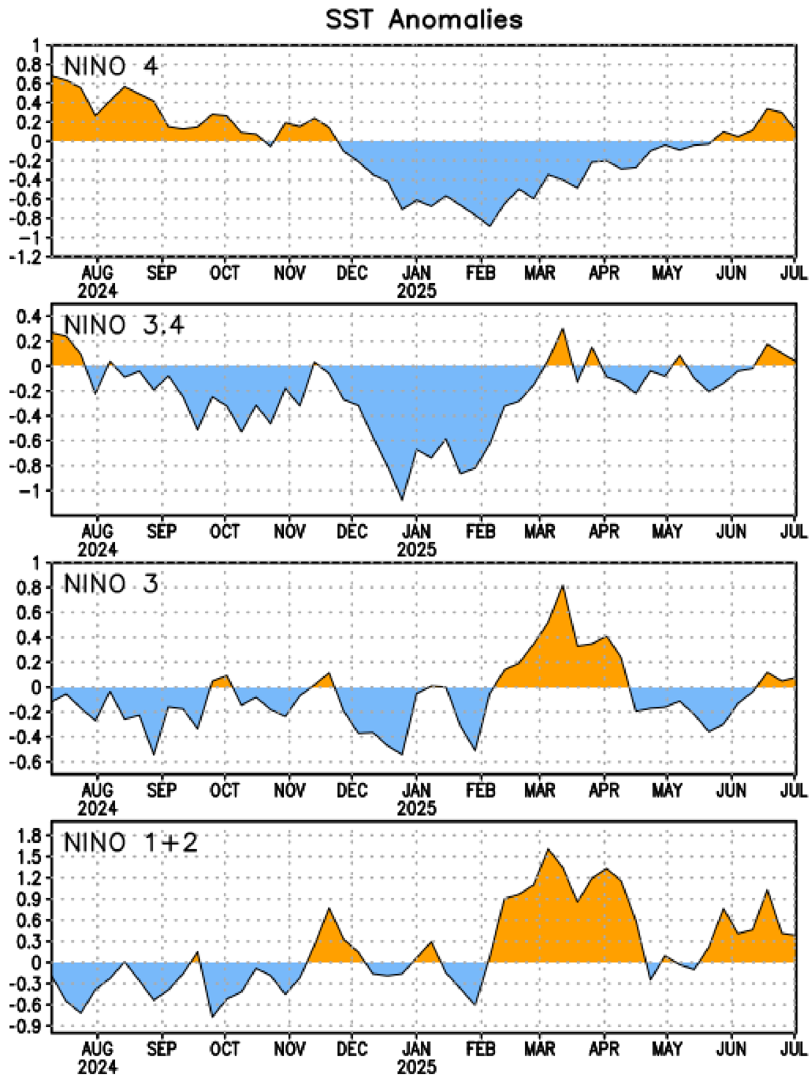


Figure 15: SST anomalies for several ENSO regions over the past year. Figure courtesy of the Climate Prediction Center.

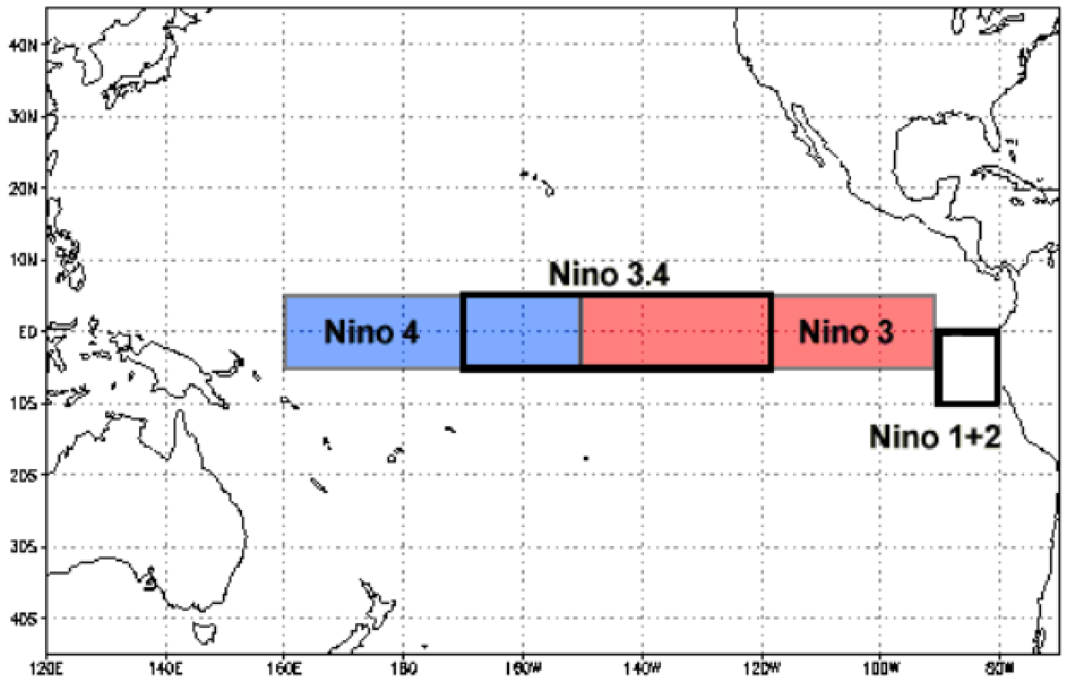


Figure 16: Location of ENSO SST regions used in Figure 15. Figure courtesy of the National Centers for Environmental Information.

Equatorial upper-ocean heat content anomalies in the eastern and central tropical Pacific have stayed slightly above average over the past month (Figure 17). Current SST anomalies are close to their long-term averages across the entire equatorial eastern and central Pacific (Figure 18).

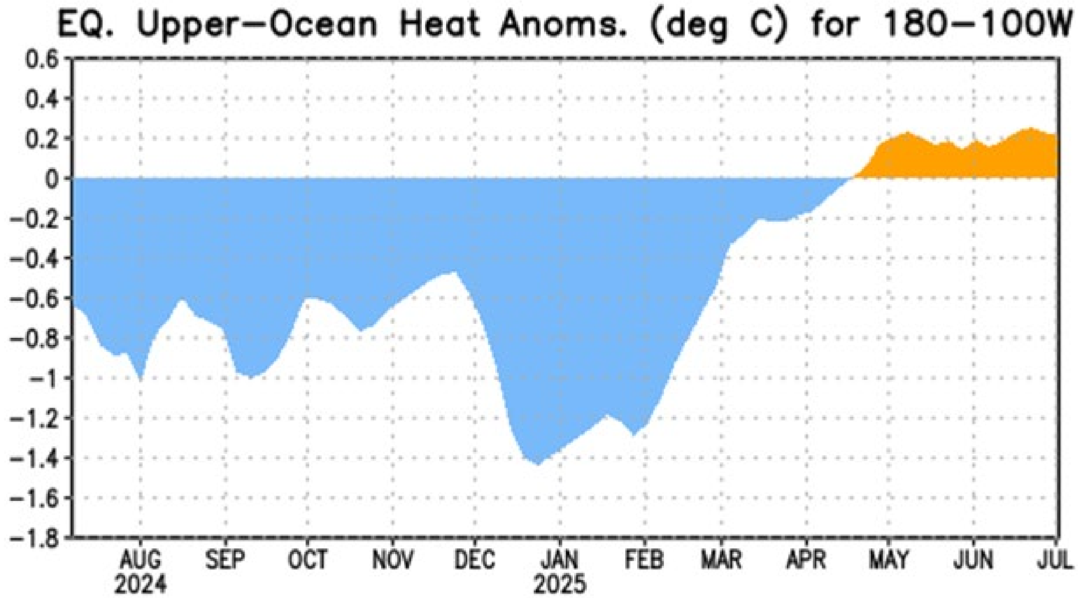


Figure 17: Central and eastern equatorial Pacific upper ocean (0–300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

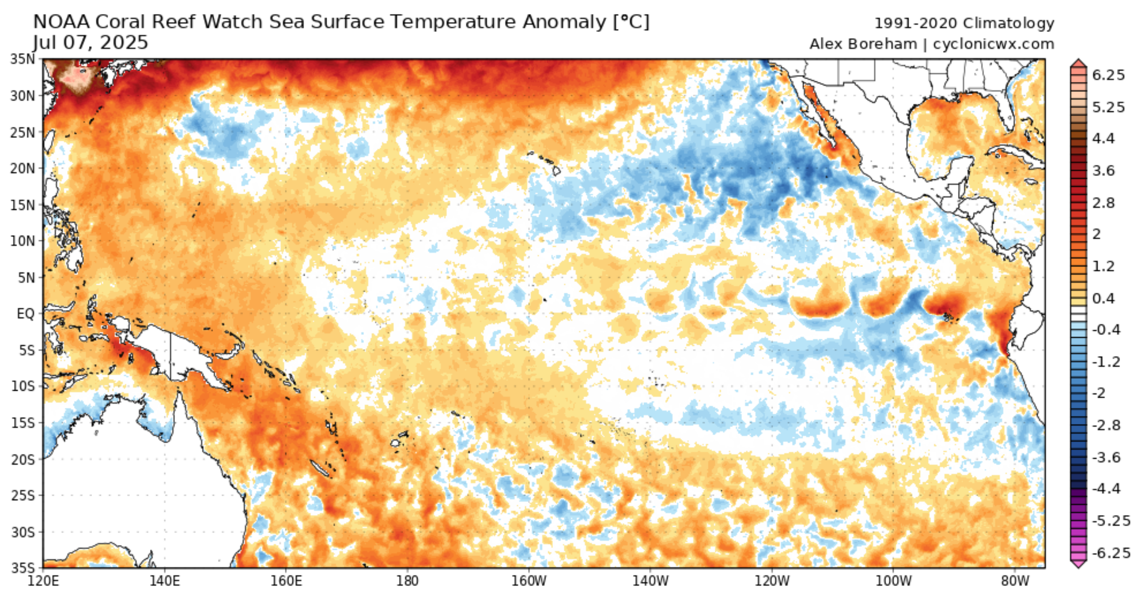


Figure 18: Current SST anomalies across the tropical and subtropical Pacific. Figure courtesy of cyclonicwx.com.

Table 9 displays May and June SST anomalies for several Nino regions. As noted earlier, over the past month, SST anomalies have slightly increased across the eastern and central tropical Pacific.

Table 9: May and June SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. June minus May SST anomaly differences are also provided.

Region	May SST Anomaly (°C)	June SST Anomaly (°C)	June – May SST Anomaly (°C)
Nino 1+2	+0.2	+0.6	+0.4
Nino 3	-0.2	-0.1	+0.1
Nino 3.4	0.0	0.0	0.0
Nino 4	0.0	+0.2	+0.2

Following robust upwelling (cooling) oceanic Kelvin wave activity throughout the second half of 2024 and during January of 2025 (Figure 19), oceanic Kelvin wave activity has been relatively weak. The continued prevalence of relatively strong trade winds across the central tropical Pacific has likely helped inhibit any significant development towards El Niño (Figure 20).

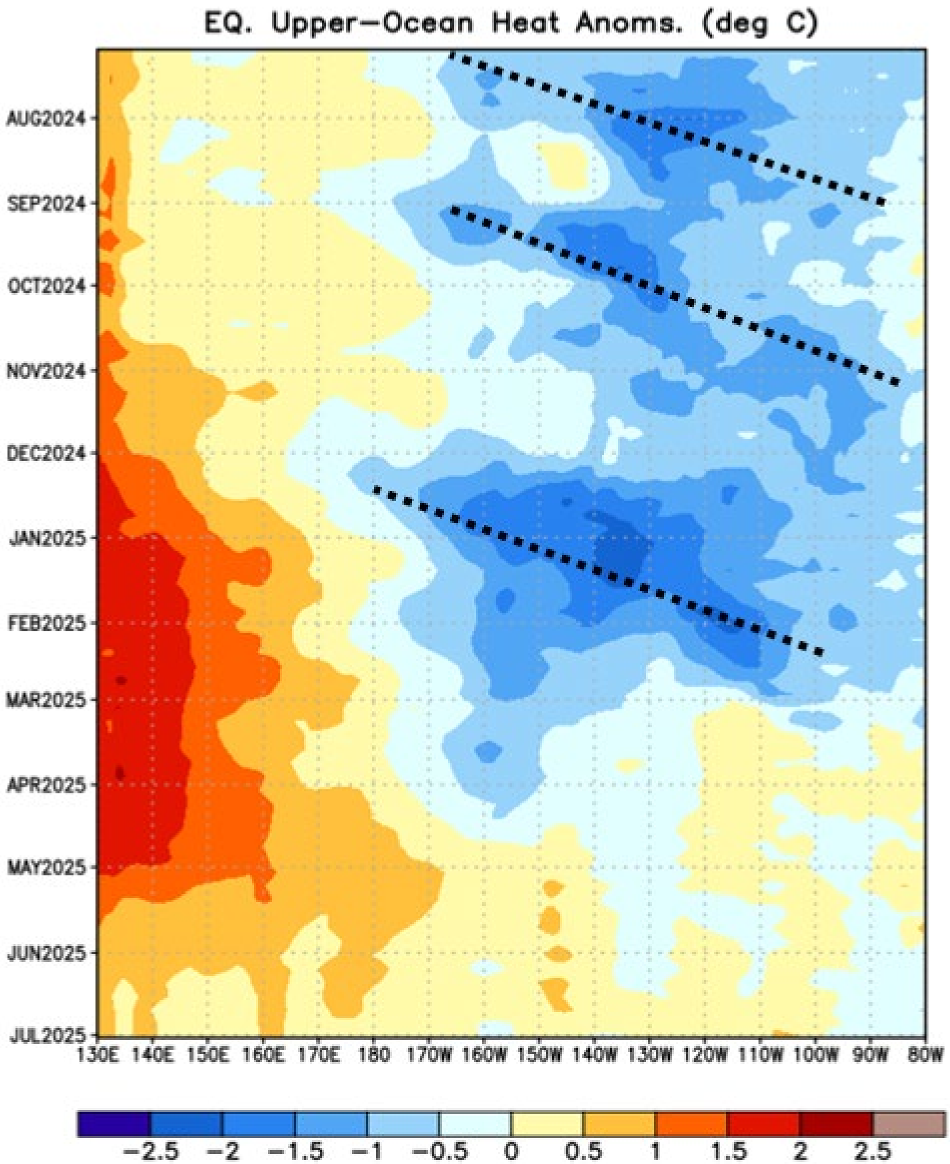


Figure 19: Upper-ocean (0–300 meter) heat content anomalies in the tropical Pacific since July 2024. Long dashed lines indicate downwelling Kelvin waves, while short dashed lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases. Over the past several months, no coherent Kelvin wave activity has been diagnosed per this analysis from the Climate Prediction Center.

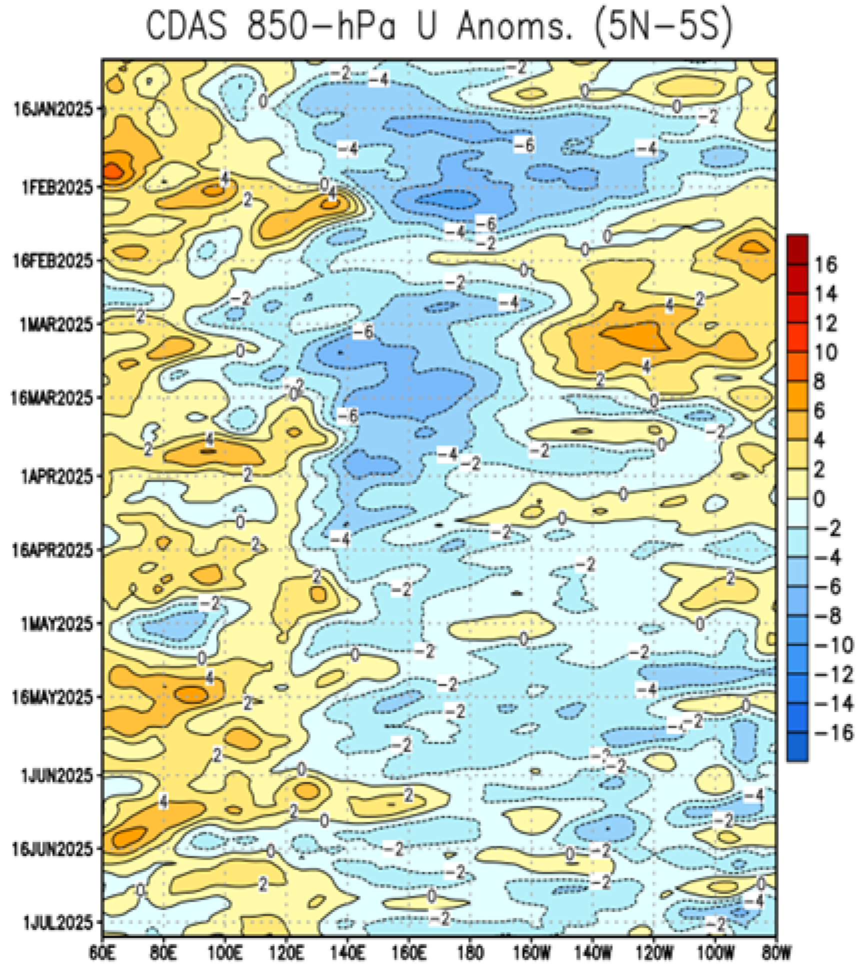


Figure 20: Anomalous equatorial low-level winds spanning from 120°E to 80°W. Figure courtesy of Climate Prediction Center.

Low-level winds are forecast to be stronger than normal across the central tropical Pacific for the next several weeks (Figure 21). These strong trades should inhibit any transition towards El Niño and potentially cause anomalous cooling across the various Nino regions as the peak of the Atlantic hurricane season approaches.

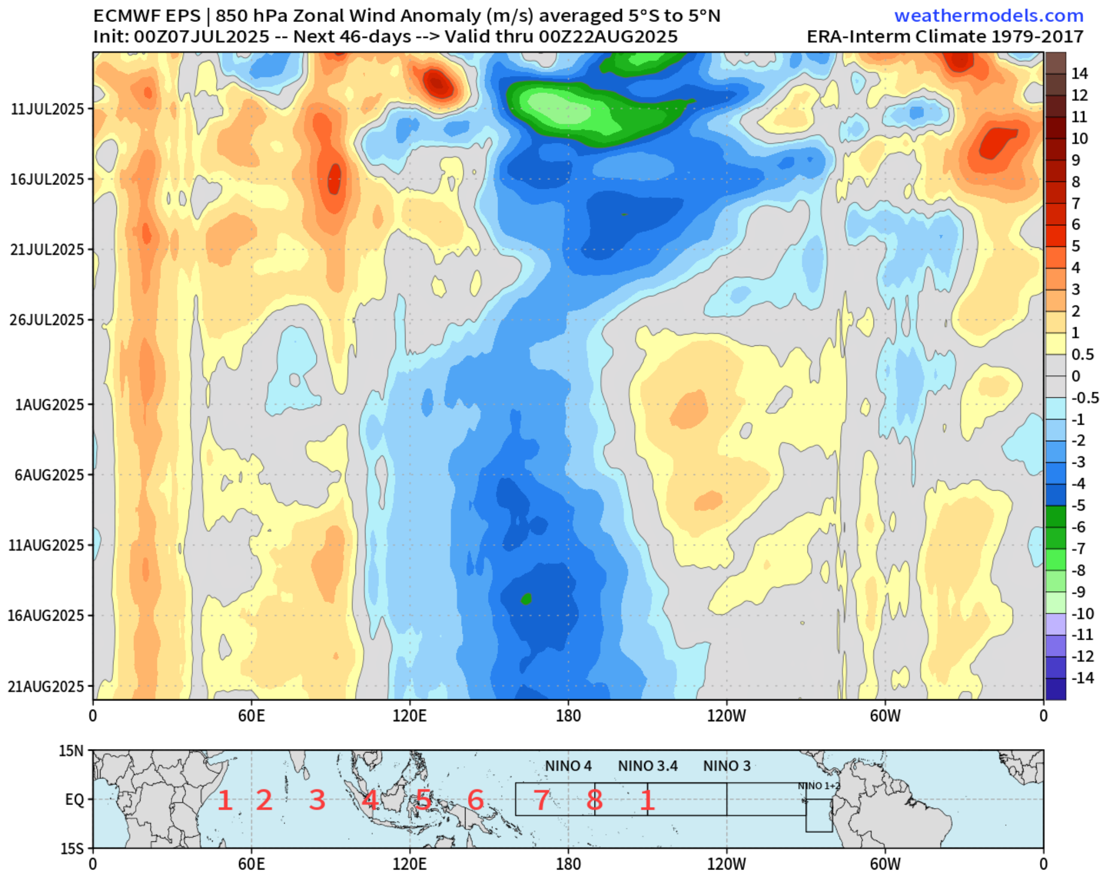


Figure 21: ECMWF forecast 850-hPa zonal equatorial winds through 21 August. Figure courtesy of weathermodels.com.

The latest plume of ENSO predictions from several statistical and dynamical models is primarily clustered around ENSO neutral conditions for the peak of the Atlantic hurricane season from August–October (Figure 22).

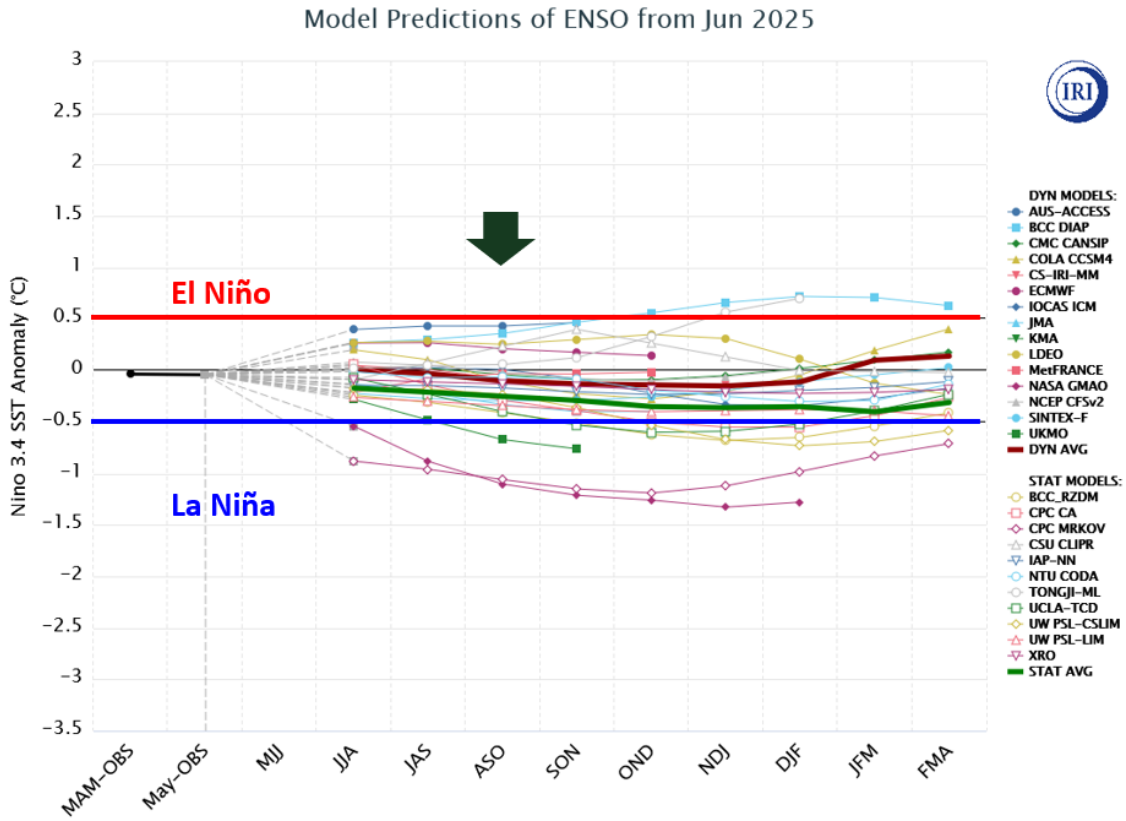


Figure 22: ENSO forecasts from various statistical and dynamical models for Nino 3.4 SST anomalies based on late May to early June initial conditions. The black arrow delineates the peak of the Atlantic hurricane season (August–October). Figure courtesy of the International Research Institute (IRI).

The latest official forecast from NOAA favors ENSO neutral conditions relative to La Niña for August–October, with a much lower chance of El Niño. NOAA is currently predicting a 59% chance of ENSO neutral, a 32% chance of La Niña, and a 9% chance of El Niño for the peak of the Atlantic hurricane season (Figure 23).

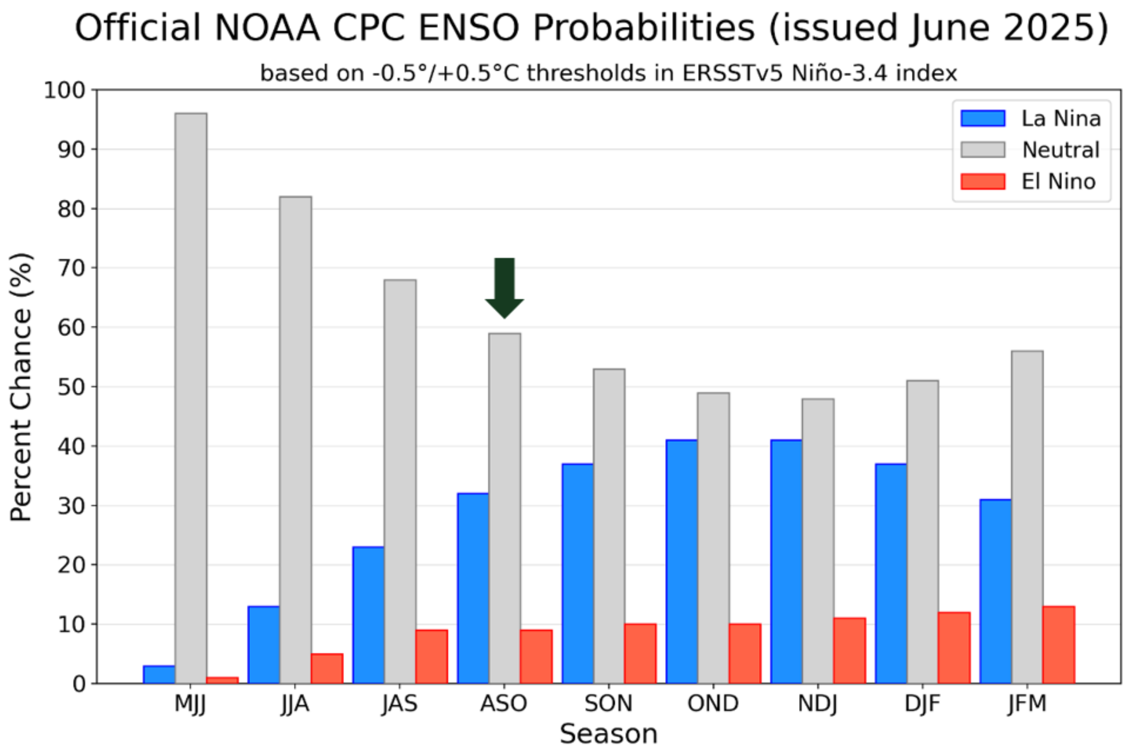


Figure 23: Official probabilistic ENSO forecast from NOAA. The black arrow delineates the peak of the Atlantic hurricane season (August–October).

Based on the above information, our best estimate is that we will have ENSO neutral conditions for the peak of the Atlantic hurricane season. The projected robust trade wind surge (Figure 21) could send the tropical Pacific to cool neutral ENSO conditions in the next couple of months.

5 Current Atlantic Basin Conditions

Currently, SSTs are slightly warmer than normal across the tropical Atlantic and Caribbean and much warmer than normal in the eastern mid-latitude Atlantic (Figure 24). Over the past several weeks, trade winds across the Caribbean have been much stronger than normal, resulting in considerable anomalous cooling in that region due to increased evaporation and mixing (Figure 25). Farther east in the tropical Atlantic, trade winds have been closer to their long-term average, resulting in little change in SST anomalies over the past few weeks.

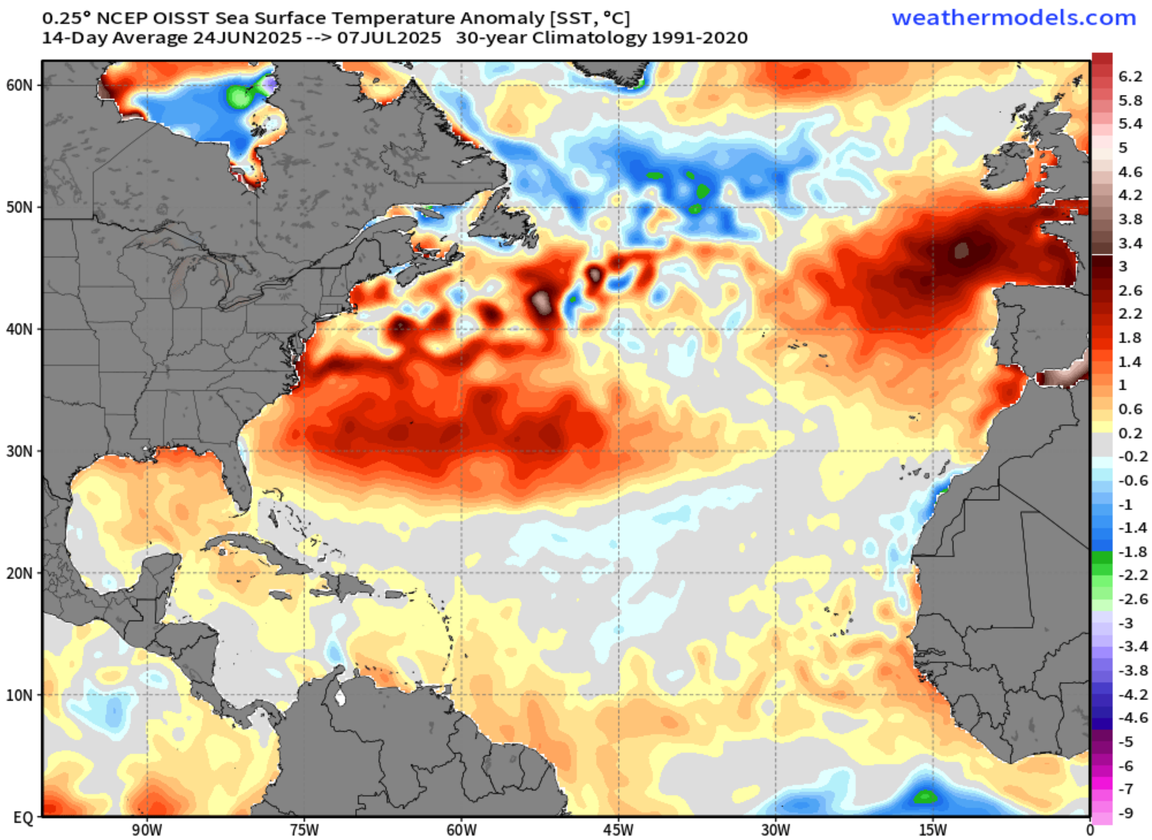


Figure 24: North Atlantic SST anomalies averaged from 24 June – 7 July.

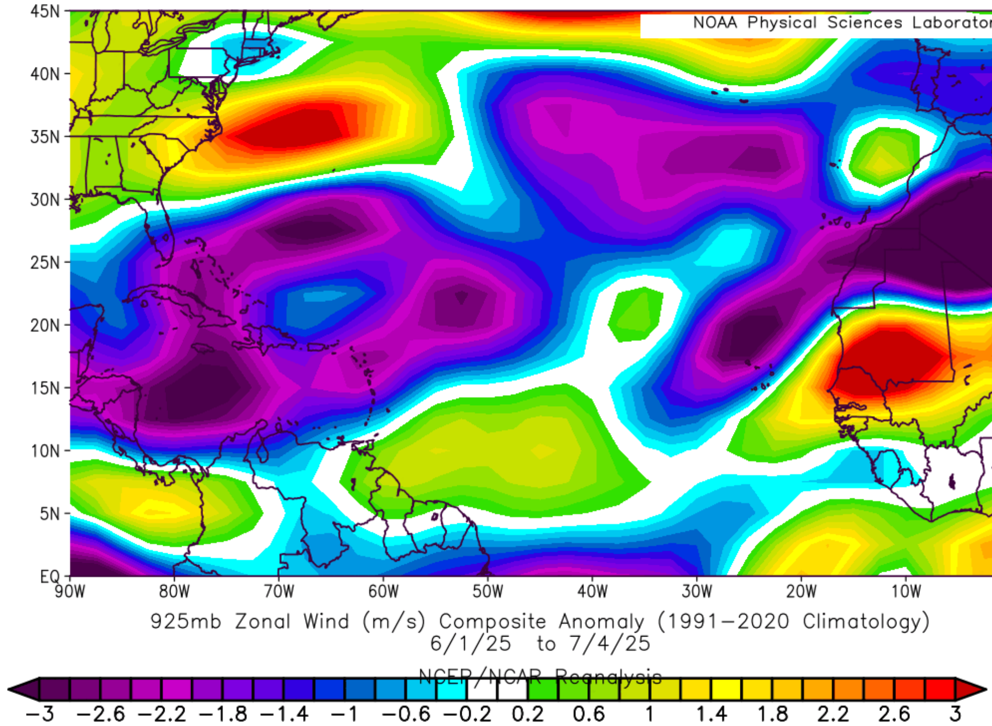


Figure 25: 925 hPa zonal wind anomalies across the North Atlantic Ocean averaged from 1 June to 4 July 2025.

Figure 26 shows the forecast for the next ~4 weeks of low-level winds across the Atlantic. Trade winds are forecast to be much weaker than normal in the eastern and central tropical Atlantic for the next two weeks, likely resulting in some anomalous warming there. Farther west in the basin, trade winds are forecast to be near average. Overall, the current SST anomaly pattern of enhanced warmth in the eastern subtropical and mid-latitude Atlantic correlates relatively well with what is typically seen in July before active Atlantic hurricane seasons (Figure 27).

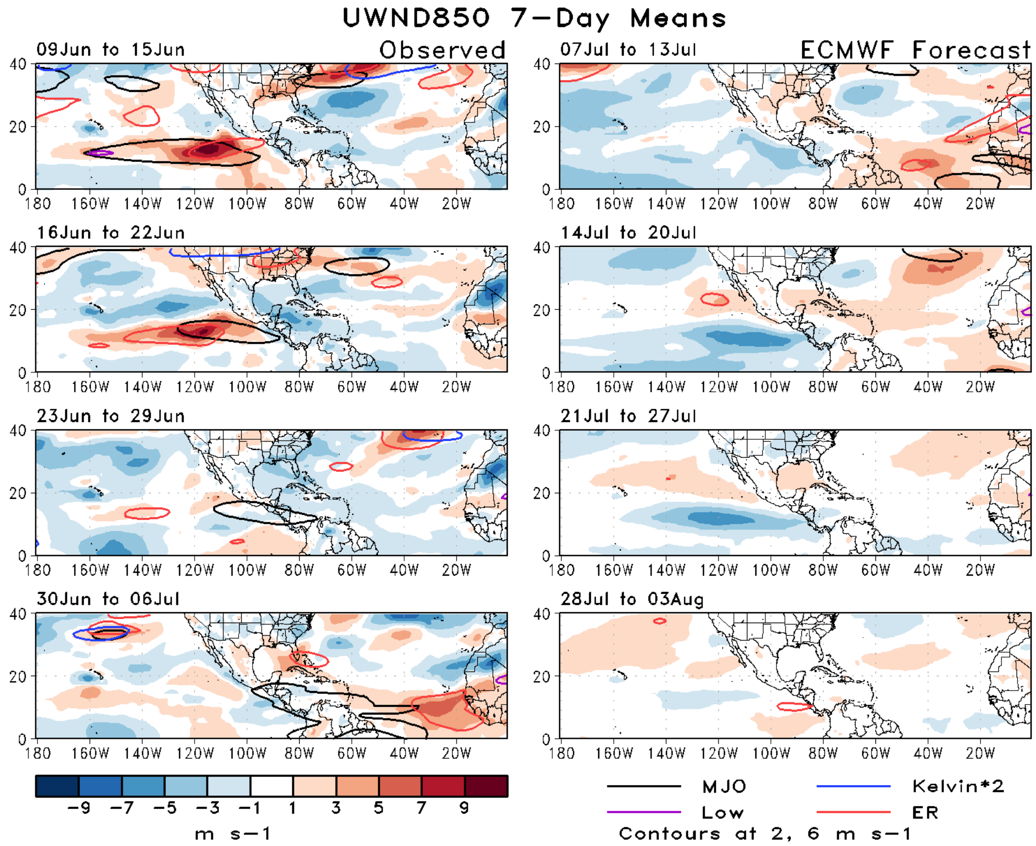


Figure 26: Observed low-level zonal winds across portions of the Western Hemisphere over the past four weeks and predicted low-level zonal winds by ECMWF through 3 August. Figure courtesy of Nick Novella (NOAA/Climate Prediction Center).

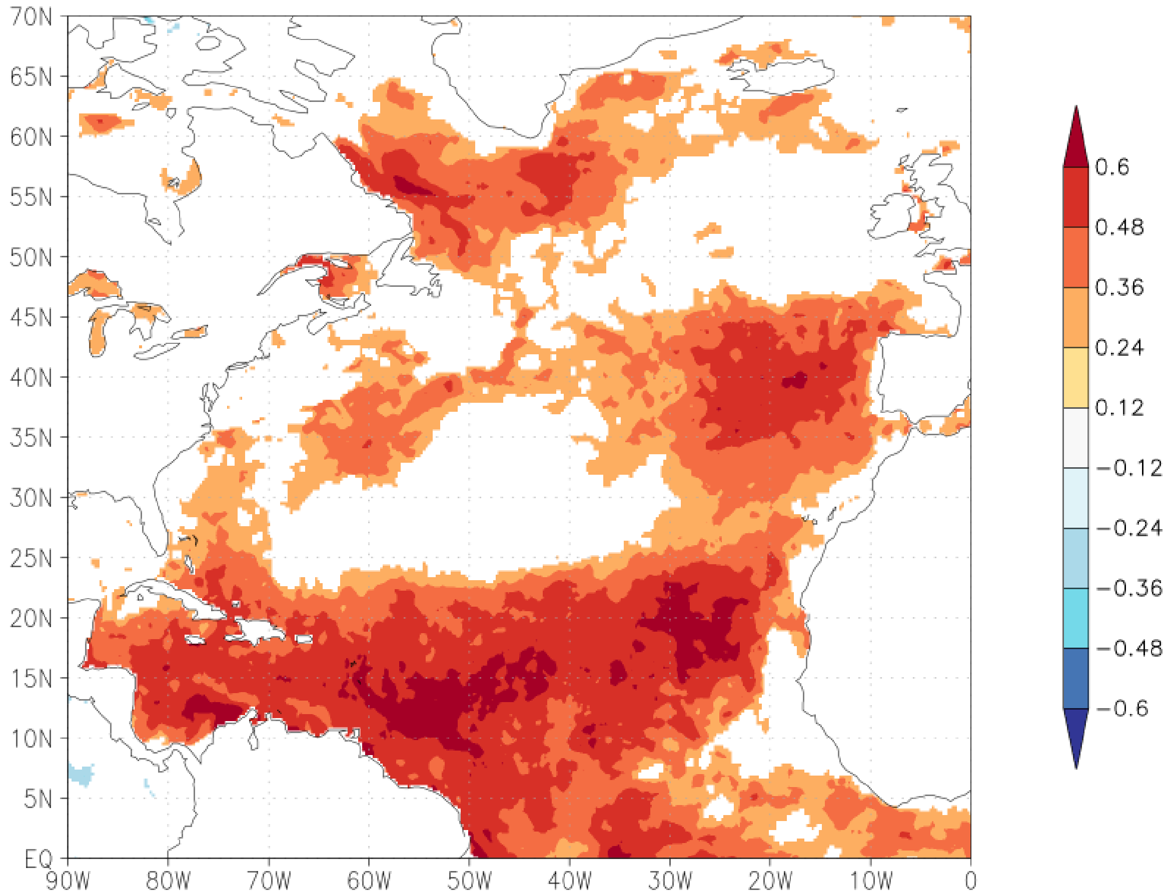


Figure 27: Rank correlations between July sea surface temperatures in the North Atlantic and annual Atlantic ACE from 1982–2024.

As noted earlier, the primary reason for the slight reduction in our seasonal hurricane forecast is due to strongly enhanced Caribbean vertical wind shear over the past few weeks. Shear since 1 June has been elevated by an average of 15–20 kt relative to normal across the Caribbean (Figure 28). Western tropical Atlantic vertical wind shear correlates quite strongly with Atlantic ACE, with 30-day-average correlations growing strongly between late June and mid-July (Figure 29).

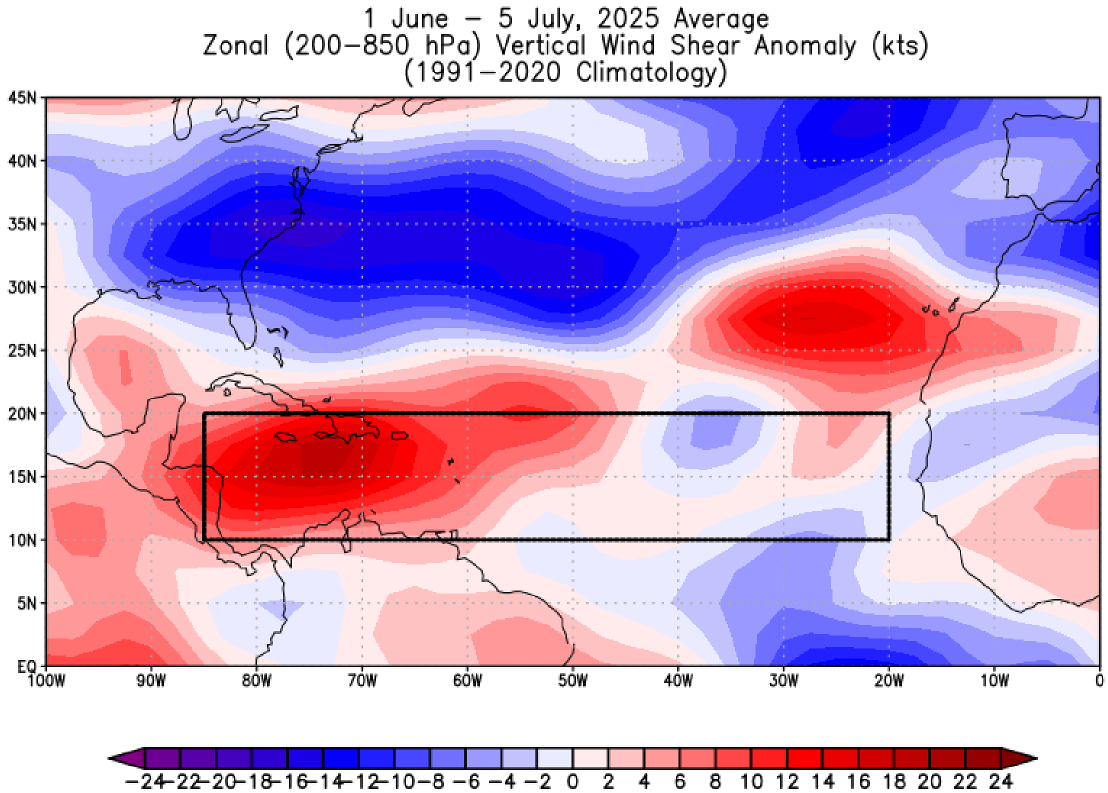


Figure 28: 1 June – 5 July-averaged zonal vertical wind shear anomalies across the tropical and subtropical Atlantic.

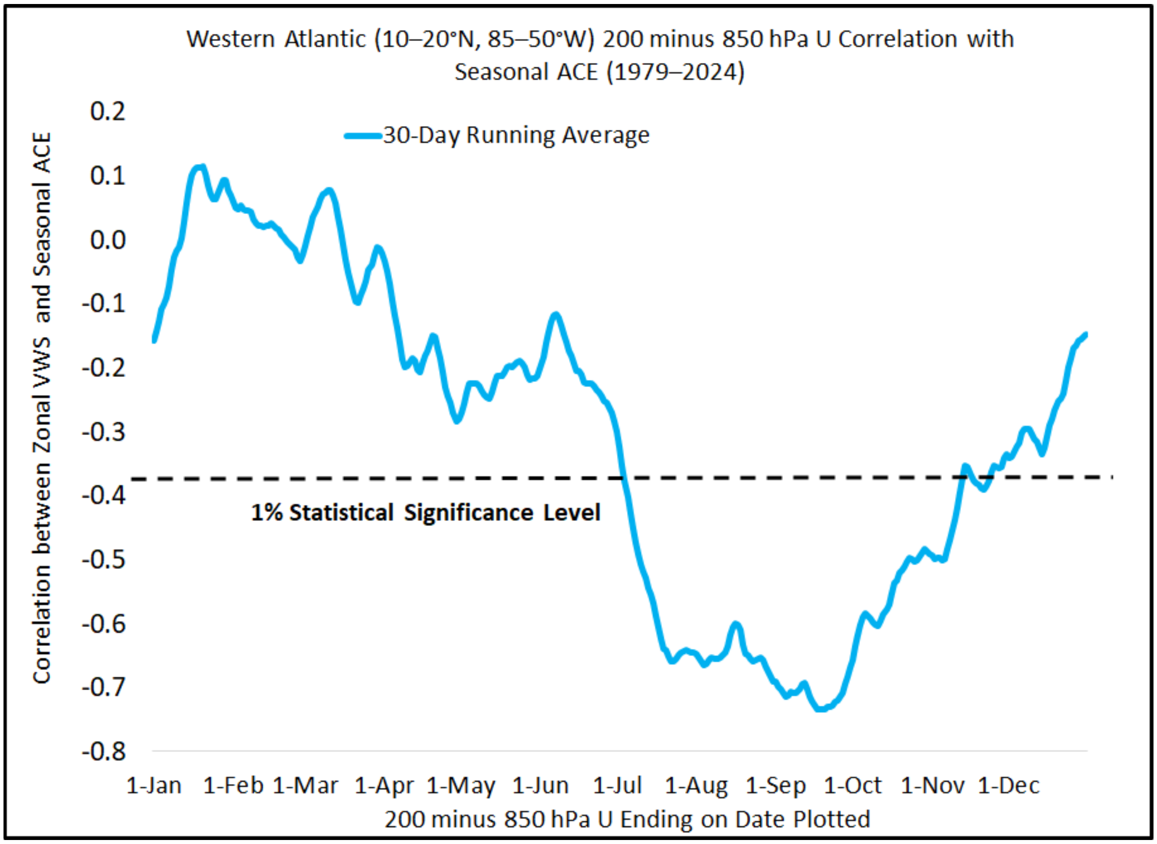


Figure 29: 30-day average correlations between western tropical Atlantic (10–20°N, 85–50°W) zonal vertical wind shear and seasonal Atlantic ACE.

Caribbean vertical wind shear is forecast to remain above normal for the next few weeks per the latest forecast from ECMWF (Figure 30). There are some indications that the tropical circulation may shift towards a more Atlantic TC-favorable vertical wind shear regime in August, with enhanced sinking motion across the eastern Pacific and enhanced rising motion across Africa and the Indian Ocean (Figure 31). These circulation patterns typically result in reduced vertical wind shear across the tropical Atlantic and Caribbean.

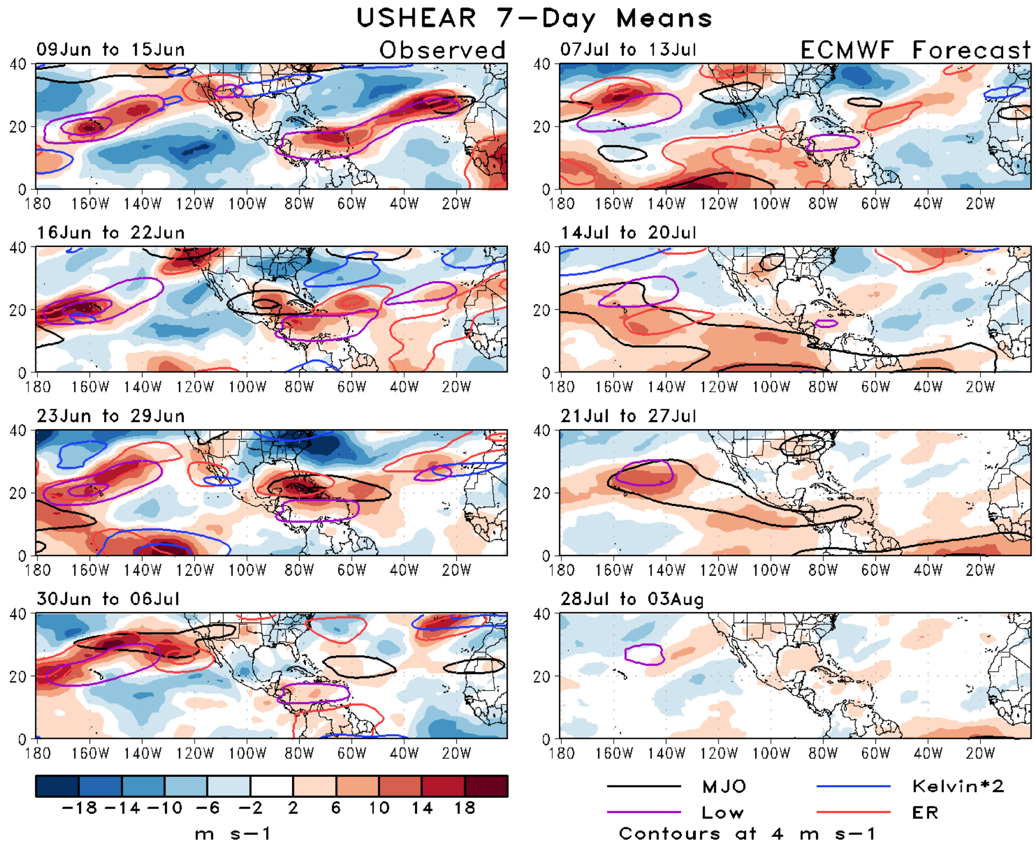


Figure 30: Observed 200 minus 850 hPa zonal wind shear and predicted zonal wind shear by ECMWF through 3 August. Figure courtesy of Nick Novella (NOAA/Climate Prediction Center).

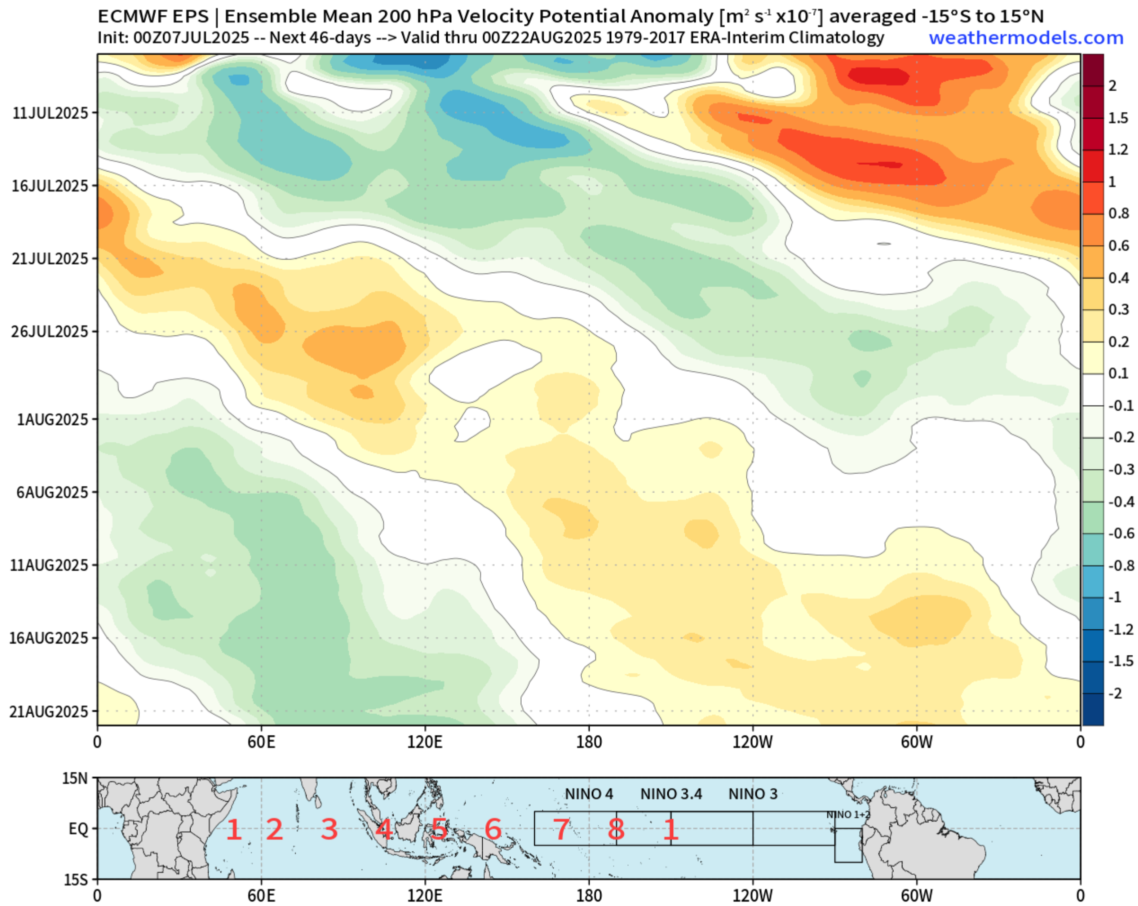


Figure 31: Forecast of 200 hPa tropical velocity potential anomalies by ECMWF through 21 August. Negative upper-level velocity potential anomalies indicate rising motion, while positive upper-level velocity potential anomalies indicate sinking motion. Figure courtesy of weathermodels.com.

So far, tropical Atlantic dust has been running somewhat below normal (Figure 32). Higher tropical Atlantic dust during June/July typically is associated with quieter Atlantic hurricane seasons, while lower tropical Atlantic dust during June/July is associated with busier hurricane seasons. Overall, the lack of dust so far this year is consistent with our outlook for a slightly above-normal season.

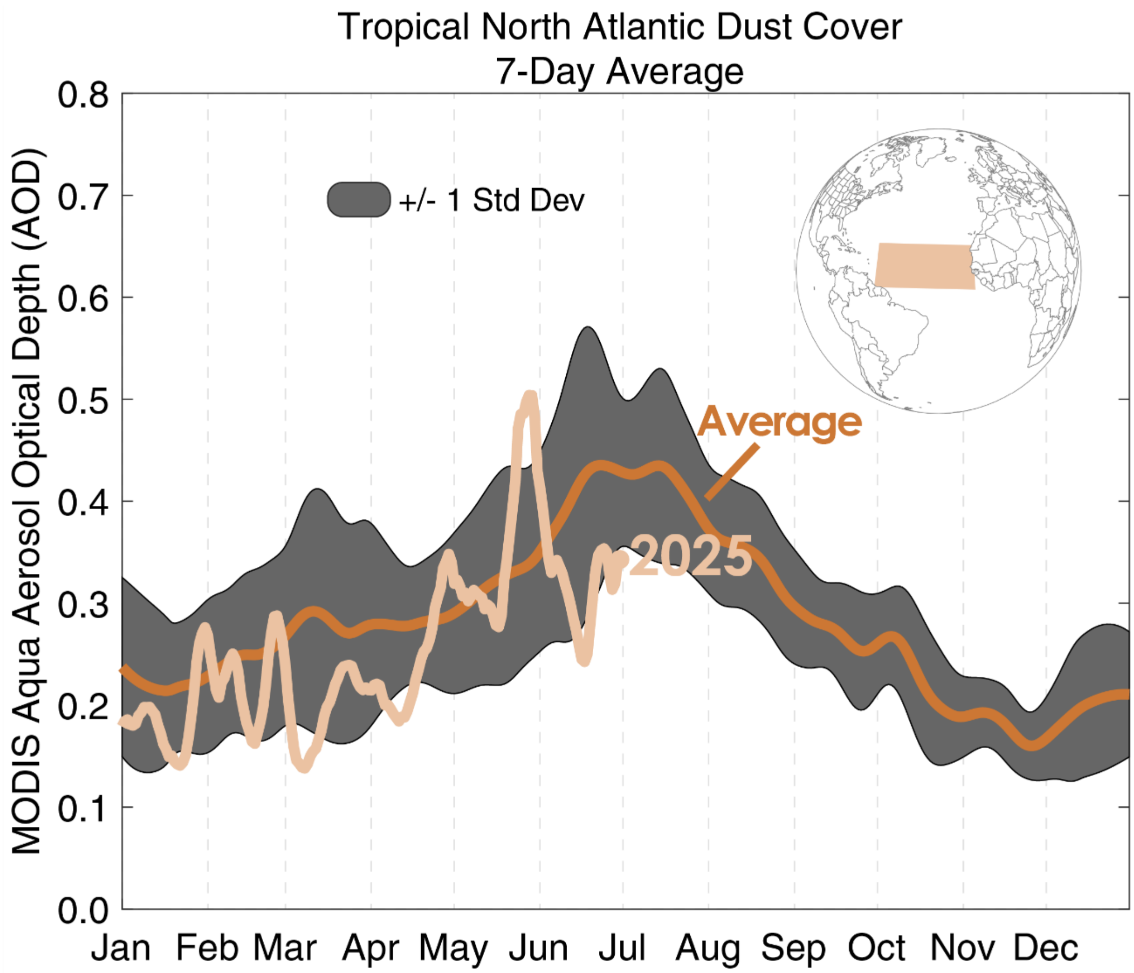


Figure 32: Tropical North Atlantic aerosol optical depth in 2025 compared with the 2002–2024 average. Figure courtesy of Michael Lowry (WPLG).

6 West Africa Conditions

The West African monsoon has gotten off to a somewhat sluggish start, with precipitation averaged across the Sahel slightly below normal during June/early July (Figure 33). The West African monsoon is predicted to pick up substantially relative to normal in the next few weeks, with the ECMWF forecasting well above-normal precipitation across the Sahel through mid-August (Figure 34). An active West African monsoon is typically associated with more active Atlantic hurricane seasons.

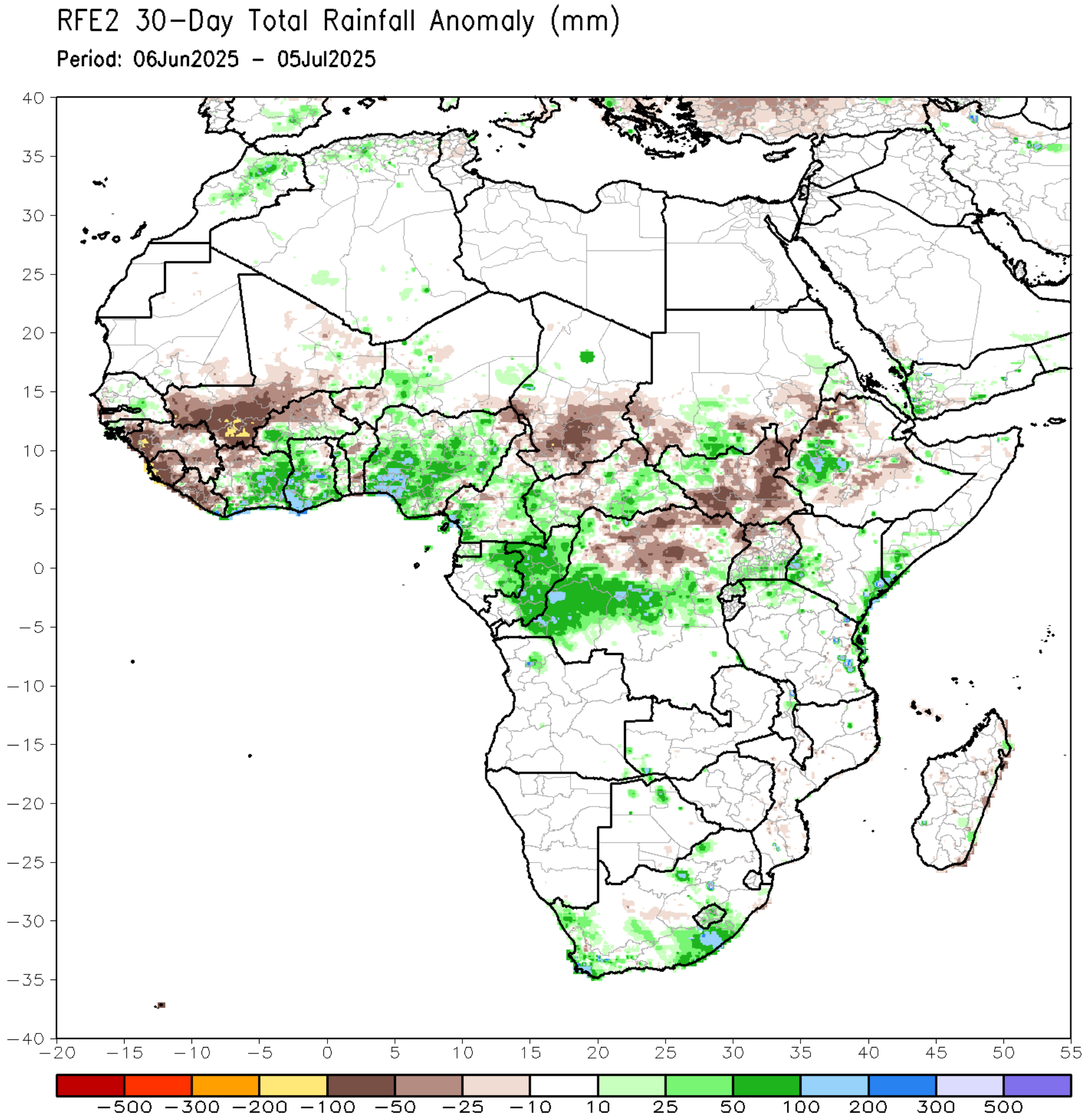


Figure 33: 6 June – 5 July rainfall estimates from the African Rainfall Estimation Algorithm, version 2.

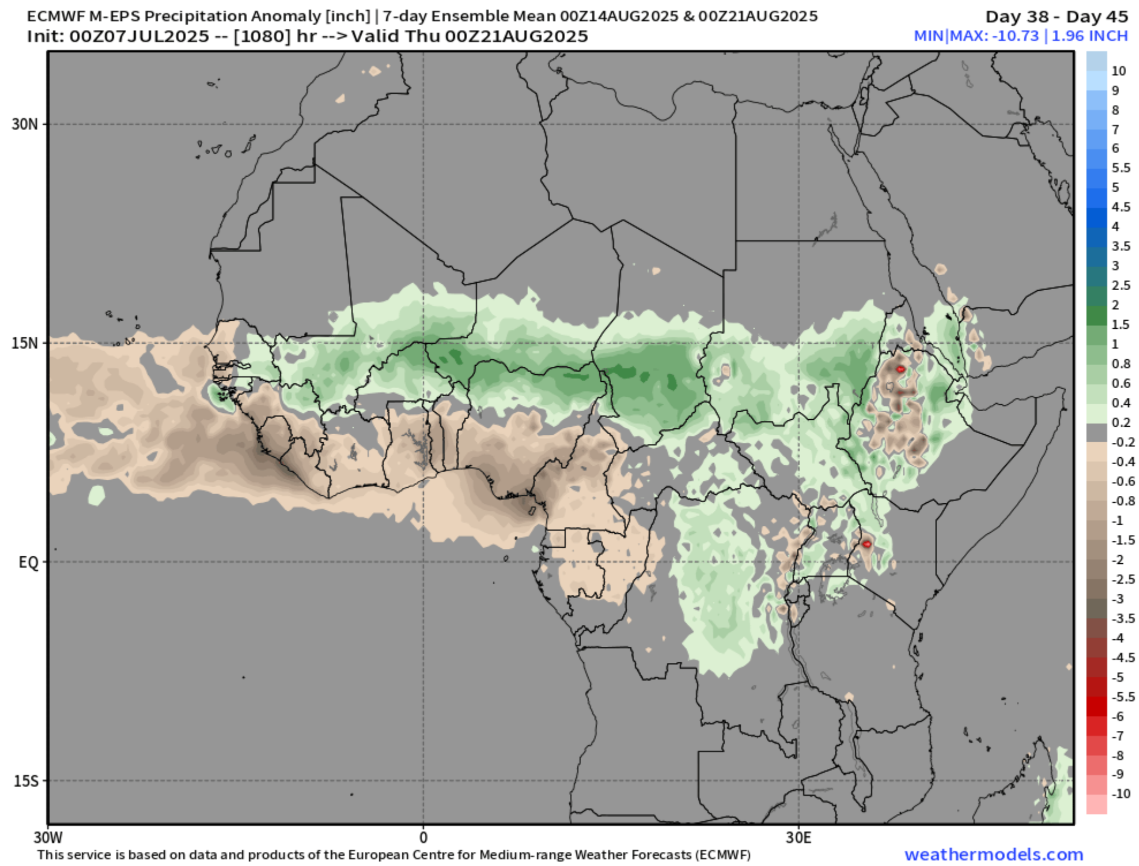


Figure 34: ECMWF predicted precipitation anomalies across tropical and North Africa through 21 August.

7 Tropical Cyclone Impact Probabilities for 2025

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.

We have shown that net landfall probability is 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. As was done last year, we adjust 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 10 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 2025. Landfall probabilities are slightly 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 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 10: Post 8-July probability of >=1 named storm, hurricane and major hurricane tracking within 50 miles of each coastal state from Texas to Maine. Probabilities are provided for both the 1880–2020 climatological average as well as the probability for 2025, based on the latest CSU seasonal hurricane forecast.

			2025 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		64%	32%	10%		58%	28%	8%
Connecticut		25%	9%	2%		22%	8%	1%
Delaware		26%	7%	1%		23%	6%	1%
Florida		90%	62%	33%		86%	56%	29%
Georgia		69%	35%	7%		63%	30%	6%
Louisiana		72%	43%	17%		66%	38%	14%
Maine		25%	8%	2%		21%	7%	1%
Maryland		35%	13%	1%		31%	11%	1%
Massachusetts		37%	17%	3%		33%	14%	3%
Mississippi		59%	32%	9%		53%	28%	8%
New Hampshire		21%	6%	2%		18%	6%	1%
New Jersey		26%	8%	1%		23%	7%	1%
New York		30%	11%	2%		26%	9%	2%
North Carolina		74%	43%	9%		68%	38%	8%
Rhode Island		23%	9%	2%		20%	8%	1%
South Carolina		63%	33%	10%		57%	29%	8%
Texas		67%	41%	18%		61%	36%	16%
Virginia		51%	23%	2%		46%	20%	1%

8 Summary

An analysis of a variety of different atmosphere and ocean measurements (through June) which are known to have long-period statistical relationships with the upcoming season's Atlantic tropical cyclone activity, as well as output from dynamical models, indicate that 2025 will have slightly above-average activity. While most of our model guidance calls for a hyperactive season, extremely strong Caribbean shear in June and above-average projected Caribbean shear through most of July is the reason why we have reduced our forecast a bit from our earlier outlooks.

9 Forthcoming Updated Forecasts of 2025 Hurricane Activity

We will be issuing a final seasonal update of our 2025 Atlantic basin hurricane forecasts on **Wednesday 6 August**. On 6 August, we will also begin issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August–October. A verification and discussion of all 2025 forecasts will be issued on **Thursday, 20 November**. All of these forecasts will be available on our website.

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 35 displays correlations between observed and predicted Atlantic hurricanes from 1984–2024, from 1984–2013 and from 2014–2024, respectively. Correlation skill has improved at all lead times in recent years, with the most noticeable improvements at longer lead times. While eleven 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

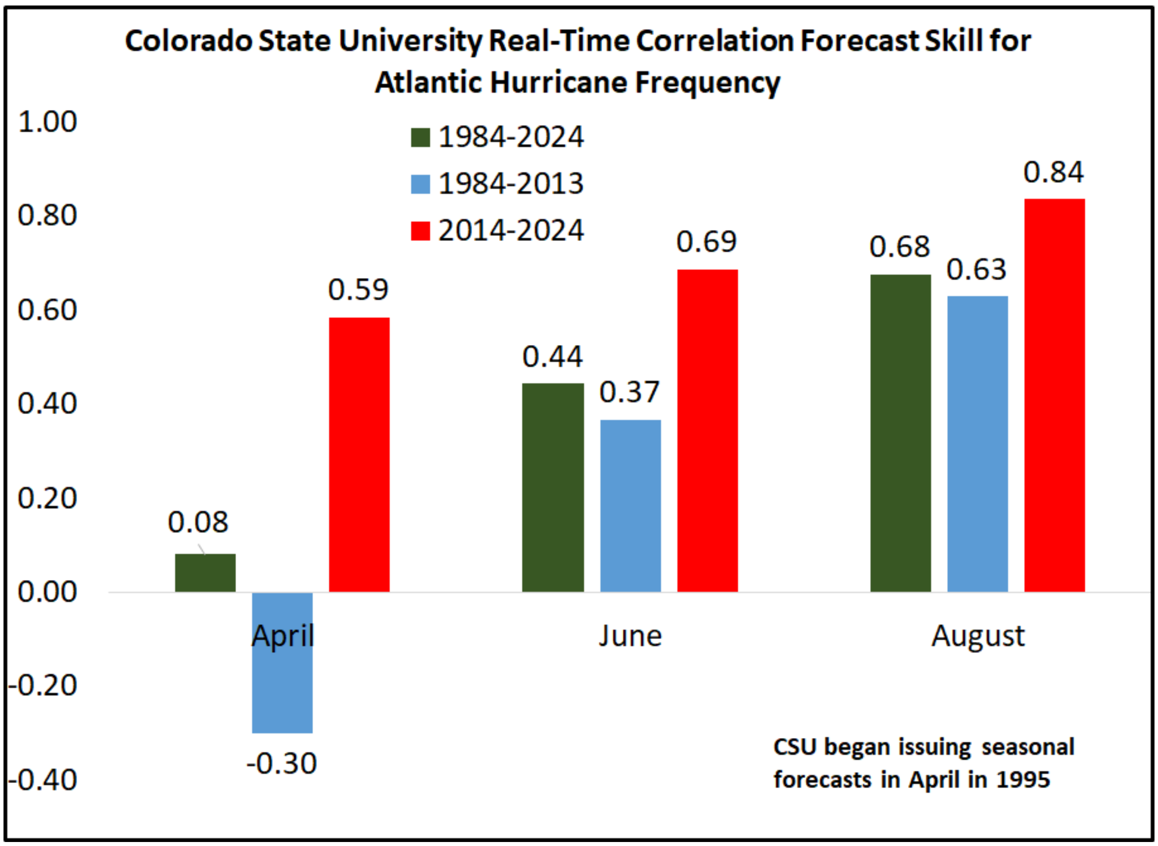


Figure 35: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2024 and 1984–2024, respectively.