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

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

(as of 1 June 2023)

By Philip J. Klotzbach[1], Michael M. Bell[2] and Alexander J. DesRosiers[3]
In Memory of William M. Gray[4]

This discussion as well as past forecasts and verifications are available online at
http://tropical.colostate.edu

Jennifer Dimas, Colorado State University media representative, is coordinating media inquiries into this forecast. She can be reached at 970-491-1543 or
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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2023

Forecast Parameter and 1991-2020 Average (in parentheses)	Issue Date 13 April 2023	Issue Date 1 June 2023	Observed Activity Through May 31 2023	Total Seasonal Forecast (Includes Unnamed Storm*)
Named Storms (14.4)	13	14	1	15
Named Storm Days (69.4)	55	57.75	2.25	60
Hurricanes (7.2)	6	7	0	7
Hurricane Days (27.0)	25	30	0	30
Major Hurricanes (3.2)	2	3	0	3
Major Hurricane Days (7.4)	5	7	0	7
Accumulated Cyclone Energy Index (123)	100	123	2	125
ACE West of 60°W (73)	55	68	2	70
Net Tropical Cyclone Activity (135%)	105	132	3	135

*The National Hurricane Center noted on May 11th that an unnamed subtropical storm formed in the Atlantic in January. As such, this storm is now counted as a 2023 system. Since the formal report on the unnamed storm has yet to be written, we are currently using the Naval Research Laboratory track file on the system for its statistics.

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 - 43% (average from 1880–2020 is 43%)

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

3) Gulf Coast from the Florida Panhandle (west and north of Cedar Key, Florida) westward to Brownsville - 27% (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) 47% (average from 1880–2020 is 47%)

ABSTRACT

Information obtained through May indicates that the 2023 Atlantic hurricane season will have activity near the 1991–2020 average. We estimate that 2023 will have an additional 14 named storms (average is 14.4), 57.75 named storm days (average is 69.4), 7 hurricanes (average is 7.2), 30 hurricane days (average is 27.0), 3 major (Category 3-4-5) hurricanes (average is 3.2) and 7 major hurricane days (average is 7.4). The National Hurricane Center recently identified that a subtropical storm formed in January, so counting that system, we are predicting 15 total named storms in the basin this year. The probability of U.S. major hurricane landfall is estimated to be near the long-period average. We predict Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity in 2023 to be approximately 100 percent of their 1991–2020 average.

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

The tropical Pacific is currently characterized by warm neutral ENSO conditions. El Niño development appears imminent. However, the intensity of a potential El Niño event remains uncertain. El Niño typically reduces Atlantic hurricane activity through increases in vertical wind shear. However, sea surface temperatures in the eastern and central tropical Atlantic are near or at record levels, so despite the high potential for an El Niño, the impacts on tropical Atlantic/Caribbean vertical wind shear may not be as strong as is typically experienced given the extremely warm Atlantic.

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

The early June forecast has good long-term skill when evaluated in hindcast mode. The skill of CSU’s forecast updates increases as the peak of the Atlantic hurricane season approaches. We also present probabilities of exceedance for hurricanes and Accumulated Cyclone Energy to give interested readers a better idea of the uncertainty associated with these forecasts.

Why issue extended-range forecasts for seasonal hurricane activity?

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

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early June. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged with regards to the probability of an active or inactive hurricane season for the coming year. Our early June statistical and statistical/dynamical hybrid models show strong evidence on ~25–40 years of data that significant improvement over a climatological forecast can be attained. We would never issue a seasonal hurricane forecast unless we had models developed over a long hindcast period which showed skill. We also now include probabilities of exceedance to provide a visualization of the uncertainty associated with these predictions.

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

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

Acknowledgment

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

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

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

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

We thank Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre for providing data and insight on the statistical/dynamical models. We have also benefited from meteorological discussions with Louis-Philippe Caron, Dan Chavas, Jason Dunion, Brian McNoldy, Paul Roundy, Carl Schreck, Mike Ventrice and Peng Xian over the past few years.

DEFINITIONS AND ACRONYMS

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

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

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

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

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

Hurricane (H) - A tropical cyclone with sustained low-level winds of 74 miles per hour (33 ms^{-1} or 64 knots) or greater.

Hurricane Day (HD) - A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or is estimated to have hurricane-force winds.

Indian Ocean Dipole (IOD) - An irregular oscillation of sea surface temperatures between the western and eastern tropical Indian Ocean. A positive phase of the IOD occurs when the western Indian Ocean is anomalously warm compared with the eastern Indian Ocean.

Madden Julian Oscillation (MJO) – A globally propagating mode of tropical atmospheric intra-seasonal variability. The wave tends to propagate eastward at approximately 5 ms^{-1}, circling the globe in roughly 30-60 days.

Major Hurricane (MH) - A hurricane which reaches a sustained low-level wind of at least 111 mph (96 knots or 50 ms^{-1}) at some point in its lifetime. This constitutes a category 3 or higher on the Saffir/Simpson scale.

Major Hurricane Day (MHD) - Four 6-hour periods during which a hurricane has an intensity of Saffir/Simpson category 3 or higher.

Named Storm (NS) - A hurricane, a tropical storm or a sub-tropical storm.

Named Storm Day (NSD) - As in HD but for four 6-hour periods during which a tropical or sub-tropical cyclone is observed (or is estimated) to have attained tropical storm-force winds.

Net Tropical Cyclone (NTC) Activity –Average seasonal percentage mean of NS, NSD, H, HD, MH, MHD. Gives overall indication of Atlantic basin seasonal hurricane activity. The 1991-2020 average value of this parameter is 135.

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

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

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

Sea Surface Temperature Anomaly (SSTA) – Differences in sea surface temperature compared to the long-term average.

Thermohaline Circulation (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 40th year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. Our research team has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. This year's June 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 less of a relationship to a predictand by itself but to have an important influence when included with a set of 2–3 other predictors.

2 June Forecast Methodology

2.1 June Statistical Forecast Scheme

We have modified our June statistical forecast scheme from what has been used during the past few years. The current iteration of the forecast model uses ECMWF Reanalysis 5 (ERA5; Hersbach et al. 2020) for both parameters. Due to the switch in input sea surface temperature (SST) dataset from NOAA OI SST to ERA5, we now extend the model back to 1979. We redeveloped the model over 1979–2020 and then applied the model to the 2021 and 2022 Atlantic hurricane seasons. This model shows significant skill in cross-validated (e.g., leaving the year out of the developmental model that is being predicted) hindcasts of Accumulated Cyclone Energy (ACE) ($r = 0.68$) over the period from 1979–2022 (Figure 1).

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

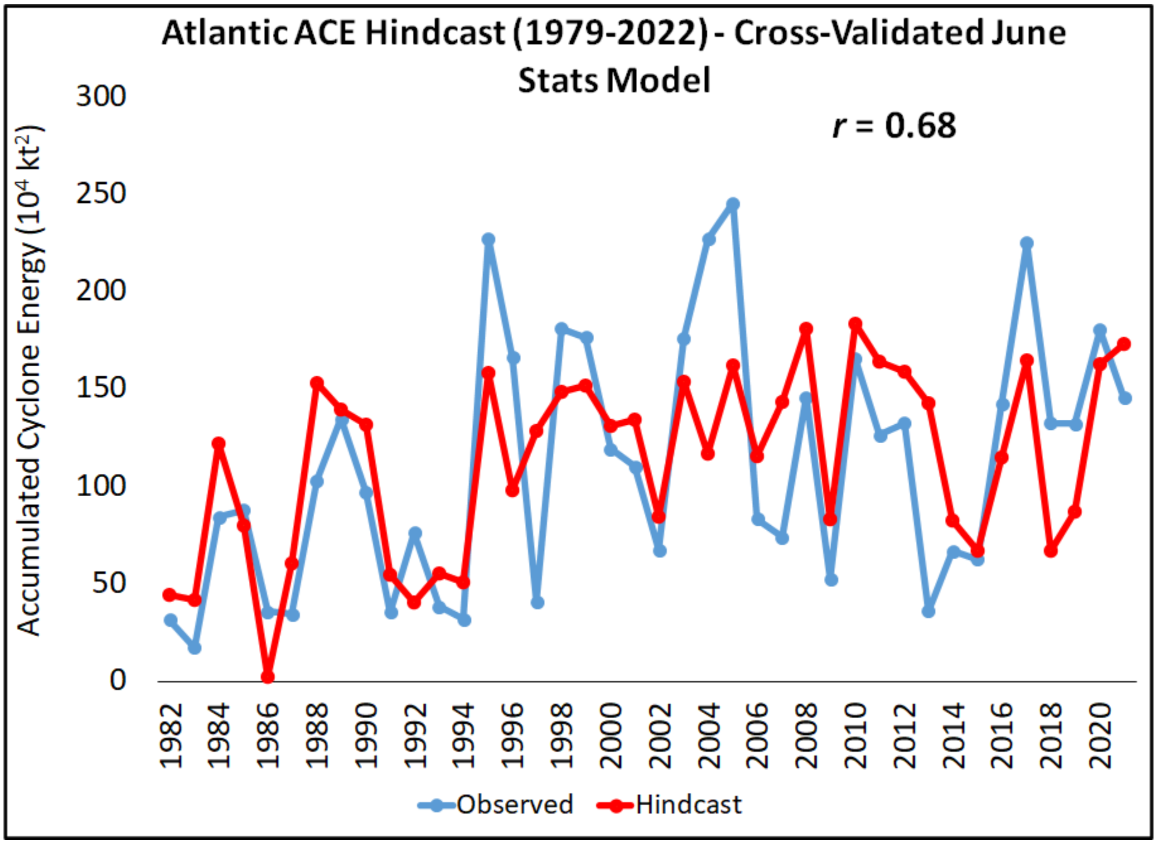

Figure 1: Observed versus early June cross-validated hindcast values of ACE for the statistical model from 1979–2022.

June Forecast Predictors

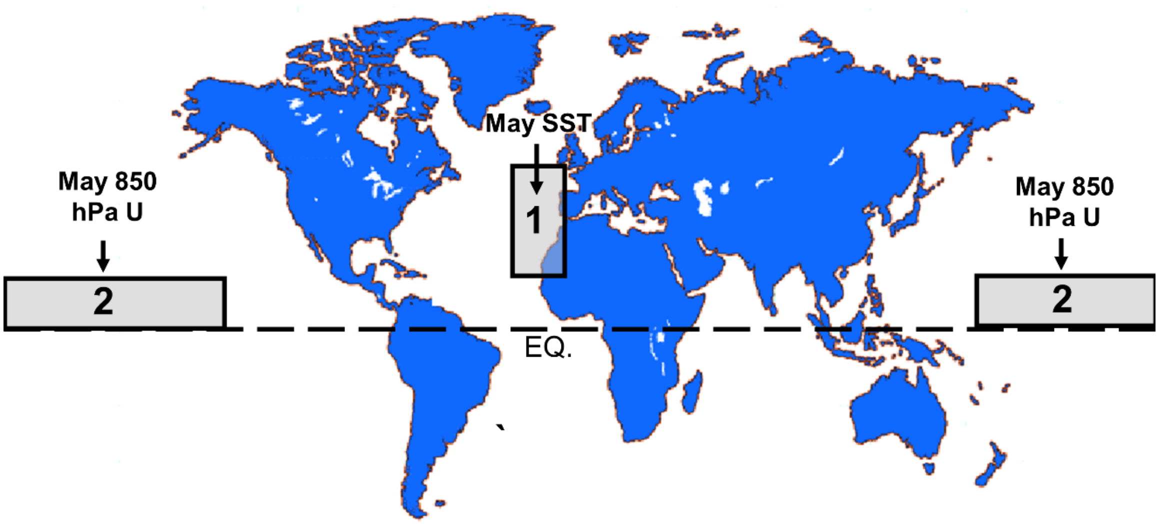

Figure 2: Location of predictors for the early June extended-range statistical prediction for the 2023 hurricane season.

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

Predictor	Correlation w/ ACE
1) May SST (15°N–50°N, 30°W–10°W) (+)	0.58
2) May 850 hPa U (0°N–20°N, 160°E–140°W) (-)	-0.57

Table 2: Listing of early June 2023 predictors for the 2023 hurricane season. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity. SD stands for standard deviation.

Predictor	2023 Forecast Value	Impact on 2023 TC Activity
1) May SST (15°N–50°N, 30°W–10°W) (+)	+3.1 SD	Strongly Enhance
2) May 850 hPa U (0°N–20°N, 160°E–140°W) (-)	+0.4 SD	Slightly Suppress

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

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Forecast	Final Forecast
Named Storms (NS) (14.4)	18.2	15
Named Storm Days (NSD) (69.4)	95.6	60
Hurricanes (H) (7.2)	9.9	7
Hurricane Days (HD) (27.0)	41.3	30
Major Hurricanes (MH) (3.2)	4.8	3
Major Hurricane Days (MHD) (7.4)	12.5	7
Accumulated Cyclone Energy (ACE) (123)	185	125
Net Tropical Cyclone Activity (NTC) (135%)	197	135

The locations and brief descriptions of the predictors for our early June statistical forecast are now discussed. Both predictors correlate with physical features during August through October that are known to be favorable for elevated levels of hurricane activity. These factors are all generally related to August–October vertical wind shear in the Atlantic Main Development Region (MDR) from 10–20°N, 70–20°W as shown in Figure 3.

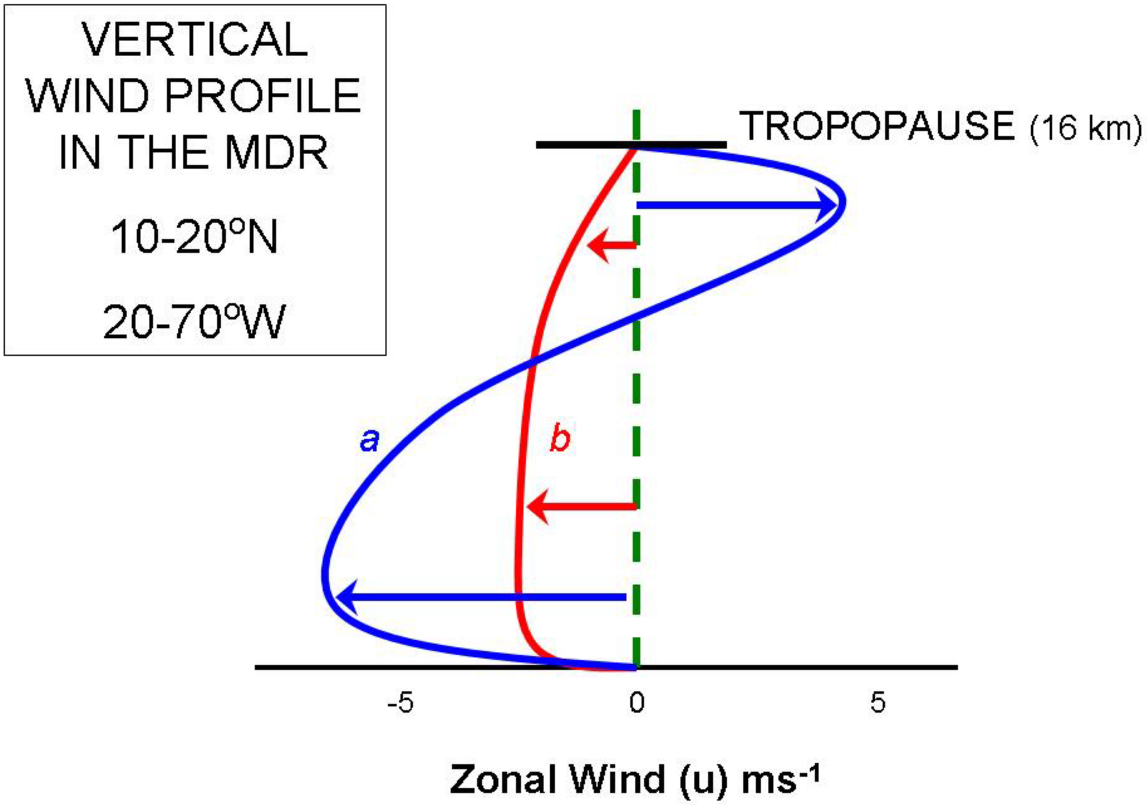

Figure 3: Vertical wind profile typically associated with (a) inactive Atlantic basin hurricane seasons and (b) active Atlantic basin hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

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

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

(15°N–50°N, 30°W–10°W)

Warmer-than-normal SSTs in the tropical and subtropical Atlantic during May are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the boreal spring and summer (Knaff 1997). Positive SSTs in May 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* =0.57) with ACE from 1979–2022. Predictor 1 also strongly correlates (*r* = 0.68) with August–October values of the SST component of the Atlantic Meridional Mode (AMM) (Kossin and Vimont 2007) from 1979–2022. The AMM has been shown to impact Atlantic hurricane activity through alterations in the position and intensity of the Atlantic Inter-Tropical Convergence Zone (ITCZ). Changes in the Atlantic ITCZ bring about changes in tropical Atlantic vertical and horizontal wind shear patterns and in tropical Atlantic SST patterns.

Predictor 2. May 850 hPa U in the tropical central Pacific (-)

(0°N–20°N, 160°E–140°W)

Stronger-than-normal low-level winds during May in the central tropical Pacific are associated with enhanced upwelling which drives anomalous cooling in the central and eastern tropical Pacific, inhibiting the development of El Niño conditions. This relationship can be clearly demonstrated by a significant correlation between Predictor 2 with the August–October-averaged Oceanic Nino Index (*r* = 0.68). As would be expected given this significant correlation, Predictor 2 also correlates 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 5).

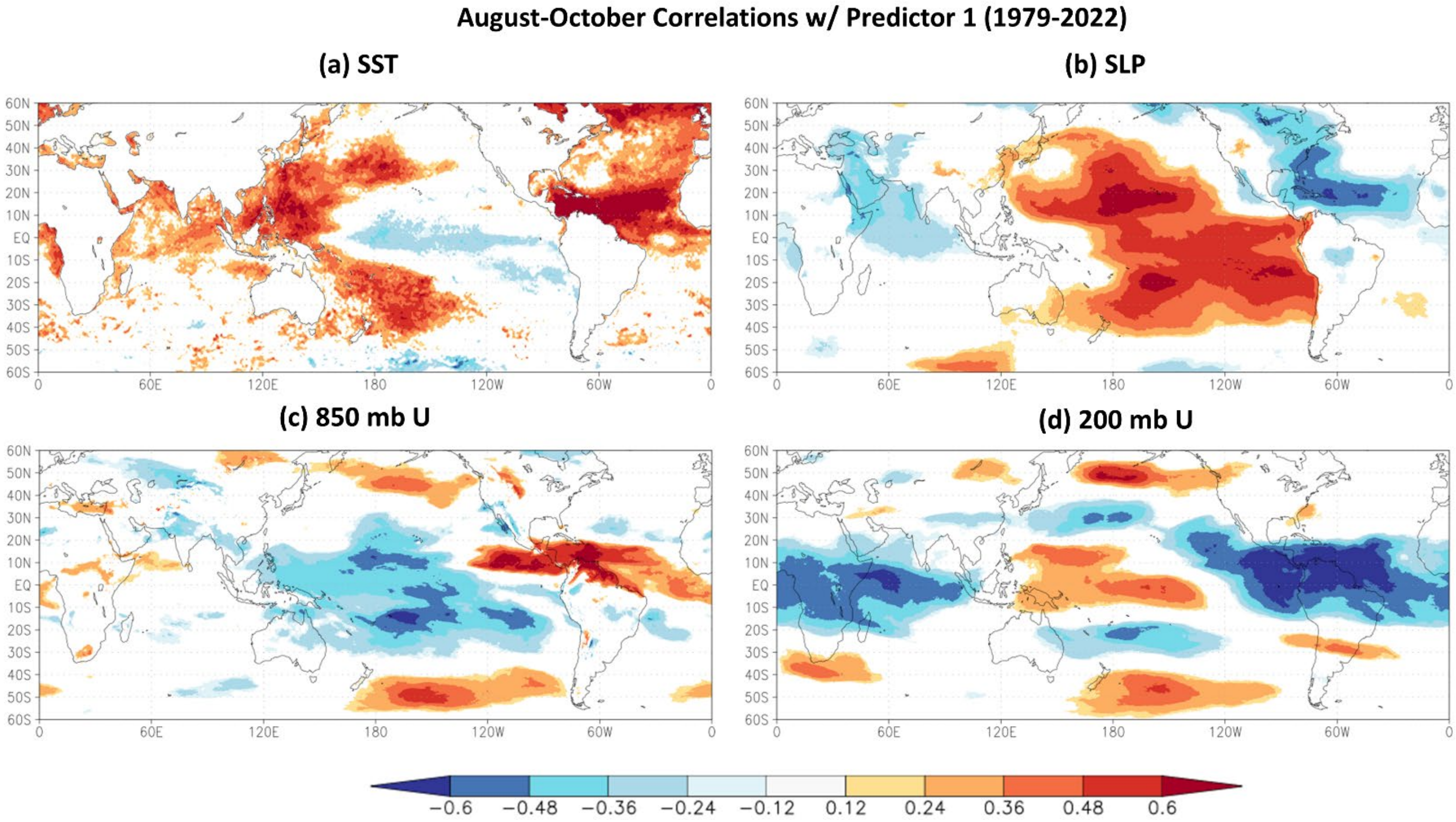

Figure 4: Rank correlations between May SST in the tropical and subtropical Atlantic (Predictor 1) and (panel a) August–October sea surface temperature, (panel b) August–October sea level pressure, (panel c) August–October 850 hPa zonal wind and (panel d) August–October 200 hPa zonal wind. All four of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

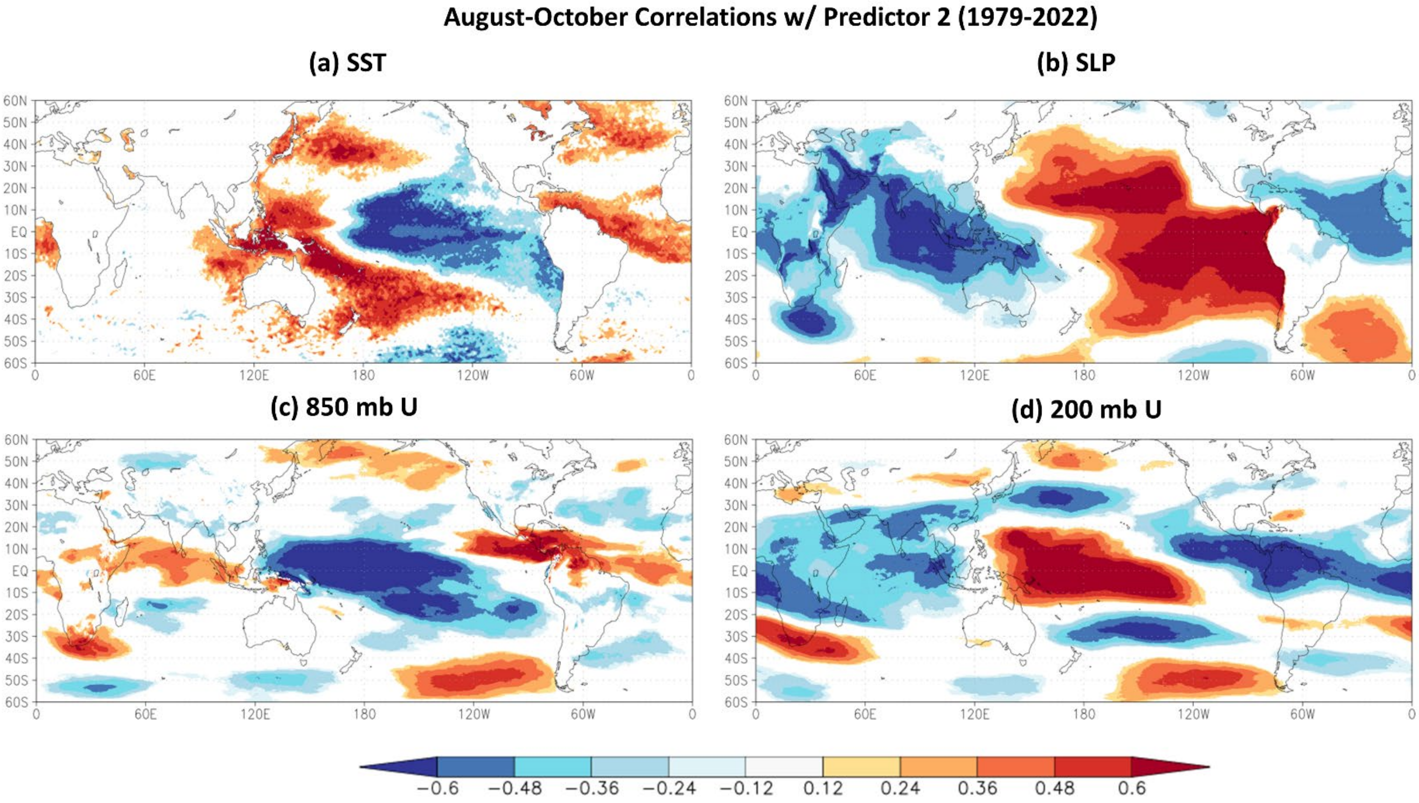

Figure 5: As in Figure 4 but for May 850 hPa zonal wind in the tropical central Pacific. The sign of the predictor has been reversed for ease of comparison with Figure 4.

2.2 June Statistical/Dynamical Forecast Schemes

We developed a statistical/dynamical hybrid forecast model scheme that we used for the first time in 2019. This model, developed in partnership with Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre, originally used output from the ECMWF SEAS5 model to forecast the input to our early August statistical forecast model. We have modified our statistical/dynamical model this year and now use four different models: ECMWF, UK Met, JMA and CMCC. We examine model forecasts of August-September SSTs in the eastern/central equatorial Pacific and in the eastern/central North Atlantic. We then use the forecasts of these individual parameters to forecast ACE for the 2023 season. All other predictands (e.g., named storms, major hurricanes) are calculated based on their historical relationships with ACE.

a) ECMWF Statistical/Dynamical Model Forecast

Figure 6 displays the locations of the two forecast parameters, while Table 4 displays ECMWF's forecasts of these parameters for 2023 from a 1 May initialization date. The ECMWF model is predicting the warmest eastern/central North Atlantic on record (since 1981) and the third warmest equatorial eastern/central tropical Pacific on record (trailing 1997 and 2015). Despite the model's forecast for a strong El Niño, the extreme warmth that is predicted for the eastern/central North Atlantic results in an above-average forecast from this model. Figure 7 displays cross-validated hindcasts of ECMWF hindcasts of ACE from 1981–2022, while Table 5 presents the forecast from ECMWF for the 2023 Atlantic hurricane season.

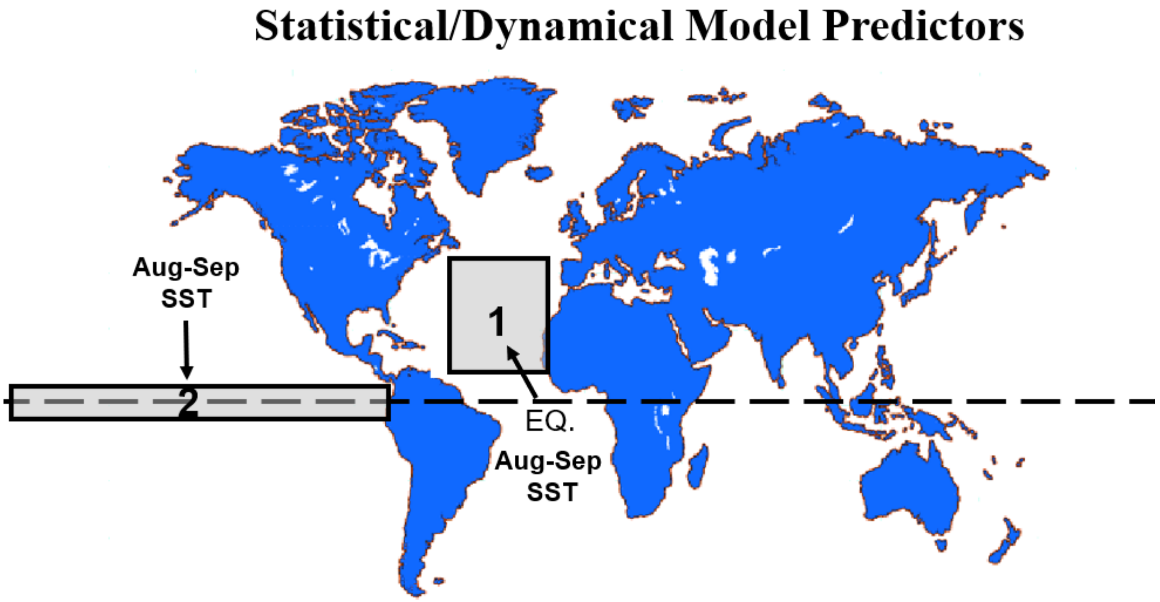

Figure 6: Location of predictors for our early June statistical/dynamical extended-range statistical prediction for the 2023 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August-September conditions in the two boxes displayed and uses those predictors to forecast ACE.

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

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) ECMWF Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+3.4 SD	Strongly Enhance
2) ECMWF Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+2.1 SD	Strongly Suppress

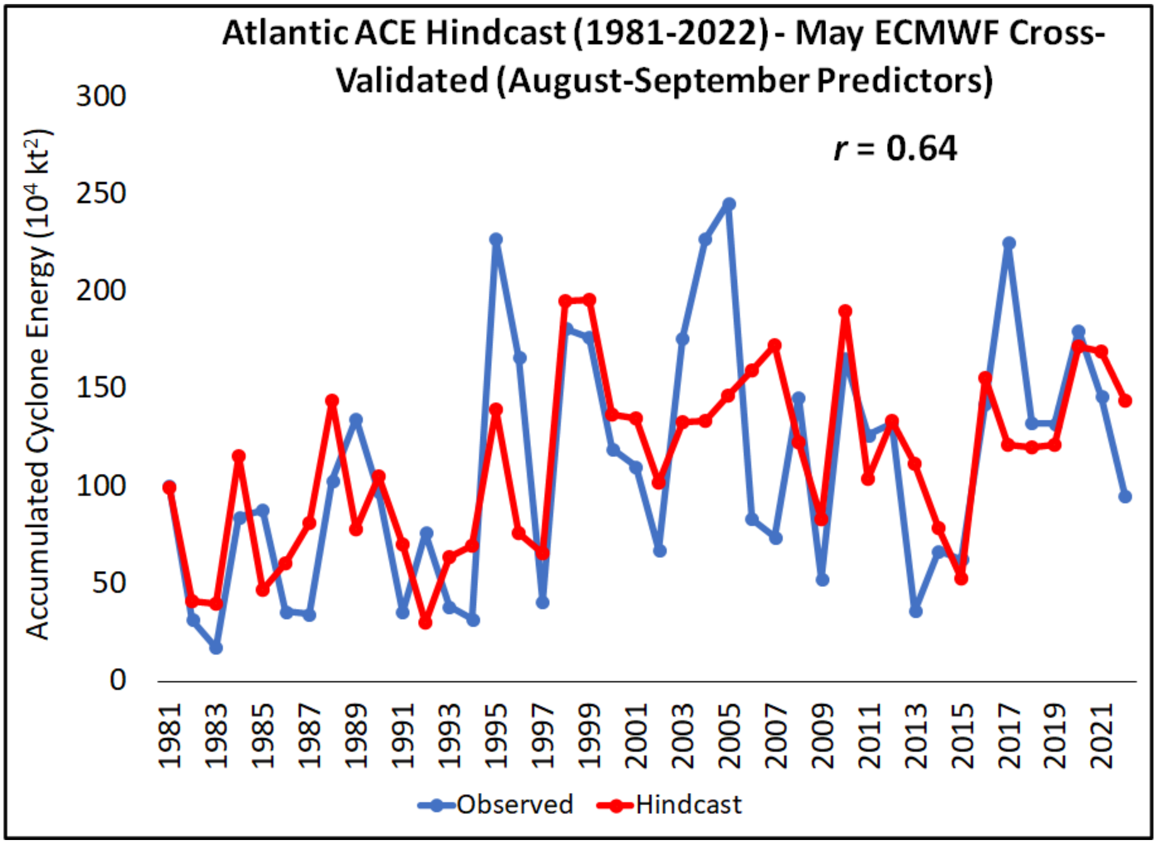

Figure 7: Observed versus cross-validated statistical/dynamical hindcast values of ACE for 1981–2022 from ECMWF.

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

Forecast Parameter and 1991–2020 Average (in parentheses)	ECMWF Hybrid Forecast	Final Forecast
Named Storms (14.4)	16.5	15
Named Storm Days (69.4)	83.8	60
Hurricanes (7.2)	8.7	7
Hurricane Days (27.0)	34.9	30
Major Hurricanes (3.2)	4.1	3
Major Hurricane Days (7.4)	10.2	7
Accumulated Cyclone Energy Index (123)	157	125
Net Tropical Cyclone Activity (135%)	169	135

b) UK Met Office Statistical/Dynamical Model Forecast

Table 6 displays the UK Met Office forecasts of the August parameters for 2023 from a 1 May initialization date. Similar to ECMWF, the UK Met Office is calling for the third strongest El Niño on record (trailing 1997 and 2015) but also the warmest central/eastern North Atlantic on record. Figure 8 displays hindcasts for the UK Met

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

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

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) UK Met Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+4.5 SD	Strongly Enhance
2) UK Met Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.9 SD	Strongly Suppress

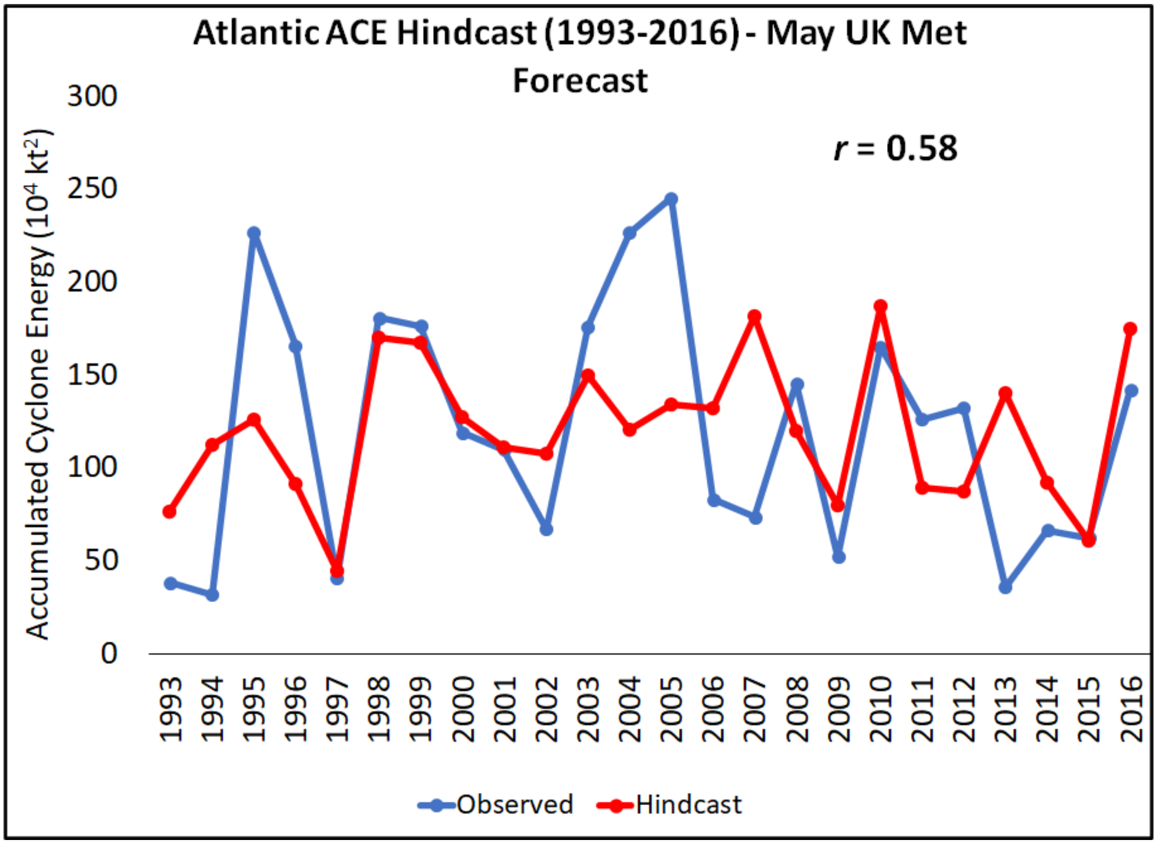

Figure 8: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the UK Met Office.

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

Forecast Parameter and 1991–2020 Average (in parentheses)	Met Office Hybrid Forecast	Final Forecast
Named Storms (14.4)	15.8	15
Named Storm Days (69.4)	79.2	60
Hurricanes (7.2)	8.3	7
Hurricane Days (27.0)	32.3	30
Major Hurricanes (3.2)	3.8	3
Major Hurricane Days (7.4)	9.3	7
Accumulated Cyclone Energy Index (123)	146	125
Net Tropical Cyclone Activity (135%)	158	135

c) JMA Met Office Statistical/Dynamical Model Forecast

Table 8 displays the JMA forecasts of the August parameters for 2023 from a 1 May initialization date. JMA is also calling for the 3rd strongest El Niño on record (trailing 1997 and 2015) and the warmest central/eastern North Atlantic on record. Figure 9 displays JMA hindcasts of ACE from 1993–2016, while Table 9 presents the forecast from the JMA for the 2023 Atlantic hurricane season. The statistical/dynamical model based off of JMA is calling for a well above-average 2023 Atlantic hurricane season.

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

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) JMA Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+3.9 SD	Strongly Enhance
2) JMA Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+1.7 SD	Strongly Suppress

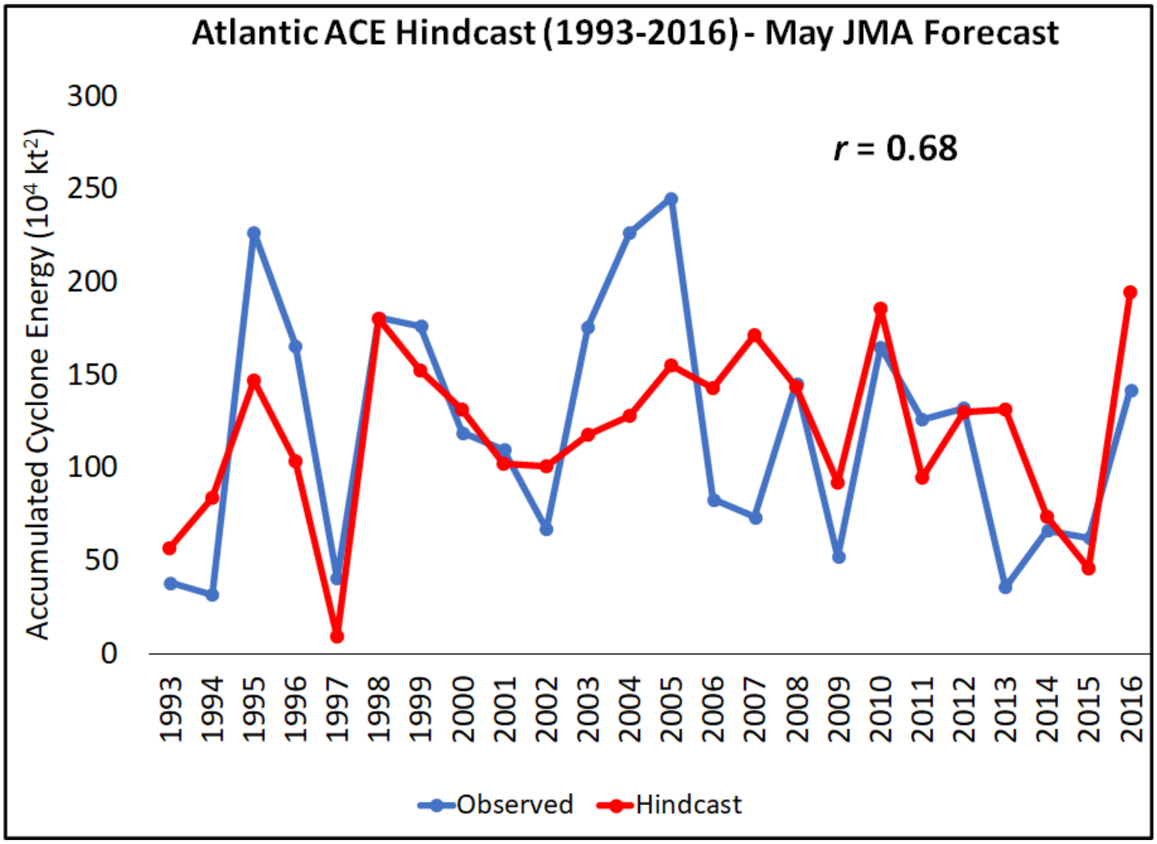

Figure 9: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the JMA.

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

Forecast Parameter and 1991–2020 Average (in parentheses)	JMA Hybrid Forecast	Final Forecast
Named Storms (14.4)	17.5	15
Named Storm Days (69.4)	90.5	60
Hurricanes (7.2)	9.4	7
Hurricane Days (27.0)	38.5	30
Major Hurricanes (3.2)	4.5	3
Major Hurricane Days (7.4)	11.5	7
Accumulated Cyclone Energy Index (123)	173	125
Net Tropical Cyclone Activity (135%)	185	135

d) CMCC Statistical/Dynamical Model Forecast

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

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

Predictor	Values for 2023 Forecast	Effect on 2023 Hurricane Season
1) CMCC Prediction of Aug-Sep SST (10–45°N, 60–20°W) (+)	+4.5 SD	Strongly Enhance
2) CMCC Prediction of Aug-Sep SST (5°S–5°N, 180–90°W) (-)	+2.1 SD	Strongly Suppress

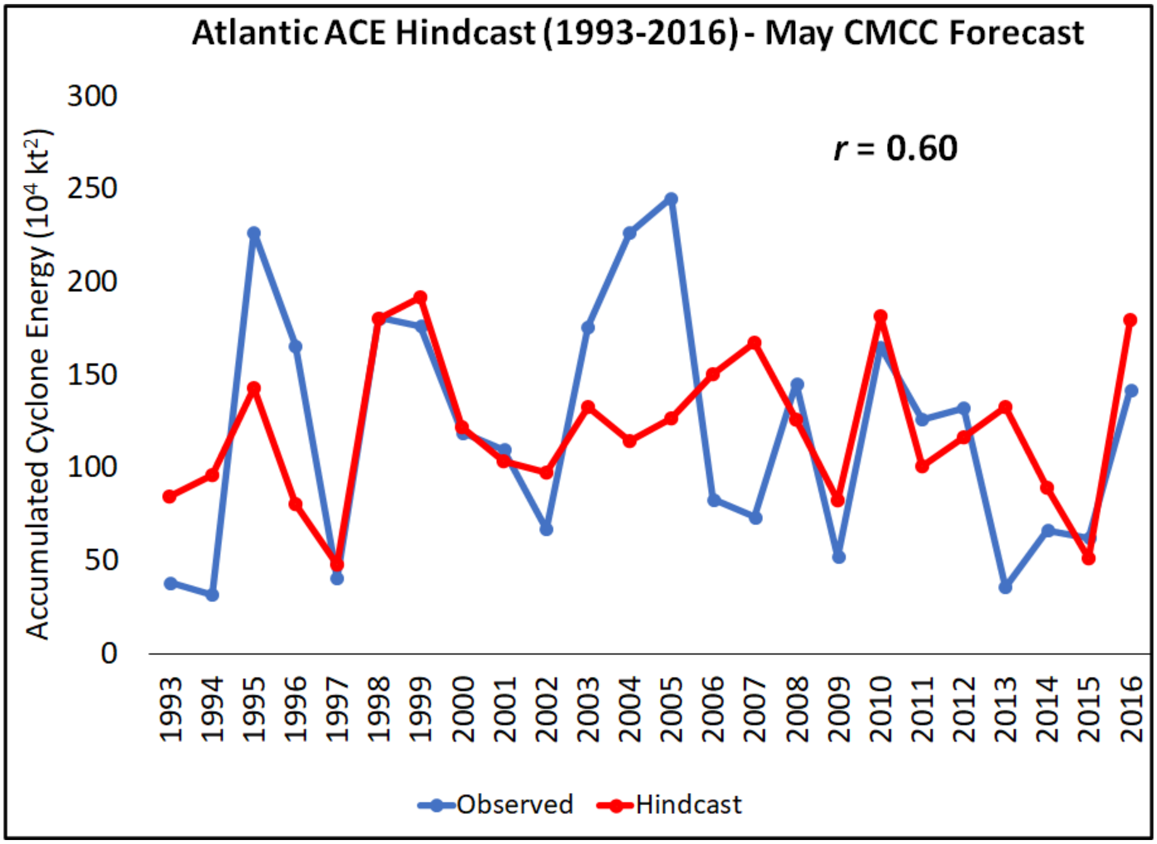

Figure 10: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the CMCC.

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

Forecast Parameter and 1991–2020 Average (in parentheses)	CMCC Hybrid Forecast	Final Forecast
Named Storms (14.4)	16.1	15
Named Storm Days (69.4)	81.3	60
Hurricanes (7.2)	8.4	7
Hurricane Days (27.0)	33.5	30
Major Hurricanes (3.2)	3.9	3
Major Hurricane Days (7.4)	9.7	7
Accumulated Cyclone Energy Index (123)	151	125
Net Tropical Cyclone Activity (135%)	163	135

2.3 June Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2023. These years also provide useful clues as to likely levels of activity that the forthcoming 2023 hurricane season may bring. For this early June 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 May 2023 conditions and, more importantly, projected August–October 2023 conditions. Table 12 lists our analog selections, while Figure 11 shows the composite August–October SST in our five analog years.

We searched for years that were generally characterized by neutral or La Niña conditions the previous winter and had El Niño conditions during the peak of the Atlantic hurricane season (August–October). We also selected years that had above-average SSTs in the tropical Atlantic. We anticipate that the 2023 hurricane season will have activity near the average of our five analog years. We note that there are not any excellent analogs for what we anticipate for August–October 2023. In the recent historical record, we have not had a robust El Niño with near-record warm Atlantic SSTs.

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

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1951	12	67.00	8	34.25	3	4.50	126.3	126.2
1957	8	41.25	3	21.00	2	3.75	78.7	77.6
1969	18	92.25	12	40.25	5	6.50	165.7	181.7
2004	15	93.00	9	45.50	6	22.25	226.9	231.6
2006	10	58.00	5	21.25	2	2.00	83.3	86.8
Average	12.6	71.4	7.4	30.7	3.2	7.3	133	135
2023 Forecast	**15**	**60**	**7**	**30**	**3**	**7**	**125**	**135**

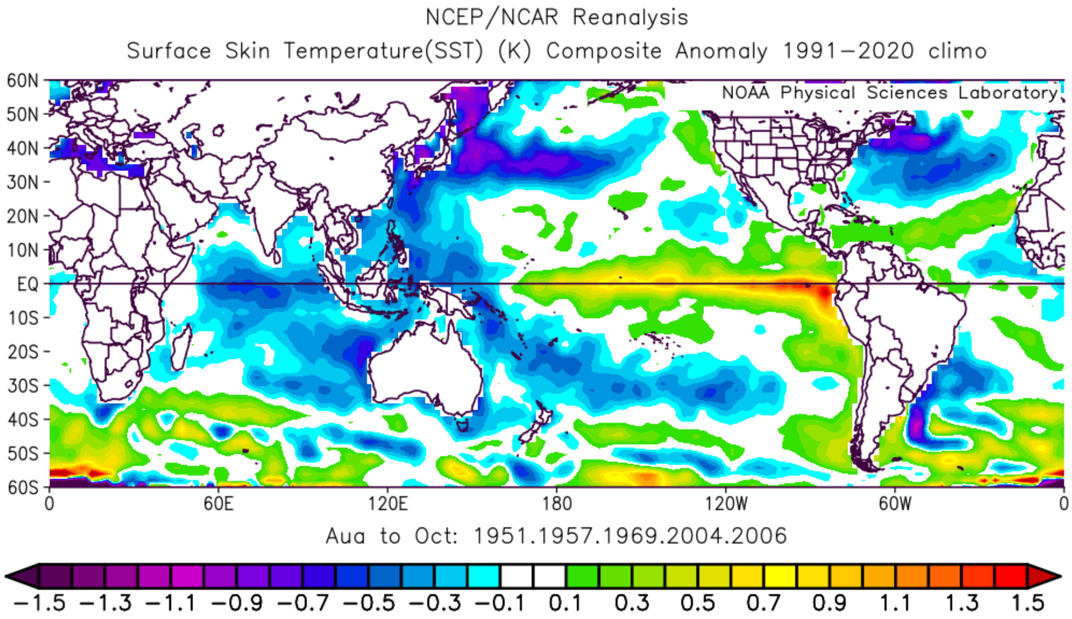

Figure 11: Average August–October SST anomalies in our five analog years.

2.4 ACE West of 60°W Forecast

For the first time this year, we are explicitly forecasting ACE occurring west of 60°W. While there is a relatively robust relationship between basinwide ACE and North Atlantic landfalling hurricanes (defined as hurricanes making landfall west of 60°W) since 1950, there is an improved relationship between North Atlantic landfalling hurricanes and ACE west of 60°W (Figures 12 and 13).

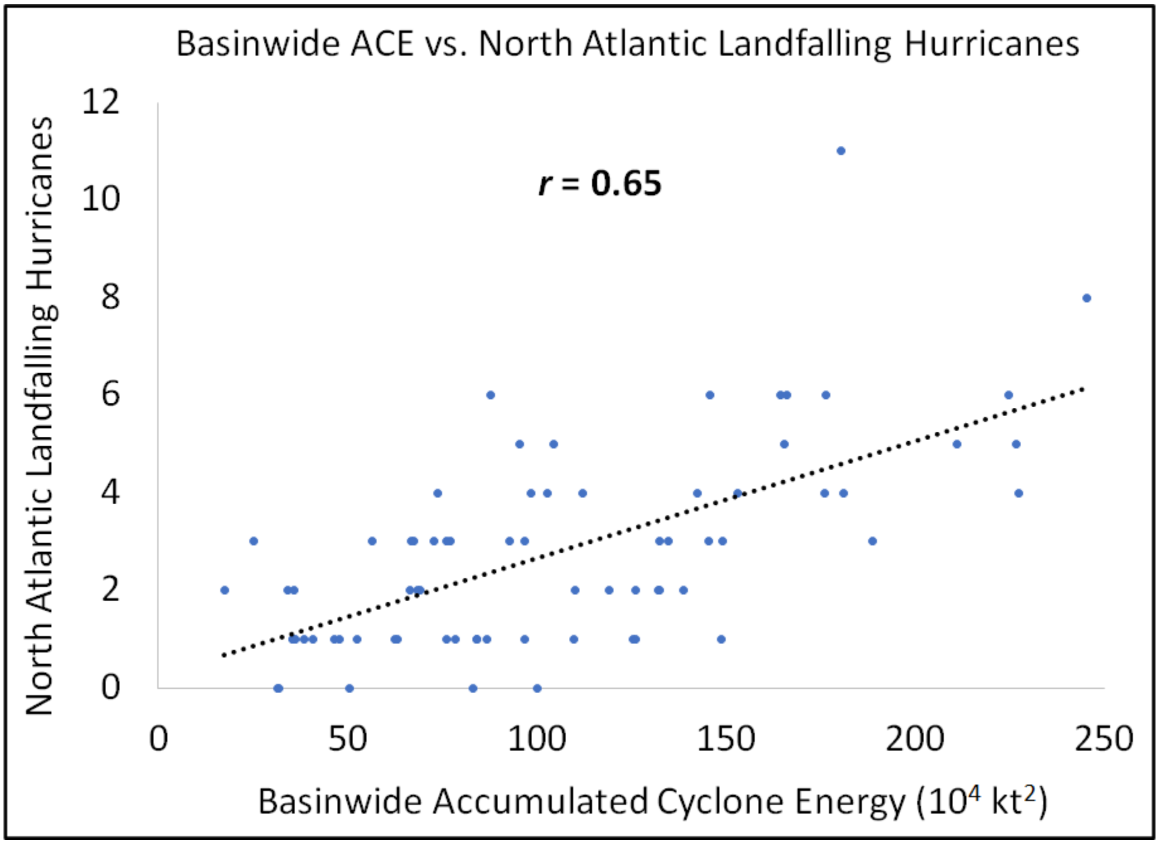

Figure 12: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

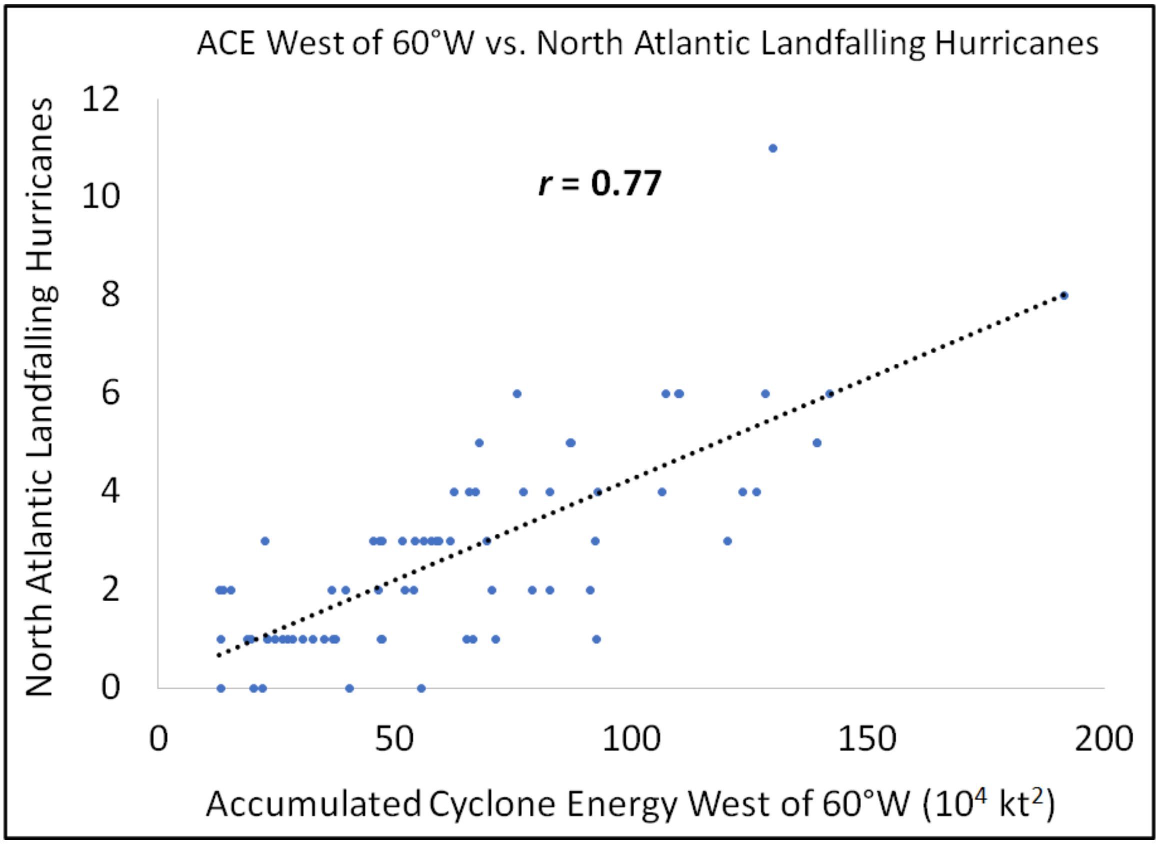

Figure 13: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

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

We find that 52% of basinwide ACE occurs west of 60°W in El Niño years, while 60% of basinwide ACE occurs west of 60°W in La Niña years. In neutral ENSO years, 59% of basinwide ACE occurs west of 60°W (Figure 14). Given that we are favoring El Niño with this outlook, we are estimating ~55% of basinwide ACE to occur west of 60°W in 2023. More research on additional impact-relevant metrics will be forthcoming in future forecasts.

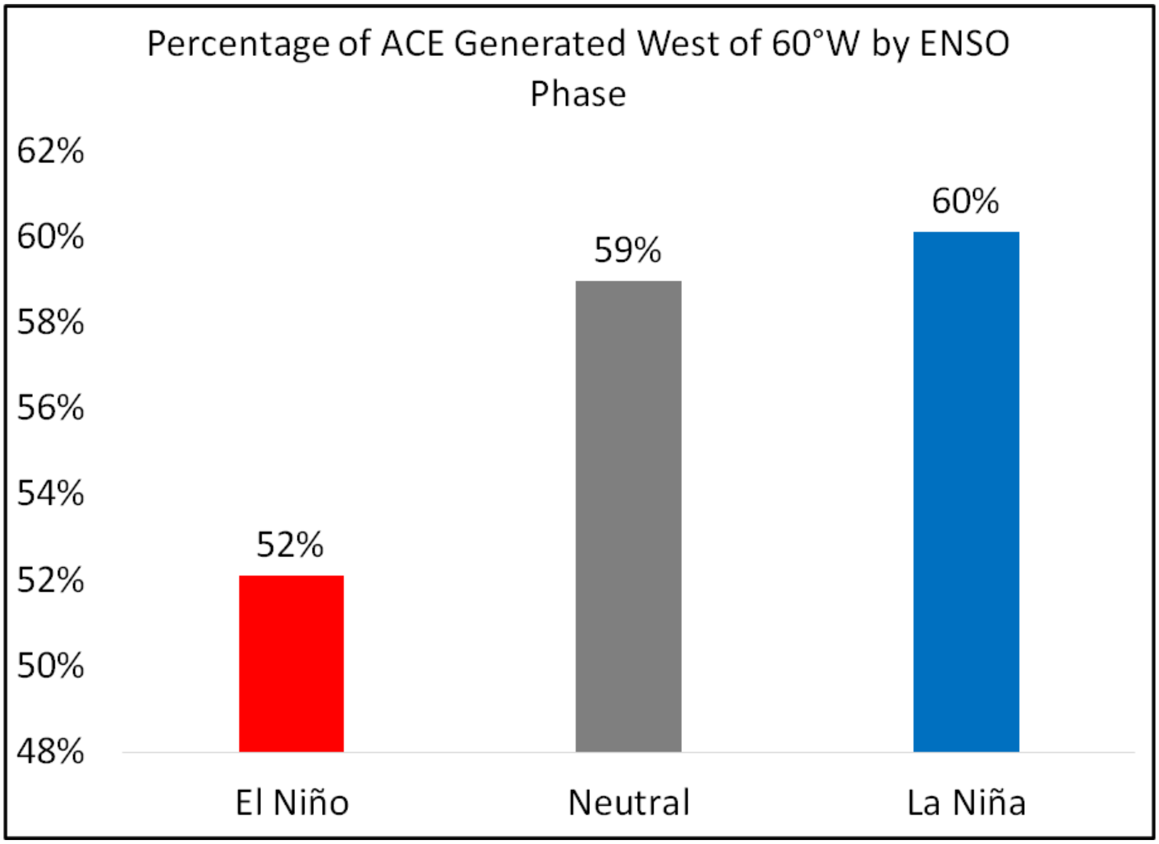

Figure 14: Percentage of ACE generated west of 60°W by ENSO phase.

2.5 June Forecast Summary and Final Adjusted Forecast

Table 13 shows our final adjusted early June forecast for the 2023 season which is a combination of our statistical scheme, our statistical/dynamical schemes, our analog scheme and qualitative adjustments for other factors not explicitly contained in any of these schemes. The various forecast models range from a near-average season to a well above-average season. Our final forecast favors the lower guidance due to an anticipated transition to a moderate/strong El Niño for the peak of the 2023 Atlantic hurricane season. As noted earlier, there is larger-than-normal uncertainty associated with this forecast.

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

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Scheme	ECMWF Scheme	Met Office Scheme	JMA Scheme	CMCC Scheme	Analog Scheme	6-Scheme Average	Adjusted Final Forecast
Named Storms (14.4)	18.2	16.5	15.8	17.5	16.1	12.6	16.1	15
Named Storm Days (69.4)	95.6	83.8	79.2	90.5	81.3	71.4	83.6	60
Hurricanes (7.2)	9.9	8.7	8.3	9.4	8.4	7.4	8.7	7
Hurricane Days (27.0)	41.3	34.9	32.3	38.5	33.5	30.7	35.2	30
Major Hurricanes (3.2)	4.8	4.1	3.8	4.5	3.9	3.2	4.1	3
Major Hurricane Days (7.4)	12.5	10.2	9.3	11.5	9.7	7.3	10.1	7
Accumulated Cyclone Energy Index (123)	185	157	146	173	151	133	158	125
Net Tropical Cyclone Activity (135%)	197	169	158	185	163	135	168	135

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, uncertainty is higher than normal with this year's seasonal hurricane forecast.

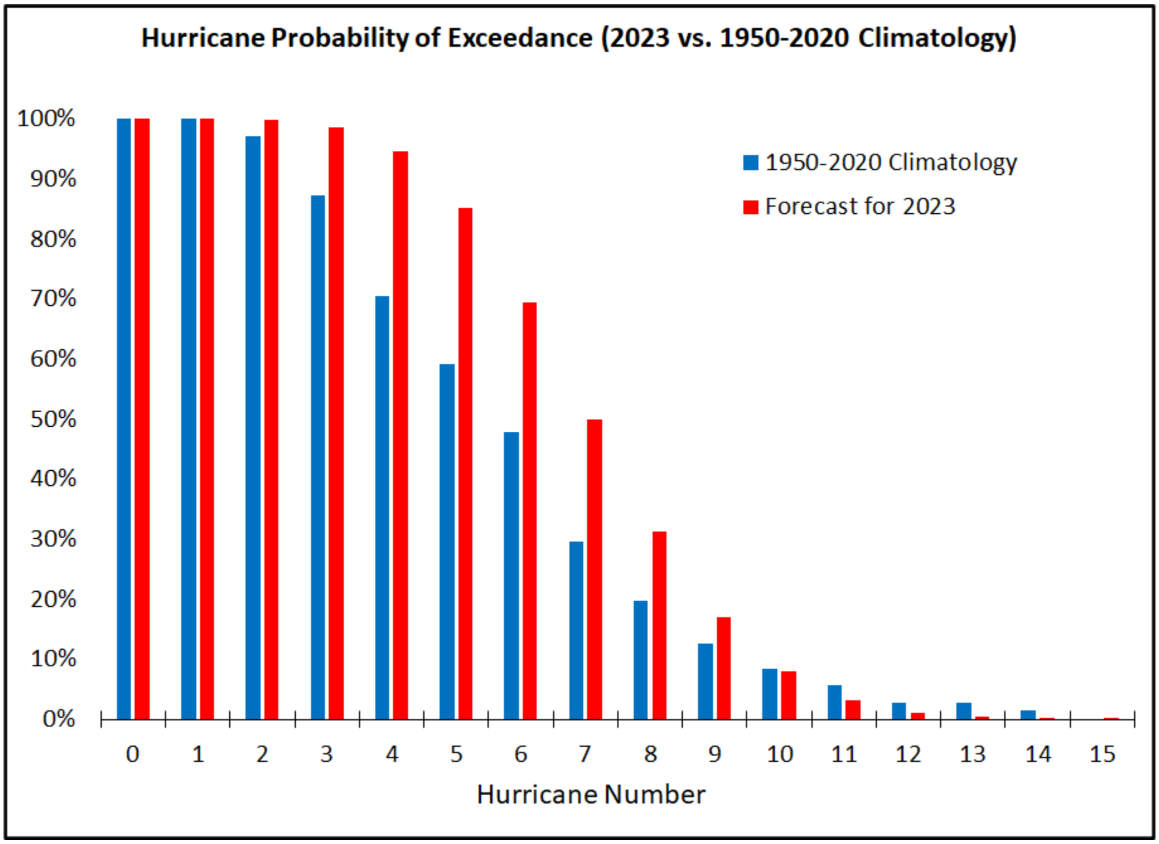

Figure 15: Probability of exceedance plot for hurricane numbers for the 2023 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950–2020 have had more than two hurricanes.

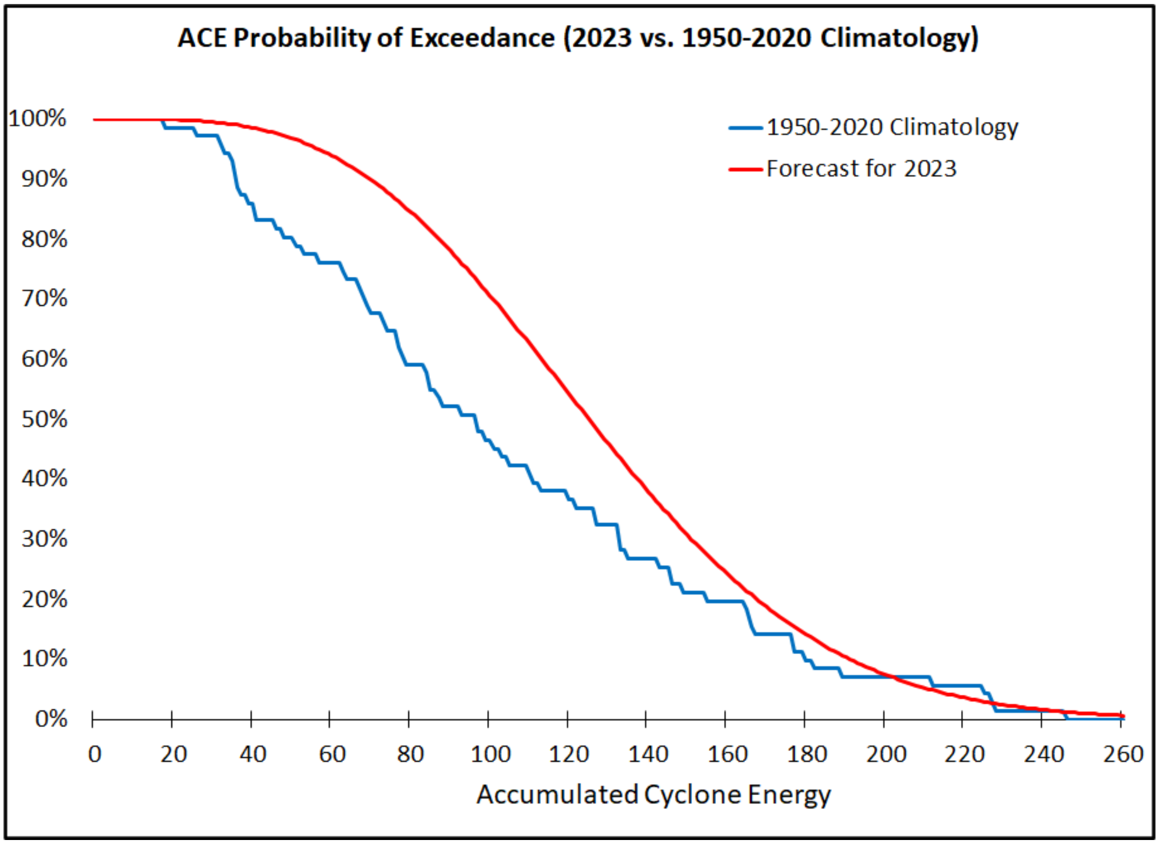

Figure 16: As in Figure 15 but for ACE.

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	2023 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	15	12 – 18
Named Storm Days (NSD)	60	40 – 81
Hurricanes (H)	7	5 – 9
Hurricane Days (HD)	30	18 – 44
Major Hurricanes (MH)	3	2 – 5
Major Hurricane Days (MHD)	7	4 – 11
Accumulated Cyclone Energy (ACE)	125	79 – 178
ACE West of 60°W	70	40 – 107
Net Tropical Cyclone (NTC) Activity	135	89 – 186

4 ENSO

Over the past couple of months, the tropical Pacific has continued to anomalously warm and is now approaching the El Niño threshold (Figure 17). ENSO events are partially classified by NOAA based on SST anomalies in the Nino 3.4 region, which is defined as 5°S–5°N, 170–120°W. El Niño events are typically defined to be when SST anomalies are >=0.5°C in the Nino 3.4 region. Over the past couple of months, SST anomalies have increased across most of the tropical Pacific, with the 0.5°C threshold recently being reached in the Nino 3.4 region.

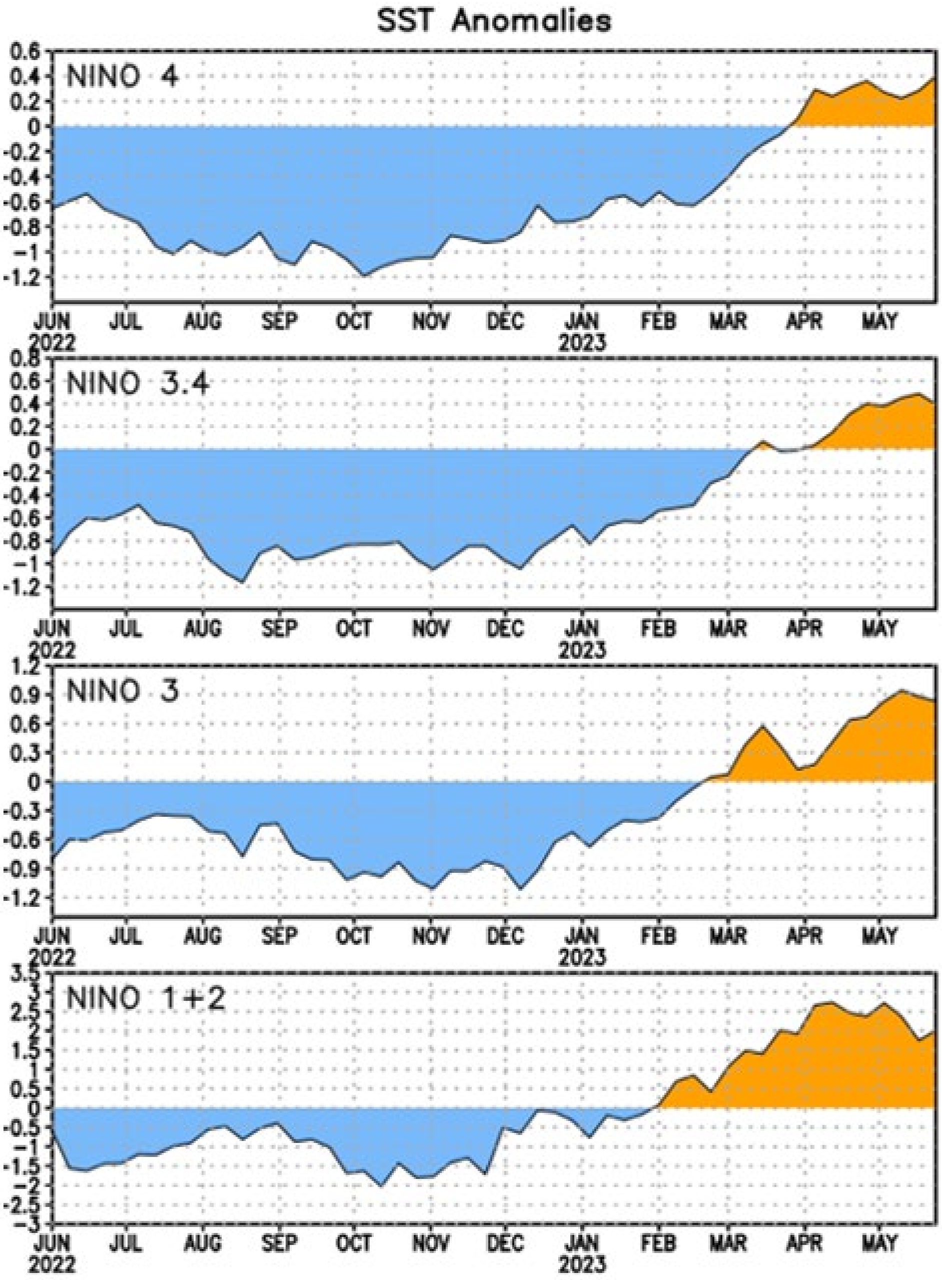

Figure 17: SST anomalies for several ENSO regions over the past year. Figure courtesy of Climate Prediction Center.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific have generally increased over the past several weeks (Figure 18). Recently, there has been a very strong westerly wind burst associated with developing tropical cyclone

Mawar in the western North Pacific (Figure 19). This westerly wind burst has likely initiated another downwelling oceanic Kelvin wave that should cause additional anomalous warming in the eastern and central tropical Pacific.

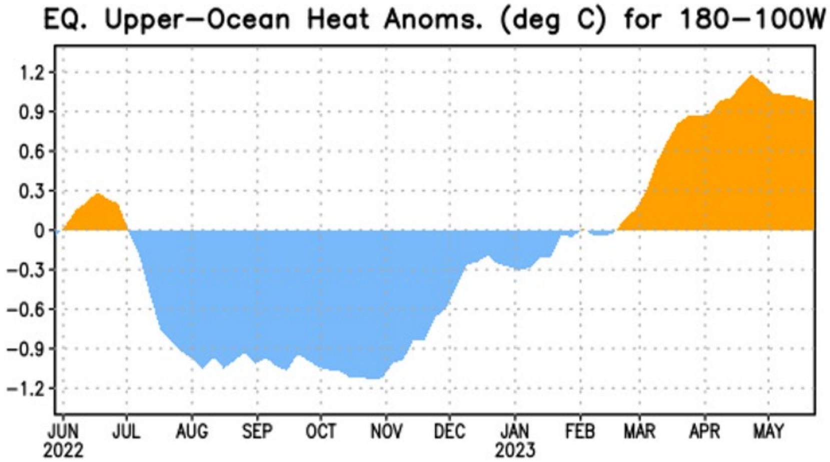

Figure 18: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

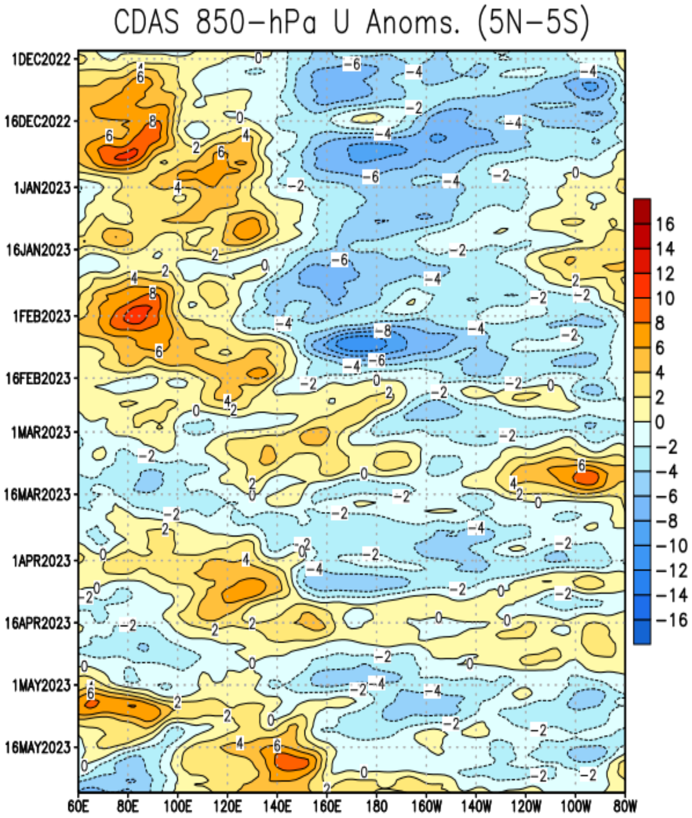

Figure 19: Anomalous equatorial low-level winds spanning from 60°E to 80°W. Figure courtesy of Climate Prediction Center.

SSTs are currently above-normal across the eastern and central tropical Pacific, with the strongest warm anomalies in the far eastern tropical Pacific (Figure 20). The western North Pacific is warmer than normal, while the current spatial pattern of SSTs in the North Pacific (e.g., warm anomalies across most of the North Pacific and cold anomalies off of the west coast of California) are indicative of a continued negative phase of the Pacific Decadal Oscillation.

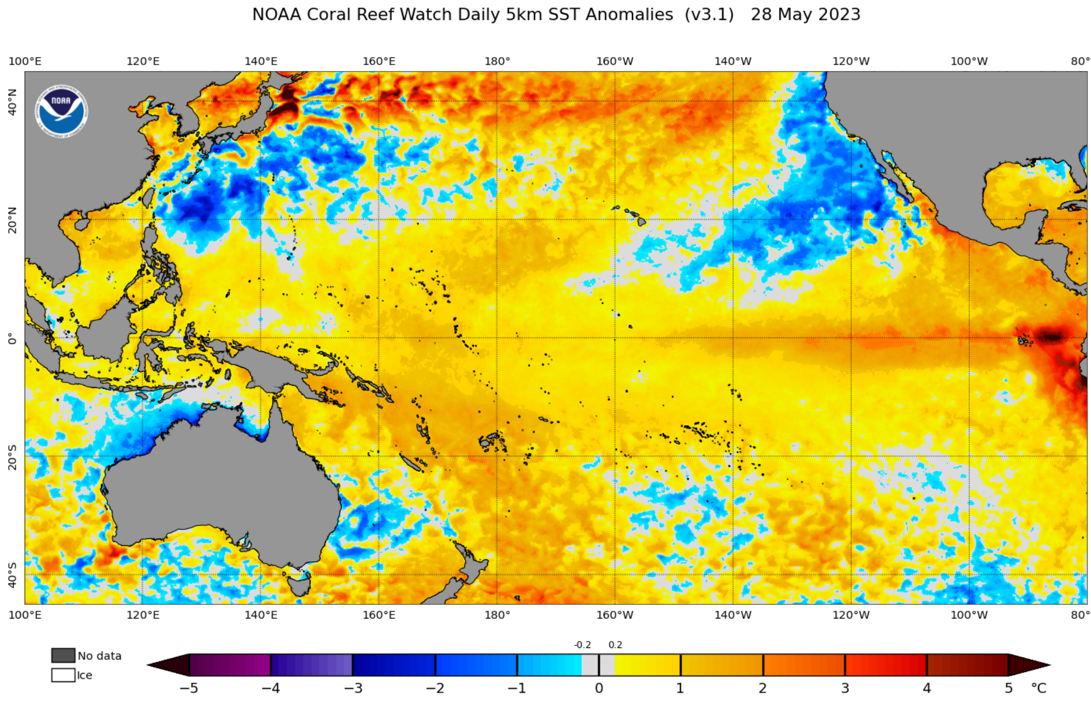
NOAA Coral Reef Watch Daily 5km SST Anomalies (v3.1) 28 May 2023

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

Table 15 displays March and May SST anomalies for several Nino regions. Over the past two months, SST anomalies have warmed across the tropical Pacific.

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

Region	March SST Anomaly (°C)	May SST Anomaly (°C)	May – March SST Anomaly (°C)
Nino 1+2	+1.5	+2.1	+0.6
Nino 3	+0.4	+0.9	+0.5
Nino 3.4	0.0	+0.4	+0.4
Nino 4	-0.1	+0.3	+0.4

A downwelling (warming) Kelvin wave, denoted by the long dashed line, reached the far eastern tropical Pacific in early May (Figure 21). As mentioned earlier, these Kelvin waves are typically triggered by anomalous low-level winds in the tropical Pacific. We are beginning to see evidence that the recent strong westerly wind burst west of the International Date Line has triggered another downwelling Kelvin wave.

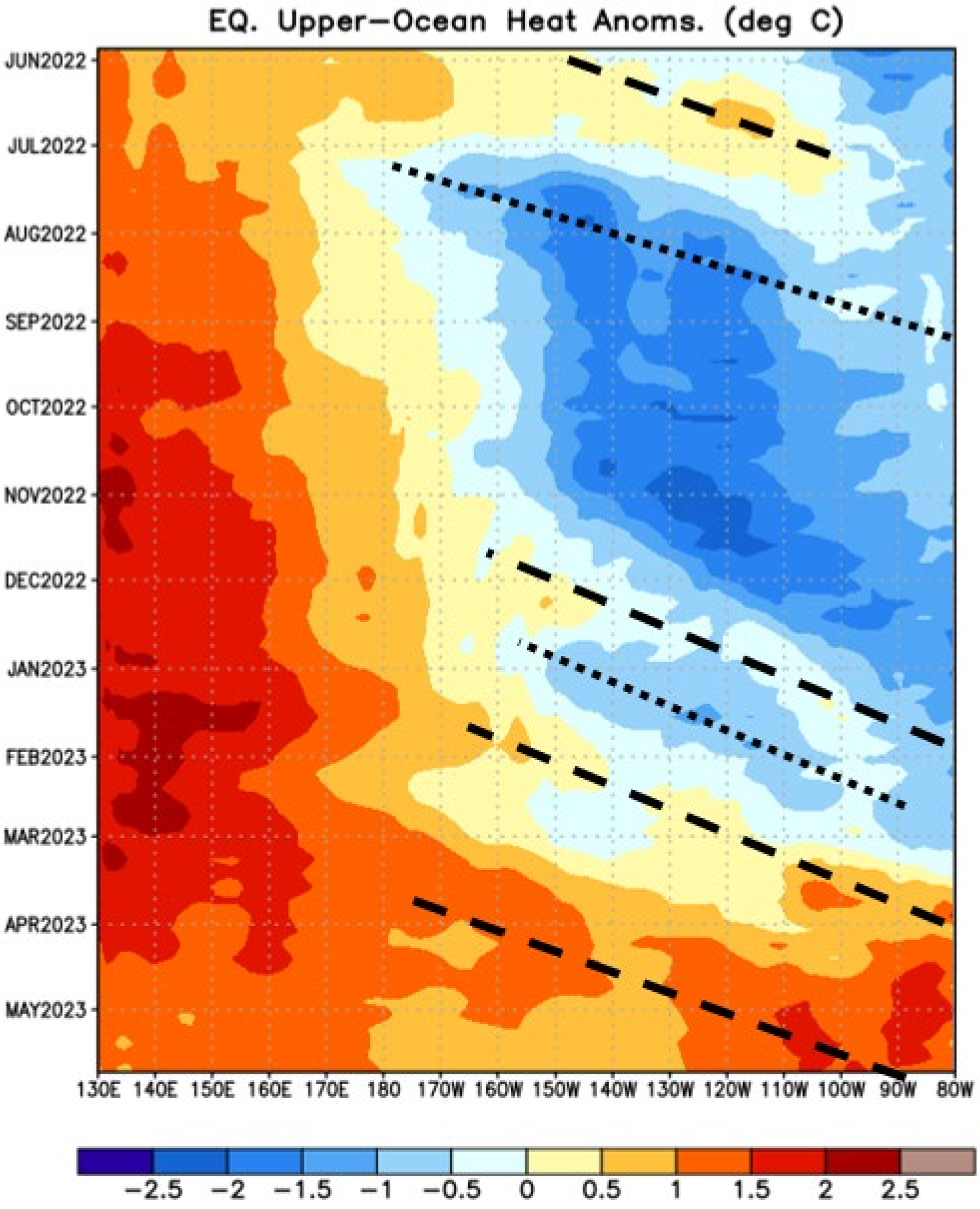

Figure 21: Upper-ocean heat content anomalies in the tropical Pacific since June 2022. Dashed lines indicate downwelling Kelvin waves, while dotted lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases. Figure courtesy of Climate Prediction Center.

Current sub-surface temperature anomalies across the tropical Pacific are conducive for El Niño development, although they are not quite as favorable for El Niño in late May as they were in either 1997 or 2015 (Figures 22 and 23). At this point, our best estimate is that we will have a robust El Niño, but likely not quite as strong as 1997 or 2015.

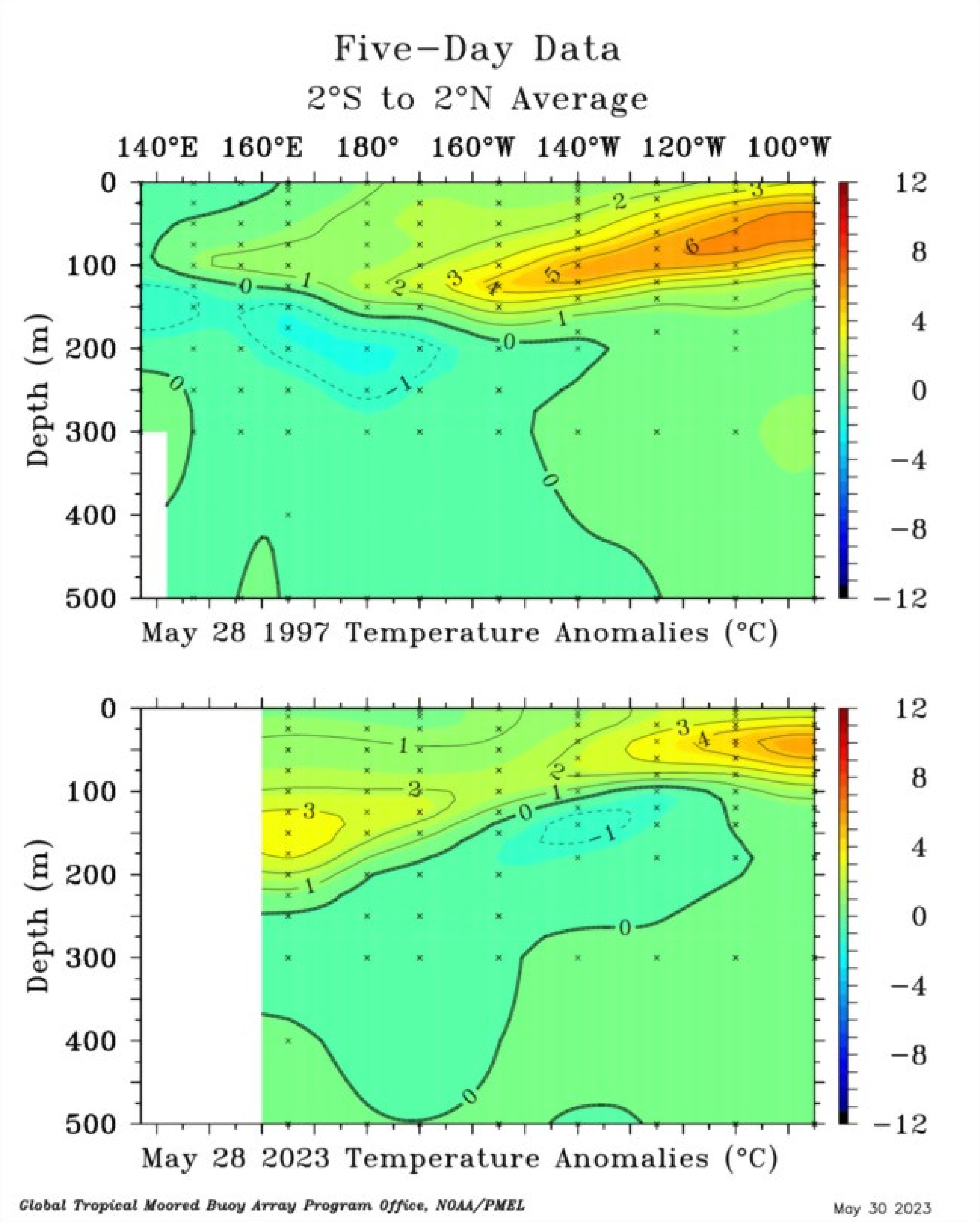

Figure 22: Late May upper-ocean temperature anomalies in (top panel) 1997 and in (bottom panel) 2023).

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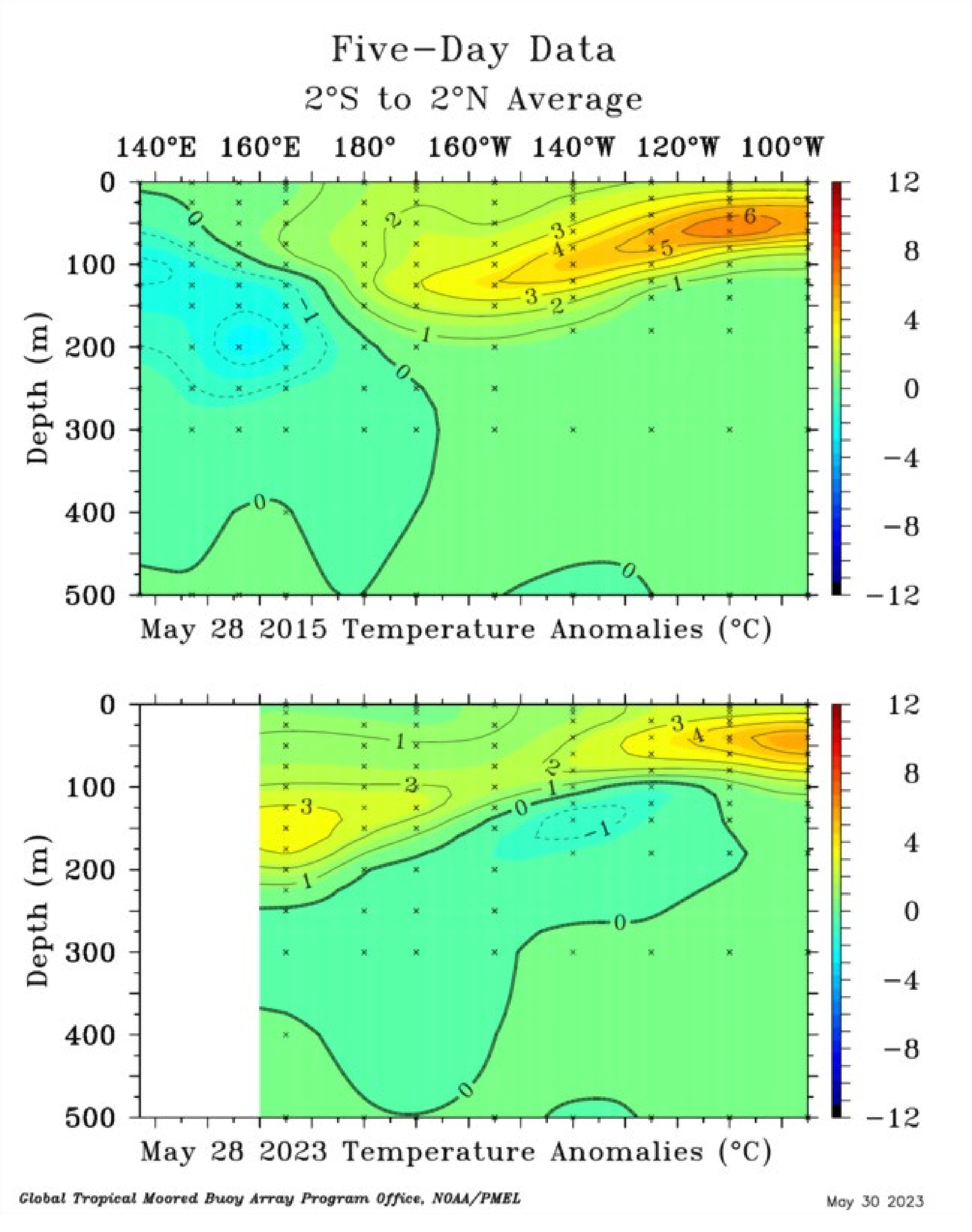


Figure 23: Late May upper-ocean temperature anomalies in (top panel) 2015 and in (bottom panel) 2023.

Over the next several months, we will be closely monitoring low-level winds over the tropical Pacific. Anomalous low-level westerlies have begun to dominate the eastern and central tropical Pacific. While we are likely to get stronger trades across most of the tropical Pacific in the next couple of weeks, associated with continued eastward propagation of the MJO, trade winds across most of the tropical Pacific are likely to be relatively weak towards the end of June extending through the middle of July (Figure 24). The anomalously strong eastern/central tropical Pacific trade winds that were commonplace over the past several years, associated with the long-lived La Niña event that predominated, have disappeared in the past couple of months.

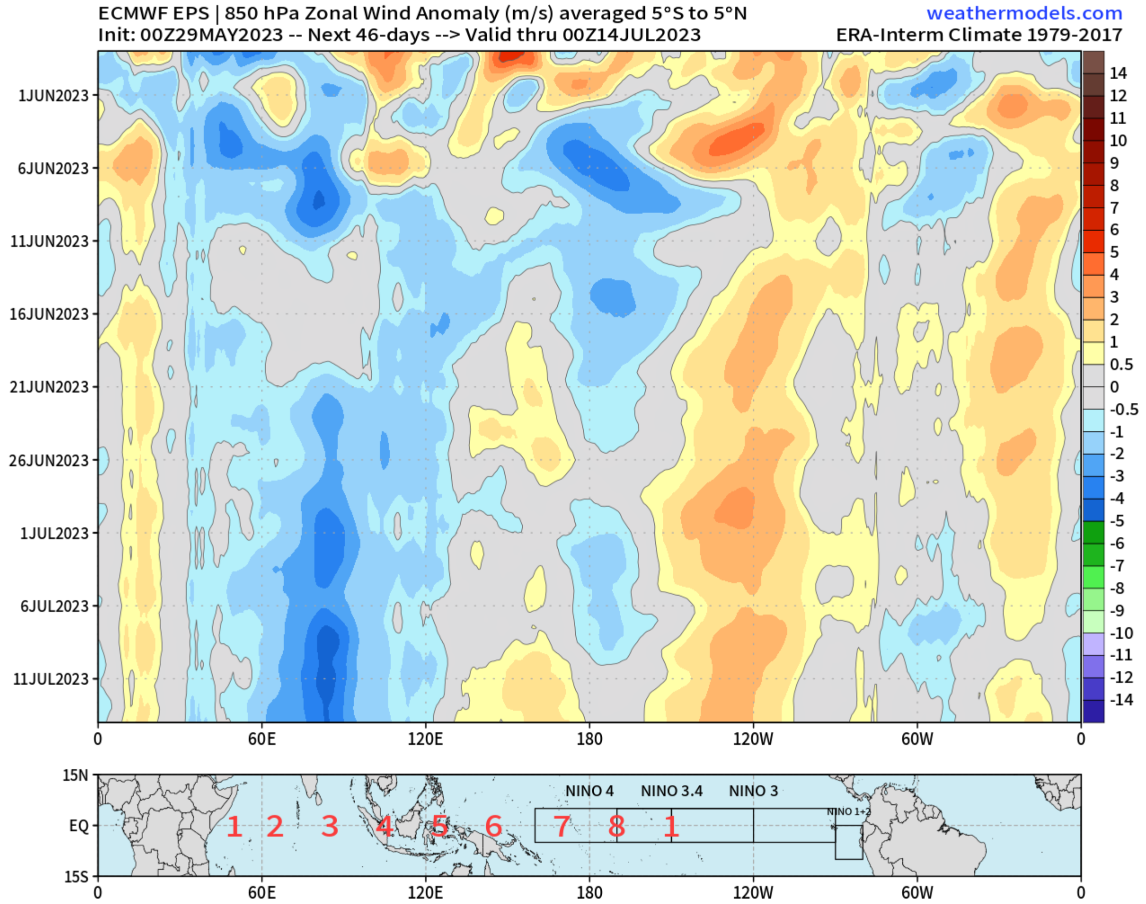


Figure 24: ECMWF forecast 850-hPa zonal equatorial winds for the next 46 days. Figure courtesy of weathermodels.com.

The latest plume of ENSO predictions from several statistical and dynamical models shows considerable spread by the peak of the Atlantic hurricane season in August–October (Figure 25), but the majority of models are favoring a robust El Niño. Dynamical models are tending to be more aggressive with El Niño development than statistical models.

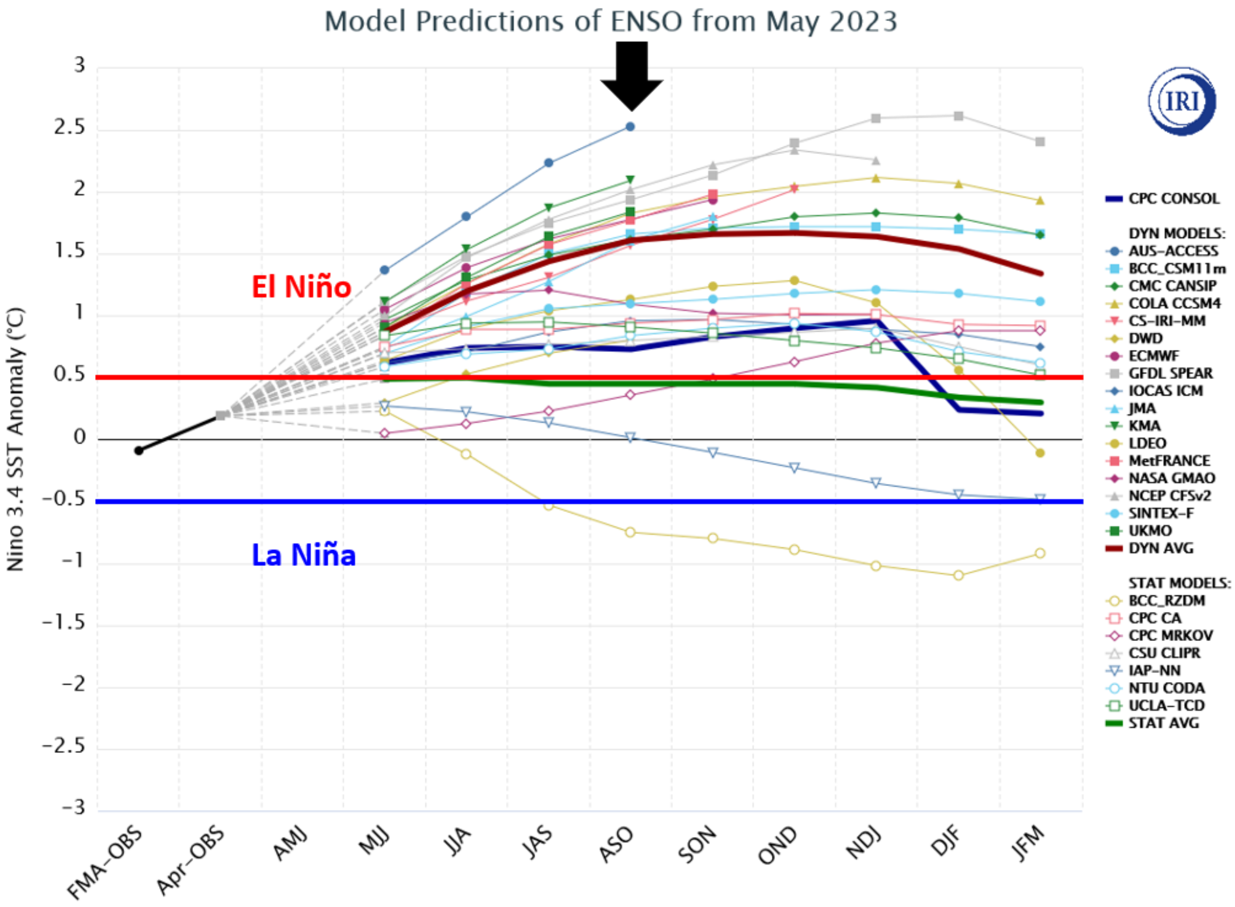


Figure 25: ENSO forecasts from various statistical and dynamical models for Nino 3.4 SST anomalies based on late April to early May initial conditions. Most models are calling for El Niño for August–October. Figure courtesy of the International Research Institute (IRI). The black arrow delineates the peak of the Atlantic hurricane season (August–October).

The latest official forecast from NOAA also strongly favors El Niño for August–October. NOAA is currently predicting a 93% chance of El Niño, and a 7% chance of ENSO neutral conditions for the peak of the Atlantic hurricane season (Figure 26).

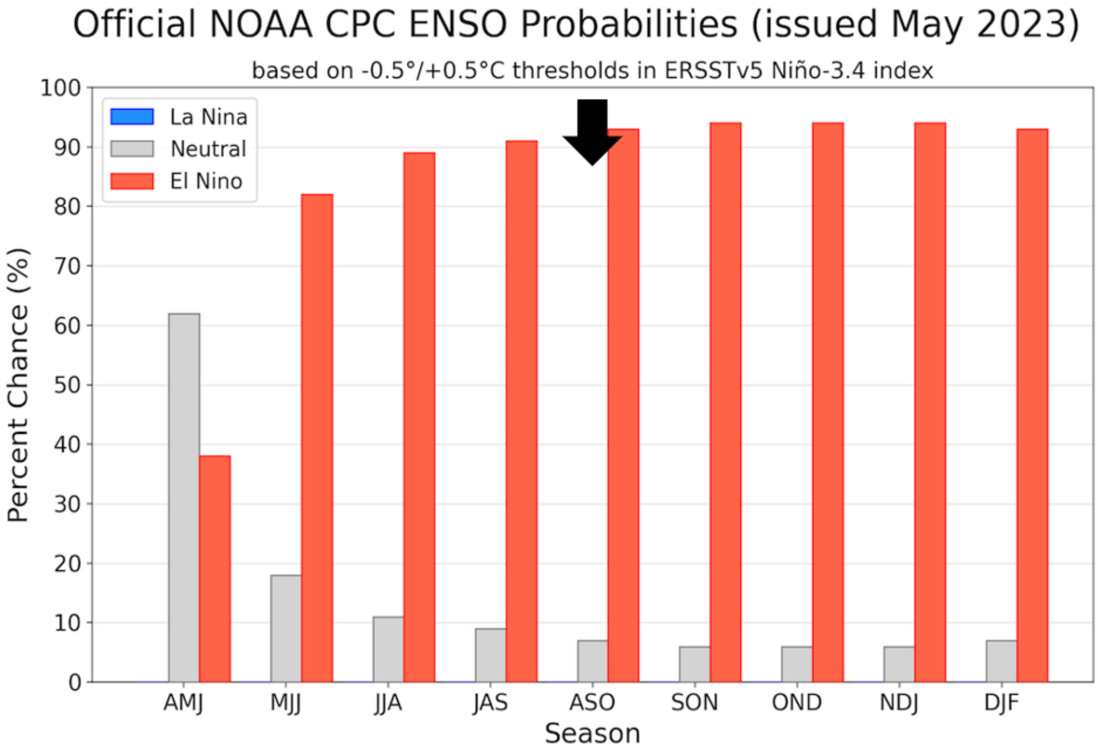


Figure 26: Official probabilistic ENSO forecast from NOAA. The black arrow delineates the peak of the Atlantic hurricane season (August–October).

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

5 Current Atlantic Basin Conditions

Currently, SSTs are well above normal across almost the entire North Atlantic (Figure 27). We have been monitoring SSTs in the region from 0-45°N, 45-10°W, as this region in May historically has relatively high correlations (~0.6) with seasonal Atlantic ACE (Figure 28). SSTs are the warmest on record (since 1979) using the most recent 30-day averages. The five years with the warmest SSTs after 2023 were (in descending order from 2nd warmest): 2010, 2005, 1995, 2021, and 2020. Four out of those five seasons were classified as hyperactive Atlantic hurricane seasons by NOAA, while 2021 was classified as an above-average season. None of those seasons had El Niño conditions, however.

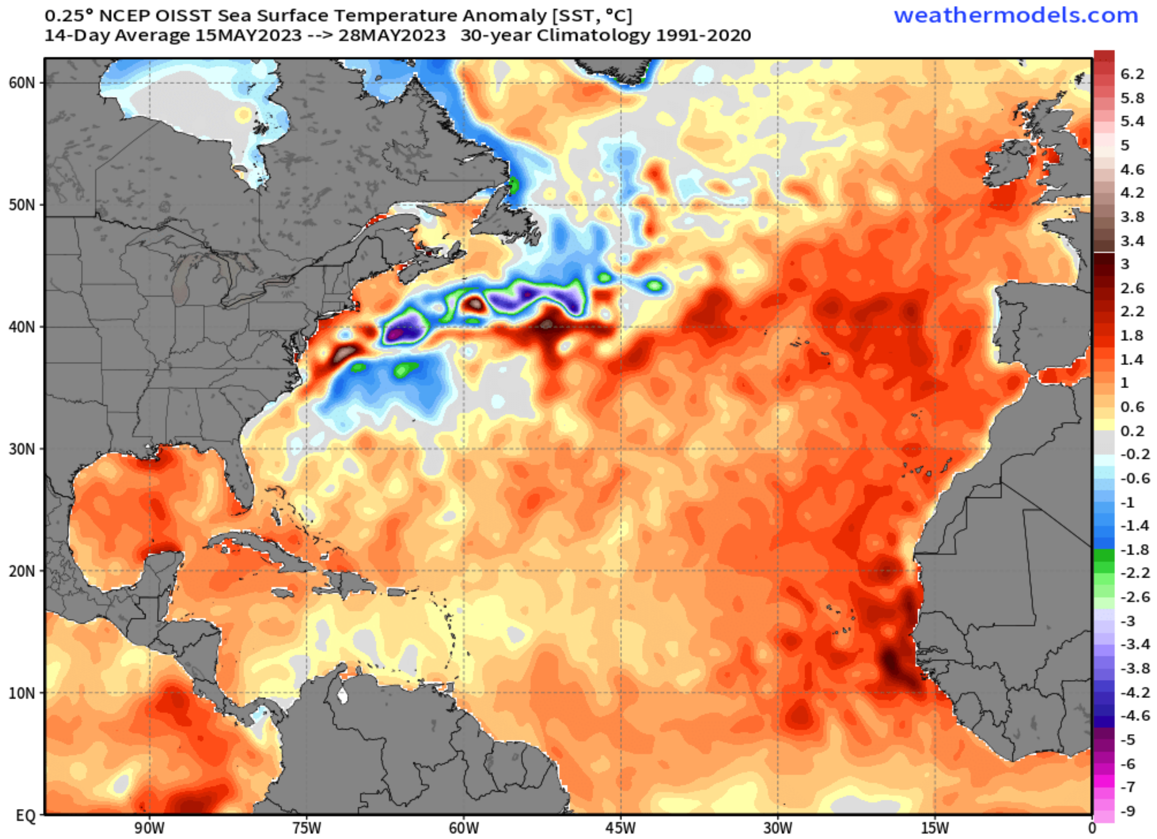


Figure 27: Late May 2023 SST anomaly pattern across the Atlantic Ocean.

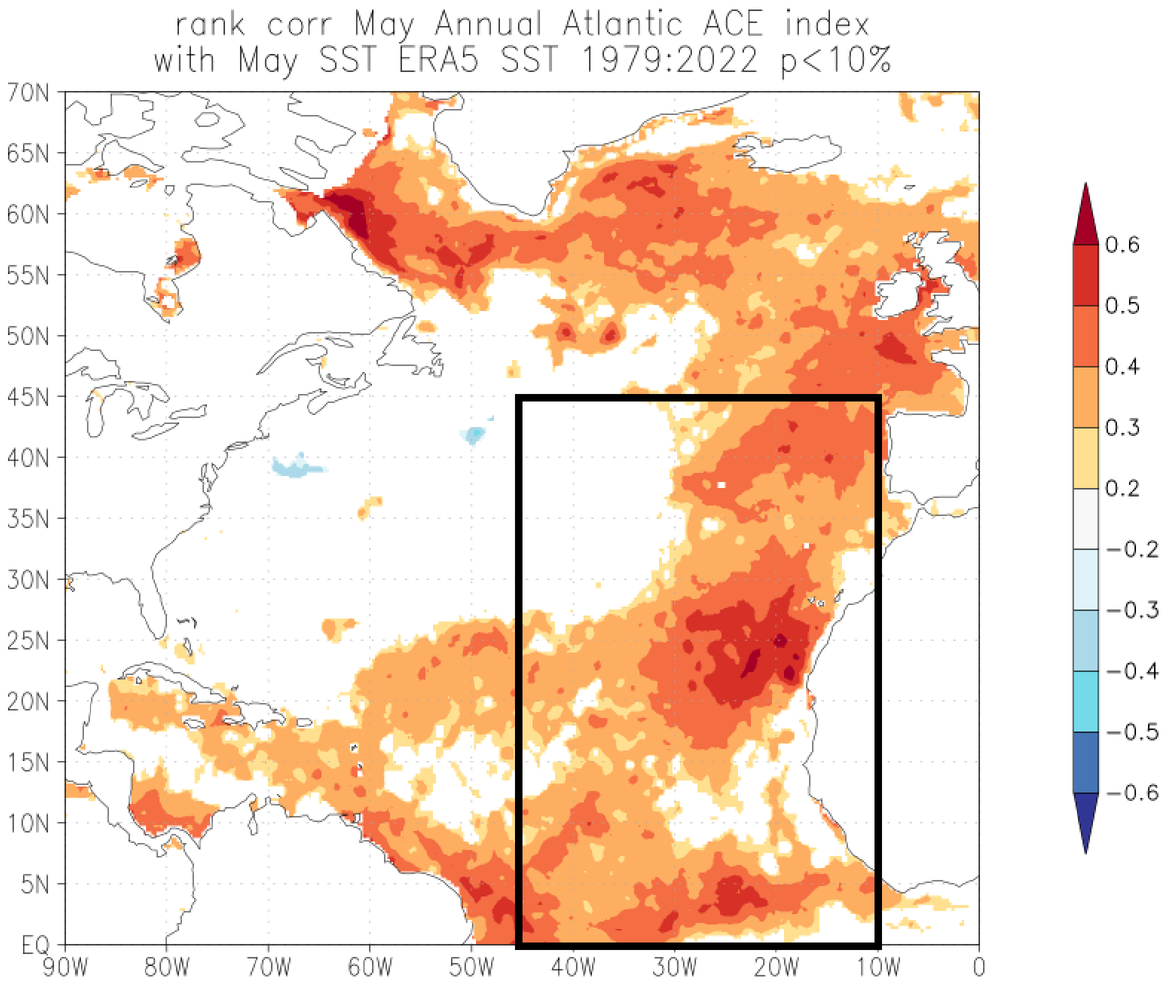


Figure 28: Rank correlations between May sea surface temperatures in the North Atlantic and annual Atlantic ACE from 1979-2022. The black rectangle denotes the region discussed in the previous paragraph (0-45°N, 45-10°W).

The North Atlantic Oscillation was generally in its negative phase from late February through the middle of May (Figure 29), although it has trended positive over the past couple of weeks. Associated with this negative phase has been weaker-than-normal trade winds across most of the tropical and subtropical eastern Atlantic (Figure 30). These weaker trades have led to less evaporation and mixing, leading to considerable anomalous warming in the eastern and central part of the basin.

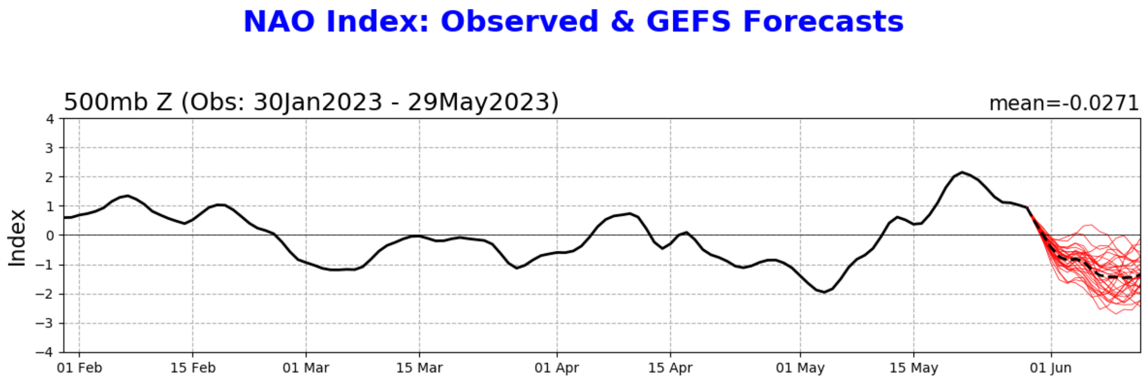


Figure 29: Observed values of the North Atlantic Oscillation since late December and forecasts of the North Atlantic Oscillation from the Global Ensemble Forecast System for the next 15 days.

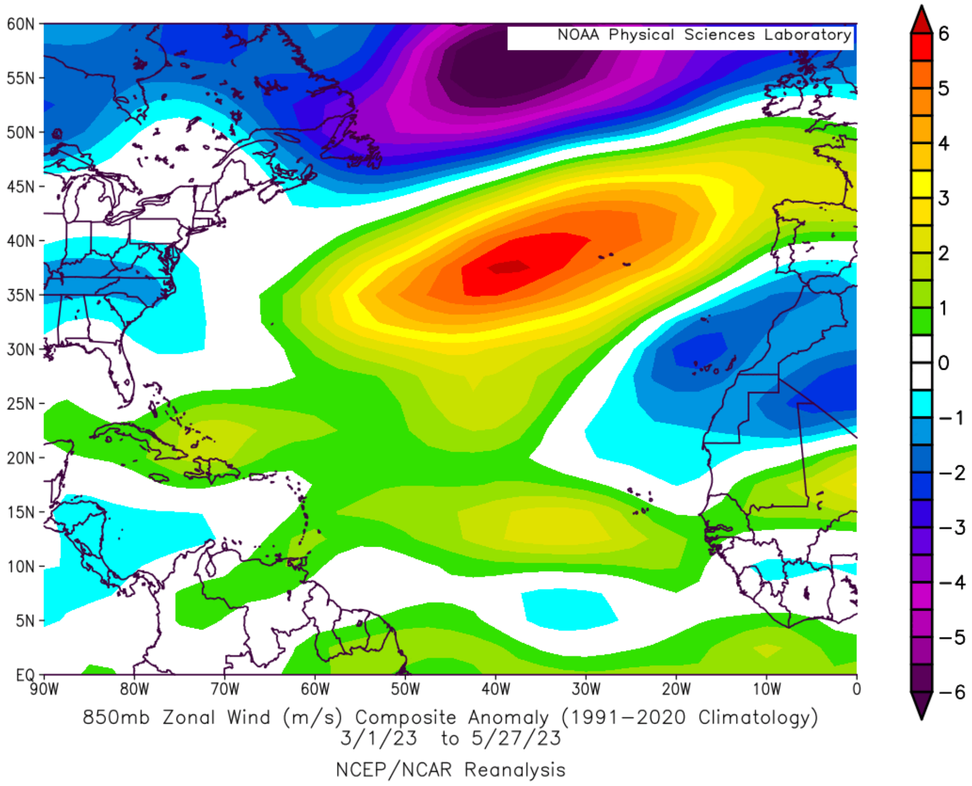


Figure 30: Zonal wind anomalies across the North Atlantic Ocean from March 1, 2023 through May 27, 2023.

Figure 31 shows the forecast for the next few weeks of low-level winds across the Atlantic from the Climate Forecast System. In general, tropical Atlantic trade winds are forecast to be weaker than average for the next few weeks, indicating potential for continued anomalies warming. The forecast for weaker trades matches well with the forecast for a transition back to a predominately negative phase of the North Atlantic Oscillation throughout June by ECMWF's Ensemble Prediction System (Figure 32).

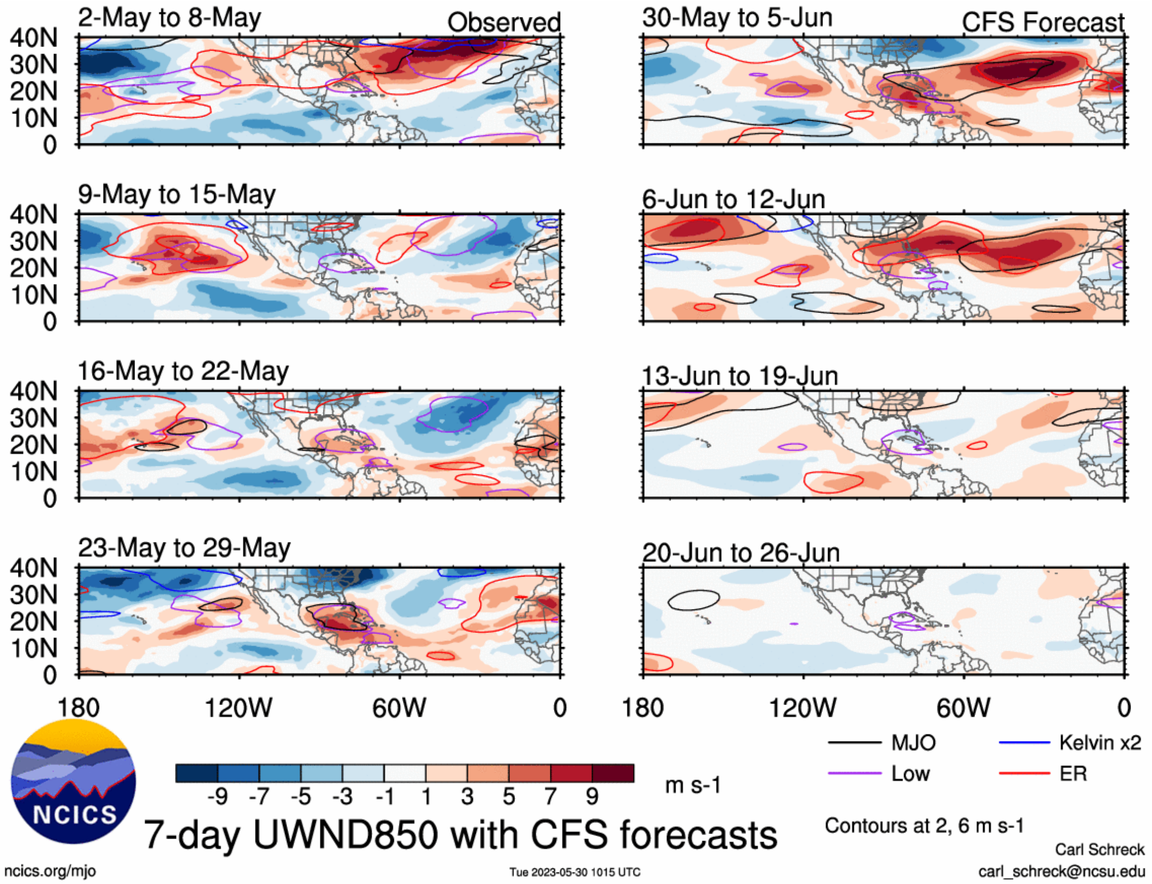


Figure 31: Observed low-level zonal winds across portions of the Western Hemisphere over the past four weeks and predicted low-level zonal winds from the Climate Forecast System for the next four weeks. Figure courtesy of Carl Schreck.

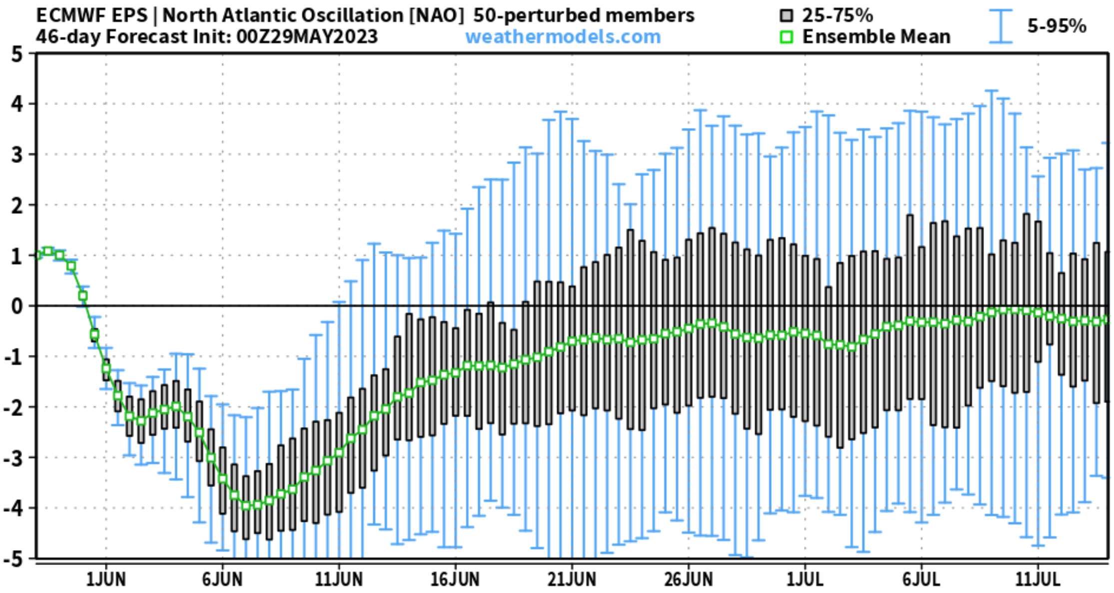


Figure 32: Forecast values of the North Atlantic Oscillation for the next 46 days from ECMWF's Ensemble Prediction System.

6 Tropical Cyclone Impact Probabilities for 2023

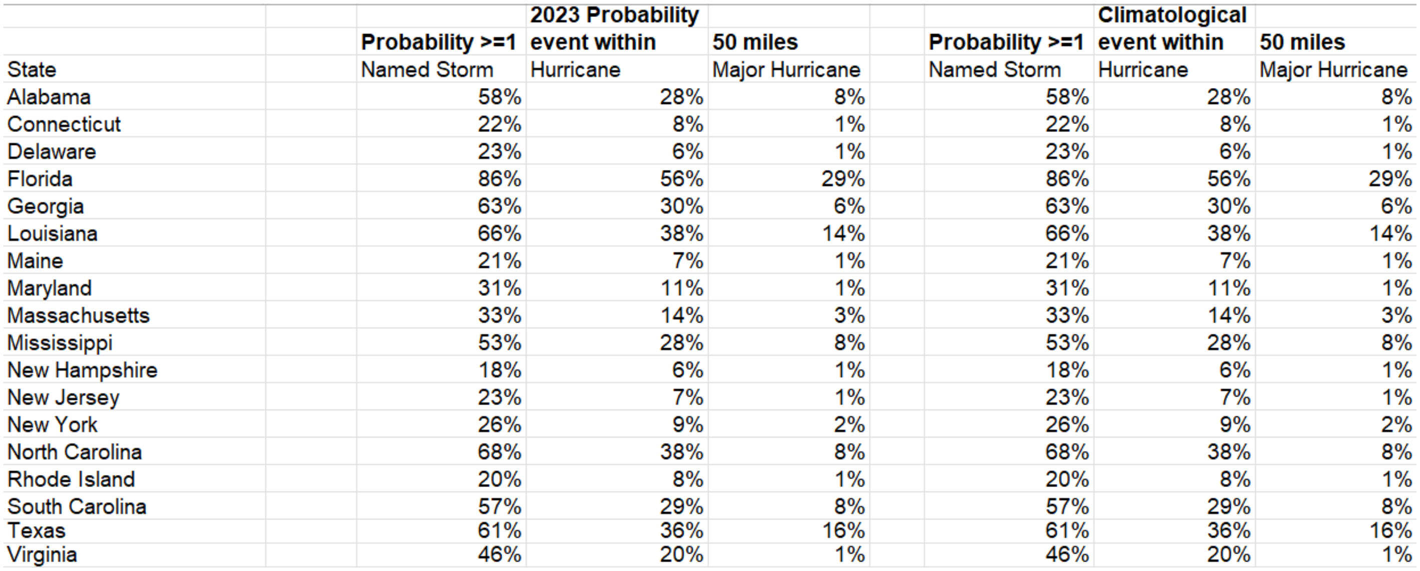
This year, we continue to calculate the impacts of tropical cyclones for each state and county/parish along the Gulf and East Coasts, tropical cyclone-prone provinces of Canada, states in Mexico, islands in the Caribbean and countries in Central America. We have used NOAA's Historical Hurricane Tracks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

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

Table 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 2023. Landfall probabilities are near their long-term averages. Probabilities for other Atlantic basin landmasses are available on our website.

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

Table 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 2023, based on the latest CSU seasonal hurricane forecast.



		2023 Probability			**Climatological**	
	Probability >=1	**event within**	**50 miles**	**Probability >=1**	**event within**	**50 miles**
State	Named Storm	Hurricane	Major Hurricane	Named Storm	Hurricane	Major Hurricane
Alabama	58%	28%	8%	58%	28%	8%
Connecticut	22%	8%	1%	22%	8%	1%
Delaware	23%	6%	1%	23%	6%	1%
Florida	86%	56%	29%	86%	56%	29%
Georgia	63%	30%	6%	63%	30%	6%
Louisiana	66%	38%	14%	66%	38%	14%
Maine	21%	7%	1%	21%	7%	1%
Maryland	31%	11%	1%	31%	11%	1%
Massachusetts	33%	14%	3%	33%	14%	3%
Mississippi	53%	28%	8%	53%	28%	8%
New Hampshire	18%	6%	1%	18%	6%	1%
New Jersey	23%	7%	1%	23%	7%	1%
New York	26%	9%	2%	26%	9%	2%
North Carolina	68%	38%	8%	68%	38%	8%
Rhode Island	20%	8%	1%	20%	8%	1%
South Carolina	57%	29%	8%	57%	29%	8%
Texas	61%	36%	16%	61%	36%	16%
Virginia	46%	20%	1%	46%	20%	1%

7 Summary

An analysis of a variety of different atmosphere and ocean measurements (through May) which are known to have long-period statistical relationships with the upcoming season's Atlantic tropical cyclone activity, as well as output from dynamical models, indicate that 2023 will have near-average activity. The big question marks with this season's predictions revolve around the strength of El Niño and how anomalously warm the tropical and subtropical Atlantic is for the peak of the hurricane season. We stress again that there is greater-than-normal uncertainty associated with this outlook.

8 Forthcoming Updated Forecasts of 2023 Hurricane Activity

We will be issuing seasonal updates of our 2023 Atlantic basin hurricane forecasts on **Thursday 6 July, and Thursday 3 August**. We will also be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August–October. A verification and discussion of all 2023 forecasts will be issued on **Thursday, 30 November**. All of these forecasts will be available on our website.

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 33 displays correlations between observed and predicted Atlantic hurricanes from 1984–2013, from 2014–2022 and from 1984–2022, respectively. Correlation skill has improved at all lead times in recent years, with the most noticeable improvements at longer lead times. While nine years is a relatively short sample size, improvements in both modeling and physical understanding should continue to result in future improvements in seasonal Atlantic hurricane forecast skill. More detailed verification statistics are also available at: https://tropical.colostate.edu/archive.html#verification

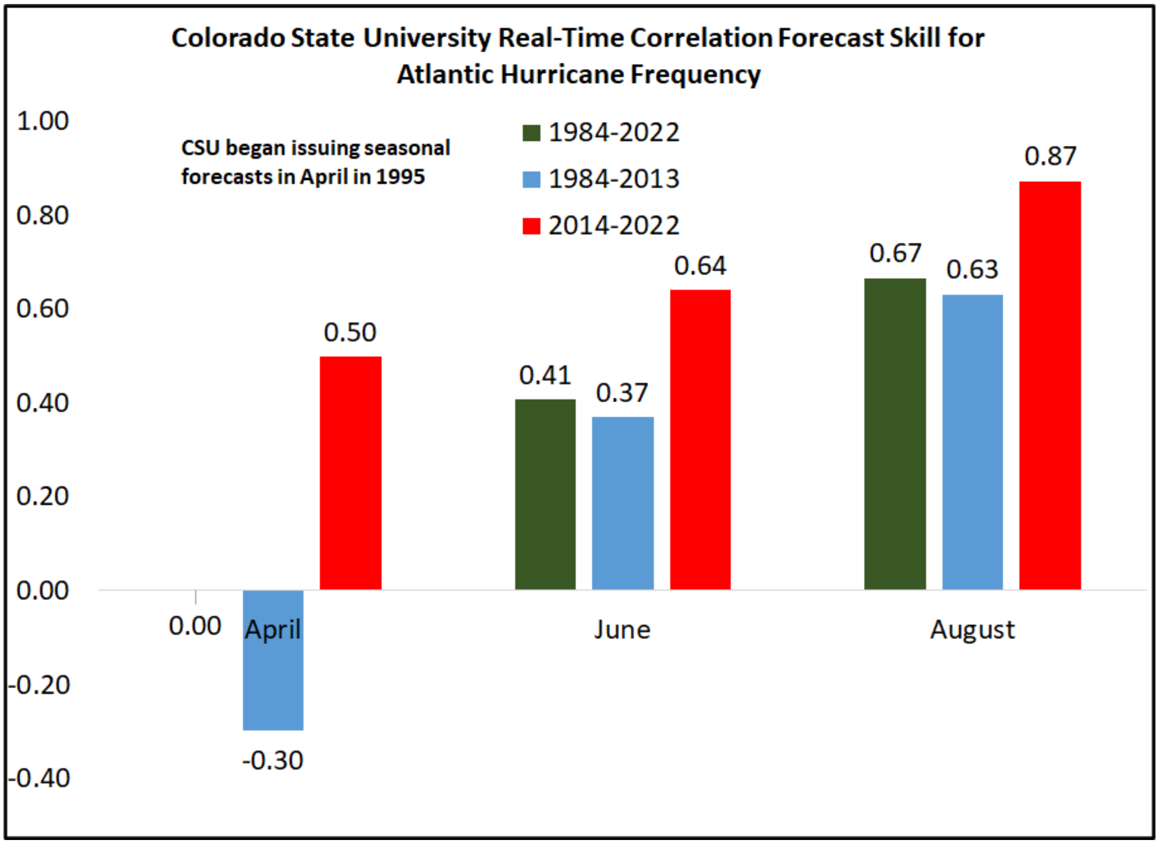


Figure 33: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2022 and 1984–2022, respectively.