ANNUAL SUMMARY

Atlantic Hurricane Season of 2009

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(Manuscript received 27 April 2010, in final form 23 November 2010)

ABSTRACT

The 2009 Atlantic season was marked by below-average tropical cyclone activity with the formation of nine tropical storms, the fewest since the 1997 Atlantic hurricane season. Of these, three became hurricanes and two strengthened into major hurricanes (category 3 or higher on the Saffir–Simpson Hurricane Wind Scale). In addition, there were two tropical depressions that did not reach storm strength. The numbers of tropical storms and hurricanes were below the long-term averages of 11 named storms and 6 hurricanes, although the number of major hurricanes equaled the long-term average of 2. Many of the cyclones remained relatively weak. Only one tropical cyclone, Tropical Storm Claudette, made landfall in the United States, although Ida affected the northern Gulf Coast as a tropical storm before moving inland as an extratropical cyclone. Hurricane Bill and Tropical Storm Danny indirectly affected the East Coast by producing high surf, rip currents, and beach erosion; Bill also produced tropical storm conditions over Bermuda and parts of Atlantic Canada. Hurricane Ida made landfall in Nicaragua and also affected parts of Honduras, the Yucatan Peninsula of Mexico, and western Cuba. Tropical Storm Erika had minor effects on the northern Leeward Islands, mainly in the form of light rain, and Tropical Storm Grace moved through the Azores with little impact. The death toll from the 2009 Atlantic tropical cyclones was six.

A verification of National Hurricane Center official forecasts during 2009 is also presented. Official track errors and forecast skill set records for accuracy at lead times between 24 and 72 h. Official intensity forecast errors were mostly larger than the previous 5-yr means, although intensity forecast skill was at or above historical highs since the intensity skill baseline [i.e., Decay-Statistical Hurricane Intensity Forecast model version 5 (Decay-SHIFOR5)] errors were well above average.

1. Introduction

Tropical cyclone activity during the 2009 Atlantic season (Fig. 1 and Table 1) was below average with the formation of nine tropical storms, the fewest number of named storms since the 1997 Atlantic hurricane season. Three of the storms became hurricanes and two strengthened to major hurricane status [maximum 1-min winds of greater than 96 kt (1 kt = 0.5144 m s^{-1}), corresponding to category 3 or greater on the Saffir–Simpson Hurricane Wind Scale (Saffir 1973; Simpson 1974; Schott et al. 2010)].[1] In addition, there were two tropical depressions that did not reach storm strength. The numbers of tropical storms and hurricanes were below the long-term averages of 11 named storms and 6 hurricanes, but the number of major hurricanes equaled the long-term average of 2. Although the first tropical depression formed in late May, the season's first tropical storm did not occur until 11 August and marked the latest formation of a tropical or subtropical storm in a season since 1983, when Hurricane Alicia formed on 15 August (Case and Gerrish 1984). Thereafter, tropical cyclone activity occurred in every month through November. In terms of accumulated cyclone energy [(ACE; Bell et al. 2000), the sum of the squares of the maximum wind speed at 6-h intervals for (sub)tropical storms and hurricanes], activity in 2009 was about 60% of the long-term (1951–2000) median value of 87.5×10^4 kt^2 (Bell et al. 2010). By this measure, 2009 was the quietest season since 1997.

The below-normal tropical cyclone activity in the Atlantic appears to be the result of the El Niño that

[1] As of the 2010 hurricane season, the Saffir–Simpson Hurricane Scale has been revised and renamed the Saffir–Simpson Hurricane Wind Scale in order to emphasize that the scale only addresses hurricane-related wind impacts. The scale no longer includes central pressure, and it does not address the other hurricane-related impacts of storm surge, rainfall-induced flooding, and tornadoes.

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DOI: 10.1175/2010MWR3476.1

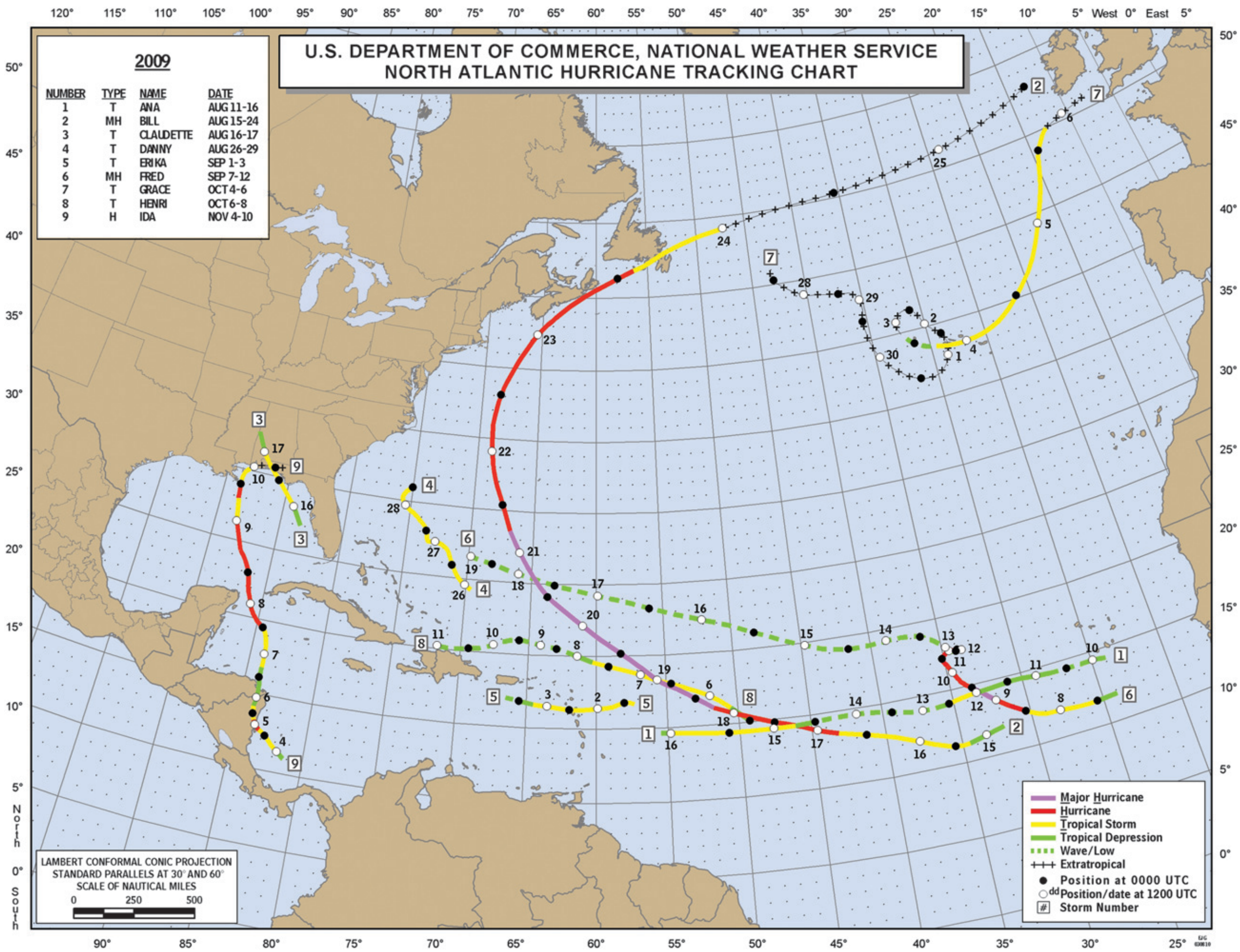

FIG. 1. Tracks of tropical storms and hurricanes in the Atlantic basin in 2009, including the extratropical and low stages.

began in June 2009 and became strong by the end of the hurricane season. This below-normal activity occurred even though sea surface temperatures (SSTs) were anomalously warm across much of the Atlantic basin. Indeed, an area-averaged SST anomaly of +0.50°C occurred across the Main Development Region (MDR; green box in Fig. 2) for the August–October peak months of the season (Bell et al. 2010). In El Niño years, however,

TABLE 1. 2009 Atlantic hurricane season statistics.

No.	Name	Class[a]	Dates[b]	Max 1-min wind (kt)	Min SLP (mb)	Direct deaths	U.S. damage ($ million)
1	Ana	TS	11–16 Aug	35	1003	0	0
2	Bill	MH	15–24 Aug	115	943	2	0
3	Claudette	TS	16–17 Aug	50	1005	2	Minor[c]
4	Danny	TS	26–29 Aug	50	1006	1	0
5	Erika	TS	1–3 Sep	45	1004	0	0
6	Fred	MH	7–12 Sep	105	958	0	0
7	Grace	TS	4–6 Oct	55	986	0	0
8	Henri	TS	6–8 Oct	45	1005	0	0
9	Ida	H	4–10 Nov	90	975	1	Minor[c]

[a] Tropical storm (TS), wind speed 34–63 kt (17–32 m s^{-1}); hurricane (H), wind speed 64–95 kt (33–49 m s^{-1}); major hurricane (MH), hurricane with wind speed 96 kt (50 m s^{-1}) or higher.
[b] Dates begin at 0000 UTC and include the tropical and subtropical depression stages but exclude the extratropical stage.
[c] Only minor damage was reported, but the extent of the damage was not quantified.

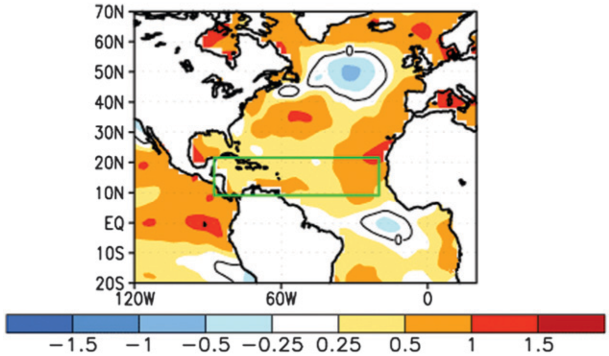

FIG. 2. The SST departures (shaded, °C) during August–October 2009 relative to 1971–2000 monthly means. SST data are from the NOAA Extended Reconstructed Sea Surface Temperature (ERSST) V3b database (Smith et al. 2008). The green box denotes the MDR. (Images courtesy of the NOAA/Climate Prediction Center.)

upper-level westerly winds at 200 mb over the Caribbean Sea tend to be stronger, which increases vertical wind shear and suppresses Atlantic hurricane activity (Gray 1984). In 2009, an enhanced and persistent tropical upper-tropospheric trough (TUTT) developed at 200 mb over the Caribbean Sea and the central Atlantic Ocean. The TUTT increased vertical wind shear across the MDR and produced anomalous upper-level convergence (Fig. 3), which led to reduced rising motion and a relative lack of deep convection in the tropics. These factors overwhelmed the contribution of the higher-than-normal SSTs to reduce tropical cyclone activity in 2009.

The season's storms produced relatively minor effects on land. Hurricane Bill produced tropical storm–force winds in Bermuda while its center passed well west of the island, and it later made landfall in Newfoundland, Canada, as a tropical storm. Bill also generated large swells across the western Atlantic that resulted in high surf and rip currents along most of the East Coast. Tropical Storm Claudette, the only tropical cyclone to make landfall in the United States, came ashore in the Florida Panhandle and produced relatively minor damage. Flooding and mud slides occurred in parts of the northern Leeward Islands and the Greater Antilles from Tropical Storm Erika. Ida produced the most significant damage of the season when it made landfall in Nicaragua as a category 1 hurricane and generated heavy rainfall across portions of Nicaragua, Honduras, the Yucatan Peninsula of Mexico, and western Cuba. Ida also produced tropical storm–force winds and storm surge along the northern Gulf of Mexico coast from Louisiana to the Florida Panhandle before it became extratropical shortly before moving inland. The season's tropical cyclones caused six deaths in the United States. All the fatalities resulted from dangerous marine conditions, and some occurred when the storms were located well offshore.

2. Individual storm summaries

The individual cyclone summaries below are based on poststorm meteorological analyses by the National Hurricane Center (NHC) using in situ and remotely sensed data from geostationary and polar-orbiting satellites, aircraft reconnaissance, weather radars, ships, buoys, and conventional land-based surface and upper-air observations. In-depth descriptions of data sources used by the NHC to analyze tropical cyclones have been provided in previous seasonal summaries (e.g., Franklin and Brown 2008), and more recently by Rappaport et al. (2009).

Poststorm analyses result in the creation of a ''best track'' database for each cyclone, consisting of 6-hourly representative estimates of the cyclone's center location, maximum sustained (1-min average) surface (10 m) wind, minimum sea level pressure (SLP), and maximum extent of 34-, 50-, and 64-kt winds in each of the four ordinal (northeast, southeast, southwest, and northwest) quadrants of the cyclone. A system is designated as a tropical cyclone in the best track if it satisfies the following definition: ''A warm-core, non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters with organized deep convection and a closed surface wind circulation about a well-defined center'' (NOAA/Office of the Federal Coordinator for Meteorology 2009). The tracks and statistics for the season's tropical storms and hurricanes, including their depression, extratropical, and remnant low stages (if applicable), are shown in Fig. 1 and Table 1, respectively. (Tabulations of the 6-hourly best-track positions and intensities can be found in the NHC Tropical Cyclone Reports available online at http://www.nhc.noaa.gov/pastall.shtml.)[2] The dates given for each cyclone in Table 1 only include the tropical and subtropical cyclone stages.

Damage in the United States due to this season's tropical cyclones was relatively minor and quantitative estimates are not available. Descriptions of the type and scope of damage are taken from a variety of sources, including local and international government officials, media reports, and local National Weather Service (NWS) Weather Forecast Offices (WFOs) in the affected areas. Tornado counts are based on reports provided by the WFOs and/or the NWS Storm Prediction Center. The strength of the tornadoes is rated using the enhanced Fujita (EF) scale (Texas Tech University 2006). Tables

[2] These reports contain storm information omitted here because of space limitations, including additional surface observations and a forecast and warning critique.

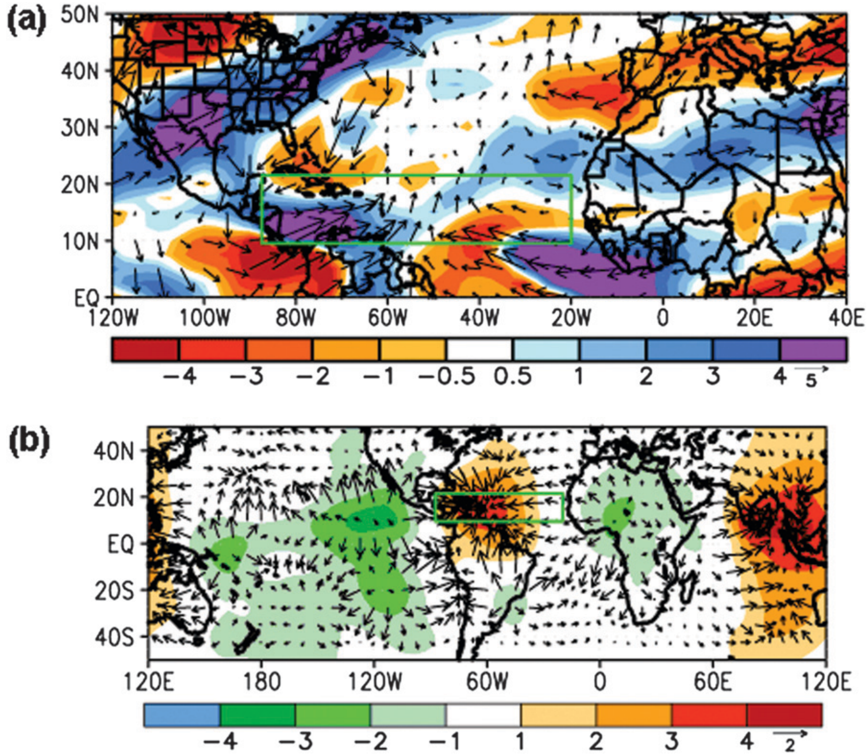

FIG. 3. (a) August–October 2009 departures from normal of 200–850-mb vertical wind shear magnitude (m s^{-1}) and vectors. Green box denotes the MDR. (b) August–October 2009 departures from normal 200-mb velocity potential (m^2 s^{-1}, shading) and divergent wind vectors (m s^{-1}). In both (a) and (b), the vector scale is on the right-hand side of the color bar. Data are from the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis (Kalnay et al. 1996). Departures are with respect to the 1971–2000 monthly means. (Images courtesy of the NOAA/Climate Prediction Center.)

of selected observations are also provided for selected cyclones. All dates and times are based on Universal Coordinated Time (UTC).

a. Tropical Storm Ana, 11–16 August

Ana developed from a tropical wave that moved off the west coast of Africa on 8 August. The wave moved slowly westward and developed a large curved band of convection, which was followed by the formation of a small surface low along the wave axis on 10 August. Deep convection began to consolidate near the center of circulation, and the low became a tropical depression by 0600 UTC 11 August while centered about 200 n mi west of the Cape Verde Islands. The depression strengthened, becoming a tropical storm on 12 August, but the deep convection near the center diminished later that day. Ana weakened to a tropical depression at 0000 UTC 13 August and then degenerated to a remnant low 6 h later when it was located about 675 n mi west of the Cape Verde Islands; the weakening was apparently due to a combination of easterly shear, cool sea surface temperatures, and dry air in the mid- to upper levels of the atmosphere.

The remnant low continued to move westward across the tropical Atlantic on 13 August but produced little deep convection. However, thunderstorm activity increased near the center early on 14 August, and Ana regenerated into a tropical depression by 0000 UTC 15 August, while centered about 935 n mi east of the Lesser Antilles. Six hours later, Ana again became a tropical storm and maintained that status for a little over a day. Westerly shear and dry air aloft then caused Ana to weaken back to a depression by 1200 UTC 16 August while centered about 350 n mi east of the Lesser Antilles. Satellite data and aircraft reconnaissance observations suggest that Ana lost its well-defined center between 1200 and 1800 UTC that day while moving rapidly westward at 20–25 kt, and the depression degenerated into a tropical wave before reaching the Lesser Antilles.

Ana's estimated peak intensity of 35 kt occurred when the cyclone first reached tropical storm strength on 12 August and again when it restrengthened on 15 August,

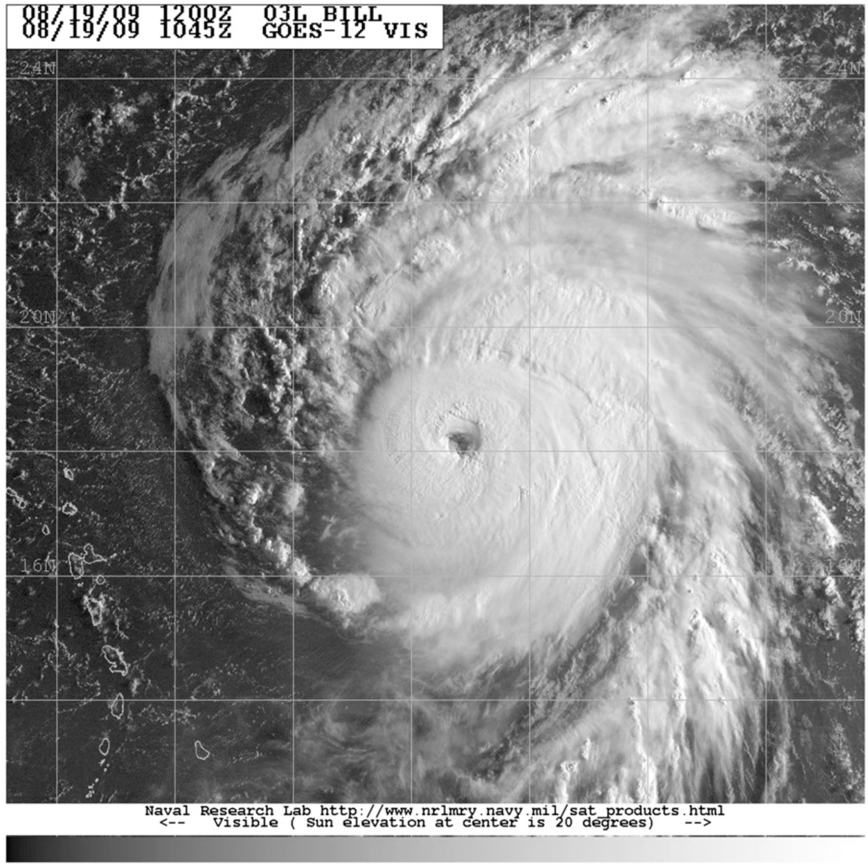

FIG. 4. *GOES-12* visible satellite image of Hurricane Bill at 1045 UTC 19 Aug 2009 near the time of the cyclone's maximum intensity. (Image courtesy of the Naval Research Laboratory Marine Meteorology Division.)

and is based on Dvorak satellite intensity estimates (Dvorak 1984). No casualties or damage were reported in association with Ana.

b. *Hurricane Bill, 15–24 August*

1) Synoptic history

Bill originated from a vigorous tropical wave and associated broad area of low pressure that moved off the west coast of Africa on 12 August. The system moved westward to the south of the Cape Verde Islands on 13 August, and deep convection became more consolidated with a few curved rainbands developing primarily on the southern side of the disturbance on 14 August. It is estimated that the low became a tropical depression at 0600 UTC 15 August while centered about 330 n mi west-southwest of the Cape Verde Islands. The depression steadily strengthened over the east-central tropical Atlantic within an environment of light vertical wind shear, and it became a tropical storm at 1800 UTC 15 August. Bill then became a hurricane at 0600 UTC 17 August, when it was located about midway between the Cape Verde Islands and the Lesser Antilles. Bill continued to strengthen, and became a category 4 hurricane 2 days later at 0600 UTC 19 August with an estimated peak intensity of 115 kt when it was centered about 300 n mi east-northeast of the northern Leeward Islands. Figure 4 shows a visible satellite image of Bill at 1045 UTC 19 August, near the time of its peak intensity.

Bill maintained its status as a category 4 hurricane for about a day. The hurricane had been steered west to west-northwestward near 15 kt for several days by deep easterly flow to the south of a subtropical ridge, but it accelerated to near 20 kt as it turned northwestward between the subtropical high and a large midtropospheric trough near the East Coast. Vertical shear began to increase because of the trough, and Bill started to slowly weaken on 20 August.

The center of Bill passed about 150 n mi west of Bermuda on 22 August, by which time the hurricane had weakened to category 2 strength. Nevertheless, the wind field associated with the hurricane was expanding, and

Bill produced tropical storm–force winds on Bermuda. The system then recurved toward the northeast with increasing speed and brushed the southern coast of Nova Scotia early on 23 August. Bill weakened to a tropical storm and made landfall on the Burin Peninsula of Newfoundland at 0300 UTC 24 August with maximum sustained winds of 60 kt and a minimum central pressure of 978 mb. It then crossed the southeastern portion of Newfoundland and became an extratropical cyclone over the North Atlantic by 1200 UTC that day. The system moved eastward for a couple of days and was absorbed by a larger extratropical cyclone near the British Isles early on 26 August.

2) Meteorological statistics

Bill's analyzed maximum intensity of 115 kt is based on a blend of surface-adjusted flight-level winds from aircraft reconnaissance and surface data from the Stepped-Frequency Microwave Radiometer (SFMR) instrument (Uhlhorn et al. 2007). The cloud pattern of the hurricane had the best presentation at 0600 UTC 19 August, when there was a distinct eye surrounded by very cold convective tops. Around that time, the 3-h average objective T numbers reached a peak of 7.0 (140 kt) using the advanced Dvorak technique (Olander and Velden 2007). However, reconnaissance aircraft data during that period did not support surface winds that strong. The peak 700-mb flight-level wind measured by the aircraft was 140 kt at 2323 UTC 19 August, but dropsonde and SFMR data indicated that the intensity was lower than what the standard 90% adjustment from that flight level would suggest (Franklin et al. 2003). The larger-than-normal discrepancy between the flight-level and surface winds is likely associated with the size of Bill's eye, which had grown to a diameter of 30 n mi by 19 August. Similar deviations from the standard flight-level to surface wind adjustment have been observed in other hurricanes with large eyes, such as Hurricane Isabel in 2003 (Beven and Cobb 2004). Bill's minimum central pressure, estimated by reconnaissance data to be 943 mb, occurred at 0000 UTC 21 August as the eye was increasing in size, about 42 h after the hurricane attained its peak intensity.

Selected surface observations from land stations and buoys are given in Table 2. In Bermuda, an instrument at an elevation of 78 m at the Bermuda Maritime Operation Centre measured a sustained 1-min wind of 65 kt, and an elevated instrument at Commissioner's Point reported a sustained wind of 53 kt with a gust to 85 kt. The highest storm-total rainfall in Bermuda was 14.0 mm at the Civil Air Terminal. In Canada, the highest measured sustained wind was 52 kt with a gust to 67 kt on Sable Island, located about 95 n mi southeast of mainland Nova Scotia. In addition, Cape Race, Newfoundland, reported a sustained wind of 50 kt with a gust to 71 kt. The highest storm-total rainfall was 71.9 mm at Queensport, Nova Scotia, and 71.1 mm at Gander, Newfoundland, and the highest storm surge was 0.94 m at St. Lawrence, Newfoundland.

The highest wind observation from a marine station was 67 kt with a gust to 80 kt from the National Oceanic and Atmospheric Administration (NOAA) buoy 41044, located over the west-central Atlantic about 315 n mi northeast of the northern Leeward Islands. Environment Canada buoy 44150 located on La Have Bank reported a sustained wind of 58 kt with a gust to 73 kt.

3) Casualty and damage statistics

Large swells, high surf, and rip currents generated by Bill caused two deaths in the United States. Although warnings about the dangerous waves had been posted along the coast, over 10 000 people gathered along the shore in Acadia National Park, Maine, on 24 August to witness the event. One wave swept more than 20 people into the ocean; 11 people were sent to the hospital, and a 7-yr-old girl died. Elsewhere, a 54-yr-old swimmer died after he was washed ashore by large waves and found unconscious in New Smyrna Beach, Florida.

Reports from Environment Canada indicated that tens of thousands of residences lost power in Nova Scotia. Road washouts and localized freshwater floods were common in Nova Scotia and Newfoundland. Storm surge and large waves also caused coastal flooding that damaged infrastructure along the coasts of these provinces. Large swells and heavy surf from Bill also affected areas in the Greater Antilles, the Bahamas, and Bermuda. The Meteorological Service of the Dominican Republic reported that waves produced coastal flooding and damage along the northern coast of that nation.

c. Tropical Storm Claudette, 16–17 August

Claudette originated from a well-defined tropical wave that moved off the west coast of Africa early on 7 August. The wave moved west-northwestward across the Atlantic for several days, and an area of disturbed weather formed near the northern end of the wave axis on 13 August, just after the system passed the Lesser Antilles. The cluster of clouds and showers moved west-northwestward and passed over the Bahamas on 14 August and then moved through the Straits of Florida and the Florida Keys on 15 August. Satellite and radar imagery indicated that a well-defined midlevel circulation associated with the disturbance passed just south of the Keys that day, and a broad area of surface low pressure subsequently developed early on 16 August as the system was moving into the extreme southeastern Gulf of Mexico. By 0600 UTC, the low-level circulation became sufficiently well defined

TABLE 2. Selected surface observations from Hurricane Bill, 15–24 Aug 2009.

	Min SLP		Max surface wind speed					
Location	Time (UTC) and date	Pressure (mb)	Time (UTC) and date[a]	Sustained (kt)[b]	Gust (kt)	Storm surge (m)[c]	Storm tide (m)[d]	Tot rain (mm)
Bermuda								
Bermuda Civil Air Terminal (TXKF)		1011.3	2344 UTC 21 Aug	40	52			14.0
Bermuda Maritime Operation Centre[e]			0412 UTC 22 Aug	65	68			
Fort Prospect[f]			2320 UTC 21 Aug	34	58			
St. David's[g]			0340 UTC 22 Aug	45	64			
Commissioner's Point[h]			2340 UTC 21 Aug	53	85			
Nova Scotia								
Sable Island	2000 UTC 23 Aug	994.1	2000 UTC 23 Aug	52	67			9.4
St. Paul Island			0000 UTC 24 Aug	45	55			18.3
McNabs Island			1900 UTC 23 Aug	38	48	0.64		
Grand Etang	2200 UTC 23 Aug	989.7	0000 UTC 24 Aug	38	48			
Hart Island	2000 UTC 23 Aug	981.5	0000 UTC 24 Aug	37	50			
Queensport								71.9
Newfoundland								
Cape Race	0500 UTC 24 Aug	988.9	0500 UTC 24 Aug	50	71			2.8
Sagona Island	0300 UTC 23 Aug	983.7	0700 UTC 24 Aug	43	55			
Argentia	0500 UTC 24 Aug	985.4	0000 UTC 24 Aug	37	51	0.76		30.5
Bonavista	0600 UTC 24 Aug	986.1	0900 UTC 24 Aug	37	49			26.7
St. Lawrence	0300 UTC 24 Aug	983.5	0400 UTC 24 Aug	34	52	0.94		
Gander								71.1
Alliston								66.8
Prince Edward Island								
East Point	2100 UTC 23 Aug	992.3	2000 UTC 23 Aug	36	49			54.6
Charlottetown	2000 UTC 23 Aug	996.0	2000 UTC 23 Aug	26	35	0.70		22.9
New Brunswick								
Shediac						0.70		
St. Stephen								47.2
NOAA buoys[i]								
41041—Mid-Atlantic	1808 UTC 17 Aug	972.1	1652 UTC 17 Aug	50	60			
41044—South Atlantic	0358 UTC 20 Aug	991.7	0358 UTC 20 Aug	67	80			
41049—Atlantic (South)	0847 UTC 21 Aug	1000.7	1146 UTC 21 Aug	44	50			
41048—west Bermuda[j]	0736 UTC 22 Aug	993.1	0911 UTC 22 Aug	52	62			
44008—Nantucket	0550 UTC 23 Aug	993.6	0353 UTC 23 Aug		39			
44011—Georges Bank	0850 UTC 23 Aug	965.5	0700 UTC 23 Aug	42	58			
Environment Canada buoys								
44150—La Have Bank	1300 UTC 23 Aug	980.8	1300 UTC 23 Aug	58	73			
44137—East Scotia Slope	1500 UTC 23 Aug	1001.1	1500 UTC 23 Aug	46	62			
44139—Banqureau Banks	0100 UTC 24 Aug	1000.5	2300 UTC 23 Aug	40	54			
44251—Nickerson Bank	0500 UTC 24 Aug	992.0	0300 UTC 24 Aug	38	52			
44141—Laurentian Fan	2200 UTC 23 Aug	1007.8	2200 UTC 23 Aug	38	50			
44138—southwest Grand Banks	0500 UTC 24 Aug	1006.6	0600 UTC 24 Aug	38	50			
44258—Halifax Harbour	1700 UTC 23 Aug	982.3	1600 UTC 23 Aug	31	44			
Other buoys								
44024—Northeast Channel[k]	1200 UTC 23 Aug	974.7	1400 UTC 23 Aug	33	42			
44636 (drifting: 45.8°N, 56.3°W)	0300 UTC 24 Aug	992.1	0300 UTC 21 Aug	56				

[a] Date and time are for the sustained wind when both sustained and gust winds are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based Automated Surface Observing System (ASOS) reports are 2 min; buoy-averaging periods are 8 min.
[c] Storm surge is water height above the normal astronomical tide level.
[d] Storm tide is water height above the National Geodetic Vertical Datum (1929 mean sea level).
[e] Instrument elevation is 78 m with a 1-min wind-averaging period.
[f] Instrument elevation is 70 m.
[g] Instrument elevation is 48 m.
[h] Instrument elevation is 80 m.
[i] Except as noted, anemometer height is 5 m.
[j] Anemometer height is 10 m.
[k] Gulf of Maine Ocean Observing System.

and the deep convection became organized enough to designate the system as a tropical depression, centered about 50 n mi west-southwest of Sarasota, Florida.

The depression was located within an environment of diffluent southerly upper-tropospheric flow, and it strengthened into a tropical storm by 1200 UTC 16 August. Further strengthening occurred rather quickly, and Claudette reached its peak intensity of 50 kt by 1800 UTC that day while centered about 35 n mi south of Apalachicola, Florida. After that point, southwesterly-to-westerly vertical shear began to increase, and Claudette's cloud pattern became less organized. The cyclone weakened slightly as it approached the Florida Panhandle and made landfall near Fort Walton Beach, Florida, around 0530 UTC 17 August with maximum sustained winds of 40 kt. Claudette moved into southern Alabama and weakened to a tropical depression later that morning. The cyclone dissipated by 0000 UTC 18 August near the Alabama–Mississippi border.

Claudette's estimated peak intensity of 50 kt is based on the highest of the reliable SFMR measurements from Air Force Reserve Hurricane Hunter missions. A peak SFMR wind speed of 58 kt was reported by reconnaissance aircraft, but this measurement appears inaccurate because of contamination by heavy rainfall.

Selected surface observations from Claudette are given in Table 3. The highest sustained wind observation was a 10-min-average wind speed of 44 kt at an elevation of 35 m from the Tyndall Air Force Base Tower Coastal-Marine Automated Network (C-MAN) site, located about 25 n mi offshore of the Florida Panhandle. An unofficial station from the Weather Underground network in Eastpoint, Florida, measured a sustained wind of 43 kt and a gust to 57 kt. The highest rainfall total was 118.4 mm at Milligan, Florida, and the maximum reported storm surge heights were 0.91 m at an unofficial site in Indian Pass, Florida, and 0.89 m from a National Ocean Service (NOS) gauge in Apalachicola.

Two people died as a direct result of Claudette. A 28-yr-old male drowned near the Broadwater Condominiums in Panama City Beach, Florida, and a 45-yr-old man was missing and presumed drowned near Shell Island, just to the southwest of Panama City. Claudette's other impacts were minimal and consisted of minor tree damage, sporadic power outages, and some beach erosion.

d. *Tropical Storm Danny, 26–29 August*

Danny developed from a tropical wave that moved westward across the coast of Africa on 18 August. Shower activity associated with the wave increased in organization for a short time on 22 August, but westerly vertical wind shear prevented further development of the system. On 24 August, shower activity again increased as the wave interacted with an upper-level trough. An Air Force Reserve Hurricane Hunter aircraft flew into the disturbance the next day and reported a large area of tropical storm–force winds but no closed circulation. Satellite imagery and Quick Scatterometer (QuikSCAT) data indicated that a closed surface circulation developed near 0900 UTC 26 August, and the system became a tropical storm at that time about 430 n mi east of Nassau in the Bahamas. Because of its interaction with the upper-level trough, Danny had a nonclassic structure and somewhat resembled a subtropical cyclone, with the strongest winds and most of the deep convection displaced from the center of circulation, and a radius of maximum winds near 120 n mi.

Danny moved erratically northwestward and strengthened slightly, reaching a peak intensity of 50 kt on 27 August. Southwesterly vertical wind shear then increased and caused Danny to gradually weaken as it continued to move toward the northwest. On 28 August a strong upper-level trough moved northeastward across the southeastern United States and caused Danny to turn northeastward. A new low pressure area then developed near the North Carolina coast early on 29 August in association with the upper-level trough, and Danny degenerated into a surface trough about 240 n mi southeast of Wilmington, North Carolina. The remnants of Danny were then absorbed into a developing frontal zone while the new low moved northeastward into New England late on 29 August and brought heavy rain and gusty winds to Nova Scotia on 30 August.

The highest surface wind report from the SFMR was 45 kt at 0600 UTC 27 August. QuikSCAT data near 2255 UTC 26 August and 1007 UTC 27 August showed several 45-kt wind vectors. Danny's peak intensity of 50 kt is based on a combination of these data.

There were two reliable marine-based observations of tropical storm–force winds associated with Danny. NOAA buoy 41047, located northeast of the Bahamas, reported a 10-min wind of 39 kt at 0600 UTC 27 August with a peak gust of 48 kt at 0553 UTC. In addition, the buoy reported a minimum pressure of 1007.1 mb at 0650 UTC 27 August. An elevated instrument on the *Carnival Miracle* (H3VS) cruise ship reported 37-kt winds at 0100 UTC 27 August.

Danny caused 1 death, a 12-yr-old boy who drowned near Corolla, North Carolina, in heavy surf generated by the storm.

e. *Tropical Storm Erika, 1–3 September*

Erika formed from a tropical wave that moved off the west coast of Africa on 25 August. The wave moved quickly westward and generated a broad area of low pressure on 27 August, centered about 340 n mi southwest

TABLE 3. Selected surface observations from Tropical Storm Claudette, 16–17 Aug 2009.

Location	Min SLP		Max surface wind speed			Storm surge	Storm tide	Tot rain
	Time (UTC) and date	Pressure (mb)	Time (UTC) and date[a]	Sustained (kt)[b]	Gust (kt)	(m)[c]	(m)[d]	(mm)
Florida								
International Civil Aviation Organization (ICAO) sites								
Apalachicola Municipal Airport (KAAF)	2153 UTC 16 Aug	1014.2	2153 UTC 16 Aug	31	45			80.0
Crestview (KCEW)	0526 UTC 17 Aug	1013.2	0526 UTC 17 Aug	20	34			
Destin–Ft. Walton Beach Airport (KDTS)	0453 UTC 17 Aug	1007.7	0416 UTC 17 Aug	24	39			
Panama City (KPFN)	2353 UTC 16 Aug	1013.7	0310 UTC 17 Aug	21	34			53.6
Tallahassee (KTLH)	2153 UTC 16 Aug	1017.5	1834 UTC 16 Aug	22	34			
Tyndall AFB (KPAM)	0336 UTC 17 Aug	1016.5	0336 UTC 17 Aug	29	37			
Valparaiso (KVPS)	0555 UTC 17 Aug	1011.4	0514 UTC 17 Aug		39			
Coastal-Marine Automated Network (C-MAN) Sites								
Tyndall AFB Tower C (SGOF1)[e]	2200 UTC 16 Aug	1013.5	2000 UTC 16 Aug	44	52			
National Ocean Service (NOS) sites								
Clearwater Beach (CWBF1)						0.39	1.25	
Cedar Key (CDRF1)						0.48	1.58	
Apalachicola (APCF1)	2200 UTC 16 Aug	1014.2	1824 UTC 16 Aug	29	40	0.89	0.93	
Panama City (PACF1)	2306 UTC 16 Aug	1013.3	0400 UTC 17 Aug	24	41	0.38	0.90	
Pensacola (PCLF1)						0.45	0.83	
Sites from other government agencies								
Eglin AFB Main	0531 UTC 17 Aug	1005.4	0531 UTC 17 Aug		43			
University networks								
Shell Point COMPS (SHPF1)	2106 UTC 16 Aug	1016.8	2106 UTC 16 Aug	32	40			
Public/other								
Alligator Point			1937 UTC 16 Aug	42	51			
Cape San Blas								99.8
Crestview (CRVF1)								99.3
Eastpoint (KFLEASTP2)	2100 UTC 16 Aug	1010.9	2048 UTC 16 Aug	43	57			
East Pass Destin (EPSF1)						0.70[e]	0.87	
Fort Walton (FWLF1)						0.52[e]	0.70	
Indian Pass						0.91	1.07	
Lanark Village			2030 UTC 16 Aug	28	35			
Milligan (MLGF)								118.4
Port St. Joe								101.6
Alabama								
ICAO sites								
Andalusia (K79J)	0756 UTC 17 Aug	1015.8	0714 UTC 17 Aug		35			
NOS sites								
Dauphin Island (DPIA1)						0.33	0.81	
NOAA buoys								
42036—west Tampa	1250 UTC 16 Aug	1013.2	1820 UTC 16 Aug	32[f]	39			

[a] Date and time are for the sustained wind when both sustained and gust winds are listed.
[b] Except as noted, sustained wind averaging periods for Coastal Marine Automated Network (C-MAN) and land-based Automated Surface Observing System (ASOS) reports are 2 min; buoy-averaging periods are 8 min.
[c] Storm surge is water height above the normal astronomical tide level.
[d] Storm tide is water height above Mean Lower Low Water (MLLW).
[e] Estimated.
[f] 10-min averaged wind.

of the southernmost Cape Verde Islands. Shower and thunderstorm activity associated with the low began to show signs of organization the following day, but then diminished early on 29 August. Convection redeveloped on 30 August as the low moved over warmer waters about 950 n mi to the east-southeast of the Leeward Islands. The low continued to produce showers and thunderstorms over the next 24–36 h, and scatterometer data indicated that the system was producing winds near tropical storm strength. However, the disturbance did not have a well-defined low-level circulation center at that time and therefore could not be designated a tropical cyclone.

On 1 September, microwave and geostationary satellite imagery indicated that the center became better defined. A U.S. Air Force Reserve reconnaissance aircraft investigating the area around 1800 UTC that day found a broad closed circulation with maximum sustained winds of 45 kt, and the system was designated a tropical storm while centered about 250 n mi east of Guadeloupe. The circulation center initially was exposed to the west of a large cluster of deep convection at the time of formation, although aircraft observations several hours later indicated that a new center had formed closer to the deep convection. The improved organization was short lived however, and the following reconnaissance flight around 0600 UTC 2 September again found the center well to the southwest of the main convective areas.

Erika moved generally westward, and the low-level center remained exposed well to the west of the strongest convection. The 200-mb wind pattern at that time appeared conducive for strengthening, but westerly winds below this level were producing strong vertical wind shear, and Erika weakened to an intensity of 35 kt by the time its center moved over Guadeloupe around 1800 UTC 2 September.

After Erika moved into the Caribbean Sea, thunderstorm activity redeveloped near the center of circulation early on 3 September, and aircraft data indicated that the storm reintensified slightly. The deep convection weakened later that day and became further removed from the low-level center, and Erika became a tropical depression by 1800 UTC while centered about 70 n mi south-southeast of St. Croix in the U. S. Virgin Islands. The depression degenerated into a remnant low 6 h later and moved west-northwestward, dissipating after 0600 UTC 4 September as it passed about 70 n mi south of the southwestern tip of Puerto Rico.

Erika's estimated peak intensity of 45 kt is based on a combination of a reliable SFMR surface wind of 46 kt and a peak 1500-ft flight-level wind measurement of 52 kt. Several SFMR wind observations between 50 and 56 kt were measured by Air Force reconnaissance flights, but these were observed in heavy rainfall and at a time when the SFMR instrument experienced numerous dropouts, rendering the data questionable.

There were no reports of sustained tropical storm–force winds at land stations in association with Erika, and storm-total rainfall was generally light. Antigua reported a 1-min sustained wind of 30 kt with a gust to 38 kt at 0706 UTC 3 September and also measured a storm-total rainfall of 49.2 mm. Elsewhere, the ship *Canelo Arrow* (C6OM8) reported 35-kt winds at 0300 UTC 3 September.

There were no reports of damage or casualties in association with Erika.

f. Hurricane Fred, 7–12 September

Fred originated from a tropical wave that crossed the west coast of Africa early on 6 September. A broad area of low pressure formed east of the deep convection around 1800 UTC that day as the system moved westward between 15 and 20 kt. The forward motion of the system slowed to less than 15 kt early the next day, and deep convection near the low-level center gradually increased in organization. The disturbance became a tropical depression around 1800 UTC 7 September while centered about 190 n mi south-southeast of the island of Brava in the Cape Verde Islands. A curved convective band developed south and west of the center during the next 6 h, and the depression strengthened into a tropical storm while centered about 195 n mi south-southwest of Brava.

Fred moved westward to the south of a subtropical ridge over the eastern Atlantic and intensified quickly. An intermittent eye feature was noted in infrared satellite imagery by late on 8 September, and Fred became a hurricane around 0000 UTC 9 September while centered about 360 n mi west-southwest of Brava. Subsequent microwave imagery confirmed the formation of an eye, and the hurricane rapidly intensified over the next 12 h, reaching an estimated peak intensity of 105 kt by 1200 UTC that day (Fig. 5). During the 24-h period ending at 1200 UTC 9 September, the intensity of Fred increased by 55 kt, including a 35-kt increase in 12 h. During the period of rapid intensification, the hurricane turned toward the west-northwest as it moved around the western periphery of the subtropical ridge located over Africa.

Microwave imagery on 9 September suggested that an eyewall replacement may have begun, and Fred's intensification ceased later that same day. A combination of the eyewall replacement and increasing southwesterly vertical wind shear ahead of a mid- to upper-level trough over the central Atlantic disrupted the inner core of the hurricane and induced weakening. The trough caused Fred to turn toward the north-northwest late on 10 September and then toward the northeast on 11 September. The cyclone continued to steadily weaken during this time due to

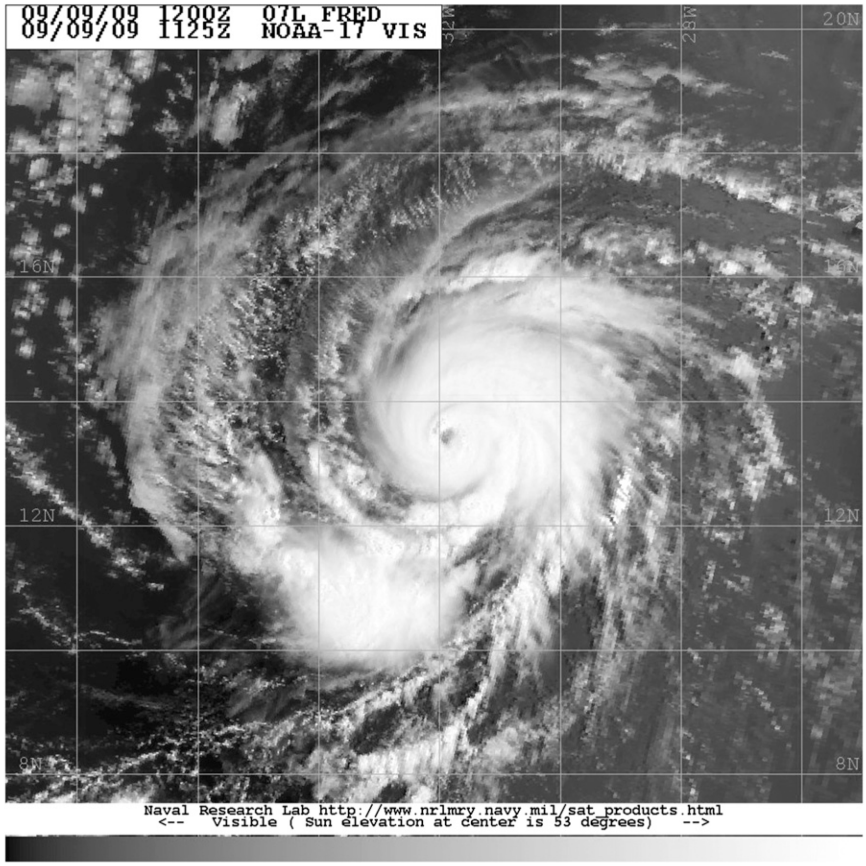

FIG. 5. *NOAA-17* visible satellite image of Hurricane Fred at 1125 UTC 9 Sep 2009 near the time of the cyclone's maximum intensity. (Image courtesy of the Naval Research Laboratory Marine Meteorology Division.)

increasing vertical wind shear and lower sea surface temperatures, and microwave imagery suggested that the midlevel center became displaced to the north and northeast of the low-level center by late on 10 September. Fred weakened to a tropical storm by 1800 UTC 11 September as it turned toward the east and moved at a speed of less than 5 kt.

Vertical shear continued to increase, and the low-level circulation center became completely decoupled from the remaining deep convection. Fred degenerated into a remnant low by 1800 UTC 12 September when all of the organized deep convection dissipated, while centered about 495 n mi west of Santo Antão in the Cape Verde Islands. The remnant low completed an anticyclonic loop in weak steering currents and then turned toward the west on 13 September under the influence of a low-level ridge to its north. Deep convection redeveloped several times as the low moved generally westward or west-northwestward for nearly a week, but this activity never gained enough organization or maintained sufficient temporal continuity to result in the reformation of a tropical cyclone. By 19 September, the remnant low became elongated ahead of a frontal trough situated off the southeastern coast of the United States, and the low dissipated after 1200 UTC that day while located about 450 n mi southwest of Bermuda.

Fred's estimated peak intensity is based on a 3-h average objective Dvorak intensity estimate of 105 kt centered at 1200 UTC 9 September (Olander and Velden 2007). Fred's peak intensity makes it only 1 of 2 hurricanes on record (the other being Hurricane Julia in 2010) to be of category 3 strength or higher while located south of 30°N and east of 35°W.[3]

g. Tropical Storm Grace, 4–6 October

Grace had nontropical origins, developing from a large extratropical low that formed along a cold front on

[3] The assessment of the intensity of most tropical cyclones in this part of the Atlantic basin would have been difficult prior to the beginning of Dvorak classifications from polar-orbiting satellites in 1972.

27 September about 410 n mi east of Cape Race, Newfoundland. The low became occluded early on 28 September and moved southeastward and then eastward for a couple of days before turning and accelerating to the south on 30 September just to the west of the Azores. On 1 October, the low turned northeastward and began to make a counterclockwise loop across the central and western Azores while still attached to an occluded front. The structure of the low began to evolve the next day, with the development of a 30 n mi radius of maximum winds distinct from a broader area of maximum winds located 250–300 n mi from the center. At this point, the low was only producing intermittent episodes of deep convection.

Satellite imagery suggested that the warm sector of the cyclone wrapped entirely around the center of the low by 1800 UTC 3 October, leading to an erosion of the frontal structure near the cyclone's center. Over the next 12 h, organized deep convection persisted, marking the transformation of the system to a tropical storm at 0600 UTC 4 October while it was centered over the western Azores about 115 n mi west of Lajes. A subtropical stage, typical of this sort of evolution, is not considered to have occurred here because Grace had developed a small radius of maximum winds and had separated from the upper low by the time the deep convection became persistent. Grace became a tropical storm over cold SSTs of around 21°C, but this is within the historical norms; two systems since 1982, Tropical Storm Ana (2003) and Hurricane Lili (1984), formed over SSTs that were as cold as or colder than those associated with Grace. Historical records indicate that Grace is the only cyclone that became a tropical storm as far northeast over the Atlantic Ocean.[4]

While passing through the Azores later on 4 October, Grace strengthened and developed an eyelike feature surrounded by a ring of relatively deep convection. The cyclone accelerated eastward then northeastward over the northeastern Atlantic Ocean as it became embedded in deep-layer southwesterly flow, and it reached its estimated peak intensity of 55 kt around 0000 UTC 5 October (Fig. 6). Grace then moved north-northeastward at around 25 kt over increasingly colder water and merged with a frontal boundary by 0600 UTC 6 October, becoming an extratropical low about 200 n mi west-southwest of Cork, Ireland. The small extratropical low moved east-northeastward over the Celtic Sea and dissipated by 0000 UTC 7 October as it approached Wales in the United Kingdom.

Grace's estimated peak intensity of 55 kt is based on Dvorak intensity estimates of 55 kt and an estimate of 55 kt from a QuikSCAT pass at 0634 UTC 5 October. Although Grace has been deemed tropical rather than subtropical, subtropical intensity estimates using the Hebert–Poteat technique were 55–65 kt (Hebert and Poteat 1975).

Even though Grace moved through the Azores, its small tropical storm–force wind field remained primarily over water between the islands. The highest reported winds were a sustained wind of 27 kt with a gust to 38 kt from Ponta Delgada on São Miguel Island and a sustained wind of 25 kt with a gust to 33 kt from the island of Santa Maria. One ship, the *Cap Castillo* (A8PI5), reported a sustained wind of 39 kt at 0600 UTC 5 October, while located about 95 n mi south of the center of Grace.

There were no reports of damage or casualties associated with Grace.

h. Tropical Storm Henri, 6–8 October

Henri developed from a tropical wave that moved off the west coast of Africa on 1 October. Disorganized showers and thunderstorms occurred intermittently near the wave axis over the next couple of days, and a broad low formed on 4 October while convection increased over a large area. Satellite and scatterometer data indicated that the low became better defined the next day, and the system acquired enough organization to be considered a tropical depression at 0000 UTC 6 October, while centered about 675 n mi east of the Lesser Antilles. At this time, the deep convection was displaced east of the center due to strong southwesterly vertical wind shear.

The depression moved west-northwestward and became a tropical storm 6 h later, with the low-level center still on the western edge of the deep convection. Some strengthening occurred on 7 October when thunderstorm activity increased near the center, and Henri reached a peak intensity of 45 kt around 0600 UTC. Subsequently, vertical wind shear increased, and the center again became exposed. Henri weakened to a tropical depression near 0600 UTC 8 October and then degenerated to a remnant low 12 h later about 135 n mi north-northeast of Anguilla. The remnant low moved west-northwestward for a day or so before high pressure built in over the western Atlantic Ocean. This caused the low to move west-southwestward for a couple of days before the circulation was distorted by the high terrain of Hispaniola, resulting in its dissipation.

i. Hurricane Ida, 4–10 November

1) Synoptic history

Ida's genesis was associated with a poorly defined tropical wave that reached the western Caribbean Sea

[4] Again it is worth noting that the accuracy of the historical record in this part of the basin is questionable before the beginning of routine Dvorak classifications in 1972 or before the advent of scatterometry.

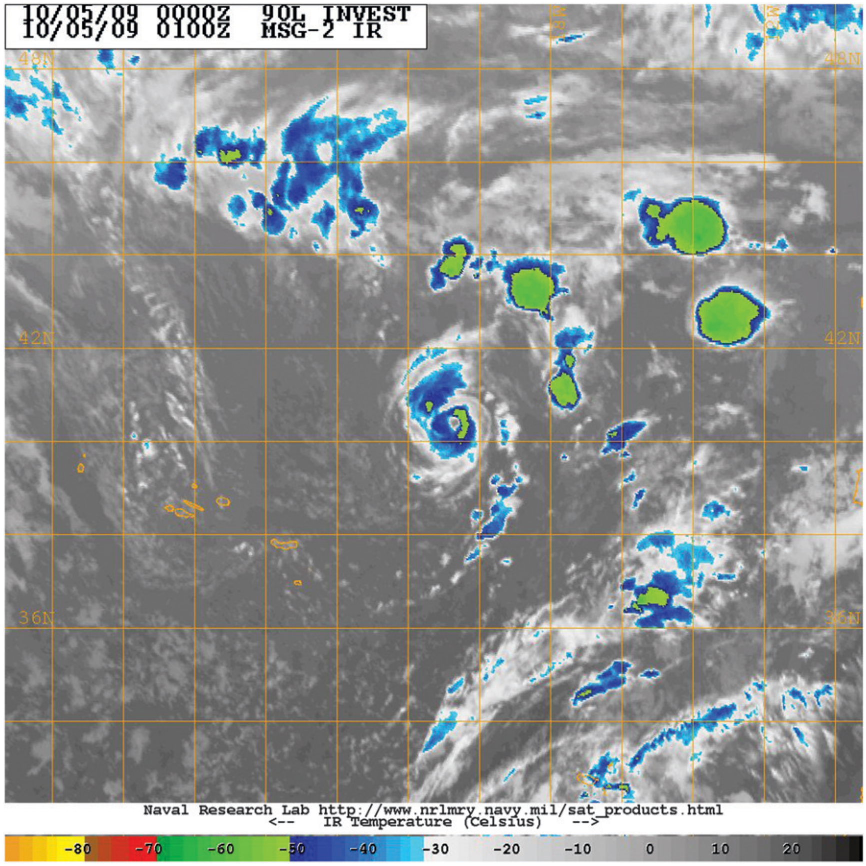

FIG. 6. *Meteosat-9* infrared satellite image of Tropical Storm Grace at 0100 UTC 5 Oct 2009 near the time of the cyclone's peak intensity as it moved northeastward away from the Azores. (Image courtesy of the Naval Research Laboratory Marine Meteorology Division.)

on 1 November. The wave moved into a large low-level cyclonic gyre located over the southwestern Caribbean Sea, Central America, and the adjacent eastern North Pacific Ocean and spawned a low on 2 November over the southwestern Caribbean Sea. The low moved very little for the next couple of days, but deep convection developed while an upper-level anticyclone formed over the western Caribbean and provided an environment of light vertical wind shear. Surface pressures fell, and it is estimated that a tropical depression formed at 0600 UTC 4 November just to the southeast of San Andres Island, Colombia.

Convective bands began to wrap around the center of the depression, and the system became a tropical storm 6 h later while it headed slowly northwestward toward the coast of Nicaragua. An environment of light vertical wind shear and warm ocean waters was favorable for strengthening, and Ida became a hurricane at 0600 UTC 5 November just offshore the coast of Nicaragua. Ida passed over the Corn Islands and made landfall in the vicinity of Rio Grande on the east coast of Nicaragua at 1200 UTC with 70-kt maximum sustained winds. The hurricane steadily weakened as it moved northward over the high terrain of Nicaragua and Honduras for about 30 h, and it reemerged over water just north of the eastern tip of Honduras as a tropical depression. Ida restrengthened quickly over the warm waters of the northwestern Caribbean Sea, and it regained hurricane status at 0000 UTC 8 November. It then reached its peak intensity of 90 kt while it moved northward over the Yucatan Channel at 0000 UTC 9 November.

Ida moved northward at a faster forward speed as it entered the southeastern Gulf of Mexico, where strong shear removed the convection from the low-level center and resulted in the hurricane weakening to a tropical storm. Shortly after 1500 UTC 9 November, convection redeveloped near the center, and Ida abruptly regained hurricane strength at 1800 UTC when it was approaching the mouth of the Mississippi River. Just as quickly, however, Ida weakened when it began to move over cooler shelf waters, and a new round of vertical wind shear, associated with a short-wave trough, removed the

TABLE 4. Selected surface observations from Hurricane Ida, 4–10 Nov 2009.

Location	Min SLP: Time (UTC) and date	Min SLP: Pressure (mb)	Max surface wind speed: Time (UTC) and date[a]	Max surface wind speed: Sustained (kt)[b]	Max surface wind speed: Gust (kt)	Storm surge (m)[c]	Storm tide (m)[d]	Tot rain (mm)
Nicaragua								
Bluefields								63.5
Bonanza								215.9
Corn Island								188.0
Puerto Cabezas								231.1
San Juan del Sur								76.2
Honduras								
Amapala								121.9
Puerto Lempira								180.3
Roatan								43.2
Cuba								
Arroyo de Mantua								114.3
Cabo San Antonio								119.4
Cortes								132.1
General Bolivar								210.8
Guane								195.6
Isabel Rubio								154.9
La Bajada								175.3
La Coloma								94.0
Las Martinas								157.5
Mantua								91.4
Manuel Lazo								317.5
Punta de Cartas								149.9
San Juan y Martinez								91.4
Sandino								177.8
Louisiana								
International Civil Aviation Organization (ICAO) sites								
Belle Chase (KNBG)	0755 UTC 10 Nov	1009.9	2119 UTC 9 Nov		38			
Boothville (KBVE)	0351 UTC 10 Nov	1004.7	2351 UTC 9 Nov		50			29.5
New Orleans-Lakefront (KNEW)	0853 UTC 10 Nov	1009.5	2141 UTC 9 Nov		39			3.0
New Orleans-Louis Armstrong Airport (KMSY)			2129 UTC 9 Nov		36			
Coastal-Marine Automated Network (C-MAN) Sites								
Southwest Pass (BURL1)	2200 UTC 9 Nov	1004.5	2110 UTC 9 Nov	50	59			
National Ocean Service (NOS) sites								
Cypremort Point (8765251)						0.52	0.93	
Port Fourchon (8762075)						0.56	0.95	
Grand Isle (GISL1)	2130 UTC 9 Nov	1007.9	2354 UTC 9 Nov	33	44	0.68	0.79	
Pilot's Station East – Southwest Pass (PSTL1)	2236 UTC 9 Nov	1003.9	2236 UTC 9 Nov	52	64	0.76	1.10	
Shell Beach (SHBL1)	0630 UTC 10 Nov	1007.4	0012 UTC 10 Nov	43	55	1.71	1.86	
New Canal Station (NWCL1)	0730 UTC 10 Nov	1010.0	2130 UTC 9 Nov		36	0.98	1.07	
Bayou LaBranch (LABL1)						0.71	0.79	
Sites from other government agencies								
Bayou Bienvenue (USACE)						1.09[j]	1.55	
Bayou Dupre (USACE)						1.27[j]	1.66	
Bay Gardene (USGS)						1.99[j]	2.23	
University networks								
South Timbalier Block 52–LSU (SPLL1)			2100 UTC 9 Nov	35	41			

TABLE 4. (*Continued*)

Location	Min SLP		Max surface wind speed			Storm surge (m)[c]	Storm tide (m)[d]	Tot rain (mm)
	Time (UTC) and date	Pressure (mb)	Time (UTC) and date[a]	Sustained (kt)[b]	Gust (kt)			
			Public/other					
Coastal Research Station (CRSL1)			0021 UTC 10 Nov	35	47			10.7
			Mississippi					
			ICAO sites					
Biloxi (KBIX)			0432 UTC 10 Nov		42			
Gulfport (KGPT)								63.2
Pascagoula (KPQL)			0432 UTC 10 Nov		39			
			NOS sites					
Bay Waveland Yacht Club (WYCM6)			0736 UTC 10 Nov	38	48	1.15	1.42	
Gulfport Outer Range (GPOM6)			0242 UTC 10 Nov	37	45			
Gulfport – West Pier (GWPM6)			0306 UTC 10 Nov	34	46			
Pascagoula NOAA Laboratory (PNLM6)						0.97	1.36	
Pascagoula – Dock E. Port (ULAM6)						1.09	1.52	
Petit Bois Island (PTBM6)			0454 UTC 10 Nov	40	51			
			Sites from other government agencies					
Jackson County EOC	0554 UTC 10 Nov	1008.8	0541 UTC 10 Nov	33	41			
			Public/other					
Pascagoula CO-OP								86.9
Ocean Springs CO-OP								71.9
			Alabama					
			ICAO sites					
Gulf Shores (KJKA)			0100 UTC 10 Nov		38			
Mobile (KMOB)			0705 UTC 10 Nov		41			
			C-MAN sites					
Dauphin Island (DPIA1)	1100 UTC 10 Nov	1001.4	2350 UTC 9Nov		42	0.78	1.18	
			NOS sites					
Coast Guard Sector Mobile (MCGA1)						0.58	0.90	
Fort Morgan (FMOA1)	1136 UTC 10 Nov	1001.1	1330 UTC 10 Nov	40[k]	46			
Mobile State Docks (OBLA1)						0.80	1.29	
			Public/other					
Elberta (3.1 SSW)								148.3
Foley (0.5 SE)								167.9
Middle Bay Light			1500 UTC 10 Nov	35				
Orange Beach (3 NE)								128.0
Summerdale (2.5 ESE)								155.7
Theodore (3 S)								127.0
Weeks Bay (WKXA1)						0.85	1.27	
			Florida					
			ICAO sites					
Destin (KDTS)			0710 UTC 10 Nov		40			
Pensacola (KPNS)			0550 UTC 10 Nov		38			
Pensacola Naval Air Station (KNPA)			0732 UTC 10 Nov		37			
			C-MAN sites					
Pulaski Shoal Light (PLSF1)			2000 UTC 8 Nov	37				
Sand Key (SANF1)			1700 UTC 8 Nov	40				
Tyndall AFB Tower C (SGOF1)			0300 UTC 10 Nov	41	50			

TABLE 4. (*Continued*)

Location	Min SLP		Max surface wind speed			Storm surge (m)[c]	Storm tide (m)[d]	Tot rain (mm)
	Time (UTC) and date	Pressure (mb)	Time (UTC) and date[a]	Sustained (kt)[b]	Gust (kt)			
NOS sites								
Pensacola (PCLF1)						0.87	1.21	
Panama City (PACF1)						0.81	1.17	
Apalachicola (APCF1)			0448 UTC 10 Nov		38	0.96	1.36	
Cedar Key (CDRF1)						0.65	1.55	
Public/other								
Bellview (1.7 NW)								129.3
Ensley (2.1 ENE)								136.1
Gonzales (2.5 NW)								171.2
Pensacola (USGS)								124.7
NOAA buoys[e] and oil rigs								
42056—Yucatan Basin[f]	0346 UTC 8 Nov	985.6	0319 UTC 8 Nov	64	75			
42001—Middle Gulf[f]	0850 UTC 9 Nov	1006.7	2124 UTC 8 Nov		39			
41003	1150 UTC 9 Nov	1006.0	1200 UTC 9 Nov	39	50			
42039—ESE Pensacola	0650 UTC 10 Nov	1008.2	1820 UTC 9 Nov	38	49			
42007—SSE Biloxi	0850 UTC 10 Nov	1002.4	0320 UTC 10 Nov	36	45			
42012—Orange Beach, AL	1150 UTC 10 Nov	1002.6	0100 UTC 10 Nov	36	49			
42872—*Deepwater Horizon* (MS Canyon 727)[g]			2125 UTC 9 Nov	98				
42887—*Thunder Horse* (MS Canyon 778)[h]			1300 UTC 9 Nov	58				
42363—*Mars* (MS Canyon 807)[i]			2100 UTC 9 Nov	60				

[a] Date and time are for the sustained wind when both sustained and gust winds are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based Automated Surface Observing System (ASOS) reports are 2 min; buoy-averaging periods are 8 min.
[c] Storm surge is water height above the normal astronomical tide level.
[d] Storm tide from NOS stations is water height above mean lower low water (MLLW). All others are height above the North American Vertical Datum of 1988 (NAVD88).
[e] Except as noted, anemometer height is 5 m.
[f] Anemometer height is 5 m.
[g] Anemometer height is 97 m.
[h] Anemometer height is unknown.
[i] Anemometer height is 122 m.
[j] Estimated.
[k] Anemometer height is 33 m.

convection from the center. The trough caused the storm to turn toward the northeast and east, and Ida became extratropical when it became associated with a baroclinic zone a few hours before moving inland along the Alabama coast at 1200 UTC 10 November. Ida had a large wind field, and tropical storm–force winds affected a portion of the northern Gulf of Mexico coast before the cyclone became extratropical. The extratropical cyclone dissipated over the Florida Panhandle by 1200 UTC 11 November, but its remnants contributed to the formation of a separate strong extratropical low that affected the East Coast during the following few days.

2) METEOROLOGICAL STATISTICS

Ida's analyzed intensity as a hurricane just before landfall in Nicaragua is based on 3-h average objective Dvorak T numbers (Olander and Velden 2007). The estimated peak intensity of 90 kt while Ida was over the Yucatan Channel is based on a blend of surface-adjusted flight-level winds, satellite intensity estimates, and SFMR data. The estimated second peak intensity of 75 kt over the northern Gulf of Mexico at 2100 UTC 9 November is based on an SFMR observation of 73 kt at 1935 UTC and a 1-min mean wind of 98 kt at 2125 UTC from a sensor mounted at an elevation of 97 m on the *Deepwater Horizon* (Mississippi Canyon 727) oil platform. The latter observation corresponds to a surface wind of about 80 kt based on the standard eyewall wind profile (Franklin et al. 2003).

Selected surface observations from land stations and buoys are given in Table 4. No reports of strong winds were received from Nicaragua or Honduras because of the sparse distribution of surface observations. The highest rainfall amounts received in the region were 231.1 mm at Puerto Cabezas, Nicaragua; 180.3 mm at

Puerto Lempira, Honduras; and 317.5 mm at Manuel Lazo, Cuba. NOAA buoy 42056 in the northwestern Caribbean Sea reported a maximum 1-min sustained wind of 64 kt with a gust to 75 kt at 0319 UTC 8 November.

In the United States, the highest reported sustained wind was 52 kt with a gust to 64 kt at 2236 UTC 9 November from a National Ocean Service (NOS) sensor at 24-m elevation from Pilot's Station East on the Southwest Pass of the Mississippi River. A National Data Buoy Center C-MAN station also located at Southwest Pass measured a sustained wind of 50 kt with a gust to 59 kt at an elevation of 31 m at 2110 UTC 9 November. Ida produced a storm surge along the northern Gulf Coast from Florida to Louisiana. The highest reported surges occurred on the western side of Ida's circulation due to a long period of easterly winds funneling water into Chandeleur Sound and Lake Borgne before the passage of the center of the storm; maximum amounts were 1.99 m from a gauge in Bay Gardene, Louisiana, and 1.71 m from an NOS gauge at Shell Beach, Louisiana. Farther east, the maximum reported surges by state were 1.15 m at the Bay Waveland Yacht Club, Mississippi; 0.85 m at Weeks Bay, Alabama; and 0.96 at Apalachicola, Florida. Rainfall totals were largest from southern Mississippi to the Florida Panhandle, with a maximum of 167.9 mm at Foley, Alabama.

3) CASUALTY AND DAMAGE STATISTICS

The Meteorological Service of Nicaragua indicated that about 6000 residents along the Caribbean coast were affected by Ida. More than 80% of the houses and schools were demolished in the village of Karawala, and the Corn Islands were hit especially hard. However, no deaths from Ida were reported from this region. Although media reports attributed roughly 120 deaths in El Salvador to Ida, these fatalities were associated with a separate area of low pressure off the Pacific coast of Central America. Only minor damage from wind and storm surge flooding occurred along the northern Gulf Coast, but a 70-yr-old man died when he piloted his boat in the Mississippi River to assist two men who were ultimately rescued by the U.S. Coast Guard.

3. Nondeveloping depressions

a. Tropical Depression One, 28–29 May

Tropical Depression One formed just before the official start of the Atlantic hurricane season, originating from a decaying frontal boundary located north of the Greater Antilles. The western end of the front moved northward on 25 May in response to a mid-to-upper-level short-wave trough moving across Florida, and an area of low pressure developed along that part of the boundary on 26 May, about 250 n mi south-southeast of Wilmington, North Carolina. The low moved northeastward over the next day or so with limited deep convection, and it produced scattered shower activity across parts of eastern North Carolina while it came within 75 n mi of the Outer Banks. A cluster of deep convection developed near the low on 28 May, and it is estimated that the system became a tropical depression by 0600 UTC that day, centered about 150 n mi east-northeast of Cape Hatteras. The depression moved over the warm waters of the Gulf Stream and produced intermittent bursts of deep convection, but it was unable to maintain this convection when westerly vertical wind shear increased on 29 May. The depression moved over colder water north of the Gulf Stream and degenerated to a remnant low around 0000 UTC 30 May, about 300 n mi south-southeast of Halifax, Nova Scotia. Of the 28 known tropical or subtropical cyclones to have formed in May, Tropical Depression One had the northernmost genesis location. It should be noted, however, that only cyclones that ultimately reached storm strength appear in the historical records prior to 1967.

b. Tropical Depression Eight, 25–26 September

Tropical Depression Eight developed from a tropical wave that moved off the west coast of Africa on 23 September. A broad surface low formed in association with the wave about midway between the west coast of Africa and the southernmost Cape Verde Islands by 1200 UTC 23 September, but shower and thunderstorm activity was sporadic. The deep convection became more organized with increased banding a couple of days later, and it is estimated that a tropical depression formed at 1800 UTC 25 September, centered about 435 n mi west of the Cape Verde Islands. The associated deep convection decreased significantly during the next 6–12 h as the depression moved northwestward, and moderate southwesterly shear and marginal sea surface temperatures prevented intensification. The short-lived depression dissipated into a trough of low pressure by 1800 UTC 26 September.

4. Forecast verifications and warnings

For all operationally designated tropical (or subtropical) cyclones in its area of responsibility, NHC issues an official forecast of each cyclone's center location and maximum 1-min surface wind speed. Forecasts are issued every 6 h and contain projections valid 12, 24, 36, 48, 72, 96, and 120 h after the forecast's nominal initial time (0000, 0600, 1200, or 1800 UTC). At the conclusion of the season, forecasts are evaluated and verified by comparing the projected positions and intensities to the corresponding

TABLE 5. Homogenous comparison of official and CLIPER5 track forecast errors in the Atlantic basin for the 2009 season for all tropical and subtropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast period (h)						
	12	24	36	48	72	96	120
2009 mean OFCL error (n mi)	30.1	44.5	61.8	73.2	119.2	197.9	292.3
2009 mean CLIPER5 error (n mi)	51.0	102.6	166.5	225.1	345.8	462.6	569.8
2009 mean OFCL skill relative to CLIPER5 (%)	41.0	56.6	62.9	67.5	65.5	57.2	48.7
2009 mean OFCL bias vector [° (n mi)$^{-1}$]	328/2	118/2	150/15	167/39	174/67	170/82	174/202
2009 No. of cases	122	98	76	61	49	38	22
2004–08 mean OFCL error (n mi)	32.1	54.9	77.1	99.0	147.0	200.3	263.6
2004–08 mean CLIPER5 error (n mi)	45.8	95.7	152.8	208.6	306.2	393.6	472.9
2004–08 mean OFCL skill relative to CLIPER5 (%)	29.9	42.6	49.5	52.5	52.0	49.1	44.3
2004–08 mean OFCL bias vector [° (n mi)$^{-1}$]	303/6	306/14	311/22	315/30	313/31	334/27	010/49
2004–08 No. of cases	1726	1565	1404	1259	1020	808	651
2009 OFCL error relative to 2004–08 mean (%)	−6	−19	−20	−26	−19	−1	11
2009 CLIPER5 error relative to 2004–08 mean (%)	11	7	9	8	13	18	20

poststorm analyzed "best track" positions and intensities for each cyclone. A forecast is included in the verification only if the system is classified in the final best track as a tropical or subtropical cyclone at both the forecast's initial time and at the projection's valid time. All other stages of development (e.g., tropical wave, low, extratropical, etc.) are excluded. For verification purposes, forecasts from special advisories[5] do not supersede the original forecast issued for that synoptic time. Additional information on verification of NHC official forecasts and model guidance is provided by Franklin (2010).

Track forecast error is defined as the great-circle distance between a cyclone's forecast position and the best-track position at the forecast verification time, while track forecast skill represents a normalization of forecast error against some standard or baseline, and is positive when the forecast error is smaller than the error from the baseline. To assess the degree of skill in a set of track forecasts, the track forecast error can be compared with the error from the climatology and persistence 5-day statistical model (CLIPER5), which contains no information about the current state of the atmosphere (Neumann 1972; Aberson 1998). If CLIPER5 errors are abnormally low during a given season, for example, it indicates that the year's storms were more predictable than usual.

Table 5 presents the results of the NHC official track forecast verification for the 2009 season, along with results averaged for the previous 5-yr period (2004–08). In 2009, the NHC issued 144 Atlantic basin forecasts, a number well below the average over the previous 5 yr. Hurricane Bill accounted for almost three-quarters of the 120-h forecasts. Mean track errors ranged from 30 n mi at 12 h to 292 n mi at 120 h. The errors were smaller in 2009 than during the previous 5-yr period at all forecast periods except at 120 h, although the sample size at that time is likely too small for a meaningful comparison. In addition, forecast projections established all-time low errors from 24 to 72 h. Track forecast skill over CLIPER5 ranged from 41% at 12 h to 68% at 48 h, with records for skill being set at 24–72 h.

Mean vector biases, as shown in Fig. 7, were southward (i.e., the official forecast tended to fall south of the

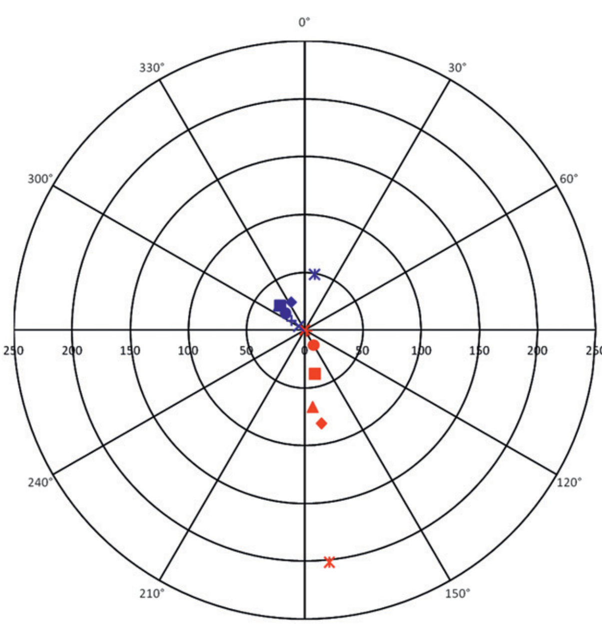

FIG. 7. Radial plot of forecast track vector biases (n mi and °) for NHC official 2009 Atlantic track forecasts (red) and for the previous 5-yr (2004–08) mean of official track forecasts (blue) for 12 h (×), 24 h (+), 36 h ($\hat{x}$), 48 h (□), 72 h (△), 96 h (◇), and 120 h (☆).

[5] Special advisories are issued whenever an unexpected significant change has occurred or when U.S. watches or warnings are issued between regularly scheduled advisories. The current practice of retaining and verifying the original advisory forecast began in 2005.

TABLE 6. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the Atlantic basin for the 2009 season for all tropical and subtropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast period (h)						
	12	24	36	48	72	96	120
2009 mean OFCL error (kt)	6.4	11.4	14.9	17.5	20.6	19.5	16.6
2009 mean Decay-SHIFOR5 error (kt)	7.9	14.3	19.7	23.5	28.0	29.2	25.3
2009 mean OFCL skill relative to Decay-SHIFOR5 (%)	19.0	20.3	24.4	25.5	26.4	33.2	34.4
2009 OFCL bias (kt)	0.6	1.7	−0.1	−2.5	−4.3	−1.6	5.2
2009 No. of cases	122	98	76	61	49	38	22
2004–08 mean OFCL error (kt)	7.1	10.5	12.8	14.7	18.1	19.0	20.9
2004–08 mean Decay-SHIFOR5 error (kt)	8.5	12.3	15.3	17.7	20.8	23.1	23.2
2004–08 mean OFCL skill relative to Decay-SHIFOR5 (%)	16.5	14.6	16.3	16.9	13.0	17.7	9.9
2004–08 OFCL bias (kt)	0.2	0.4	0.1	−0.3	−0.5	−2.1	−2.5
2004–08 No. of cases	1726	1565	1404	1259	1020	808	651
2009 OFCL error relative to 2004–08 mean (%)	−10	9	16	19	14	3	−21
2009 Decay-SHIFOR5 error relative to 2004–08 mean (%)	−7	16	29	33	35	26	9

verifying position) and were most pronounced at the longer lead times (e.g., the bias was about 70% of the mean error at 120 h). In comparison, vector biases for the previous 5-yr mean (2004–08) official track forecasts were smaller and northwestward (i.e., the mean official forecast over the previous 5 yr tended to fall northwest of the verifying position). Examination of along- and cross-track errors for 2009 shows that the biases at the longer lead times were almost exclusively along-track and slow.

Intensity forecast error is defined as the absolute value of the difference between the forecast and best-track intensity at the forecast verifying time. Intensity forecast skill is assessed by using the Decay-Statistical Hurricane Intensity Forecast model version 5 (Decay-SHIFOR5 or DSHIFOR5) as the baseline. The DSHIFOR5 forecast is obtained by initially running SHIFOR5, the climatology and persistence model for intensity that is analogous to the CLIPER5 model for track (Jarvinen and Neumann 1979; Knaff et al. 2003). The output from SHIFOR5 is then adjusted for land interaction by applying the decay rate of DeMaria et al. (2006). The application of the decay component requires a forecast track, which here is given by CLIPER5. The use of DSHIFOR5 as the intensity skill benchmark was introduced in 2006. On average, DSHIFOR5 errors are about 5%–15% lower than SHIFOR5 in the Atlantic basin from 12 to 72 h.

Table 6 presents results of the NHC official intensity forecast verification for the 2009 season, along with results averaged for the preceding 5-yr period. Mean intensity forecast errors in 2009 ranged from about 6 kt at 12 h to a high of 21 kt at 72 h, then 17 kt at 120 h. The 120-h official intensity error set a record for accuracy, although the sample size (i.e., 22) was exceedingly small. Forecast biases did not exhibit any strong tendencies. Except at 12 h, the DSHIFOR5 errors were well above their 5-yr means, indicating that the season's storms were unusually difficult to forecast. The DSHIFOR5 errors were so high that record forecast skill was achieved at 12, 72, 96, and 120 h despite the official forecast errors being larger than their 5-yr means.

A hurricane (tropical storm) warning is a notice that 1-min sustained winds of hurricane (tropical storm) force are expected within a specified coastal area within the next 24 h.[6] A watch means that the conditions were possible within that area within the next 36 h. Table 7 shows the watch and warning lead times for cyclones that affected or had the potential to affect the United States in 2009. The issuance of watches and/or warnings for territories outside of the United States is the responsibility of their respective governments, and those statistics are not presented here. Because observations are generally inadequate to determine when hurricane or tropical storm conditions first reach the coastline, the lead time is defined here as the time between the issuance of the watch or warning and the time of landfall or the closest point of approach of the cyclone center to the coastline. This definition will usually result in an overestimation of lead times for preparedness actions, particularly for hurricanes, since tropical storm conditions can arrive several hours prior to the onset of hurricane conditions.

The tropical storm watches and warnings issued for Ana, Danny, and Erika did not verify because all three cyclones dissipated before bringing tropical storm conditions to the

[6] NHC has extended its watch and warning lead times by 12 h for the 2010 season, so that a hurricane or tropical storm warning signifies that 1-min sustained tropical storm force winds are expected to begin within the next 36 h. A watch now means those conditions are possible within the next 48 h. Verification of watches and warnings in this report abides by the previous 2009 standards.

TABLE 7. Watch and warning lead times (defined as the time between the issuance of the watch or warning and the time of landfall or closest approach of the center to the coastline) for tropical cyclones affecting the United States in 2009. If multiple watch or warning types (TS or H) were issued, the type corresponding to the most severe conditions experienced over land is given.

Storm	Landfall or point of closest approach	Watch and/or warning type	Watch lead time (h)	Warning lead time (h)
Ana	U.S. Virgin Islands and Puerto Rico	TS	Dissipated prior to approaching watch area	None issued
Claudette	Near Fort Walton Beach, Florida	TS	None issued	20.5
Danny	North Carolina Outer Banks	TS	Dissipated prior to approaching watch area	None issued
Erika	U.S. Virgin Islands and Puerto Rico	TS	Weakened below TS strength before reaching watch area	Weakened below TS strength before reaching warning area
Ida*	Mouth of the Mississippi River, Louisiana	H	33	21

* Ida became extratropical before moving inland along the Alabama coast.

coast. The warnings issued for Claudette and Ida did not quite achieve the desired 24-h lead time, each being issued about 3 h too late.

Acknowledgments. The cyclone summaries are based on Tropical Cyclone Reports written by the NHC Hurricane Specialists, including the authors and Jack Beven, Eric Blake, John Cangialosi, Michael Brennan, Daniel Brown, Todd Kimberlain, and Richard Pasch. These reports are available online at http://www.nhc.noaa.gov/2009atlan.shtml. The forecast verification summary is based on the NHC Forecast Verification Report written by James Franklin and is available online at http://www.nhc.noaa.gov/verification/pdfs/Verification_2009.pdf. The NWS Climate Prediction Center provided information on the climatology of the 2009 season. Ethan Gibney of the I.M. Systems Group at the NOS Coastal Services Center produced the track chart. Much of the local impact information contained in the individual storm summaries was provided by the meteorological services of the affected countries. In the United States, much of the local impact information is compiled by the local NWS Weather Forecast Offices. The NWS National Data Buoy Center and the National Ocean Service provided summaries of data collected from their agencies.

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