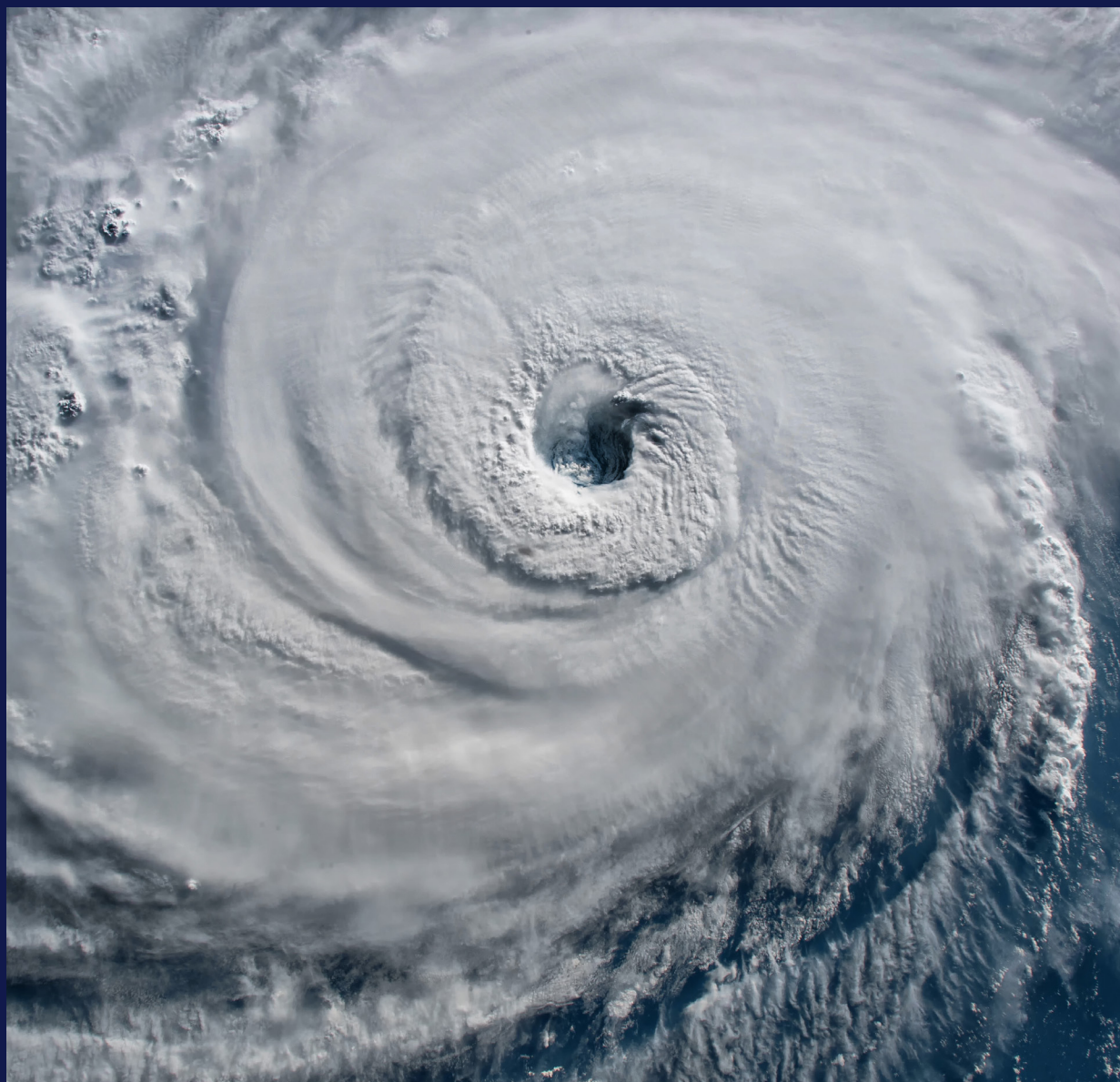
MOODY'S

EXECUTIVE SUMMARY

2024 Northern Hemisphere tropical cyclone outlook

NORTH ATLANTIC AND WESTERN NORTH PACIFIC
MOODY'S RMS™ EVENT RESPONSE REPORT



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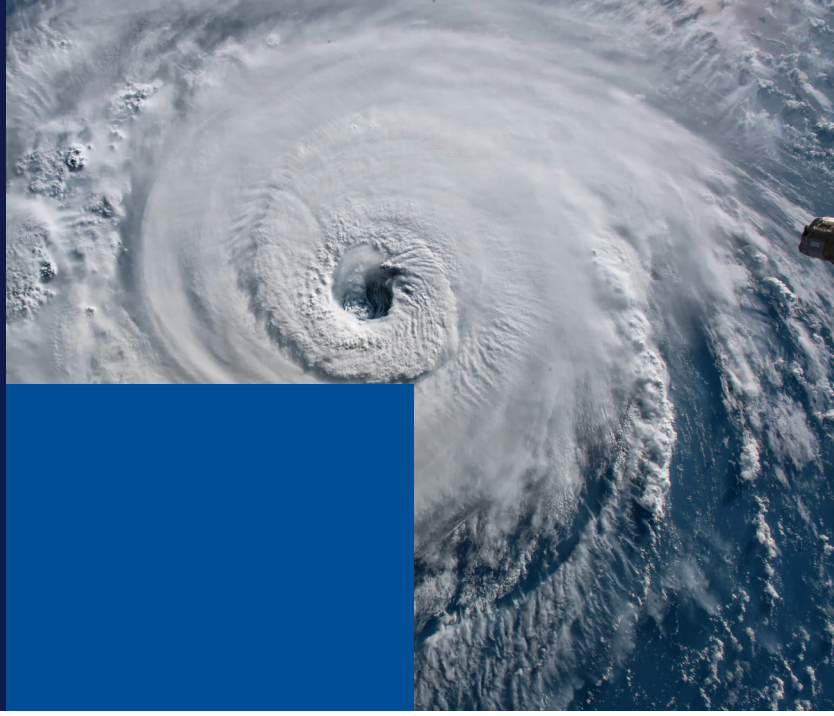


Despite an active North Atlantic hurricane season last year, there was only one landfall in the U.S. in 2023. Idalia became the first major hurricane to make landfall in Florida's Big Bend region and to impact the state's northwestern coastal area since the 1896 Cedar Keys Hurricane.

Idalia served as an important reminder of the devastating impacts that natural catastrophes can have, even in previously largely unaffected areas. It brought destructive hurricane-force winds and a catastrophic storm surge to much of northwestern Florida. Idalia's strongest winds were limited to a small area near landfall in a sparsely populated section of the Florida coastline, owing to the storm's compact structure, which limited its market impact.

AN ACTIVE 2024 HURRICANE SEASON EXPECTED

According to the latest seasonal tropical cyclone forecasts issued by numerous meteorological agencies and groups, there is a strong consensus that the 2024 North Atlantic hurricane season is expected to be above average, with some forecasts suggesting a hyperactive season is not out of the question.

The forecasts reflect the combined influence of several key seasonal oceanic and atmospheric factors that typically influence intraseasonal hurricane activity in the North Atlantic, primarily North Atlantic sea surface temperatures and the El Niño-Southern Oscillation (ENSO).

Sea surface temperatures in the North Atlantic are at or near record warm levels across most of the tropical and eastern portions of the subtropical North Atlantic, and they are expected to remain at or near record levels throughout the coming months. Warmer sea surface temperatures typically result in a more active North Atlantic hurricane season owing to the increased energy available for cyclogenesis and intensification.

ENSO is expected to transition into a La Niña phase by the fall, and perhaps even in time for the peak months of the hurricane season between August and October. La Niña conditions in the equatorial Pacific typically result in a

"There is a strong consensus that the 2024 North Atlantic hurricane season is expected to be above average, with some forecasts suggesting a hyperactive season is not out of the question."

more active North Atlantic hurricane season due to decreases in vertical wind shear and increased instability across the basin. Even if cool-neutral ENSO conditions prevail, an active hurricane season could still be possible given the hurricane-conducive oceanic conditions in the North Atlantic.

Last year's hurricane season was characterized by a tug-of-war. In 2023, ENSO was in an El Niño phase, which marginally hindered activity, while record warm sea surface temperatures in the North Atlantic promoted activity. There is expected to be no such tug-of-war in 2024, with the warmer-than-average North Atlantic sea surface temperatures and ENSO's transition to a La Niña phase both expected to promote hurricane activity in the basin.

While oceanic and atmospheric conditions are primed and look set to result in an active year, we cannot be as certain of the influence of several other subseasonal factors, which can modulate tropical cyclone activity on a weekly or monthly basis and are difficult to forecast at seasonal timescales. Such factors can include the North Atlantic Oscillation (NAO), the Saharan Air Layer (SAL), and the Madden-Julian Oscillation (MJO).

Although the North Atlantic has primarily been the focus of tropical cyclones in the past several years, Moody's RMS Event Response stands ready to react in the Western North Pacific Basin if the focus switches. In 2021, we expanded this outlook report to cover seasonal forecasts in the Asia-Pacific region, and this year's report once again includes Western North Pacific typhoon activity forecasts for 2024.

"Sea surface temperatures in the North Atlantic are at or near record warm levels across most of the tropical and eastern portions of the subtropical North Atlantic."

FASTER EVENT RESPONSE AND MORE COMPREHENSIVE ANALYTICS

Although only time will tell what unfolds this season, Moody's RMS™ Event Response and the (re)insurance industry are no strangers to active hurricane seasons. Seven of the last eight seasons (2016–23) were classified as above normal, two of which were designated as extremely active (2017 and 2020).

While long-term statistics indicate that the probability of a hurricane making landfall in the U.S. increases during more active seasons, there are notable exceptions to this tendency. However, we are reminded that it only takes one landfalling event to make a season costly or memorable.

Landfalls are ultimately decided by the trajectory and path of an individual tropical cyclone. This is dependent on both the broadscale and local synoptic factors at the time of formation, which is not possible to skillfully forecast at seasonal timelines.

Whatever the final storm count in 2024, Moody's RMS Event Response remains committed to supporting our customers during active hurricane events. Last year, we marked our fastest reaction time to a landfalling major U.S. hurricane with Idalia.

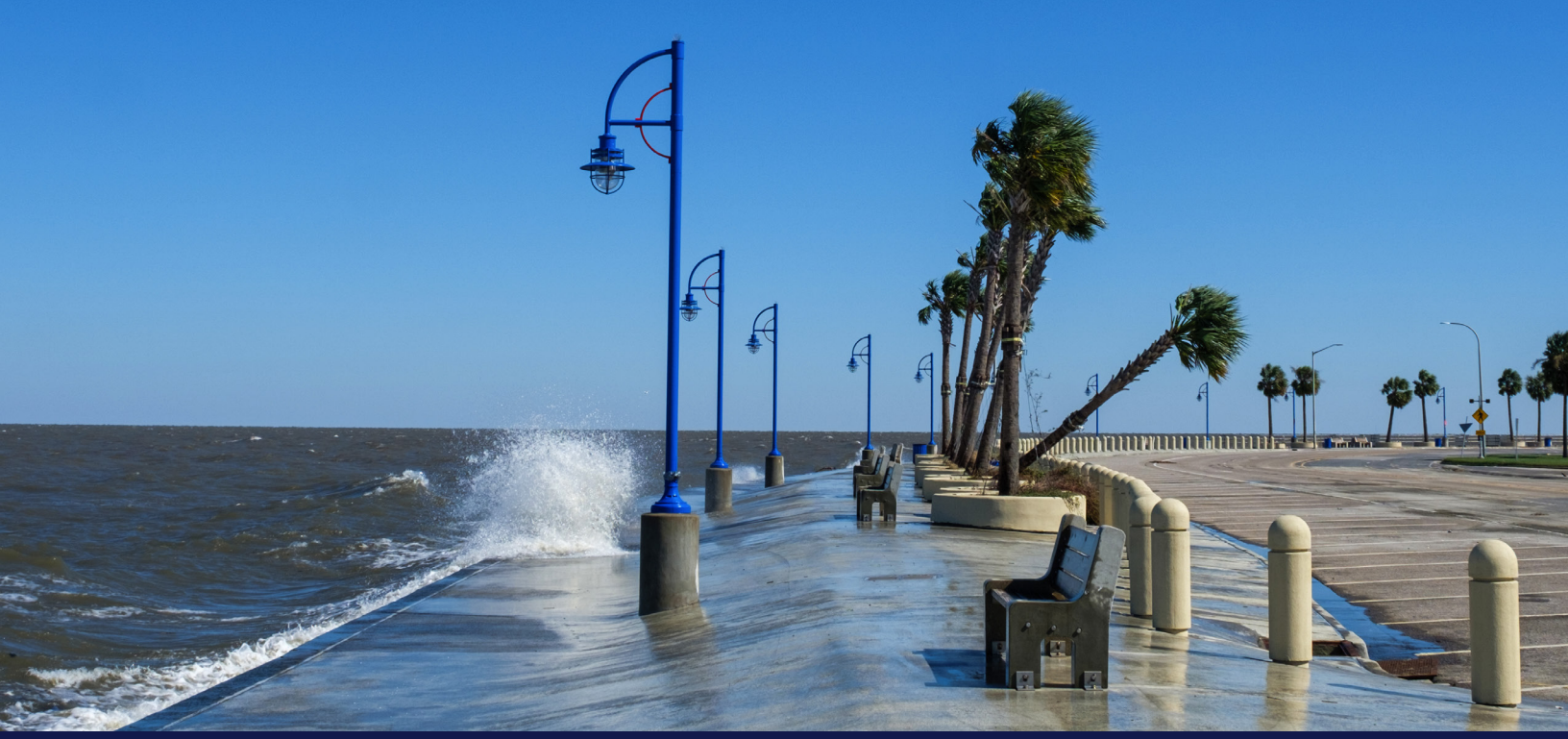
Just five days after landfall, we released our industry loss estimate and associated suite of optimized post-landfall wind and storm surge modeling and accumulation information. This is a testament to our event response workflow process enhancements and innovations over the last few years that have helped improve efficiency and reduce delivery timelines.

We continue to work diligently to build on our recent advancements and provide our customers with faster and more comprehensive analytics. For instance, the Moody's ExposureIQ™ application on the Moody's Intelligent Risk Platform™ now puts Moody's RMS Event Response and Moody's HWind insights into our customers hands like never before, with around-the-clock automated updates every few hours.

As a trusted partner, Moody's RMS Event Response is once again ready to inform your critical business processes with reliable information during the year's most impactful events.

Mohsen Rahnama
Chief Risk Modeling Officer,
Insurance Solutions, Moody's

> **"Whatever the final storm count in 2024, Moody's RMS Event Response remains committed to supporting our customers during active hurricane events."**



2024 North Atlantic seasonal forecasts

The North Atlantic hurricane season officially runs from June 1 to November 30. Several forecasting agencies and groups issue preseason forecasts to provide an indication of potential storm activity for the upcoming season. This report presents and evaluates the latest available forecasts at the time of publication.

Table 1, on the next page, shows the most recent forecasts, including those from the National Oceanic and Atmospheric Administration, two of the most widely known forecast groups of Colorado State University and Tropical Storm Risk, and several other agencies. Also displayed are a few climatological averages and 2023's activity count.

TABLE 1: Summary of the most recent 2024 North Atlantic seasonal tropical cyclone forecasts, average activity for specific periods, and seasonal activity for 2023

Forecast agency	Forecast date	Tropical storms	Hurricanes	Major hurricanes	ACE index
National Oceanic and Atmospheric Administration	May 23	17–25	8–13	4–7	145–237
Colorado State University	April 4[1]	19–27	8–14	3–7	151–260
Tropical Storm Risk	May 30	24	12	6	226
UK Met Office	May 22	16–28	8–16	2–6	131–293
European Centre for Medium-Range Weather Forecasts	May 5	18–27	9–16	n/a	171–317
Servicio Meteorológico Nacional	May 6	20–23	9–11	4–5	n/a
North Carolina State University	April 16	15–20	10–12	3–4	n/a
University of Pennsylvania	April 4	27–39	n/a	n/a	n/a
University of Arizona	April 8	18–24	9–13	4–6	116–196
AccuWeather	March 27	20–25	8–12	4–7	175–225
The Weather Company	April 18	24	11	6	n/a
1950–2023 average[2]		**12.3**	**6.5**	**2.6**	**105.7**
1991–2020 average[3]		**14.4**	**7.2**	**3.2**	**122.3**
1995–2023 average[4]		**15.8**	**7.7**	**3.5**	**133.6**
2013–23 average[5]		**16.9**	**7.7**	**3.4**	**132.1**
2023 North Atlantic hurricane season		**14**	**8**	**2**	**95.1**

Forecasts

The seasonal activity forecasts presented in Table 1 are made using either dynamical weather models, statistical models, or a combination of the two.

Dynamical weather models, such as those partly used by the National Oceanic and Atmospheric Administration, the UK Met Office, and the European Centre for Medium-Range Weather Forecasts, calculate the real-life physical atmospheric and oceanic processes from a perturbed set of initial environmental conditions. An ensemble of forecasts is produced to provide an indication of the range and probability of possible outcomes occurring.

Statistical models, such as those used by Tropical Storm Risk, University of Pennsylvania, and University of Arizona, derive statistical relationships between environmental factors and historical activity, which are then applied to the current environmental conditions to forecast activity for the upcoming season. The forecast ranges are typically based on the historical accuracy of the prediction scheme.

[1] This is the latest available forecast from Colorado State University (CSU) at the time of writing (June 1). CSU is expected to provide an updated forecast on June 11.
[2] Storms only given official names since 1950.
[3] This represents the latest National Oceanic and Atmospheric Administration three-decade U.S. Climate Normals.
[4] Representing the recent high-activity era of the Atlantic Basin since 1995.
[5] Representing the most recent decade.

Some seasonal activity forecasts, such as those issued by Colorado State University, use a combination of statistical and statistical/dynamical hybrid models.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION'S FORECAST

The National Oceanic and Atmospheric Administration (NOAA) outlook for the 2024 North Atlantic hurricane season indicates that an above-average season is very likely, with a very low probability that the season could be near or below normal.

The outlook indicates an 85 percent probability that the season will be above normal,[6] a 10 percent probability that the season will be near normal,[7] and just a 5 percent probability that the season will be below normal.[8]

NOAA's forecast calls for a 70 percent probability that the 2024 season will produce:

- → 17–25 named storms
- → 8–13 hurricanes
- → 4–7 major hurricanes[9]
- → Accumulated Cyclone Energy (ACE)[10] index of 145–237

The predicted ranges for activity in 2024 are centered well above NOAA's 1991–2020 U.S. Climate Normals[11] seasonal average of 14 named storms, seven hurricanes, and three major hurricanes. The 1951–2020 median ACE index value is 96.7.

NOAA will update its forecast at the beginning of August, just before the historical peak of North Atlantic hurricane activity.

LANDFALL FORECASTS

Long-term statistics indicate that the probability of a hurricane making landfall in the U.S. increases during more active seasons. When issuing landfall probability forecasts, some agencies use statistical models to examine the relationship between the number and intensity of historical landfalls and the observed and forecast climatological conditions.

The forecasts that follow are the most recent as of June 1—not including NOAA, which does not make seasonal hurricane landfall predictions.

NOAA's forecast calls for a 70 percent probability that the 2024 season will produce:

17–25
named storms

8–13
hurricanes

4–7
major hurricanes

145–237
Accumulated Cyclone Energy (ACE) index of 145–237

[6] NOAA defines an above-normal season as one with an ACE index above 126.1 (corresponding to more than the 67th percentile of the 1951–2020 median), with a range of 11 to 30 named storms, six to 15 hurricanes, and two to seven major hurricanes.
[7] NOAA defines a near-normal season as one with an ACE index between 73.0 and 126.1 (corresponding to between the 33rd and 67th percentiles of the 1951–2020 median), with a range of six to 18 named storms, three to nine hurricanes, and one to four major hurricanes.
[8] NOAA defines a below-normal season as one with an ACE index below 73.0 (corresponding to less than the 33rd percentile of the 1951–2020 median), with a range of four to 14 named storms, two to six hurricanes, and zero to two major hurricanes.
[9] A major hurricane is classified as Category 3 or higher.
[10] Accumulated Cyclone Energy (ACE) index is calculated as the square of the sum of the maximum sustained wind speed (in knots) at six-hour intervals for the duration of the storm at tropical storm strength (35 knots) or greater.
[11] NOAA's U.S. Climate Normals are three-decade averages of climatological variables, including temperature and precipitation, updated every 10 years. The 1991–2020 U.S. Climate Normals represent the most recent suite of data products.

Colorado State University (CSU) estimates the probability of at least one named storm, hurricane, and major hurricane tracking within 50 miles of each U.S. coastal state. According to CSU, Florida (75 percent), Louisiana (56 percent), North Carolina (56 percent), and Texas (54 percent) have the highest probability of a hurricane within 50 miles of the coast during 2024. CSU anticipates a 62 percent probability of at least one major hurricane making landfall in the U.S. this season (the 1880–2020 average is 43 percent) and a 66 percent probability of at least one major hurricane tracking through the Caribbean (the 1880–2020 average is 47 percent).

Tropical Storm Risk (TSR) forecasts five tropical storms and three hurricanes to make landfall over the contiguous U.S. in 2024. TSR anticipates the U.S. landfalling ACE index[12] to be 4.9, well above the 1991–2020 (2.7) and 2014–23 (3.5) averages. Probabilistically, TSR assigns a 71 percent chance that the U.S. landfalling ACE index will be above average,[13] a 23 percent chance that it will be near average,[14] and only a 6 percent chance that it will be below average.[15]

AccuWeather forecasts four to six named storms (of any intensity) to directly impact the mainland U.S., Puerto Rico, or the U.S. Virgin Islands during the 2024 season.

Uncertainty in seasonal forecasts of landfalling storms is far greater than the uncertainty in seasonal forecasts of overall hurricane activity. Individual storm tracks are highly sensitive to the location of cyclogenesis and the local atmospheric and oceanic conditions and weather patterns during the season.

Although the probability of a hurricane making landfall in the U.S. increases during more active seasons, there are notable exceptions to this tendency. In 2010, 19 named storms and 12 hurricanes developed in the North Atlantic Basin, but only one tropical storm made landfall in the U.S. Conversely, during the relatively quiet 1992 season, Hurricane Andrew, among the costliest hurricanes in U.S. history, was one of only seven named storms to develop. It only takes one event to make a season costly or memorable.

“It only takes one event to make a season costly or memorable.”

[12] Tropical Storm Risk considers the U.S. landfalling ACE index to be the sum of ACE of all systems of at least tropical storm strength over the mainland U.S.
[13] Above average corresponds to a U.S. landfalling ACE index value historically in the upper tercile (>3.19).
[14] Near average corresponds to a U.S. landfalling ACE index value historically in the middle tercile (1.18 to 3.19).
[15] Below average corresponds to a U.S. landfalling ACE index value historically in the lower tercile (<1.18).

Key drivers of the 2024 North Atlantic hurricane seasonal activity forecasts

The forecasts of an above-average season reflect the influence of several key seasonal oceanic and meteorological factors, including the El Niño-Southern Oscillation (ENSO), sea surface temperatures in the tropical Atlantic, and the Atlantic Multidecadal Oscillation/Variability (AMO/AMV).

The forecast state of these variables for the upcoming hurricane season, their possible impact on North Atlantic hurricane activity, and the overall confidence at this lead time are outlined in Table 2.

TABLE 2: Overview of key seasonal oceanic and meteorological factors anticipated to influence activity in 2024, expected impact on activity, and level of confidence in the forecast

Seasonal factor	Forecast state during August–October 2024	Possible impact on North Atlantic hurricane activity	Confidence in the forecast at this lead time
El Niño-Southern Oscillation (ENSO)	Moderate-to-strong La Niña conditions likely to develop through the summer and fall; timing of onset and magnitude uncertain	La Niña conditions typically enhance activity by decreasing vertical wind shear in the Caribbean and tropical North Atlantic	Moderate-to-high confidence that La Niña conditions will develop through the summer and fall; moderate confidence on the timing and magnitude
Atlantic sea surface temperatures	Much warmer than average, record warmth in some areas	Enhanced activity, especially in the main development region	High
Atlantic Multidecadal Oscillation/Variability (AMO/AMV)	Positive AMO/AMV phase	Enhanced activity	Moderate-to-high

"The forecasts of an above-average season reflect the influence of several key seasonal oceanic and meteorological factors."

A large proportion of the uncertainty associated with seasonal hurricane activity forecasts can be attributed to the uncertainty about which ENSO phase will materialize during the peak months of the hurricane season during August, September, and October (ASO).

As of May 2024, ENSO-neutral conditions are observed in the Pacific Ocean. The latest available ENSO status update (May 27) prepared by the Climate Prediction Center, the National Center for Environmental Prediction (NCEP), and the National Weather Service (NWS) indicates that a transition from ENSO-neutral conditions is expected in the next couple of months, with a greater than 80 percent chance of La Niña conditions persisting into the Northern Hemisphere winter.

Should ENSO transition to a La Niña phase through the 2024 North Atlantic hurricane season, and in the absence of influence from any other factors, activity would be expected to be above normal. If, as multiple forecasts predict, ENSO transitions to a La Niña phase between June and July and develops further into a strong event, and in the absence of influence from any other factors, a larger increase in activity above normal could be expected.

The forecast emergence of La Niña conditions is further supported by a forecast weakening of vertical wind shear anomalies between August and October, particularly in the main development region. Forecast models are predicting well-below-average vertical shear of –1.996 ms^{-1} during ASO, a record low for the North American Multi-Model Ensemble (NMME) modeling system.

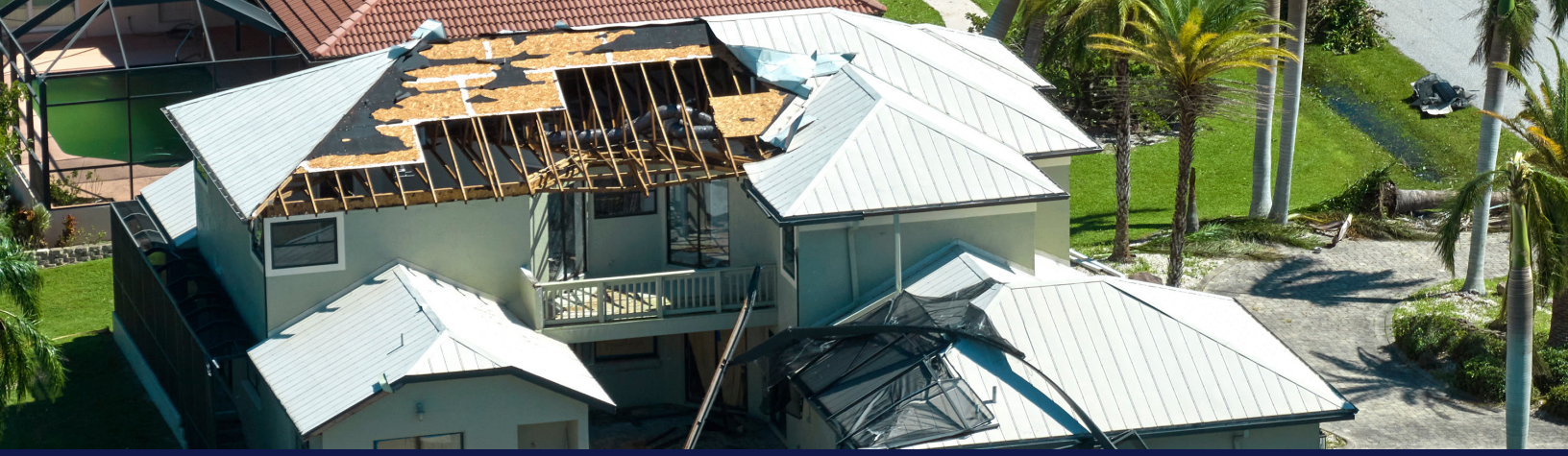
Decreased vertical shear is also generally associated with weaker-than-normal trade winds and, in the absence of other factors, they would indicate higher-than-average tropical activity. Trade winds across the main development region are forecast to be 1.78±0.79 ms^{-1} weaker than normal between July and September.

Sea surface temperatures in the main development region of the tropical North Atlantic are nearly at record high, with an area-averaged temperature anomaly of approximately +1.22°C. Models forecast above-average departures for the period covering the peak months of the hurricane season between August and October 2023, with many areas forecast to experience anomalies of +0.55°C to +1.05°C.

This also supports the notion that the AMO/AMV is currently in a positive (warm) phase, which is representative of a high-activity era. Warmer sea surface temperatures and a positive AMO/AMV phase typically enhance tropical activity by providing increased energy and moisture to the environment.

The combination of these factors have resulted in the overall forecast for an above-average season in 2024. Other factors, such as the North Atlantic Oscillation (NAO), the Madden-Julian Oscillation (MJO), and the Saharan Air Layer (SAL), can influence tropical cyclone activity on a weekly or monthly basis but are difficult to forecast at seasonal timescales.

“Should ENSO transition to a La Niña phase through the 2024 North Atlantic hurricane season, and in the absence of influence from any other factors, activity would be expected to be above normal.”



2024 Western North Pacific seasonal forecasts

The Western North Pacific typhoon season runs throughout the calendar year with no seasonal boundaries, although most of the activity typically occurs between May and November. Unlike in the North Atlantic Basin, the number of seasonal forecasts for the Western North Pacific Basin is not exhaustive. Several agencies issue forecasts to provide an indication of potential storm activity for the peak months of the year.

Table 3 shows the latest available forecasts at the time of publication. Also displayed are several climatological averages and 2023's activity count.

TABLE 3: Summary of the most recent 2024 Western North Pacific typhoon forecasts, average activity for specific periods, and seasonal activity for 2023

Forecast agency	Forecast date	Tropical storms	Typhoons
Tropical Storm Risk	May 7	25	15
European Centre for Medium-Range Weather Forecasts	May 5	16–23	7–14
1951–2023 average		**27.9**	**15.8**
1991–2020 average[16]		**25.1**	**13.3**
2023 Western North Pacific typhoon season		**25**	**10**

[16] The years 1991–2020 are the most recent Japan Meteorological Agency (JMA) climate period.

Forecasts

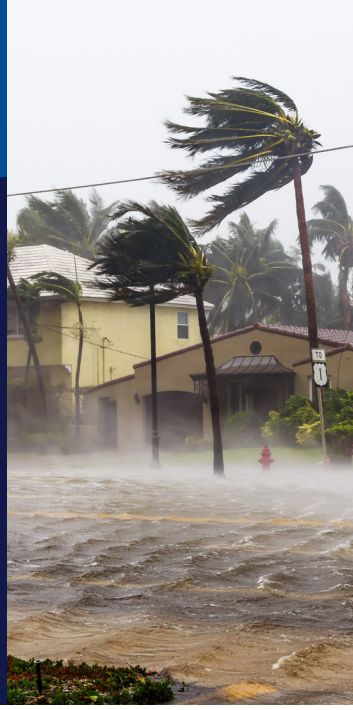
Tropical Storm Risk (TSR) predicts that activity in the Western North Pacific Basin during 2024 will be slightly below average, with the development of approximately 25 tropical storms, of which 15 are predicted to intensify into typhoons. The expected ACE index value of 225 is below TSR's 30- and 10-year climate averages of 301 and 257, respectively. TSR's forecast indicates a 66 percent probability that the season will be below normal,[17] a 24 percent probability that the season will be near normal,[18] and a 10 percent probability the season will be above normal.[19]

The latest European Centre for Medium-Range Weather Forecasts (ECMWF) seasonal forecast predicts 16 to 23 tropical storms will develop in the Western North Pacific Basin between June and November, and seven to 14 of these will develop into typhoons. These forecasts are slightly below or near the ECMWF's 10-year running climatology of 20.9 tropical storms and 13.1 typhoons. The ECMWF forecasts the six-month ACE index to be 40 to 80 percent of its 10-year running climatology.

The Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) forecasts 10 to 13 tropical cyclones to enter the Philippine Area of Responsibility[20] (PAR) between May and October 2024. PAGASA forecasts one or two tropical cyclones to enter the PAR in both May and June, and two or three tropical cyclones per month to enter the PAR between July and October.

[17] TSR defines a below-normal season as one with an ACE index in the lower third of the 1991–2020 Climate Normals, which is equivalent to an ACE index value less than 258.
[18] TSR defines a near-normal season as one with an ACE index in the middle third of the 1991–2020 Climate Normals, which is equivalent to an ACE index value between 259 and 328.
[19] TSR defines an above-normal season as one with an ACE index in the upper third of the 1991–2020 Climate Normals, which is equivalent to an ACE index value greater than 328.
[20] The Philippine Area of Responsibility, in the Western North Pacific, encompasses the waters of the Philippine Sea and South China Sea near the Philippines. The Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) monitors tropical cyclone development in this region and assigns Philippine-specific storm names.

Key drivers of the 2024 Western North Pacific seasonal activity forecasts



The forecasts of a slightly below to near-average year in the Western North Pacific Basin reflect the influence of the key seasonal oceanic and meteorological factors, including the El Niño-Southern Oscillation (ENSO) and sea surface temperatures in the Western North Pacific. The forecast state of these variables for the period between August and October, the possible impact on Western North Pacific tropical cyclone activity, and the overall confidence at this lead time are outlined in Table 4.

TABLE 4: An overview of the key seasonal oceanic and meteorological factors that are anticipated to influence activity in 2024, the expected impact on activity, and the level of confidence in the forecast

Seasonal factor	Forecast state during August–October 2024	Possible impact on Western North Pacific typhoon activity	Confidence in the forecast at this lead time
El Niño-Southern Oscillation (ENSO)	Moderate-to-strong La Niña conditions likely to develop through the summer and fall; timing of onset and magnitude uncertain	Decreased activity overall; shift of the cyclogenesis region eastward	Moderate-to-high confidence that La Niña conditions will develop through the summer and fall; moderate confidence on the timing and magnitude
Western North Pacific sea surface temperatures	Warmer than average	Enhanced activity	Medium

Most ENSO forecast models favor the development of La Niña conditions during the Northern Hemisphere summer. La Niña conditions generally result in stronger easterly trade winds, an increase in vertical wind shear, and a decrease in atmospheric instability in the region. The combination of these typically inhibits cyclogenesis and intensification, resulting in a slightly less active year.

Sea surface temperatures across the Western North Pacific Basin are expected to be above average between July and November. The waters immediately surrounding the Philippines and the South China Sea are expected to be between +0.5°C and +1°C above average, while areas off the northeastern coast of Japan are expected to be between +0.5°C and +1.5°C above average. Warmer sea surface temperatures typically enhance tropical activity by providing increased energy and moisture to the environment.

Warmer sea surface temperatures are generally associated with a negative phase of the Pacific Decadal Oscillation (PDO). As of May 2024, while the PDO is in a strong negative phase—which typically tends to suppress typhoon activity in the Western North Pacific Basin—the statistical correlation between the spring PDO phase and forecasted typhoon activity for the upcoming year is weak. Consequently, the level of activity for the hurricane season remains uncertain.

“Most ENSO forecast models favor the development of La Niña conditions during the Northern Hemisphere summer.”

MOODY'S

Moody's insurance solutions have shaped the world's view of risk for over 30 years, leading the catastrophe risk industry that we helped to pioneer. Our unmatched science, technology, innovation, and 300+ catastrophe risk models help risk and insurance leaders evaluate and manage the risks of natural and man-made disasters.

+1.212.123.4567
clientservices@moodys.com

EMEA
+44.20.1234.5678
clientservices.emea@moodys.com