2014
North Atlantic Hurricane Season Review

WHITEPAPER

Executive Summary

The 2014 Atlantic hurricane season was a quiet season, closing with eight named storms, six hurricanes, and two major hurricanes (Category 3 or stronger).

Forecast groups predicted that the formation of El Niño and below average sea surface temperatures (SSTs) in the Atlantic Main Development Region (MDR)[1] through the season would inhibit development in 2014, leading to a below average season. While 2014 was indeed quiet, these predictions didn't materialize.

The scientific community has attributed the low activity in 2014 to a number of oceanic and atmospheric conditions, predominantly anomalously low Atlantic mid-level moisture, anomalously high tropical Atlantic subsidence (sinking air) in the Main Development Region (MDR), and strong wind shear across the Caribbean. Tropical cyclone activity in the North Atlantic basin was also influenced by below average activity in the 2014 West African monsoon season, which suppressed the development of African easterly winds.

The year 2014 marks the longest period on record – nine consecutive years since Hurricane Wilma in 2005 – that no major hurricanes made landfall over the U.S., and also the ninth consecutive year that no hurricane made landfall over the coastline of Florida.

The U.S. experienced only one landfalling hurricane in 2014, Hurricane Arthur. Arthur made landfall over the Outer Banks of North Carolina as a Category 2 hurricane on July 4, causing minor damage. While Mexico and Central America were impacted by two landfalling storms and the Caribbean by three, Bermuda suffered the most substantial damage due to landfalling storms in 2014.Hurricane Fay and Major Hurricane Gonzalo made landfall on the island within a week of each other, on October 12 and October 18, respectively.

Early 2015 hurricane season forecasts by Colorado State University (CSU) and Tropical Storm Risk (TSR) predict higher tropical cyclone activity in the Atlantic Basin than observed in 2013 and 2014.

2014 marks the longest period on record – nine consecutive years – that no major hurricanes made landfall over the U.S.

[1]The Main Development Region spans the tropical Atlantic Ocean and the Caribbean Sea between 10-20°N, 20-80°W

OVERVIEW OF THE 2014 NORTH ATLANTIC HURRICANE SEASON

The Atlantic hurricane season runs from June 1 to November 30. Hurricane season activity is characterized by the number of named storms, hurricanes, and major hurricanes[2] in the Atlantic throughout this period. The 2014 season was characterized by below average named storm and major hurricane activity, though near average hurricane activity (*see Figure 1*). The season closed with eight named storms, of which six were classified as hurricanes. Of the six hurricanes, two reached major hurricane strength.

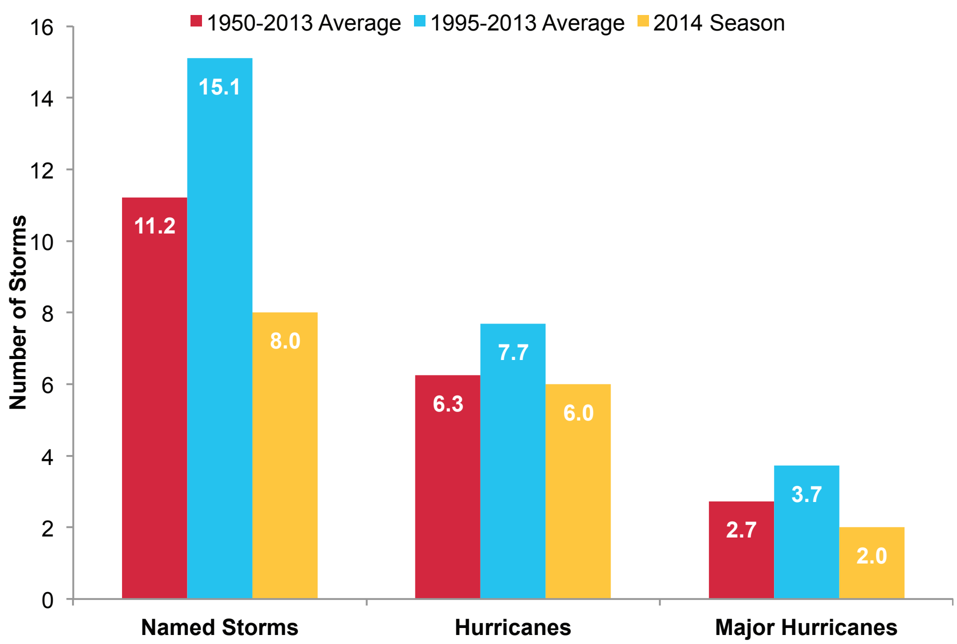


Figure 1: Comparison of the 2014 North Atlantic hurricane season storms to the long-term and recent averages (data from Hurricane Research Division)

The 2014 season saw the lowest number of named storms in 17 years, since 1997. Eight named storms formed in 2014, 47% below the 1995-2013 recent average[3] (15.1) and 29% below the 1950-2013 long-term average[4] (11.2).

The total of six hurricanes in 2014 is 16% below the recent average (7.7) and 5% below the long-term average (6.3). Of the 2014 hurricanes, three reached Category 1 strength, one reached Category 2 strength, and two reached major hurricane strength (Category 3 and above), as defined by the Saffir-Simpson Hurricane Wind Scale (SSHWS). The number of major hurricanes during the 2014 season was 46% below the recent average3 (3.7) and 26% below the long-term average4 (2.7).

The only hurricane that made landfall over the U.S. in 2014 was Hurricane Arthur, the first named storm of the season, which made landfall over the southern end of North Carolina's Outer Banks, on Friday July 4 as a weak Category 2 hurricane with wind speeds of 100 mph (155 km/hr).

No major hurricanes made landfall in the U.S. in 2014. The last major hurricane to make U.S. landfall was Hurricane Wilma in 2005, meaning the U.S. has gone nine years without a major hurricane landfall. Since relatively reliable landfall data became available, the U.S. has never had a nine-year period without a major hurricane landfall (Masters, 2014). In 2012, Sandy reached major hurricane strength, but weakened significantly and transitioned to an extratropical system prior to landfall along the coast of southern New Jersey.

Major Hurricane Gonzalo was the strongest hurricane of the 2014 season and reached peak intensity as a Category 4 hurricane over the North Atlantic with maximum wind speeds of 145 mph (230 km/hr) on Wednesday, October 15. Prior to reaching peak intensity, Gonzalo made landfall over Antigua, in the Caribbean, on Monday, October 13 as a Category 1 hurricane before strengthening and making direct landfall over Bermuda on Friday, October 17 as a Category 2 hurricane (see
Figure 3).

The Accumulated Cyclone Energy (ACE[5]) index provides an alternative assessment of hurricane activity and defines the intensity and duration of tropical cyclones. As displayed in Figure 2, in 2014, the ACE index was 66, 36% lower than the long-term (1950–2013) average of 102 (black dotted line; WeatherBELL), and the fifth lowest that has been observed during the short-term (1995-2013) average (black dashed lineFigure2).

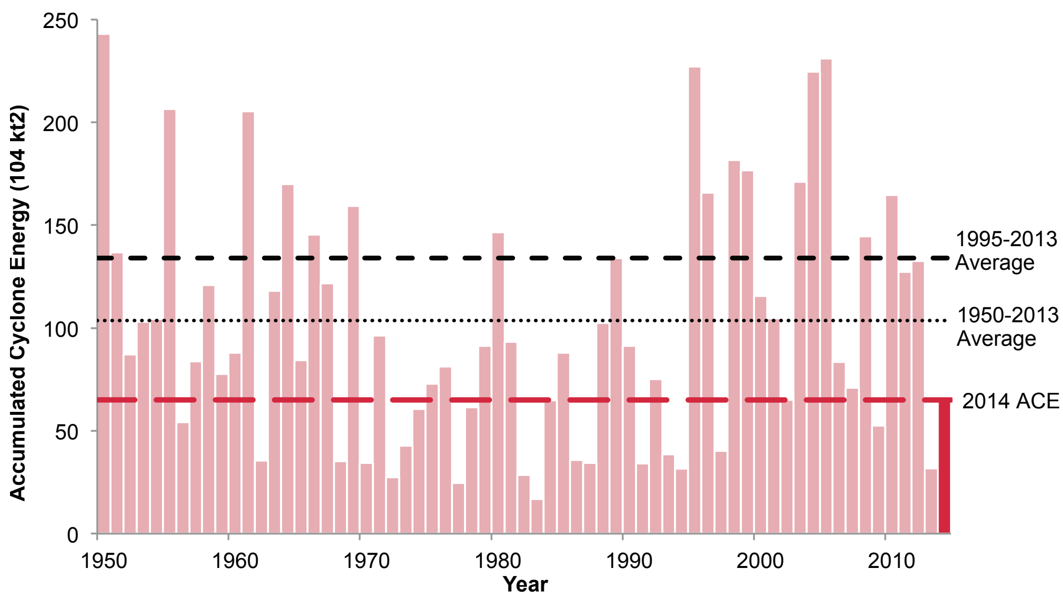


Figure 2: Atlantic hurricane season ACE totals and averages 1950–2013 (data from WeatherBELL)

[2] Named storms are defined as systems that reach tropical storm strength or above on the Saffir-Simpson Hurricane Wind scale (SSHWS) (NHC, 2014). The term hurricane is given to a system that reaches Category 1 on the SSHWS, while a major hurricane is classified as a Category 3 or higher on the SSHWS (NHC, 2014).

[3] Since 1995, it's widely recognized that the Atlantic Basin has been in a period of elevated activity compared to the long- term historical average of history, driven by a positive phase in the Atlantic Multi-decadal Oscillation (AMO).

[4] The historical database for landfalling hurricanes is generally agreed to be complete since 1900. However, the record of hurricane activity in the Atlantic Basin itself is generally agreed to be complete only from 1950 onward, following increases in aircraft reconnaissance and the onset of satellite technology.

[5] ACE is calculated as the square of the sum of the maximum sustained wind speed (in knots) at 6-hour intervals for the duration of the storm at tropical storm status or greater (sustained wind speeds of 35 knots or higher). The unit of ACE is $10^4 kn^2$.

THE 2014 NORTH ATLANTIC STORMS AND THEIR IMPACTS

As outlined previously, only one storm, Hurricane Arthur, made landfall over the U.S. in 2014. Two storms made landfall over Mexico and Central America: Tropical Storm Dolly made landfall over Mexico and Tropical Storm Hanna made landfall over Honduras and Nicaragua. The Caribbean was impacted by three landfalling storms in 2014: Hurricane Bertha, Hurricane Cristobal, and Major Hurricane Gonzalo; while two landfalls occurred over Bermuda: Hurricane Fay and Major Hurricane Gonzalo.

The 2014 season's hurricane activity is illustrated inFigure 3 and Figure 4 4 below.

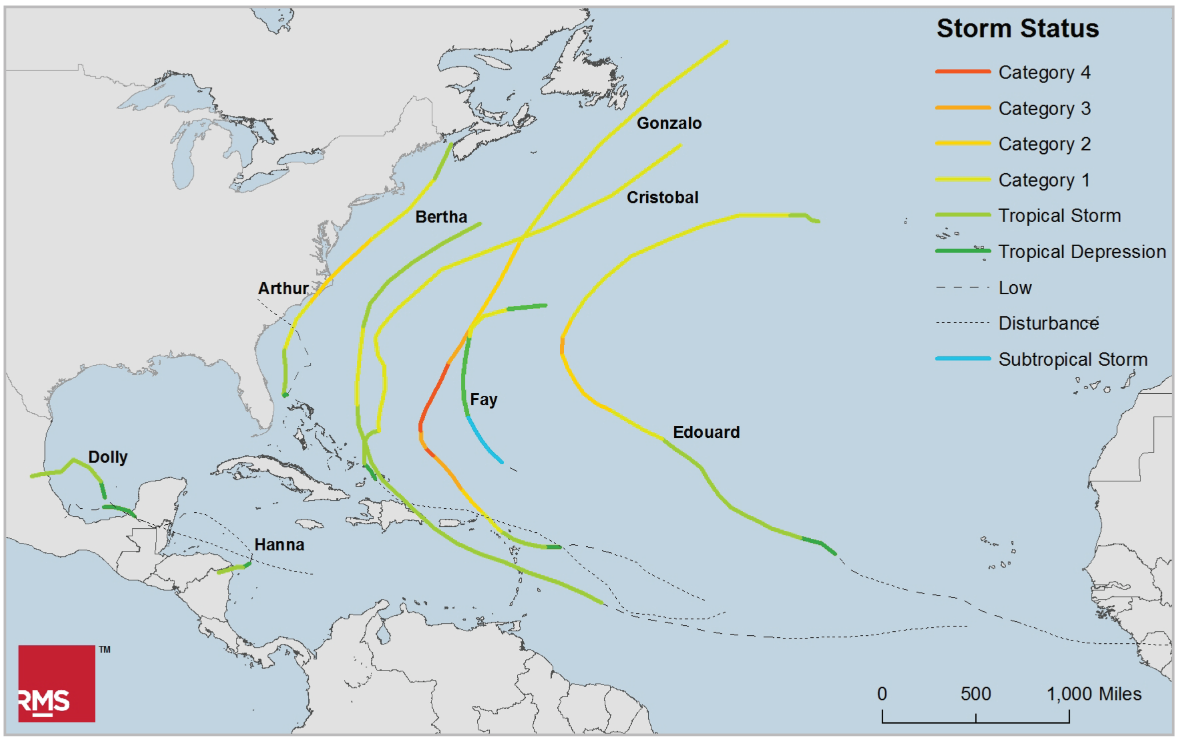


Figure 3: The 2014 Atlantic storm tracks and intensities (data from the NHC)

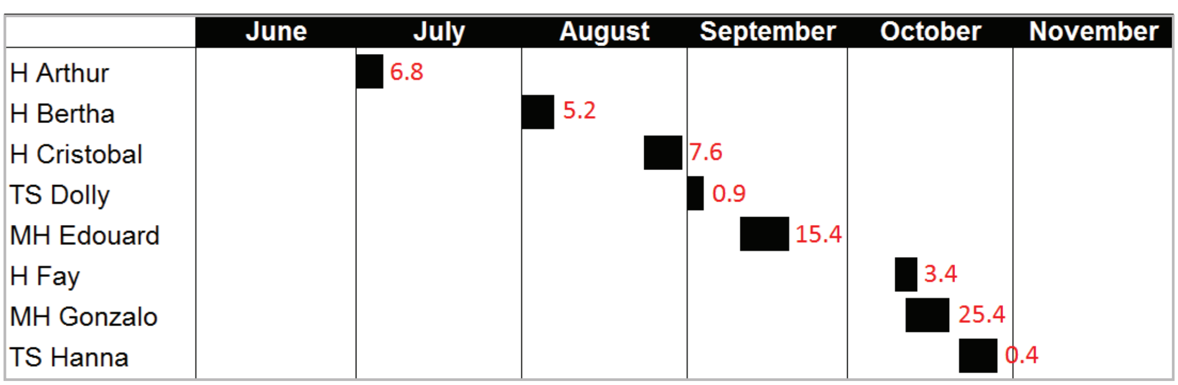


Figure 4: Timeline of the 2014 Atlantic hurricane season (data from the NHC as of December 9 2014; TS = Tropical Storm, H = Hurricane, MH = Major Hurricane) with ACE vales for each storm given in red (data from WeatherBELL as of December 9 2014)

Hurricane Arthur

The first named storm of the season, Hurricane Arthur, formed on Tuesday, July 1, 65 mi (105 km) east of Florida. Despite a strong upper level trough, Arthur tracked north and intensified to a Category 1 hurricane on July 3, 130 mi (210 km) off the southeast coast of Georgia. Arthur intensified as the system tracked northeast parallel to the coast and made landfall over the southern end of North Carolina's Outer Banks, near Cape Lookout, on Friday, July 4 as a weak Category 2 hurricane. After landfall, the system accelerated northeastward and weakened before turning extratropical and passing over the maritime Canadian provinces of New Brunswick and Nova Scotia.

Arthur brought up to 5 in (127 mm) of rainfall to North Carolina and storm surge heights of 3 to 6 ft (0.91 to 1.83 m), causing coastal flooding in the town of Salvo along the northern Outer Banks. More than 150 buildings were damaged and 44,000 power outages were recorded across the state.

On Friday, July 4 and Saturday, July 5, heavy rainfall and flash flooding were reported in Massachusetts as Arthur tracked approximately 100 mi (165 km) offshore. More than 10,300 power outages were reported in Massachusetts, 19,000 in Maine, and 1,600 in Vermont.

Arthur's remnants then passed the Canadian Maritimes. Damage to electrical infrastructure from fallen trees knocked out power to more than 290,000 buildings, with Nova Scotia and New Brunswick the worst affected areas. One fatality was reported in Canada as a result of Hurricane Arthur.

Hurricane Bertha

Bertha tracked through the Caribbean as a tropical storm and made landfall over Martinique on August 2 before making landfall over the Dominican Republic and the Turks and Caicos the following day. Light wind shear allowed Bertha to rapidly intensify and reach Category 1 status on August 4, 220 mi (350 km) northeast of the Bahamas. After this time, Bertha gradually weakened while tracking northeast and transitioned to an extratropical system northwest of Bermuda on August 6.

Bertha brought strong winds and heavy rainfall to the Caribbean as it tracked through the islands. Rainfall amounts of 5 in (127 mm) were recorded in Puerto Rico, with isolated amounts reaching 8 in (200 mm). More than 150,000 power outages were reported in the Lesser Antilles on August 1, 80,000 on the island of Martinique. A further 39,000 power outages were recorded in Puerto Rico on August 2. Airports and ferry services in Puerto Rico and the Dominican Republic were disrupted on August 1 and 2. No injuries were reported in the Caribbean.

Bertha's remnants tracked northeast across the Atlantic as an extratropical system and brought heavy rainfall and strong winds to the U.K. and localized flooding to England from August 8 to August 12. Approximately 80 homes were damaged in East Riding, Norfolk, Cambridge, and Lincolnshire. More than 1,600 power outages were reported across the U.K., while many ferry services on the southern coast were cancelled and more than 60 flights were cancelled at Heathrow Airport.

Hurricane Cristobal

Cristobal formed from a tropical wave that developed in the Atlantic Hurricane Main Development Region (MDR). Having organized to a tropical depression east of the Lesser Antilles, Cristobal tracked northwest across the Caribbean, bringing torrential rain to the Dominican Republic, Haiti, and Puerto Rico. The system was declared a tropical storm on August 24, 70 mi (120 km) northwest of the Turks and Caicos Islands and strengthened to a Category 1 hurricane on August 26, east of the Bahamas. Cristobal then tracked northeast and remained a Category 1 hurricane until it transitioned to a strong extratropical cyclone 560 mi (910 km) east of Nova Scotia on August 29.

As a result of heavy rainfall, two fatalities were reported in the Dominican Republic. In Haiti, 32 homes were damaged as a result of strong winds and heavy rainfall. In Puerto Rico, 23,500 power outages were reported. Up to 12 in (300 mm) of rainfall caused floodwaters of 5 ft (1.5 m) in the Turks and Caicos, which flooded homes and caused one fatality.

Tropical Storm Dolly

On September 1, a tropical wave crossed the Yucatán Peninsula, Mexico and rapidly strengthened as it entered the Bay of Campeche, Gulf of Mexico. Dolly was declared a tropical storm on September 2 and made landfall over the eastern Mexican state of Veracruz, 30 mi (45 km) south of the city of Tampico, the next day. After tracking west over land and losing its well-defined center of circulation, Dolly dissipated over eastern Mexico on September 3.

Dolly brought up to 8 in (200 mm) of rainfall to northern portions of Veracruz. The town of Cabo Rojo, Veracruz was hit hardest. More than 200 homes were flooded, 80 of which sustained significant damage. On September 4, flooding was reported in the port city of Veracruz, causing two raised streets to collapse, damaging cars and structures. One fatality was attributed to Tropical Storm Dolly.

Major Hurricane Edouard

Edouard was the first major hurricane of the 2014 season and the first major hurricane in the North Atlantic Basin since Major Hurricane Sandy in 2012, though unlike Sandy, Edouard remained a large distance from land.

Edouard formed as a result of a tropical wave that exited the west coast of Africa and began tracking west-northwest across the Atlantic hurricane MDR. On September 12, Edouard was classified as a tropical storm; it intensified to a Category 1 hurricane on September 15, 800 mi (1,300 km) southeast of Bermuda. Over a 24-hour period, the system intensified as it curved to the northeast, reaching Category 3 hurricane status, 420 mi (675 km) east of Bermuda. Edouard weakened as it continued tracking northeast across the Atlantic and transitioned to an extratropical cyclone on September 19.

Hurricane Fay

On October 10, a subtropical depression was identified north of the Leeward Islands. Fay tracked northwest over the North Atlantic, towards Bermuda, and on October 11 became a tropical storm and the sixth named storm of the 2014 season. Strong wind shear prevented the system from intensifying rapidly as it neared Bermuda, though Fay strengthened to a Category 1 hurricane just prior to landfall on the east coast of the island on October 12, with maximum sustained winds of 80 mph (130 km/hr). Fay was the first hurricane to make a direct landfall in Bermuda since Hurricane Emily in 1987. After landfall, Fay curved to the east before dissipating over the North Atlantic Ocean.

Fay's strong winds uprooted trees and caused damage to a number of roofs and shutters in Bermuda. Approximately 18,000 homes on the island were affected by power outages on October 12 and many public transportation systems, including bus services and Bermuda's LF International Airport, experienced disruption. No casualties or major injuries were reported.

Major Hurricane Gonzalo

What would become the second major hurricane of the 2014 season formed east of the Lesser Antilles on October 12. Gonzalo made landfall on the island of Antigua as a tropical storm prior to intensifying to a Category 1 hurricane on October 13.

Gonzalo make its second landfall the following day on the island of Anguilla as a Category 1 hurricane. Tracking over the Caribbean, Gonzalo intensified rapidly, reaching major hurricane status (Category 3) on October 14 and strengthening to a Category 4 hurricane on October 15. Gonzalo weakened prior to reaching Bermuda and made landfall over the island as a Category 2 hurricane on October 18. The storm continued to track northeast and became extratropical by October 21. The storm's remnants impacted the U.K. on October 21.

Gonzalo is the strongest storm to impact Bermuda since Major Hurricane Fabian, which passed just to the west of the island as a Category 3 hurricane in early September 2003, producing maximum sustained wind speeds near 120 mph (195 km/hr) and peak gusts of 165 mph (270 km/hr). Approximately 35,700 of the island's 36,000 metered homes experienced power outages as Gonzalo made landfall on October 18. Transport links, schools, and government buildings experienced disruption, though no major damage was reported across the island.

Prior to impacting Bermuda, Gonzalo brought heavy rainfall and strong winds to the Caribbean Leeward Islands, damaging homes, toppling trees, and causing power outages; however, no widespread major damage was reported. The Virgin Islands and Puerto Rico experienced light rainfall, with no significant damage. One fatality and a dozen injuries were reported on the island of St. Martin.

The remnants of Gonzalo tracked across the North Atlantic, bringing strong winds, localized heavy rainfall and flooding to southeast Europe. Austria, Hungry, Bosnia, Croatia, and Greece were impacted by heavy rainfall. Bosnia fared the worst; 900 buildings were flooded and two people died.

Tropical Storm Hanna

The remnants of Tropical Storm Trudy, which formed in the East Pacific and brought widespread flooding to southern Mexico on October 18, traveled across Central America and entered the Bay of Campeche, Gulf of Mexico on October 20. The remnants of Trudy tracked southeast and re-intensified to become the eighth and final named storm of the 2014 season on October 27 – named Tropical Storm Hanna in the Atlantic. Hanna curved to the west and made landfall over Honduras and Nicaragua on October 27 before rapidly dissipating the same day over northeast Nicaragua.

The National Hurricane Center (NHC) issued a tropical storm warning for Punta Patuca, Honduras to Puerto Cabezas, Nicaragua on October 27. Hanna was expected to bring rainfall amounts of up to 5 in (125 mm), though no reports of heavy rainfall emerged over northeastern Nicaragua and eastern Honduras. No damage or casualties associated with Hanna were reported.

REVIEW OF THE 2014 SEASON FORECASTS

Many forecast groups predicted that 2014 would be a quiet season with below average activity rates in the Atlantic, with fewer than the recent average3 and long term average4 of tropical storms, hurricanes, and major hurricanes. While the 2014 season ended with below average activity in terms of named storms and major hurricanes and near average hurricane activity, the reasons for this were not those predicted. Instead, other oceanic and atmospheric conditions influenced the low basin activity of 2014, which is discussed in the following section “Role of the Ocean and Atmosphere in the 2014 Season Activity”.

Table 1 shows the 2014 seasonal forecasts from the three main forecasting groups: Colorado State University (CSU), Tropical Storm Risk (TRS), and National Oceanic and Atmospheric Administration Climate Prediction Center (NOAA CPC). Long-term (1950-2013) and recent (1995-2013) activity averages are also presented.

Forecast Group	Named Storms	Hurricanes	Major Hurricanes	ACE Index[4] ($10^4 kt^2$)
CSU (31 July)	10	4	1	65
TSR (5 August)	12 (±3)	6 (±2)	2 (±1)	70(±41)
NOAA CPC (7 August)	7 to 12	3 to 6	0 to 2	-
1950 – 2013 Average	11.2	6.2	2.7	101.8
1995 – 2013 Average	15.1	7.6	3.7	132.7
2014 Season	**8**	**6**	**2**	**66**

Table 1: Summary of the 2014 Atlantic Basin seasonal forecasts, average activity, and 2014 season storm totals.

The 2014 forecasts from all three groups predicted below average activity, with the number of tropical storms, hurricanes, and major hurricanes below the long-term average4and recent average3. Predicted ACE values were significantly below the long term and recent averages, suggesting short lived storms would occur, which was also reflected by the low number of major hurricanes forecasted.

The 2014 forecasts anticipated a below-average season in the Atlantic Basin due to a combination of interrelated atmospheric and oceanic conditions including:

• Below-average sea surface temperatures (SSTs) observed in the Atlantic Main Development Region (MDR) during the first half of 2014, which were expected to continue throughout the 2014 season

• The expected formation of El Niño conditions in the Pacific Basin as part of the El Niño-Southern Oscillation (ENSO), notably during the August to October peak of hurricane season, which would typically decrease hurricane activity in the Atlantic Basin

The forecasters' 2014 condition predictions, however, proved somewhat inaccurate. Increasing SSTs from the end of July to the end of the season were recorded in the tropical and subtropical Atlantic, while neutral ENSO conditions persisted across the basin throughout the season.

ROLE OF THE OCEAN AND ATMOSPHERE IN THE 2014 SEASON ACTIVITY

The 2014 season closed as expected despite inaccurate forecasts of sea surface temperatures (SSTs) and ENSO conditions by many main forecasting groups. Oceanic and atmospheric conditions unable to be predicted more than a few weeks in advance were the key factors in suppressing tropical cyclone activity in 2014. The following conditions resulted in a particularly quiet 2014 Atlantic hurricane season:

• Anomalously low Atlantic mid-level moisture in the Main Development Region (MDR) from July to September

• Anomalously high tropical Atlantic subsidence over the MDR during the peak months of hurricane season August to October

• Above average levels of wind shear across the Caribbean in September and October

These three conditions, which create unfavorable conditions for tropical cyclone development, also contributed to the low tropical cyclone activity of the 2013 season. In 2013, these conditions were the result of the weakening of the Atlantic Multi-Decadal Oscillation (AMO)[6], though it is unclear at this time if this is the case for the 2014 season.

The following section discusses the conditions generally used for seasonal forecasts, as well as the factors that contributed to suppressed activity in 2014.

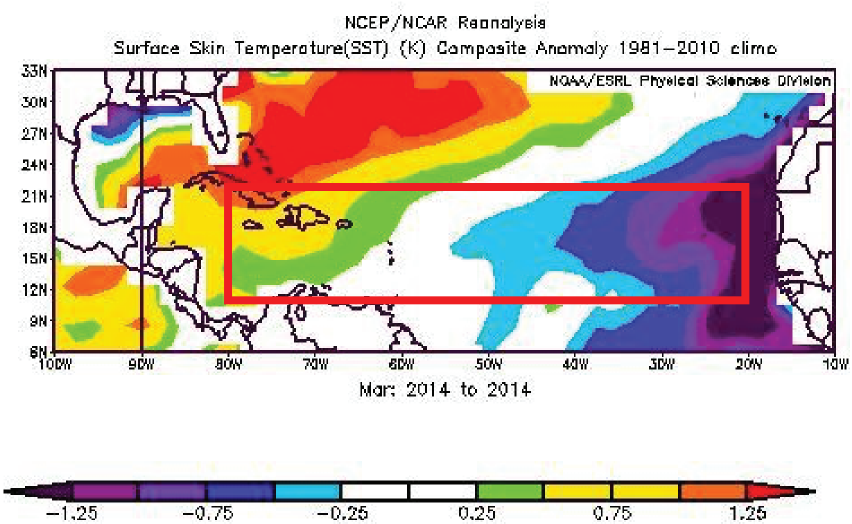
[6] The Atlantic Multi-decadal Oscillation (AMO) is a mode of natural variability occurring in the North Atlantic Ocean, which has its principle expression in the sea surface temperature (SST) field and is identified as a coherent pattern of variability in basin-wide North Atlantic SSTs with a period of 60-80 years.

Atlantic Sea Surface Temperature (SSTs)

The North Atlantic Basin was characterized by significant changes in sea surface temperatures (SSTs) during the course of the 2014 season, as was the case in the 2013 season. In March, low SST anomalies[7] were observed in the tropics, while warm SST anomalies were recorded off the U.S. East Coast (Figure 5A). Klotzbach and Gray (2014a) have established that these anomalies were associated with a weak thermohaline circulation (THC) across the North Atlantic.

Over the following months, a negative North Atlantic Oscillation (NAO) developed, weakening trade winds and reducing the mixing and upwelling of cooler sub-surface waters in the MDR, which resulted in warming SSTs. SSTs continued to warm from the end of July (Figure 5B), while SSTs off the U.S. East Coast cooled thorughout this period.

SSTs in the North Atlantic continued to warm throughout the remainder of the hurricane season due to the negative NAO, resulting in warm SSTs observed in November 2014 (Figure 5C) that would typically be associated with an active hurricane season. Conversely, negative SST anomalies developed off U.S. East Coast.



[7] An anomaly is defined as a parameter that deviates from the average. Anomalies are important in the scientific community they represent the difference between the observed and theoretically expected data.

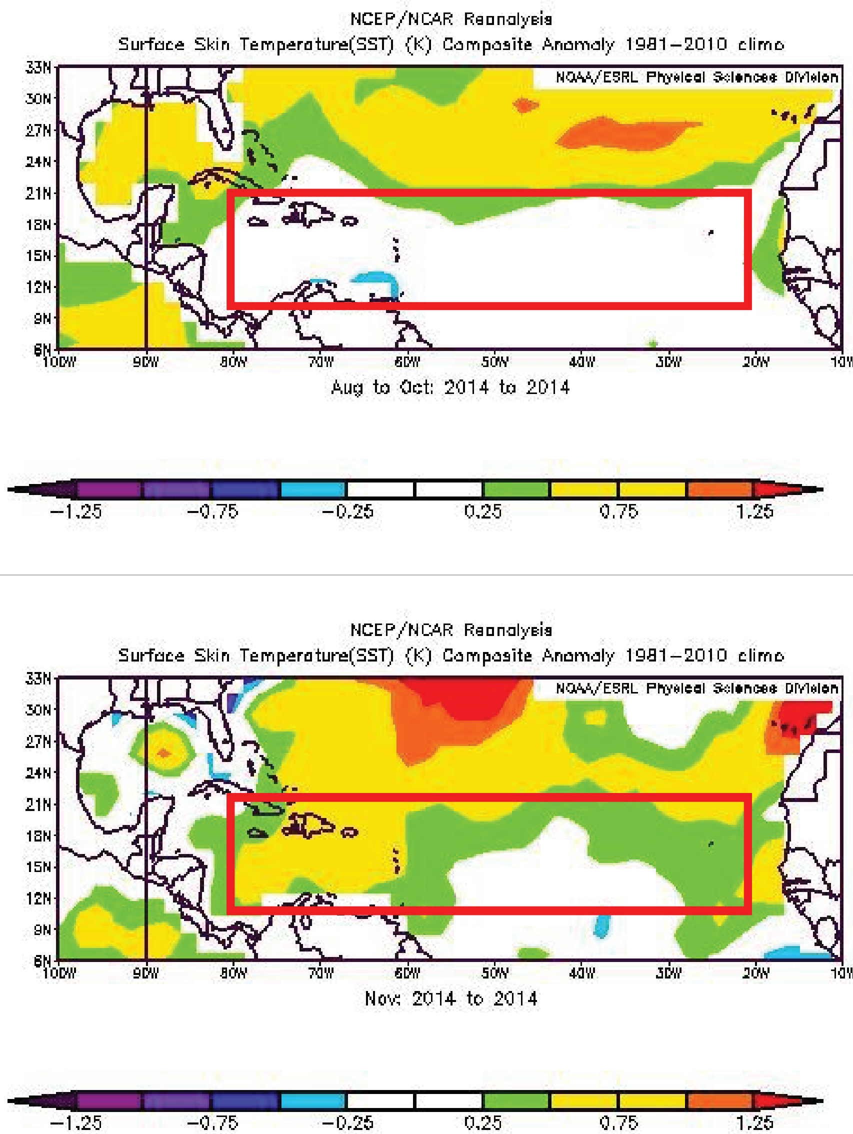


Figure 5: Anomalous SST changes across the North Atlantic Basin (°C) with the MDR in red (image from NOAA/ERSL). A) March 2014 B) August to October 2014 C) November 2014

El Niño Southern Oscillation (ENSO)

There is a strong relationship between ENSO and hurricane activity (Gray, 1984). El Niño events (ENSO warm phase) in the Pacific Basin inhibit hurricane activity due to teleconnections that increase vertical wind shear over the Atlantic MDR, with the reverse true for La Niña events. ENSO neutral conditions generally neither enhance nor suppress tropical cyclone activity in the Atlantic, with near-average wind shear levels over the main development region.

Despite the prediction of a weak to moderate El Niño event by most forecasting groups, neutral ENSO conditions persisted across the tropical Pacific throughout the 2014 North Atlantic hurricane season (Figure 6). The strong vertical wind shear and mass subsidence observed across most of the basin, which are discussed in more detail later, contributed to conditions in the North Atlantic behaving similarly to an El Niño.

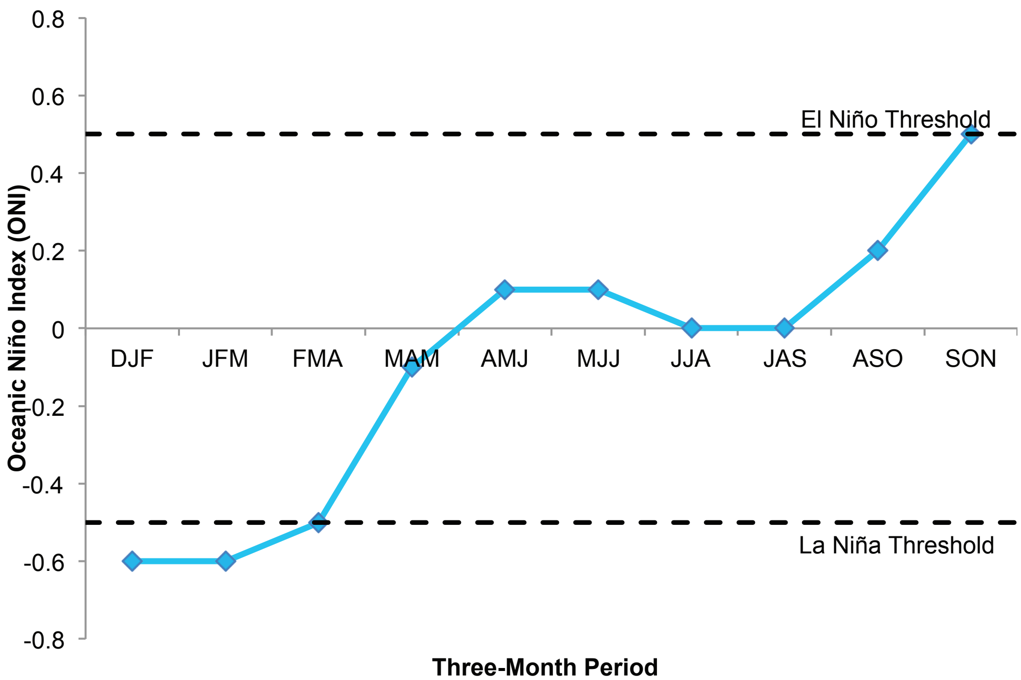


Figure 6: The 2014 Oceanic Niño Index (ONI) [three-month running mean of ERSST.v3b SST anomalies in the Niño 3.4 region (5°N–5°S, 120°–170°W)], based on the 1971–2010 base period (°C). Months of the year are abbreviated with first letter, e.g., A=April or August). Data from NOAA CPC. El Niño/La Niña Conditions are defined by six or more consecutive months above/below the (-)0.5°C threshold.

Madden-Julian Oscillation (MJO)

The Madden-Julian Oscillation (MJO) is an intra-seasonal oscillation of tropical rainfall that often cycles every 30–60 days. It is characterized by an eastward progression of large regions of both enhanced and suppressed tropical rainfall.

There is evidence to show that the MJO modulates tropical cyclone activity by providing a large-scale environment that is both favorable and unfavorable for development (Klotzbach, 2010): MJO-related descending motion is unfavorable for tropical storm development, while an ascending motion is favorable for thunderstorm formation and tropical storm development.

The MJO variability was relatively inactive during the peak months of the 2014 Atlantic hurricane season, having no significant impact on tropical storm development.

Tropical Atlantic Sea Level Pressure

An important factor contributing to low activity in the 2014 season was the sea level pressure (SLP) in the tropical and subtropical Atlantic. Tropical cyclone activity in the North Atlantic Basin can be enhanced by lower SLP in the tropical Atlantic, due to increased instability and increased low-level moisture. The 2014 hurricane season experienced slightly below average SLP in the tropics and above average SLP anomalies in the subtropical Atlantic (Figure 7). Although slightly below SLP was observed in the tropics, this did not increase hurricane activity in the basin. The increased SLP in the subtropical Atlantic had a greater impact on the MDR, reducing tropical cyclone activity and contributing to the below-average season in 2014.

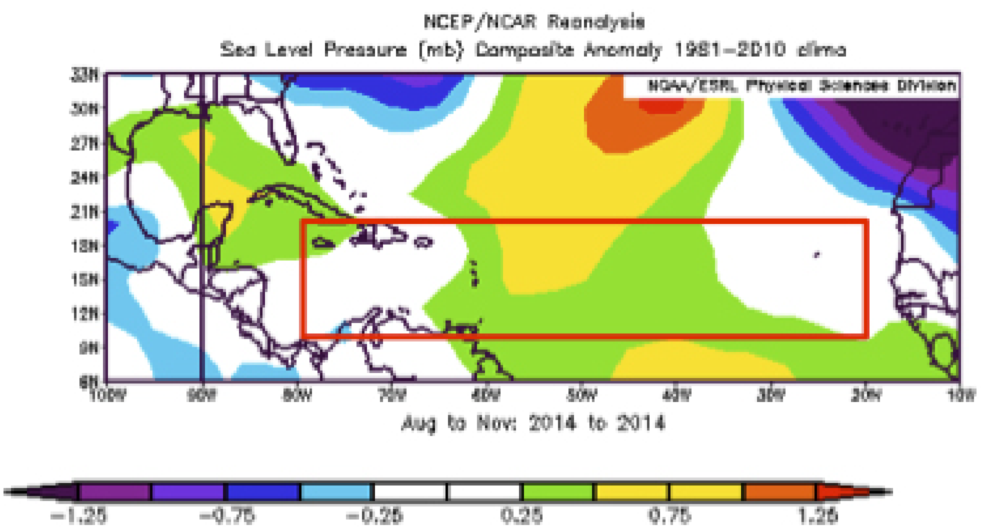


Figure 7: August to November 2014 anomalous SLP changes across the North Atlantic Basin (mb) with the MDR in red (image from NOAA/ERSL).

Tropical Atlantic Vertical Wind Shear

Although vertical wind shear was near average across much of the MDR in 2014, anomalously strong vertical wind shear was observed across the Caribbean and the south of the Gulf of Mexico (Figure 8), which likely played a role in restricting tropical cyclone formation and development.

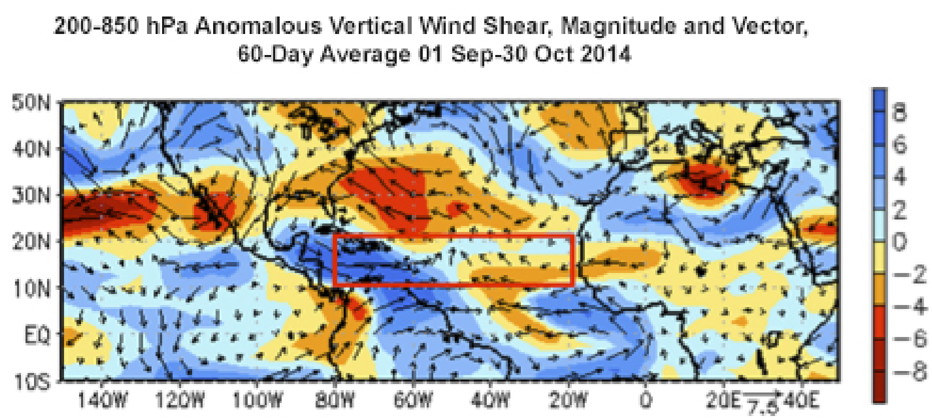


Figure 8: Anomalous vertical wind shear observed across the Atlantic from September 1 to October 30, 2014 (ms-1) (image from NOAA/NCEP). The MDR is in red.

Figure 9 shows the standardized anomalies of 200-850 mb zonal wind shear (the east-west component of shear) for the tropical Atlantic (10-20°N, 60-20°W) and the Caribbean (10-20°N, 88-60°N), with respect to the 1981-2010 climatology. Zonal wind shear for the peak three months of the Atlantic hurricane season (August, September, and October) is

illustrated. The zonal wind shear was near average across the tropical Atlantic during 2014, though the wind shear was much stronger across the Caribbean, particularly in September (Figure 8). According to Klotzbach and Gray (2014a), the wind shear experienced in the Caribbean in September was the second strongest on record since 1950, with the strongest occurring in 1972. As strong vertical wind shear can limit tropical storm activity, the above average shear observed in the Caribbean likely contributed to the low activity observed during the 2014 Atlantic hurricane season. This elevated level of wind shear is more typically associated with a weak to moderate El Niño year, rather than the neutral ENSO conditions which persisted throughout 2014. In 2013 strong vertical wind shear in the Caribbean was attributed to a weakened AMO, though it is unclear if this is the case for the 2014 season

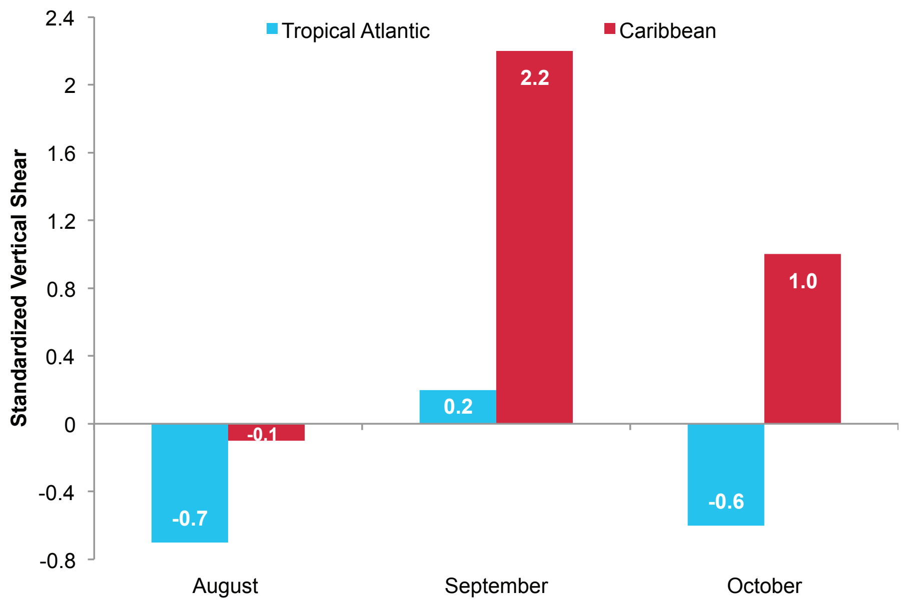


Figure 9: Anomalous vertical wind shear (in standard deviations) during August, September, and October for the Tropical Atlantic and the Caribbean (data source Klotzbach and Gray, 2014a).

Tropical Atlantic Moisture

As was the case in the 2013 North Atlantic hurricane season, one of the main contributing factors to this year's inactive season was the anomalous dryness that persisted across the tropical Atlantic throughout the peak months of MDR formation (July–September).

Moist air in the low and mid-levels of the atmosphere is critical for tropical cyclone development. Dry air hinders development by increasing the energy barrier that must be overcome to allow air to rise up from the water's surface. Figure 10 shows the anomalous 500-mb relative humidity during the three-month period from July through September 2014. During this period, relative humidity was low across the MDR, with even drier anomalies noted to the south of MDR.

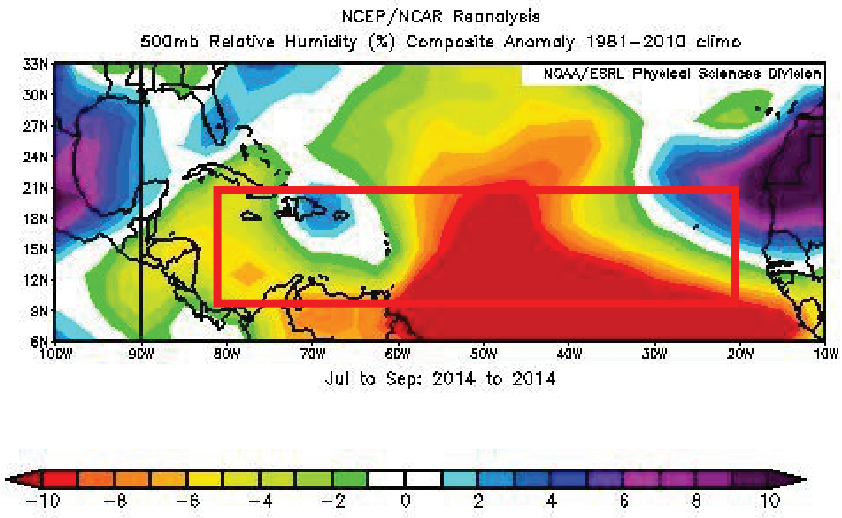


Figure 10: July to September 2014 500 mb relative humidity moisture anomalies (%). Image from NOAA/ERSL. The MDR is in red.

Tropical Atlantic Subsidence

Another potential reason for the relative inactivity in 2014 in the North Atlantic is anomalous atmospheric subsidence (sinking air) across the MDR. The peak MDR formation months (July to September) were characterized by a significant anomalous sinking motion. This sinking motion suppressed the deep convective development necessary for tropical cyclone formation and maintenance. This is measured by upper-level velocity potential anomalies, as shown in Figure 11 for the tropical Atlantic, where positive velocity potential at upper levels indicates an upper-level convergence and sinking motion. It appears that from July to September, a high proportion of the MDR and Caribbean was experiencing anomalous subsidence, which would have acted to inhibit tropical cyclone development.

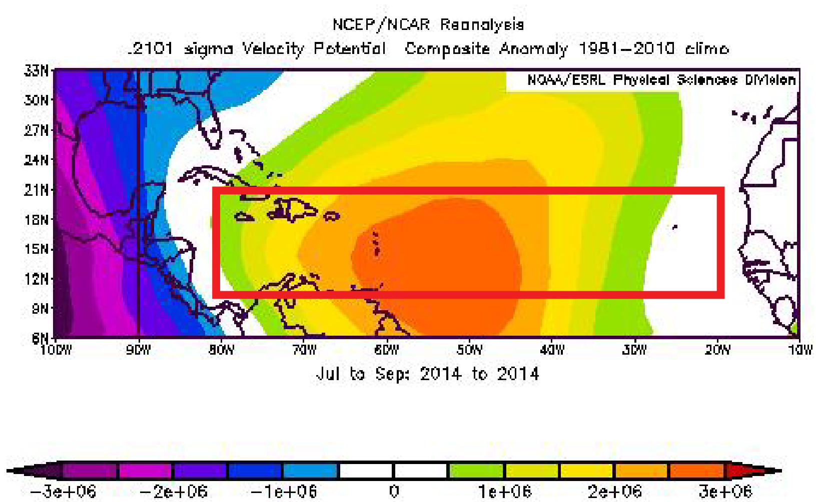


Figure 11: Upper-level velocity potential anomalies July to September 2014 (m*m/s) (image from NOAA/ERSL). The MDR is highlighted in red.

According to Klotzbach and Gray (2014a), the sinking motion over the MDR persisted across the season and from August to October 2014 was the third strongest on record since 1979.

Steering Currents

Steering currents in the troposphere, resulting from atmospheric pressure patterns across the northern hemisphere, determine the movement of storm systems. In 2014, as has been the case for several years, an elongated region of relatively low atmospheric pressure known as anomalous troughing dominated the U.S. East Coast. This anomalous troughing peaked in the eastern and western North Atlantic Basin from August to October, as seen in Figure 12. This resulted in a predominant steering flow that prevented storms progressing towards the U.S. East Coast, reducing tropical cyclone activity in the region. As previously mentioned, the U.S. has now gone nine years without a landfalling major hurricane, the longest period on record.

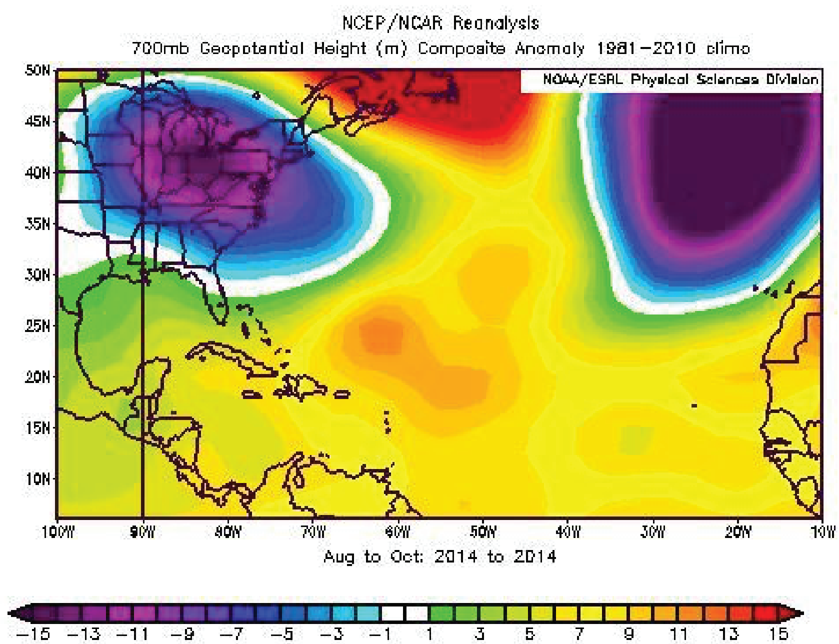


Figure 12: 700 mb geopotential height anomalies (m) in the eastern and western North Atlantic Basin from August to October 2014 (image from NOAA/ERSL).

OUTLOOK FOR THE 2015 NORTH ATLANTIC HURRICANE SEASON

Early forecasts for the 2015 North Atlantic hurricane season were issued in December 2014 by TSR and CSU. TSR issued its first forecast for the 2015 hurricane season on December 9, predicting 13 (±4) tropical storms, 6 (±3) hurricanes, and 2 (±2) major hurricanes, approximately 20% below the long-term average (1950-2013). TSR have forecast that the 2015 season ACE index will reach 79 (±58) with a 24% probability that the index will be above the long-term average (1950-2013), a 32% probability it will be near average, and a 44% chance that the index will be below average. TSR notes a large degree of uncertainty associated with its December forecast. This is associated with the low forecasting skill this far in advance of the hurricane season (TSR, 2014).

On December 11, CSU issued a qualitative discussion of features likely to affect the 2015 Atlantic hurricane season, rather than a specific quantitative forecast. According to Klotzbach and Gray (2014b), the 2015 Atlantic hurricane season will be determined by the strength of the thermohaline circulation (THC) and AMO, as well as the state of ENSO. CSU expect a positive AMO and a strong THC will return to the Atlantic during the 2015 season; however, it is unclear whether the presently developing weak El Niño will persist throughout the 2015 season. Despite the quiet seasons in 2013 and 2014, CSU believe the Atlantic Basin is still in an active phase, which began in 1995.

As in previous years, NOAA does not release a seasonal forecast prior to late May.

The number of storms that will make landfall on an Atlantic coastline or over the Caribbean in 2015 will be determined by the weather patterns and steering currents through the season, which cannot not be predicted this far in advance.

RMS will provide an in-depth review of the seasonal forecasts and the oceanic and atmospheric conditions for the 2015 hurricane season in June 2015, along with a detailed overview of its Event Response offerings for the 2015 season.

References

Gray, W.M. (1984). “Atlantic seasonal hurricane frequency. Part I: El Niño and the 30 mb quasi-biennial oscillation influences.” Monthly Weather Review, 112. 1649–1668.

Hurricane Research Division http://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html

Klotzbach, P. J. (2010). “On the Madden-Julian Oscillation-Atlantic Hurricane Relationship.” J. of Climate, 23. 282–293

Klotzbach, P. J. and W.M. Gray (2014a). “Summary of the 2014 Atlantic Tropical Cyclone Activity and Verification of Author’s Seasonal and Two-Week Forecasts”. Department of Atmospheric Science: Colorado State University

Klotzbach, P. J. and W.M. Gray (2014b). “Qualitative Discussion of Atlantic Basion Seasonal Hurricnae Activity for 2015”. Department of Atmospheric Science: Colorado State University

Masters (2014). The 2014 Atlantic Hurricane Season Ends With Below-Average Activity

NHC (2014). http://www.nhc.noaa.gov/aboutgloss.shtml#t

TSR (2014). Extended Range Forecast for Atlantic Hurricane Activity 2015

WeatherBell Models. http://models.weatherbell.com/tropical.php

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