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

We anticipate that the 2024 Atlantic basin hurricane season will be extremely active. Current El Niño conditions are likely to transition to La Niña conditions this summer/fall, leading to hurricane-favorable wind shear conditions. Sea surface temperatures in the eastern and central Atlantic are currently at record warm levels and are anticipated to remain well above average for the upcoming hurricane season. A warmer-than-normal tropical Atlantic provides a more conducive dynamic and thermodynamic environment for hurricane formation and intensification. This forecast is of above-normal confidence for an early April outlook. We anticipate a well 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 4 April 2024)

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In Memory of William M. Gray[6]

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2024

Forecast Parameter and 1991–2020 Average (in parentheses)	Issue Date 4 April 2024
Named Storms (NS) (14.4)	23
Named Storm Days (NSD) (69.4)	115
Hurricanes (H) (7.2)	11
Hurricane Days (HD) (27.0)	45
Major Hurricanes (MH) (3.2)	5
Major Hurricane Days (MHD) (7.4)	13
Accumulated Cyclone Energy (ACE) (123)	210
ACE West of 60°W (73)	125
Net Tropical Cyclone Activity (NTC) (135%)	220

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

1) Entire continental U.S. coastline – 62% (average from 1880–2020 is 43%)

2) U.S. East Coast Including Peninsula Florida (south and east of Cedar Key, Florida) – 34% (average from 1880–2020 is 21%)

3) Gulf Coast from the Florida Panhandle (west and north of Cedar Key, Florida) westward to Brownsville – 42% (average from 1880–2020 is 27%)

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

1) 66% (average from 1880–2020 is 47%)

ABSTRACT

Information obtained through March 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), 115 named storm days (average is 69.4), 11 hurricanes (average is 7.2), 45 hurricane days (average is 27.0), 5 major (Category 3-4-5) hurricanes (average is 3.2) and 13 major hurricane days (average is 7.4). The probability of U.S. and Caribbean 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 approximately 170 percent of their long-term averages.

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 April 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 off of 25–40 years of past data from the European Centre for Medium Range Weather Forecasts, the UK Met Office, the Japan Meteorological Agency and the Centro Euro-Mediterraneo sui Cambiamenti Climatici model as four additional forecast guidance tools. This model guidance is unanimously pointing towards a hyperactive season.

The tropical Pacific is currently characterized by El Niño conditions. These El Niño conditions are likely to transition to neutral ENSO conditions in the next few weeks and then to La Niña conditions by the peak of the Atlantic hurricane season. La Niña typically increases Atlantic hurricane activity through decreases in vertical wind shear. This year’s sea surface temperatures in the eastern and central tropical Atlantic are much warmer than normal, also favoring an active Atlantic hurricane season via dynamic and thermodynamic conditions that are conducive to developing hurricanes.

The early April forecast is the earliest seasonal forecast issued by Colorado State University and has modest long-term skill when evaluated in hindcast mode. While the skill of this prediction is low, our confidence is higher than normal this year for an early April forecast given how hurricane-favorable the large-scale conditions appear to be. The skill of CSU’s forecast updates increases as the peak of the Atlantic hurricane season approaches. We also present probabilities of exceedance for hurricanes and Accumulated Cyclone Energy to give interested readers a better idea of the uncertainty associated with these forecasts.

Why issue extended-range forecasts for seasonal hurricane activity?

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

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early April. 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 April statistical and statistical/dynamical hybrid models show strong evidence on ~25–40 years of data that significant improvement over a climatological forecast can be attained. We would never issue a seasonal hurricane forecast unless we had models developed over a long hindcast period which showed skill. We also now include probabilities of exceedance to provide a visualization of the uncertainty associated with these predictions.

We issue these forecasts to satisfy the curiosity of the general public and to bring attention to the hurricane problem. There is a general interest in knowing what the odds are for an active or inactive season. One must remember that our forecasts are based on the premise that those global oceanic and atmospheric conditions which preceded comparatively active or inactive hurricane seasons in the past provide meaningful information about similar trends in future seasons.

It is also important that the reader appreciate that these seasonal forecasts are based on statistical and dynamical models which will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin these storms will strike. The probability of landfall for any one location along the coast is very low and reflects the fact that, in any one season, most U.S. coastal areas will not feel the effects of a hurricane no matter how active the individual season is.

Acknowledgment

These seasonal forecasts were developed by the late Dr. William Gray, who was lead author on these predictions for over 20 years and continued as a co-author until his death in 2016. In addition to pioneering seasonal Atlantic hurricane prediction, he conducted groundbreaking research on a wide variety of other topics including hurricane genesis, hurricane structure and cumulus convection. His investments in both time and energy to these forecasts cannot be acknowledged enough.

We are grateful for support from Ironshore Insurance, the Insurance Information Institute, Weatherboy and IAA. We acknowledge a grant from the G. Unger Vetlesen Foundation for additional financial support.

Colorado State University's seasonal hurricane forecasts have benefited greatly from a number of individuals that were former graduate students of William Gray. Among these former project members are Chris Landsea, John Knaff and Eric Blake. We also would like to thank Jhordanne Jones, recent Ph.D. graduate in Michael Bell's research group, for model development and forecast assistance over the past several years. 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-Jimenez 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. 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.

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 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 April forecast is based on a statistical model as well as output from statistical/dynamical models from the European Centre for Medium-Range Weather Forecasts (ECMWF), the UK Met Office, the Japan Meteorological Agency (JMA) and the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC). These models show skill at predicting TC activity based on ~25–40 years of historical data. We also select analog seasons, based on currently-observed conditions as well as conditions that we anticipate for the peak of the Atlantic hurricane season. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by these analyses. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic basin TC activity and landfall probability. We believe that seasonal forecasts must be based on methods that show significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided that the atmosphere continues to behave in the future as it has in the past.

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

2 April Forecast Methodology

2.1 April Statistical Forecast Scheme

Our current April statistical forecast model uses ECMWF Reanalysis 5 (ERA5; Hersbach et al. 2020). This model was developed on data from 1979–2020, was independently tested on data for 2021 and 2022 and was used for the real-time forecast for 2023. This model shows significant skill in cross-validated hindcasts of Accumulated Cyclone Energy (ACE) (r = 0.70) over the period from 1979–2023 (Figure 1). Cross-validation entails that for each year being forecast, the equation is developed on all other years in the hindcast but excluding the year being forecast. So a forecast for 1979 would be based on a hindcast equation developed on 1980–2020, a forecast for 1980 would be based on a hindcast equation developed on 1979 and 1981–2020, etc.

Figure 2 displays the locations of each predictor, while Table 1 displays the individual linear correlations between each predictor and ACE over the 1979–2023 hindcast/forecast period. All predictors correlate significantly at the 5% level using a two-tailed Student's t-test, and each year is assumed to represent an individual degree of freedom. Table 2 displays the 2024 observed values for each of the three predictors in the statistical forecast scheme. Table 3 displays the statistical model output for the 2024 hurricane season. The two SST predictors call for an extremely active Atlantic hurricane season, while the 200 hPa zonal wind predictor calls for a near-average season. The three predictors in combination call for an extremely active season.

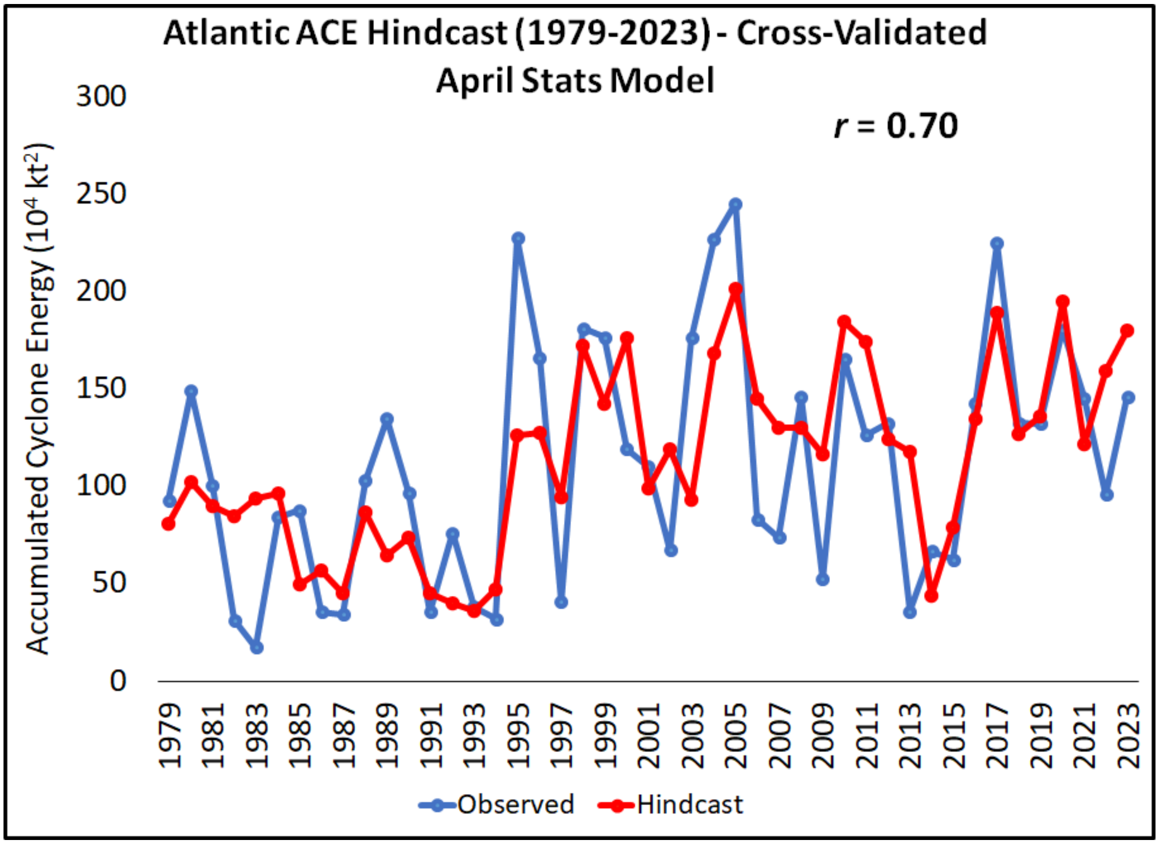

Figure 1: Observed versus early April cross-validated hindcast values of ACE for the statistical model from 1979–2023.

Statistical Model Predictors

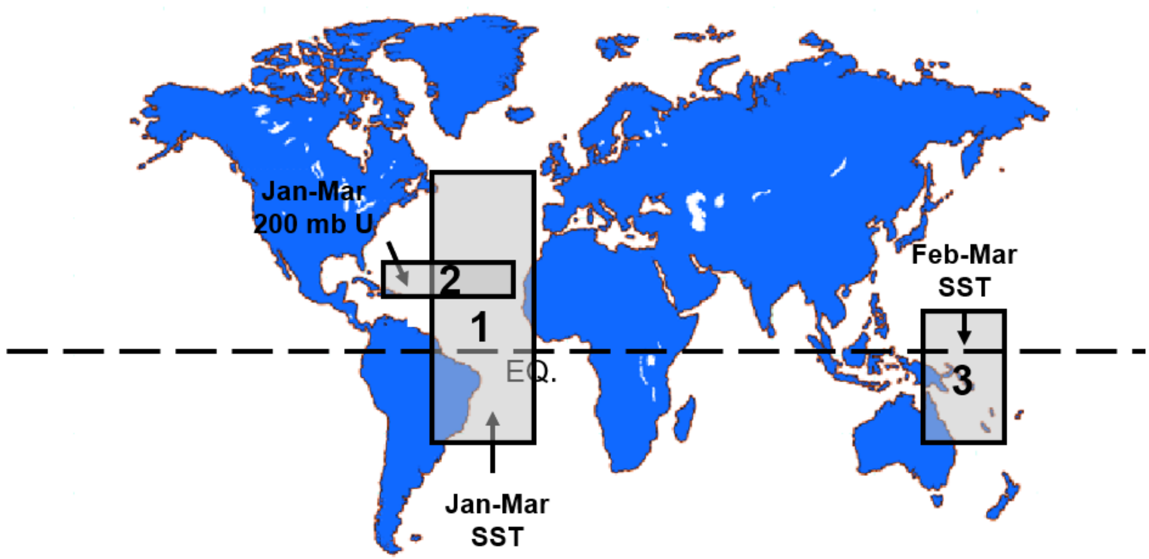

Figure 2: Location of predictors for our early April extended-range statistical prediction for the 2024 hurricane season.

Table 1: Linear correlation between early April predictors and ACE over the period from 1979–2023.

Predictor	Correlation w/ ACE
1) January–March SST (30°S–50°N, 40°W–10°W) (+)	0.56
2) January–March 200 hPa U (17.5°N–27.5°N, 60°W–20°W) (+)	0.43
3) February–March SST (30°S–15°N, 140°E–170°E) (+)	0.52

Table 2: Listing of early April 2024 predictors for the 2024 hurricane season. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity. SD stands for standard deviation.

Predictor	2024 Forecast Value	Impact on 2024 TC Activity
1) January–March SST (30°S–50°N, 40°W–10°W) (+)	+4.6 SD	Strongly Enhance
2) January–March 200 hPa U (17.5°N–27.5°N, 60°W–20°W) (+)	-0.1 SD	Neutral
3) February-March SST (30°S–15°N, 140°E–170°E) (+)	+1.9 SD	Enhance

Table 3: Statistical model output for the 2024 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)	24.9	23
Named Storm Days (NSD) (69.4)	130.8	115
Hurricanes (H) (7.2)	13.6	11
Hurricane Days (HD) (27.0)	60.4	45
Major Hurricanes (MH) (3.2)	7.0	5
Major Hurricane Days (MHD) (7.4)	19.5	13
Accumulated Cyclone Energy (ACE) (123)	269	210
Net Tropical Cyclone Activity (NTC) (135%)	283	220

The locations and brief descriptions of the predictors for our early April statistical forecast are now discussed. It should be noted that all predictors correlate positively 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.

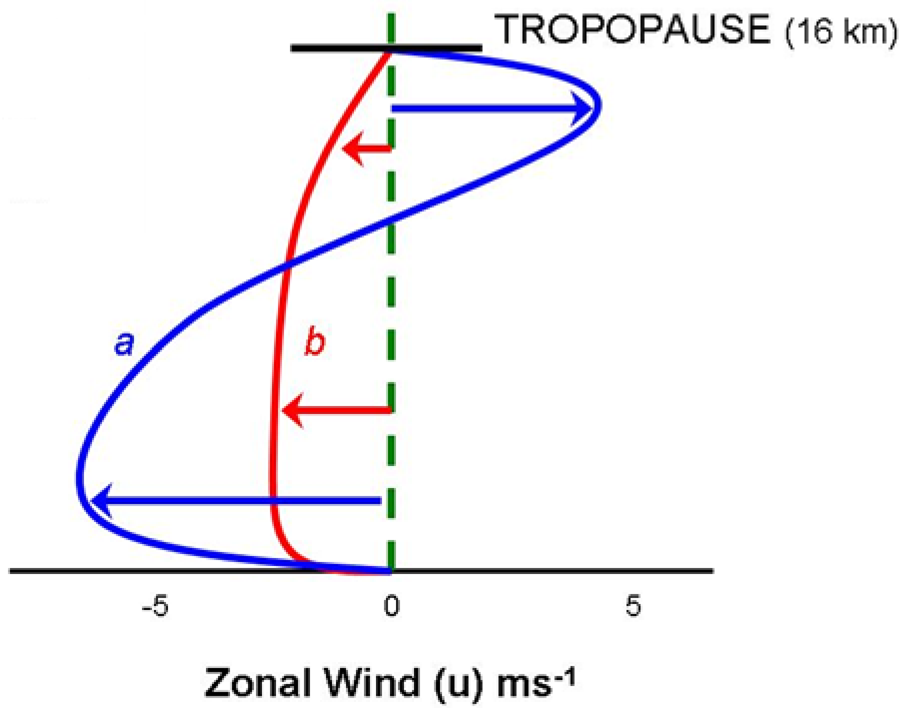

Figure 3: Vertical wind profile in the MDR typically associated with (a) inactive Atlantic basin hurricane seasons and (b) active Atlantic basin hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

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

<u>Predictor 1. January–March SST in the tropical and subtropical eastern Atlantic (+)</u>

(30°S–50°N, 40°W–10°W)

Warmer-than-normal SSTs in the tropical and subtropical Atlantic during the January–March time period are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the boreal spring (Knaff 1997). Anomalously warm SSTs in January–March 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 three of these August–October features are commonly associated with active Atlantic basin hurricane seasons, through reductions in vertical wind shear, increased vertical instability and increased mid-tropospheric moisture, respectively. Predictor 1 correlates quite strongly (*r* =0.56) with ACE from 1979–2022. Predictor 1 also strongly correlates (*r* = 0.56) with August–October values of the SST component of the Atlantic Meridional Mode (AMM) (Kossin and Vimont 2007) from 1979–2022. The AMM has been shown to impact Atlantic hurricane activity through alterations in the position and intensity of the Atlantic Inter-Tropical Convergence Zone (ITCZ). Changes in the Atlantic ITCZ bring about changes in tropical Atlantic vertical and horizontal wind shear patterns and in tropical Atlantic SST patterns.

<u>Predictor 2. January–March 200 hPa U in the subtropical North Atlantic (+)</u>

(17.5°N–27.5°N, 60°W–20°W)

Anomalously strong winds at upper-levels in the subtropical North Atlantic are associated with anomalously low pressure in the tropical and subtropical Atlantic during January–March. Stronger-than-normal westerly winds at upper levels in the subtropics are also associated with reduced anticyclonic wavebreaking (and associated reduced vertical wind shear) during the peak of the Atlantic hurricane season (Jones et al. 2022). As has been shown in prior work (Knaff 1997), when the Azores High is weaker than normal, Atlantic trade winds are also weaker than normal. These weaker trades inhibit ocean mixing and upwelling, thereby causing anomalous warming of tropical Atlantic SSTs. These warmer SSTs are then associated with lower-than-normal sea level pressures which can create a self-enhancing feedback that relates to lower pressure, weaker trades and warmer SSTs during the hurricane season (Figure 5) (Knaff 1998). All three of these factors are associated with active hurricane seasons. This predictor is also negatively correlated with tropical central Pacific SSTs during August–October, indicating that La Niña-like conditions are favored during the boreal summer when anomalously strong upper-level winds predominate over the Atlantic during January–March.

<u>Predictor 3. February–March SST in the western tropical/subtropical Pacific (+)</u>

(30°S–15°N, 140°E–170°E)

Anomalous warmth in the western tropical/subtropical Pacific is associated with lower pressure in the western tropical Pacific and higher pressure in the eastern tropical Pacific, thereby driving stronger trade winds across the tropical Pacific that inhibit El Niño development. The development of anomalously high pressure in the eastern tropical Pacific then drives anomalously weak trade winds in the tropical Atlantic, feeding back into both reduced shear and anomalously warm SSTs in the tropical Atlantic by the peak of the Atlantic hurricane season (August–October) (Figure 6).

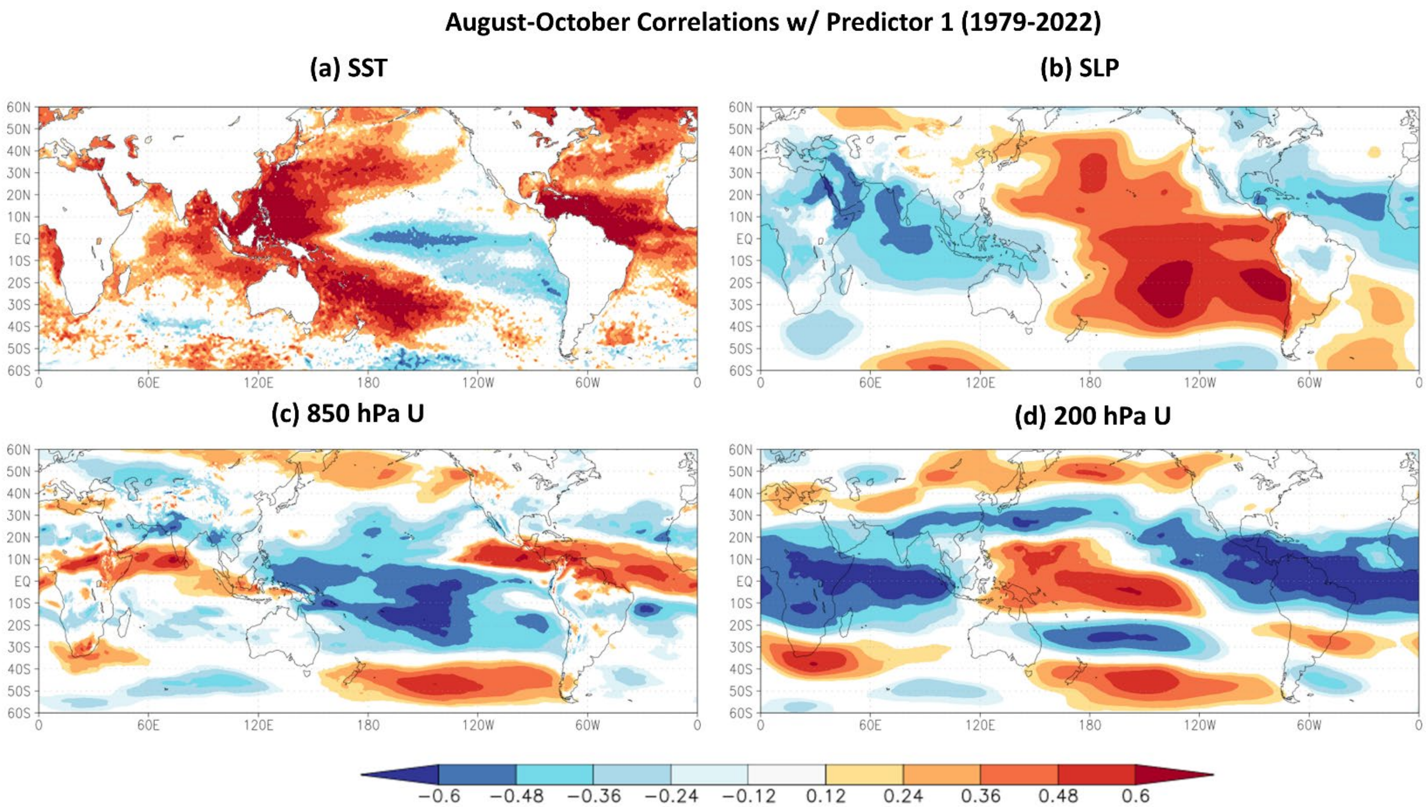

Figure 4: Rank correlations between January–March SST in the tropical and subtropical Atlantic (Predictor 1) and (panel a) August–October sea surface temperature, (panel b) August–October sea level pressure, (panel c) August–October 850 hPa zonal wind and (panel d) August–October 200 hPa zonal wind.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

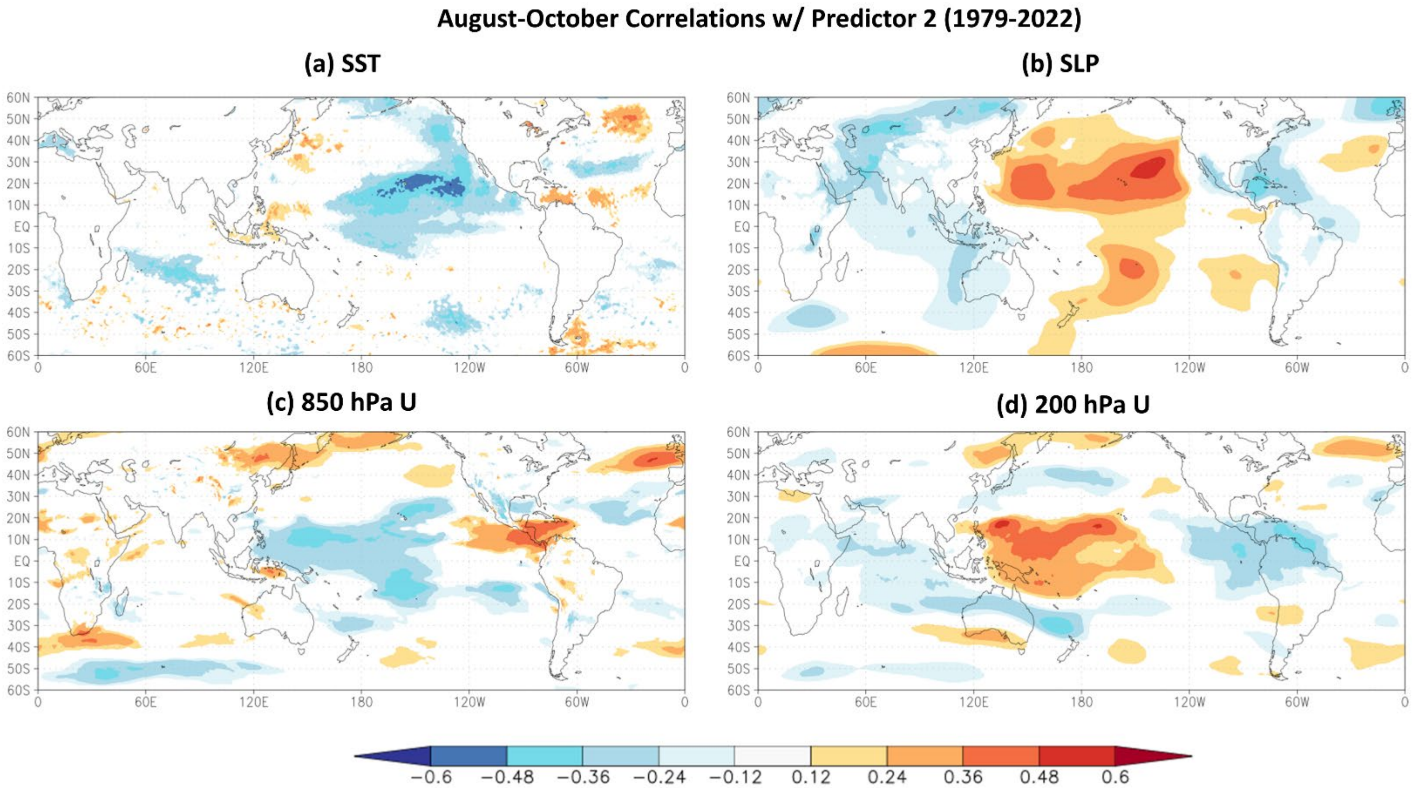

Figure 5: As in Figure 4 but for January–March 200 hPa zonal wind in the subtropical North Atlantic.

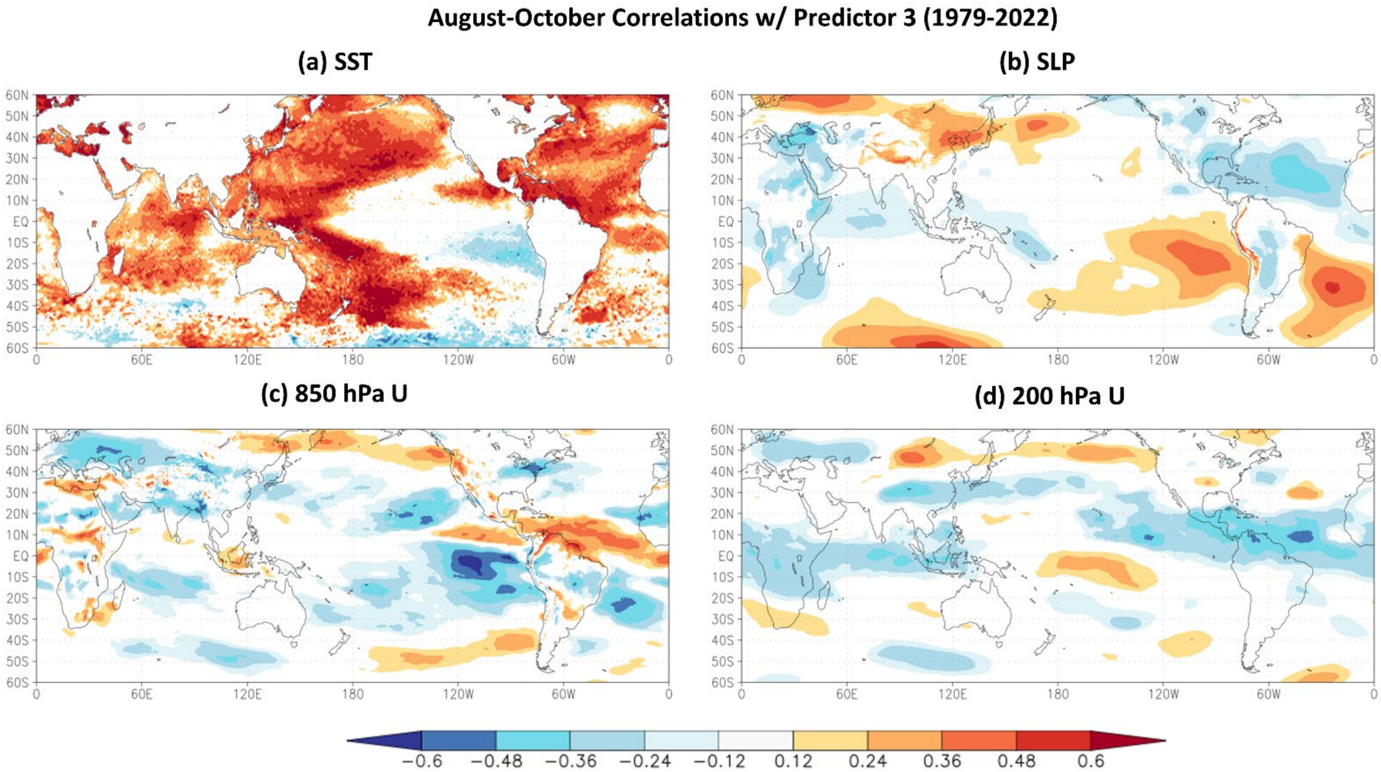

Figure 6: As in Figure 4 but for February–March SST in the western tropical/subtropical Pacific.

2.2 April 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, namely, ECMWF, UK Met, JMA and CMCC, to forecast August 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. These model forecasts extend out six months, which is why all forecasts here examine August data.

a) ECMWF Statistical/Dynamical Model Forecast

Figure 7 displays the locations of the two forecast parameters, while Table 4 displays ECMWF's forecasts of these parameters for 2024 from a 1 March initialization date. The ensemble average of the ECMWF model is predicting the warmest eastern/central North Atlantic on record (since 1981) and a cool neutral/weak La Niña. This combination yields the highest predicted ACE on record for this forecast scheme.

Figure 8 displays cross-validated hindcasts for ECMWF forecasts of ACE from 1981–2023, while Table 5 presents the forecast from ECMWF for the 2024 Atlantic hurricane season.

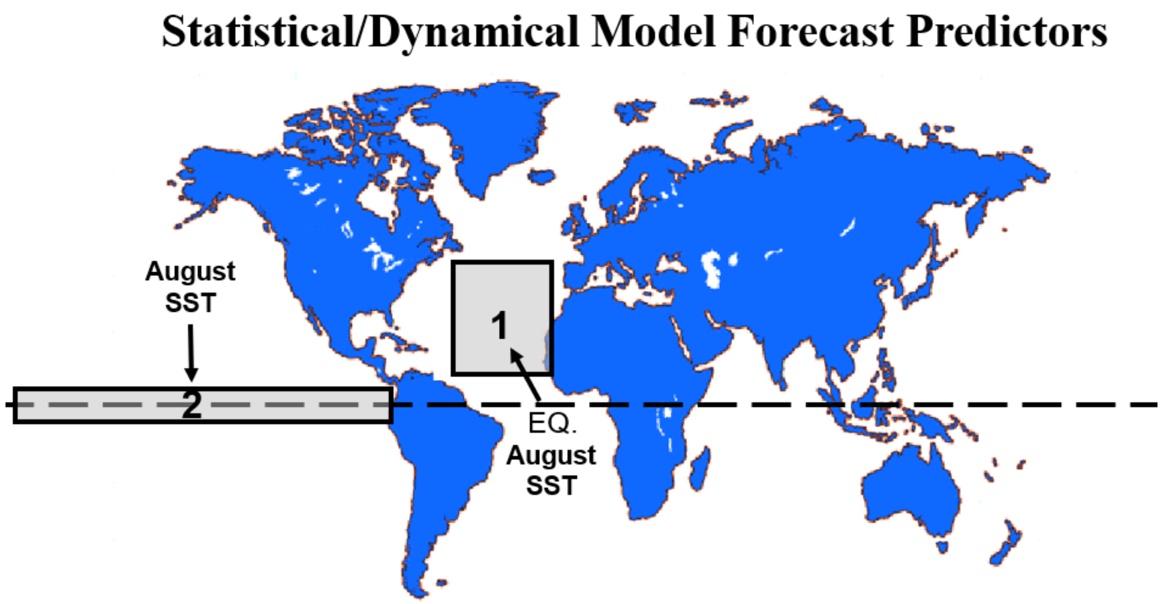

Figure 7: Location of predictors for our early April statistical/dynamical extended-range statistical prediction for the 2024 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August SSTs in the two boxes displayed and then uses those predictors to forecast ACE.

Table 4: Listing of predictions of August large-scale conditions from ECMWF model output, initialized on 1 March. 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 August SST (10–45°N, 60–20°W) (+)	+3.2 SD	Strongly Enhance
2) ECMWF Prediction of August SST (5°S–5°N, 180–90°W) (-)	-0.6 SD	Enhance

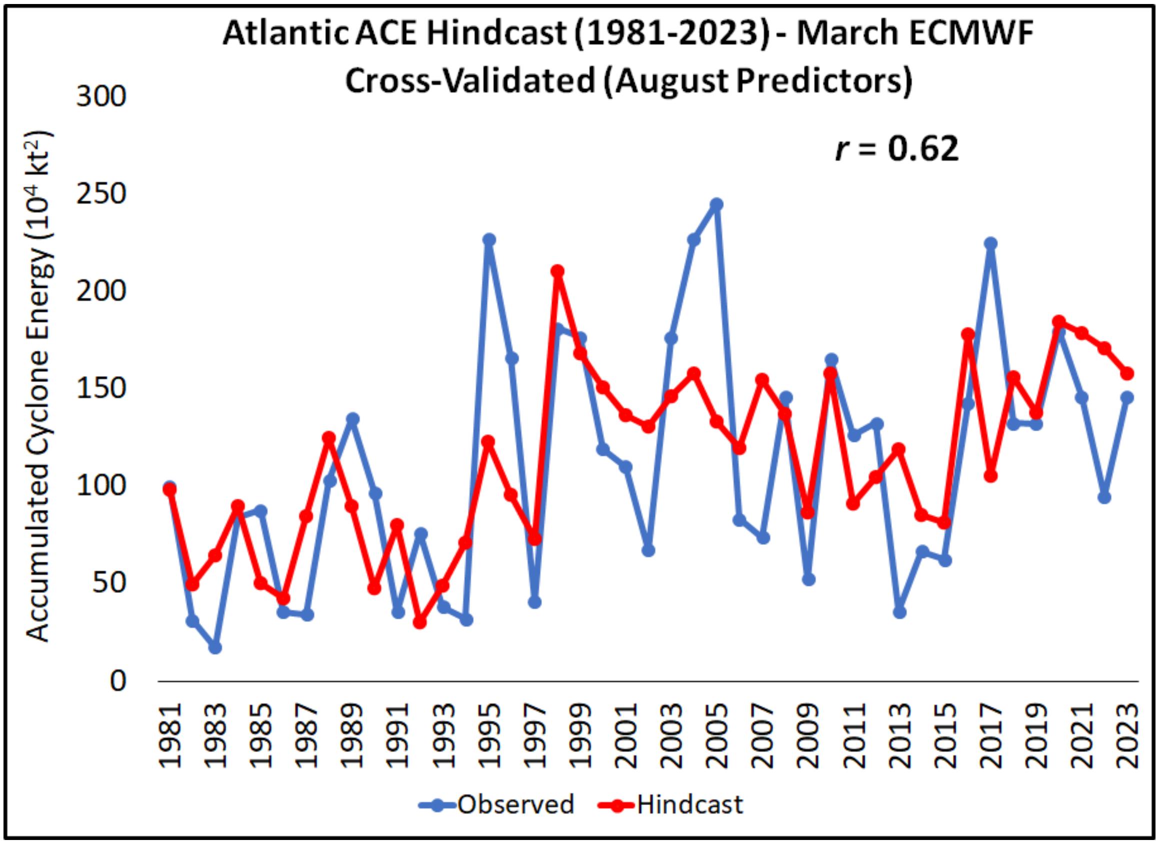

Figure 8: Observed versus cross-validated statistical/dynamical hindcast values of ACE for 1981–2023 from ECMWF.

Table 5: 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)	22.7	23
Named Storm Days (69.4)	115.7	115
Hurricanes (7.2)	12.0	11
Hurricane Days (27.0)	52.2	45
Major Hurricanes (3.2)	6.1	5
Major Hurricane Days (7.4)	16.5	13
Accumulated Cyclone Energy Index (123)	233	210
Net Tropical Cyclone Activity (135%)	247	220

b) UK Met Office Statistical/Dynamical Model Forecast

Table 6 displays the UK Met Office forecasts of the August parameters for 2024 from a 1 March initialization date. The ensemble average from the UK Met Office dynamical model (GloSea6) is calling for a warmer central/eastern North Atlantic than in any year in the hindcast period from 1993–2016 and a robust La Niña. Figure 9 displays hindcasts for the UK Met Office of ACE from 1993–2016, while Table 7 presents the forecast from the statistical/dynamical model guidance based off GloSea6 for the 2024 Atlantic hurricane season.

Table 6: Listing of predictions of August large-scale conditions from UK Met model output, initialized on 1 March. 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 August SST (10–45°N, 60–20°W) (+)	+4.2 SD	Strongly Enhance
2) UK Met Prediction of August SST (5°S–5°N, 180–90°W) (-)	-1.7 SD	Enhance

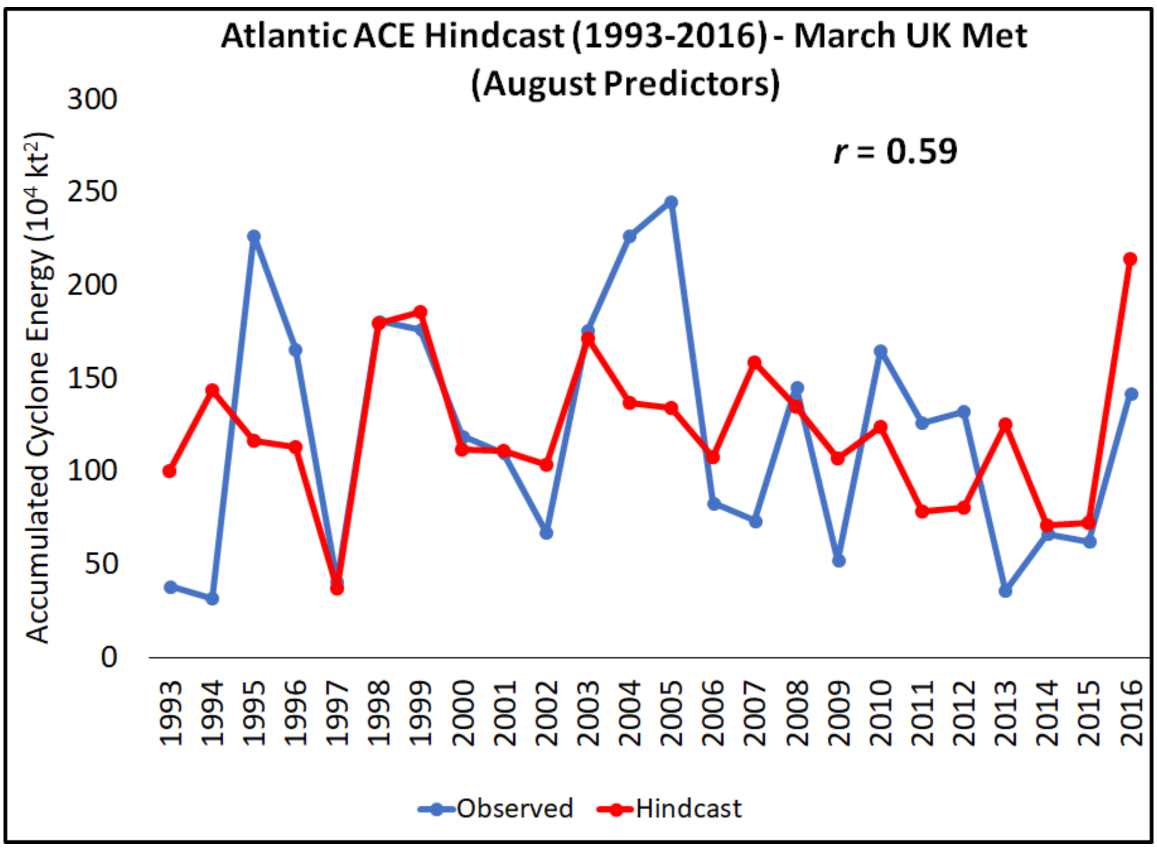

Figure 9: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the UK Met Office.

Table 7: Statistical/dynamical model output from the UK Met Office for the 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)	23.2	23
Named Storm Days (69.4)	119.1	115
Hurricanes (7.2)	12.4	11
Hurricane Days (27.0)	54.0	45
Major Hurricanes (3.2)	6.3	5
Major Hurricane Days (7.4)	17.2	13
Accumulated Cyclone Energy Index (123)	241	210
Net Tropical Cyclone Activity (135%)	255	220

c) JMA Met Office Statistical/Dynamical Model Forecast

Table 8 displays the JMA forecasts of the August parameters for 2024 from a 1 March initialization date. The ensemble average from the JMA dynamical model is calling for a warmer central/eastern North Atlantic than in any year in the hindcast period from 1993–2020 and a weak La Niña. Figure 10 displays hindcasts for the JMA of ACE from 1993–2020, while Table 9 presents the forecast from the JMA for the 2024 Atlantic hurricane season. The statistical/dynamical model based off of JMA is also calling for an extremely active Atlantic hurricane season in 2024.

Table 8: Listing of predictions of August large-scale conditions from JMA model output, initialized on 1 March. 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 August SST (10–45°N, 60–20°W) (+)	+3.3 SD	Strongly Enhance
2) JMA Prediction of August SST (5°S–5°N, 180–90°W) (-)	-0.8 SD	Enhance

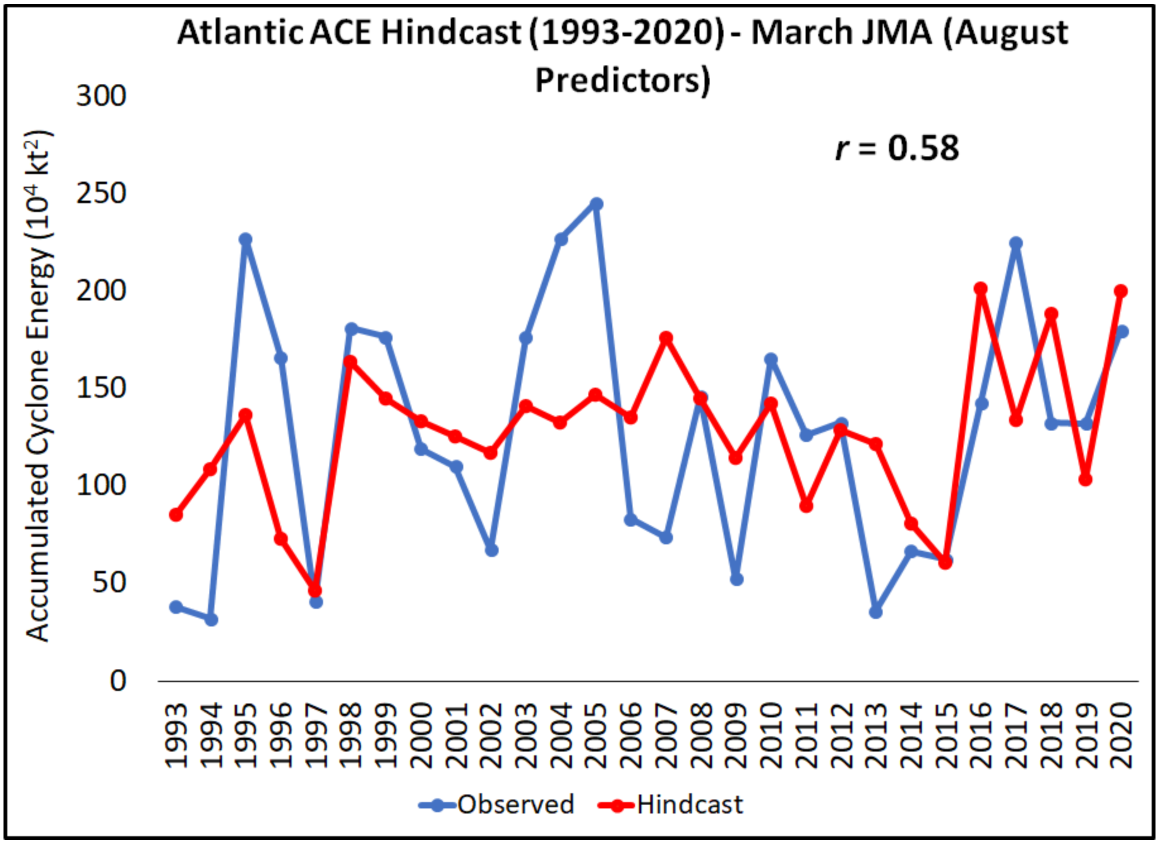

Figure 10: Observed versus statistical/dynamical hindcast values of ACE for 1993–2020 from the JMA.

Table 9: 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)	22.4	23
Named Storm Days (69.4)	114.0	115
Hurricanes (7.2)	11.8	11
Hurricane Days (27.0)	51.3	45
Major Hurricanes (3.2)	6.0	5
Major Hurricane Days (7.4)	16.2	13
Accumulated Cyclone Energy Index (123)	229	210
Net Tropical Cyclone Activity (135%)	243	220

d) CMCC Statistical/Dynamical Model Forecast

Table 10 displays the CMCC forecasts of the August parameters for 2024 from a 1 March initialization date. The ensemble average from the CMCC dynamical model is calling for a warmer central/eastern North Atlantic than in any year in the hindcast period from 1993–2016 and a robust La Niña. Figure 11 displays hindcasts for the CMCC of

ACE from 1993–2016, while Table 11 presents the forecast from the CMCC for the 2024 Atlantic hurricane season. The statistical/dynamical model based off of CMCC is calling for the most ACE on record for an Atlantic hurricane season, primarily due to an even warmer eastern/central tropical Atlantic than the other model guidance is predicting.

Table 10: Listing of predictions of August large-scale conditions from CMCC model output, initialized on 1 March. 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 August SST (10–45°N, 60–20°W) (+)	+4.8 SD	Strongly Enhance
2) CMCC Prediction of August SST (5°S–5°N, 180–90°W) (-)	-1.5 SD	Enhance

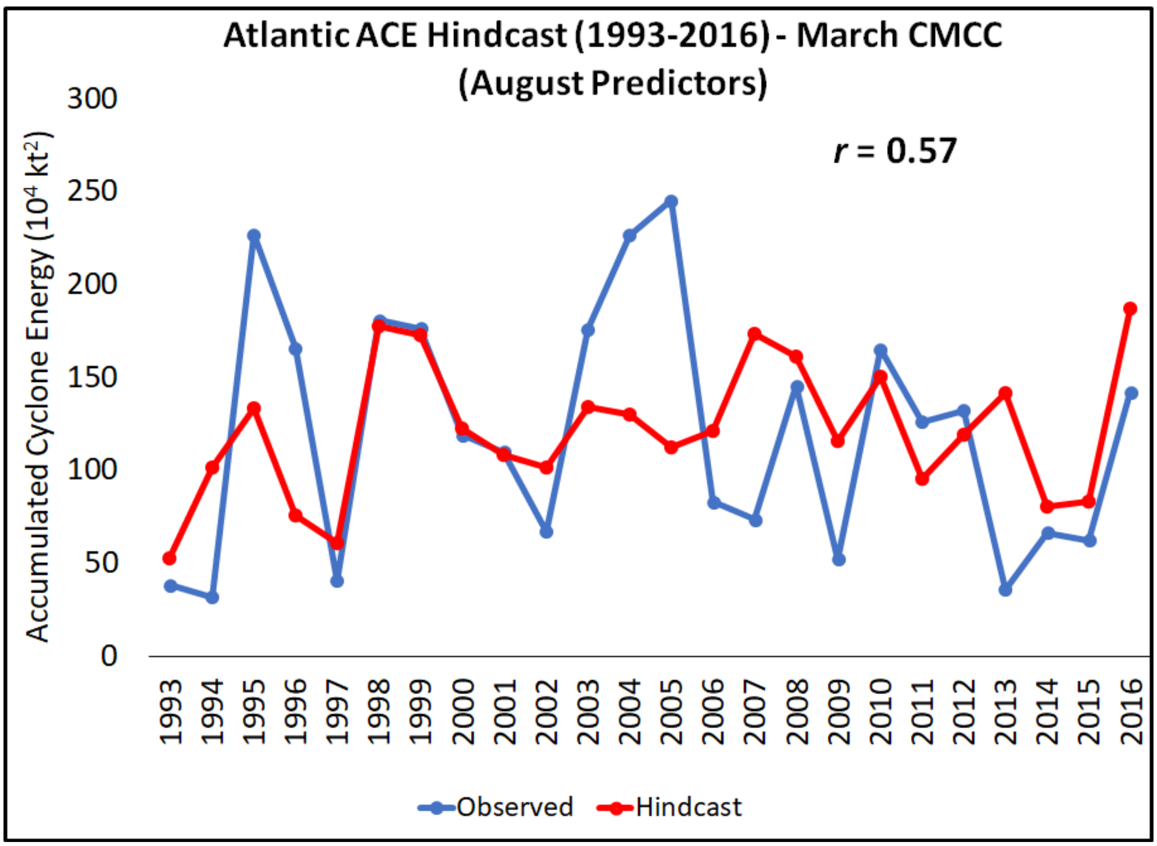

Figure 11: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the CMCC.

Table 11: Statistical/dynamical model output from the CMCC for the 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)	25.6	23
Named Storm Days (69.4)	135.4	115
Hurricanes (7.2)	14.1	11
Hurricane Days (27.0)	63.0	45
Major Hurricanes (3.2)	7.3	5
Major Hurricane Days (7.4)	20.4	13
Accumulated Cyclone Energy Index (123)	280	210
Net Tropical Cyclone Activity (135%)	294	220

2.3 April Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2024. These years also provide useful clues as to likely levels of activity that the forthcoming 2024 hurricane season may bring. For this early April 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 March 2024 conditions and, more importantly, projected August–October 2024 conditions. Table 12 lists our analog selections, while Figure 12 shows the composite August–October SST in our five analog years.

We searched for years that were generally characterized by El Niño conditions the previous winter and had La Niña conditions during the peak of the Atlantic hurricane season (August–October). We also selected years that had well above-average SSTs in the tropical Atlantic, although none of these years had SSTs in the tropical Atlantic in March that were as warm as they are now. We anticipate that the 2024 hurricane season will have activity near the average of our five 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 1878 and 1926 given the extremely limited observational network available in those years.

Table 12: Analog years for 2024 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1878	12	90.00	10	50.25	2	10.00	180.9	161.6
1926	11	86.75	8	58.50	6	22.75	229.6	230.3
1998	14	87.25	10	48.50	3	9.50	181.2	168.6
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	17.2	95.3	10.8	46.2	4.6	12.3	187.5	198.5
2024 Forecast	**23**	**115**	**11**	**45**	**5**	**13**	**210**	**220**

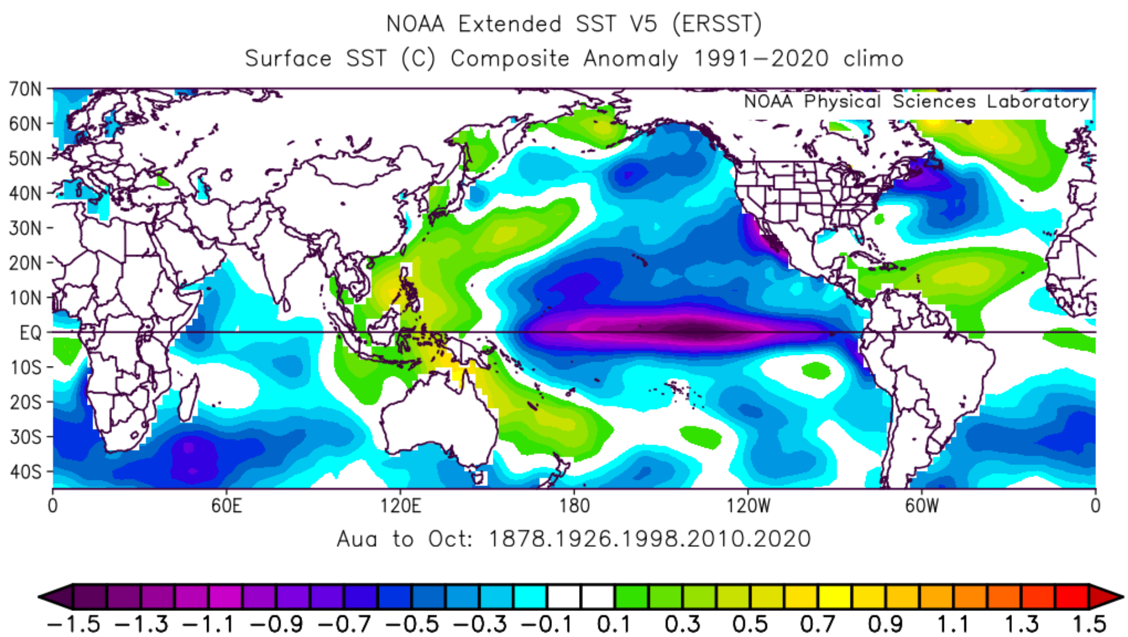

Figure 12: Average August–October SST anomalies in our five analog years.

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 13 and 14) since 1950.

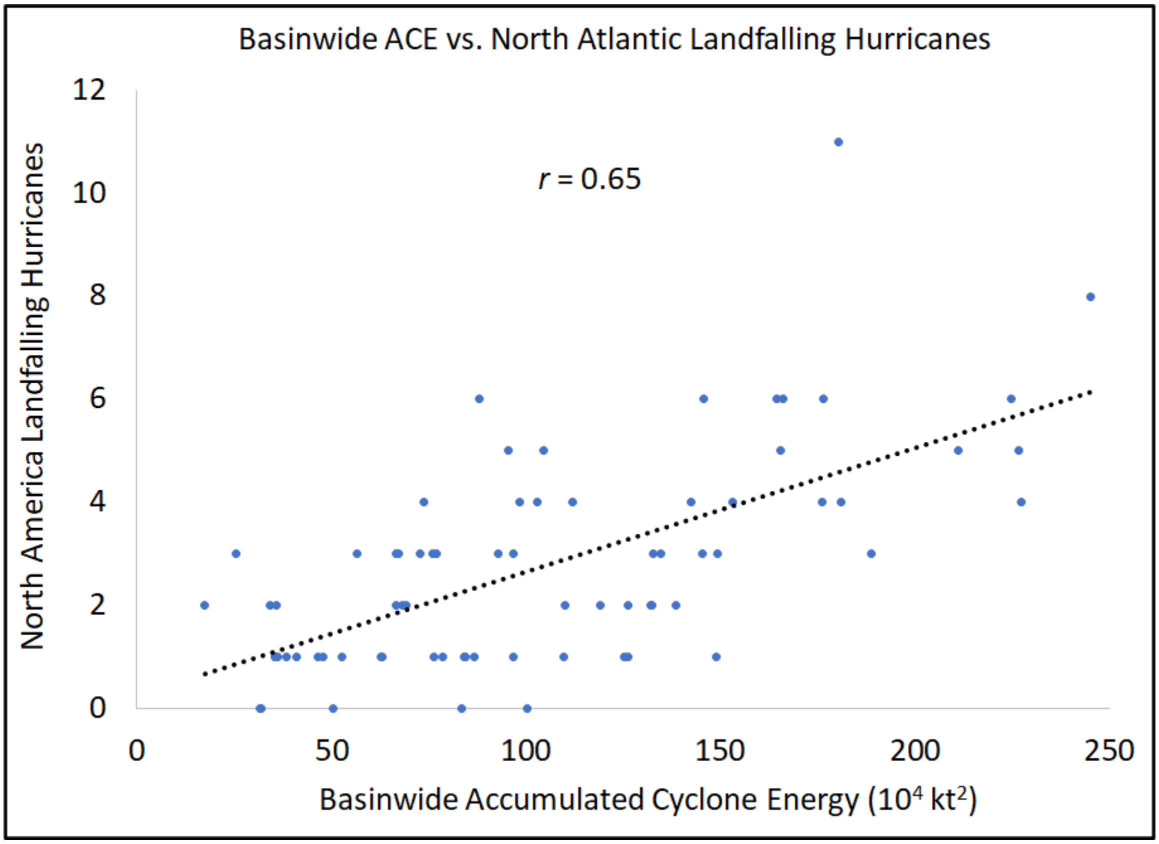

Figure 13: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

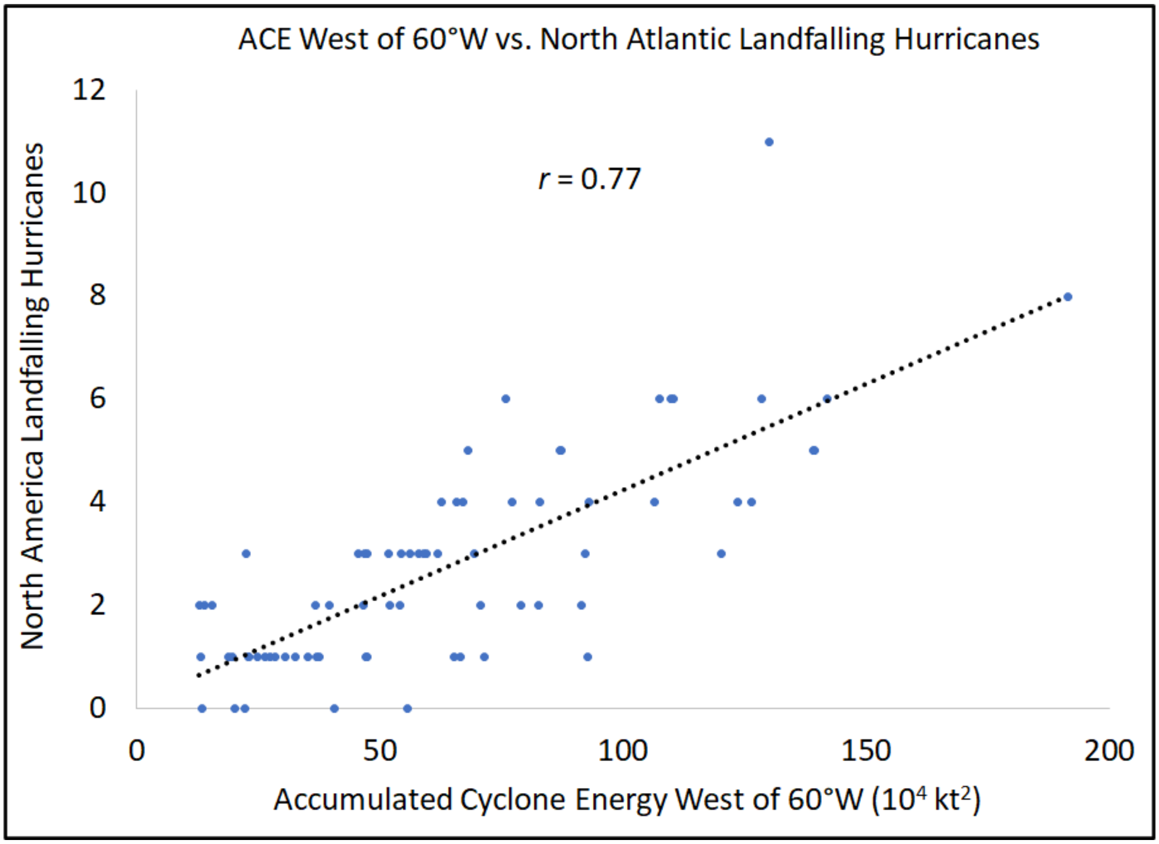

Figure 14: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

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

We find that 52% of basinwide ACE occurs west of 60°W in El Niño years, while 60% of basinwide ACE occurs west of 60°W in La Niña years. In neutral ENSO years, 59% of basinwide ACE occurs west of 60°W. 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.

2.5 April Forecast Summary and Final Adjusted Forecast

Table 13 shows our final adjusted early April forecast for the 2024 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. All of our forecast model guidance is calling for a hyperactive season. While there remains considerable uncertainty with any seasonal hurricane forecast issued in early April, the confidence in our prediction is higher than normal for an early April outlook. This is our highest prediction that we have ever issued with our April outlook. Our prior highest April forecast was for nine hurricanes, which we have called for several times since we began issuing April forecasts in 1995.

Table 13: Summary of our early April statistical forecast, our statistical/dynamical forecasts, our analog forecast, the average of these six schemes and our adjusted final forecast for the 2024 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)	24.9	22.7	23.2	22.4	25.6	17.2	22.7	23
Named Storm Days (69.4)	130.8	115.7	119.1	114.0	135.4	95.3	118.4	115
Hurricanes (7.2)	13.6	12.0	12.4	11.8	14.1	10.8	12.5	11
Hurricane Days (27.0)	60.4	52.2	54.0	51.3	63.0	46.2	54.5	45
Major Hurricanes (3.2)	7.0	6.1	6.3	6.0	7.3	4.6	6.2	5
Major Hurricane Days (7.4)	19.5	16.5	17.2	16.2	20.4	12.3	17.0	13
Accumulated Cyclone Energy Index (123)	269	233	241	229	280	188	240	210
Net Tropical Cyclone Activity (135%)	283	247	255	243	294	199	254	220

3 Forecast Uncertainty

This season we continue to use probability of exceedance curves as discussed in Saunders et al. (2020) to quantify forecast uncertainty. In that paper, we outlined an approach that uses statistical modeling and historical skill of various forecast models to arrive at a probability that particular values for hurricane numbers and ACE would be exceeded. Here we display probability of exceedance curves for hurricanes and ACE (Figures 15 and 16), using the error distributions calculated from both normalized cross-validated statistical as well as the cross-validated statistical/dynamical hindcasts from SEAS5. Hurricane numbers are fit to a Poisson distribution, while ACE is fit to a Weibull distribution. Table 14 displays one standard deviation uncertainty ranges (~68% of all forecasts within this range). This uncertainty estimate is also very similar to the 70% uncertainty range that NOAA provides with its forecasts. We use Poisson distributions for all storm parameters (e.g., named storms, hurricanes and major hurricanes) while we use a Weibull distribution for all integrated parameters except for major hurricane days (e.g., named storm days, ACE, etc.). We use a Laplace distribution for major hurricane days. As noted earlier, we are more confident than normal for an April forecast given how robust our primary predictors are (e.g., likely La Niña, extremely warm Atlantic sea surface temperatures) for an active Atlantic hurricane season.

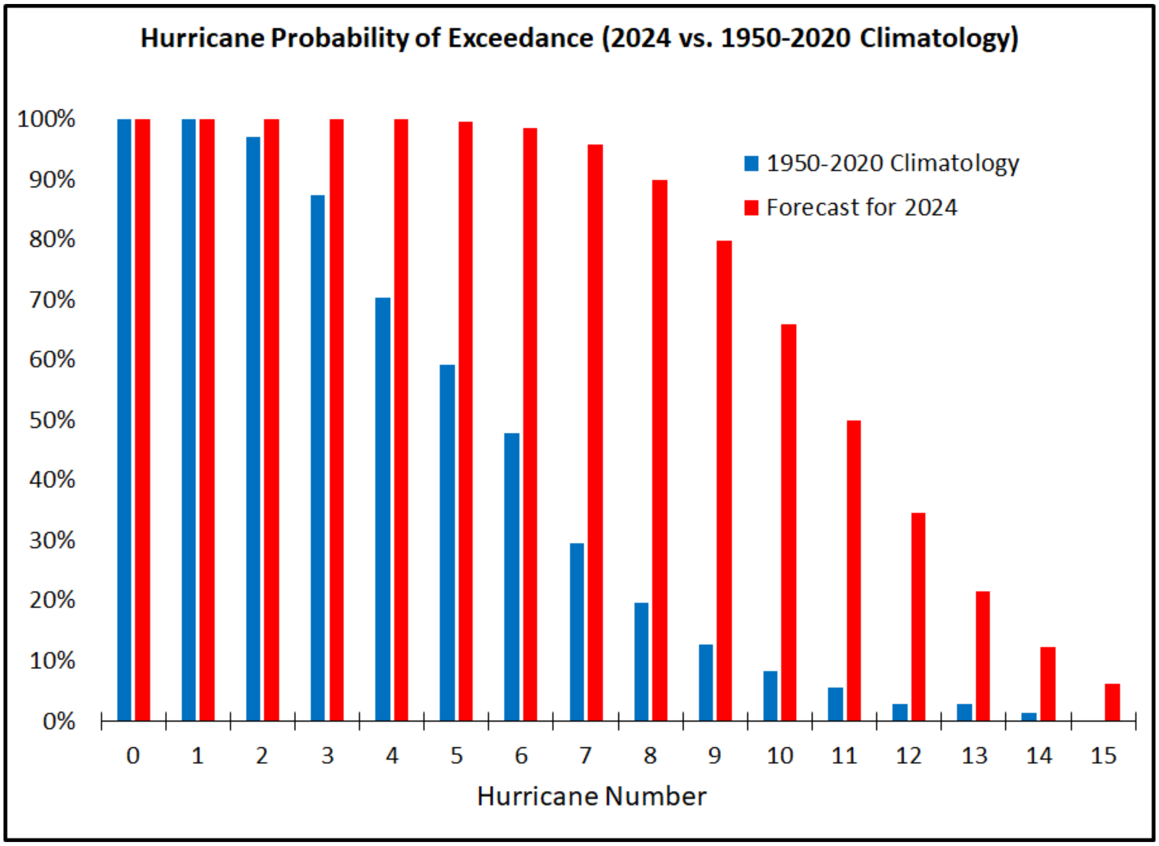

Figure 15: Probability of exceedance plot for hurricane numbers for the 2024 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950–2020 have had more than two hurricanes.

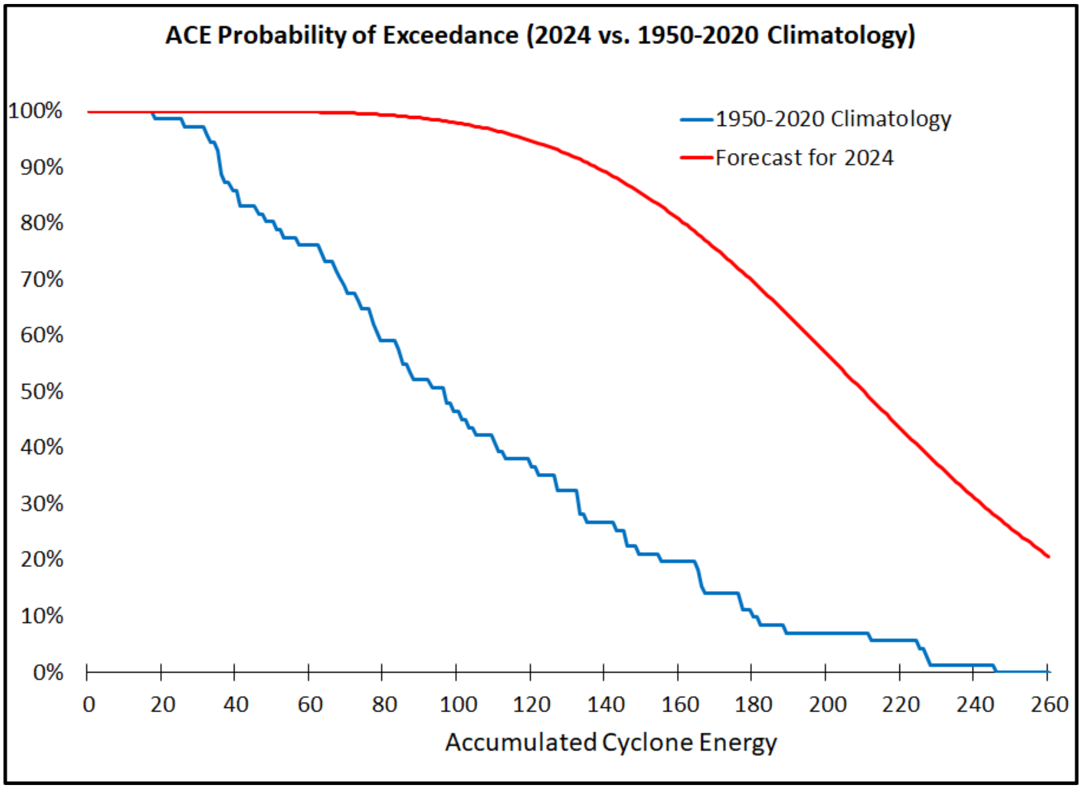

Figure 16: As in Figure 15 but for ACE.

Table 14: Forecast ranges for each parameter. Note that the forecast spread may not be symmetric around the mean value, given the historical distribution of tropical cyclone activity.

Parameter	2024 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	23	19 – 27
Named Storm Days (NSD)	115	91 – 130
Hurricanes (H)	11	8 – 14
Hurricane Days (HD)	45	30 – 61
Major Hurricanes (MH)	5	3 – 7
Major Hurricane Days (MHD)	13	8 – 20
Accumulated Cyclone Energy (ACE)	210	151 – 260
ACE West of 60°W	125	83 – 172
Net Tropical Cyclone (NTC) Activity	220	164 – 279

4 ENSO

Over the past several months, El Niño conditions in the tropical Pacific have gradually weakened (Figure 17). SST anomalies have decreased across the entire tropical Pacific, with the strongest anomalous cooling taking place in the far eastern tropical Pacific. Figure 18 displays the locations of the various Nino regions displayed in Figure 17.

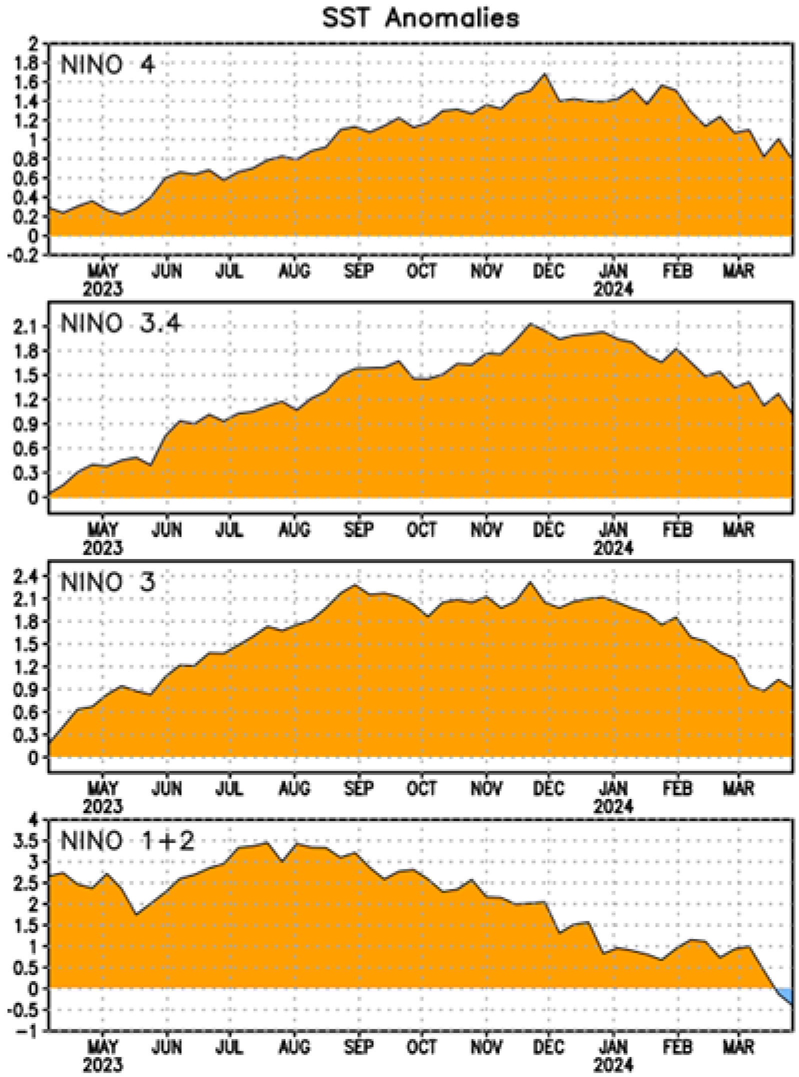

Figure 17: SST anomalies for several ENSO regions over the past year. Figure courtesy of Climate Prediction Center.

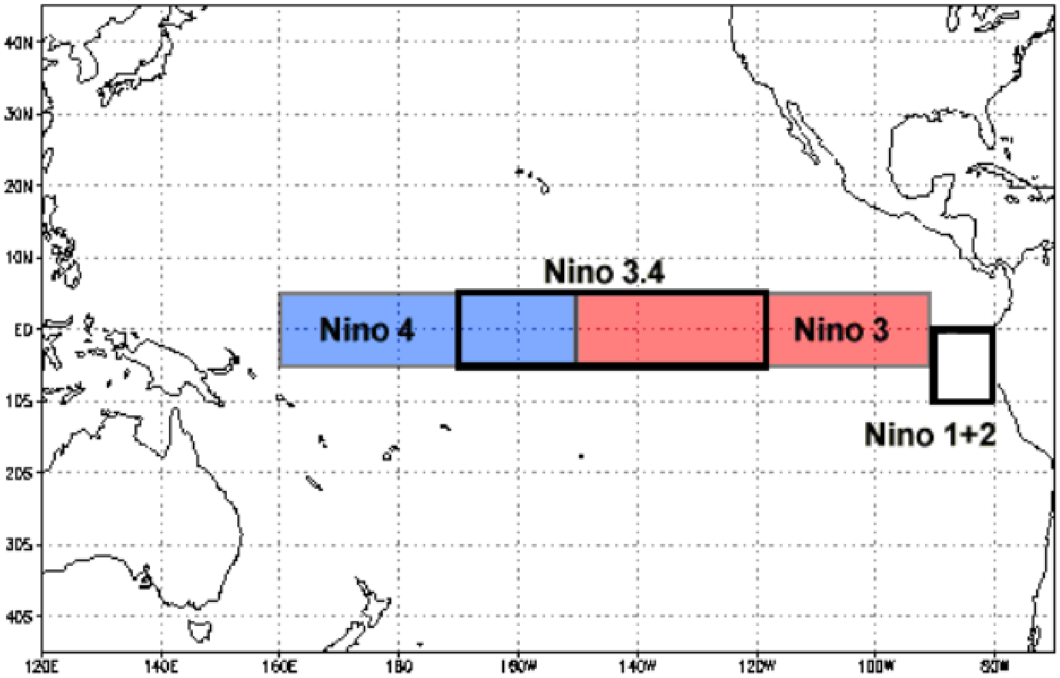

Figure 18: Location of ENSO SST regions used in Figure 17. Figure courtesy of the National Centers for Environmental Information.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific have decreased rapidly over the past several weeks and have recently become negative (Figure 19). Anomalously strong trade winds have triggered two upwelling oceanic Kelvin waves. These upwelling oceanic Kelvin waves have caused anomalous cooling in the eastern and central tropical Pacific.

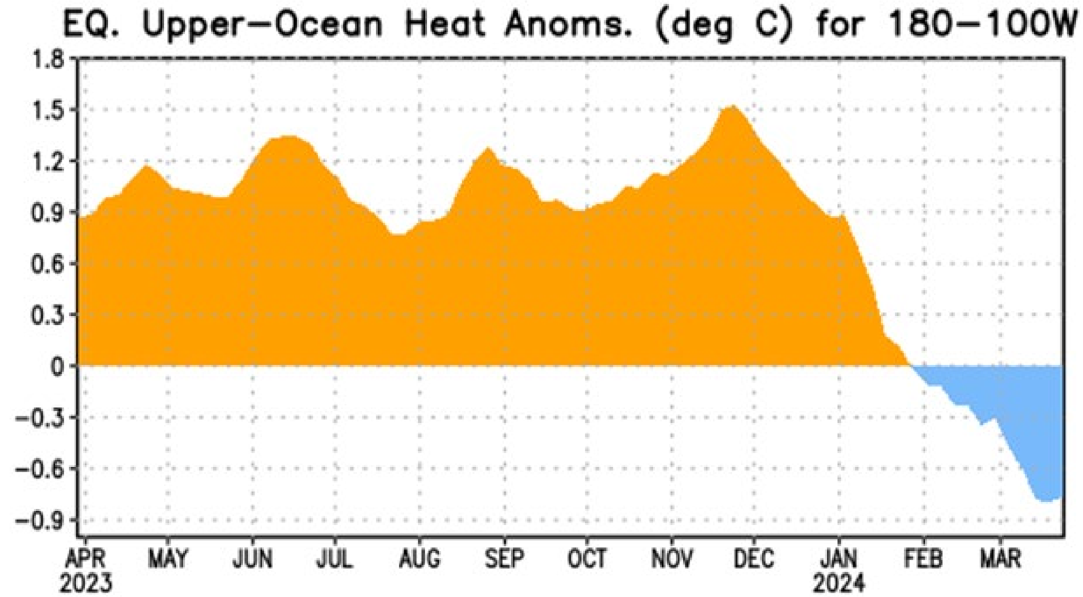

Figure 19: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

SSTs remain above-normal across most of the equatorial Pacific, with slightly below-normal SSTs beginning to emerge in parts of the far eastern tropical Pacific (Figure 20). The western North Pacific is warmer than normal, while the current spatial pattern of SSTs in the North Pacific (e.g., well above-average SST anomalies across most of the North Pacific and near to slightly above-average SSTs off the west coast of California) are indicative of a negative phase of the Pacific Decadal Oscillation.

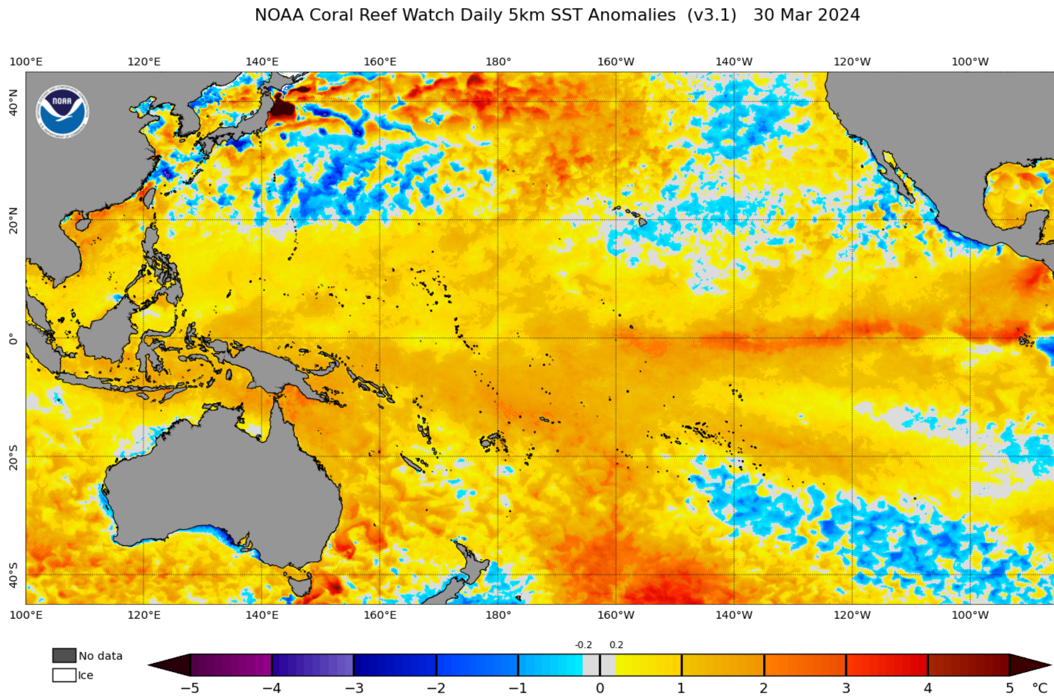

Figure 20: Current SST anomalies across the tropical and subtropical Pacific.

Table 15 displays January and March SST anomalies for several Nino regions. Over the past two months, SST anomalies across the entire eastern and central tropical Pacific have cooled.

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

Region	January SST Anomaly (°C)	March SST Anomaly (°C)	March – January SST Anomaly (°C)
Nino 1+2	+0.8	+0.3	-0.5
Nino 3	+1.9	+0.9	-1.0
Nino 3.4	+1.8	+1.2	-0.6
Nino 4	+1.5	+0.9	-0.6

An upwelling (cooling) oceanic Kelvin wave, denoted by the short dashed line, is currently approaching the west coast of South America after transiting most of the tropical Pacific (Figure 21). Another upwelling oceanic Kelvin wave has recently formed and is propagating eastward across the central tropical Pacific. As mentioned earlier, these Kelvin waves are typically triggered by anomalous low-level winds in the tropical Pacific. These upwelling Kelvin waves were likely forced by anomalous low-level easterlies that occurred to the west of the International Date Line (180°W) in early to mid-January and mid-February, respectively (Figure 22).

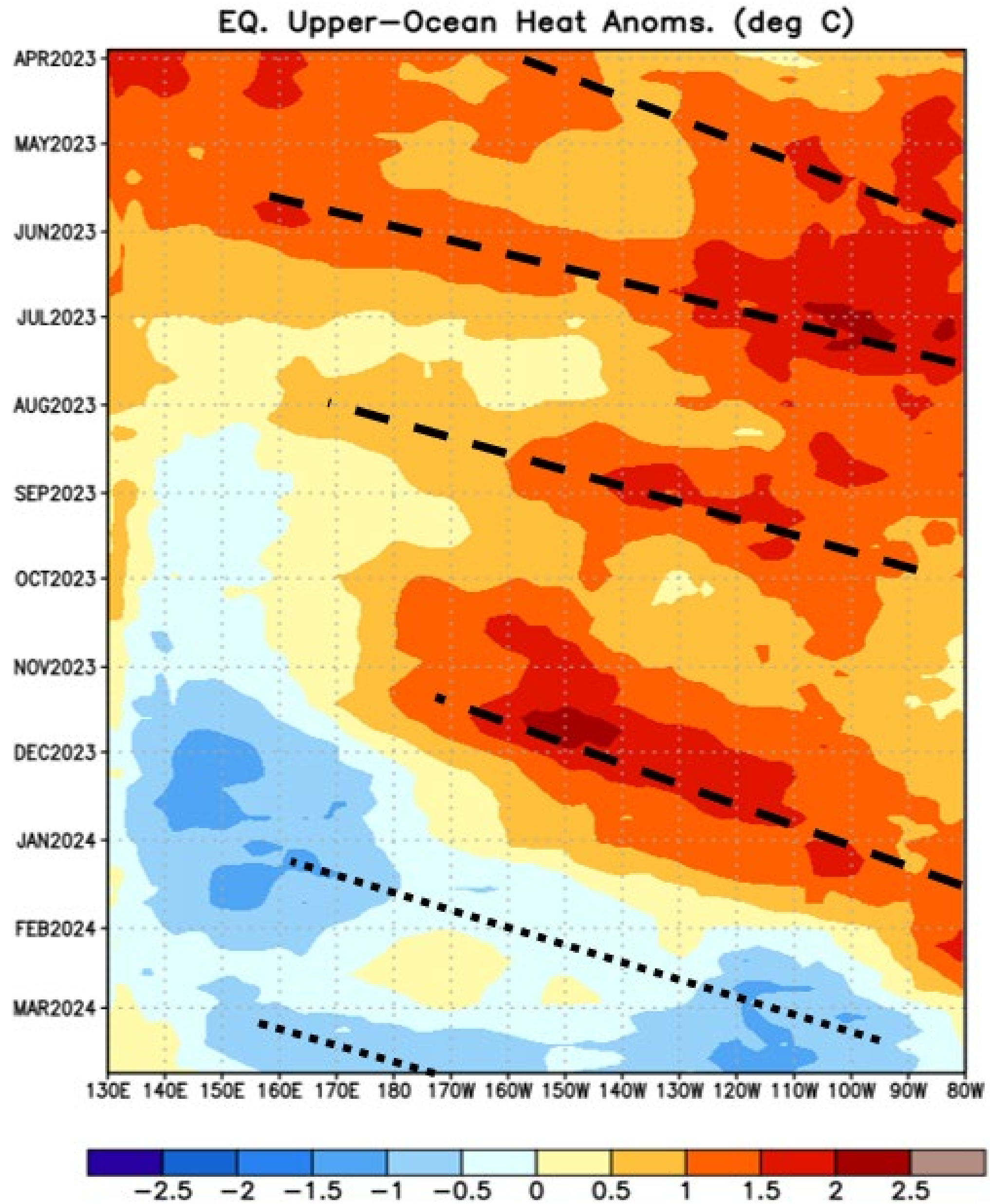

Figure 21: Upper-ocean (0–300 meter) heat content anomalies in the tropical Pacific since April 2023. Long dashed lines indicate downwelling Kelvin waves, while short dashed lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases. Figure courtesy of Climate Prediction Center.

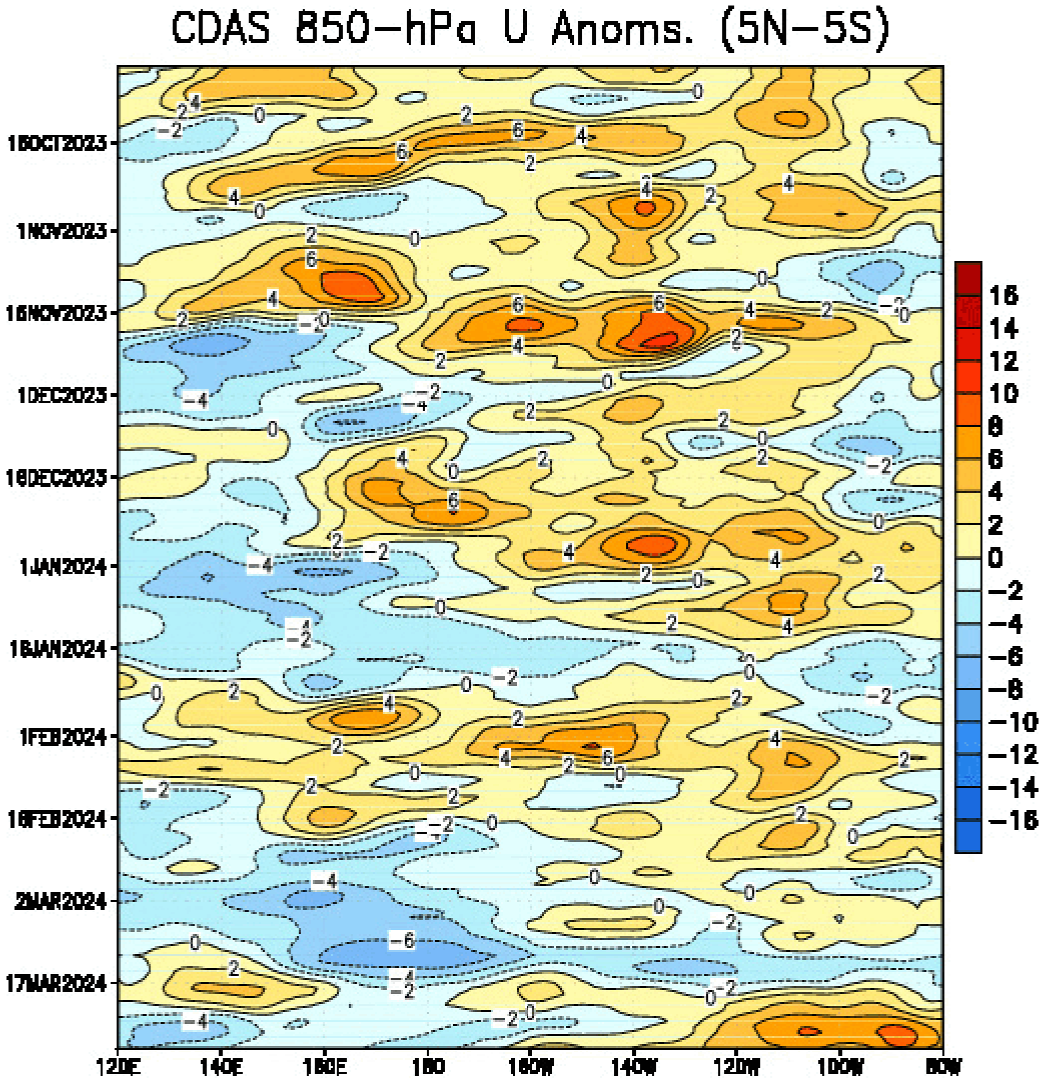

Figure 22: Anomalous equatorial low-level winds spanning from 120°E to 80°W. Figure courtesy of Climate Prediction Center.

Over the next several months, we will be closely monitoring low-level winds over the tropical Pacific. Anomalous low-level easterlies are forecast to develop to the west of the International Date Line and likely persist and expand eastward for the next couple of weeks (Figure 23). This is another signal that El Niño conditions are weakening and are likely to transition to neutral ENSO conditions in the next couple of months.

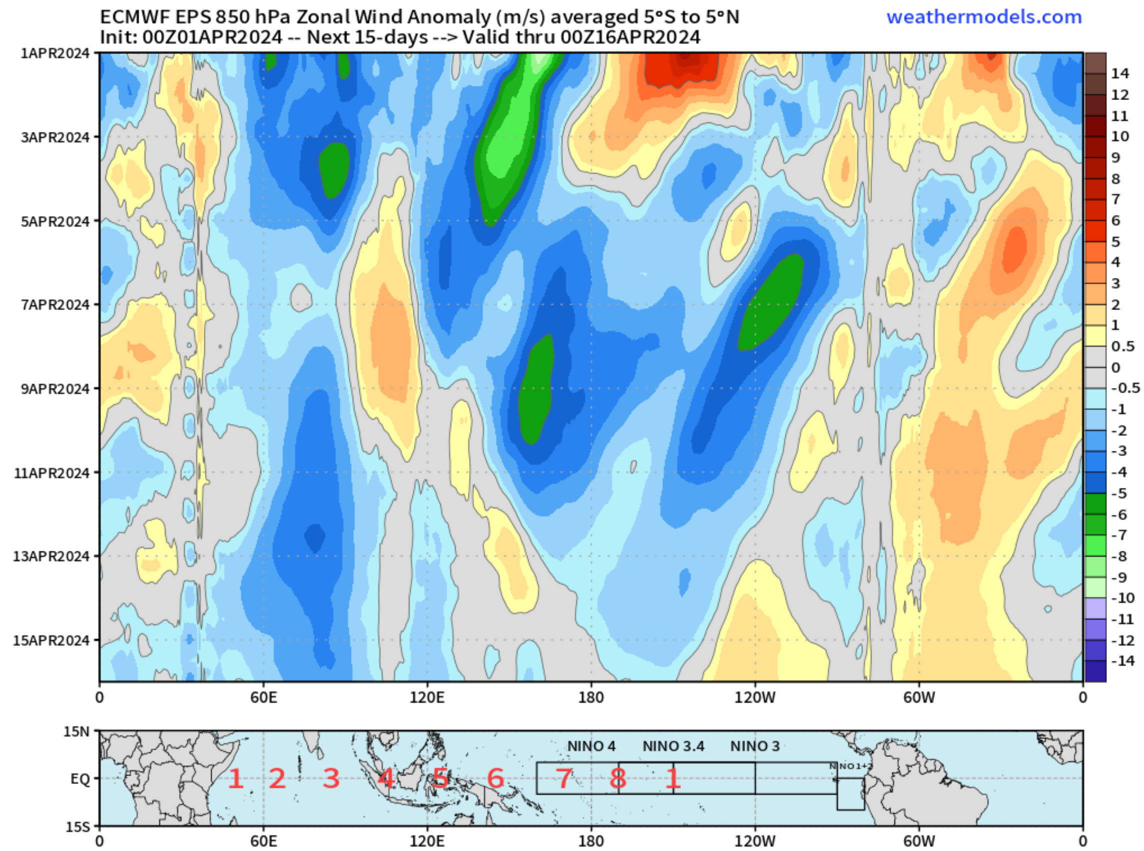

Figure 23: Forecast 850-hPa zonal equatorial winds for the next 15 days. Figure courtesy of weathermodels.com.

There is always considerable uncertainty with the future state of El Niño during the Northern Hemisphere spring. The latest plume of ENSO predictions from several statistical and dynamical models shows considerable spread by the peak of the Atlantic hurricane season in August–October (Figure 24). However, all models are forecasting El Niño to be gone, with most models forecasting La Niña to develop by the peak of the Atlantic hurricane season.

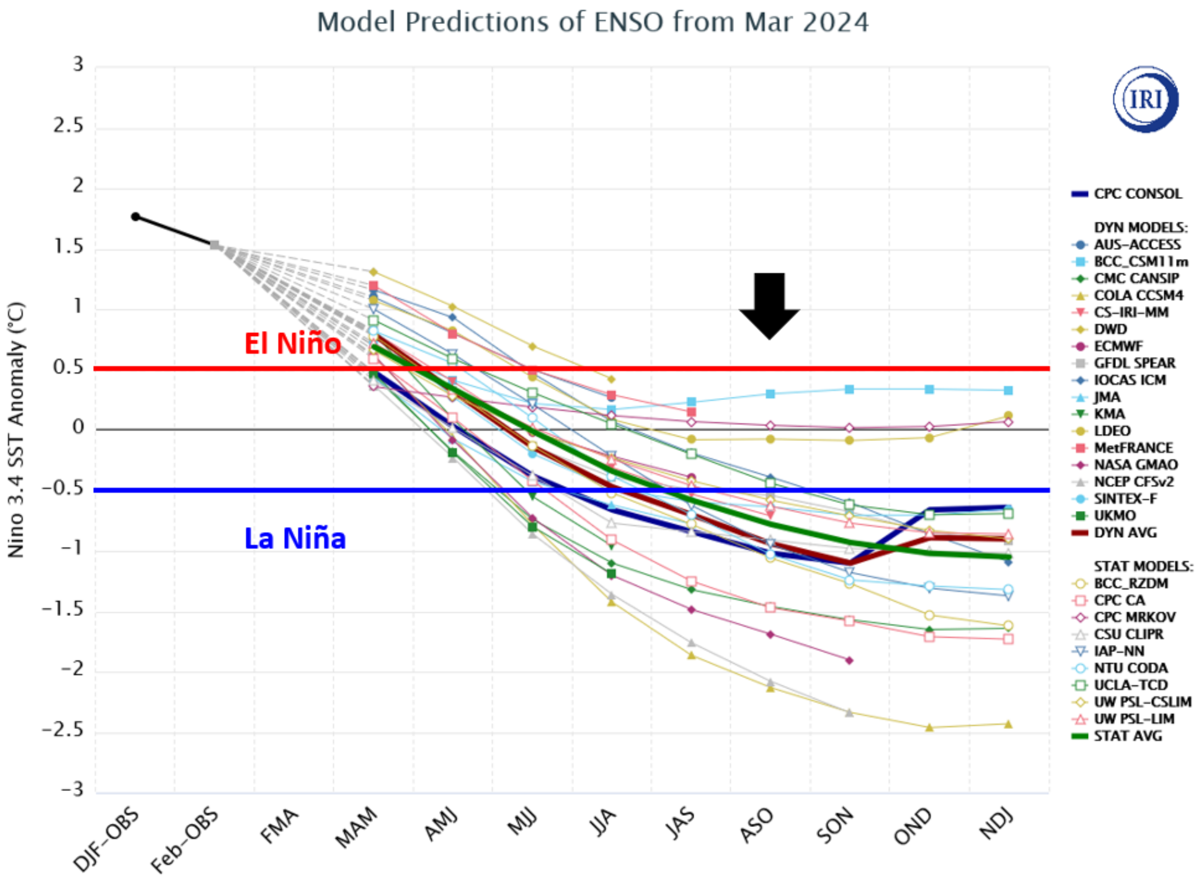

Figure 24: ENSO forecasts from various statistical and dynamical models for Nino 3.4 SST anomalies based on late February to early March initial conditions. All models call for either ENSO neutral or La Niña or conditions for August–October. The black arrow delineates the peak of the Atlantic hurricane season (August–October). Figure courtesy of the International Research Institute (IRI).

The latest official forecast from NOAA strongly favors La Niña for August–October. NOAA is currently predicting an 82% chance of La Niña, a 17% chance of ENSO neutral conditions and a 1% chance of El Niño for the peak of the Atlantic hurricane season (Figure 25).

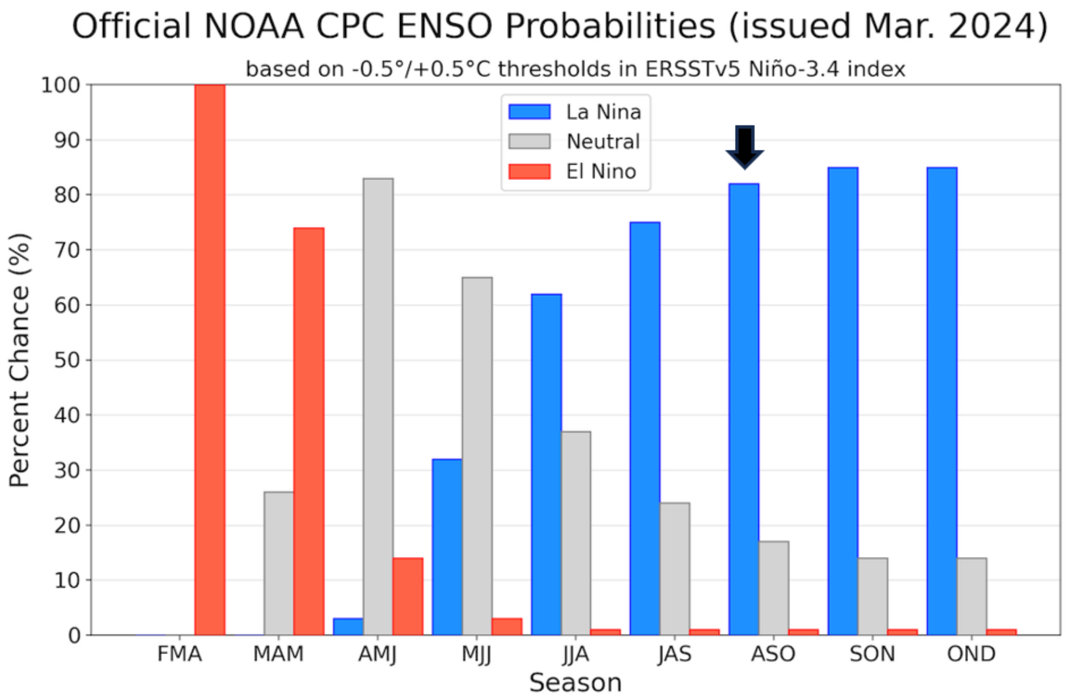

Figure 25: Official probabilistic ENSO forecast from NOAA. The black arrow delineates the peak of the Atlantic hurricane season (August–October).

Based on the above information, our best estimate is that we will have La Niña conditions for the peak of the Atlantic hurricane season. As noted earlier, there remains some uncertainty if we transition to La Niña. Even if we do not transition to La Niña, we would anticipate cool neutral ENSO conditions. Cool neutral ENSO conditions would still likely lead to a very busy Atlantic hurricane season given how hurricane-conducive current atmospheric-oceanic conditions are across the tropical and subtropical Atlantic (discussed in the next section).

5 Current Atlantic Basin Conditions

Currently, SSTs are at record warm levels across most of the tropical and the eastern part of the subtropical Atlantic (Figure 26). Over the past several months, trade winds across most of the tropical and the eastern subtropical Atlantic have been weaker than normal, helping to reinforce the extremely warm SSTs that have predominated across the Atlantic over the past ~12 months (Figure 27). Weaker trade winds lead to less evaporation and mixing, favoring anomalous warming. Figure 28 shows the forecast for the next ~2 weeks of low-level winds across the Atlantic. In general, trade winds are forecast to be near to slightly weaker than average, indicating that extremely warm SST anomalies are likely to continue. Overall, the current SST anomaly pattern correlates very well with what is typically seen in active Atlantic hurricane seasons (Figure 29).

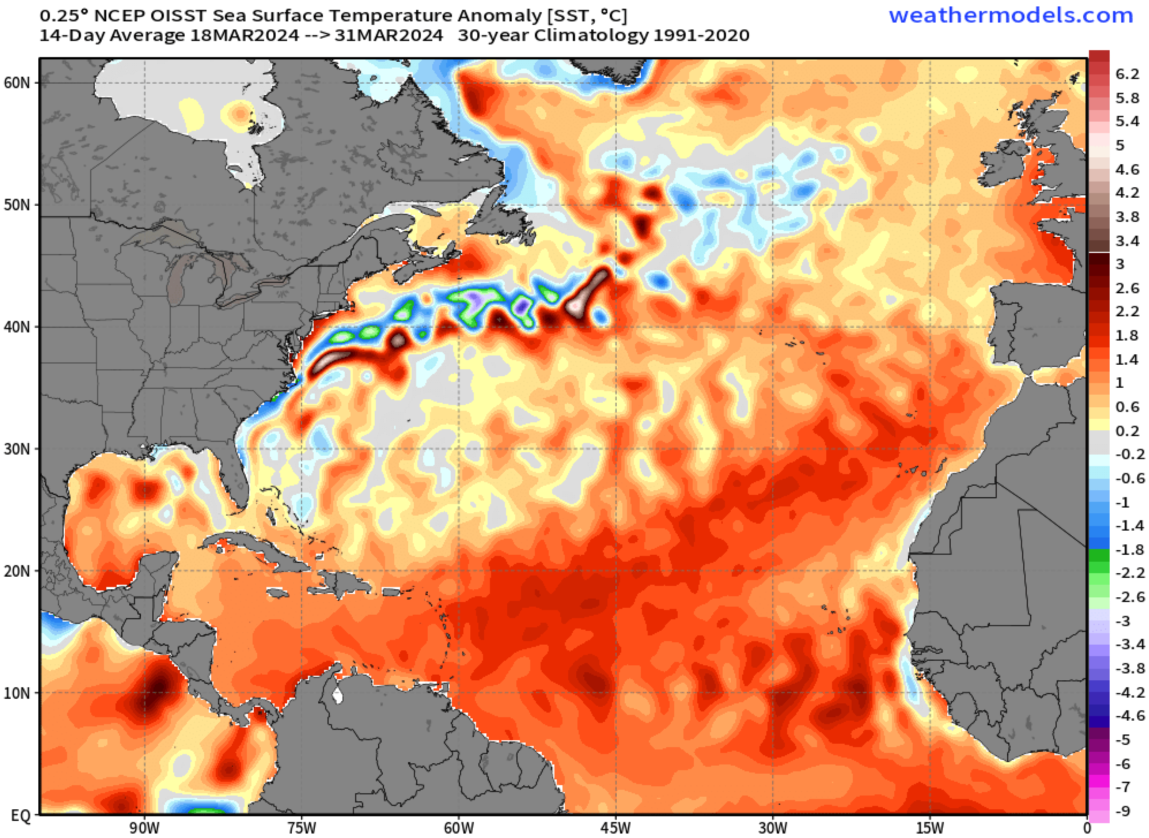

Figure 26: Late March 2024 North Atlantic SST anomalies.

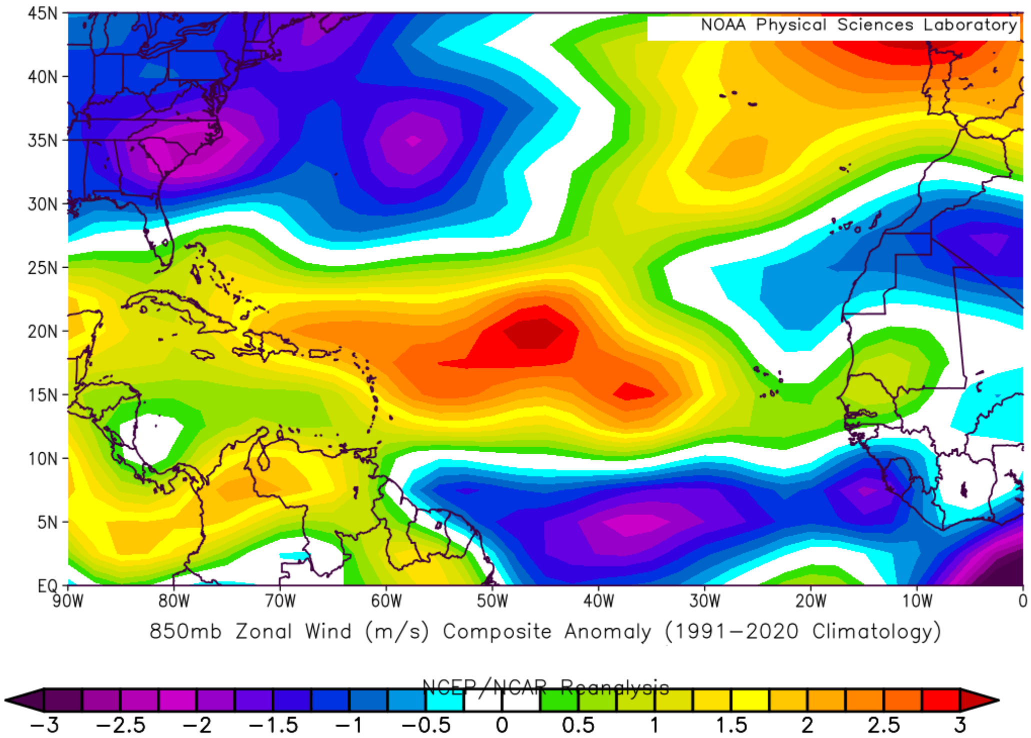

Figure 27: Zonal wind anomalies across the North Atlantic Ocean from December 2023 through March 2024.

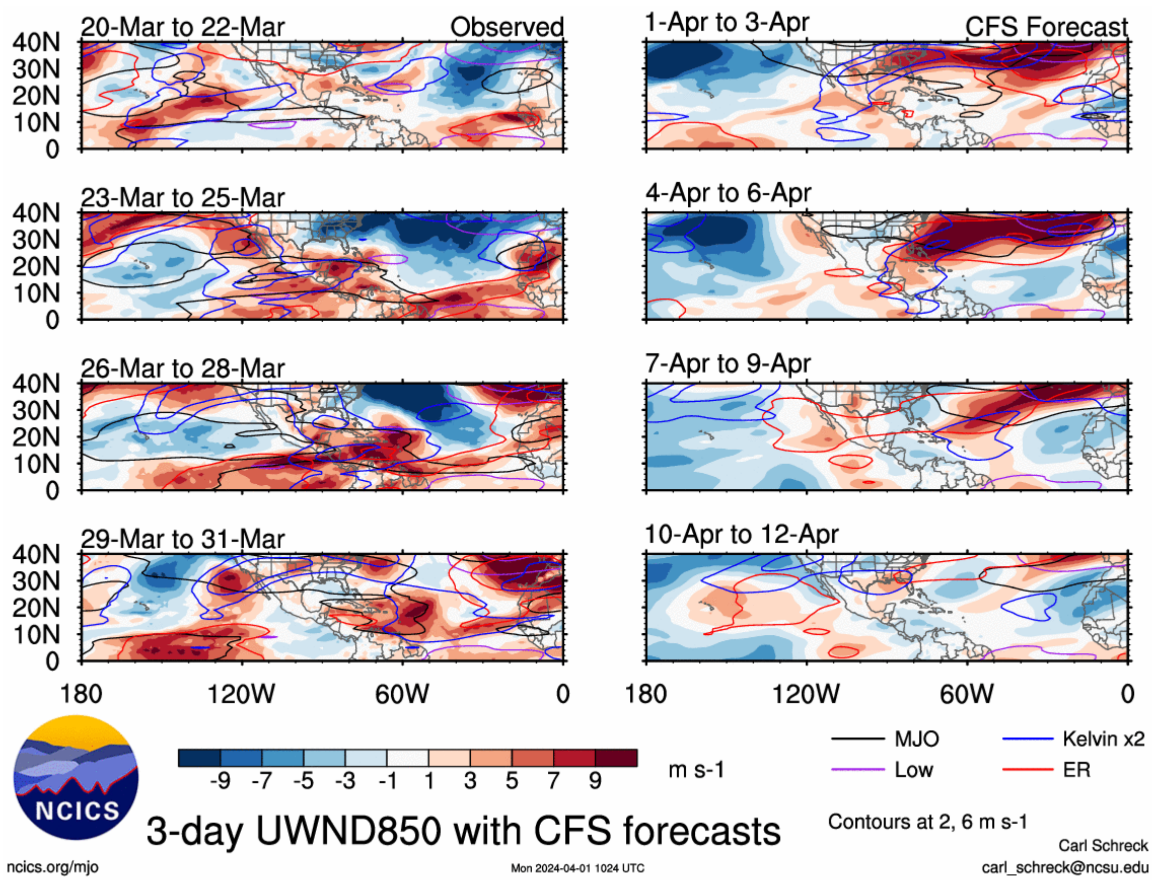

Figure 28: Observed low-level zonal winds across portions of the Western Hemisphere over the past four weeks and predicted low-level zonal winds from the Climate Forecast System through 12 April. Figure courtesy of Carl Schreck.

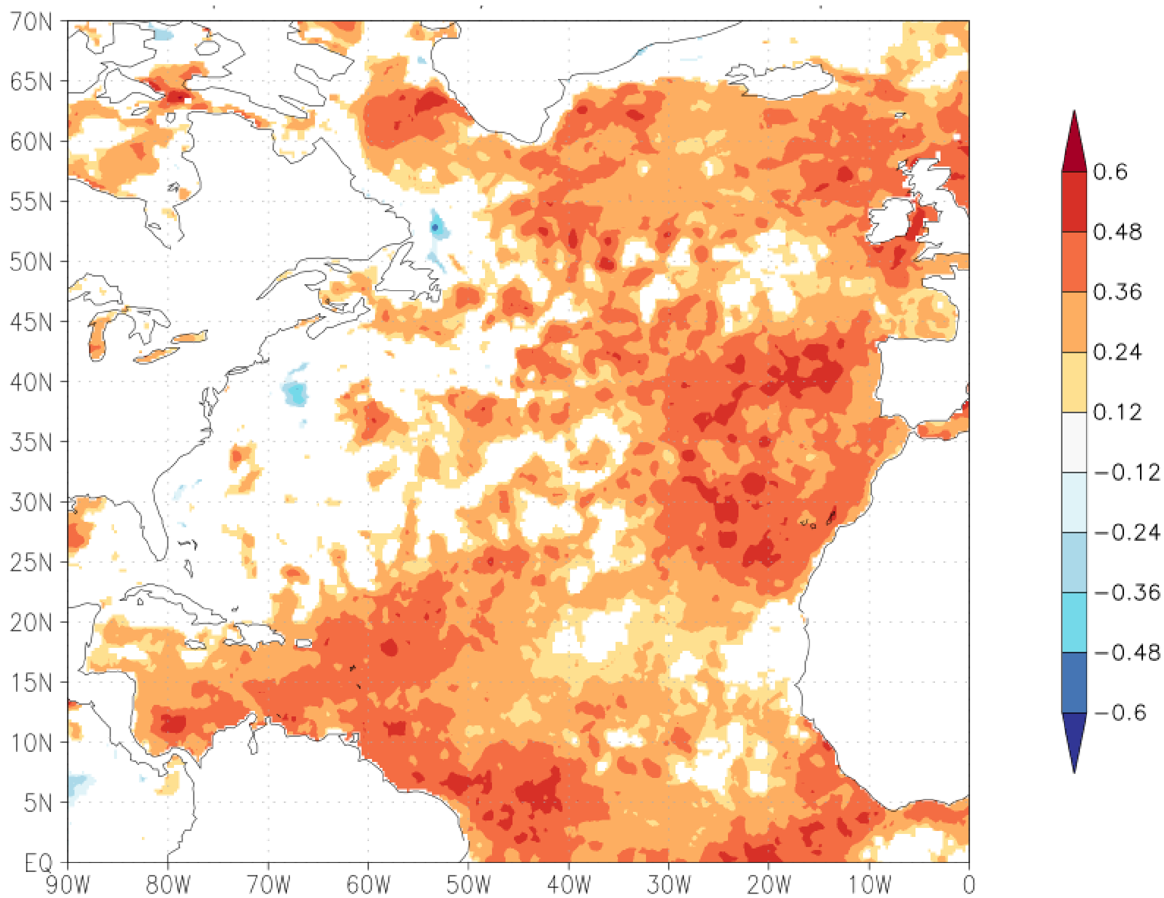

Figure 29: Rank correlations between April sea surface temperatures in the North Atlantic and annual Atlantic ACE from 1982–2023.

6 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 is shown to be linked to overall Atlantic basin ACE. Long-term statistics show that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of hurricane landfalls for various landmasses in the basin. 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 16 displays the climatological odds of storms tracking within 50 miles of each state along the Gulf and East Coasts along with the odds in 2024. Landfall probabilities are well 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 16: 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 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	78%	43%	14%	58%	28%	8%
Connecticut	35%	13%	2%	22%	8%	1%
Delaware	35%	10%	1%	23%	6%	1%
Florida	96%	75%	44%	86%	56%	29%
Georgia	82%	46%	10%	63%	30%	6%
Louisiana	84%	56%	23%	66%	38%	14%
Maine	34%	11%	2%	21%	7%	1%
Maryland	47%	18%	1%	31%	11%	1%
Massachusetts	49%	23%	5%	33%	14%	3%
Mississippi	72%	43%	13%	53%	28%	8%
New Hampshire	29%	9%	2%	18%	6%	1%
New Jersey	35%	11%	1%	23%	7%	1%
New York	41%	16%	4%	26%	9%	2%
North Carolina	85%	56%	13%	68%	38%	8%
Rhode Island	32%	13%	2%	20%	8%	1%
South Carolina	76%	44%	14%	57%	29%	8%
Texas	80%	54%	25%	61%	36%	16%
Virginia	65%	31%	2%	46%	20%	1%

7 Summary

An analysis of a variety of different atmosphere and ocean measurements (through March) 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 predictions are if the extreme anomalous warmth in the tropical and eastern subtropical Atlantic persists or begins to weaken, as well as the strength of La Niña if it does develop.

8 Forthcoming Updated Forecasts of 2024 Hurricane Activity

We will be issuing seasonal updates of our 2024 Atlantic basin hurricane forecasts on **Tuesday 11 June**, **Tuesday 9 July, and Tuesday 6 August**. We will also be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August–October. A verification and discussion of all 2024 forecasts will be issued on **Tuesday, 26 November**. All of these forecasts will be 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 30 displays correlations between observed and predicted Atlantic hurricanes from 1984–2013, from 2014–2023 and from 1984–2023, 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 at: https://tropical.colostate.edu/archive.html#verification

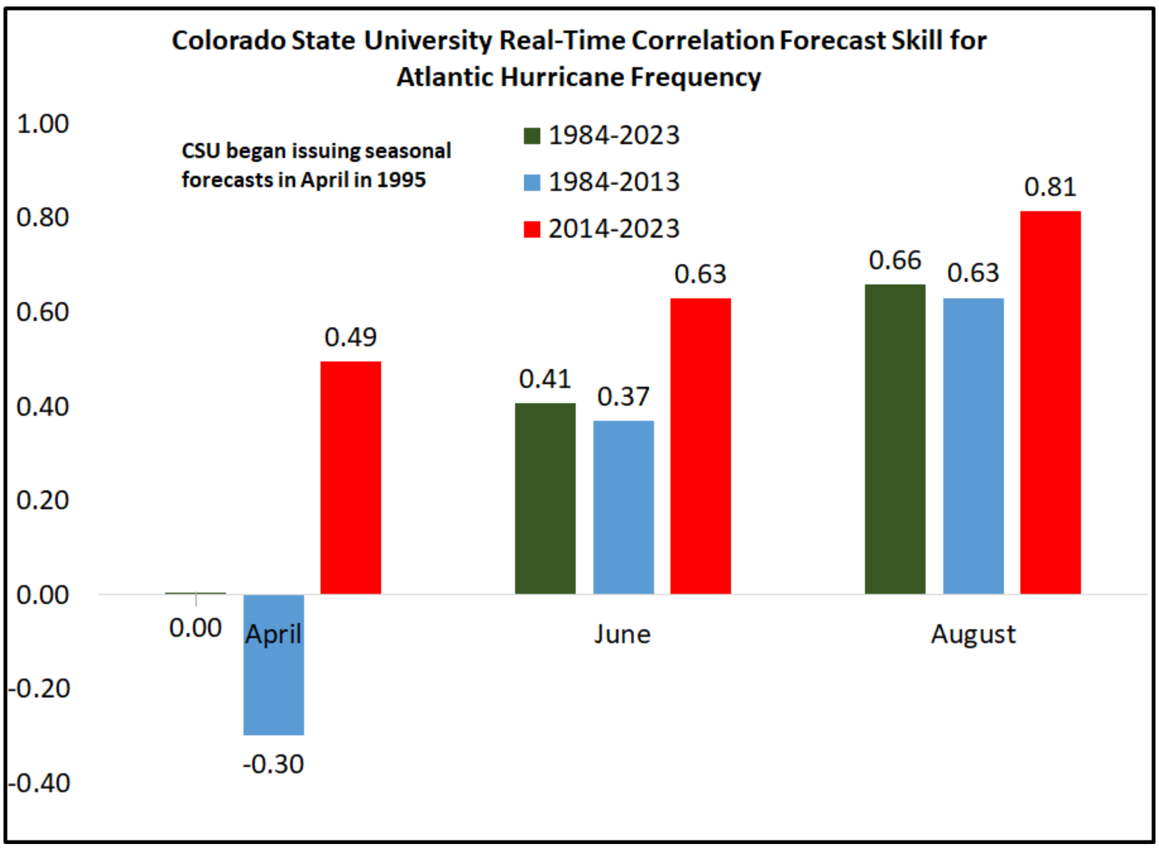

Figure 30: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2023 and 1984–2023, respectively.