SUMMARY OF 2025 ATLANTIC TROPICAL CYCLONE ACTIVITY AND VERIFICATION OF AUTHORS' SEASONAL AND TWO-WEEK FORECASTS

The 2025 Atlantic hurricane season was an above-normal season based on NOAA's definition, with a near-average number of named storms, a below-average number of hurricanes and an above-average number of major hurricanes. The seasonal forecasts for ACE verified well, while some other parameters were over- or under-forecast given the unusual distribution of storms this year. The season's most significant hurricane was Hurricane Melissa, which made landfall as a Category 5 hurricane in Jamaica. The warm Atlantic combined with cool neutral ENSO/weak La Niña led to somewhat hurricane-favorable conditions in 2025, although with a marked peak season lull in activity.

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In Memory of William M. Gray[6]

This discussion as well as past forecasts and verifications are available online at
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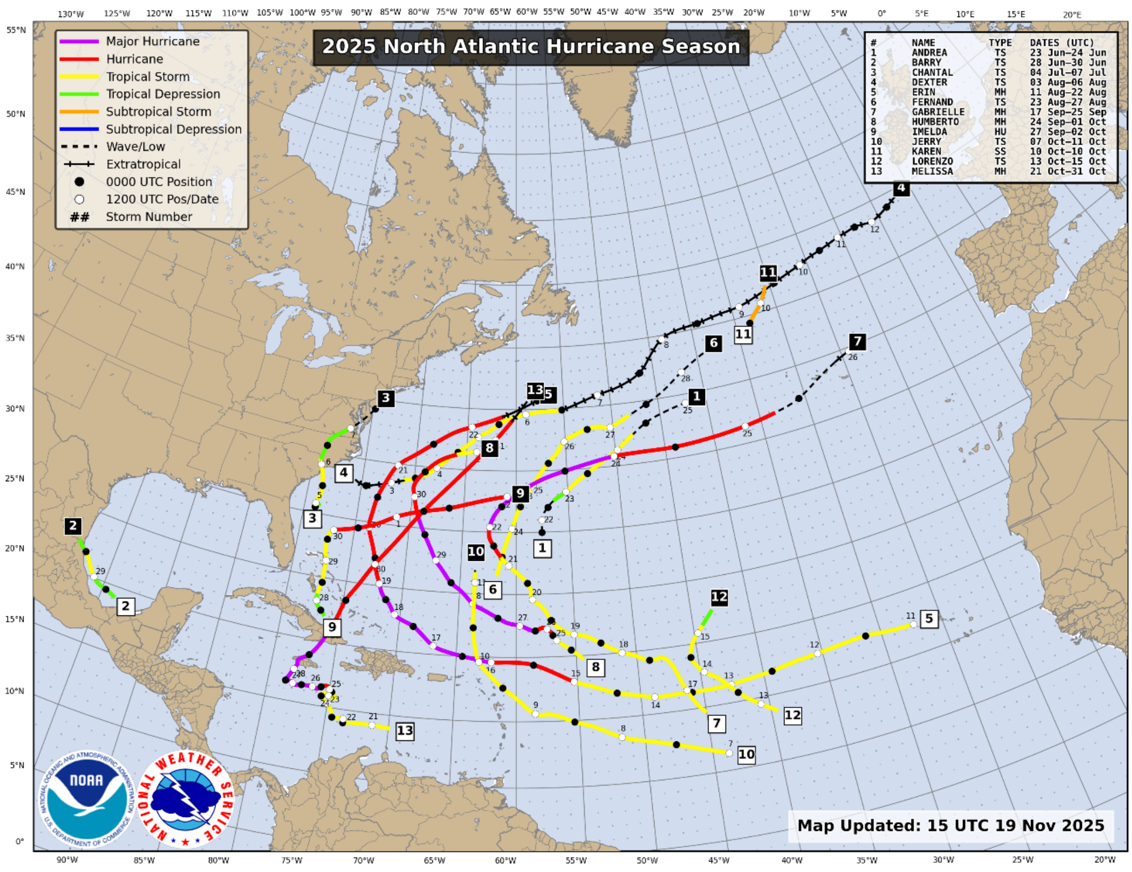
ATLANTIC BASIN SEASONAL HURRICANE FORECASTS FOR 2025

Forecast Parameter and 1991–2020 Average (in parentheses)	Issue Date 3 April 2025	Issue Date 11 June 2025	Issue Date 9 July 2025	Issue Date 6 August 2025	**Observed 2025 Activity Thru 11/19**	% of 1991–2020 Average
Named Storms (NS) (14.4)	17	17	16	16	**13**	90%
Named Storm Days (NSD) (69.4)	85	85	80	80	**59.50**	86%
Hurricanes (H) (7.2)	9	9	8	8	**5**	69%
Hurricane Days (HD) (27.0)	35	35	30	30	**24.75**	92%
Major Hurricanes (MH) (3.2)	4	4	3	3	**4**	125%
Major Hurricane Days (MHD) (7.4)	9	9	8	8	**11.50**	155%
Accumulated Cyclone Energy (ACE) (123)	155	155	140	140	**133**	108%
ACE West of 60°W (73)	93	93	87	87	**100**	137%
Net Tropical Cyclone Activity (NTC) (135%)	165	165	145	145	**141**	104%



2025 Atlantic basin tropical cyclone tracks through 19 November. 13 named storms, 5 hurricanes and 4 major hurricanes occurred. Figure courtesy of National Hurricane Center.

ABSTRACT

This report summarizes tropical cyclone (TC) activity which occurred in the Atlantic basin during 2025 and verifies the authors' seasonal Atlantic basin forecasts. Also verified are six two-week Atlantic basin forecasts issued during the peak months of the hurricane season that were based on a combination of current activity, model forecasts and the phase of the Madden–Julian oscillation (MJO). We also issued an October–November Caribbean hurricane forecast that correctly anticipated a busy late-season for the Caribbean, although Hurricane Melissa generated more Accumulated Cyclone Energy (ACE) in the Caribbean than anticipated by our model.

The first quantitative seasonal forecast for 2025 was issued on 3 April with updates on 11 June, 9 July and 6 August. These seasonal forecasts also contained estimates of the probability of US and Caribbean hurricane landfall during 2025. We also continued to forecast Accumulated Cyclone Energy (ACE) west of 60°W. This metric successfully forecast a higher percentage of overall ACE west of 60°W relative to basinwide ACE, although the percentage was higher than anticipated.

The 2025 hurricane season was officially above normal based on NOAA's ACE definition (126.2–159.6 ACE). Major hurricanes, major hurricane days, ACE and NTC were slightly to somewhat above their long-term averages, while other metrics were slightly to somewhat below their long-term averages. The season had a relatively low number of hurricanes (5), but had three Category 5 hurricanes, trailing only 2005 for the most Category 5 hurricanes in Atlantic season on record.

Our July and August seasonal forecasts verified slightly better than did our April and June forecasts. Overall, we would characterize the seasonal forecast as successful, given our primary forecast metric is ACE. However, the seasonal totals broke down in a highly unusual way for the given ACE (e.g., fewer but powerful hurricanes).

Six consecutive two-week forecasts were issued during August–October – the peak months of the Atlantic hurricane season. These forecasts were based on current hurricane activity, predicted activity by global models and MJO phases. The forecasts predicted whether the upcoming two-week period would be in the above-normal, normal, or below-normal tercile (e.g., top third, middle third or bottom third of the distribution). These forecasts predicted the tercile with the highest probability in 4 out of the 6 outlooks that were issued.

Cool neutral ENSO conditions prevailed for most of the 2025 Atlantic hurricane season, before transitioning to weak La Niña conditions during October. These cool neutral ENSO conditions favored below-normal tropical Atlantic and Caribbean vertical wind shear. Vertical wind shear during August–October of 2025 was somewhat weaker than normal, although not as weak as last year.

Tropical Atlantic sea surface temperatures were above normal throughout the peak of the 2025 hurricane season. These anomalously warm waters helped fuel the above-normal season that occurred.

While the season ended up above-normal, similar to what happened last year, there was a marked peak season lull in activity that occurred between 29 August–16 September when the Atlantic had no named storm activity. This period is typically the peak of the Atlantic hurricane season. The lull was likely due to a combination of factors including a dry and stable tropical Atlantic, pronounced upper-tropospheric trough activity that increased vertical wind shear and sinking motion over Africa that suppressed West African precipitation and easterly wave (e.g., TC seed) amplitude.

The hurricane season was extremely benign for continental US impacts, with only one tropical storm (Chantal) making landfall. However, Hurricane Melissa caused devastation when it made landfall in Jamaica as a Category 5 hurricane. Melissa then made an additional landfall in Cuba as a Category 3 hurricane before tracking through the southeastern Bahamas as a Category 2 hurricane.

DEFINITIONS AND ACRONYMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Acknowledgment

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

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1 Preliminary Discussion

1a. Introduction

The year-to-year variability of Atlantic basin hurricane activity is the largest of any of the globe's tropical cyclone (TC) basins. There has always been and will continue to be much interest in knowing if the coming Atlantic hurricane season is going to be unusually active, very quiet or near average. There was never a way of objectively determining how active the coming Atlantic hurricane season was going to be until the early to mid-1980s when global data sets became more accessible.

Analyzing the available data in the 1980s, we found that the coming Atlantic seasonal hurricane season did indeed have various precursor signals that extended backward in time for up to 6–8 months before the start of the season. These precursor signals involved El Niño-Southern Oscillation (ENSO), Atlantic sea surface temperatures (SSTs) and sea level pressures, West African rainfall, the Quasi-biennial oscillation and several other global parameters. Much effort has since been expended by our project's current and former members (along with other research groups) to try to quantitatively maximize the best combination of hurricane precursor signals to give the highest amount of reliable seasonal hindcast skill. We have experimented with many various combinations of precursor variables and now find that our most reliable statistical forecasts utilize a combination of three or four variables.

A cardinal rule that has always been followed is to issue no forecast for which we do not have substantial hindcast skill extending back in time for at least 30 years. We now use the high resolution ERA5 dataset as the input to our statistical models. These data products are available in near-real time, allowing us to use the same datasets to make predictor estimates that we used to develop the statistical models.

Beginning with the April 2019 forecast, CSU also began issuing statistical-dynamical model forecasts. In 2025, these predictions used the ECMWF climate model (SEAS5), Met Office climate model (GloSea6), Japan Meteorological Agency (JMA) climate model and Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) model to predict large-scale conditions in August–September that are known to significantly impact Atlantic hurricane activity. These statistical-dynamical forecasts have shown skill at predicting Accumulated Cyclone Energy (ACE) based on hindcast data since 1981 for SEAS5 and since 1993 for GloSea6, JMA and CMCC.

The explorative process to skillful prediction should continue to develop as more data becomes available and as more robust relationships are found. There is no one best forecast scheme that can always be confidently applied. We have learned that precursor relationships can change with time and that one must be alert to these changing relationships. For instance, earlier seasonal forecasts relied heavily on the stratospheric Quasi-biennial oscillation and West African rainfall. These precursor signals have not worked as well in recent years. Because of this, other precursor signals have been substituted in their place. As new data and new insights are gathered in the coming years, it is to be expected that our forecast schemes will be revised in future years. Keeping up with the changing global climate system, using new data signals, and exploring new physical relationships is a full-time job. Success can never be measured by the success of a few real-time forecasts but only by long-period hindcast relationships and sustained demonstration of real-time forecast skill over a decade or more.

1b. Seasonal Forecast Theory

We find that one can explain about 50–60% of the variance in year-to-year hurricane activity when combining 3–4 semi-independent atmospheric-oceanic parameters together. The best predictors (out of a group of 3–4) do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain a portion of the variance of seasonal hurricane activity that is not associated with the other variables. It is possible for an important hurricane forecast parameter to show only a marginally significant correlation with the predictand by itself but to have an important influence when included with a set of 2–3 other predictors.

2 Tropical Cyclone Activity for 2025

Figure 1 and Table 1 summarize Atlantic basin TC activity that occurred in 2025. Overall, the season was above normal, per NOAA's definition (126.2–159.6 ACE; Table 2). The National Hurricane Center is currently in the process of writing up reports on all 2025 TCs.

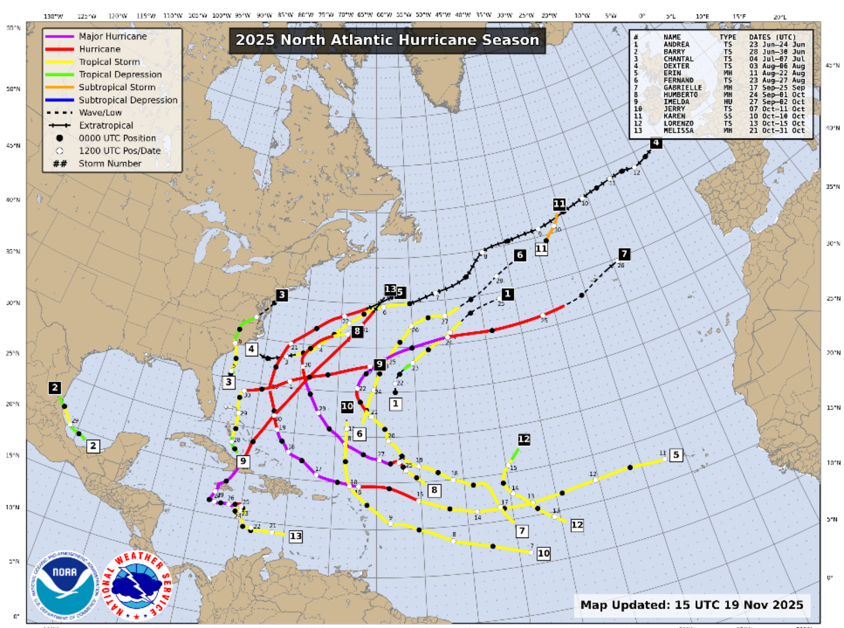

Figure 1: 2025 Atlantic basin TC tracks through 19 November. 13 named storms, 5 hurricanes and 4 major hurricanes occurred. Figure courtesy of National Hurricane Center.

Table 1: Observed 2025 Atlantic basin TC activity through 19 November. Data is calculated from the NHC operational best track and may differ slightly from what was provided in NHC's real-time advisories.

Real-Time North Atlantic Ocean Statistics by Storm for 2025

Year	Storm#	Name	Dates TC Active	Max Wind (kts)	MSLP (mb)	Named Storm Days	Hurricane Days	Major Hurricane Days	Accumulated Cyclone Energy
2025	1	ANDREA	6/24-6/24	35	1014	0.50	0.00	0.00	0.2
2025	2	BARRY	6/29-6/30	40	1006	0.75	0.00	0.00	0.4
2025	3	CHANTAL	7/5-7/6	50	1002	1.25	0.00	0.00	0.8
2025	4	DEXTER	8/4-8/7	45	999	3.50	0.00	0.00	2.2
2025	5	ERIN	8/11-8/22	140	915	11.25	7.25	3.00	32.2
2025	6	FERNAND	8/23-8/28	50	1000	4.50	0.00	0.00	3.1
2025	7	GABRIELLE	9/17-9/25	120	948	8.50	4.00	2.00	19.0
2025	8	HUMBERTO	9/24-10/1	140	924	7.00	5.25	3.25	26.7
2025	9	IMELDA	9/28-10/2	85	966	4.00	2.25	0.00	7.0
2025	10	JERRY	10/7-10/11	55	999	4.25	0.00	0.00	4.0
2025	11	KAREN	10/10-10/10	40	998	1.00	0.00	0.00	0.6
2025	12	LORENZO	10/13-10/15	50	999	2.50	0.00	0.00	1.7
2025	13	MELISSA	10/21-10/31	160	892	10.50	6.00	3.25	34.7

Table 2: NOAA's Atlantic hurricane season definitions.

Forecast Category	ACE
Extremely Active	>159.6
Above-Normal	126.2–159.6
Normal	73.0–126.1
Below-Normal	<73.0

3 Special Characteristics of the 2025 Hurricane Season

The 2025 hurricane season ended up an above-normal season, although with an unusual distribution of storm activity for an above-normal season, as discussed earlier. Several notable records were set over the course of the year, along with other statistics that we think are noteworthy. Most statistics displayed below are from the National Hurricane Center's operational best track.

Below is a selection of some of the notable statistics from the 2025 season:

Seasonal Statistics

- 5 hurricanes formed in the Atlantic. That is the fewest hurricanes to form in a single season since 2015, when 4 hurricanes formed.

- 3 hurricanes reached Category 5 intensity (Erin, Humberto and Melissa). That is the 2nd most on record for the Atlantic, trailing only 2005 which had 4 Category 5 hurricanes. No other season has had more than 2 Category 5 hurricanes.

- 11.5 major hurricane days occurred in the Atlantic. That is the most since 2021 and the 9th most in the active Atlantic era that began in 1995.

- Only 1 named storm (Chantal) and 0 hurricanes made landfall in the continental US this year. The last season with 0 hurricane landfalls in the continental US was 2015.

- 133 ACE were generated during 2025, making the season above-normal by NOAA's definition. 9 out of the past 10 Atlantic hurricane seasons have been either above-normal or extremely active by NOAA's definition, with the only exception being 2022 – classified as a normal season.

Intra-Seasonal Statistics

- No named storms formed in the Atlantic between 24 August–16 September. The last time that this occurred was in 1992. Prior to 1992, the last time we had no named storm formations between 24 August–16 September was in 1939.

- No hurricanes formed in the Atlantic between 16 August–20 September. The last time that this happened was in 1956.

- No ACE occurred in the Atlantic between 29 August–16 September. The last time that this occurred was in 1992.

- The Atlantic had only one hurricane through 21 September. This is the first time since 1994 with only one Atlantic hurricane through 21 September.

- The Atlantic had only six named storm formations through 16 September. The last season with fewer than six named storm formations through 16 September was 2014.

- 0 ACE was generated in the Caribbean through 20 October – the first time that this has occurred since 1997.

- 93 ACE was generated in the Atlantic since 17 September – the 5th most on record from 17 September – onwards in the satellite era (since 1966).

Multi-Storm Statistics

- Four storms (Erin, Gabrielle, Humberto and Melissa) underwent extreme rapid intensification (50+ kt 24 hr^{-1}). 2025 tied 2005, 2008 and 2020 for the most 50+ kt 24 hr^{-1} intensifying storms on record.

Individual Storm/Landfall Statistics

- Hurricane Erin's peak intensification rate was 75+ kt 24 hr^{-1} . That ties Matthew (2016) for the 4th fastest Atlantic 24-hr intensification on record, trailing Wilma (2005; 95 kt 24 hr^{-1}), Felix (2007; 85 kt 24 hr^{-1}) and Milton (2024; 80 kt 24 hr^{-1}).

- Hurricane Erin's lowest pressure was 915 hPa – the lowest for an Atlantic hurricane during August since Dean (2007; 905 hPa)

- Hurricane Humberto's lowest pressure was 924 hPa – the lowest for an Atlantic hurricane during September since Dorian (2019; 910 hPa)

- Hurricane Melissa's lowest pressure was 892 hPa – tied for the 3rd lowest for an Atlantic hurricane on record with the Labor Day Hurricane (1935), trailing Wilma (2005, 882 hPa) and Gilbert (1988, 888 hPa).

- Hurricane Melissa's strongest winds were 160 kt – trailing only Allen (1980; 165 kt) for the strongest winds for an Atlantic hurricane on record. Melissa is tied with several other Atlantic hurricanes at 160 kt peak maximum sustained winds.

- Hurricane Melissa's landfall in Jamaica at 160 kt is tied for the strongest winds for an Atlantic landfall on record. Melissa is tied with the Labor Day Hurricane (1935) in the Florida Keys and Dorian (2019) on Abaco Island in The Bahamas.

- Hurricane Melissa's landfall pressure of 892 hPa is tied with the Labor Day Hurricane (1935) in the Florida Keys for the strongest landfall on record by pressure.

4 Quantitative Verification of 2025 Atlantic Hurricane Forecasts

4.1 Verification of Seasonal Forecasts

Table 3 is a comparison of our forecasts for 2025 for four different lead times along with this year's observations. These predictions generally verified well for ACE, with some metrics over-forecast and others under-forecast, given the unusual distribution of storm intensities given the observed ACE (e.g., fewer hurricanes and more major hurricanes). The April and June forecasts were a bit of an over-forecast for most parameters, with the exception of major hurricanes, major hurricane days and ACE west of 60°W.

Table 3: Verification of our 2025 seasonal hurricane predictions.

Forecast Parameter and 1991–2020 Average (in parentheses)	Issue Date 3 April 2025	Issue Date 11 June 2025	Issue Date 9 July 2025	Issue Date 6 August 2025	Observed 2025 Activity Thru 11/19
Named Storms (NS) (14.4)	17	17	16	16	13
Named Storm Days (NSD) (69.4)	85	85	80	80	59.50
Hurricanes (H) (7.2)	9	9	8	8	5
Hurricane Days (HD) (27.0)	35	35	30	30	24.75
Major Hurricanes (MH) (3.2)	4	4	3	3	4
Major Hurricane Days (MHD) (7.4)	9	9	8	8	11.50
Accumulated Cyclone Energy (ACE) (123)	155	155	140	140	133
ACE West of 60°W (73)	93	93	87	87	100
Net Tropical Cyclone Activity (NTC) (135%)	165	165	145	145	141

Table 4 provides the same forecasts but using the ~70% confidence intervals for each forecast calculated using the methodology outlined in Saunders et al. (2020). More details can be found in the individual seasonal forecasts, but in summary, we fit our cross-validated errors to various statistical distributions to more robustly calculate the uncertainty ranges with our forecasts. Forecast quantities that fell within the 70% confidence interval are highlighted in bold-faced font. About 72% of all forecast parameters fell within the 70% confidence interval in 2025. As noted earlier, this season had fewer hurricanes and more major hurricanes and major hurricane days than would be anticipated given the observed ACE.

Table 4: Verification of CSU's 2025 seasonal hurricane predictions with 70% confidence intervals.

Forecast Parameter and 1991–2020 Average (in parentheses)	Issue Date 4 April 2025	Issue Date 11 June 2025	Issue Date 9 July 2025	Issue Date 6 August 2025	Observed 2025 Activity Thru 11/19
Named Storms (NS) (14.4)	14 – 20	14 – 20	**13 – 19**	**13 – 19**	13
Named Storm Days (NSD) (69.4)	62 – 109	63 – 107	60 – 101	61 – 99	59.50
Hurricanes (H) (7.2)	7 – 12	7 – 11	6 – 10	6 – 10	5
Hurricane Days (HD) (27.0)	**22 – 50**	**23 – 49**	**19 – 43**	**20 – 42**	24.75
Major Hurricanes (MH) (3.2)	**2 – 6**	**2 – 6**	**2 – 4**	**2 – 4**	4
Major Hurricane Days (MHD) (7.4)	**6 – 14**	**6 – 14**	**5 – 12**	**5 – 12**	11.50
Accumulated Cyclone Energy (ACE) (123)	**102 – 215**	**105 – 211**	**95 – 191**	**98 – 187**	133
ACE West of 60°W (73)	**57 – 136**	**59 – 133**	**56 – 124**	**58 – 121**	100
Net Tropical Cyclone Activity (NTC) (135%)	**113 – 222**	**116 – 218**	**101 – 193**	**104 – 190**	141

We successfully predicted a higher percentage of basinwide ACE occurring west of 60°W this season. Cool ENSO neutral and La Niña typically favor more storm formations in the western part of the basin, which was certainly the case in 2025 (Figure 1). In 2025, the percentage of ACE west of 60°W relative to total ACE was quite high (77%). Given how high ACE was in the western half of the basin, it is remarkable that the season had very little in the way of impacts besides Melissa. Our forecast ACE west of 60°W was 60–62% of basinwide ACE depending on the forecast. For our seasonal forecasts, ACE west of 60°W is calculated on an ENSO-weighted percentage of basinwide ACE, with La Niña typically producing higher ACE west of 60°W than El Niño.

4.2 Verification of Two-Week Forecasts

This is the 16th year that we have issued shorter-term forecasts of tropical cyclone activity (TC) starting in early August. These two-week forecasts are based on a combination of observational and modeling tools. The primary tools that are used for this forecast are as follows: 1) current storm activity, 2) National Hurricane Center Tropical Weather Outlooks, 3) forecast output from global models, and 4) the current and projected state of the MJO (Figure 2). Figure 2 displays MJO propagation from 1 August to 31 October. In general, the MJO was relatively weak and disjointed from the latter part of August through September, with occasional westward propagation in the MJO index indicating that other modes of equatorial variability (e.g., equatorial Rossby waves) were more dominant. During October, the MJO did amplify in phase 1 and then propagated eastward through the rest of the month. Phases 1–3 of the MJO tend to be favorable for Atlantic TC activity and may have played a role in enhancing the African easterly wave that served as the seed for Hurricane Melissa.

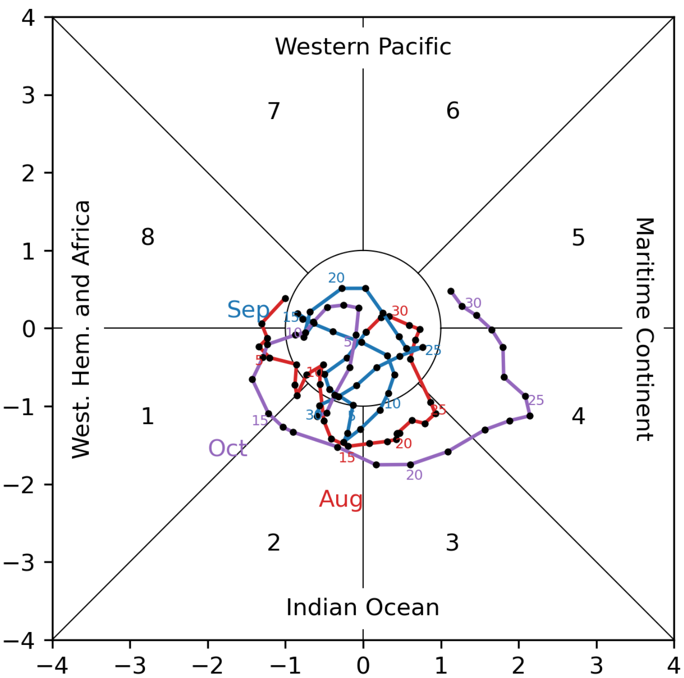

Figure 2: Propagation of the Madden-Julian oscillation (MJO) based on the Wheeler-Hendon classification scheme over the period from 1 August to 31 October. The Maritime Continent refers to Indonesia and the surrounding islands. RMM stands for Real-Time Multivariate MJO. Figure courtesy of Carl Schreck.

The metric that we tried to predict with these two-week forecasts is ACE, which is defined to be the square of a named storm's maximum wind speed (in 10^4 knots^2) for each 6-hour period of its existence over the two-week forecast period. These forecasts are too short in length to show significant skill for individual event parameters such as named storms and hurricanes.

Our forecast definition of above-normal, normal, and below-normal ACE periods are defined by ranking observed activity in the satellite era from 1966–2024 and defining above-normal, normal and below-normal two-week periods based on terciles. Since there are 59 years from 1966–2024, we include the 20 years with the most ACE from October 15–28 as the upper tercile, the 19 years with the least ACE as the bottom tercile, while the remaining 20 years are counted as the middle tercile.

Table 5 displays the six two-week forecasts that were issued during the 2025 hurricane season and shows their verification. We assigned the highest probability to the correct category for four of the six two-week periods and missed the other two forecasts by one category. The forecast which had the worst verification was the period from 3 September to 16 September when we predicted normal activity and had 0 ACE. This period was park of the prolonged lull which dominated during the peak of the TC season and will be discussed in detail later in this report.

Table 5: Two-week Atlantic ACE forecast verification for 2025. Forecasts that verified in the correct category (the category with the highest probability assigned) are highlighted in green, while forecasts that missed by one categories are highlighted in blue. The probability listed in the "Predicted ACE" column in parentheses is the forecast probability for that particular category, while the probability listed in the observed ACE category was the probability assigned for the ACE category that was observed.

Forecast Period	Category with Highest Probability	Observed ACE
8/6 – 8/19	**Above-Normal (>6) (55%)**	**Above-Normal (26) (55%)**
8/20 – 9/2	**Normal (6–22) (85%)**	**Normal (12) (85%)**
9/3 – 9/16	**Normal (9–36) (65%)**	**Below-Normal (0) (15%)**
9/17 – 9/30	**Normal (11-25) (60%)**	**Above-Normal (49) (15%)**
10/1 – 10/14	**Above-Normal (>10) (59%)**	**Above-Normal (12) (59%)**
10/15 – 10/28	**Above-Normal (>7) (50%)**	**Above-Normal (26) (50%)**

4.3 Verification of October–November Caribbean ACE Forecast

In 2011, we published a paper detailing a model that forecast October–November Caribbean hurricane days (Klotzbach 2011) using the state of ENSO and SSTs in the western tropical Atlantic and Caribbean (e.g., the Atlantic Warm Pool). In an article published on the October–November portion of the 2020 Atlantic hurricane season (Klotzbach et al. 2022), we revised the model slightly to use the ENSO Longitude Index (Williams and Patricola 2018) to assess the state of ENSO and now use ACE as our primary forecast metric.

For our predictor model for 2025, the ENSO Longitude Index was slightly negative in July–September, indicating cool neutral ENSO conditions. The Atlantic warm pool was very warm during July–September. These two predictors, in combination, favored an active end to the Atlantic hurricane season in the Caribbean, although not as active as was observed (e.g., one of the strongest hurricanes on record).

We define ACE generated in the region between 10–20°N, 88–60°W as Caribbean ACE. The two-predictor model that comprises the Caribbean ACE forecast called for 12 ACE during October–November, in comparison with the 1991–2020 average October–November Caribbean ACE which is 8. While our model did correctly predict above-average ACE, we did significantly under-predict the observed value of 28 (Table 6). All of the October–November Caribbean ACE was generated by Melissa. Vertical wind shear in the Caribbean during October was below normal (Figure 3), favoring TC activity during this time.

Table 6: CSU's October–November Caribbean ACE forecast vs. observed ACE. The number in parentheses in the first column is the 1991–2020 average ACE.

Forecast Period/Quantity	Forecast ACE	Observed ACE
Oct–Nov Caribbean ACE (8)	12	28

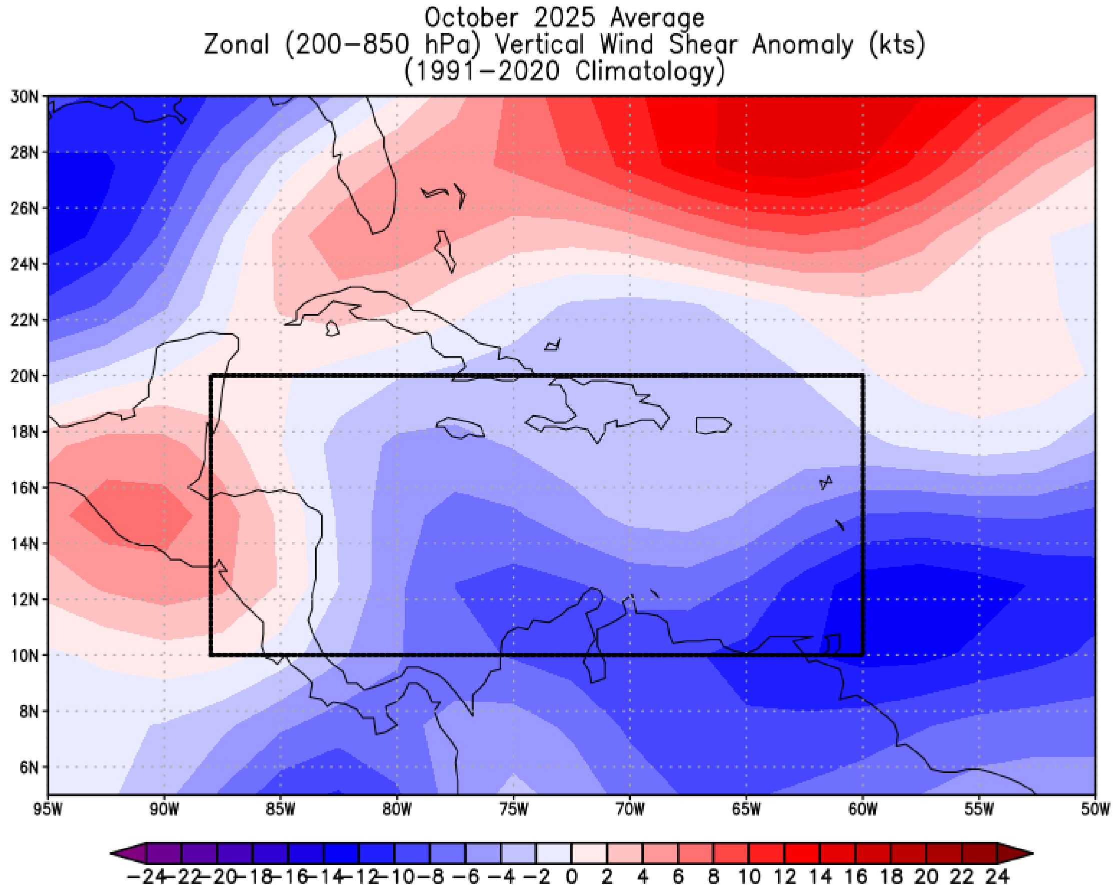

Figure 3: Western Atlantic zonal vertical wind shear anomalies during October 2025. The black rectangle denotes the region that we define as the Caribbean for our October–November ACE calculations.

5 Landfall Analysis

The 2025 Atlantic hurricane season was very quiet for continental US landfalls (Figure 4), with only one tropical storm making landfall (Chantal), resulting in ~$500 million USD in damage according to Gallagher Re's 3rd quarter report. 2025 is the first year with no continental US hurricane landfalls since 2015. The average number of continental US landfalls (excluding multiple landfalls from the same system) from 1900–2020 are 3.2 named storms, 1.6 hurricanes and 0.5 major hurricanes per year.

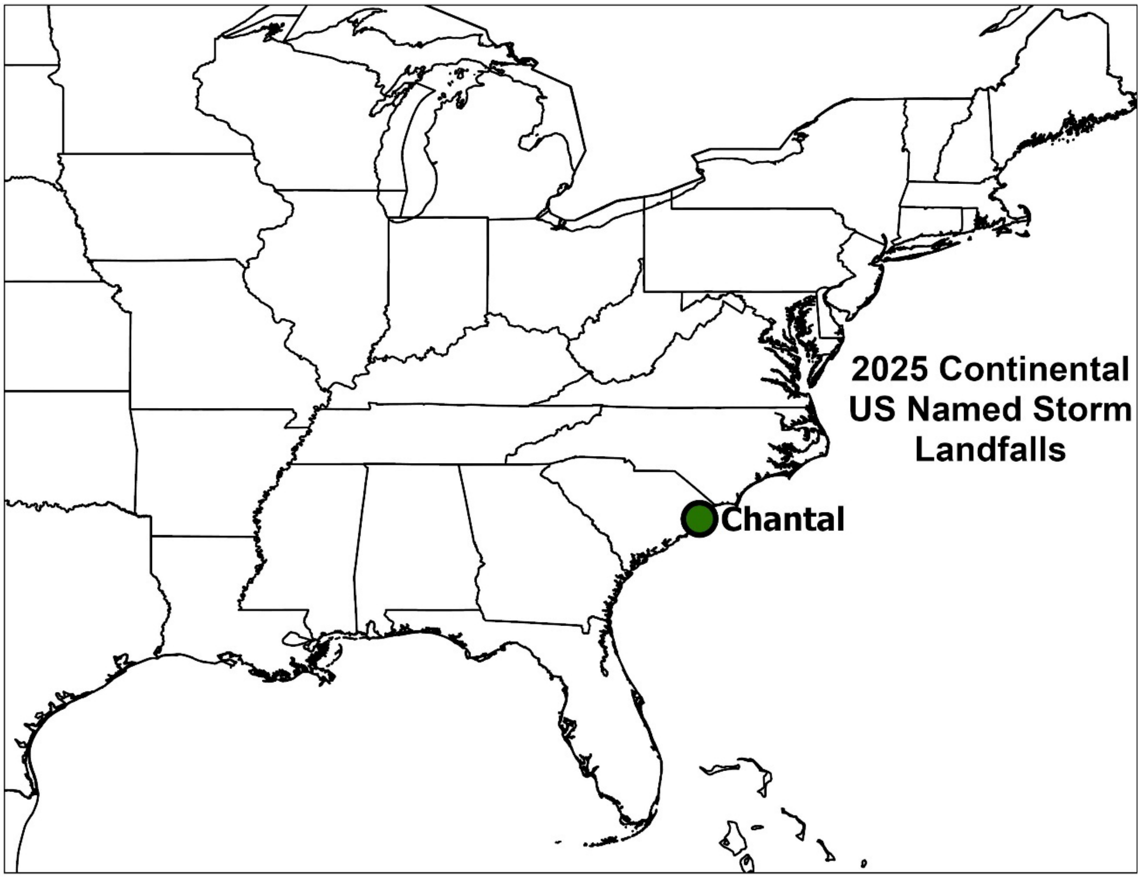

Figure 4: Location of the named storms making landfall in the continental US during the 2025 Atlantic hurricane season.

This year, we continued to calculate the impacts of TCs for each state and county/parish along the Gulf and East Coasts, tropical cyclone-prone provinces of Canada, islands in the Caribbean and countries in Central America. We 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 allowed for TCs that may have made landfall in an immediately adjacent region to be counted for all regions that were near 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. These probabilities were then adjusted based on our forecast of ACE west of 60°W relative to the 1991–2020 climatology.

The 2025 Atlantic hurricane season was predicted to be slightly to somewhat above average depending on lead time, which consequently led us to forecast slightly to somewhat above average continental US hurricane landfall probabilities. As an example, Table 7 displays the landfall probabilities that were issued with the 11 June 2025 outlook. We would have anticipated more continental US landfalling hurricane activity than occurred given both predicted as well as observed ACE west of 60°W.

Table 7: Probability of >=1 named storm, hurricane and major hurricane tracking within 50 miles of each coastal state from Texas to Maine based on our 11 June outlook. Probabilities were provided for both the 1880–2020 climatological average as well as the probability for 2025, based on the 11 June CSU seasonal hurricane forecast of ACE west of 60°W.

		2025 Probability			Climatological	
	Probability >=1	**event within**	**50 miles**	**Probability >=1**	**event within**	**50 miles**
State	Named Storm	Hurricane	Major Hurricane	Named Storm	Hurricane	Major Hurricane
Alabama	67%	34%	10%	58%	28%	8%
Connecticut	27%	9%	2%	22%	8%	1%
Delaware	28%	8%	1%	23%	6%	1%
Florida	92%	65%	35%	86%	56%	29%
Georgia	72%	37%	8%	63%	30%	6%
Louisiana	74%	46%	18%	66%	38%	14%
Maine	26%	9%	2%	21%	7%	1%
Maryland	37%	13%	1%	31%	11%	1%
Massachusetts	40%	18%	4%	33%	14%	3%
Mississippi	62%	35%	9%	53%	28%	8%
New Hampshire	22%	7%	2%	18%	6%	1%
New Jersey	28%	9%	1%	23%	7%	1%
New York	32%	12%	3%	26%	9%	2%
North Carolina	76%	46%	9%	68%	38%	8%
Rhode Island	25%	9%	2%	20%	8%	1%
South Carolina	66%	35%	10%	57%	29%	8%
Texas	70%	44%	19%	61%	36%	16%
Virginia	54%	24%	2%	46%	20%	1%

6 Summary of Hurricane Season Atmospheric/Oceanic Conditions

In this section, we go into more detail discussing large-scale conditions that we believe significantly impacted the full 2025 Atlantic basin hurricane season. In Section 7, we examine in more detail three drivers of the pronounced Atlantic hurricane lull that occurred from 29 August – 16 September and how conditions changed with these three drivers to allow a busy finish to the season.

6.1 ENSO

The 2025 August-October-averaged value of the Oceanic Nino Index was -0.5°C, which puts it at the weak end of the threshold necessary for La Niña. We anticipated either cool neutral ENSO or weak La Niña for the peak of the 2025 Atlantic hurricane season.

The dynamical and statistical models initialized during the late winter/early spring provided decent guidance for ENSO SSTs during the peak of the Atlantic hurricane season. We do note that forecasts issued during the spring of 2025 from ECMWF were generally too warm for ENSO. For example, Figure 5 displays the ECMWF seasonal forecast for Niño 3.4 from 1 April. The observed values were near or below the low end of the ensemble spread at most lead times.

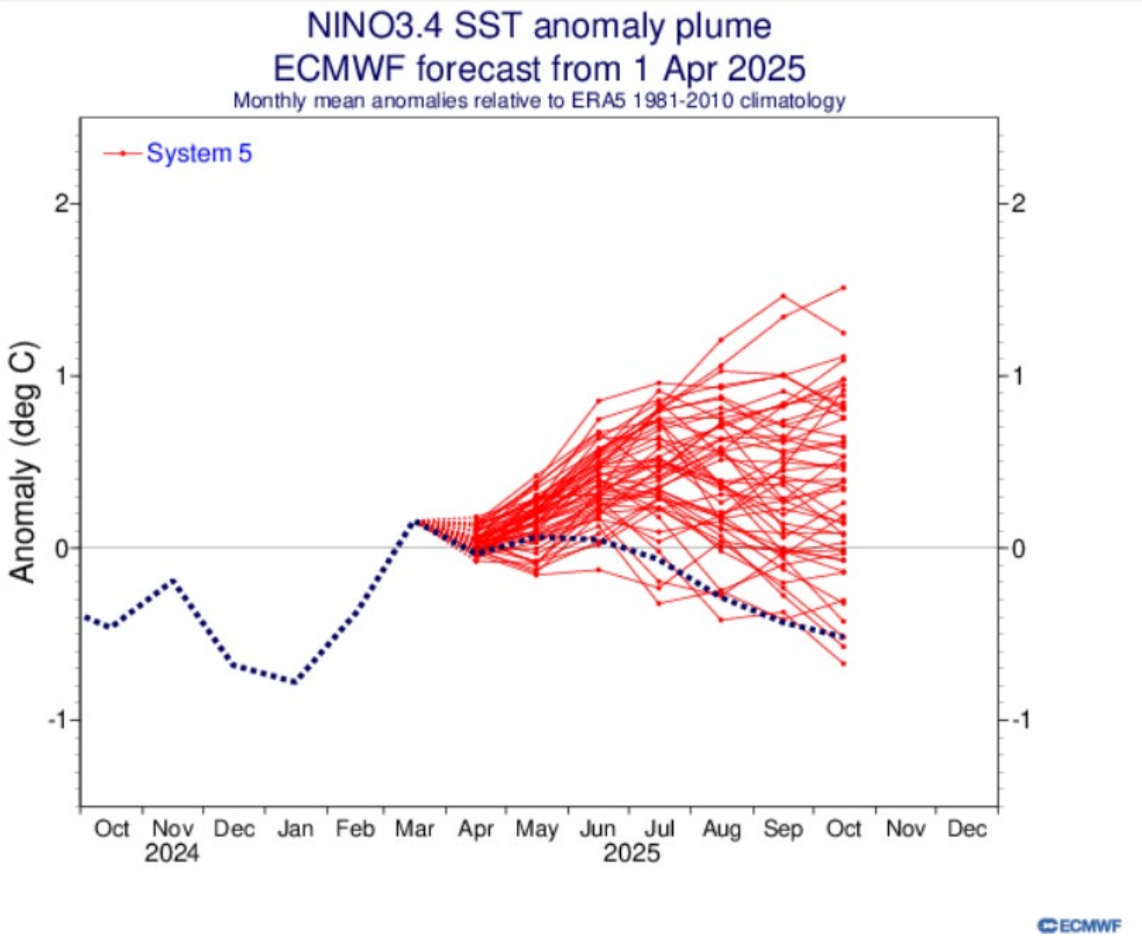

Figure 5: ECMWF ensemble prediction for Niño 3.4 from 1 April 2025. The blue dotted line represents the observed value.

La Niña during last winter weakened during the early part of 2025, transitioning to neutral ENSO conditions for most of the spring/summer. However, over the past couple of months, most ENSO regions have cooled again, and NOAA recently declared that La Niña is back. Table 8 displays anomalies in the various Niño regions in January, April, July and October 2025, respectively.

Table 8: January 2025 anomalies, April 2025 anomalies, July 2025 anomalies, and October 2025 anomalies for the Niño 1+2, Niño 3, Niño 3.4 and Niño 4 regions. SST anomaly differences from January 2025 are in parentheses.

Region	January 2025 Anomaly (ºC)	April 2025 Anomaly (ºC)	July 2025 Anomaly (ºC)	October 2025 Anomaly (ºC)
Niño 1+2	-0.2	+0.6 (+0.8)	+0.5 (+0.7)	0.0 (+0.2)
Niño 3	-0.2	0.0 (+0.2)	0.0 (+0.2)	-0.4 (-0.2)
Niño 3.4	-0.7	-0.2 (+0.5)	-0.1 (+0.6)	-0.5 (+0.2)
Niño 4	-0.6	-0.2 (+0.4)	+0.1 (0.7)	-0.3 (+0.3)

An additional way to visualize changes in ENSO that occurred over the past year is to look at upper-ocean heat content anomalies in the eastern and central tropical Pacific (Figure 6). Upper-ocean heat content anomalies were well below average in December 2024. Those anomalies rapidly increased to slightly above average by late April. They remained at slightly above average levels through the end of June before dropping to below average over the past couple of months. Current upper-ocean heat content anomalies of -0.6°C are consistent with weak La Niña conditions.

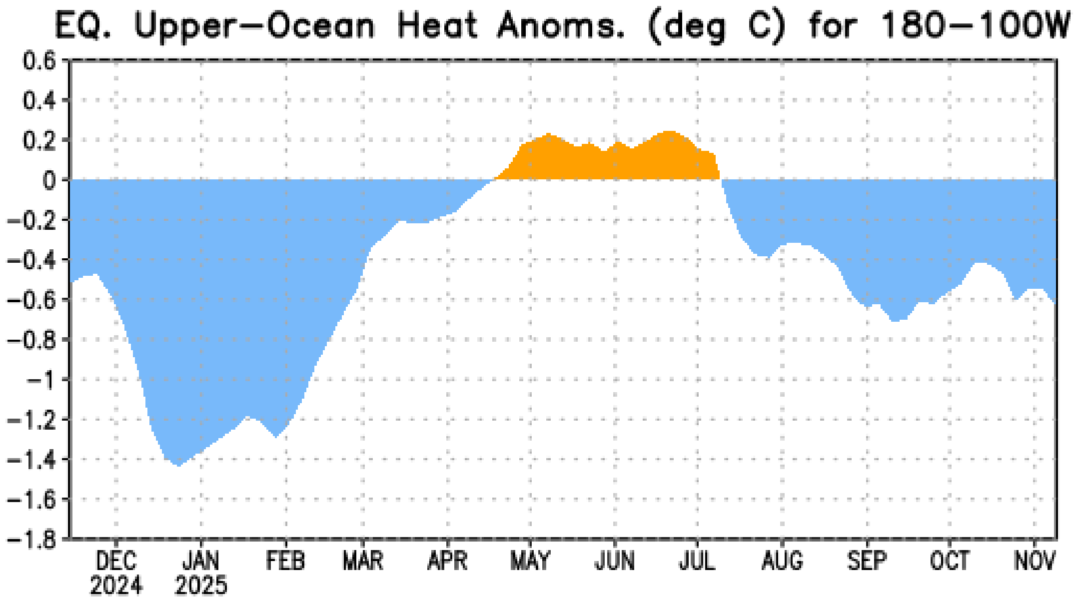

Figure 6: Upper ocean (0–300 meter) heat content anomalies in the eastern and central tropical Pacific from December 2024–November 2025. Figure courtesy of NOAA.

6.2 Intra-Seasonal Variability

The MJO index was generally favorable for Atlantic hurricane activity during the middle of August (e.g., Phases 2–3) when Hurricane Erin formed and reached Category 5 intensity (Figure 2). Phases 8–3 typically favor lower levels of vertical wind shear across the Main Development Region (MDR; 10–20°N, 85–20°W) than do Phases 4–7. However, during the latter part of August through early October, the MJO was quite weak and incoherent, with limited eastward propagation. This lack of coherent MJO activity made for challenging sub-seasonal forecasts (see Section 4.2 for more discussion of CSU's subseasonal forecasts). The mid-October Phase 1–3 pulse of the MJO may have helped invigorate the easterly wave that served as the seed for Hurricane Melissa.

When looking at monthly ACE in 2025 compared with normal (Figure 7), the above-average August fits in well with the broadly favorable MJO that occurred that month. September, as previously noted, had weak MJO activity, so it likely played a limited role in modulating TC activity that month. October had broadly favorable MJO conditions during the early to middle part of the month, favoring an active month.

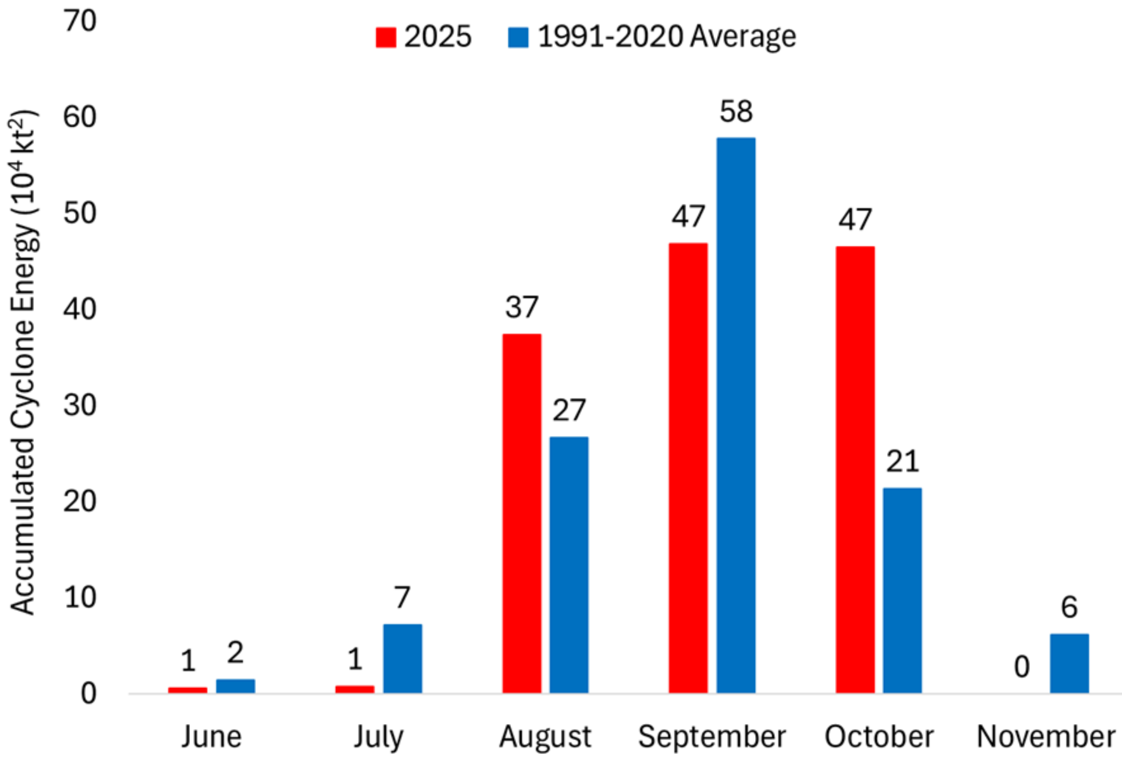

Figure 7: Atlantic Accumulated Cyclone Energy generated by month during 2025 (blue columns) compared with the 1991–2020 average (red columns).

Table 9 displays the number of storms that were first named in each phase of the MJO over the course of the 2025 Atlantic hurricane season. 9 out of the 13 storms that formed in 2025 did so during Phases 8–3, which are typically considered to be more favorable for Atlantic TC activity than Phases 4–7.

Table 9: TC formations by MJO phase during the 2025 Atlantic hurricane season.

MJO Phase	TC Formations
1	4
2	2
3	2
4	3
5	0
6	0
7	1
8	1

6.3 Atlantic SST

The 2025 Atlantic hurricane season had much warmer than normal SSTs across the MDR during August–October. While MDR-averaged SSTs were cooler than they were during August–October of either 2023 or 2024, they were still ~0.6°C above the 1991–2020 average (Figure 8). In general, trade winds were weaker than normal across the Caribbean (Figure 9), resulting in reduced evaporation that led to the extremely warm SSTs that helped fuel Melissa's explosive intensification to a Category 5 hurricane. Farther east in the basin, the trade wind signals were more mixed, likely contributing to the anomalous warmth being concentrated in the western part of the basin.

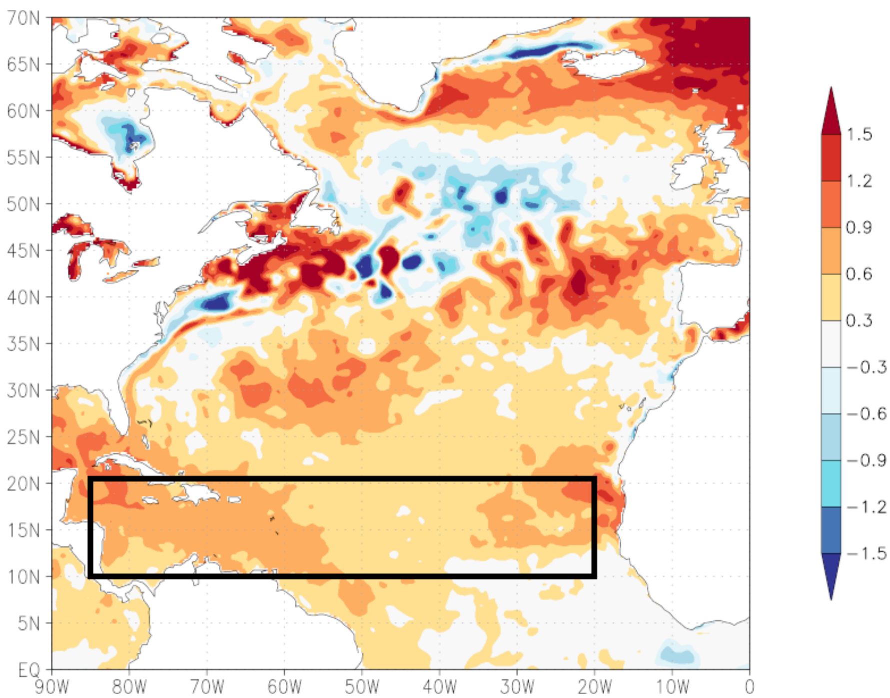

Figure 8: 2025 August–October-averaged SST anomalies. The black rectangle denotes the MDR.

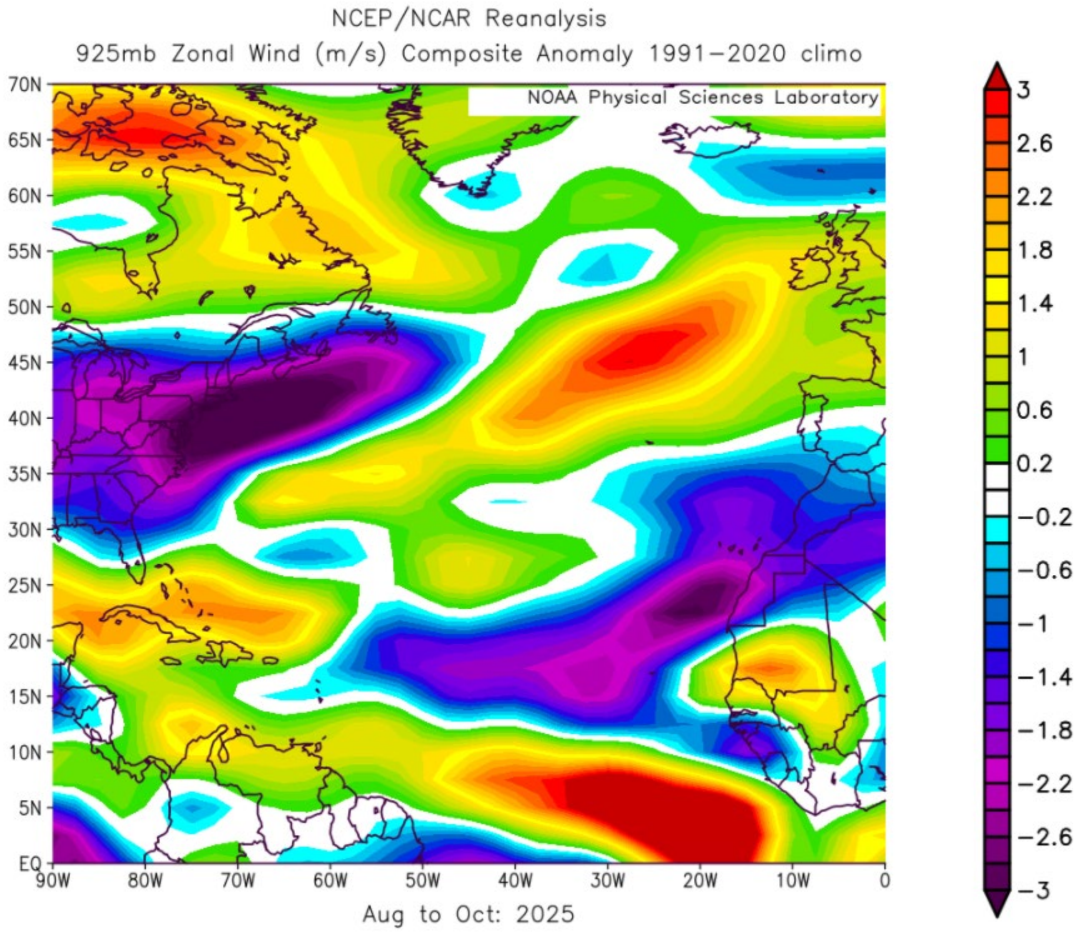

Figure 9: 2025 August–October-averaged 925 hPa zonal wind anomalies.

6.5 Tropical Atlantic Vertical Wind Shear

During August through October, vertical wind shear anomalies were well below average across the MDR (Figures 10, 11), although not as low as they were last year, when they were the lowest on record (since 1950). This reduced shear was correctly anticipated by our seasonal forecasts. During the same three-month period, Atlantic ACE was above the long-term average. Overall, the ACE-shear relationship observed in August–October 2025 fit well with the long-term ACE-shear relationship (Figure 12). Similar to last year, we note that vertical wind shear was quite high in the subtropics (Figure 10). This high shear was likely a driving factor why all hurricanes in 2025 formed from African easterly waves (e.g., no baroclinic hurricane formations at higher latitudes).

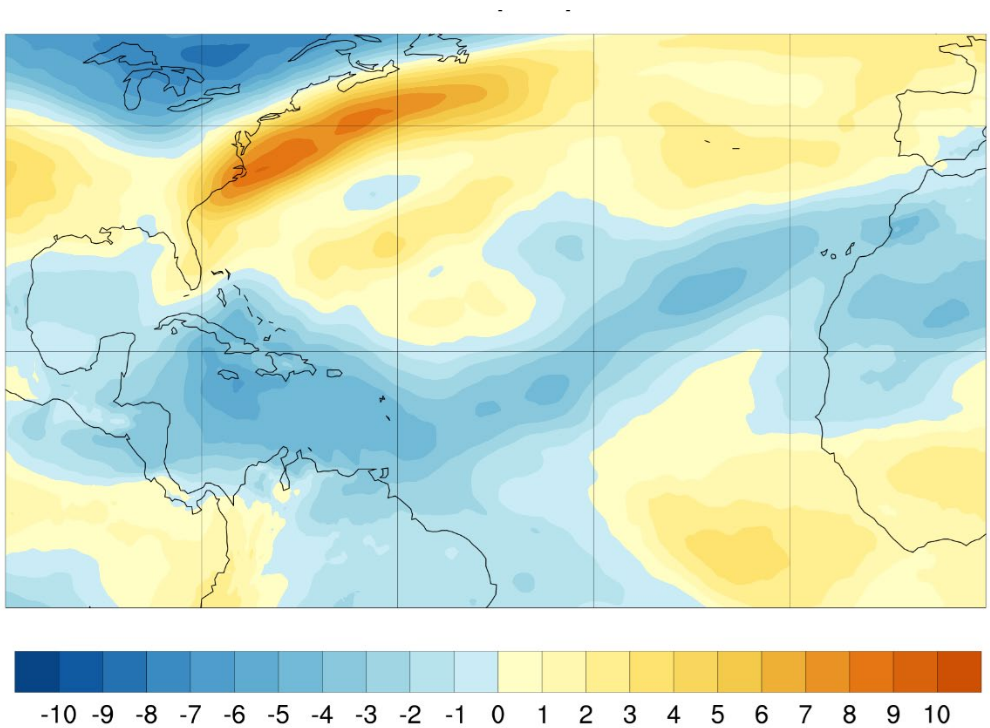

Figure 10: Anomalous North Atlantic vertical wind shear (m s^{-1}) from August–October 2025.

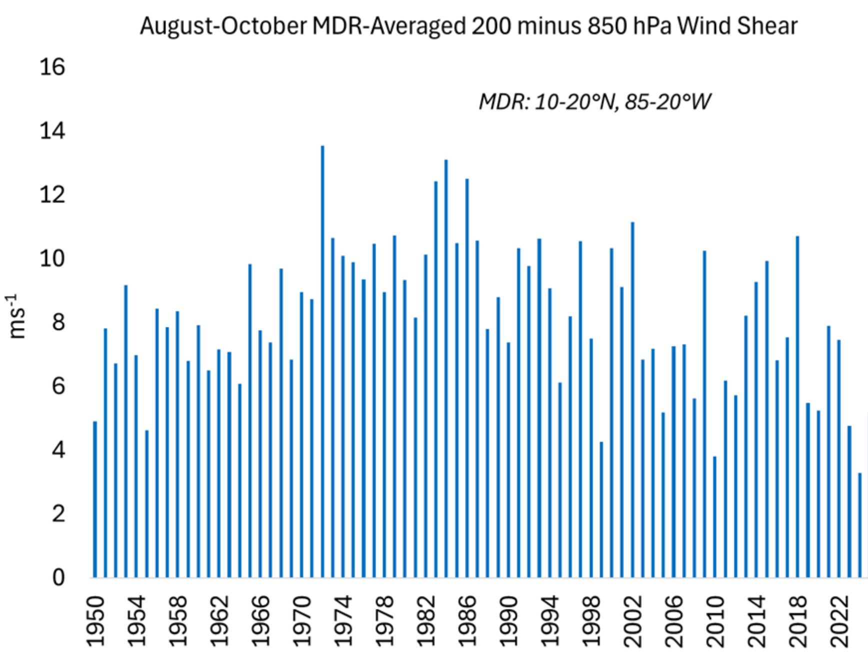

Figure 11: Timeseries of August–October-averaged MDR vertical wind shear from 1950–2025.

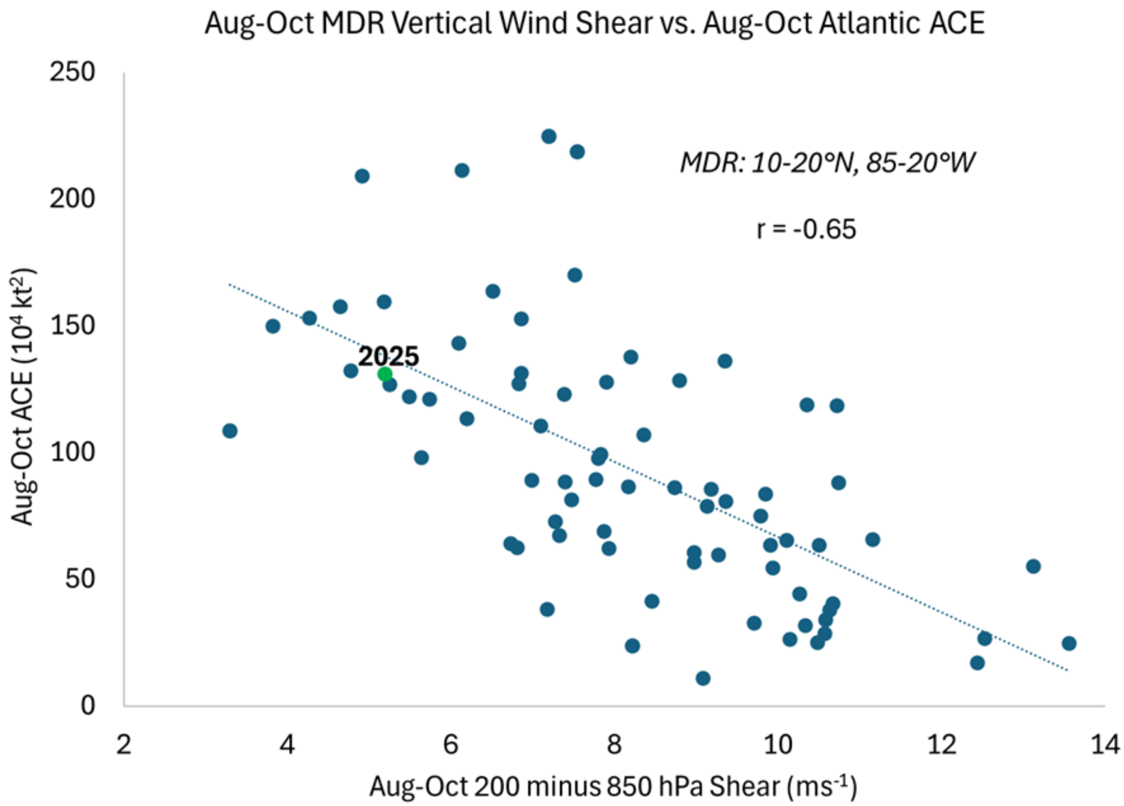

Figure 12: Relationship between August–October-averaged vertical wind shear and August–October-averaged Atlantic ACE. The green dot and label denote 2025.

7 Analysis of Mid-Season Lull and Busy End to the Season

Here we briefly discuss three potential drivers of the mid-season lull that occurred from 29 August to 16 September, as well as the busy end to the 2025 hurricane season. We also wrote a discussion, posted on our website on 9 September, that discussed this mid-season lull in somewhat more detail.

From 29 August to 16 September, the Atlantic generated no ACE – the first time with no Atlantic named storm activity between those two dates since 1992. Similar to last year, this lull was surprising given that large-scale conditions were generally TC favorable (e.g., warm Atlantic and cool neutral ENSO). Here we investigate three primary reasons for the mid-season lull and then discussion how those three drivers changed to support the busy end to the 2025 season.

1) Dry and stable tropical Atlantic

The Atlantic struggled to produce deep convection throughout most of the lull, with vertical instability below normal throughout the season (Figure 13). However, climatologically, vertical instability increases throughout September through most of

October, likely one of the reasons why the Atlantic was able to break out of the lull with several significant hurricanes from mid-September through late October.

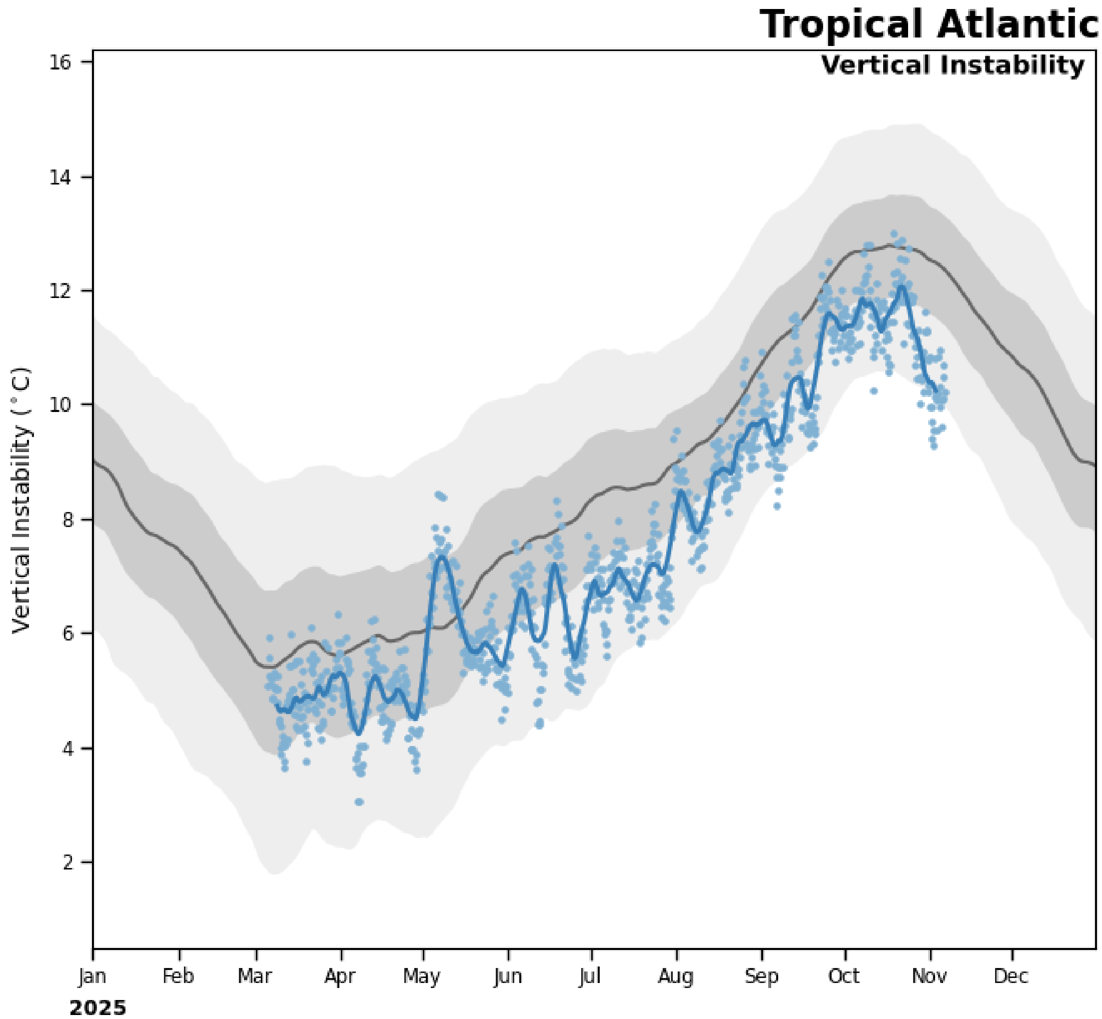

Figure 13: Observed tropical Atlantic vertical instability (blue line) compared with the 1991–2020 average (black line). Figure courtesy of the Cooperative Institute for Research in the Atmosphere.

During the lull, most of the subtropical Atlantic was dominated by high pressure anomalies, resulting in anomalous flow out of the north on the eastern flank of the anomalous high pressure region (Figure 14). These northerly winds brought dry air from the subtropics and mid-latitudes into the tropics, suppressing TC formation chances.

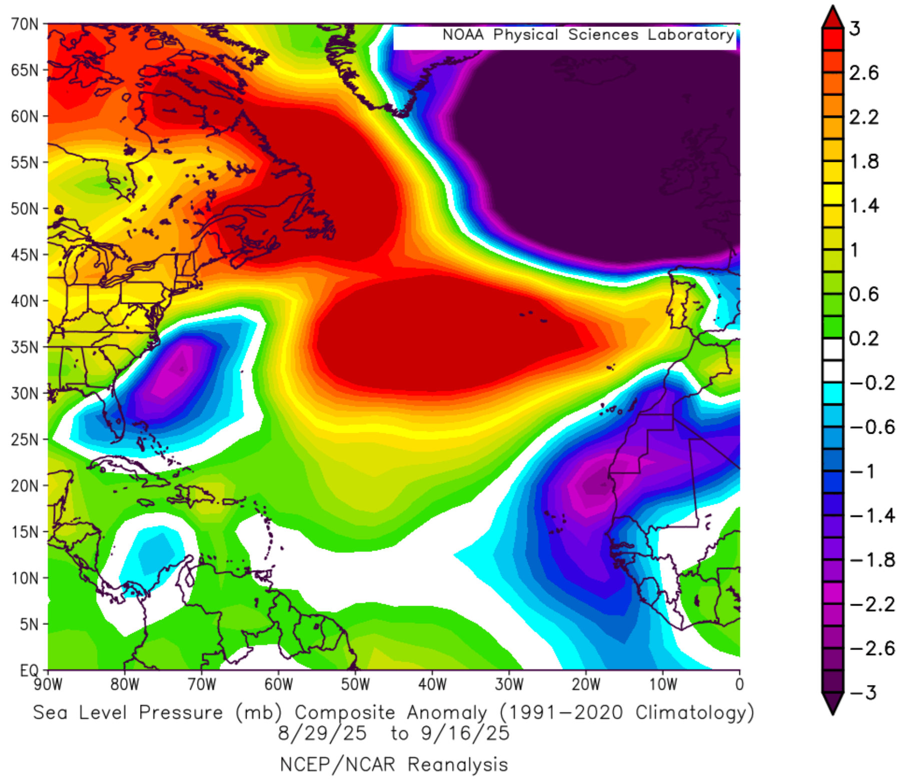

Figure 14: Atlantic sea level pressure anomalies from 29 August to 16 September.

From mid-September through late October, sea level pressure anomalies became more conducive for Atlantic TC activity, with anomalous low pressure in the western Atlantic and high pressure in the central Atlantic combining to generate southerly anomalies in the central Atlantic (Figure 15), enhancing moisture in the region where most of the TCs tracked during the busy end to the season (Figure 1).

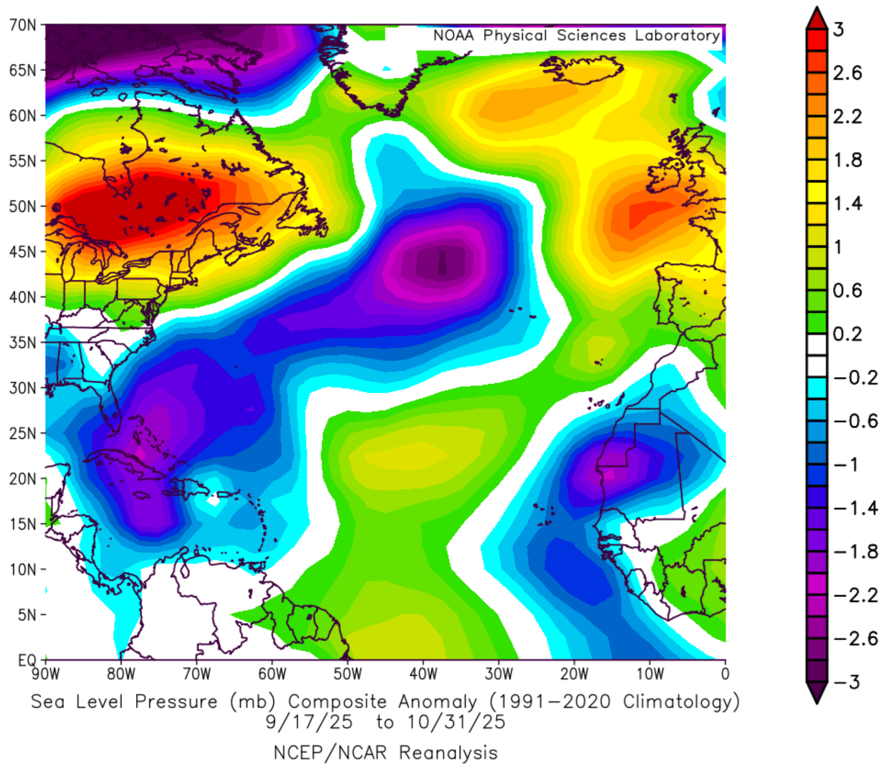

Figure 15: Atlantic sea level pressure anomalies from 17 September to 31 October.

2) Tropical upper-tropospheric trough development

A tropical upper-tropospheric trough (TUTT) developed across the western Atlantic during this season's lull. TUTTs are upper-level cold lows that typically develop near Hispaniola and are commonly associated with two features that are detrimental for TC development: increased vertical wind shear and increased mixing of dry air from the subtropics into the tropics. Figure 16 highlights the TUTT that developed in 2025 by showing lower upper-level heights near Hispaniola relative to surrounding areas.

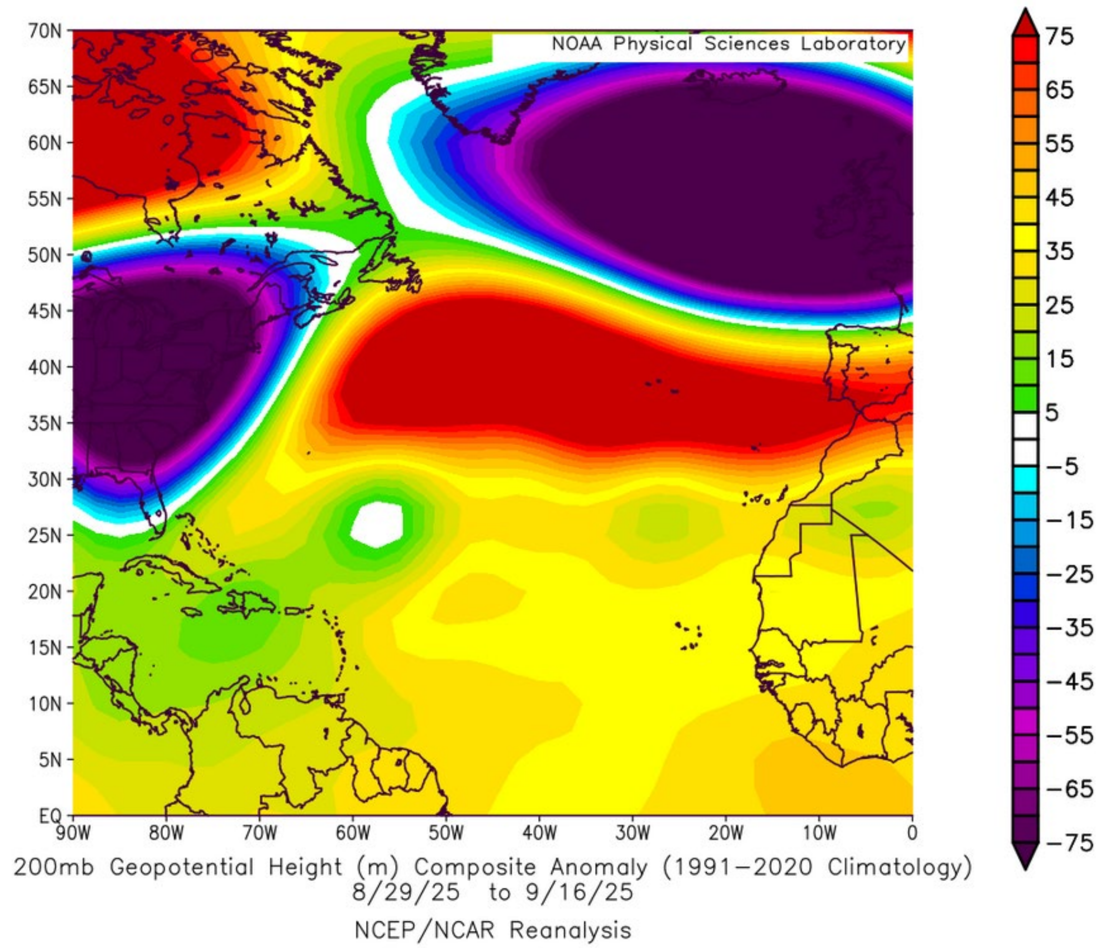

Figure 16: 200 hPa geopotential height anomalies from 29 August–16 September.

As would be expected with the TUTT that developed, vertical wind shear was generally elevated across the MDR during the lull (Figure 17), with especially pronounced shear in the western and central Atlantic.

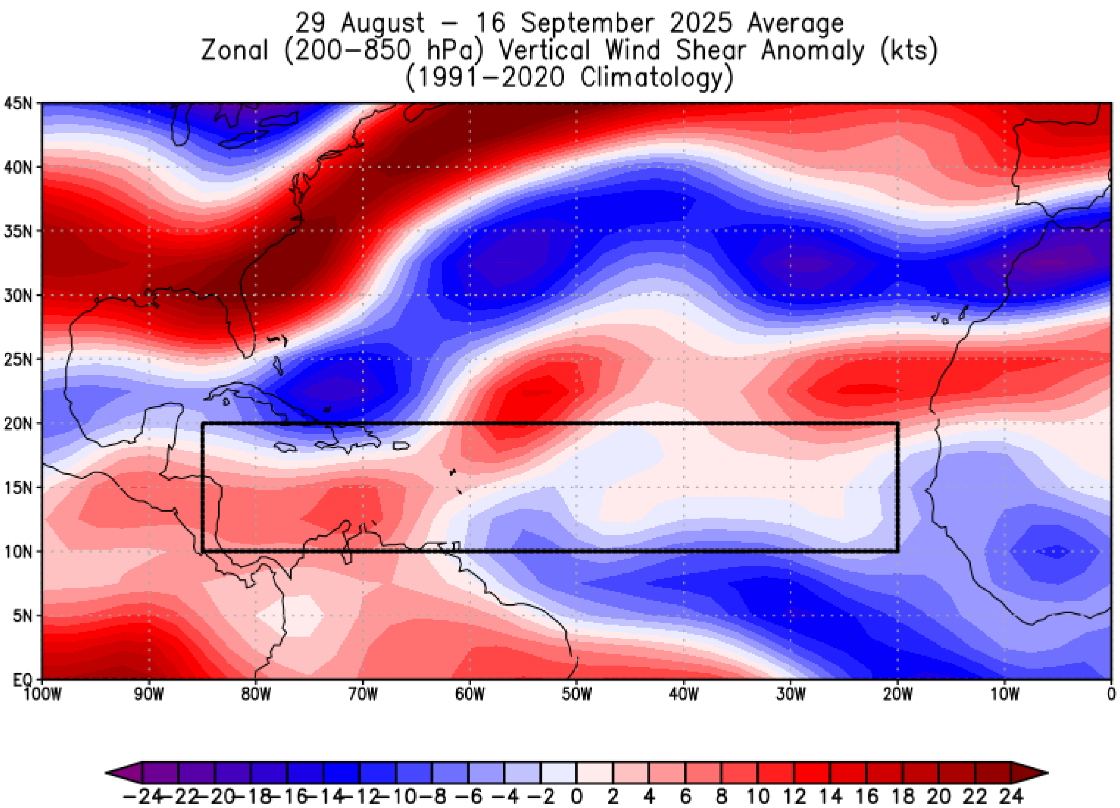

Figure 17: Anomalous North Atlantic vertical wind shear (kt) from 29 August–16 September 2025. The black rectangle denotes the MDR.

As typically occurs with TUTTs, the highly amplified TUTT moved southwest and weakened during the middle of September. From the middle of September through late October, there was little evidence of TUTT activity across the Atlantic, with generally pronounced ridging across the subtropical Atlantic (Figure 18). Vertical wind shear across the MDR became much more conducive for TC activity during this time as well, with well below-average vertical wind shear favoring the busy end to the season that occurred (Figure 19).

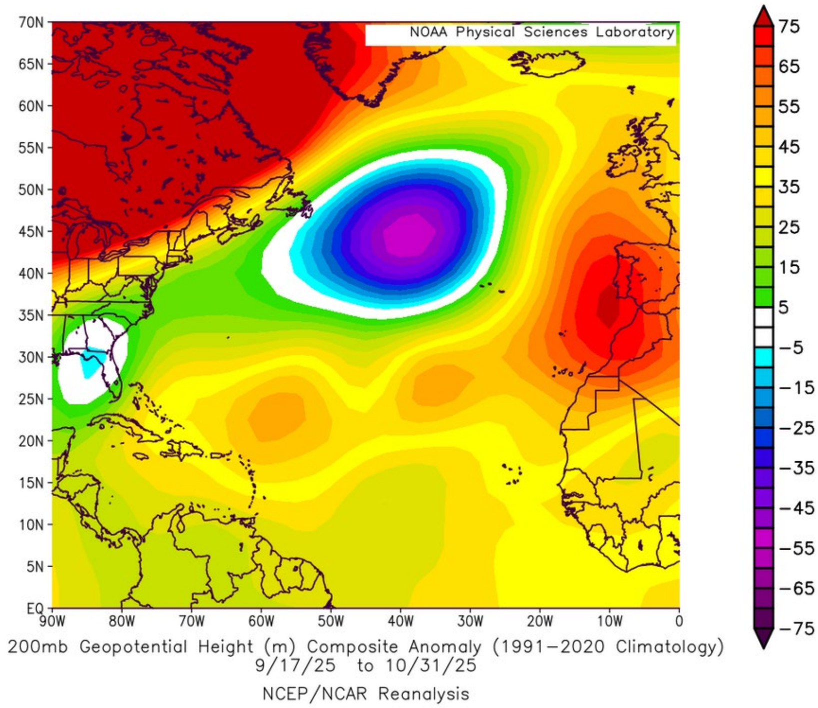

Figure 18: 200 hPa geopotential height anomalies from 17 September–31 October.

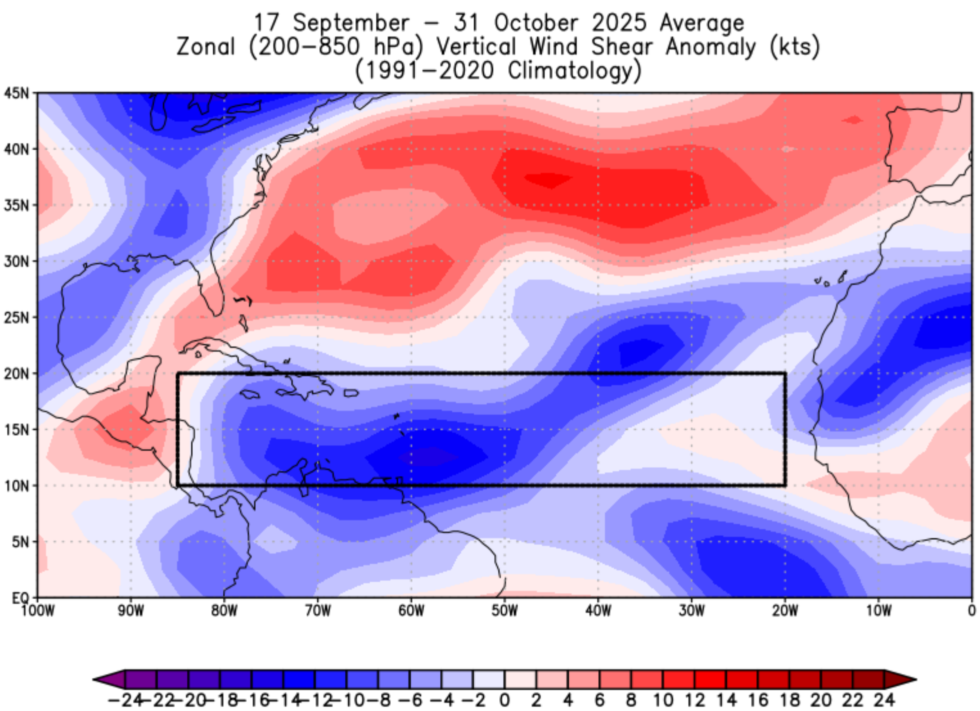

Figure 19: Anomalous North Atlantic vertical wind shear (kt) from 17 September–31 October 2025. The black rectangle denotes the MDR.

3) Anomalous subsidence and dryness over West Africa

During the lull, we generally had pronounced subsidence over West Africa (Figure 20). This subsidence led to reduced precipitation over West Africa (Figure 21), likely due to weaker African easterly waves. The most negative precipitation anomalies were concentrated near Senegal and The Gambia, where African easterly waves often emerge from Africa during the peak of the Atlantic hurricane season. In general, higher amplitude (e.g., stronger) African easterly waves are more likely to form into TCs than are weaker African easterly waves.

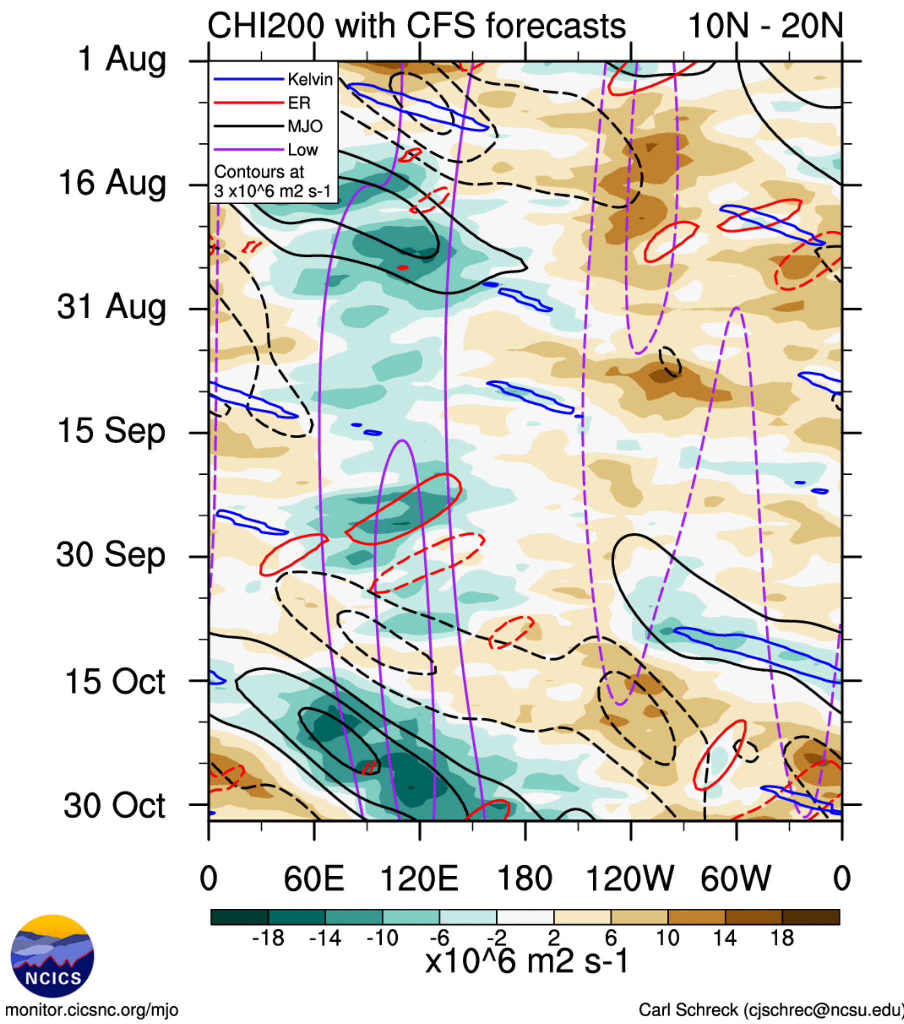

Figure 20: Anomalous 200 hPa velocity potential anomalies averaged from 10–20°N from 1 August–31 October. The various contours highlight different equatorial wave filtering as well as the low-frequency state. Note that there was relatively little MJO activity between late August and early October. Figure courtesy of Carl Schreck.

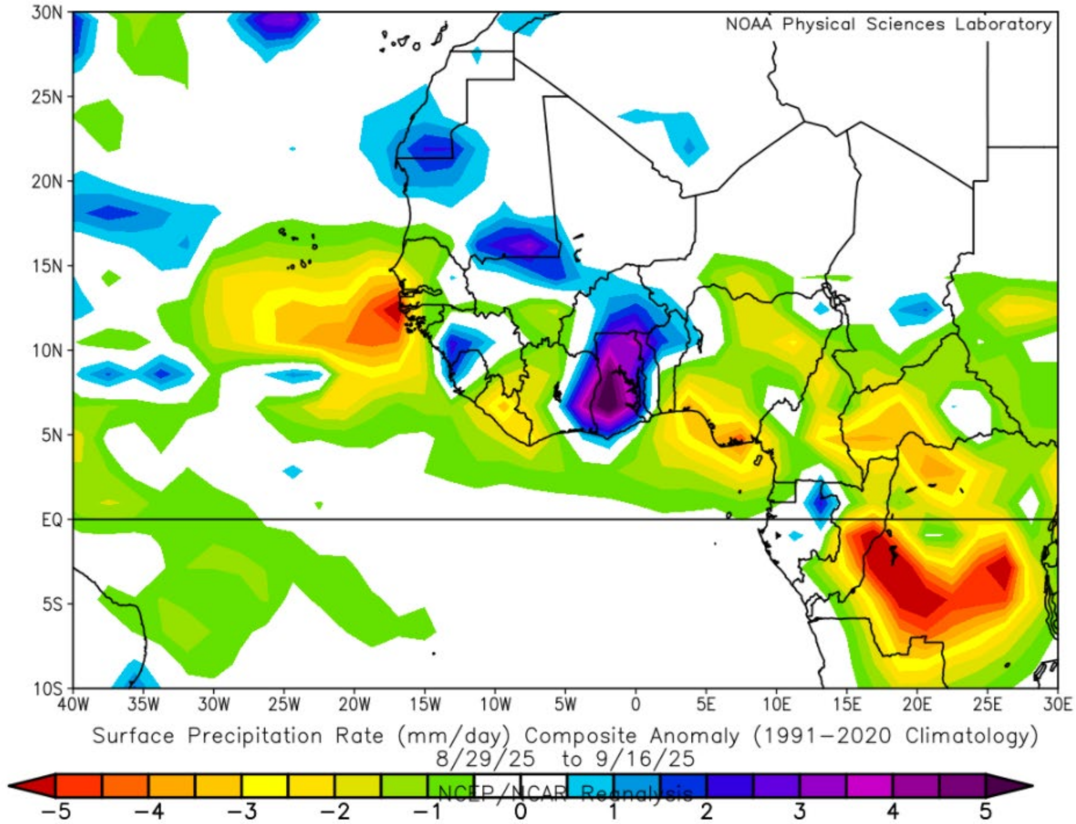

Figure 21: Observed precipitation over the eastern tropical Atlantic and western/central Africa from 29 August–16 September.

As subsidence was reduced later in September through mid-October (Figure 20), precipitation anomalies were enhanced from 5–10°N west of the West African coast (Figure 22), which is more typical latitudes for African easterly waves emerging off of Africa late in the hurricane season.

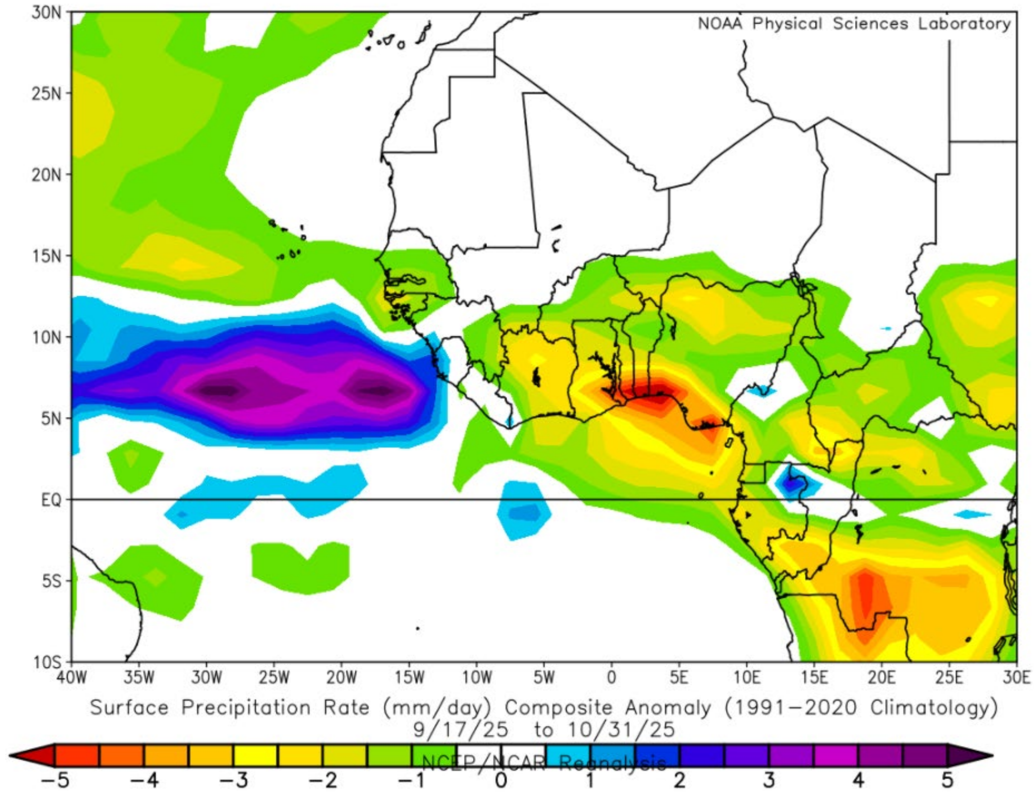

Figure 22: Observed precipitation over the eastern tropical Atlantic and western/central Africa from 17 September–31 October.

8 Forecasts of 2026 Hurricane Activity

We will be issuing our first outlook for the 2026 hurricane season on Thursday, 9 April 2026. This April forecast will include the dates of all our updated 2026 forecasts. All these forecasts will be made available online.

8 Verification of Previous Forecasts

Figure 23 displays the observed versus predicted real-time CSU August hurricane forecasts from 1984–2025. The forecast correlates with observations at 0.67, indicating that CSU's August seasonal hurricane forecast can explain ~45% of the variance in observed Atlantic hurricane counts.

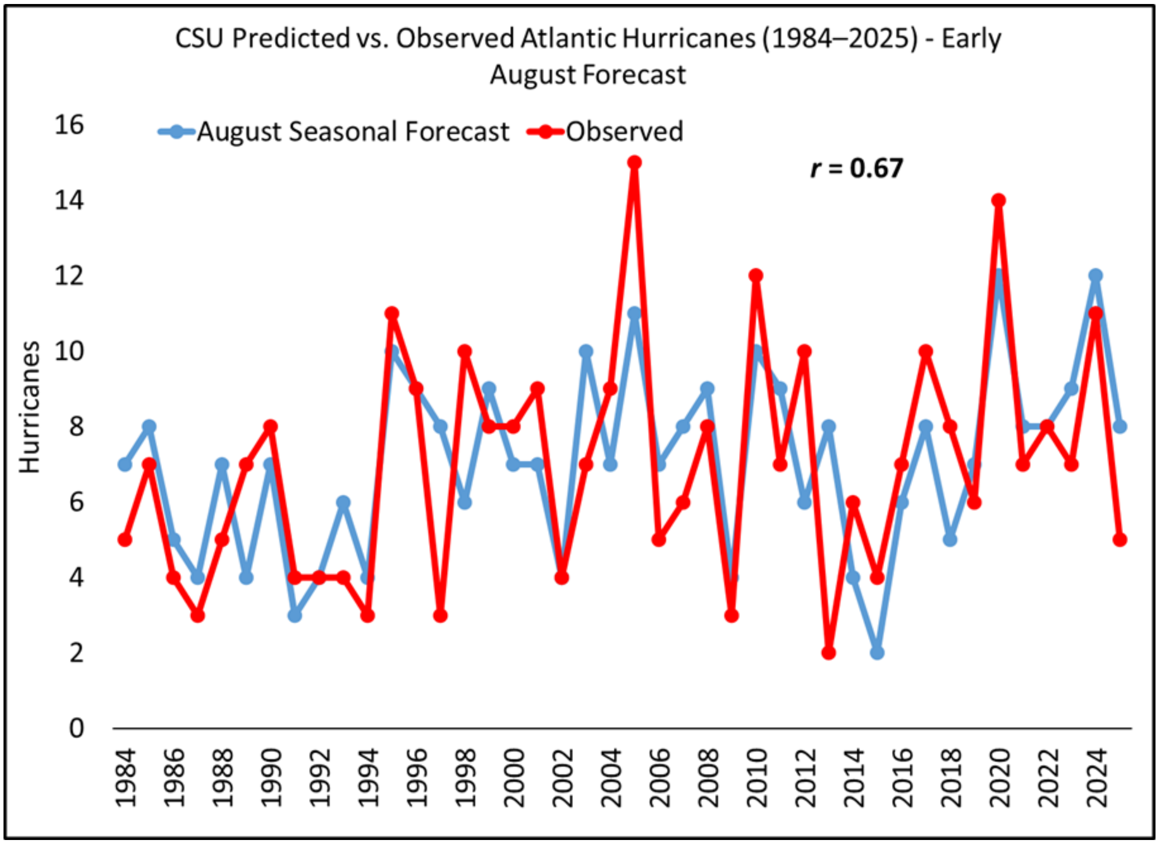

Figure 23: Observed versus predicted Atlantic named storms from 1984–2025.

CSU's seasonal hurricane forecasts have generally shown improvement in recent years, likely due to a combination of improved physical understanding, adoption of statistical/dynamical models and more reliable reanalysis products. Figure 24 displays correlations between observed and predicted Atlantic hurricanes from 1984–2013, from 2014–2025 and from 1984–2025, respectively. Correlation skill has improved at all lead times in recent years for hurricanes, with the most noticeable improvements at longer lead times. While twelve 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.

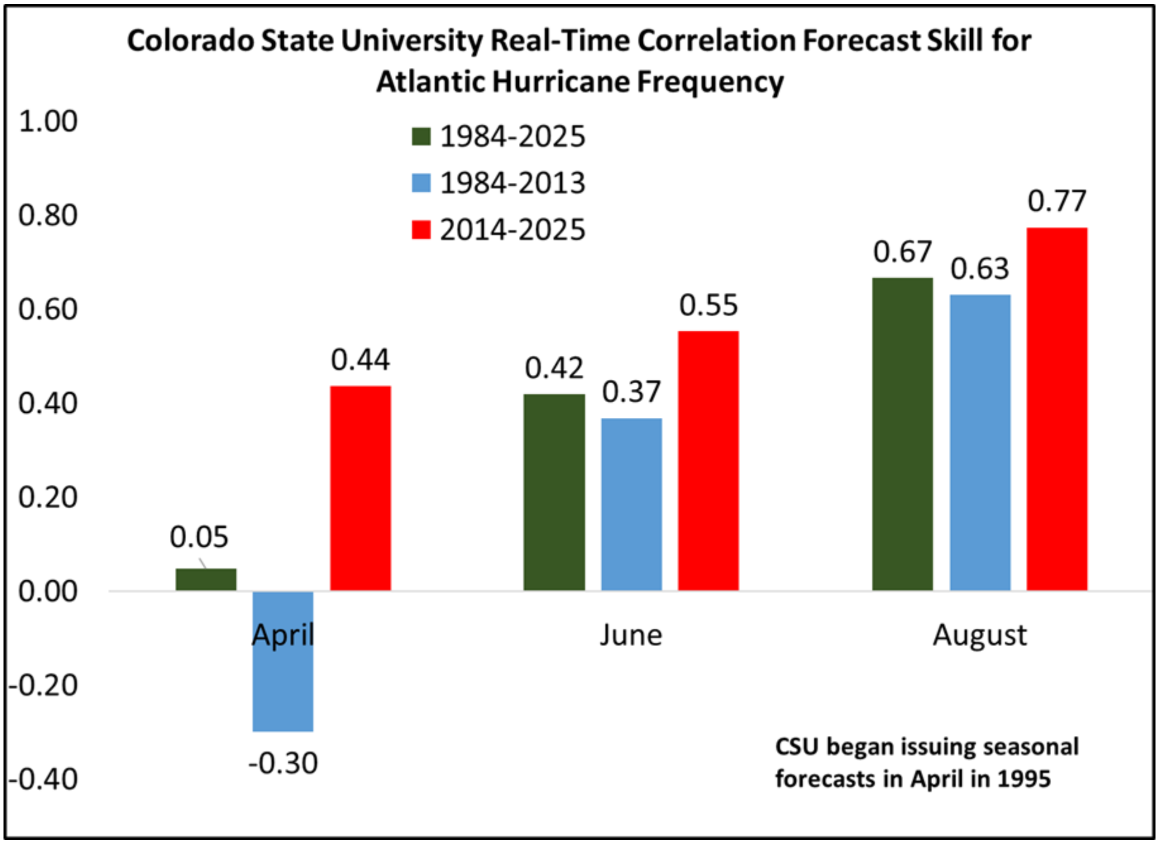

Figure 24: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2025 and 1984–2025, respectively.