DISCUSSION OF 2024 ATLANTIC HURRICANE SEASON TO DATE AND FORECAST THOUGHTS ON THE REST OF THE SEASON

The 2024 Atlantic hurricane season got off to an extremely fast start, with Hurricane Beryl becoming the earliest Category 5 hurricane in the Atlantic on record. Hurricanes Debby and Ernesto followed in early and mid-August, respectively, leading to a well above-average season through the middle part of August. However, since Ernesto dissipated on 20 August, the Atlantic has had no named storm activity. As we near the climatological peak of the Atlantic hurricane season, we discuss the 2024 season in detail, including several possible reasons for the recent dearth in Atlantic hurricane activity. These reasons include: 1) a northward-shifted monsoon trough resulting in African easterly waves emerging at too far north of a latitude, 2) extremely warm upper-level temperatures resulting in stabilization of the atmosphere, 3) too much easterly shear in the eastern Atlantic, and more recently 4) unfavorable subseasonal variability associated with the Madden-Julian oscillation. We believe that it is likely a combination of these factors (and perhaps others) that have led to this recent quiet period. We still do anticipate an above-normal season overall, however, given that large-scale conditions appear to become more favorable around the middle of September. We note that we are not issuing a new seasonal forecast with this discussion.

(as of 3 September 2024)

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With Special Assistance from Carl J. Schreck III[5]
In Memory of William M. Gray[6]

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ATLANTIC BASIN SEASONAL HURRICANE FORECASTS FOR 2024

Forecast Parameter and 1991-2020 Average (in parentheses)	Issue Date 4 April 2024	Issue Date 11 June 2024	Issue Date 9 July 2024	Issue Date 6 August 2024
Named Storms (NS) (14.4)	23	23	25	23
Named Storm Days (NSD) (69.4)	115	115	120	120
Hurricanes (H) (7.2)	11	11	12	12
Hurricane Days (HD) (27.0)	45	45	50	50
Major Hurricanes (MH) (3.2)	5	5	6	6
Major Hurricane Days (MHD) (7.4)	13	13	16	16
Accumulated Cyclone Energy (ACE) (123)	210	210	230	230
ACE West of 60°W (73)	125	125	140	140
Net Tropical Cyclone Activity (NTC) (135%)	220	220	240	240

ATLANTIC BASIN ACTIVITY THROUGH 3 SEPTEMBER 2024

Forecast Parameter and 1991–2020 Average thru Sept. 3 (in parentheses)	Observed	% of 1991–2020 Average
Named Storms (NS) (7.0)	5	71%
Named Storm Days (NSD) (27.4)	24.5	89%
Hurricanes (H) (2.7)	3	111%
Hurricane Days (HD) (8.9)	12	135%
Major Hurricanes (MH) (1.1)	1	91%
Major Hurricane Days (MHD) (2.4)	4.5	188%
Accumulated Cyclone Energy (ACE) (43)	55	128%
ACE West of 60°W (28)	46	164%
Net Tropical Cyclone Activity (NTC) (51%)	56	110%

MOTIVATION FOR DISCUSSION ISSUANCE

There has been considerable discussion amongst meteorologists, the media and the general public about the recent quiet period for Atlantic hurricane activity. We felt it was important to issue a formal discussion describing some of the weather phenomena that have likely been responsible for the recent quiet period and provide a qualitative discussion about the potential for hurricane activity for the rest of the season.

Acknowledgment

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

We thank several current members of Michael Bell's research group who have provided valuable comments and feedback throughout the discussion preparation process. These members include: Tyler Barbero, Delián Cólon Burgos, Jen DeHart, Nick Mesa, Angelie Nieves-Jiménez and Isaac Schluesche. We would also like to thank Michael Lowry and Andrew Hazleton for their keen insights on the vagaries of the 2024 Atlantic hurricane season.

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 additional 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.

As always, we are eternally grateful to Dr. William Gray, the founder of the seasonal hurricane forecast at CSU. His pioneering work on Atlantic hurricane prediction on multiple timescales has underpinned all of our forecasts at CSU for 41 years.

1 Recap of Reasons for Active Hurricane Season Outlook

This is the 41st year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. As shown on page 2, CSU's forecasts for the 2024 hurricane season were extremely aggressive, calling for one of the busiest Atlantic hurricane seasons on record. CSU was not alone in this extremely active hurricane season forecast. Amongst the groups listed on the Seasonal Hurricane Predictions platform, all predicted an above-average season, with the average of all of the seasonal forecasts calling for 11 hurricanes (Figure 1).

Figure 1: Atlantic seasonal hurricane forecasts for the 2024 season as displayed on the Seasonal Hurricane Predictions platform (https://seasonalhurricanepredictions.org/).

Two of the primary reasons for the hyperactive Atlantic hurricane season forecast were the continued extremely warm Atlantic as well as the likely transition to La Niña conditions. Figure 2 displays observed global sea surface temperatures in early August, immediately before the latest batch of seasonal forecasts were released by most groups. The Atlantic's Main Development Region (MDR, 10–20°N, 85–20°W) was the 2nd warmest on record (since 1979) in early August, trailing only 2023. ENSO neutral conditions were present across the tropical Pacific, with indications that the trend away from El Niño towards La Niña were likely to continue. La Niña is typically associated with reduced levels of Atlantic vertical wind shear (Figure 3).

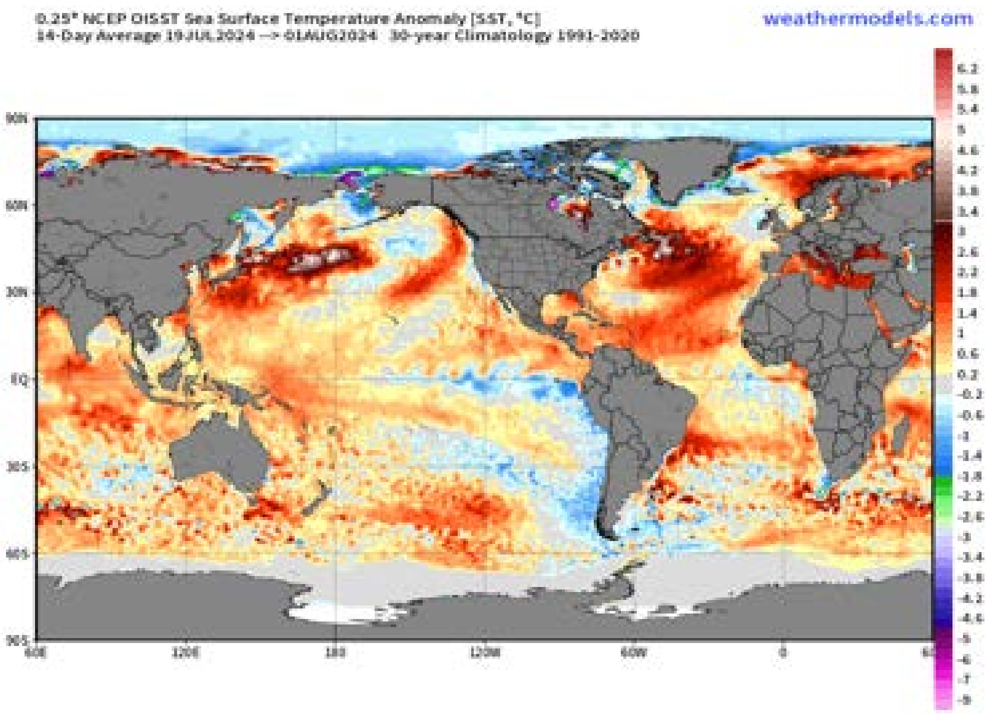

Figure 2: Observed sea surface temperatures averaged from 19 July – 1 August 2024. Figure courtesy of weathermodels.com.

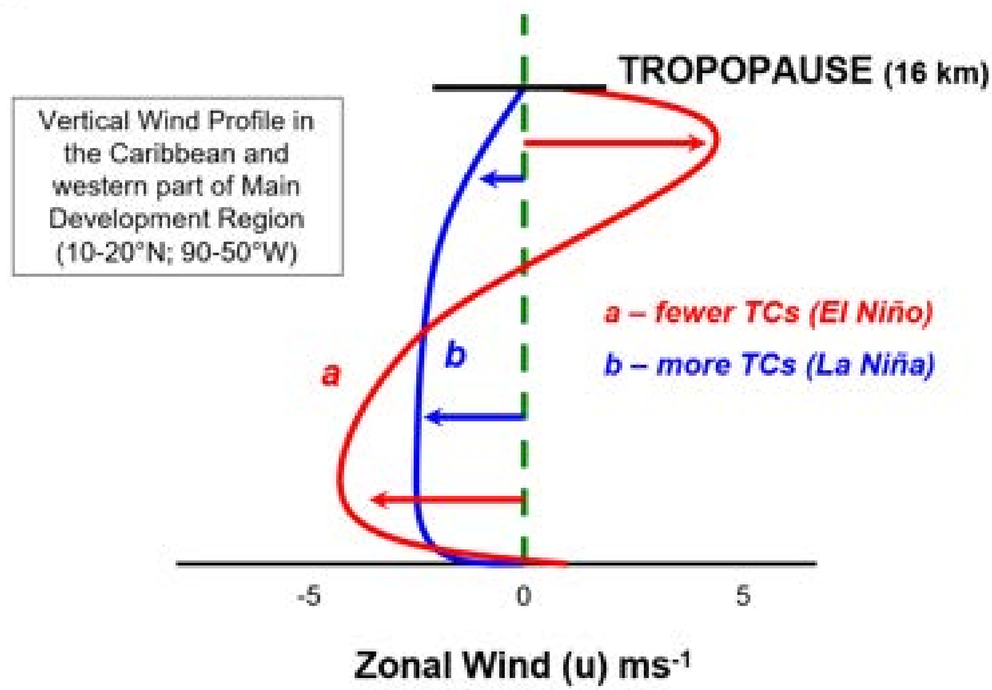

Figure 3: Typical Caribbean/western Atlantic vertical wind shear profile in El Niño vs. La Niña.

In addition to an extremely favorable sea surface temperature configuration, the West African monsoon was very vigorous in July (Figure 4). Rainfall across the Sahel in July was well above average, indicative of a northward-shifted monsoon trough and vigorous easterly waves which have been shown to be favorable for an active Atlantic hurricane season

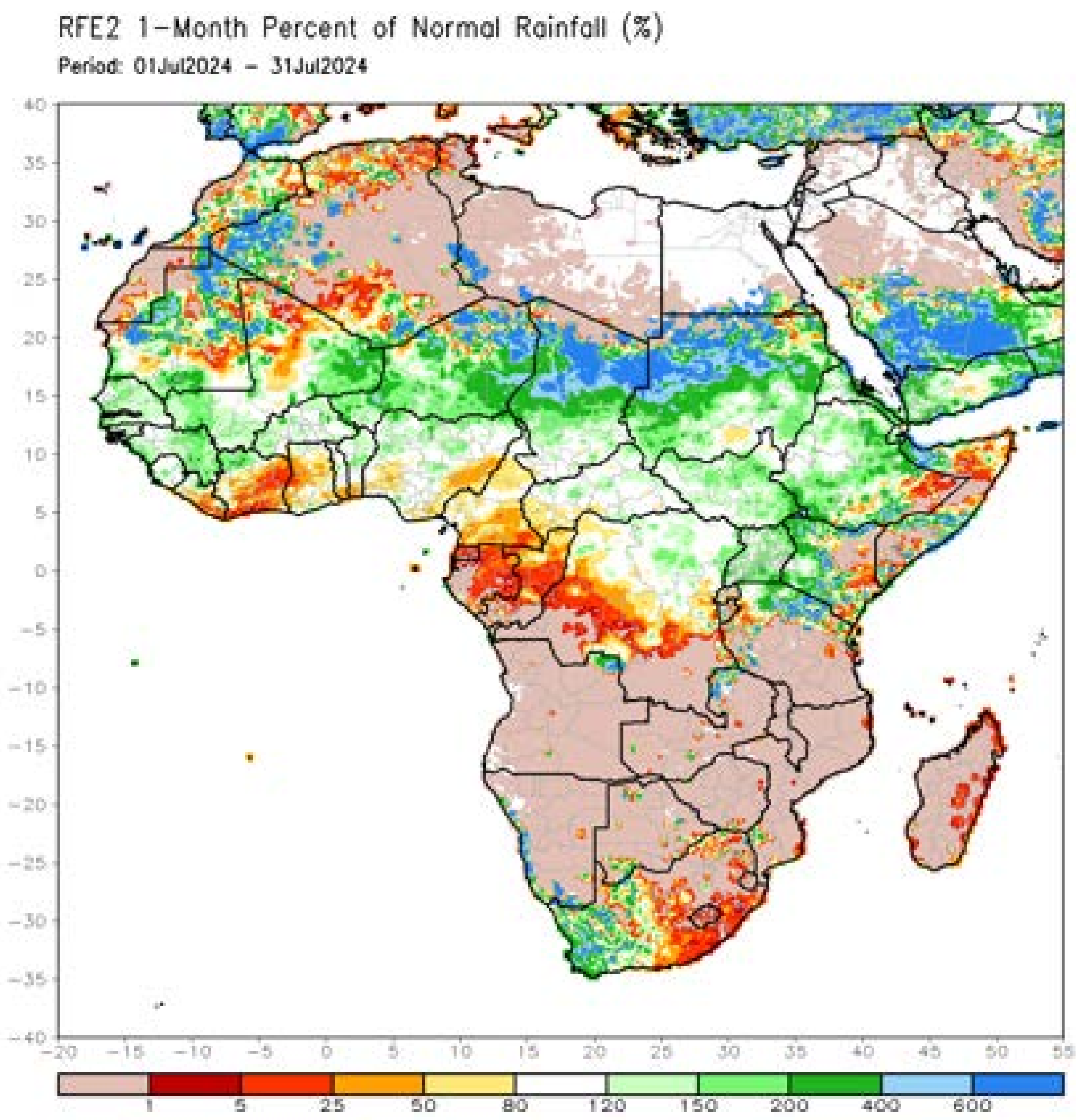

Figure 4: Observed precipitation over Africa in July 2024. Precipitation across the Sahel was well above average. Figure courtesy of Climate Prediction Center.

We generally had weaker than normal zonal winds across the tropical Atlantic in July (Figure 5). These weaker winds are associated with enhanced low-level vorticity across the MDR, helping to favor the spin-up of tropical cyclones.

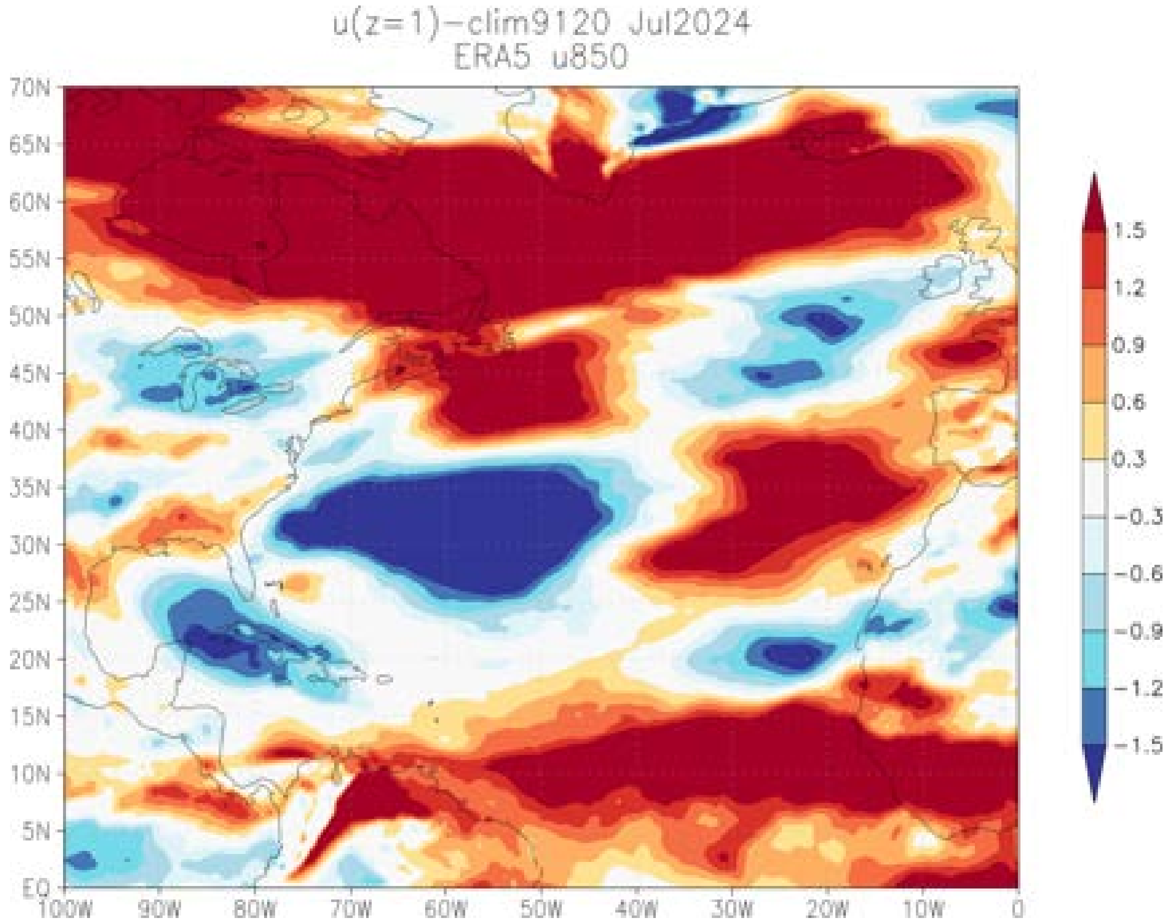

Figure 5: Observed 850 hPa zonal winds in July 2024 across the North Atlantic. Figure courtesy of KNMI Climate Explorer.

We also had Hurricane Beryl in late June-July (Figure 6). In general, early season Atlantic hurricane activity has little correlation with overall Atlantic hurricane activity. However, when this activity occurs in the tropical Atlantic (south of 23.5°N, east of 75°W), it is often a harbinger of a very active season. Hurricane Beryl was an extremely impressive hurricane, generating the most ACE of any individual hurricane activity prior to 1 August on record. All seasons since 1900 with a hurricane in the tropical Atlantic prior to 1 August were classified as above-normal seasons using NOAA's ACE definition (>126.1 ACE): 1916, 1926, 1933, 1961, 1996, 2005, 2008, 2018, 2020 and 2021. The average of these seasons produced 10 hurricanes and an ACE of 184. Several of these years were prior to the satellite era (before 1966), and it is consequently likely that hurricanes and ACE were underestimated.

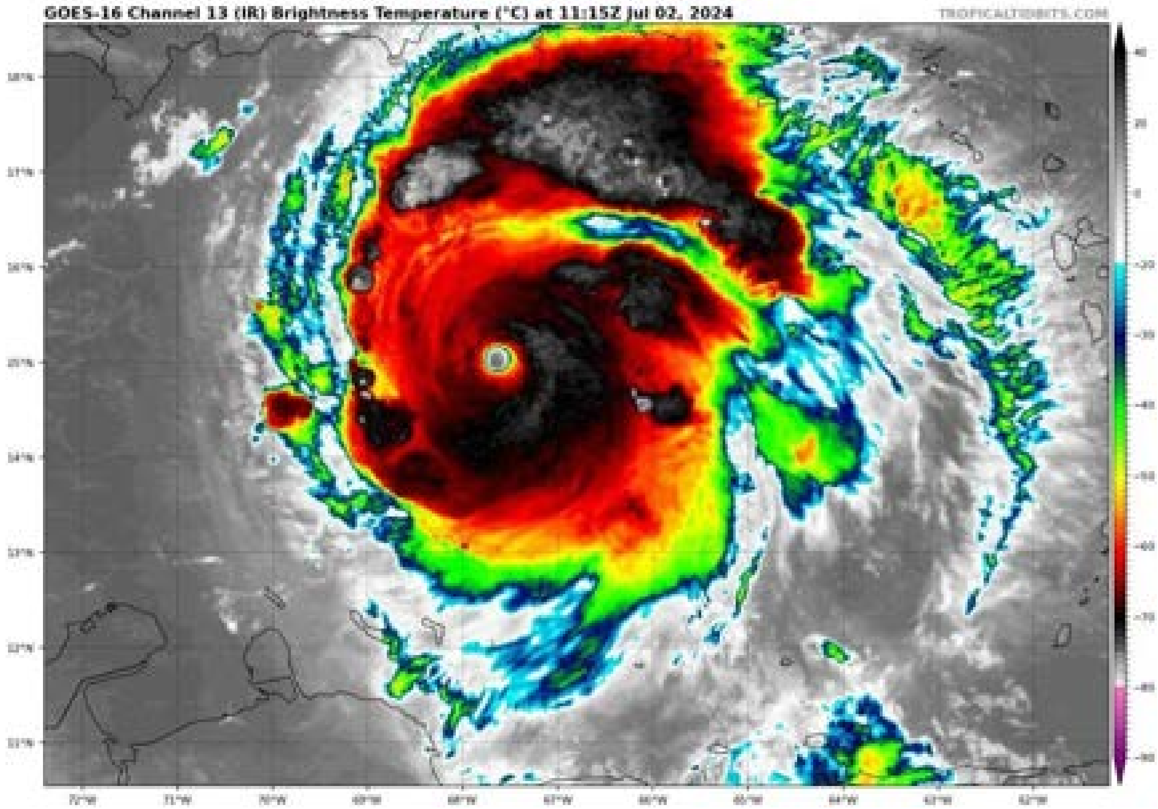

Figure 6: Infrared satellite image of Hurricane Beryl as a Category 5 hurricane on 2 July 2024. Figure courtesy of Tropical Tidbits.

2 Recent Quiet Period for Atlantic Hurricane Activity

Following Hurricane Beryl, the Atlantic hurricane season remained quite active, with two additional hurricanes (Debby and Ernesto) forming by 14 August. Only four other hurricane seasons in the satellite era (1966–onwards) had three hurricanes by 14 August: 1966, 1968, 1995 and 2005.

However, since that time, the Atlantic hurricane season has gotten extremely quiet. The Atlantic has produced no named storm formations since Ernesto on 12 August. Only one other time in the satellite era has the Atlantic not produced any named storms between 13 August and 3 September. That other year was 1968. This pronounced quite period is especially remarkable given that it coincides with the time of year where the Atlantic climatologically gets very busy (Figure 7).

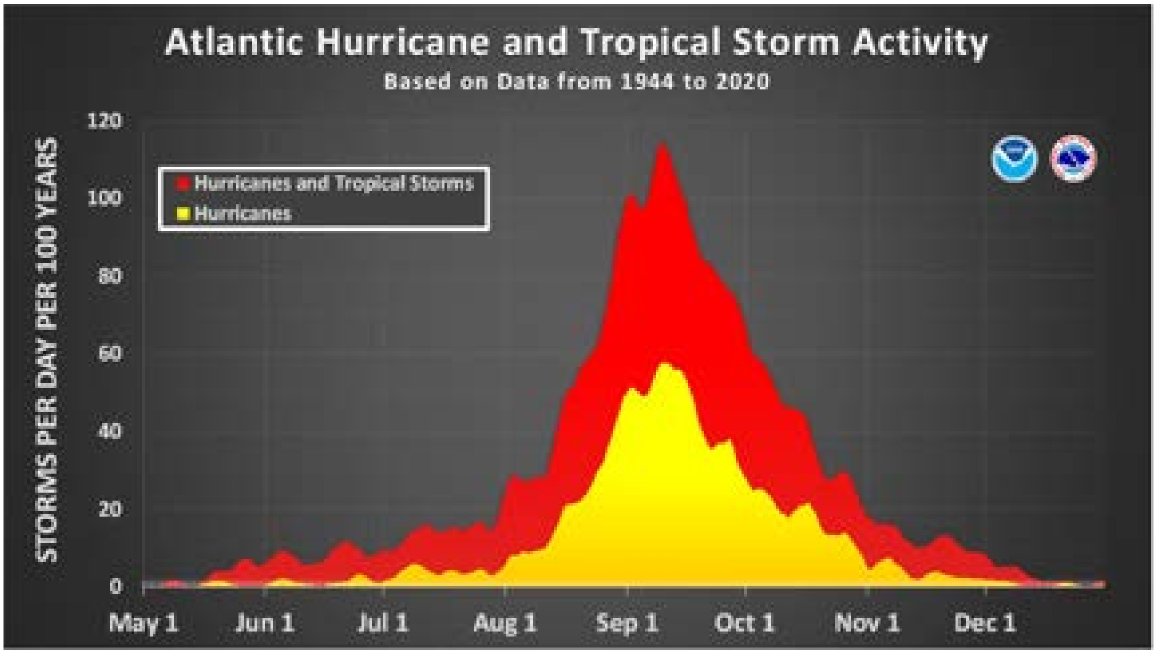

Figure 7: Atlantic tropical cyclone climatology. Figure courtesy of NOAA.

So the big question is why the season has gotten so quiet? We do not think that there is one straightforward reason but several factors in combination that likely conspired to quiet the season.

1) Northward-shifted monsoon trough

While normally a vigorous and northward-shifted monsoon trough favors an active Atlantic hurricane season, the current sea surface temperature configuration of an extremely warm Main Development Region combined with relatively cool sea surface temperatures near the equator may have helped push the monsoon trough too far north (Figure 8). If we look at low-level zonal wind anomalies during August, anomalous low-level westerly winds extend north to ~20°N, favoring the northward shift in the monsoon trough (Figure 9). While as noted earlier, a northward-shifted monsoon trough is typically favorable for an active Atlantic hurricane season, the monsoon trough has shifted so far north in 2024 that easterly waves are emerging over the cold waters of the northeast Atlantic west of Mauritania. This far northerly track also brings down dry air from the subtropics, helping to squelch deep convection in the tropics (Figure 10). The Climate Prediction Center's Africa desk has also noted a pronounced northward shift in the Intertropical Front in recent weeks (Figure 11).

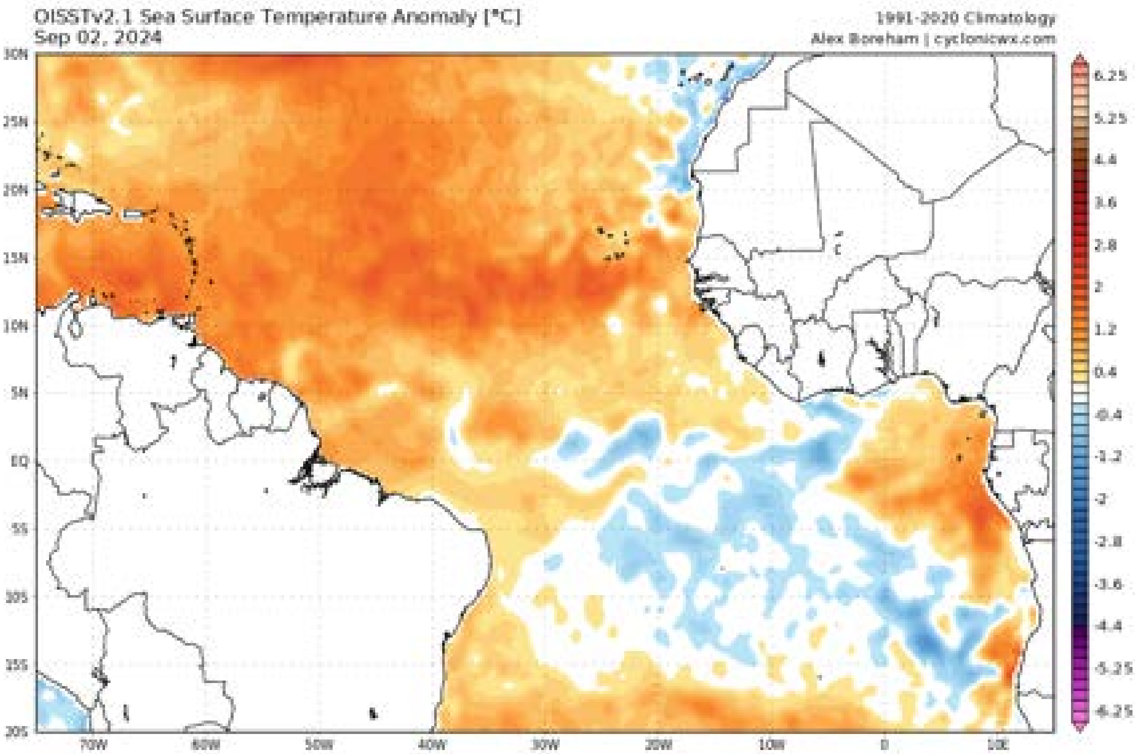

Figure 8: Observed tropical Atlantic sea surface temperature anomalies. Figure courtesy of cyclonicwx.com.

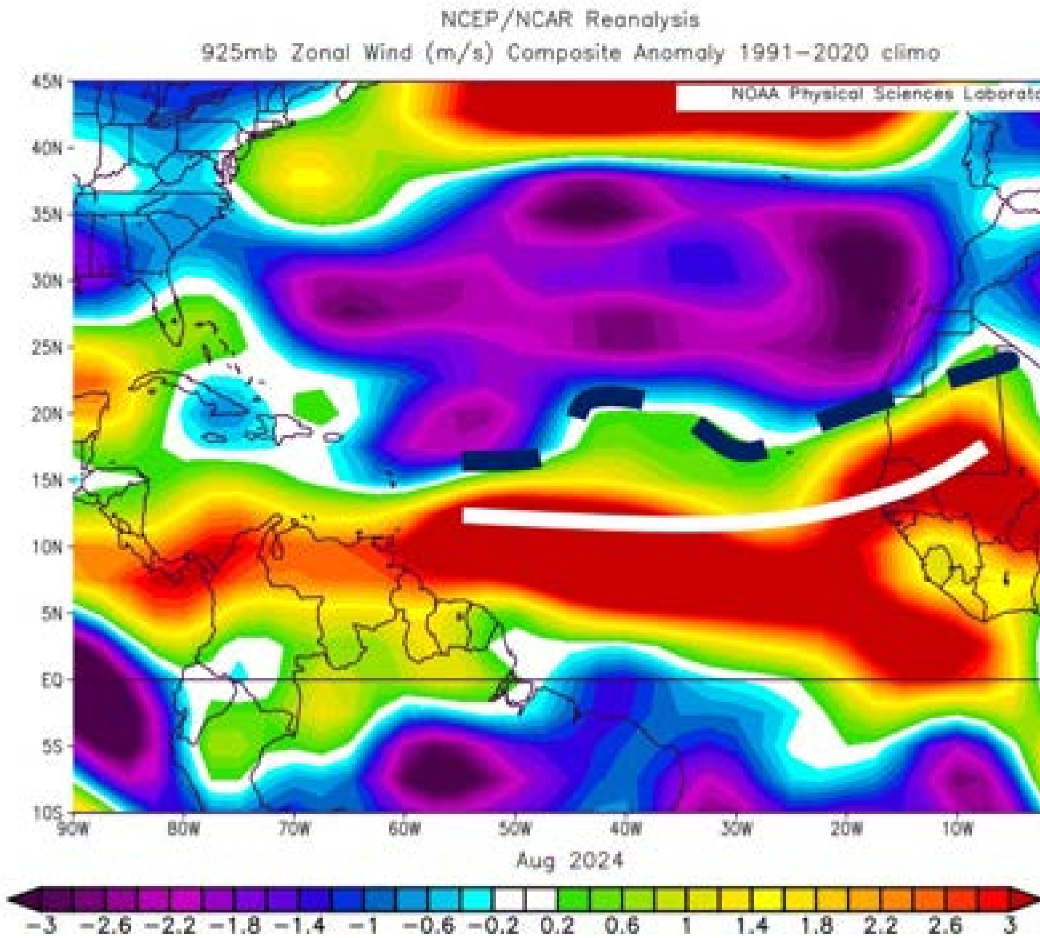

Figure 9: Observed August 925 hPa zonal winds across the tropical Atlantic along with an approximate placement of the monsoon trough in August 2024 (blue dashed line) relative to an estimated hurricane optimal line (white solid line).

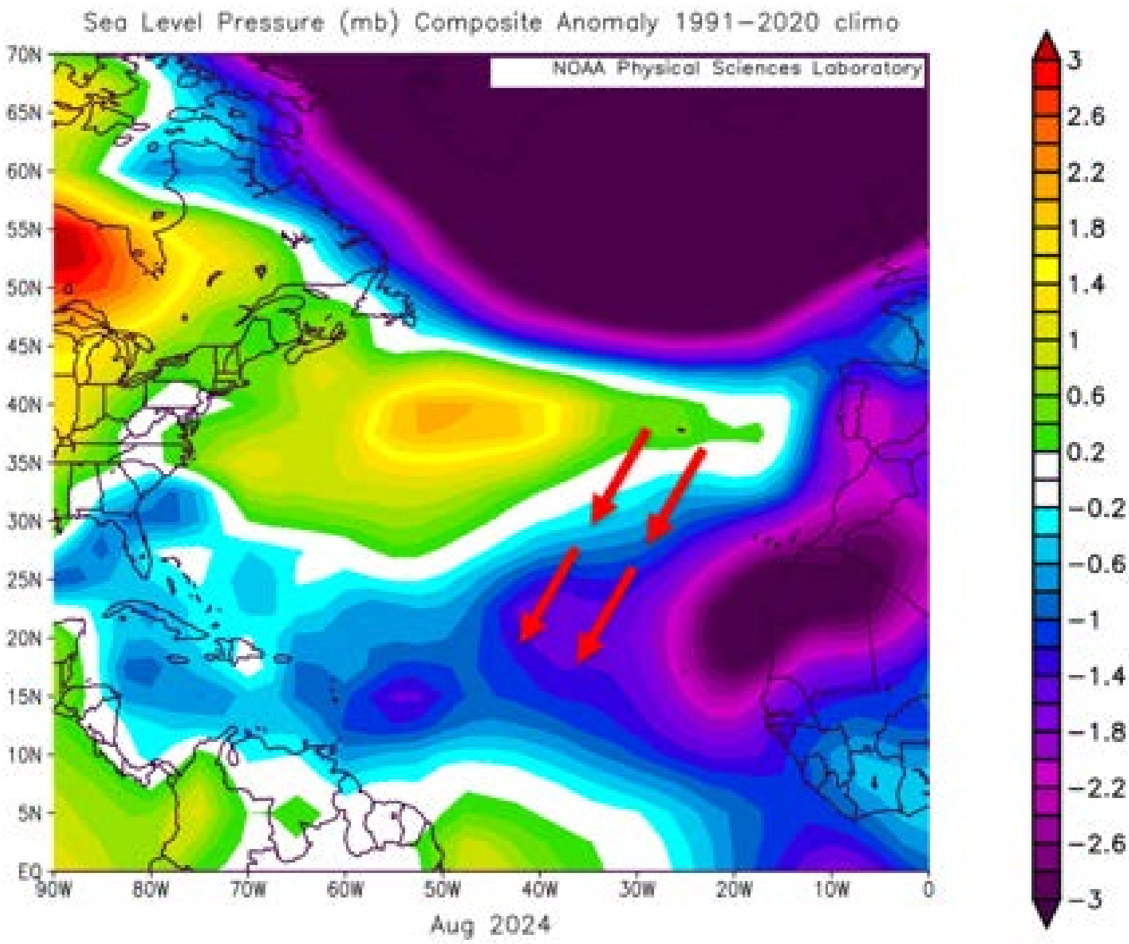

Figure 10: Observed sea level pressure anomalies in August 2024 and associated low-level wind flow across the eastern subtropical Atlantic.

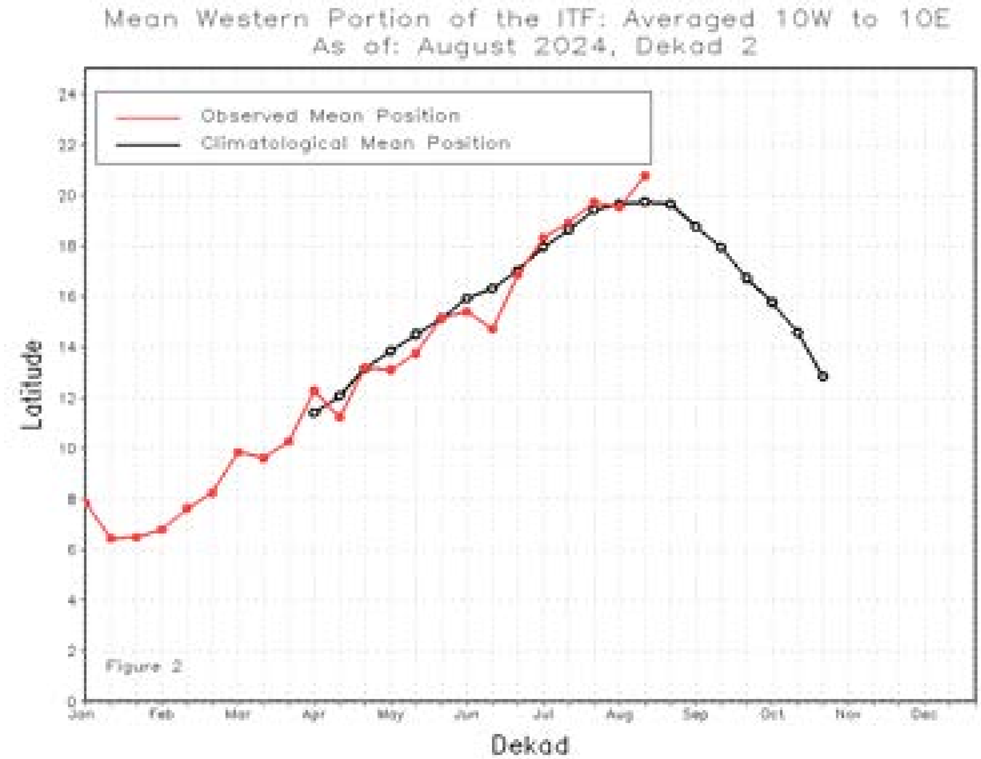

Figure 11: Mean climatological western portion of the intertropical front from 10°W to 10°E (black line) and observed value in 2024 (red line) as analyzed by the Climate Prediction Center.

2) Upper-tropospheric warming

As noted earlier, the Atlantic MDR remains extremely warm right now (Figure 12). Normally a warm Atlantic favors an active Atlantic hurricane season via lower sea level pressures, a more unstable atmosphere, reduced levels of vertical wind shear and additional fuel for hurricane formation. In addition to the extremely warm sea surface temperatures, upper ocean heat content is at near-records levels as well, with values close to what were observed in 2023 at this time (Figure 13). So from a sea surface temperature/ocean heat perspective, the Atlantic hurricane season should be extremely active.

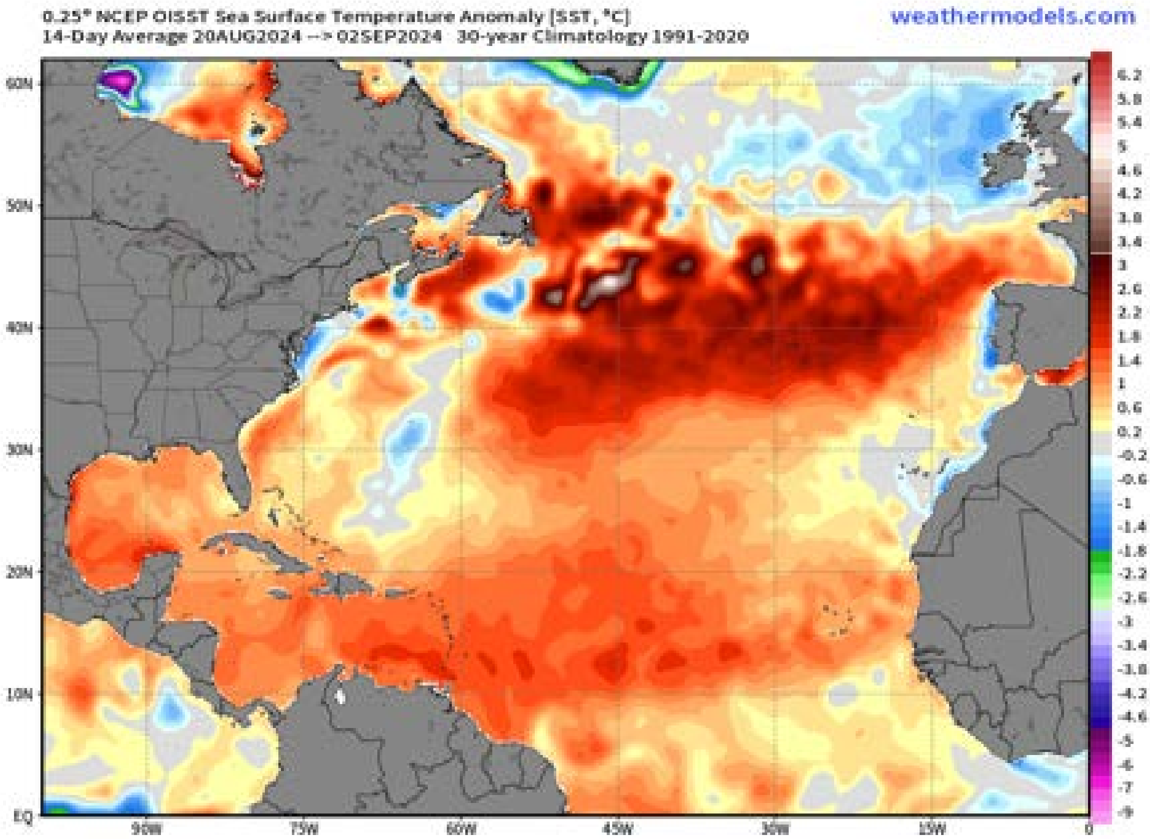

Figure 12: Observed North Atlantic sea surface temperature anomalies. Figure courtesy of weathermodels.com.

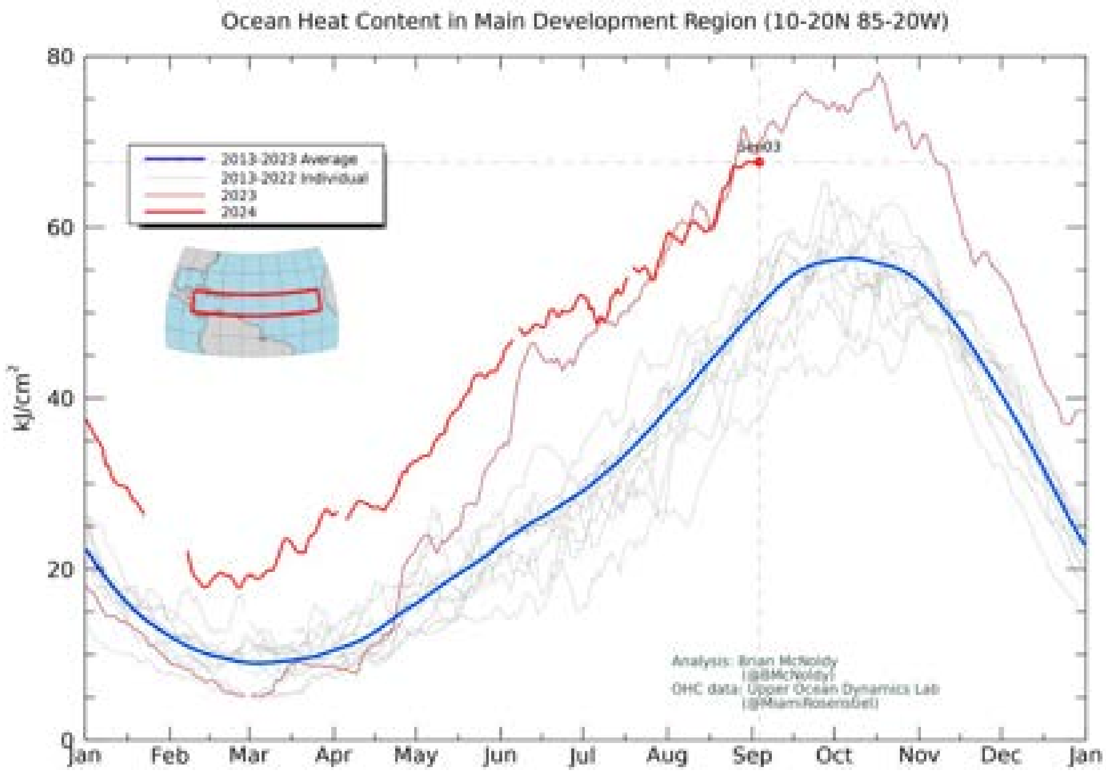

Figure 13: Observed Atlantic upper ocean heat content anomalies (dark red line), 2023 anomalies (light red line), individual years from 2013 to 2022 (dark gray lines) and the 2013–2023 average (blue line). Figure courtesy of Brian McNoldy (University of Miami).

However, compared with 2023, upper-tropospheric temperatures are warmer this year in the MDR (Figure 14). This increase in upper-tropospheric temperatures may be causing a stabilizing effect that is suppressing deep convection across the MDR.

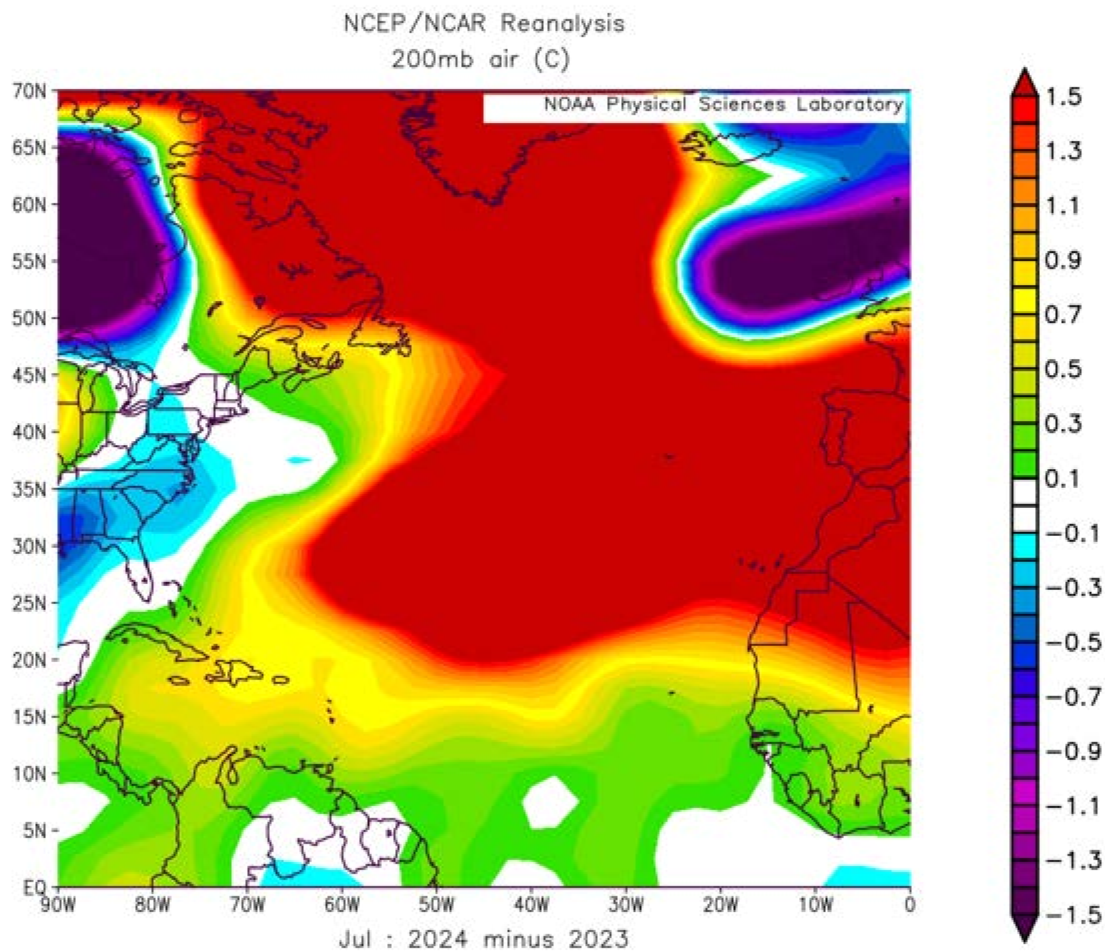

Figure 14: July 2024 minus July 2023 200 hPa temperatures.

Historically, there has not been much of a relationship between the difference in upper-level temperatures minus SST, but the upper-level temperatures are much warmer relative to SSTs in 2024 than they were in any other year (Figure 15). Perhaps this is a sign that upper-tropospheric warming, likely linked to El Niño on annual timescales and anthropogenic warming on decadal timescales, could cause additional stability issues in future years. Of course, this stability argument would argue against storms like Hurricane Beryl, which became the earliest Category 5 hurricane on record.

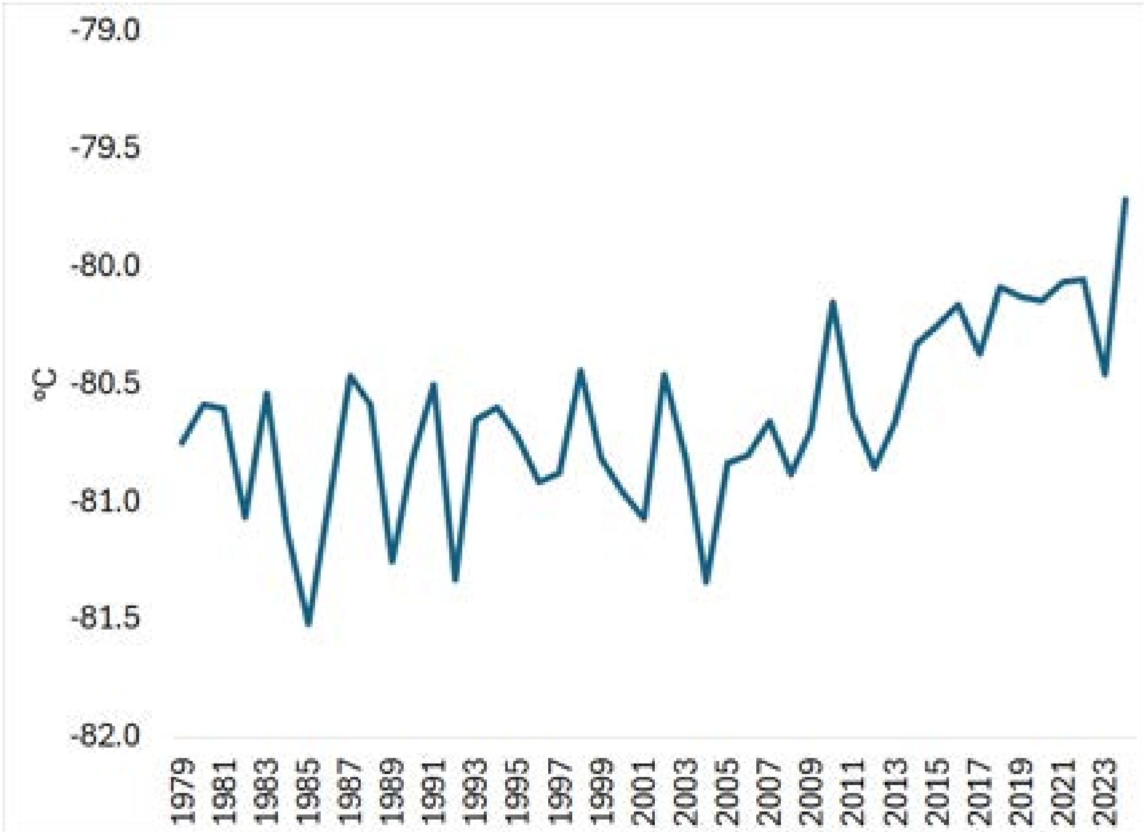

Figure 15: July 200 hPa temperatures minus sea surface temperatures from 1979–2024.

3) Too much easterly shear in the eastern Atlantic

In August 2024, the entire tropical Atlantic has been characterized by pronounced easterly upper-level zonal wind anomalies (Figure 16). These upper-level easterly anomalies extend all the way into Africa, indicative of an extremely vigorous African monsoon. While these upper-level easterly anomalies reduce shear in the western and central Atlantic (where the background shear is westerly), these upper-level easterly anomalies increase easterly shear in the eastern Atlantic (where the background shear is easterly) (Figure 17). This increase in easterly shear may be one reason why we have seen a very anemic performance of easterly waves that have emerged off of Africa at relatively low latitudes in recent weeks.

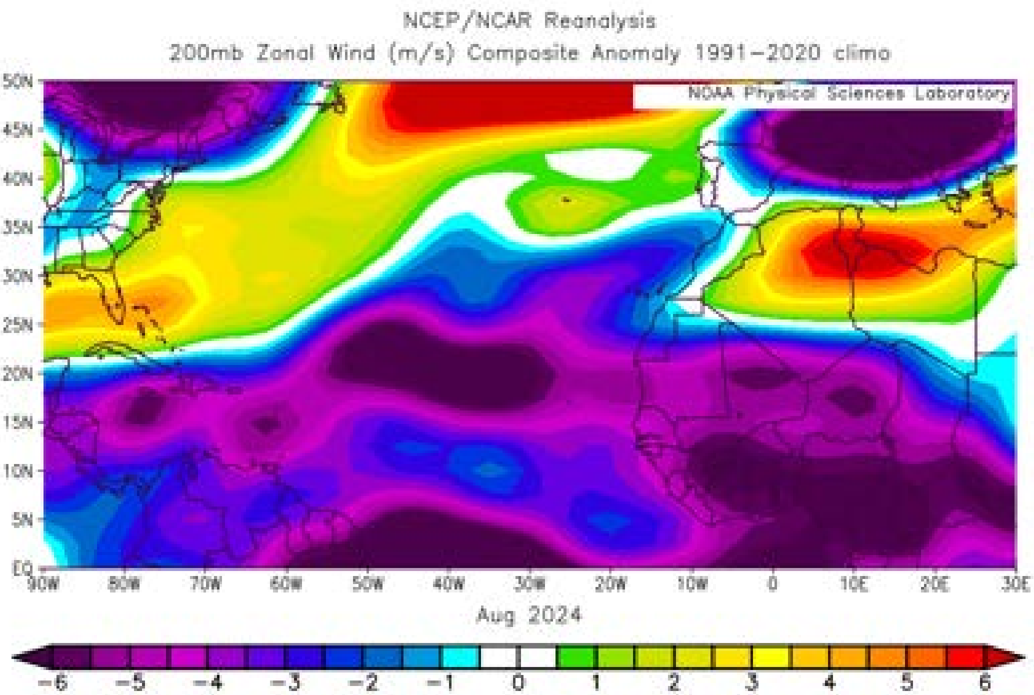

Figure 16: 200 hPa zonal wind anomalies during August 2024.

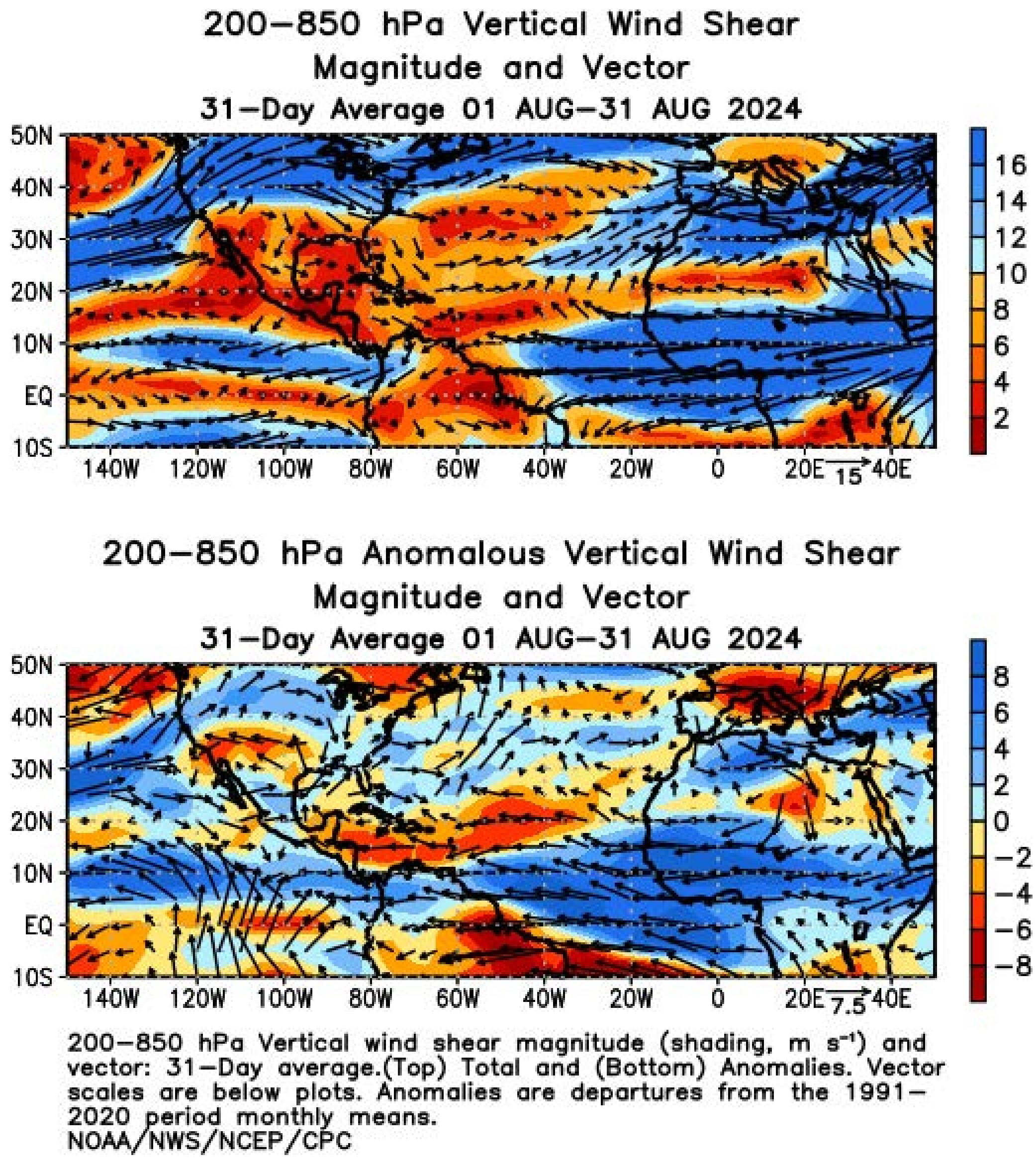

Figure 17: Observed vertical wind shear during August 2024. Figure courtesy of NOAA.

4) Recent unfavorable large-scale conditions from the Madden-Julian oscillation

While the Madden-Julian oscillation was broadly favorable for Atlantic hurricane activity during late August, it has since moved eastward and is now located over the Maritime Continent (Figure 18). Associated with these phases has been an increase in vertical wind shear that is currently being amplified by a tropical upper-tropospheric trough that is digging into the central Atlantic. Figures 19 and 20 highlight the latest ECMWF ensemble forecast for vertical wind shear for the next 1–5 days and 6–10 days, respectively. Enhanced vertical wind shear will likely continue to suppress tropical cyclone activity for the next ~10 days, with shear becoming more conducive in 11–15 days (Figure 21).

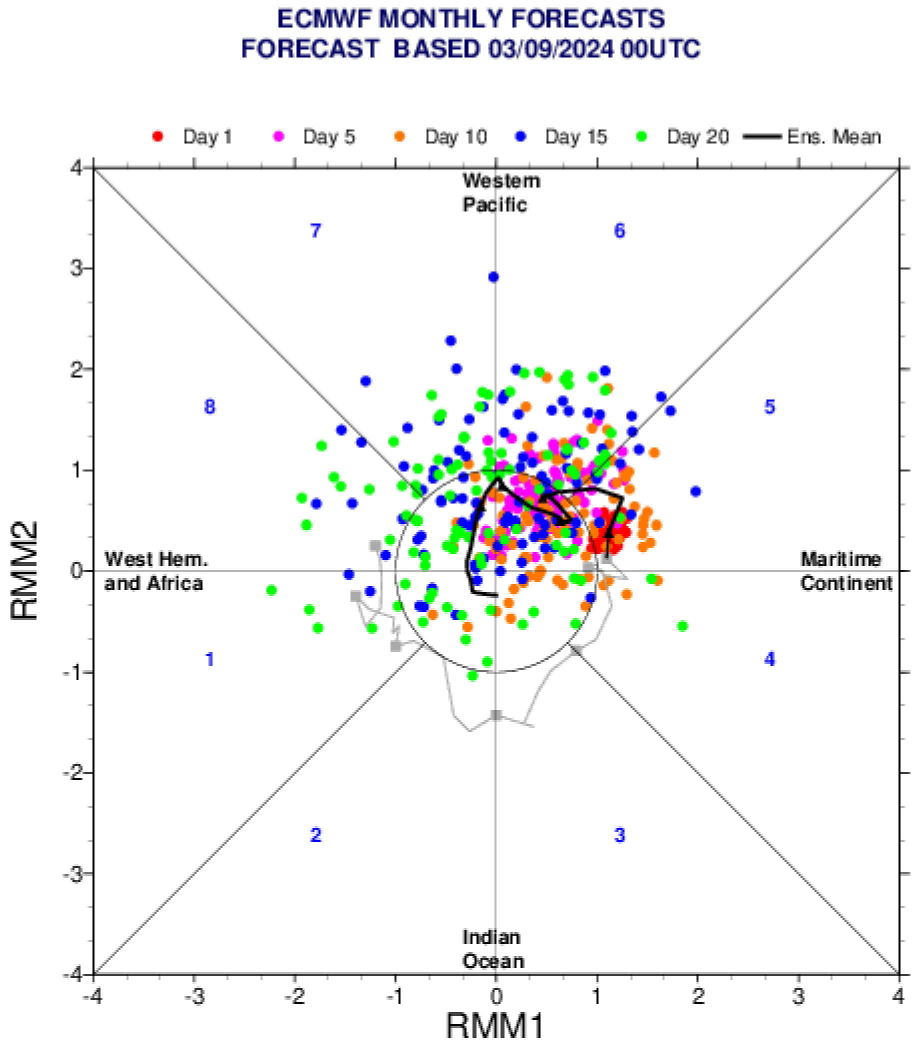

Figure 18: Observed propagation of the Madden-Julian oscillation and forecast propagation for the next 20 days from the ECMWF ensemble.

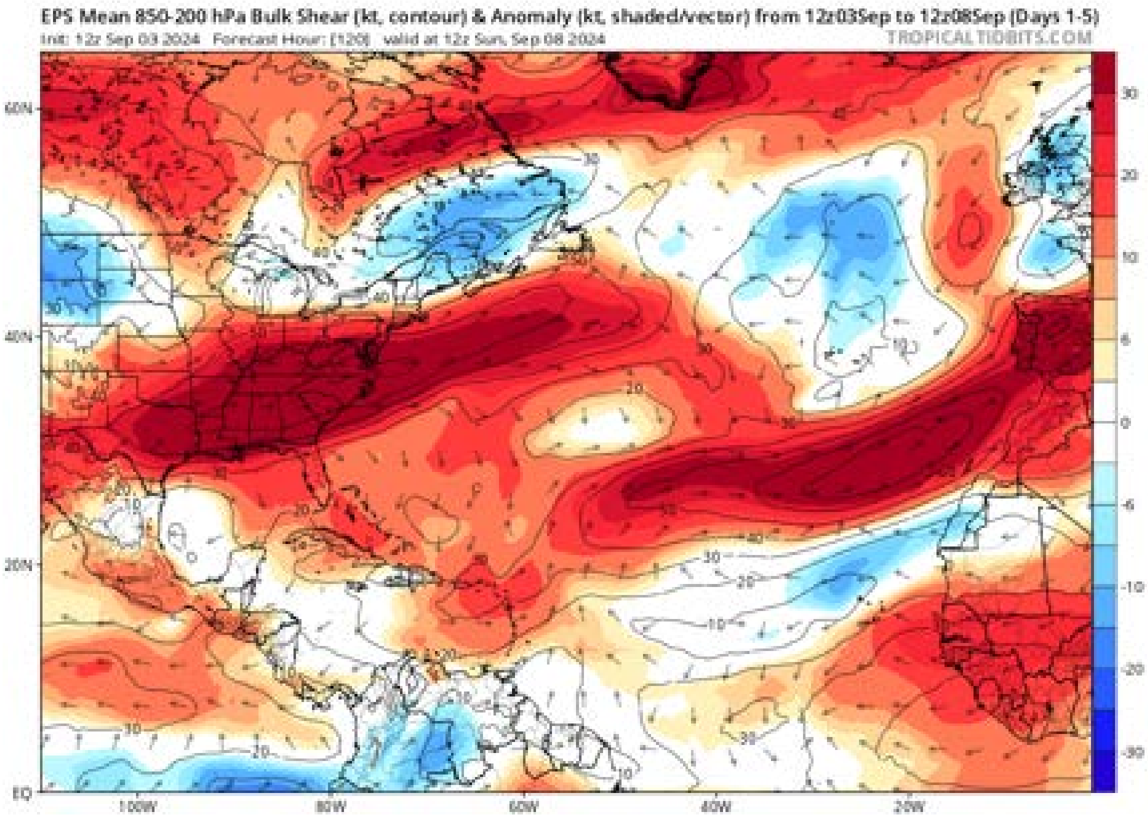

Figure 19: Forecast vertical wind shear across the North Atlantic for days 1–5 from the ECMWF ensemble. Figure courtesy of Tropical Tidbits.

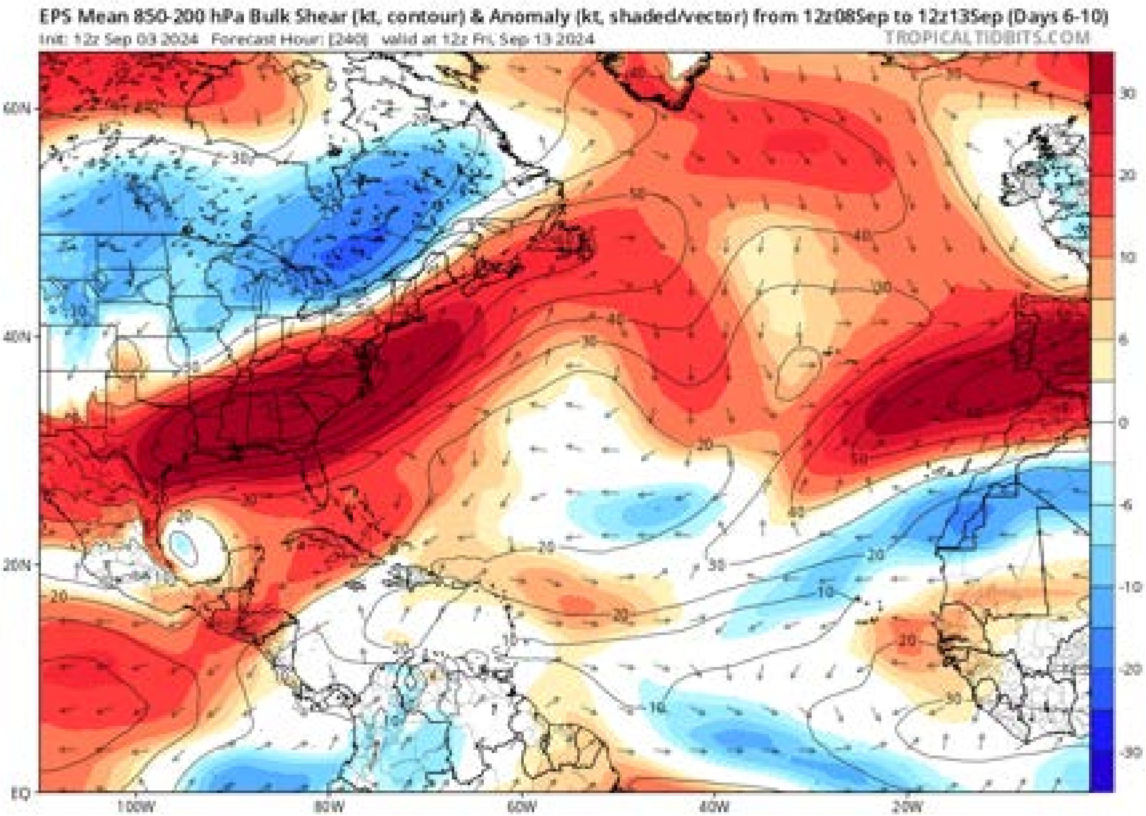

Figure 20: Forecast vertical wind shear across the North Atlantic for days 6–10. Figure courtesy of Tropical Tidbits.

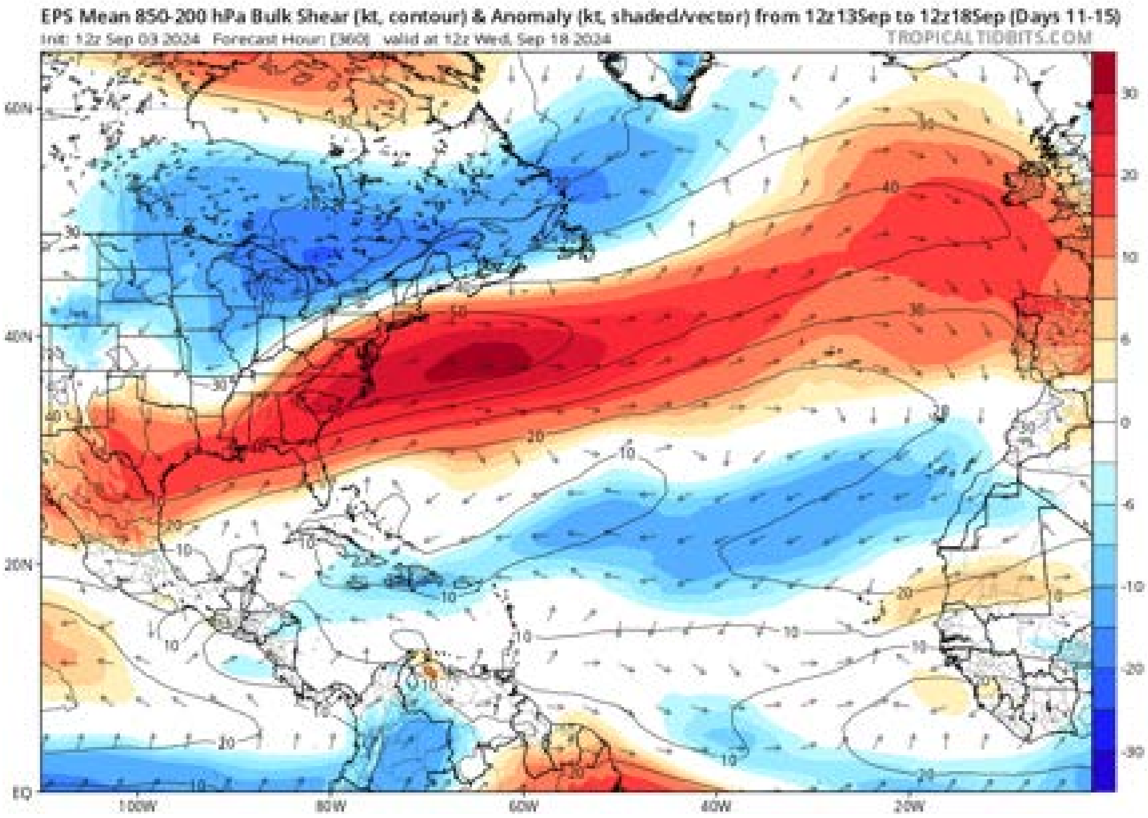

Figure 21: Forecast vertical wind shear across the North Atlantic for days 11–15. Figure courtesy of Tropical Tidbits.

3 What Does the Rest of the Atlantic Hurricane Season Have in Store?

So far, it has been a tale of two hurricane seasons, with the first part of the season being extremely busy followed by extremely quiet. Are there any signs that the Atlantic hurricane will get busy again? As noted in our recently-released two-week forecast, we are anticipating below-normal activity over the next two weeks due to both unfavorable Madden-Julian oscillation conditions and a relative lack of tropical cyclone activity forecast by the ensembles.

However, the Atlantic hurricane season does not end in mid-September. We still have an extremely warm Atlantic and a tropical Pacific that will likely be trending more towards La Niña as the season progresses. Figure 22 displays current sea surface temperature anomalies, while Figure 23 displays changes in sea surface temperatures over the past two weeks. A pronounced trade wind surge across the tropical Pacific (Figure 24) has caused significant cooling in the central tropical Pacific and will likely lead to a strong upwelling oceanic Kelvin wave over the next few weeks. The most recent forecast from NOAA also anticipates a trend towards La Niña over the next few months (Figure 25). Typically, La Niña and a warm Caribbean enhance late season storm activity due to a strengthening of the Caribbean/Central American gyre. CSU issues an operational October-November Caribbean forecast, which will likely call for an active late season in the Caribbean given its two input parameters are ENSO and Caribbean sea surface temperatures.

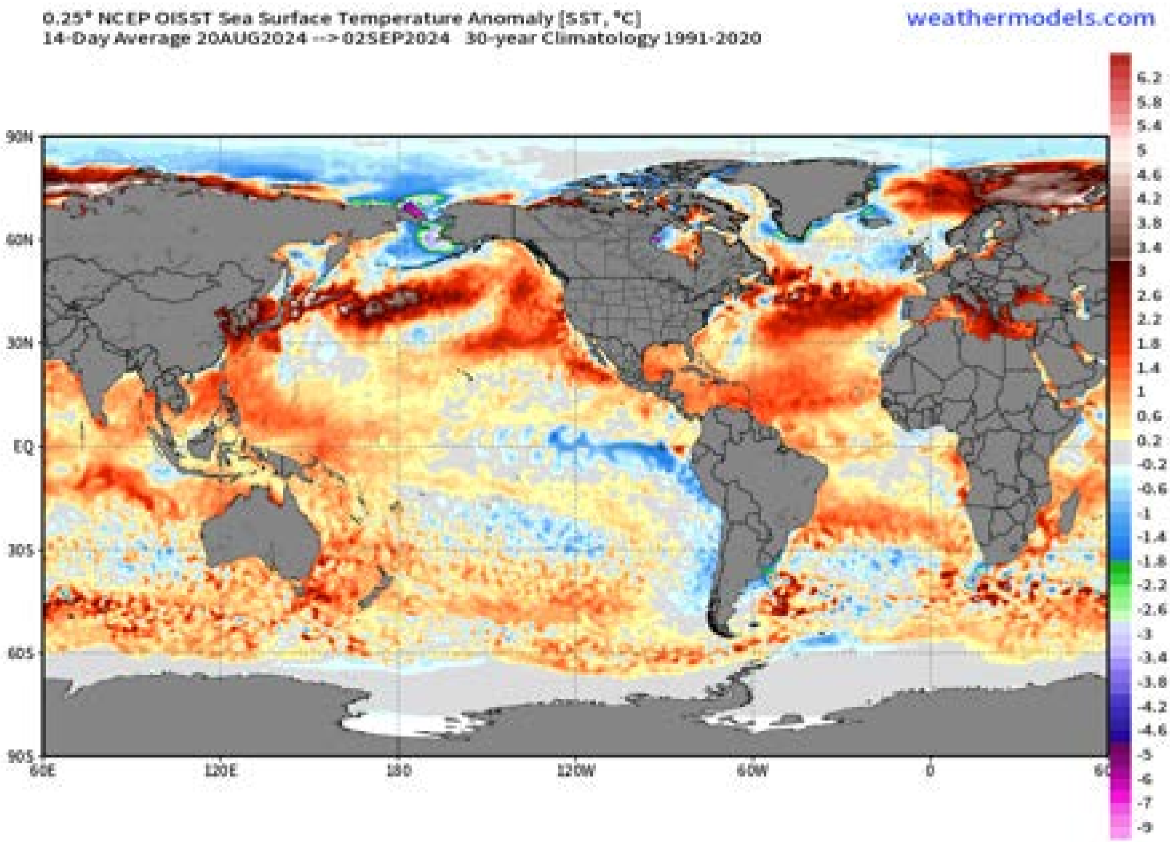

Figure 22: Current global sea surface temperature anomalies. Figure courtesy of weathermodels.com.

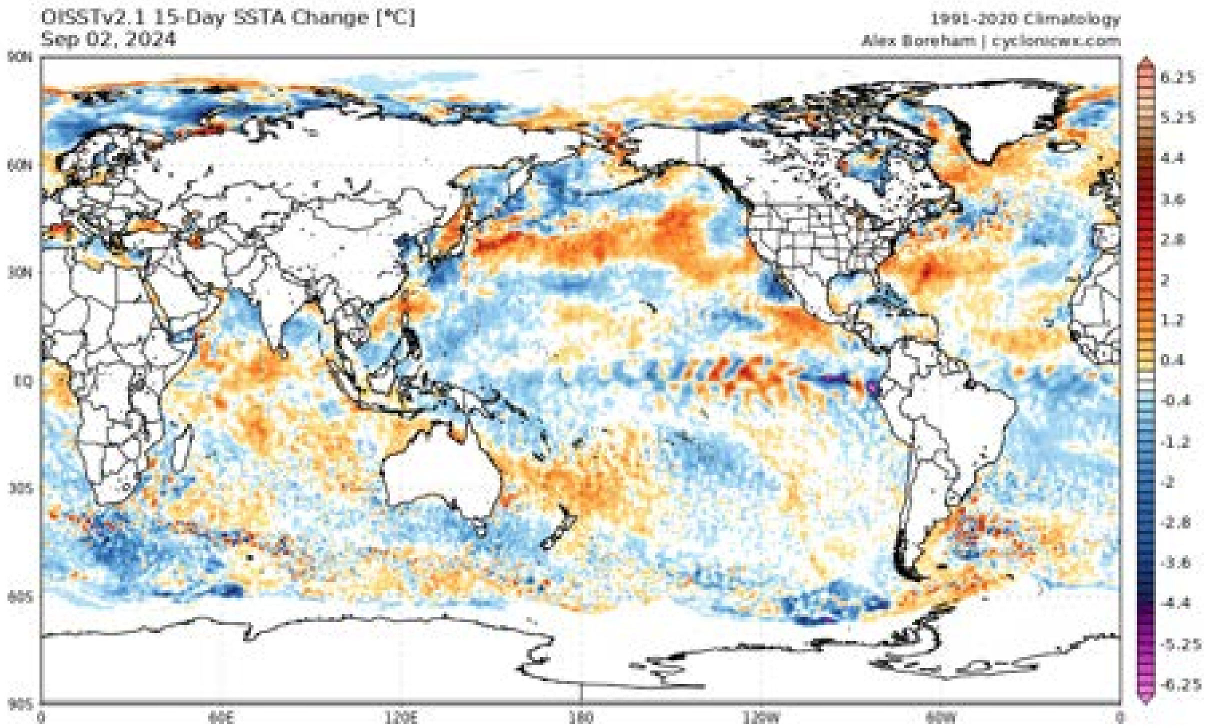

Figure 23: Sea surface temperature anomaly changes over the past 15 days. Sea surface temperature anomalies have cooled considerably across the tropical central Pacific, likely driven by the robust trade wind surge that is currently ongoing. Figure courtesy of cyclonicwx.com.

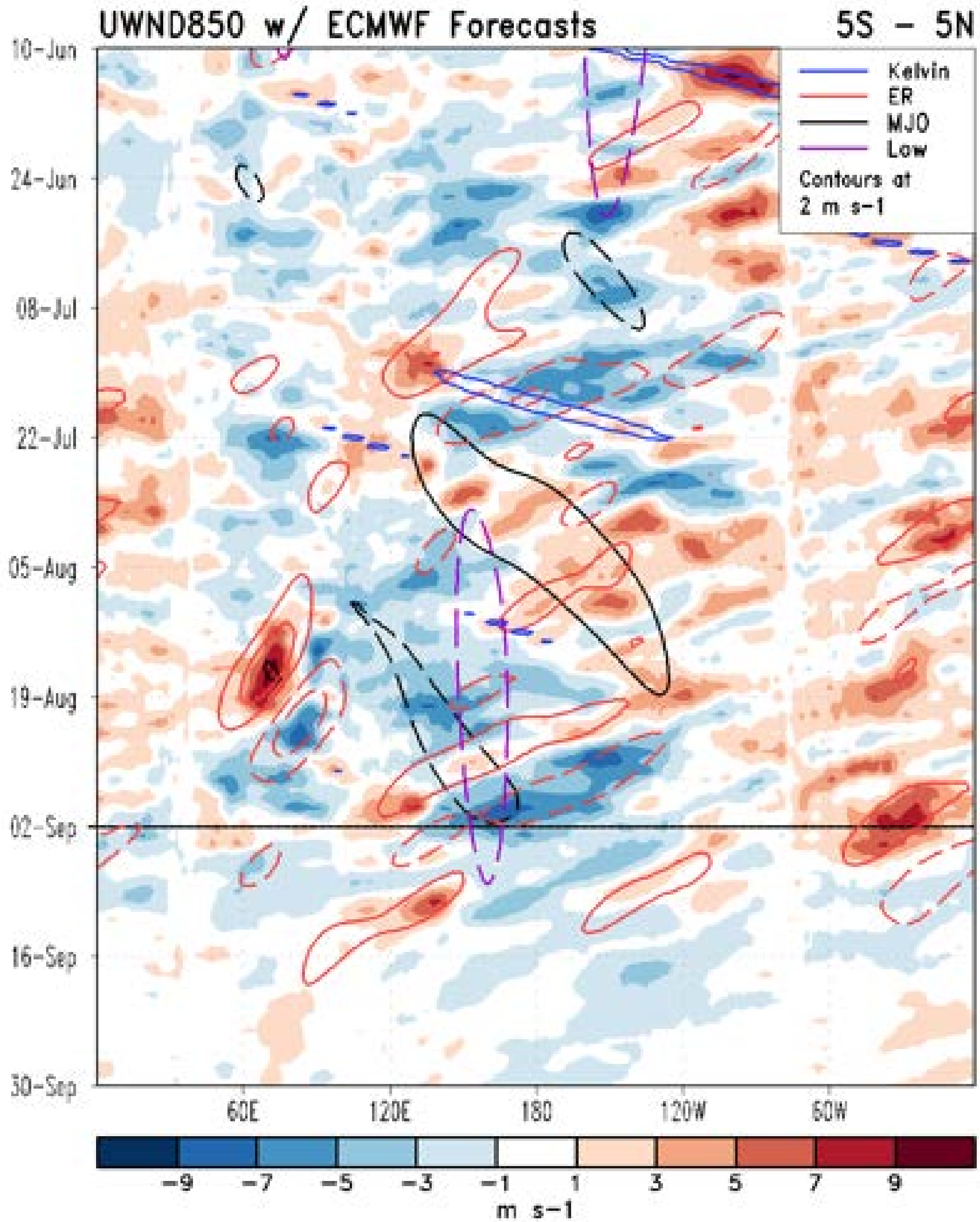

Figure 24: Observed equatorial zonal winds at 850 hPa and forecast winds from ECMWF through the end of September. Figure courtesy of Nick Novella (NOAA/CPC).

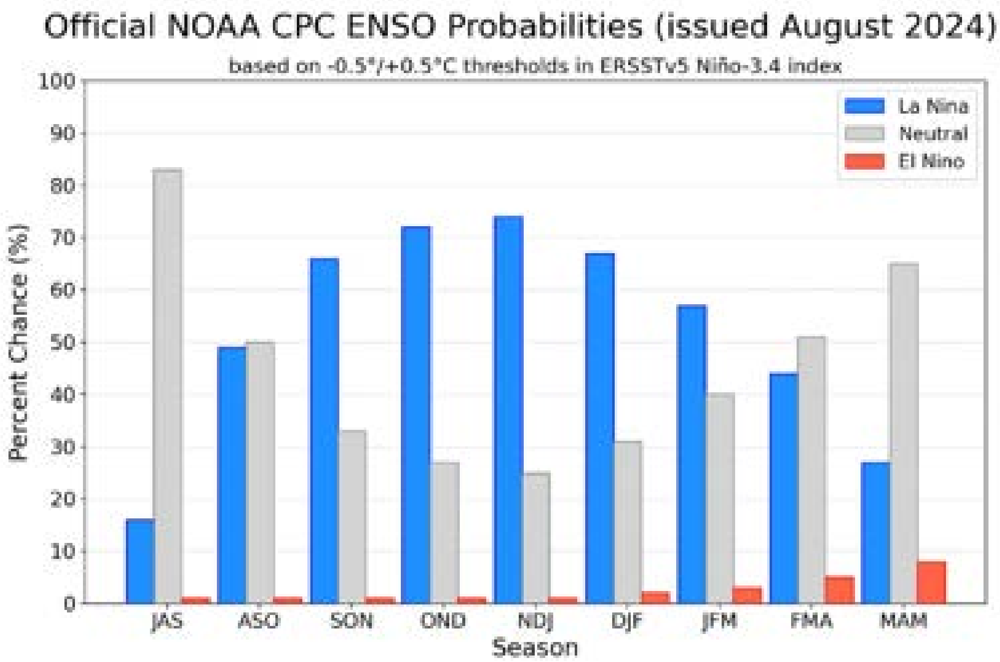

Figure 25: Latest probabilistic NOAA ENSO forecast.

After the current enhanced vertical wind shear associated with less conducive Madden-Julian oscillation conditions, vertical wind shear should be considerably reduced across the tropical Atlantic for the second half of September (Figure 26). ECMWF is forecasting anomalous easterly shear across the entire MDR for the latter part of September. While the background climatological shear is easterly in the eastern part of the basin in August, that background shear transitions to westerly as we move later in September. Consequently, easterly shear anomalies across the entire basin mean the basin becomes more conducive for hurricane formation from a shear perspective.

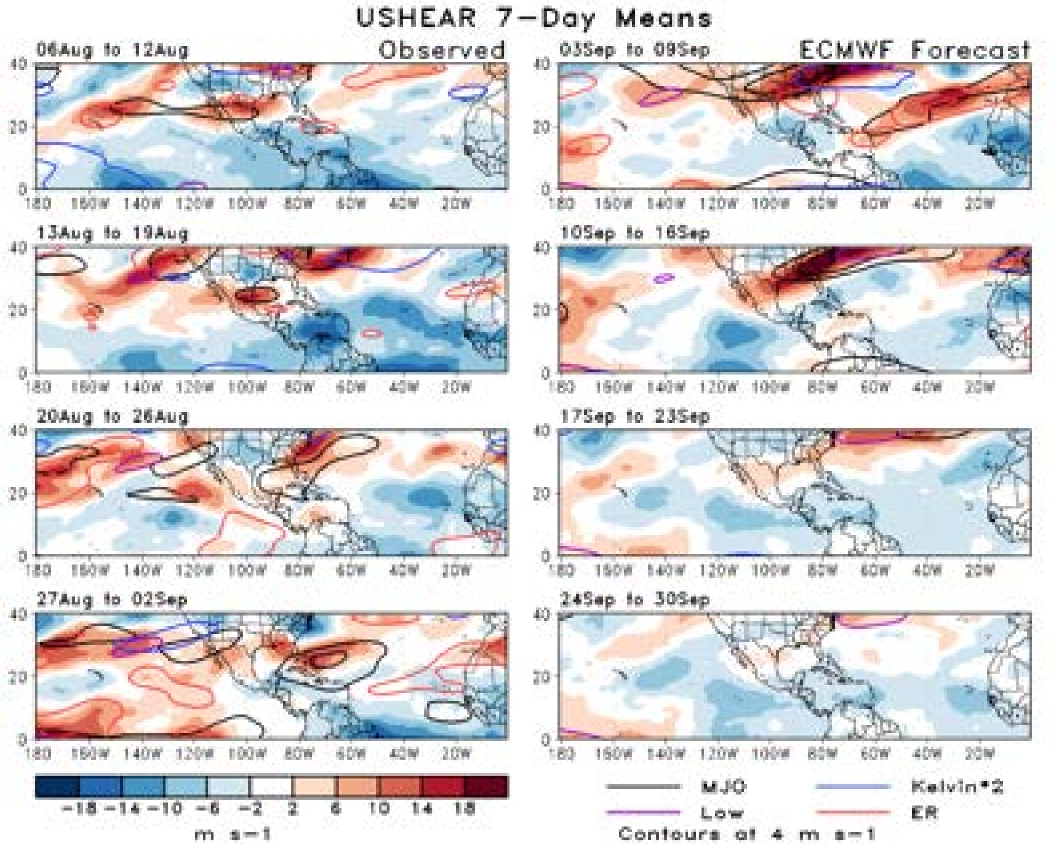

Figure 26: Observed (from 6 August to 2 September) and ECMWF ensemble forecast (from 3 September to 30 September) zonal wind shear.

One of the big issues plaguing the Atlantic has been the monsoon trough being so far north that the easterly waves emerging from Africa are coming off at too far north of a latitude to reach hurricane-conducive conditions. However, as the hurricane season progresses, the climatological African Intertropical Front shifts back southward in September (Figure 27).

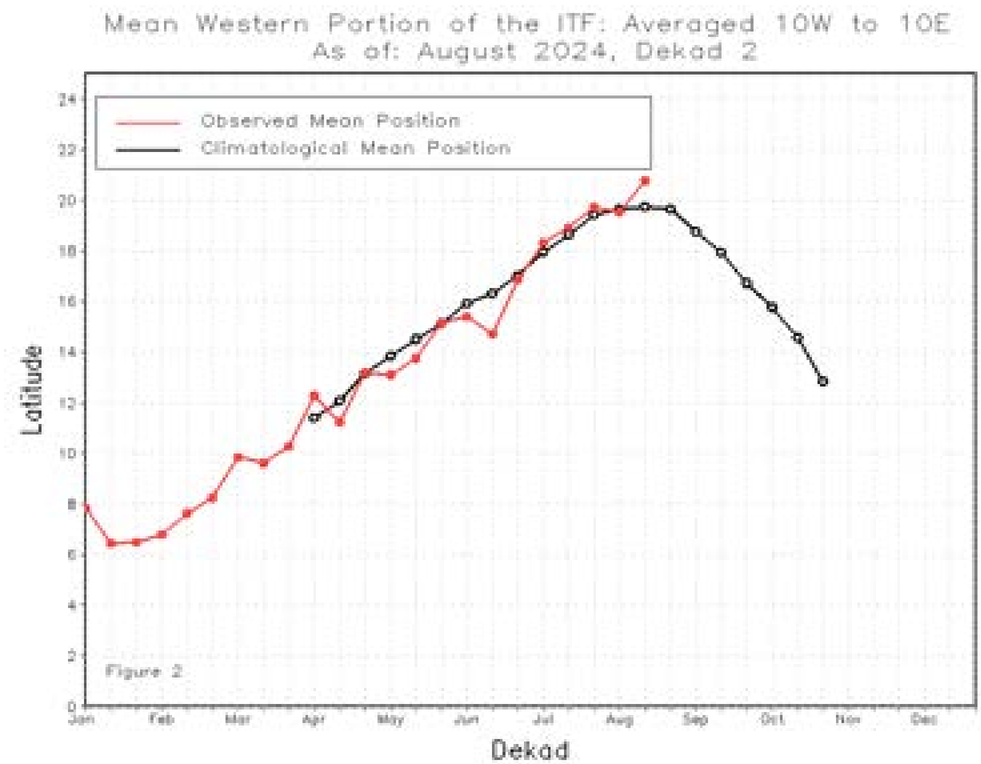

Figure 27: Mean climatological western portion of the intertropical front from 10°W to 10°E (black line) and observed value in 2024 (red line) as analyzed by the Climate Prediction Center.

The atmospheric stability issue should somewhat get rectified as we get later into the Atlantic hurricane season. Climatologically, sea surface temperatures and ocean heat content (Figure 28) increase through late September/early October, while upper-level temperatures begin to cool (Figure 29).

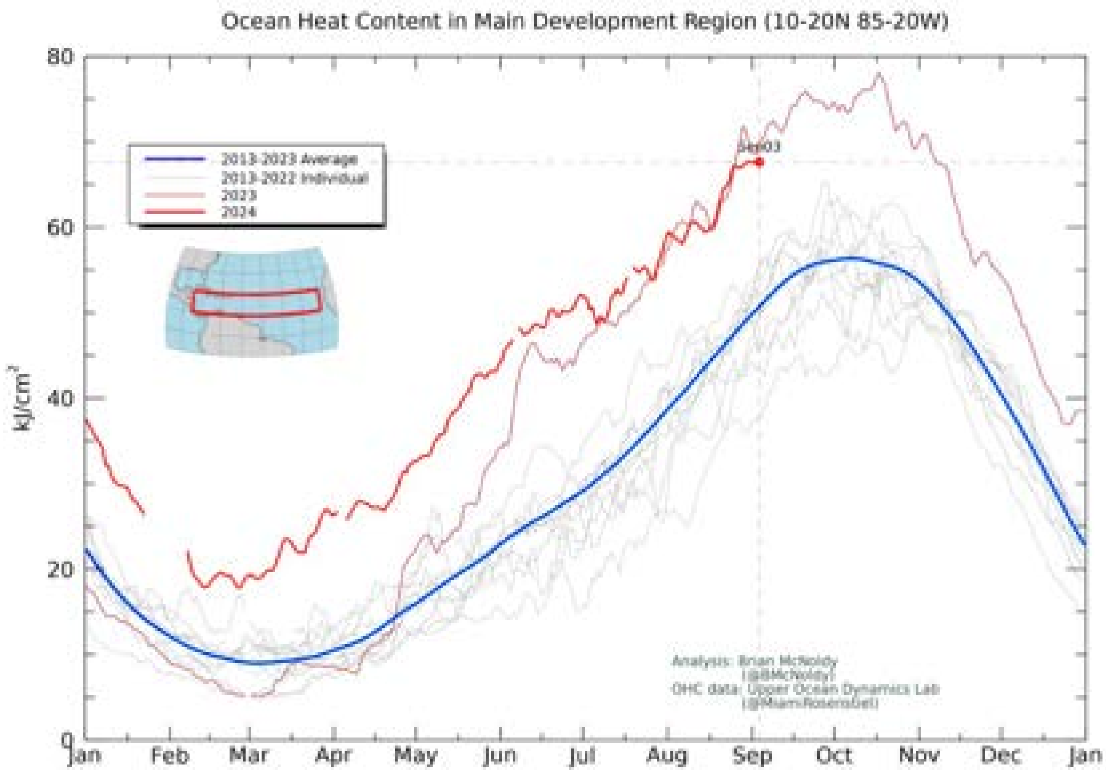

Figure 28: Observed Atlantic upper ocean heat content anomalies (dark red line), 2023 anomalies (light red line), individual years from 2013 to 2022 (dark gray lines) and the 2013–2023 average (blue line). Figure courtesy of Brian McNoldy (University of Miami).

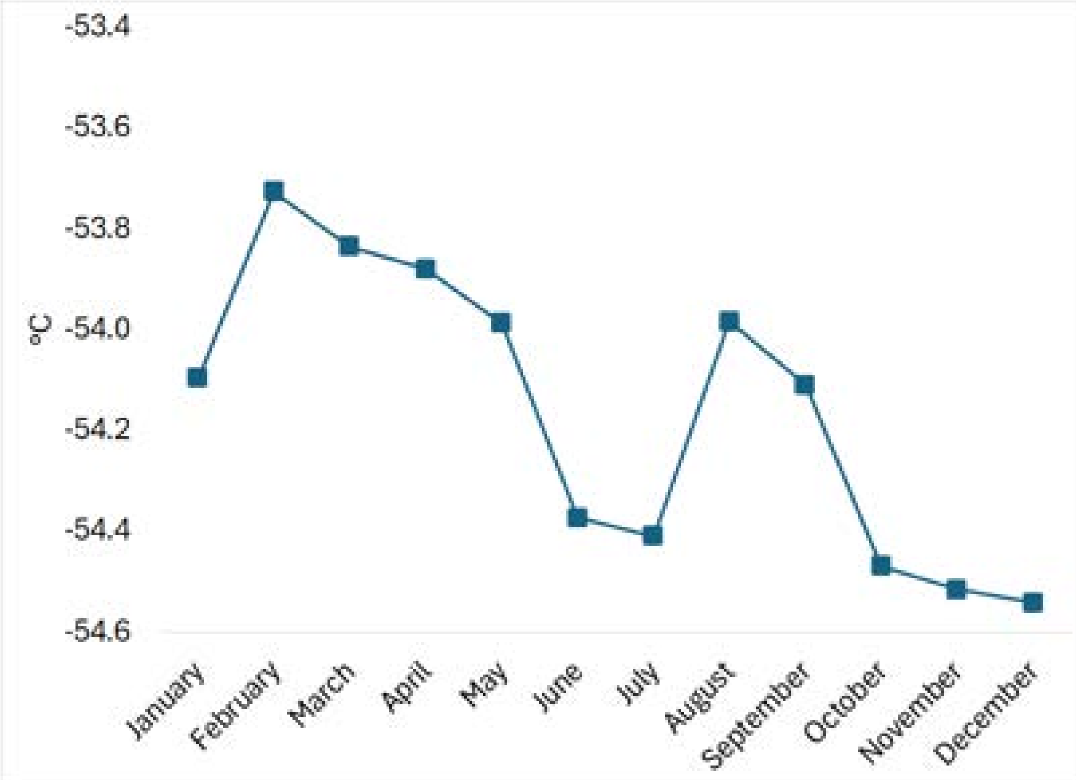

Figure 29: Average 200 hPa temperatures by month based on a 1991–2020 climatology.

Lastly, we thought it would be instructive to see what the average second half and record second half of the Atlantic hurricane season looked like (Table 1). Climatologically, the peak of the Atlantic hurricane season is 10 September, so this table displays what average and record activity has looked like from 10 September – onwards. In this case, we are counting a storm's intensity class based on the day that it first reached that intensity. So, if a storm formed on 8 September but became a hurricane on 11 September, it would count as 0 named storms and 1 hurricane in this analysis.

Table 1: Average and peak values of Atlantic hurricane from 10 September – onwards. Also displayed are the years where these levels were reached.

Forecast Parameter	Average	Peak Value	Year(s) Peak Occurred
Named Storms (NS)	6.3	13	2005, 2020
Named Storm Days (NSD)	36.7	76.5	2020
Hurricanes (H)	3.9	9	2010, 2020
Hurricane Days (HD)	15.4	38	1926
Major Hurricanes (MH)	1.7	6	2020
Major Hurricane Days (MHD)	3.8	13.75	1926
Accumulated Cyclone Energy (ACE)	67	151	1926
ACE West of 60°W	38	104	1926
Net Tropical Cyclone Activity (NTC)	70	162	2020

If the season were to have no named storm activity through 9 September and then had an average season for the remainder of the season, it would end up classified at the high end of NOAA's average Atlantic hurricane season. NOAA classifies hurricane seasons based on ACE, and the total ACE for the season would be 122 (55 observed + 67 average 10 September–onwards). An above-average season based on NOAA's definition is >126.3 ACE. Obviously if the season were to take a more active trajectory, there would still be time to reach the hyperactive ACE threshold (>159.6 ACE). Again assuming no ACE generated through 9 September, the Atlantic would need to produce ~104 additional ACE. Seven years in the satellite era (since 1966) have produced >=104 ACE from 10 September-onwards: 1967, 1998, 1999, 2004, 2005, 2017, and 2020.

So at this point, while it would be highly unlikely for CSU's seasonal hurricane forecasts to exactly verify, there is still potential that a hyperactive season could be reached. Of course, the season is quiet at the moment with no immediate indications of a rapid ramp-up. CSU will be extensively monitoring large-scale conditions throughout the remainder of the season and will include additional extensive discussion in its end-of-the-year verification issued on 26 November.